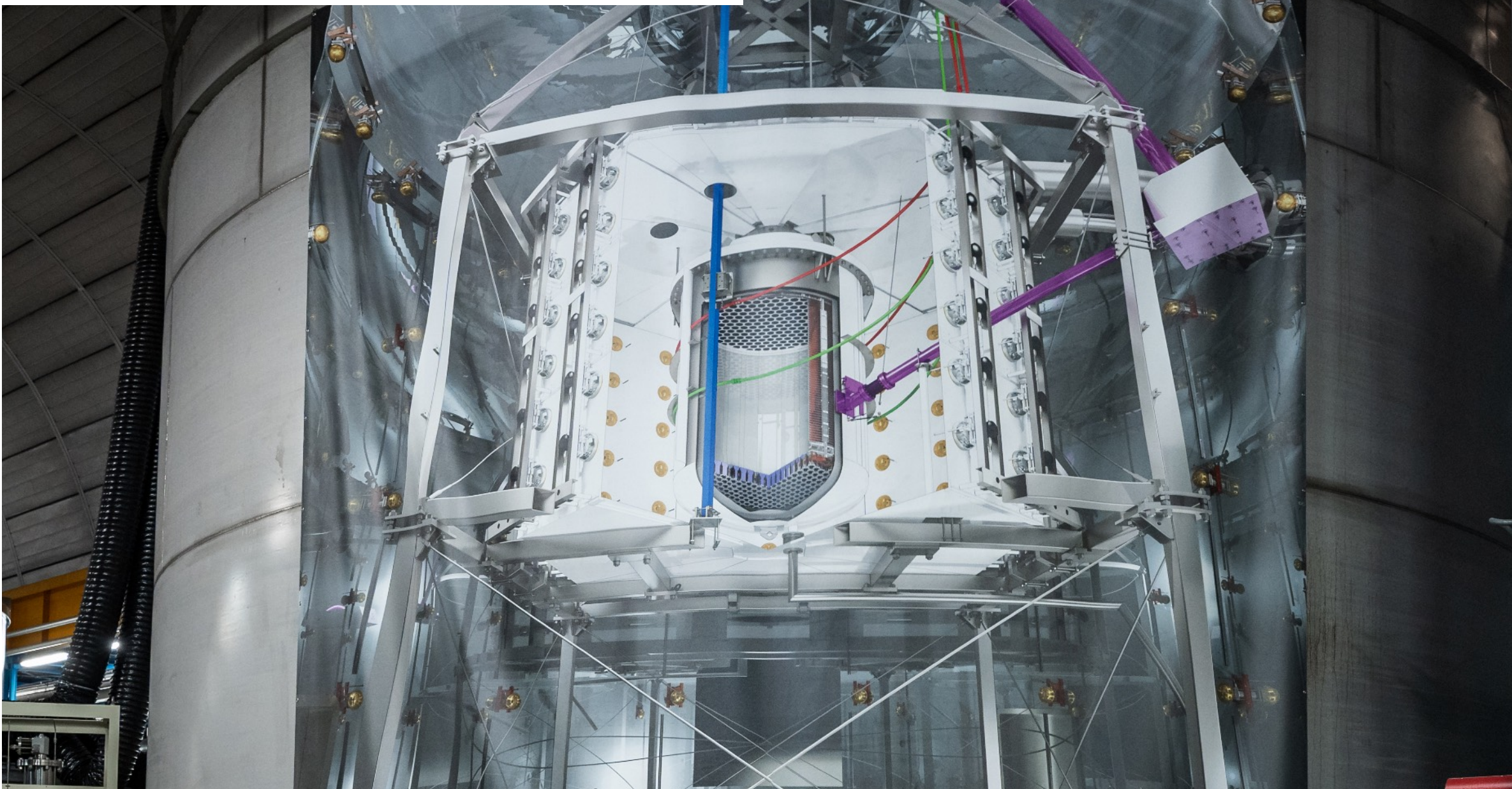


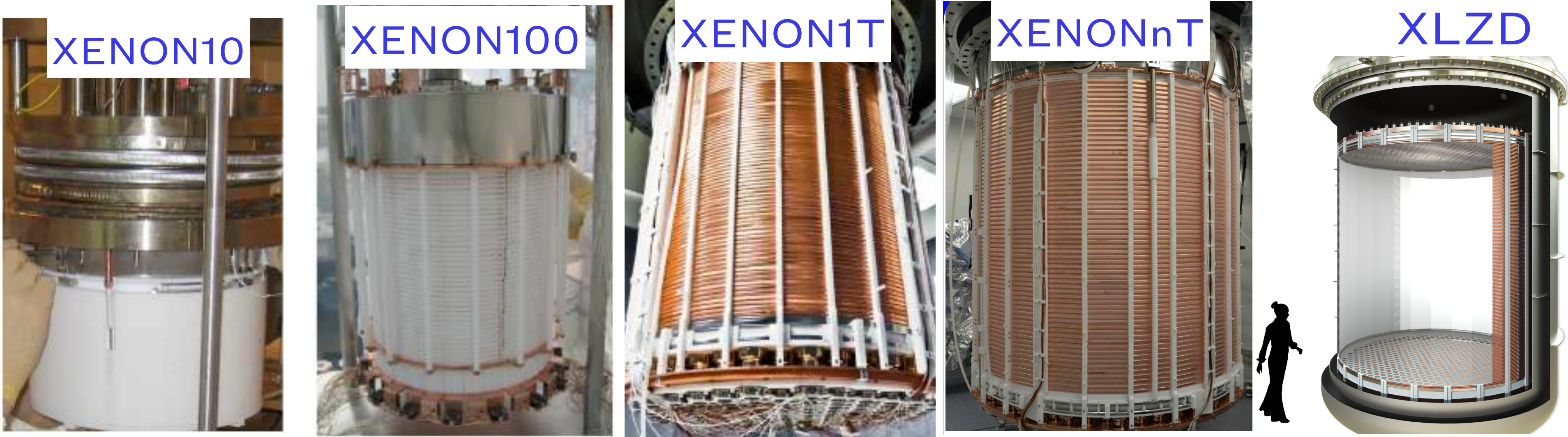


The XENONnT experiment and its latest status

MASATOSHI KOBAYASHI (ISEE, NAGOYA-U) , 2026/09/02 TEVPA2026 IN TENDO, JAPAN

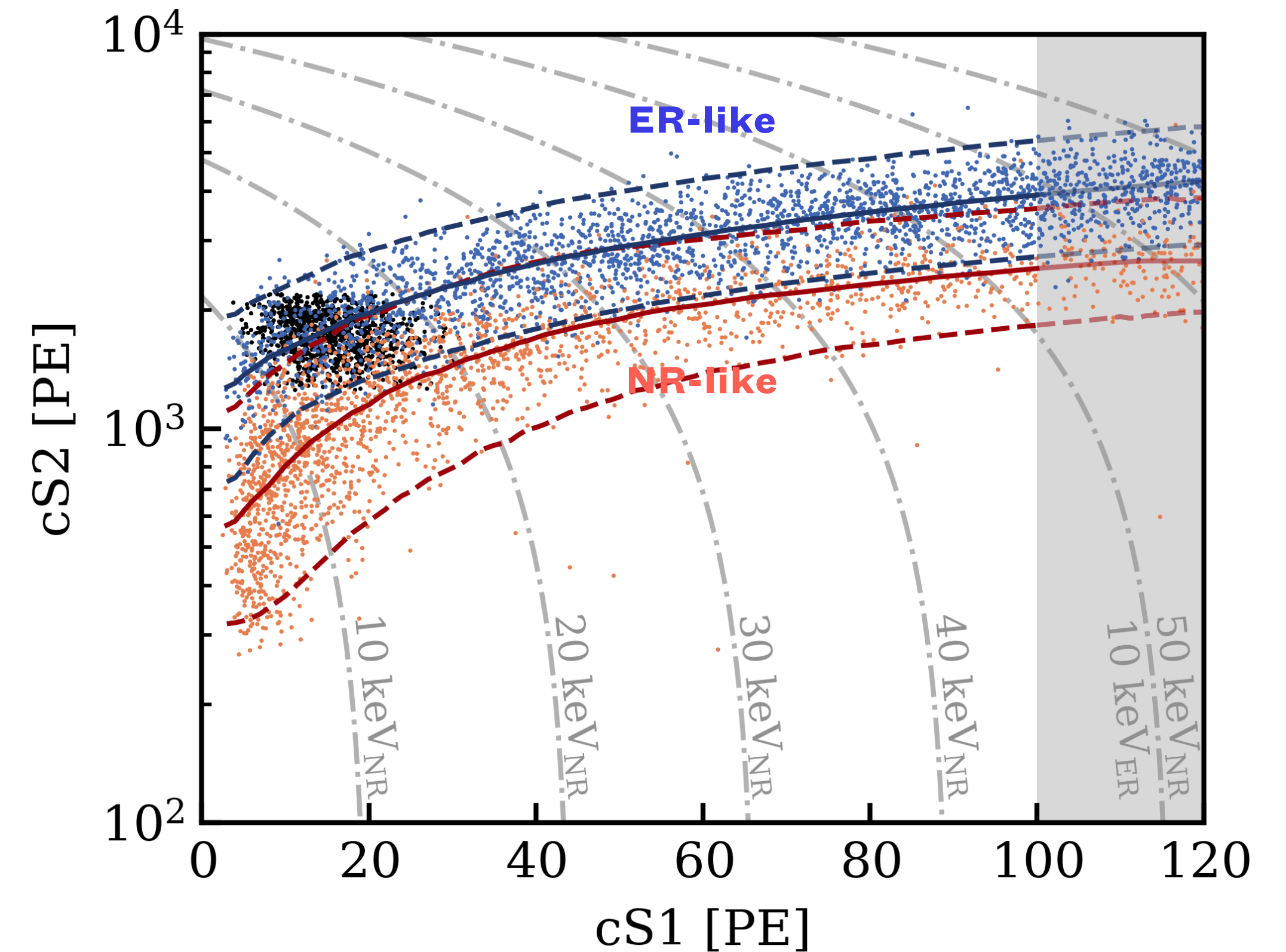
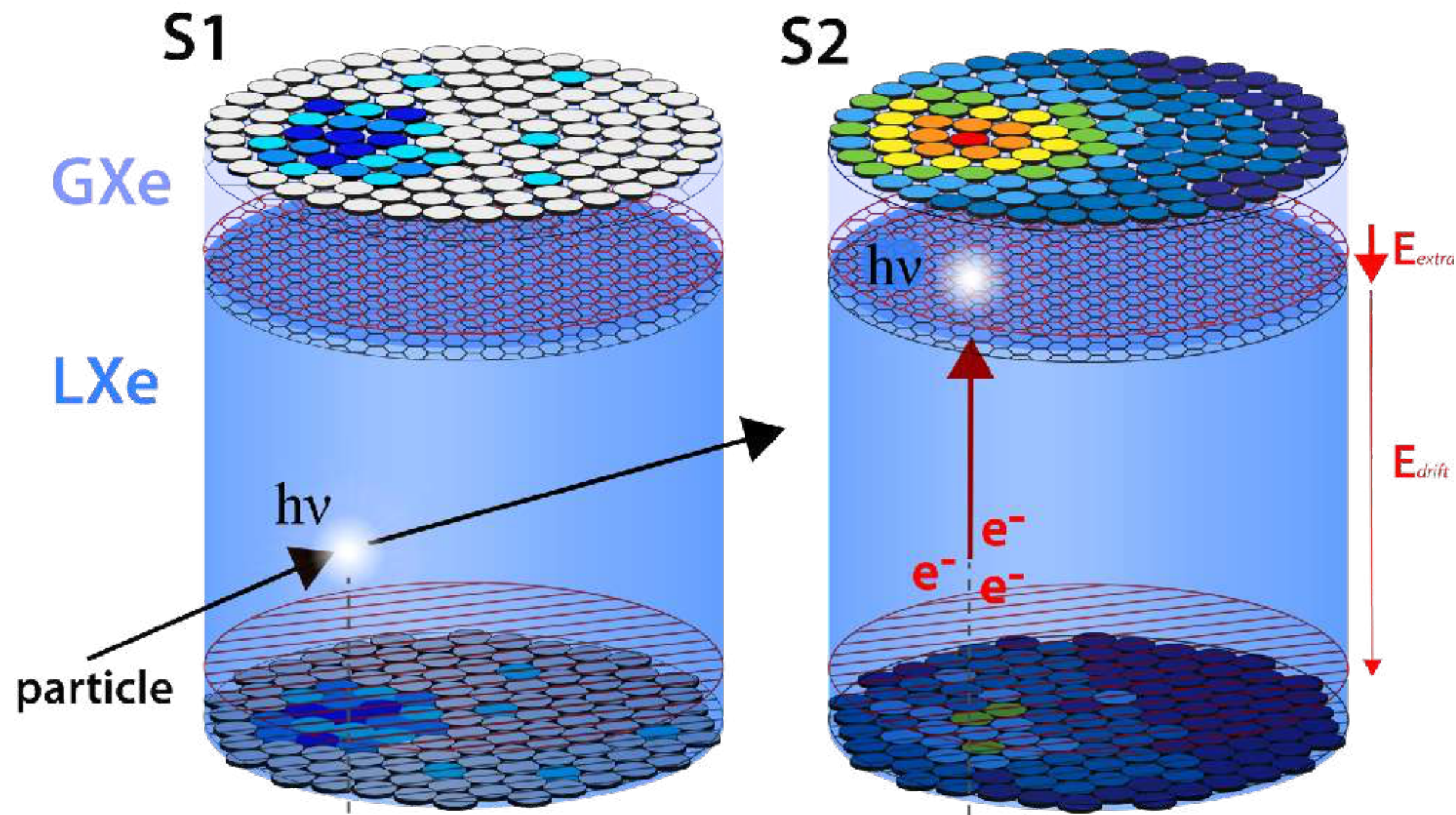
The XENON project

- XENON experiment: Rare event search experiment using liquid xenon detector
 - Dark matter, solar neutrinos, neutrino-less double beta decay,...
- Currently, **XENONnT** experiment is ongoing at LNGS, Italy



Years	2005 - 2007	2008 - 2016	2012 - 2018	2019 - NOW	mid 2030s -
Total Xe mass	25 kg	161 kg	3200 kg	8500 kg	60 - 100 t
WIMPs sensitivity	$\sim 10^{-43} \text{ cm}^2$	$\sim 10^{-45} \text{ cm}^2$	$\sim 10^{-47} \text{ cm}^2$	$\sim 10^{-48} \text{ cm}^2$	$\sim 10^{-49} \text{ cm}^2$

Liquid Xenon Time Projection Chamber

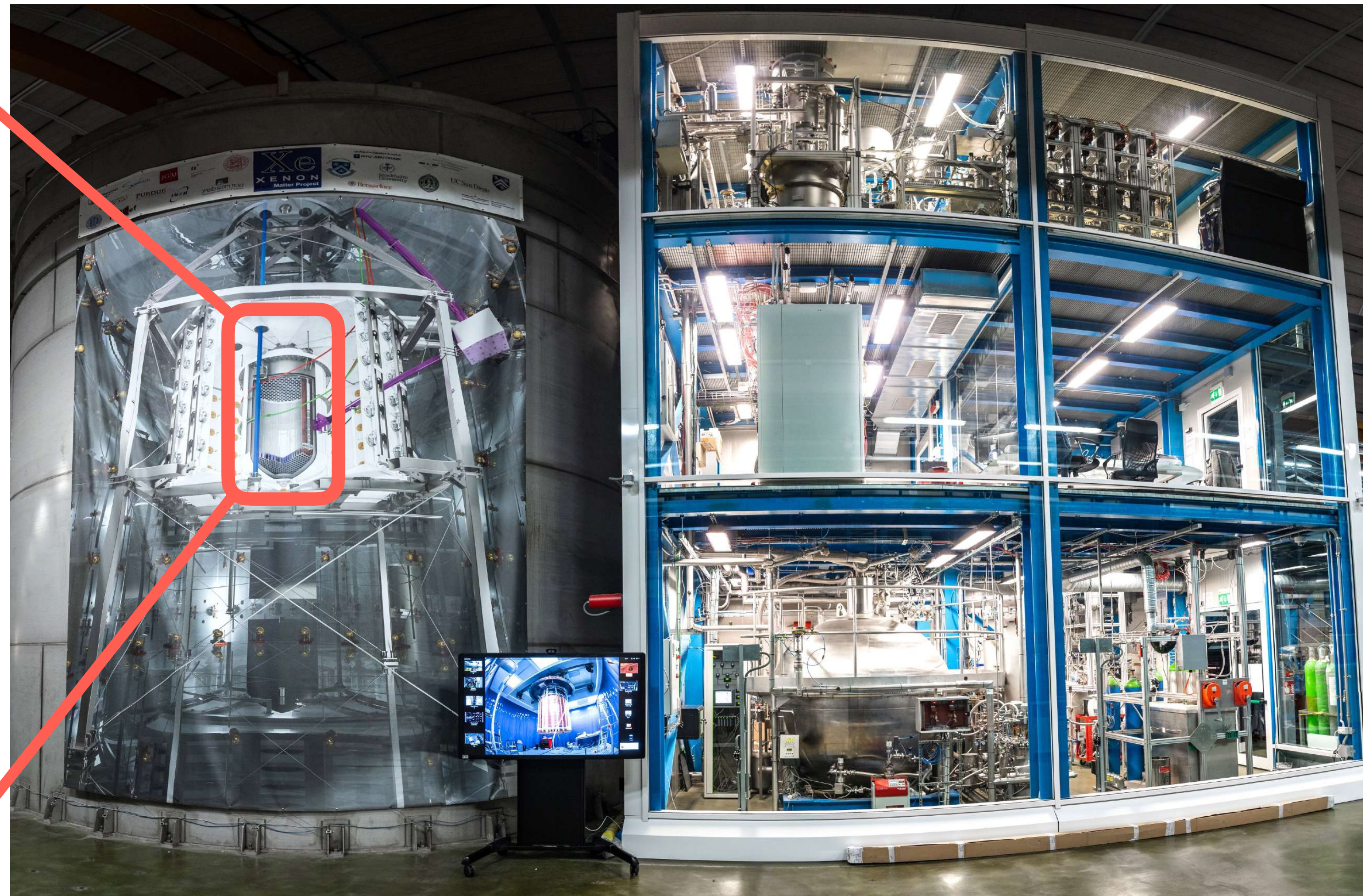
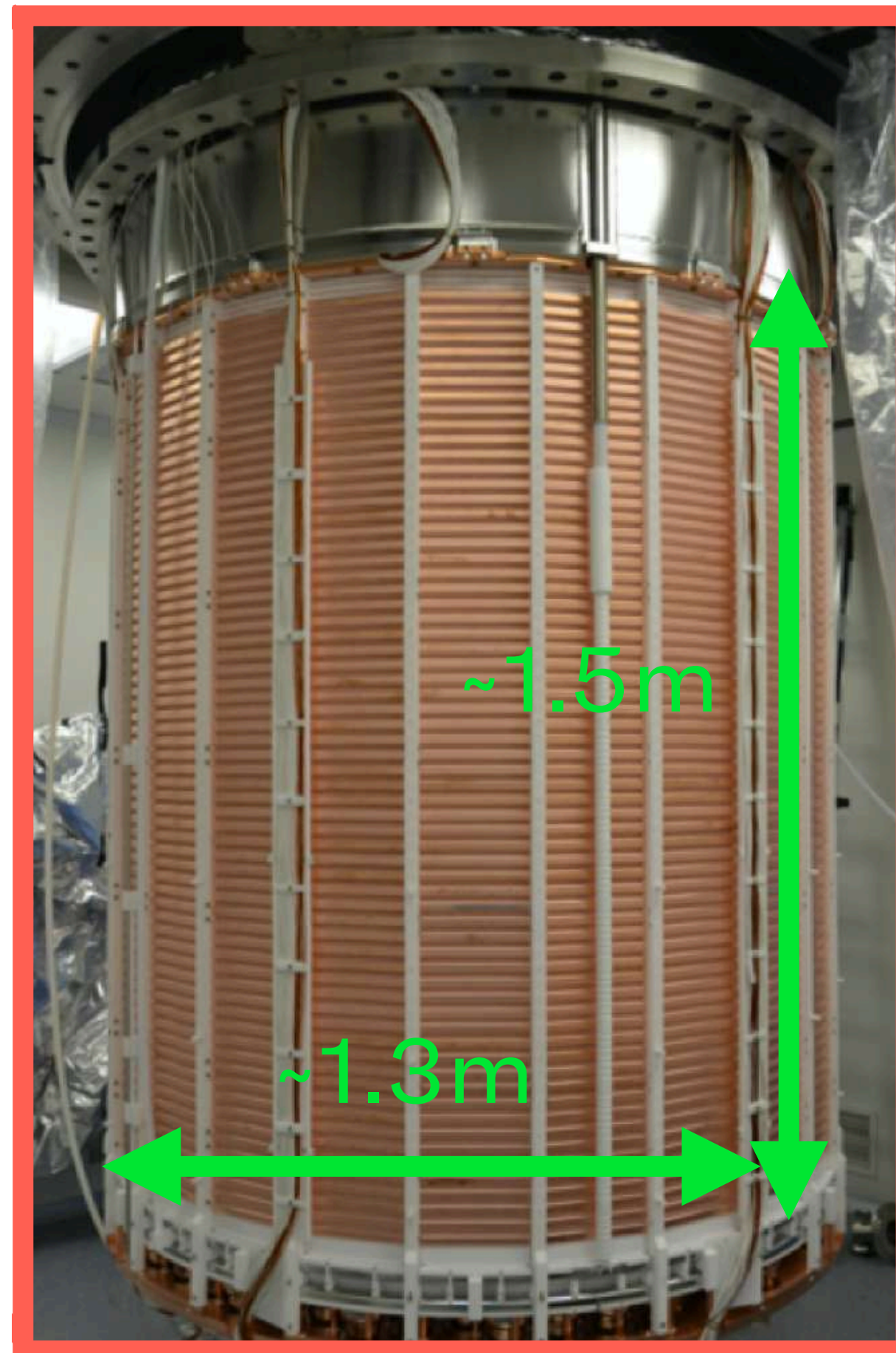


- Dual phase detector: LXe and GXe
- Particles generate signals in LXe
 - S1 signal: Scintillation photon
 - S2 signal: Ionization electrons

- S1/S2 depends on the type of interaction
 - Electronic recoils: lowE- ν , γ ray, β ray, ...
 - Nuclear recoils: WIMPs, Neutron, ...

