Latest results from XENONnT

WIMP and neutrinos direct searches

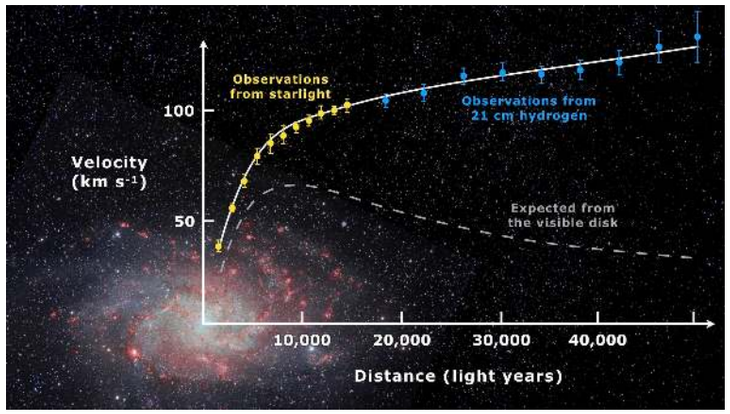
Gian Marco Lucchetti

On behalf of the XENON collaboration

The search for Dark Matter

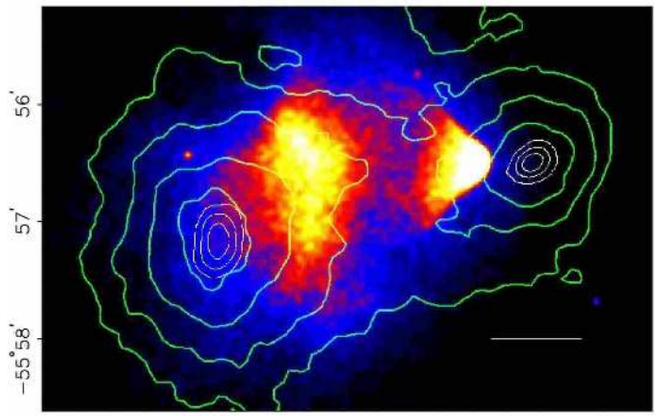
Many evidences of the presence of extra mass in our universe:

Galaxy rotation curves



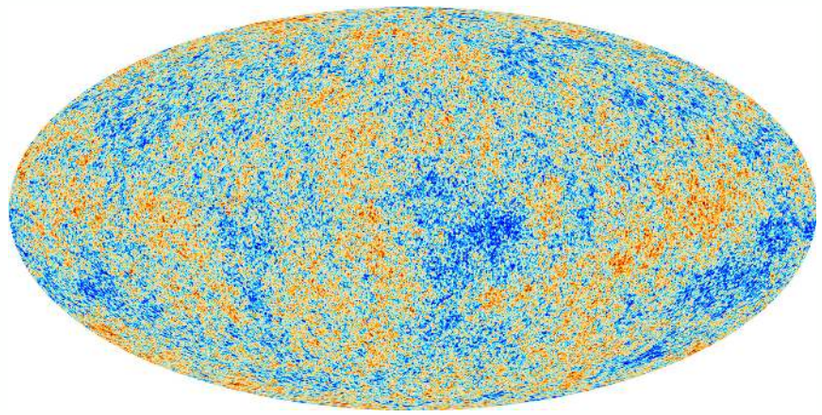
Ram Chandra Gotame

Galaxy cluster collisions



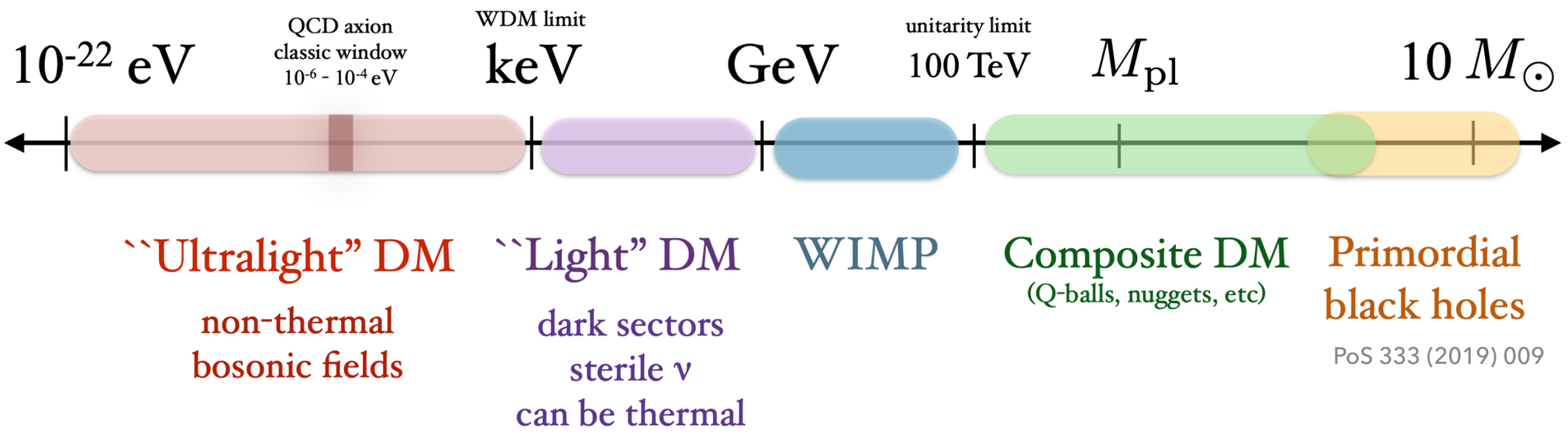
Douglas Clowe *et al* 2006 *ApJ* **648** L109

CMB anisotropies



ESA and the Planck Collaboration

which can be explained by the presence of a new neutral massive particle:

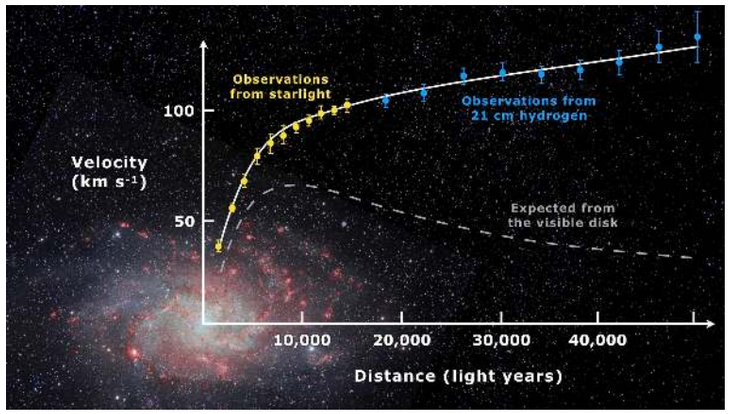


PoS 333 (2019) 009

The search for Dark Matter

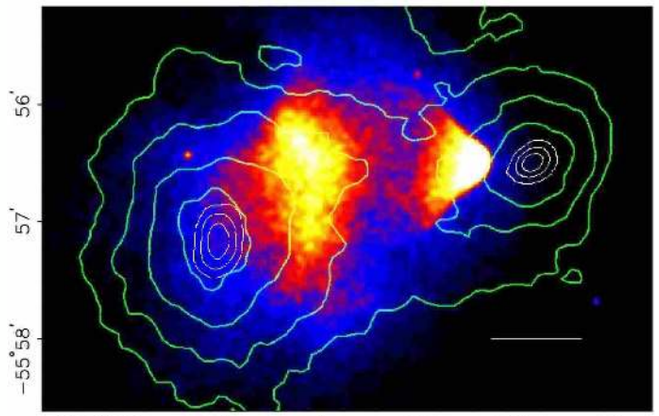
Many evidences of the presence of extra mass in our universe:

Galaxy rotation curves



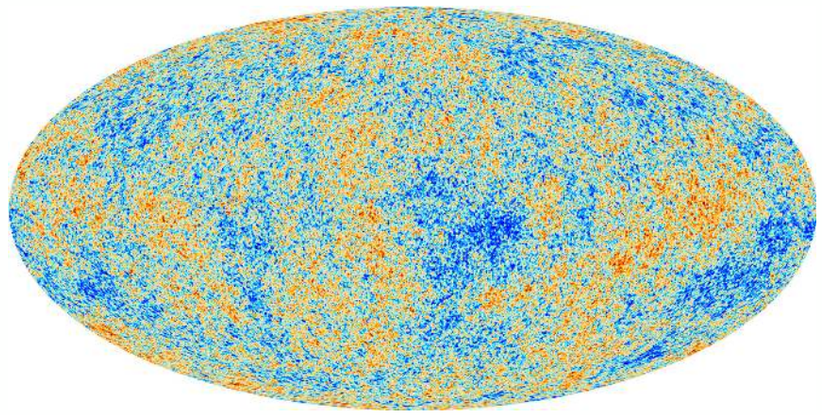
Ram Chandra Gotame

Galaxy cluster collisions



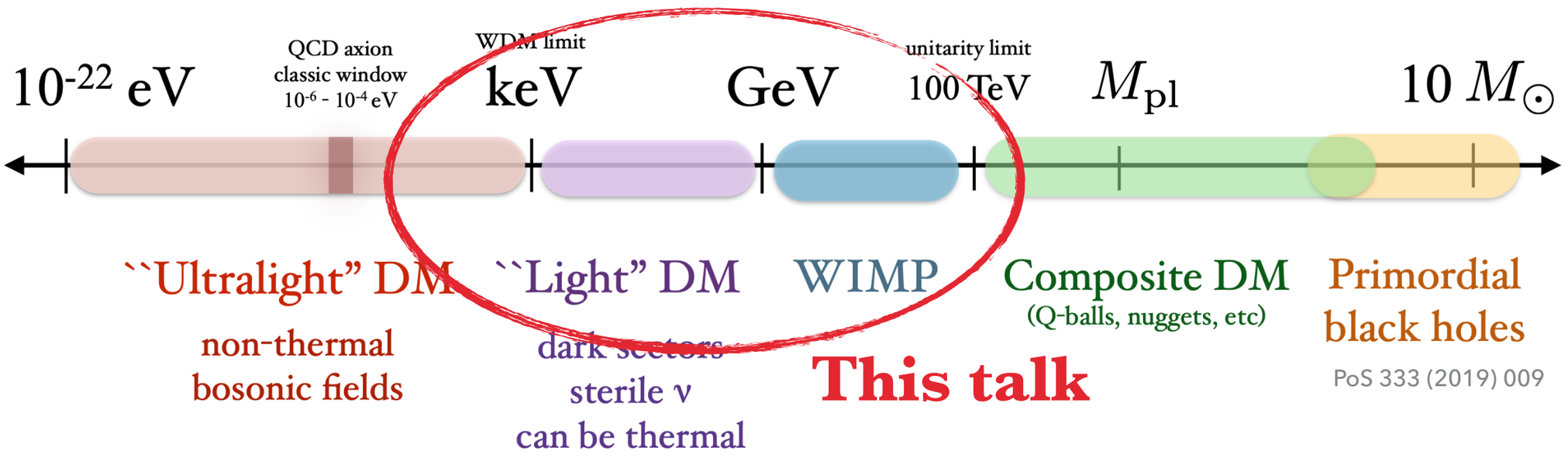
Douglas Clowe *et al* 2006 *ApJ* **648** L109

CMB anisotropies



ESA and the Planck Collaboration

which can be explained by the presence of a new neutral massive particle:

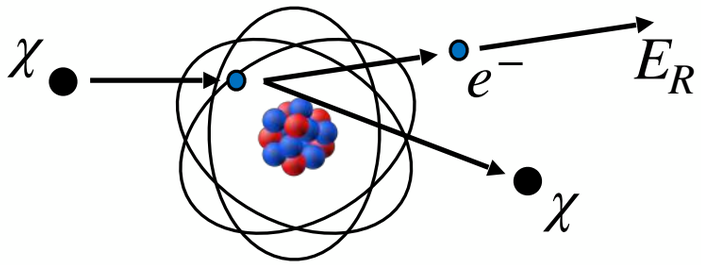


PoS 333 (2019) 009

The search for Dark Matter

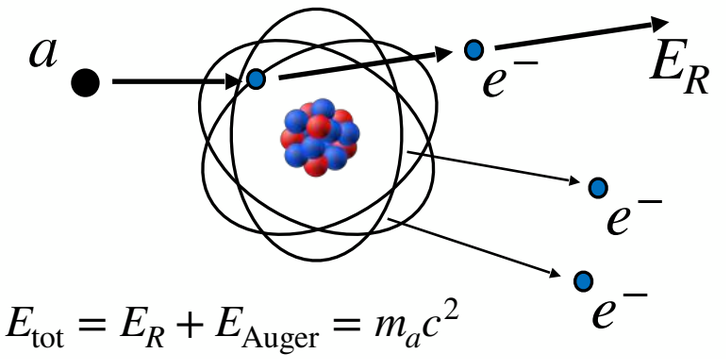
Electronic Recoils (ER)

Elastic scattering



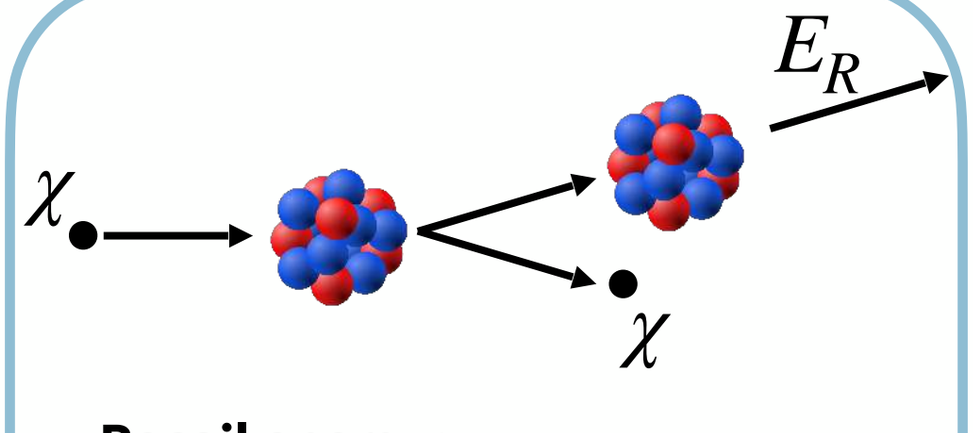
$$E_R \sim 4E_{\rm kin}\frac{m_\chi m_e}{(m_\chi+m_e)^2} \gtrsim 10\ keV_{ER} \simeq 1\ keV_{NR}$$

DM absorption



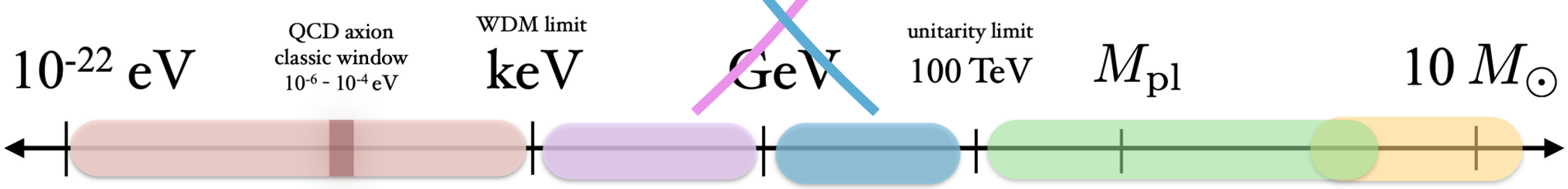
$$E_{\rm tot} = E_R + E_{\rm Auger} = m_a c^2$$

Nuclear Recoils (NR)



Recoil energy:

$$E_R \sim 4E_{\rm kin}\frac{m_\chi m_N}{(m_\chi+m_N)^2} \gtrsim 10\ keV_{NR}$$



``Ultralight" DM
non-thermal bosonic fields

``Light" DM
dark sectors sterile ν can be thermal

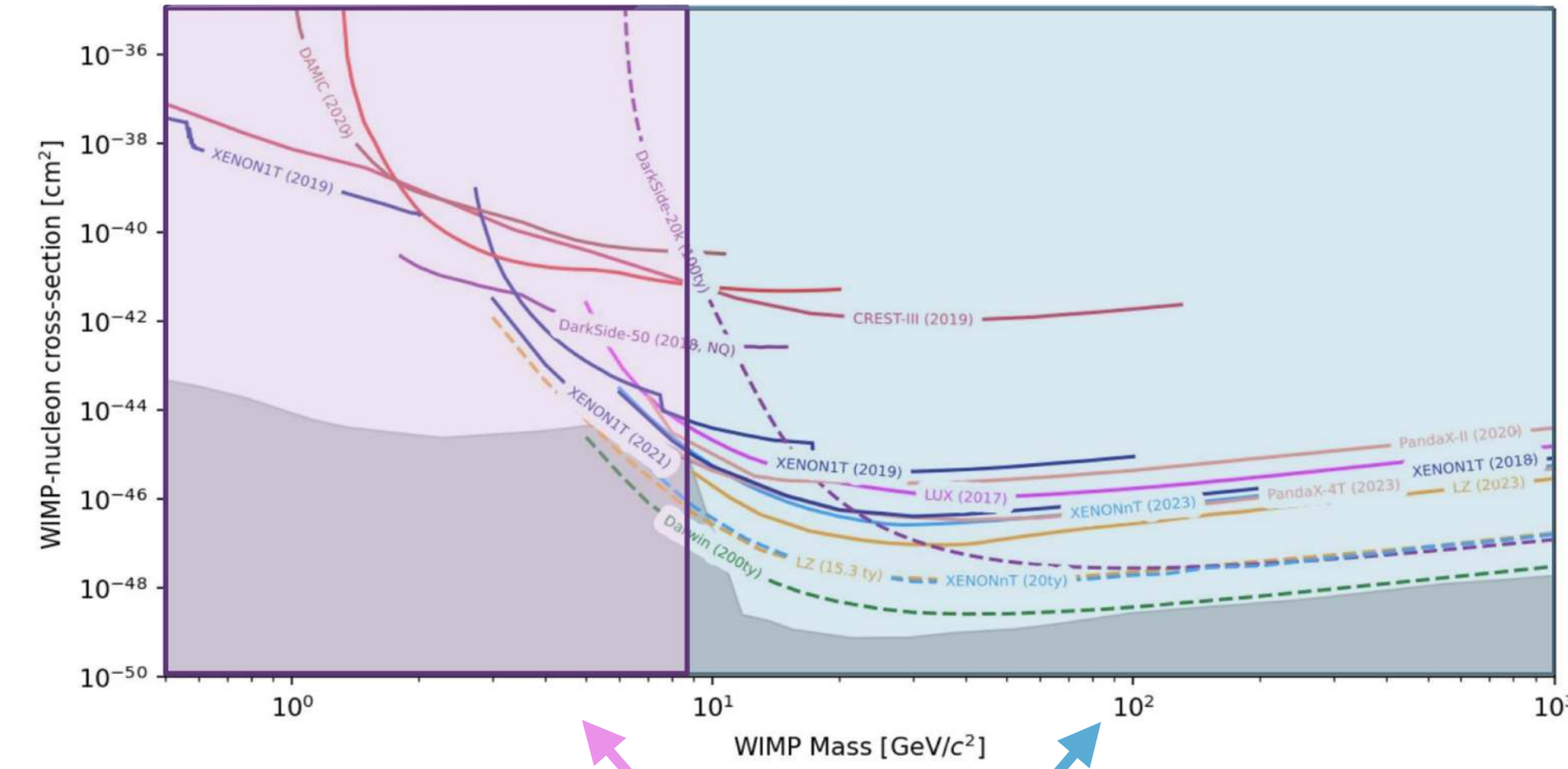
WIMP

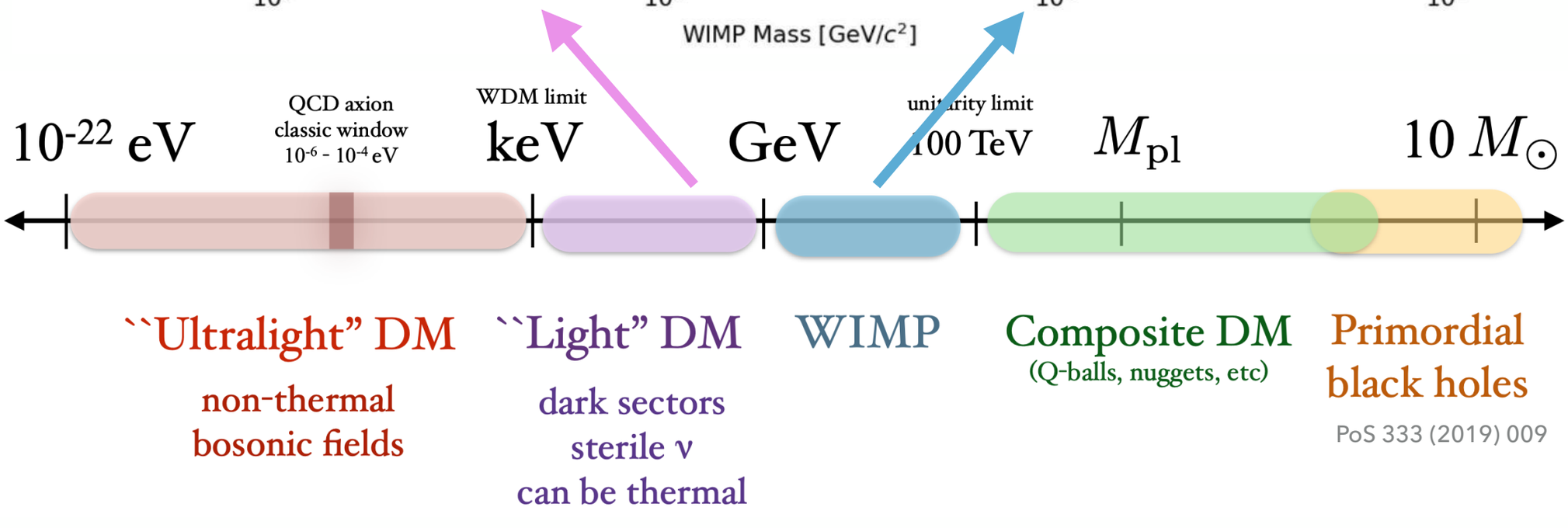
Composite DM
(Q-balls, nuggets, etc)

Primordial black holes

PoS 333 (2019) 009

The search for Dark Matter



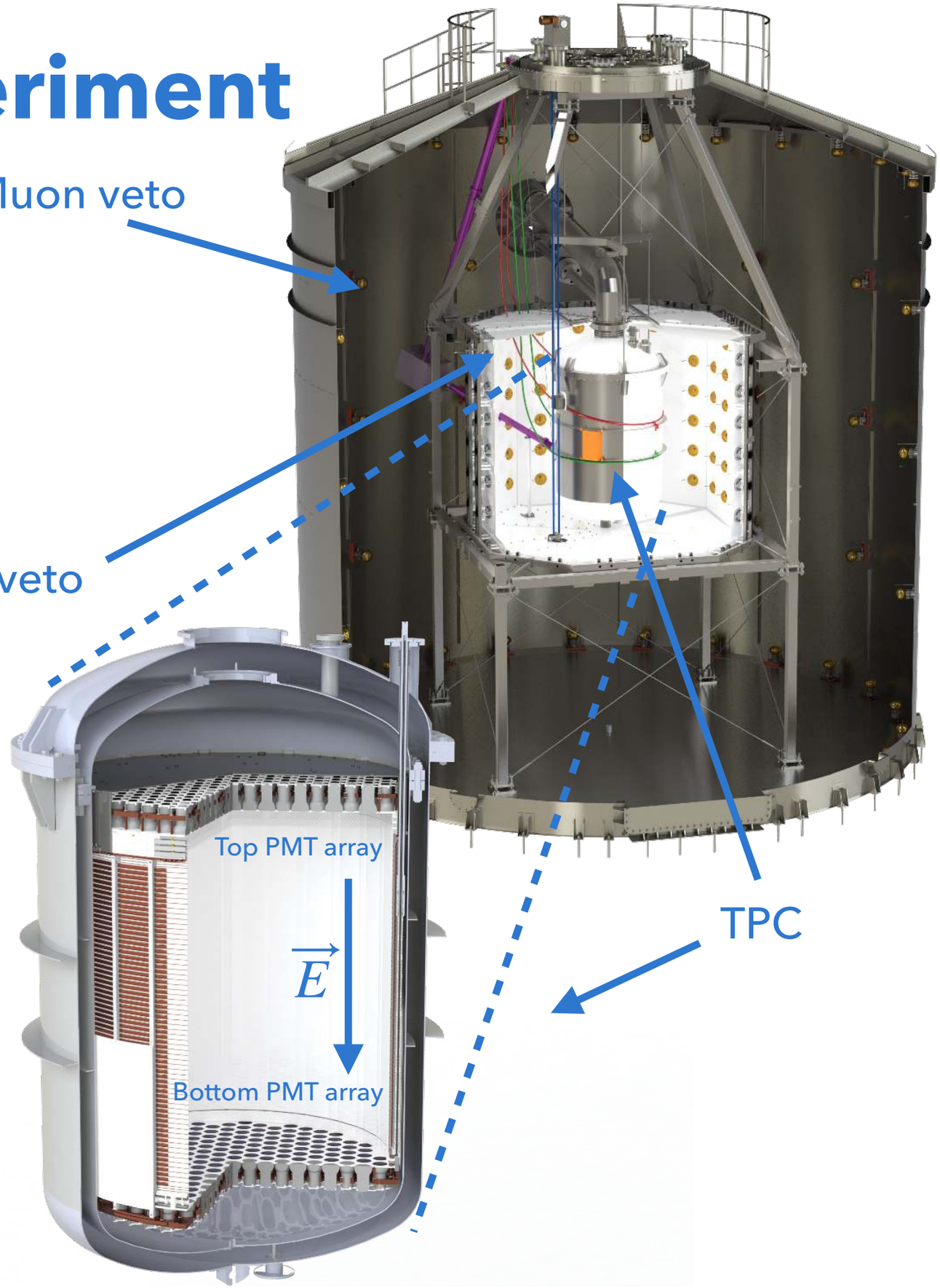


The XENONnT experiment

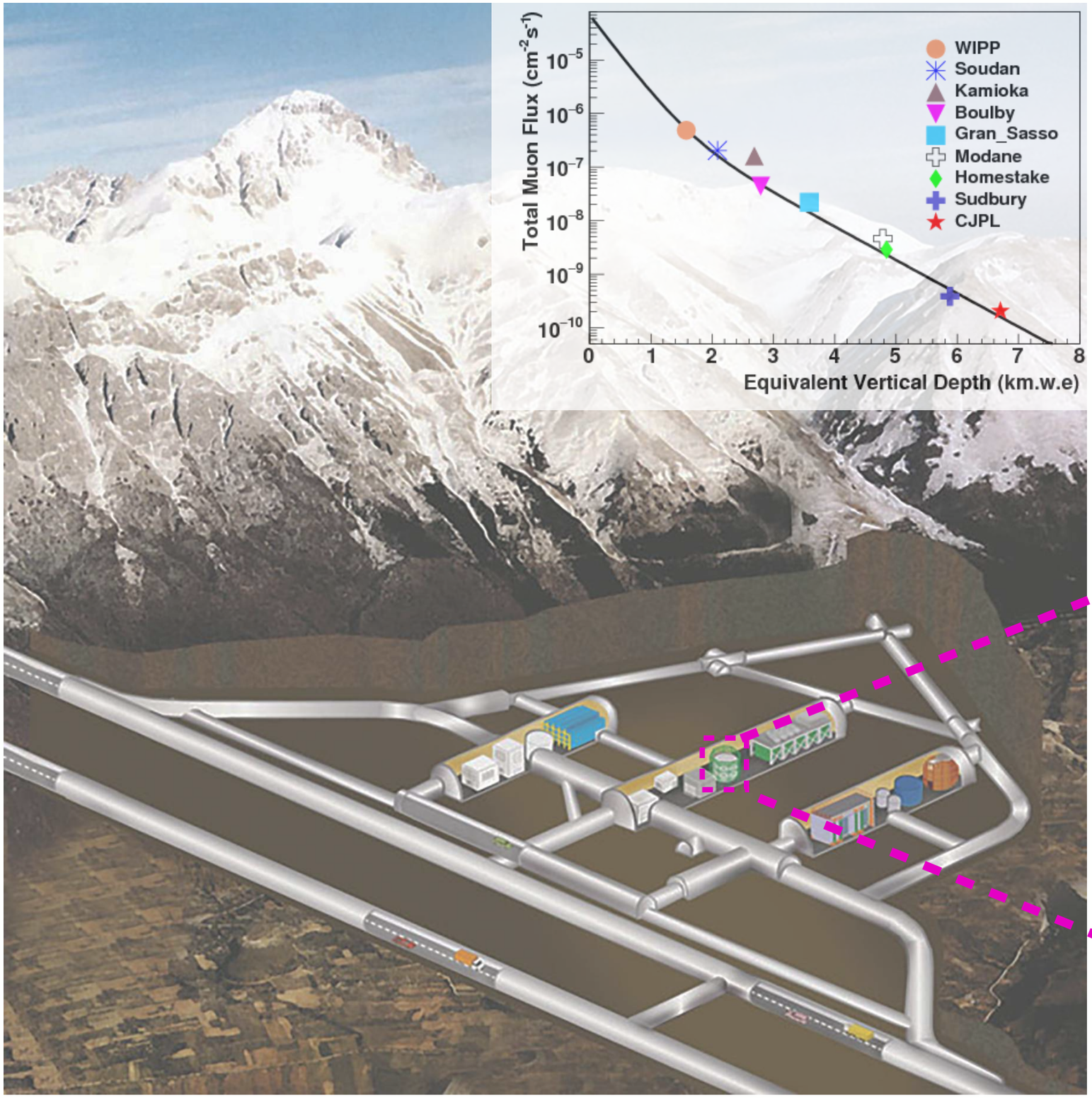
Muon and neutron veto (MV & NV):

- 700 t Gd loaded **water Cherenkov veto detectors**.
- Both passive and active shield **against cosmogenic and radiogenic neutrons.**
- 84 and 120 PMTs covering their surface

- **TPC**:
  - **Dual phase time-projection chamber.**
  - 8.5 t of liquid and gaseous xenon, 5.9 t of active target.
  - 494 PMTs divided in two arrays (top and bottom).
  - 23 V/cm drift electric field.



