Collider and Dark Matter Phenomenology in Classically Scale Invariant Higgs Sector

A.F., J. Ren, *arXiv:1405.0498 [hep-ph]*
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May 21, 2014

Central Idea..

Bardeen (FERMILAB-CONF-95-391-T, FERMILAB-CONF-08-118- T); Aoki & Iso (2012)

- *Classical scale invariance* as a "custodial symmetry" to protect the Higgs mass from large quantum corrections (potential solution to Hierarchy problem)

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- Works only if *no other physical scale* near to and above the weak scale (or with a "small" coupling to weak scale)

Foot, Kobakhidze, McDonald & Volkas (2013); Allison, Hill & Ross (2014)

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- *CP*-even scalars mix to produce *two physical Higgs* bosons (one with a mass 125 GeV), *CP*-odd pseudoscalar is a stable DM candidate (due to *CP*-symmetry)
- Constrain the model by theoretical and experimental bounds $\Longrightarrow$ *Small* mixing between electroweak and singlet sectors ($\sin\omega \lesssim 0.2$), *second Higgs* with suppressed couplings, *heavy* TeV mass DM

Scale Invariant Higgs Sector: *Tree-Level*

- Scale invariant Lagrangian:

$$\mathcal{L}_{\text{scalar}} = (D^\mu H)^\dagger D_\mu H + \partial^\mu S^* \partial_\mu S - V^{(0)}(H,S) \qquad H = \frac{1}{\sqrt{2}}\begin{pmatrix} \sqrt{2}\,\pi^+ \\ v_\phi + \phi + i\pi^0 \end{pmatrix}, \qquad S = \frac{1}{\sqrt{2}}(v_\eta + \eta + i\chi)$$

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CP-symmetric and flavor universal

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  - First minimize the tree-level $V^{(0)}(H,S)$ at a scale Λ (the tree-level couplings run at quantum level) $\Longrightarrow$ Define a "flat direction" between the two scalar fields:

$$\frac{v_\phi^2}{v_\eta^2} = \frac{-3\lambda_m^+(\Lambda)}{\lambda_\phi(\Lambda)} = \frac{\lambda_\eta(\Lambda)}{-3\lambda_m^+(\Lambda)} \qquad (\textit{dimensional transmutation})$$

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  - The one-loop corrections become dominant along this particular direction, where they lift the flatness $\Longrightarrow$ True physical vacuum!!

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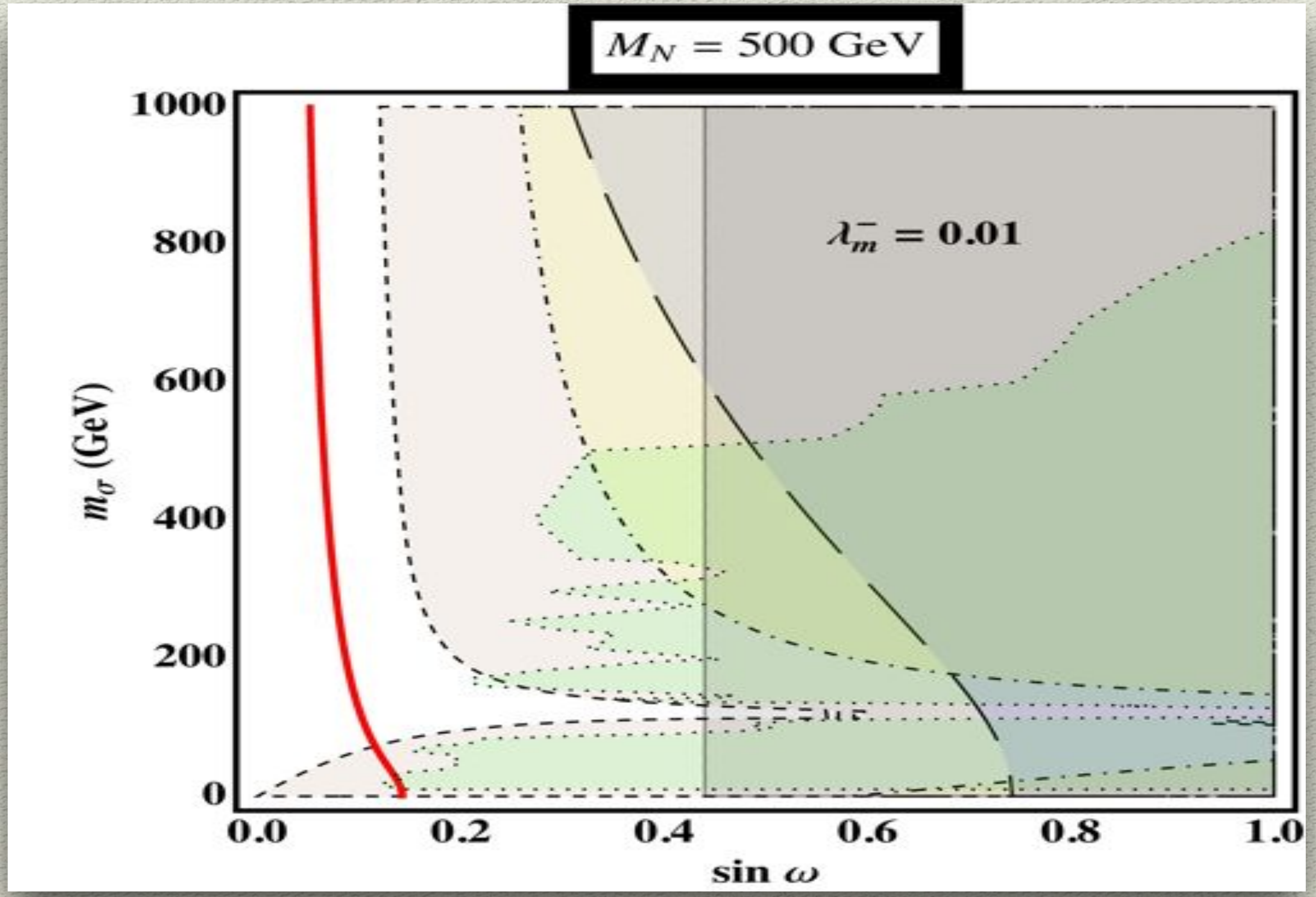

