SEARCH FOR DARK MATTER WITH

THE XENONnT EXPERIMENT

Lanqing Yuan (UChicago), on behalf of XENON collaboration

Feb 19 2024, Lake Louise Winter Institute 2024

XENON COLLABORATION: ~170 SCIENTISTS, 29 INSTITUTIONS, 12 COUNTRIES

xenonexperiment.org

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
- WWU Münster — Münster
- Uni Freiburg — Freiburg
- JGU — Mainz
- Max-Planck-Institut für Kernphysik — Heidelberg
- Nikhef — Amsterdam
- Stockholm University — Stockholm
- Coimbra
- Subatech — Nantes
- LPNHE Paris — Paris
- INFN Torino — Torino
- Bologna
- Università degli Studi dell'Aquila — L'Aquila
- INFN LNGS — Assergi
- Napoli

MIDDLE EAST

- מכון ויצמן למדע Weizmann Institute of Science — Rehovot
- جامعة نيويورك أبوظبي NYU Abu Dhabi — Abu Dhabi

ASIA

- 清华大学 Tsinghua University — Beijing
- 西湖大学 Westlake University — Hangzhou
- Shenzhen
- 東京大学 The University of Tokyo — Tokyo
- Nagoya University — Nagoya
- Kobe University — Kobe

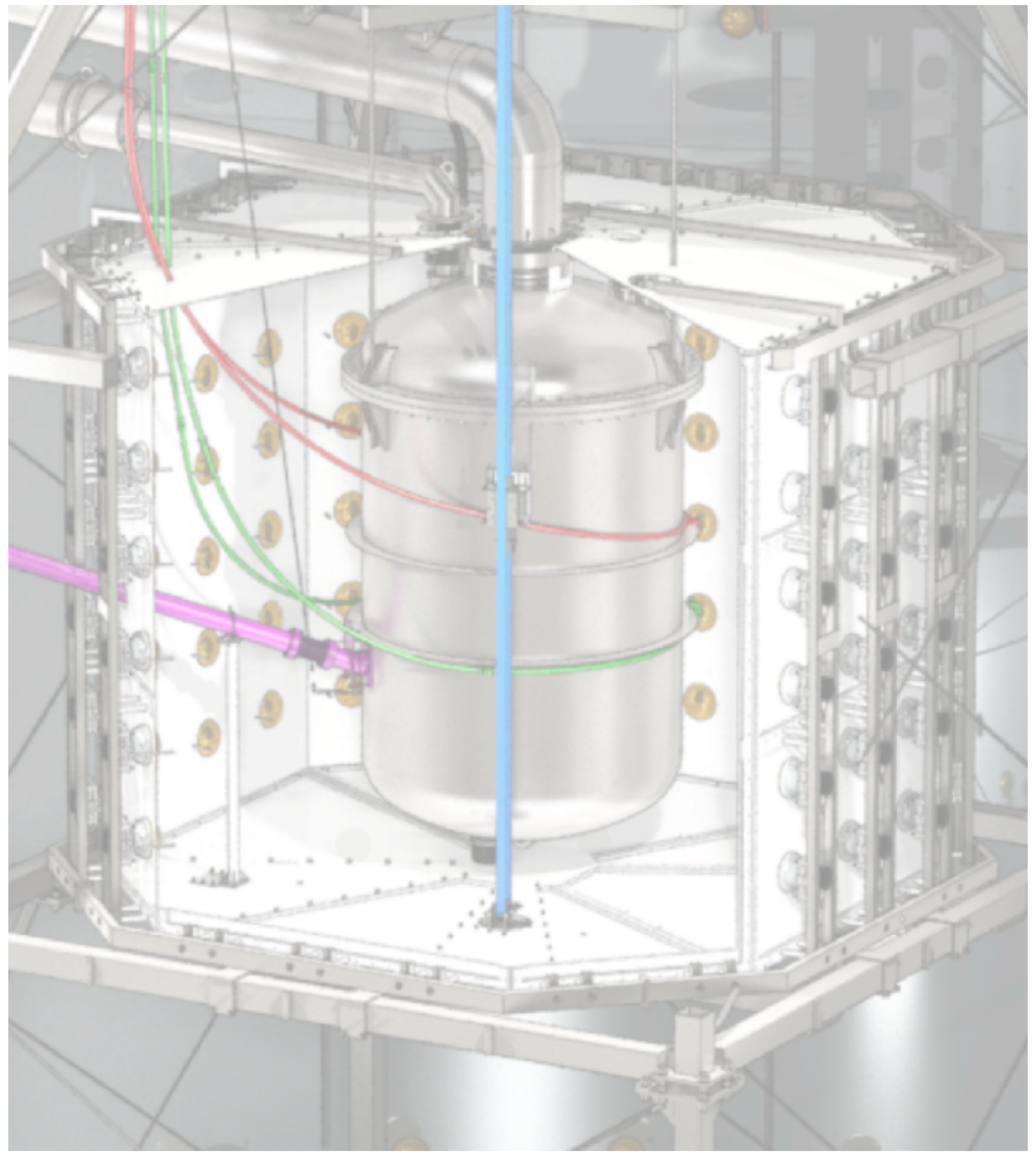
JINST 18 P07054 (2023)
JCAP 11 031 (2020)
arxiv: 2402.10446

3 NESTED DETECTORS: TPC/NV/MV SHARING SAME DAQ

LXe Time Projection Chamber (TPC)

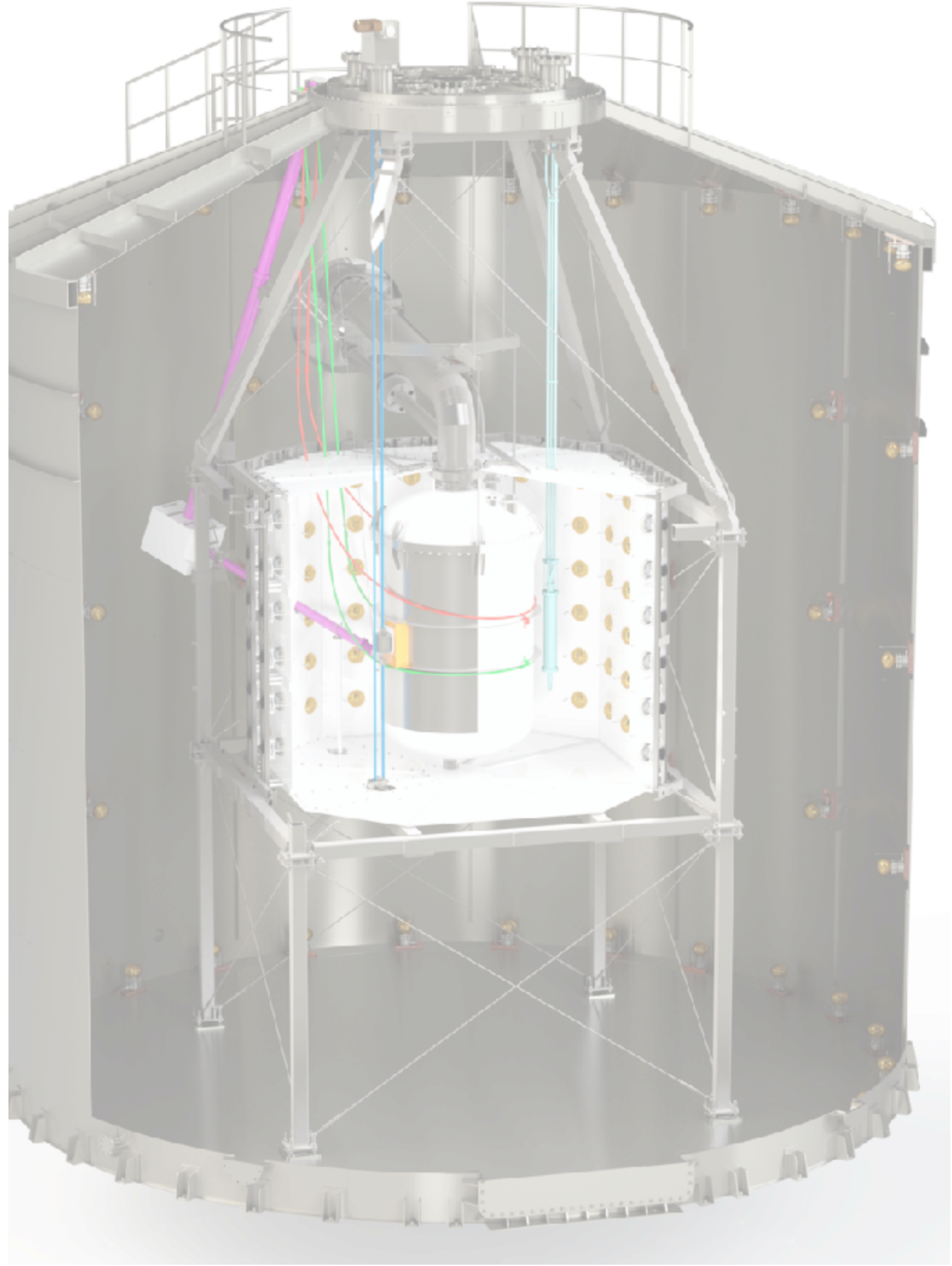
- **5.9t** active target mass
- including ~8.9% ^{136}Xe by natural abundance
- active target diameter/height: 1.3m/1.5m
- 494 Hamamatsu 3″ PMTs

Gd-salted water-based neutron Cherenkov Detector Neutron Veto (NV)



- (Pure water for published results so far)
- 120 8″ high QE PMT
- 33 m^3 volume
- Use neutron capture to tag neutron events at the efficiency of **53%** in pure water
- High reflectivity expanded PTFE

Water-based muon Cherenkov Detector Muon Veto (MV)



- Diameter/Height 9.6m/10.2m, 700t water
- High reflectivity inner coating
- 84 Hamamatsu 8″ PMTs
- Active veto against muon-induced neutrons
- Passive veto against gamma rays and neutrons from natural radioactivity

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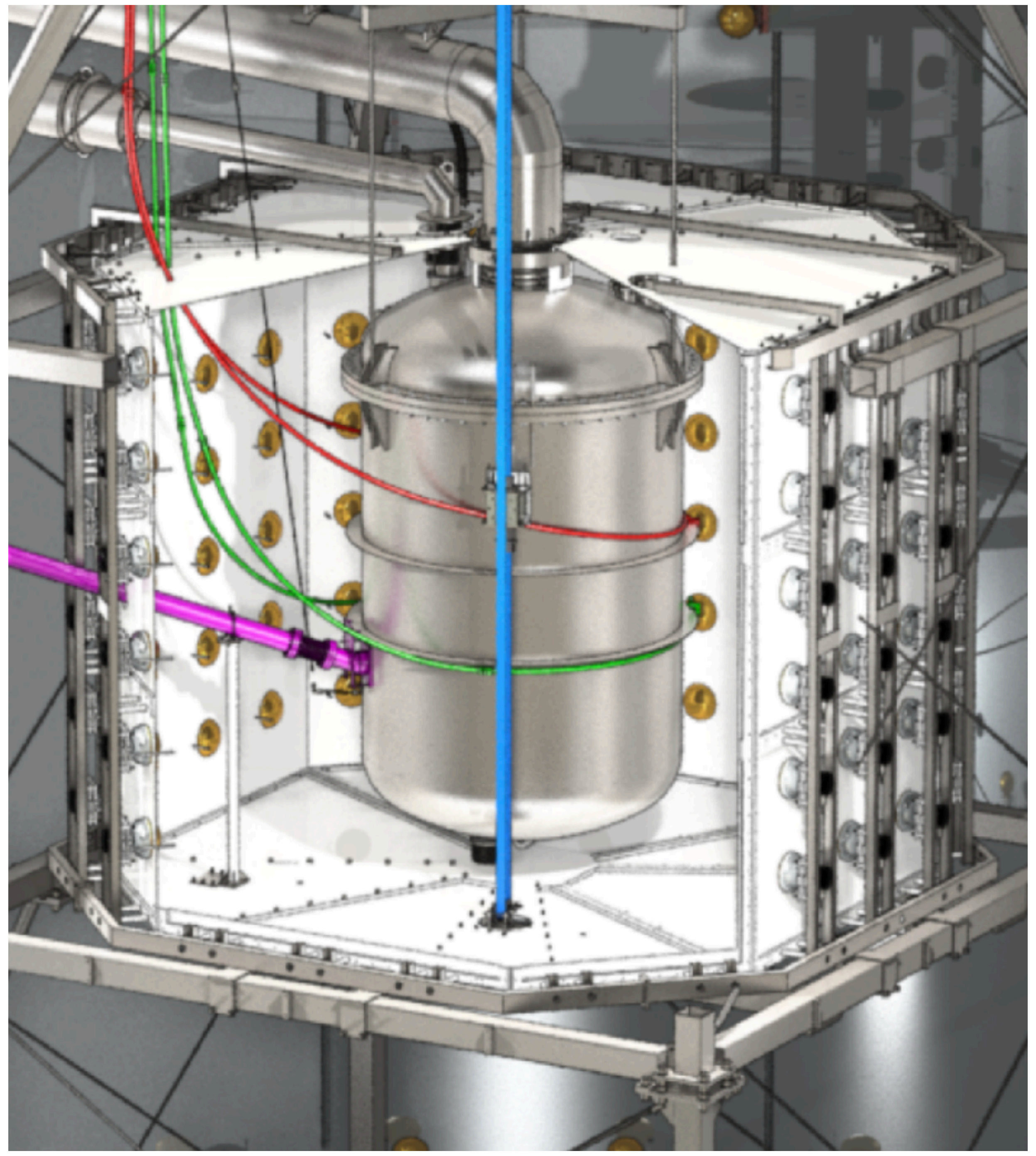

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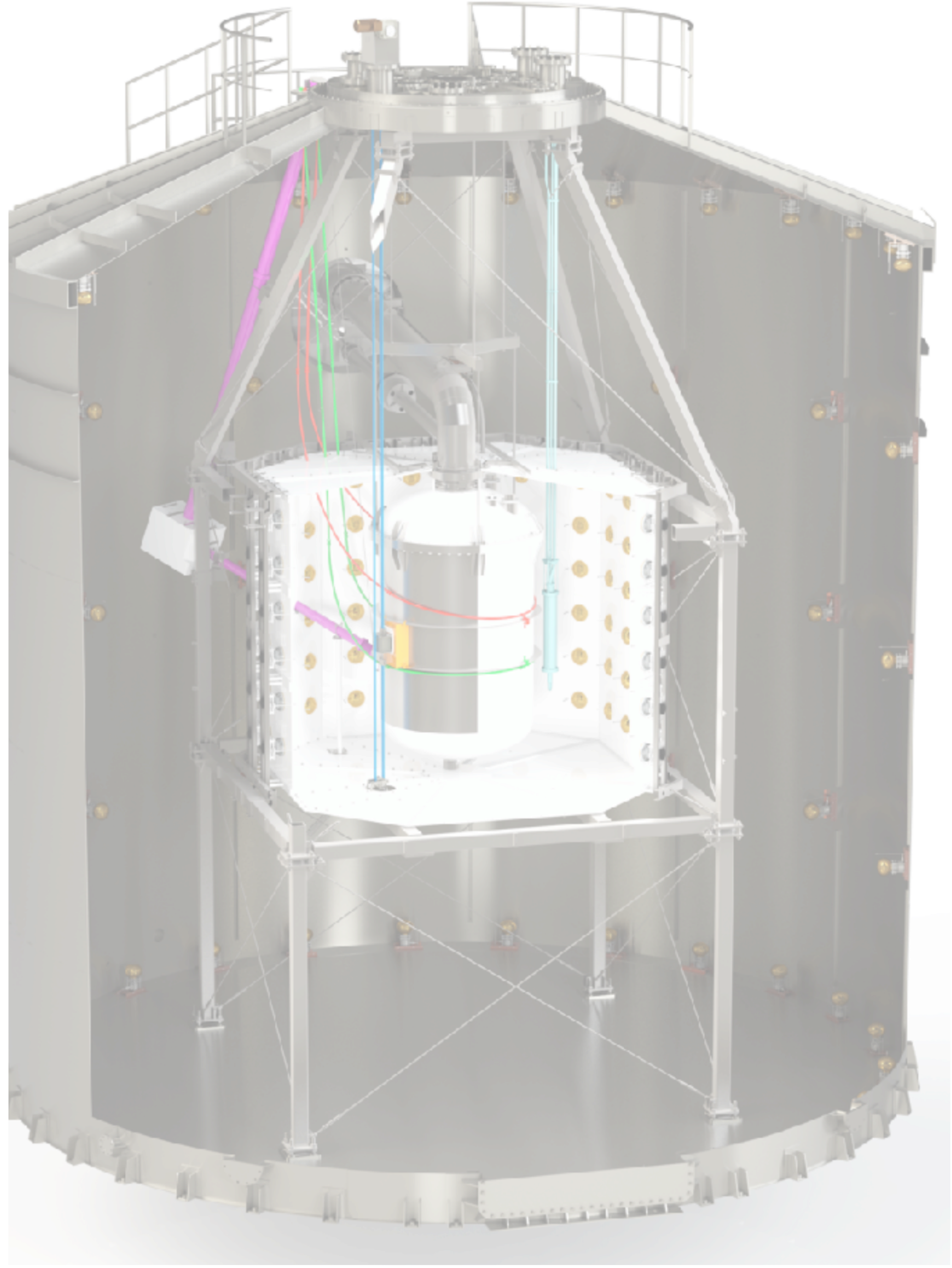

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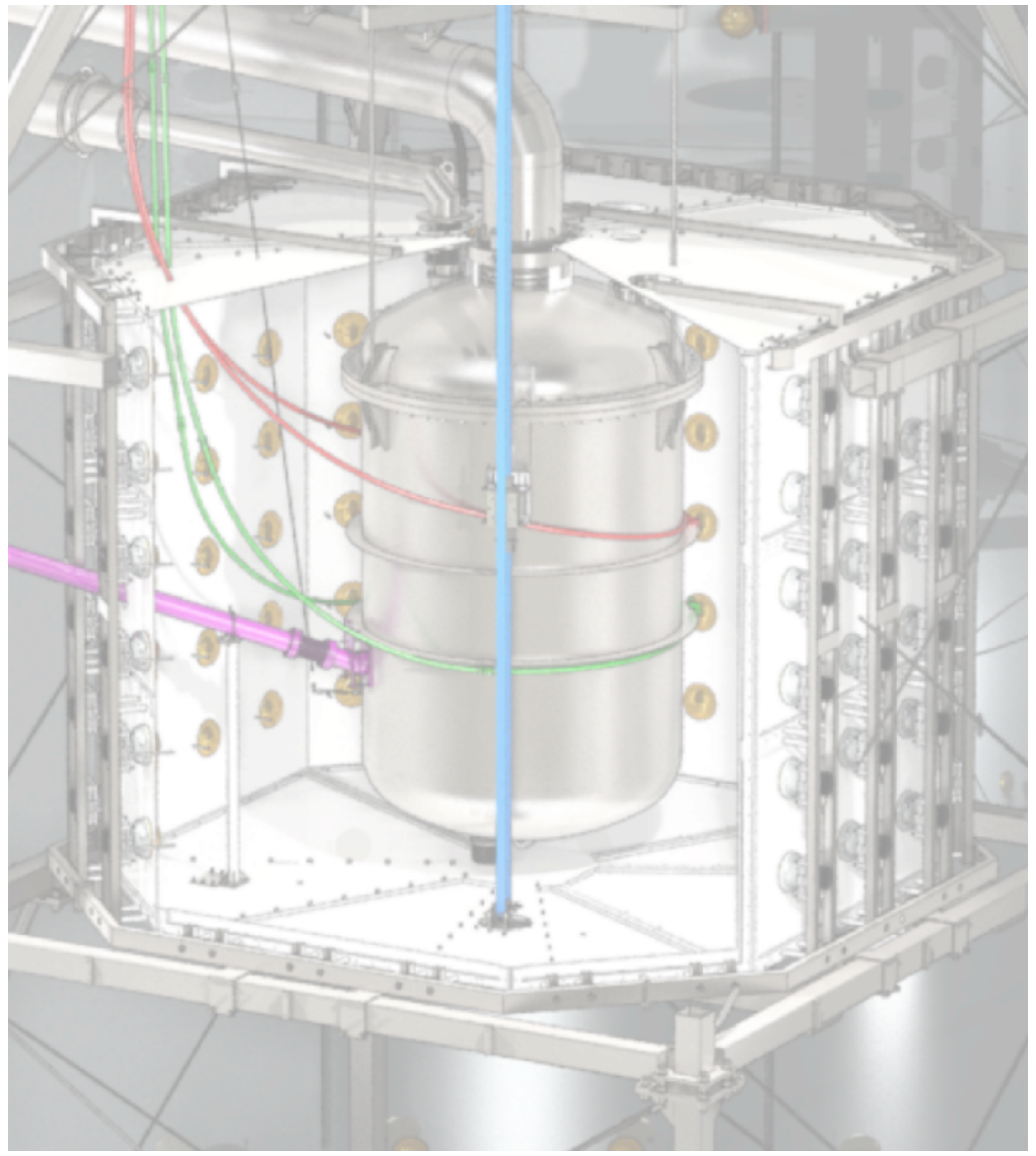

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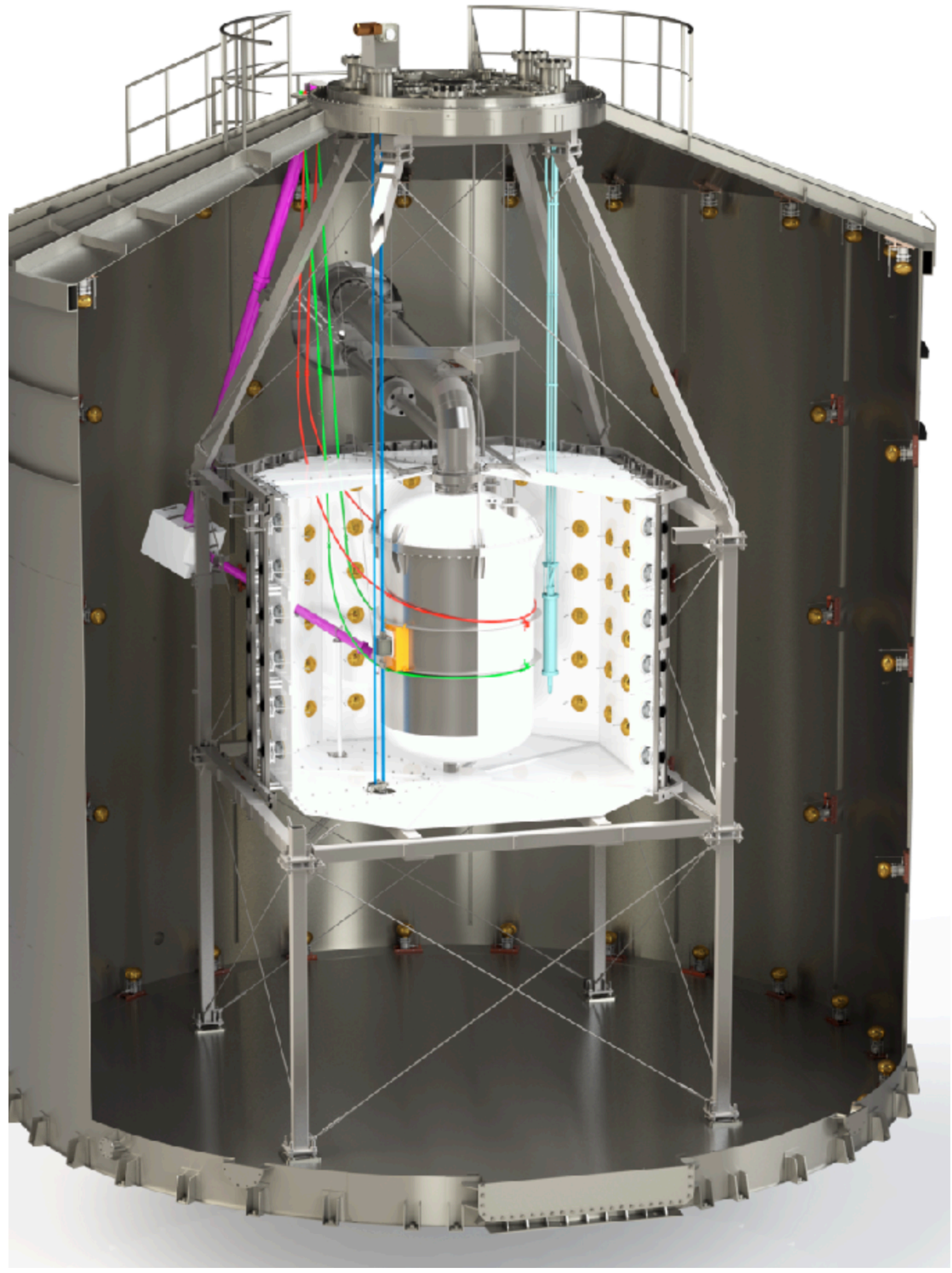

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XENON1T → XENONnT

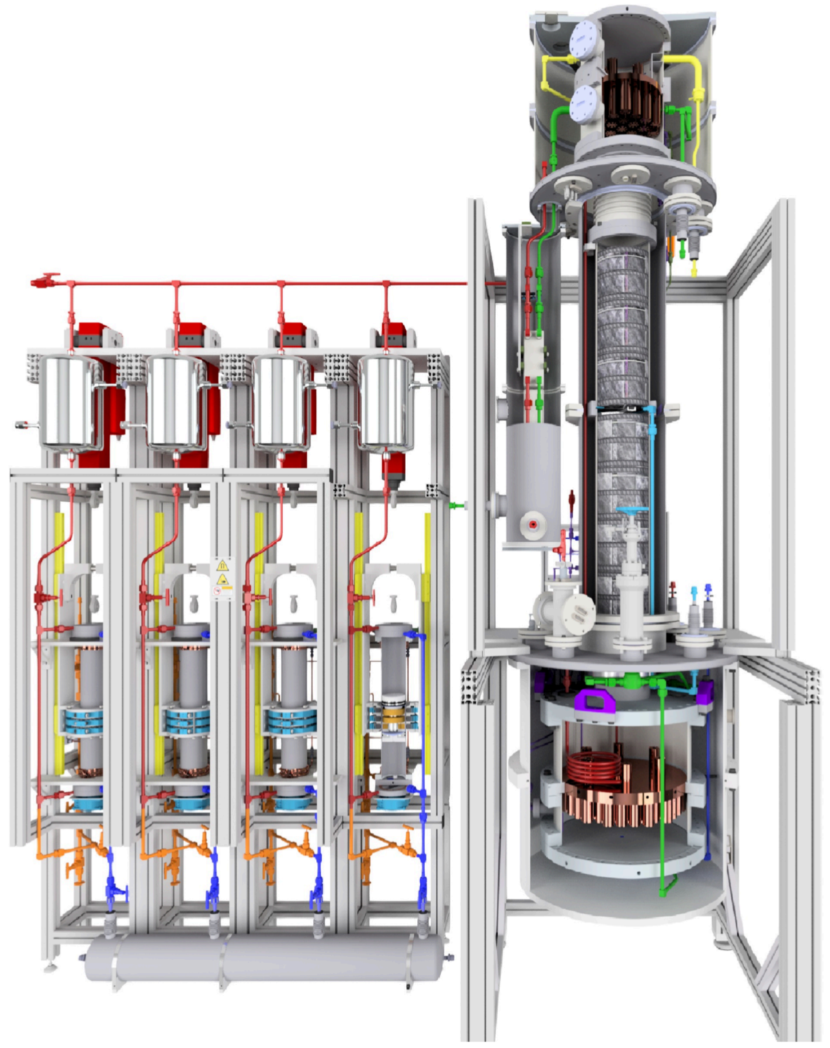
- X3 Larger target mass (X4 fiducial mass): lower material background & more exposure

JINST 18 P07054 (2023)

- Triggerless Data Acquisition: All data above per-channel threshold stored long term

https://github.com/XENONnT

- Open-source & faster processing software; Advanced computing structure
- **Additional LXe purification: e-lifetime 0.65ms → ~15ms**
- **Radon Distillation: ^{222}Rn suppressed to ~1.8 μBq/kg**



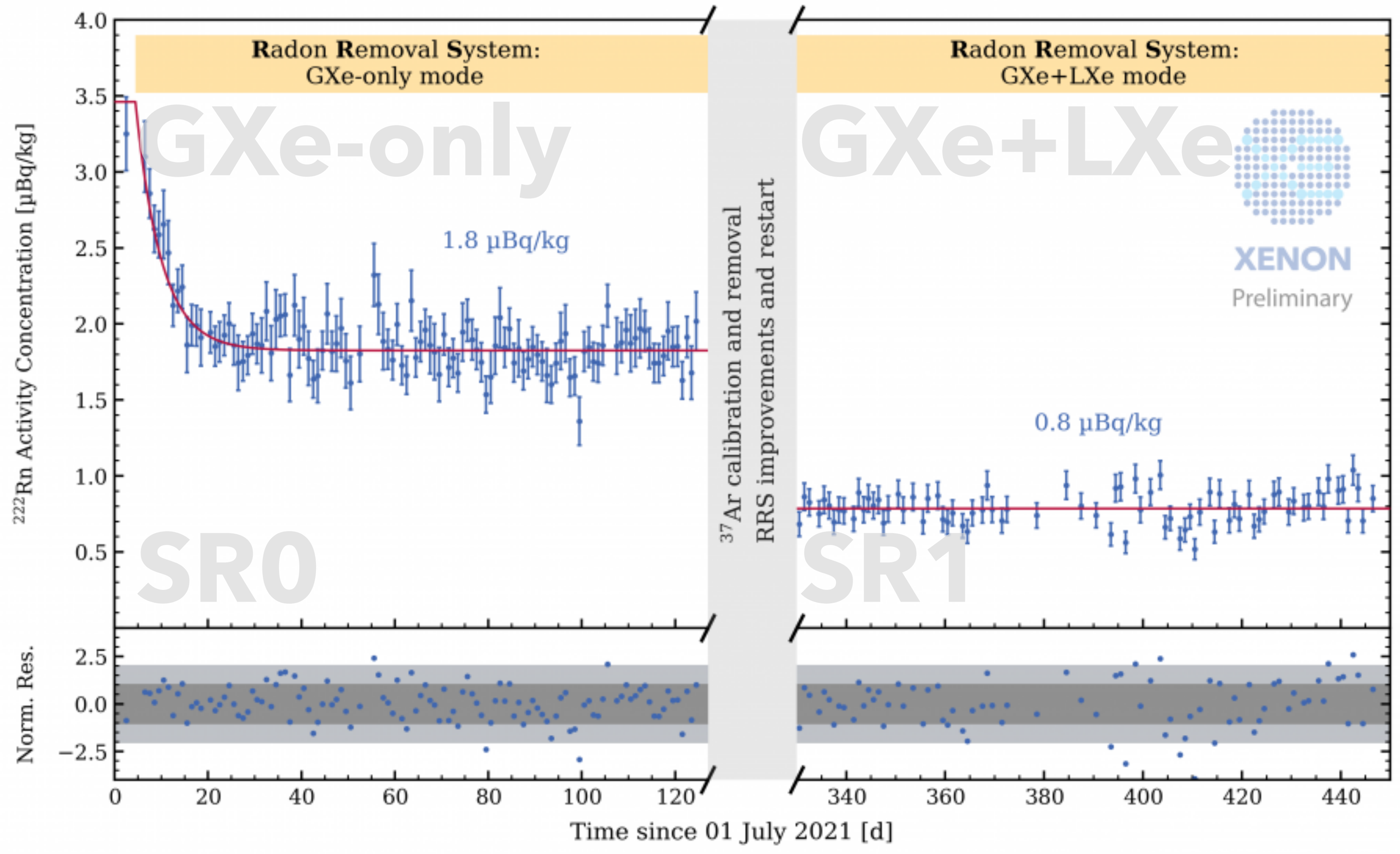
Radon Removal System

Eur. Phys. J. C 82, 1104 (2022)

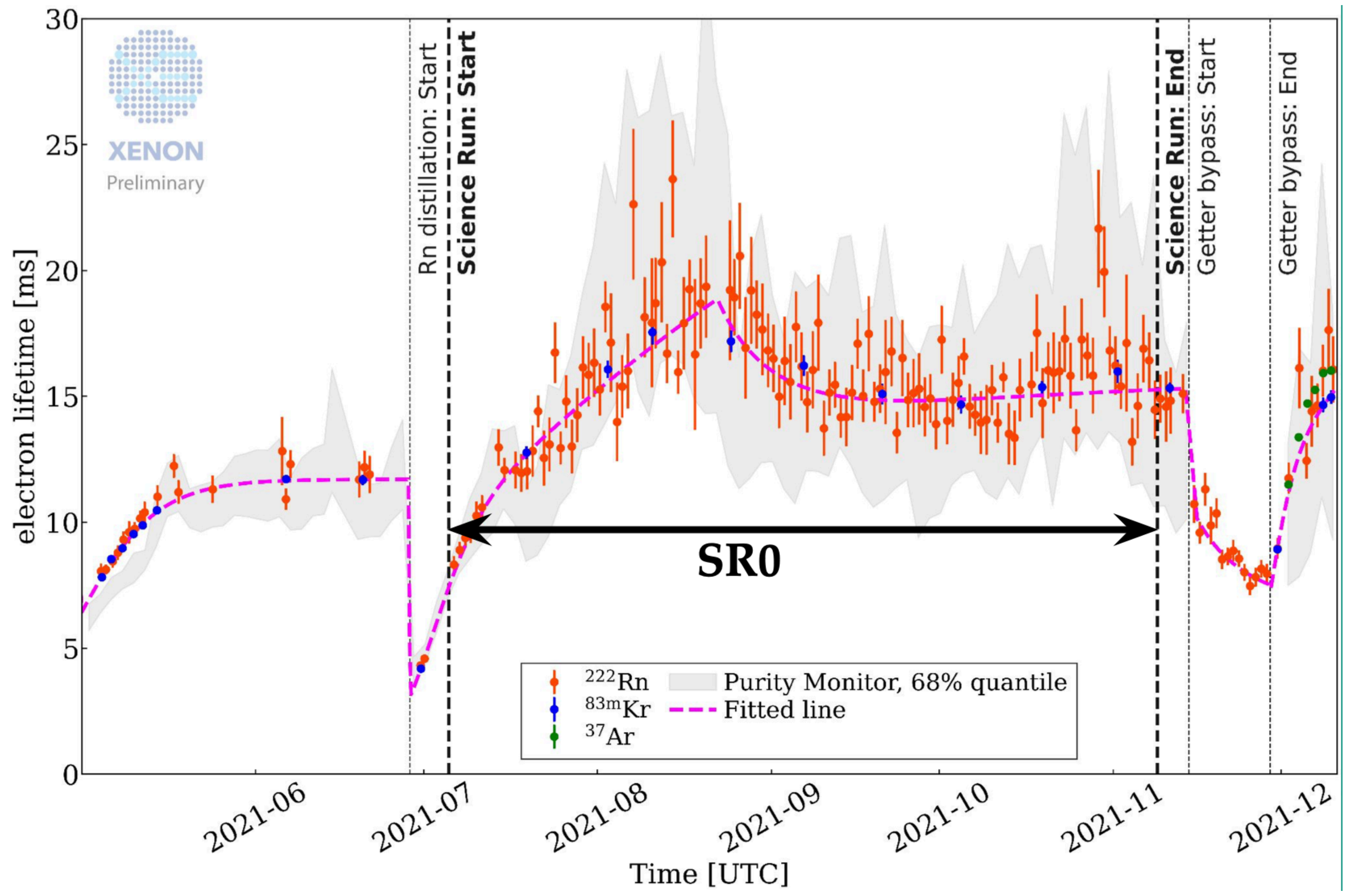
LXe Purification System

Eur. Phys. J. C 82, 860 (2022)

- ^{222}Rn (major ER background) mostly from pipes, cables & cryogenic system
- Continuous distillation at ~70kg/h
- Initial ^{222}Rn concentration: 4.3μBq/kg → 1.8μBq/kg

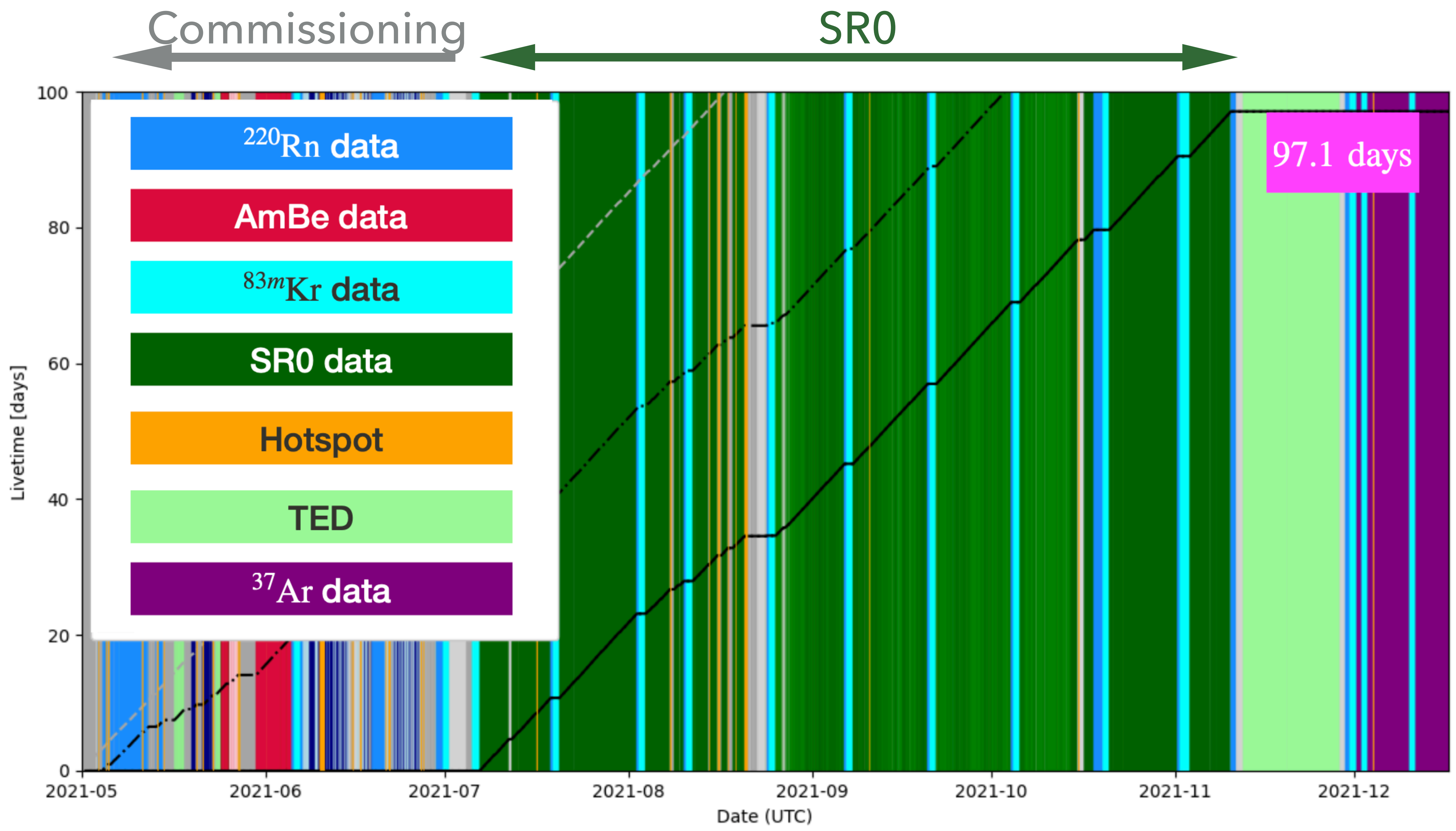


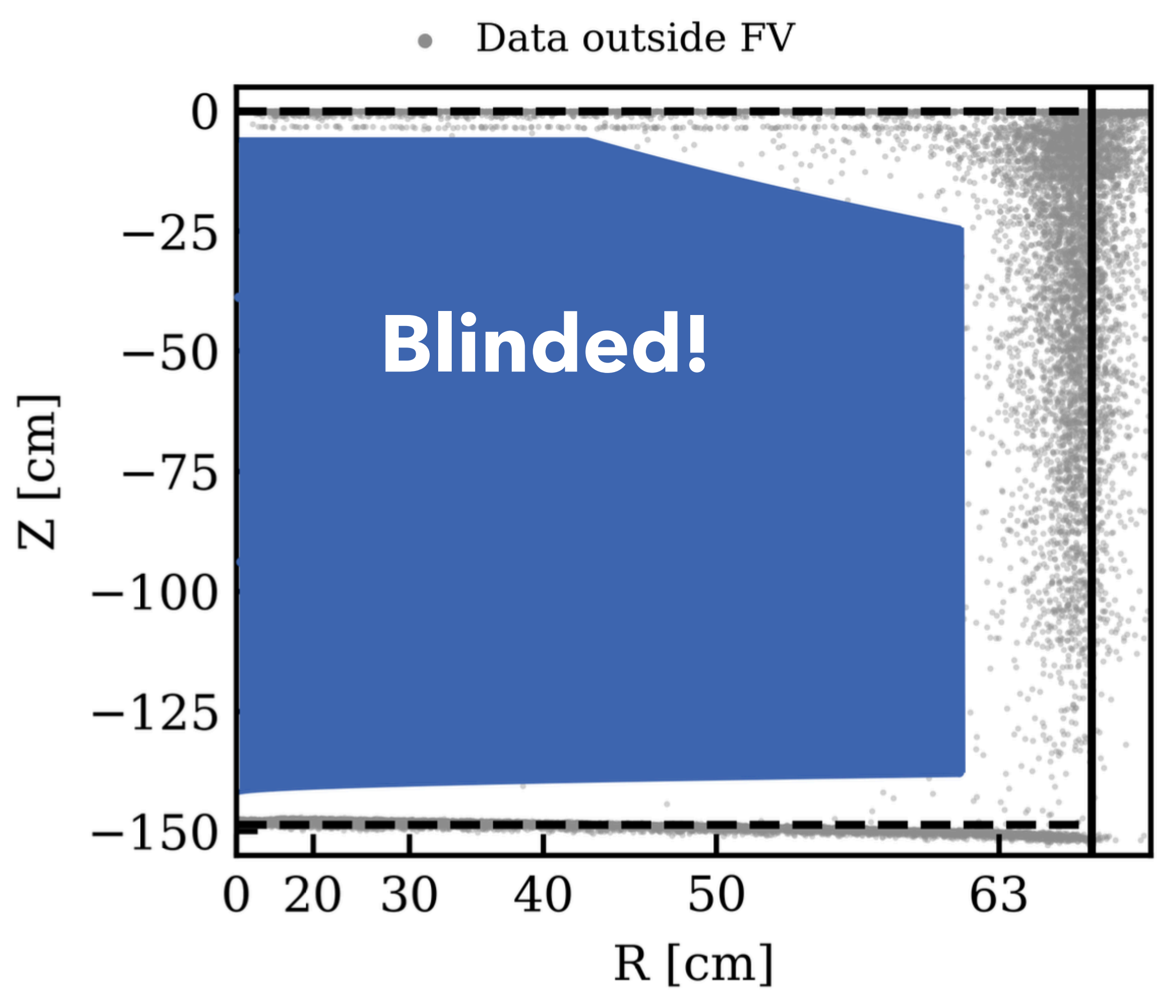
- Removing electronegative impurities (H_2O and O_2)
- Only ~14% charge loss for a full drift length 1.5m
- LXePUR: Up to 16 tonne/day

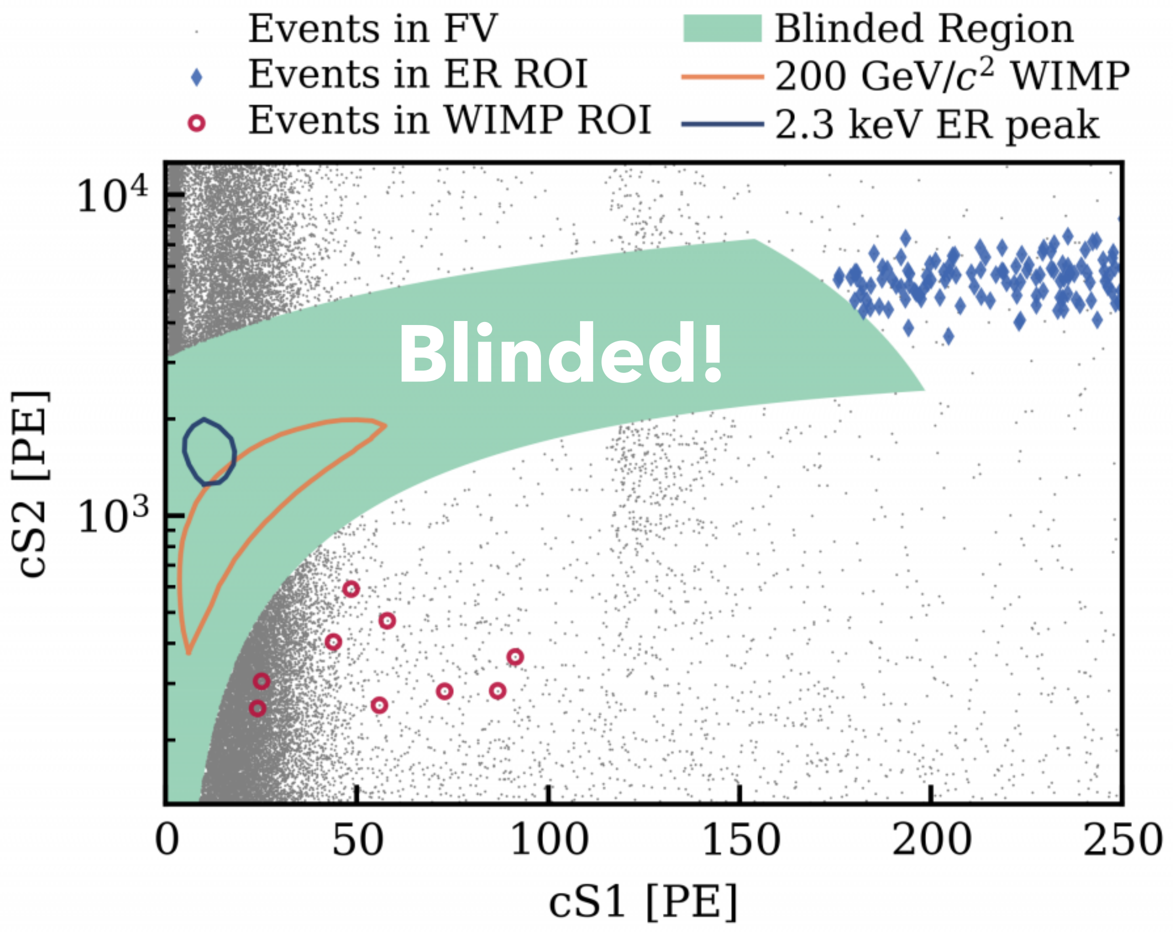


FIRST SCIENCE RUN: SR0

- 97.1 days of exposure → **~1.1 tonne·year** exposure, with Fiducial Volume (FV)
    - 4.18±0.13 tonne for Nuclear Recoil (NR) search
    - 4.37±0.14 tonne for Electronic Recoil (ER) search
- **Blind analysis** in FV and low energy region for both NR and ER







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  - 4.18±0.13 tonne for Nuclear Recoil (NR) search
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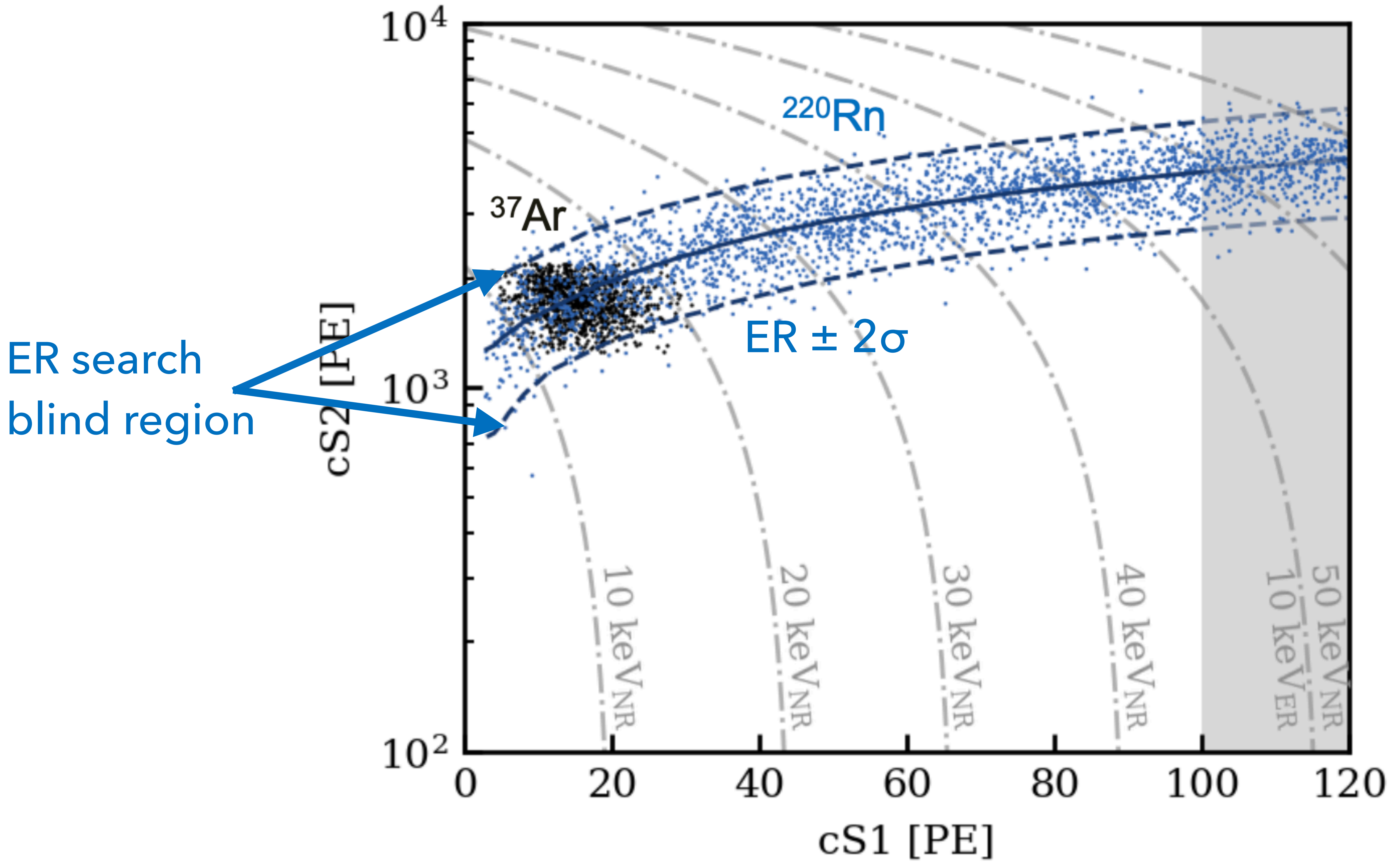
- Blind analysis in FV and low energy region for both NR and ER
- **Calibrations:**

Extremely stable detector response: <~1% Light/Charge Yield fluctuation over SR0

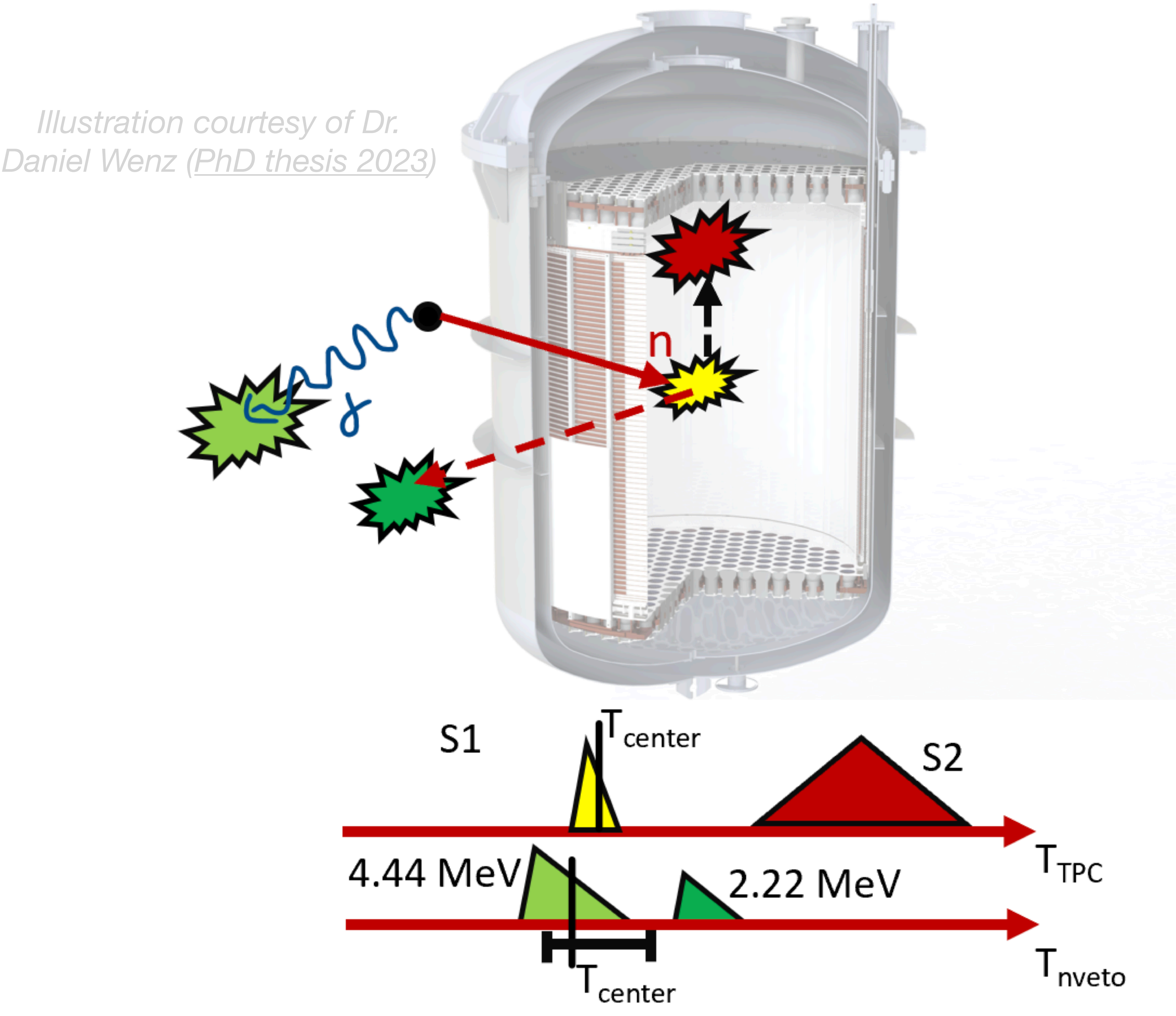
  - ^{83m}Kr: Uniformly distributed gamma events
  - **^{220}Rn: ER band**
  - **^{37}Ar: Uniformly distributed 2.8 keV ER events**