XENONnT detector

- The XENONnT detector is located at Laboratori Nazionali del Gran Sasso (LNGS), Italy
- Underground area: suppress muon background



Recent results from XENONnT

- Main focus of this talk:
 - **Measurement of Low energy solar neutrinos in keV scale** [ArXiv: 2608.29450](#)
- Also analysis for a lot of other physics are ongoing:
 - ^8B solar neutrino via CEvNS + search for Low-mass WIMPs [PRL. 137, 091807](#)
 - Search for Heavy WIMPs [PRL, 133 191002](#)
 - Search for Magnetic Inelastic DM [ArXiv: 2608.15149](#)
- ... and more!

Measuring solar-pp neutrinos in XENONnT

Solar neutrino measurements in XENONnT

- Measurement of solar neutrinos: one of the main target for XENONnT

- Ultra-low radioactive BG

- Low threshold

- Ton-scale mass

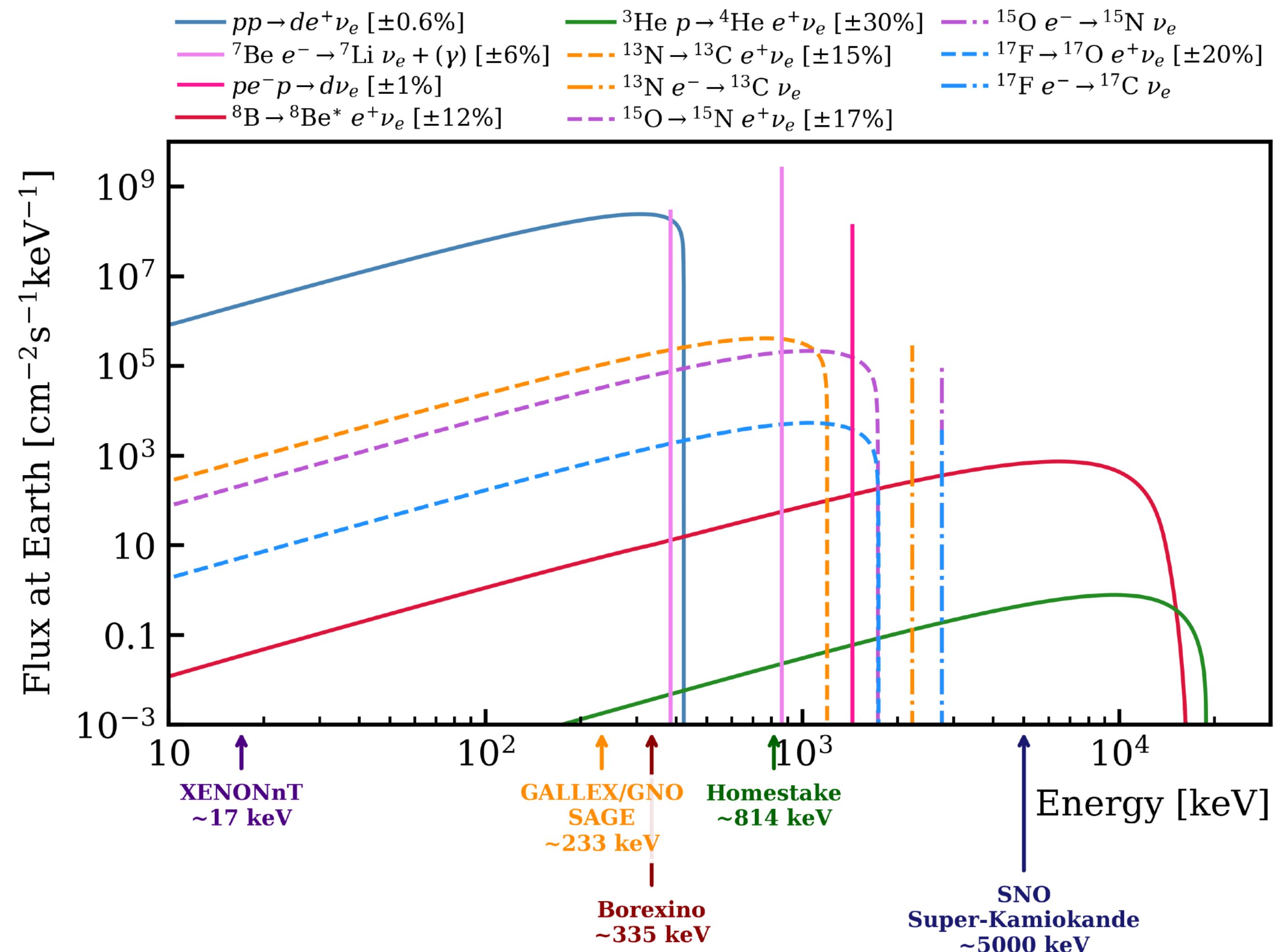
- Multiple channels for solar neutrino measurement:

1. keV scale: via the electronic recoil

- $pp + {}^7\text{Be}$

2. MeV scale: via the nuclear recoil

- ${}^8\text{B}$, hep, ...



Solar neutrino measurements in XENONnT

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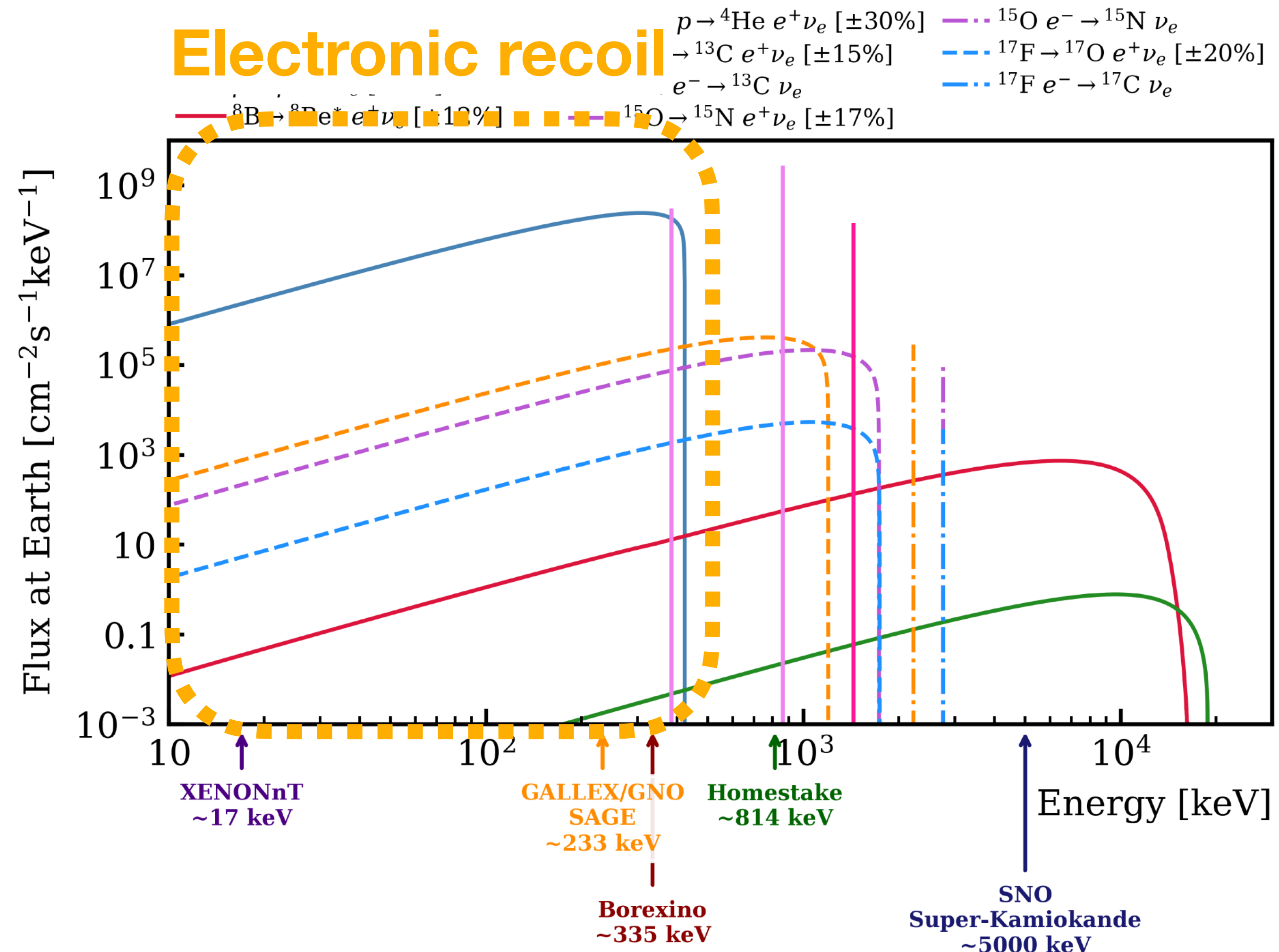
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1. keV scale: via the electronic recoil

- $pp + {}^7\text{Be}$

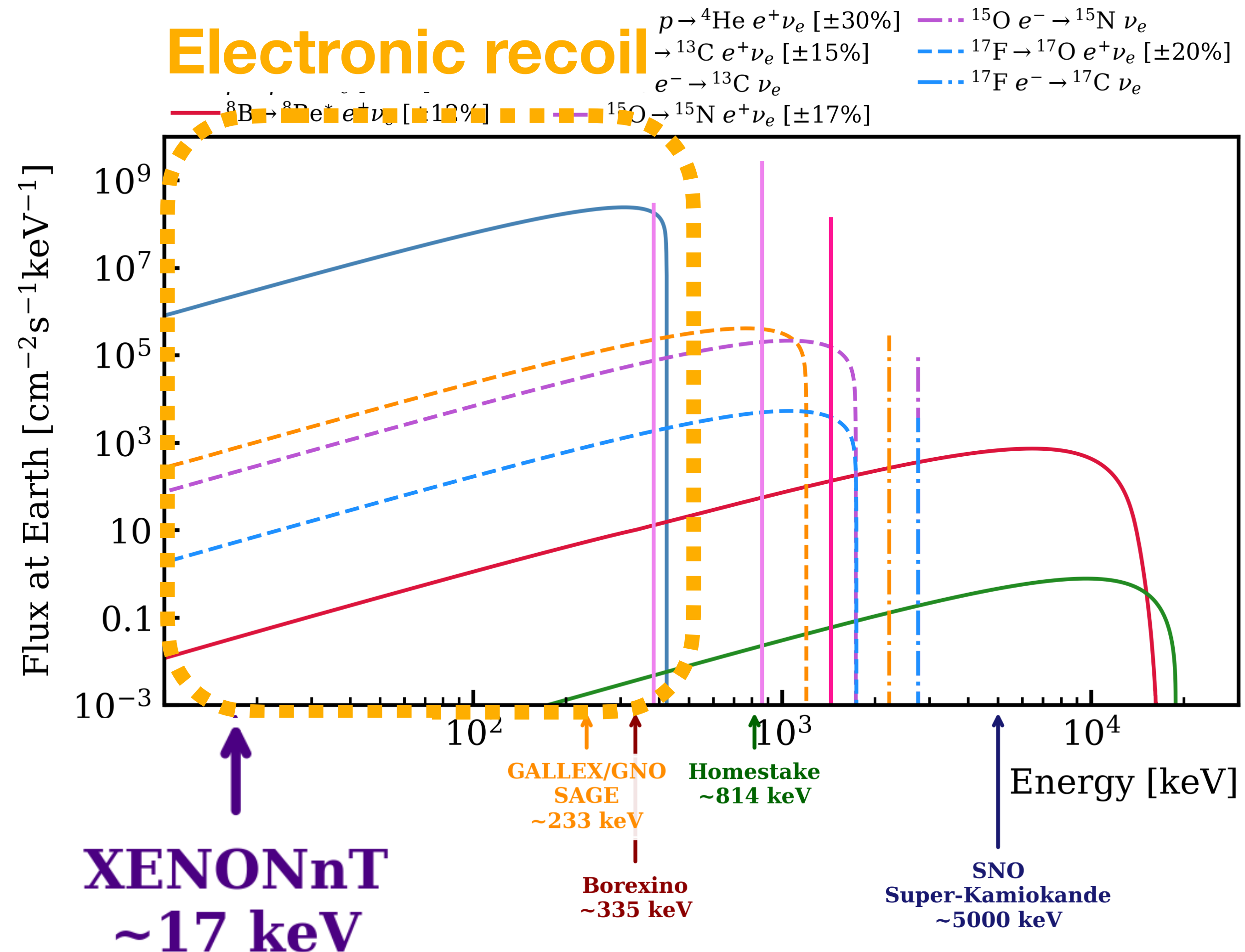
2. MeV scale: via the nuclear recoil

- ${}^8\text{B}$, hep, ...



Measuring solar-pp neutrinos in XENONnT

- **Measurement via the electronic recoil events:**
 - Sensitive for low energy neutrino (pp, ^7Be)
- Advantage of XENON: lower threshold
 - XENON detector: $\sim 1\text{keVee}$
 - Corresponds to $\sim 17\text{keV}$ neutrino



Analysis for XENONnT initial data (SR0, 2022)

- Right: first science run by XENONnT (SR0)

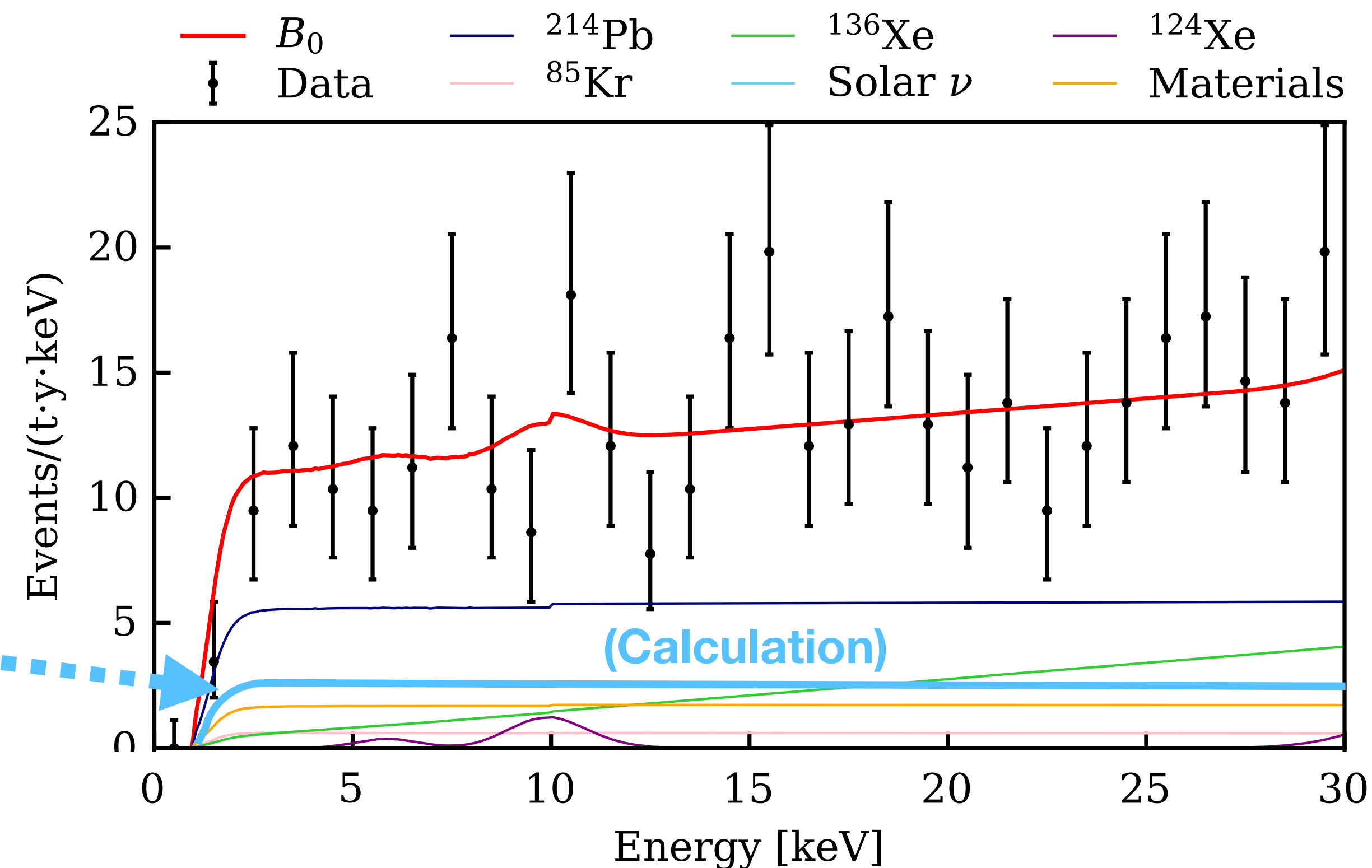
- Good agreement between **Data** and **BG**

- Main target for the analysis: peak-like signals

- “XENON1T Excess”: ex. solar-axions

- => **solar-nu signal** was calculated by Borexino's result

XENONnT SR0 data



Analysis for XENONnT initial data (SR0)

- Right: first science run by XENONnT (SR0)

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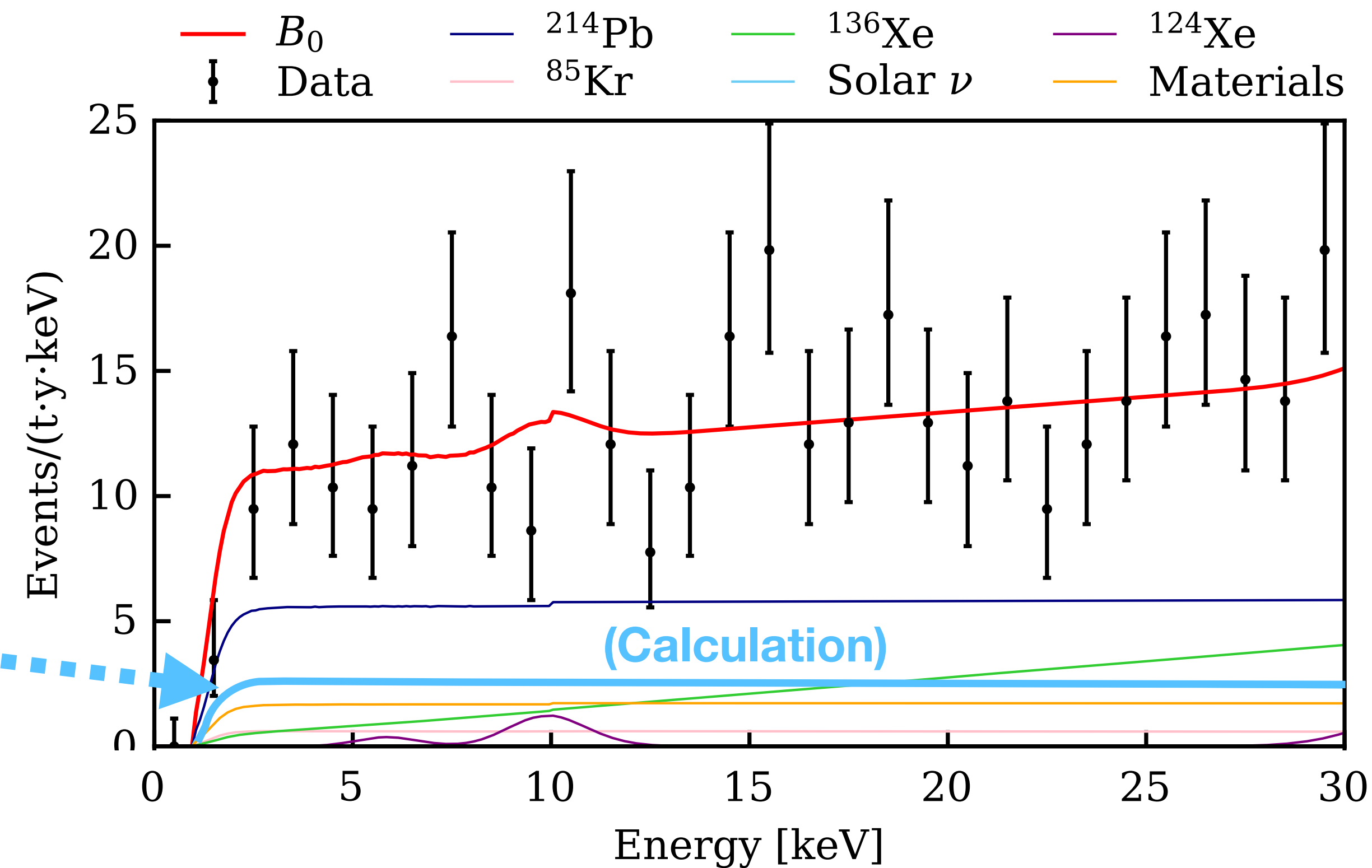
- “XENON1T Excess”: ex. solar-axions

- => **solar-nu signal** was calculated by Borexino's result

- To search for the solar-nu signal, precise understanding of other BG is essential

