Catching a Criminal: Confirming the $U(1)_{L_\mu - L_\tau}$ Solution to the Muon's Anomalous Magnetic Moment Using Neutrinos

Based on **2104.03297**

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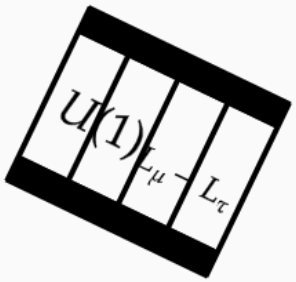
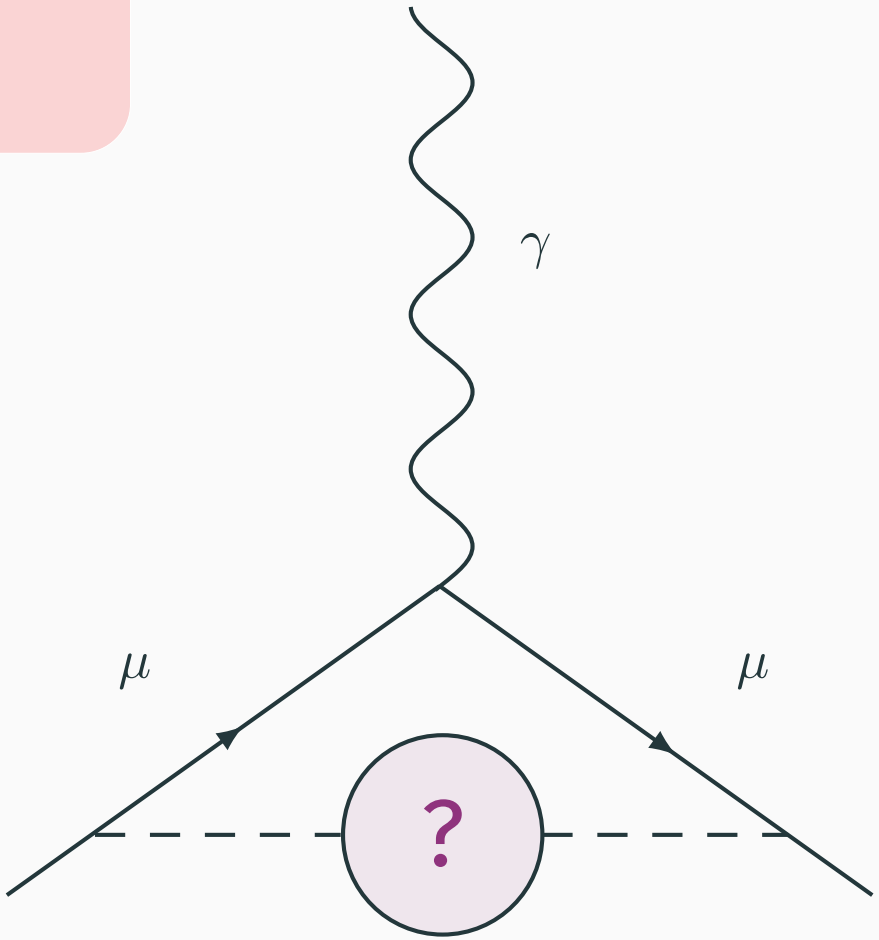
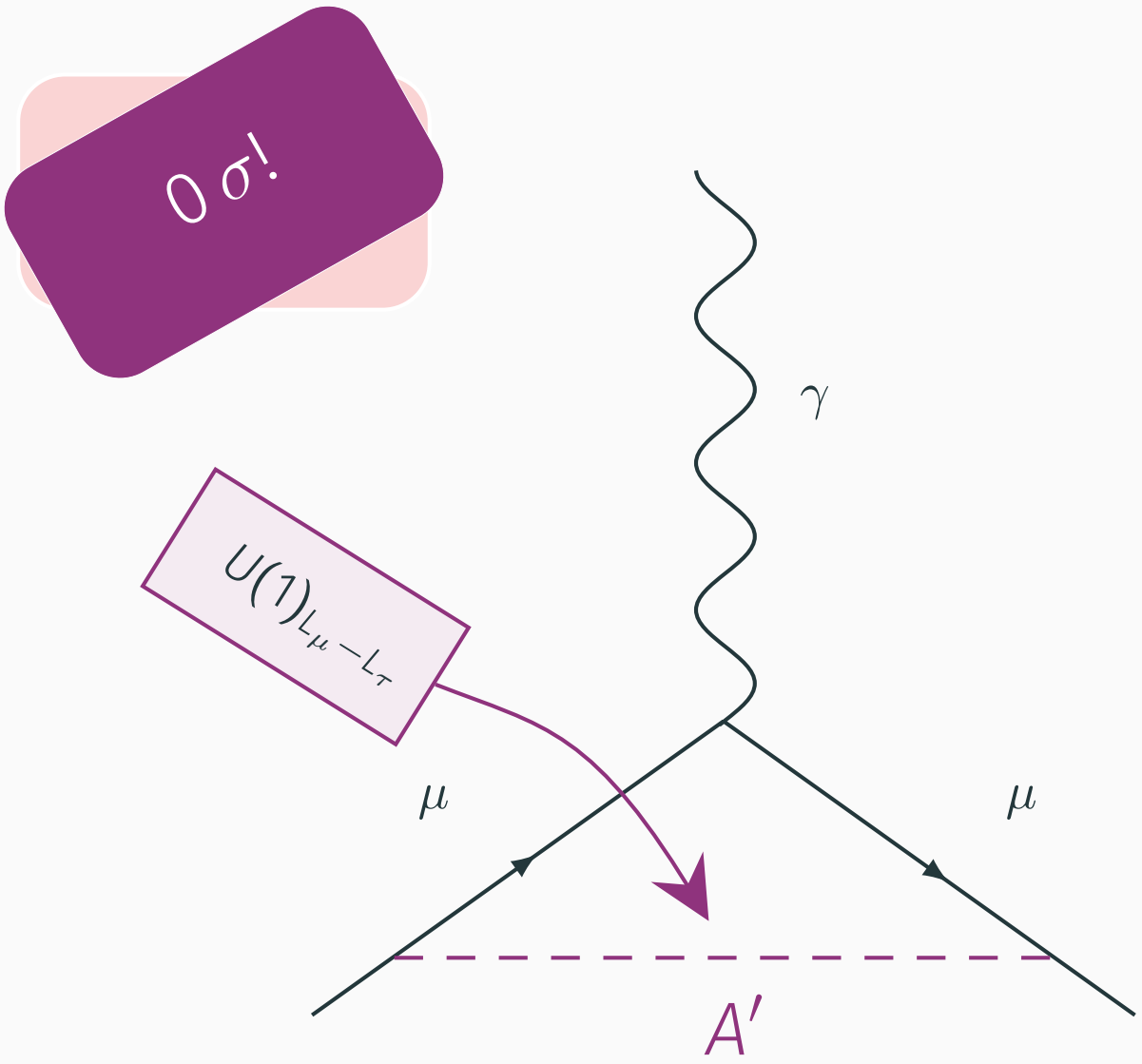
UK HEP Forum 2021



$4.2\,\sigma$




0 σ!
γ
$U(1)_{L_\mu - L_\tau}$
μ
μ
A'

The Challenge

Should the $U(1)_{L_\mu - L_\tau}$ hidden photon be responsible for the tension in $(g-2)_\mu$, how can we confirm this?