  (^{37}Ar was removed by krypton distillation after SR0)



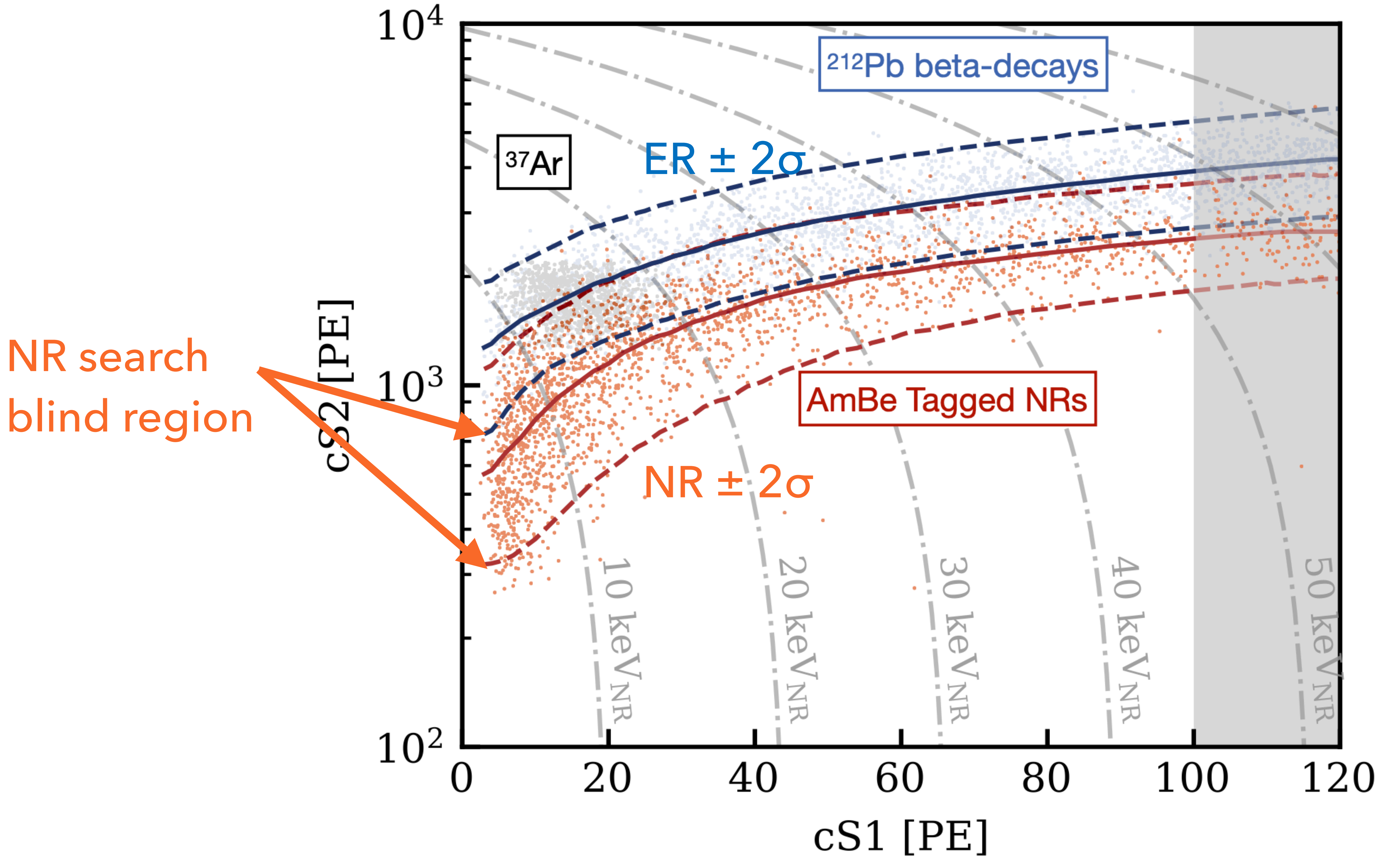
- Uniformly distributed in TPC
- ^{220}Rn is useful to study detector response/data selection of ER
- ^{37}Ar is especially helpful in modeling near energy threshold
- Combined ^{37}Ar with ^{220}Rn to fit microphysics+detector response model

FIRST SCIENCE RUN: SR0



- **AmBe: NR band**

  Neutron events tagged by time coincidence between S1 in TPC and 4.44 MeV gamma event in NV



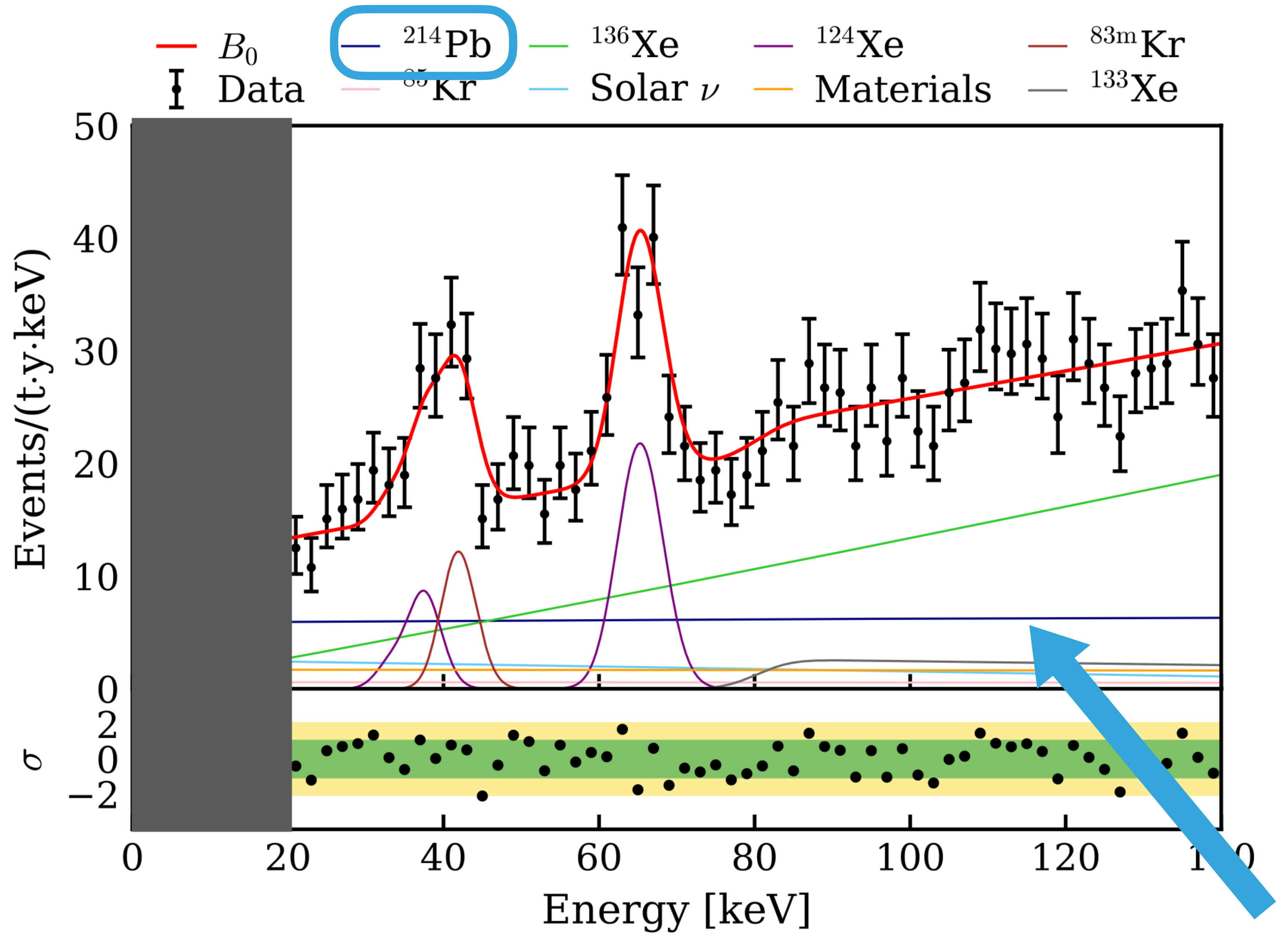
- Neutrons mostly from ^{9}Be capturing ^{241}Am's α-decay
- Pure neutron (99.99% purity) events tagged by NV in a 400 ns wide coincidence window
- Fitted with microphysics+detector response model for NR

UNBLINDING LOW ER SEARCH

- ER background built on low energy ER sideband
    - **Dominated by flat beta spectrum from ^{222}Rn daughter: ~1/7 of XENON1T thanks to Radon Distillation and more xenon**

Eur. Phys. J. C 82, 1104 (2022)

PRL 129, 161805 (2022)

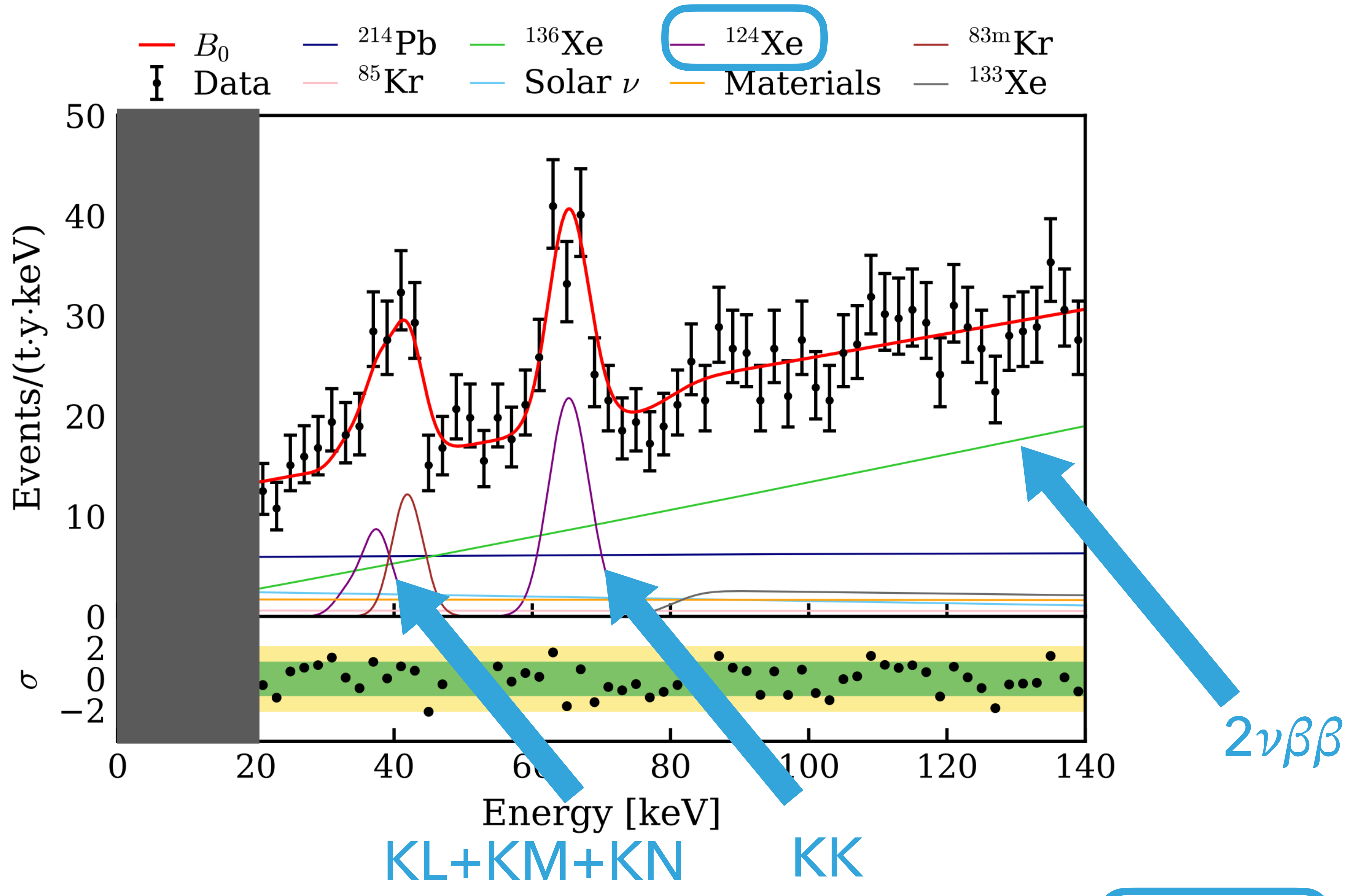


1 Rn atom in 10mol xenon!

UNBLINDING LOW ER SEARCH

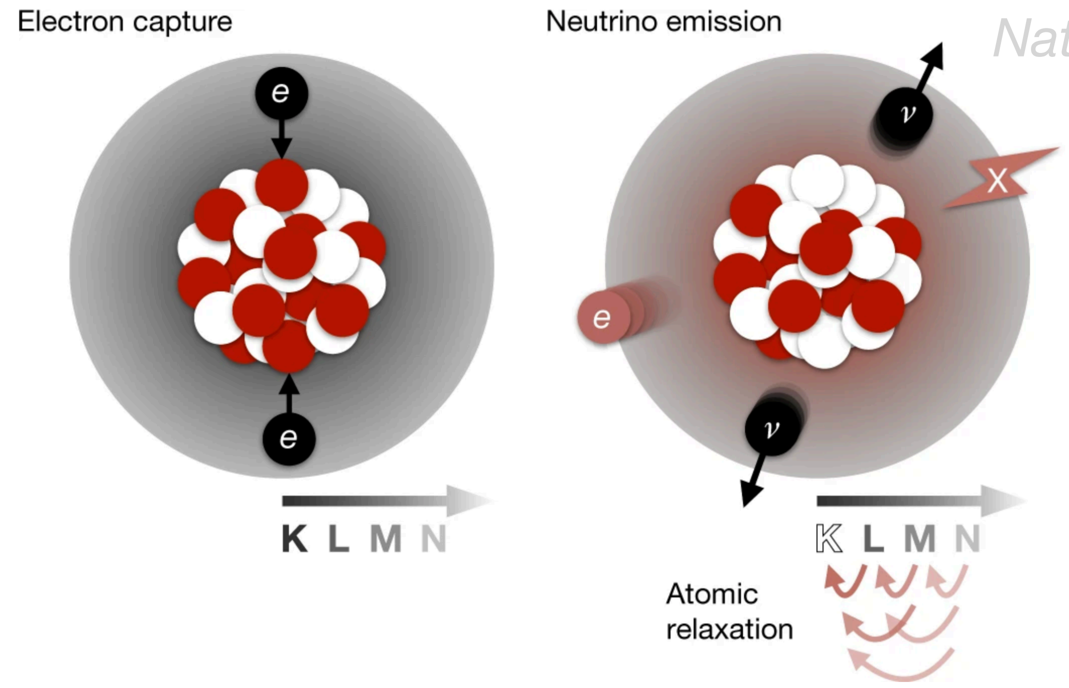
- ER background built on low energy ER sideband
  - Dominated by flat beta spectrum from ^{222}Rn daughter: ~1/7 of XENON1T thanks to Radon Distillation and more xenon
  - **Can clearly see double weak processes, and used them for calibration**

PRL 129, 161805 (2022)



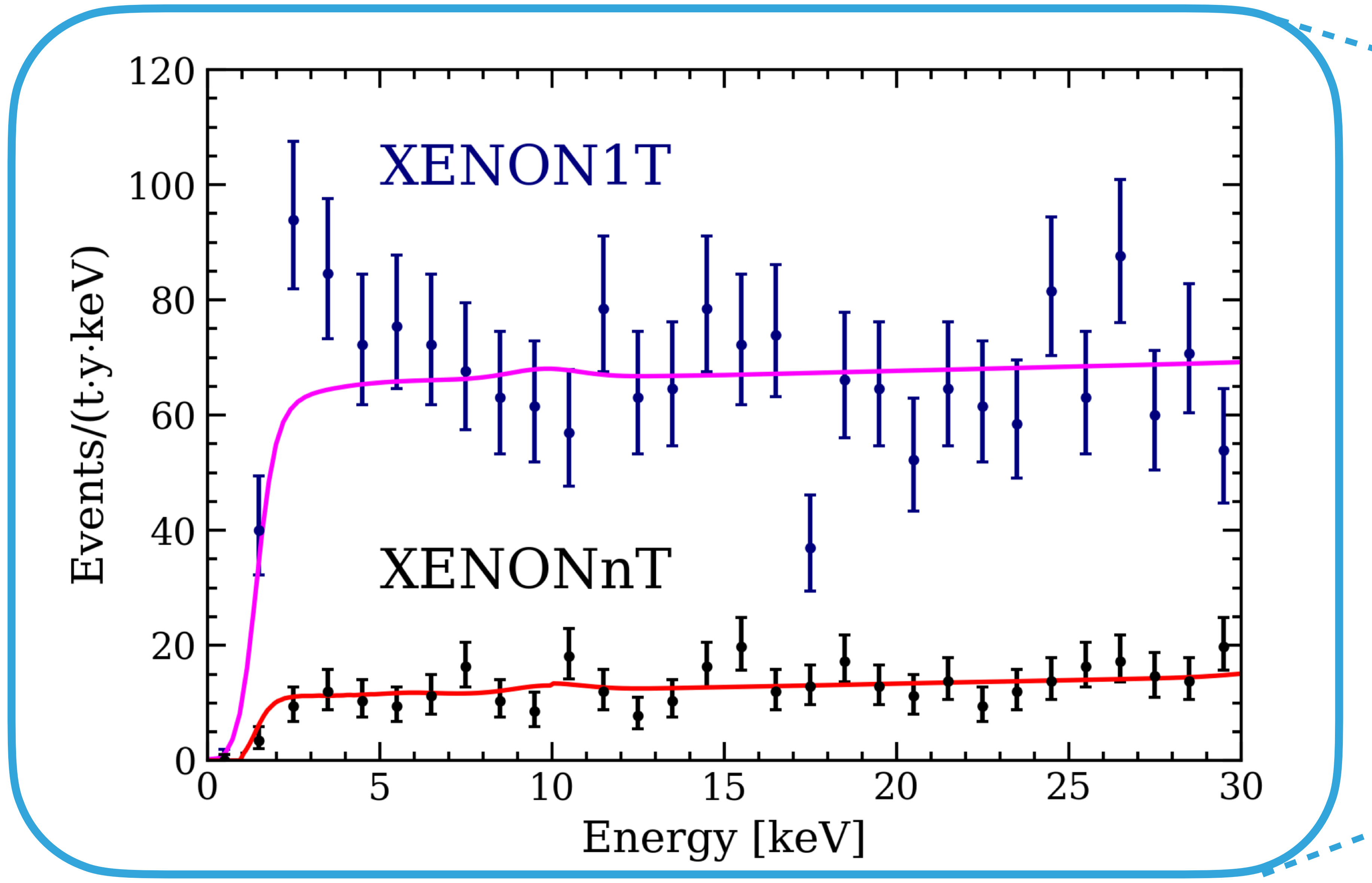
$$T_{1/2}^{2\nu\mathrm{ECEC}} = (1.15 \pm 0.13_{\mathrm{stat}} \pm 0.14_{\mathrm{sys}}) \times 10^{22}\mathrm{yr}$$

WAS RAREST PROCESS EVER OBSERVED

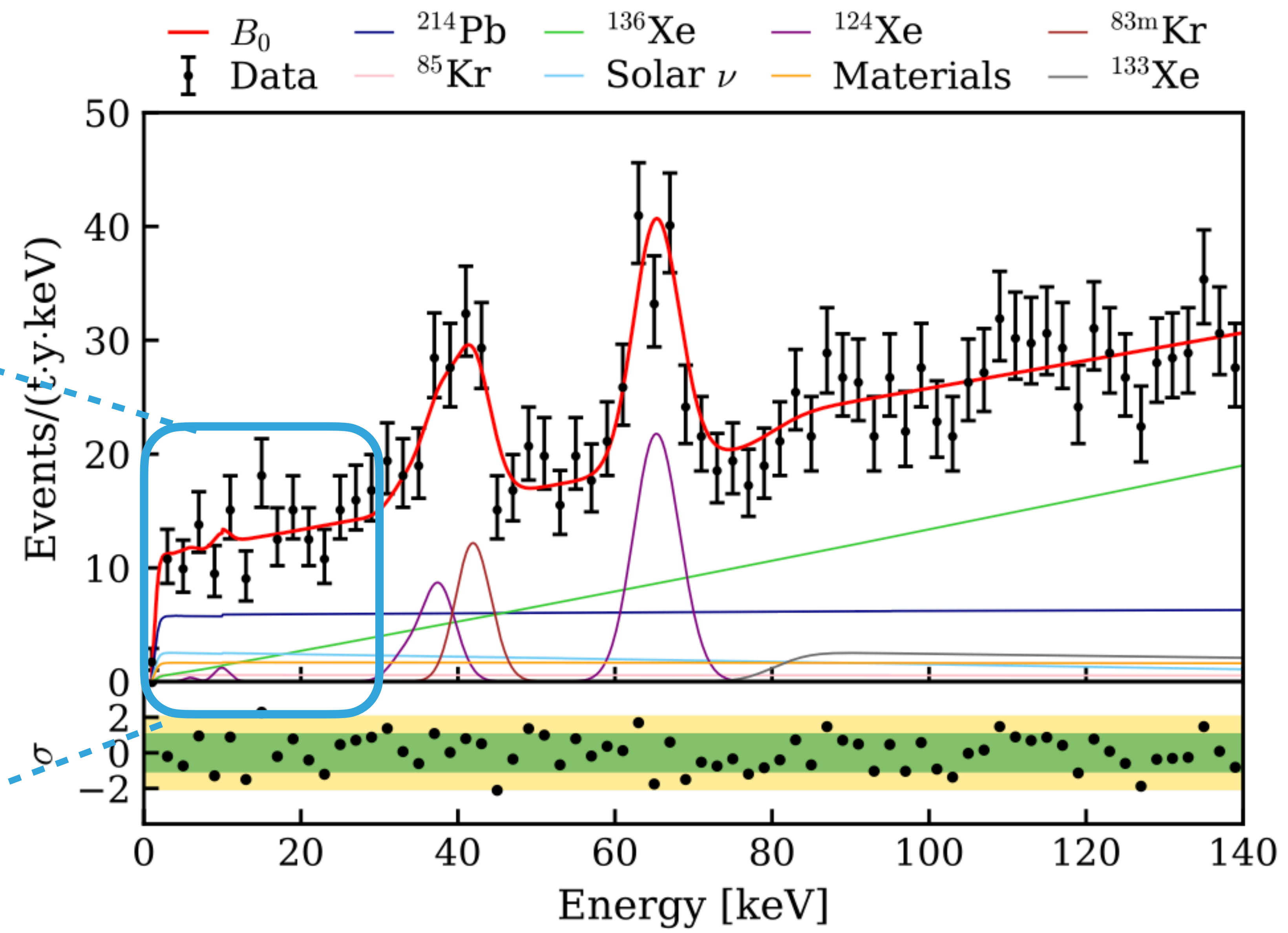


Nature 568, 532–535 (2019)

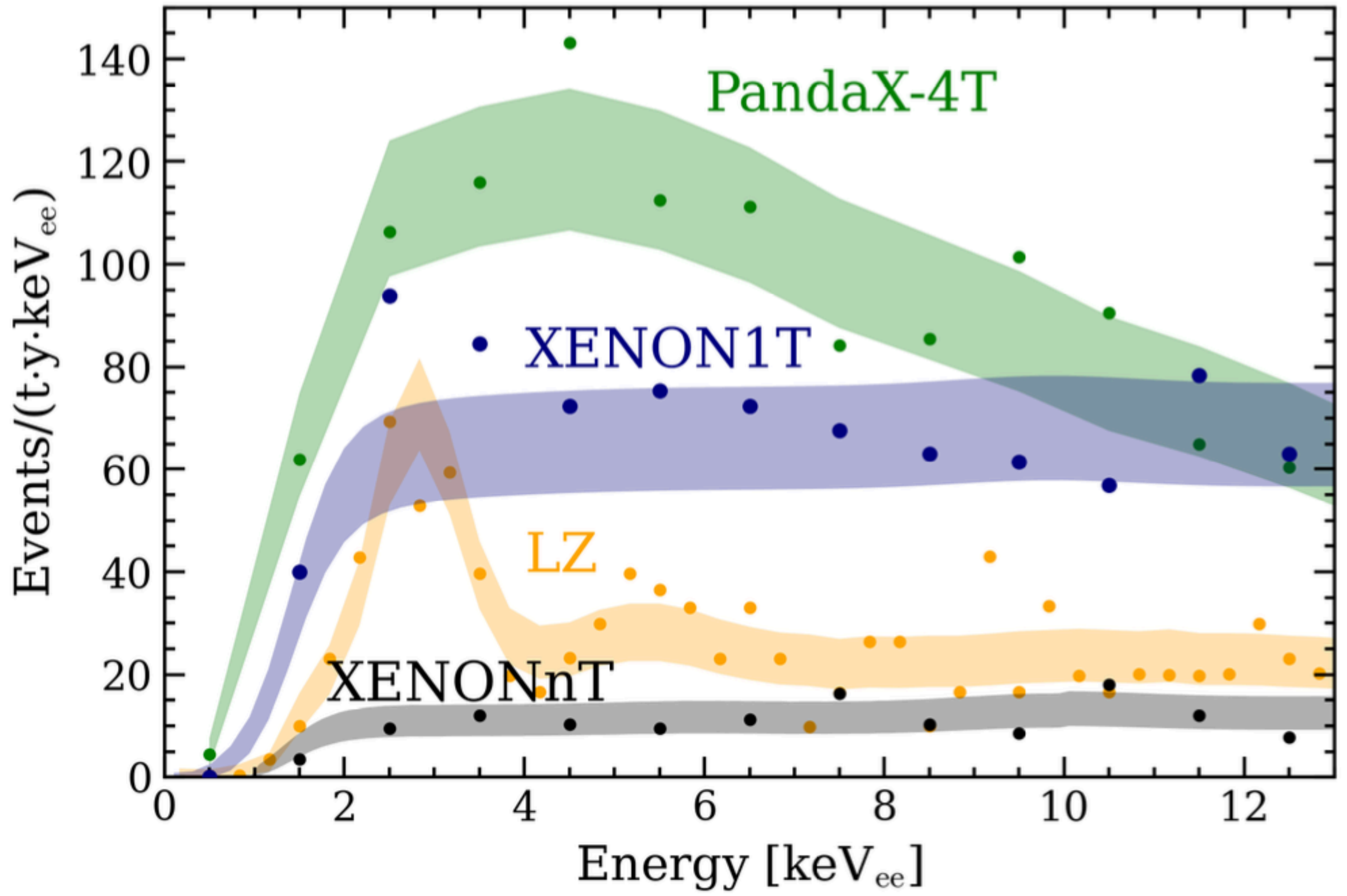
UNBLINDING LOW ER SEARCH



PRL 129, 161805 (2022)

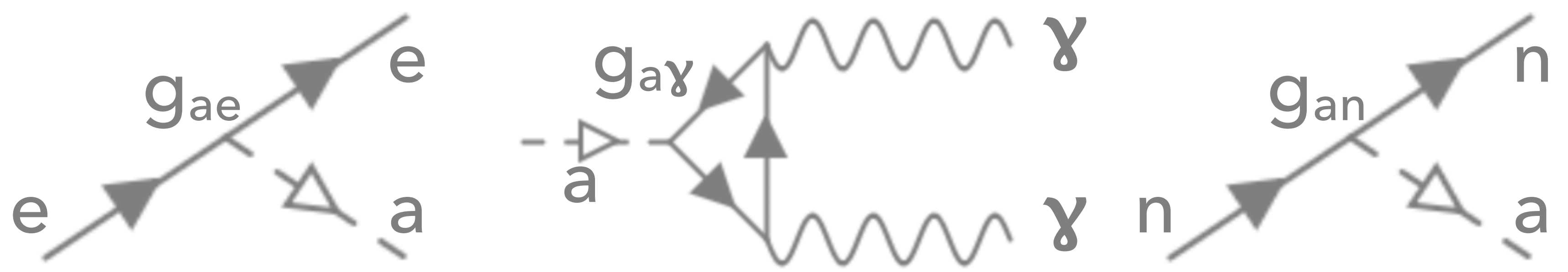


- Unblinding result
  - **Unprecedented low background**
  - **XENON1T excess was most likely tritium**
    PRD 102, 072004 (2020)
  - The signal characterization analysis has been cross-checked with an independent analysis using a Bayesian Network PRD 108, 012016 (2023)



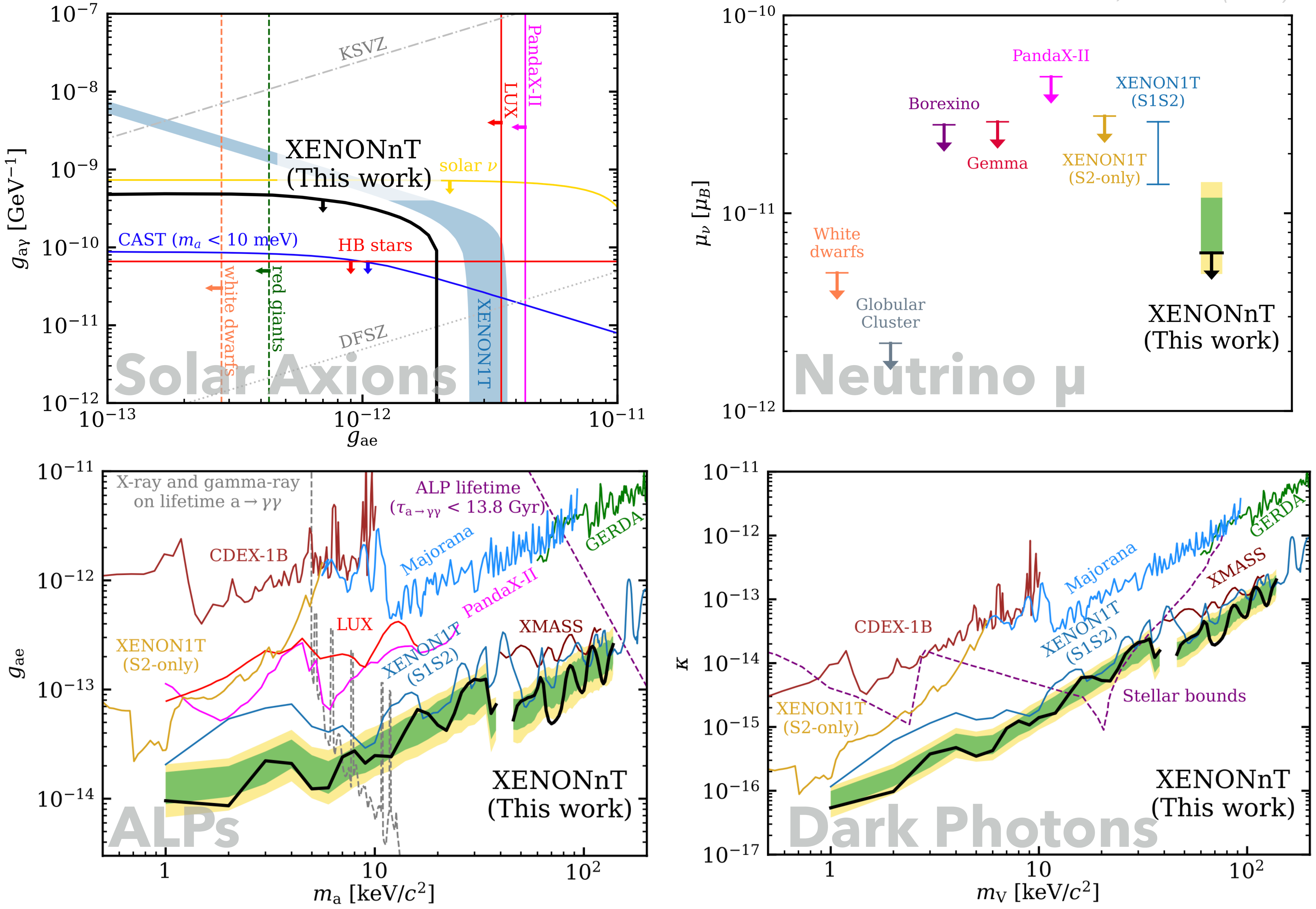
PRL 129, 161805 (2022)
PRL 129, 161804 (2022)
PRD 102, 072004 (2020)
PRL 131, 041002 (2023)

LIMITS ON BSM PHYSICS: LEADING AMONG NON-ASTRONOMICAL OBSERVATIONS



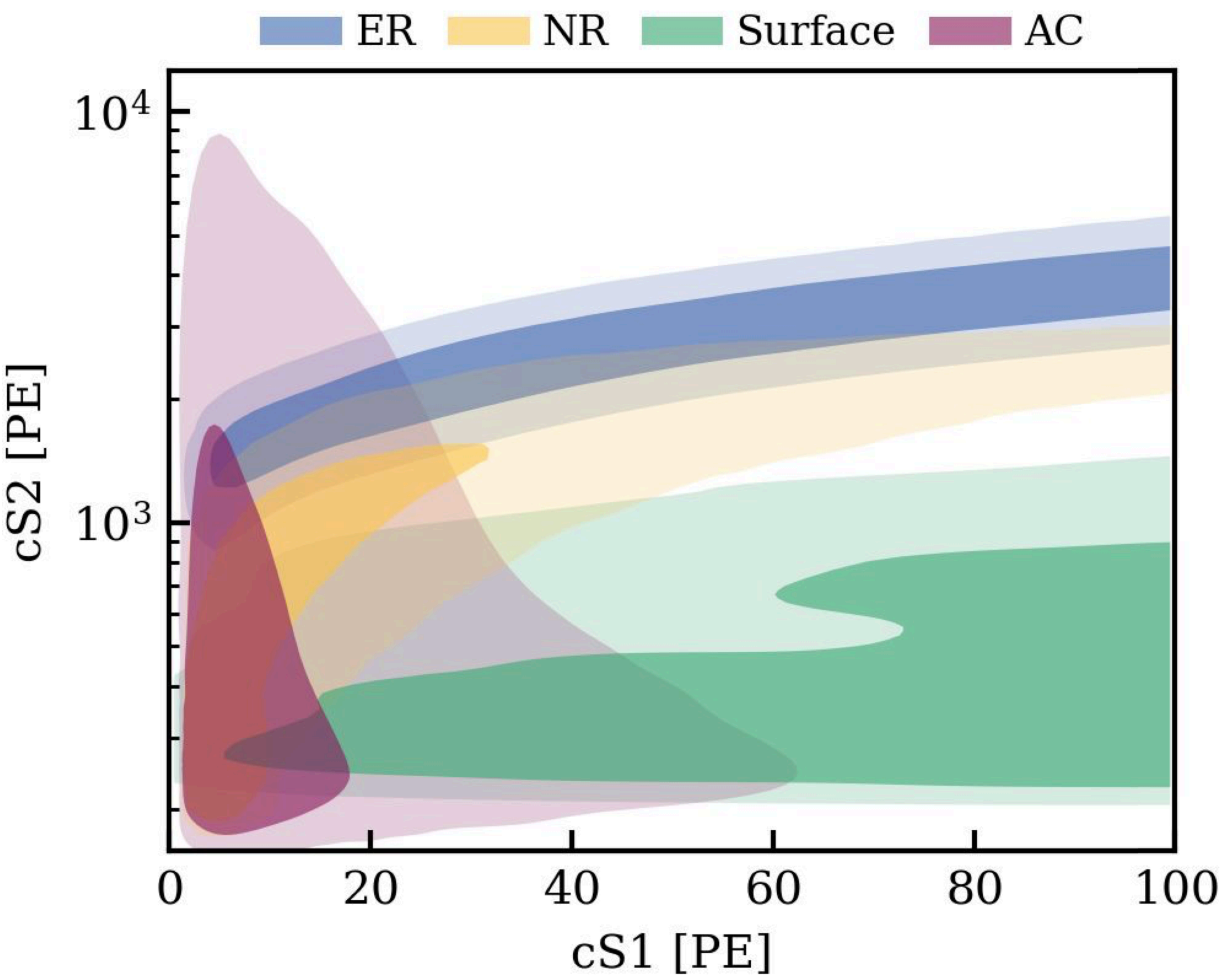
- **Solar axions**
  - Inference done in (g_{ae}, $g_{a\gamma}$, g_{an}) but projected in 2D
- **Neutrino magnetic moment**
  - Using solar neutrinos
- **Bosonic DM**
  - Axion-like Particles (ALPs) and dark photons

PRL 129, 161805 (2022)



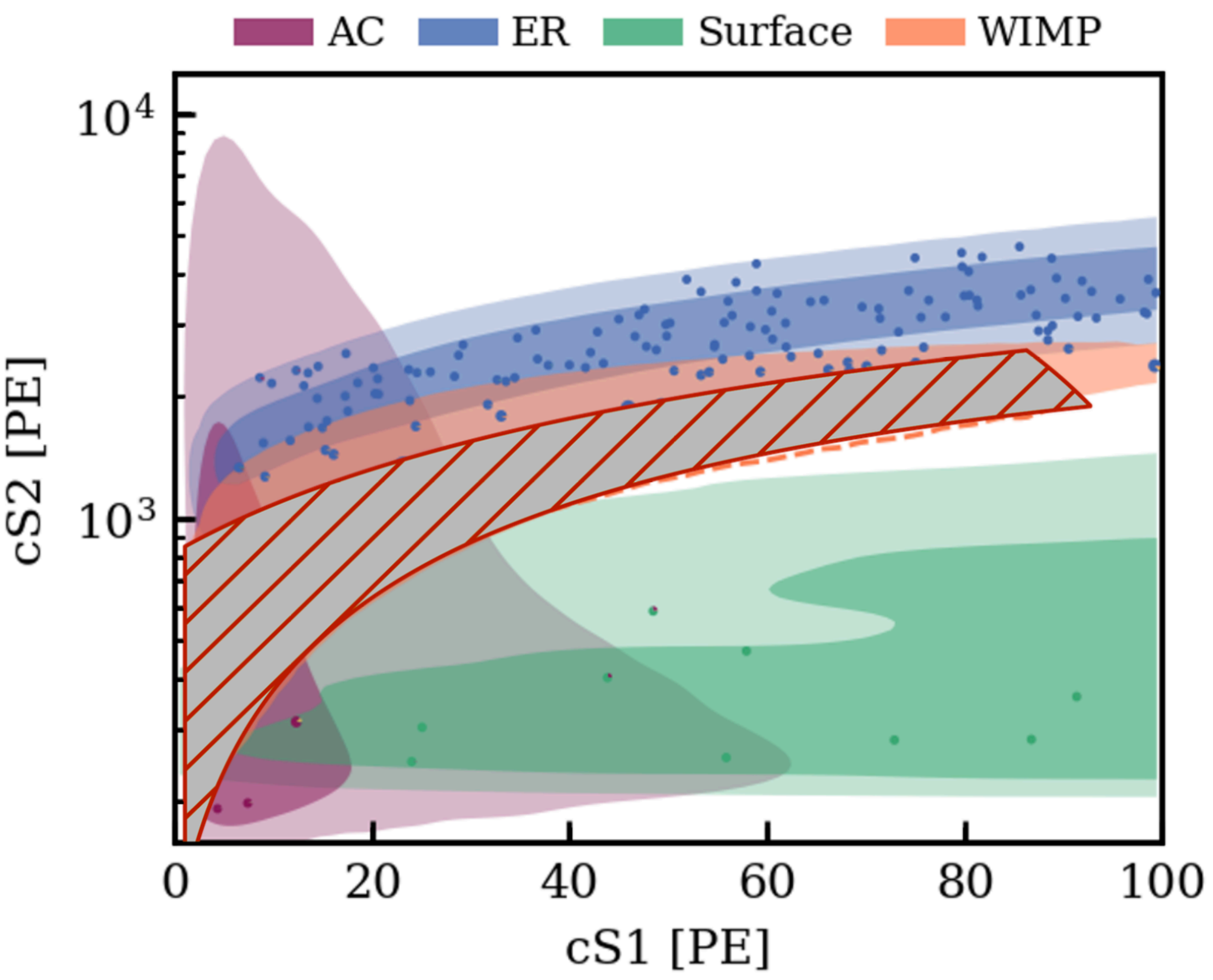
BACKGROUNDS IN NR SEARCH

- **Low ER leakage into NR blind region**
  - Dominated by beta decays from ^{214}Pb, a daughter of ^{222}Rn
  - Estimated fraction events below NR band median: 1.1%
- **Accidental coincidences**
  - Random unphysical pairing of S1 and S2 signals
  - Strongly suppressed based on a gradient boosted decision tree, using S2 shape, R and Z information
- **Surface background model**
  - "Surface" events due to ERs from ^{210}Pb plate out at detector walls (with charge loss)
  - Use events reconstructed outside the fiducial volume and a KDE to create a smooth template for ROI
- **NR background**
  - Neutron events from spontaneous fission and (α,n) reactions
  - Modeled in a combination of data-driven approach and MC



UNBLINDING NR SEARCH

	Nominal	Best Fit	
		ROI	Signal-like
ER	134		
Neutrons	$1.1^{+0.6}_{-0.5}$		
CEνNS	0.23 ± 0.06		
AC	4.3 ± 0.9		
Surface	14 ± 3		
Total Background	154		
WIMP	-		
Observed	-		



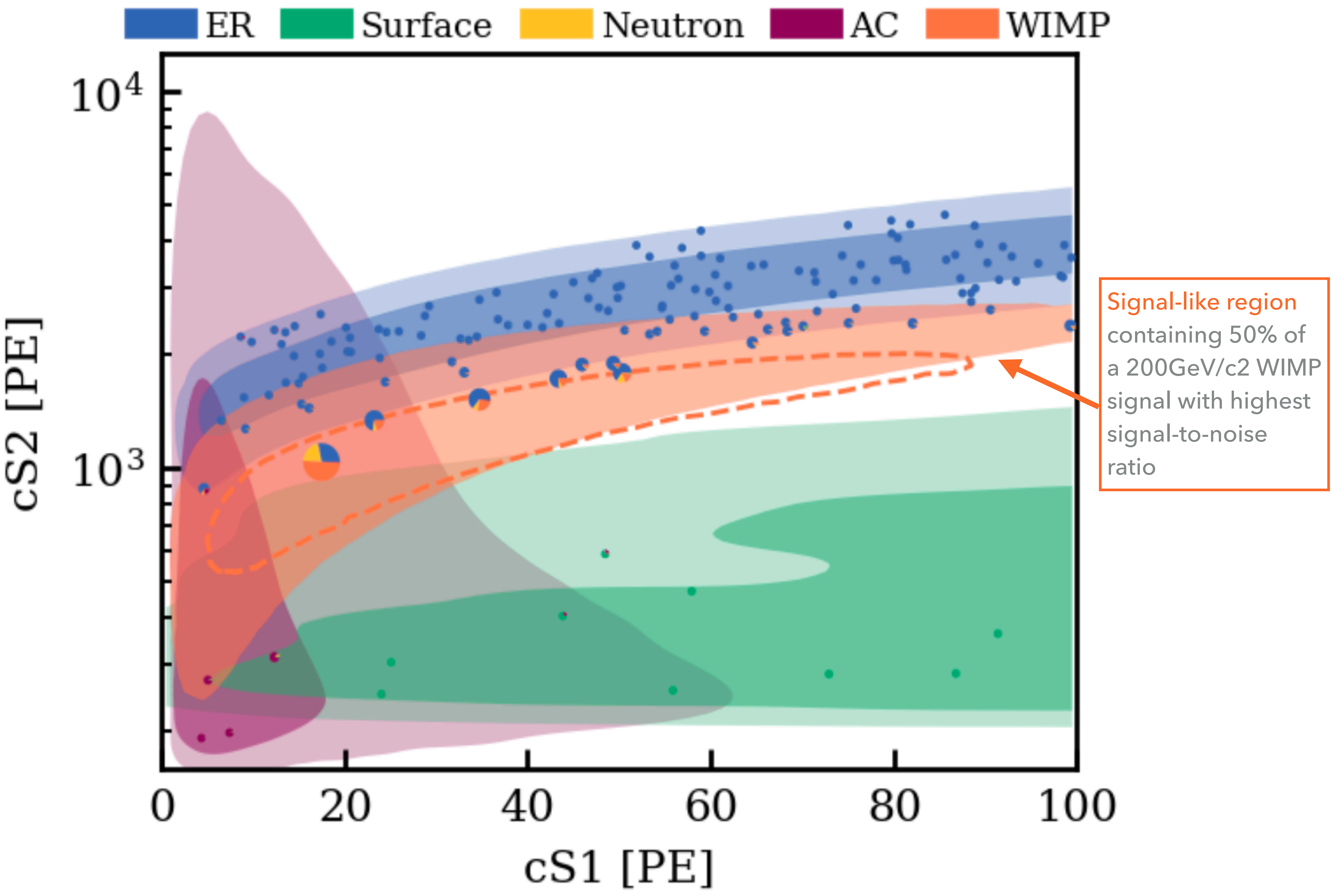
UNBLINDING NR SEARCH

- **No significant excess**

	Nominal	Best Fit	
	ROI		Signal-like
ER	134	135^{+12}_{-11}	0.92 ± 0.08
Neutrons	$1.1^{+0.6}_{-0.5}$	1.1 ± 0.4	0.42 ± 0.16
CEνNS	0.23 ± 0.06	0.23 ± 0.06	0.022 ± 0.006
AC	4.3 ± 0.9	$4.4^{+0.9}_{-0.8}$	0.32 ± 0.06
Surface	14 ± 3	12 ± 2	0.35 ± 0.07
Total Background	154	152 ± 12	$2.03^{+0.17}_{-0.15}$
WIMP	-	2.6	1.3
Observed	-	152	3

PRL 131, 041003 (2023)

152 events in NR/ER search region, 16 in NR blinded region



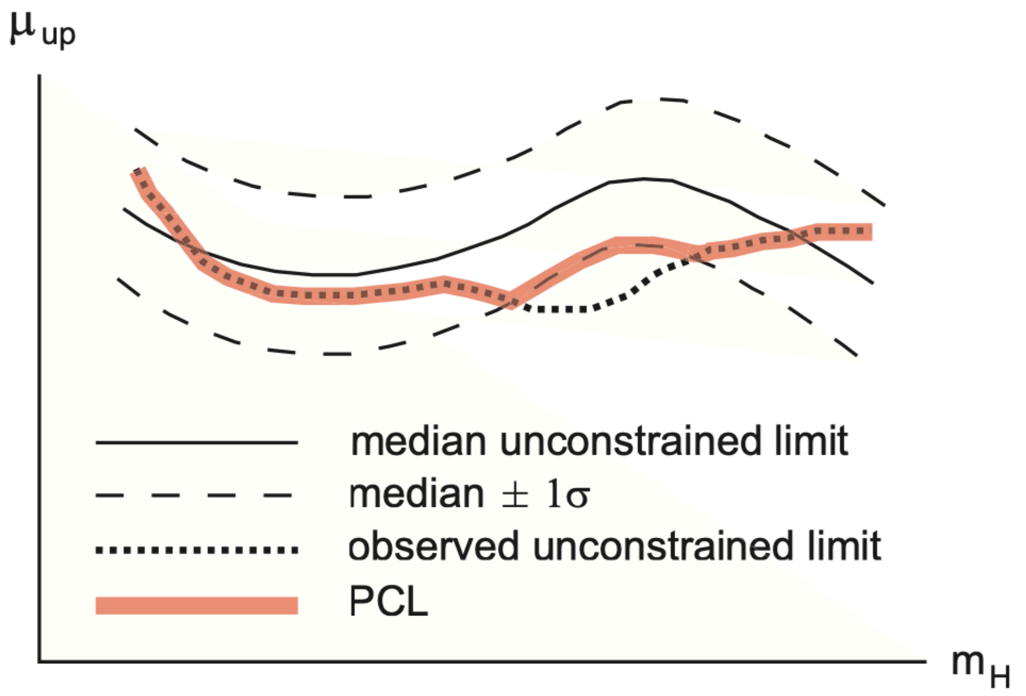
(Assuming there is WIMP!) Event represented with pie-chart showing the fraction of the best-fit PDF for a 200 GeV mass WIMP

LIMITS ON WIMP SI INTERACTION WITH NUCLEONS

- Median upper limit @ 90% confidence (Feldman-Cousin construction obtained by MC) for Log-Profiled-Likelihood-ratio

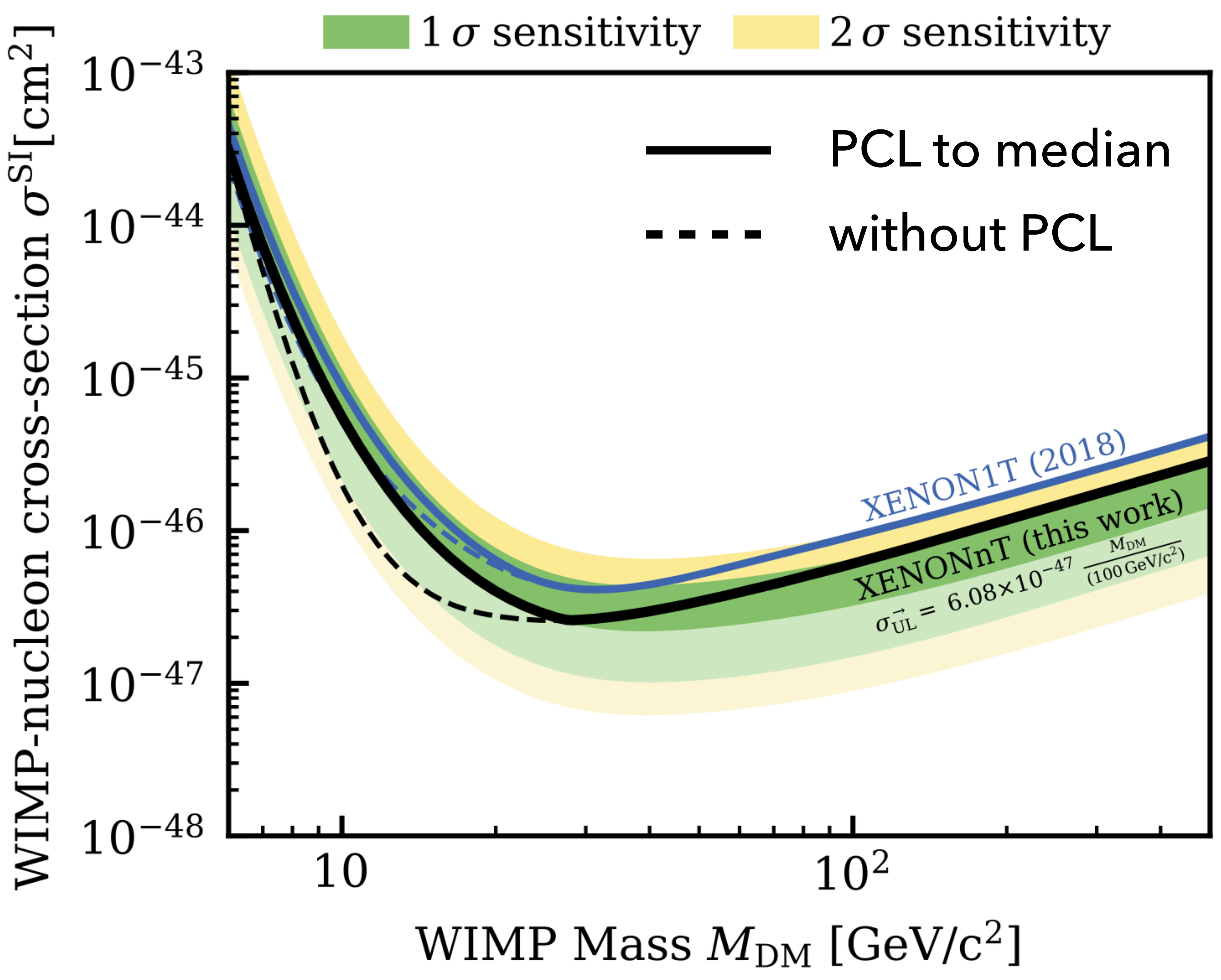
$$q(\sigma) = -2\log\frac{L(\sigma,\hat{\hat{\theta}})}{L(\hat{\sigma},\hat{\theta})}$$

- **Blinded WIMP dark matter search with 1.1 tonne-year exposure**



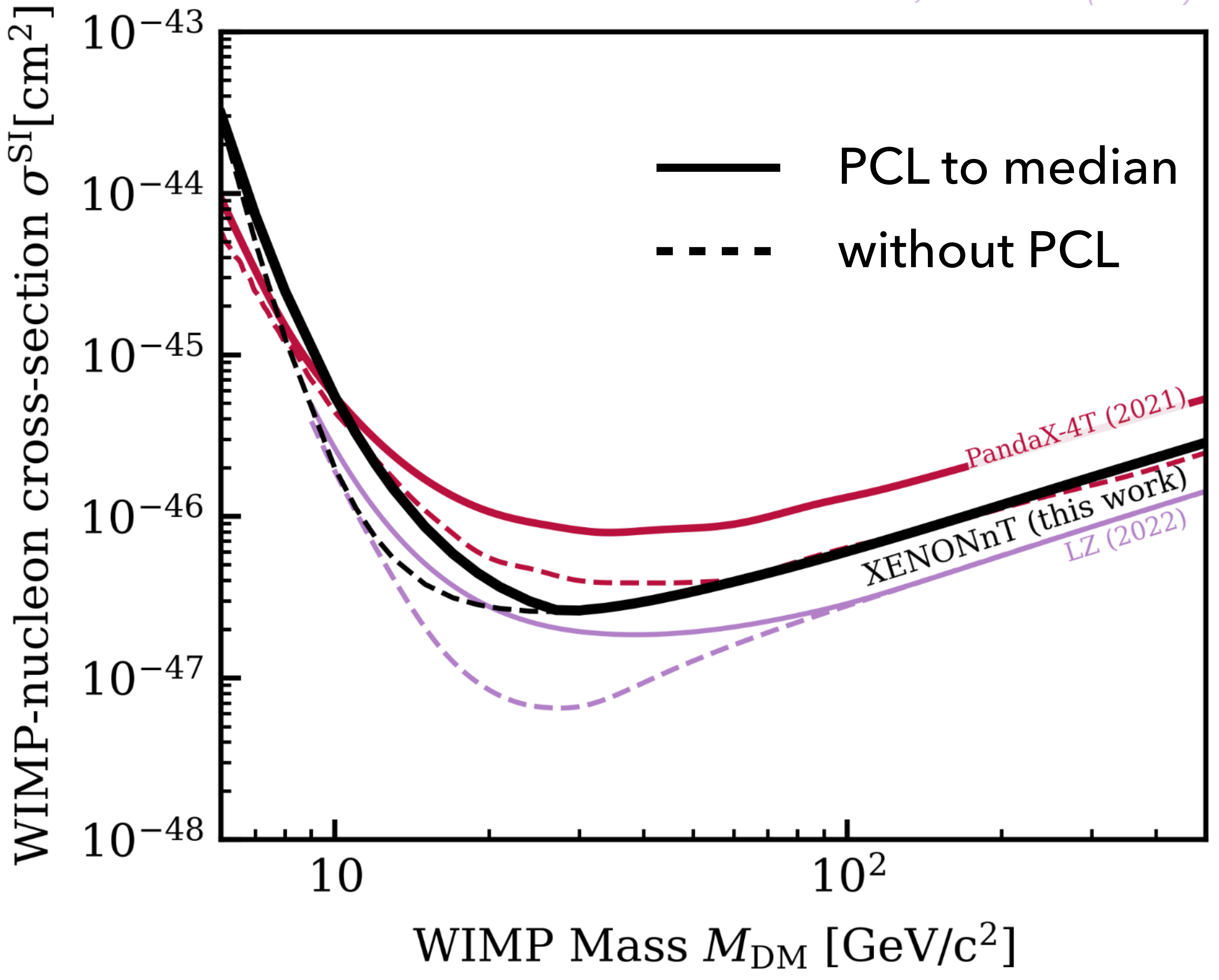
Power constraint limits (PCL) to avoid problematic spurious exclusion

arxiv:1105.3166.



