

From Pair-Generated Fock Structure to Physical Particle Semantics

Completed Bose/Fock representations, analytic carrier realization, and the boundary of asymptotic particle identity in a machine-checked gauge-field model

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[doi:10.5281/zenodo.22820148](https://doi.org/10.5281/zenodo.22820148)

Abstract

We study the first nontrivial sector of the current-constrained Gaussian family developed in the preceding papers. For each positive scale triple,

$$P_2\Psi_a = V_a \bar{A}_a^\dagger \Omega, \quad a \in (0, \infty)^3,$$

and the normalized seed $\Xi_a = V_a^{-1}P_2\Psi_a$ is faithful to the Gaussian modulus. Its canonical degree-two coefficients recover the pair kernel K_a , while its norm is

$$\|P_2\Psi_a\|^2 = \frac{V_a^2}{2} \|K_a\|_{\text{HS}}^2.$$

We ask what representation-theoretic and particle-theoretic content follows from this finite seed.

The pair has an exact completed Bose realization and is unitarily equivalent to an independently defined degree-two Fock subspace. The same unitary intertwines completed Lorentz and translation actions, yielding a Poincaré representation on the full pair space, together with the associated shadow and crossing operations. These statements fix the Fock grading and spacetime-symmetry representation of the generated pair without yet assigning a complete asymptotic particle interpretation to its one-particle coordinates.

A separate analytic construction now realizes every coordinate in the sixty-element Gaussian bank as a nonzero one-particle Hilbert/Fock state. These states transport injectively to a retained constrained carrier, remain nonzero, and lie in the kernel of its Hodge-type operator; an associated relational-response functional is defined for every coordinate. This gives an inhabited analytic realization of the full coordinate bank. The stronger asymptotic-particle junction tested here remains more restrictive. A previously supplied particle dictionary covers only a proper subset of the coordinates, and the native kinetic and null asymptotic translation generators are inequivalent.

The resulting picture is stratified. Exact Fock degree, analytic carrier realization, and asymptotic particle identity are distinct pieces of structure. The first two are realized here; the last still requires compatible particle data and dynamics. This separation provides the starting point for the next paper, where the Gaussian pair geometry is used to formulate the gravitational source and radiative-response problem.

1 Introduction

The first two papers in this series lead to a completed Gaussian family whose structure is unusually concentrated in its pair data. The current constraint selects Ψ_a , while the all-orders recurrence determines a symmetric kernel K_a and a closed quadratic creator $\bar{A}_a^\dagger$ [1, 2]. The particle sectors satisfy

$$P_{2n}\Psi_a = \frac{V_a}{n!}(\bar{A}_a^\dagger)^n\Omega, \quad P_{2n+1}\Psi_a = 0, \quad (1)$$

so the first nonvacuum component is

$$P_2\Psi_a = V_a\bar{A}_a^\dagger\Omega. \quad (2)$$

After removing the positive vacuum coefficient,

$$\Xi_a := V_a^{-1}P_2\Psi_a = \bar{A}_a^\dagger\Omega, \quad (3)$$

the map $a \mapsto \Xi_a$ is injective. Canonical coefficient functionals recover K_a from Ξ_a , so the first generated pair is already a faithful coordinate on the Gaussian family even though the exact current constraint requires the completed all-orders state.

This raises a representation question before it raises a particle question. A degree-two vector may satisfy Bose exchange and carry a unitary spacetime-symmetry action without its underlying one-particle coordinates having been identified with a particular asymptotic particle spectrum. Conversely, a coordinate may admit a nonzero analytic Hilbert-space realization without fixing the mass shell, helicity, polarization quotient, charges, and translation dynamics required by a full asymptotic interpretation. The purpose of this paper is to keep these layers separate inside the same construction.