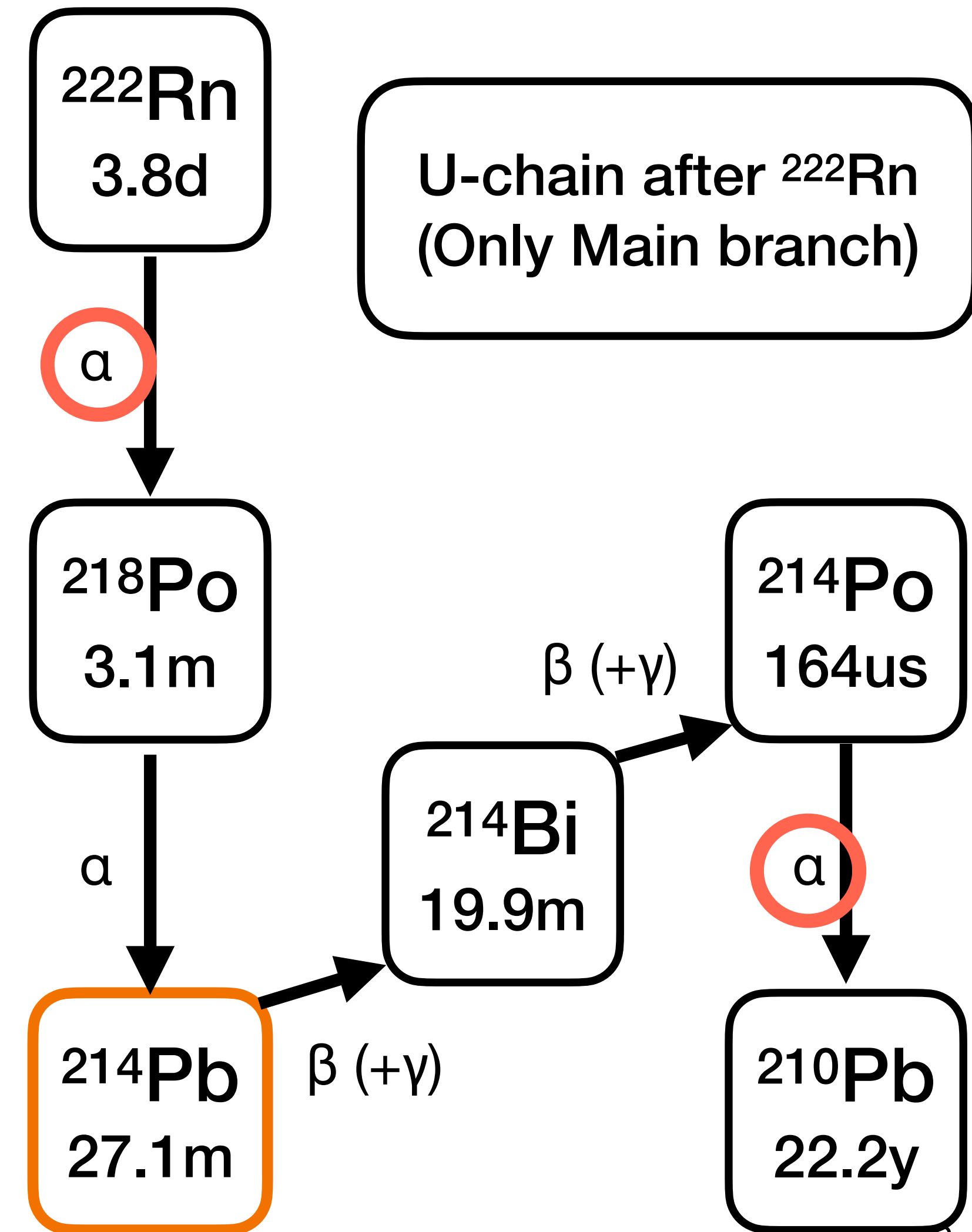
- Radon-induced ^{214}Pb , ^{85}Kr , γ -rays,...

XENONnT SR0 data



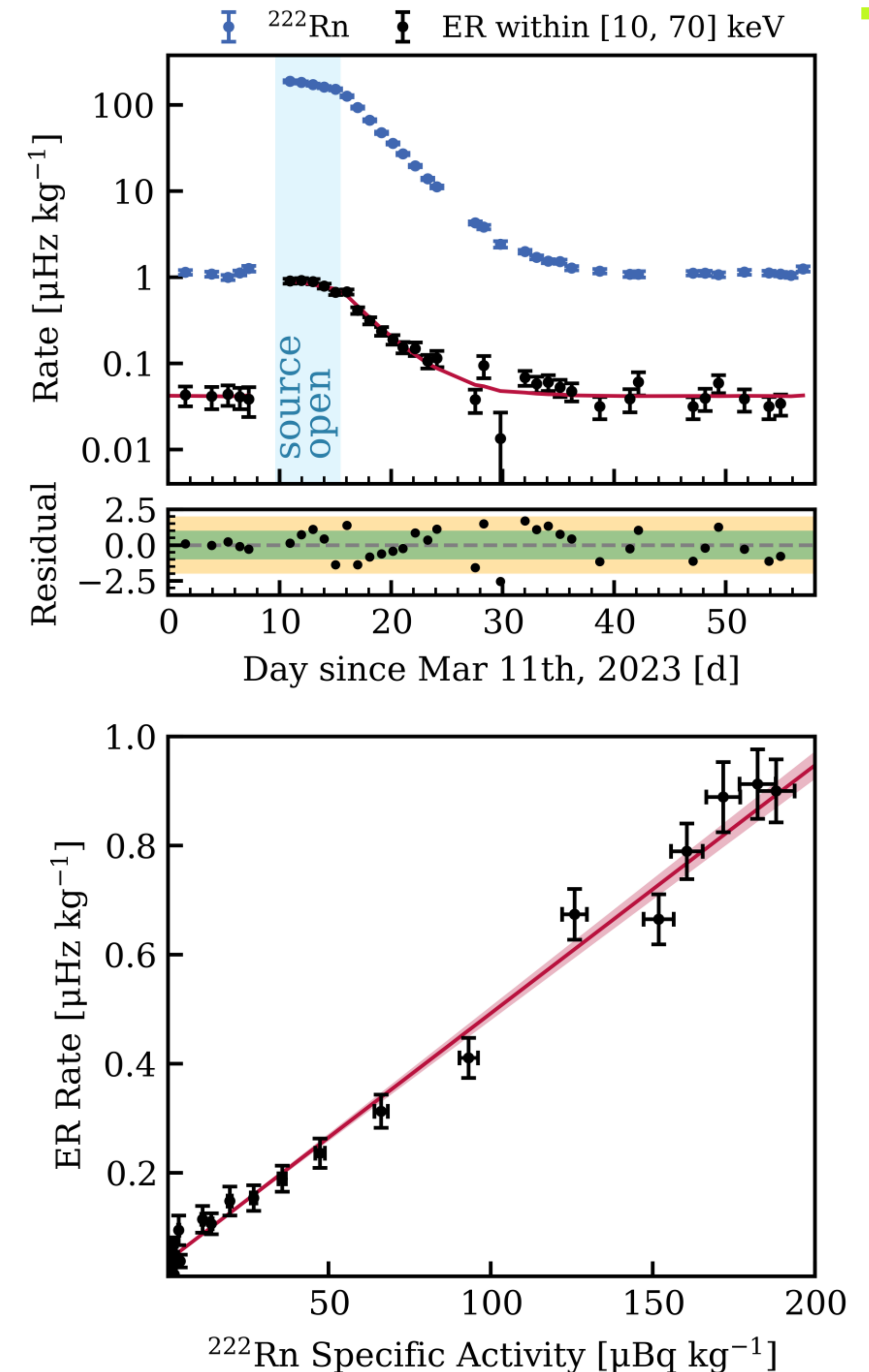
^{214}Pb background

- Radon-induced ^{214}Pb : largest BG component
 - Reduced by Radon distillation system
 - β decay of ^{214}Pb creates BG events
 - ^{222}Rn can be counted using α decay; but daughters cannot.
- Ex. in SR0:
 - $1.7 (^{222}\text{Rn}) > ^{214}\text{Pb} > 0.78 (^{214}\text{Po})$ [uBq/kg]
- To search for solar-nu signal, we need to reduce the uncertainty down to ~5% level!



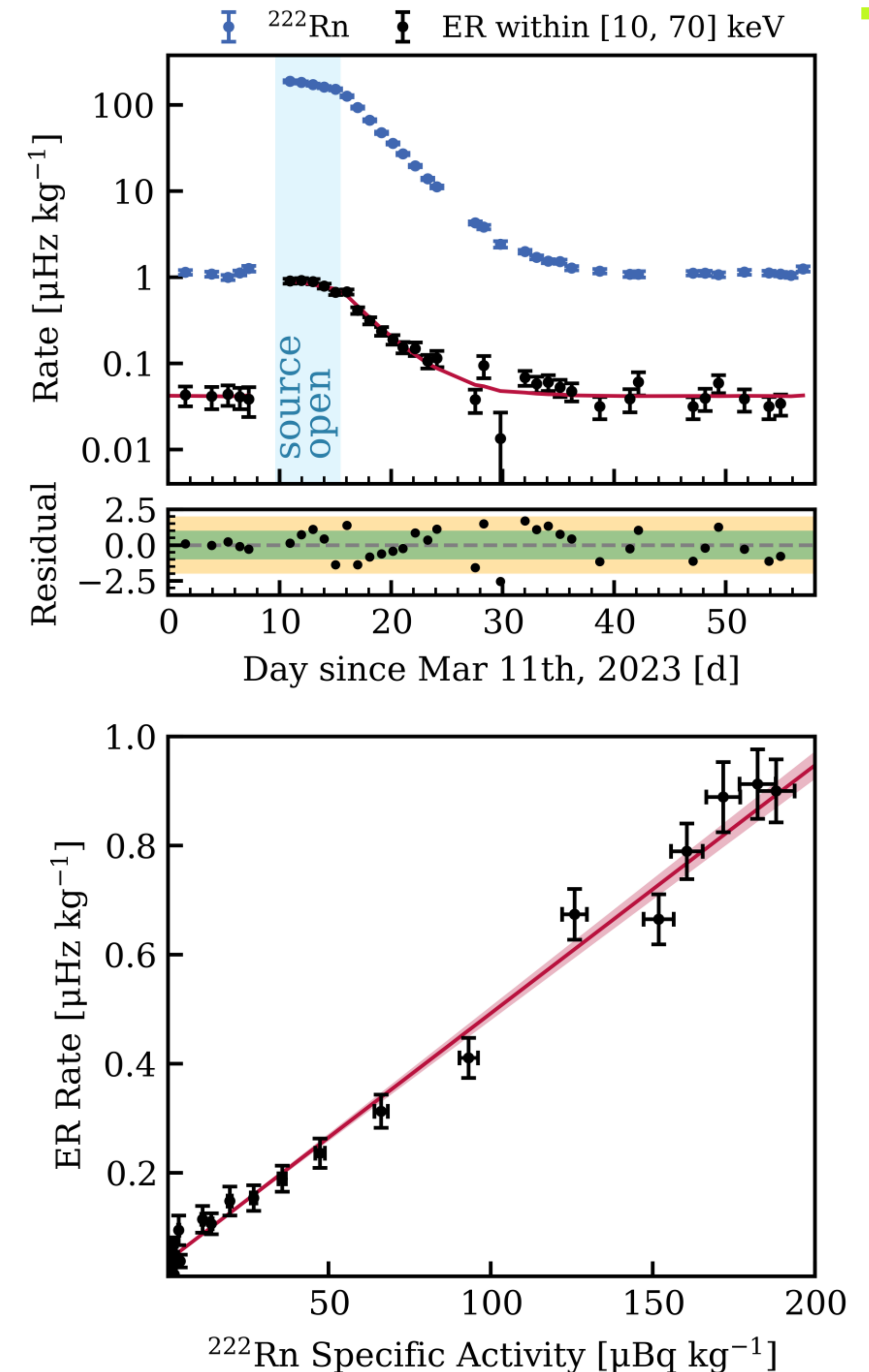
^{214}Pb background

- Result of the ^{222}Rn calibration
- [Rate of α] vs [Rate of ER (10-70keV)]
- $^{214}\text{Pb} \propto ^{222}\text{Rn}$: $\epsilon R_{\text{Pb}} = a \cdot R_{\text{Rn}} + b$
 - a: Ratio between ^{222}Rn and ^{214}Pb
 - b: BG other than ^{214}Pb
 - ϵ (calc): correction by branching ratio, efficiency etc



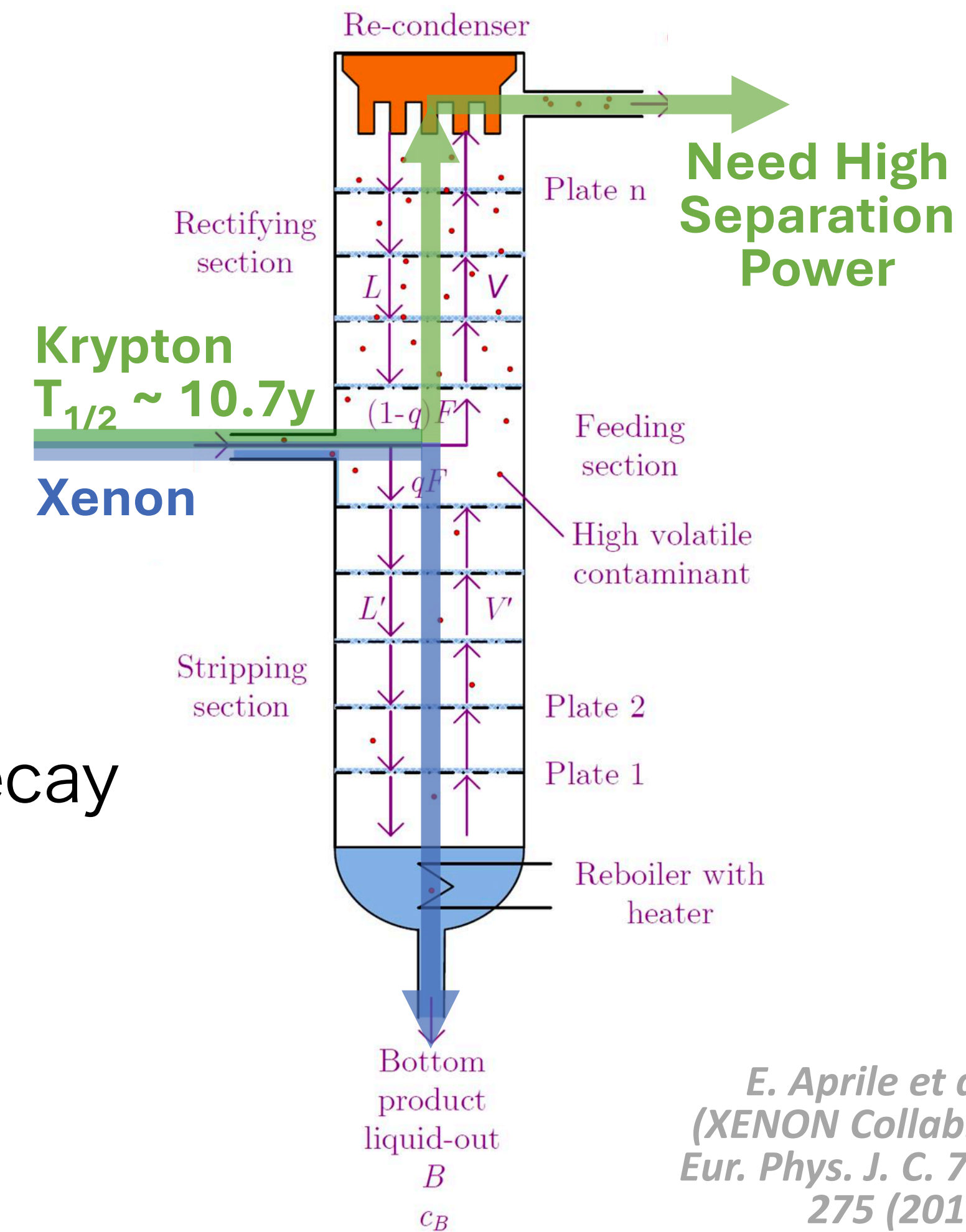
^{214}Pb background

- Fit result:
 - $a = 0.66 \pm 0.03$ [Bq/Bq]
- Note:
 - 1 Bq of ^{222}Rn $\Leftrightarrow$ 0.66 Bq of ^{214}Pb
 - Uncertainty reduced to ~4.5% level
 - (i.e. ~40% for previous analysis)
- Estimated specific activity of ^{214}Pb
 - 1.39 ± 0.07 [uBq/kg] for SR0
 - 0.76 ± 0.03 [uBq/kg] for SR1b



Kr-induced background

- Other major BG : Kr-induced β
- Kr-induced β
 - β decay of ^{85}Kr ($Q=687\text{keV}$)
 - Removed by our own distillation ($<0.1\text{ ppt}$ for Kr)
 - Mass spectrum analysis for sampled gas
 - Confirmed by analytical estimation using rare decay mode of ^{85}Kr
- Estimated concentration of Kr (ppq: 10^{-15})
 - 82 ± 23 [ppq] for SR0
 - 170 ± 70 [ppq] for SR1
- Converted to Kr85 activity with its abundance

