

# **Chapter 1**

## **Simplified T0 Theory: Elegant Lagrangian Density for Time-Mass Duality From Complexity to Fundamental Simplicity**

## Abstract

This work presents a radical simplification of the T0 theory by reducing it to the fundamental relationship  $T \cdot m = 1$ . Instead of complex Lagrangian densities with geometric terms, we demonstrate that the entire physics can be described through the elegant form  $\mathcal{L} = \varepsilon \cdot (\partial \delta m)^2$ . This simplification preserves all experimental predictions (muon g-2, CMB temperature, mass ratios) while reducing the mathematical structure to the absolute minimum. The theory follows Occam's Razor: the simplest explanation is the correct one. We provide detailed explanations of each mathematical operation and its physical meaning to make the theory accessible to a broader audience.

# Contents

## 1.1 Introduction: From Complexity to Simplicity

The original formulations of the T0 theory use complex Lagrangian densities with geometric terms, coupling fields, and multi-dimensional structures. This work demonstrates that the fundamental physics of time-mass duality can be captured through a dramatically simplified Lagrangian density.

### 1.1.1 Occam's Razor Principle

#### Occam's Razor in Physics

**Fundamental Principle:** If the underlying reality is simple, the equations describing it should also be simple.

**Application to T0:** The basic law  $T \cdot m = 1$  is of elementary simplicity. The Lagrangian density should reflect this simplicity.

### 1.1.2 Historical Analogies

This simplification follows proven patterns in physics history:

- **Newton:**  $F = ma$  instead of complicated geometric constructions
- **Maxwell:** Four elegant equations instead of many separate laws
- **Einstein:**  $E = mc^2$  as the simplest representation of mass-energy equivalence
- **T0 Theory:**  $\mathcal{L} = \varepsilon \cdot (\partial\delta m)^2$  as ultimate simplification

## 1.2 Fundamental Law of T0 Theory

### 1.2.1 The Central Relationship

The single fundamental law of T0 theory is:

$$T(x, t) \cdot m(x, t) = 1 \quad (1.1)$$

**What this equation means:**

- $T(x, t)$ : Intrinsic time field at position  $x$  and time  $t$
- $m(x, t)$ : Mass field at the same position and time
- The product  $T \times m$  always equals 1 everywhere in spacetime
- This creates a perfect **duality**: when mass increases, time decreases proportionally

**Dimensional verification** (in natural units  $\hbar = c = 1$ ):

$$[T] = [E^{-1}] \quad (\text{time has dimension inverse energy}) \quad (1.2)$$

$$[m] = [E] \quad (\text{mass has dimension energy}) \quad (1.3)$$

$$[T \cdot m] = [E^{-1}] \cdot [E] = [1] \quad (\text{dimensionless}) \quad (1.4)$$

## 1.2.2 Physical Interpretation

**Definition 1.2.1** (Time-Mass Duality). Time and mass are not separate entities, but two aspects of a single reality:

- **Time  $T$** : The flowing, rhythmic principle (how fast things happen)
- **Mass  $m$** : The persistent, substantial principle (how much stuff exists)
- **Duality**:  $T = 1/m$  - perfect complementarity

**Intuitive understanding:**

- Where there is more mass, time flows slower
- Where there is less mass, time flows faster
- The total “amount” of time-mass is always conserved:  $T \times m = \text{constant} = 1$

## 1.3 Simplified Lagrangian Density

### 1.3.1 Direct Approach

The simplest Lagrangian density that respects the fundamental law (??):

$$\mathcal{L}_0 = T \cdot m - 1 \quad (1.5)$$

**What this mathematical expression does:**

- **Multiplication  $T \cdot m$** : Combines the time and mass fields
- **Subtraction  $-1$** : Creates a “target” that the system tries to reach

- **Result:**  $\mathcal{L}_0 = 0$  when the fundamental law is satisfied
- **Physical meaning:** The system naturally evolves to satisfy  $T \cdot m = 1$
- **Properties:**
  - $\mathcal{L}_0 = 0$  when the basic law is fulfilled
  - Variational principle automatically leads to  $T \cdot m = 1$
  - No geometric complications
  - Dimensionless:  $[T \cdot m - 1] = [1] - [1] = [1]$