We first complete the pair itself. Let $\mathcal{H}_{\text{Bose}}$ denote the exchange-fixed two-particle Hilbert space and $\mathcal{F}_{\text{nat}}^{(2)}$ the independently selected degree-two Fock target. There is a unitary map

$$U_{\text{BF}} : \mathcal{H}_{\text{Bose}} \xrightarrow{\simeq} \mathcal{F}_{\text{nat}}^{(2)}, \quad (4)$$

for which

$$U_{\text{BF}}\Phi_a^{\text{Bose}} = \Psi_{a,\text{Fock}}^{(2)}. \quad (5)$$

The target has exact particle degree two. Diagonal Lorentz and translation actions preserve the Bose subspace and assemble into a Poincaré representation, which is transported through U_{BF} to the Fock target. Thus the generated seed has a complete representation-theoretic realization at the level of Bose symmetry, Fock grading, and spacetime covariance.

There is now also a second, independent positive result. Every coordinate in the finite Gaussian label bank admits a nonzero analytic one-particle Hilbert/Fock representative. These representatives survive an injective map into a retained constrained carrier, where they obey the established Hodge-type condition, and a relational-response functional is available for each coordinate. This construction extends analytic support to the whole finite bank. It does not, by itself, identify those coordinates with a common asymptotic particle spectrum.

The distinction becomes concrete when compared with an earlier supplied particle dictionary. That map reaches only a proper subset of the Gaussian coordinates, while the stronger asymptotic

junction tested by the current construction would also require the original kinetic time evolution to coincide with the null asymptotic one. The two exact generators disagree. Hence the old coverage result is best understood as a statement about one particular dictionary, whereas the obstruction on this asymptotic route is dynamical as well as semantic.

This separation is useful in celestial representation theory, where one-particle states may be reorganized into Lorentz principal-series representations before the tensor product is decomposed into irreducible multiparticle channels [9, 10, 11]. The present paper stops at the boundary between pair representation and asymptotic qualification. Paper 4 turns instead to dynamics, asking how the Gaussian pair geometry and covariance enter a gravitational source and radiative response; the explicit multiplicity-free celestial Clebsch–Gordan decomposition belongs to the subsequent paper.

1.1 Relation to nearby work

The separation between Fock quanta and asymptotic particles is familiar from relativistic quantum theory. In Wigner’s classification, particle content is tied to unitary Poincaré representations and little-group data [3, 4]; in interacting or curved-spacetime settings, the relation between fields, Fock excitations, and asymptotic particle states requires additional structure [5, 6]. Here the same distinction appears in a finite, explicitly generated pair sector.

The representation-theoretic construction is standard in broad outline. The completed Bose space is the symmetric part of a two-particle tensor product, and the corresponding two-creator map gives its Fock realization [7, 8]. What is specific to the present model is the provenance of the pair: it is fixed by the matter-current recurrence, its normalized seed is faithful to the Gaussian modulus, and the completed Bose/Fock map is required to reproduce that generated state exactly.

The celestial setting adds another useful distinction. Principal-series one-particle representations can be tensored before any irreducible multiparticle decomposition is performed, a point emphasized in recent work on multiparticle states and celestial OPE blocks [11]. We use this ordering here. The pair carrier and its Poincaré action are established first; analytic coordinate realizations are then separated from the stronger question of asymptotic particle identity. The diagonal two-particle Clebsch–Gordan problem is left to the later radiative stage of the series.

2 The generated two-particle sector

For every $a \in (0, \infty)^3$, define

$$\Psi_a^{(2)} := P_2 \Psi_a. \quad (6)$$

By the sector reconstruction theorem,

$$\Psi_a^{(2)} = V_a \bar{A}_a^\dagger \Omega, \quad \Psi_a^{(2)} \neq 0. \quad (7)$$

Thus no new two-particle ansatz is introduced in this paper: the state considered here is the first generated sector of the completed Gaussian from Paper 2.

It is useful to separate the positive vacuum amplitude from the intrinsic pair coordinate. Define

$$\Xi_a := V_a^{-1} \Psi_a^{(2)} = \bar{A}_a^\dagger \Omega. \quad (8)$$

The normalized seed is nonzero for every admissible scale and is faithful:

$$\Xi_a = \Xi_b \implies K_a = K_b \implies a = b. \quad (9)$$

Canonical degree-two coefficient functionals $\mathcal{R}_{rs}$ recover the pair kernel according to

$$\mathcal{R}_{rs}(\Xi_a) = \frac{K_a(r, s)}{\mathcal{N}_{rs}}, \quad (10)$$

where $\mathcal{N}_{rs} \neq 0$ is the fixed occupation normalization for the selected two-coordinate row. In this sense the first nontrivial sector already contains enough finite information to identify the Gaussian modulus, even though Paper 2 proves that no finite truncation is itself an exact current-physical state.

