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Zurich^{UZH}



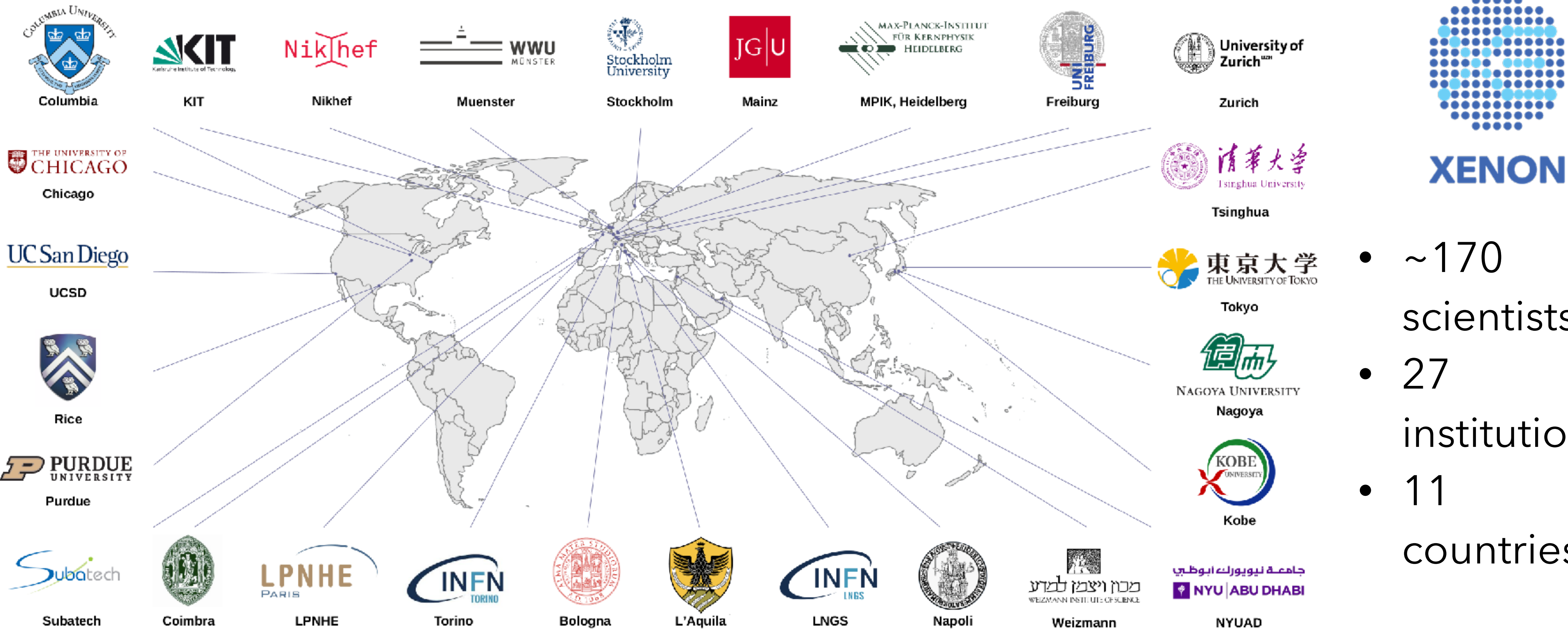
Direct Dark Matter Detection: Recent Results from XENON

CHIPP 2021

Christian Wittweg
Baudis Group

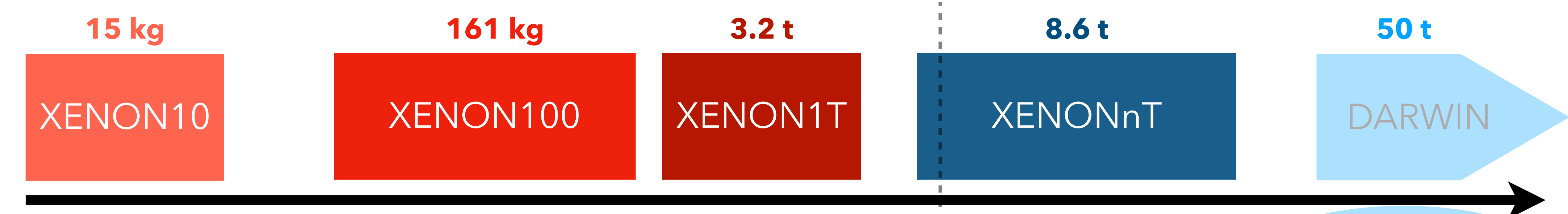


The XENON Collaboration



- ~170 scientists
- 27 institutions
- 11 countries

XENON Dark Matter Project



2 pixels

Exposure 0.87 kg • yr

48 kg • yr

1 t • yr

20 t • yr

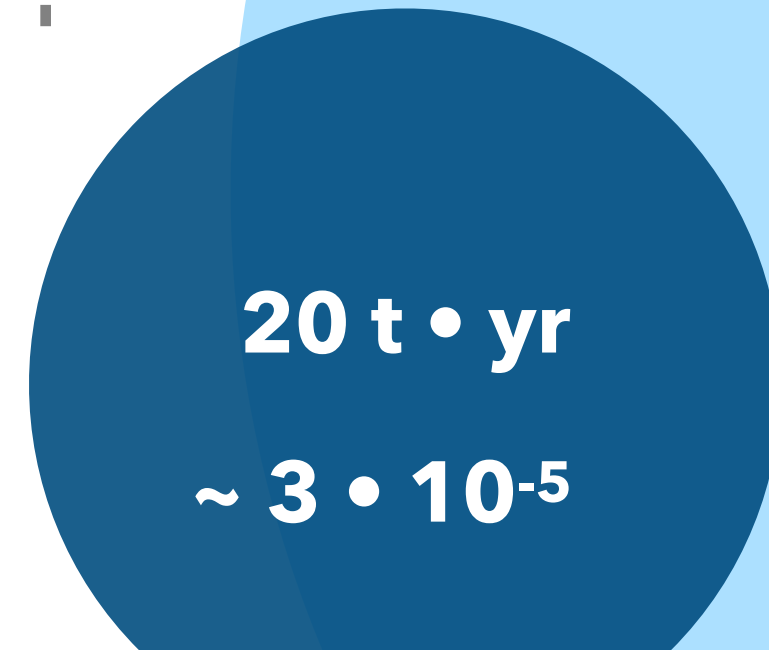
200 t • yr

BG index ~ 1

$\sim 5 \cdot 10^{-3}$

$\sim 2 \cdot 10^{-4}$

$\sim 3 \cdot 10^{-5}$



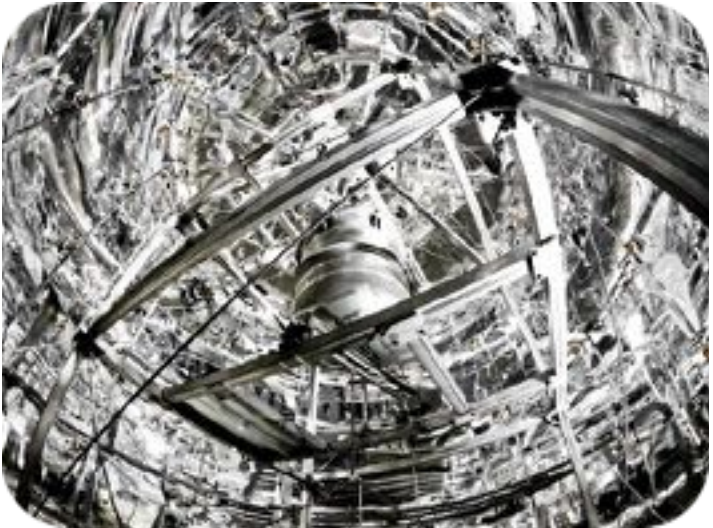
XENON1T at LNGS (2016-2018)



1500 m overburden
(3600 m.w.e.)



TPC



Water Cherenkov
muon veto

LNGS hall B

700 t
pure water

84
8" PMTs

Cryostat



Cryogenics
and purification

DAQ and
slow control

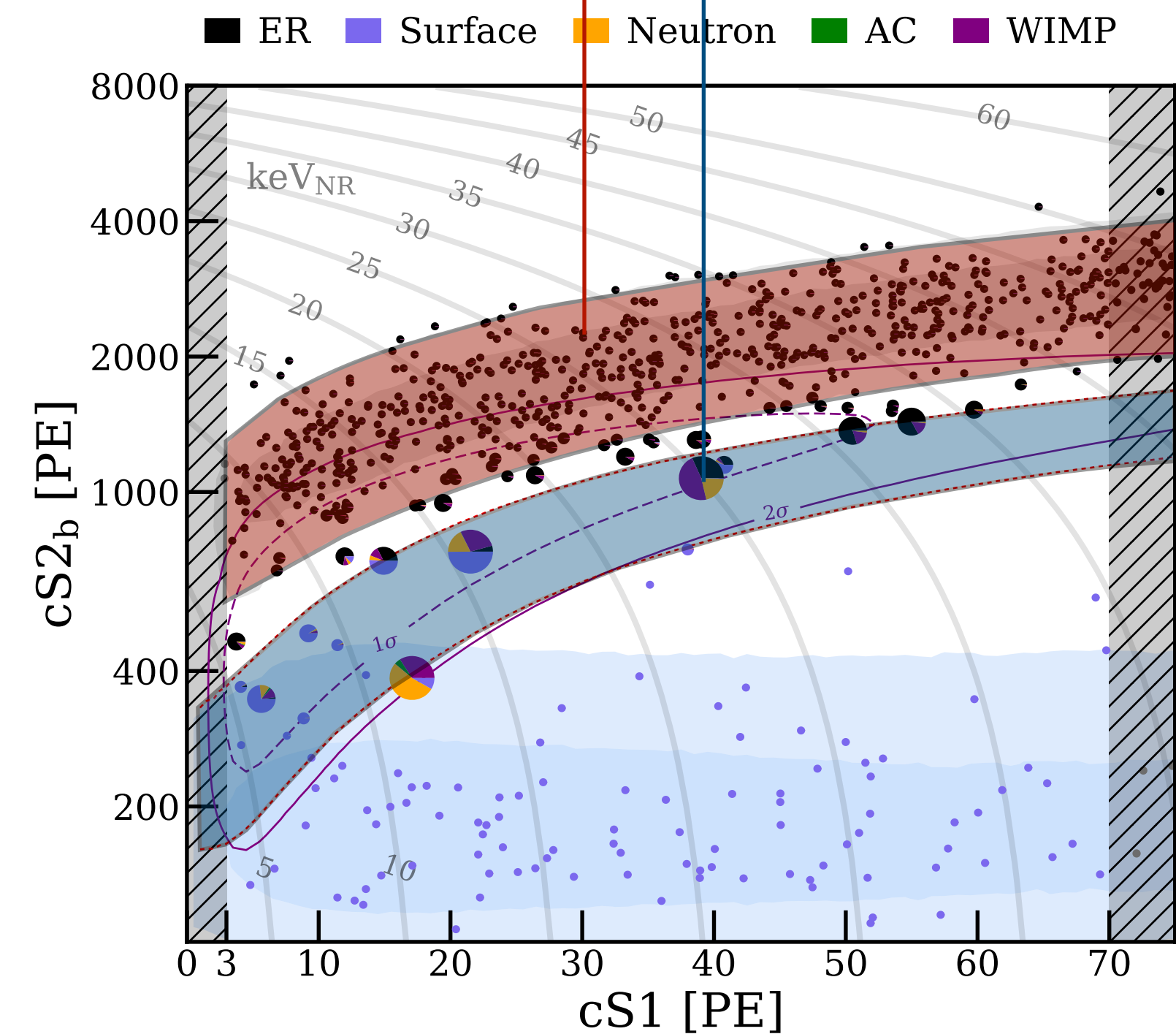
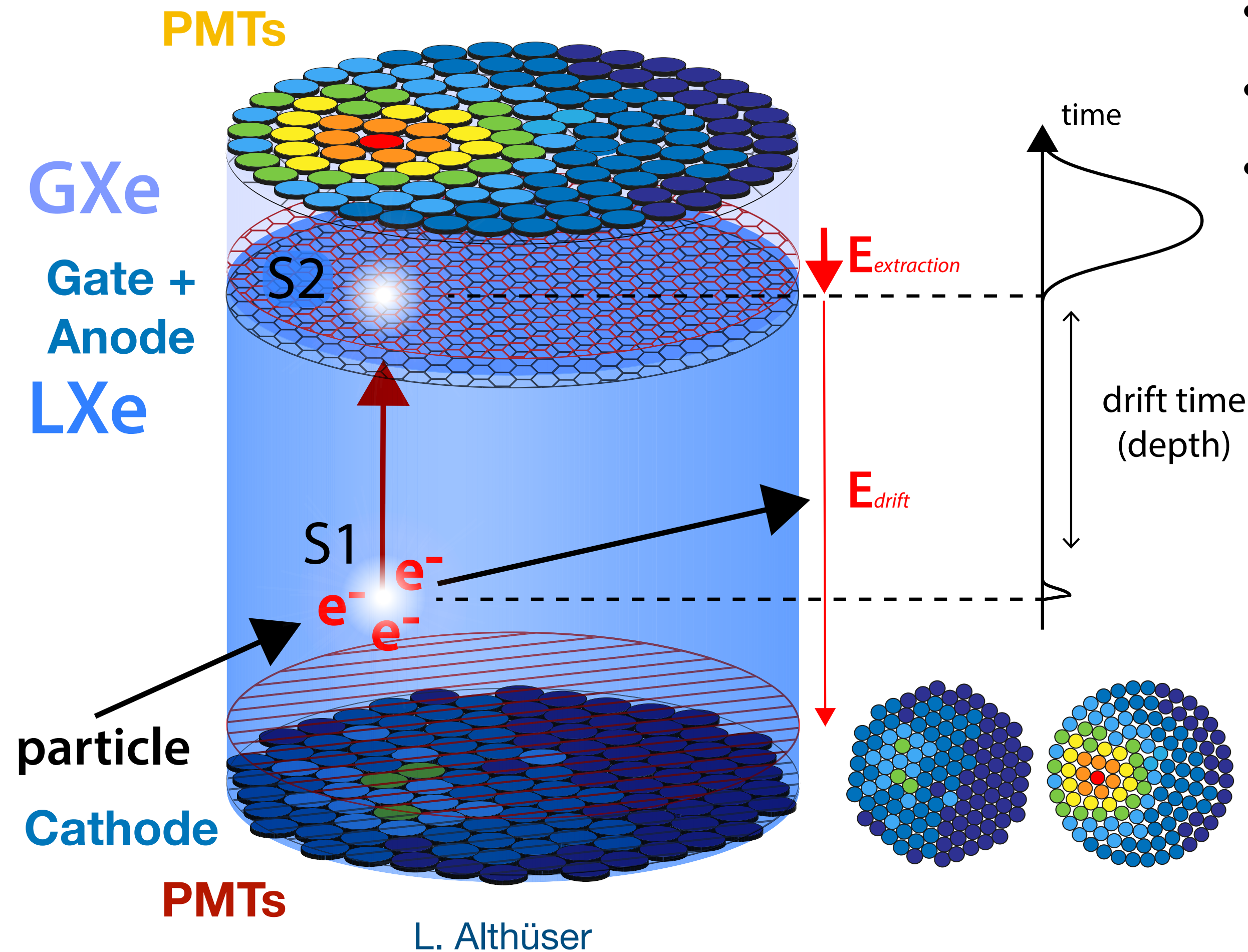
Krypton
distillation