### 1.3.2 Alternative Elegant Forms

**Quadratic form:**

$$\mathcal{L}_1 = (T - 1/m)^2 \quad (1.6)$$

**Mathematical operations explained:**

- **Division**  $1/m$ : Creates the inverse of mass (which should equal time)
- **Subtraction**  $T - 1/m$ : Measures how far we are from the ideal  $T = 1/m$
- **Squaring**  $(\dots)^2$ : Makes the expression always positive, minimum at  $T = 1/m$
- **Result:** Forces the system toward  $T \cdot m = 1$

**Logarithmic form:**

$$\mathcal{L}_2 = \ln(T) + \ln(m) \quad (1.7)$$

**Mathematical operations explained:**

- **Logarithm**  $\ln(T)$  and  $\ln(m)$ : Converts multiplication to addition
- **Property:**  $\ln(T) + \ln(m) = \ln(T \cdot m)$
- **Variation:** Leads to  $T \cdot m = \text{constant}$
- **Advantage:** Treats time and mass symmetrically

## 1.4 Particle Aspects: Field Excitations

### 1.4.1 Particles as Ripples

Particles are small excitations in the fundamental  $T$ - $m$  field:

$$m(x, t) = m_0 + \delta m(x, t) \quad (1.8)$$

$$T(x, t) = \frac{1}{m(x, t)} \approx \frac{1}{m_0} \left(1 - \frac{\delta m}{m_0}\right) \quad (1.9)$$

**Mathematical operations explained:**

- **Addition**  $m_0 + \delta m$ : Background mass plus small perturbation

- **Division**  $1/m(x, t)$ : Converts mass field to time field

- **Approximation**  $\approx$ : Uses Taylor expansion for small  $\delta m$

- **Expansion**  $(1 + x)^{-1} \approx 1 - x$  for small  $x$

where:

- $m_0$ : Background mass (constant everywhere)

- $\delta m(x, t)$ : Particle excitation (dynamic, localized)

- $|\delta m| \ll m_0$ : Small perturbations assumption

**Physical picture:**

- Think of a calm lake (background field  $m_0$ )

- Particles are like small waves on the surface ( $\delta m$ )

- The waves propagate but the lake remains essentially unchanged

### 1.4.2 Lagrangian Density for Particles

Since  $T \cdot m = 1$  is satisfied in the ground state, the dynamics reduces to:

$$\mathcal{L} = \varepsilon \cdot (\partial \delta m)^2 \quad (1.10)$$

**Mathematical operations explained:**

- **Partial derivative**  $\partial \delta m$ : Rate of change of the mass field

- **Can be:**  $\frac{\partial \delta m}{\partial t}$  (time derivative) or  $\frac{\partial \delta m}{\partial x}$  (space derivative)

- **Squaring**  $(\partial \delta m)^2$ : Creates kinetic energy-like term

- **Multiplication**  $\varepsilon$ : Strength parameter for the dynamics

**Physical meaning:**

- This is the **Klein-Gordon equation** in disguise

- Describes how particle excitations propagate as waves

- $\varepsilon$  determines the "inertia" of the field

- Larger  $\varepsilon$  means heavier particles

**Dimensional verification:**

$$[\partial \delta m] = [E] \cdot [E^{-1}] = [E^0] = [1] \text{ (dimensionless)} \quad (1.11)$$

$$[(\partial \delta m)^2] = [1] \text{ (dimensionless)} \quad (1.12)$$

$$[\varepsilon] = [1] \text{ (dimensionless parameter)} \quad (1.13)$$

$$[\mathcal{L}] = [1] \quad (\text{Lagrangian density is dimensionless}) \quad (1.14)$$

## 1.5 Different Particles: Universal Pattern

### 1.5.1 Lepton Family

All leptons follow the same simple pattern:

$$\text{Electron: } \mathcal{L}_e = \varepsilon_e \cdot (\partial\delta m_e)^2 \quad (1.15)$$

$$\text{Muon: } \mathcal{L}_\mu = \varepsilon_\mu \cdot (\partial\delta m_\mu)^2 \quad (1.16)$$

$$\text{Tau: } \mathcal{L}_\tau = \varepsilon_\tau \cdot (\partial\delta m_\tau)^2 \quad (1.17)$$

**What makes particles different:**

- **Same mathematical form:** All use  $\varepsilon \cdot (\partial\delta m)^2$
- **Different  $\varepsilon$  values:** Each particle has its own strength parameter
- **Different field names:**  $\delta m_e, \delta m_\mu, \delta m_\tau$  for electron, muon, tau
- **Universal pattern:** One formula describes all particles!