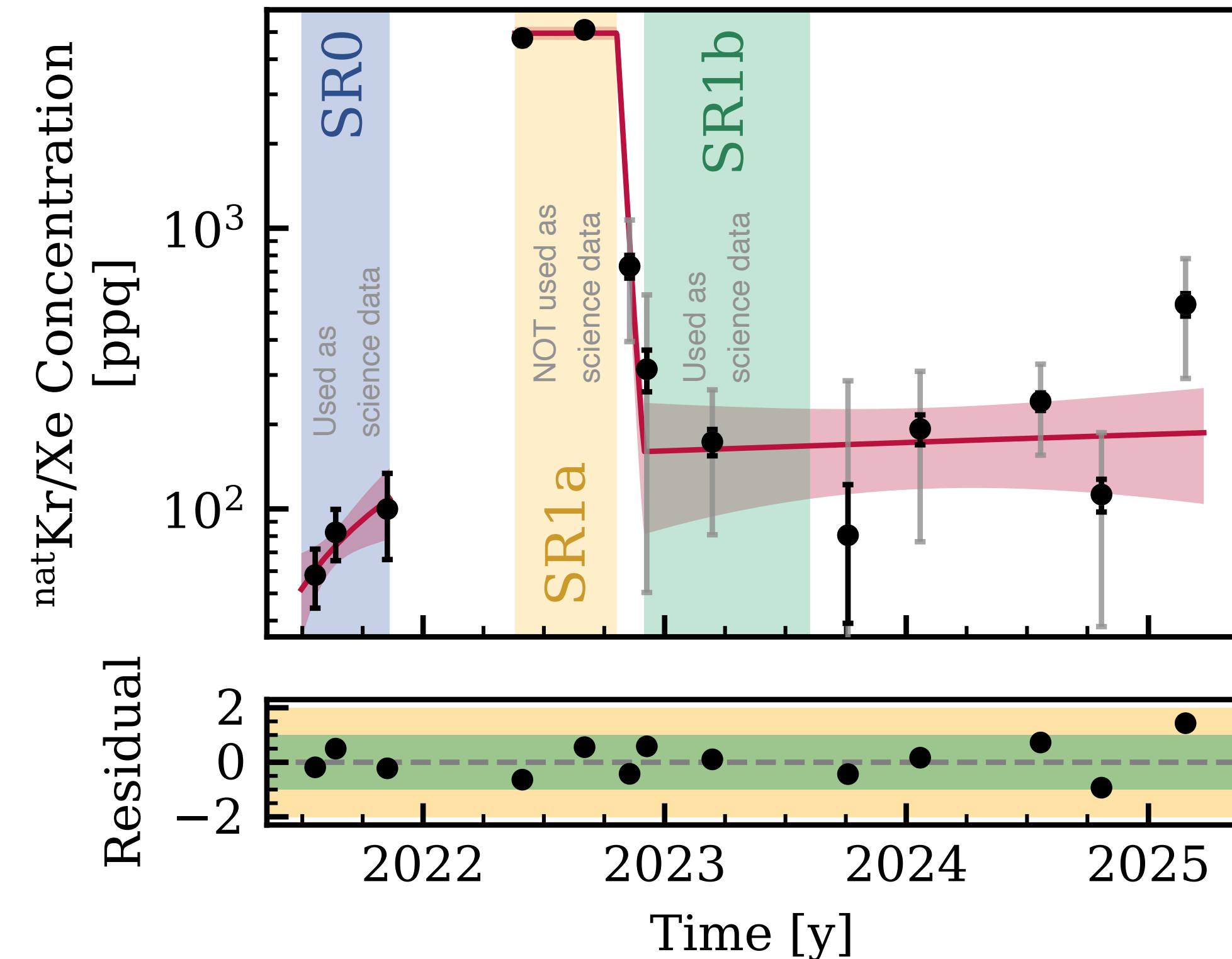


*E. Aprile et al.
(XENON Collab.),
Eur. Phys. J. C. 77,
275 (2017)*

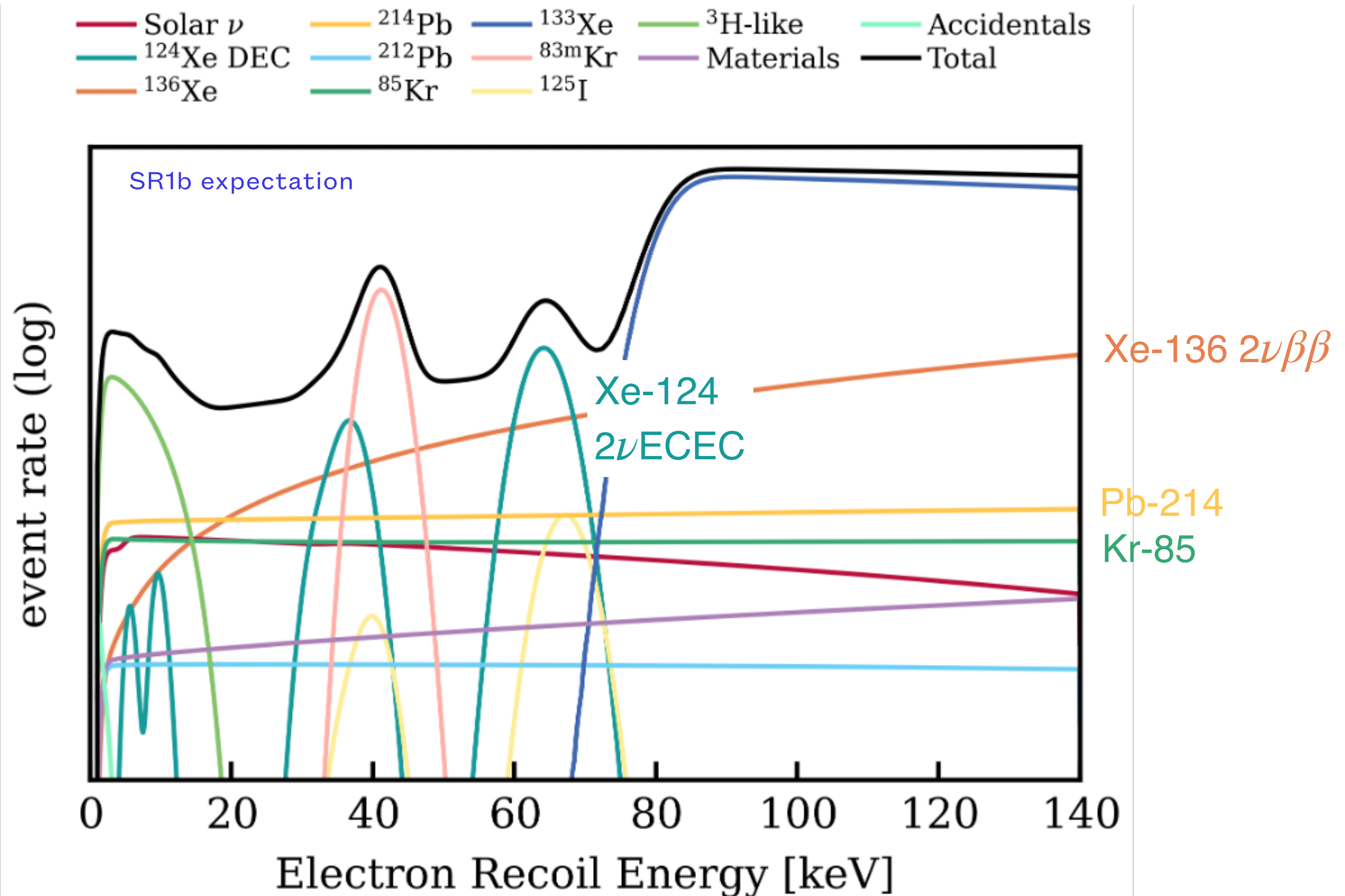


Kr-induced background

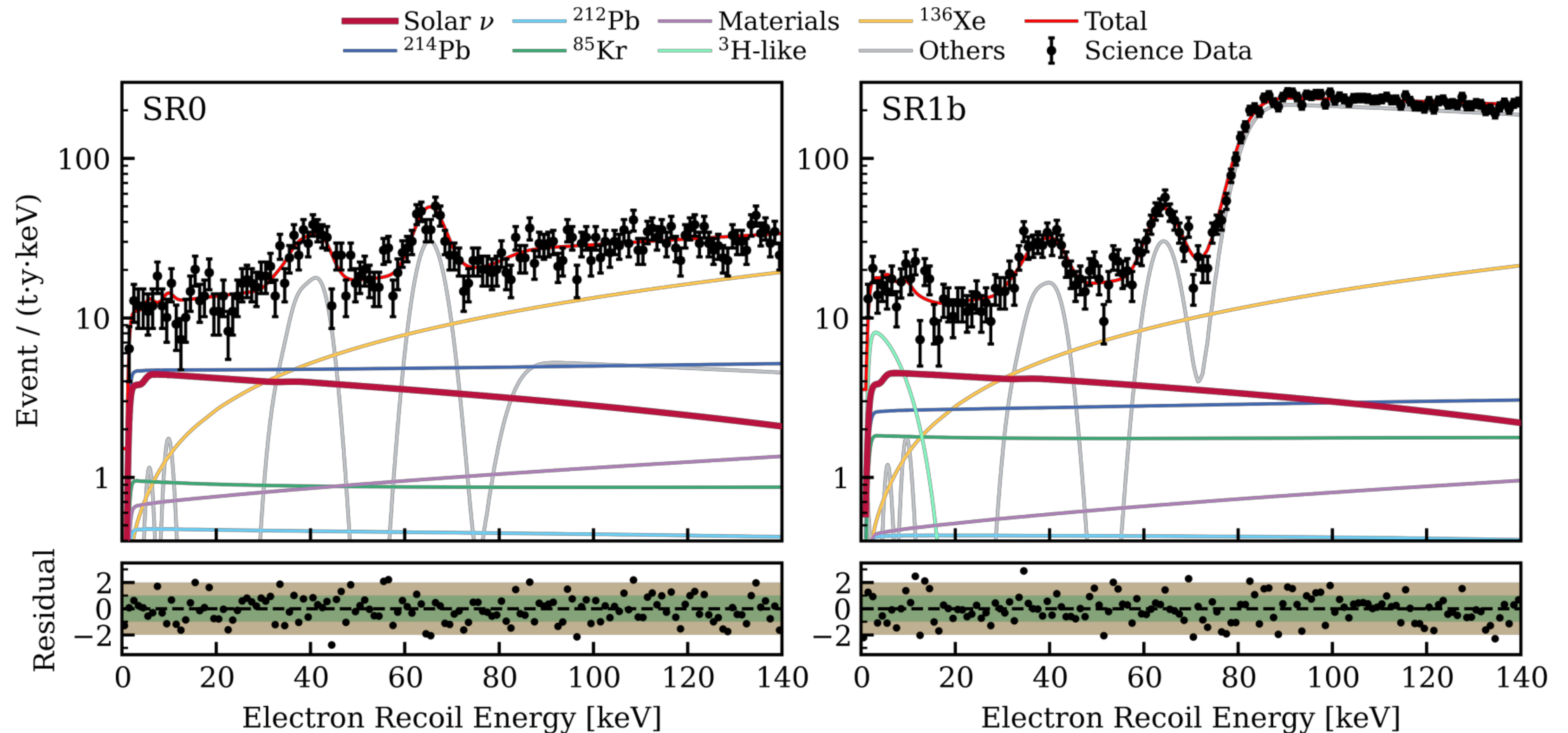
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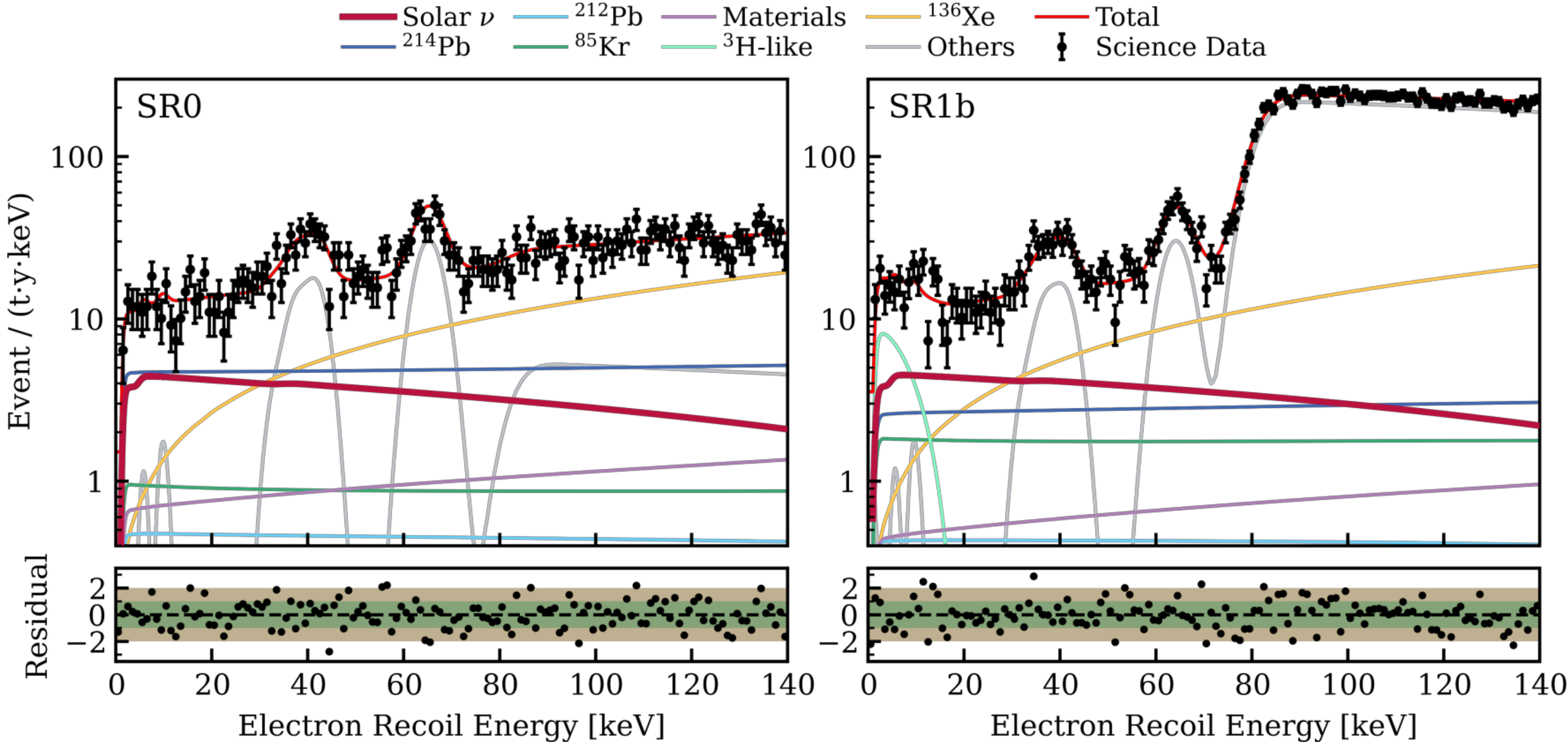
Background model



Fit result



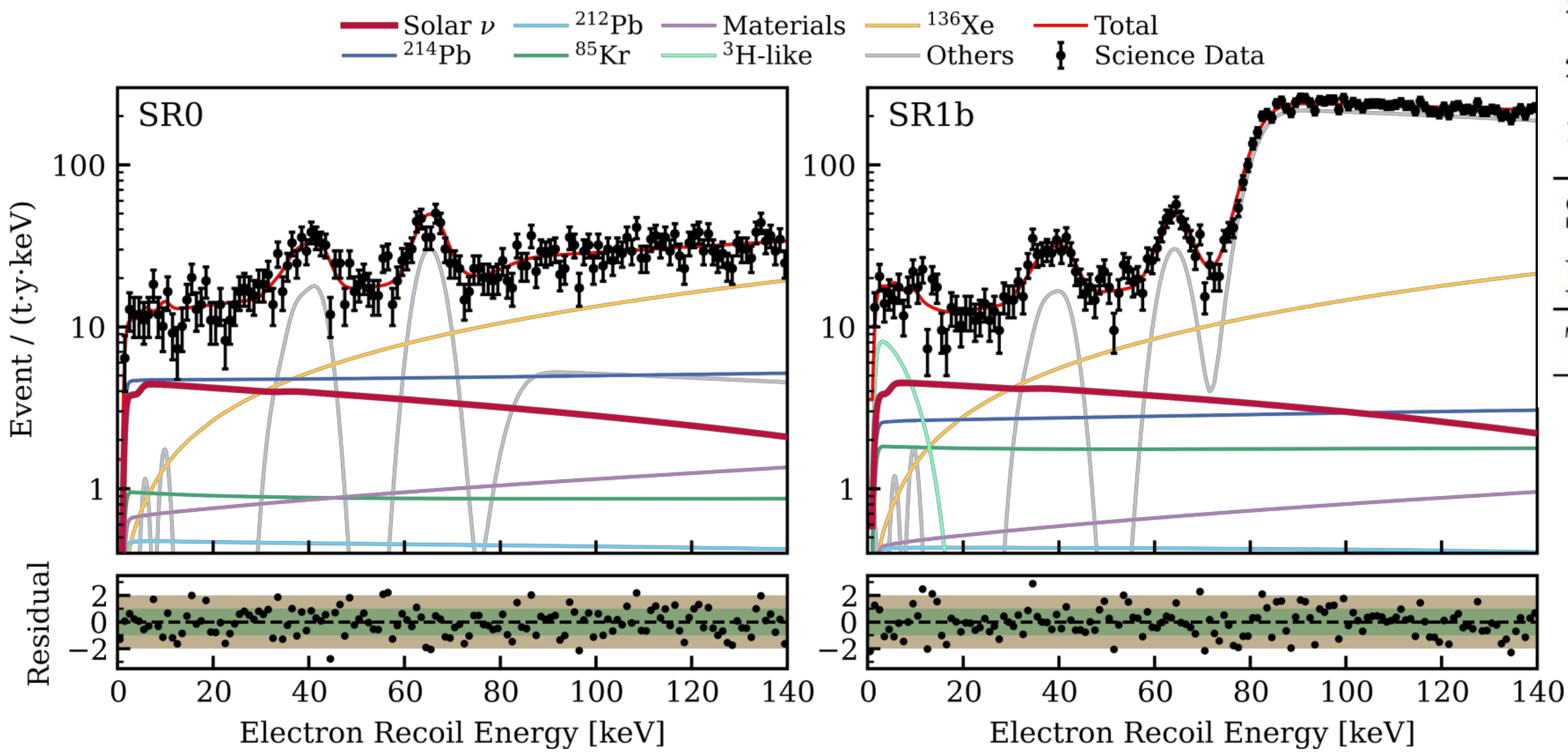
Fit result



	SR0	
	Nominal	Best-fit
Solar ν	295	500 ± 70
^{124}Xe DEC	270	343 ± 22
^{214}Pb	740 ± 40	740 ± 30
^{212}Pb	68 ± 13	68 ± 12
^{85}Kr	130 ± 40	130 ± 30
Materials	160 ± 40	150 ± 30
$^3\text{H-like}$	—	—
^{136}Xe	1460 ± 50	1430 ± 40
^{133}Xe	140	310 ± 60
$^{83\text{m}}\text{Kr}$	free	98 ± 14
^{125}I	—	—
Accidentals	0.4 ± 0.3	0.5 ± 0.3

	SR1b	
	Nominal	Best-fit
Solar ν	287	660 ± 90
^{124}Xe DEC	351	445 ± 28
^{214}Pb	538 ± 24	537 ± 23
^{212}Pb	80 ± 10	80 ± 10
^{85}Kr	390 ± 170	330 ± 110
Materials	137 ± 17	136 ± 17
$^3\text{H-like}$	233	92 ± 18
^{136}Xe	1990 ± 70	1950 ± 60
^{133}Xe	15937	16740 ± 140
$^{83\text{m}}\text{Kr}$	free	111 ± 19
^{125}I	39	0 ± 30
Accidentals	1.3 ± 0.1	1.3 ± 0.1

Uncertainty budget

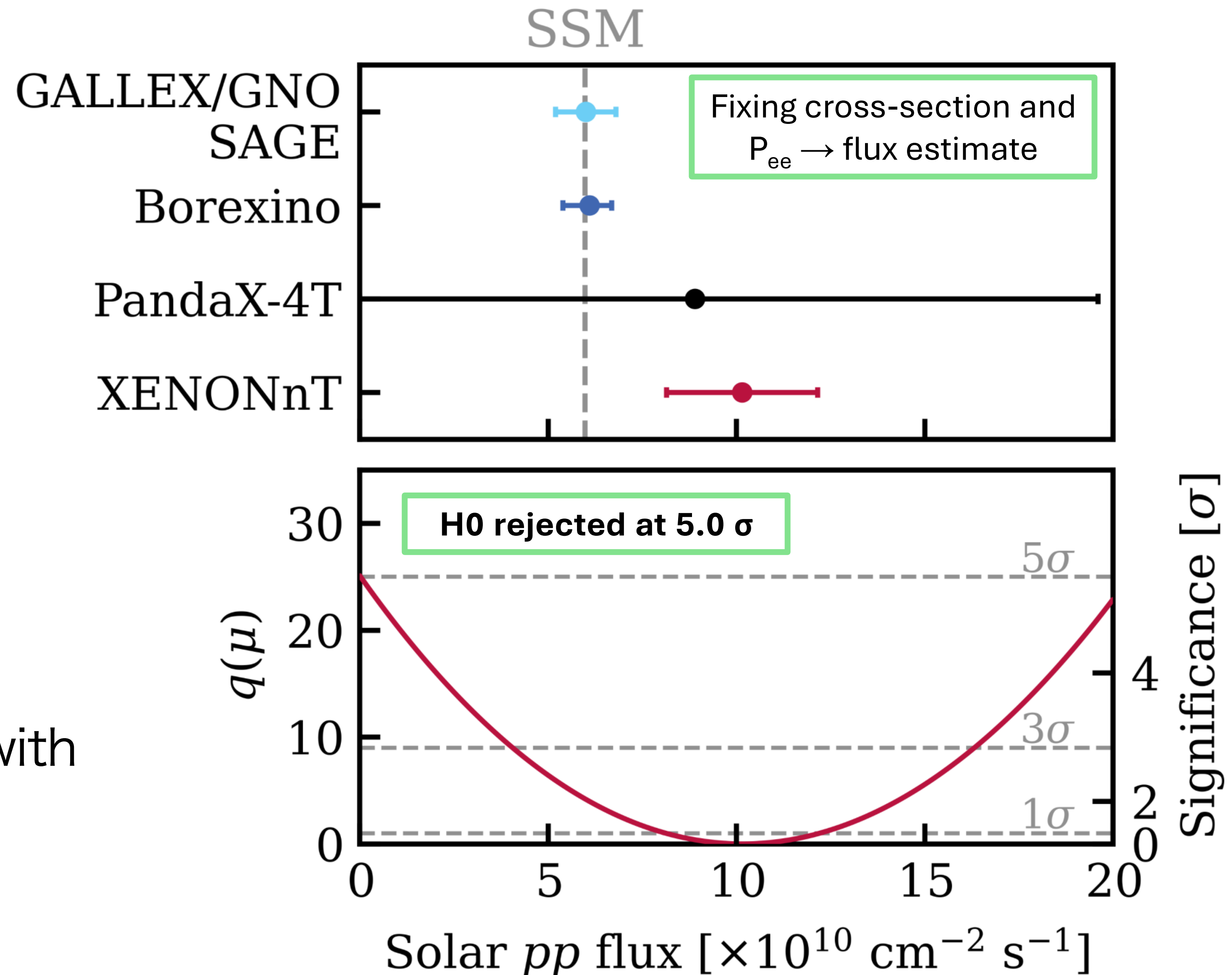


	σ_- (%)	σ_+ (%)
Fiducial volume	9.7	10
Efficiency	9.0	7.7
Energy bias	2.9	4.1
Energy resolution	1.3	1.4
^{214}Pb correlated uncertainty	4.3	4.1
^{214}Pb spectral shape	1.1	1.1
^{136}Xe spectral shape	1.0	1.0
Systematic uncertainty	14	14
Profile-likelihood uncertainty	14	14
Total	20	20

- Uncertainty from profile-likelihood: 14%
- Non-rate systematic parameters introduces additional 14% systematic uncertainty

