NAGOYA UNIVERSITY
ISEE
INSTITUTE FOR SPACE-EARTH
ENVIRONMENTAL RESEARCH

Xe
XENON
Dark Matter Project

Observation of Excess Electronic Recoil Events in XENON1T

XENON collaboration + X. Mougeot

arXiv:2006.09721

Masaki Yamashita for the XENON collaboration

2020/07/22 RIKEN iTHEMS DM WG Webinar

www.xenonexperiment.org
: https://twitter.com/XENONexperiment
: https://www.facebook.com/XENONexperiment
: https://www.instagram.com/xenon_experiment/

New York Times
2020/June/17

OUT THERE

Seeking Dark Matter, They Detected Another Mystery

Do signals from beneath an Italian mountain herald a revolution in physics?

Outline

- XENON1T Detector
- What is Electronic Event?
- Background model
  - + Tritium
  - + Solar Axion
  - + neutrino magnetic moment
  - + Bosonic dark matter
- Future prospect

XENON1T Experiment

The XENON Collaboration: ~170 scientists

Columbia RPI Nikhef Muenster KIT Stockholm Mainz MPIK, Heidelberg Freiburg

Chicago

UCSD

Rice

Purdue

Zurich

Tokyo

Nagoya

Coimbra Subatech LPNHE LAL Bologna LNGS Torino Napoli Weizmann NYUAD Kobe

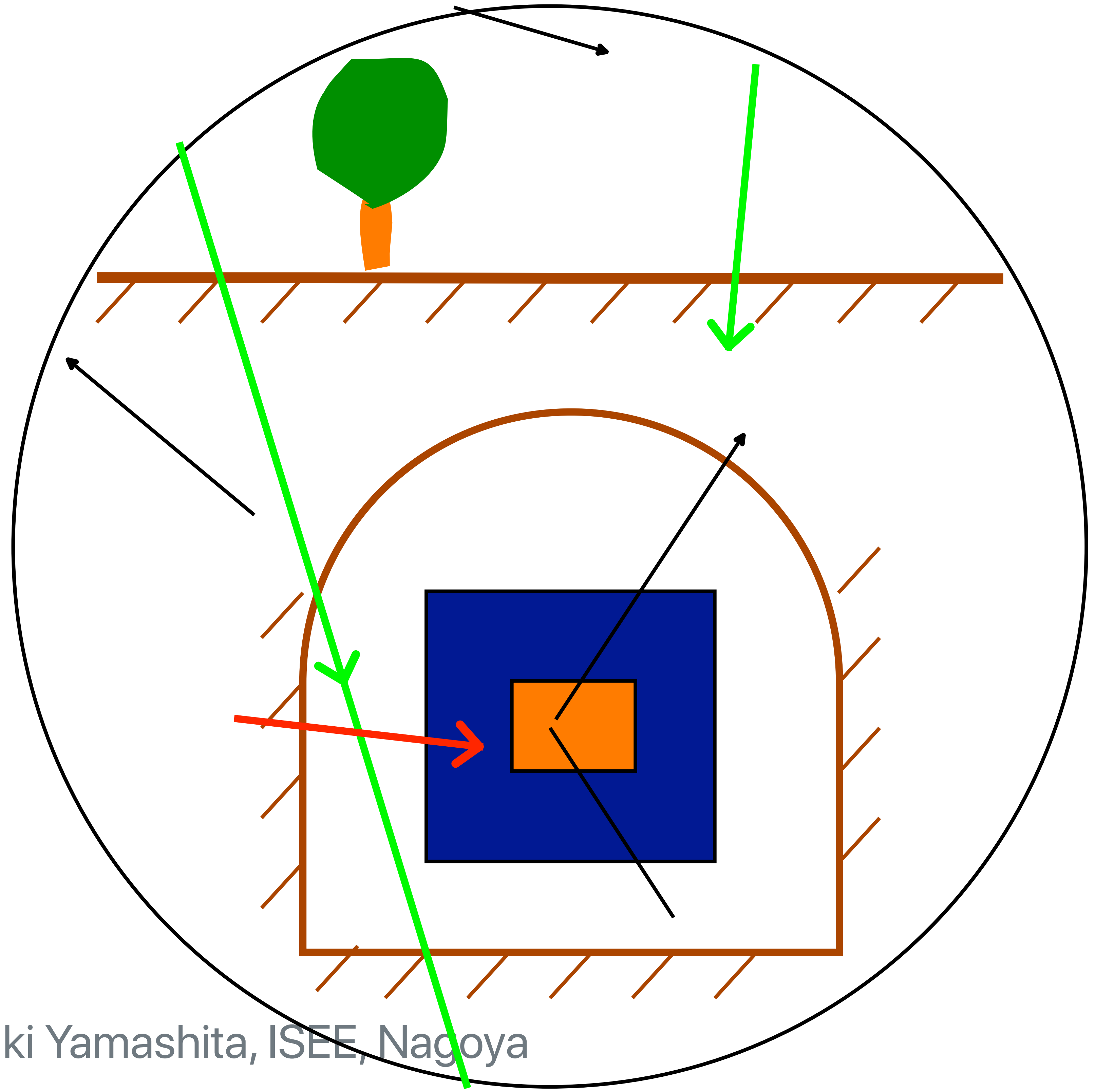
XENON Technical Meeting, May 12-14, 2020

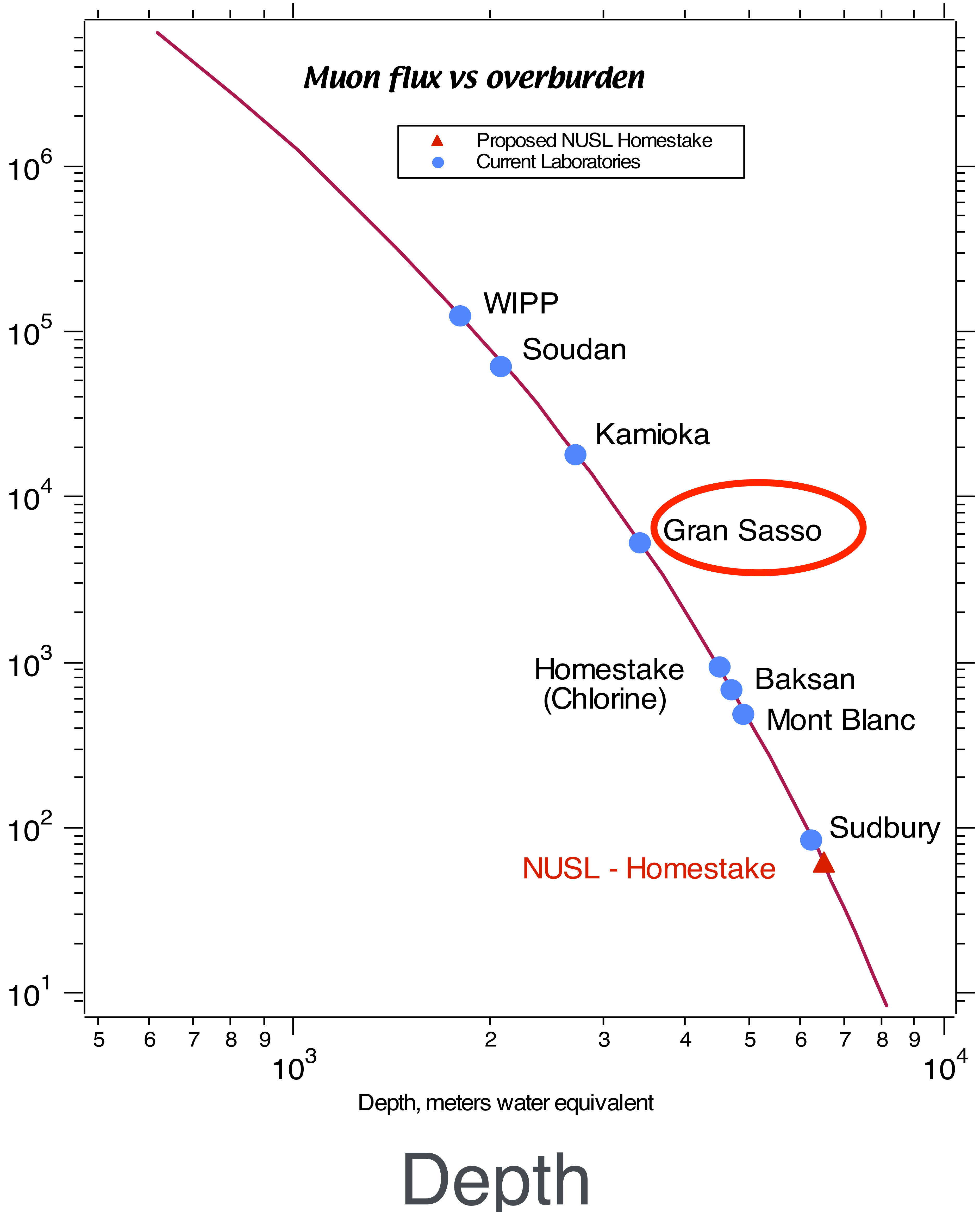
Very quick introduction for underground experiment

Searching for rare events
(hopefully beyond standard model)

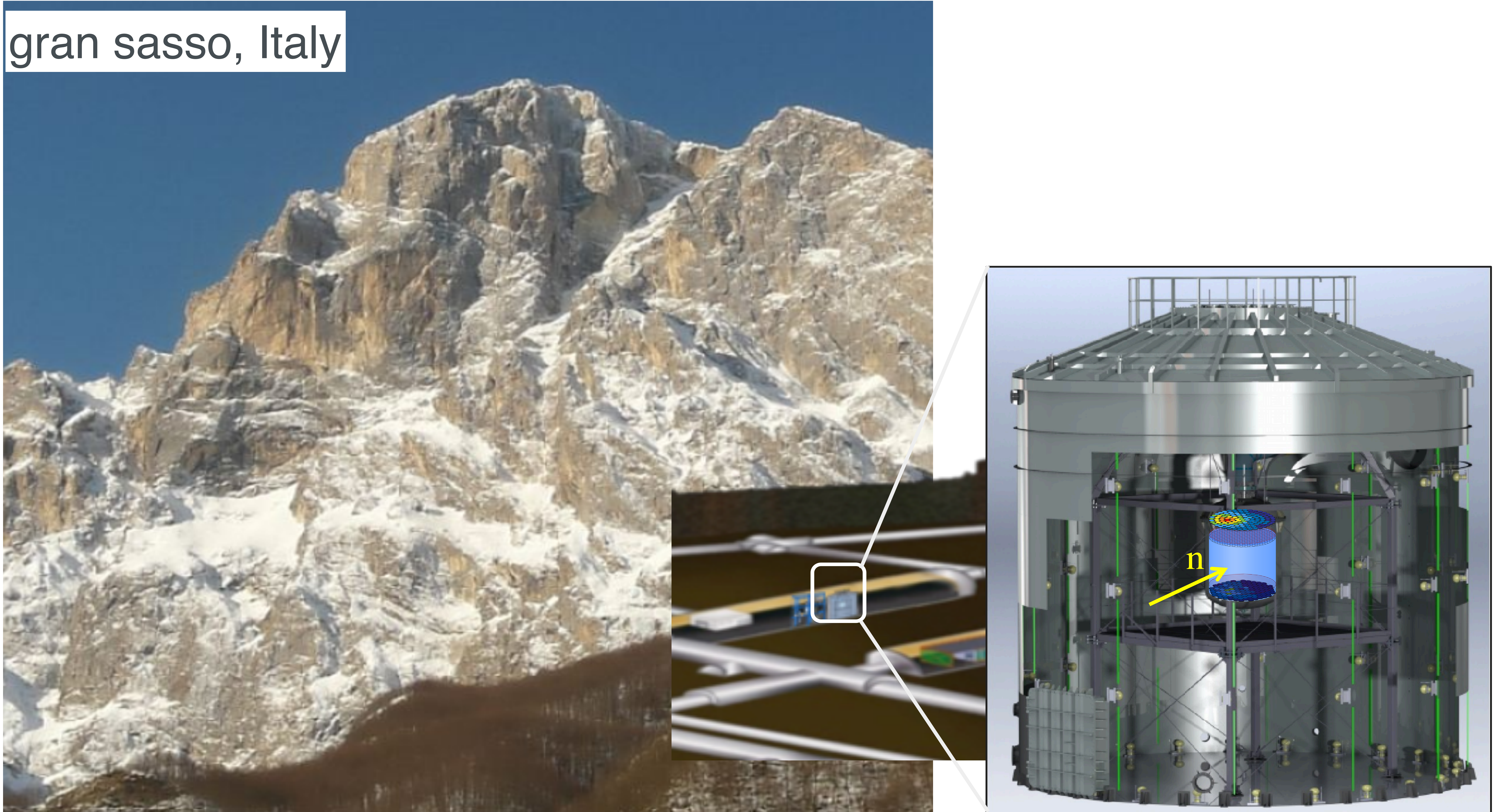
A few Hz cosmic ray go though your hand at the surface.

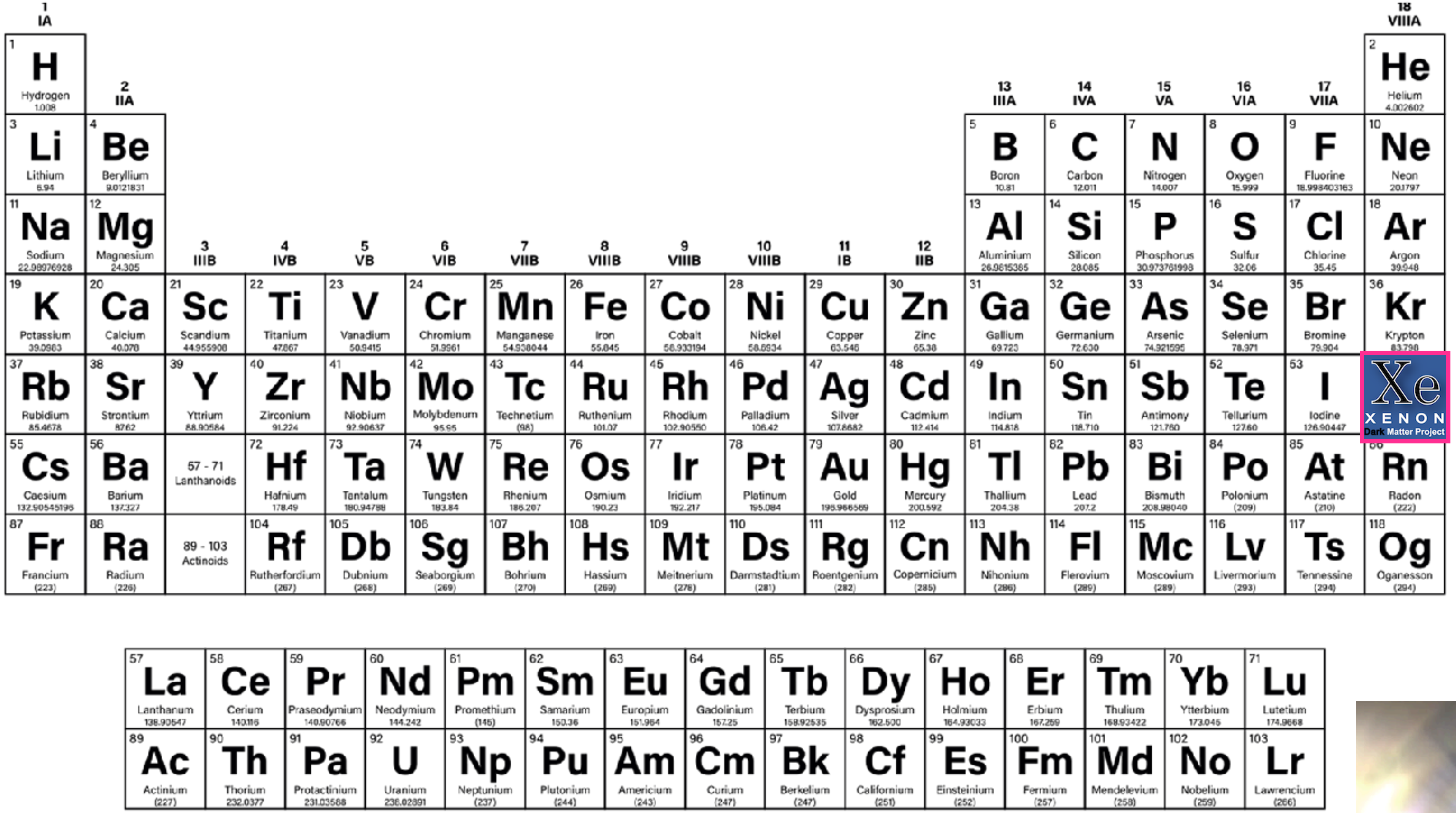
About 1/10⁵ or smaller in the underground.





XENON1T at Gran Sasso, Italy





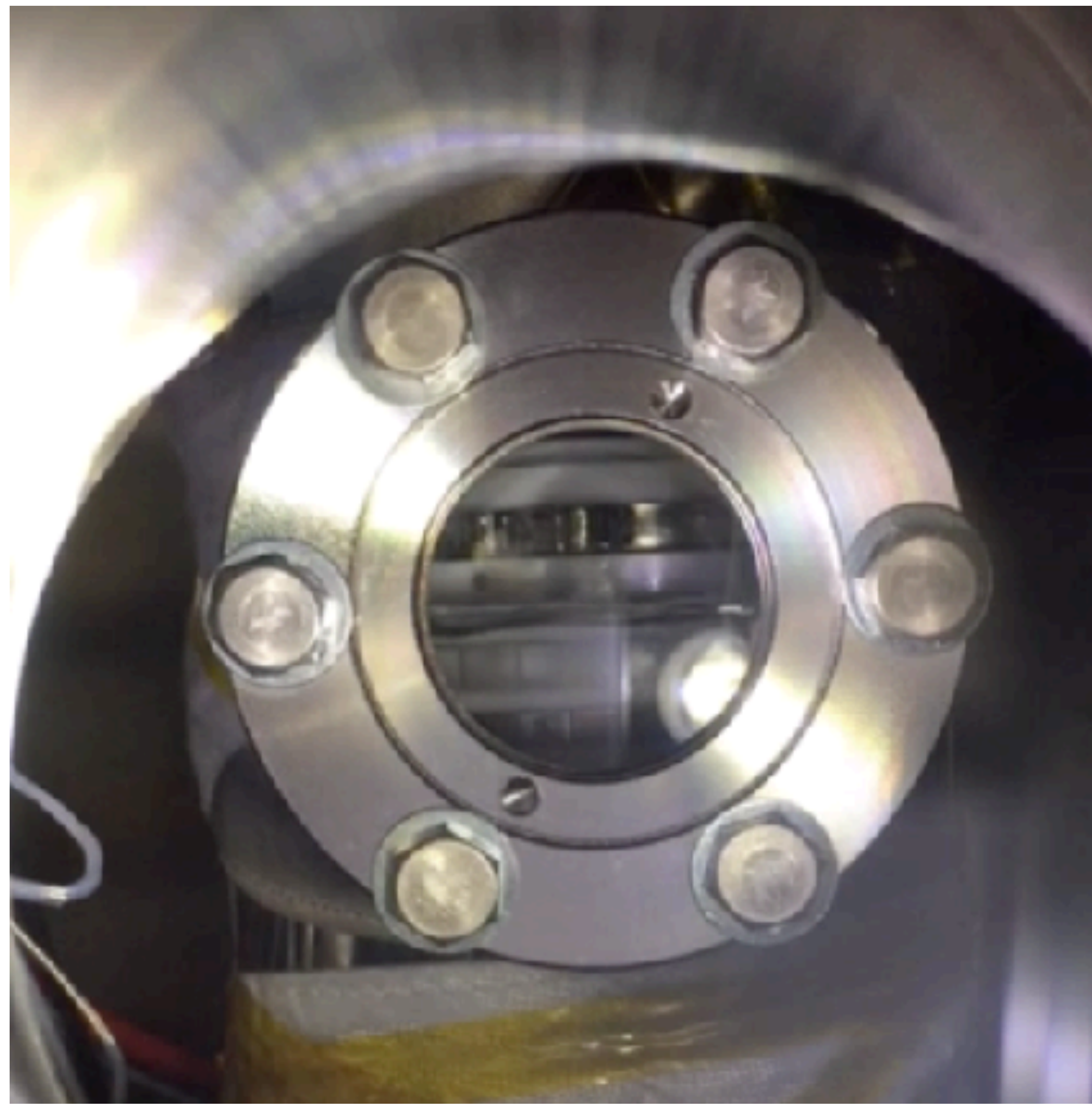
1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 **H** Hydrogen 1.008																	2 **He** Helium 4.002602
3 **Li** Lithium 6.94	4 **Be** Beryllium 9.0121831											5 **B** Boron 10.81	6 **C** Carbon 12.011	7 **N** Nitrogen 14.007	8 **O** Oxygen 15.999	9 **F** Fluorine 18.998403163	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.98976928	12 **Mg** Magnesium 24.305											13 **Al** Aluminium 26.9815385	14 **Si** Silicon 28.085	15 **P** Phosphorus 30.973761998	16 **S** Sulfur 32.06	17 **Cl** Chlorine 35.45	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955908	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938044	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933194	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.38	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.630	33 **As** Arsenic 74.921595	34 **Se** Selenium 78.971	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.798
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90584	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90637	42 **Mo** Molybdenum 95.95	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.414	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	**Xe** XENON Dark Matter Project
55 **Cs** Caesium 132.90545196	56 **Ba** Barium 137.327	57 - 71 Lanthanoids	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.94788	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.084	79 **Au** Gold 196.966569	80 **Hg** Mercury 200.592	81 **Tl** Thallium 204.38	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98040	84 **Po** Polonium (209)	85 **At** Astatine (210)	**Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 - 103 Actinoids	104 **Rf** Rutherfordium (267)	105 **Db** Dubnium (268)	106 **Sg** Seaborgium (269)	107 **Bh** Bohrium (270)	108 **Hs** Hassium (269)	109 **Mt** Meitnerium (278)	110 **Ds** Darmstadtium (281)	111 **Rg** Roentgenium (282)	112 **Cn** Copernicium (285)	113 **Nh** Nihonium (286)	114 **Fl** Flerovium (289)	115 **Mc** Moscovium (289)	116 **Lv** Livermorium (293)	117 **Ts** Tennessine (294)	118 **Og** Oganesson (294)

57 **La** Lanthanum 138.90547	58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90766	60 **Nd** Neodymium 144.242	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92535	66 **Dy** Dysprosium 162.500	67 **Ho** Holmium 164.93033	68 **Er** Erbium 167.259	69 **Tm** Thulium 168.93422	70 **Yb** Ytterbium 173.045	71 **Lu** Lutetium 174.9668
89 **Ac** Actinium (227)	90 **Th** Thorium 232.0377	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.02891	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (266)

$z=54$

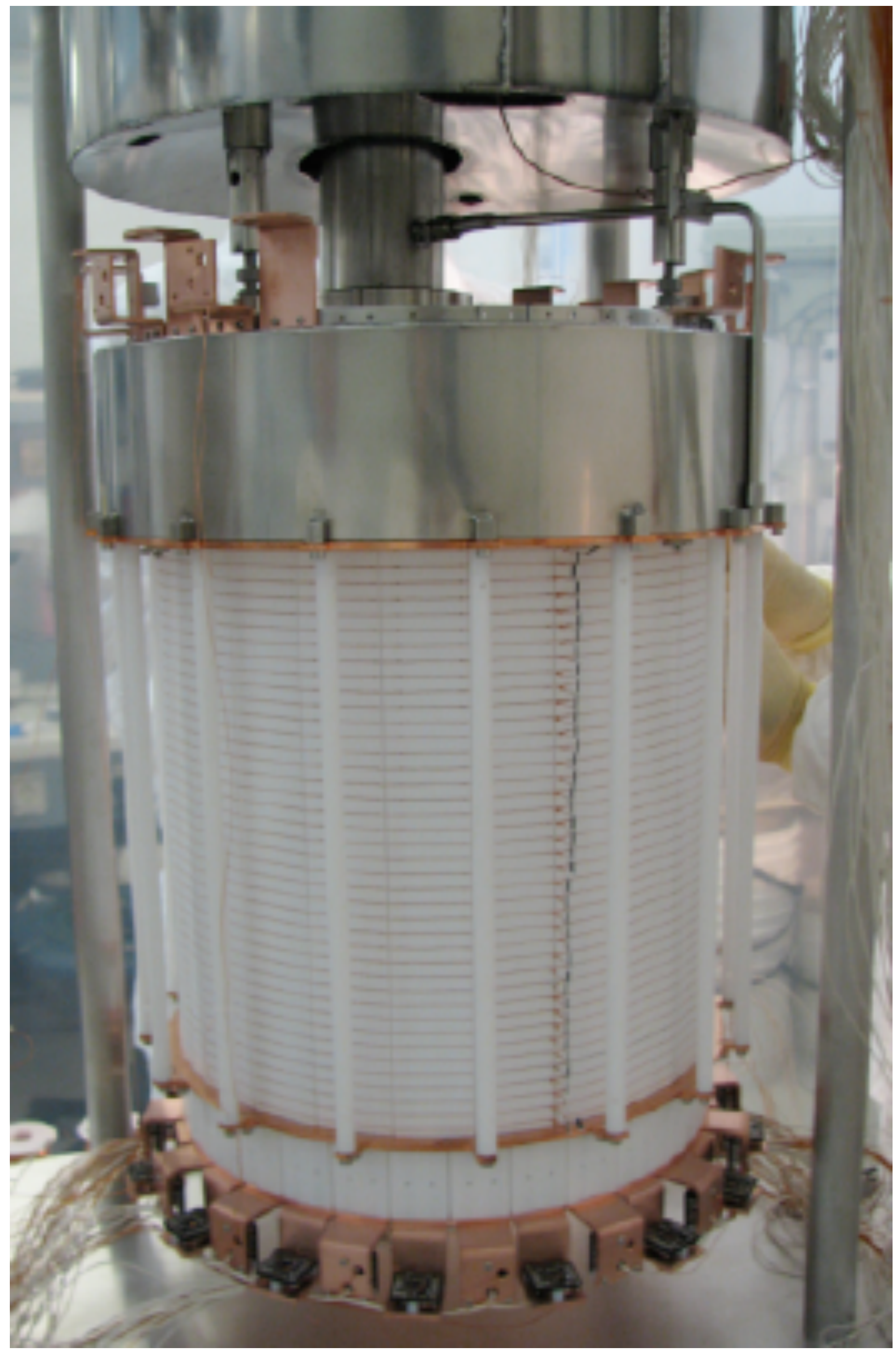
$A \sim 131$

$\rho \sim 3\ \mathrm{g/cm^3}$



History of XENON Experiment


XENON10


XENON100

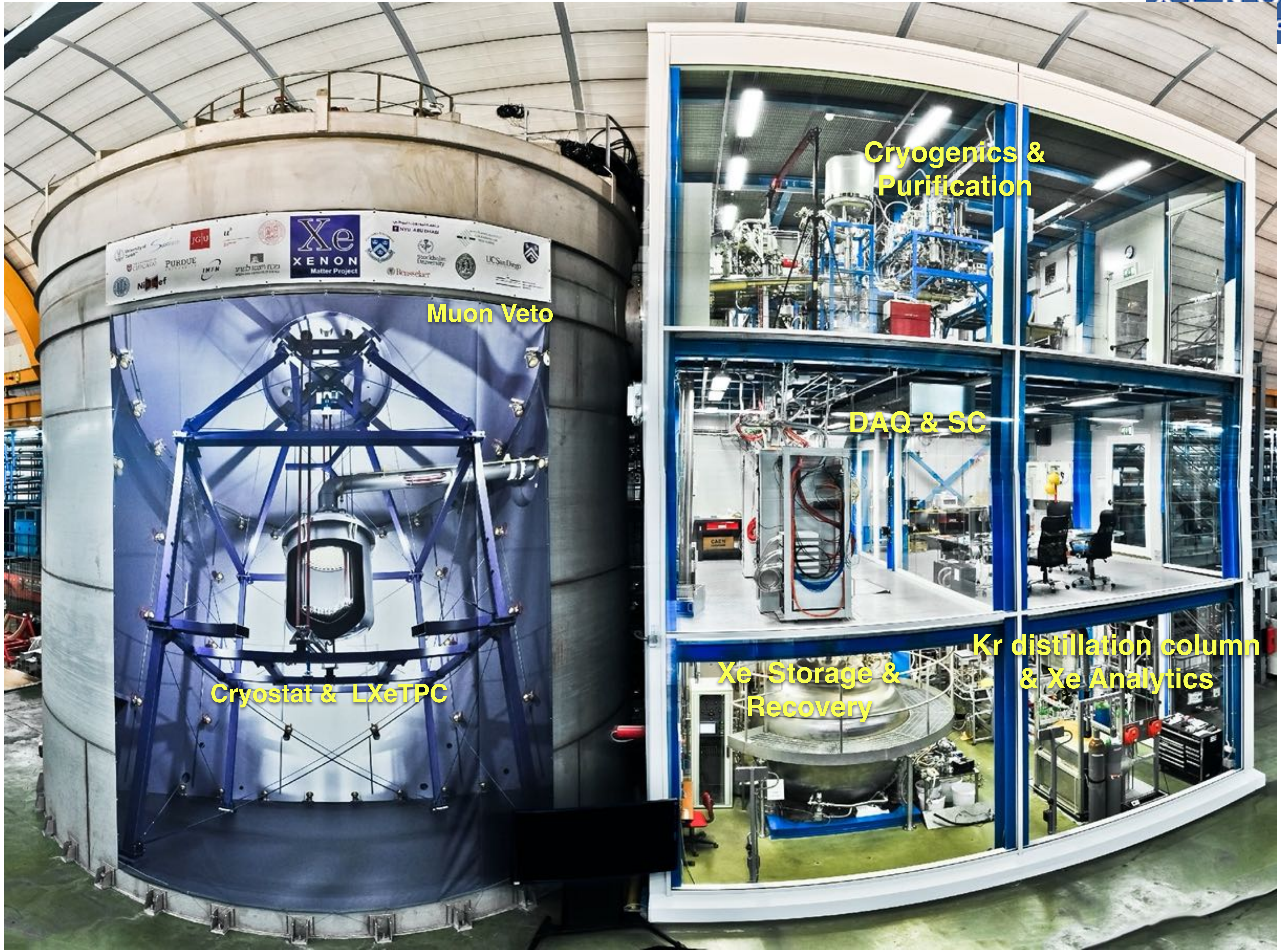

XENON1T


XENONnT

2005-2007	2008-2016	2012-2018	2019-202x
25 kg - 15cm drift	161 kg - 30 cm drift	3.2 ton - 1 m drift	8 ton - 1.5 m drift
~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2

XENON1T Detector

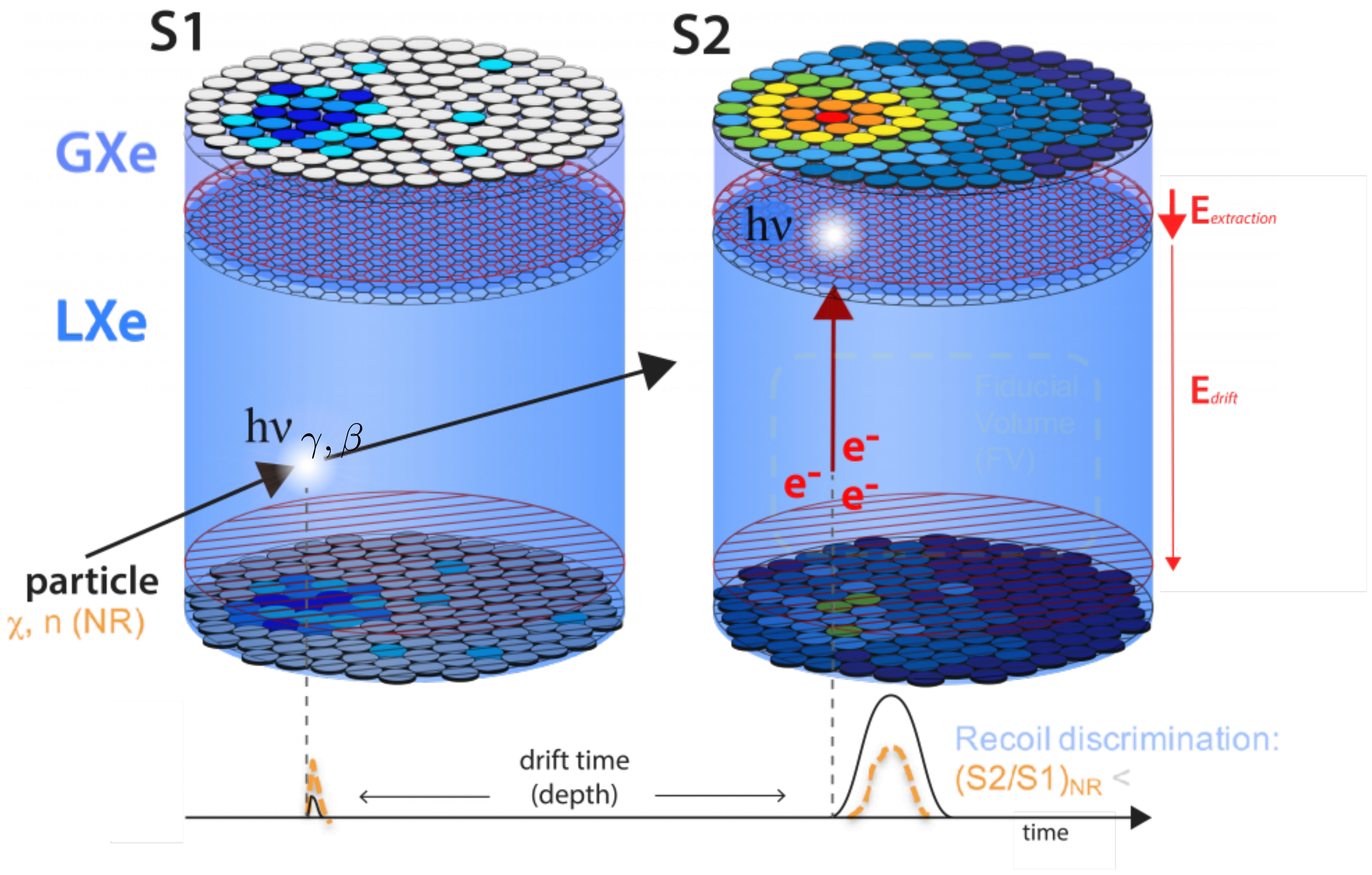
- Direct Dark Matter (WIMP) search detector
- 3.2 tonne total/ 1 tonne fiducial LXe
- Two phase Xe TPC
- ~250 x 3 inch PMTs
- 2012-2018 (terminated)



