CONTEXTUAL TRANSFORMATIONS IN TIMBRAL SPACES

by

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Abstract

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This dissertation introduces a methodology for the analysis of timbral structures. The focus is on how to organize theoretical constructs based on timbral objects and their transformations in a musical composition. Transformational theory, artificial intelligence theory, music cognition, and psychoacoustics will serve as references while constructing multiple parallel approaches to the questions that arise from the perception of timbre-oriented music, i.e. electro-acoustic music, questions such as categorization and behaviors of sonic objects, processes that relate them, and challenges of new formal organizations. My intention is to supply analytical tools that are flexible and accessible enough to contribute to and coexist with pitch-based approaches. A generalized semantic theory of timbre is not the objective; this dissertation offers more of a cognitive exercise in how to uncover/discover contextual group operations in a timbral space

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Chapter One

Introduction-Analyzing Timbre

The general goal of this dissertation is to develop some analytical concepts from David Lewin's timbral GIS (Generalized Interval Systems) in order to analyze timbrally conscious music.[1] Such repertoire encompasses acoustic repertoire as well as works from electronic music, electroacoustic music, and spectral music; works from composers like Ligeti, Scelsi, Xenakis, Sciarrino, Stockhausen, Lachenmann, and Nono, to name a few. My intention is to supply analytical tools that are flexible and accessible enough to contribute to and coexist with pitch-based approaches.

The analysis of timbre has stayed in the margins of music analysis in the North-American music theory community in the past. Very few of the articles published in the *Journal of Music Theory* and in *Music Theory Spectrum* since 1993 have sonic objects and their transformations–timbral transformations–as their analytical subject.[2] This

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[1] David Lewin, *Generalized Musical Intervals and Transformations* (New Haven: Yale University Press, 1987), 81-87.

[2] The same is true for papers presented in JMT/AMS meetings between the same years. However, starting after WWII, European scholars produced vastly concerning timbre and its morphology. Schaefferian timbral morphology is well documented by Schaeffer and his followers: Pierre Schaeffer, *Traité Des Objets Musicaux* (Paris: Editions du Seuil, 1966); Pierre Schaeffer, *Solfège De L'objet Sonore* (Paris: Les Presses Artistiques, 1998); Michel Chion, *Guide Des Objets Sonores: Pierre Schaeffer Et La Recherche Musicale* (Paris: INA-GRM/Buchet-Chastel, 1983); François Bayle, *Pierre Schaeffer: L'oeuvre Musicale* (Paris: INA/ GRM, 1990). On the other hand, research at Institut de Recherche et Coordination Acoustique/Musique (IRCAM) pave the way to many discoveries and technological innovations in acoustics, psychoacoustics, music perception, sound synthesis, and musical representations. A good summary of articles offered in Jean Baptiste Barrière, *Le Timbre, Métaphore Pour La Composition* (Paris: Christian Bourgois/ IRCAM, 1991); see also Jean-Claude Risset and David L. Wessel, "Exploration of Timbre by Analysis and Synthesis," in *The Psychology of Music,* 2nd Edition, ed. Diana Deutsch (New York: Academic Press, 1982), 113-69. On compositional issues concerning timbre, see Pierre Boulez, "Le Timbre Dans La Littérature Instrumentale De La Vingtième Siècle," in *Seminar on Timbre* (Paris: IRCAM, 1985); Gérard Grisey, "La Musique, Le Devenir Des Sons," *La Revue Musicale-L'Itinéraire* (1991): 291-300; and Tristan Murail, "Questions De Cible," *Entretemps* 8 (September 1989): 147-72.

exclusion is a result of a concentration on the different modalities of organization of pitch material (e.g., restriction to twelve pitch classes) taken as a sufficient, if not unique, explanation of musical expression. Schenkerian analysis and pitch-class set analysis search for patterns, structure, and other relevant cognitive means in the pitch domain, whereas timbre is the sole agent that carries, communicates, and shapes such information in a musical setting. Exclusively pitch-material-based analysis leads to a flattened analytical surface neglecting the combination and interaction of various elements that contribute to the structure and morphology of a musical network. How can we overcome such avoidance that leads to the exclusion of timbre as a significant constituent of music-analytical thinking?

In chapter four of Lewin's *Generalized Musical Intervals and Transformations*, under the title "Some Timbral GIS Models," Lewin describes certain GIS models based on specific sound types (harmonic-steady sounds) and designs a system of sound classes that reflect "certain aspects of their timbral profiles." He goes on to build more complex GIS structures and builds a space of "time points" ($a_1 \ldots\ldots a_n$) where he can model a class of sounds with a certain developing spectrum by placing them on a temporal map:

> Supposing the time points a1 through a5 to be dense enough so as to catch salient features of the sound-class involved (e.g. times when some partial has a pronounced local maximum or local minimum value), then we can consider this sketch to be a good approximation for a continuous relief map that characterizes the class of sounds with respect to its developing spectral *signature*.[3]

The specific objective of this dissertation is to show that musical spaces of timbral constructs have group properties. My approach, departing from Lewin's suggestion

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[3] Lewin, *Generalized Musical Intervals and Transformations*, 83.

about the spectral “signature” of a sound-class, develops a dynamic understanding of these sound-classes. I suggest that a sound-class, to which I will refer hereafter as timbral class, is a dynamic structure that is hard to define precisely given a certain time point because the components of a timbre-class have a variety of, and most of the time unpredictable, behaviors through time. Segmentation of timbre as a fixed entity causes an epistemological problem, which is in contradiction with the nature of the object that we observe; the old definition of timbre as a specific superposition and ordering of frequencies (partials), most likely, is the origin of this problem.

Our hearing mechanism is sensitive to the temporal information regarding sound. The time trajectory of a single sound can be compartmentalized into various stages: first, an initial excitation that starts the sound usually called transients (or attack transients); second, a sustain period where the energy reaches a more or less steady state after a decay in the original energy; and finally, the release stage wherein the source energy ceases to be exerted and, as a result, the sound fades out over a certain period of time. The mechanical motion of the eardrum converts these time-domain pressure variations through the ossicles (the hammer, anvil and stirrup) to the oval window membrane. This membrane propagates a wave in the fluid of the cochlea that stimulates the hair cells on the basilar membrane. The cochlear filtering and periodicity detection are the result of the frequency analysis of these hair cells. They are attached to the nerves that transmit the result of the frequency analysis to the brain. From there on, we are in the domain of the perceptual, consequently of the cultural.

Whether a sound is pitched or non-pitched depends on the complexity of the relations within its spectrum. The French mathematician Jean-Baptiste-Joseph Fourier

(1768-1830) found that any periodic waveforms could be represented as a sum of sinusoidal waves, or sine waves, which are the simplest mathematical model to represent periodic motion. Each periodic component has its particular frequency, amplitude, and phase information and it is usually described as a *partial*. A sine wave is a solution of a linear differential or partial-differential equation. Consequently, the information about the internal periodic organization of a sound, namely the design of its Fourier components, can be used to construct the original sound wave, a process that we call sound synthesis. The acoustician Herman von Helmholtz (1821-1894) extended Fourier's analysis to comprise non-periodic waveforms by "a continuous distribution of sine waves, in which amplitude and phase are a function of frequency."[4]

Thanks to Max Matthews and others, recent developments in acoustics and psychoacoustics have shown that timbre is a dynamic structure, which is defined by the existence of many sub-components and their nonlinear interaction through time.[5] These sub-components are related to the time domain as well as to the frequency domain. For example, attack transients have been proven to be a major factor in the perception of timbre, as stated by Risset and Wessel: "Tape-recorder manipulation has made it easy to demonstrate the influence of time factors on tone quality. For instance, playing a piano tone backwards gives a non-piano-like quality, although the original and the reversed

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[4] John R. Pierce, "The Nature of Musical Sound," in *The Psychology of Music,* 2nd edition, ed. Diana Deutsch (New York: Academic Press, 1999), 7.

[5] Max Mathews, "Introduction to Timbre," in *Music, Cognition, and Computerized Sound,* ed. Perry R. Cook (Cambridge, Massachusetts: the MIT Press, 2001); John R. Pierce, *The Science of Musical Sound* (New York: Scientific American Library, 1983.) See also Jean-Claude Risset and David L. Wessel, "Exploration of Timbre by Analysis and Synthesis," in *The Psychology of Music,* 2nd edition, ed. Diana Deutsch (New York: Academic Press, 1982), 113-169; Stephen McAdams, "Perspectives on the Contribution of Timbre to Musical Structure," *Computer Music Journal* 23/2 (1999): 85-102.

sound have the same spectra."[6] This discrepancy is caused by the temporal position of transients and the weight that the human hearing mechanism attaches to them.

This kind of discrepancy occurs often in nature because most physical systems are inherently nonlinear in nature. A nonlinear system is a system whose output is not proportional to its input. Unlike linear systems, nonlinear systems are not represented by the superimposition of the responses of the system to the stimuli.[7] For example, the simple changes in one part of the meteorological system produce complex effects throughout.

In any musical instance, various timbral constructs interact and form highly complex aural structures. This complexity is not only an external feature of the sound phenomenon but an internal one. In sound, various components move and interact erratically, in a nonlinear fashion. Sound has a chaotic internal structure: no picture will describe faithfully its anatomy. The same is true for timbral perception. The nature of timbre is in the domain of the perception: it is an esthesic process. This is the core of an epistemological problem. Pitch is a poietic material. In other words, it is associated with the domain of the creator of art. It is *out-of-time*. It belongs to the composer's conceptual domain, whereas timbre is the utterance, the realization of any sort of poietic process.

Thus, as Nattiez claims, "a symbolic form... is not some 'intermediary' in a process of 'communication' that transmits the meaning intended by the author to the audience. It is instead the result of a complex *process* of creation (the poietic process)

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[6] Jean-Claude Risset, and David Wessel, "Exploration du Timbre par Analyse et Synthèse," in *Le Timbre, Métaphore pour la Composition*, ed. J.B. Barrière (Paris: C. Bourgois Editeur and Ircam, 1991), 102-131.

[7] "A system L is generally said to be linear if whenever an input u_1 yields an output $L(u_1)$ and an input u_2 yields an output $L(u_2)$, we also have $L(c_1u_1 + c_2u_2) = c_1L(u_1) + c_2L(u_2)$ where c_1,c_2 = arbitrary real or complex numbers." Thomas Kailiath, *Linear Systems* (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1980), 2.

that has to do with the form as well as the content of the work. It is also the point of departure for a complex process of reception (the esthesic process) that *reconstructs* a 'message'."[8]

The musical message is communicated via auditory streams; it is reasonable to think that sound is the *objectification* of conceptual data. It assures that all the poietic material is mediated in order to take form as streams. The sound is the *only* reality in music–it belongs to the domain of the Real in Lacanian terminology– owing to the fact that it is experienced via physical stimuli, via sensory input; it is *praxis*. The meaning of timbre is in Time and *in-time*.

It is not difficult to recognize the difficulties in the representational paradigm of western music. Boulez acknowledges that,

> pitch and duration seem to me to form the basis of a compositional dialectic, while intensity and timbre belong to secondary categories. The history of universal musical practice bears witness to this scale of decreasing importance, as is confirmed by the different stages of notational development. Systems of notating both pitch and rhythm always appear highly developed and coherent, while it is often difficult to find codified theories for dynamics or timbre, which are mostly left to pragmatism or ethics (hence the numerous taboos concerning the use of certain instruments or of the voice).[9]

Timbre, sound color, tone-color: Since Debussy's dedicated involvement with timbre as a building material of music, several theorists, more from acoustics and psychoacoustics than music theory proper, showed a limited interest in how we perceive sounds. At the conclusion of his *Harmonielehre,* Arnold Schoenberg talks about the structural potentials of "tone color," *Klangfarbe*:

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[8] Jean-Jacques Nattiez, *Music and Discourse: Toward a Semiology of Music*, trans. Carolyn Abbate (Princeton, N.J.: Princeton University Press, 1990), 17.

[9] Pierre Boulez, *Boulez on Music Today*, trans. Susan Bradshaw and Richard Rodney Bennett (London: Faber and Faber, 1971), 37.

> The evaluation of tone color, the second dimension of tone, is in a much less cultivated, much less organized state than is the aesthetic evaluation of [pitch]. Nevertheless, we go right on boldly connecting sounds with one another, contrasting them with one another, simply by feeling; and it has never yet occurred to anyone to require of a theory that it should determine laws by which one may do that sort of thing… Now, if it is possible to create patterns out [of] pitch[es], patterns we call 'melodies,' progressions, whose coherence evokes an effect analogous to thought processes, then it must also be possible to make progressions out of…'tone color,' progressions whose relations with one another work with a kind of logic entirely equivalent to that logic which satisfies us in the melody of pitches.[10]

In a recent reading of Schoenberg's ideas about *Klangfarbe*, Alfred Cramer points out that the word conveyed more than what we think of it today. Claiming Schoenberg as being in harmony with the theories of Helmholtz, Cramer argues that Schoenberg used the concept to refer "to an idealized hearing of tones for the timbral contributions of frequencies rather than for pitch values" much like the *harmonies-timbres* of spectral composers of the 1970's.[11] Cramer relocates *Klangfarbe* to the domain of sound by taking it apart from its backdrop function for pitch-based analysis.

When Michel Chion talks about Schaefferian theory he claims that "the term sound object refers to every sound phenomenon and event perceived as a whole, as a coherent entity and heard by means of reduced listening which targets it for itself, independently of its origin or its meaning."[12] For Schaffer, *objet sonor* exists only in the perceptual domain: it is not a physical phenomenon but rather a sonic unit that resides in the listening process, or esthesic process and it is only accessible through reduced listening–a mode of listening where the listener deliberately separates the sound from its

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[10] Arnold Schoenberg, *Theory of Harmony,* trans. Roy E. Carter (Berkeley: University of California Press, 1978), 421.

[11] Alfred Cramer, "Schoenberg's *Klangfarbenmelodie:* A Principle of Early Atonal Harmony," *Music Theory Spectrum* 24/1 (Spring, 2002): 2.

[12] Michel Chion, *Guide des Objets Sonores: Pierre Schaeffer et la Recherche Musicale* (Paris: INA-GRM/Buchet-Chastel, 1983), 113.

source and concentrates on its properties. On the other hand, as Chion points out, "the sound object represents a global perception, which remains identical through different hearings; an organized unit, which can be compared to a 'gestalt' in the meaning of the psychology of form."[13]

Schaeffer suggests some clarifications about the nature of sound object:

a) The sound object is not the sound body,

b) The sound object is not the physical signal,

c) The sound object is not a recorded fragment,

d) The sound object is not a notated symbol on a score,

e) The sound object is not a state of mind (it remains the same across different listening modes).[14]

Wayne Slawson presents a theory of *sound color*, which he places as a subset of timbre, and defines it by the dissociation of temporal, instrumental, or any other qualitative attributes.[15] He criticizes previous approaches for their lack of search for invariance and its related operations within the various typologies that they theorized. He concentrates especially on formant structure of vowels as the dimension of invariance. In a two-dimensional *sound color* space, he places an *x-axis* representing the frequency of the first resonance, or formant, and a *y*-axis representing the frequency of the second formant. Slawson seeks operations such as transposition and inversion in that sound color space timbre via reduced dimensions of laxness, openness, and acuteness.

On the other hand, Fred Lerdahl suggests that timbre can be organized hierarchically by

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[13] Michel Chion, *Guide des Objets Sonores*, 124.

[14] Pierre Schaffer, *Solfège de l'Objet Sonor*e (Paris: Les Presses Artistiques, 1998), 53-59.

[15] Wayne Slawson, *Sound Color* (Berkeley and Los Angeles: University of California Press, 1985).

the use of concepts such as timbral consonance and dissonance.[16] Dichotomies such as *Bright-Dull*, *Sharp Attack-Slow Attack* form the dissonance-consonance poles: for example, an oboe is more dissonant than a clarinet, a crescendo from *niente* is more consonant than a *sforzando* attack. This theory of consonance-dissonance suggests naturally that there exists a certain concept of timbral distance that can be calculated according to the distance from the most consonant timbre. The timbral scale that Lerdahl proposes is "a linear ordering of timbres at fixed intervals along a given dimension or combination of dimensions," these dimensions having the potential of reflecting the multidimensionality of timbral phenomenon.

The categorization of timbre depends on the degree of similarity between objects. However, the nature of that similarity and the degree of similarity are two different issues. The former relates to perception while the latter relates to arithmetic/numerical quantification models based on a spatial distance metaphor. Research on these questions gained ground with the psychoacoustic research done by John Grey. In *An Exploration of Musical Timbre*, Grey categorized subjective comparisons—provided by a group of trained musicians—between sounds within a metric distance in the space of the parameters and proposed a three-dimensional timbre space based on similarity rating between sixteen instrumental sounds.[17] Following in his footsteps, many researchers, like Stephen McAdams, searched for properties that defined the amount of change of a timbral motion in a timbral space. McAdams defined a timbre interval as a "vector in space connecting two timbres" that has a specific length (the distance between the

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[16] Fred Lerdahl, "Timbral Hierarchies," *Contemporary Music Review* 2/1 (1987): 135-60.

[17] John M. Grey, *An Exploration of Musical Timbre,* Report STAN-M-2, Stanford University, 1975.

timbres) and a specific orientation.[18] His original claim was that if the perceptual domain were continuous and linear then vectorial relations would point toward timbral similarity relations. However, research showed that

> the use of timbre intervals as an integral part of a musical discourse runs the risk of being difficult to achieve with complex and idiosyncratic sound sources, since they will in all probability have specificities of some kind or another. The use of timbre intervals may, in the long run, be limited to synthesized sounds in which the dimensions of variation can be controlled and tested to ensure that no specificities are present to distort the perceptual relations among them.[19]

Appropriating transformational thinking is an effort to move away from this Cartesian perspective. Concentrating solely on measuring topological distances to measure similarity/equivalence can provoke analytical fetishism with objects—timbral ones in this case—placing them as the sole focus, whereas a transformational attitude mitigates their ontological and ahistorical weight. Contextual transformations shift the focus from the identity of the objects toward their motion in time.

In *New Images of Musical Sound*, Robert Cogan provides spectral photographs of musical works in order to theorize what he calls the *sonic design* of musical work.[20] Through thirteen sonic dichotomies, such as “grave-acute,” “attack-no attack,” “beatless-beating, “and so on, Cogan analyzes a musical work, or segments of it, and come up with a system that evaluates the change between segments of music according to the aforementioned dichotomies. Positive, negative, a mixture of both, and neutral are the classifications of those evaluations. Although it is successful as a theory of sound, as

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[18] Stephen McAdams, “Perspectives on the Contribution of Timbre to Musical Structure,” *Computer Music Journal* 23/3 (Autumn, 1999): 94.

[19] Stephen McAdams, “Perspectives on the Contribution of Timbre to Musical Structure,” 95.

[20] Robert Cogan, *New Images of Musical Sound* (Cambridge, Mass.: Harvard University Press, 1984).

Richard Swift points out, "the adjectival characteristics" of the dichotomies constitute merely "banal binary oppositions."[21] A further critique, as expressed by Stephen Malloch, points out that Cogan uses spectral data as "direct representations of our perception" and "objects in themselves, rather than as representations of data, which can be manipulated further."[22]

This dissertation introduces a methodology for the analysis of timbral structures. The focus is on how to organize theoretical constructs based on timbral objects and their transformations in a musical composition. Transformational theory, artificial intelligence theory, music cognition, and psychoacoustics will serve as references while constructing multiple parallel approaches to the questions that arise from the perception of timbre-oriented music, i.e. electro-acoustic music, questions such as categorization and behaviors of sonic objects, processes that relate them, and challenges of new formal organizations. I will look for small portions in the timbral organization that can be agents of meaning. I will consider significant timbral local instances, treat them as *moments,* aspects of timbral classes then try to construct meta-structures not by induction but by the dialectic of these small moments and laying the groundwork for a more generalized theory. A generalized semantic theory of timbre is not the objective; this dissertation offers more of a cognitive exercise in how to uncover/discover contextual group operations in a timbral space. As Lewin observes:

> It is unfair to demand of a musical theory that it always address our sonic intuitions faithfully in all potentially musical contexts under all circumstances. It is enough to ask that the theory do so in a sufficient number of contexts and circumstances. Perhaps, too, it is fair to ask that the theory be *potentially* able to

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21 Richard Swift, Review of Cogan (1984), *Journal of Music Theory* 30 (1986): 277-83

22 Stephen Malloch, "Timbre and Technology: An Analytical Partnership," *Contemporary Music Review* 19/2 (2000): 160.

> address our intuitions is any given musical situation, provided that the situation develops in a suitable musical manner.[23]

[23] Lewin, *Generalized Musical Intervals and Transformations*, 85, emphasis original.

Chapter Two

Notation and Segmentation of Timbral Classes

The analytical model proposed by this dissertation requires classification and modeling of various timbres within a certain musical context. As we have seen, this effort of generalization of timbre has been a subject for many research projects and continues to be an important issue in contemporary research. Although the traditional theory focuses on contextual features, recent research in psychoacoustic and music psychology reveals the fact that there are inherent and immanent features of timbre that are not dependent on a circumstantial musical setting. Timbre resides in the perceptual realm as a multi-dimensional aspect of sound phenomenon.[1] It is possible to represent in a generalized form some of the features that are relevant to musical analysis. Existing labeling/categorization systems are vague and difficult to work with. Schaeffer's *reduced hearing* and the resulting classification of *sound objects* are mostly static by nature; labeling takes most of the analytical energy.[2]

The purpose of this chapter is to provide timbral descriptors that can be used as instances/nodes in a timbral transformational network. Instead of reduction, the

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[1] Stephen McAdams, "Perspectives on the Contribution of Timbre to Musical Structure," *Computer Music Journal* 23/3 (1999): 85-102.

[2] Pierre Schaeffer, *Traité des objets musicaux* (Paris: Editions du Seuil, 1966). For a detailed discussion on Schaeffer's *sound object* and a critique of its contemporary usage see Brian Kane, "L'Objet Sonore Maintenant: Pierre Schaeffer, Sound Objects and the Phenomenological Reduction," *Organized Sound* 12/1 (2007): 15.

modeling simply leaves out features that are considered negligible for the analysis and maps only the invariant elements relevant to the analyst. The main goal is to identify a sound object in a specific musical context by mapping out *some* of its features and then to follow that object through the transformations that it performs as well as its network of relations with other objects. Brian Fennelly has made an early attempt to design a symbolic representation in order to classify timbral generalizations.[3] The analytical apparatus of this dissertation is based on a revised and upgraded version of Fennelly's original taxonomy as a naming convention for timbre-classes.

2.1 The Work of Fennelly

2.1.1 Description of Fennelly's Taxonomy

Fennelly proposes a classification of "sound images" in order to establish a terminology that will serve as the basis of an analytic language. The format represents essential features of a sound, such as timbre, envelope, and enhancements. The formula that describes a certain sound consists of X_S that describes the spectral components; Y_C that describes the envelope controls of attack type and dynamic curve; and a third term E that describes any further defining characteristics that do not belong to the previous features. This formula could also be applied to "linear 'voices' or groups of elements of identical timbre and attack."[4] The labeling can be enhanced further by the addition of both sub- and super-scripts next to each term that details additional characteristics. The

[3] Brian Fennelly, "A Descriptive Language for the Analysis of Electronic Music," *Perspectives of New Music* 6/1 (1967): 79-95.

[4] Fennelly, "A Descriptive Language for the Analysis of Electronic Music," 82.

possibilities can be summarized as follows: $X_{Sr}{}^{t}Y_{Cd}{}^{i}E$. Let us take a closer look at Fennelly's implementation of each of the formula's terms.

2.11.1 Timbre X_S

X_S is assigned to the description of the timbral characteristics of a particular sound. Fennelly classifies the analyzed sounds into two subcategories: the *basic electronic signals* and the *environmentally related sounds*. A further categorization is reserved for the distinction of pitched and noise-related sounds. Figure 2.1 shows his table illustrating those subdivisions.

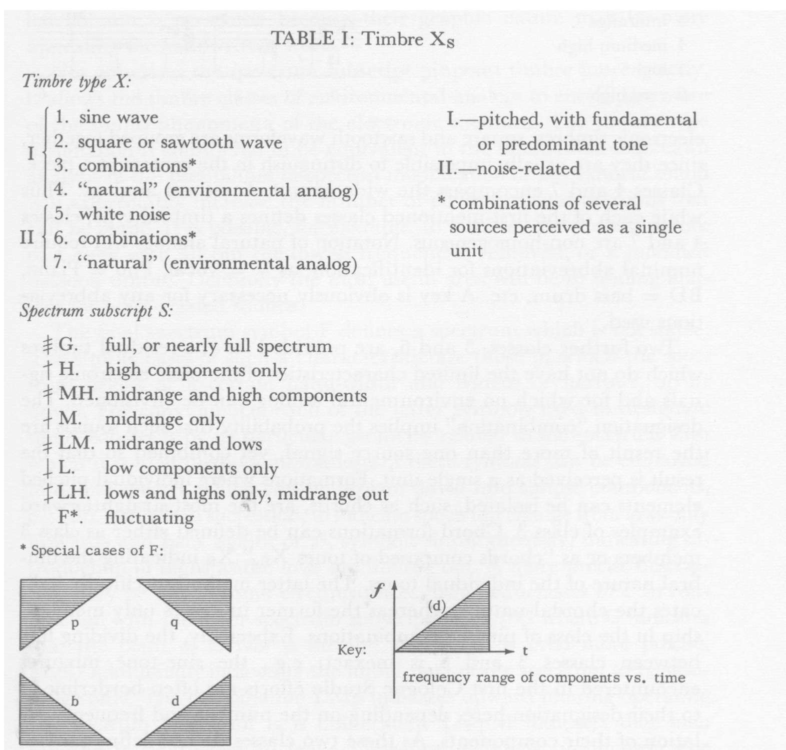

TABLE I: Timbre X_S

Timbre type X:

I
1. sine wave
2. square or sawtooth wave
3. combinations*
4. "natural" (environmental analog)

II
5. white noise
6. combinations*
7. "natural" (environmental analog)

I.—pitched, with fundamental or predominant tone
II.—noise-related

* combinations of several sources perceived as a single unit

Spectrum subscript S:

G. full, or nearly full spectrum
H. high components only
MH. midrange and high components
M. midrange only
LM. midrange and lows
L. low components only
LH. lows and highs only, midrange out
F*. fluctuating

* Special cases of F:

Figure 2.1 Fennelly's classification for X and S

Specific numbers identify the different timbral classes: classes 1, 2 and 5 refer to sine wave, square or sawtooth wave, and white noise respectively. Classes 4 and 7 refer to natural analogs; while the previous classes of electronic timbres are timbre classes by themselves, these classes of natural analogs are non-homogeneous. Therefore, Fennelly advises the use of abbreviations to identify the natural source (e.g. V = Vocal, Pno = Piano etc.).

Classes 1, 2, 3, and 4 are under the previously mentioned pitched subcategory, whereas 5, 6, and 7 are under the noise-related subcategory. Classes 3 and 6 generalize any "residual timbres, which do not have the limited characteristics of the basic electronic signals and for which no environmental analog can be envisioned."[5] Therefore, Fennelly uses "combination" classes in order to generalize those timbres that do not belong to any of the previously mentioned classes. Chord formation belongs to class 3 if "it is the result of more than one source signal, but the perceived timbre is a single unit."

For example, in *Studie I* (1953), Stockhausen merely used sine waves in order to "compose" timbres: "An irrevocable step became necessary: I returned to the element which is the basis of all sound multifariousness: to pure vibration, which can be produced electrically and which is called a sine wave."[6] The whole piece, in this case, can be seen as an articulation of Fennelly's timbre class 1, while various operations on those signals such as addition or subtraction of partials, applying various envelopes, reverberation, serve as a basis for composing the local instances of class 1. During the first minute of his subsequent electroacoustic work *Gesang der Jünglinge* (1955-56), Stockhausen's

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[5] Fennelly, "A Descriptive Language for the Analysis of Electronic Music," 84.

[6] Karlheinz Stockhausen, *Electronic Music 1952-1960, no. 3 from the complete edition* (Stockhausen Verlag), accompanying booklet.

usage of timbre clearly left the domain of class 1 and shifted toward timbral configurations of classes 3 and 6. The class 1 components (sine waves) mix with the class 4 components (vocal sounds of a twelve-year-old boy) so well that often the perceived timbre does not belong to any of them but to combination classes 3 and 6. The third orchestral piece of Schoenberg's *Five Pieces for Orchestra,* op. 16 (1909), commonly referred to by its 1912 title *Farben*, is a perfect example of such combination for the acoustic domain. Formed by a texture of "natural" sounds that belongs to pitched domain, the resulting sound unit is a member of class 3.

Fennelly's timbre description is "fine-tuned" by the spectrum subscript S. This subscript refers to any spectral domain operation that defines the particularity of a specific sound, such as filtering partials out of a complex spectrum as well as superimposing pure sine waves in order to build spectra, as exemplified in the early works of Stockhausen at the Cologne Studio. The symbols define the particular aspects of a spectrum that belong to the already described timbre X. The letter G refers to the full or nearly full spectrum; H, M, and L refer to the various frequency range components (high, mid-range, and low respectively), and they combine among themselves to define certain characteristic frequency areas (e.g., LH for lows and highs only, mid-range out; MH for mid-range and high components). The symbol F refers to a fluctuating spectrum, such as a spectrum that has a certain bandwidth, widening or narrowing up or down. Such simple spectral movements can be described by additional letters that are related to specific geometrical schema given by Fennelly (Fig. 1). The letters p, q, b, and d designate the spectral movements that can be used in combination while defining spectra (e.g., db indicates a spectral change from lows only, upwards and back again).

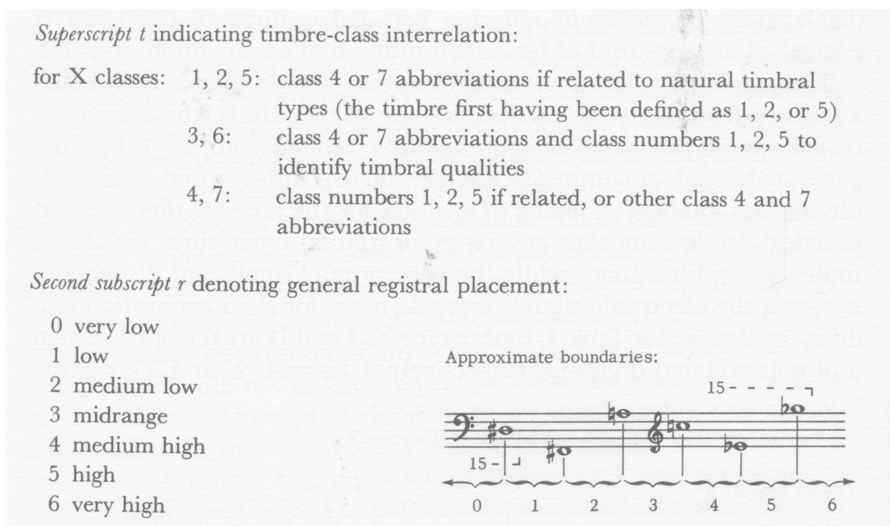
Fennelly's superscript t to X provides "an additional refinement by relating a secondary timbral image to a defined timbre type indicating an intersection of the two."[7] Figure 2.2 shows Fennelly's summary of possibilities. Here are some examples from Fennelly's article to illustrate the relationship of superscript t to the timbre type X and to the subscript S:

2_L^1 : a class 2 waveform filtered almost to the point of a sine wave with low components

2_{LM}^{bsn} : bassoon-like sound with low and mid components

2_L^{tba} : tuba-like with low components

bell^1 : bell-like sound with sine-tone structure.[8]



Superscript t indicating timbre-class interrelation:

for X classes: 1, 2, 5: class 4 or 7 abbreviations if related to natural timbral types (the timbre first having been defined as 1, 2, or 5)

3, 6: class 4 or 7 abbreviations and class numbers 1, 2, 5 to identify timbral qualities

4, 7: class numbers 1, 2, 5 if related, or other class 4 and 7 abbreviations

Second subscript r denoting general registral placement:

0 very low
1 low
2 medium low
3 midrange
4 medium high
5 high
6 very high

Figure 2.2 Fennelly's classification for t and r

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[7] Fennelly, "A Descriptive Language for the Analysis of Electronic Music," 86.

[8] "Notation of natural analogs will require nominal abbreviations for identification, as V=vocal, Pno=Piano, BD=bass drum etc. A key is obviously necessary for any abbreviations used." in Fennelly, "A Descriptive Language for the Analysis of Electronic Music," 84.

A second subscript r denotes a general registral placement; 0 (very low) up to 6 (very high). The boundaries of the arbitrarily divided frequency range are approximate and context-dependant.

2.1.1.2 Envelope Y_{Cd}^{i}

In the Y_C part of the formula, Y is the attack type, and the subscript C defines the continuation –sustain– qualities of the timbre X_S. Figure 2.3 reproduces Fennelly's summary of possibilities.

TABLE II: Envelope Y_C

Attack Y:		*Continuation subscript C:*	
A	very slow growth	a	steady state
B	slow growth	b	increasing intensity (crescendo)
C	moderate growth	c	decreasing intensity (diminuendo)
D	rapid growth	d	not classifiable due to context
O	attack imperceptible	f	fluctuating intensity (possibly defined in terms of a, b, & c)

Superscript i to denote intensity relation of Y to C:

- l loud
- m medium
- s soft
- o attack characteristics appear to be without transients

Second subscript d indicating general area of component duration or signal pacing: (Symbols define a "duration register" or speed range of specified ambitus.)

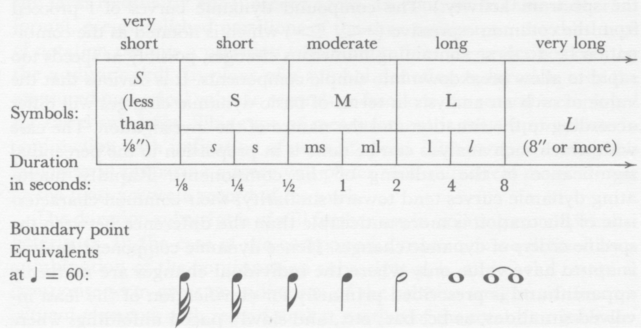

Figure 2.3 Fennelly's classification for Y and C

Y classes are generalized based on “the perceived firmness of the attack” and labeled as A, B, C, and D, indicating very slow, slow, moderate, and rapid growth, respectively. Class 0 refers to an undetectable attack, *niente* in common musical terminology. The subscript C denotes trivial sustain qualities after the attack type Y: steady state, crescendo, and diminuendo. These continuation classes are labeled a, b, and c respectively, whereas letter d is used in contexts where there are no specific delimitations, or where it is impossible to perceive a specific sustained quality because of the intensity or rapidity of the passage. Class f refers to fluctuating intensity resulting in compound dynamic curves, which can be defined in most contexts in terms of a, b, and c. Let us look at Figure 2.4 in order to clarify some Y class groupings applied to Webern’s Five Pieces for Orchestra, op. 10, no. 4.

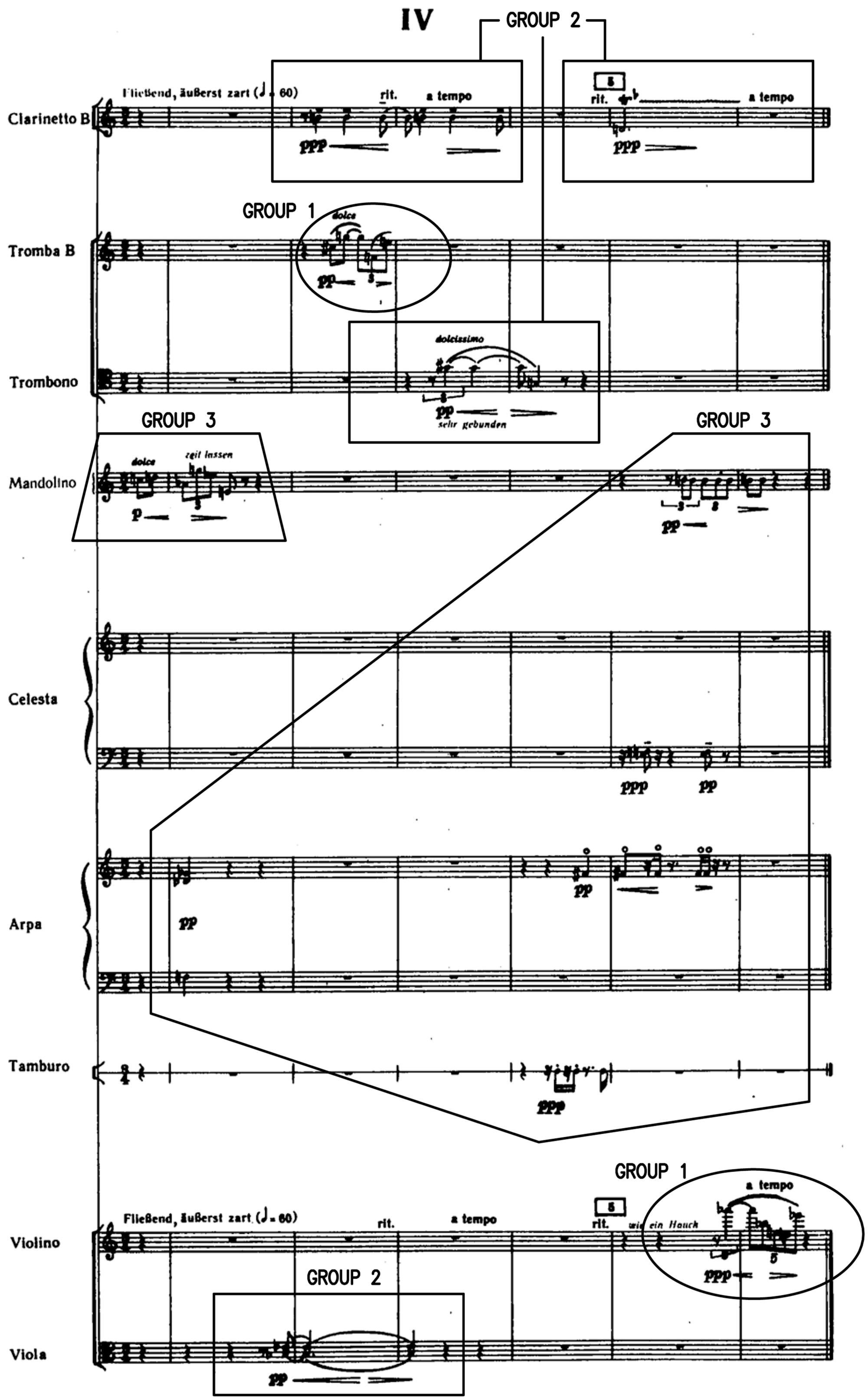

Figure 2.4 Webern Five Pieces for Orchestra, op. 10, no. 4

Group 1 refers to the moderate growth labeled as C. The group 1 members are circled in Figure 2.4. According to Fennelly's taxonomy, the trumpet in m. 2 is labeled as TRP_G C and the violin in m. 6 as VLN_GC. Natural sources have full spectrum, hence the full spectrum subscript G. Group 2 categorizes attack class B, slow growth. Viola, clarinet, and trombone timbres are labeled VLA_GB, CL_GB, and TRB_GB, respectively. They are shown in rectangles in Figure 2.4. Group 3 collects timbres that have firm attacks throughout the piece. Mandolin, harp, celesta, and snare drum are members of the attack class D. They are labeled as $MAND_GD$, $HARP_GD$, CEL_GD, and SNR_GD. We can add sustain quality subscripts to those descriptors. The viola in m. 2 becomes VLA_GB_{bc}, where b stands for increasing intensity and c for decreasing intensity. The continuation subscripts can be combined (bc for crescendo and decrescendo), as shown here for the viola descriptor, in order to display the fluctuating intensity.

