*NuCo 2021*
*28th July 2021*

# Solar Neutrinos,
## sterile neutrinos
### and Dark Matter Experiments


Collaborators:

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Jie Sheng

Pedro S. Pasquini
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Shanghai Jiao Tong University

Tsung-Dao Lee Institute

State of Art Dark Matter Detectors

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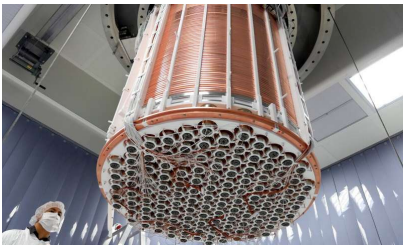

Credit: Kavli Institute for the Physics and Mathematics of the Universe

XENON1T

INFN Laboratori Nazionali del Gran Sasso in Italy

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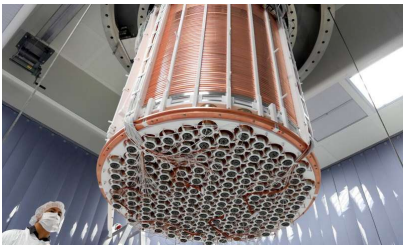

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China Jin-Ping Underground Laboratory.

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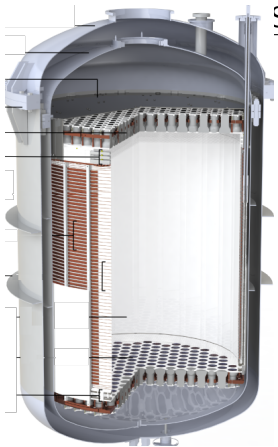

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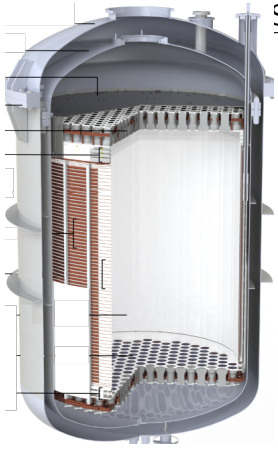

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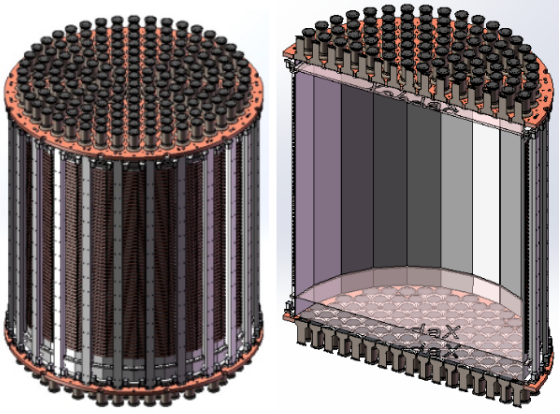

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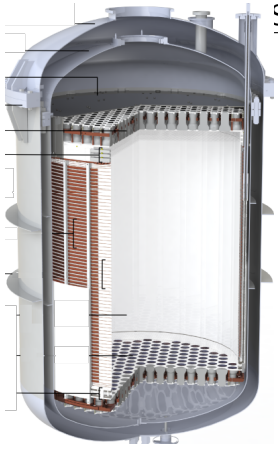

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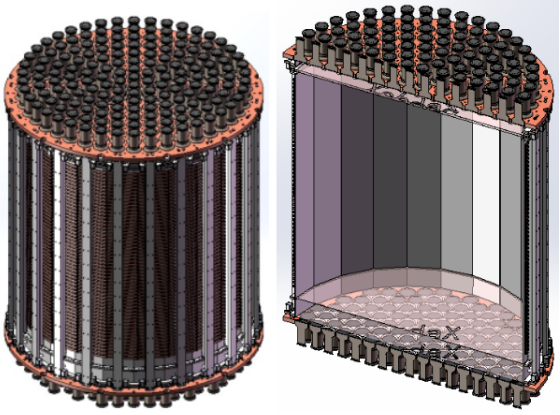
XENONnT

Also:
Lux-Zeplin
Darwin



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Very low detection threshold ($\sim$ 1 keV).

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can distinguish nuclear recoil (NR) from electron recoil (ER)

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Eur.Phys.J.C 77 (2017) 12, 881

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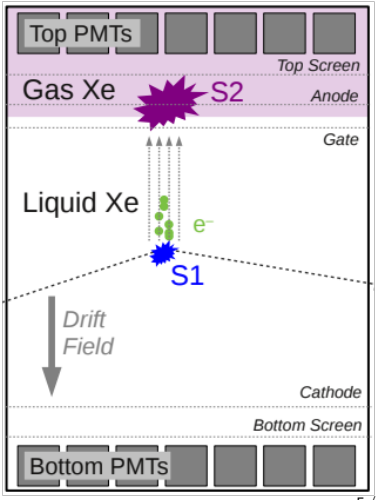

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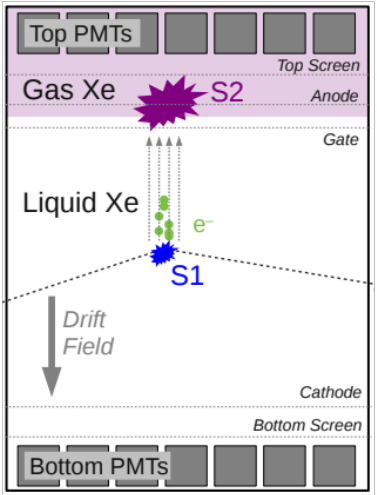

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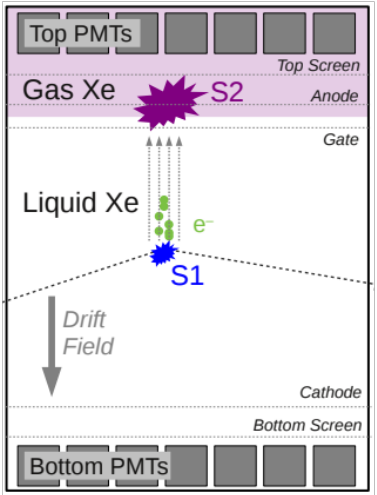

