

The Big Block Theory: A Mathematical Framework for Multiple Realities Based on CERN High-Energy Physics Data

Andrew Bull
University of Hong Kong

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Abstract

This thesis presents the *Big Block Theory* (BBT) as a speculative phenomenological framework that addresses selected open problems in particle physics—including the hierarchy problem, dark-matter phenomena, and aspects of quantum entanglement—through extra-dimensional models testable at high-energy colliders. Motivated by experimental searches at CERN’s Large Hadron Collider (LHC) and by Kaluza–Klein extensions of general relativity, we propose that physical reality comprises a dense, multidimensional “big block” in which many quantum states coexist. Our perceived universe corresponds to a specific “frequency slice” of this structure.

Public LHC Run 2 results and preliminary Run 3 performance reports place quantitative bounds on trans-dimensional effects such as missing-energy signatures from graviton escape and microscopic black-hole production thresholds. A unified energy-accounting formalism is introduced,

$$E_{\text{tot}} = \sum_{n=0}^N E_n w_n, \quad \sum_{n=0}^N w_n = 1, \quad (1)$$

linking apparent missing energy in pp collisions to energy flux into extra-dimensional blocks. While no anomalous signatures have been definitively observed, current limits are consistent with—and constrain—BBT parameter space. The framework suggests qualitative avenues toward understanding quantum correlations across space-like separations and the apparent weakness of gravity.

1 Introduction

The Standard Model (SM) of particle physics is extraordinarily successful, yet it leaves fundamental questions unresolved: the large separation between the electroweak and Planck scales (hierarchy problem), the identity of dark matter, the origin and persistence of quantum entanglement at macroscopic separations, and the small but nonzero cosmological constant. String theory offers an ambitious unification program but presently lacks direct, unique experimental confirmation at accessible energies.

This work explores an alternative, deliberately minimalistic phenomenological framework—the *Big Block Theory* (BBT)—in which the observed $3 + 1$ dimensional universe is one of many “blocks” (or slices) of a higher-dimensional structure. Different blocks can exchange energy under extreme conditions, providing collider-accessible handles. BBT borrows mathematical tools from Kaluza–Klein theory and large/warped extra-dimension scenarios, but it is intentionally agnostic about ultraviolet completion; its immediate goal is to organize existing collider constraints and motivate new, falsifiable measurements.

The remainder of this document is organized as follows. Section 2 outlines the theoretical foundations and defines the frequency-slice concept. Section 2.1 summarizes

the LHC data used to constrain BBT. Section 3 translates experimental searches (missing energy, KK resonances, microscopic black holes, and quantum correlations) into BBT parameter bounds. Section 4 develops the mathematical formalism. Section 5 sketches implications for the hierarchy problem, dark matter, and entanglement. Section 6 proposes future experimental probes. Section 7 compares BBT with string theory. Conclusions and future directions appear in Section 8.

2 Theoretical Foundations

We model the total quantum state of the full multidimensional structure as

$$\Psi_{\text{tot}}(t) = \sum_{n=0}^N A_n \Psi_n e^{i\omega_n t}, \quad (2)$$

where Ψ_n denotes the state associated with block (or extra-dimensional sector) n , A_n an amplitude, and ω_n a characteristic frequency parameter. Normalization $\sum_n |A_n|^2 = 1$ is assumed. Our perceived universe corresponds to a dominant sector (say $n = 0$) with $|A_0|^2 \approx 1$; high-energy processes may transiently populate $n > 0$ sectors.

A central phenomenological postulate is *trans-dimensional energy accounting*: energy injected into block n carries a dimensionless weight w_n satisfying $\sum_n w_n = 1$. Observable energy deficits in collider events (after known SM sources such as neutrinos are accounted for) bound $\sum_{n>0} w_n$ and hence the coupling of visible matter to hidden blocks.