Comparison to other **blinded** analysis

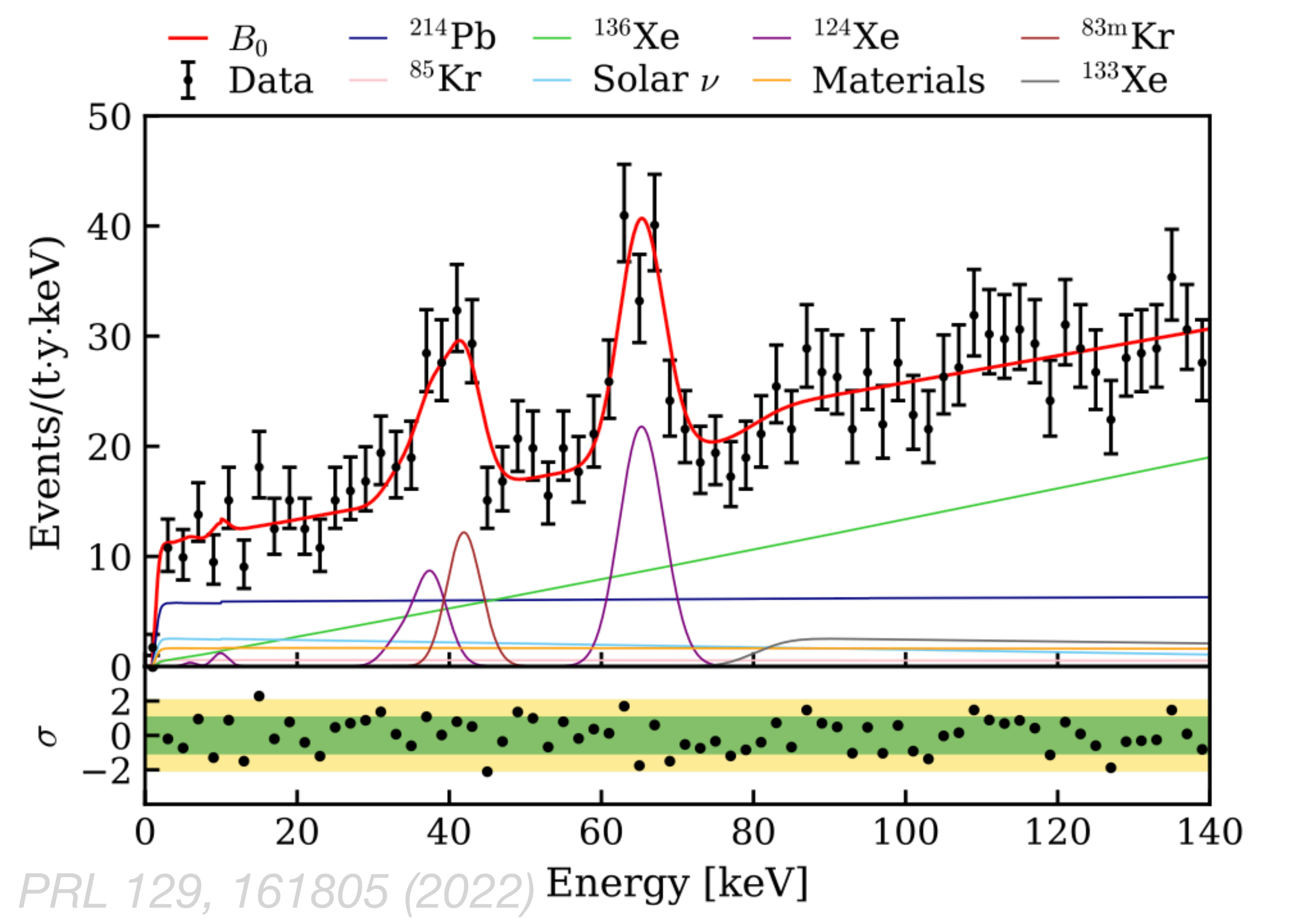
PRL 131, 041003 (2023)
PRL 121, 111302 (2020)
PRL 129, 161804 (2022)
PRL 131, 041002 (2023)



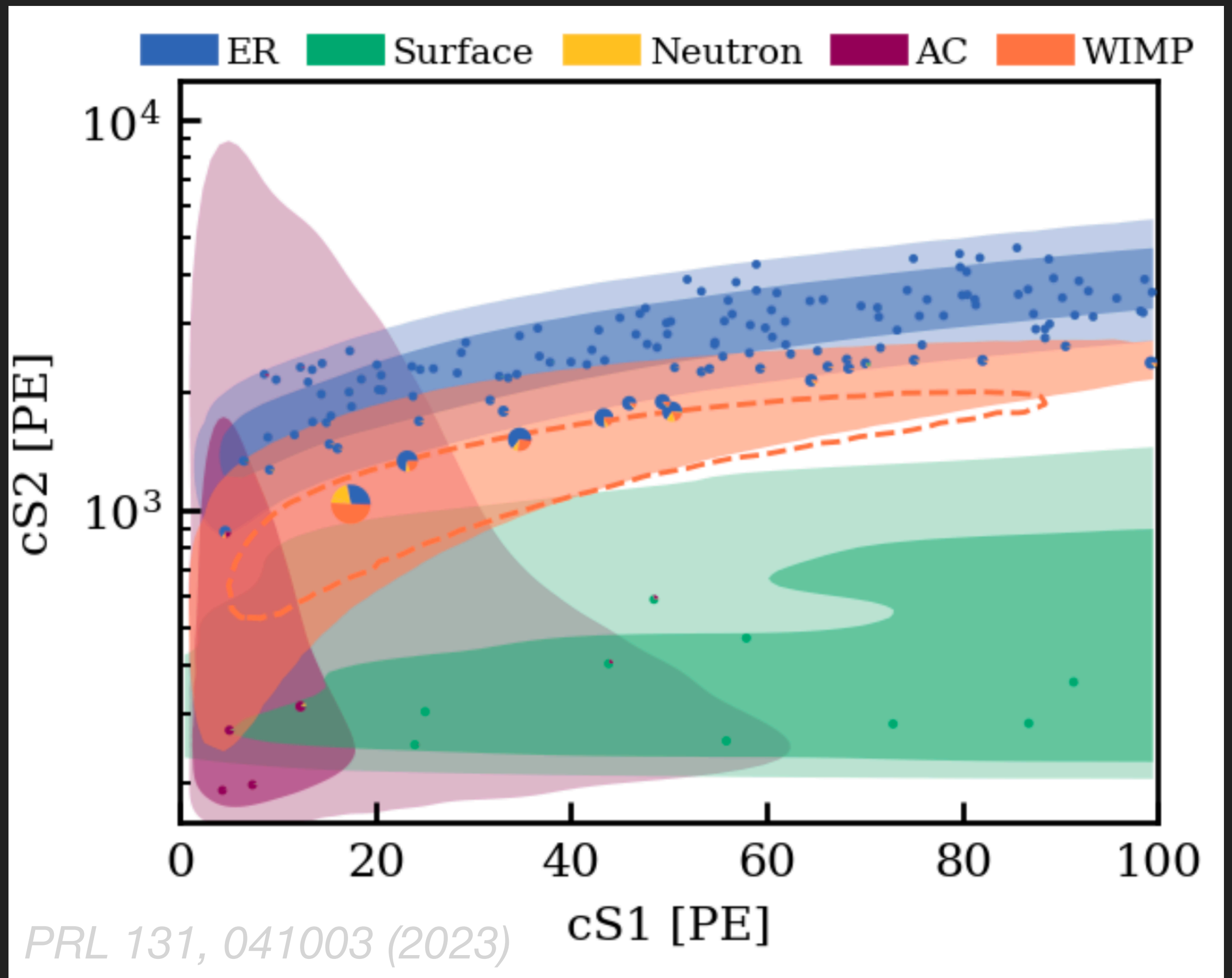
Comparison to other **unblinded** analysis

CONCLUSIONS AND OUTLOOK

- Blinded analysis of ER data with 1.1 tonne-year exposure
  - Excluded XENON1T excess
  - Unprecedented low ER background (15.8±1.3) events/(tonne·year·keV)
- Blinded WIMP dark matter search with same data in SR0
- SR1 data taking ongoing for many months
  - Further reduction of 222Rn content due to GXe + LXe radon distillation
  - Lower neutron background powered by Gd-loading NV
- Searches in other channels ongoing: S2-only, CEνNS…
- Next generation in preparation…



PRL 129, 161805 (2022)

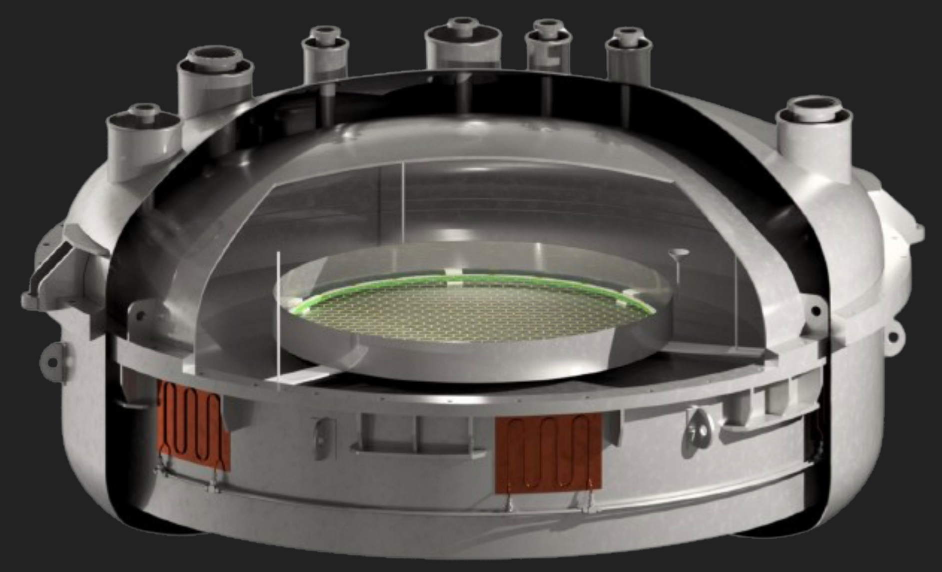


PRL 131, 041003 (2023)

DARWIN: TOWARDS THE ULTIMATE DARK MATTER DETECTOR

PRL 127, 251802 (2023)

- Main goal: to reach the "neutrino fog" with ~50t xenon
- R&D: full scale demonstrators in progress
- Consortium merging DARWIN/XENON/LZ: XLZD

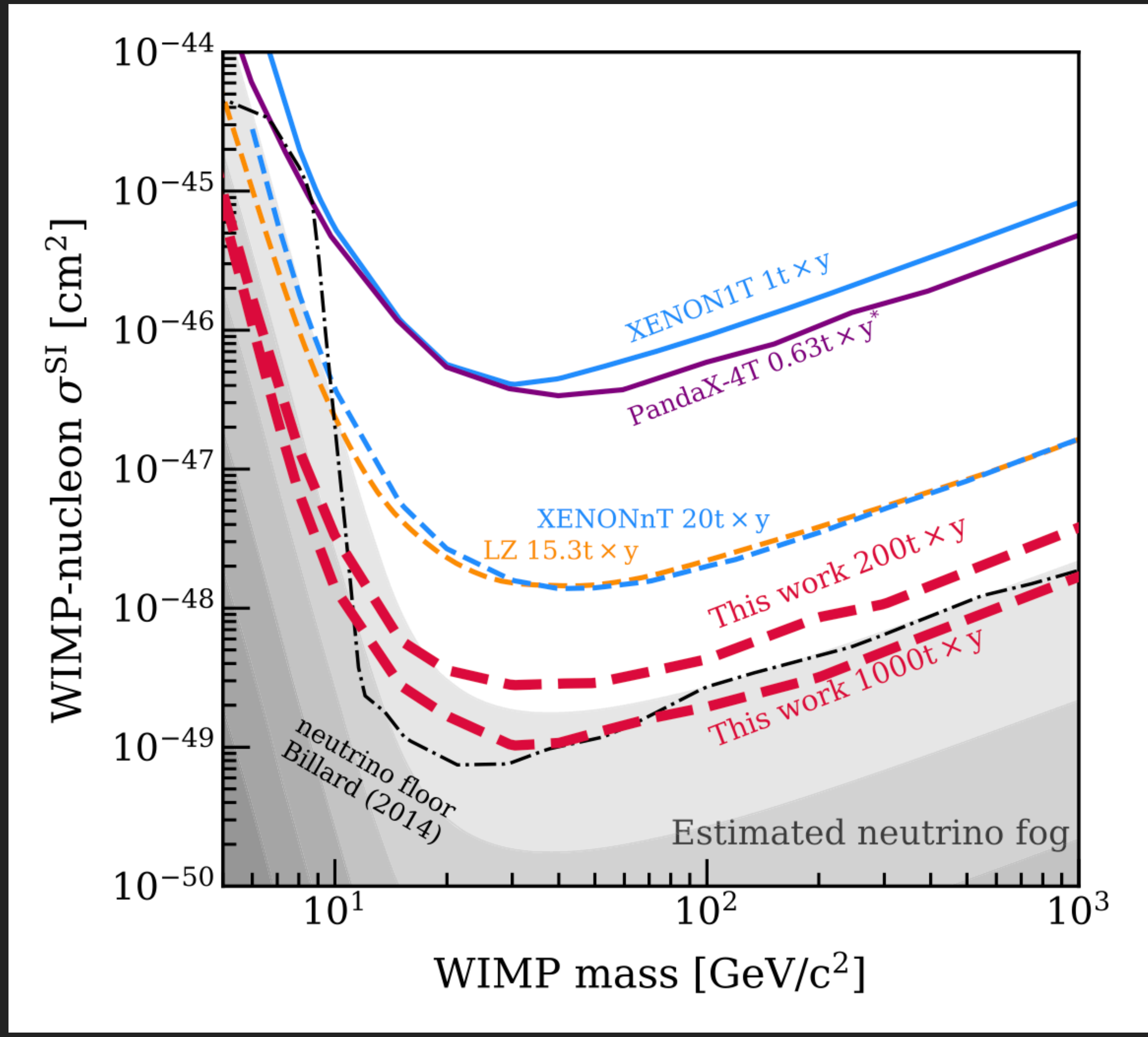


PANCAKE at University of Freiburg: 2.75m diameter

arxiv:2312.14785

Xenonscope at University of Zurich: 2.6m drift length

JINST 16 P08052 (2021)



The shaded gray area indicates the 'neutrino fog', specifically where more than 1, 10, 100, etc neutrino events are expected in the 50% most signal-like S1/S2 region.

J. Phys. G: Nucl. Part. Phys. 50 013001 (2023)

QUESTIONS?

xenonexperiment.org

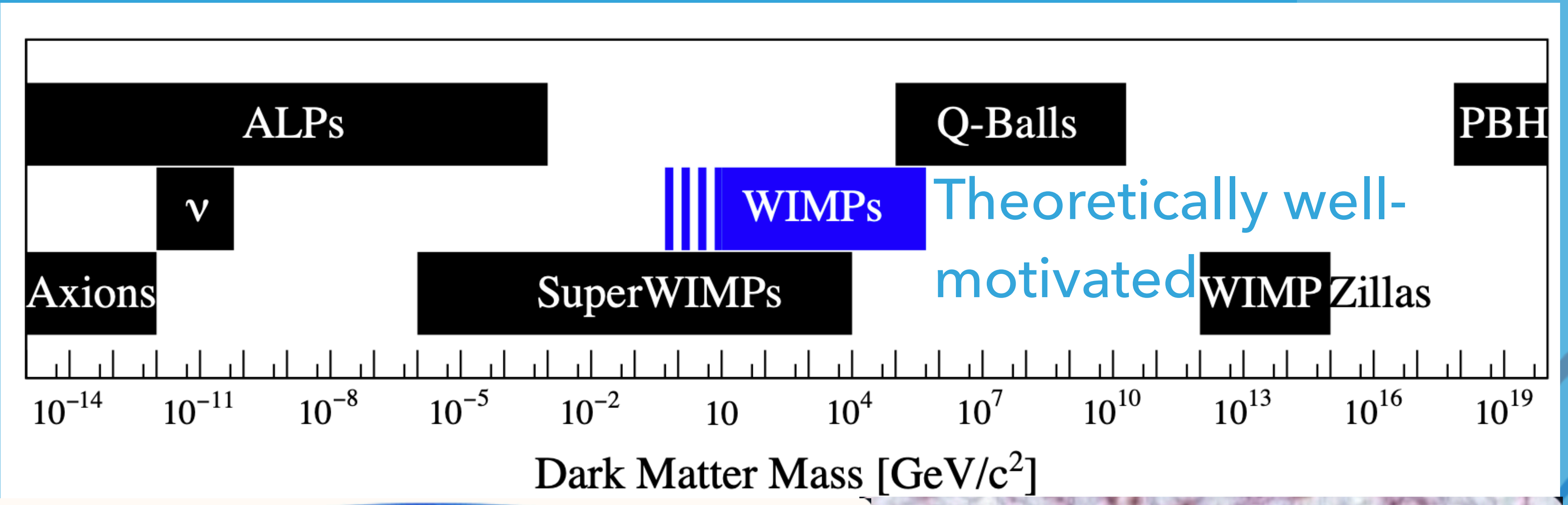
@XENONexperiment

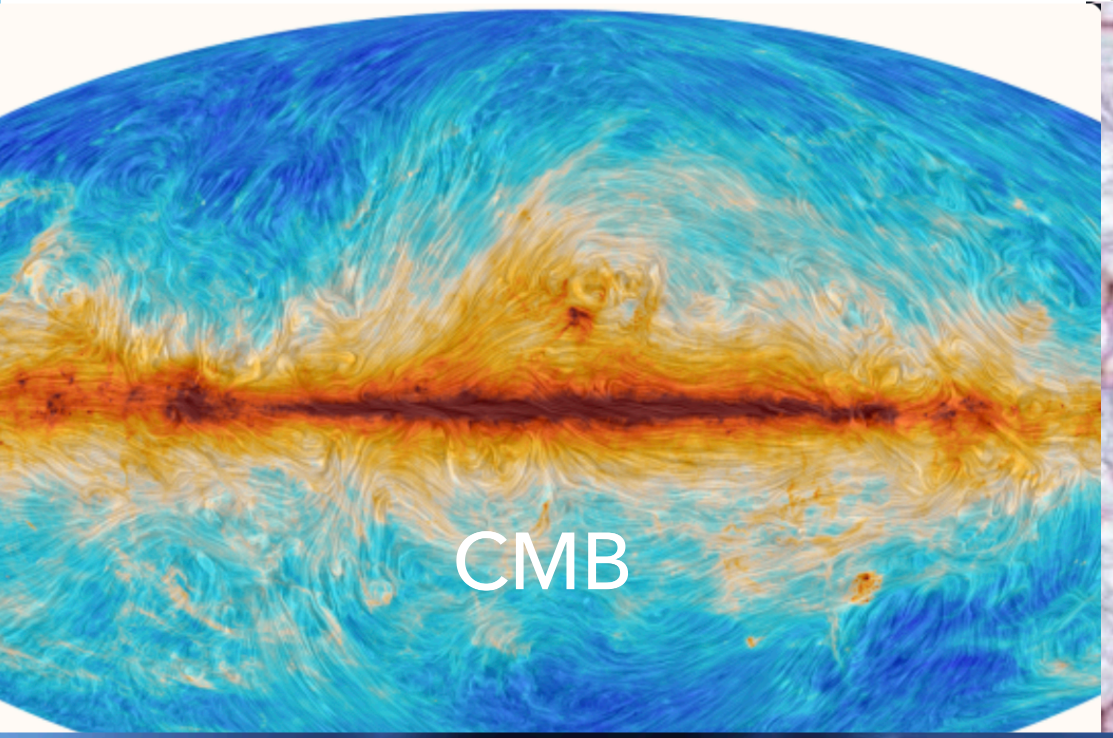
@xenon_experiment

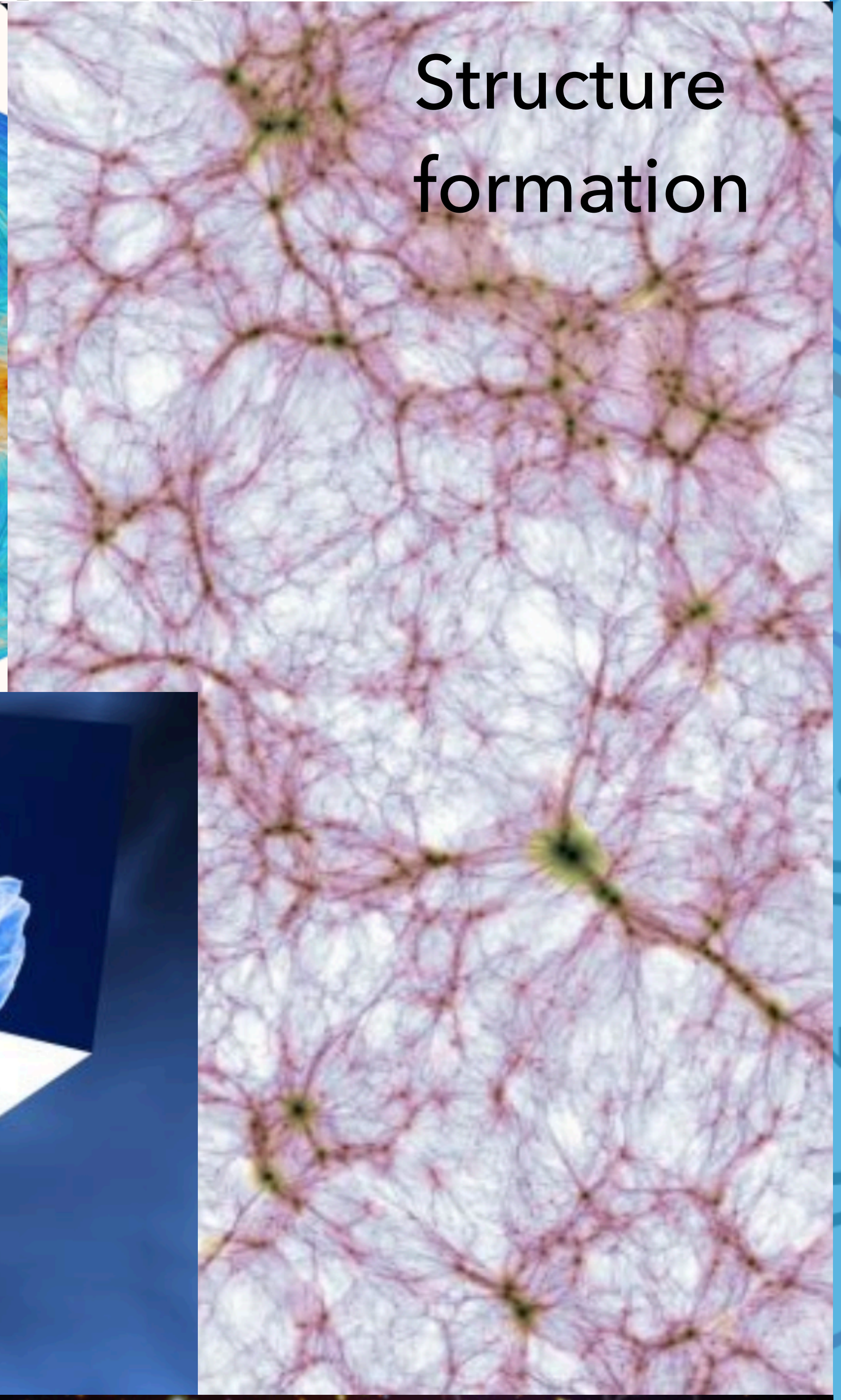
@XENONexperiment

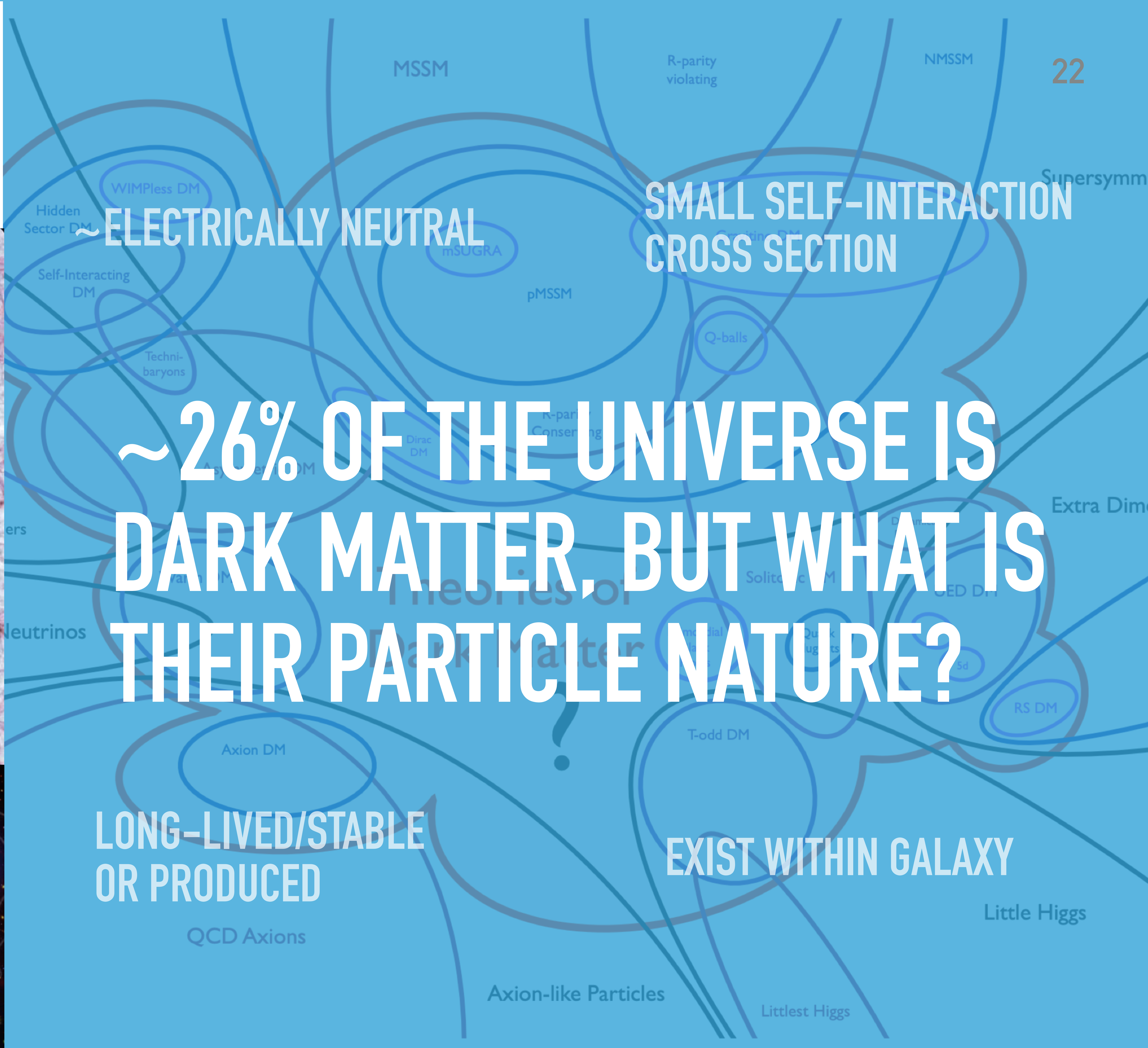
XENON

BACKUP









~ELECTRICALLY NEUTRAL

SMALL SELF-INTERACTION CROSS SECTION

~26% OF THE UNIVERSE IS DARK MATTER, BUT WHAT IS THEIR PARTICLE NATURE?

LONG-LIVED/STABLE OR PRODUCED

EXIST WITHIN GALAXY

DIRECT DETECTABILITY OF DARK MATTER

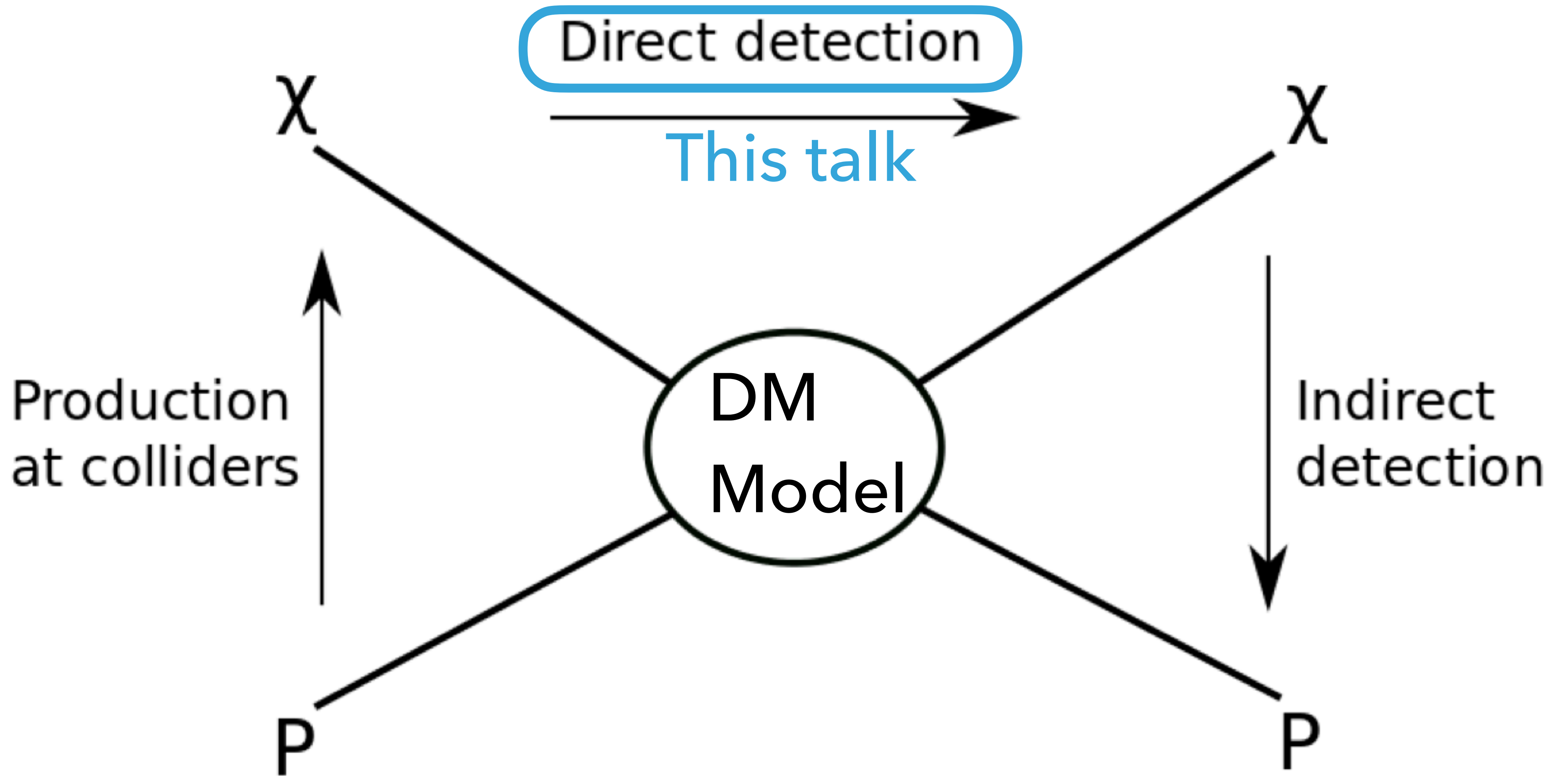
- Direct Detection: record the rare occasions that particle DM scatters off a target material

PHYSICAL REVIEW D VOLUME 31, NUMBER 12 15 JUNE 1985

Detectability of certain dark-matter candidates

Mark W. Goodman and Edward Witten
Joseph Henry Laboratories, Princeton University, Princeton, New Jersey 08544
(Received 7 January 1985)

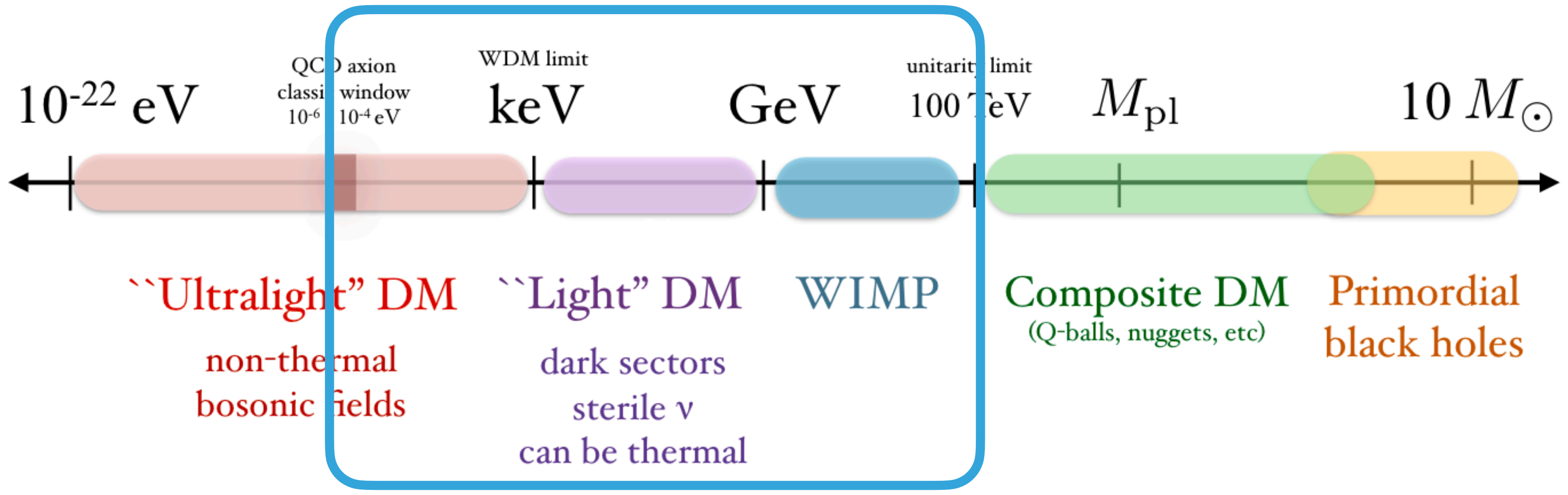
We consider the possibility that the neutral-current neutrino detector recently proposed by Drukier and Stodolsky could be used to detect some possible candidates for the dark matter in galactic halos. This may be feasible if the galactic halos are made of particles with coherent weak interactions and masses $1-10^6$ GeV; particles with spin-dependent interactions of typical weak strength and masses $1-10^2$ GeV; or strongly interacting particles of masses $1-10^{13}$ GeV.



DIRECT DETECTABILITY OF DARK MATTER

- WIMP: Supersymmetry
- Axion: strong CP problem

This talk



- Direct Detection: record the rare occasions that particle DM scatters off a target material
- Differential rate per unit target mass:

number of target per unit target mass

DM-SM scattering cross section

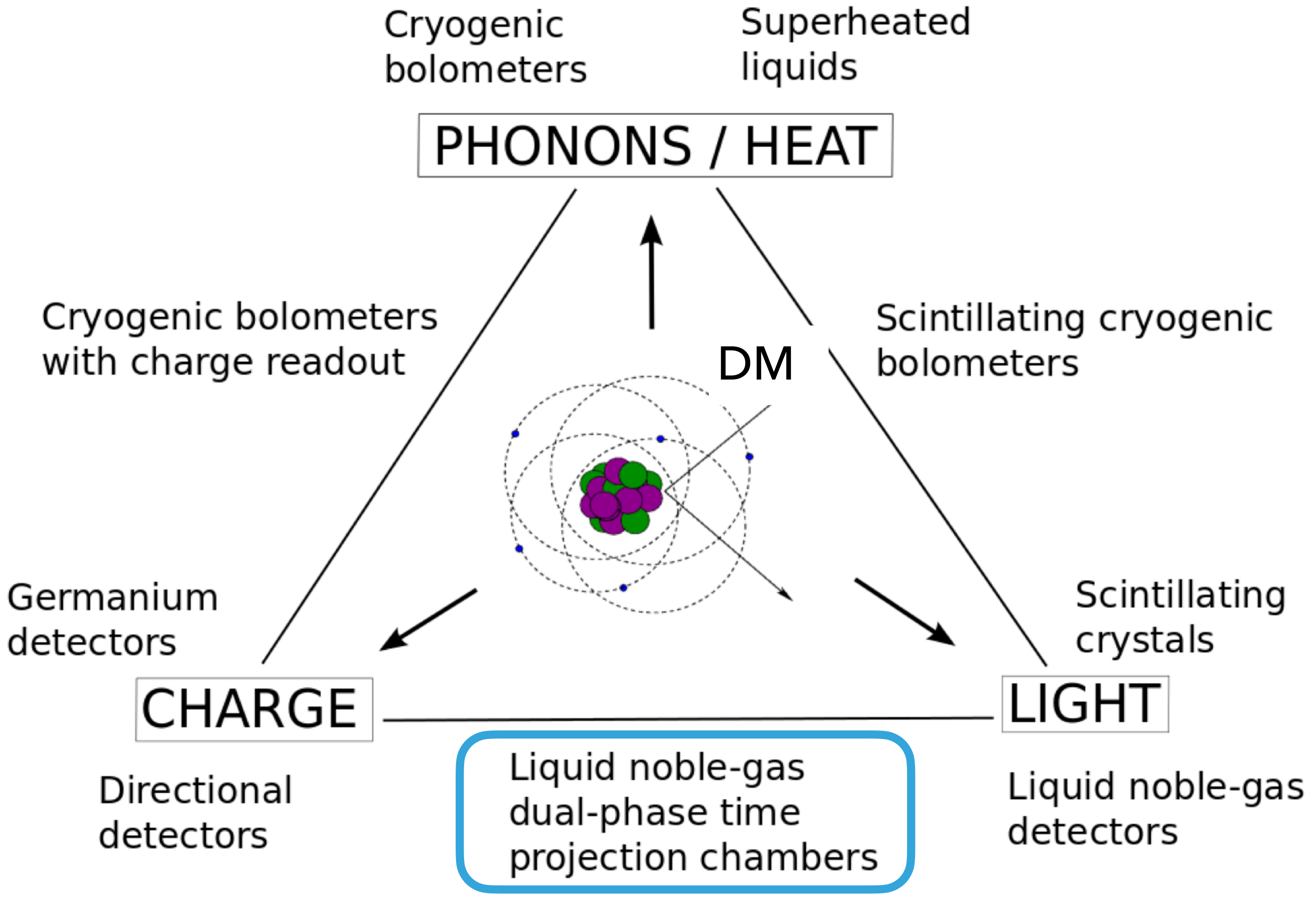
Want to measure this!

$$\frac{dR}{dE_R} = N_T n_\chi \int \boxed{\frac{d\sigma}{dE_R}} v f(\mathbf{v})\, d^3\mathbf{v}$$

Recoil energy spectrum

DM number density

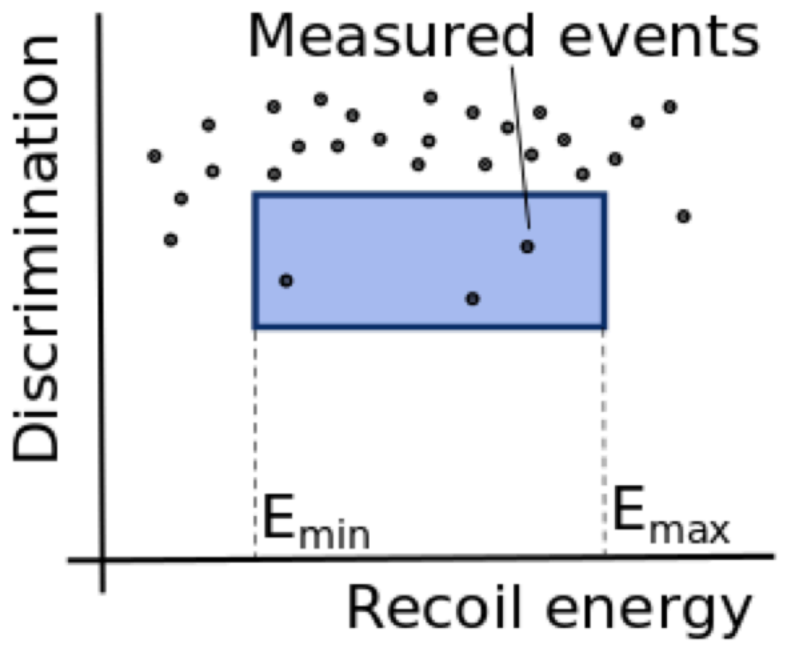
DM velocity distribution

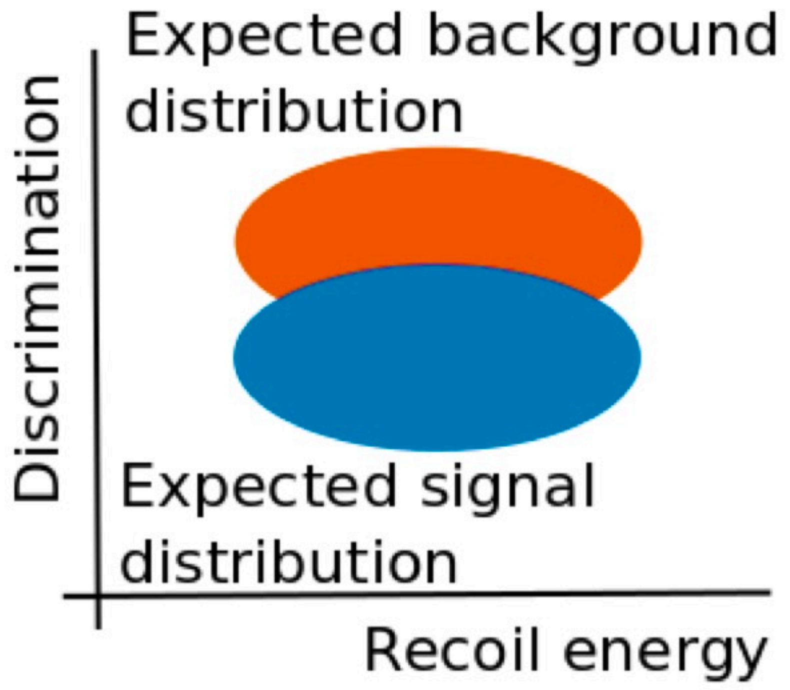


This talk

RESULT OF A DIRECT DETECTION EXPERIMENT (WITH DISCOVERY POWER)

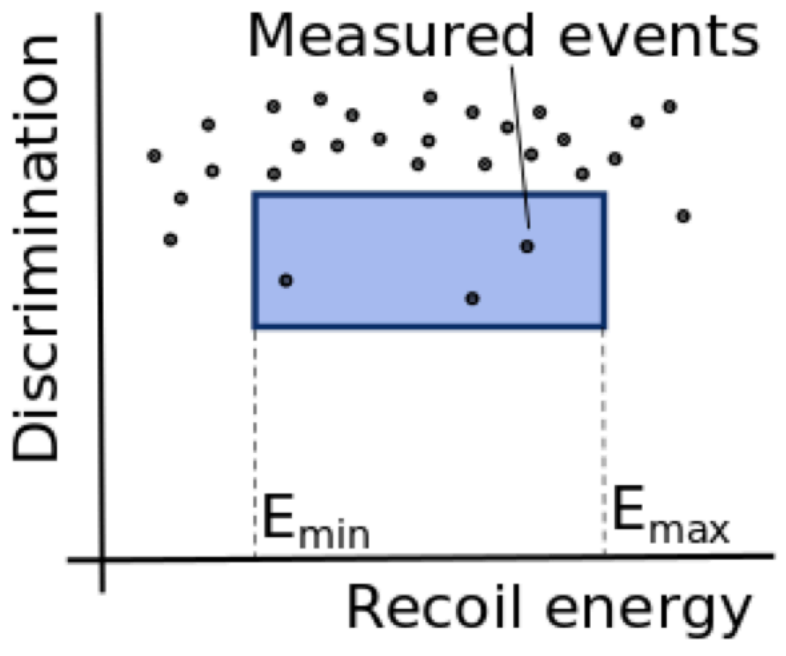
- "Counting experiment"
  - Select a signal region where the ratio of signal to expected background is high
  - Estimate the background in search space

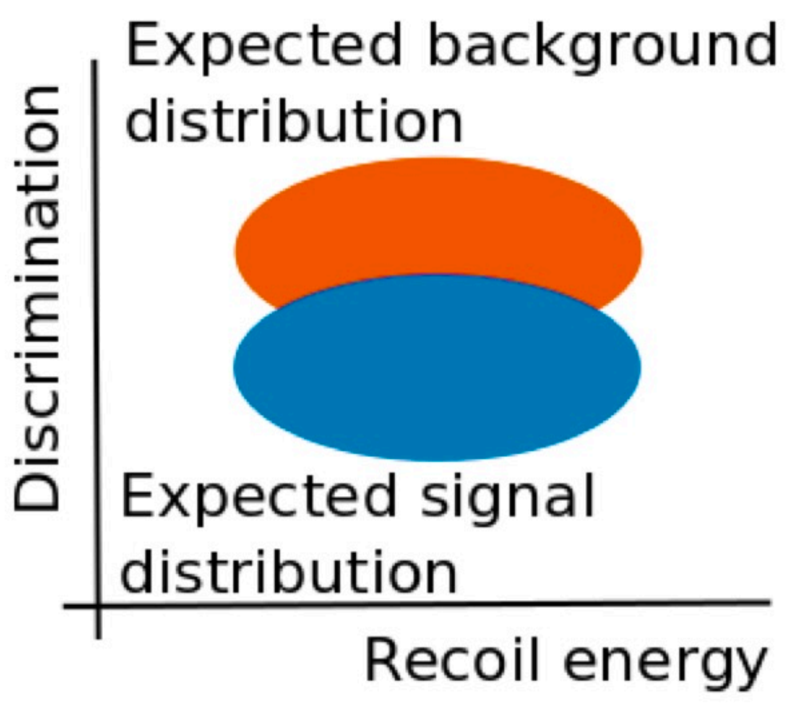


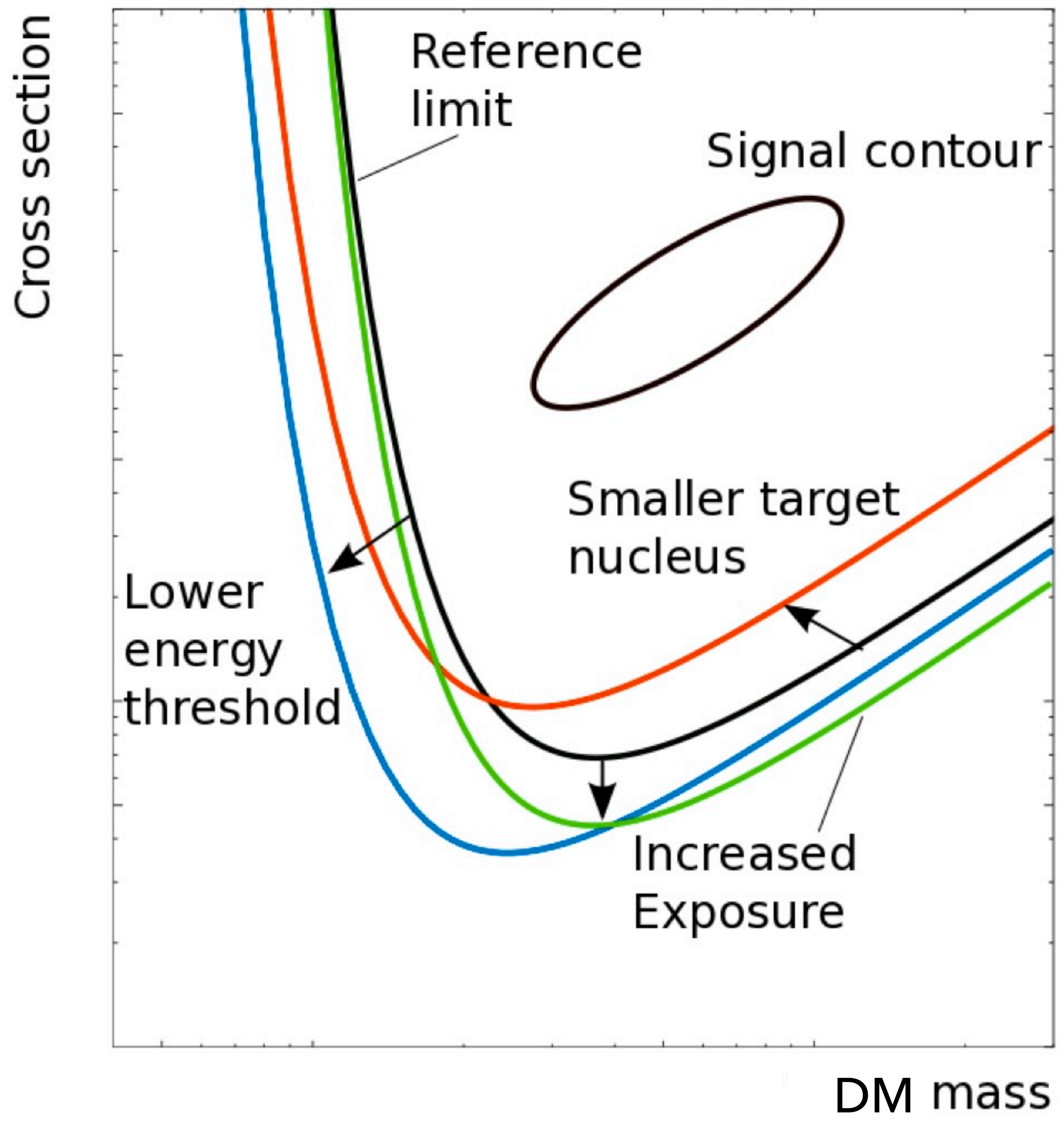


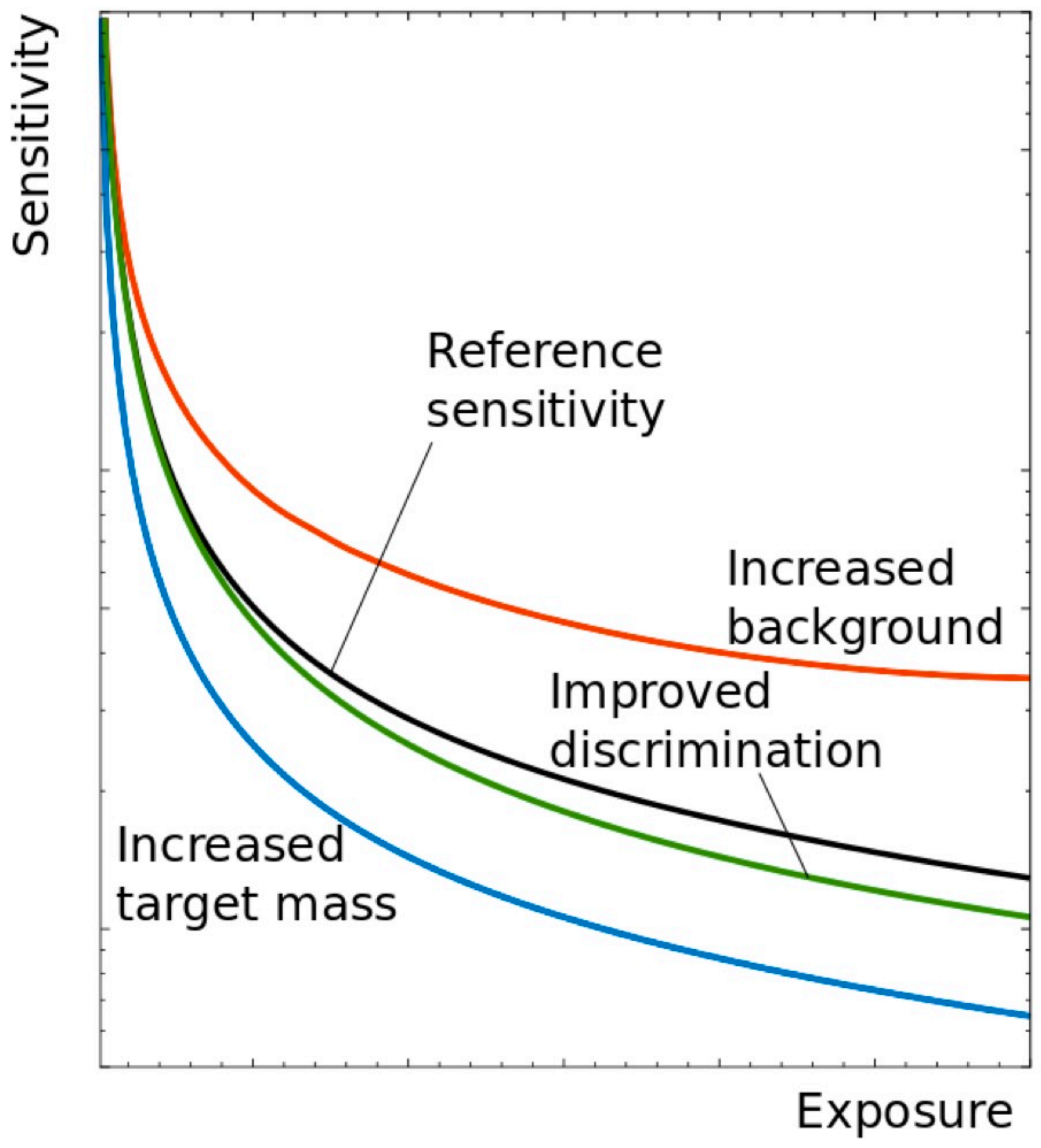
RESULT OF A DIRECT DETECTION EXPERIMENT (WITH DISCOVERY POWER)