1. Which experiments can test its characteristic properties?
2. How sensitive will they be? (Likelihood analysis)

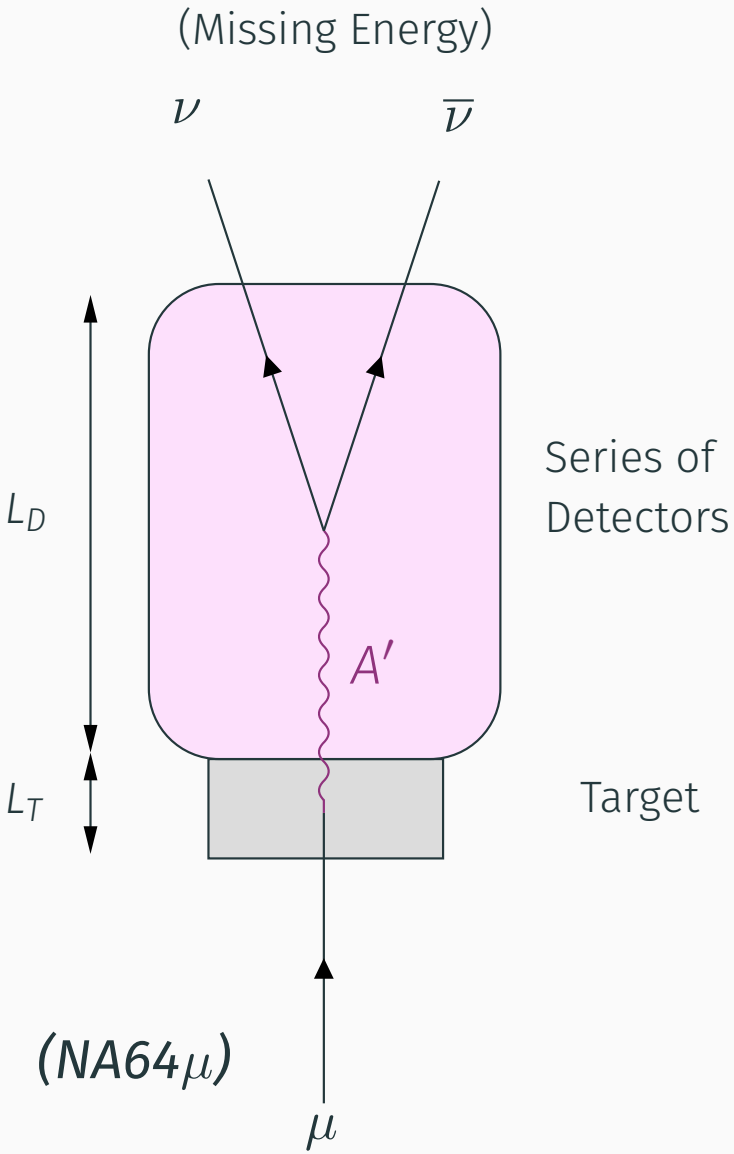
The Properties of the $U(1)_{L_\mu - L_\tau}$ Hidden Photon

P1: Coupling to the second generation leptons (μ, ν_μ)

P2: A kinetic mixing with γ of $|\varepsilon_{\mu\tau}| \simeq g_{\mu\tau}/70$

P3: Coupling to the third generation leptons (τ, ν_τ)

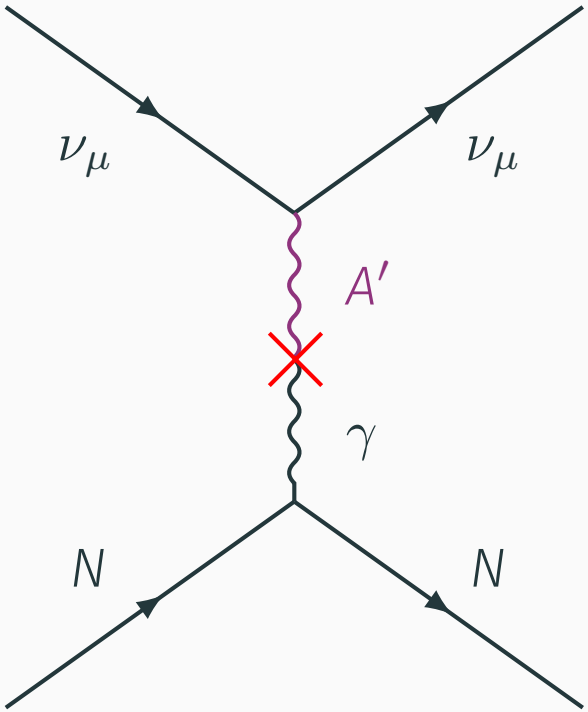
Muon Beams Capture the Coupling



Direct coupling to μ through $g_{\mu\tau}$

Muon beam experiments can test *half of* P1!

CEνNS at Spallation Sources Manage the Mixing

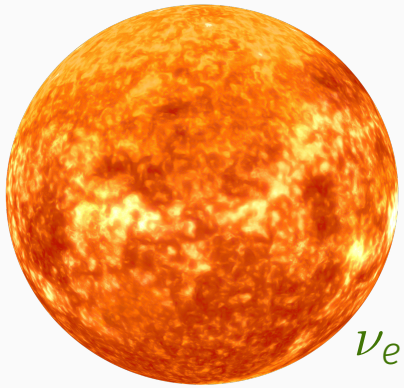


CEνNS through kinetic mixing with photon.

Sensitive to product $g_{\mu\tau}\varepsilon_{\mu\tau}$

CEνNS at spallation sources can test other half of P1 and test P2!

Direct Detection Experiments Test the Tau



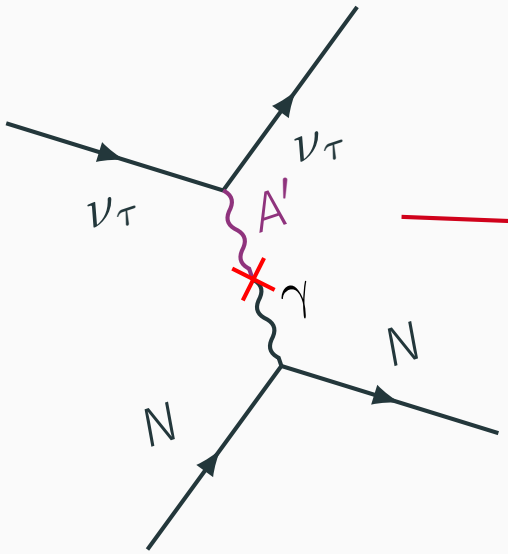
ν_e

ν Osc.

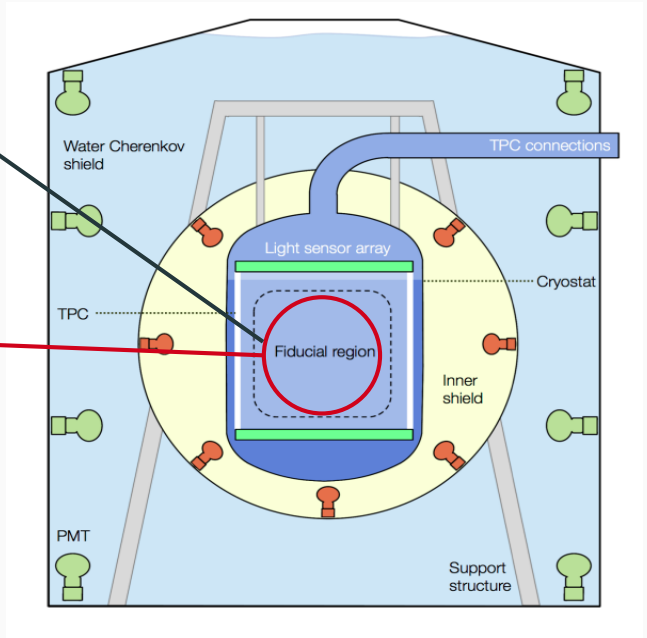
ν_τ

CEνNS: Now with ν_τ!