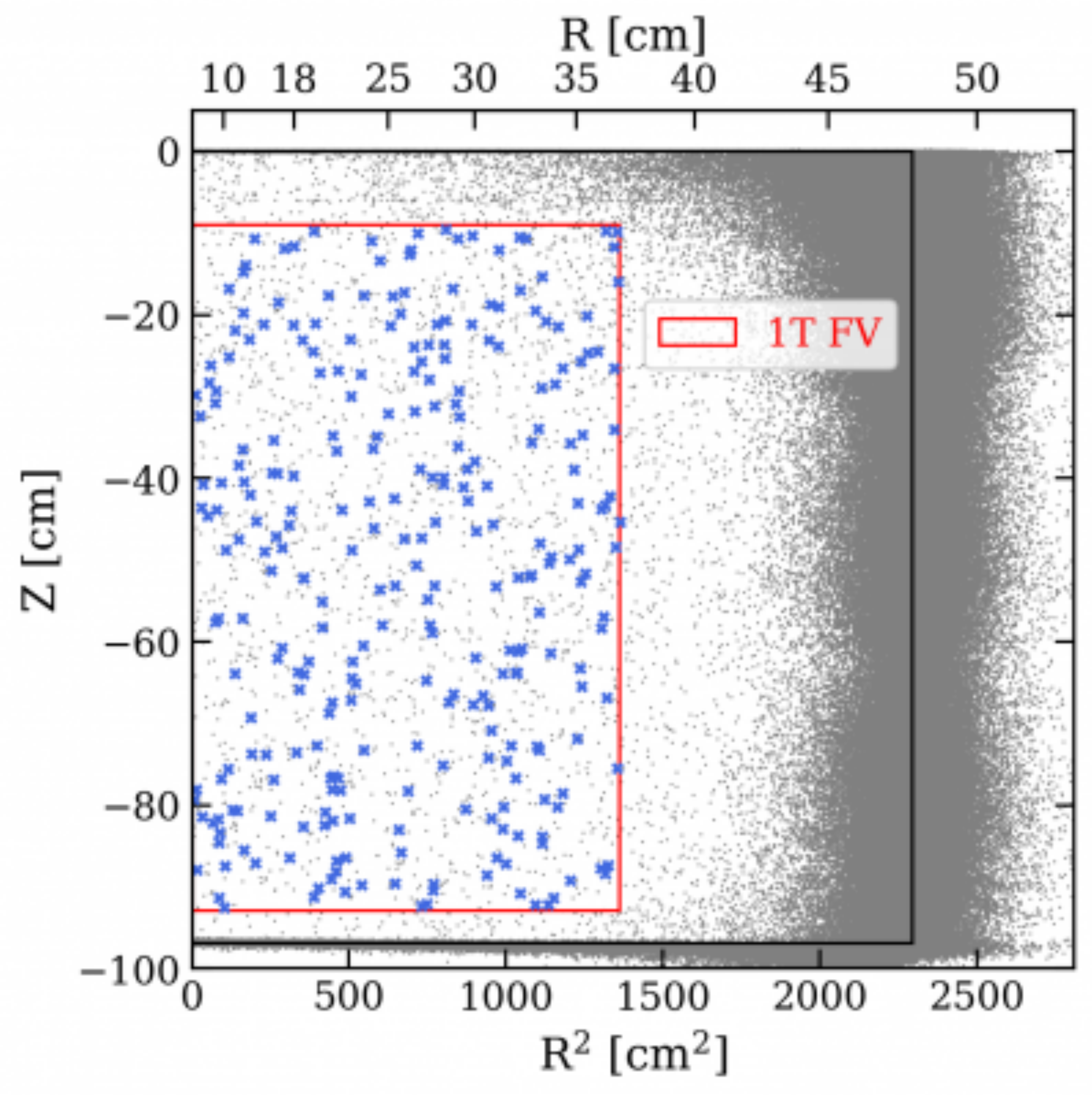
Two-phase Xe Time Projection Chamber

- **Scintillation light - S1**
- **Ionization electron -S2**

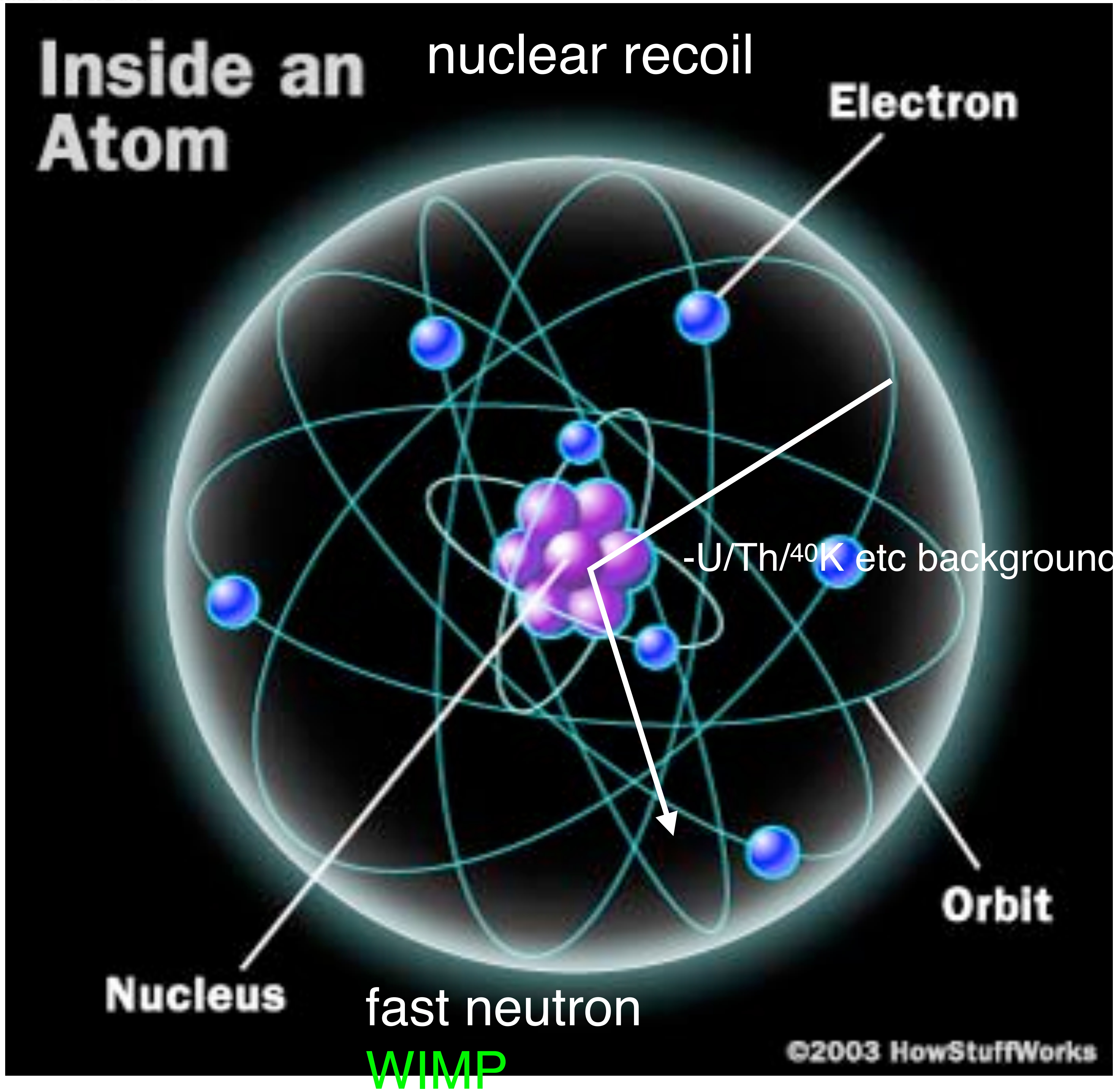
- two signals for each event:
  - 3D event imaging: x-y (S2) and z (drift time)
  - self-shielding, surface event rejection, single vs multiple scatter events
  - Particle identification using S2/S1 ratio (nuclear recoil vs beta, gamma)



ER



Interaction with dark matter

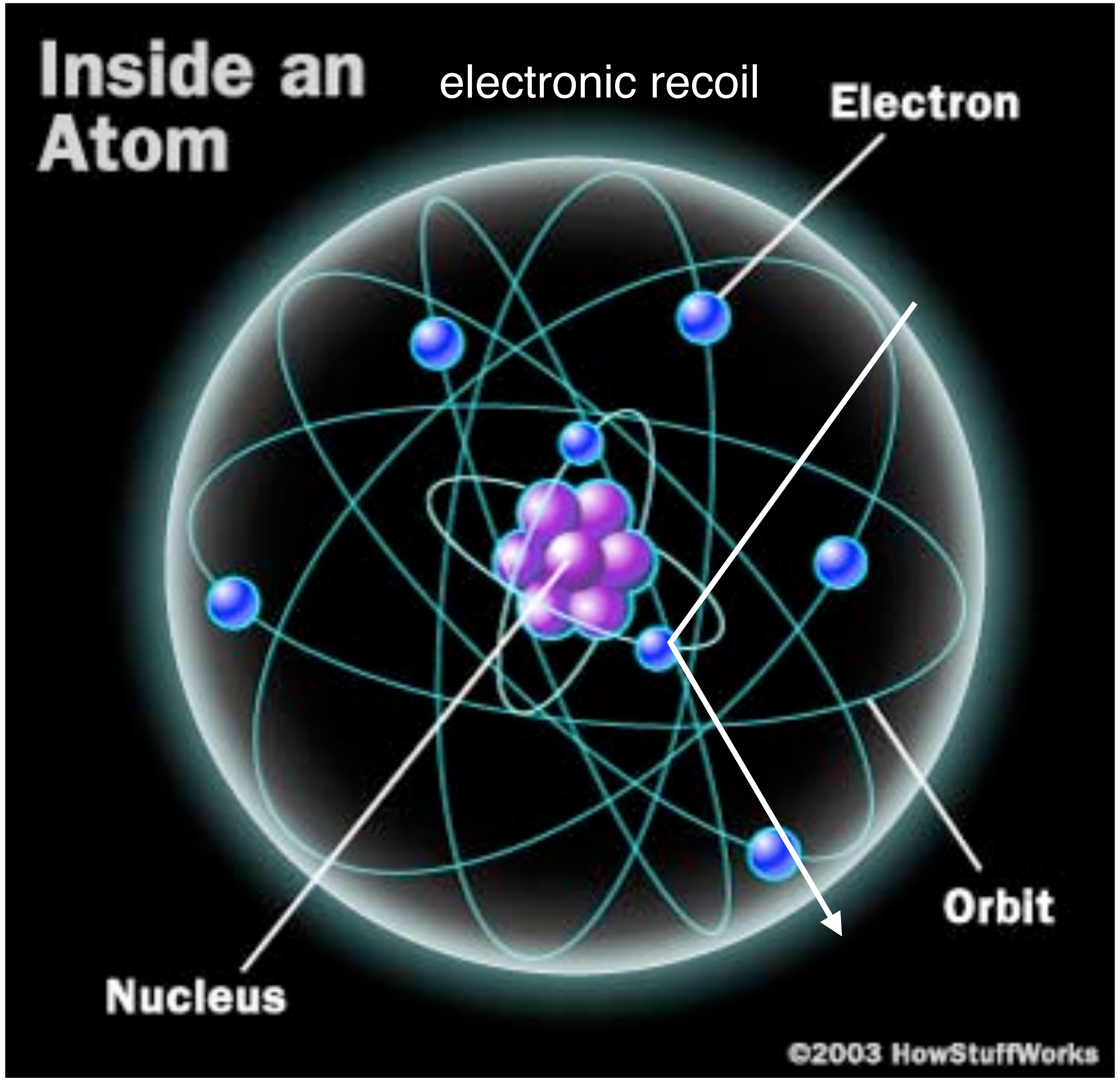


nuclear recoil

-U/Th/^{40}K etc background

fast neutron

WIMP

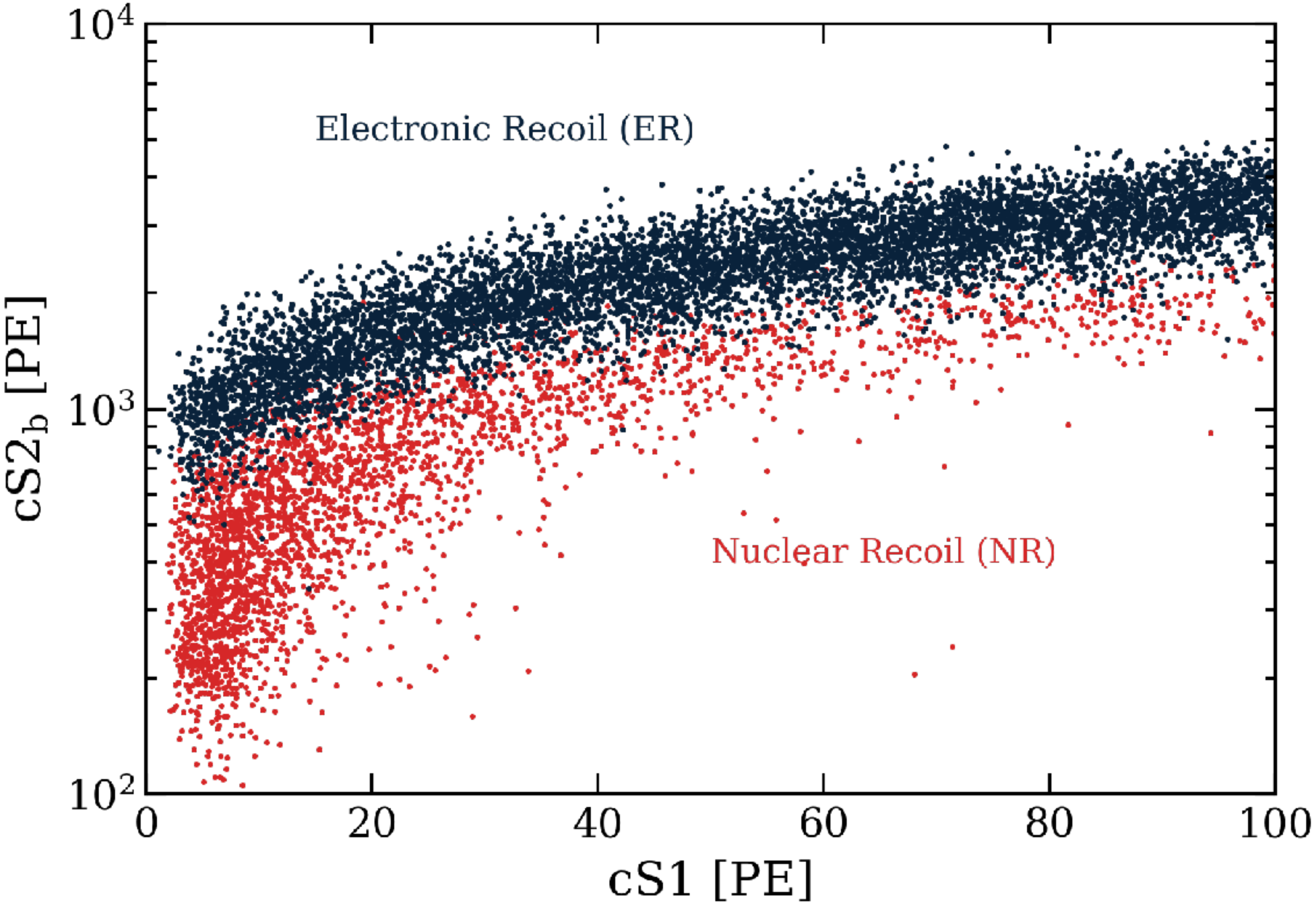


electronic recoil

Two-phase Xe Time Projection Chamber

- Recoil type discrimination from ratio of charge (S2) to light (S1)

- Ionization electron -S2

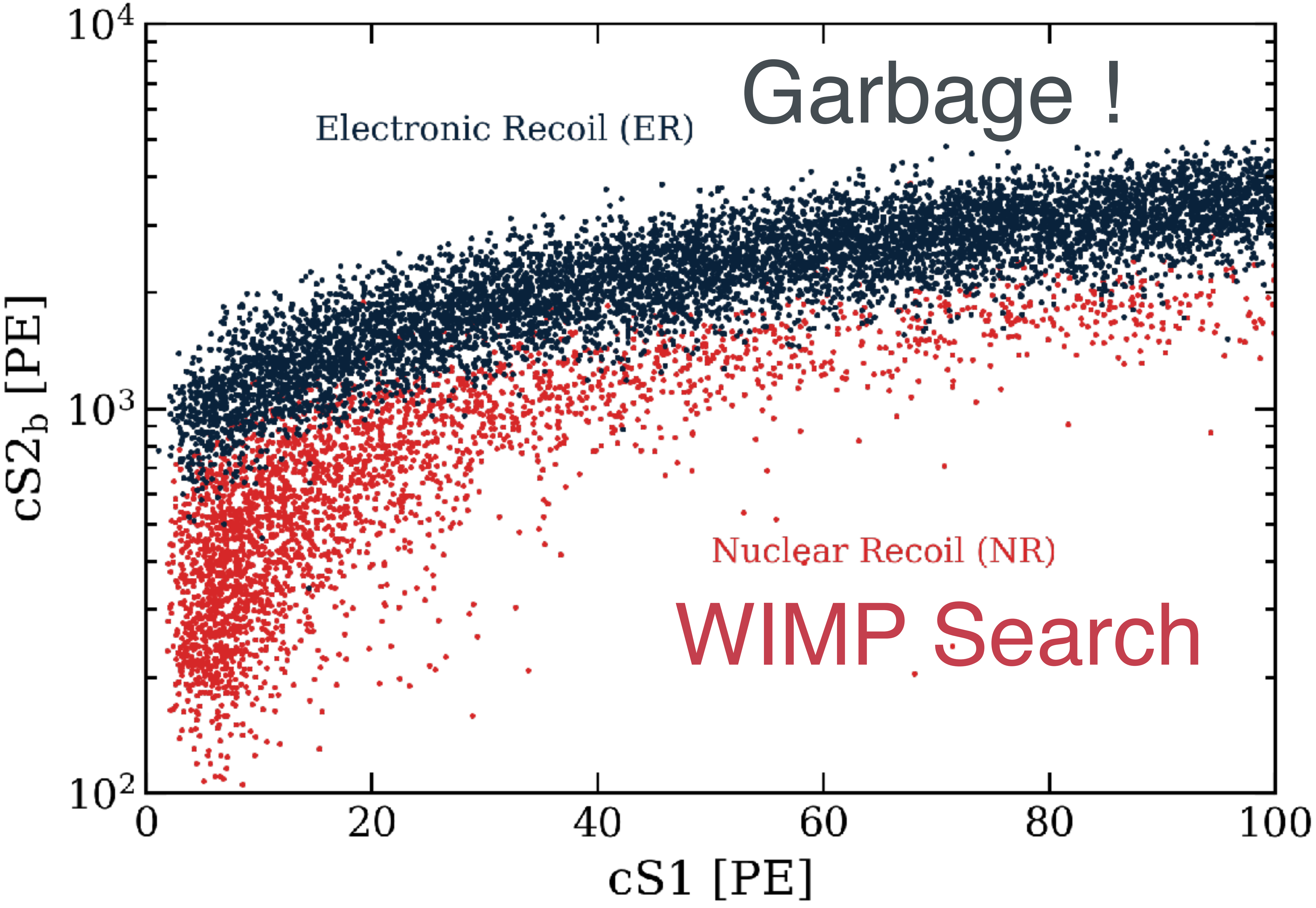


- Scintillation light - S1

Two-phase Xe Time Projection Chamber

- Recoil type discrimination from ratio of charge (S2) to light (S1)

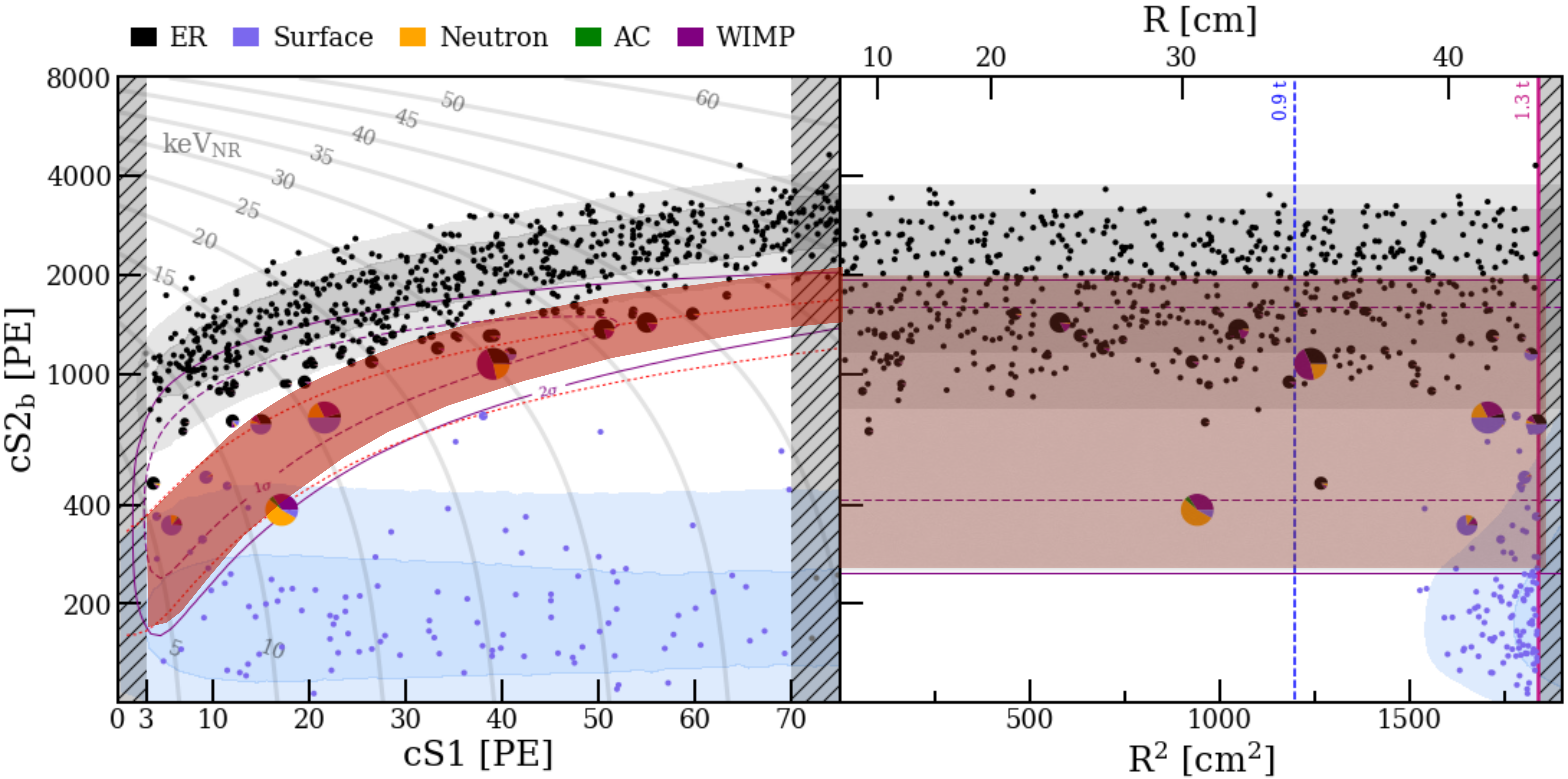
- Ionization electron -S2



- Scintillation light - S1

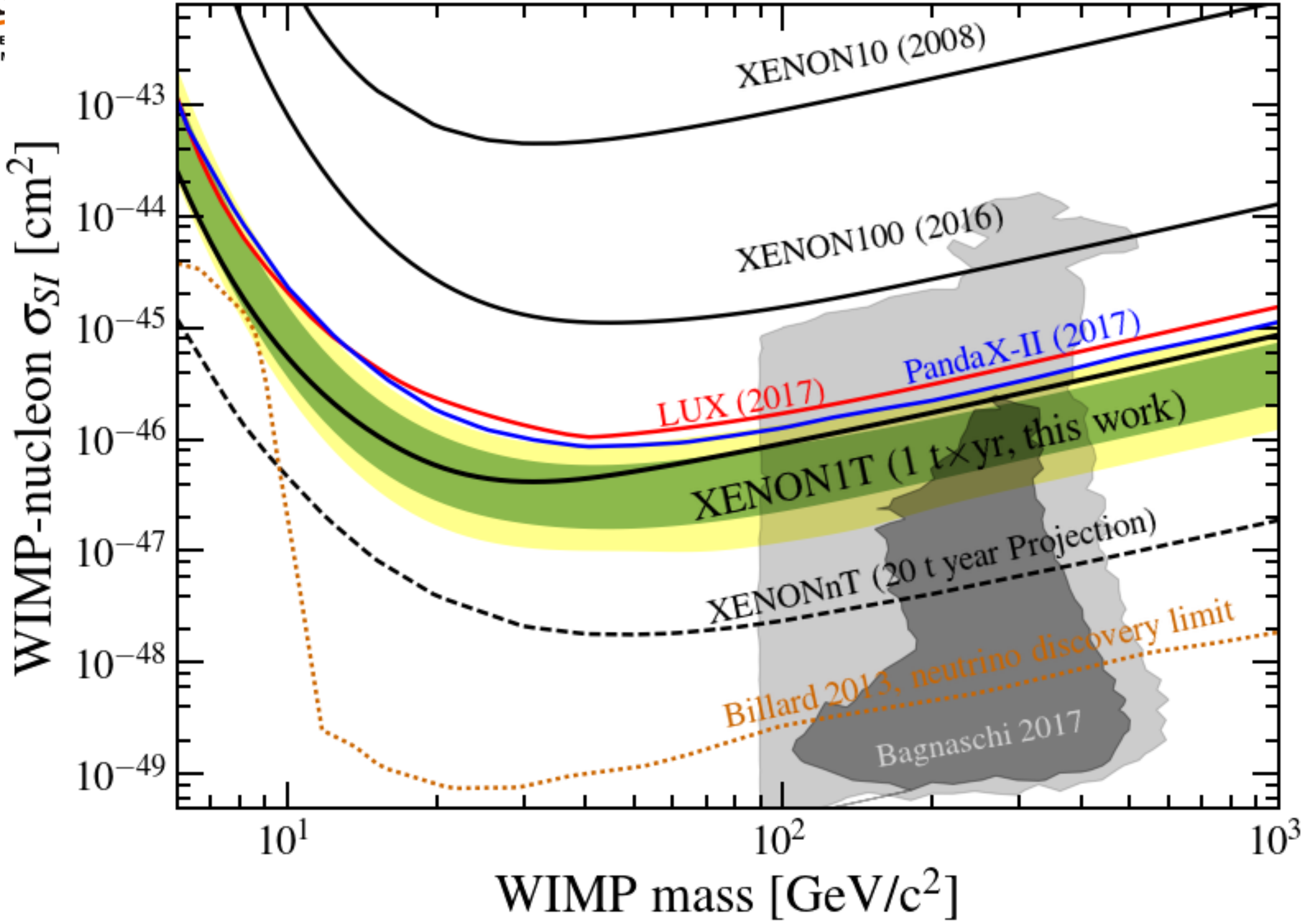
XENON1T WIMPs Search - 2018

One ton-year of search for WIMPs induced nuclear recoils

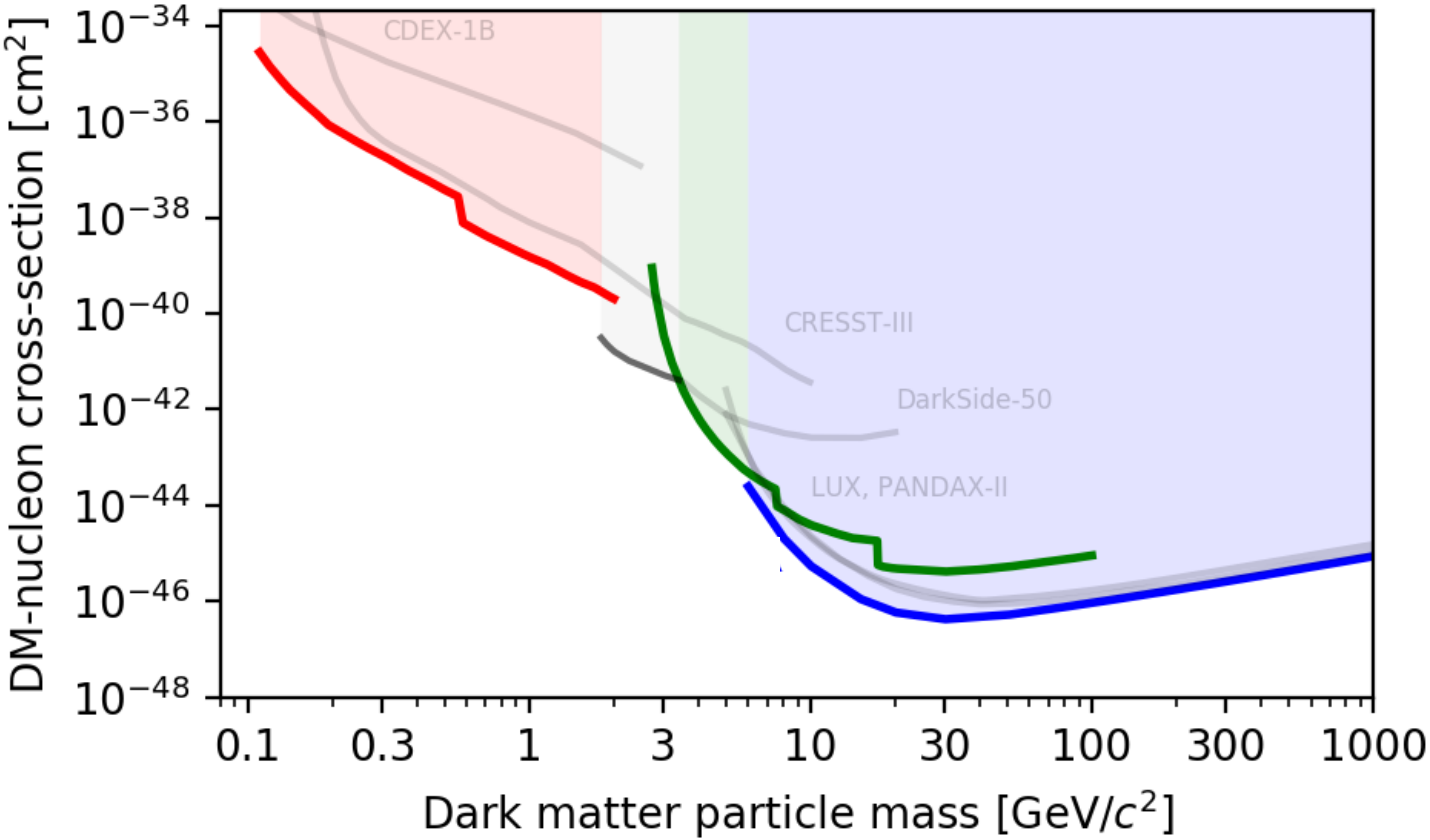


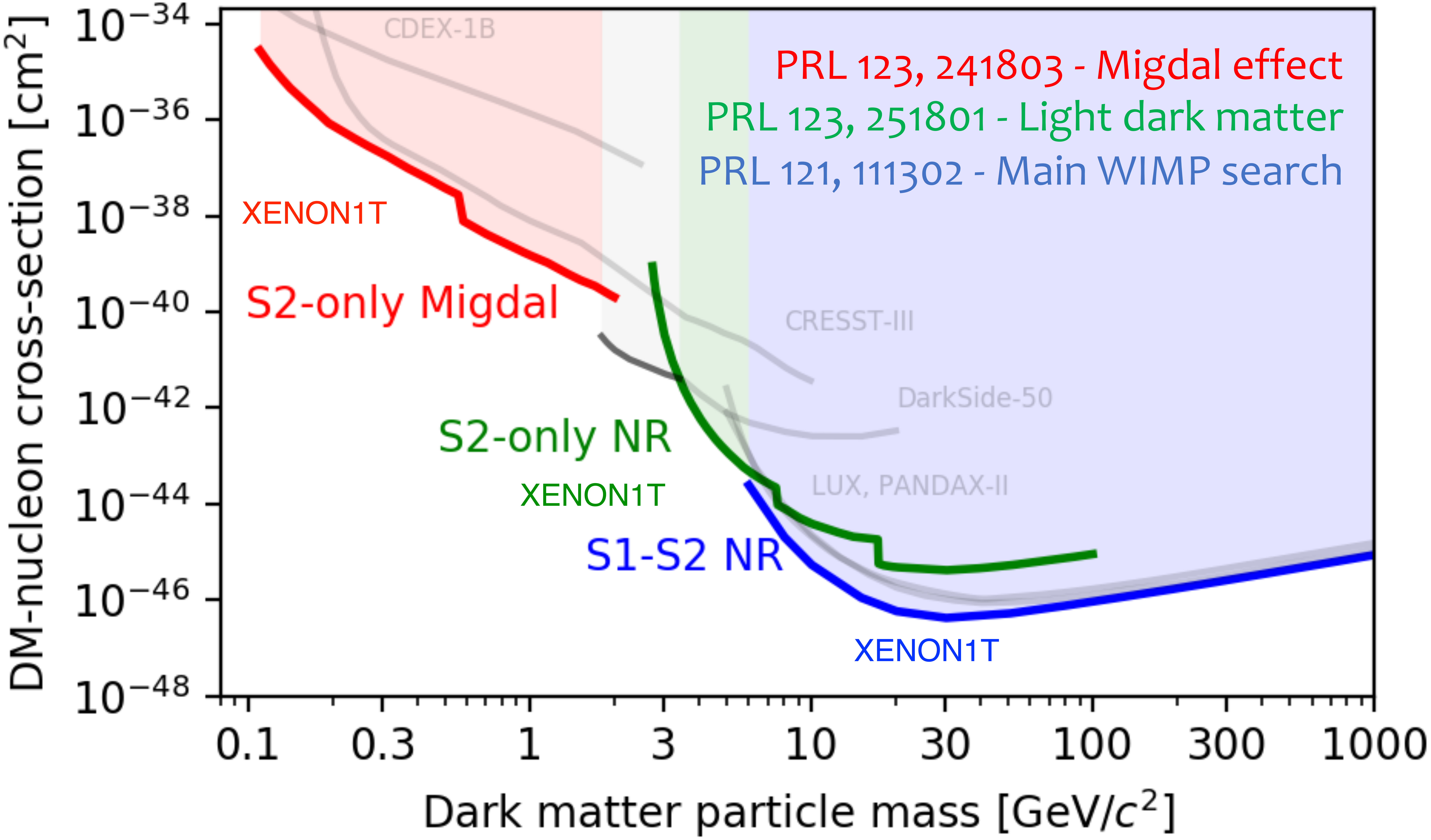
Most stringent result on WIMP Dark Matter down to 3 GeV/c² masses *[PRL 121, 111302 + PRL 123, 251801]*

