The XENON1T Low-Energy Excess (And Other Exciting Results)

Dr. Erwann Masson

IJCLab — Orsay, France

On behalf of the XENON Collaboration

Particle Physics Seminars at BNL — 19 Nov. 2020

On Dark Matter & Liquid Xenon

Dark Matter in a nutshell

- A **non-luminous matter** is needed to explain what is observed in the Universe **at all scales**

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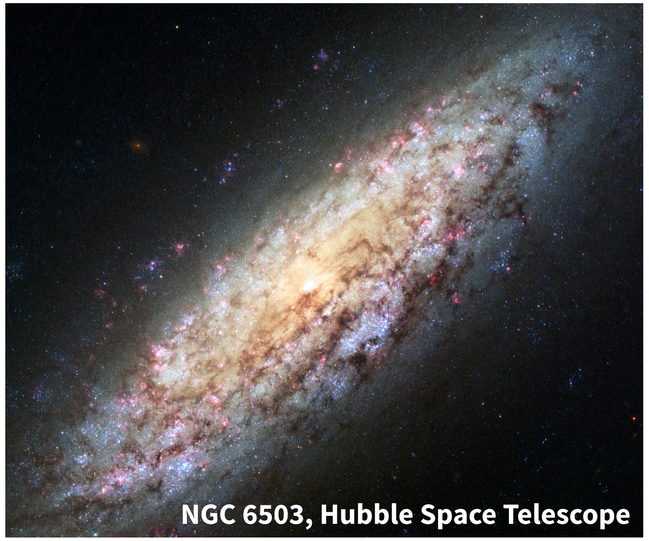
20–60 kpc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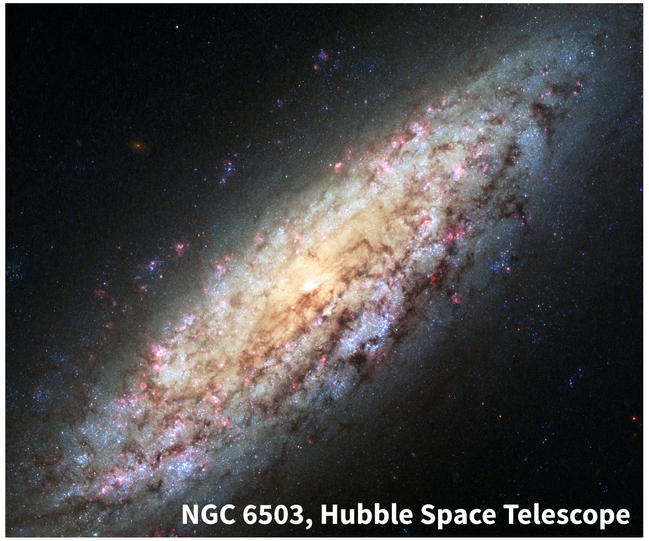

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2–10 Mpc

Bullet Cluster, Chandra X-ray Observatory

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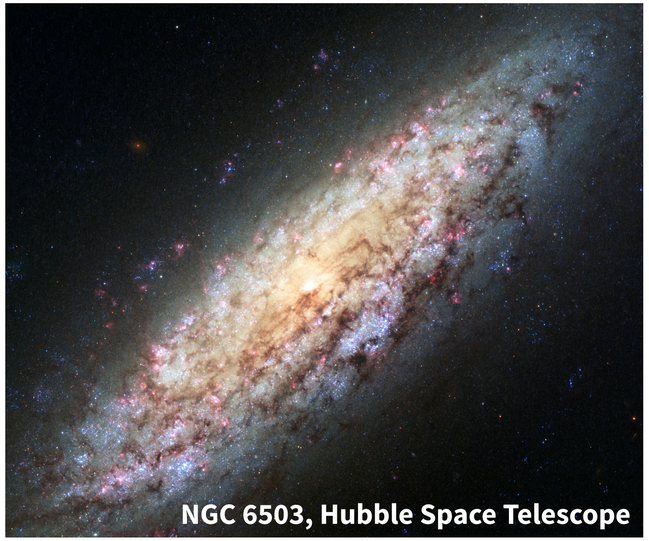
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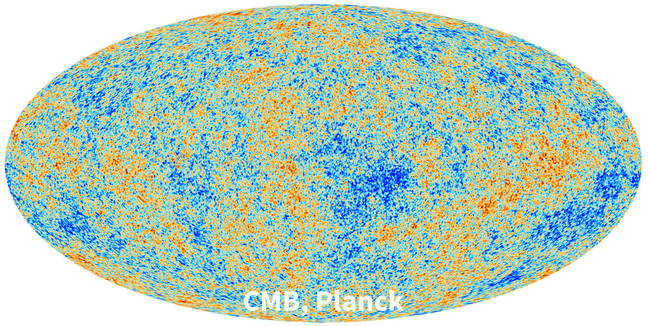
4 Gpc


CMB, Planck

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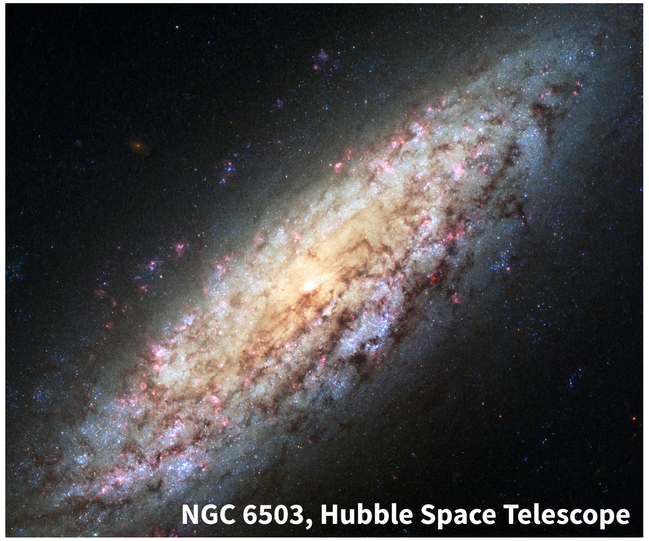
- Most promising candidate in particle physics
  → **Weakly Interacting Massive Particles (WIMPs, χ)**

WIMP (expected) ID card

- High mass, $m_\chi \in$ **GeV/c^2–TeV/c^2**
- Low velocity, $v_0 \approx$ **220 km/s** (locally)
- Very low interaction cross section, $\sigma_{\text{int}} \in 10^{-41}$–$10^{-48}$ **cm^2**
- Elastically scatters off atomic nuclei
  → **Nuclear Recoils (NR) $\lesssim$ 100 keV**

20–60 kpc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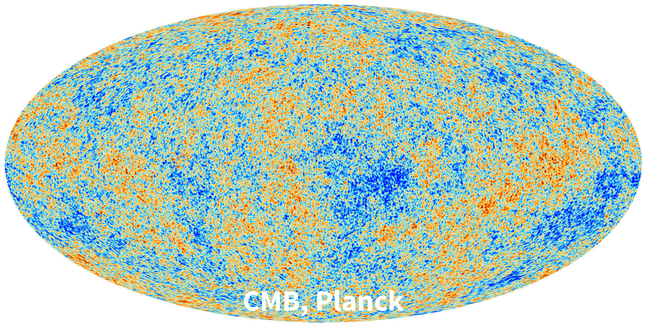
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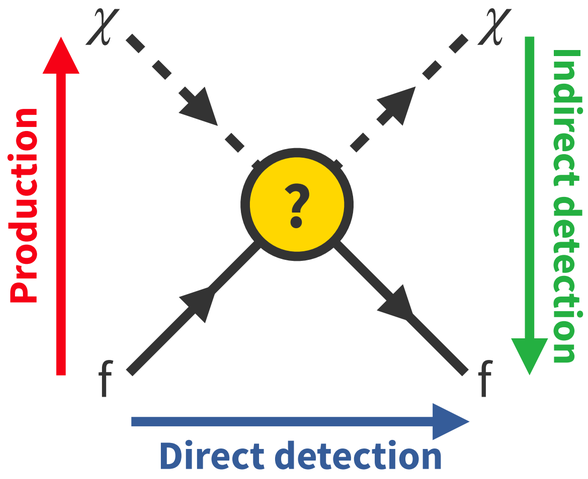

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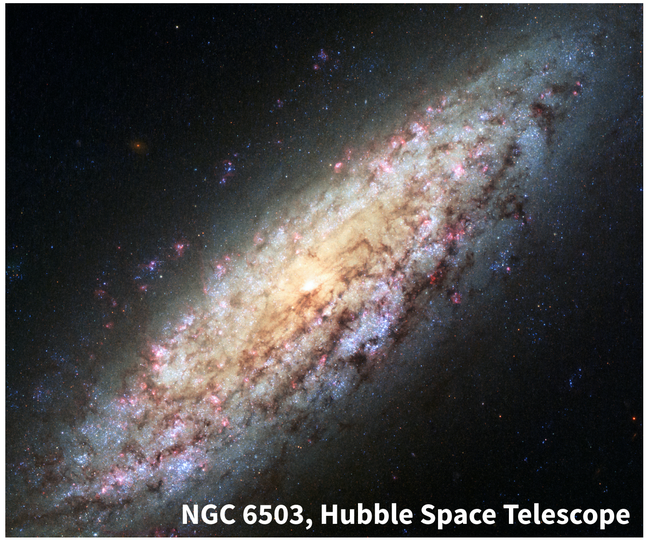
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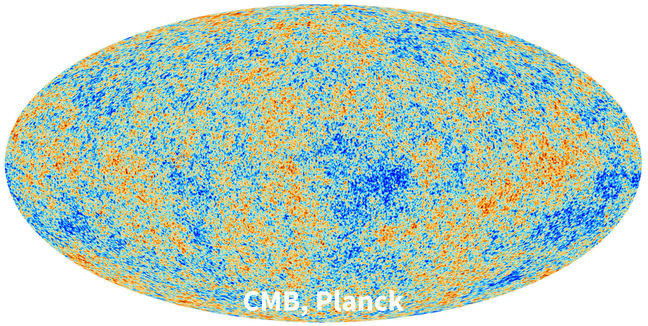
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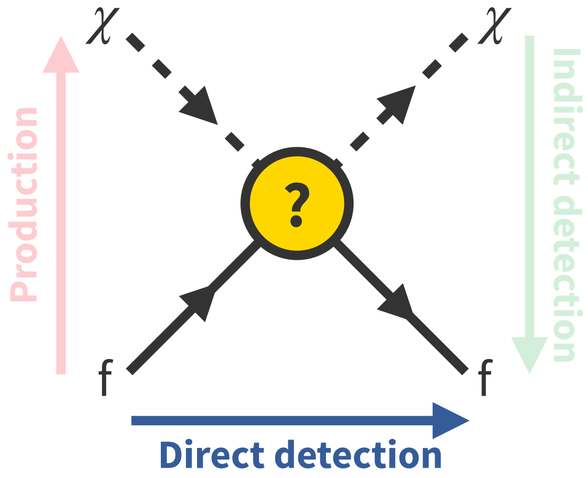
Xe
XENON
Dark Matter Project



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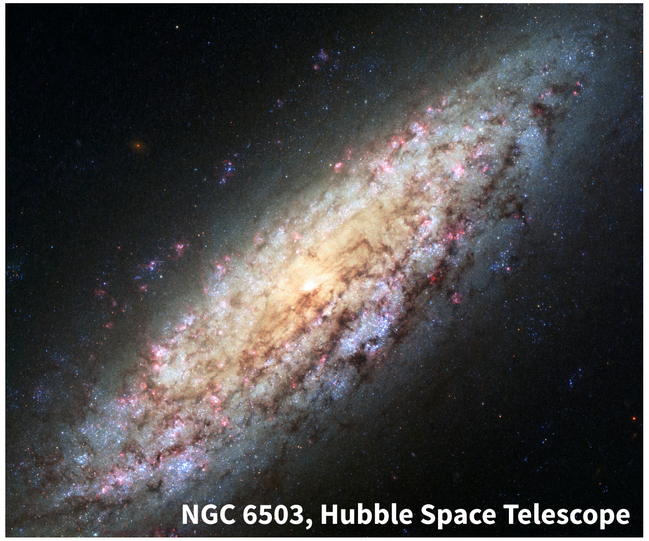
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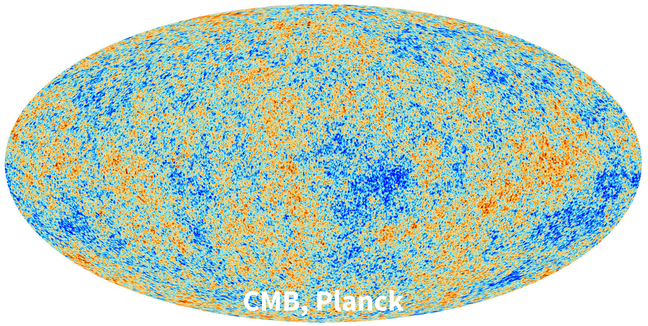
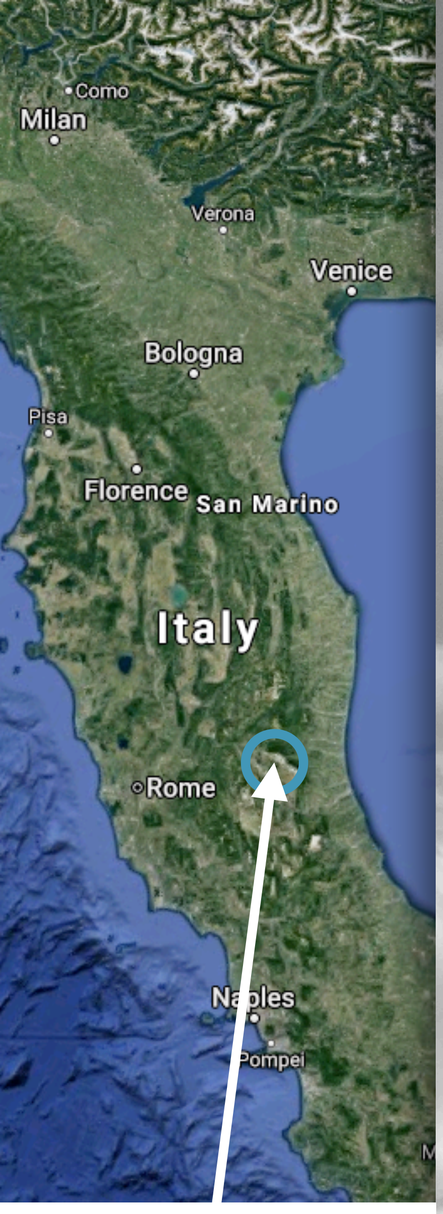

CMB, Planck

The XENON Collaboration

Columbia
Nikhef
Muenster
KIT
Stockholm
Mainz
MPIK, Heidelberg
Freiburg
Zurich
Chicago
Tsinghua
UCSD
Tokyo
Rice
Nagoya
Purdue
Kobe
Coimbra
Subatech
LPNHE
IJCLab
Torino
Bologna
L'Aquila
LNGS
Napoli
Weizmann
NYUAD

The XENON Collaboration (in COVID times)


Como
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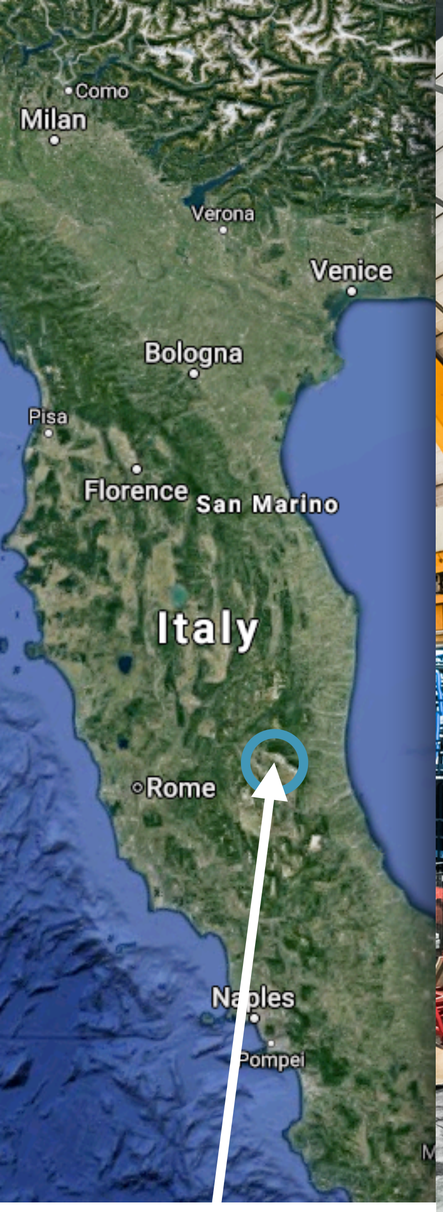
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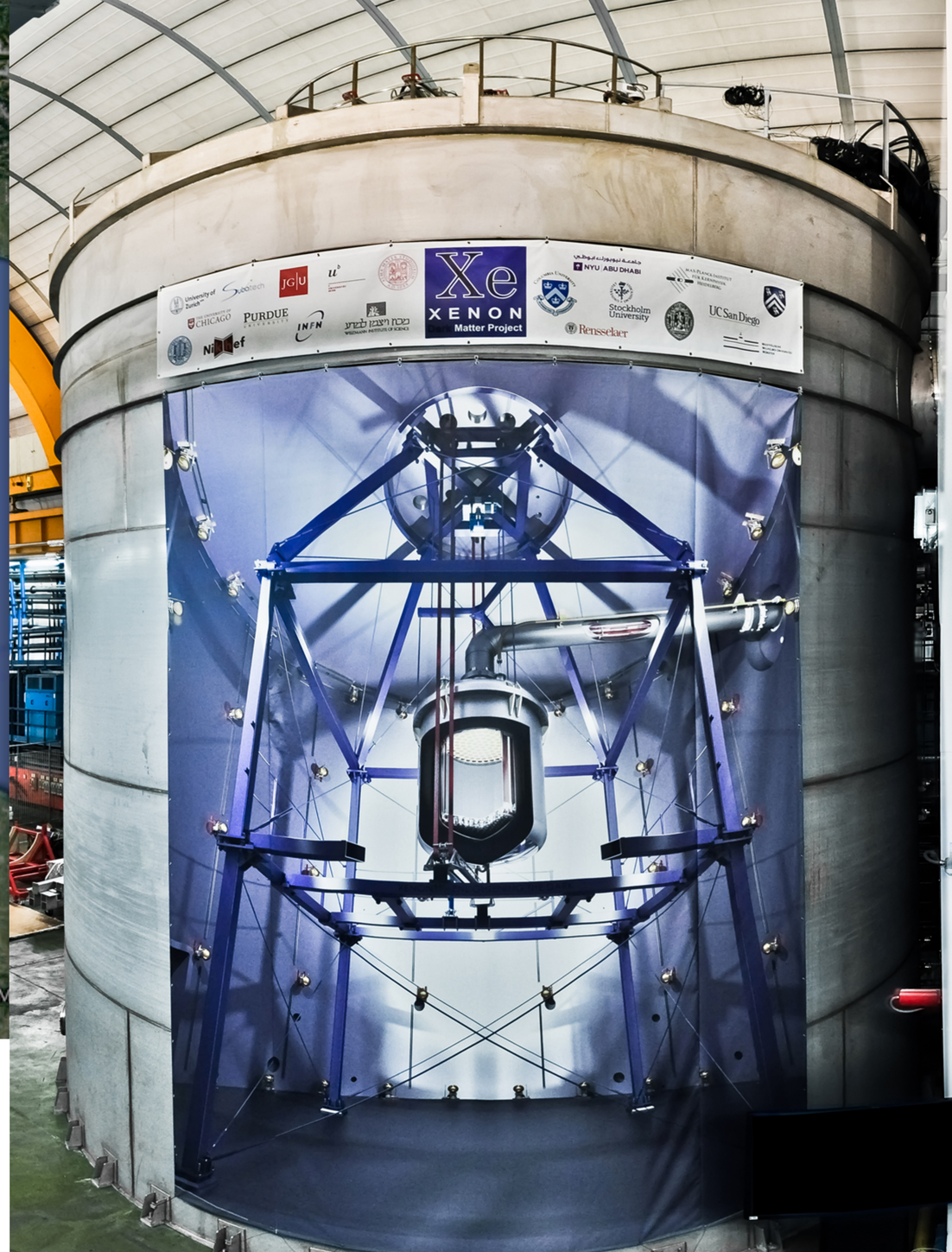
Xe
XENON
Matter Project
NYU ABU DHABI
Stockholm University
Rensselaer
UC San Diego
PURDUE
INFN


CAEN


Como
Milan
Verona
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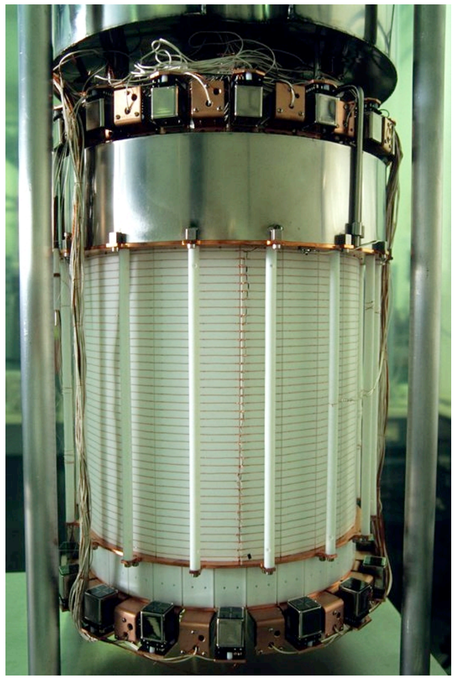
Dual-Phase TPC
Water Čerenkov
Muon Veto
Cryogenics & Xenon Purification
Electronics & Data Acquisition
Xenon Storage,
Recovery & Distillation

The XENON Program

PRL 100 (2008) 021303
PRD 94 (2016) 122001
PRL 121 (2018) 111302

XENON10
2005–2007

25 kg LXe
15 cm drift length
$\sigma_{SI} \sim 9 \times 10^{-44}$ cm^2
at 100 GeV/c^2 (2007)



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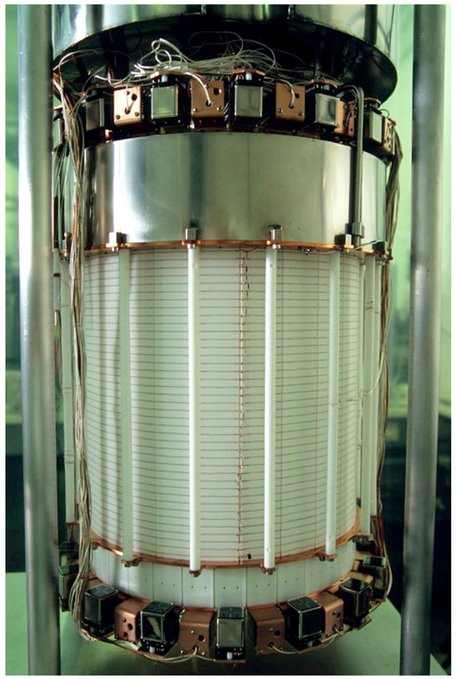

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XENONnT
2020–2025

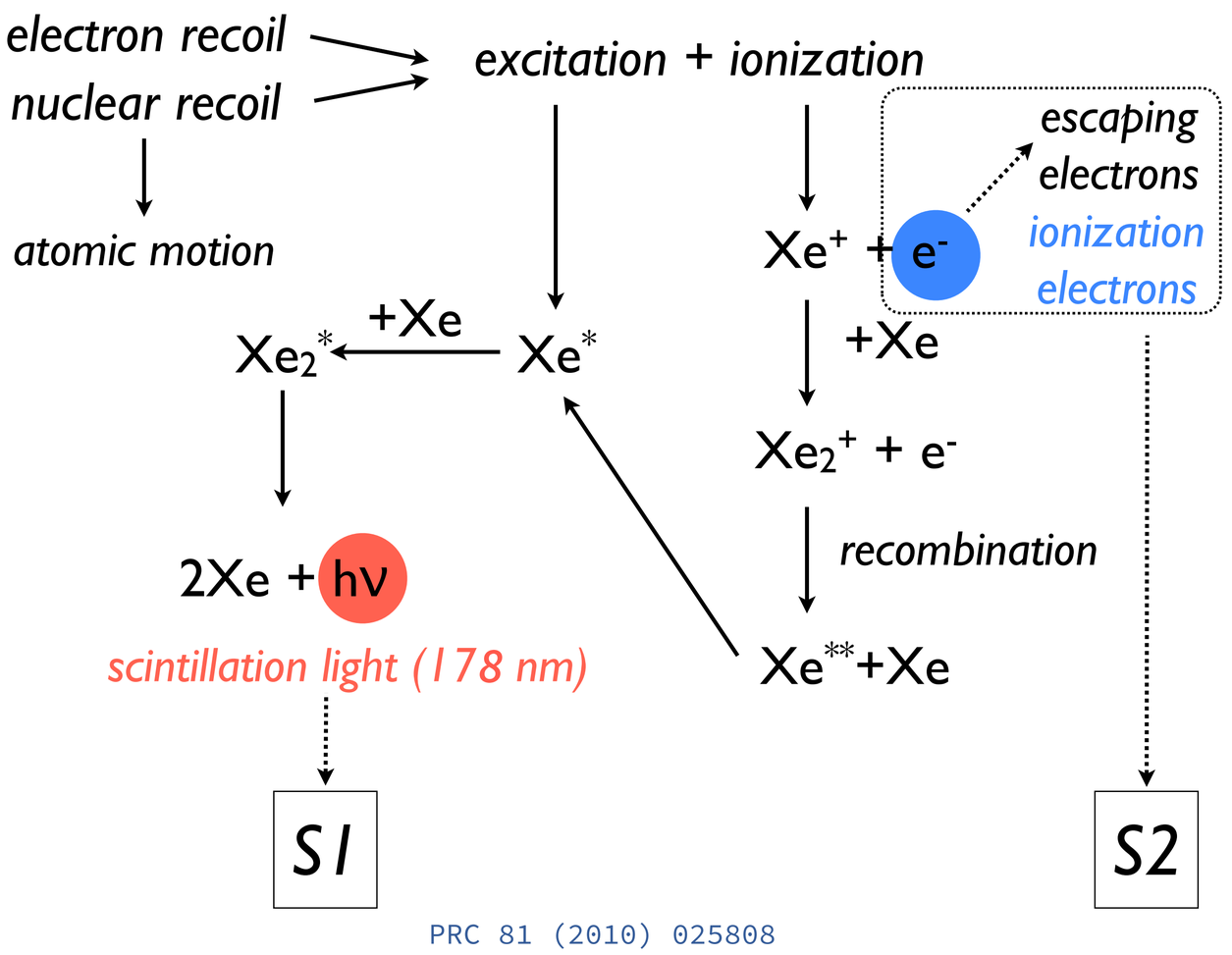
NOW

8.4 t LXe
1.5 m drift length
$\sigma_{SI} \sim 2 \times 10^{-48}$ cm^2
at 50 GeV/c^2 (20 t × yr)

Liquid Xenon as a detection medium

Liquid Xenon (LXe) ID card

- Atomic number $Z = 54$
- High mass number, $\langle A \rangle = 131$
- High density at 177 K, $\langle \rho \rangle = 2.86$ g/cm^3
- No long-lived radioisotopes in WIMP ROI
- Efficient UV scintillator (178 nm)



PRC 81 (2010) 025808

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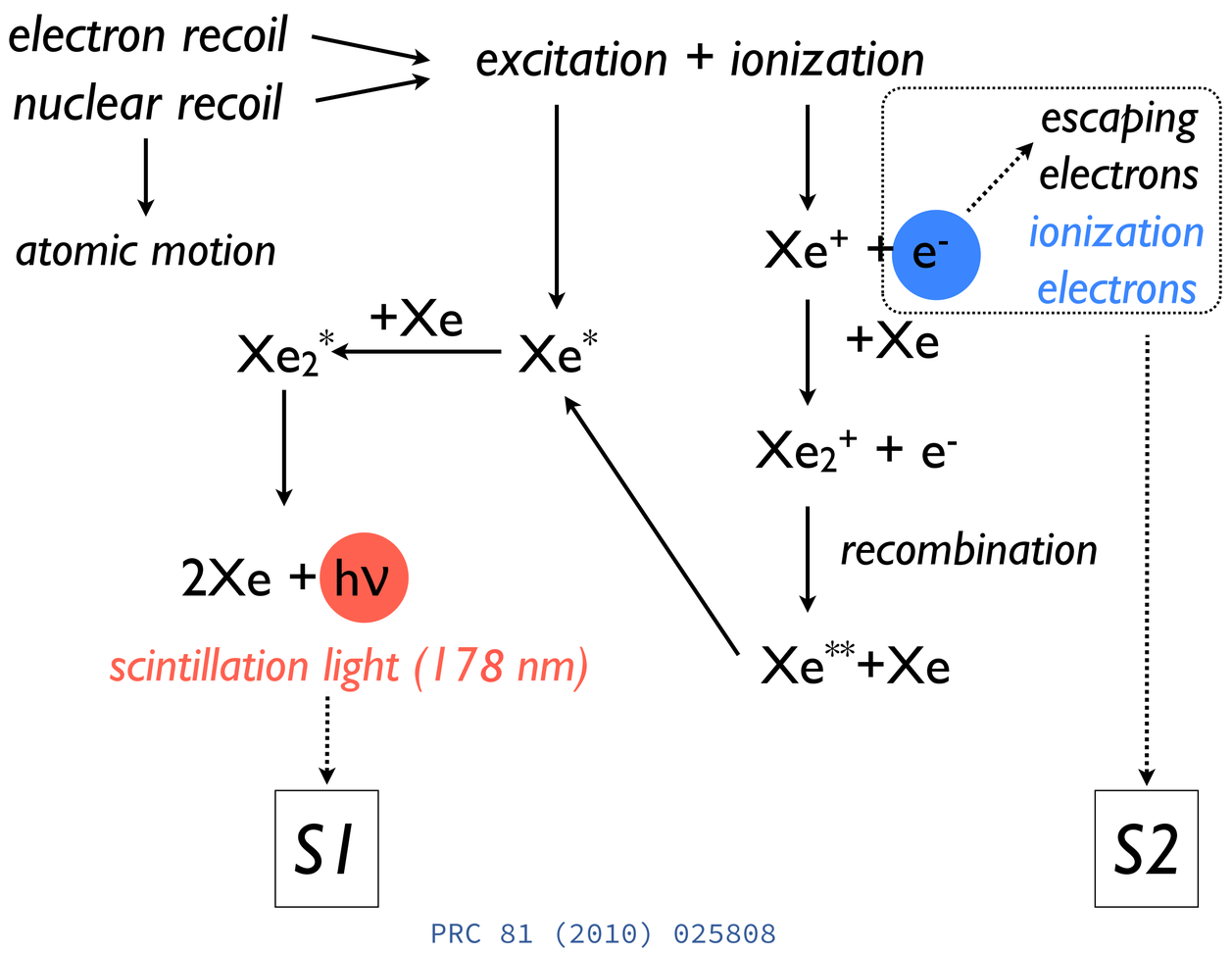

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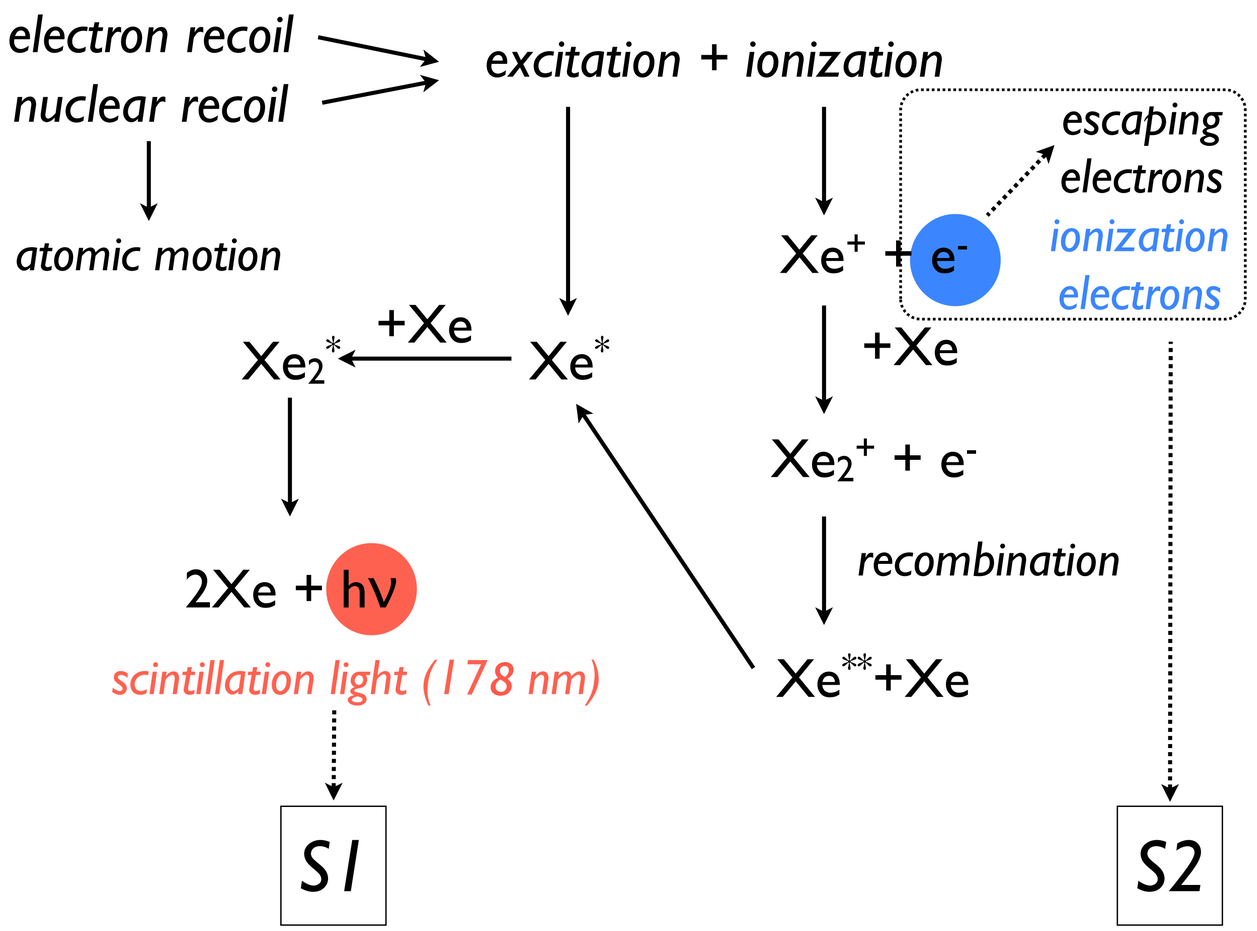

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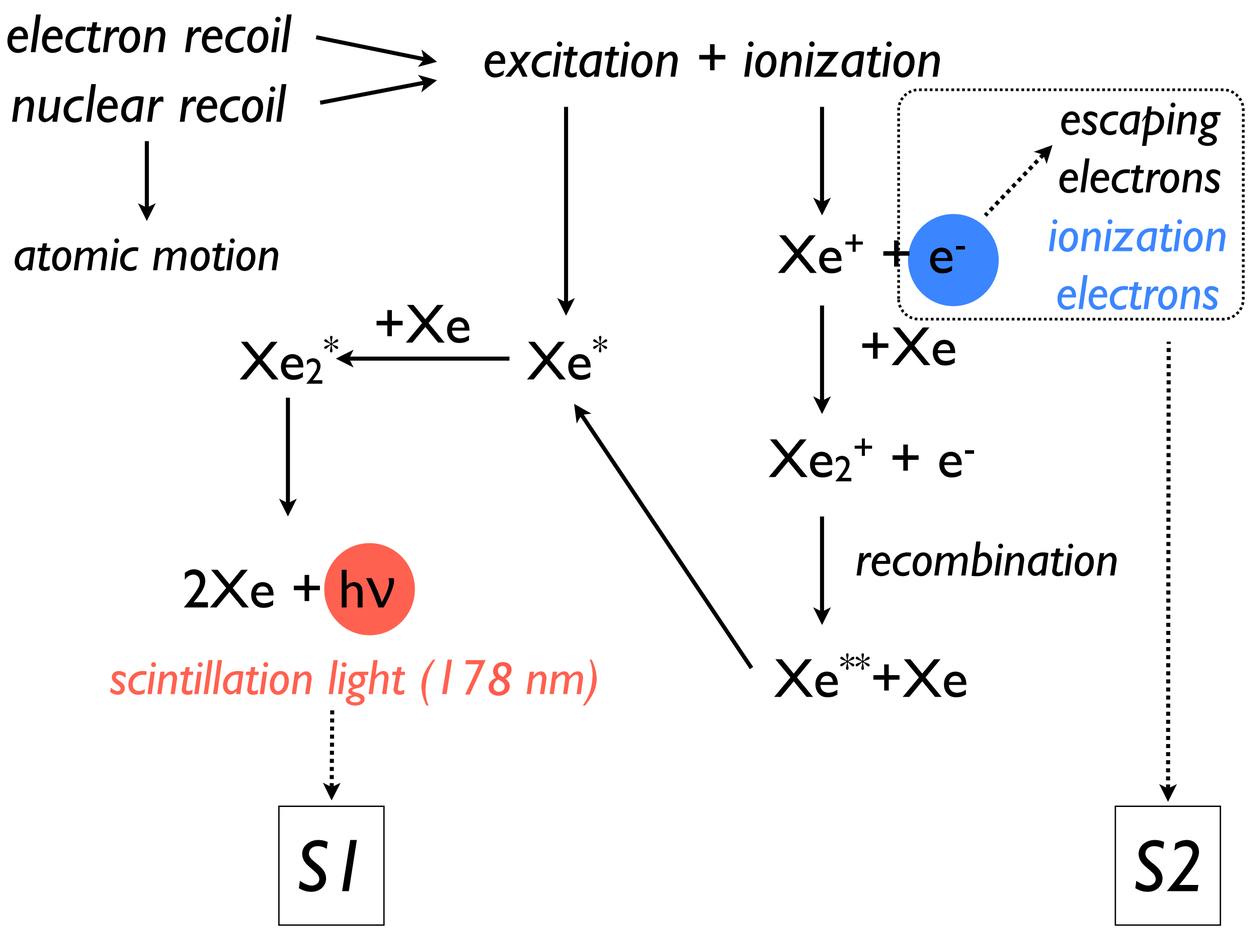

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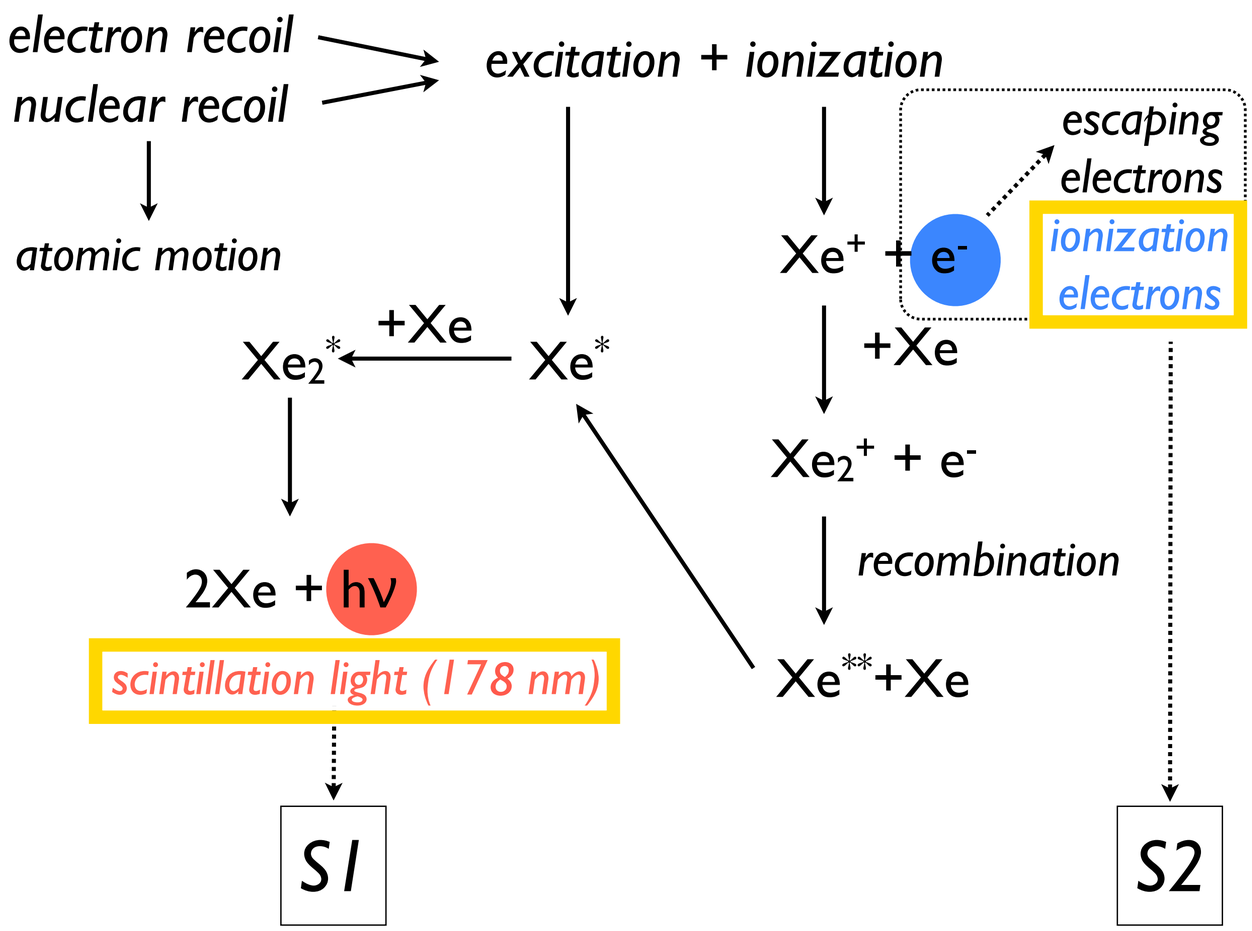

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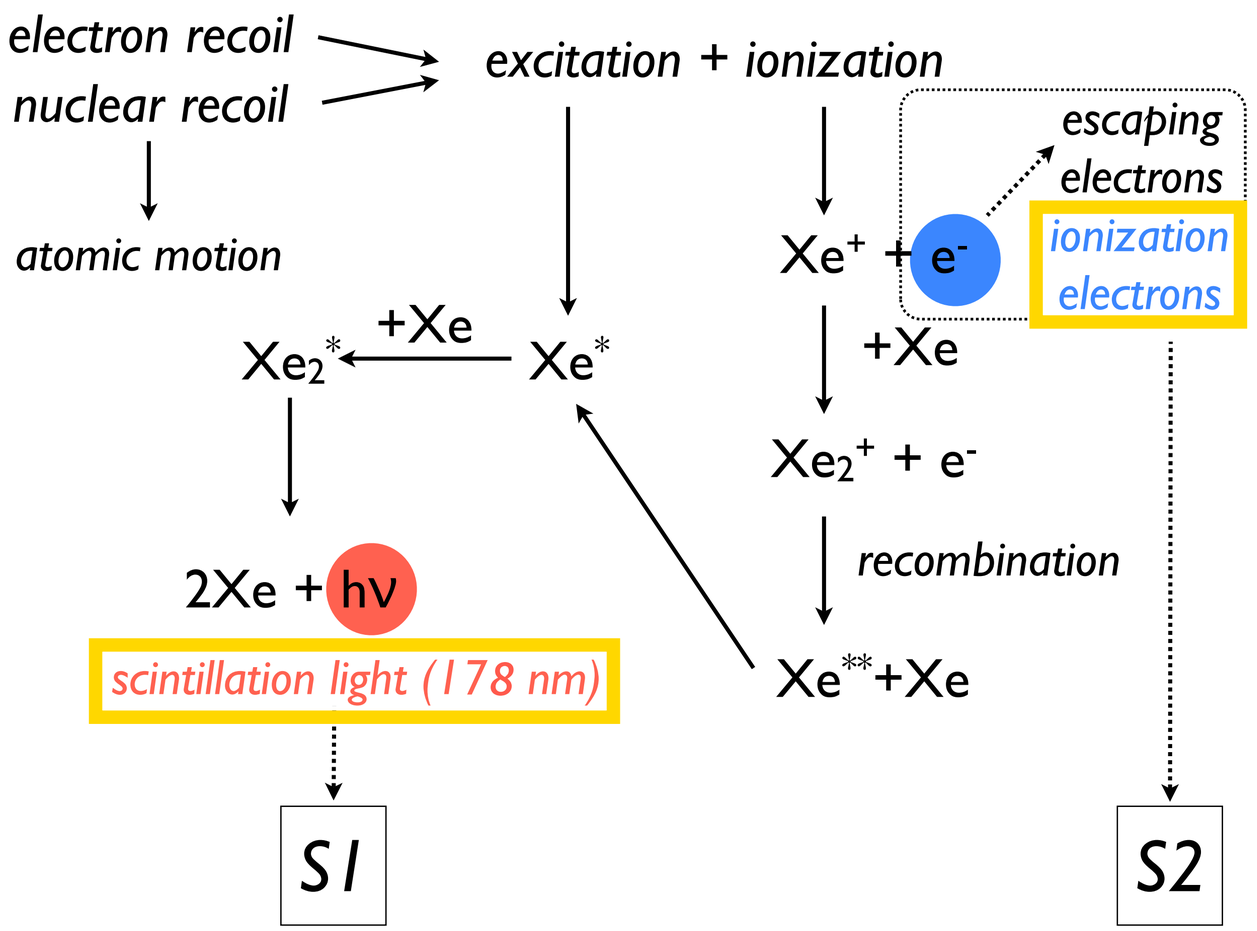

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- **Maximised** interaction cross section ($\propto A^2$)
- High stopping power and **self-shielding**
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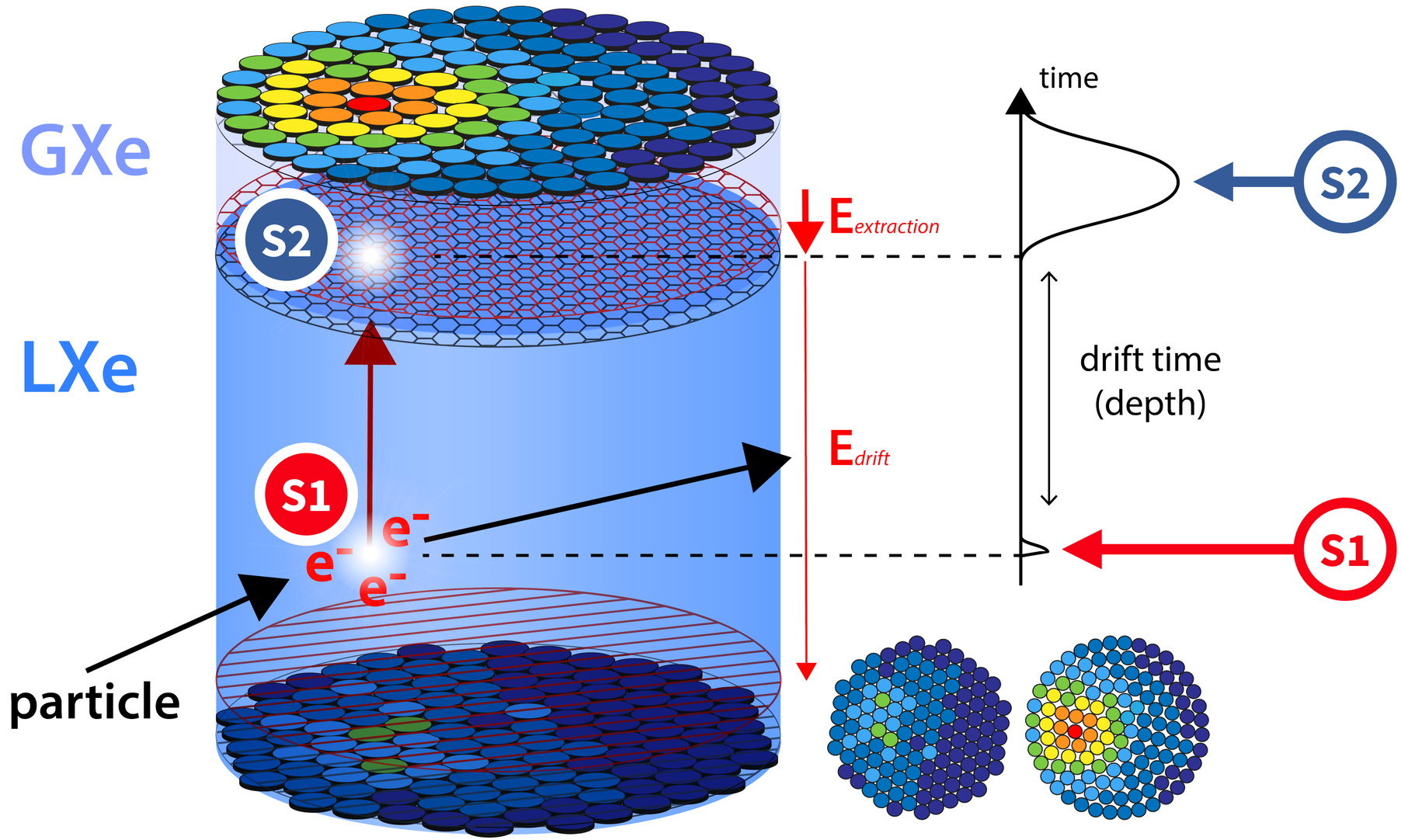
- Powerful DM discrimination combining **scintillation and ionisation** properties
- **Scalable** → well suited to DM search and evolving projects like **XENON**

Detecting particles with a dual-phase TPC



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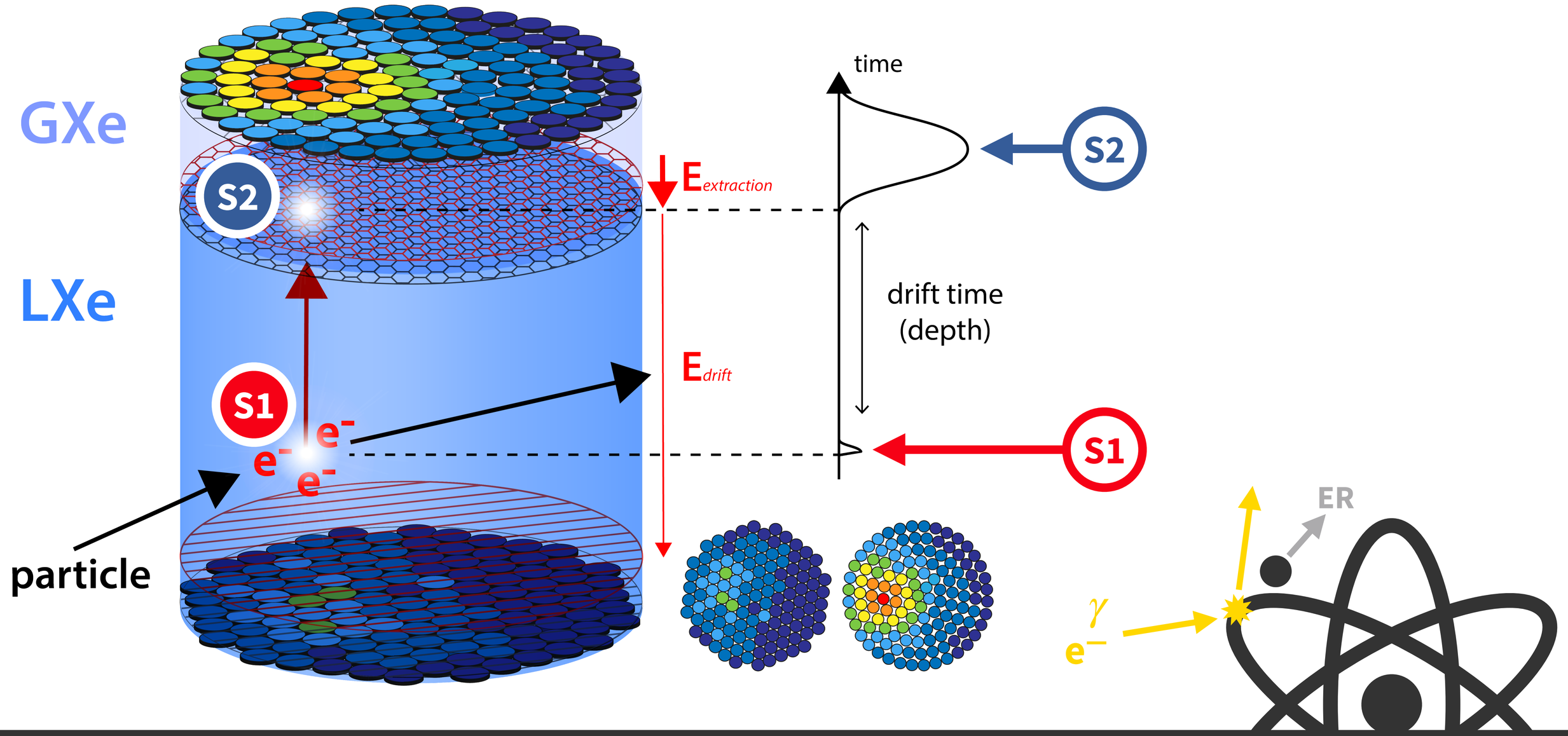

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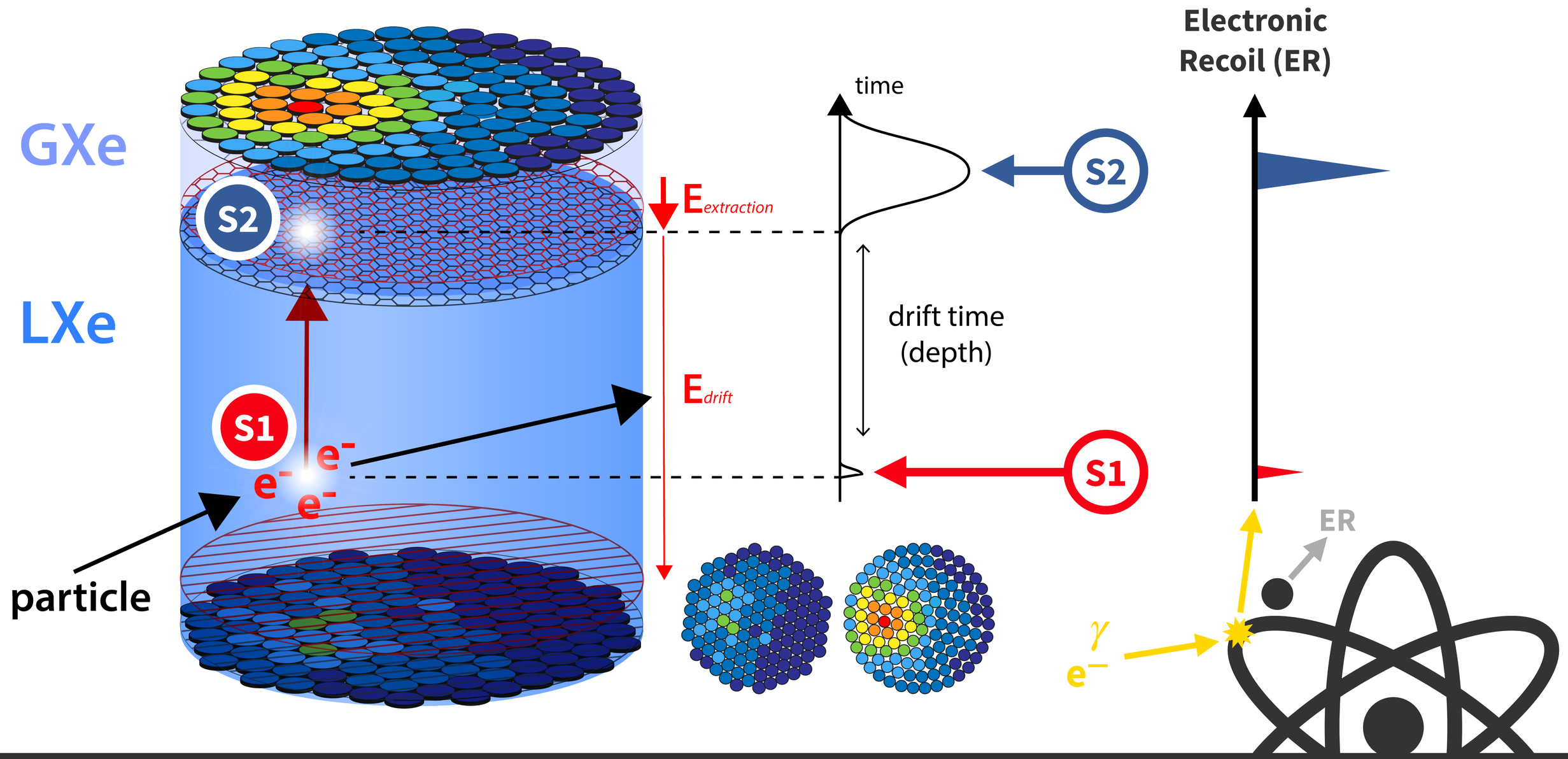