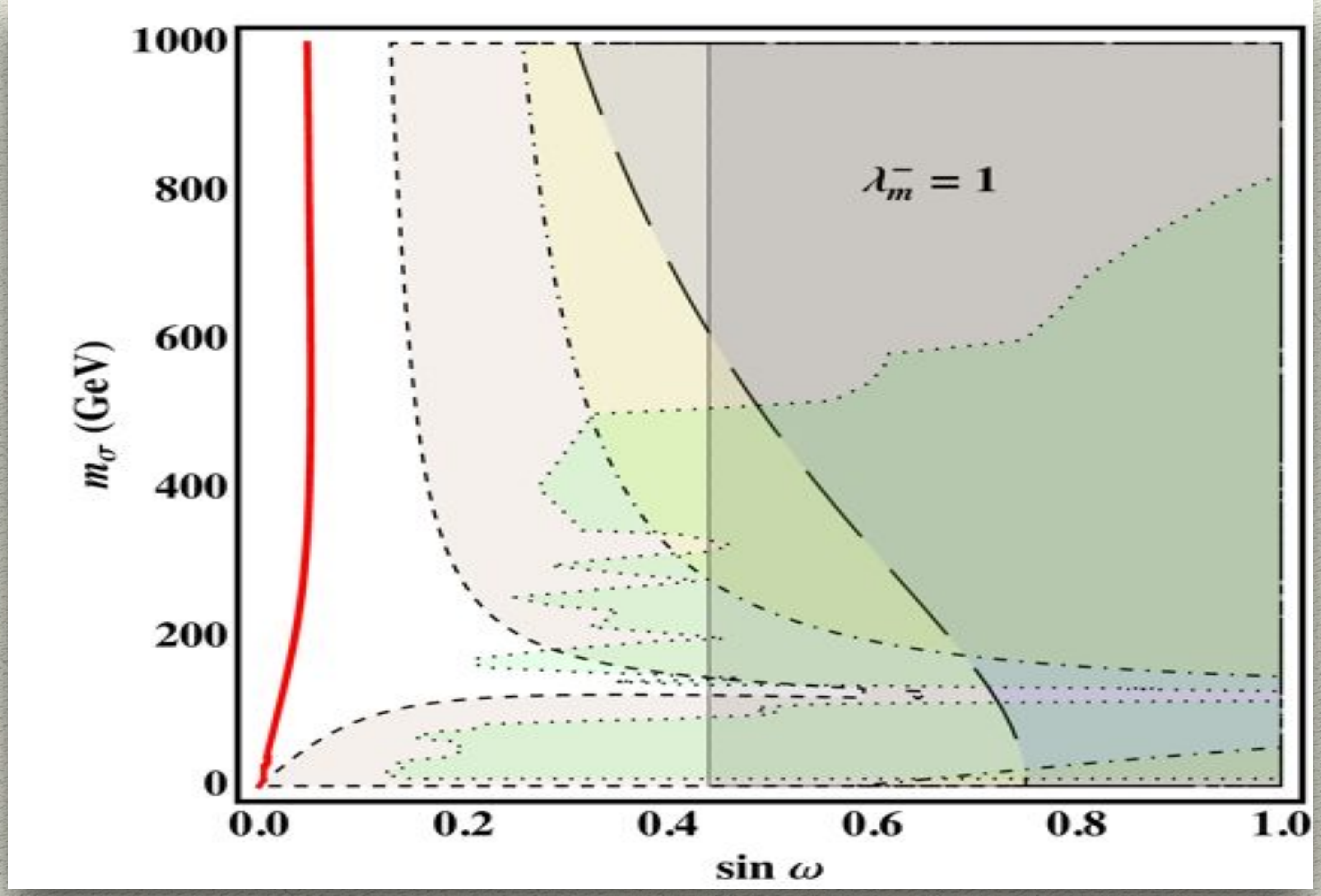

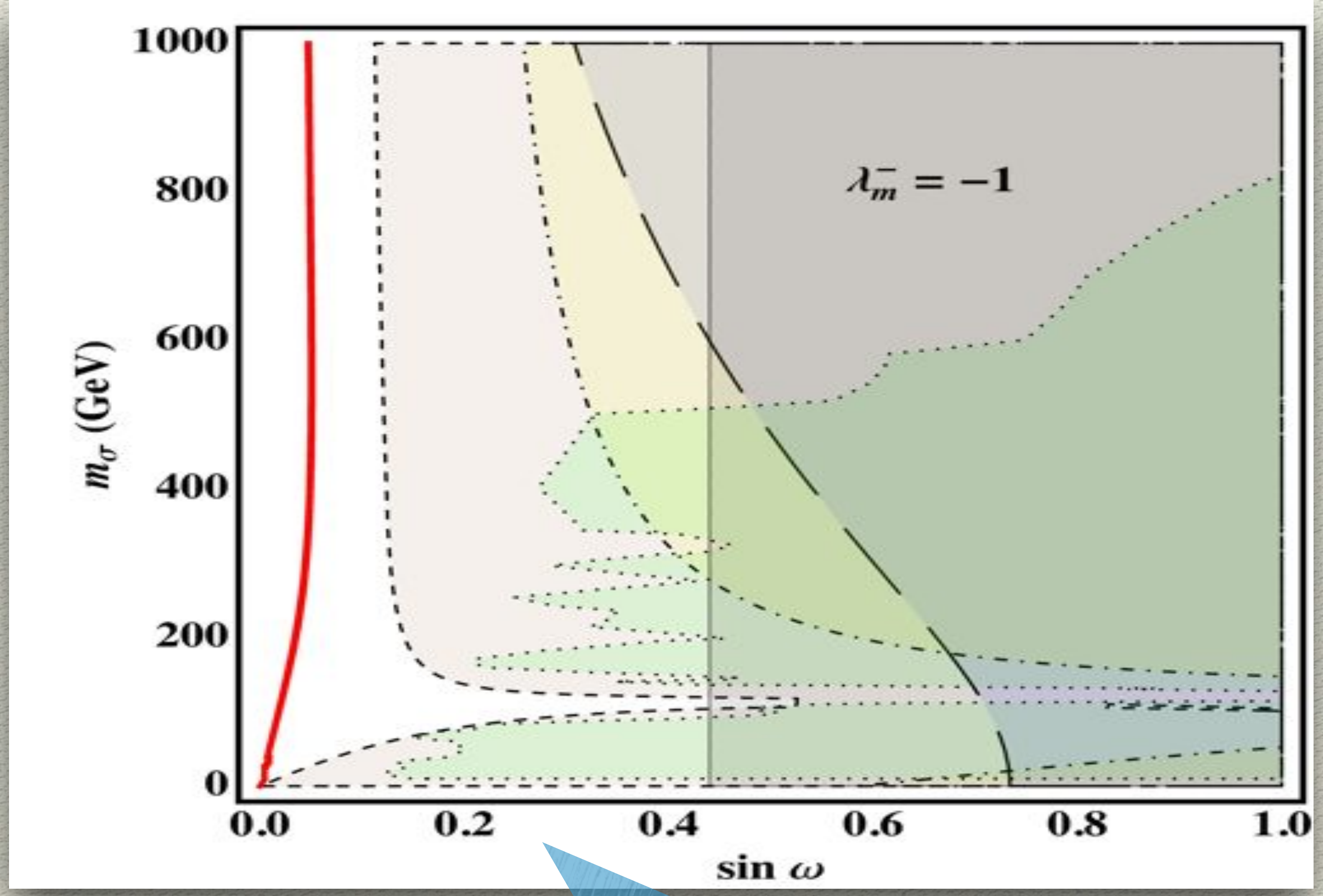

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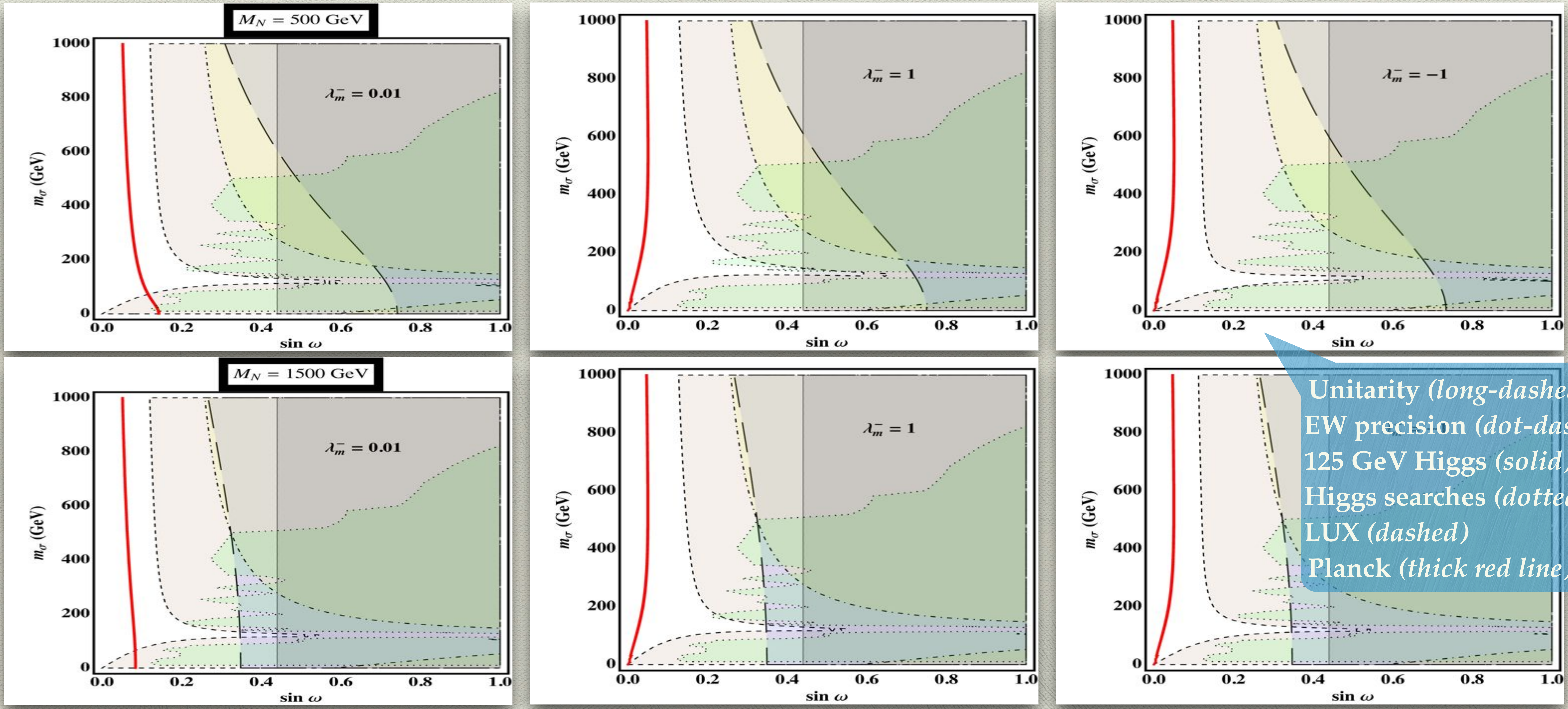

