XENONnT latest results

XENON

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on behalf of XENON collaboration
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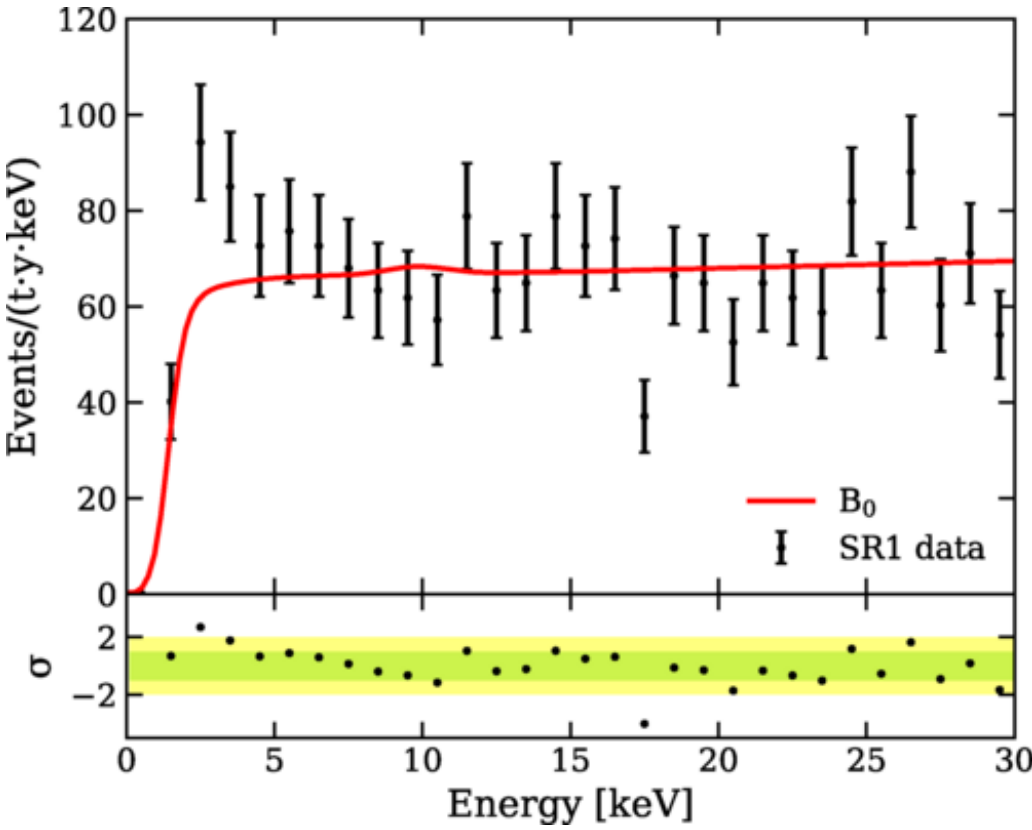
GRAPPA GRavitation AstroParticle Physics Amsterdam

Nikhef

2020 – ER excess in XENON1T

Excess in Electronic recoils below 7 keV

- Fits peak at 2.3 keV peak, $\sim 3\sigma$.
- $^{37}\mathrm{Ar}$?
  - Removed by online Kr distillation. Air leak explanation requires > 13 l/y, upper limit is 0.9 l/year
- $^{3}\mathrm{H}$?
  - Possibly - not water but as tritiated hydrogen. Required rate much greater than expected from purification.
- New physics?
  - Solar axions, dark photons, neutrino magnetic moment, many more



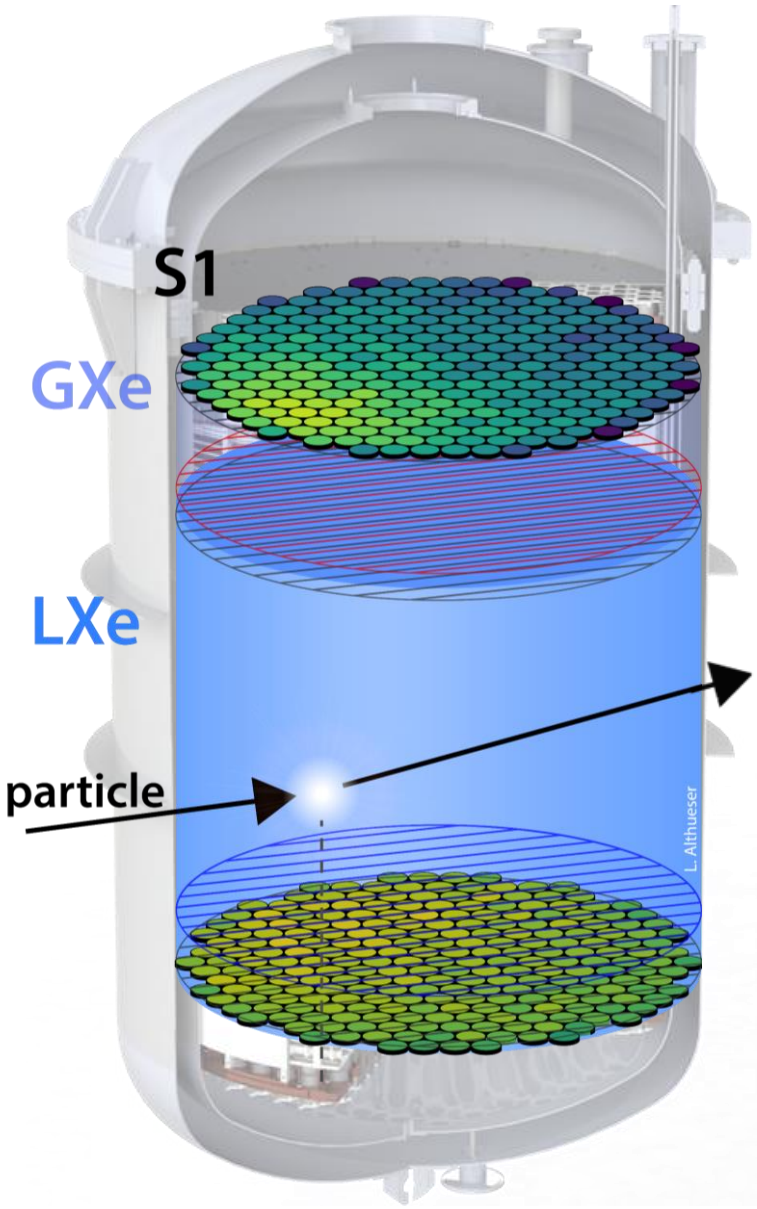
XENON1T: PRD 102.072004

Columbia
KIT
Nikhef
Muenster
Stockholm
Mainz
MPIK, Heidelberg
Freiburg
Zurich

Chicago
Tsinghua
UCSD
Tokyo
Rice
Nagoya
Purdue
Kobe
Subatech
Coimbra
LPNHE
Torino
Bologna
L'Aquila
LNGS
Napoli
Weizmann
NYUAD