Xenon
storage

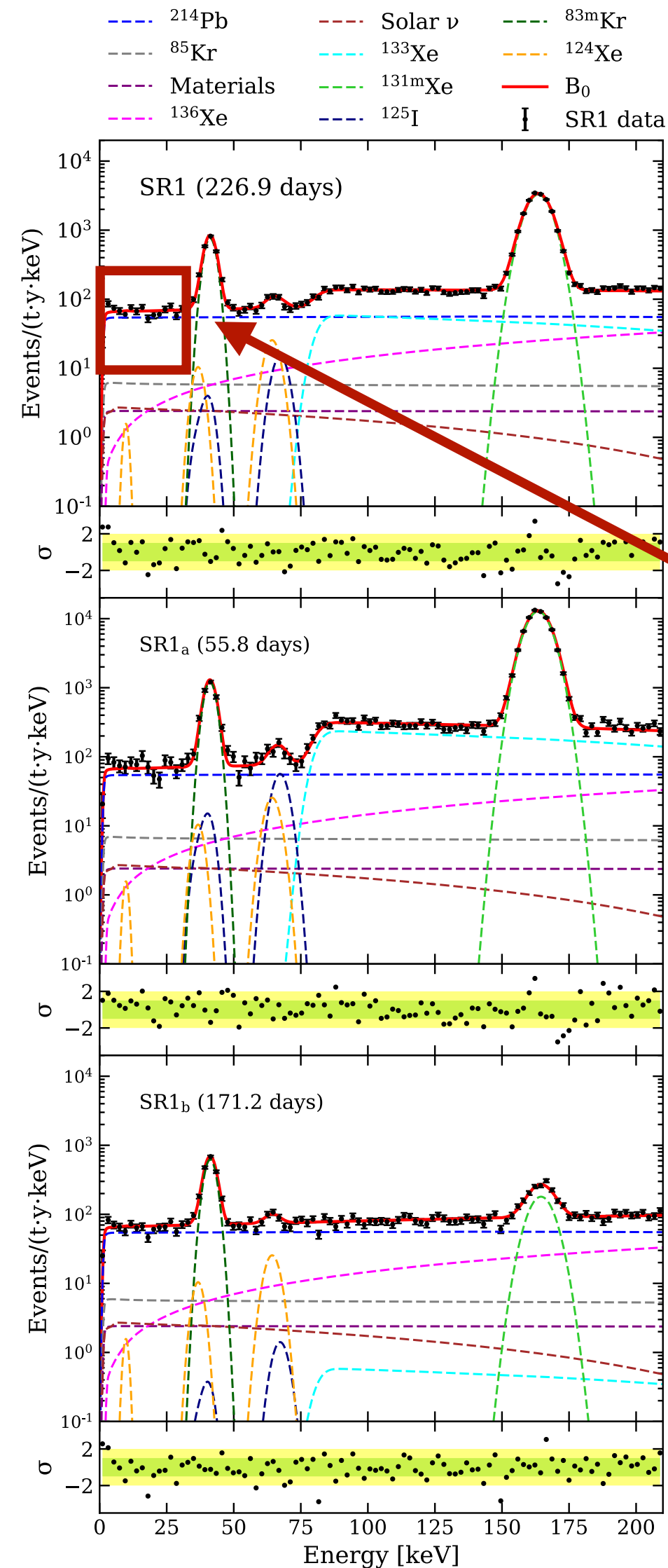
Dual-Phase Time Projection Chamber

Scintillation and ionization:

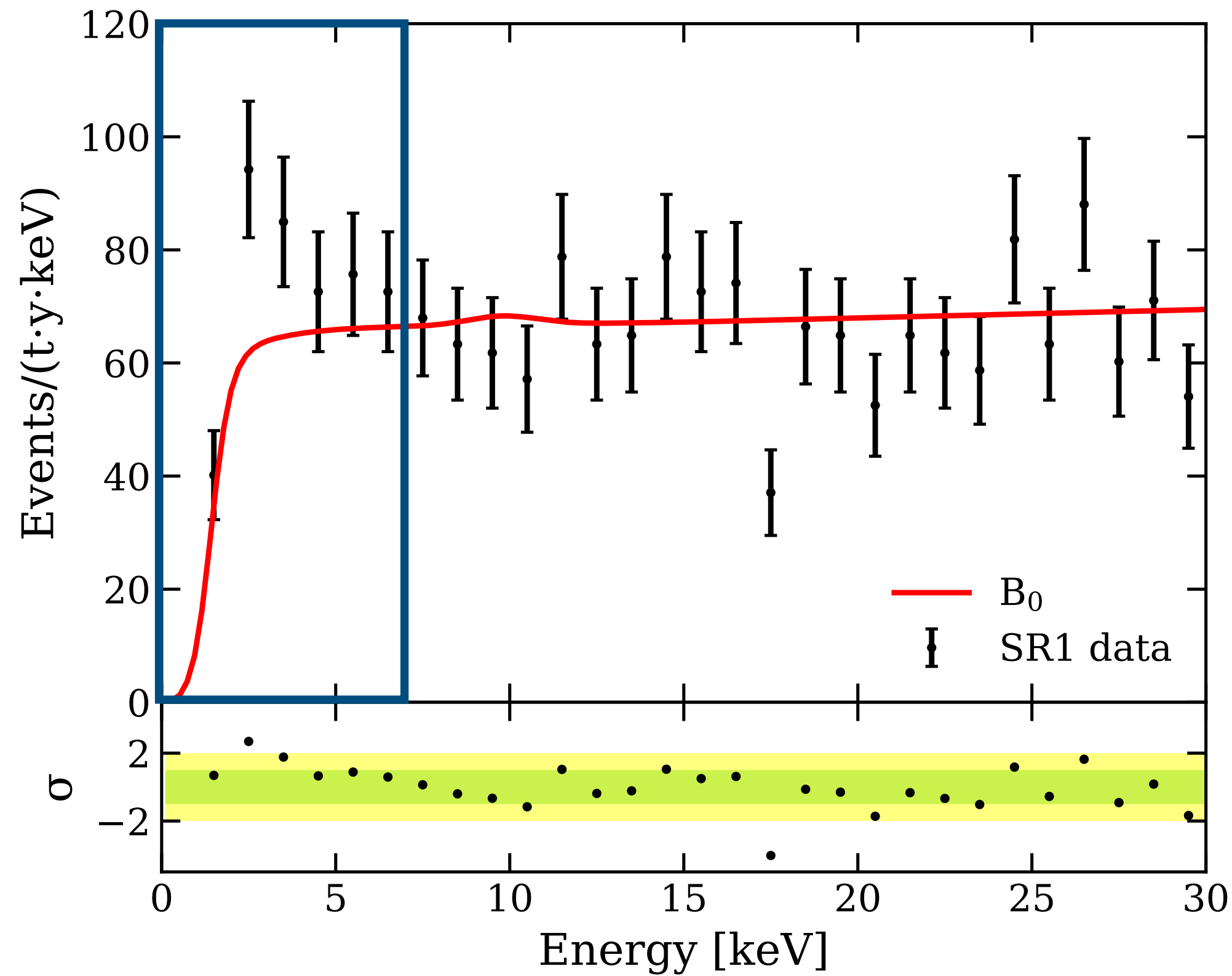
- Prompt light signal (**S1**)
- Secondary light in GXe from drifted charges (**S2**)
- Position reconstruction (**x, y, z**), calorimetry (**E**) and interaction type (**ER/NR**)



Low-Energy Electronic Recoil Excess



Phys. Rev. D 102 (2020) 7, 072004



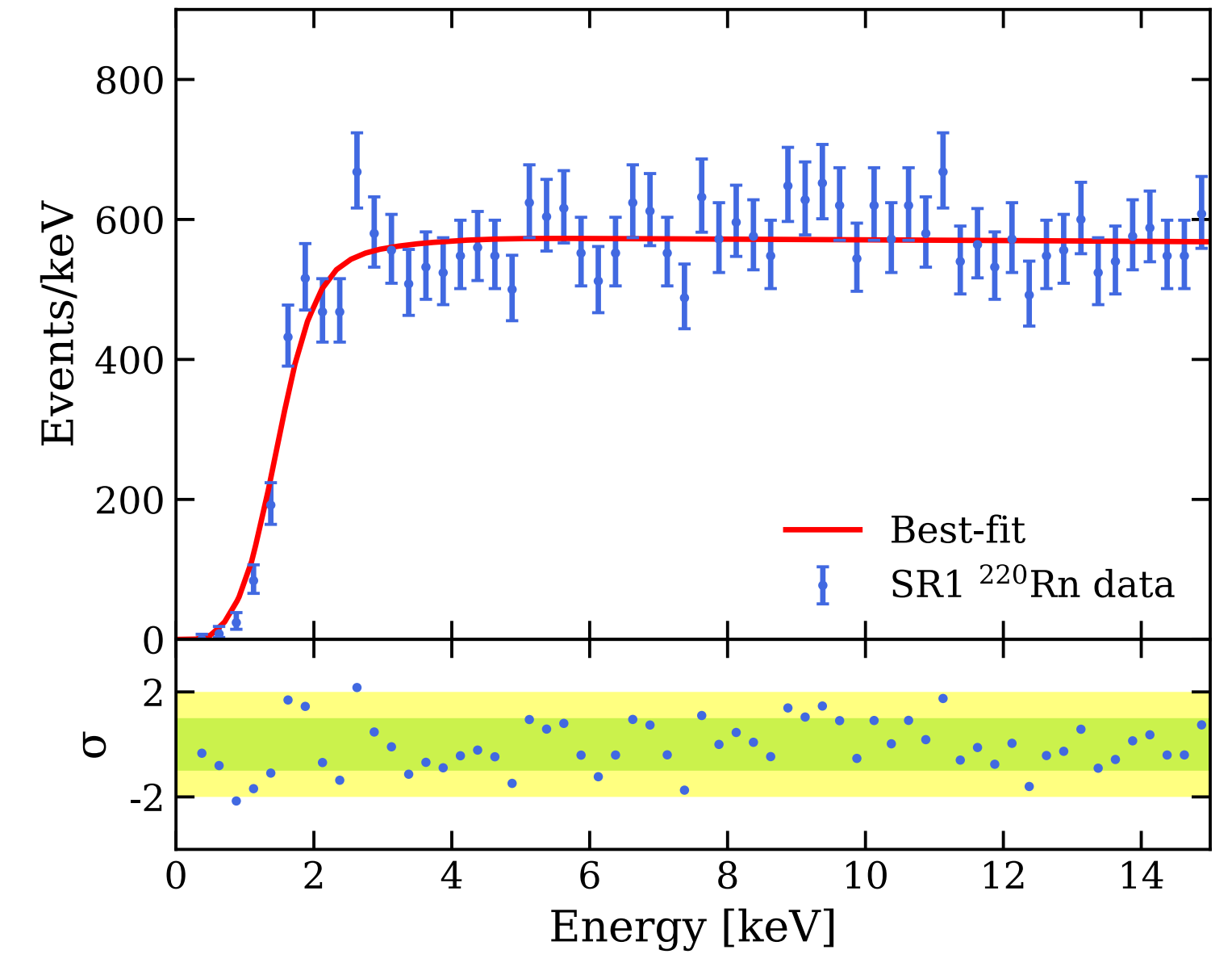
Excess between 1-7 keV

- **285 events** observed vs. **232 ± 15 events** expected from best-fit background
- 3.3 σ fluctuation from Poisson counting
- Unbinned likelihood ratio tests for signal models