Fennelly adds further attack qualities to the envelope Y_C by using superscript i, which defines the loudness of the attack, labeled as l, m, and s, for loud, medium, and soft, respectively. The final symbol 0 refers to attack characteristics that have no specific attack transients. For example, *sforzando* is a dynamic marking that emphasizes the loudness of attack transients; therefore any instrumental timbre with such marking qualifies for this superscript i. A hypothetical *sforzando* on the viola timbre of the previous paragraph will change the descriptor into $VLA_GB_{bc}^{l}$.

A second additional category permits the durational measurement, which is labeled by subscript d. This subscript d can measure the duration inside of single sounds or the distance between attack points of an instrumental line. All measurements refer to duration in terms of seconds and there are three different types of notation used as shown at the bottom of Figure 2.3. The first one is symbolic notation *S* S M L *L*, which stands for very short, short, moderate, long, and very long. A finer definition can be obtained by using lower-case letter symbols to distinguish different shades of symbolic notation. For example, S, which refers to events shorter than half a second and longer than one-eighth of a second, could be subdivided into *s* and s to distinguish two events that fall under the class "short," with one being relatively longer than the other. The second type of notation for subscript d is to codify the durational measurement in seconds and the third type is to use musical notation in order to denote the boundary points of different time segmentations. Subscripts C and d can be combined in order to obtain a compound symbolic syntax in case of a long sound with unfolding changes in envelope:

$Y_{C1d1C2d2...Cndn.}$

In Figure 2.4, the viola in mm. 1-3 deserves a duration subscript L, VLA_GB_{bcL}, for having approximately four and a half seconds of duration. The clarinet part gets an M subscript in mm. 2-3, CL_GB_M, because each of its articulations takes approximately one second. The same clarinet gets an L subscript, CL_GB_L, in m. 5 because of its full measure duration–3 seconds. Following the clarinet label can give us an idea about its durational stretch; a more interesting approach is to look for descriptors that have L labels in the work. The viola in mm. 1-3, the trombone in mm. 3-4, which is the remaining L label candidate, and the clarinet in m.5 form an L-durational layer that gets interrupted. All the L-durational partners have group 2 membership except the clarinet in mm. 2-3. This odd-member-out suggests a legitimate question: does an M-duration timbre on the same pitch, dynamic, and articulation melt down to an L-duration, or does it play an ambivalent role, being neither one or the other? This question will be one of the central points of the following sections of this chapter, especially when discussing auditory scene analysis.

2.1.1.3 Enhancement E

The final term E refers to any feature that is added to $X_S Y_C$ that does not belong to the timbre or envelope characteristics of a particular sound. Fennelly's nomenclature, shown in Figure 2.5, proposes manifold subgroups, each of them dedicated to a specific binding feature such as reverberation, modulation, glissando, feedback and so on. For example, nr, r, R, and R_o represent no reverberation, some noticeable reverberation, high reverberation, and reverberation only, respectively.

TABLE III: Enhancement E

0	none		
nr	no reverberation	v	"natural" vibrato
r	some noticeable reverberation	V	"abnormal" vibrato
R	high reverberation		
R_o	reverberation only	b	beating
g	glissando during decay (↑↓)	I	iteration
G	glissando connecting pitch levels (↑↓)	FB	feedback
VS	variable speed	L	use of loops
AM	amplitude modulation other than vibrato		
FM	frequency modulation other than vibrato		

Figure 2.5 Fennelly's classification of E

2.1.2. Application of Fennelly's Taxonomy

In the final paragraph of his article, Fennelly offers a short analysis of Bülent Arel's *Fragment* (1960) to demonstrate the practical use of his timbral naming convention.[9] The piece is an electronic music composition by a Turkish composer. Figure 2.6 reproduces Fennelly's graphic overview of the work and its timbral content.

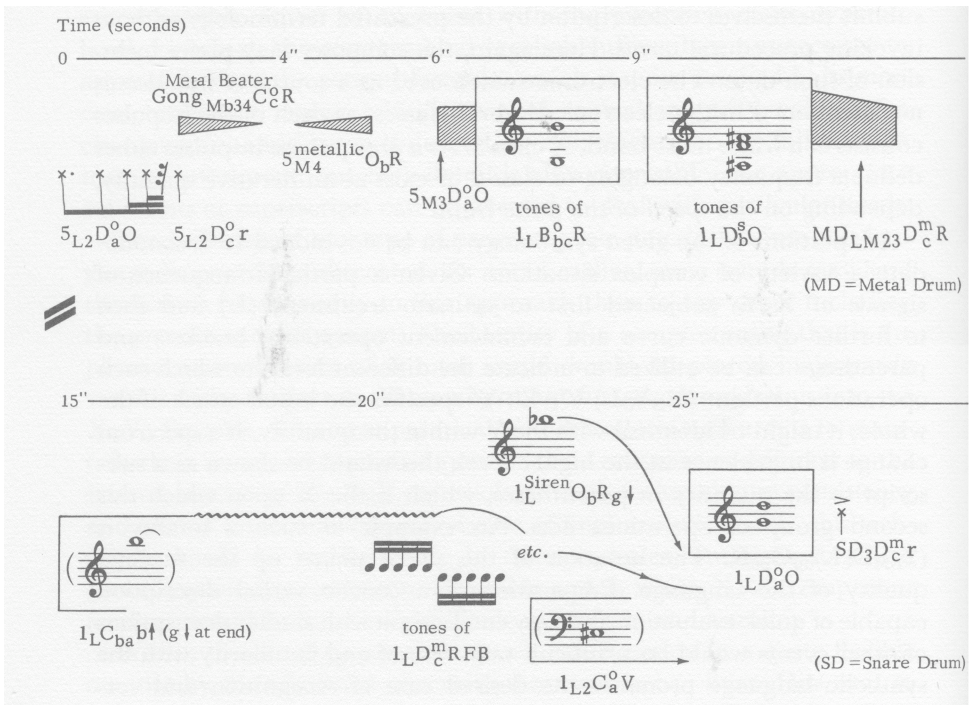

Figure 2.6 Fennelly's application of his taxonomy to *Fragment* (1960)

A closer look to the first four seconds of the analysis shows the labels in practice. $5_{L2}D_a{}^oO$ and $5_{L2}D_c{}^or$ stand for white noise as shown by their timbre descriptor 5; the first subscript L tells us that there are only low components and the second subscript 2 denotes the registral placement of those spectral components as medium low. The envelope section of the label ($Y_{Cd}{}^i$) starts with D and it tells us that both sounds have rapid growth,

[9] Fennelly, "A Descriptive Language for the Analysis of Electronic Music," 94.

namely firm attacks. Both sounds have no characteristic attack transients; the first sound has a steady continuation where the second sound diminishes in intensity as illustrated by an "a" and "c" in their subscript respectively. The enhancement part shows that the second white noise has some noticeable reverberation (E label is r) whereas the first one lacks such (or any) enhancement (E label is 0).

Gong $^{\text{Metal Beater}}{}_{\text{Mb34}}C^{0}{}_{c}R$ is a more complex descriptor: it is a natural analog, a gong, played with a metal beater as shown in the superscript. The subscript shows a fluctuating spectrum of midrange components: b illustrates a spectral filtering that narrows down toward the bottom. 3 and 4 are for registral denotation of midrange and medium high respectively. It has a moderate attack (C) and a decreasing intensity (c). It has no specific attack characteristics (0) and it is enhanced by a lot of reverberation (R). It is followed by $5^{\text{metallic}}{}_{\text{M4}}O_{b}R$, a medium-high white noise that midrange spectrum and metallic characteristics. It is coming from *niente*, imperceptible attack (O), and it increases in intensity (b) with a lot of reverberation.

As one can notice, Fennelly's work is remarkable in terms of segmentation and the classification of sonic units. The descriptive language that he developed constitutes a point of departure for the timbral class notation that is the kernel of the theoretical framework of this dissertation.

2.2 Toward Timbre Classes

2.2.1 Critique of Fennelly's Taxonomy

The theoretical apparatus of Fennelly is tailored almost exclusively for electronic music of the time in which the article was written. If we look at the main timbre descriptor, we can see that it refers to basic electronic signals, which were provided by the oscillators common to all electronic music studios at the end of the 1960's: "Hence the motivation for the present project: to provide a systematic, straight-forward means for the *concise identification and characterization of sounds* encountered in tape literature."[10] This historically limited view of electronic music is the first item to update in order to obtain a more "flexible core capable of extension and development for the particular instance."[11] When we have such an updated core, this descriptive system will be capable to suit the needs of not only electronic music but also the entire acoustic realm of contemporary music.

One seldom, if at all, encounters clearly identifiable sine waves or sawtooth waves in contemporary electro-acoustic music. Most of the textures fall under classes 3 and/or 4 for pitched sources and under 6 and/or 7 for non-pitched sources. For timbral analysis of acoustic-only components and their transformations, one should stay in class 4 for pitched instruments. The arbitrary assignments of numbers to timbre classes can be omitted without loss of meaning or function and can be replaced by a less numerical, more verbal description. As a result, the superscript t will be obsolete most of the times and can be removed from the timbre class descriptor.

2.2.2 Envelope descriptors and other considerations for timbre class notation

According to Fennelly's notation, the two fundamental components of the envelope descriptor consist of a timbre class's attack and sustain qualities. The envelope descriptor gives crucial information about the morphology of the sonic units, about how

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[10] Fennelly, "A Descriptive Language for the Analysis of Electronic Music," 80. (emphasis added)

[11] Fennelly, "A Descriptive Language for the Analysis of Electronic Music," 80.

the overall shape of the timbre class changes over time between timbre spaces. In Fennelly's work, attack type and the nature of continuation are again labeled with letters, which makes it difficult to comprehend the timbre class's morphological standing in an analytical context. The additions of superscript i is for the intensity relation of the attack to sustain qualities and of subscript d is for durational measurements assure that there is no symbolic help to visualize the envelope. Moreover, the italic use of S in durational subscript d for "very short" where the regular typeface S stands for "short," as well as the use of small case s and *s* as a subset of S, are all highly perplexing.

A more intuitive approach to represent the envelope is to use a modified version of the classic synthesizer format ADSR: attack, decay, sustain, and release. This envelope representation, first designed by Ussachevsky, enables us to conceive evolutionary shapes of sounds as contours in 2-D space.

Robert Morris put forward a theory of contour space in which he defined contour as "an ordered set of n distinct (contour-) pitches, with or without repetitions, numbered (not necessarily adjacently) in ascent from x to y (x< y). Normalized contours are numbered from 0 to n - 1. Contours can be written as strings of integers or as graphs." [12] Inspired by the contour theory developed by Robert Morris, Elizabeth West Marvin proposes "a duration space, analogous to contour space, that models relative duration in the same way that contour space models relative pitch height."[13] She quotes Gérard

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[12] Robert D. Morris, "New Directions in the Theory and Analysis of Musical Contour," *Music Theory Spectrum* 15/2 (1993): 206. See also Robert D. Morris, *Composition with Pitch-Classes: A Theory of Compositional Design* (New Haven: Yale University Press, 1987).

[13] Elizabeth West Marvin, "The Perception of Rhythm in Non-Tonal Music: Rhythmic Contours in the Music of Edgard Varèse," *Music Theory Spectrum* 13/1 (1991): 65.

Grisey as a composer who understands the importance of the perception of the relative durations in non-beat based music:

> Without a reference pulse we are no longer talking of rhythm but of durations. Each duration is perceived quantitatively by its relationship to preceding and successive durations. This is the case in the rhythmic writing of Messiaen and of the serialist school. In fact, a micro-pulse allows the performer or conductor to count and execute these durations, but it only exists as a way of working and has no perceptual reality. The more complex the durations ... the more our appreciation of them is only relative (longer or shorter than ...).[14]

Marvin presents a duration space (or d-space) "as a type of temporal space consisting of elements arranged from short to long. Elements in d-space are termed durations (durs) and are numbered in order from short to long, beginning with 0 up to (n-l), where n equals the number of elements in the segment and where the precise, calibrated duration of each dur is ignored and left undefined."[15]

The approach of this dissertation uses an envelope representation that involves four digits that give information about four duration segments of evolutionary states of a sound; therefore the cardinality of the segment group is fixed. The first digit represents the time for a sound to reach its peak level, namely the attack time. The second digit stands for the time it takes to reach its sustain level, namely decay time. The third digit is where the envelope descriptor diverges from the ADSR convention: it represents the duration of the sustained part of the sound instead of the classic ADSR descriptor that represents the level of the sustained sound. Finally, the fourth digit is for release time, the time it takes for a sound to fade out.

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[14] Gérard Grisey, "Tempus ex Machina: A Composer's Reflection on Musical Time," *Contemporary Music Review* 2 (1987): 240.

[15] Marvin, "The Perception of Rhythm in Non-Tonal Music," 66.

In order to represent four morphological segments of the envelope, four digits seem the most suitable; therefore to scale, or to calibrate, durational information that exceeds a single digit in base 10 helps us to obtain a clear picture about the shape of a specific timbre in four digits. In this case, 9 will be the maximum value that a digit can get and 0 will be the minimum. 0 as a minimum value in first position means that an attack is almost instantaneous, very typical for plugged or percussive instruments, whereas 0 in the last position means that the sound stops immediately, very typical for woodwinds, brass, or keyboard instruments without the sustain pedal pressed. Such an envelope contour can be represented by an array notation; for example <2 1 7 1> translates as follows: slow attack, moderate decay, long sustain, and short release.

Let us imagine a timbre class TC that has 25 seconds of total duration and that has the internal loudness design such as 5 seconds of attack time, no decay, 17 seconds of sustain time and 3 seconds of release time; the contour of such an envelope is <5 0 17 3>. That contour can be reduced to <2 0 3 1> by taking the digit that has the minimum non-zero value as 1 and reducing the others accordingly. We will take the value 3 of <5 0 17 3>, rename it as 1, and approximate all the other values in order to obtain the contour with smaller numbers. The reduced contour <2 0 3 1> is fairly congruent with the original contour. We can integrate this envelope descriptor to the timbral descriptor as TC_{2031} whenever the analysis entails supplementary data about the shape of timbre classes. Such contour notation facilitates the detection of morphological similarity between timbre classes. As Morris states, the contour "can be interpreted as pitches, dynamics or chord densities in time… Contours need not even be temporal."[16] In this

[16] Morris, "New Directions in the Theory and Analysis of Musical Contour," 206.

case, we will refer to these contours as *morphological contours*, since they reflect the durational shapes–or envelope signatures– of timbre classes.

The integration of dynamic information into the envelope descriptor is very useful. However, the methodology proposed by this dissertation will disregard the dynamic component and will concentrate merely on the morphological contour of the timbre class when it is necessary. The morphological metrics of timbre classes, that is their similarity and/or proximity relations of their shape based on a measurable distance unit, are beyond the scope of my research, although they may constitute a natural coda to the current study.

2.2.3 Revisions for Enhancements

Enhancements are, as in Fennelly's taxonomy, subgroup qualities that contribute to timbre and envelope properties. They are the most context-dependent aspect of the timbre-class definitions. Any attribute that is not related to source quality, spectrum profile, sound morphology, and durational data could be incorporated as suffixes to the existing timbre class formulation. The methodology for this dissertation will not use enhancements in order to keep the focus on timbre classes and their transformations.

2.2.4 Context-dependent classes as opposed to fixed timbre classes

Let us look at a simple example in order to see how context-dependent timbre descriptors work in segmenting a musical passage into its timbral components. Figure 2.7 shows the opening bars of Stockhausen's *Zeitmasse*.

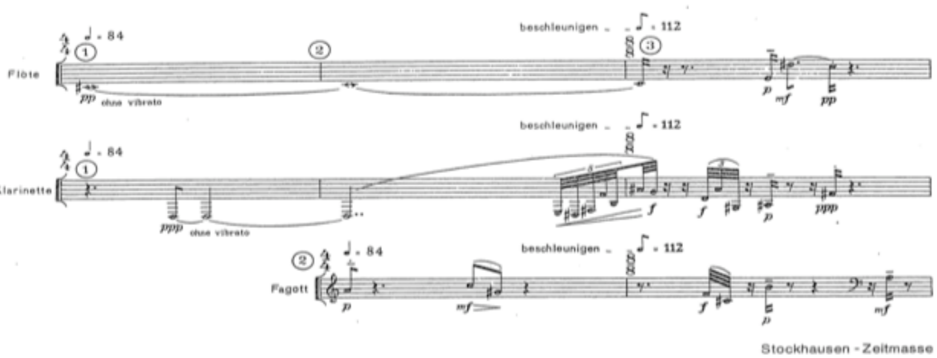

Figure 2.7 First Bars of *Zeitmasse* by Karlheinz Stockhausen

There are various timbre-conscious ways to look at this passage: we can take the flute's C# and the clarinet's D as if they belong to the same sound unit and therefore to the same layer that is sustained without any stress and that works as a drone, a background to the bassoon's attacked notes. These attacked notes disrupt the sustained quality of the drone layer, as one can see in the clarinet line at the end of the second measure, forcing it to morph to a pointillistic space. In this version we can segment the passage into two timbral layers; FL-CL-LONG, the C# and D, and ATTACKED starting with the bassoon in measure 2, contaminating the passage by making it more and more transient and sparse. Another way to consider the segmentation is to group the sustained notes of the flute and clarinet with the ones of the bassoon and to create a conjoint layer where the attacked notes become a part of the same layer. Then we can hear the passage as if it is going from sustained lines toward attacked points and being in dialectical relation with the pointillistic space that follows. In this case one timbral descriptor is enough to characterize it formally: SUSTAINTOATTACKED. Which one of these descriptors will be more rewarding in the analysis of the rest of the piece is an open question.

Nevertheless the second descriptor has potential to act more than a local one; it can perform a generalized task of modeling a certain kind of sonic behavior that reveals more than a circumstantial grouping. The generalized features of certain descriptors enable us to consider them as timbre classes. These classes belong to the specific piece of study, but they can still prove themselves to be analytically rewarding and suggestive of different modes of listening.

What does make us realize the timbral groups? One could argue that the clarinet line in measure 2 can be seen as an instrumental gesture and that the timbral groupings are merely incidental. Some core concepts of cognitive psychology, especially the ones that are associated with auditory perception, are instrumental in discerning timbral classes.

2.3 Auditory Perception and Timbre: Gestalt Revisited

Albert S. Bregman in his renowned book *Auditory Scene Analysis: The Perceptual Organization of Sound* presents scientific evidence gathered from various experiments, which he conducted over a span of twenty years, on how the human auditory system codifies "streams" of sound into meaningful entities. The perception of sound is performed through what he calls "scene analysis": our auditory system operates on sensory data (i.e., incoming sounds) and organizes them as "auditory streams" in order to obtain a "useful representation of reality."[17] An auditory stream is "our perceptual grouping of the parts of the neural spectrum that go together."[18]

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[17] A.S. Bregman, *Auditory Scene Analysis: The Perceptual Organization Of Sound* (Cambridge, Mass: M.I.T. Press, 1990), 3.

[18] Bregman, *Auditory Scene Analysis*, 9.

Diana Deutsch, along with Bregman and others, argues that those auditory streams are grouped together according to a number of laws that are pertinent to vision but work as efficiently in the auditory realm.[19] Those laws are very similar to the ones that were unraveled by Gestalt psychologists in the beginning of the twentieth century as a predictive model for human perception of visual phenomena. They are in accordance with the principle of *prägnanz* (conciseness) and they are operative while grouping visual components into meaningful streams. In auditory scene analysis, if there are strong resemblances between stream units then there is a high probability that they will be grouped as coming from the same source, which is in accordance to the similarity rule. By the same argument, dissimilar sounds are predicted to come from different origins. Similarity in terms of audio can invoke the various aspects of sound phenomenon. In Bregman's words, "sounds of similar timbres will group together so that the successive sounds of oboe will segregate from those of the harp."[20] The next significant rule is the one of proximity: spatial or temporal proximity pulls the components together compared to the ones that are further apart.

The auditory scene analysis parallels two more Gestalt principles: the law of

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[19] R. L. Gregory, *The Intelligent Eye,* (New York: McGraw-Hill, 1970); N. S. Sutherland, "Object recognition" in E. C. Carterette & M. P. Friedman (Eds.), *Handbook of Perception Vol. III* (New York: Academic Press, 1973), 157–186; J. Hochberg, "Organization and the Gestalt Tradition," in E. C. Carterette & M. P. Friedman (Eds.), *Handbook of Perception Vol. I* (New York: Academic Press, 1974), 180–211; Diana Deutsch, "Musical Illusions," *Scientific American* 233/4 (1975), 92–l04; A. S Bregman, "The Formation of Auditory Streams," in J. Requin (Ed.), *Attention and Performance Vol. VII* (Hillsdale, NJ: Erlbaum, 1978), 63–76; I. Rock, "The Description and Analysis of Object and Event Perception," in K. Boff, L. Kaufman, & J. Thomas (Eds.), *Handbook of Perception and Human Performance* (New York: Wiley, 1986), 1–77.

For the Gestalt principles in music see Diana Deutsch, "Grouping Mechanisms in Music" in *The Psychology of Music, 2nd ed.* (New York: Academic Press, 1999), 299-348. See also James Tenney and Larry Polansky, "Temporal Gestalt in Music," *Journal of Music Theory* 24/2 (1980): 205-241.

[20] Bregman, *Auditory Scene Analysis*, 19.

common fate and the law of closure. The law of common fate is a "common motion within a subgroup that binds that group together perceptually and at the same time segregates it from the other group." The law of closure is the tendency of closing the gaps in a given form, line or structure. This law is best exemplified with the phenomenon of masking where "a loud sound covers up or drowns out a softer one."[21] This creates an "illusion of continuity" as in the case of a long flute note interrupted by loud orchestral chords; the illusion is the one of a continuous flute line even though the flute rests during the interrupting chords. We can use this example to go over the mechanisms of organization applied to the sensory data: first, segregation, which helps us distinguish the flute line from the background noise and also from the intervening chords. Segregation is a requisite for audio scene analysis; it is a parsing mechanism by which we organize and categorize sensory input in order to form conceptual or perceptual representations of the world surrounding us. According to Bregman, this segregation can be made primitively, which requires the hypothesis that at least some segregation faculty is innate, or schema-based, which stems from learning patterns, in other words culture. This organizational mechanism is twofold: one process deals with the grouping of sensory input according their temporal position and integrating them in a sequential stream (i.e., melody and rhythm), while the other deals with integrating synchronous components into their respective stream according to their spectral components. The first one, the sequential grouping, or integration, relates to the symbolic features that are represented horizontally in western music notation while the latter simultaneous grouping, or integration, relates to the vertical properties such as chords, harmony, or timbre.

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[21] Bregman, *Auditory Scene Analysis*, 27.

This tendency of our auditory system to group musical features is at the core of the basic hypothesis of this dissertation: timbral features can be generalized to be more than local imprints. In the last quarter of the twentieth century, sound has been proven to be much more than a linear system by Max Matthews, Jean-Claude Risset, John Pierce, and others. These scholars describe sound as a very complex phenomenon wherein the attack transients, the relative amplitude and the phase of partials, the physical behavior such as the resonance and excitation modes of the instrument, and the manifold components interact nonlinearly to make up the physical phenomenon, namely sound.[22] Complex systems develop *emergent properties*; when the components form a higher-order system, the newly formed properties –the emergent properties– of the whole are to some extent different from those of their components. According to Jeffrey Goldstein, emergence refers to "the arising of novel and coherent structures, patterns, and properties during the process of self-organization in complex systems." [23] Peter A. Corning gives a summary of the common characteristics of emergence introduced by Goldstein: "radical novelty (features not previously observed in the system); coherence or correlation (meaning integrated wholes that maintain themselves over some period of time); a global or macro 'level' (i.e., there is some property of 'wholeness'); it is the product of a dynamical process (it evolves); and it is 'ostensive'— it can be perceived."[24]

Our auditory system applies groupings to sensory data in order to create a

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[22] Max Mathews, "Introduction to Timbre" in ed. Perry R. Cook, *Music, Cognition, and Computerized Sound* (Cambridge, Massachusetts: the MIT Press, 2001); John R. Pierce *The Science of Musical Sound* (New York: Scientific American Library, 1983.) See also Jean-Claude Risset and David L. Wessel, " Exploration of Timbre by Analysis and Synthesis" in Diana Deutsch, ed. *The Psychology of Music,* (New York: Academic Press, 1982): 113-169; Stephen McAdams, "Perspectives on the Contribution of Timbre to Musical Structure," *Computer Music Journal* 23/2 (1999): 85-102

[23] Jeffrey Goldstein, "Emergence as a Construct: History and Issues," *Emergence* 1 (1999): 49-72.

[24] Peter A. Corning, "The Re-Emergence of 'Emergence': A Venerable Concept in Search of a Theory," *Complexity* 7/6 (2002): 18-30.

distinction between the parts and the general composition of a sound so that a particular combination of components has a specific meaning divergent from its constituent parts. This is so especially when it comes to timbre; timbre arises from the simultaneous organization of auditory streams at a macro level as well as sequential and simultaneous organization at a micro level. The technique of orchestration is based on this concept of emergent properties where one hears the overall sound signature of a certain composer instead of the combination of instrumental parts. Bregman calls this an auditory chimaera: "[Music] may want the listener to accept the simultaneous roll of the drum, clash of the cymbal, and brief pulse of noise from the woodwinds as a single coherent event with its own striking properties. The sound is chimeric in the sense that it does not belong to any single environmental object."[25] The resultant auditory stream is an integrated aural image, a chimeric percept, that does not refer to any real–environmental–sound but rather to a fictional construct, located hierarchically at a higher perceptual level. Stephen McAdams refers to those percepts as *virtual sources*; Pierre Boulez calls them *phantasmagoric instruments*.[26] Milton Babbitt mentions "the *misidentification* of timbral families, and the inability to identify components in a complex as a result of the precise synchronization of attacks of the component frequencies."[27]

When we go back to the Stockhausen example (Fig. 2.8), we can develop a whole new perspective regarding the previously mentioned aural strategies for hearing the

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[25] In Greek mythology, a *chimaera* is a fire-breathing female monster with a lion's head, a goat's body, and a serpent's tail. Bregman, *Auditory Scene Analysis*, 460.

[26] Stephen McAdams, *Spectral Fusion, Spectral Parsing, and the Formation of Auditory Images* (Doctoral Dissertation, Stanford University, 1984); Pierre Boulez, "Le Timbre Dans la Littérature Instrumentale de la Vingtième Siècle" (Paper Presented at the Seminar on Timbre, Institut de Recherche et Coordination Acoustique/Musique, Paris, April 13-17,1985).

[27] Milton Babbitt, "The Synthesis, Perception, and Specification of Musical Time" in *The Collected Essays of Milton Babbitt* ed. Stephen Peles et al. (Princeton: Princeton University Press, 2003): 176.

passage: the first strategy consists of two distinct layers called FL-CL-LONG and ATTACKED that segregate the passage according to their timbral features and group them into their respective stream. Sustained notes go together and form one stream, whereas attacked notes form another one. This auditory phenomenon reflects the aforementioned grouping procedures: the two streams are segregated according to the rule of similarity. The sustained layer is differentiated from the attacked one via simultaneous integration that analyzes synchronous features of flute, clarinet, and bassoon, in this case the attack transients being the most significant feature. At the same time, sensory inputs that are considered similar by the auditory scene are grouped together. This togetherness is fortified by the rule of common fate: the sustained stream (FL-CL-LONG) will attract any new input that carries the characteristic of "less transients" and "continuity" whereas the attacked stream (ATTACKED) will pull every element that has "more transient" and "less continuous." This auditory schema will be in effect until the thresholds that originally formed the stream are strongly challenged. The blurring of what constitutes "continuous," for example, will force the auditory stream to reconsider grouping mechanisms and the membership requirements. In our example, the scene is very transparent and the streams are well formed. ATTACKED is superimposed on FL-CL-LONG in m. 2, then FL-CL-LONG disappears.

The other strategy was suggesting that the whole passage be considered as a closed space where the sustained stream conjoined with attacked notes forms SUSTAINTOATTACKED. Such representation invokes chimeric percepts. The long notes of the flute and the clarinet introduce a timbral space where the attacked notes of the bassoon are also member of the same space. That space is an extended space of timbral events wherein a certain collection sonic objects are structurally and dynamically bound to each other. Such collections, or groupings, display behaviors of complex systems where an evolving and ostensive global whole, the timbral space, has a certain coherence and novelty.

If we want to approach the analysis from a timbral perspective it is more pleasing to suggest that the space formed by two contrasting timbral components in the first two measures is processed to such an extent that in m. 3 all the sustained elements are filtered out. "Disappeared" and "filtered out" are not just trivial choices of terms but rather they denote a mode of hearing the passage for the analyst from two different perspectives. The difference between the two strategies is a matter of analytical distance. The first strategy operates at the immediate perceptual level, while the second is schema-based; it requires a shift of perspective. It gives us the flexibility to zoom out from the immediacy of streams and to consider the field of possibilities suggested by the *limina.*[28] Musical analysis of timbral structures will benefit the most from these two strategies without choosing one over the other. The timbral idiosyncrasies of each piece of music require auditory scene analysis in order to segment the musical surface while building meta-groups of sensory input, groups of groups, or as we call it timbral spaces, helps us to consider the shift of perspective that we need in order to suggest new modalities of listening. The latter strategy is also closely related to a mode of hearing favored by the initiators of French Spectral Music, especially by Gérard Grisey, who preferred to call his music as *musique liminale*.[29]

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[28] From *limen,* a threshold below which a stimulus is not perceived or is not distinguished from another.

[29] Gérard Grisey, "La Musique, Le Devenir des Sons," *La Revue Musicale-L'Itinéraire* 421-424 (1991): 291-300.

Figure 2.8 reproduces the opening measures of *Partiels* (1975) by Gérard Grisey.

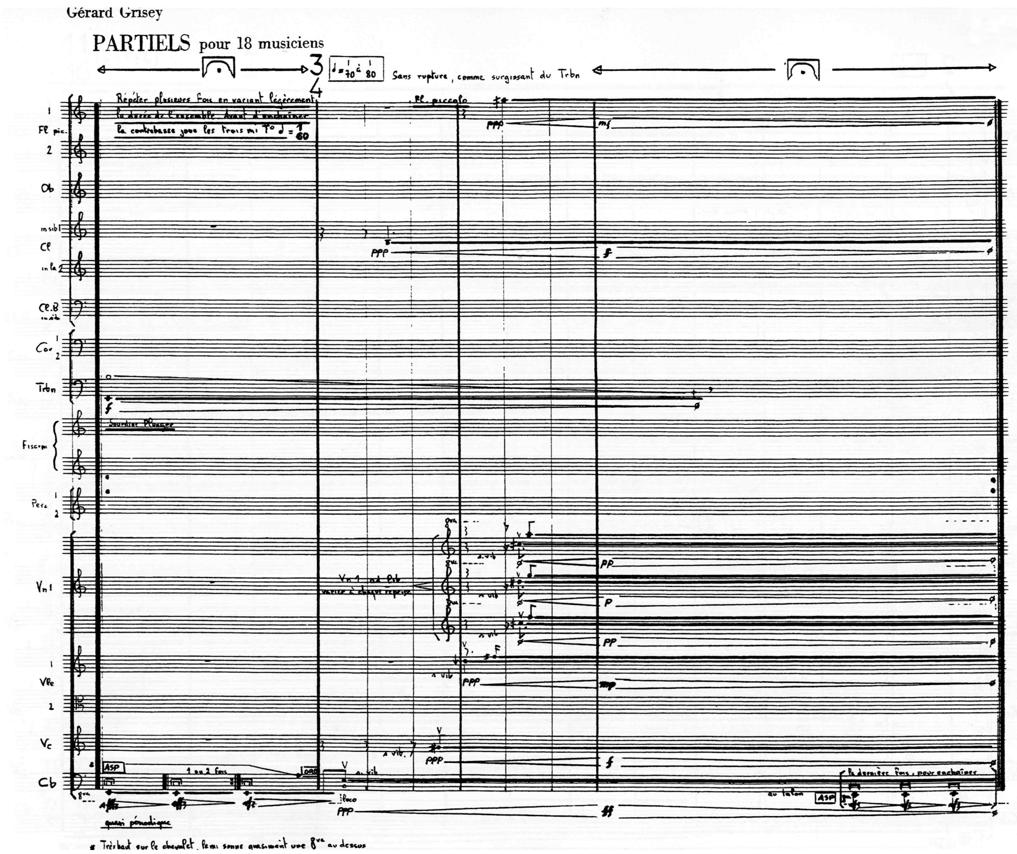

Figure 2.8 The opening measures of *Partiels* (1975) by Grisey. Reproduced by kind permission of Universal Music MGB Publications.

Here we can see how the composer makes use of the timbral properties of a single note event and turns it into a timbral object, pushing it around the threshold of becoming a timbre class. The single note event is an attacked low E in the contrabass and trombone. After several iterations of this contrabass E1, the rest of the ensemble builds gradually the spectrum of E2 in the trombone by playing the frequencies of the spectrum as instrumental lines. This musical idea covers approximately the first four minutes of the musical surface while, within each iteration of the overall idea, the “composed spectrum” of the E goes through variations. This reflects one of the early processes of spectral music, namely "instrumental synthesis," where members of an acoustic ensemble play instrumental parts that reflect the partials of previously analyzed and composed spectra.[30] Thus the ensemble is treated as a sonic entity–a Gestalt instrument– that produces sonic structures rather than instrumental "voices." This technique envisages that the sonic architecture of the whole ensemble becomes an agent that manipulates micro-level information regarding the sonic material –spectrum analysis–in order to transcode it into macro-level information regarding form, time, and timbre. The E1 of the contrabass is presented at a higher perceptual level; its subsequent decomposition into its constituents gradually foreshadows the initial integration into an auditory stream. The constituents of the E spectrum are varied with each repetition in order to reflect the complexity within the natural sound phenomenon–assured by the unpredictability of the motion and the morphology of the partials– as well as to micro-transform the musical material to alter the percept, to reshape it with Time. As Joshua Fineberg notes, the instrumentally synthesized version of E generates "an amplification and transfiguration of the trombone note," and opens a "doorway to a vast new domain of sound found within the original sound." [31] This play of threshold between a model (trombone's E) and its sonic construction (instrumental synthesis of the spectrum of that E) uncovers the structural relationship between two sonic units. The constructed part bears resemblances, or carries "spectral signature" as David Lewin called it, to the model by mapping certain sonic invariants of the spectrum to a higher perceptual hierarchy.[32] We might call this level E-

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[30] Joshua Fineberg, "Guide to the Basic Concepts and Techniques of Spectral Music," *Contemporary Music Review* 19/2 (2000): 85

[31] Joshua Fineberg, "Musical Examples," *Contemporary Music Review* 19/2 (2000): 117

[32] David Lewin, *Generalized Musical Intervals and Transformations* (New Haven: Yale University Press, 1987), 83.

SPECT, for spectrum of E, a timbre class whose subsequent local transformations will reorganize the musical surface and our understanding of it. The varied repetition ensures that the stream E-SPECT exposes its emergent properties those, which one cannot hear–realize–while in state E.

In that case, we can apprehend E-SPECT as a class wherein each member is filtered through a dynamic process of micro-variation to reach a new state; nevertheless they contribute to the sonic paradigm, or in other words “E-SPECTness.”

Conclusion

As we have seen, timbre class is defined by a certain representation of sonic units generalizable to go beyond the local instances/realizations. Timbre classes are sets of sounds robust enough to reach above the musical context in order to suggest timbral models with potentialities to incite new manners of hearing a musical situation.

The next chapter will introduce some concepts on how these timbre classes form groups and interact dynamically inside of these groups. Timbre class groups will form timbral configuration spaces and structural relations between members of these groups will form what we will call timbral paths.

Chapter Three

Transformations Of Timbre-Classes

Let us recall the main hypothesis of this dissertation: musical spaces of timbral constructs are audible, composable, and they have group properties. The purpose of this analytical apparatus is not to do a vain reverse engineering concerning timbral compositions. I am rarely concerned with how timbral configurations–or chimeras– are achieved, even less with what they mean when they are ripped apart from their music-ecological system.

The focus is to gain a perspective on the transformational activity of timbral constructs: in other words, how they act and mediate their own network of meaning. As Klumpenhouwer clarifies, "Transformational thinking does not involve 'observed measures of extension.' Under transformational thinking, activity, rather than measurement, mediates the objects at hand."[1] In Chapter 7 of *Generalized Musical Intervals and Transformations*, Lewin proposes the group of numbers that represents intervals (IVLS) by revealing their transformational properties. Dmitri Tymoczko observes that, unlike the traditional pc interval labels, members of this group "describe

[1] Henry Klumpenhouwer, "Essay: In Order to Stay Asleep as Observers: The Nature and Origins of Anti-Cartesianism in Lewin's Generalized Musical Intervals and Transformations," *Music Theory Spectrum* 28/2 (2006): 280.

what they do to the objects in the space."[2] Lewin states:

> From this point of view, the interval labels the transformation itself; it is a name for "a way of moving" (from anywhere to somewhere else), rather than a relation between fixed points in musical space; it labels a *res fabricans* rather than a *res extensa*.[3]

In timbral sets, it is problematic to prioritize IVLS, the group of intervals. Suppose two timbral GIS: S1 is piano sounds made by hitting piano keys, IVLS, pitch intervals, and int(x,y) is a bijective function which maps the members of IVLS into S1. This is GIS1. S2 is piano sounds made by scraping piano strings, IVLS pitch intervals again, and int(p,q) is a bijective function which maps the members of IVLS into S2. This GIS2. It is possible to use the GIS1 to make music, as did many composers who wrote for the keys of the piano. Nonetheless, it is possible to conceive a piece of music played solely by scraping the strings of the piano. In GIS2, the sonic effect of scraping will be noisy, most of the time without a perceivable pitch. However D1 will still sound lower than A#1. This lowness is not reflected by the pitch interval characteristic of IVLS; it is hard to talk about some pitch interval between D1 and A#1 when both are scraped. Yet, we can point, although paradoxically, to an immeasurable unit of difference.

In this case we can see that IVLS works as a group of intervals that has two very separate functions: in GIS1, IVLS refers to a Cartesian pitch domain as a group of pitch intervals. In GIS2, IVLS works as a geographical map–a tablature– pointing to the strings of the piano. Lewin observes:

In any of these cases, our perception of an "interval" involved in the situation arises

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[2] Dmitri Tymoczko, "Lewin, Intervals, and Transformations: a Comment on Hook," *Music Theory Spectrum* 30/1 (2008): 165.

[3] David Lewin, "Forte's 'Interval Vector, My Interval Function', and Regener's 'Common-Note Function,'" *Journal of Music Theory* 21/ 2 (Autumn, 1977): 233-4.