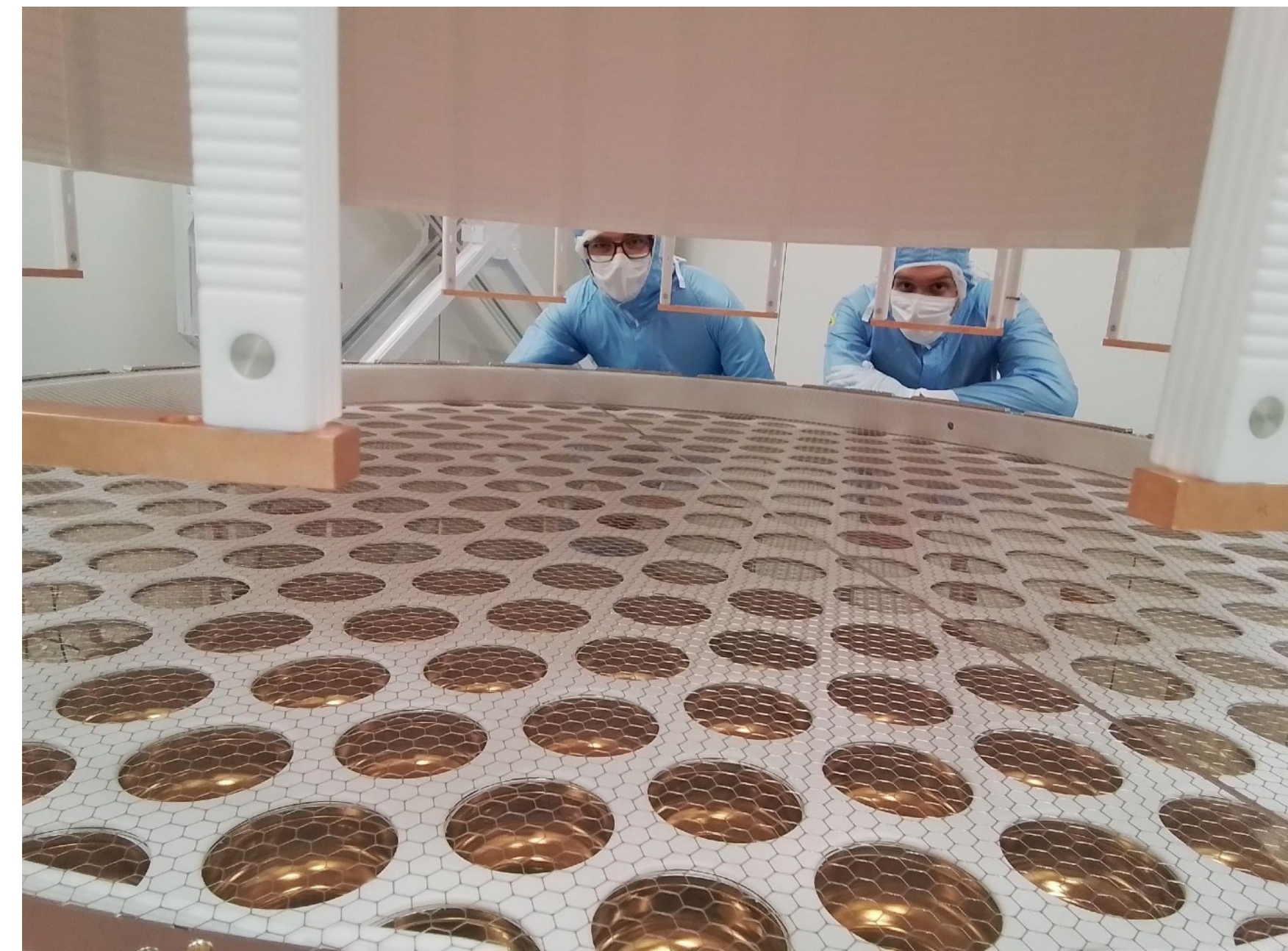
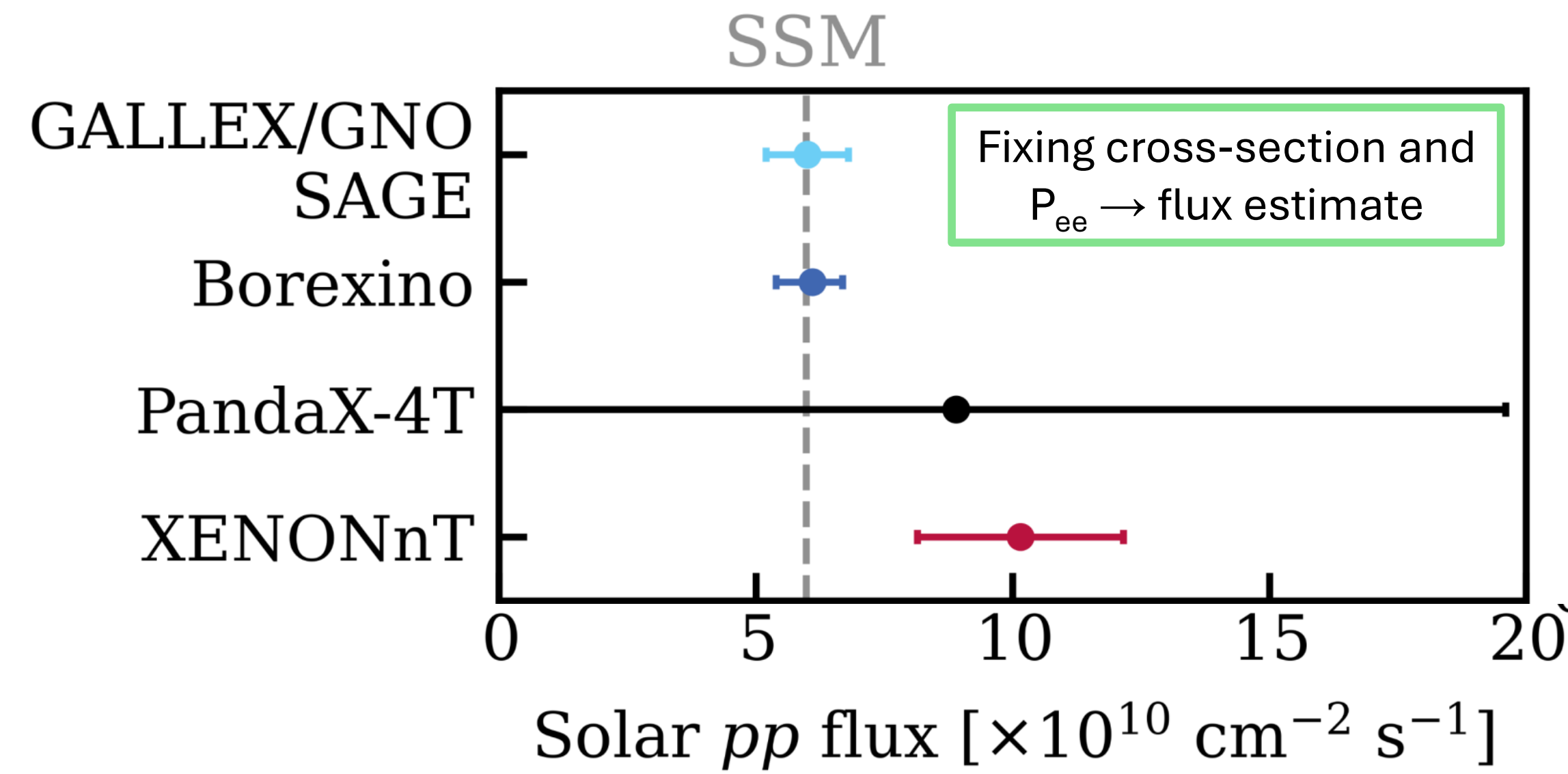
Fit result

- Best fit flux for pp component:
 - $(10.2 \pm 2.0) \times 10^{10} [\text{cm}^{-2} \text{ s}^{-1}]$
- Ratio between the pp and 7Be are fixed
- Note that PandaX-4T's recent pre-print shows $(8.5 \pm 3.5) \times 10^{10} \text{ cm}^{-2} \text{ s}^{-1}$
- Measured pp flux is consistent with Borexino result at 1.9σ
- Reject null-hypothesis by 5.0σ



Summary

- **XENONnT experiment:** large-scale liquid xenon experiment for DM/neutrino/axion/...
- Measurement of solar neutrinos in XENON:
 - **MeV-scale (^8B)** ... via CEvNS NR process
 - PRL. 137, 091807
 - **keV-scale (pp + ^7Be)** ... via ER process
 - Very recently released: (ArXiv: 2608.29450)
 - Reduction of uncertainty for Rn-induced BG to 5%
 - Final result: $(10.2 \pm 2.0) \times 10^{10} [\text{cm}^{-2} \text{ s}^{-1}]$
 - **Reject null-hypothesis by 5.0σ**
- **The detector is being upgraded** with new electrode, and the analysis for other physics channels are ongoing.
Stay tuned!



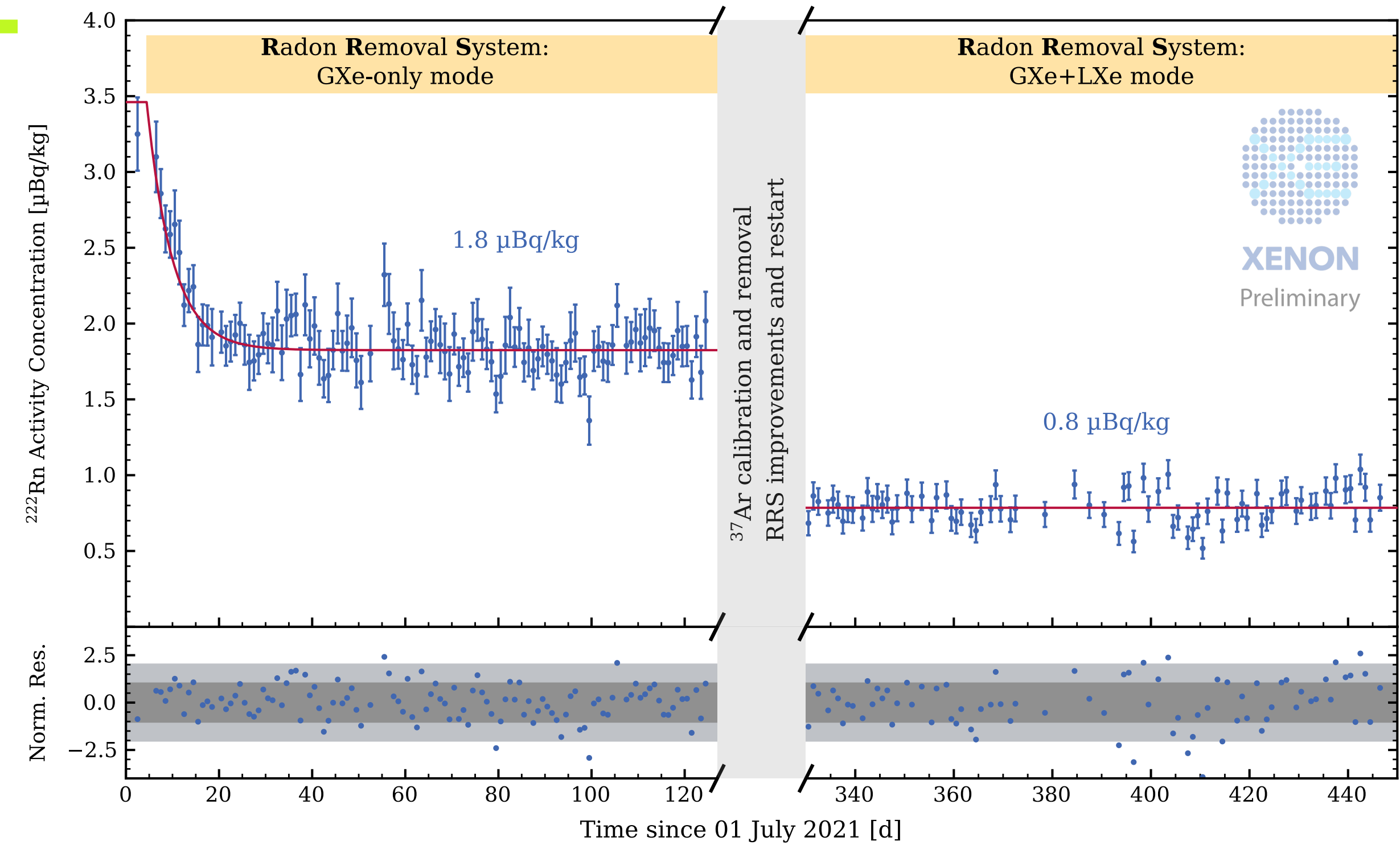
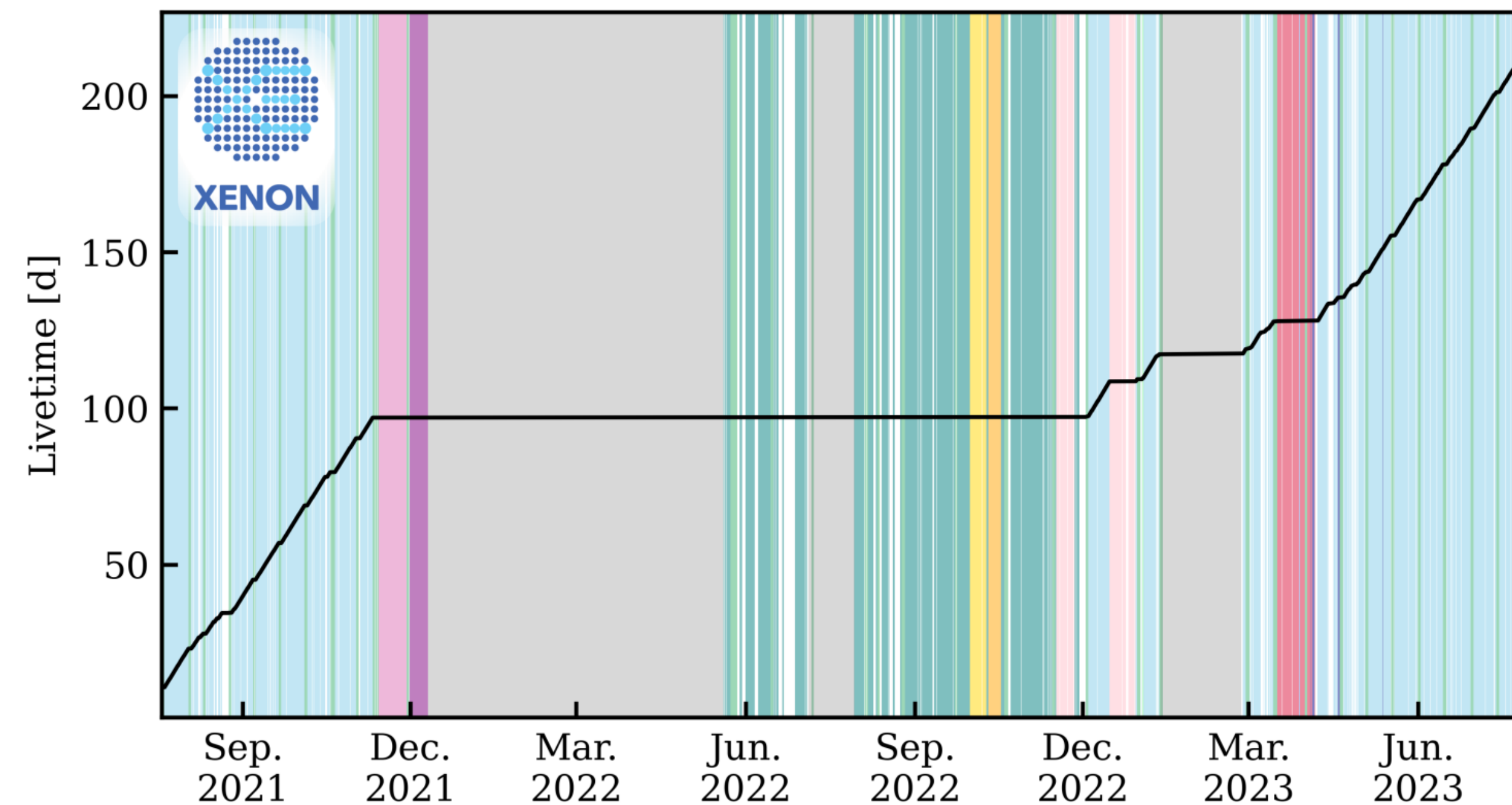
Back Up

Exposure

SR0: ~ 96 days

SR1(b): ~ 118 days

Science Mode ^{220}Rn ^{222}Rn High- ^{85}Kr S1-only mode
 $^{83\text{m}}\text{Kr}$ ^{232}Th AmBe science data Livetime:
 ^{88}YBe ^{88}Y ^{37}Ar Tritium-enhanced mode ~214 days



- Exposure:

- SR0: 0.26 [year] × 4.37 [ton]

- SR1: 0.51 [year] × 4.00 [ton]

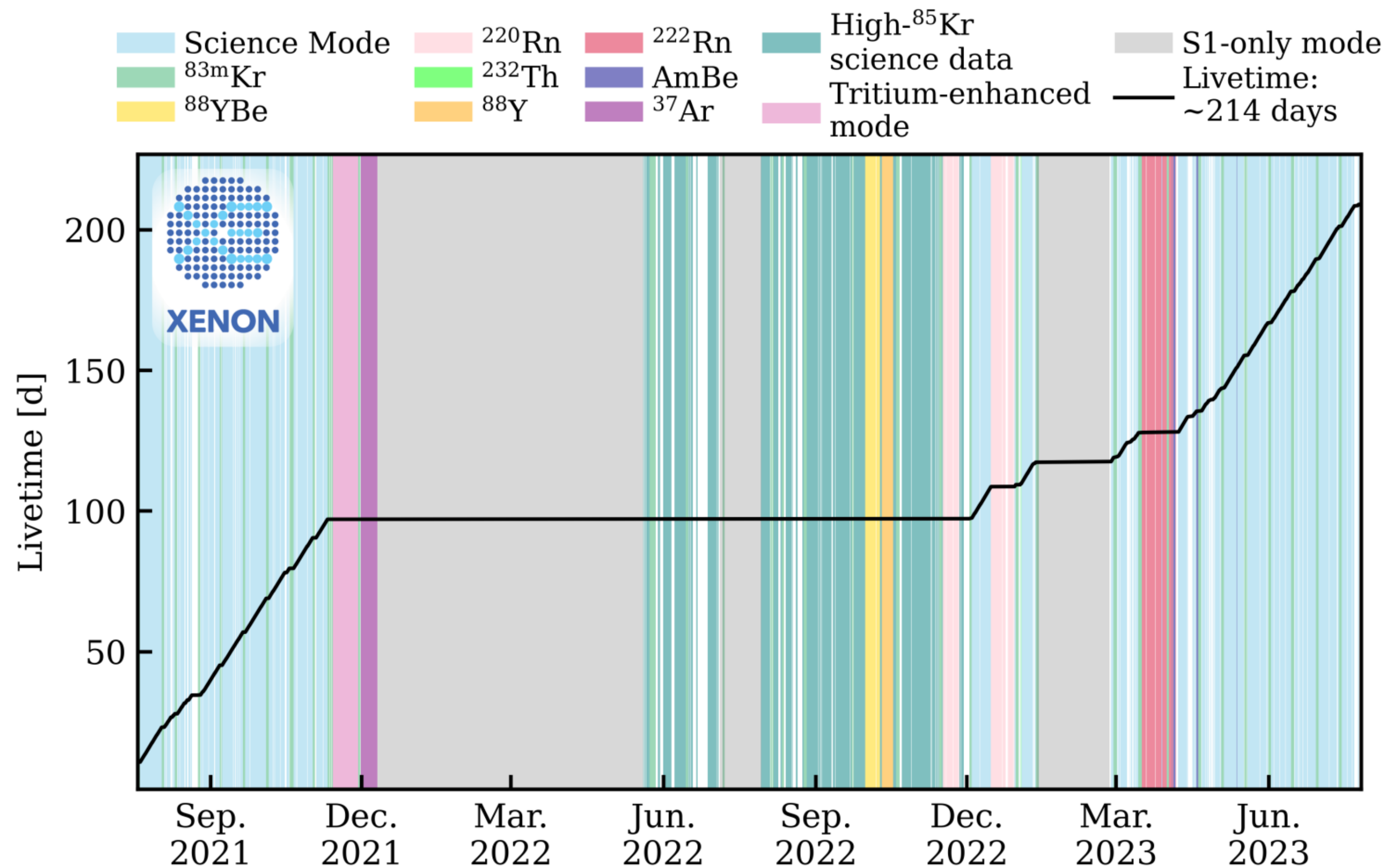
- Between SR0 and SR1, radon removal system was upgraded:

- 1.8 → 0.9 [μBq/kg]