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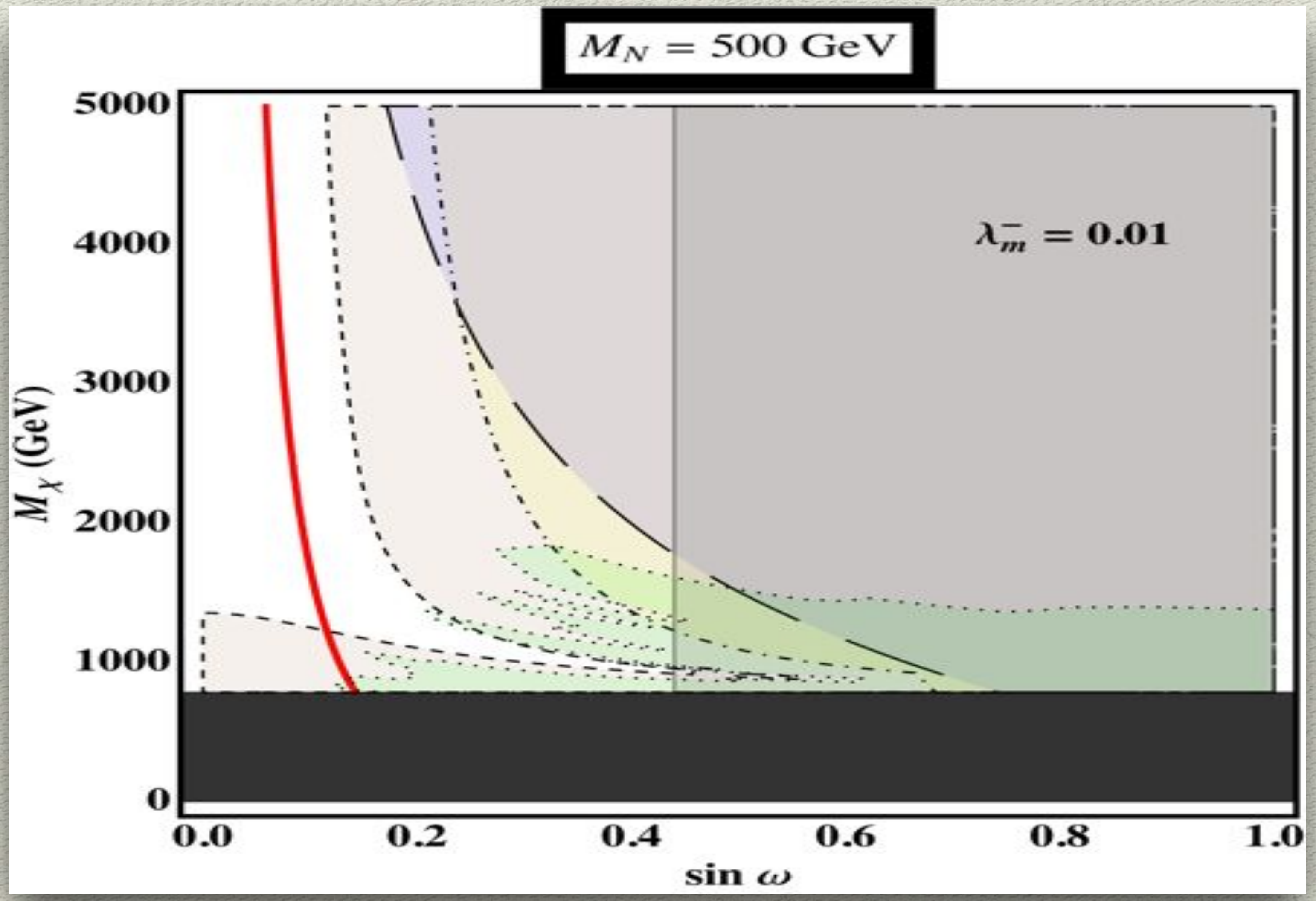