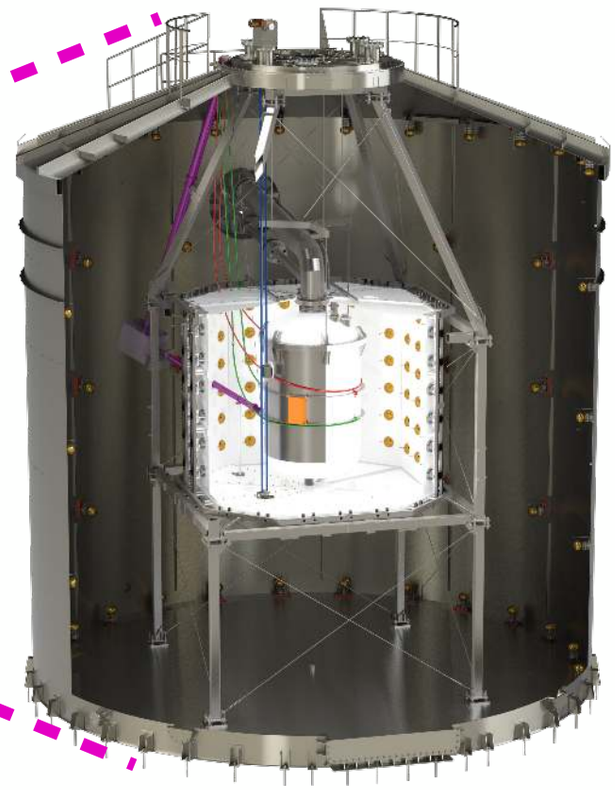
XENONnT @LNGS



The INFN Laboratori Nazionali del Gran Sasso (LNGS) located under 1400 m of rock, shielding the laboratories from cosmic rays.

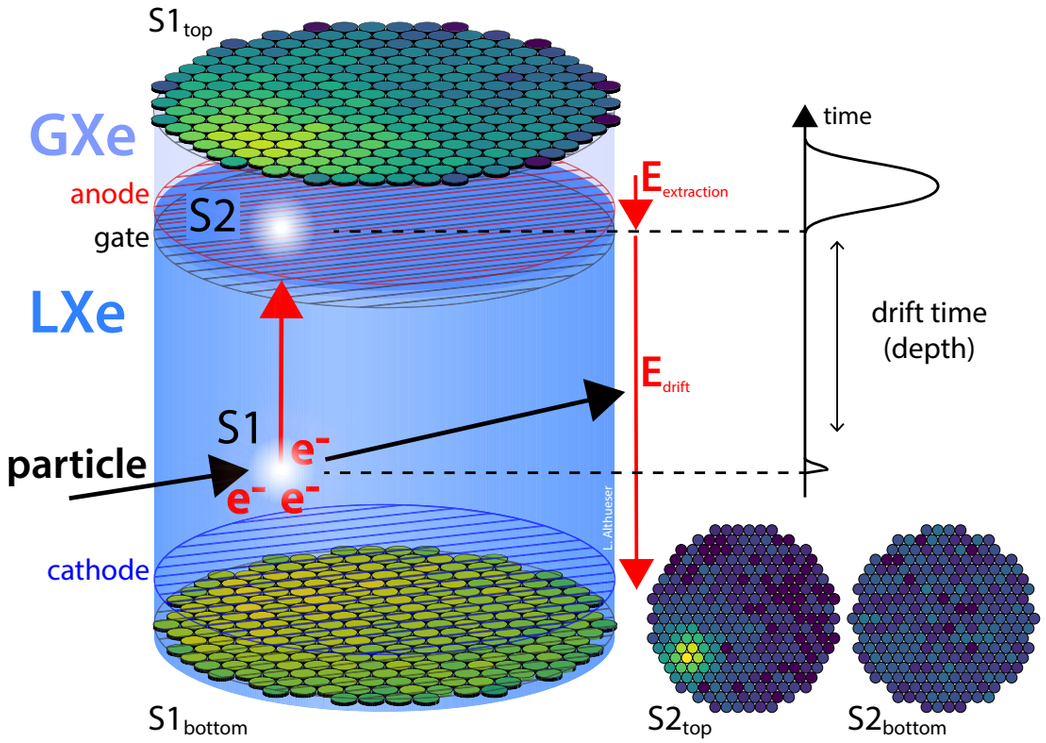
$\rightarrow 10^6\ \mu$ reduction factor

XENONnT



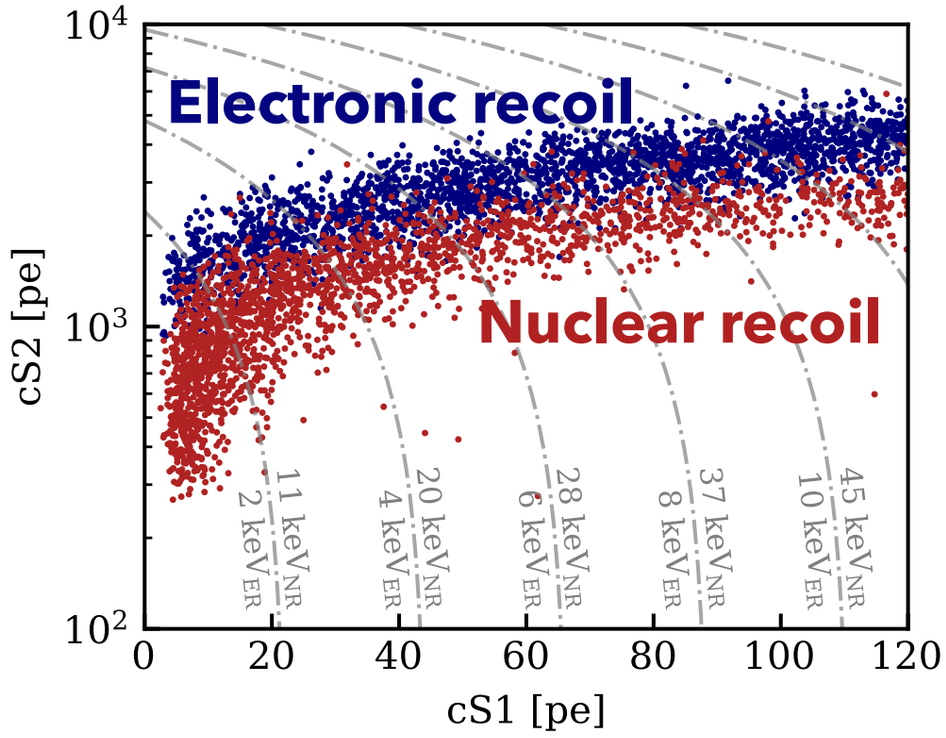
Detection principle of TPCs

- **Signal detection:**
  - Prompt scintillation (S1) + ionization e⁻ in liquid xenon.
  - Electric field drifts e⁻ towards gaseous xenon.
  - Electrons produce a delayed scintillation signal (S2) at the top of the TPC.



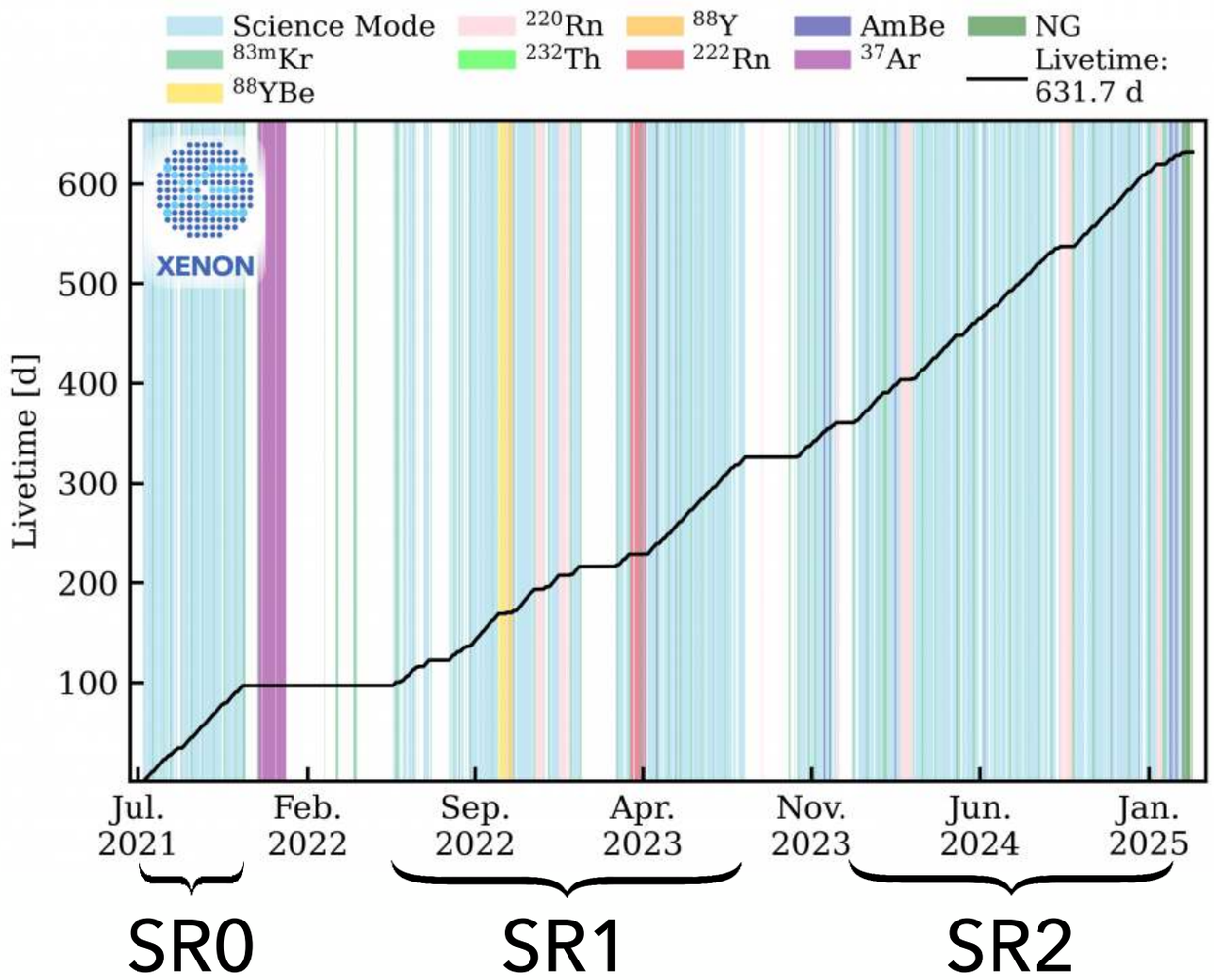
- **3D reconstruction:**
  - x and y from top PMTs.
  - z from drift time × drift velocity.

- **Signal discrimination:**
  - S2/S1 ratio → ER/NR discrimination.



XENONnT science search

- **Fiducial mass of ~ 4 tonne.**
- Three science runs (SR):
  - **SR0 (95.1 days).**
  - **SR1 (186.5 days):** Radon Removal System in high-flow mode (^{222}Rn activity < 1μBq/kg).
    - **SR1a (66.6 days):**
      - Higher ER rate from ^{85}Kr, ^{37}Ar, ^{3}H.
    - **SR1b (119.9 days):**
      - Low ^{85}Kr, ^{37}Ar after cryogenic distillation.
      - ^{3}H still present.
  - **SR2 (~300 days).**

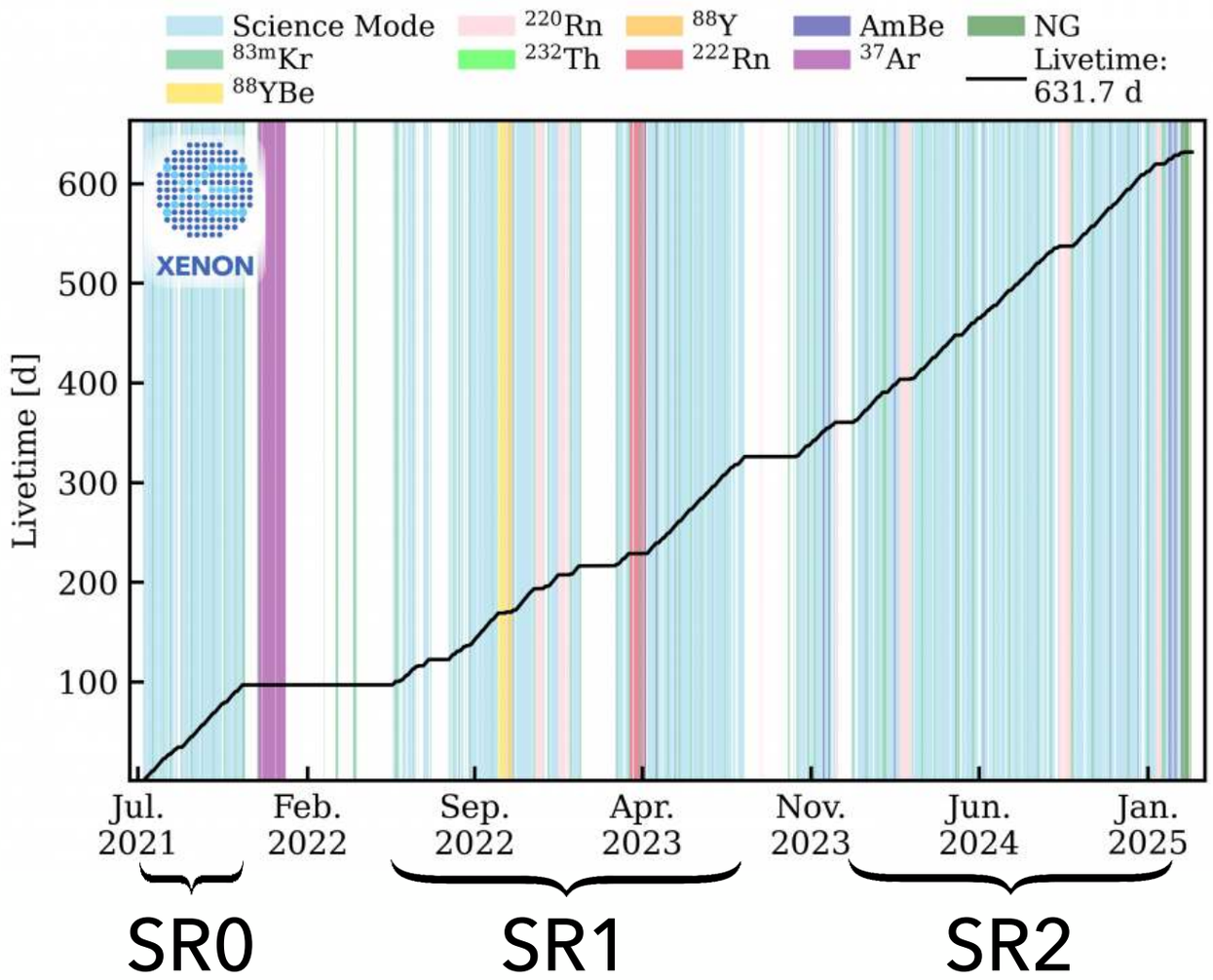


Science Publications:

SR0	SR0 + SR1	SR0+SR1+SR2
Search of new physics in ER	First indication of solar ν	S2-only search
WIMP search in NR	First search of light DM in neutrino fog	
	WIMP search with 3.1 ty	

XENONnT science search

- **Fiducial mass of ~ 4 tonne.**
- Three science runs (SR):
  - **SR0 (95.1 days).**
  - **SR1 (186.5 days):** Radon Removal System in high-flow mode (^{222}Rn activity < 1μBq/kg).
    - **SR1a (66.6 days):**
      - Higher ER rate from ^{85}Kr, ^{37}Ar, ^{3}H.
    - **SR1b (119.9 days):**
      - Low ^{85}Kr, ^{37}Ar after cryogenic distillation.
      - ^{3}H still present.
  - **SR2 (~300 days).**



Science Publications:

SR0	SR0 + SR1	SR0+SR1+SR2
Search of new physics in ER	First indication of solar ν	S2-only search
WIMP search in NR	First search of light DM in neutrino fog	
	WIMP search with 3.1 ty	

This talk

WIMP search: reconstruction and efficiencies

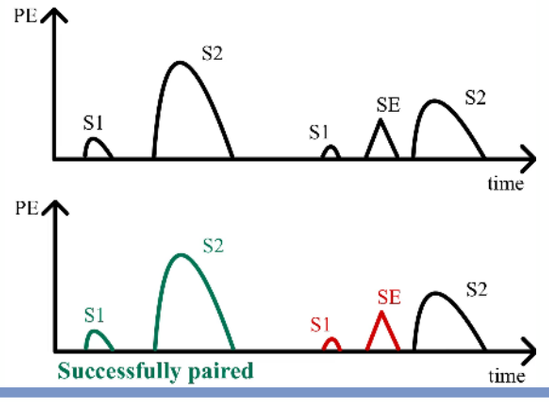
Phys. Rev. Lett. 135 (2025), 221003

Peak reconstruction/Detection: dominated by 3-fold requirement (3 PMTs to be in coincidence) for S1.

Selection:

S1/S2 is signal-like, S2 consistent with e^- diffusion, quality cuts, etc …

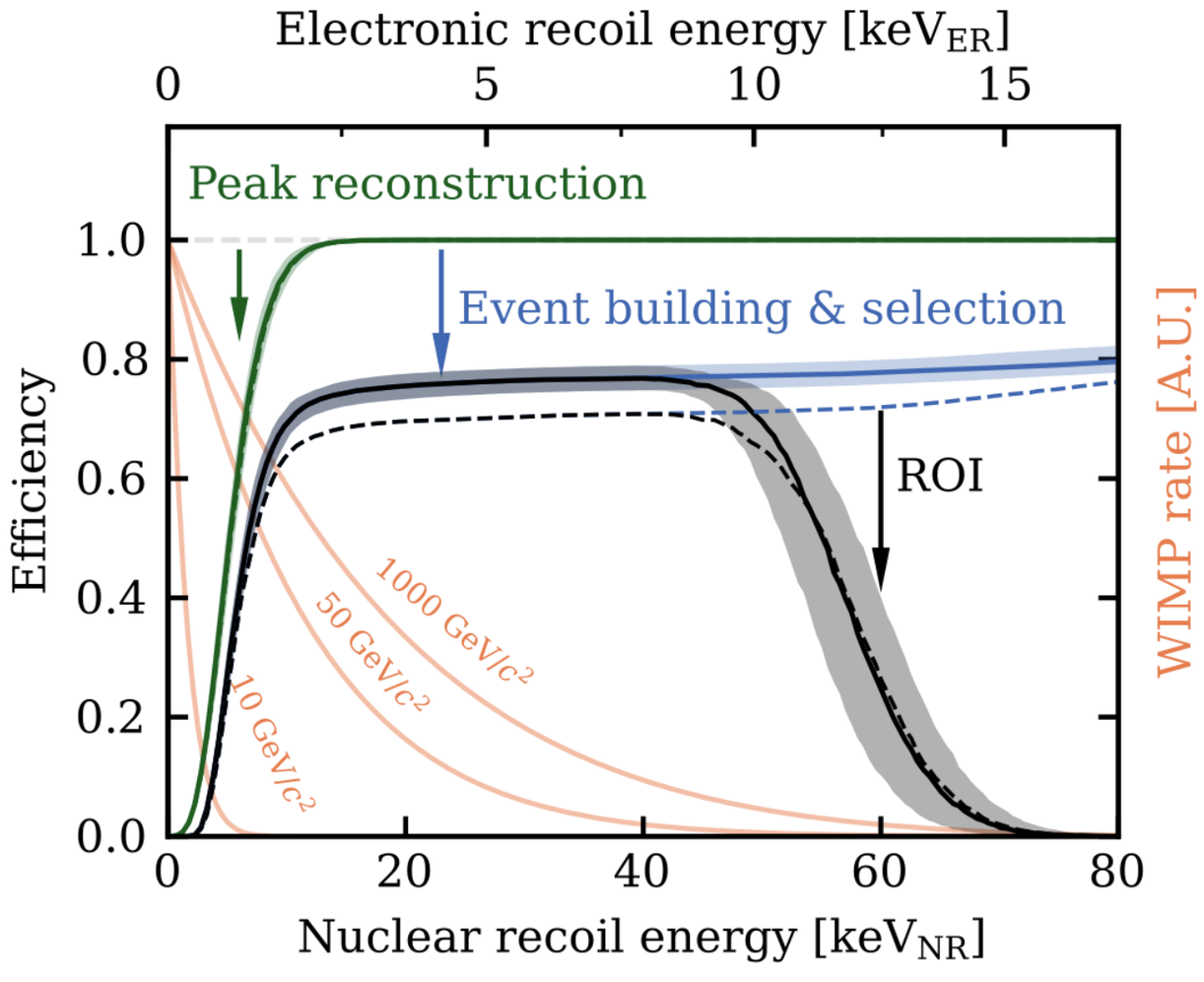
Event building: whether an event is successfully reconstructed.



Region of Interest (ROI)

cS1 ∈ [0,100] PE and cS2 ∈ $[10^{2.1},10^{4.1}]$ PE.

*(cS1/cS2 = corrected S1/S2)



WIMP search: Background

Phys. Rev. D 111 (2025), 103040

ER background

- **β-decays** from ^{222}**Rn** chain and ^{85}**Kr**
- ^{124}**Xe DEC,**
- **solar $\nu - e$ scattering.**

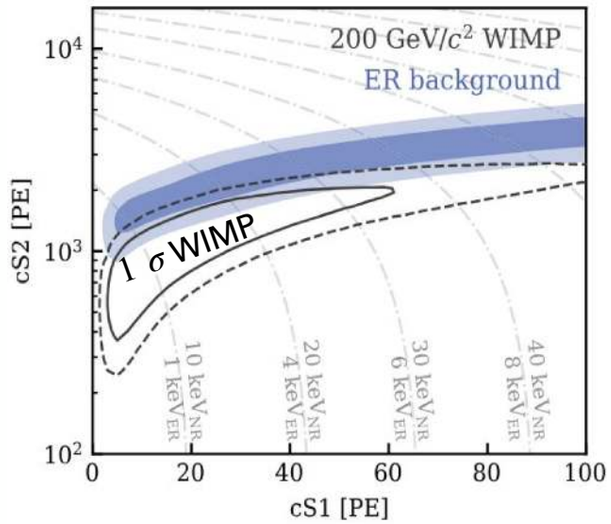
Shape constrained by ^{220}Rn calibration data.

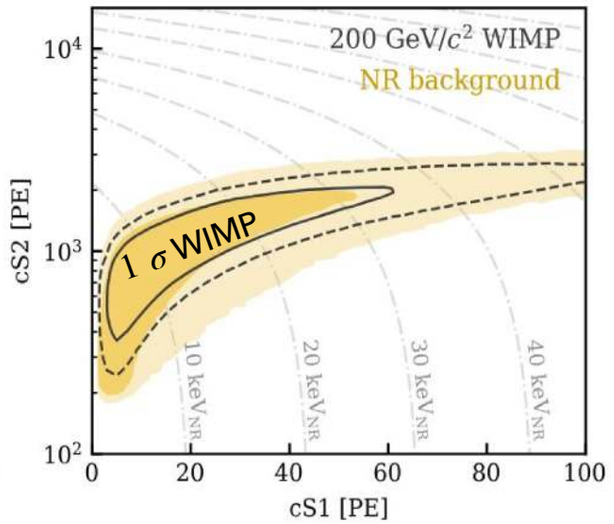
Rate constrained by fit to reconstructed spectrum in [20,140] keV_{ER}.

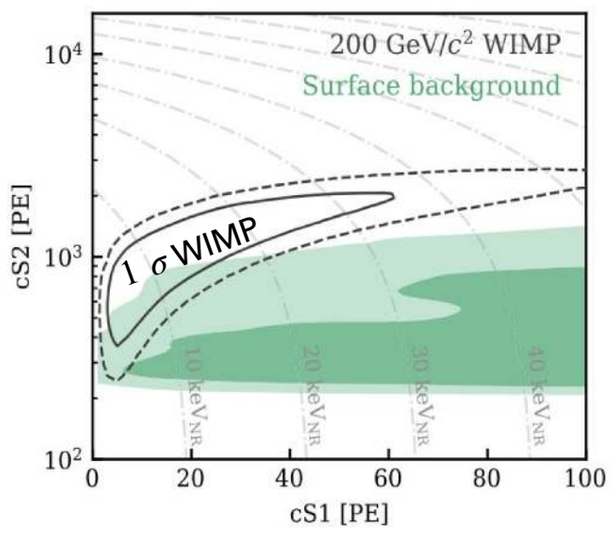
Surface background

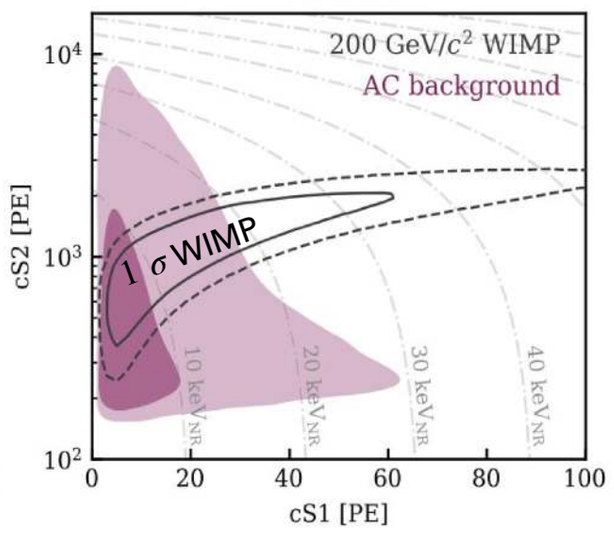
- **Pb decay chain**
  Plate-out effect from the PTFE walls.

Rate constrained by a data-driven method and validated with events outside FV.









NR background

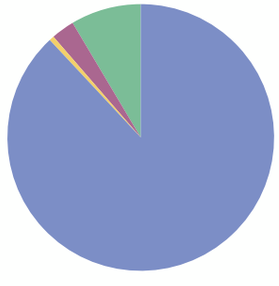
- **Radiogenic neutrons**
  Constrained by sideband of multi-scatter events and single-scatter events tagged by n-Veto.
- **CEvNS events in RoI**
  Constrained by neutrino flux and uncertainties in NR emission model.

Accidental coincidence

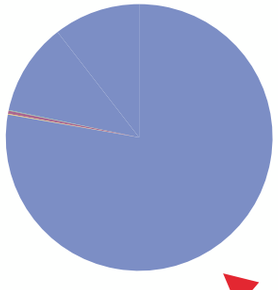
- **Accidental pairing of isolated S1-S2**

Modeled by a data-driven method.

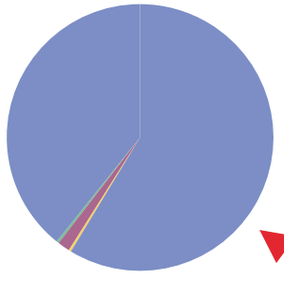
Validation and uncertainty estimation through a dedicated sideband unblinding.



SR0



SR1a



SR1b

Accidental leakage of impurities increased ER bkg

WIMP search: SR0 + SR1 results

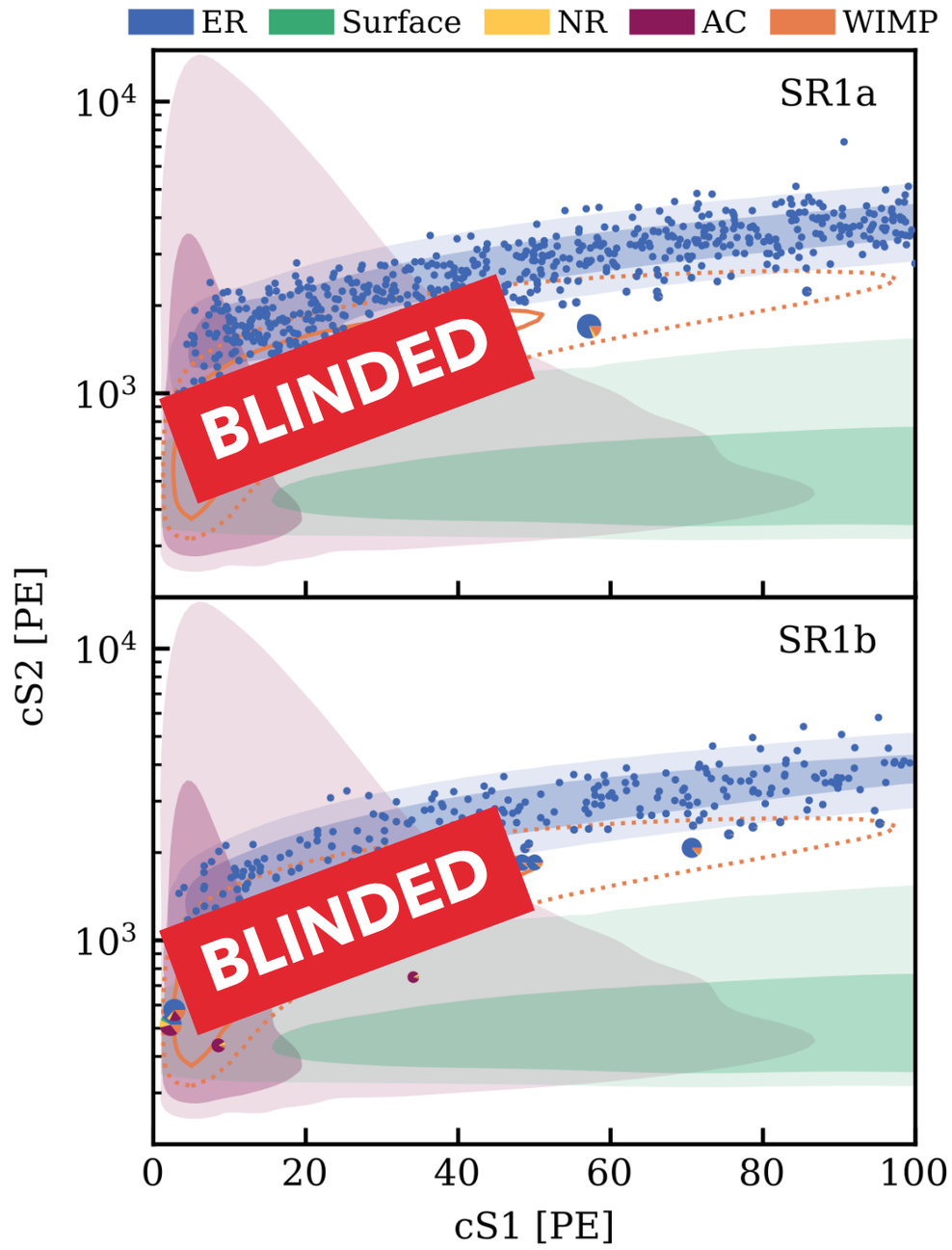
Phys. Rev. Lett. 135 (2025), 221003

Total exposure: 3.5 tonnes year.

Inference using a **profile likelihood test statistic** in **(cS1,cS2,r)** space.

Distance between the event and the axis of the TPC

- **SR0 re-analysis:**
  - Already unblinded data kept untouched.
  - Updated neutron background model.
- **SR1 blind analysis:**
  - Blinded events in WIMP ROI.



WIMP search: SR0 + SR1 results

Phys. Rev. Lett. 135 (2025), 221003

Total exposure: 3.5 tonnes year.