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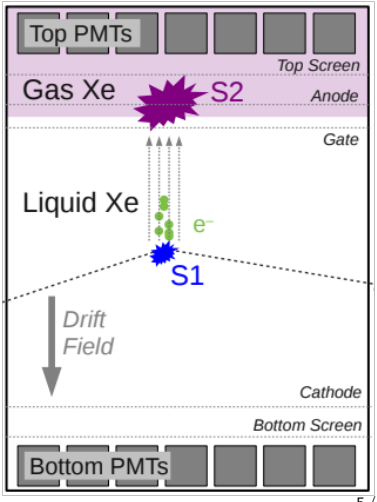
- S1/S2 produced by NR and ER are different! (can reach 99% discrimination power)



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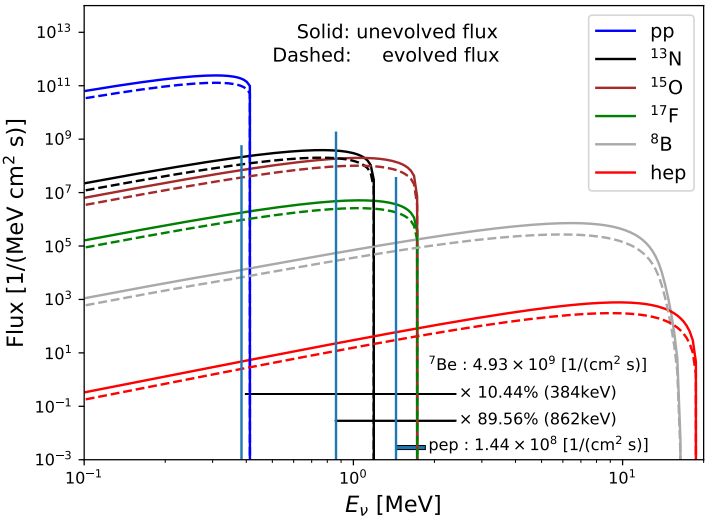


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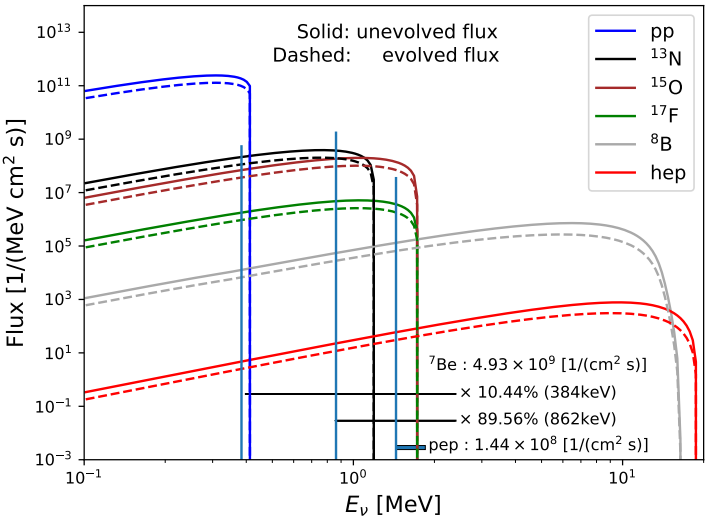


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Very Intense Flux (specially PP chain ($E_\nu \lesssim 400$ keV))

Astrophys.J. 835 (2017) 2, 202

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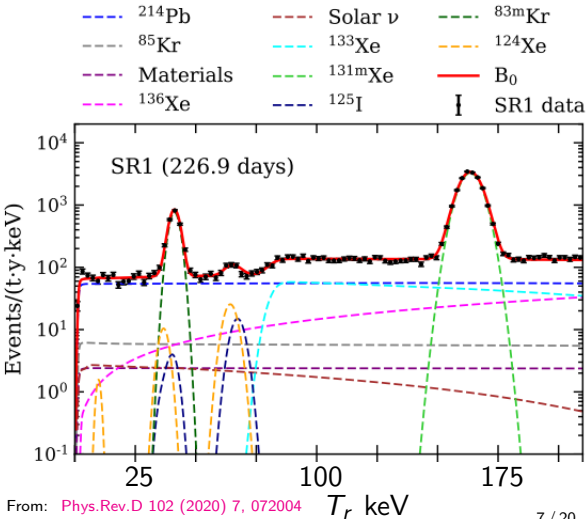


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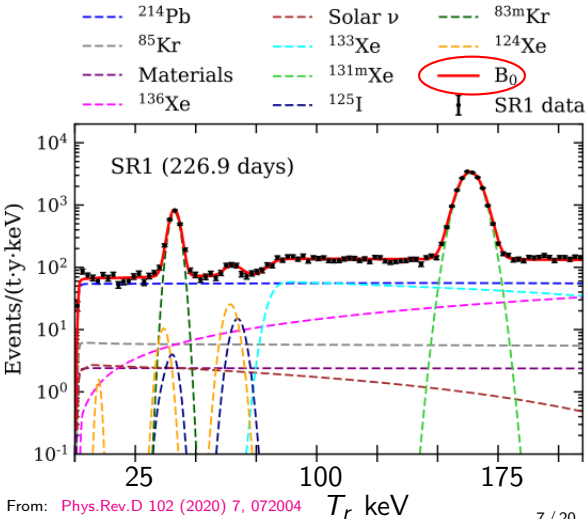


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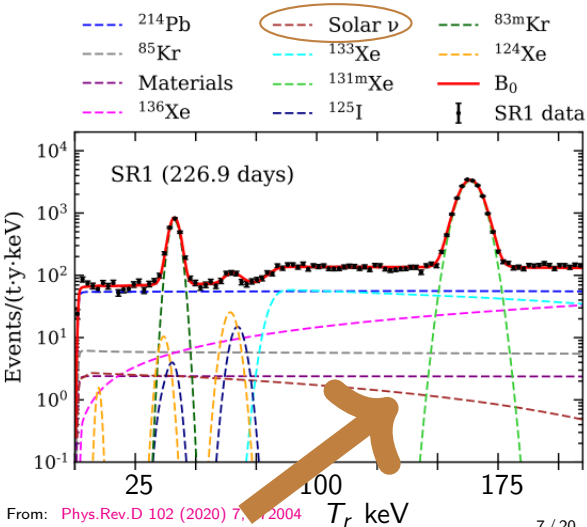