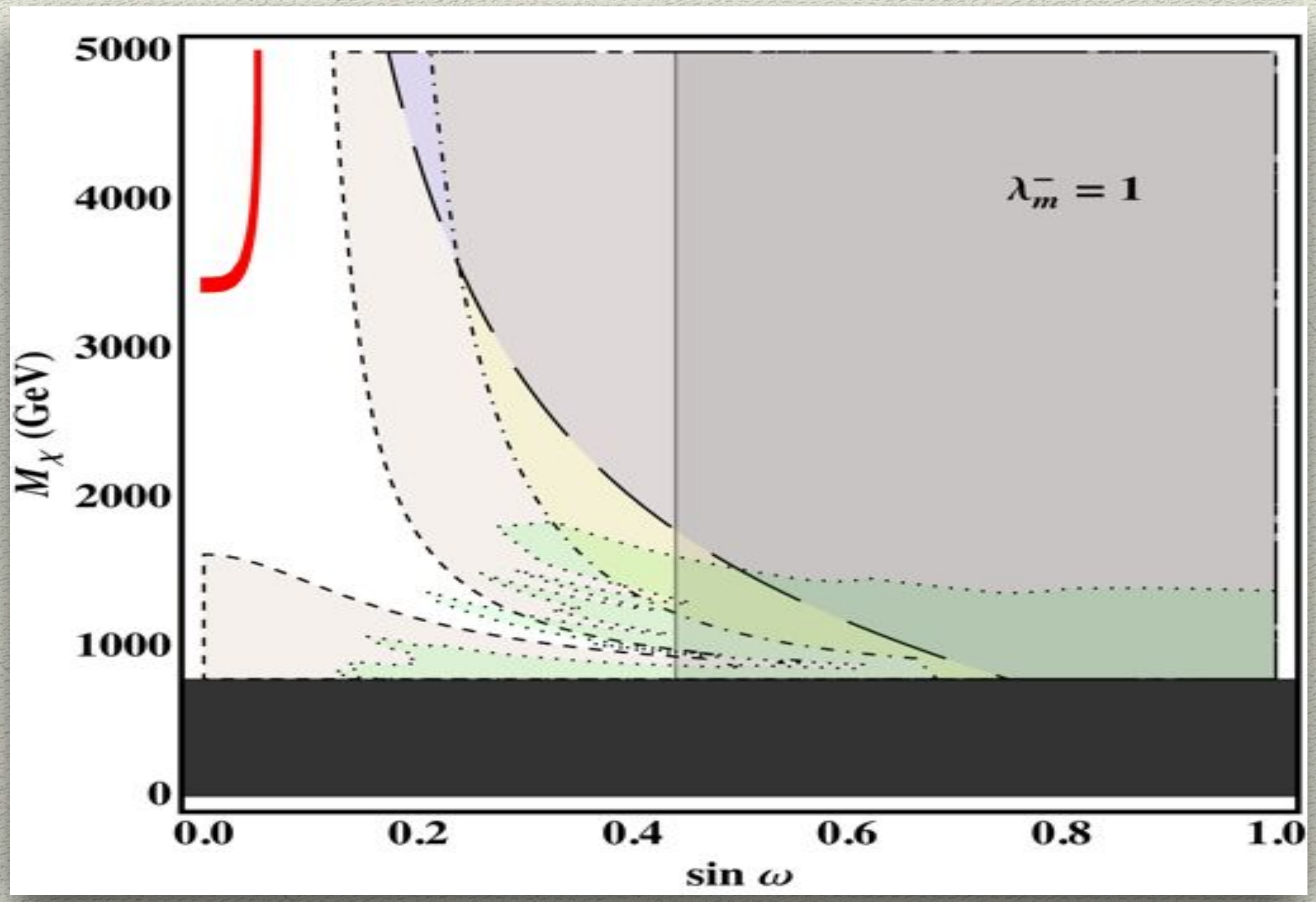

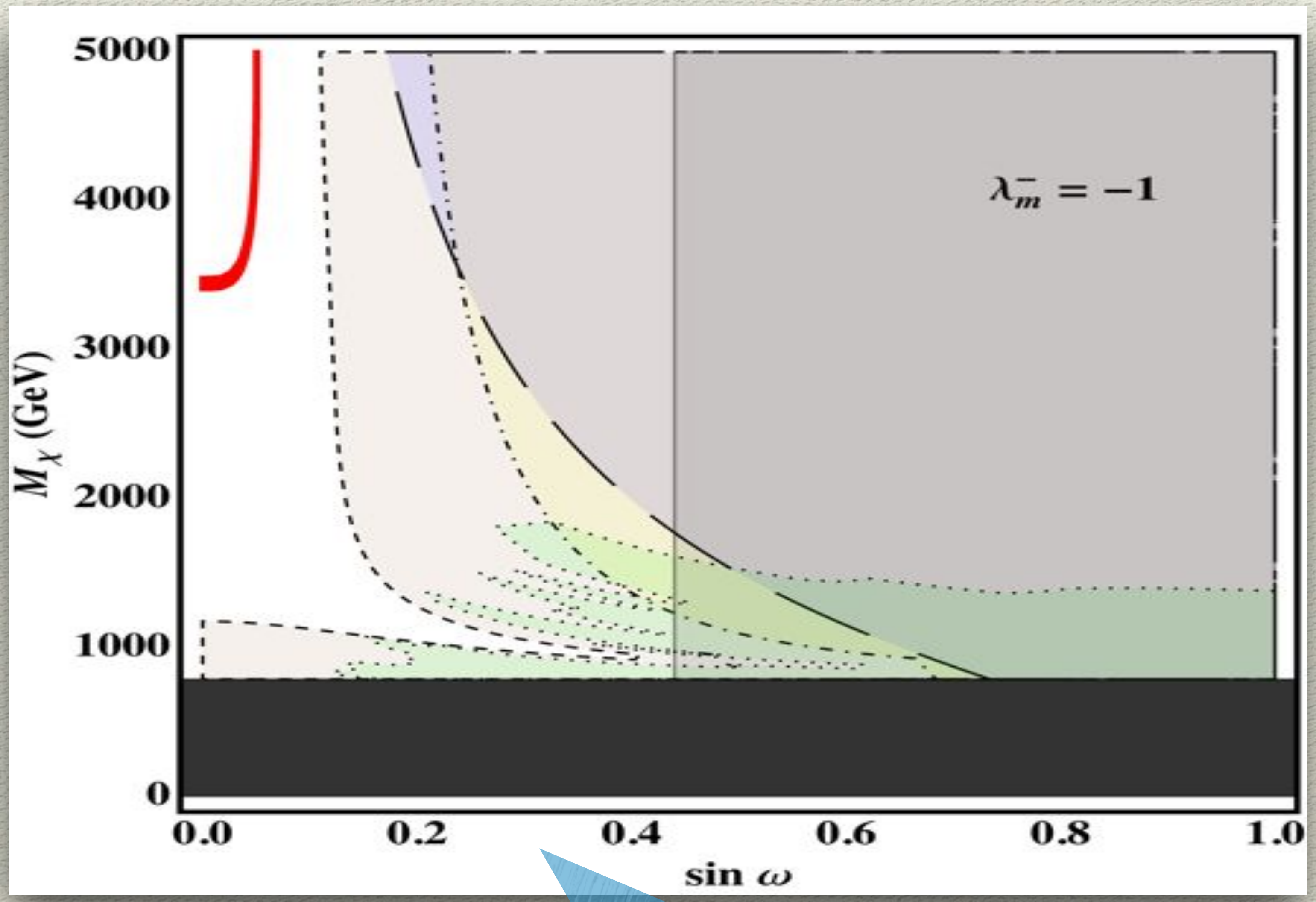

Unitarity *(long-dashed)*
EW precision *(dot-dashed)*
125 GeV Higgs *(solid)*
Higgs searches *(dotted)*
LUX *(dashed)*
Planck *(thick red line)*

