Update from the

XENON dark matter project

OBSERVATION OF EXCESS ELECTRONIC-RECOIL EVENTS IN XENON1T

arXiv:2006.09721

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On behalf of:
XENON Collaboration and X. Mougeot

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UPPSALA UNIVERSITY
10th September 2020

XENON
Dark Matter Project

XENON Technical Meeting, May 12-14, 2020

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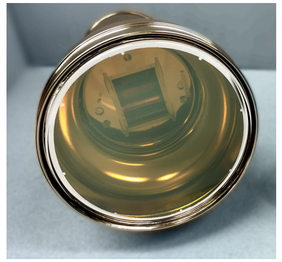
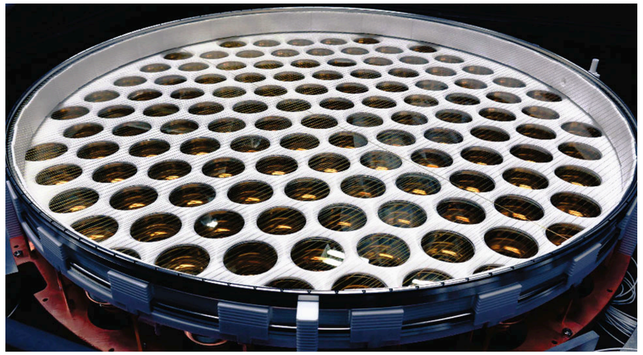
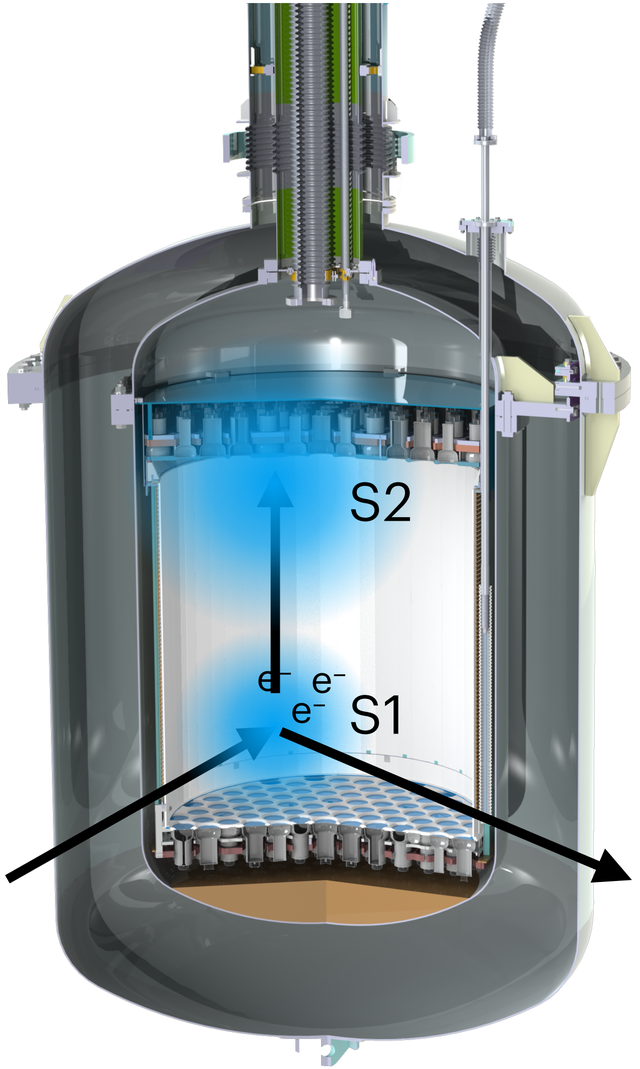
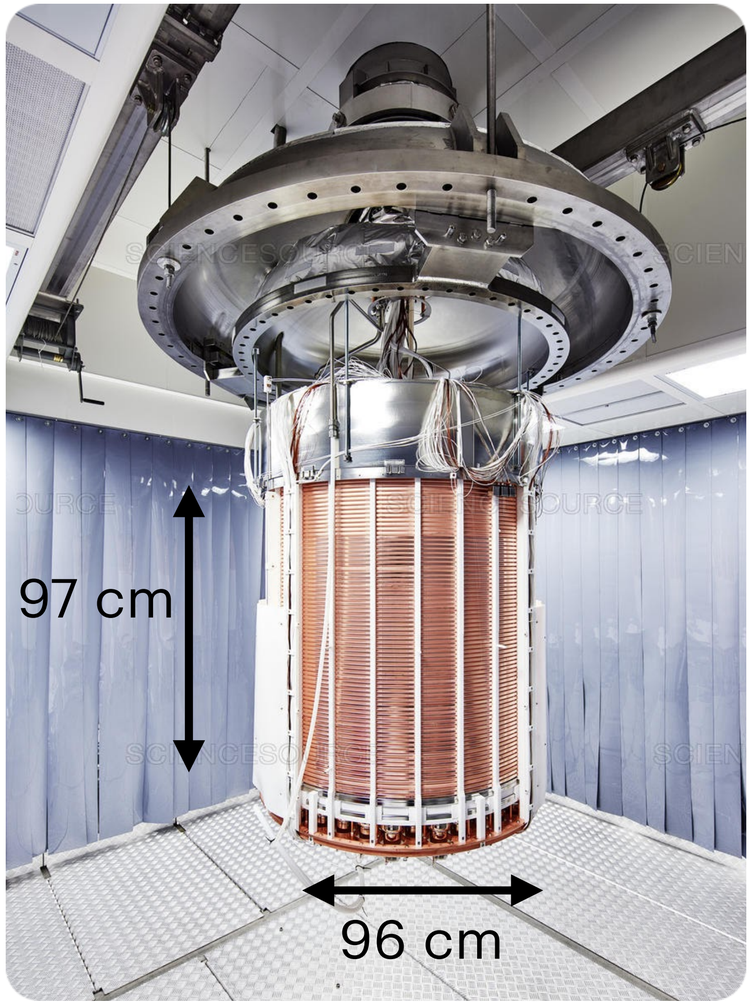
The TPC