WIMP Search Result



Phys.Rev.Lett. 121 (2018) no.11, 111302


CDEX-1B
CRESST-III
DarkSide-50
LUX, PANDAX-II
DM-nucleon cross-section [cm^2]
10^{-34}
10^{-36}
10^{-38}
10^{-40}
10^{-42}
10^{-44}
10^{-46}
10^{-48}
0.1
0.3
1
3
10
30
100
300
1000
Dark matter particle mass [GeV/c^2]


PRL 123, 241803 - Migdal effect
PRL 123, 251801 - Light dark matter
PRL 121, 111302 - Main WIMP search
CDEX-1B
XENON1T
S2-only Migdal
CRESST-III
DarkSide-50
S2-only NR
XENON1T
LUX, PANDAX-II
S1-S2 NR
XENON1T
DM-nucleon cross-section [cm^2]
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10^{-46}
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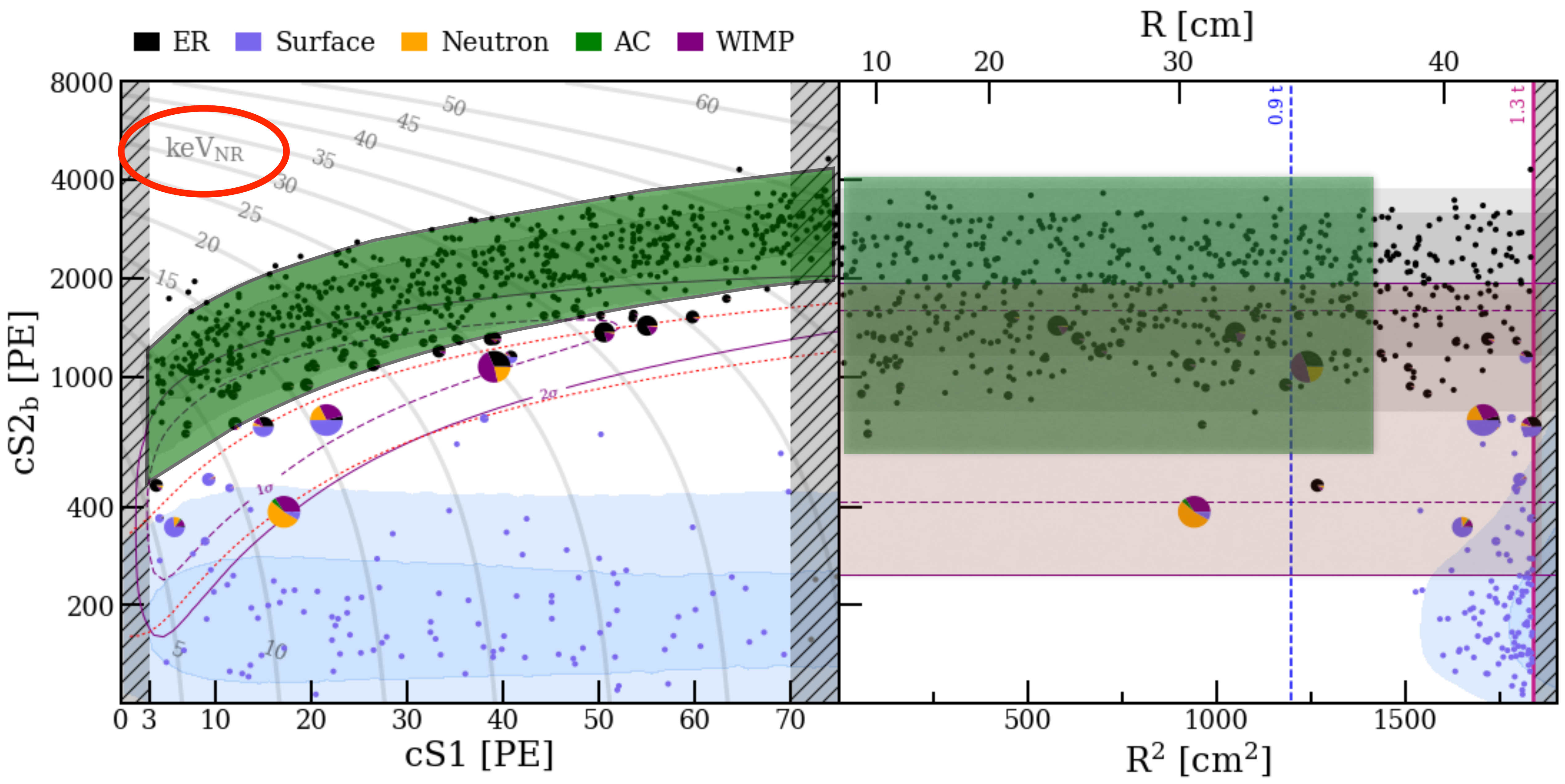
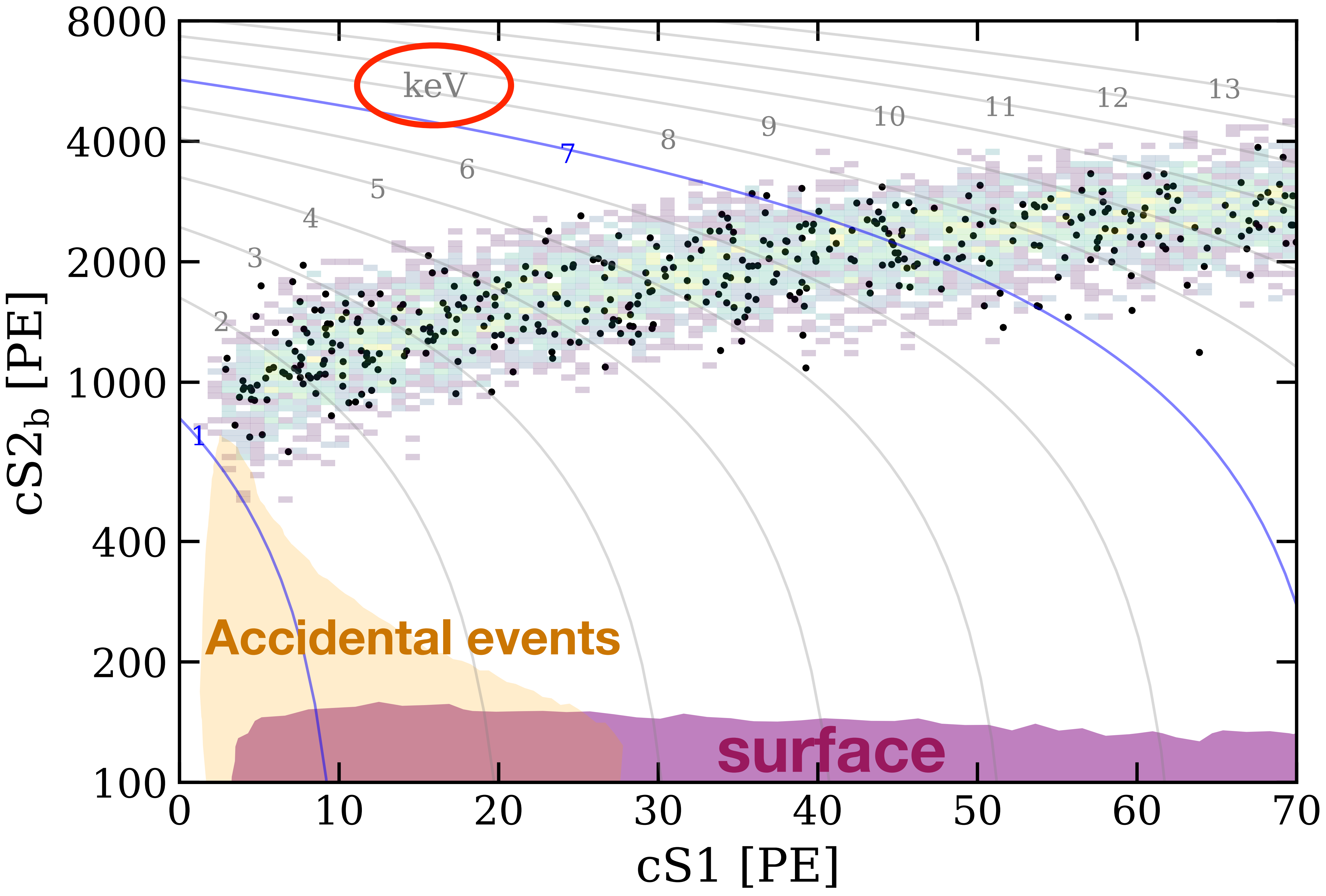
0.1
0.3
1
3
10
30
100
300
1000
Dark matter particle mass [GeV/c^2]

XENON1T ER band





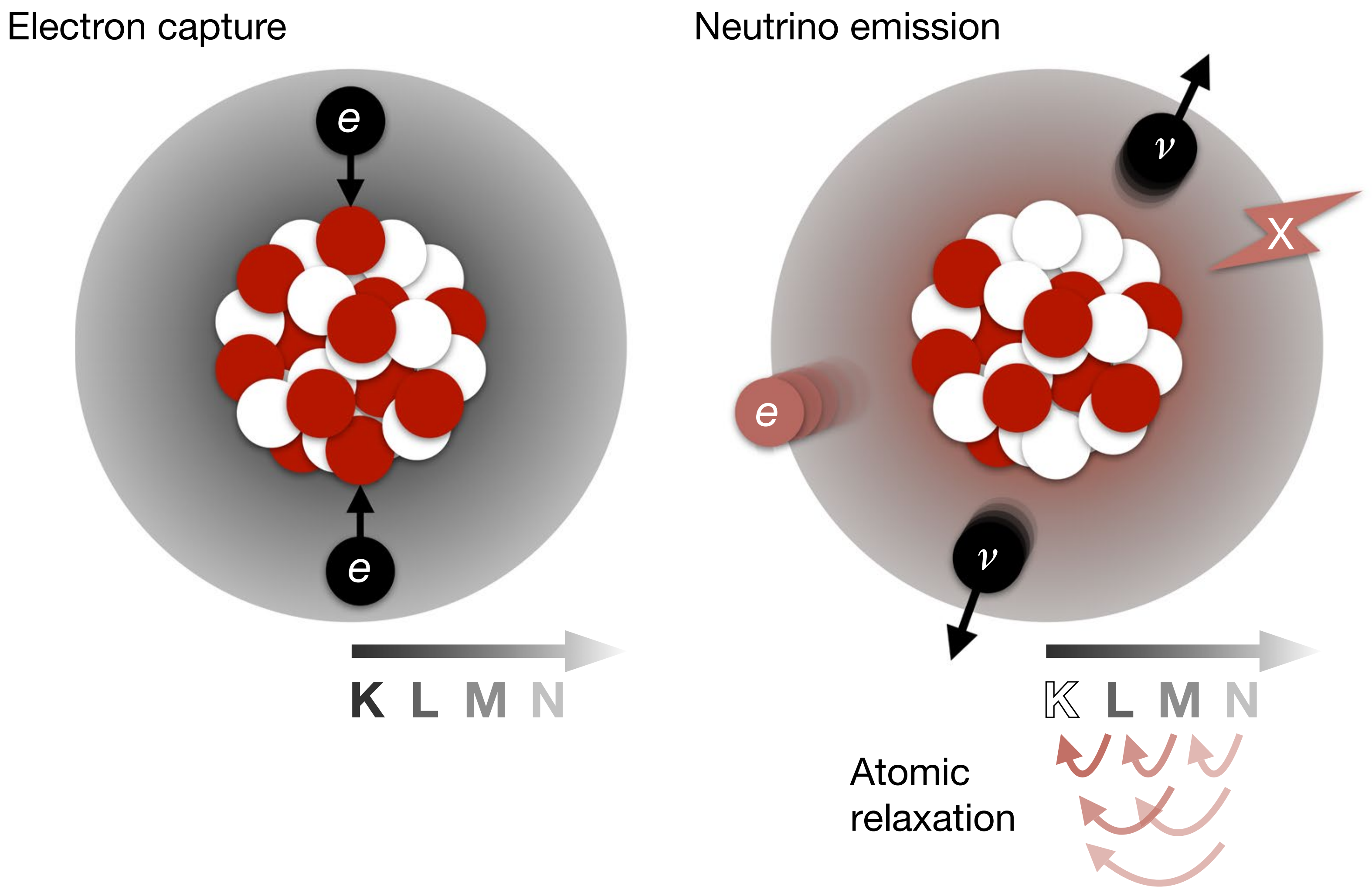
Nuclear recoil energy scale -> Electronic recoil energy scale

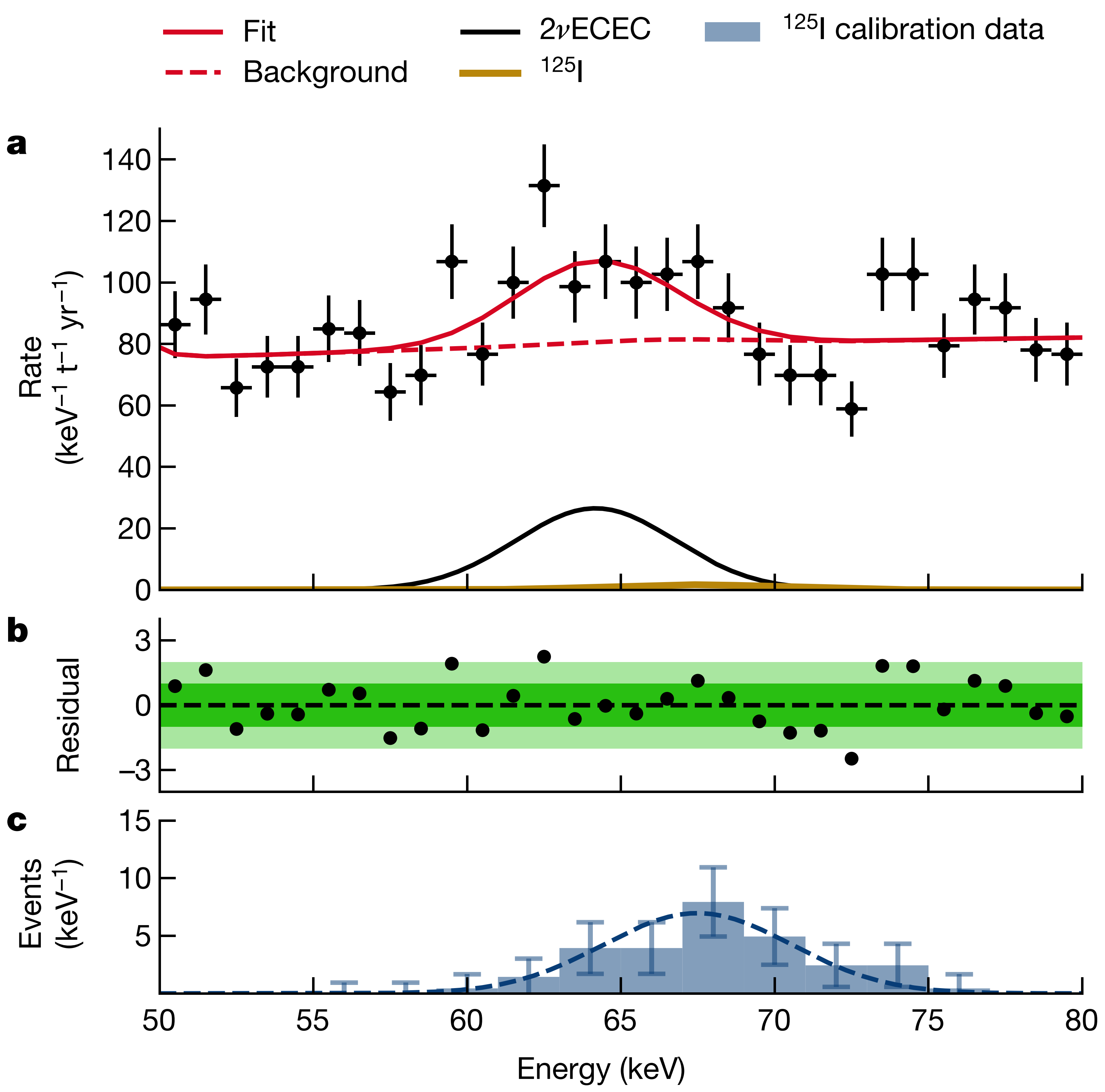
In the past …

LETTER Nature 568, 532–535
https://doi.org/10.1038/s41586-019-1124-4

Observation of two-neutrino double electron capture in ^{124}Xe with XENON1T

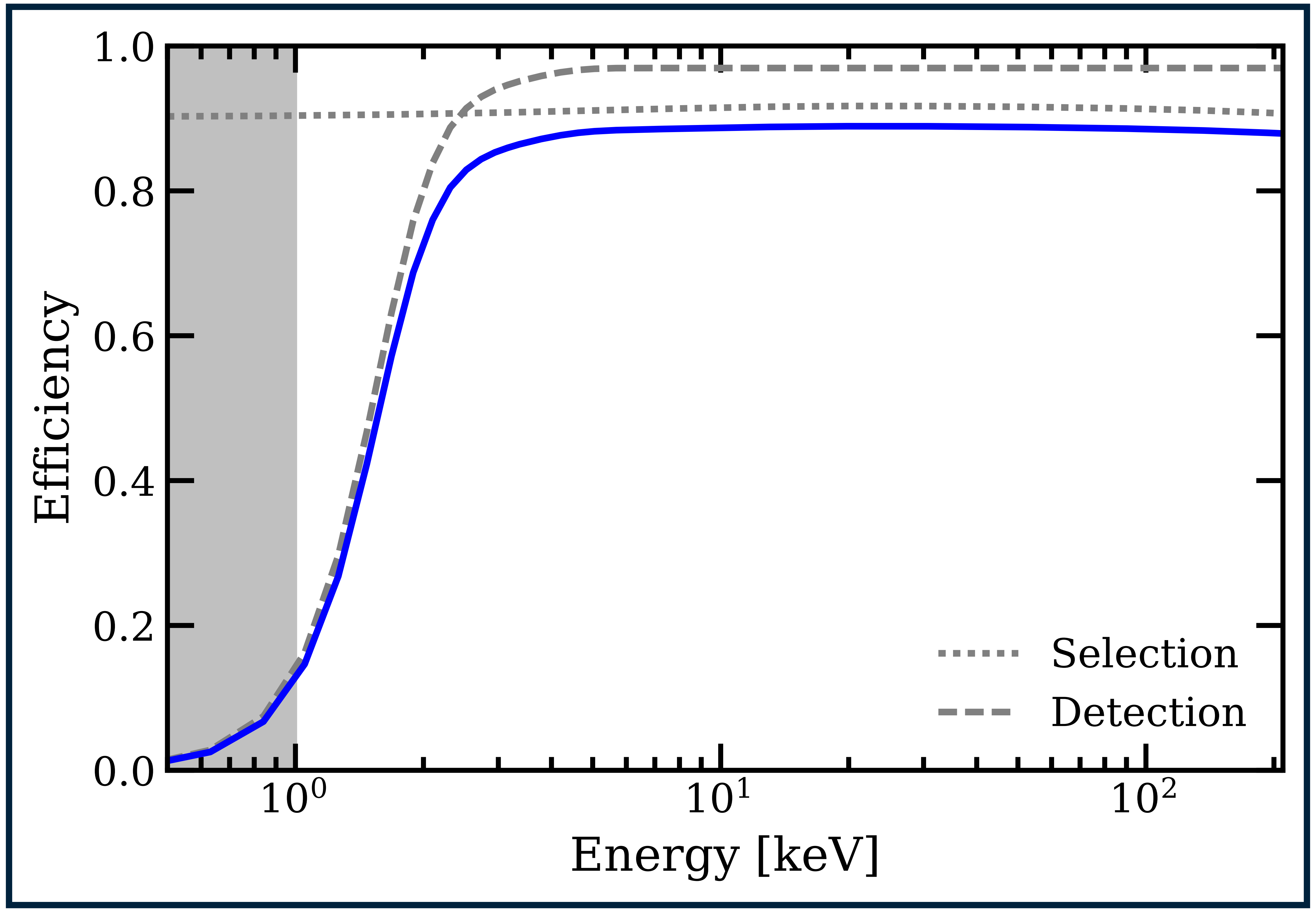
XENON Collaboration*

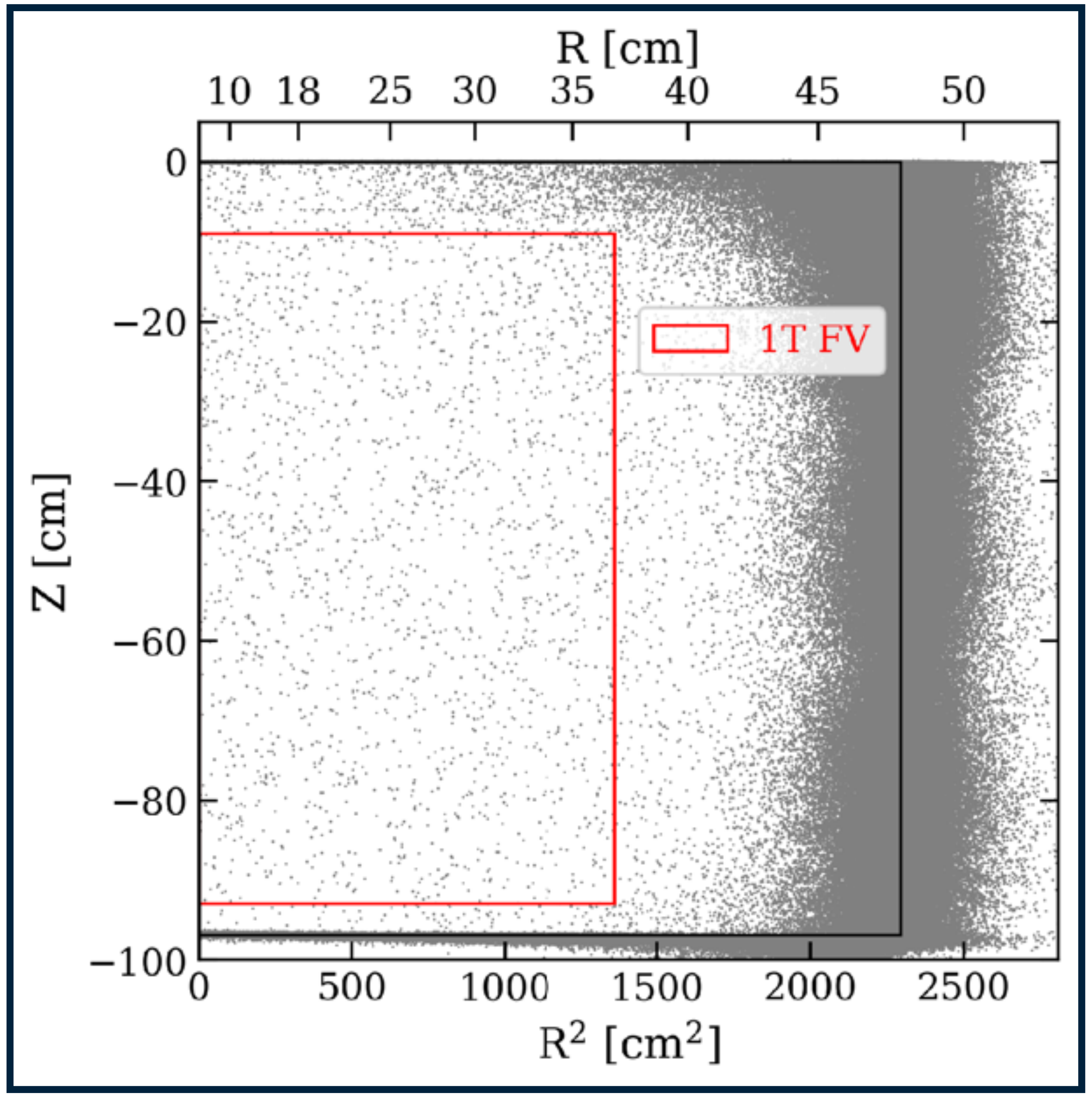




The direct observation of 2vECEC in 124Xe with the XENON1T dark-matter detector.
The corresponding half-life of 1.8 × 1022 years is the longest measured directly so far.

Signal Efficiency and Fiducial volume



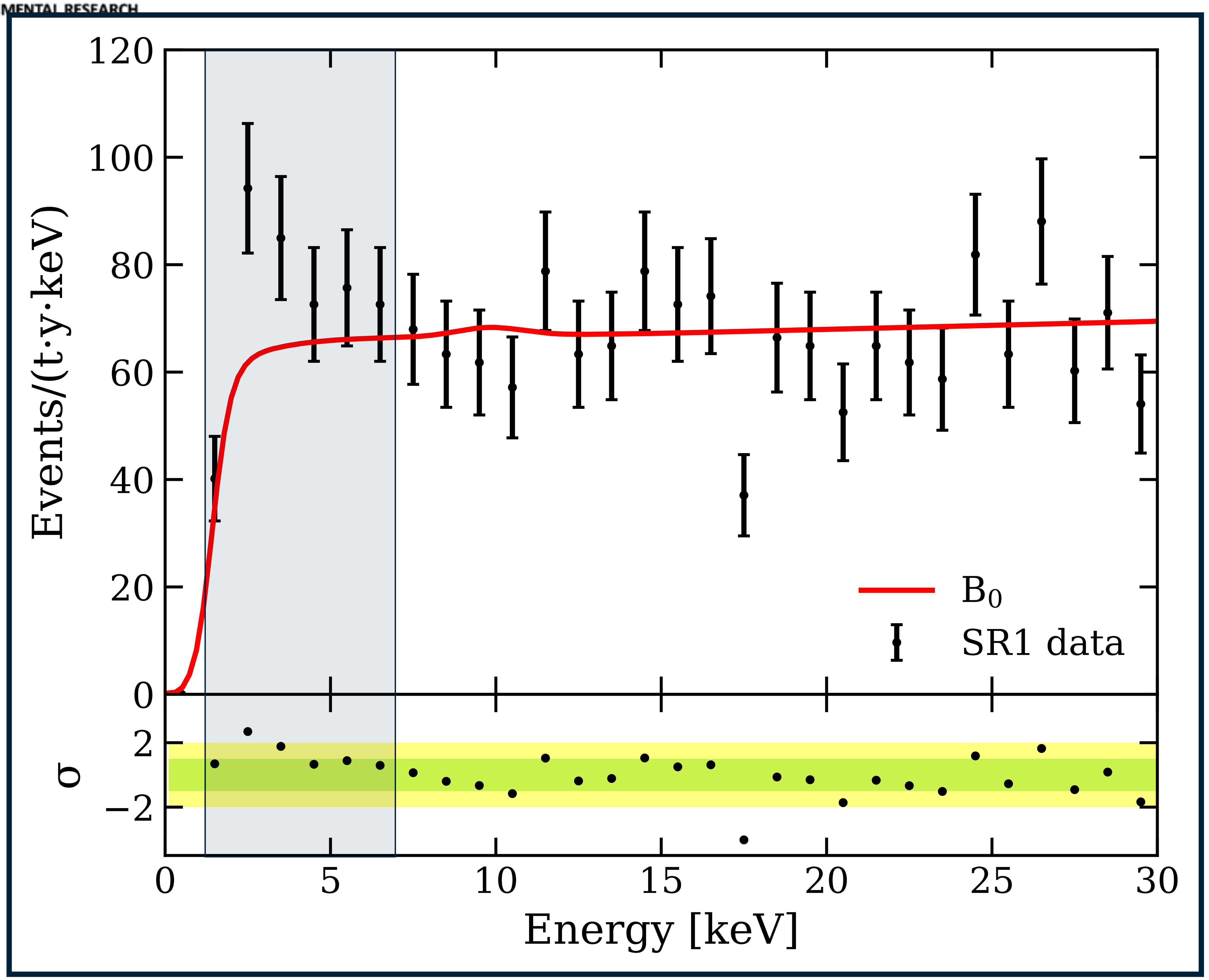


Similar selection criteria as WIMPs search in 2018

Reduced fiducial volume for ER search

High acceptance for ER energy > 2 keV

The Low Energy Excess (ER)



Excess between 1- 7 keV!

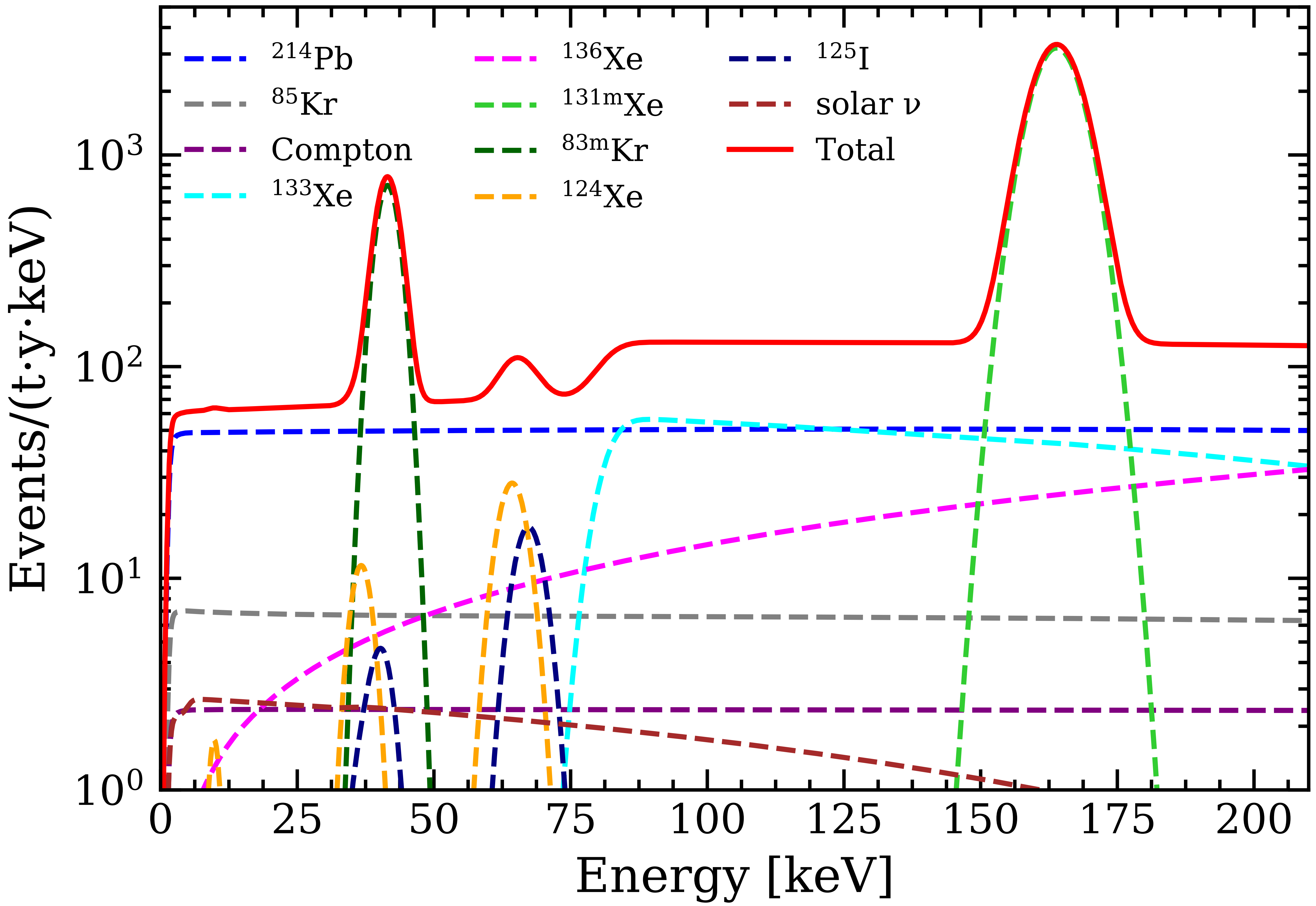
Expectation: 232±15

Observation: 285

Excess is most abundant between 2-3 keV

Background model

Search for an excess above background.