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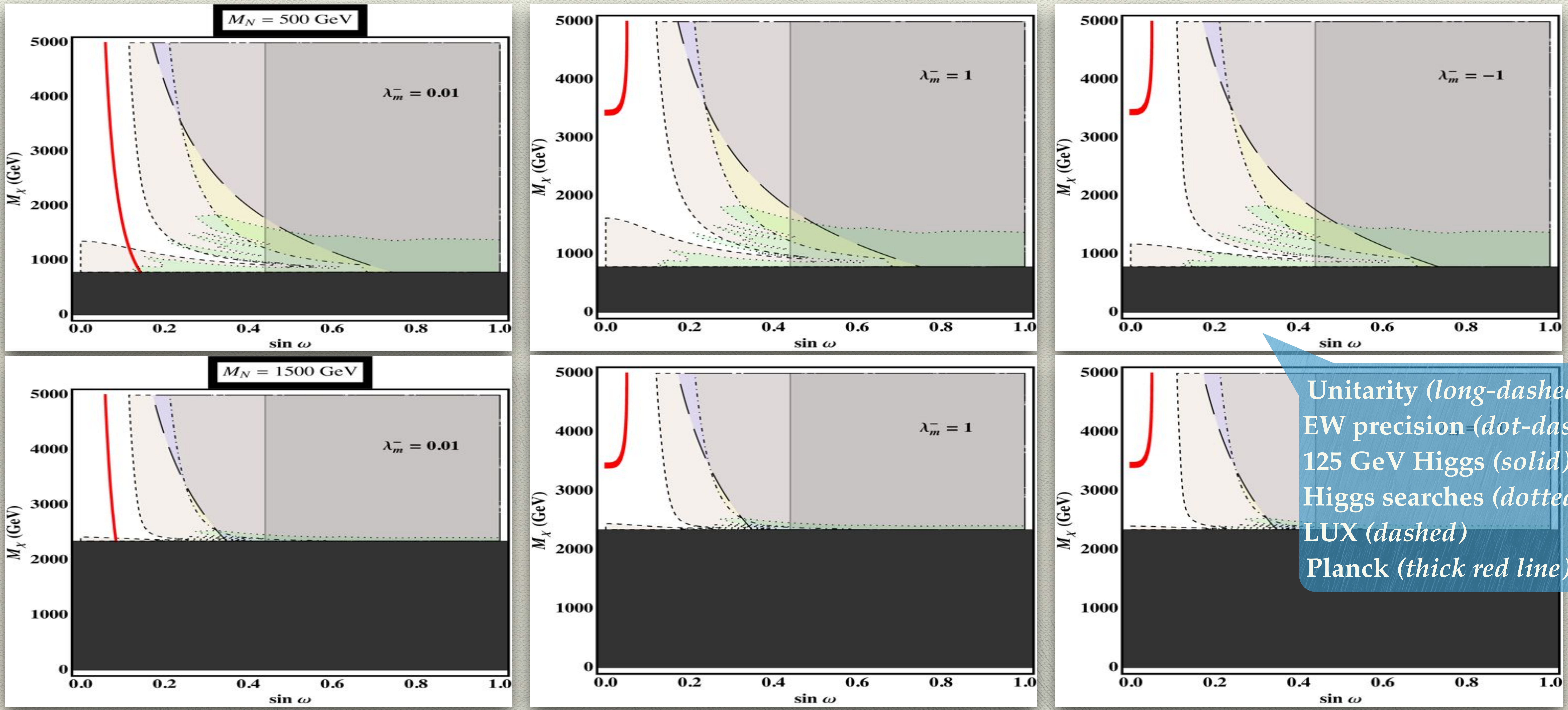