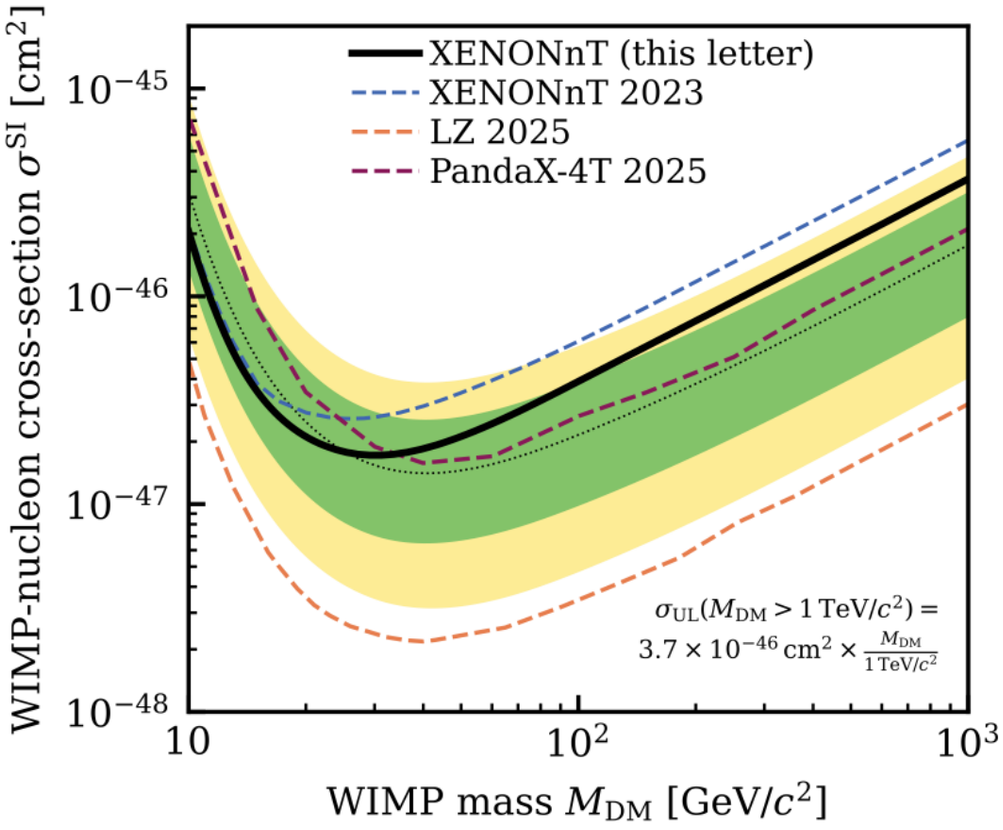
Inference using a **profile likelihood test statistic** in **(cS1,cS2,r)** space.

- **SR0 re-analysis:**
  - Already unblinded data kept untouched.
  - Updated neutron background model.
- **SR1 blind analysis:**
  - Blinded events in WIMP ROI.

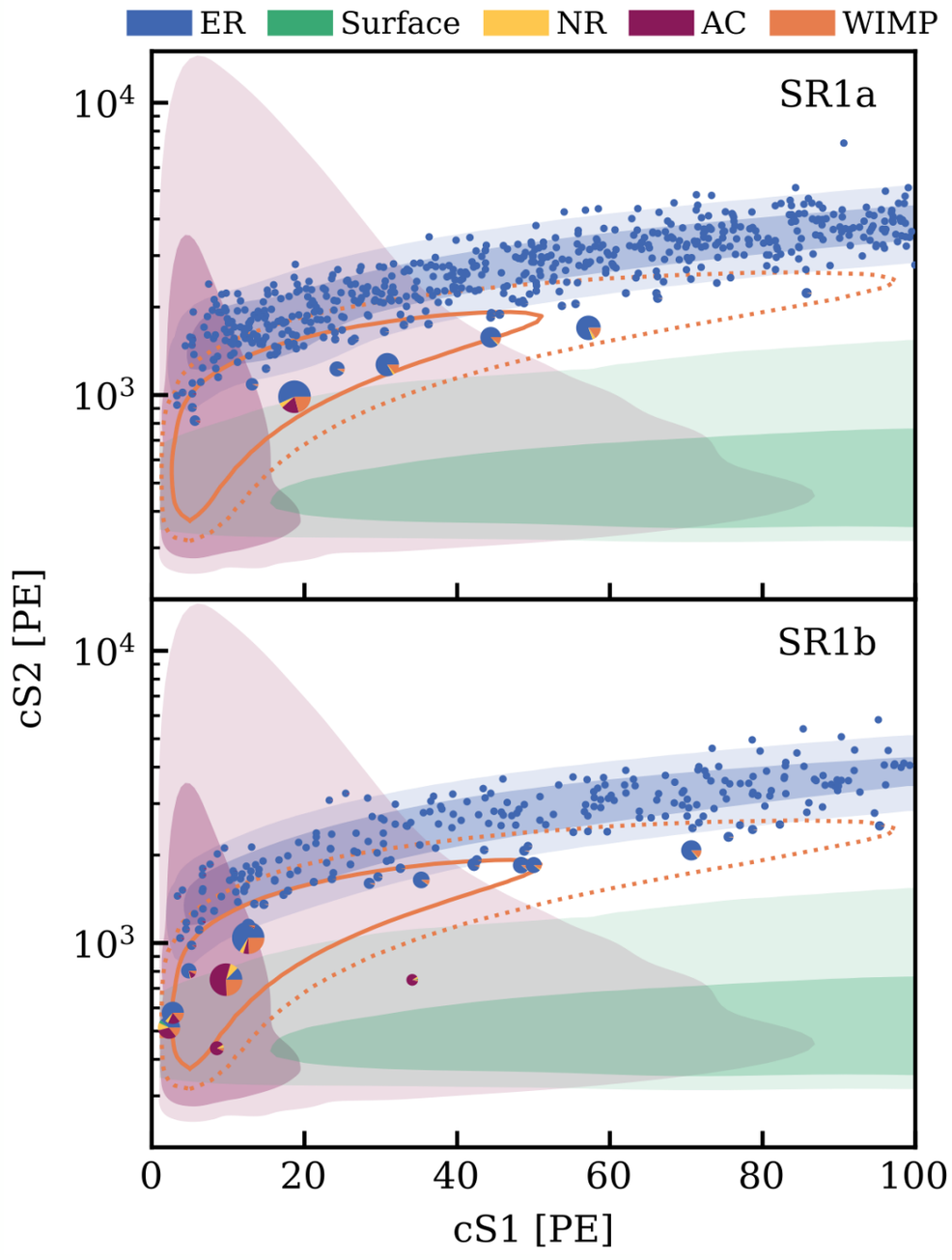
New limits on WIMP-nucleon cross section:

$1.7 \times 10^{-47}\,\mathrm{cm}^2$ **at** $m_\chi = 30\ \mathrm{GeV}/c^2$.

Factor 1.8 improvement wrt SR0.



No excess over background



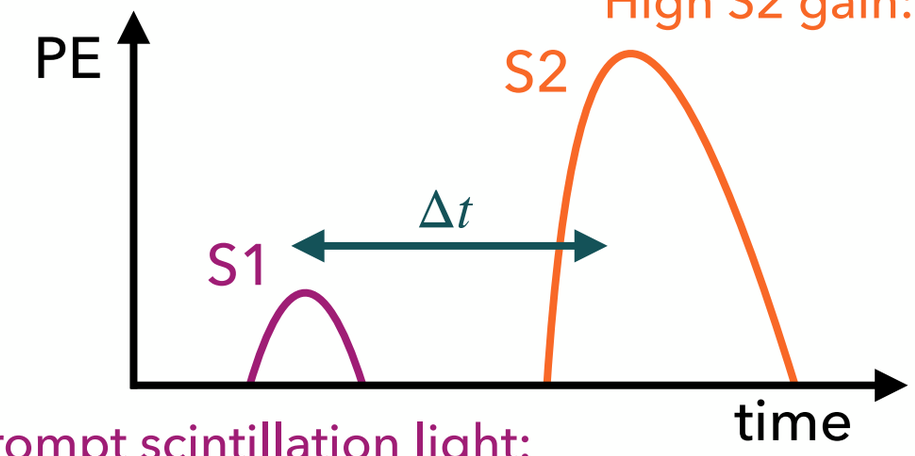
S2-only search

arXiv:2601.11296 [hep-ex]

Usual WIMP search:

Secondary scintillation light:

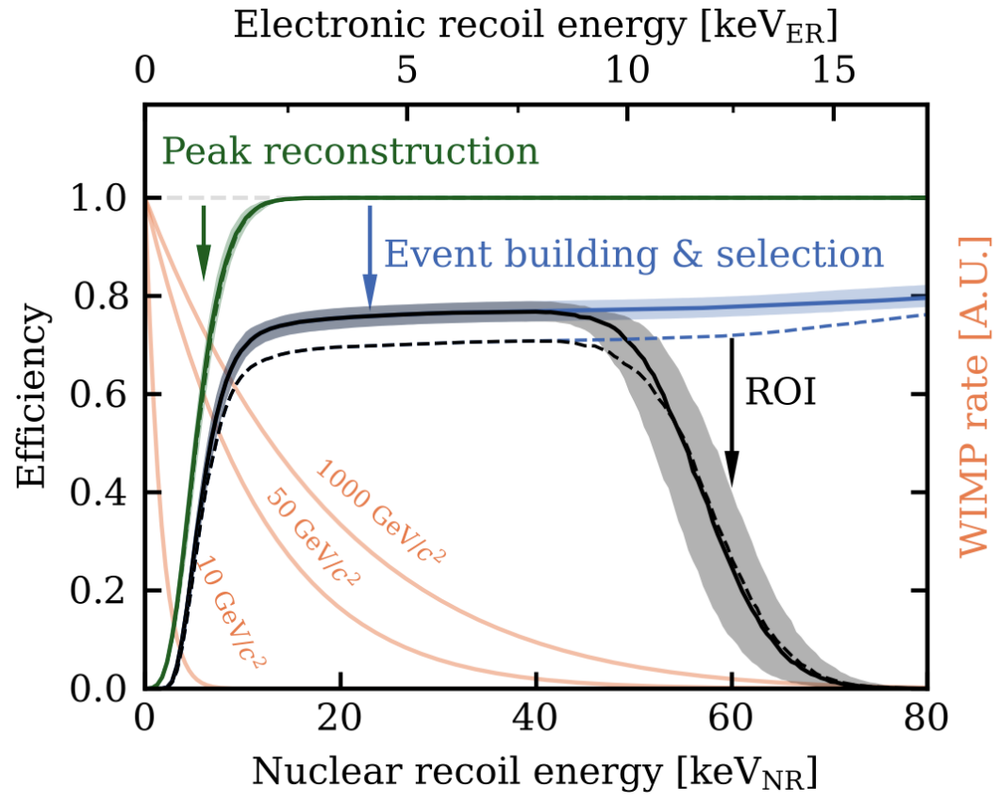
High S2 gain: $g_2 \simeq 15$ PE/e^-



Prompt scintillation light:

Small S1 gain: $g_1 \simeq 0.1$ PE/photon

S1+S2



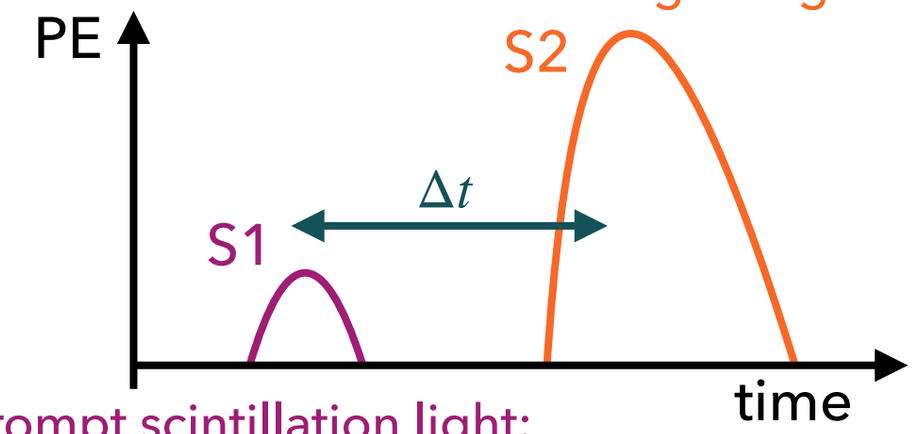
S2-only search

arXiv:2601.11296 [hep-ex]

Usual WIMP search:

Secondary scintillation light:

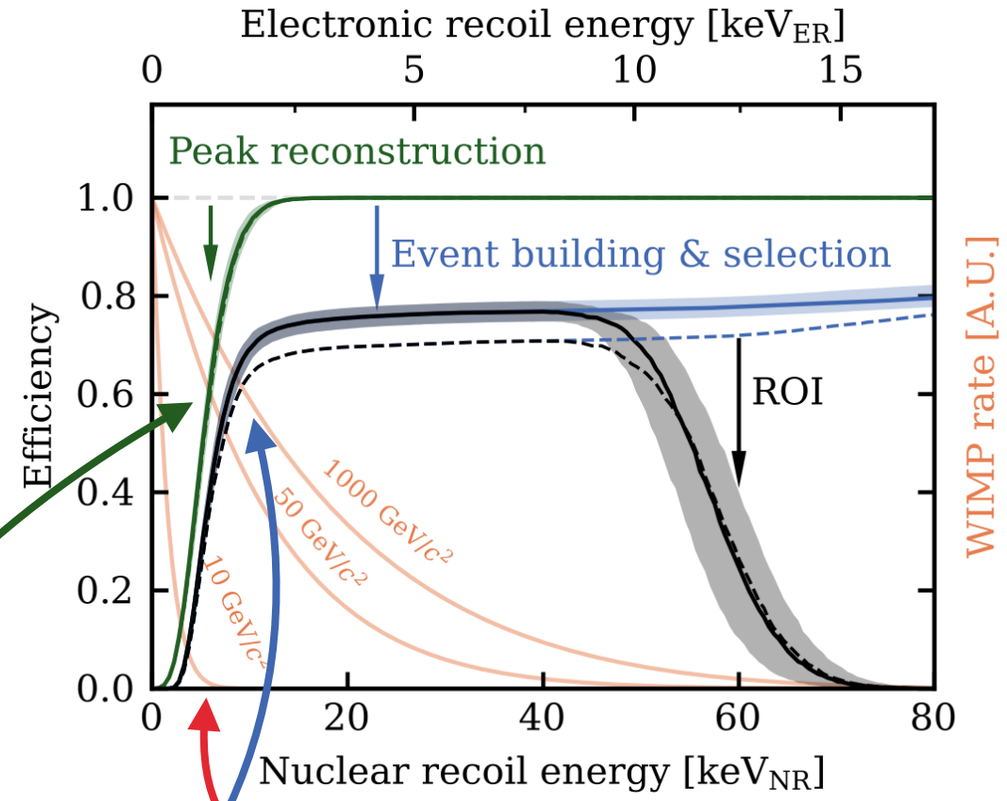
High S2 gain: $g_2 \simeq 15$ PE/e^-



Prompt scintillation light:

Small S1 gain: $g_1 \simeq 0.1$ PE/photon

S1+S2



S1+S2 → few keV threshold

3 PMTs in coincidence for S1

$\rightarrow S1 > 3\ PE$

S1-S2 pairing, selection cuts.

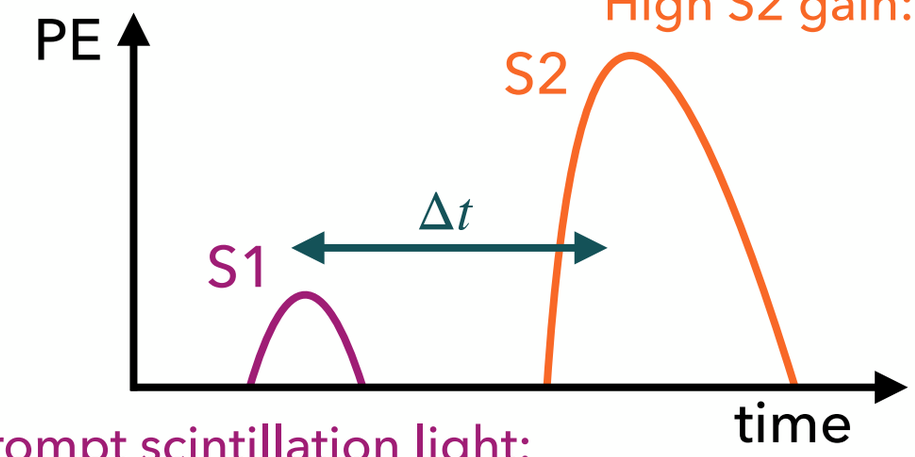
S2-only search

arXiv:2601.11296 [hep-ex]

Usual WIMP search:

Secondary scintillation light:

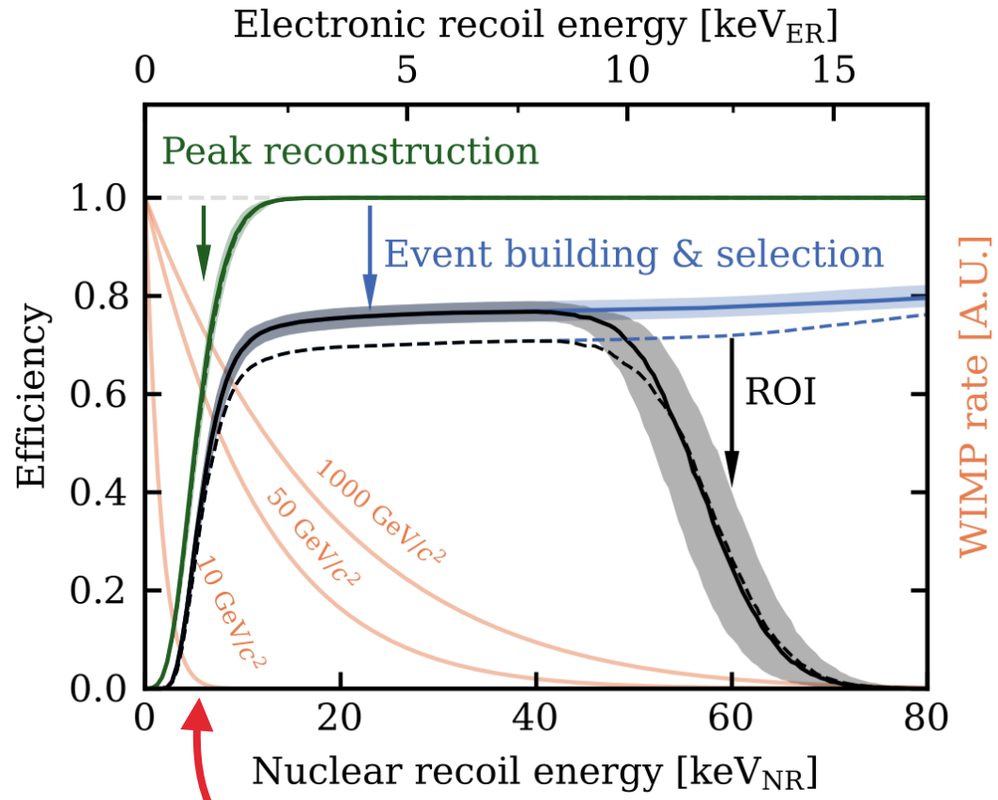
High S2 gain: $g_2 \simeq 15$ PE/e^-



Prompt scintillation light:

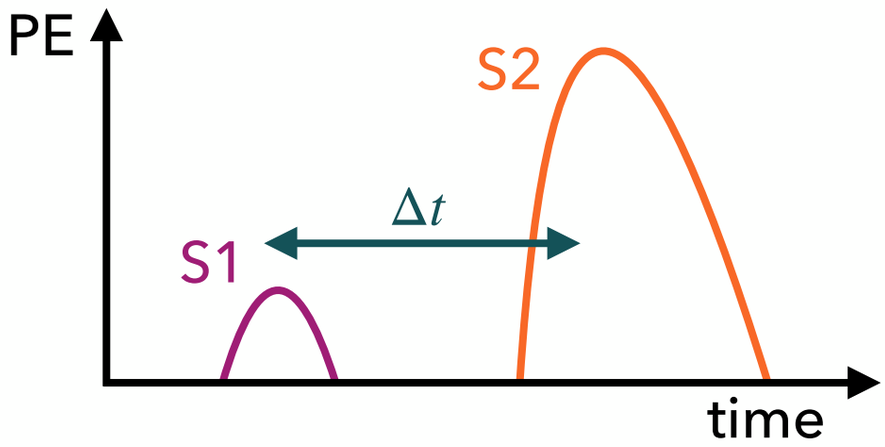
Small S1 gain: $g_1 \simeq 0.1$ PE/photon

S1+S2



S1+S2 → few keV threshold

S2-only search:



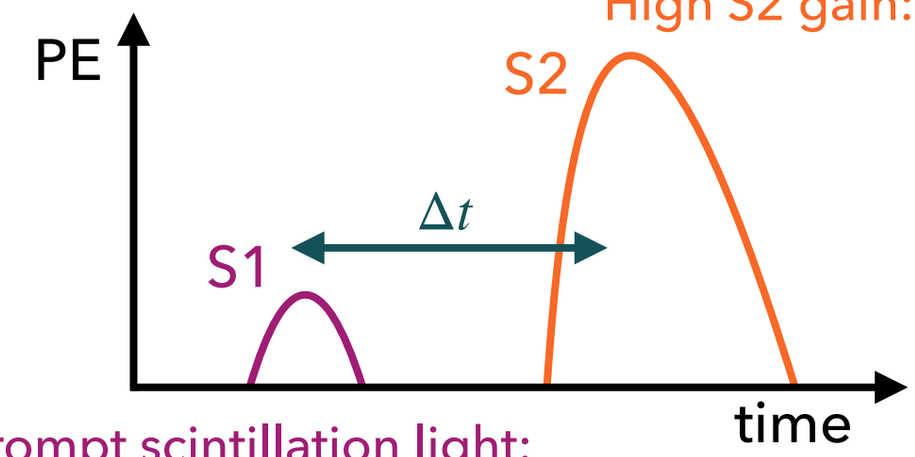
S2-only search

arXiv:2601.11296 [hep-ex]

Usual WIMP search:

Secondary scintillation light:

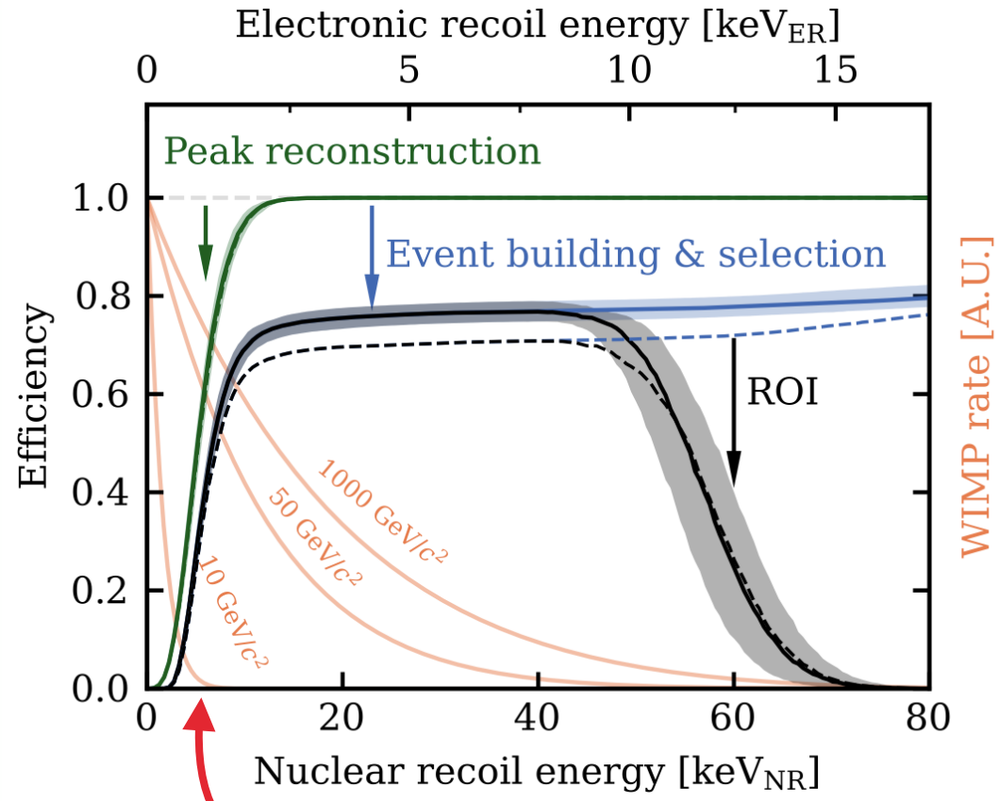
High S2 gain: $g_2 \simeq 15$ PE/e^-



Prompt scintillation light:

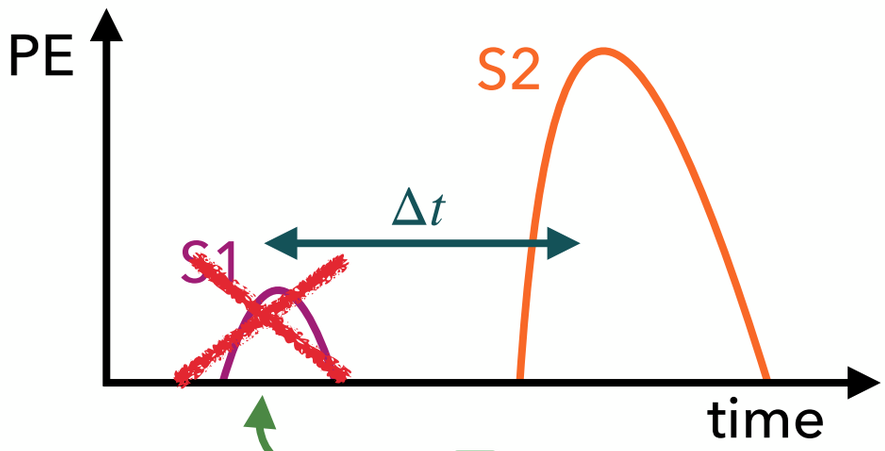
Small S1 gain: $g_1 \simeq 0.1$ PE/photon

S1+S2



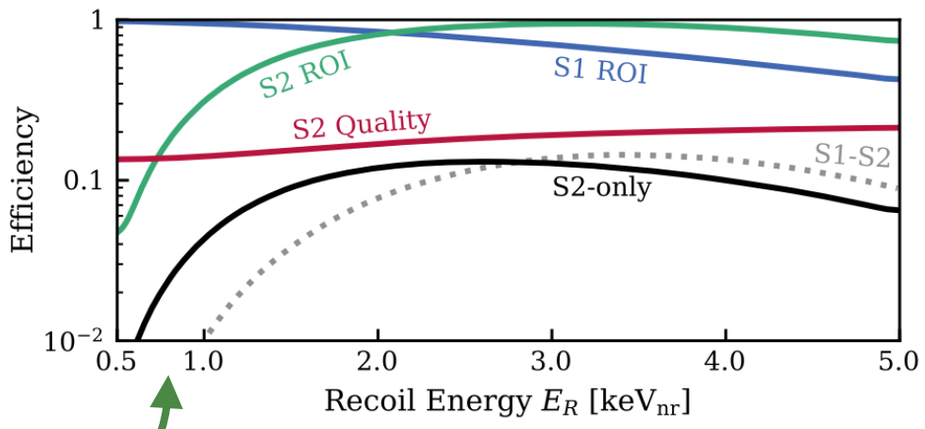
S1+S2 → few keV threshold

S2-only search:



✅ Remove S1 → < 1 keV threshold

S2-only



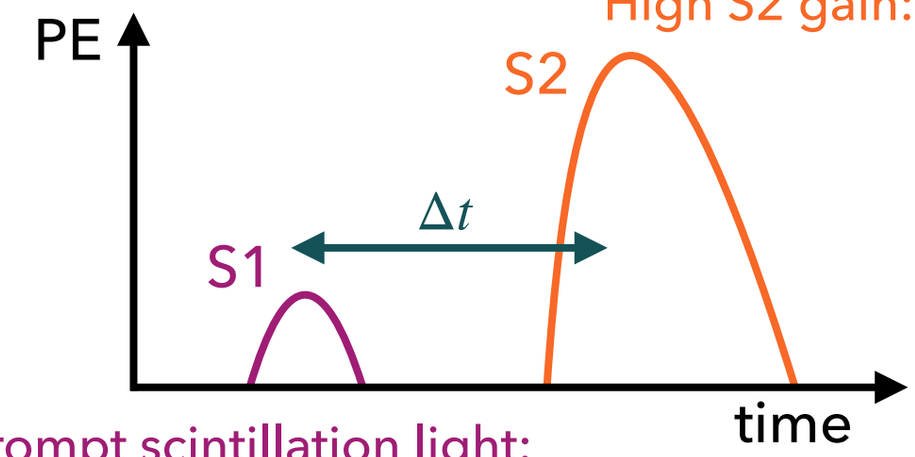
S2-only search

arXiv:2601.11296 [hep-ex]

Usual WIMP search:

Secondary scintillation light:

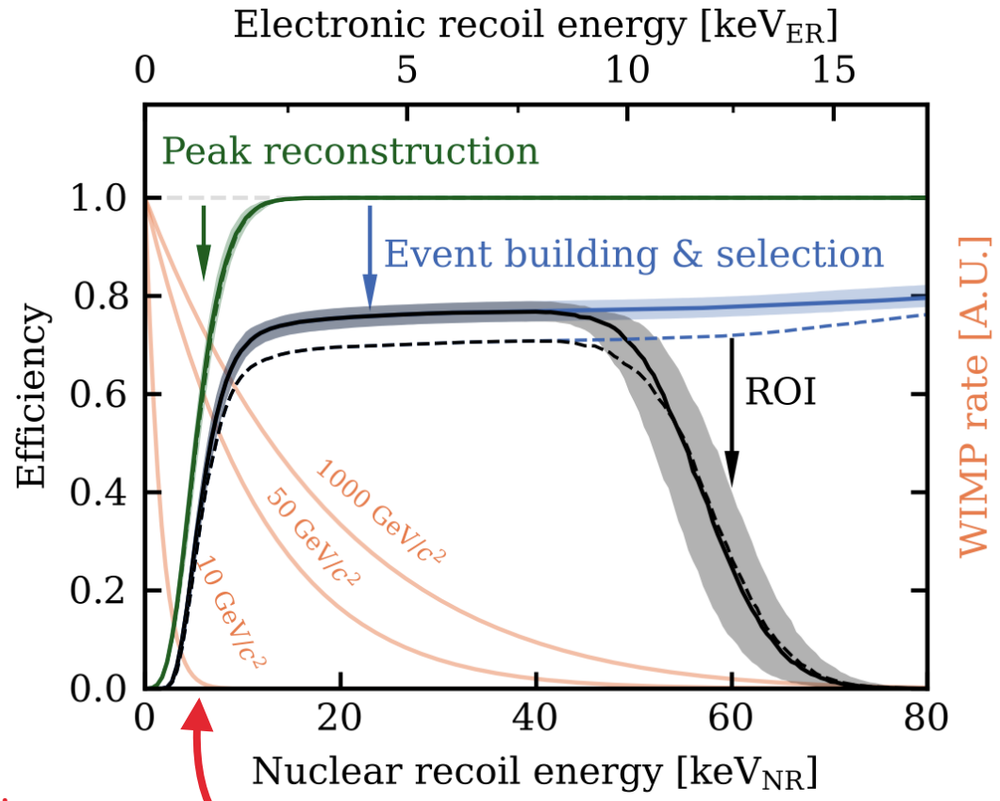
High S2 gain: $g_2 \simeq 15$ PE/e^-



Prompt scintillation light:

Small S1 gain: $g_1 \simeq 0.1$ PE/photon

S1+S2



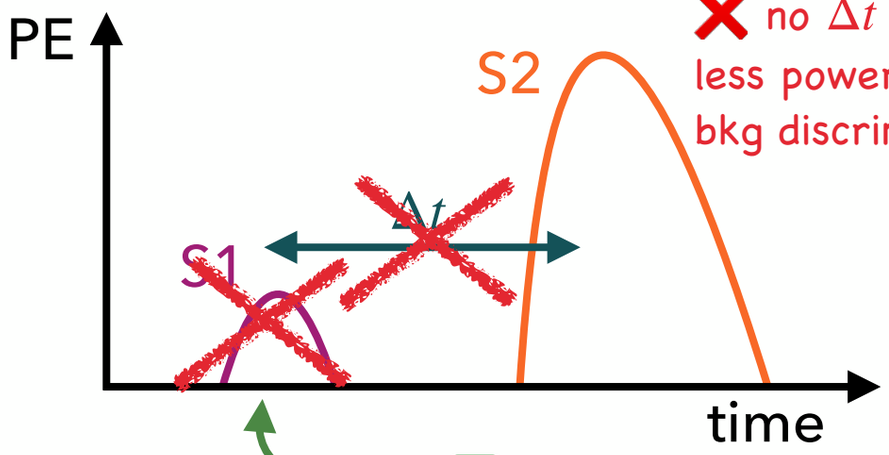
❌ no S1 no NR/ER discrimination

S1+S2 → few keV threshold

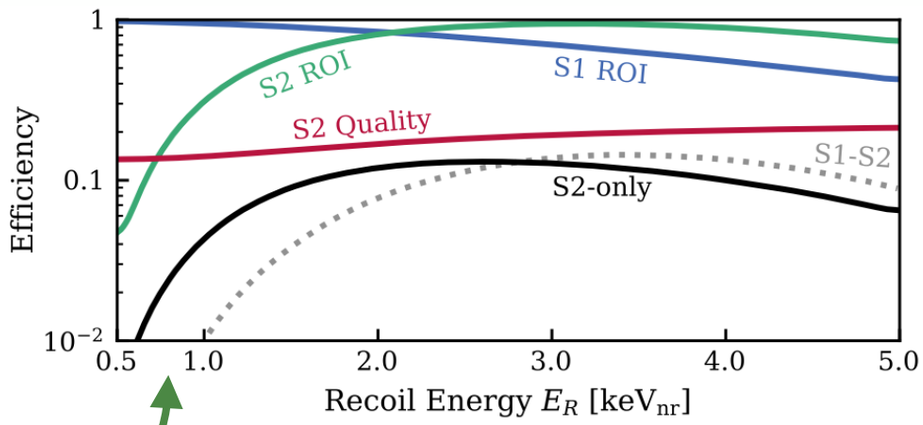
S2-only search:

❌ no Δt → no z position

less powerful top-bottom bkg discrimination



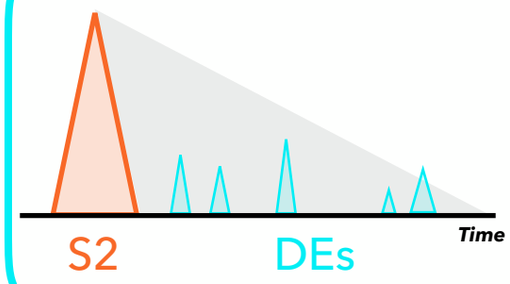
S2-only



✅ Remove S1 → < 1 keV threshold

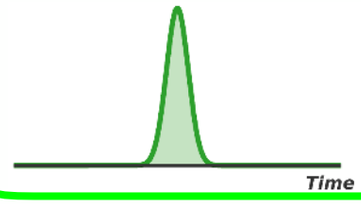
S2-only search: backgrounds

arXiv:2601.11296 [hep-ex]

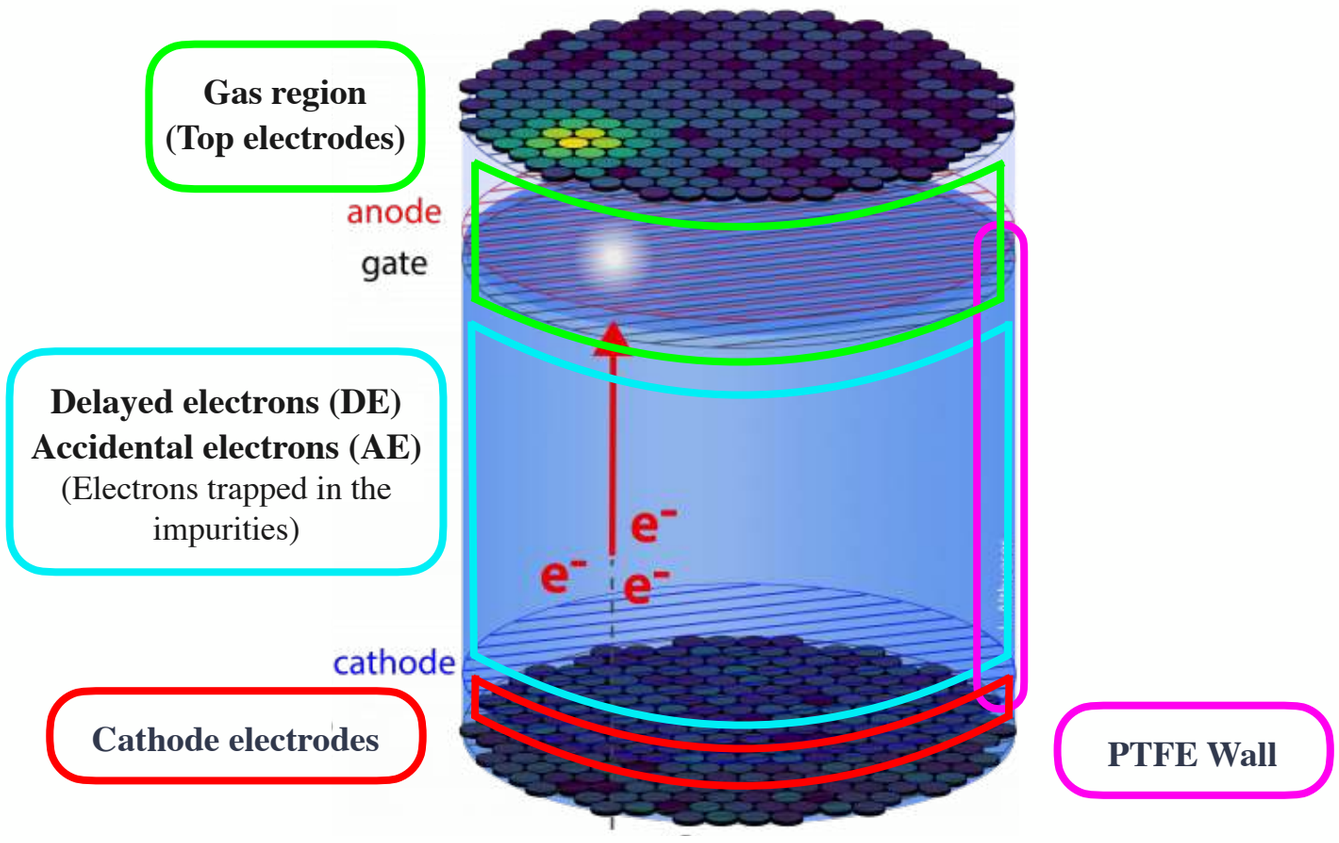


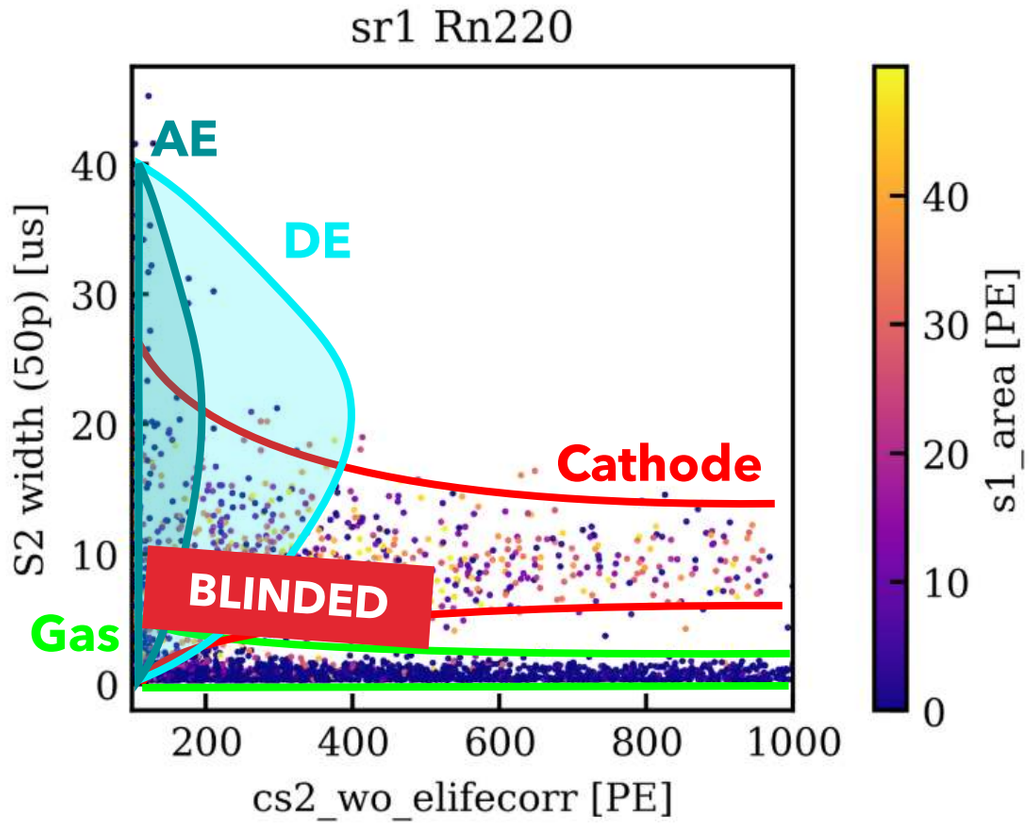
Delayed Electrons (DE):

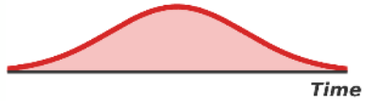
- Position & Time correlated with the parent S2.
- Large S2 width due to the peak merging
- Correlation-based CNF and BDT machine



Gas: S2 width < 3 us due to smaller diffusion





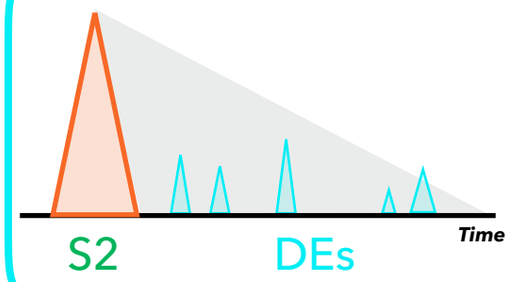


Cathode: S2 width ~ 10 us large overlap with signal region waveform-based BDT machine

Images credits: Yongyu Pan

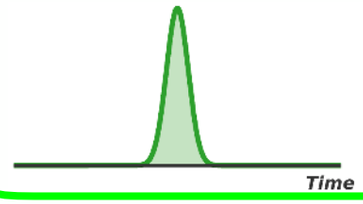
S2-only search: backgrounds

arXiv:2601.11296 [hep-ex]



Delayed Electrons (DE):

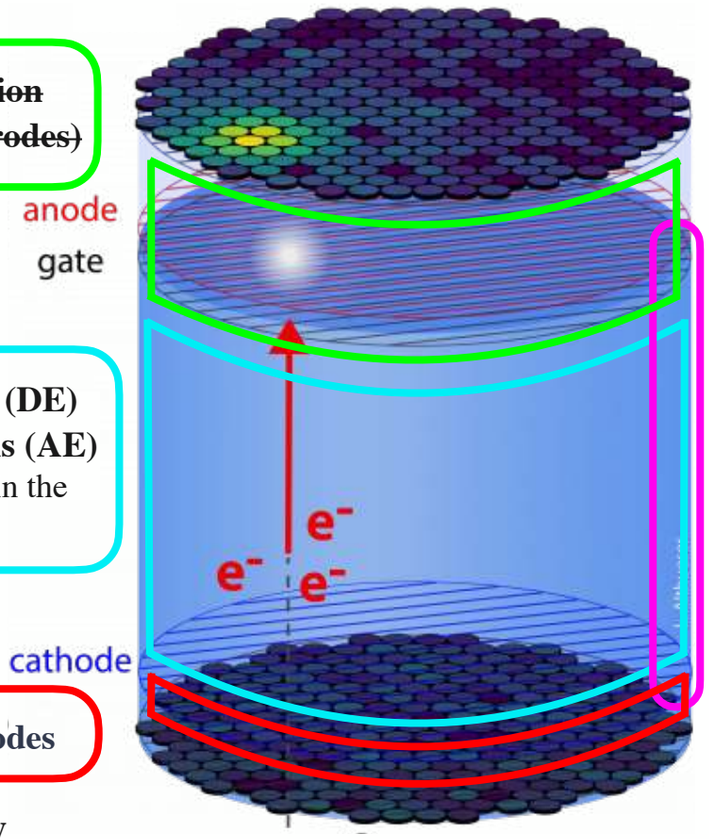
- Position & Time correlated with the parent S2.
- Large S2 width due to the peak merging
- Correlation-based CNF and BDT machine



~~**Gas**: S2 width < 3 us due to smaller diffusion~~

~~Gas region (Top electrodes)~~

Negligible after width cut



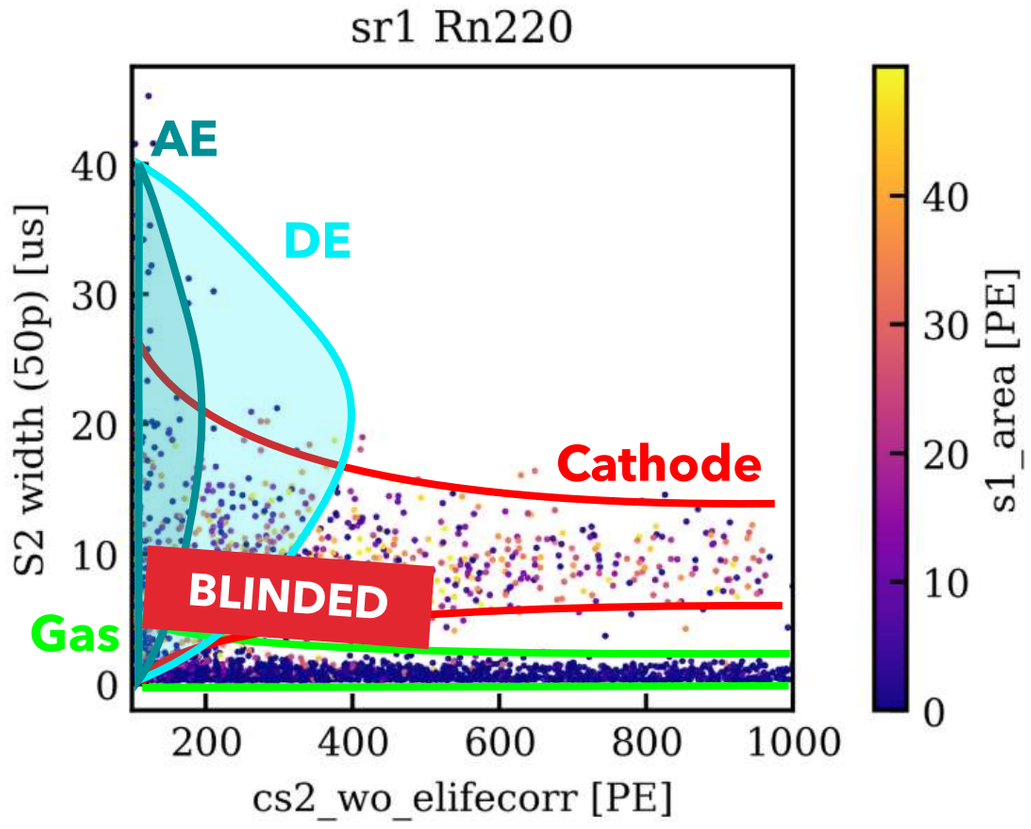
Delayed electrons (DE)
Accidental electrons (AE)
(Electrons trapped in the impurities)

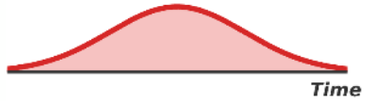
Cathode electrodes

Simulation by data-driven sidebands

~~**PTFE Wall**~~

Negligible after radius cut





Cathode: S2 width ~ 10 us large overlap with signal region waveform-based BDT machine

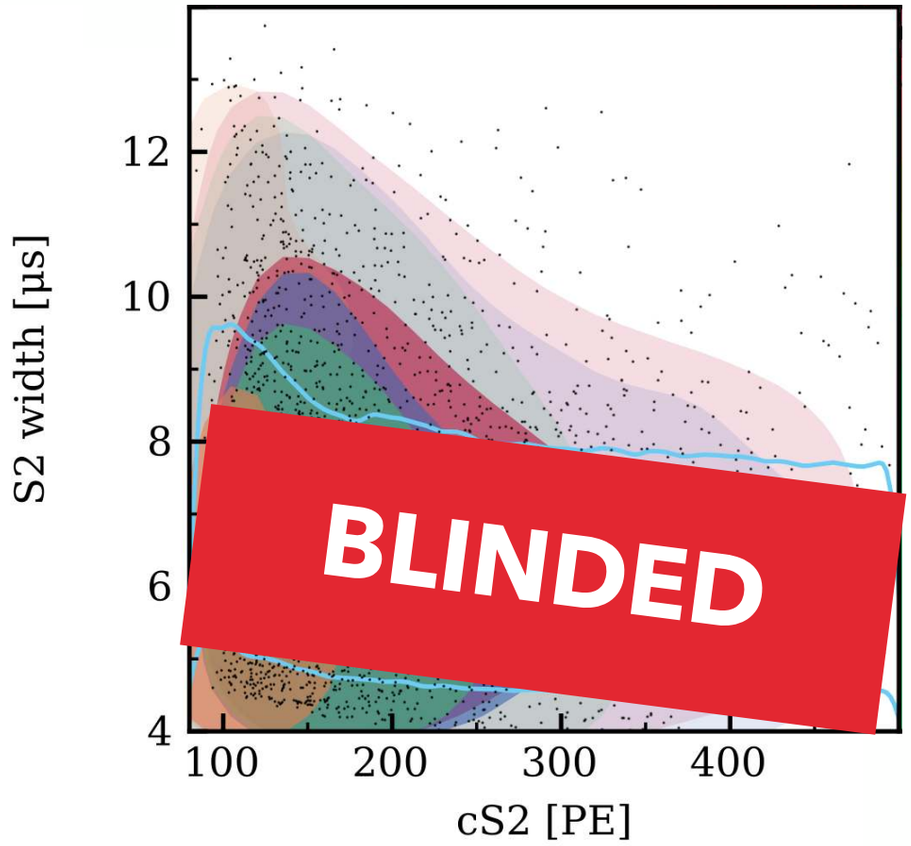
Images credits: Yongyu Pan

S2-only search: SR0+1+2 results

arXiv:2601.11296 [hep-ex]

Results for blinded S2-only search:

- Total exposure: 7.83 tonnes year
- 3 Science Runs (SR0,SR1,SR2)
- Profile likelihood test statistic in cS2 space
- Cathode background is dominant while accidental electron (AE) primarily contribute to the lowest energy bin.

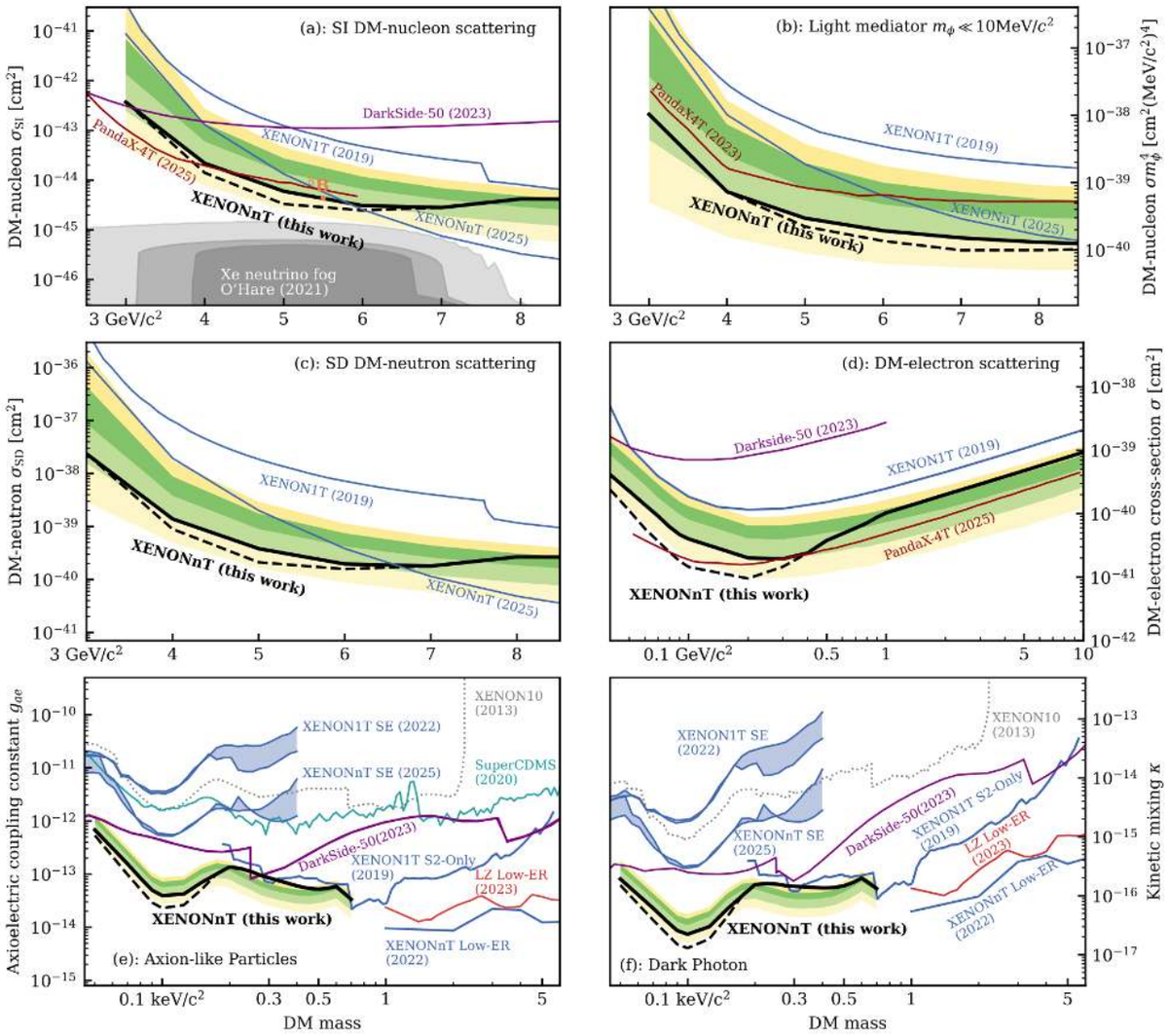


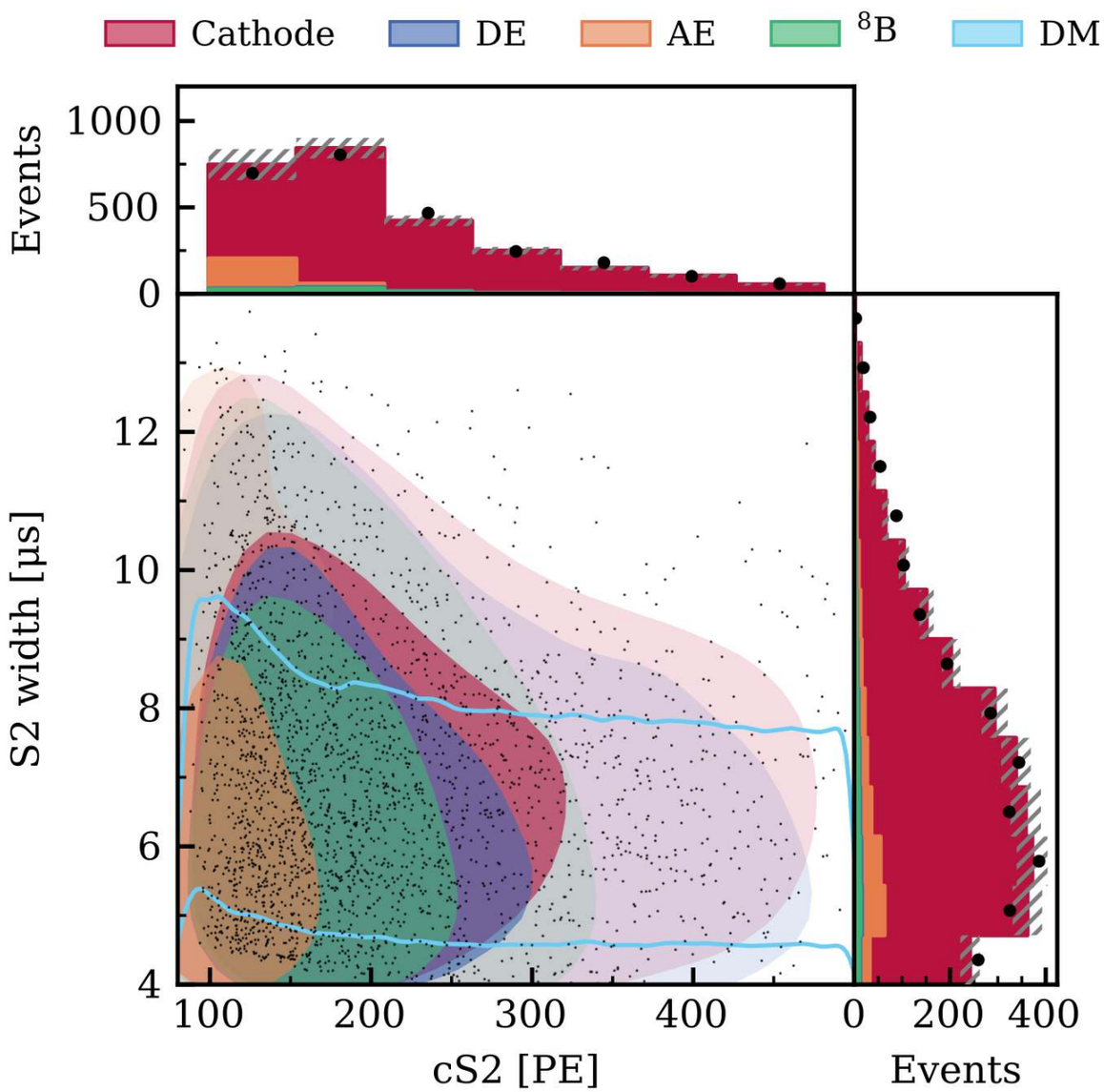
S2-only search: SR0+1+2 results

arXiv:2601.11296 [hep-ex]

Results for blinded S2-only search:

- Total exposure: 7.83 tonnes year
- 3 Science Runs (SR0,SR1,SR2)
- Profile likelihood test statistic in cS2 space
- Cathode background is dominant while accidental electron (AE) primarily contribute to the lowest energy bin.



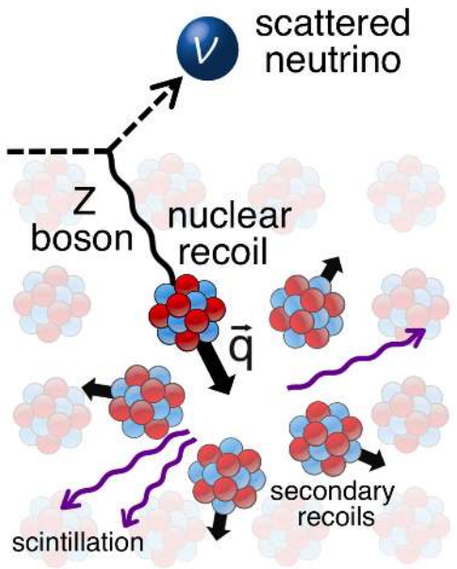


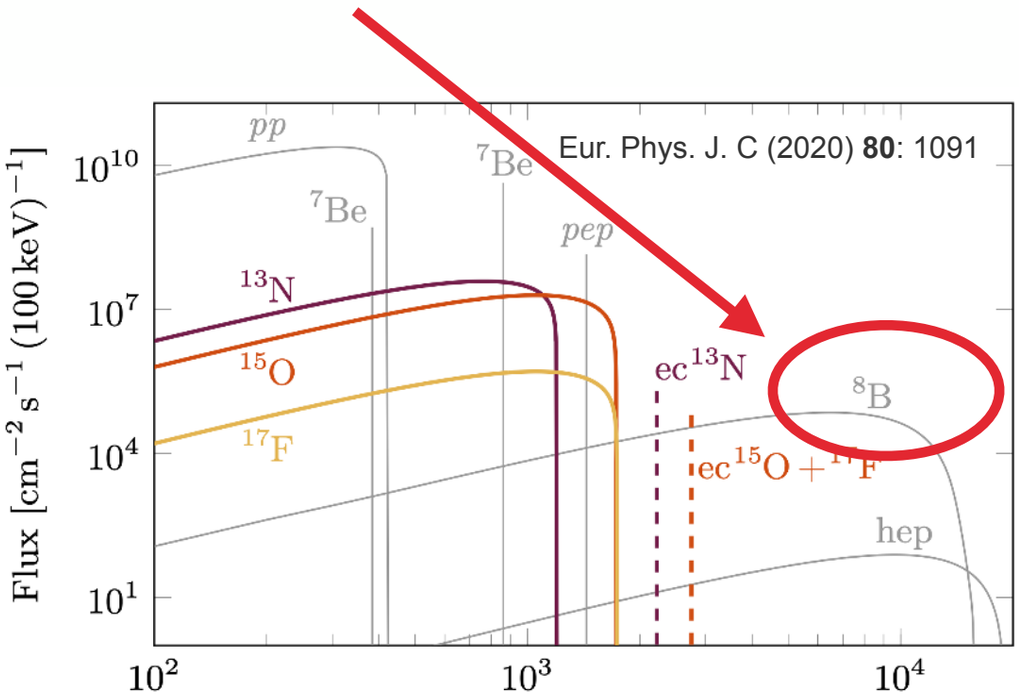
^{8}B CEvNS search

Phys. Rev. Lett. 133 (2024), 191002

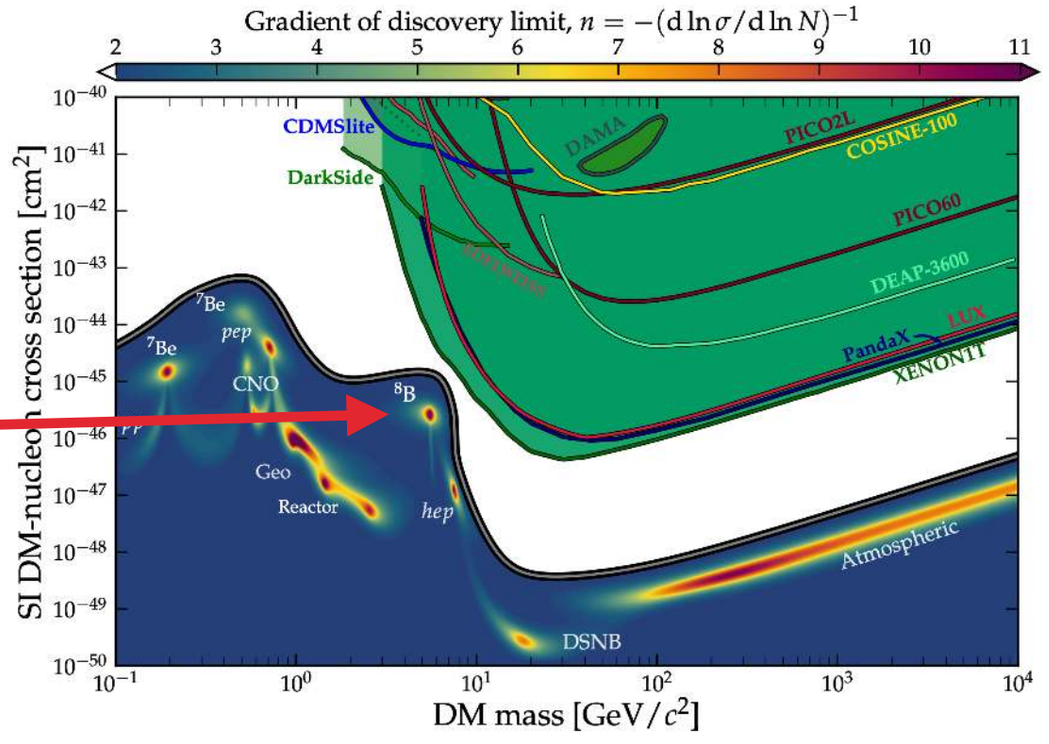
Coherent Elastic ν-Nucleus Scattering (CEvNS).