- "Counting experiment"
  - Select a signal region where the ratio of signal to expected background is high
  - Estimate the background in search space
- **Two most important tasks**
  - **Understand how signals and background look like**
  - **Discriminate background events in search region**



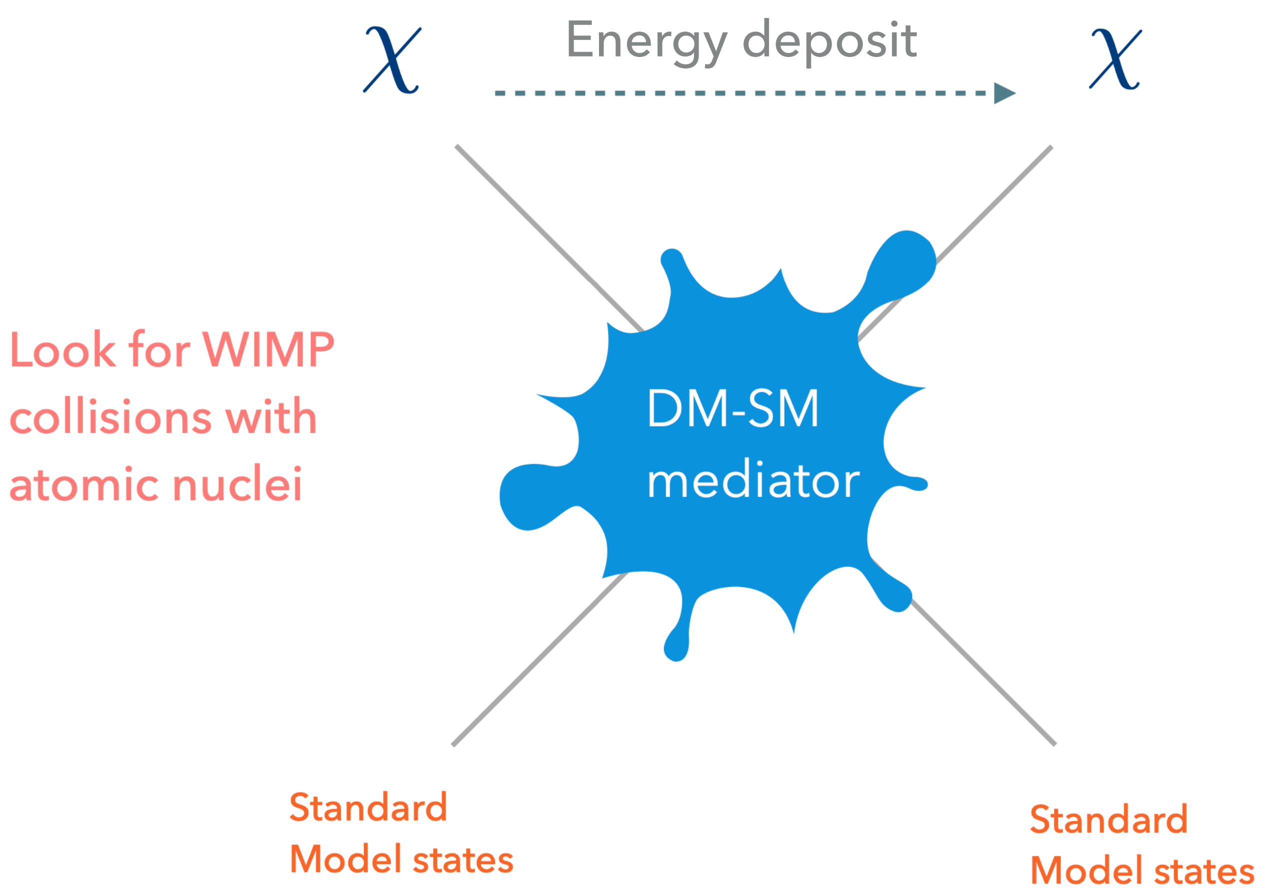


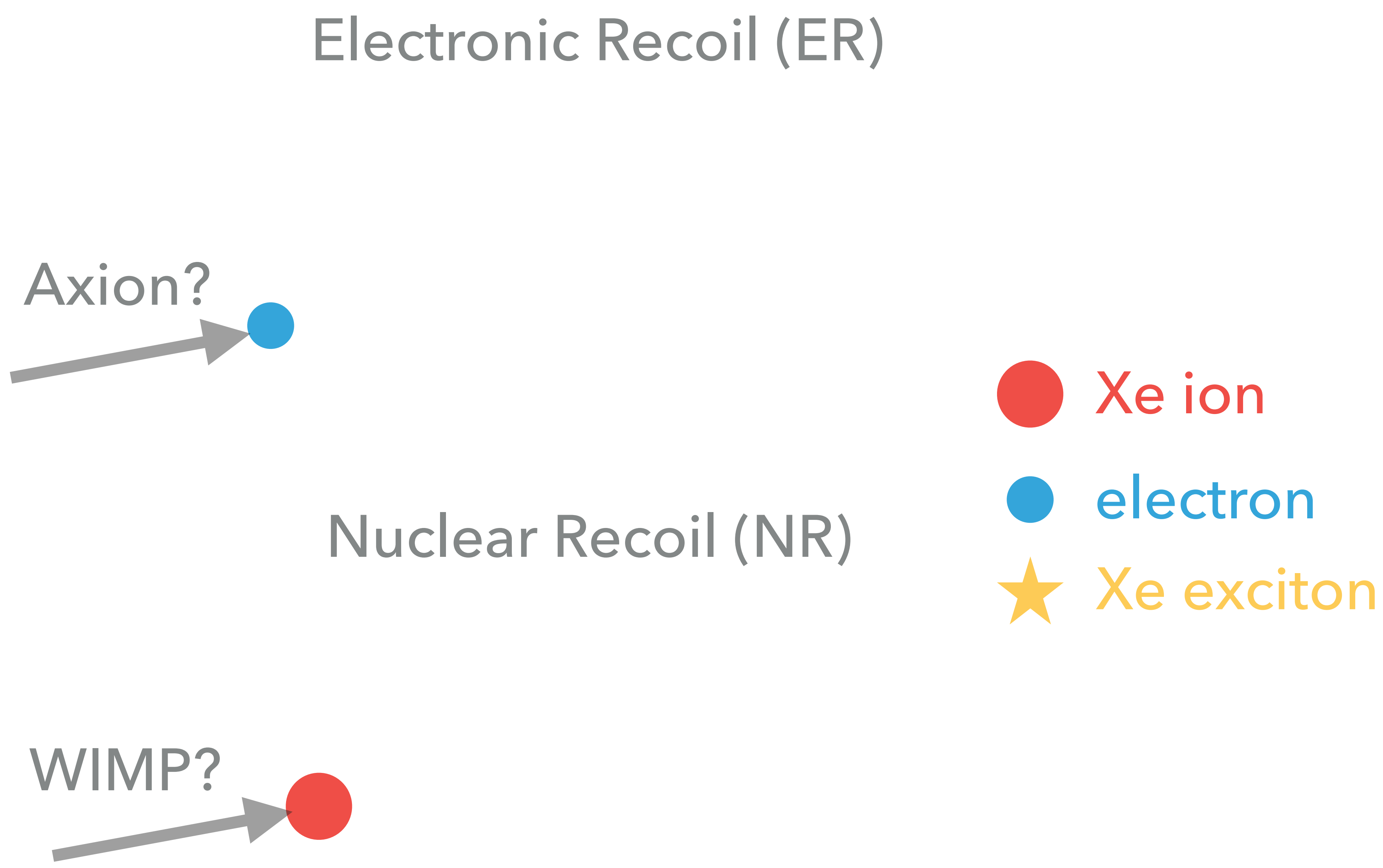




EXAMPLE DETECTOR: OBSERVABLE SIGNALS IN XENON

- **Incident particles (including DM) deposit energy via some mediator into xenon atom**





EXAMPLE DETECTOR: OBSERVABLE SIGNALS IN XENON

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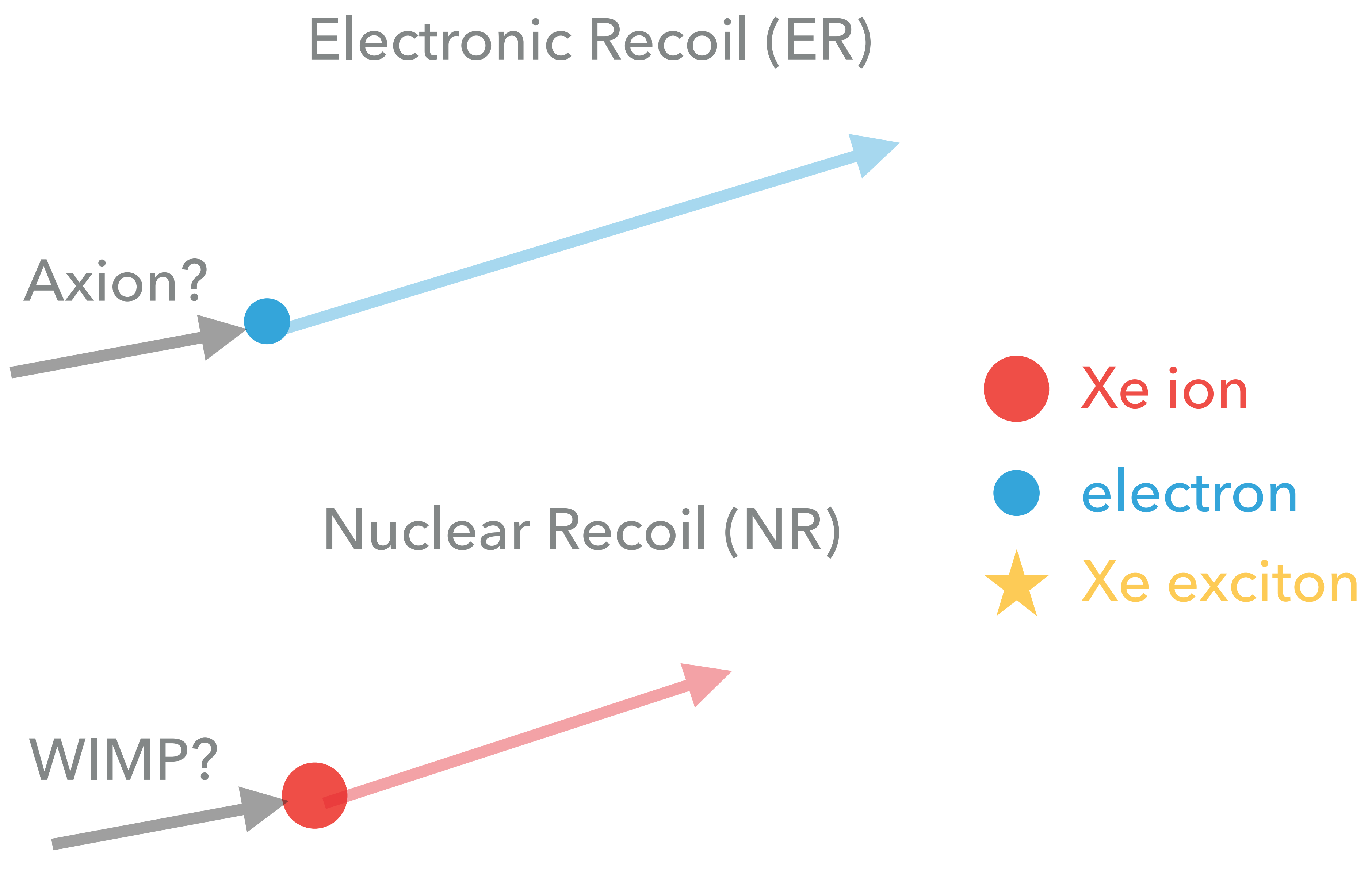
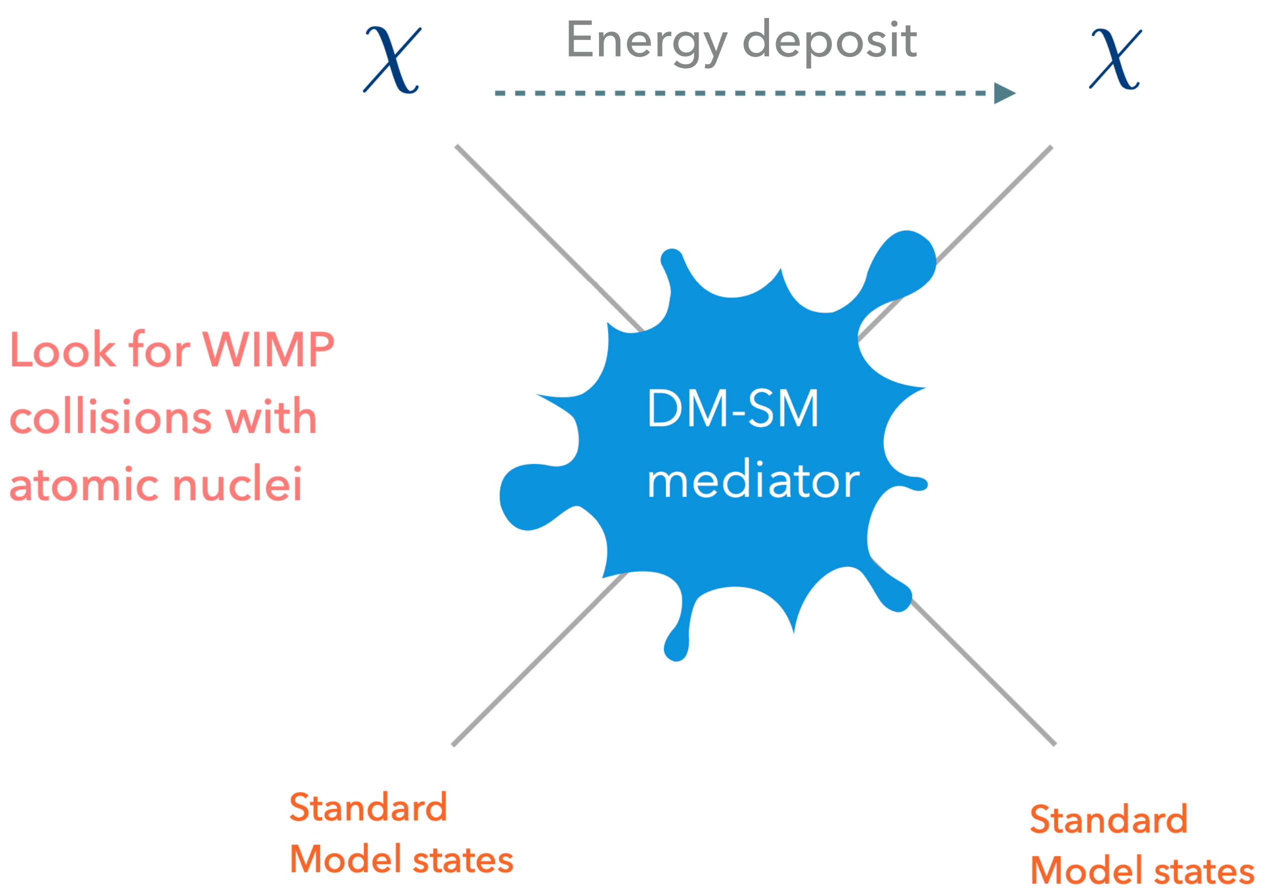
- **Initial interaction leads to either recoiled xenon ion or electron**





EXAMPLE DETECTOR: OBSERVABLE SIGNALS IN XENON

- Incident particles (including DM) deposit energy via some mediator into xenon atom
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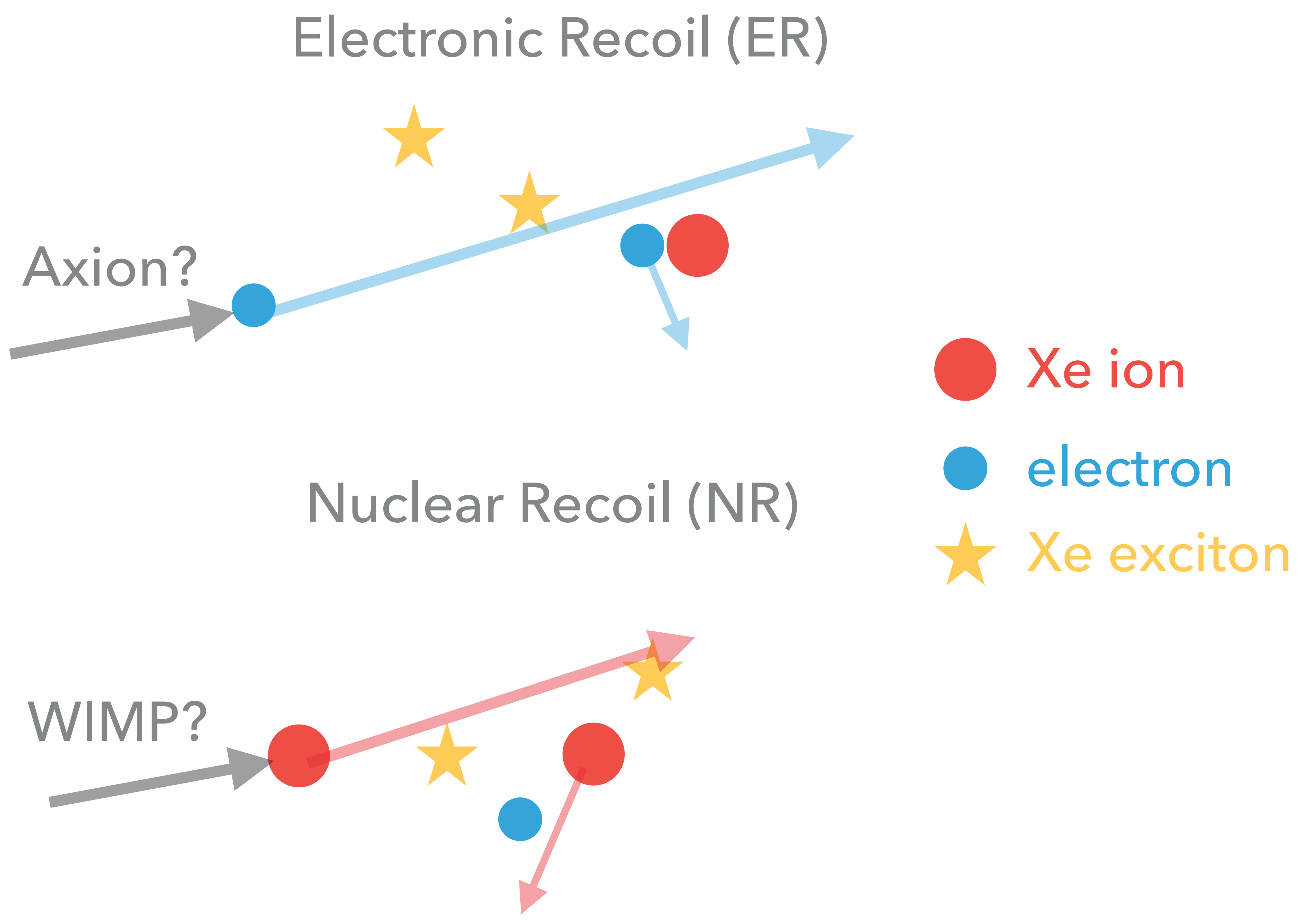
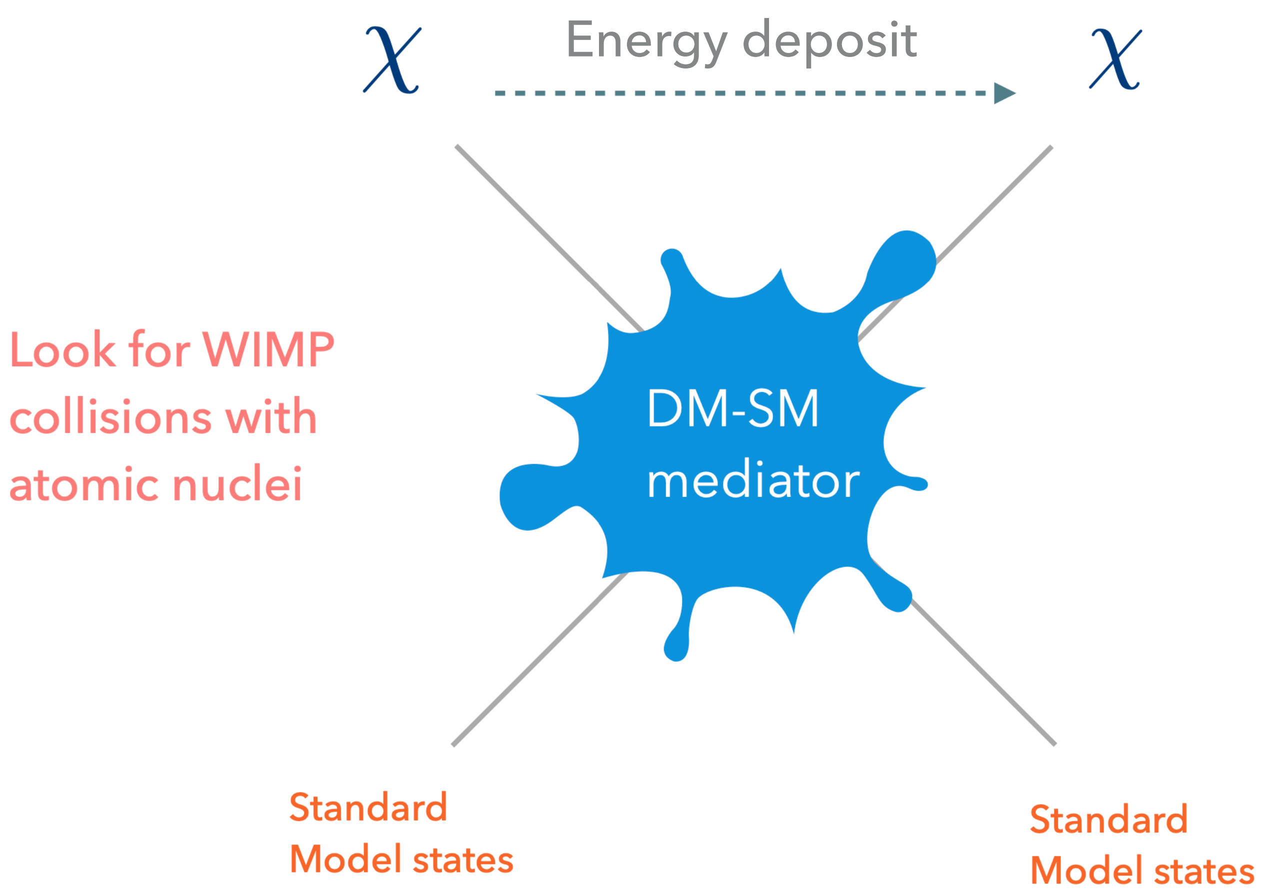
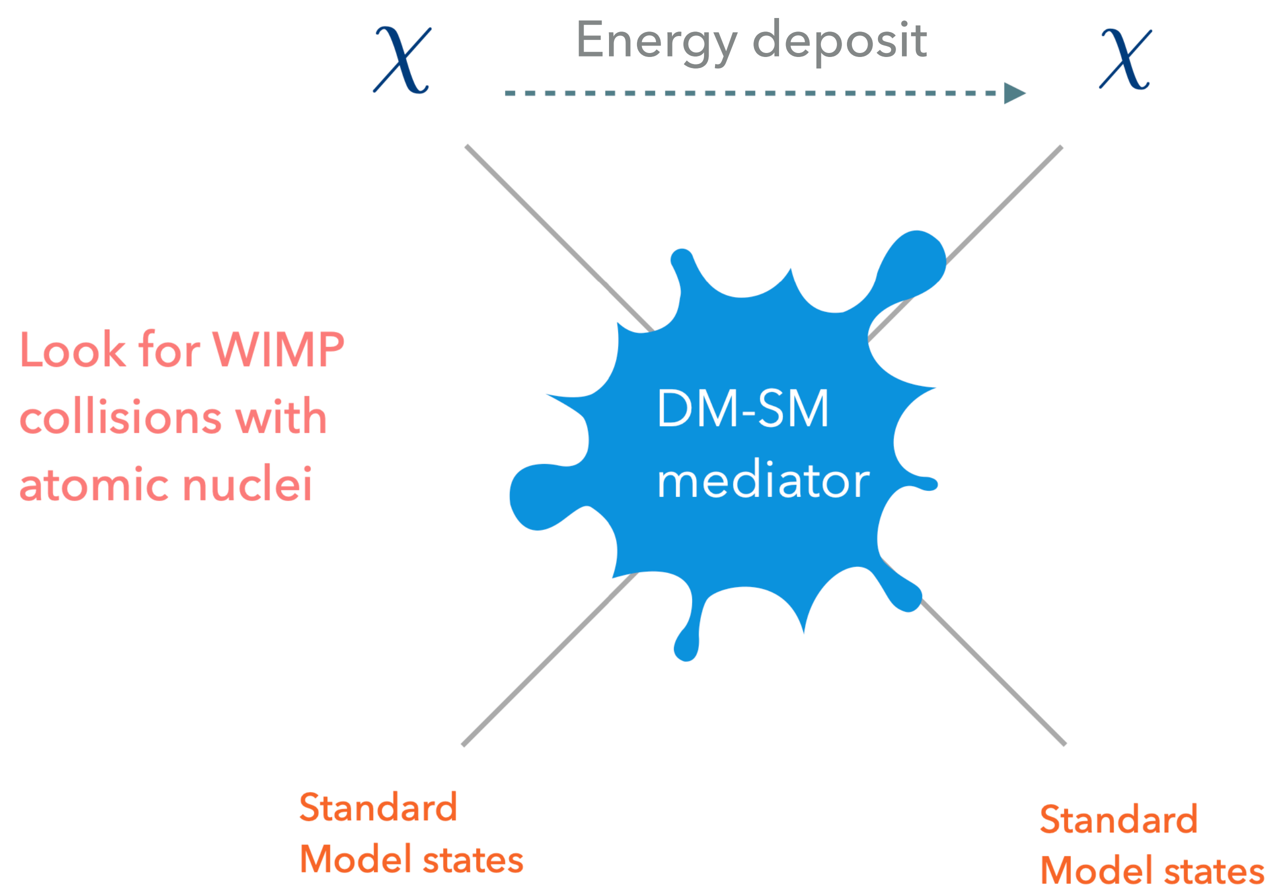
- **The recoiled ion/electron scatter intensely with other xenon atoms, leading to either ionization or excitation**

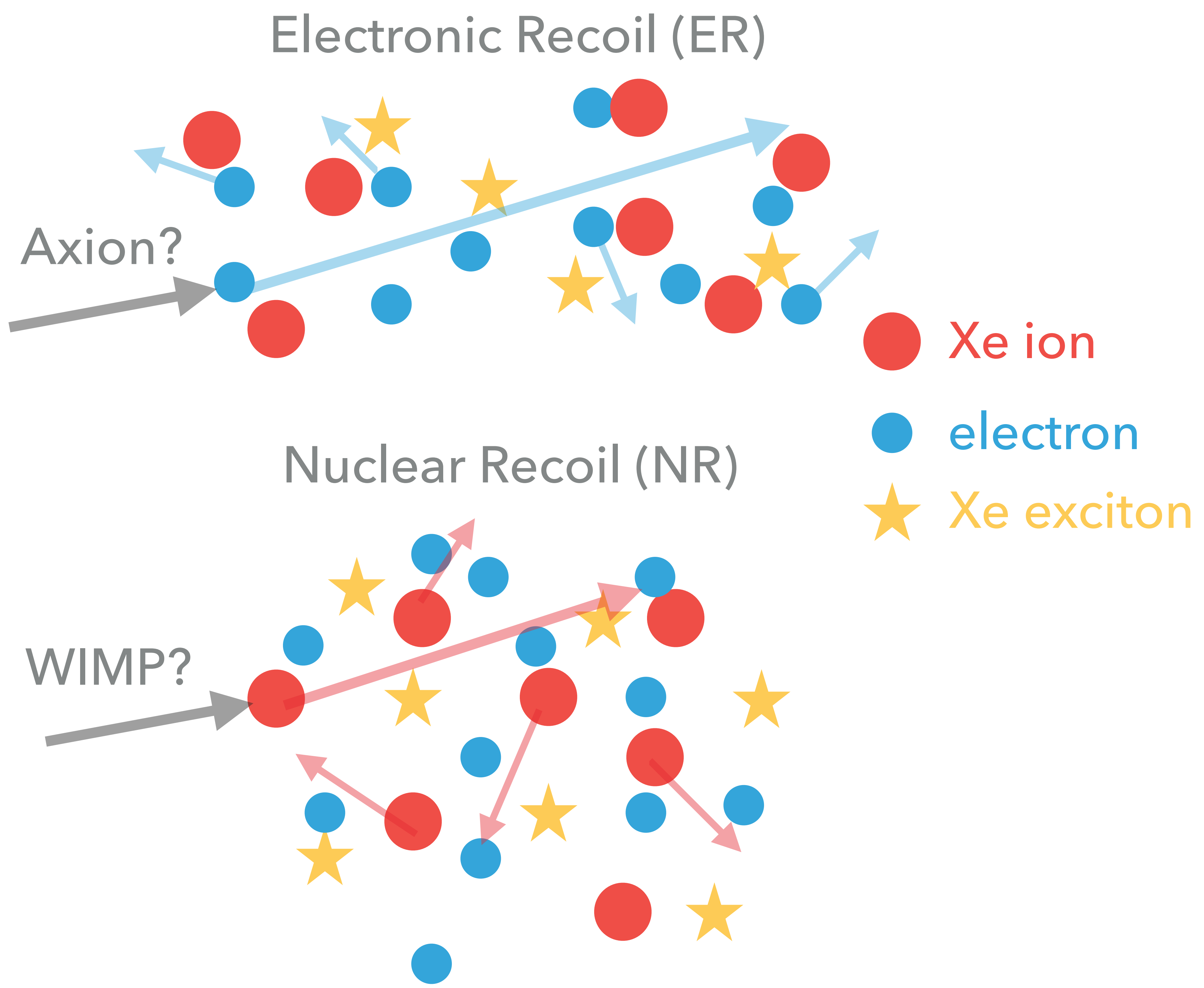




EXAMPLE DETECTOR: OBSERVABLE SIGNALS IN XENON

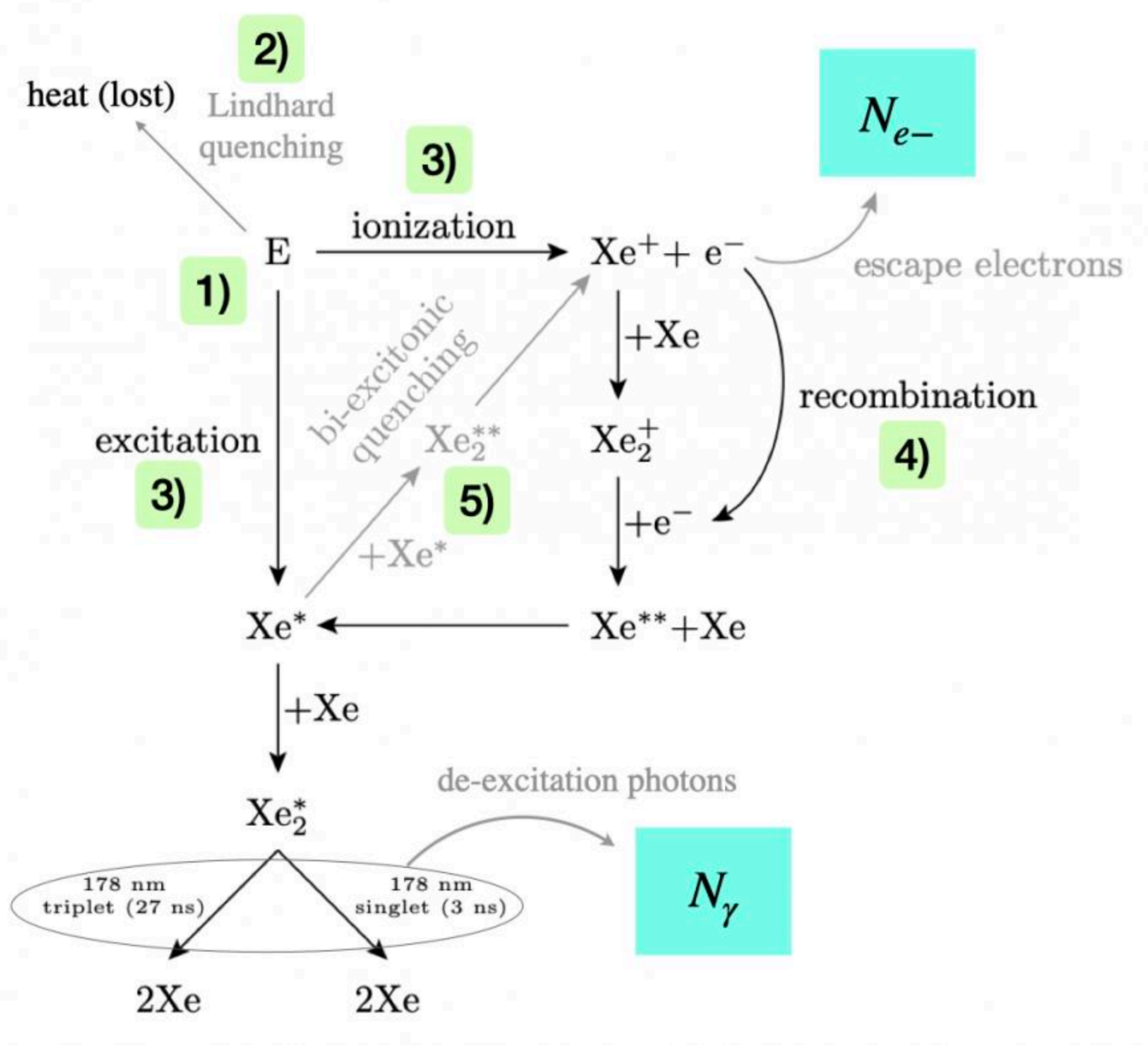
- Incident particles (including DM) deposit energy via some mediator into xenon atom
- Initial interaction leads to either recoiled xenon ion or electron
- The recoiled ion/electron scatter intensely with other xenon atoms, leading to either ionization or excitation
- **Iterate processes above with incident particle replaced by secondary particles (either electron or xenon ion)**

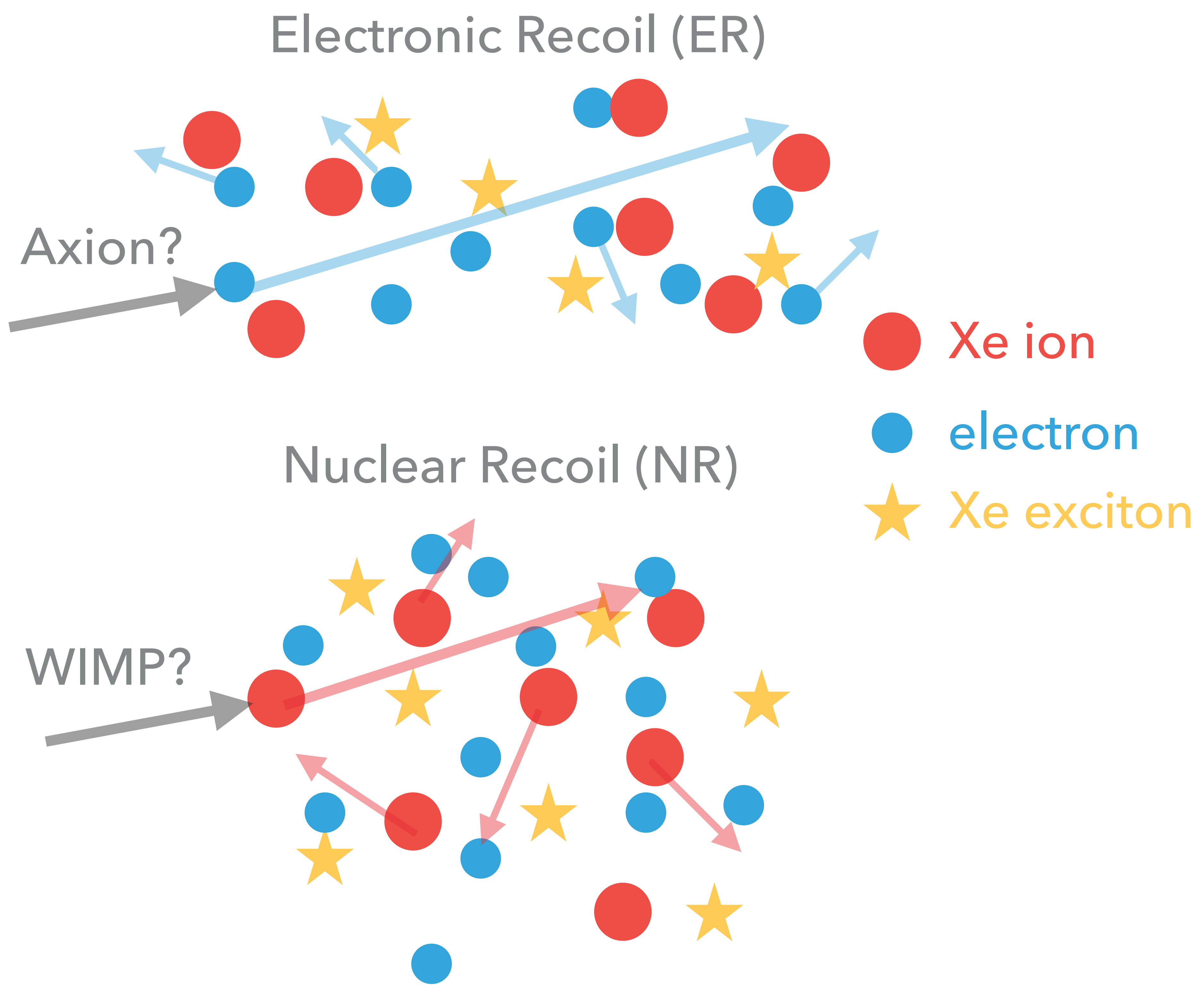




Different ratio of excitation/ion in NR/ER & density/shape of tracks thus recombination ratio → Discrimination power for NR/ER

EXAMPLE DETECTOR: OBSERVABLE SIGNALS IN XENON





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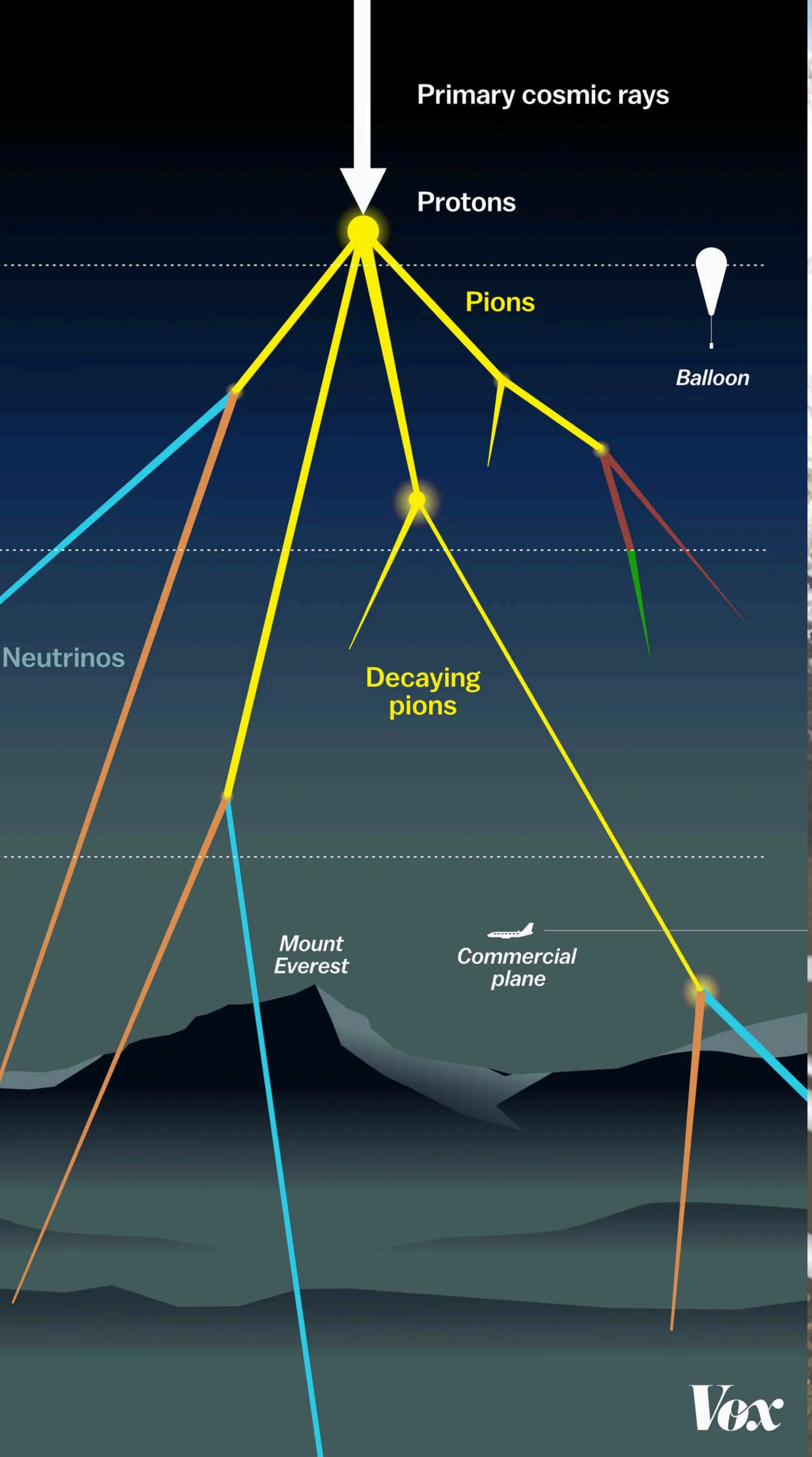
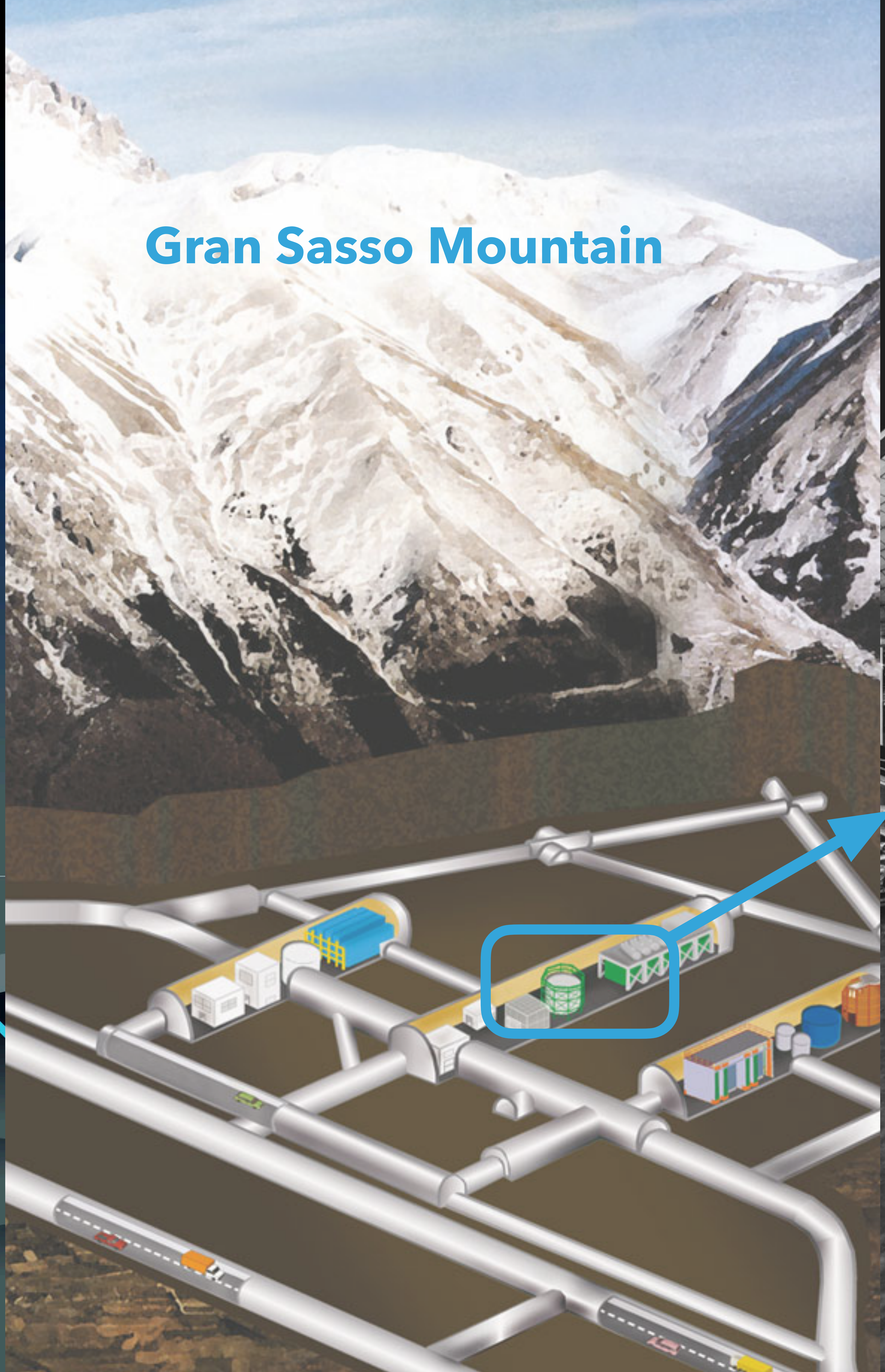


Primary cosmic rays
Protons
Pions
Balloon
Neutrinos
Decaying pions
Mount Everest
Commercial plane
Vox

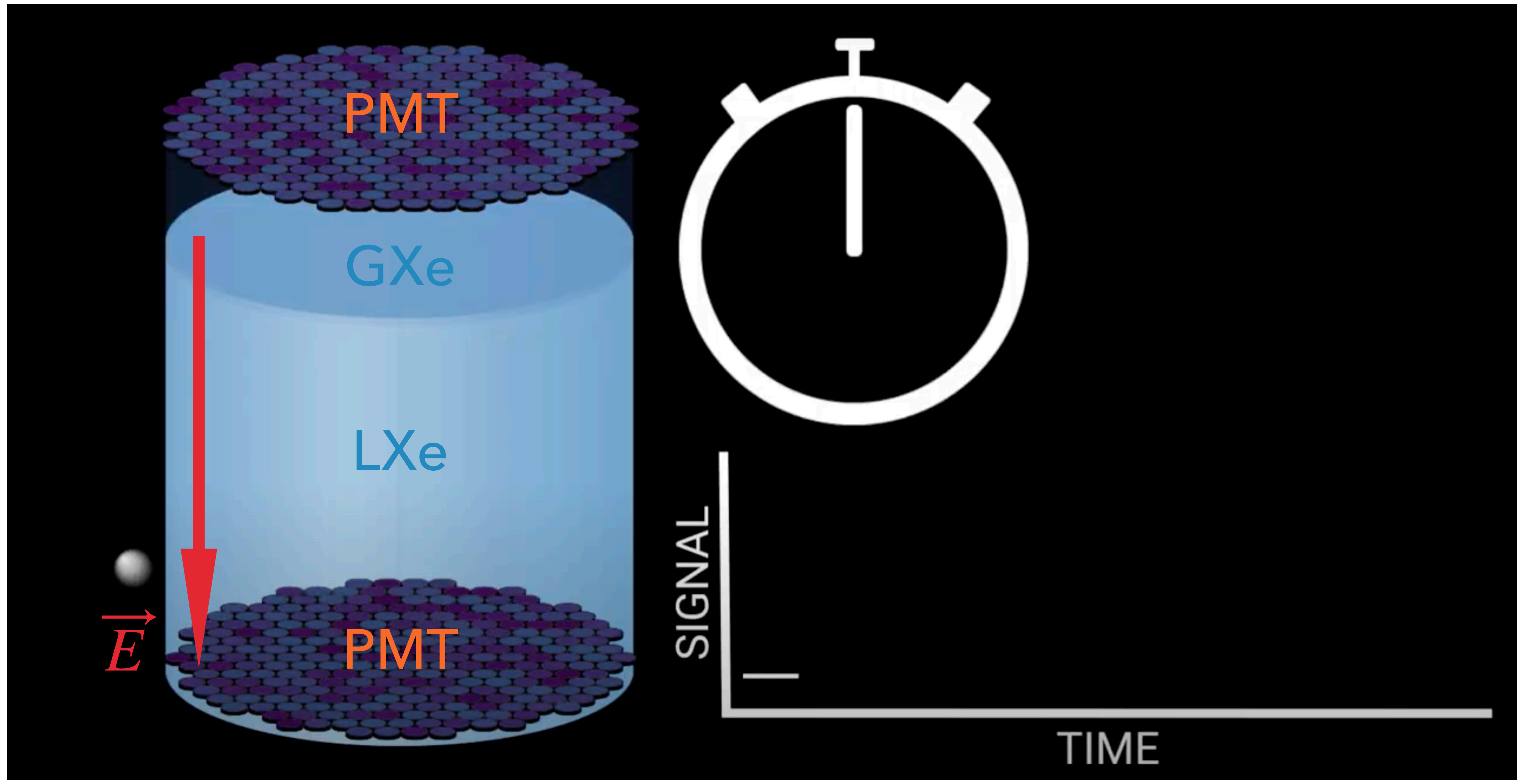


Gran Sasso Mountain

Infrastructures
Detectors

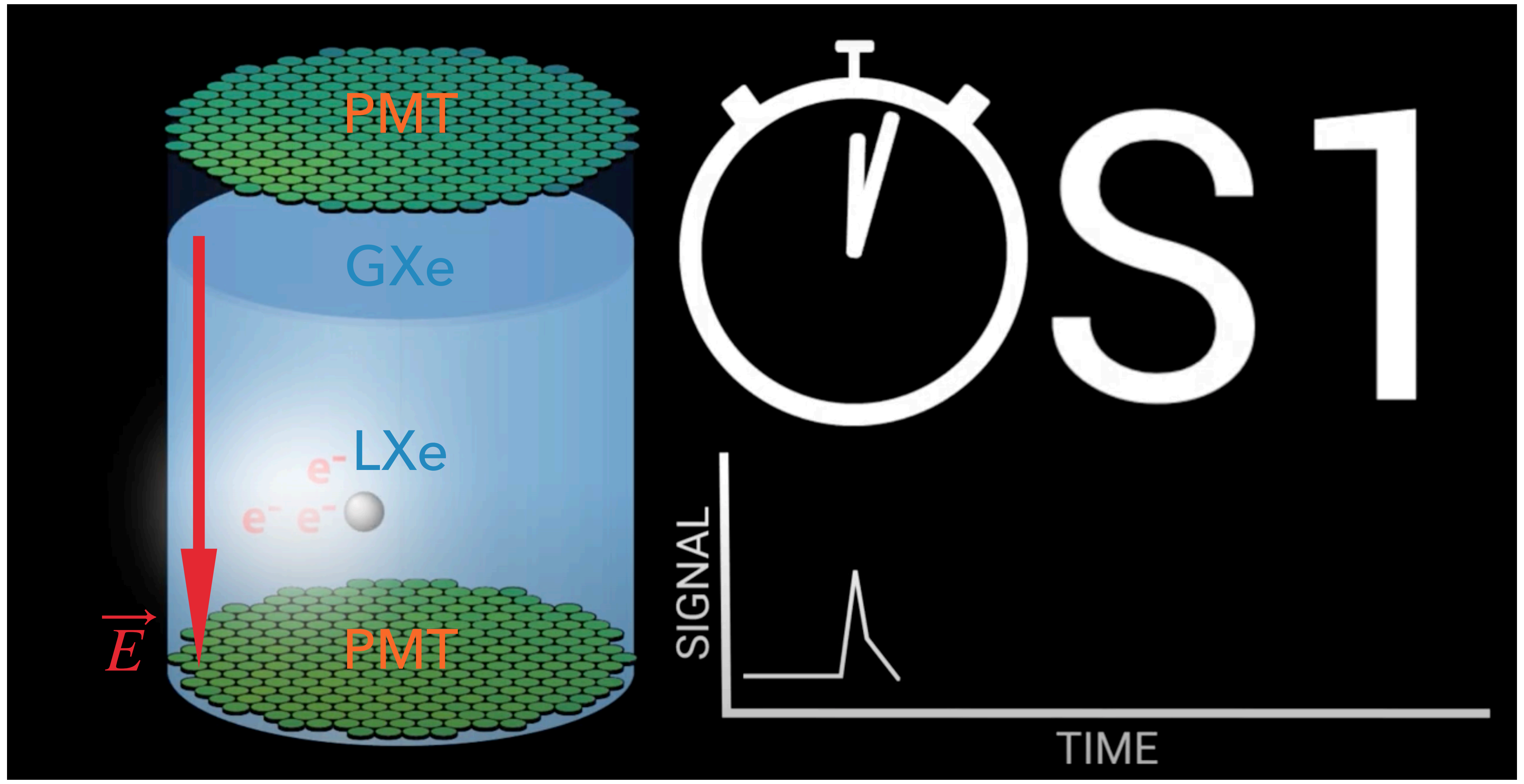
TPC WORKING PRINCIPLE

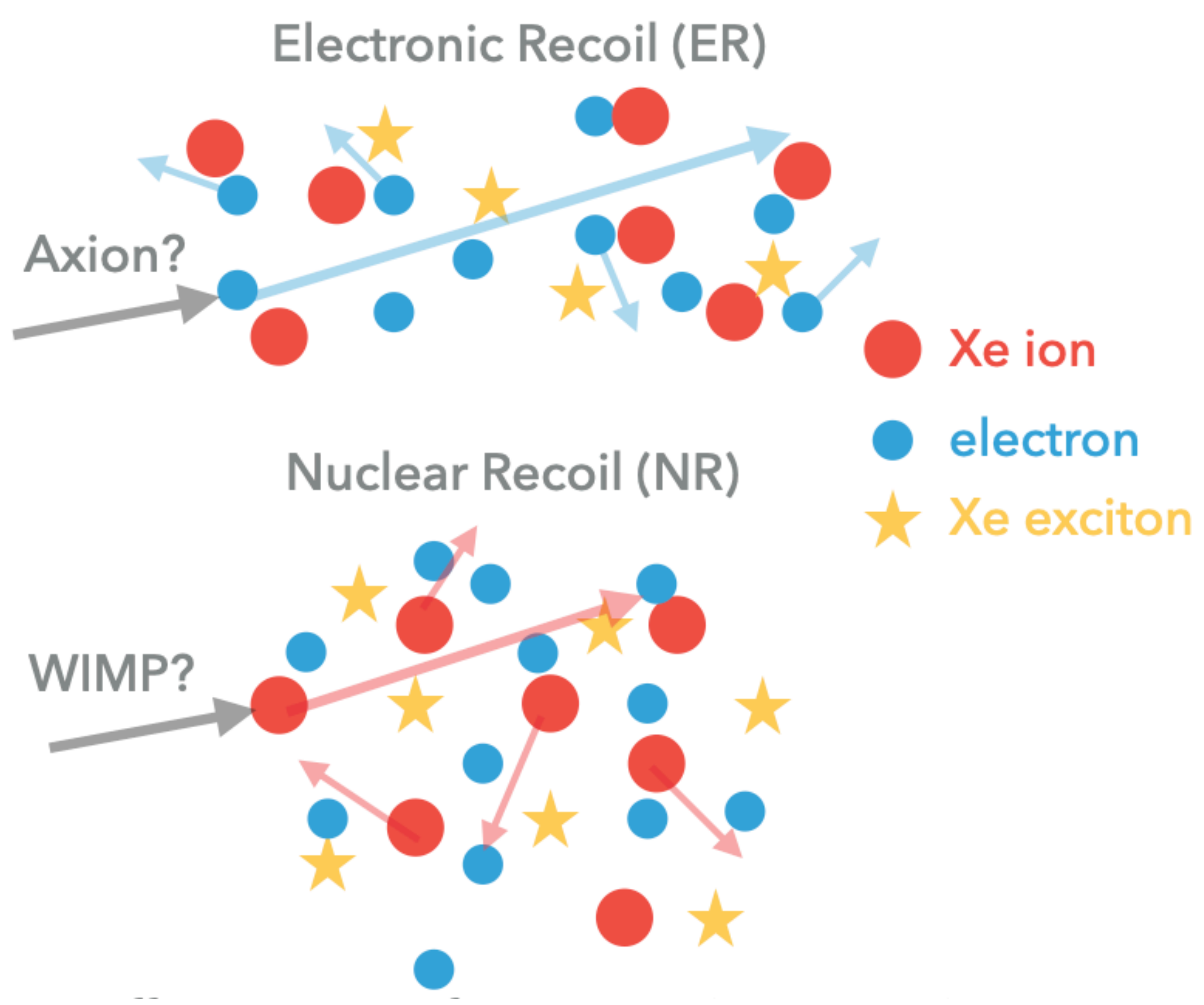
- **Dual Phase Xenon Time Projection Chamber**



