Equation of the Universe

Proton

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Author: Glenn R. King
Independent Researcher, Akron, Ohio, USA
Email: Gking@DMsHelper.com

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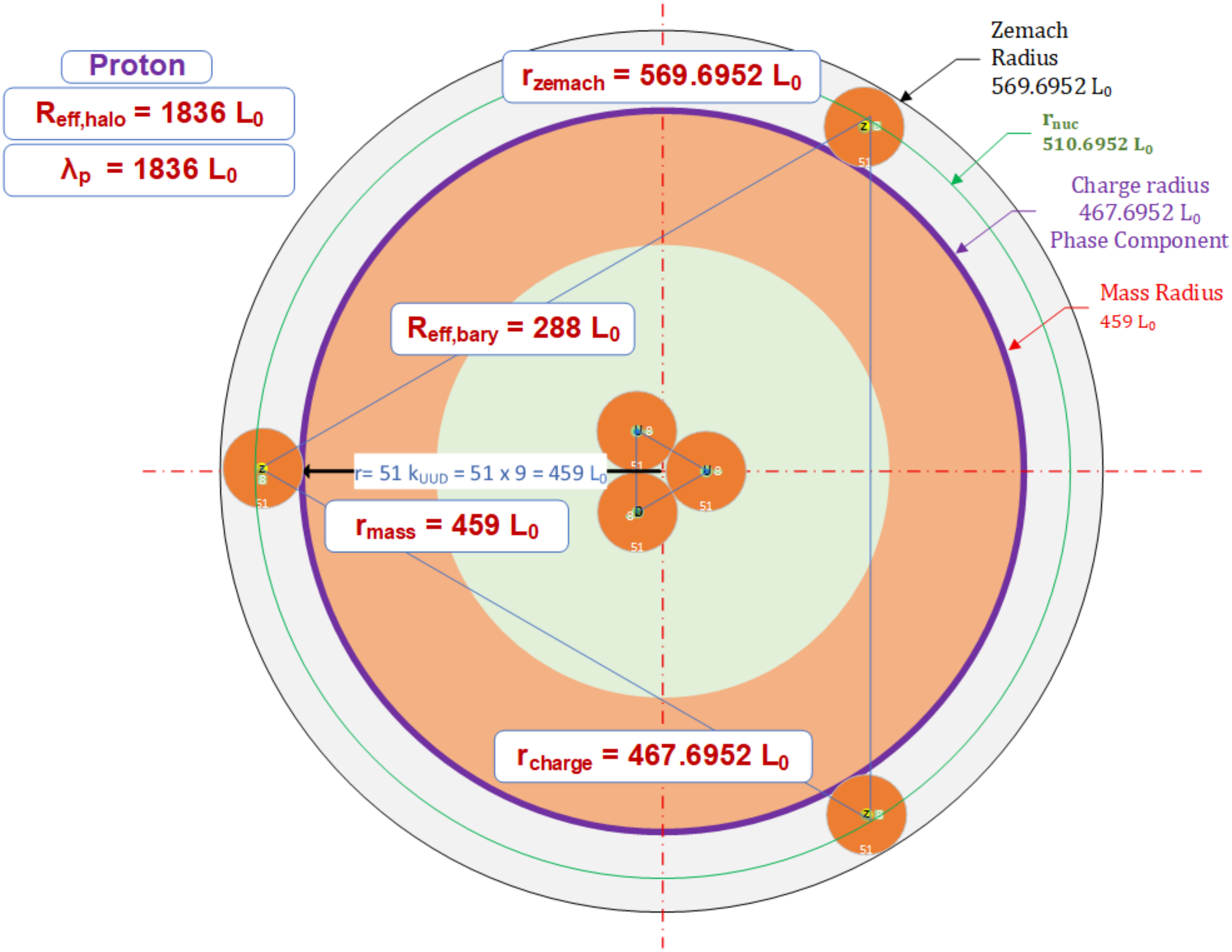

Figure 1

A **Proton** is a UUD triad surrounded by a Zeteon-triad. The zeteon halos from Z-triad touch the UUD triad halo reach. The combination of the six CPPs creates the proton's overall R_{eff}.

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§0 — Phase Identity and Physical Role

0.1 Definition

The Proton is the first stable composite CPP region formed post–Freeze-Out.

Key Property: This configuration produces the smallest self-sustaining regional curvature basin capable of persisting across King cycles. It consists of a tightly bound set of six CPPs:

- 2 Uniteons (U)
- 1 Deniteon (D)
- 3 Zeteons (Z)

Composite Expression: Proton = (2U + 1D) core + 3Z triad

The proton's native signed charge expression is carried by the UUD phase topology and resolves as $+q_0$. The Zeteon triad is closure-only and contributes no net charge component. Here $q_0 \equiv \Delta A$is the native CPP signed phase-channel amplitude, not the SI elementary charge e. The SI charge response is introduced only through the Coulomb-response bridge defined in the CPP document.

UUDZZZ is the first configuration that satisfies all three formation conditions:

1. **Directional axis defined** (2U)
2. **Orthogonal smoothing present** (1D)
3. **Complete ledger buffering** (3Z)

It is:

- Self-sustaining
- Bounded
- Cycle-stable
- Spatially coherent

We have several radii that naturally fall out of our geometry and are associated with observed proton radius.

- r_{mass} = curvature-only (mass) = 459 → mass closure
  r_E = closure geometry radius= 467.6952 → charge radius (rest energy)
- r_Z = Z-conditioned convolution radius= 569.6952 → Zemach
- r_M = Under the 459 L_0 mass calibration, the closure geometry radius 467.6952 L_0 maps to 0.857 fm. This lies within the commonly reported range of the proton magnetic radius r_M, suggesting that magnetic-channel observables couple to the phase-completed closure boundary rather than the curvature-only boundary.

