XENONnT/XLZD実験の現状と極低放射能技術

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On behalf of the XENON Collaboration

XENONnT

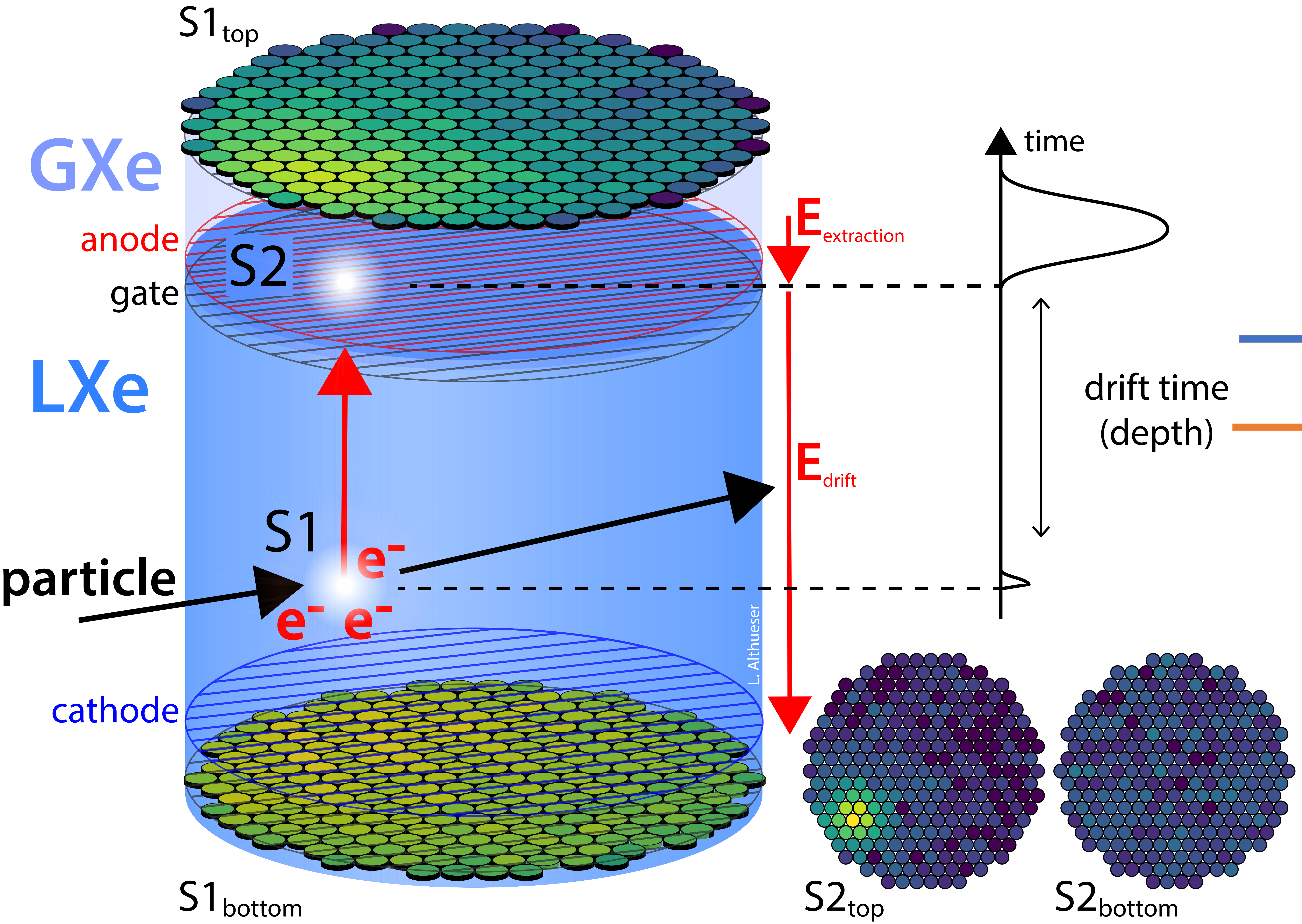
XENON Collaboration

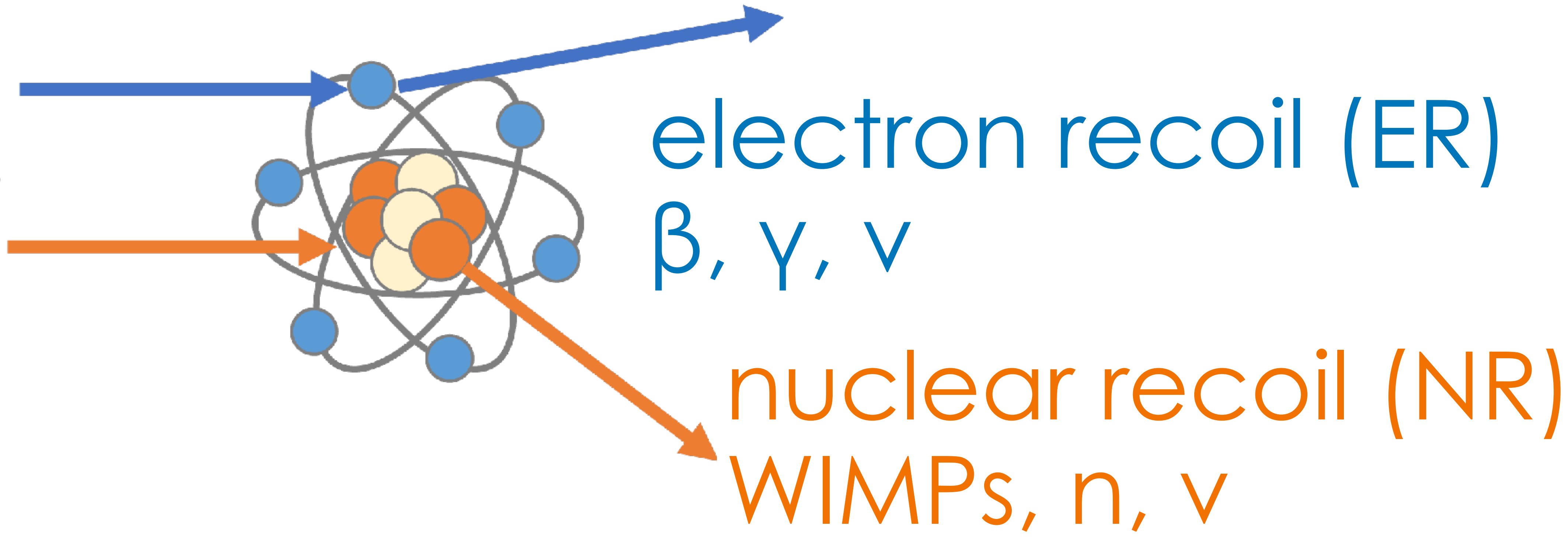
> 200 scientists
29 institutions
12 countries

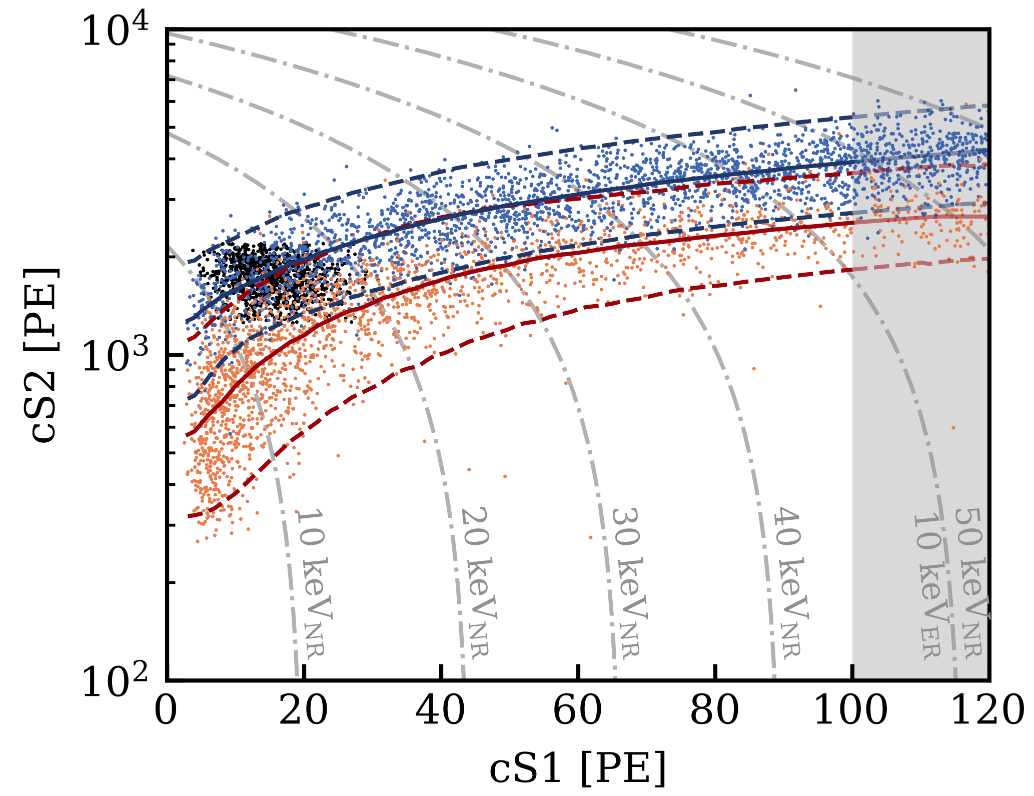
XENONnT TPC

Dual phase Liq. Xe TPC w/ **5.9 t** sensitive mass

- Self shielding
- 3D vertex reconstruction
  - x, y : S2 hit pattern
  - z : drift time
- ER/NR discrimination by S2/S1 ratio







