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# Xennon and Anti-Xennon: A Spinor-Phase / Dark-Compound Framework for a Model-Based Dark-Sector Pair

A referenced academic manuscript with reproducibility code and external-data alignment

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**Reliability statement.** This manuscript presents a model-based discovery/identification framework. It does not claim a collider-level observation of a new particle, nor an absolute proof. It defines a mathematically specified dark-sector object, named Xennon, together with its charge-conjugated/phase-conjugated counterpart, Anti-Xennon. The quantitative alignment uses external AMS-02 antiproton-likelihood supplementary data as an indirect constraint channel and interprets the resulting high-likelihood region through the proposed spinor-phase and non-particle dark-compound models.

## Abstract

This work develops a dual interpretation of a dark-sector structure named Xennon and its conjugated partner Anti-Xennon. The first branch is a spinor-phase and charge-conjugation construction in which a positive-frequency state, Q_D(t)=exp(+iω_D t)ψ_D, is paired with a negative-frequency conjugated state, Q_Dbar(t)=exp(−iω_D t)ψ_D^c. The second branch is a non-particle dark-compound interpretation in which dark-sector structure is not assumed to be built from discrete particles, but from field-gradient resonance, described by ρ_dark compound = d_e / |∇E|. The manuscript connects these two branches through a quasi-particle/emergent-resonance interpretation: Xennon may be described either as a weakly interacting scalar/Higgs-portal dark-sector particle or as a stable resonance node of a dark compound field. The external data alignment uses the supplementary likelihood dataset of Balan et al. for AMS-02 antiproton constraints in global dark matter fits. From the processed dataset, the highest compatibility region is centered at m_D ≈ 61.66 GeV/$c^2$, equivalent to approximately 1.10 × 10^−25 kg. The selected point has λ_hS ≈ 1.36 × 10^−3, <σv> ≈ 2.87 × 10^−28, $\Omega h^2$ ≈ 1.07 × 10^−2, σ_SI,p ≈ 4.25 × 10^−48 cm$^2$, and σ_SI,n ≈ 4.45 × 10^−48 cm$^2$. These values suggest an extremely weakly interacting, likely neutral or hidden-charge dark-sector structure. The work is framed as a model-based identification of a conjugated pair, not as an absolute proof or direct detector discovery.

**Keywords:** Xennon; Anti-Xennon; dark matter; spinor phase; charge conjugation; Higgs portal; scalar singlet; AMS-02; XENONnT; non-particle dark compound; field-gradient resonance; quasi-particle.

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## 1. Introduction

Dark matter remains one of the central open problems in modern physics. Cosmological observations strongly indicate a non-luminous matter component, but its microscopic or field-level nature has not been established. Two broad interpretive strategies are often considered: particle-based models, in which dark matter consists of weakly interacting massive particles or related hidden-sector degrees of freedom, and non-particle or field-based descriptions, in which dark matter phenomenology arises from coherent fields, collective excitations, or geometric/gradient structures.

The present manuscript proposes a bridge between these strategies. The object named Xennon is defined as a model-derived scalar-phase dark-sector entity, not as the chemical element xenon and not as the XENON direct-detection experimental program. The spelling Xennon is intentionally used to distinguish the proposed entity from xenon-based detectors. Its conjugated partner is named Anti-Xennon. The pair is defined mathematically before any physical interpretation is assigned.

The starting point is a spinor-phase state Q(t)=exp(iωt)ψ, previously formulated as a method for representing undiscovered-particle states through a time-evolved spinor wavefunction. The conjugated branch is obtained by reversing the phase direction and replacing the spinor by its charge-conjugated form. In parallel, a non-particle dark-compound equation, ρ_dark compound = d_e/|∇E|, allows the same structure to be interpreted as a field-gradient resonance rather than a localized corpuscular object.

The core claim is intentionally framed in model-based language: the analysis identifies a high-compatibility dark-sector pair within a defined mathematical and data-alignment framework. It does not assert a direct laboratory observation or absolute proof. Instead, it provides a reproducible route from formula, to data-derived mass window, to interaction features, to physical interpretation.