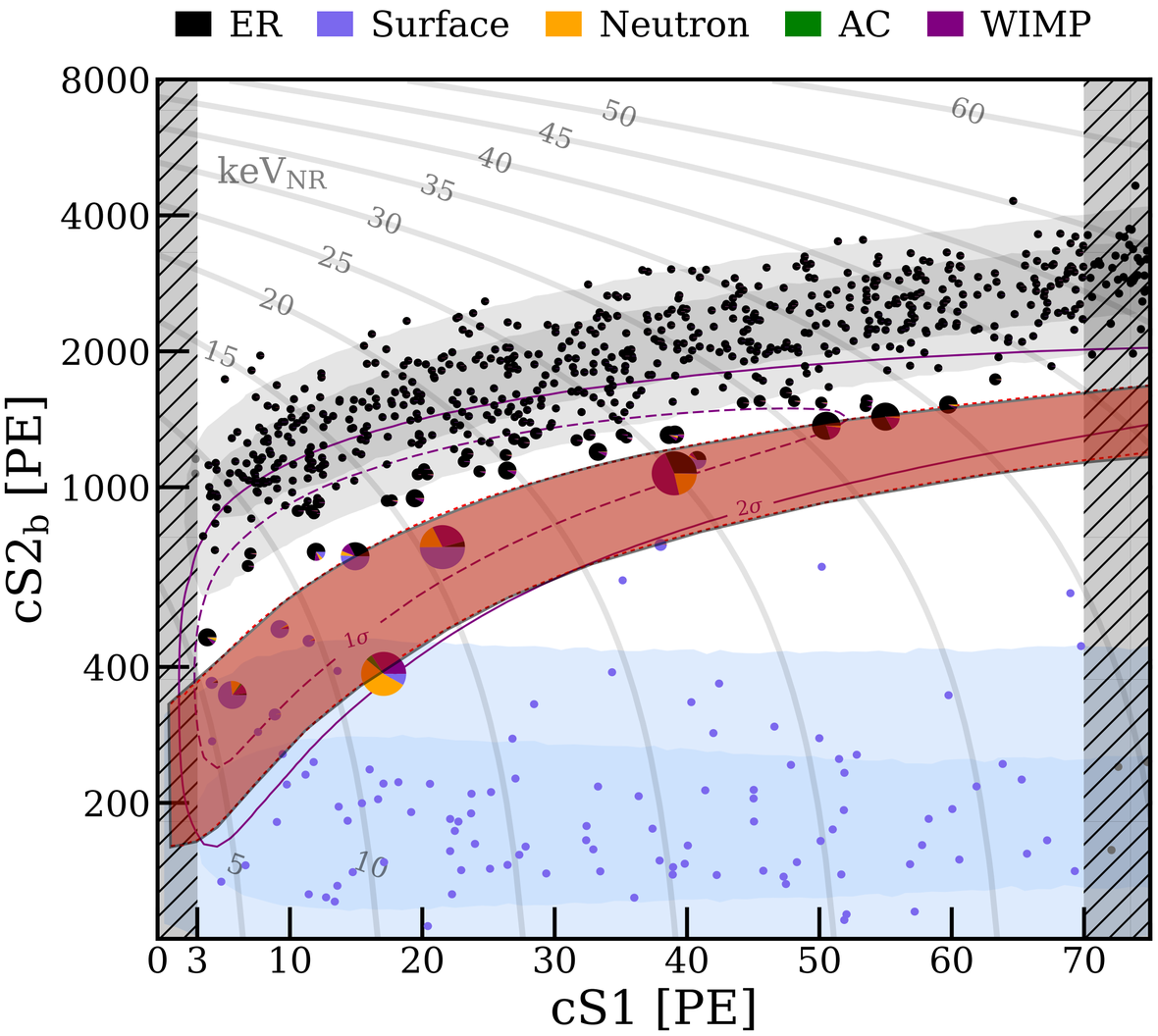


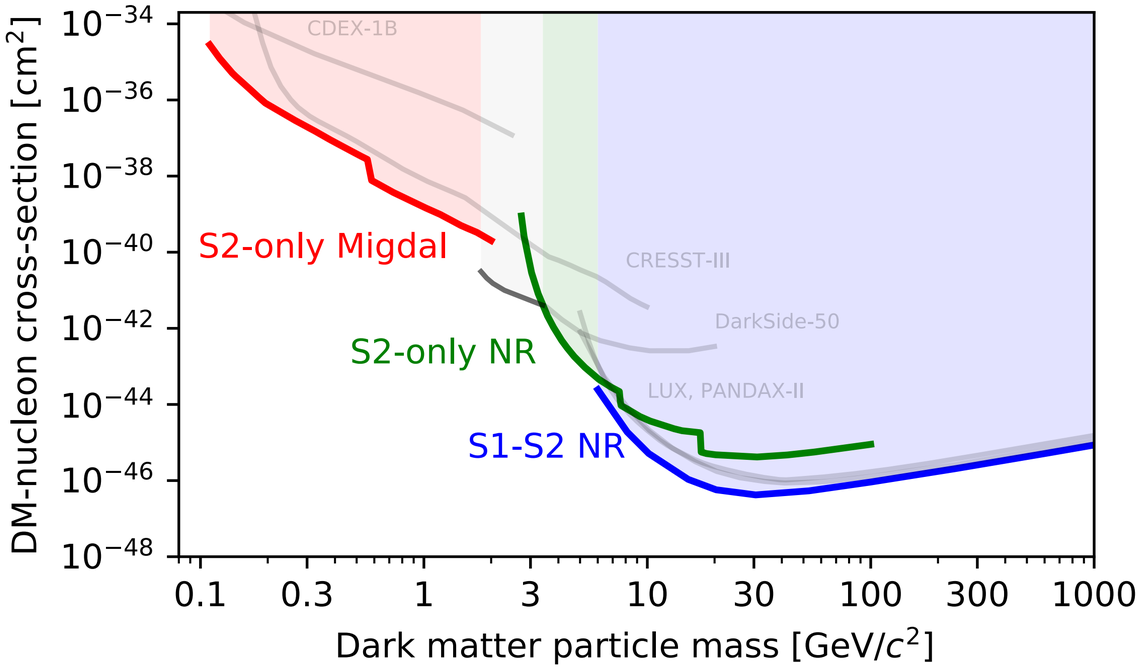






Nuclear recoil searches



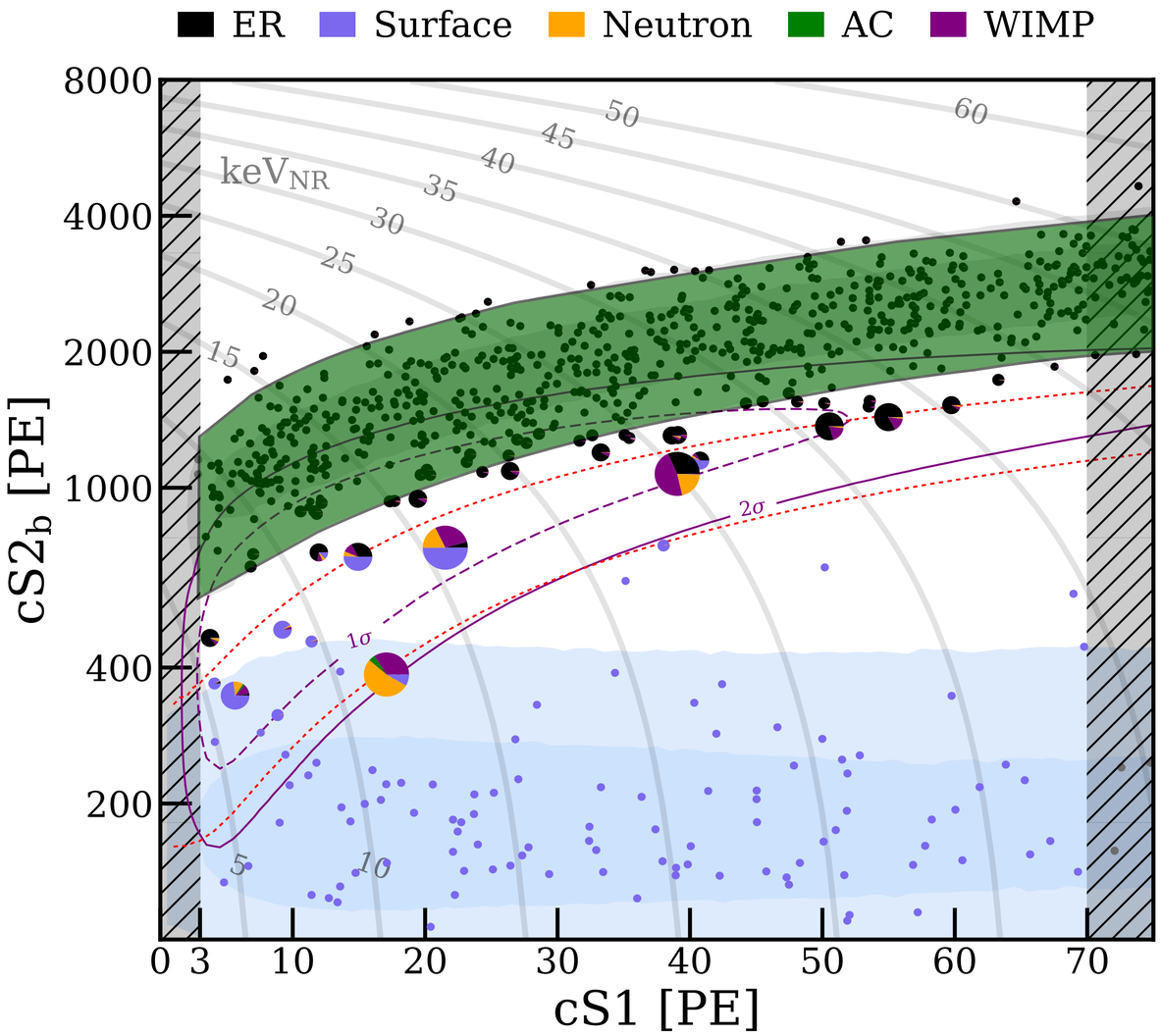


PRL 123, 241803 (2019) — S2-only Migdal

PRL 123, 251801 (2019) — S2-only NR

PRL 121, 111302 (2018) — S1 and S2 search

What about the electronic recoils?