DD experiments can begin to test P3!

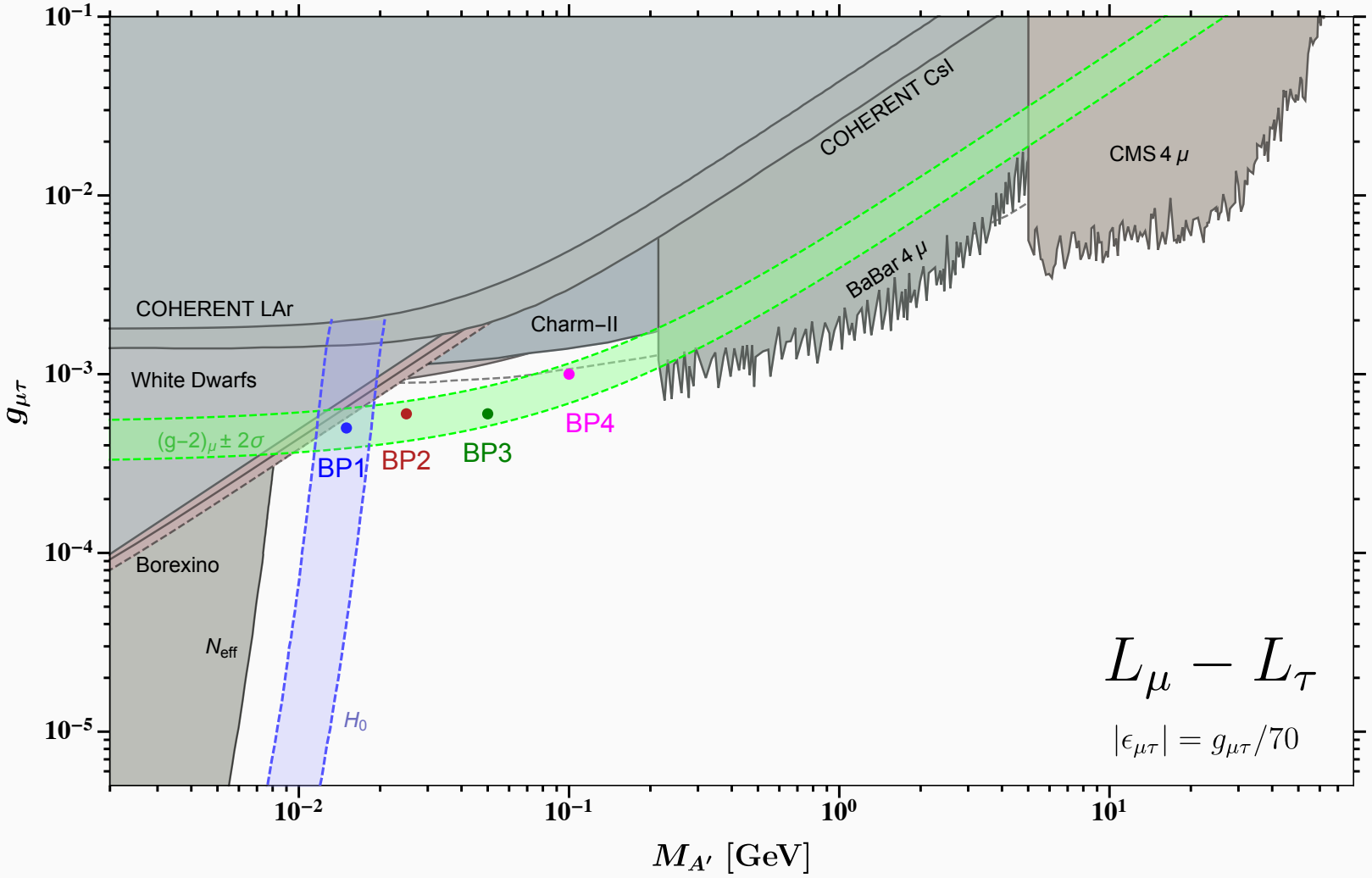


DARWIN

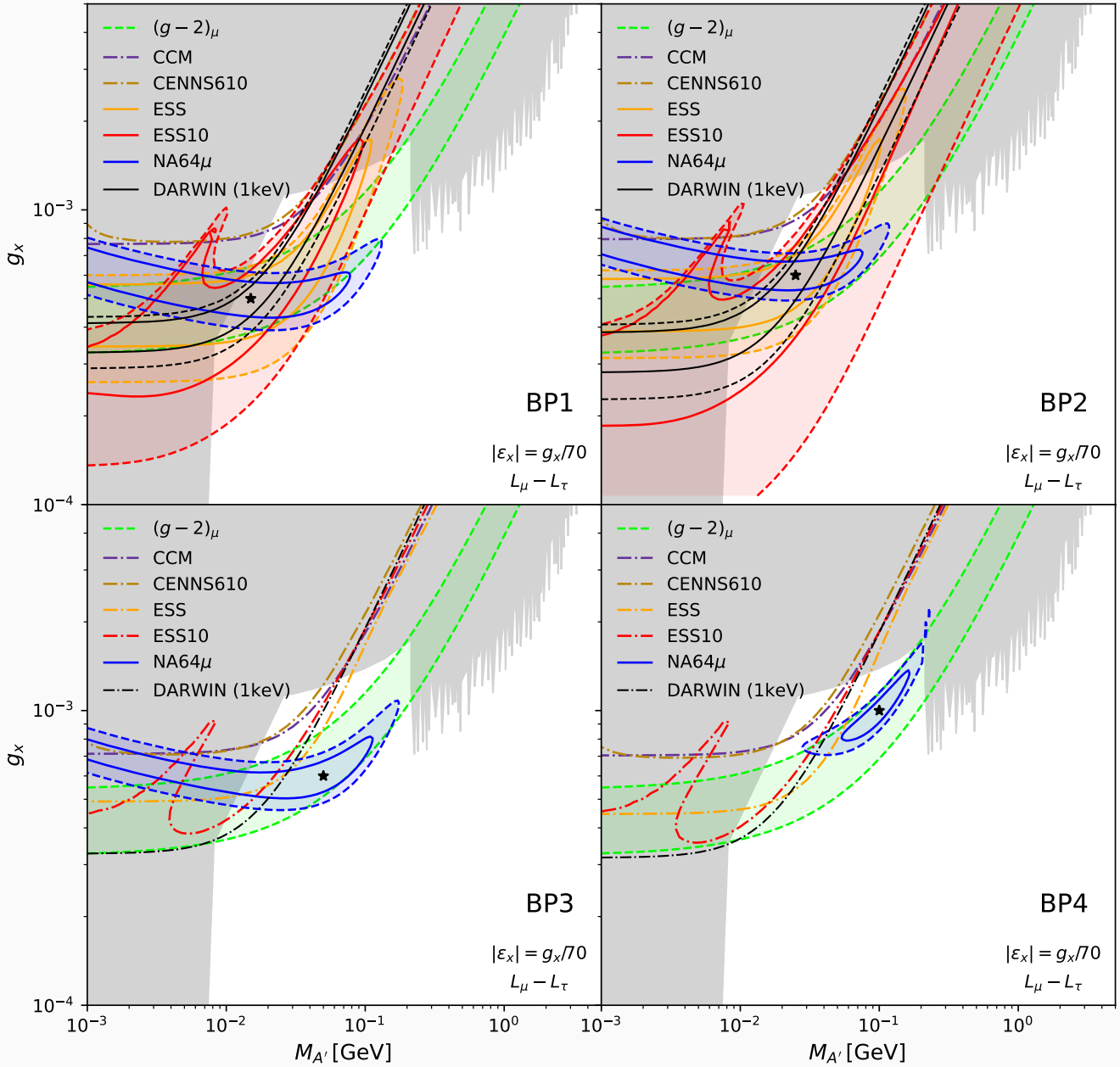


[J. Aalbers et al. 1606.07001]

Where to Look?



