Update from the

XENON dark matter project

OBSERVATION OF EXCESS ELECTRONIC-RECOIL EVENTS IN XENON1T

PRD 102, 072004 (2020)

PATRAS WORKSHOP
16th June 2021

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On behalf of:
XENON Collaboration

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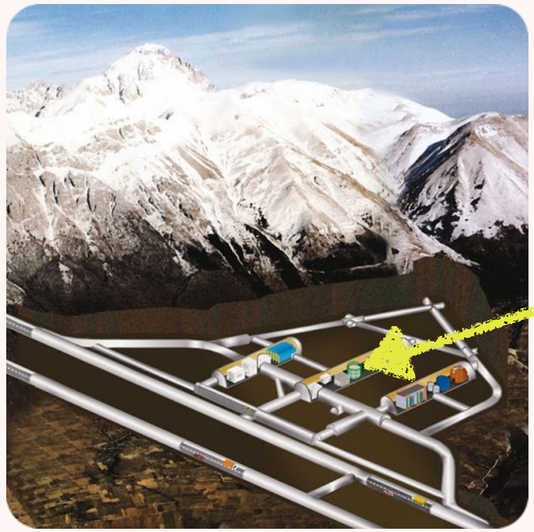
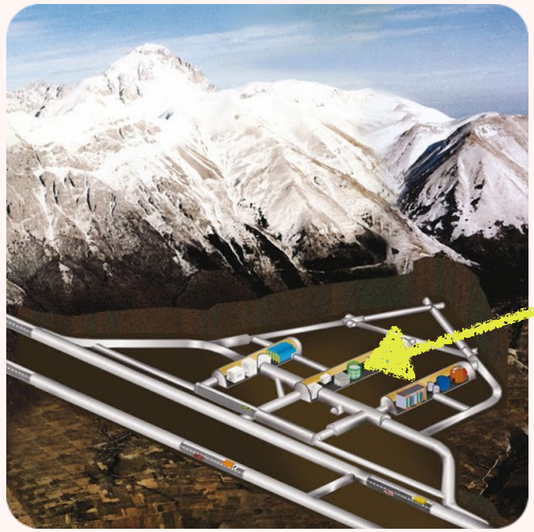


Laboratori Nazionali
del Gran Sasso
Italy



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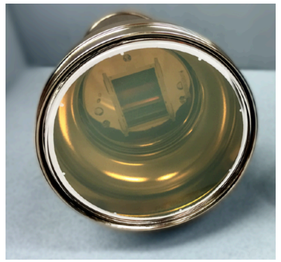
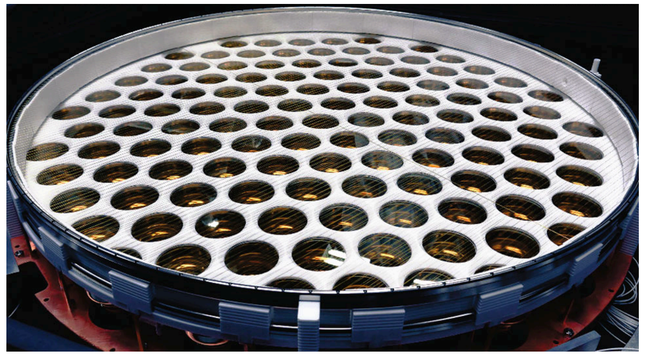
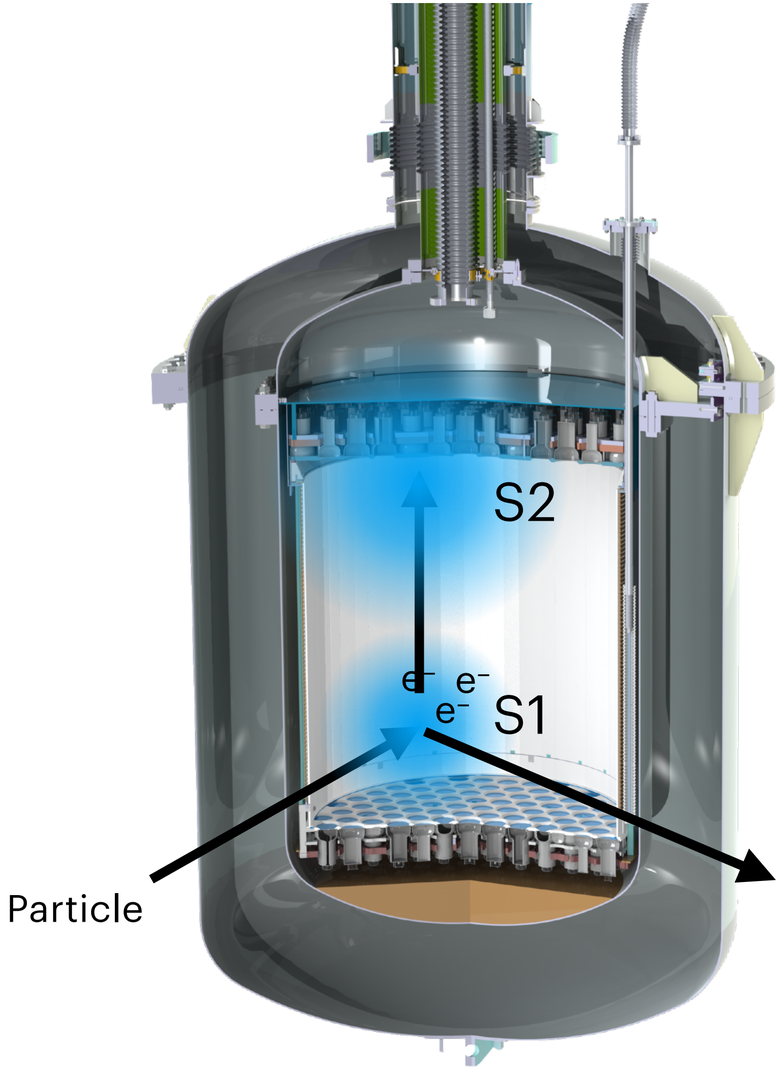
The TPC