0.2 cosmology baryon fraction

The **best-fit cosmology baryon fraction.** Using Planck 2018 base-ΛCDM values ($\Omega_b h^2 \approx 0.0224$, $\Omega_c h^2 \approx 0.120$), the baryon fraction of total matter is (See _EOTU_CPP_Base_v3.41.13 or above)

$$f_b = \frac{\Omega_b}{\Omega_b + \Omega_c} \approx \frac{0.0224}{0.0224 + 0.120} \approx 0.157 \approx \frac{8}{51} = 0.1568627$$

Using the locked geometric based on the measured value ratio Baryonic (Core)/Dark Matter (Halo).

All halo and core radii are expressed as integer multiples of L_0.

$$\boxed{L_0 = 64}, \qquad \frac{r_C(k)}{r_H(k)}, \qquad \frac{r_C(1)}{r_H(1)} = \frac{8}{51}$$

0.3 Reference Values

- Proton Radius values (measured)
  - Proton radius (curvature only) = $R_p(\mu_p) \approx 0.8253$ fm (curvature only)
  - Charge Radius = $R_p(\sin(\theta)) \approx 0.8409$ fm (Phase only)
  - Zemach radius = $R_p(\mu_p + \sin(\theta)) \approx 1.045(16)$ fm
- proton mass (measured) = 938.272 MeV
- λ_p= Wavelength $= 1836\ L_0$ (Used in calculating Bonding and Ionization)

§1 — Proton UUD core with Z-triad shell

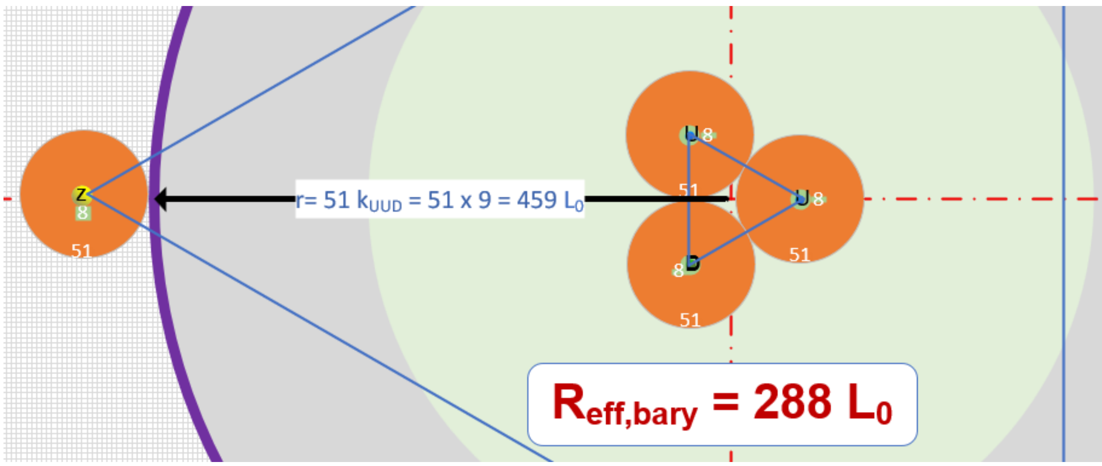
$$m_f(p) \equiv m_p = \left(m_p^{UUD} + m_{Z\Delta} + \Delta m_{int}\right), E_p = \Gamma(m_{UUD} + m_{Z\Delta} + \Delta m_{int})^2$$

$$m_p = 30{,}061.2454 \ + 0 + \ 569.5347 = 30{,}630.7801$$

Notably, the internal coherence term Δm_int numerically matches the Z-conditioned convolution index that maps to the Zemach radius, indicating that the same phase-geometry structure governs both rest-mass completion and magnetic-channel spatial convolution.

1.1 Mass from geometry

Use the effective reach of the UUD core to set the mass of the proton based on number of CPPs in the UUD triad. For planar triad composites, the effective reach index is defined as $k_{\text{CPP}} = N_{\text{CPP}}^2$.



curvature-only UUD core mass from radius 2D circular inventory:

$$N_\circ = \pi r^2$$

$$N_\circ(k_{\text{UUD}}) = \pi\,(r\,k_{\text{UUD}})^2 = \pi(51\,k_{\text{UUD}})^2$$

Where

- $N_{\text{UUD}} = 3$
- $k_{\text{CPP}}(UUD) \equiv \ k_{\text{UUD}} = (N_{\text{UUD}})^2 = 9$
- $r_E(k_{\text{UUD}}) = 51\,k_{\text{UUD}} = 459\,L_0$

The UUD core reach defines the curvature-only mass-factor projection. The associated closure geometry maps near the measured proton charge-radius scale.

$$m_p^{UUD} = \sqrt{\frac{N_\circ}{3}} = \sqrt{\frac{\pi}{3}}\,(51 \cdot 9)\,L_0 = \sqrt{\frac{\pi}{3}}\,(459)\,L_0 = 30{,}061.2454$$

1.2 Proton Reach $R_{\text{eff,p}}$ $N_{\text{UUDZZZ}} = 6$

$$k_{\text{UUDZZZ}} = 6^2 = 36$$

$$R_{\text{eff}}(k) = (51\, k_{\text{UUDZZZ}})\, L_0$$

$$R_{\text{eff,p}} = 51(36)\, L_0 = 1836\, L_0$$

The composite core for baryonic then becomes:

$$\text{R}_{\text{eff}}, \text{baryonic } = \frac{8}{51}\, 1836\, L_0 = 288\, L_0$$

1.3 Z-triad curvature term for an equilateral triad

The halo of the Zeteons (51 L_0)touch the outside of proton r_{mass} at 467.6952 . creating a Z-halo diameter thickness of $2r_H = 102L_0$. Therefore, the overall radius from the center with this shell is 569.6952. this corresponds to the Zemach Radius. The Z-conditioned shell contributes to spatial convolution observables (e.g., Zemach radius) but carries no rest-mass contribution

$$m_{Z\Delta} = 0$$

1.4 Phase difference between Components Δm_{int}

Δm_{int} is the core-internal coherence factor for the UUD triad It represents the minimum internal phase-alignment weight required for the three CPPs to behave as a single rigid core region. Rather than averaging global phase and geometric factors, the interaction is evaluated per edge of the equilateral triad. Each edge contributes a coherence weight

$$w(\Delta\phi, \theta) = \cos\left(\frac{\Delta\phi}{2}\right) \cos\,(\theta)$$

where Δφ is the phase separation between the two CPPs and θ is the geometric embedding angle of that edge within the 60° triad. The total internal coherence factor g_{UUD} is obtained by summing the per-edge weights over the three edges of the UUD triangle.