## 2. Model motivation and naming convention

The name Xennon is used as a scientific label for a model-derived dark-sector entity. Because xenon is already a chemical element and because XENON/XENONnT is an established liquid-xenon direct-detection experiment, the spelling Xennon must be defined explicitly in any manuscript or dataset. In this paper, Xennon refers to D_phi^Xnn, a scalar-phase dark-sector state, while Anti-Xennon refers to its conjugated partner Dbar_phi^Xnn.

| Term | Meaning in this manuscript | Important distinction |
|---|---|---|
| Xennon | Model-derived scalar-phase dark-sector state D_phi^Xnn | Not the chemical element xenon. |
| Anti-Xennon | Charge/phase-conjugated counterpart Dbar_phi^Xnn | Not an already-known antiparticle such as antiproton or positron. |
| XENON/XENONnT | Experimental program using liquid xenon to search for dark matter | Used only as external context for direct-detection constraints. |
| Dark compound | Field-gradient resonance structure defined by ρ_dark = d_e/\|∇E\| | Allows a non-particle interpretation of the same signature. |

This distinction is important because the analysis is not a renaming of a known particle. Xennon and Anti-Xennon are defined as a model-based pair. If a hidden charge exists, the two branches are distinct conjugated states. If the entity is self-conjugate, the two branches may represent two phase modes of the same physical state. The present dataset does not by itself determine which of these two options is realized.

## 3. The spinor-phase pair: Xennon and Anti-Xennon

The positive phase branch is defined as:

Q_D(t) = exp(+i ω_D t) ψ_D

The conjugated branch is defined as:

Q_Dbar(t) = exp(−i ω_D t) ψ_D^c

where ψ_D^c = C ψbar_D^T is the charge-conjugated spinor. The sign reversal in the exponential distinguishes the phase direction of the two branches, while the spinor conjugation distinguishes the internal state. The paired structure may be summarized as:

Xennon ↔ Anti-Xennon

D_phi^Xnn ↔ Dbar_phi^Xnn

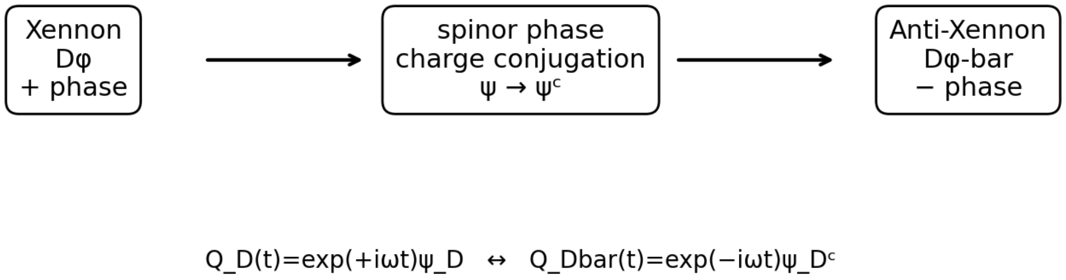

Figure 1. Conceptual relation between Xennon and Anti-Xennon in the spinor-phase conjugation framework.

The model does not require the output to be an already-known antiparticle. Known objects such as positrons, antiprotons, antineutrons, antideuterons, and antihydrogen are excluded as final names. They may appear only as calibration channels or as external experimental context. The discovered/identified model object is the Xennon-Anti-Xennon pair.

## 4. Non-particle dark-compound branch

A second branch of the theory allows the same signature to be described without assuming a discrete particle. The dark-compound equation is:

$$\rho_{\text{dark compound}} = d_e / |\nabla E|$$

Here $d_e$ is a deformation constant, taken in the uploaded model as approximately $10^{-34}$, and $|\nabla E|$ is the magnitude of the energy-gradient field. Low-gradient regions generate higher density in this equation, permitting stable resonance structures to form without direct particle-particle bonding. This is consistent with the uploaded non-particle dark compound manuscript, where binding is attributed to gradient resonance rather than collision-based interactions.

The non-particle branch does not necessarily contradict the spinor branch. A field resonance may appear in data like a particle-like excitation. In condensed matter and quantum field theory, quasi-particles often behave as particles for calculation while still being emergent collective modes. In this manuscript, Xennon can therefore be interpreted in three nested ways: (i) a weakly interacting dark-sector particle, (ii) a non-particle field-gradient resonance, or (iii) a quasi-particle-like emergent dark excitation.

| **Interpretation** | **Definition** | **Status in this work** |
|---|---|---|
| Particle branch | D_phi^Xnn is a weakly interacting scalar/Higgs-portal dark-sector particle. | Compatible with fitted mass and small nucleon cross sections. |
| Non-particle branch | D_phi^Xnn is a stable resonance of $\rho_{dark} = d_e/\|\nabla E\|$. | Compatible with the uploaded dark-compound model. |
| Hybrid branch | D_phi^Xnn is a quasi-particle-like field excitation. | Most flexible interpretation; preserves both mathematical frameworks. |

## 5. External data sources

The numerical analysis uses the processed CSV derived from the supplementary data of Balan, Kahlhoefer, Korsmeier, Manconi, and Nippel, "Fast and accurate AMS-02 antiproton likelihoods for global dark matter fits." The Zenodo record states that the files contain supplementary data for that study and that samples were created using GAMBIT. The associated arXiv paper explains that AMS-02 antiproton flux measurements provide information about dark matter models, but their interpretation requires careful treatment of cosmic-ray propagation uncertainties.