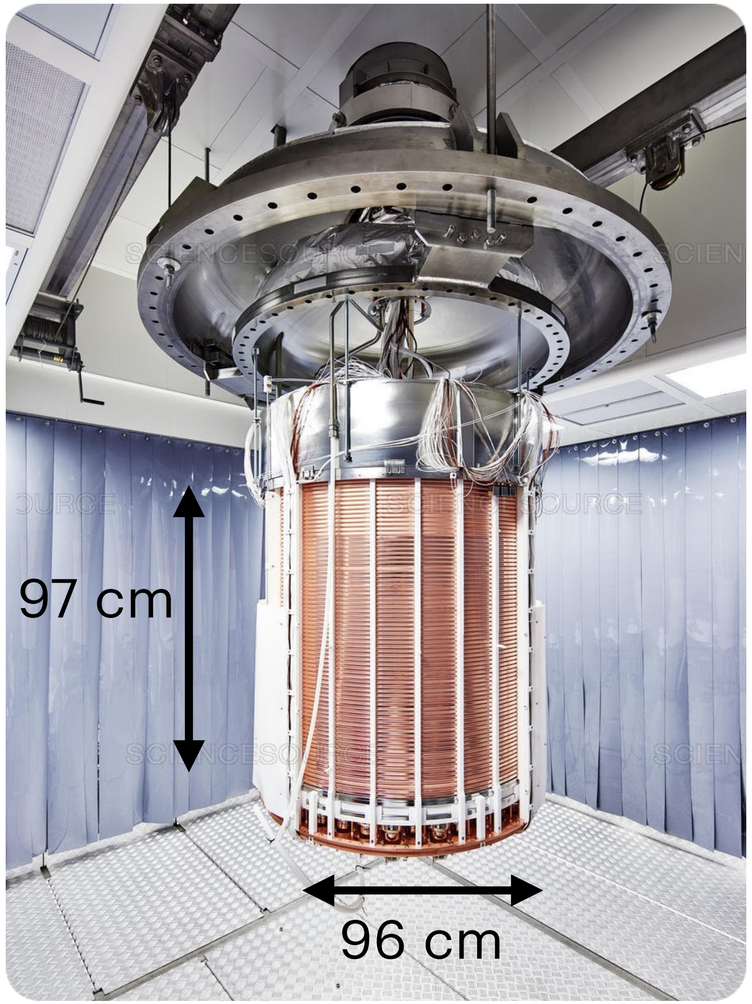




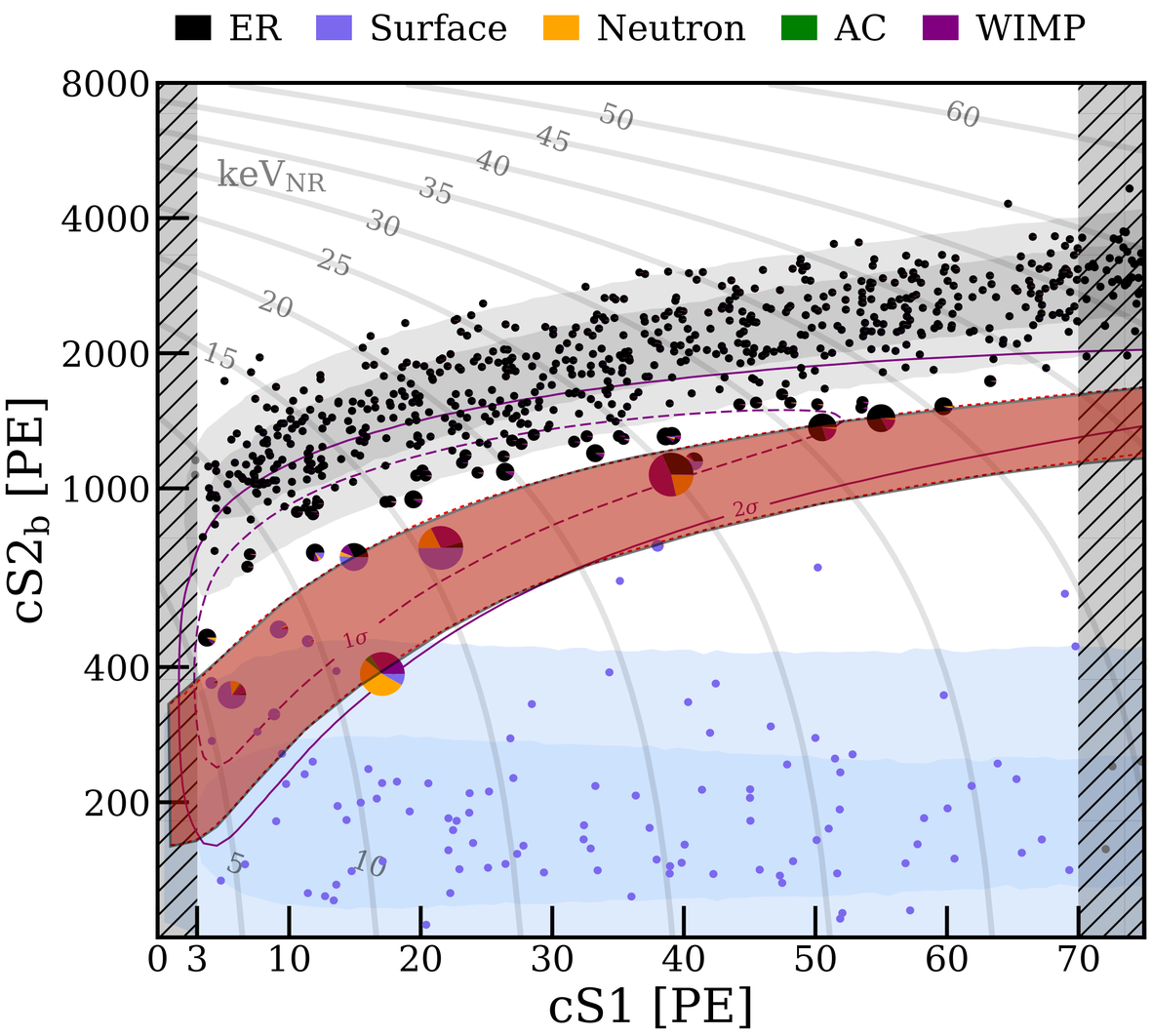
2 t Liquid xenon in TPC
3.2 t in total

248 PMTs

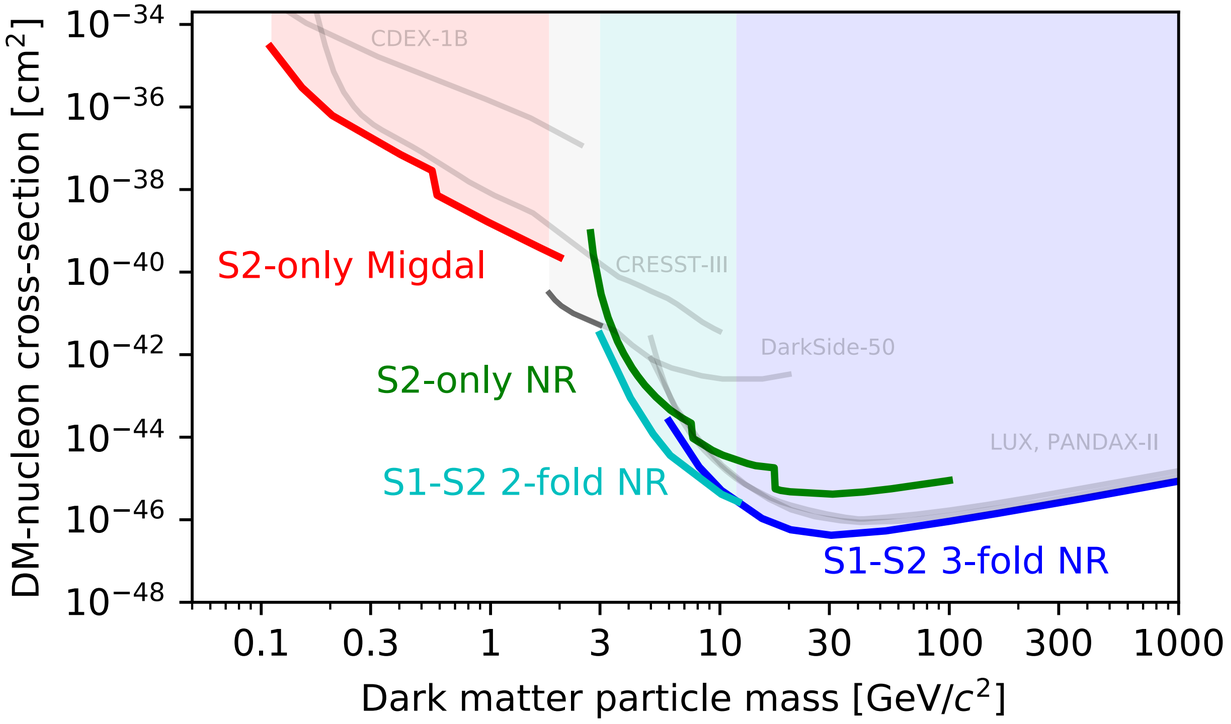




Nuclear recoil searches

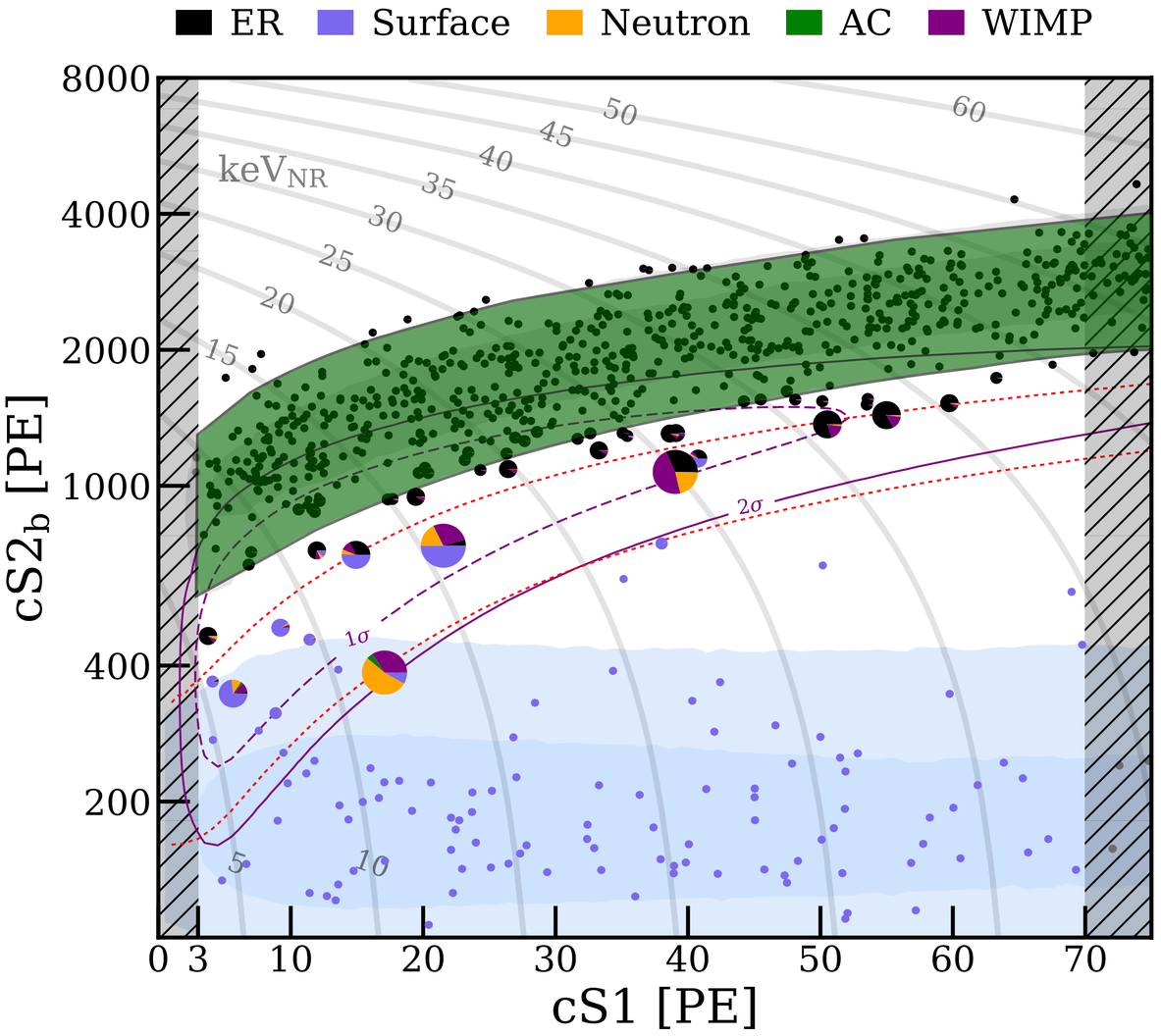


No excess of NR events found



PRL 123, 241803 (2019)
PRL 123, 251801 (2019)
PRL 126, 091301 (2021)
PRL 121, 111302 (2018)

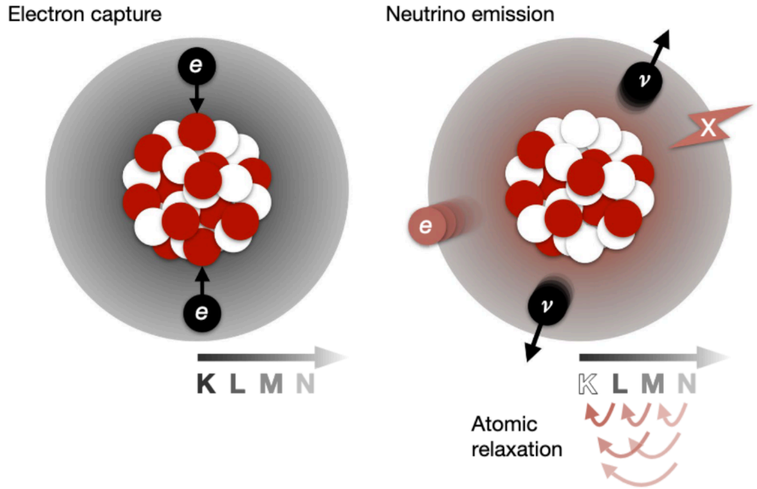
What about the electronic recoils?



This talk

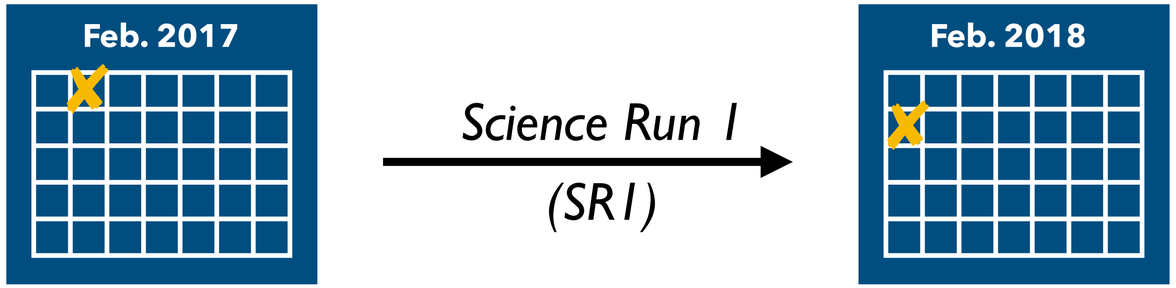
Search for excess above known BGs

Nature 568, 532 (2019)
— Double electron capture ^{124}Xe



This talk: low energies (up to 10 keV)