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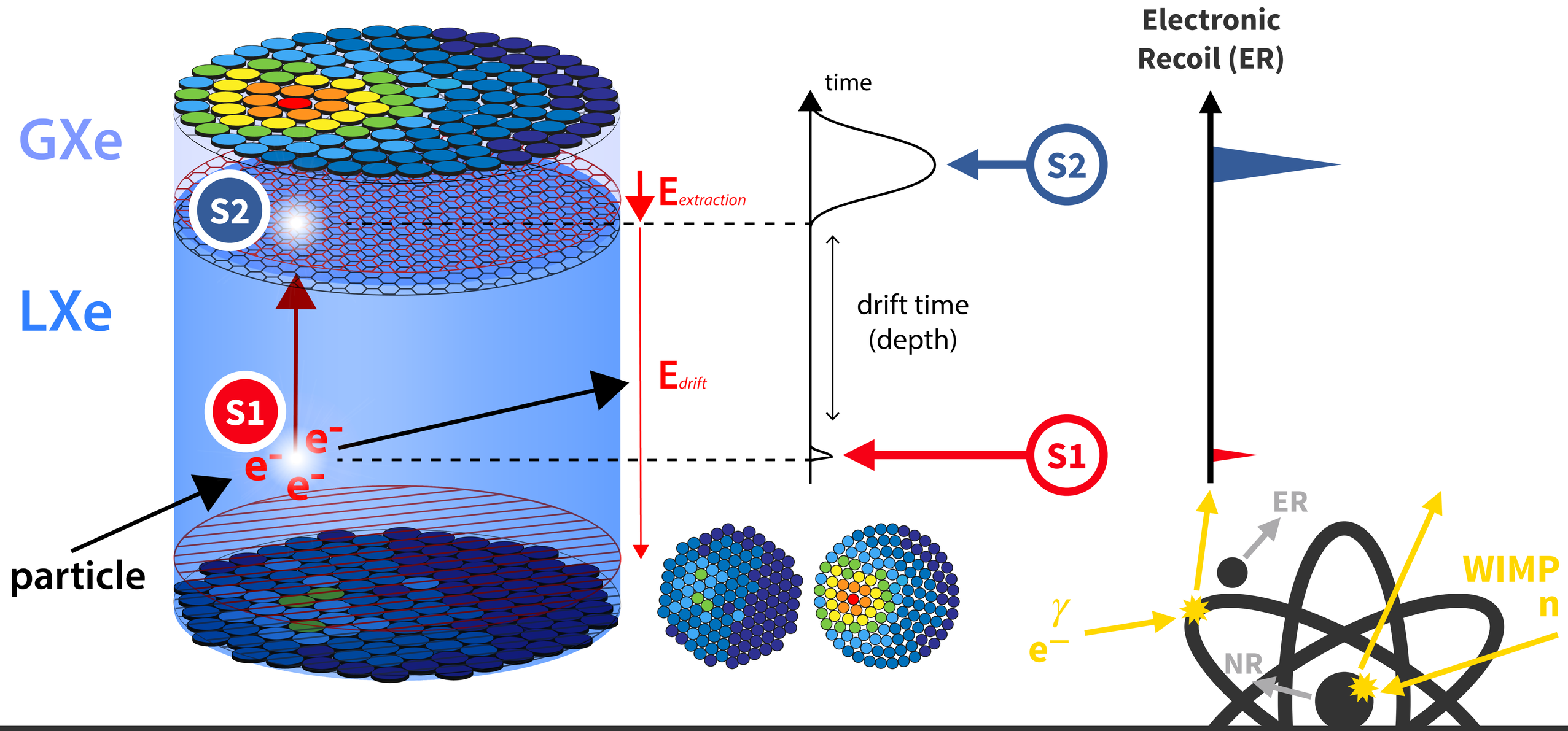

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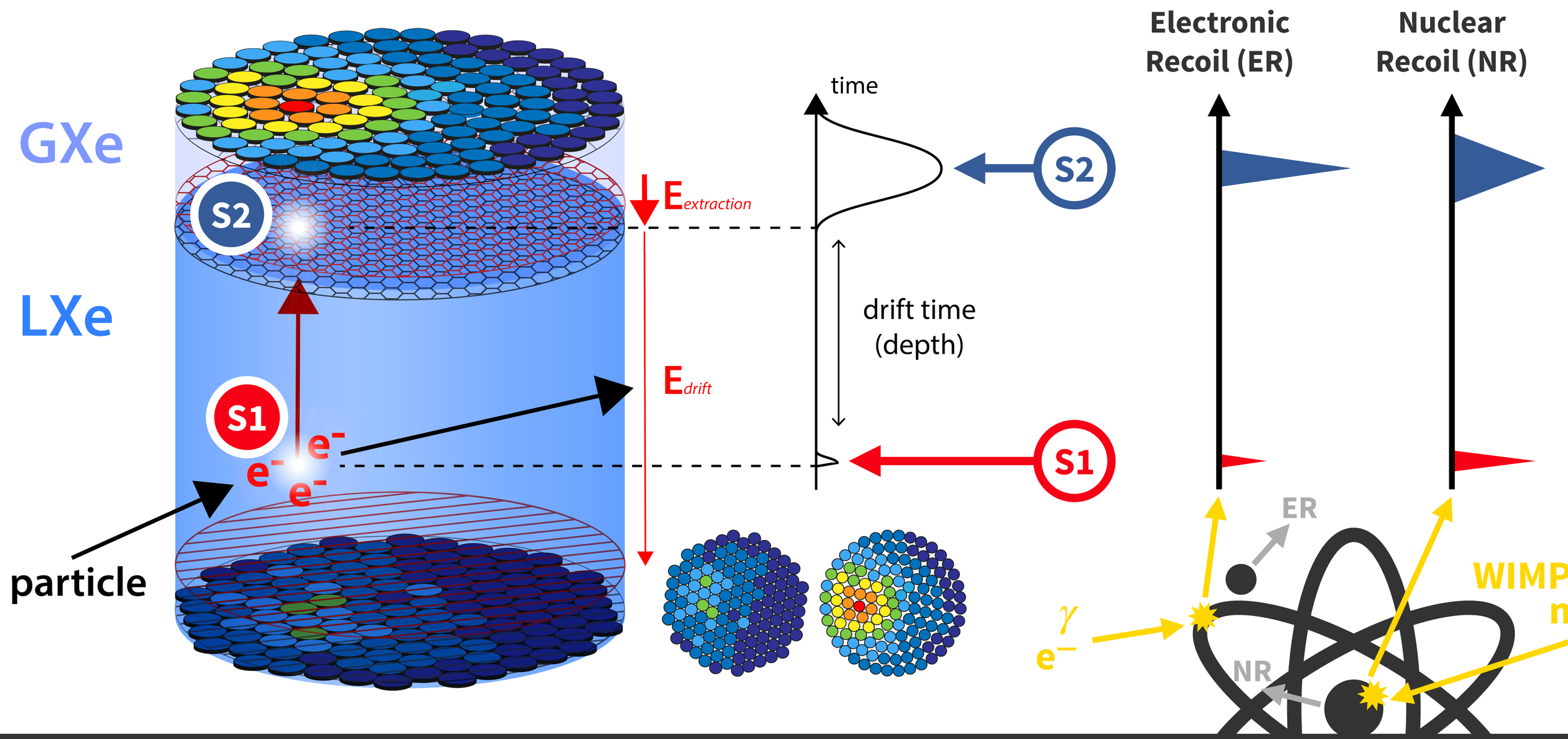

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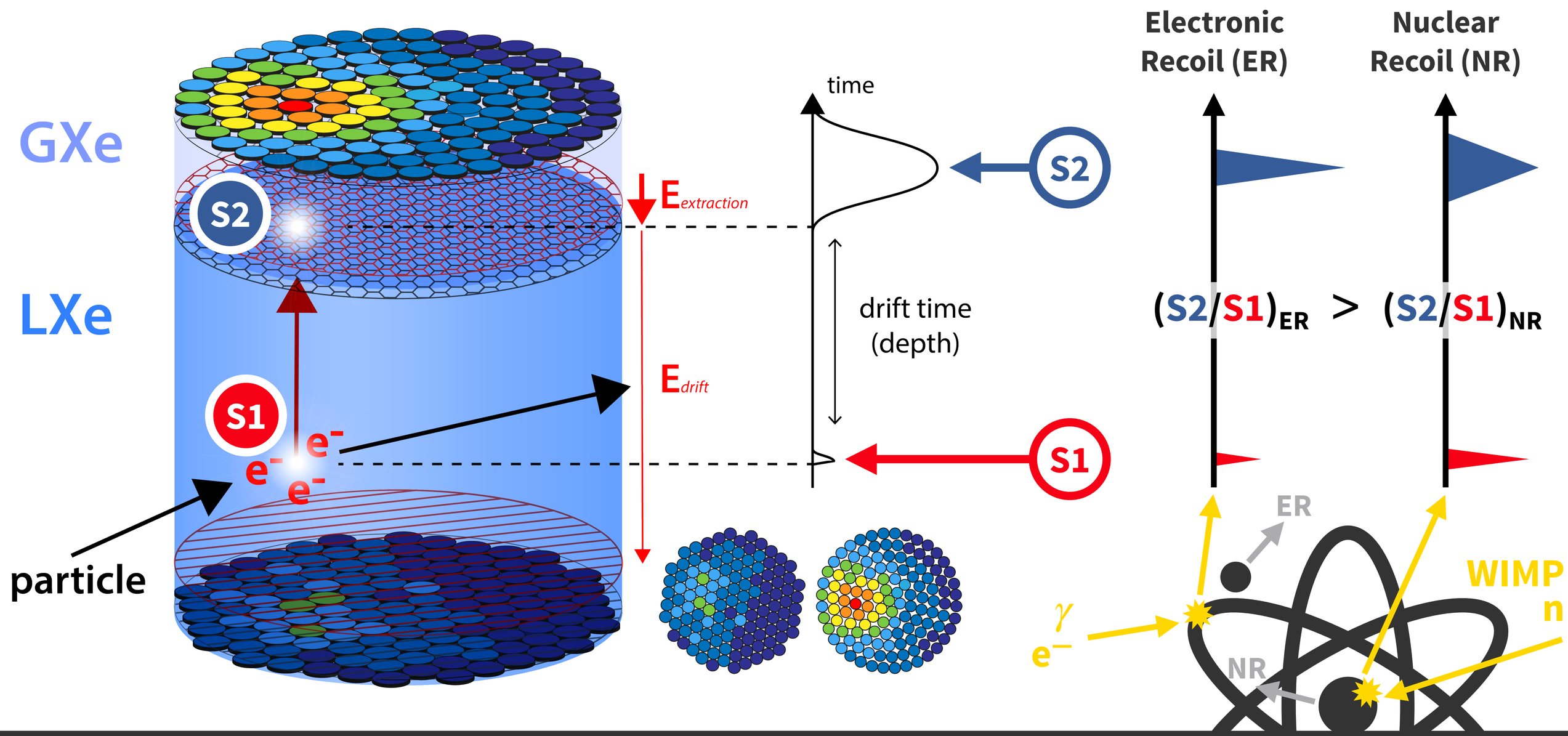
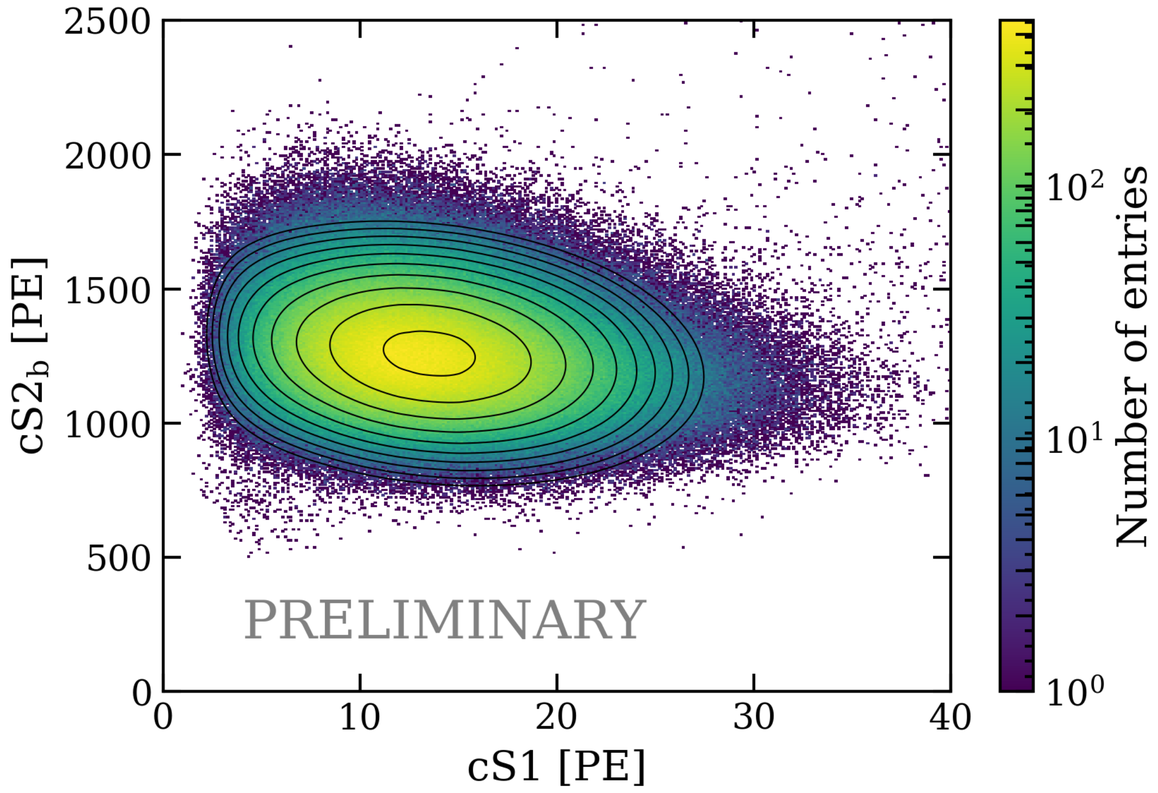
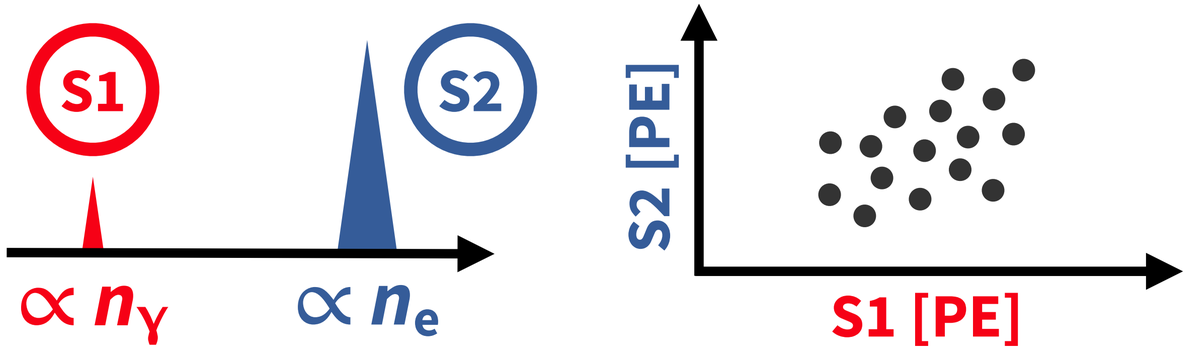


Reconstructing energy





$$E = W(n_\gamma + n_e)$$

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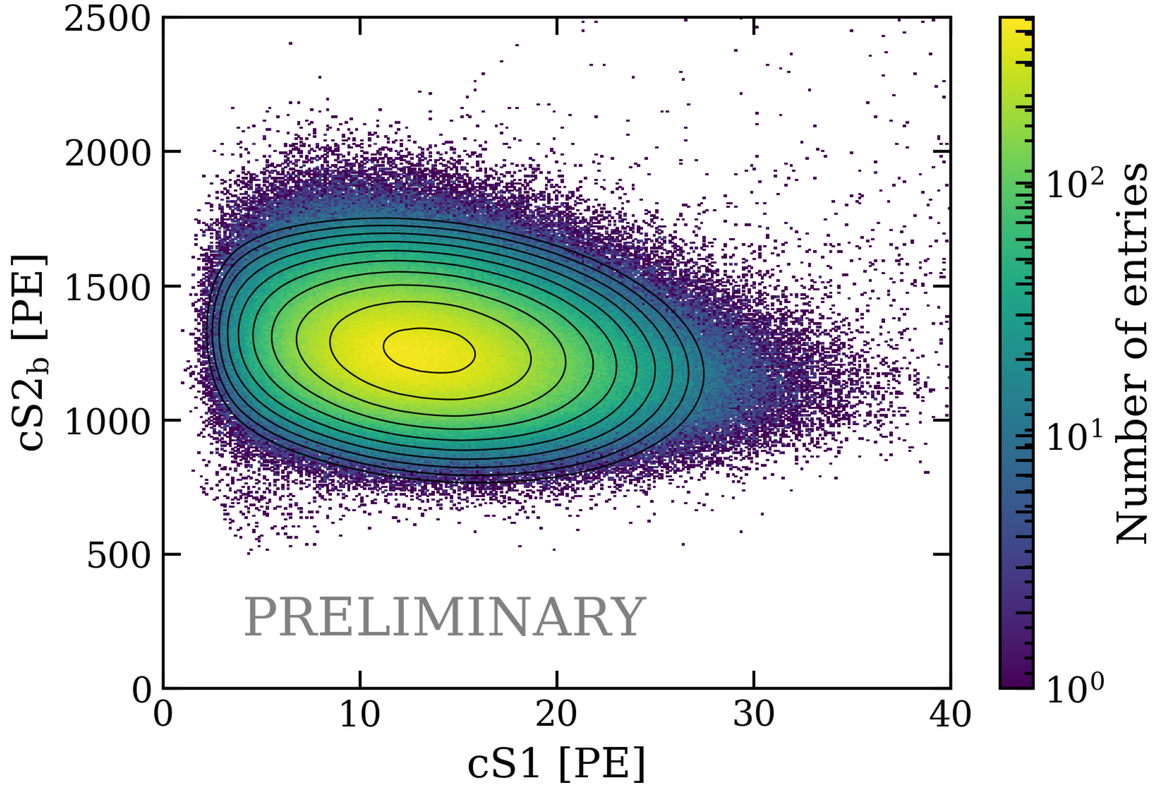

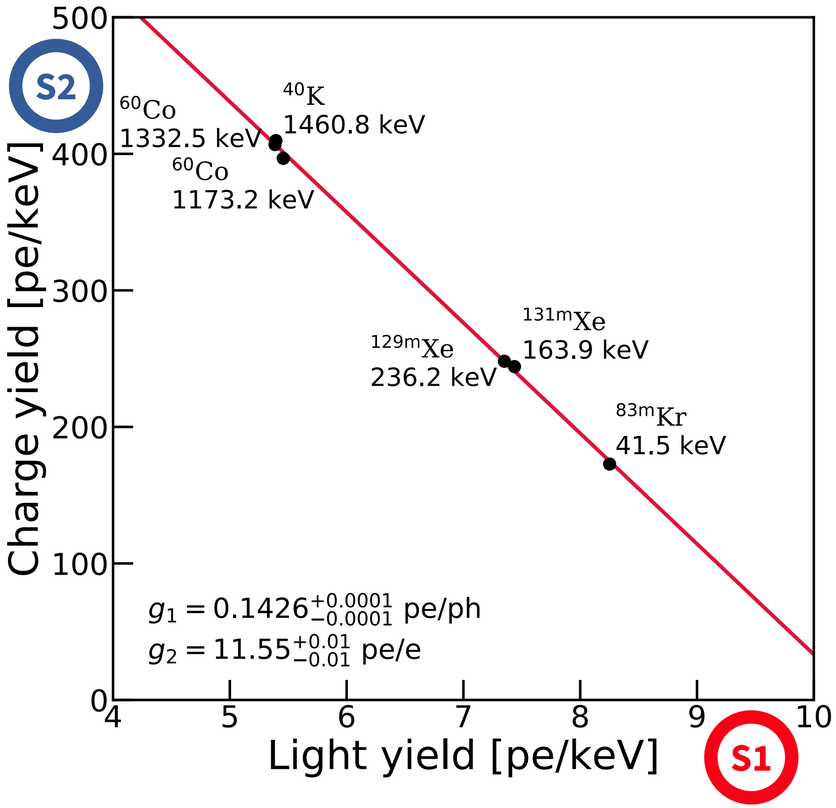

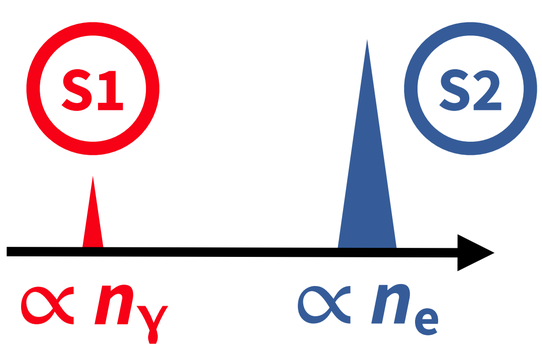

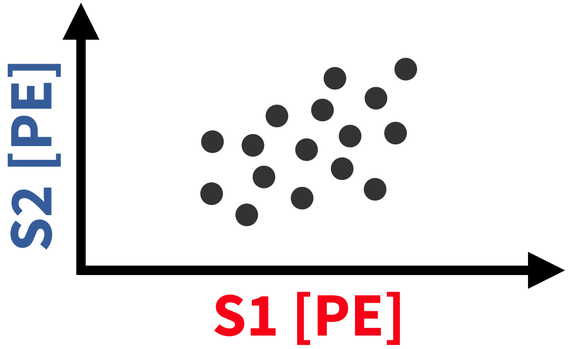

$$E = W(n_\gamma + n_e)$$
$$= W\left(\frac{S1}{g_1} + \frac{S2}{g_2}\right)$$

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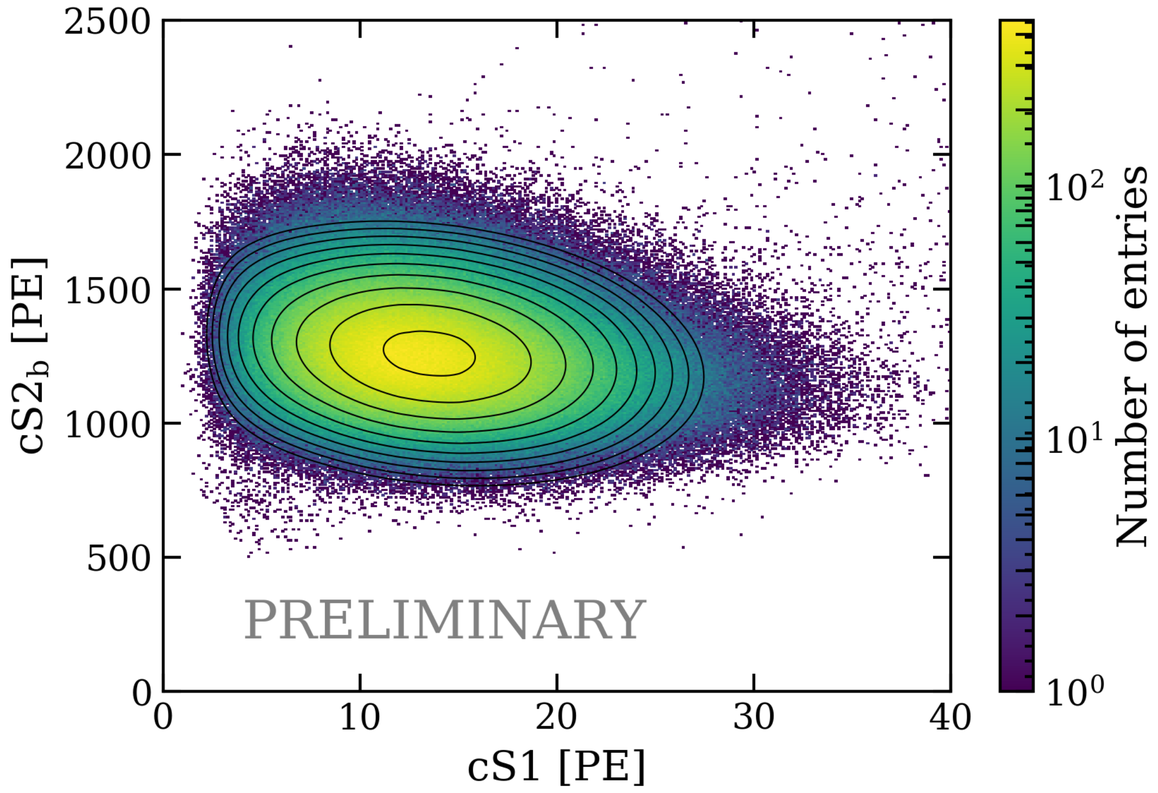
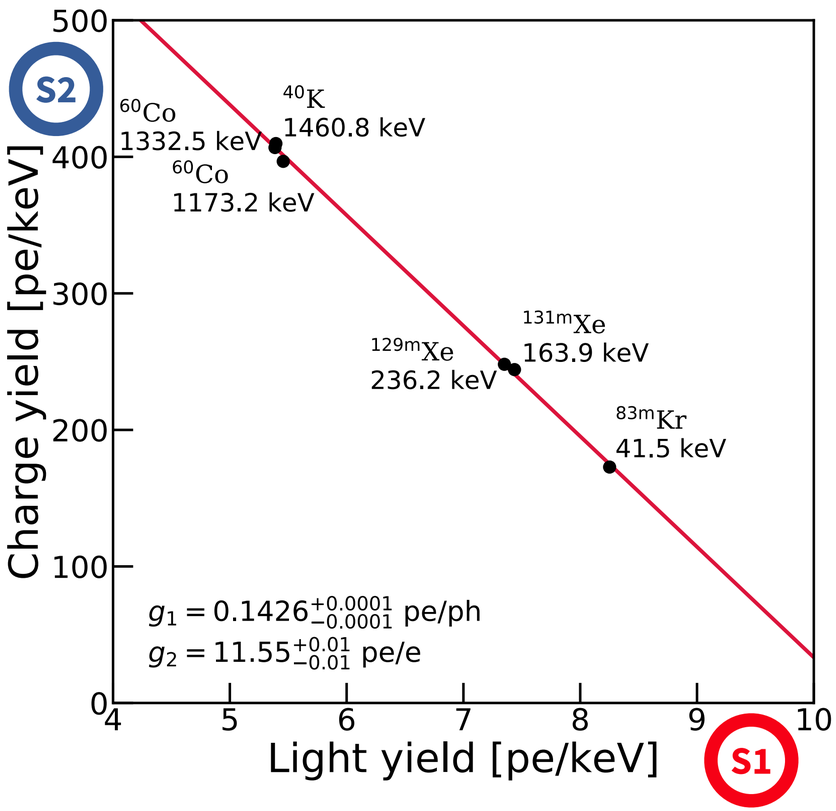
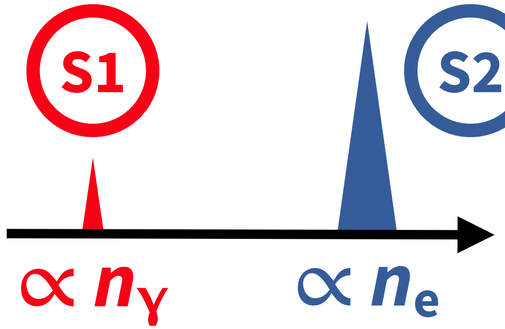
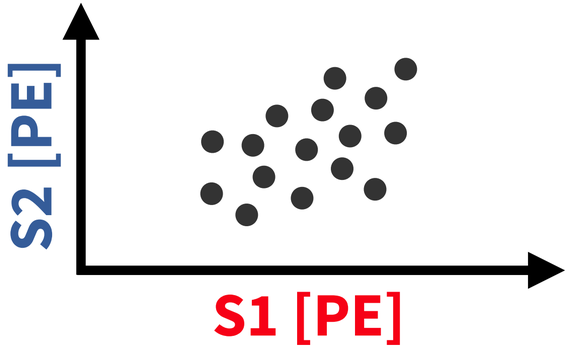
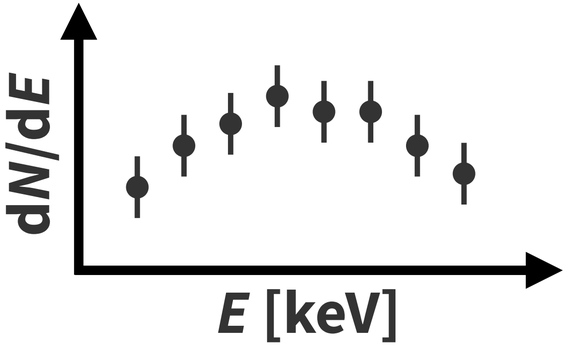




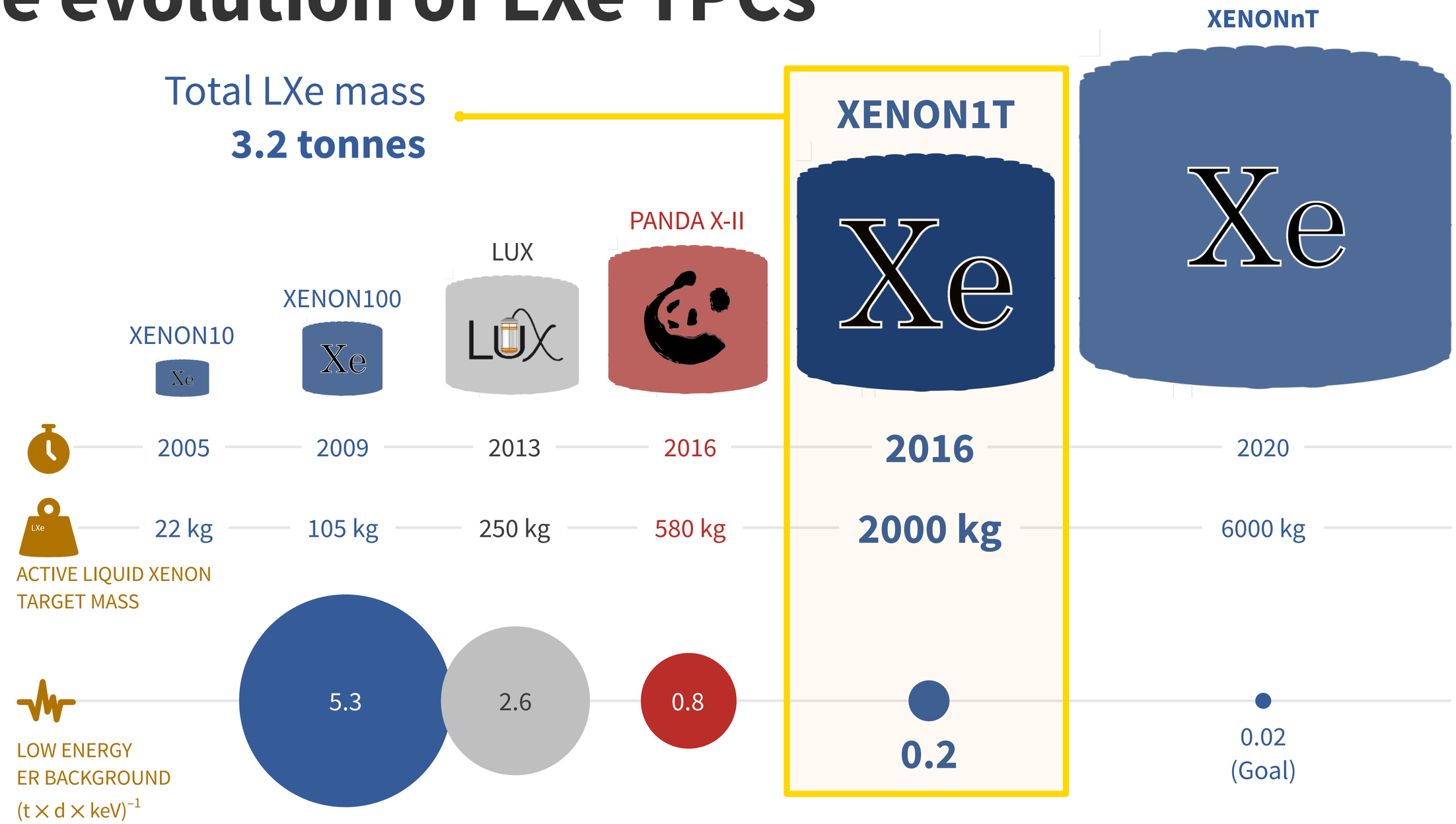




$$E = W(n_\gamma + n_e) = W\left(\frac{S1}{g_1} + \frac{S2}{g_2}\right)$$



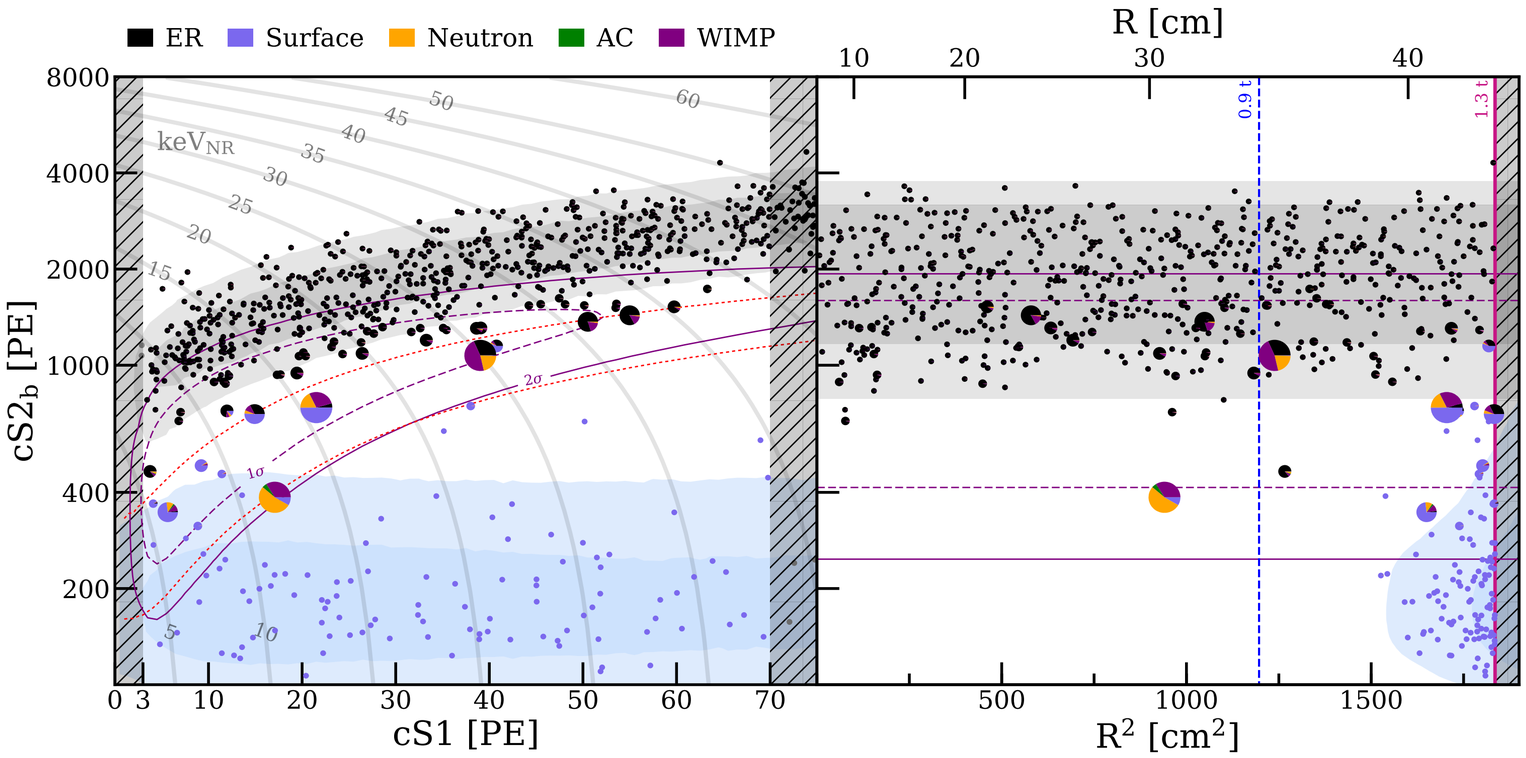
The evolution of LXe TPCs



What XENON1T found so far

High-mass WIMP-nucleus interactions

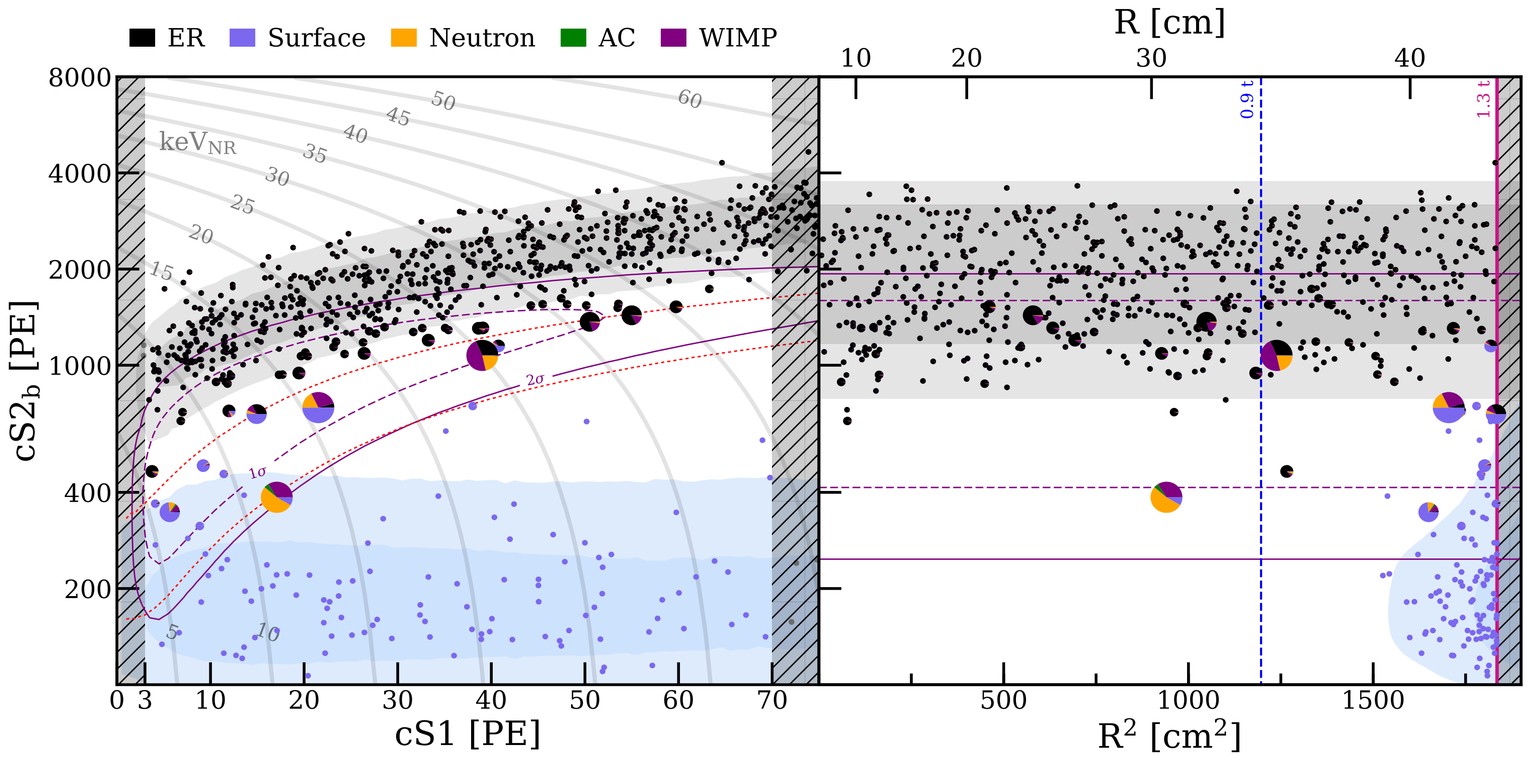
PRL 121 (2018) 111302

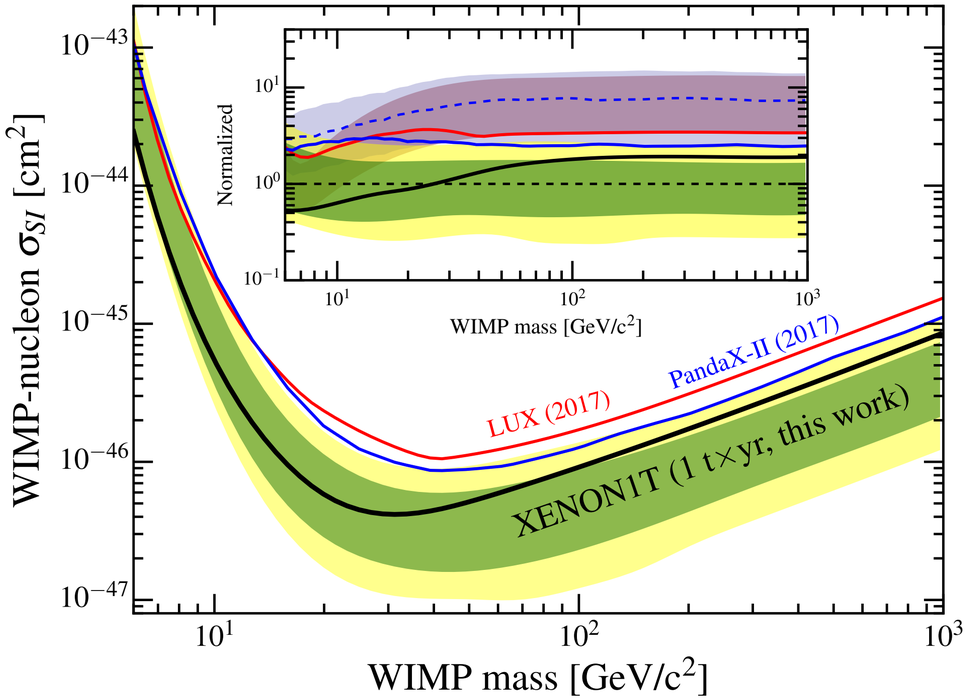


- A few events in the region of interest but **no significant excess** over background

High-mass WIMP-nucleus interactions

PRL 121 (2018) 111302

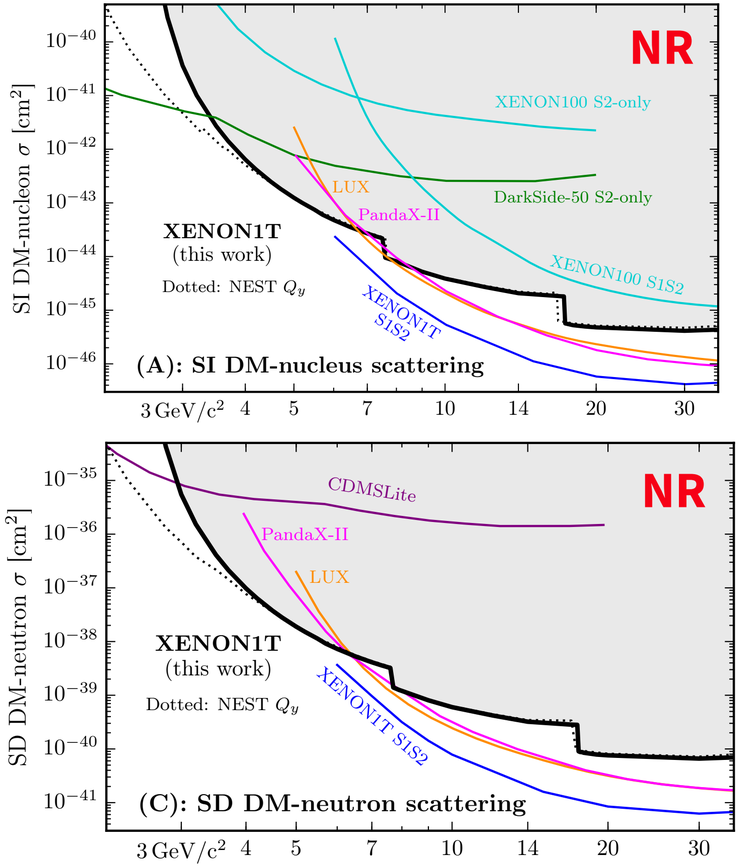




- A few events in the region of interest but **no significant excess** over background
- To date, **strongest limit** to the WIMP-nucleon cross section for WIMPs **above 6 GeV/c^2**
- Unprecedented minimum of **4.1×10^{-47} cm^2** at **30 GeV/c^2** (90% C.L.)

Light DM search (S2-only)

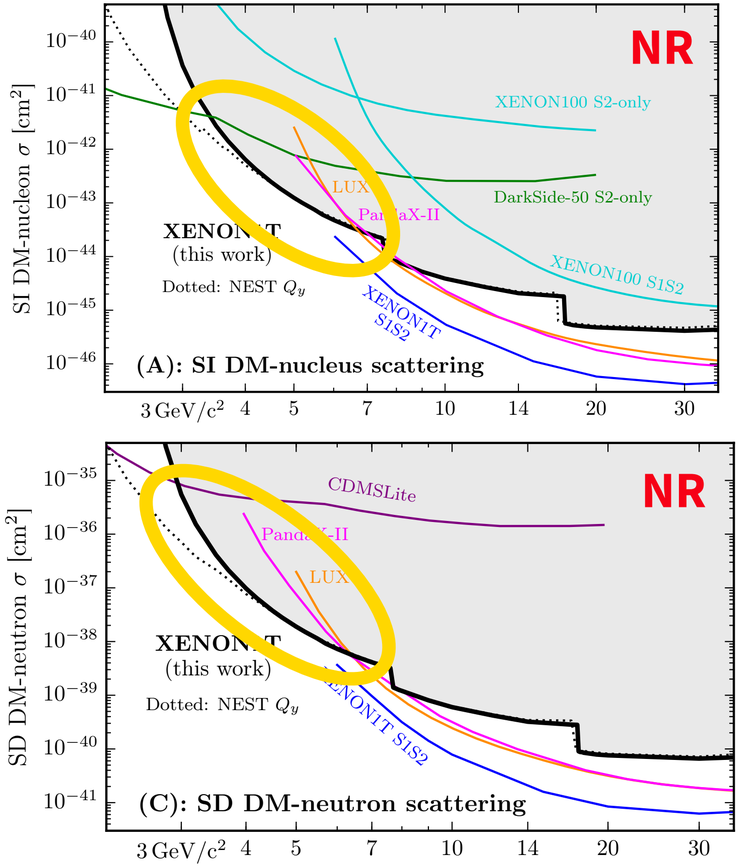
PRL 123 (2019) 251801



- Analysis using the **ionisation signal (S2) only** → access to 2–3 times lower energies

Light DM search (S2-only)

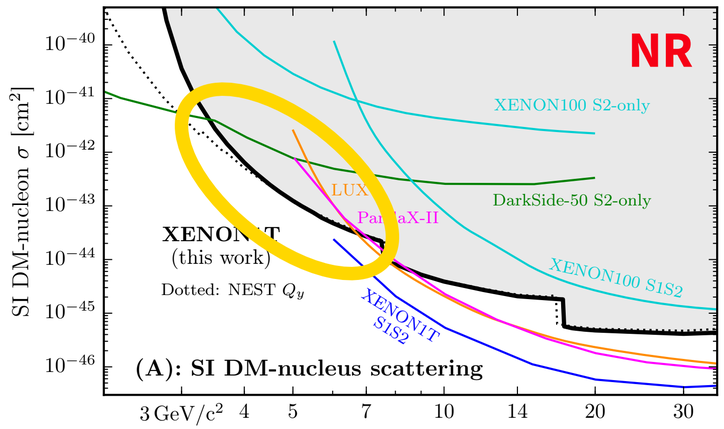
PRL 123 (2019) 251801

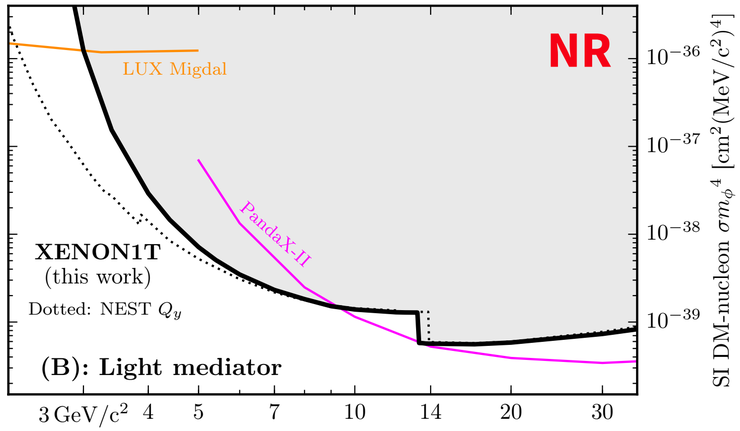


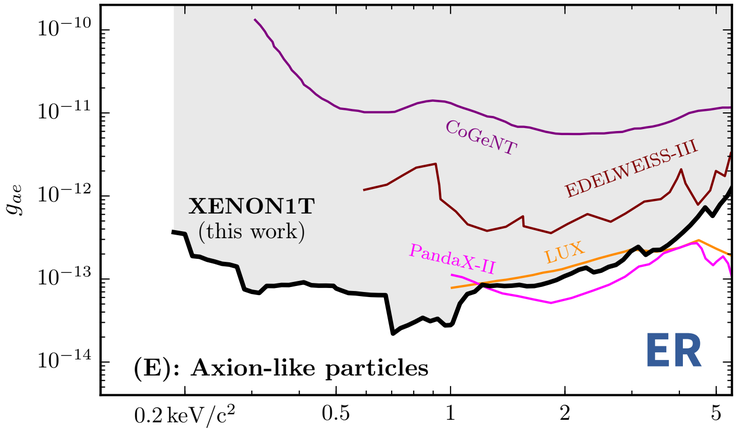
- Analysis using the **ionisation signal (S2) only** → access to 2–3 times lower energies
- Best sensitivity to low-mass DM-matter interactions **below 6 GeV/c^2**

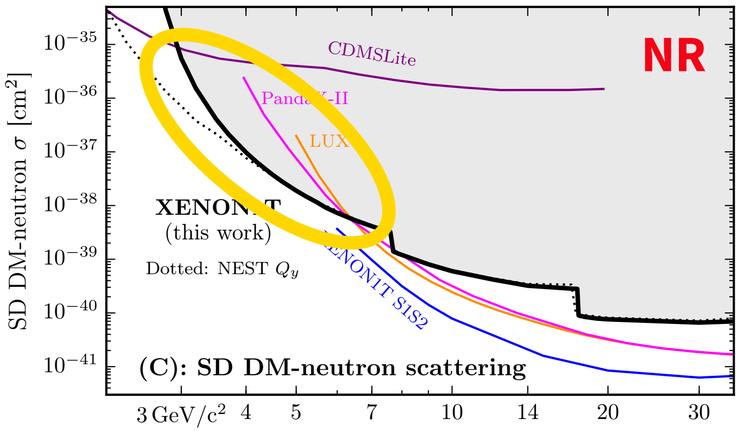
Light DM search (S2-only)

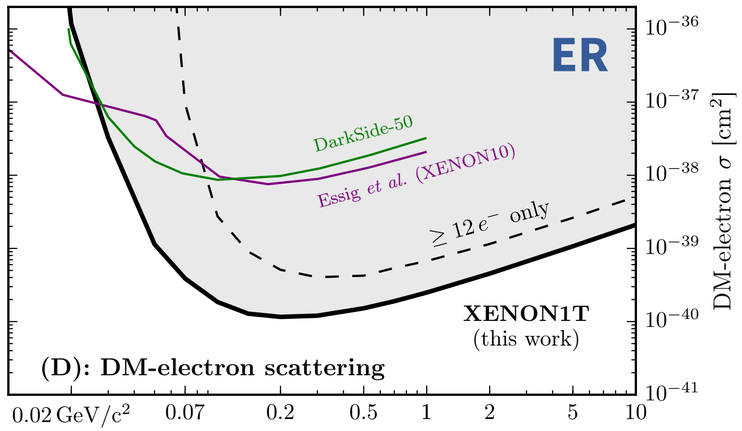
PRL 123 (2019) 251801

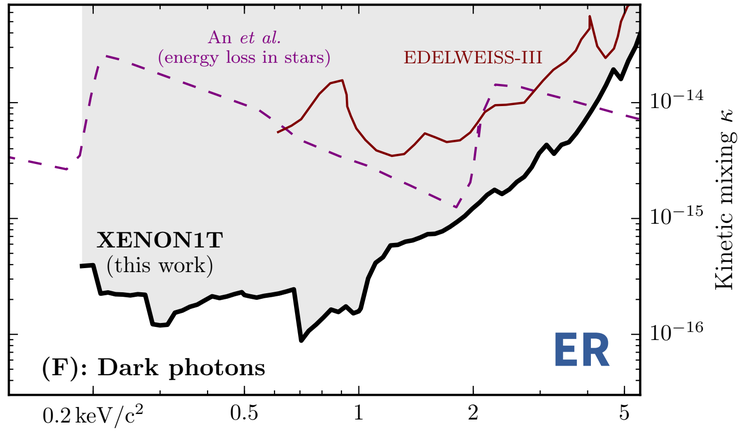








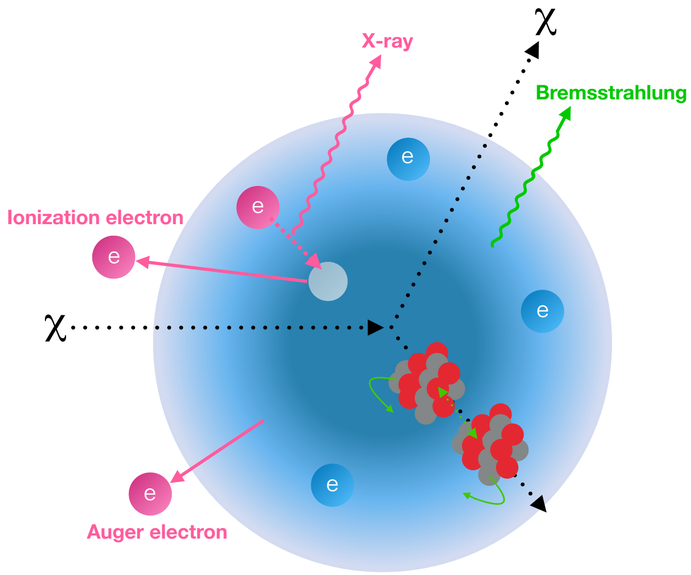




- Analysis using the **ionisation signal (S2) only** → access to 2–3 times lower energies
- Best sensitivity to low-mass DM-matter interactions **below 6 GeV/c^2**
- **New constraints on various models**, from DM-electron scatterings to axion-like particles

Light DM search (Migdal & Brems)

PRL 123 (2019) 241803

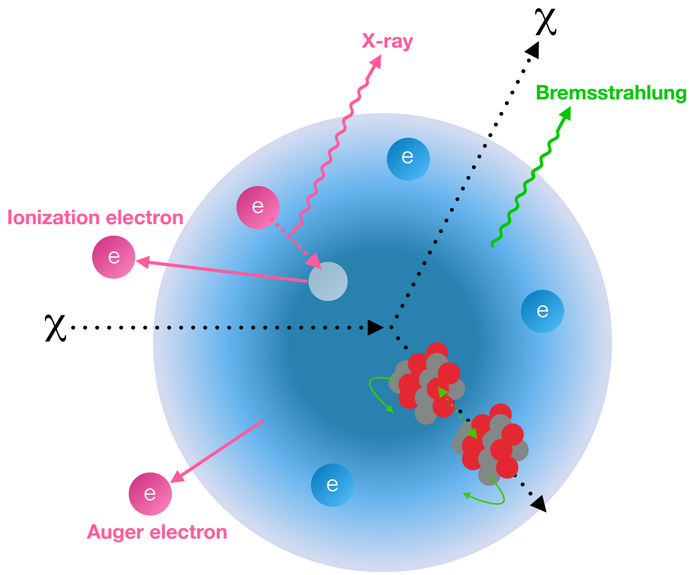


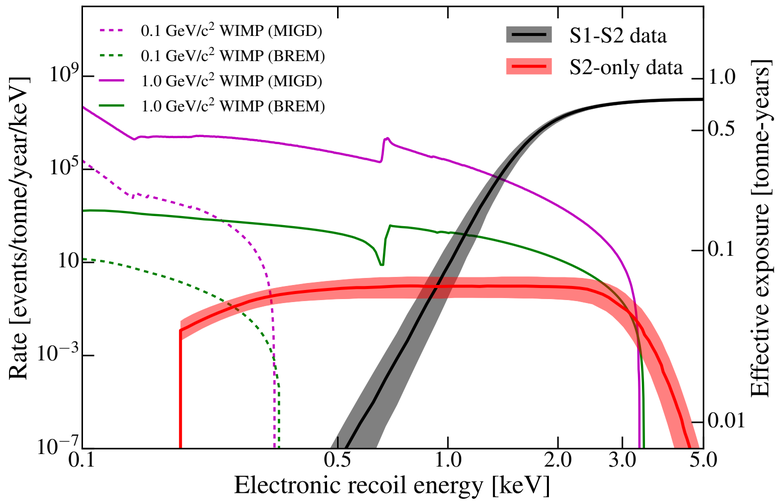
- Taking advantage of the **post-NR lag** between the nucleus and orbital electrons motion

  → **Migdal** and **Bremsstrahlung** $\lesssim$ 1 keV **ER** radiation

Light DM search (Migdal & Brems)