This component is part of the mass of the proton and maps to the r_{mass}

$$\Delta m_{int} = 256\, g_{UUD} = 256\,(2.22474488) = 569.5347$$

Calculating Δm_{int}

- Two U–D edges: $\Delta\phi_{UD} = \frac{\pi}{2}, \theta = \frac{\pi}{6}$ (30° projection - half-phase edges)
- One U–U edge: $\Delta\phi_{UU} = 0, \theta = 0$ (aligned edge / no projection)
- The factor $\sqrt{3}/2$ arises from the intrinsic 60° angular separation between adjacent vertices in an equilateral triad. It is not introduced as a coupling constant; it is the geometric cosine of the embedding angle.

$$g_{UUD} = \left[2\cos\left(\frac{\pi}{4}\right)\ \cos(\pi/6) + 1\right] = 2\left(\frac{\sqrt{2}}{2}\right)\left(\frac{\sqrt{3}}{2}\right) + 1 = \frac{\sqrt{6}}{2} + 1 = \ 2.2247$$

$$\Delta m_{int} = 256\, g_{UUD} = 256\ (2.22474488) = 569.5347$$

Compute it:

- $\cos(\pi/4) = 0.70710678$
- $\cos(\pi/6) = 0.86602540$

$$g_{UUD} = 2(0.70710678)(0.86602540) + 1 = 2(0.61237244) + 1 = 1.22474488 + 1 = 2.22474488$$

1.5 Proton Energy

Measured proton rest energy ≈ 938.2720813 MeV (30,631.2272)

$$\boxed{E_R = \Gamma(m_{UUD} + m_{Z\Delta} + \Delta m_{int})^2 = \Gamma\ (30{,}630.7801)^2 \approx 938.2446895\ \text{MeV}}$$

Energy difference

$$\Delta E = 938.2720813 - 938.2446895 = 0.0273918\ \text{MeV}$$

Percent Energy difference

$$\%\Delta = \frac{\Delta E}{E_p^{meas}} \times 100 = \frac{-0.0273918}{938.2720813} \times 100 = -0.002919\%$$

The calculated value is approximately 0.002919% below the measured proton rest energy.

1.6 Proton Native Charge Descriptor

$$q_{cpp}(\theta, \Phi) = q_0 \sin(\theta + \Phi)$$

For the proton core:

$$\Phi_U = \pi, \Phi_D = \frac{3\pi}{2}, \Phi_Z = 0$$

The UUD core phase descriptor is:

$$\mathcal{P}_{UUD}(\theta) = 2q_0 \sin(\theta + \pi) + q_0 \sin\left(\theta + \frac{3\pi}{2}\right)$$

$$\mathcal{P}_{UUD}(\theta) = -2q_0 \sin\theta - q_0 \cos\theta$$

The Zeteon triad is closure-only in resolved charge:

$$\mathcal{P}_{\triangle Z, \partial K} = 0$$

At the King-cycle boundary, the proton Region resolves as:

$$q_p = +q_0$$

where the positive sign follows the proton/electron sign convention.

1.7 Proton Wavelength

The proton wavelength is defined by the full closed $UUDZZZ$ Region reach. It is not introduced as an independent fitted quantity. It follows directly from the six-CPP closed proton Region:

The proton contains:

$$N_{UUDZZZ} = 6$$

For planar Region closure, the effective reach index is:

$$k_{CPP} = N_{CPP}^2$$

Therefore, for the proton:

$$k_{UUDZZZ} = 6^2 = 36$$

The proton effective reach is:

$$R_{eff,p} = 51k_{UUDZZZ}\,L_0 = 51(36)L_0 = 1836L_0$$

The proton wavelength is identified with the full effective Region reach:

$$\lambda_p \equiv R_{eff,p} = 1836\,L_0$$

The baryonic participation reach is the core fraction of the same full Region envelope:

$$R_{eff,bary,p} = \frac{8}{51}(1836L_0) = 288L_0$$

Thus the proton carries two related geometric scales:

$$\lambda_p = R_{eff,p} = 1836L_0, \qquad R_{eff,bary,p} = 288L_0$$

The distinction is that λ_p is the full propagated proton Region scale, while $R_{eff,bary,p}$ is the participating baryonic core fraction of the same Region envelope. It is therefore the proton wavelength used throughout the theory in interaction, bonding, ionization, and curvature carrier products.

§2 — Proton Chain

2.1 Proton Breakdown Chain v1.0 (High → Low)

Energy is curvature inventor:

$$E = \kappa_E \, \mu$$

So for any distorted proton overlap state:

$$E(\text{state}) = \kappa_E \, \mu(\text{state})$$

Expand μ around the closed proton

Closed proton (UUDZZZ) has some baseline curvature inventory μ_p. When the Z-triad is distorted, the total curvature inventory becomes:

$$\Delta\mu(\text{state}) = \mu_p + \mu_{\text{excess}}(\Delta\theta, r, \Delta\phi)$$

The form is the quadratic approximation Near closure; the lowest nontrivial term is quadratic:

$$\Delta\mu_{\text{excess}} \approx A_\theta \theta^2 + A_r r^2 + A_\phi \phi^2$$

Multiply by κ_E and you get your displayed form:

$$E_{P4} \approx E_{p,0} + \alpha_\theta \theta^2 + \alpha_r R^2 + \alpha_\phi \phi^2$$

where:

- $\alpha_\theta = \kappa_E A_\theta$ (angular coefficient)
- $\alpha_r = \kappa_E A_r$ (radial coefficient)
- $\alpha_\phi = \kappa_E A_\phi$ (phase coefficient)

$\alpha_\theta \theta^2$ is the **Triad angular defect:** if the Z's are not at 120°, the triad stops being curvature-efficient → more curvature must be carried/stored to maintain the state.