10 BG components

Intrinsic

^{214}**Pb** ^{136}**Xe**

^{85}**Kr** ^{124}**Xe**

Neutron activated

^{131m}**Xe**

^{133}**Xe**

^{125}**I**

Materials

Solar neutrinos

Predicted energy spectra based on detailed modeling of each background component

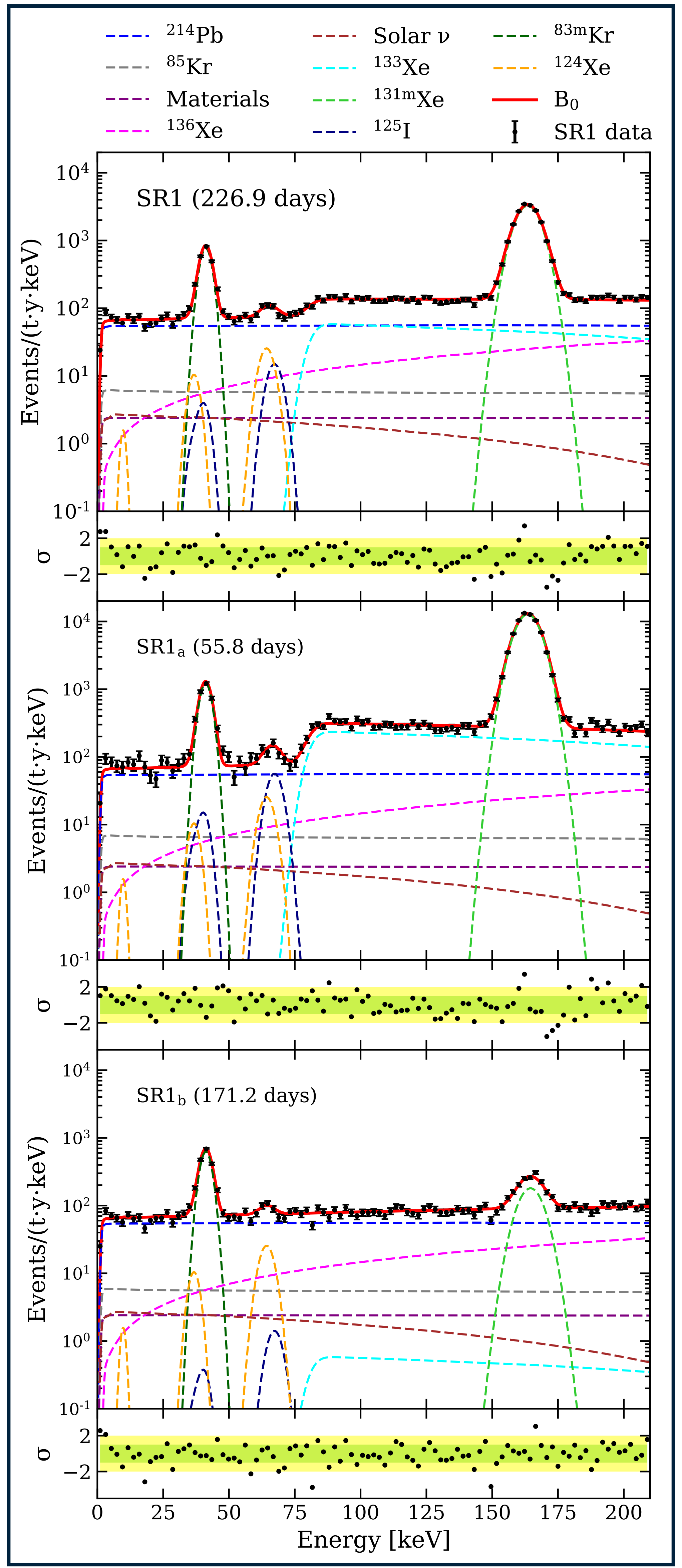
Rates constrained by measurements and/or time dependence , except ^{214}Pb and ^{124} Xe

Background fit

SR1(all)

SR1a

SR1b



Unbinned profile likelihood analysis

$$\mathcal{L}(\mu_s, \boldsymbol{\mu_b}, \boldsymbol{\theta}) = \mathrm{Poiss}(N|\mu_{tot}) \times \prod_i^N \left(\sum_j \frac{\mu_{b_j}}{\mu_{\mathrm{tot}}} f_{b_j}(E_i, \boldsymbol{\theta}) + \frac{\mu_s}{\mu_{\mathrm{tot}}} f_s(E_i, \boldsymbol{\theta}) \right) \times \prod_m C_{\mu_m}(\mu_{b_m}) \times \prod_n C_{\theta_n}(\theta_n), \tag{14}$$

$$\mu_{\mathrm{tot}} \equiv \sum_j \mu_{b_j} + \mu_s,$$

Profile over the nuisance parameters

Combining the likelihoods of the 2 partitions

$$\mathcal{L} = \mathcal{L}_{\mathrm{a}} \times \mathcal{L}_{\mathrm{b}}$$

What is this?

Background?

Signal? (Beyond Standard Model)

What is this?

Background?

Signal? (Beyond Standard Model)

Solar Axions

- QCD axion

= Axions would also be produced in the Sun, with kinetic energies ~ keV

Neutrio Magnetic moment

In the (extended) SM:

$$\mu_\nu \approx 3 \times 10^{-19} \left(\frac{m_\nu}{\text{eV}}\right) \mu_B$$

A larger value would imply new physics, and possibly solve Dirac vs Majorana.

Bosonic Dark matter

- **candidate for Warm Dark Matter**
- **Axion-like particles like QCD axions.**
- **allows for ALPs to take on higher masses than QCD axions**

What is this?

Background?

β-decay of tritium?

Low-energy (Q value 18.6 keV)
Long half life (12.3 years)
Atmospherically “abundant” and cosmogenically produced in xenon

Removed by purification system?

Signal? (Beyond Standard Model)

Solar Axions

- QCD axion
= Axions would also be produced in the Sun, with kinetic energies ~ keV

Neutrio Magnetic moment

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Bosonic Dark matter

- **candidate for Warm Dark Matter**
- **Axion-like particles like QCD axions.**
- **allows for ALPs to take on higher masses than QCD axions**

@XENONexperiment (twitter)

タイムラインにトピックも表示しましょう

これらのトピックについてのトップツイートがホームタイムラインに表示されます。

XENONexperiment @XENONex... · 2日

XENON1T observed an excess of electronic events at low energy. What's the origin of such excess in your opinion? (see arxiv.org/abs/2006.09721)
Ps. If "other option", write below (e.g. blue spaghetti monster)

171票 · 残り2日と8時間

Statistical Inference

Unbinned likelihood ratio tests

Profiled over nuisance parameters

$$q(\mu_s) = -2\ln\frac{\mathcal{L}(\mu_s, \hat{\hat{\boldsymbol{\mu}}}_b, \hat{\hat{\boldsymbol{\theta}}})}{\mathcal{L}(\hat{\mu}_s, \hat{\boldsymbol{\mu}}_b, \hat{\boldsymbol{\theta}})},$$

statistical significance:
→ q(0)

Solar Axions

3 independent* parameters

ABC rate
Primakoff rate
^{57}Fe rate

→

3-dimensional confidence volume

g_{ae}
$g_{a\gamma}$
g_{an}^{eff}

**No assumptions about specific QCD axion models*

Toy-MC methods for significance

Neutrino Magnetic Moment

1 parameter

solar ν rate enhancement

→

1-dimensional confidence interval

μ_ν

smoothly transitions from upper- to two-sided limit at 3σ. (K.D. Morå, arXiv:1809.02024)

Tritium

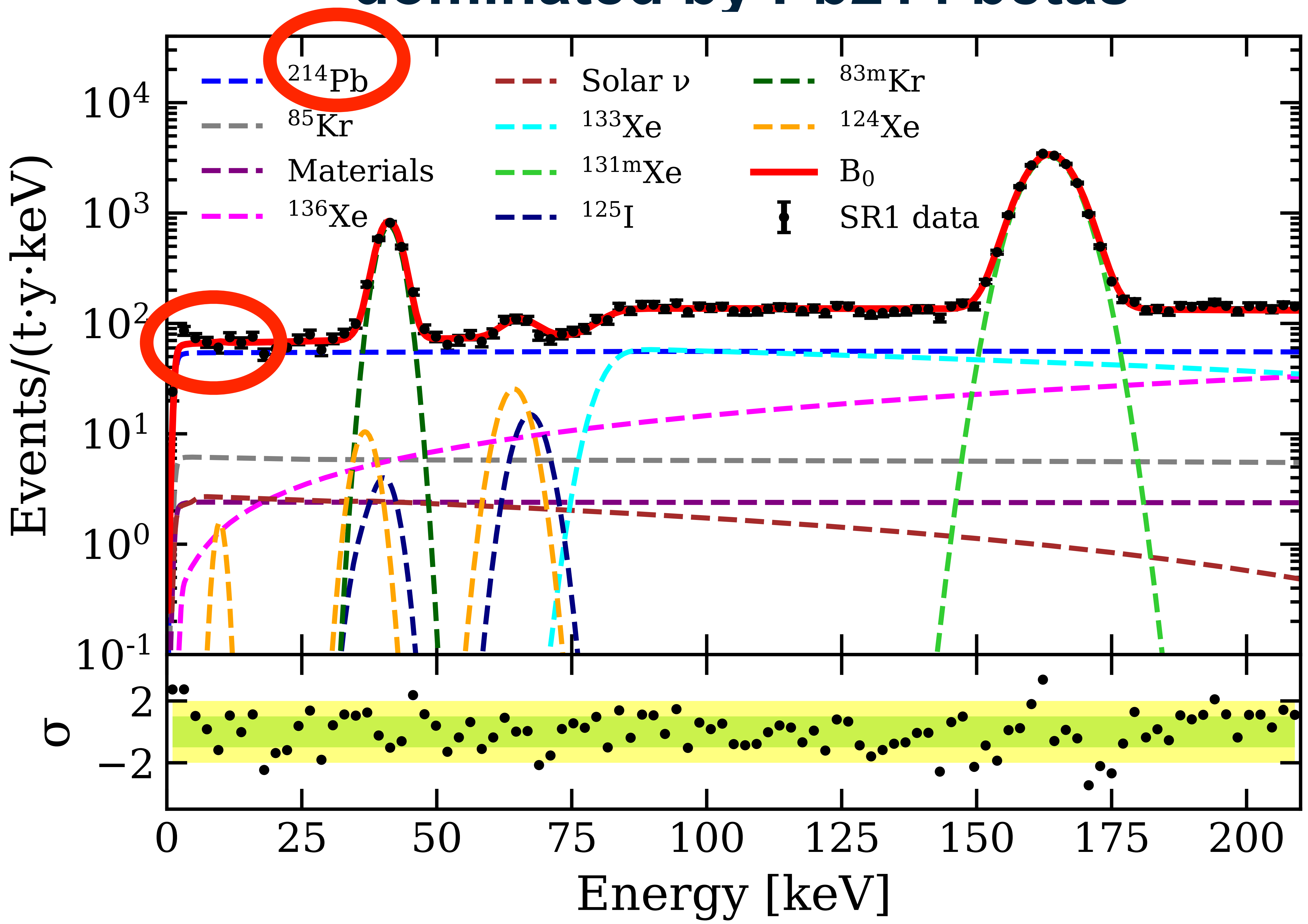
Solara Axion

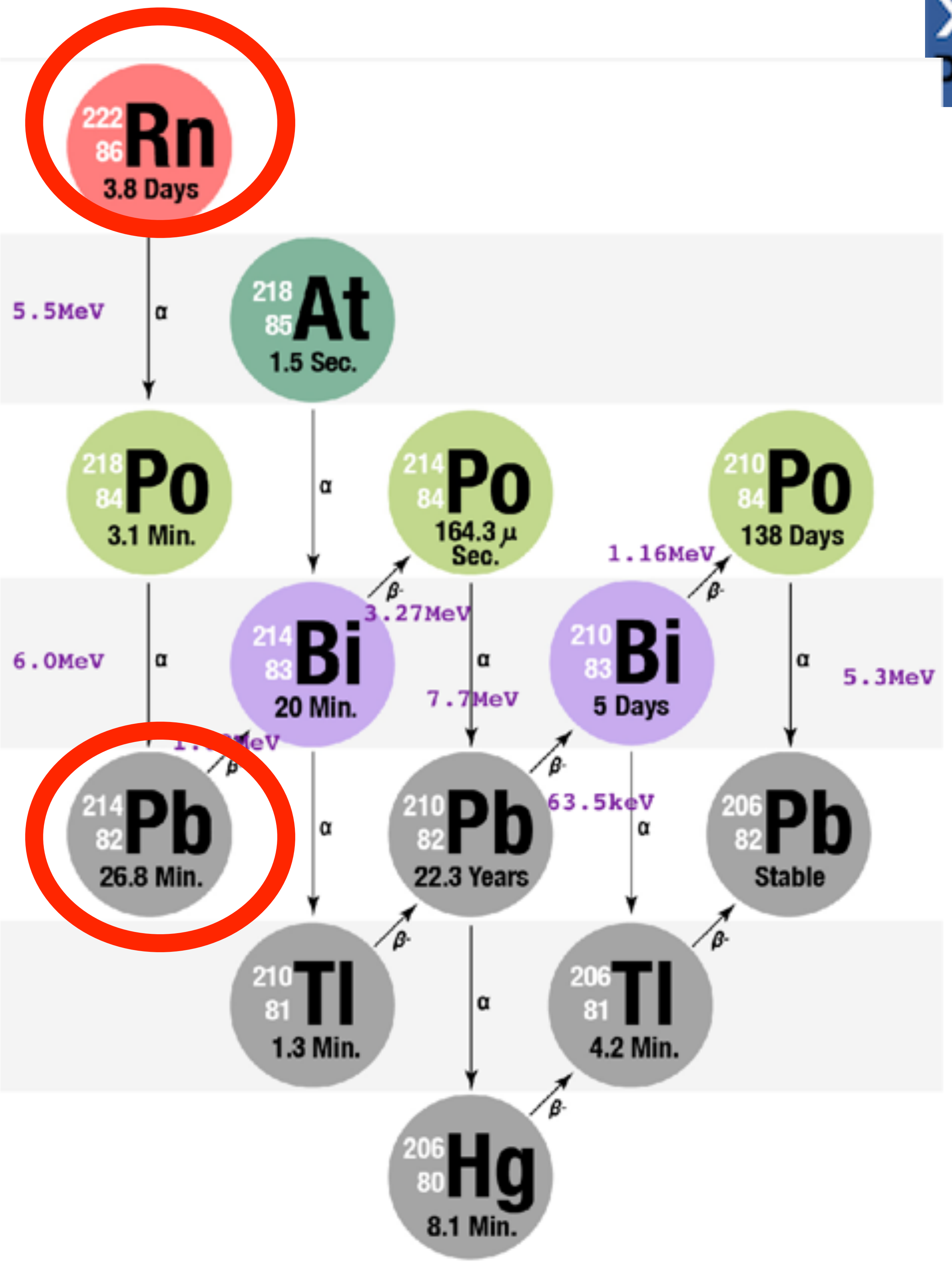
Neutrino magnetic moment + others

The XENON1T ER Background

- ER is the dominant background
- Surface background & neutron distribution are not uniform. Spatial likelihood is taken into consideration.

dominated by Pb214 betas



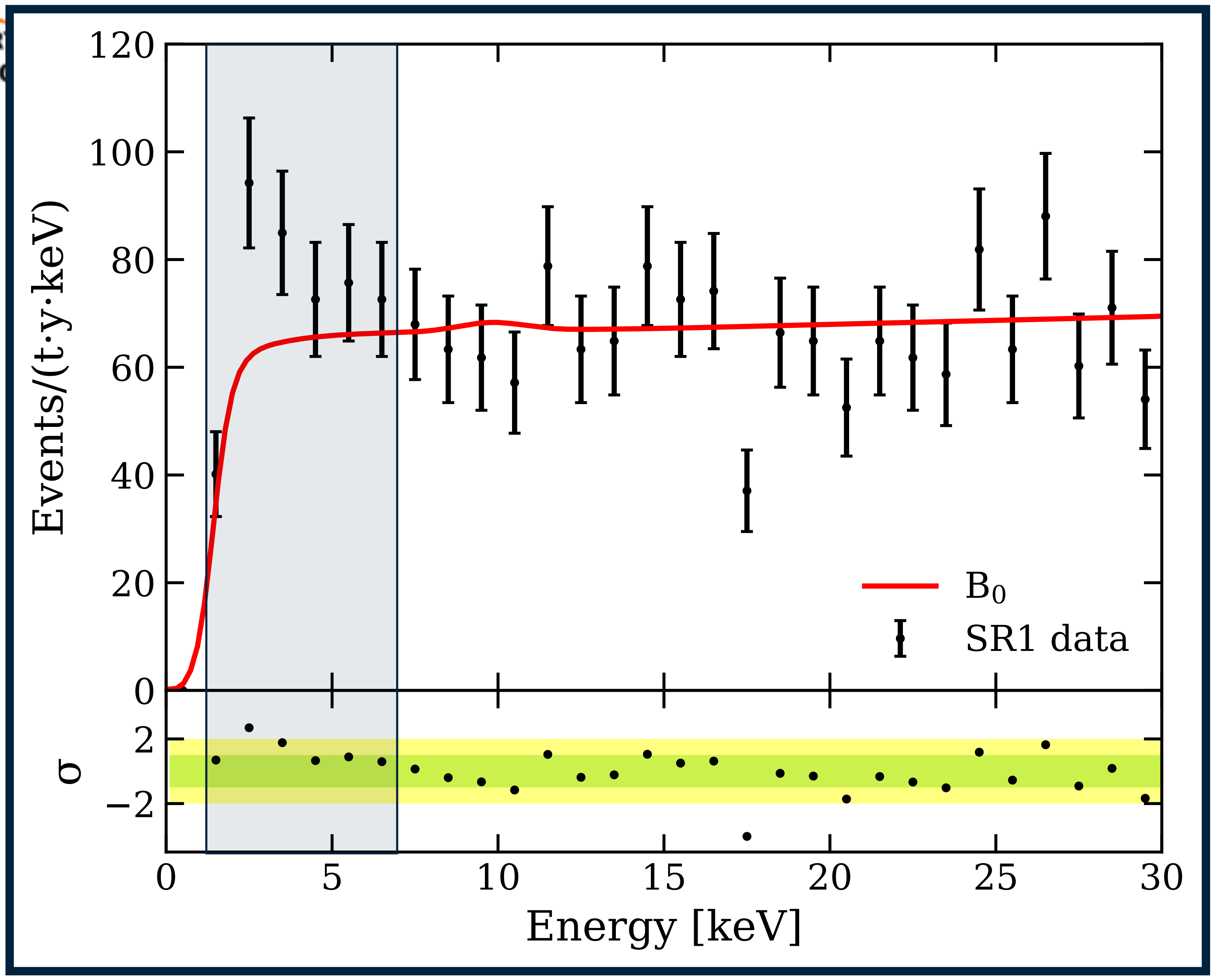


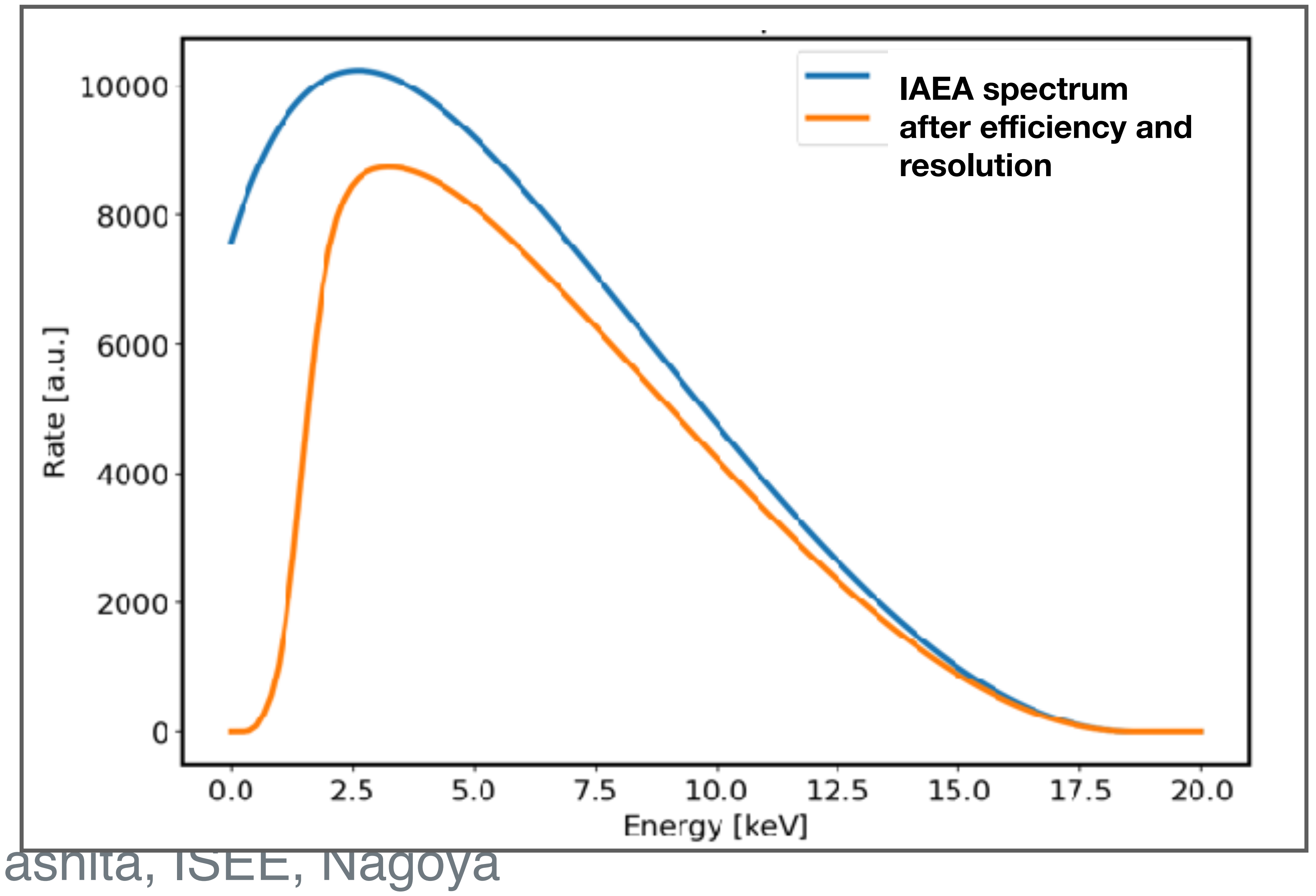
Decent matching across the whole energy range 1-210 keV

(76 +/- 2) events/(t·y·keV) in [1, 30] keV

Lowest background rate ever achieved in this energy range!

Tritium (^{3}H) ?





Low energy (Q-value 18.6keV)

Long half life (12.3 years)

Two possible ways to introduce tritium:

Cosmogenic production

Atmospherically abundant

Tritium Fit

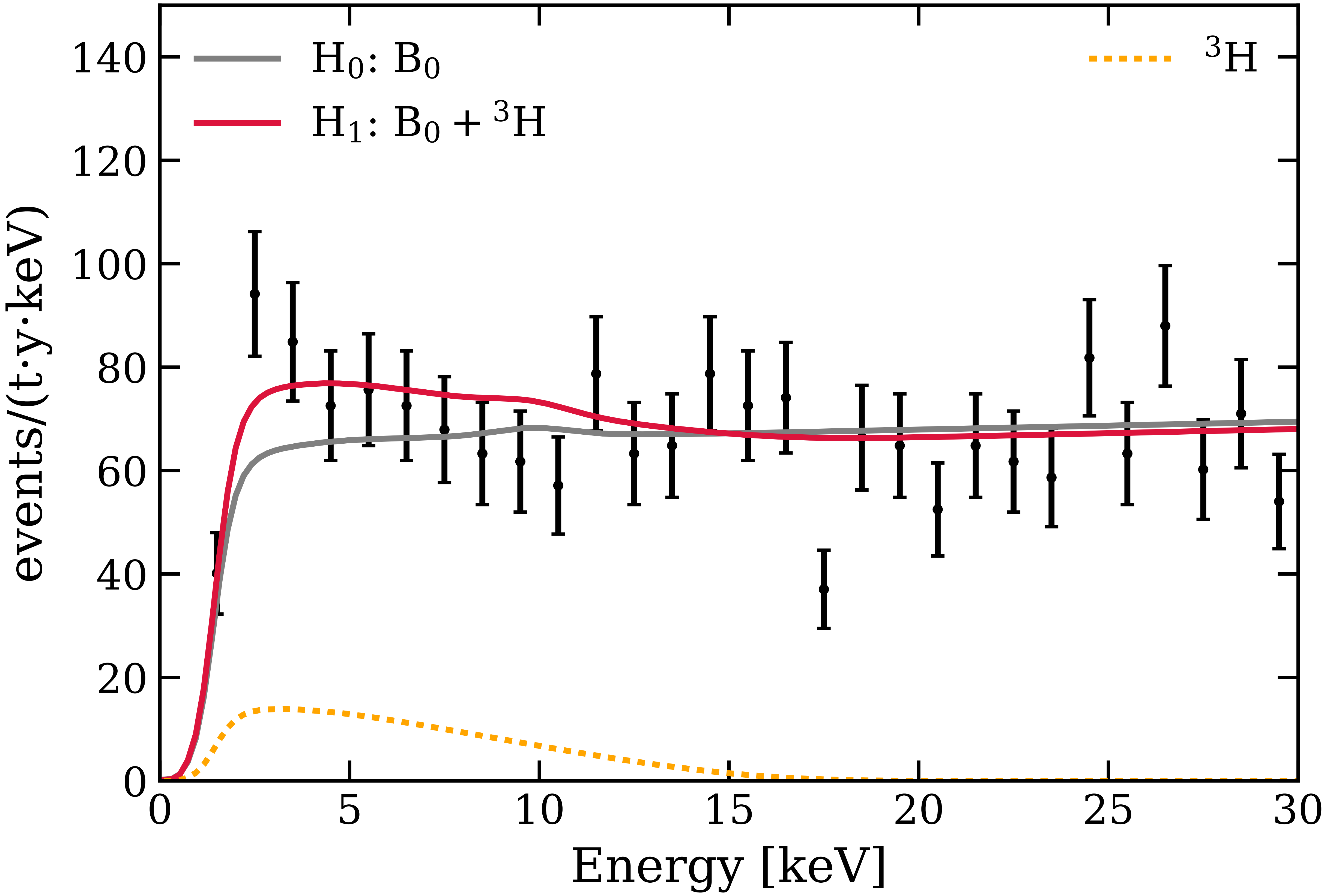
Tritium favored over background-only at 3.2σ

Tritium Rate

$$159 \pm 51\,\mathrm{events}/(\mathrm{t} \cdot \mathrm{y})$$

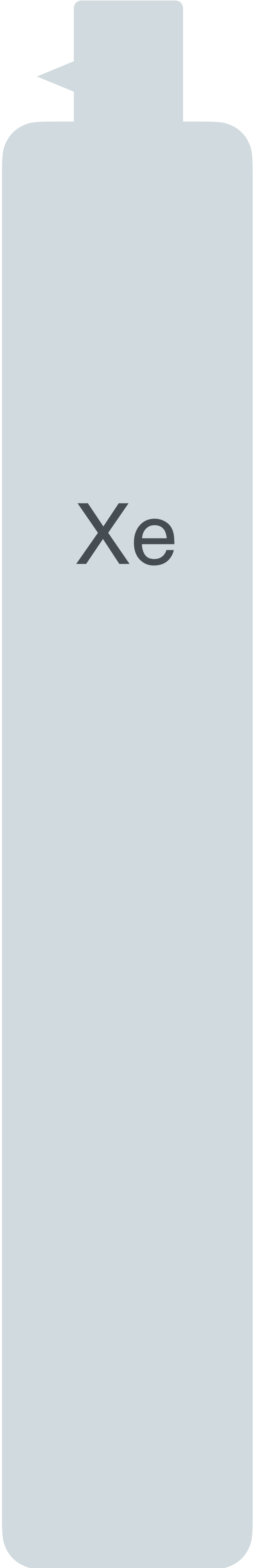
^{3}H:Xe concentration

$$6.2 \pm 2.0 \times 10^{-25}\ \mathrm{mol/mol}$$



Masaki Yamashita, ISEE, Nagoya

Tritium hypothesis

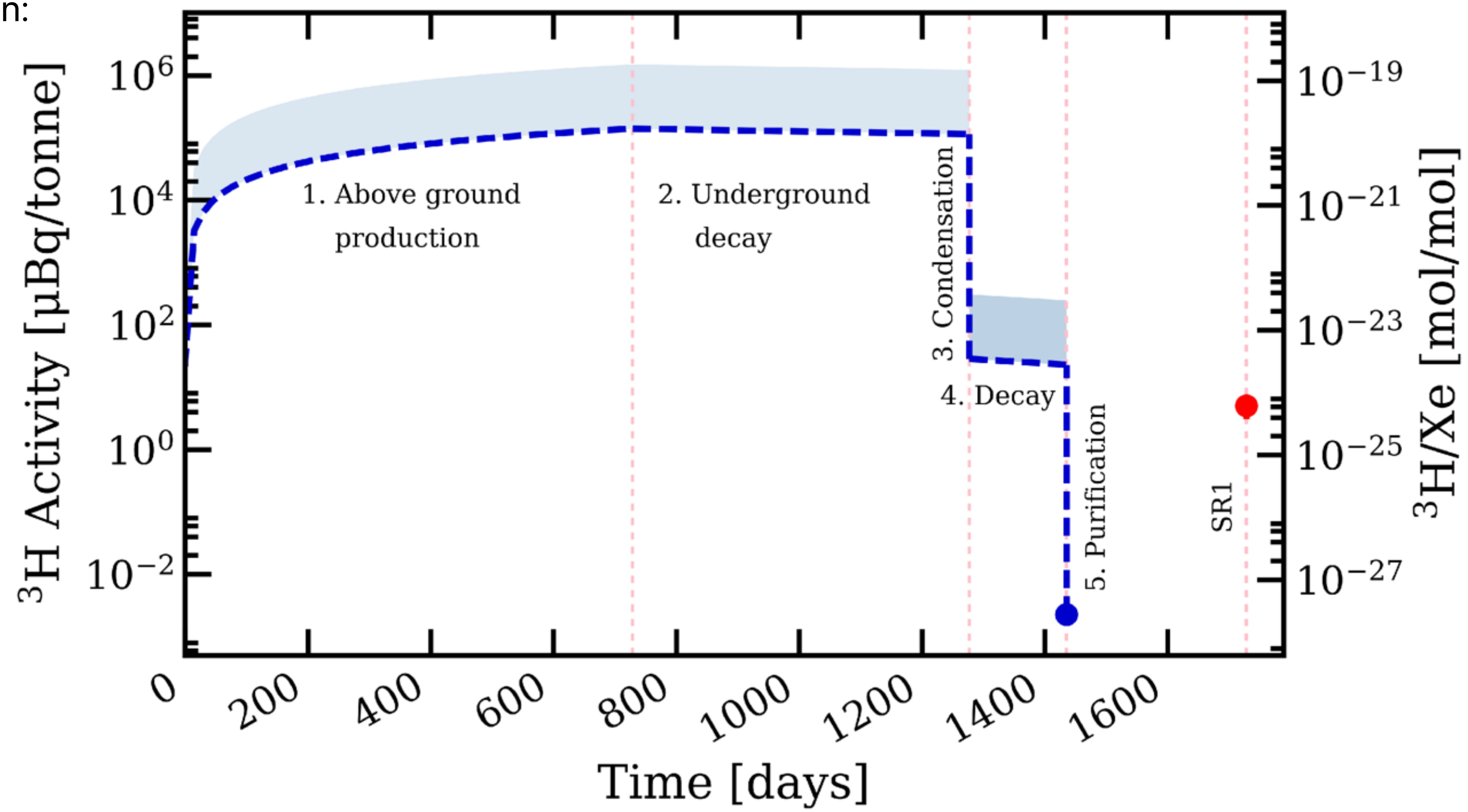


Cosmogenic activation of xenon:
~32 tritium atoms/kg/day
(Zhang, 2016)

1 ppm water in bottles implies tritium forms predominately HTO.

Efficient removal (99.99%) in purification system (SAES getter with hydrogen removal unit)

From purification and handling, this component seems unlikely.