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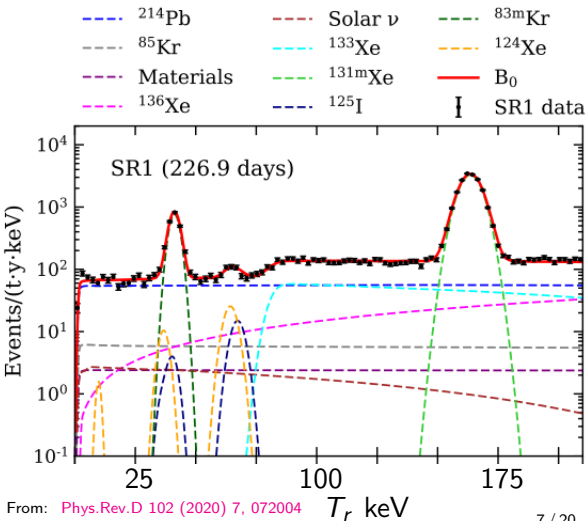


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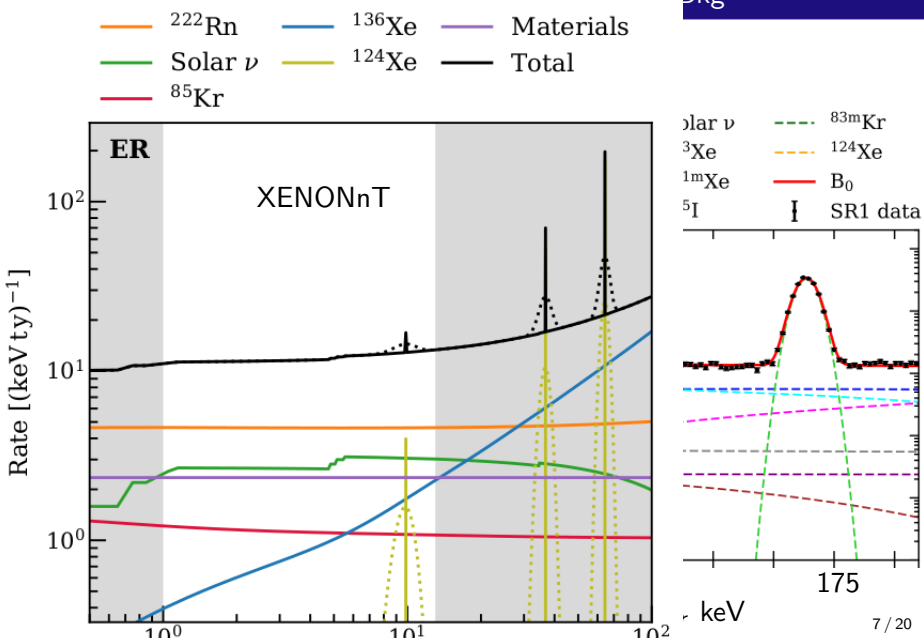

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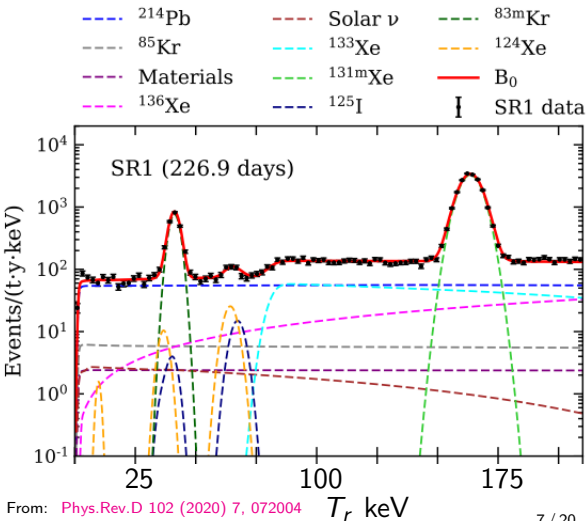


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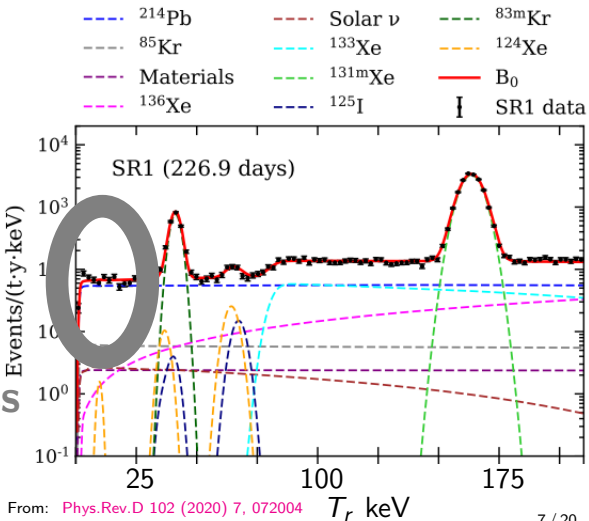


