The XENON1T Electronic Recoil Excess

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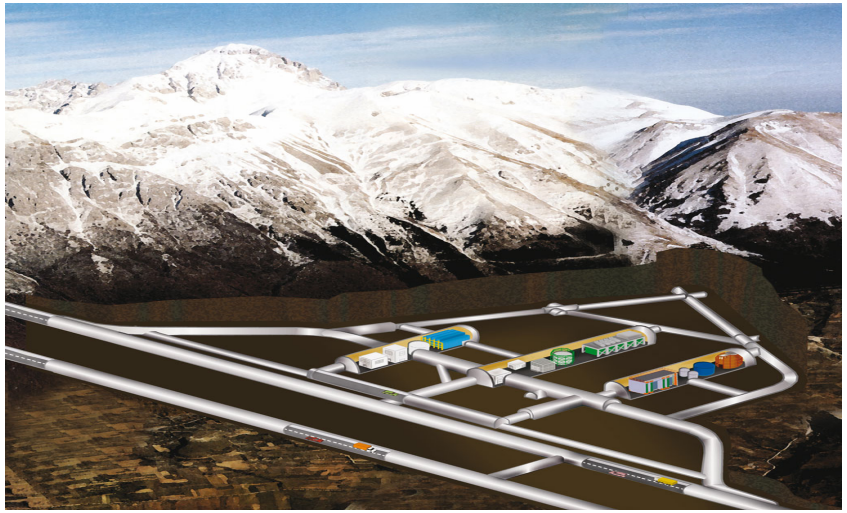
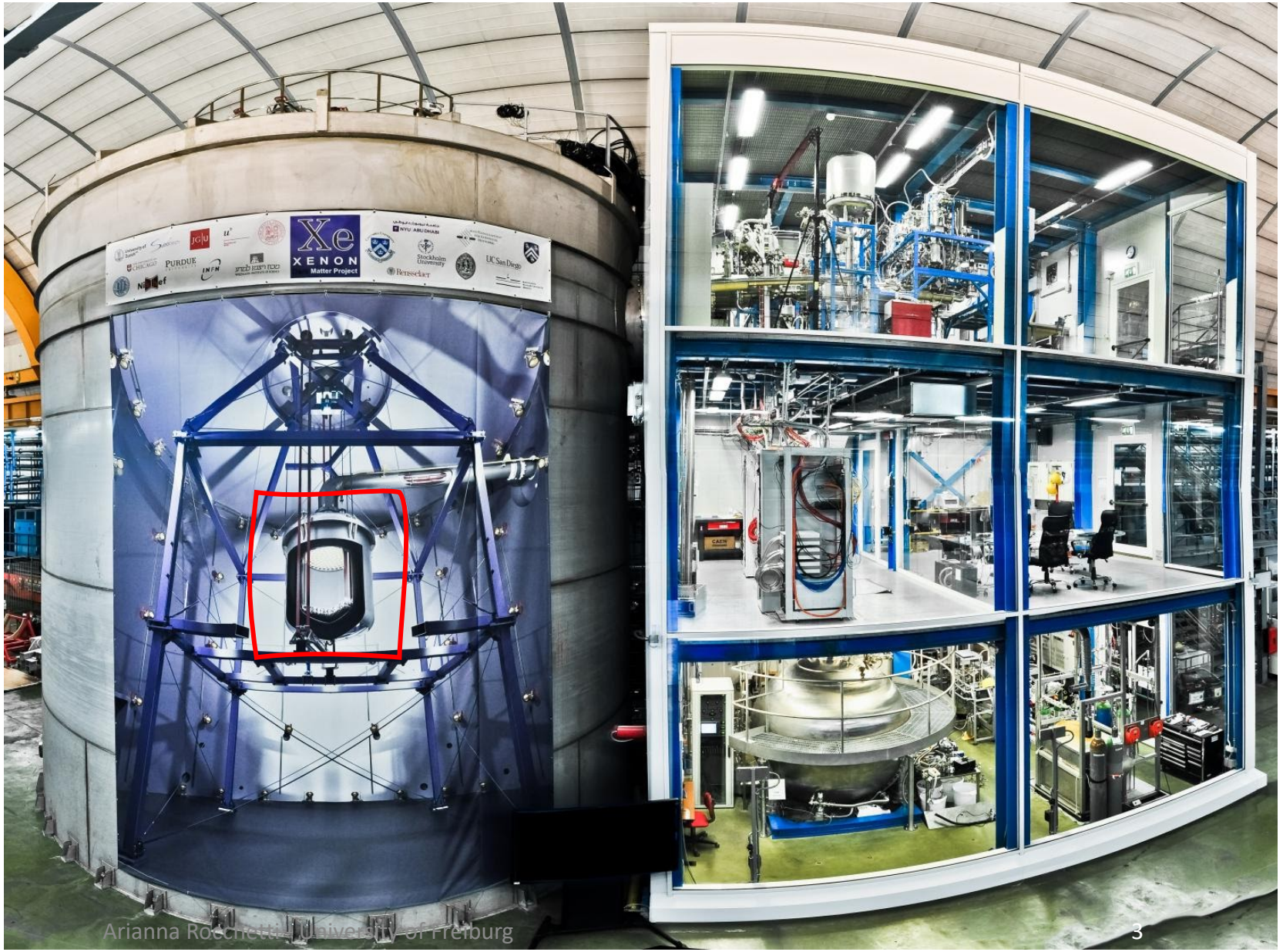
On behalf of the XENON collaboration + X. Mougeout

The XENON Collaboration

The XENON1T Detector



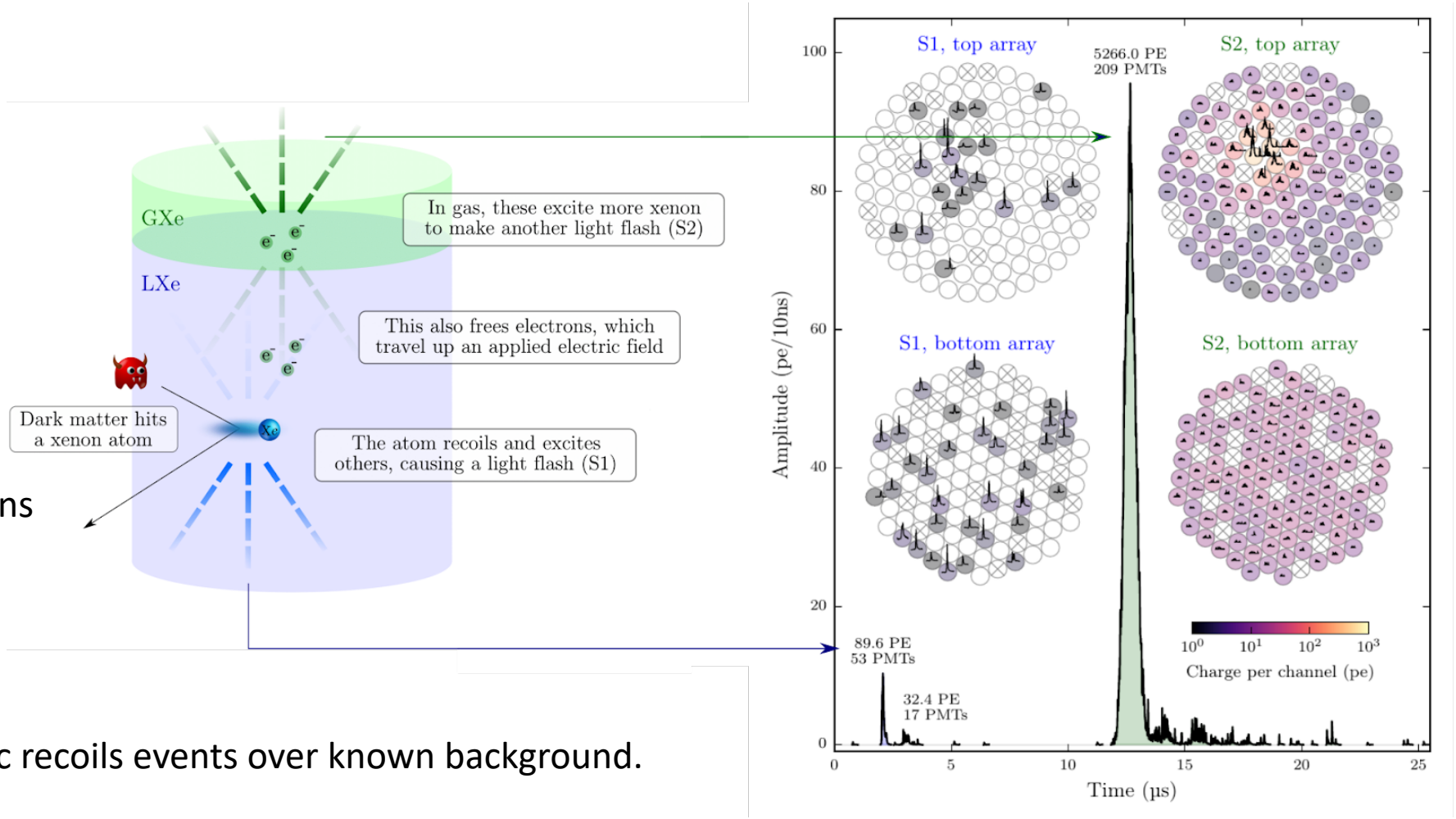


Dual – Phase Time Projection Chamber (TPC)

The XENON1T TPC:

- 3D reconstruction of interaction site:
  (x, y) from S2 hit patterns
  z from electron drift time

- S2/S1 signal discrimination
  Nuclear recoil: WIMP, neutrons
  Electron recoil: ɣ and e^-



We look for an excess of electronic recoils events over known background.