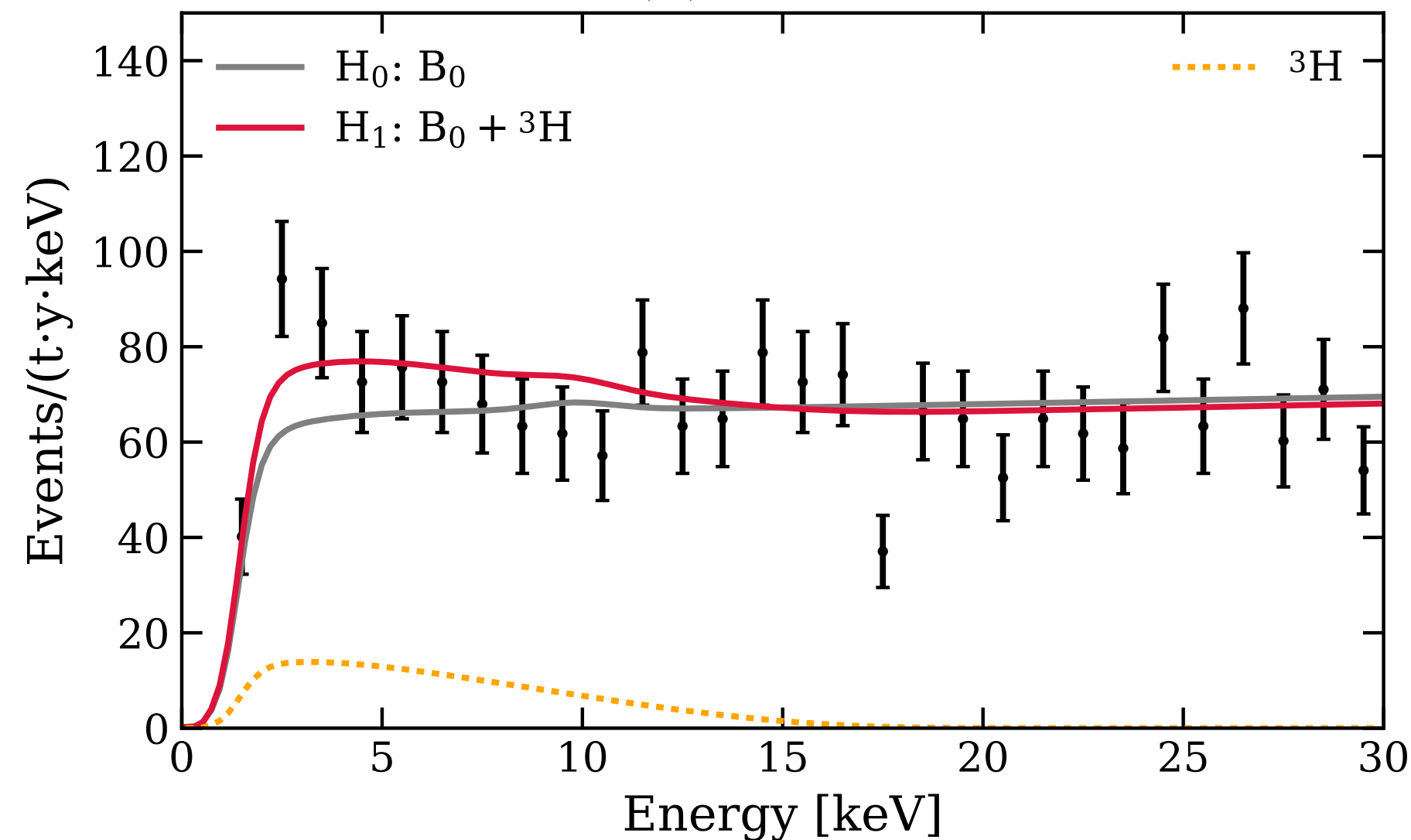
Possible Known Physics Origins

- Mismodeling of detector threshold
- Instrumental background
- Binning artifacts
- Simulated shape of background spectra
- **^{37}Ar** from an air leak
- **Tritium** (^3H) from cosmogenic activation, leaks, emanation from materials...

Unlikely or cannot account for size of the excess.



(a) Tritium



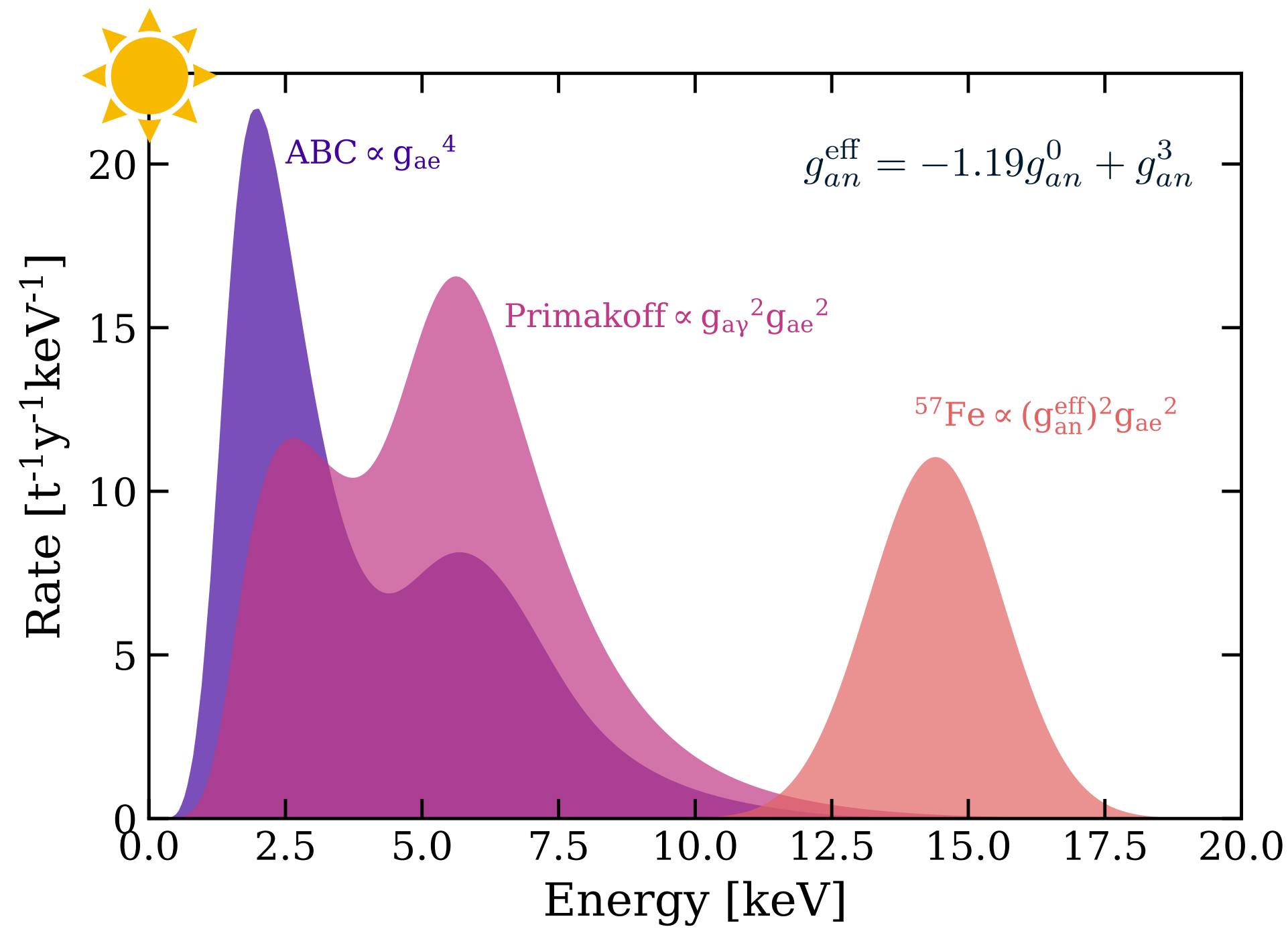
Tritium signal favored over background-only at **3.2σ**

Bosonic Dark Matter or ^{37}Ar ?

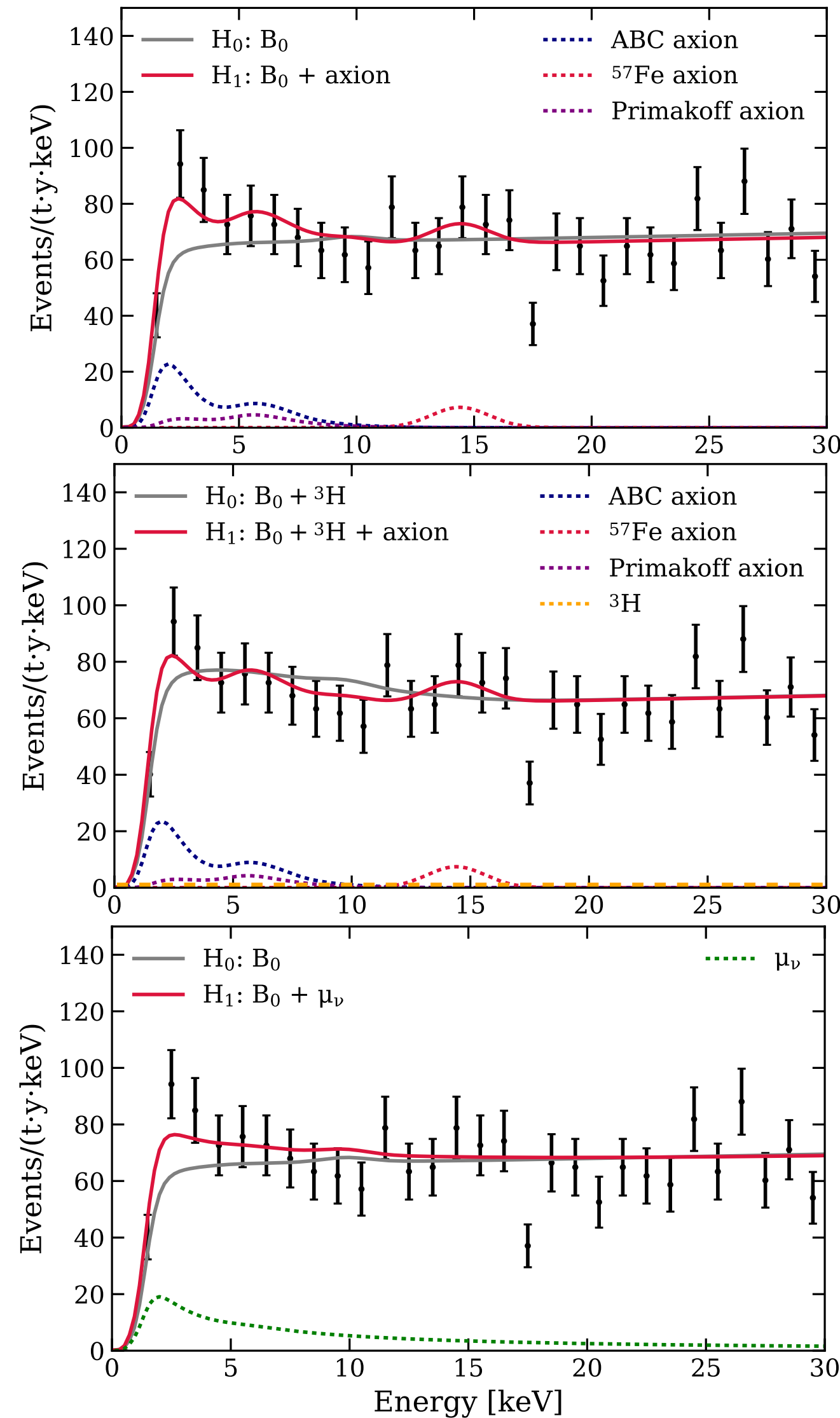
Monoenergetic peak at 2.3 ± 0.2 keV favored over background-only at **3.0σ (global)**

Leak would need to be large and can be constrained with ^{85}Kr !

Solar Axions or Solar Neutrinos?



- 3 solar axion components measured via axioelectric effect
- Finite neutrino magnetic moment
- Tension with other experiments and astrophysics
- Need more data to distinguish tritium and BSM signals