[DA DC AC PF. **2104.03297**; D. Amaral et al. **2006.11225**]

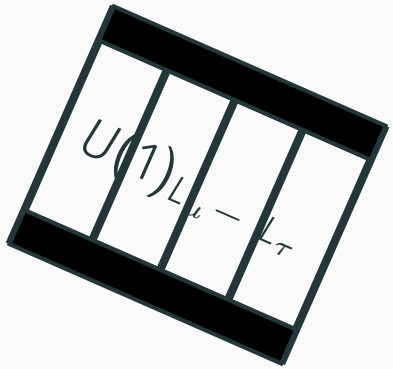


[DA DC AC PF. 2104.03297]

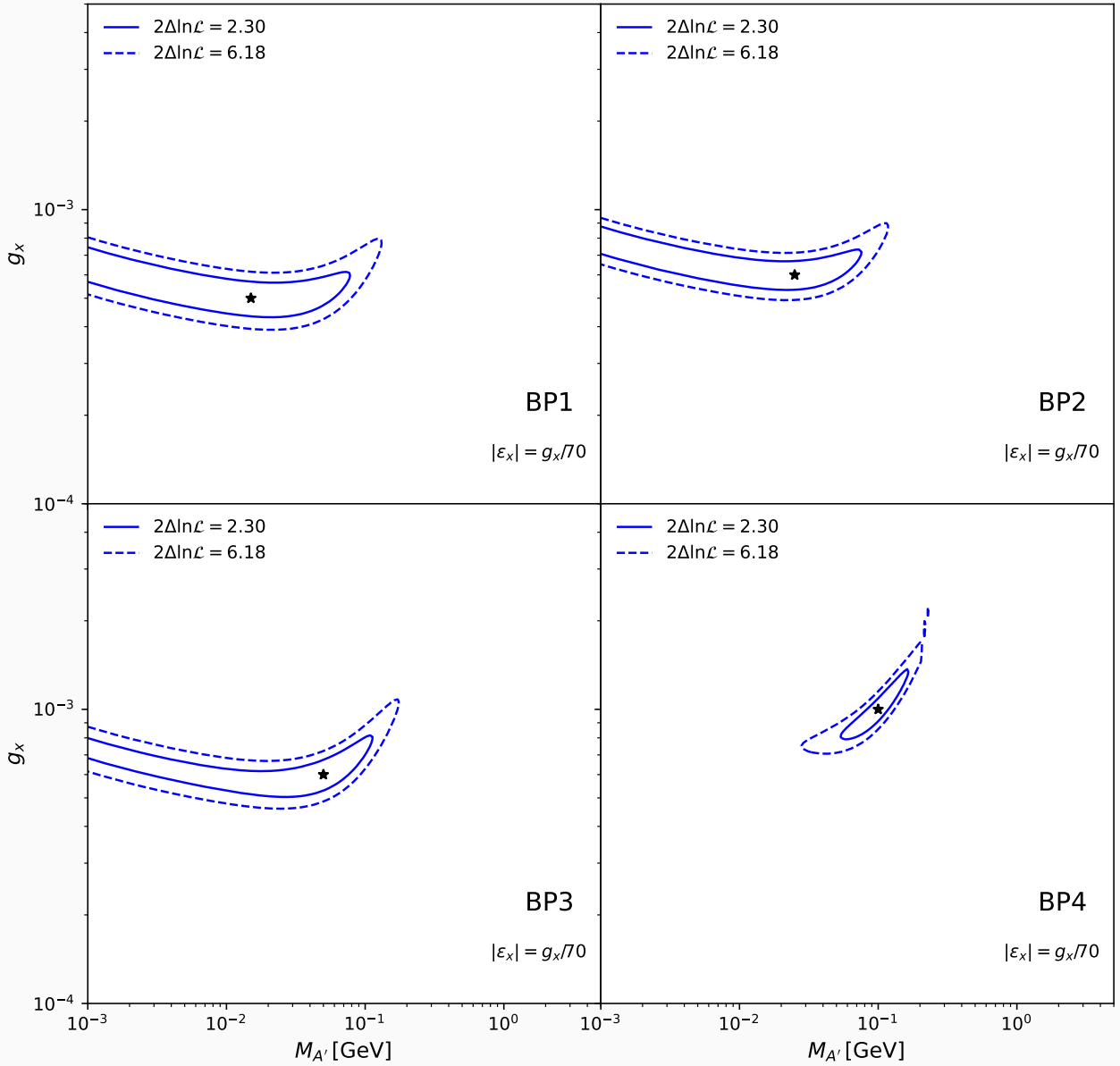
The Strategy

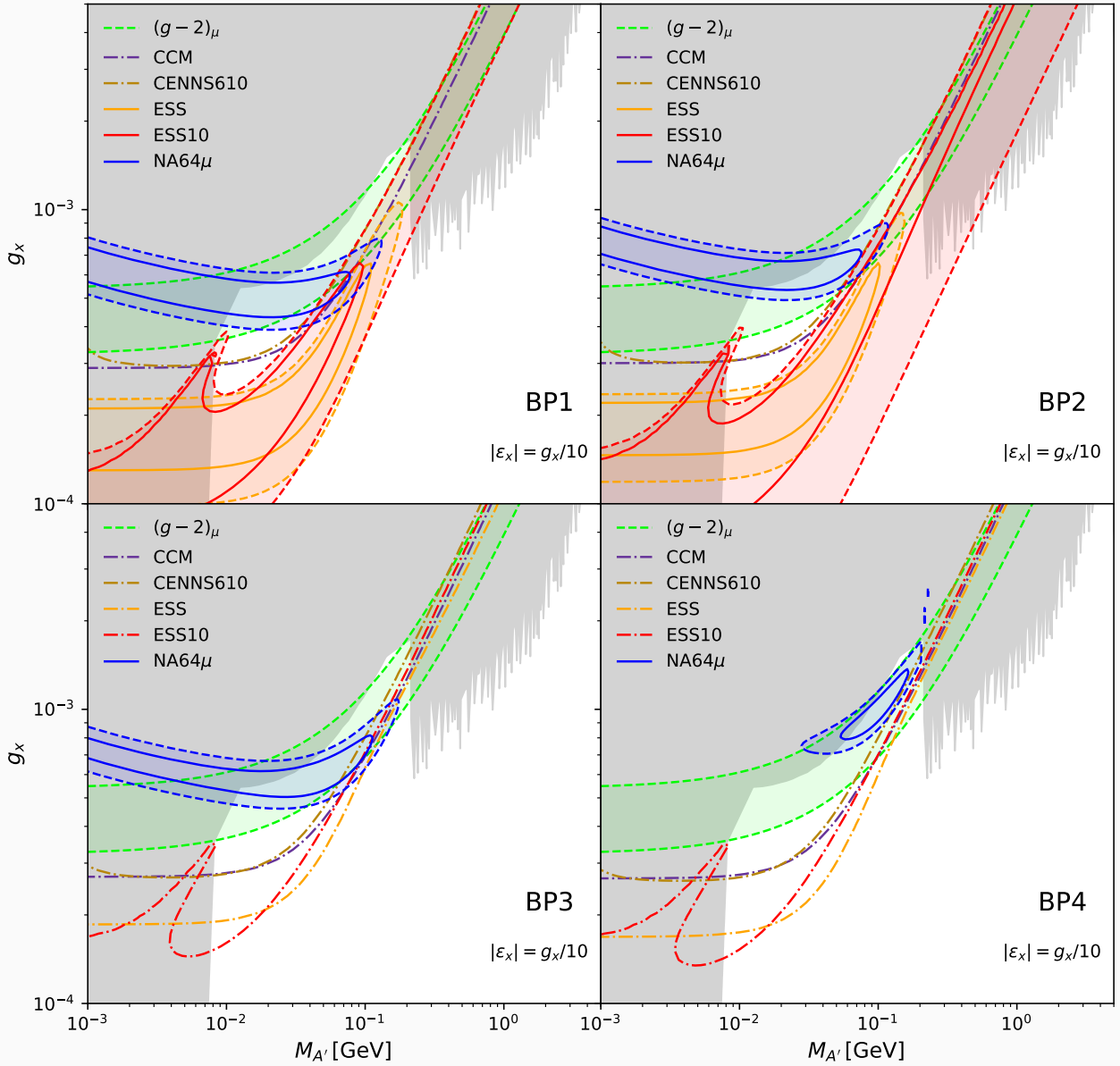
1. Muon beam experiments test one half of P1
2. Spallation tests other half of P1 and can test P2
3. DD experiments test P3