The Background Model

Background model B_0: 10 components

Intrinsic
^{214}Pb ^{85}Kr
^{136}Xe ^{124}Xe

Materials

Neutron activated
^{131m}Xe , ^{133}Xe, ^{125}I

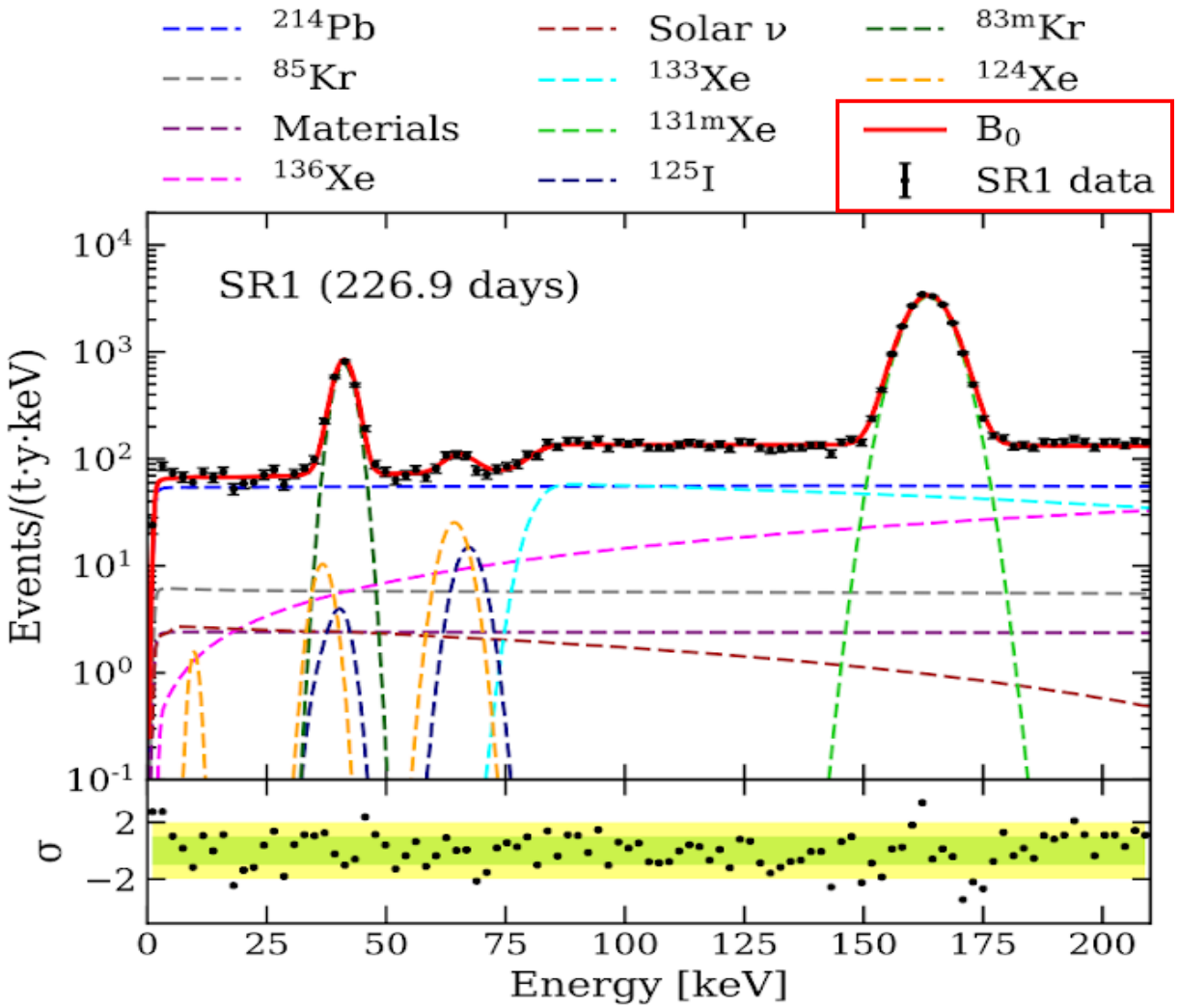
Solar Neutrinos

- Background sources modeled with Geant4
- Most rates constrained by other measurements or time dependence
- Lowest background rate ever achieved:

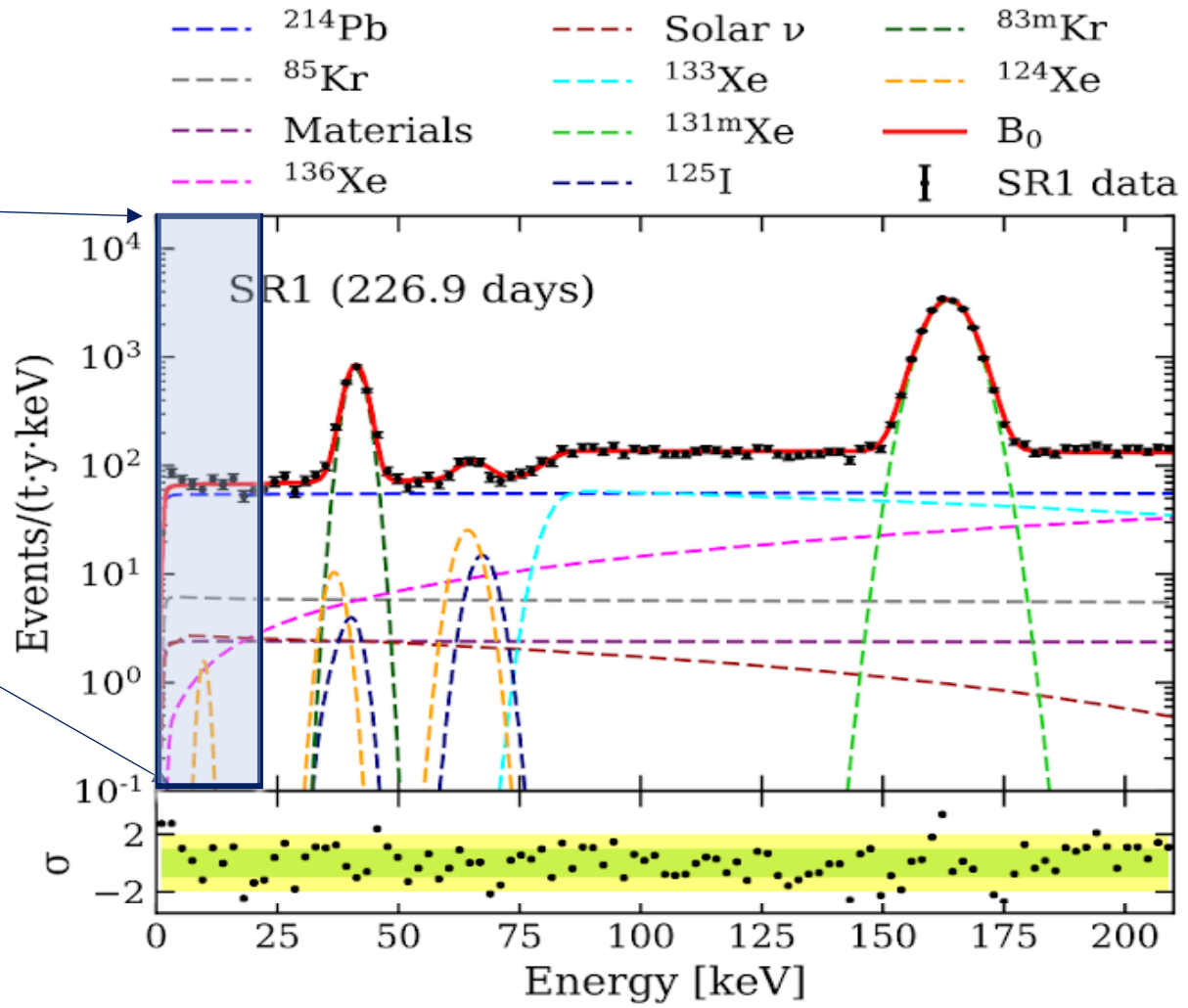
  (76 +/- 2) events/(t · keV · y)

  in [1, 30] keV
- Good agreement between MC and data

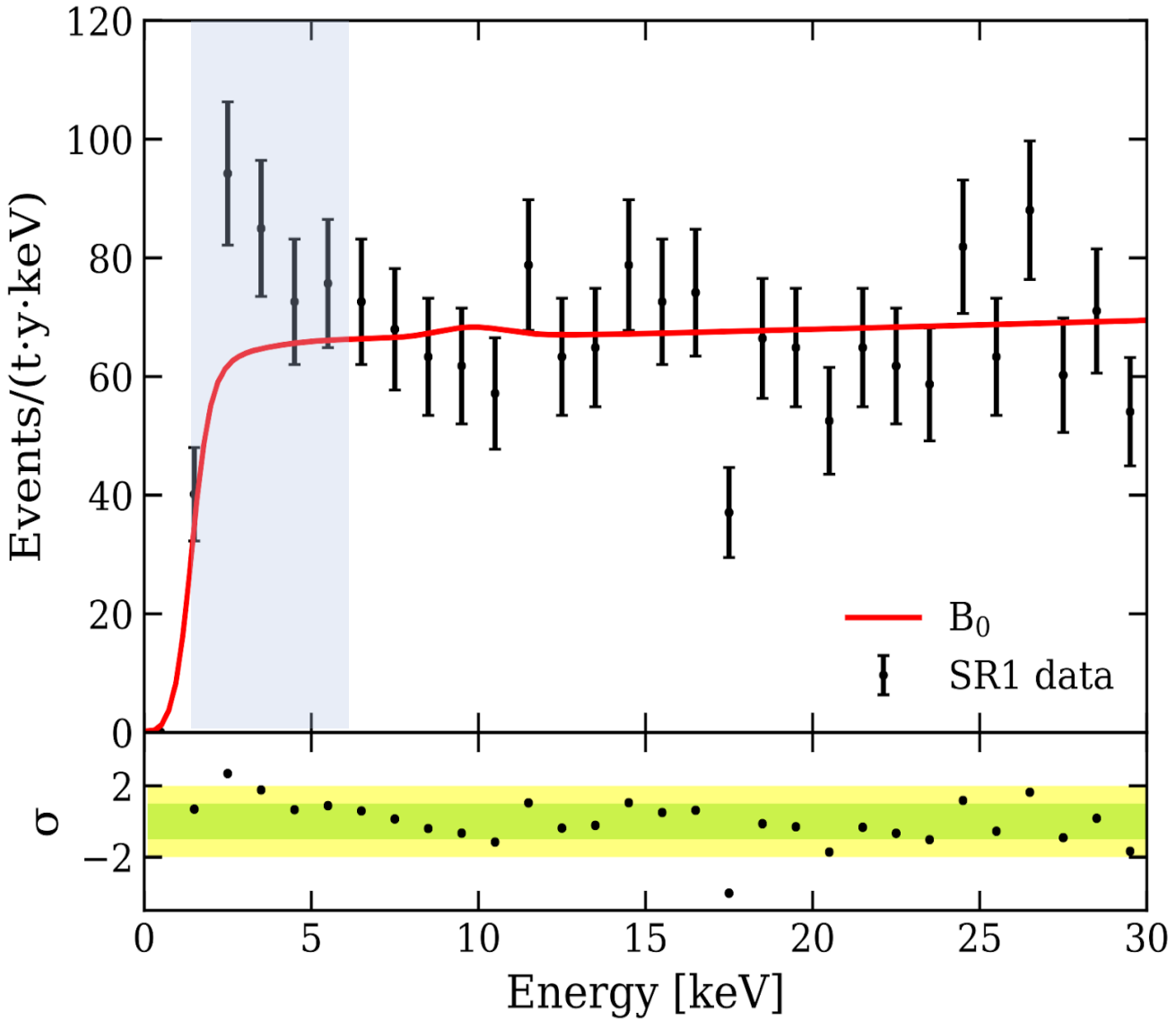
Expected contributions:



The Background Model



The Excess



Event selection:

- Exposure: 0.65 t · y
- Single scatter events within [1, 210] keV_{ee}
- Consider efficiencies of reconstruction and data quality cuts

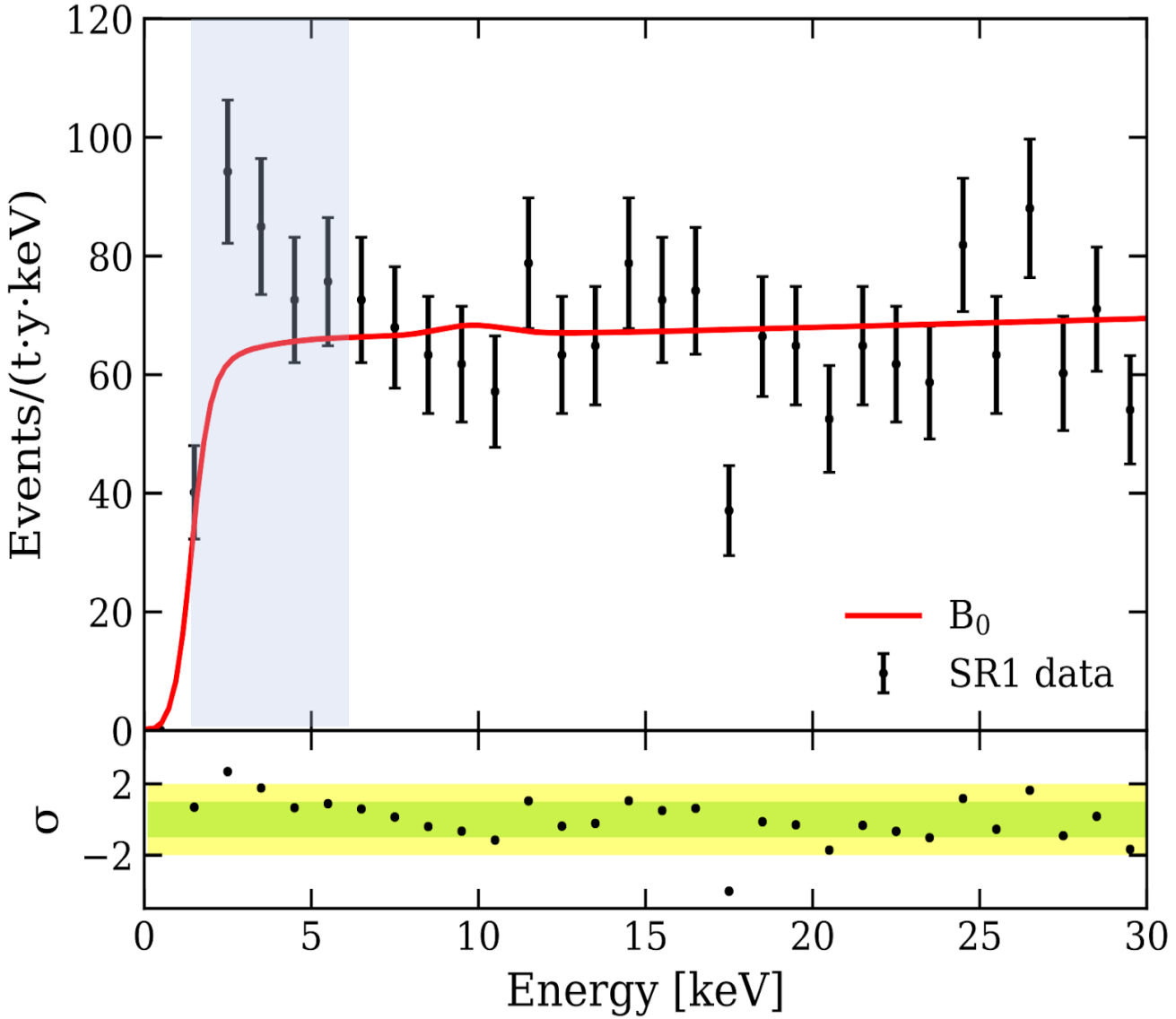
Excess between 1 – 7 keV !

Expectation: 232 +/- 15
Observation: 285

Unbinned profile likelihood for the main analysis

Unbinned energy points below 30kev and background model available on Zenodo.

The Excess

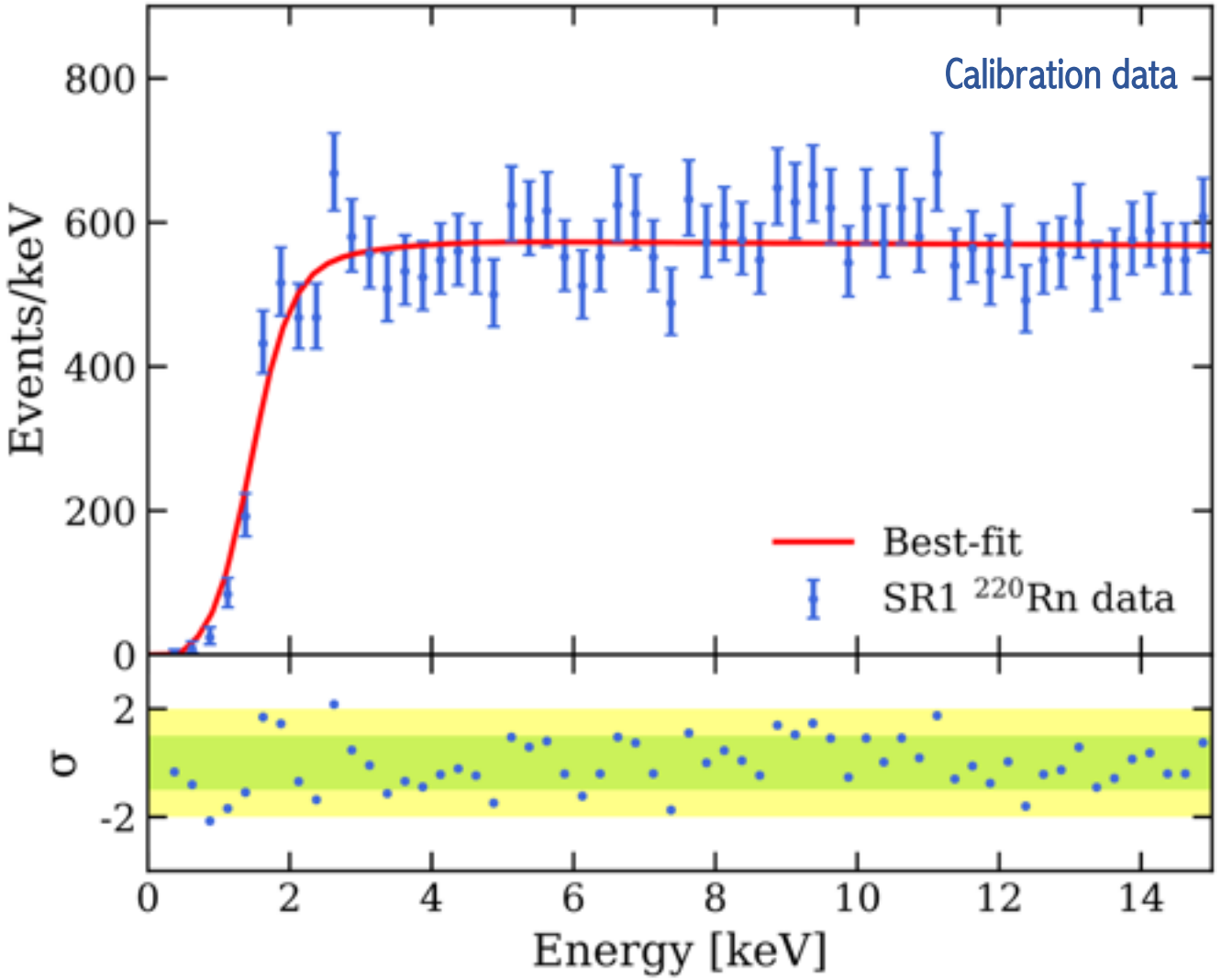


Background mismodeling?

Missed Background?

New physics?

Background mismodeling



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New physics?

- ^{220}Rn (^{212}Pb , β-decay) calibration data validates our model even at sub 1keV energies
- Excess not at the threshold fall-off: Doubling analysis threshold, excess persists
- Absence of large systematics

Fit to **calibration data**: theoretical β-decay model + efficiency using same unbinned likelihood frameword as main analysis

Missed background

Potential background source can be:

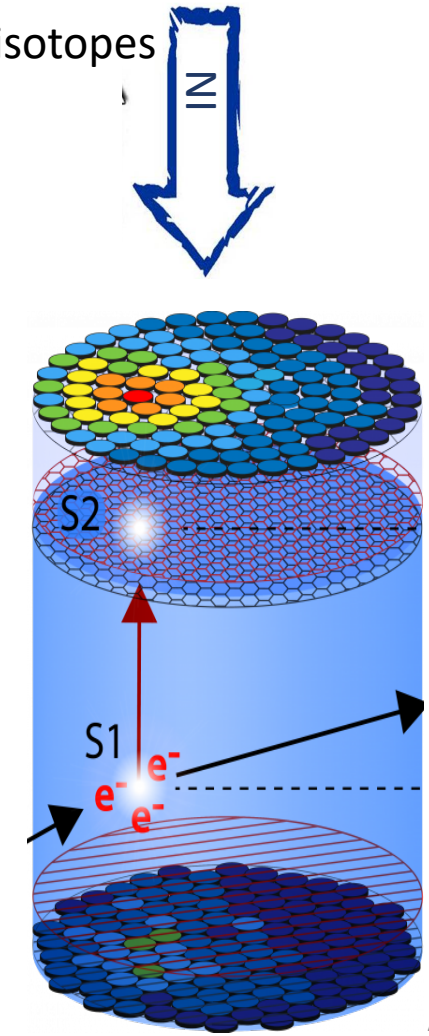
- cosmogenically activated isotopes

^{127}Xe

$\tau_{1/2}$ ~ 36 days

- Decayed,
- no γ detected.