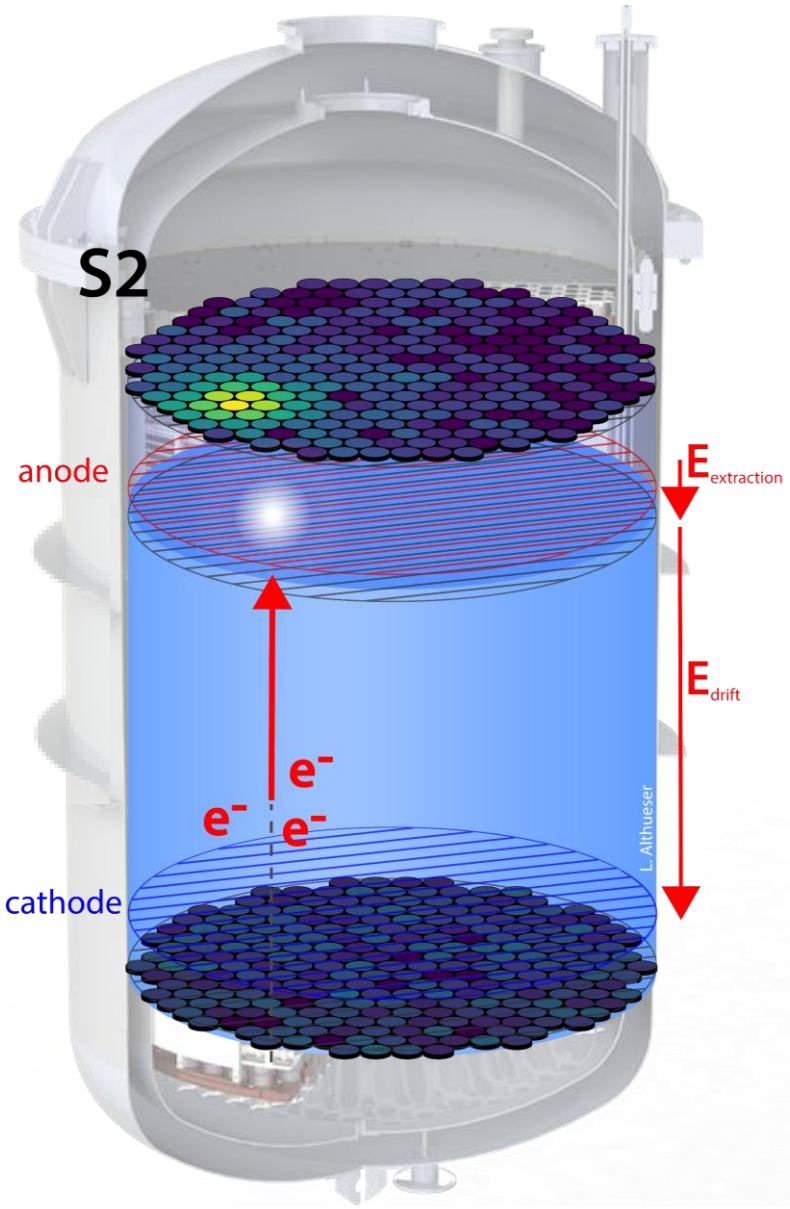
Working principles

- Energy deposit causes scintillation light (S1) and liberates electrons



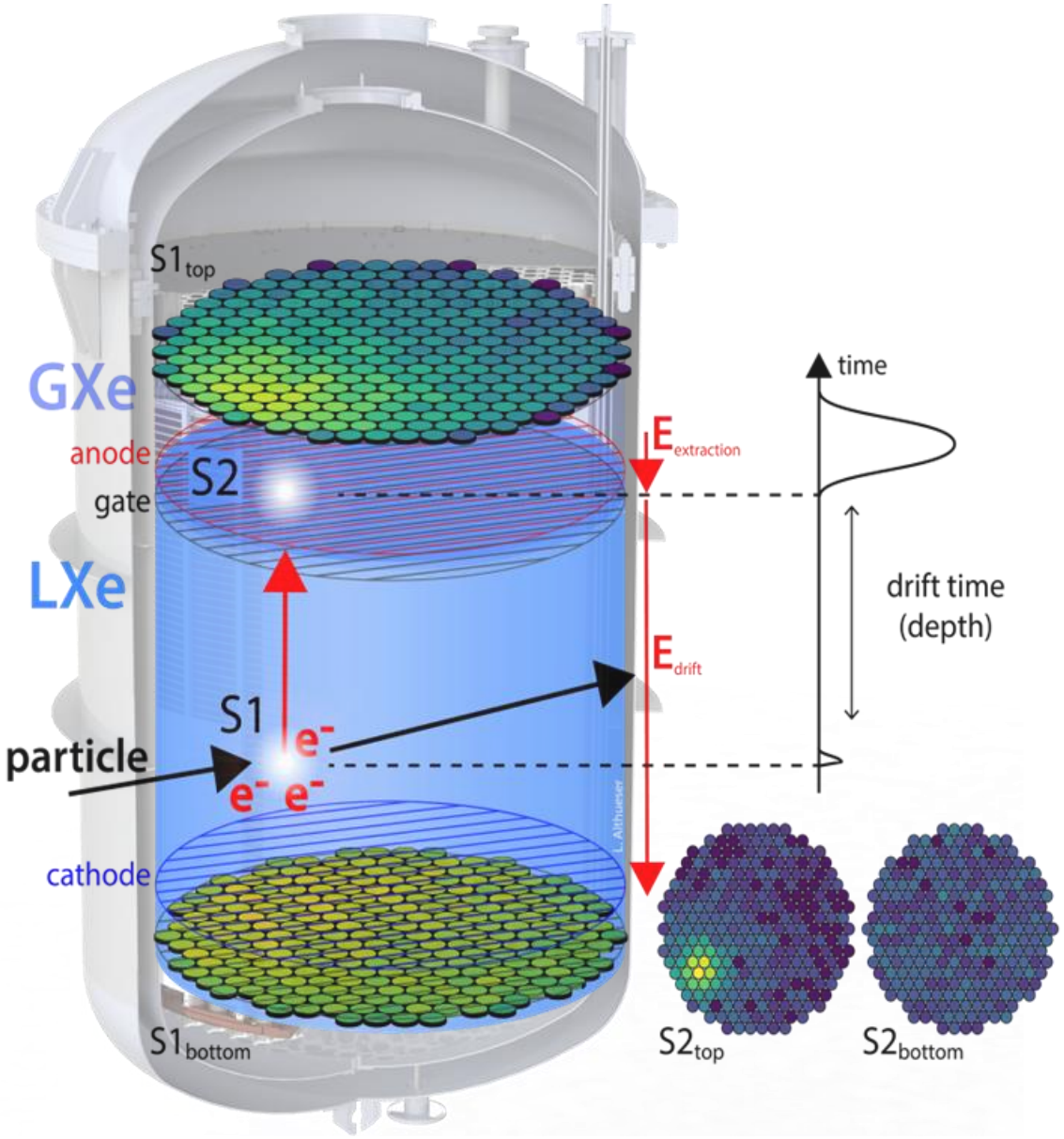
Working principles

- Energy deposit causes scintillation light (S1) and liberates electrons
- Electrons drift to surface
- Extraction field accelerates electrons → S2



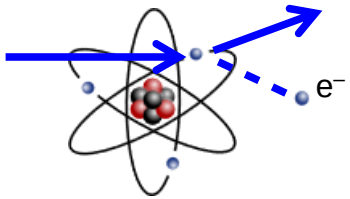
Working principles

- Energy deposit causes scintillation light (S1) and liberates electrons
- Electrons drift to surface
- Extraction field accelerates electrons → S2
- Obtain position:
  - z from drift time
  - x, y from hit pattern

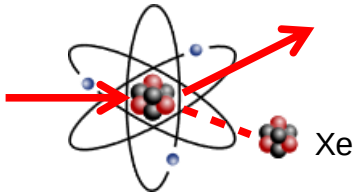


Electronic / nuclear recoils

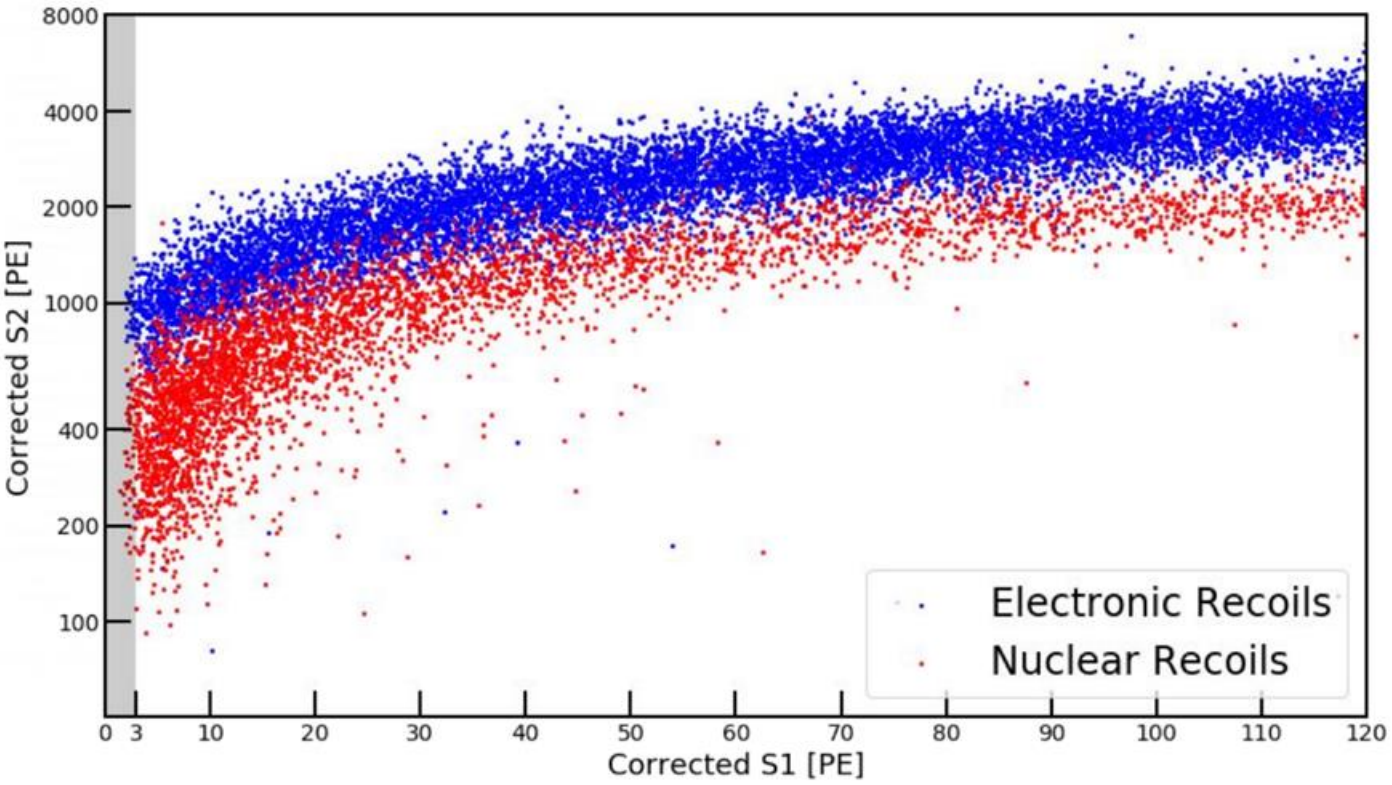
Particle identification by S2/S1 ratio



ER: γ, β, ν

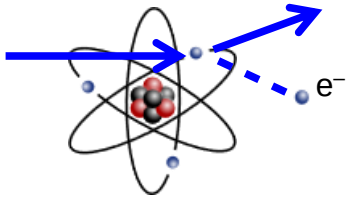


NR: n, WIMPs, ν



Electronic / nuclear recoils - both blinded!