The low energy excess



226.9 live days

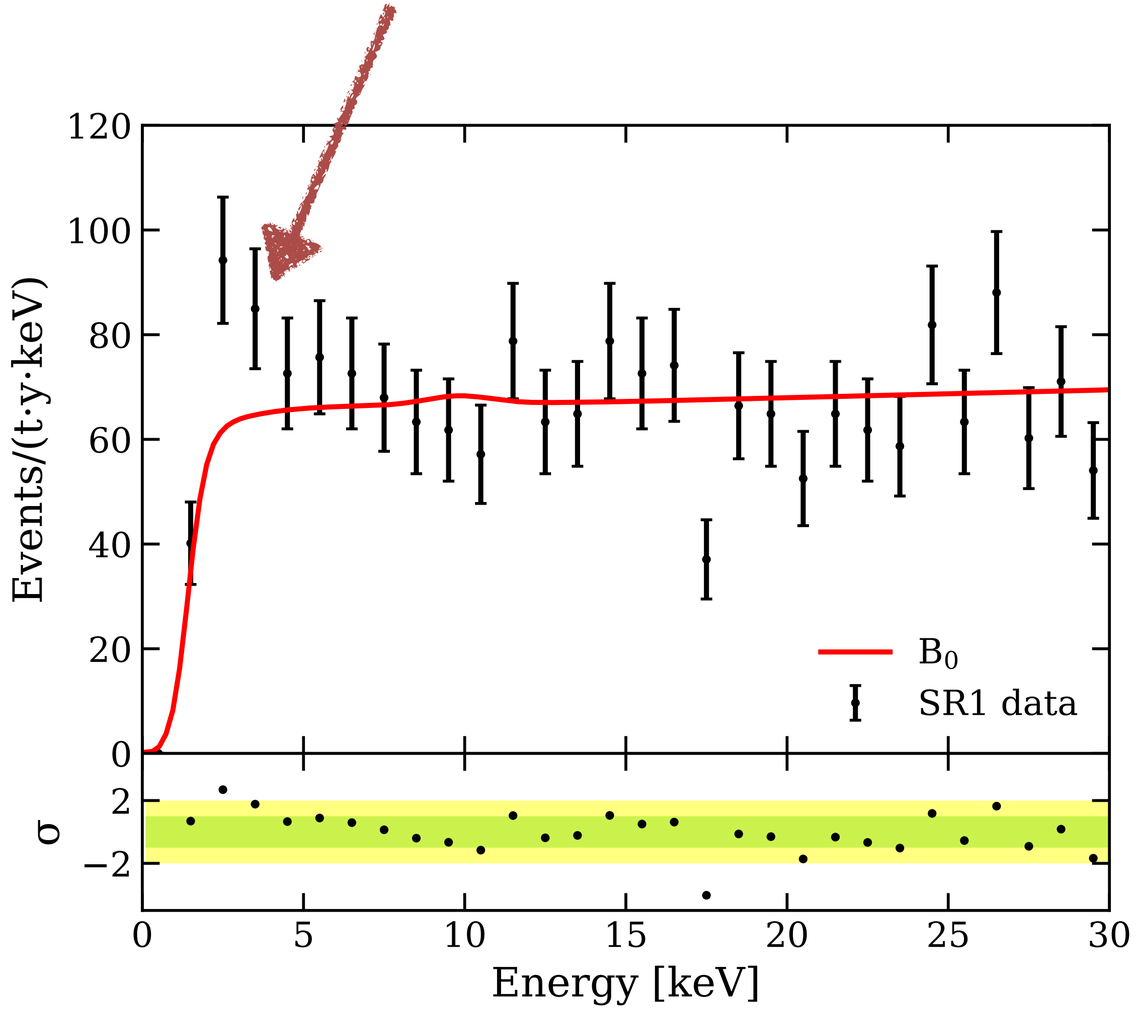
1 tonne fiducial volume

[1, 210] keV energy range

Consider efficiencies of reconstruction and data quality cuts

Threshold at 10% detection efficiency

3.3 σ fluctuation between 1 and 7 keV

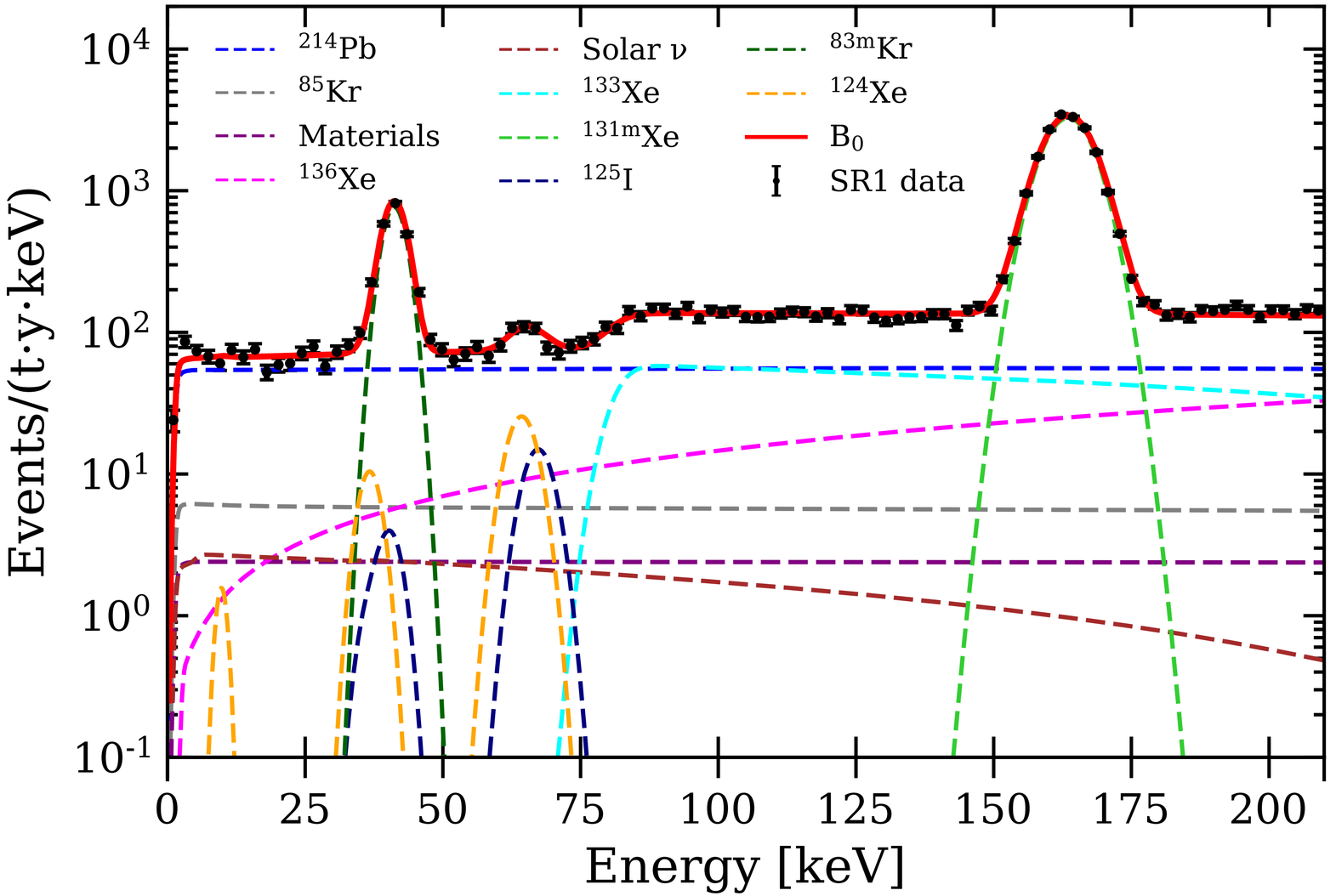


Background modelling

Background sources modelled with Geant4

Most rates constrained by other measurements or time dependence

Search for excess over known backgrounds between 1 and 210 keV



Efficiency and energy reconstruction

Mistake in energy reconstruction?

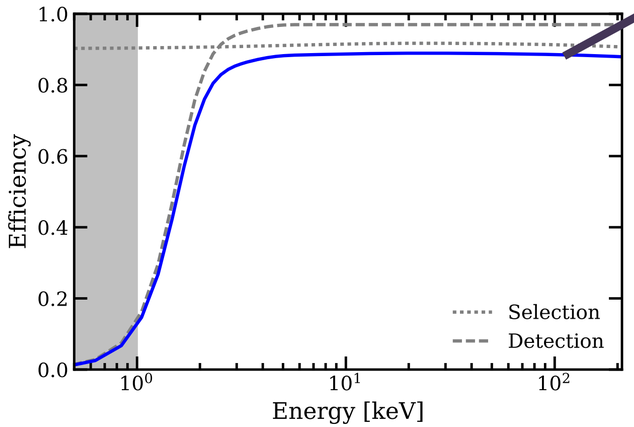
Mis-modelled efficiency?