- Standard model process first predicted in 1974 and observed by COHERENT in 2017.
- Previously never observed with Xe detector or from astrophysical source.
- Solar ν from ^{8}B.





- Highest rate of detectable signals in LXe detectors:
  - Elastic ν-N scattering: $\sigma \propto N_n^2$.
  - Low-energy NR (< 3 keV).
- Indistinguishable from 6 GeV WIMP.
- Region where DM experiments are limited by irreducible background from solar or atmospheric neutrinos.



Prog. Part. Nucl. Phys. 131 (2023) 104043

^{8}B CEvNS search: results

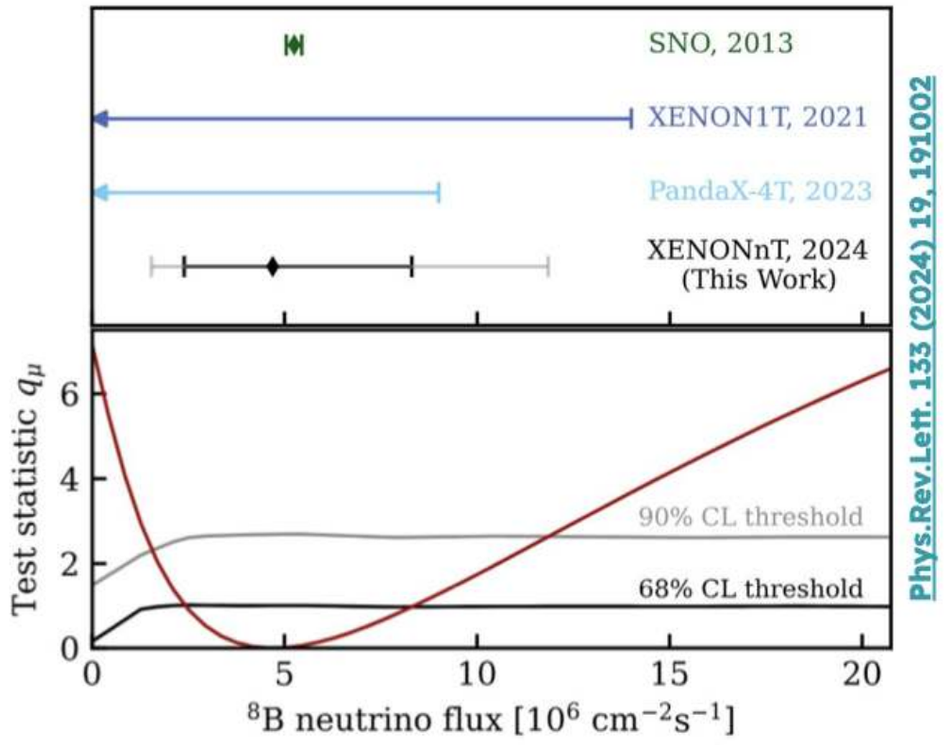
Phys. Rev. Lett. 133 (2024), 191002

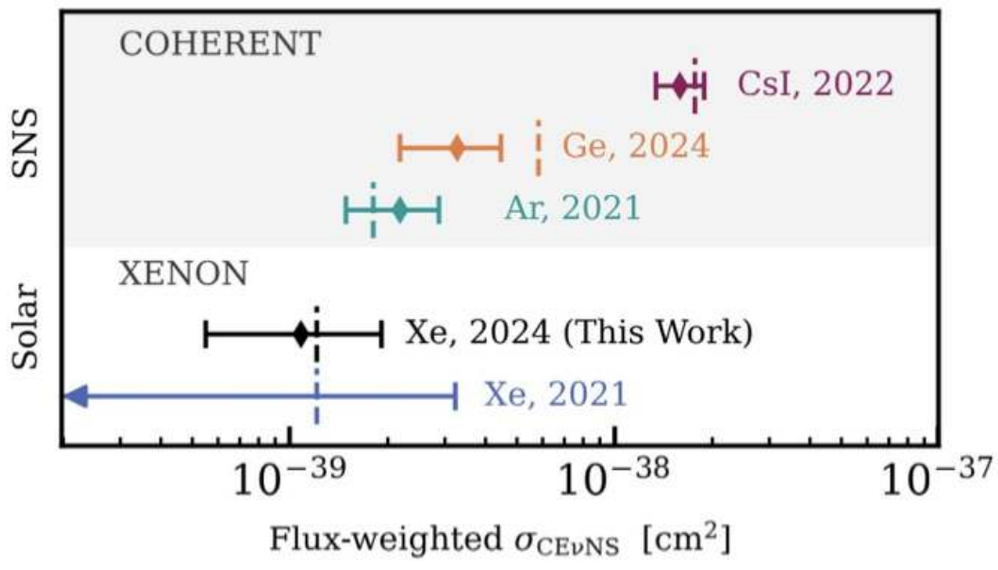
- **Total SR0+1 exposure: 3.51 tonne year.**
- Inference with a 4-D binned likelihood in 3^4 bins.

	Expected	Best fit
Background	26.4 ± 1.4	26.3 ± 1.4
Signal	11.9 ± 4.5	$10.7^{+3.7}_{-4.2}$

SIGNIFICANCE OF 2.73σ

- **First measurement of CEvNS from astrophysical neutrinos in a xenon target**
  - Obtained at same time with PandaX-4T (~ 1 t $\times$ y, 2.64σ).
- **Measurement of solar ^{8}B flux**
  - Fixed cross-section, fit for the flux.
  - Result: $\Phi = 4.7^{+3.6}_{-2.3} \times 10^6$ cm^{-2} s^{-1}.
  - Compatible with SNO measurement.
- **Measurement of CEvNS cross-section in Xe**
  - Fixed neutrino flux, fit for cross section.
  - Result: $\sigma = 1.1^{+0.8}_{-0.5} \times 10^{-39} cm^2$.
  - Compatible with Standard Model prediction.
  - Consistent with PandaX-4T results.

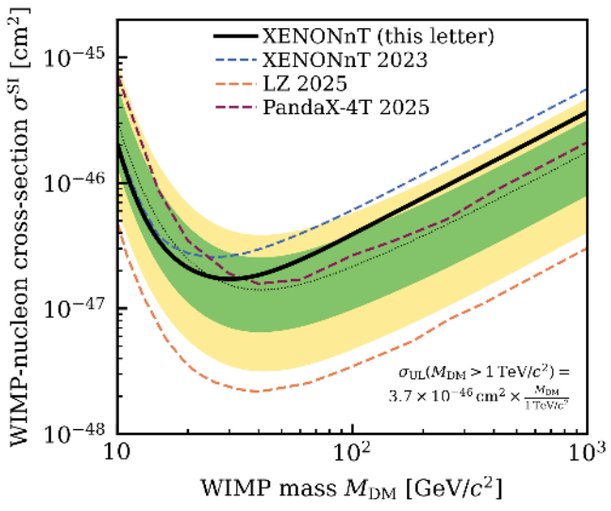




Summary and outlook

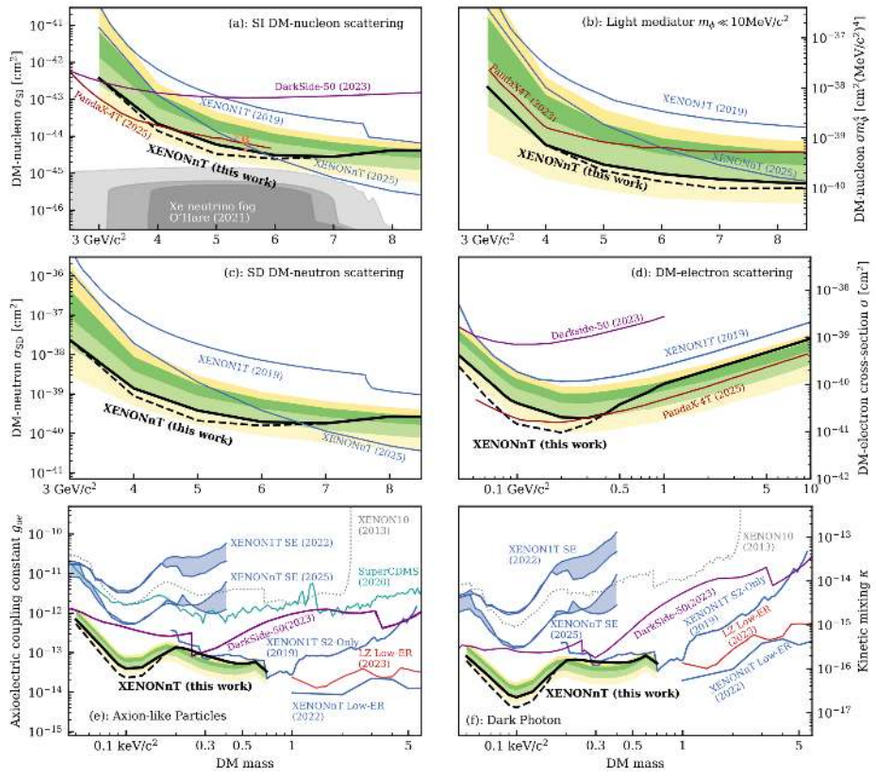
WIMP

- **New limits on WIMP-nucleon cross section:**
  $\sigma = 1.7 \times 10^{-47}$ cm^2
  at $m_\chi = 30$ GeV/c^2.
- Factor **1.8** improvement wrt SR0.



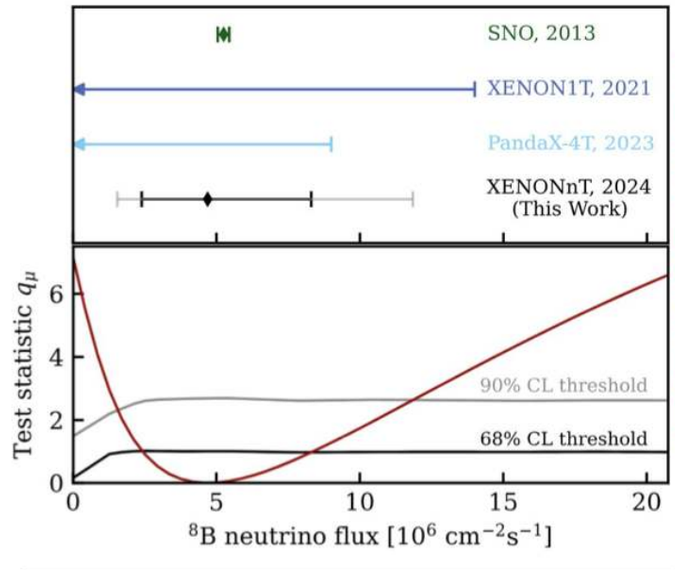
S2-only search

- **New limits on DM-nucleon, DM-e$^-$, ALPs and Dark Photons**



^{8}B CEvNS

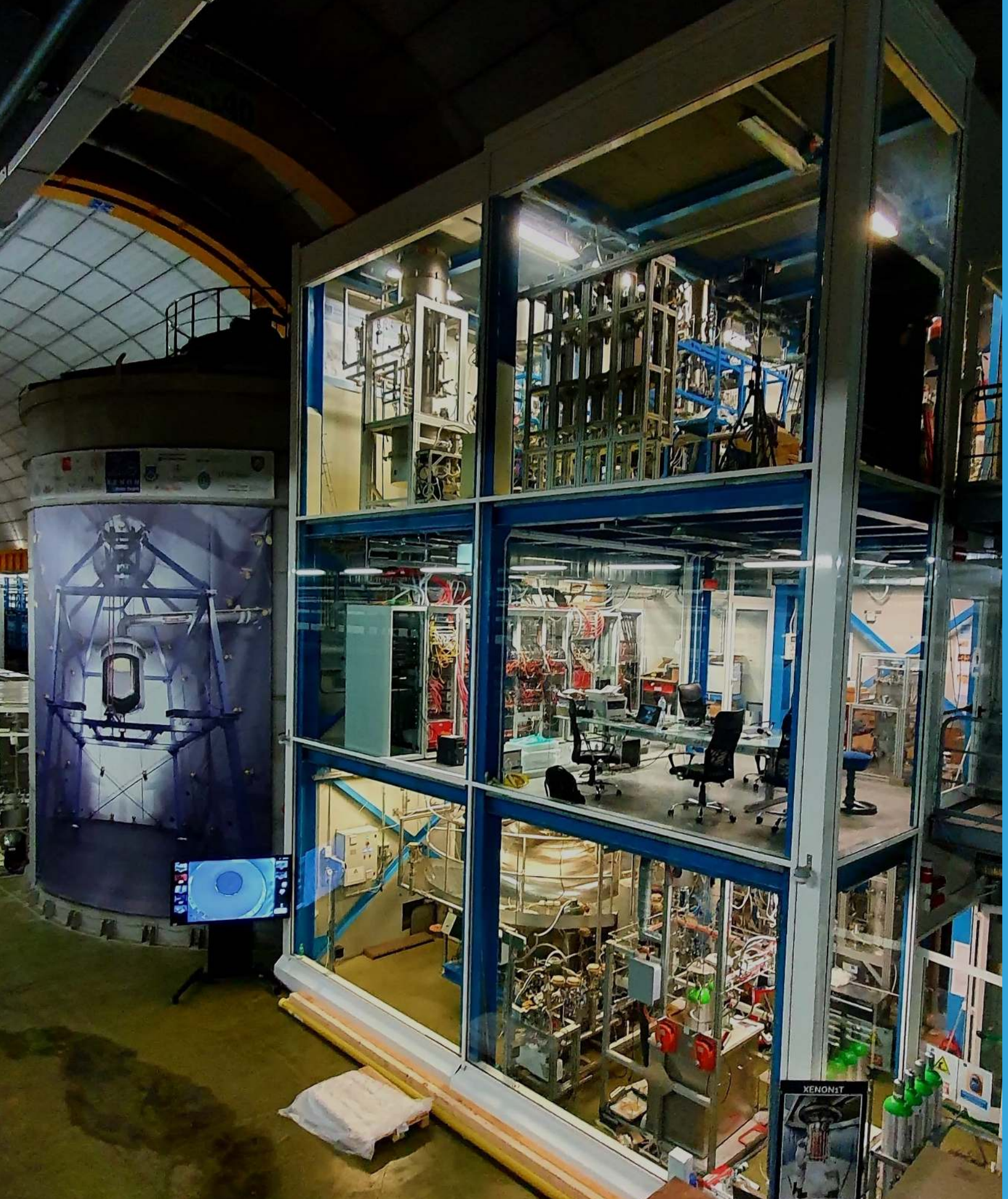
- **Observed ^{8}B CEvNS at $2.73\ \sigma$:** 1st observation in a xenon experiment and with astrophysical neutrinos.



Outlook

- **Ongoing searches:** Solar 8B CEvNS and WIMP searches with SR0+1+2, solar-pp neutrinos via e- scattering, Supernova neutrinos, $0\nu\beta\beta$ and much more.
- **Detector status:** upgrade operations are concluded, the detector is under commissioning.
- **XLZD:** Xenon-Lux Zeplin-Darwin collaboration established to build the next gen-LXe TPC with up to 60t target mass.

THANKS FOR YOUR ATTENTION!



BACKUP

The XENON collaboration

AMERICA

- UC San Diego — San Diego
- Houston
- The University of Chicago — Chicago
- Columbia University in the City of New York — New York City
- Purdue University — Lafayette

EUROPE

- Zurich
- KIT Karlsruhe Institute of Technology — Karlsruhe
- Universität Münster — Münster
- Uni Freiburg — Freiburg
- JGU — Mainz
- Max-Planck-Institut für Kernphysik Heidelberg — Heidelberg
- Universität Heidelberg Zukunft seit 1386 — Heidelberg
- Nikhef — Amsterdam
- Stockholm University — Stockholm
- 1290 Universidade de Coimbra — Coimbra
- Subatech — Nantes
- LPNHE Paris — Paris
- INFN Torino — Torino
- Università degli Studi di Bologna — Bologna
- Università degli Studi dell'Aquila — L'Aquila
- INFN LNGS — Assergi
- Università degli Studi di Napoli Federico II — Napoli

MIDDLE EAST

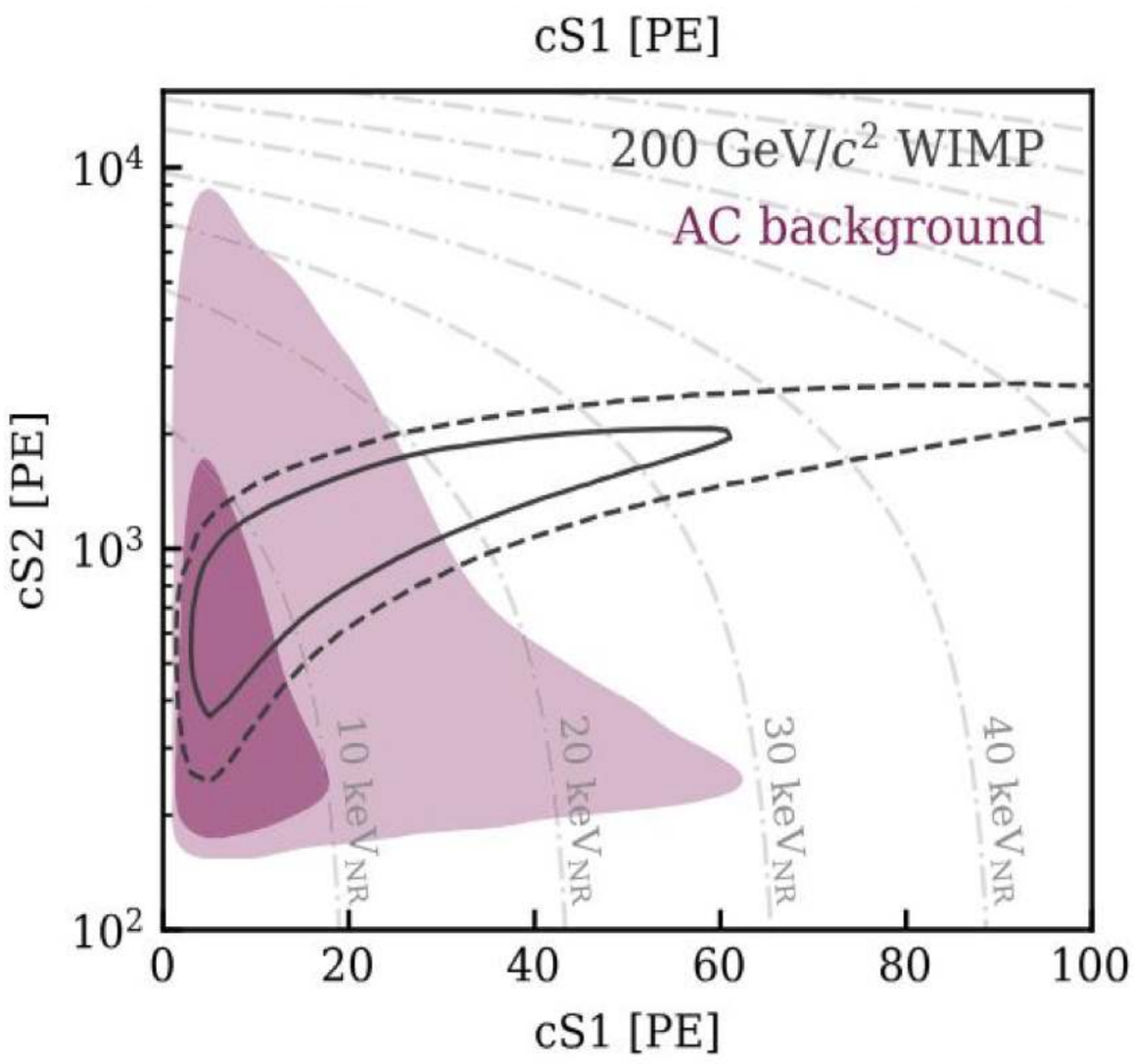
- Weizmann Institute of Science — Rehovot
- NYU Abu Dhabi — Abu Dhabi

ASIA

- 清華大學 Tsinghua University — Beijing
- 西湖大學 Westlake University — Hangzhou
- The Chinese University of Hong Kong, Shenzhen — Shenzhen
- 東京大学 The University of Tokyo — Tokyo
- Nagoya University — Nagoya
- Kobe University — Kobe

Accidental Coincidences (ACs)

- ACs are accidental pairings of Isolated S1 and isolated S2 signals. Major background near threshold.

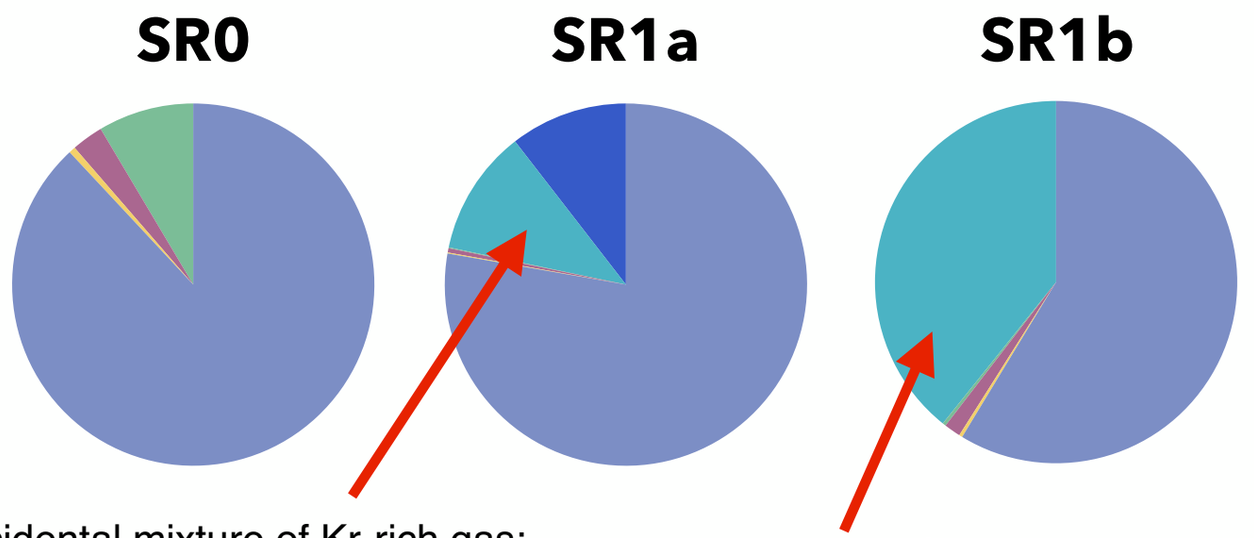


WIMP search: Background

Phys. Rev. Lett. 135 (2025), 221003

ER background

- **β-decays** from ^{222}**Rn** chain and ^{85}**Kr**
- ^{124}**Xe DEC,**
- **solar $\nu - e$ scattering.**
- ^{3}**H like**
- ^{37}**Ar**



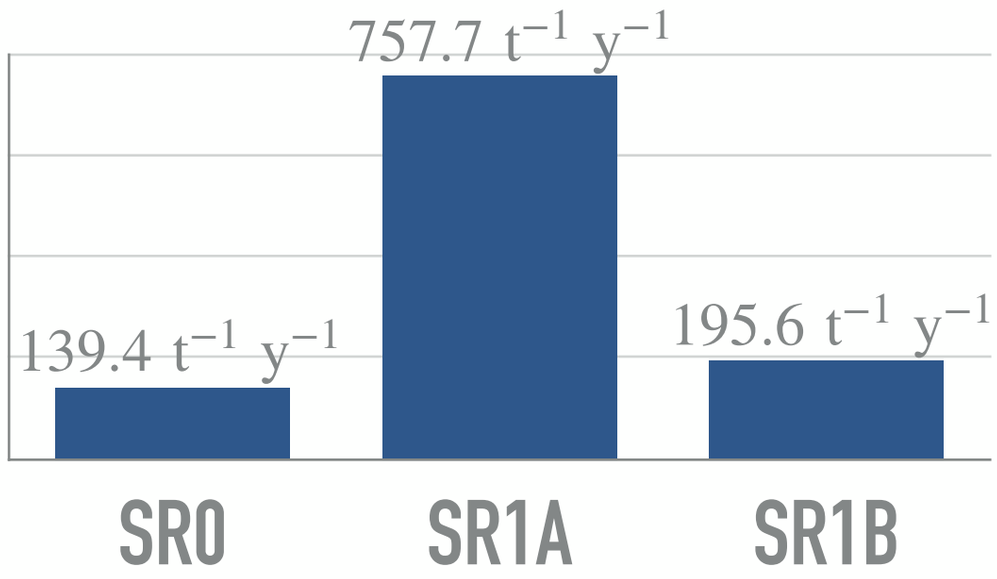
NR background

- **Radiogenic neutrons**
  Constrained by sideband of multi-scatter events and single-scatter events tagged by n-Veto.
- **CEvNS events in RoI**
  Constrained by neutrino flux and uncertainties in NR emission model.

Surface background

- **Pb decay chain**
  Plate-out effect from the PTFE walls.

Rate constrained by a data-driven method and validated with events outside FV.



Accidental coincidence

- **Accidental pairing of isolated S1-S2**

Modeled by a data-driven method.

Validation and uncertainty estimation through a dedicated sideband unblinding.

WIMP best fit

Phys. Rev. Lett. 135 (2025), 221003

- Expectation values of the nominal (pre-fit) and best-fit models for SR0 (1.09 tonne× year), SR1a (0.73 tonne× year), and SR1b (1.31 tonne × year), including an unconstrained WIMP signal with a mass of 200 GeV/c^2.
- Equal background colors indicate which components share a scaling parameter, coupling their rates across different science runs.

	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	

S2-only search: best fit

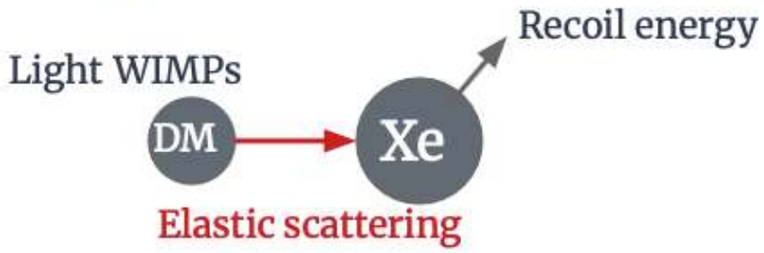
arXiv:2601.11296 [hep-ex]

- Expected and best-fit event numbers of each background component and a $6\ \mathrm{GeV/c^2}$ DM assuming the DM–nucleon SI interactions in three science runs for the science ROI are listed.
- Good agreement between the background predictions and observed events.
- Only systematic uncertainties are included in the quoted expectations.