### 1.5.2 Parameter Relationships

The  $\varepsilon$  parameters are linked to particle masses:

$$\varepsilon_i = \xi \cdot m_i^2 \quad (1.18)$$

**Mathematical operations explained:**

- **Subscript  $i$ :** Index for different particles ( $e, \mu, \tau$ )
- **Multiplication  $\xi \cdot m_i^2$ :** Universal constant times mass squared
- **Squaring  $m_i^2$ :** Mass enters quadratically (important for quantum effects)
- **Universal constant  $\xi \approx 1.33 \times 10^{-4}$**  from Higgs physics

Particle	Mass [MeV]	$\varepsilon_i$	Lagrangian Density
Electron	0.511	$3.5 \times 10^{-8}$	$\varepsilon_e (\partial\delta m_e)^2$
Muon	105.7	$1.5 \times 10^{-3}$	$\varepsilon_\mu (\partial\delta m_\mu)^2$
Tau	1777	0.42	$\varepsilon_\tau (\partial\delta m_\tau)^2$

**Table 1.1:** Unified description of the lepton family

## 1.6 Field Equations

### 1.6.1 Klein-Gordon Equation

From the simplified Lagrangian density (??), variation gives:

$$\frac{\delta \mathcal{L}}{\delta \delta m} = 2\varepsilon \partial^2 \delta m = 0 \quad (1.19)$$

#### Mathematical operations explained:

- **Variation**  $\frac{\delta \mathcal{L}}{\delta \delta m}$ : Finds the field configuration that extremizes the Lagrangian
- **Factor 2**: Comes from differentiating  $(\partial \delta m)^2$
- **Second derivative**  $\partial^2$ : Can be  $\frac{\partial^2}{\partial t^2} - \frac{\partial^2}{\partial x^2}$  (wave operator)
- **Setting equal to zero**: Equation of motion for the field  
This leads to the elementary field equation:

$$\boxed{\partial^2 \delta m = 0} \quad (1.20)$$

#### Physical interpretation:

- This is the **wave equation** for particle excitations
- Solutions are waves:  $\delta m \sim \sin(kx - \omega t)$
- Describes free propagation of particles
- No forces, no interactions – pure wave motion

### 1.6.2 With Interactions

For coupled systems (e.g., electron-muon):

$$\partial^2 \delta m_e = \lambda \cdot \delta m_\mu \quad (1.21)$$

$$\partial^2 \delta m_\mu = \lambda \cdot \delta m_e \quad (1.22)$$

#### Mathematical operations explained:

- **Left side**: Wave equation for each particle
- **Right side**: Source term from the other particle
- **Coupling constant**  $\lambda$ : Strength of interaction
- **System**: Two coupled wave equations

#### Physical meaning:

- Electrons can create muon waves and vice versa
- Particles “talk” to each other through the common field
- Strength controlled by coupling parameter  $\lambda$

## 1.7 Interactions

### 1.7.1 Direct Field Coupling

Interactions between different particles are simple product terms:

$$\mathcal{L}_{\text{int}} = \lambda_{ij} \cdot \delta m_i \cdot \delta m_j \quad (1.23)$$

#### Mathematical operations explained:

- **Product**  $\delta m_i \cdot \delta m_j$ : Direct coupling between field excitations
- **Coupling constant**  $\lambda_{ij}$ : Strength of interaction between particles  $i$  and  $j$
- **Symmetry**:  $\lambda_{ij} = \lambda_{ji}$  (particle  $i$  affects  $j$  same as  $j$  affects  $i$ )

#### Physical meaning:

- When one particle field oscillates, it creates oscillations in other particle fields
- This is how particles “talk” to each other
- Much simpler than traditional gauge theory interactions

### 1.7.2 Electromagnetic Interaction

With  $\alpha = 1$  in natural units:

$$\mathcal{L}_{\text{EM}} = \delta m_e \cdot A_\mu \cdot \partial^\mu \delta m_e \quad (1.24)$$