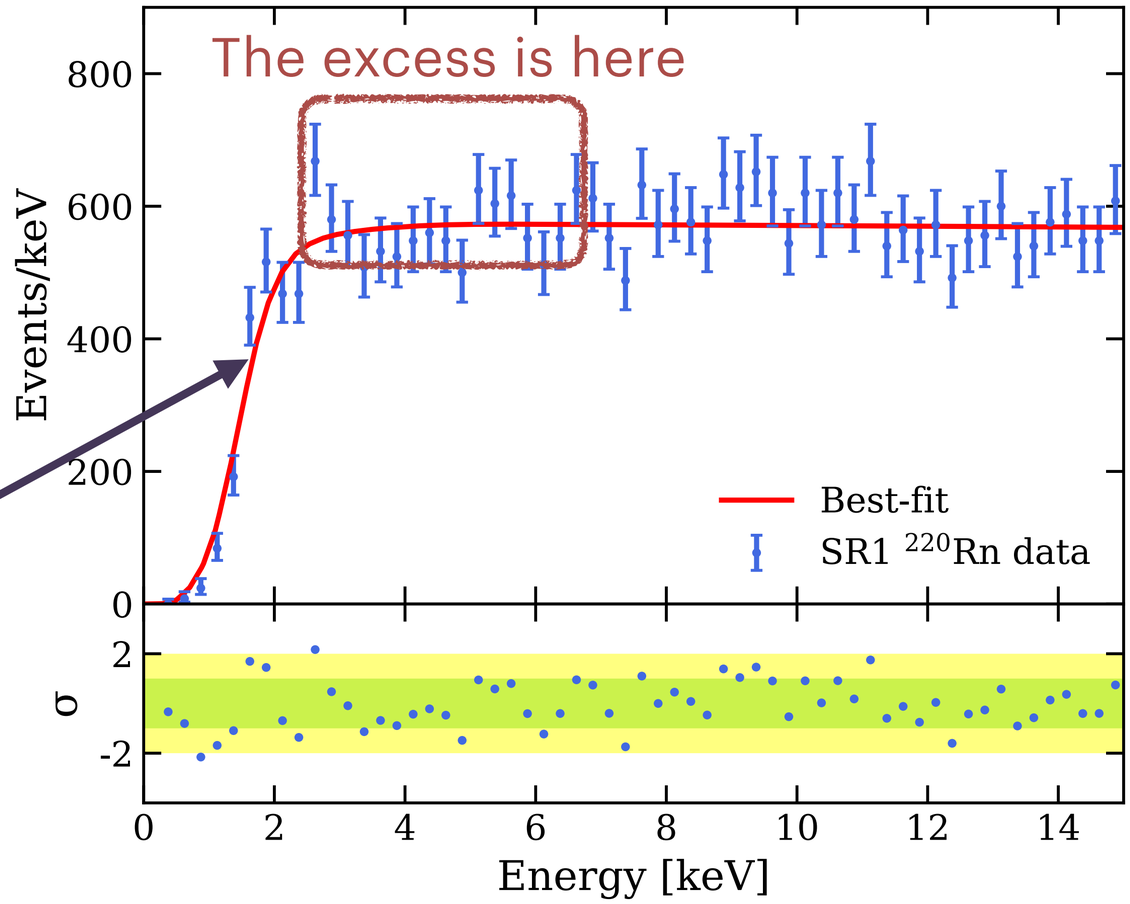
Look at Rn-220 calibration data

Beta-decay just like dominant background

p-value 0.58

Cannot explain the excess





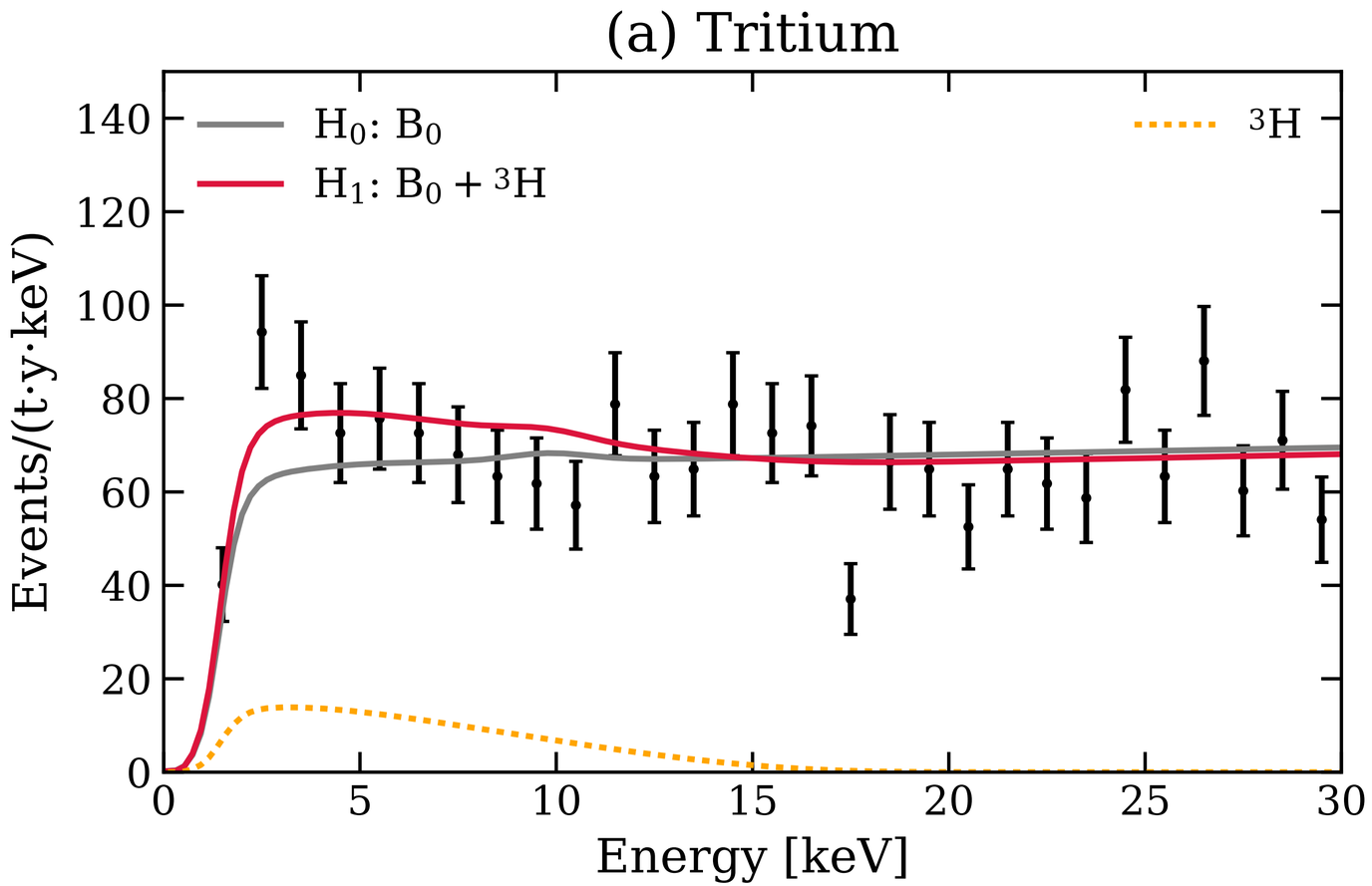
IT COULD BE A NEW BACKGROUND

Tritium

3.2σ over background

(159 ± 51) ev/keV/t/yr

< 3 atoms ^{3}H / kg Xe



Beta decay

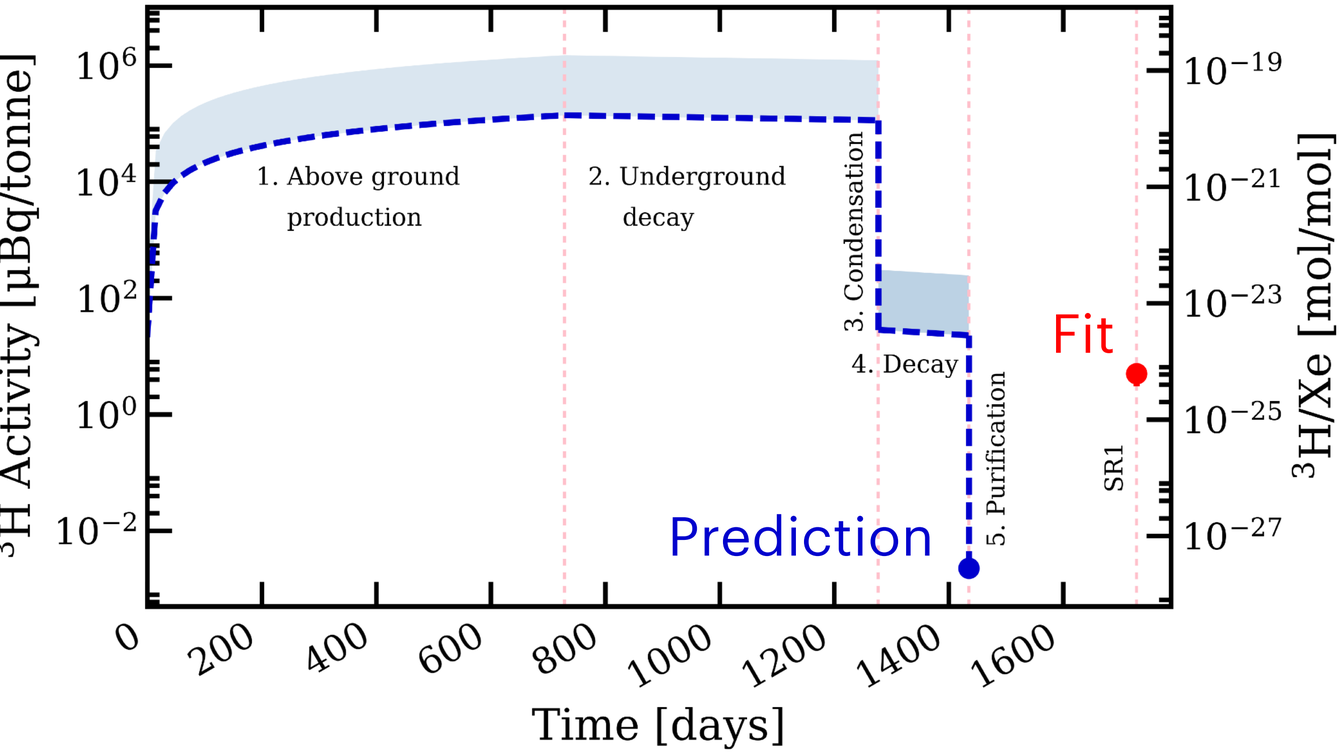
Q value 18.6 keV

Half life 12.3 years

Where from?

Emanation from detector materials neither confirmed nor ruled out

Tritium — possible origins



Where from?

Cosmogenic activation?

Xe spallation
31.58/kg/d at sea level
(Zhang et al., Astropart. Phys 84, 62 (2016)

Seems unlikely

Tritium — possible origins

Where from?

Emanation from detector materials?

Atmospheric abundance $(5—10)\times10^{-18}$ HTO/H_2O

Best fit $\Longrightarrow$ 60—120 ppb H_2O+H_2

Can neither confirm nor rule out tritium

All other significances reported both with and without tritium in BG mode

HTO

Light yield $\Longrightarrow$ O(1) ppb H_2O

HT

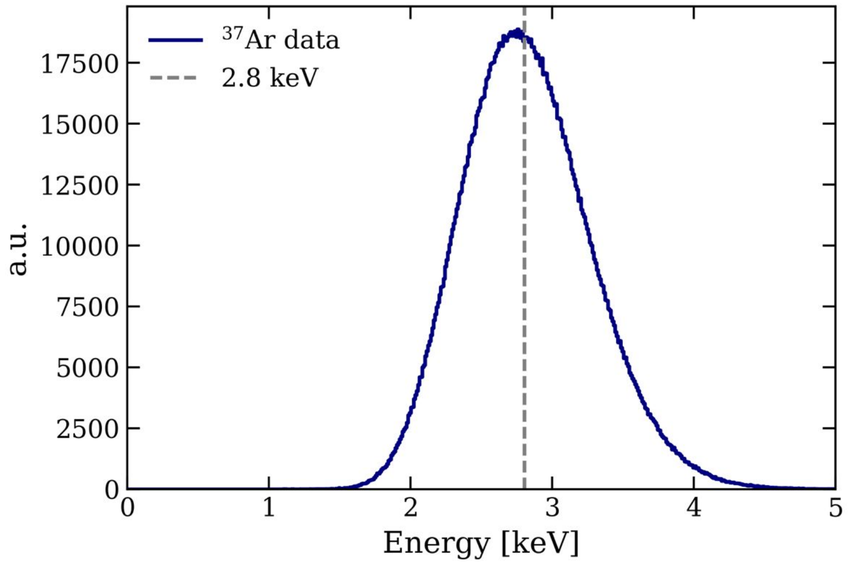
Electron lifetime (xenon purity) $\Longrightarrow$ < ppb O_2-equivalent impurities

Argon-37

2.8 keV energy released after EC

X-rays / Auger electrons

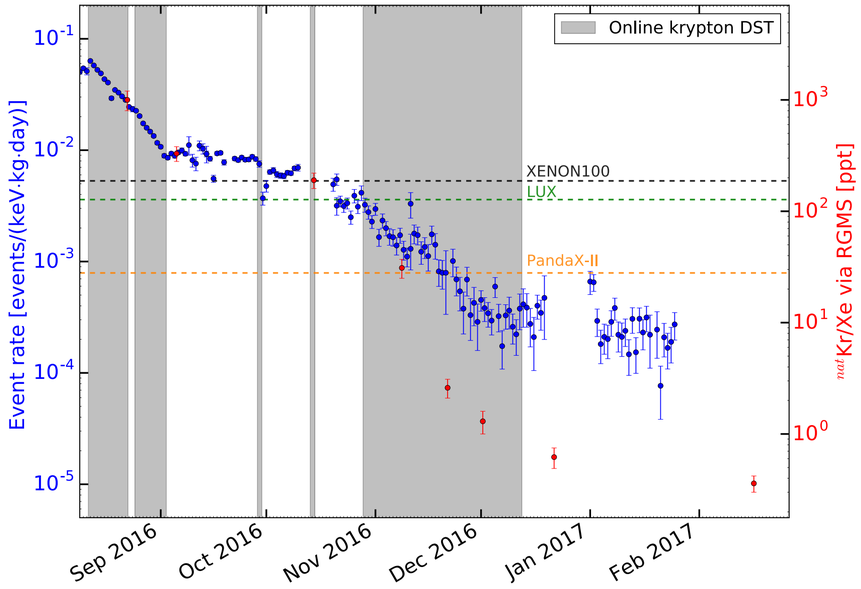
Tested as calibration source



Where from?

Always present? No, removed by distillation

Air leak? Would also introduce Kr



Ruled out

COULD IT BE NEW PHYSICS?