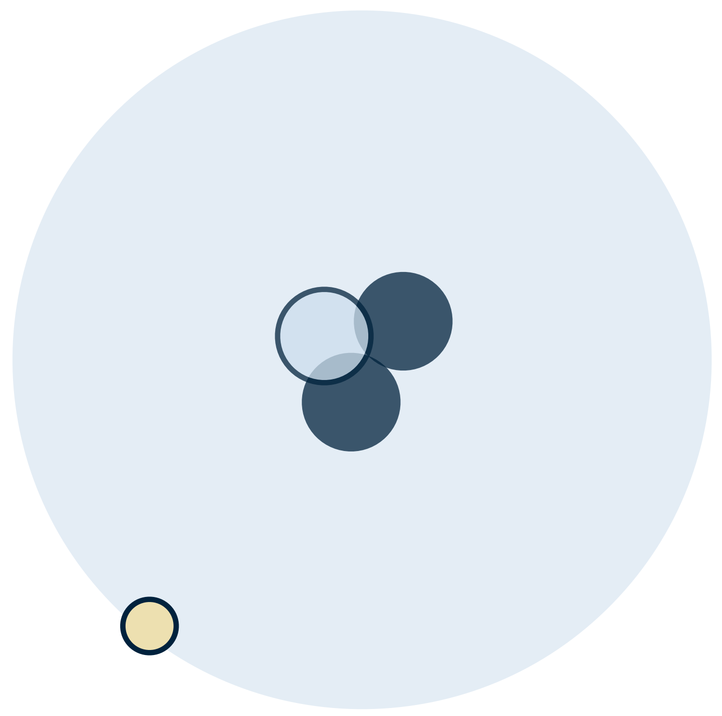


(note: tritium from activation While underground is negligible.)

Tritium Hypothesis

Any T in xenon gas *prior to* filling would be removed.

What about T emanating from materials in equilibrium with removal?



Atmospheric abundance in materials

HTO:H_2O concentration*

(assume same for HT)

$$5\text{–}10 \times 10^{-18}\ \mathrm{mol/mol}$$

Required (H_2O + H_2):Xe concentration to explain excess

60–120 ppb

H_2O

H_2O:Xe concentration constrained from light yield measurement

O(1) ppb

H_2

H_2:Xe concentration not constrained by any measurement.

O2-equivalent concentration is **<ppb** from xenon purity measurement (e-lifetime)

H_2 would require equilibrium emanation rate ~100x higher than electronegative impurities.

---

*IAEA/WMO, "Global Network of Isotopes in Precipitation. The GNIP Database." https://nucleus.iaea.1723org/wiser(2015).

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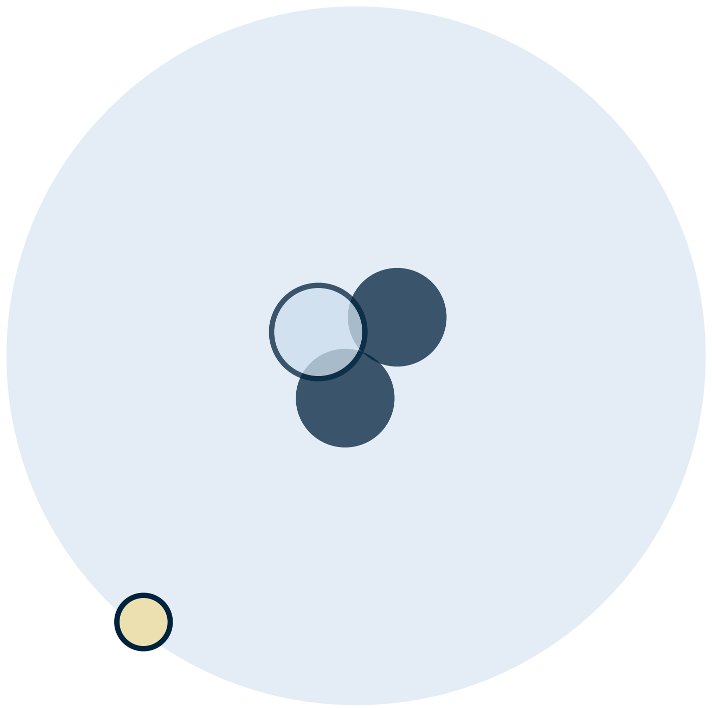

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H_2O

Unlikely

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Maybe?

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(assume same for HT)

$$5\text{–}10 \times 10^{-18}\ \mathrm{mol/mol}$$

ppb

And there are additional uncertainties...

- Unknown radiochemistry in liquid xenon environment (isotopic exchange, diffusion, solubility, etc.)
- Presence of other tritiated molecules?

H_2O:Xe concentration constrained from light yield measurement

O(1) ppb

onstrained by

measurement.

Maybe?

O2-equivalent concentration is **<ppb** from xenon purity measurement (e-lifetime)

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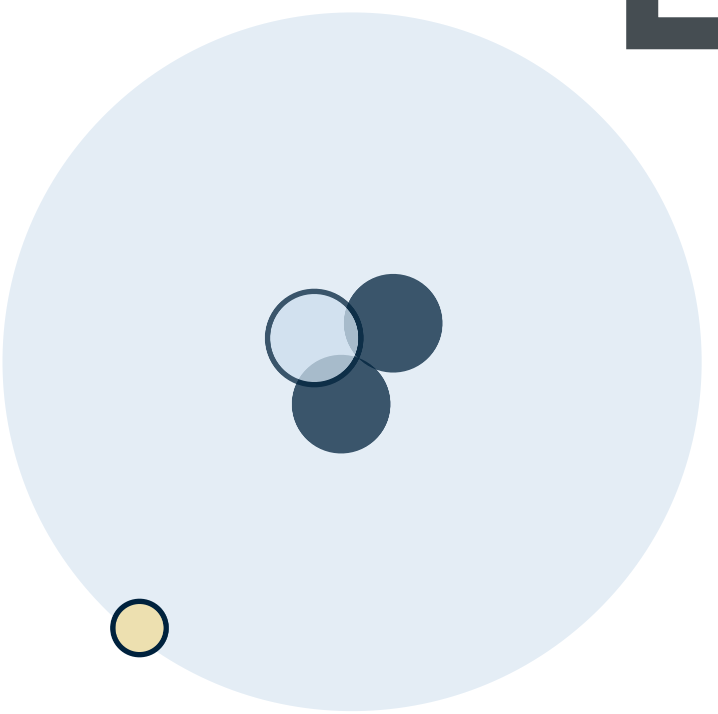

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Tritium

Solara Axion

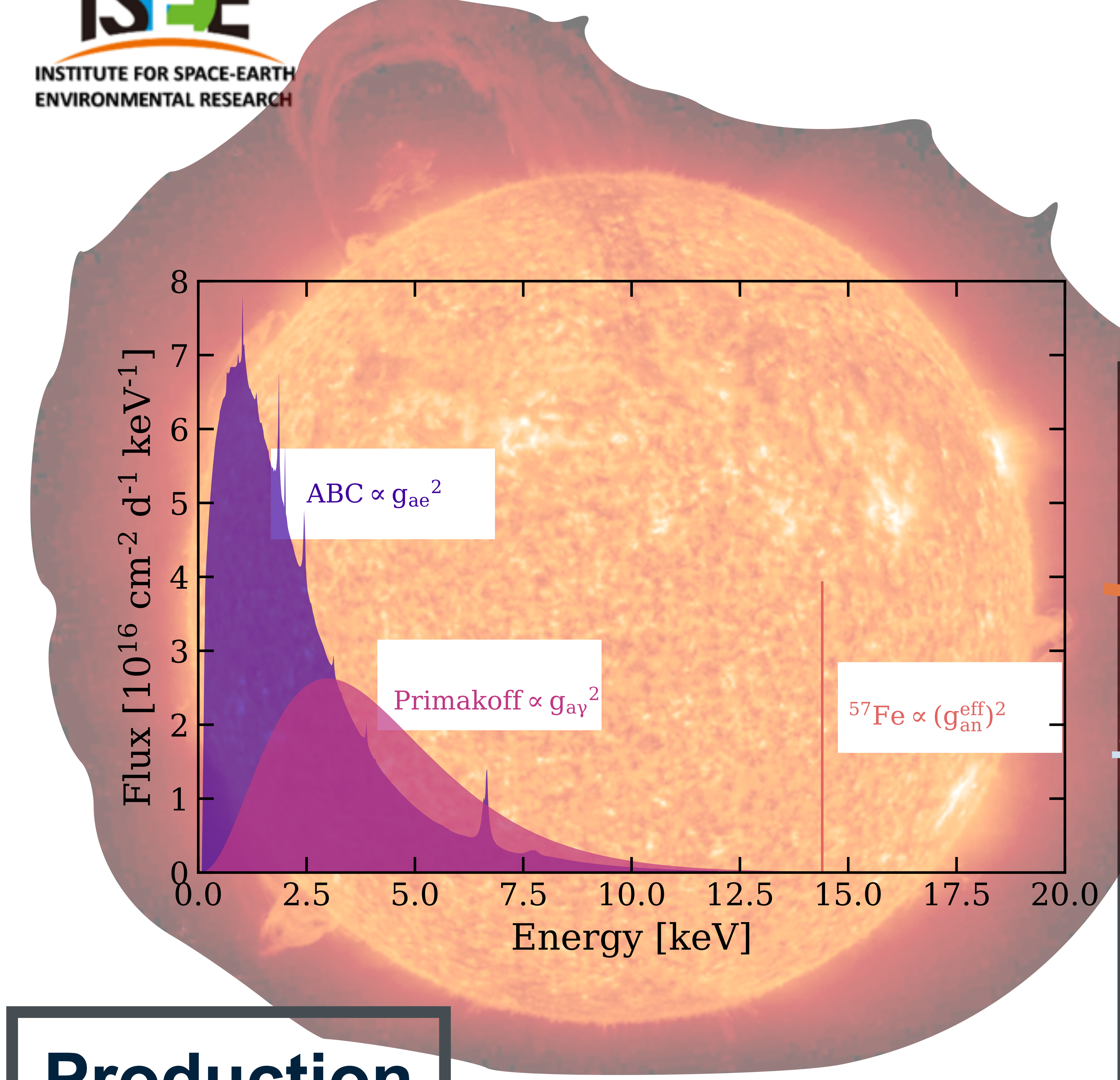
Neutrino magnetic moment + others

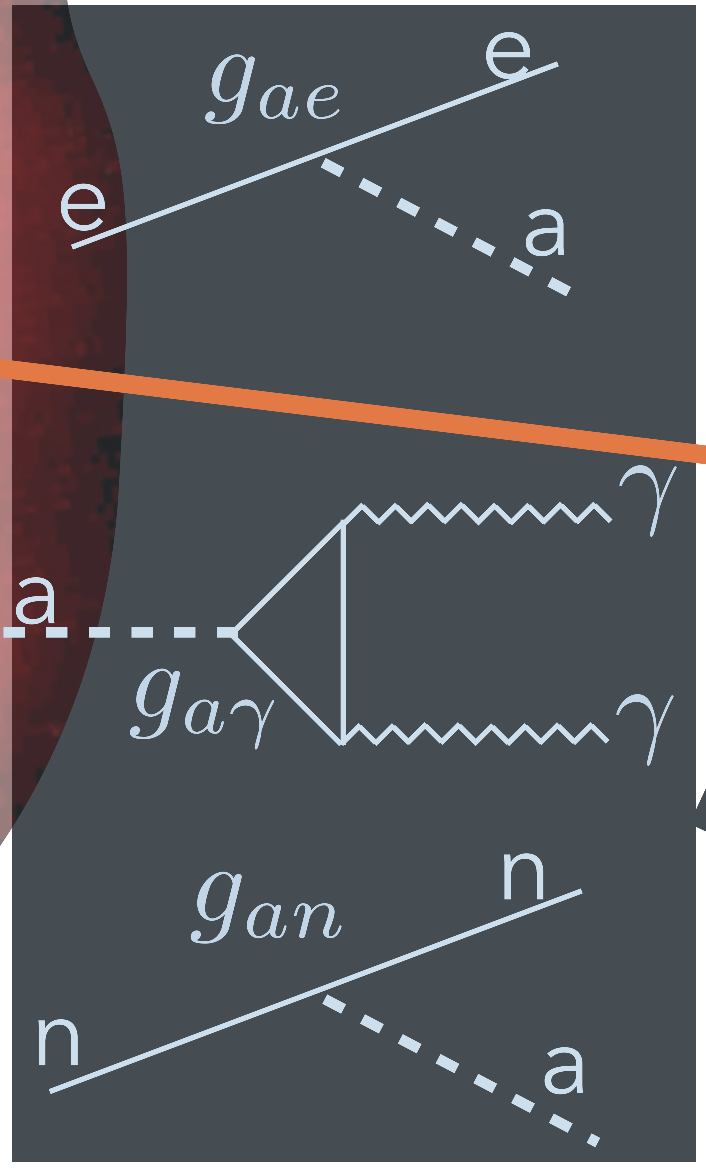
Solar Axion

Axion

Solution to the “strong CP problem”

Natural candidates of the dark matter

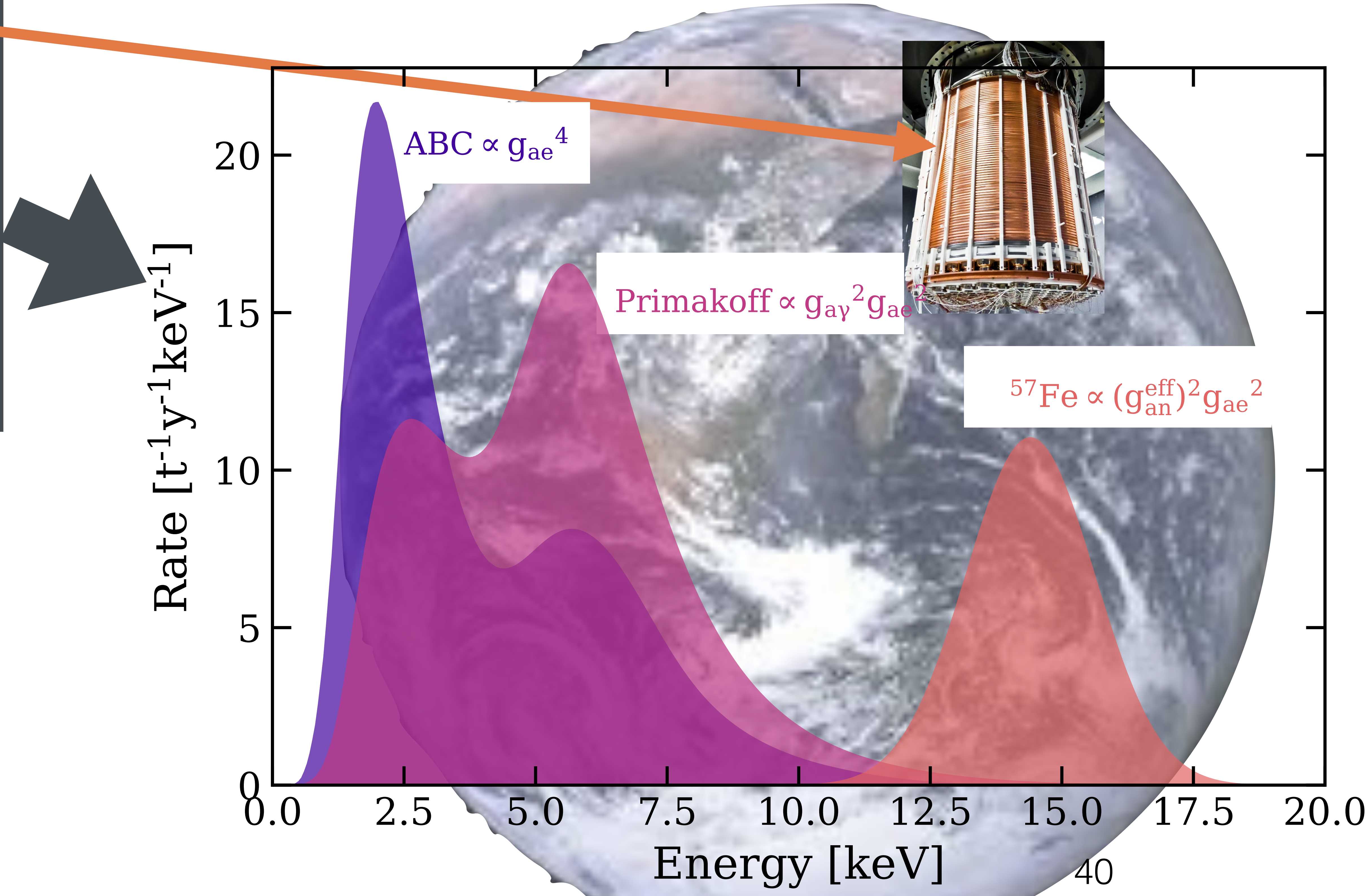




Detection

Axions would also be produced in the Sun, with kinetic energies ~ keV

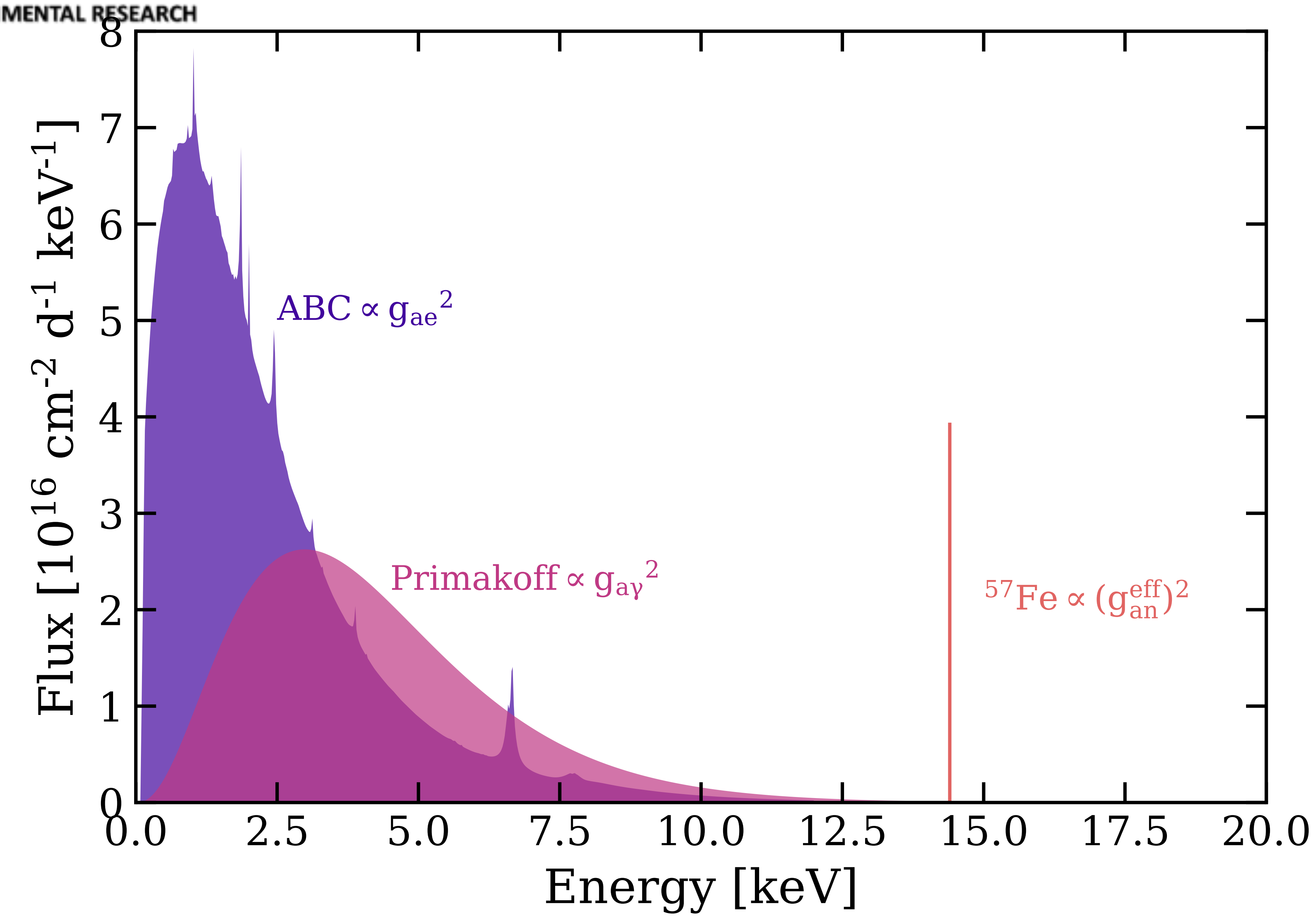
However, solar axion is not a dark matter.



Production

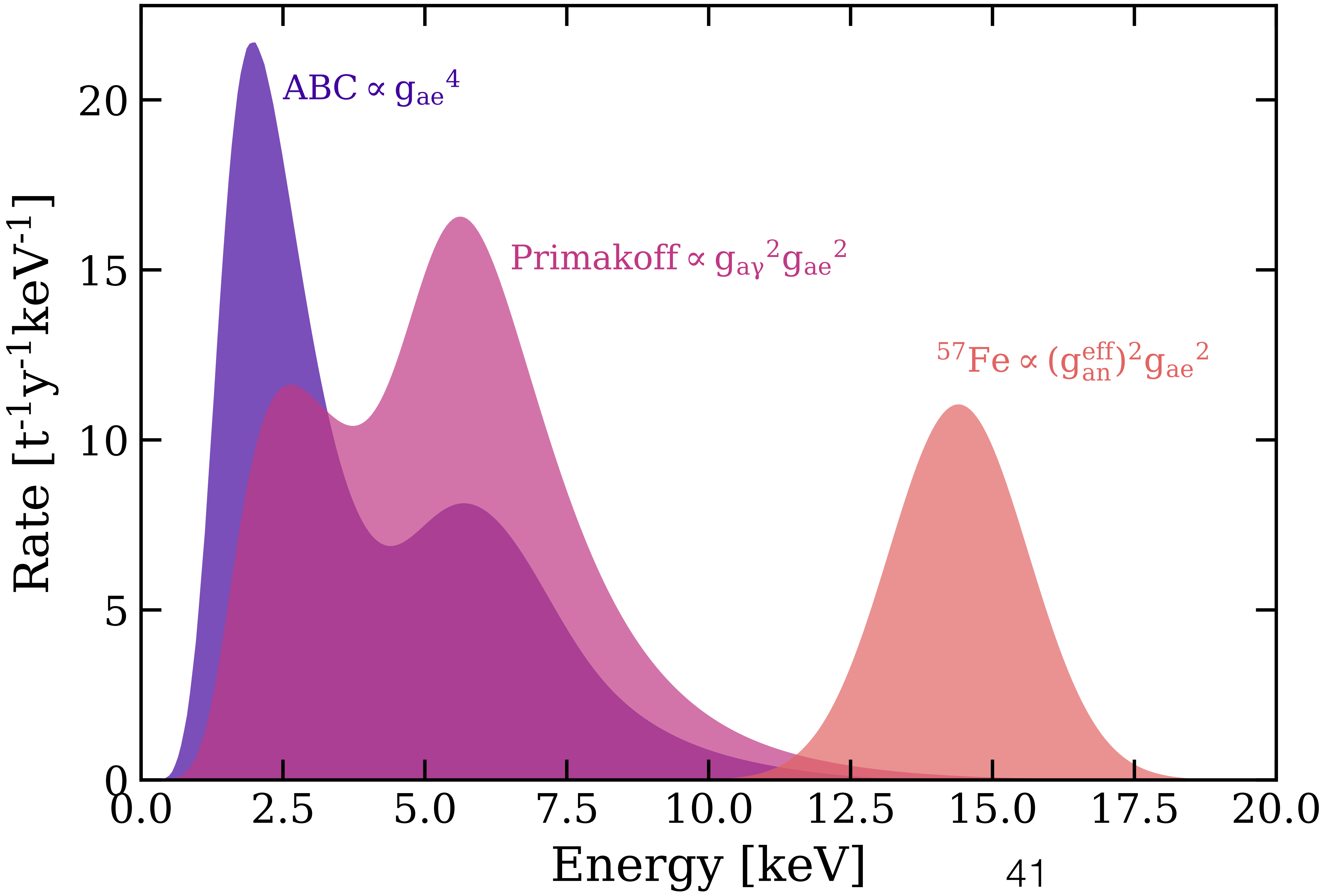
- **ABC axion (Redondo 2013, Dimopoulos 1986) (atomic recombination, Bremsstrahlung, Compton)**
- **Primakoff (Primakoff 1951, Dicus 1978)**
- **M1 transition of 57Fe (Moriyama 1995)**

Solar Axion



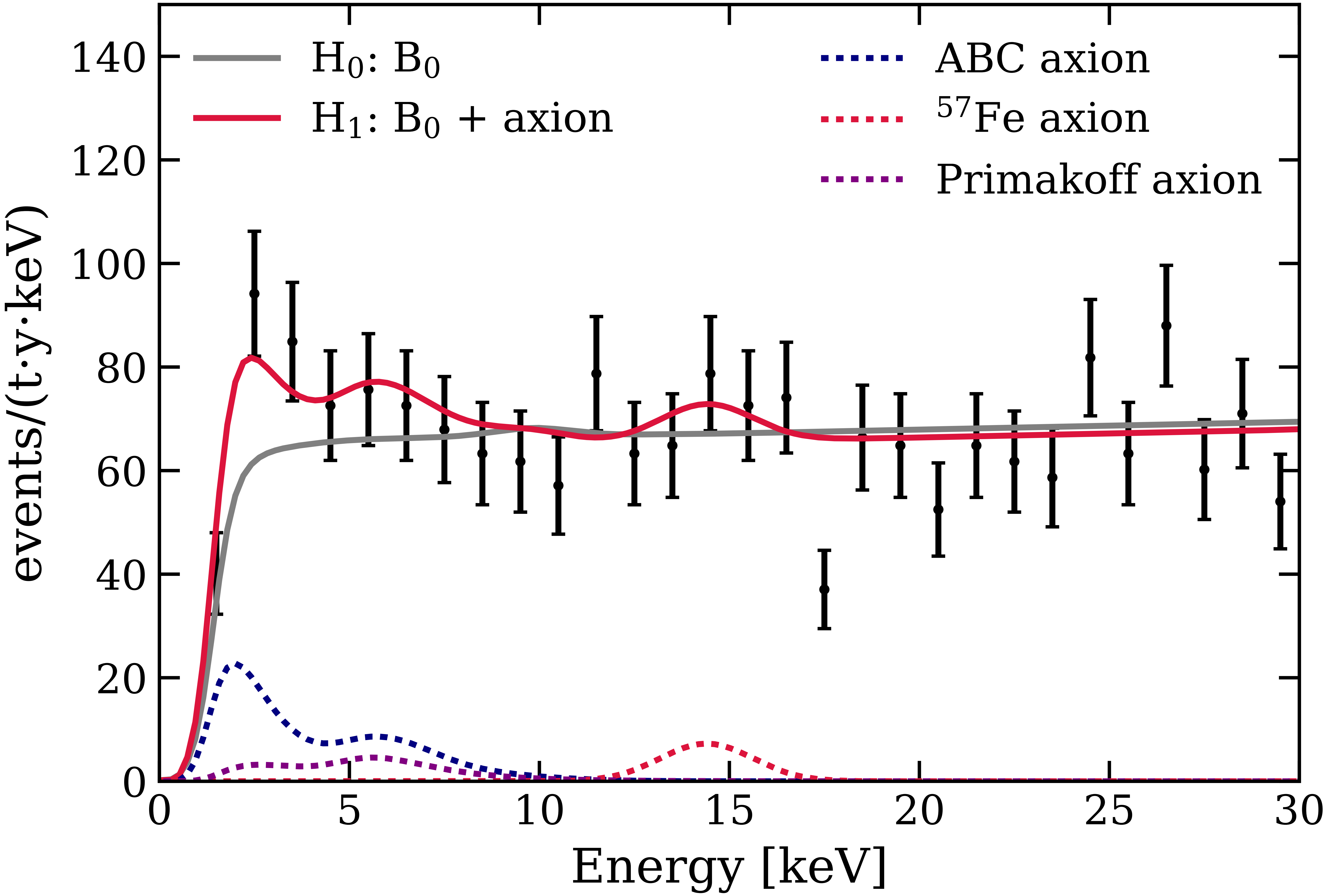
Axioelectric effect

$$\sigma_{ae} = \sigma_{pe} \frac{g_{ae}^2}{\beta} \frac{3E_a^2}{16\pi\alpha m_e^2} \left(1 - \frac{\beta^{2/3}}{3}\right)$$



Fitting Axions to the Excess

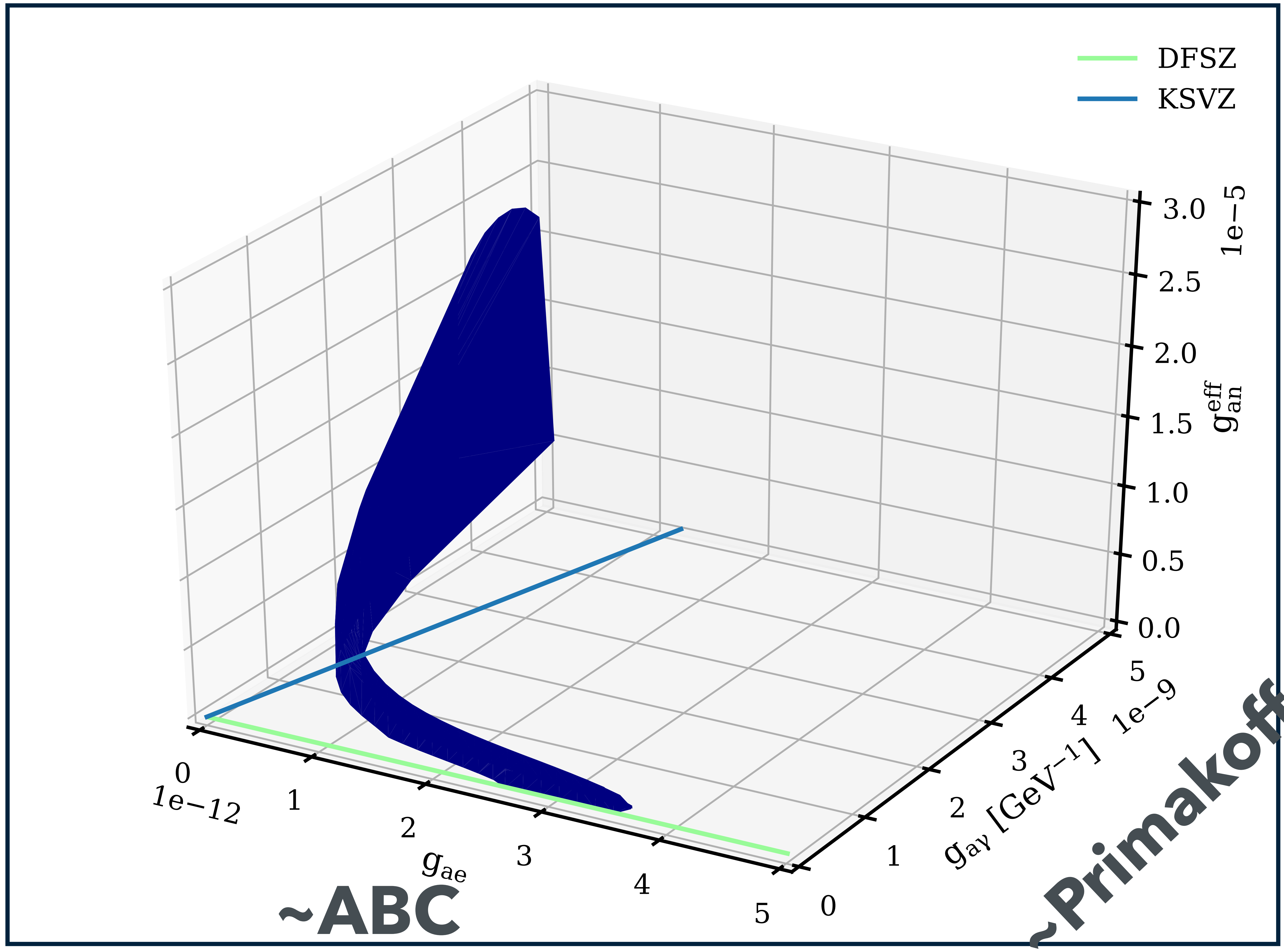
- Unbinned profile likelihood analysis
- XENON1T BG + Axion (ABC, Primakov, 57Fe)
- + Tritium background will com later.



Axion favored over background-only at 3.5σ

Solar Axion Results

3D confidence volume (90% C.L.)