$\alpha_r R^2$is the **Radial displacement**: pulling a Z away from its closure radius increases curvature burden (reach/lean mismatch) → more curvature inventory**.**

$\alpha_\phi \phi^2$ is the **phase defect:** it is not energy directly -neutrino channel is Δμ=0), but phase defect *forces* geometry that typically increases curvature inventory before resolution. In a local expansion, it appears as an effective contribution to Δμ because phase misalignment prevents re-closure and keeps curvature in overlap longer**.**

2.2 P-4 — Z-Class De-Coupling (Non-Reclosure)

Trigger: overlap drives Z-triad decoupled long enough that UUDZZZ cannot re-lock → "no-proton-out" basin.

$$E_{P4} = \kappa_E[\mu_p + \mu_{\text{excess}}(\theta, r)] \iff E_Z \approx 91.19 \text{ GeV}$$

$$\boxed{E_Z = \kappa_E\, \mu_*(c_\theta\, \hat{\theta}_{\mathrm{crit}}^2 + c_r\, \hat{r}_{\mathrm{closure}}^2)} E_Z \approx 91.19 \text{ GeV (see appendix C)}$$

where

- μ_p= total curvature inventory of the closed proton (UUDZZZ). That is your ground state.
- $\mu_{\mathrm{excess}}(\theta, r)$= additional curvature inventory required when:
  - Z triad is angularly distorted
  - Z is radially displaced

P-4 boundary occurs when:

$$\mu_{\mathrm{excess}} = \mu_{\mathrm{decouple}}$$

$\Delta\mu_{\mathrm{decouple}}$ is the curvature inventory corresponding to the minimal geometric configuration that places any Z outside the capture basin.

The P-4 boundary is reached when the Z-triad exits the closure capture basin during the interaction window:

$$\mu_{\mathrm{excess}} \geq \mu_{\mathrm{decouple}}$$

where

$$\mu_{\mathrm{decouple}} = \mu(\theta_{\mathrm{crit}}, r_{\mathrm{closure}})$$

and

- θ_{crit}= angular deviation at which triad no longer self-corrects
- r_{closure}= radial distance beyond which Z cannot be re-captured during overlap

Mapping to energy:

$$\kappa_E(\mu_p + \mu_{\mathrm{decouple}}) = 91.19 \text{ GeV}$$

Decouple means:

$$r_Z > r_{\mathrm{capture}} \text{ during } N_{\mathrm{overlap}} \text{ King cycles}$$

Then define (See Appendix B for derivation of N_{overlap}):

$$N_{\mathrm{overlap}} \approx 2.1 \times 10^6 \text{ King Cycles}$$

This overlap time is universal for the proton decay

2.3 P-3 — W-Class Phase-Gate (Mixed Exhaust)

Trigger: overlap opens a **mandatory phase exhaust channel** (neutrino-admissible) while curvature exhaust remains active.

$$E_{P3} = \kappa_E\left[\mu_p + \mu_{\mathrm{excess}}(\theta, r)\right] \iff E_W \approx 80.37 \text{ GeV}$$

$$\boxed{E_W = \kappa_E\, \mu_*(c_\theta\, \hat{\theta}_{\text{gate}}^2 + c_r\, \hat{r}_{\text{gate}}^2)}\, E_W \approx 80.37 \text{ GeV (see appendix C)}$$

where

- μ_p= total curvature inventory of the closed proton (UUDZZZ).
- $\mu_{\text{excess}}(\theta, r)$= additional curvature inventory required when:
  - Z triad is angularly distorted
  - Z is radially displaced (but remains capturable)

A **phase gate** is crossed **before** the Z-triad exits the capture basin:

$$|\, \Delta\phi\, | \geq \phi_{\text{gate}} \text{ while } r_Z < r_{\text{capture}}$$

Meaning:

- Z has not escaped (so proton can, in principle, re-lock),
- but phase imbalance is now large enough that **phase exhaust is mandatory**.

P-3 is defined by the coexistence of:

$$\mu_{\text{excess}} > 0 \text{ and } |\Delta\phi| \geq \phi_{\text{gate}}$$

So the overlap must resolve through **curvature exhaust** (photons, Δμ) and **phase exhaust** (neutrino channel, Δμ = 0) in the same event window.

$$r_Z < r_{\text{capture}} (\text{capturable})$$

So P-3 is explicitly the “gate-before-escape” regime.

Phase-gate crossing must occur within the overlap window:

$$|\Delta\phi| \geq \phi_{\text{gate}} \text{ during } N_{\text{overlap}} \text{ King cycles} \approx 2.1 \times 10^6$$

P-3 is reached when the overlap remains geometrically capturable, but phase imbalance crosses a gate that forces mixed exhaust, mapping the boundary to the ~80.37 GeV landmark.

Mapping to energy:

$$\kappa_E(\mu_p + \mu_{\text{gate}}) = 80.37 \text{ GeV}$$

2.4 P-2 — π^0-Class Curvature Exhaust (Fast Curvature Dump)

Trigger: overlap resolves by **curvature-only export** (photons) while proton re-closure remains available.

$$E_{P2} = \kappa_E\left[\mu_p + \mu_{\text{excess}}(\theta, r)\right] \iff E_{\pi^0} \approx 135\ \text{MeV}$$

$$\boxed{E_{\pi 0} = \kappa_E\, \mu_*\left(c_\theta\, \hat{\theta}_{\pi 0}^2 + c_r\, \hat{r}_{\pi 0}^2\right)} \approx 135\ \text{MeV (see appendix C)}$$

where

- μ_p= total curvature inventory of the closed proton (UUDZZZ).
- $\mu_{\text{excess}}(\theta, r)$= additional curvature inventory required when:
    - Z triad is angularly distorted
    - Z is radially displaced (but remains capturable)

P-2 is defined by the absence of mandatory phase exhaust (no phase gate):

$$|\ \Delta\phi\ | < \phi_{\text{gate}}$$

Meaning:

- phase imbalance remains below the threshold that requires neutrino-channel resolution,
- the overlap can resolve by curvature export alone.

but with:

$$\mu_{\text{excess}} > 0 \text{ and } |\ \Delta\phi\ | < \phi_{\text{gate}}$$

So the overlap must resolve through **curvature exhaust** (photons, $\Delta\mu$) and does **not** require phase exhaust ($\Delta\mu = 0$ channel) in the same event window.