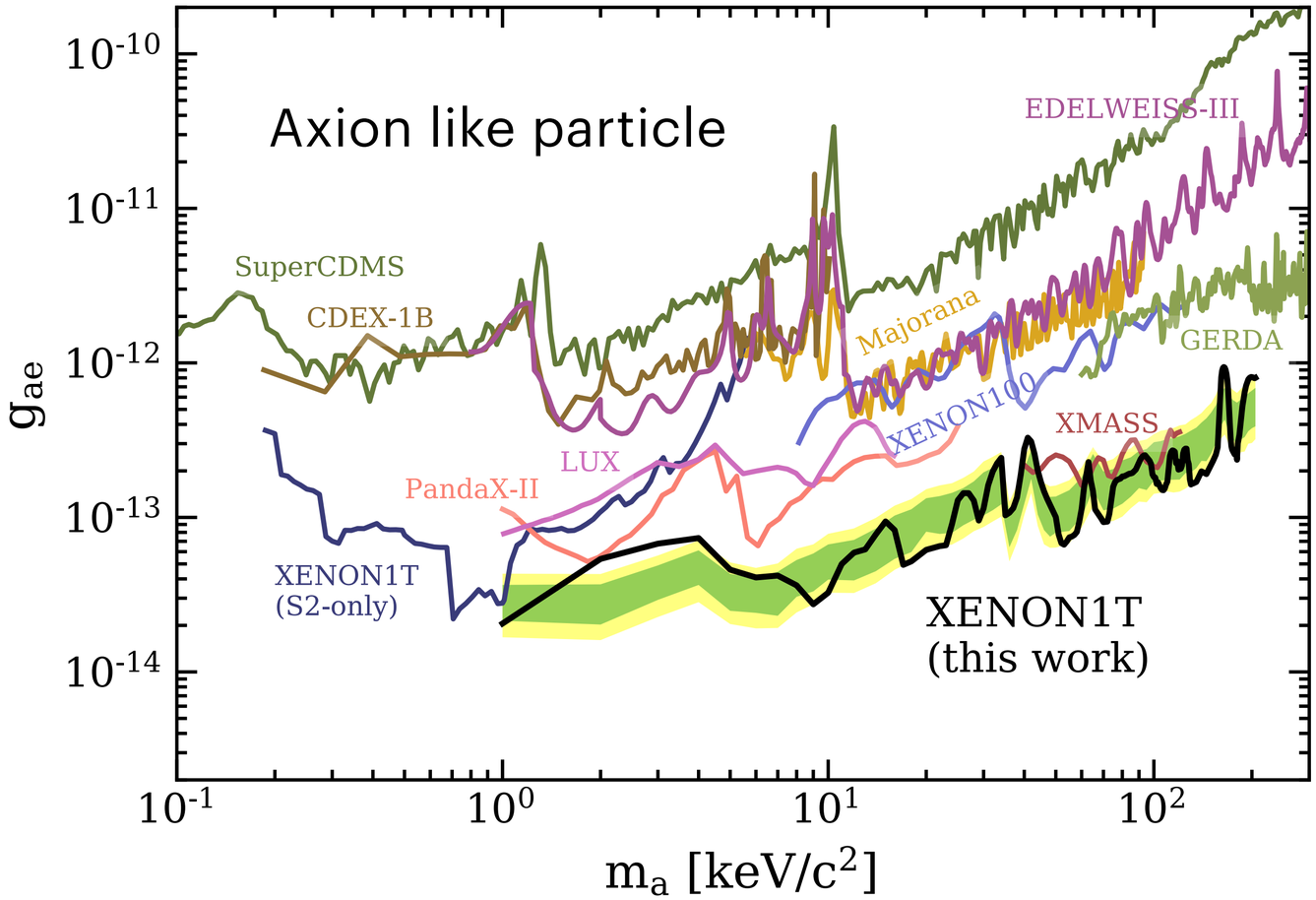
Bosonic dark matter

Search for a mono-energetic peak

Could be dark matter,
e.g. axion-like particle or dark photon

Most significant at 2.3 ± 0.2 keV

No > 3σ excess ⟹ only report limits



Mono-energetic peak: 3.0σ over background (global)

Neutrino magnetic moment

Mag. Moment: 3.2σ over background

with ^{3}H: 0.9σ over background + ^{3}H

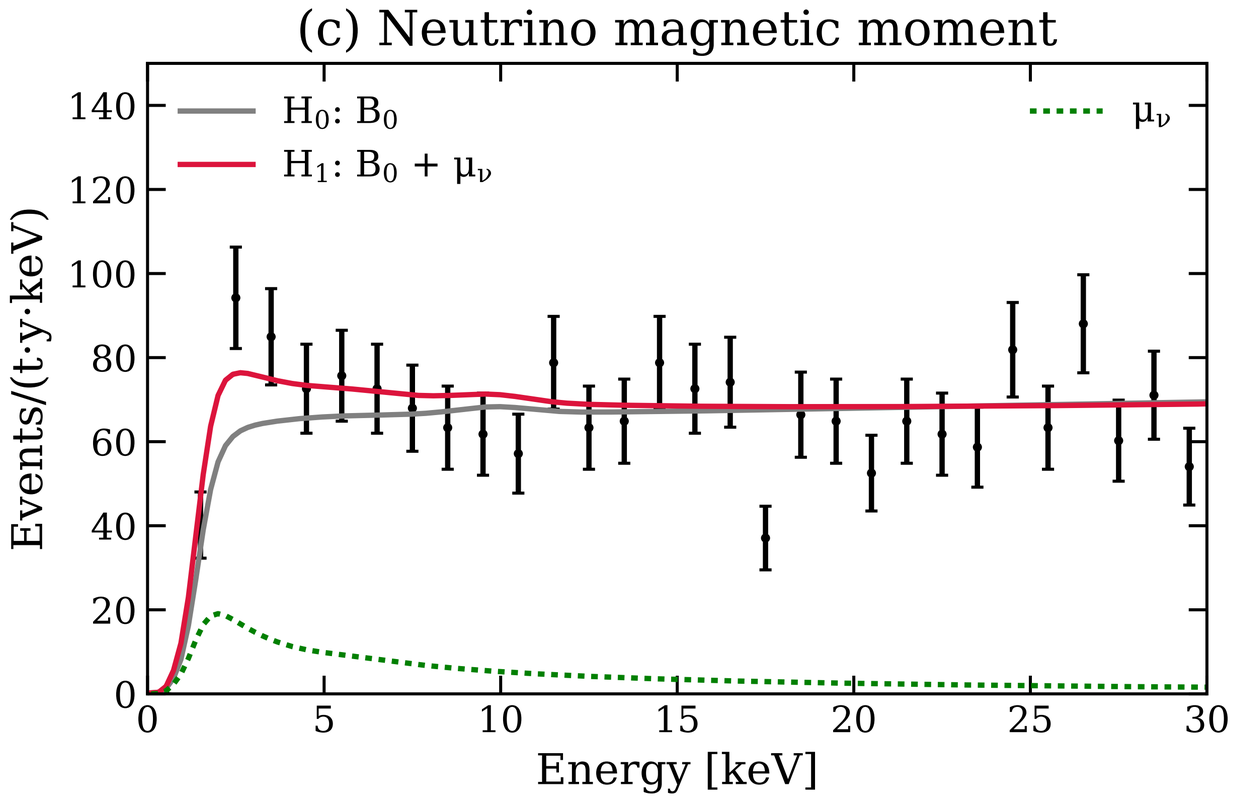
$\mu_\nu : (1.4 - 2.9) \times 10^{-11} \mu_B$

$\gtrsim 10^{-15} \mu_B \Longrightarrow$ Majorana neutrinos

Compatible with other experiments

In tension with astrophysical constraints

arXiv 1910.10568, 1907.00115



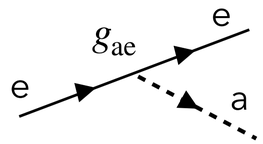
Solar axions

Production

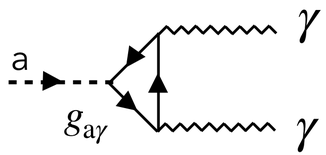
Solar physics

1. ABC

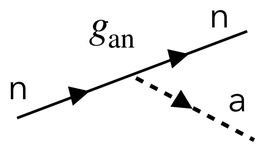
(atomic recombination and de-excitation, bremsstrahlung and Compton)



2. Primakoff

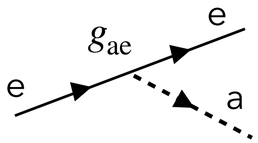


3. ^{57}Fe



Detection

Axioelectric effect

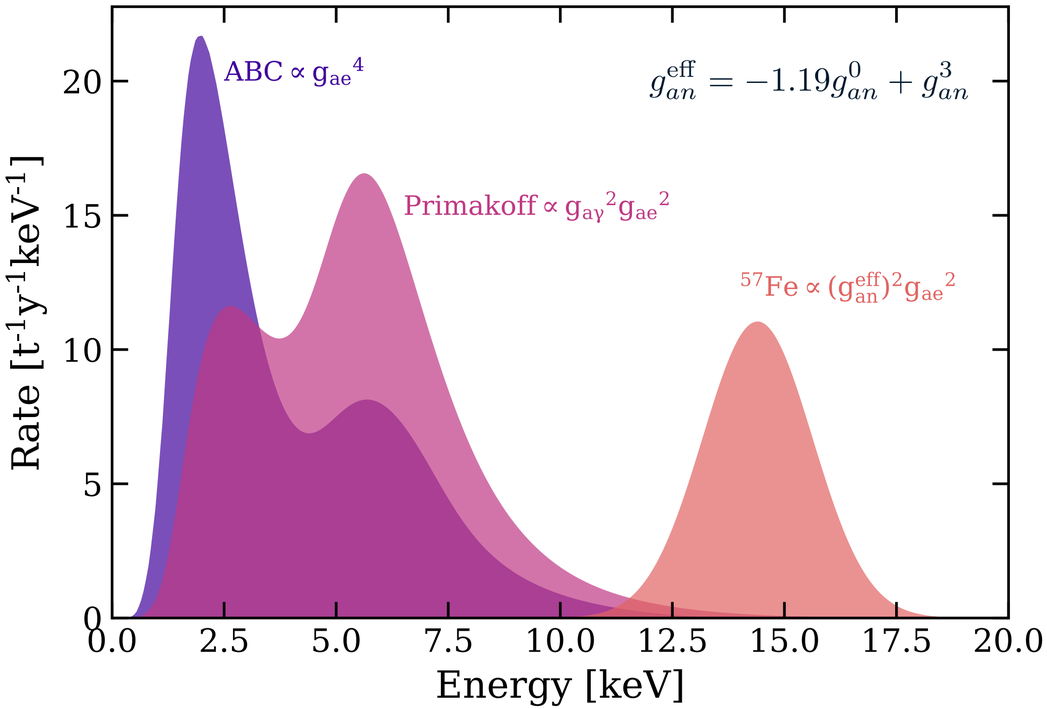


$$\sigma_{ae} = \sigma_{pe} \frac{g_{ae}^2}{\beta} \frac{3E_a^2}{16\pi\alpha m_e^2} \left(1 - \frac{\beta^{2/3}}{3}\right)$$