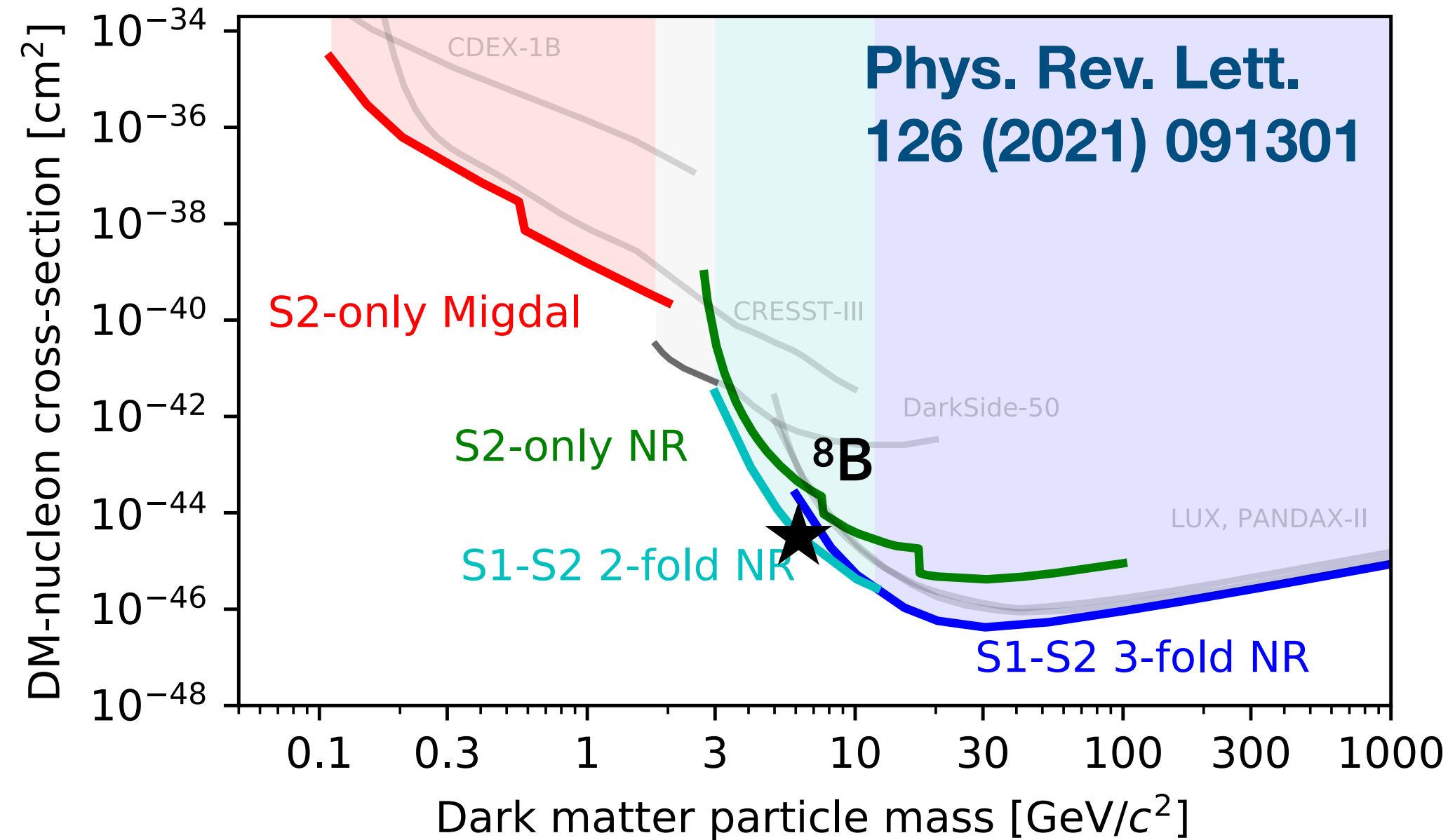
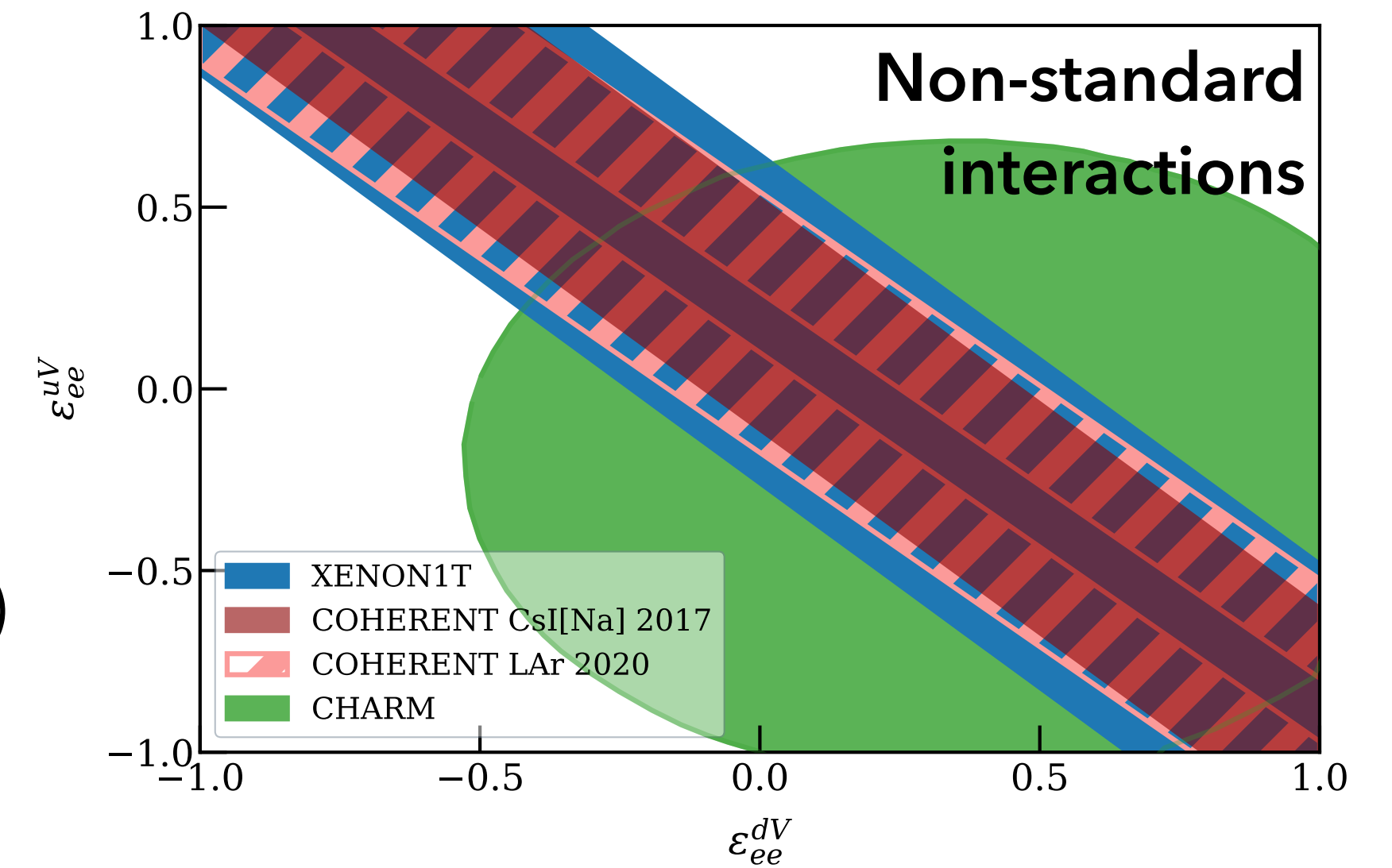
Solar axions favored over background-only at **3.4 σ**

Axion + 3H favored over 3H hypothesis at **2.0 σ**

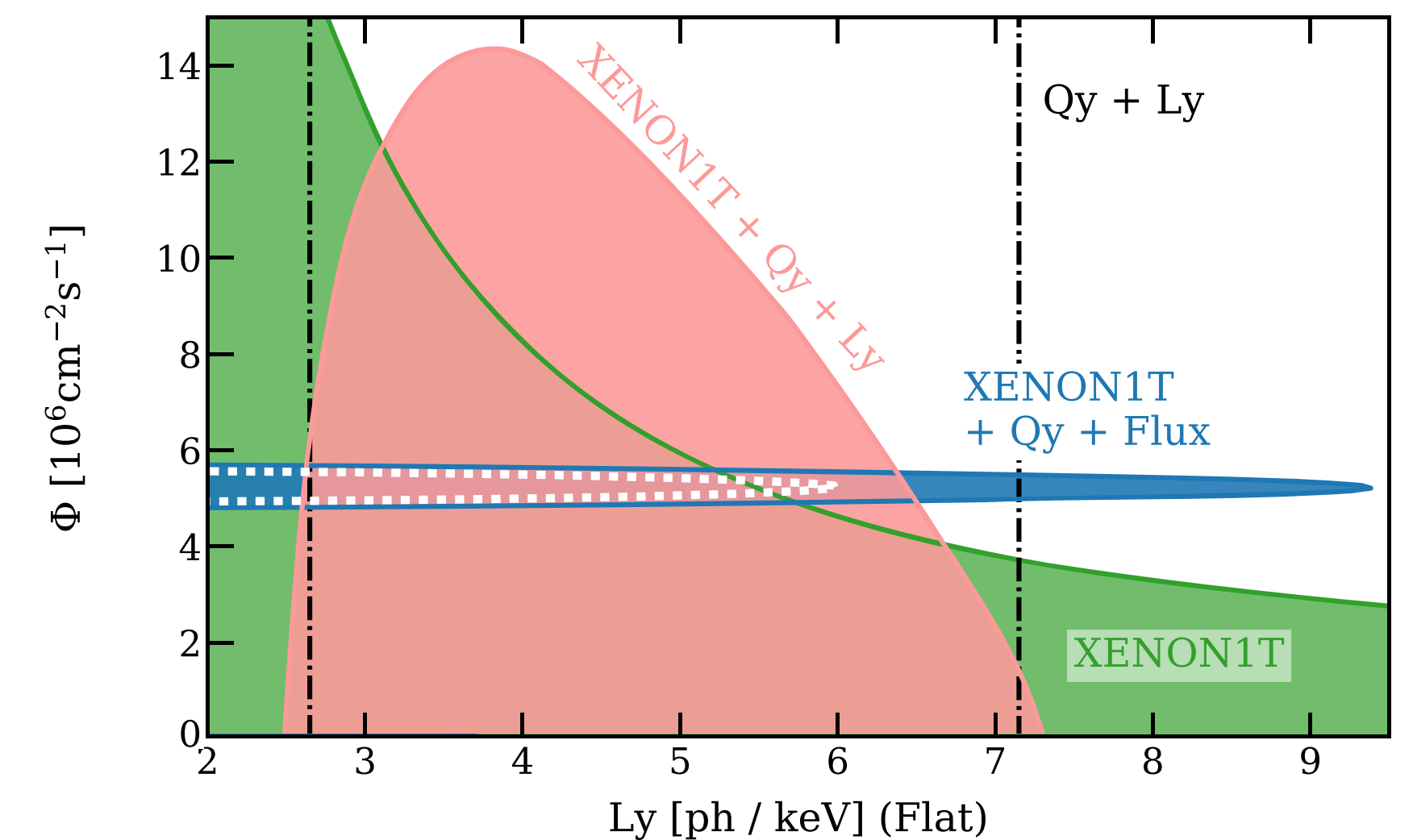
Neutrino magnetic moment favored over background-only at **3.2 σ**

XENON1T Low Energy Nuclear Recoils

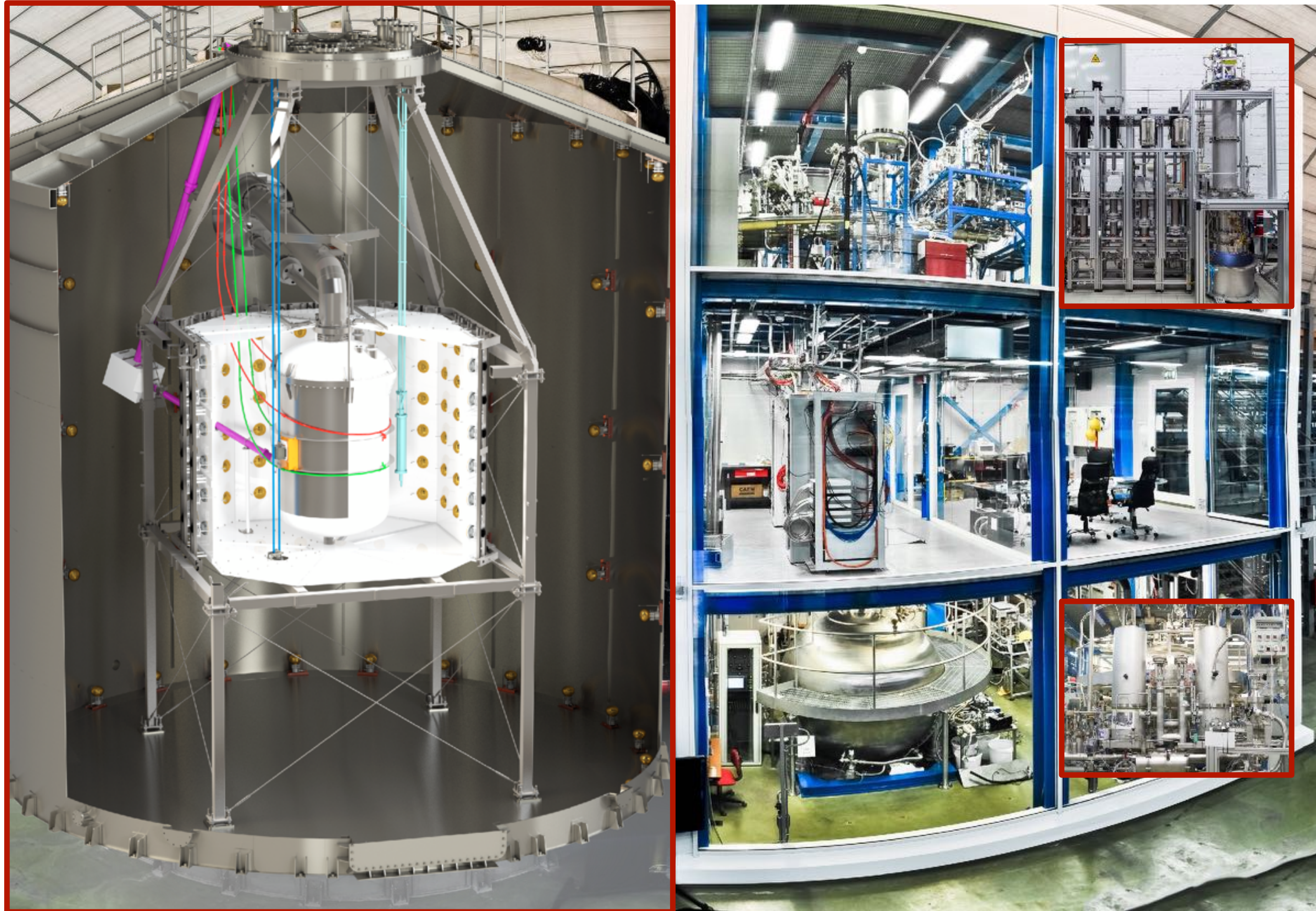
- Energy threshold driven by S1 coincidence criterion: light in at least 3 PMTs to suppress accidental coincidences
- Reanalysis of dark matter science data with 2-PMT threshold
 - Solar ^8B neutrinos and non-standard interactions
 - Low-energy detector response (\approx how much signal is visible)
 - Low-mass WIMPs