TPC WORKING PRINCIPLE

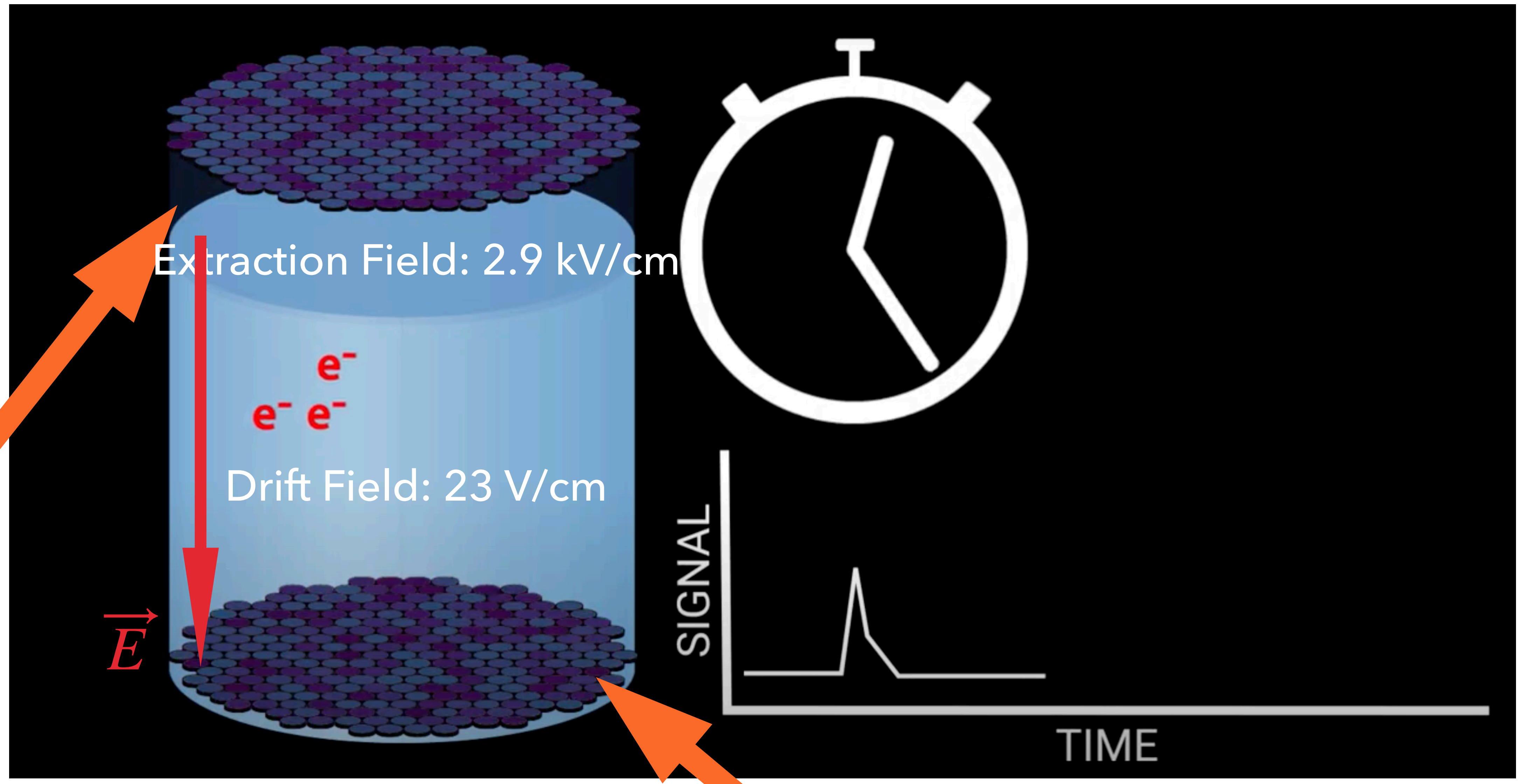
- Dual Phase Xenon Time Projection Chamber
  - **An interaction deposits energy, scintillation photons (S1) and charge is liberated. S1 photons reaches photomultiplier tubes.**

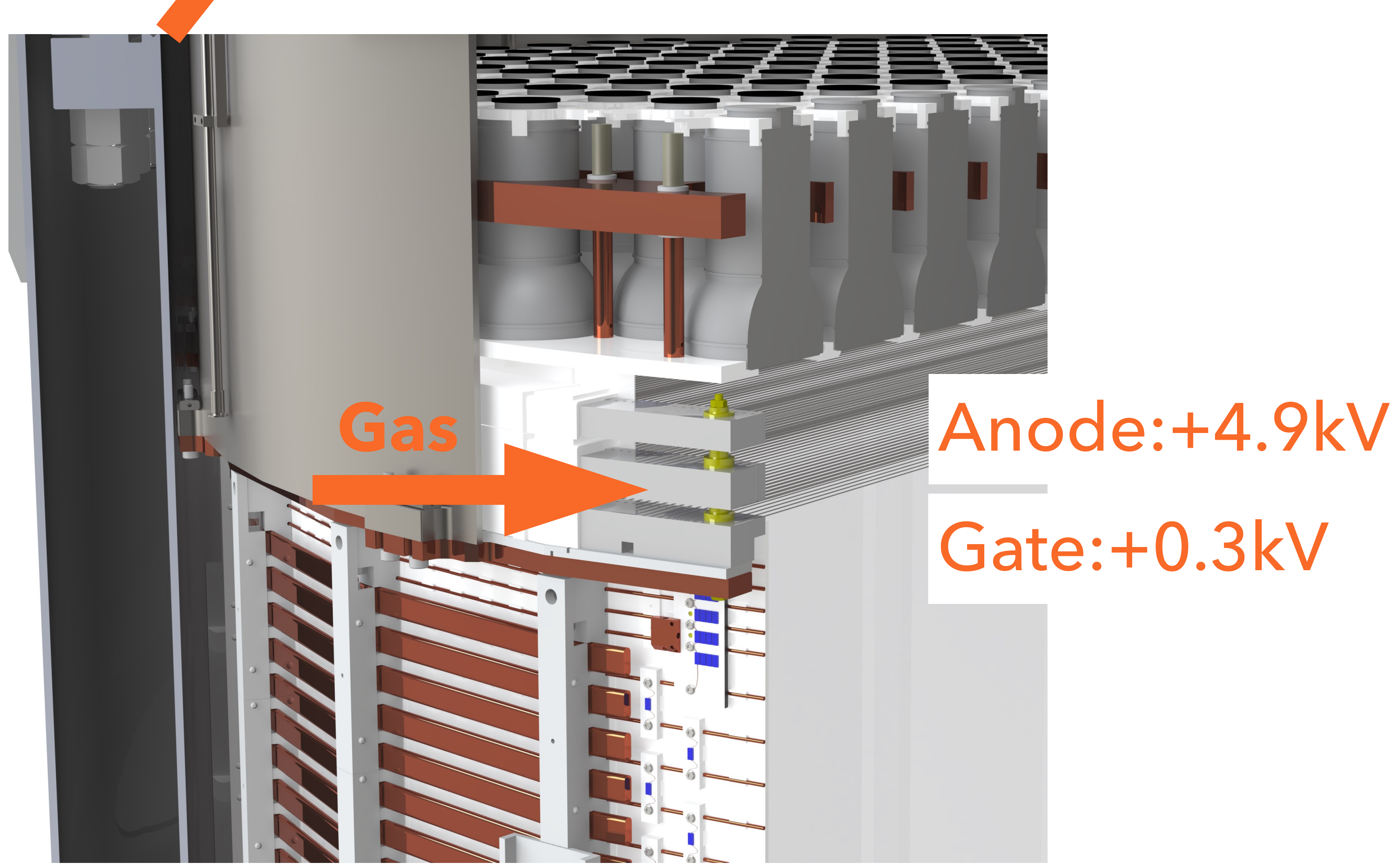


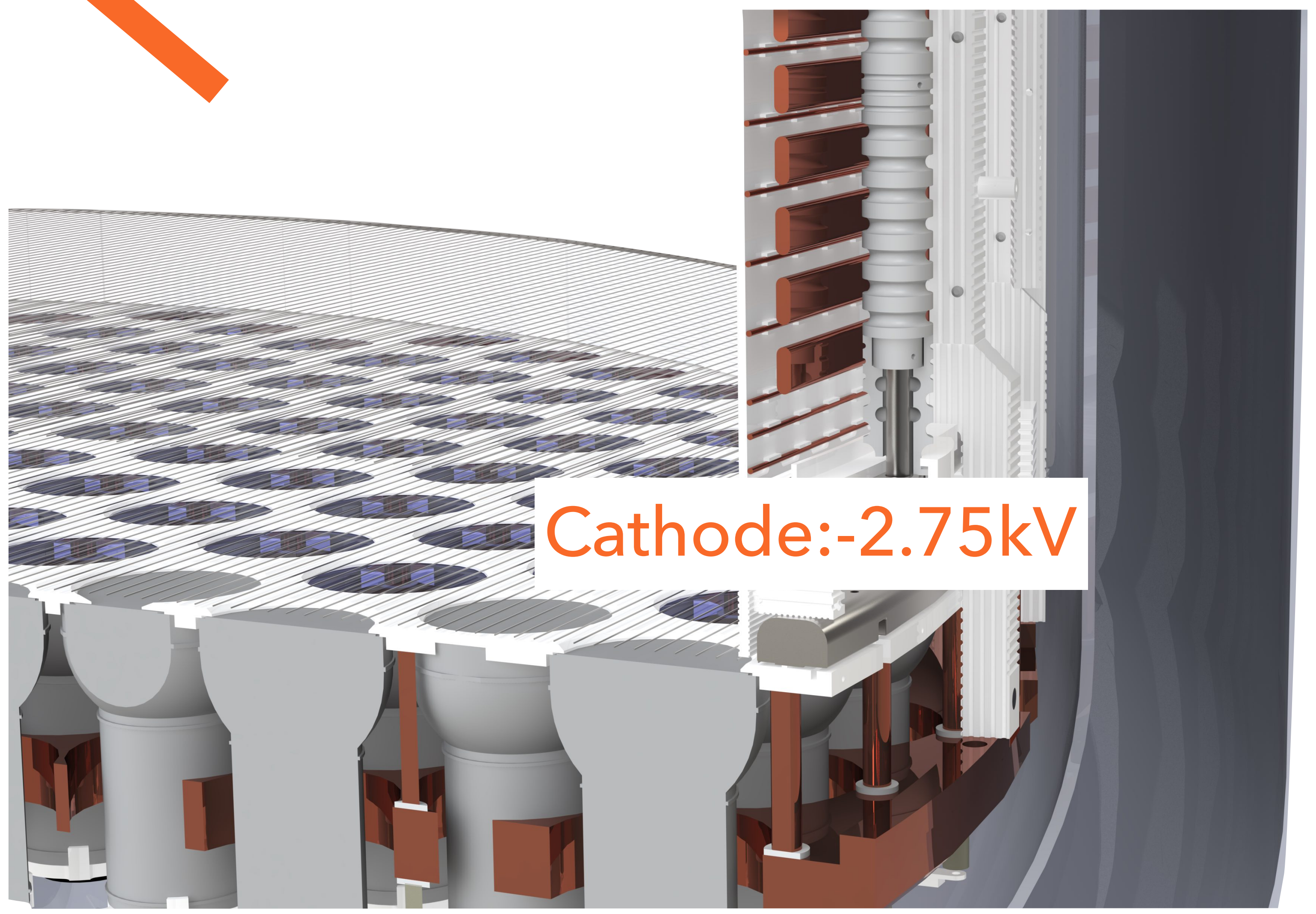


TPC WORKING PRINCIPLE

- Dual Phase Xenon Time Projection Chamber
  - An interaction deposits energy, scintillation photons (S1) and charge is liberated. S1 photons reaches photomultiplier tubes.
  - **Escaped electrons drift up.**







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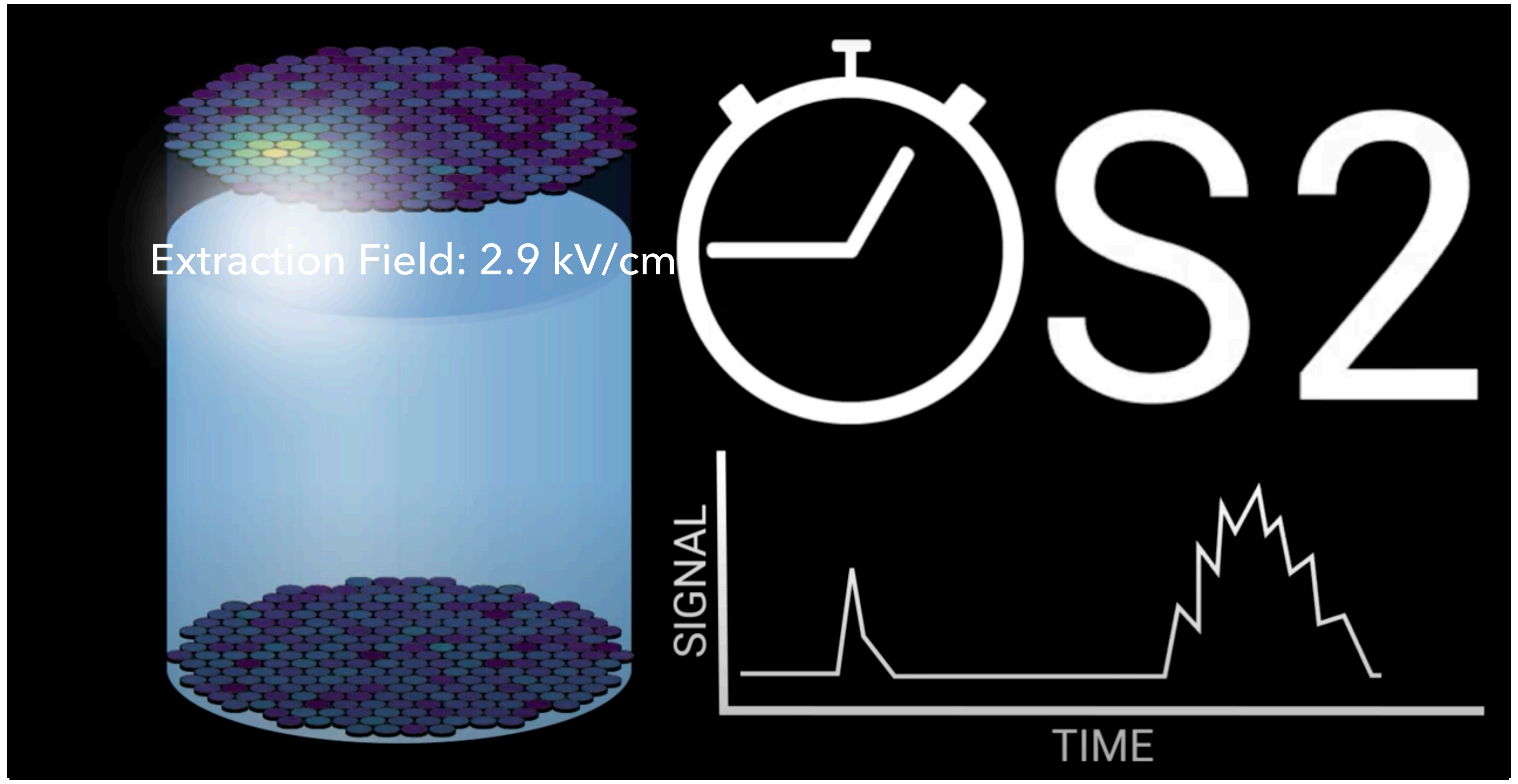
  - **Electrons get extracted out of liquid surface by a stronger field, making stronger scintillation (S2).**



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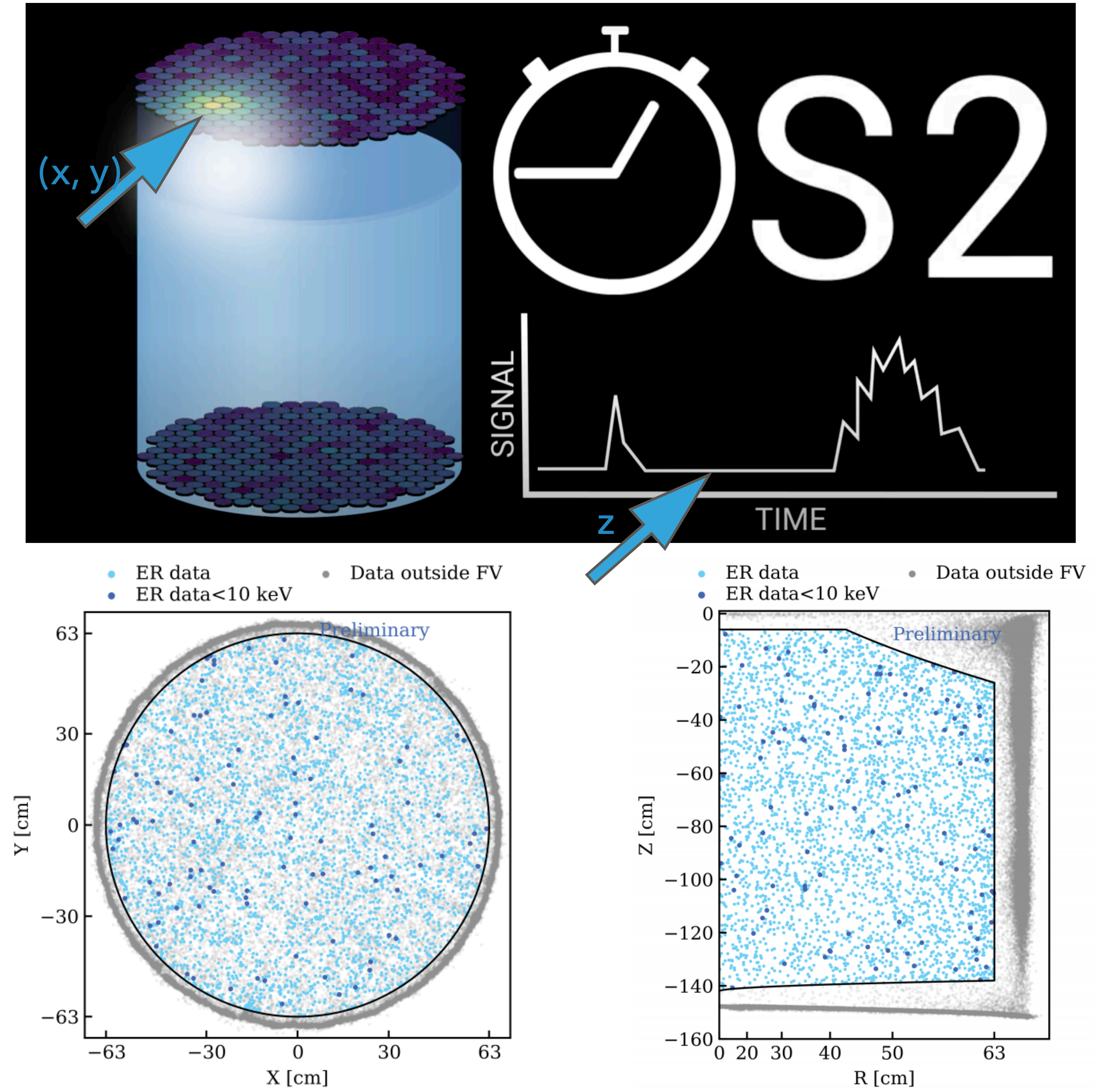
- **3D position reconstruction→Fiducial Volume**



XENONnT SR0 ER background events

TPC WORKING PRINCIPLE

- Dual Phase Xenon Time Projection Chamber
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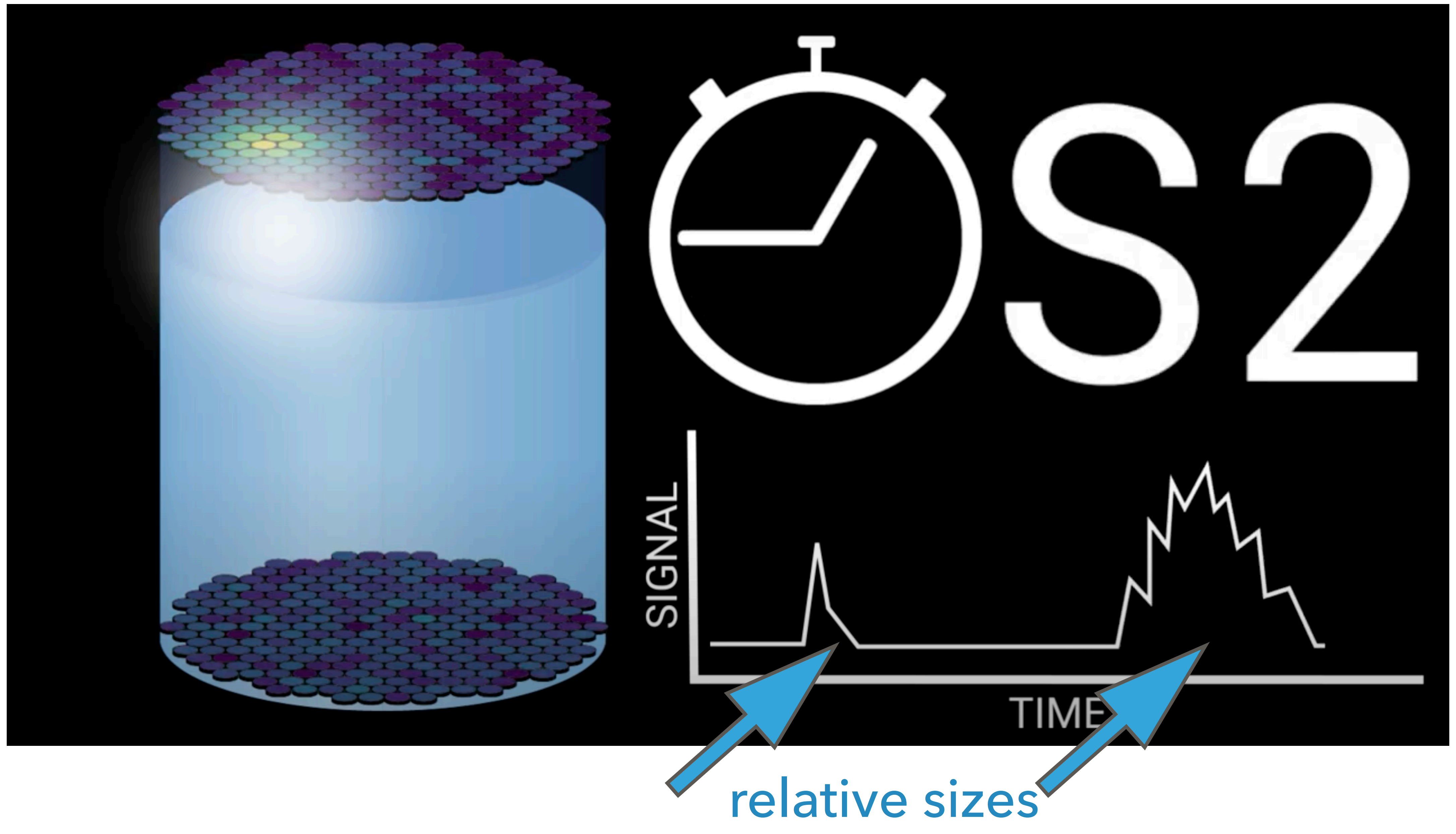
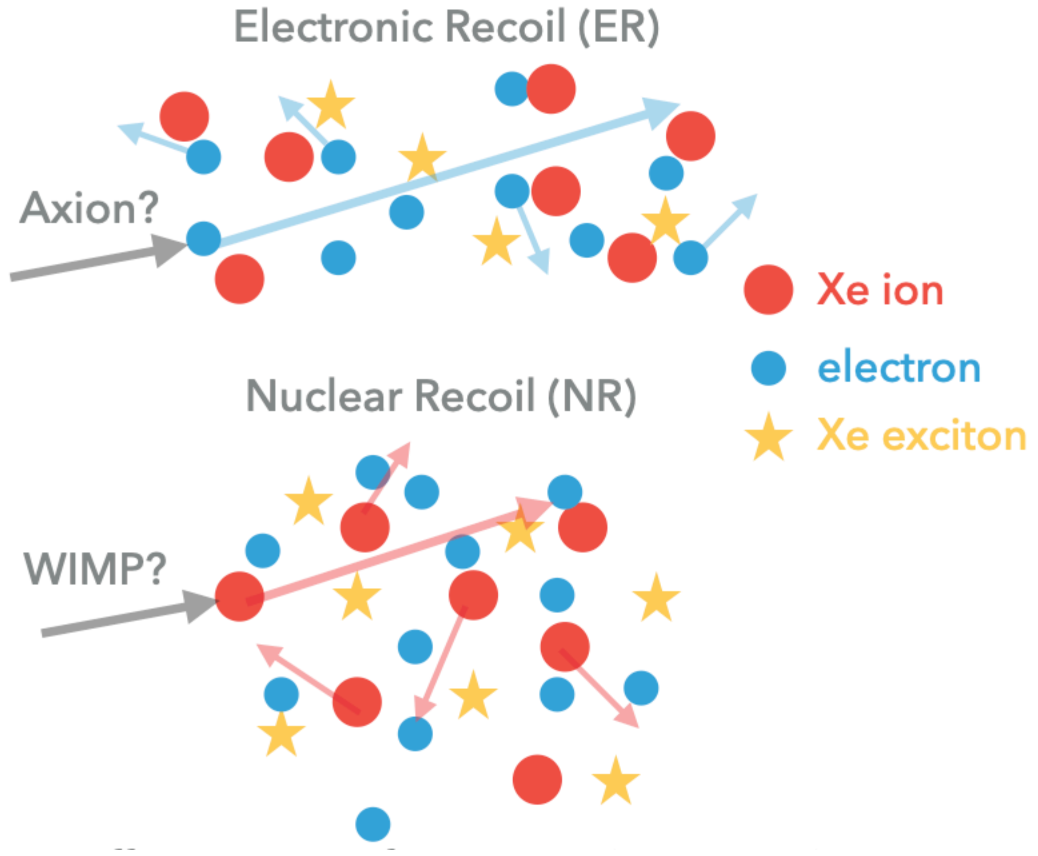
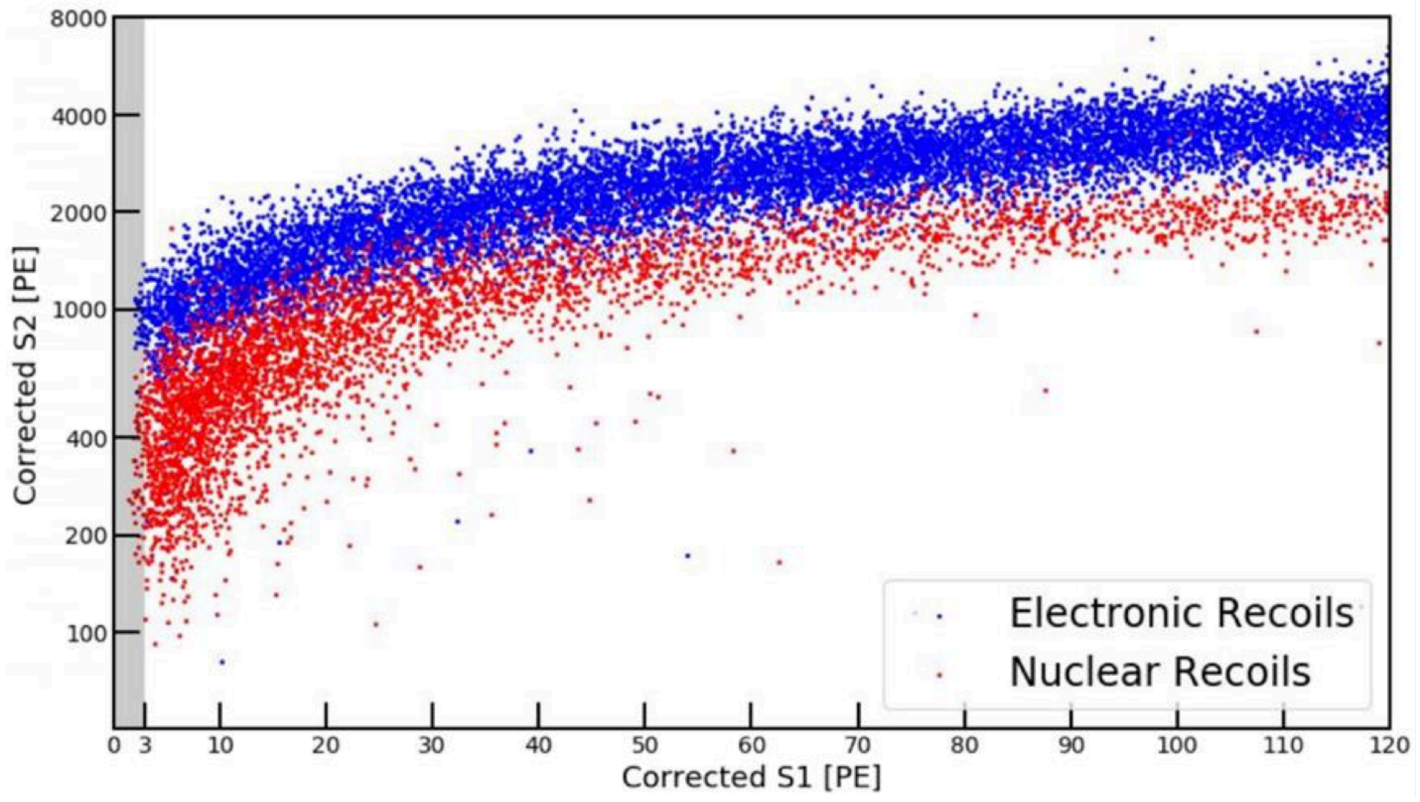
    - Electrons get extracted out of liquid surface by a stronger field, making stronger scintillation (S2).
- 3D position reconstruction→Fiducial Volume
- **ER/NR discrimination**







Example NR/ER band a previous generation XENON detector

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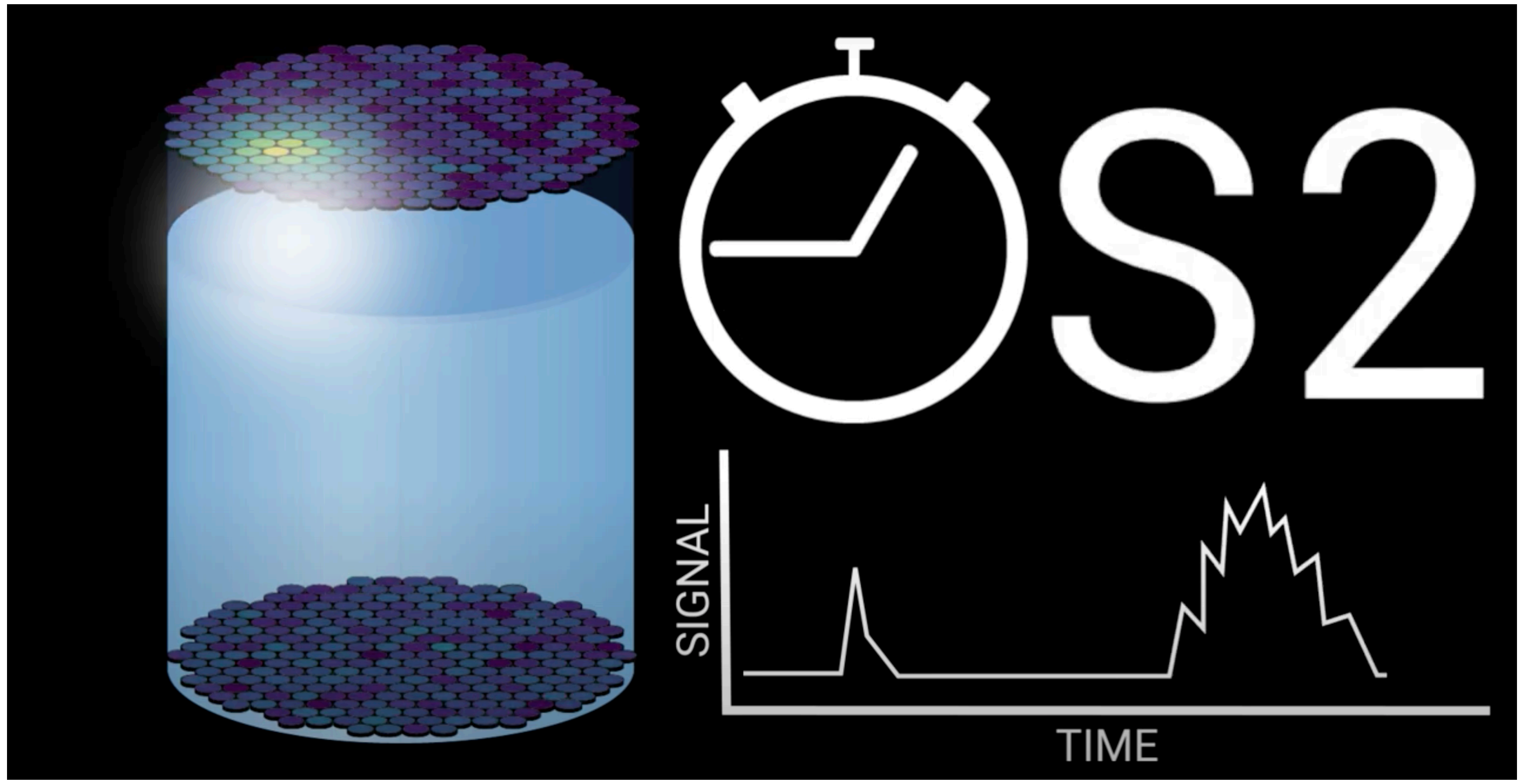
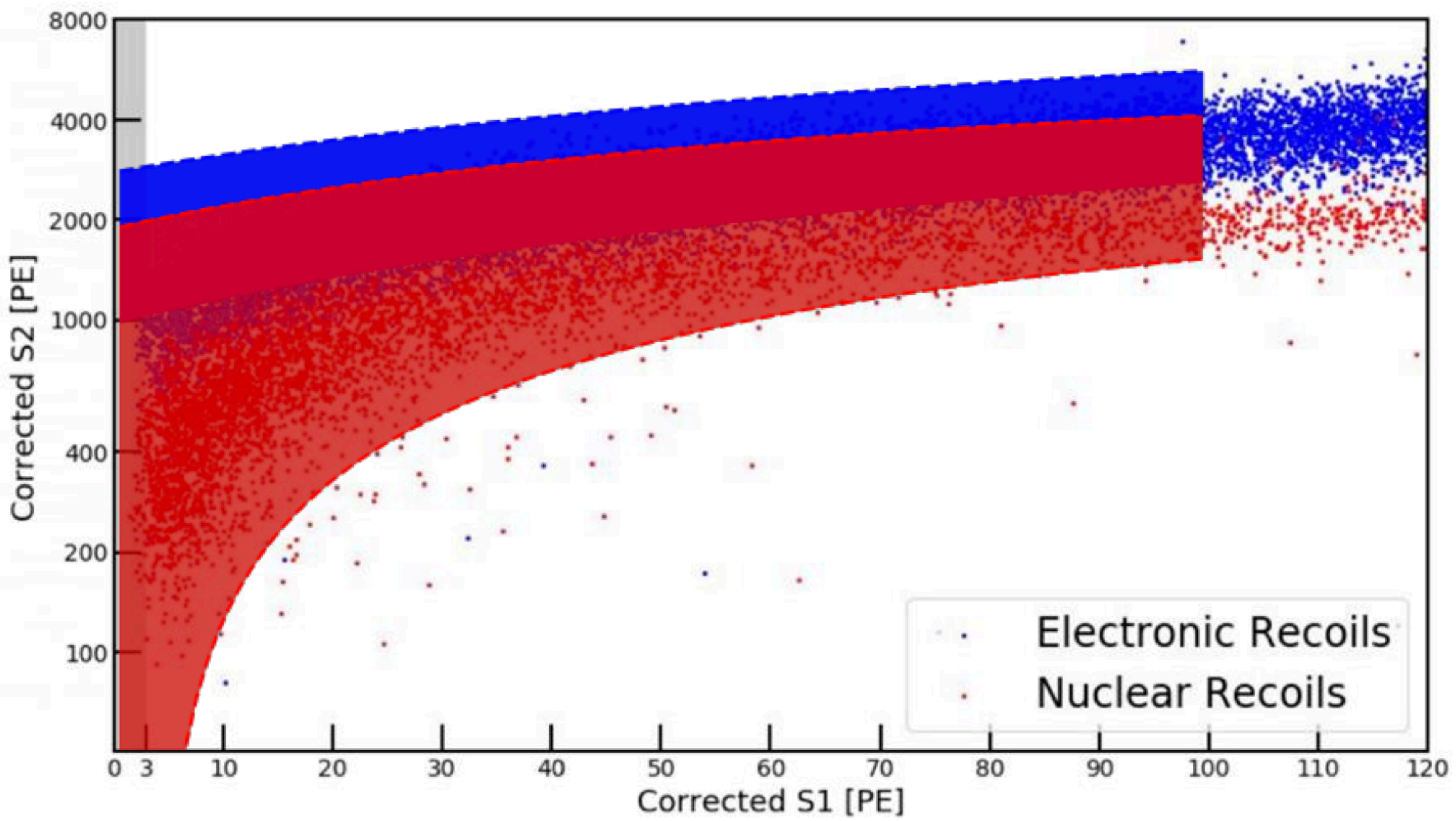
  - Electrons get extracted out of liquid surface by a stronger field, making stronger scintillation (S2).
- 3D position reconstruction→Fiducial Volume
- ER/NR discrimination
- **Blind analysis inside FV for <10keV!**





Example NR/ER band a previous generation XENON detector

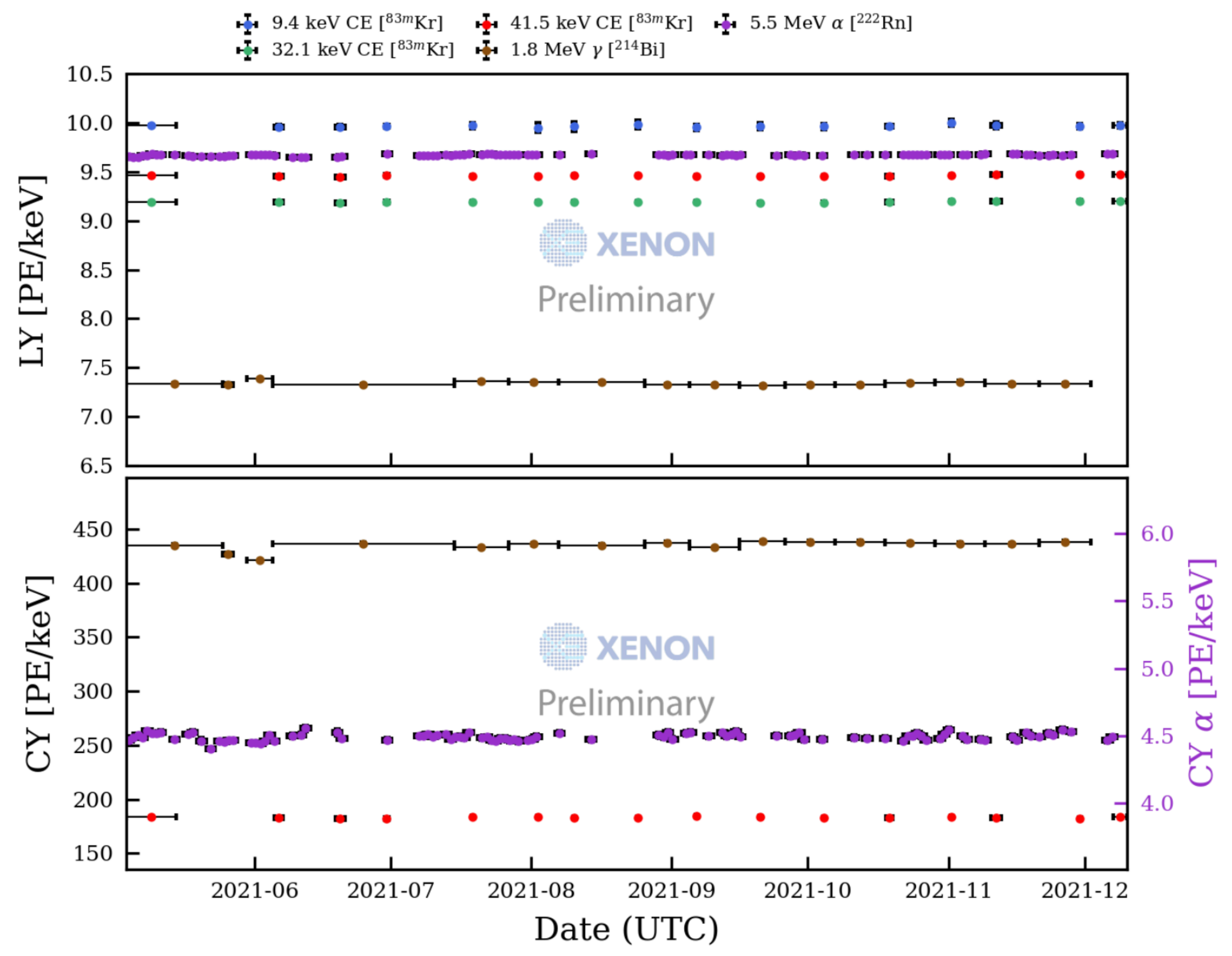
RADON REMOVAL STRATEGY

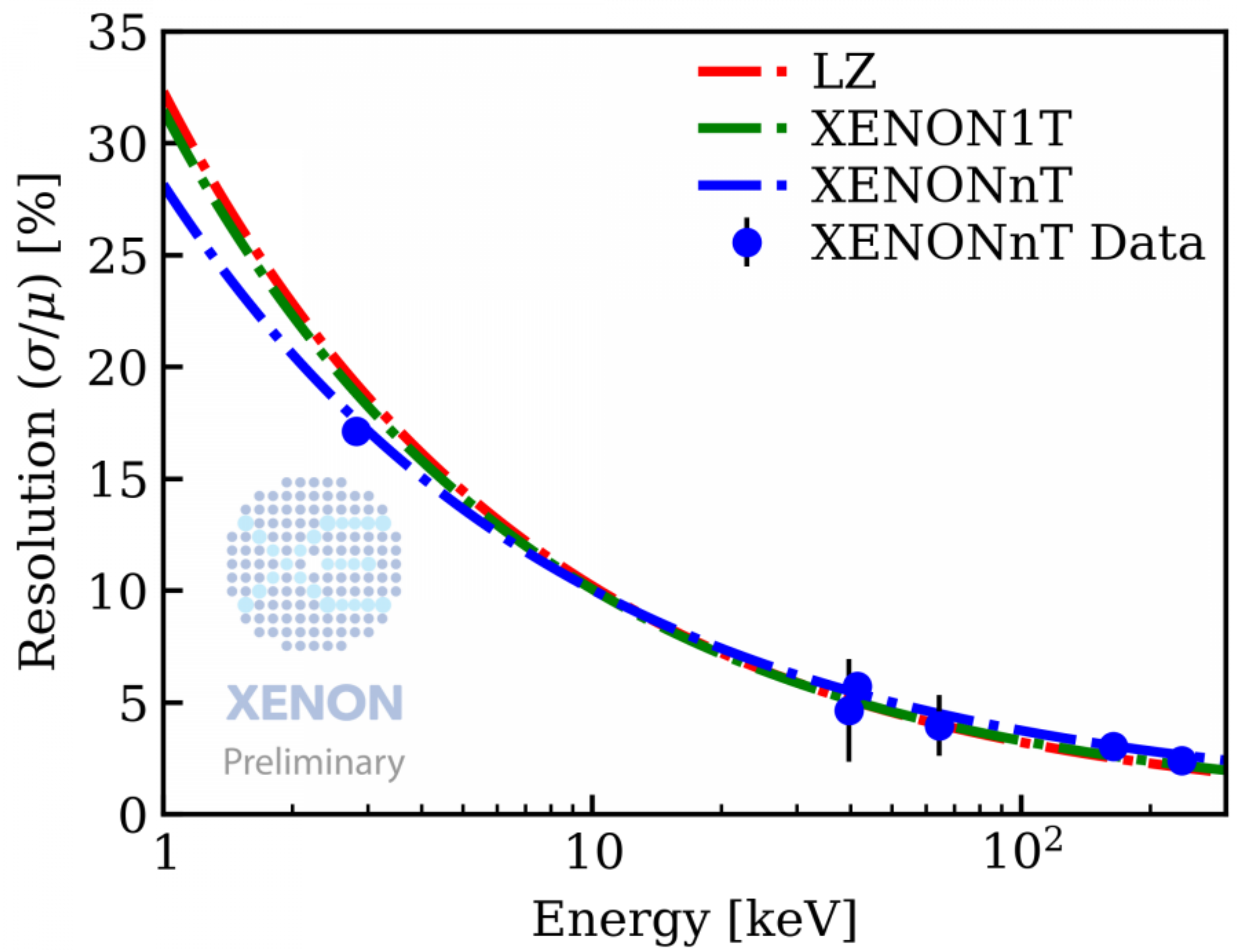
		System	Variable	Value [μBq/kg]	
Sources in contact of LXe	Type 1a ~50%	LXe TPC	k_{TPC}	1.11	Extracted and bring it to the Radon Removal System
		Inner vessel	k_{IV}	0.30	
		GXe PUR	k_{GP}	0.21	
		LXe PUR	$k_{LP,I}$	$(1-\epsilon_{LP})\times 0.43$	
		RRS-outlet	$k_{RRS,I}$	0.19	
Sources in contact of GXe	Type 1b ~50%	CRY	k_{CRY}	1.36	Extracted before the radon undergoes the phase-change
		Cables	k_{C}	0.85	
Sources in upstream of RRS	Type 2 ~0%	RRS-inlet	$k_{RRS,II}$	0.3	Easily removed by RRS
		LXe PUR	$k_{LP,II}$	$\epsilon_{LP}\times 0.43$	

FIRST SCIENCE RUN: SR0

- 4.18±0.13/4.37±0.14 ton fiducial volume for NR/ER search & 97.1 days of exposure → ~1.1 ton·year exposure
- **Calibrations:**

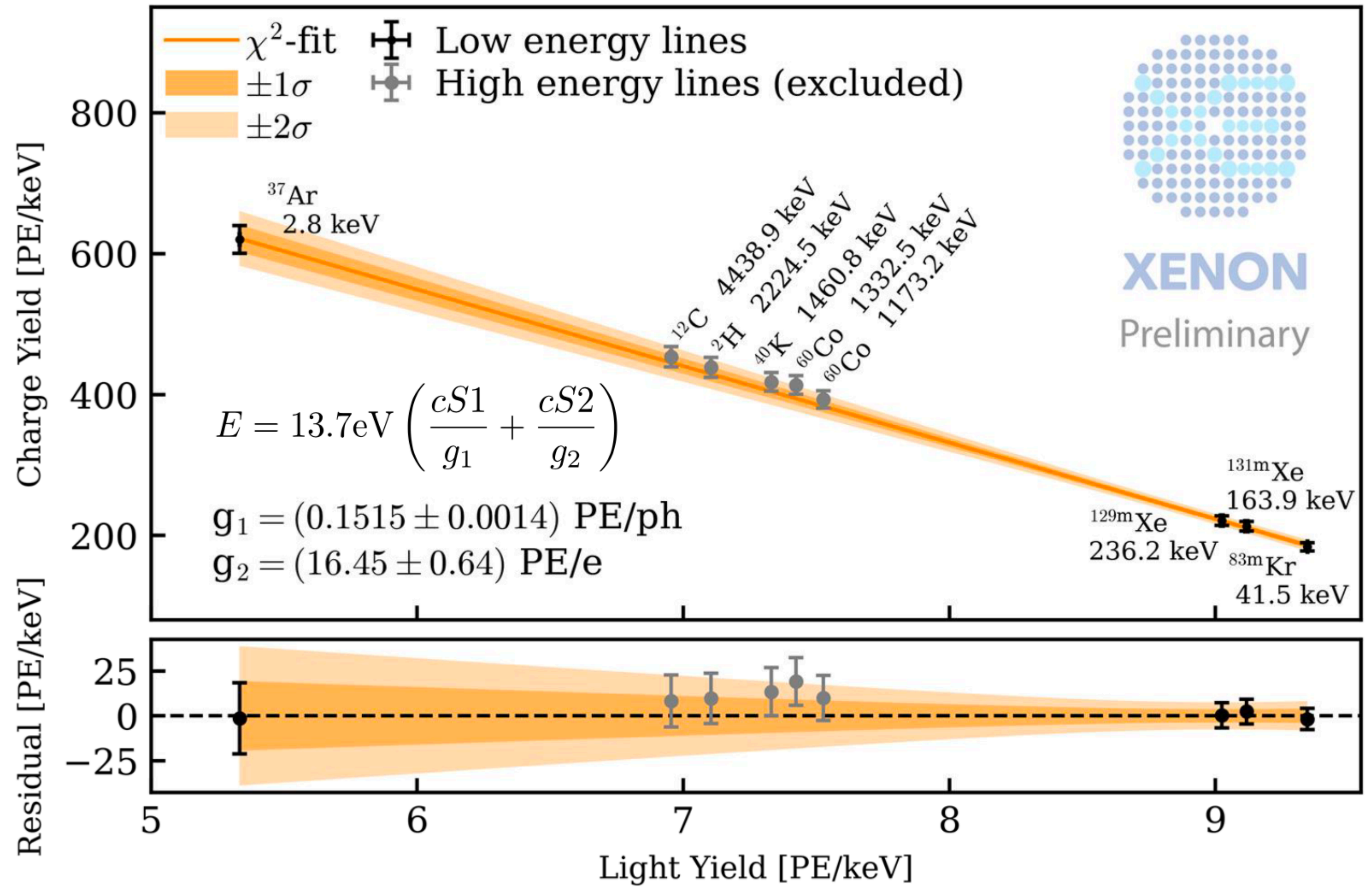
Extremely stable detector response: <~1% LY/CY fluctuation over SR0