Together, they make for a powerful strategy for potentially confirming the $U(1)_{L_\mu - L_\tau}$ hidden photon as the culprit of $(g-2)_\mu$!



Backup





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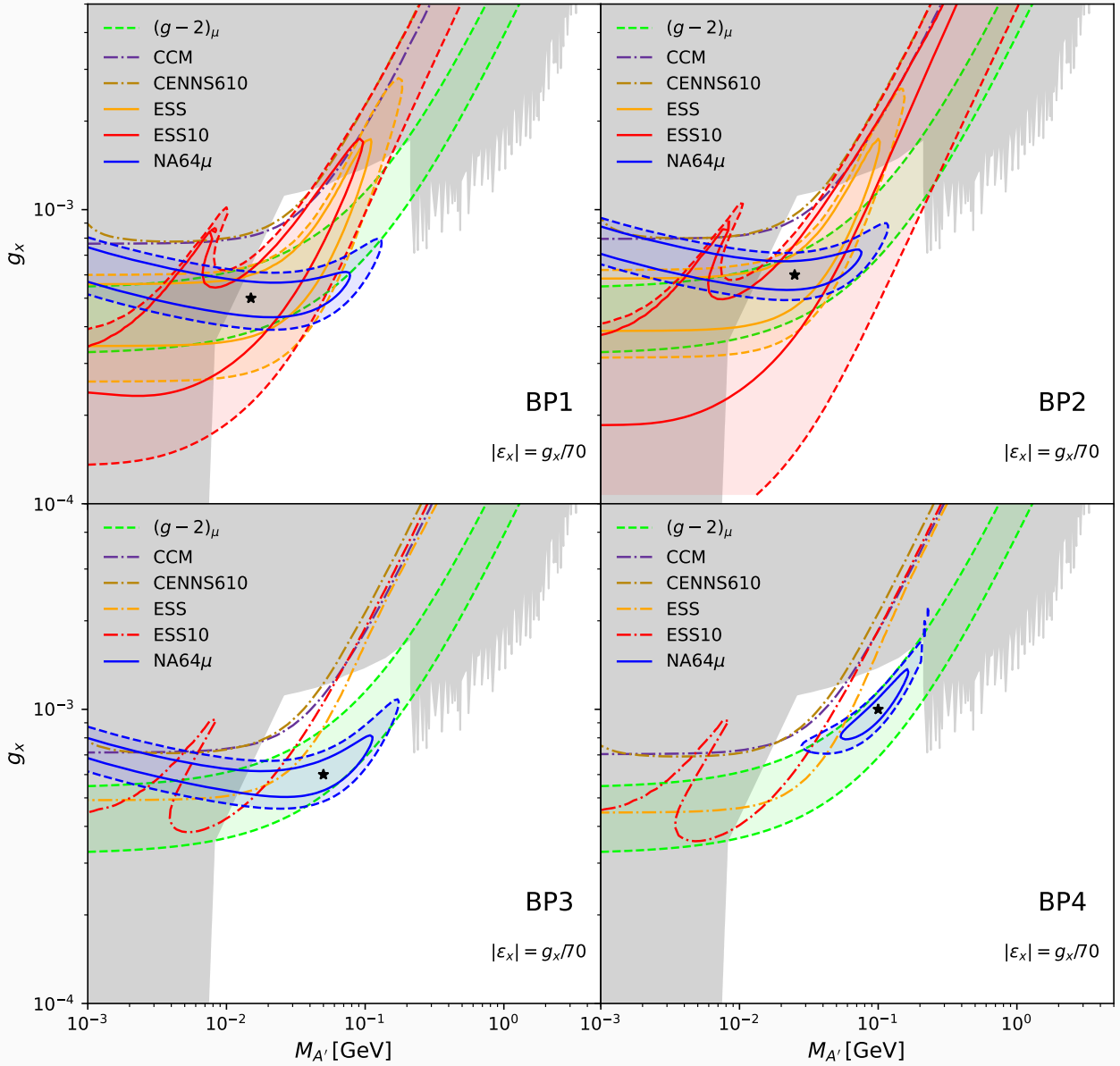