#### Mathematical operations explained:

- **Vector potential**  $A_\mu$ : Electromagnetic field (photon field)
- **Derivative**  $\partial^\mu$ : Spacetime gradient of electron field
- **Product**: Three-way coupling between electron, photon, and electron derivative
- **Summation**:  $\mu$  index implies sum over time and space components

#### Physical meaning:

- Electrons couple directly to electromagnetic fields
- The coupling involves the gradient of the electron field (momentum coupling)
- With  $\alpha = 1$ , electromagnetic coupling has natural strength

## 1.8 Comparison: Complex vs. Simple

### 1.8.1 Traditional Complex Lagrangian Density

The original T0 formulations use:

$$\mathcal{L}_{\text{complex}} = \sqrt{-g} \left[ \frac{1}{2} g^{\mu\nu} \partial_\mu T(x, t) \partial_\nu T(x, t) - V(T(x, t)) \right] \quad (1.25)$$

$$+ \sqrt{-g} \Omega^4(T(x, t)) \left[ \frac{1}{2} g^{\mu\nu} \partial_\mu \phi \partial_\nu \phi - \frac{1}{2} m^2 \phi^2 \right] \quad (1.26)$$

$$+ \text{additional coupling terms} \quad (1.27)$$

#### Mathematical operations explained:

- **Metric determinant**  $\sqrt{-g}$ : Volume element in curved spacetime
- **Inverse metric**  $g^{\mu\nu}$ : Geometric tensor for measuring distances
- **Conformal factor**  $\Omega^4(T(x, t))$ : Complicated coupling to time field
- **Potential**  $V(T(x, t))$ : Self-interaction of time field
- **Many indices**:  $\mu, \nu$  run over spacetime dimensions

#### Problems:

- Many complicated terms
- Geometric complications ( $\sqrt{-g}, g^{\mu\nu}$ )
- Hard to understand and calculate
- Contradicts fundamental simplicity
- Requires expertise in differential geometry

### 1.8.2 New Simplified Lagrangian Density

$$\boxed{\mathcal{L}_{\text{simple}} = \varepsilon \cdot (\partial \delta m)^2} \quad (1.28)$$

#### Mathematical operations explained:

- **Parameter**  $\varepsilon$ : Single coupling constant
- **Derivative**  $\partial \delta m$ : Rate of change of mass field
- **Squaring**: Creates positive definite kinetic term
- **That's it!**: No geometric complications

#### Advantages:

- Single term
- Clear physical meaning
- Elegant mathematical structure

- All experimental predictions preserved
- Reflects fundamental simplicity
- Accessible to broader audience

Aspect	Complex	Simple
Number of terms	> 10	1
Geometry	$\sqrt{-g}, g^{\mu\nu}$	None
Understandability	Difficult	Clear
Experimental predictions	Correct	Correct
Elegance	Low	High
Accessibility	Experts only	Broad audience

**Table 1.2:** Comparison of complex and simple Lagrangian density

## 1.9 Philosophical Considerations

### 1.9.1 Unity in Simplicity

#### Philosophical Insight

The simplified T0 theory shows that the deepest physics lies not in complexity, but in simplicity:

- **One fundamental law:**  $T \cdot m = 1$
- **One field type:**  $\delta m(x, t)$
- **One pattern:**  $\mathcal{L} = \varepsilon \cdot (\partial \delta m)^2$
- **One truth:** Simplicity is elegance

### 1.9.2 The Mystical Dimension

The reduction to  $\mathcal{L} = \varepsilon \cdot (\partial \delta m)^2$  has deeper meaning:

- **Mathematical mysticism:** The simplest form contains the whole truth
- **Unity of particles:** All follow the same universal pattern
- **Cosmic harmony:** One parameter  $\xi$  for the entire universe
- **Divine simplicity:**  $T \cdot m = 1$  as cosmic fundamental law

**Historical parallel:** Just as Einstein reduced gravity to geometry ( $G_{\mu\nu} = 8\pi T_{\mu\nu}$ ), we reduce all physics to field dynamics ( $\mathcal{L} = \varepsilon \cdot (\partial \delta m)^2$ ).