PRL 123 (2019) 241803

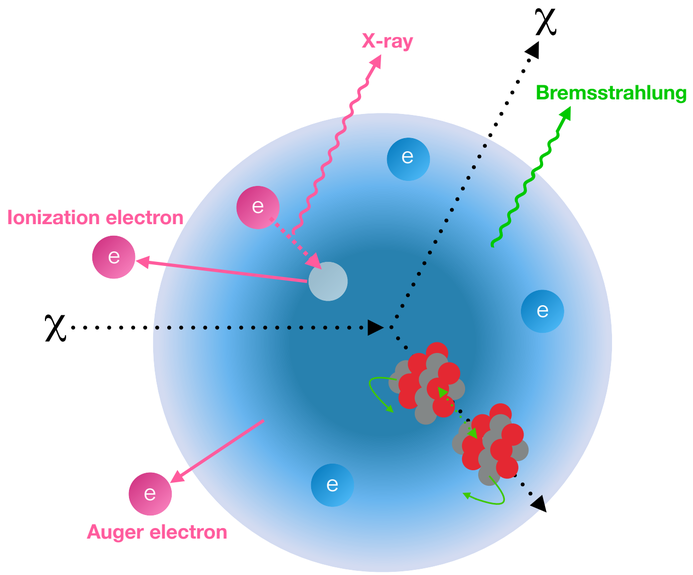


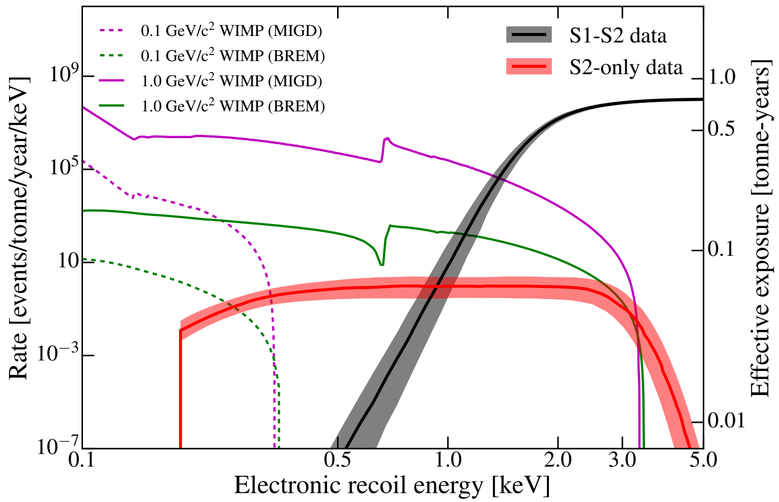


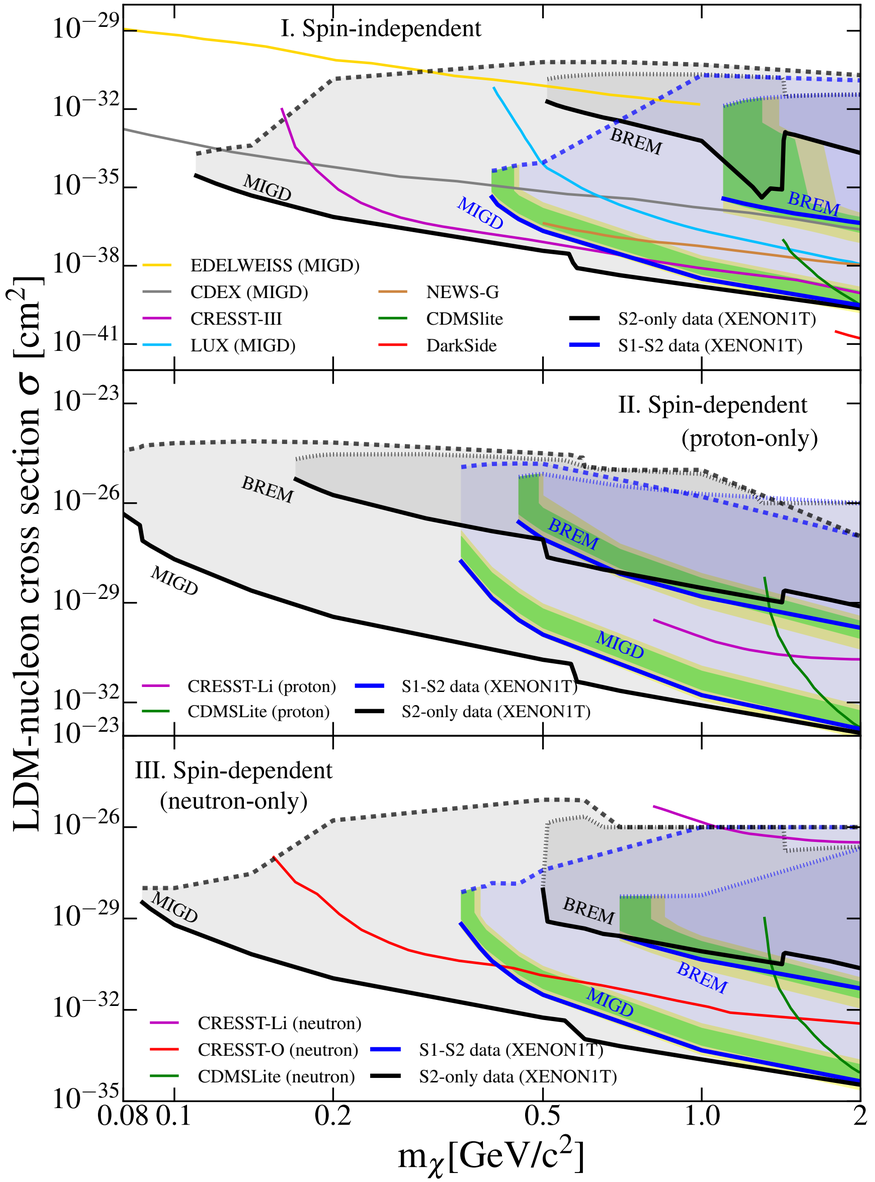
- Taking advantage of the **post-NR lag** between the nucleus and orbital electrons motion
  → **Migdal** and **Bremsstrahlung** $\lesssim$ 1 keV **ER** radiation
- Using S2 alone → sensitivity to DM **down to 85 MeV/c^2**

Light DM search (Migdal & Brems)

PRL 123 (2019) 241803

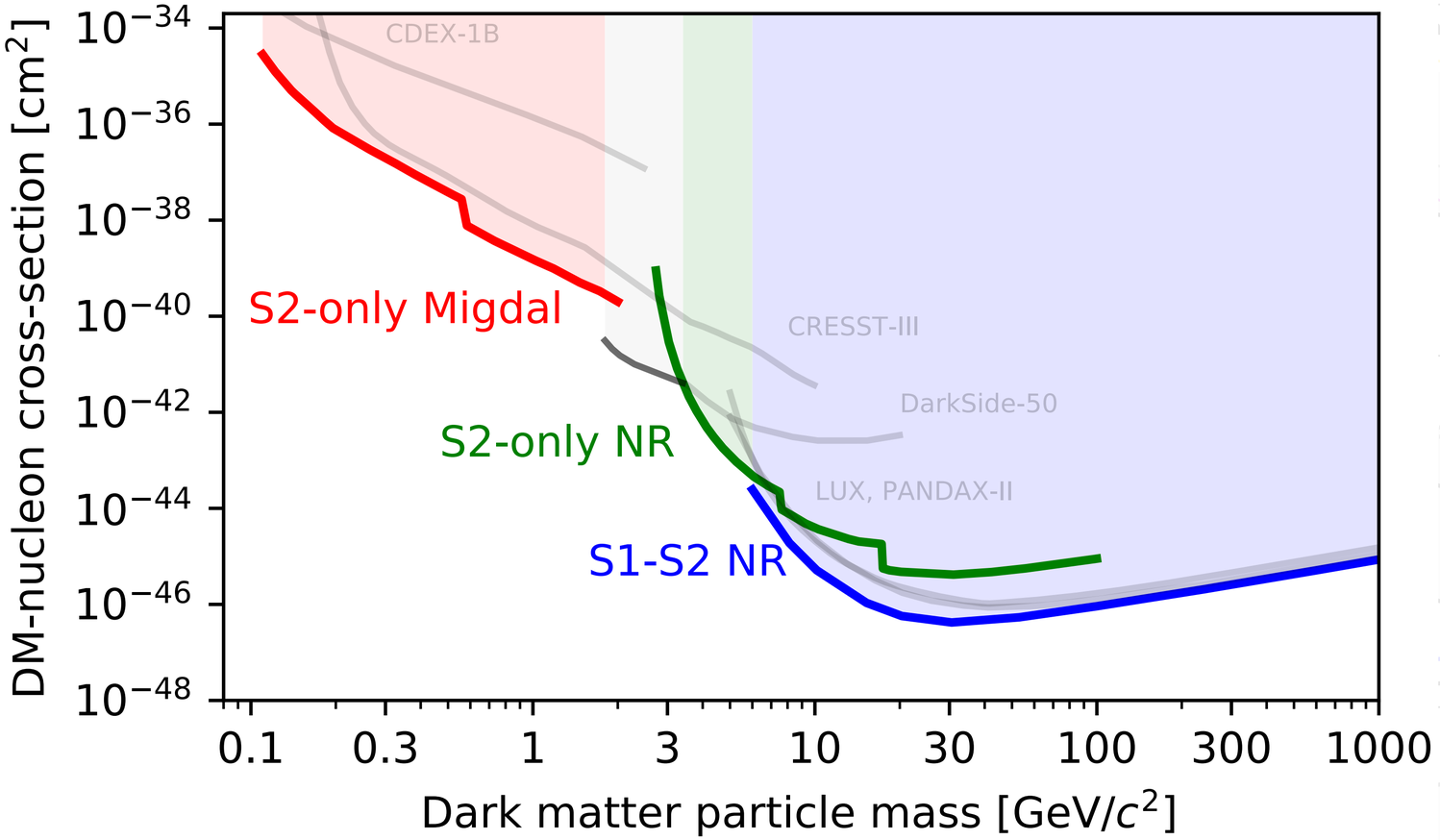






- Taking advantage of the **post-NR lag** between the nucleus and orbital electrons motion
  → **Migdal** and **Bremsstrahlung** $\lesssim$ 1 keV **ER** radiation
- Using S2 alone → sensitivity to DM **down to 85 MeV/c^2**
- Best upper limits for DM masses **below ~ 2 GeV/c^2**

Light DM search (Migdal & Brems)

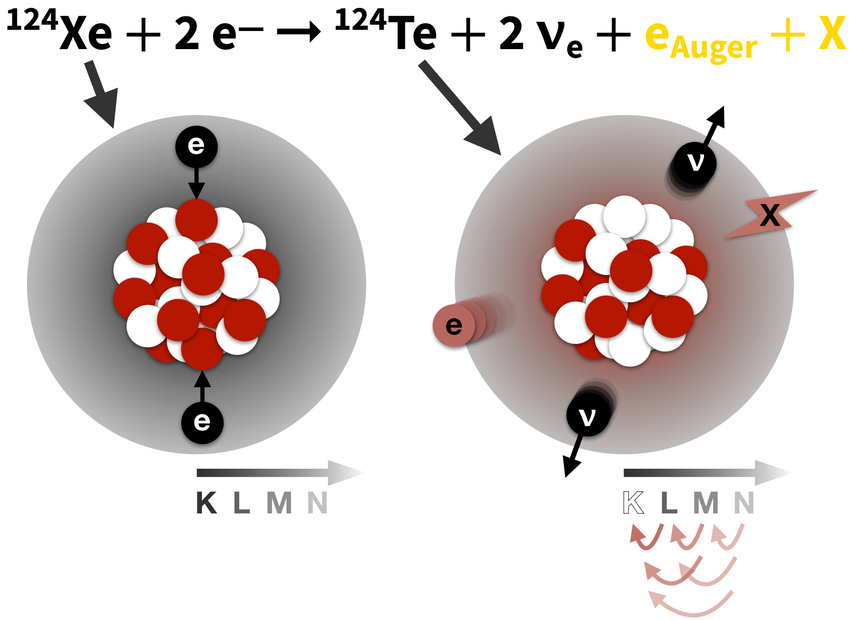


- Taking advantag
  nucleus and orb
  → **Migdal** and **Bremsstrahlung** ≳ 1 keV ER radiation
- Using S2 alone → sensitivity
- Best upper limits for DM mas

Leading (most of) the searched DM mass range!

2ν Double Electron Capture in ^{124}Xe

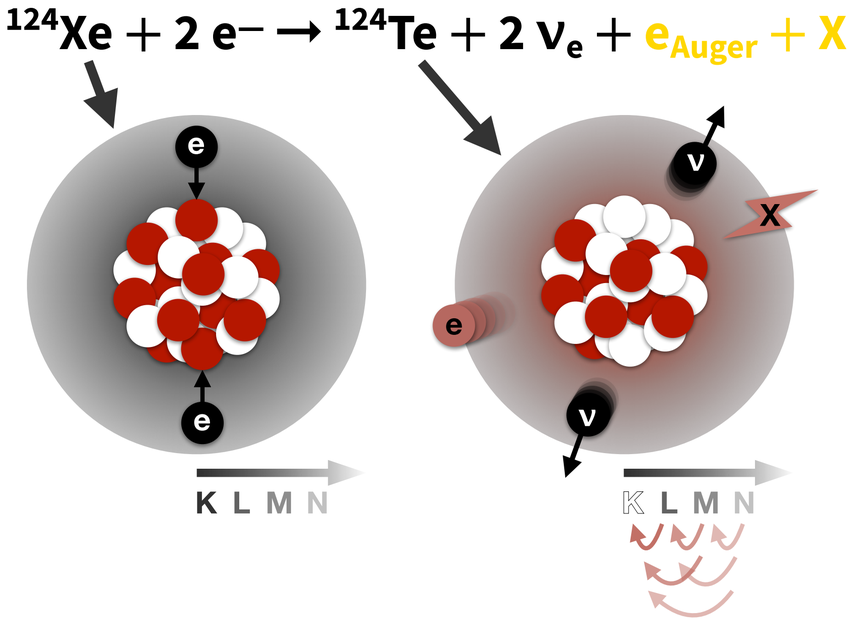
Nature 568 (2019) 7753

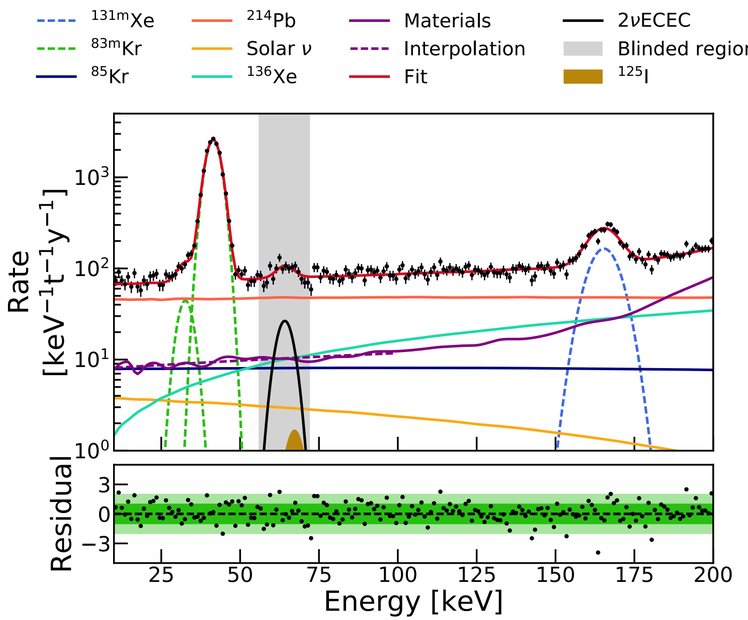


- Extremely rare process, never observed before

2ν Double Electron Capture in ^{124}Xe

Nature 568 (2019) 7753

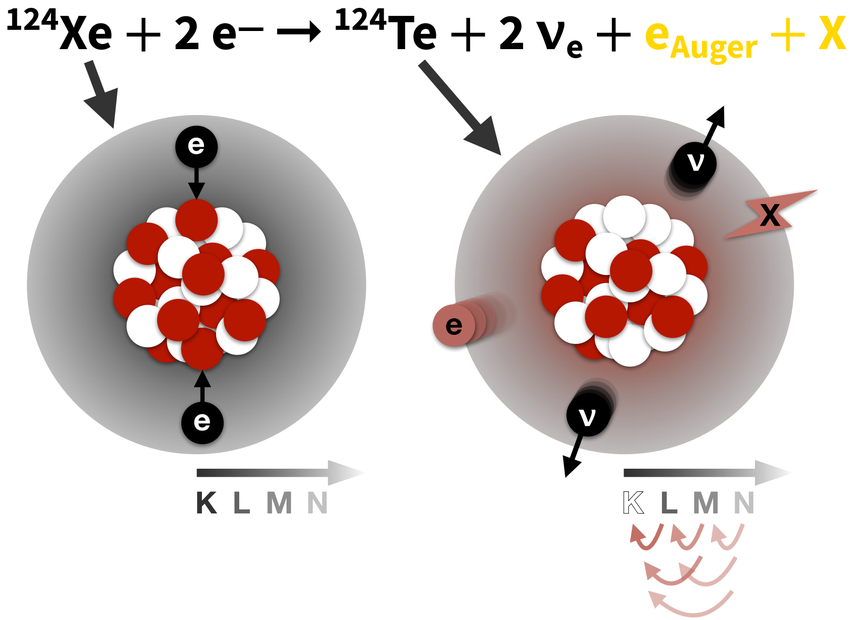


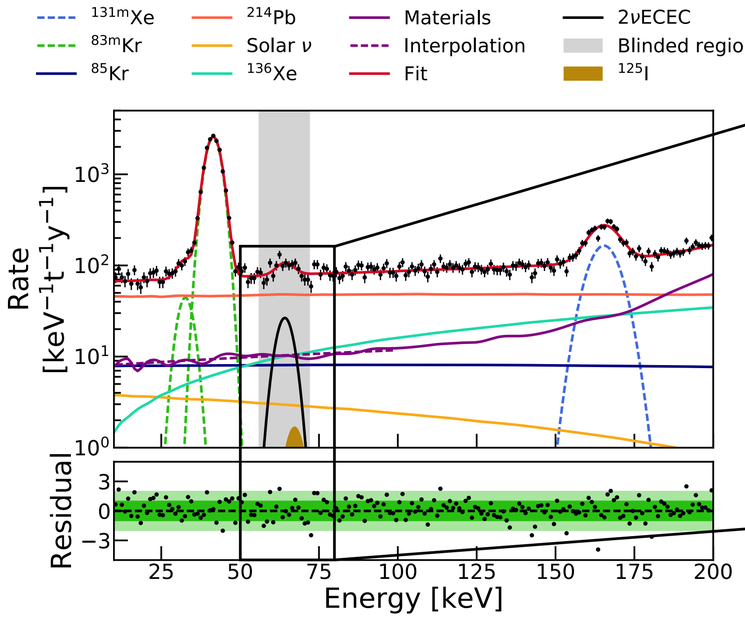


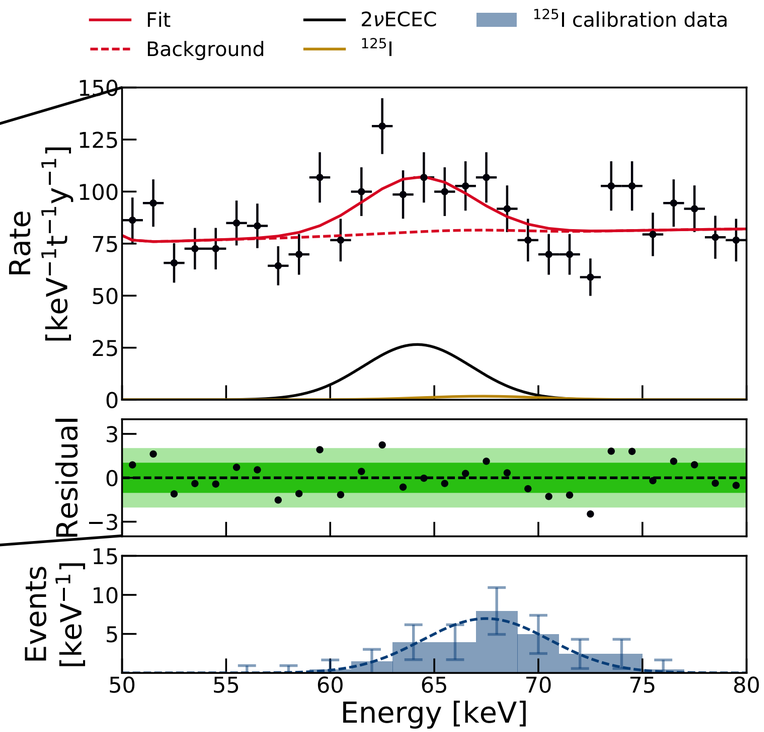
- Extremely rare process, never observed before
- K-shell electron capture → **X-rays and e$_{Auger}$ (64.3 keV)**

2ν Double Electron Capture in ^{124}Xe

Nature 568 (2019) 7753



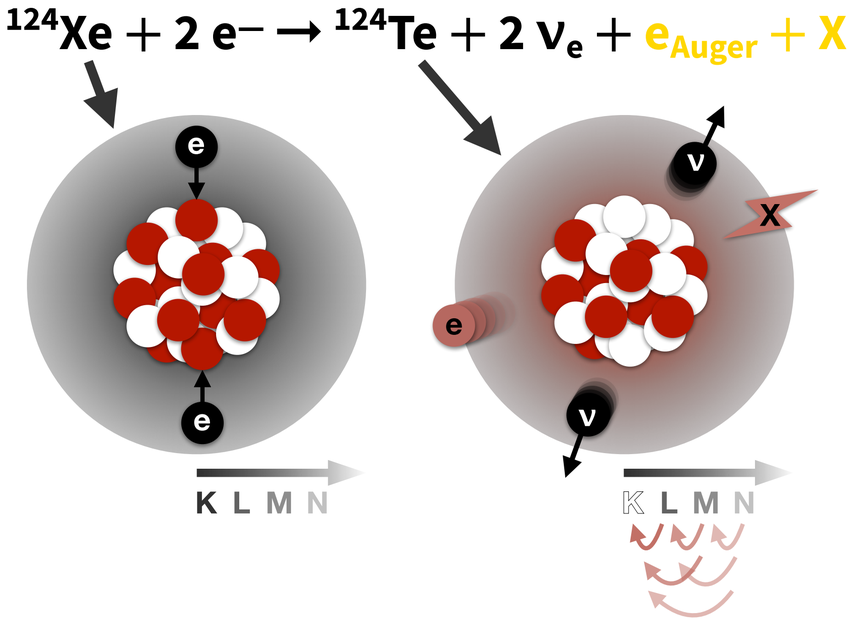


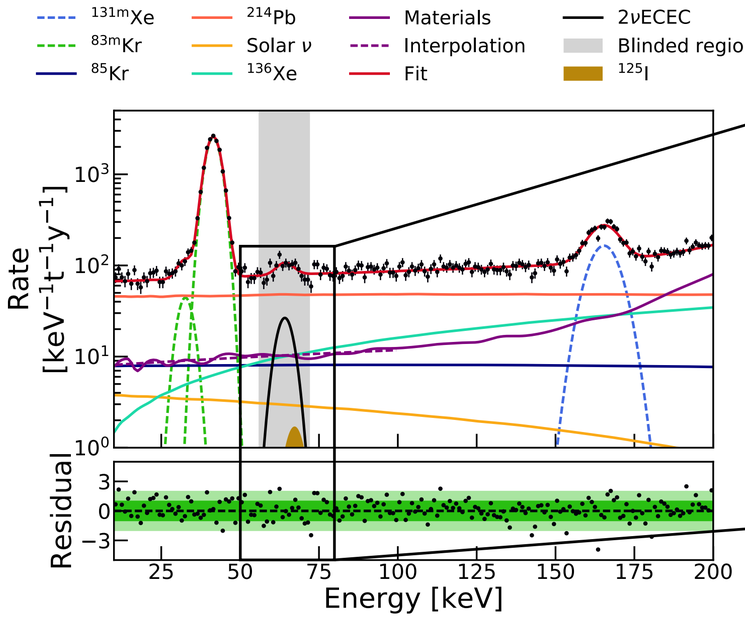


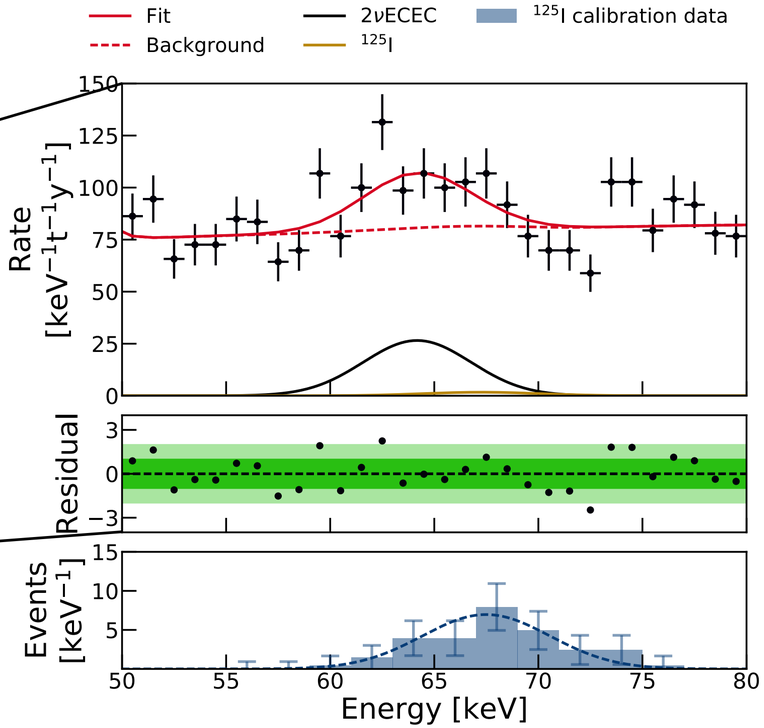
- Extremely rare process, never observed before
- K-shell electron capture → **X-rays and e_{Auger} (64.3 keV)**
- ^{124}Xe ∼ 1 kg/t LXe → **126 2νECEC events** (4.4σ above bkg.)

2ν Double Electron Capture in ^{124}Xe

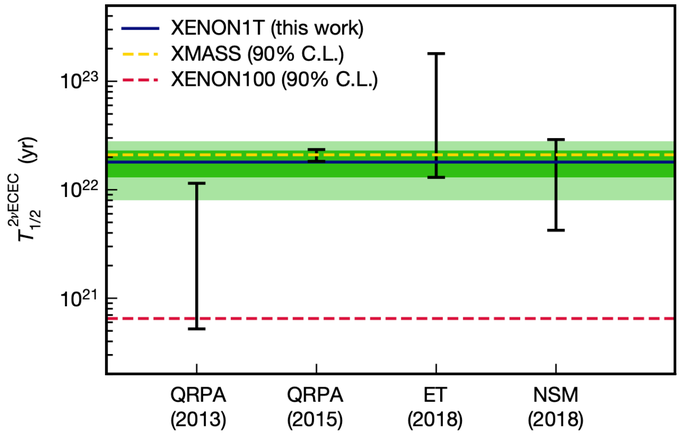
Nature 568 (2019) 7753



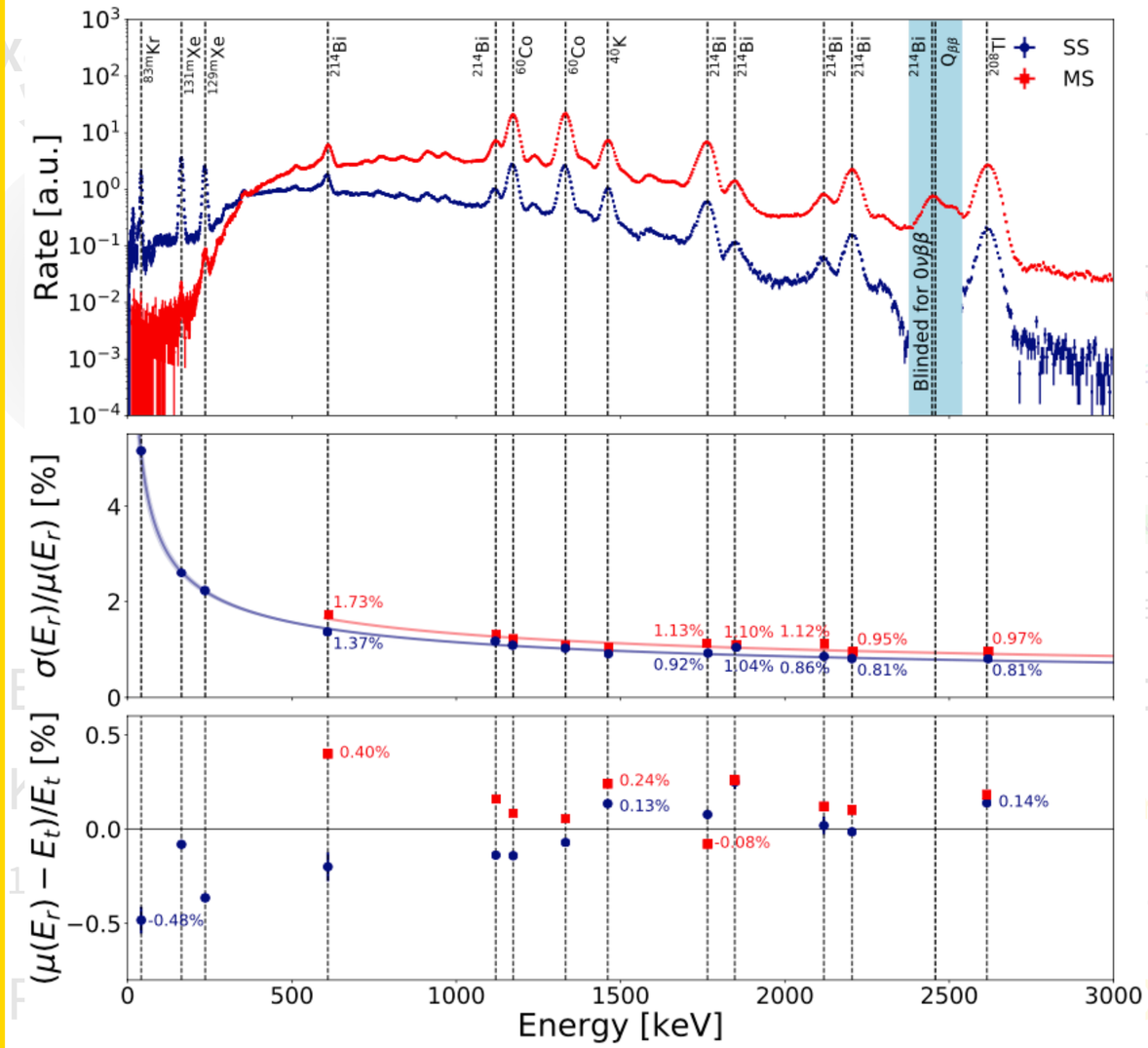




- Extremely rare process, never observed before
- K-shell electron capture → **X-rays and e_{Auger} (64.3 keV)**
- ^{124}Xe ∼ 1 kg/t LXe → **126 2νECEC events** (4.4σ above bkg.)
- Resulting half-life → **$T_{1/2} = (1.8 \pm 0.5_{stat} \pm 0.1_{sys}) \times 10^{22}$ yr**
- Unprecedented sensitivity to **rare decay searches**



2ν Double Electron Capture in ^{124}Xe



Best energy resolution ever achieved by a Dark Matter experiment

(0.80 ± 0.02)% at 2.46 MeV

EPJC 80 (2020) 785

Sets the stage for 0νββ decay search with ^{136}Xe

The Low-Energy ER Excess

An excess of events

PRD 102 (2020) 072004

PHYSICAL REVIEW D **102,** 072004 (2020)

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Excess electronic recoil events in XENON1T

E. Aprile,[1] J. Aalbers,[2] F. Agostini,[3] M. Alfonsi,[4] L. Althueser,[5] F. D. Amaro,[6] V. C. Antochi,[2] E. Angelino,[7] J. R. Angevaare,[8] F. Arneodo,[9] D. Barge,[2] L. Baudis,[10] B. Bauermeister,[2] L. Bellagamba,[3] M. L. Benabderrahmane,[9] T. Berger,[11] A. Brown,[10] E. Brown,[11] S. Bruenner,[8] G. Bruno,[9] R. Budnik,[12,*] C. Capelli,[10] J. M. R. Cardoso,[6] D. Cichon,[13] B. Cimmino,[14] M. Clark,[15] D. Coderre,[16] A. P. Colijn,[8,†] J. Conrad,[2] J. P. Cussonneau,[17] M. P. Decowski,[8] A. Depoian,[15] P. Di Gangi,[3] A. Di Giovanni,[9] R. Di Stefano,[14] S. Diglio,[17] A. Elykov,[16] G. Eurin,[13] A. D. Ferella,[18,19] W. Fulgione,[7,19] P. Gaemers,[8] R. Gaior,[20] M. Galloway,[10,‡] F. Gao,[1] L. Grandi,[21] C. Hasterok,[13] C. Hils,[4] K. Hiraide,[22] L. Hoetzsch,[13] J. Howlett,[1] M. Iacovacci,[14] Y. Itow,[23] F. Joerg,[13] N. Kato,[22] S. Kazama,[23,§] M. Kobayashi,[1] G. Koltman,[12] A. Kopec,[15] H. Landsman,[12] R. F. Lang,[15] L. Levinson,[12] Q. Lin,[1] S. Lindemann,[16] M. Lindner,[13] F. Lombardi,[6] J. Long,[21] J. A. M. Lopes,[6,‖] E. López Fune,[20] C. Macolino,[24] J. Mahlstedt,[2] A. Mancuso,[3] L. Manenti,[9] A. Manfredini,[10] F. Marignetti,[14] T. Marrodán Undagoitia,[13] K. Martens,[22] J. Masbou,[17] D. Masson,[16] S. Mastroianni,[14] M. Messina,[19] K. Miuchi,[25] K. Mizukoshi,[25] A. Molinario,[19] K. Morå,[1,2] S. Moriyama,[22] Y. Mosbacher,[12] M. Murra,[5] J. Naganoma,[19] K. Ni,[26] U. Oberlack,[4] K. Odgers,[11] J. Palacio,[13,17] B. Pelssers,[2] R. Peres,[10] J. Pienaar,[21] V. Pizzella,[13] G. Plante,[1] J. Qin,[15] H. Qiu,[12] D. Ramírez García,[16] S. Reichard,[10] A. Rocchetti,[16] N. Rupp,[13] J. M. F. dos Santos,[6] G. Sartorelli,[3] N. Šarčević,[16] M. Scheibelhut,[4] J. Schreiner,[13] D. Schulte,[5] M. Schumann,[16] L. Scotto Lavina,[20] M. Selvi,[3] F. Semeria,[3] P. Shagin,[27] E. Shockley,[21,¶] M. Silva,[6] H. Simgen,[13] A. Takeda,[22] C. Therreau,[17] D. Thers,[17] F. Toschi,[16] G. Trinchero,[7] C. Tunnell,[27] M. Vargas,[5] G. Volta,[10] H. Wang,[28] Y. Wei,[26] C. Weinheimer,[5] M. Weiss,[12] D. Wenz,[4] C. Wittweg,[5] Z. Xu,[1] M. Yamashita,[23,22] J. Ye,[26,**] G. Zavattini,[3,††] Y. Zhang,[1] T. Zhu,[1] and J. P. Zopounidis,[20]

(XENON Collaboration)[‡‡]

X. Mougeot[29]

An excess of events

PRD 102 (2020) 072004

PHYSICAL REVIEW D **102,** 072004 (2020)

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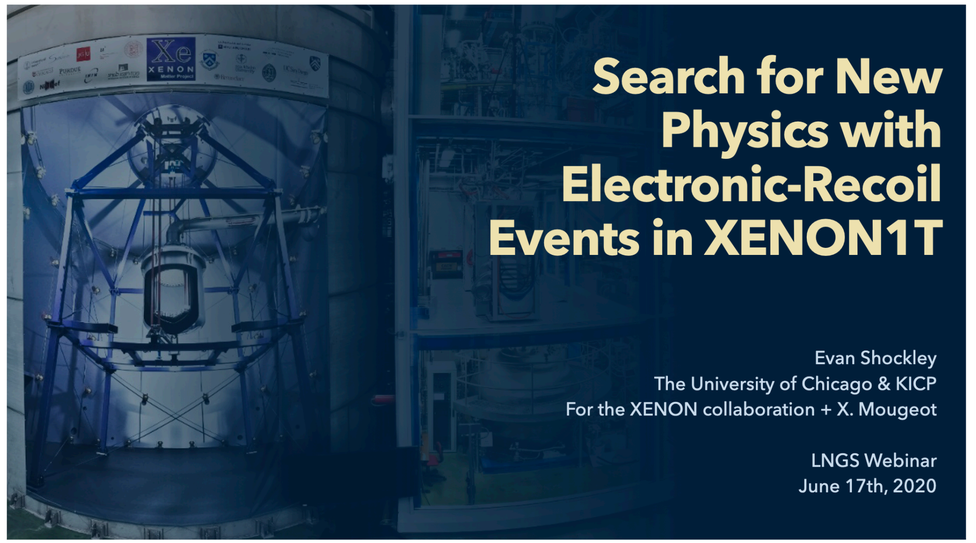
(XENON Collaboration)[‡‡]

X. Mougeot[29]



Released on
17 June

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PRD 102 (2020) 072004

PHYSICAL REVIEW D **102,** 072004 (2020)

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E. Aprile,[1] J. Aalbers,[2] F. Agostini,[3] M. Alfonsi,[4] L. Althueser,[5] F. D. Amaro,[6] V. C. Antochi,
J. R. Angevaare,[8] F. Arneodo,[9] D. Barge,[2] L. Baudis,[10] B. Bauermeister,[2] L. Bellagamba,[3] M. L.
T. Berger,[11] A. Brown,[10] E. Brown,[11] S. Bruenner,[8] G. Bruno,[9] R. Budnik,[12,*] C. Capelli,[10] J. M. R. Ca
B. Cimmino,[14] M. Clark,[15] D. Coderre,[16] A. P. Colijn,[8,†] J. Conrad,[2] J. P. Cussonneau,[17] M. P. Deco
P. Di Gangi,[3] A. Di Giovanni,[9] R. Di Stefano,[14] S. Diglio,[17] A. Elykov,[16] G. Eurin,[13] A. D. Ferella,
P. Gaemers,[8] R. Gaior,[20] M. Galloway,[10,‡] F. Gao,[1] L. Grandi,[21] C. Hasterok,[13] C. Hils,[4] K. Hira
J. Howlett,[1] M. Iacovacci,[14] Y. Itow,[23] F. Joerg,[13] N. Kato,[22] S. Kazama,[23,§] M. Kobayashi,[1] G. Ko
H. Landsman,[12] R. F. Lang,[15] L. Levinson,[12] Q. Lin,[1] S. Lindemann,[16] M. Lindner,[13] F. Lomb
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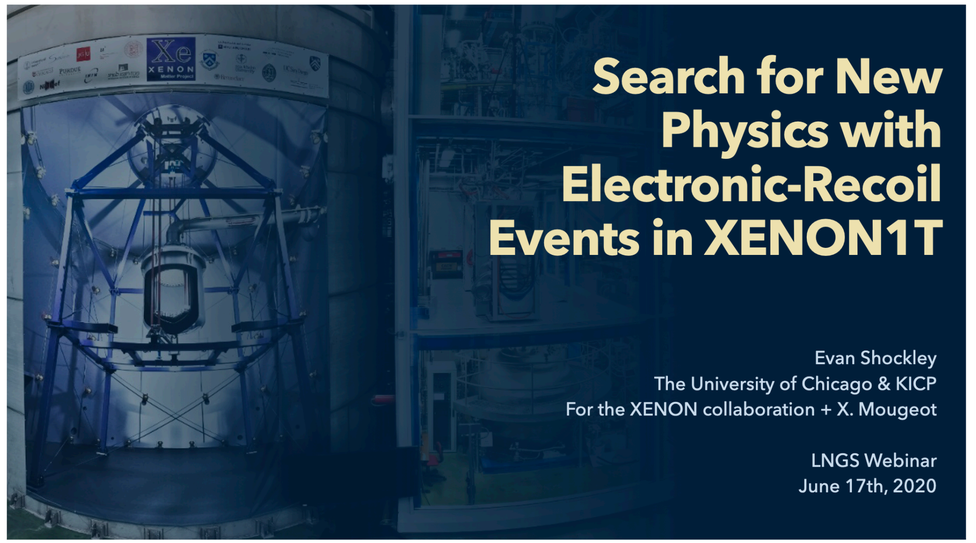
M. Yamashita,[23,22] J. Ye,[26,**] G. Zavattini,[3,††] Y. Zhang,[1] T. Zhu,[1] and J. P. Zopounidis,[20]

(XENON Collaboration)[‡‡]

X. Mougeot[29]



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Dark matter hunt yields unexplained signal

By Paul Rincon
Science editor, BBC News website

Le Monde

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Favoris

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L'expérience Xenon1T, installée dans le laboratoire souterrain de Gran Sasso pour traquer la matière noire a enregistré un signal inattendu. S'agit-il d'une particule encore jamais observée ou d'une contamination du dispositif ?

Par Nathaniel Herzberg • Publié le 19 juin 2020 à 14h23 - Mis à jour le 22 juin 2020 à 15h59

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Dark Matter Experiment Finds Unexplained Signal

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Researchers say there are three possible explanations for the anomalous data. One is mundane. Two would revolutionize physics.

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Laboratorio del Gran Sasso, registrati segnali anomali nella caccia alla materia oscura: sono gli assioni?

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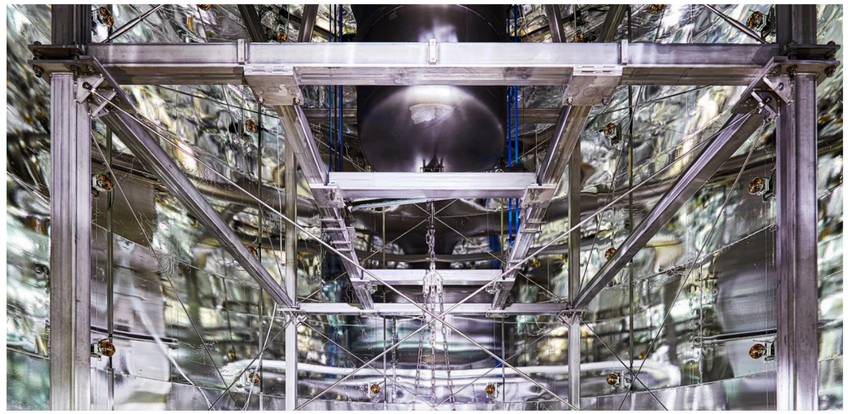

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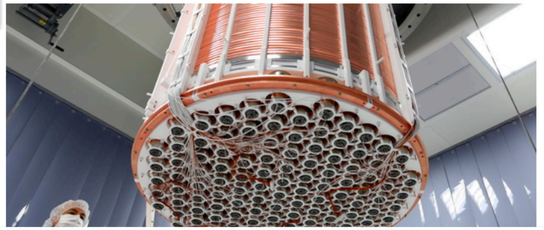
Giovedì 18 Giugno 2020 di Enzo Vitale



Ancora una volta la parola che più si accosta al termine Fisica è Italia. E seppur con la dovuta cautela gli scienziati vanno a passo di piombo, gli aventi accaduti nei **Laboratori del Gran Sasso** prefigurano scena

The observation

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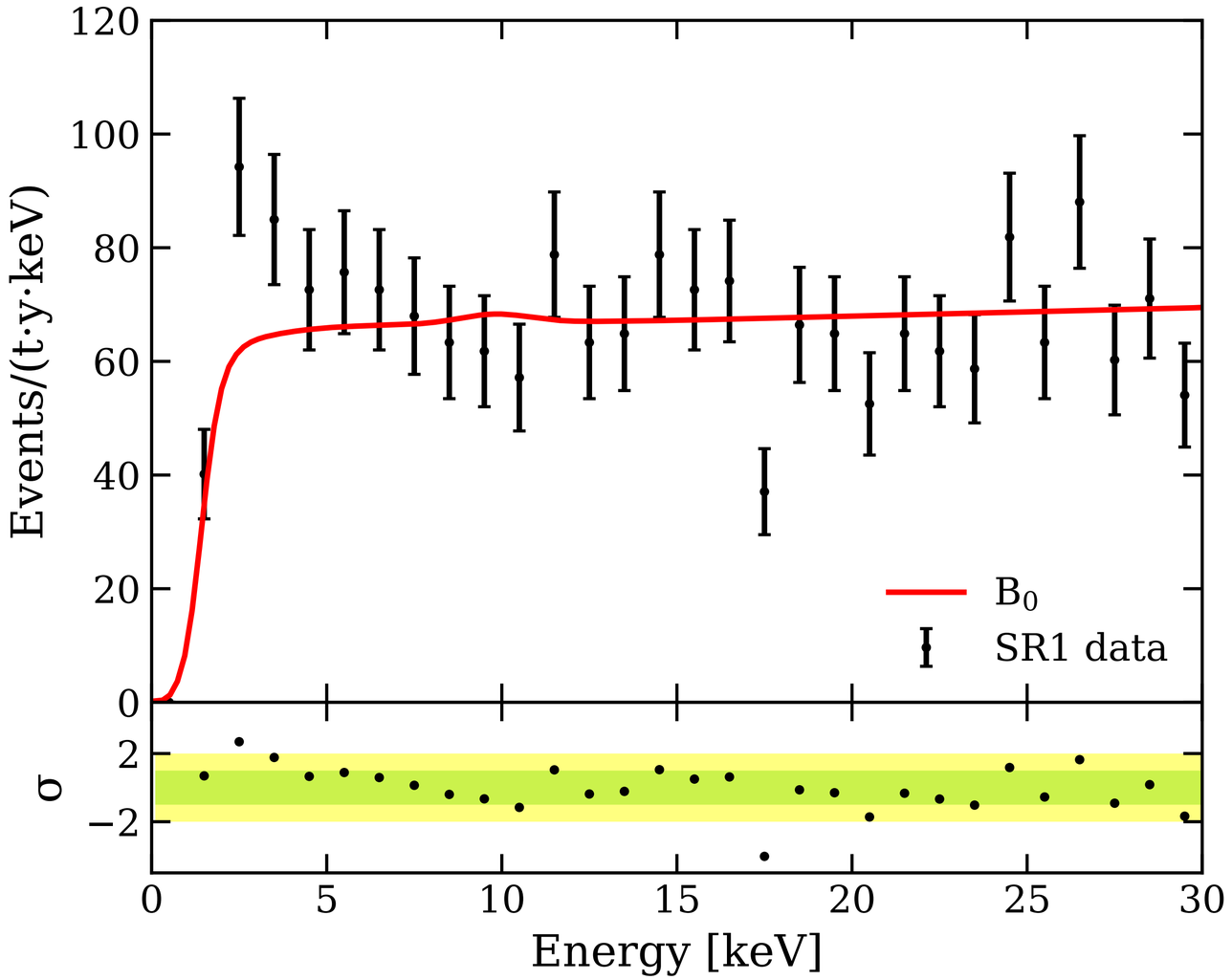

The observation

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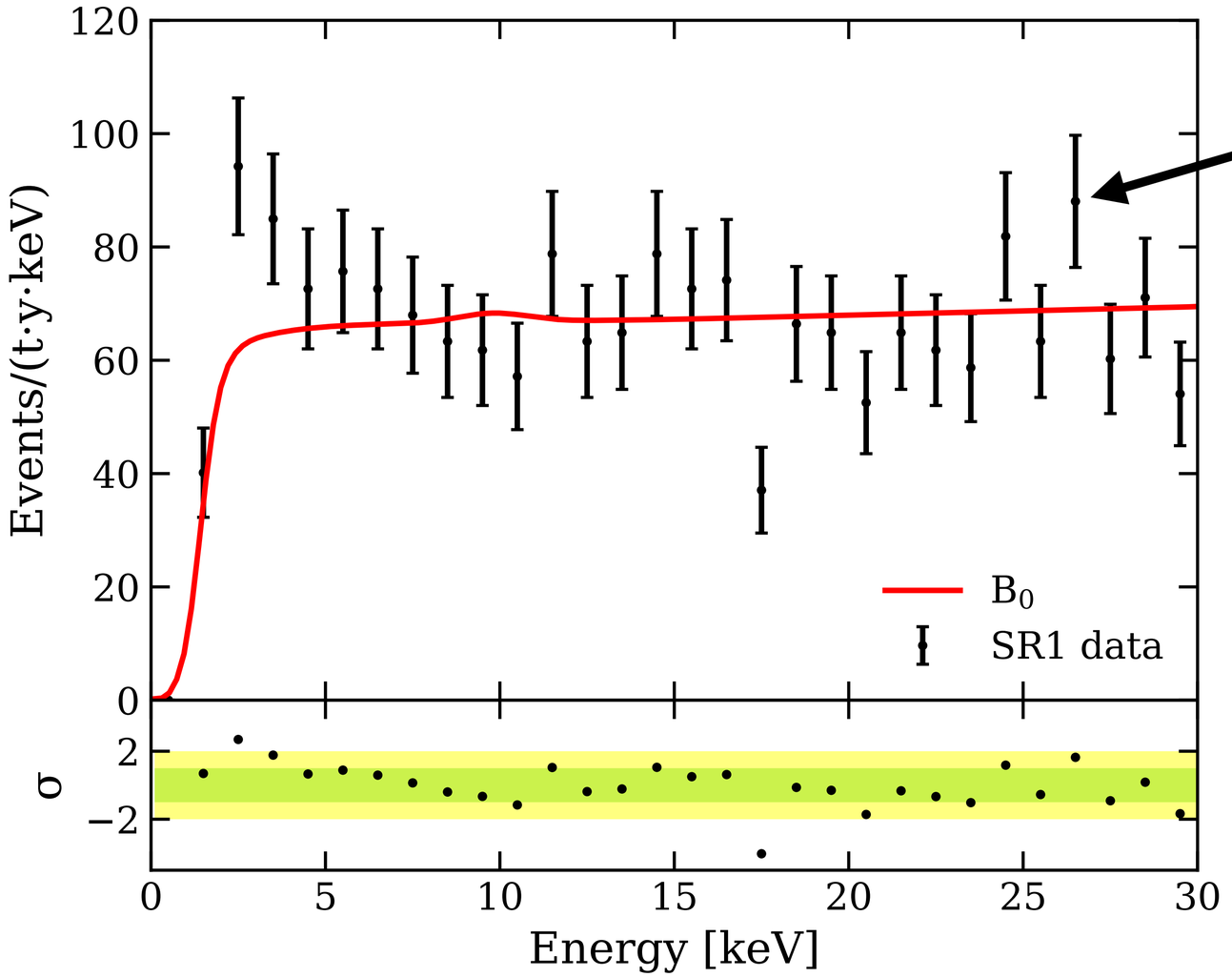

- Carefully selected **electronic recoil data** from XENON1T Science Run 1

The observation

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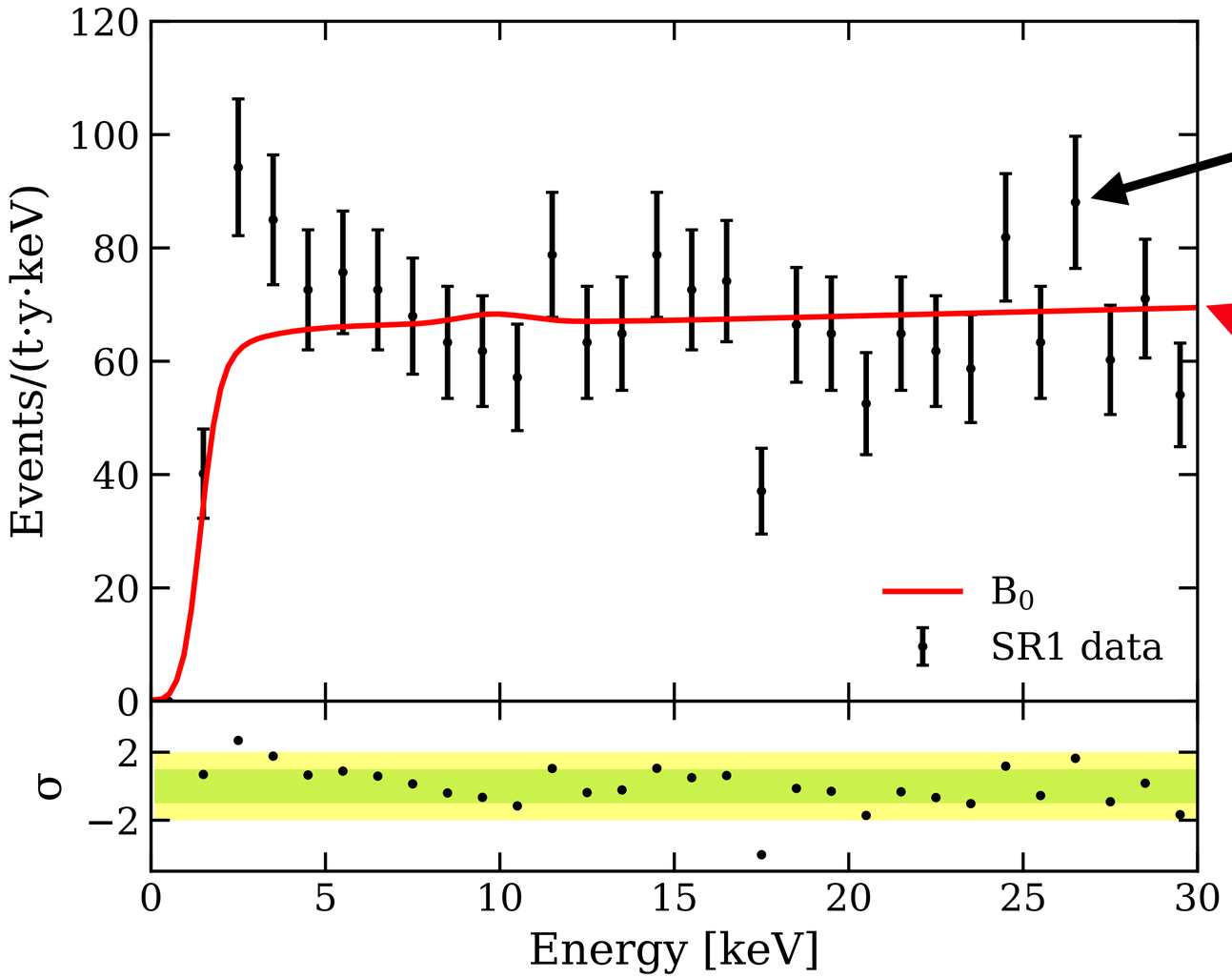

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- Comprehensive **background model**

The observation

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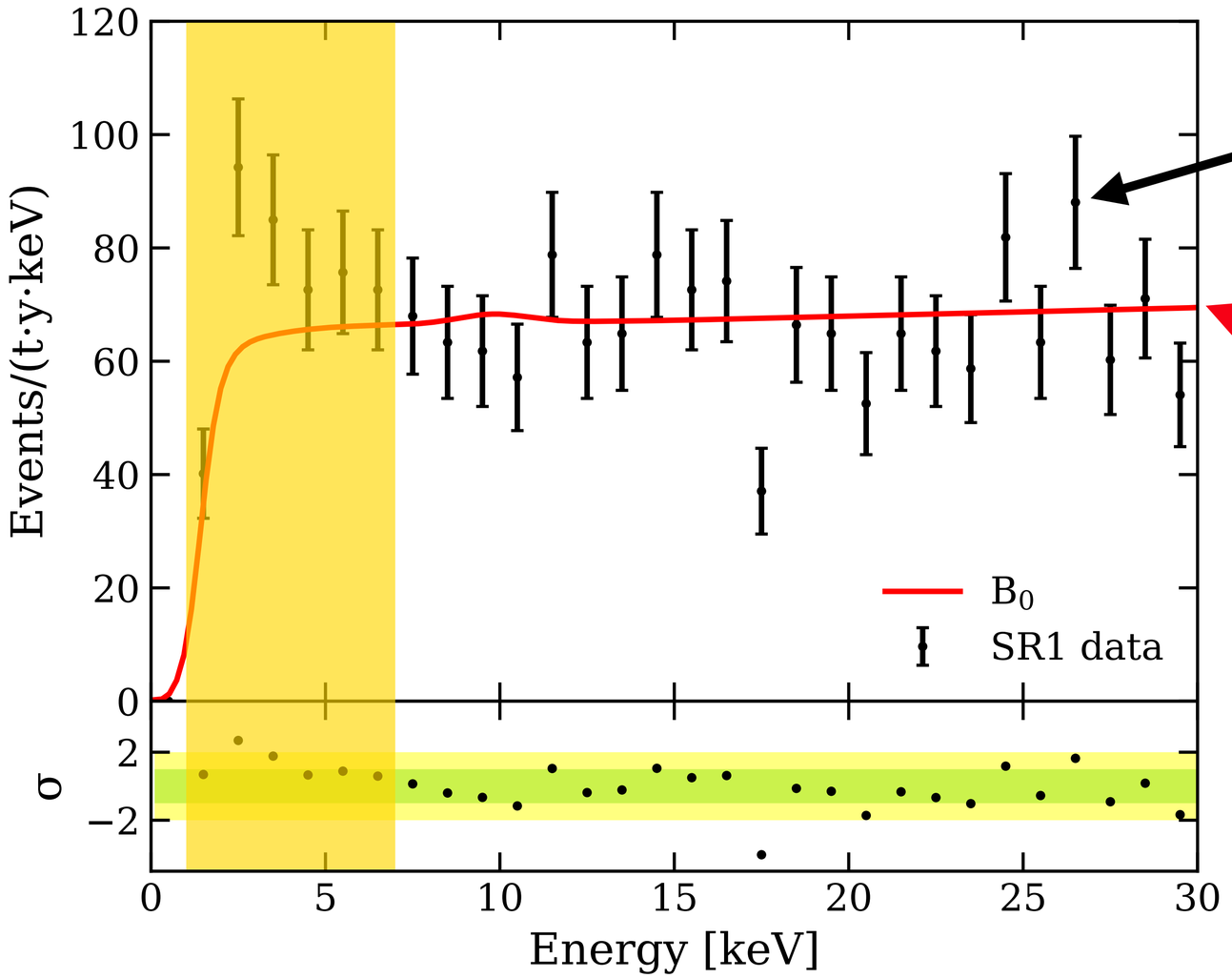

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Observed 285 events

Expected (232 ± 15) events in 1–7 keV

→ ∼ 3.3σ Poissonian fluctuation!