> not directly and *a priori*, but indirectly as a symptomatic fallout from our perception of a transformational situation. In summary, what is at issue here is on the one hand the extent to which the idea of an "interval" in at least some sense can be attached context-free to "the" relation of x and y, prior to whatever systems of transformation one might develop and indeed determining just which transformations are developed. […]In this connection, any such relation must be context-dependent, first because we need a certain larger musical context if we are to be sure of the relation A(x) = y as opposed to the relation B(x) = y (we may not be able to be sure, or indeed desire to), and second because the outlook implies, as an abstract larger theoretical context, a certain gamut or universe of material over which the transformations operate, within which x and y are embedded.[4]

This context-dependency is at the heart of the analytical model that this dissertation puts forward. Departing from Lewin, the objective is to fathom a set of timbral functions as "a symptomatic fallout from our perception of a transformational situation."

3.1 An Analytical Model for Timbre Compositions

I propose a set of analytical concepts from low level to high level:

TS: Timbral segments/Sonic objects: analytical frames of timbre groupings

TC: Timbral classes: abstracted timbre classes of invariance of local realizations

TP: Transformational/Timbral paths: dynamic relations/operations/functions that are between TS's or TC's

TCS: Timbral Configuration Space: a space of timbral functions

We dealt with TS and TC in Chapter 2. Now we will conceptualize Timbral Paths and

[4] Lewin, "Forte's 'Interval Vector,'" 231-232.

Timbral Configuration Spaces.

3.2 Timbral Functions or Timbral Paths

In order to see the potentiality of timbral constructs, I will define them as dynamic timbral functions in musical context and suggest analyzing contextual transformations that relate them; naturally, these timbral functions have multiple components that could be represented in an array of potentialities. Whether all the potential qualifications are considered will depend on the contextual transformations and on the topographic/perceptional space to which they belong. This space is the concept of *Configuration Space* that I borrow from artificial intelligence theory:

> Assume that the world and a robot (or set of robots) have been defined. The configuration space, C, is a topological space generated by the set of all possible configurations. Each configuration $g \in C$ corresponds to a transformation that can be applied to the robot, A. A complicated problem such as determining how to move a piano from one room to another in a house can be reduced using C-space concepts determining a path in C. In other words, the piano (3D rigid body) becomes a moving point in C. (...) This space of transformations is termed the configuration space, which represents a powerful representation that unifies a broad class of path planning problems in a single mathematical framework.[5]

I find useful the relation of this concept of path planning with the conception of a musical space and the path of the timbral object that it involves. Musical spaces and motions are useful metaphorical transfers for our understanding of music.[6] Music-theoretical models for the concept of space include Lerdahl's Tonal Pitch Space or

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[5] Steven M. LaValle, *Planning Algorithms* (New York : Cambridge University Press, 2006) Also available online at http://msl.cs.uiuc.edu/planning/. The quotations are from the 2003 online version of the book (pp. 59-65) when it was a work in progress.

[6] The extensive literature on this subject includes: Nicholas Cook, *Music, Imagination, and Culture* (Oxford: Clarendon Press, 1990); Roger Scruton, *The Aesthetics of Music* (Oxford: Clarendon Press, 1997); and Lawrence M. Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (New York: Oxford University Press, 2002).

Morris's Voice Leading Spaces.[7] The inherent difficulty of applying these constructs to timbral analysis lies in the fact that they rely on pre-defined concepts of tonal functions or twelve pitch-classes, which are irrelevant most of the time when it comes to timbral analysis. Consequently, I propose a Timbral Configuration Space (TCS) that takes account of all motions and contextual transformations of the timbral objects in a defined musical surface.

Dynamic concepts of *Transformational Paths* (TP) will be helpful in translating timbral motions and transformations:

> A path, P, is a continuous function, P: [0; 1] → X, in which X is a topological space. Note that a path is a function, not a set of points. Each point along the path is given by P (s) for some s ∈ [0; 1].[8]

Let us imagine two timbral objects X and Y that we hear in a sequence. Y bears some resemblance to X in that it has some invariance that enables us to perceive Y as a variation of X. We can say that Y is chronologically related to X while keeping some timbral features intact and changing others. The chronological order is important because we only hear Y as varied X if and only if we hear X first. X, in this case, constitutes a model, a temporary ideal so that as soon as we hear Y we will catch some "X-ness" in it. This "X-ness" in Y is strongly related to our discussion of timbre class (TC) in Chapter 2 of this dissertation.

Yet, Y is not X. There are some timbral features that change over time that makes us perceive Y somewhat "not X" but "X-ish." If I am X, the timbral features that I have to change in order for me to become Y, in other words, the path that I have to walk to

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[7] Fred Lerdahl, *Tonal Pitch Space* (New York: Oxford University Press, 2001); Robert D. Morris, "Voice-Leading Spaces," *Music Theory Spectrum* 20/2 (Autumn, 1998): 175-208

[8] Steven M. LaValle, *Planning Algorithms*, 119.

become Y is what we call a *timbral path.* Since I am not a primate but a timbre, I can walk more that one path simultaneously to become Y. Some of my timbral features will remain invariant–my X-ness– through that path while some of them will change.

Would any timbral operation qualify as TP? The requirement is simple: if an object, which is a member of a TC, sees some of its features changed under TP then the answer to the question is affirmative. Lewin states that contextually some transformations have internal (or spatial) character while some have a progressive (dynamic) one: "The 'internal' transformations make a thing or each of two things very like itself; the 'progressive' transformations make an earlier thing very like a later, different thing."[9] The degree of change enables us to distinguish two types of TP: internal and progressive. The degree of invariance of X in Y is what makes a path internal or progressive.

> What I wish to emphasize is that our theoretical format enables us to distinguish a formally different function for T_5 and T_7 than for T_6, T_1 T_8 etc. in this context. T_5 and T_7 we can call "internal," "spatial," "prolongational" etc. These transformations have to do with static, internal features of various events. The importance of T_5 has to do with the fact, e.g., that T_5 (lh) has two common tones with lh itself; this does not involve any relationship in time between lh and something else that comes before or after. In contrast, the "kinetic", "dynamic" or "progressive" transformations T_6, T_1 T_8, I, J and K assume importance because of the relative similarities between one thing (rh), when suitably transformed, and a *subsequent* and *different* thing (lh) to which it is moving.[10]

If a TP leaves no X-ness in Y, which means that Y loses its membership in TC (X), then it is a progressive transformation, a membership changing operation. If X-ness remains in Y after going through a TP, then it is an internal transformation. This implies

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[9] David Lewin , "Transformational Techniques in Atonal and Other Music Theories," *Perspectives of New Music* 21/1-2 (Autumn, 1982 - Summer, 1983): 343.
[10] David Lewin , "Transformational Techniques,"342.

that some TSs are immune to the transformational power of TPs.

There are two sets of timbral functions:

1) **Internal:** Functions that articulate and enforce class membership; identity based operations. In a family of sonic objects (TC), this kind of TPs maps TC members onto TC members. Therefore they articulate some degree of invariance.
2) **Progressive**: Functions that change class membership; transformations that map some TC onto some other TC. They articulate how the invariance that defines a certain internal function changes over some unit.

A set of internal functions is called Timbral Configuration Space.

Without going any further, let us have a look at some examples of timbral paths. Figure 3.1 reproduces the opening measures of *Partiels* (1975) by Gérard Grisey.

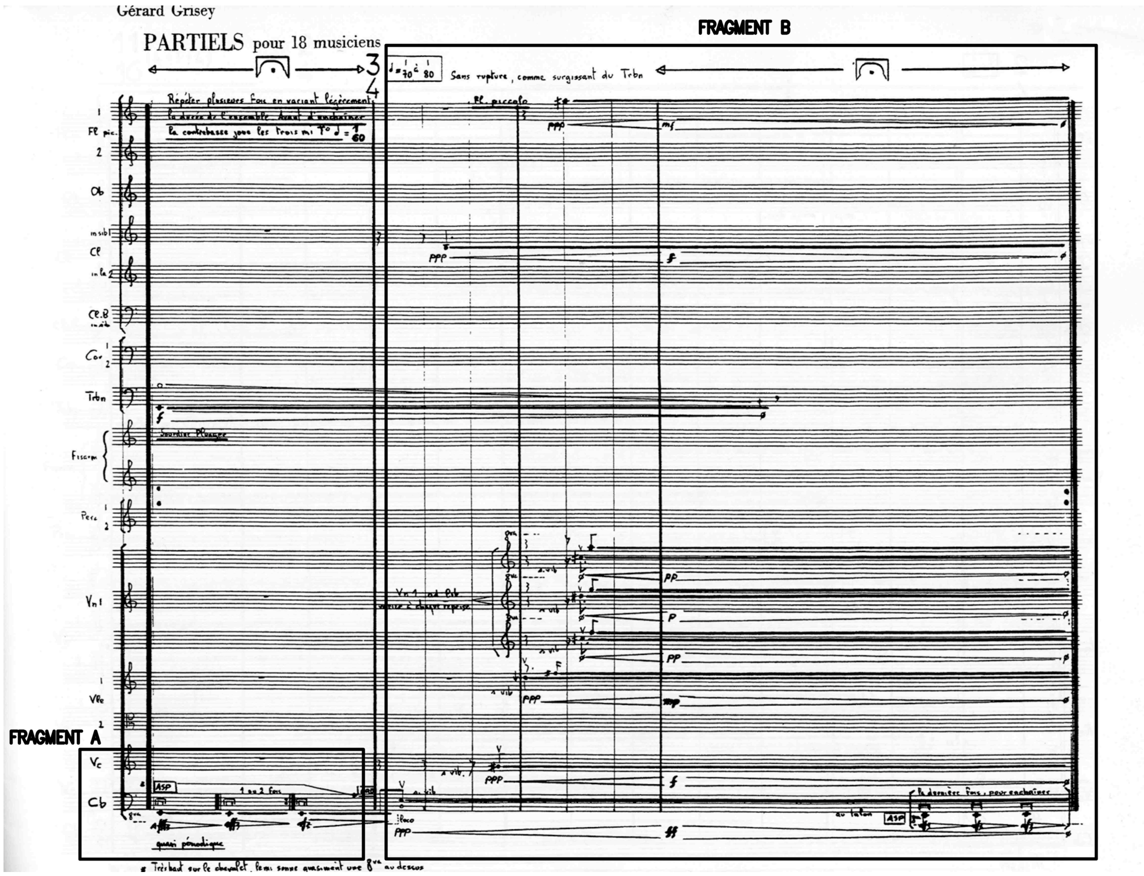

Figure 3.1 The opening measures of *Partiels* (1975) by Grisey. Reproduced by kind permission of Universal Music MGB Publications.

This example is an already familiar one: the introductory measures of Grisey's Partiels comprise a strong set of transformations. First we hear the trombone and contrabass note E attacked harshly (Fragment A), then transformed into an instrumental synthesis of the spectrum of E, namely E-SPECT (Fragment B) as illustrated in Figure 3.1. Fragment B–two violins, viola, violoncello, contrabass, clarinet, and piccolo parts–is characterized by long crescendi. Instrumental lines increase from PPP to various dynamic levels, which model the amplitudes of the partials of E. One can hear a very simple distinct feature of this fragment: it constitutes an antithesis to the attacked E's of the fragment A. Simultaneous onsets group objects into one perceptual stream due to the principle of integration, as we have seen in Chapter 2. As McAdams states, "the attack asynchrony and the decomposition of verticalities into horizontalities would concur to reduce the degree of perceptual fusion. Reduced fusion would mean greater segregation."[11] When we hear Fragment B articulating E while the onset decomposition occurs, the robustness of the context disintegrates in order to suggest that the sonic paradigm has shifted.

We can claim a timbral path that affects the attacks, the onsets types, of the timbres involved: STRIPATTACK is a transformation that wipes out the sharpness–or fastness–of the attacks. We can use our labeling convention to represent that function and use ADSR method to define the envelope of E:

$$\text{STRIPATTACK } (E_{1001}) = E_{0011}$$

STRIPATTACK is a progressive function: although objects that walk that path can still be recognizable, research shows that attack transients are of primordial importance in timbre recognition. (see Chapter 1, footnote 6) STRIPATTACK changes the class membership. There is a radical change between E and E-SPECT. Nevertheless, it does not suffice to change the whole auditory paradigm.

$$E \xrightarrow{\text{STRIPATTACK}} \text{some aspect of E-SPECTness}$$

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[11] Stephen McAdams, "Perspectives on the Contribution of Timbre to Musical Structure," *Computer Music Journal* 23/3 (Autumn, 1999): 99.

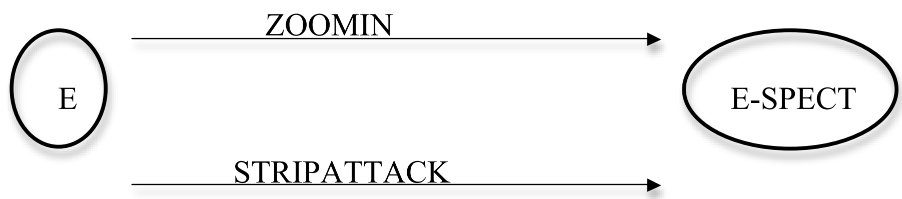
A closer look at the concept of instrumental synthesis reveals the fact that the gesture of bringing out the partials, which are below the threshold of hearing, in other words moving from Fragment A to Fragment B is itself a transformation. It brings out some partials above the threshold of hearing, the very counterpart of the concept of zooming in visual domain in that we surpass our physical limitation via an auxiliary tool. In that case, we can talk about a function ZOOMIN that transforms a certain timbral construct by revealing/simulating its internal design:

$$\text{ZOOMIN (E)} = \text{SOMEPARTIALS } (n, n+1, \ldots, n+b)$$

where n is the partial rank and b is the highest boundary.

$$E \xrightarrow{\text{ZOOMIN}} \text{some aspect of E-SPECTness}$$

The timbral construct E is affected by the timbral paths STRIPATTACK and ZOOMIN. Neither ZOOMIN nor STRIPATTACK has the power of mapping E onto E-SPECT alone. It is a combined path, a multi-level transformation that occurs in order for E to become E-SPECT. As it has been stated earlier the timbres can walk multiple paths at the same time. This is not a mere coincidence, but most of the time an obligatory fact for timbral paths to be effective in the realm of changing sonic paradigms.



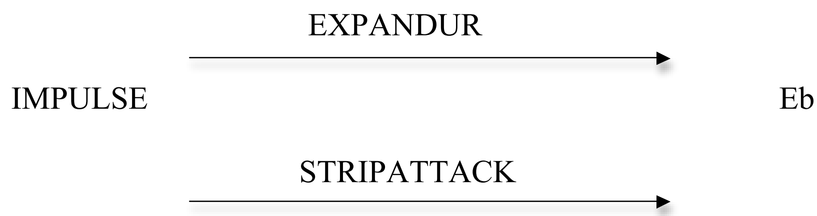
That is how a set of internal timbral functions can be contaminated by dynamic functions in order to move from one timbral space to another. In this case we can define a combined transformation X, which is the product of STRIPATTACK and ZOOMIN.

STRIPATTACK * ZOOMIN= X Transform

X (E) → E-SPECT

Here, X is a generalization of timbral paths STRIPATTACK and ZOOMIN on a hyper-plane; we use X to reduce the number of variables, to represent the entire configuration, which comprise Fragment A and B. X belongs to a group of hyper-timbral paths.

The second example is from Stockhausen's *Kontakte*, approximately seventeen minutes into the piece. It is the moment when we hear an electronic source descending in pitch and becoming an impulse, which in turn becomes a sustained Eb. Here again we can see a double action of timbral paths. Impulse and Eb represent two clearly distinct sonic spaces. The impulse moves to Eb synchronously via STRIPATTACK and a new path: EXPANDUR.



STRIPATTACK (IMPULSE) → Eb

EXPANDUR (IMPULSE) → Eb

We can clearly imagine a sound preserving some of its timbral class membership while expanding its duration within reasonable boundaries. So here again we have a combination of dynamic and internal timbral functions. This is not a coincidence: these two examples are clearly selected because of the fact that they represent a clear move from one sonic paradigm to another. This move is the result of the presence of a timbral dynamic function in the mix. One can hear sonic textures that do not move anywhere, while all the members of the set that defines the members of a timbral space are internal. Any mono-timbral musical work would qualify as an example as would most of the electronic textures of the ambient music of the 1990's.

While it is possible to deduce timbral paths from the aural experience, we can also enrich our timbral space by theoretical compliments of those paths. Therefore, we can claim the imaginary counterpart of EXPANDUR, some sort of timbral path that will contract the durations. For example, the sustained Eb in *Kontakte* will become an impulse when its durations are contracted. CONTRACTDUR is a theoretical inverse of

EXPANDUR. By the same token, we can imagine that ADD-ATTACK is a theoretical inverse of STRIPATTACK.

CONTRACTDUR (Eb) → IMPULSE

CONTRACTDUR $^{-1}$ → EXPANDUR

ADD-ATTACK $^{-1}$ → STRIPATTACK

Whether these imaginary paths belong to the original set, timbral space, is an open question. Their presence raises the issue that if they belong to the original space, although we do not hear them, they are the reasons of some perceptual expectations when it comes to timbre. In other words, timbral paths are already equipped with the potentialities of becoming what they are not. It is as if all the possible configurations are collapsed in order for us to hear what we hear.

3.3 Timbral Configuration Spaces

> The position of a single particle is specified by giving its three coordinates, *x, y*, and *z*. To specify the positions of two particles, six coordinates are needed, x_1, y_1, z_1, x_2, y_2, z_2. If there are *N* particles, 3*N* coordinates will be needed. Imagine a system of 3*N* mutually orthogonal coordinates in a 3*N*-dimensional space (a space of more than three dimensions is a purely mathematical construction, sometimes known as a hyperspace). To specify the exact position of one single point in this space, 3*N* coordinates are needed. However, one single point can represent the entire configuration of all *N* particles in the problem. Furthermore, the path of that single point as a function of time is the complete solution of the problem. This 3*N*-dimensional space is called configuration space.[12]

[12] "mechanics." Encyclopædia Britannica. 2009. Encyclopædia Britannica Online. 14 Jul. 2009 <http://www.britannica.com/EBchecked/topic/371907/mechanics>.

The configuration space definition articulates a very vivid metaphor that translates to the musical experience of timbrally constructed work. A listener moves in time with the recognition of some objects also moving in time. The musical experience is to establish relations among these objects according to the musical culture, a set of values and functions that creates auditory models. While in musical works with known figures, establishing these relations is more straightforward, in musical works with relatively less identifiable objects, timbral objects, the task becomes harder.

Let us clarify that a timbral configuration space (TCS) is not just a collection of timbral objects: it is a space or a set of timbral functions. It is a constructed space defined by the membership to the functions between TSs.[13] Here is why:

An object A is followed by another object B. Whether B relates to A depends on the following conditions:

1) B is A: repetition.
2) B is a version of A: surface variation.
3) B is not A but logically bound with A: cause-effect. For example, B is a fade-in, a crescendo, and A is a musical hit.
4) B is not A but B takes on some features of A and develops them in a way that A cannot: dialectical. For example, a trumpet sforzando dovetailed and spectrally expanded by a string section.

As long as B follows one of these rules, we can talk about a certain coherence of

[13] The most common notion of configuration space in mathematics C_nX is the set of n-element subsets of a topological space X. This set is given a topology by considering it as the quotient $C_nX = F_nX / \Sigma_n$ where $F_nX = \{(x_1, \cdots, x_n) \in X^n : x_i \neq x_j \forall\, i \neq j\}$ where Σ_n is the symmetric group acting by permuting the coordinates of F_nX. Typically, C_nX is called the configuration space of n unordered points in X and F_nX is called the configuration space of n ordered or coloured points in X.

relation among the elements that a musical construct comprises: that is the definition of structure. That coherence resides in the dynamic relations between objects, not in the objects themselves. Any object that has a type of relation in the group of RELATIONS with another object will share some identifiable, coherent, and audible relationship.

For example, suppose B goes through a process that filters lower partials of object A, a piano sound. Whenever we hear A, any note on the piano, we hear B, the filtered version of it. Another object C, a bass clarinet sound, appears. C is not a filtered version of A. Whenever we hear C, we hear D the filtered version of C. The coherence resides in the relation between A and B and C and D. We can talk about a TP called TRANS, in which any object introduced will see its lower partials filtered out. This is not only the timbral characteristic of TRANS but of the space that is defined and aurally identified by the relations between timbral objects.

$$\mathrm{TRANS}(A) \rightarrow B$$

$$\mathrm{TRANS}(C) \rightarrow D$$

We have a domain X(A, C) and a co-domain Y(B,D) and an operation TRANS: X→Y We can call B and D the images of A and C respectively. The elements and their images together form a transformation relation, a morphism. Wherever A and C belong, so do B and D. The set of objects, their images and the functions that relate them, form the space TCS. In other words, TCS is a closed set of group homomorphisms. TCS is not a group but a space that has group properties.

In order to assure the group structure, we must have an identity element that maps an object onto itself. For timbral objects, it is hard to imagine a timbral object that will accomplish such task. Timbral transformations are contextual in the sense that they create their group structure according to the transformation. The presence of an identity element is purely a theoretical matter. In order to establish a group structure, it is possible to imagine a virtual identity element K in every domain such that

$K \bullet A \rightarrow A$

or

$A \bullet A^{-1} \rightarrow K$

However, a group structure that has no identity element, like a semigroup, is more suitable for timbral transformations.

Any object in TCS will have an image in the same TCS. Therefore, the timbral path (TP) of the timbral object (x) can be defined as:

$$TP\ (Func)\ (x) \rightarrow (x')$$

$$\text{If } x \in TCS \text{ then } x' \in TCS$$

A transformational path defined by a timbral function maps x onto x'; if x is a member of a Timbral Configuration Space (TCS), then x' is also a member of the same TCS.

The similarity of timbres is not easily quantifiable. The issue of similarity of timbral constructs is very different from the similarity of pitch classes. In pitch-class domain, the degree of similarity is a matter of measuring the distance of pitch-class X to pitch-class Y where X is not Y ($X \neq Y$). The interval INT between X and Y shows how far Y is away from the unison (mod12); in other words, INT is an abstract device telling how much Y is not X.

In timbral spaces, that is spaces that contain objects that we consider timbrally related, the measurability of intervals, which are the distances concerning similarity, is a matter of continuous yet inconclusive research. (See Chapter 1) However, that does not prevent us from pointing out that one can perceive that an object A is more similar to an object B than it is to an object C. These perceived distances form a group of phenomenological distances (TDIST), a group of immeasurable yet tangible constructs.

The vagueness of distances is not to evade but to encourage. This ambiguity of similarity units has paradoxically a clarifying effect when we have to distinguish TCS's from each other. When something contextually out of TDIST happens, it is a strong sign that the relations inside the space have changed. We have a strong case that by the radical change in TDIST, group of similarity relations, we have moved from one TCS to another. Figure 3.2 reproduces the last measures of *Ionisation* by Edgard Varèse.

Figure 3.2 *Ionisation* (1931) by Edgard Varèse, Rehearsal No:13. Reproduced by kind permission of Universal Music MGB Publications.

The last sixteen measures of Varèse's *Ionisation* exemplify such distinctness where the motion from one TCS to another is apparent. At rehearsal number 13, we hear the piano, crotales, and the glockenspiel surface in the music for the first time just for sixteen measures. This is the first time, after four minutes and forty-five seconds, that we hear idiophones and the piano, playing harmonies that are possible only with instruments that have definite pitches. The similarity relations that are established with percussive instruments and the sirens up until that moment are put in such a perspective with the harmonic chimerae that the previous relations are impossible to uphold. The new timbral constructs bring their own paradigm, so that we hear everything within the new group of relations. This is an example of the radical change that signals that we have moved from one TCS to another.

To sum up, our timbral space has S, a family of timbral objects; TDIST, a group of similarity relations; and a least one TP $(x,y) \rightarrow z$, a timbral function that maps x onto y where x and y are member of S and z is a member of TDIST.

3.3 Conclusion

With this chapter, we introduced several concepts that help to define, model, and consider how the activity "from anywhere to somewhere else" is achieved when we concentrate on timbre. The next chapter will examine the timbral spaces and timbral transformations in Tristan Murail's *Winter Fragments.*

Chapter Four

An Analysis of Tristan Murail's *Winter Fragments*

This chapter presents an analytical application of Timbral Configuration Space and Timbral Paths for Tristan Murail's *Winter Fragments* (2000), a composition for chamber ensemble and electronics. This work is dedicated to Gérard Grisey, the prolific composer of spectral music, who passed away in 1998. The ensemble is a typical Pierrot ensemble with the addition of an electronic keyboard (marked as Clavier in the score) that triggers pre-prepared electronic sounds. The result is a texture marked by fusion between acoustic and electronic sounds that carries the repetition and transformation of several melodic cells with identifiable contours.

For the sake of simplicity, I will proceed chronologically through the piece and I will incorporate timbral attributes as the focal interest. Figure 4.1 shows the introductory measures.

Figure 4.1 *Winter Fragments*: mm. 1-4. Reproduced by kind permission of Editions Henry Lemoine.

The segmentation of this passage is very straightforward:

1) Piano chord accompanied by electronics
2) Melody played by the flute
3) Electronic line echoing the flute melody
4) Violin and cello notes imitating and prolonging the flute melody

The grouping of the piano chord with electronics is based on the Gestalt concept onset synchronicity. As shown by Bregman and others, the closer onsets are to each other, the more likely that we will perceive them as belonging to the same event. In this case temporal proximity binds together the piano chord and the electronic sound.

Spectral composers tend to call musical verticalities Harmony-Timbres, so I will use the label HT1 for the combination of the piano dyad (F#5 and F#6) with the electronics. The electronic complement is formed by ring modulation (RM) of the first four harmonics of F#5 spectrum. Curtis Roads explains: "In digital systems, RM is simply the multiplication of two bipolar signals by one another. That is, a carrier signal *C* is multiplied by a modulator signal *M*."[1] When we multiply two signals–modulation in technical terminology– we get a pair of sidebands in the spectrum of the resulting signal. Any change in the spectrum, in the frequency domain, will affect the timbre because timbre relies significantly on the relationship of the fundemental with partials, with respect to their frequencies and amplitudes. Curiously enough, "these sidebands are the sum and the difference of the frequencies *C* and *M*." In this case, the frequency of A1 (modulator) is subtracted from and summed to the frequencies of the first four partials of F#5 (each being a carrier). For example, just for the F#5

Freq(F#5)+Freq(A1) and Freq(F#5)-Freq(A1)

740 Hz +55 Hz and 740 Hz-55 Hz

795 Hz and 685 Hz will be added to the spectrum. The operation will continue until every carrier is exhausted; the final result is a very rich spectrum compared to the original.

Figure 4.2 illustrates a sub-patch from Patchwork software, an algorithmic composition aid, showing the process that created that sonority.[2]

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[1] Curtis Roads, *Computer Music Tutorial* (Cambridge, Mass.: MIT Press, 2000), 216-17.
[2] Patchwork is a software tool for computer-assisted-composition developed at IRCAM by M. Laurson, J. Duthen and C. Rueda. It is a visual interface for LISP programming language and it is used by many European composers with highly diverse musical and aesthetic backgrounds, including Antoine Bonnet, Brian Ferneyhough, Gérard Grisey, Paavo Heininen, Magnus Lindberg, Claudy Malherbe, Tristan Murail, and Kaija Saariaho in the 1980s. I am grateful to Tristan Murail for sharing his patches with me.

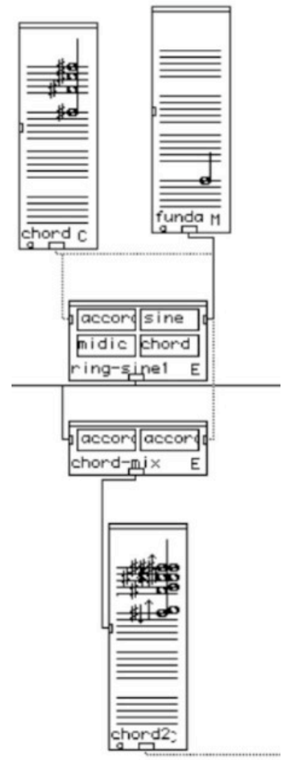

Figure 4.2 Resulting Harmony of Ring Modulation Process

The second element, played by electronics in mm.2-4, is obtained by the spectrum analysis of a Mongolian chant. The chant is analyzed and re-synthesized through a synthesizer built in Max/MSP, applying different spectral manipulations to the analysis file in real-time, thus facilitating the aural response of the composer to the various results of the operations. The manipulated ninth and tenth harmonics of the chant, through Patchwork, create the electronic line that gives the illusion of imitating the flute melody. It is as if the last two notes of the flute melody are propagated into an echo chamber. I will call this segment ECHO. Figure 4.3 shows Murail's Patchwork algorithm. On bottom left, *Position Match* (List 8 and List 9) boxes isolate 9th and 10th partials of the Mongolian chant.

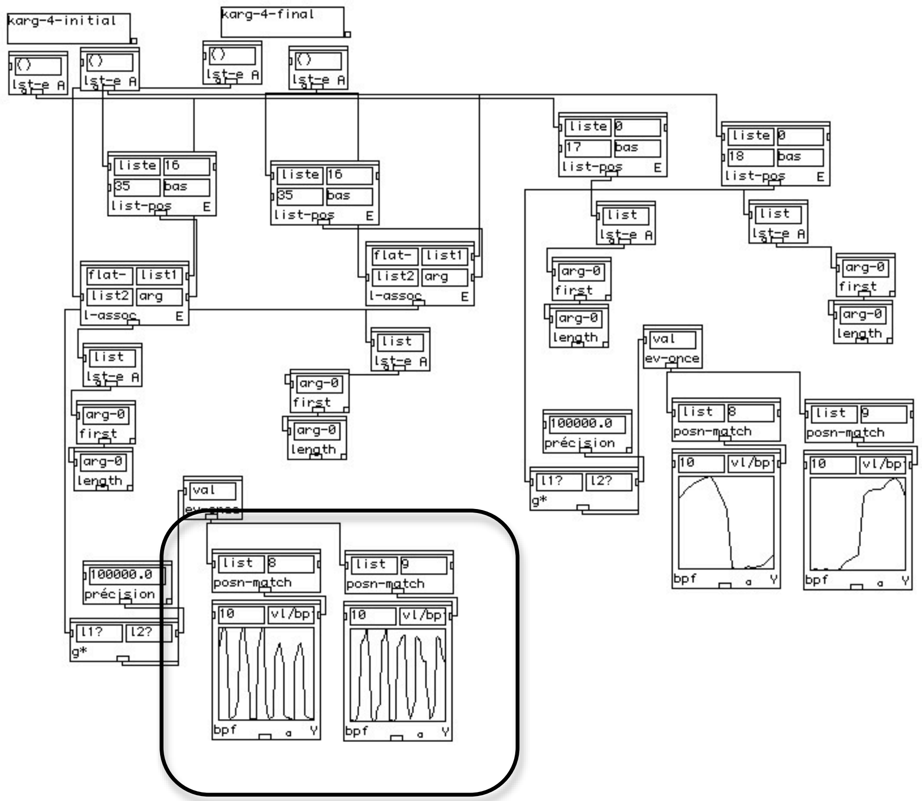

Figure 4.3 Murail's Patchwork Algorithm.

The third component, the three-note flute melody ML1, is a combination of HT1 and ECHO. It starts from the piano chord (F#) and moves toward ECHO, therefore creating a bridge between two distinct components. ML1 shares the same onset with HT1: it prolongs the F# of the HT1 and turns it into a horizontal line. Whether this line is the tail of HT1 or a separate object is not answered at this moment. What is clear is that HT1 is the impetus that gives rise to ML1. ML1 and HT1 form together an auditory chimera.

The violin and cello harmonics produce the fourth component. While imitating the flute melody, they create the illusory effect of freezing this melody in time by sustaining the flute pitches. HT1 is a bright timbre that metamorphoses to a collection that could be defined as pale: the electronic line is colored by a small amount of higher rank harmonics, whereas the strings play with artificial harmonics, thus without fundamental frequencies. Their resulting timbre is very close to pure sine waves, in this case lacking the richness of their source. Time is smoothed out, the forward motion is suspended: this is a rupture of the momentum of the opening chimera. I will use the label FREEZE to refer to the violin and cello notes.

The interdependent relations of components reveal the fact that they belong to a network of relations; they thereby let us define a perceptional sonic space. The ambiguity of the roles and functions of different elements will be carried on throughout the space. Figure 4.4 illustrates a parsing of the components into timbral segments.

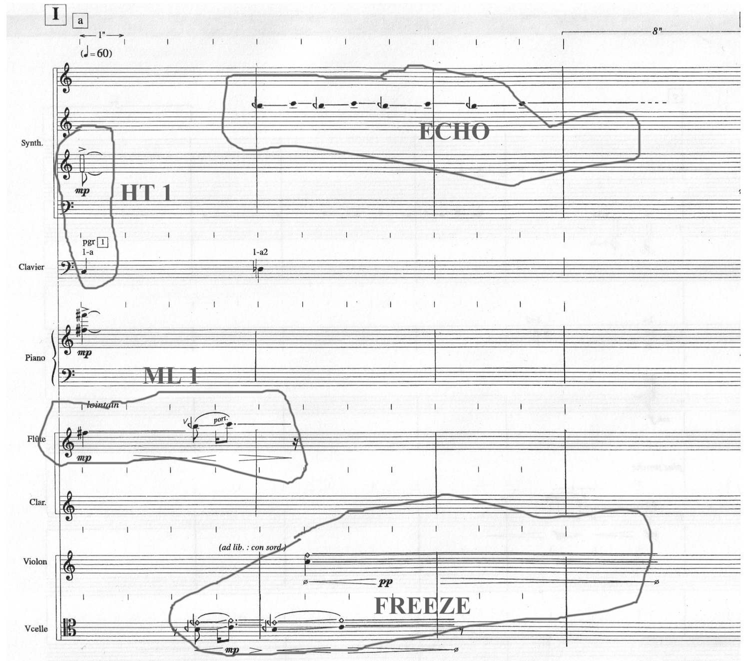

Figure 4.4 *Winter Fragments*, mm. 1-4. Reproduced by kind permission of Editions Henry Lemoine.

ECHO and FREEZE are presented here as timbral objects: ECHO repeats the last notes of ML1 while FREEZE dovetails ML1 and preserves some of its features. We can see that these two objects are in a dialectical relationship with HT1-ML1 complex. As soon as we identified the relation between the objects, we can say that there is one function that takes HT1-ML1 and maps onto FREEZE. In other words there is a path to walk for ML1 to lose some features and keep some others. I will perform an epistemological stretch and label this timbral path with the same name as its destination, namely FREEZE. Here is why: Xenakis advised that the pre-compositional materials, such as the various combinations of tones and tetrachords of Byzantine music that he studied particularly, present a category called *outside-time.* These materials are outside of time because they are not challenged or altered by any structure *in-time*. These are "abstract structuring principles whose definition does not imply a temporal order."[3] For example, the identity of tetrachord is independent of its manifestation in a piece of music, which is an in-time structure.

One of the hypotheses of this dissertation is that sound is an *in-time* structure. Timbral constructs are dynamic–time dependent– because they rely on the sound phenomenon, which is transitory and esthesic. As Grisey puts it, "object and process are analogous. The sound object is nothing but a contracted process, the process is nothing but an expanded sound object."[4] The process, or the transformation, that involves freezing some features of HT1-ML1 chimera presents itself as the object at the same time. What it is (the object) is what it does and what happens (the transformation) is what it is.

$$TP_{FREEZE}\ (HT1\text{-}ML1) \rightarrow FREEZE$$

The same is true for ECHO; it transforms the last two notes of ML1 into an obsessive pattern that fades out.

$$TP_{ECHO}\ (HT1\text{-}ML1) \rightarrow ECHO$$

ECHO and FREEZE are internal functions that do not alter the sonic paradigm: the features of HT1-ML1 are simply prolonged. Those internal functions compose a hyper-transformation that I will call DISSOLVE:

$$ECHO*FREEZE \rightarrow DISSOLVE$$

In addition, HT1 produces a sharp attack, a stimulus for others that dissolves in a span of ten to twelve seconds. Because every musical event is initiated by a crescendo

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3 Curtis Roads, *Microsound* (Cambridge, Mass.: MIT Press, 2001), 38.

4 Gérard Grisey, "Tempus Ex Machina, Reflections d'un Compositeur sur le Temps Musicale," in Guy Lelong (ed.) *Écrits ou L'invention de la Musique Spectrale* (Clamecy: Éditons MF, 2008), 84.

from *niente*, the space does not have any other significant attack points. We can therefore propose the now-familiar STRIPATTACK path to describe the movement of HT1 to other components.

Departing from the dissolution relations between timbral constructs, I propose a TCS1 to describe the space of the internal transformations among HT1, ECHO, ML1, and FREEZE.

Throughout the first one and a half minutes, this space is intact in terms of timbral content. Nevertheless, the components go through various transformations. The melody played by the flute undergoes a series of transformations that will be called EXPAND. Figure 4.5 shows various instances of ML1: the ordinates show frequencies, the abscissas show time. The frequencies of each note are given below abscissas in order to be precise.

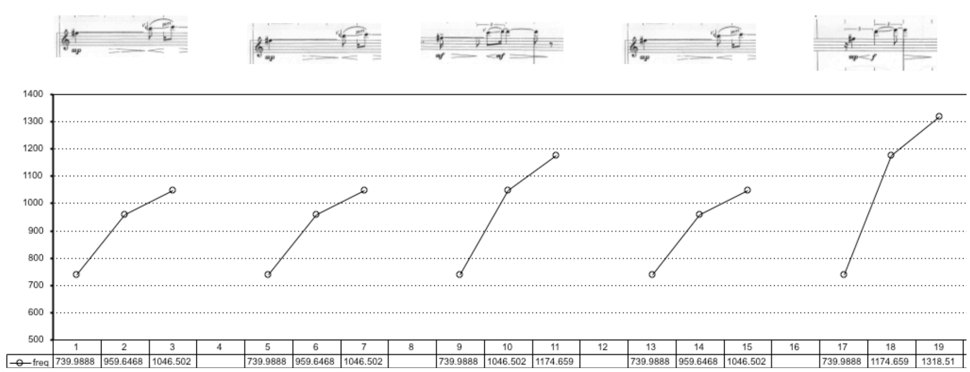


Figure 4.5. Transformation EXPAND of ML1 (flute)

The transformational path EXPAND maps the flute melody timbrally onto itself. The musical surface gains a momentum because of the pitch variation but nevertheless the ML1 class membership of each utterance stays invariant.

TP $_{\text{EXPAND}}$ (ML1) → (ML1)

Since ML1 belongs to TCS1, all its transformational path partners belong to this local path that is to the same timbral configuration space. However, we will soon see a change in ML1, which will affect the electronics first. ECHO changes its onset content, and modifies its function of exact replication; instead, two new pitches are featured. Figure 4.6 illustrates that moment in the music.