Particle identification by S2/S1 ratio



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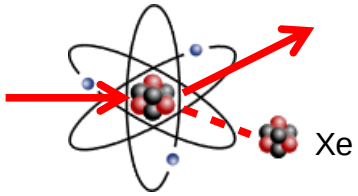

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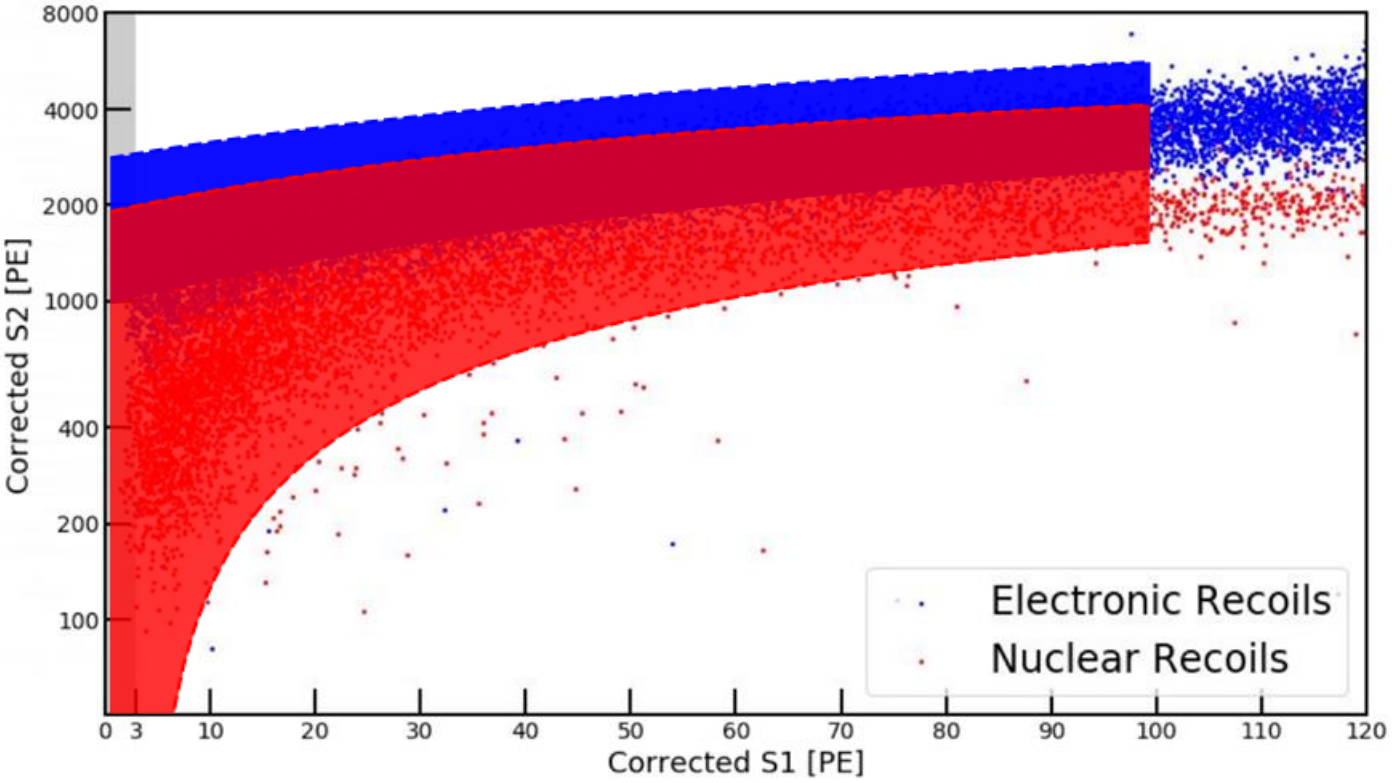
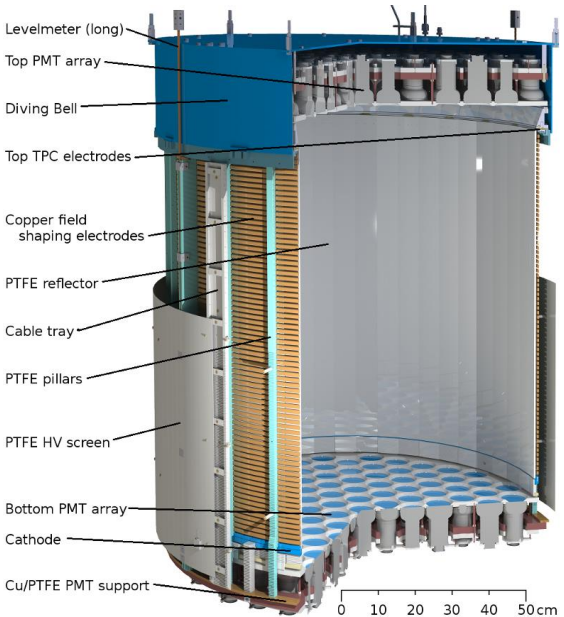


XENON1T → XENONnT

- 3× higher target mass (~6t)
- 2× more PMTs (494)
- Projected WIMP sensitivity down to ~30× lower cross-sections (for 20 t·y exposure)
- Carefully selected materials to minimize backgrounds (Eur. Phys. J. C (2022) 82:599)
- Field shaping rings



XENONnT

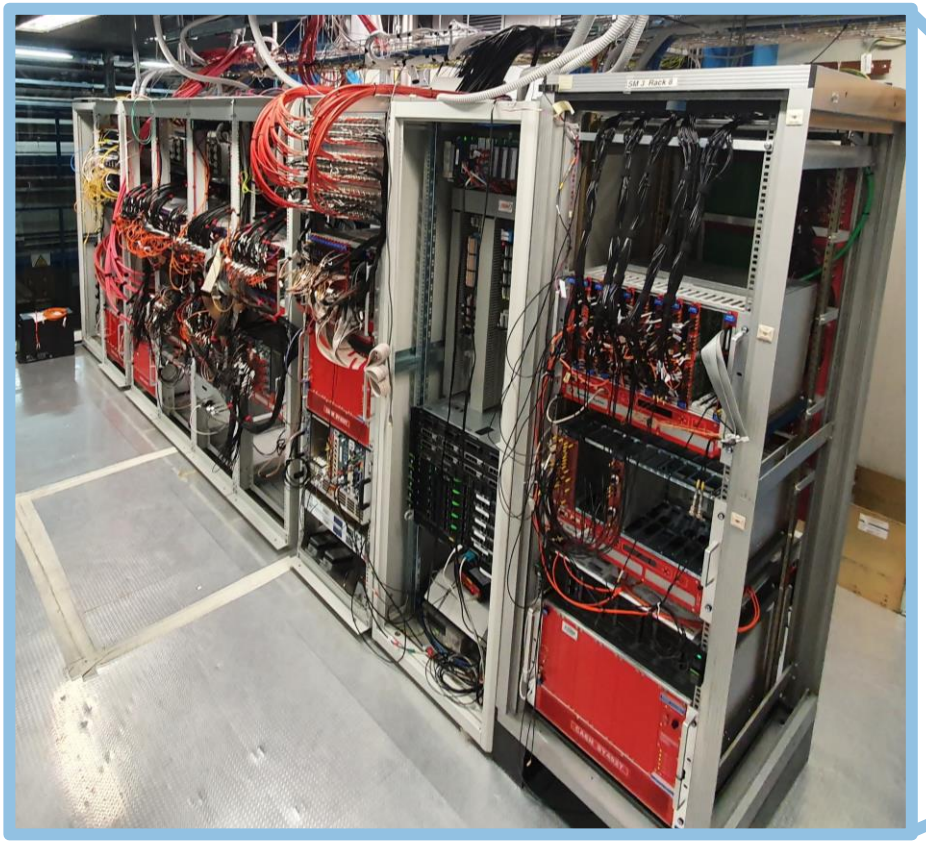
Liquid purification

- New liquid xenon purification technique (arXiv:2205.07336) with replaceable filter units + extremely low radon emanation (in science run mode).
- High flow of 2 liters liquid xenon / minute, reach very high purity in < 1 week, 18 h to exchange the entire volume