Its unnormalized norm is controlled by the same kernel. Writing

$$w_{2,a} := \|\Psi_a^{(2)}\|^2,$$

one finds

$$w_{2,a} = \frac{V_a^2}{2} \|K_a\|_{\text{HS}}^2 > 0. \quad (11)$$

At the finite regulator the one-particle label space has finite dimension. The Hilbert–Schmidt norm is therefore a finite sum of squared kernel entries, with Eq. (11) including both repeated-label and distinct-label occupations.

The positive-orthant construction extends an earlier admissible-scale realization. On the overlap, the finite P_2 state, its celestial image, the sector weight, and the normalized pair wave agree exactly with the earlier definitions. We will therefore use a single notation for both descriptions.

3 Bose and Fock realizations

3.1 The completed Bose pair

Let $\mathcal{H}_1$ be the completed one-particle celestial Hilbert space used for the native labels. The ordered two-particle carrier is

$$\mathcal{H}_1 \hat{\otimes} \mathcal{H}_1,$$

and the exchange unitary τ acts by swapping the two tensor factors. The Bose pair space is the closed fixed subspace

$$\mathcal{H}_{\text{Bose}} = \{\Phi : \tau\Phi = \Phi\}. \quad (12)$$

The orthogonal Bose projector is $P_+ = (\mathbf{1} + \tau)/2$. For pure tensors,

$$\langle P_+(u \otimes v), P_+(x \otimes y) \rangle = \frac{1}{2} (\langle u, x \rangle \langle v, y \rangle + \langle v, x \rangle \langle u, y \rangle), \quad (13)$$

and the projected algebraic tensors form a dense subspace.

The pair kernel gives a corresponding completed Bose vector

$$\Phi_a^{\text{Bose}} \in \mathcal{H}_{\text{Bose}}$$

with

$$\tau\Phi_a^{\text{Bose}} = \Phi_a^{\text{Bose}}, \quad \|\Phi_a^{\text{Bose}}\|^2 = w_{2,a}. \quad (14)$$

Since $w_{2,a} > 0$, this vector is nonzero for every positive scale triple.

3.2 The independently selected Fock sector

The target Fock space is fixed independently of the Bose map. We select the closed subspace

$$\mathcal{F}_{\text{nat}}^{(2)} \subset \mathcal{F}_{\text{cel}}$$

whose nonzero occupation rows are precisely those obtained by adding two native bosonic one-particle labels. Equivalently,

$$\psi \in \mathcal{F}_{\text{nat}}^{(2)} \iff \psi(n) = 0 \text{ whenever } n \text{ is not a native two-particle occupation.} \quad (15)$$

Every nonzero row in this subspace has total particle number two, and the completed particle projector acts as

$$P_2\psi = \psi, \quad \psi \in \mathcal{F}_{\text{nat}}^{(2)}. \quad (16)$$

On the dense algebraic pair core, the number operator satisfies

$$N_{\text{Fock}}\phi = 2\phi. \quad (17)$$

The completed statement is Eq. (16); Eq. (17) records the corresponding unbounded-operator statement on its algebraic domain.

3.3 The Bose/Fock unitary

The two-creator map is first defined on algebraic pair tensors. Exchange symmetry removes the antisymmetric kernel, while Eq. (13) gives an isometry on the resulting Bose core. This isometry extends continuously to the completion, and a separate density argument shows that its range is all of $\mathcal{F}_{\text{nat}}^{(2)}$. Hence

$$U_{\text{BF}} : \mathcal{H}_{\text{Bose}} \xrightarrow{\cong} \mathcal{F}_{\text{nat}}^{(2)} \quad (18)$$

is unitary.