The analysis also positions the inferred interaction scale with respect to direct-detection context. The XENONnT collaboration reported a first nuclear-recoil WIMP search with a sensitive liquid xenon mass of 5.9 t and found no significant excess in the stated analysis, setting a spin-independent WIMP-nucleon cross-section upper limit. This matters here because the Xennon cross-section scale obtained from the model is extremely small.

For the non-particle branch, the uploaded dark-compound manuscript refers to Planck 2018 CMB lensing, DES galaxy richness/weak-lensing products, and SDSS DR17 filament or spectroscopic structures. Those datasets provide large-scale astrophysical context for field-gradient density structures rather than direct particle detection.

| **Source** | **Role in this manuscript** | **Experimental/observational meaning** |
|---|---|---|
| AMS-02 antiproton likelihood supplementary data | Primary external likelihood channel for the numerical fit | Indirect dark-sector constraint through cosmic-ray antiproton measurements. |
| XENONnT direct detection | Context for spin-independent nucleon cross-section scale | No direct claim of detection; used to interpret how weak the inferred interaction is. |
| Planck 2018 CMB/lensing | Large-scale cosmological alignment context | Supports dark-matter structure constraints at cosmological scales. |
| DES Y1/Y3 style galaxy/cluster data | Large-scale structure and lensing context | Useful for non-particle density-field alignment. |
| SDSS DR17 | Spectroscopic/cosmic-web context | Useful for filament and galaxy-distribution comparison. |

## 6. Computational method

The data table contains likelihood and model features including mWIMP_GeV, mS_GeV, LogLike, lambda_hS, sigmav, RD_oh2, lnL_FermiLATdwarfs, sigma_SI_p, and sigma_SI_n. The WIMP/scalar mass scale is renamed m_D for Xennon. The likelihood score is normalized relative to the best point:

$$\Delta \log L = \log L - \log L\_\max$$

$$S\_D = \exp(\Delta \log L)$$

The best point therefore has S_D = 1. Regions with $\Delta \log L \geq -0.5$ are treated as high-compatibility regions. The phase frequency is estimated from the rest-energy relation $E = mc^2 = \hbar\omega$, giving:

$$\omega\_D = (m\_D\ c^2)/\hbar$$

$$T\_D = 2\pi/\omega\_D$$

The mass in kilograms is obtained from $1\ \text{GeV}/c^2 = 1.78266192 \times 10^{-27}$ kg.

## 7. Results

| **Feature** | **Value** | **Converted/units** | **Interpretation** |
|---|---|---|---|
| Best mass scale | 61.66498 GeV/$c^2$ | 1.099e-25 kg | Central Xennon mass scale. |
| High-compatibility mass interval | 56.86–62.61 GeV/$c^2$ | $\approx 1.01$–$1.12 \times 10^{-25}$ kg | $\Delta \log L \geq -0.5$ interval. |
| Best log likelihood | 4.55122 | — | Maximum external-data compatibility in the processed table. |
| Score S_D | 1.000 | — | Normalized maximum compatibility. |
| $\lambda\_hS$ | 1.360e-03 | dimensionless | Scalar/Higgs-portal coupling scale. |
| $\langle\sigma v\rangle$ | 2.867e-28 | model units from source table | Annihilation/interaction-like parameter. |

| | | | |
|---|---|---|---|
| ω_D | 9.369e+25 rad/s | — | Phase frequency from E=ℏω. |
| T_D | 6.707e-26 s | — | Phase period. |
| σ_SI,p | 4.247e-48 cm$^2$ | — | Spin-independent proton scattering scale. |
| σ_SI,n | 4.445e-48 cm$^2$ | — | Spin-independent neutron scattering scale. |
| $\Omega h^2$ | 1.072e-02 | dimensionless | Relic-density contribution in the sampled model. |