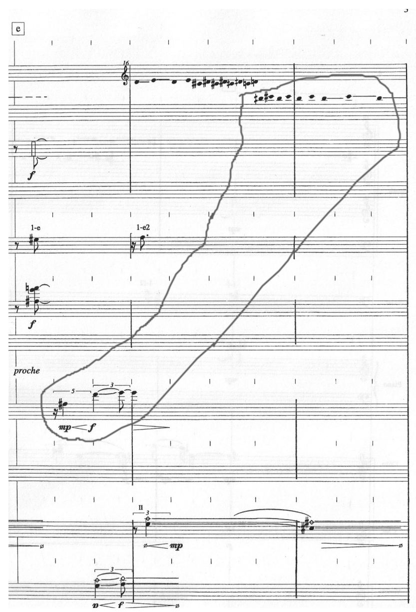


Figure 4.6 Additional Pitches in ECHO. Reproduced by kind permission of Editions Henry Lemoine.

As soon as Rehearsal F is heard, an important change occurs in ML1: the three pitches are not only expanded (remember the EXPAND path) but also, by the addition of two new pitches, the cardinality of ML1 changes from three to five. Figure 4.7 shows the new composition of ML1. We will soon explore the importance of this five-note phrase.

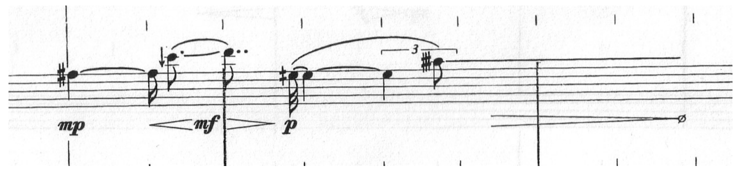


Figure 4.7 First Appearance of Five-Note Phrase in Rehearsal F. Reproduced by kind permission of Editions Henry Lemoine.

A significant amount of transformation of the initial components occurs at Rehearsal F, which is an instance in TCS1. One can speak of an increase of tension throughout the first minute, and Rehearsal F is a relative climax. This fact affects not only the theoretical space but also the surface of the music. Leaving aside a clearly audible shift in harmonic space, the instrumental design, which defines the timbral space significantly, is influenced by these transformations: the violin has ceded its role to the clarinet. At the one-and-a-half-minute mark, Rehearsal G in the score, the initial elements of TCS1 return at the same pitch level. Nonetheless, the complete TCS has gained momentum: the components move faster in time compared to their previous occurrences.

At Rehearsal H, at approximately one minute and 48 seconds, an important shift occurs: most of the components of TCS1 disappear from the surface of the music. Figure 4.8 shows the new objects that replace the components of TCS1.

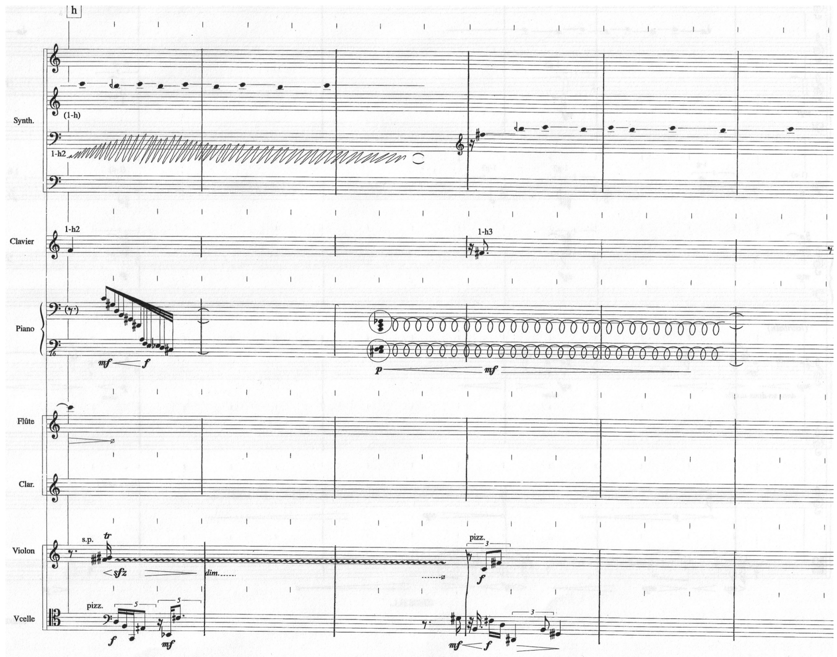


Figure 4.8 *Winter Fragments*: Rehearsal H. Reproduced by kind permission of Editions Henry Lemoine.

This is a clear disruption of the established sonic paradigm. The electronics outline a new harmony-timbre where the piano and the strings' pizzicati color that space, the latter with a sort of interrupted pulsation effect. Considering this clear rupture, we can say that we face a new space, TCS2, containing the various transformations of HT 2 (piano, electronics), ECHO (electronics), and PIZZ (violin, cello).

Let us look at these components in detail. HT2 is defined by a chord articulated in electronics along with trills and downward and upward arpeggios in the piano part. The electronics' chord is based on a tam-tam analysis. The resultant spectrum data are reshaped, filtered, and distorted in order to obtain various timbral transformations.

Figure 4.9 is the Patchwork patch showing the tam-tam sound object's various transformations obtained by frequency distortion, filtering, and transposition.

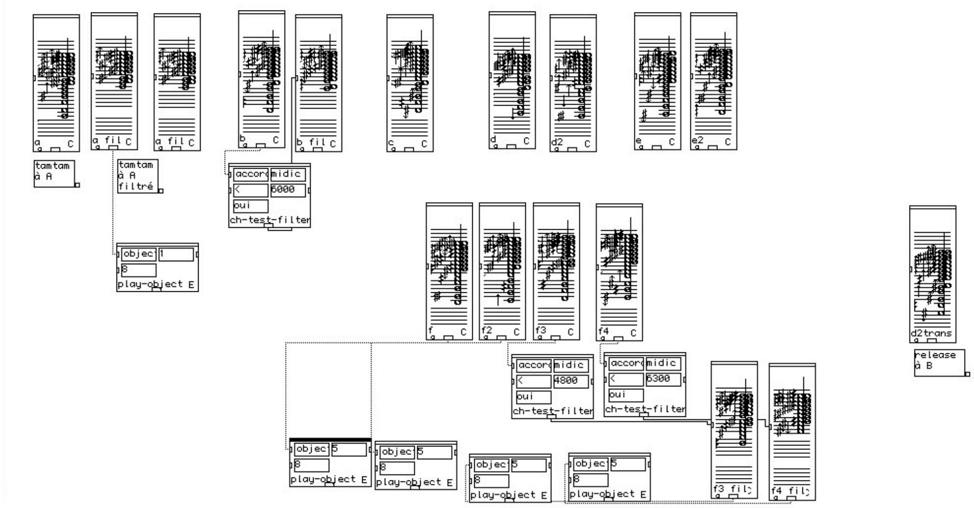
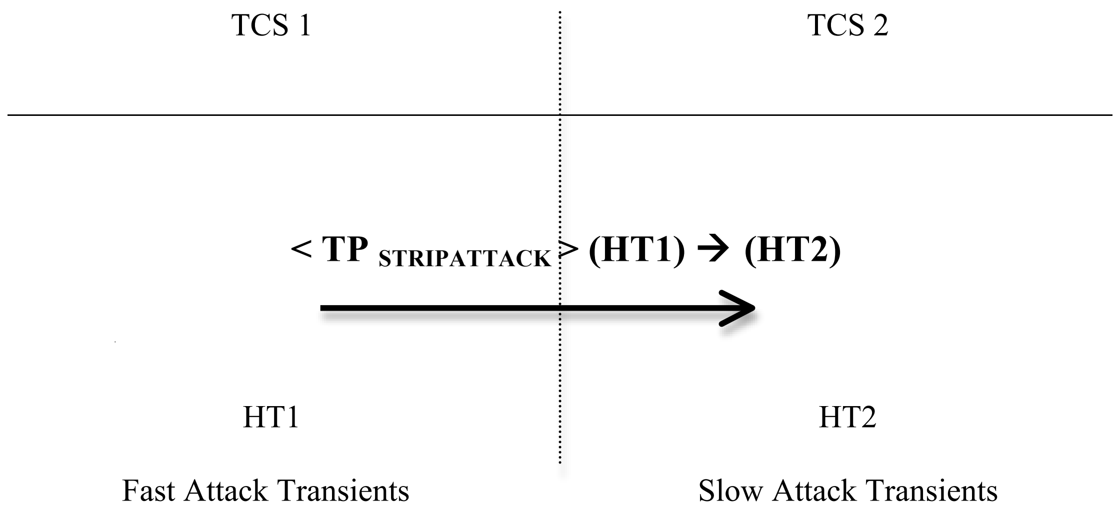


Figure 4.9 Various Transformations of Tam-tam Timbre

The ECHO in the electronics states ML1 with the insertion of F# into the initial ECHO figure. One tends to hear ECHO in TCS1 as an echo of the flute melody. Nevertheless, when it returns at TCS2, it reveals itself not as an echo of the flute melody, but rather as an echo of ML1 of TCS1 in the new TCS2 milieu. Thus, ECHO discloses itself as a diachronic echo instead of a synchronic one. The local component reaches far back and functions as a bridge between two different perceptual spaces, nesting the past into the present, as a reminiscence.

Violin and cello pizzicato figures derive their pitch material from the pitch space created by HT2. The sharp pizzicato attacks are an important timbral feature of TCS2: they relate by their timbral envelope to the HT1, the only component with a sharp attack so far. In addition, their temporal behavior is the first appearance of a clear rhythmical statement. Taken together, these hesitating pizzicato pulsations and muted piano define a transient momentum along with dark and sharp timbral features.

Before going any further in the piece, I want to focus on some relationships between TCS1 and TCS2. TCS1 starts with a sharp attack formed by an inharmonic component, a ring-modulated piano chord, and a harmonic component, the piano sound itself, if one considers it a harmonic timbre. On the other hand, TCS2 opens with an inharmonic timbre with slow attack, re-synthesized tam-tams, and a harmonic component, the piano's arpeggios. At this moment, one can backtrack to a local component of TCS1, STRIPATTACK, and find out that this is not only a perceptual component but also a hyper-transformational path working between TCS1 and TCS2: the sharp attack of HT1 (ring-modulated F#) progresses toward slowly attacked electronics HT2 (originating from tam-tam). This is the consequence of the "designed ambiguity" incorporated in the internal dynamics of the piece. Figure 4.10 illustrates that hyper-transformational path between two TCSs.



Local TP: STRIPATTACK

Figure 4.10 Hyper-transformational Path Operating between HT1 and HT2

With Rehearsal I in the score, after the establishment of TCS2, the components of TCS1 return to the musical surface (Figure 4.11).

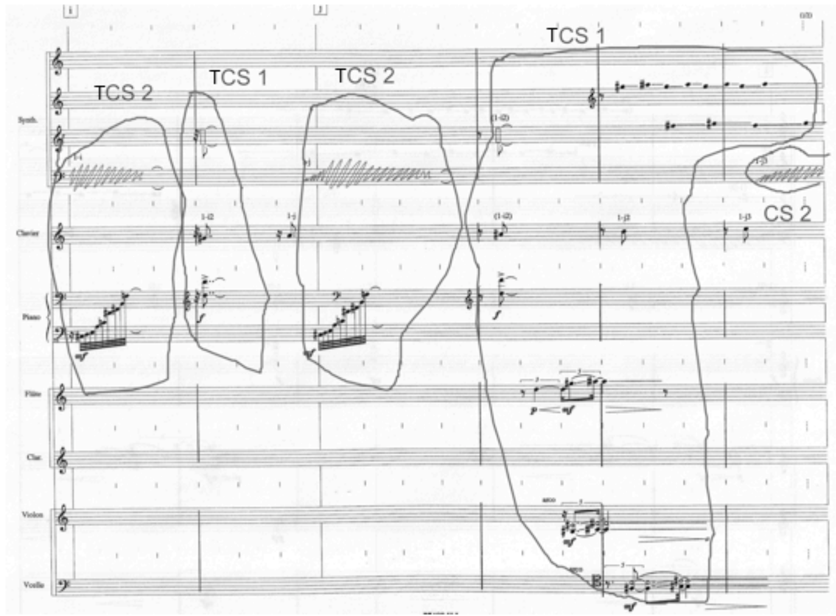


Figure 4.11 Merging Two Sonic Environments TCS1 and TCS2 in Rehearsal I.

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However, F#5 of ML1 is now transposed down to D5.[5] HT1 and ML1 follow this transformation and develop their TCS1 behaviors in this transposed pitch space. This is a new paradigm: TCS2 acted as a disruption during the flow of TCS1 and functioned as a "shifter," transforming the pitch space. The importance of this passage is noticeable if one realizes that the components of TCS2 do not drop out of the musical surface. The articulation of HT2 continues in electronics while all the components of TCS1 recover. One can say that two TCSs cohabit the same surface, while the ML1 brings back the foreground material on the top of this shared space.

[5] Note that the transposition of ML1 in Rehearsal J is not a linear one; even when there are 24 equal divisions of the octave, in order to obtain this pitch level, one first must transpose ML1 down by 400 cents, then distort the upper notes by 1.019 and 1.031 respectively. Transposition is a contextual tool in order to assure the sonic concordance between components within a given timbre space (private communication with the composer).

This melodic articulation is clearly a five-note phrase, first seen when formed by the additional notes in ECHO (Figure 4.6), not imitating the melody but contributing to it, then formed by the five attack points in the flute line (Figure 4.7), and now returning at Rehearsal K as a particular statement. Figure 4.12 shows the flute melody with five notes.

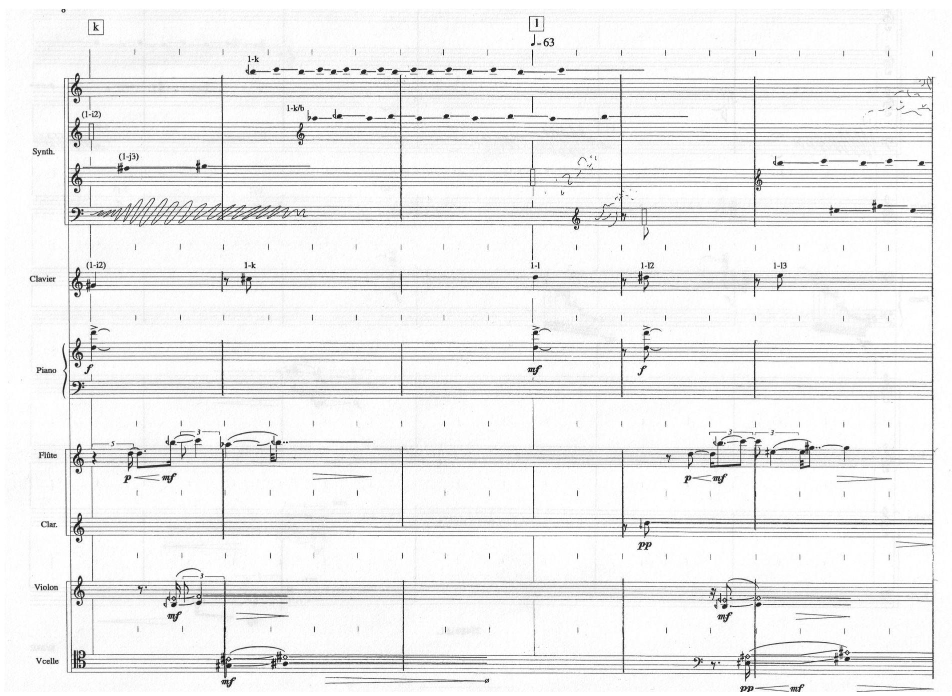

Figure 4.12 *Winter Fragments*: Rehearsals K and L. Reproduced by kind permission of Editions Henry Lemoine.

This is where the melody undergoes another type of transformation: interpolation. Interpolation here is a gradual modification between two poles: the five-note melody, the starting pole, moves toward another five-note figure. Figure 4.13 illustrates the result of the process and Figure 4.14 shows its musical realization.

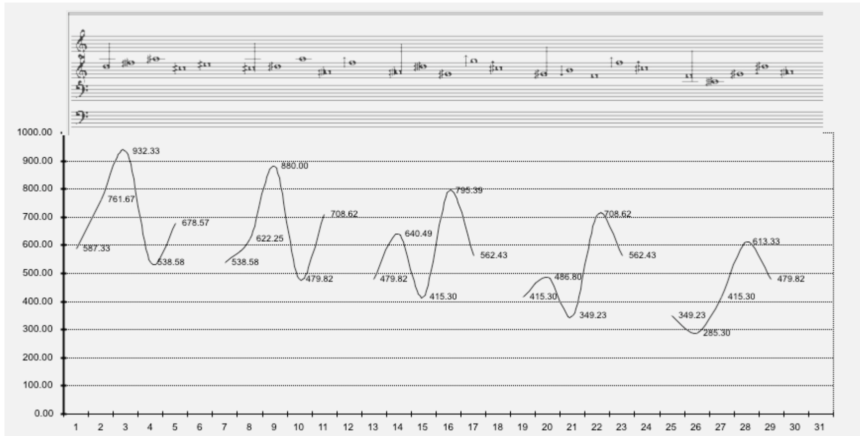

Figure 4.13 Melodic Interpolation between Rehearsals L and Q

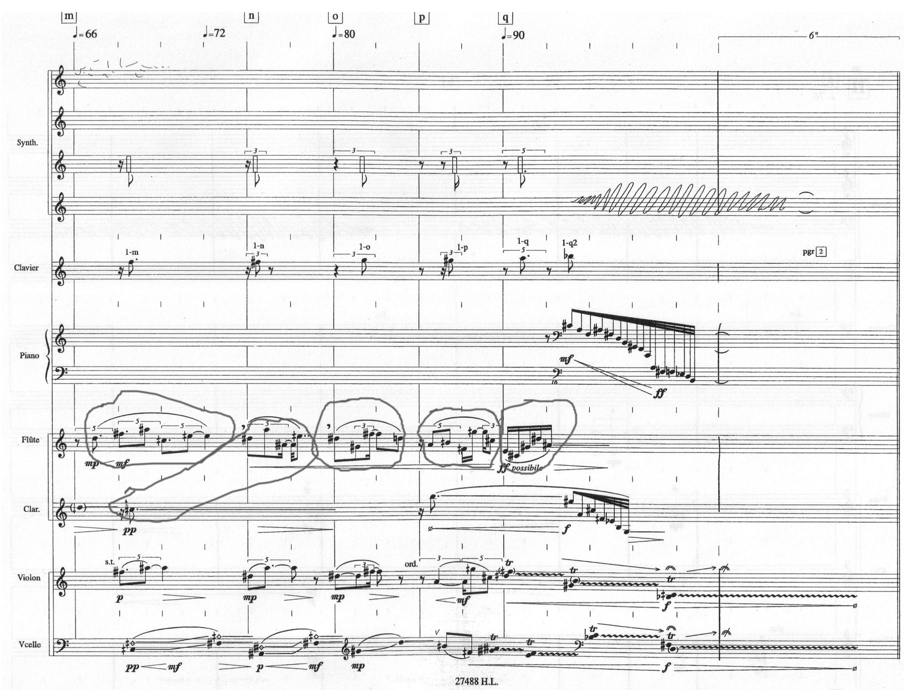

Figure 4.14 Realization of the Same Interpolation on the Musical Surface. Reproduced by kind permission of Editions Henry Lemoine.

The interpolation occurring from Rehearsal L to Rehearsal Q is a directed metamorphosis of an object. The composer calls this process "vectorisation of discourse."[6] Thus, interpolation is a transformational path where:

$$TP_{\text{INTERPOLATE}}(x) \rightarrow (y)$$

The last five-note melody is quoted from the opening of *Prologue*, a composition for viola by Gérard Grisey, as shown in Figure 4.15. This melody is structurally significant in that it becomes the basic material for violin and cello at the last two minutes of the piece; the piece ends with cello stating variations of *Prologue* over and over again.[7]

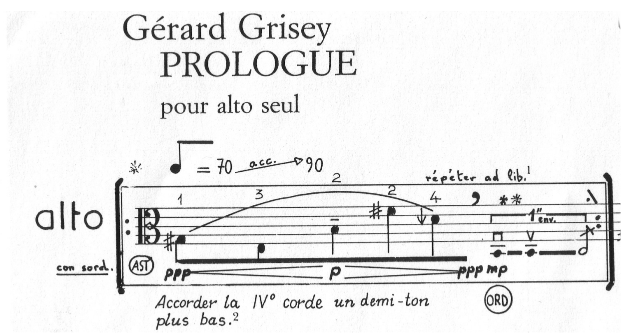

Figure 4.15 Gérard Grisey, *Prologue* for Solo Viola. Reproduced by kind permission of Universal Music MGB Publications.

This change of identity of a musical object is a concept inherent to spectral thought, where the harmony, melody, timbre, and rhythm are "façades" of the same phenomenon, namely sound. Therefore, many musical instances do not lend themselves to uni-functional and uni-directional perception, but rather to a multitude of different interpretations. As I mentioned before, this designed ambiguity inscribes itself into the

[6] Tristan Murail, "Questions de cible," *Entretemps* 8 (September 1989): 147-172.

[7] It is also worth mentionning that *Winter Fragments* is dedicated to the memory of Grisey who passed away two years before the date of composition.

musical discourse and generates multi-layered and multi-dimensional readings. The perceptual focus is shifted to different strata. This ambiguity is emphasized by the conjoint surface of TCS1 and TCS2 during Section II; all the components of two configuration spaces become prominent, and FREEZE is heard less and less after Rehearsal F. This is because the rhythmic grid becomes increasingly dense; one can hear a more agitated surface where FREEZE would not function. Simply put, there is no time to freeze.

With the beginning of Section III the sonic paradigm is distorted one more time: the conjoint space of TCS1 and TCS2 engenders an unheard TCS. Figure 4.16 shows Section III of *Winter Fragments*.

Figure 4.16 Section III of *Winter Fragments*. Reproduced by kind permission of Editions Henry Lemoine.

The electronics' material comes from a glass spectrum. The glass sound is analyzed and resynthesized in order to replicate very rich high frequency of the glass. The cascading figures of flute, clarinet, piano and electronics, CASCADE, are derived from an interpolation process between ML1 and PROLOGUE. Both ML1 and PROLOGUE are verticalized into chords and then interpolated. The first three chords of this process give the characteristic melody and shape of the CASCADE. Figure 4.17 illustrates that process.

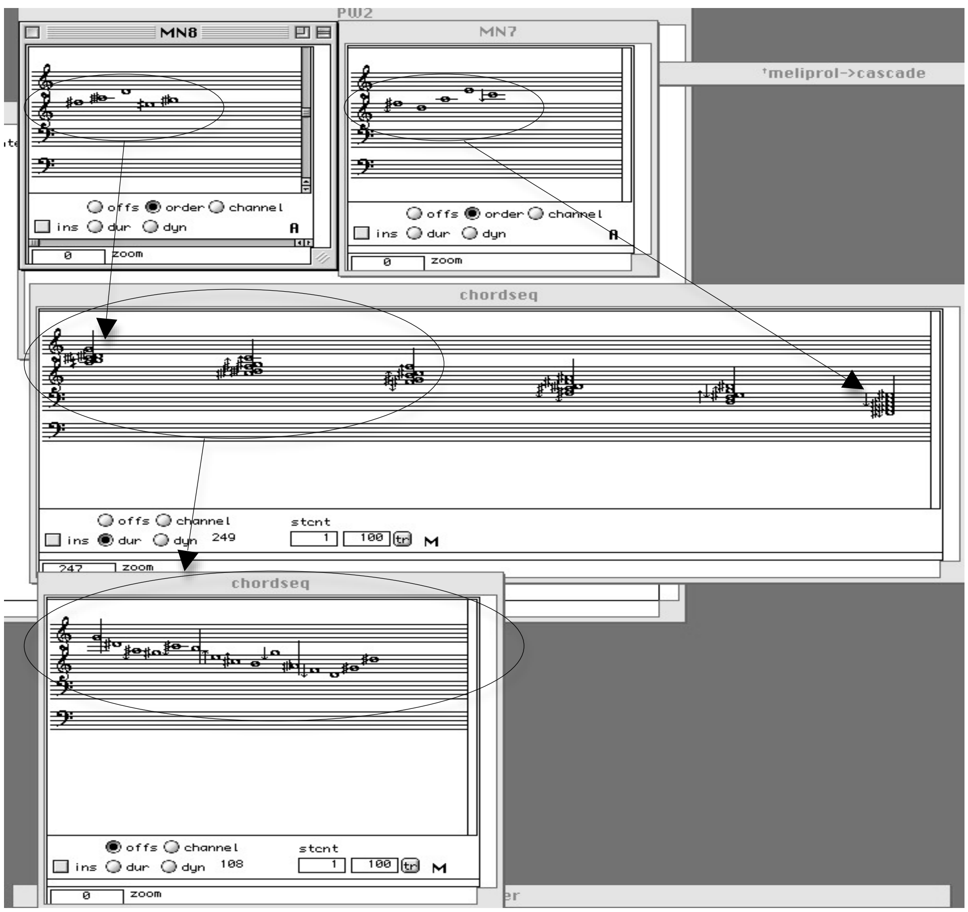

Figure 4.17 Interpolation between ML1 and PROLOGUE.

CASCADE has common characteristics with HT1: HT1 was a bright timbre, which was a combination of piano chord and ring modulation. HT1 defined also the harmonic space and its "fast attack to dissolution " was a key component. The electronics in CASCADE have extremely bright timbre—as source and synthesis— which is combined with the instruments playing at their brightest register. The deceleration of gesture is reminiscent of dissolution component of TCS1. This deceleration brings back an interpolation of CASCADE with PROLOGUE. Whenever the component dissolves, it is morphed into PROLOGUE.

PIZZ is a component of TCS2 reappearing in TCS3. The hesitating pulsations of previous space become iterating short impulsions. Therefore, one can say that CASCADE is a fragmentation of HT 1 with PIZZ. The cohabitation of PIZZ in TCS3 with CASCADE fortifies this argument.

From this moment on, *Winter Fragments* becomes an interplay of components that make up the TCSs. Timbrally speaking, the introduction is over. We hear more and more layers of timbral polyphonies: a fugue of timbral paths. TCS1 with its dissolving impetuses, TCS2 with its hesitating pulses, and TCS3 with its bursts of energy define those strata. It is worthy to note that TCSs have certain quintessence bound with their source. TCS1 is based on a piano note (F#5) analysis, TCS2 on a tam-tam analysis, TCS3 on a glass analysis. The source materials become more and more inharmonic while the spaces become more and more dense in terms of onset activity. The increase in the roughness of source material has a correlation with the momenta of these sets of timbral paths. Timbral analysis helps us gain insight on various considerations such as the fuzzy but positive isomorphism between momenta and roughness of source materials, between the dissolving character of CASCADE and TSC1, the hyper-transformational path STRIPATTACK between TCS1 and TCS2. It is only rewarding to be able hear such transformations that are not conveyed to us through other analytical approaches that have other parameters as basis.

CONCLUSION

This chapter concentrated on analytical application of timbral paths and timbral configuration spaces. These concepts help us to the model timbral constructs by mapping certain sonic invariants to a higher perceptual hierarchy. In *Winter Fragments*, there are many satisfying parallaxes that are enabled by the timbral ways of listening to and looking at the music. For example, to conceptualize a local TP acting as a hyper-transformational path between two spaces is very enriching as well as the possibility to experience the piece different than the general tendency of hearing it through the evolutionary perspective of the flute motif. Against this surface listening, TCSs suggest a richer listening experience and more rewarding similarity/equivalence relations.

Chapter 5

Conclusion

As this dissertation suggests, musical structures that originate from timbre are as valuable as structures based on pitch, contour, and rhythm. Analyzing timbre invokes theoretical categories that can bring about certain structural consistencies, can suggest new ways of listening, and, most importantly, can "complicate our understanding of a piece of music."[1] To gain access to the parallax view of a piece of music, which is an historical and social artifact, is the most rewarding part of music-theoretical activity. In order to accomplish that, various levels of structure defined within a certain space—be it timbral, pitch, contour—should be able to interact and change one's grasp of musical context. Furthermore, those spaces should be mediated to suggest new understandings about higher-level abstraction interactions. For example in Chapter 4, STRIPATTACK transforms objects and spaces at the same time, ECHO turns out to be a container of contextual reminiscences, pitch transformations are affected by timbral procedures, and vice versa. Timbral transformations suggest a new kind of ear training that will enable the cognition of high-level timbral structures. When such enterprise is accomplished, there is a possibility that one can hear STRIPATTACK not only between two objects (this is trivial) but also between two spaces: that means hearing an abstraction (TP) that

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[1] Henry Klumpenhouwer, "Reconsidering Klumpenhouwer Networks: a Response," *Music Theory Online* 13/3 (September 2007).

moves between two "abstractions of abstractions" (TCS).

The discussions of the musical works by Varèse, Grisey, and Murail gave rise to a number of timbral paths: STRIPATTACK, ADDATTACK, ECHO, FREEZE, EXPANDUR, CONTRACTDUR, IMPULSE, and ZOOMIN have potentials to become robust enough to reach above their contextuality in order to become generalized timbral operations. With such operations, we will be one step closer to talk about timbral networks, structural recursion, and isography.

The recent work of many cognitive scientists shows that human beings use sensory data derived from the world around us to model cognitive images.[2] We use these sensorimotor images, like Verticality, Centre-Periphery, Balance, Path, Container, and Cycle, to make sense of our daily perceptual experiences. Lawrence Zbikowski applies the image schemata to music and explains how we use these *image schemas* to transliterate one form of pattern into another by metaphorical projections called *cross-domain mapping*.[3] Candace Brower reports that "Lakoff and Nunez propose that mathematical systems such as algebra, analytical geometry, number theory and set theory begin with axioms which are image-schematic in nature, then build through successive layerings of image-schematic mappings towards increasingly higher levels of complexity and abstraction."[4] Mathematics and music share the "capacity of embodied imagination" in order to produce internally coherent systems.

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[2] Mark Johnson, *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason* (Chicago: University of Chicago Press, 1987).

[3] Lawrence M. Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis* (New York: Oxford University Press, 2002).

[4] Candace Brower, "Paradoxes of Pitch Space," *Music Analysis* 27/1 (2008): 94.

There is no reason for timbral structures not to benefit from mathematical systems in order to implement cognitive structures that suggest provocative listenings based on network of timbral relations. More involvement with mathematics and future collaborations with mathematicians will pave the way to more abstract structures that will fill the current void in timbral network domain. This dissertation remains an introductory attempt that hopes to trigger various stances that will contradict, question, and challenge many of our sonic intuitions.

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METATHESIS

by

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A dissertation submitted to the Graduate Faculty in Music in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York

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dissertation requirement for the degree of Doctor of Philosophy.

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Abstract

METATHESIS

by

TOLGA TUZUN

Adviser: Professor David Olan

Metathesis was composed between March 2006-October 2006 and premiered on October 13, 2006 at Espace de Projection, IRCAM by Nicolas Crosse. It is for two contrabasses, one in a conventional vertical playing position, the other in a horizontal position within the reach of the left hand of the performer. The electronic part is diffused through 18 physical outputs over 18 speakers. There are three computers running at the same time for real-time processing via Max/MSP.

Metathesis takes advantage of the potentialities of TCSs in order to conceptualize *an écriture* of electroacoustic music via techniques and categories provided by the symbolic representation within the discussed framework. Sound synthesis stands as an instance of the general compositional strategy based on timbral multiplicity and interaction. Consequently, maintaining simultaneously an overall vision alongside of a local focus on compositional material while articulating the interaction/negation of temporary grids of meaning based on divergent and elusive narrative timbral perspectives becomes possible only theoritical constructs such as TCS.

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I am grateful to Tristan Murail for all the inspiration and discernment that he provided while studying composition with him in New York.

CONTENTS

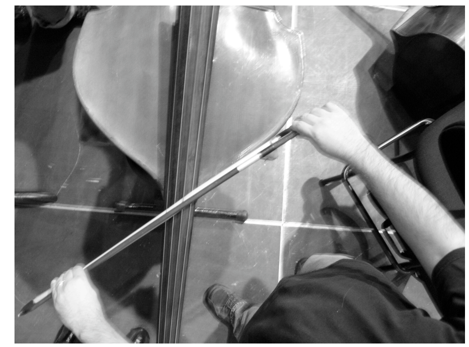
Metathesis is written for one player playing 2 contrabasses, one in a traditional vertical position (labeled CB1 on the score), the other positioned horizontally (labeled CB2 on the score), on a stand in the reach of the player.

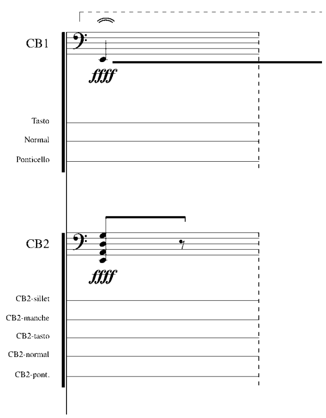
The vertical contrabass sounds one octave lower than written.

The string II is tuned one quarter tone higher (D𝄲) and the string III one quarter tone lower (A𝄳).

The string IV is tuned one semitone lower (E♭).

The horizontal contrabass is played with a bow that is fixed on the strings by detaching the hairs of the bow and passing them under the strings III and I. When the bow is reattached, it should touch the strings II and IV with the outside of the hairs and the strings I and III with the wood side of the hairs. The fixed bow is played by pushing down and pulling up while sliding through the strings from the bridge to the nut.





Bow position graph for the Contrabass 1 (Vertical)

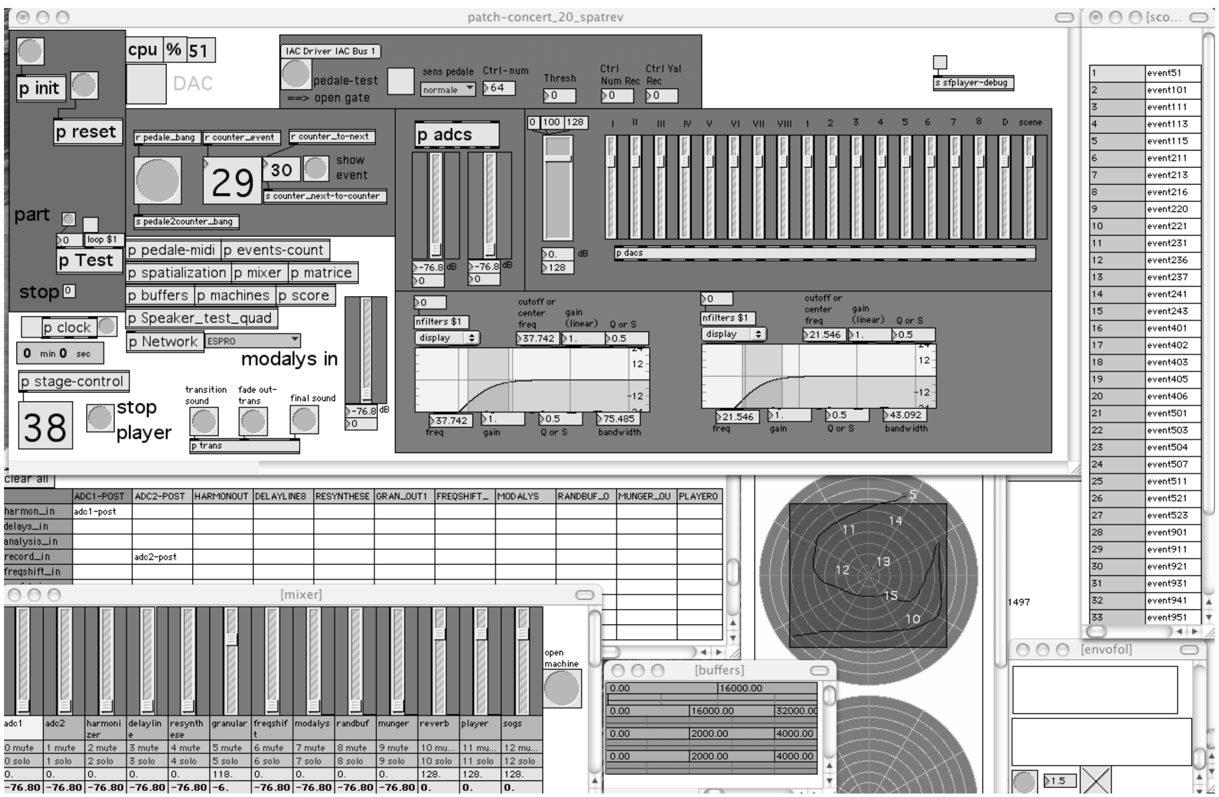
Fixed bow notation

Bow position graph for the Contrabass 2 (Horizontal)
Sillet: Nut; Manche: Neck, Fingerboard

The electronic part involves the use of three computers and two digital audio cards for a total of 18 physical outputs. The first computer runs a master Max/MSP patch dedicated to real-time signal processing as well as coordinating others. (see picture below)

The second is solely assigned to real-time physical modeling synthesis using Modalys scripts running through Max/MSP.

The third is on the stage cueing the instrumentalist in order to facilitate passages that are proportionally notated.



Metathesis is diffused through 18 speakers:

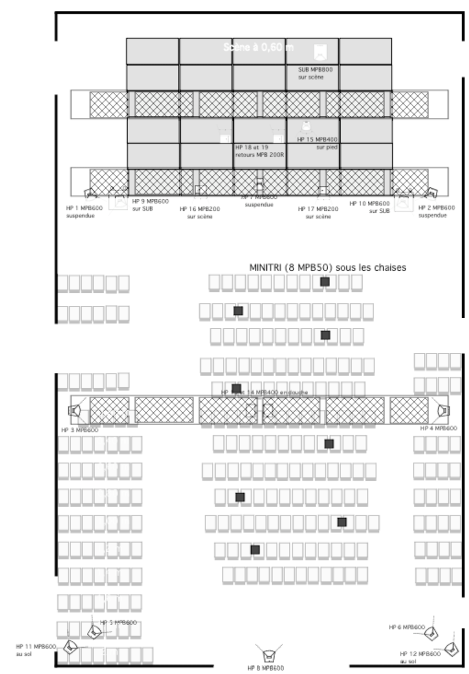
8 full-range speakers circularly located around the audience.

8 small speakers positioned quasi-randomly under the audience chairs.

1 full-range speaker attached to the ceiling projecting downward.

1 full-range speaker positioned on the stage in front of the horizontal contrabass.

The whole system is supported by 4 sub-woofers.



Metathesis was premiered on October 13 2006 at Espace de Projection, IRCAM-Paris by Nicolas Crosse.