	1T	nT
Max. drift time	0.67 ms	2.2 ms
Electron lifetime	0.65 ms	> 10 ms

Triggerless DAQ

- Triggerless: all data above per channel threshold stored long term
- Fully live processing
- Open-source software: straxen (straxen@github)

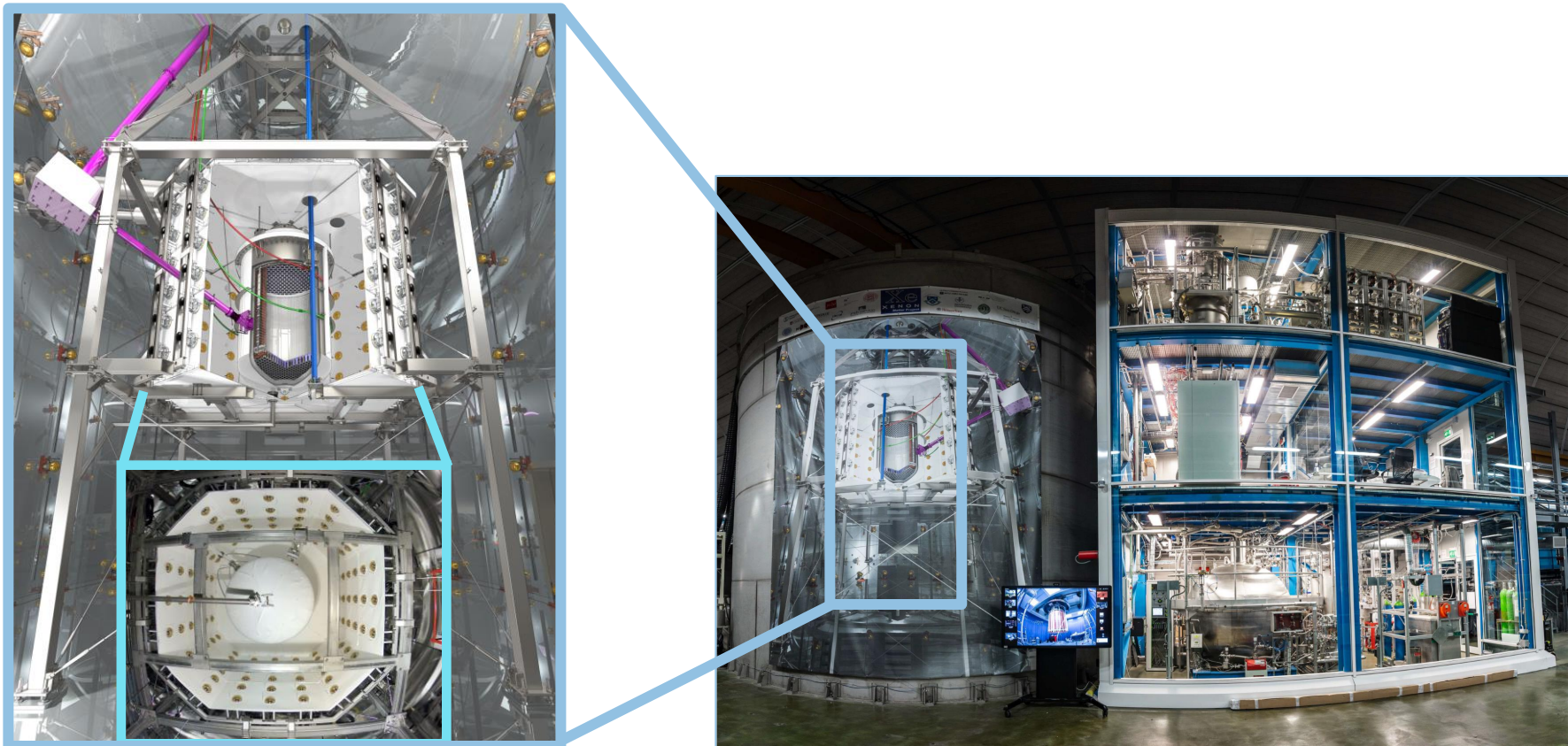


Radon distillation

- $^{222}\mathrm{Rn}$ is primary source of background
- Newly developed Rn column (arXiv:2205.11492) handles large xenon flows using radon-free compressors and heat exchangers
- For first science run, the column operated in gas-only mode
- Able to reach $< 1\mu\mathrm{Bq/kg}$ in science running mode

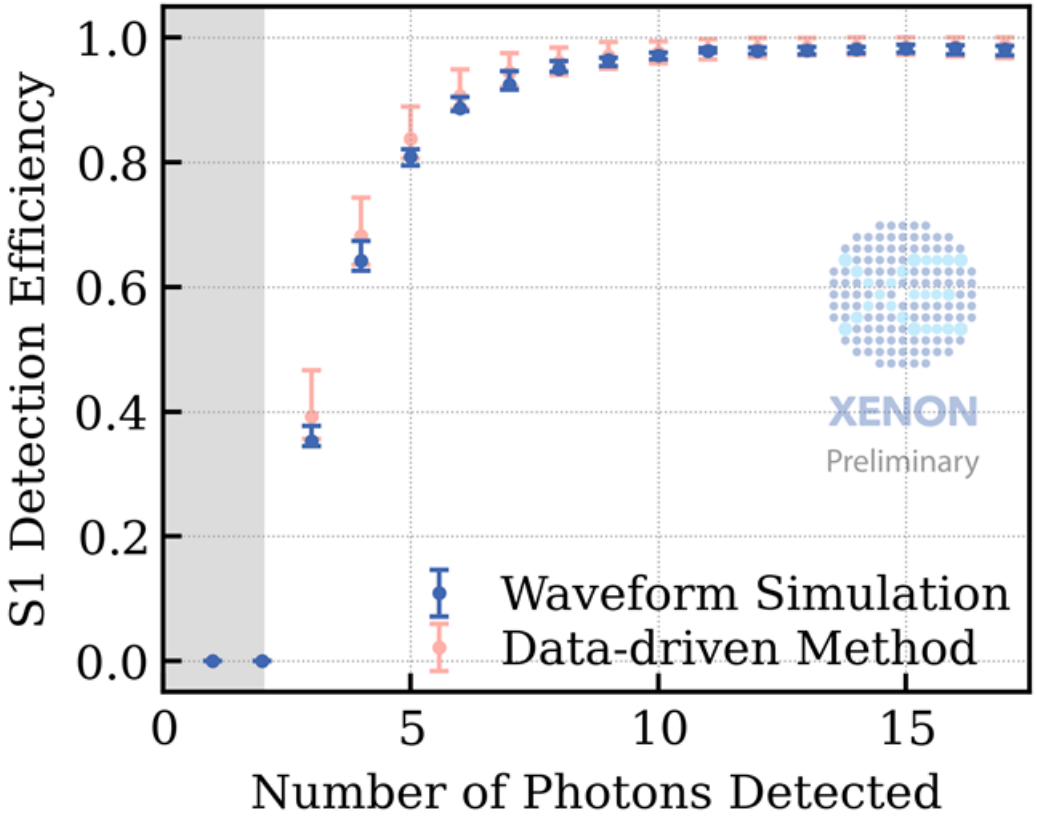
Neutron veto

- In addition to the Cherenkov Muon veto; the new Neutron veto.
- The Neutron veto is vital for WIMP search by tagging neutrons, we expect ~0.3 neutrons per t·y (JCAP 11 (2020) 031).
- Neutron tagging efficiency is currently 68%.
  With projected (planned) Gd-doping → 87%.