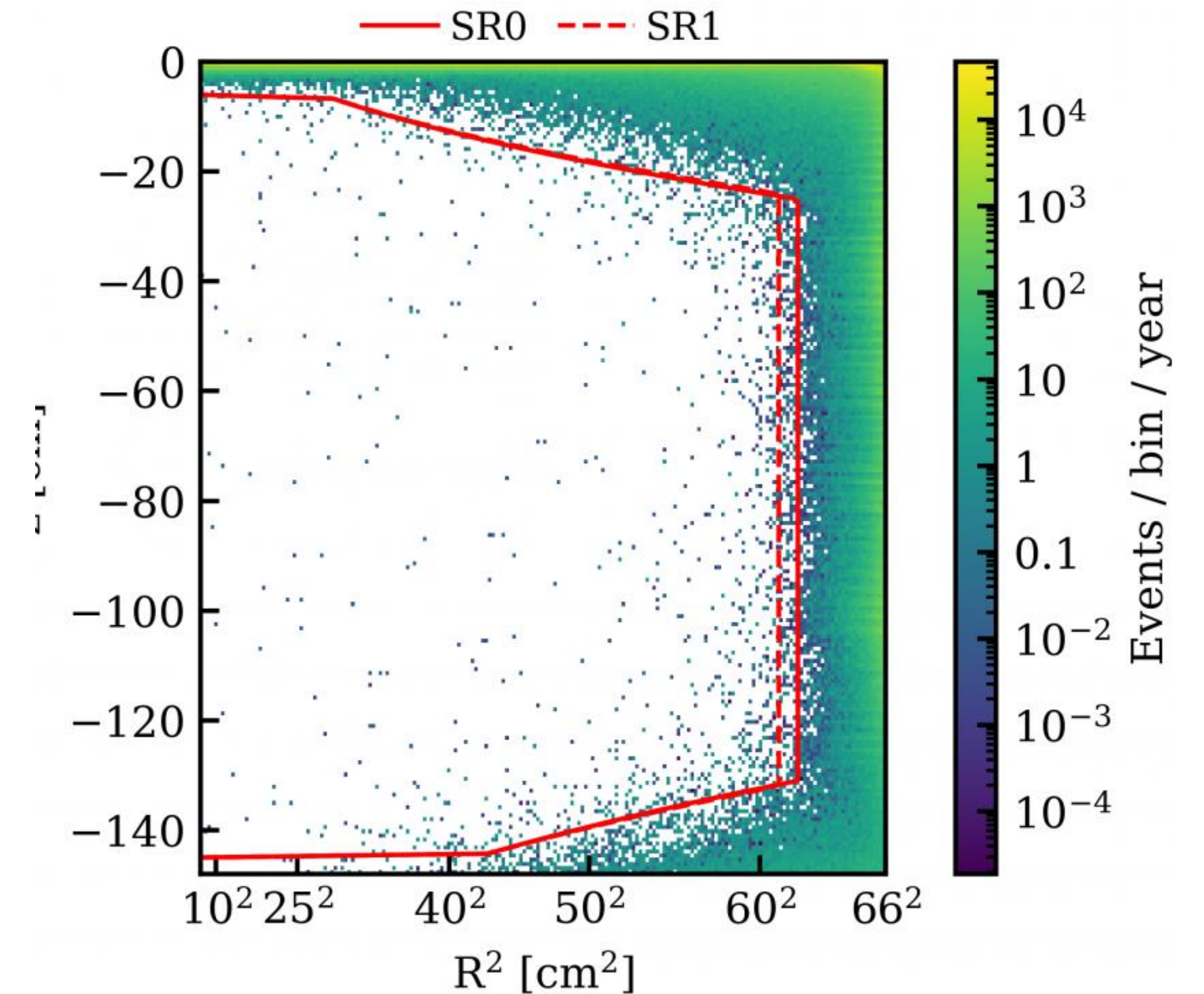
Exposure

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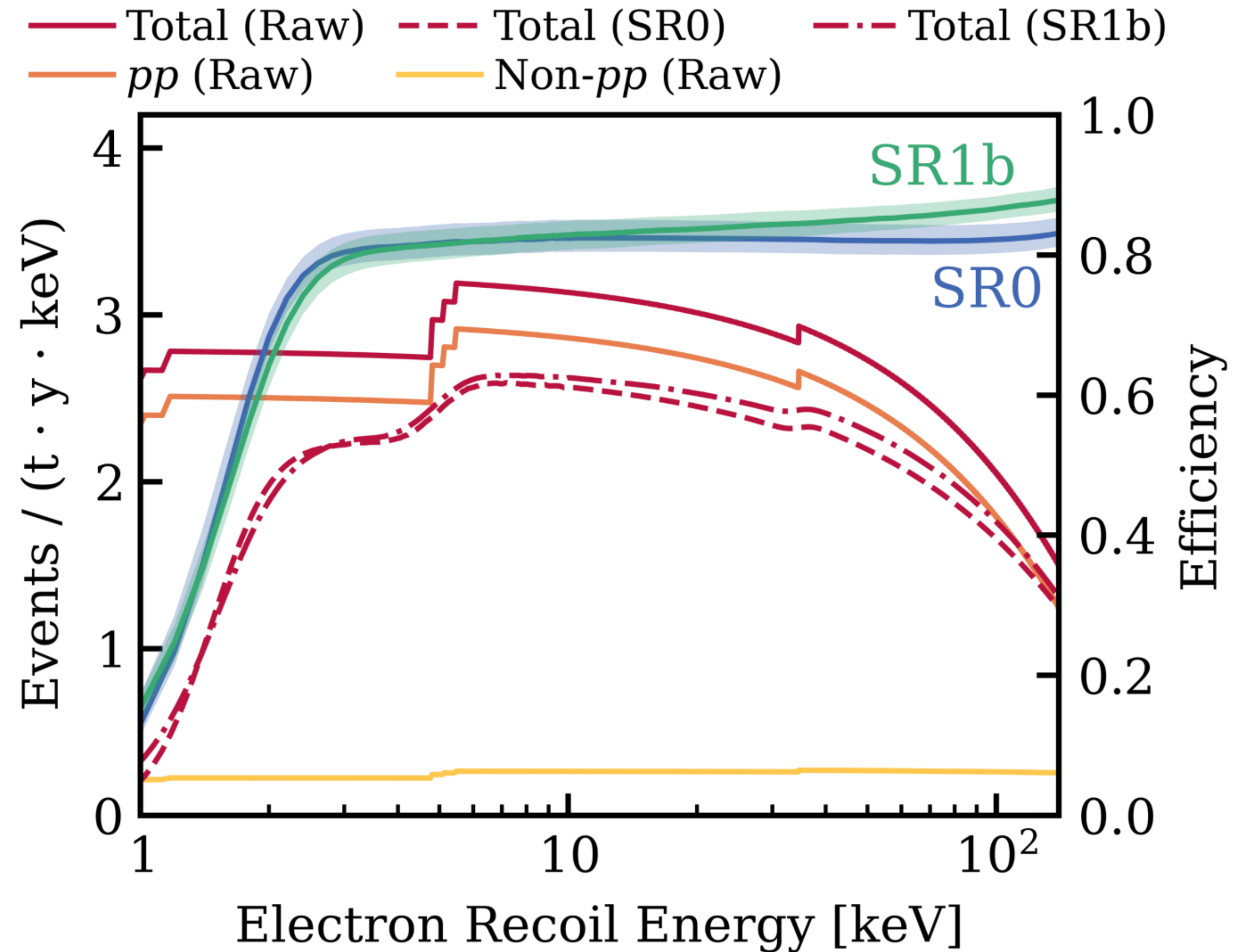
SR1(b): ~ 118 days



ROI: [1, 140] keV
 Optimized base on material radioactivity
 SR0 (SR1): ~ 4.13 (4.24) tons



Signal efficiency



Energy Calibration

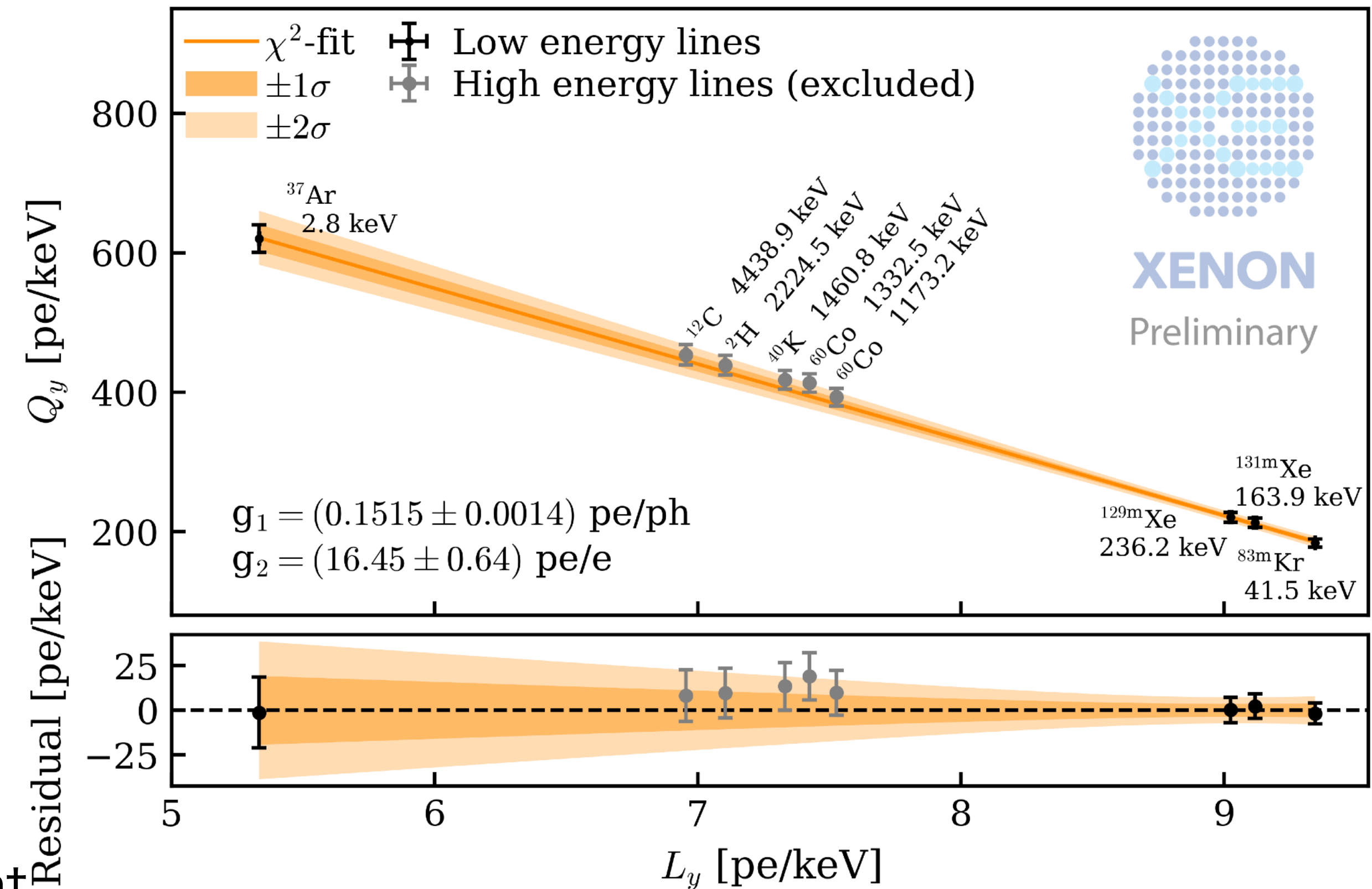
$$E = (n_{ph} + n_e) \cdot W = \left(\frac{cS1}{g1} + \frac{cS2}{g2} \right) \cdot 13.7(\text{eV})$$

- cS1, cS2; “corrected” the detector uniformity

- g1 and g2: detector-specific gain constant
 - Extracted from calibration data

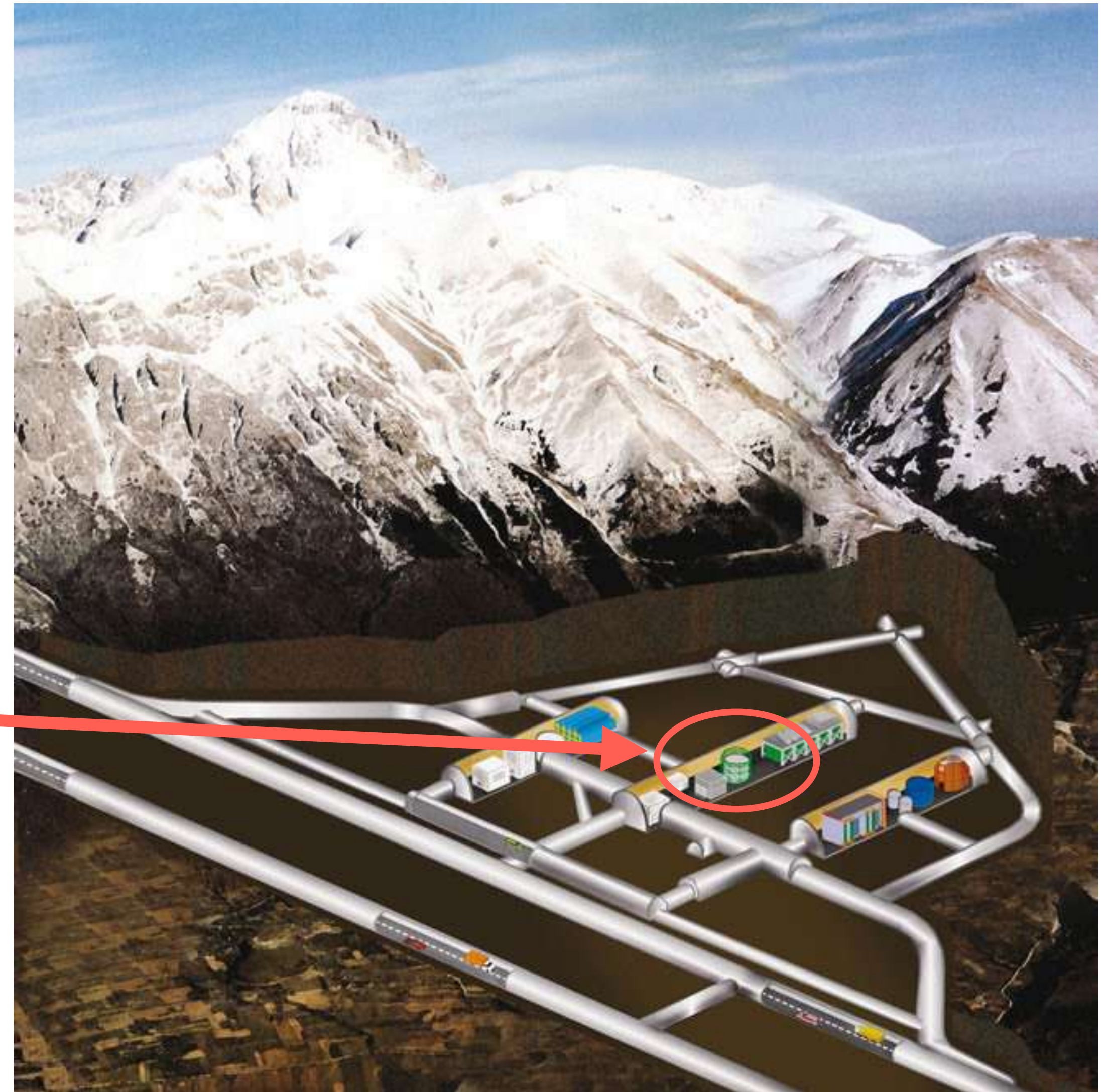
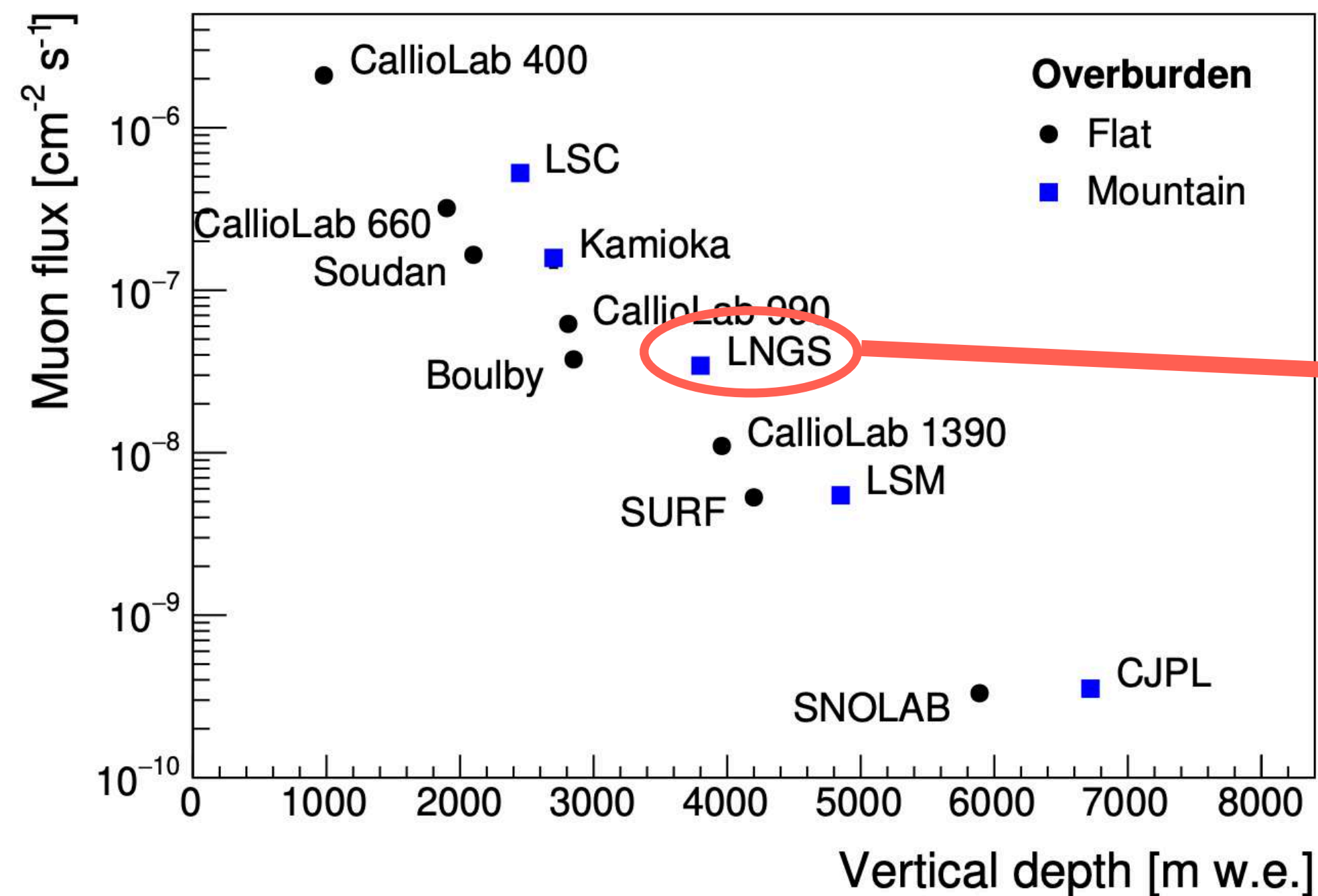
$$Q_y = -\frac{g2}{g1} \cdot L_y + \frac{g2}{W} \quad (Q_y = cS_2/E, \quad L_y = cS_1/E)$$

- Using g1 and g2, reconstruct energy of each event



The XENONnT

- The XENONnT detector is located at Laboratori Nazionali del Gran Sasso (LNGS), Italy
- Underground area: suppress muon background
 - 1500 m of rock $\sim$ 3600 m.w.e
 - Suppress muon flux to 10^{-6} of surface area