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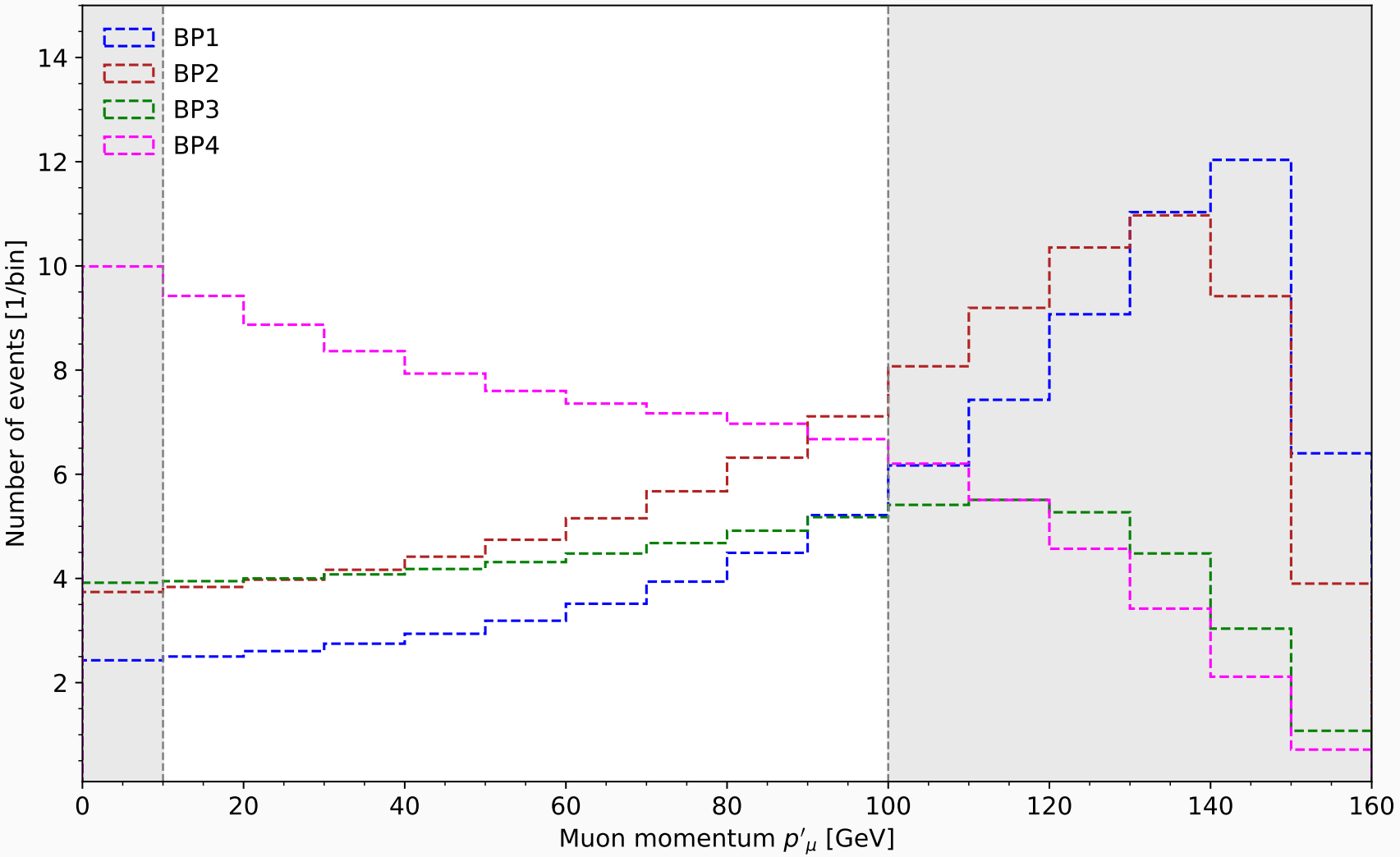
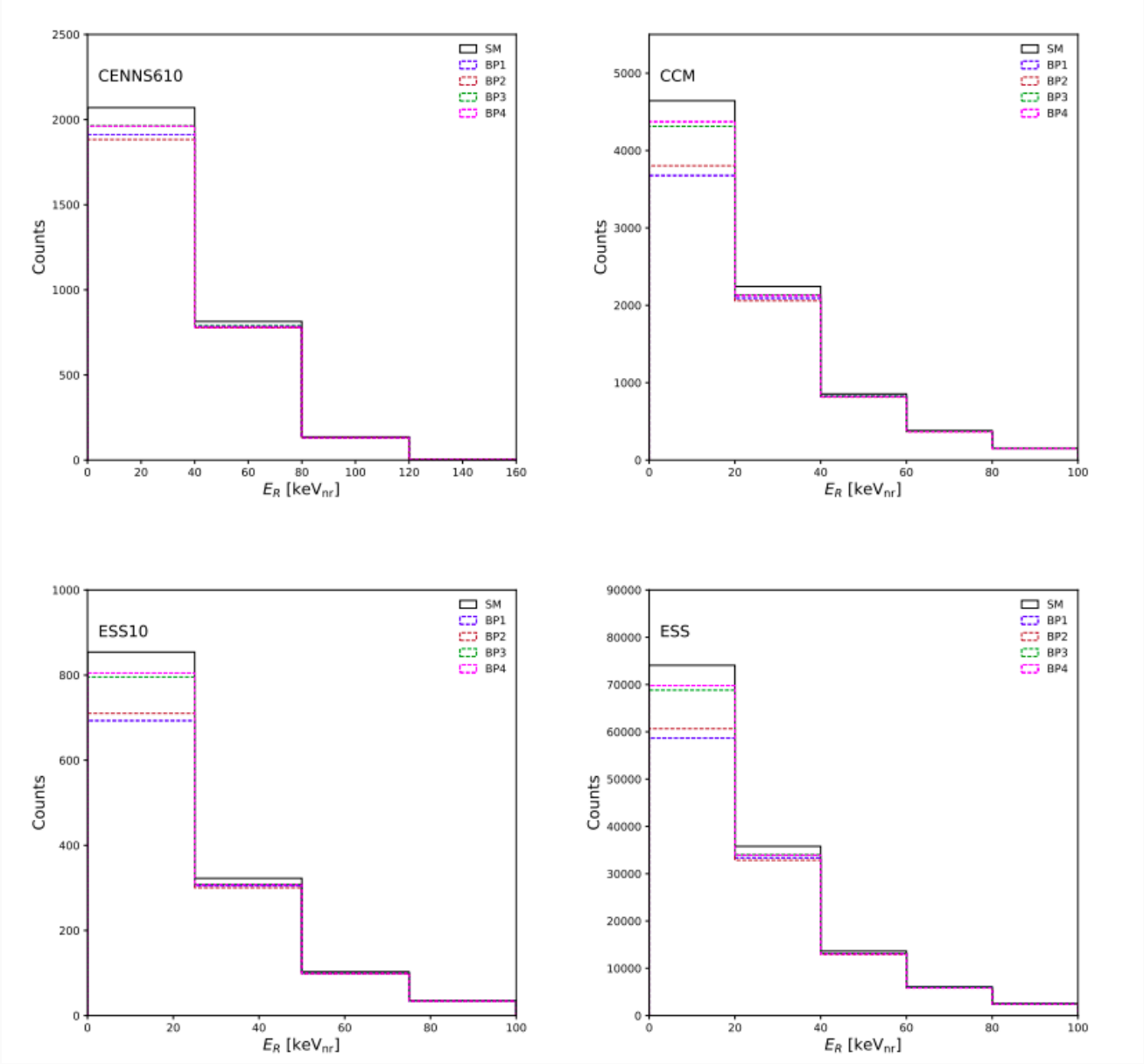


[DA DC AC PF. **2104.03297**]