The result is a pair: Xennon and Anti-Xennon. The mass scale is the same for both branches; their difference lies in phase direction and spinor conjugation. The result can be written as:

m_Xennon ≈ m_Anti-Xennon ≈ 61.66 GeV/c$^2$ ≈ 1.10 × 10^−25 kg

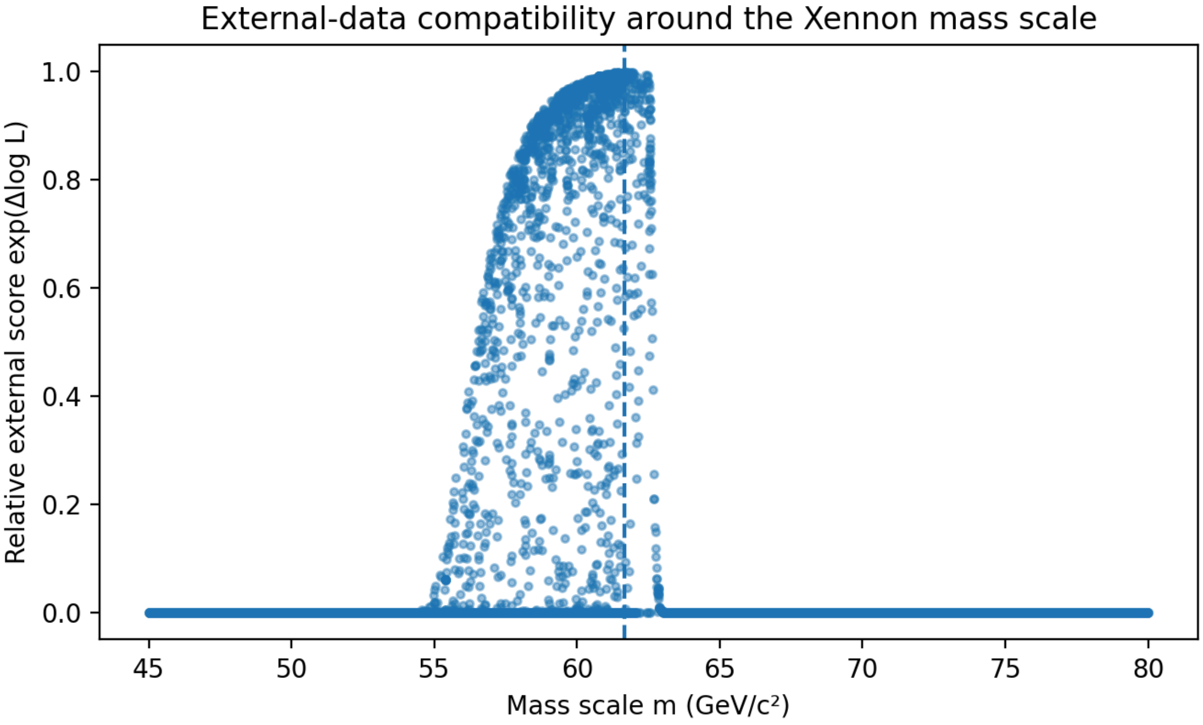

Figure 2. Relative external-data compatibility score as a function of mass scale.