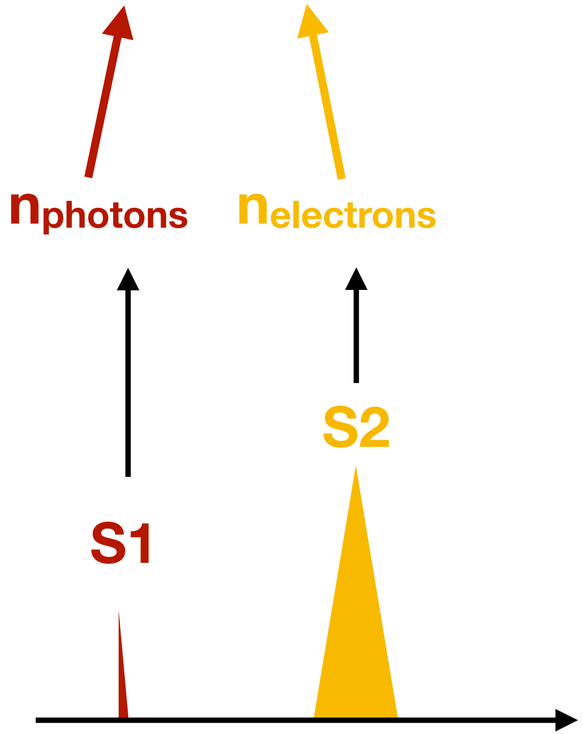


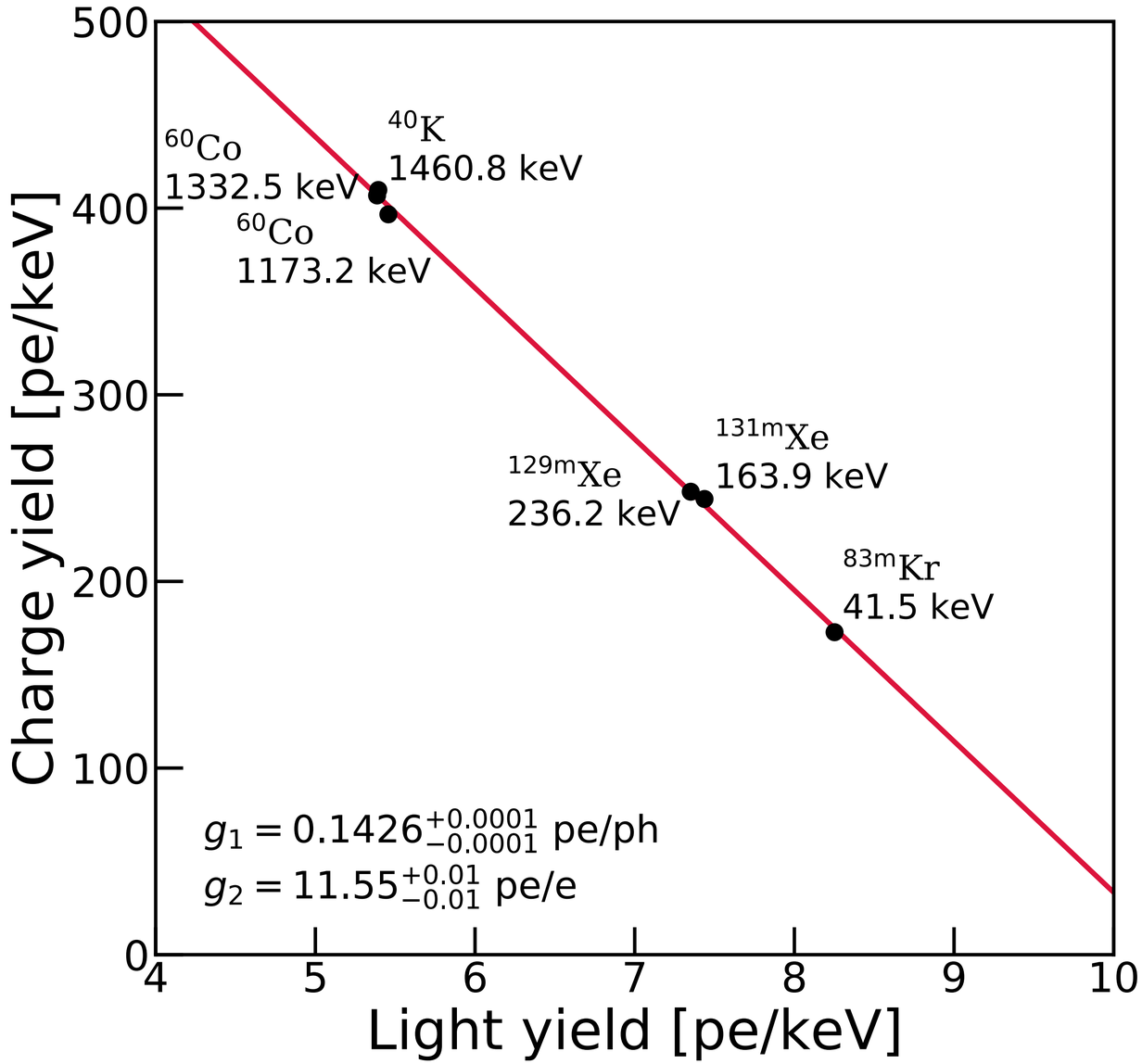
This talk

Search for excess above known BGs

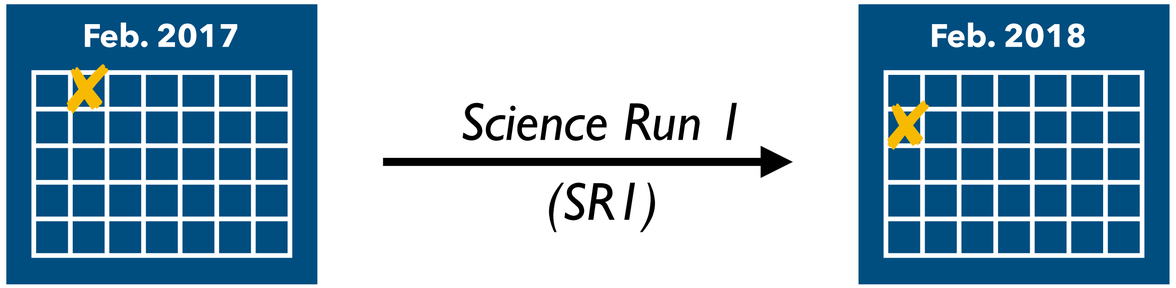
Energy reconstruction

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





The low energy excess



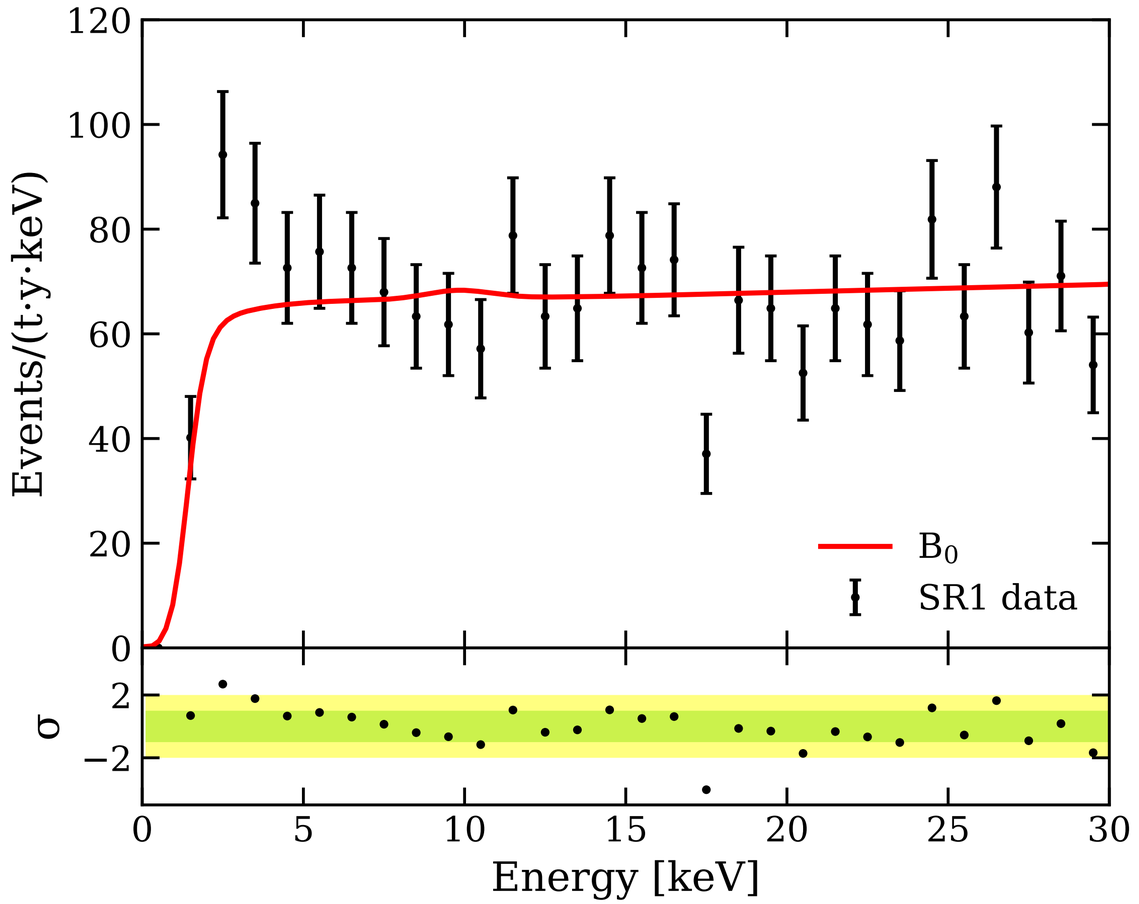
226.9 live days