Duration: 10 mn.

metathesis

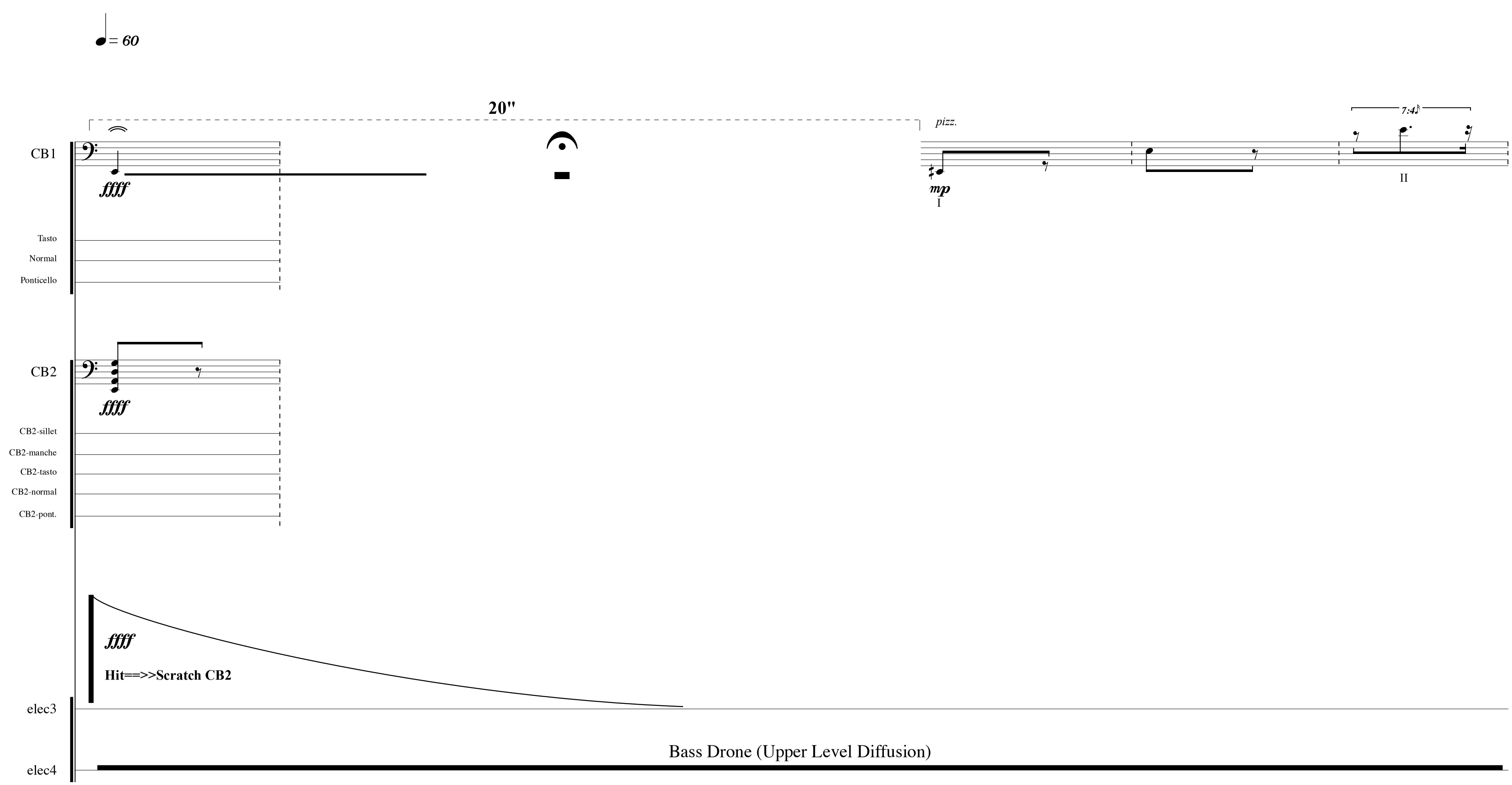
1 Grammar the transposition of sounds or letters in a word.

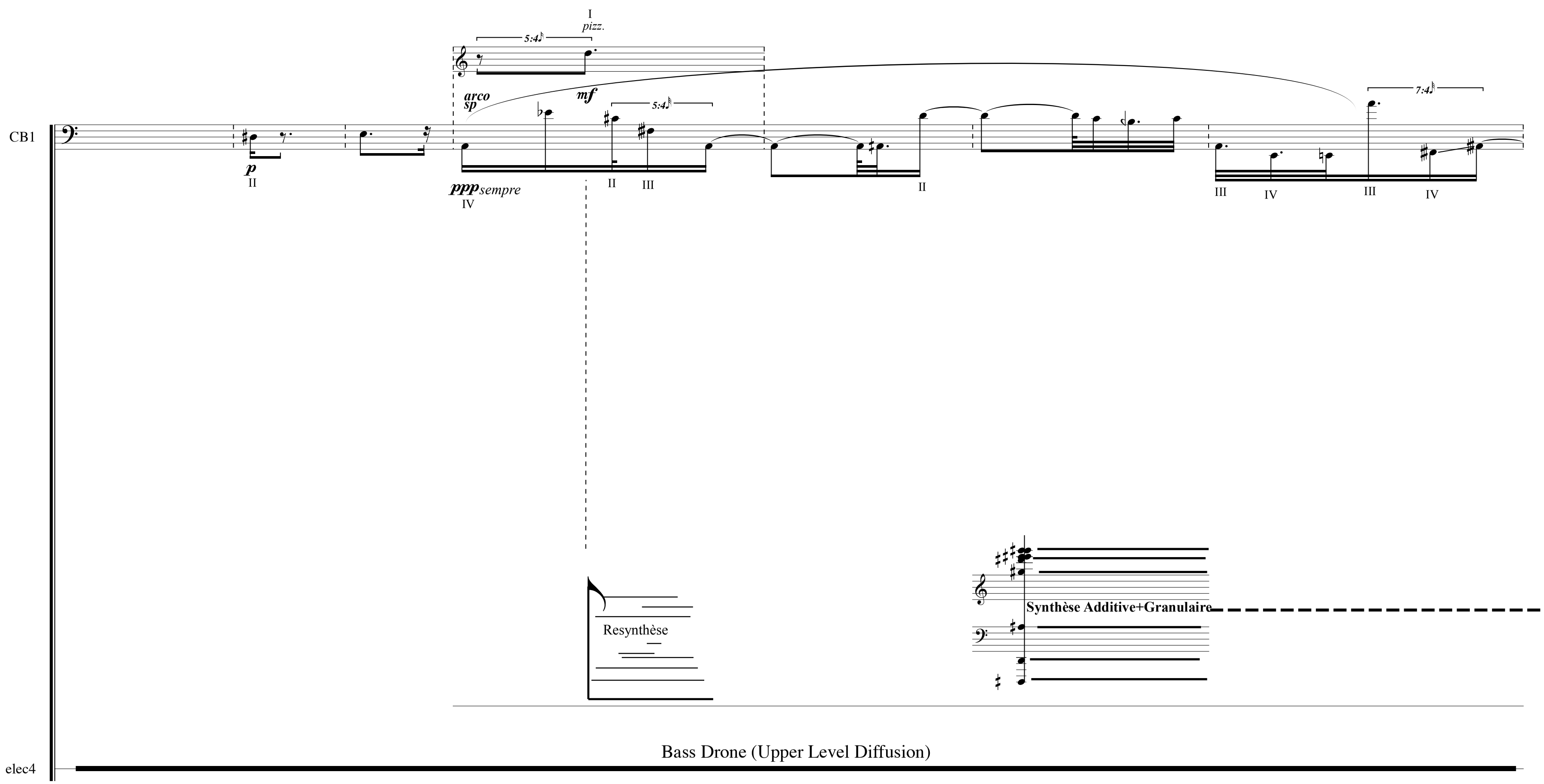
2 (also **metathesis reaction**) Chemistry a reaction in which two compounds exchange ions, typically with precipitation of an insoluble product. Also called **double decomposition**

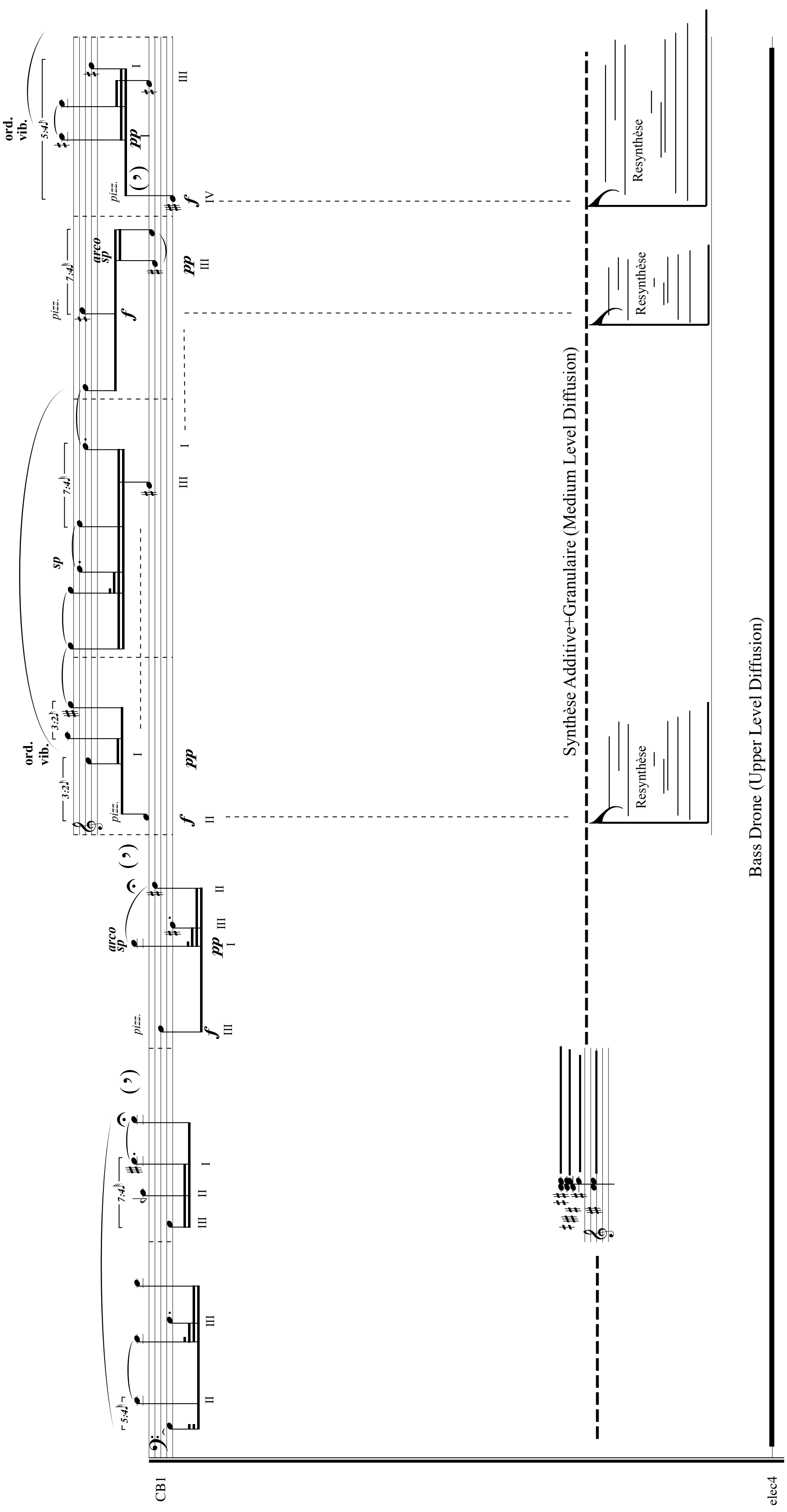
...and from thereon, a dialogue between two identities; passive/horizontal with a limited excitation–a fixed bow carving and forging– and active/vertical with its restless lack of stability...two narratives that don't share anything in common, cohabiting a surface wherein they allude to each other by the mediation/orientation of electronics, dissolving their respective identities into each other whilst eluding the narrative, establishing a game of perspective and uncertainty of subjectivity...with the vanishing of the thread, there comes the lack of presence/present with its temporary grids of meaning based on adrift perspective, whilst surface becomes the object and the subject of this elusive meaning and motion touches that surface rather than incising it...destruction is inevitable as in every discourse...no direction, no power, no values, no god…

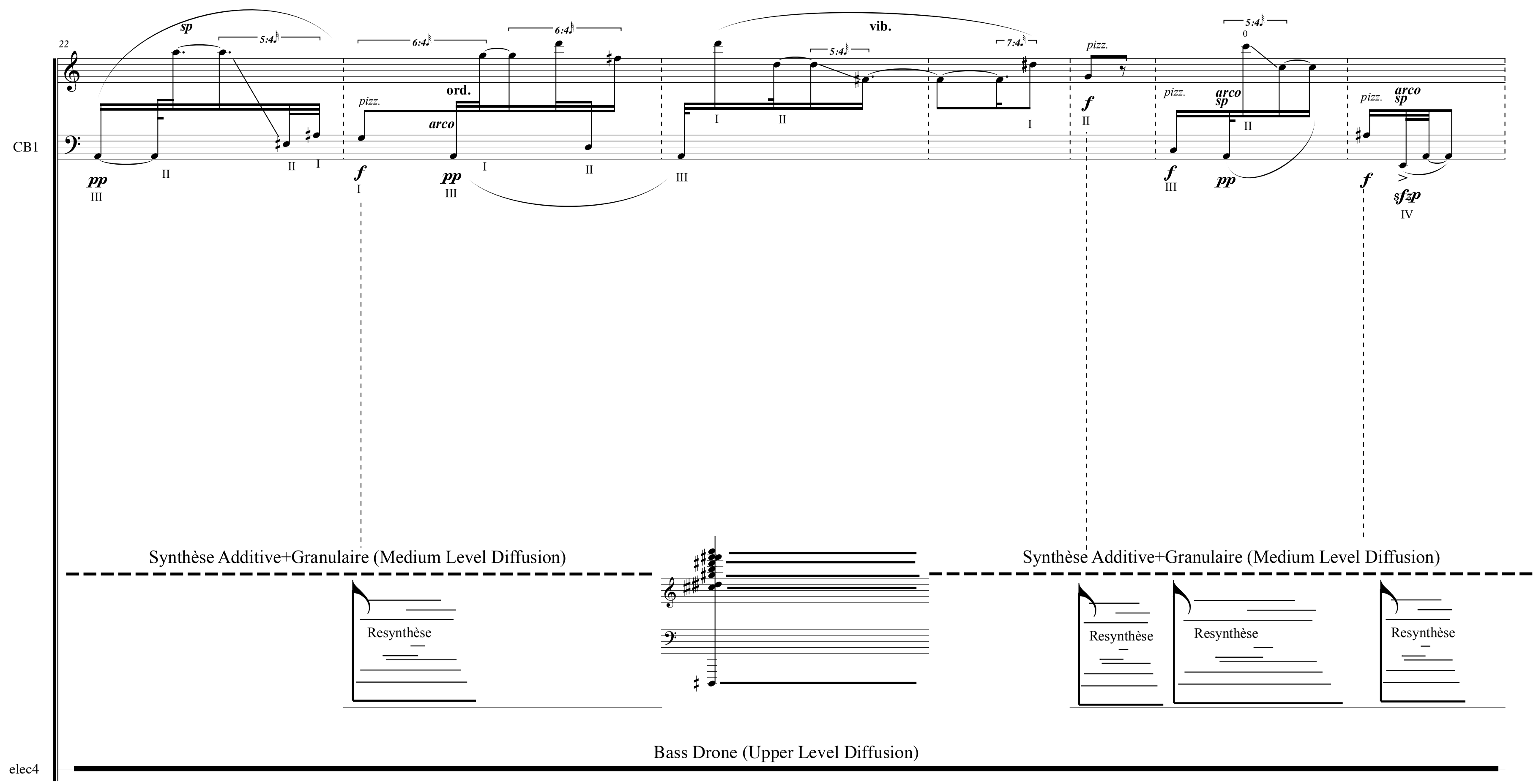
Metathesis
for 2 double-basses and electronics

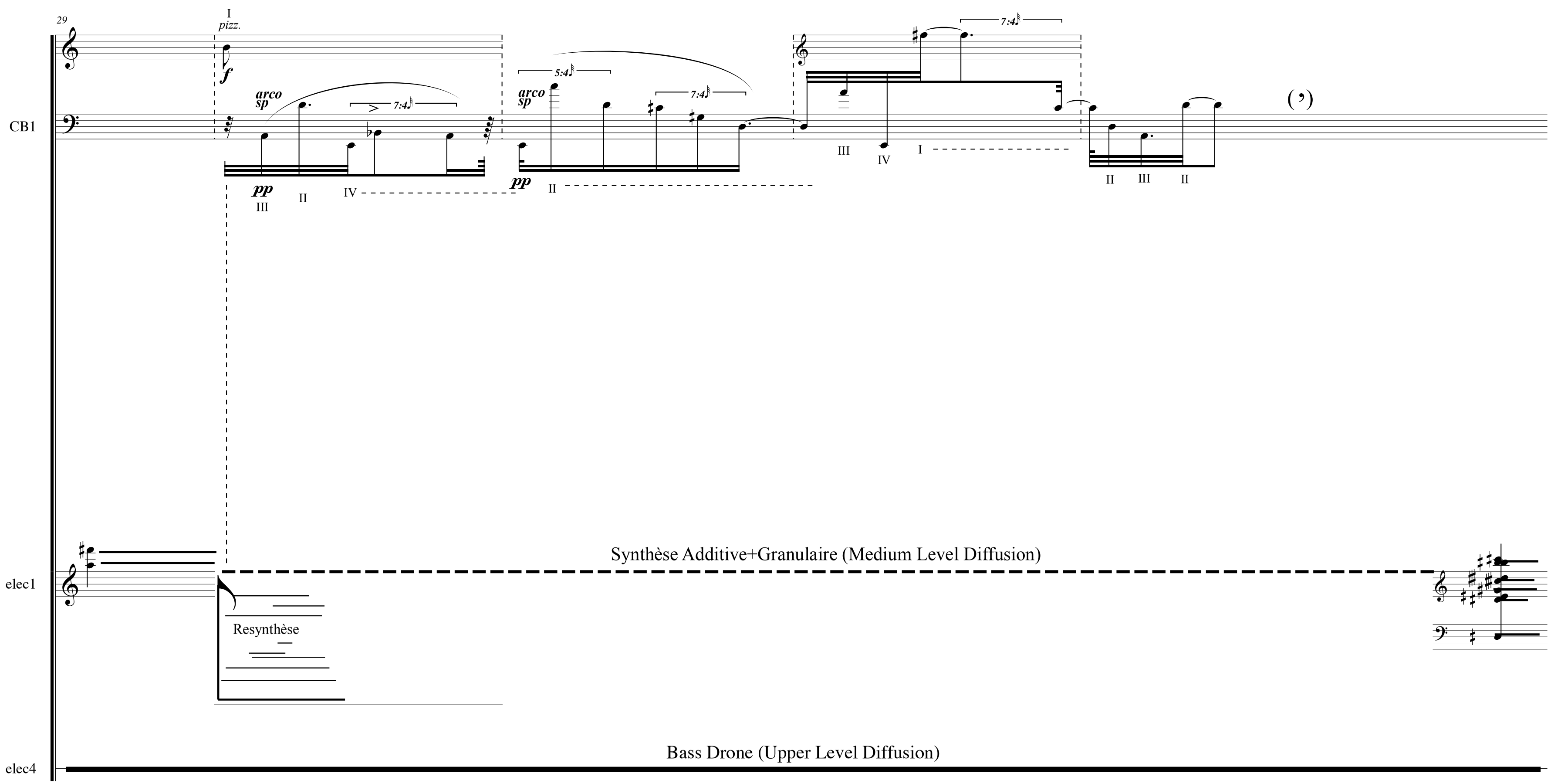
Tolga Tüzün
August 2006, Paris

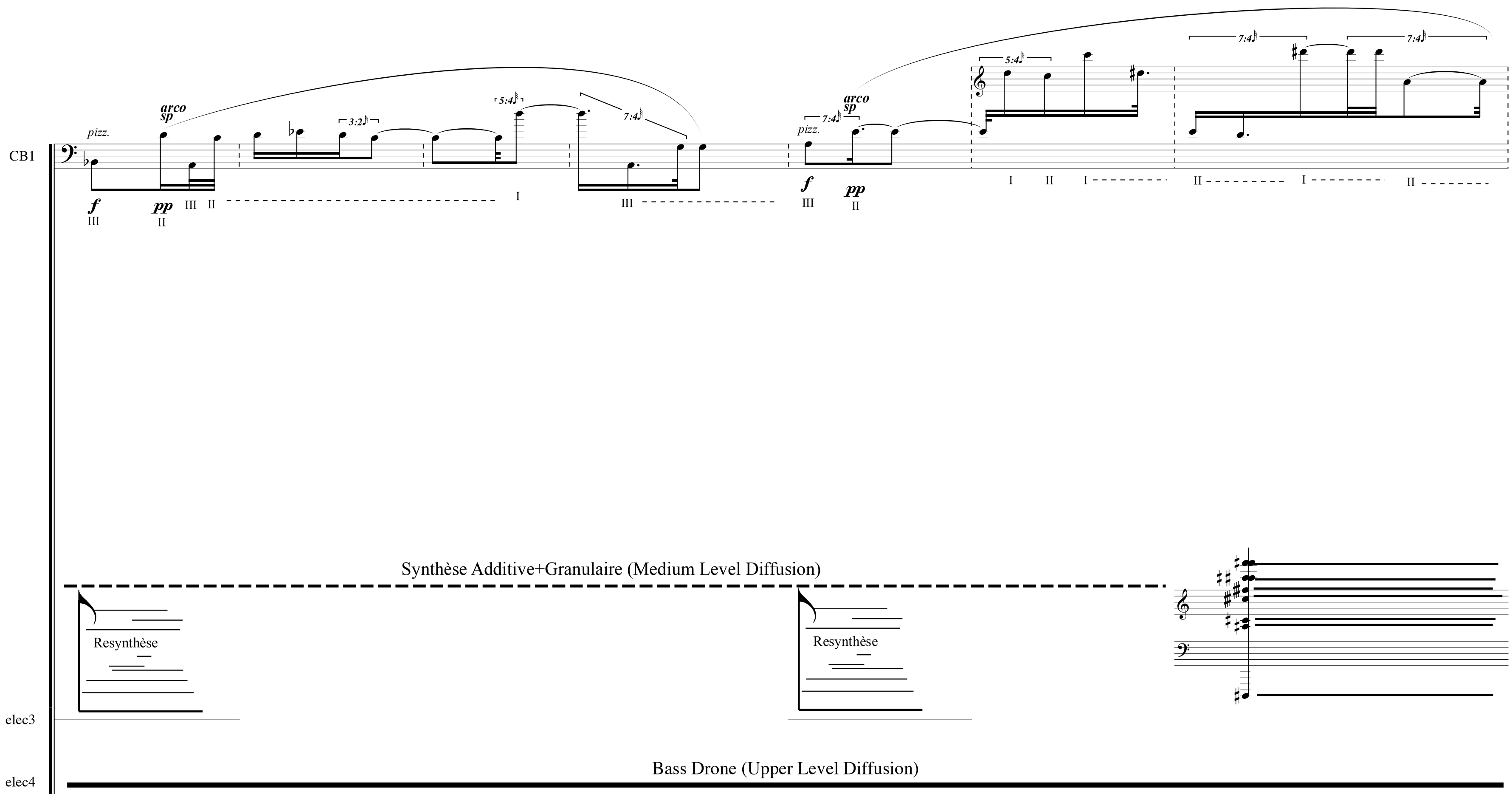


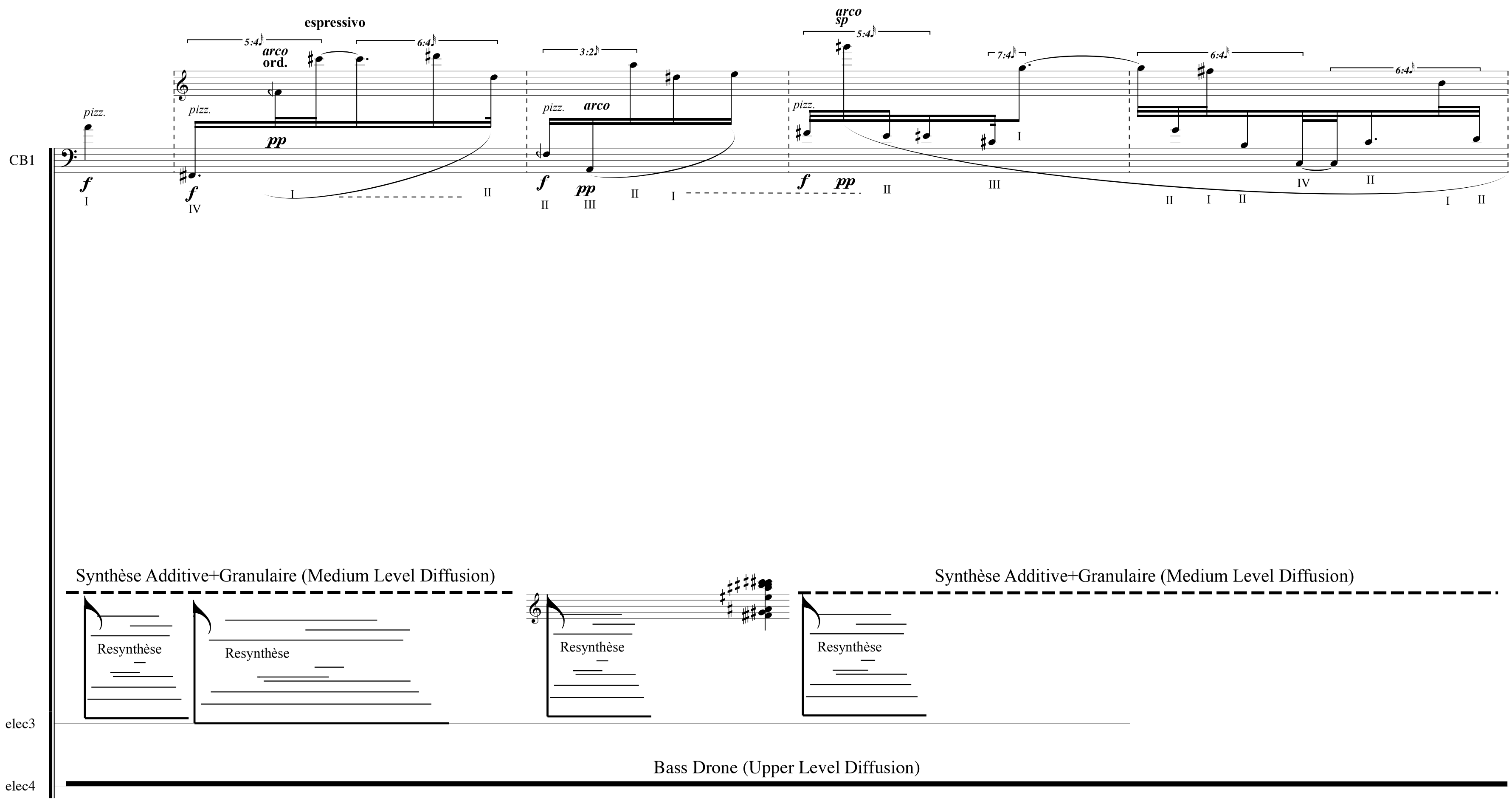

CB1
p
II
arco
sp
ppp sempre
IV
5:4
I
pizz.
mf
II
III
II
III
IV
7:4
Resynthèse
Synthèse Additive+Granulaire
Bass Drone (Upper Level Diffusion)
elec4

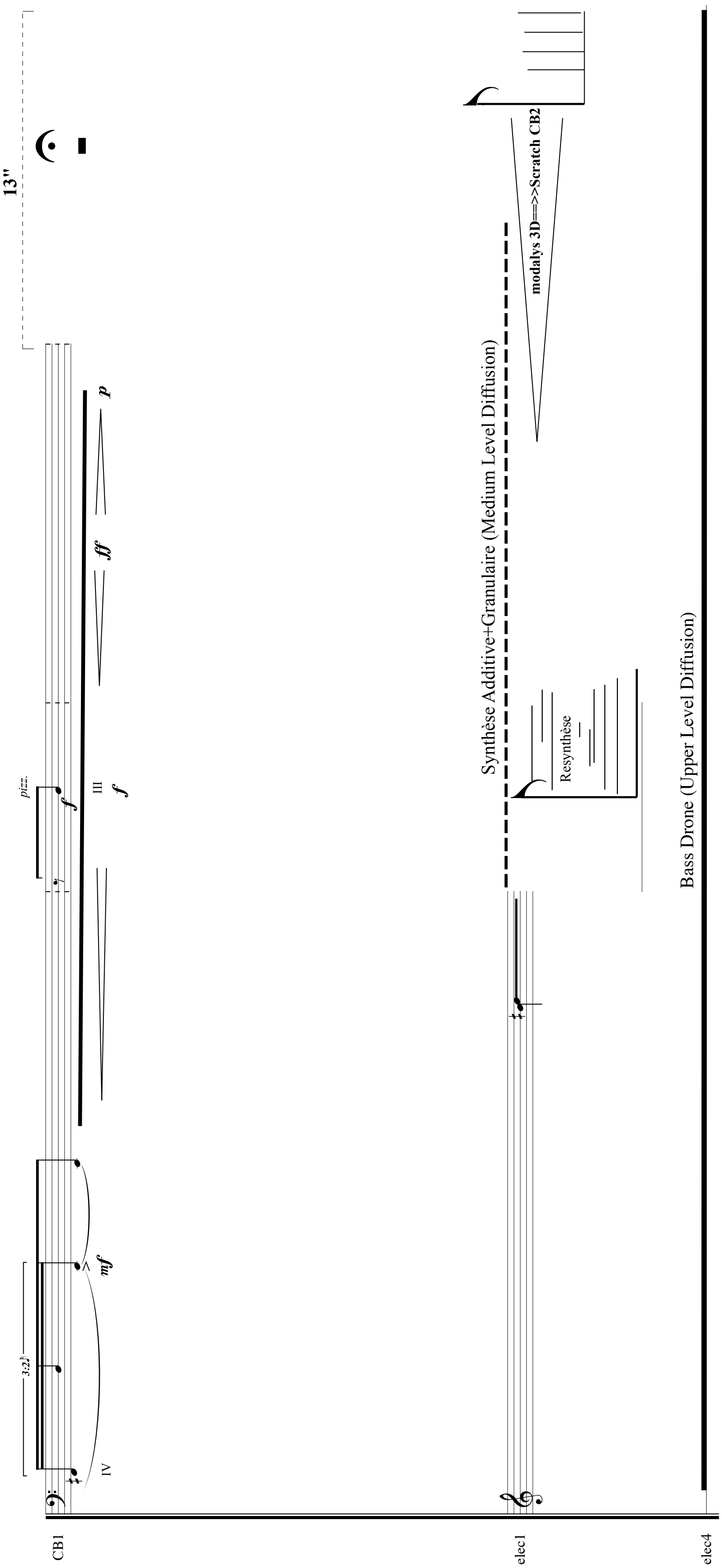

CB1
elec4
pizz.
arco
sp
ord.
vib.
f
pp
5:4
7:4
3:2
Synthèse Additive+Granulaire (Medium Level Diffusion)
Resynthèse
Bass Drone (Upper Level Diffusion)

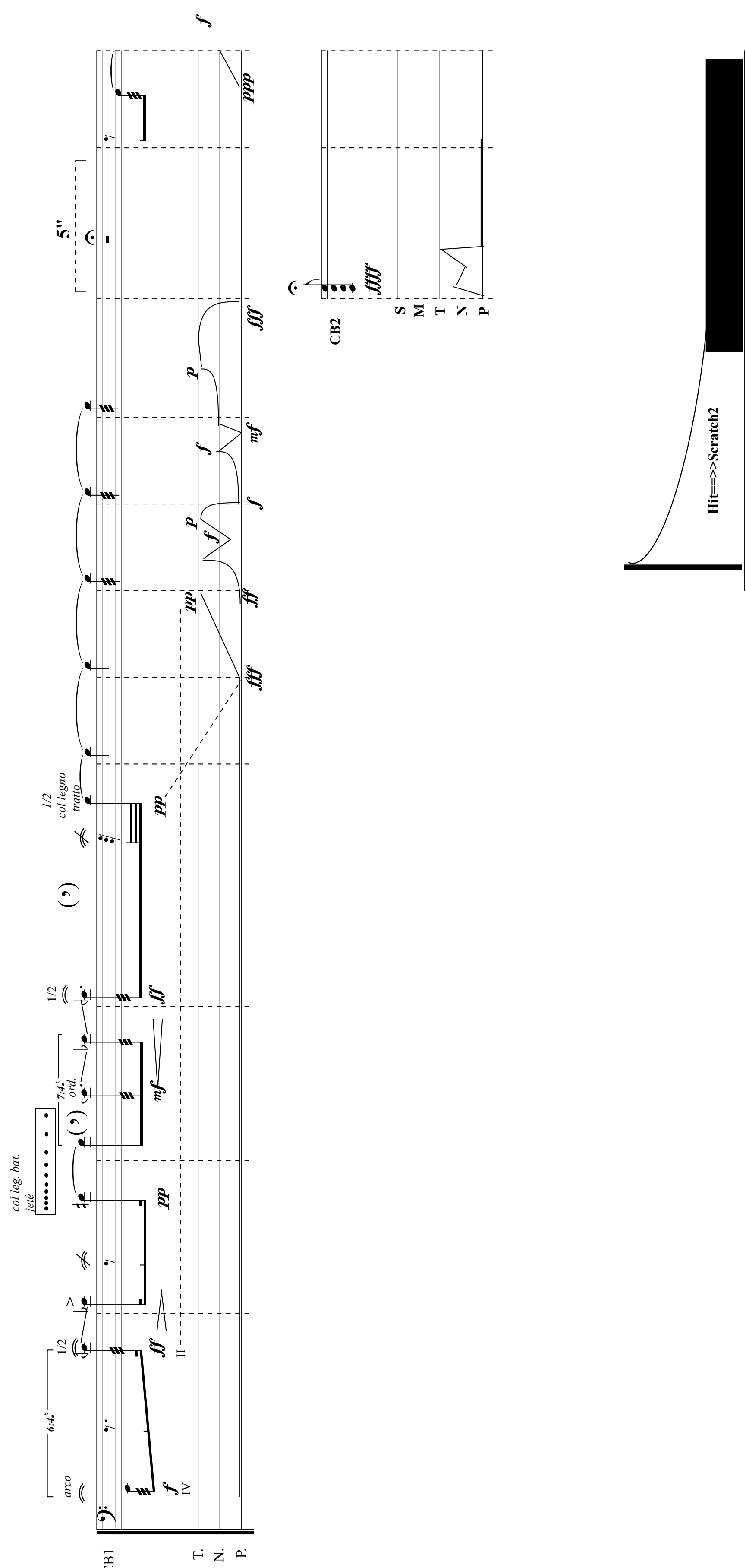

22
CB1
sp
pp
pizz.
ord.
arco
f
vib.
pizz.
arco
sp
sfzp
Synthèse Additive+Granulaire (Medium Level Diffusion)
Resynthèse
Resynthèse
Resynthèse
Resynthèse
Synthèse Additive+Granulaire (Medium Level Diffusion)
Bass Drone (Upper Level Diffusion)
elec4

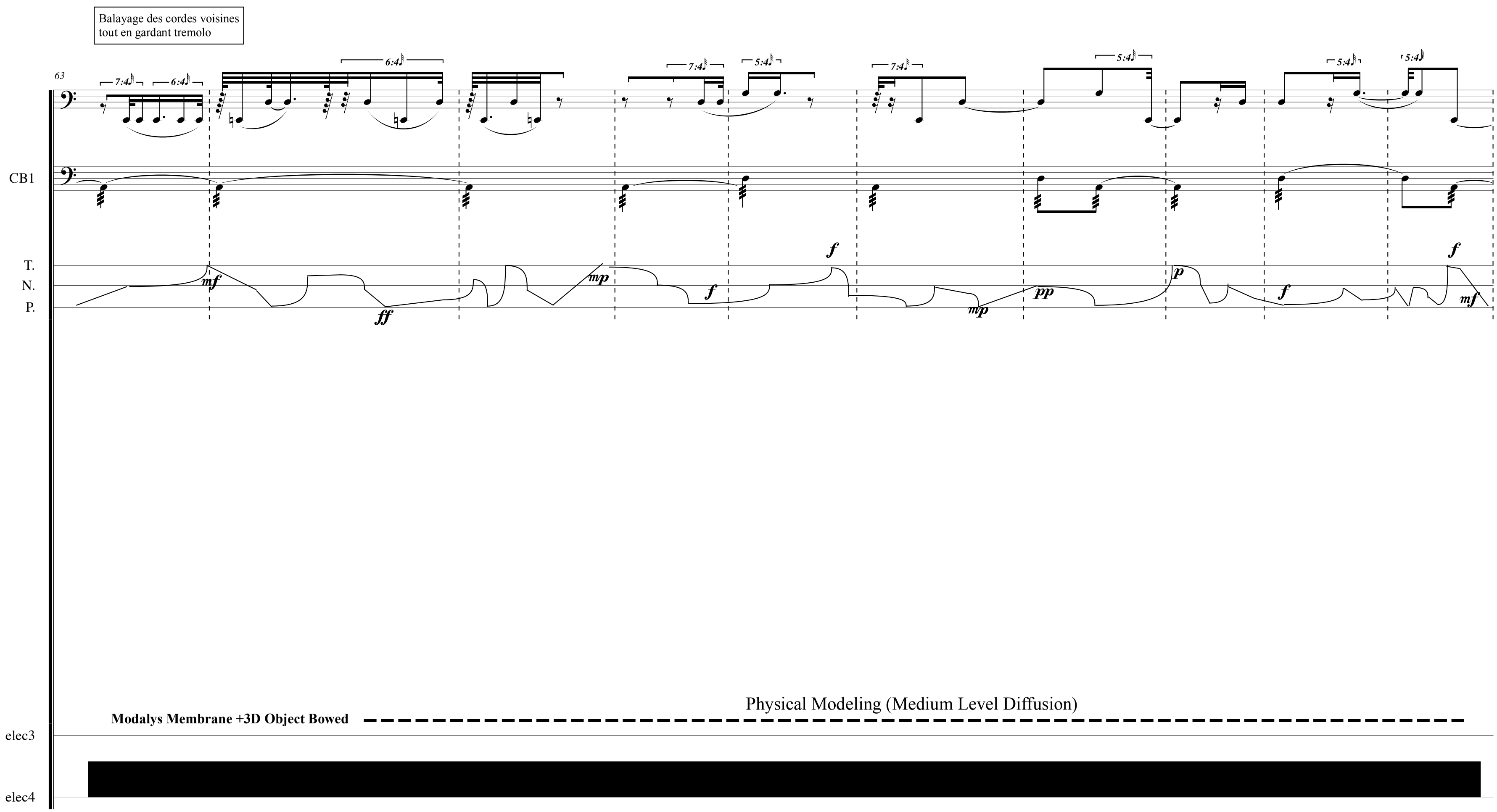

29
CB1
I
pizz.
f
arco
sp
pp
III
II
IV
7:4
5:4
III
IV
I
II
III
II
(’)
elec1
Synthèse Additive+Granulaire (Medium Level Diffusion)
Resynthèse
elec4
Bass Drone (Upper Level Diffusion)