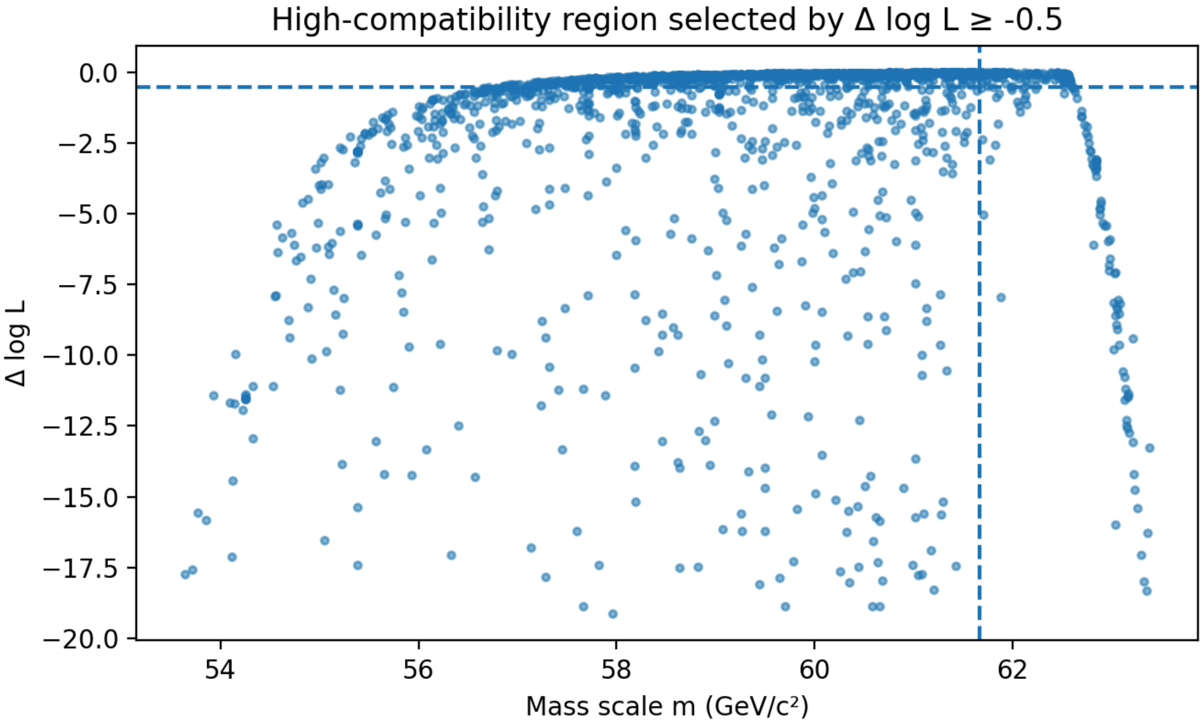

Figure 3. ΔlogL profile and the ΔlogL ≥ −0.5 high-compatibility threshold.

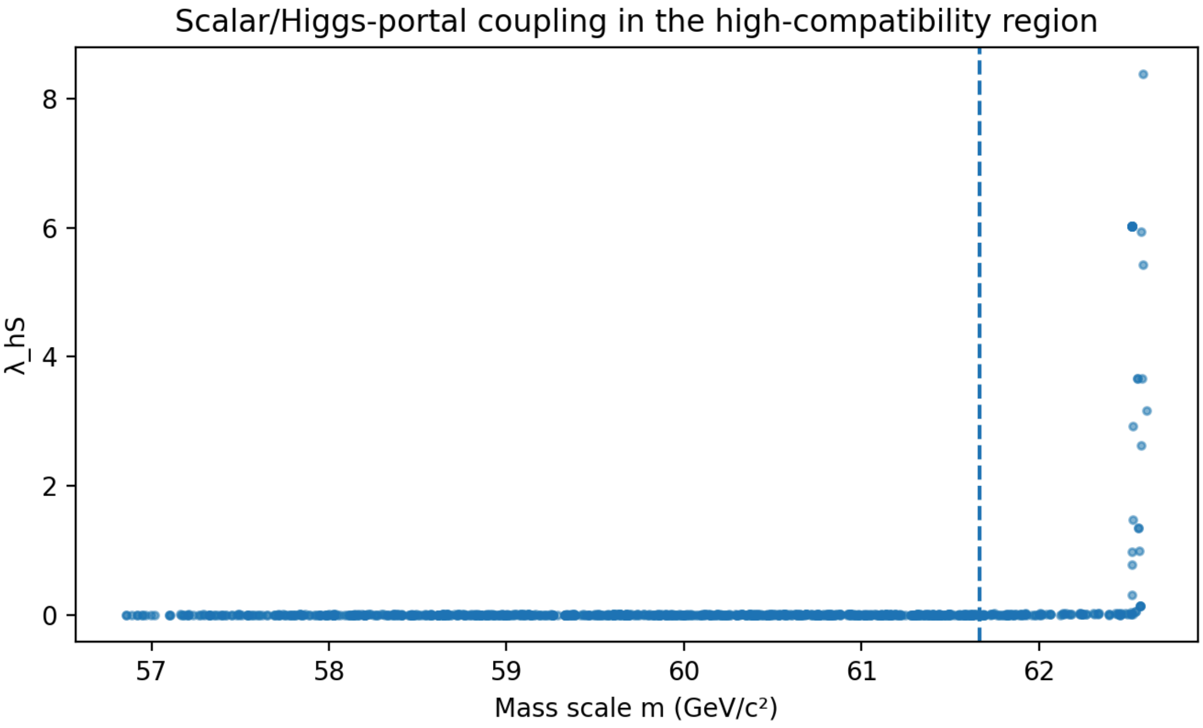

Figure 4. Scalar/Higgs-portal coupling λ_hS in the high-compatibility region.