Z remains capturable:

$$r_Z < r_{\text{capture}}$$

So proton re-lock is permitted once curvature excess is exported.

P-3 occurs where $E_{P2} < E_{P3} < E_{P4}$ and equivalently $\mu_{P2} < \mu_{P3} < \mu_{P4}$

Curvature exhaust occurs during the same overlap window:

$$\mu_{\text{excess}} > 0 \text{ during } N_{\text{overlap}} \text{ King cycles } \approx 2.1 \times 10^6$$

P-2 is reached when the overlap remains geometrically capturable and below the phase-gate threshold, so curvature surplus resolves through photon exhaust only, mapping the boundary to the ~135 MeV curvature packet landmark.

2.5 P-0 — Re-Closure Basin (Proton-Out)

Trigger: overlap remains within the closure capture basin and resolves all defects such that the proton re-locks as **UUDZZZ**.

$$E_{P0} = \kappa_E\left[\mu_p + \mu_{\text{excess}}(\theta, r)\right]$$

where

- μ_p= total curvature inventory of the closed proton (UUDZZZ).
- $\mu_{\text{excess}}(\theta, r)$= additional curvature inventory during overlap due to Z-triad distortion/displacement.

Re-closure requires that both geometry and phase return below gating thresholds within the overlap window:

$$r_Z < r_{\text{capture}}$$
$$|\Delta\phi| < \phi_{\text{gate}}$$

and the curvature excess is fully exhausted:

$$\mu_{\text{excess}} \to 0$$

Therefore:

$$E_{P0} = \kappa_E \mu_p \iff 938.272 \text{ MeV}$$

If the above conditions are met during the overlap window (N_{overlap} King cycles), then:

$$\text{UUDZZZ re-locks} \Rightarrow \text{protons survive the event}$$

P-0 is the re-closure regime in which Z remains capturable, phase never requires mandatory exhaust, and curvature excess is fully exported so the proton returns to the closed UUDZZZ state.

Appendix B — Interaction Time for Proton

At ~91 GeV CM energy: Proton Lorentz factor:

$$\gamma \approx \frac{91\ \text{GeV}}{0.938\ \text{GeV}} \approx 97$$

Proton rest radius:

$$R_p \approx 0.84\ \text{fm}$$

Lorentz contracted overlap thickness:

$$\Delta x \approx \frac{2R_p}{\gamma}$$

$$\Delta x \approx \frac{2(0.84\ \text{fm})}{97} \approx 0.017\ \text{fm}$$

Convert to time:

$$\tau_{\text{interaction}} \approx \frac{\Delta x}{c} \approx \frac{1.7 \times 10^{-17}\ \text{m}}{3 \times 10^{8}} \approx 5.7 \times 10^{-26}\ \text{s}$$

Appendix C — Make μ_{excess} explicit

Define **dimensionless defect measures** (so units never get messy):

$$\hat{\theta} \equiv \frac{\theta}{120^\circ}, \qquad \hat{r} \equiv \frac{r - R_0}{R_0}$$

Then define the **excess curvature inventory** as:

$$\boxed{\mu_{\text{excess}}(\theta, r) = \mu_*(c_\theta\, \hat{\theta}^{\,2} + c_r\, \hat{r}^{\,2})}$$

where:

- μ_*= the **curvature-inventory scale** for Z-triad distortion in a proton overlap (units: "Δμ")
- c_θ, c_r= **dimensionless response weights**

Energy mapping stays EOTU-native:

$$\boxed{E_{\text{excess}} = \kappa_E\, \mu_{\text{excess}}}$$

Immediate payoff: you can solve *ratios* without knowing $\kappa_E$or μ_*

Divide equations to eliminate $\kappa_E \mu_*$:

$$\boxed{\frac{E_W}{E_Z} = \frac{c_\theta\, \hat{\theta}^{\,2}_{\text{gate}} + c_r\, \hat{r}^{\,2}_{\text{gate}}}{c_\theta\, \hat{\theta}^{\,2}_{\text{crit}} + c_r\, \hat{r}^{\,2}_{\text{closure}}}}$$

Numerically:

$$\frac{E_W}{E_Z} = \frac{80.37}{91.19} \approx 0.8813466$$

So your minimal gate-defect "size" is **88.1%** of the decouple-defect "size" (in the weighted quadratic metric).

Similarly:

$$\boxed{\frac{E_{\pi 0}}{E_Z} = \frac{0.135}{91.19} \approx 0.0014804}$$

So the P-2 packet regime corresponds to **0.148%** of the P-4 decouple metric.

That's an immediately usable, model-internal ordering constraint.

How you fully determine μ_*, c_θ, c_r You need **one additional EOTU choice**, and then it's solvable:

Set the P-4 minimal configuration as the unit metric:

$$\boxed{c_\theta\, \hat{\theta}^{\,2}_{\text{crit}} + c_r\, \hat{r}^{\,2}_{\text{closure}} = 1}$$

Then:

$$\boxed{\mu_* = \frac{E_Z}{\kappa_E}}$$

and the other rungs become direct predictions:

$$c_\theta\,\hat{\theta}_{\text{gate}}^2 + c_r\,\hat{r}_{\text{gate}}^2 = \frac{E_W}{E_Z} \approx 0.8813466$$

$$c_\theta\,\hat{\theta}_{\pi 0}^2 + c_r\,\hat{r}_{\pi 0}^2 = \frac{E_{\pi 0}}{E_Z} \approx 0.0014804$$

At that point, your "unknowns" are no longer α's; they're **geometric thresholds** ($\theta_{\text{crit}}, r_{\text{closure}}, \theta_{\text{gate}}, r_{\text{gate}}, \dots$) — which is exactly where EOTU wants the uncertainty to live.