Science run (exposure)	SR0 (1.50 t · y)		SR1 (2.44 t · y)		SR2 (3.89 t · y)	
Component	Expectation	Best fit	Expectation	Best fit	Expectation	Best fit
Cathode	480 ± 70	477^{+25}_{-24}	660 ± 70	726^{+28}_{-27}	1210 ± 90	1080 ± 30
Delayed electron	1.3 ± 0.5	1.3 ± 0.5	0.34 ± 0.07	0.34 ± 0.07	17.2 ± 2.3	17.1 ± 2.3
Accidental electron	97 ± 17	89 ± 13	108 ± 8	106 ± 8	–	
^{8}B CEνNS	21 ± 5	18^{+5}_{-4}	29 ± 7	26^{+7}_{-6}	32.3 ± 8	29^{+8}_{-6}
Total background	600 ± 80	586 ± 28	800 ± 80	858^{+30}_{-29}	1260 ± 100	1130 ± 30
Observed	583		864		1107	

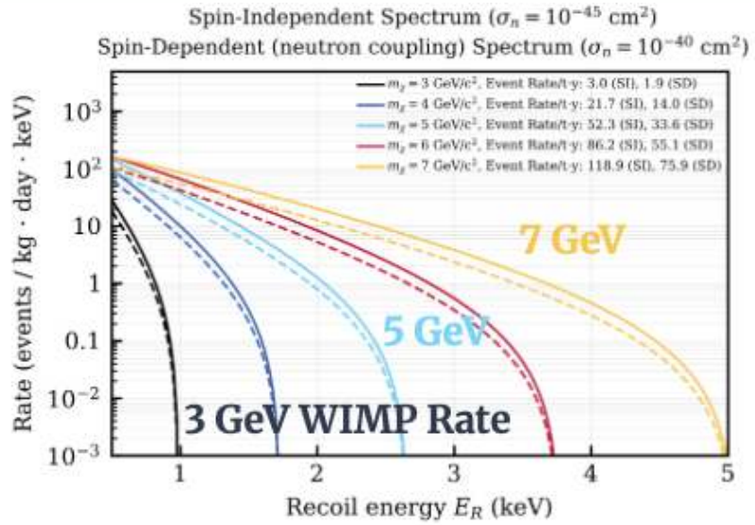
S2-only search: signal model

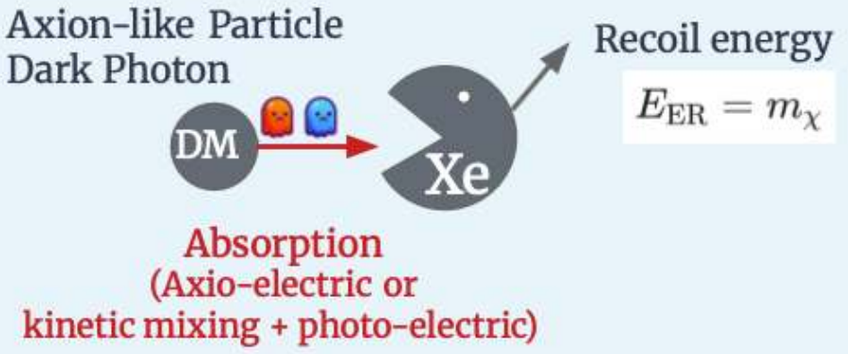
arXiv:2601.11296 [hep-ex]



$$\frac{dR}{dE_R} = \frac{\rho_0}{m_\chi m_{\mathrm{Xe}}} \int_{v_{min}}^{v_{esc}} f(v) v \frac{d\sigma_{\chi-\mathrm{Xe}}}{dE_R}(v)\, dv$$

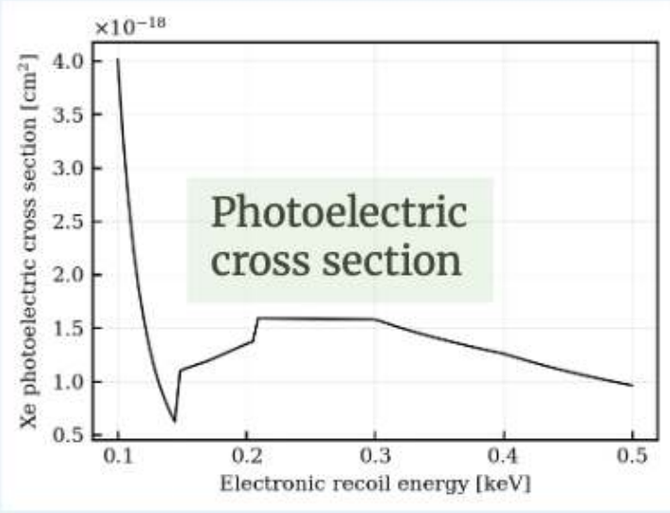
DM & Xe Properties | DM Velocity | Model Dependent Cross section

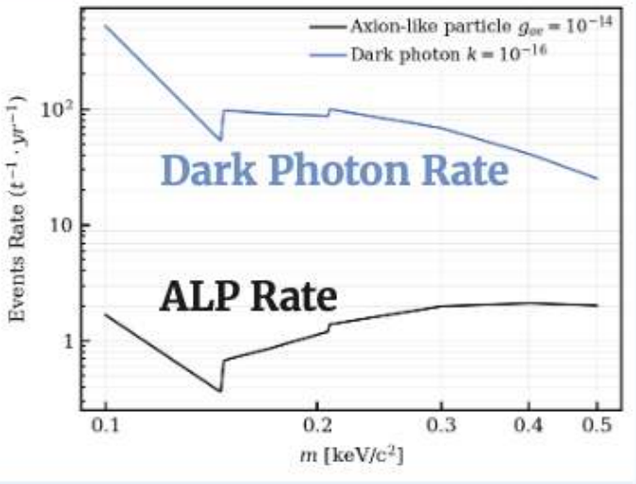




$$R_{\mathrm{DP}} \propto \epsilon^2 \cdot \frac{\sigma_{\mathrm{PE}}}{m_{\mathrm{DP}}}$$

$$R_{\mathrm{ALP}} \propto g_{ae}^2 \cdot m_{\mathrm{ALP}} \cdot \sigma_{\mathrm{PE}}$$





Images credits: Yongyu Pan

S2-only search: signal model

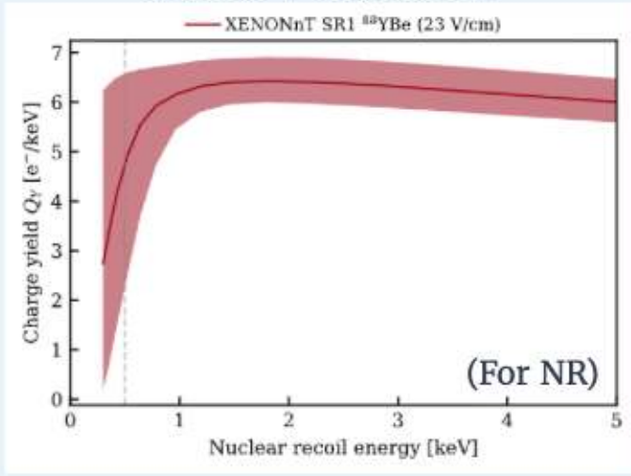
arXiv:2601.11296 [hep-ex]

Recoil Energy Spectrum → • Charge Yield • Detection & Data Selection Efficiency → **Signal Prediction**

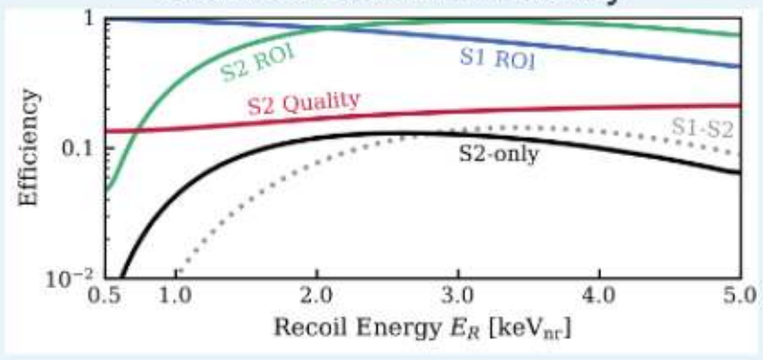
Light WIMPs

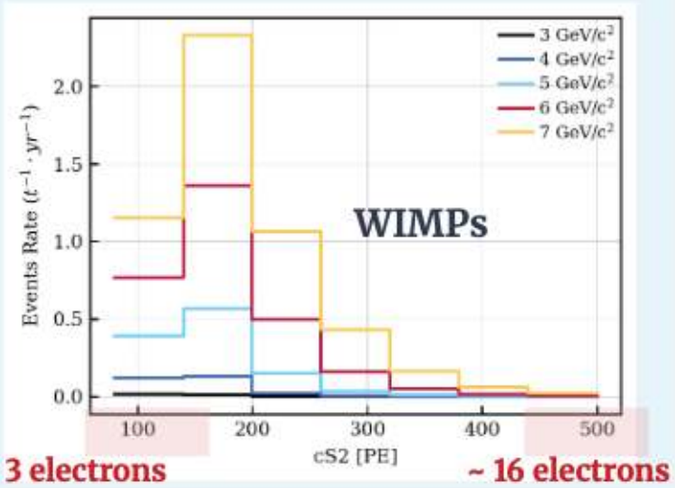
Axion-like Particle
Dark Photon

Charge Yield:
E_recoil ⇒ N_electrons

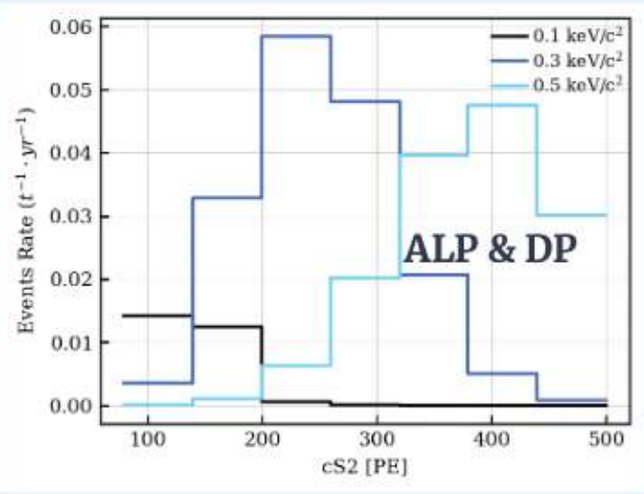


Data Selection Efficiency





~ 3 electrons ~ 16 electrons

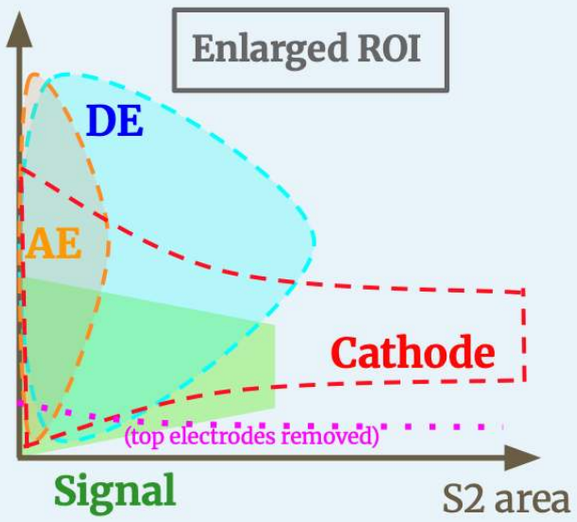


Images credits: Yongyu Pan

S2-only search: bkg modeling

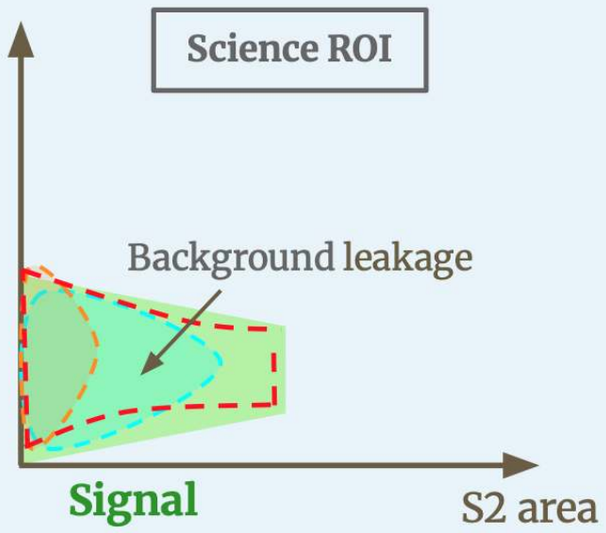
What we have now:

DE, AE, cathode background modeling in full space



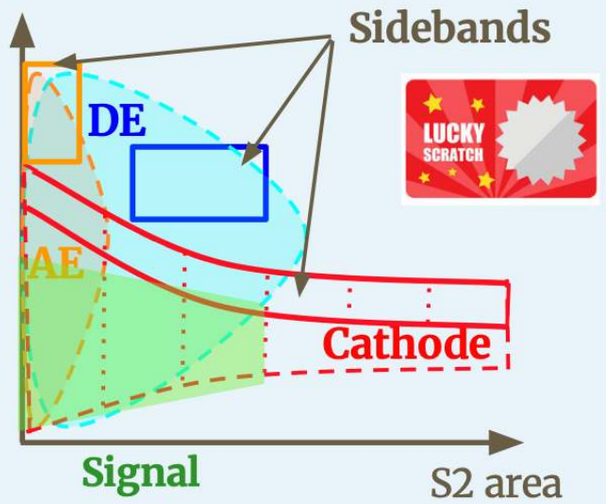
Objective:

Estimate the DE, AE, cathode background in **blinded** Signal ROI



Sideband technique:

Unblind the sideband region, correct and normarlize the background modeling in Signal ROI.



- Background validation is done on Rn220 calibration and Rn222 dataset in different SRs

Images credits: Yongyu Pan

S2-only search: bkg summary

	Top electrodes / Gas events	Cathode electrodes
Origins	Radioactivity from ^{222}Rn decay chain	
Key features	Small S2 width < 4 us due to small drift length ~few cm	Large S2 width spread [0, 20] us due to large drift length ~140 cm
Cut Development	S2 width cut	BDT machine using waveform features
Remaining events after cut	Negligible	Simulation- and data-driven modeling

	Delayed Electrons (DE)	Accidental Electrons (AE)
Origins	(DE: one-time emission, AE: pile-up of different emissions)	
Key features	Large S2 width due to peak merging	
	Position & Time correlated with the parent S2	Poor pile-up PMT pattern
Cut Development	BDT machine using the above correlation	S2 pattern cut
Remaining events after cut	Data-driven modeling	

Table credits: Yongyu Pan

Solar pp chain

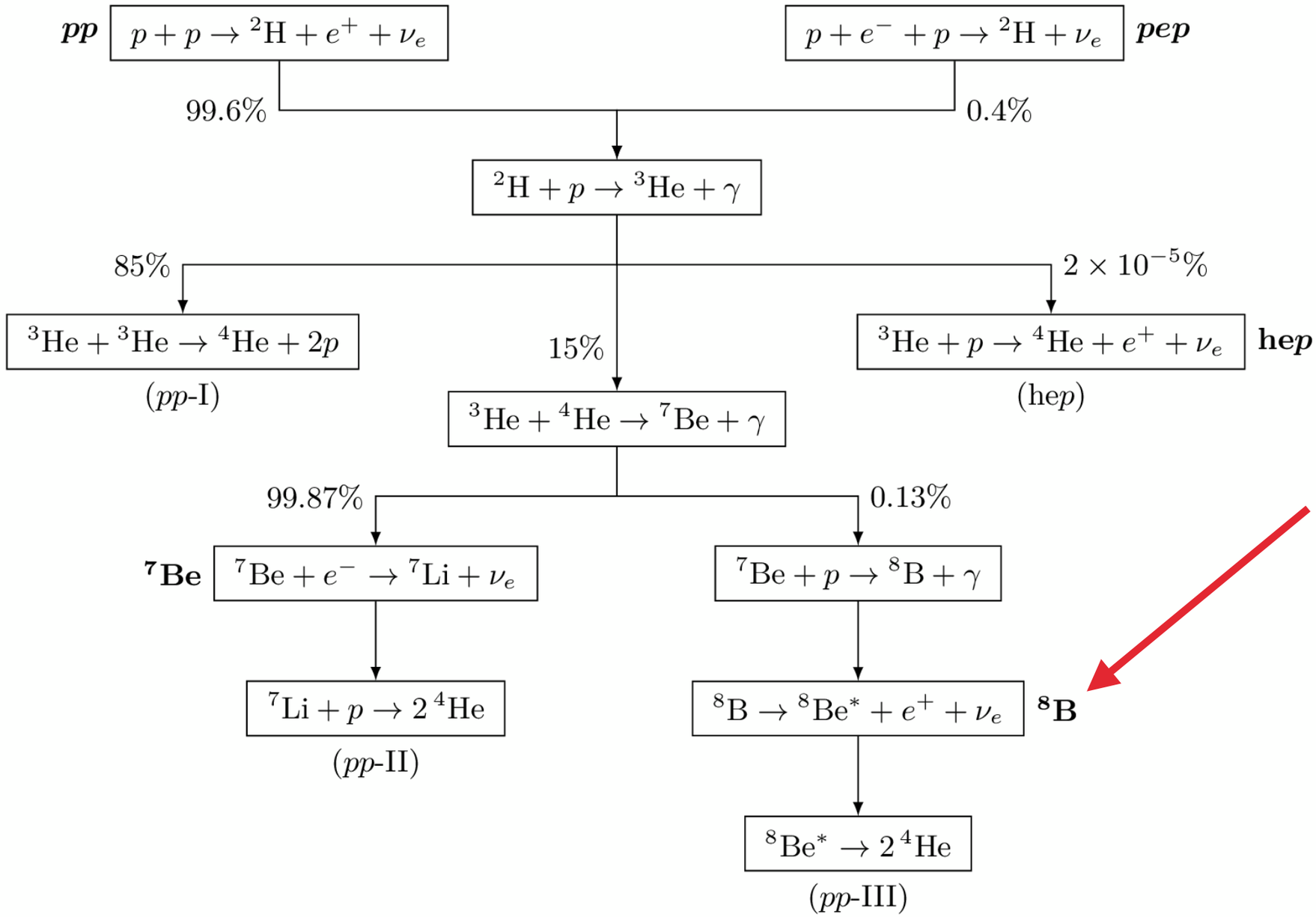
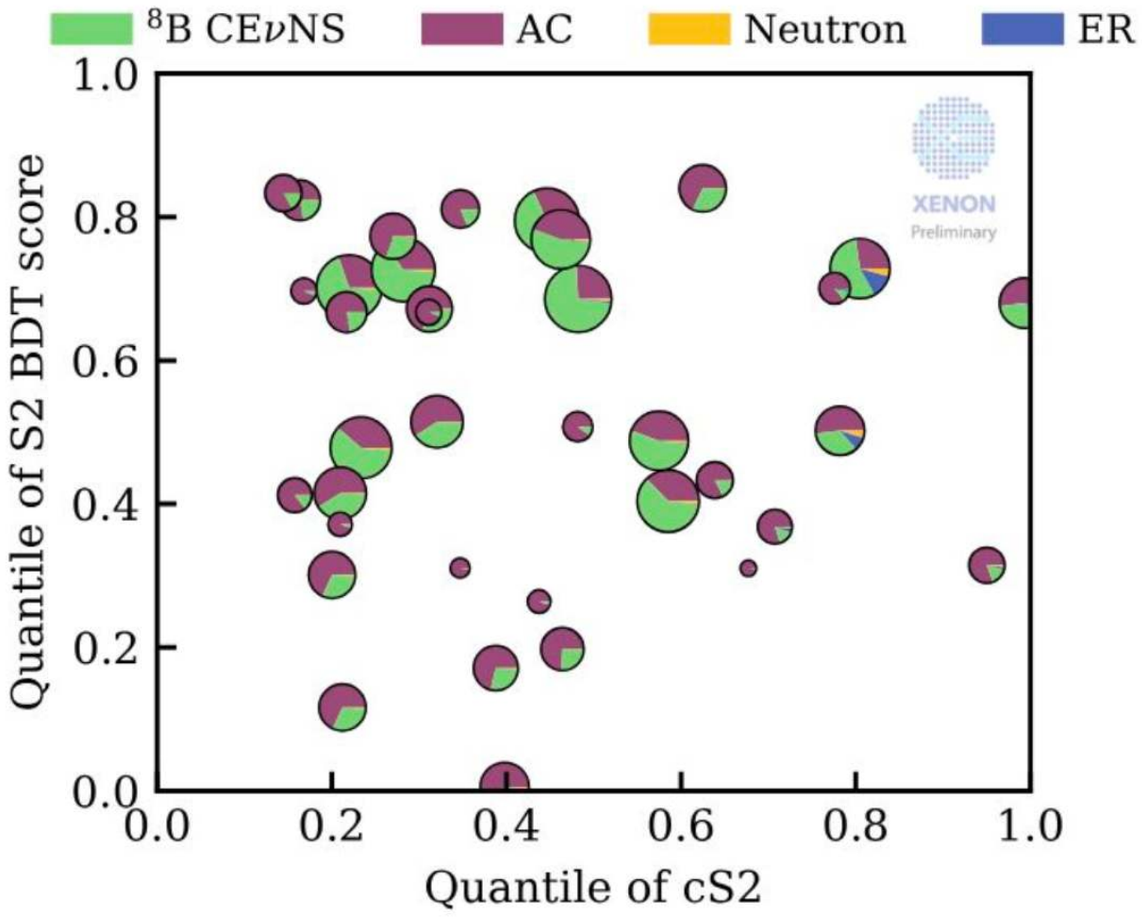


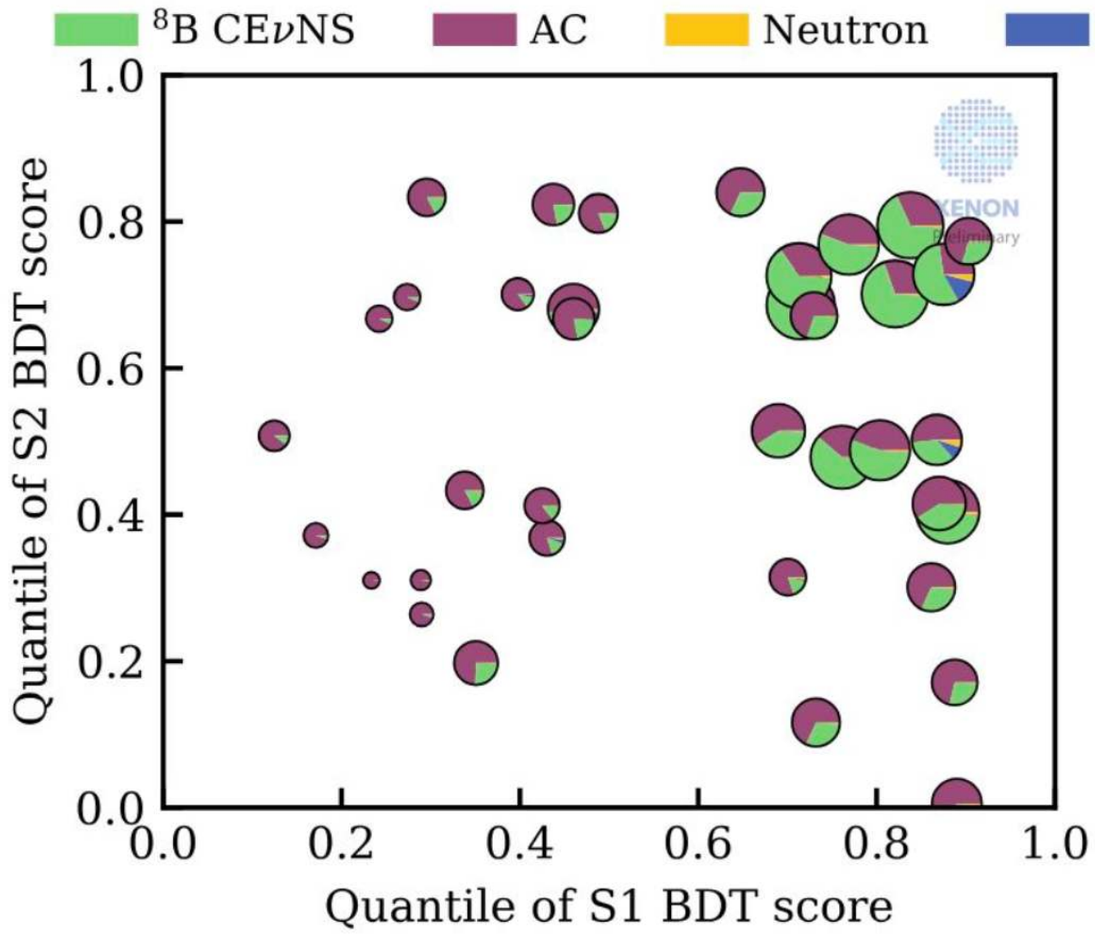
Table credits: Yongyu Pan

^{8}B CEvNS: results

Phys. Rev. Lett. 133 (2024), 191002

- Distribution of events in the analysis dimensions of CEvNS search. All data points are represented as pie charts indicating the fraction of the likelihood from the best-fit model evaluated at the data point. The scatter size is scaled according to the CEvNS likelihood fraction for visualization only.

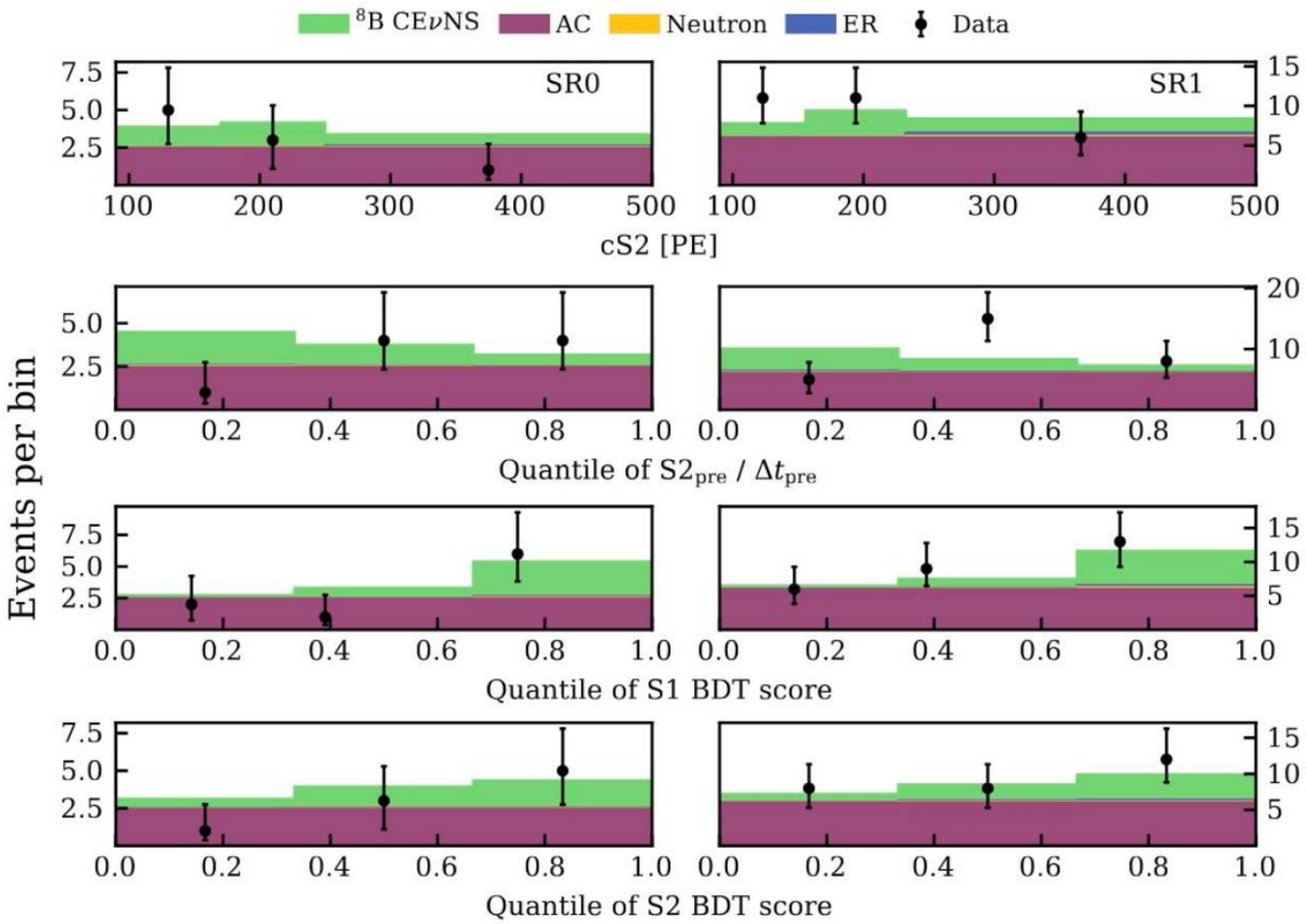




^{8}B CEvNS: results

Phys. Rev. Lett. 133 (2024), 191002

- Distributions of best-fit signal and background, together with the data in the projected analysis dimensions summing both science runs.



SR0 **SR1**

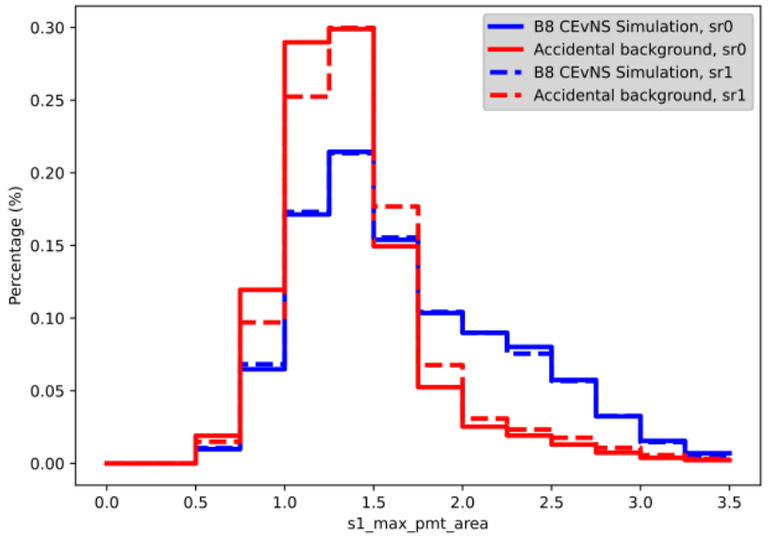
Component	Expectation	Best-fit
AC (SR0)	7.5 ± 0.7	7.4 ± 0.7
AC (SR1)	17.8 ± 1.0	17.9 ± 1.0
ER	0.7 ± 0.7	$0.5^{+0.7}_{-0.6}$
Neutron	$0.5^{+0.2}_{-0.3}$	0.5 ± 0.3
Total background	$26.4^{+1.4}_{-1.3}$	26.3 ± 1.4
^{8}B	$11.9^{+4.5}_{-4.2}$	$10.7^{+3.7}_{-4.2}$
Observed	37	

^{8}B CEvNS: S1 BDT Features

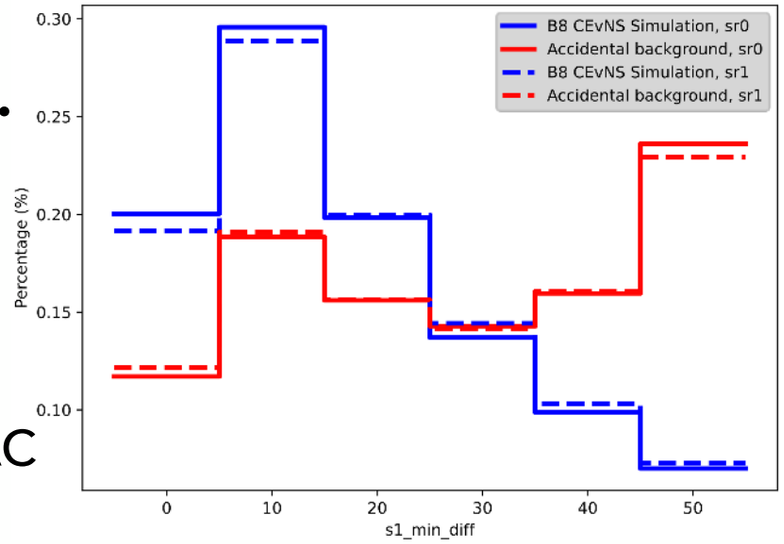
Phys. Rev. Lett. 133 (2024), 191002

In order of importance:

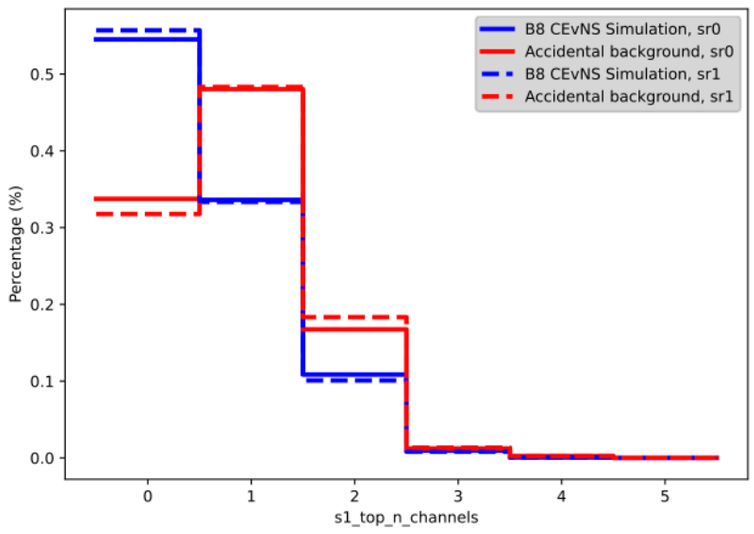
1) Max S1 hit area.
ACs are mostly lone hits: S1 > 2PE on one PMT is unlikely to be AC.