Excluded.



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^{37}Ar $\tau_{1/2}$ ~ 35 days

^{127}Xe $\tau_{1/2}$ ~ 36 days

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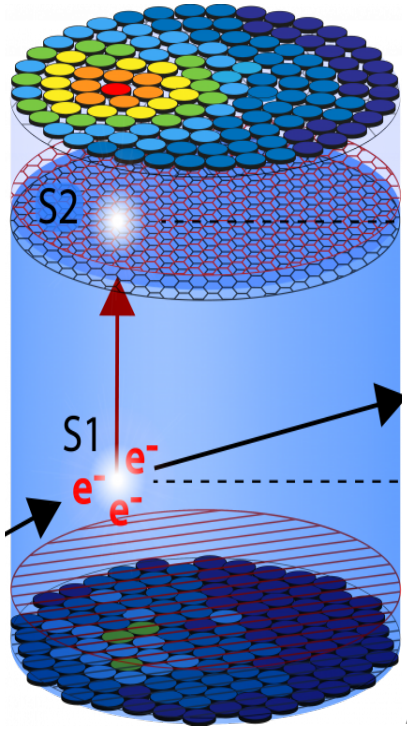
Excluded.

IN

- abundant in atmosphere and leak in
- already present in the xenon gas



OUT

- removed by distillation

- Reduced by distillation to < 1 ev / (t · y)
- Expected rate from leak < 5.2 ev / (t · y)

→ 1/13 of the rate necessary to make up the excess. **Excluded.**

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Missed background

Potential background source can be:

- cosmogenically activated isotopes

^{37}Ar $\tau_{1/2}$ ~ 35 days

^{3}H $\tau_{1/2}$ ~ 12 years

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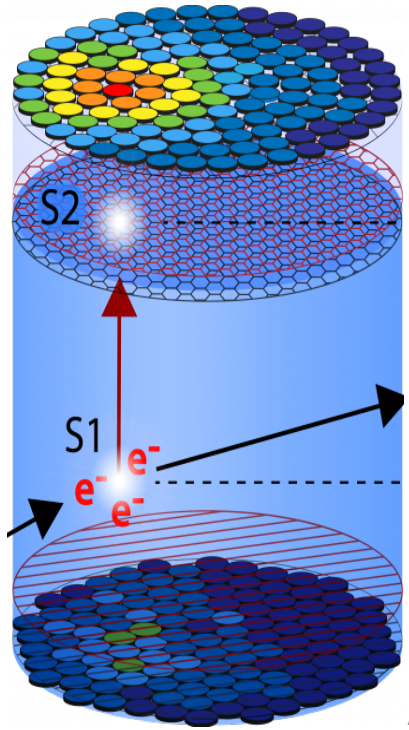


IN

- emanated from materials

^{3}H $\tau_{1/2}$ ~ 12 years

OUT

- removed by distillation

Background mismodeling?

Missed Background?

New physics?

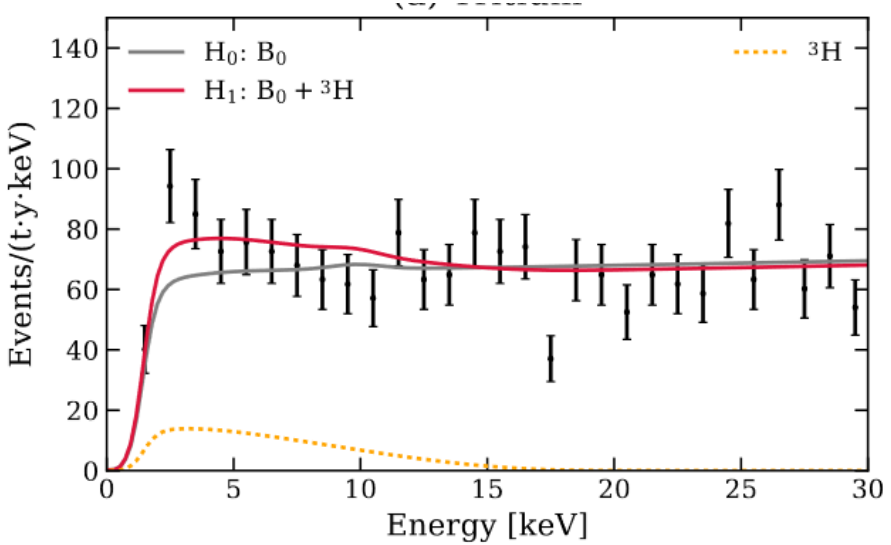
^{3}H

- β emitter
- Q-value 18.6keV
- $\tau_{1/2}$ ~ 12 years

Tritium

- We search for a ^{3}H signal on top of the background model
- The **^{3}H** hypothesis vs **B_0** favoured at 3.2σ
- Best fit :

  ^{3}H/ Xe = **(6.2 +/- 2.0) 10^{-25} mol/mol**



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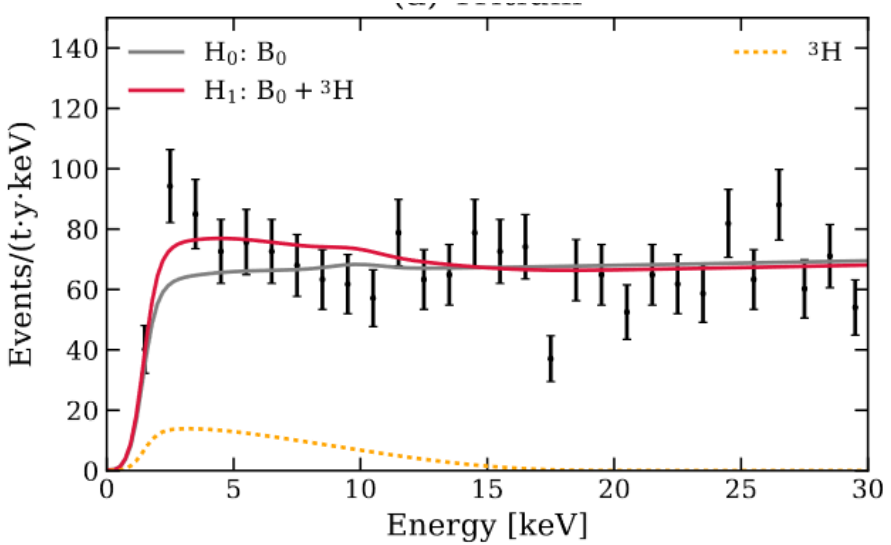

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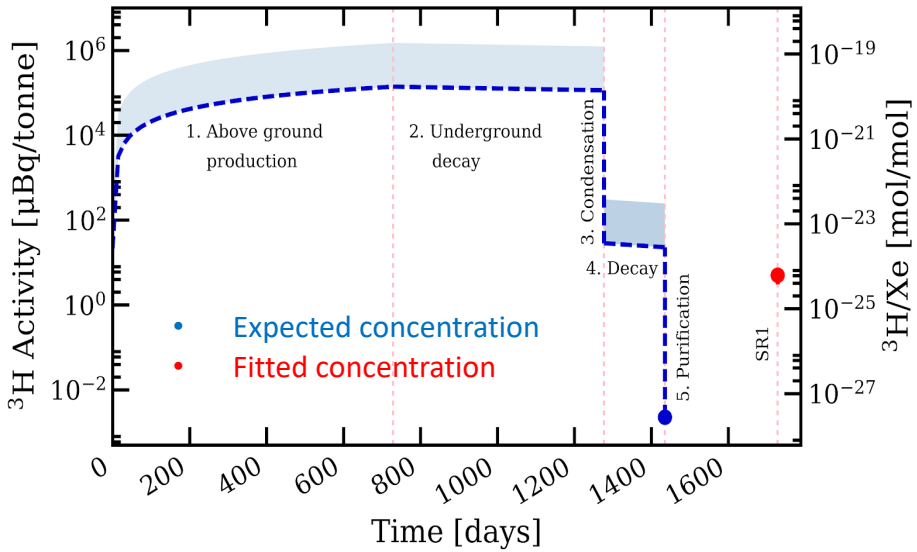
New physics?

^3H from cosmogenic activation & emanation from detector materials.



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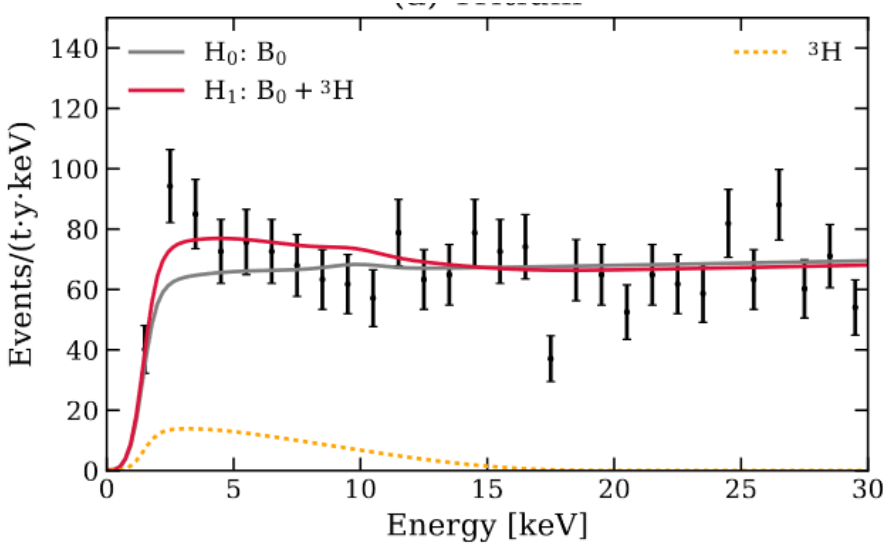


Background mismodeling?

Missed Background?

New physics?