XENONnT Timeline

2020 **Construction**
2020.03 – 12

2021 **Commissioning**
2021.01 – 06

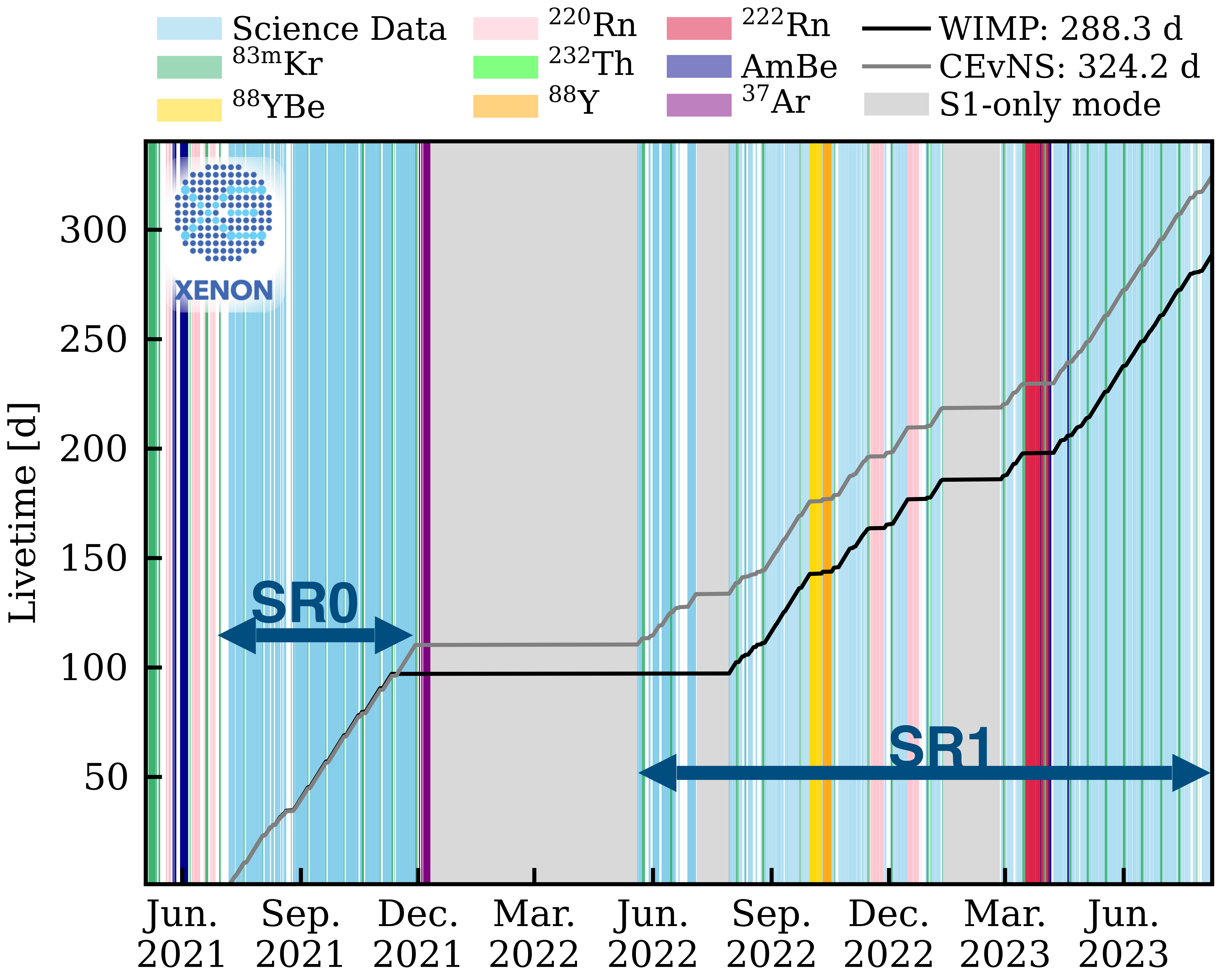
Science Run 0 (SR0)
2021.07 – 11

2022 **Science Run 1 (SR1)**
2023 2022.05 – 2023.08

GdSO loading into veto detector

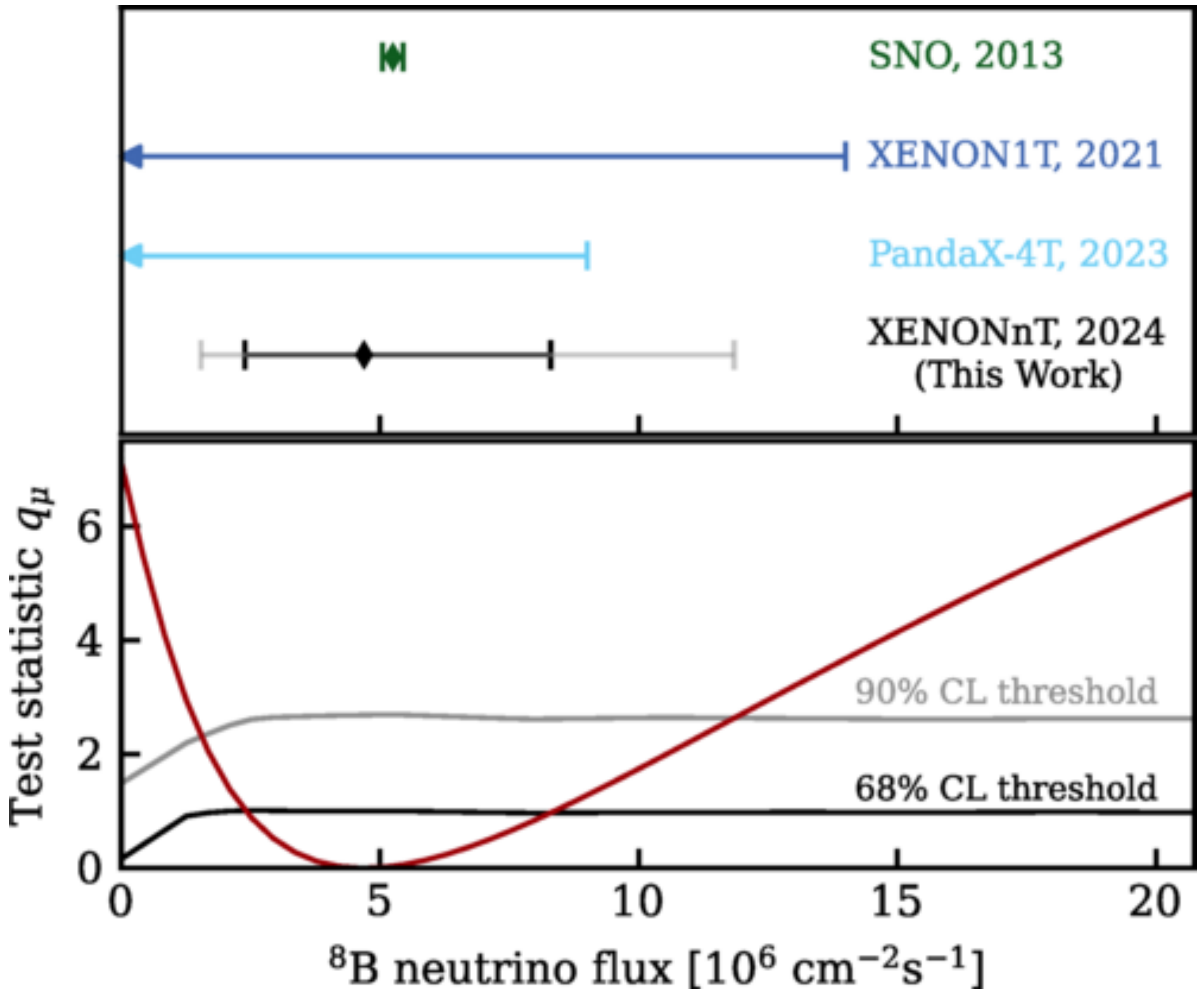
Science Run 2 (SR2)
2023.10 –

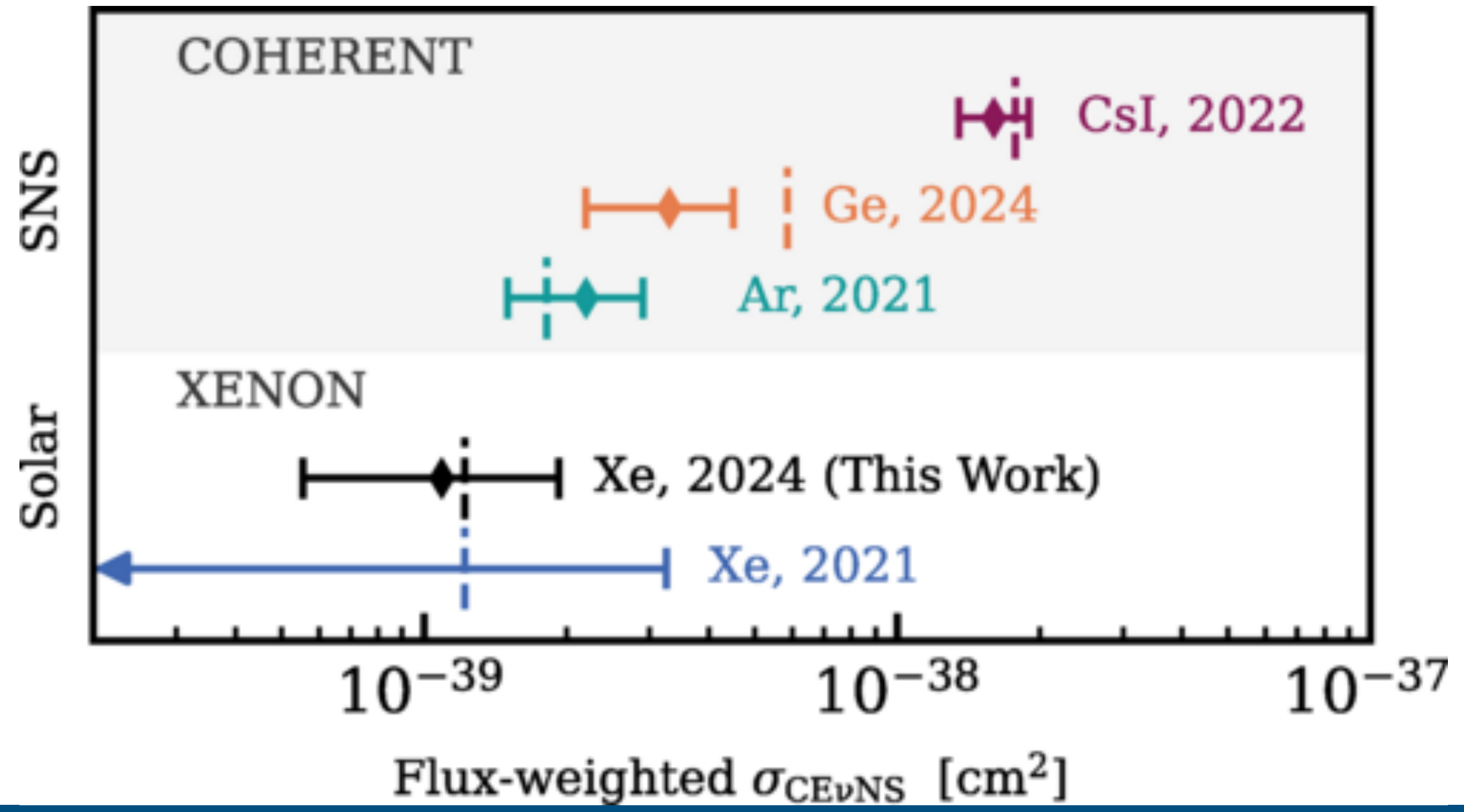
2024
2025



PRL **133**, 191002 (2024)

Recent results: Solar ^8B CEvNS





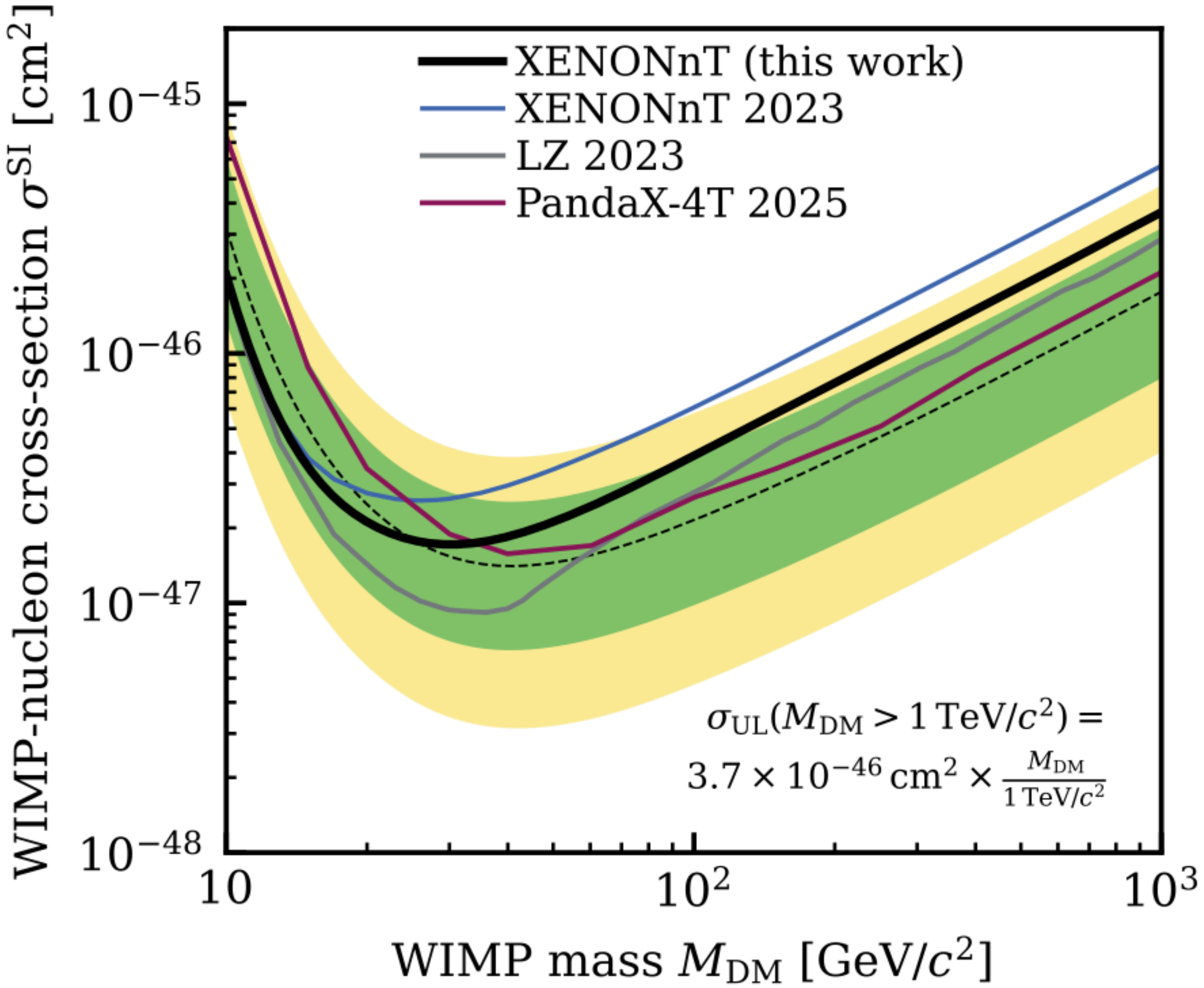
First indication of Solar ^8B ν CEvNS
(**C**oherent **E**lastic ν-**N**ucleus **S**cattering)

- 2-fold S1 → lower threshold
- Main BG: Accidental Coincidence (AC)
  : mistakenly paired S1 and S2
- **2.73 σ** significance

Component	Expectation	Best fit
AC (SR0)	7.5 ± 0.7	7.4 ± 0.7
AC (SR1)	17.8 ± 1.0	17.9 ± 1.0
ER	0.7 ± 0.7	$0.5^{+0.7}_{-0.6}$
Neutron	$0.5^{+0.2}_{-0.3}$	0.5 ± 0.3
Total background	$26.4^{+1.4}_{-1.3}$	26.3 ± 1.4
^8B	$11.9^{+4.5}_{-4.2}$	$10.7^{+3.7}_{-4.2}$
Observed	37	