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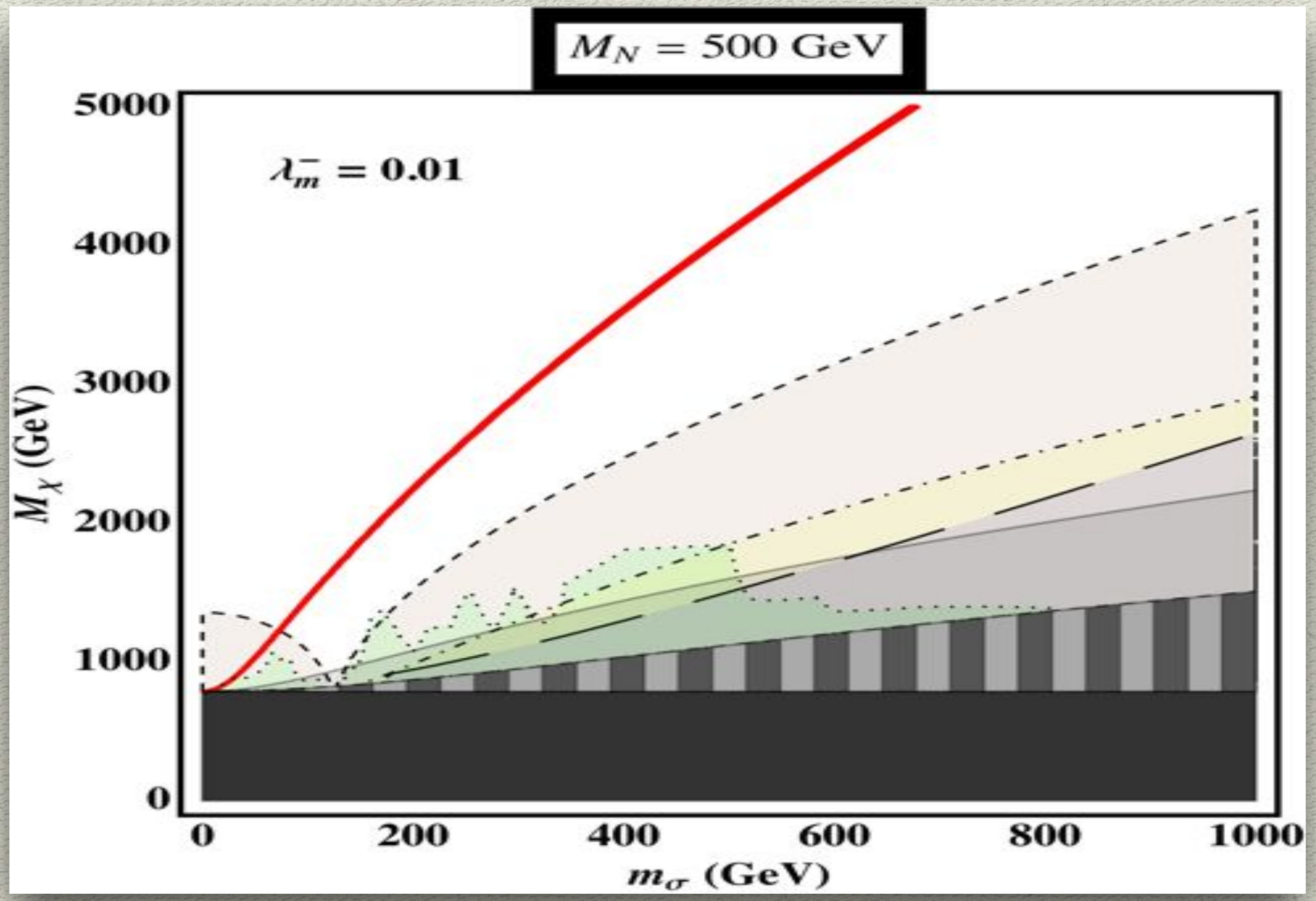