The observation

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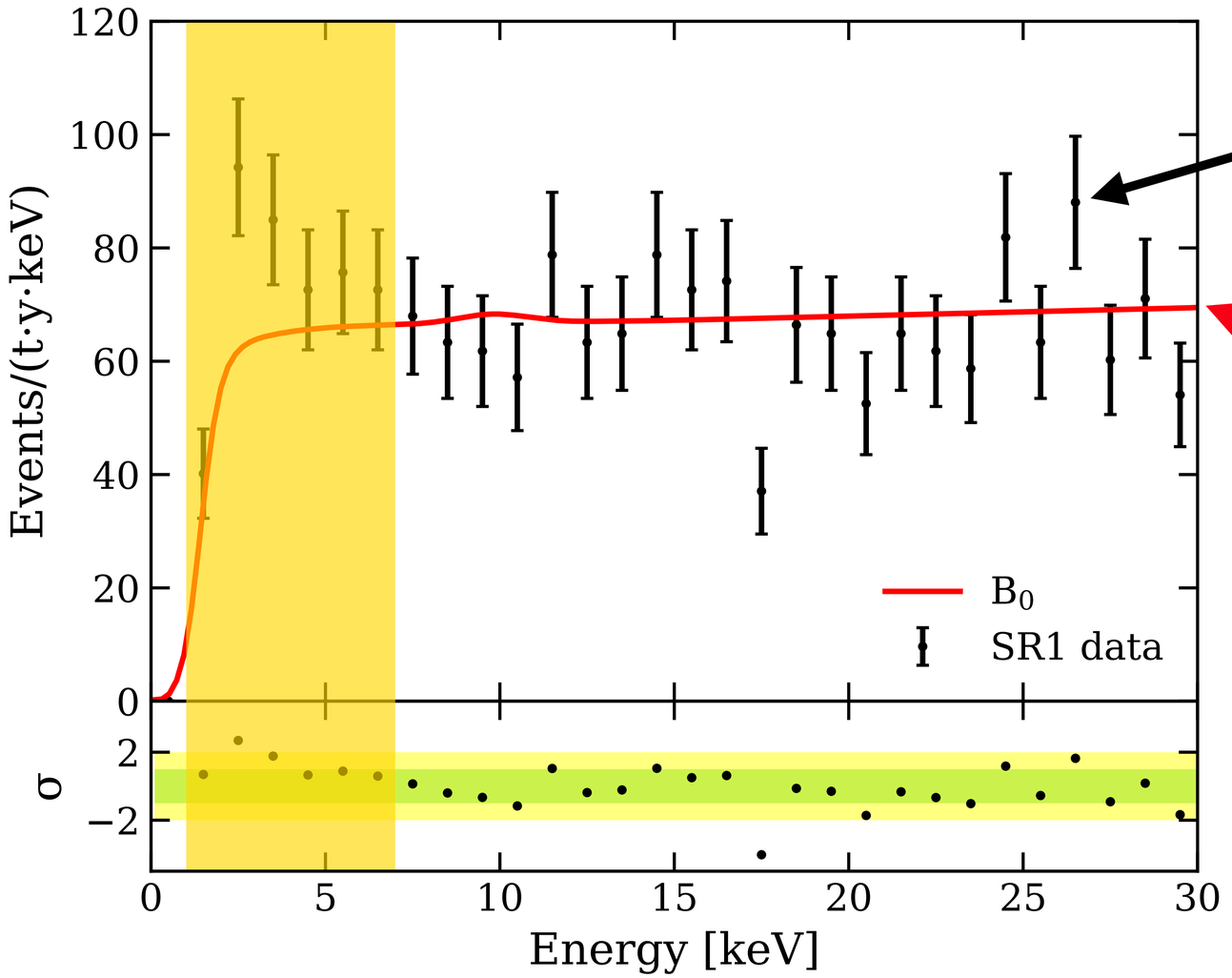

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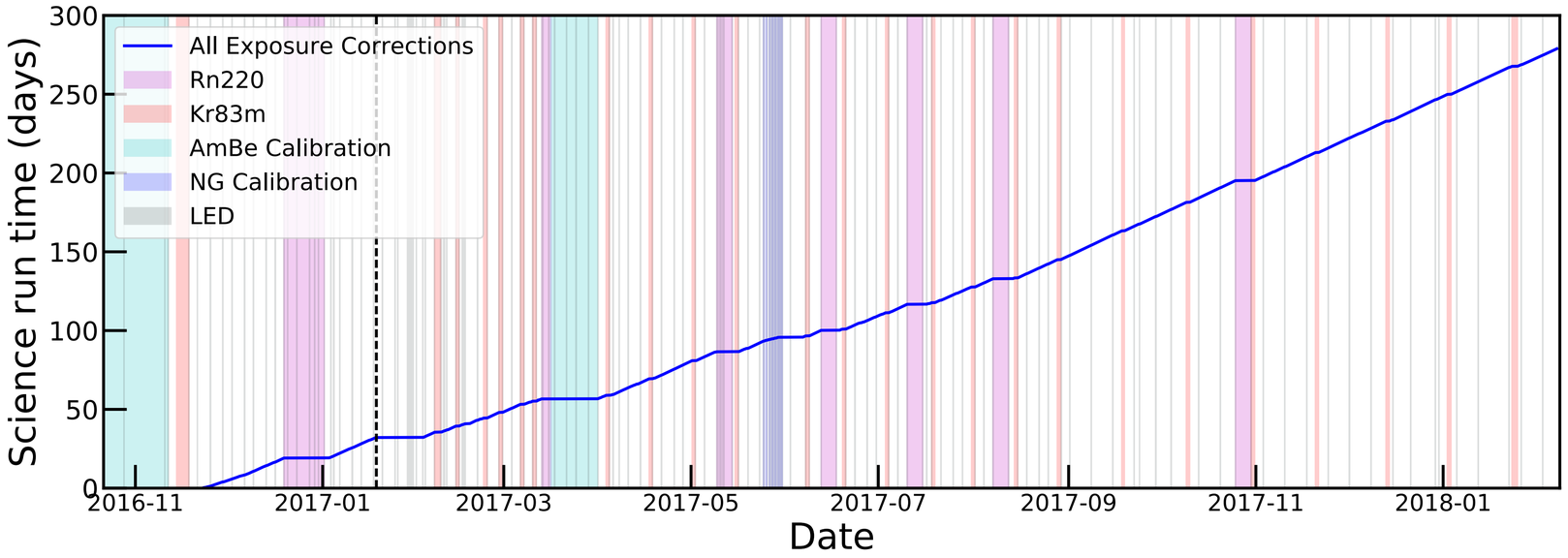
- Comprehensive **background model**

Observed 285 events
Expected (232 ± 15) events in 1–7 keV
→ ∼ 3.3σ Poissonian fluctuation!

- What is going on here?

Data selection

PRD 100 (2019) 052014
PRD 102 (2020) 072004



- Science Run 1 (SR1, Feb. 2017– Feb. 2018) data → **226.9 d effective live time**
  (+ 24.4 d cross-check data from post-SR1 SR2 with 20% less ER background)

Data selection

PRD 100 (2019) 052014
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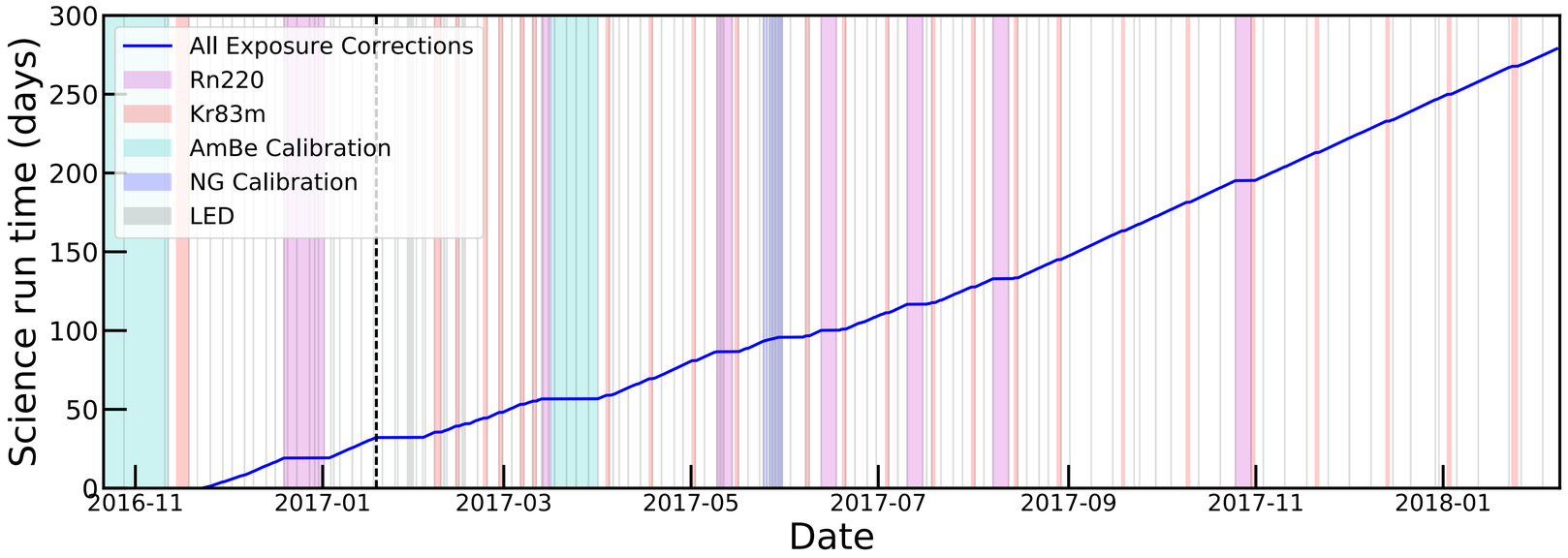

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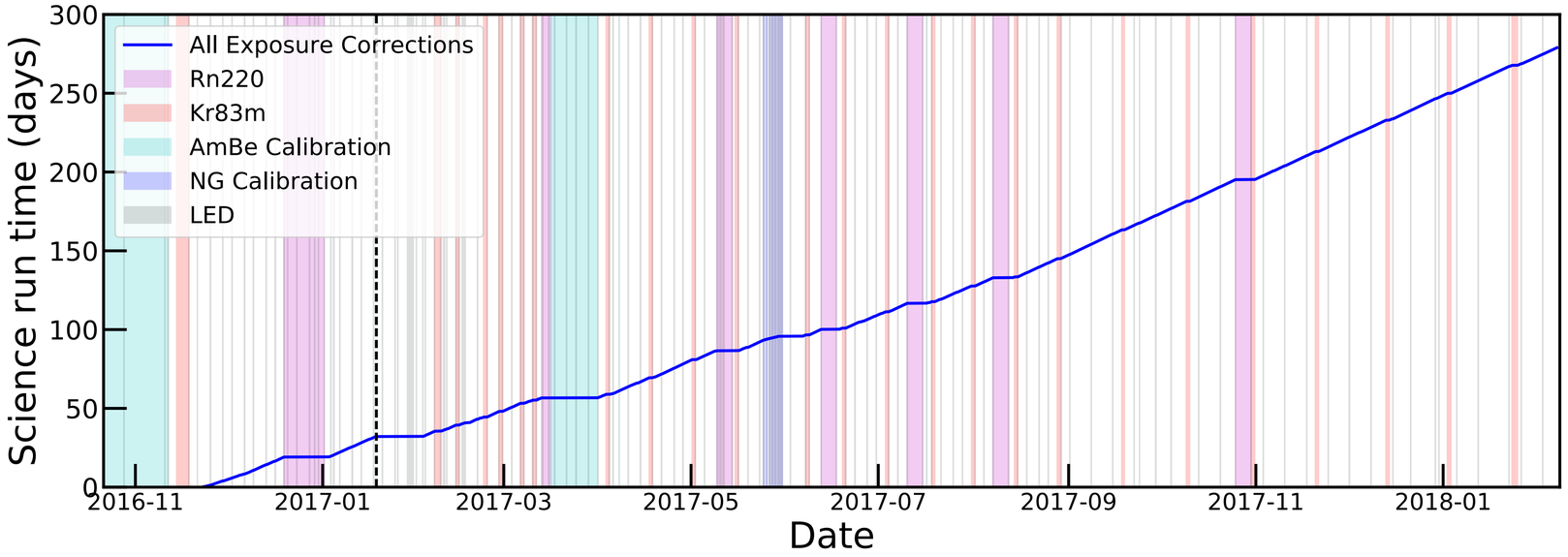
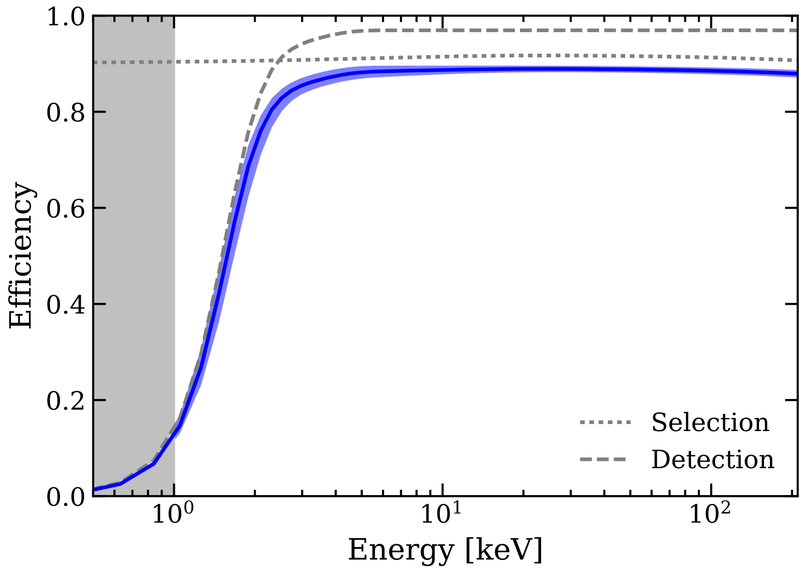
0.65 t × yr total exposure

Data selection

PRD 100 (2019) 052014
PRD 102 (2020) 072004





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  (+ 24.4 d cross-check data from post-SR1 SR2 with 20% less ER background)
- Surface and material background mitigation → **1 042 kg LXe fiducial volume**
- Selection of high S2 threshold, single scatter events (+ other requirements) **in 1–210 keV**

0.65 t × yr total exposure

Background model B_0

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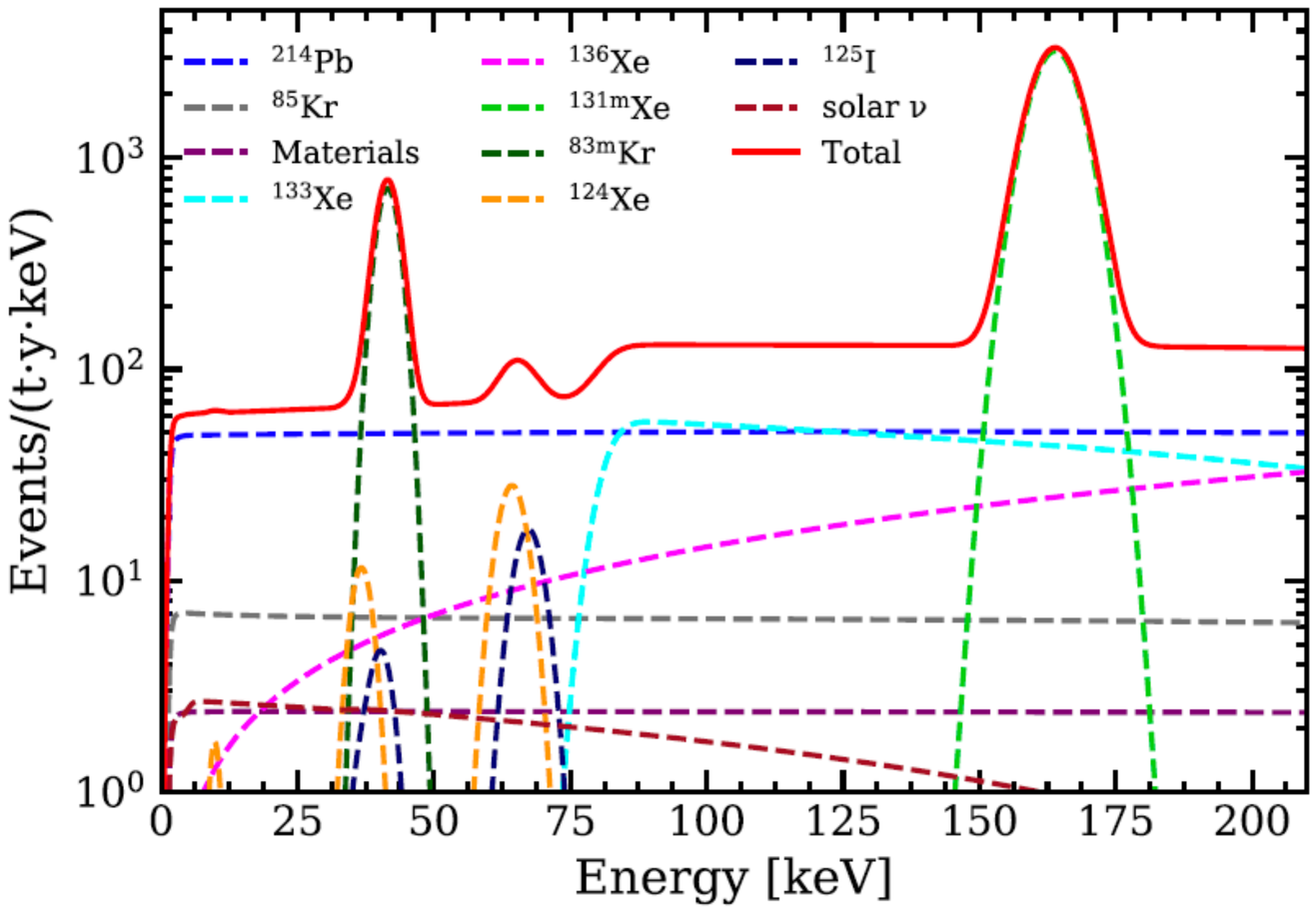

- **10-component** background model (dominated by ^{214}Pb β decay from ^{222}Rn emanation)

Background model B_0

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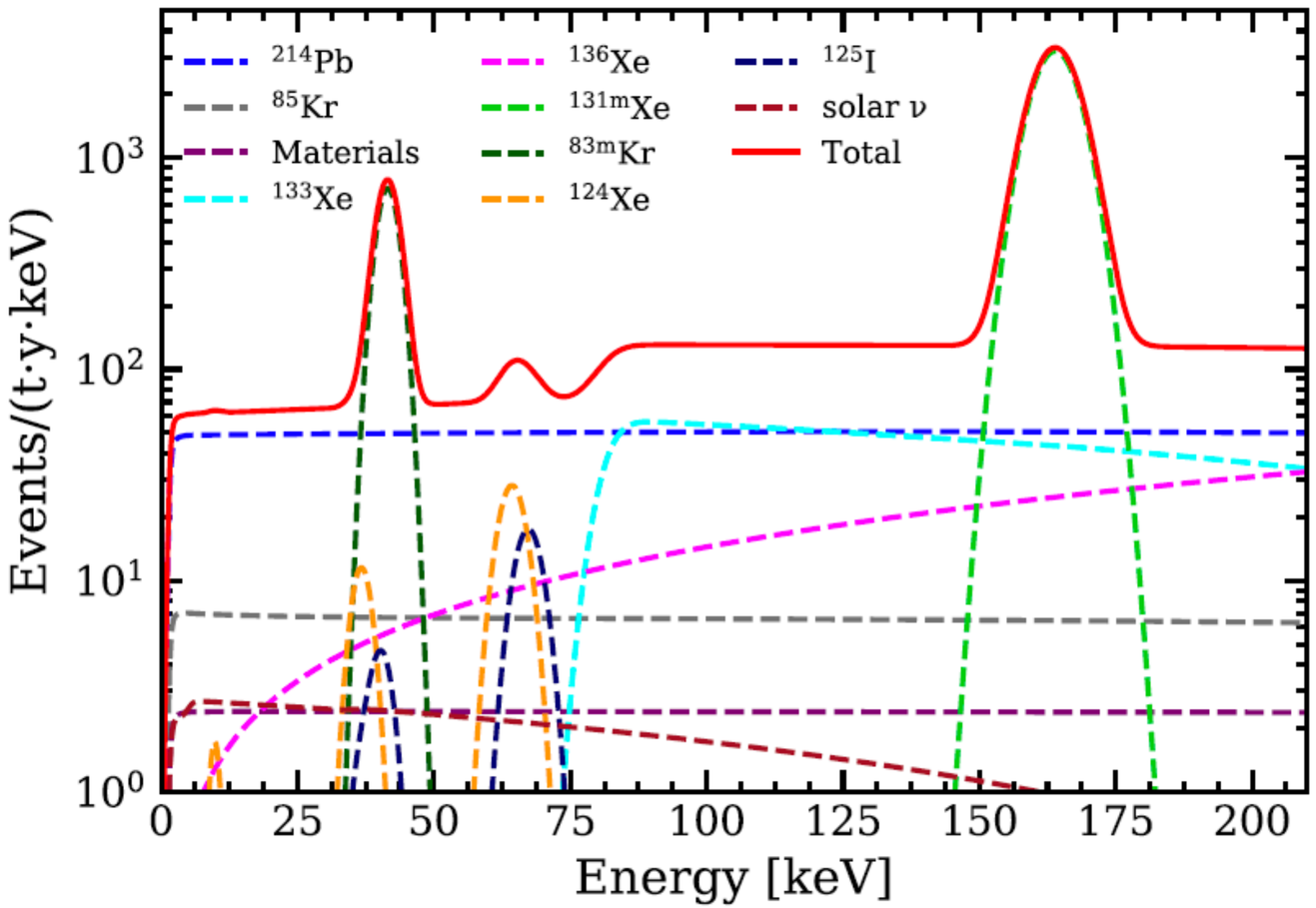

Intrinsic sources

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

continuous spectra

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Background model B_0

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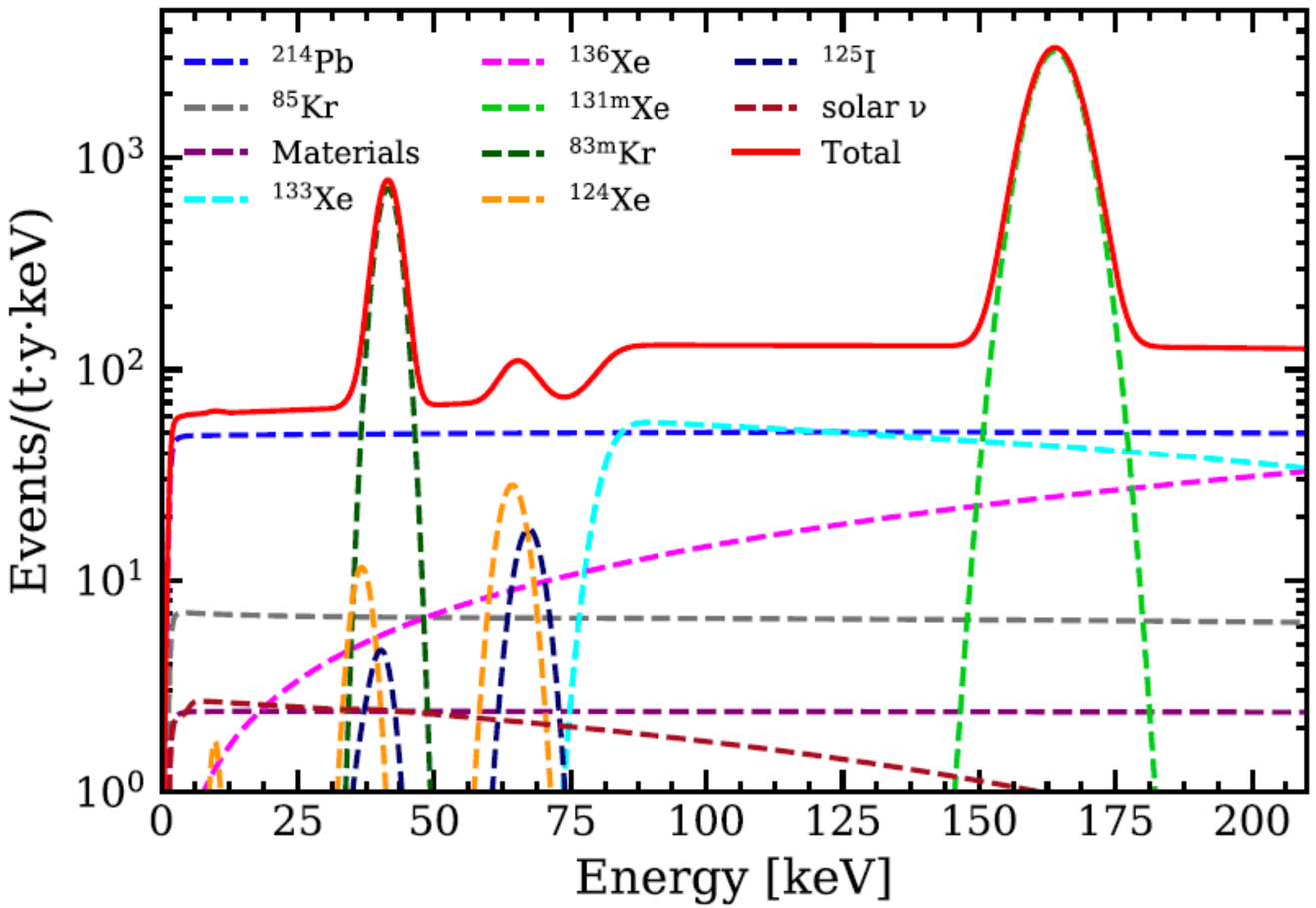

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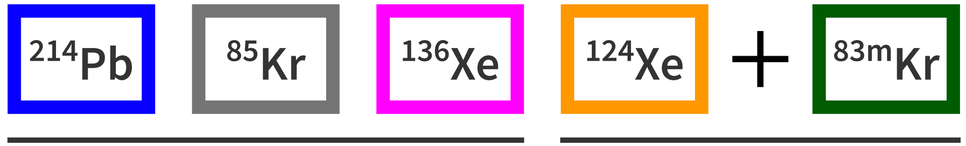

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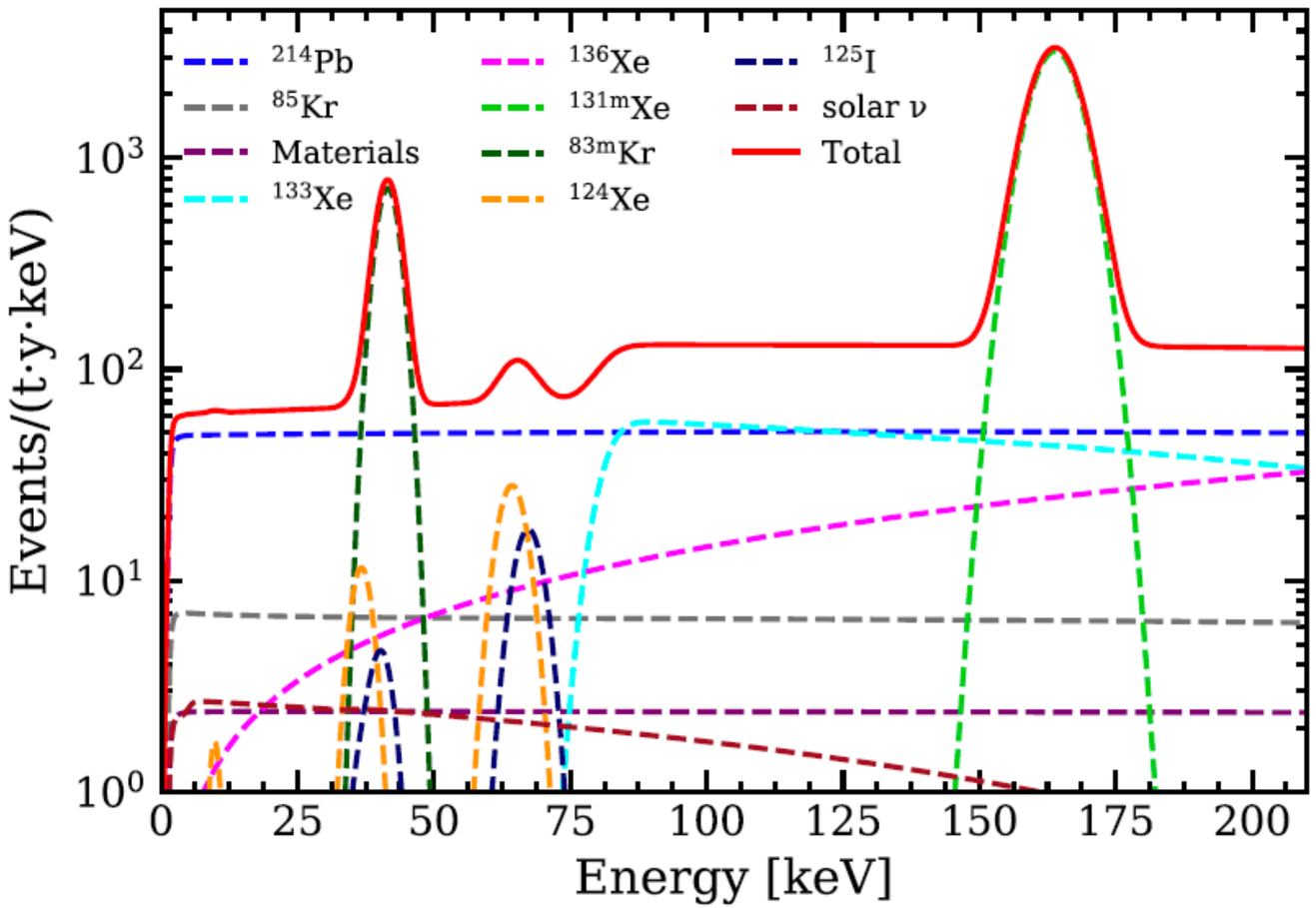

Intrinsic sources

^{214}Pb ^{85}Kr ^{136}Xe ^{124}Xe + ^{83m}Kr

continuous spectra *peaks*

Neutron-activated

^{133}Xe

continuous spectrum

- **10-component** background model (dominated by ^{214}Pb β decay from ^{222}Rn emanation)

Background model B_0

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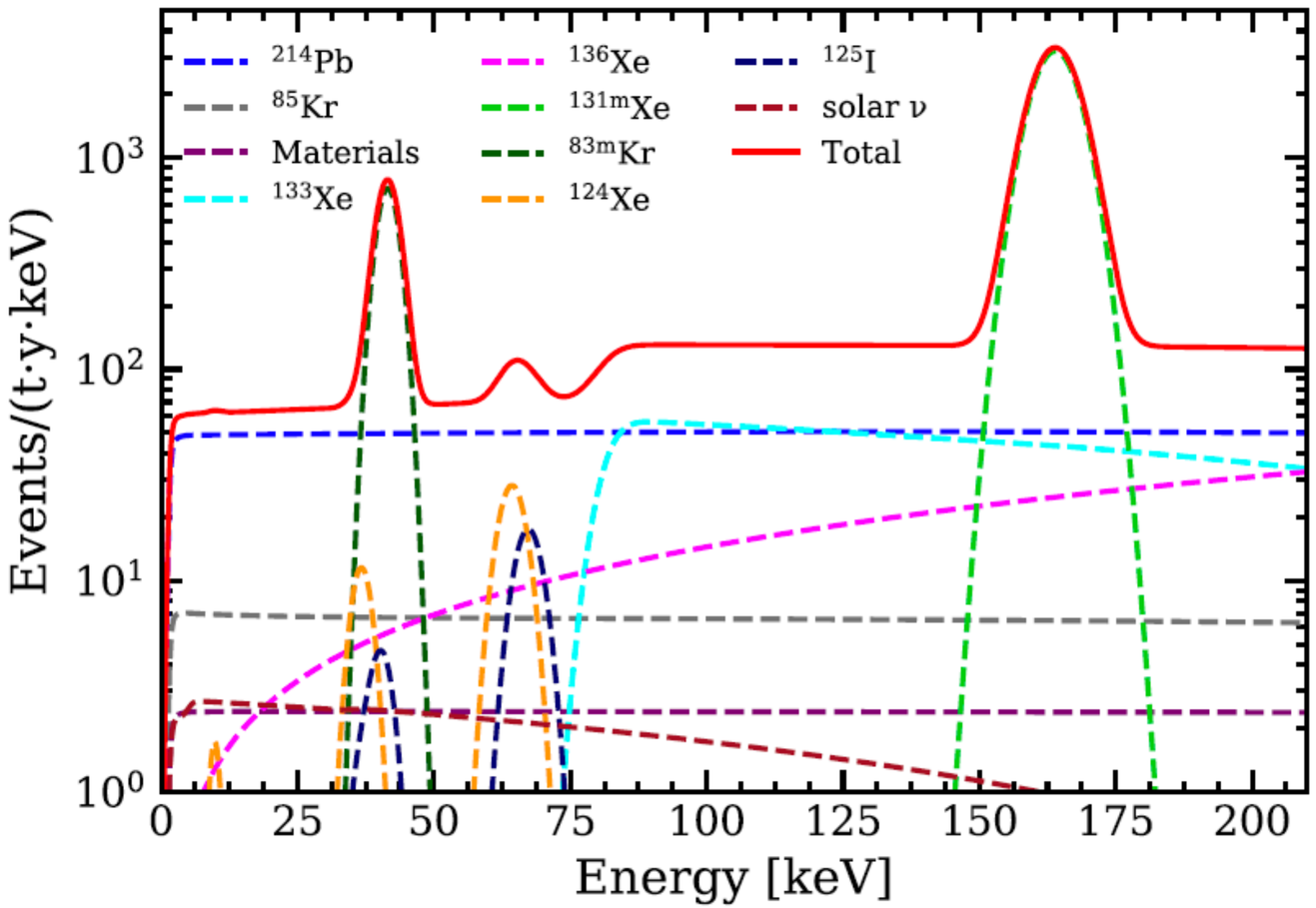

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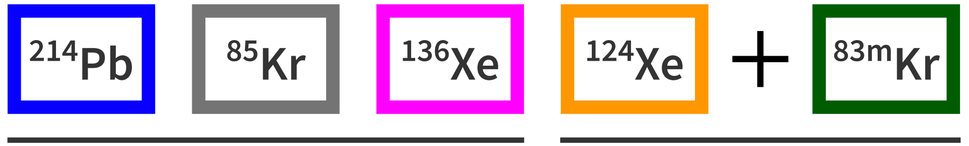

continuous spectra *peaks*

Neutron-activated

continuous spectrum *peaks*

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Background model B_0

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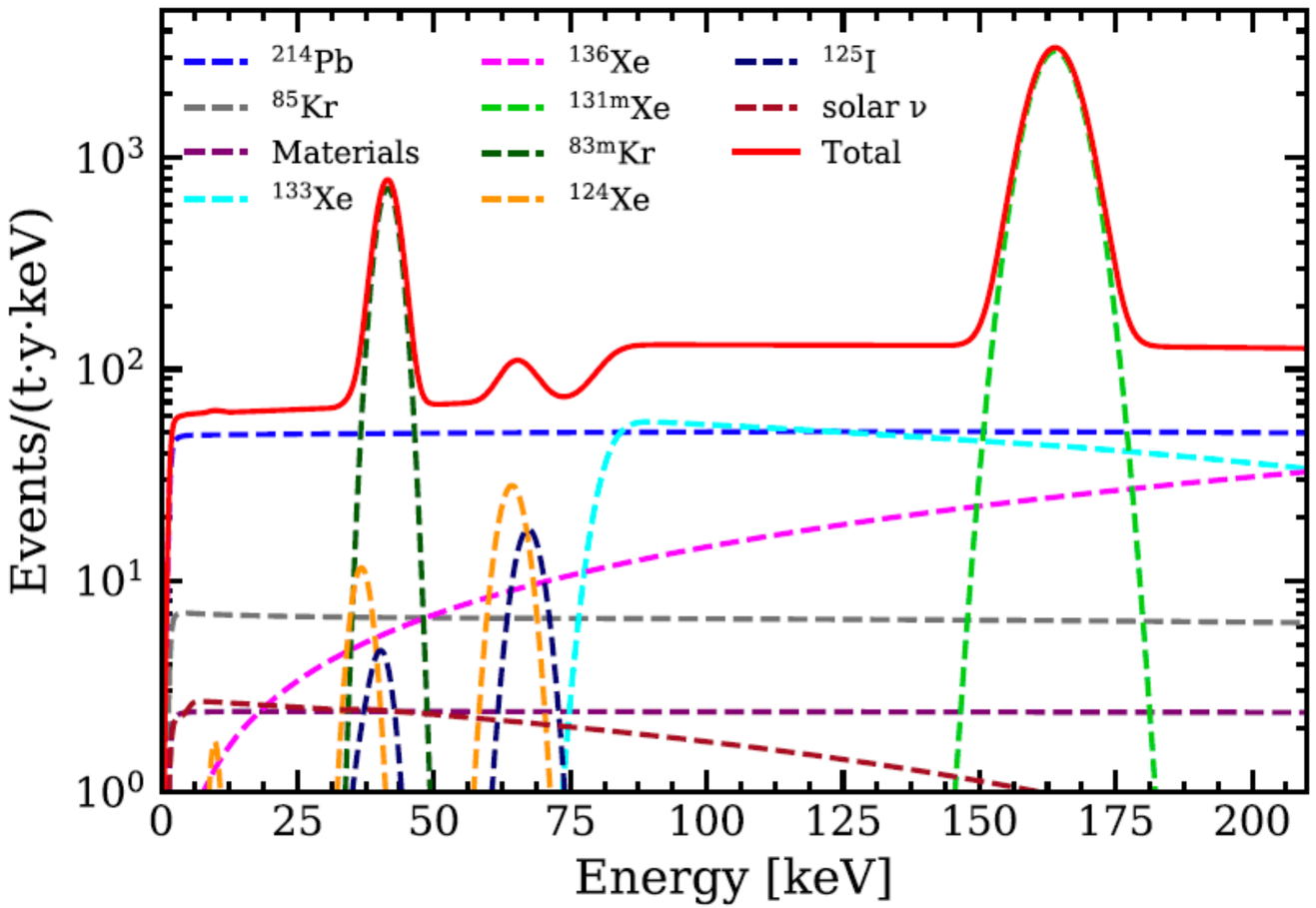

Intrinsic sources

^{214}Pb ^{85}Kr ^{136}Xe ^{124}Xe + ^{83m}Kr

continuous spectra *peaks*

Neutron-activated

^{133}Xe ^{131m}Xe ^{125}I

continuous spectrum *peaks*

Detector materials γ

Solar neutrinos

both continuous spectra

- **10-component** background model (dominated by ^{214}Pb β decay from ^{222}Rn emanation)
- Theoretical and GEANT4 spectra, **convolved with detector effects** (resolution, efficiency)

Data-model matching

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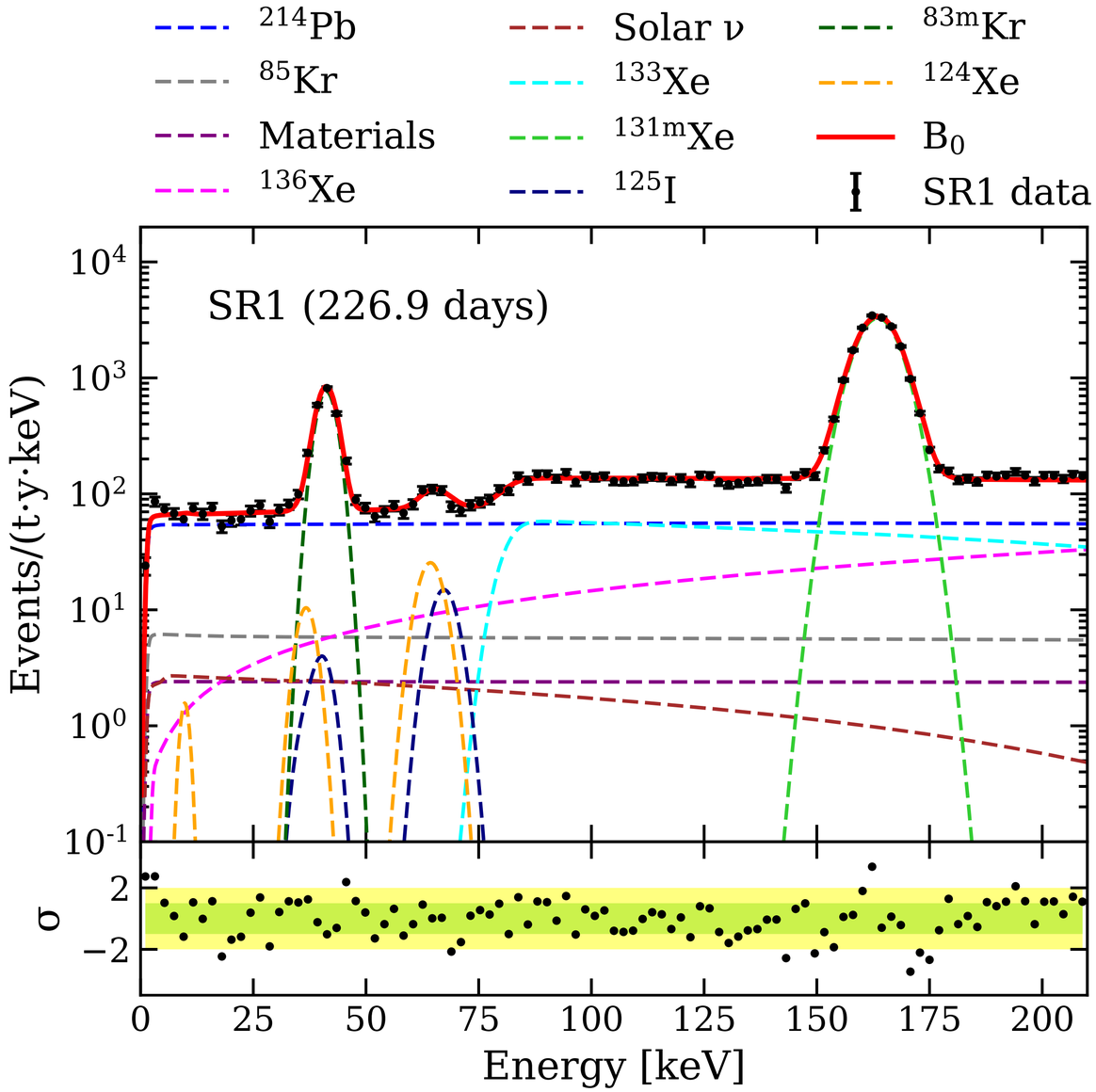

- Fitting with an **unbinned profile likelihood** (data binned for display)

Data-model matching

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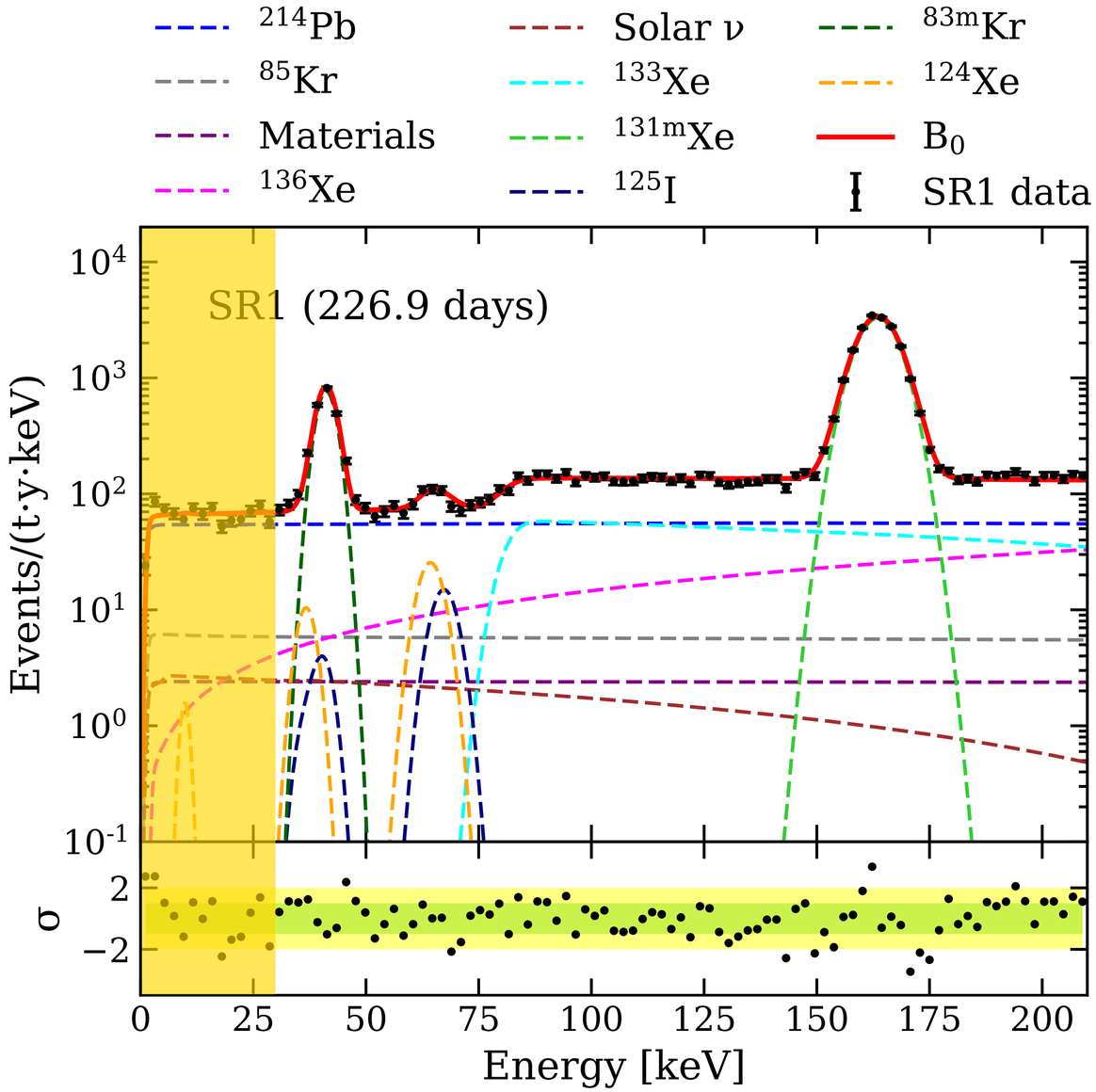

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- Very good fit over the studied energy range (1–210 keV), **but look closer…**

Data-model matching

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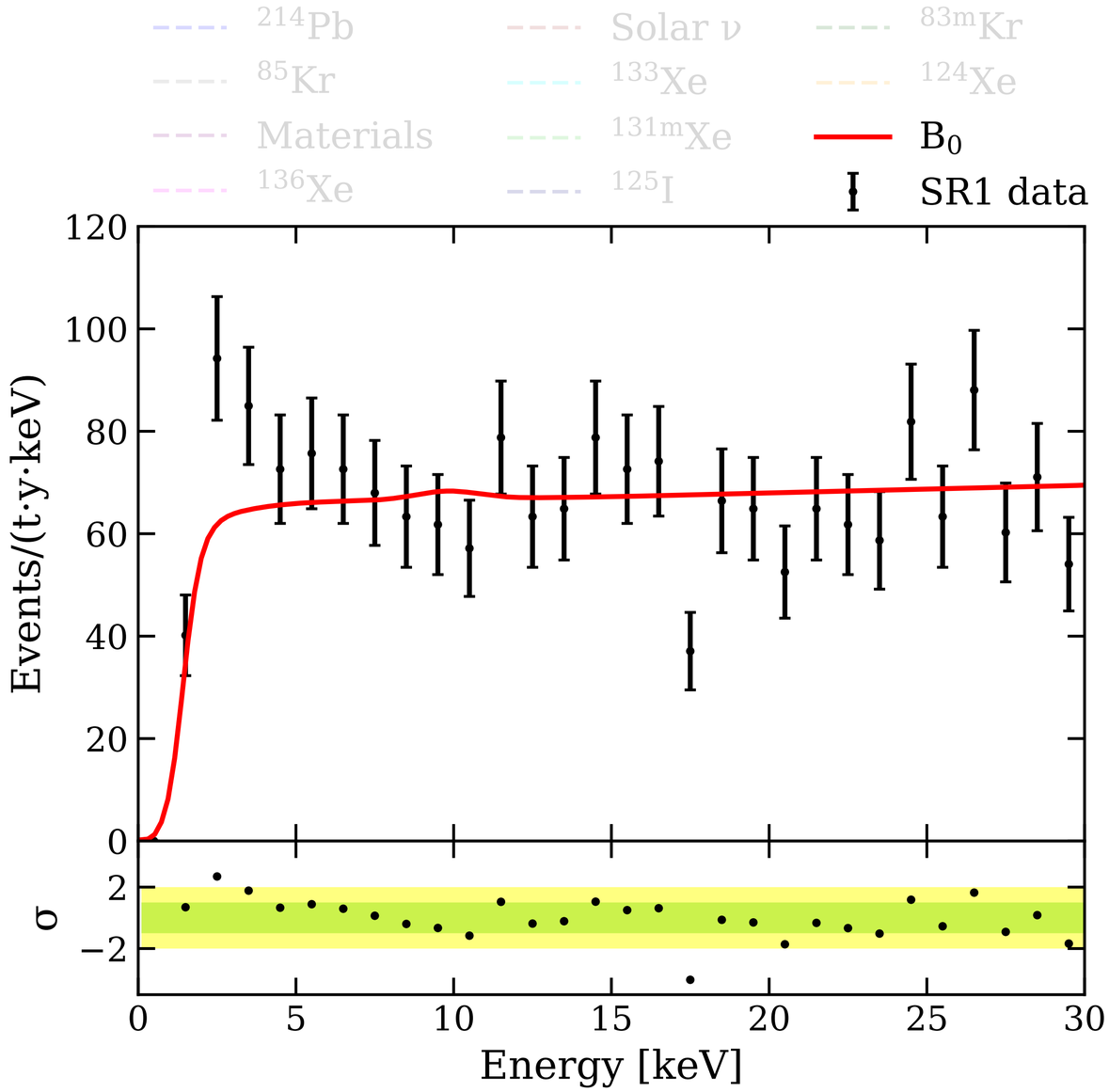

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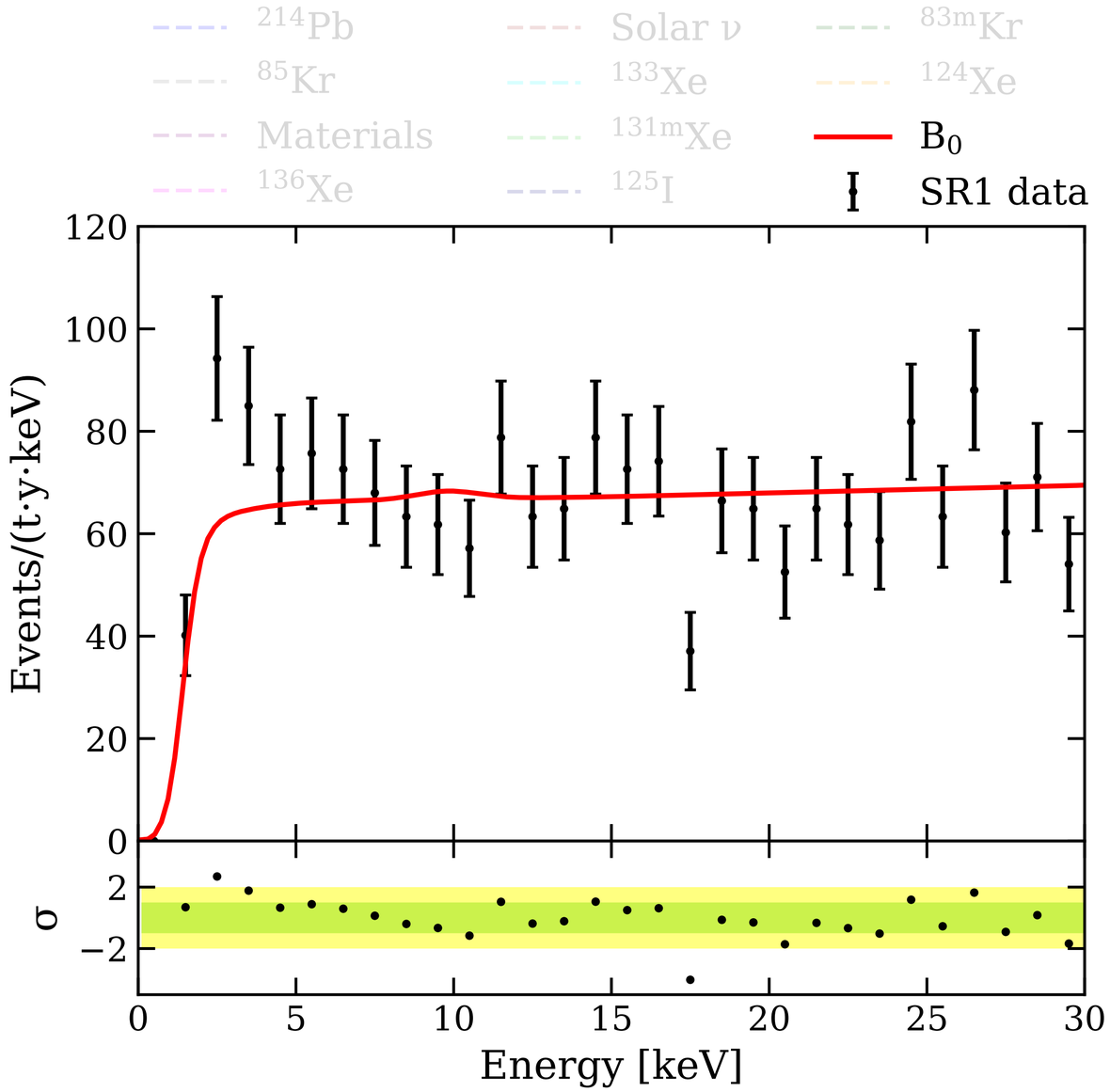

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Lowest background rate ever achieved in 1–30 keV!