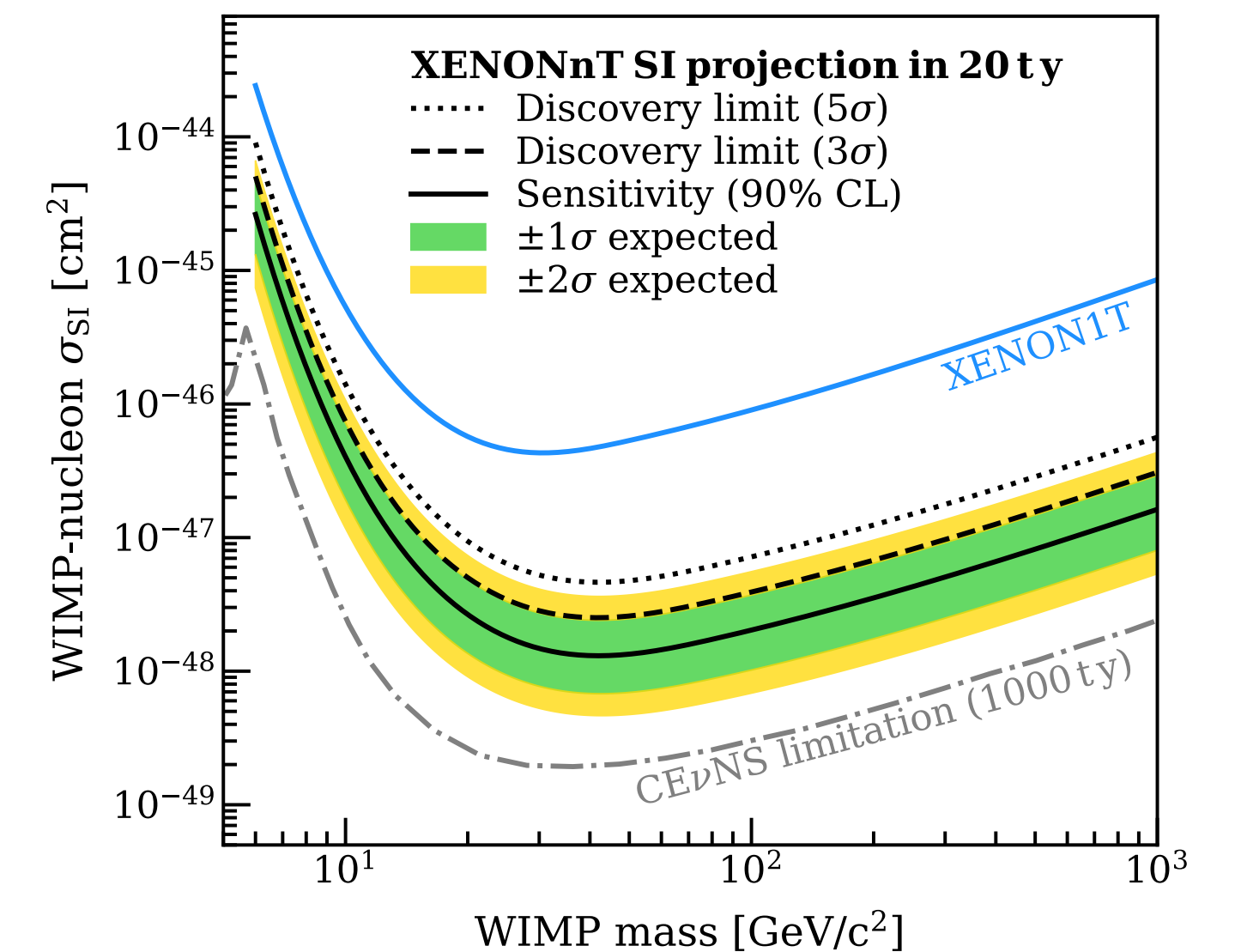
Projections of 90 % confidence volumes for different sets of external constraints



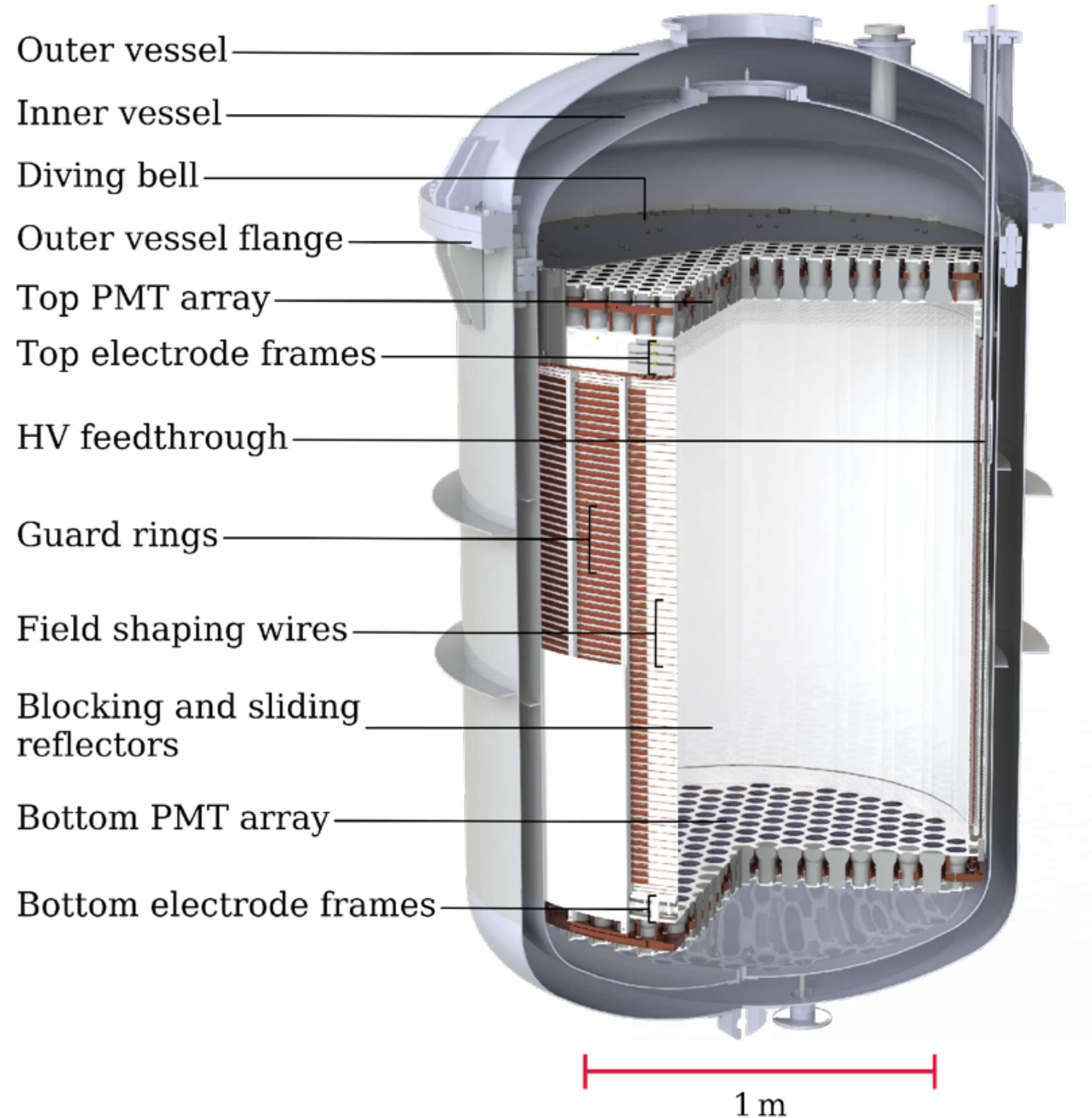
Upgrading to XENONnT



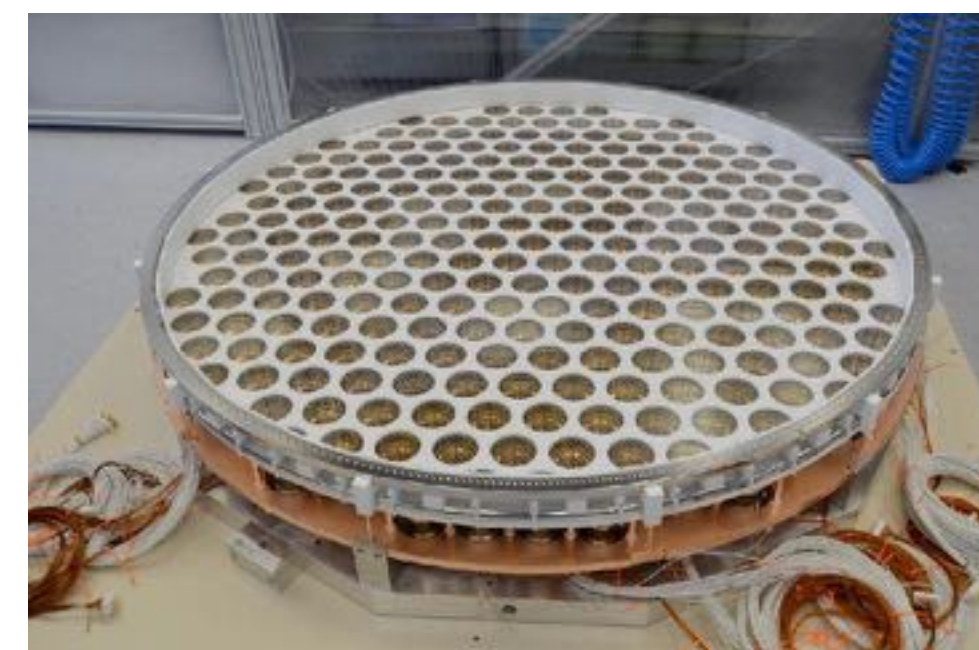
- Larger TPC with more PMTs
- Neutron veto and Gd handling system
- Liquid xenon purification
- Radon distillation column
- WIMPs, low-energy excess, $0\nu\beta\beta$,



XENONnT Time Projection Chamber

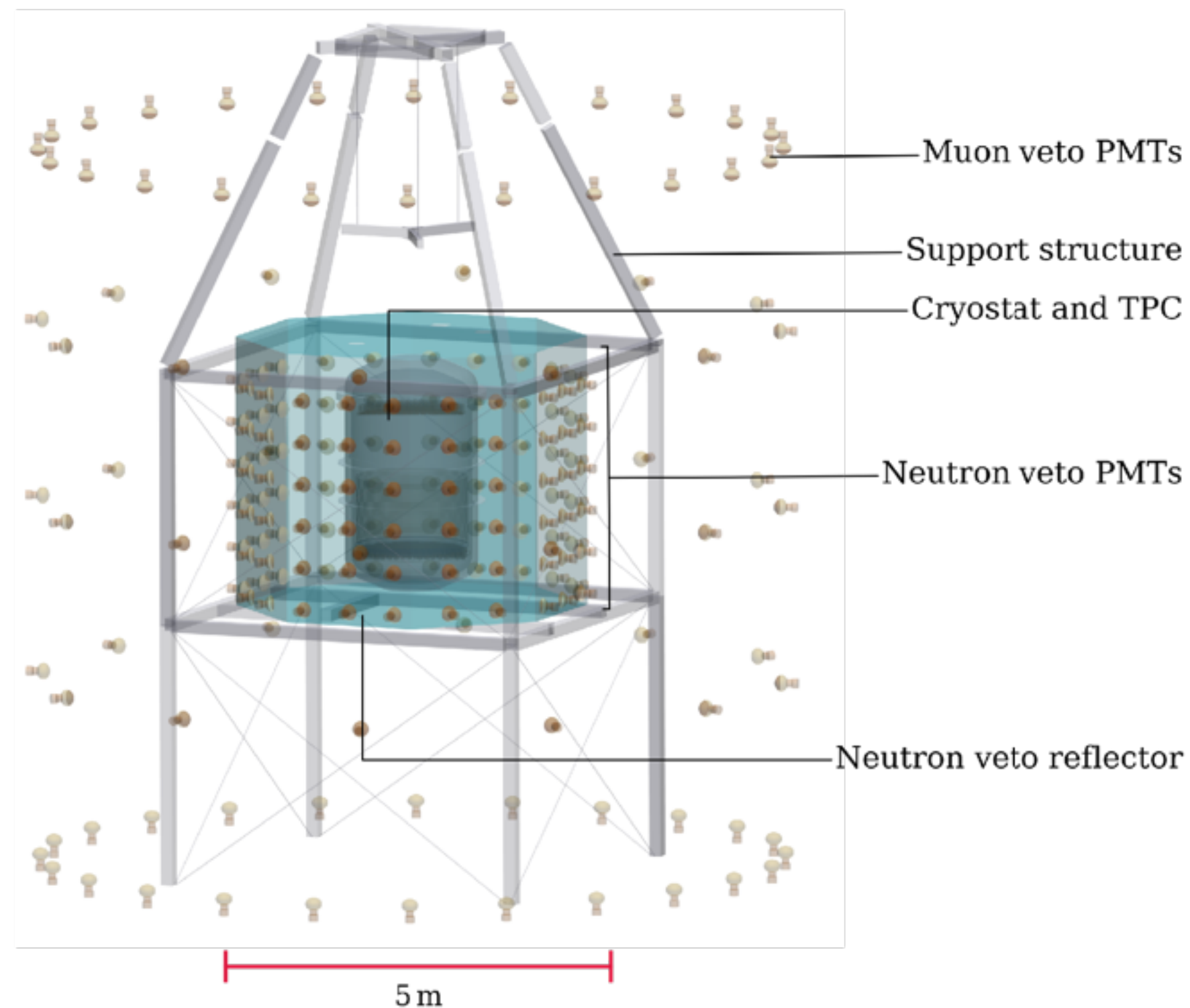


- Total xenon mass 8.6 t with 5.9 t active mass
- 4.0 t fiducial volume for WIMP search
- 494 PMTs
- 1.5 m drift, 1.3 m diameter