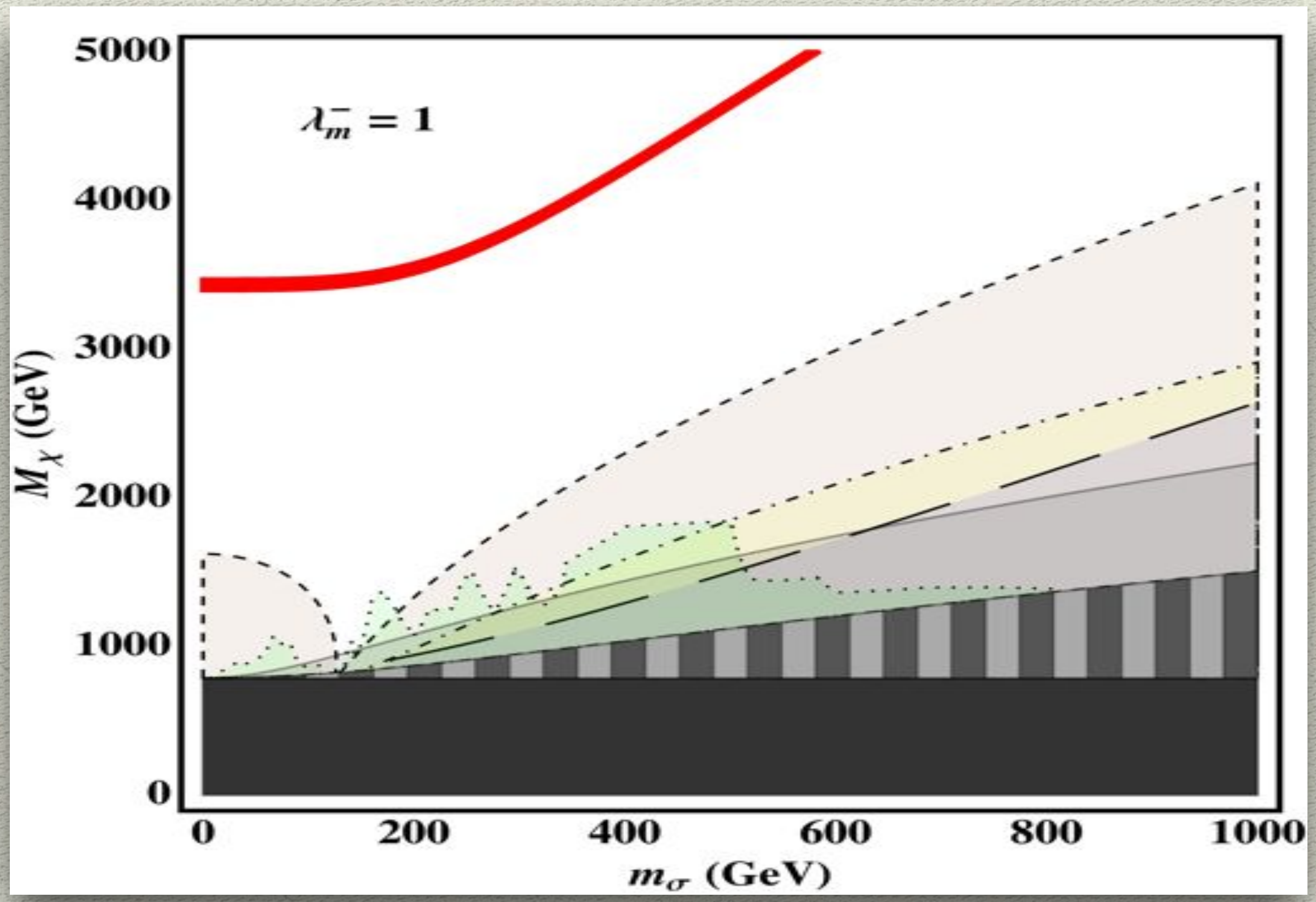
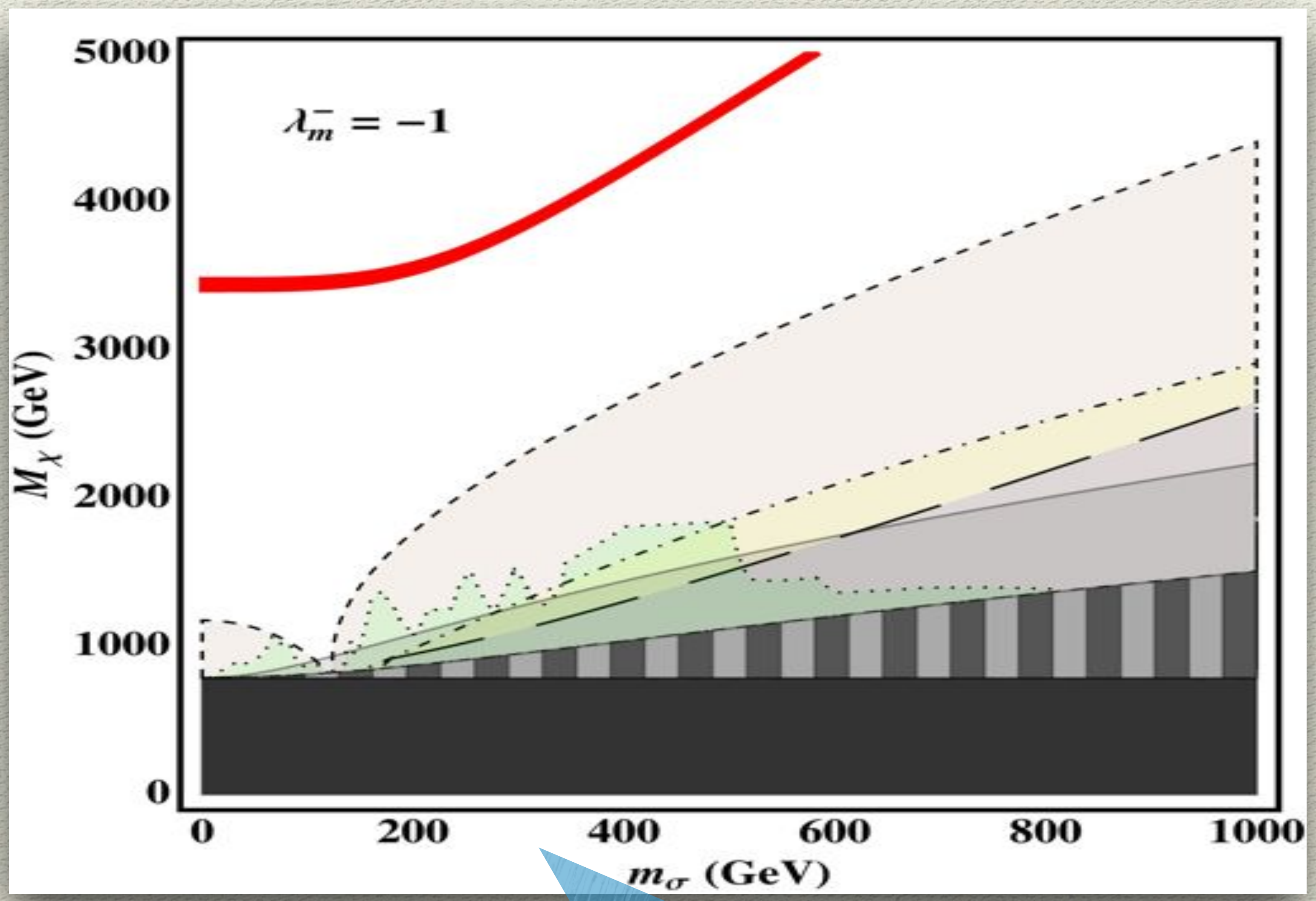
Summarized Exclusion Plots:
m_σ-M_χ