(76 ± 2) events/(t × yr × keV)

Data-model matching

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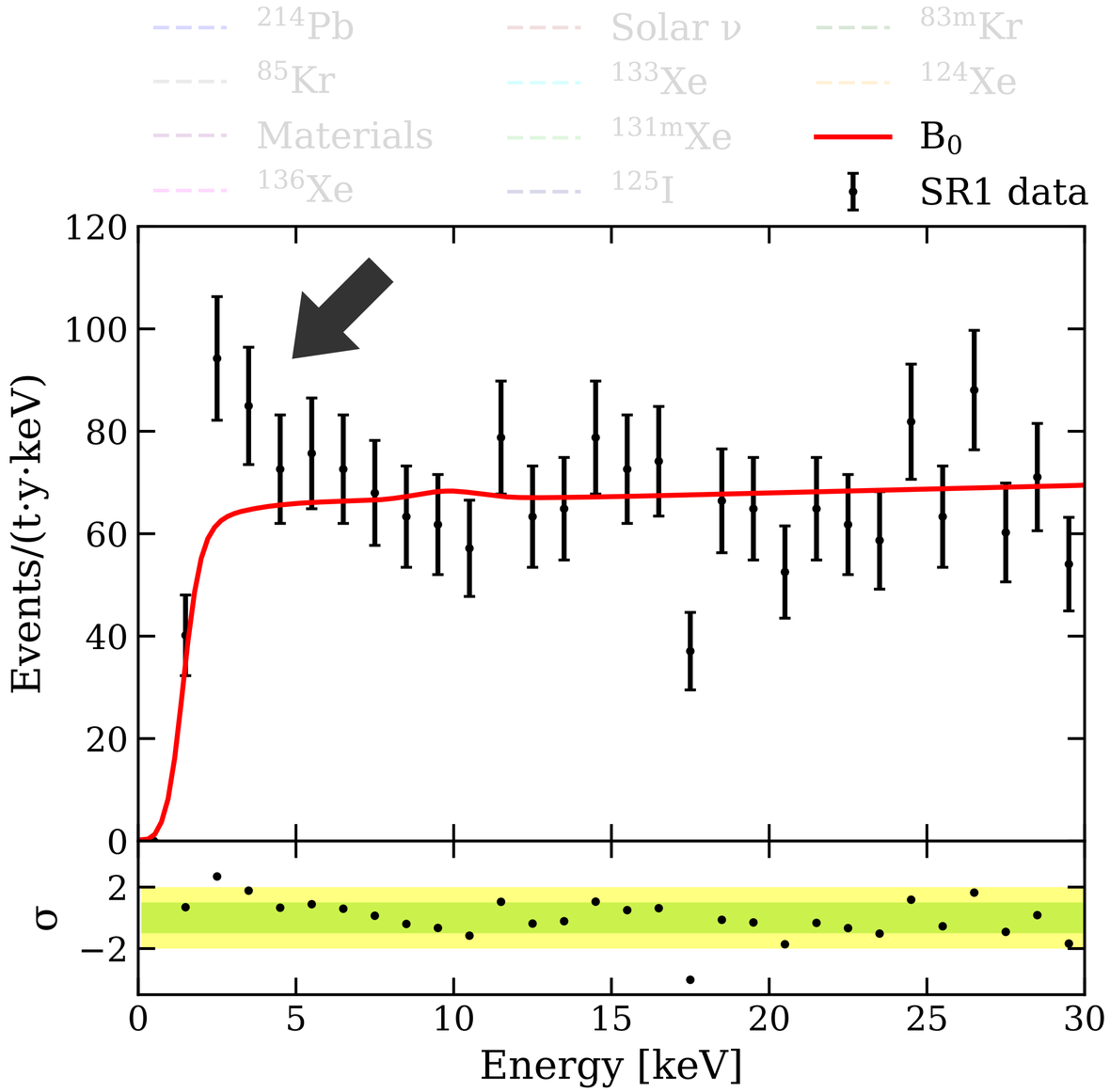

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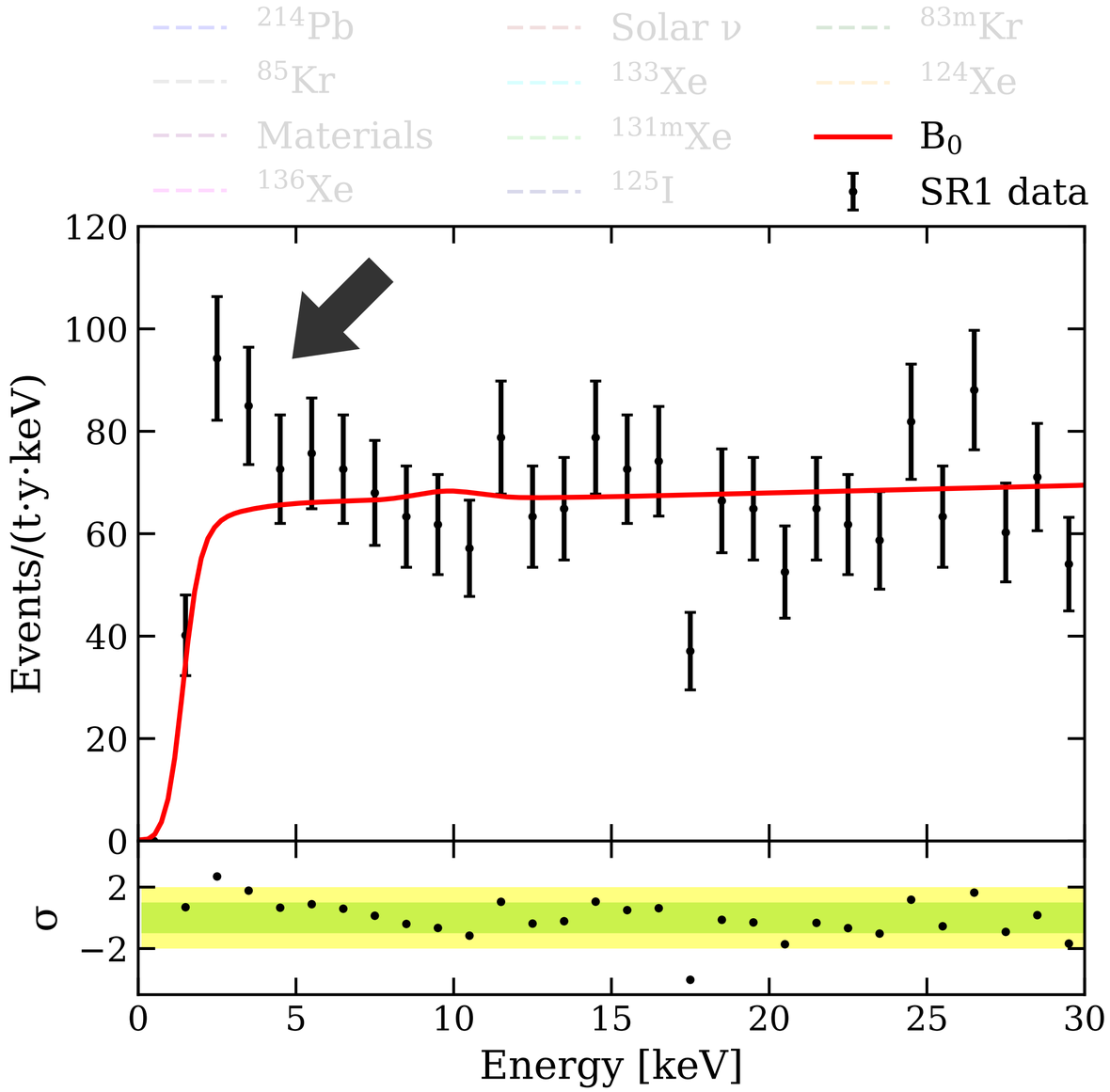
Statistical fluke?

Data-model matching

PRD 102 (2020) 072004



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Statistical fluke?

Systematic effects?

Data-model matching

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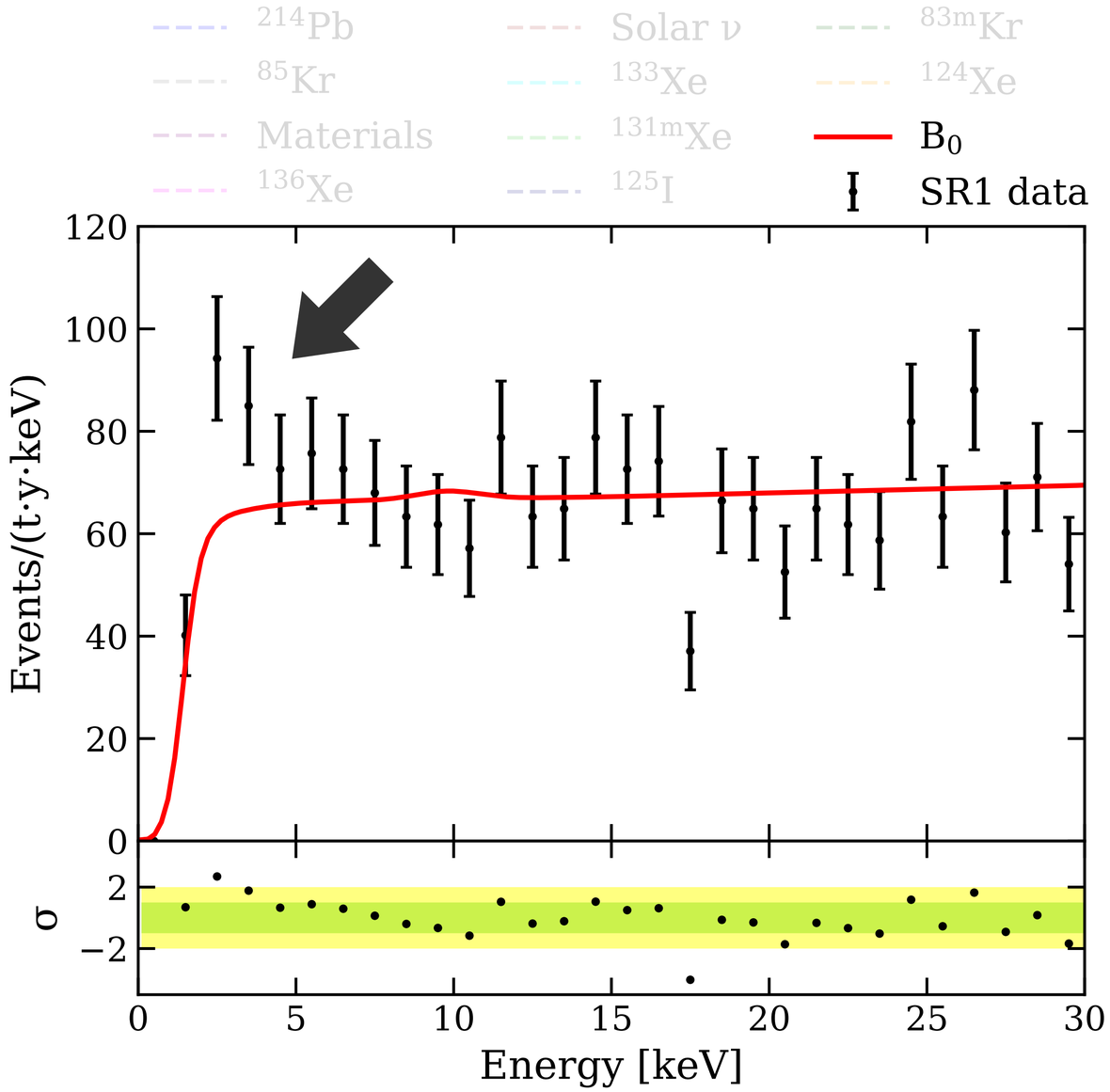

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Unexplored background?

Data-model matching

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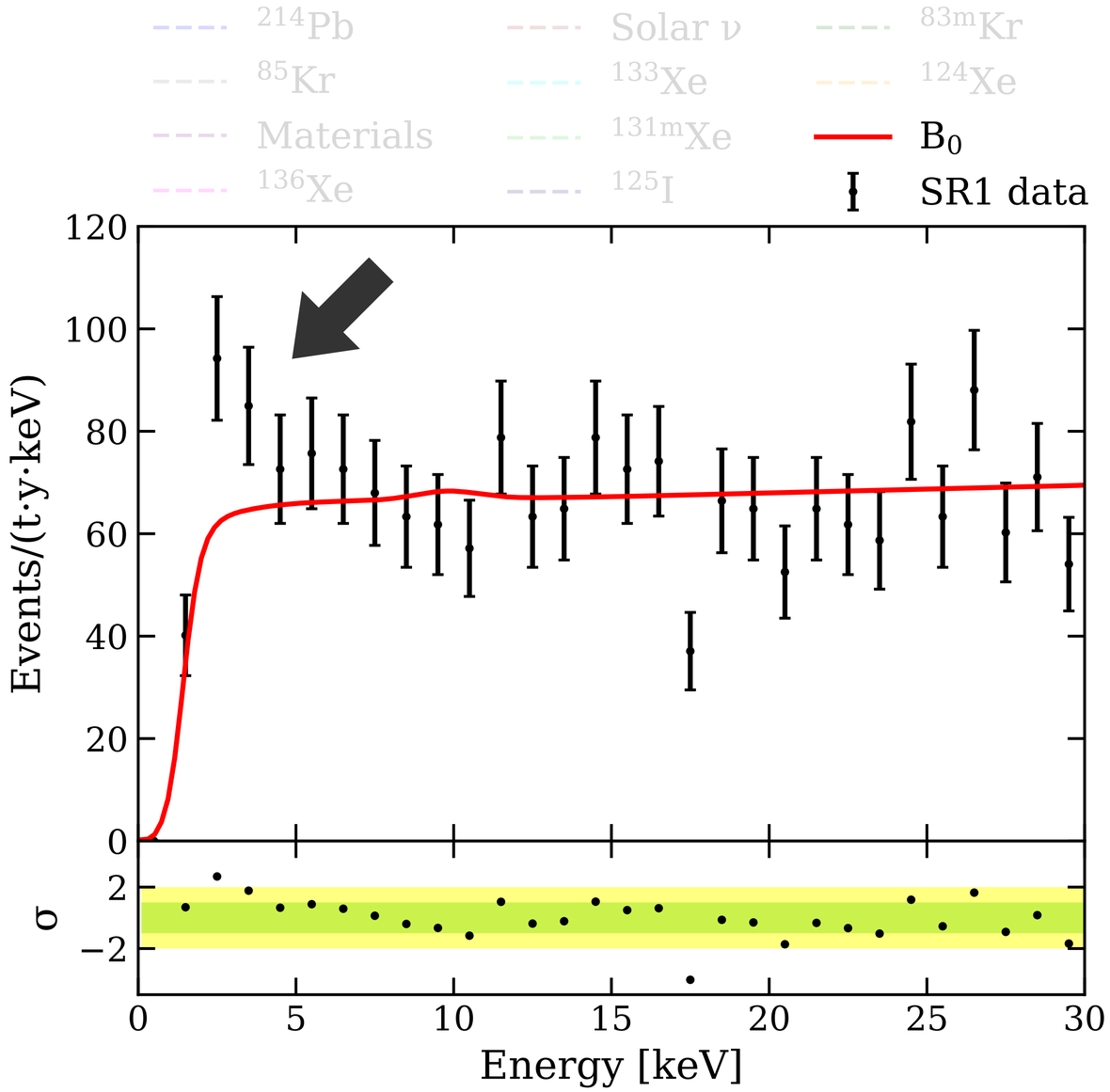

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Statistical fluke?

Systematic effects?

Unexplored background?

New physics?

Statistical fluke?

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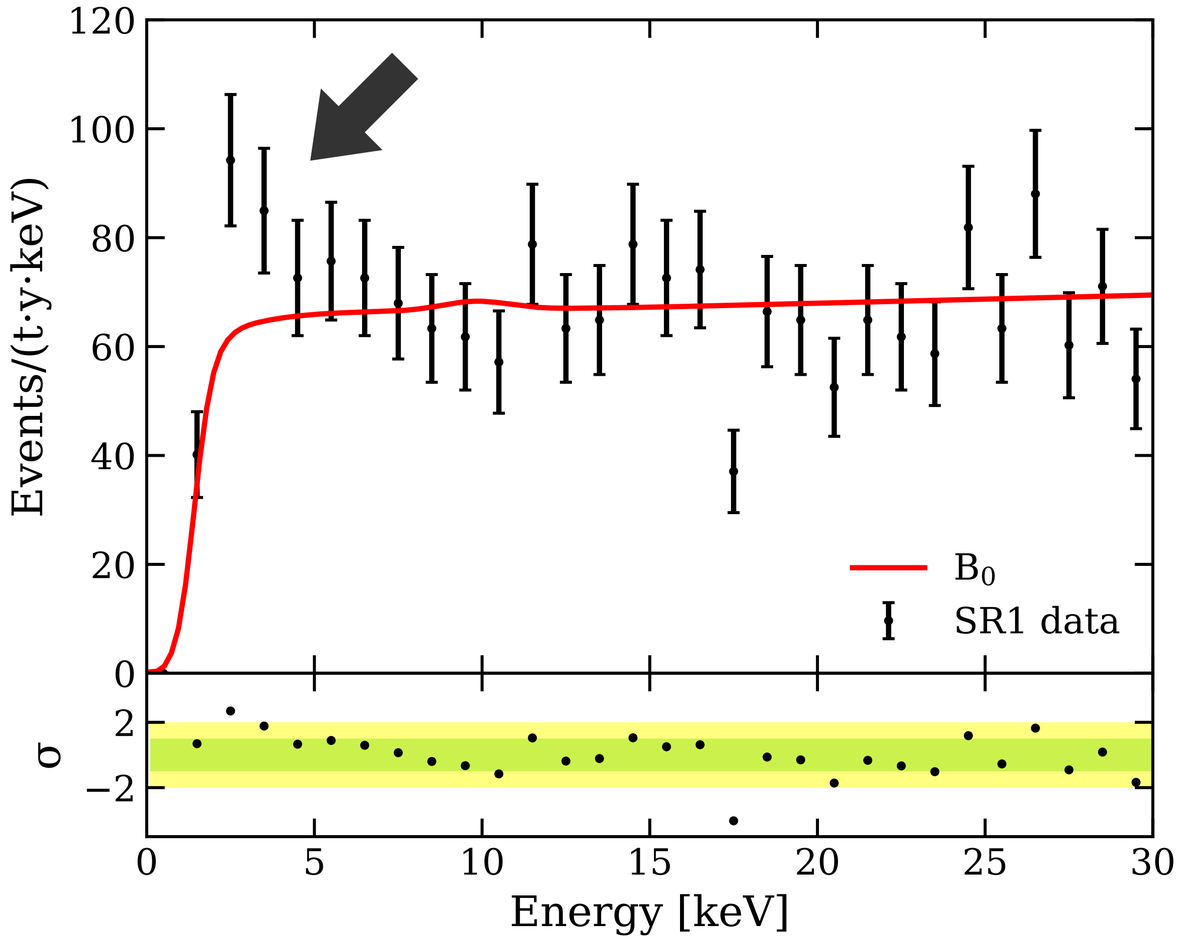

Statistical fluke?

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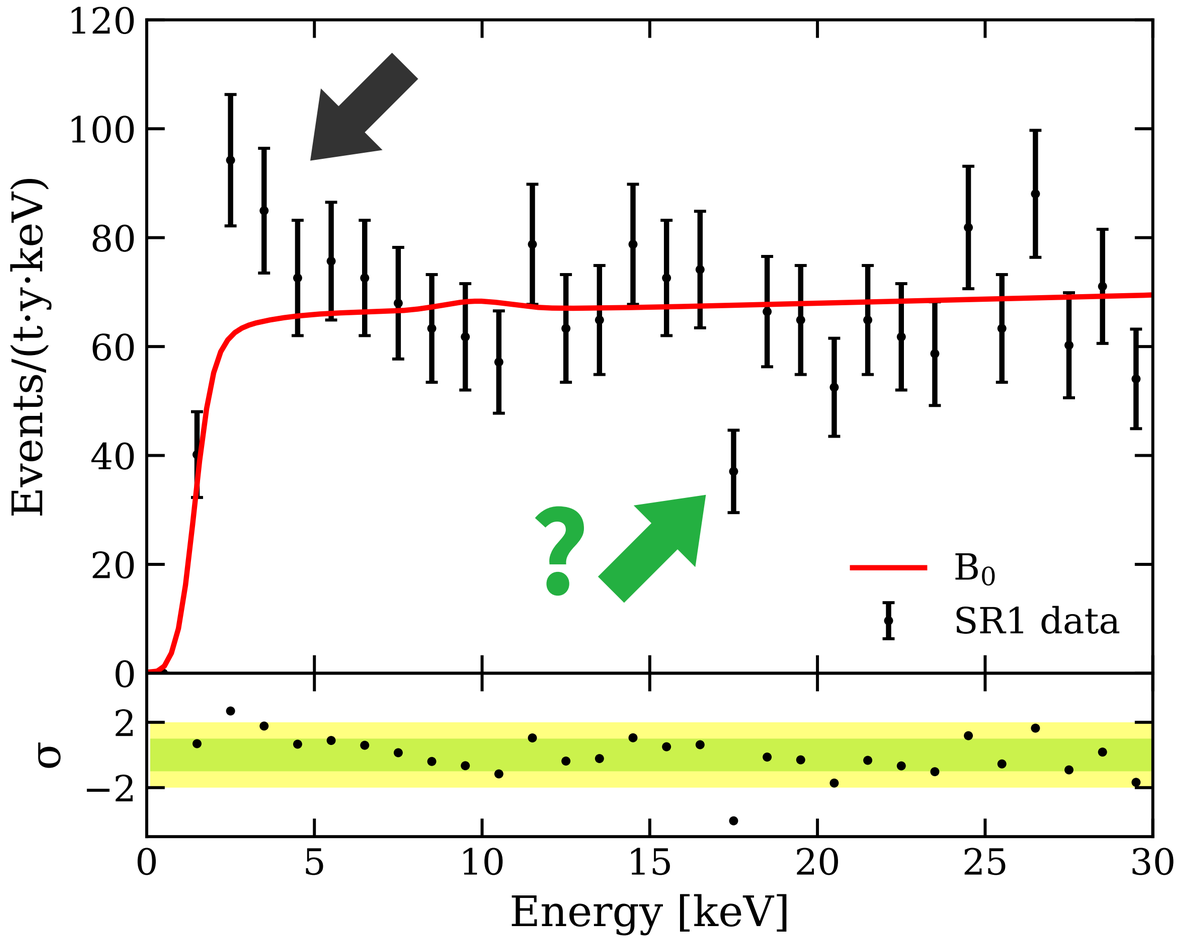

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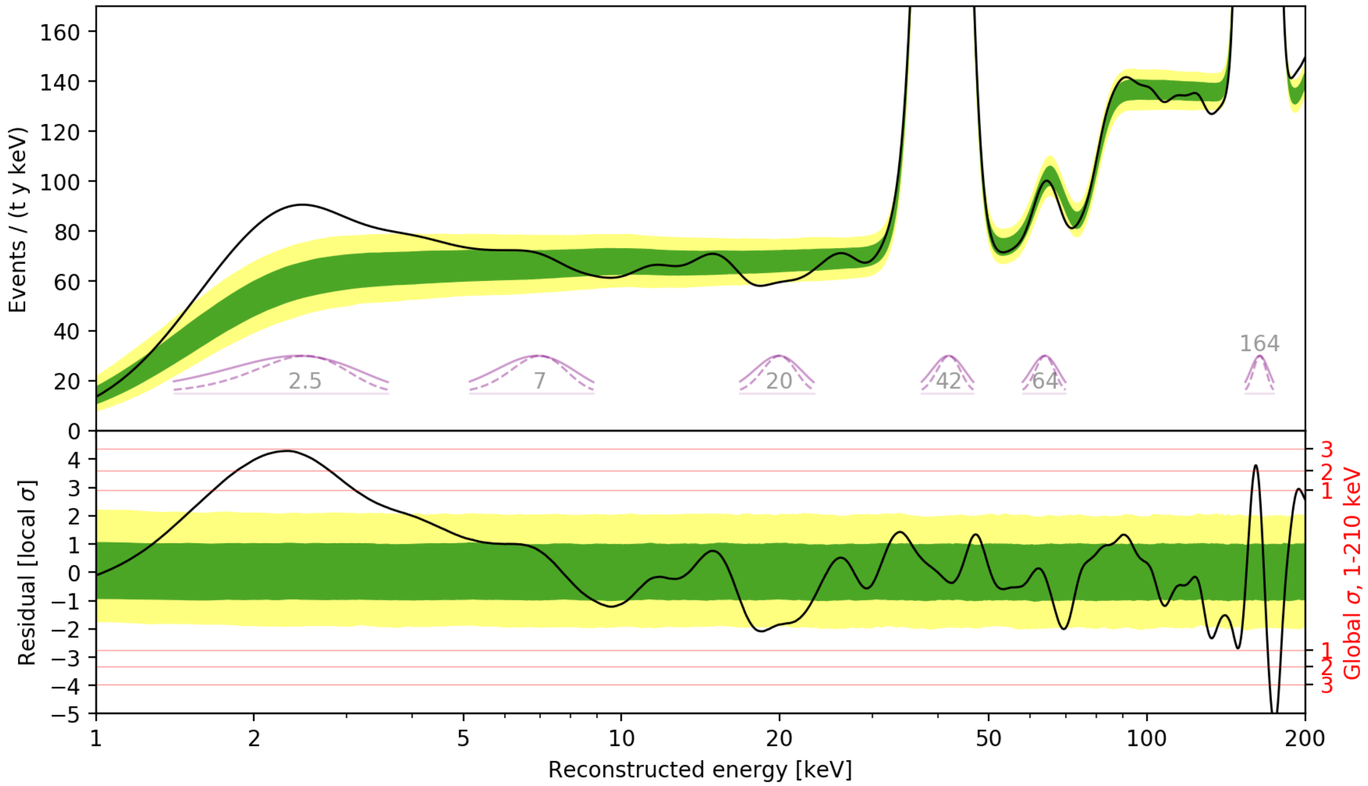

- KDE with energy resolution as width → **low-energy excess still significant**, the rest no

Statistical fluke?

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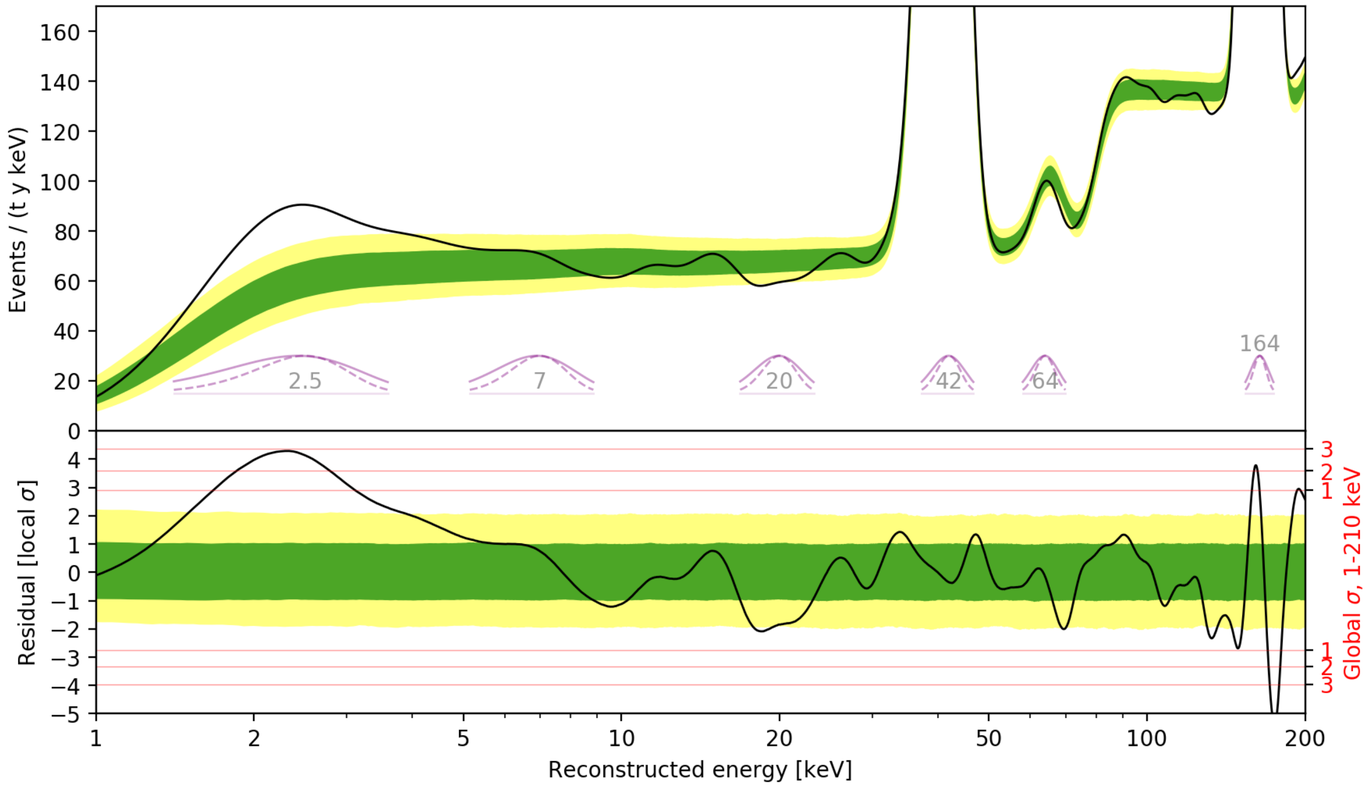

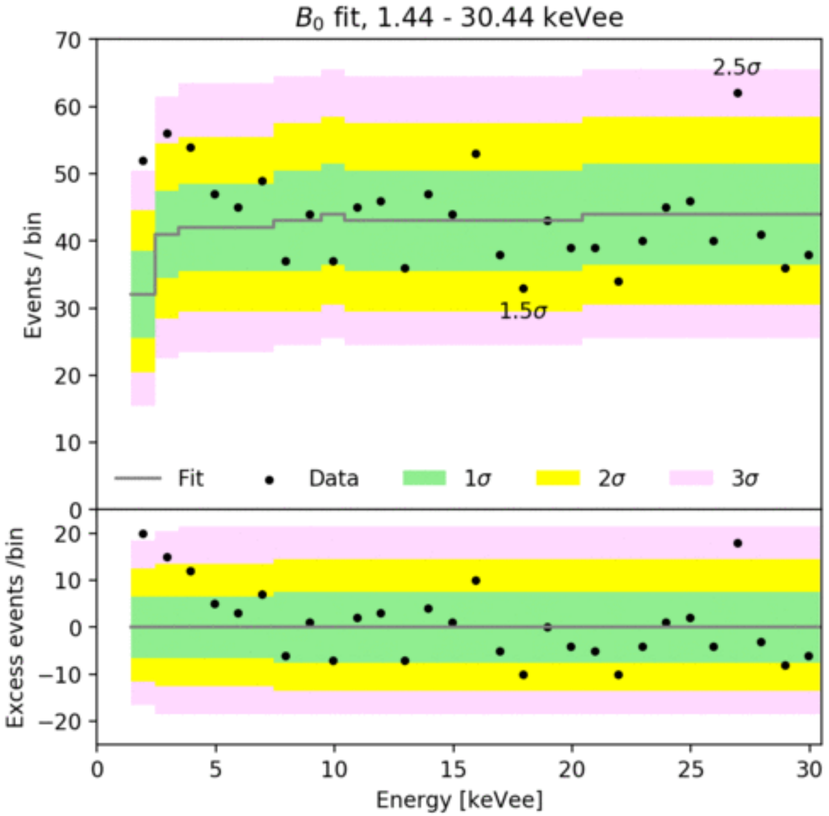

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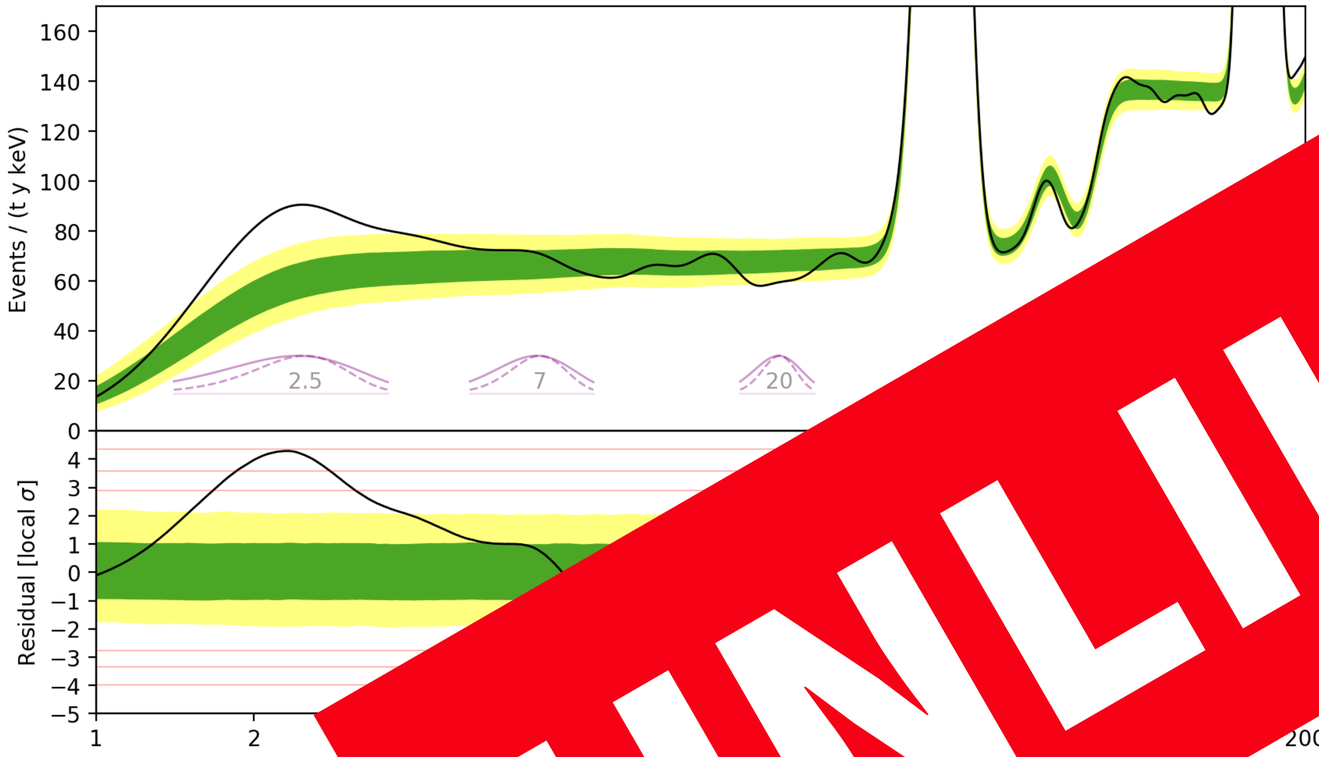
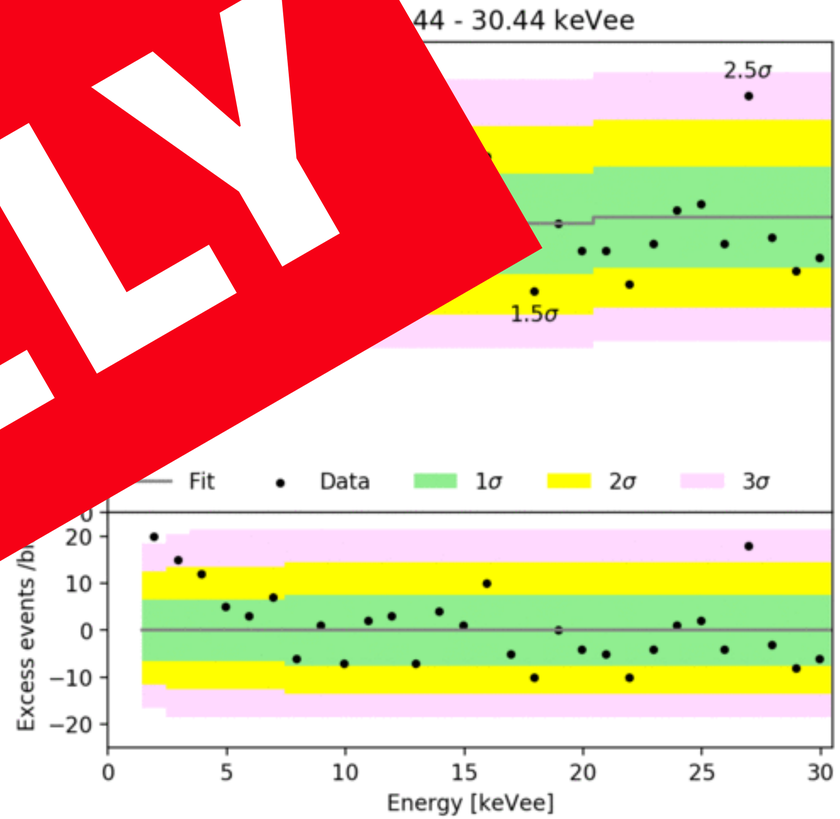
- Display binning change → bin width smaller than energy resolution, **low-energy excess robustly visible across several bins**, the rest no

Statistical fluke?

PRD 102 (2020) 072004





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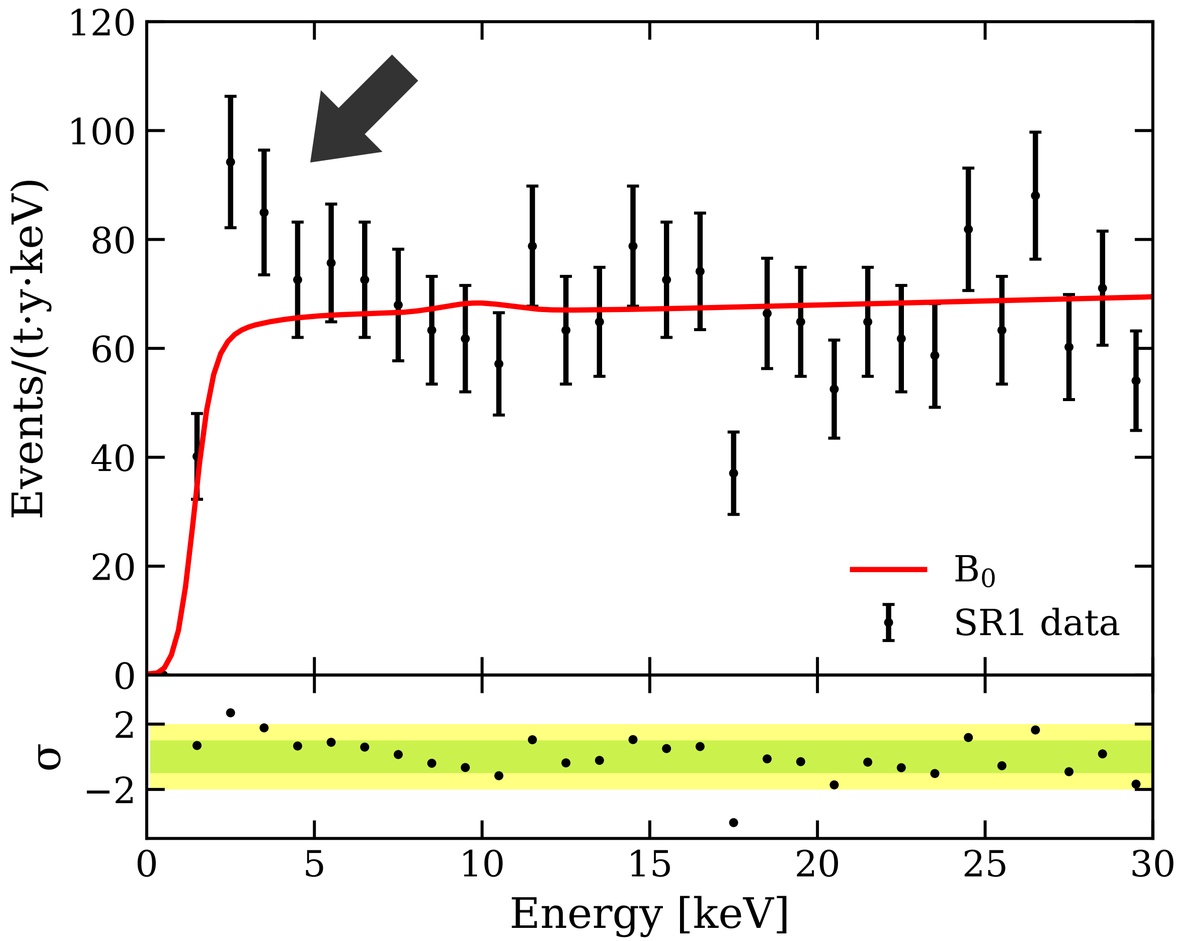

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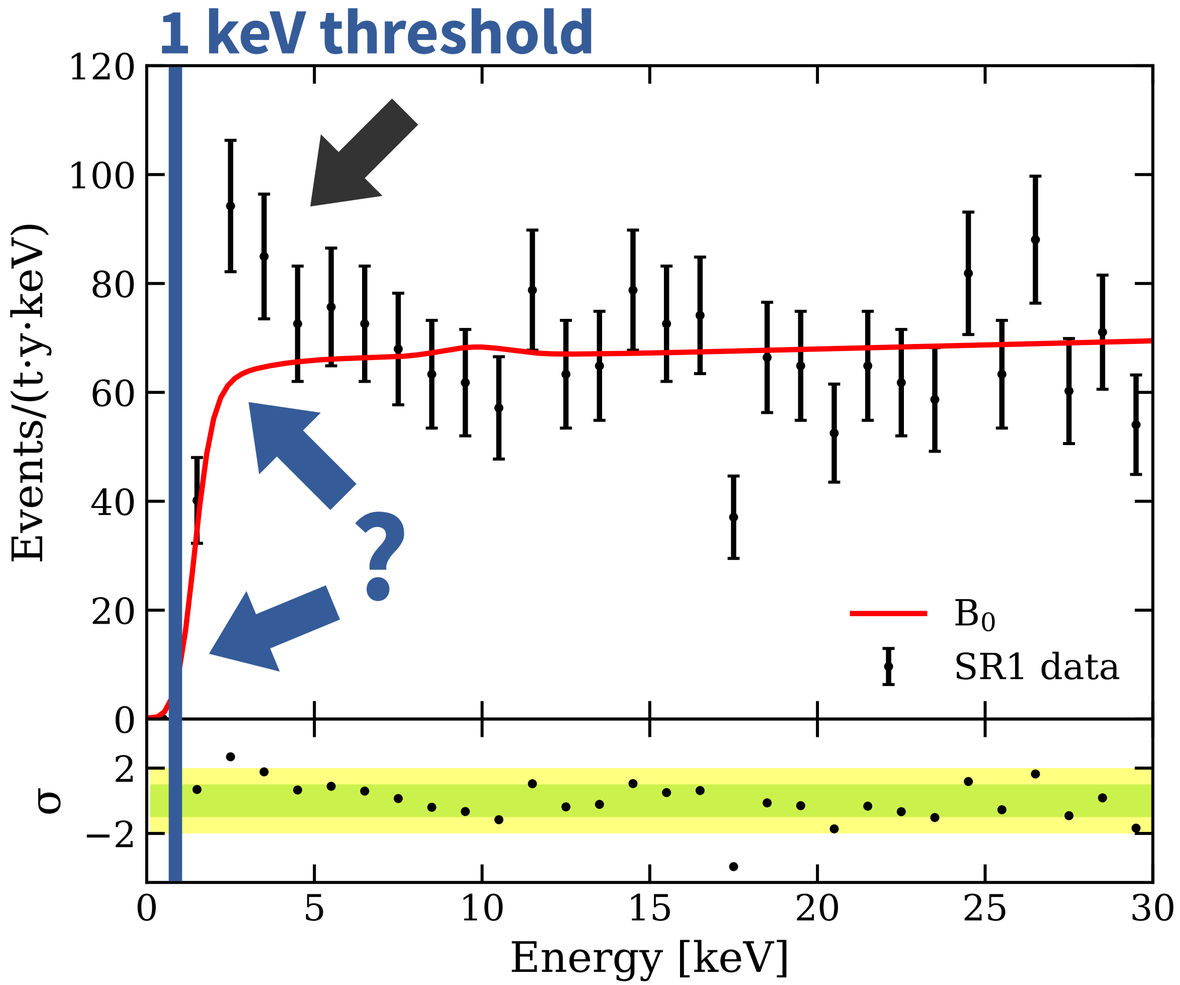
PRD 102 (2020) 072004



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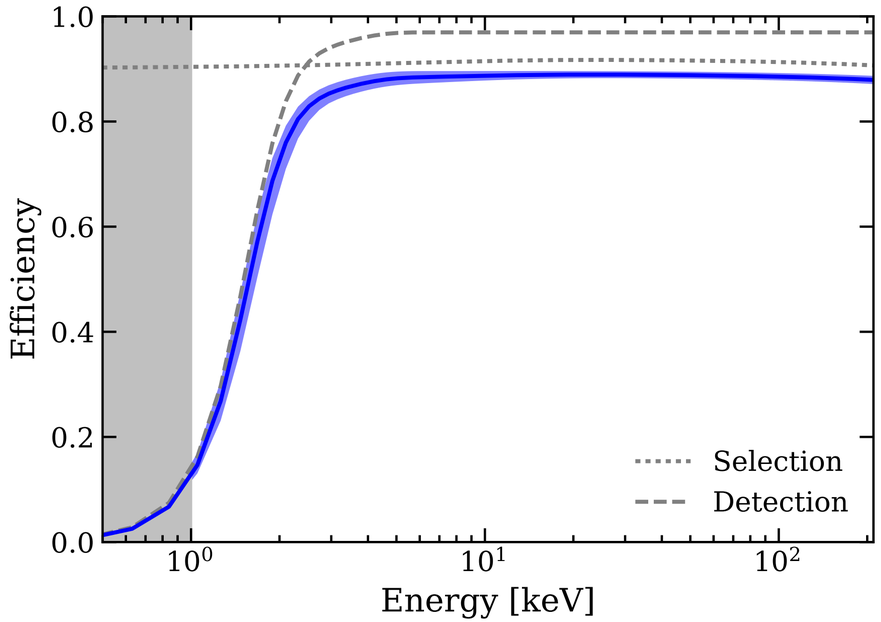
  (∼ 85% detection efficiency at 2–3 keV)
- Still present if threshold is **doubled**

PRD 102 (2020) 072004



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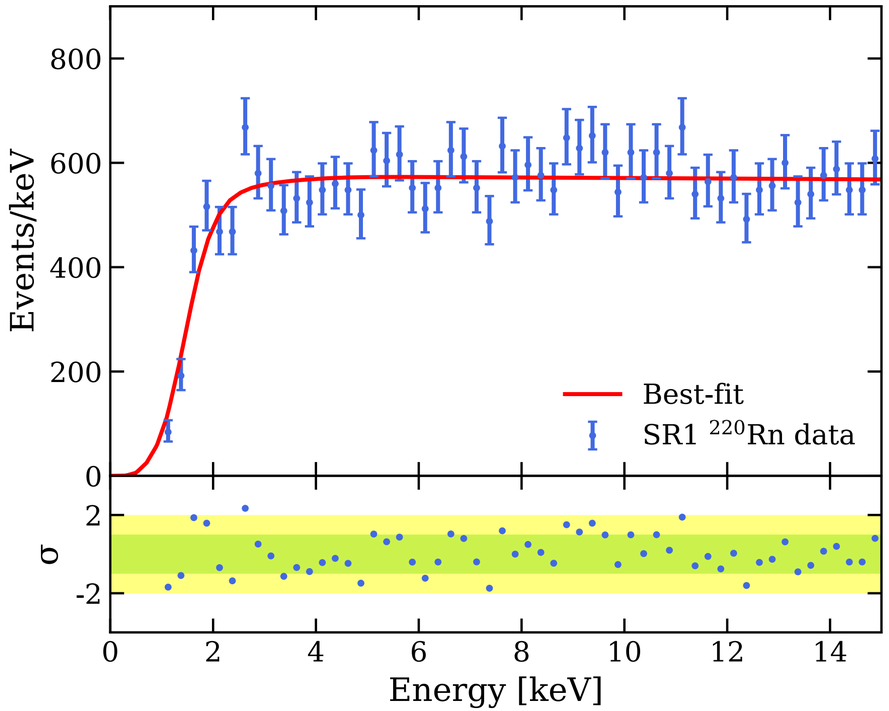
PRD 102 (2020) 072004



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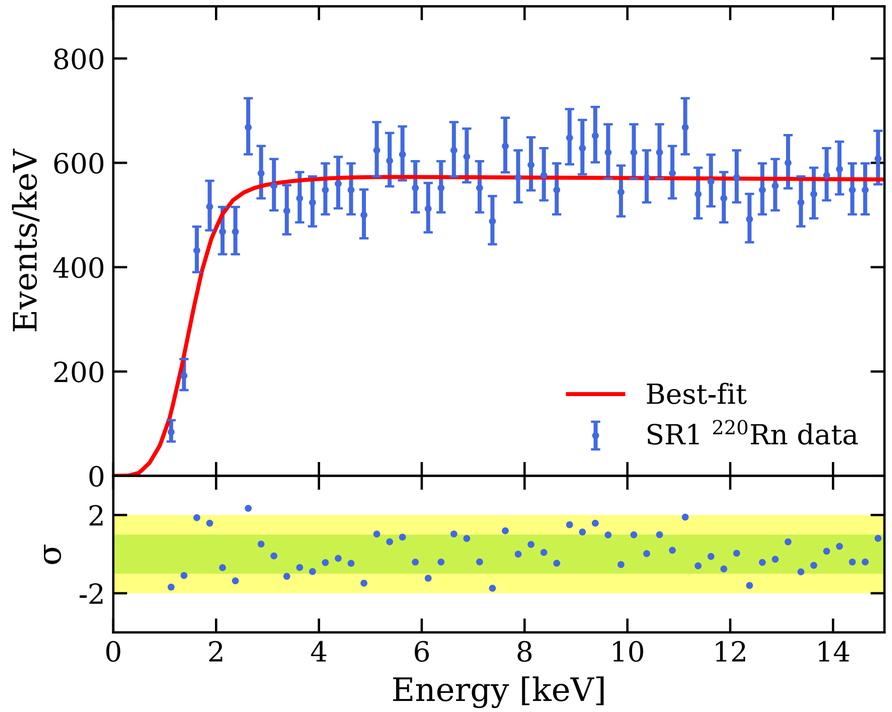

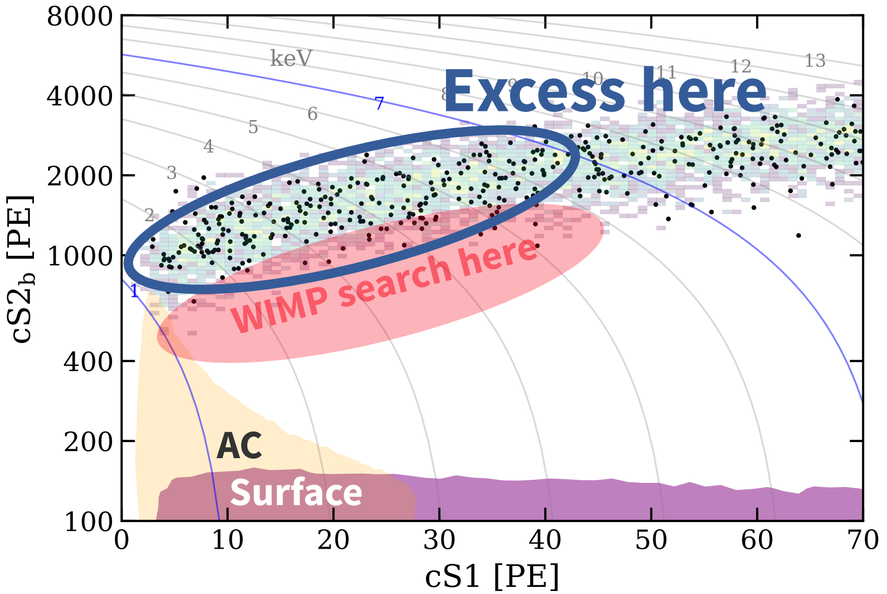

- Surface events → **absent from the search region** thanks to fiducialisation
- Accidental Coincidences (AC events) → **tightly constrained** and well-understood (S1, S2) signature

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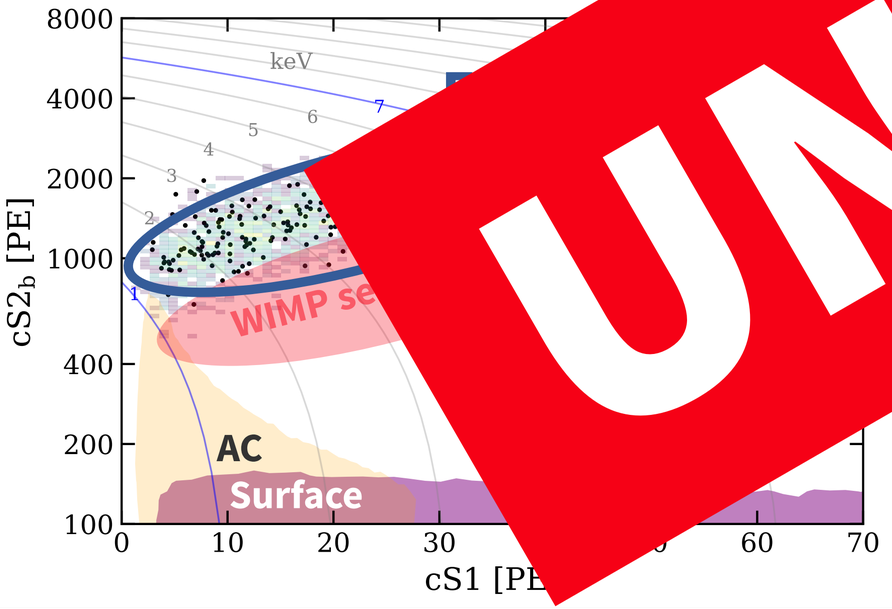
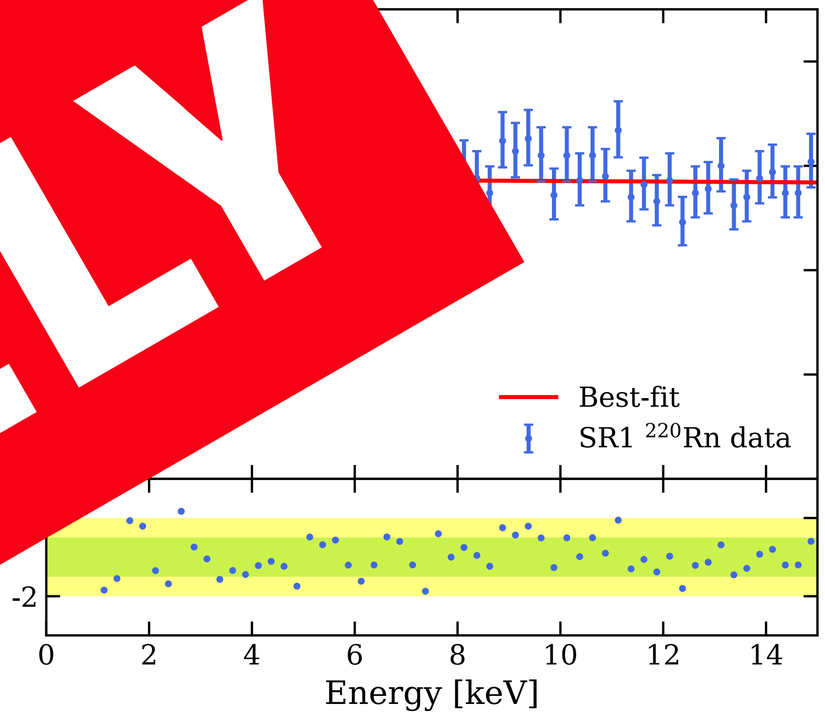


PRD 102 (2020) 072004



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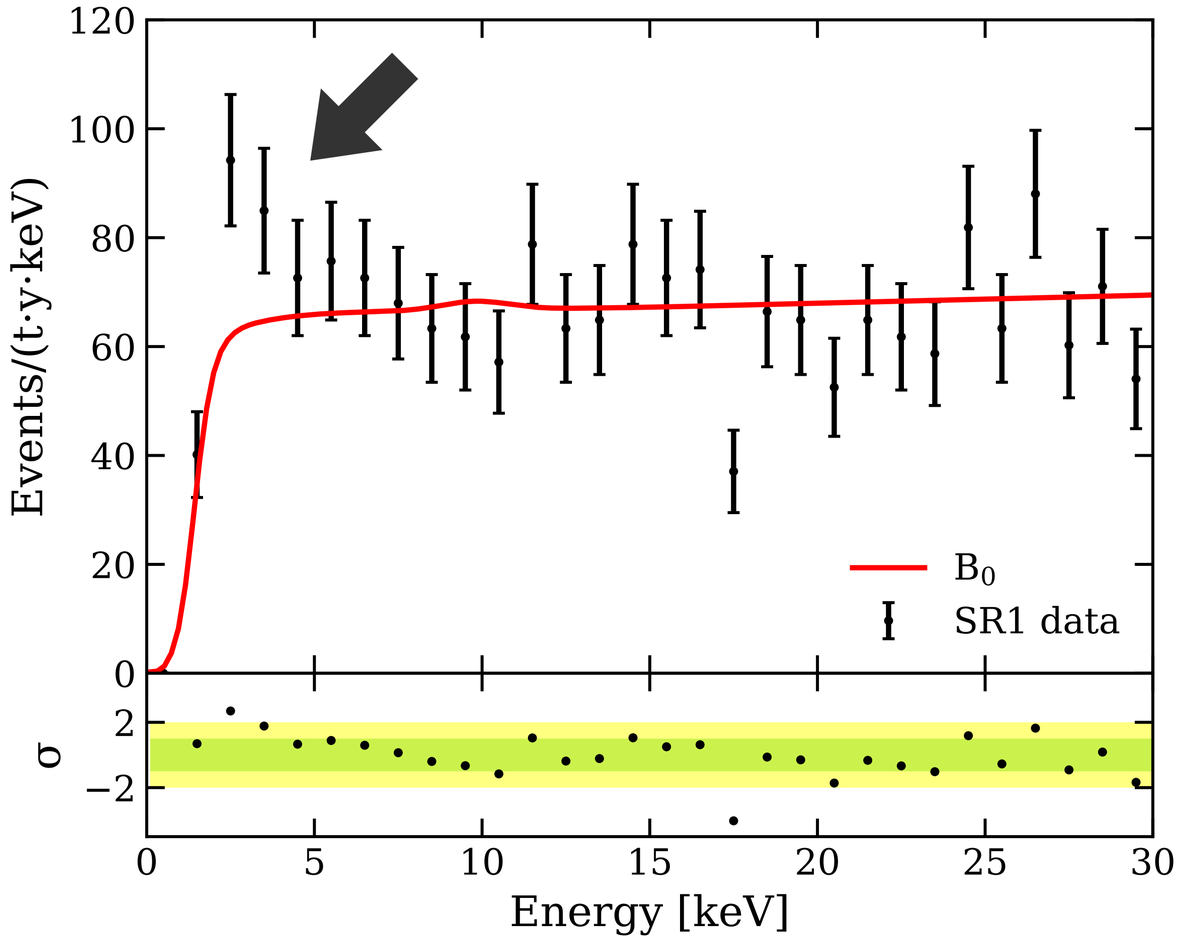
Unexplored background?