1 tonne fiducial volume

[1, 210] keV energy range

Consider efficiencies of reconstruction and data quality cuts

Threshold at 10% detection efficiency



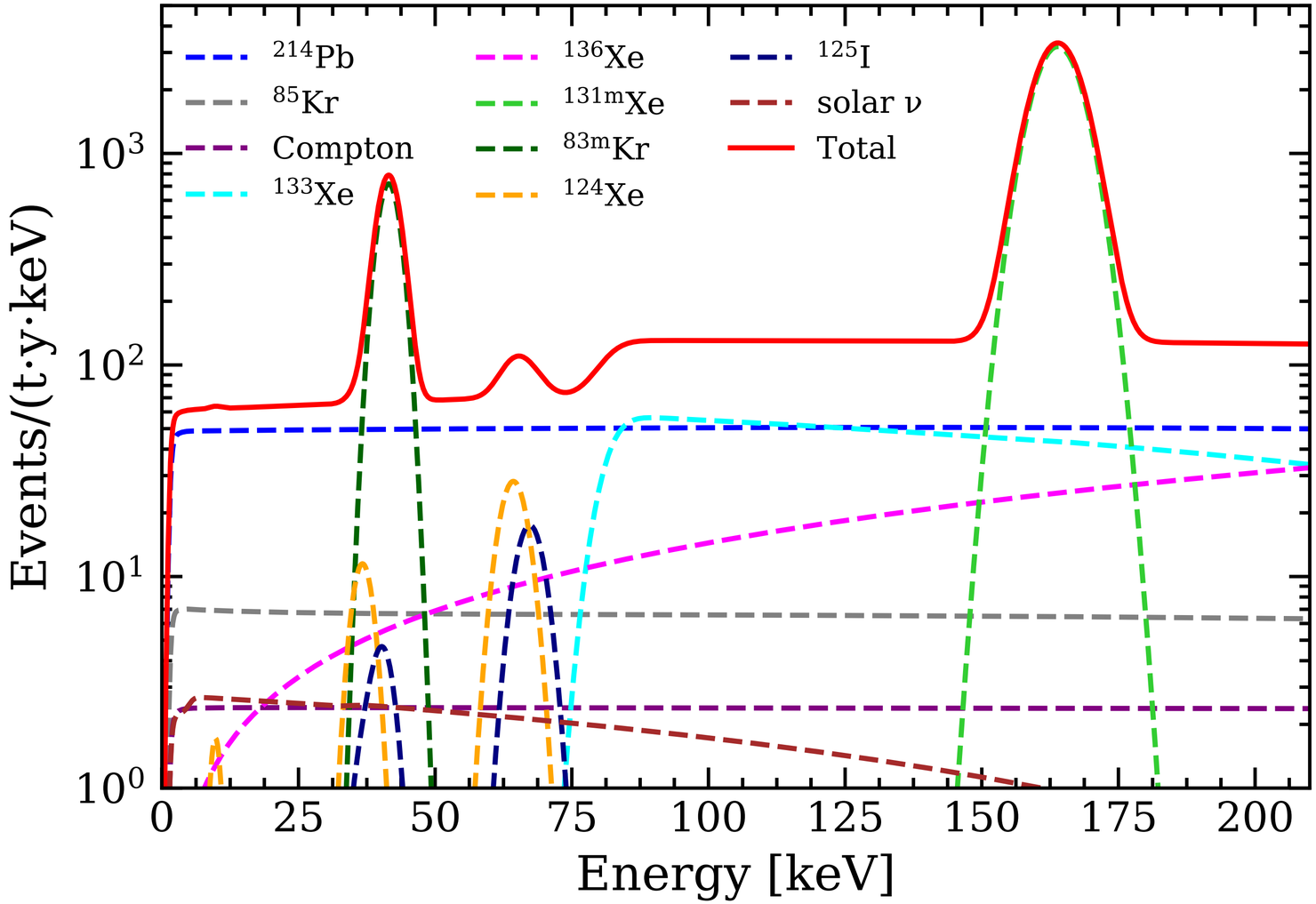
BACKGROUND MODELLING

Backgrounds

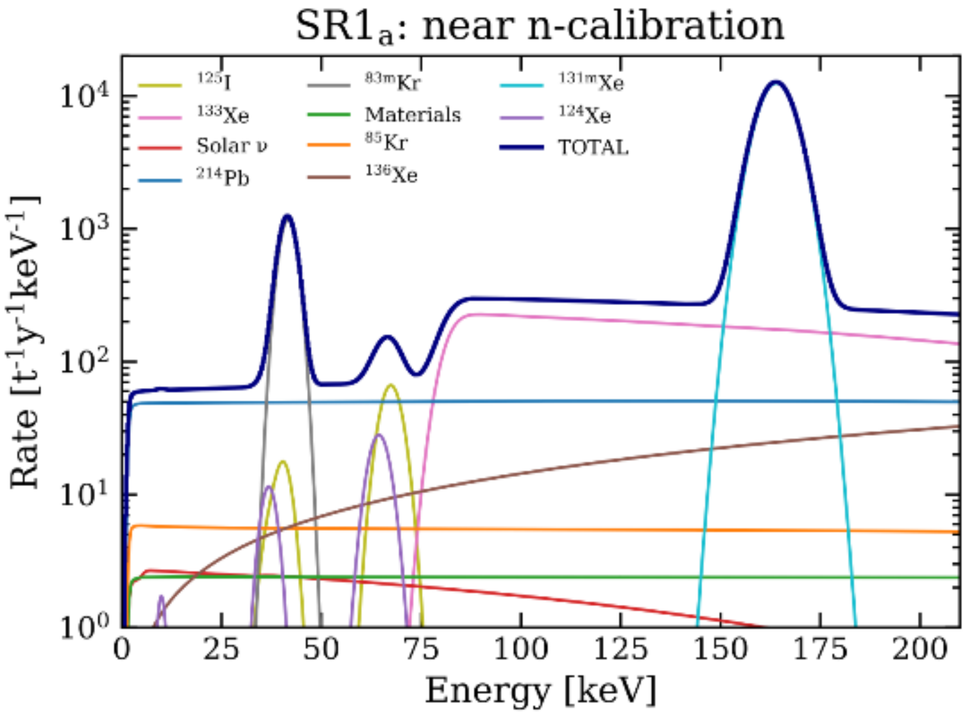
Background sources modelled with Geant4