XENONnT Neutron Veto

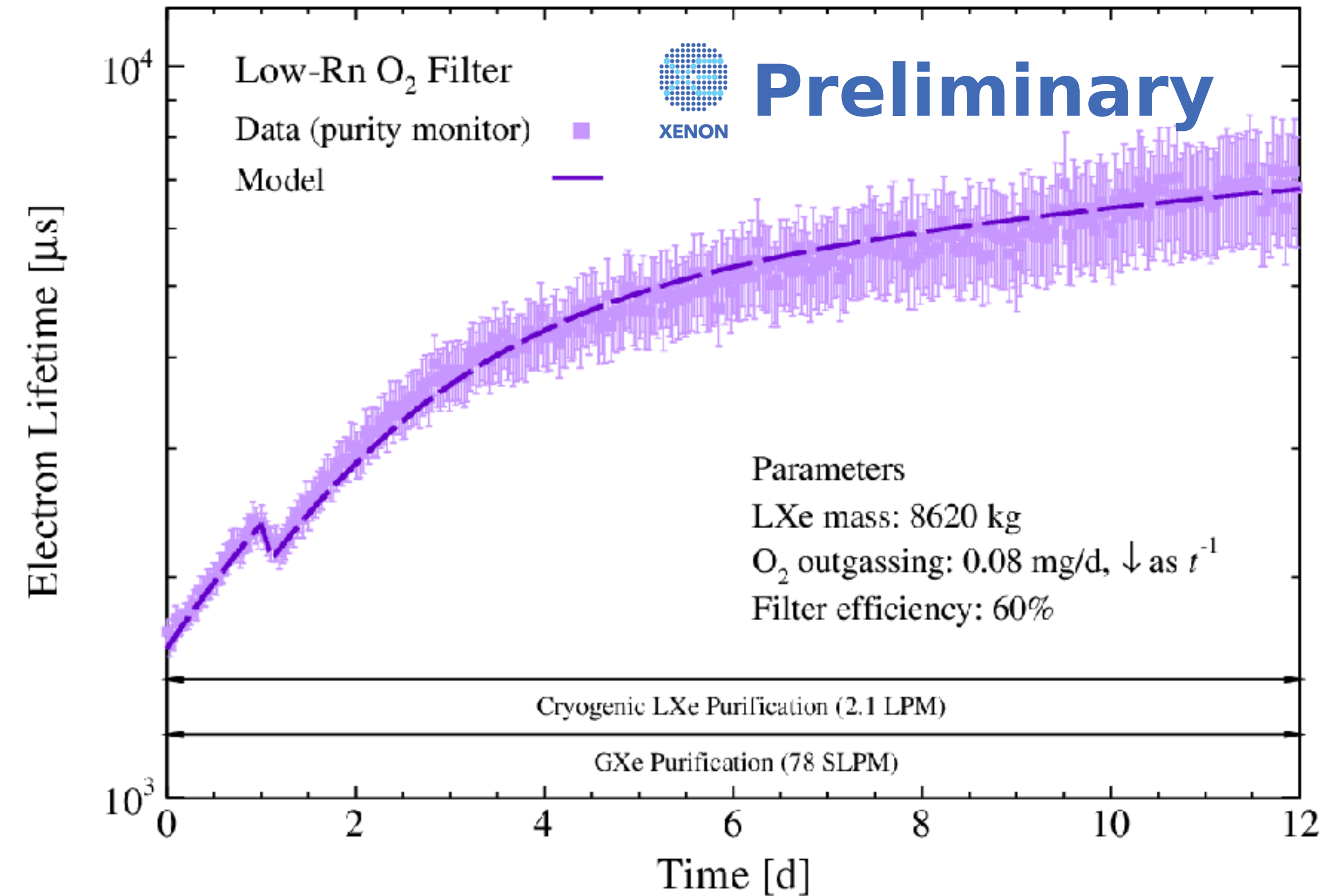
- Gadolinium-doped water Cherenkov detector with 0.5 % $Gd_2(SO_4)_3$
- Optically separate inner region of existing muon veto
- 120 additional PMTs
- Projected 87 % neutron tagging efficiency



XENONnT Liquid Purification



XENON1T: 0.6 ms \approx 0.9 x maximum drift-time with gas-only purification



- High purification flux for removing electronegative impurities: 2 l /min LXe \approx 350 kg/h
- Low-Rn filters for science data taking
- Achieved electron-lifetime of 7 ms

XENONnT Radon Distillation Column

Radon-free compressor
as heat pump



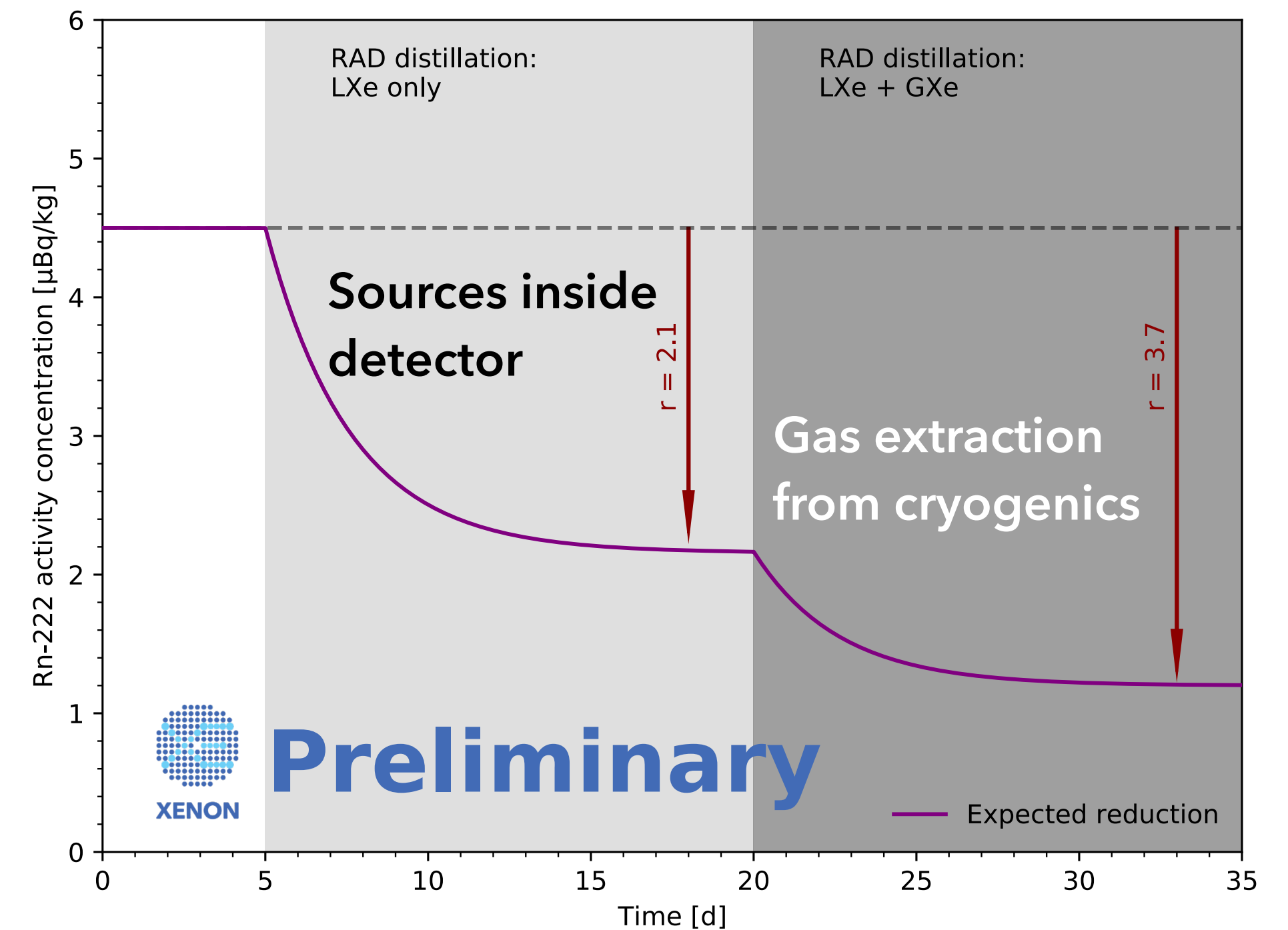
LN2/Xe heat
exchanger

Xenon

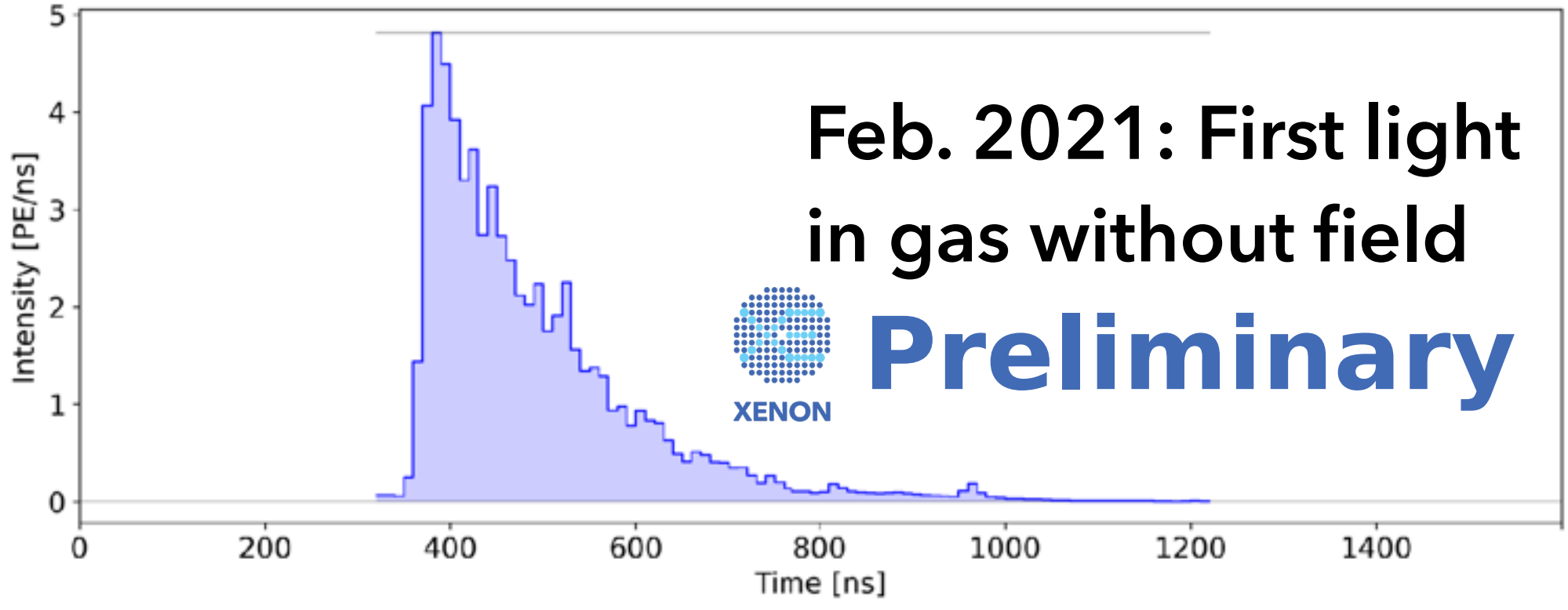
Radon

Reboiler and
Xe/Xe heat
exchanger

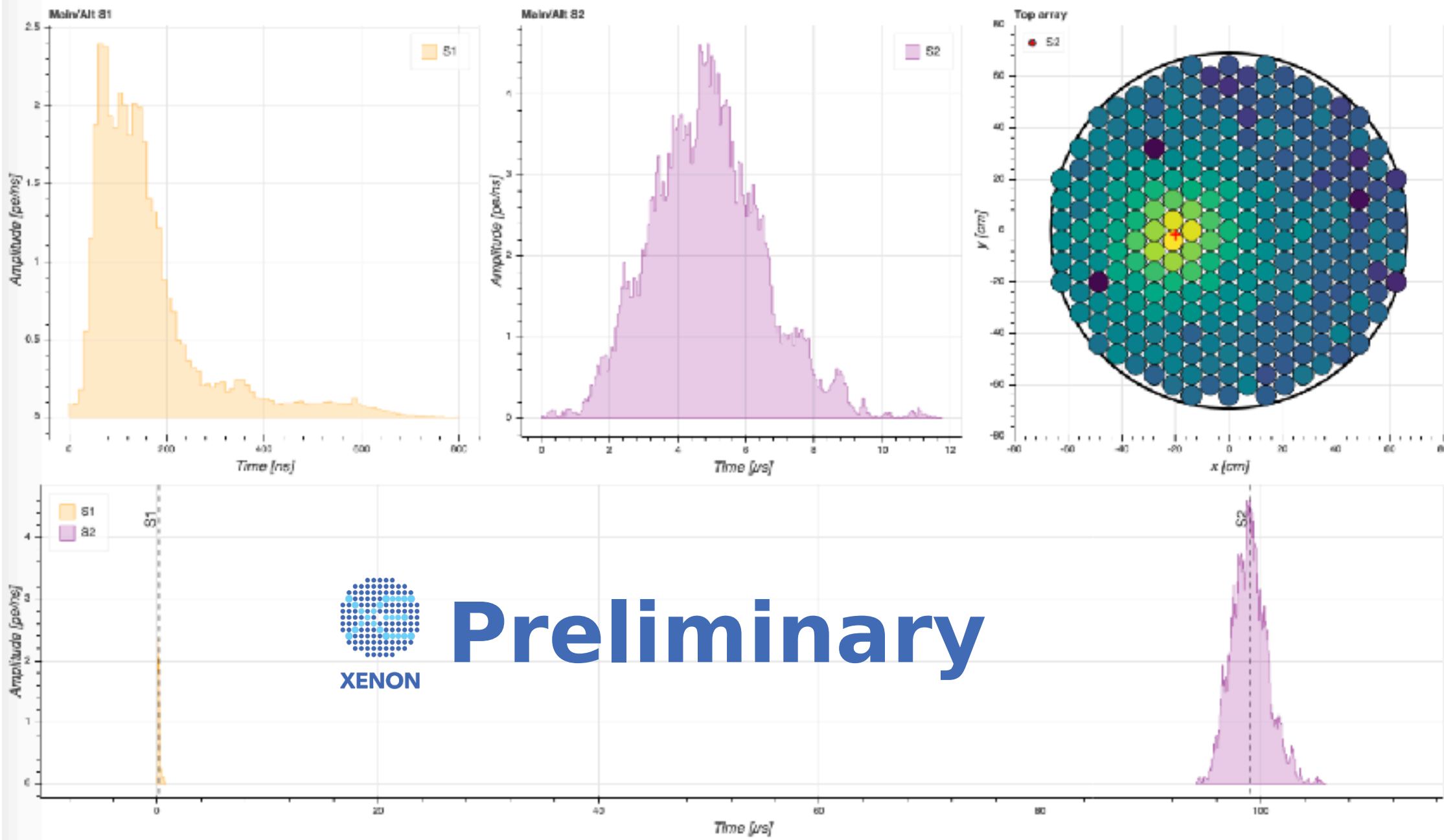
- Constantly remove emanating radon from xenon using difference in vapor pressure
- Remove radon faster than it emanates and decays
- Liquid xenon inlet and outlet with 0.4 l/min LXe \approx 70 kg/h