2.1 LHC Data Sets and Run Periods

The phenomenological constraints we apply to BBT are derived from public LHC Run 2 searches and, where noted, preliminary Run 3 performance reports. Run 2 corresponds to proton–proton (pp) collisions at a center-of-mass energy of $\sqrt{s} = 13$ TeV acquired between 2015 and 2018, with final integrated luminosities of 139 fb^{-1} for ATLAS and 137 fb^{-1} – 138 fb^{-1} for CMS (analysis dependent). Run 3 operation at $\sqrt{s} = 13.6$ TeV began in July 2022 following LS2 upgrades and delivered substantial additional luminosity; by the early shutdown on 29 November 2024, ATLAS had recorded roughly 196 fb^{-1} of pp data at 13.6 TeV (preliminary)¹, and the 2025 data-taking season is underway. These data define the experimental landscape within which BBT parameters must reside. [1, 2]

3 Experimental Constraints from the LHC

3.1 Missing-Energy Searches and ADD-like Limits

Collider searches for large extra dimensions in mono-object final states with large missing transverse momentum set stringent lower limits on the fundamental Planck scale M_D . Using 139 fb^{-1} of 13 TeV pp data, ATLAS excludes $M_D < 11.2$ TeV for $n = 2$ extra dimensions, 7.1 TeV for $n = 4$, and 5.9 TeV for $n = 6$ (observed 95% CL). [3] A complementary CMS analysis combining 2016–2018 data (137 fb^{-1}) yields $M_D < 10.7$ TeV ($d = 2$), 6.8 TeV ($d = 4$), and 5.5 TeV ($d = 6$) exclusions. [4] These bounds directly constrain the BBT energy-leakage scale when BBT blocks are identified with ADD dimensions.

¹Year-end performance summary; final calibrated luminosities may differ.

Table 1: ATLAS 95% CL lower limits on the fundamental Planck scale M_D in $4 + n$ dimensions from monojet+ E_T^{miss} search at $\sqrt{s} = 13$ TeV using 139 fb^{-1} (2015–2018). Observed and expected values in TeV.

n	Expected M_D [TeV]	Observed M_D [TeV]
2	$11.6^{+1.0}_{-1.0}$	$11.2^{+1.0}_{-1.3}$
3	$8.6^{+0.6}_{-0.6}$	$8.5^{+0.6}_{-0.8}$
4	$7.2^{+0.4}_{-0.4}$	$7.1^{+0.4}_{-0.6}$
5	$6.4^{+0.3}_{-0.3}$	$6.4^{+0.3}_{-0.5}$
6	$5.9^{+0.2}_{-0.2}$	$5.9^{+0.3}_{-0.4}$

Table 2: CMS 95% CL lower limits on M_D in $4 + d$ dimensions from monojet/monoV + p_T^{miss} search at $\sqrt{s} = 13$ TeV using 137 fb^{-1} (2016–2018).

d	Expected M_D [TeV]	Observed M_D [TeV]
2	12.2	10.7
3	9.0	8.0
4	7.4	6.8
5	6.6	6.0
6	5.9	5.5
7	5.6	5.2

3.2 Kaluza–Klein Resonances

The BBT framework predicts towers of Kaluza–Klein (KK) excitations with masses

$$m_{KK,n} = \sqrt{m_0^2 + \left(\frac{n}{R}\right)^2}, \quad (3)$$

where R is an effective compactification radius. LHC searches for high-mass resonances in dilepton, dijet, and diphoton channels set lower bounds of order $1/R \gtrsim 4$, model dependent. [5]

3.3 Microscopic / Quantum Black Holes

Low-scale gravity scenarios that permit microscopic (quantum) black-hole formation are constrained by high-mass final-state searches. An ATLAS search in ℓ +jet invariant masses (140 fb^{-1} , 13 TeV) sets threshold mass limits $M_{\text{th}} > 9.2$ TeV in an ADD benchmark and > 6.8 TeV in an RS1 benchmark. [6] A CMS search for lepton-flavor-violating dileptons ($e\mu$, $e\tau$, $\mu\tau$; 138 fb^{-1}) finds no excess and excludes benchmark QBH thresholds up to 5.6, 5.2, and 5.0 TeV, respectively. [7] These null results imply that any BBT-induced strong-gravity transition must occur above the quoted scales (channel dependent).

3.4 RS Graviton / Warped Blocks

Diphoton resonance and continuum searches probe warped extra-dimensional scenarios analogous to BBT “warped blocks.” A comprehensive CMS analysis of high-mass diphoton events (138 fb^{-1} , 13 TeV) excludes Randall–Sundrum graviton masses below roughly

2.2–5.6 TeV across couplings $0.01 < k/\bar{M}_{Pl} < 0.2$, and sets ADD mass-scale limits M_S in the 7.1–11.1 TeV range (convention dependent). [8] ATLAS Run 2 diphoton results at comparable luminosity show similar sensitivity, excluding multi-TeV RS graviton masses for $k/\bar{M}_{Pl} \sim 0.1$. [9]

Schematic graviton-emission scaling. At parton level, graviton emission rates in ADD-like scenarios scale approximately as

$$\hat{\sigma} \propto \frac{1}{M_D^{n+2}} \hat{s}^{n/2}, \quad (4)$$

up to order-unity convention factors (GRW/HLZ/Hewett) and parton-luminosity integrals; see Refs. [3–5] for full expressions and experimental implementations.