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

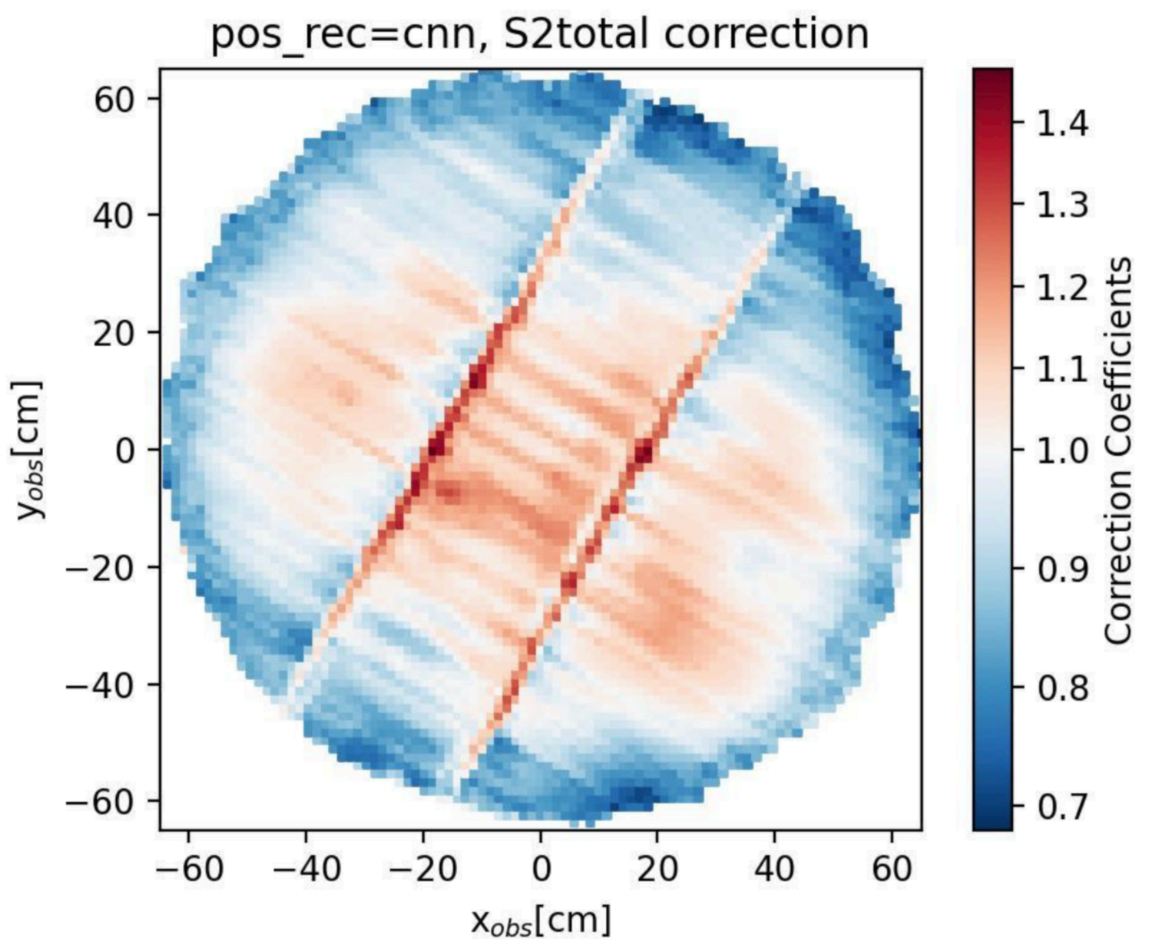
$$E = W\left(\frac{S1}{g_1} + \frac{S2}{g_2}\right)$$



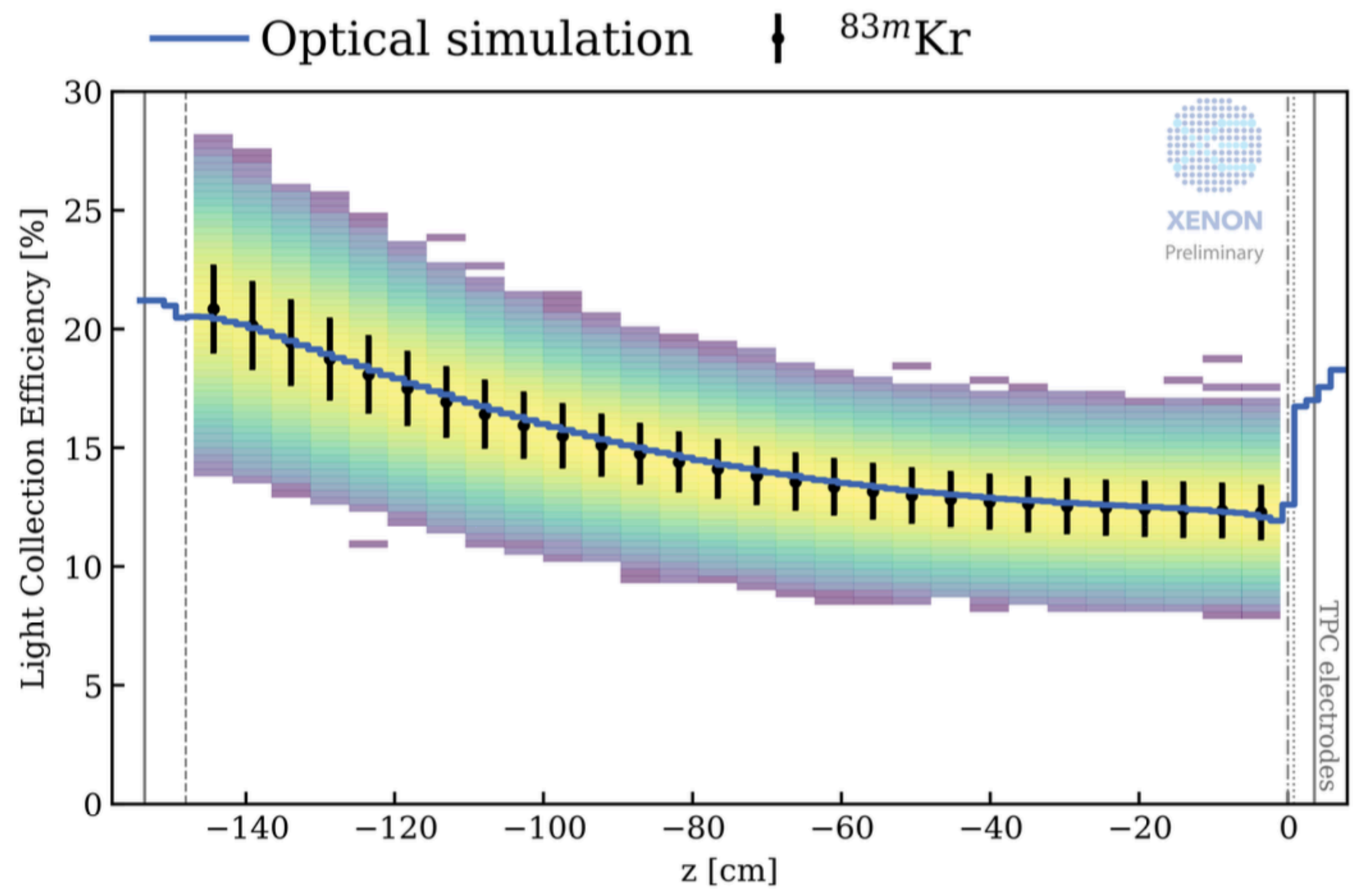
FIRST SCIENCE RUN: SR0

- 4.18±0.13/4.37±0.14 ton fiducial volume for NR/ER search & 97.1 days of exposure → ~1.1 ton·year exposure
- Calibrations:
  - **^{83m}Kr: Uniformly distributed gamma events**

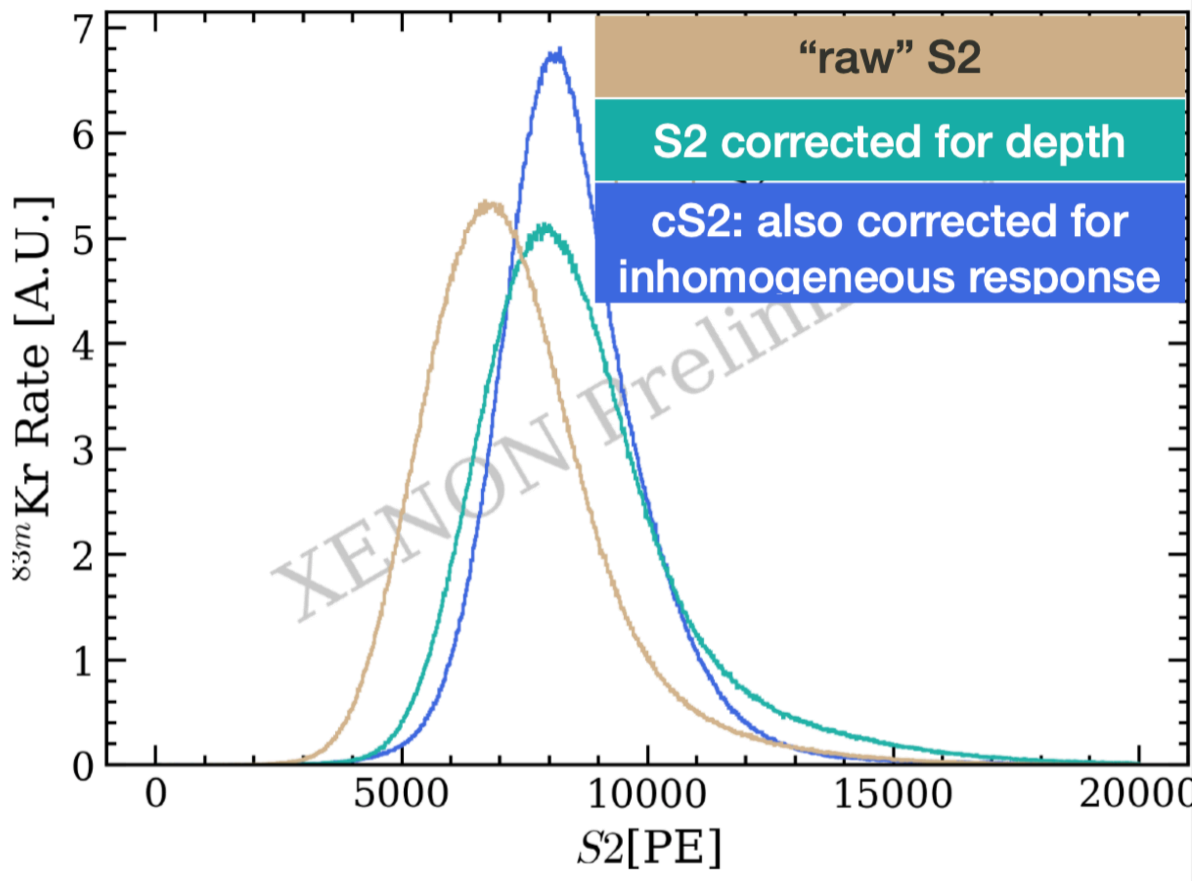
Relative size correction for S2s in x-y plane

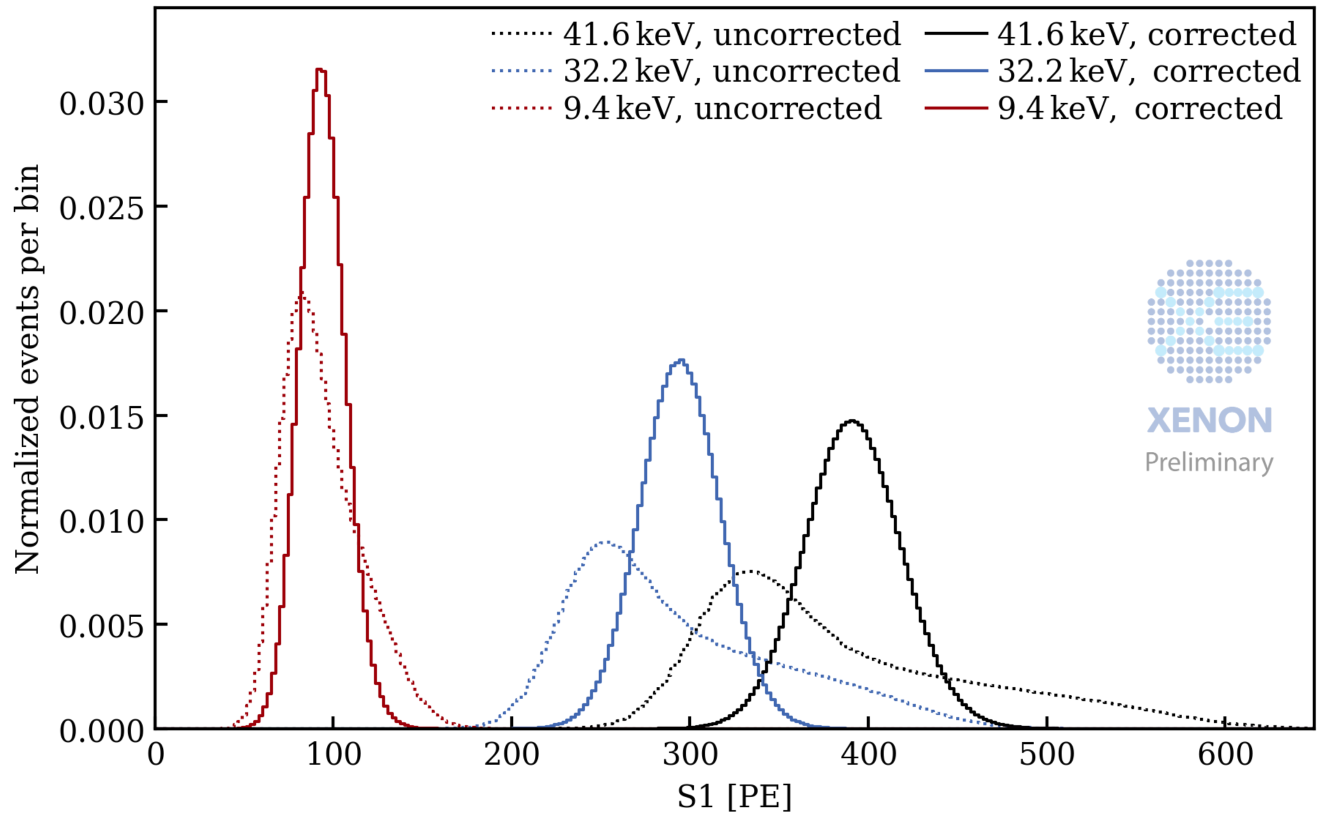


Tuned MC to match photon propagation attenuation along z



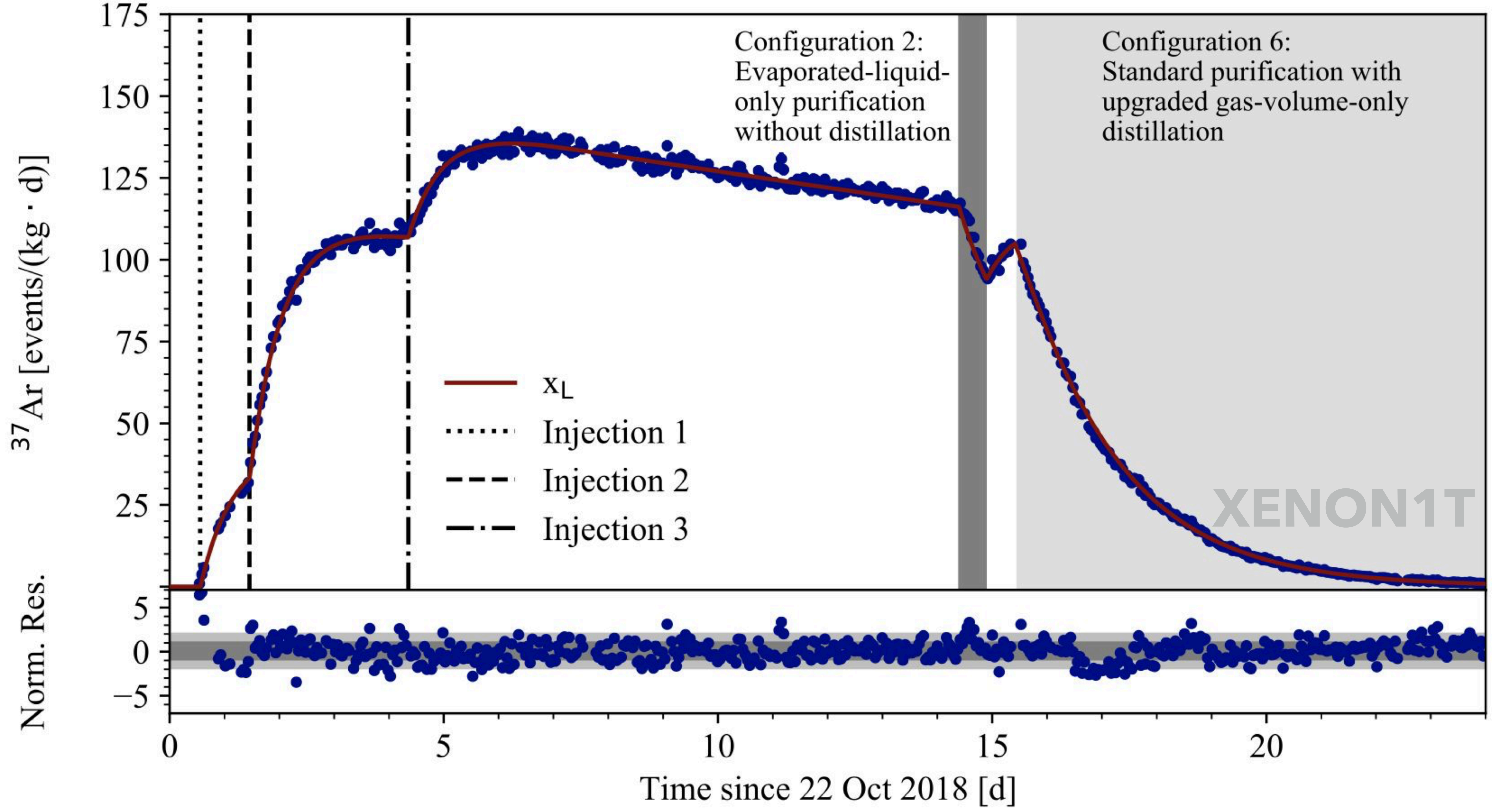
Useful for reconstruction uniformity correction and detector response monitoring.



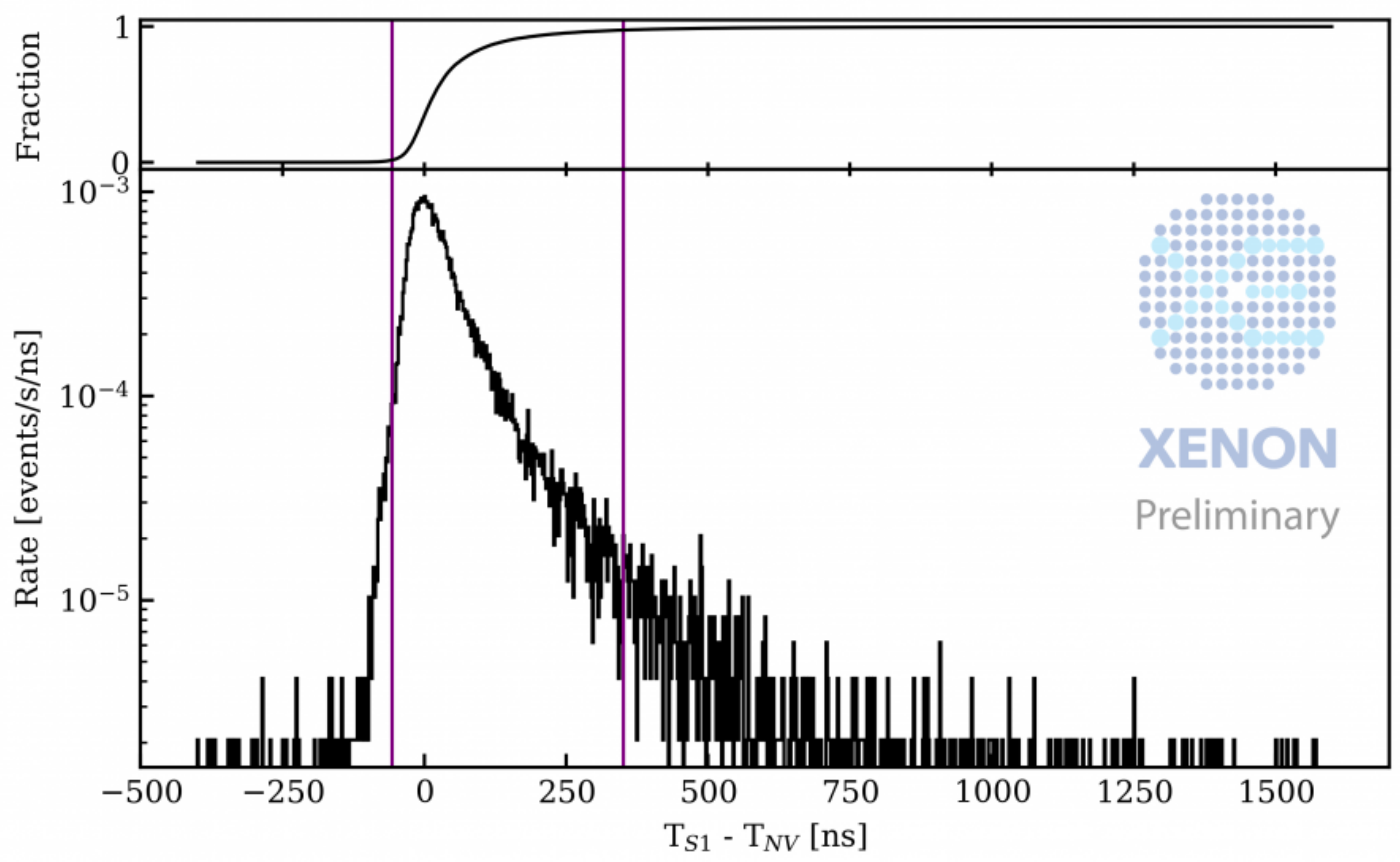


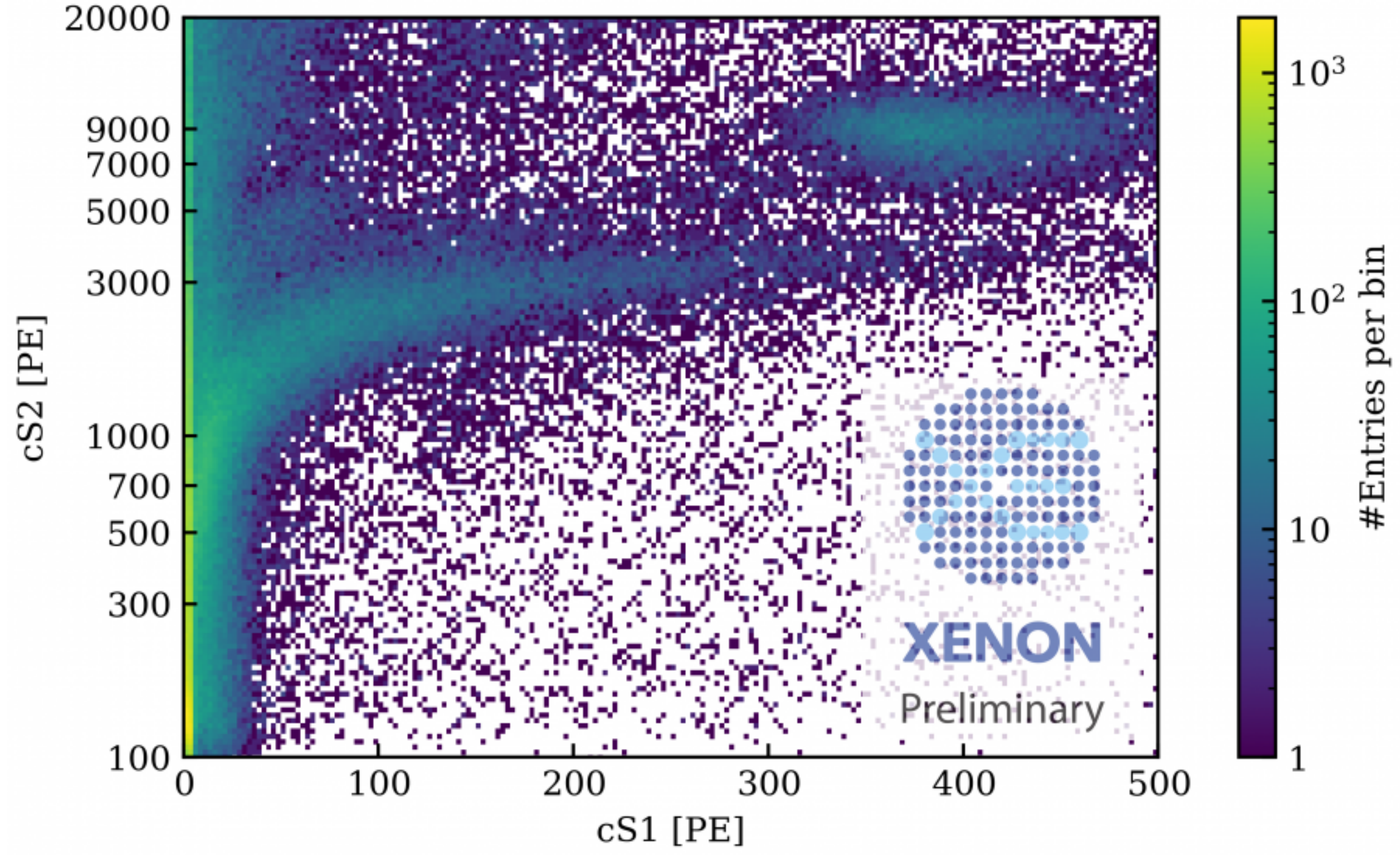
^{37}Ar REMOVAL

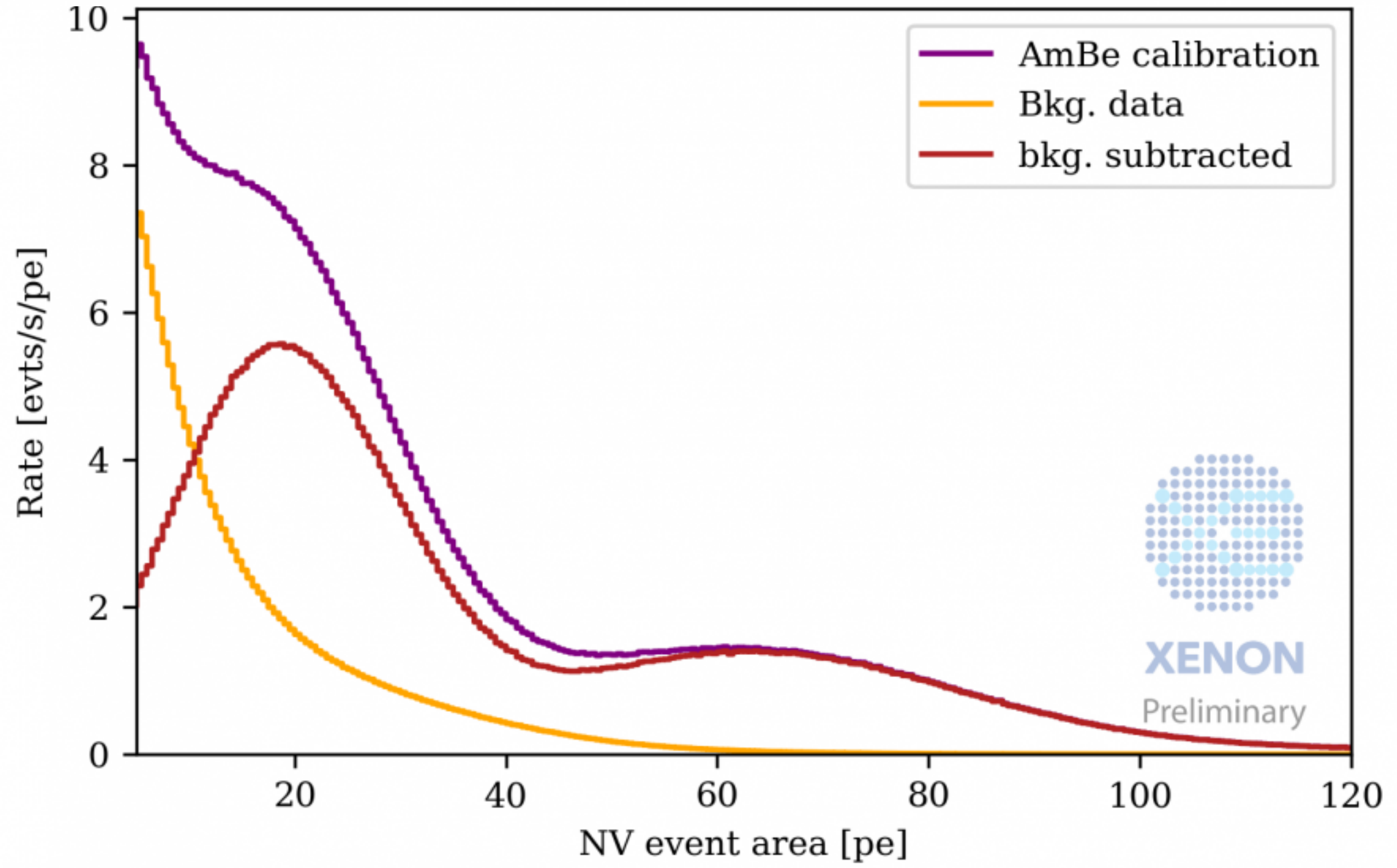
Progress of Theoretical and Experimental Physics, Volume 2022, Issue 5, id.053H01, 21 pp.

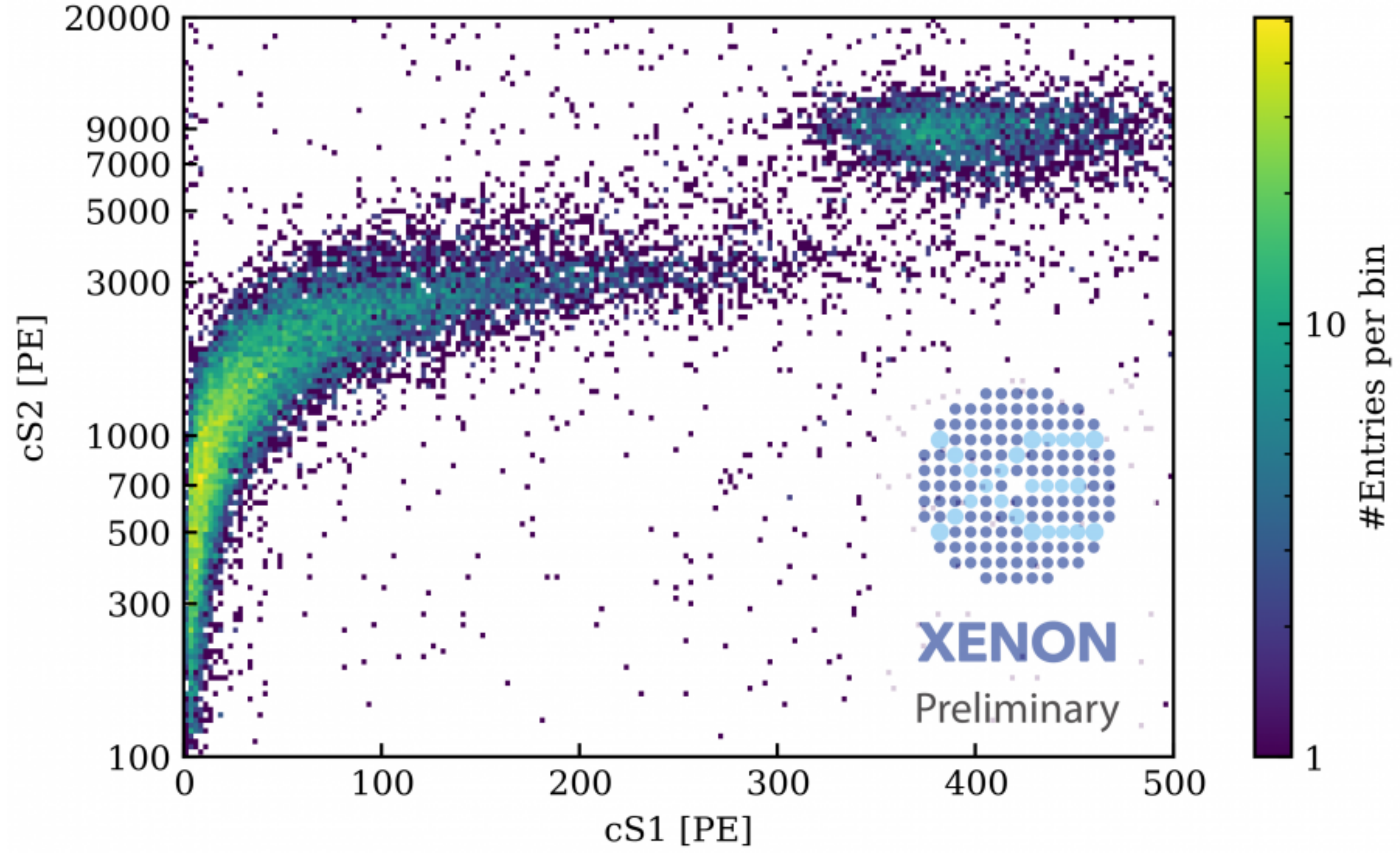


AmBe CALIBRATION: NV COINCIDENCE SELECTION



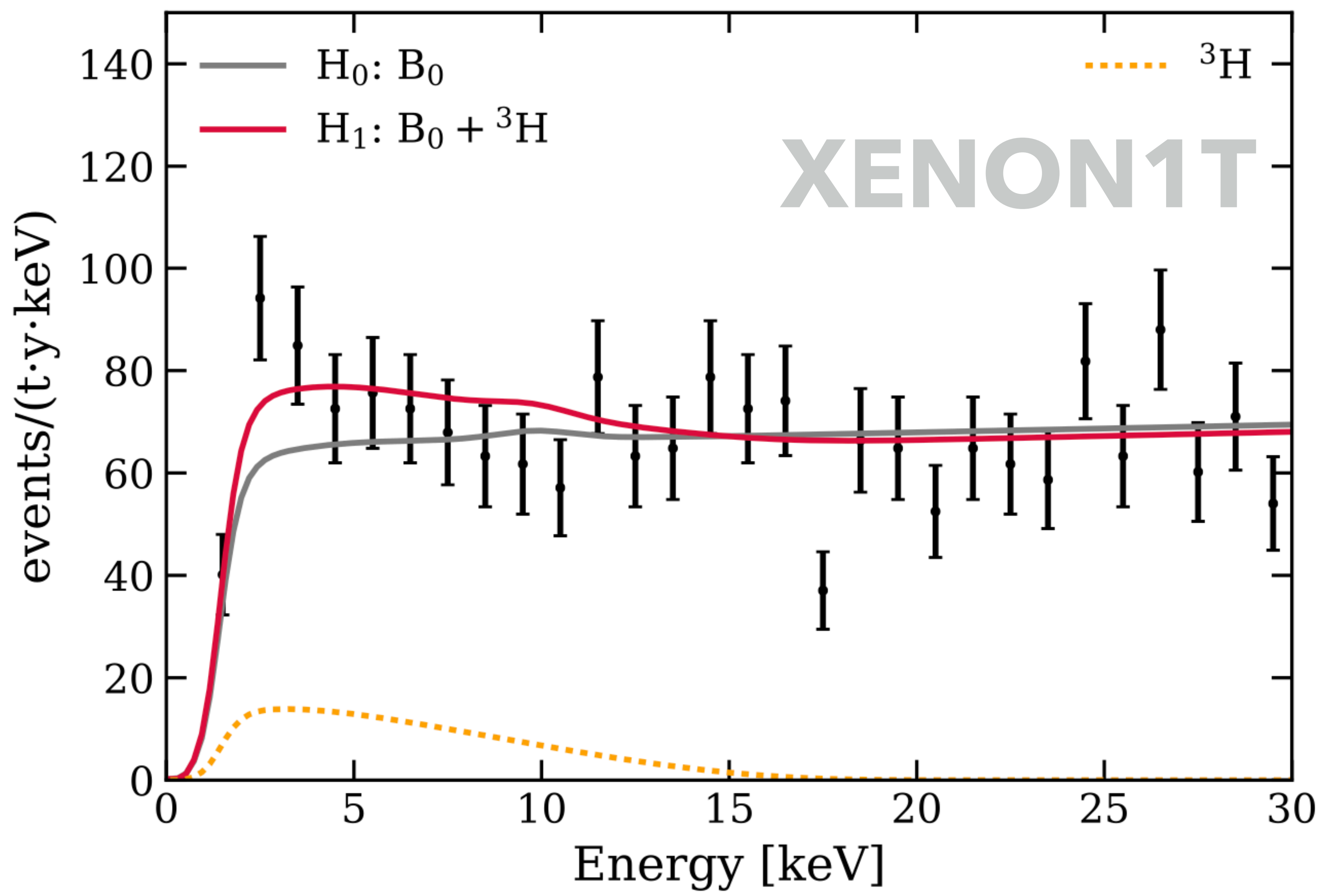


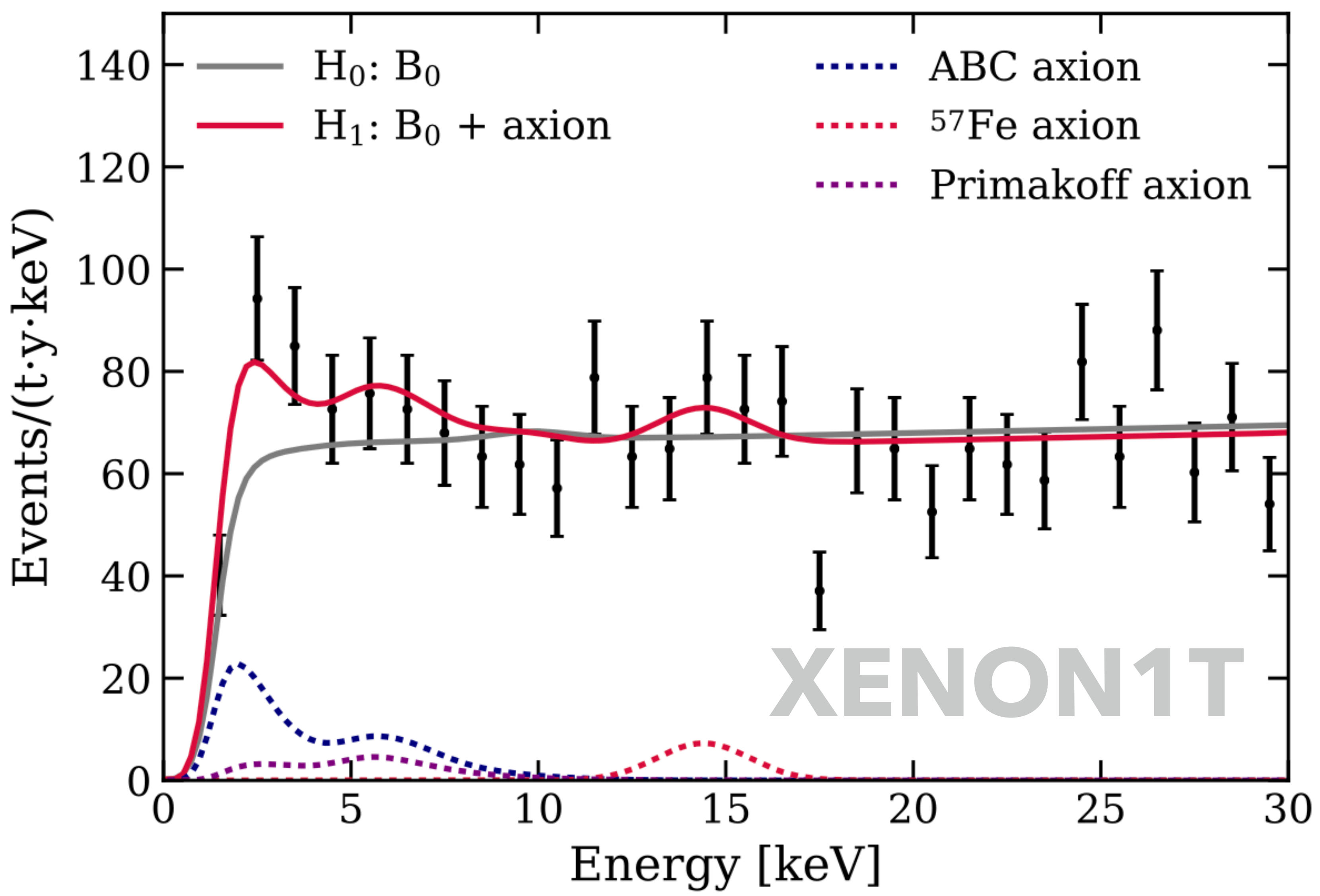




XENON1T LOW ER EXCESS

- In 2020, XENON1T observed an excess in electronic recoil energy spectrum, above expected background
  - Could be tritium traces, which cannot be confirmed or excluded by XENON1T
  - If not tritium, then could be new physics like solar axions (3.4σ), neutrino magnetic moment (3.2σ) etc.
- **XENONnT top priority: Confirm or exclude this excess**

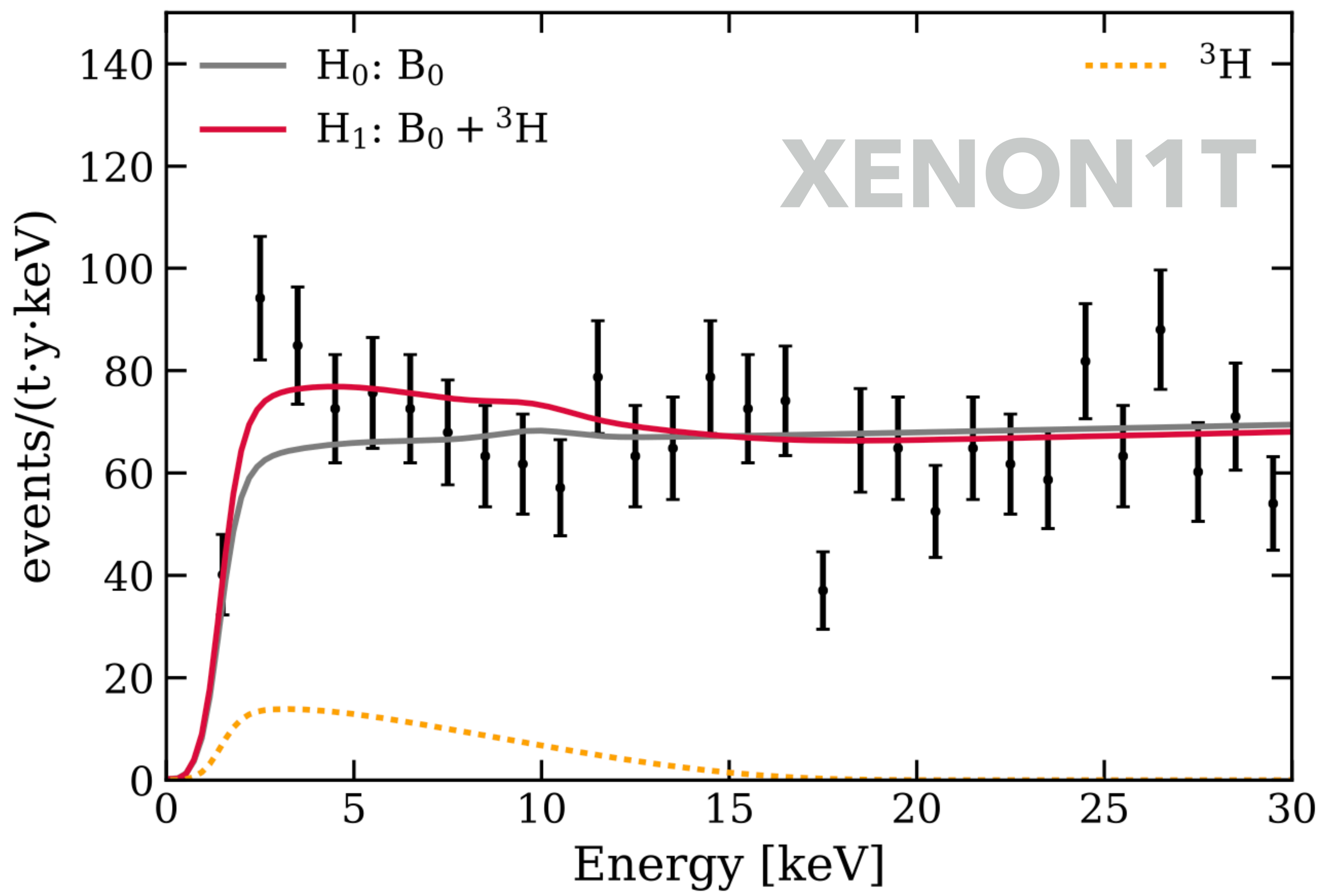


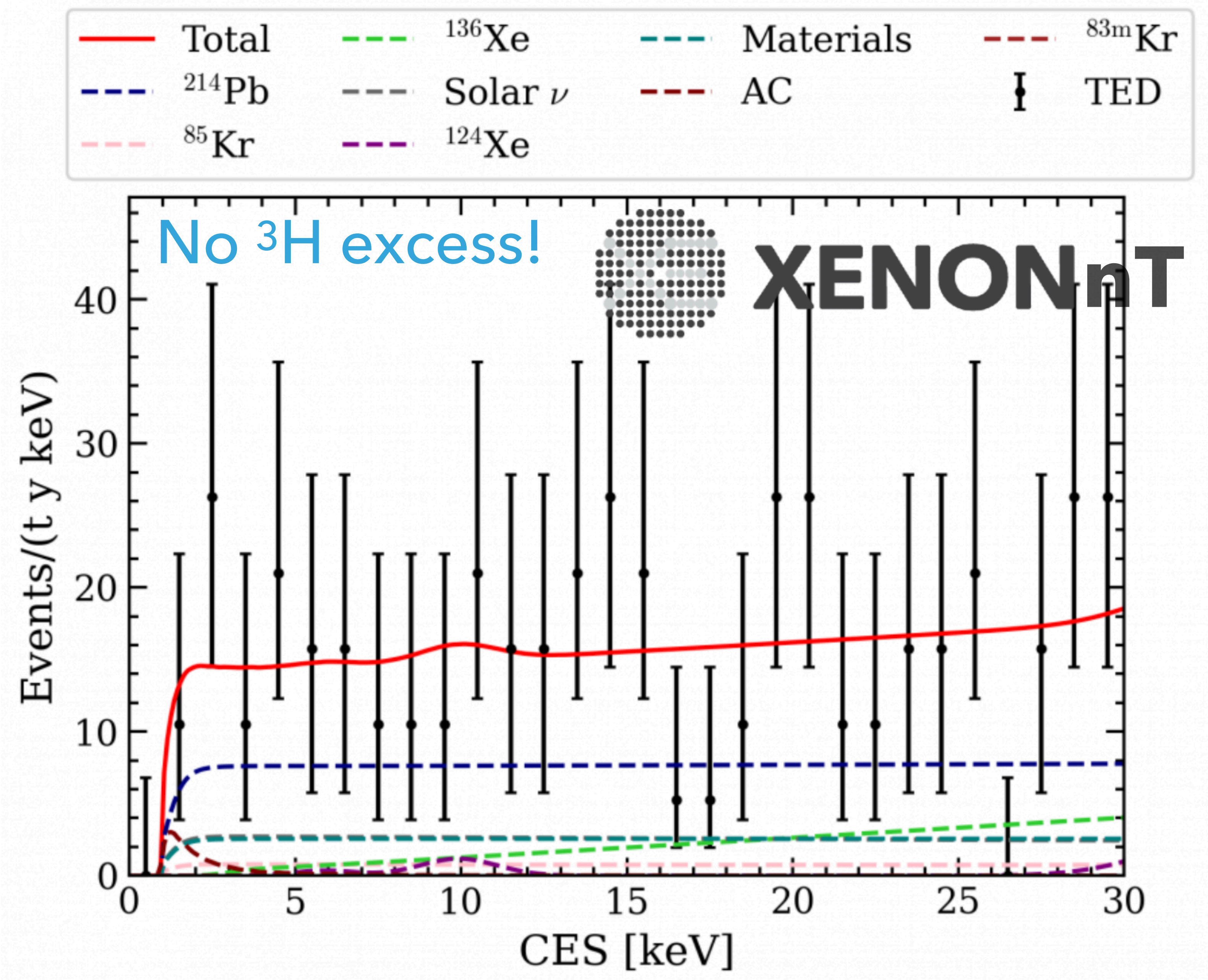


Based on axis-electric effect

DECOUPLING TRITIUM

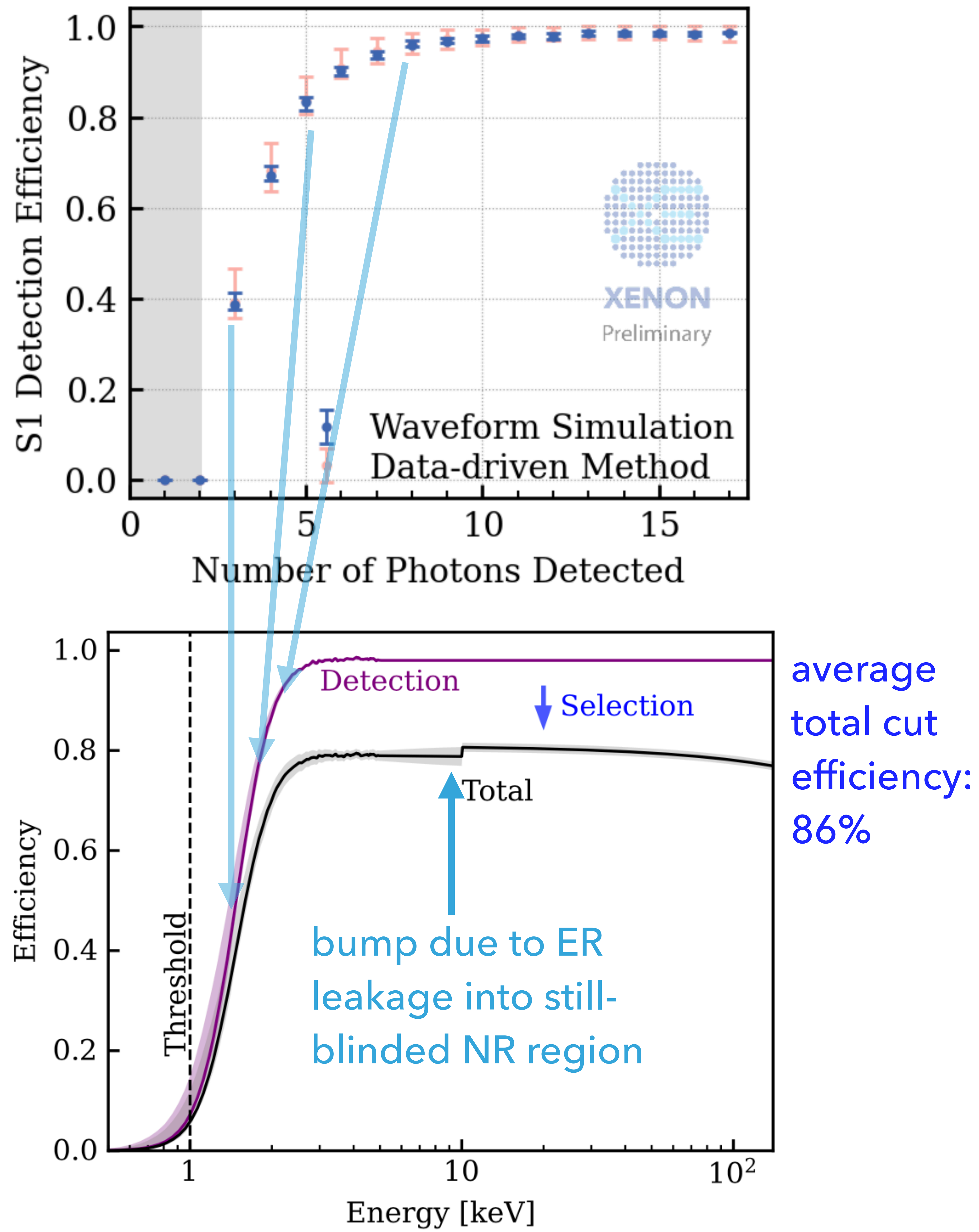
- Better tritium reduction in XENONnT
  - Two months of outgassing, and purification of gaseous xenon with Zr getters and 3 weeks of gaseous xenon cleaning reduces possible hydrogen contamination…
- Tritium Enhanced Data
  - Bypassing getters in the purification loop would increase the equilibrium hydrogen concentration in the detector at least 10 times higher.
  - Taken data for 14.3 days after main SR0 for blind analysis, enough to conclude **tritium is NOT a significant background in XENONnT**.