Excess

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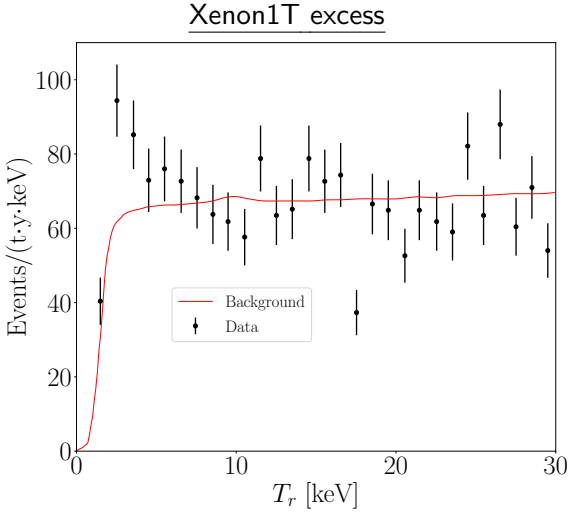
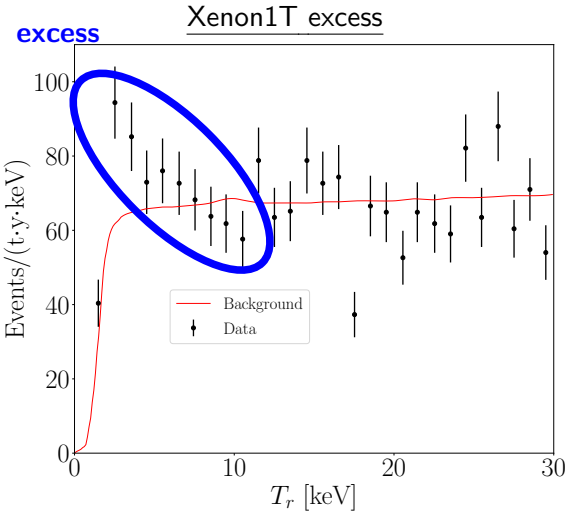
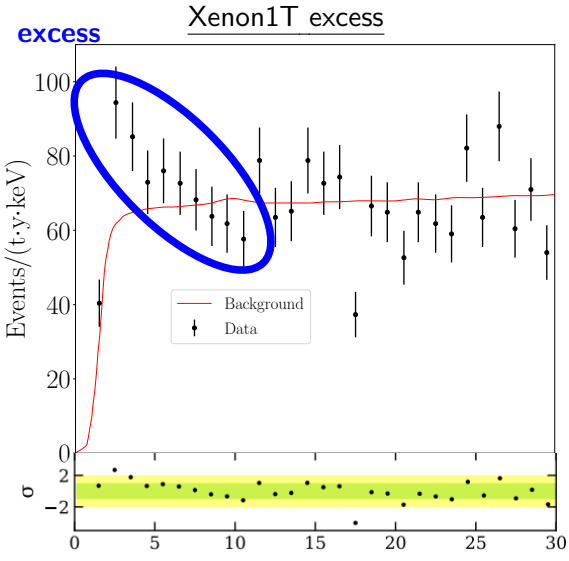
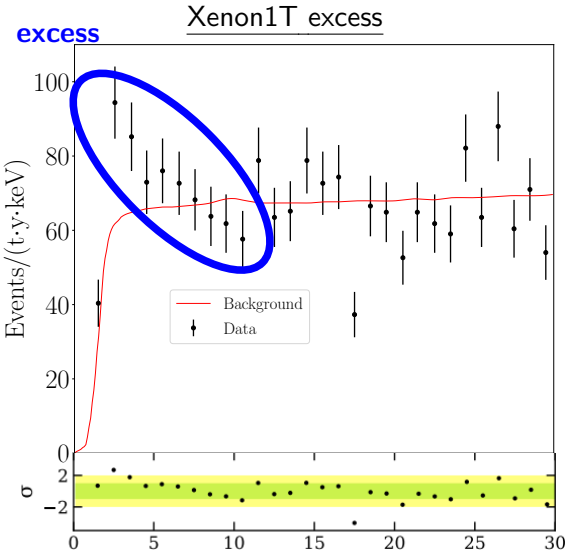
## New excess near threshold!




Xenon1T excess
excess
Events/(t·y·keV)
100
80
60
40
20
0
0
10
20
30
$T_r$ [keV]
Background
Data




285 observed versus 232±15 expected $\sim 3.5\sigma$.

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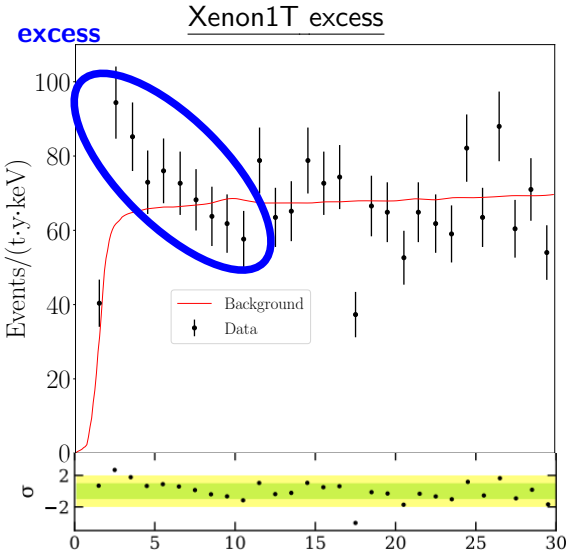


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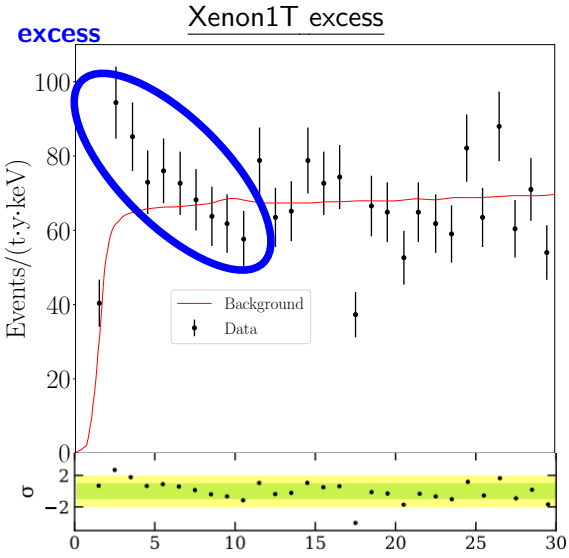


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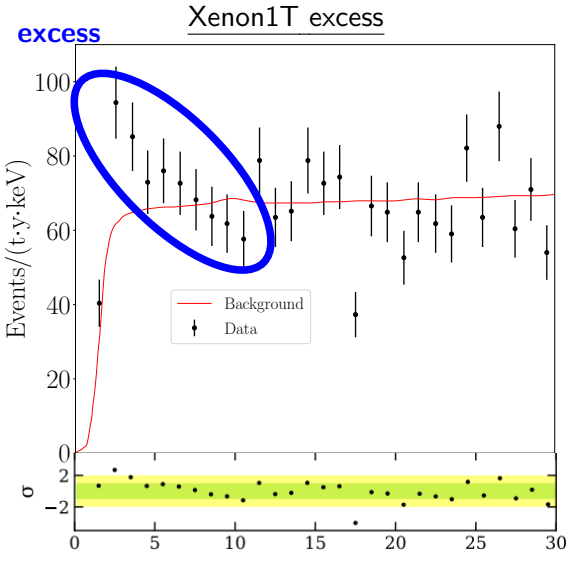