PRD 102 (2020) 072004



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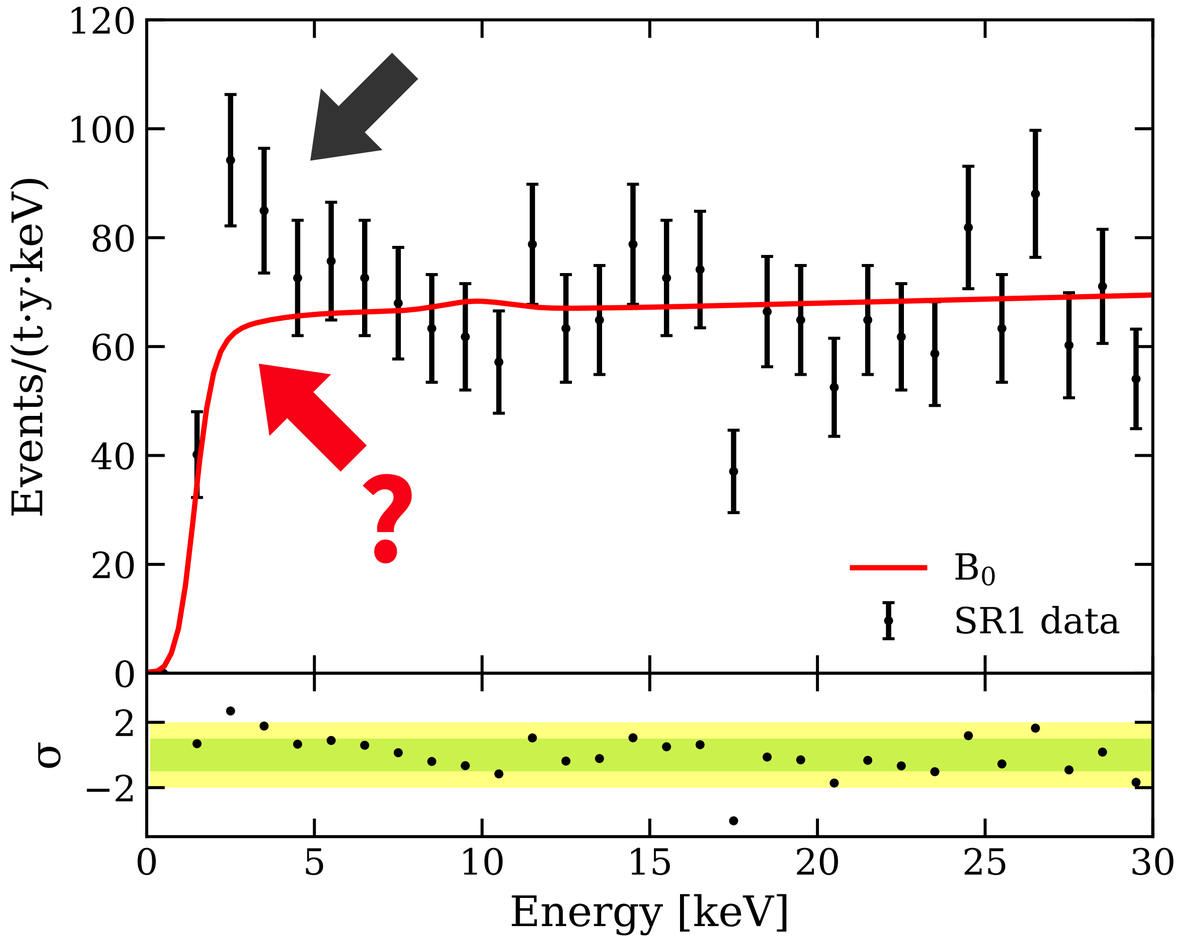
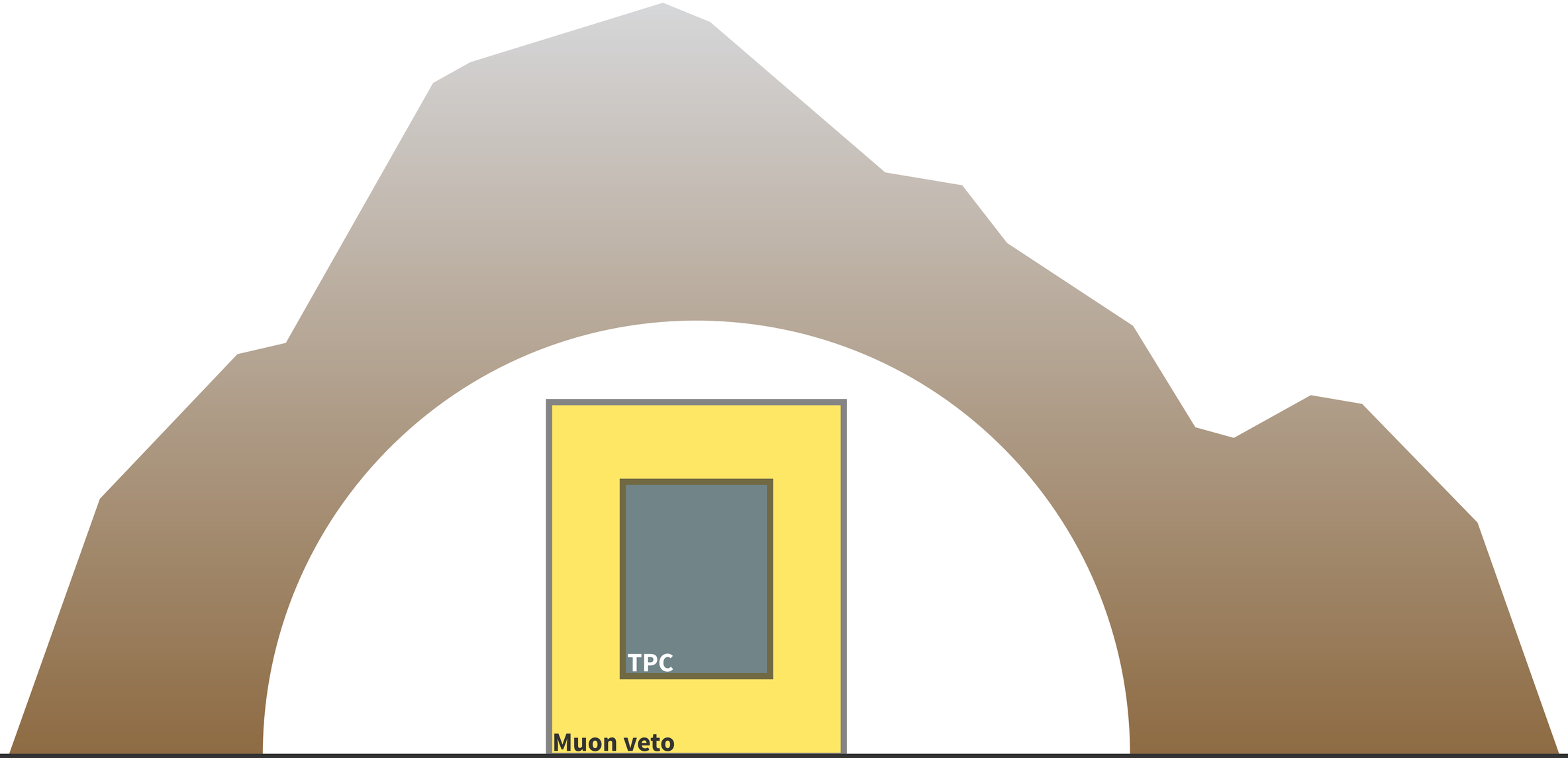
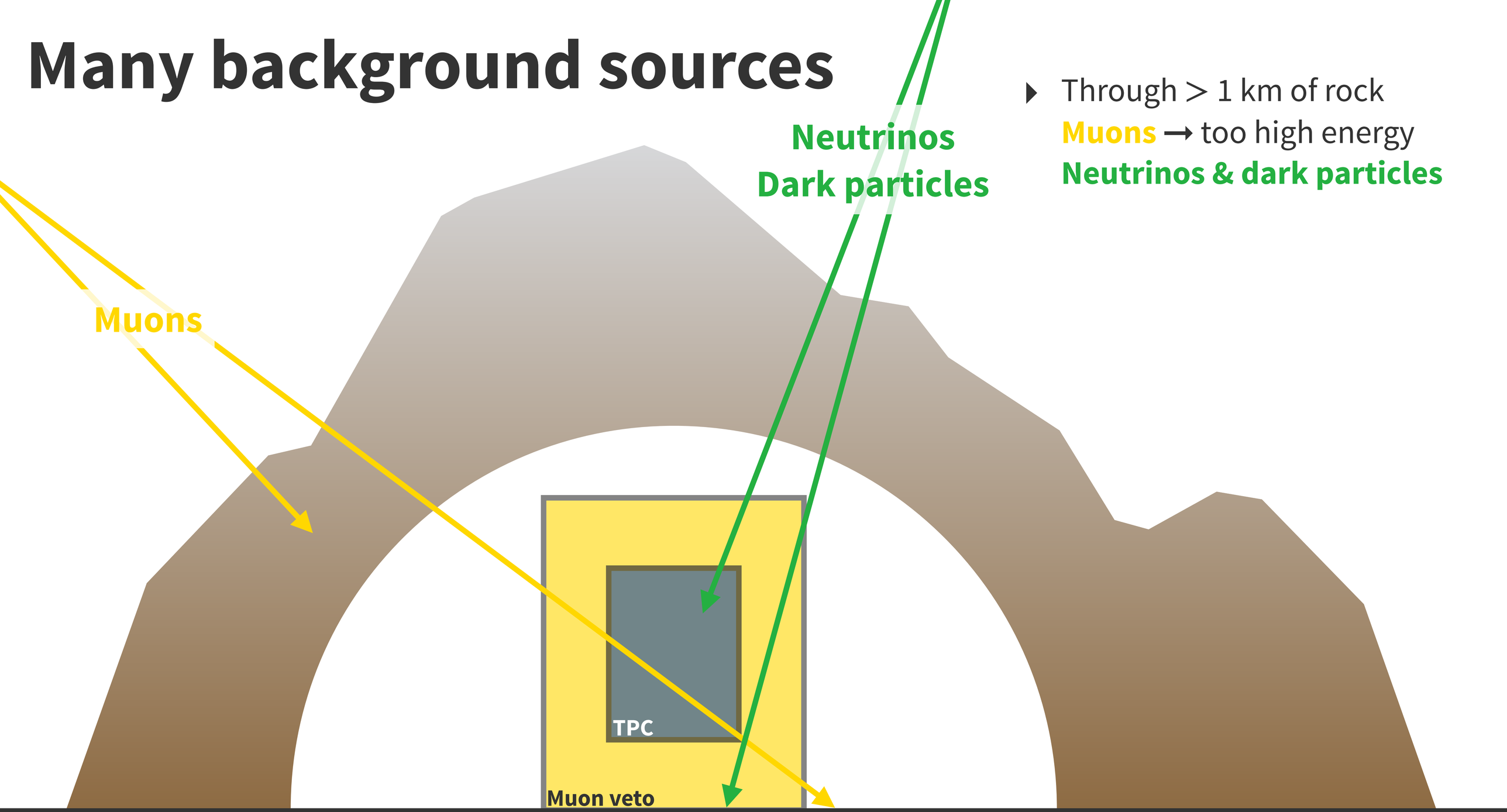


Many background sources



Many background sources

- Through > 1 km of rock
  Muons → too high energy
  Neutrinos & dark particles



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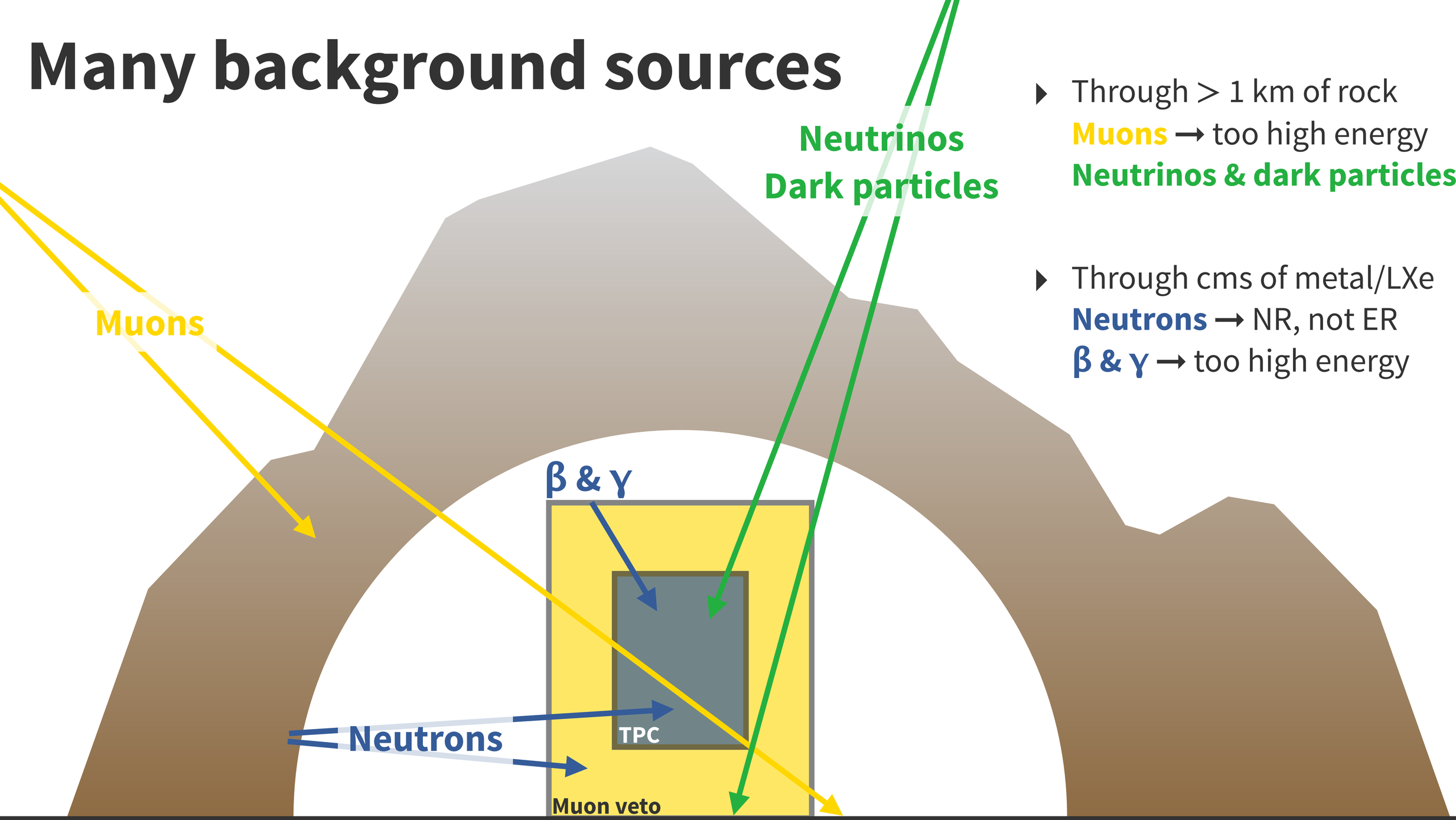

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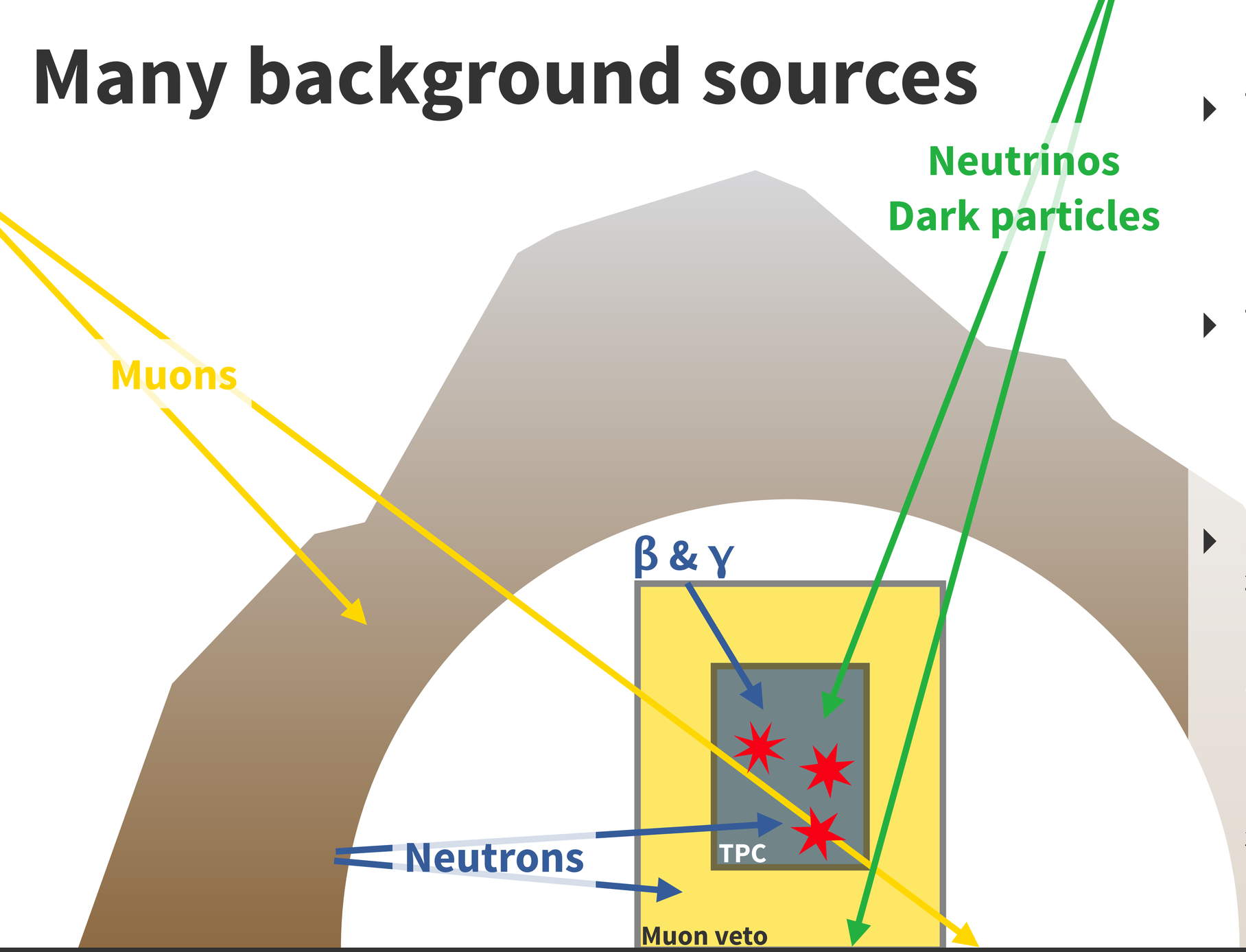

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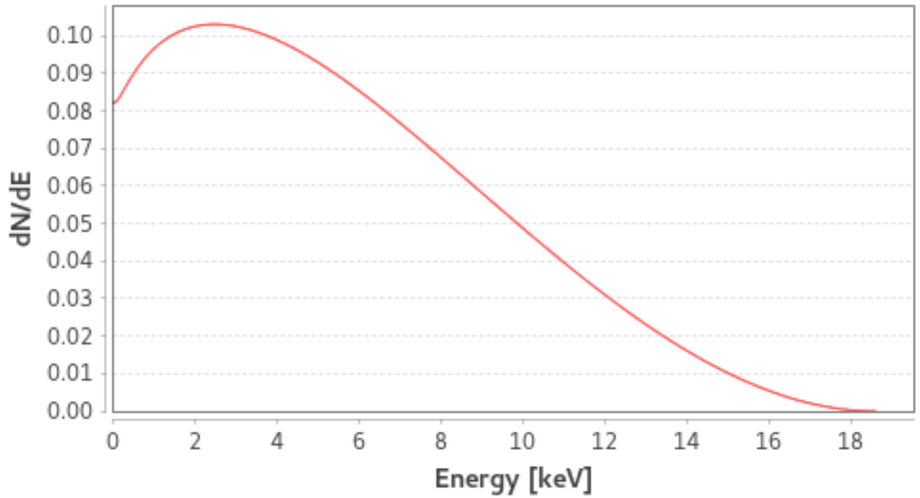
- **Infiltrating LXe**
  ^{214}Pb, **^{85}Kr**, **^{136}Xe**, etc.
  → taken into account
  ^{127}Xe, **^{37}Ar**
  → too short half-life
  → 13 × higher rate needed
  ^{3}H (Tritium)
  → why not?

The tritium hypothesis

NDS 130 (2015) 1–20
PRD 102 (2020) 072004

- **Never observed before** as background in LXe TPCs
- β^- emitter $\rightarrow$ $Q_\beta = 18.6$ keV, $t_{1/2} = 12.3$ yr
- Cosmogenic activation? Atmospheric abundance?



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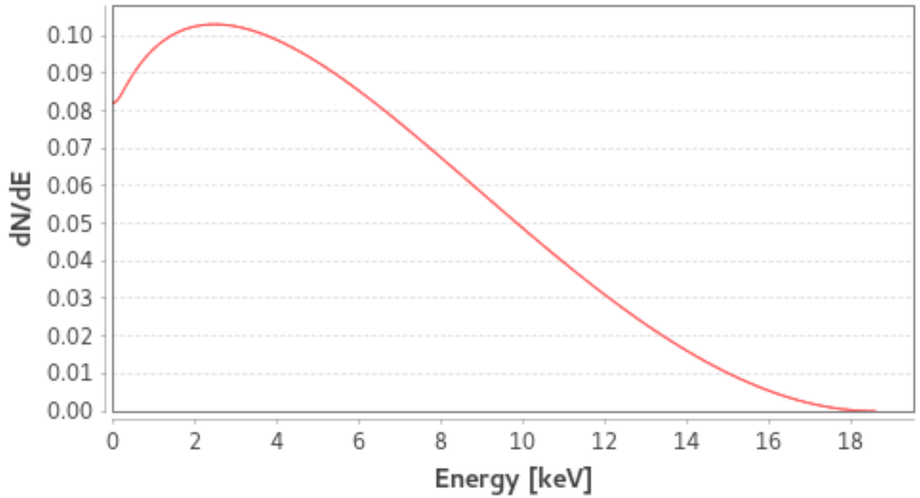
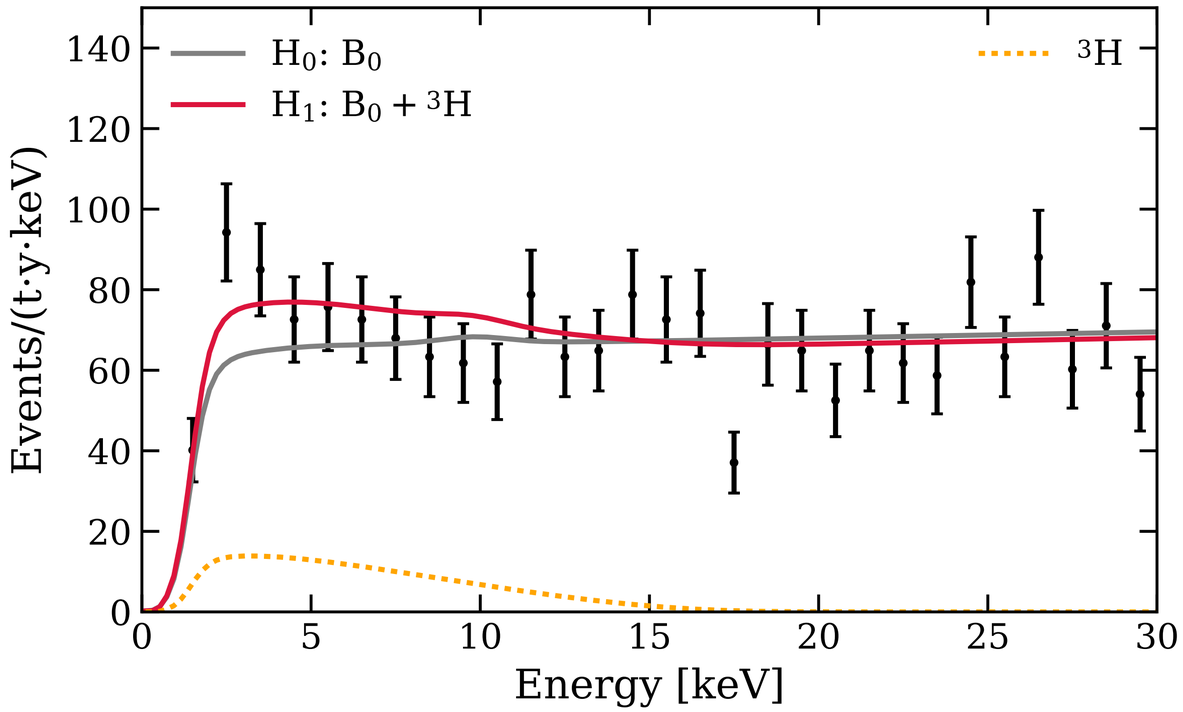




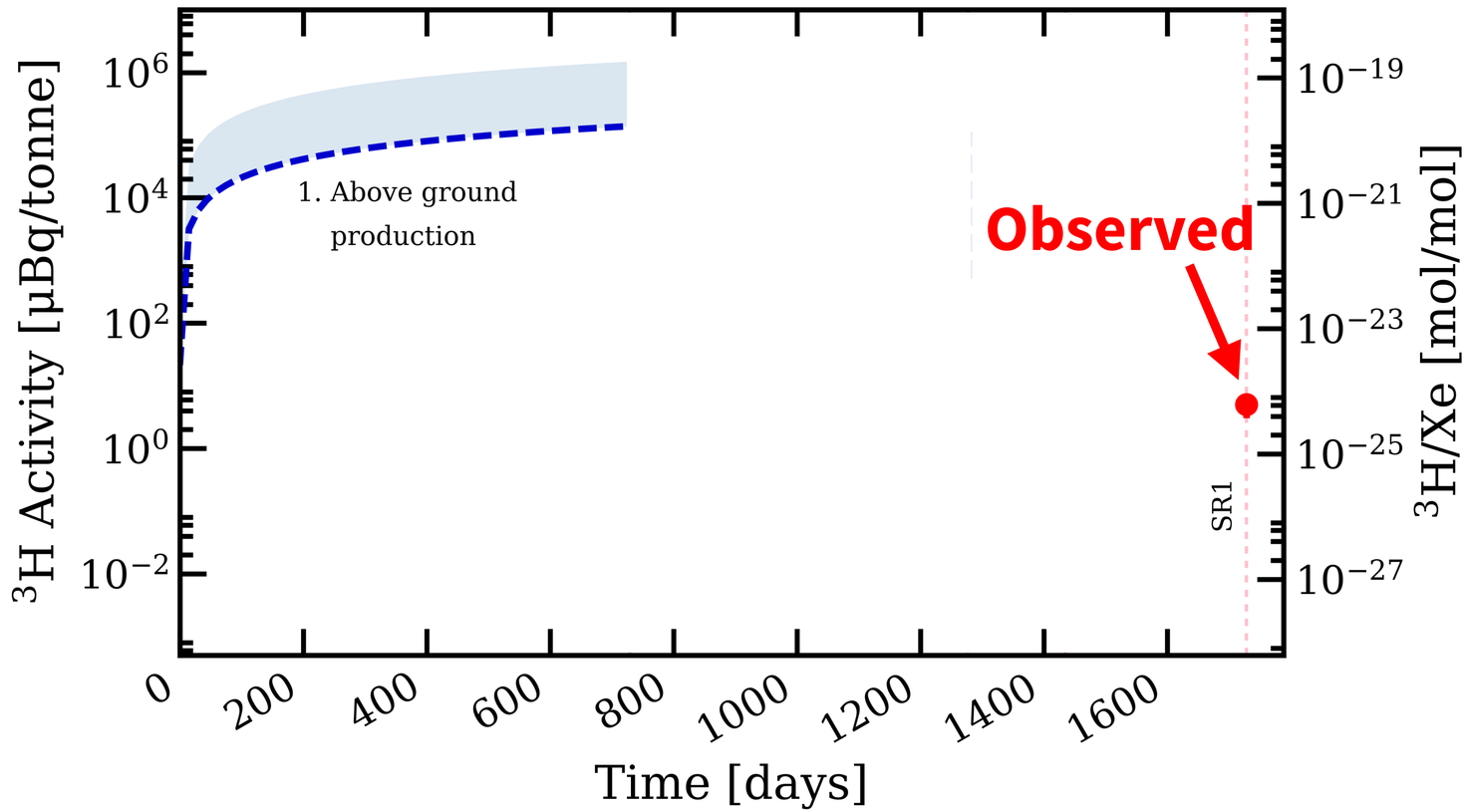
Tritium hypothesis favoured over B_0 at 3.2σ

- Fitted rate → (159 ± 51) events/(t × yr)
- ${}^3H/Xe = (6.2 \pm 2.0) \times 10^{-25}$ mol/mol
  → **$\lesssim$ 3 tritium atoms/kg of xenon**

Tritium from the cosmos?

PRD 102 (2020) 072004

1. Xenon gas storage above ground → ∼ 32 tritium atoms/(kg × d) → **tritiated water (HTO)** with ∼ 1 ppm water impurities



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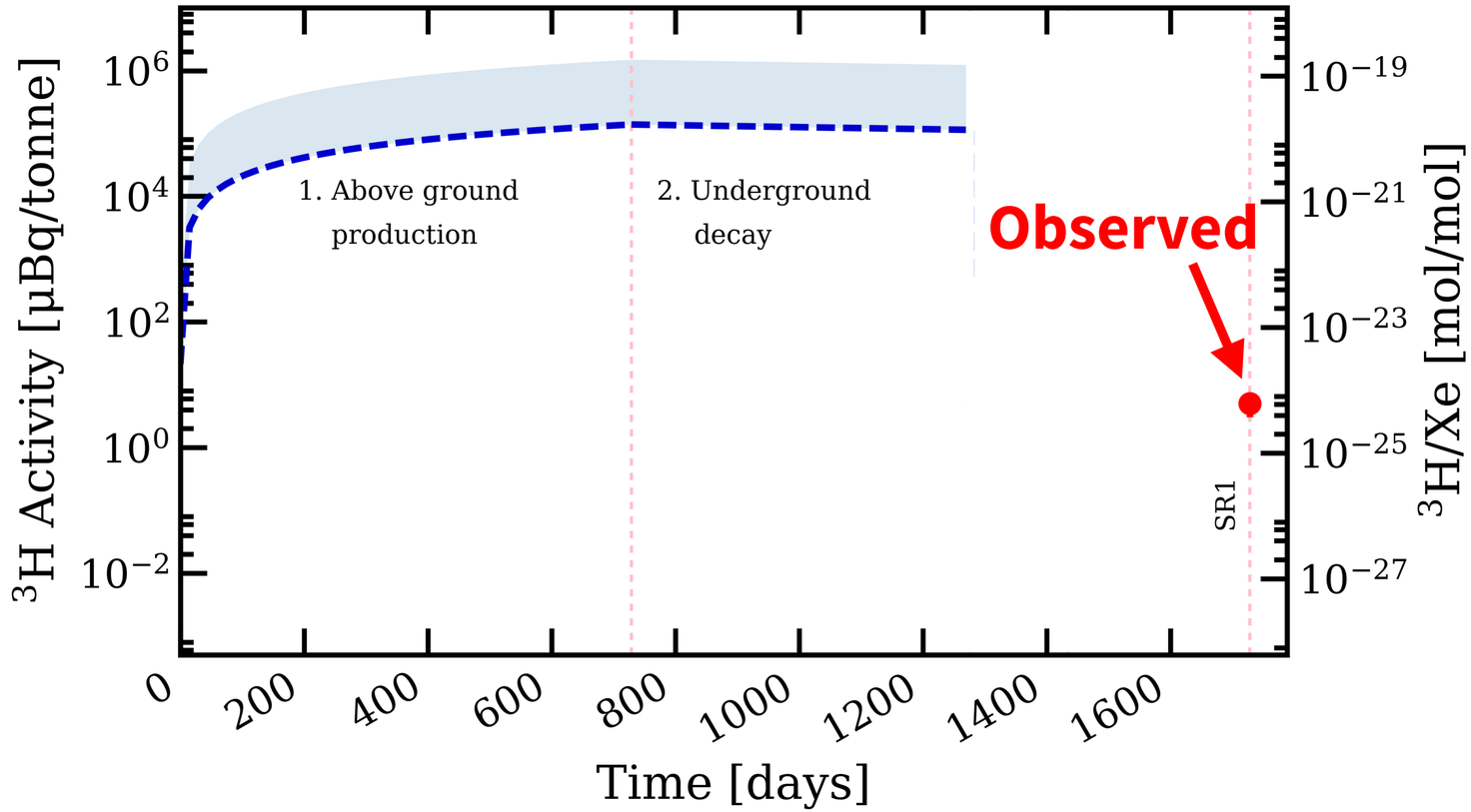

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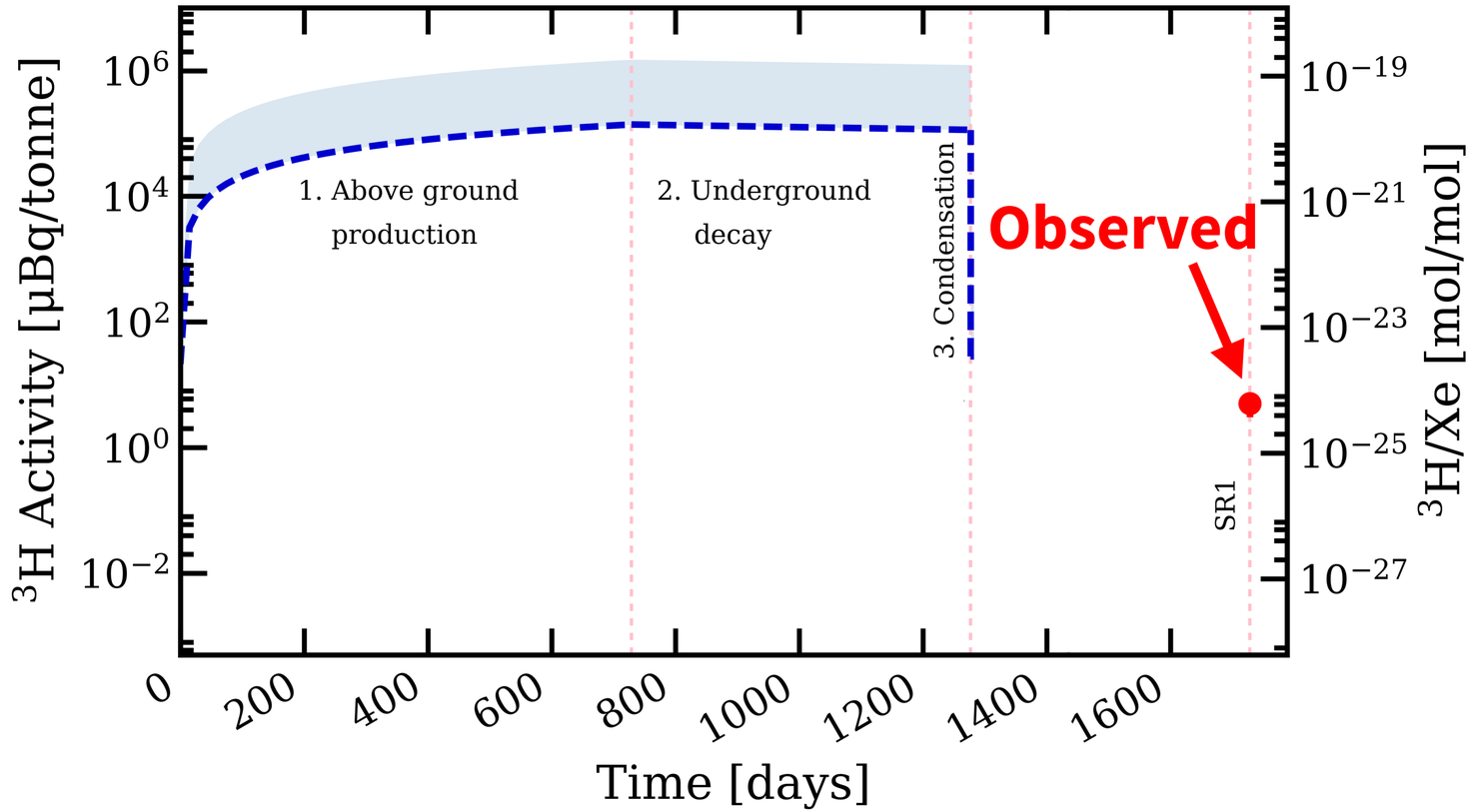

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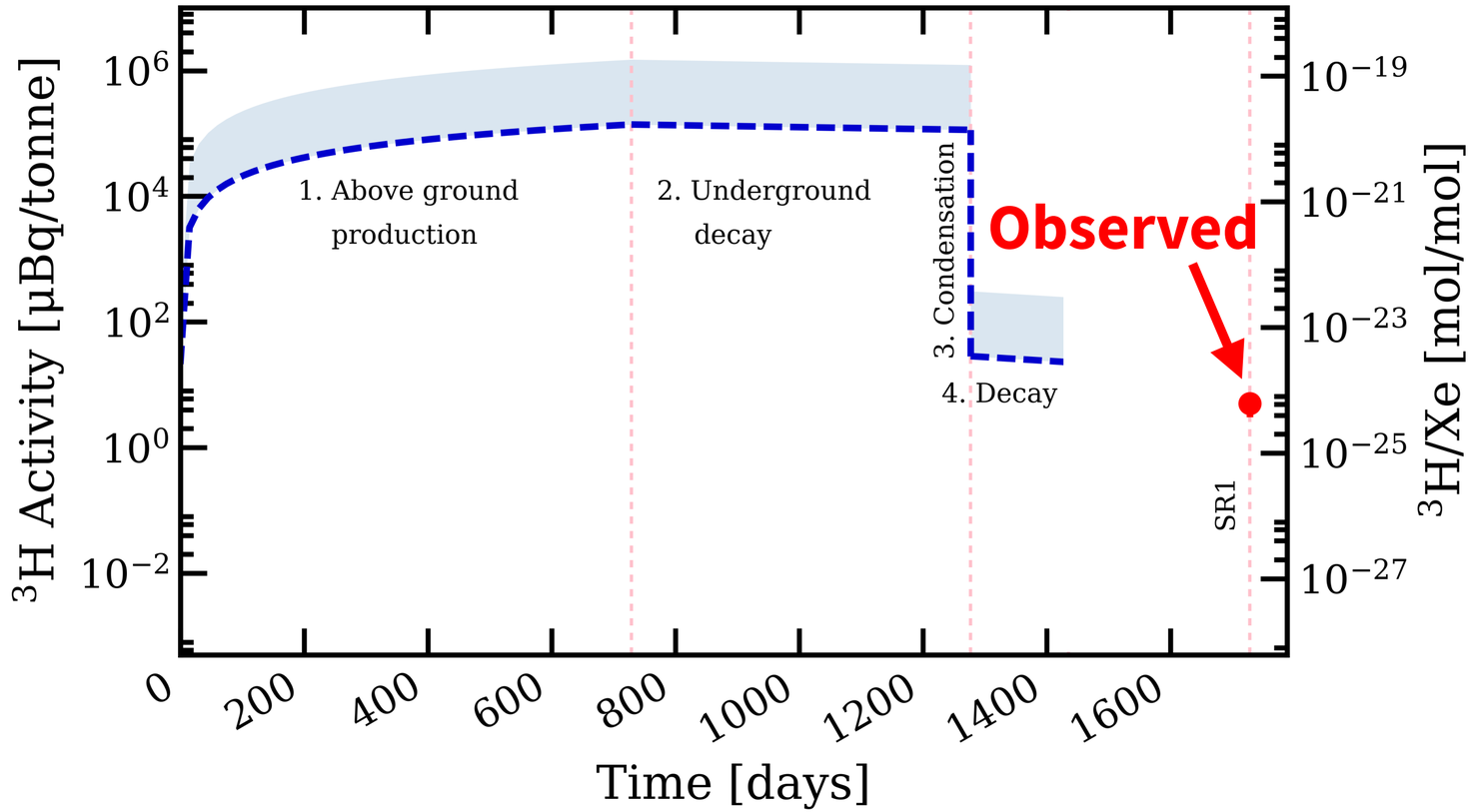

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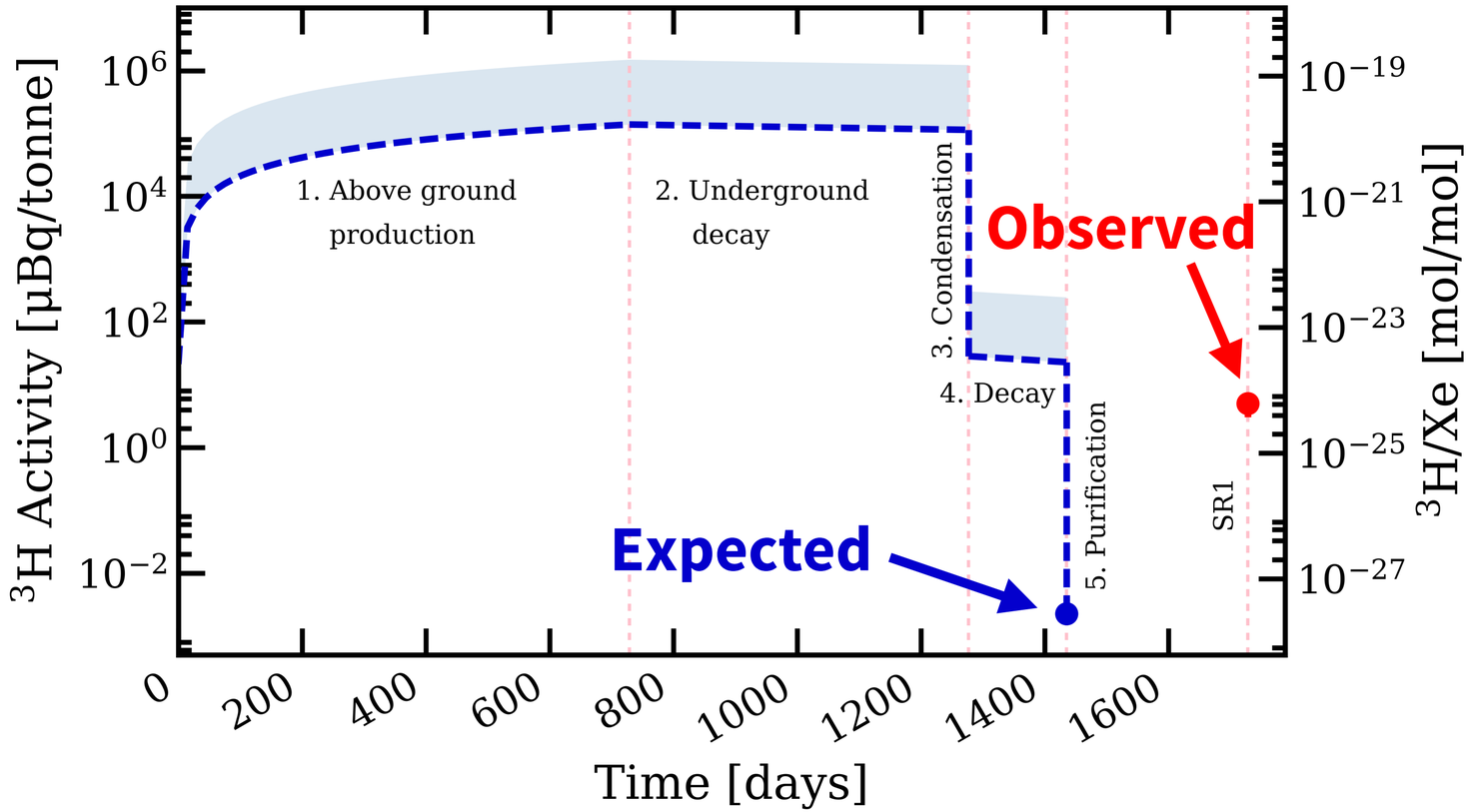
   → **99.99% water removal** (including HTO)



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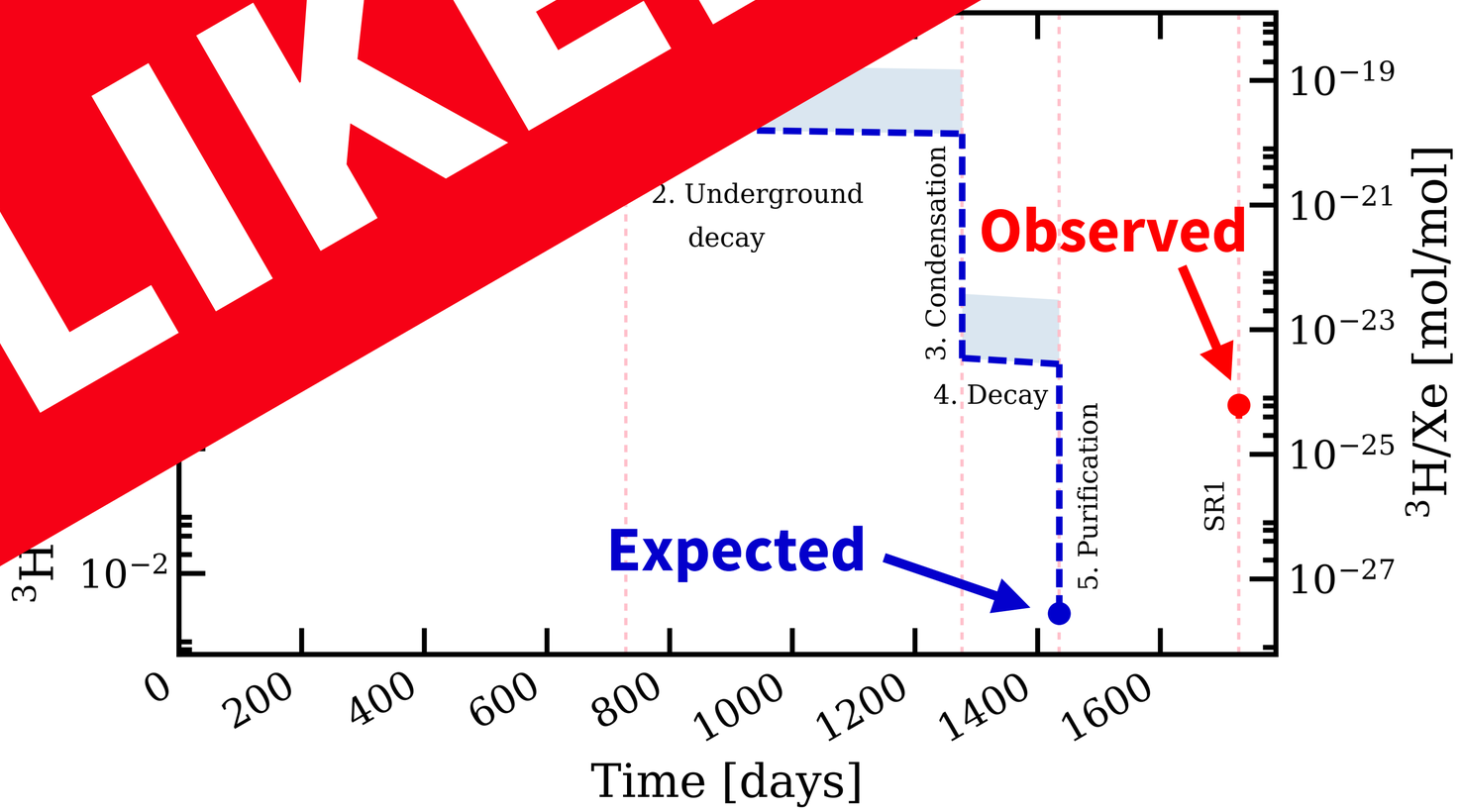
UNLIKELY



Tritium from the atmosphere?

PRD 102 (2020) 072004

- Atmospheric abundance → tritium stored as **tritiated water (HTO) or hydrogen (HT)** in detector materials, then **emanating in xenon**
- $HTO/H_2O = (5–10) \times 10^{-18}$ mol/mol, **assuming** the same value for HT/H_2
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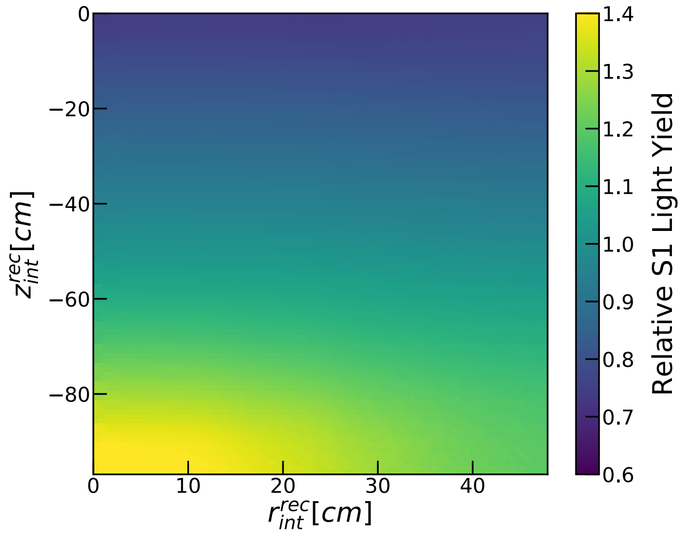

Light yield measurement

↓

$H_2O/Xe = O(1)$ ppb

↓

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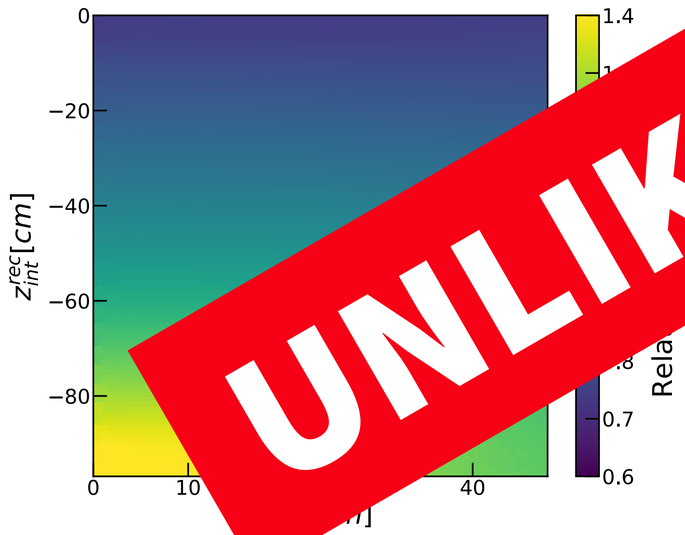

UNLIKELY

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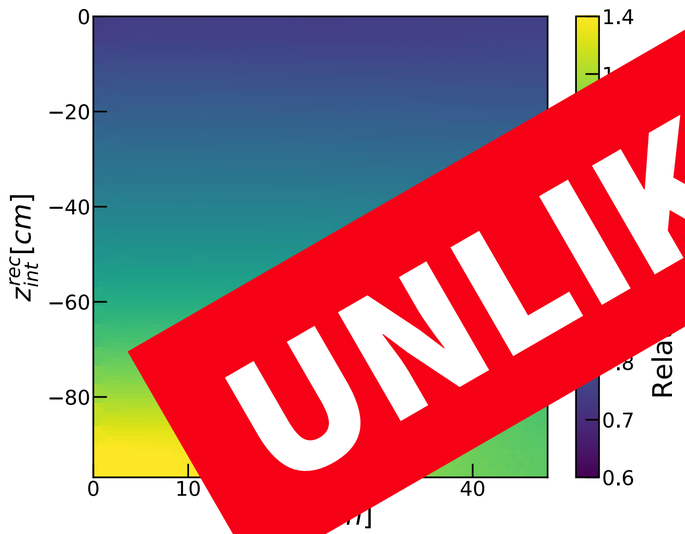

UNLIKELY

…nt

↓

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Tritiated hydrogen (HT)

Electron lifetime measurement

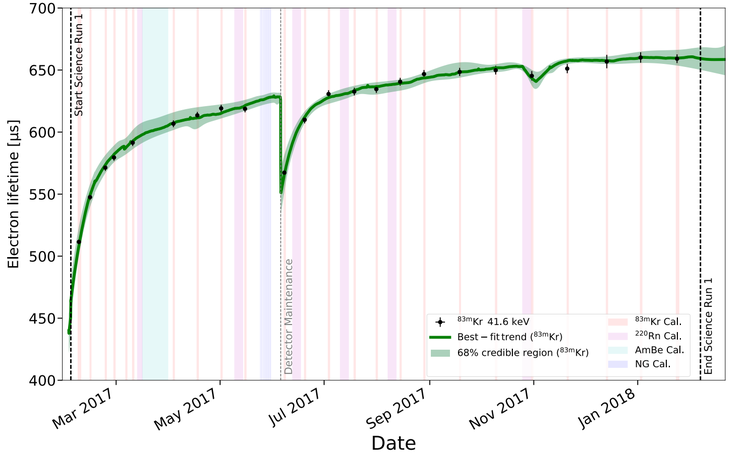
↓

No H_2 measurement

O_2-eq./Xe < 1 ppb

↓

100 × more H_2 required to explain the excess



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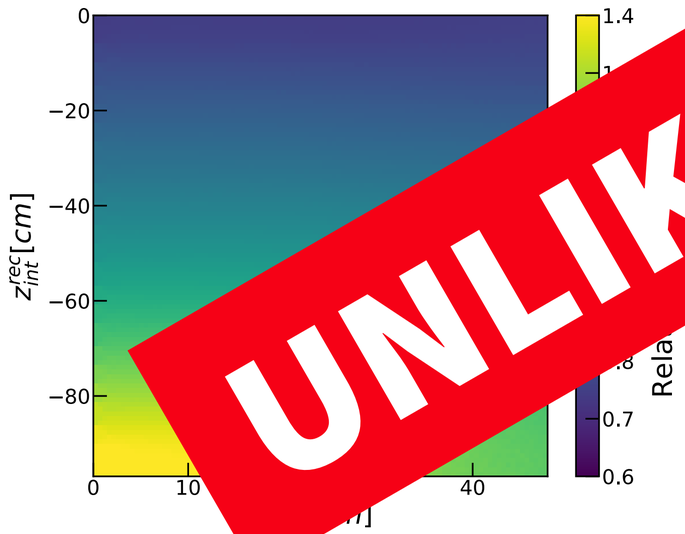

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Tritiated hydrogen (HT)

Electron lifetime measurement

↓

No H_2 measu…

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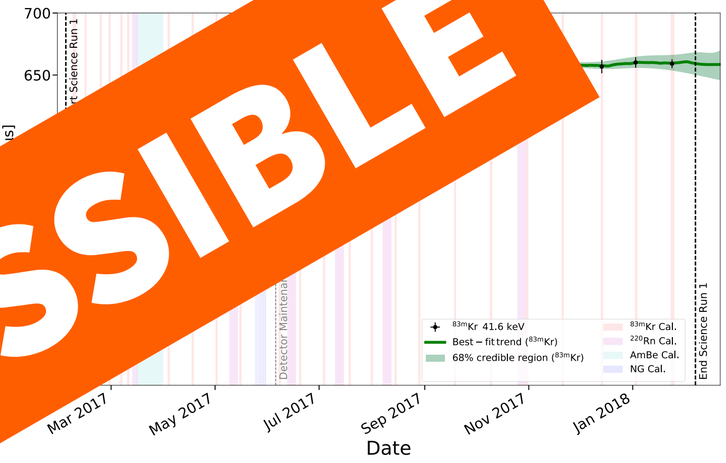

POSSIBLE

100 × …$_2$ required to explain the excess

New physics?