Efficiencies

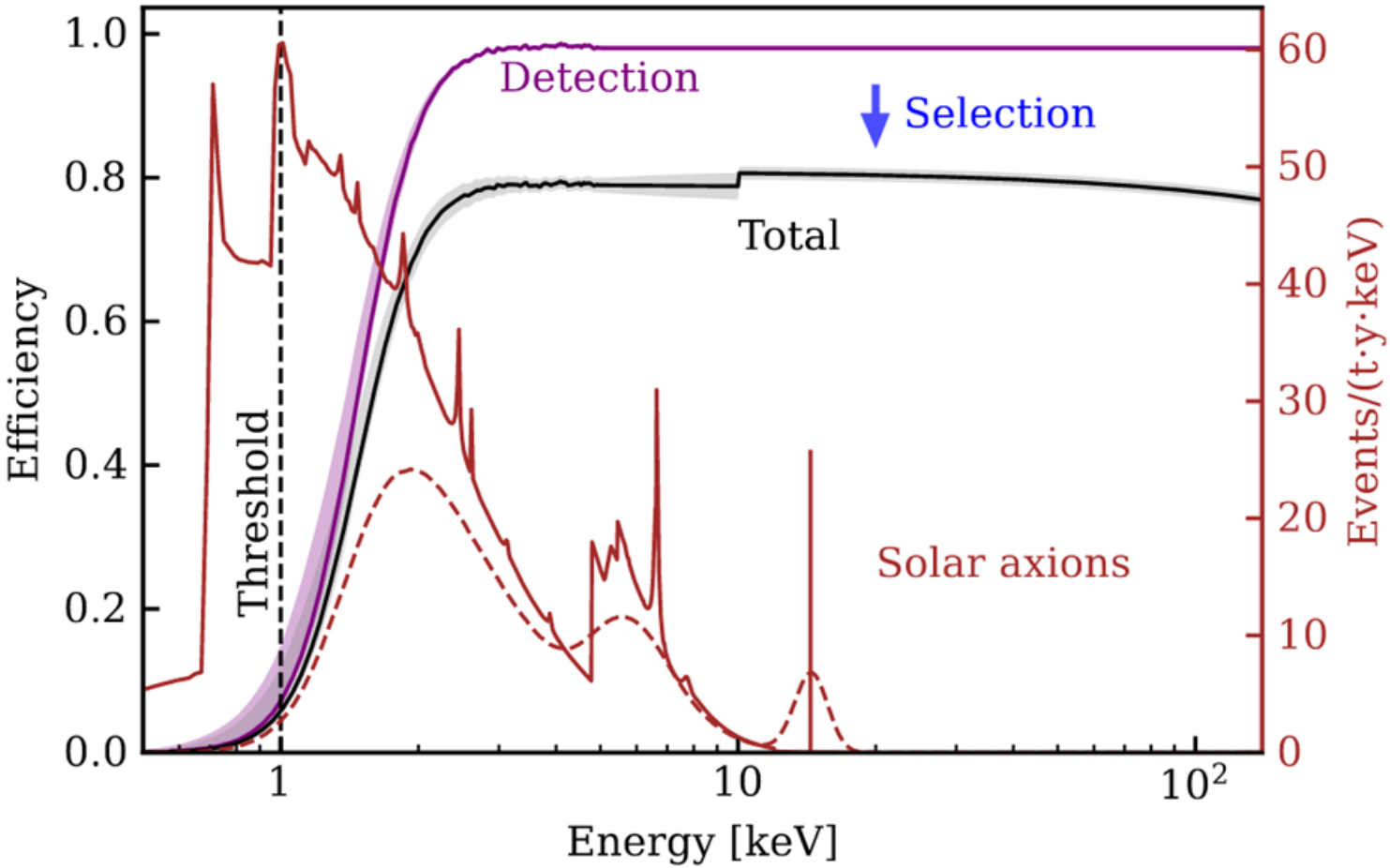
- Detection efficiency validated using simulation & data driven method
- The data driven method resamples hits from reconstructed S1 signals to validate reconstruction efficiency
- Good agreement between two approaches



Efficiencies

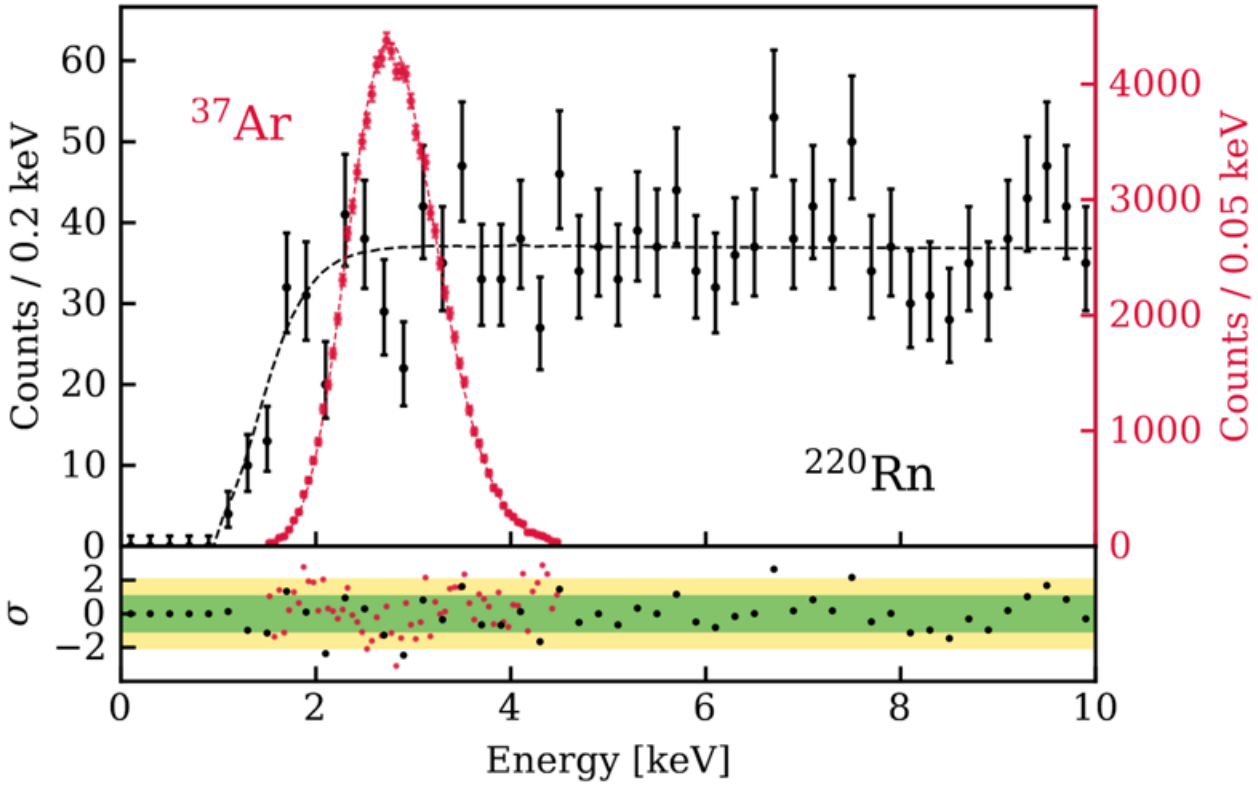
Total efficiency

- Step near 10 keV is due to the NR blinding.
- Average data-quality cut acceptance ~86%



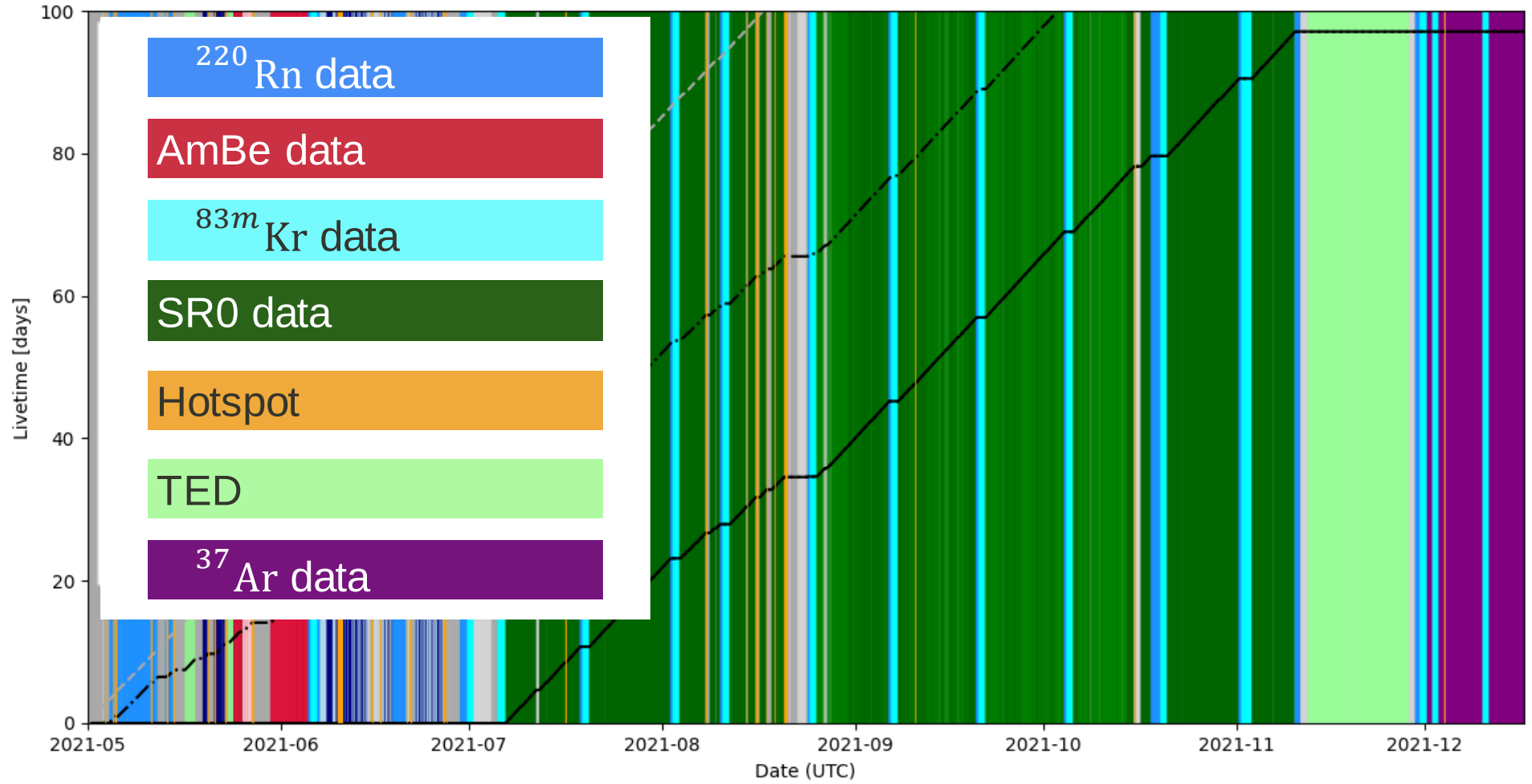
Calibration

- Validate models with $^{220}\mathrm{Rn}$ and $^{37}\mathrm{Ar}$ calibration sources
- Detector response
- Energy resolution
- Corrections of detector response non-uniformities (S1 → cS1, S2 → cS2)