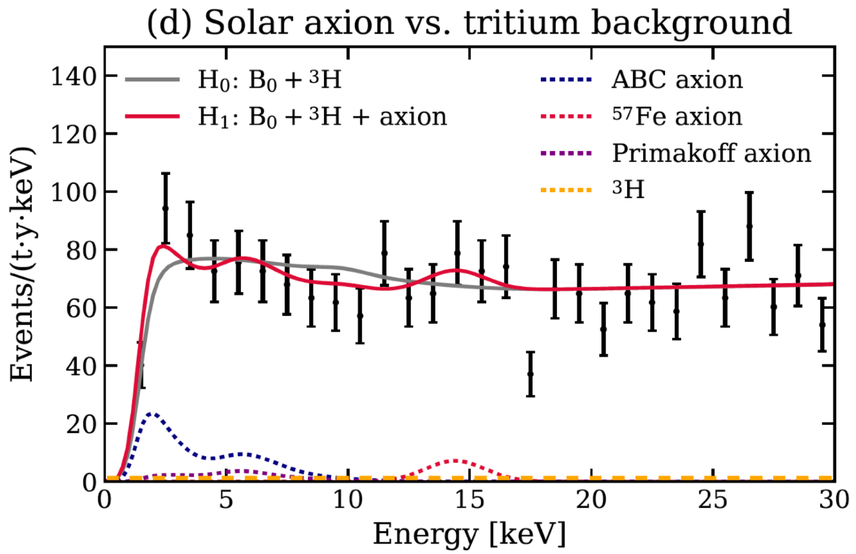
We ignore the inverse Primakoff effect

Reconstruction

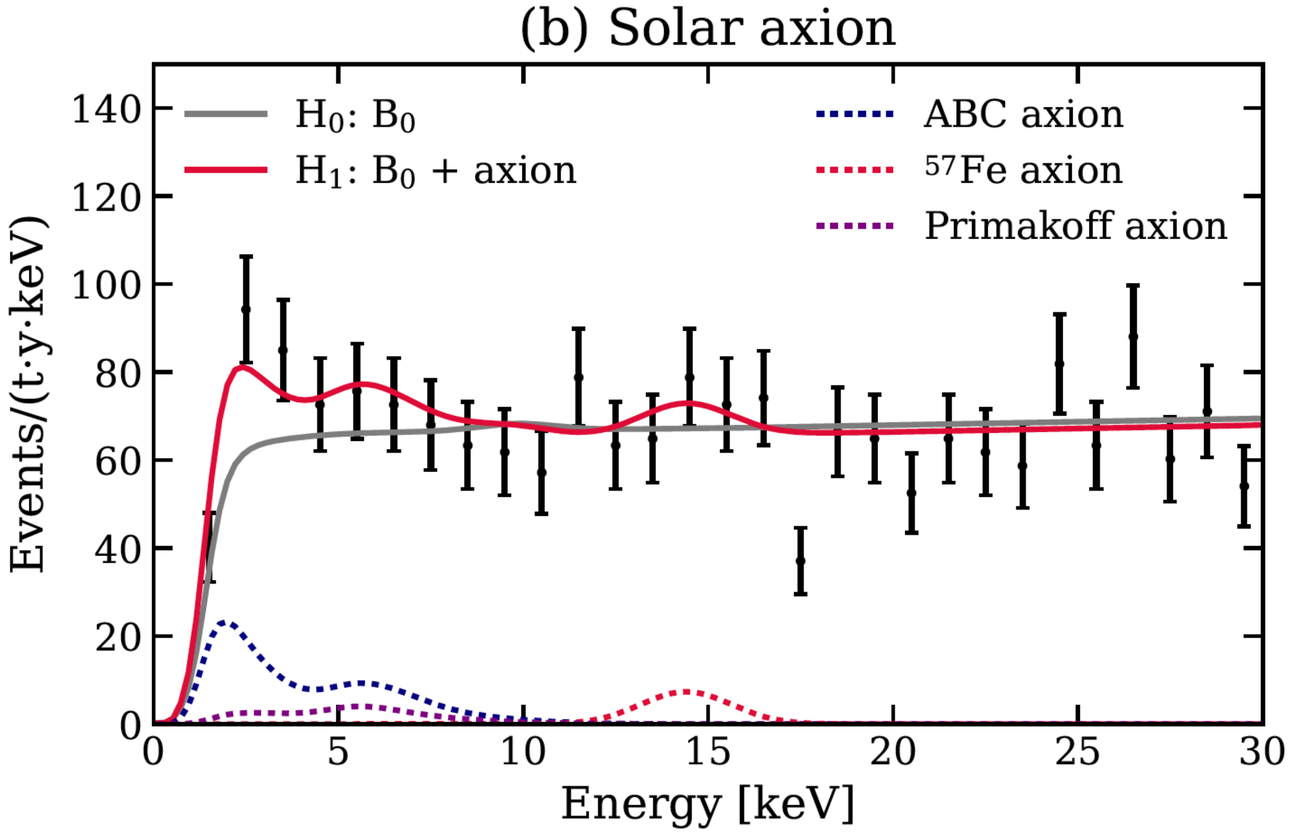
XENON1T resolution, efficiency



Solar axions



Solar axions only: 3.4σ over background
Axions + ^{3}H: 2.0σ over background + ^{3}H



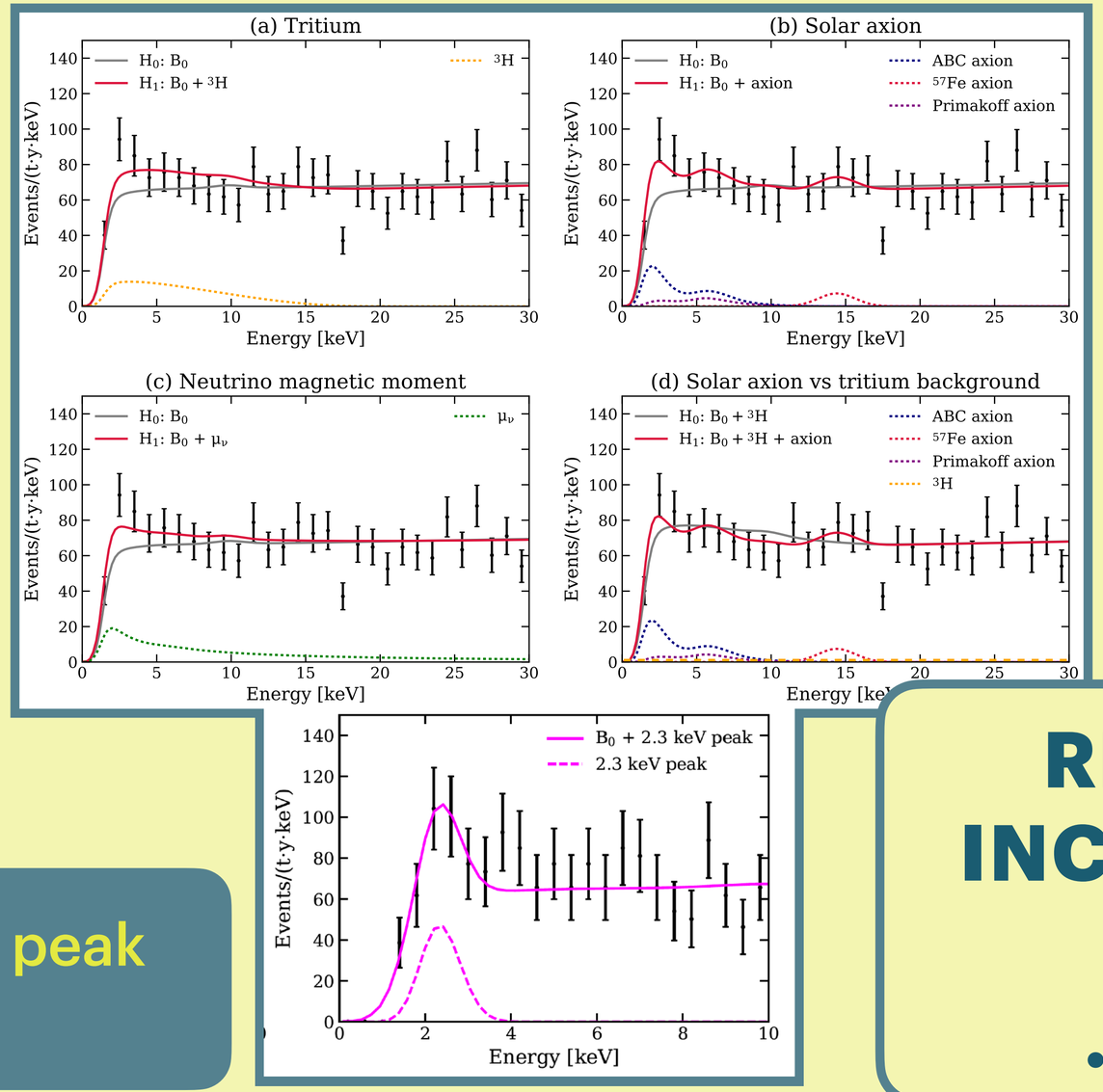
In tension with astrophysical constraints
e.g. from stellar cooling

(arXiv 1708.02111)

Tritium
3.2σ

μ_ν
3.2σ

Mono-energetic peak
3.0σ



Solar axions
3.4σ

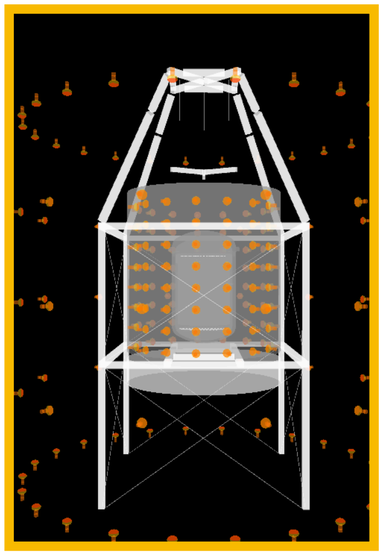
Axions + ${}^3H$
2.0σ

RESULTS ARE INCONCLUSIVE...

...FOR NOW

XENONnT

Some of what's new in XENONnT



Neutron veto

- Separated region of existing muon veto
- 120 additional PMTs
- Gd in the water tank
- 0.5 % $Gd_2(SO_4)_3$

⟹Lower BG

Larger TPC

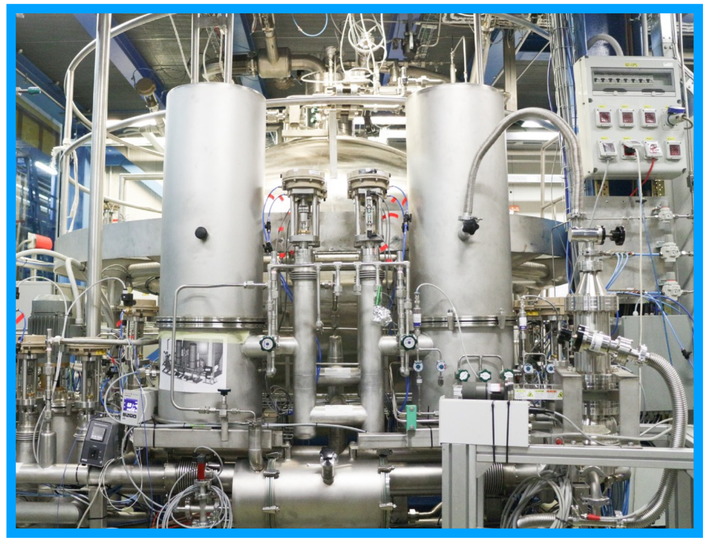
- Total 8.4 t LXe
- 5.9 t in TPC
- ~ 4 t fiducial
- 248 → 494 PMTs