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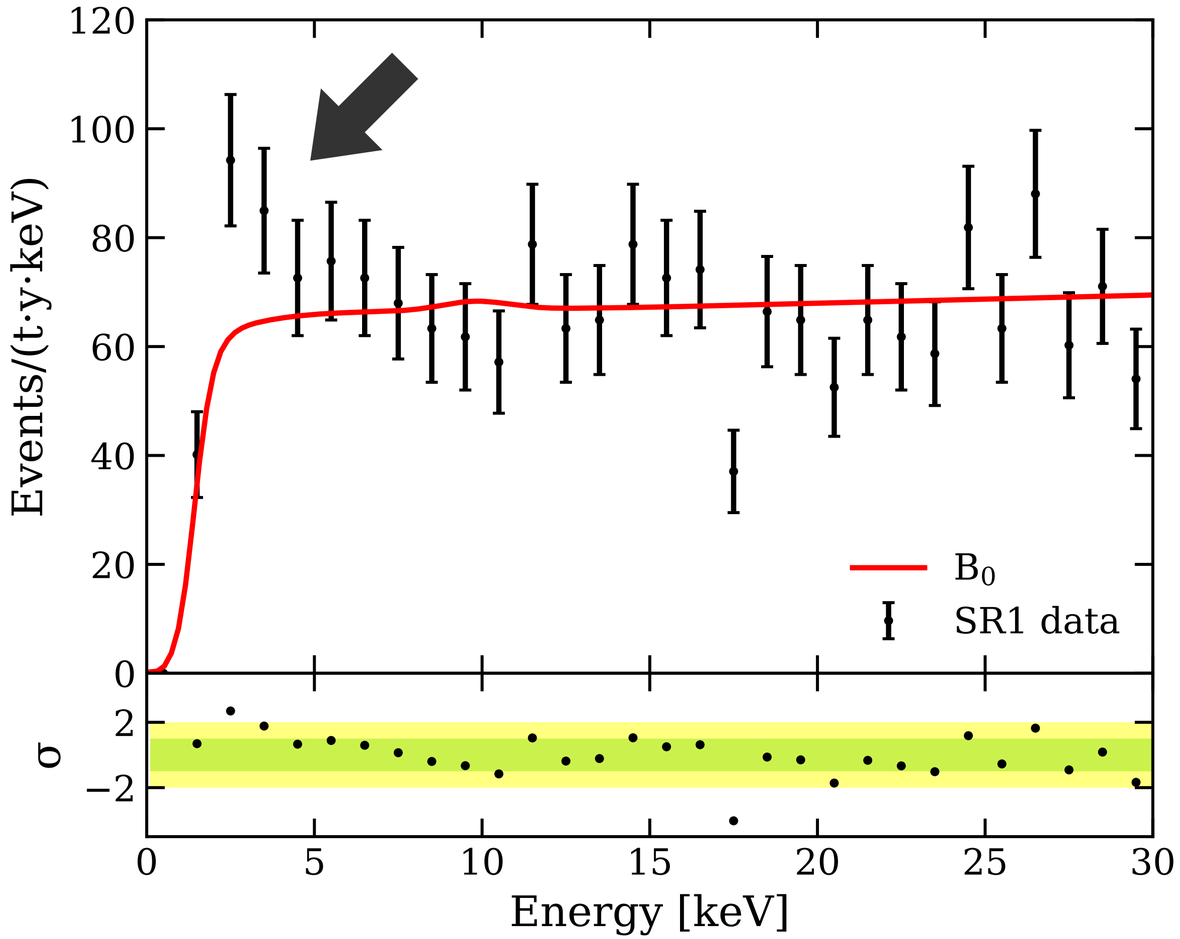

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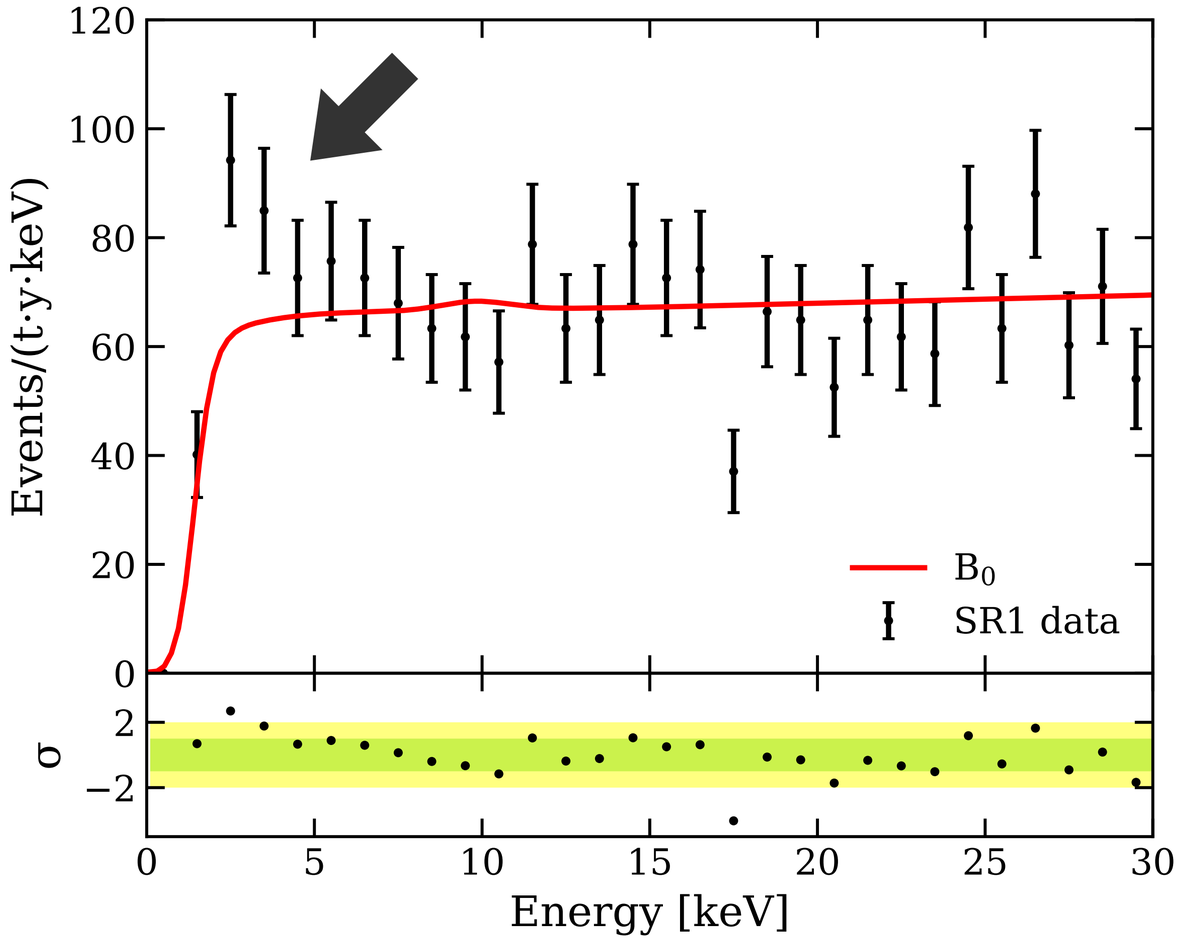
Statistical fluke?



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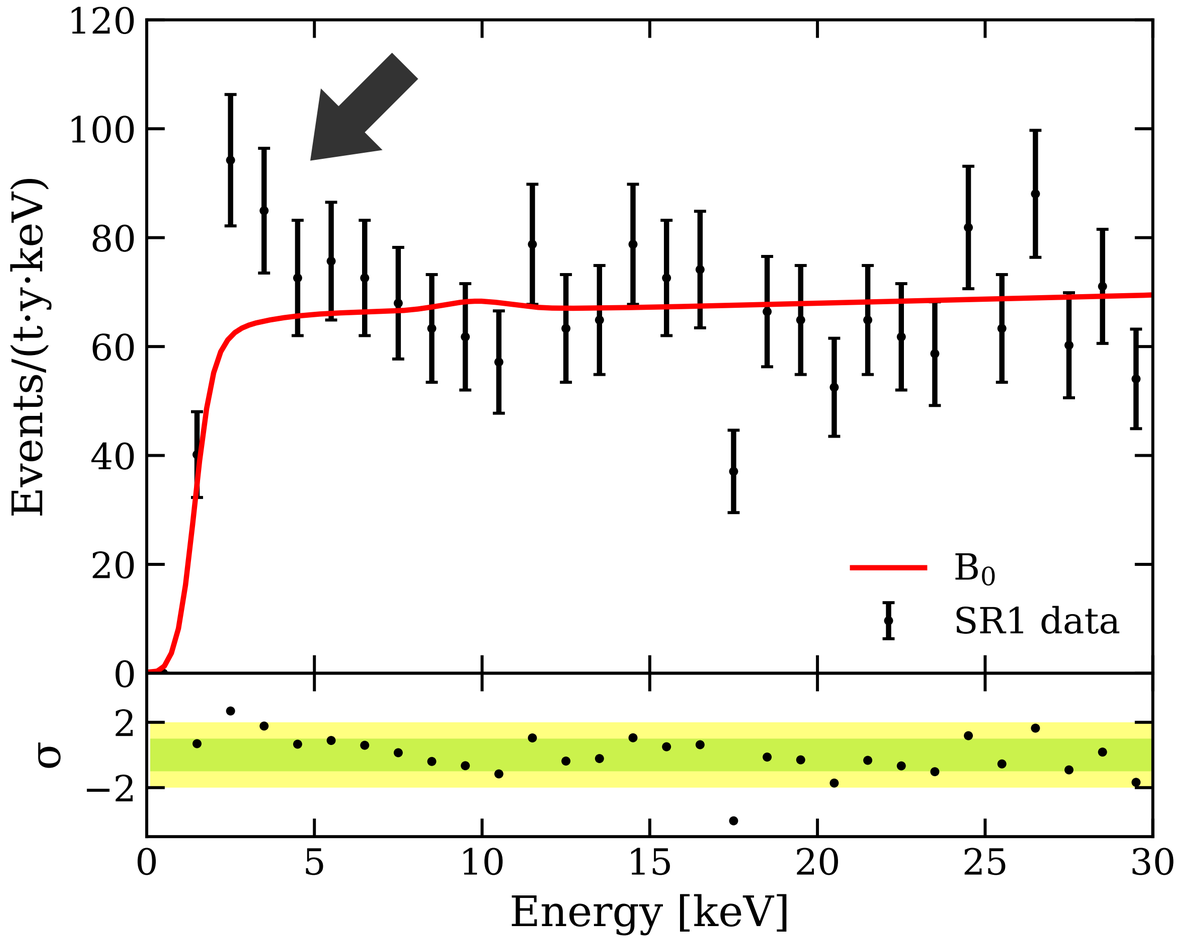

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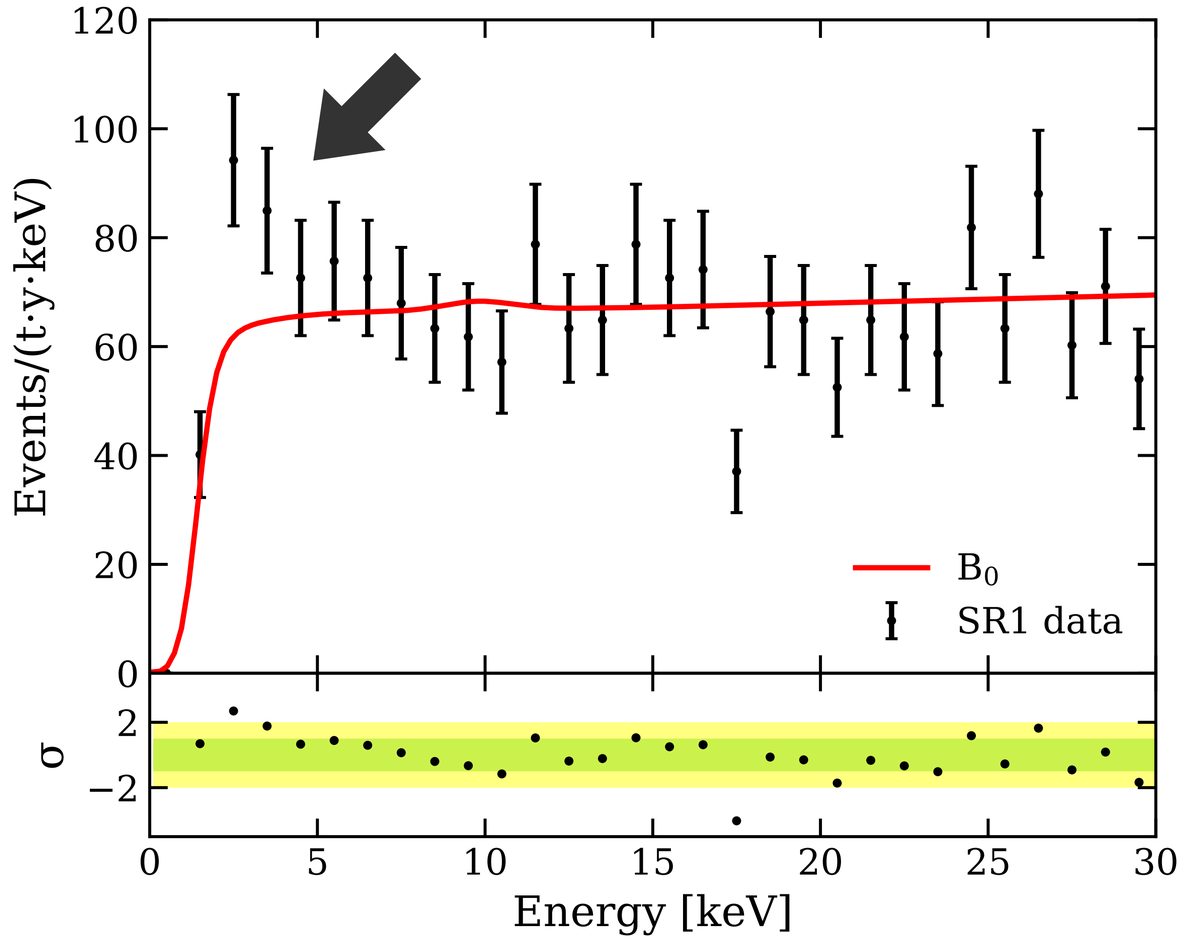

Systematic effects?

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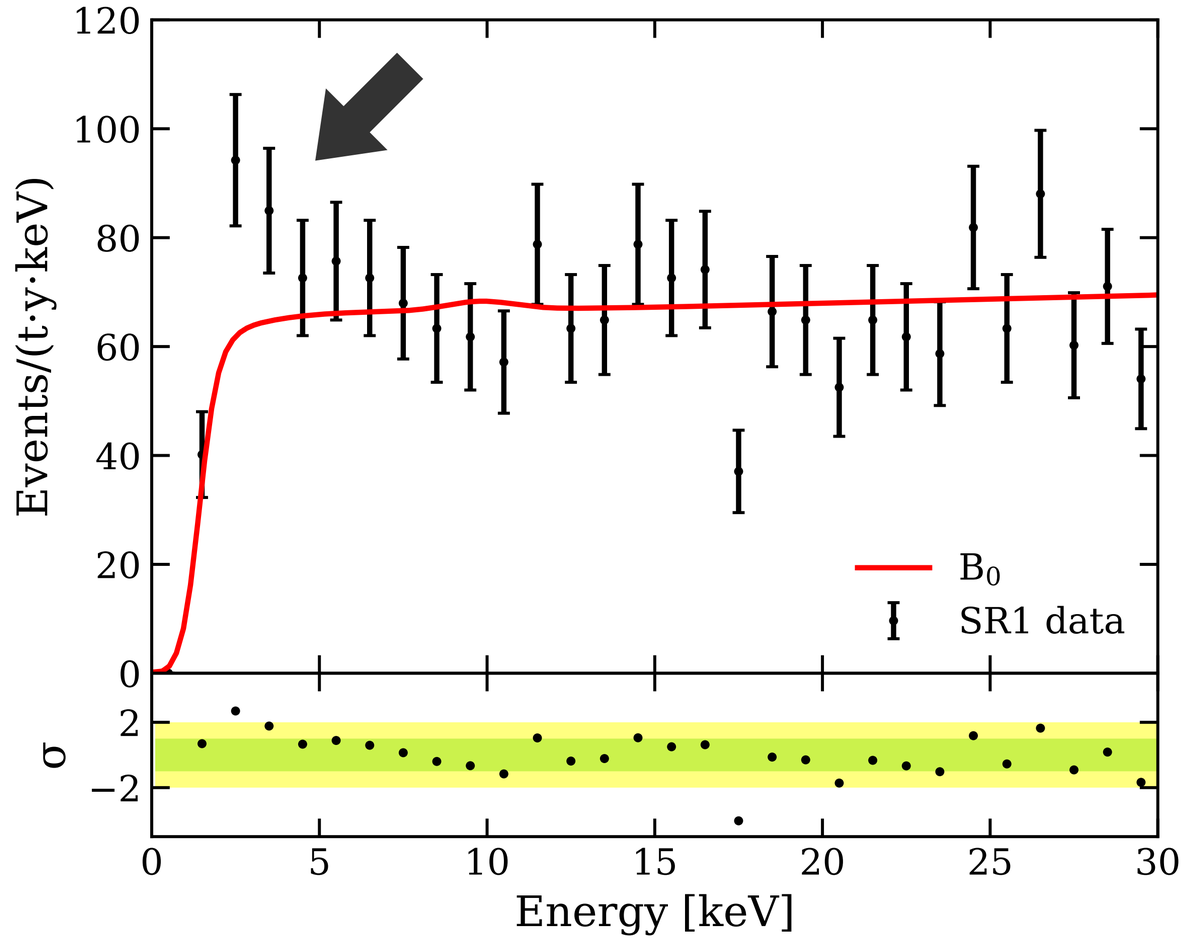

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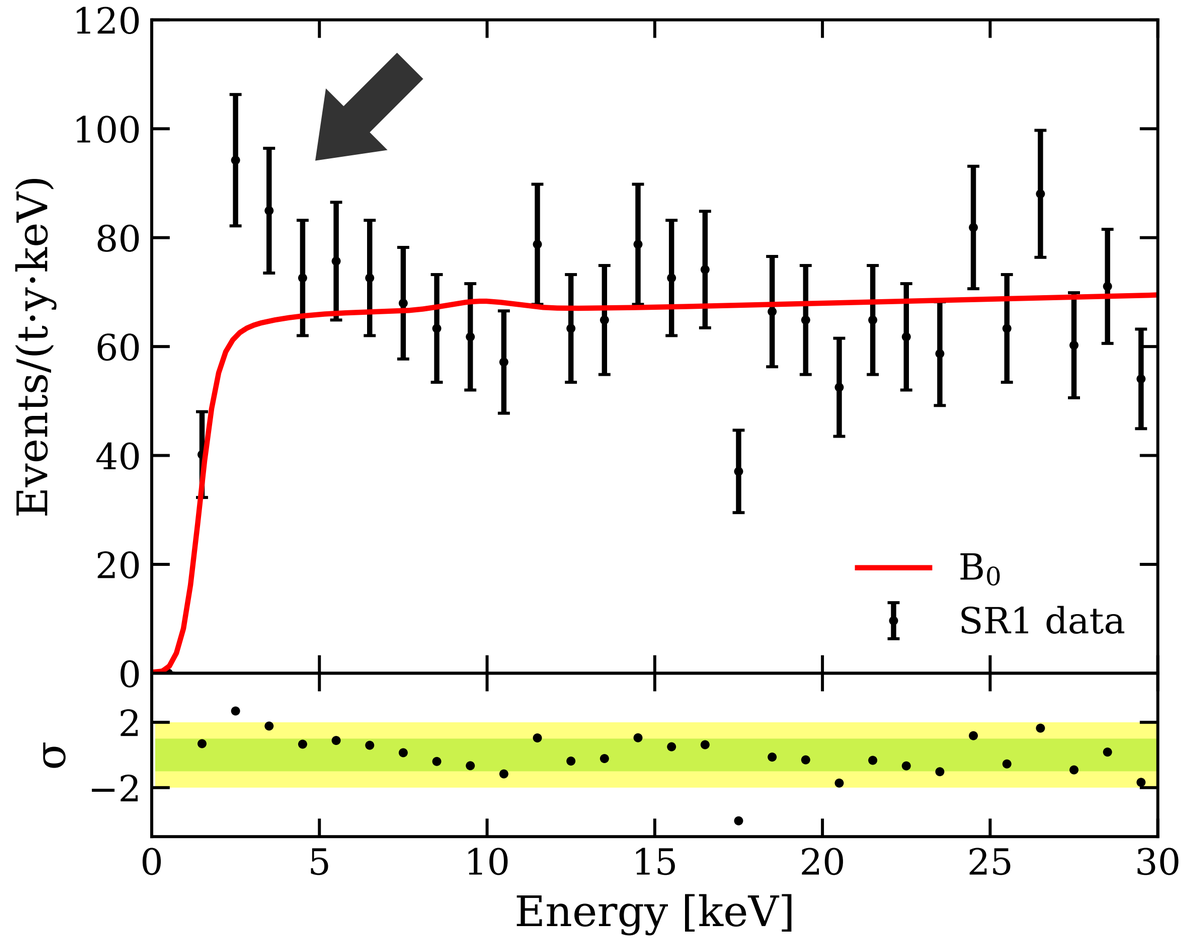

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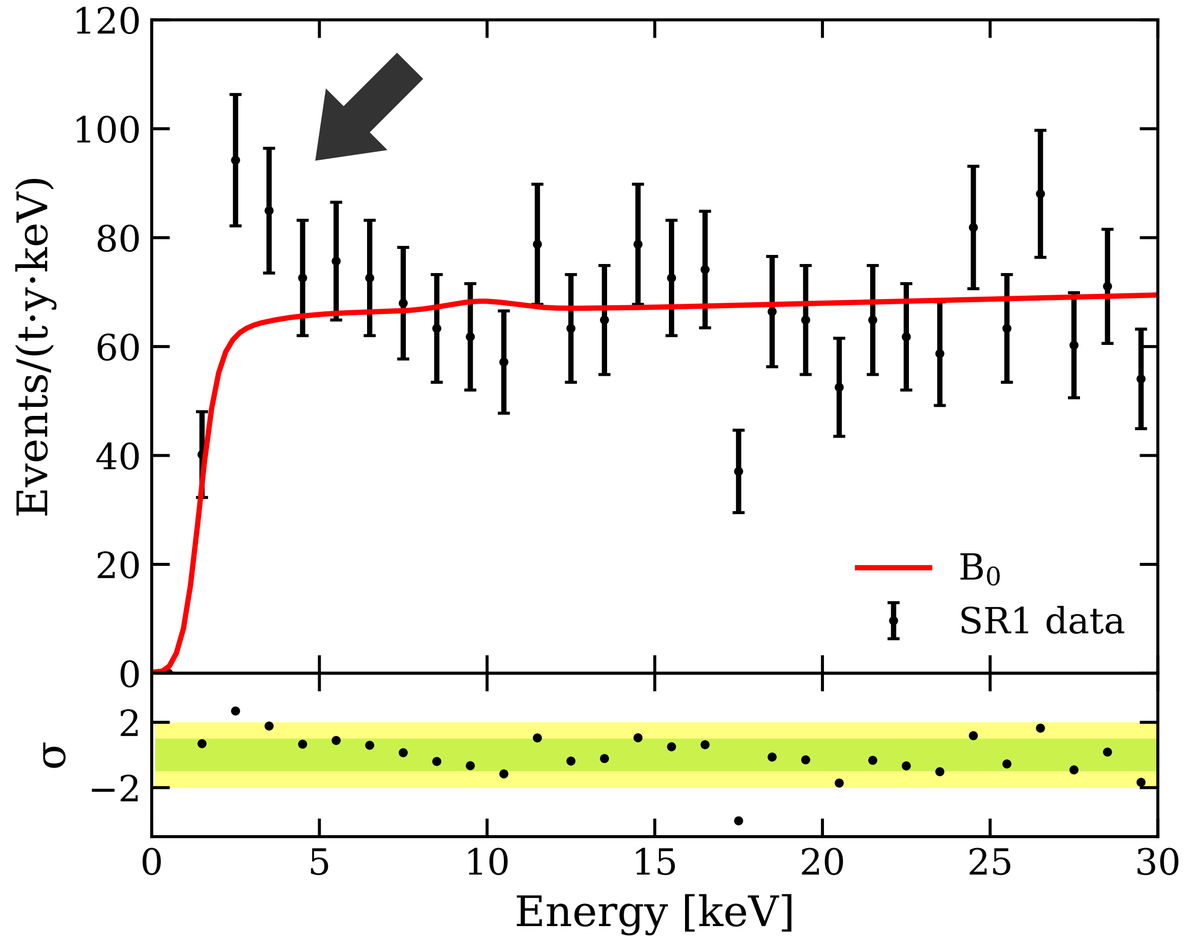

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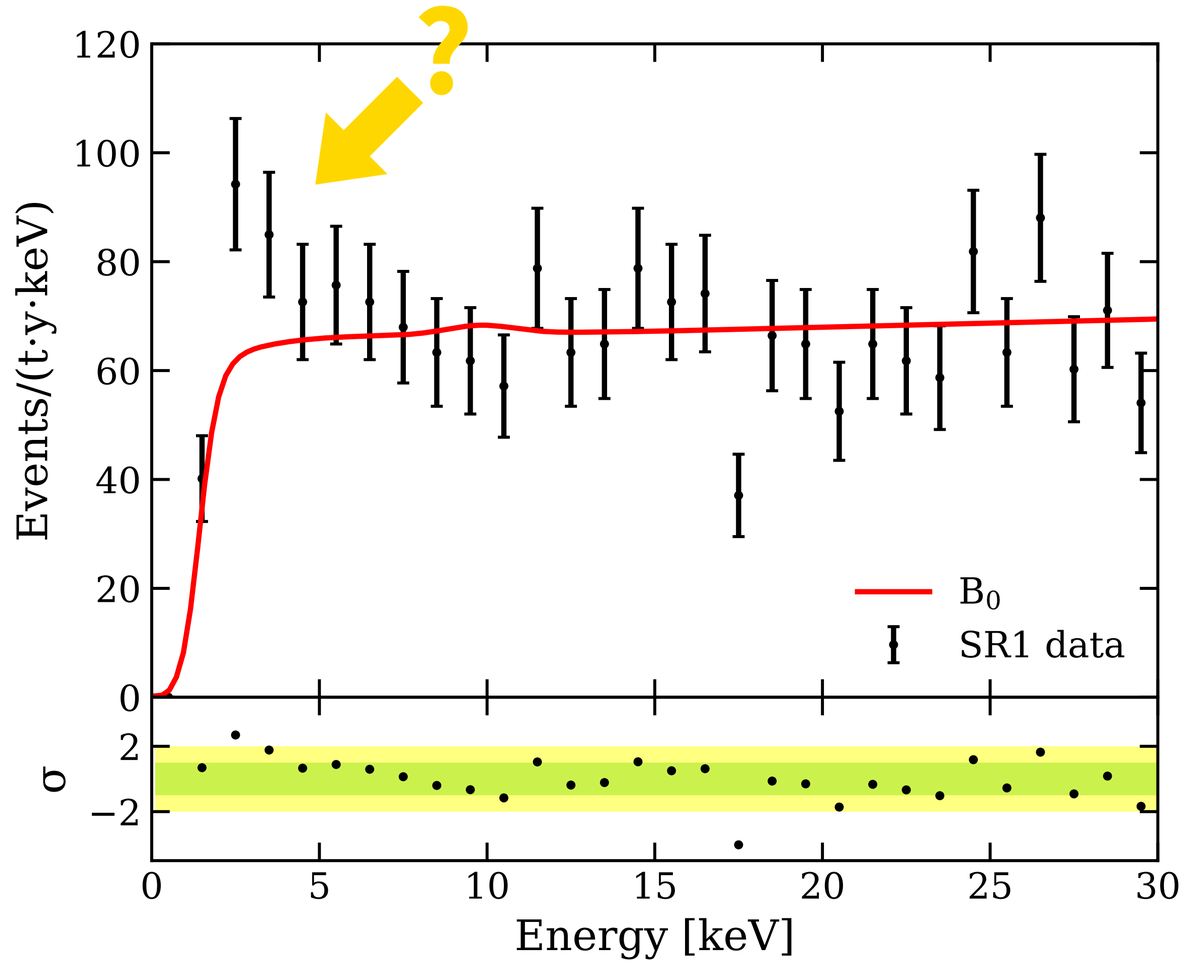

New physics?

Many models, three approaches considered in our paper

The axion hypothesis

PRD 102 (2020) 072004

- Hypothetical particle suggested as a **QCD strong *CP* problem solution**
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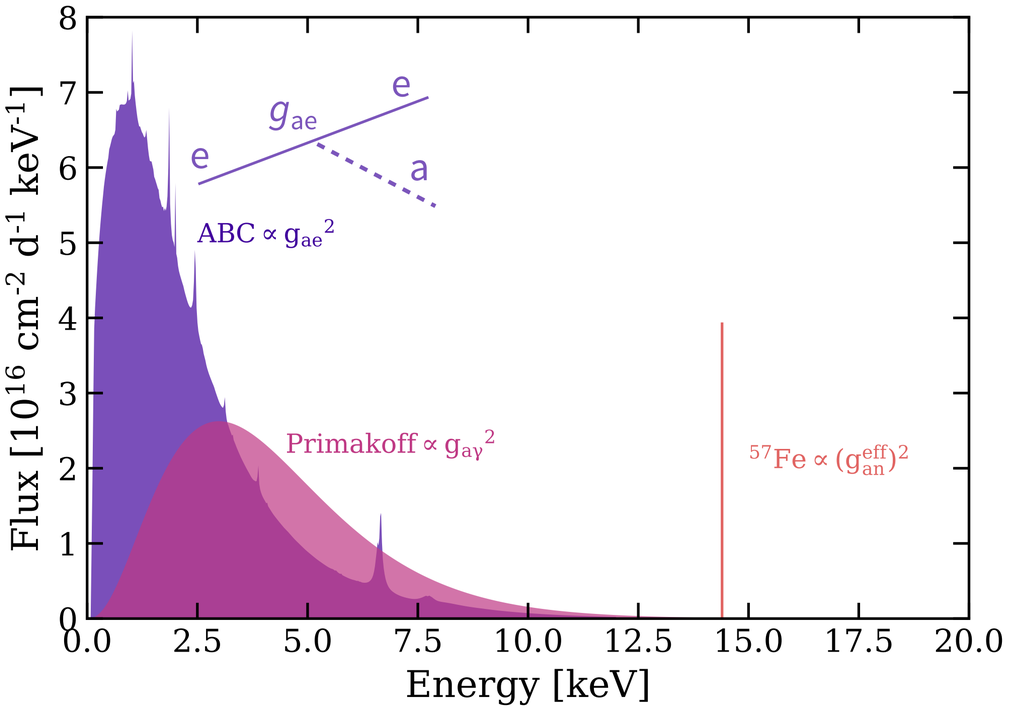

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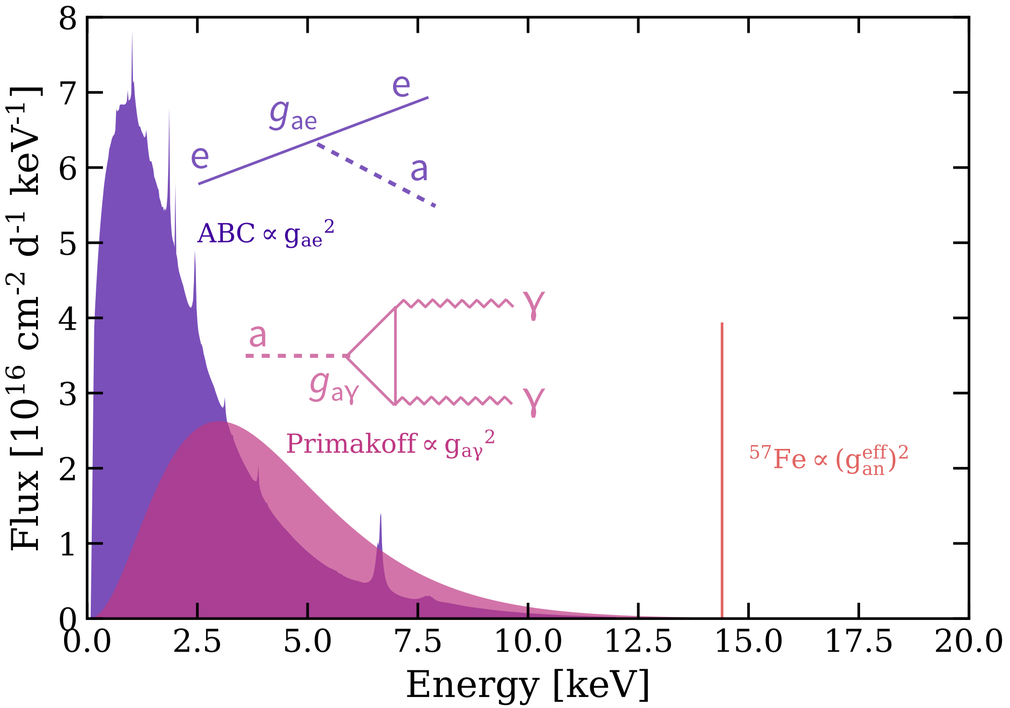

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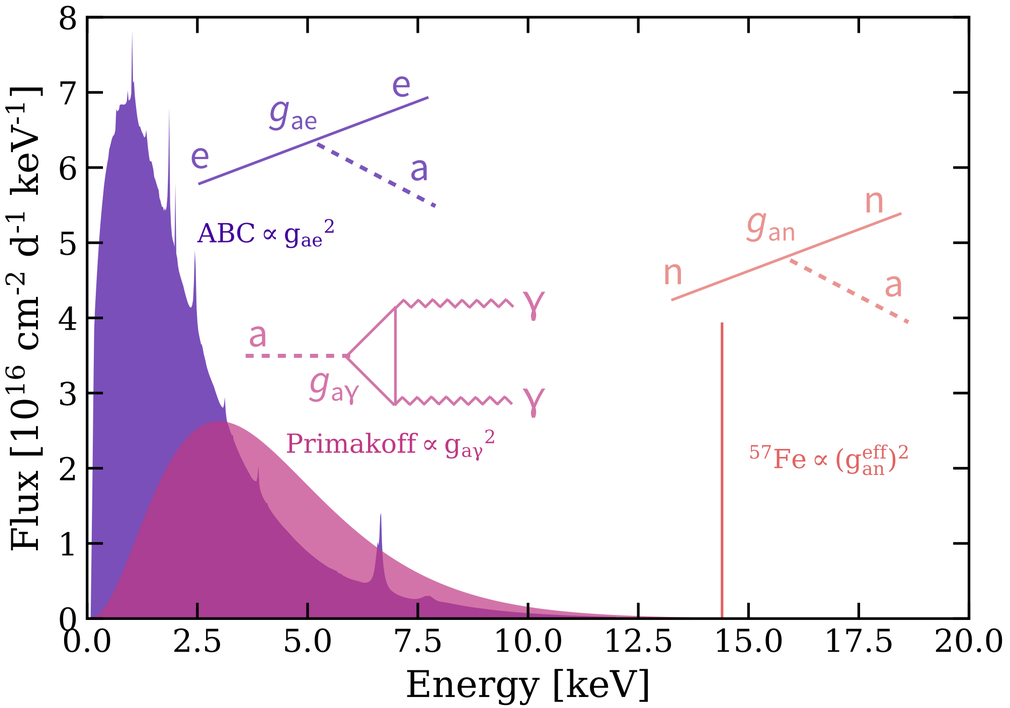

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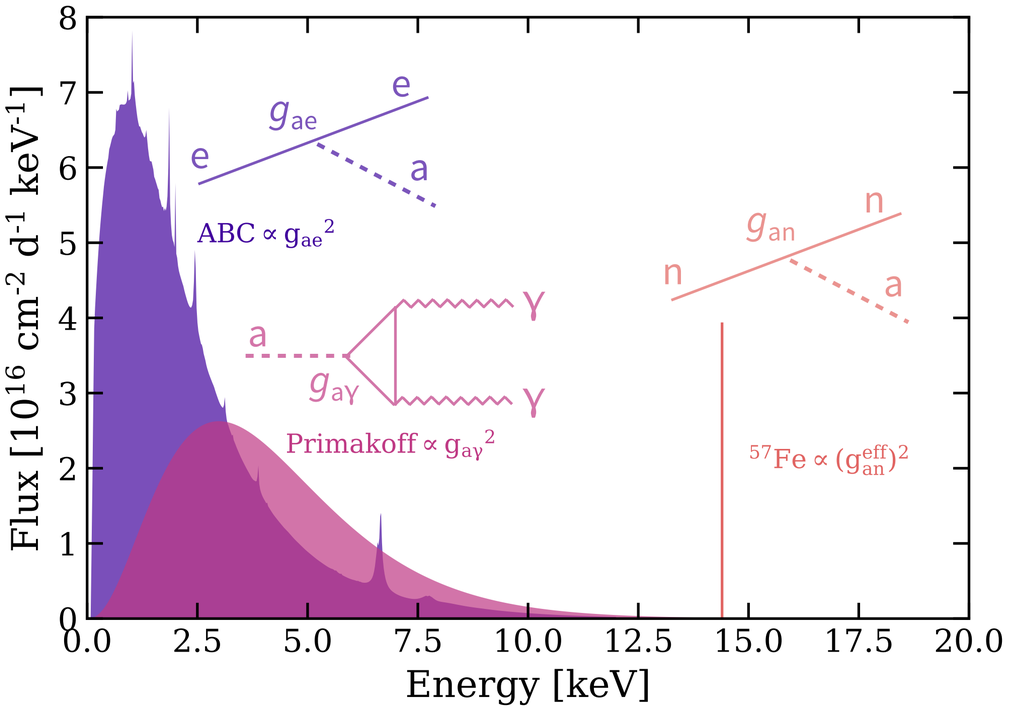

Xe
XENON
Dark Matter Project

Detection via axioelectric effect
$\propto (g_{ae})^2$
$\otimes$
Reconstruction effects

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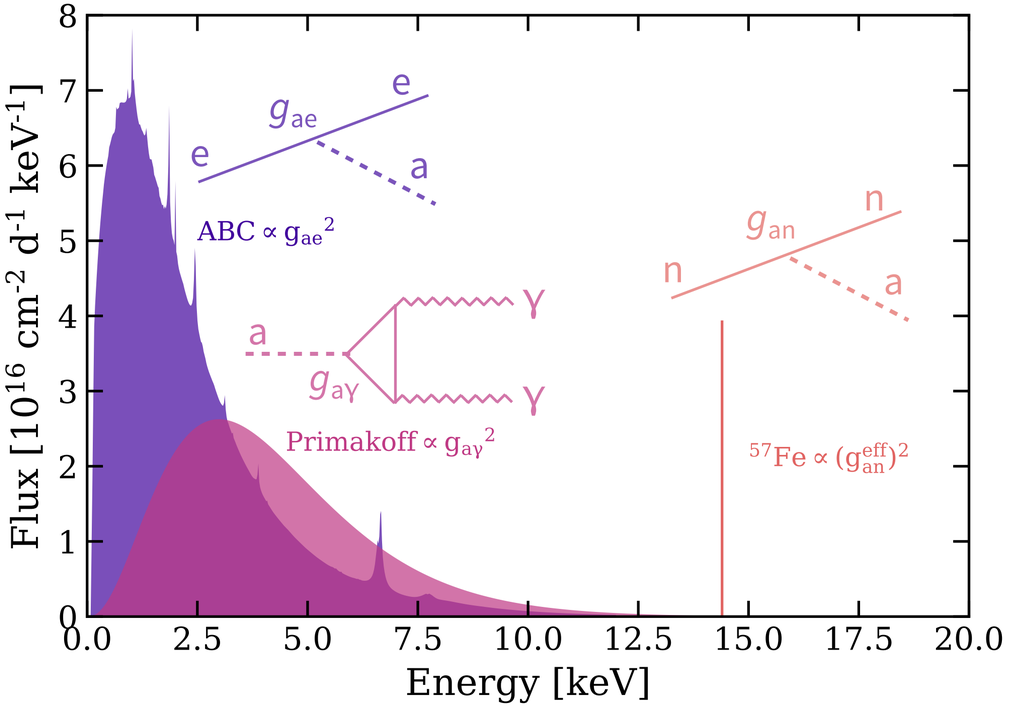

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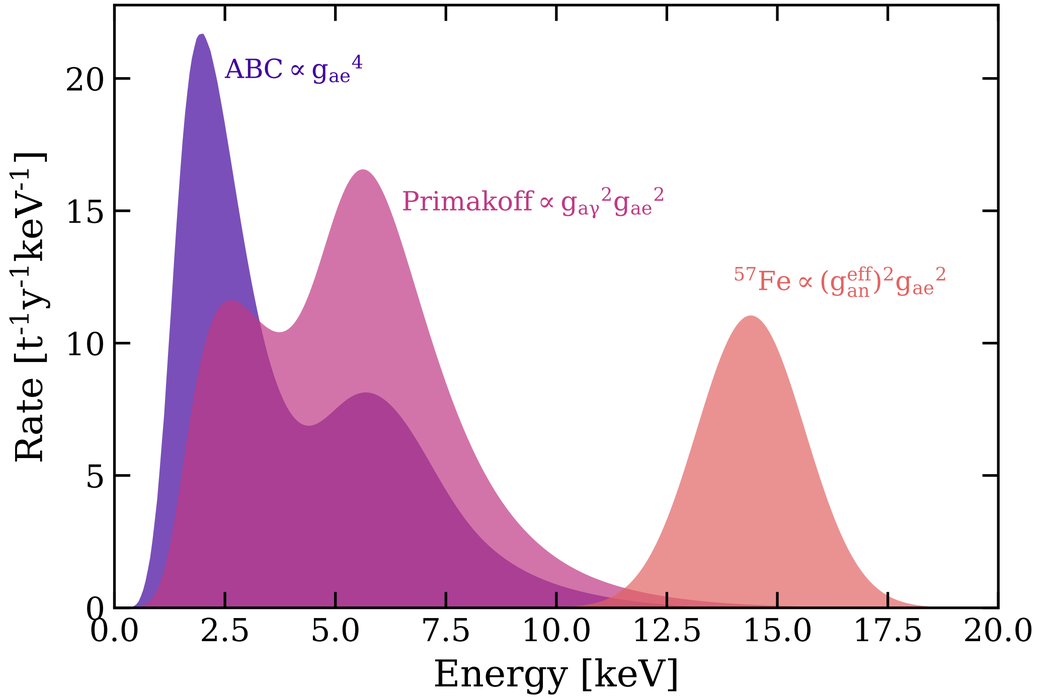
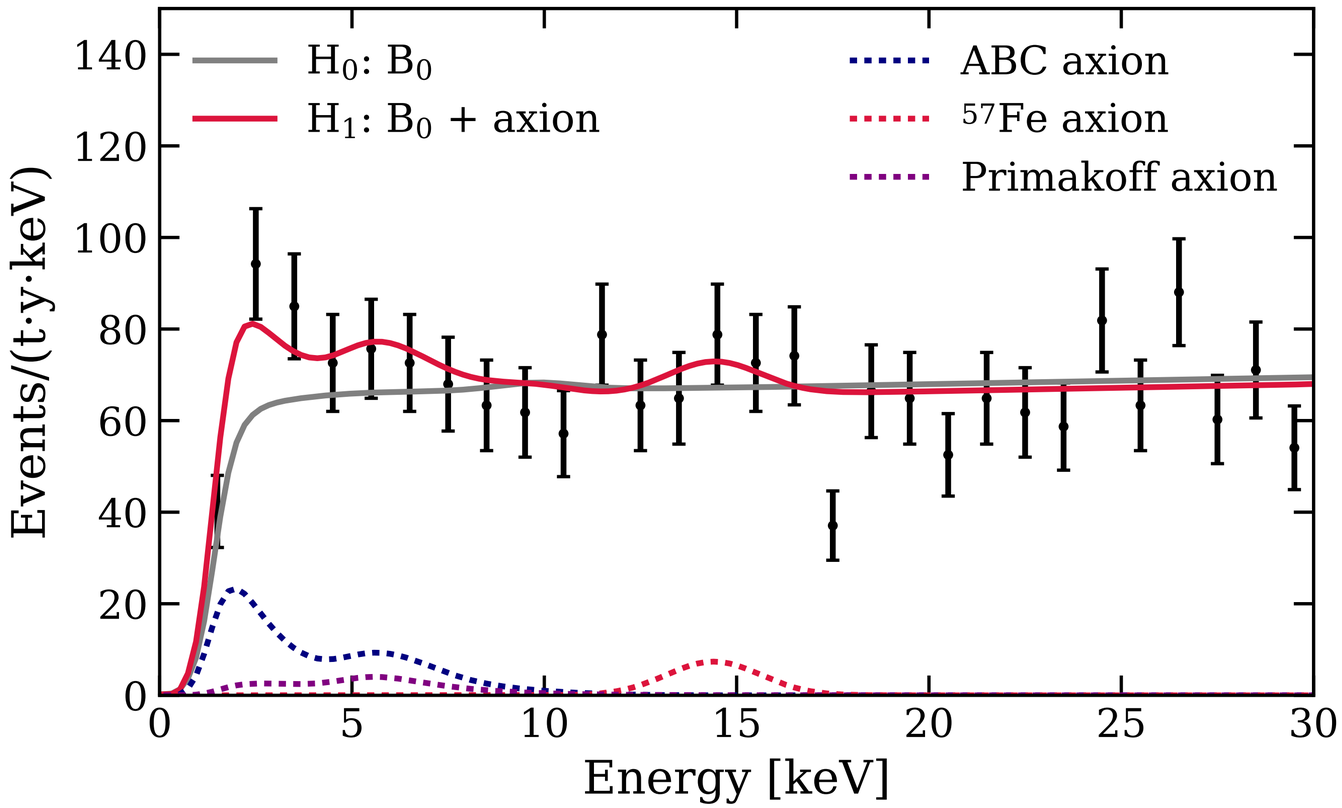


Solar axion results

PRD 102 (2020) 072004



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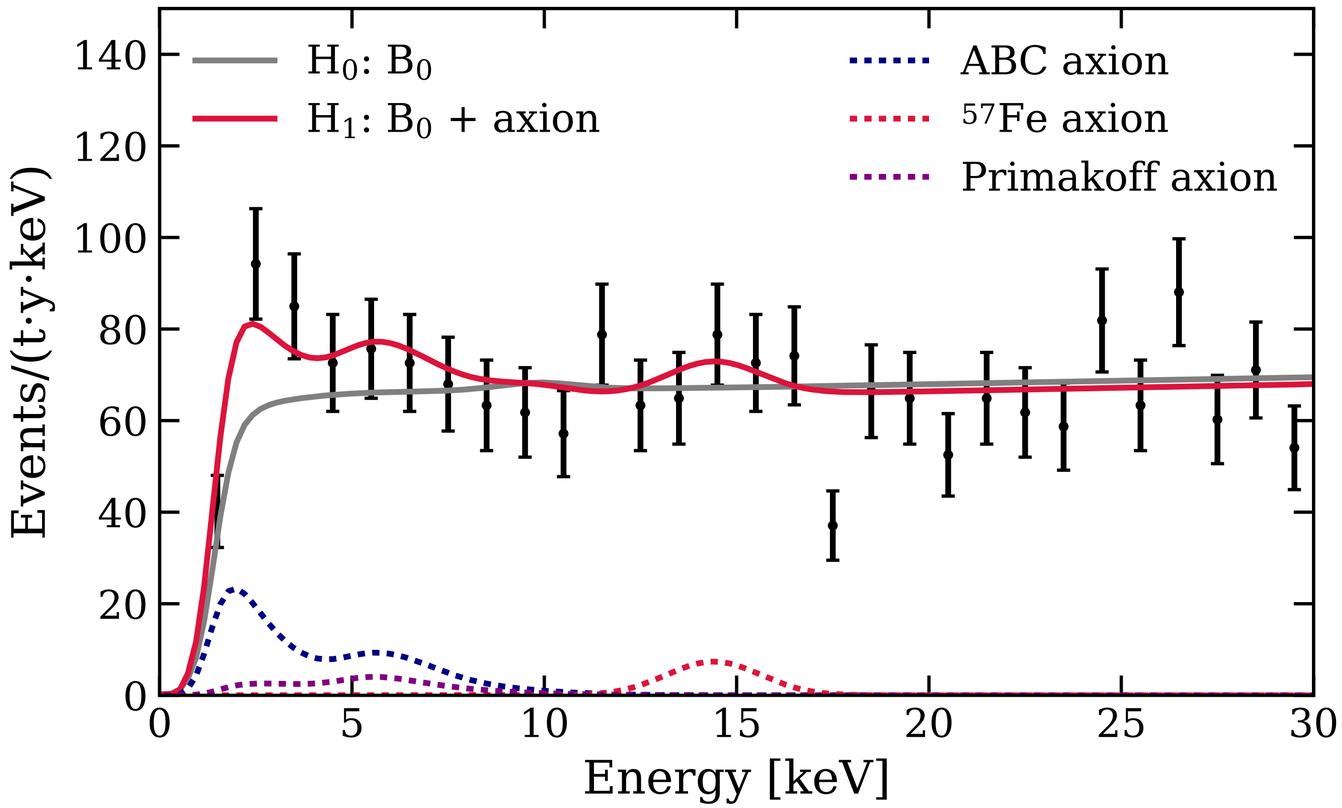

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Axion hypothesis favoured over B_0 at 3.4σ

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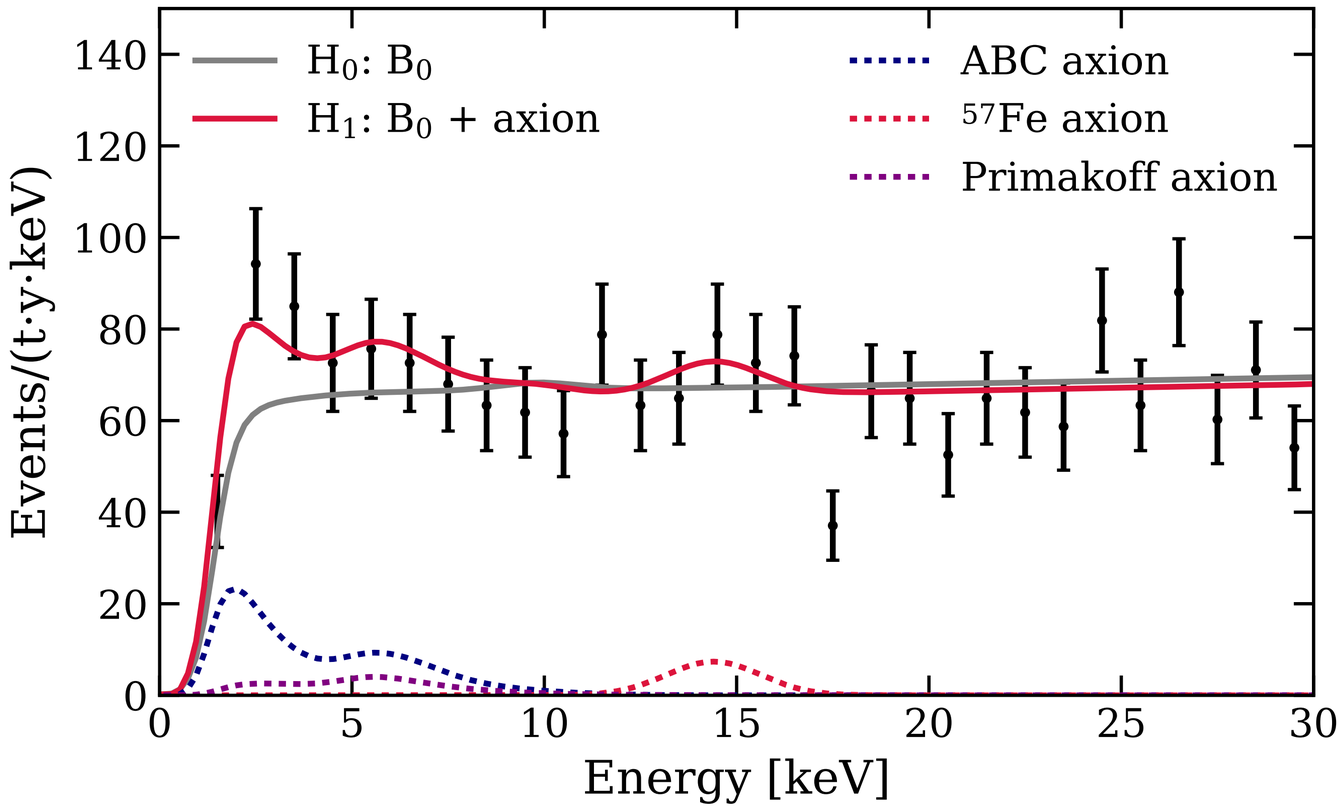
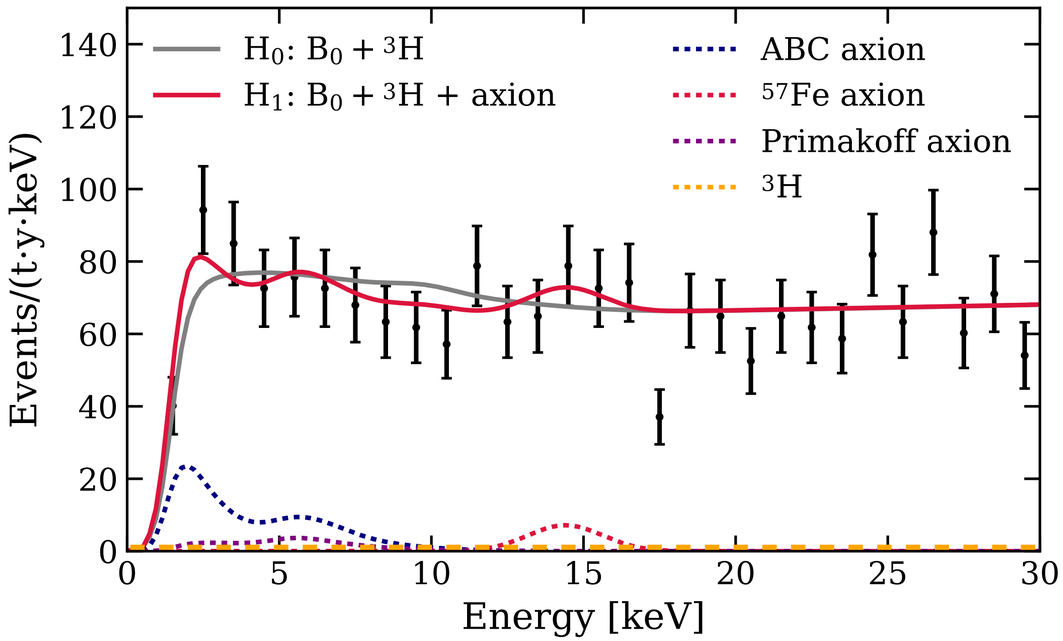


Axion hypothesis favoured over B_0 at 3.4σ

- Simultaneous search for **ABC**, **Primakoff** and **^{57}Fe** axions (unconstrained components in the fit)
- Axion hypothesis **still favoured over B_0 + tritium** at 2.0σ



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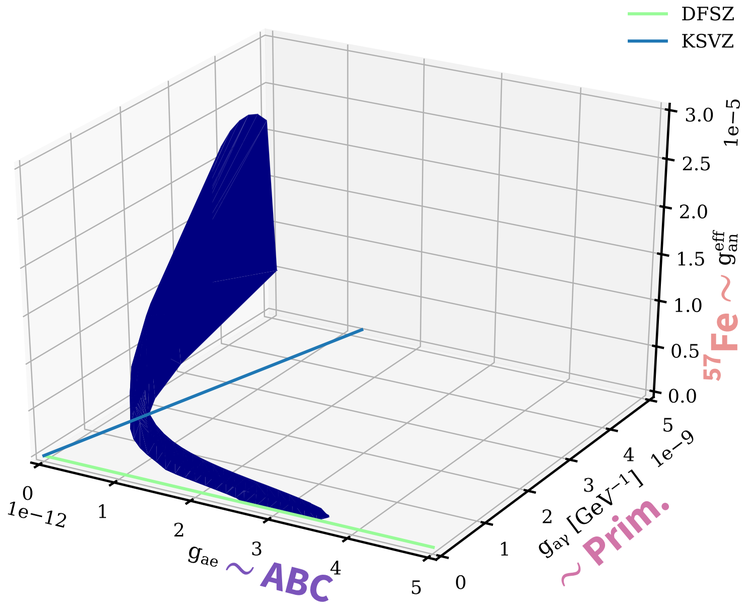
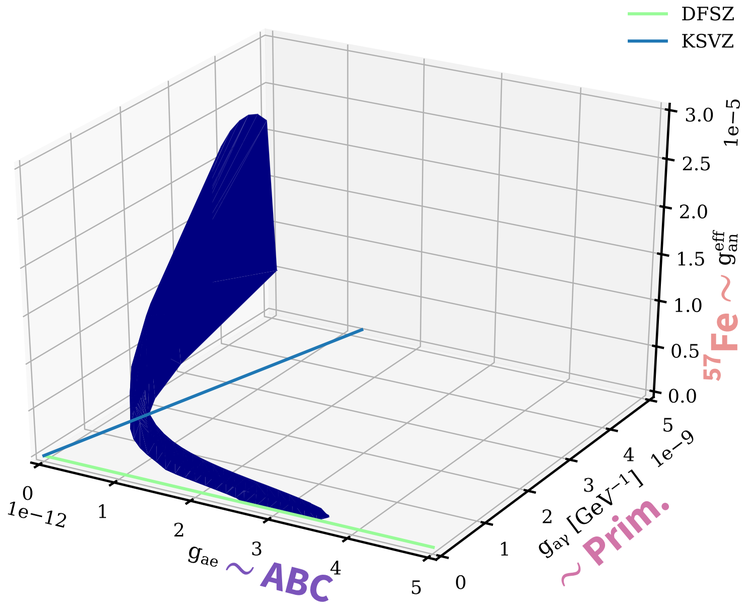
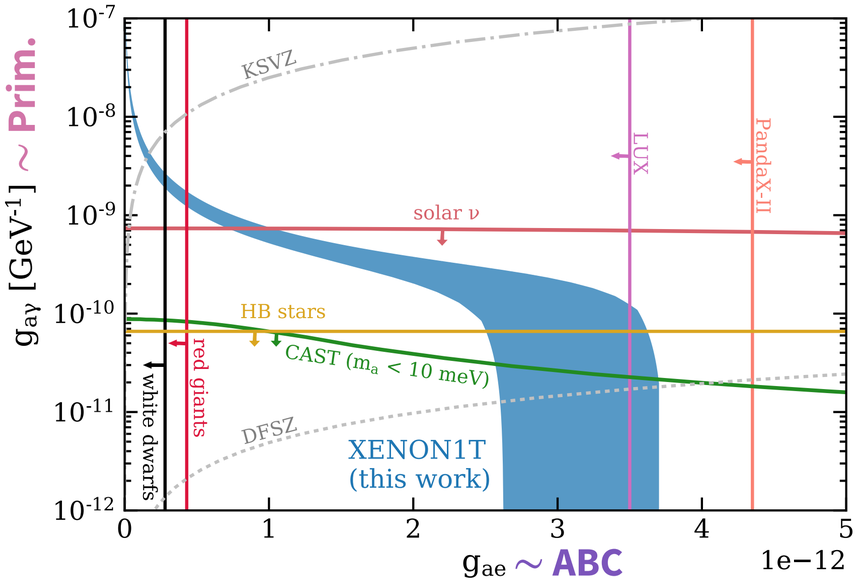