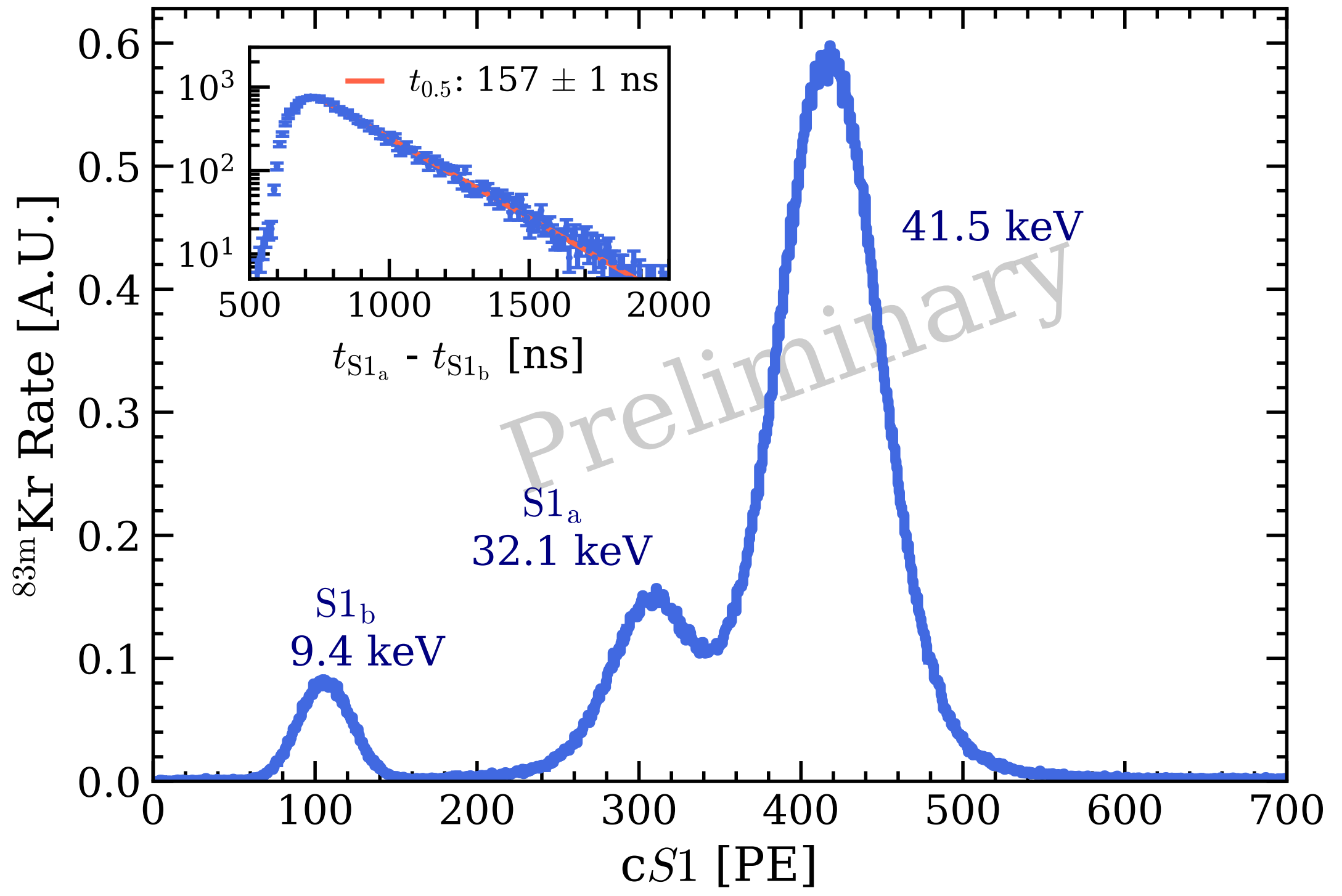
XENONnT Commissioning



S1 + S2 event in dual-phase with field



Identification of ^{83m}Kr calibration events



Now recording science data!

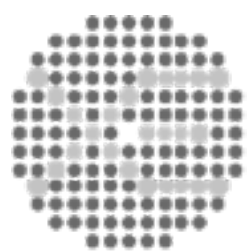
Summary



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- XENON1T saw an unexpected excess of low-energy nuclear recoils of unknown origin.
- A low threshold search for ^8B neutrinos yielded improved low-mass WIMP limits and constraints on detector response.
- XENONnT is taking science data and will improve on XENON1T with 1/7th the background and 20x more data



www.xenonexperiment.org

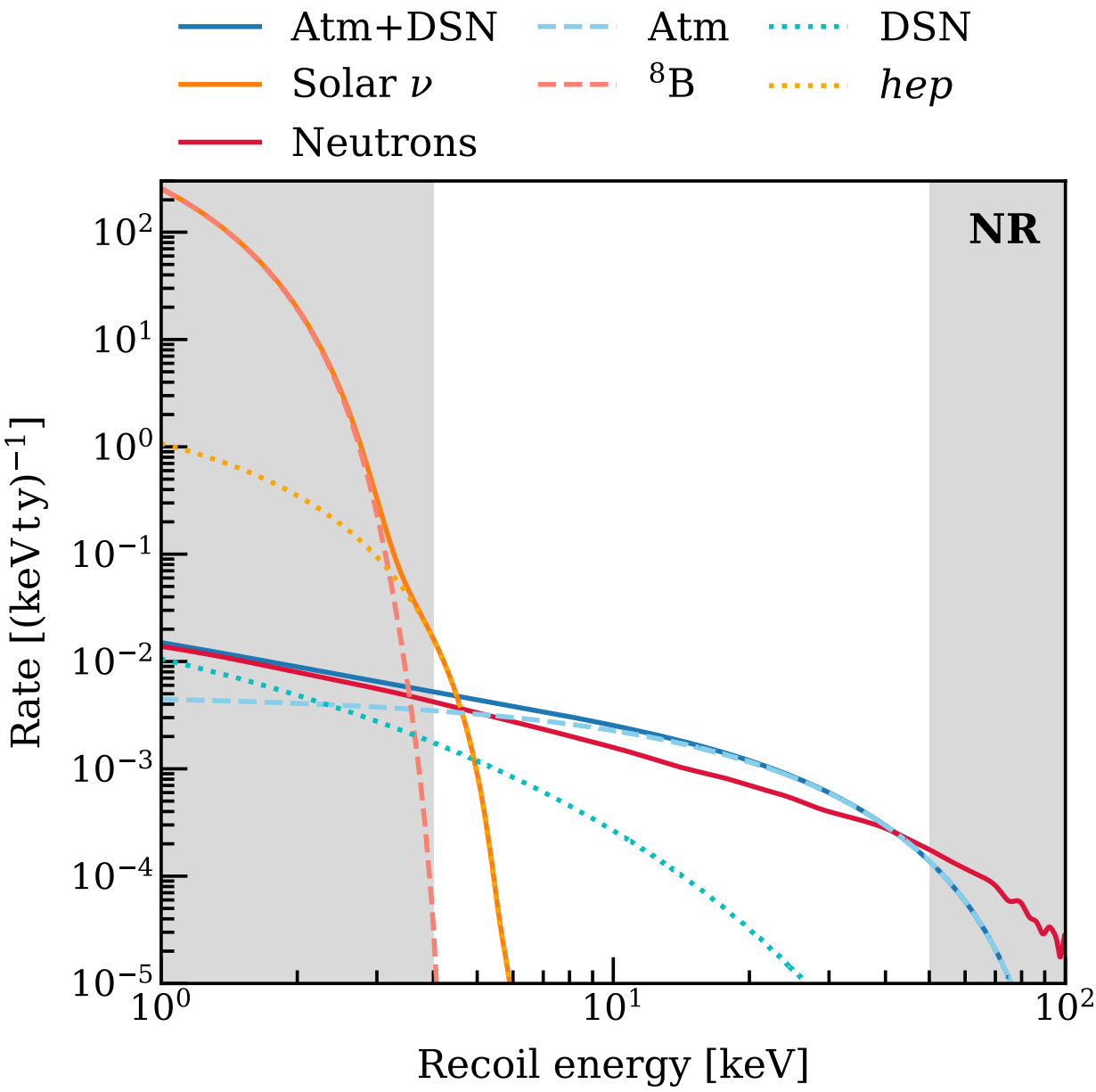
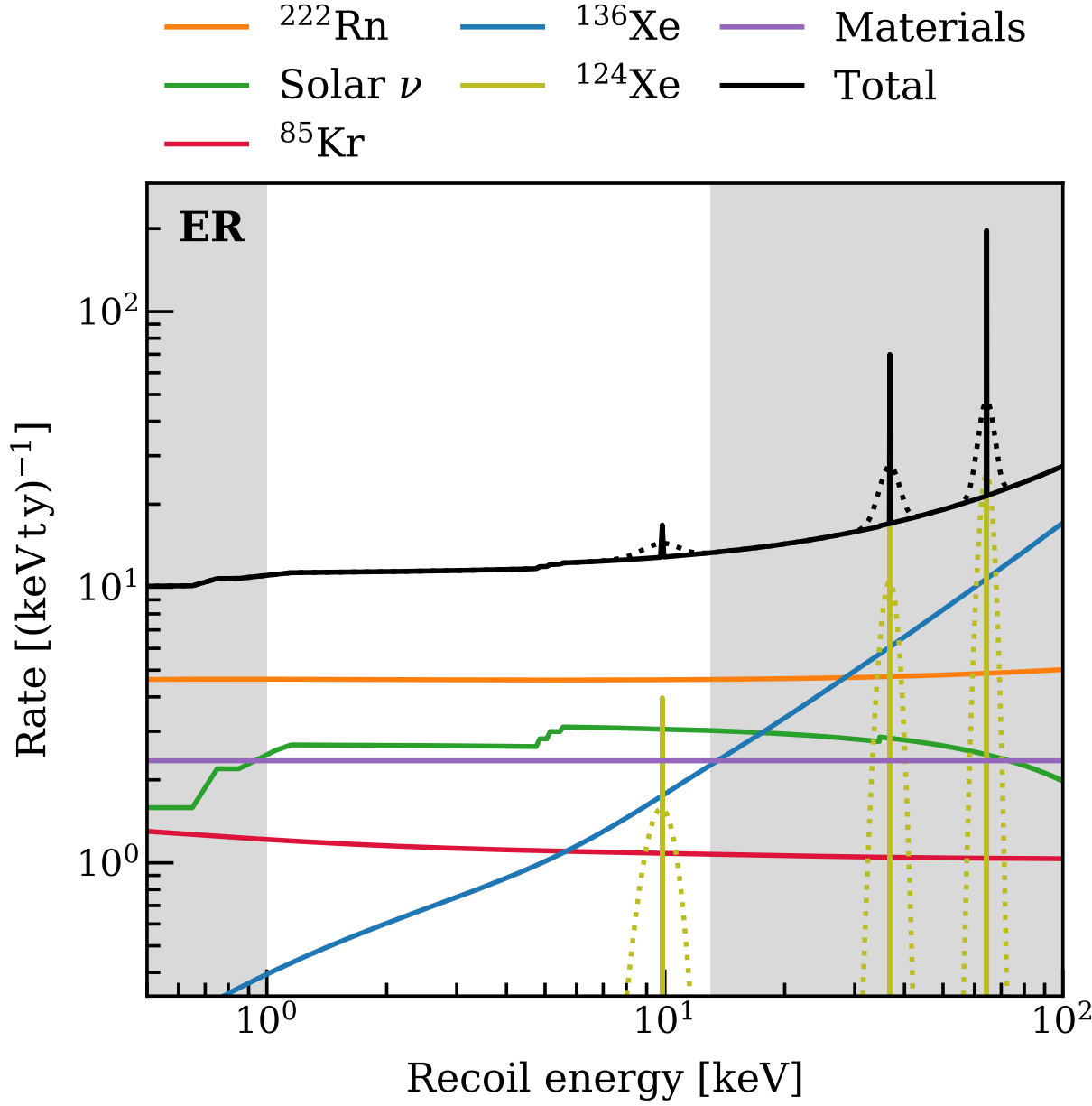


[instagram.com/xenon_experiment](https://www.instagram.com/xenon_experiment)