Appendix D – Neutral Pion from p + p collision

The following reaction thresholds and lifetimes are external measured comparison anchors. The EOTU interpretation is the curvature-exhaust classification, not the origin of the measured particle labels.

Annotated: $p + p \rightarrow p + p + \pi^0 \rightarrow p + p + 2\gamma$

The "curvature-only packet" (invariant)

The neutral pion has fixed rest-mass budget:

$$m_{\pi^0} c^2 \approx 134.98 \text{ MeV}$$

and decays overwhelmingly to:

$$\pi^0 \rightarrow \gamma + \gamma$$

In the π^0rest frame, each photon carries:

$$E_\gamma = \frac{m_{\pi^0} c^2}{2} \approx 67.5 \text{ MeV}$$

Timescale (the entire existence of the π^0 state)

Mean lifetime:

$$\tau(\pi^0) \approx 8.43 \times 10^{-17} \text{ s (PDG lifetime/width compilation).}$$

In your King-cycle units (using your $\tau_0$value from EOTU):

$$N_K = \frac{\tau(\pi^0)}{\tau_0} \approx 3.16 \times 10^{15} \text{ cycles}$$

So the **curvature-only resolution completes in ~**3×10^{15} King cycles.

Outcome summary (EOTU language): curvature overload → **forced EM exhaust** → **2γ**, no neutrinos, no leptons, no weak chain.

The channel and what "intact p-p" means

A proton beam on a stationary proton can produce a neutral pion while leaving **two protons in the final state** (identity preserved). This is an **inelastic** channel (new particle created), but baryons remain protons.

Threshold (lab frame, fixed target)

The **threshold kinetic energy** for $pp \rightarrow pp\pi^0$in the lab (one proton at rest) is about **280 MeV**. For $p + p \rightarrow p + p + \pi^0$, this yields the $\sim$ 280 MeV result (the "extra" above 135 MeV is momentum-conservation overhead).

A standard closed-form expression for a reaction $1 + 2 \rightarrow a + b + c$ with target 2 at rest is:

$$E_{1,\text{thr}} = \frac{(m_a + m_b + m_c)^2 - (m_1^2 + m_2^2)}{2m_2} c^2, \;\; T_{\text{thr}} = E_{1,\text{thr}} - m_1 c^2$$

Using that same geometric shape but elevated closure level gives:

$$r^\star_{\text{charge}} \approx 490.91\, L_0, \qquad r^\star_{\text{mass}} \approx 500.21\, L_0, \qquad r^\star_Z \approx 609.30\, L_0,$$

$$R^\star_{\text{eff,bary}} \approx 308.02\, L_0, \qquad R^\star_{\text{eff,halo}} \approx 1963.63\, L_0.$$

If instead you split the pion rest-mass budget **symmetrically across the two protons**,

$$E^\star = 938.2446895 + 67.4884 = 1005.7330895 \text{ MeV}, \qquad m^\star_f = 31713.2952, \alpha = 1.03534076,$$

which gives the excited values:

$$r^\star_{\text{charge}} \approx 475.22\, L_0, \qquad r^\star_{\text{mass}} \approx 484.22\, L_0, \qquad r^\star_Z \approx 589.83\, L_0,$$

$$R^\star_{\text{eff,bary}} \approx 298.18\, L_0, \qquad R^\star_{\text{eff,halo}} \approx 1900.89\, L_0.$$

Appendix Z — Proton Allowed and Disallowed States

0.1 Stage 1 – The Proteon (U + D + Z → UDZ)

We start with three independent CPPs that come together in proximity (pre FO):

- **Uniteon (U)** — Φ = π
- **Deniteon (D)** — Φ = 3π/2
- **Zeteon (Z)** — Φ = 0

Each has:

- a **time/phase waveform**:

$$\delta A_i(\theta)$$

- a **radial envelope**:

$$g_i(r)$$

So locally the fabric deviation is:

$$\delta A_{\text{total}}(r,\theta) \approx g_U(r)\delta A_U(\theta) + g_D(r)\delta A_D(\theta) + g_Z(r)\delta A_Z(\theta)$$

This equation is the entire interaction story.

0.1.1 Stage 1 — Independent existence (large separation)

At large distances:

- The radial envelopes barely overlap.
- Each CPP deposits its deviation in its own neighborhood.
- The fabric relaxes locally between them back to the dormant baseline.

There is no shared burden. No composite exists yet.

0.1.2 Stage 2 — U and D approach

As U and D get closer:

- Their envelopes begin to overlap.
- The overlap region sees:

$$\delta A_{UD}(r,\theta) \approx g_U(r)\delta A_U(\theta) + g_D(r)\delta A_D(\theta)$$

Since U and D are phase-separated by π/2:

- They do not directly cancel.
- They do not fully reinforce.
- They produce a **rotating composite deviation**.

This is important:

A U–D pair alone does **not settle**.
It produces a cyclic torsion in the fabric.

0.1.3 Stage 3 — Z enters the overlap region

Now introduce the Zeteon. Z has Φ = 0. That means its waveform is aligned with the dormant baseline reference. Its deviation:

$$\delta A_Z(\theta)$$

is not radial-driving or orthogonal-driving — it is **ledger-balancing**.

When Z overlaps with the U–D pair, the total deviation becomes:

$$\delta A_{UDZ}(r,\theta) = g_U \delta A_U + g_D \delta A_D + g_Z \delta A_Z$$

Now something different happens.

What the fabric does (this is the key)

Without Z:

- The U–D pair produces a rotating cyclic stress.
- There is no configuration that minimizes excursion over a full King cycle.

With Z:

- The Z contribution provides a **phase anchor**.
- It absorbs part of the excursion at the points of maximum cyclic deviation.
- It reduces peak-to-peak stress in the overlap region.

The system now has a configuration in which:

- The radial lean from U,
- The quadrature stabilization from D,
- The baseline anchoring from Z,

combined into a **bounded cyclic excursion**. The fabric no longer must continuously torque. The three-body system can **relax into a stable configuration**.

0.2 Stage 2 - The Second Uniteon Arrives (UDZ + U → UUDZ)

We begin with a stable **UDZ composite**.