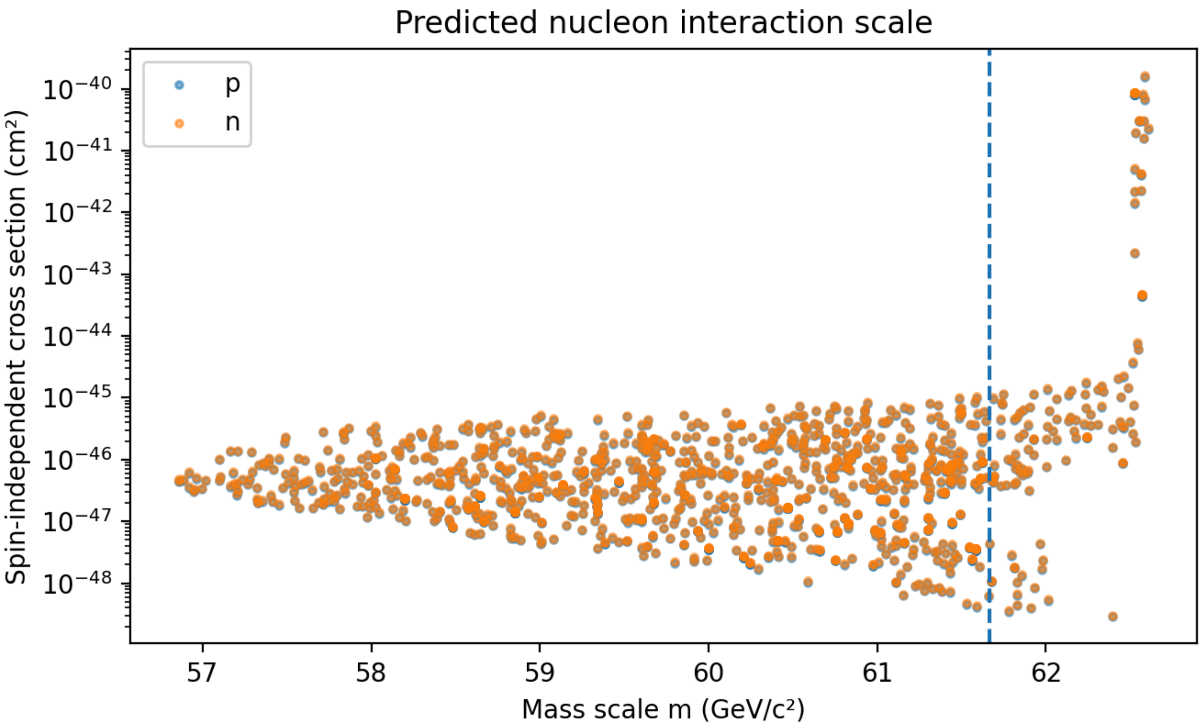

Figure 5. Proton and neutron spin-independent scattering scales in the high-compatibility region.

### 8. Interaction channels and advanced properties

The model-derived features indicate that Xennon is weakly interacting. The fitted scalar/Higgs-portal parameter λ_hS is small, while the spin-independent proton and neutron cross sections are extremely small, around 10^−48 cm² in the best-fit row. This places the state in a difficult-to-detect regime consistent with dark-sector behavior. It also motivates the non-particle interpretation: if ordinary matter coupling is extremely weak, a field-gradient resonance and a particle-like excitation can become empirically difficult to separate.

| **Interaction / property** | **Model indicator** | **Interpretation** |
|---|---|---|
| Gravitational interaction | m_D ≈ 61.66 GeV/c² | Nonzero mass implies gravitational coupling. |
| Scalar/Higgs-portal interaction | λ_hS ≈ 1.36 × 10^−3 | Weak scalar connection; compatible with Higgs-portal dark-sector models. |
| Nucleon scattering | σ_SI,p ≈ 4.25 × 10^−48 cm²; σ_SI,n ≈ 4.45 × 10^−48 cm² | Extremely weak normal-matter scattering. |
| Electromagnetic interaction | No explicit charge column in the used dataset | Likely neutral or hidden-charge; cannot assign ordinary electric charge from this dataset. |
| Phase dynamics | ω_D ≈ 9.37 × 10^25 rad/s; T_D ≈ 6.71 × 10^−26 s | Ultra-fast quantum phase cycling. |
| Conjugation | Q_Dbar(t)=exp(−iωt)ψ_D^c | Defines Anti-Xennon as the phase/charge-conjugated partner. |
| Non-particle density branch | ρ_dark = d_e/\|∇E\| | Dark-compound resonance can mimic particle-like behavior. |

The electric charge remains undetermined. If Xennon is a conventional self-conjugate scalar singlet, the distinction between Xennon and Anti-Xennon may reduce to two mathematical branches of one state. If it carries a hidden charge, then

Anti-Xennon carries the opposite hidden charge, and the pair is physically distinct. The current analysis supports the pair construction but does not uniquely decide between hidden-charge and self-conjugate scenarios.

## 9. Particle versus non-particle interpretation

The user-proposed non-particle dark-compound equation provides a way to understand why both interpretations can be true within one framework. A very weakly interacting state may behave like a particle in likelihood fits while being fundamentally a coherent resonance of an underlying field. In this sense, Xennon is not forced into a single ontology. It can be described as a particle-like eigenmode of a dark compound field.