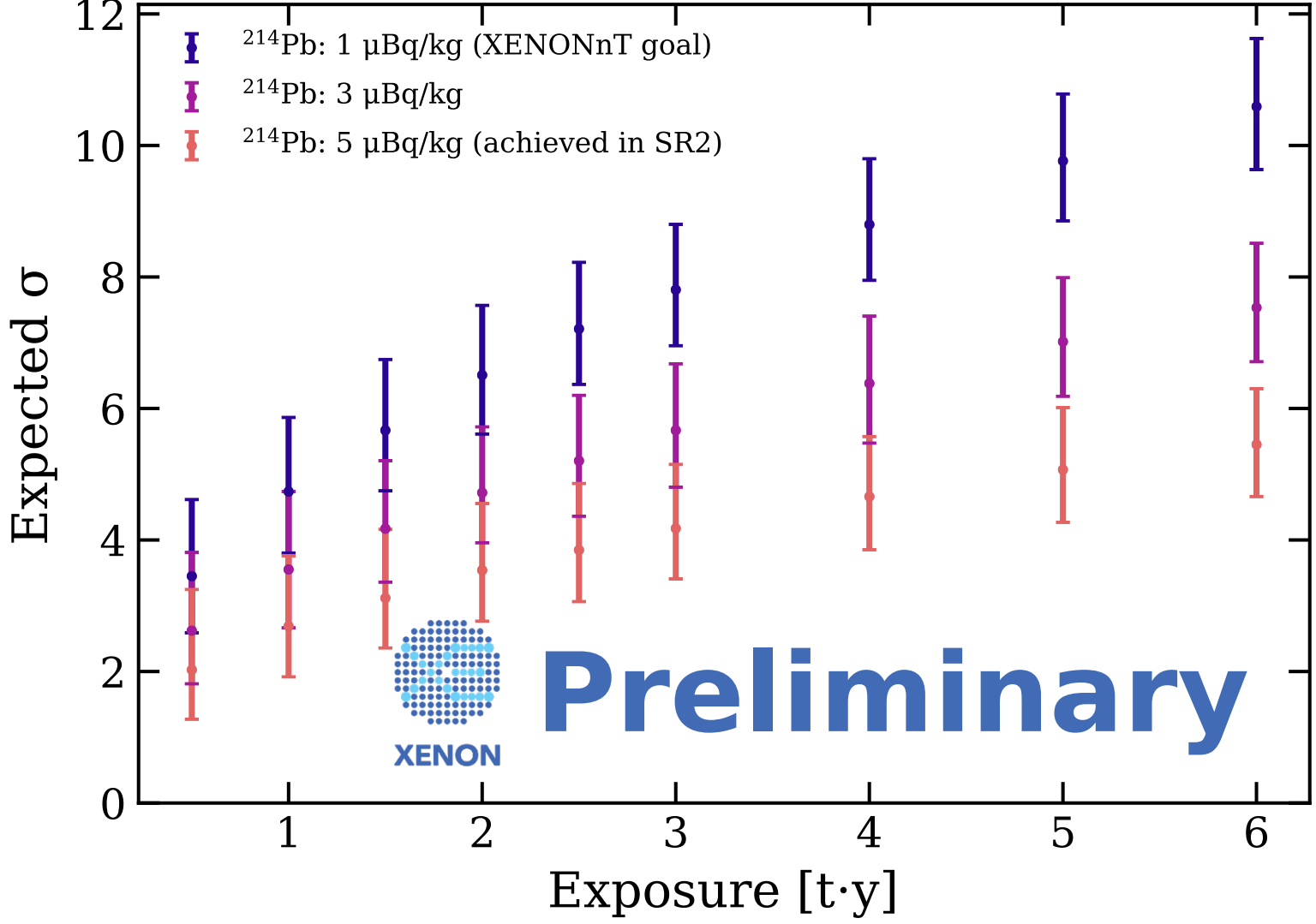
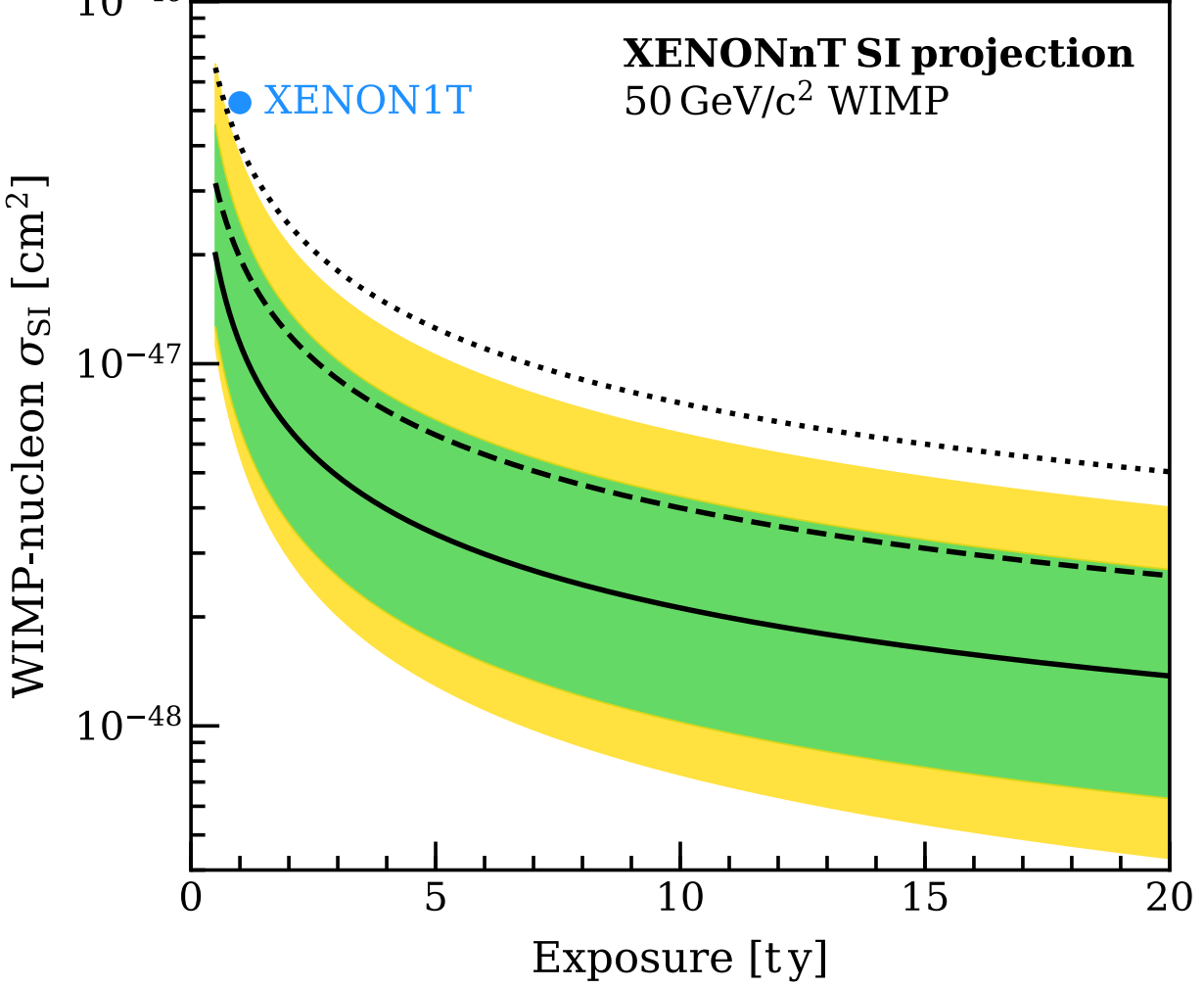
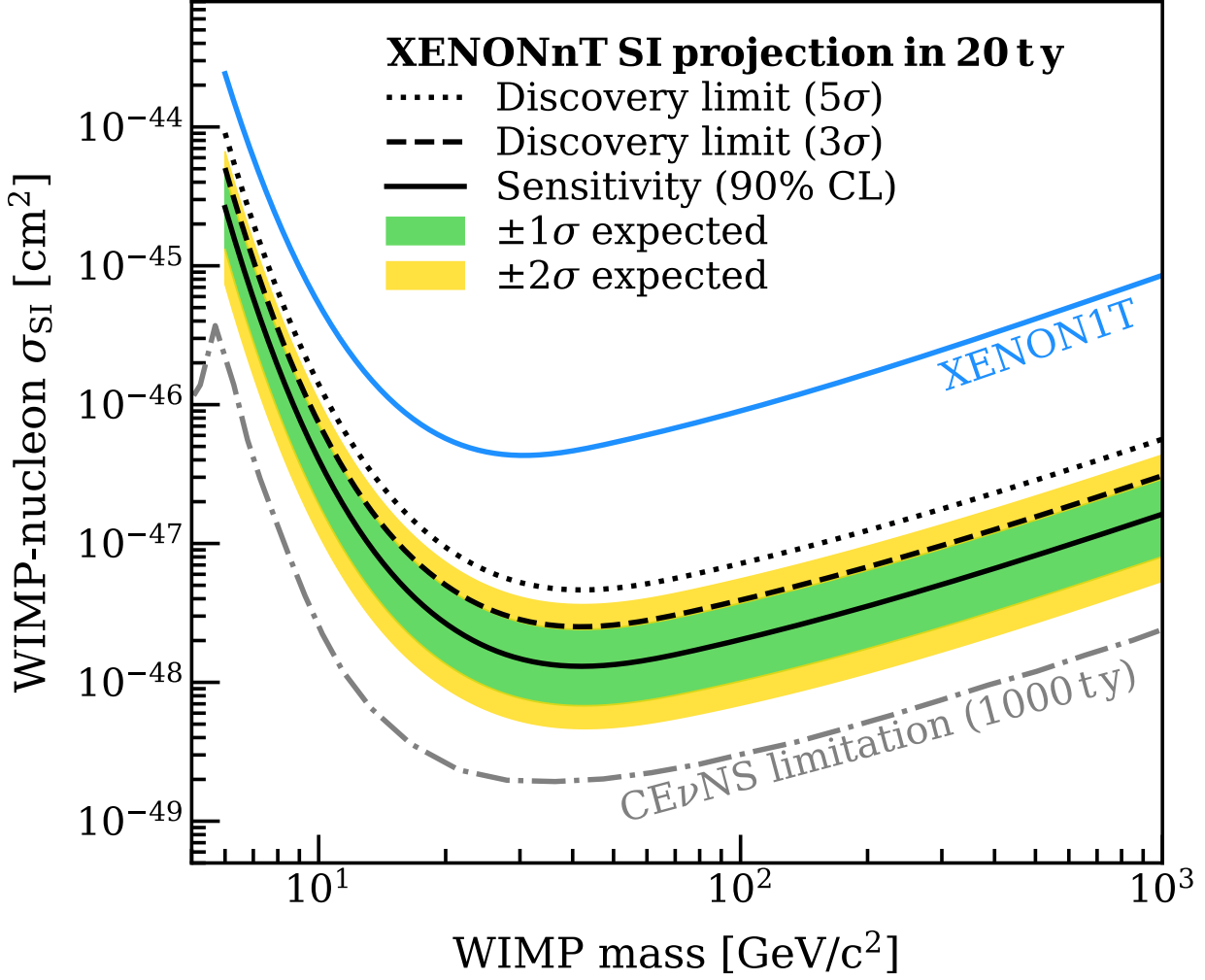


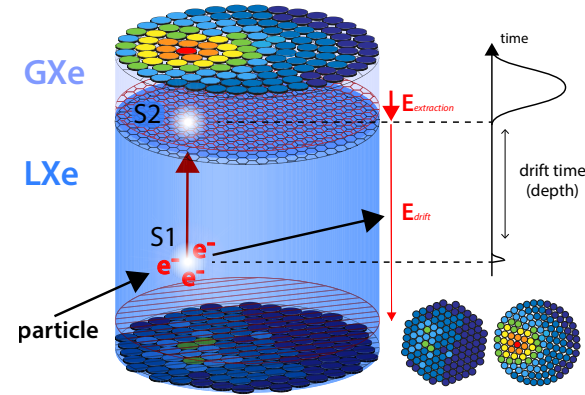
twitter.com/xenonexperiment

XENONnT Physics Reach



- Reach world-record low background in 4 t fiducial volume
- Probe WIMP-nucleon cross-sections down to 10⁻⁴⁸ cm²
- Investigate origin of low-energy ER excess and discriminate hypothetical BSM signal from tritium background
- 0νββ, solar neutrinos, ...

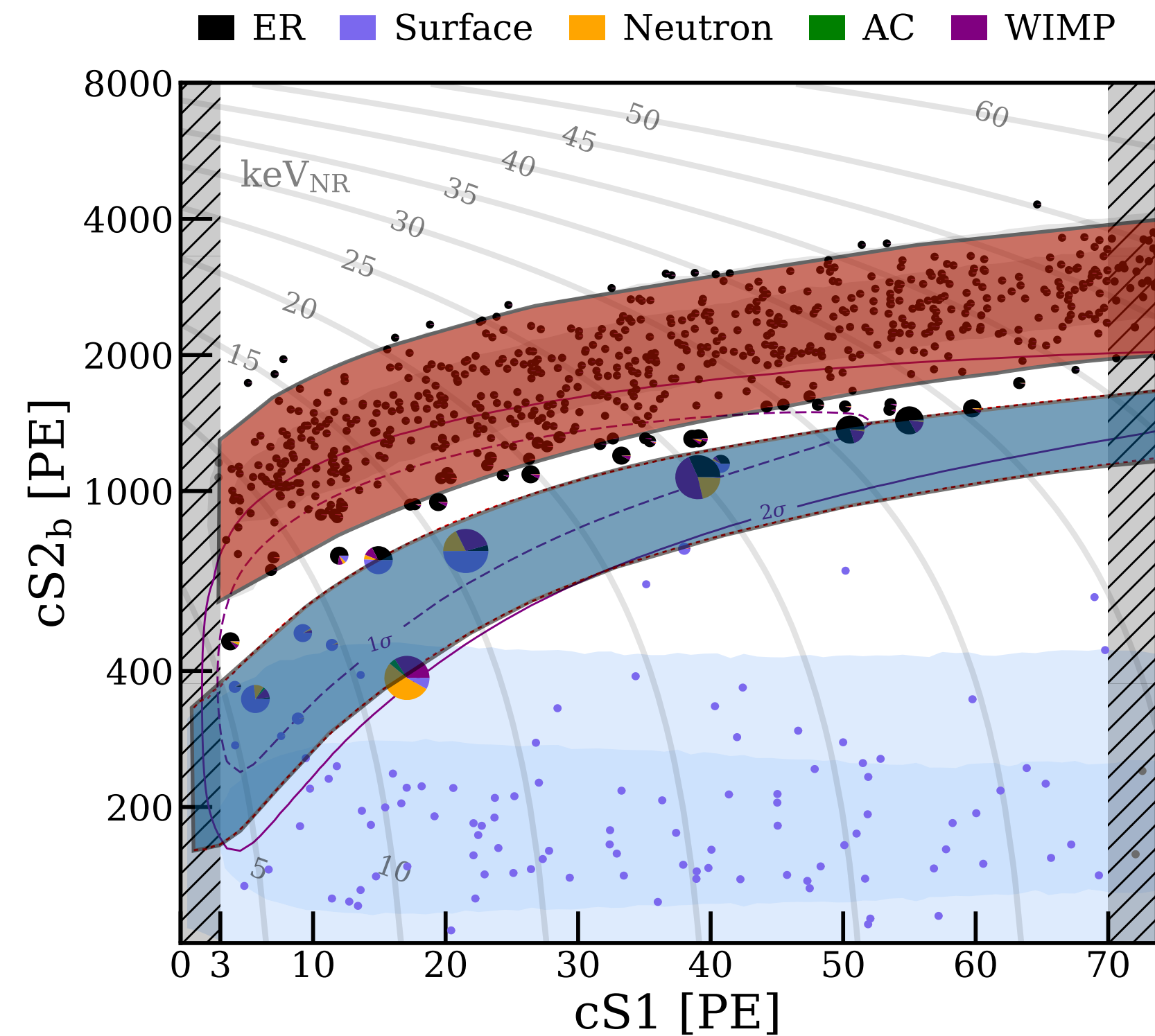




Dual signal enables discrimination of interaction type.

Nuclear Recoils

- CEvNS
- WIMP search over wide mass range
- Very low background from neutrons, neutrinos



Electronic Recoils:

- Backgrounds, mostly intrinsic ^{222}Rn
- Searches for excess above background ($0\nu\beta\beta$, $2\nu\text{ECEC}$, axions and bosonic dark matter)