Science run 0 (SR0)

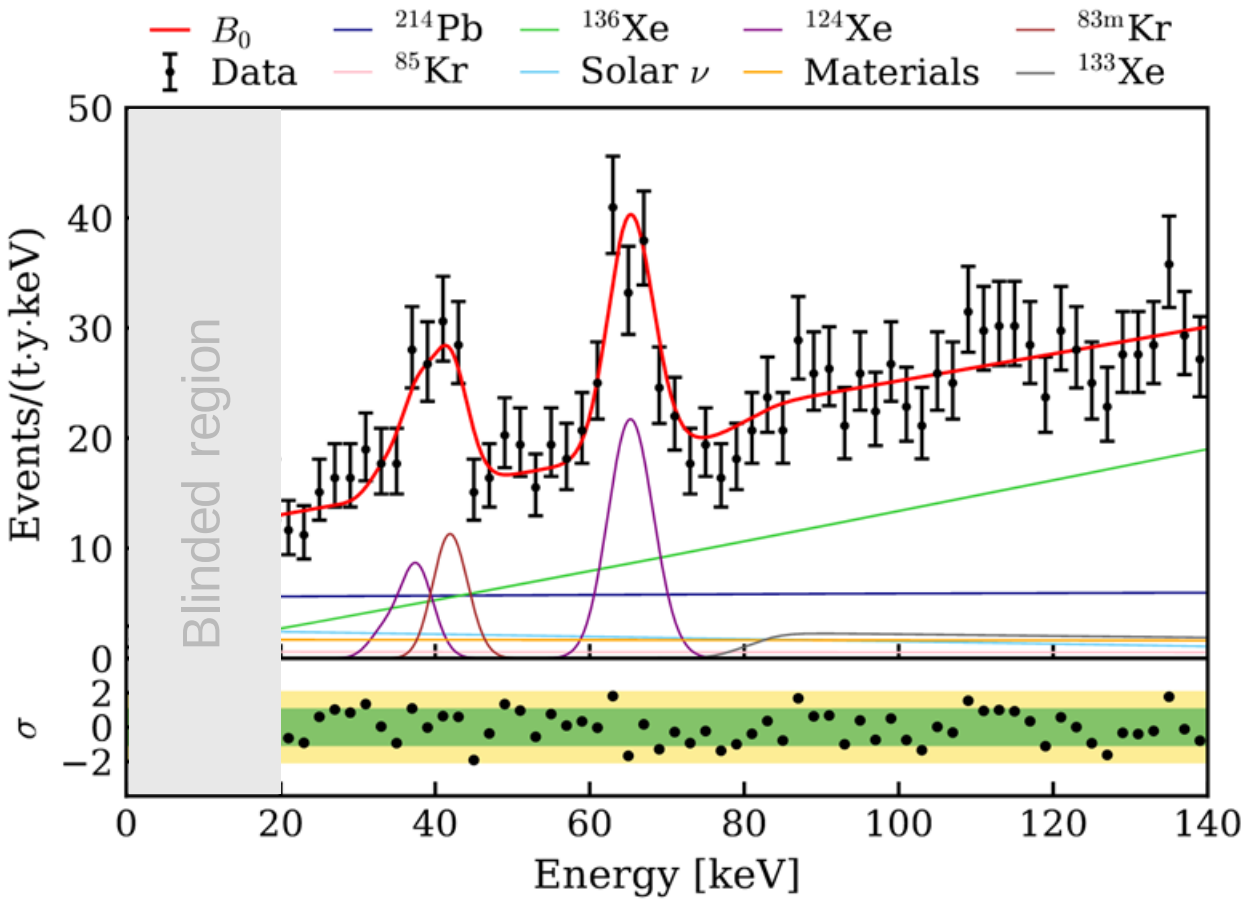
- 97.1 days of Science data



ER spectrum

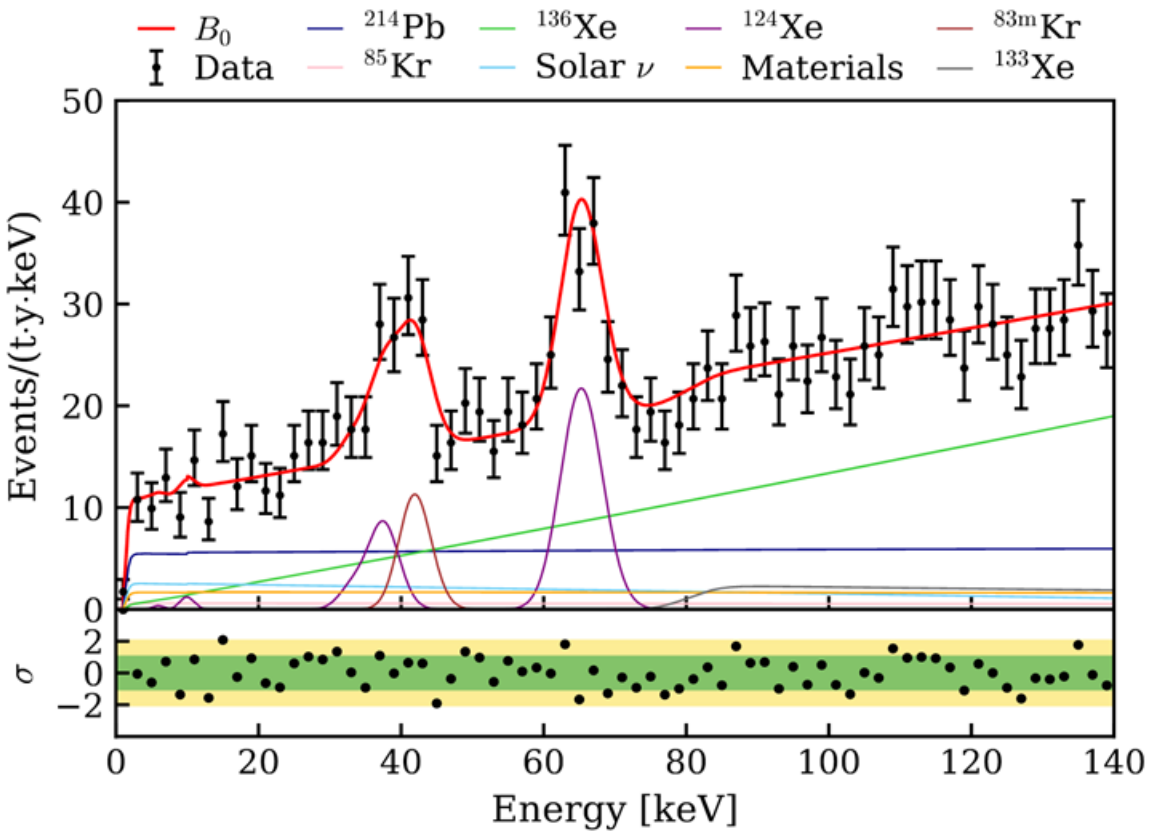
Initial estimates of background:

- External measurement
- Data-driven accidental coincidence model
- Verification in side-band