4 Mathematical Framework

We extend general relativity to $D = 4 + n$ dimensions with line element

$$ds^2 = \eta_{\mu\nu} dx^\mu dx^\nu + g_{ij}(y) dy^i dy^j, \quad (5)$$

where y^i span the extra dimensions. A simple phenomenological parameterization of dynamic compactification is

$$R_i(t) = R_0 \left[1 + \epsilon_i \cos(\omega_i t + \phi_i) \right], \quad (6)$$

with small modulation amplitude ϵ_i . Large oscillations are strongly constrained by precision tests of gravity and equivalence principle measurements; here we treat $\epsilon_i \ll 1$ and focus on high-energy excitations probed at colliders. [5]

The BBT Hamiltonian is decomposed as

$$H_{\text{tot}} = H_{\text{SM}} + H_{\text{grav}} + H_{\text{int}}, \quad (7)$$

with interaction term

$$H_{\text{int}} = \sum_{n=1}^N g_n \int d^4x \bar{\psi} \gamma^\mu \psi \phi_n(x), \quad (8)$$

where ϕ_n encodes excitations of block n (scalar proxy field). This schematic coupling suffices to illustrate collider signatures; a gauge-invariant completion is left to future work.

5 Implications for Fundamental Physics

5.1 Unified Event-Yield Accounting

For any signal hypothesis the expected number of selected events is

$$N_{\text{sig}} = \mathcal{L} \times \sigma_{\text{sig}} \times \epsilon \times \mathcal{B}, \quad (9)$$

with integrated luminosity \mathcal{L} , production cross section σ_{sig} , selection efficiency ϵ , and relevant branching fraction \mathcal{B} .

5.2 Hierarchy Problem

In $4+n$ dimensions the relationship between the $(4+n)$ -dimensional and observed Planck scales reads

$$M_D^{2+n} = M_{Pl}^2 V_n, \quad (10)$$

where V_n is the volume of the compact space. For sufficiently large V_n (large extra dimensions) the fundamental scale M_D may lie at the TeV scale, offering an explanation for the apparent weakness of gravity in 4D. [5]

5.3 Dark Matter as Trans-Dimensional Leakage

If hidden blocks carry mass-energy that couples gravitationally into our slice with weight factors w_k , the effective stress-energy entering Einstein's equations is

$$T_{\mu\nu}^{(\text{tot})} = \sum_{k=0}^N w_k T_{\mu\nu}^{(k)}. \quad (11)$$

Phenomenologically, such contributions could mimic dark matter or dark energy terms; quantitative cosmological fits are left to future work.

5.4 Quantum Entanglement

Entanglement between degrees of freedom localized in spatially separated regions may persist if correlations propagate through higher-dimensional geodesics. The reduced-entropy definition

$$S_A = -\text{Tr}(\rho_A \ln \rho_A) \quad (12)$$

remains, but BBT interprets long-range correlations as probes of hidden connectivity. Recent ATLAS measurements of spin correlations in top-quark pairs provide a high-energy laboratory for such ideas. [10]

6 Future Experimental Probes

Targeted measurements that could provide discriminating power for BBT-inspired scenarios include:

- **Precision E_T^{miss} tails:** Extend mono-object analyses with differential shape fits and timing layers to distinguish delayed energy flow.
- **Angular correlations in high- p_T dileptons:** Sensitive to KK interference patterns and entanglement-inspired oscillations.
- **Multi-channel QBH searches:** Combine ℓ +jet, multi-lepton, and dijet topologies to push M_{th} reach beyond current 9 TeV scales. [6, 7]
- **High-mass diphoton + E_T^{miss} :** Joint resonance + continuum fits could sharpen RS/ADD discrimination. [8, 9]

7 Comparison with String Theory

Table 3 contrasts several broad-brush features. The intent is pedagogical; neither framework is reduced to a caricature.