The XENONnT

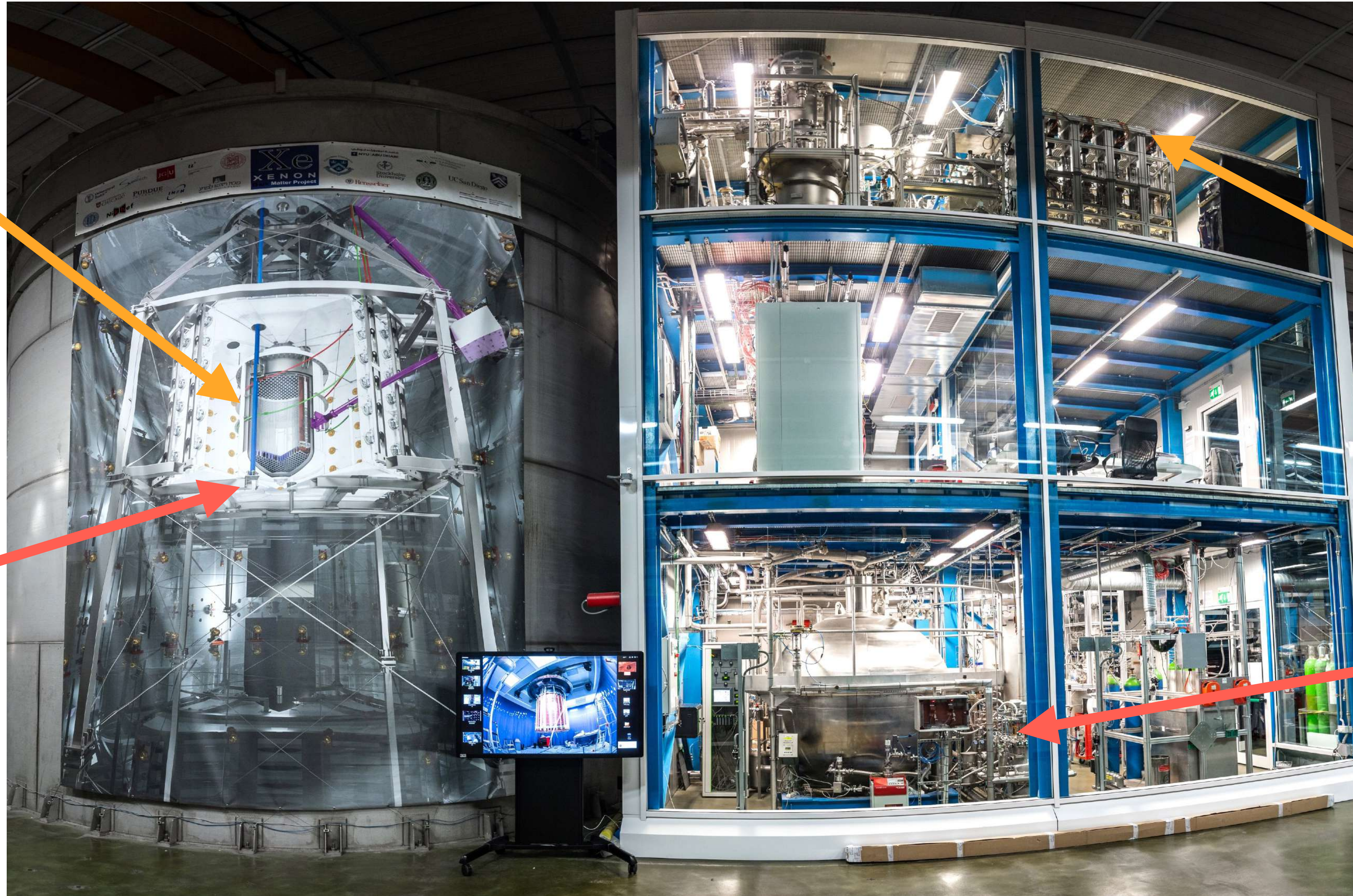
Nagoya/JP group contributions

Larger TPC
with 3x
active
volume

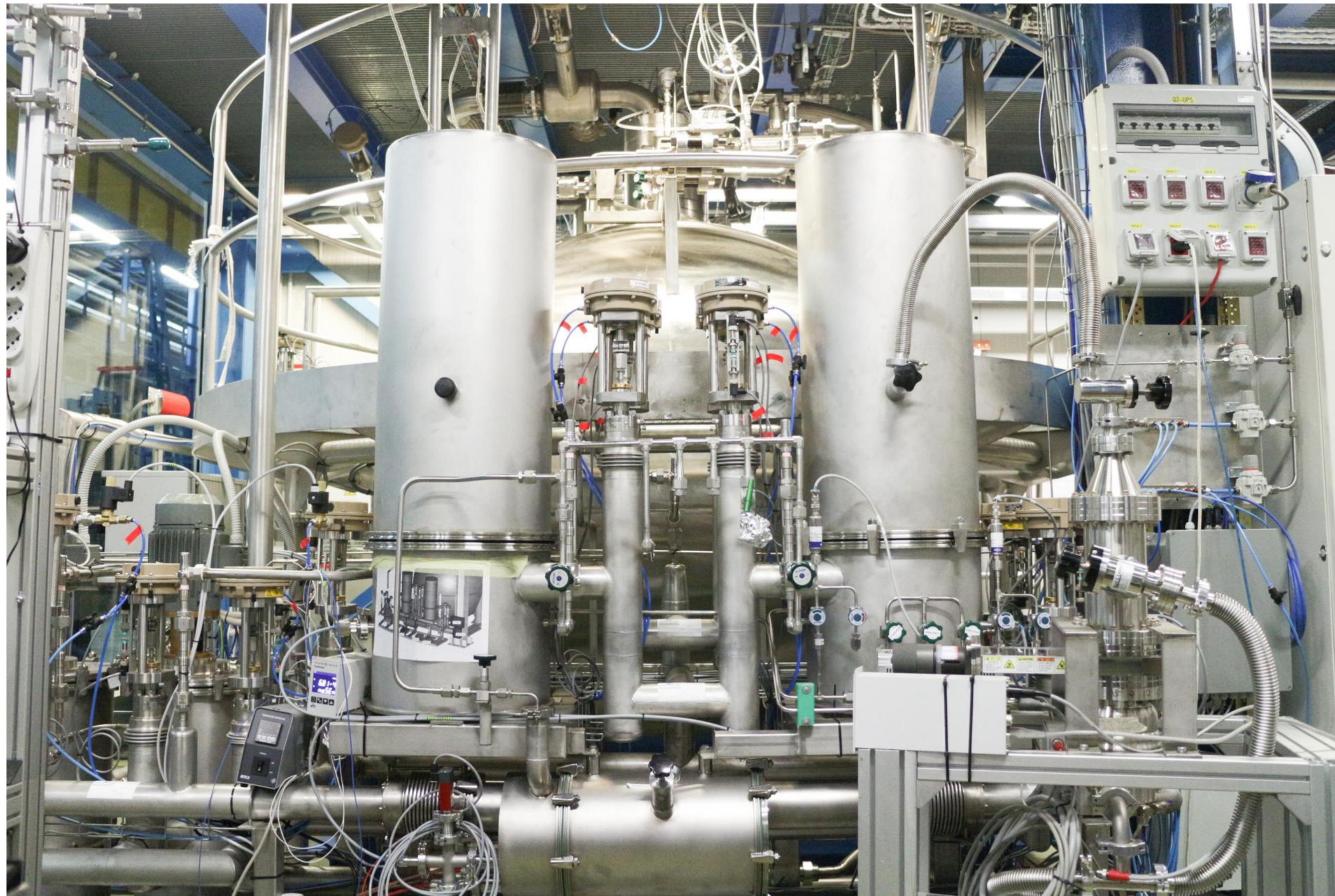
Gd-loaded
water
Cherenkov
neutron
veto

Radon
distillation
column

Liquid xenon
purification



LXe Purification



- Liquid purification system
- Direct liquid circulation with cryogenic pump
 - Speed: ~2 LPM with liquid
 - ~x500 of XENON1T system
- Real-time purity measurement with purity monitor

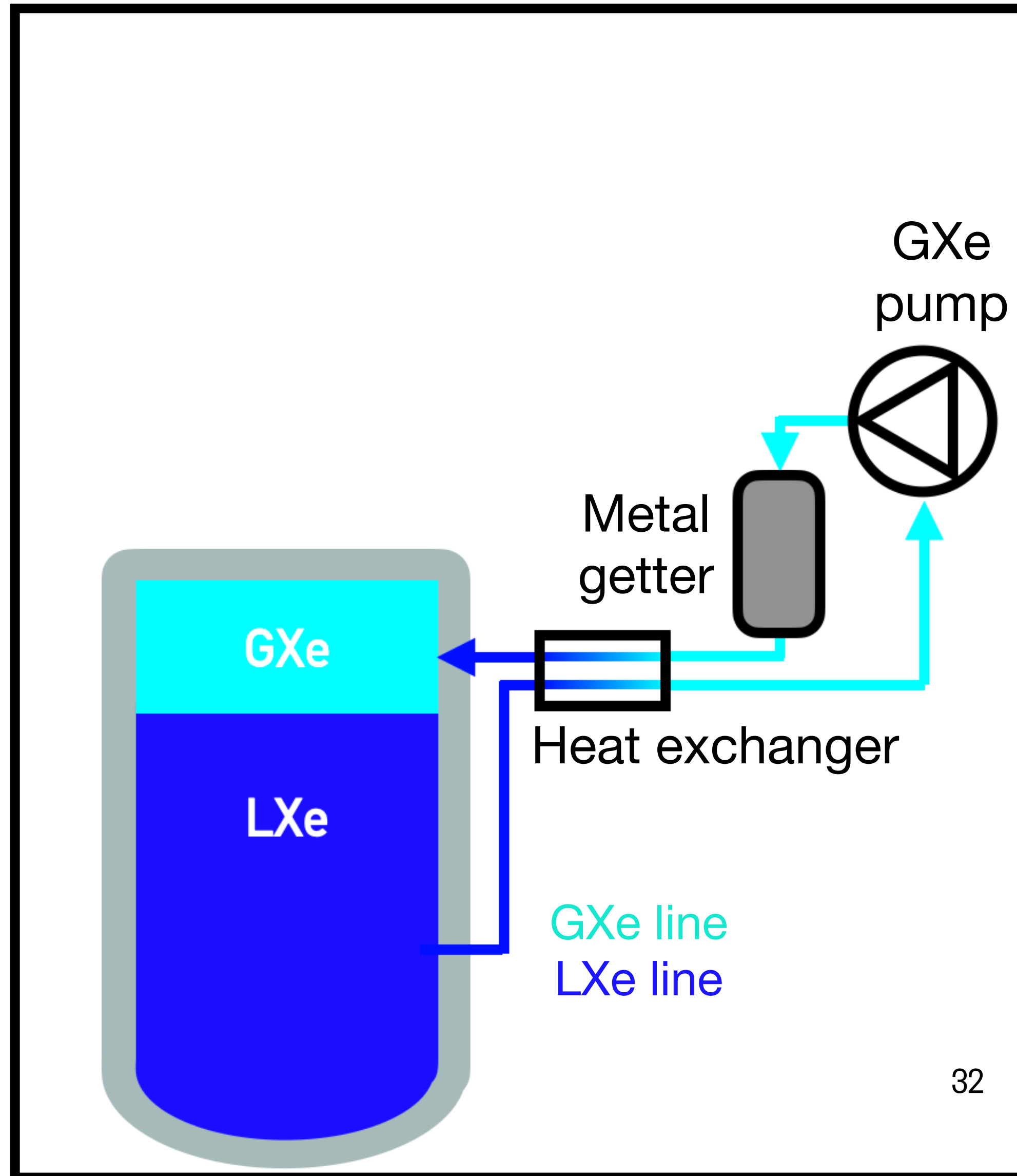
XENON Collaboration

>150 scientists, 29 institutions from 12 countries



Radon-induced background

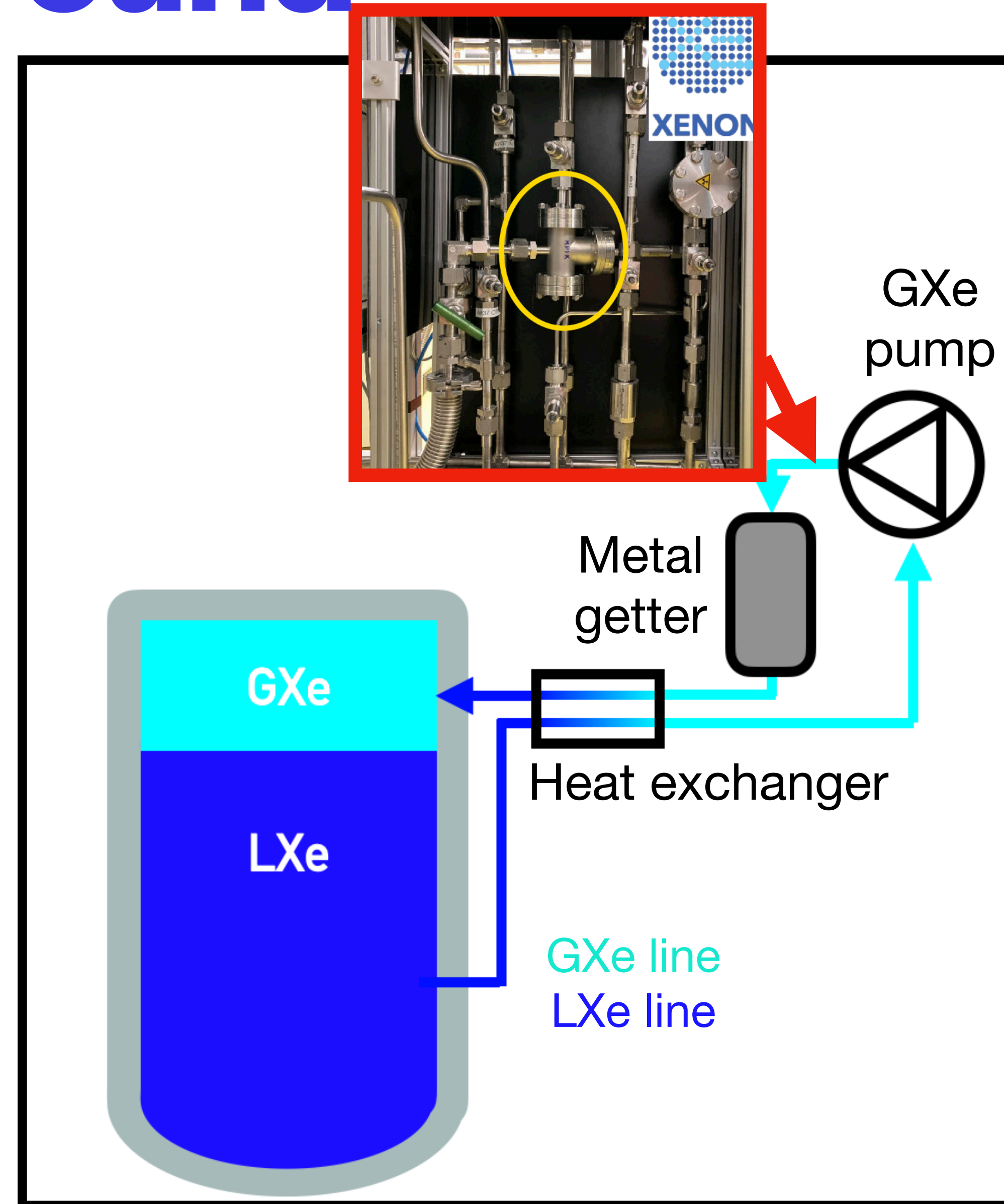
- ^{222}Rn calibration:
 - Compare [β from ^{214}Pb] vs [α from ^{222}Rn]
- Place the source in the GXe circulation system, and diffuse ^{222}Rn into the detector
 - Source: ^{226}Ra implanted SUS (~2Bq, made by MPIK^[1])
 - ^{222}Rn α : ~150 higher than normal run
 - Can be removed by distillation after the calibration



[1] F. Joerg, et al., Applied Radiation and Isotopes, 194, 110666 (2023)

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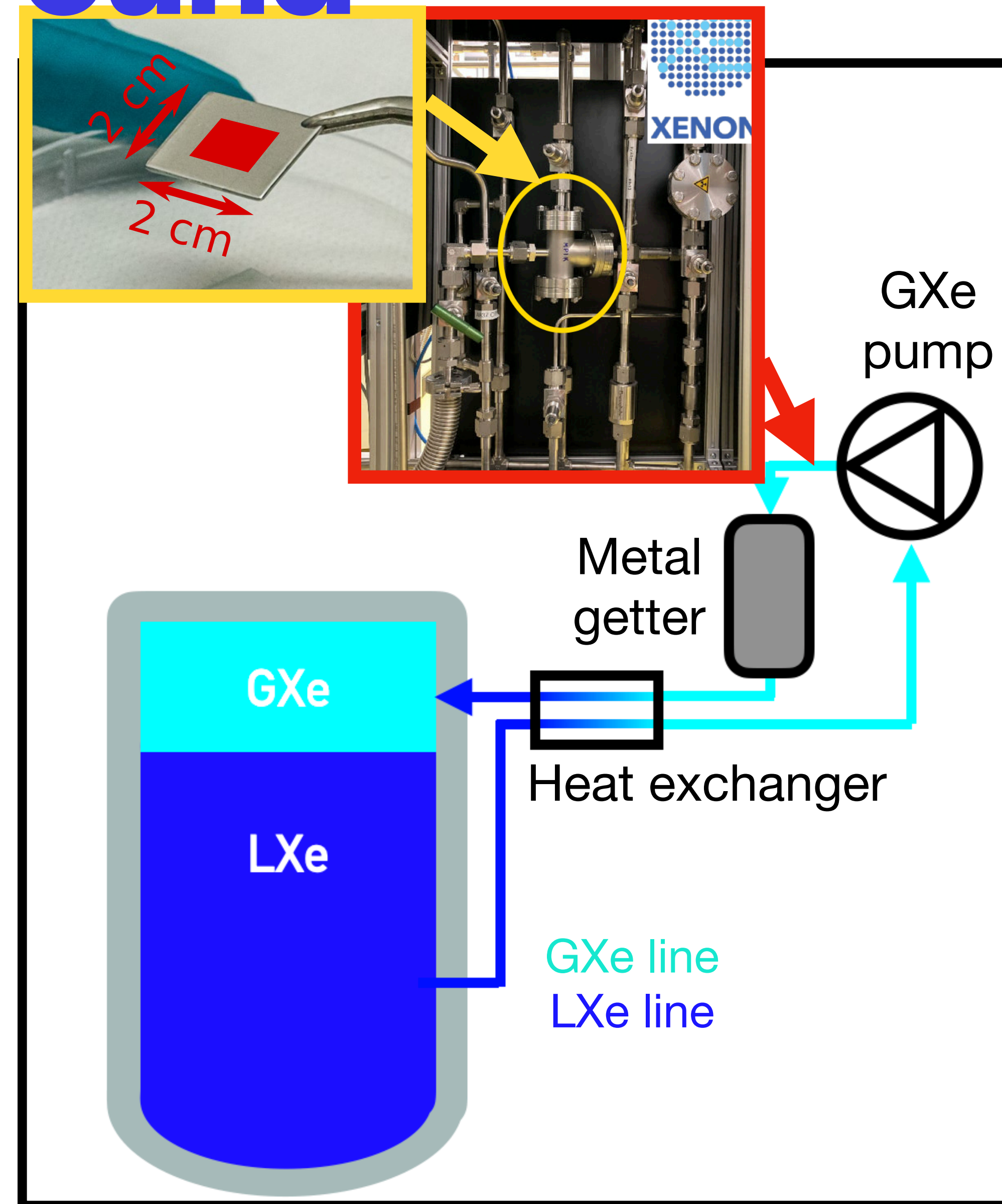
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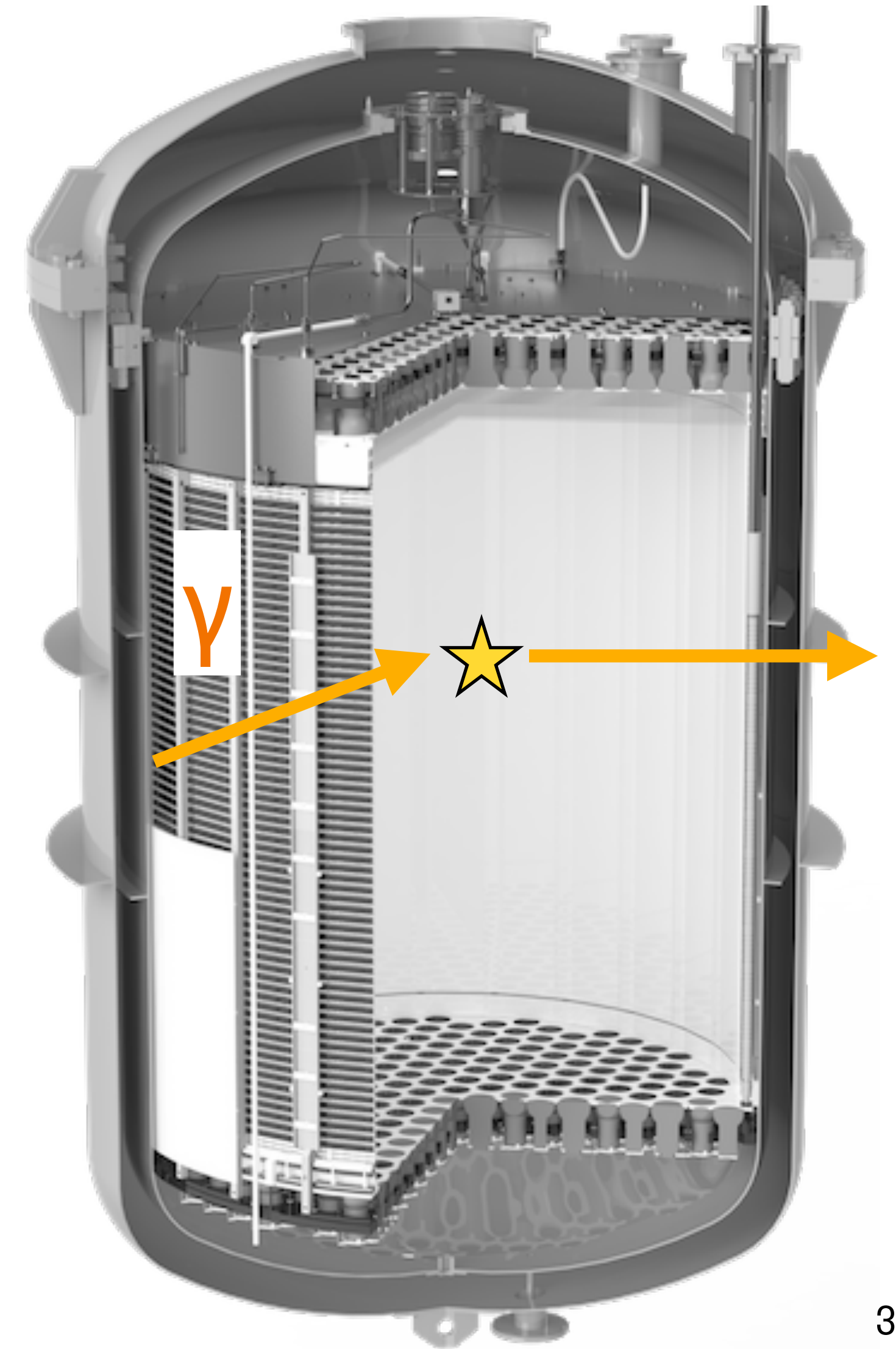
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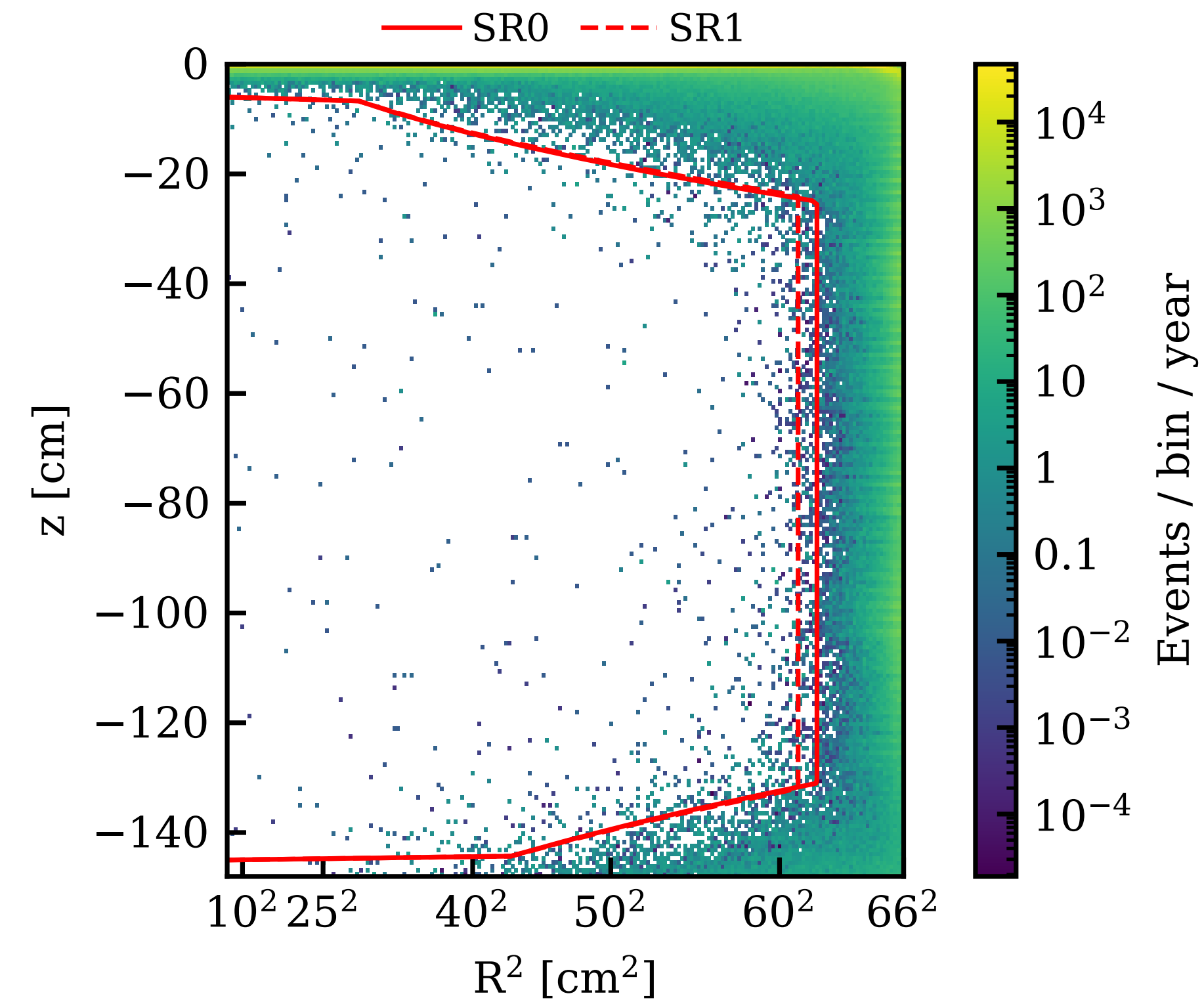
Other backgrounds