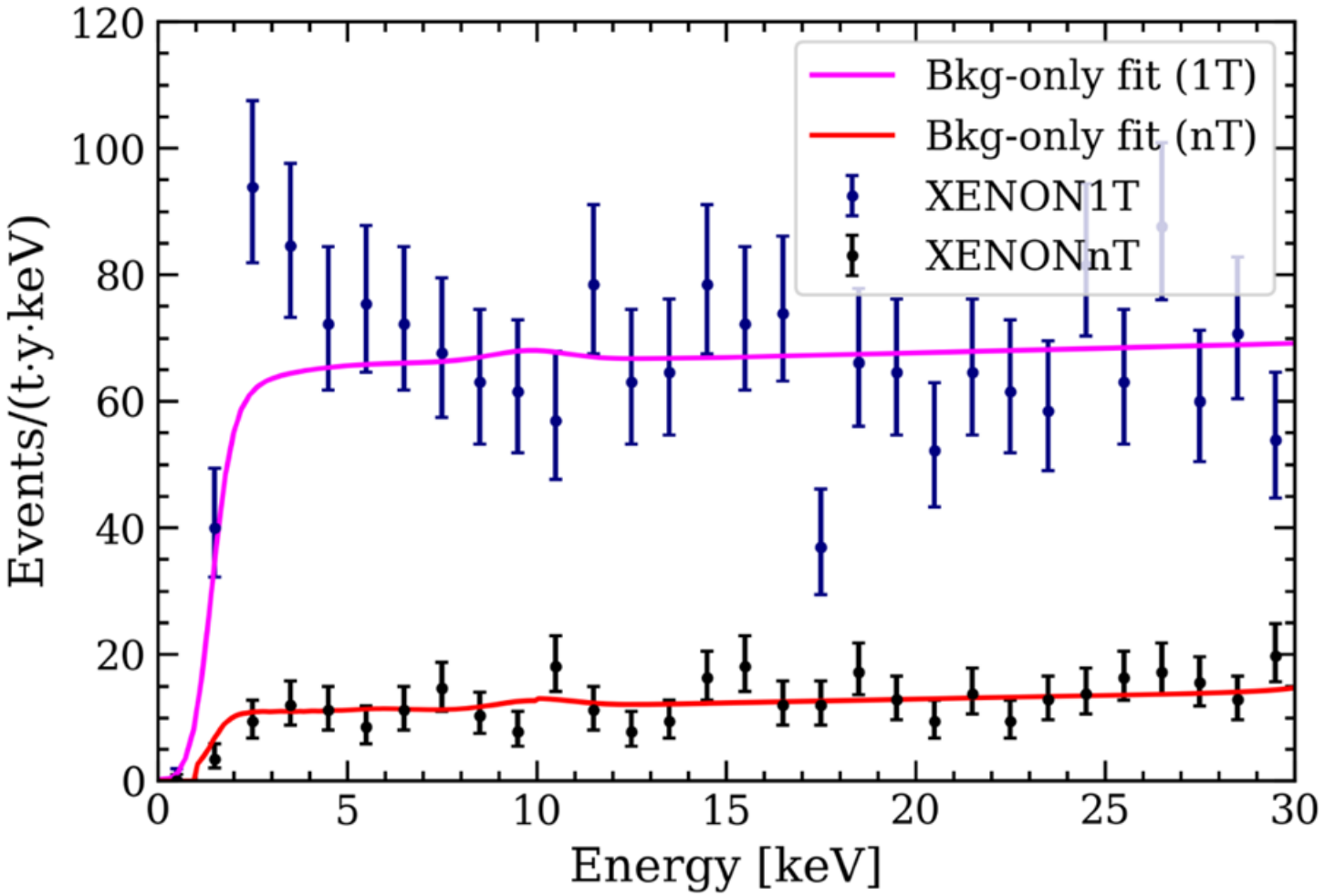
Unbinding!

- Fully blind analysis with various stages of unblinding
  - 10-20 keV side band, accidental coincidence, wall sample, full range
- Final energy range in fiducial mass of (4.37 ± 0.14) t
- No excess observed: arXiv:2207.11330



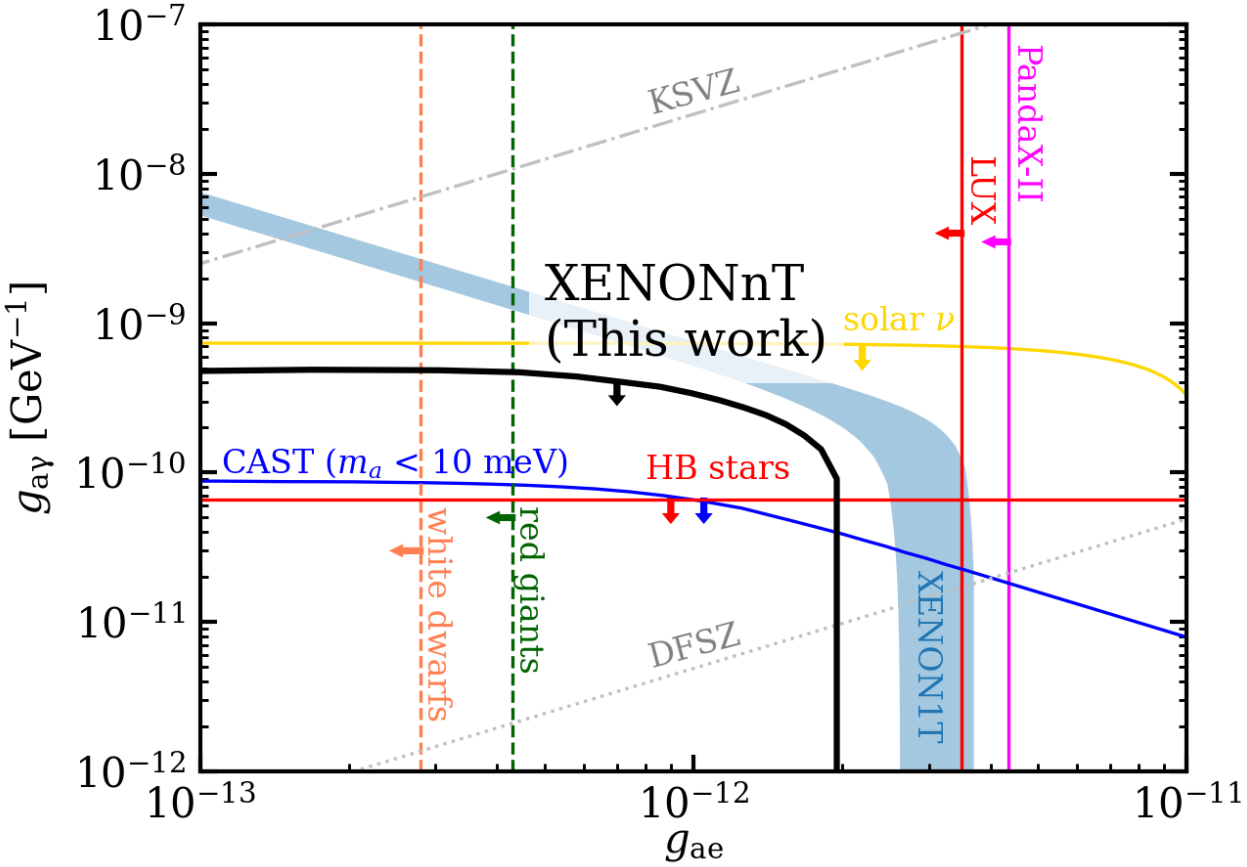
XENON1T vs. XENONnT

- Extraordinary reduction of backgrounds
- An excess of the XENON1T magnitude is excluded at 8.6 σ