Table 3: Qualitative comparison of String Theory and the Big Block Theory (BBT).

Aspect	String Theory	Big Block Theory
Extra Dimensions	Typically Planck-scale compactification	Potentially TeV-scale (phenomenological)
Testability	No unique low-energy prediction yet confirmed	Direct collider constraints (ADD-like, RS-like)
Mathematical Scope	Candidate UV completion incl. gravity	Phenomenological organizing principle
Reality Structure	Single fundamental manifold (many vacua)	Multiple interacting blocks/slices

8 Conclusions and Future Directions

We have outlined the Big Block Theory as a speculative but testable phenomenological framework inspired by extra-dimensional models and constrained by LHC data. Key points:

1. **Collider consistency.** Existing LHC searches for missing energy, high-mass diphoton resonances, and microscopic black holes impose strong bounds on any energy flow into hidden blocks; BBT survives only in parameter regions above the quoted limits.
2. **Unified energy accounting.** A simple weighted-sum formalism connects apparent missing energy to trans-dimensional flux, enabling straightforward reinterpretation of collider limits.
3. **Opportunities.** Dedicated analyses—especially precision E_T^{miss} tails, timing signatures, and multi-object correlations—could sharpen sensitivity to BBT-inspired effects.

8.1 Beyond Colliders

Potential next steps include cosmological fits with block-weight couplings, quantum-information observables (entanglement witnesses in heavy-flavor systems), and gravitational precision tests sensitive to dynamic compactification.

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Andrew Bull, University of Hong Kong. Email: Nroo.Bull@proton.me

References

- [1] CERN. The year in review: An early end to a year of strong performance for the lhc. CERN News, 2024. Published 29 Nov 2024; Run-3 luminosity performance summary.
- [2] CERN. The 2025 lhc and accelerator season is underway. CERN News, 2025. Season start; context for ongoing Run-3 data.
- [3] ATLAS Collaboration. Search for new phenomena in events with an energetic jet and large missing transverse momentum in pp collisions at $\sqrt{s}=13$ tev with the atlas detector. *JHEP*, 03:145, 2021. doi: 10.1007/JHEP03(2021)145. 139 fb-1 (2015–2018); ADD MD >11.2 TeV (n=2).
- [4] CMS Collaboration. Search for new particles in events with energetic jets and large missing transverse momentum in pp collisions at $\sqrt{s}=13$ tev. *JHEP*, 11:153, 2021. doi: 10.1007/JHEP11(2021)153. EXO-20-004; 137 fb-1; ADD MD limits up to 10.7 TeV (d=2).
- [5] Particle Data Group. Review of particle physics: Models with extra dimensions. *Prog. Theor. Exp. Phys.*, 2024. Global ADD/RS summary.
- [6] ATLAS Collaboration. Search for quantum black hole production in lepton+jet final states using pp collisions at $\sqrt{s}=13$ tev with the atlas detector. *Phys. Rev. D*, 109:032010, 2024. doi: 10.1103/PhysRevD.109.032010. 140 fb-1; Mth >9.2 TeV (ADD), >6.8 TeV (RS1).
- [7] CMS Collaboration. Search for heavy resonances and quantum black holes in e mu, e tau, and mu tau final states in pp collisions at $\sqrt{s}=13$ tev. *JHEP*, 05:227, 2023. doi: 10.1007/JHEP05(2023)227. 138 fb-1; QBH LFV thresholds up to 5.6 TeV (e mu).
- [8] CMS Collaboration. Search for new physics in high-mass diphoton events from pp collisions at $\sqrt{s}=13$ tev. *Submitted to JHEP*, 2024. EXO-22-024; 138 fb-1; RS graviton 2.2–5.6 TeV across $0.01 < k/M_{\text{pl}} < 0.2$; ADD MS 7.1–11.1 TeV.
- [9] ATLAS Collaboration. Search for high-mass diphoton resonances and nonresonant phenomena in pp collisions at $\sqrt{s}=13$ tev with the atlas detector. *Phys. Lett. B*, 822:136651, 2021. doi: 10.1016/j.physletb.2021.136651. 139 fb-1; RS graviton multi-TeV exclusions.
- [10] ATLAS Collaboration. Observation of entanglement in top-quark pairs at the lhc. *Nature*, 2024. doi: 10.1038/s41586-024-07824-z. High-energy top-quark spin correlation / entanglement.