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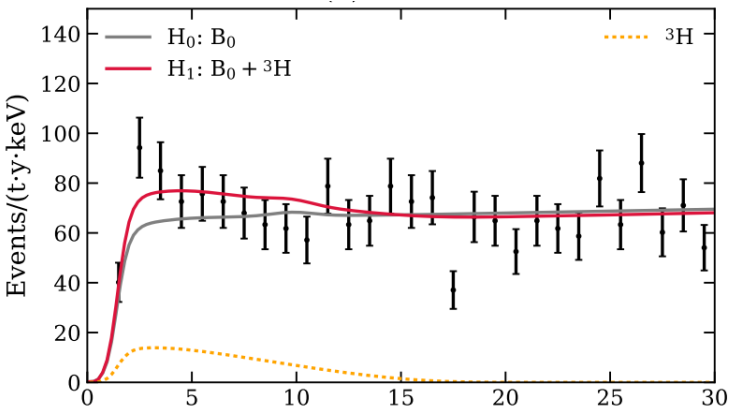

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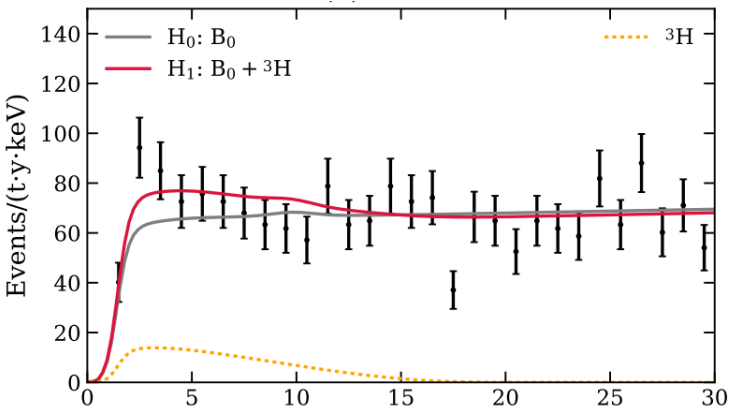
Unlikely by estimations, but it is hard to measure presence of T.



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We proposed new physics related to (solar) neutrinos

PLB 810 (2020) 135787

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$$\frac{d\sigma}{dT_r} = \frac{m_e G_F^2}{4\pi}\left[g_2^2 + g_1^2\left(1 - \frac{T_r}{E_\nu}\right)^2 - g_1 g_2 \frac{m_e T_r}{E_\nu^2}\right]$$

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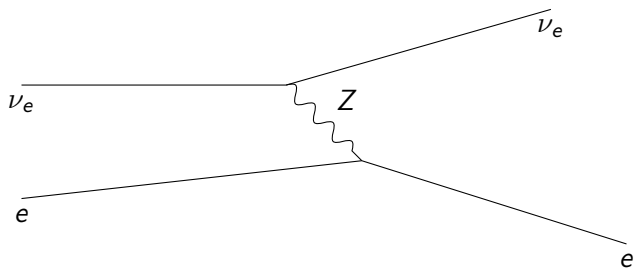

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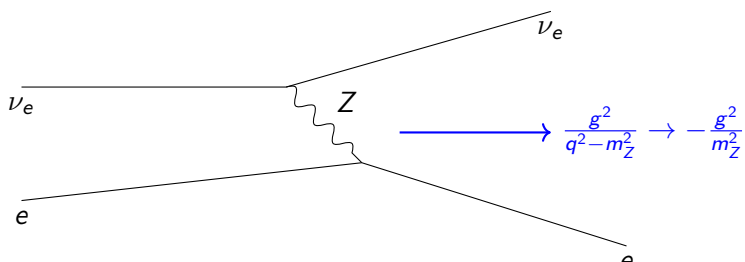

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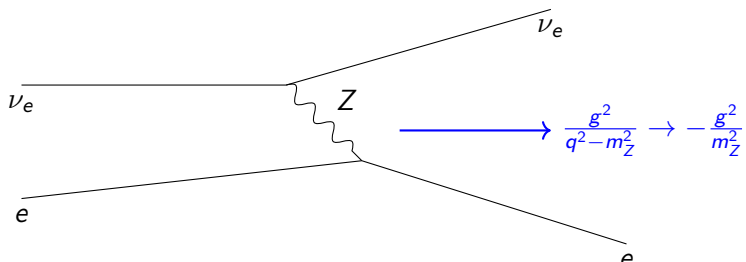


$$T_r/E_\nu \lesssim 0.1 \Longrightarrow \frac{d\sigma}{dT_R} \approx \text{mostly Flat}$$

Let's generalize it with new interactions

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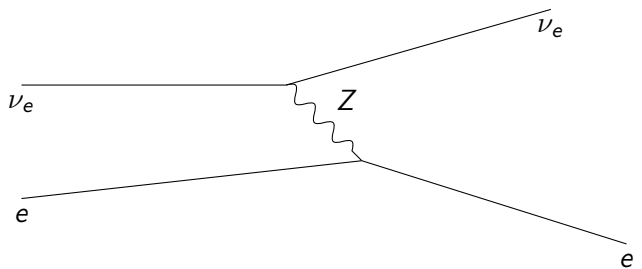

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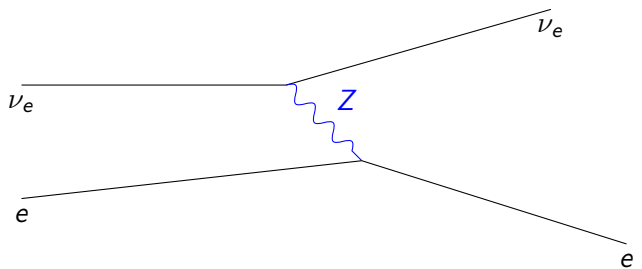