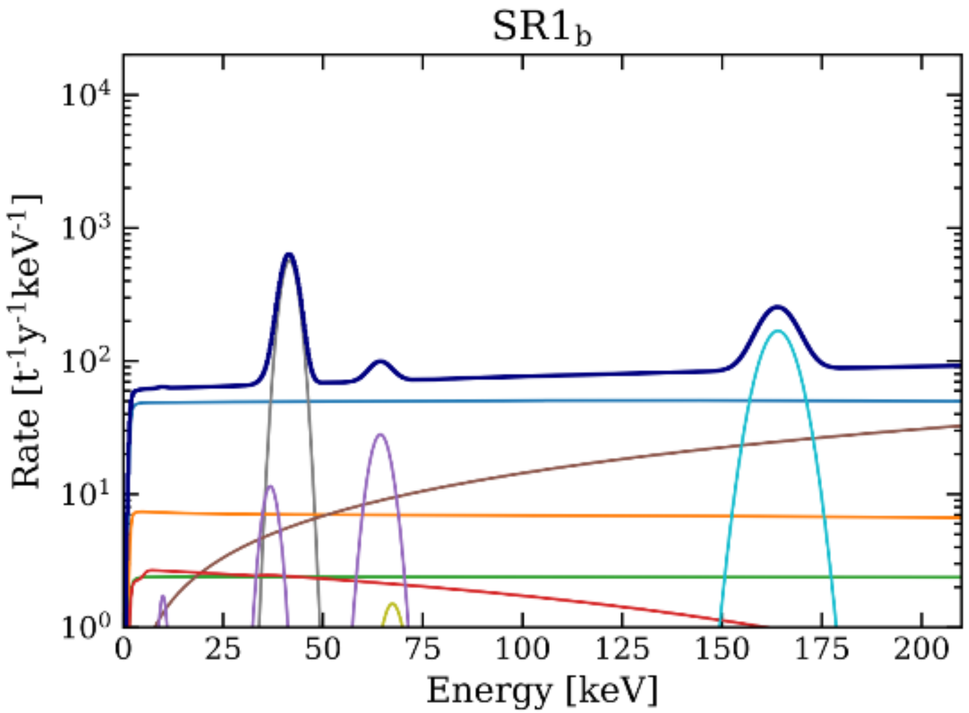
Most rates constrained by other measurements or time dependence

Search for excess over known backgrounds between 1 and 210 keV



Backgrounds





Dataset split in 2

Different rates of activated lines

IS THE EXCESS REAL?

Efficiency and energy reconstruction

Mistake in energy reconstruction?