CEνNS Spectra



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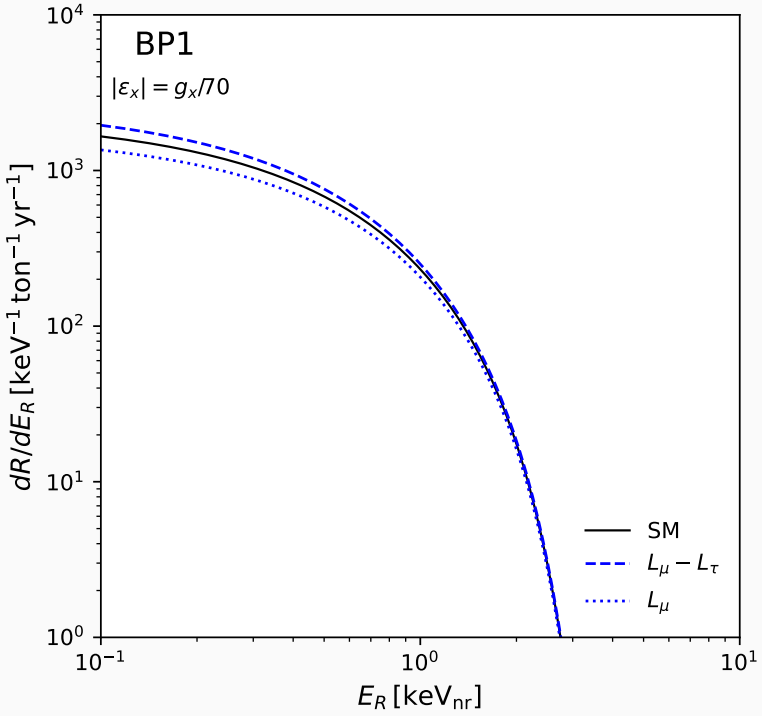
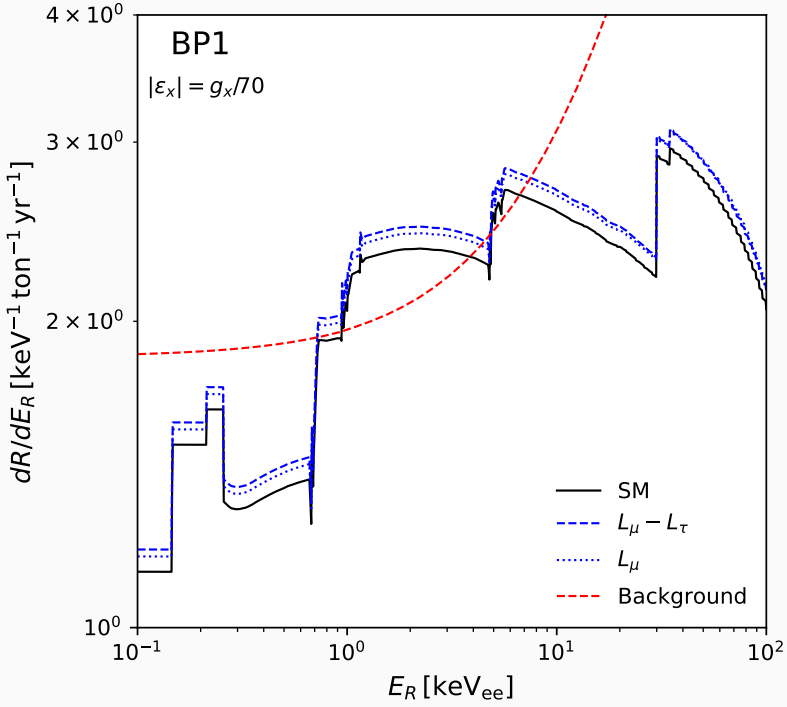
The NR Killer: A Deficit vs. An Excess





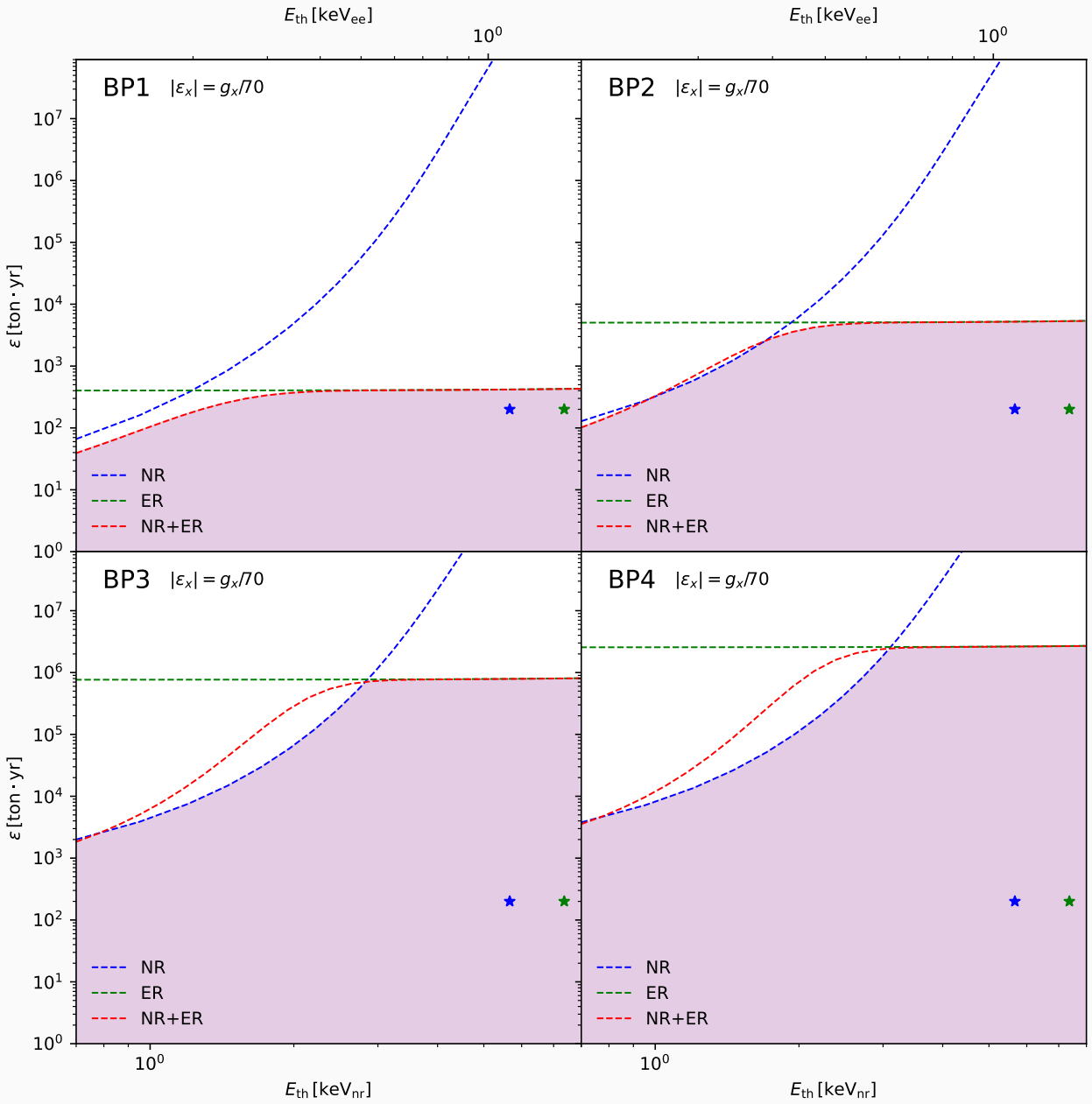
[DA DC AC PF. 2104.03297]

NRs die off quickly and ERs drowning in background! Difficult...

What $E_{\rm th}$ and ε do we need to observe an overall 5σ excess over SM?

Note: For ERs, $|c_{\rm int}| \ll |c_{\rm BSM}| \implies$ Get an excess in both models