- Other BG : Material γ and Kr-induced
- Material γ
 - Low energy compton scattering induced by γ from detector materials
 - Reduced by fiducial cut, estimation by simulation
- Kr-induced
 - β decay of ^{85}Kr ($Q=687\text{keV}$)
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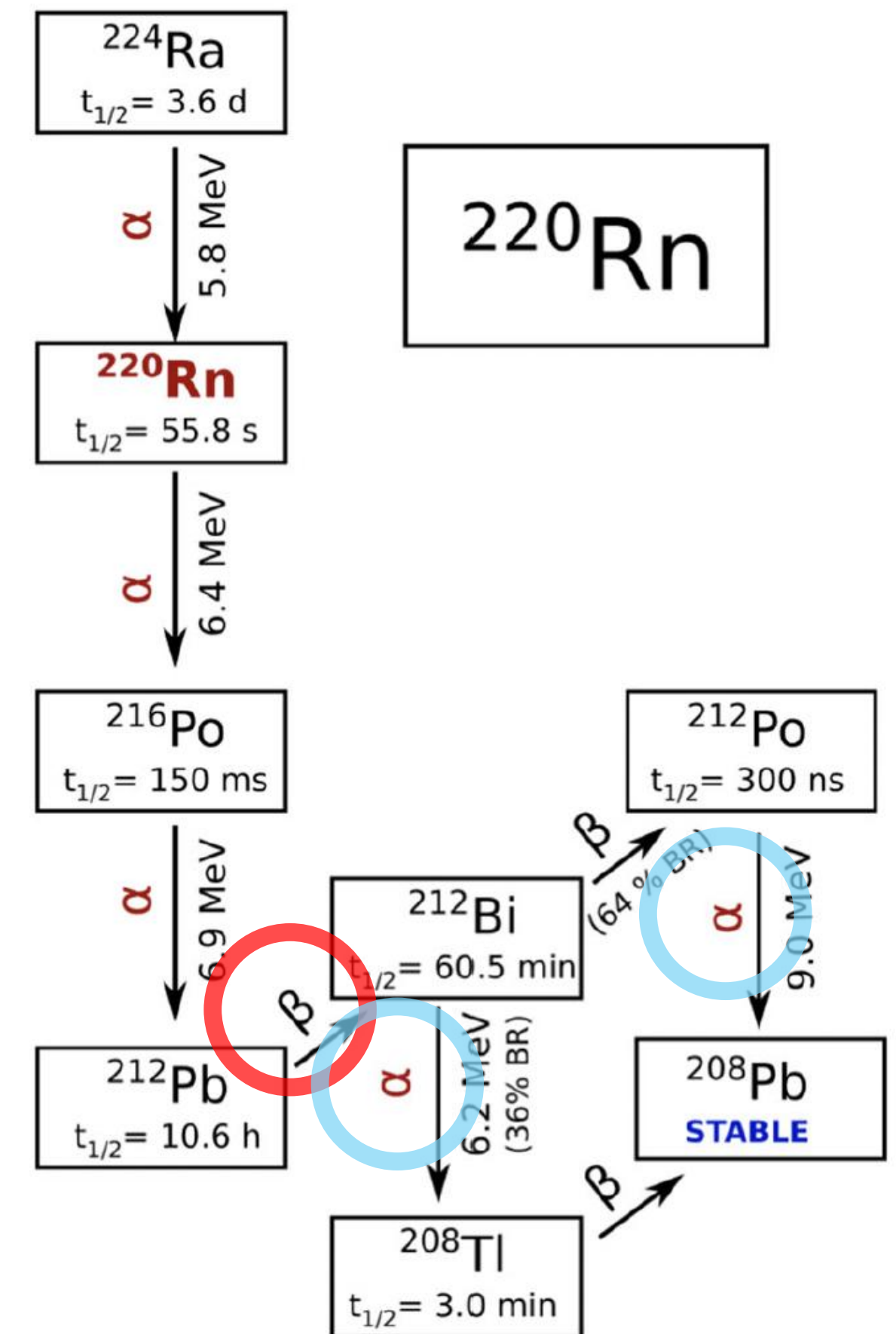
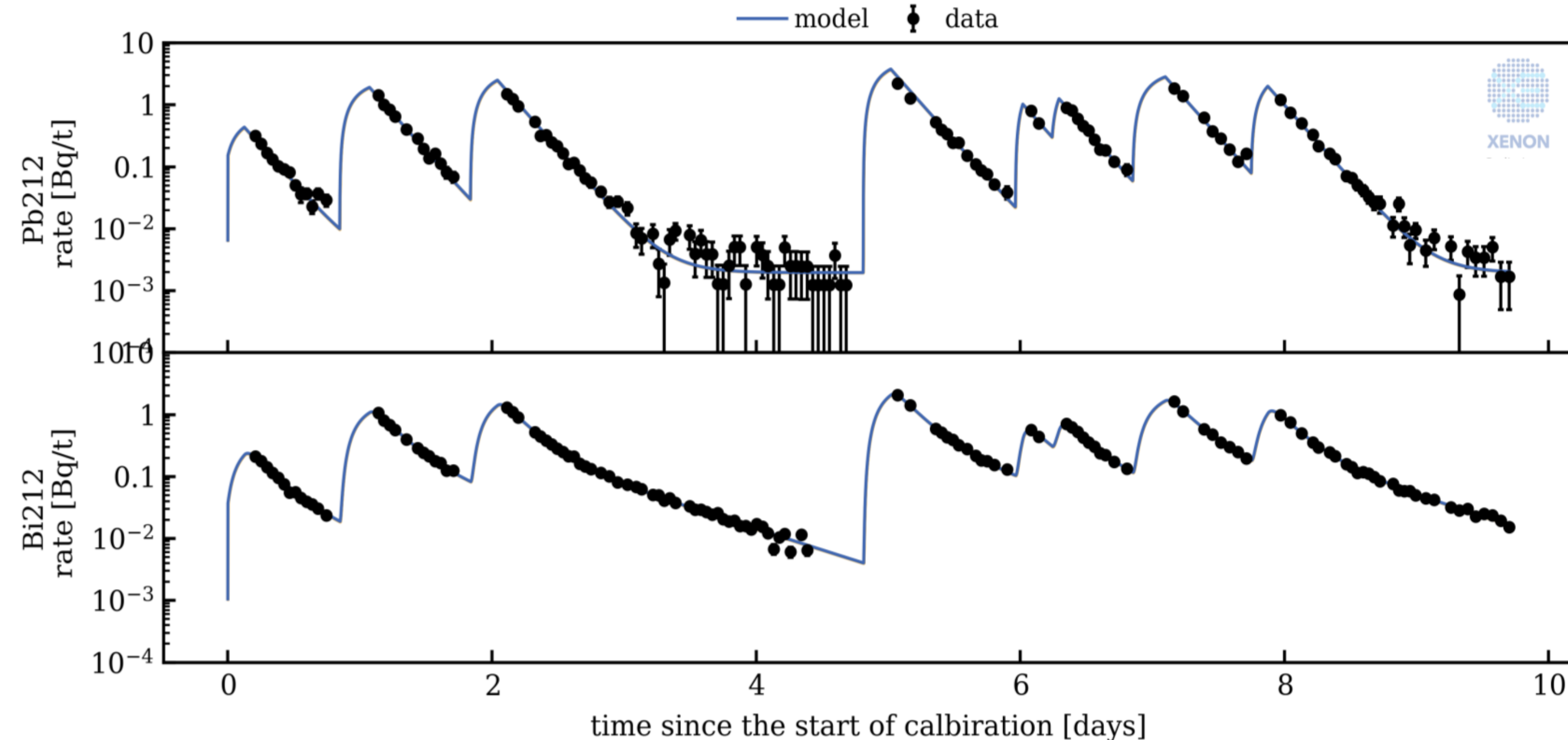
Other backgrounds

^{212}Pb β decay

Background rate roughly 1/10 of ^{214}Pb

Utilizing ^{220}Rn calibration

- ^{220}Rn and ^{216}Po short half-life => not reaching equilibrium
- Full difference equation modeling required
- Conservative systematic uncertainty: $\approx 20\%$



S. Bruenner et al., Eur. Phys. J. C. 81, 343 (2021)

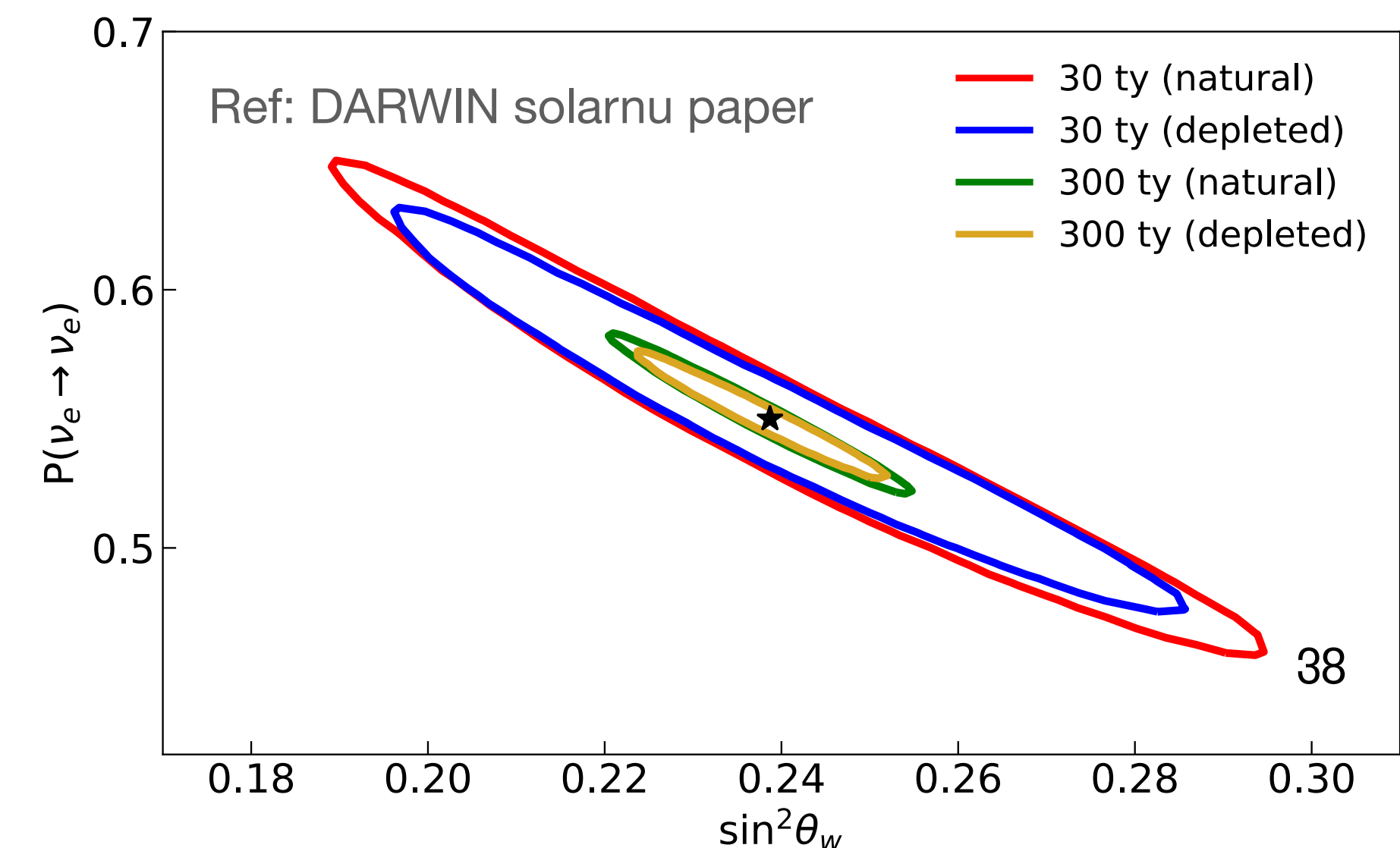
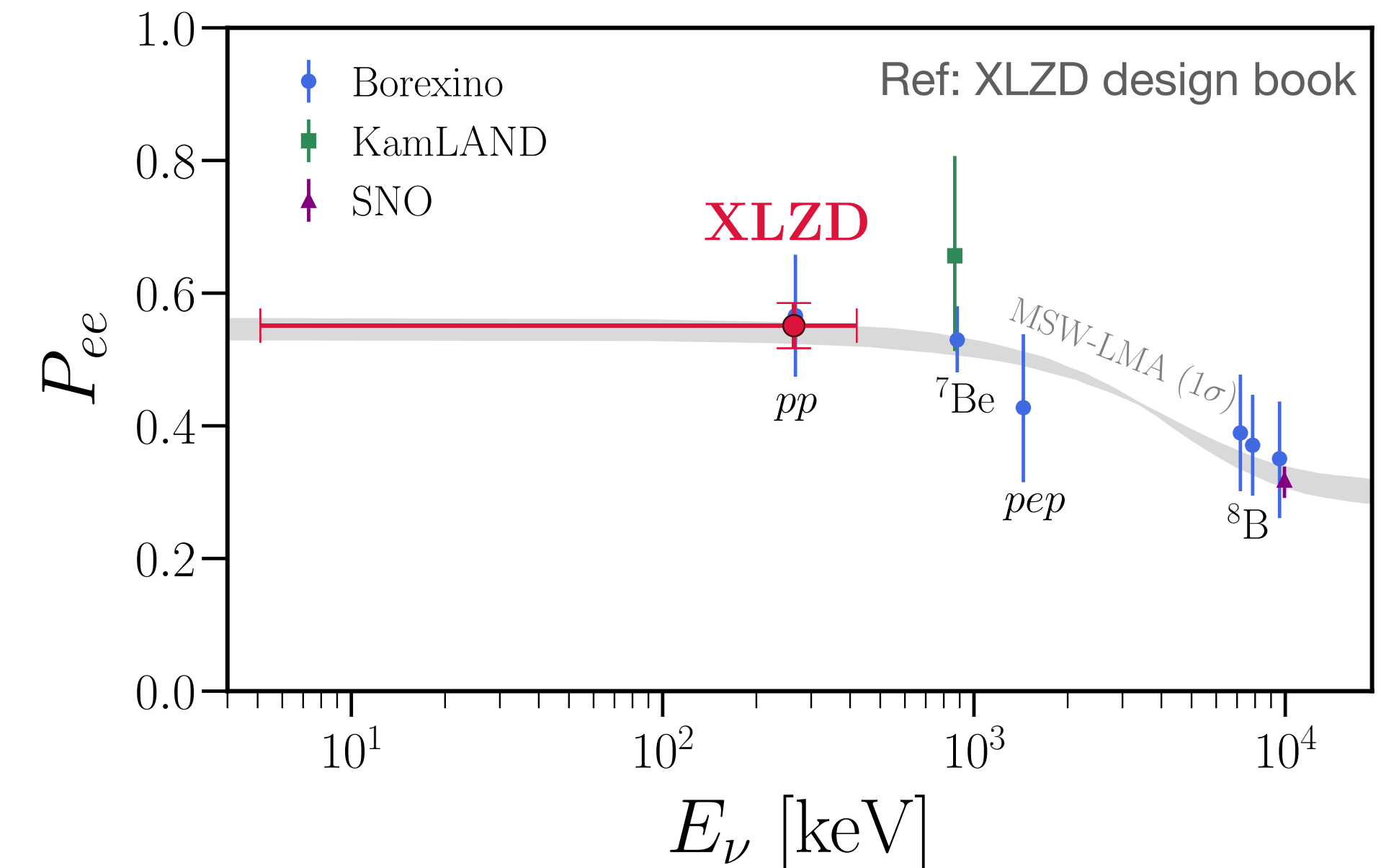
Measurement for the pp neutrino

- **Low-E neutrino physics**

- Measurement for ν_e survival probability (P_{ee})
- Measurement for the Weinberg angle
- Search for exotic neutrino interactions (ex. Magnetic moment)

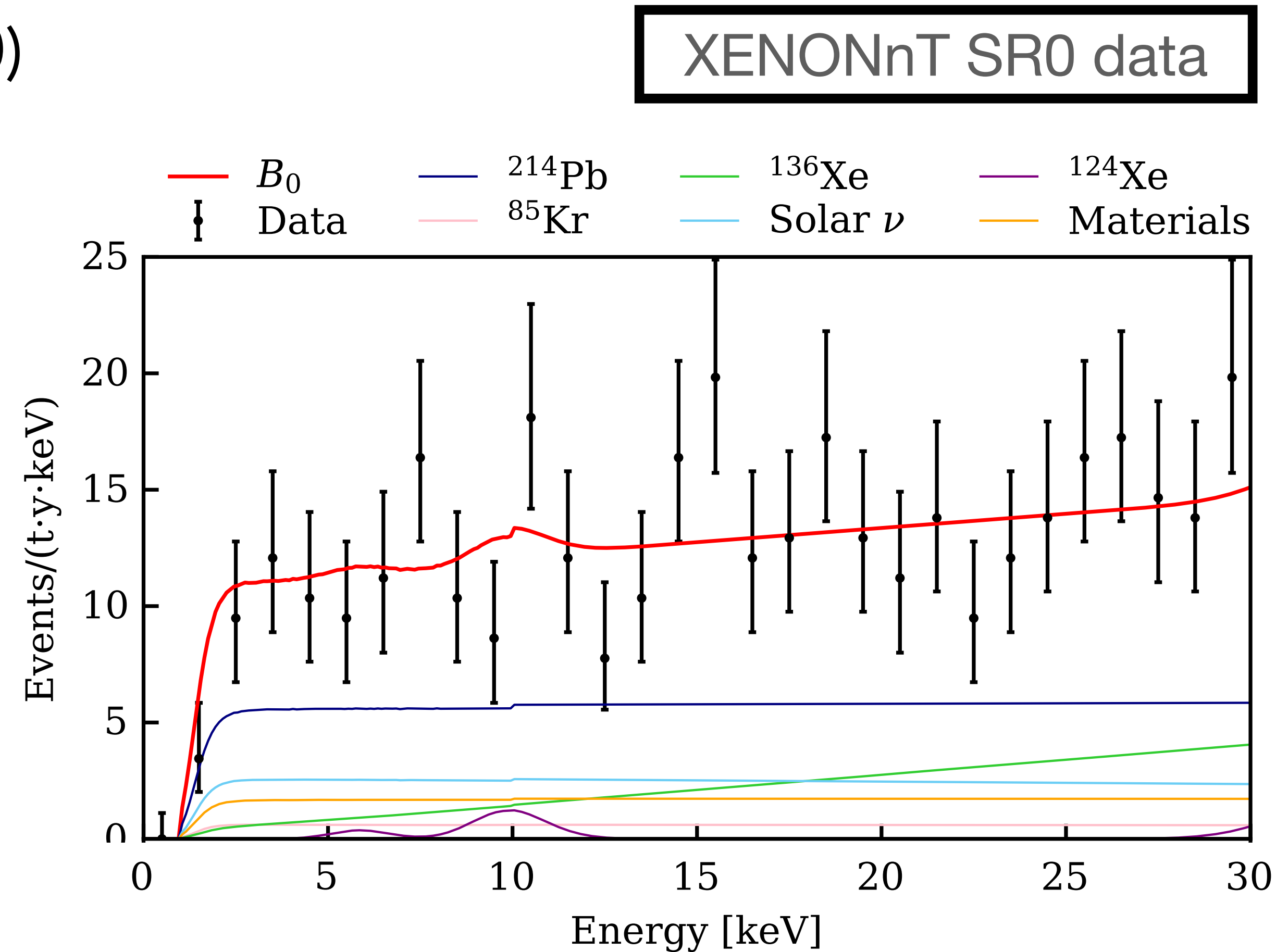
- **Goal for XENONnT: Demonstration with 3σ**

- Measurement with few % precision expected in future experiment



Analysis for XENONnT initial data (SR0)

- Right: first science run by XENONnT (SR0)
- Good agreement between **Data** and **BG**
- Main target for the analysis: peak-like signals
- “XENON1T Excess”: ex. solar-axions
- => solar-nu signal was calculated by Borexino's result



Detector upgrade

- The data taking was stopped at Apr 2025 and stated to upgrade
- In previous detector, there was an issue at the electrode
 - Shortage of cathode electrode and bottom screen electrode
- After replacing problematic electrodes and some PMTs, currently the detector is being commissioned
- Expecting $\sim x10$ better ER/NR discrimination with new electrodes