Recent results: WIMPs

arXiv:2502.18005



- - - - median sensitivity
±1 σ
±2 σ

neutron BG is suppressed by veto detector (pure water Cherenkov) w/ tagging efficiency of 53%

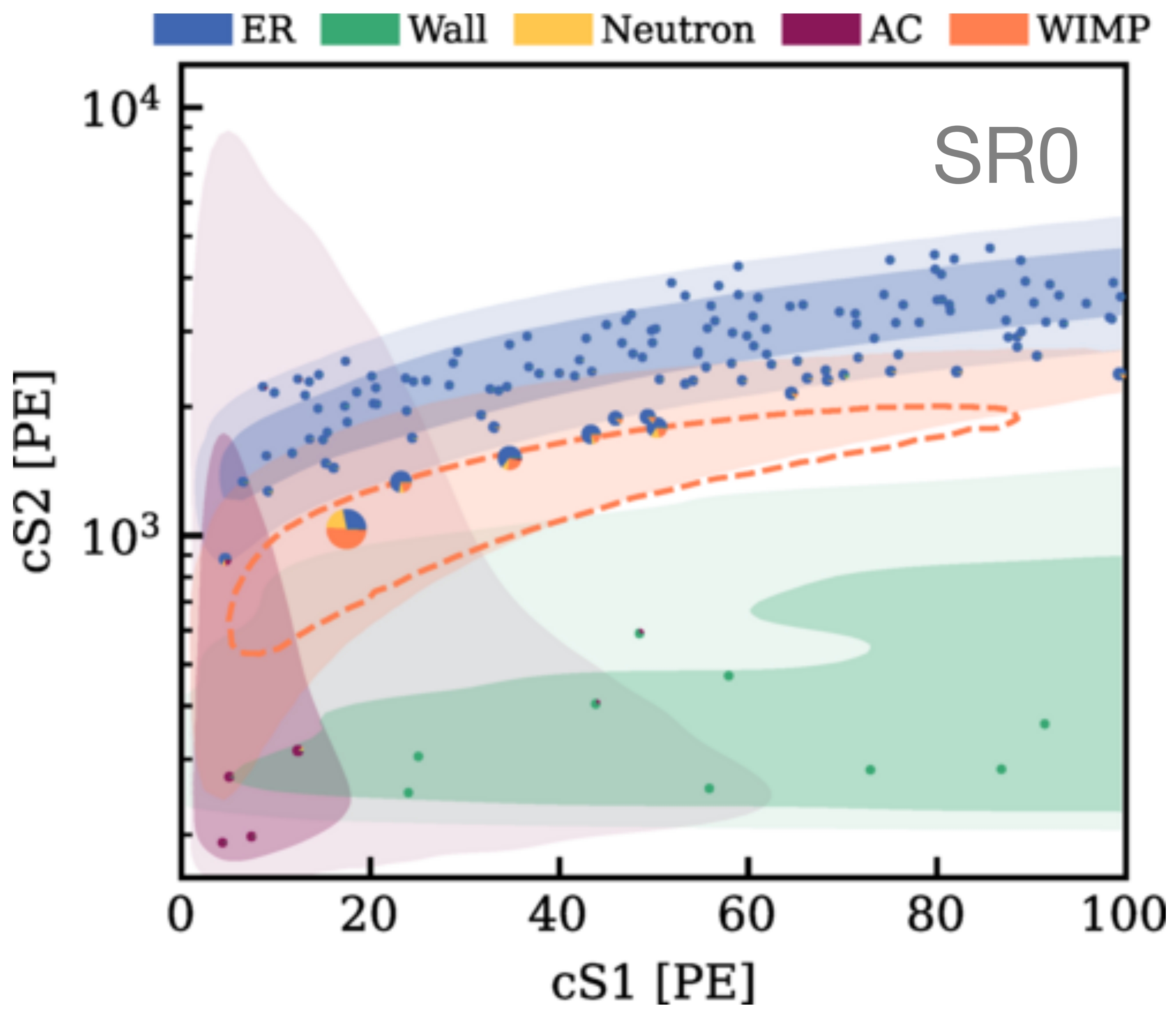
Nominal WIMPs
(**W**eakly **I**nteracting **M**assive **P**articles) search

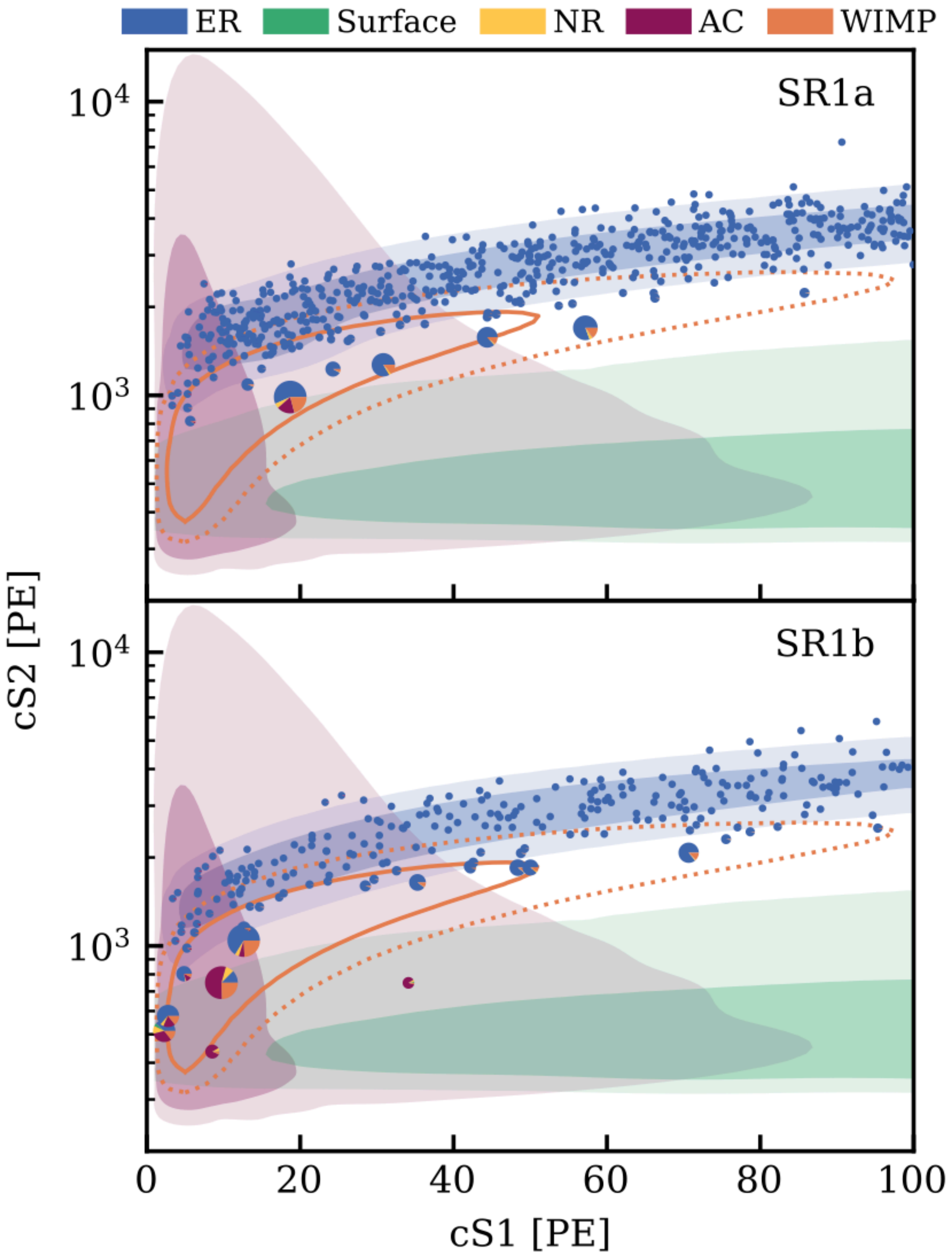
- No significant signal
- Main BG: ER leakage

Kr abundant period

	SR0		SR1a		SR1b	
	Nominal	Best fit	Nominal	Best fit	Nominal	Best fit
ER (flat)	134	136 ± 12	430 ± 30	450 ± 20	151 ± 11	154 ± 10
ER (^{3}H-like)	–	–	62	40 ± 30	101	80^{+18}_{-17}
ER (^{37}Ar)	–	–	58 ± 6	55 ± 5	–	–
Neutron	0.7 ± 0.3	0.6 ± 0.3	0.47 ± 0.19	0.45 ± 0.19	0.7 ± 0.3	0.7 ± 0.3
CEνNS (solar)	0.16 ± 0.05	0.16 ± 0.05	0.010 ± 0.003	0.010 ± 0.003	0.019 ± 0.006	0.019 ± 0.006
CEνNS (atm.+DSNB)	0.04 ± 0.02	0.04 ± 0.02	0.024 ± 0.012	0.024 ± 0.012	0.05 ± 0.02	0.05 ± 0.02
AC	4.3 ± 0.9	$4.4^{+0.9}_{-0.8}$	2.12 ± 0.18	2.10 ± 0.18	3.8 ± 0.3	3.8 ± 0.3
Surface	13 ± 3	11 ± 2	0.43 ± 0.05	0.42 ± 0.05	0.77 ± 0.09	0.76 ± 0.09
Total background	152	152 ± 12	553	550 ± 20	257	239 ± 15
WIMP (200 GeV/c^2)	–	1.8	–	1.1	–	2.1
Observed	152		560		245	

Backgrounds





ER backgrounds ^{222}Rn ^{85}Kr (^{3}H)