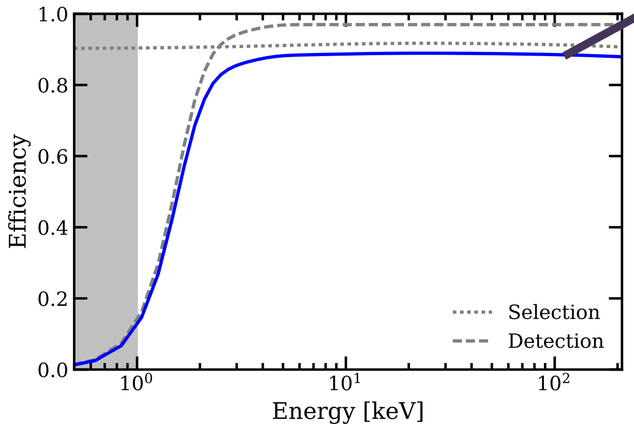
Mis-modelled efficiency?

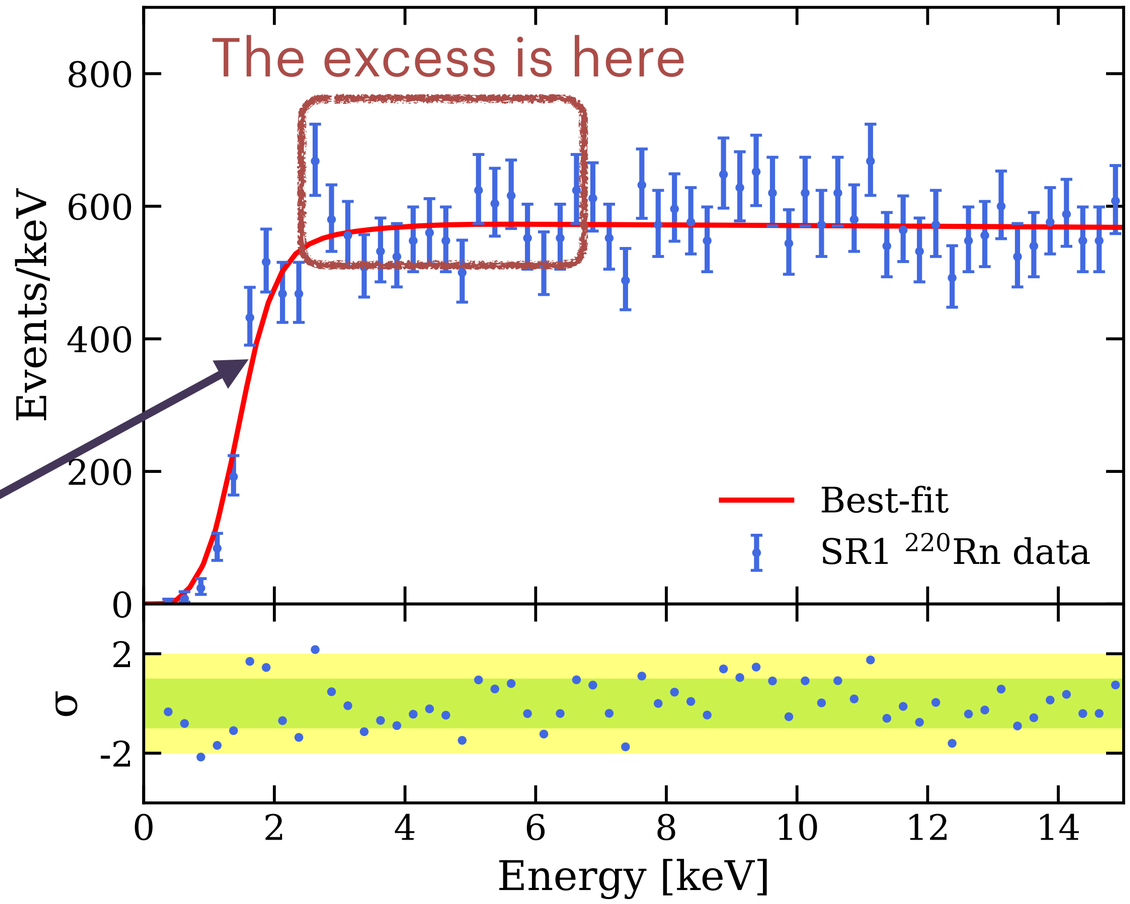
Look at Rn-220 calibration data

Beta-decay just like dominant background

p-value 0.58

Cannot explain the excess





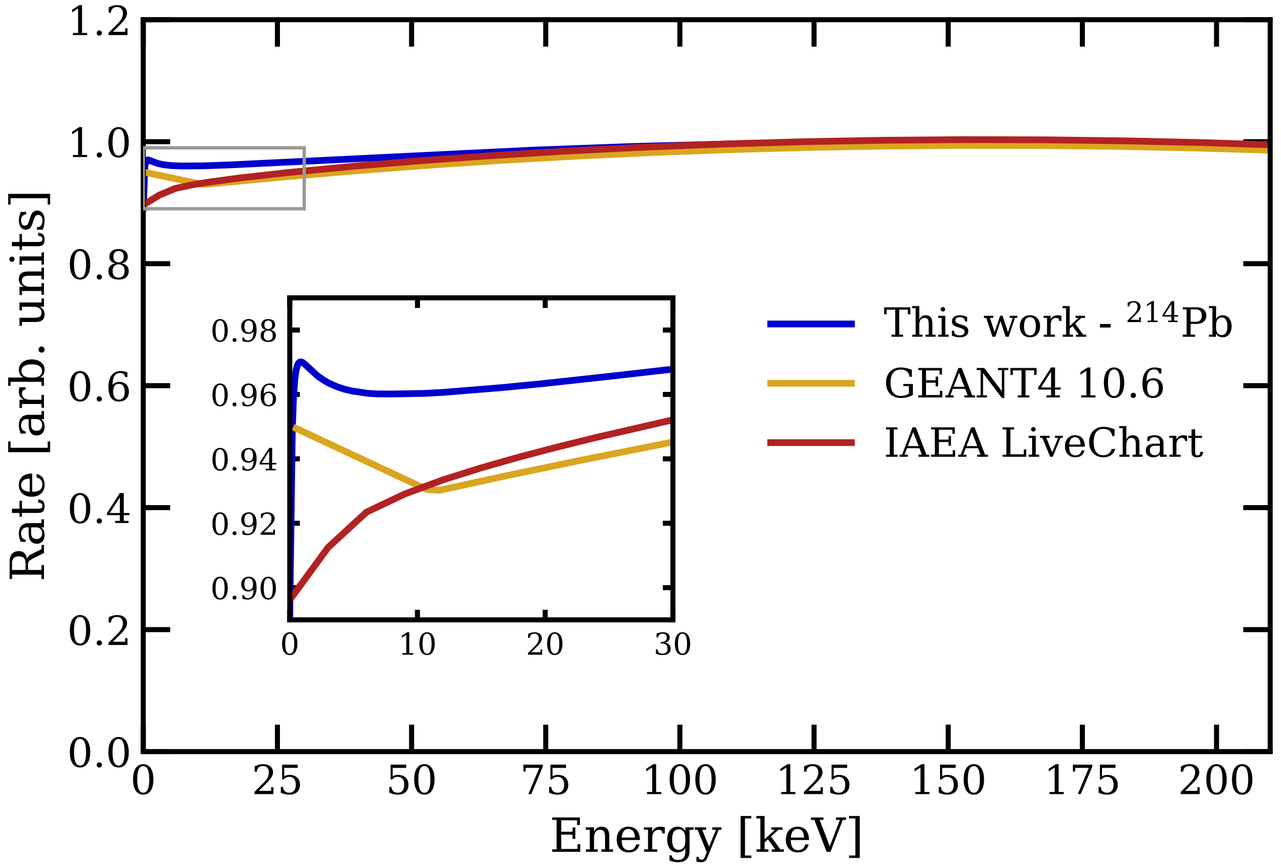
Shape of background spectrum

The Pb-214 spectrum has an enhancement at low energy

Atomic effects **do** lead to rate enhancement

Not properly considered in GEANT4