Discovering the Excess



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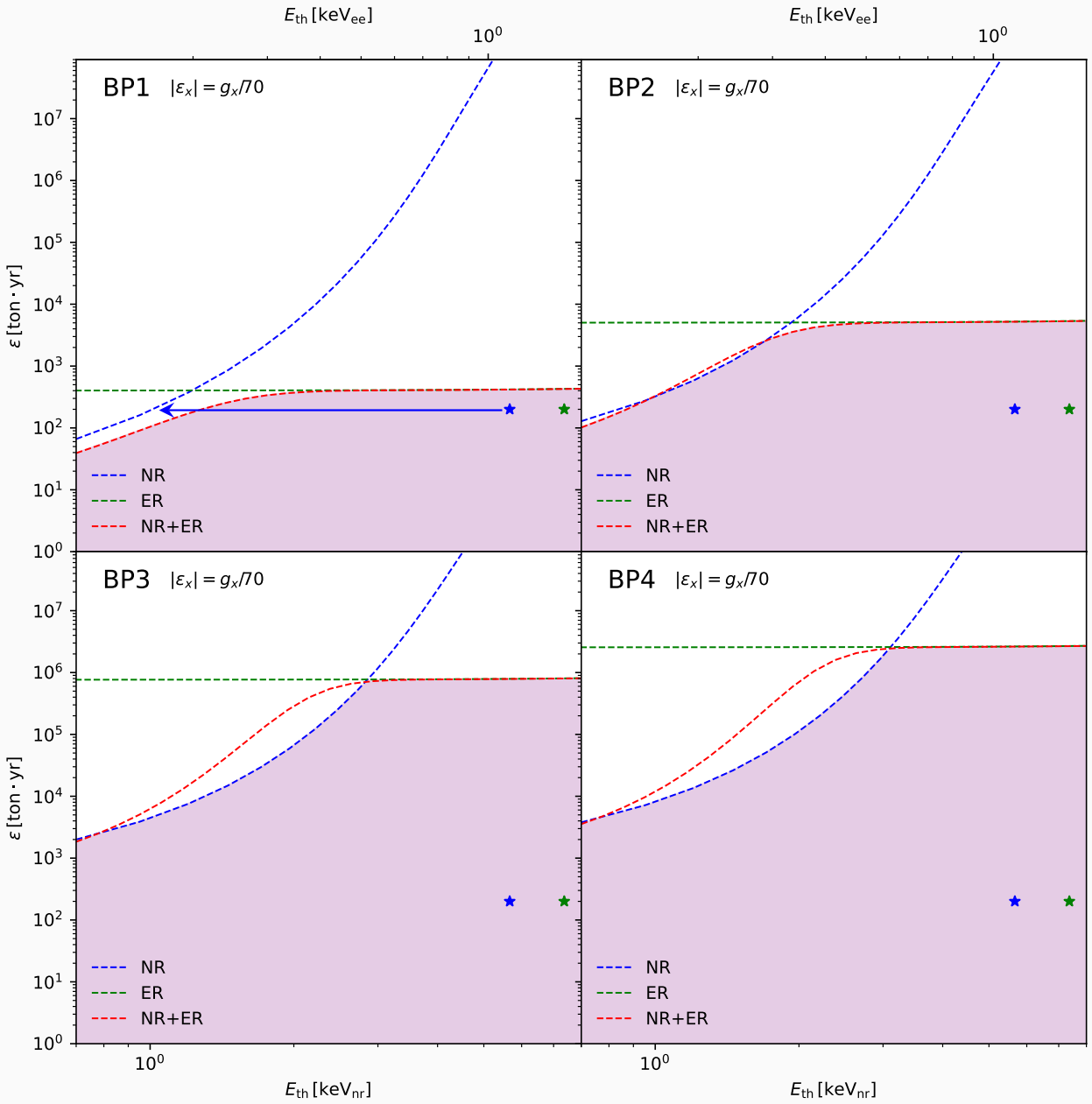
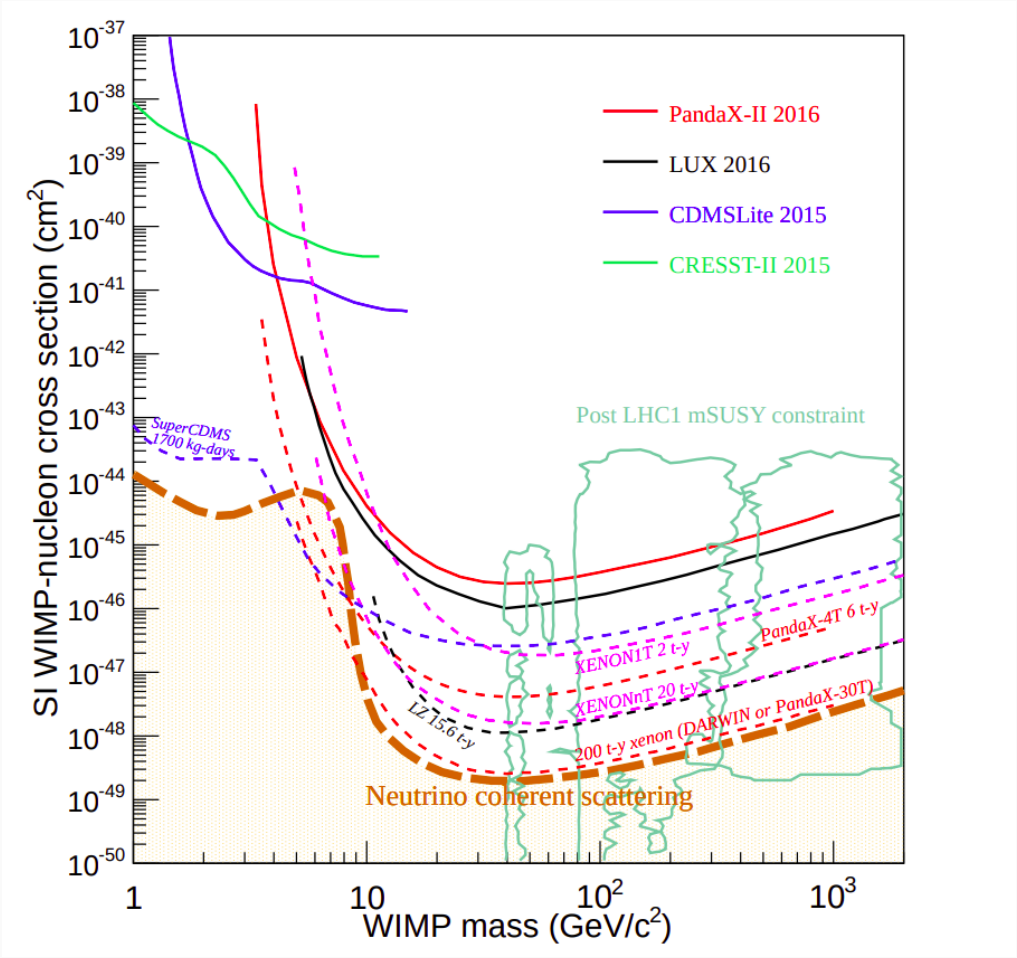
Discovering the Excess



[DA DC AC PF. 2104.03297]

How it Works: The Cosmic Punching Bag

- Dark matter detectors by trade
- But branching out to **solar** ν's!
- Bad for DM detection (irreducible bkg)...
- But good for ν detection (irreducible signal)!



[Jianglai Liu, Xun Chen, and Xiangdong Ji. 1709.00688]

Data Generation: How Much CEνNS?

$$N(g_X\varepsilon_X, M_{A'}) = \varepsilon\, n_T \sum_{\nu_\alpha} \int_{E_{\text{th}}} \int_{E_\nu^{\min}}^{E_\nu^{\max}} \epsilon(E_R)\, \underbrace{\frac{\mathrm{d}N_{\nu_\alpha}}{\mathrm{d}E_\nu}}\, \overbrace{\frac{\mathrm{d}\sigma_{\nu_\alpha N}}{\mathrm{d}E_R}}\, \mathrm{d}E_\nu \mathrm{d}E_R$$

Flavour sum (only ν_e and ν_μ!) ↓ over ν_α

↑ Binning over E_{th}

Important Scattering Physics

Experimental ν_α flux

Our hidden photon makes an appearance in cross section:

$$\frac{\mathrm{d}\sigma_{\nu_\alpha N}}{\mathrm{d}E_R} \propto c_{\text{SM}} + (g_X\varepsilon_X Q'_{\nu_\alpha}) \underbrace{c_{\text{int}}(E_R, M_{A'})}_{>0} + (g_X\varepsilon_X Q'_{\nu_\alpha})^2 c_{\text{BSM}}(E_R, M_{A'})$$

A' charge ↓

↑ Product!

$$Q'_{\nu_\alpha} = \begin{cases} 0 & \text{if } \alpha = e \\ +1 & \text{if } \alpha = \mu \\ -1 & \text{if } \alpha = \tau \end{cases}$$

We only get negative interference!