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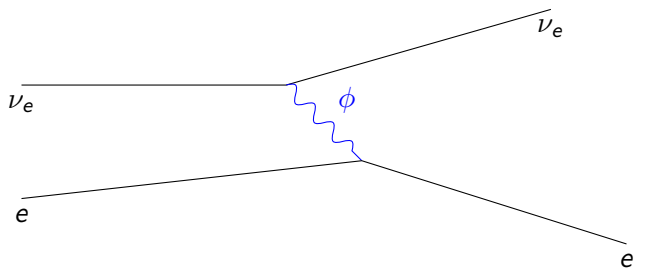
$$\frac{d\sigma}{dT_r} = 2m_e T_r \frac{(y_S^\nu y_S^e)^2(2m_e+T_r)+(y_P^\nu y_P^e)^2 T_r}{8\pi E_\nu^2(2m_e T_r+m_\phi^2)^2}$$



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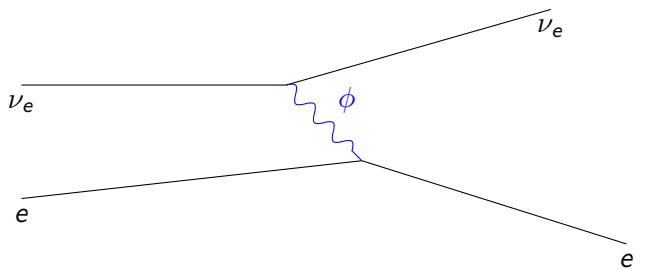

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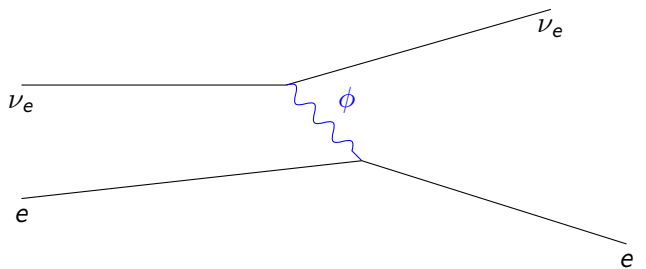

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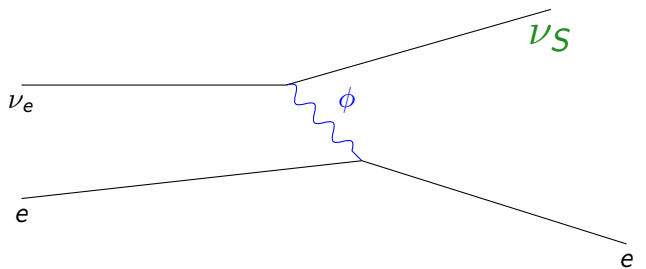

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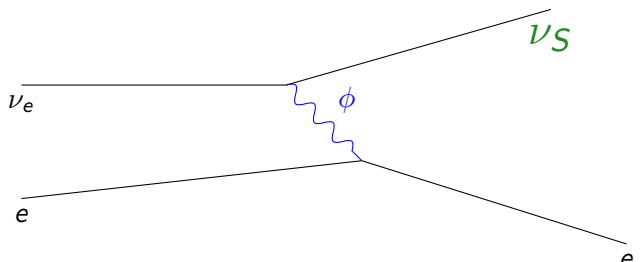


$$\mathcal{L}_{\rm int} = \bar{\nu}(y_S^\nu + \gamma_5 y_P^\nu)\phi\nu_s + \bar{e}(y_S^e + \gamma_5 y_P^e)e\phi + h.c.,$$

Sterile neutrino gives low E enhancement!

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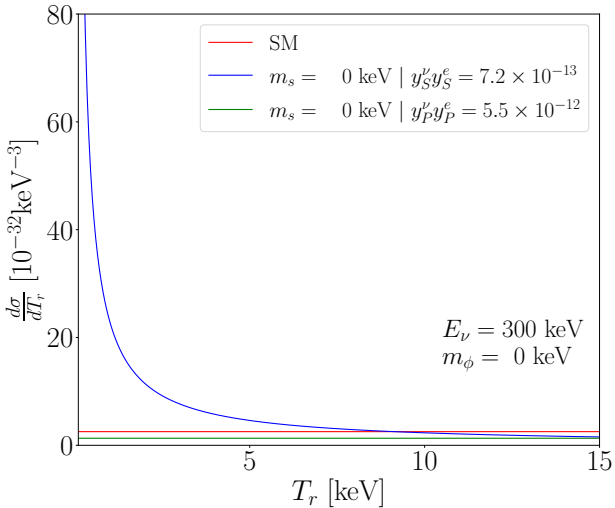

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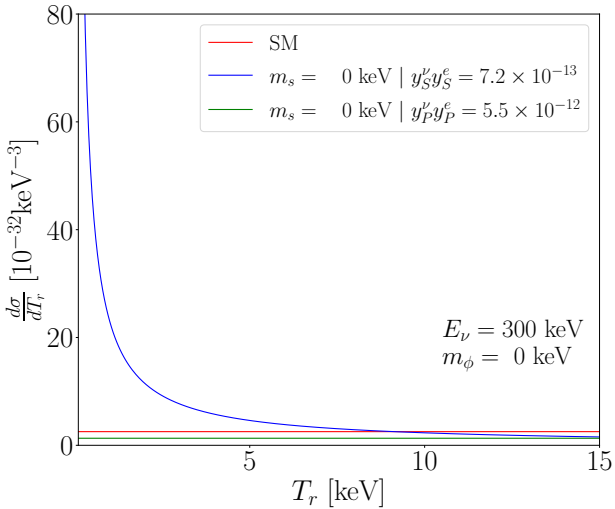


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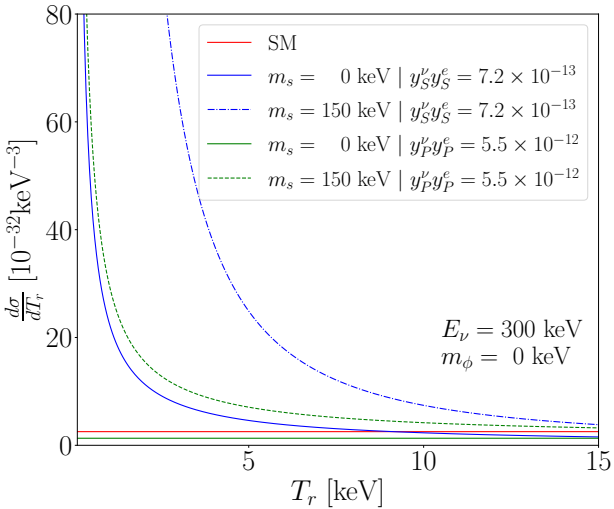