It already has:

- A defined inside–outside axis (from U)
- Orthogonal smoothing (from D)
- Ledger anchoring (from Z)

- Bounded cyclic excursion

It is not yet a proton core — but it is the first object that can attract.

0.2.1 Another Uniteon is drawn in

The UDZ composite has a **residual radial curvature lean**. Even though Z stabilizes the oscillation, the system is not fully symmetric. There remains a net phase vector:

$$\vec{V}_{UDZ} = \hat{v}(\pi) + \hat{v}(3\pi/2) + \hat{v}(0)$$

This vector is nonzero. That means:

- The surrounding fabric sees a persistent curvature gradient.
- Another CPP placed in the neighborhood will "feel" that gradient through envelope overlap.

Now imagine a second Uniteon approaching.

0.2.2 Envelope overlap with the second U

As the second Uniteon approaches the UDZ composite:

$$\delta A_{UUDZ}(r,\theta) = g_{U1}\delta A_{U1} + g_D\delta A_D + g_Z\delta A_Z + g_{U2}\delta A_{U2}$$

Because both Uniteons share Φ = π:

- Their radial deviations reinforce.
- Their phase waveforms align.
- There is no torsional competition between them.

This is crucial. Unlike the first U–D interaction (which introduced cyclic torsion), the second U does not introduce a new orthogonal component. It strengthens the existing axis.

0.2.3 The fabric Responds

When the second Uniteon overlaps:

- The radial curvature component increases.
- The quadrature smoothing from D remains.
- The baseline anchoring from Z remains.

Now the system experiences something new:

- The radial axis becomes **more rigid**.
- The curvature well deepens.
- The inside–outside distinction strengthens.

- Cycle-to-cycle variation reduces relative to amplitude.

UDZ was a *balanced trimer*.
UUDZ becomes a **directionally stabilized tetramer**.

0.2.4 Why this configuration prefers to persist

There are now:

- Two CPPs aligned along the same phase direction (π),
- One quadrature stabilizer (3π/2),
- One baseline anchor (0).

The combined vector:

$$\vec{V}_{UUDZ} = 2\hat{v}(\pi) + \hat{v}(3\pi/2) + \hat{v}(0)$$

This vector is:

- Strongly radial,
- Moderately smoothed,
- Internally bounded.

The key difference from UDZ:

- The radial axis is no longer marginal.
- It is now the dominant structural feature.

The fabric does not have to redistribute stress each cycle. The system's internal curvature becomes self-consistent. This is the first moment the configuration begins to resemble a **proton-like interior (proteon)**.

0.2.5 What curvature looks like spatially

Visually:

- UDZ had a modest basin with slight asymmetry.
- UUDZ develops a deeper single curvature basin.
- The orthogonal oscillation becomes secondary.
- The curvature field becomes centrally anchored.

At moderate distance:

- The composite acts as one object.
- External CPPs now interact with a single coherent envelope rather than separate participants.

0.2.6 Why this stage matters in the chain

UDZ allowed the system to stop fighting itself.

UUDZ allows the system to **define its identity axis**.

From here:

- Additional Zeteons can attach without disturbing the axis.
- The buffering structure can grow.
- The curvature envelope can fully close.

The direction is now fixed.

0.2.7 Why not another D or Z at this stage?

Case 1 — A Deniteon approaches UDZ

A Deniteon adds quadrature phase:

$$\delta A_{UDZD} = g_U \delta A_U + g_{D1} \delta A_D + g_{D2} \delta A_D + g_Z \delta A_Z$$

Now look at what this does.

- The orthogonal component doubles.
- The radial component does not increase.
- The ratio of torsion to axis strength increases.

What does the fabric do?

The overlap region now experiences:

- Increased cyclic torsion.
- Greater phase rotation over the King cycle.
- A larger peak-to-peak excursion.

This is higher stress than UDZ alone.

So what happens dynamically?

- The peak-to-peak cyclic deviation increases relative to UDZ alone.
- The configuration does not settle.
- The additional D drifts away as envelopes decouple.

Not because of repulsion — but because no stable composite minimum exists. You can think of it as: The combined waveform does not admit a stationary solution. So the D does not remain bound.

Case 2 — A Zeteon approaches UDZ

Now consider Z.

$$\delta A_{UDZZ} = g_U \delta A_U + g_D \delta A_D + g_{Z1} \delta A_Z + g_{Z2} \delta A_Z$$

This does reduce stress slightly. But here's the key, At UDZ stage, the dominant residual stress is not baseline imbalance. It is insufficient radial reinforcement.

Adding Z:

- Smooths slightly but the gradient that attracts the Z is weak.,
- But does not deepen the radial basin,
- Does not significantly reduce peak excursion.

So:

- Z is not strongly repelled. It just does not form a deep minimum.
- It may transiently overlap. It does not lock in.

Therefore, the next favored attachment is U, not D or Z.

0.3 Stage Three - Buffering Consolidation (UUDZ + Z → UUDZZ)

We begin with **UUDZ**:

- Two Uniteons → reinforced radial axis
- One Deniteon → quadrature stabilization
- One Zeteon → ledger anchoring

The system now has a defined inside–outside direction and bounded cyclic excursion. But it is not yet maximally relaxed. There remains **residual cyclic stress** in the overlap region.

0.3.1 a second Zeteon is attracted

Even though UUDZ is stable, the local deviation still contains:

$$\delta A_{UUDZ} = g_{U1}\delta A_U + g_{U2}\delta A_U + g_D\delta A_D + g_Z\delta A_Z$$

The radial contribution is strong (2U).
The quadrature contribution is moderate (D).
The baseline anchor (Z) dampens peak excursion — but only at one phase alignment.

Across a full King cycle, the overlap region still experiences:

- asymmetric peak stress
- slight torsional oscillation
- incomplete smoothing

The fabric "prefers" a configuration with lower peak-to-peak deviation. That means attracting additional **baseline-phase compensation**. The nearest candidate is another **Zeteon**.