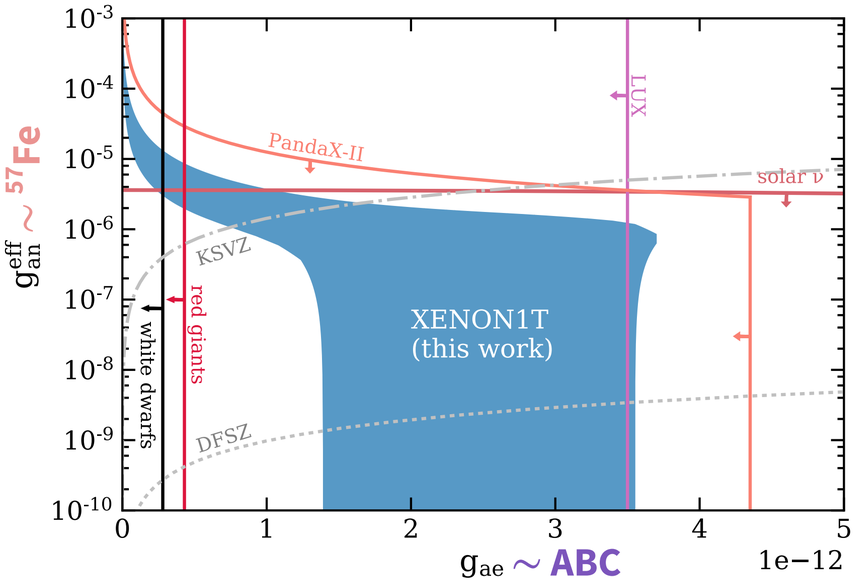
- 3D 90% C.L. volume g_{ae} vs. $g_{ae}\,g_{a\gamma}$ vs. $g_{ae}\,g_{an}^{eff}$

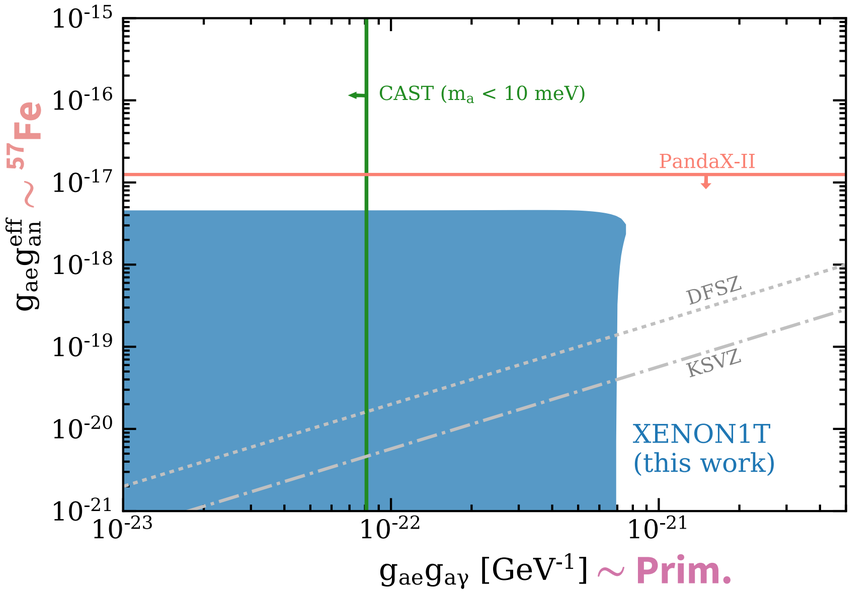
Solar axion results

PRD 102 (2020) 072004







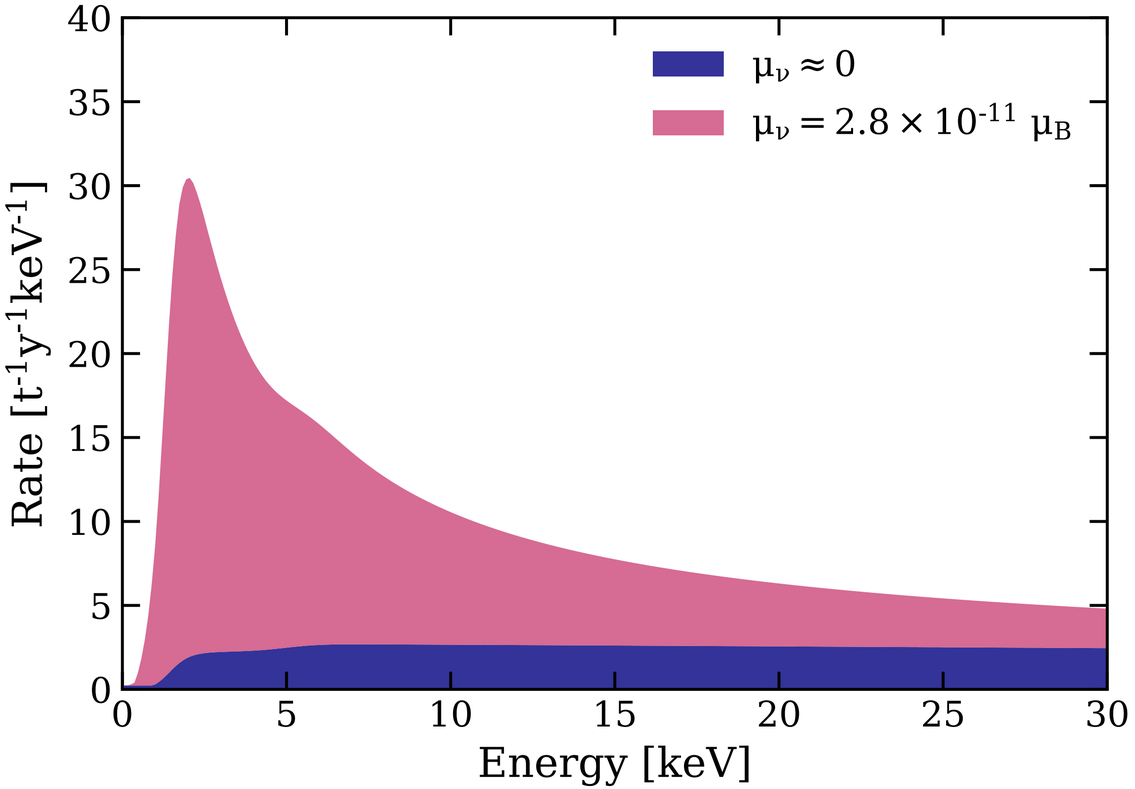


- 3D 90% C.L. volume g_{ae} vs. $g_{ae}\,g_{a\gamma}$ vs. $g_{ae}\,g_{an}^{eff}$
- Exclusion of $g_{ae} = 0$ **OR** $g_{ae}\,g_{a\gamma} = g_{ae}\,g_{an}^{eff} = 0$
- **Strong tension** with stellar cooling constraints

The ν magnetic moment hypothesis

PRD 102 (2020) 072004

- SM extensions → **magnetic moment μ_ν** enhancing ν–e⁻ cross section **at low energy**
- Cherry on top, $\mu_\nu \gtrsim 10^{-15}\,\mu_B$ → neutrinos may be **Majorana** fermions



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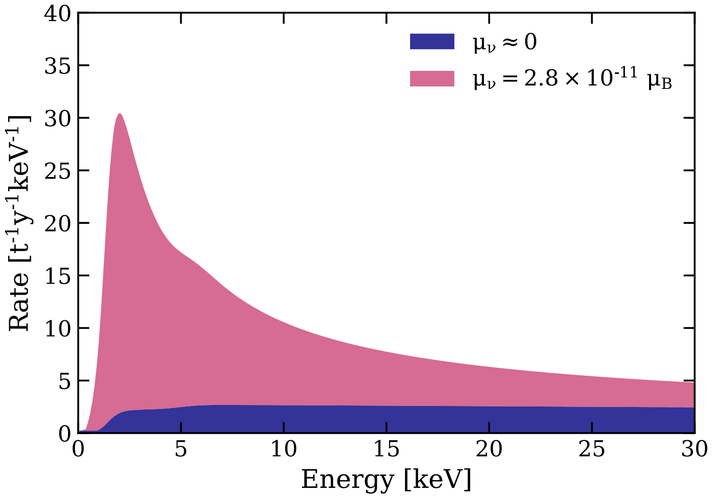

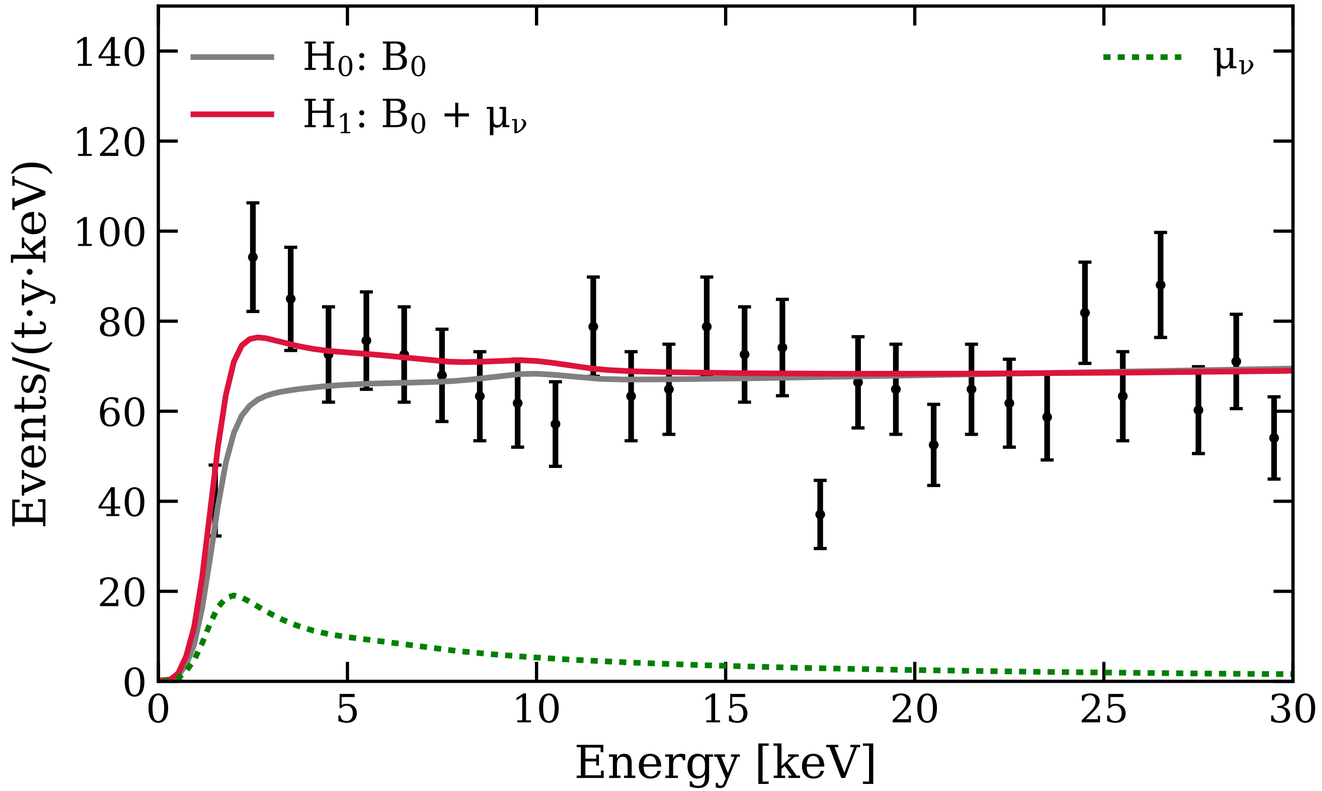

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- **Strong tension** with astrophysical limits but consistent with comparable Borexino results

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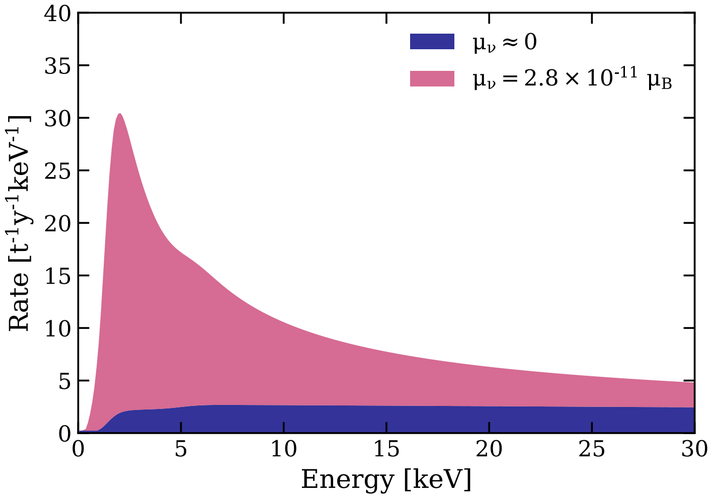
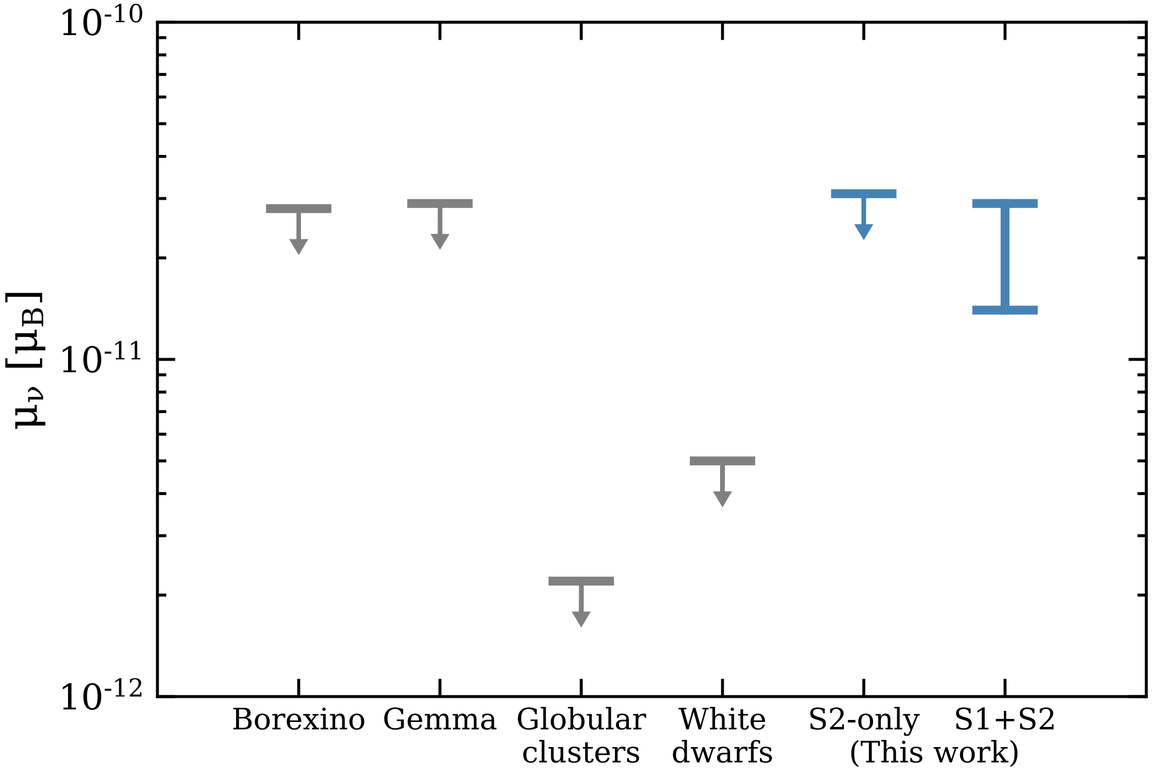




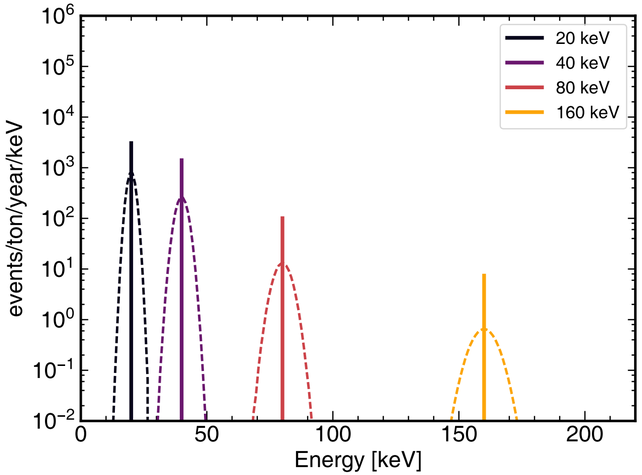
The bosonic Dark Matter hypothesis

PRD 102 (2020) 072004

- Searching for two main components as **monoenergetic peaks**

  → **Axion-Like Particles** ≈ axions ($\propto (g_{ae})^2$) with higher masses

  → **Dark photons**, could couple with photons ($\propto \kappa^2$) and be absorbed by photoelectric effect



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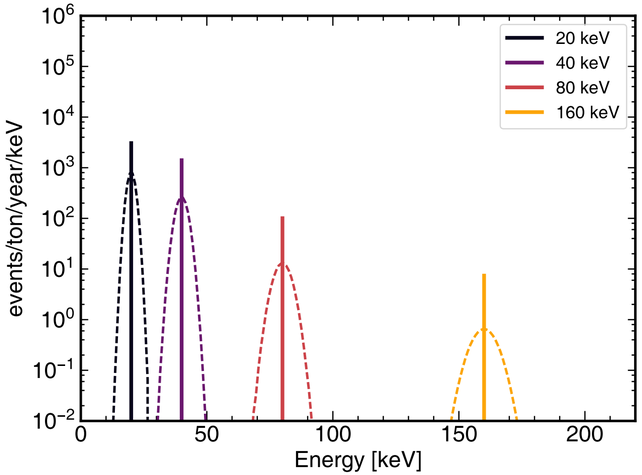
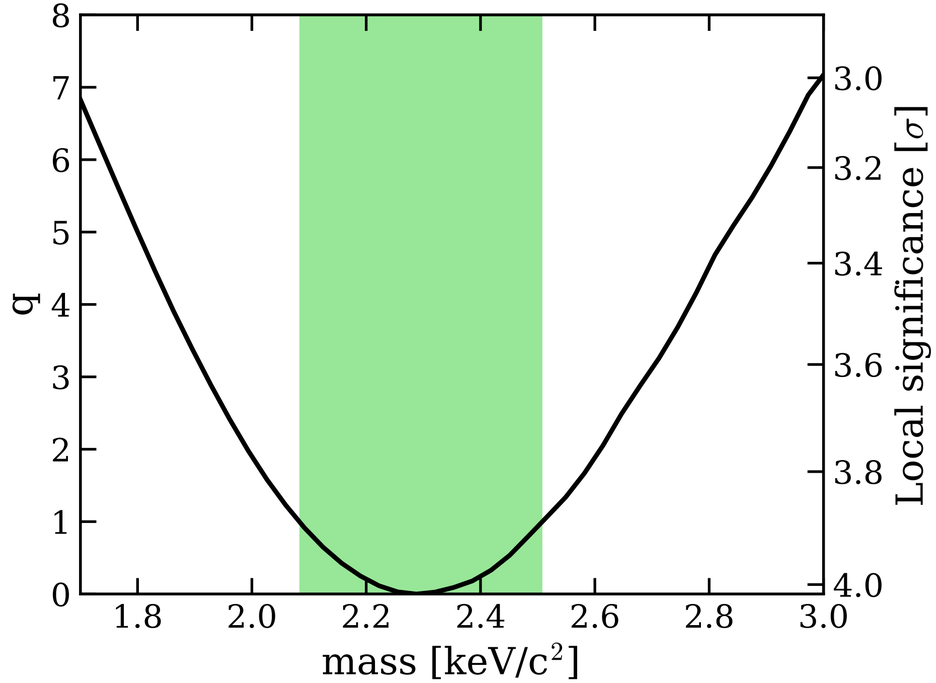
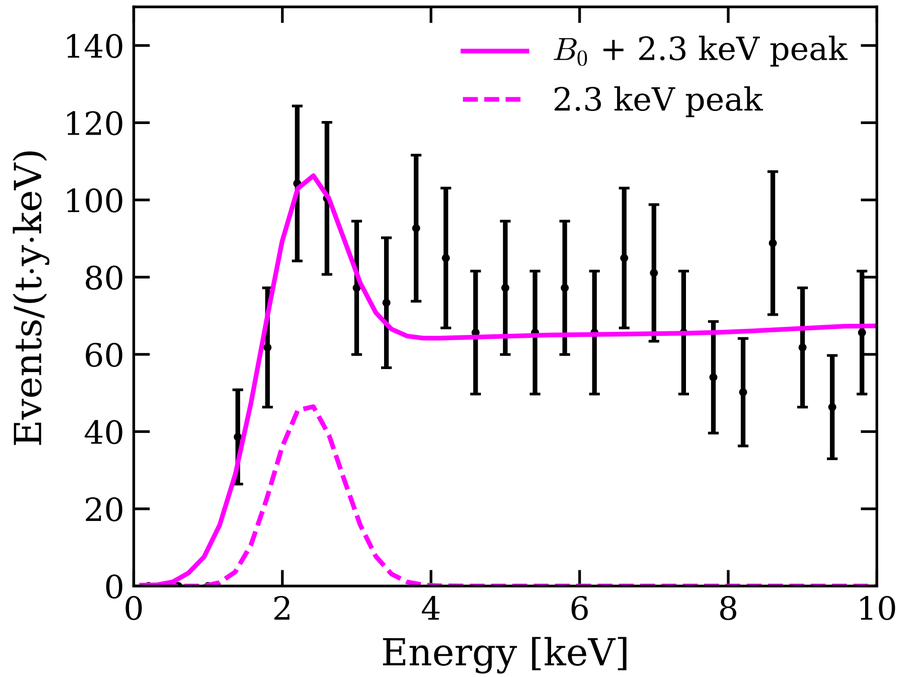


- Most significant at **(2.3 ± 0.2) keV/c²** (favoured at 3σ)





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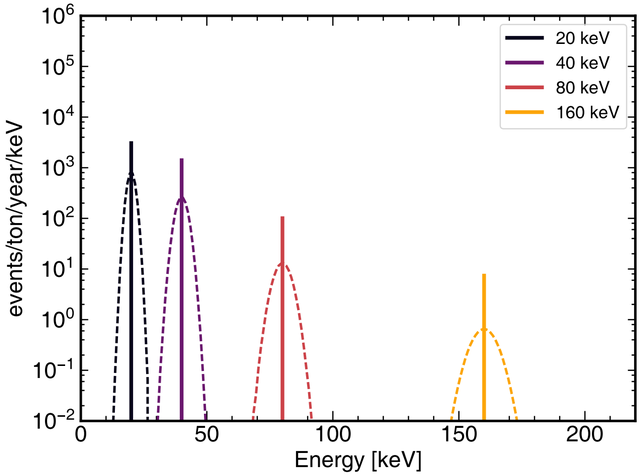
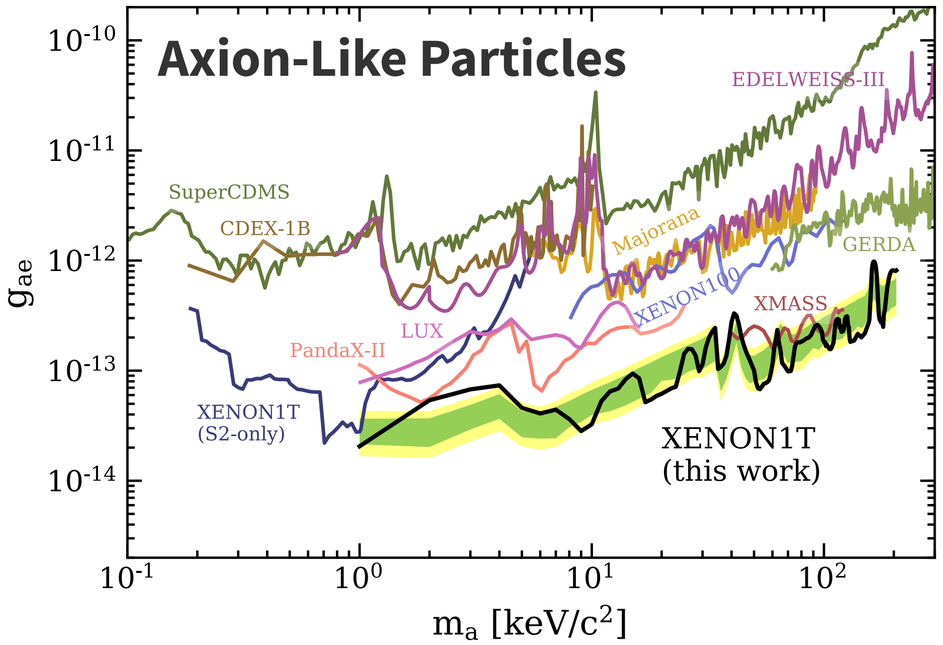
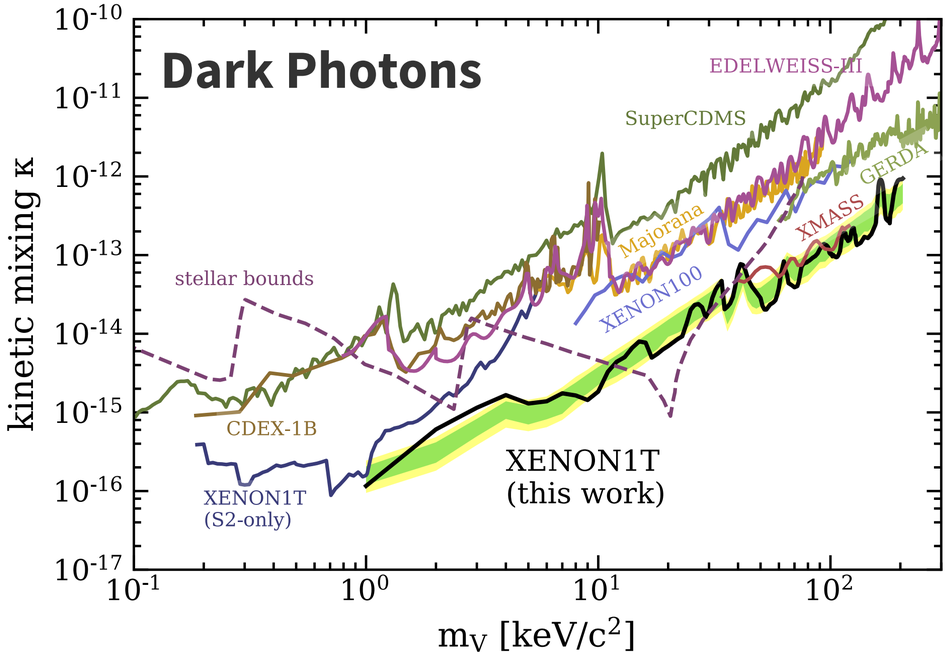


- Most significant at **(2.3 ± 0.2) keV/c²** (favoured at 3σ)
- No excess above 3σ → upper limits on g_{ae} and κ
- **Best limits overall**





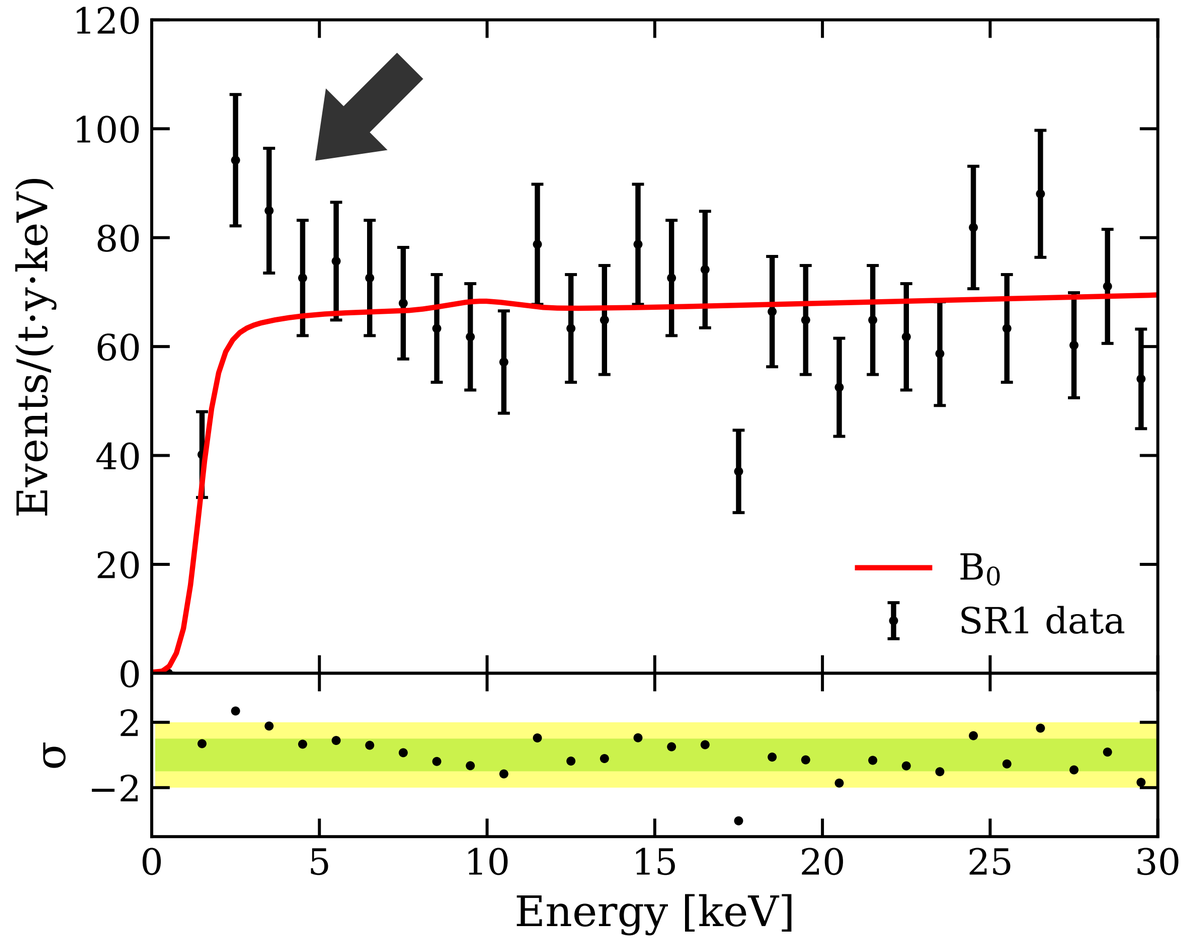
The low-energy excess

PRD 102 (2020) 072004

UNLIKELY

UNLIKELY

POSSIBLE



New physics?

Play with our data → https://doi.org/10.5281/zenodo.4273099

The low-energy excess

PRD 102 (2020) 072004

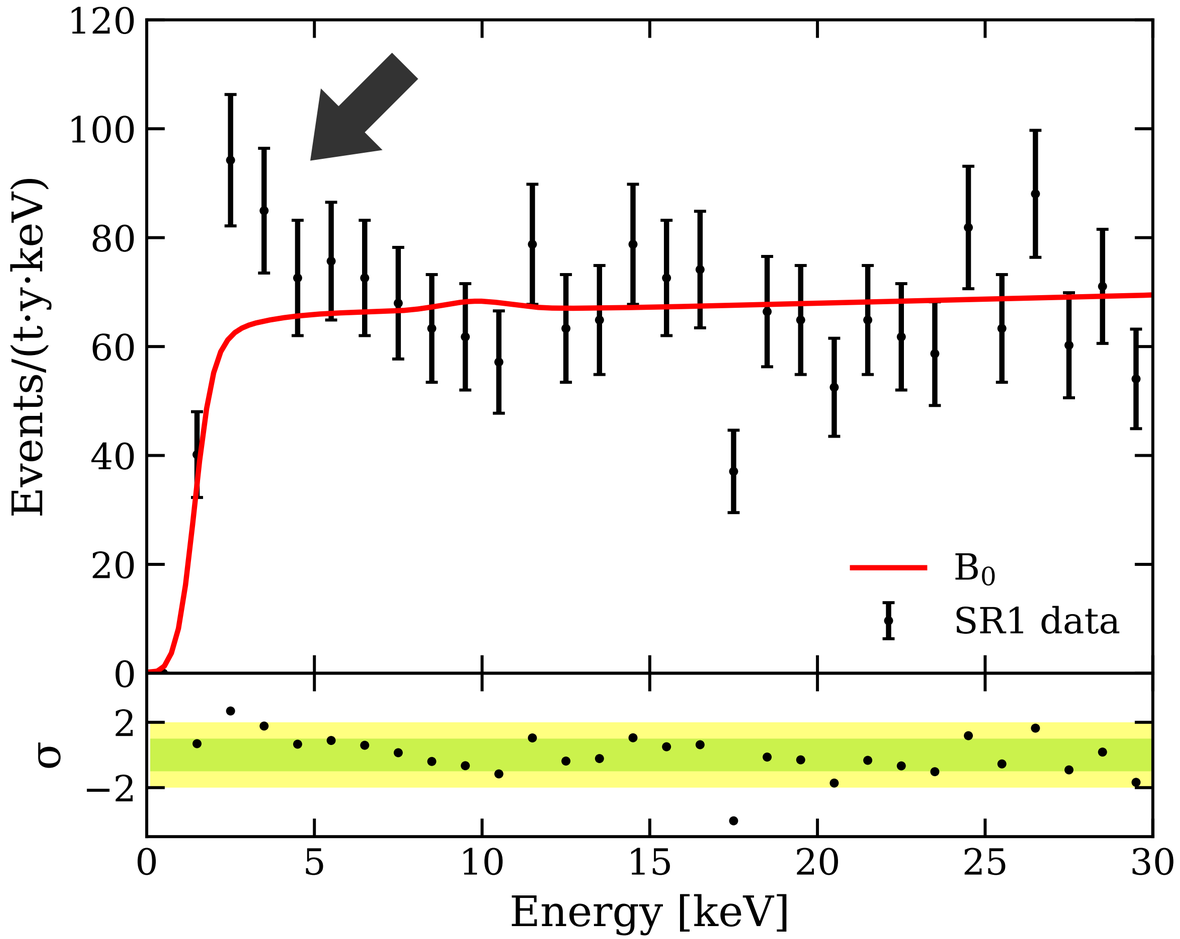
UNLIKELY

UNLIKELY

POSSIBLE

POSSIBLE

(And promising!)



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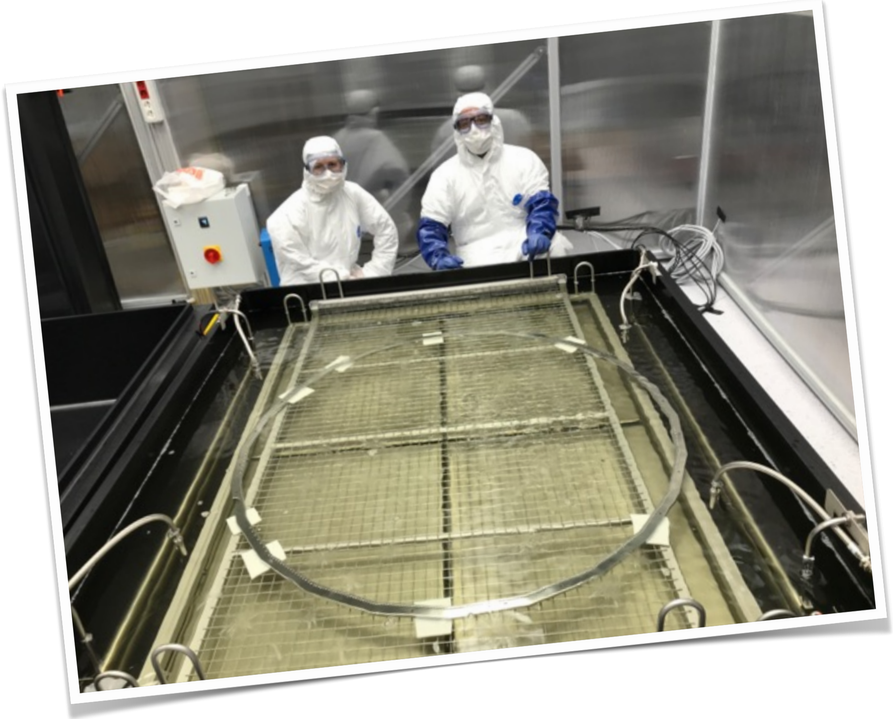
What’s next?

Meet XENONnT

Meet XENONnT



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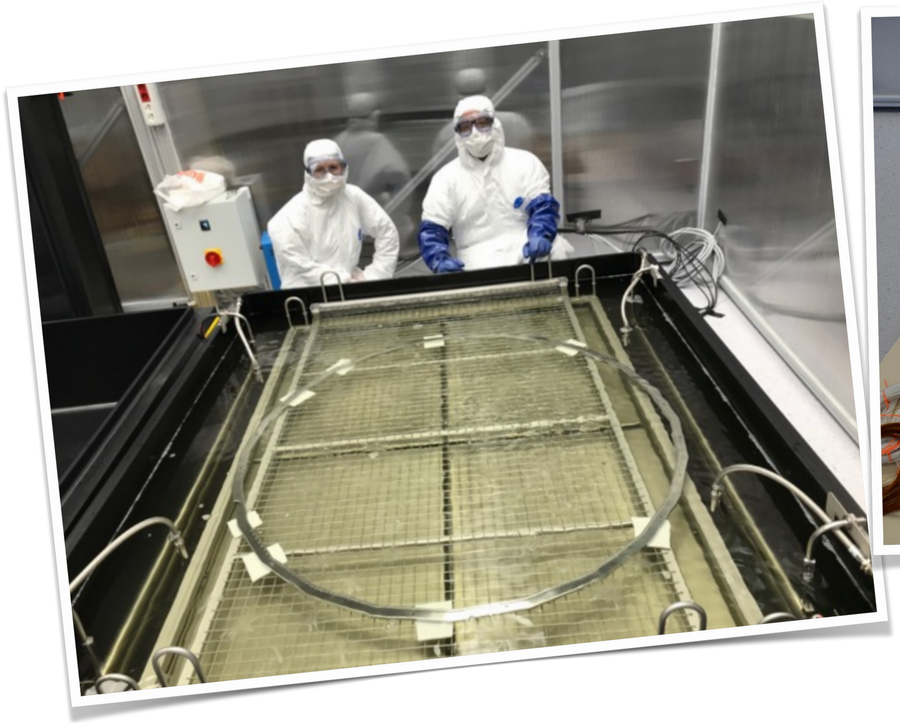

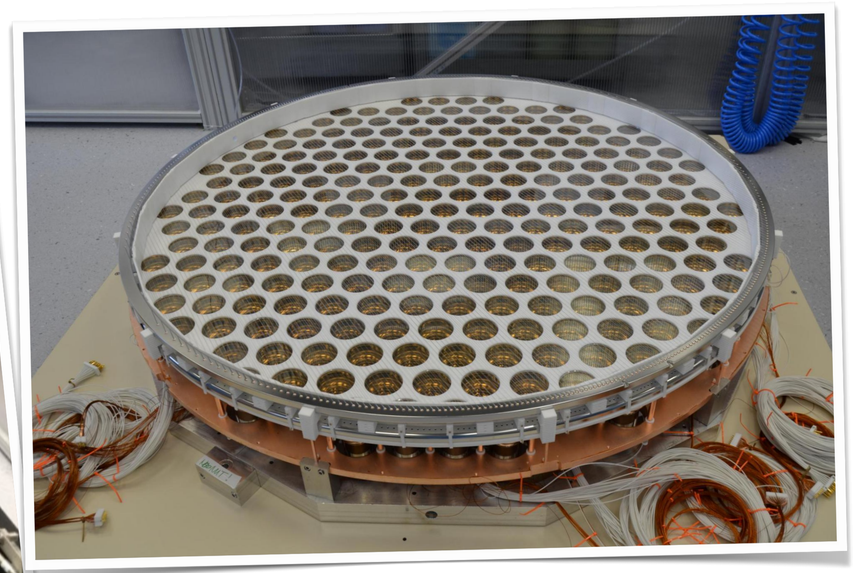

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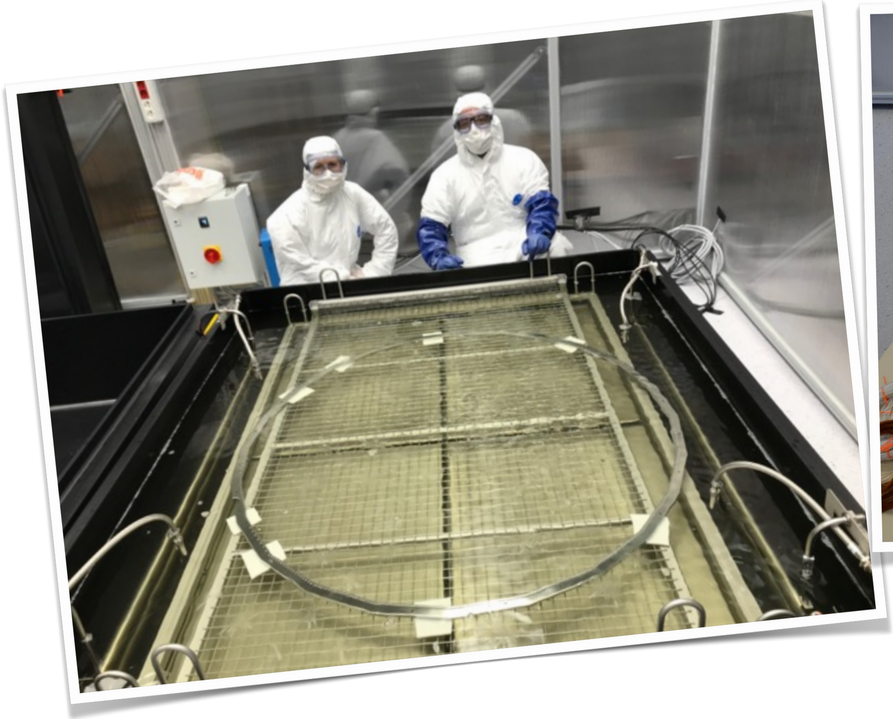

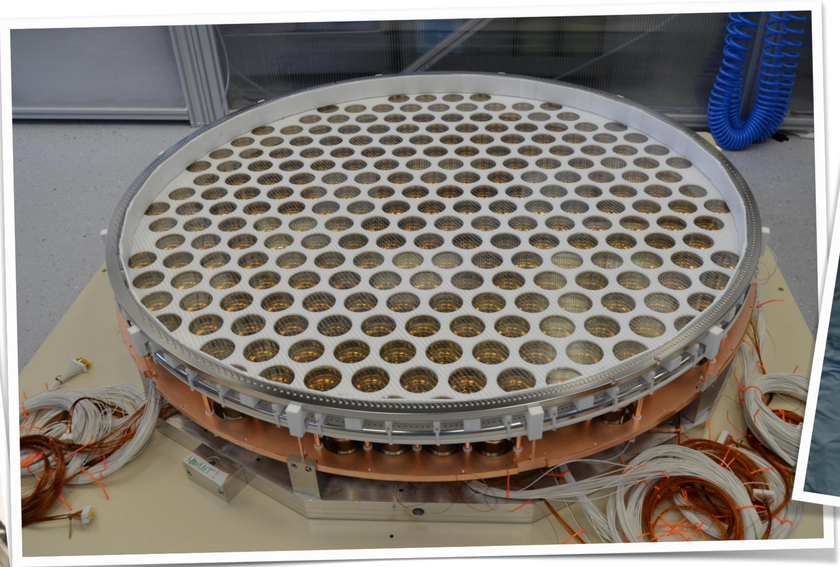

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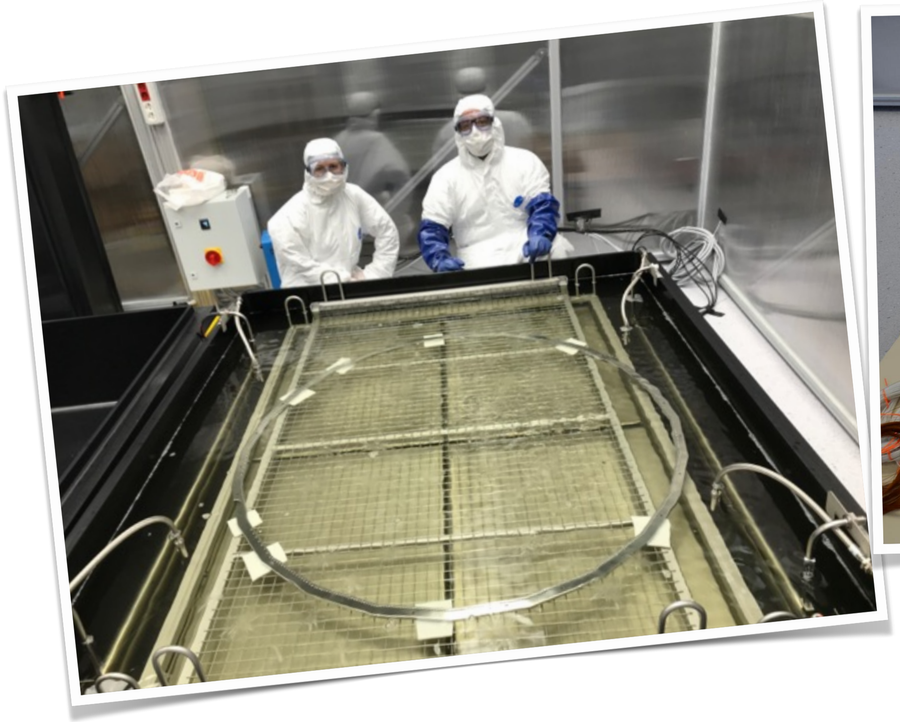
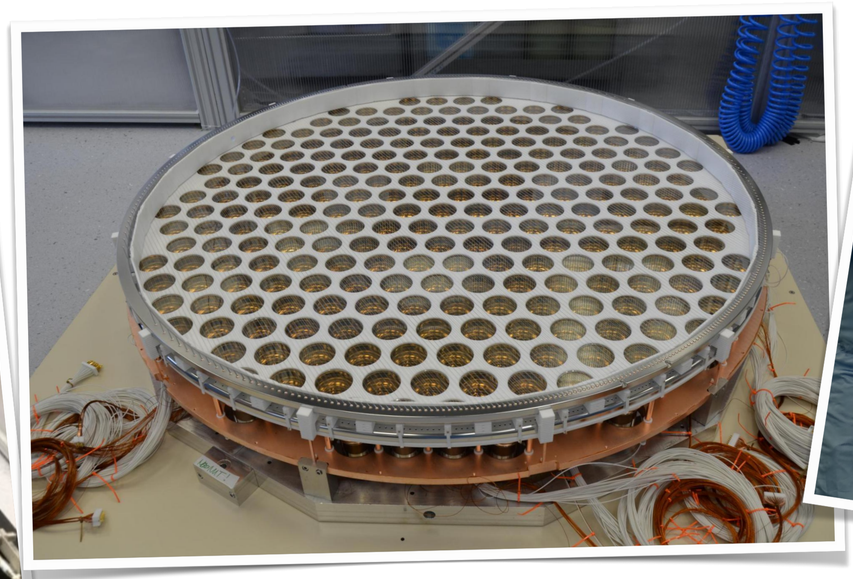
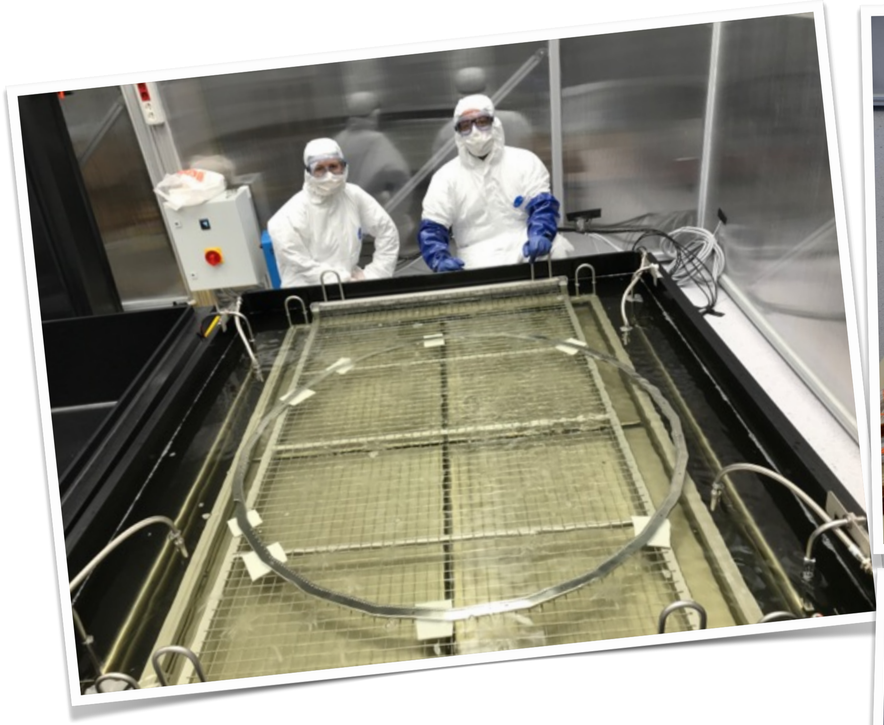
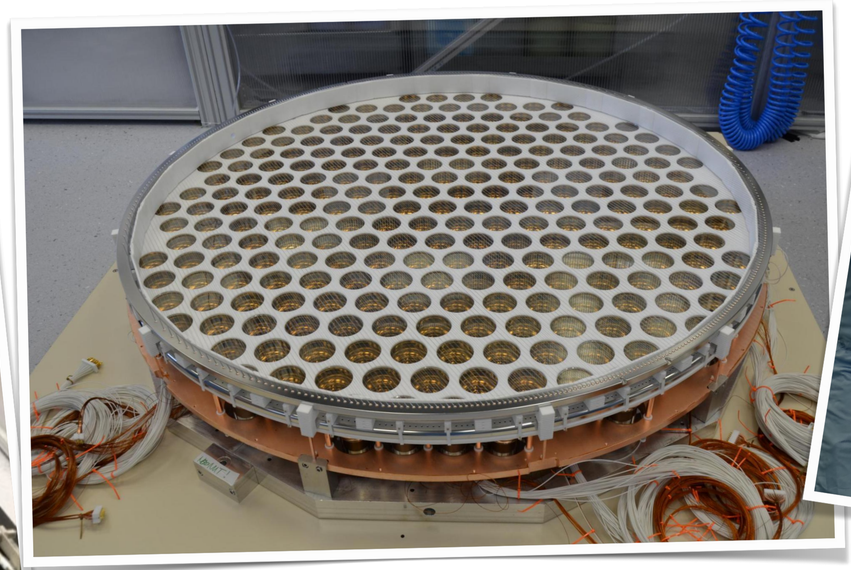


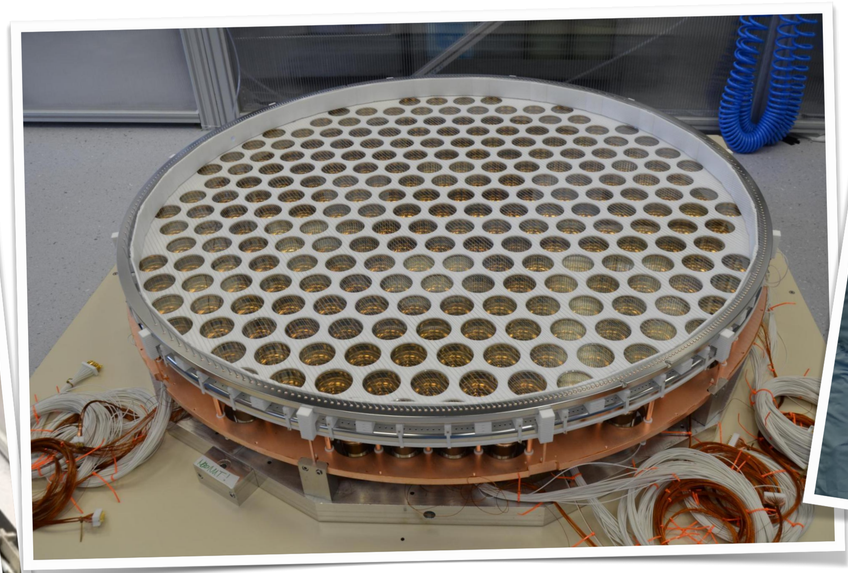


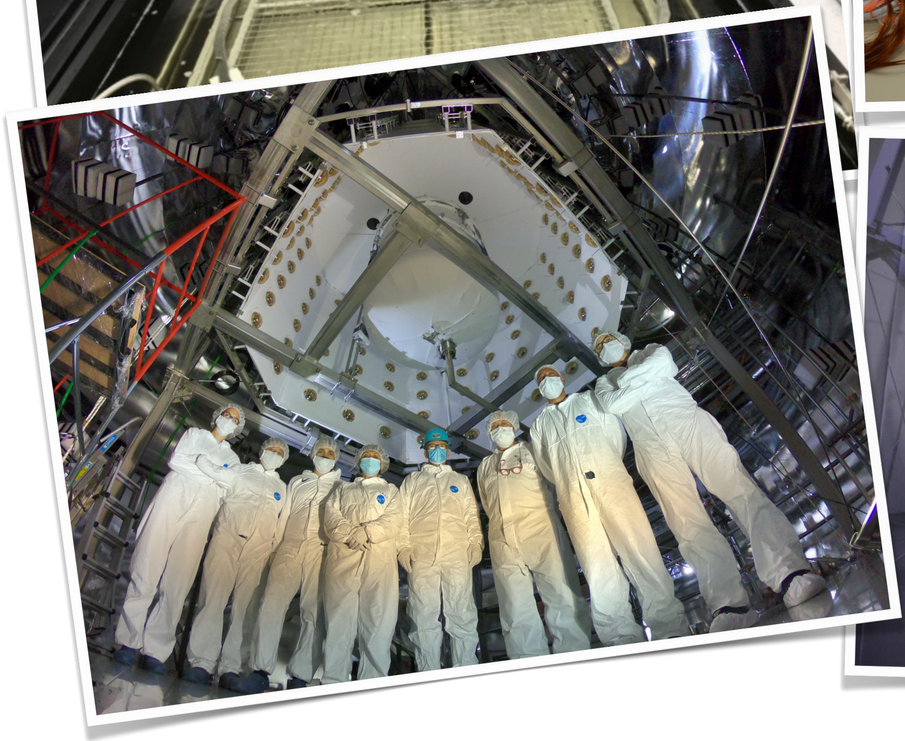
Meet XENONnT





Meet XENONnT

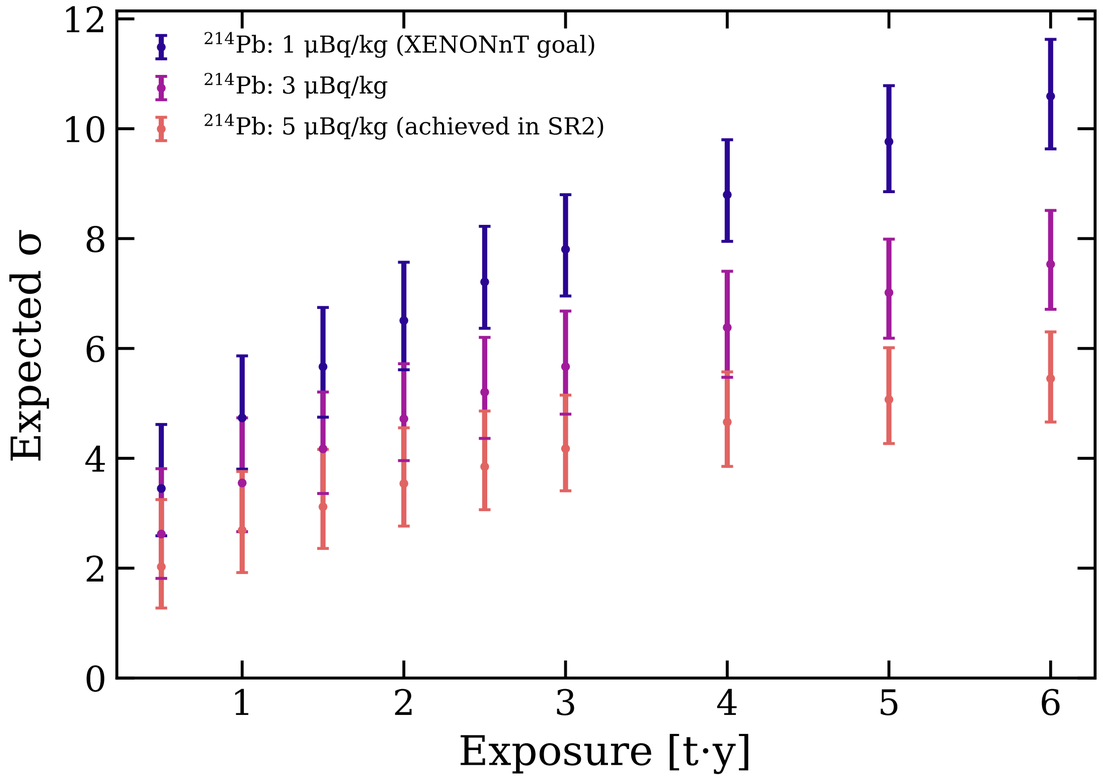




XENONnT take-home

@XENONexperiment

Data taking
Starting late 2020



Active volume
× 3

Background
1/6

Axion–tritium discrimination
A few months

Thank you for your attention!

Dr. Erwann Masson
IJCLab — Orsay, France
✉ masson@lal.in2p3.fr
@DrErwannMasson