^3H from cosmogenic activation & emanation from detector materials

To explain the excess: > 30 ppb H_20 + H_2

tritiated water **HTO**
atmospheric: (5-10) 10^{-18} HTO / H_20
Light yield measurements: O(1) ppb

gaseous tritium **HT**
assuming: (5-10) 10^{-18} H_2 / H_20
Electron lifetime: < 1 ppb 0_2-equivalent impurities

Can neither confirm nor rule out Tritium

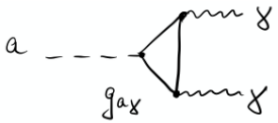
New physics

Many models to interpret the excess :

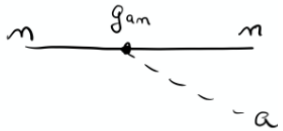
1. Solar axions

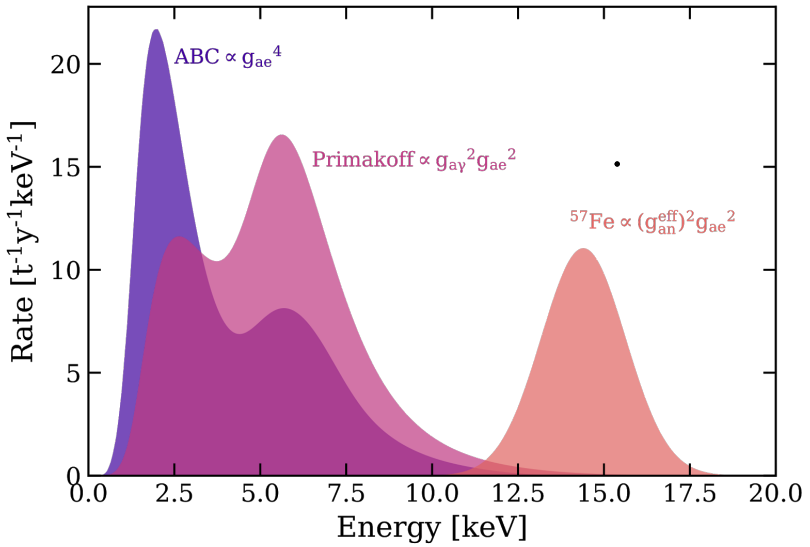
1. ABC:

2. Primakoff:



3. ^{57}Fe:





Background mismodeling?

Missed Background?

New physics?

2. Neutrino Magnetic moment

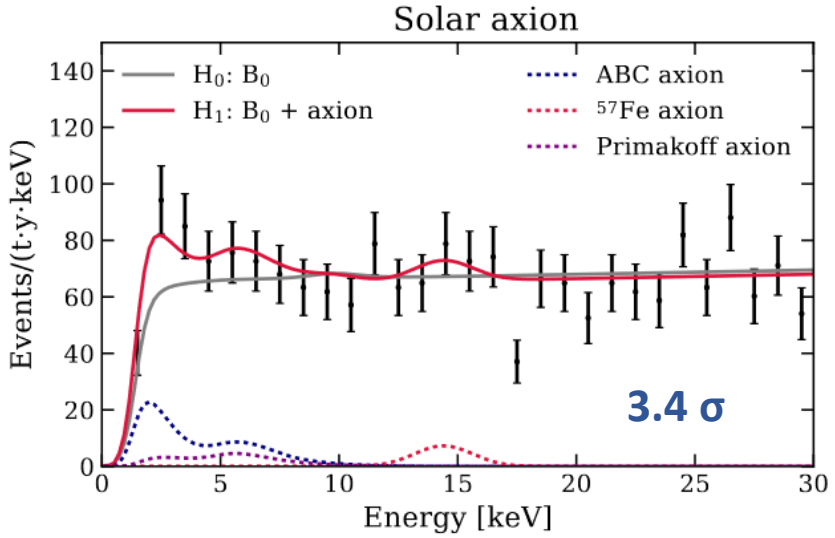
- Enhancement of the electron-neutrino cross section
- Power-law signature

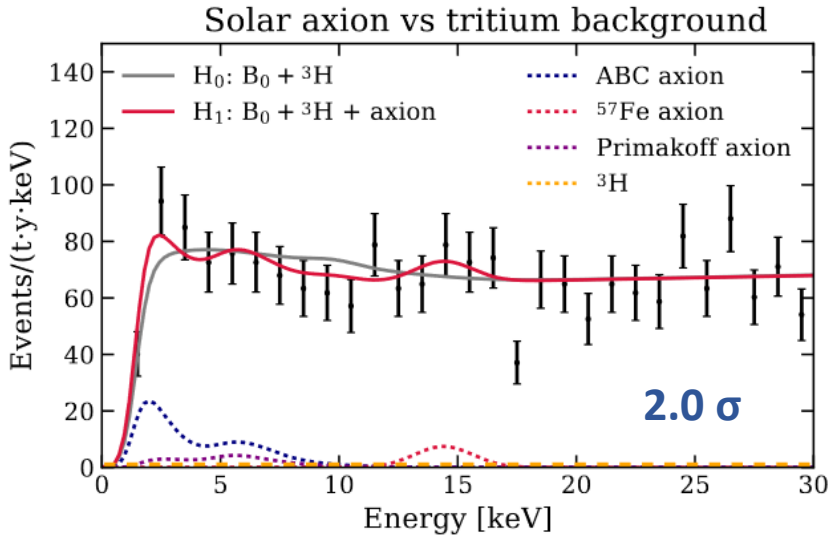
3. Bosonic Dark Matter

- Pseudoscalar boson: ALPs (Axion – like particles)
- Vector boson: Dark Photon
- Peak - like signature

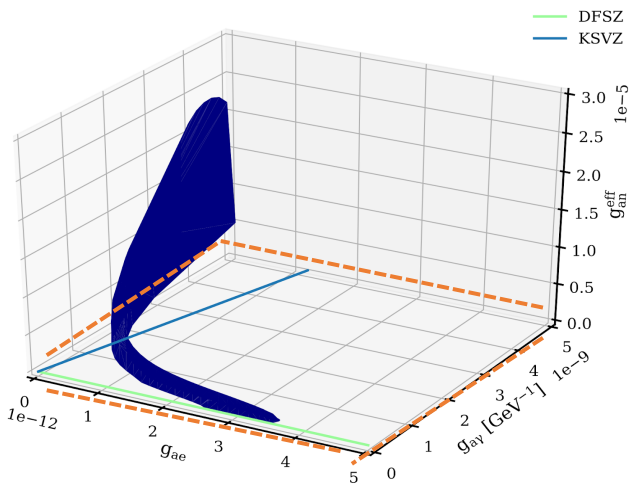
New physics: Axion

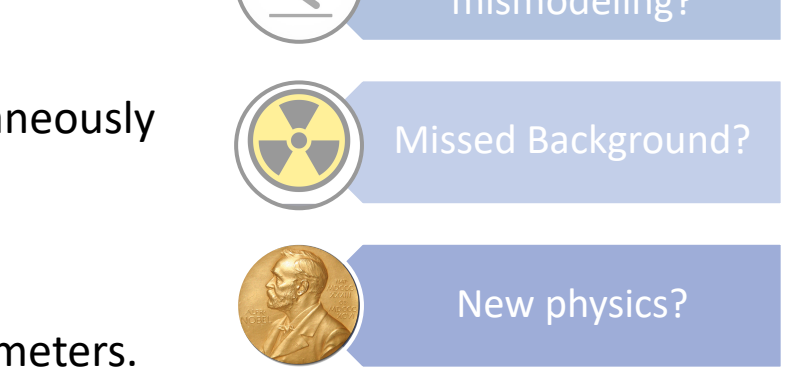
Many models to interpret the excess : let's have a deeper look into AXIONS



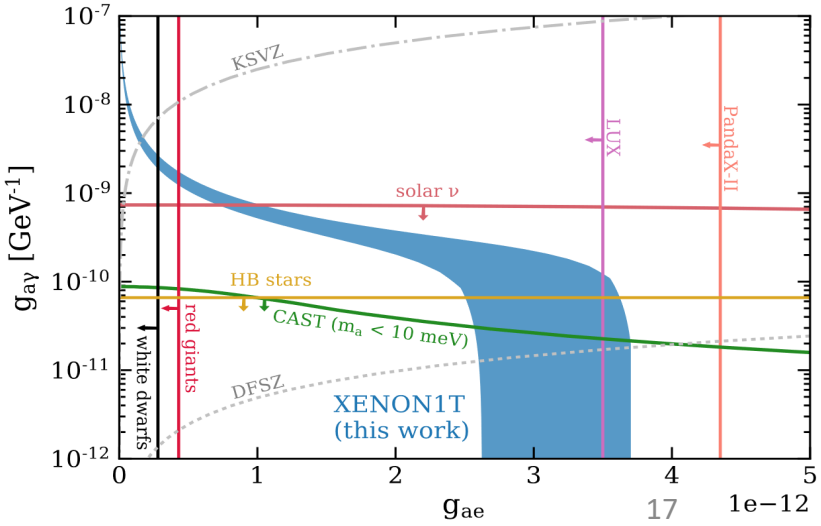


- Search for:
  ABC, **Primakoff** and **^{57}Fe** axions simultaneously
  .
- Axion hypothesis favoured at **3.4 σ**
- 3D region for the three couplings parameters.





But: strong tension with astrophysical constraints from stellar cooling



Background mismodeling?

Missed Background?

New physics?