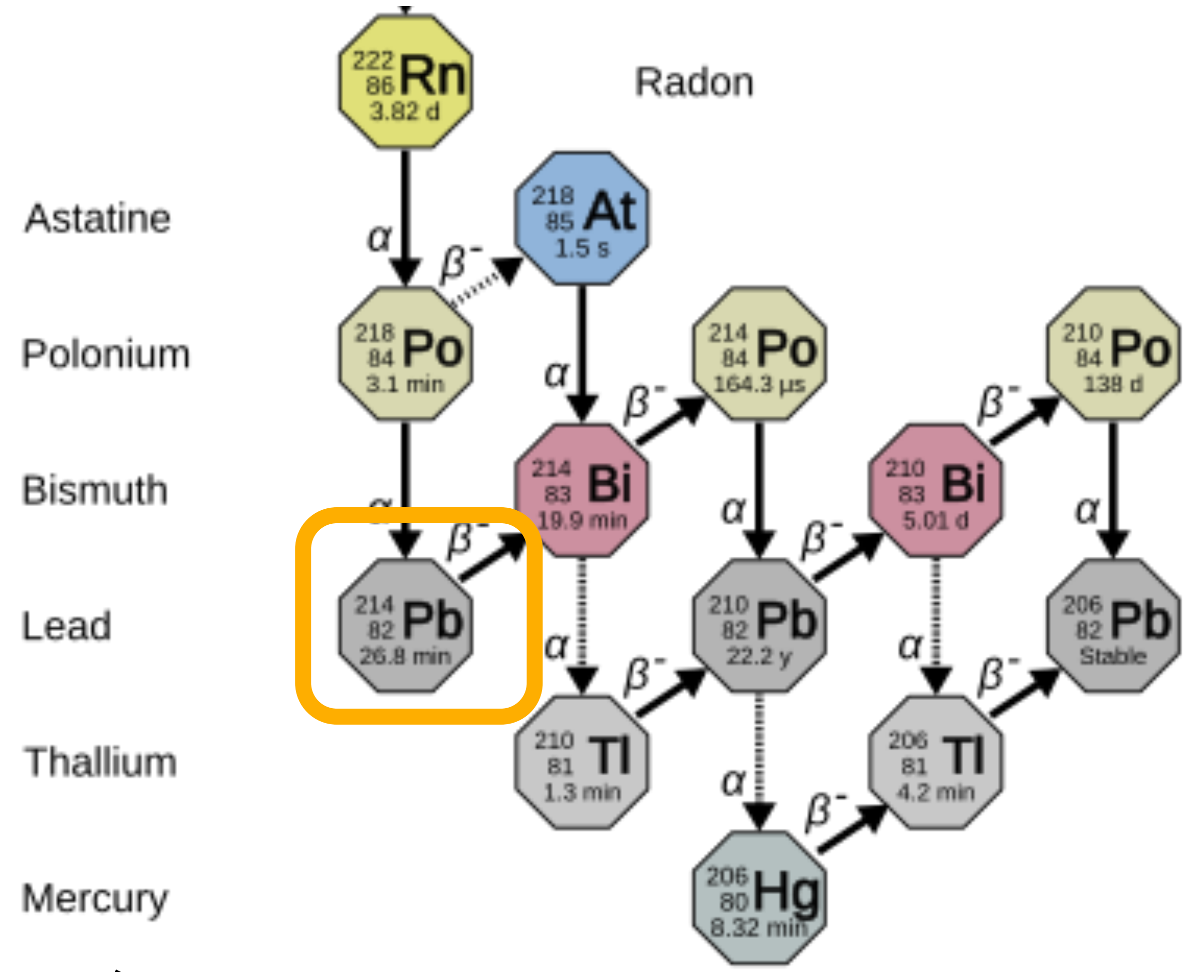
→ **Distillation**

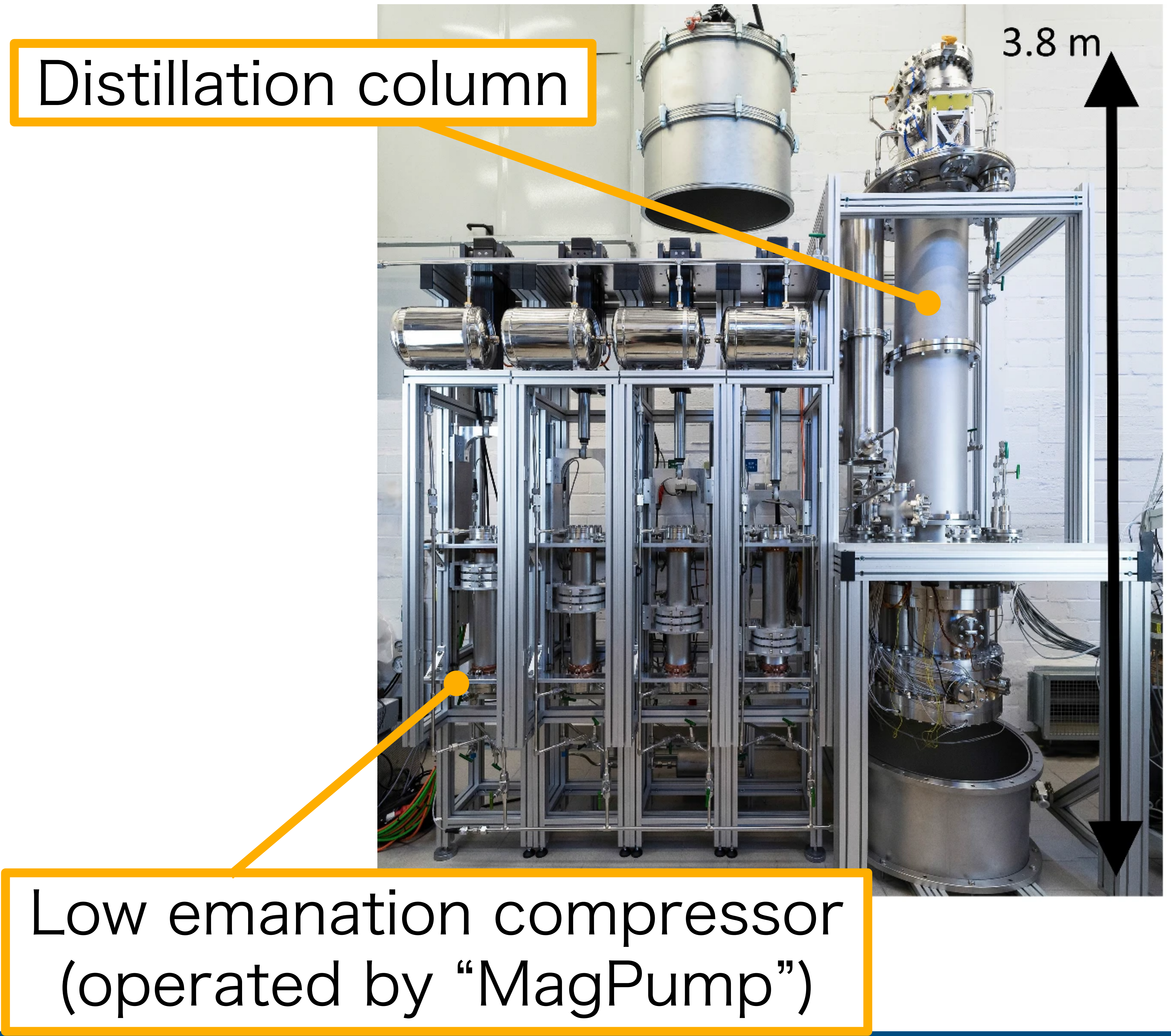
NR background **neutrons**

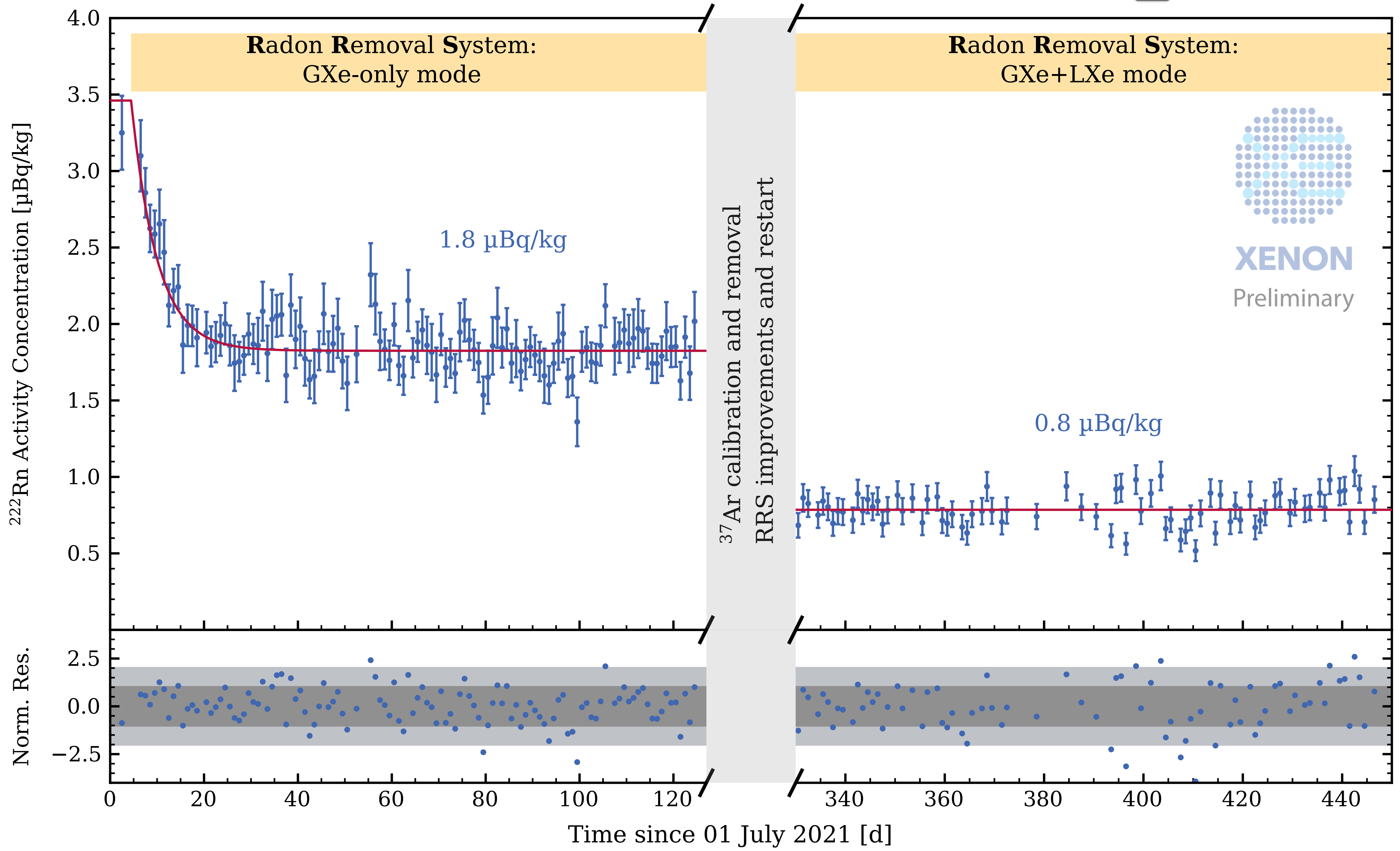
→ **Tag by Gd-Water Cherenkov**

^{222}Rn

- β-decay of daughter ^{214}Pb : flat ER background
- Emanation from detector materials
  → continuous removal by online distillation



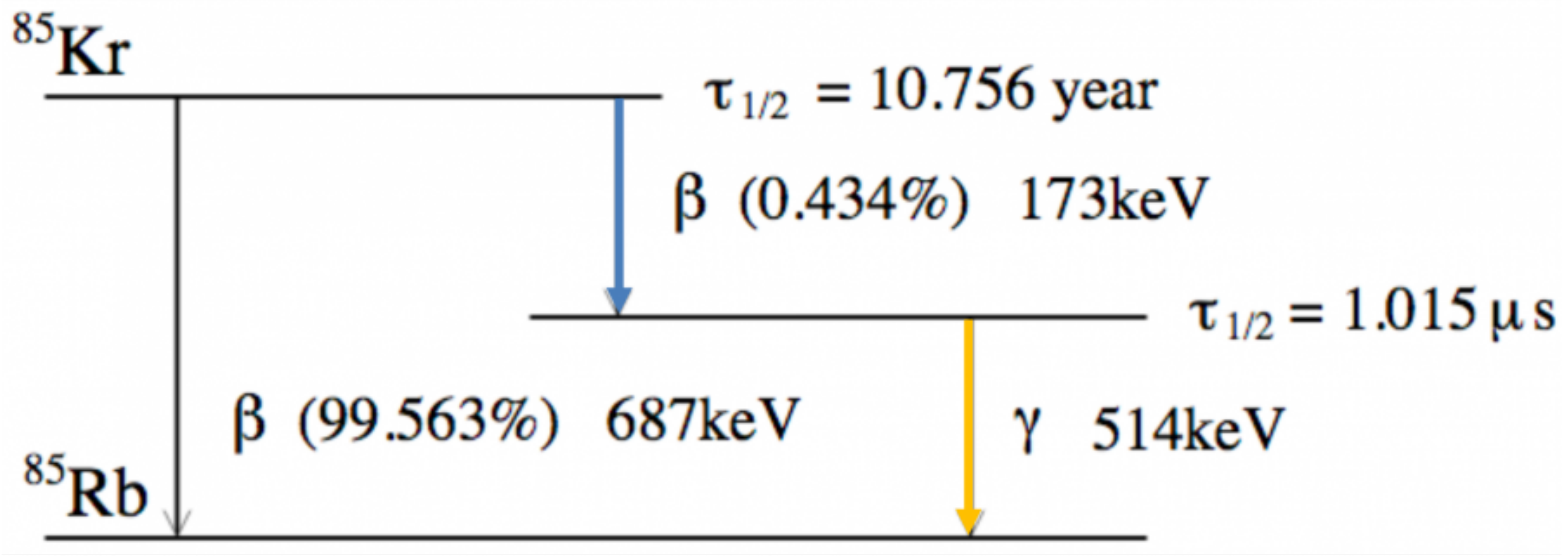




3.4 μBq/kg → 1.8 μBq/kg → 0.8 μBq/kg

^{85}Kr

- β-decay : flat ER background
- Offline distillation → reduced to < ppt
- rate is constrained in two ways