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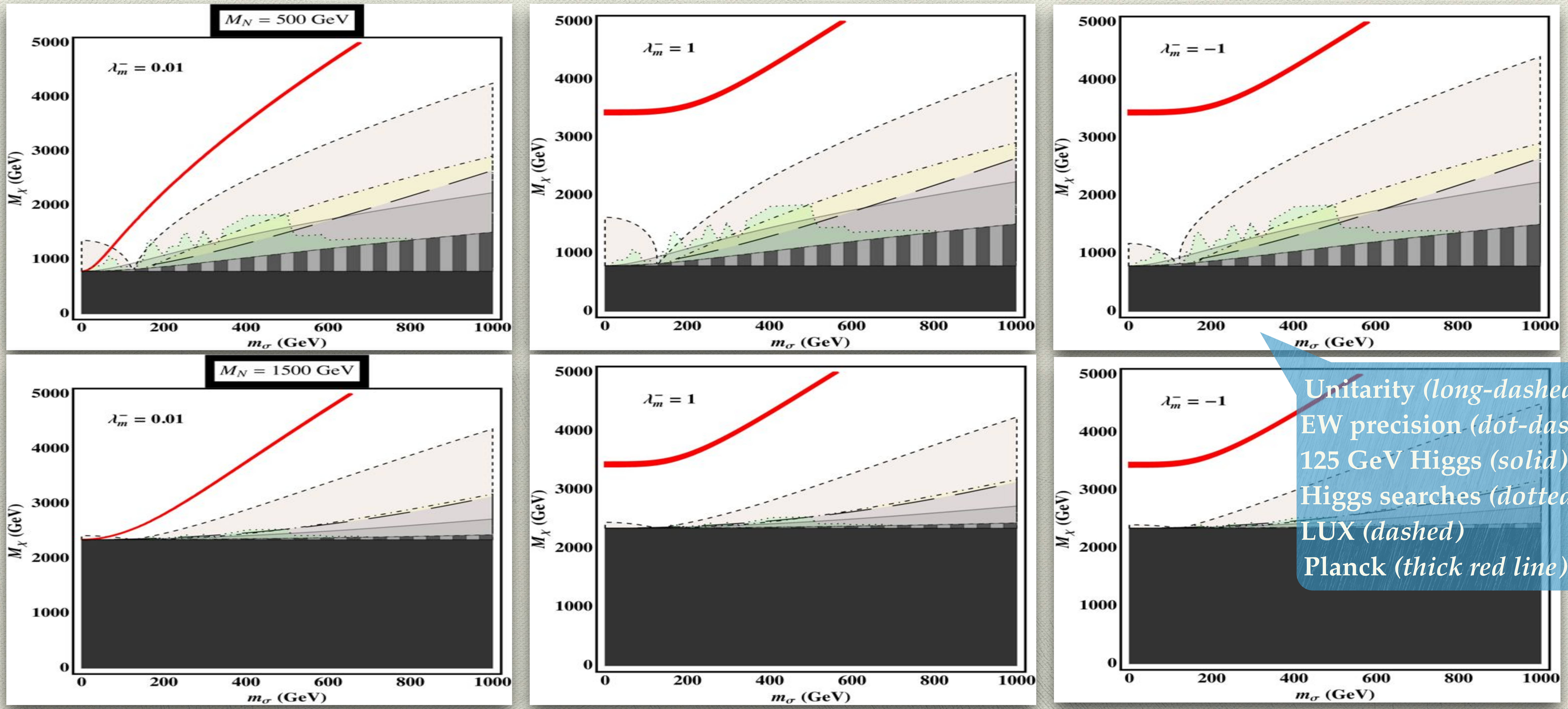

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- Scenario highly constrained and predictive $\Longrightarrow$ Small mixing between electroweak and singlet sectors ($\sin\omega \lesssim 0.2$), second Higgs with suppressed couplings (can be heavier or lighter than 125 GeV), heavy TeV mass DM

Thank you..