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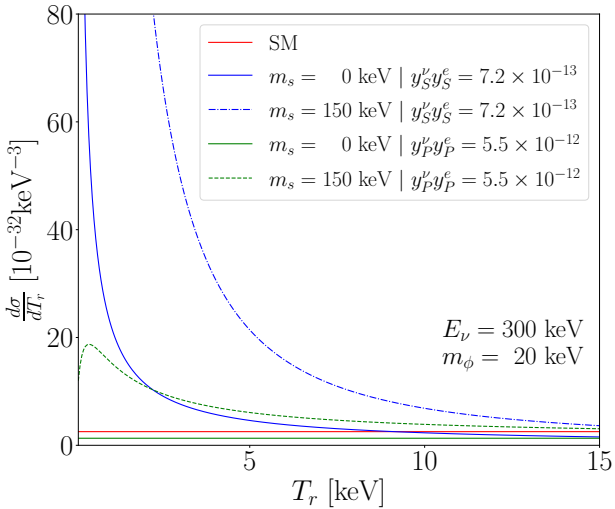


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$m_\phi > 0$ needed for NSI bounds.

Another important detail for $m_s > 0$

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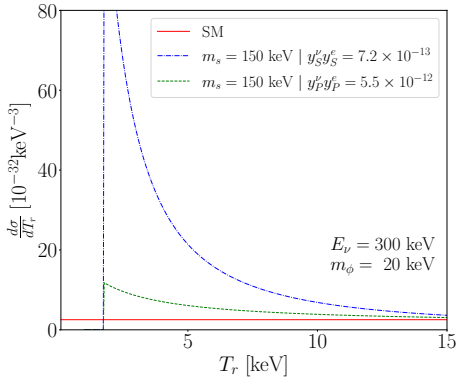

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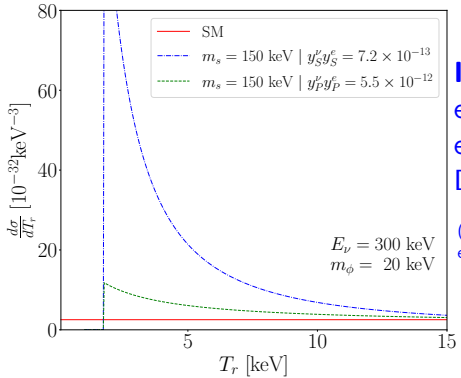


**Interesting!** If we have enough resolution, we can even get the mass of $m_s$ from DM experiments

(A bit trickier due to nuclear effects and detector resolution)

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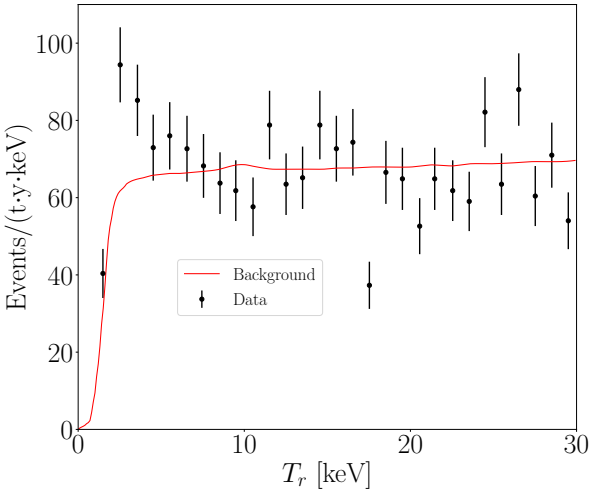

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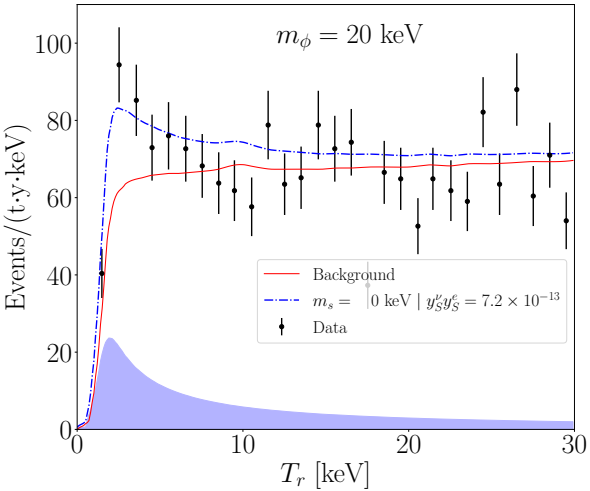

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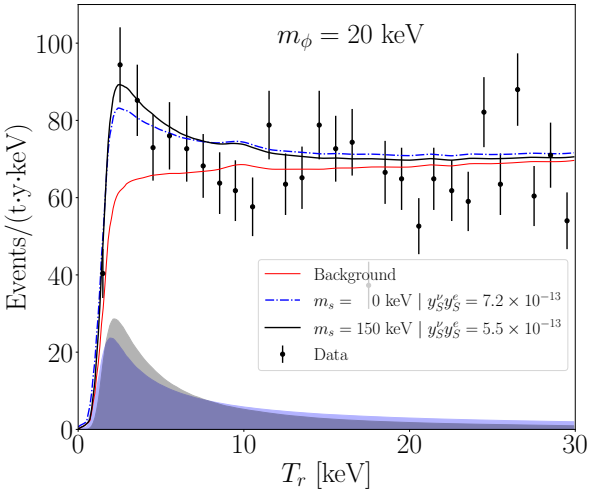

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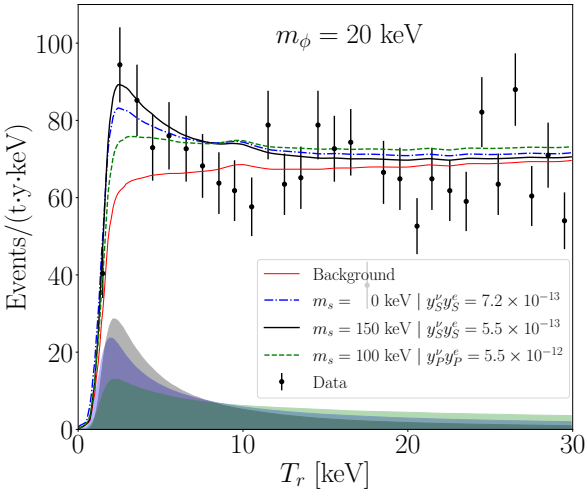