XENONnT

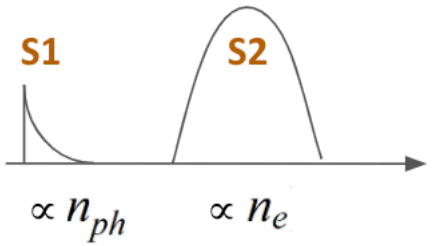
- x3 larger active volume
- $^1/_6$ background level
- new neutron veto
- new ReStoX2
  (Secondary Recovery and Storage of Xenon)
- new purification and distillation system

XENONnT will discriminate axions from tritium in few months of data.

xe-pr@lngs.infn.it
www.xenonexperiment.org
Twitter: https://twitter.com/XENONexperiment
Facebook: https://www.facebook.com/XENONexperiment
Instagram: https://www.instagram.com/xenon_experiment

Back-up SLIDES

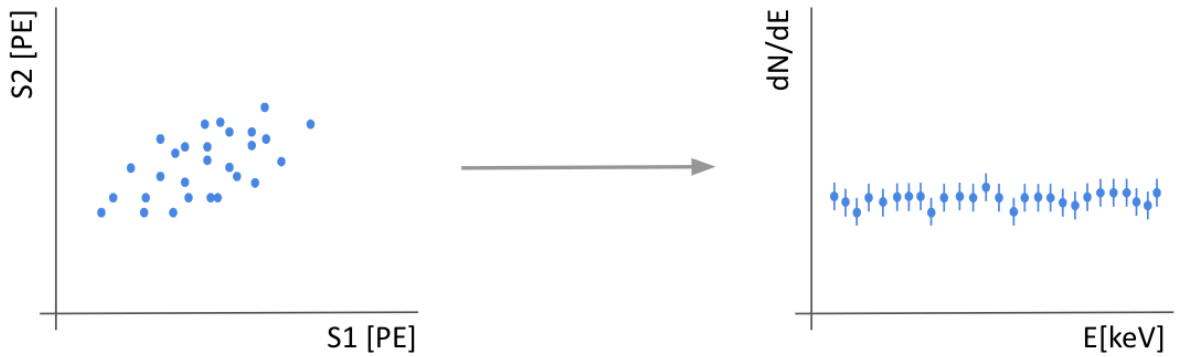
Energy reconstruction



$$E = (n_{ph} + n_e) \cdot W = \left(\frac{S1}{g1} + \frac{S2}{g2}\right) \cdot W$$