Rare gas mass spectroscopy

Measuring natKr concentration in sampled Xe

- $^{85}Kr/^{nat}Kr \sim 2\times10^{-11}$
- high sensitivity
  ~ < 100 ppq level

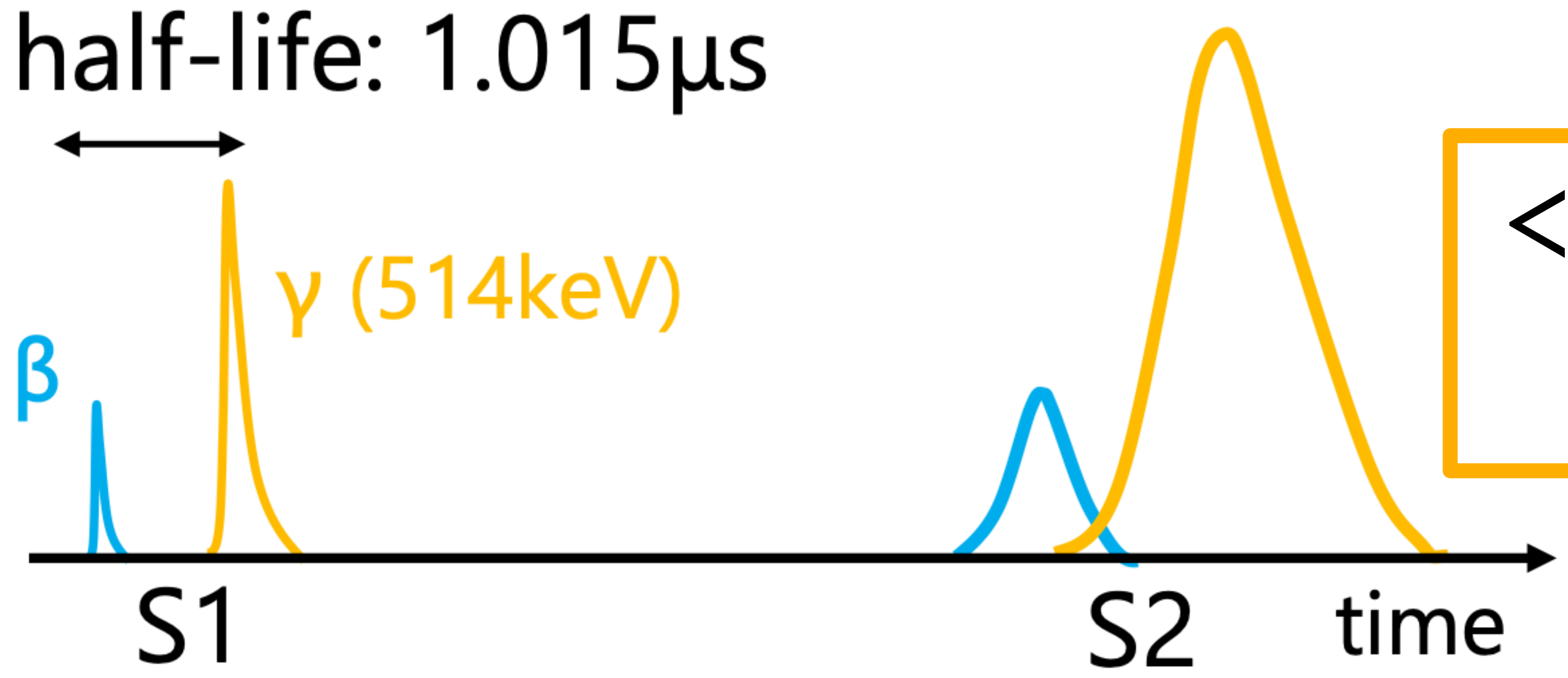
56±36 ppq in SR0

Direct constraint by rare decay mode

Y. Kaminaga (D1, ICRR)

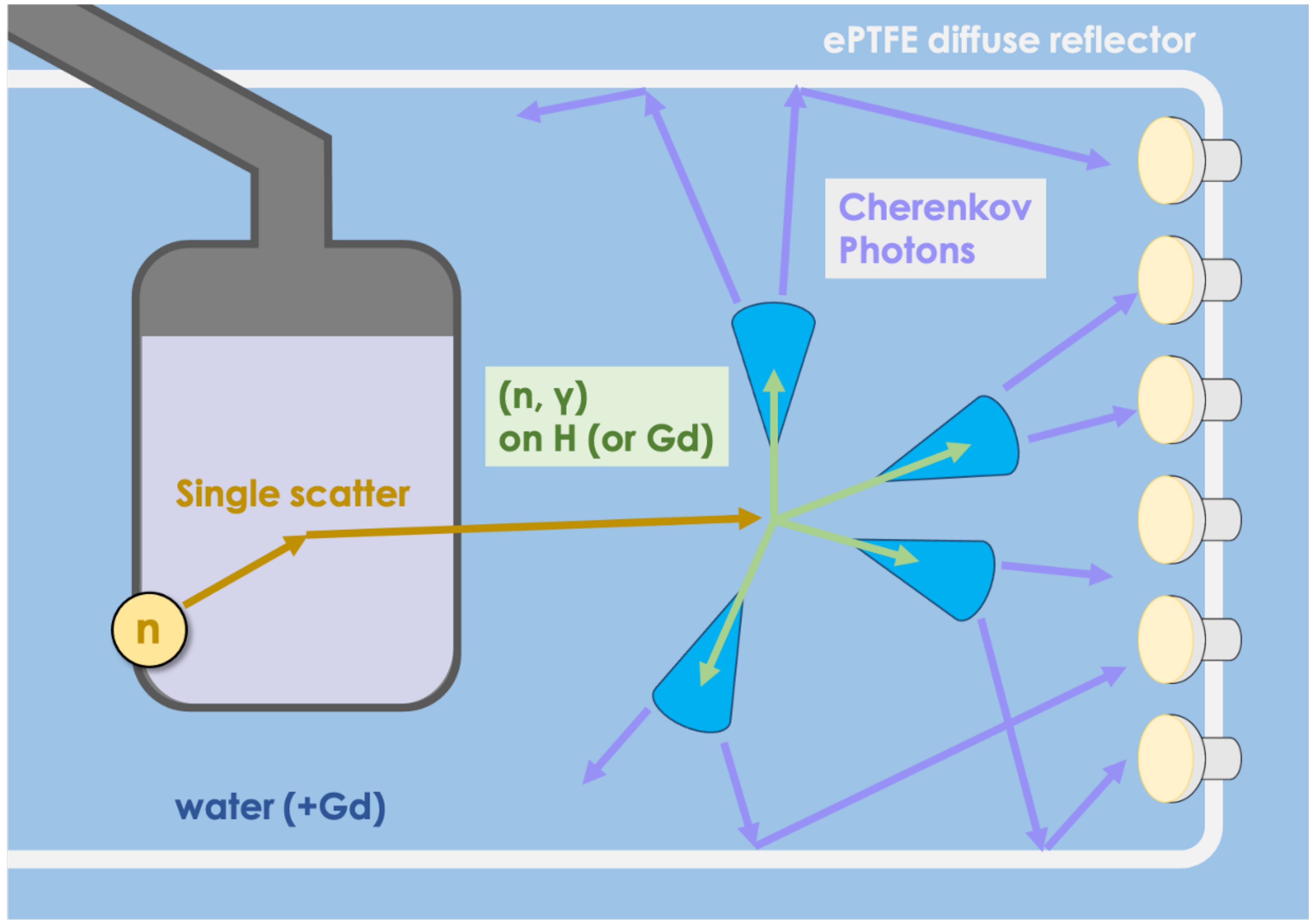
Directly constrain ^{85}Kr abundance by observing $\beta+\gamma$ mode

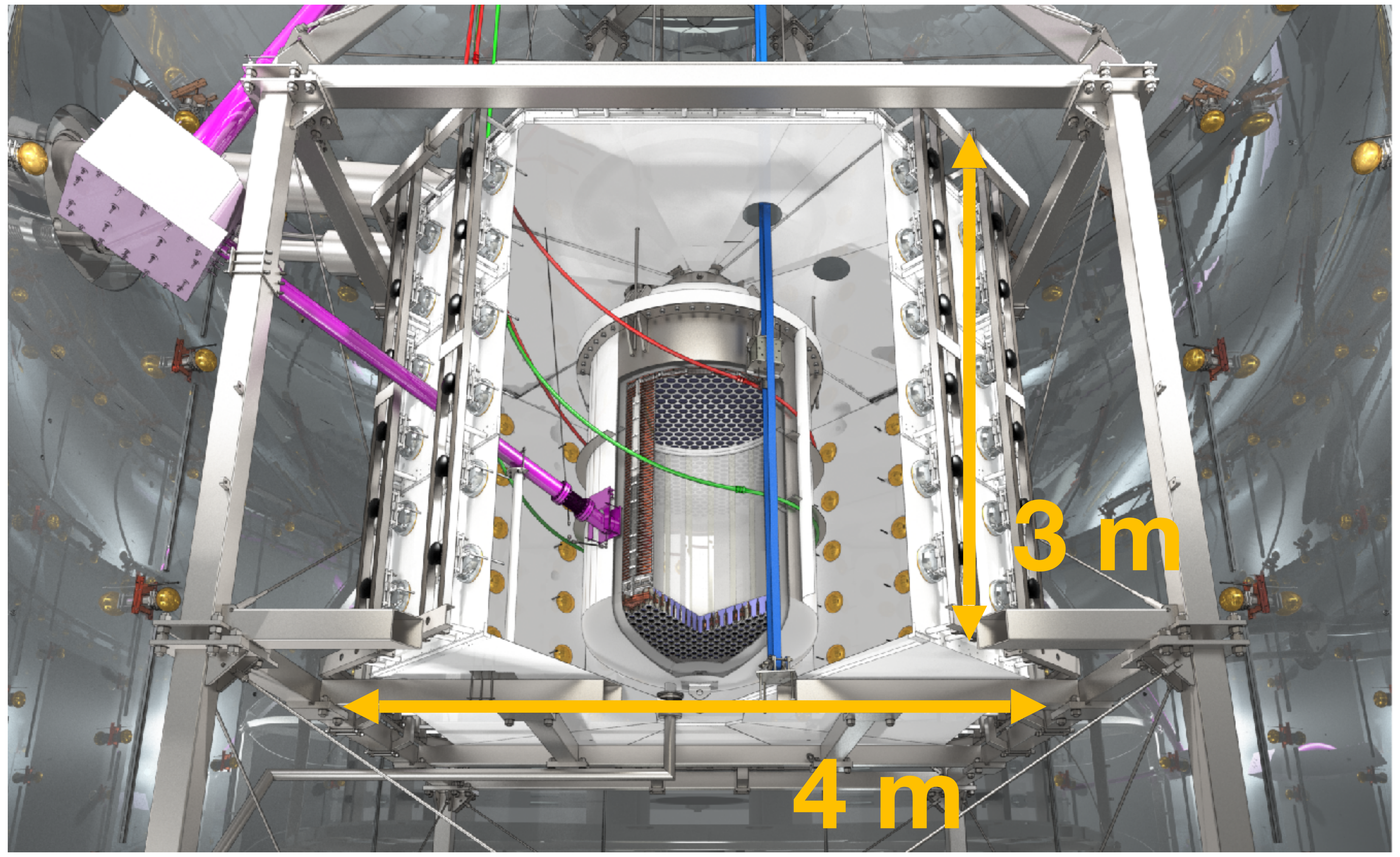
- delayed coincidence search
- independent of $^{85}Kr/^{nat}Kr$ rate



< 290 ppq (90% CL) in SR0

Neutron veto detector

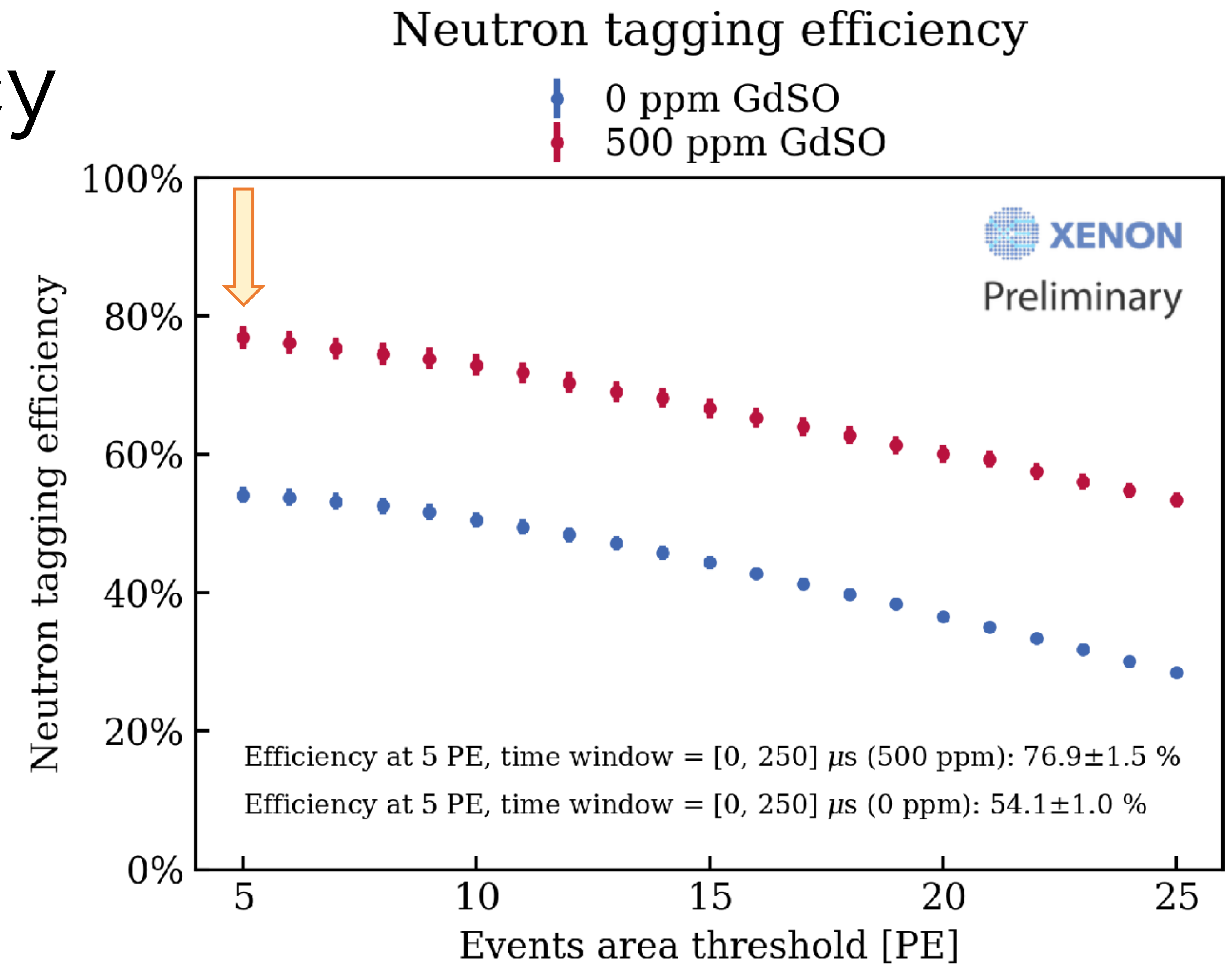




- Tagging neutrons after scattering in TPC
- Gd water Cherenkov detector
  : techniques of EGADS, SK-Gd
- 120 Low-RI 8” PMTs (Hamamatsu R5912)
- Diffuse reflection by ePTFE panels
  : > 99% reflectivity for ~ 300 nm