EFFICIENCIES

- Low energy (<~2keV ER) efficiency dominated by S1 3-fold tight-coincidence requirement
  - Estimated with detail-modeled waveform simulation (WFSim), and verified by a data-driven approach
  - Good agreement
- Higher energy (> ~2keV ER) efficiency dominated by data selection cuts
  - S2 over 500 PE
  - Nothing in veto time coincidence <300 ns
  - S1/S2 peak quality cuts
  - Fiducial Volume: 4.37 ± 0.14 ton



WIMP SEARCH IN XENON DETECTOR

- Predicted by Supersymmetry
    - Cold DM, mass in ~(GeV, TeV)
- Follow Standard Halo Model (isothermal) → Capped Maxwell velocity distribution
- DM-SM scattering (NR) rate by astrophysical inputs, particle physics (goal!) and detector physics

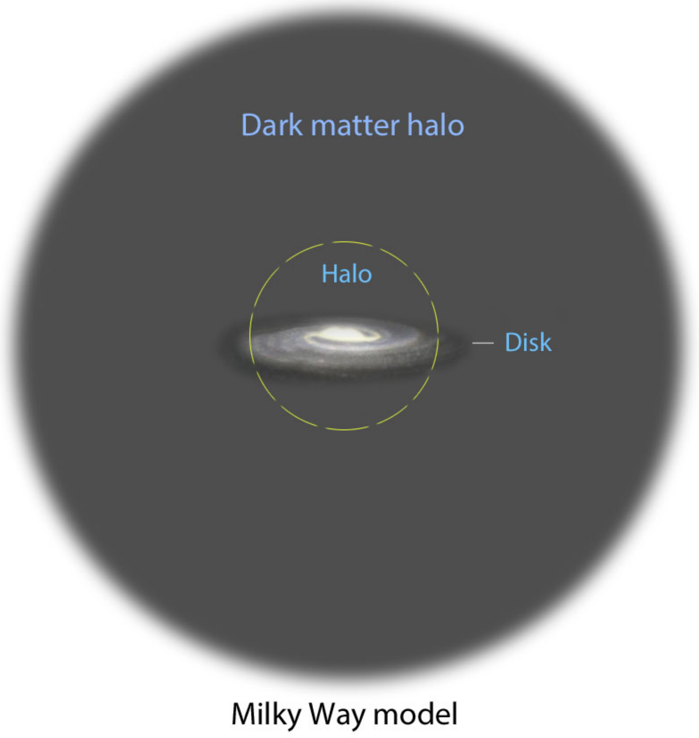
Measured rate | DM energy density | DM escape velocity | DM velocity distribution

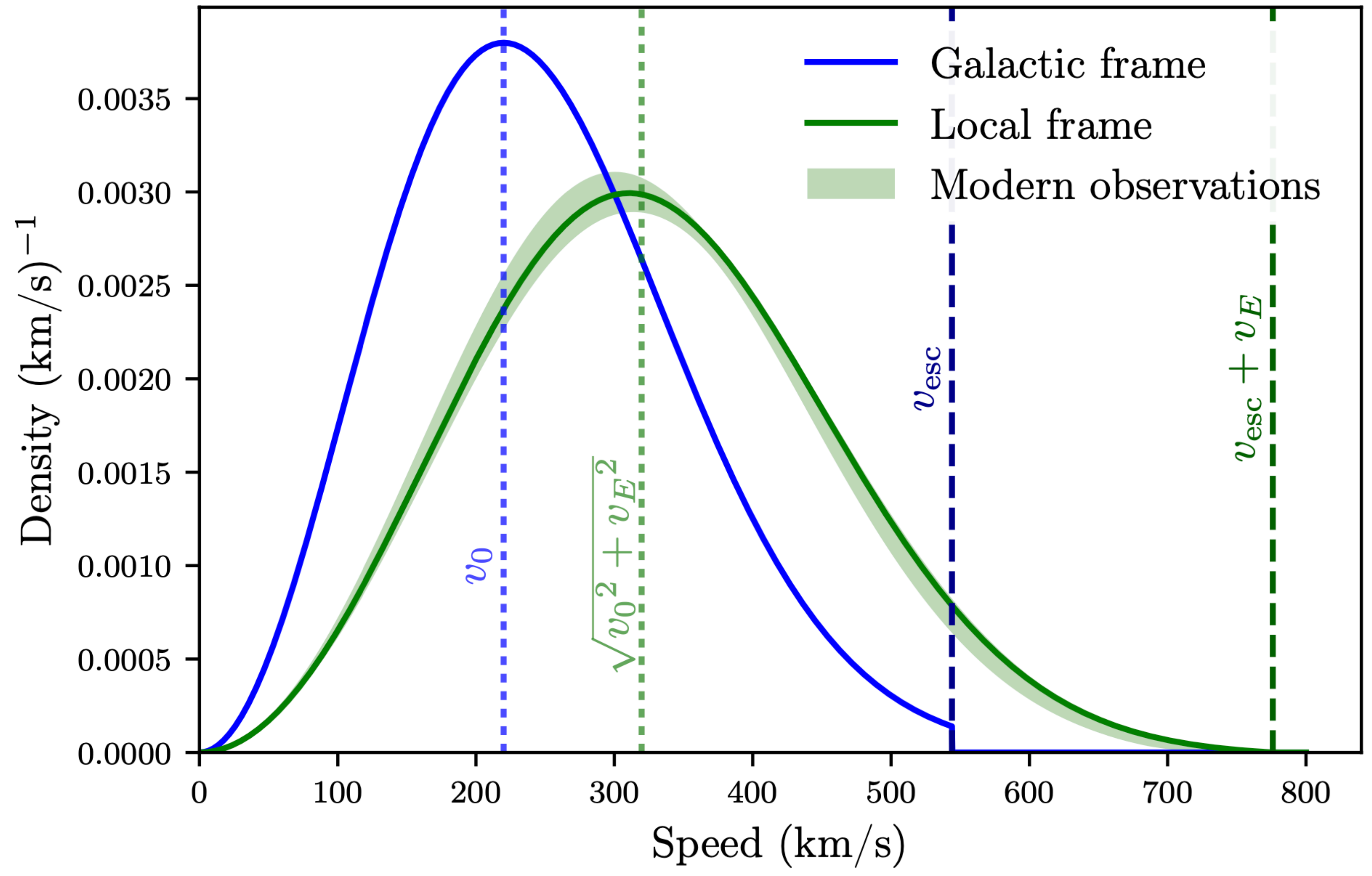
$$\frac{dR}{dE_R} = \frac{\rho}{m_\chi}\frac{1}{m_N}\int_{v_{min}}^{v_{esc}} dv\, f(v) v \frac{d\sigma}{dE_R}(v)$$

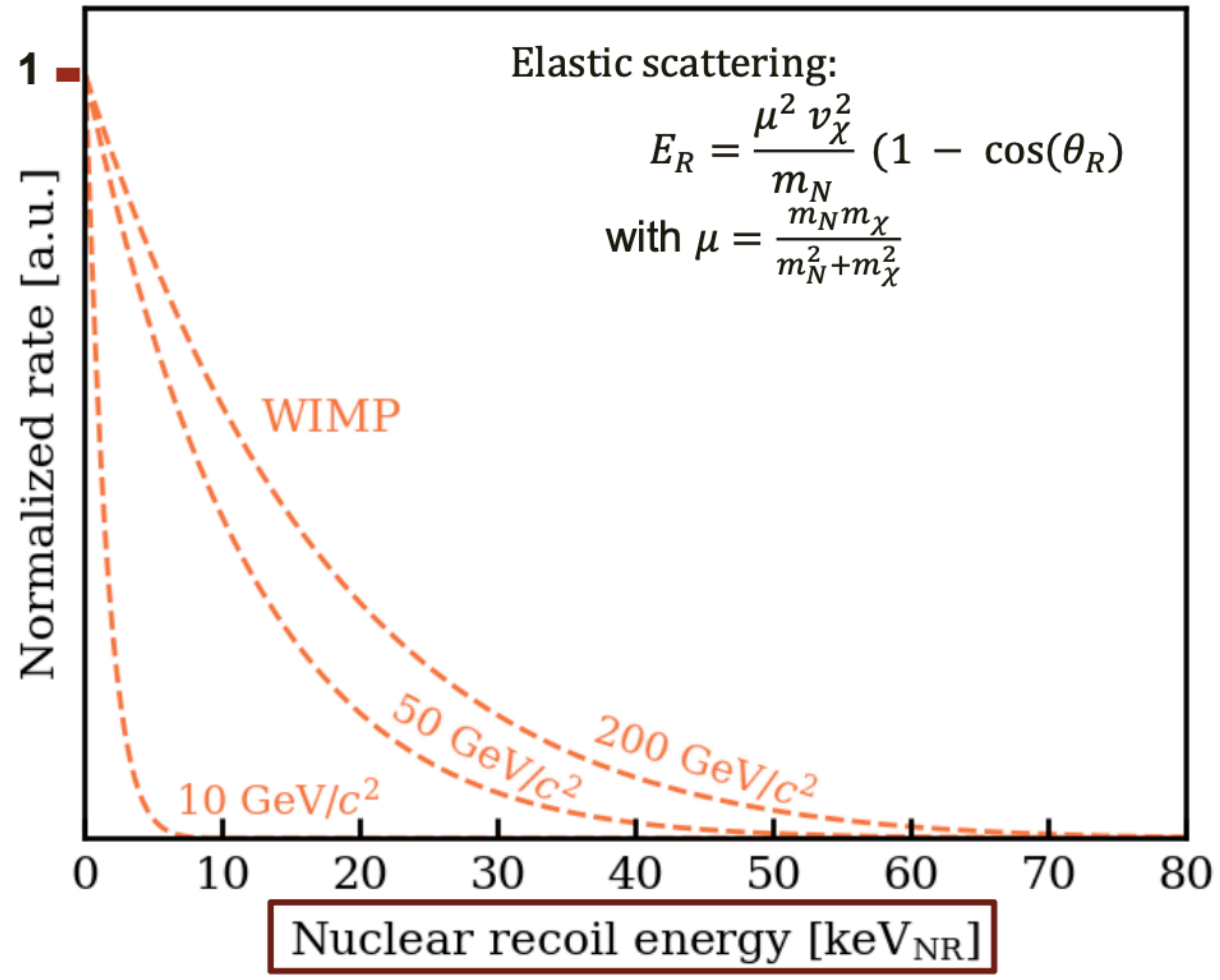
Recoil energy | **DM mass to infer** | Xenon atom mass | detector energy threshold | **DM-SM scattering cross section**

$$\frac{\mathrm{d}\sigma}{\mathrm{d}E_R} = \left[\left(\frac{\mathrm{d}\sigma}{\mathrm{d}E_R}\right)_{\mathrm{SI}} + \left(\frac{\mathrm{d}\sigma}{\mathrm{d}E_R}\right)_{\mathrm{SD}}\right]$$

$\propto A^2$ $\qquad$ $\propto j, S_n, S_p$

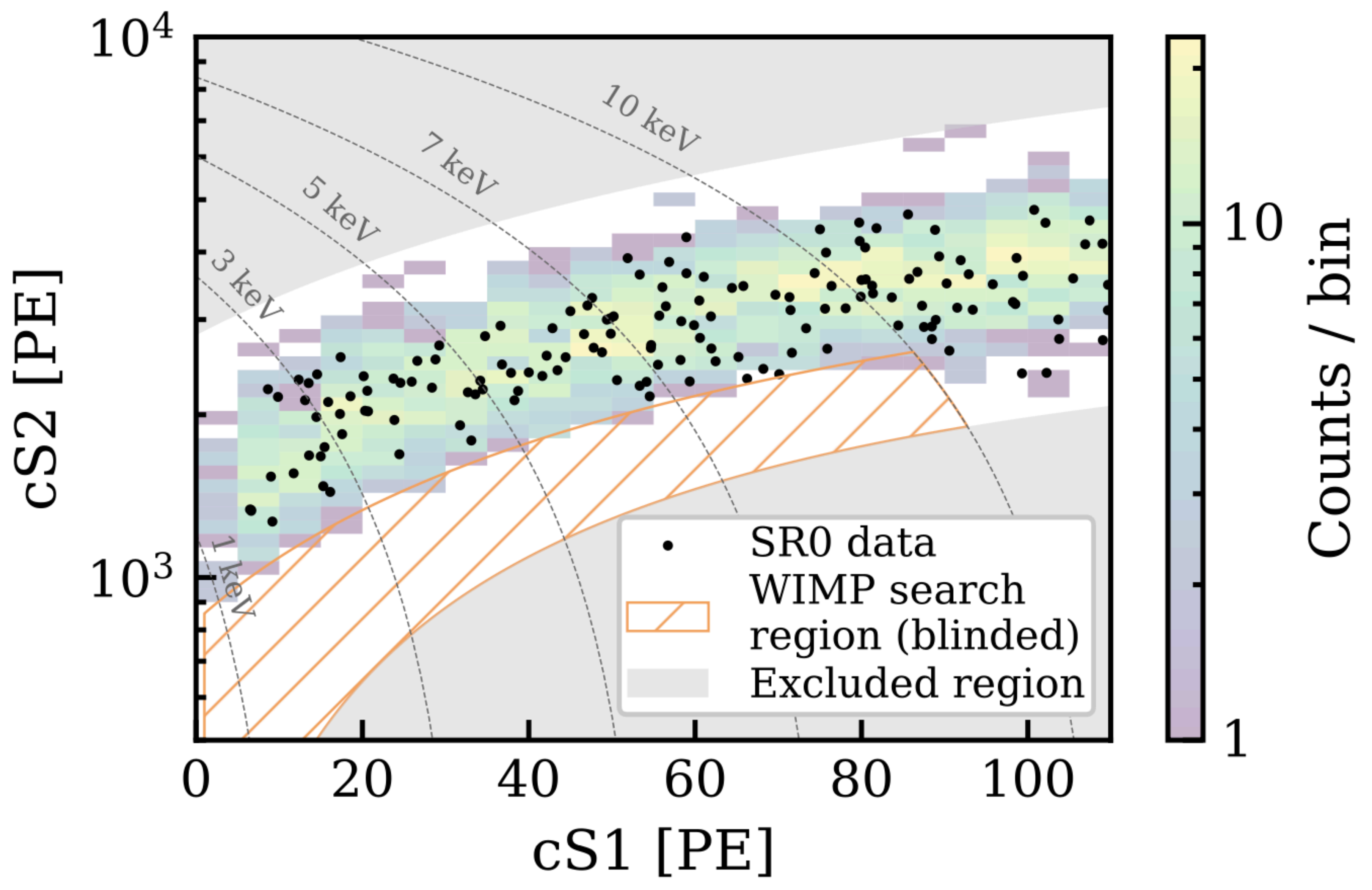


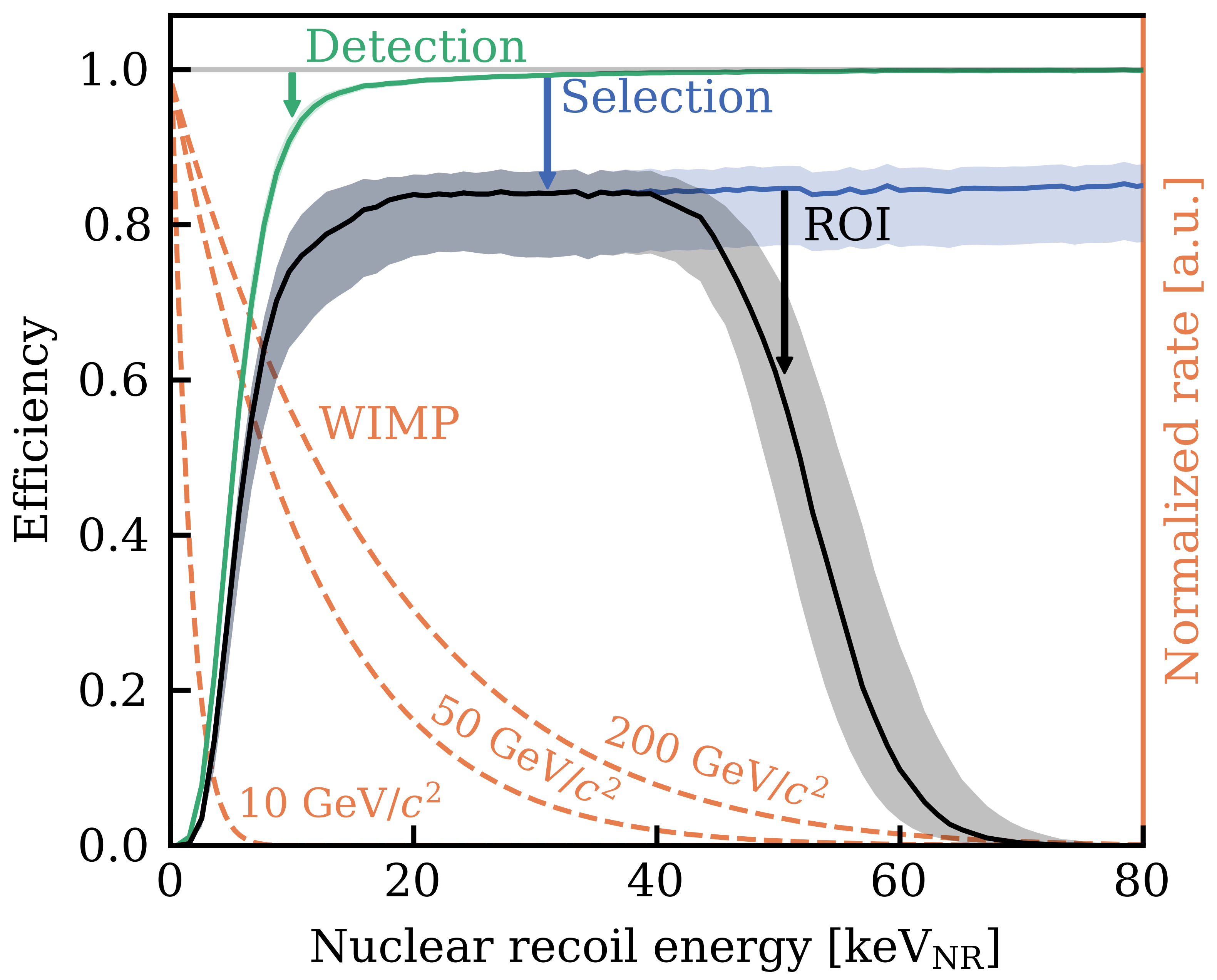




EFFICIENCIES

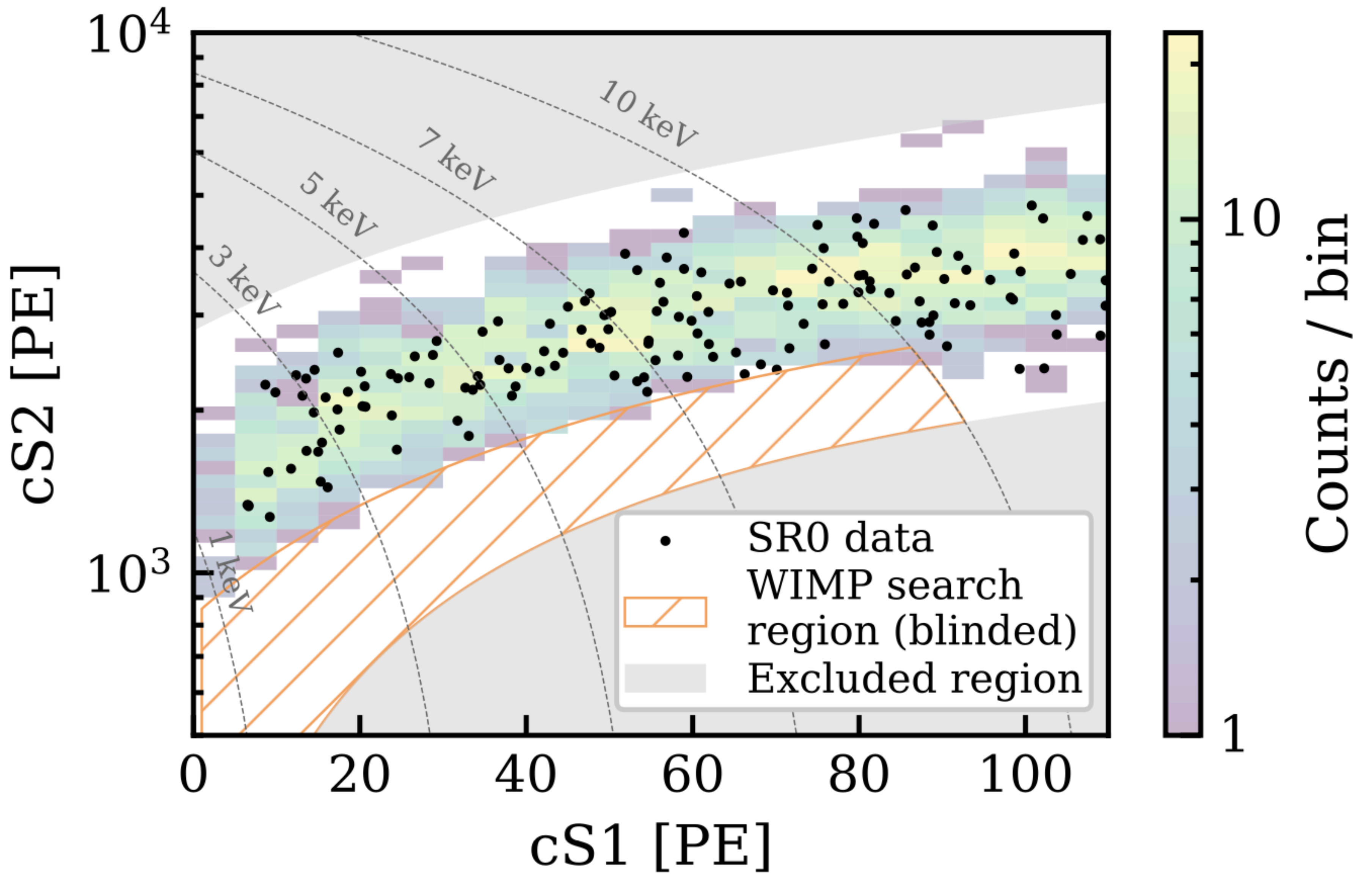
- Search in cS1-cS2 space
- Adopted same detection efficiency as a function of photons detected as in low ER search
- Almost the same S1/S2 peak quality data selection as in low ER search

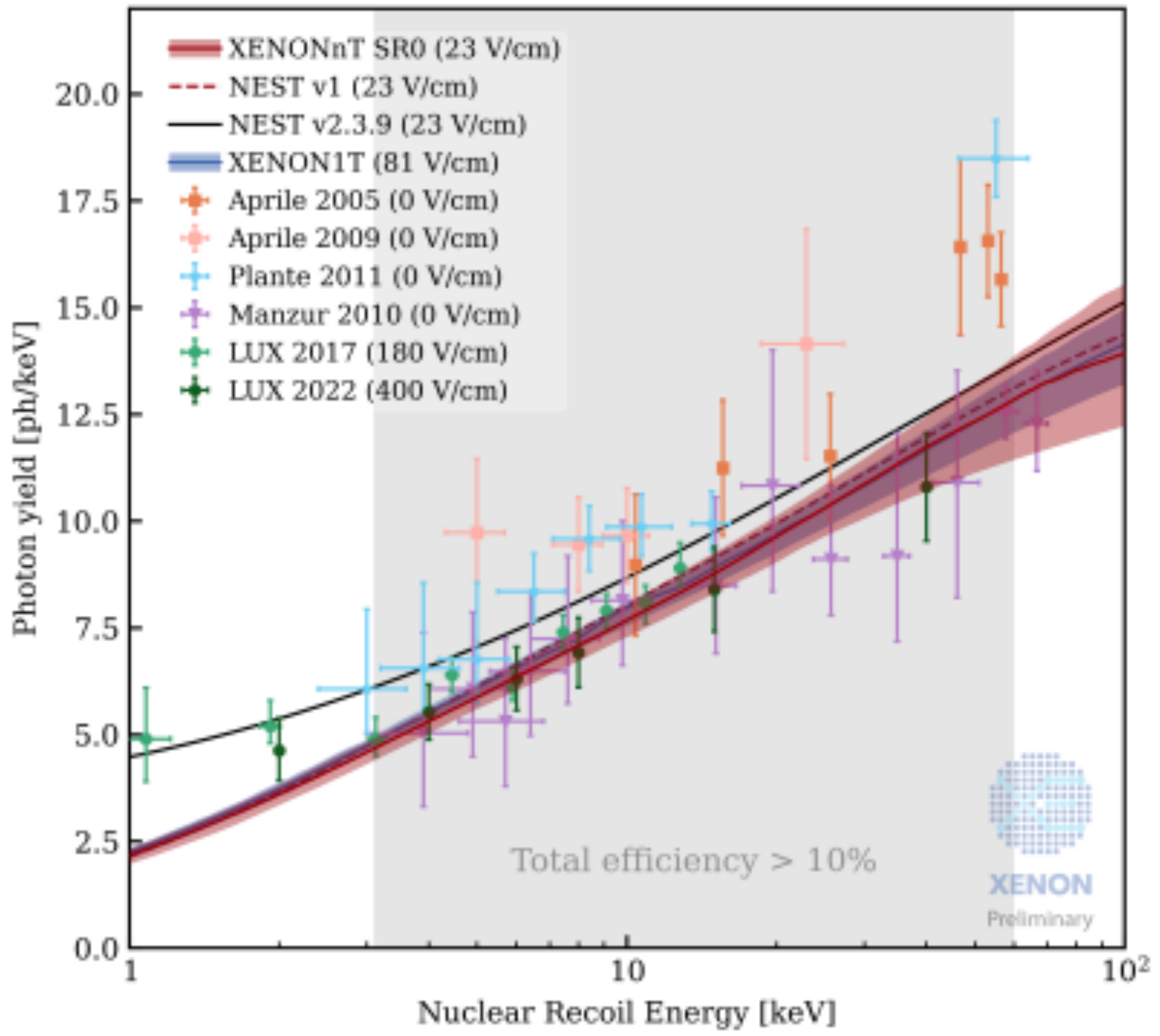


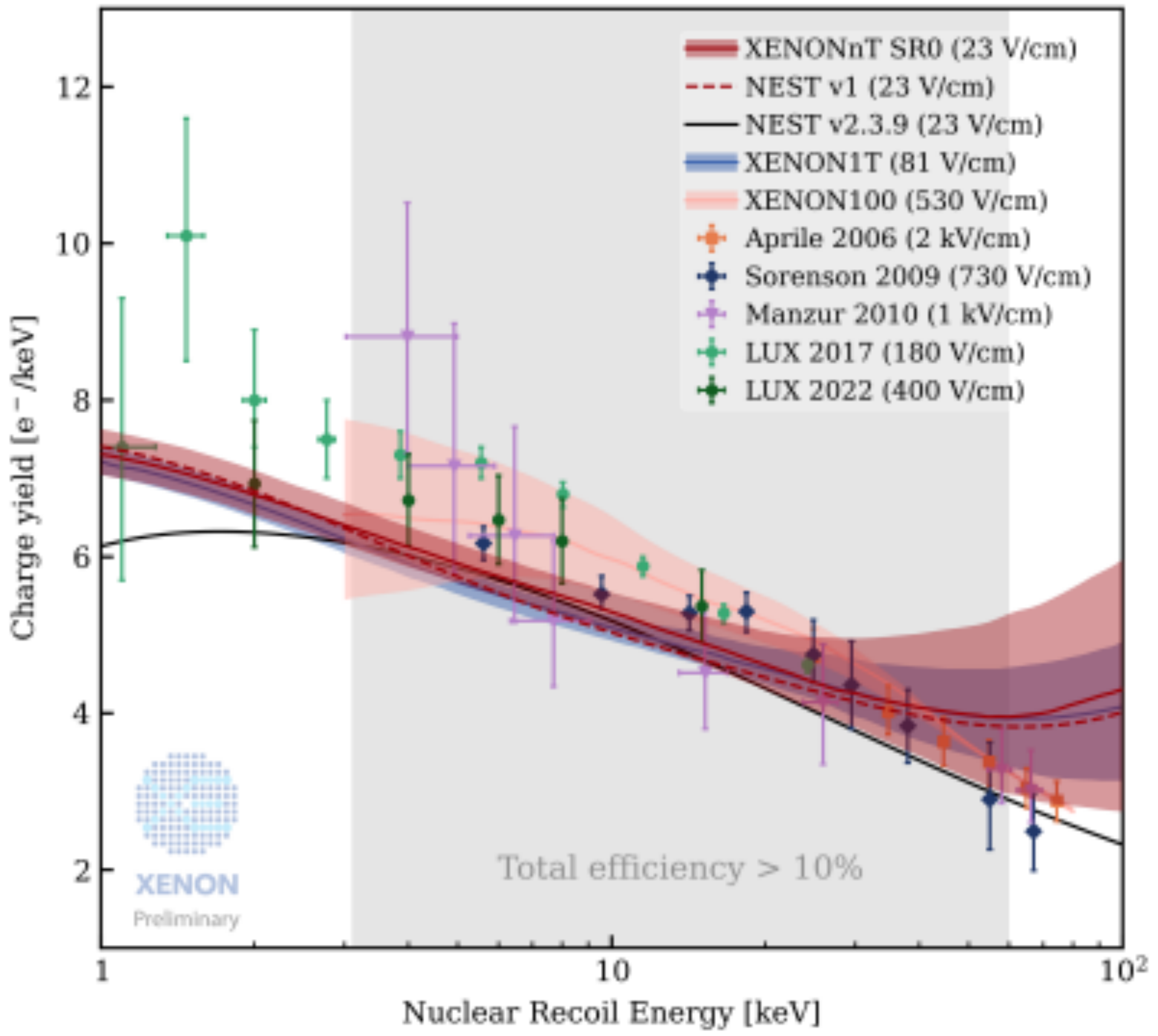


EFFICIENCIES

- **Fitted AmBe neutron calibrations to microphysics+detector model**
- **Search in cS1-cS2 space**

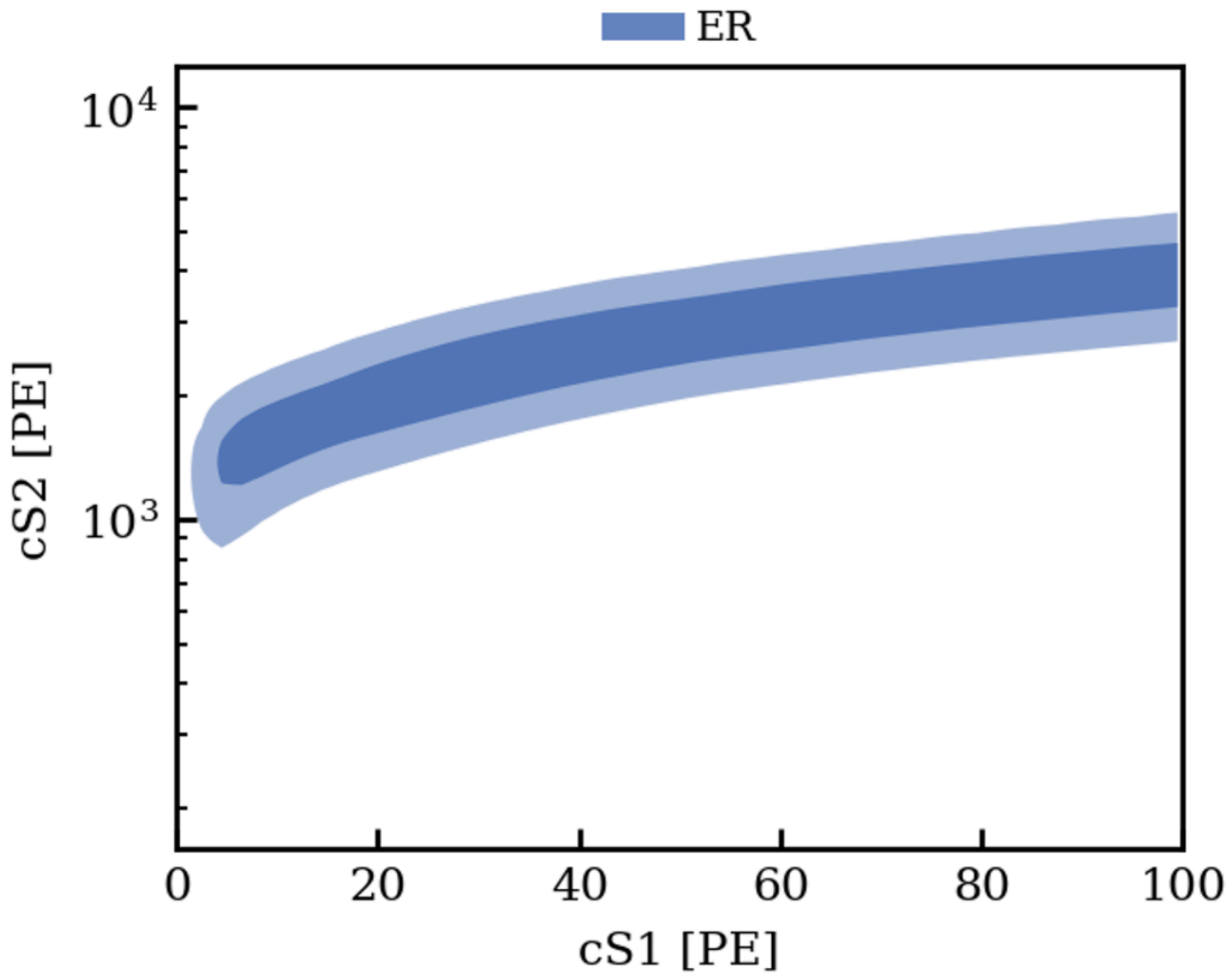


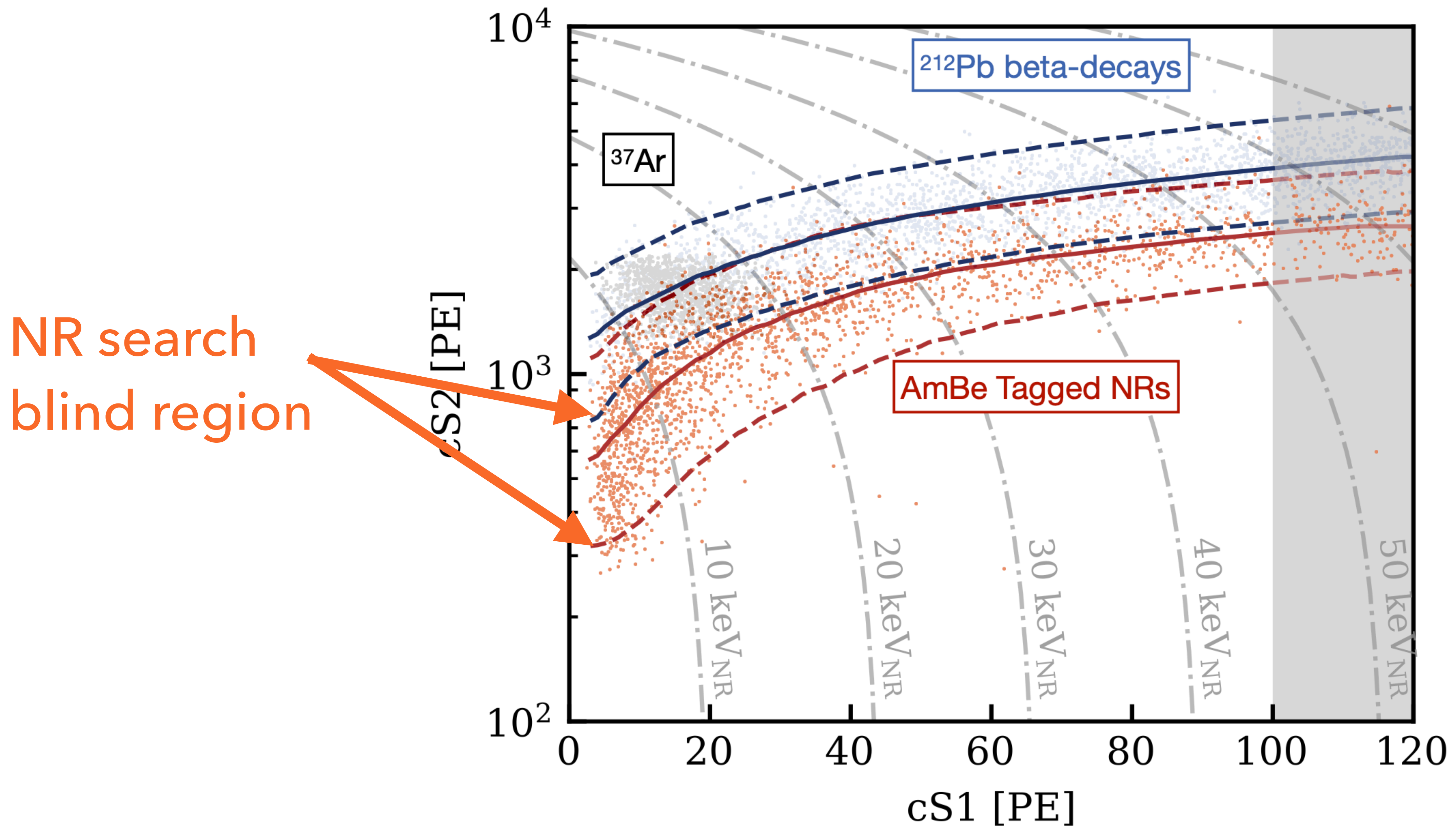




BACKGROUNDS IN NR SEARCH

- **Low ER leakage into NR blind region**
  - Dominated by beta decays from ^{214}Pb, a daughter of ^{222}Rn
  - Estimated Fraction events below NR band median: 1.1%





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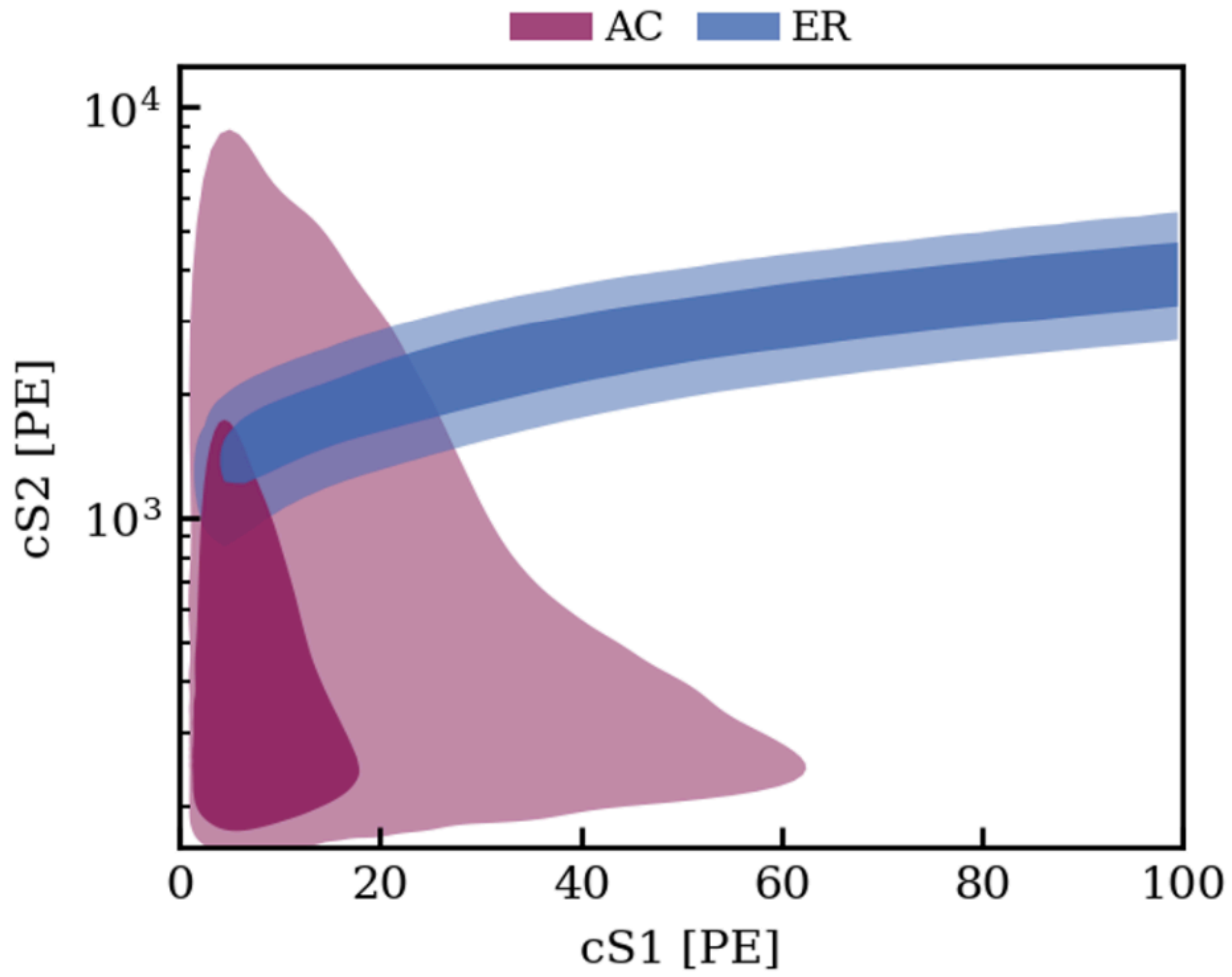
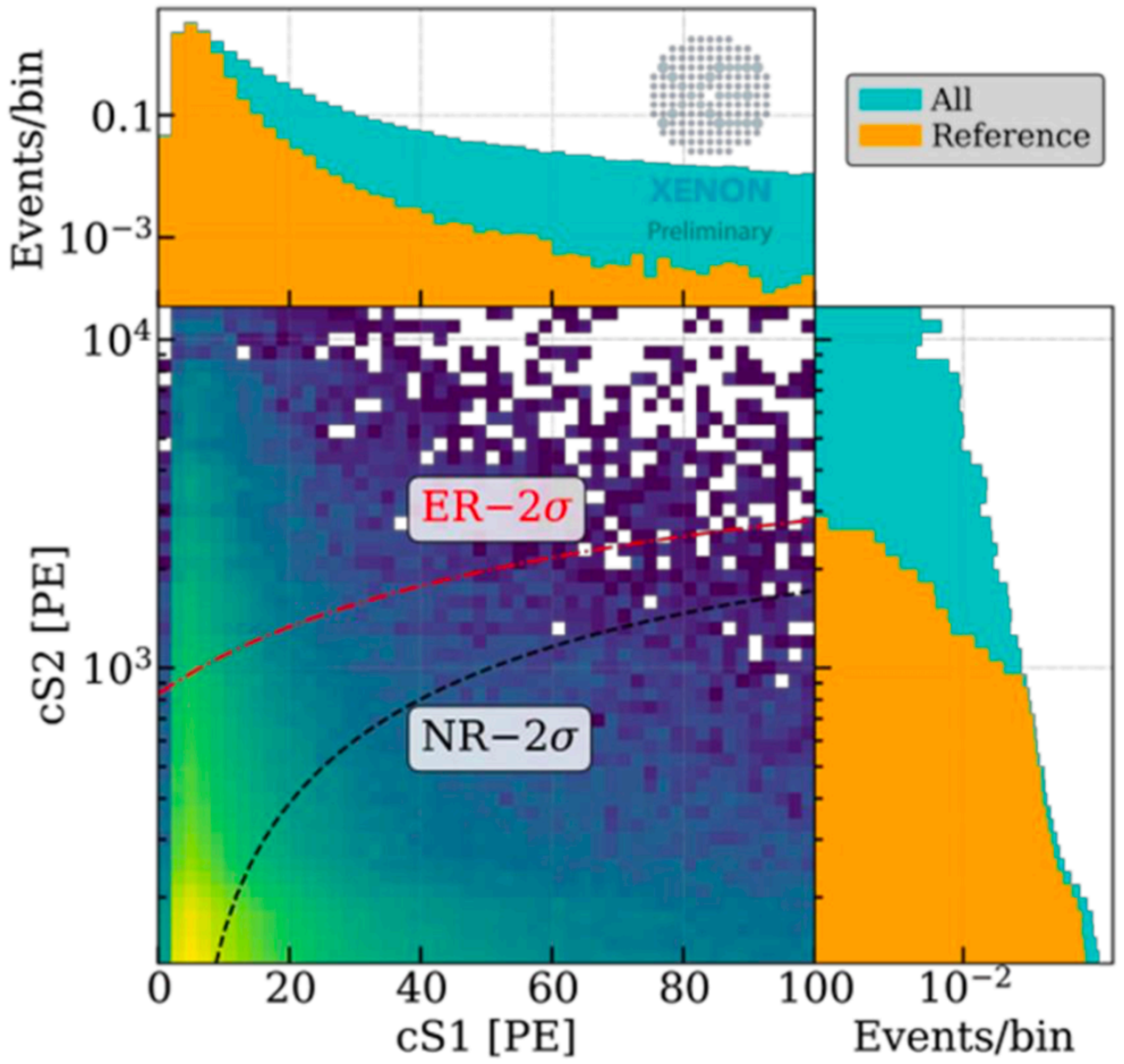


Template generated by pairing isolated S1/S2 and their ambience

validated on sidebands (all cuts but not S2 width+S2 BDT) and low energy calibrations



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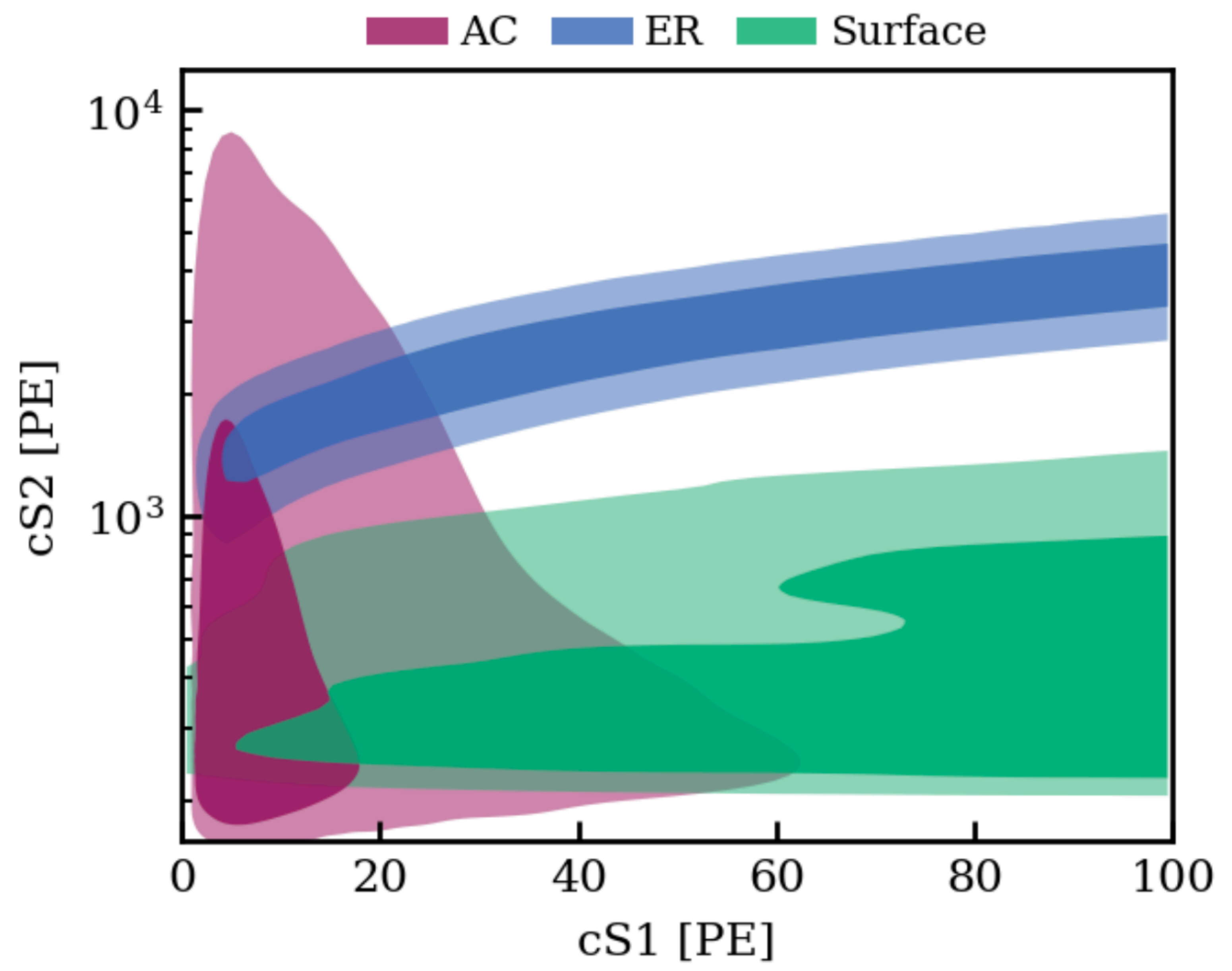
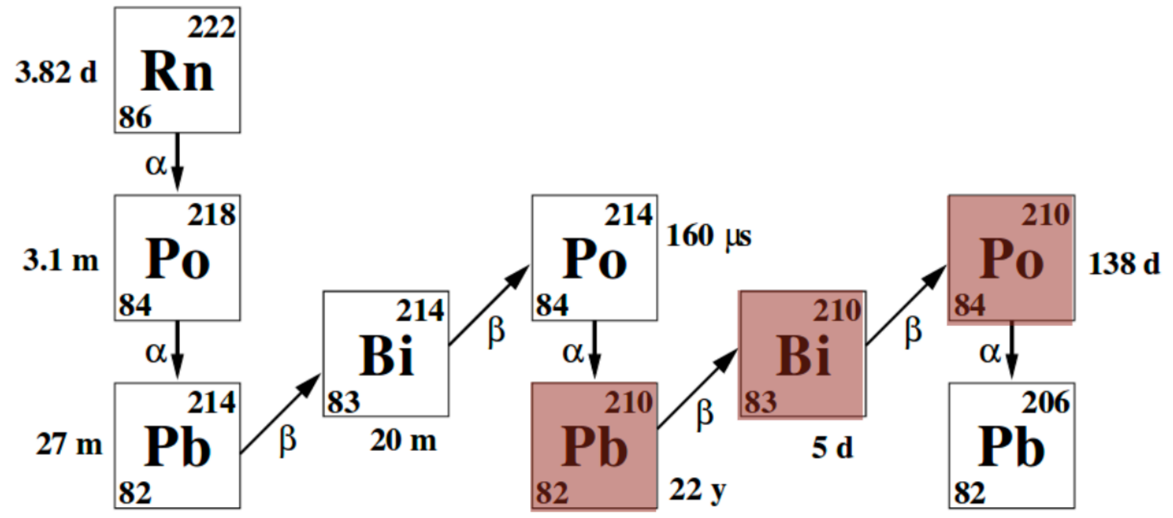
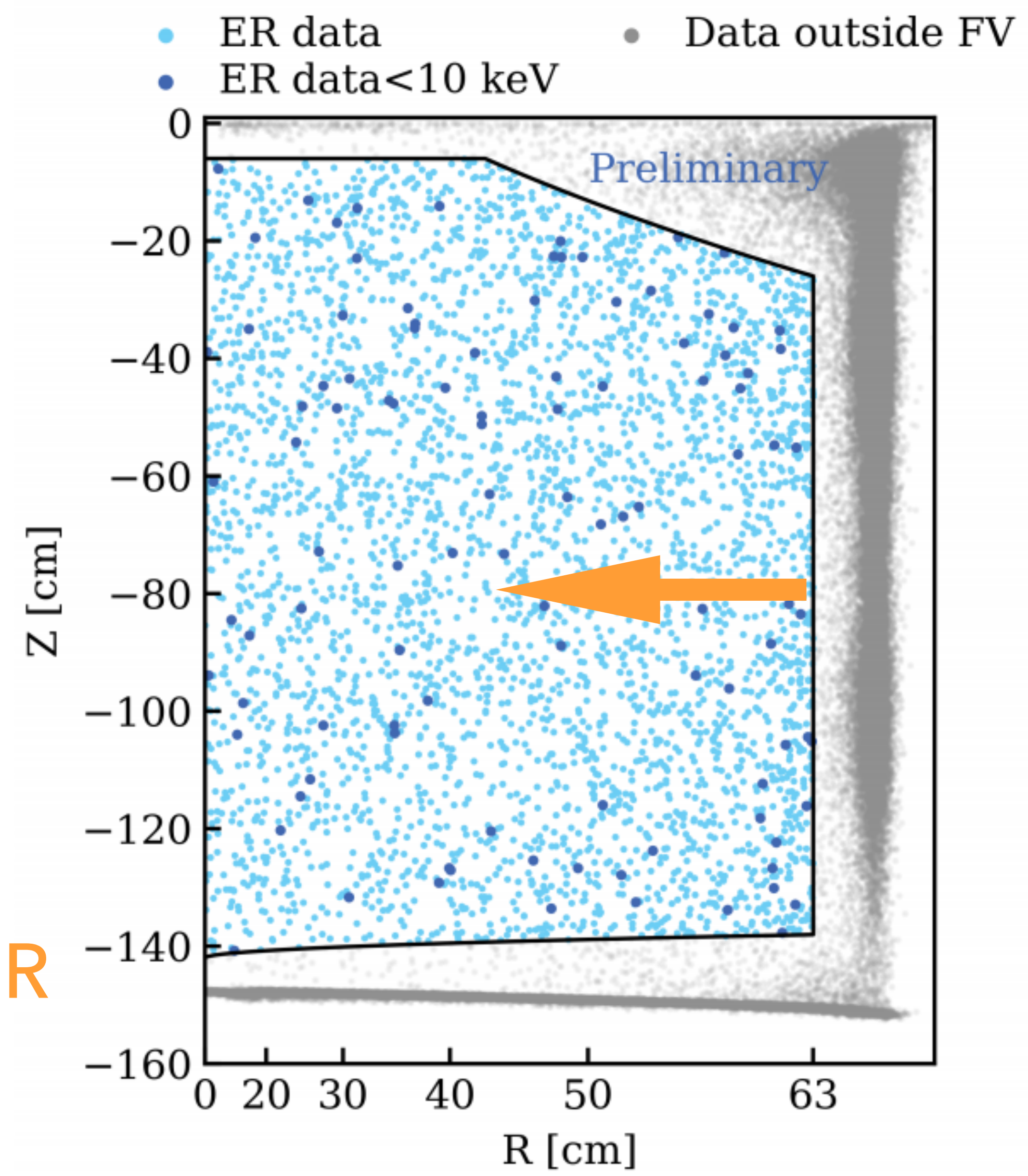
- **Surface background model**
  - "Surface" events due to ERs from ^{210}Pb plate out at detector walls (with charge loss)
  - Use events reconstructed outside the fiducial volume and a KDE to create a smooth template for ROI
  - Fine-tuned fiducial volume radius to suppress





FV is more stringent than ER



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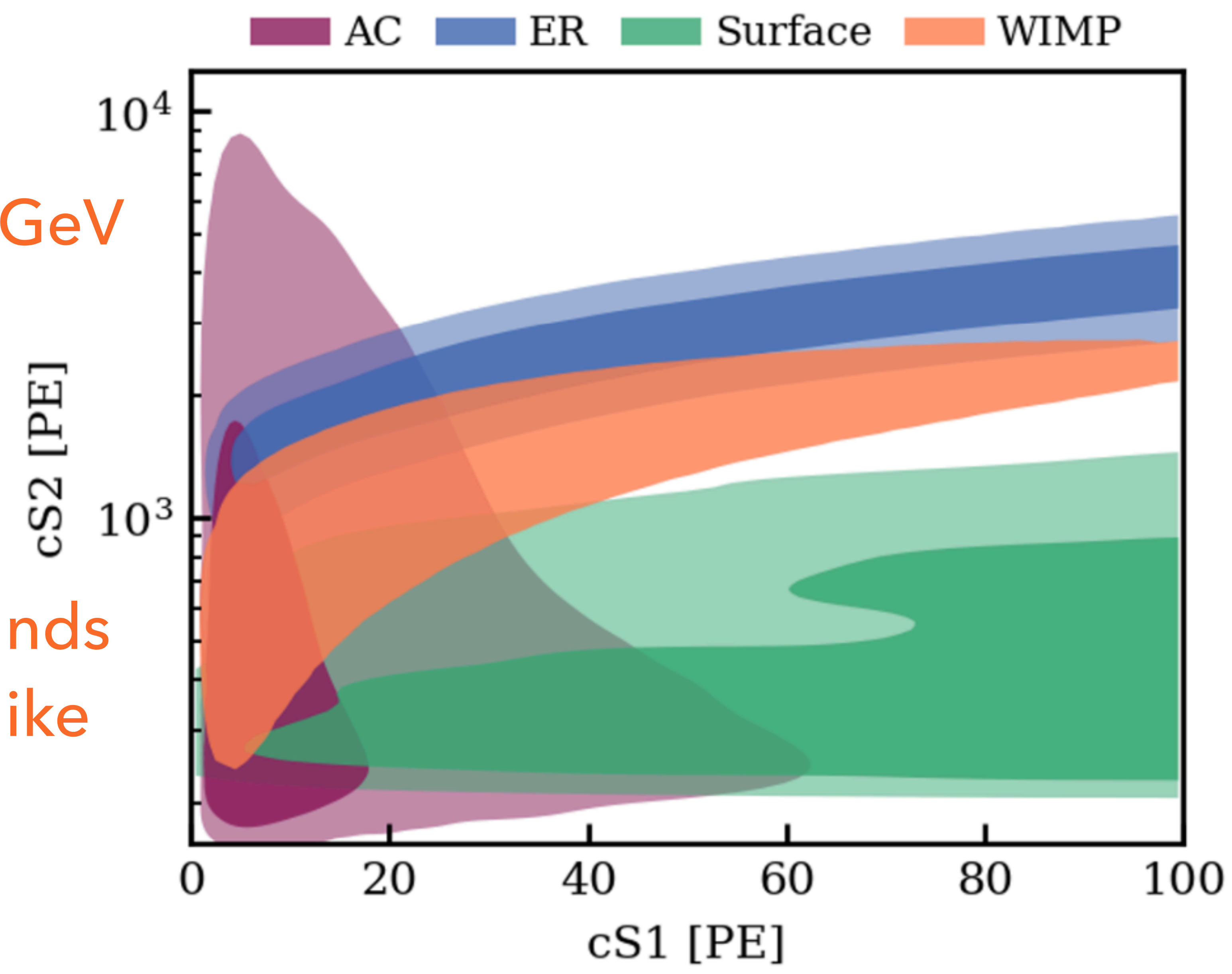
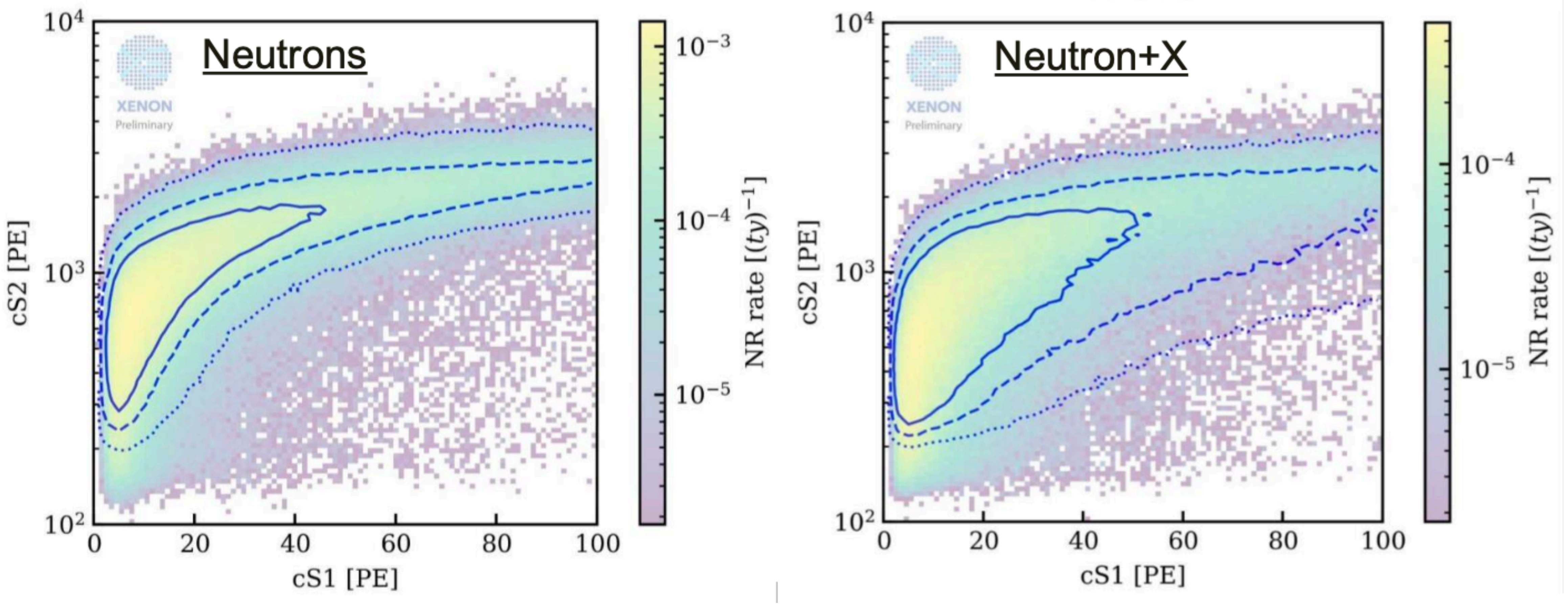
- **NR background**
  - **Neutron events from spontaneous fission and (α,n) reactions**

2σ contour of 200GeV WIMP template

Neutron backgrounds looks very similar like WIMP!