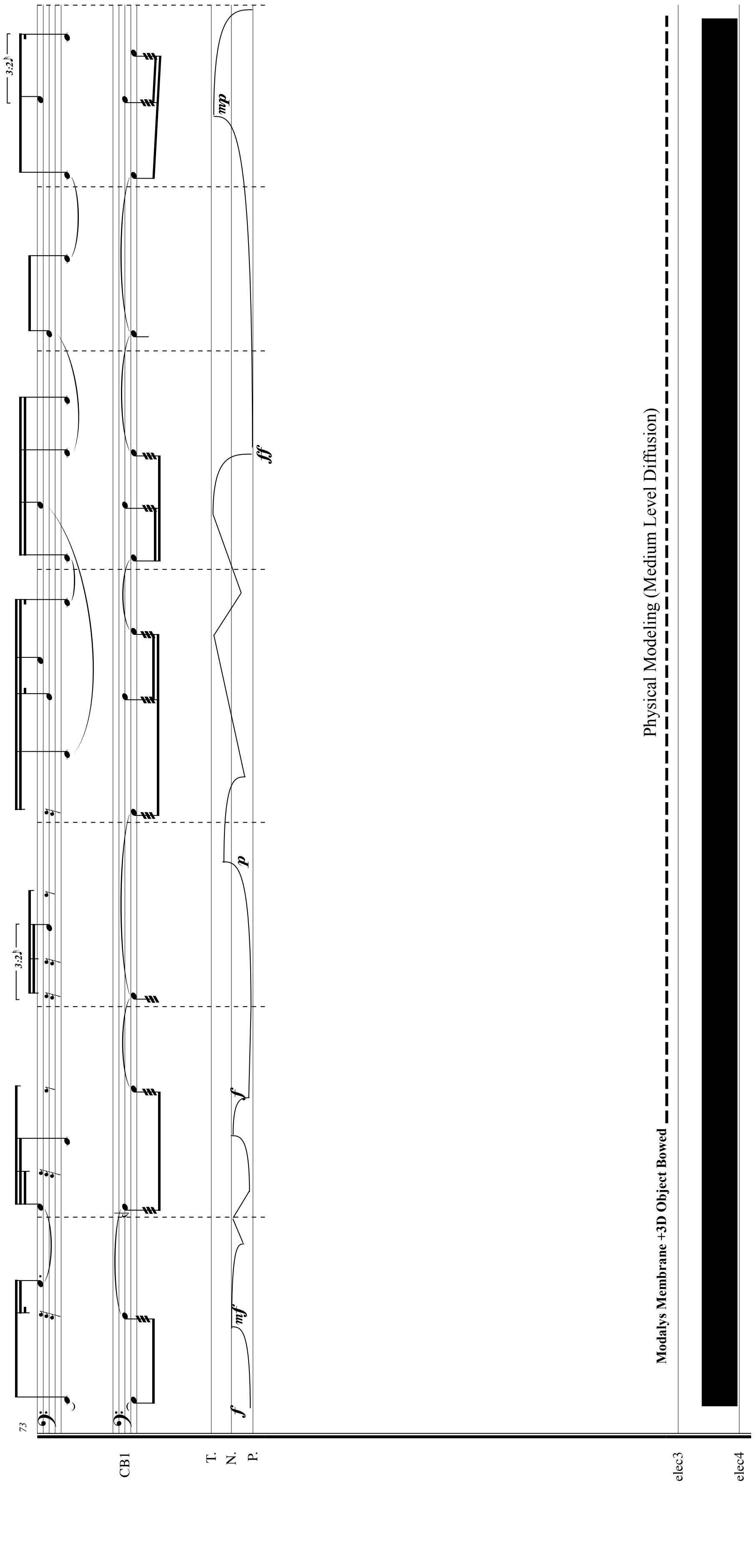

CB1
pizz.
arco
sp
f
pp
III
II
3:2
5:4
7:4
I
Synthèse Additive+Granulaire (Medium Level Diffusion)
Resynthèse
elec3
Bass Drone (Upper Level Diffusion)
elec4

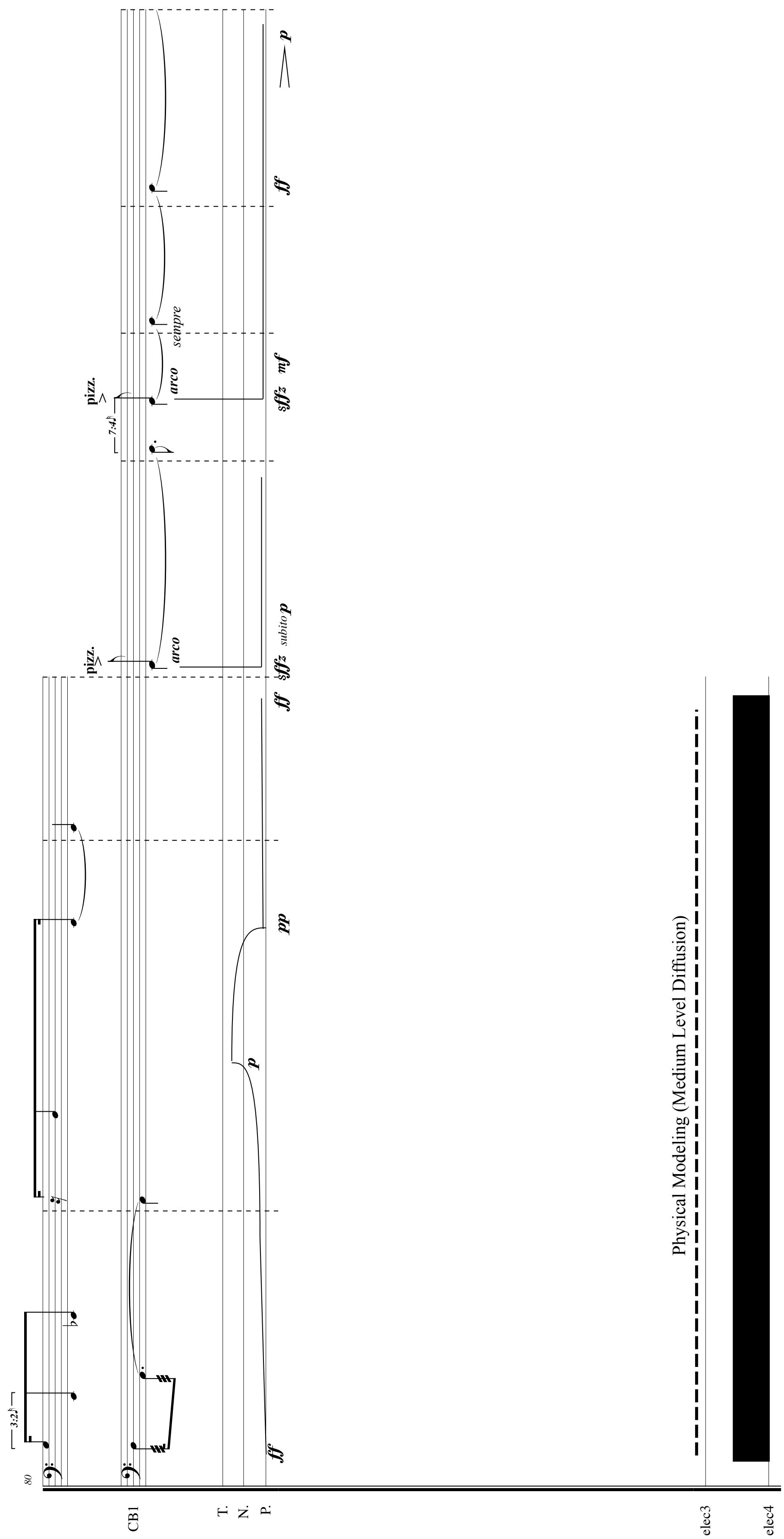

CB1
pizz.
espressivo
arco
ord.
5:4
6:4
3:2
arco
sp
7:4
f
pp
I
II
III
IV
elec3
elec4
Synthèse Additive+Granulaire (Medium Level Diffusion)
Resynthèse
Bass Drone (Upper Level Diffusion)


CB1
elec1
elec4
13"
3:2
IV
mf
pizz.
III
f
ff
p
Synthèse Additive+Granulaire (Medium Level Diffusion)
Resynthèse
modalys 3D==>Scratch CB2
Bass Drone (Upper Level Diffusion)

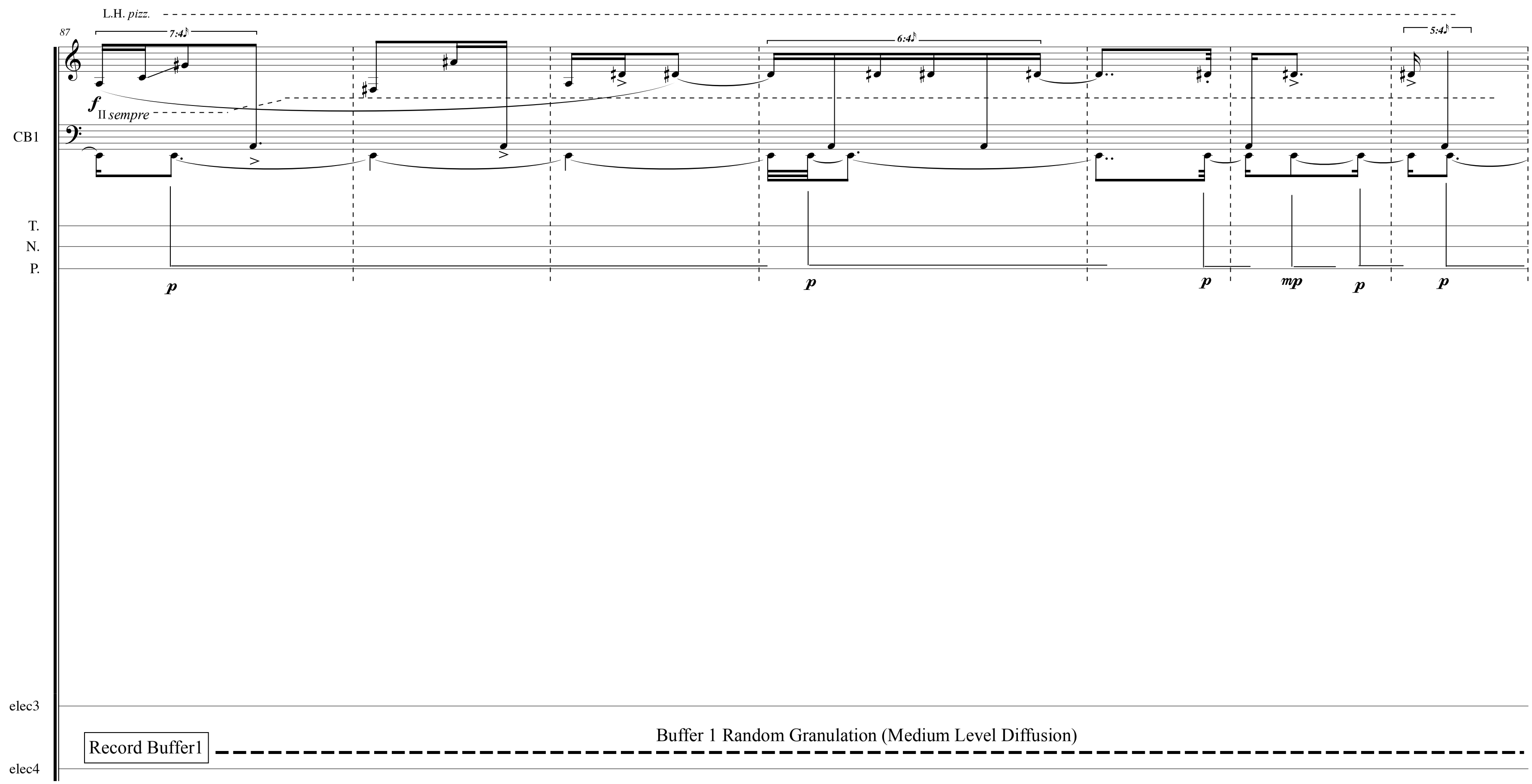

CB1
T.
N.
P.
arco
IV
6:4
1/2
II
col leg. bat.
jeté
ord.
7:4
1/2
col legno
tratto
5"
CB2
S
M
T
N
P
Hit==>Scratch2

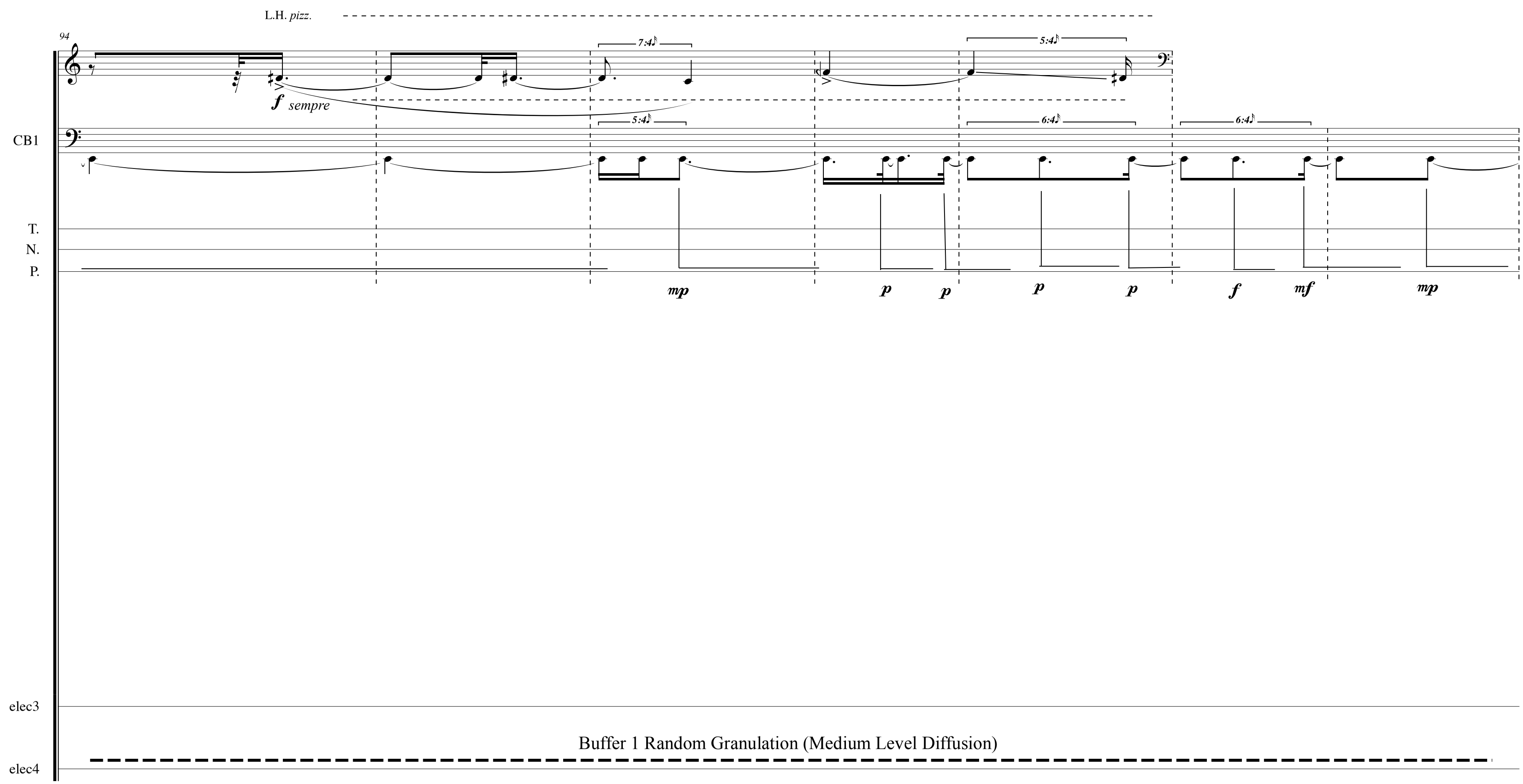

Balayage des cordes voisines
tout en gardant tremolo
63
7:4
6:4
5:4
CB1
T.
N.
P.
mf
ff
mp
f
pp
p
Modalys Membrane +3D Object Bowed
Physical Modeling (Medium Level Diffusion)
elec3
elec4


73
CB1
T.
N.
P.
f
mf
f
p
ff
mp
3:2
3:2
Modalys Membrane +3D Object Bowed
Physical Modeling (Medium Level Diffusion)
elec3
elec4

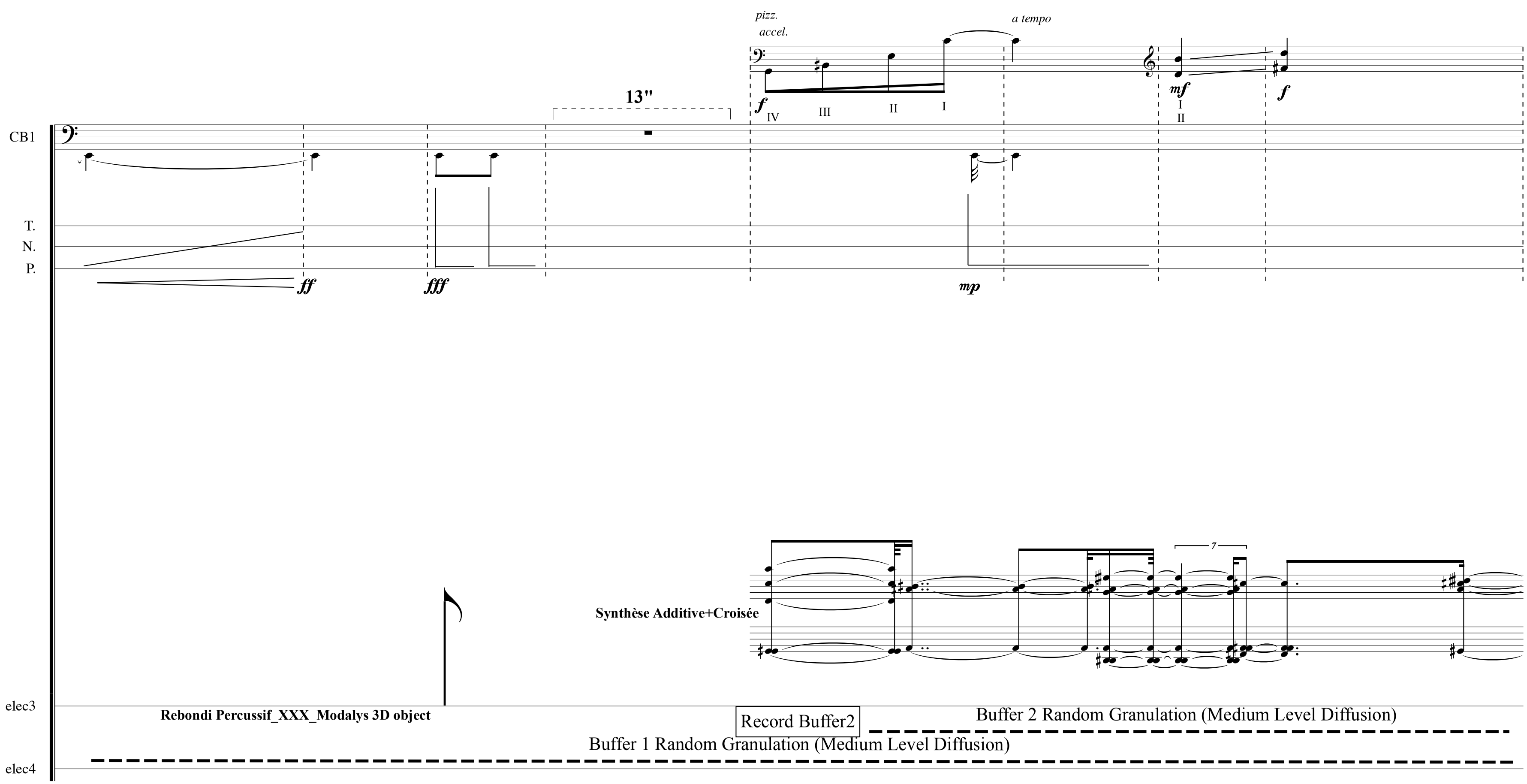


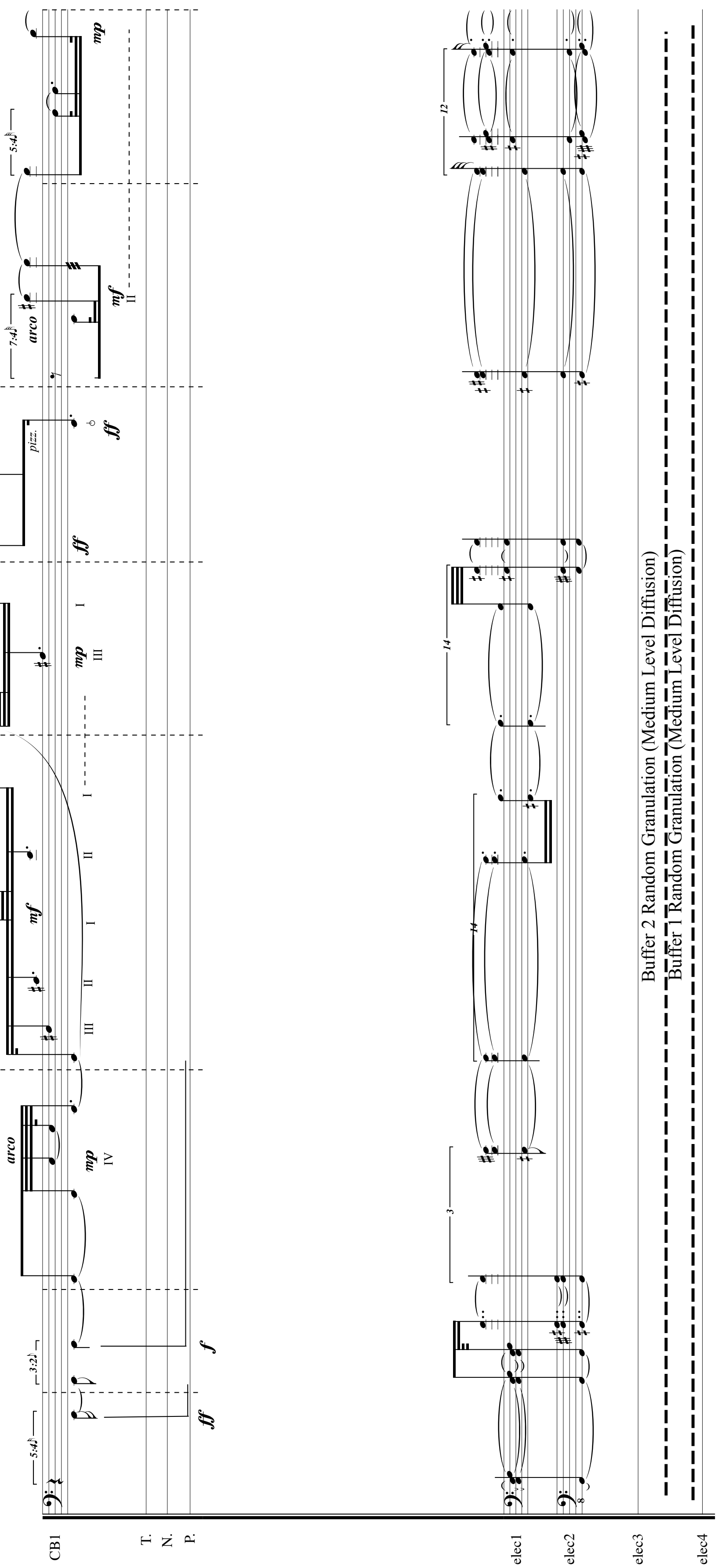
CB1
T.
N.
P.
80
3:2
ff
p
pp
pizz.
arco
sffz
subito p
7:4
mf
sempre
Physical Modeling (Medium Level Diffusion)
elec3
elec4

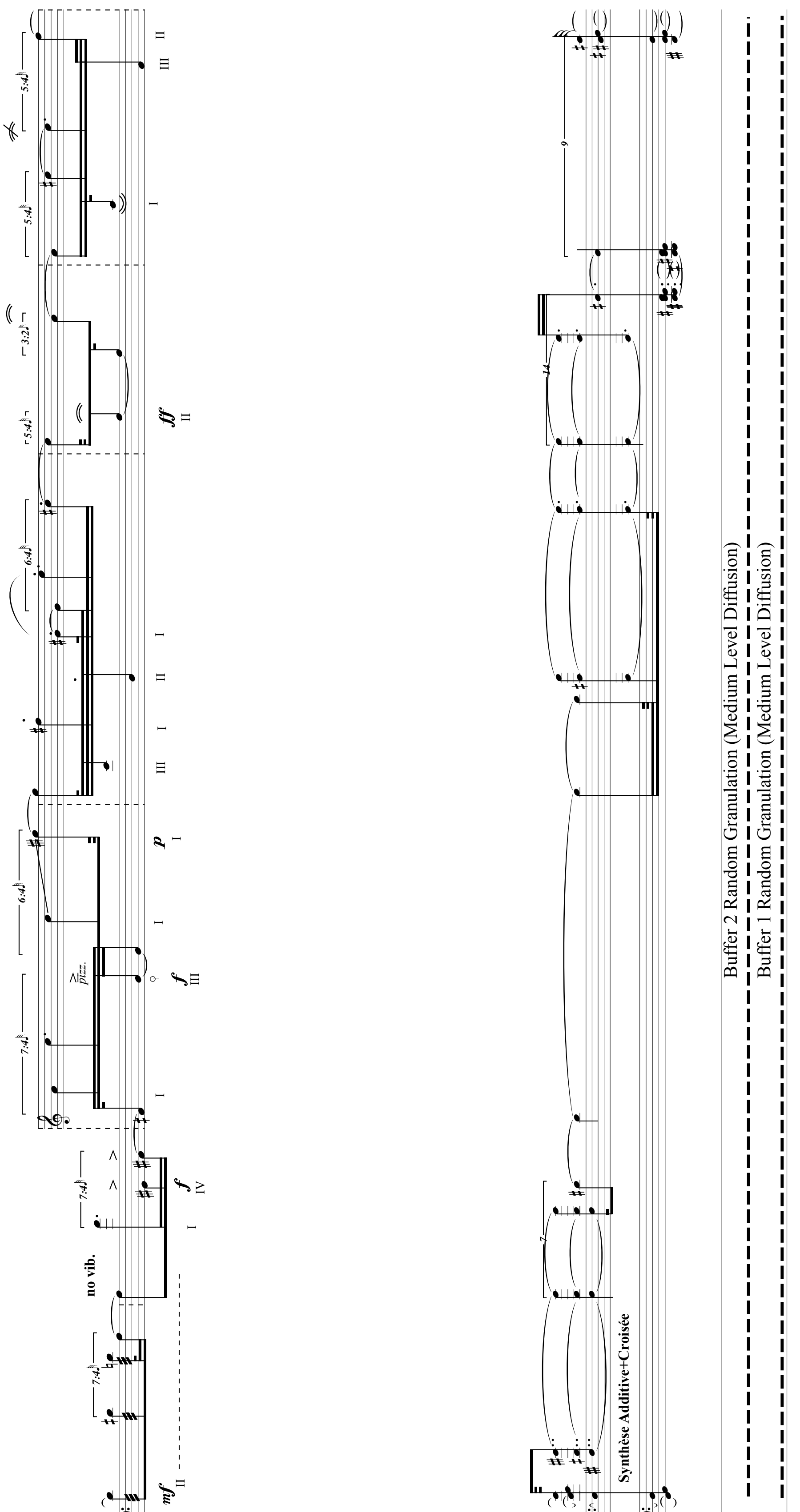

87
L.H. pizz.
7:4
6:4
5:4
f
II sempre
p
mp
CB1
T.
N.
P.
elec3
elec4
Record Buffer1
Buffer 1 Random Granulation (Medium Level Diffusion)

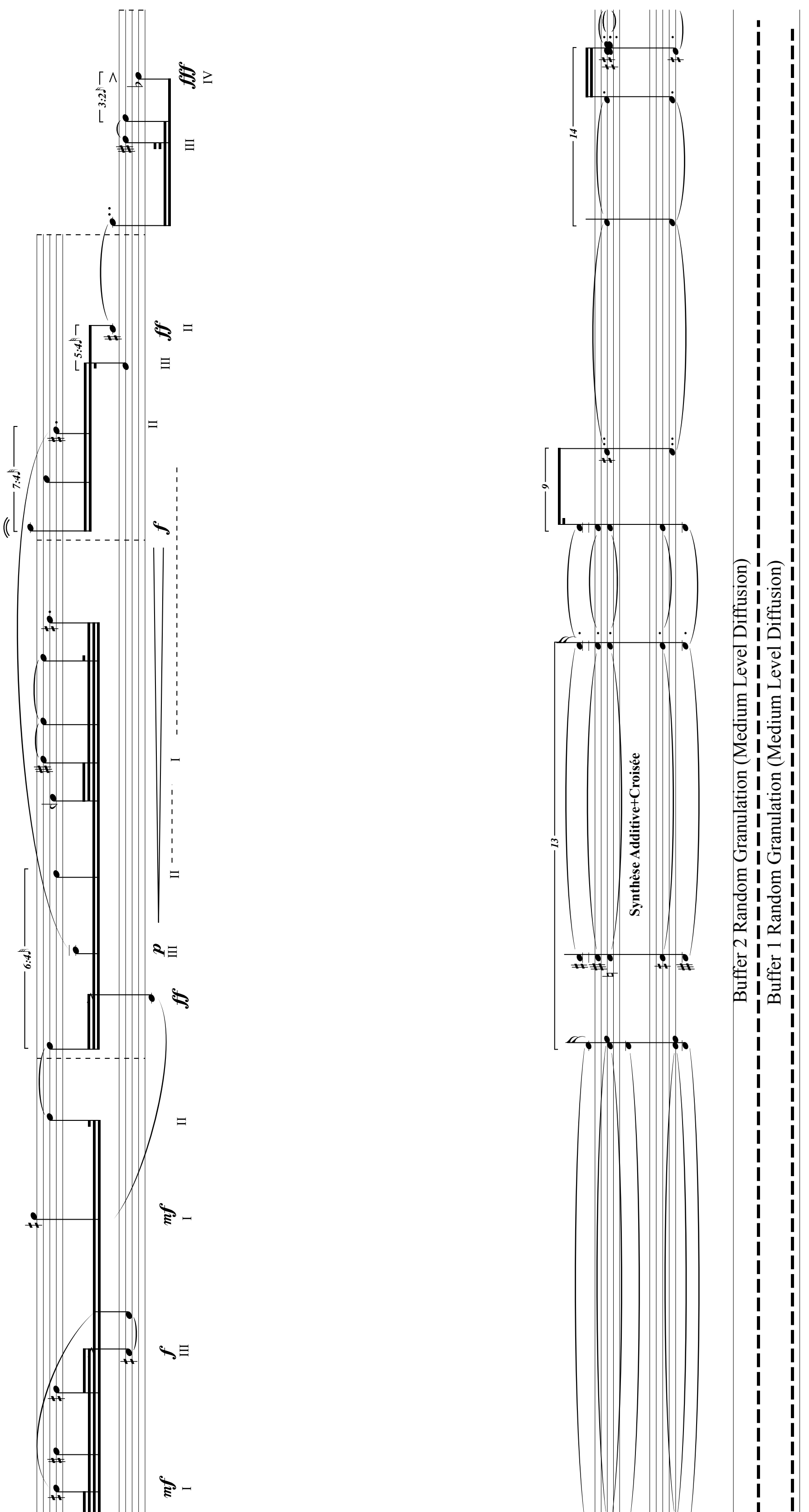


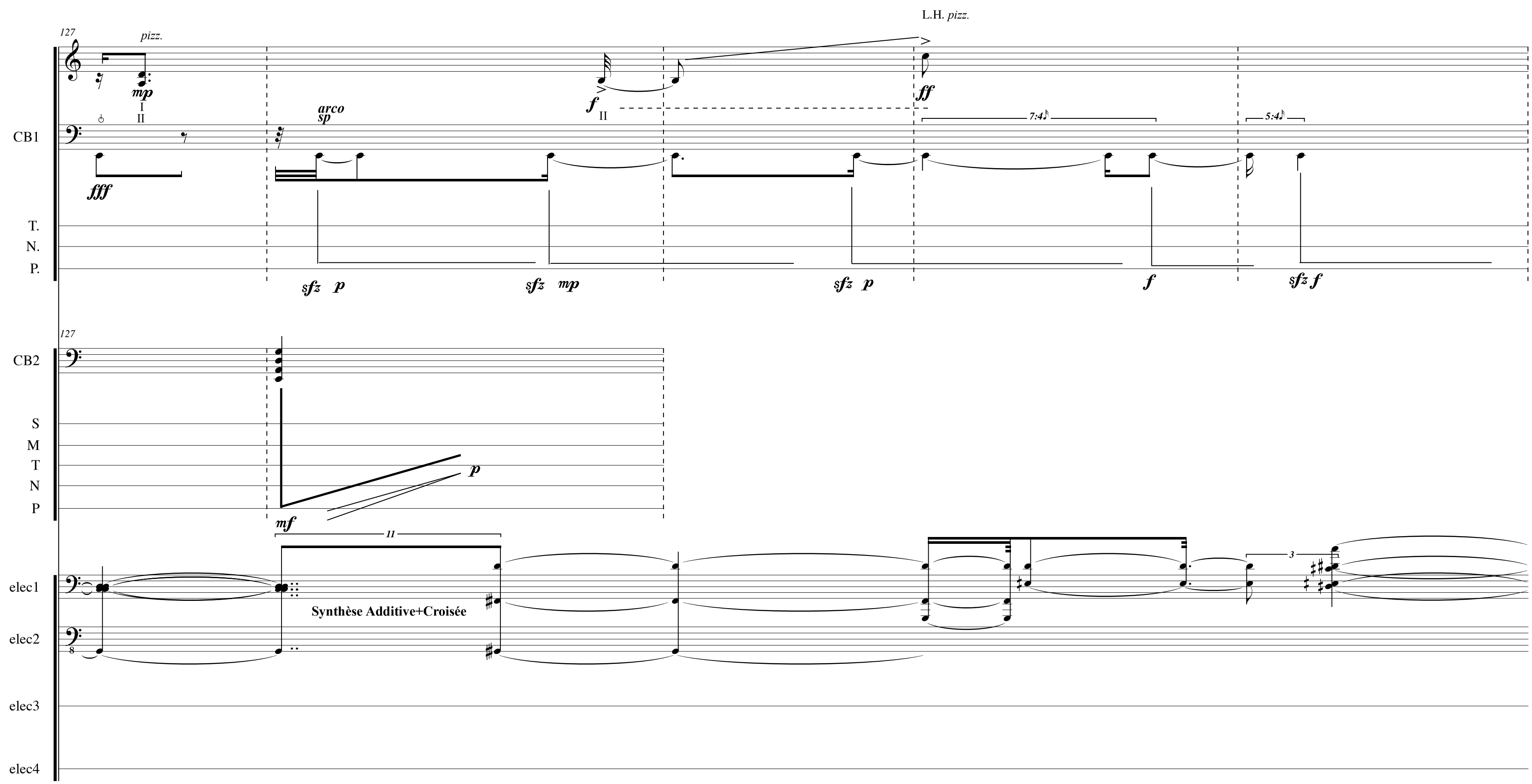
L.H. pizz.
94
CB1
T.
N.
P.
f sempre
7:4
5:4
6:4
mp
p
f
mf
elec3
elec4
Buffer 1 Random Granulation (Medium Level Diffusion)

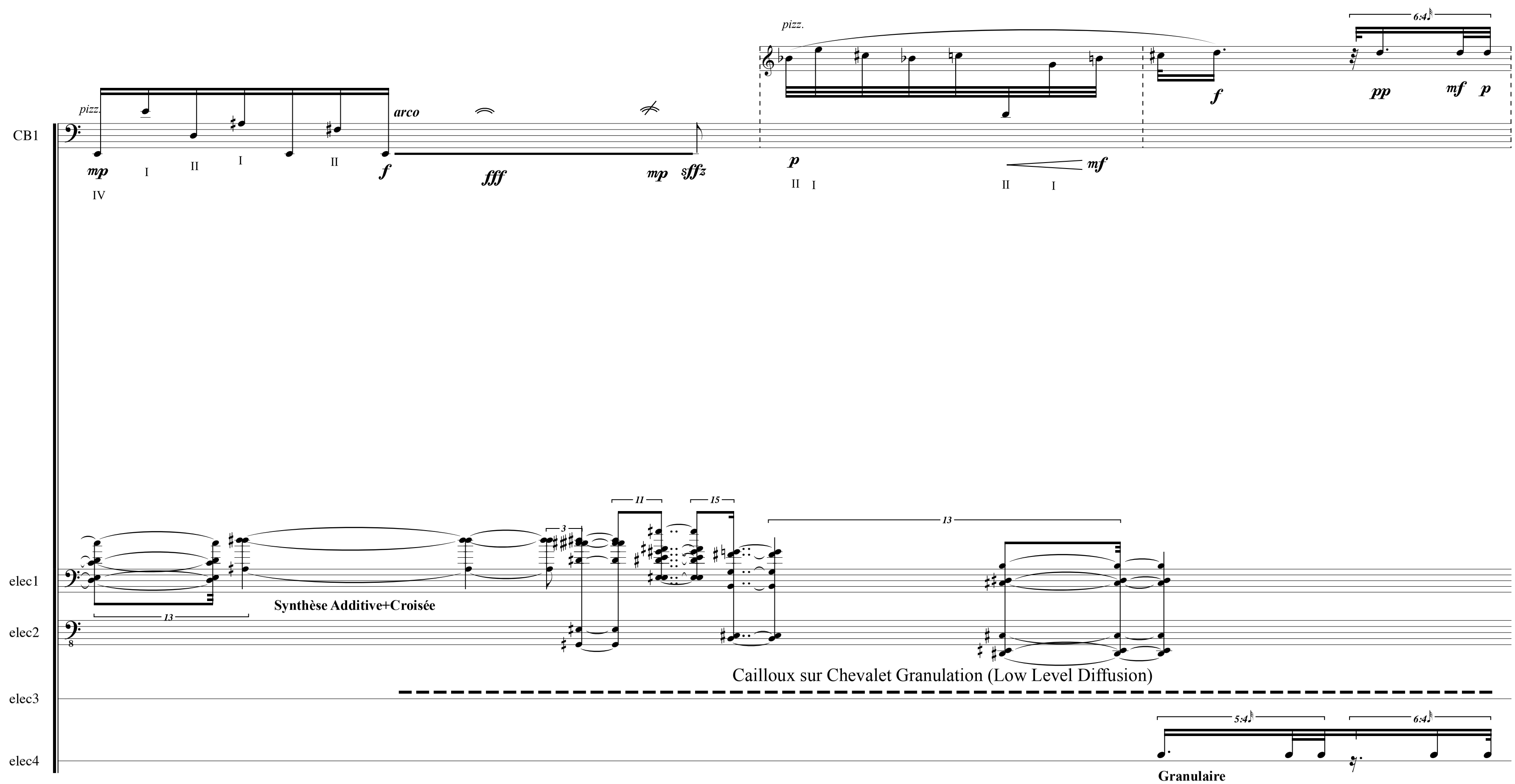

CB1
T.
N.
P.
ff
fff
13"
pizz.
accel.
a tempo
f
IV
III
II
I
mp
mf
I
II
f
7
Synthèse Additive+Croisée
elec3
Rebondi Percussif_XXX_Modalys 3D object
Record Buffer2
Buffer 2 Random Granulation (Medium Level Diffusion)
Buffer 1 Random Granulation (Medium Level Diffusion)
elec4