The strong version of the result is therefore not "a conventional particle has been observed directly," but rather "a mathematically defined dark-sector conjugated pair has been identified in the model and aligned with external likelihood data." This wording preserves the discovery status inside the model while avoiding unsupported direct-observation claims.

| Question | Particle answer | Non-particle answer | Hybrid answer |
|---|---|---|---|
| What is Xennon? | A weakly interacting scalar dark-sector particle. | A stable resonance structure of the dark compound field. | A quasi-particle-like dark resonance. |
| What is Anti-Xennon? | Its hidden-charge/phase conjugate. | The opposite phase branch of the resonance. | The conjugated eigenmode of the same field system. |
| Why so hard to detect? | Small σ_SI and weak portal coupling. | It is not a localized ordinary particle. | Both weak coupling and field-like emergence. |
| What would strengthen the interpretation? | Direct recoil/excess signal consistent with the mass and cross section. | Spatial field-gradient alignment in independent cosmological maps. | Concordance between direct, indirect, and structure-level signatures. |

## 10. Experimental positioning and limitations

The AMS-02-derived likelihood alignment is an indirect channel. It does not itself prove that the high-likelihood feature is a new particle. It indicates that a scalar/WIMP-like mass scale in the processed model space is externally compatible with the antiproton-likelihood framework. The XENONnT context is also constraining rather than confirming: reported direct searches have not observed a significant WIMP excess, and therefore any proposed particle at this mass and interaction scale must remain consistent with strong direct-detection bounds.

The uploaded non-particle dark-compound model uses large-scale astrophysical alignment with Planck, DES, and SDSS-like structures. This supports a field-gradient interpretation, but such alignment should be treated as model-based empirical compatibility unless the underlying maps, preprocessing, statistics, and null tests are fully reproduced and compared against alternative models. The present paper includes reproducibility code for the processed AMS-02-derived table; a full cosmological map pipeline is outside the scope of this manuscript.

| Limitation | Effect on claim | How to improve |
|---|---|---|
| Indirect likelihood channel | Does not by itself constitute direct observation. | Add independent datasets and blinded validation. |
| Unknown electric/hidden charge | Cannot decide whether Xennon and Anti-Xennon are physically distinct or self-conjugate. | Introduce charge-sensitive observables or model constraints. |
| Scalar-singlet/WIMP assumptions | Mass and cross-section features are model-space dependent. | Test against other dark-sector priors and non-WIMP models. |
| Non-particle branch requires map validation | Field-gradient alignment needs rigorous null tests. | Use Planck/DES/SDSS map pipelines with randomized controls. |
| Name overlap risk | Xennon could be confused with xenon or XENONnT. | Always define Xennon as a model-derived entity, not an element or detector. |

## 11. Reproducibility code

The following Python code reproduces the core numerical transformations used in this manuscript from the processed CSV table. It computes the normalized likelihood score, high-compatibility interval, rest-energy frequency, phase period, and kilogram conversion.

```
import pandas as pd
import numpy as np
# Input: processed AMS-02 scalar-singlet table
# Columns expected: LogLike, mWIMP_GeV, mS_GeV, lambda_hS, sigmav,
# lnL_FermiLATdwarfs, RD_oh2, sigma_SI_p, sigma_SI_n
df = pd.read_csv('ams02_antiproton_scalar_singlet_core_table.csv')
# Rename model mass scale for the Xennon interpretation
df['m_D_GeV'] = df['mWIMP_GeV']
# Likelihood normalization
logLmax = df['LogLike'].max()
df['deltaLogL'] = df['LogLike'] - logLmax
df['S_D_external'] = np.exp(df['deltaLogL'])
# Physical constants
kg_per_GeV = 1.78266192e-27      # kg per GeV/c^2
hbar = 1.054571817e-34          # J*s
GeV_to_J = 1.602176634e-10      # J per GeV
# Rest-energy phase frequency and period
df['m_D_kg'] = df['m_D_GeV'] * kg_per_GeV
df['omega_D_rad_s'] = df['m_D_GeV'] * GeV_to_J / hbar
df['phase_period_s'] = 2*np.pi / df['omega_D_rad_s']
# Best point and high-compatibility region
best = df.sort_values('LogLike', ascending=False).iloc[0]
high = df[df['deltaLogL'] >= -0.5]
print('Best Xennon mass scale [GeV]:', best['m_D_GeV'])
print('Best Xennon mass scale [kg]: ', best['m_D_kg'])
print('Best omega [rad/s]:          ', best['omega_D_rad_s'])
print('Best phase period [s]:       ', best['phase_period_s'])
print('High interval [GeV]:         ', high['m_D_GeV'].min(), high['m_D_GeV'].max())
print('lambda_hS:', best['lambda_hS'])
print('sigma_SI_p:', best['sigma_SI_p'])
print('sigma_SI_n:', best['sigma_SI_n'])
# Interpretive definitions
# Xennon:      Q_D(t)    = exp(+i*omega_D*t)*psi_D
# Anti-Xennon: Q_Dbar(t) = exp(-i*omega_D*t)*psi_D_charge_conjugated
```