77% tagging efficiency
@0.02% Gd

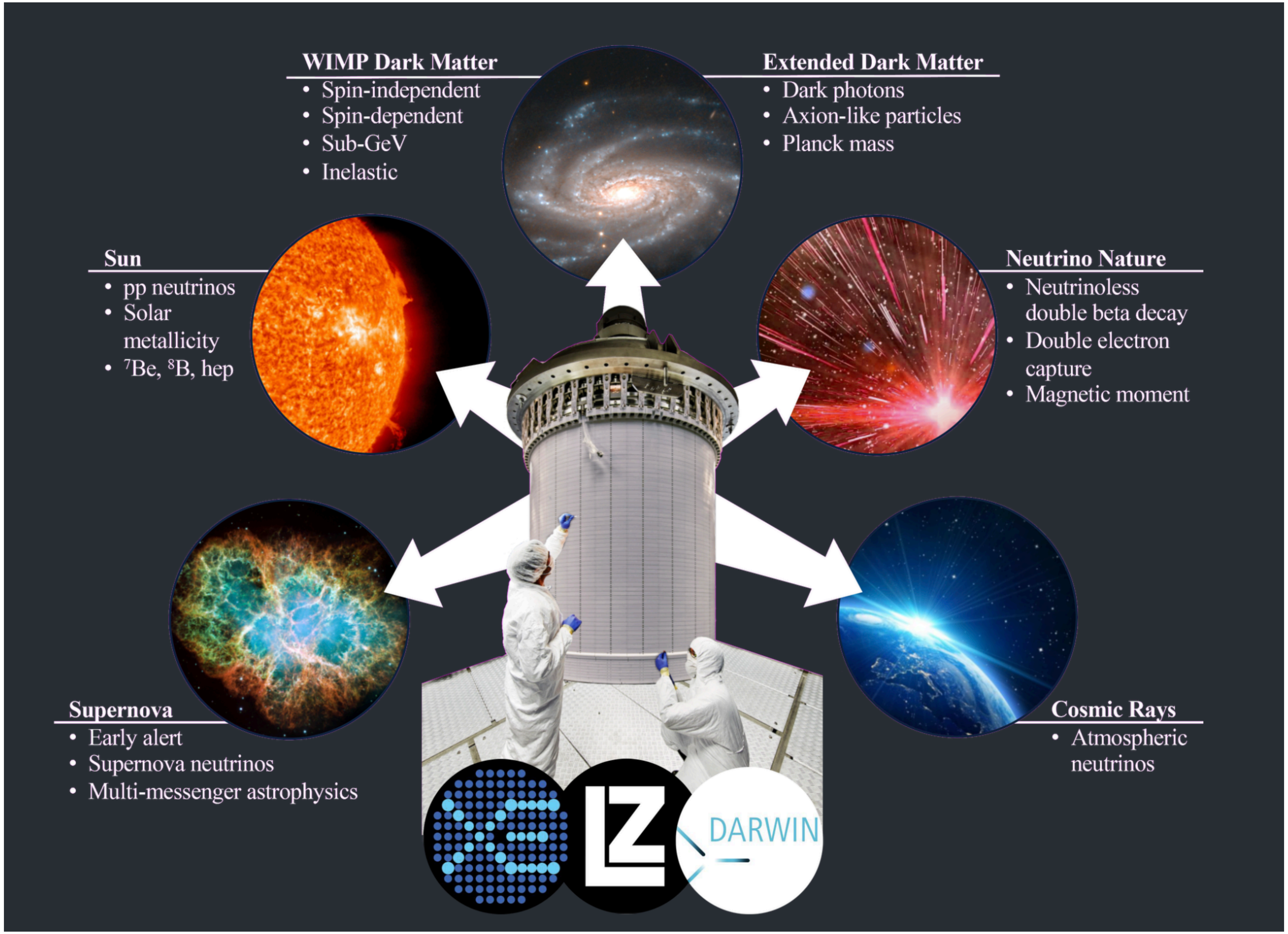
expecting 90% tagging efficiency
@0.2% Gd



XLZD

XLZD

Joining the efforts from XENON/DARWIN and LZ

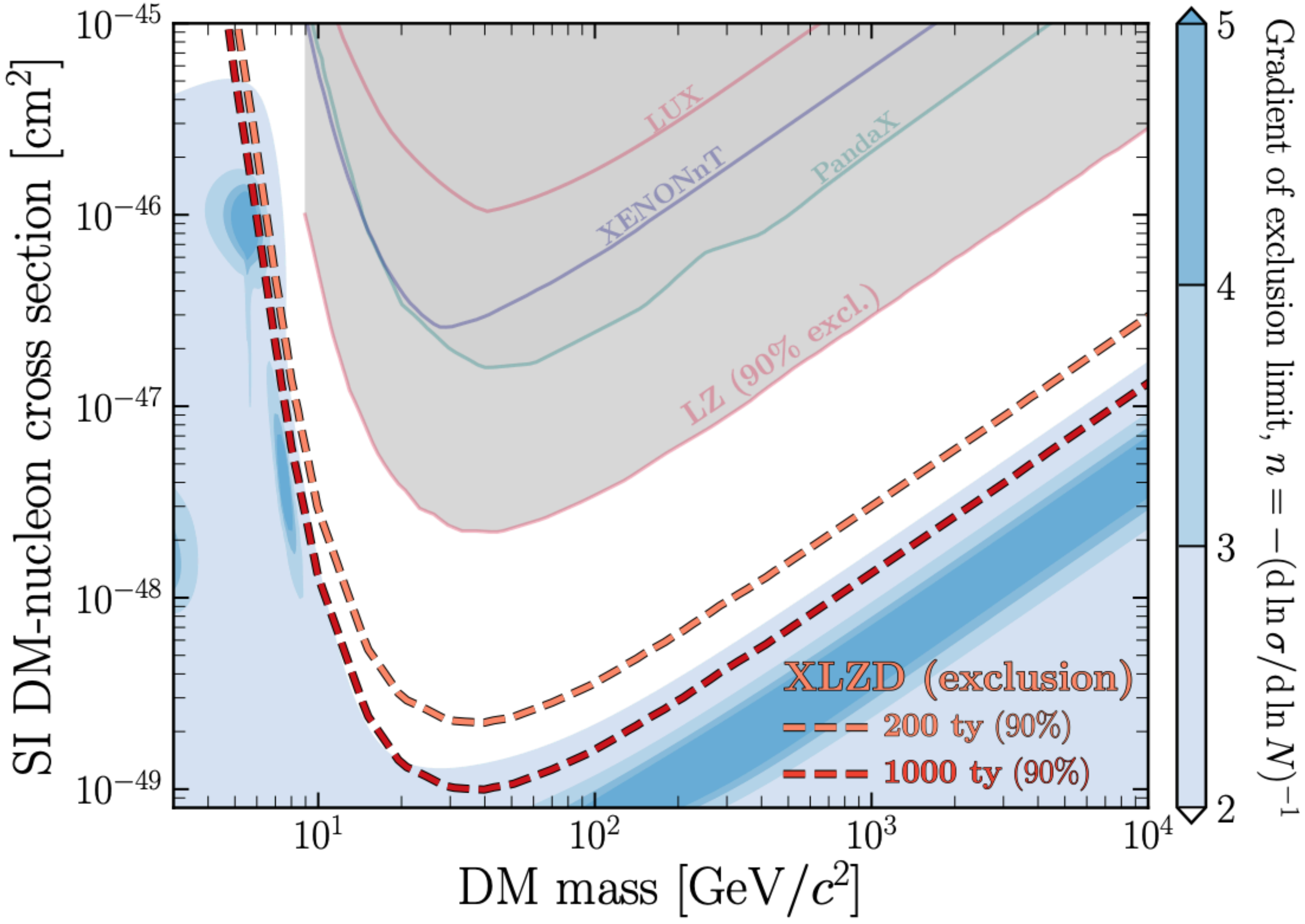


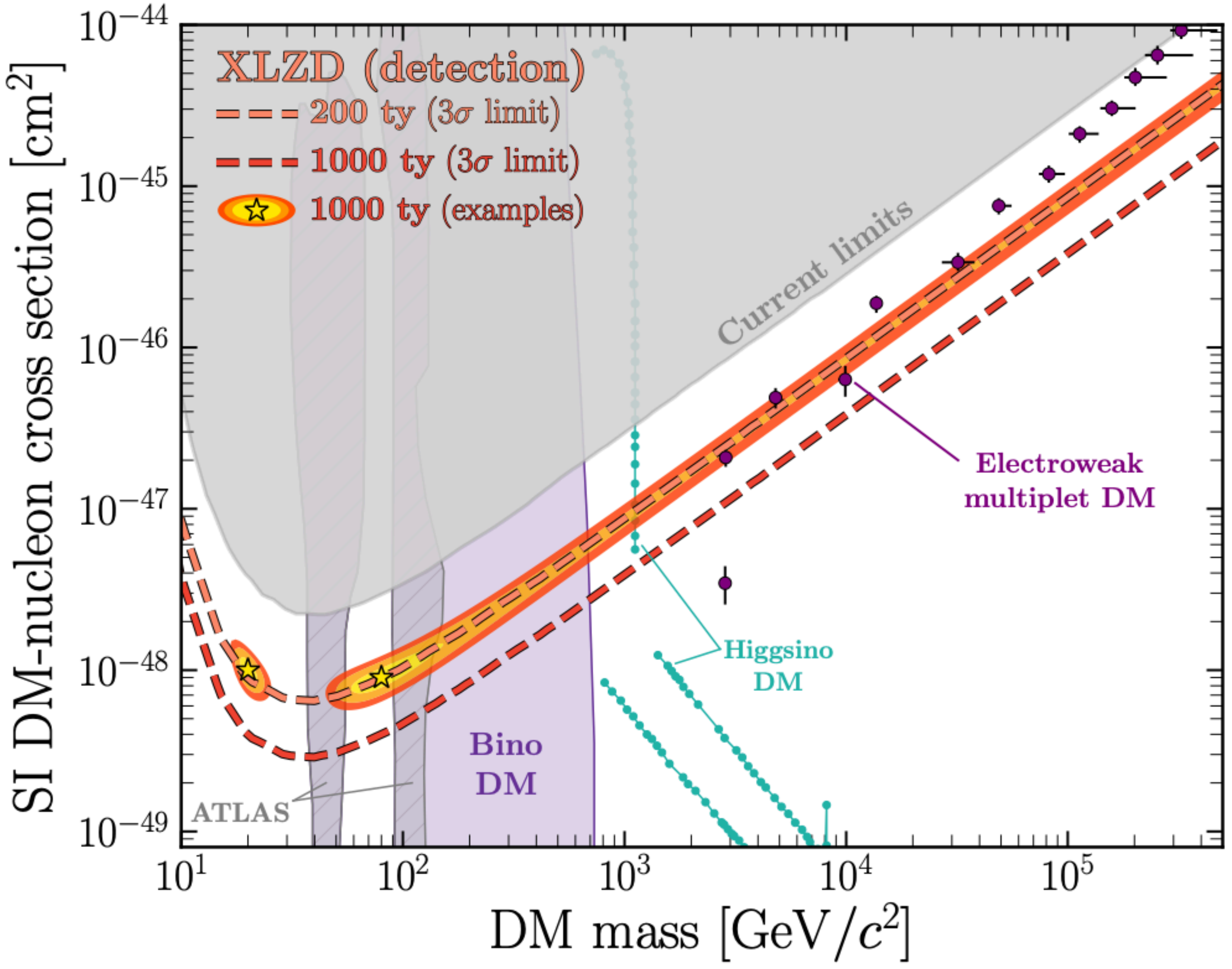
- Collaboration initiated in 2024
- step by step scaling 40 t → 60 t (or 80 t)
- aiming 1000 t·y exposure
- starting in first half of 2030s