⟹Higher exposure **and** lower BG

^{222}Rn distillation

- Reduce Rn (^{214}Pb) from pipes, cables, cryogenic system
- New

⟹Lower BG

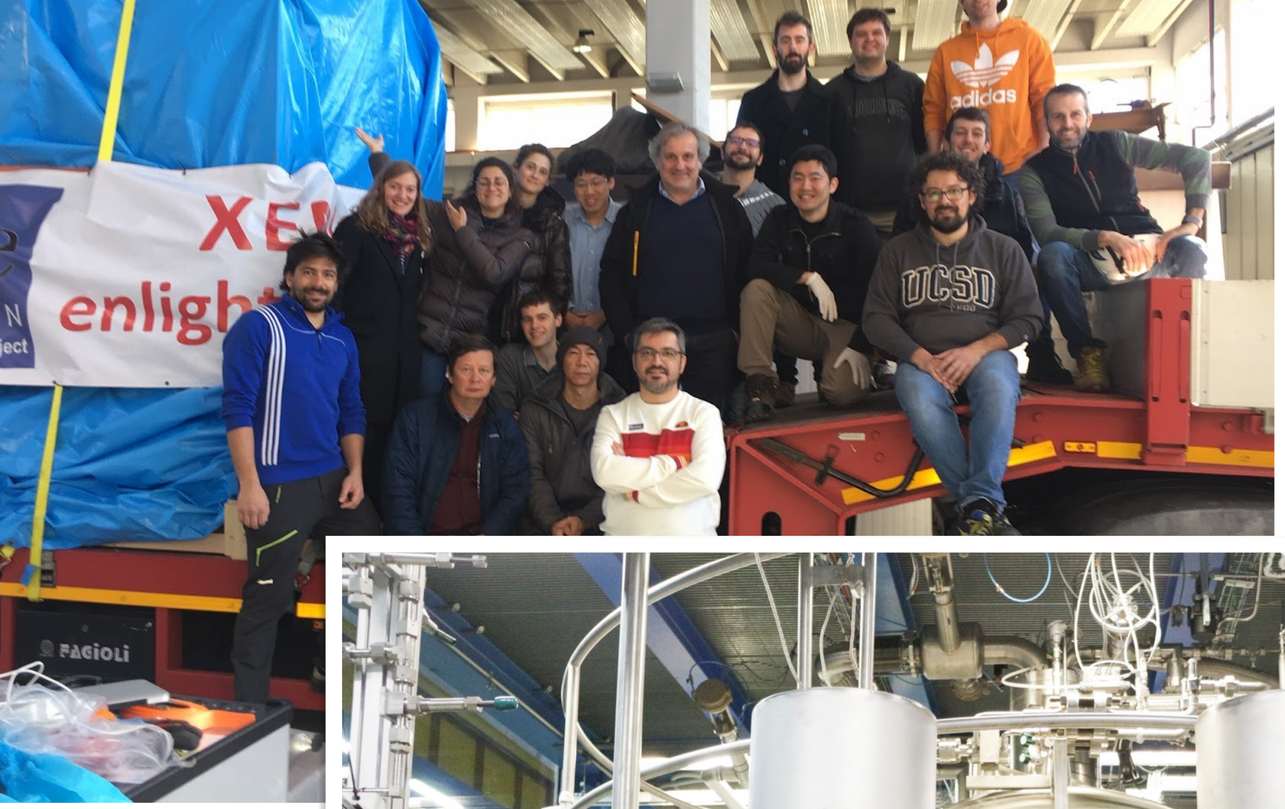


Liquid Xe purification

- Faster xenon cleaning
- 5 L/min LXe (2500 slpm)
- XENON1T ~ 100 slpm

⟹Better resolution

Lower thresholds


adidas
UCSD
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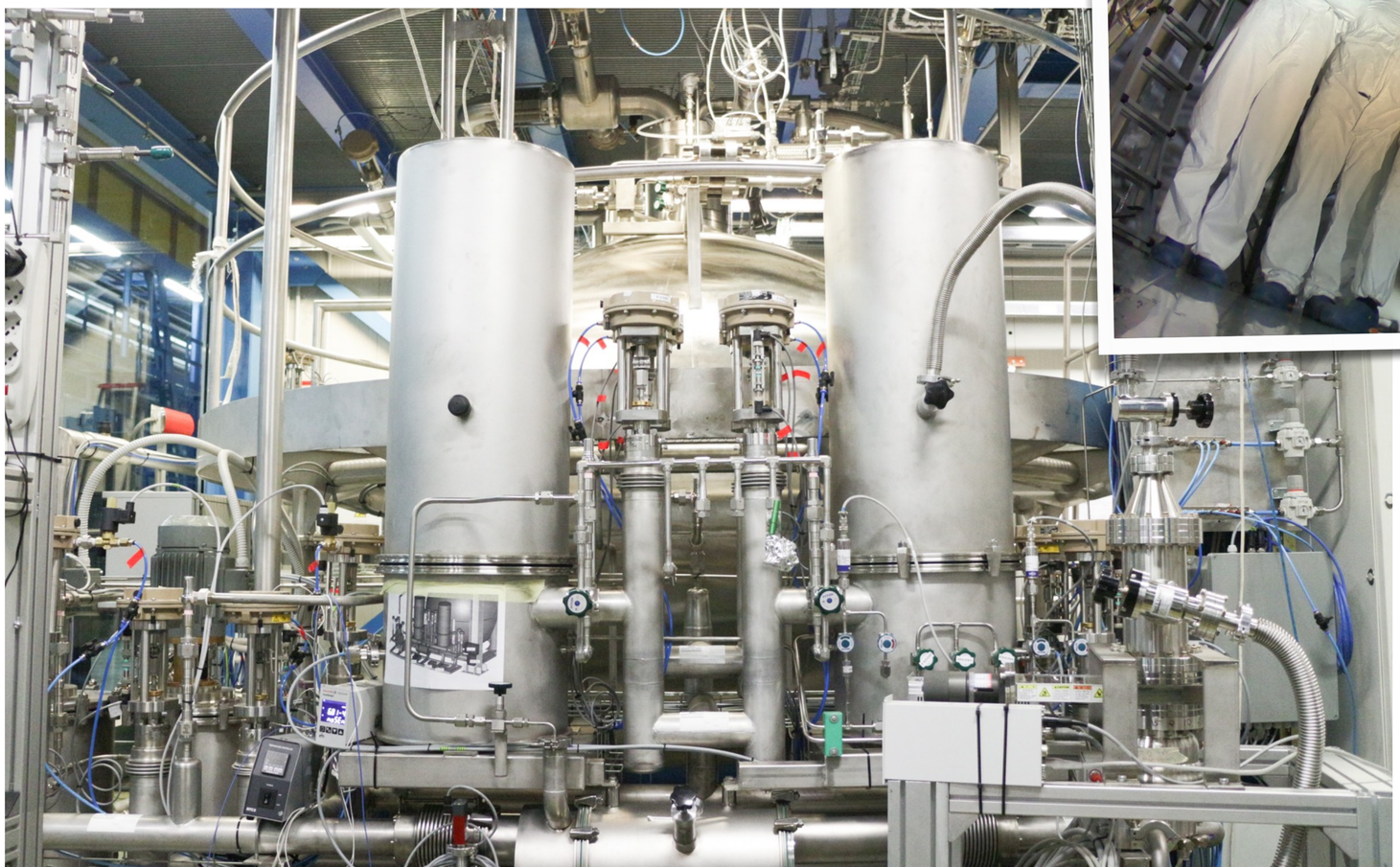
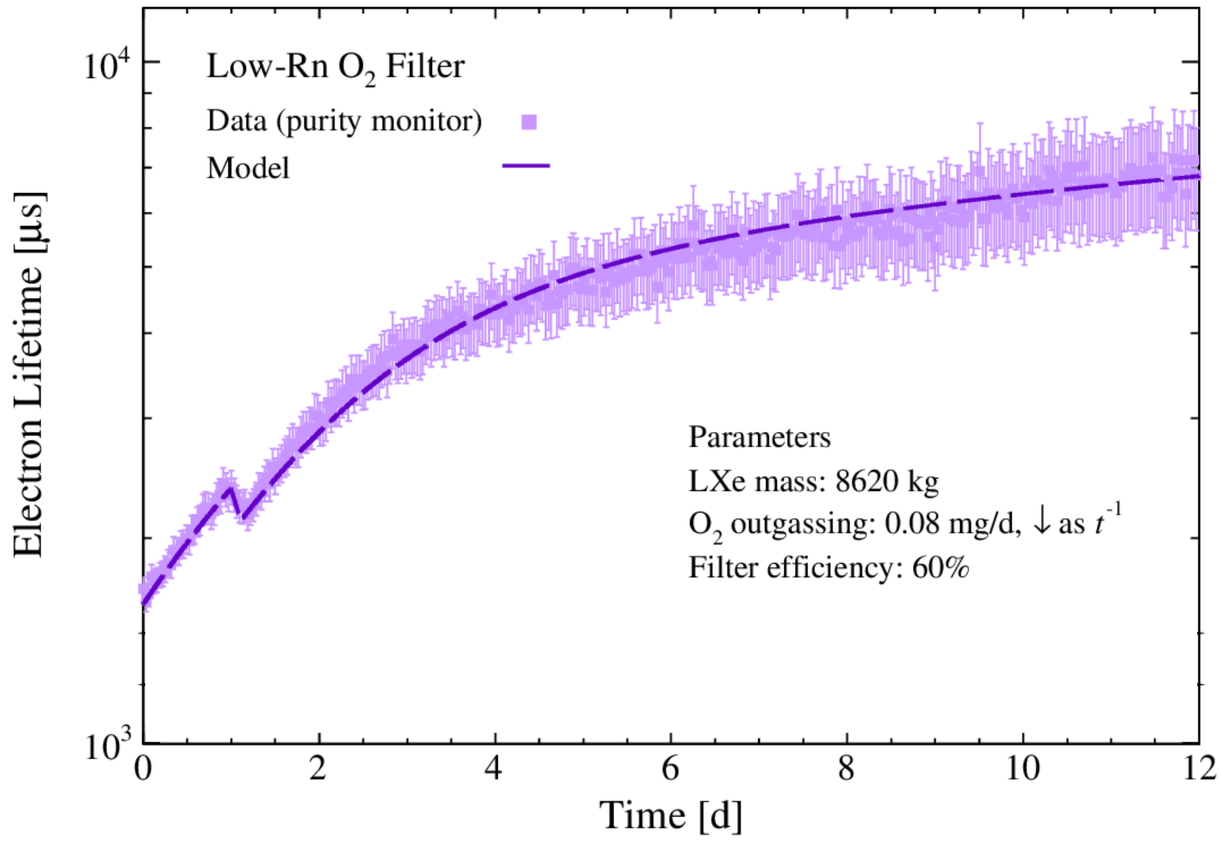
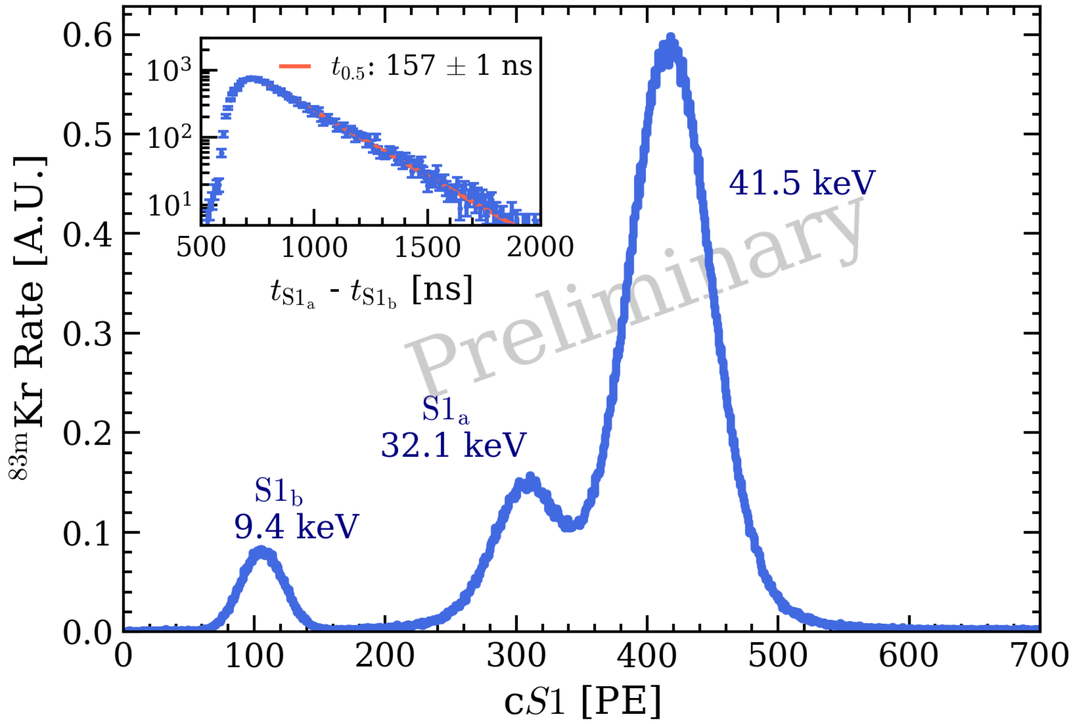