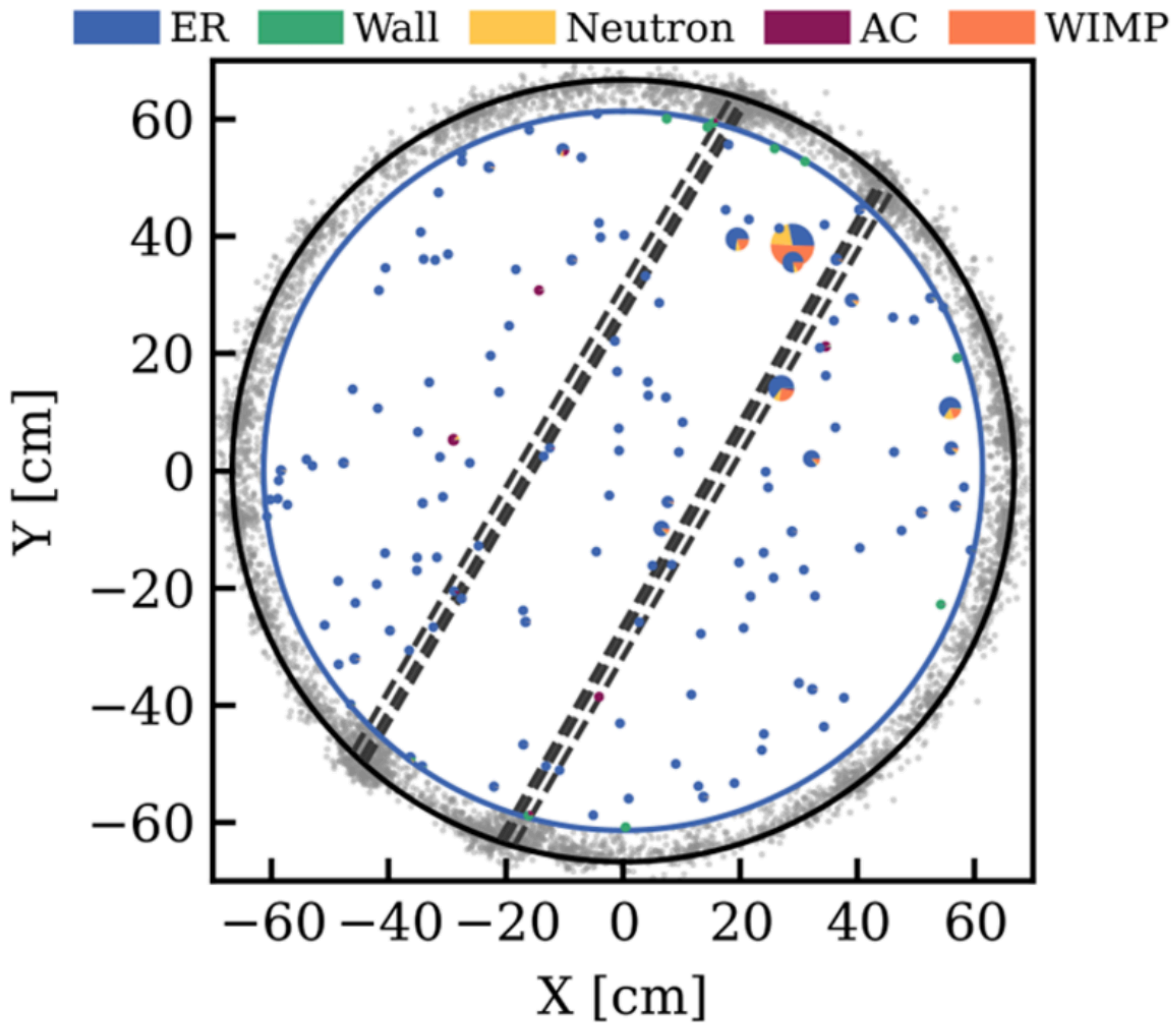


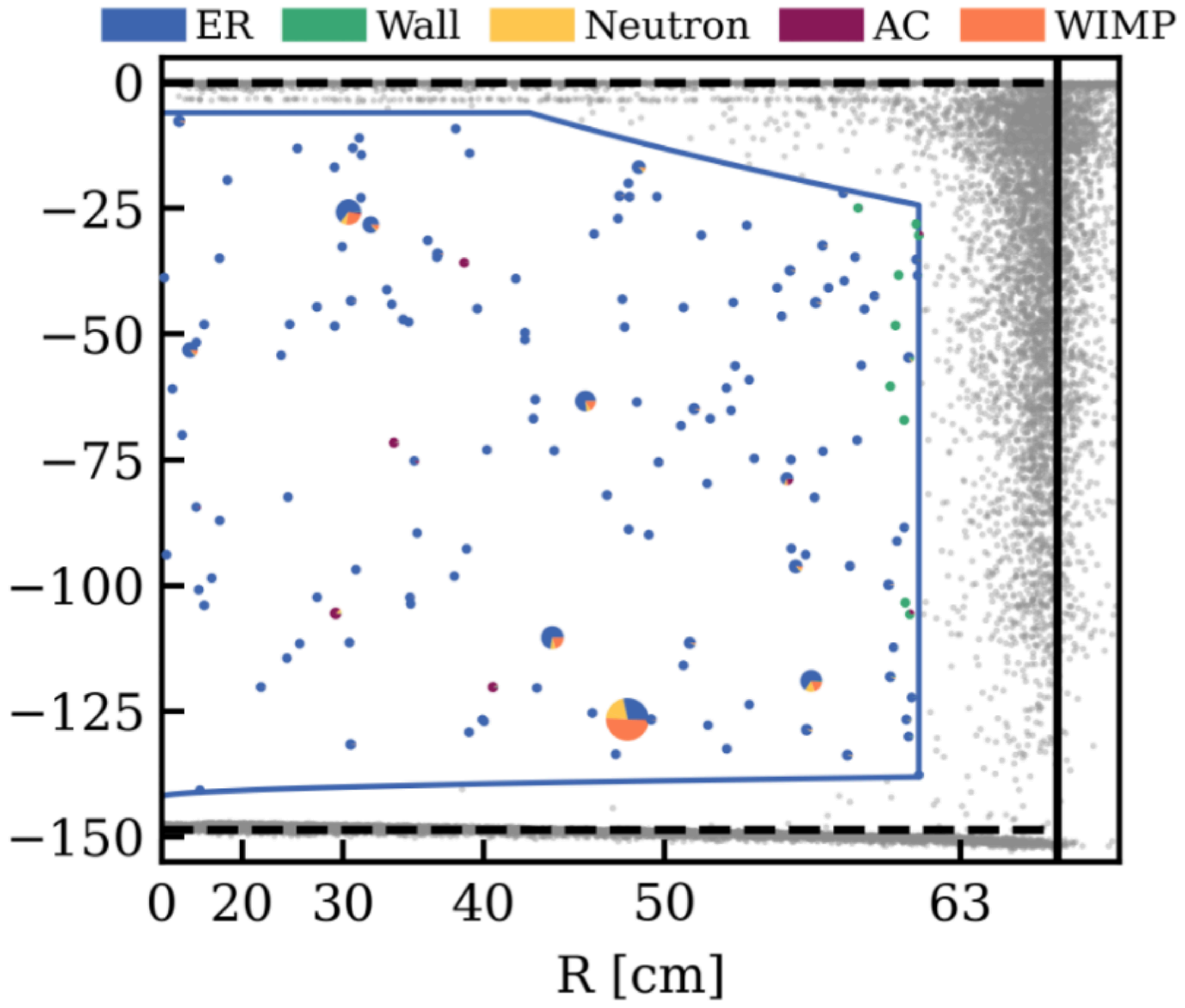


Background templates generated via full-scale Neutrons waveform simulations + analysis chain

UNBLINDING

- **Asymmetric event spatial distribution??**
- Checked x-y distribution of the following and found no spatial preference
  - Data selection cuts
  - Detector effect correction
  - Unblinded events in ER band
- No significant angular preference in materials
- No significant angular preference in unblinded ER events near NR band



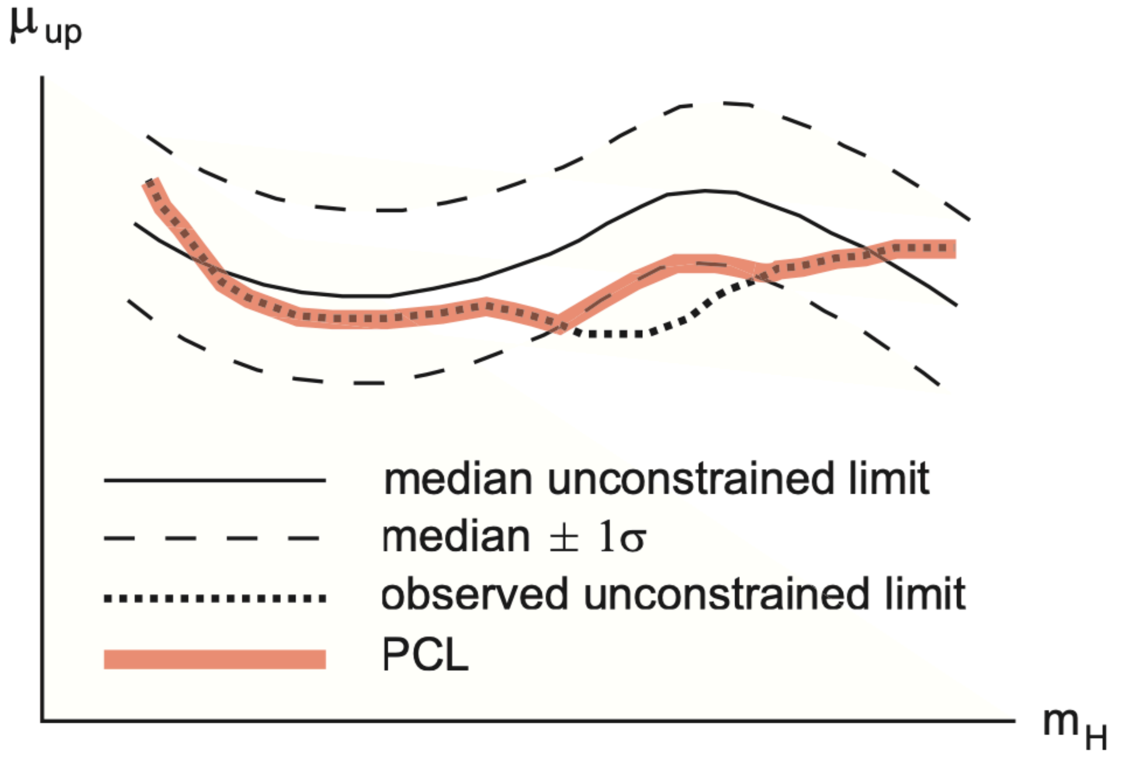


LIMITS ON WIMP SD INTERACTION WITH NUCLEONS

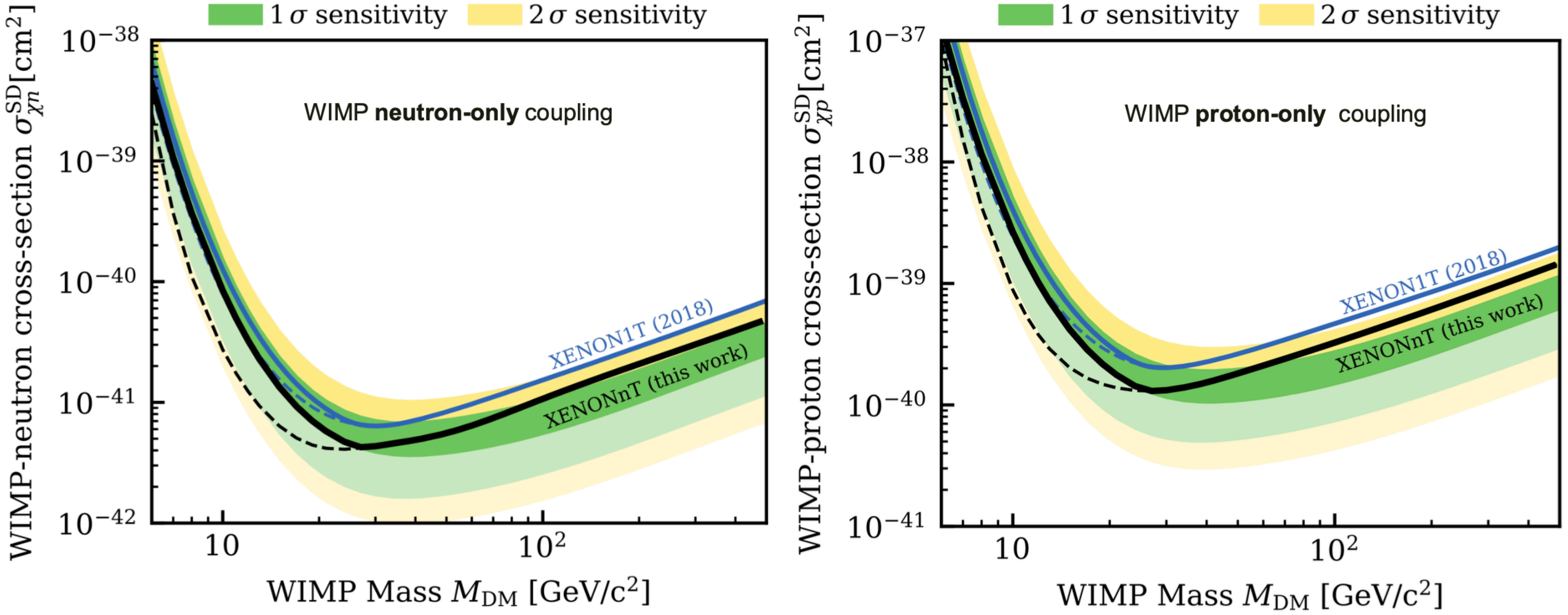
- Median upper limit @ 90% confidence (Feldman-Cousin construction obtained by MC) for Log-Profiled-Likelihood-ratio

$$q(\sigma) = -2\log\frac{L(\sigma,\hat{\hat{\theta}})}{L(\hat{\sigma},\hat{\theta})}$$

- **Blinded WIMP dark matter search with 1.1 tonne-year exposure**



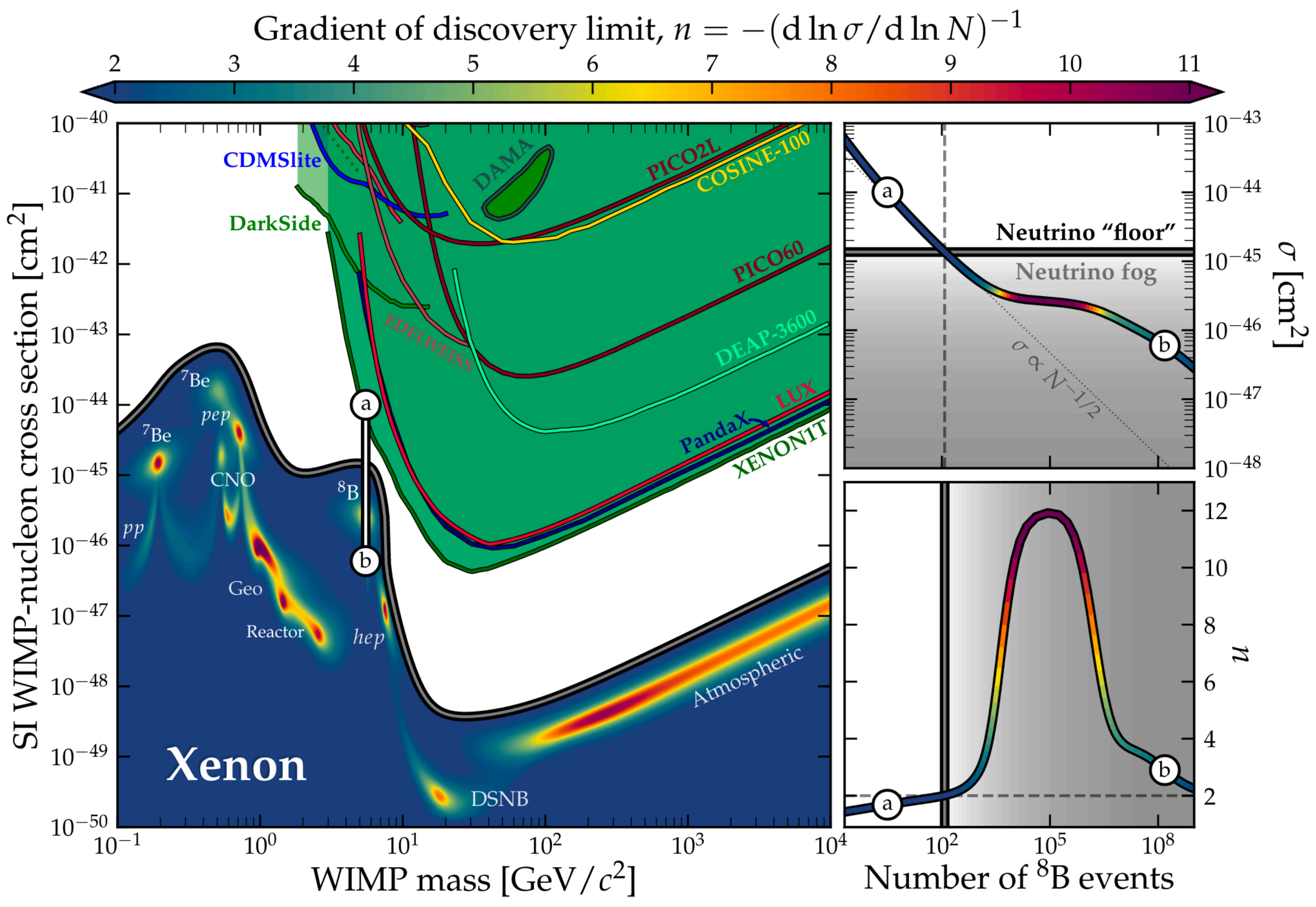
Power constraint limits (PCL) to avoid problematic spurious exclusion
arxiv:1105.3166.



Sensitive in ^{129}Xe and ^{131}Xe only

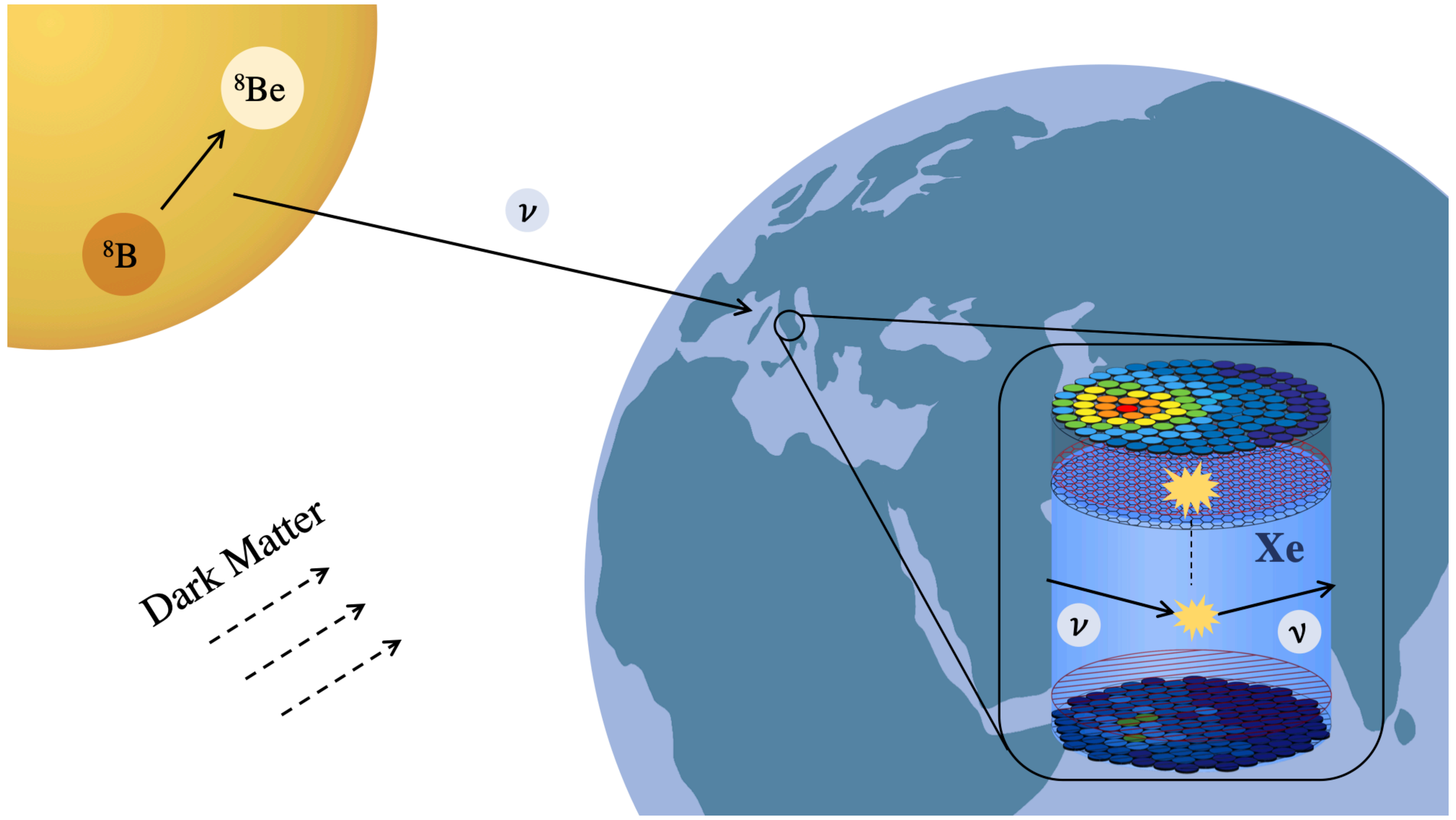
NEUTRINO FOG LANDSCAPE

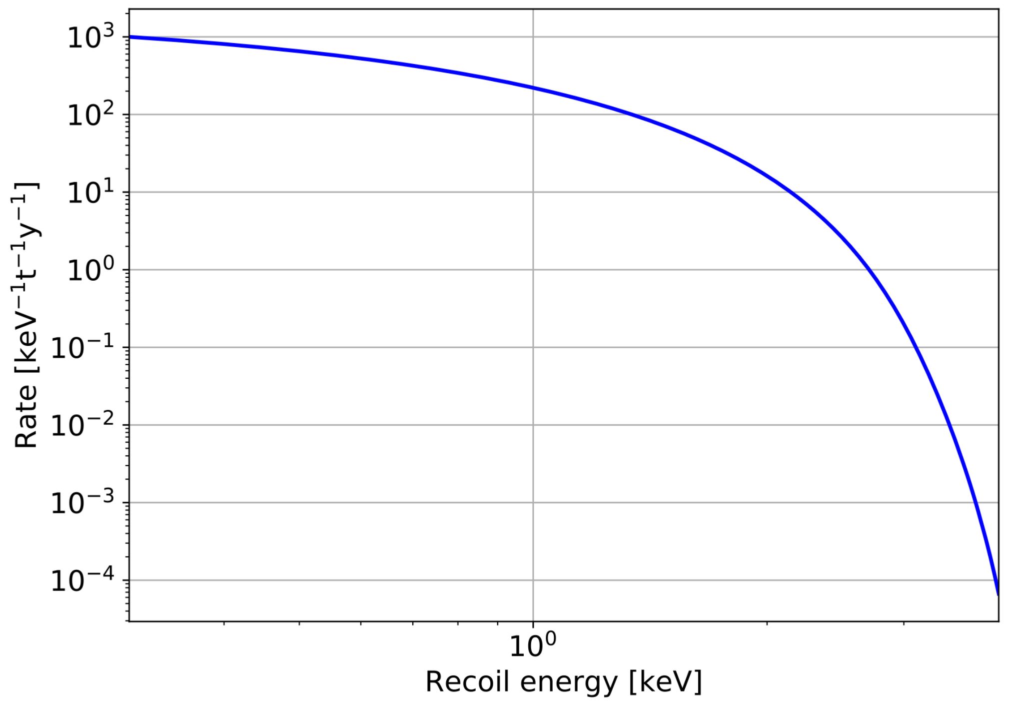
- Motivation of neutrino fog rather than floor
  - **Severity of neutrino background is highly dependent on uncertainty of neutrino flux**
    - Uncertainty improves over time
  - **The DM and neutrino signals are never perfect matches.**
    - The spectrum discrimination will help regain sensitivity for DM

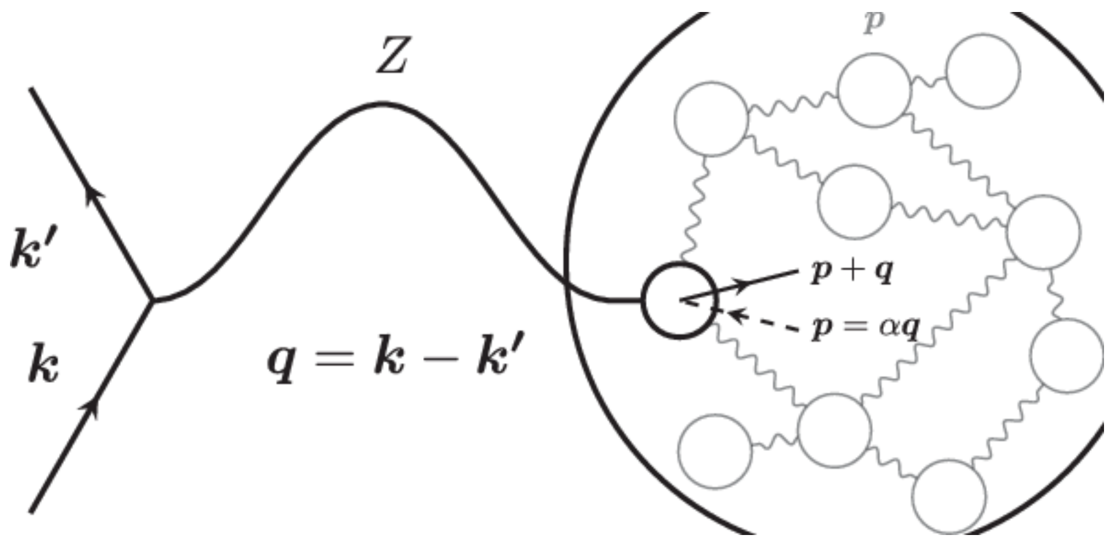


^{8}B COHERENT ELASTIC NEUTRINO-NUCLEUS SCATTERING (CEVNS)

- CEvNS: a long-wavelength (low momentum transfer) Z boson can probe the entire nucleus, and interact with it as a whole.
- "neutrino fog" from solar ^{8}B neutrinos, with ~1keV$_{NR}$ NR signature in NR







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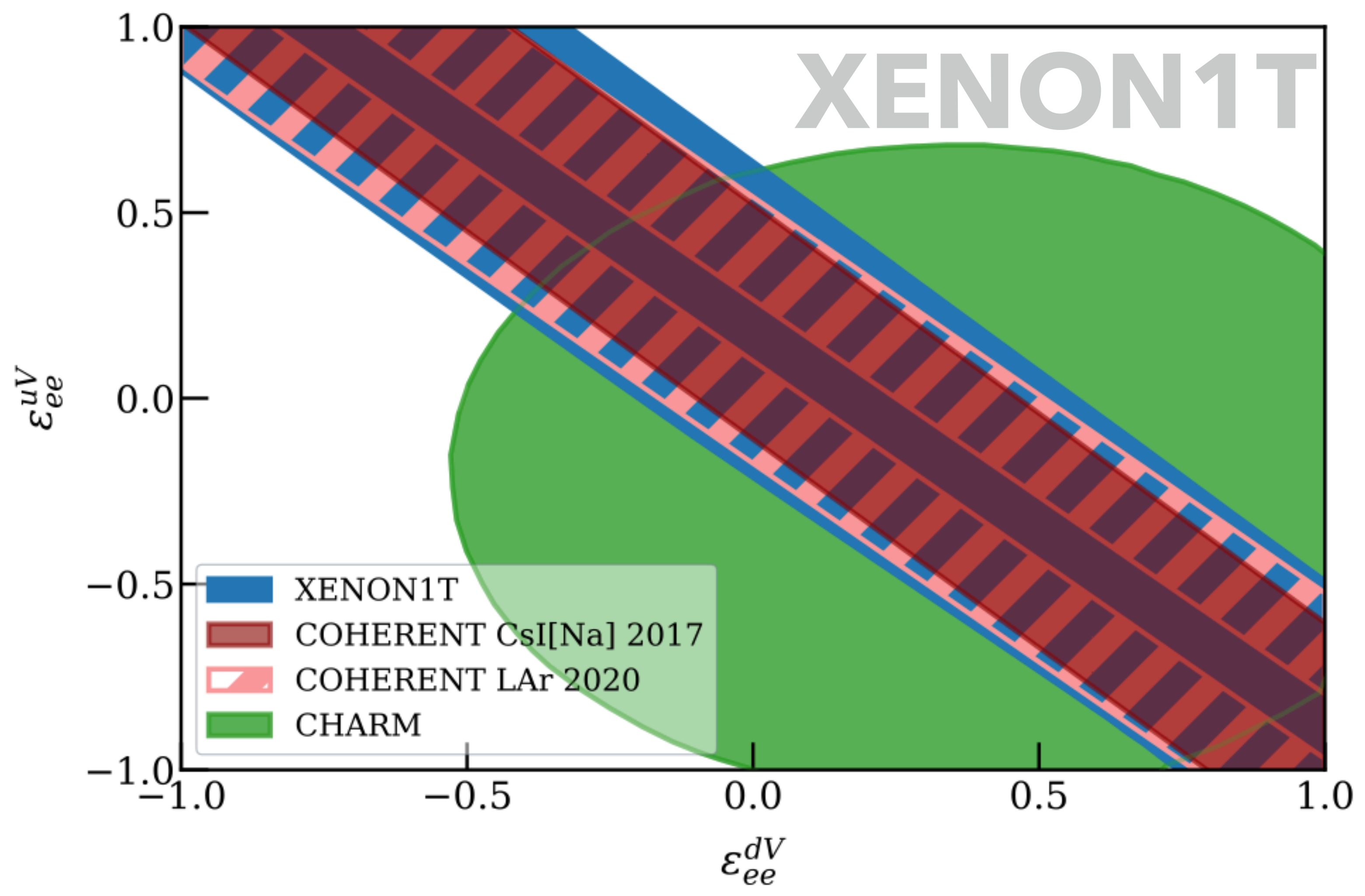
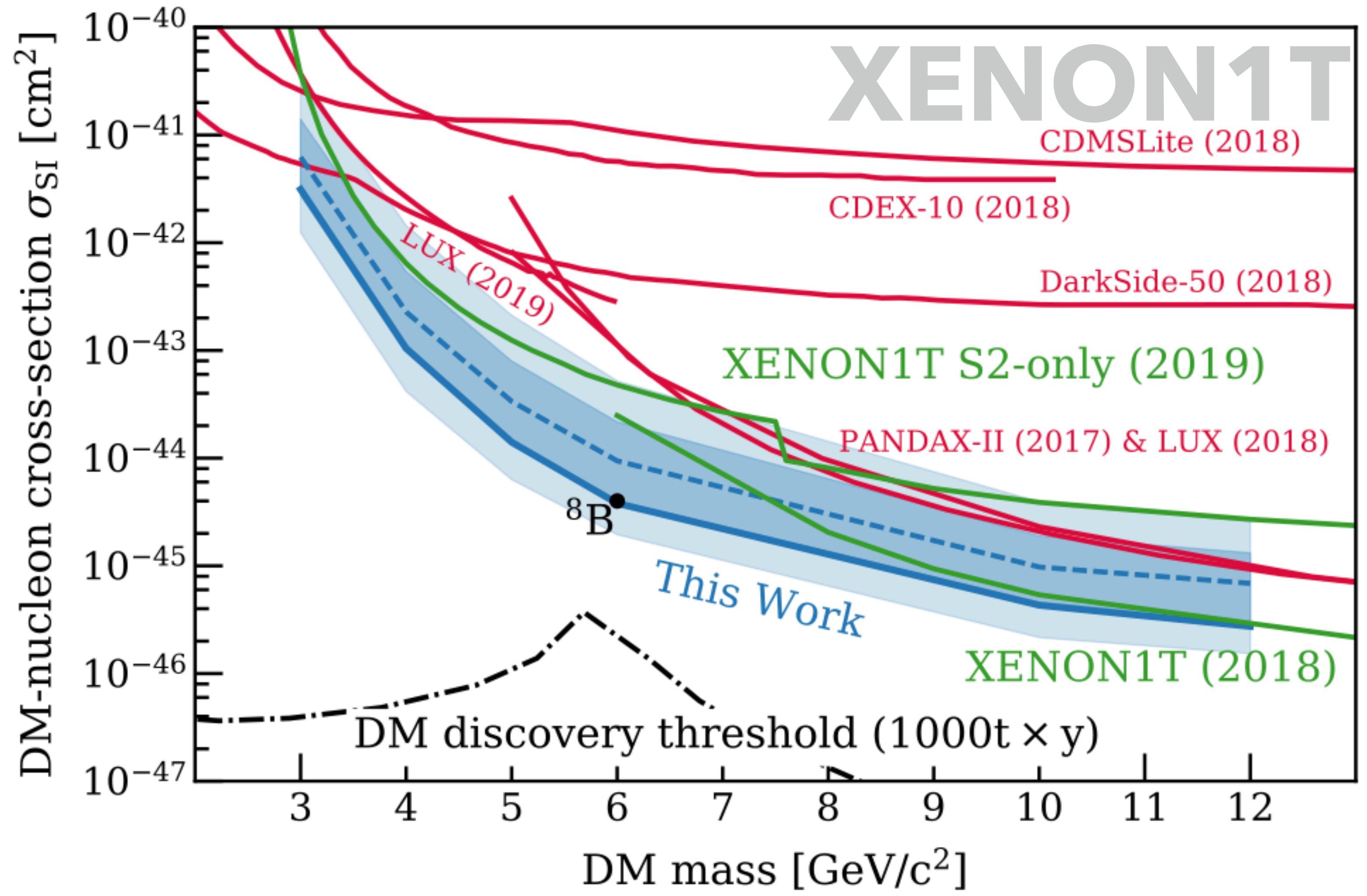
- CEvNS: a long-wavelength (low momentum transfer) Z boson can probe the entire nucleus, and interact with it as a whole
- **"neutrino fog" from solar ^{8}B neutrinos, with ~1keV$_{NR}$ NR signature in NR**
- **Same analysis searches for light dark matter**
- Challenge: increase signal acceptance ratio from ~0.05% to ~1% while controlling background
  - 3→2-fold PMT tight-coincidence
  - Lower minimum S2 requirement
- Major background: Accidental Coincidence
  - GBDT trained on S1-S2 correlation significantly suppressed AC rate



Constraints on non-standard vector couplings between the electron neutrino and quarks

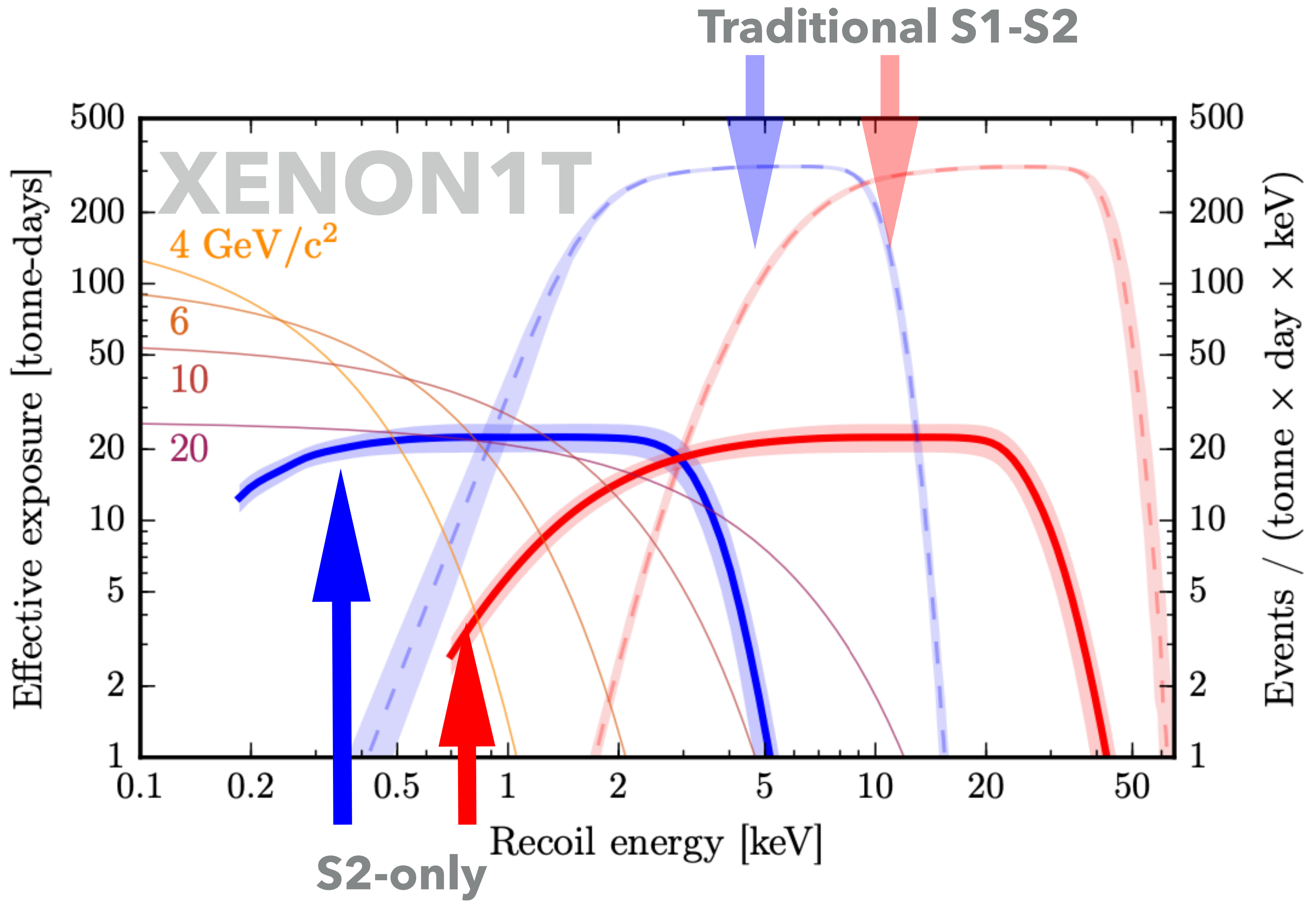
XENON1T ^{8}B CEvNS: 2 events

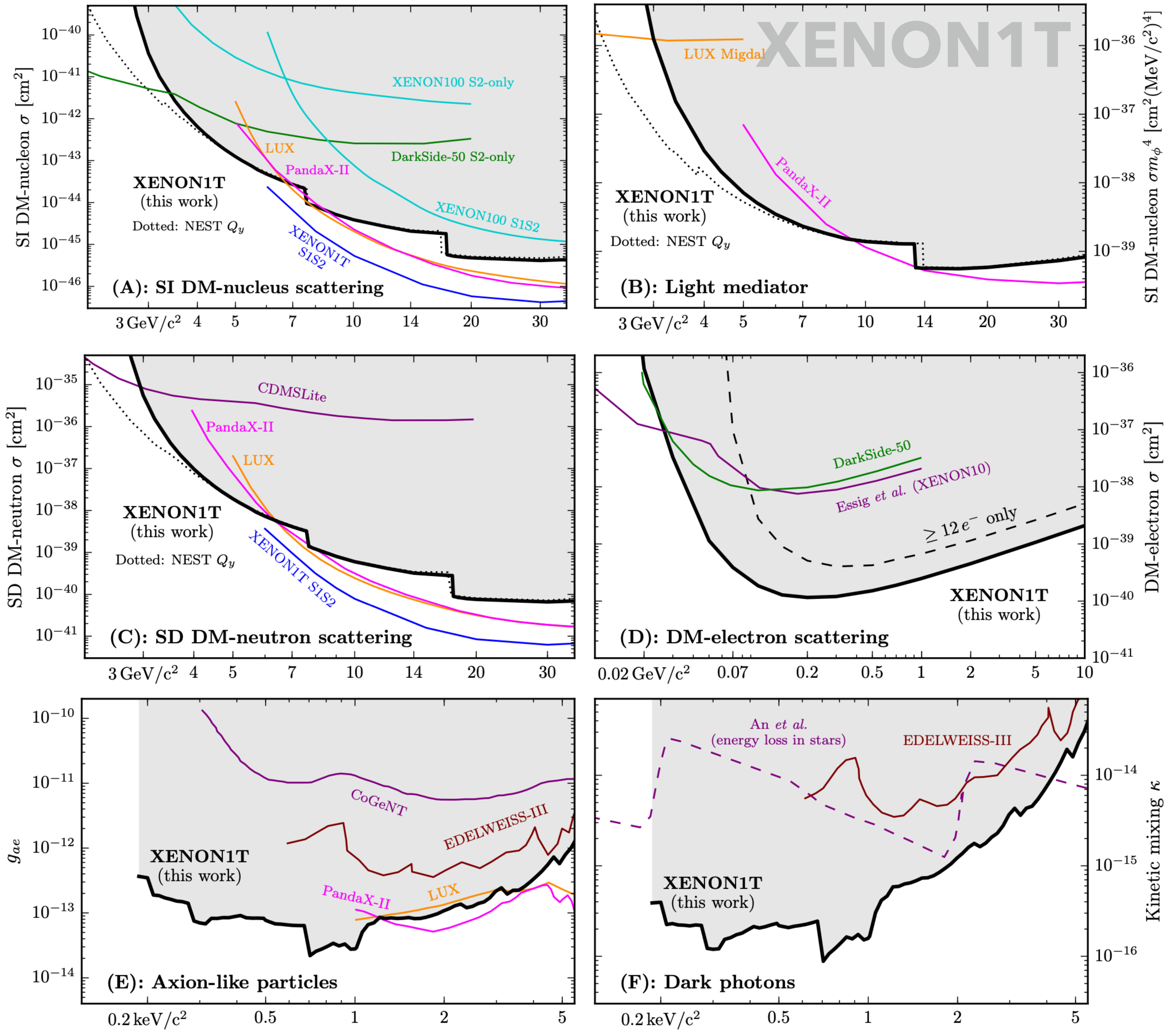


Low mass spin-independent DM-nucleon cross section

S2-ONLY SEARCH FOR LIGHT DARK MATTER

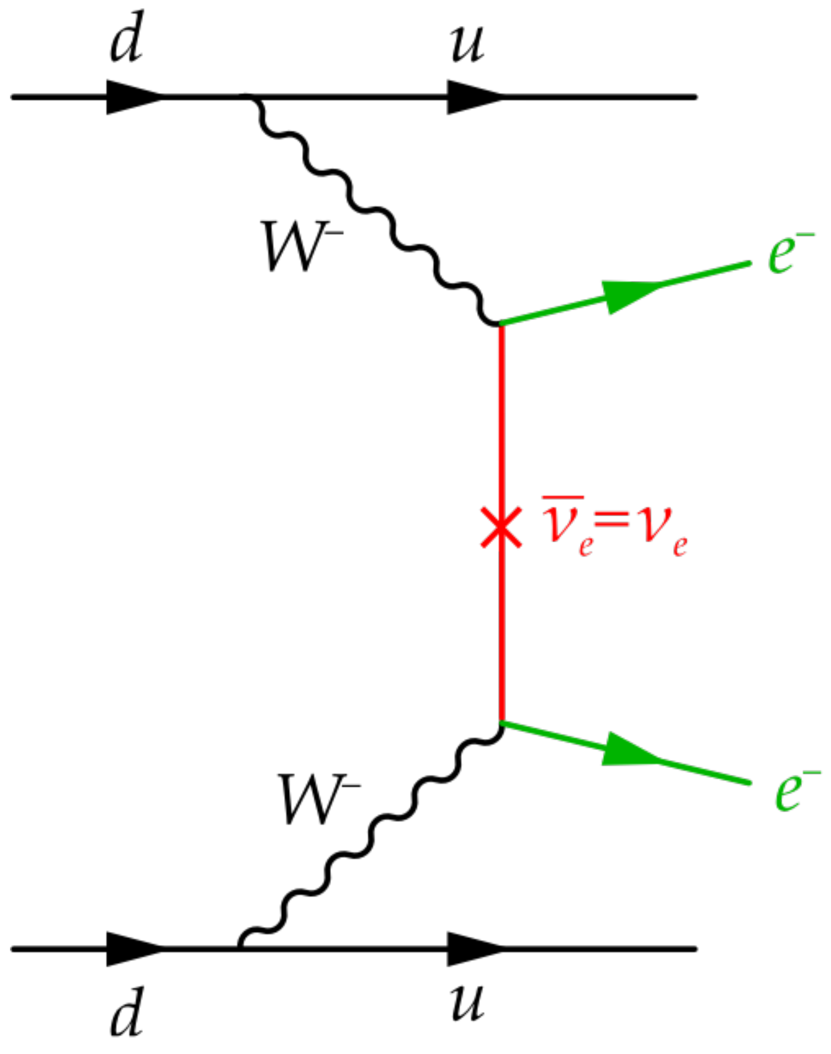
- Can extend search (without discovery power) to S2-only signals for DM with low recoil energy
- With better S2-only background modeling, larger exposure with triggerless DAQ, and very high electron lifetime, **XENONnT will give much stringent constraints soon**

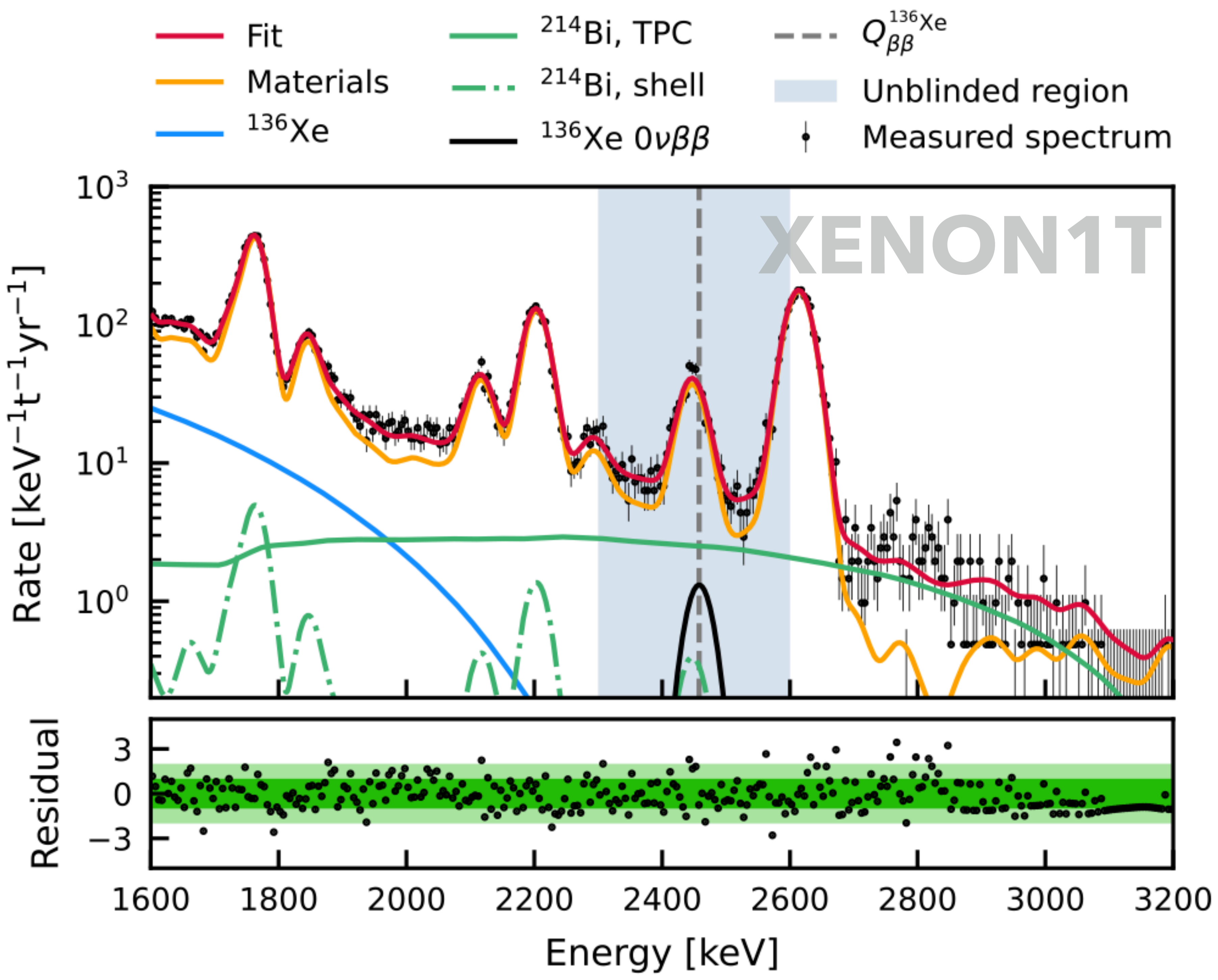




SEARCH FOR NEUTRINO-LESS DOUBLE BETA DECAY

- **XENON1T demonstrated feasibility of 0νbb search in future LXeTPC DM experiments**





SEARCH FOR NEUTRINO-LESS DOUBLE BETA DECAY

- XENON1T demonstrated feasibility of $0\nu bb$ search in future LXeTPC DM experiments
- Not competitive with dedicated experiments due to
  - Non-enriched target
  - Background optimization for DM search (SS Cryostat)
- Additional analysis work needed to push further the sensitivity to be competitive
- **XLZD approaches sensitivities of future tonne-scale $0\nu\beta\beta$ experiments while being dedicated to DM search**