✓Searching WIMPs under "Neutrino fog"
✓other various physics

XLZD expected sensitivity

arXiv:2410.17137



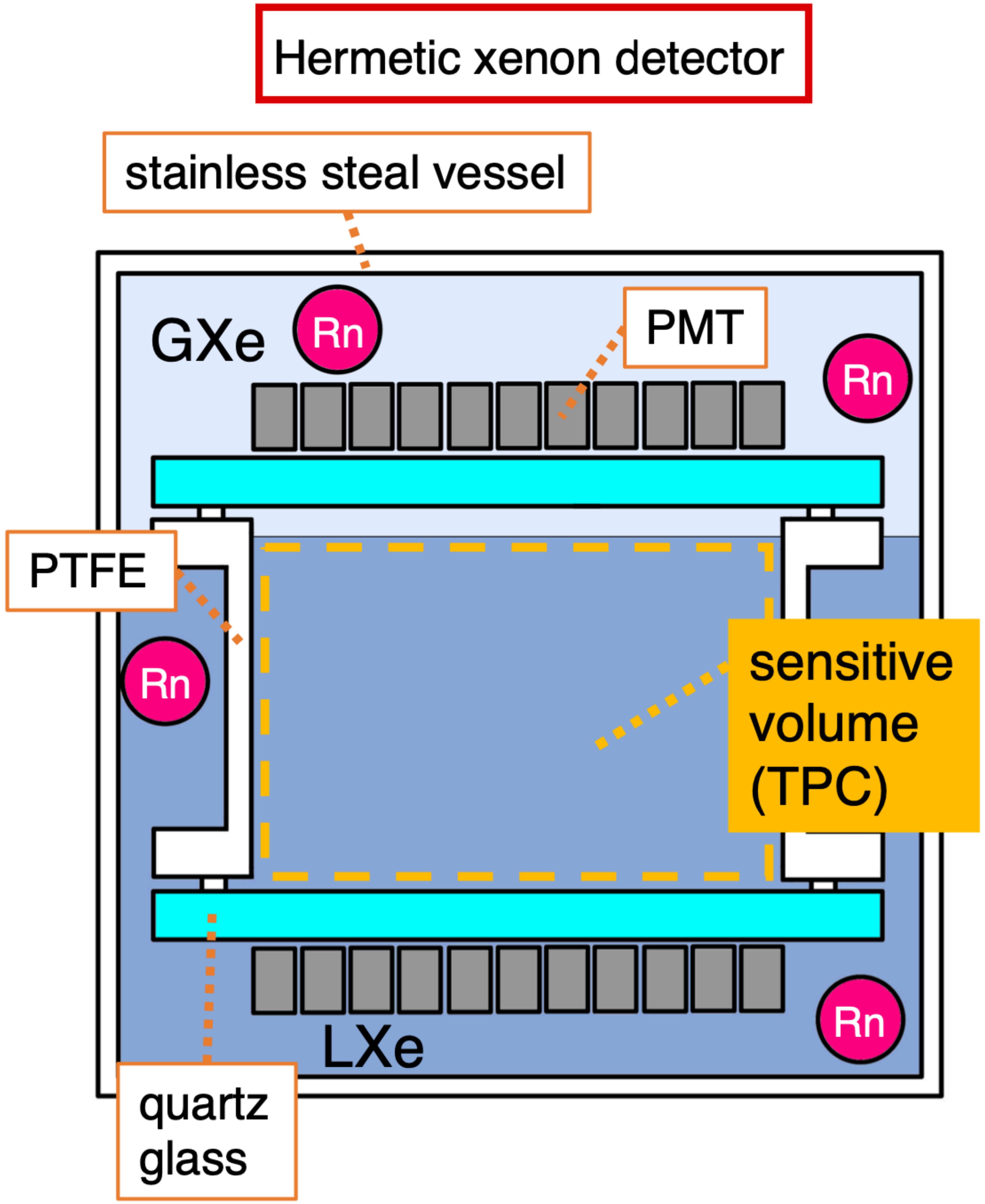


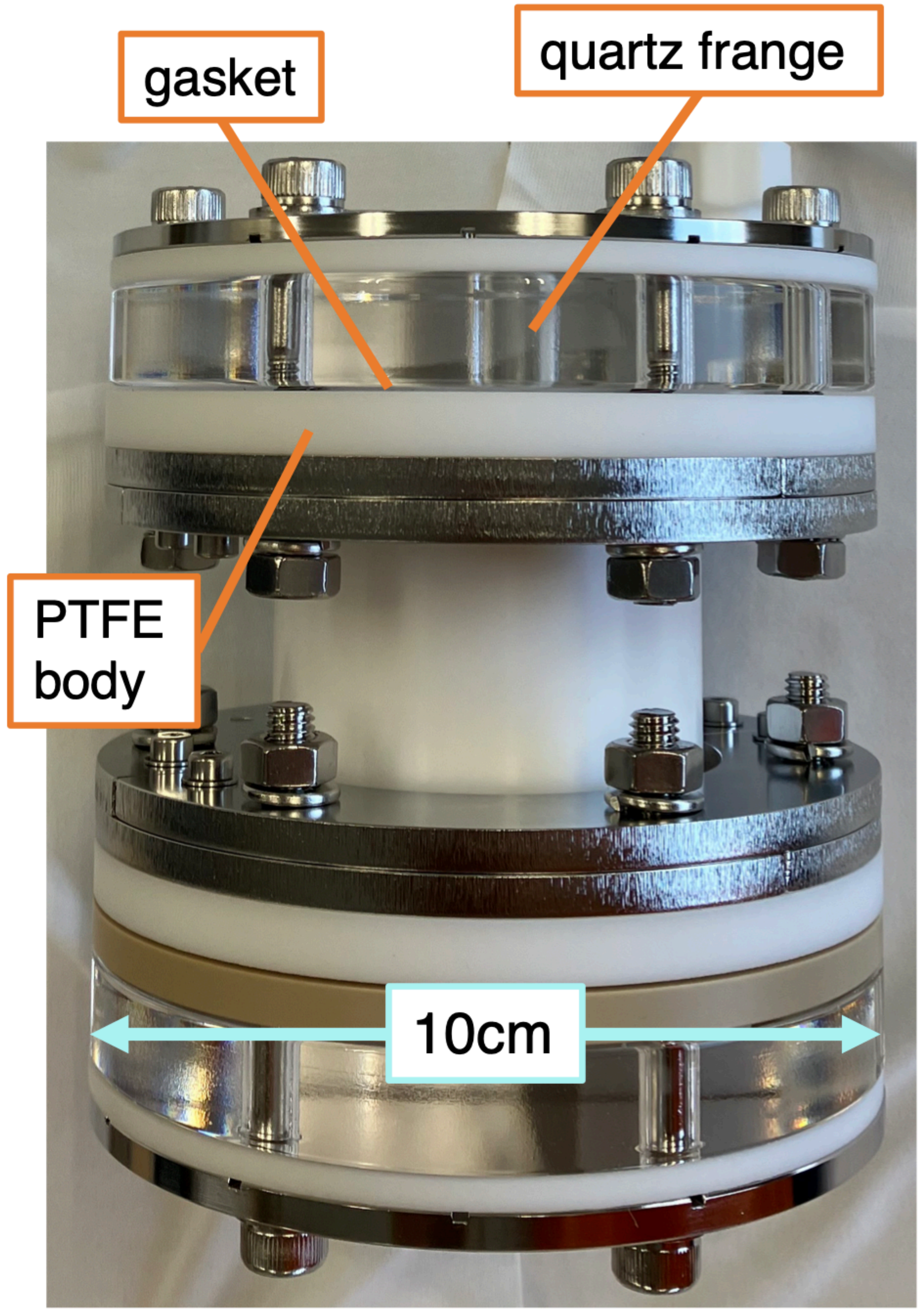
To achieve these sensitivities,

Radioactive BGs must be negligible compared with neutrino backgrounds!!

Hermetic TPC

talk at Wakate workshop by R. Miyata (M2, Nagoya)
poster by K. Fujikawa (M1, Nagoya)





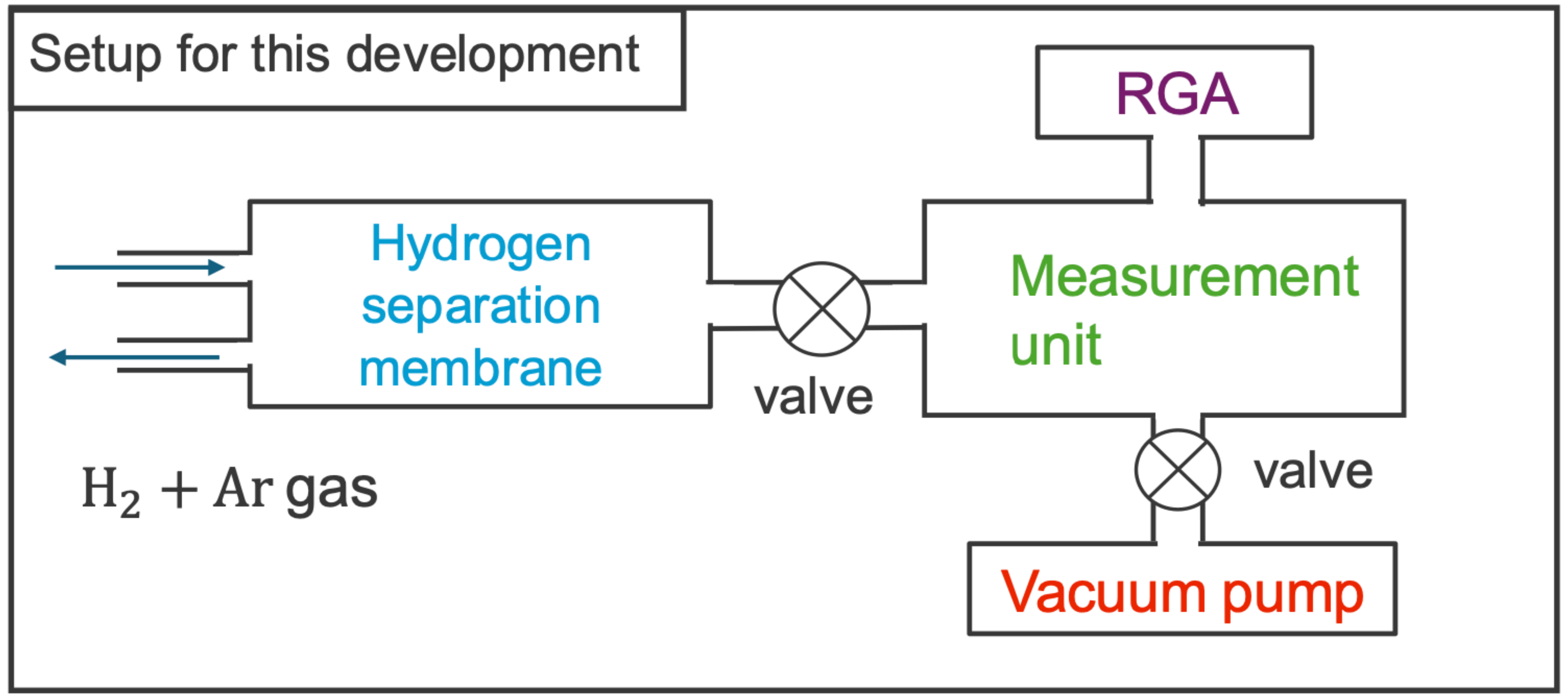
Target

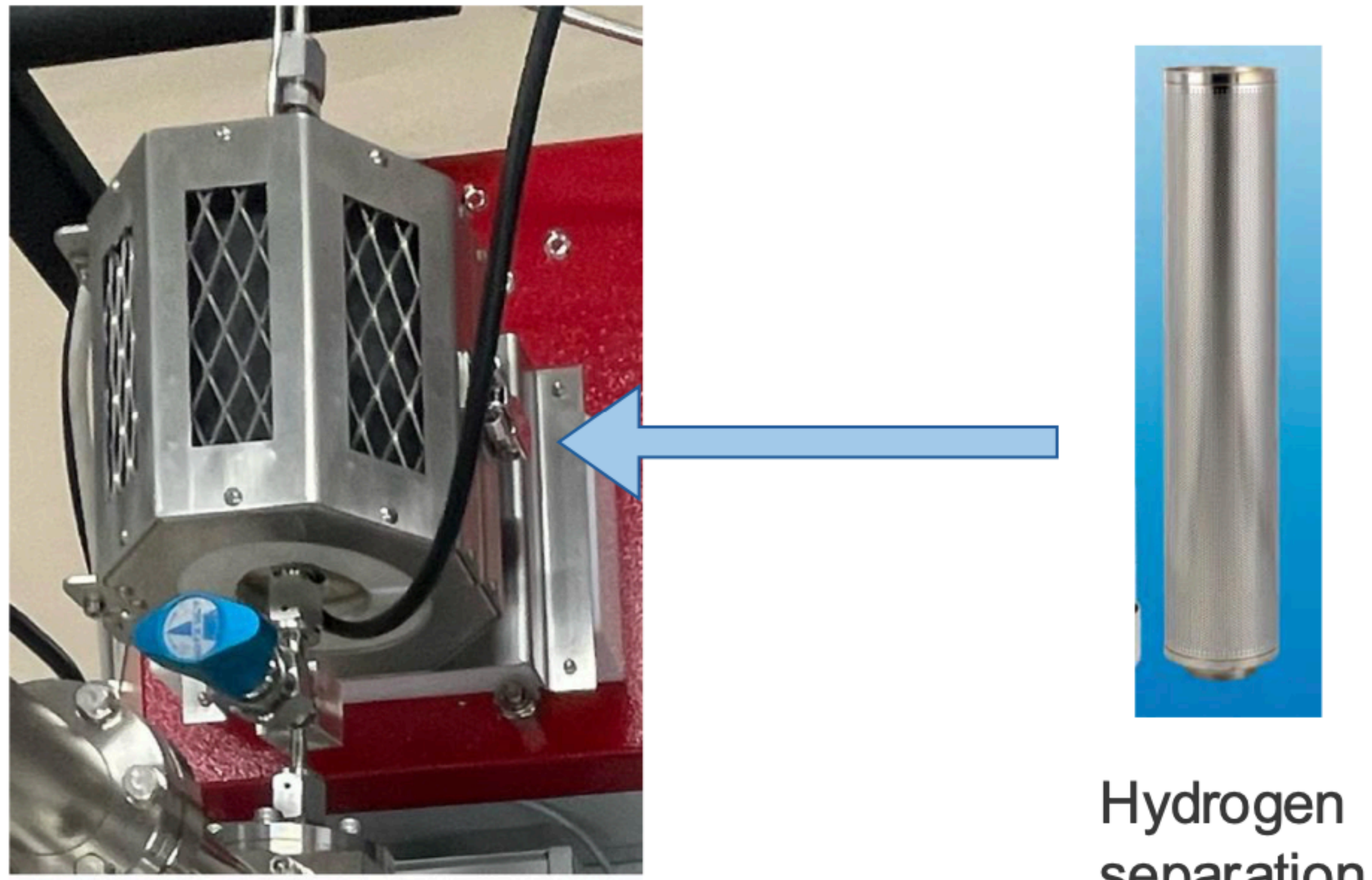
reduce ^{222}Rn < ~0.1μBq/kg
→ block emanated radon