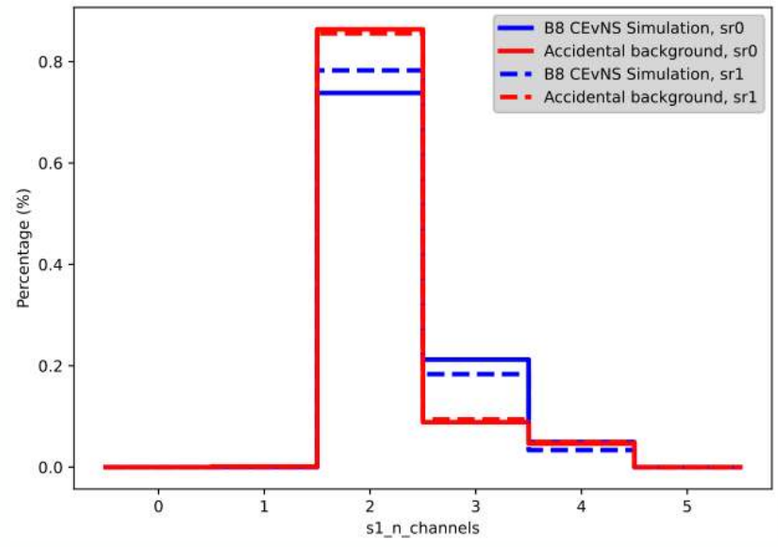
2) Min time between S1 hits.
Signal S1 pulse timing impacted by physical processes and DAQ response, AC is random



3) No. of hits in top PMT array.
Due to LXe-GXe interface, most signal S1s are collected at bottom array. ACs are random.



4) Total no. of hits. Reproduces the full recoil spectrum.



^{8}B CEvNS: S2 BDT Features

Phys. Rev. Lett. 133 (2024), 191002

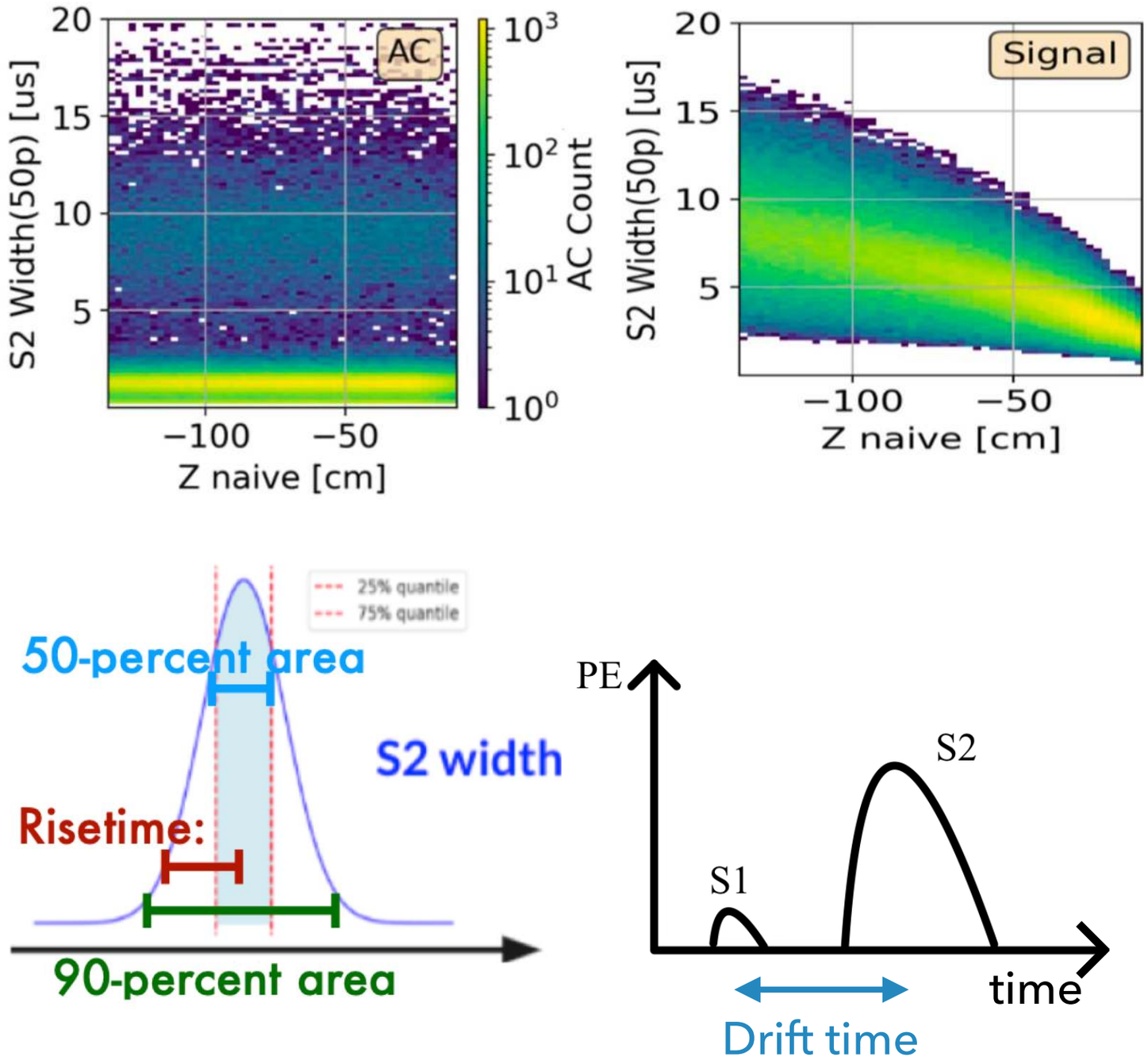
In order of importance:

1) S2 width at 50%
Width (ns) at 50% area (PE) around the maximum.

2) Rise time
Time between 10% and 50% area quantiles [ns].

3) S2 width at 90%
Width (ns) at 90% area (PE) around the maximum.

4) Drift time
Time between S1 and S2 peak.



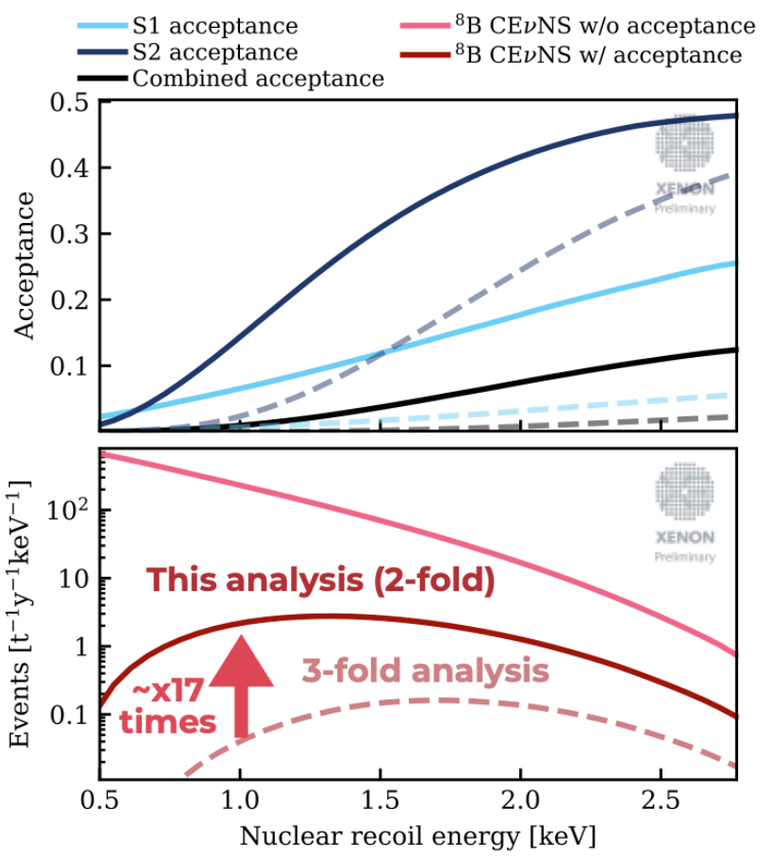
^{8}B CEvNS search: threshold and background

Phys. Rev. Lett. 133 (2024), 191002

Lowering the threshold

CEvNS are produced at **detection threshold** $\sim$ **keV$_{NR}$** , lower than the WIMP one.

- S1 with **2-fold** and **3-fold** coincidence → 17× higher ^{8}B CEvNS expected rate.
- S2 $\in (120, 500)$ PE → $(4,17)$ electrons.

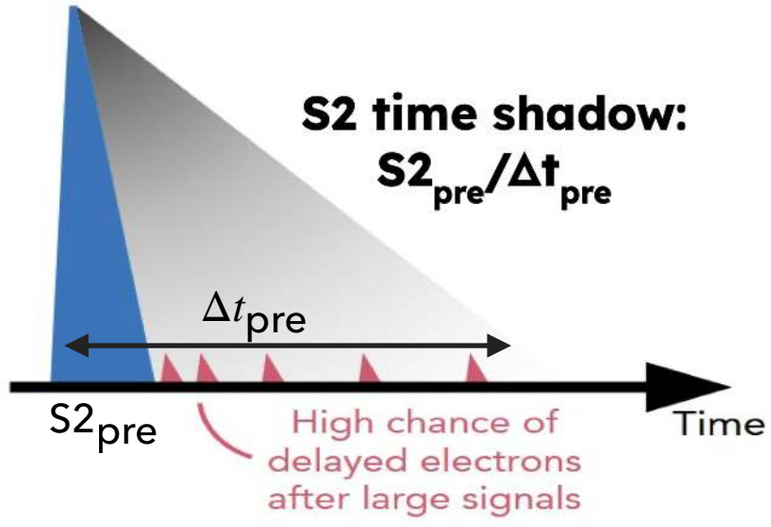


Background

- Dominated by **ACs:** $\sim$ **400 events/day.**

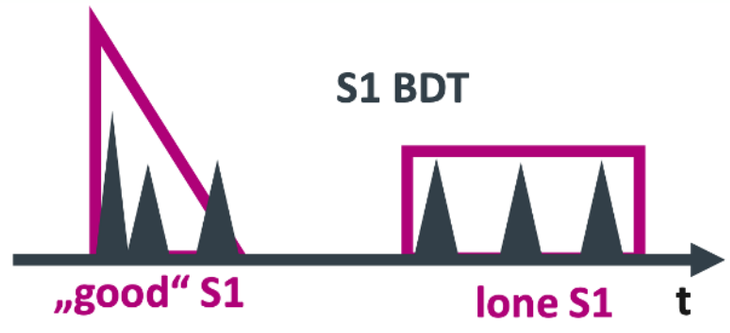
Mitigation

- Analysis cuts based on time and space information of peaks following a high energy peak ("shadow").
- **Expected AC Events after Mitigation:**
  SR0: 7.5 ± 0.7 | SR1: 17.8 ± 1.0.



Add extra analysis dimensions

- cS2.
- S2$_{pre}$/Δt_{pre}.
- Boosted data tree (BDT) score :
  - S1 BDT score from S1 hit distribution.
  - S2 BDT score from S2 signal shape and time correlation with S1.



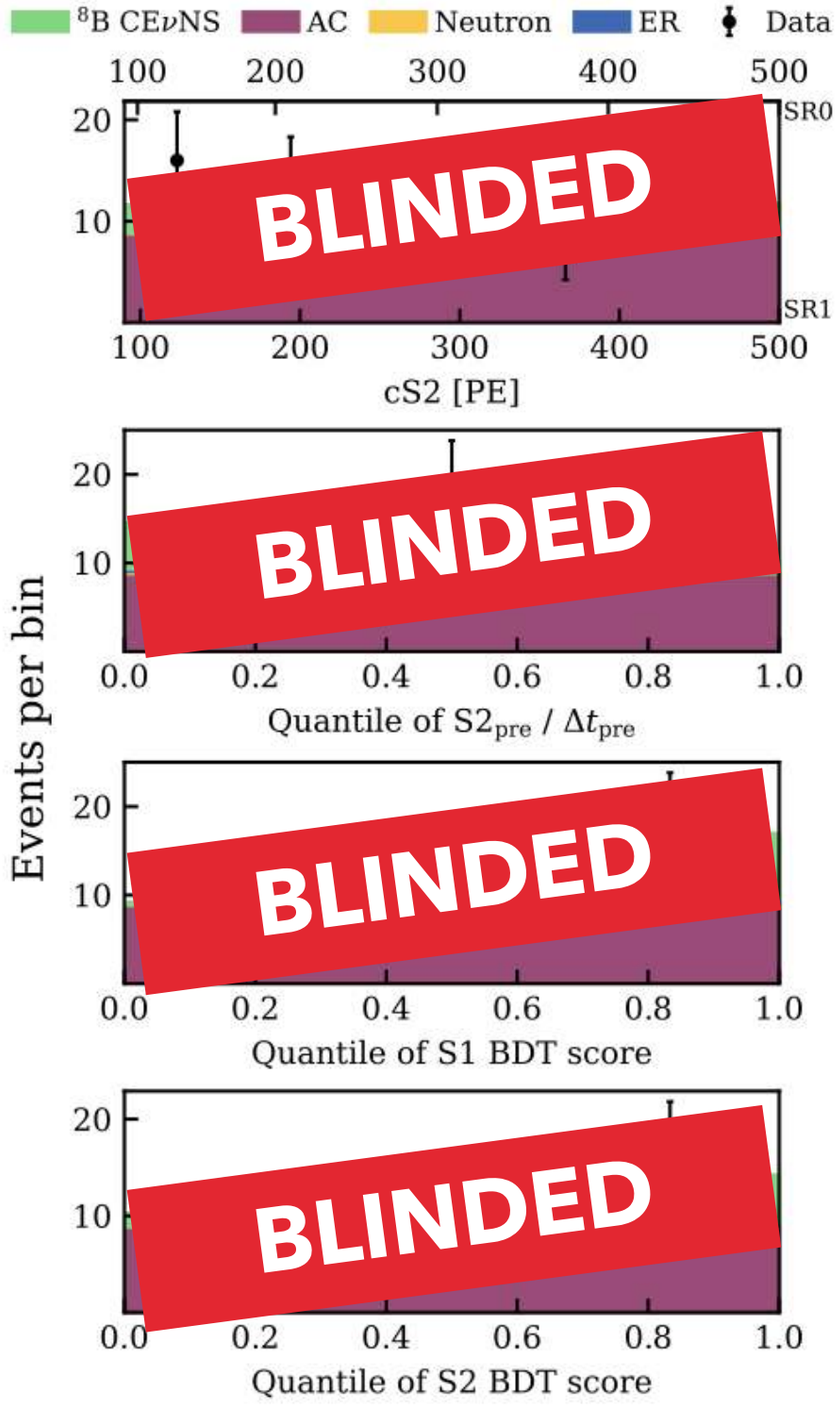
^{8}B CEvNS search: results

Phys. Rev. Lett. 133 (2024), 191002

- **Total SR0+1 exposure: 3.51 tonne year.**
- Inference with a 4-D binned likelihood in 3^4 bins.

OBSERVED EVENTS: ??

	Expected	Best fit
Background	26.4 ± 1.4	?
Signal	11.9 ± 4.5	?



^{8}B CEvNS search: results

Phys. Rev. Lett. 133 (2024), 191002

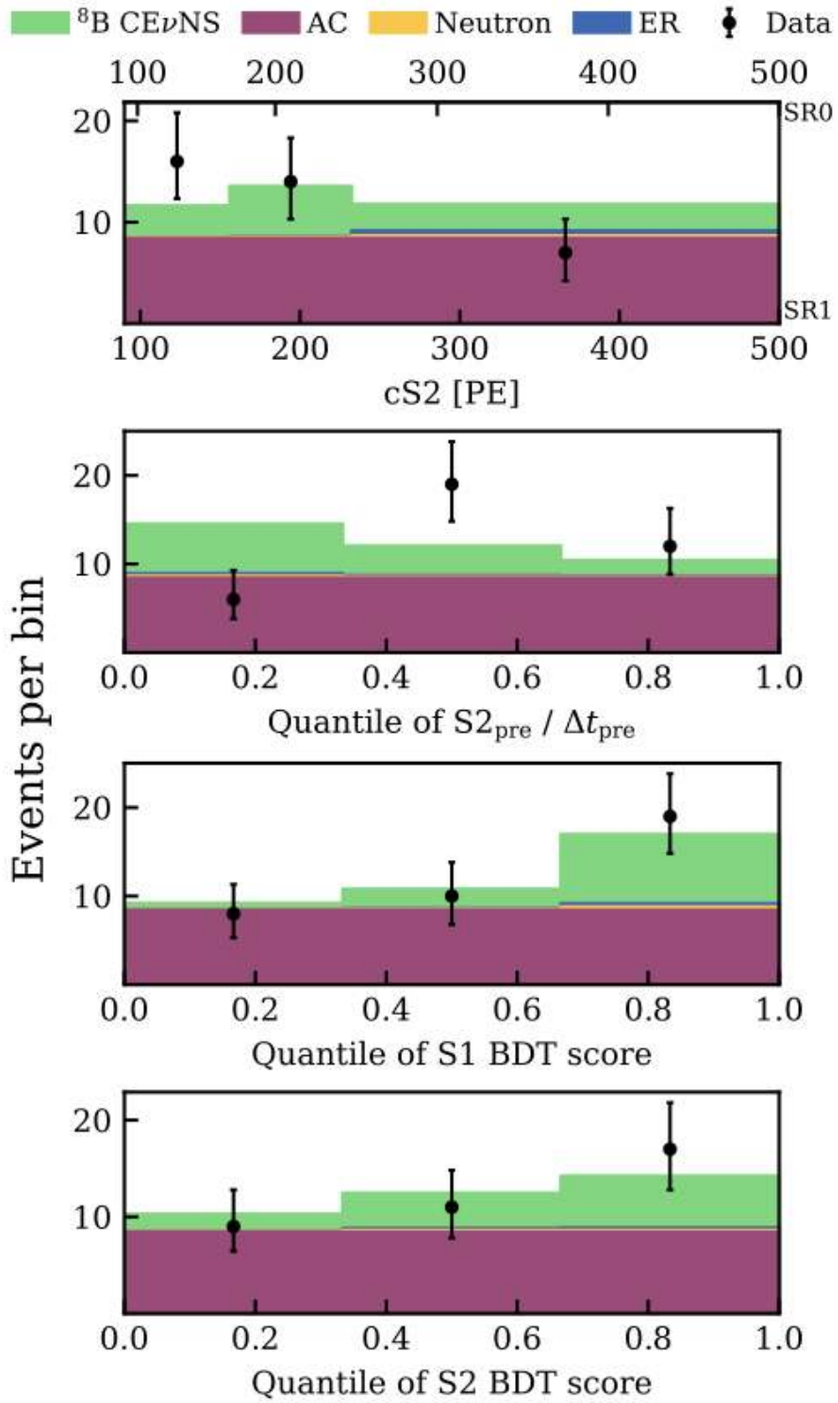
- **Total SR0+1 exposure: 3.51 tonne year.**
- Inference with a 4-D binned likelihood in 3^4 bins.

OBSERVED EVENTS: 37

	Expected	Best fit
Background	26.4 ± 1.4	26.3 ± 1.4
Signal	11.9 ± 4.5	$10.7^{+3.7}_{-4.2}$

SIGNIFICANCE OF 2.73σ

- **First measurement of CEvNS from astrophysical neutrinos and in xenon target**, obtained at same time with PandaX-4T ($\sim$ 1 t $\times$ y, 2.64σ).



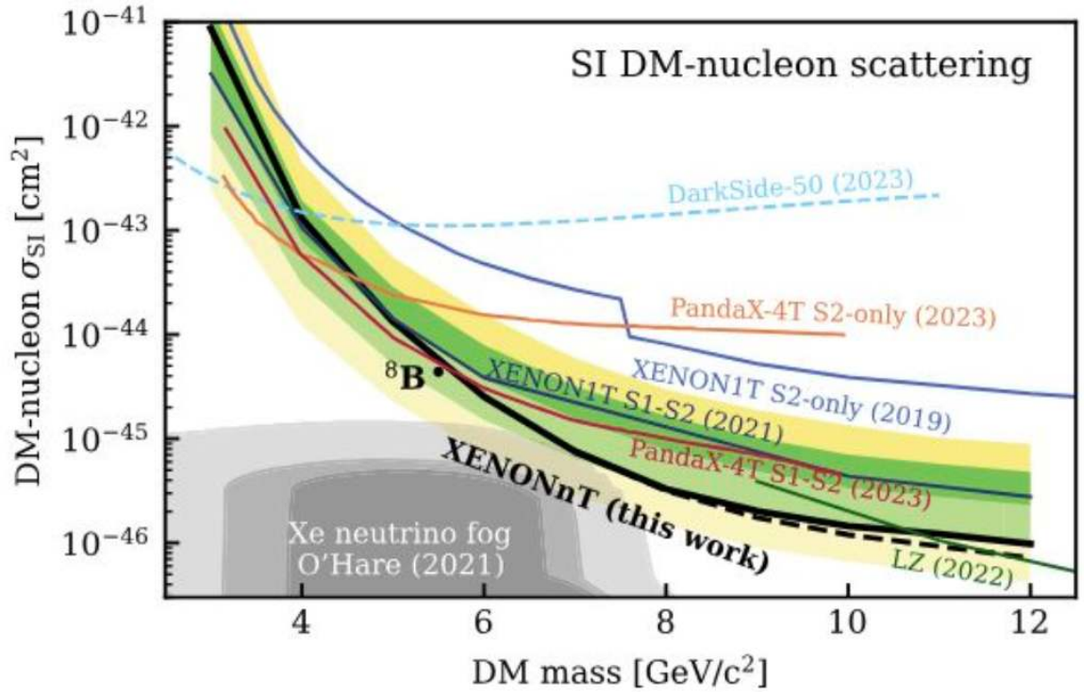
Light dark matter search

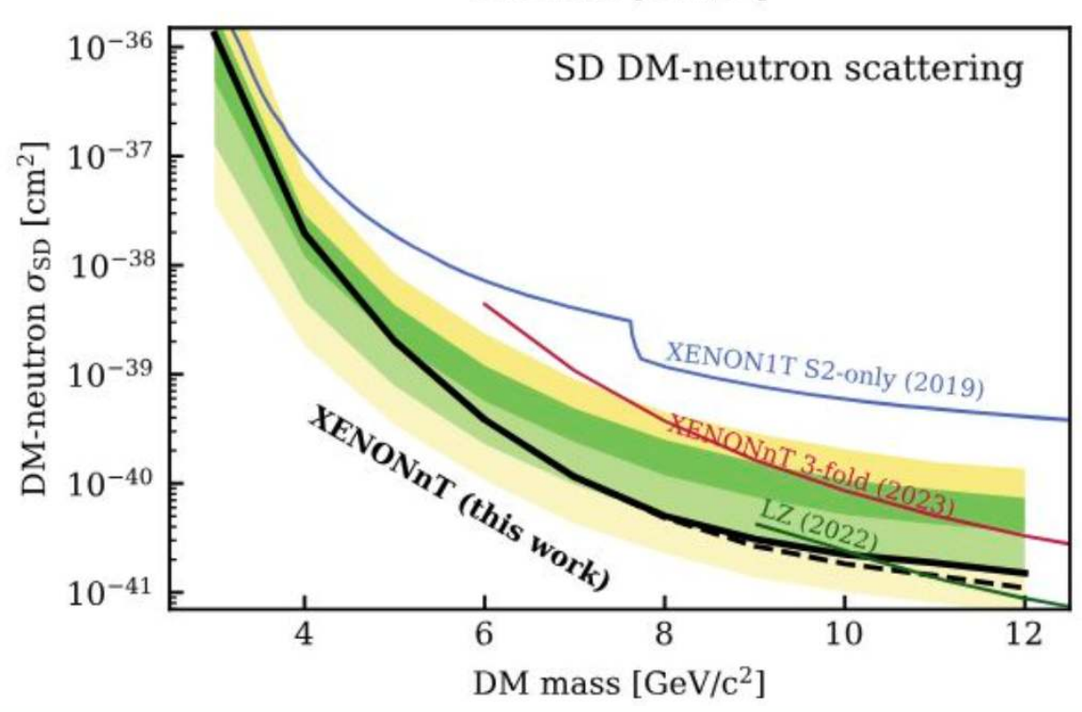
Phys.Rev.Lett. 134 (2025) 11, 111802

- First dark matter search in neutrino fog.
- Same dataset (SR0+SR1) and analysis framework used for CEvNS search (3.5 t × y).
- Now 8B CEvNS considered as a irreducible background component!

- **No excess over background observed-**

- New parameter space excluded for low-mass.
- WIMPs-nucleon cross section:
  $\sigma_{SI} > 2.5 \times 10^{-45}$ cm^2 @ 6 GeV/c^2.

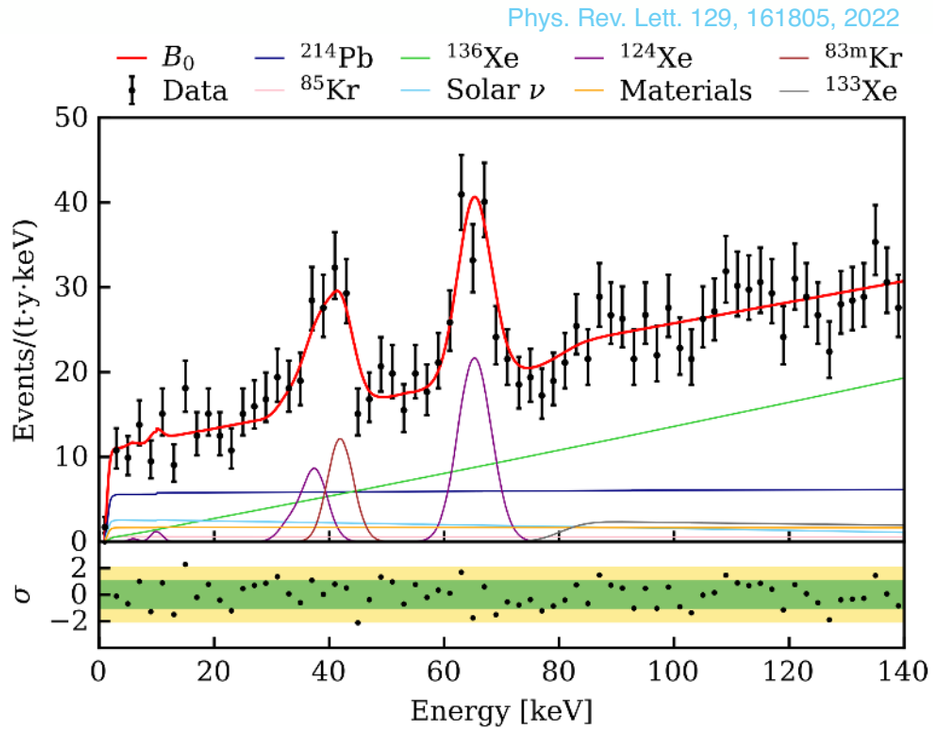


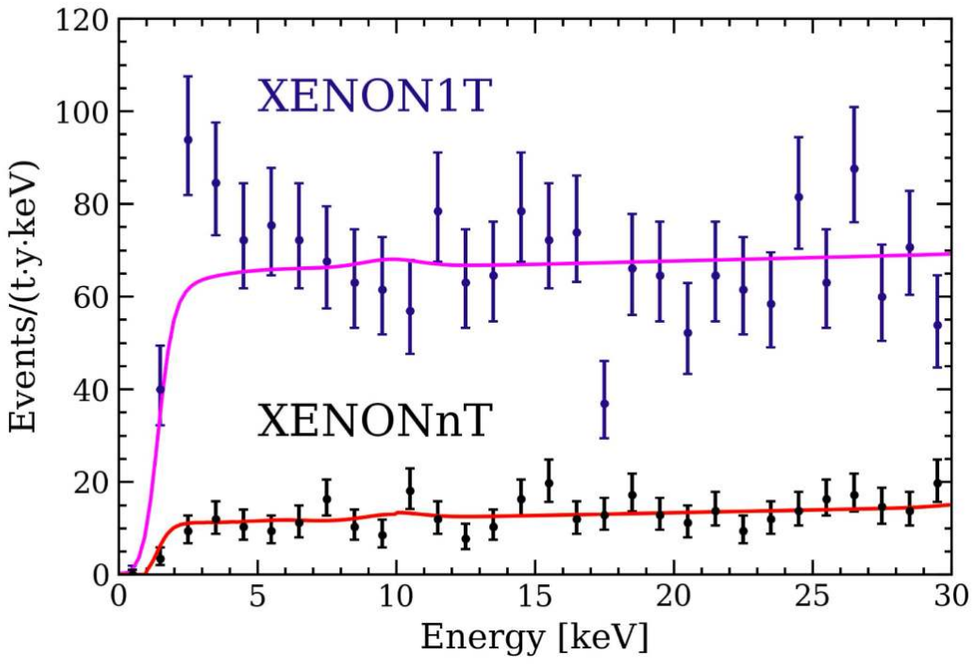


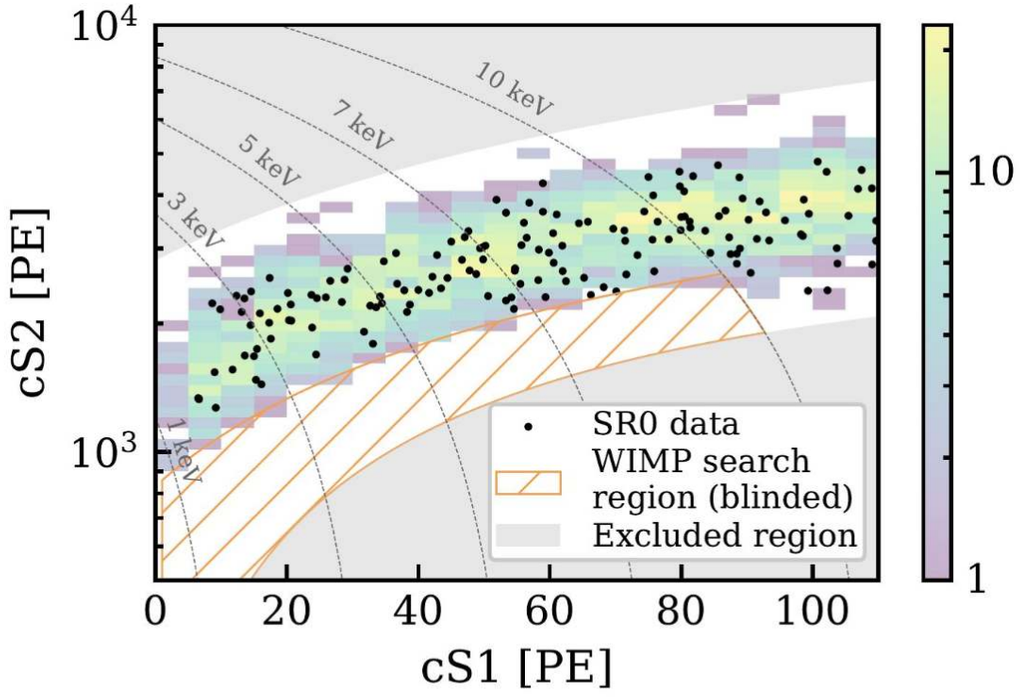
Low energy ER search in SR0

Phys. Rev. Lett. 129 (2022), 161805

- Background model including 9 components.
- Full blind analysis.
- ^{124}Xe 2νDEC (half-life $\sim 1.8 \times 10^{22}$ yr, rarest process observed, first time in XENON1T) now used for energy reconstruction.
- ^{214}Pb (from ^{222}Rn chain) dominant component below 30 keV with concentration of about 1.3 μBq/kg (1 atom in 10 mol Xe).
- Background ~5x smaller than in XENON1T.
- Lowest ER background ever for a DM experiment: (15.8 ± 1.3) events/(t · y · keV).
- An excess of the XENON1T magnitude is excluded at 8.6σ.
- XENON1T excess was probably due to ^{3}H tritium.