0.3.2 What happens when the second Z overlaps

Now:

$$\delta A_{UUDZZ} = g_{U1}\delta A_U + g_{U2}\delta A_U + g_D\delta A_D + g_{Z1}\delta A_Z + g_{Z2}\delta A_Z$$

Two important effects occur:

A. Peak stress reduction

The two Z contributions:

- distribute the baseline correction across more of the cycle
- reduce phase-specific spikes
- compress the amplitude envelope

The maximum excursion decreases.

B. Symmetry improvement

With two Zeteons:

- The ledger balancing becomes spatially symmetric.
- The radial axis remains fixed.
- Torsional residuals decrease.

The curvature basin becomes deeper and smoother.

0.3.3 What the fabric looks like spatially now

Compared to UUDZ:

- The curvature well is more centrally anchored.
- The gradient from inside to outside becomes monotonic.
- Oscillatory ripples reduce.

At intermediate distances:

- The composite now behaves as a coherent curvature object.
- External CPPs experience a single structured envelope.

This is no longer a fragile assembly — it is a robust curvature nucleus.

0.3.4 Why UUDZZ is not yet complete

Even with two Zeteons:

- Radial reinforcement from two Uniteons remains strong.
- The Deniteon still introduces quadrature phase structure.
- The buffering is improved but not maximally distributed.

There is still one imbalance:

- The radial driver (2U) exceeds the stabilizing anchor (2Z) when integrated over the cycle.

- The fabric can still lower stress slightly by adding one more Zeteon.
- Nature prefers the lower-stress configuration.

0.3.5 Why Not Another U or D?

Add either:

$$\vec{V}_{UUUDZ} = 3\hat{v}(\pi) + \hat{v}(3\pi/2) + \hat{v}(0)$$

or

$$\vec{V}_{UUDDZ} = 2\hat{v}(\pi) + 2\hat{v}(3\pi/2) + \hat{v}(0)$$

Now evaluate structurally:

- Adding U increases radial amplitude without increasing baseline compensation.
- Adding D increases torsional contribution without increasing radial balance.
- In both cases, baseline compensation remains unchanged.

In both cases, peak-to-peak cyclic deviation increases relative to UUDZ. No deeper stationary minimum forms. Therefore, neither U nor D persists at this stage.

Evolutionary interpretation

UDZ → first stable trimer
UUDZ → axis-defining nucleus
UUDZZ → stabilized curvature basin

Each stage reduces cyclic stress and increases coherence. You are not imposing identity — you are watching the fabric relax.

0.4 Stage Four – The Proton is Created (UUDZZ + Z → UUDZZZ)

We begin with **UUDZZ**:

- 2 × Uniteon → reinforced radial axis
- 1 × Deniteon → quadrature stabilization
- 2 × Zeteon → distributed buffering

The system is stable. But it is not yet *closed*. There remains a small but measurable imbalance:

- The radial driver (2U) still slightly exceeds the total baseline compensation.
- Peak deviation is reduced, but not uniformly minimized across the King cycle.

The fabric can still lower total cyclic stress.

0.4.1 Why a third Zeteon is attracted

The guiding principle through the entire formation chain has been simple:

Configurations that reduce peak-to-peak deviation are favored. At UUDZZ:

- Stress is distributed,
- but not yet isotropic around the axis.

The residual cyclic asymmetry draws in one more baseline-phase participant. That participant is another **Zeteon (Φ = 0)**.

0.4.2 The full overlap

Now the total deviation becomes:

$$\delta A_{UUDZZZ} = g_{U1}\delta A_U + g_{U2}\delta A_U + g_D\delta A_D + g_{Z1}\delta A_Z + g_{Z2}\delta A_Z + g_{Z3}\delta A_Z$$

This is the first configuration where:

- The radial driver (2U),
- The orthogonal stabilizer (D),
- The baseline anchors (3Z),

balance across the full King cycle.

0.4.3 What changes from UUDZZ → UUDZZZ

Three things happen simultaneously.

A. Peak excursion reaches minimum possible value for this composition

Additional Z buffering beyond three no longer reduces maximum cyclic stress meaningfully. The envelope has reached a **local stress minimum**.

B. Radial axis becomes cycle-invariant

With three Zeteons:

- Baseline compensation now spans the cycle.
- The radial direction no longer wobbles.
- The curvature well becomes stationary.

This is the first fully **non-rotating** configuration.

C. Envelope closure emerges

The radial curvature profile becomes:

- Monotonic inward gradient
- Single central minimum
- Smooth decay outward

There are no secondary lobes. No torsional distortions. No cyclic redistribution required. The fabric has nothing left to resolve.

0.4.4 What UUDZZZ is

0.4.5 Why not another U or D

Case A — What Happens if Another U or D Approaches UUDZZ?

Add a third U or second D:

$$\vec{V}_{UUUDZZ} = 3\hat{v}(\pi) + \hat{v}(3\pi/2) + 2\hat{v}(0)$$

0r

$$\vec{V}_{UUDDZZ} = 2\hat{v}(\pi) + \widehat{2v}(3\pi/2) + 2\hat{v}(0)$$

Now:

- Radial component increases again.
- Torsional component remains constant.
- Baseline anchor remains single.

Result:

- Peak radial excursion increases.
- Relative torsional smoothing decreases.
- The curvature basin becomes too steep.

Peak-to-peak cyclic deviation increases. No deeper stationary minimum forms. So a third U or Second D does **not** persist. Baseline anchor remains unchanged (2Z).

0.4.6 Why formation stops here

The key indicator that formation is complete:

- Adding another Z does not significantly reduce stress.
- Adding another U destabilizes radial symmetry.
- Adding another D reintroduces torsional imbalance.

UUDZZZ is a local minimum in configuration space.

It is the first composite in the evolutionary chain that:

- Cannot lower stress by adding or removing one participant.
- Has no residual cyclic frustration.
- Has a closed curvature envelope.

The final configuration contains two identical radial drivers and one orthogonal stabilizer, producing a 2+1 internal symmetry.

The configuration is the first composition in which incremental CPP addition produces only second-order changes in cyclic deviation.

Nature stops here.