On the dense algebraic core the completed map retains the original two-creator formula. For the Gaussian pair this identifies the representation with the state generated in Eq. (7):

$$U_{\text{BF}}\Phi_a^{\text{Bose}} = \Psi_{a,\text{Fock}}^{(2)}. \quad (19)$$

This is an equality of completed vectors, not only a coefficient or norm comparison.

4 Poincaré covariance and celestial structure

The one-particle celestial carrier supports unitary Lorentz and four-translation actions. Their diagonal lifts preserve the Bose subspace and obey the Lorentz–translation semidirect law, giving a Poincaré representation

$$U_{\text{Bose}} : \mathcal{P} \longrightarrow \text{U}(\mathcal{H}_{\text{Bose}}).$$

Transport through the Bose/Fock unitary gives

$$U_{\text{Fock}}(g) = U_{\text{BF}}U_{\text{Bose}}(g)U_{\text{BF}}^{-1}, \quad g \in \mathcal{P}. \quad (20)$$

The intertwining relation

$$U_{\text{BF}}U_{\text{Bose}}(g)\Phi = U_{\text{Fock}}(g)U_{\text{BF}}\Phi \quad (21)$$

holds for every completed Bose state.

For the generated pair, unitarity gives

$$U_{\text{Fock}}(g)\Psi_{a,\text{Fock}}^{(2)} \neq 0, \quad \|U_{\text{Fock}}(g)\Psi_{a,\text{Fock}}^{(2)}\|^2 = w_{2,a}. \quad (22)$$

The representation therefore carries the full positive family without changing the two-particle weight.

The same unitary intertwines the spectral shadow transform, the full-angular Knapp–Stein shadow, and kinematic incoming/outgoing crossing. These transformations act within each native label fiber; they do not alter the label itself. In particular, the celestial symmetry structure enriches the representation attached to the one-particle labels without supplying an independent particle dictionary for those labels.

5 Analytic realization and asymptotic qualification

The construction above fixes the pair as a representation-theoretic object: its one-particle coordinates live in a Hilbert space, the two-particle state is Bose symmetric, the Bose/Fock map is unitary onto an exact degree-two sector, and the completed pair carries a Poincaré action. The remaining question is how far these data extend toward an asymptotic particle interpretation.

5.1 Representation data and particle data

It is useful to organize the required structures in the hierarchy

$$\begin{aligned} \text{L}_0 &: \text{labelled one-particle degrees of freedom,} \\ \text{L}_1 &: \text{Hilbert realization,} \\ \text{L}_2 &: \text{Bose/Fock realization,} \\ \text{L}_3 &: \text{unitary spacetime-symmetry representation,} \\ \text{L}_4 &: \text{physical particle data,} \\ \text{L}_5 &: \text{physical asymptotic realization.} \end{aligned} \quad (23)$$

The pair construction realizes L_0 – L_3 . Moving to L_4 requires independent mass-shell, helicity, charge-representation, and polarization data for the one-particle coordinates. Level L_5 adds an asymptotic Hilbert carrier and a source map whose Poincaré action agrees with those data. These requirements are stronger than the existence of a Fock representation.

A later construction supplies an additional analytic realization of the coordinate bank. Let $\mathcal{L}_G$ be the finite set of Gaussian one-particle coordinates, with

$$|\mathcal{L}_G| = 60. \quad (24)$$

For every $\ell \in \mathcal{L}_G$ there is a nonzero state

$$\ell \mapsto \psi_\ell^{\text{an}} \in \mathcal{H}_{\text{an}}, \quad \psi_\ell^{\text{an}} \neq 0. \quad (25)$$

Thus analytic Hilbert/Fock support extends across the complete finite bank. This supplies more than the earlier partial particle dictionary, but it is logically separate from the asymptotic data listed at $\mathbf{L}_4$ and $\mathbf{L}_5$.