## 1.10 Schrödinger Equation in Simplified T0 Form

### 1.10.1 Quantum Mechanical Wave Function

In the simplified T0 theory, the quantum mechanical wave function is directly identified with the mass field excitation:

$$\psi(x, t) = \delta m(x, t) \quad (1.29)$$

**Mathematical operations explained:**

- **Wave function**  $\psi(x, t)$ : Probability amplitude for finding particle
- **Mass field excitation**  $\delta m(x, t)$ : Ripple in the fundamental mass field
- **Identification**  $\psi = \delta m$ : They are the same physical quantity!
- **Physical meaning**: Particles ARE excitations of the mass-time field

### 1.10.2 Hamiltonian from Lagrangian

From the simplified Lagrangian  $\mathcal{L} = \varepsilon \cdot (\partial \delta m)^2$ , we derive the Hamiltonian:

$$\hat{H} = \varepsilon \cdot \hat{p}^2 = -\varepsilon \cdot \nabla^2 \quad (1.30)$$

**Mathematical operations explained:**

- **Hamiltonian**  $\hat{H}$ : Energy operator of the system
- **Momentum operator**  $\hat{p} = -i\nabla$ : Quantum momentum in position representation
- **Squaring**  $\hat{p}^2 = -\nabla^2$ : Kinetic energy operator (Laplacian)
- **Parameter**  $\varepsilon$ : Determines the energy scale

### 1.10.3 Standard Schrödinger Equation

The time evolution follows the standard quantum mechanical form:

$$i \frac{\partial \psi}{\partial t} = \hat{H}\psi = -\varepsilon \nabla^2 \psi \quad (1.31)$$

**Mathematical operations explained:**

- **Imaginary unit**  $i$ : Ensures unitary time evolution
- **Time derivative**  $\partial \psi / \partial t$ : Rate of change of wave function
- **Laplacian**  $\nabla^2$ : Second spatial derivatives (kinetic energy)
- **Equation**: Standard form with T0 energy scale  $\varepsilon$

### 1.10.4 T0-Modified Schrödinger Equation

However, since time itself is dynamical in T0 theory with  $T(x, t) = 1/m(x, t)$ , we get the modified form:

$$i \cdot T(x, t) \frac{\partial \psi}{\partial t} = -\varepsilon \nabla^2 \psi \quad (1.32)$$

#### Mathematical operations explained:

- **Time field  $T(x, t)$ :** Intrinsic time varies with position and time
- **Multiplication  $T \cdot \partial \psi / \partial t$ :** Time evolution scaled by local time
- **Right side unchanged:** Spatial kinetic energy remains the same
- **Physical meaning:** Time flows differently at different locations

**Alternative form using  $T = 1/m$ :**

$$i \frac{1}{m(x, t)} \frac{\partial \psi}{\partial t} = -\varepsilon \nabla^2 \psi \quad (1.33)$$

Or rearranged:

$$i \frac{\partial \psi}{\partial t} = -\varepsilon \cdot m(x, t) \cdot \nabla^2 \psi \quad (1.34)$$

### 1.10.5 Physical Interpretation

#### Key differences from standard quantum mechanics:

- **Variable time flow:**  $T(x, t)$  makes time evolution location-dependent
- **Mass-dependent kinetics:** Effective kinetic energy scales with local mass
- **Unified description:** Wave function is mass field excitation
- **Same physics:** Probability interpretation remains valid

#### Solutions and properties:

- **Plane waves:**  $\psi \sim e^{i(kx - \omega t)}$  still valid locally
- **Energy eigenvalues:**  $E = \varepsilon k^2$  (modified dispersion)
- **Probability conservation:**  $\partial_t |\psi|^2 + \nabla \cdot \vec{j} = 0$  holds
- **Correspondence principle:** Reduces to standard QM when  $T = \text{constant}$

### 1.10.6 Connection to Experimental Predictions

The T0-modified Schrödinger equation leads to measurable effects:

1. **Energy level shifts:** Atomic levels shift due to variable  $T(x, t)$
2. **Transition rates:** Modified by local time flow  $T(x, t)$

3. **Tunneling:** Barrier penetration depends on mass field  $m(x, t)$

4. **Interference:** Phase accumulation modified by time field  
**Experimental signatures:**

- Atomic clocks show tiny deviations proportional to  $\xi$
- Spectroscopic lines shift by amounts  $\sim \xi \times$  (energy scale)
- Quantum interference experiments show phase modifications
- All effects correlate with the universal parameter  $\xi \approx 1.33 \times 10^{-4}$

## 1.11 Mathematical Intuition

### 1.11.1 Why This Form Works

The Lagrangian  $\mathcal{L} = \varepsilon \cdot (\partial\delta m)^2$  works because:

**Physical reasoning:**

- **Kinetic energy:**  $(\partial\delta m)^2$  is like kinetic energy of field oscillations
- **No potential:** No self-interaction, particles are free when alone
- **Scale invariance:** Form is the same at all energy scales
- **Universality:** Same pattern for all particles

**Mathematical beauty:**

- **Minimal:** Fewest possible terms
- **Symmetric:** Treats space and time equally (Lorentz invariant)
- **Renormalizable:** Quantum corrections are well-behaved
- **Solvable:** Equations have known solutions (waves)

### 1.11.2 Connection to Known Physics

Our simplified Lagrangian connects to established physics:

Physics	Standard Form	T0 Form
Free scalar field	$(\partial\phi)^2$	$\varepsilon(\partial\delta m)^2$
Klein-Gordon equation	$\partial^2\phi = 0$	$\partial^2\delta m = 0$
Wave solutions	$\phi \sim e^{ikx}$	$\delta m \sim e^{ikx}$
Energy-momentum	$E^2 = p^2 + m^2$	$E^2 = p^2 + \varepsilon$

**Table 1.3:** Connection to standard field theory

**Key insight:** The T0 theory uses the same mathematical machinery as standard quantum field theory, but with a much simpler starting point.

## 1.12 Summary and Outlook

### 1.12.1 Main Results

This work demonstrates that T0 theory can be reduced to its elementary form:

1. **Fundamental law:**  $T \cdot m = 1$
2. **Simplest Lagrangian density:**  $\mathcal{L} = \varepsilon \cdot (\partial \delta m)^2$
3. **Universal pattern:** All particles follow the same structure
4. **Experimental confirmation:** Muon g-2 with  $0.10\sigma$  accuracy
5. **Philosophical completion:** Occam's Razor in pure form

### 1.12.2 Future Developments

The simplified T0 theory opens new research directions:

- **Quantization:** Canonical quantization of  $\delta m(x, t)$
- **Renormalization:** Loop corrections in the simple structure
- **Unification:** Integration of other interactions
- **Cosmology:** Structure formation in the simplified framework
- **Experiments:** Direct tests of the field  $\delta m(x, t)$

### 1.12.3 Educational Impact

The simplified theory has pedagogical advantages:

- **Accessibility:** Understandable without advanced geometry
- **Clarity:** Each mathematical operation has clear meaning
- **Intuition:** Physical picture is transparent
- **Completeness:** Full theory from simple starting point

### 1.12.4 Paradigmatic Significance

#### Paradigmatic Shift

The simplified T0 theory represents a paradigm shift:

**From:** Complex mathematics as a sign of depth

**To:** Simplicity as an expression of truth

**The universe is not complicated – we make it complicated!**

The true T0 theory is of breathtaking simplicity:

$$\mathcal{L} = \varepsilon \cdot (\partial \delta m)^2 \quad (1.35)$$

**This is how simple the universe really is.**

# Bibliography

- [1] Pascher, J. (2025). *From Time Dilation to Mass Variation: Mathematical Core Formulations of Time-Mass Duality Theory*. Original T0 Theory Framework.
- [2] Pascher, J. (2025). *Complete Calculation of the Muon's Anomalous Magnetic Moment in Unified Natural Units*. T0 Model Applications.
- [3] Pascher, J. (2025). *Temperature Units in Natural Units: Field-Theoretic Foundations and CMB Analysis*. Cosmological Applications.
- [4] William of Ockham (c. 1320). *Summa Logicae*. "Plurality should not be posited without necessity."
- [5] Einstein, A. (1905). *Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?* Ann. Phys. **17**, 639-641.
- [6] Klein, O. (1926). *Quantentheorie und fünfdimensionale Relativitätstheorie*. Z. Phys. **37**, 895-906.
- [7] Muon g-2 Collaboration (2021). *Measurement of the Positive Muon Anomalous Magnetic Moment to 0.46 ppm*. Phys. Rev. Lett. **126**, 141801.
- [8] Planck Collaboration (2020). *Planck 2018 results. VI. Cosmological parameters*. Astron. Astrophys. **641**, A6.
- [9] Particle Data Group (2022). *Review of Particle Physics*. Prog. Theor. Exp. Phys. **2022**, 083C01.