XENOnT — watch this space



Excellent xenon purity achieved

XENONnT now being commissioned



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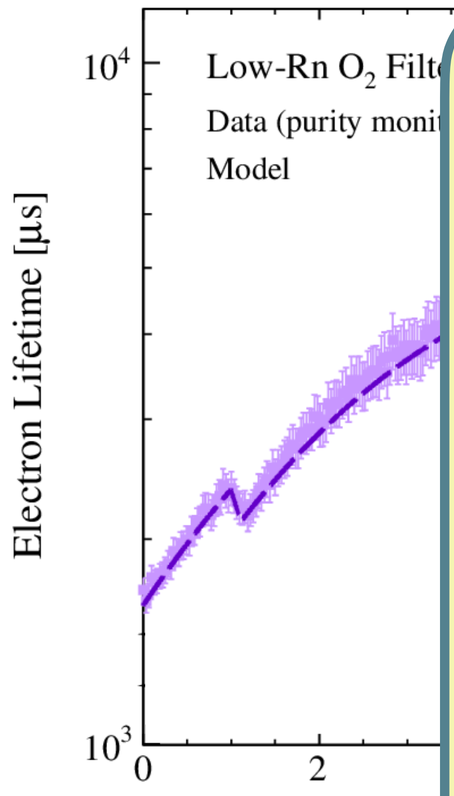
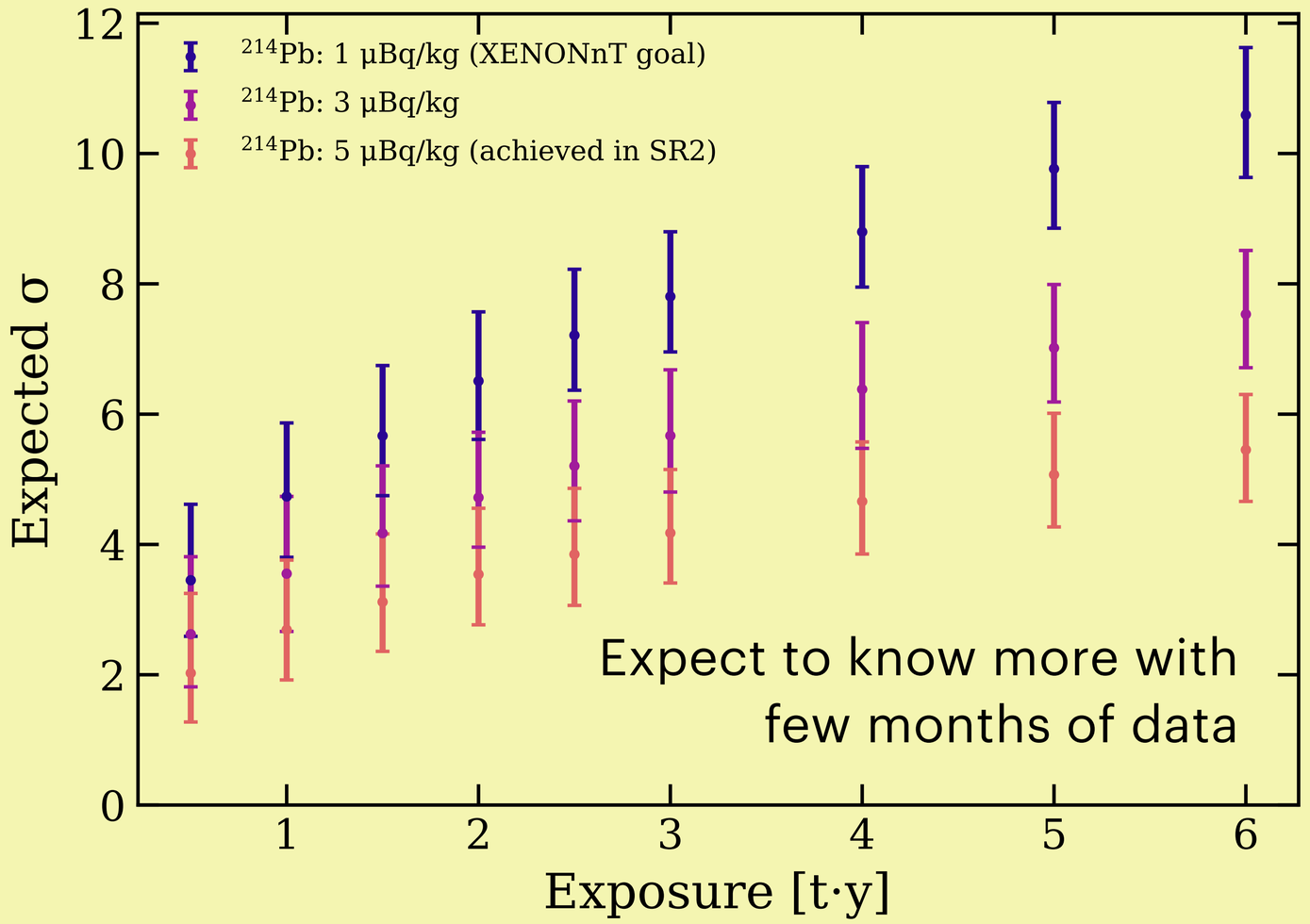


Excellent xen



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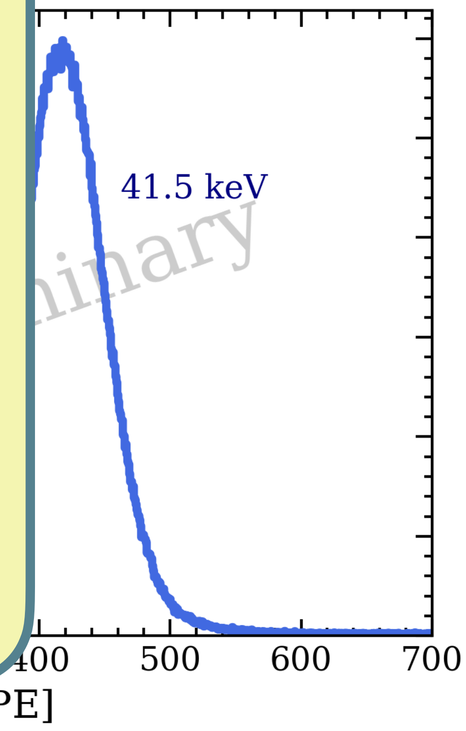

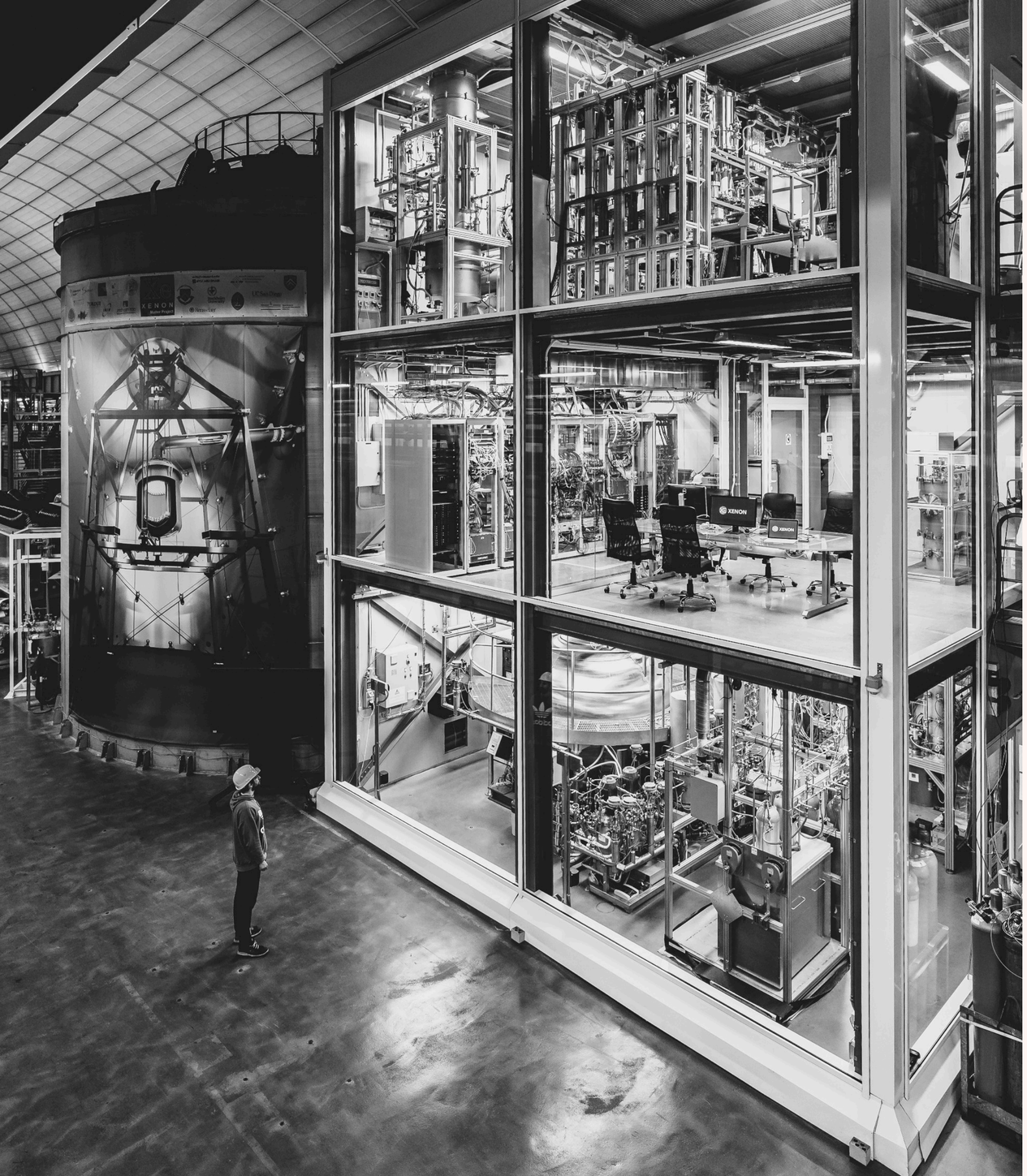

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