5.2 Transport to a constrained carrier

The analytic representatives admit an injective transport

$$J_{\text{ret}} : \mathcal{H}_{\text{an}} \longrightarrow \mathcal{H}_{\text{ret}}, \quad \psi_{\ell}^{\text{ret}} := J_{\text{ret}} \psi_{\ell}^{\text{an}}. \quad (26)$$

For every label,

$$\psi_{\ell}^{\text{ret}} \neq 0, \quad D_{\text{Hodge}} \psi_{\ell}^{\text{ret}} = 0. \quad (27)$$

The nonzero analytic state therefore survives the carrier change and lands in the kernel of the retained Hodge-type operator. On the same branch there is, for each ℓ , an associated response

$$\mathcal{R}_{\ell}^{\text{rel}} \in \mathcal{R}_{\text{rel}}. \quad (28)$$

The content of these results is an analytic realization, a constrained transport, and a total relational-response evaluation. No additional asymptotic interpretation is needed to state them.

Combining the three maps gives

$$\ell \longmapsto \psi_{\ell}^{\text{an}} \longmapsto \psi_{\ell}^{\text{ret}}, \quad D_{\text{Hodge}} \psi_{\ell}^{\text{ret}} = 0, \quad \ell \longmapsto \mathcal{R}_{\ell}^{\text{rel}}, \quad (29)$$

with nonzero states at both Hilbert-space stages.

5.3 The supplied particle dictionary

An earlier particle reduction provides a useful comparison because it asks for a more specific identification. If

$$R_{\text{part}} : \mathcal{H}_{\text{particle}} \longrightarrow \mathcal{H}_{\text{coord}}$$

denotes this map, then

$$R_{\text{part}} \text{ is not surjective.} \quad (30)$$

In the finite realization its support occupies four of the sixty coordinate labels. The later analytic construction shows that this count should be interpreted as a property of the supplied particle dictionary itself: the remaining coordinates do possess nonzero analytic representatives, although they are not reached by this particular map.

The original coordinate declaration also does not assign mass-shell, helicity, charge-representation, or polarization data to the entire bank. These data are precisely what distinguishes a general analytic realization from the stronger particle-semantic level in Eq. (23).

5.4 The translation obstruction

The current full-Gaussian asymptotic identification imposes an additional dynamical condition. The original one-particle carrier has an exact kinetic time evolution with generator E_{kin} , while

the null asymptotic realization used by this route has a generator E_{null} . A common asymptotic interpretation through this construction would require the same time-translation representation to reproduce both. Instead,

$$E_{\text{kin}} \neq E_{\text{null}}. \quad (31)$$

No single exact translation generator can therefore satisfy both requirements.

If $\mathfrak{J}_{\text{an}}$ denotes the total analytic realization and $\mathfrak{J}_{\text{asym}}^{\text{CH15}}$ the current full-Gaussian asymptotic junction tested here, the two results may be summarized as

$$\mathfrak{J}_{\text{an}} \neq \emptyset, \quad \mathfrak{J}_{\text{asym}}^{\text{CH15}} = \emptyset. \quad (32)$$

The first statement records the nonzero realization of all sixty coordinates; the second records the incompatible translation requirements of the current CH15 asymptotic construction. It is a route-specific negative result and does not exclude a later physical realization based on different carrier or dynamical data. Consequently, Fock representation, analytic carrier realization, and full asymptotic particle identity remain distinct levels of the present theory.

6 Discussion

The generated pair now admits a fairly complete description without requiring a premature particle interpretation. It is the first nonvacuum sector of a Gaussian state whose current constraint is realized only after completion, while its normalized degree-two seed is nevertheless faithful to the Gaussian modulus. The same finite vector can therefore carry complete identifying information about the family without being substituted for the completed state.

The Bose/Fock theorem adds an exact representation to this finite seed. The completed pair is exchange symmetric, has particle degree two, and transforms under a genuine Poincaré action. These statements determine how the pair sits inside the Hilbert-space representation. The later analytic construction answers a different question: whether the underlying Gaussian coordinates can be realized nontrivially on an independently constructed carrier. They can. Every coordinate acquires a nonzero analytic representative, survives injective transport to a constrained carrier, and admits the relational response described above.

The older coverage theorem and the newer analytic realization are therefore complementary. The former shows that one supplied particle dictionary does not cover the complete coordinate bank; the latter shows that analytic support nevertheless exists for every coordinate. The current CH15 asymptotic junction asks for both particle data and compatible dynamics. Its failure is sharpened by the translation comparison

$$E_{\text{kin}} \neq E_{\text{null}},$$

which places the obstruction in the attempted identification of two exact time evolutions rather than in the mere existence of Hilbert-space representatives.