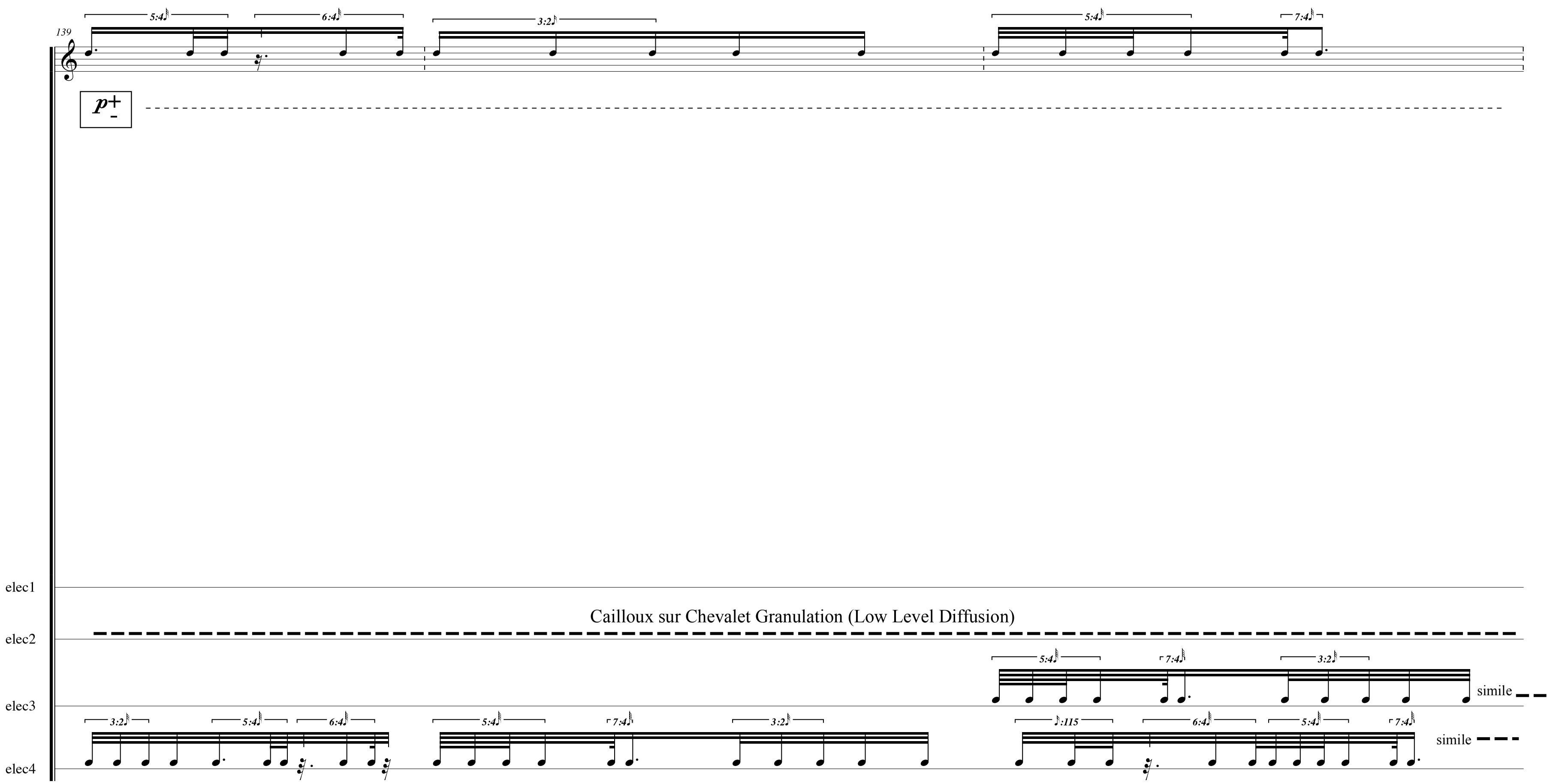

CB1
T.
N.
P.
arco
pizz.
molto vib.
elec1
elec2
elec3
elec4
Buffer 2 Random Granulation (Medium Level Diffusion)
Buffer 1 Random Granulation (Medium Level Diffusion)


CB1
elec1
elec2
elec3
elec4
no vib.
pizz.
Synthèse Additive+Croisée
Buffer 2 Random Granulation (Medium Level Diffusion)
Buffer 1 Random Granulation (Medium Level Diffusion)

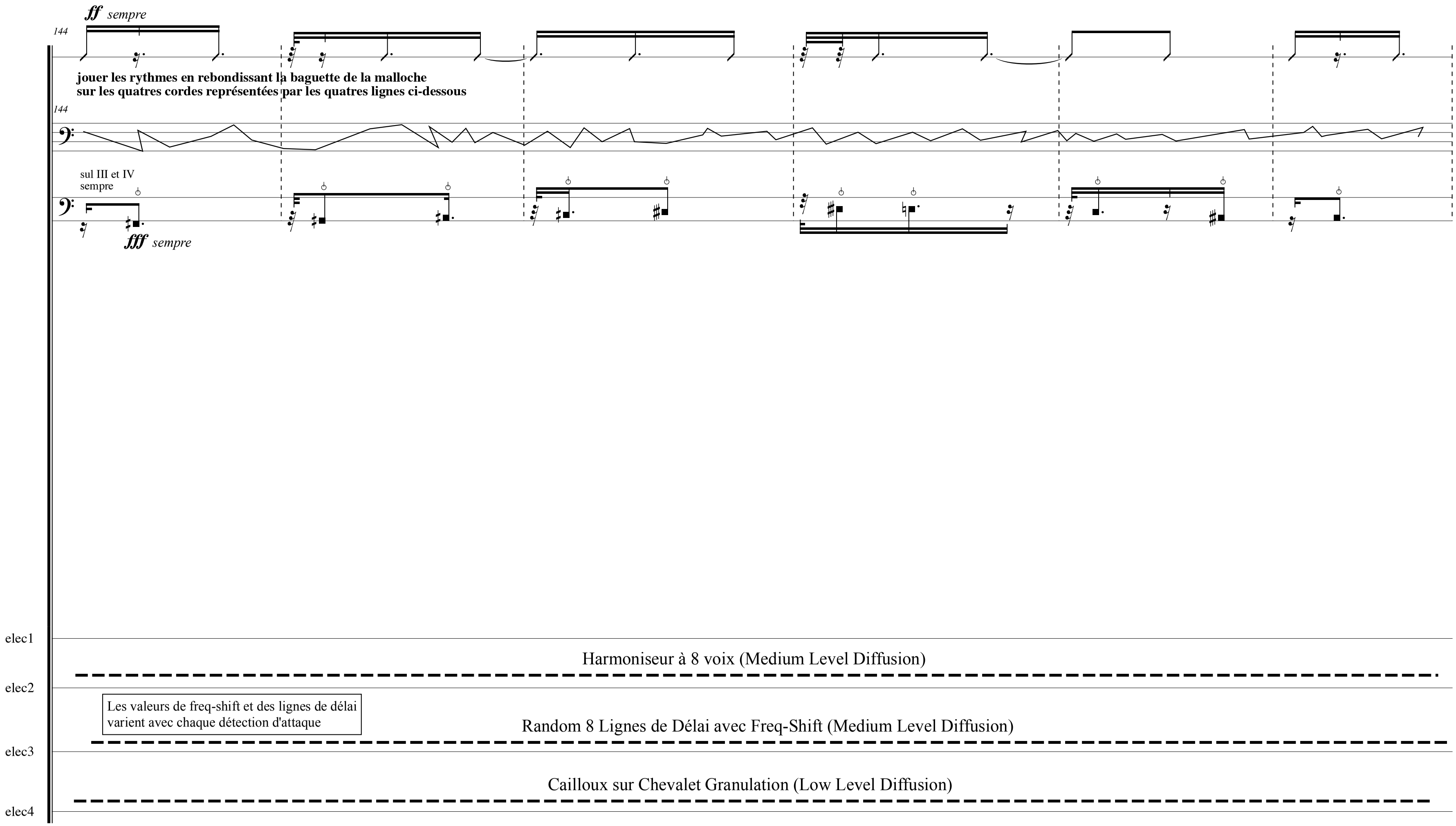

123
CB1
elec1
elec2
elec3
elec4
Synthèse Additive+Croisée
Buffer 2 Random Granulation (Medium Level Diffusion)
Buffer 1 Random Granulation (Medium Level Diffusion)

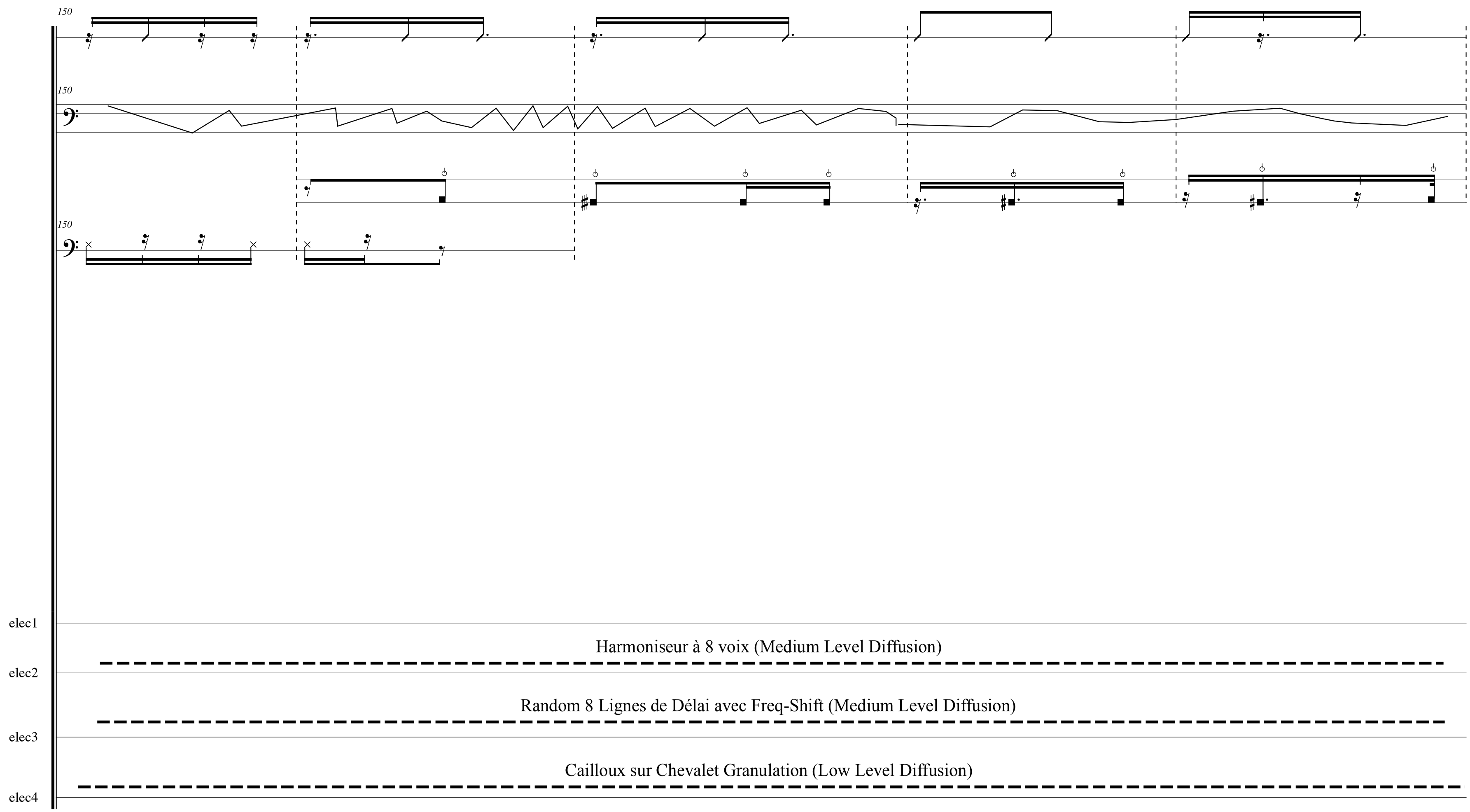

127
pizz.
L.H. pizz.
arco
sp
CB1
T.
N.
P.
sfz p
sfz mp
sfz p
f
sfz f
7:4
5:4
CB2
S
M
T
N
P
mf
p
11
elec1
elec2
elec3
elec4
Synthèse Additive+Croisée
3

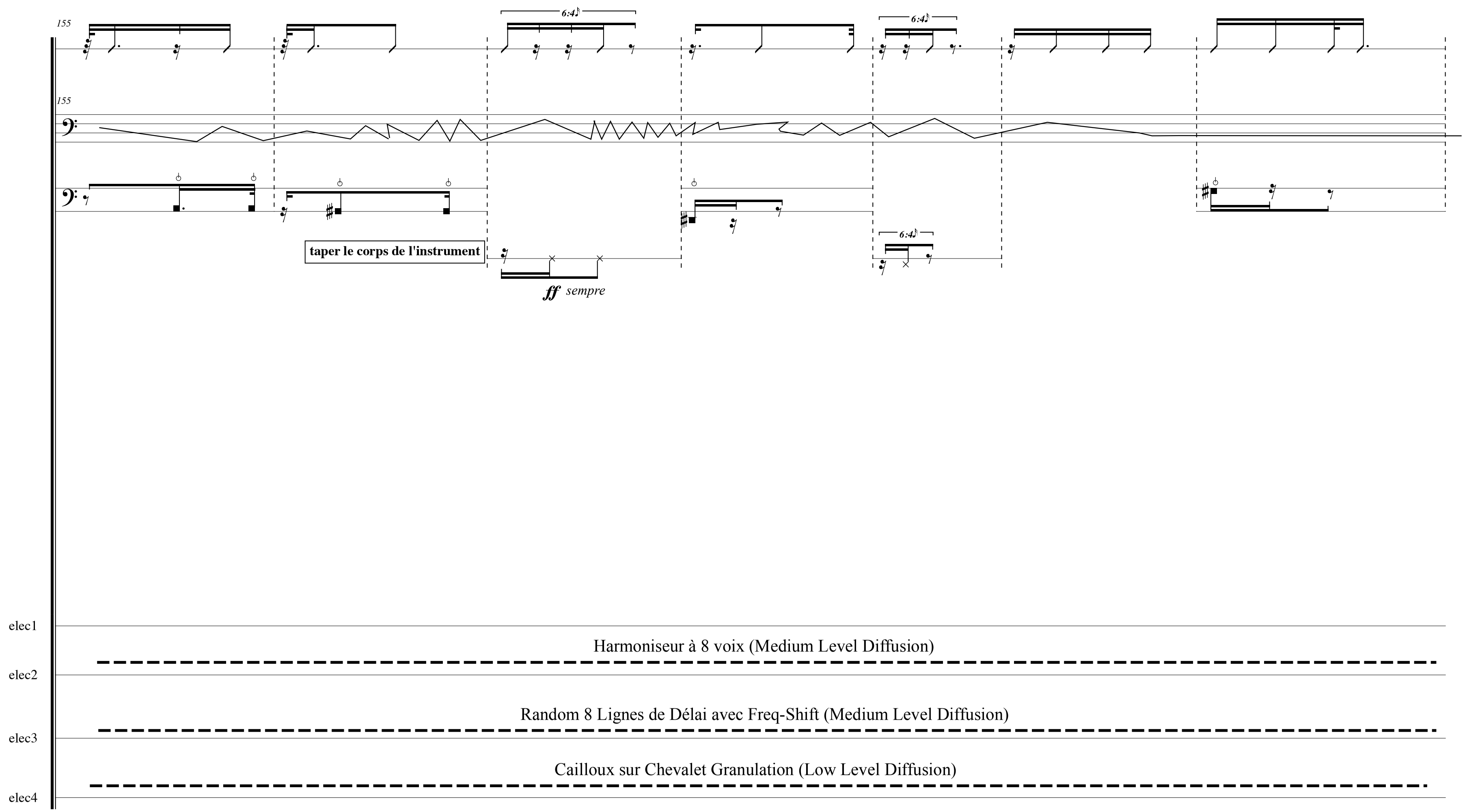

CB1
pizz.
mp
IV
I
II
I
II
f
arco
fff
mp
sffz
pizz.
p
II I
II I
mf
f
6:4
pp
mf
p
elec1
elec2
elec3
elec4
13
Synthèse Additive+Croisée
3
11
15
13
Cailloux sur Chevalet Granulation (Low Level Diffusion)
5:4
6:4
Granulaire

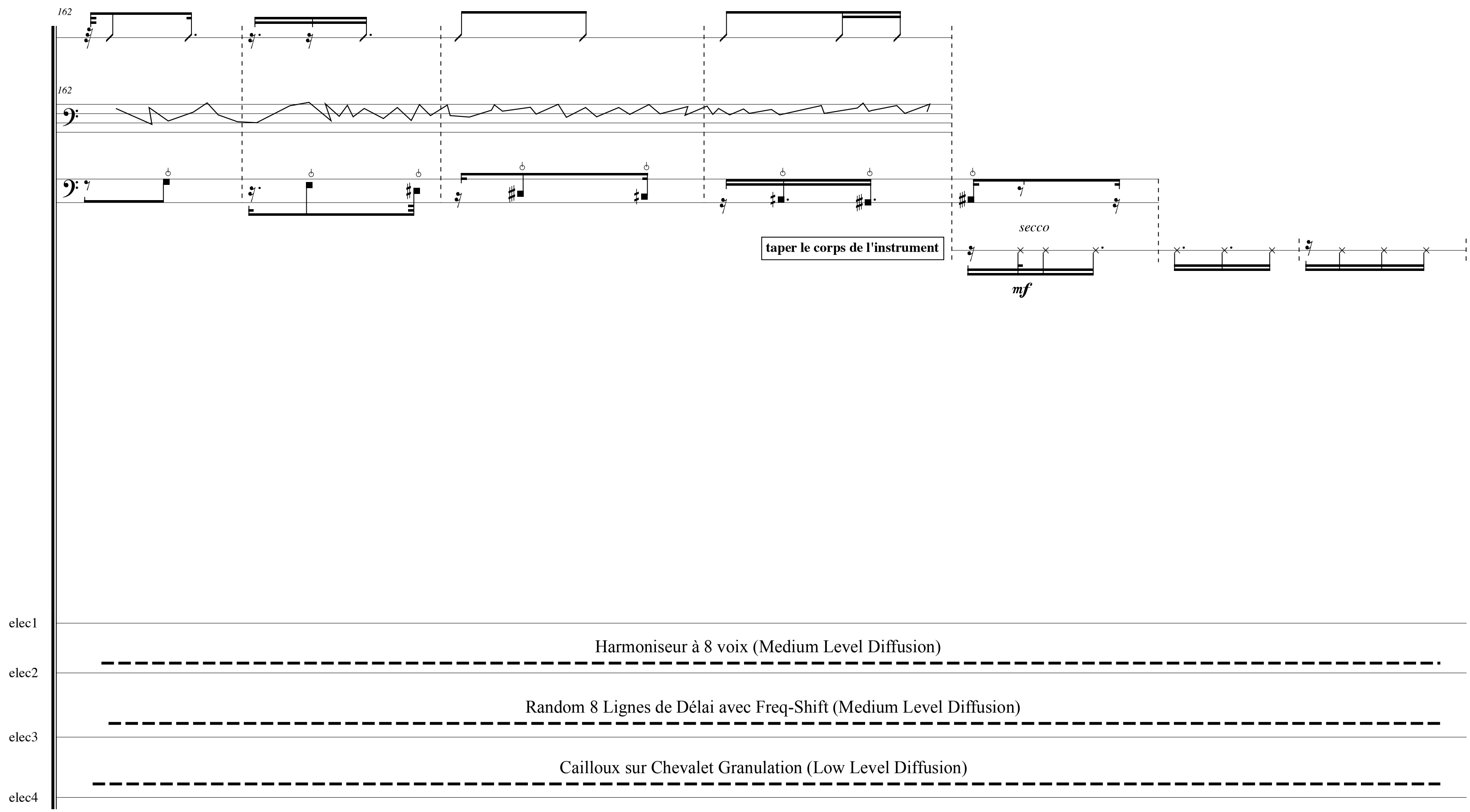

139
elec1
elec2
elec3
elec4
Cailloux sur Chevalet Granulation (Low Level Diffusion)
simile
simile

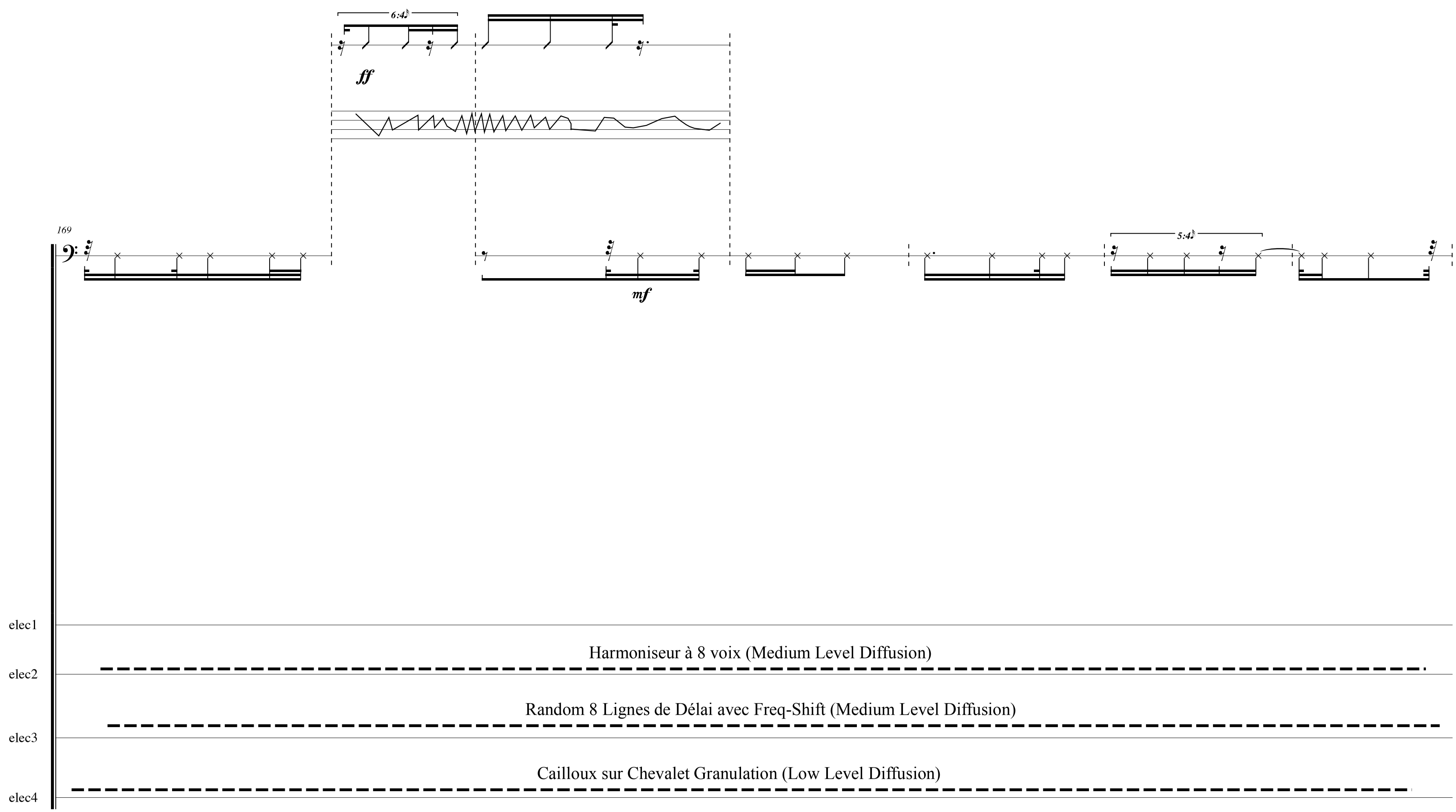

142
4"
6"
Cailloux sur Chevalet Granulation (Low Level Diffusion)
Modalys Membrane Hit
ff
elec1
elec2
elec3
elec4

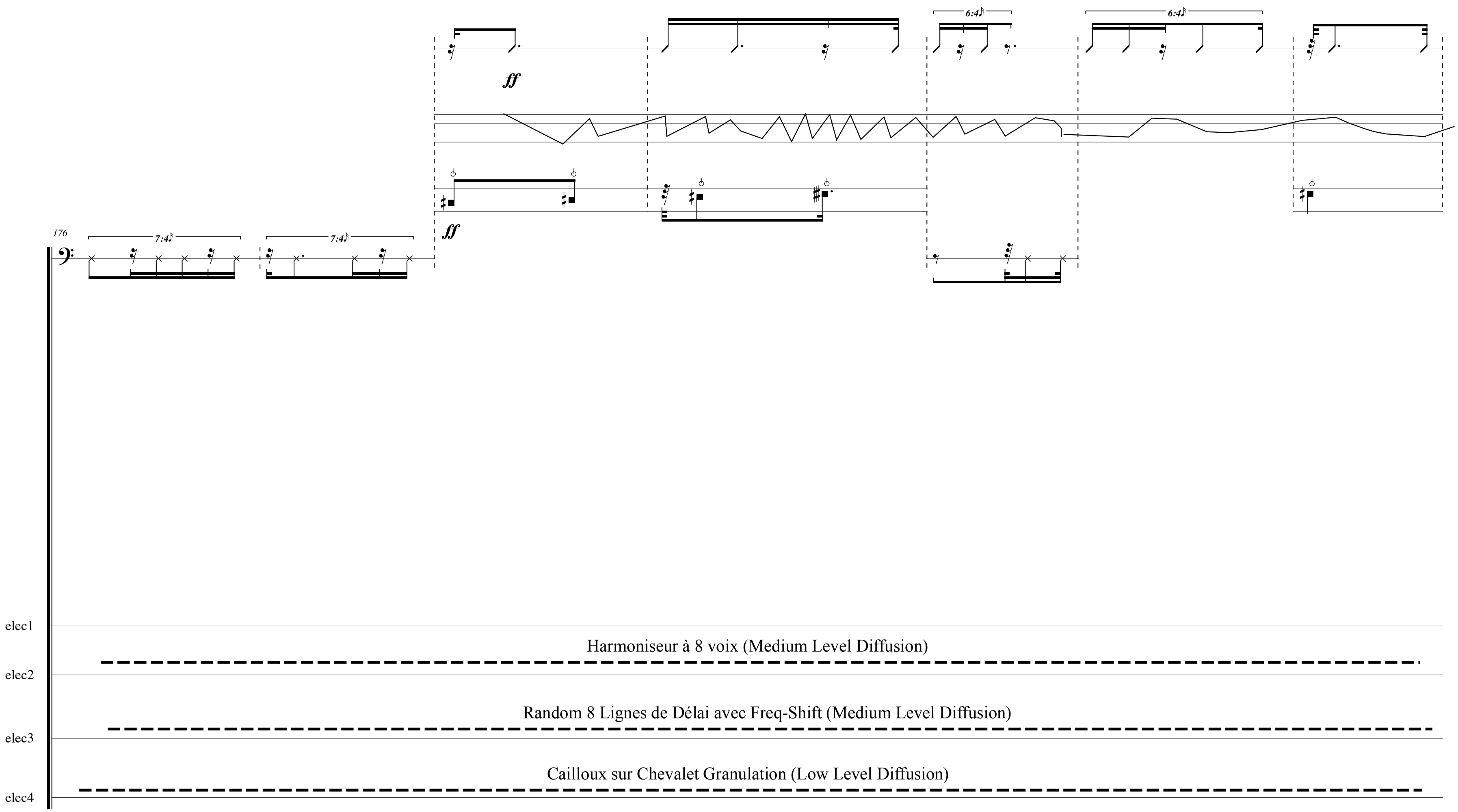

144
ff sempre
jouer les rythmes en rebondissant la baguette de la malloche
sur les quatres cordes représentées par les quatres lignes ci-dessous
144
sul III et IV
sempre
fff sempre
elec1
Harmoniseur à 8 voix (Medium Level Diffusion)
elec2
Les valeurs de freq-shift et des lignes de délai
varient avec chaque détection d'attaque
Random 8 Lignes de Délai avec Freq-Shift (Medium Level Diffusion)
elec3
Cailloux sur Chevalet Granulation (Low Level Diffusion)
elec4

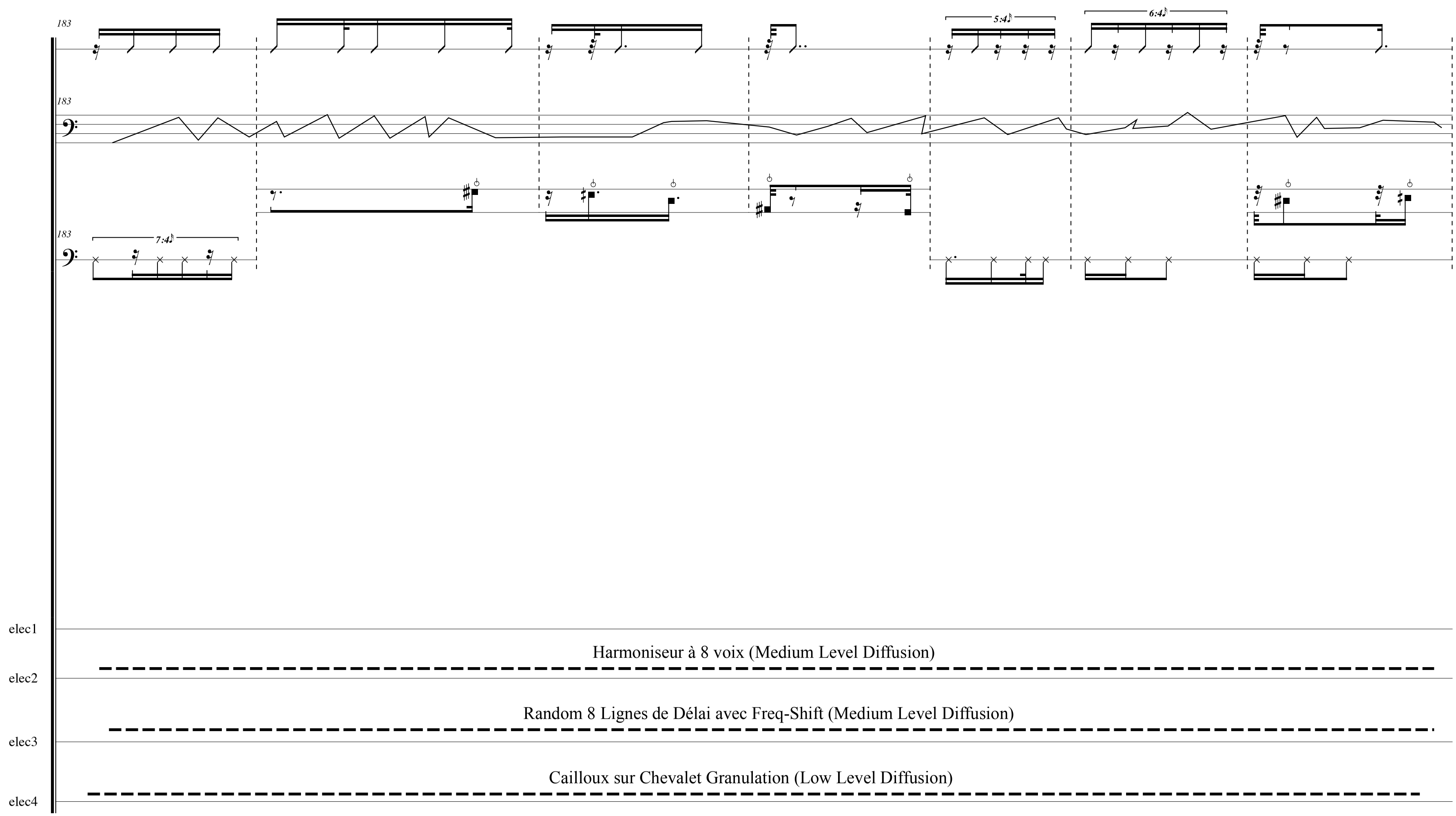

150
150
150
elec1
Harmoniseur à 8 voix (Medium Level Diffusion)
elec2
Random 8 Lignes de Délai avec Freq-Shift (Medium Level Diffusion)
elec3
Cailloux sur Chevalet Granulation (Low Level Diffusion)
elec4

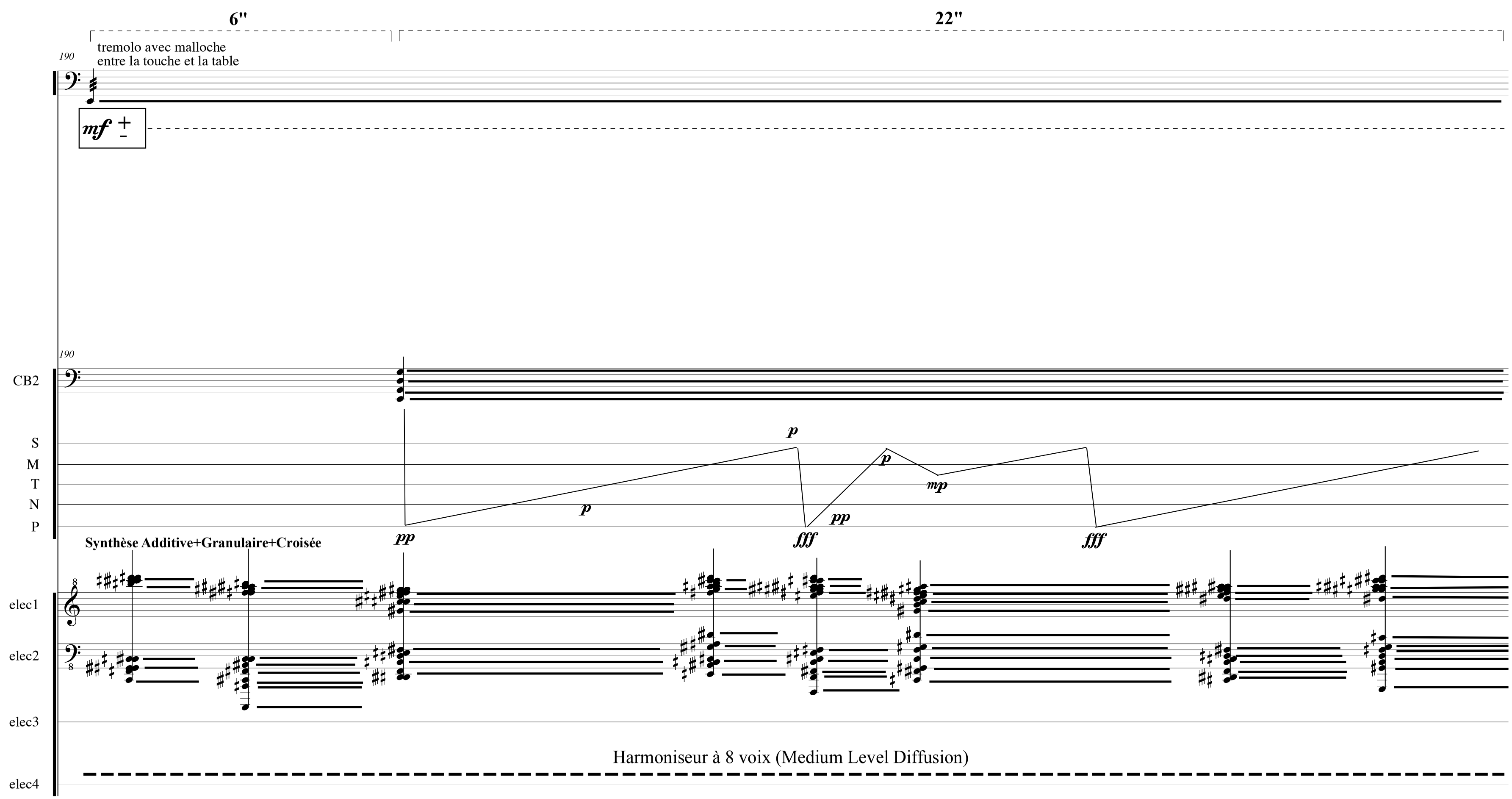

155
155
taper le corps de l'instrument
6:4
6:4
6:4
ff sempre
elec1
Harmoniseur à 8 voix (Medium Level Diffusion)
elec2
Random 8 Lignes de Délai avec Freq-Shift (Medium Level Diffusion)
elec3
Cailloux sur Chevalet Granulation (Low Level Diffusion)
elec4

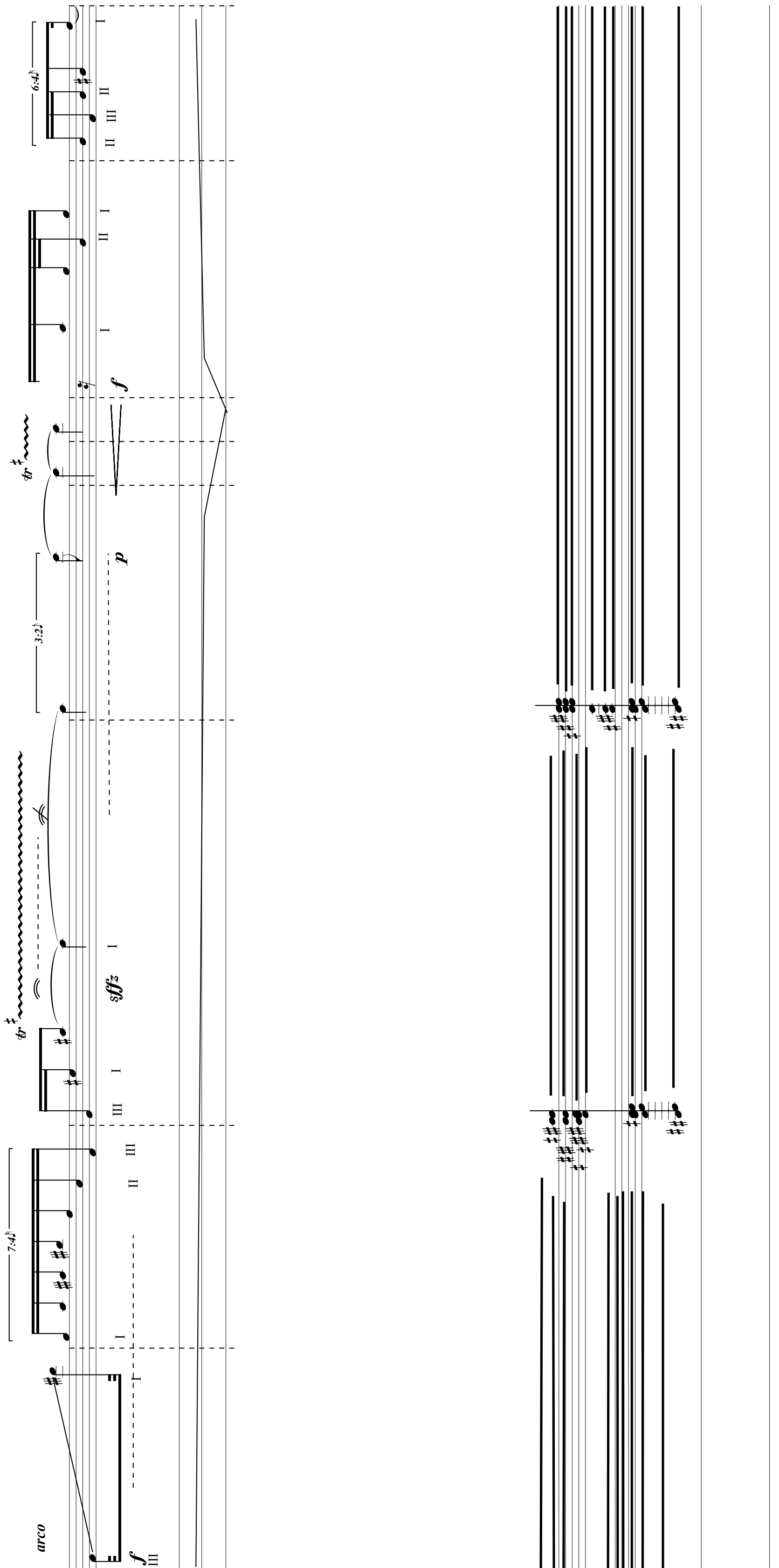

162
162
taper le corps de l'instrument
secco
mf
elec1
Harmoniseur à 8 voix (Medium Level Diffusion)
elec2
Random 8 Lignes de Délai avec Freq-Shift (Medium Level Diffusion)
elec3
Cailloux sur Chevalet Granulation (Low Level Diffusion)
elec4