Excludes one of:

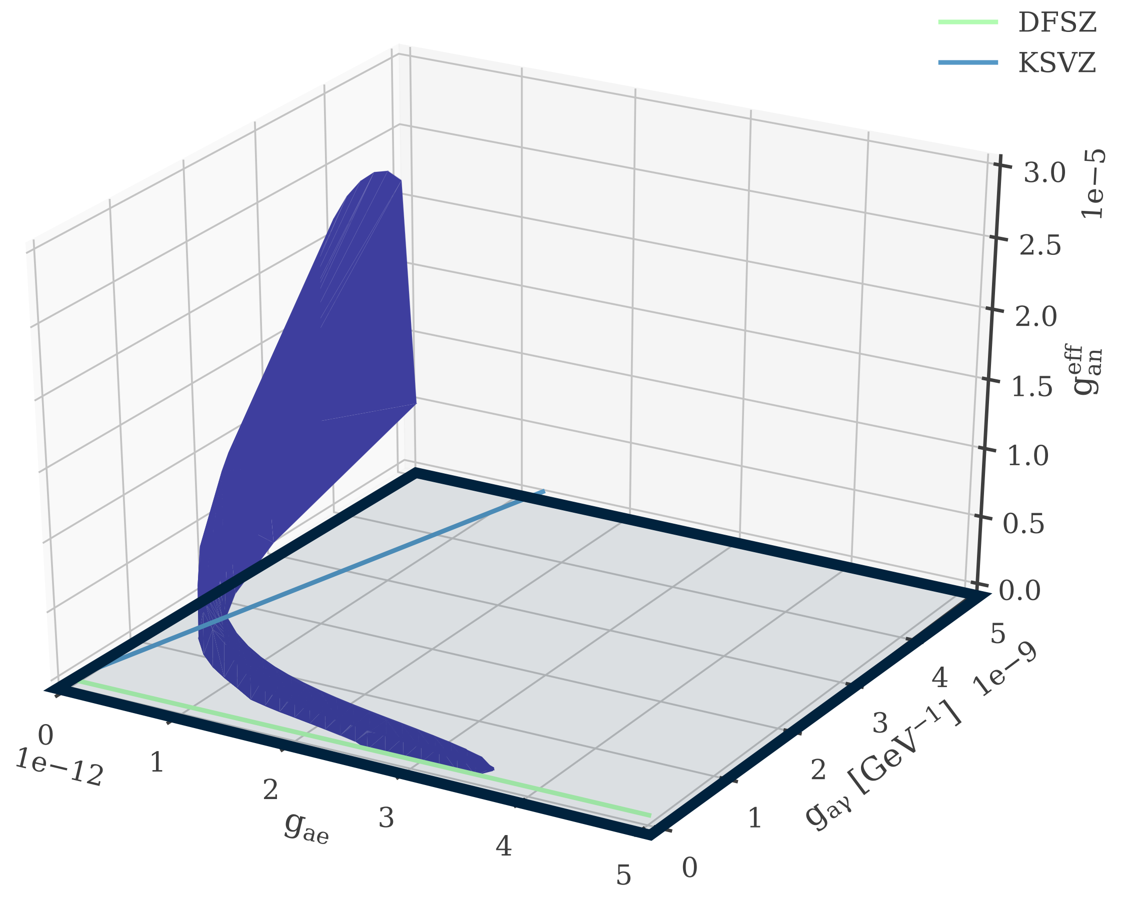
- $g_{ae} = 0$
- $g_{a\gamma} = g_{an}^{eff} = 0$

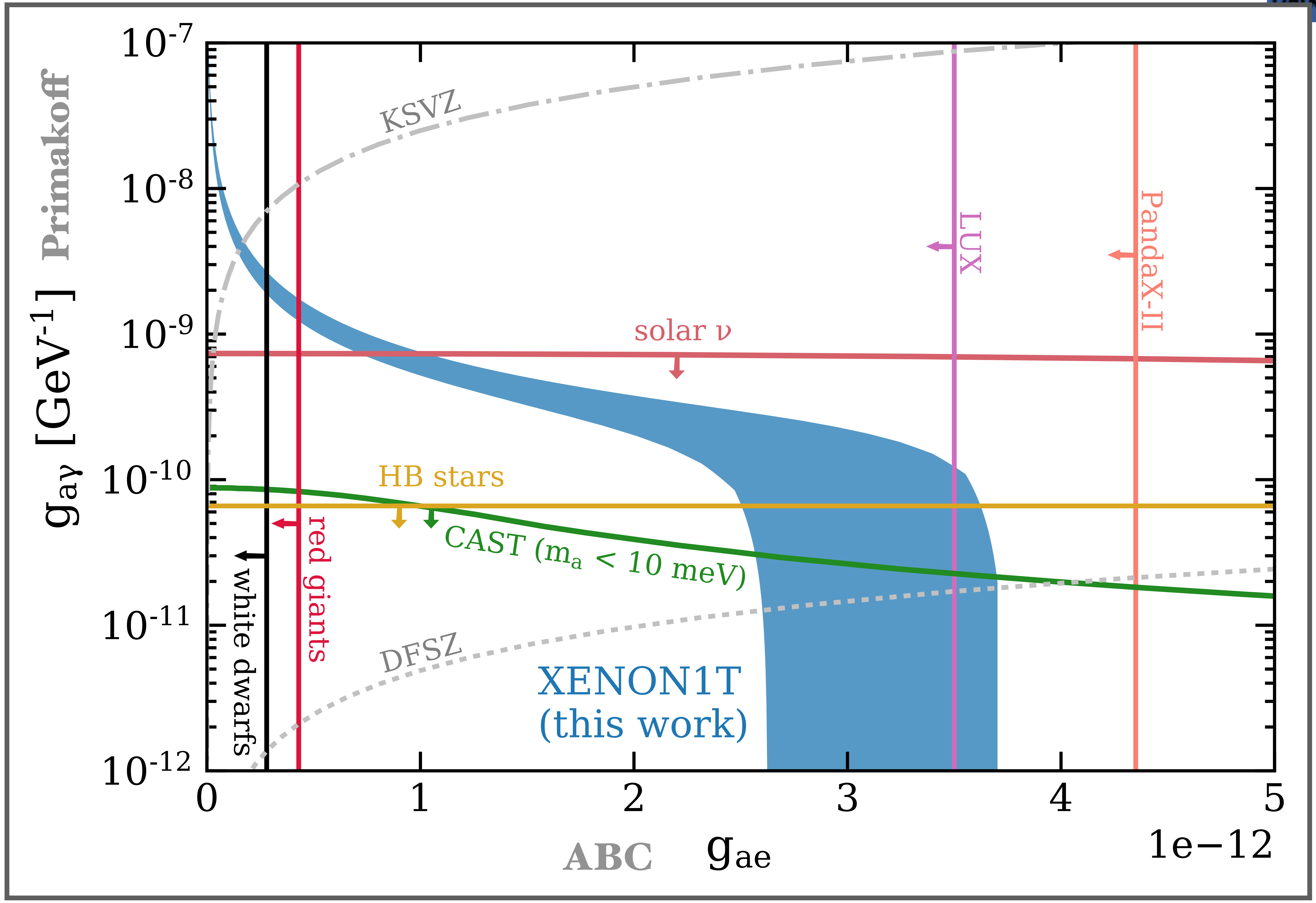
$$g_{ae} < 3.7 \times 10^{-12}$$
$$g_{ae} g_{an}^{eff} < 4.6 \times 10^{-18}$$
$$g_{ae} g_{a\gamma} < 7.6 \times 10^{-22}\ \mathrm{GeV}^{-1}$$

Allowed Parameter Space

Tension:
Red giants
White dwarfs
HB stars

- extra cooling
- if axions take away energy from starts too much..



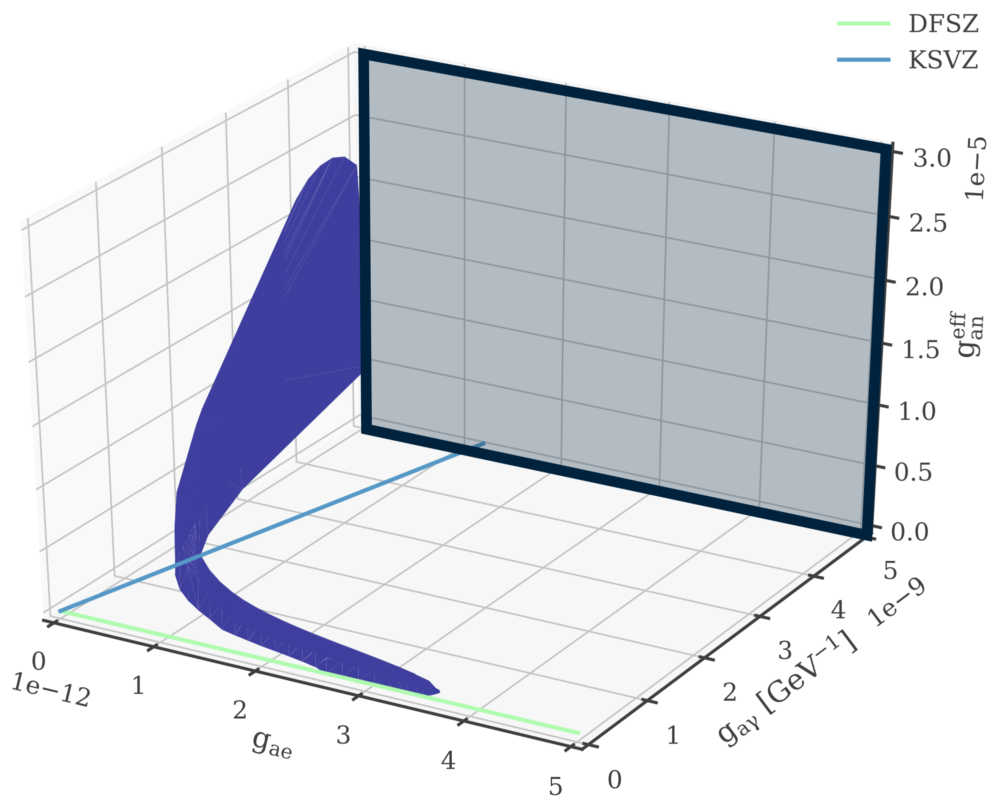


In tension with astrophysical constraints from stellar cooling

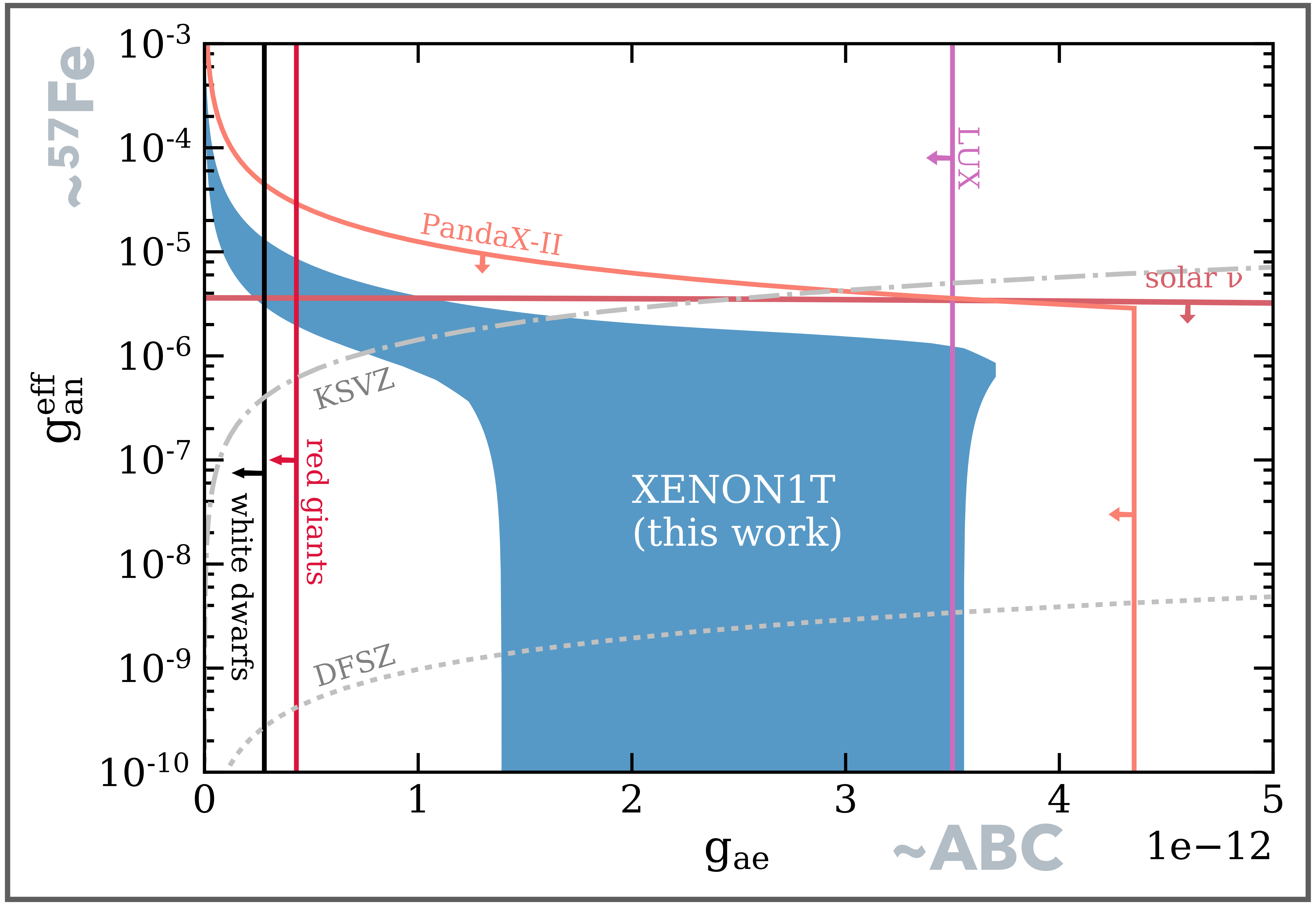
(arXiv 2003.01100)

Allowed Parameter Space

- 3D confidence volume (90% C.L.)
- Projected onto 2D regions



Profile over Primakoff



Poor fit for small ABC rate → Only accept ^{57}Fe value near best-fit

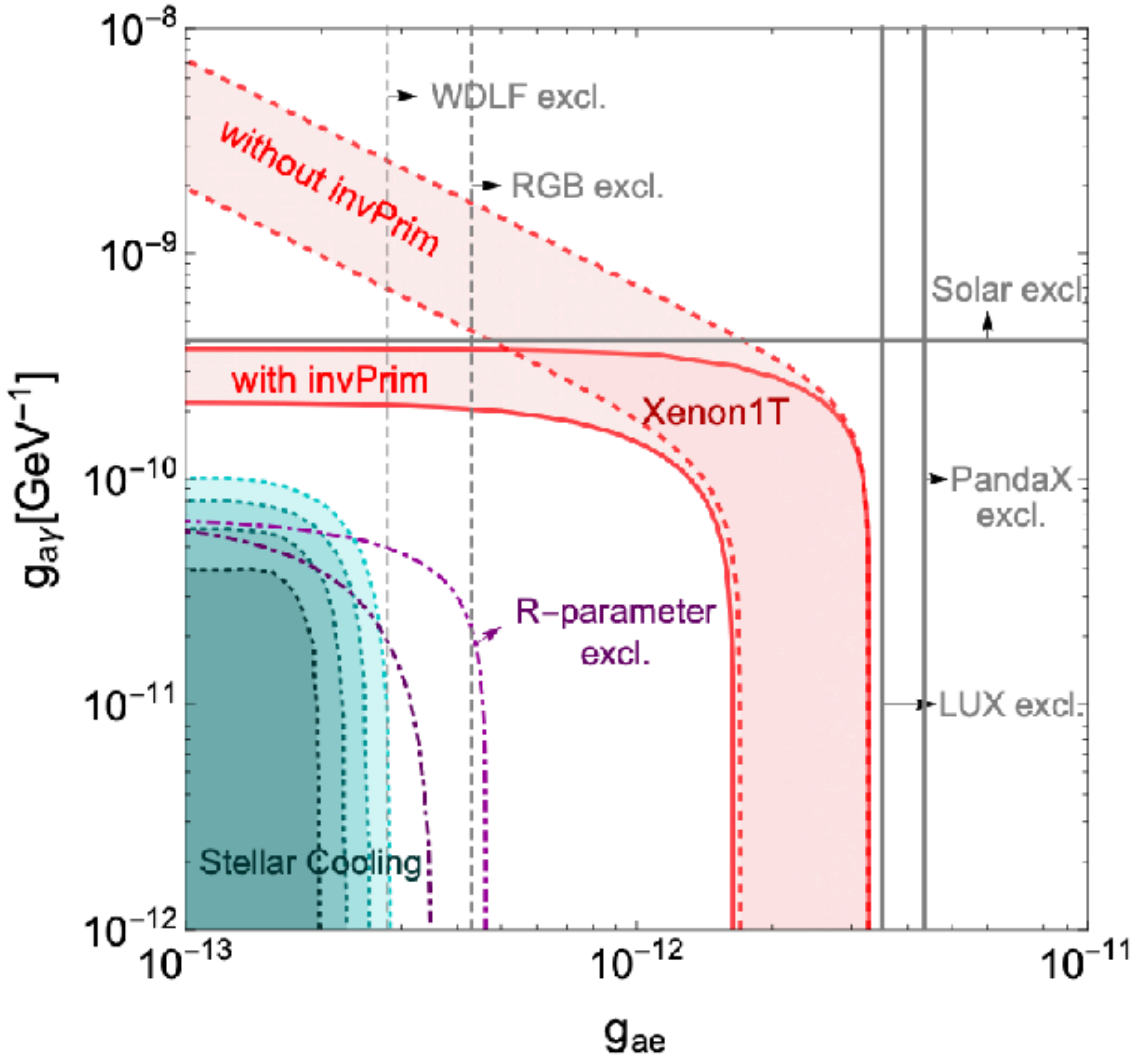
Considering the Inverse Primakoff Process

(arXiv 2006.14598v1)

Interesting additions from theorists to our data analysis

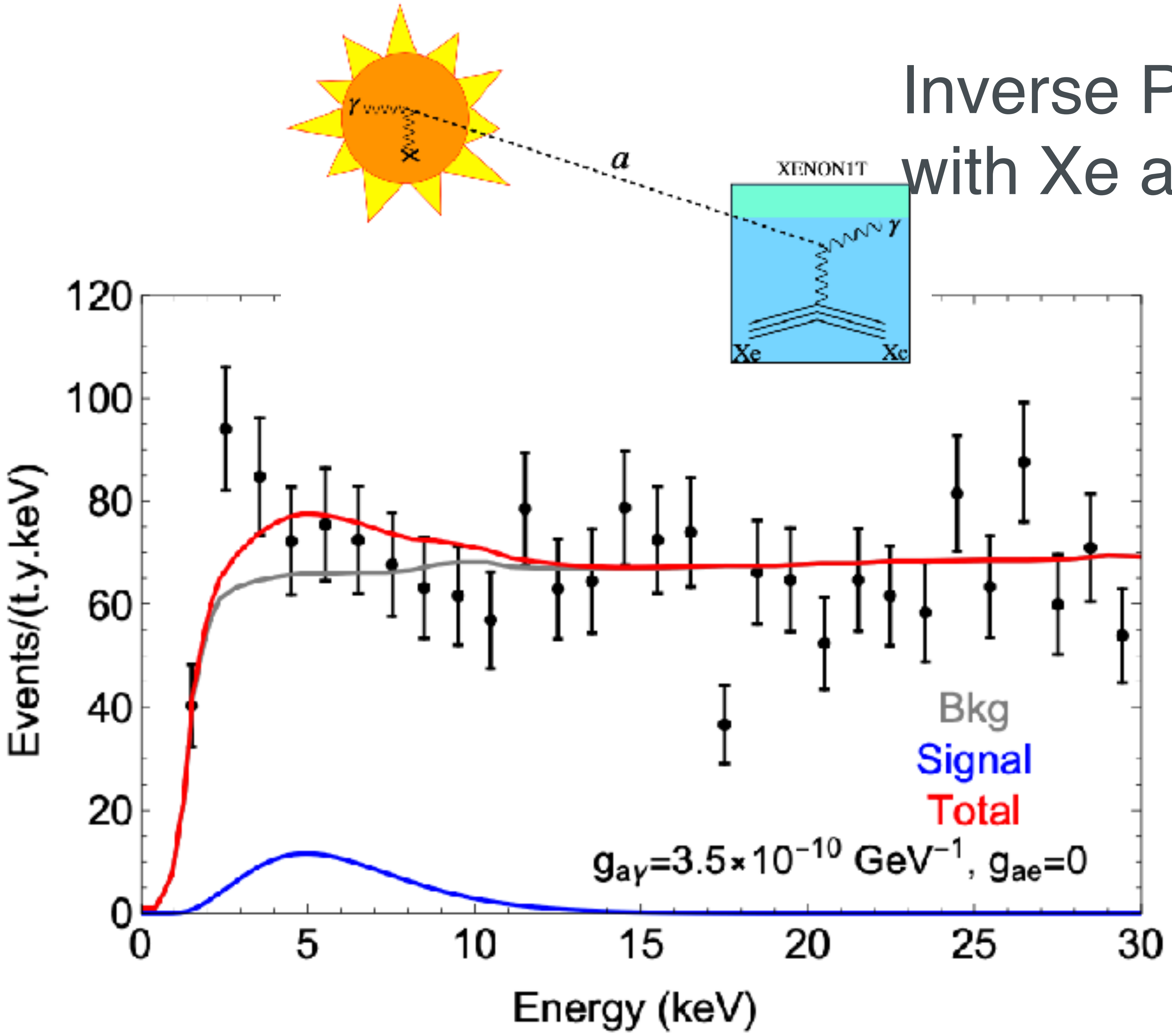
Re-examining the Solar Axion Explanation for the XENON1T Excess

Christina Gao,[1] Jia Liu,[2] Lian-Tao Wang,[2, 3] Xiao-Ping Wang,[4] Wei Xue,[5] and Yi-Ming Zhong[6]



Considering inverse Primakoff process can weaken the tension with stellar cooling constraint

Inverse Primakov with Xe atomic electric field

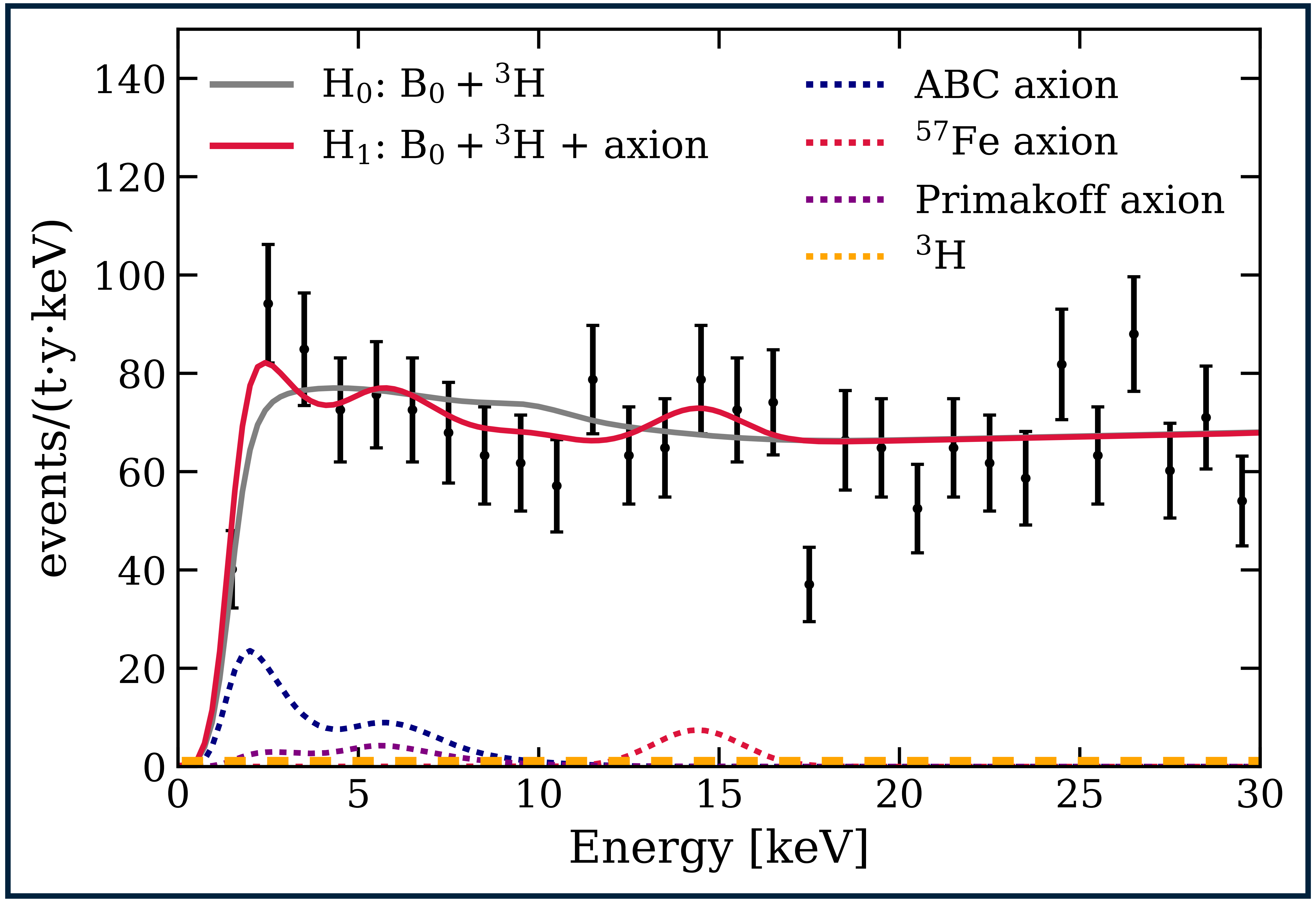


If inverse Primakoff process dominates, it will not fit the excess as good

Tritium + solar axion

Axion + ^{3}H favored over ^{3}H hypothesis at 2.1σ

Tritium (3H) is almost zero, but likelihood ratio L_{signal} vs L_{bg} is small so the significance is reduced.



Can we distinguish the two hypothesis by additional checks?

Tritium

Solara Axion

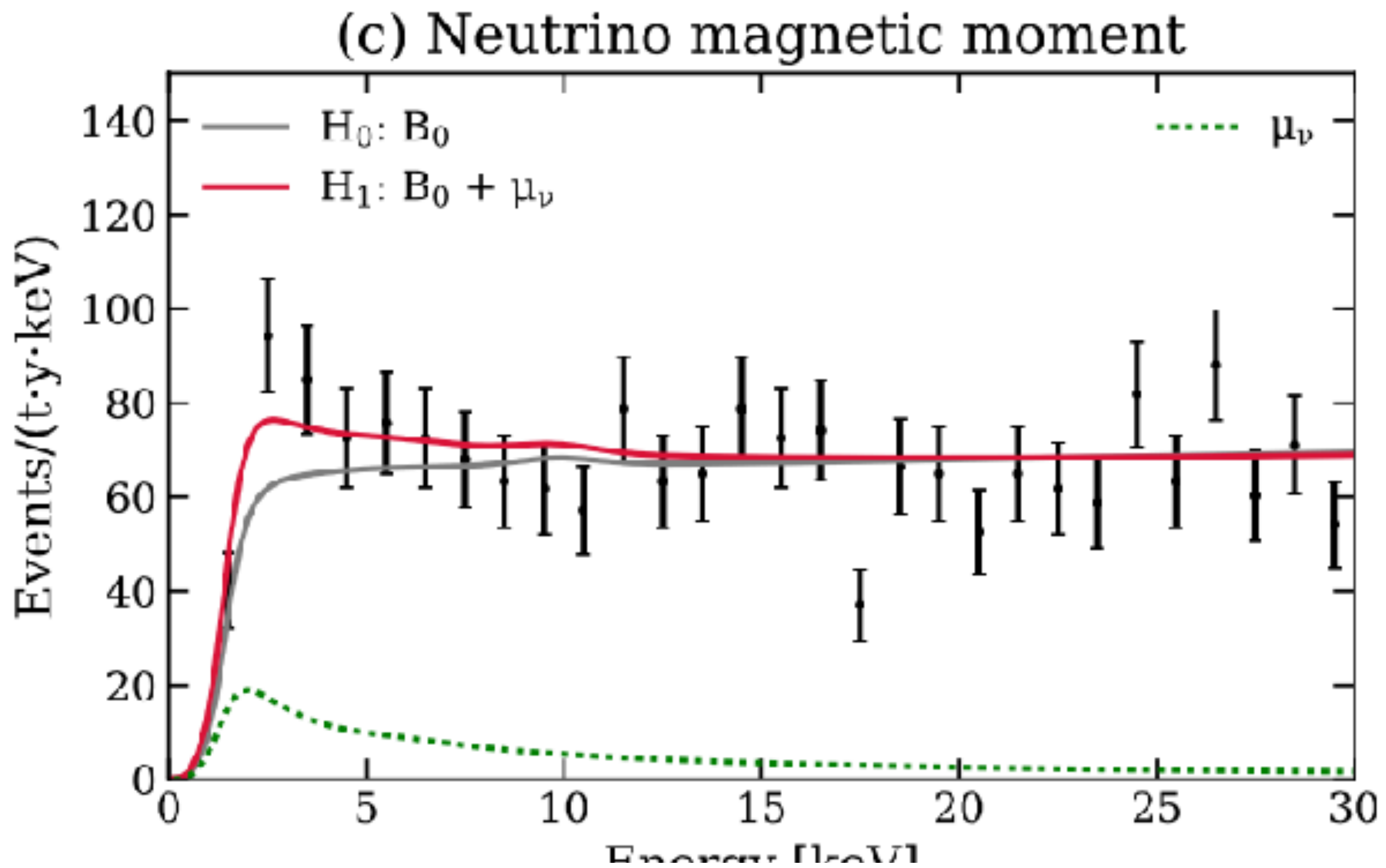
Neutrino magnetic moment + others

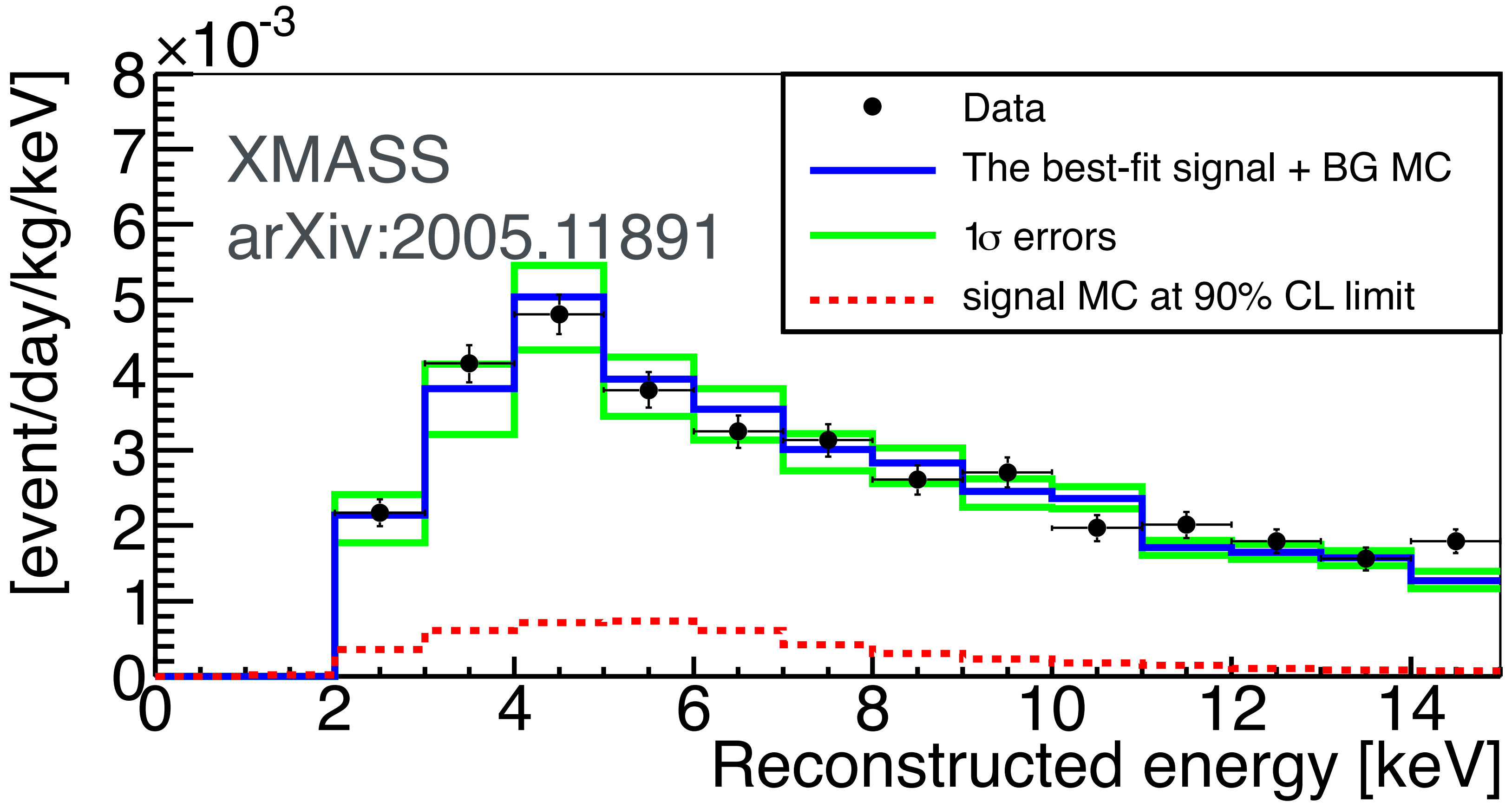
Summary and Interpretations of the Excess