This leaves a specific dynamical problem. Nothing in the present paper identifies the Gaussian pair with an independently constructed radiative pair, nor does the relational-response map by itself provide the stress tensor sourced by the completed Gaussian state. The next paper addresses this missing link by passing from the exact second-order Gaussian structure to an expectation-valued source, schematically

$$K_a \longleftrightarrow \Sigma_a \longrightarrow \omega_a^{(2)} \longrightarrow \langle T_{\mu\nu} \rangle_a \longrightarrow \mathcal{R}_a^{\text{rad}}.$$

Once a source-native radiative carrier is obtained, the subsequent paper can ask how its Bose pair decomposes into multiplicity-free celestial principal-series channels.

7 Conclusion

For each positive Gaussian parameter, the first nontrivial sector is

$$P_2\Psi_a = V_a \overline{A}_a^\dagger \Omega,$$

with normalized seed

$$\Xi_a = V_a^{-1} P_2\Psi_a = \overline{A}_a^\dagger \Omega.$$

The seed is faithful to the Gaussian modulus, its coefficient readouts recover the pair kernel, and

$$\|P_2\Psi_a\|^2 = \frac{V_a^2}{2} \|K_a\|_{\text{HS}}^2.$$

It extends to a completed Bose vector which is unitarily equivalent to an independently defined degree-two Fock sector,

$$U_{\text{BF}}\Phi_a^{\text{Bose}} = \Psi_{a,\text{Fock}}^{(2)},$$

and the unitary intertwines the completed Poincaré action together with the associated shadow and crossing structures.

The one-particle coordinate bank also admits a total nonzero analytic realization, followed by injective transport to a retained constrained carrier and a total relational-response evaluation. These results establish a genuine analytic continuation of the full finite bank beyond the earlier partial particle dictionary. A complete asymptotic particle interpretation requires additional data and, through the route studied here, encounters an exact dynamical obstruction: the kinetic and null asymptotic translation generators do not coincide.

The outcome is a stratified representation theory. Fock degree fixes the algebraic particle grading, analytic realization supplies nonzero carrier states, and asymptotic particle identity requires a further compatibility of physical data and dynamics. The next step is to determine whether the faithful Gaussian pair geometry itself supplies the source for an independently qualified radiative response.

A Lean theorem map

The main text uses representation-theoretic notation that is intentionally more general than the implementation vocabulary of the formal model. The revised manuscript combines the original CI171–CI186 semantic surface with later theorem-owned physical-realization results. The complete manuscript scope used here is audited against repository commit

3a394d268fbf2bd8e18a9a2f3d5c3fc27f3636fd.

A.1 Core representation and semantic surface

Mathematical result	Formal module
Paper 3 predecessor surface	CI171.CanonicalGeneratedPairSemanticPredecessor
Positive-orthant exact P_2 state and weight	CI172.CanonicalPositiveOrthantGaussianTwoParticleState
Exact compatibility with legacy CH12 objects	CI173.CanonicalPositiveLegacyCH12Compatibility
Full-positive completed Bose pair	CI174.CanonicalPositiveCompletedBosePair
Paper 2/Paper 3 Bose–Fock square	CI175.CanonicalGeneratedPairBoseFockSquare
Completed Bose/Fock representation certificate	CI176.CanonicalGeneratedPairBoseFockRepresentation
Exact native two-particle Fock grading	CI177.CanonicalExactConnectionPairFockGrading
Transported Lorentz/Poincaré/shadow representation	CI178.CanonicalGeneratedPairTransportedSymmetryRepresentation
Typed semantic hierarchy L_0 – L_5	CI179.CanonicalGeneratedPairTypedSemanticHierarchy
Native semantic nonpopulation	CI180.CanonicalNativeSemanticNonpopulation
Independent reduction-coverage and translation obstructions	CI181.CanonicalCurrentPhysicalizationObstructions
Original full generated-pair physical-promotion criterion	CI182.CanonicalCurrentGeneratedPairPhysicalPromotion
Strict representation/particle-semantic separation	CI183.CanonicalStrictGeneratedPairSemanticSeparation
Exact Bose/Fock unitary preservation surface	CI184.CanonicalGeneratedPairUnitaryPreservationSurface
Terminal full-positive semantic surface	CI185.CanonicalPositiveGaussianGeneratedPairSemanticSurface
Original Paper 3 boundary freeze	CI186.CanonicalPaper3Paper4BoundaryFreeze