Sealing performance was tested with small setup
→ Radon reduction rate of
$(9.1\pm1.5)\times10^{-3}$

scaled to XLZD size
→ ^{222}Rn < 8.17×10^{-3} μBq/kg

^{3}H concentration measurement





Hydrogen separation membrane module

Hydrogen separation membrane

- ^{3}H: important BG component especially for Low-E ER new physics search
- Currently no method to constrain due to the low concentration

Goal

Developing the method to measure **ppt level** hydrogen in xenon gas

→ hydrogen separation membrane + RGA

working principle is checked with O(10 ppb) H_2/Ar mixture gas

Photosensor R&D

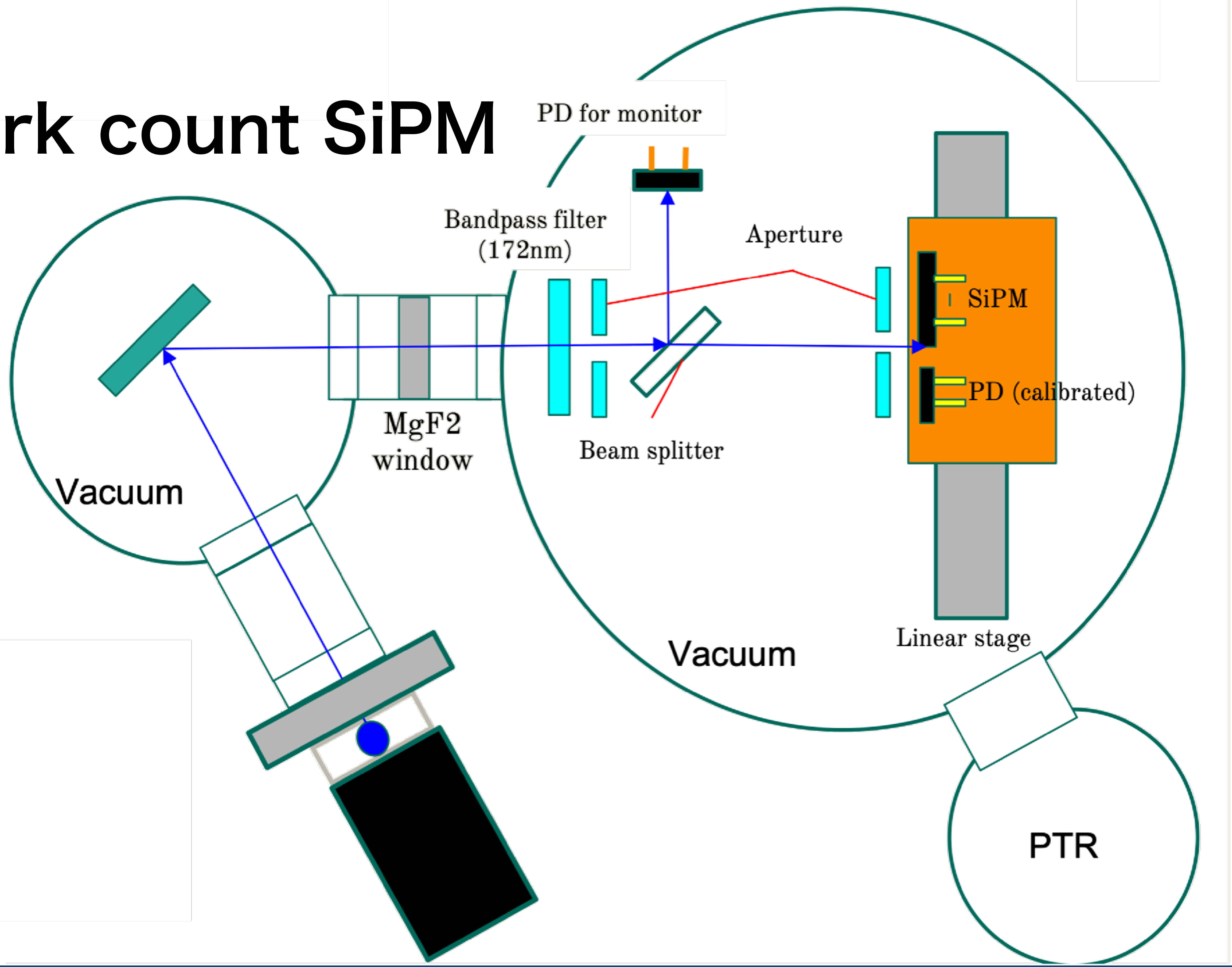
K. Hiraoka (M2, Nagoya)

U/Th in TPC components should be lowered to reduce neutron BGs.

- Stem of PMTs: one of the dominant U/Th source
  → Development of new Low-RI photosensor

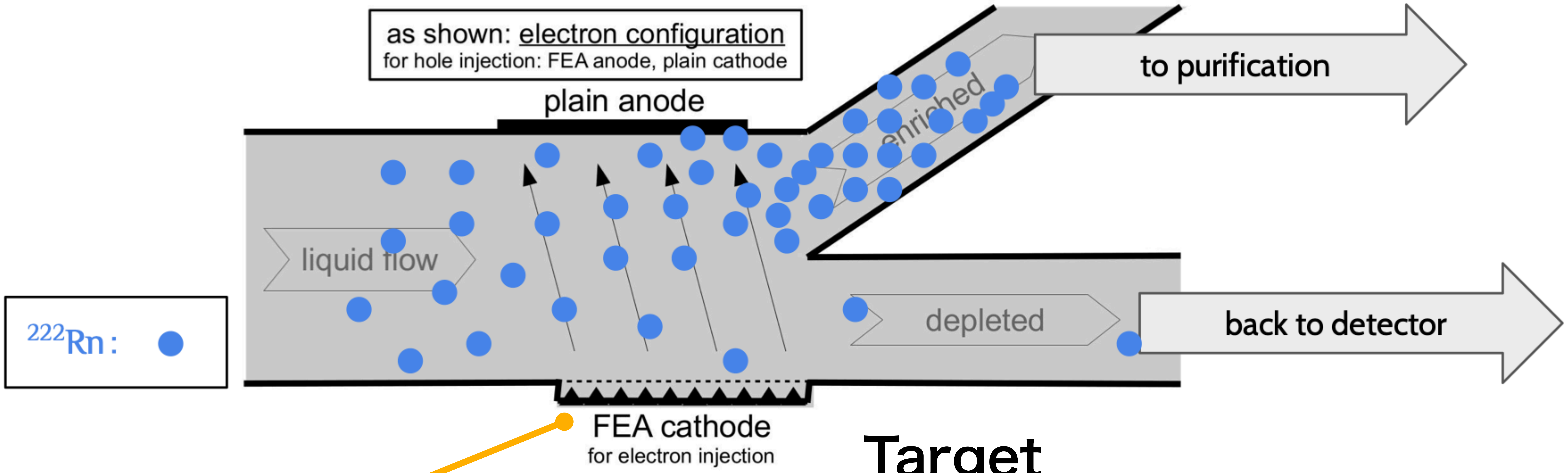
Possible solution: **VUV sensitive low dark count SiPM**

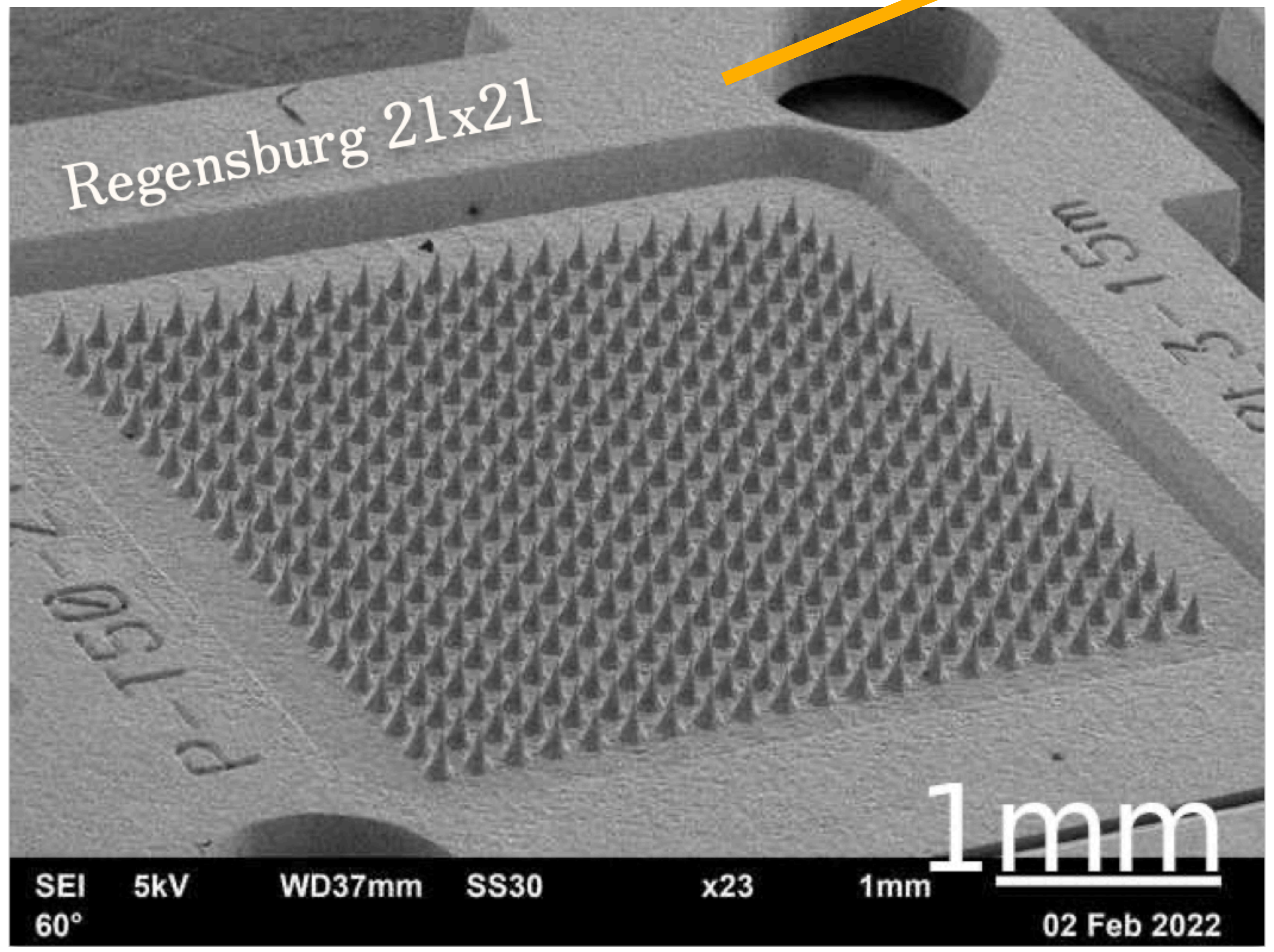
Dedicated PDE measurement system under liq. Xe temperature is developed.



^{222}Rn removal with FEA

posters by Caio (M2, IPMU)
and Xiaoxin (IPMU)





Target

Improvement in radon removal efficiency
→ concentrate radon by current injection
using **Field Emission Array** (FEA)

Successful injection of positive current
is achieved.

Summary

XENONnT

- ➢Under operation with world competing sensitivity
- ➢WIMPs search w/ SR0 + SR1 data

  σ_{SI} < 1.7x10^{-47} cm^2 (90%CL) @30 GeV
- ➢Background mitigation

  ER: distillation of radioactive noble gases

  NR: neutron tagging with Gd-Water Cherenkov detector

XLZD

- ➢Next generation dark matter project with 40--80 t LXe
- ➢WIMPs search below the neutrino fog
- ➢R&D for lowering radioactive BGs under neutrino level