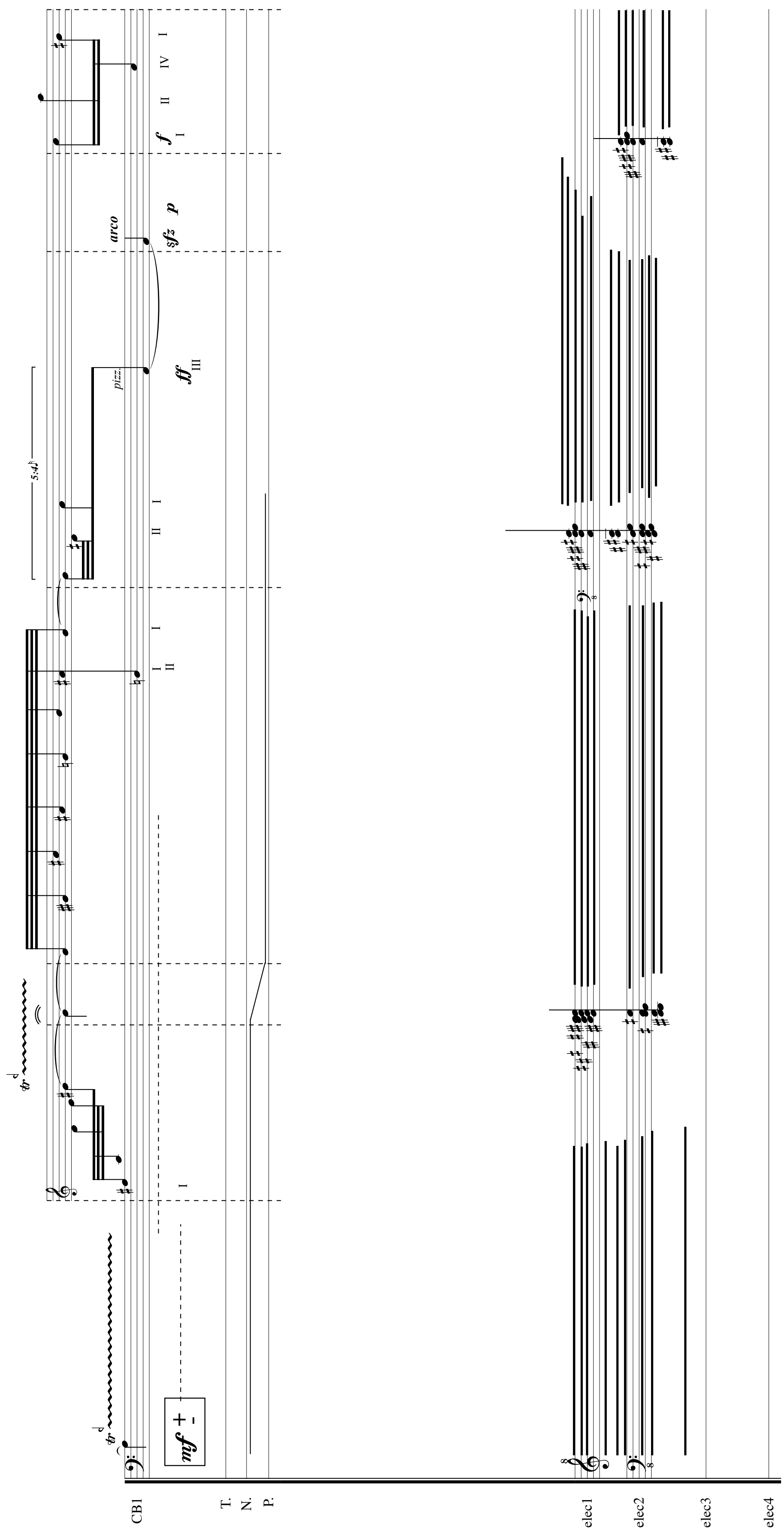

169
6:4
ff
mf
5:4
elec1
elec2
elec3
elec4
Harmoniseur à 8 voix (Medium Level Diffusion)
Random 8 Lignes de Délai avec Freq-Shift (Medium Level Diffusion)
Cailloux sur Chevalet Granulation (Low Level Diffusion)

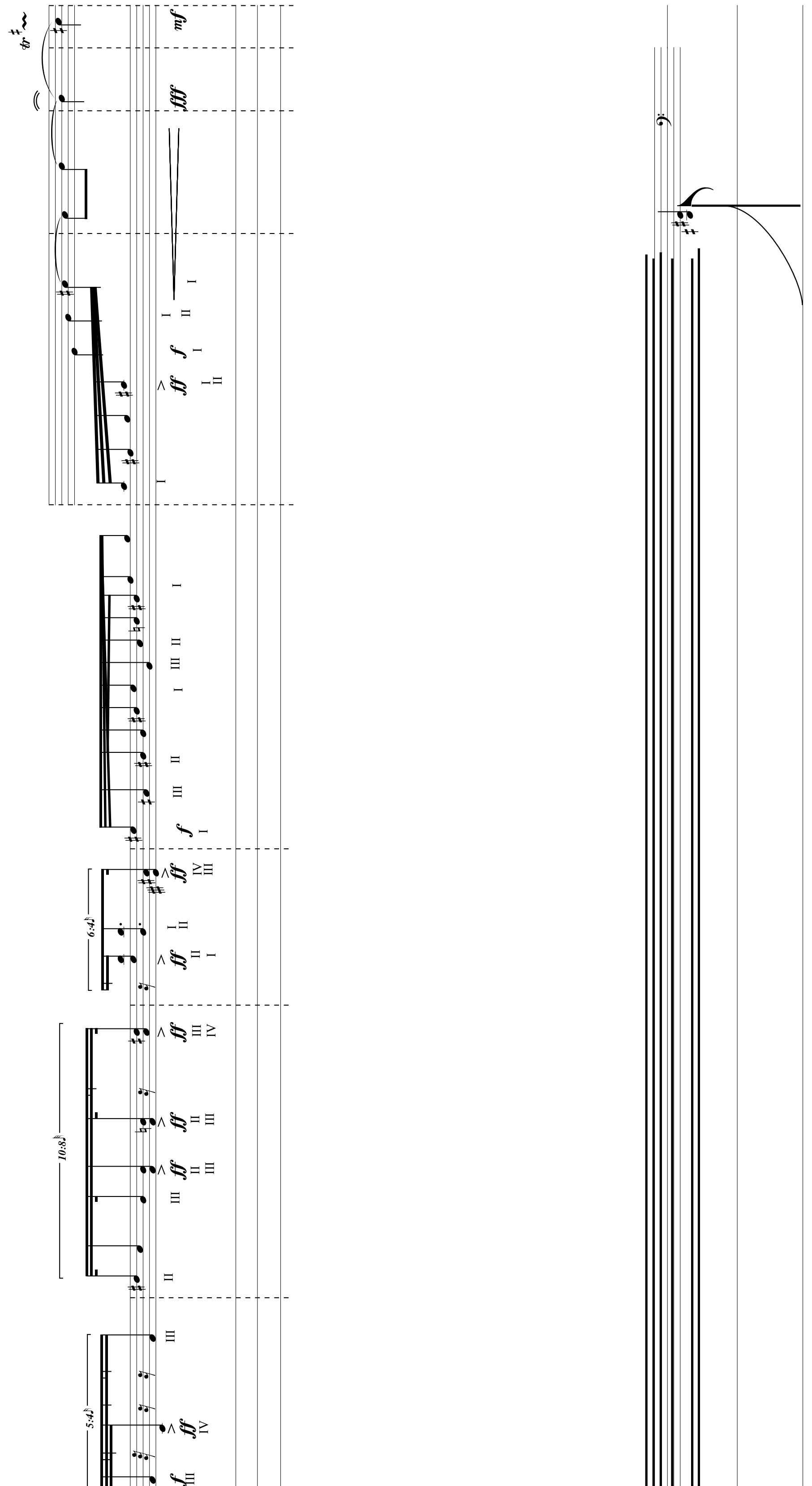

176
7:4
7:4
ff
ff
6:4
6:4
elec1
Harmoniseur à 8 voix (Medium Level Diffusion)
elec2
Random 8 Lignes de Délai avec Freq-Shift (Medium Level Diffusion)
elec3
Cailloux sur Chevalet Granulation (Low Level Diffusion)
elec4

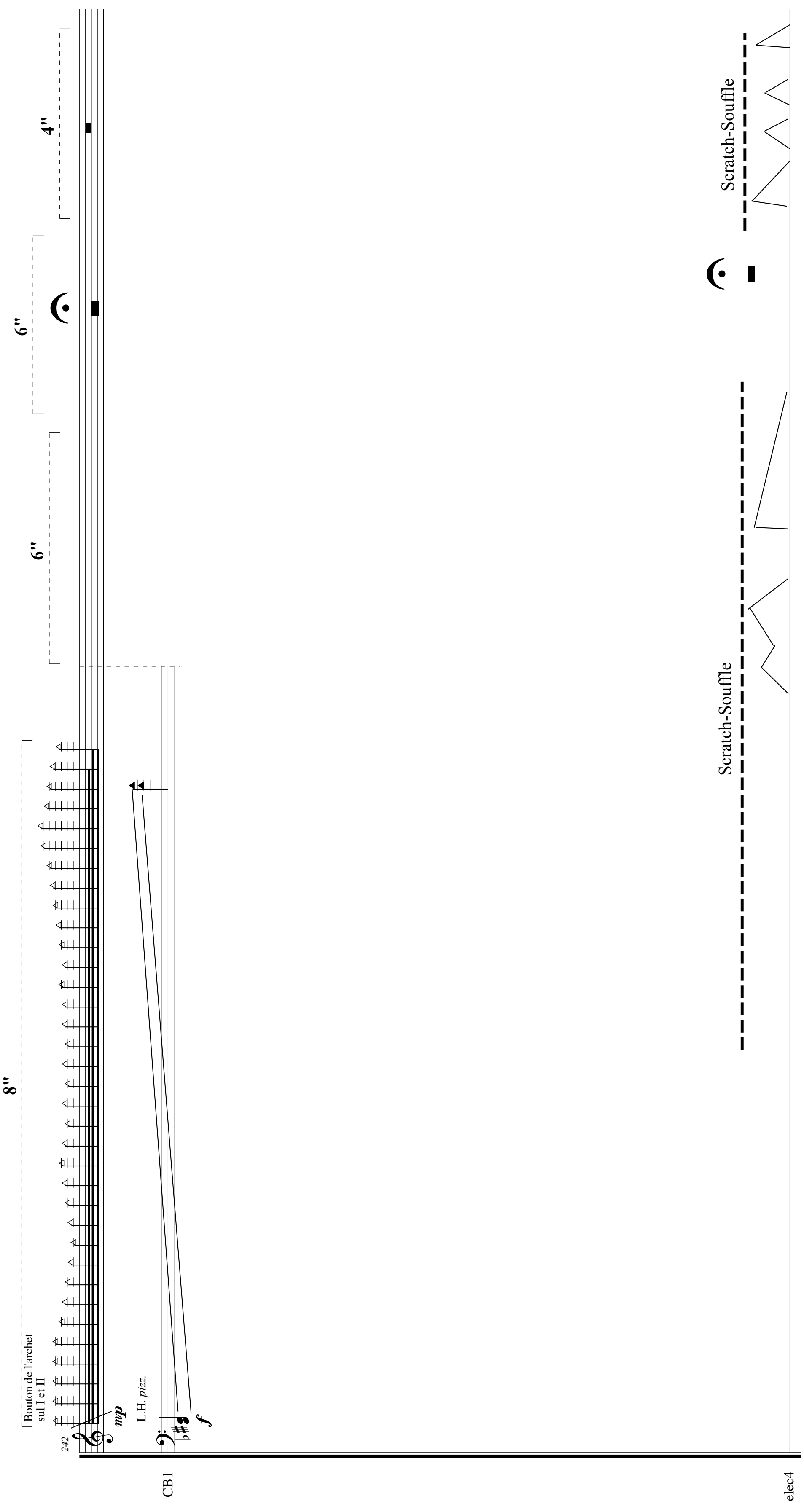

183
183
183
7:4
5:4
6:4
elec1
Harmoniseur à 8 voix (Medium Level Diffusion)
elec2
Random 8 Lignes de Délai avec Freq-Shift (Medium Level Diffusion)
elec3
Cailloux sur Chevalet Granulation (Low Level Diffusion)
elec4


6"
22"
190
tremolo avec malloche
entre la touche et la table
mf + -
190
CB2
S
M
T
N
P
p
p
p
mp
pp
pp
fff
fff
Synthèse Additive+Granulaire+Croisée
elec1
elec2
elec3
Harmoniseur à 8 voix (Medium Level Diffusion)
elec4

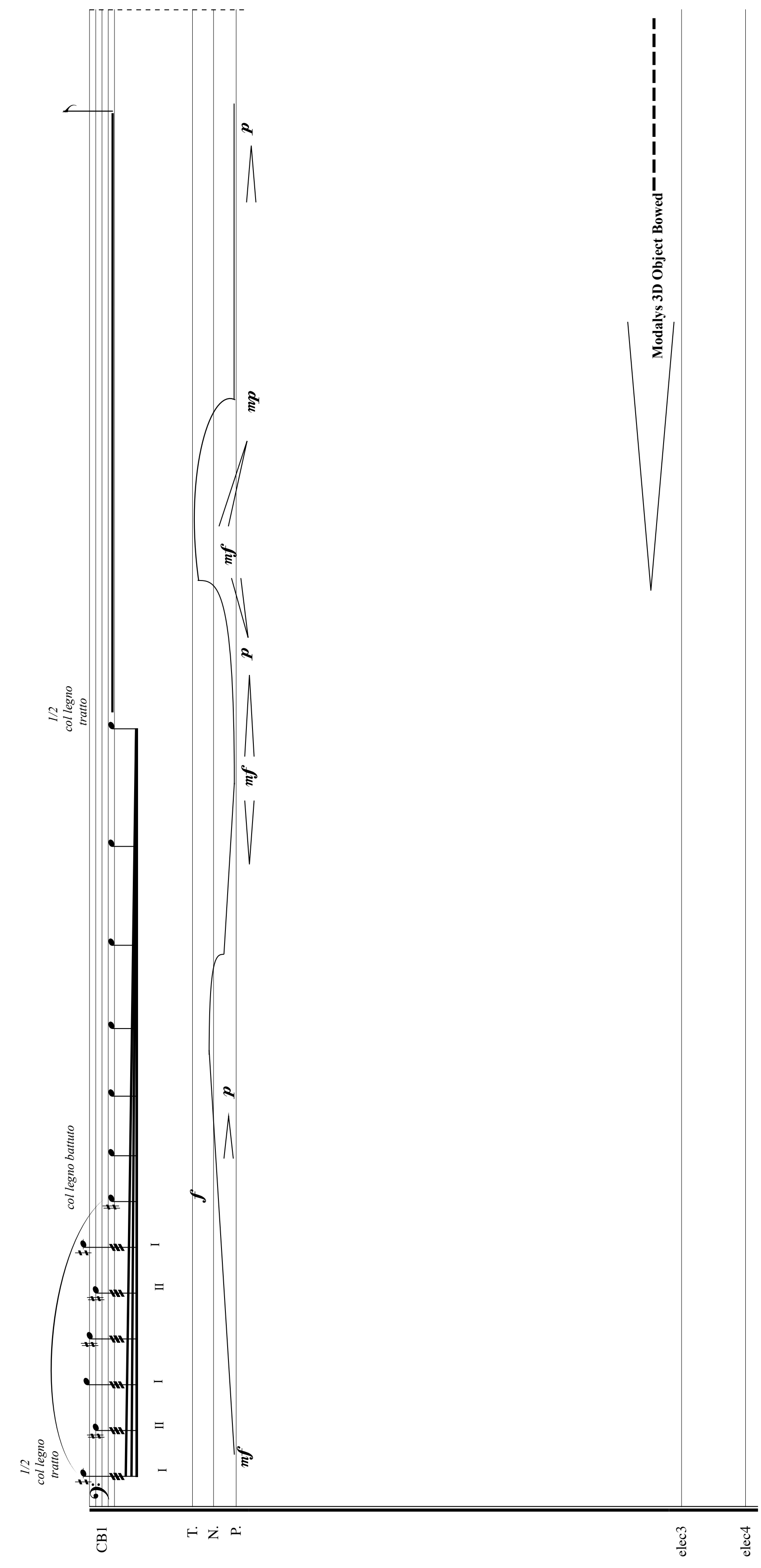

CB1
T.
N.
P.
elec1
elec2
elec3
elec4
arco
7:4
3:2
6:4
sffz

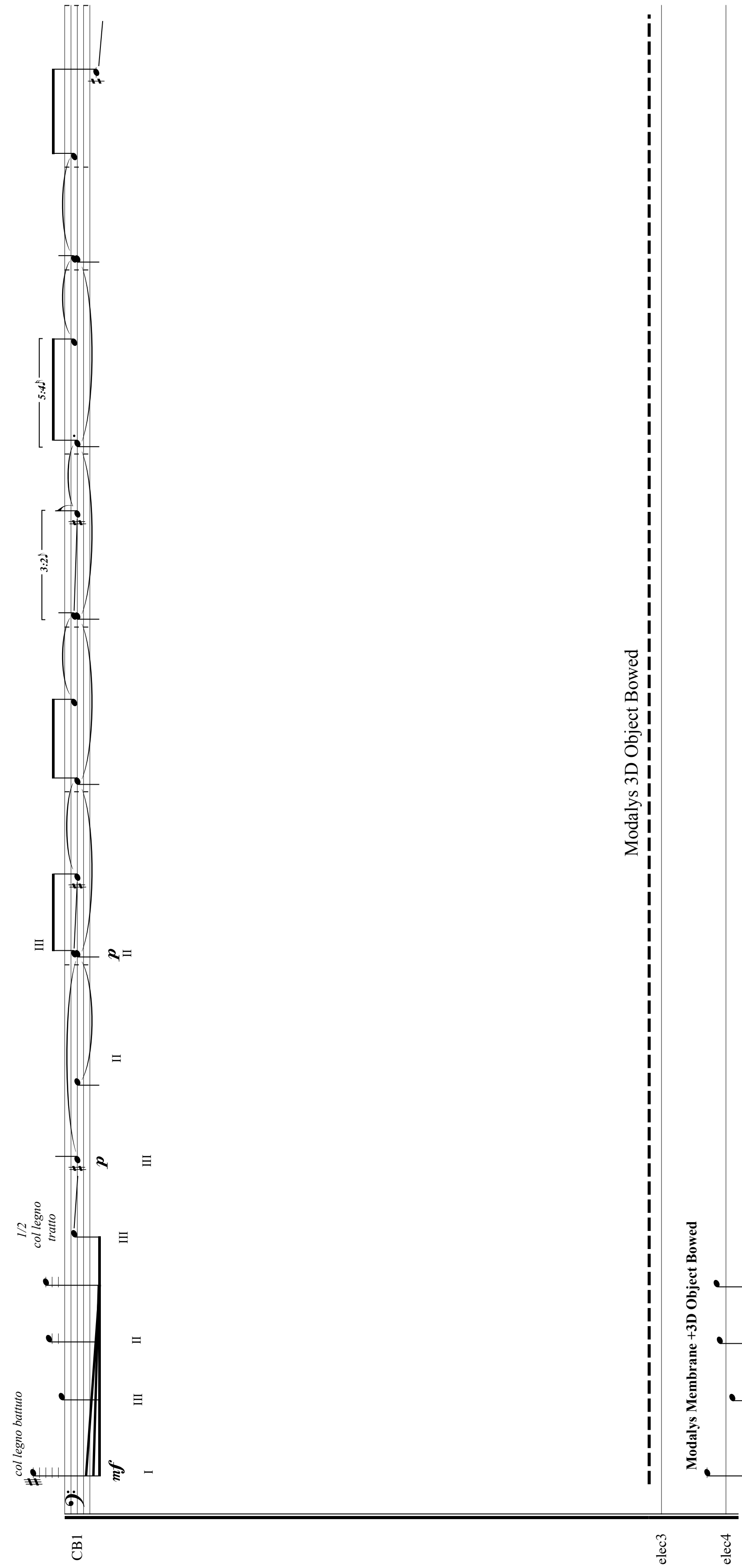

CB1
T.
N.
P.
elec1
elec2
elec3
elec4
pizz.
arco
sfz
ff
5:4

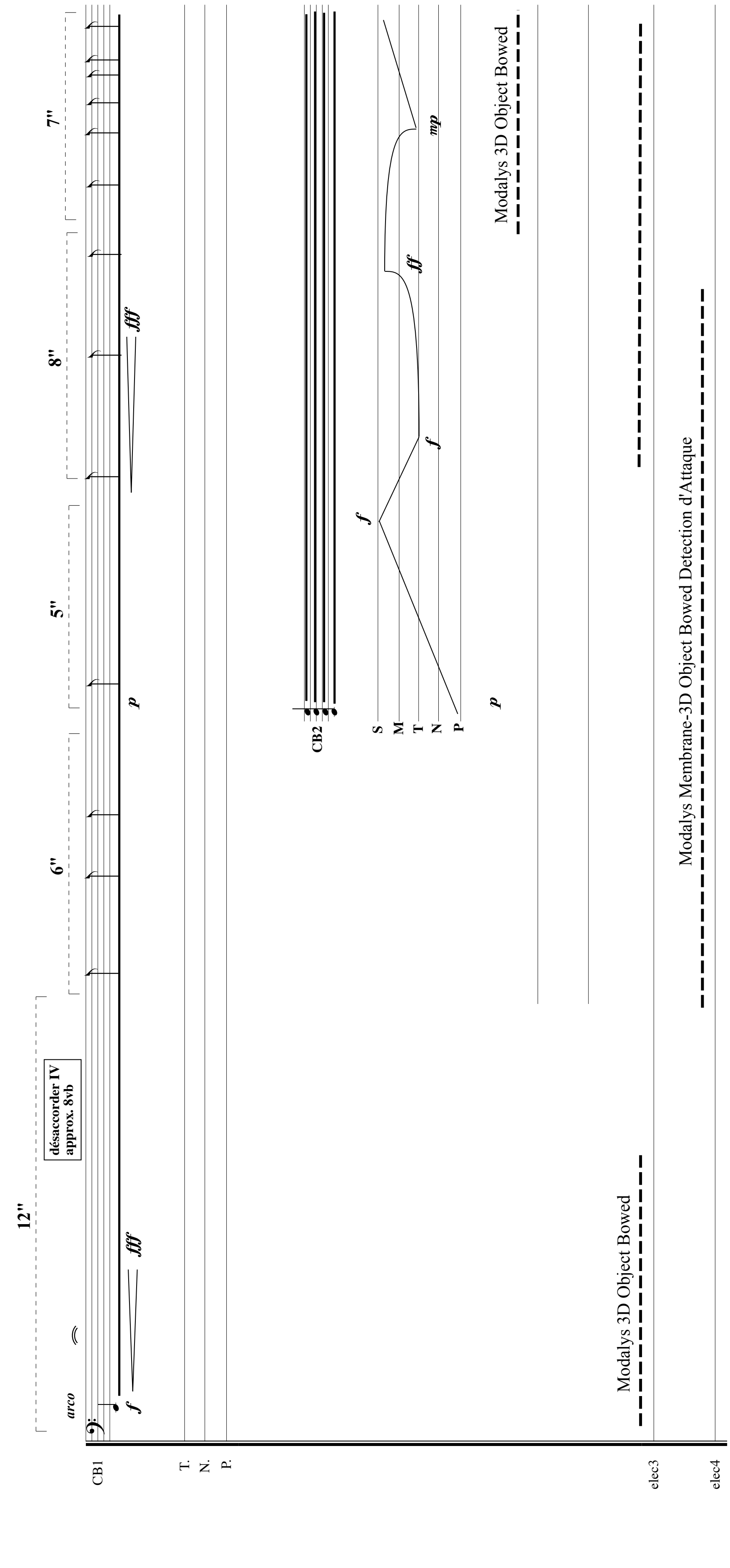

CB1
T.
N.
P.
elec2
elec3
elec4
5:4
10:8
6:4
f
ff
fff
mf

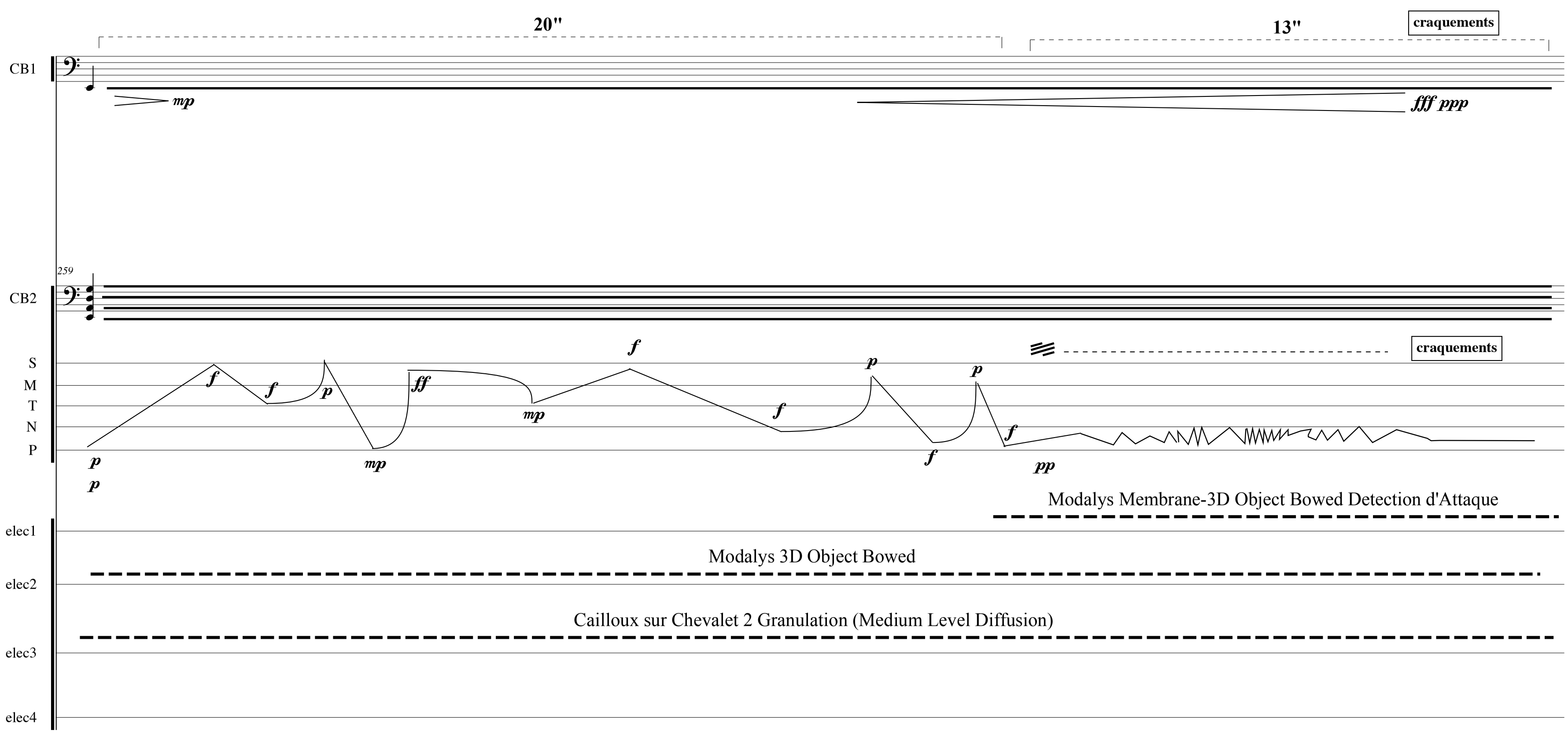


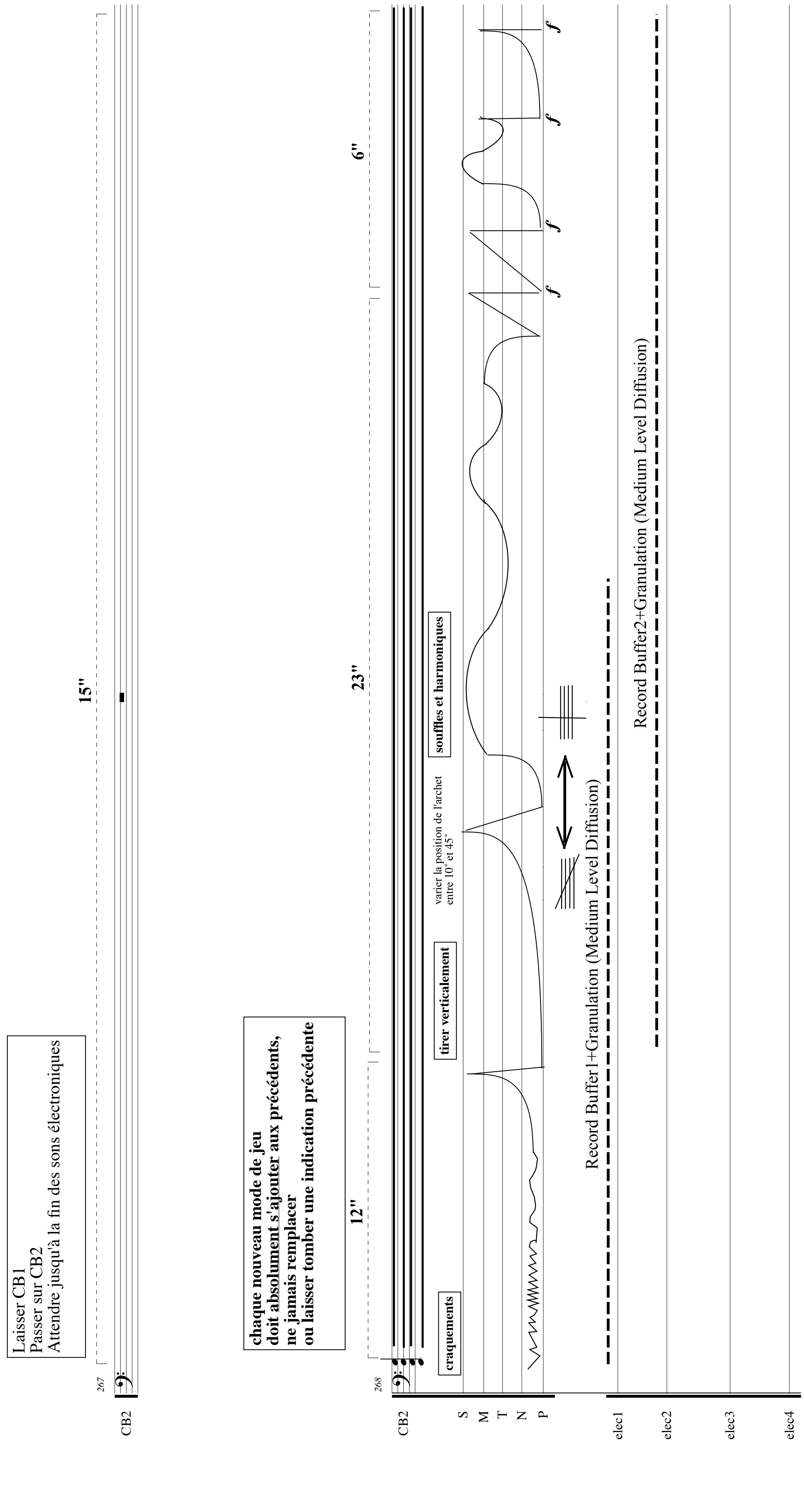
242
Bouton de l'archet
sul I et II
mp
L.H. pizz.
f
8"
6"
6"
4"
Scratch-Souffle
Scratch-Souffle
CB1
elec4

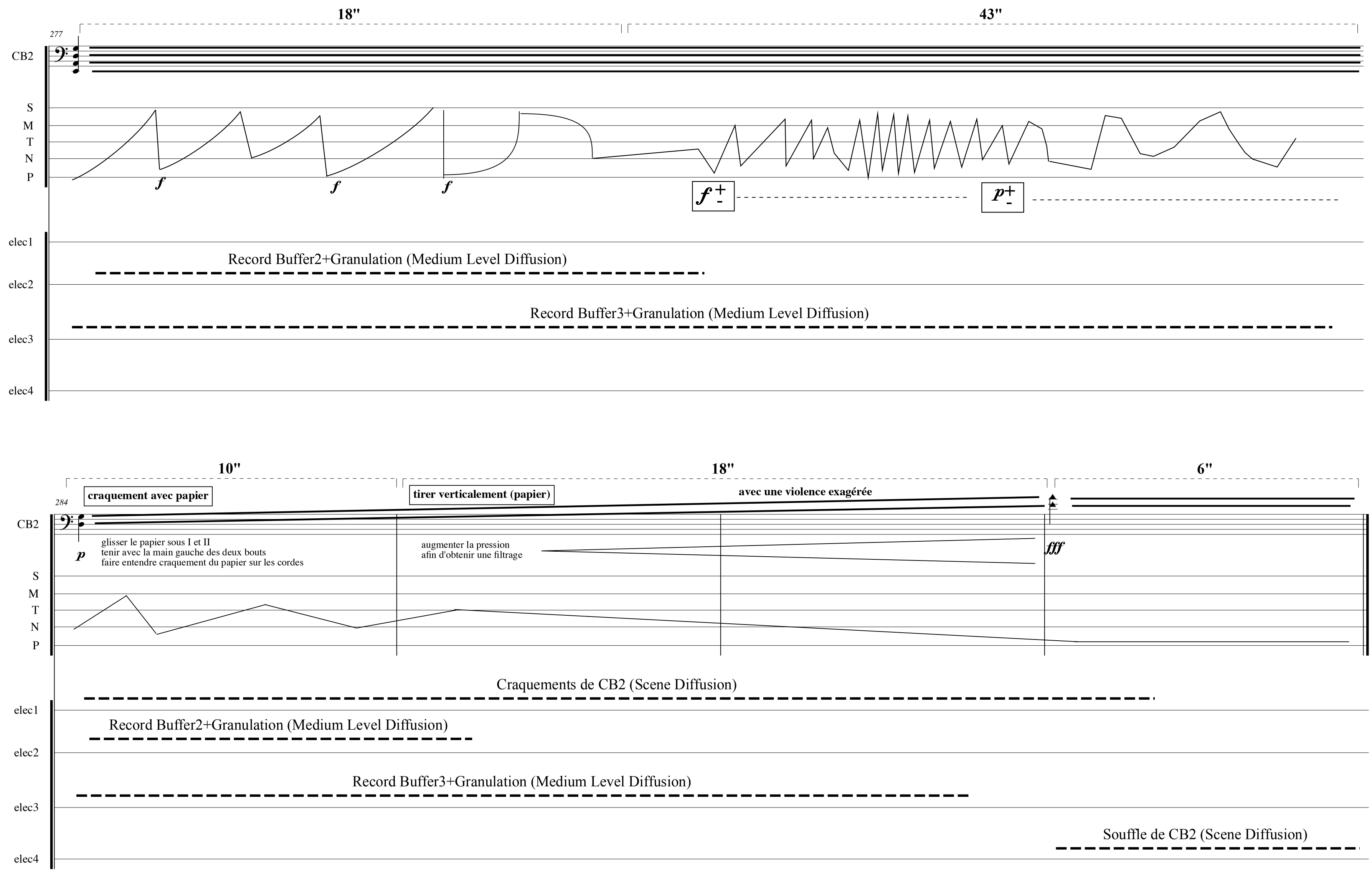

CB1
T.
N.
P.
elec3
elec4
1/2 col legno tratto
col legno battuto
1/2 col legno tratto
I
II
I
II
I
f
mf
p
mf
p
mf
mp
p
Modalys 3D Object Bowed


CB1
col legno battuto
1/2 col legno tratto
mf
p
I
II
III
3:2
5:4
elec3
Modalys 3D Object Bowed
elec4
Modalys Membrane +3D Object Bowed


CB1
T.
N.
P.
arco
12"
désaccorder IV
approx. 8vb
f
fff
6"
5"
p
8"
fff
7"
CB2
S
M
T
N
P
f
f
ff
mp
p
Modalys 3D Object Bowed
Modalys Membrane-3D Object Bowed Detection d'Attaque
Modalys 3D Object Bowed
elec3
elec4


20"
13"
craquements
CB1
mp
fff ppp
259
CB2
craquements
S
M
T
N
P
f
f
p
ff
mp
f
f
p
p
f
f
p
p
mp
pp
Modalys Membrane-3D Object Bowed Detection d'Attaque
elec1
Modalys 3D Object Bowed
elec2
Cailloux sur Chevalet 2 Granulation (Medium Level Diffusion)
elec3
elec4


Laisser CB1
Passer sur CB2
Attendre jusqu'à la fin des sons électroniques
267
CB2
15"
chaque nouveau mode de jeu
doit absolument s'ajouter aux précédents,
ne jamais remplacer
ou laisser tomber une indication précédente
268
CB2
S
M
T
N
P
12"
23"
6"
craquements
tirer verticalement
varier la position de l'archet
entre 10° et 45°
souffles et harmoniques
f
f
f
f
Record Buffer1+Granulation (Medium Level Diffusion)
Record Buffer2+Granulation (Medium Level Diffusion)
elec1
elec2
elec3
elec4


18"
43"
277
CB2
S
M
T
N
P
f
f
f
f+-
p+-
elec1
Record Buffer2+Granulation (Medium Level Diffusion)
elec2
Record Buffer3+Granulation (Medium Level Diffusion)
elec3
elec4
10"
18"
6"
craquement avec papier
tirer verticalement (papier)
avec une violence exagérée
284
CB2
p
glisser le papier sous I et II
tenir avec la main gauche des deux bouts
faire entendre craquement du papier sur les cordes
augmenter la pression
afin d'obtenir une filtrage
fff
S
M
T
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Craquements de CB2 (Scene Diffusion)
elec1
Record Buffer2+Granulation (Medium Level Diffusion)
elec2
Record Buffer3+Granulation (Medium Level Diffusion)
elec3
Souffle de CB2 (Scene Diffusion)
elec4