A.2 Later carrier and response extensions used in the revised manuscript

Mathematical result	Formal module
Exact degree-two Gaussian pair-seed carrier	CanonicalGaussianPairSeedCarrier
Normalized pair seed equals creator on vacuum	CanonicalPairSeedPairCreatorJunction
Global injectivity of the normalized pair seed	CanonicalPairSeedInjectivityDecision
Exact pair-seed coefficient readout of K_a	CanonicalPairSeedCoefficientReadout
Typed full-asymptotic junction and translation obstruction	CanonicalCH15PhysicalAsymptoticCarrierDecision
Total nonzero analytic one-particle realization of the finite coordinate bank	CanonicalGaussianH4RealizationRelation
Nonzero retained-carrier transport and Hodge constraint	CanonicalGaussianB9Transport
Total coordinate-wise relational-response evaluation	CanonicalGaussianQGResponseRelation
Analytic-carrier/full-asymptotic-junction separation	CanonicalFullGaussianJunctionRepairDecision
Aggregate finite-bank analytic/retained/response junction surface	CanonicalGaussianPhysicalJunctionSurface

The original CI171–CI186 boundary remains part of the audit trail: those modules establish the representation/particle-semantic separation without importing the later carrier-realization branch. The revised manuscript additionally reports later theorems which sharpen the interpretation of that separation. The repository names of those later surfaces are retained in the theorem map as provenance; they are not promoted into manuscript ontology and do not retroactively identify the Gaussian coordinate carrier with the old supplied particle dictionary.

B Formal development and authority boundary

The results in this paper are supported by a Lean 4 formal development maintained in a private research repository. The core Paper 3 semantic chain remains CI171–CI186; the revised manuscript additionally cites the later carrier and response modules listed above. The combined manuscript scope is audited against repository commit

3a394d268fbf2bd8e18a9a2f3d5c3fc27f3636fd,

using Lean 4 v4.28.0-rc1 and mathlib revision 5352afccd6866369be9de43f5b7ec47203555f44.

The authority boundary is intentionally stratified. The manuscript establishes exact Bose/Fock grading and transported Poincaré covariance for the generated pair, a faithful normalized pair seed, a total nonzero analytic realization of the finite coordinate bank, injective transport into a retained constrained carrier with the established Hodge-type condition, and total availability of the theorem-owned relational-response evaluation.

Repository surface names such as H4, B9, QG, Tower, and related implementation labels are formal provenance. They are retained in the theorem map where exact source correspondence matters, but they do not add manuscript-level semantic authority. In particular, a formal carrier or declaration whose internal name contains “physical” does not thereby establish asymptotic particle identity.

The manuscript does not identify the Gaussian pair with the independently qualified radiative pair. It does not claim that the retained constrained state is a complete quantum-gravity asymptotic state, that the old supplied particle map has become surjective, or that the kinetic and null asymptotic translation generators agree. The current CH15 full-Gaussian asymptotic junction tested here remains empty by the exact translation mismatch; this is not a universal obstruction to later physical realizations built from different carrier or dynamical data. The manuscript also makes no claim of an expectation-valued stress tensor, Gaussian-to-radiative source factorization, local CFT OPE, interacting collinear OPE, interacting crossing, or regulator removal.

Those exclusions determine the revised handoff. Paper 4 owns the dynamical bridge from Gaussian pair/covariance data to gravitational stress and physical radiative response. The subsequent radiative paper owns the multiplicity-free celestial Clebsch–Gordan and Plancherel decomposition.

The full research repository is not publicly accessible. Paper-scoped source review, theorem-level verification and access to relevant formal modules may be arranged in the context of professional collaboration, technical review or institutional partnership.

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