XENON1T observes ER excess events in 1-7 keV region

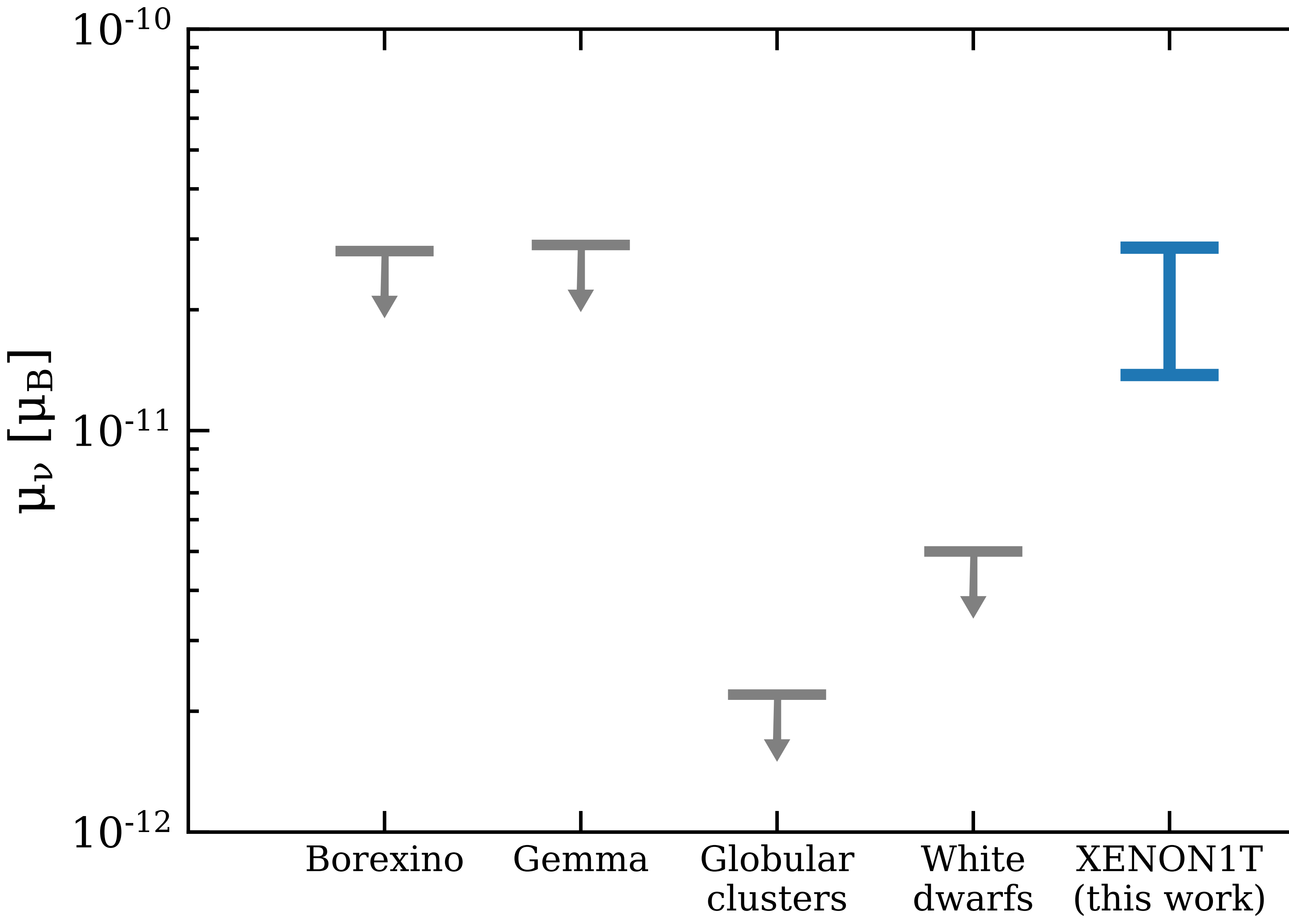
Neutrino Magnetic Moment (3.2σ)

ν magnetic moment enhance the cross section.(Solar ν in this case)





$< 1.8\times10^{-10}\ \mu_B$



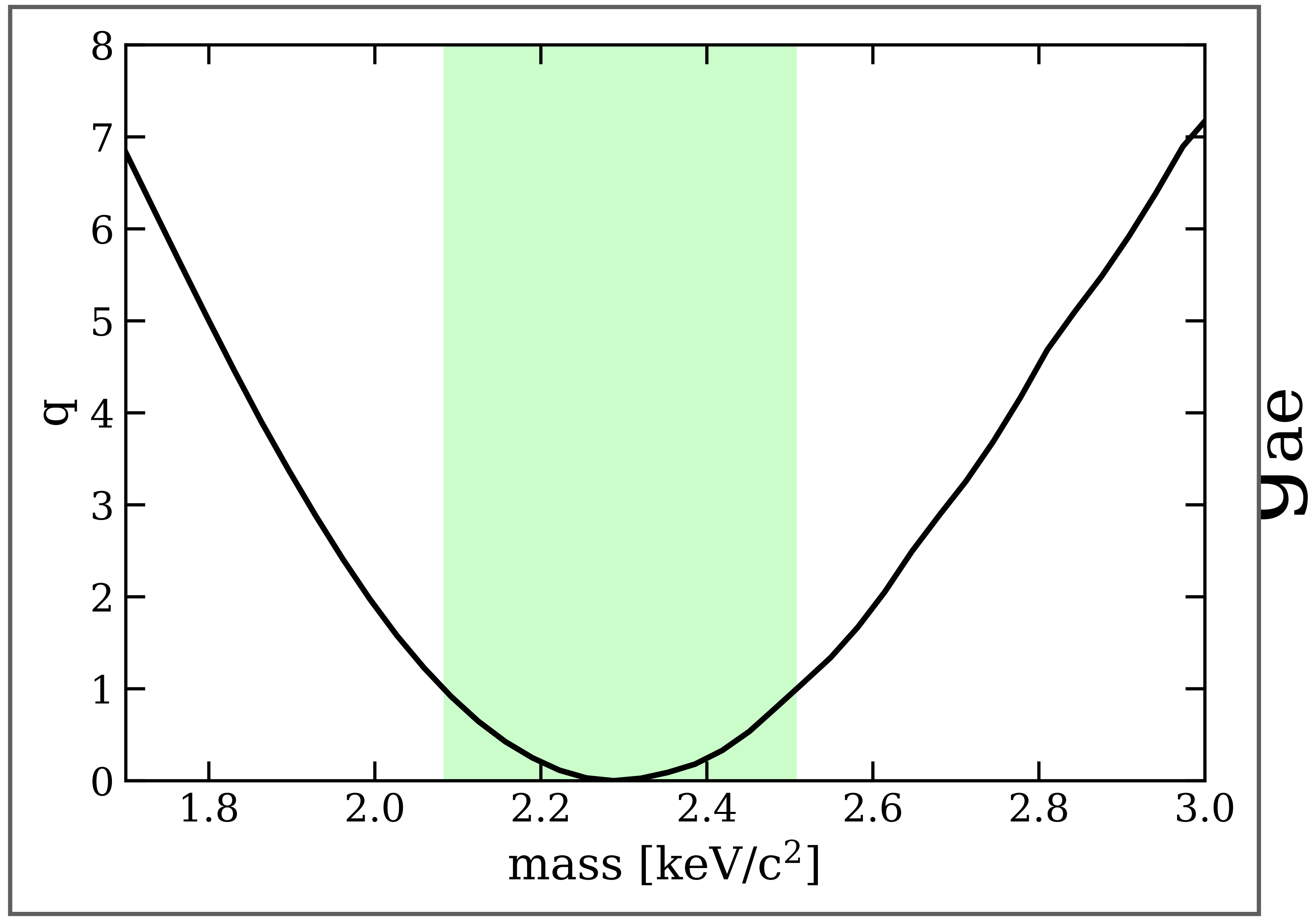
$$\mu_\nu \in (1.4,\ 2.9)\times 10^{-11}\ \mu_B$$

90% confidence interval

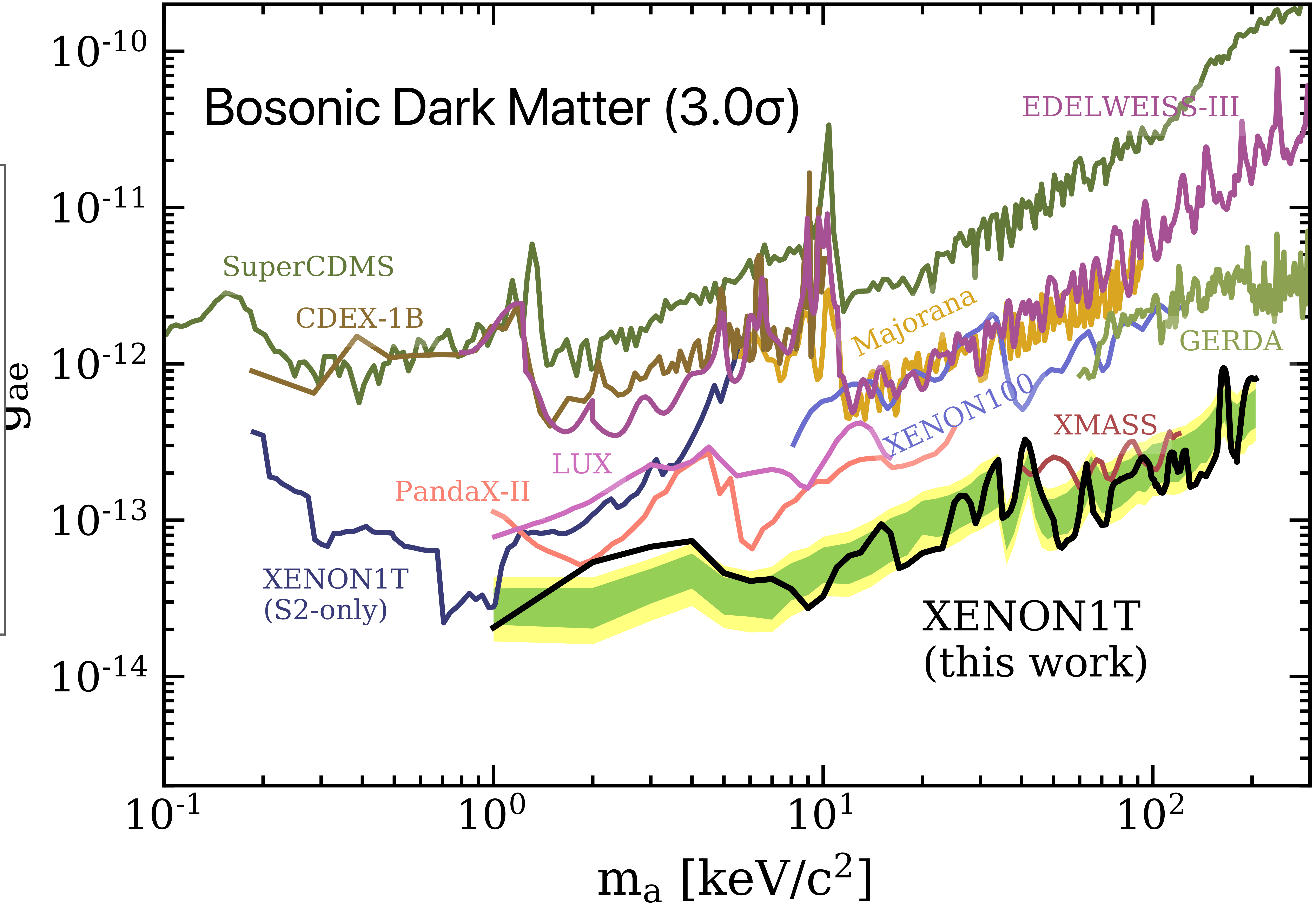
Summary and Interpretations of the Excess

XENON1T observes ER excess events in 1-7 keV region

Fitting a mono-energetic peak to the excess:
2.3 +/- 0.2 keV



Best fit: ~60 events/tonne/year
4.0 σ local significance
3.0 σ (global).



Masaki Yamashita, ISEE, Nagoya

Summary

Background?

β-decay of tritium?

3.2σ

Low-energy (Q value 18.6 keV)
Long half life (12.3 years)
Atmospherically “abundant” and cosmogenically produced in xenon

Removed by purification system?

Signal? (Beyond Standard Model)

Solar Axions

3.5σ

- QCD axion

= Axions would also be produced in the Sun, with kinetic energies ~ keV

Neutrio Magnetic moment

3.2σ

In the (extended) SM:

$$\mu_\nu \approx 3 \times 10^{-19} \left(\frac{m_\nu}{\mathrm{eV}}\right) \mu_B$$

A larger value would imply new physics, and possibly solve Dirac vs Majorana.

Bosonic Dark matter

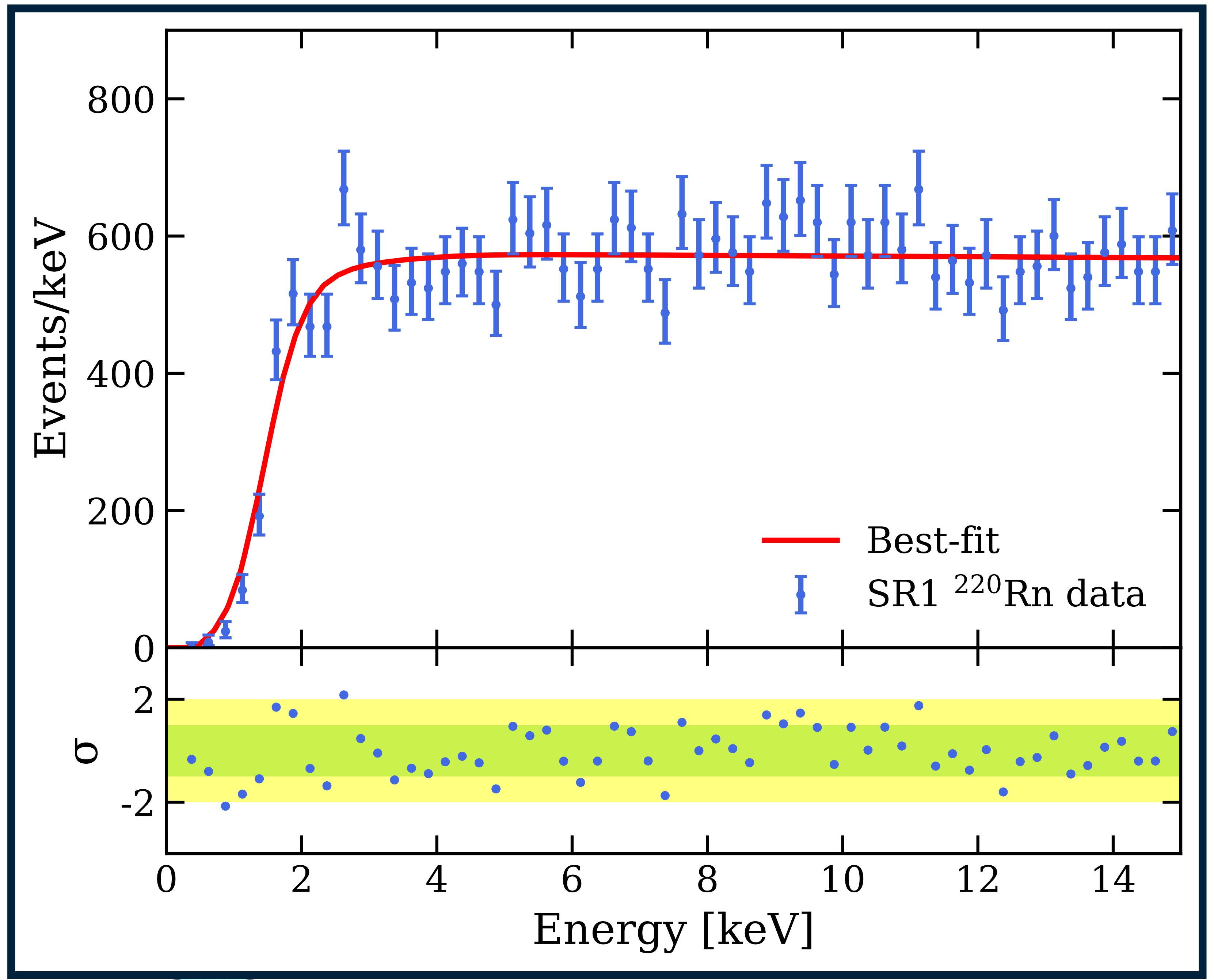
3.0σ

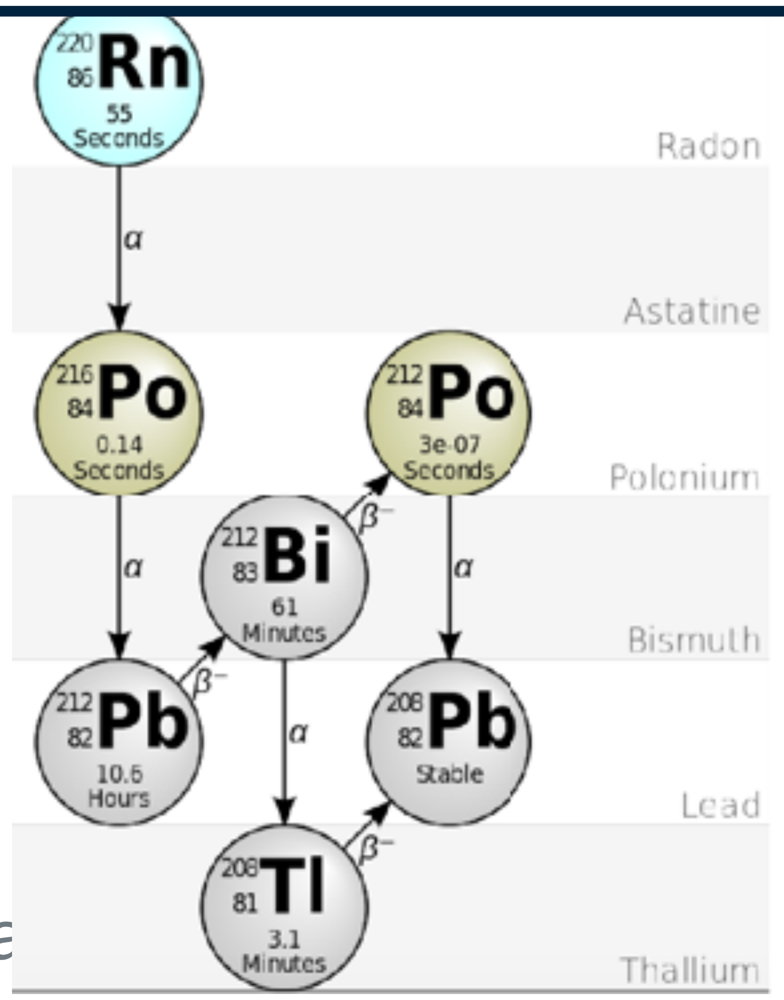
- candidate for Warm Dark Matter
- Axion-like particles like QCD axions.
- allows for ALPs to take on higher masses than QCD axions

More detail on analysis (Any systematic??)

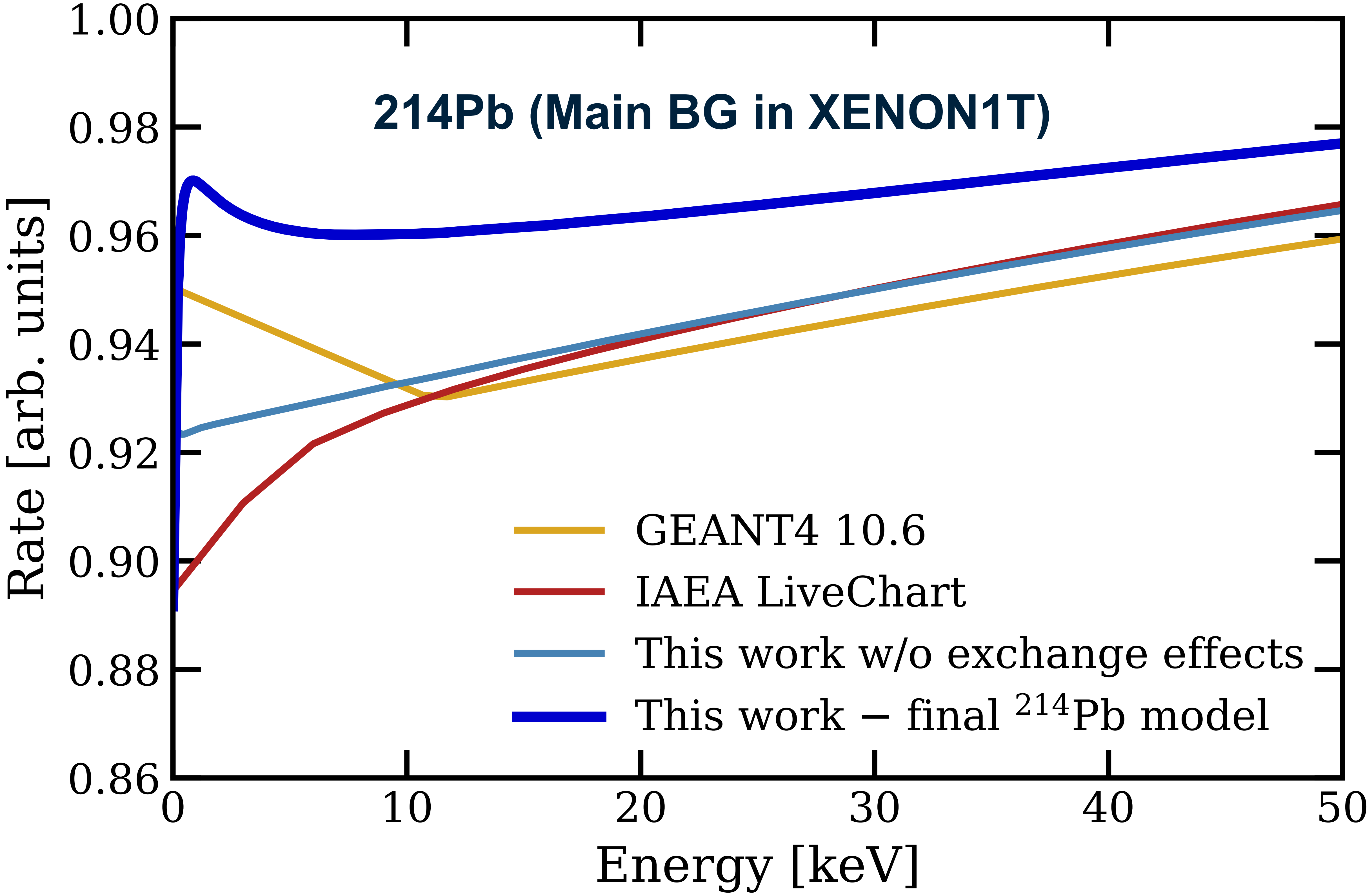
XENON1T's Response to Betas

Decent matching between data and MC down to the energy threshold <~2keV !





beta decay of Pb212 is used to calibrate detector's response to ER background



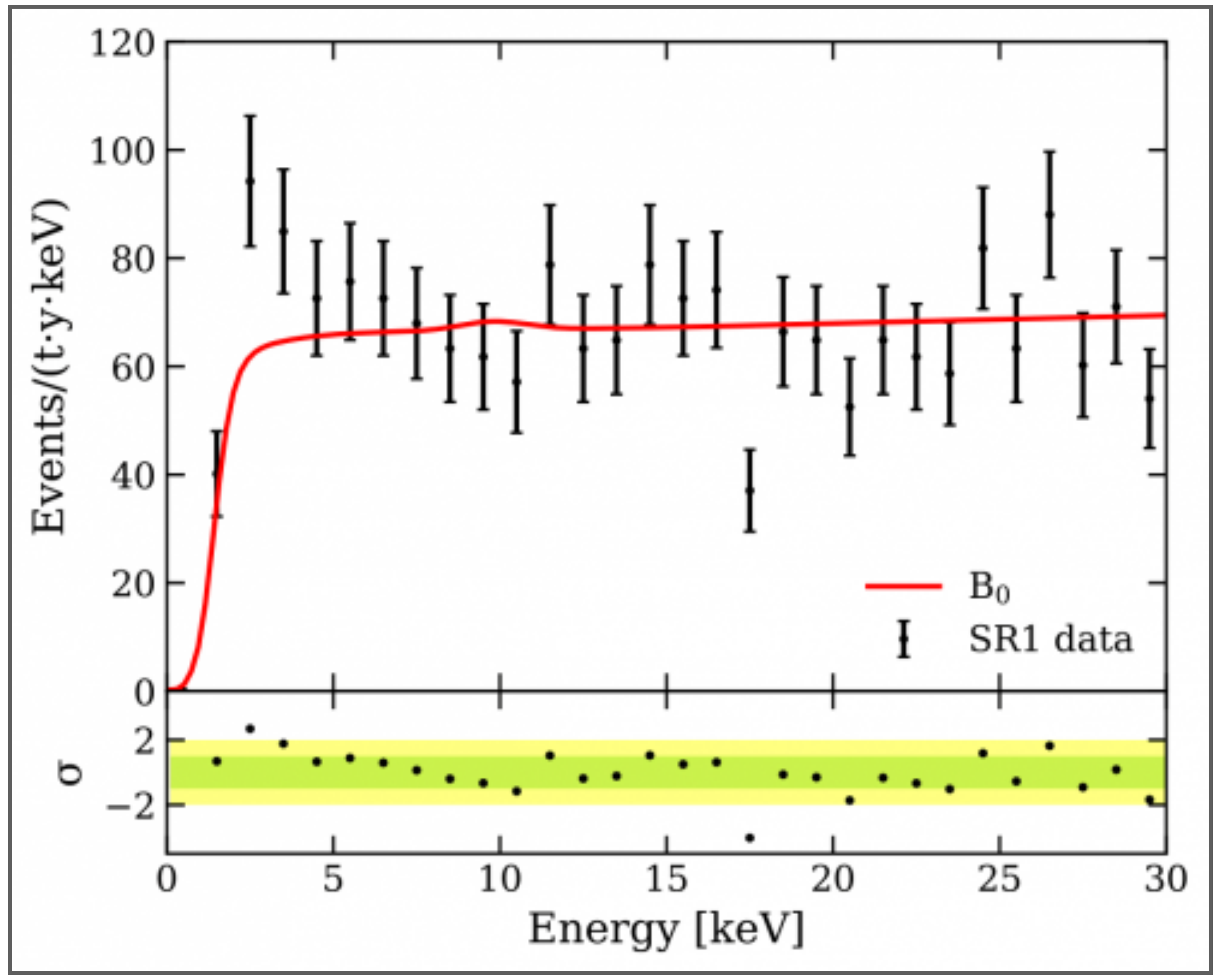
Atomic effects can increase rate at low energies, *but have a small impact.*

~6% uncertainty on the shape

~50% needed to account for excess

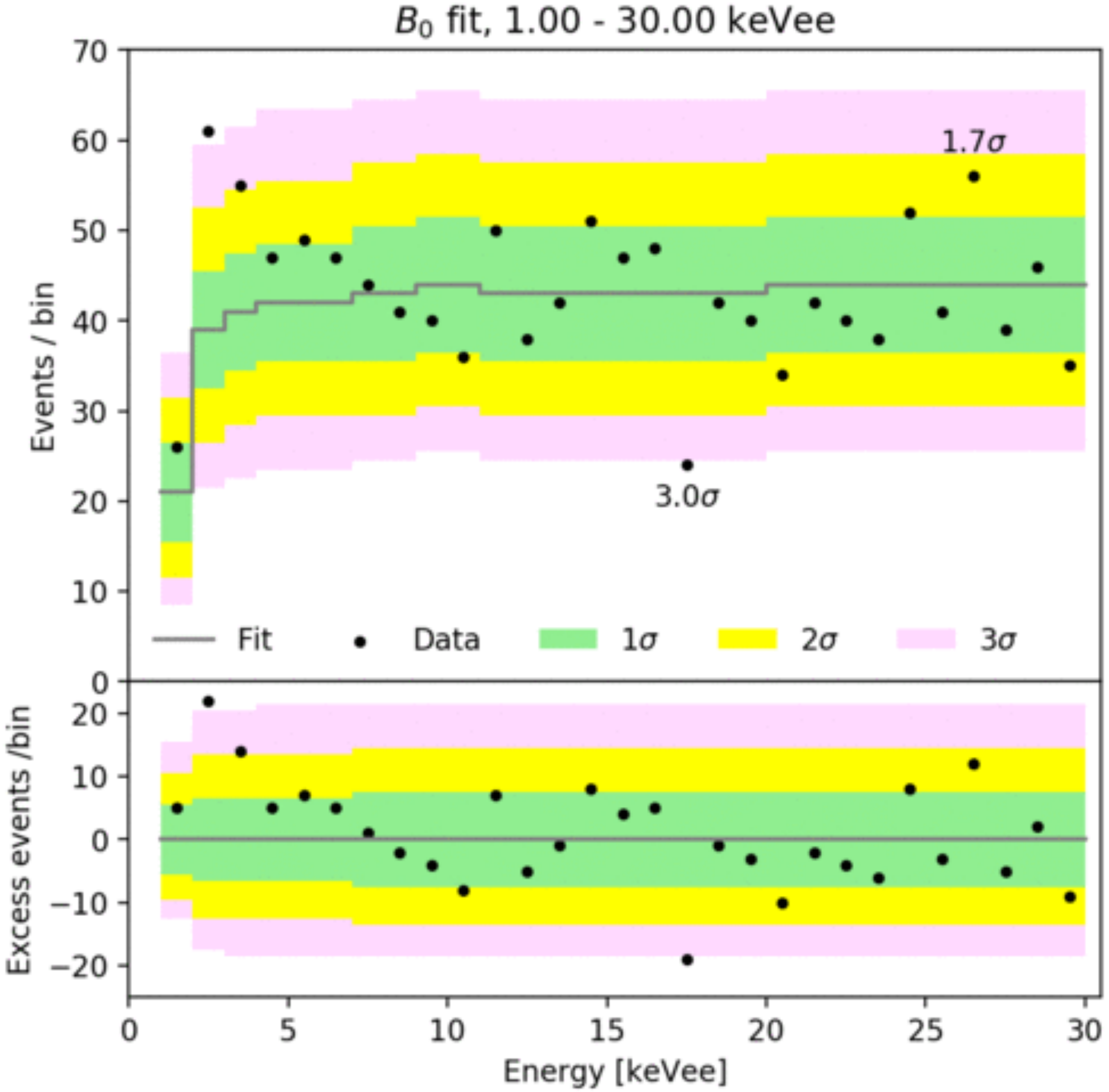
Teamed up with expert on β-decay spectra (X. Mougeot)

Fluctuations and correlations



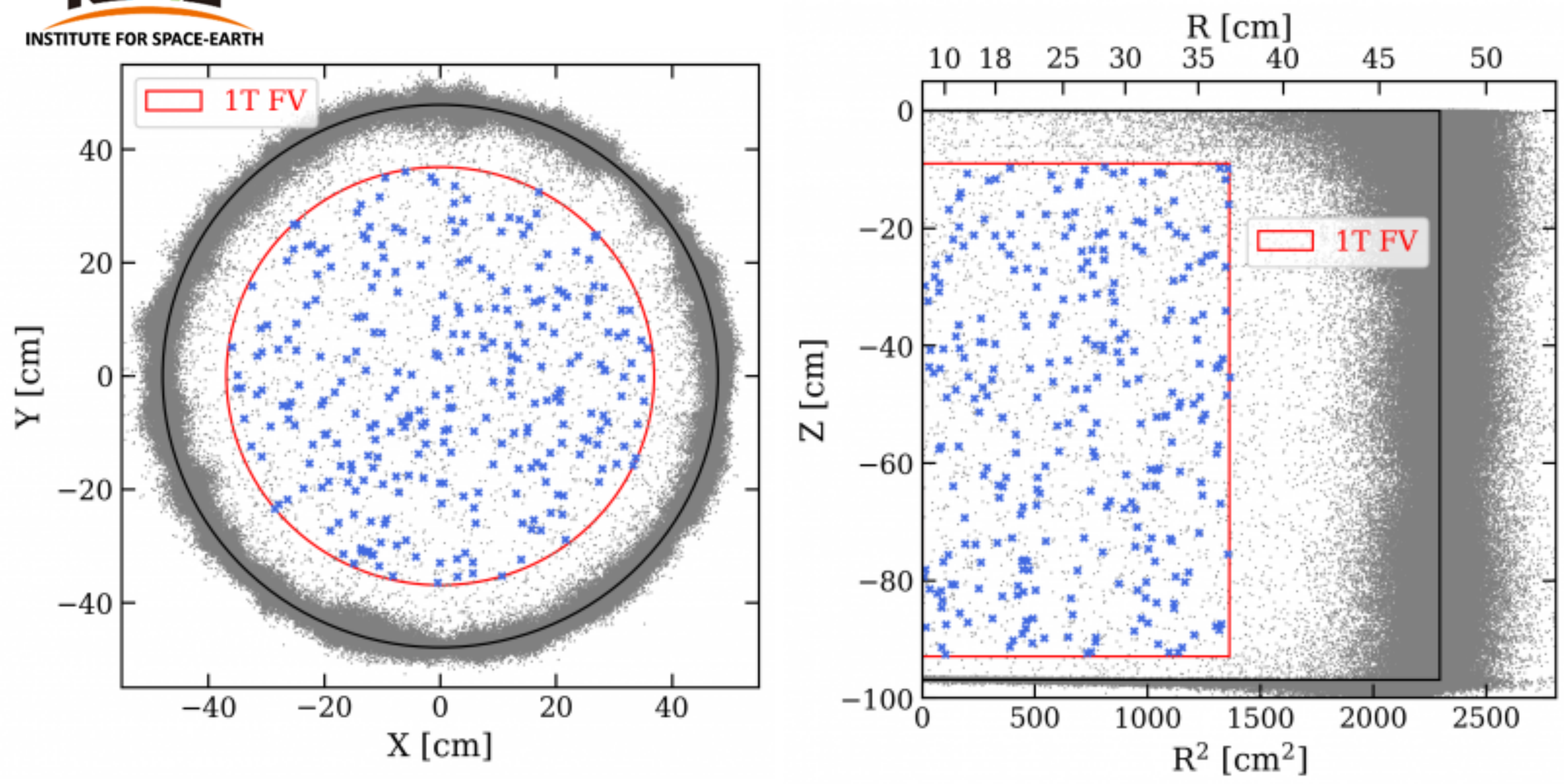
statistical fluke? (see 17 keV dip)

funny correlation? (1-10 keV rising steadily)