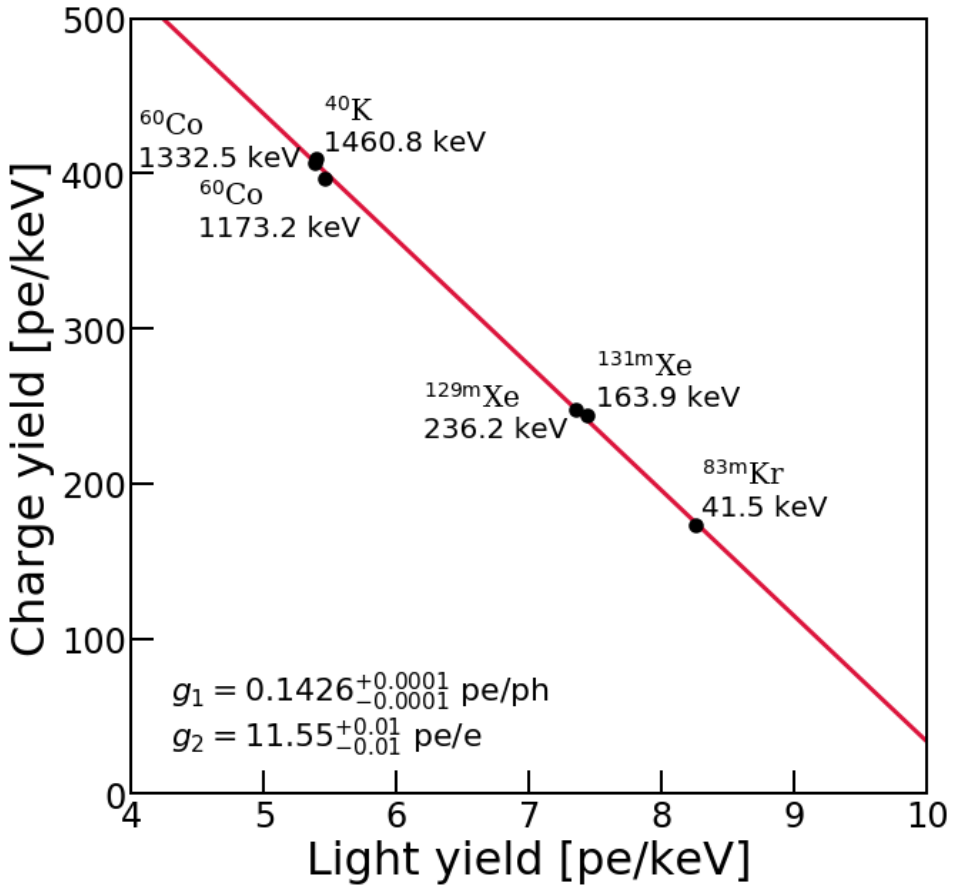
$$W = 13.7\ eV/quanta$$

$$\frac{S2}{E} = \frac{g2}{W} - \frac{g2}{g1}\frac{S1}{E}$$



2D analysis

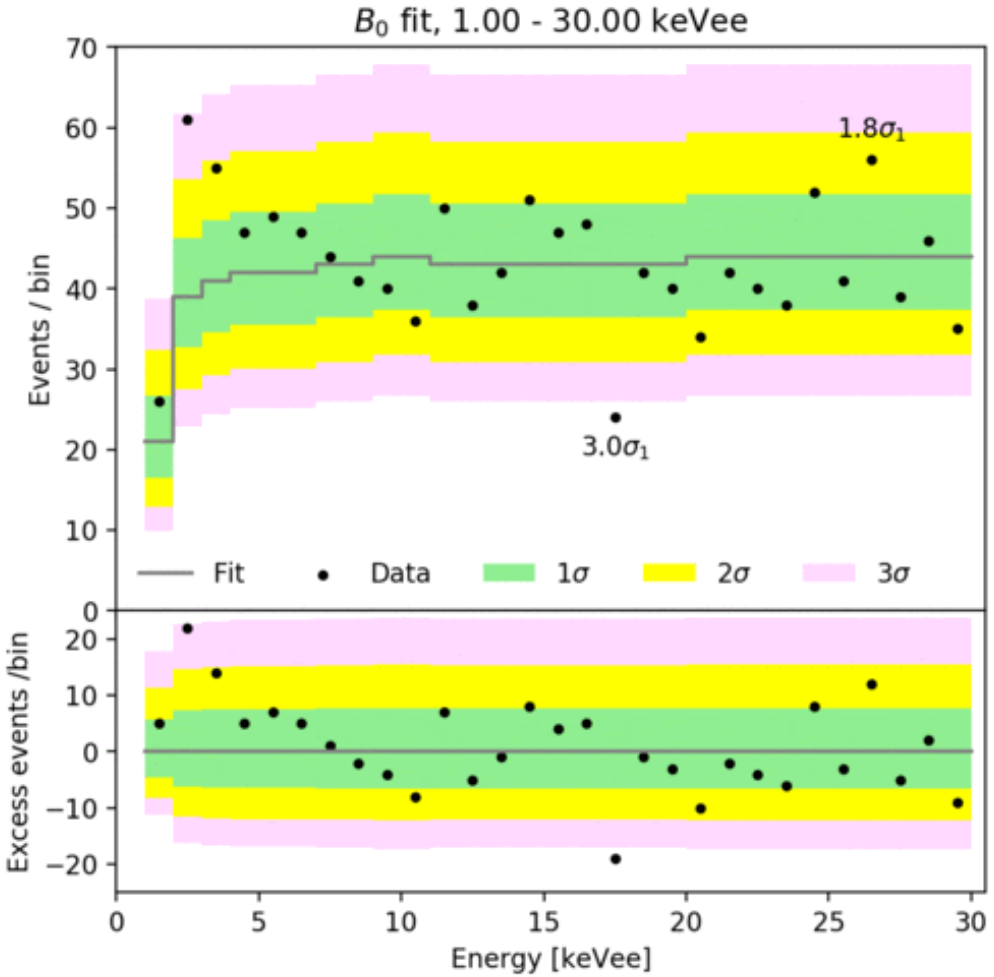
1D analysis

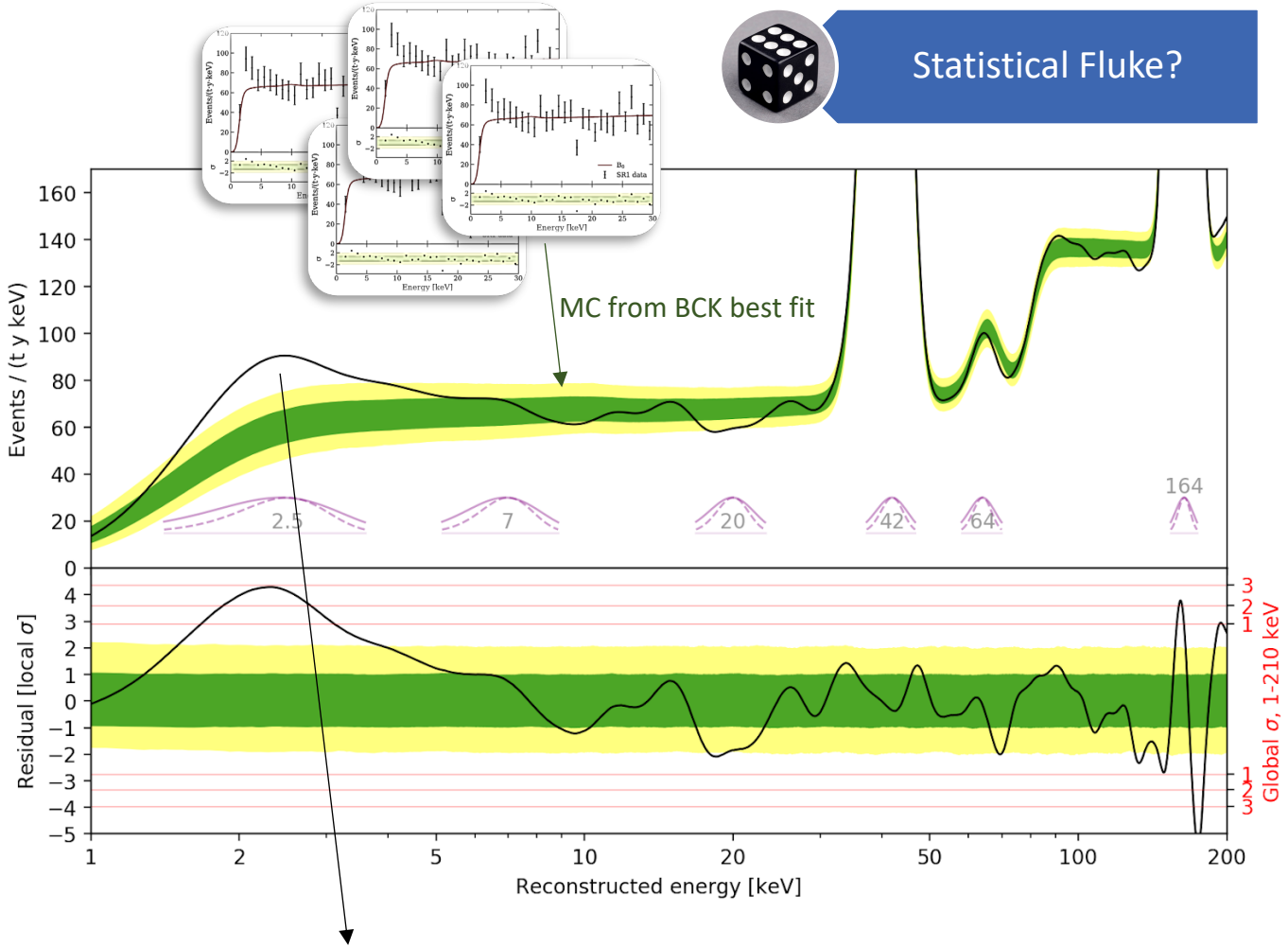


Slide credit: D. Ramírez

Statistical Fluke

Unbinned profile likelihood analysis

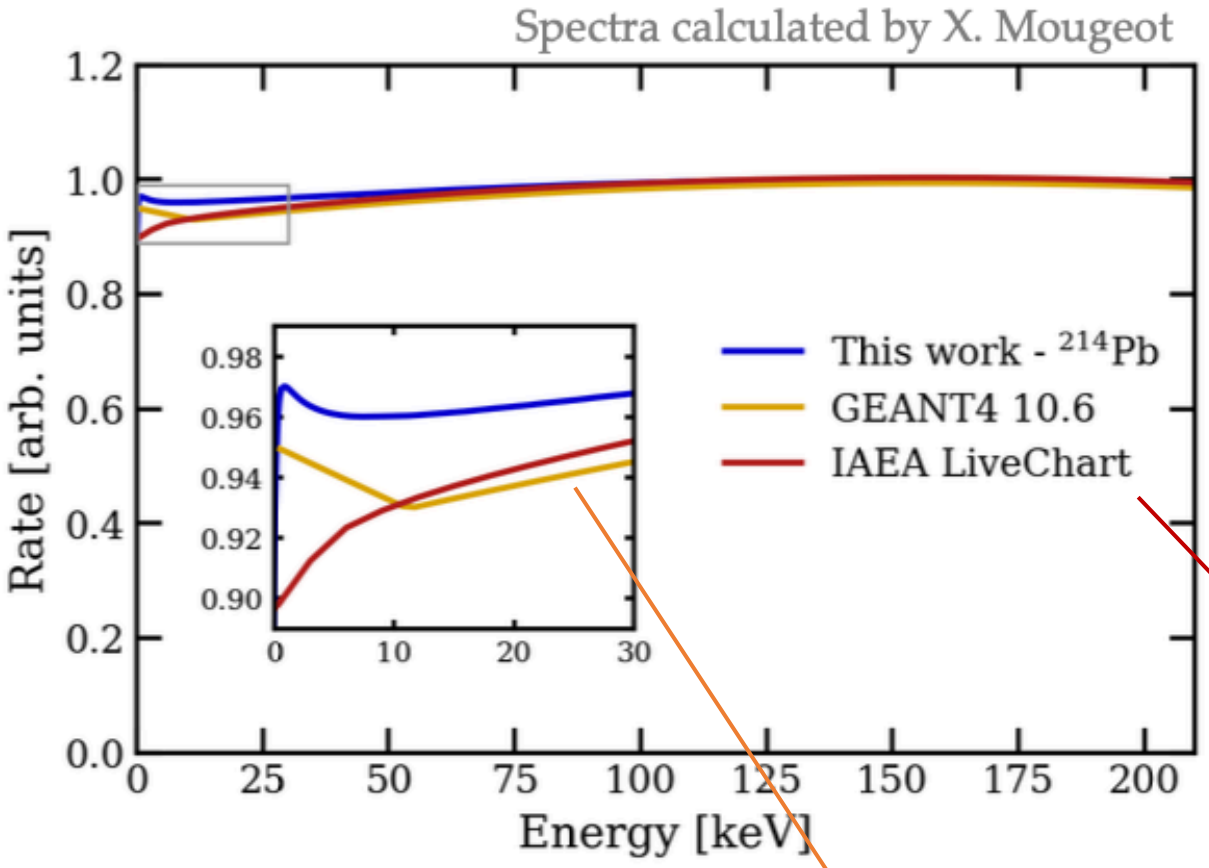




KDE with kernel proportional to Energy resolution

Slide credit: J. Aalbers

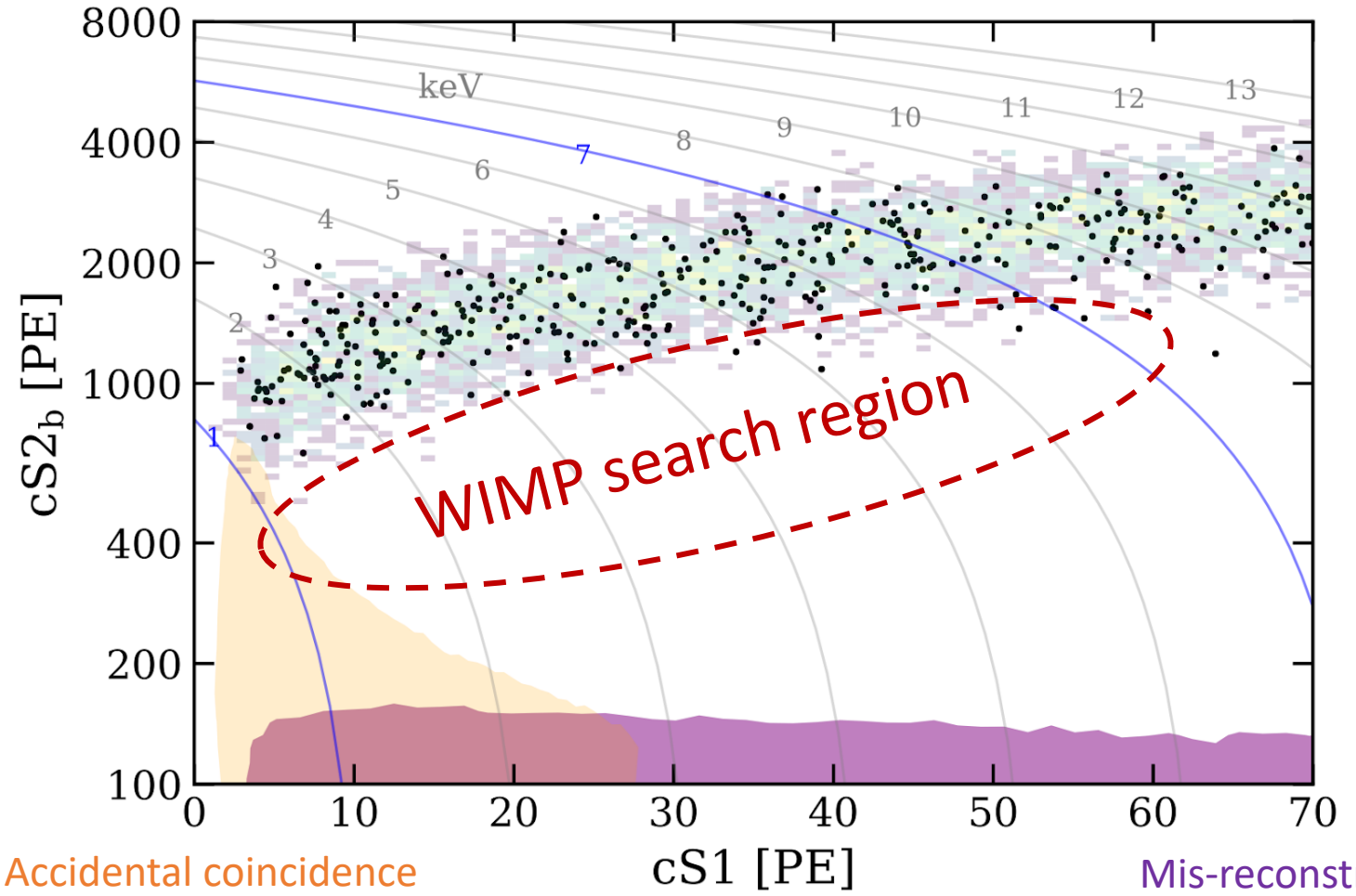
Atomic screening and **exchange effects**
can slightly increase the rate at low energies
~ 6% uncertainty on the shape, while ~ 50% needed to account for the excess



Only screening effects.

Allowed and forbidden unique transition. No exchange effects.

- Statistical Fluke?
- Background mismodeling?
- Missed Background?
- **Background shape?**
- Instrumental background?
- Time – dependent signal?
- Excess not uniform?
- New physics?



Accidental coincidence

Mis-reconstructed events from detector surfaces

- Statistical Fluke?
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- Background shape?
- **Instrumental background?**
- Time – dependent signal?
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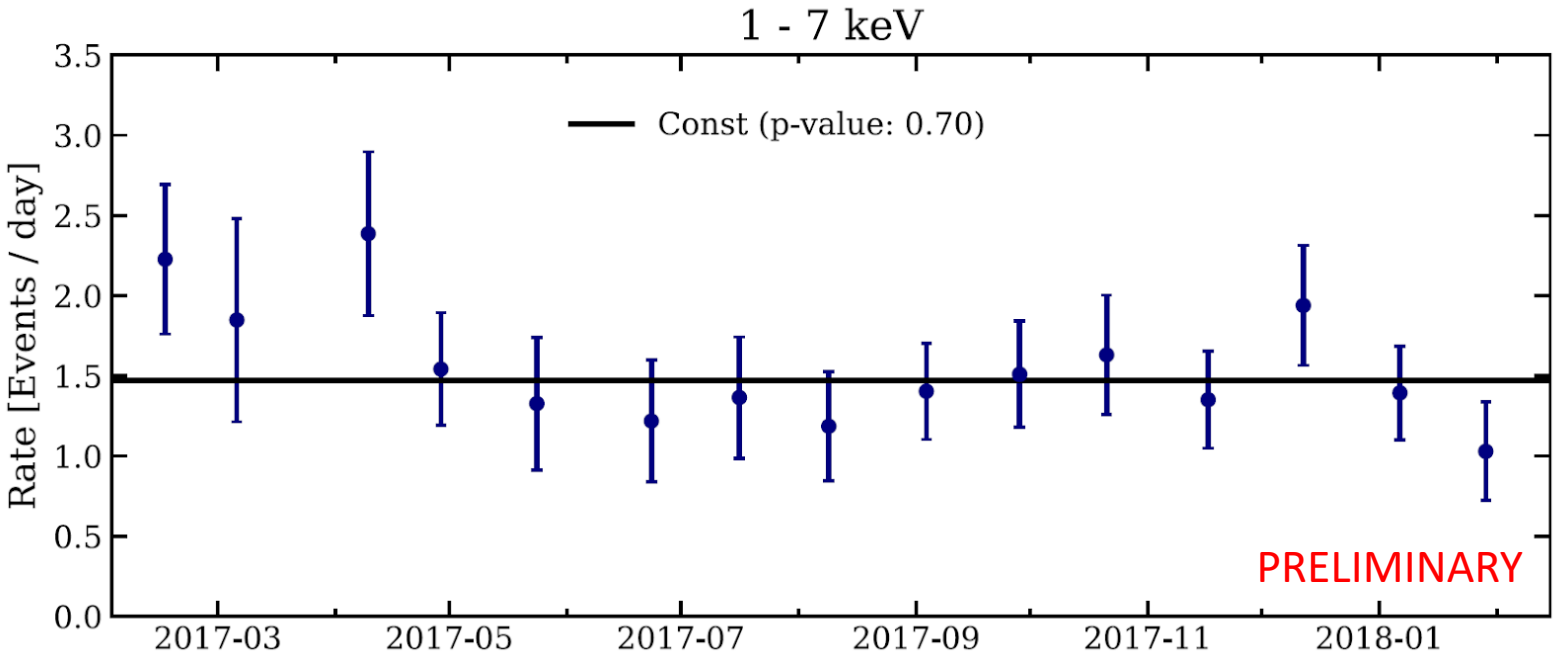
- New physics?