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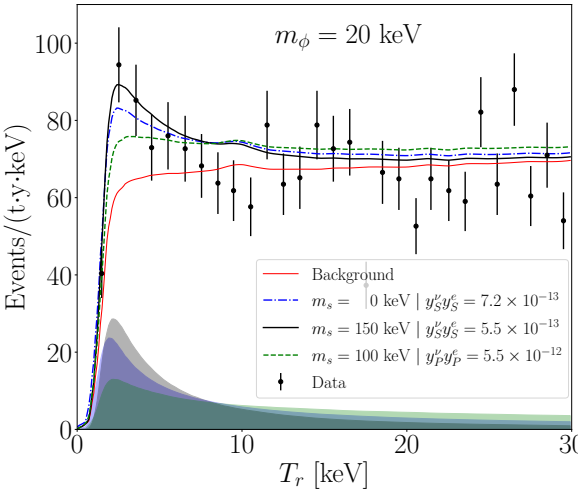


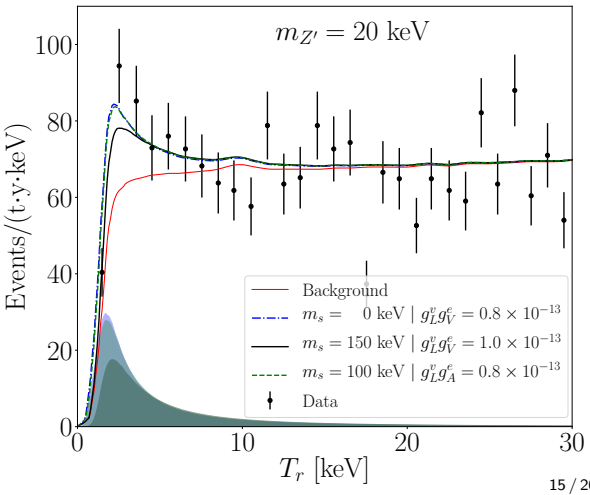

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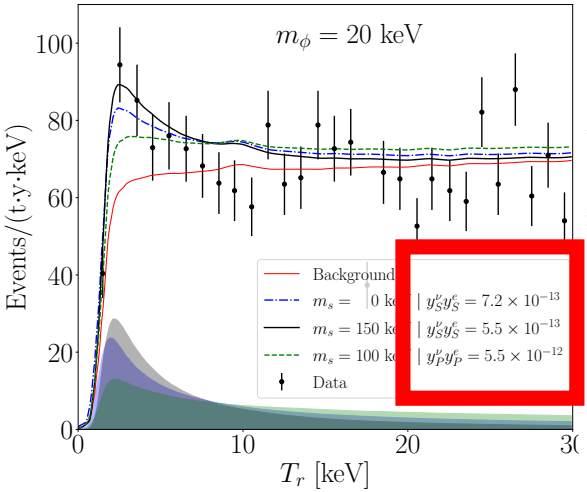
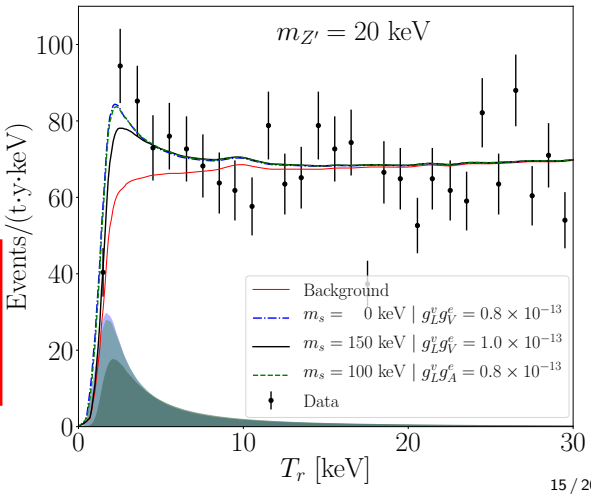
couplings $O(10^{-13})$



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NSI constrains for vector mediators: $\epsilon_{es} = \frac{g^\nu g^e}{4\sqrt{2} G_F m_{Z'}^2} \implies |g^\nu g^e| < 10^{-14} \left(\frac{m_{Z'}}{\mathrm{keV}}\right)^2$ for $\epsilon_{e\alpha}$ bounds, but it is hard to find bounds for sterile couplings. JHEP 01 (2021) 114

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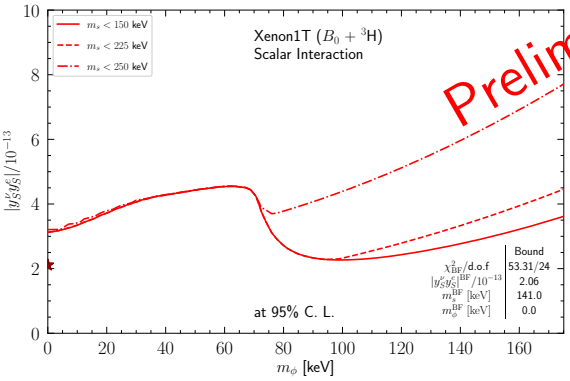
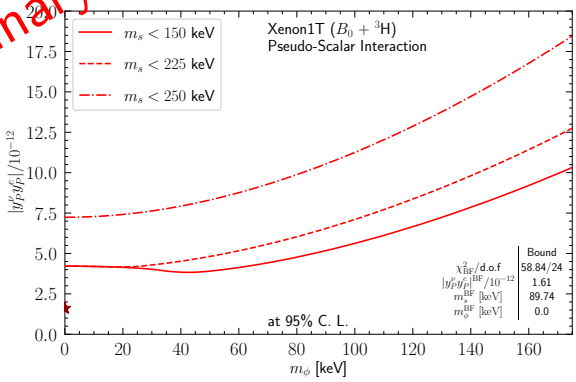
In any case: bounds on such couplings are interesting and are competitive for DM exp.

Thanks for your attention



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**Note:** Exotic scenarios are allowed (eg $\chi + \chi + e \to \chi + e$ PRL 125 (2020) 13, 131301)