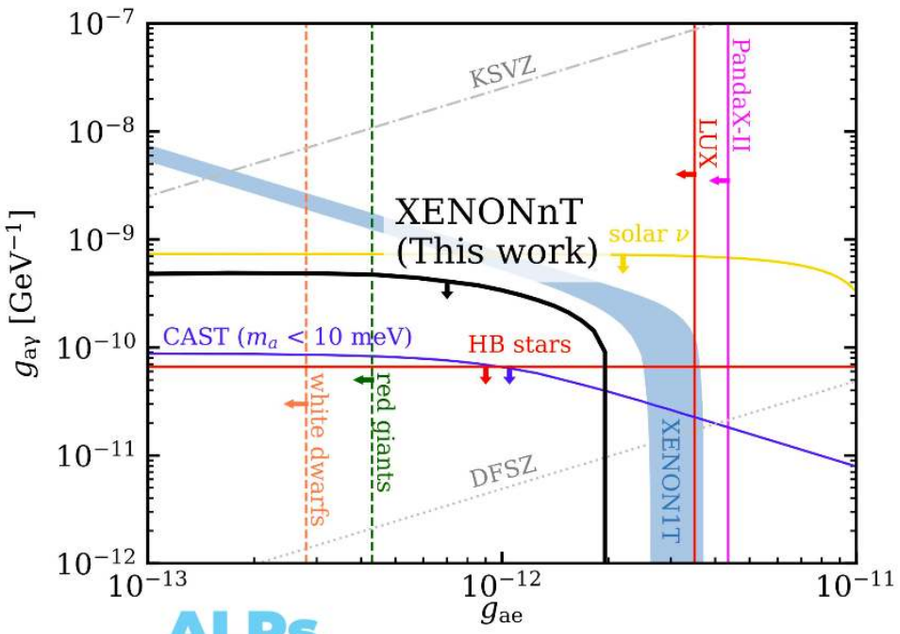


Low energy ER results in SR0

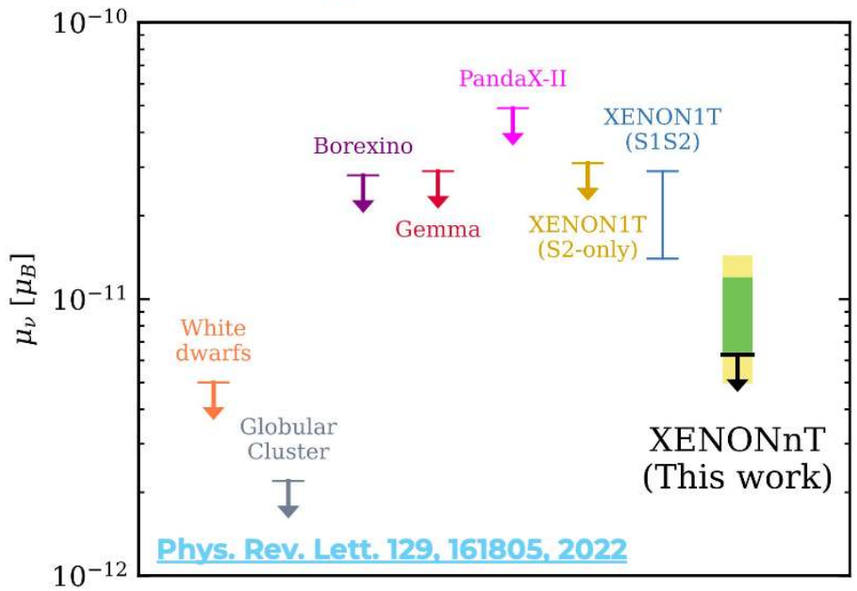
Phys. Rev. Lett. 129 (2022), 161805

- Leading limits among non-astronomical observation for physics beyond standard model.

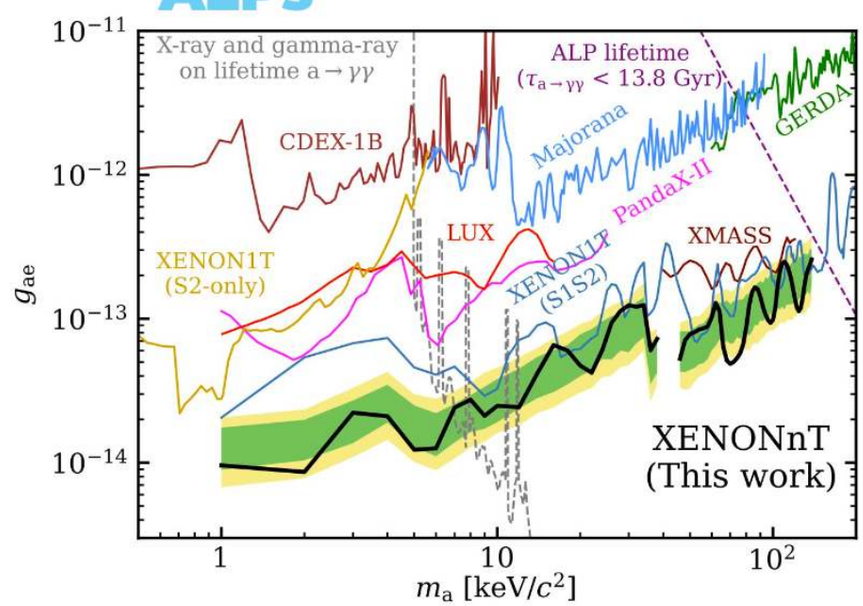
Solar axions



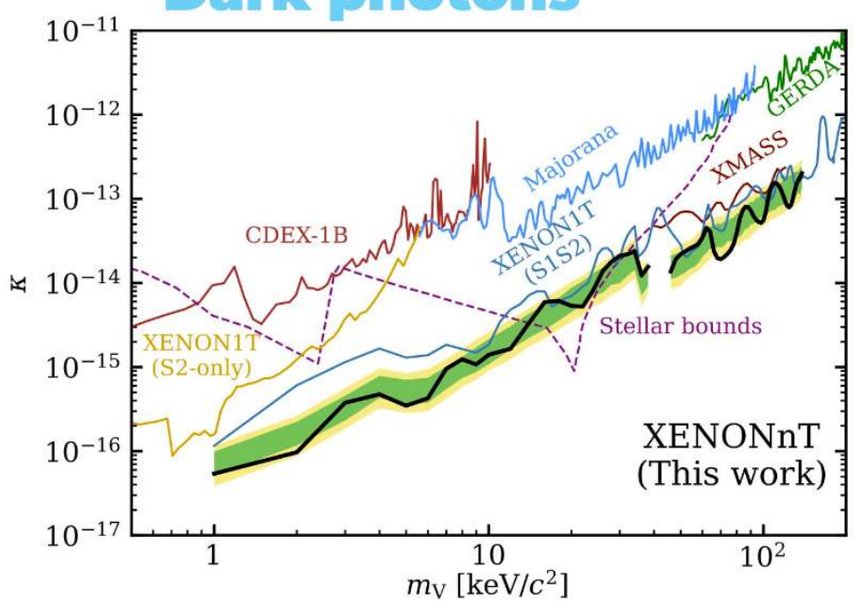
Neutrino magnetic moment



ALPs



Dark photons



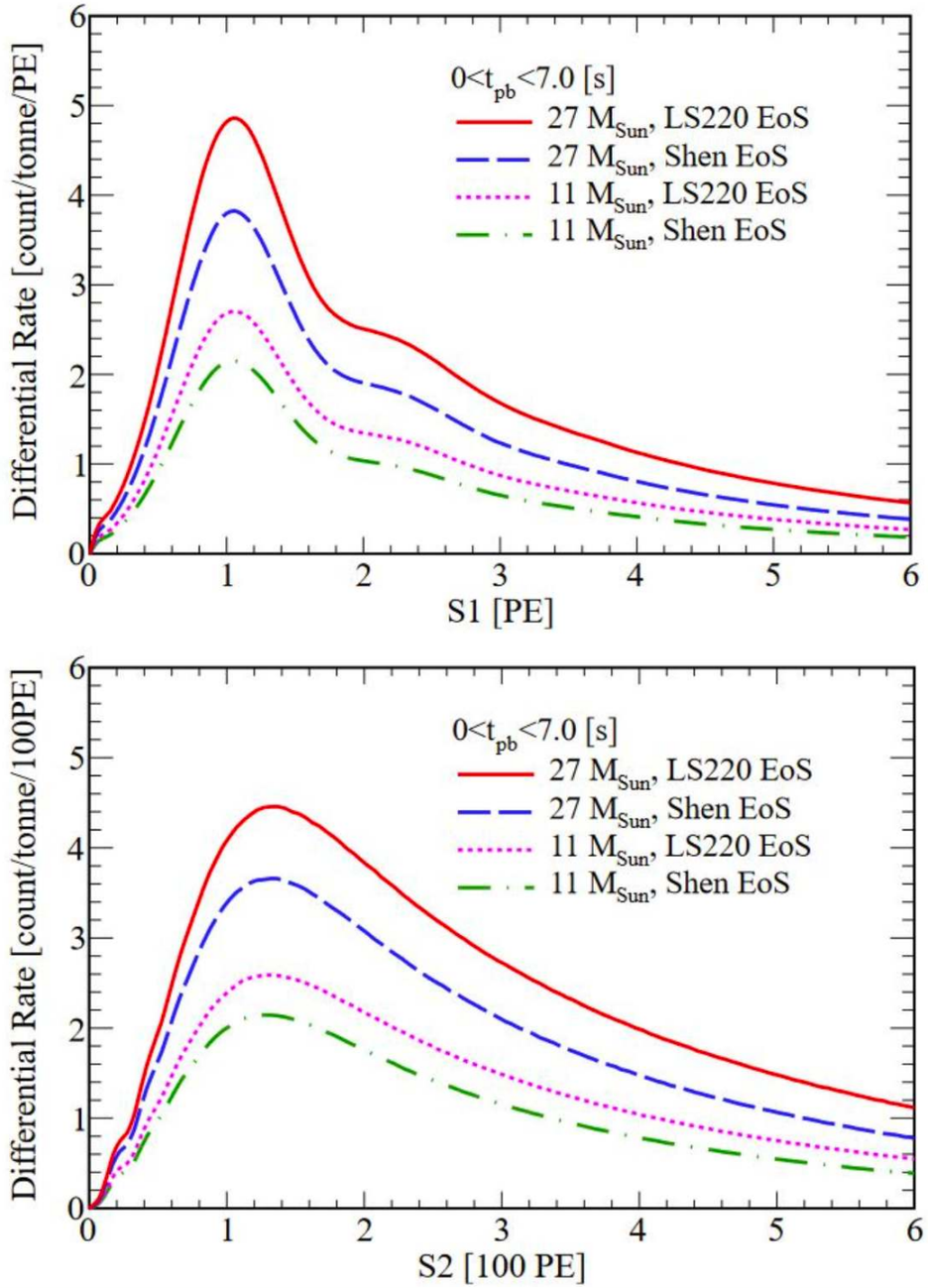
Phys. Rev. Lett. 129, 161805, 2022

XENONnT as supernova neutrino telescope

Supernova neutrino channels in XENONnT.

- **TPC**
  - 6 t of LXe.
  - $\nu_{e,\mu,\tau}$, $\bar{\nu}_{e,\mu,\tau}$via CEvNS (charged and other neutral current are subdominant).
  - Neutrinos deposit O(1) keV in LXe.
  - ~ 100 expected events from supernova at 10 kpc.
- **Muon & Neutron veto**
  - 700 t ultra-pure water.
  - $\bar{\nu}_e$ via inverse beta decay with H.
  - ~ 70 - 200 expected events from supernova at 10 kpc.

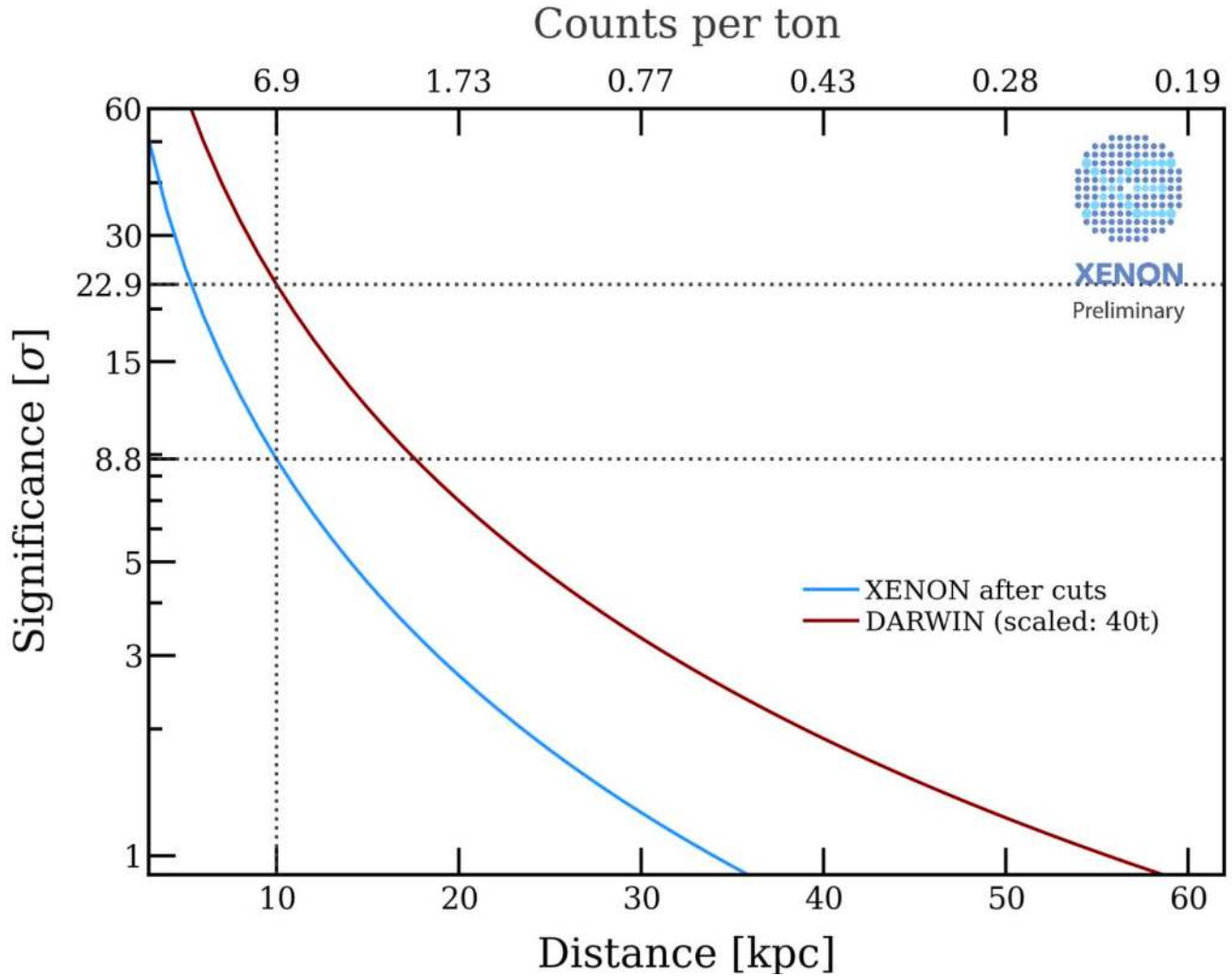
Neutrino rate in LXe

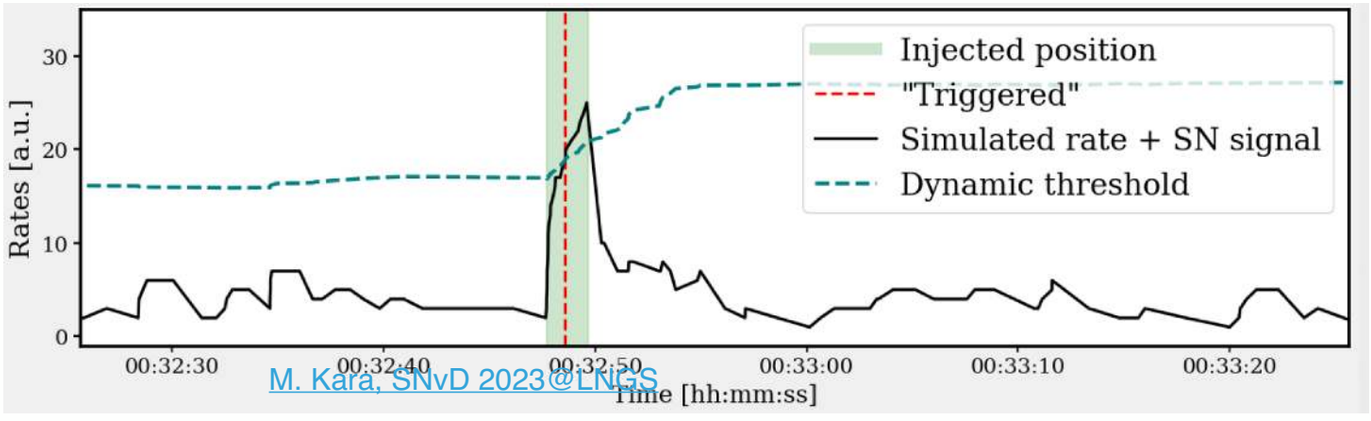


XENONnT as supernova neutrino telescope

Sensitivity projections

- Cuts can reduce background down to ~3 Hz, while average signal (SN at 10 kpc) will results in ~45 events in ~ 6 s (~ 18 background events).
- Triggerless DAQ allows continuous data taking and increases in rate with respect to a dynamic threshold can be monitored online.
- Considering signal evolution, time window can be optimized, resulting in ~8σ significance (10 kpc).





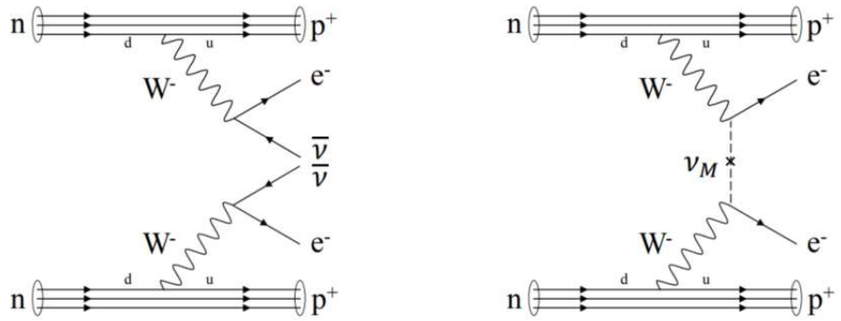
M. Kara, SNvD 2023@LNGS

Snews integration

- XENONnT is ready to join the Supernova Early Warning System (SNEWS).
- It will receive incoming alerts to check data and send possible supernova observations.

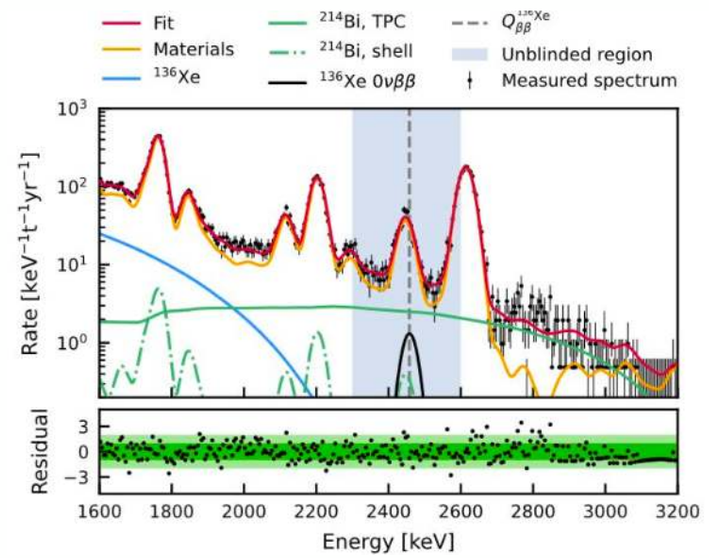
Neutrinoless $\beta\beta$ decay in ^{136}Xe

- 0νββ would demonstrate the violation of total lepton number and a nonzero Majorana component of neutrino mass.
- First observation of ^{124}Xe 2νDEC in XENON1T demonstrated sensitivity to extremely rare events.
- 2νββ decay ^{136}Xe → ^{136}Ba, with $Q^{\beta\beta}$ = (2457.83 ± 0.37) keV is a good candidate for 0νββ.
- 8.9% abundance in XENONnT.



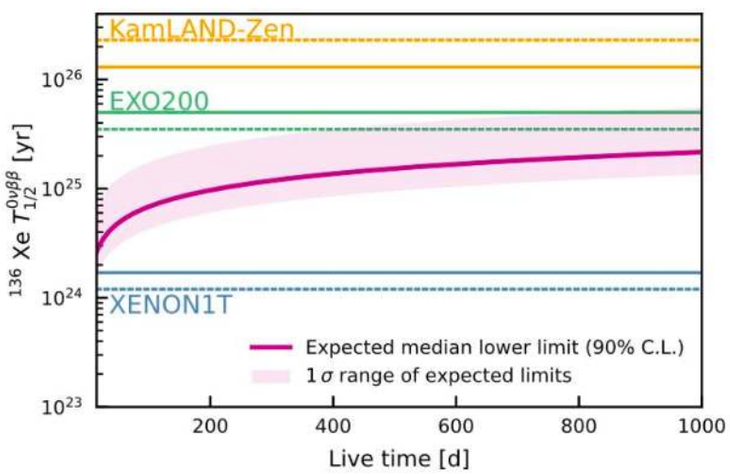
XENON1T results

- $T_{1/2}^{0\nu\beta\beta} > 1.2 \times 10^{24}$ yr with tonne-scale fiducial mass, resulting in isotope exposure of 36.16 kg × yr.
- Best results for a non enriched target detector.



XENONnT sensitivity projection

- With 275 kg × yr exposure, expected upper limit of $T_{1/2}^{0\nu\beta\beta} > 2.1 \times 10^{25}$ yr.
- Future xenon DM detector with optimized high-energy backgrounds and larger exposure can perform also 0νββ searches.



SR2: Gd-water in neutron veto

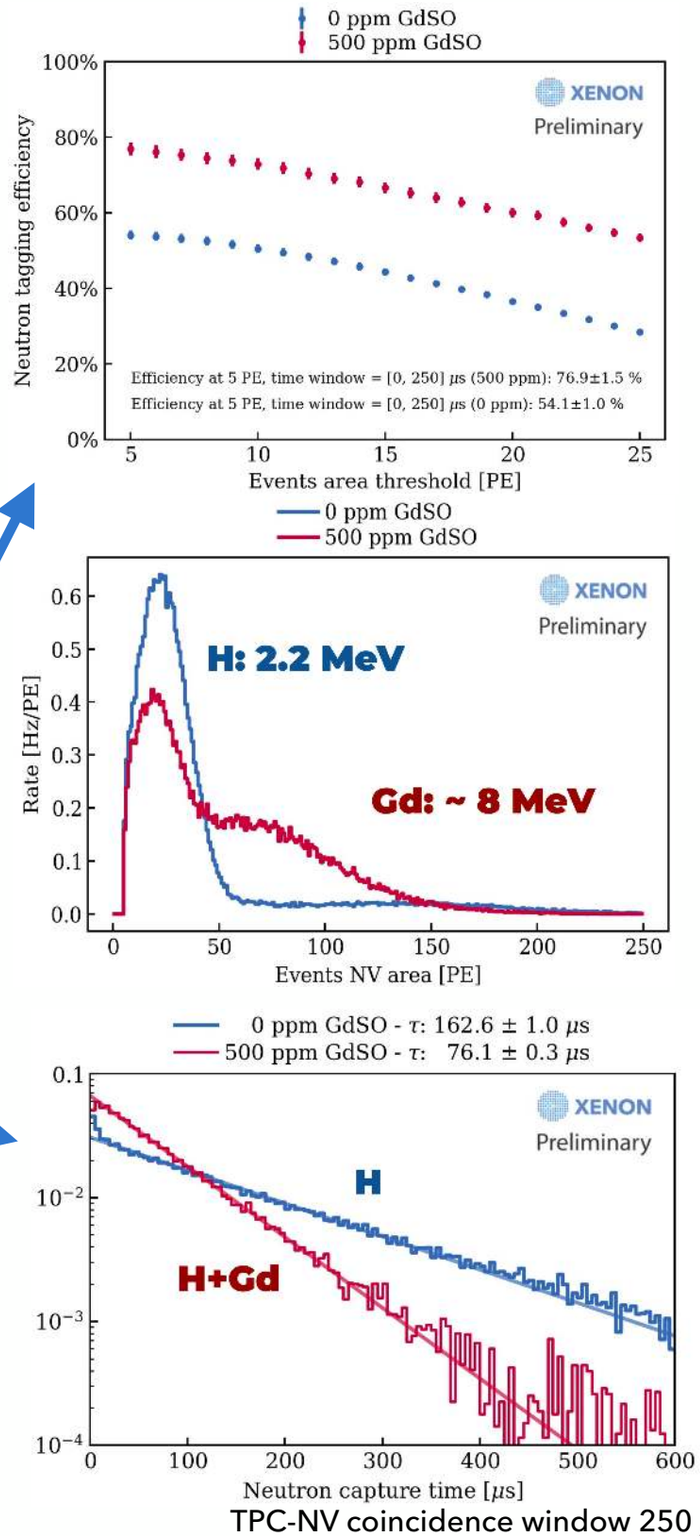
SR0+SR1: Pure water

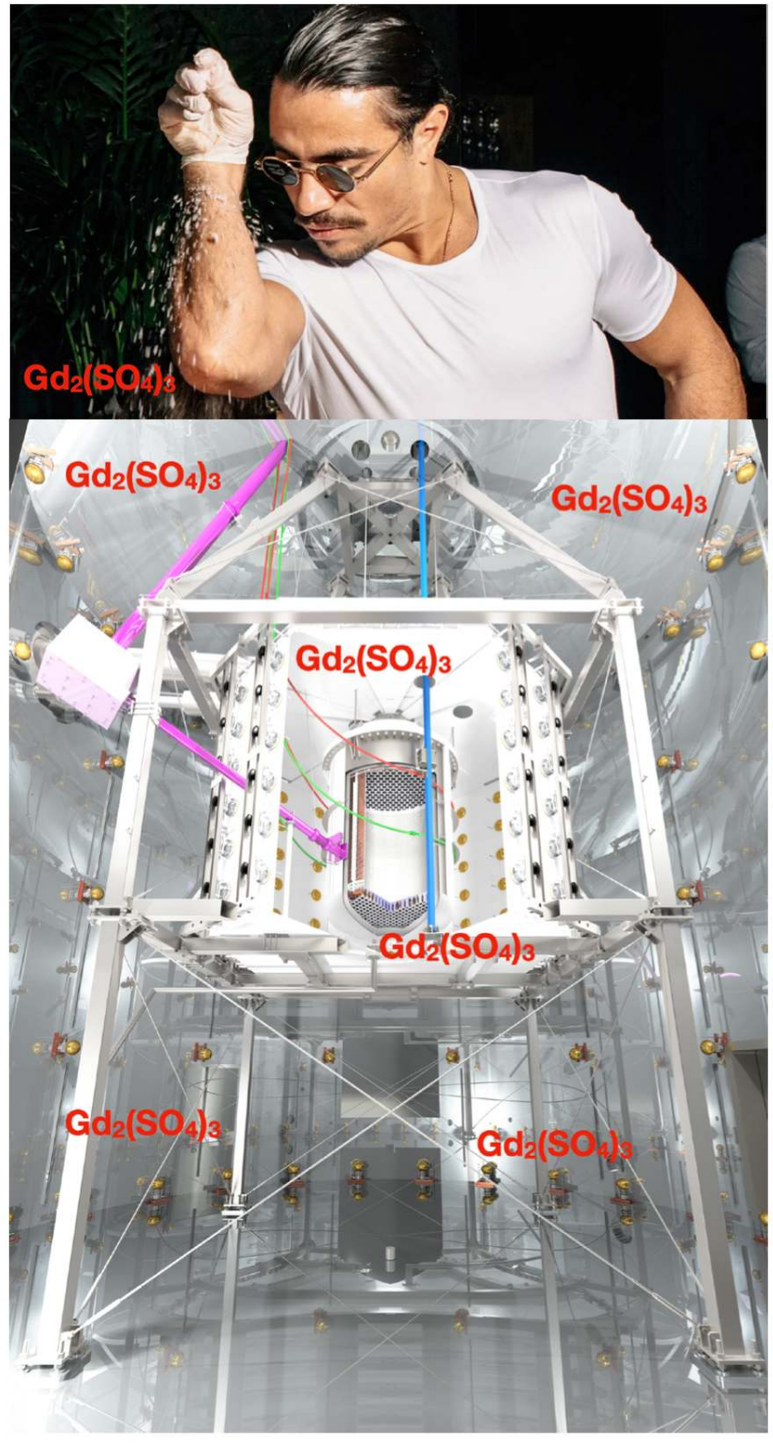
- NV tagging efficiency: **53 ± 1 %.**
- H capture: **2.2 MeV, 1 γ.**
- Capture time H-only: **160 μs.**

Gd-sulphate loading: 350 kg in 700 tons of water (500 ppm), Gd mass concentration at 0.02%.

SR2: Gd-loaded water (0.02%.)

- NV tagging efficiency: **77 ± 1 %.**
- Gd capture: **8 MeV, 3-4 γ.**
- Capture time H+Gd: 75 μs.
- **A factor 2 neutron background reduction wrt SR0 with demi-water.**
- Planned 10x higher Gd mass: expected tagging efficiency of 87%.





TPC-NV coincidence window 250 μs