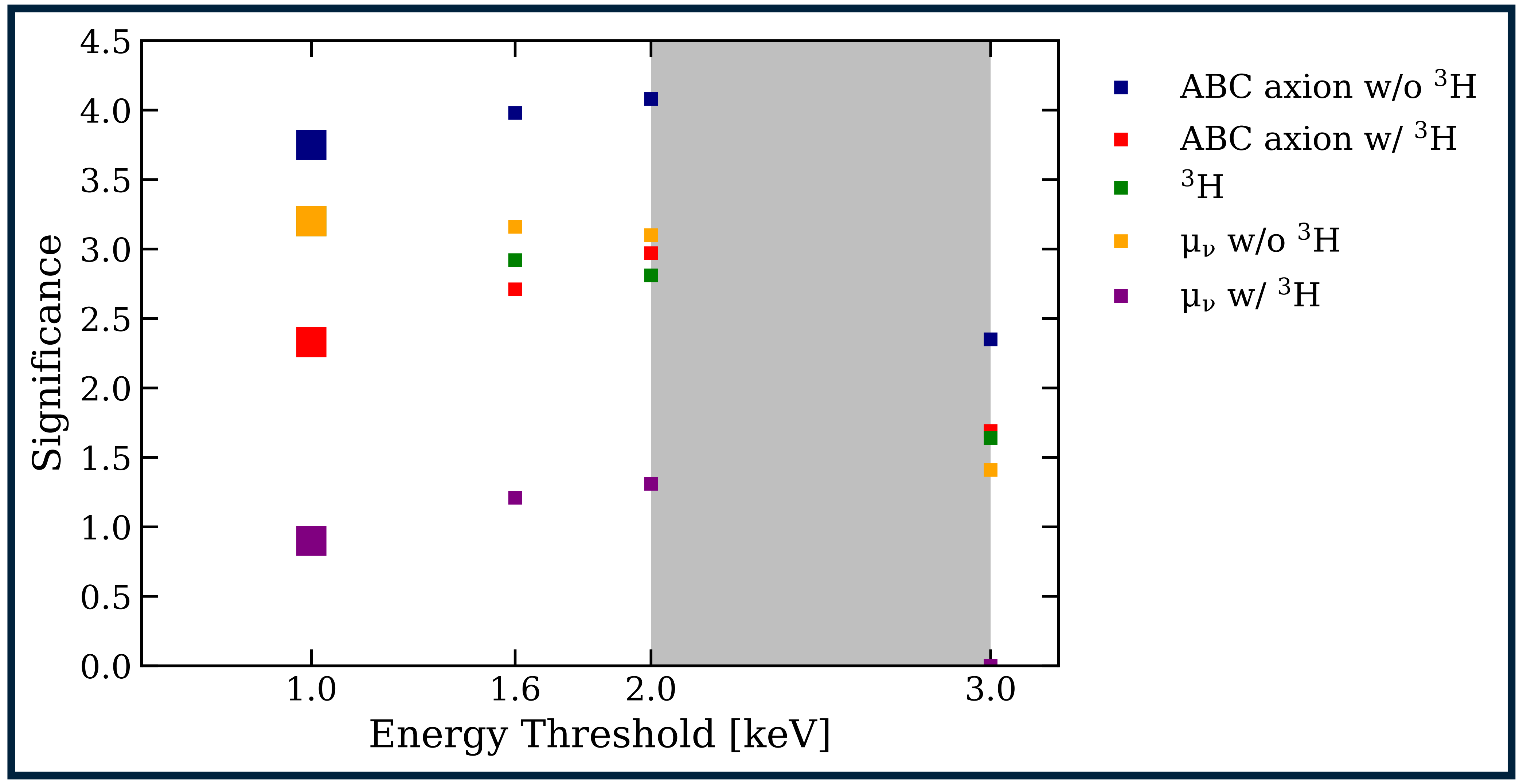


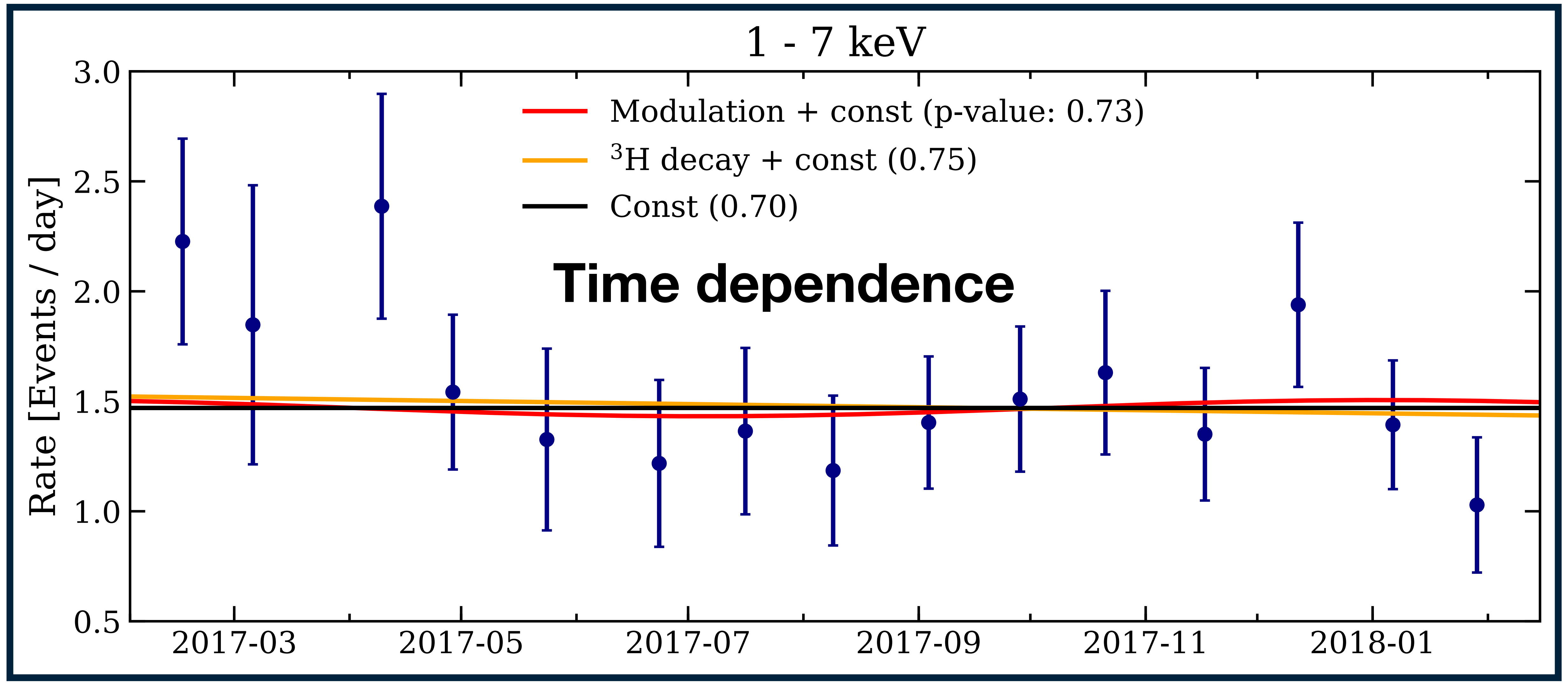
Note: we use an unbinned profile likelihood analysis

Uniformity, Energy threshold, time dependency…



Threshold effects





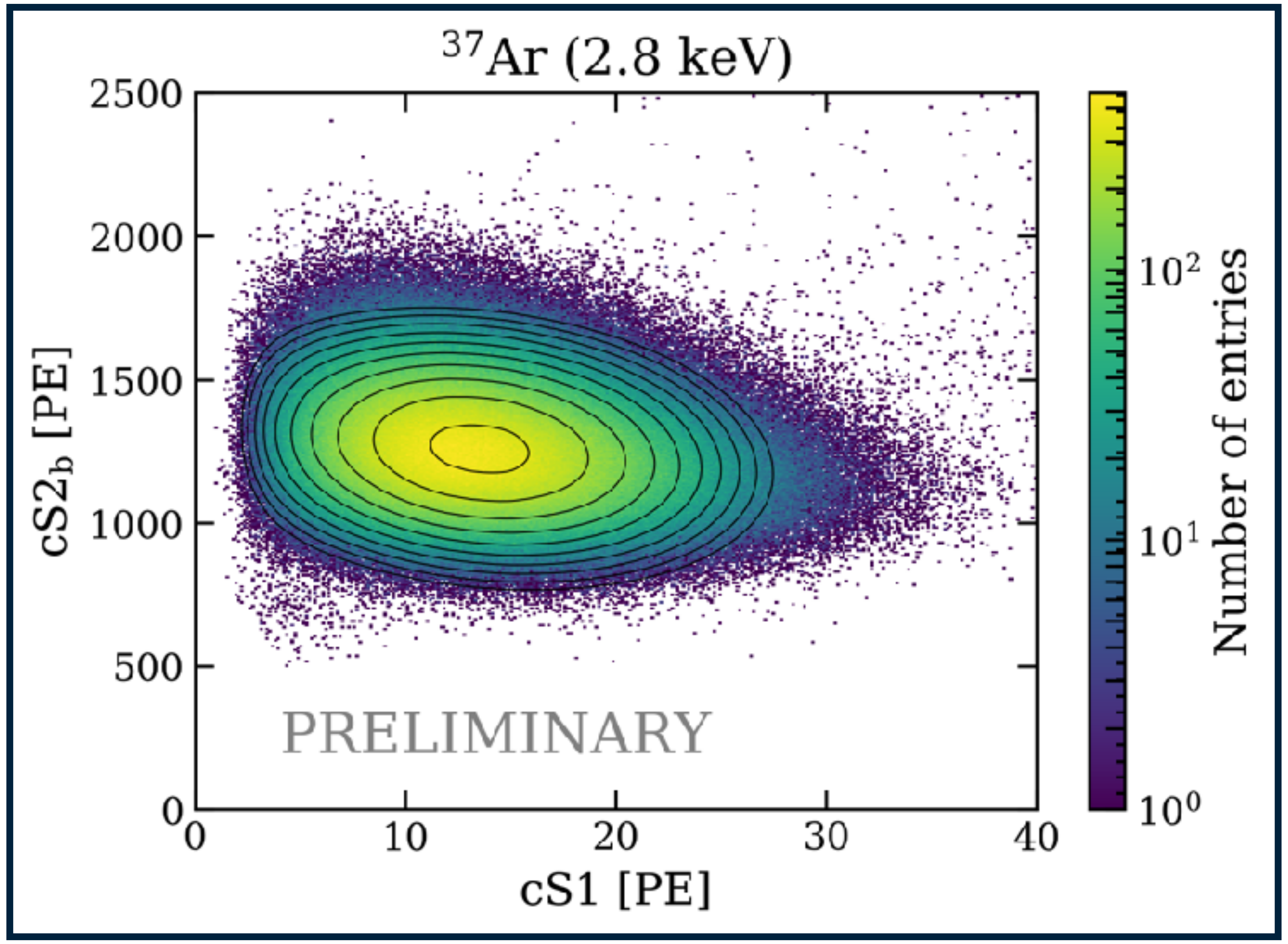
Time dependence

Energy Calibration at Low Energy

$$E = W(n_{ph} + n_e)$$

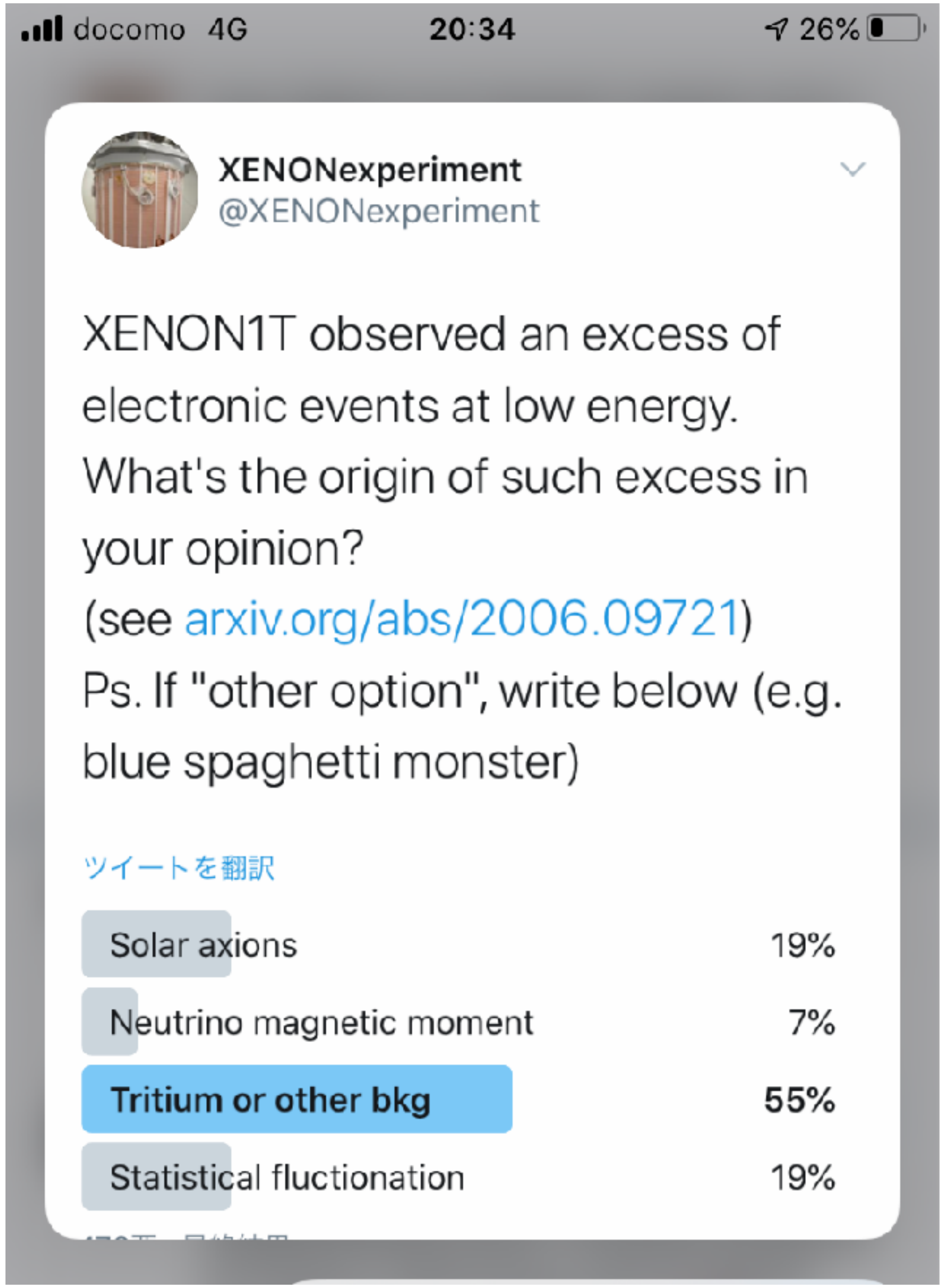
$$\boxed{E = W\left(\frac{S1}{g_1} + \frac{S2}{g_2}\right)}$$

g1 and g2: detector-specific gain **constants**



Calibration of XENON1T down to **2.8 keV**

XENON1T results are …
inconclusive.
Then?

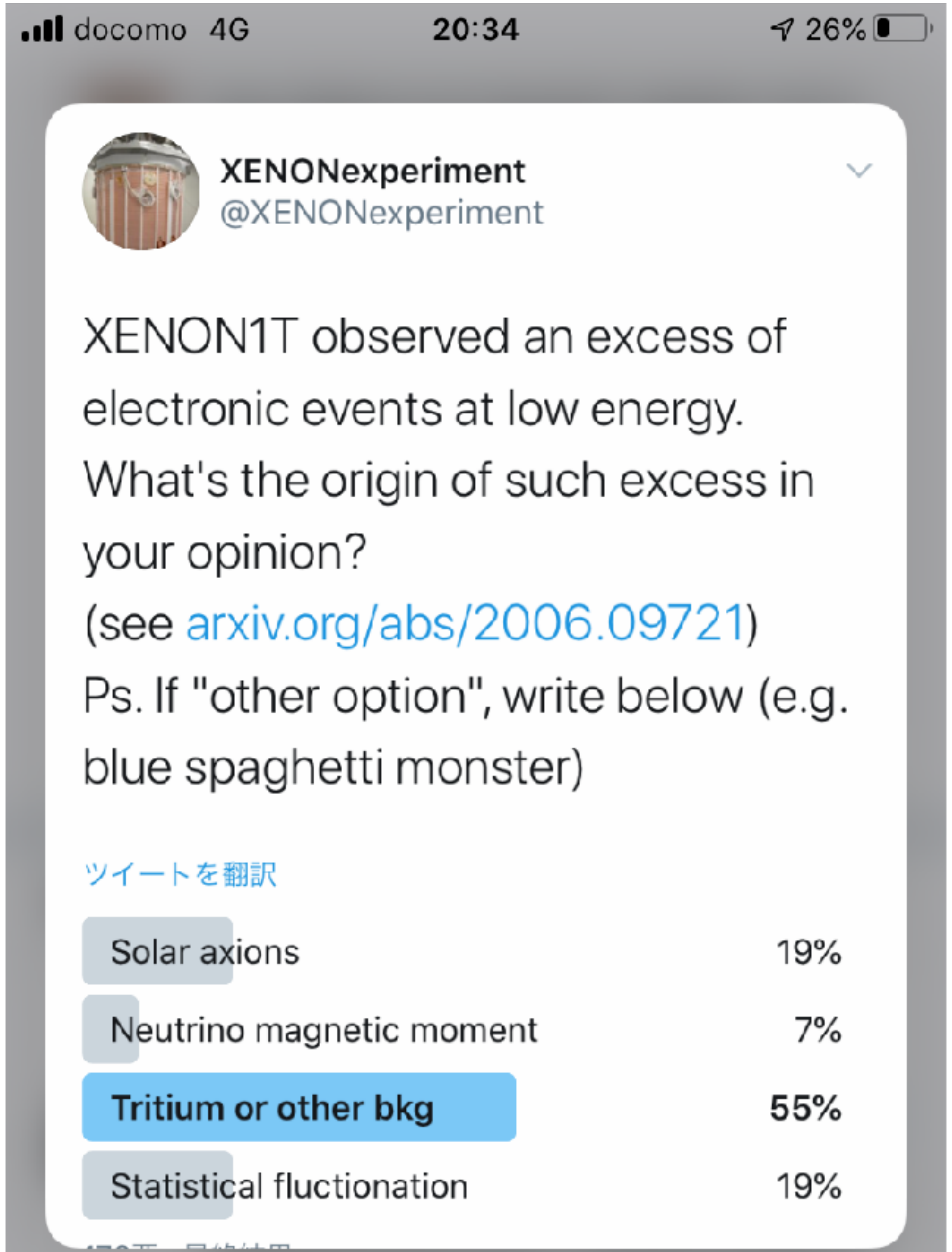


XENONexperiment
@XENONexperiment

XENON1T observed an excess of electronic events at low energy. What's the origin of such excess in your opinion?
(see arxiv.org/abs/2006.09721)
Ps. If "other option", write below (e.g. blue spaghetti monster)

ツイートを翻訳

Solar axions	19%
Neutrino magnetic moment	7%
Tritium or other bkg	**55%**
Statistical fluctionation	19%



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Others　　arXiv 88 posts

2020/09/08「ダークマター懇談会」
有志、KMI Core to Coreその他

Next Step: XENONnT

Sensitivity Paper :arXiv:2007.08796

3x

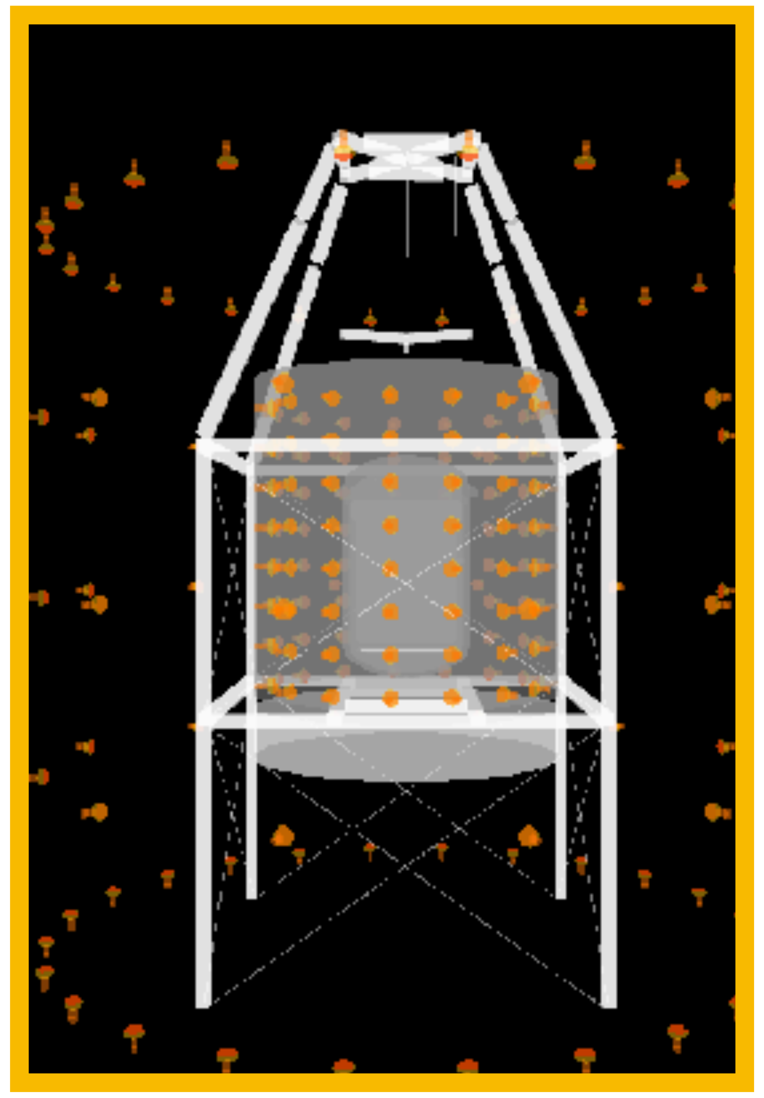
Larger active volume

~1/6

Reduced background level

Commissioning ongoing

New Apparatus in XENONnT



Neutron veto

- Inner region of existing muon veto
- optically separate
- 120 additional PMTs
- Gd in the water tank
- 0.5 % $Gd_2(SO_4)_3$

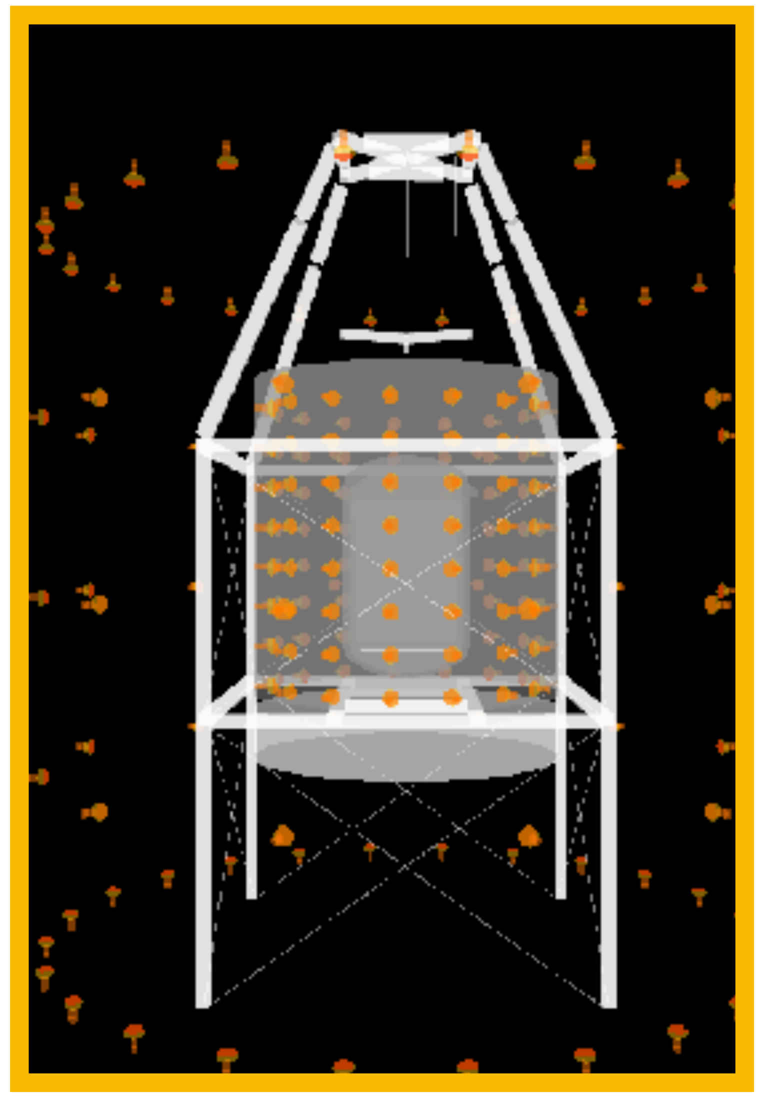
LXe purification

- Faster xenon cleaning
- 5 L/min LXe (2500 slpm)
- XENON1T ~ 100 slpm

^{222}Rn distillation

- Reduce Rn (^{214}Pb) from pipes, cables, cryogenic system
- New system, PoP in XENON1T

New Apparatus in XENONnT



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THE UNIVERSITY OF TOKYO NAGOYA UNIVERSITY

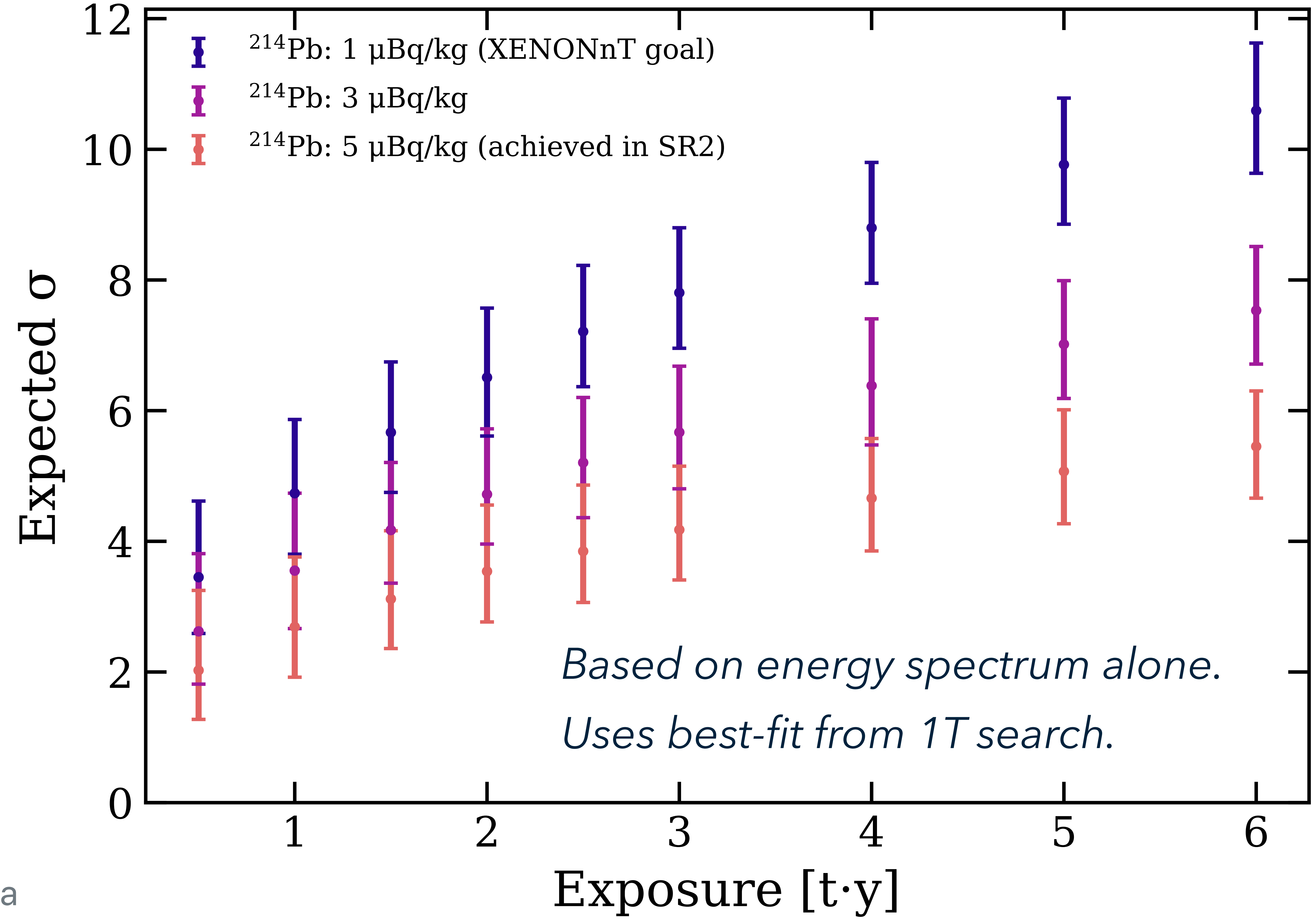
NAGOYA UNIVERSITY THE UNIVERSITY OF TOKYO

KOBE UNIVERSITY

Masaki Yamashita, ISEE, Nagoya

Next Steps: XENONnT

XENONnT will discriminate axions from tritium with ~ few months of data



Based on energy spectrum alone.
Uses best-fit from 1T search.

Summary

- ER Excess Events in XENON1T
  - Solar Axion 3.5σ
  - Neutrino Magnetic Moment (3.2σ)
  - Bosonic Dark Matter (3.0σ)
  - Tritium Background (3.0σ)
  - Solar Axion + Tritium + Background (2.1σ)
- XENONnT will tell us next year (commissioning phase now)
- Stay tune!

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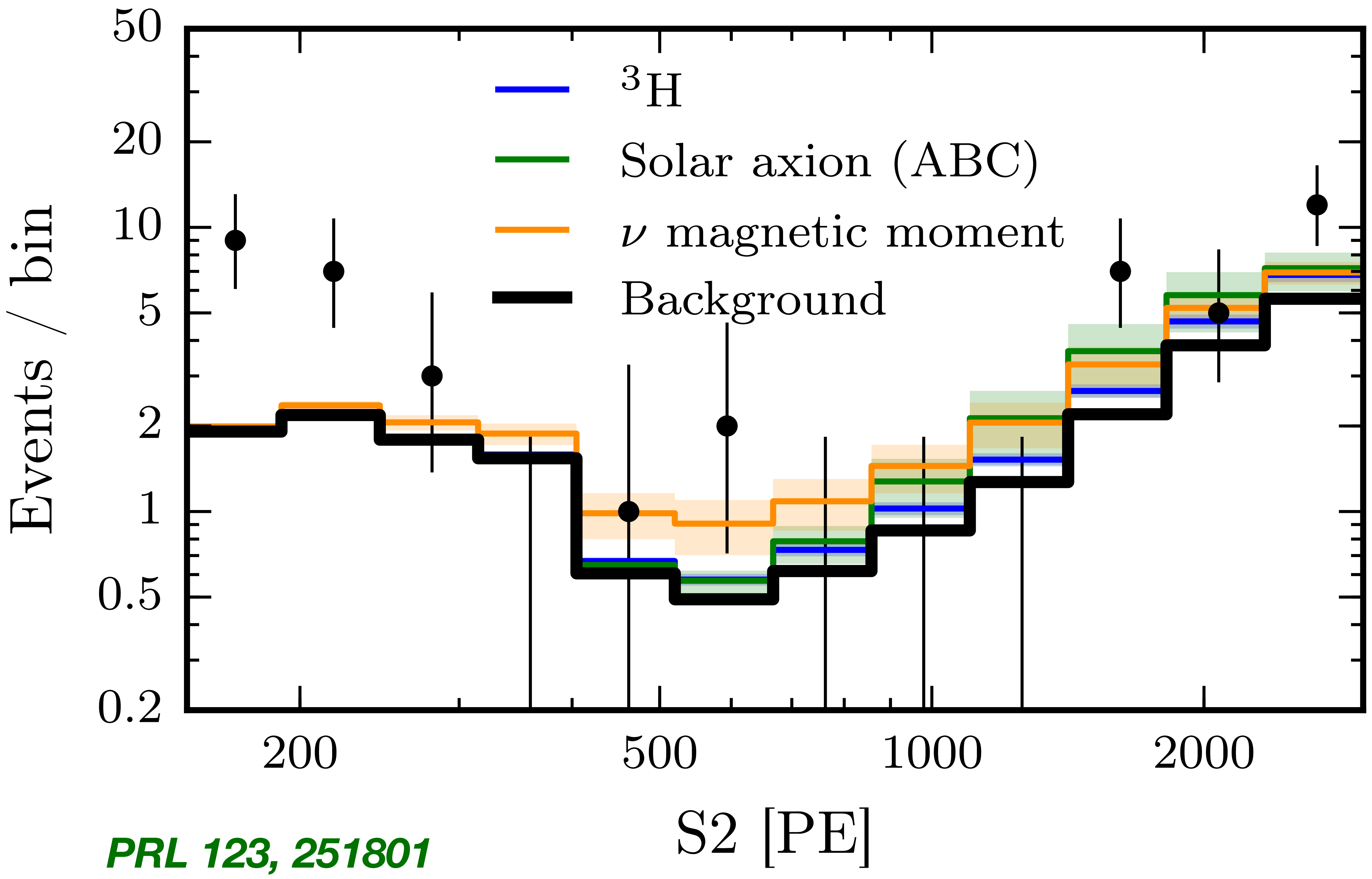
S2-only analysis



PRL 123, 251801

S2-only analysis allows for a lower energy threshold

$\mu_\nu < 3.1 \times 10^{-11}\ \mu_B$

$g_{ae} < 4.8 \times 10^{-12}$

$R_{\mathrm{H3}} < 2256$ events/t/y

consistent with this work for all 3 hypotheses

Energy Resolution