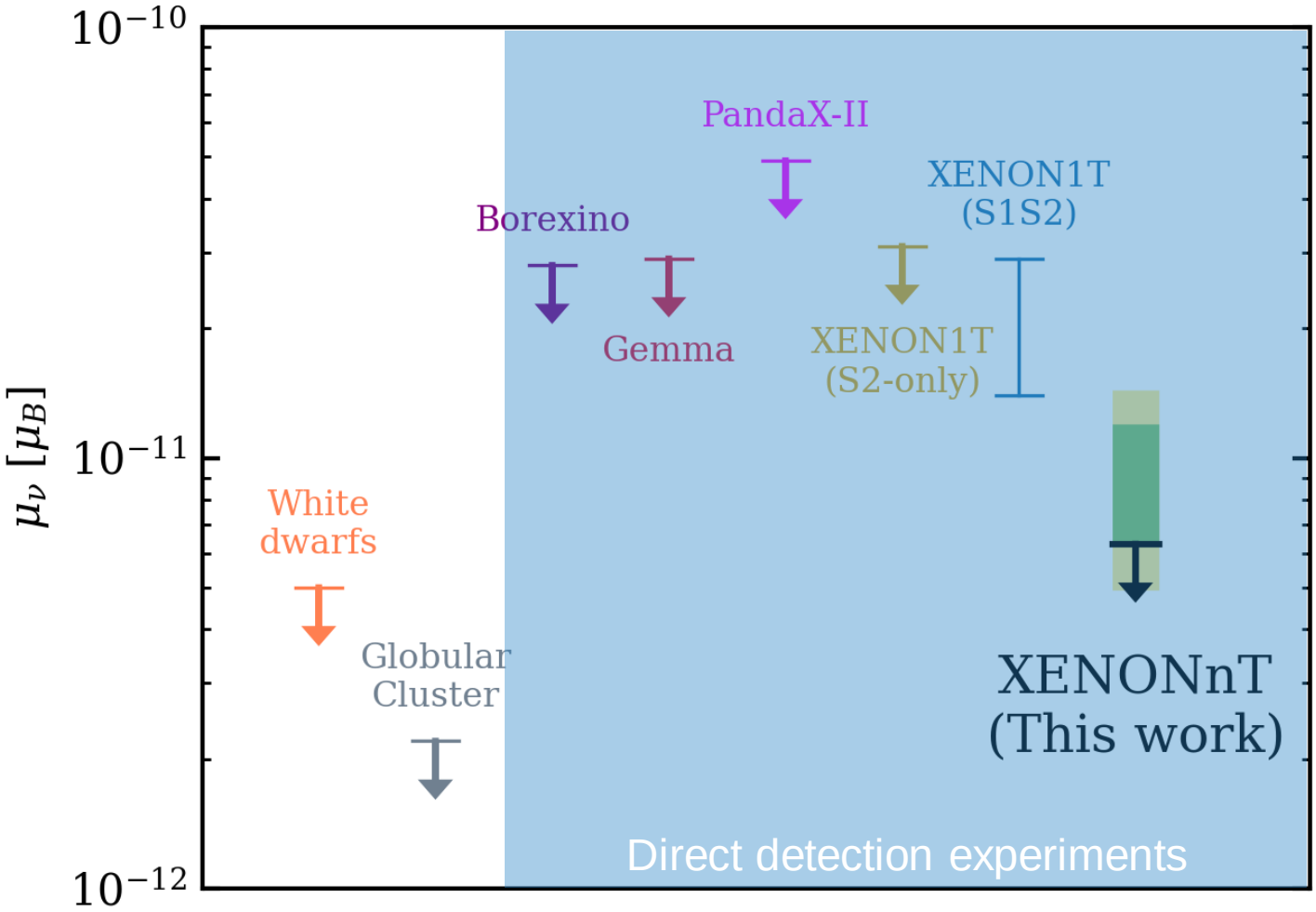
Solar axion couplings

- Axion signal assumes axio-electric- and reverse Primakoff effect
- Significantly improved constraints on axion-gamma, axion-electron and axion-nucleon coupling
- Limit for signal from $^{57}\mathrm{Fe}$ axions < 20.4 ev/(t·y) (90% C.L.)



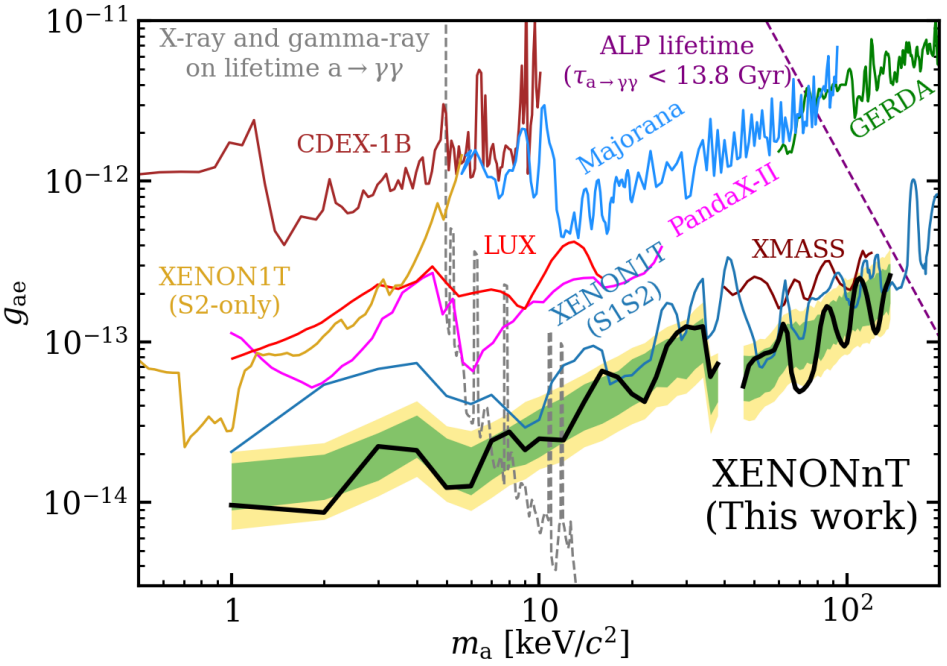
Solar Neutrino magnetic moment

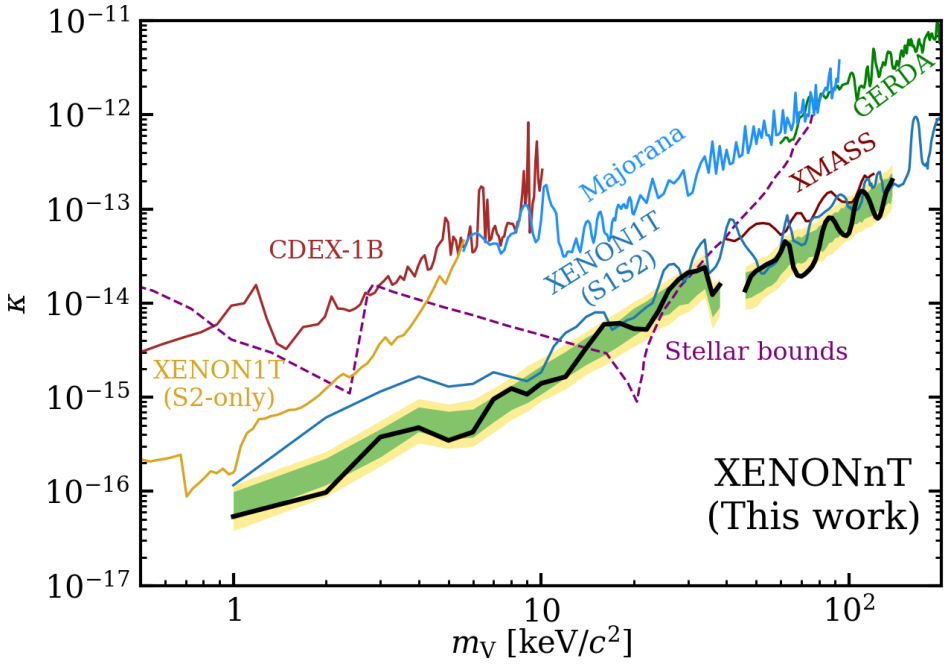
- Constraint on neutrino magnetic moment $\mu_\nu < 6.3 \times 10^{-12} \mu_B$
- The most stringent limit in any direct detection experiment!



ALPs / Dark phonons

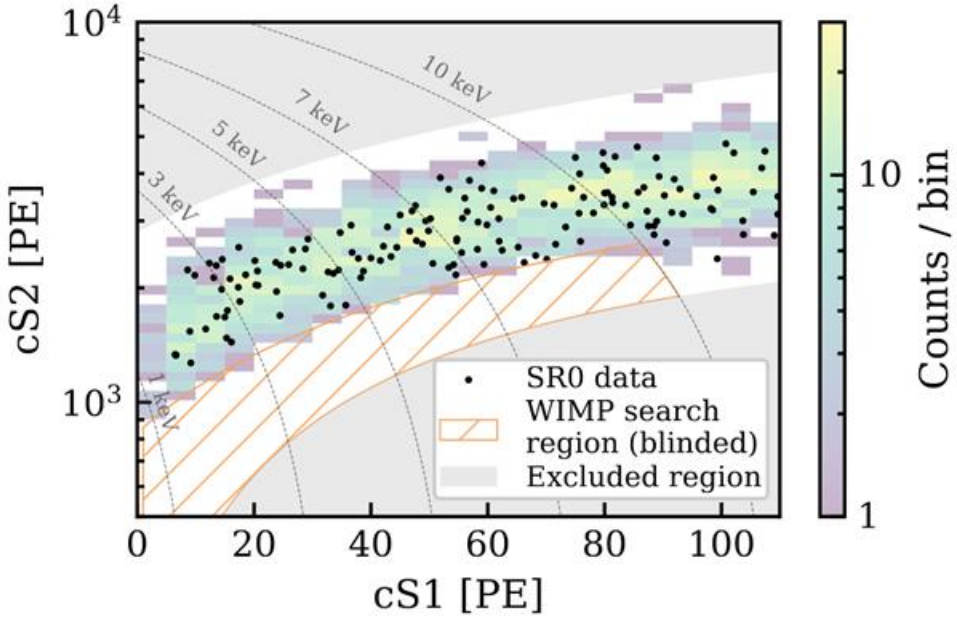
- No peak-like signals observed which would be expected from axion-like particles or dark photons
- Unconstrained normalization of $^{83m}\mathrm{Kr} \rightarrow$ no limit around 41.5 keV





Summary & outlook

- SR0:
  - Electron lifetime of > 10 ms
  - $\sim 5\times$ lower background w.r.t. 1T
- First results:
  - Blinded electronic recoil (ER) search
  - No excess observed $\rightarrow$ limits on new physics
  - XENON1T result likely due to $^{3}\mathrm{H}$
- Next step:
  - Unblind NR and WIMP analysis
  - SR1 with factor $2\times$ lower radon



Backup slides

Tritium?

- Efforts to reduce sources of excess
- Outgassing, purification and xenon cleaning reduces possible hydrogen contamination
- Special TED (tritium enhanced data) mode after SR0 ~14.3 days
  - Bypassing getters in purification loop → increase equilibrium hydrogen concentration
  - Large uncertainty:
    - best-estimate ~ several orders of magnitude
    - very conservative estimate ~ ×10
- Result of blind TED analysis → no significant levels expected in SR0