Compatible with:

- Modulation due to Earth-Sun distance to test solar axion and neutrino magnetic moment.
- ^{3}H decay + const.
- Constant

Insufficient statistic to be conclusive.



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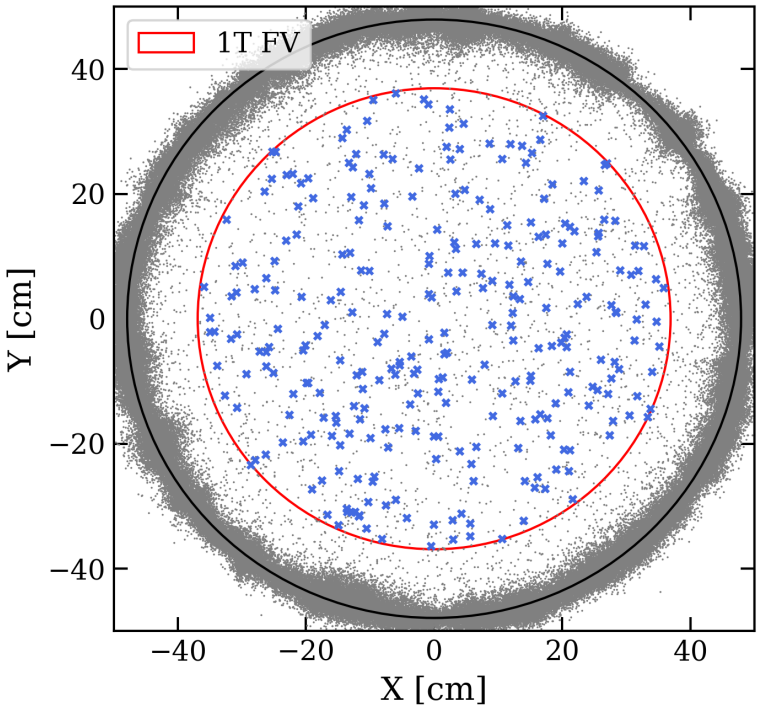

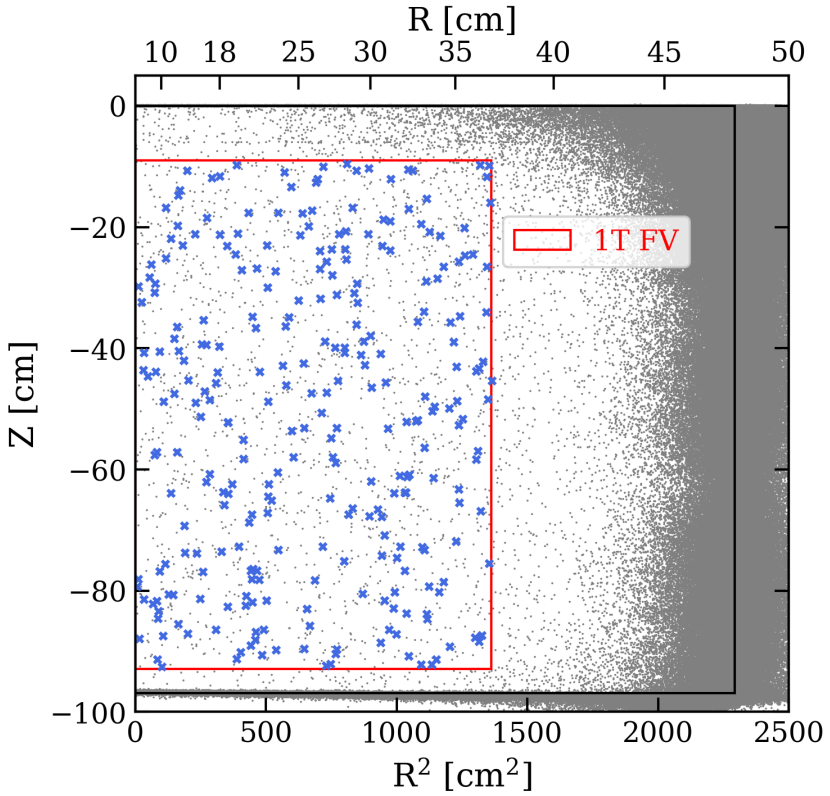

- [1 - 120] keV
- [1 - 7] keV


Statistical Fluke?


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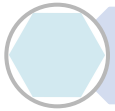
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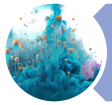
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New physics

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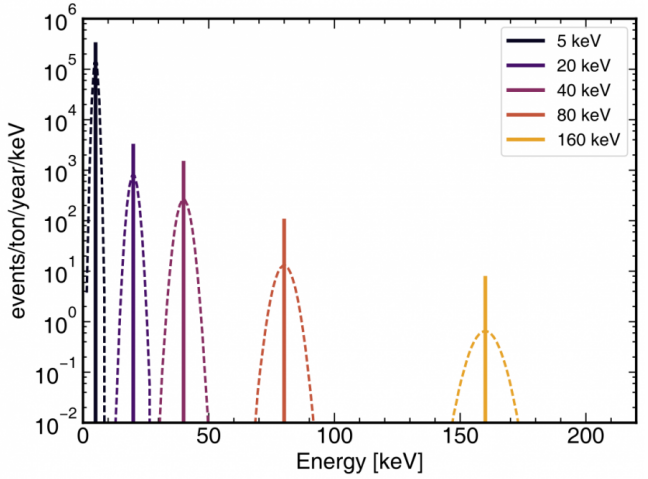
- Pseudoscalar boson: ALPs (Axion – like particles)
- Vector boson: Dark Photon

- Peak - like signature

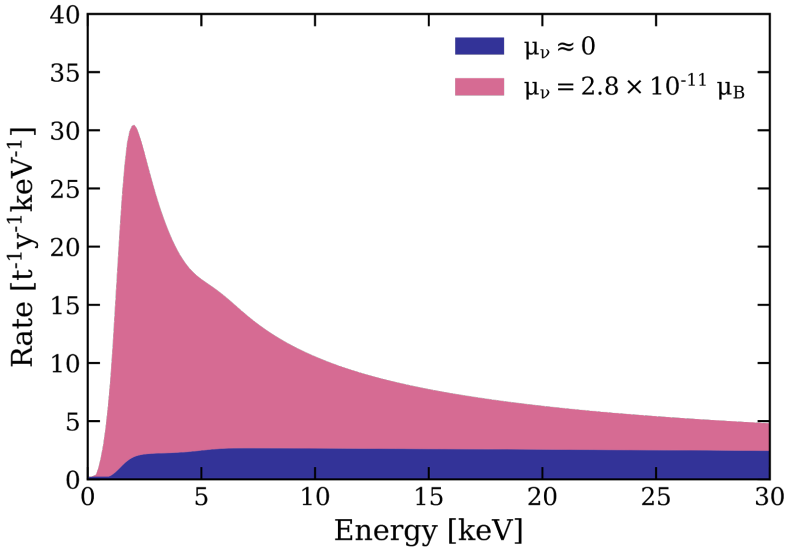


Background mismodeling?

Missed Background?

New physics?

2. Neutrino Magnetic moment

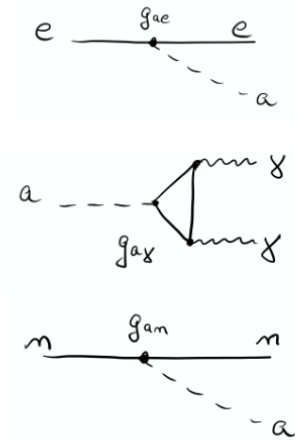


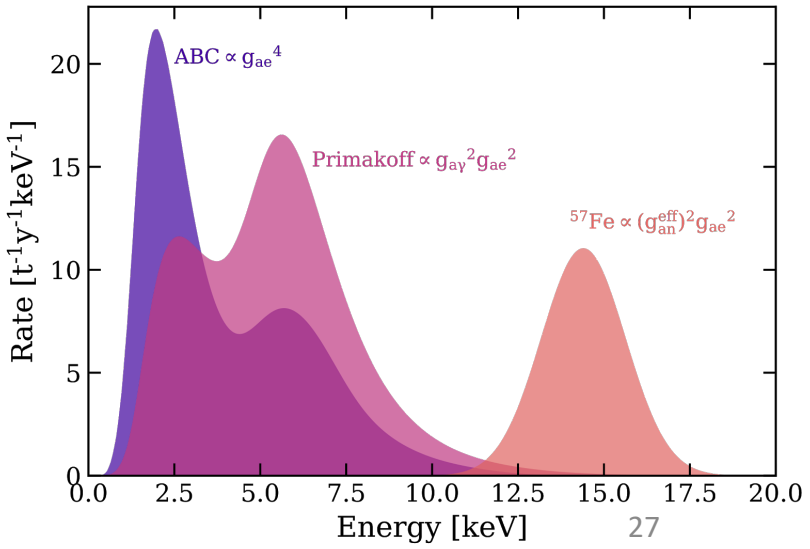
3. Solar axions

1. ABC:

2. Primakoff:

3. ^{57}Fe:





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