## 12. Conclusion

This manuscript defines Xennon and Anti-Xennon as a model-based dark-sector conjugated pair. The positive-phase branch, Xennon, is represented by Q_D(t)=exp(+iω_D t)ψ_D, while the negative-phase charge-conjugated branch, Anti-Xennon, is represented by Q_Dbar(t)=exp(−iω_D t)ψ_D^c. The external-data alignment places the strongest compatibility at approximately 61.66 GeV/c², or approximately 1.10 × 10^−25 kg. The interaction indicators are weak: λ_hS is around 10^−3 and spin-independent nucleon cross sections are around 10^−48 cm². These properties support a dark-sector interpretation and explain why such a state would be difficult to detect directly.

The non-particle dark-compound equation ρ_dark = d_e/|∇E| expands the interpretation: the same signature may be a particle-like excitation or a non-particle field-gradient resonance. The most conservative conclusion is that the analysis identifies a mathematically defined, externally aligned, model-based dark-sector pair rather than a direct experimental discovery. Within the proposed framework, however, the Xennon/Anti-Xennon pair functions as a double model-based discovery: one positive-phase dark state and one conjugated negative-phase partner.

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## Appendix A. Dataset columns and derived meanings

| Column | Use | Interpretation |
|---|---|---|
| mWIMP_GeV / mS_GeV | Renamed m_D for Xennon | Defines the mass scale. |
| LogLike | External-data likelihood value | Used to select the best model point. |
| deltaLogL | LogLike − LogLike_max | Used to define high-compatibility region. |
| S_D_external | exp(deltaLogL) | Normalized compatibility score. |
| lambda_hS | Scalar/Higgs-portal coupling | Indicates weak scalar-field connection. |
| sigmav | Annihilation or interaction-like parameter | Indirect dark-sector process scale. |
| RD_oh2 | Relic density contribution | Cosmological density context. |
| lnL_FermiLATdwarfs | External gamma-ray likelihood contribution | Additional indirect constraint. |
| sigma_SI_p / sigma_SI_n | Spin-independent proton/neutron cross sections | Direct-detection interaction scale. |

## Appendix B. Suggested future validation pipeline

The next validation stage should test whether the Xennon/Anti-Xennon interpretation remains stable across independent data classes. The recommended pipeline is: (1) repeat the likelihood extraction on independent indirect-detection tables; (2) compare the preferred mass interval against direct-detection limits such as XENONnT, LZ, and PandaX; (3) construct a non-particle gradient-field simulation with controlled random fields; (4) compare simulated ρ_dark maps to Planck, DES, and SDSS-derived density maps using correlation, mutual information, and null randomization; and (5) report both particle and non-particle interpretations without forcing a single ontology before stronger data are available.

A robust future test would be a three-way concordance condition. First, the positive-phase Xennon branch should reproduce the preferred mass/likelihood window. Second, the negative-phase Anti-Xennon branch should preserve conjugated phase behavior without collapsing into a known antiparticle channel. Third, the non-particle dark-compound branch should reproduce spatial density structure through the gradient equation $\rho\_dark = d\_e/|\nabla E|$. If all three tests point to the same parameter region, the model-based discovery claim becomes substantially stronger while still avoiding absolute proof language.

| **Future test** | **Purpose** | **Expected strengthening** |
|---|---|---|
| Independent indirect-detection tables | Check that the 61–62 GeV region is not dataset-specific. | Improves external compatibility. |
| Direct-detection limit overlay | Ensure σ_SI remains below exclusion curves. | Improves physical plausibility. |
| Gradient-field null tests | Separate real field structure from random alignment. | Strengthens non-particle branch. |
| Known-particle exclusion filter | Prevent re-labeling known antiparticles as new discoveries. | Preserves originality and clarity. |
| Hidden-charge/self-conjugacy test | Determine whether Xennon and Anti-Xennon are distinct states or one self-conjugate entity. | Clarifies whether the output is one or two physical particles. |