Teamed up with X. Mougeot (CEA) to calculate the correct spectrum



Uncertainty of 6% at low energy too small (need 50% increase)

Statistical fluctuations

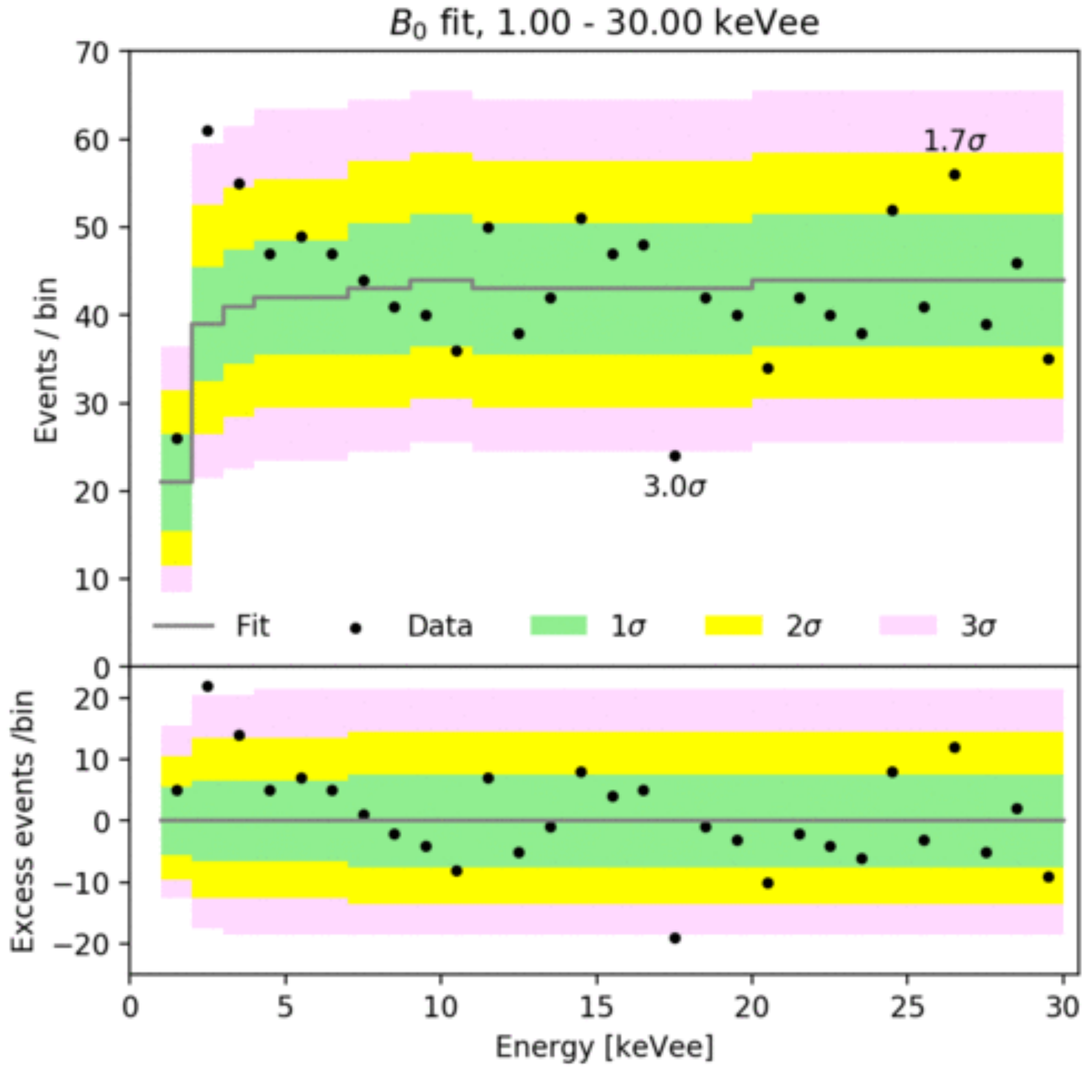
Could it be a statistical fluke?

What's with the dip at 17 keV?

Single bin too thin compared to resolution

Goes away when rebinning

We do unbinned analysis



POSSIBLE EXPLANATIONS

IT COULD BE A NEW BACKGROUND

Tritium

3.2σ over background

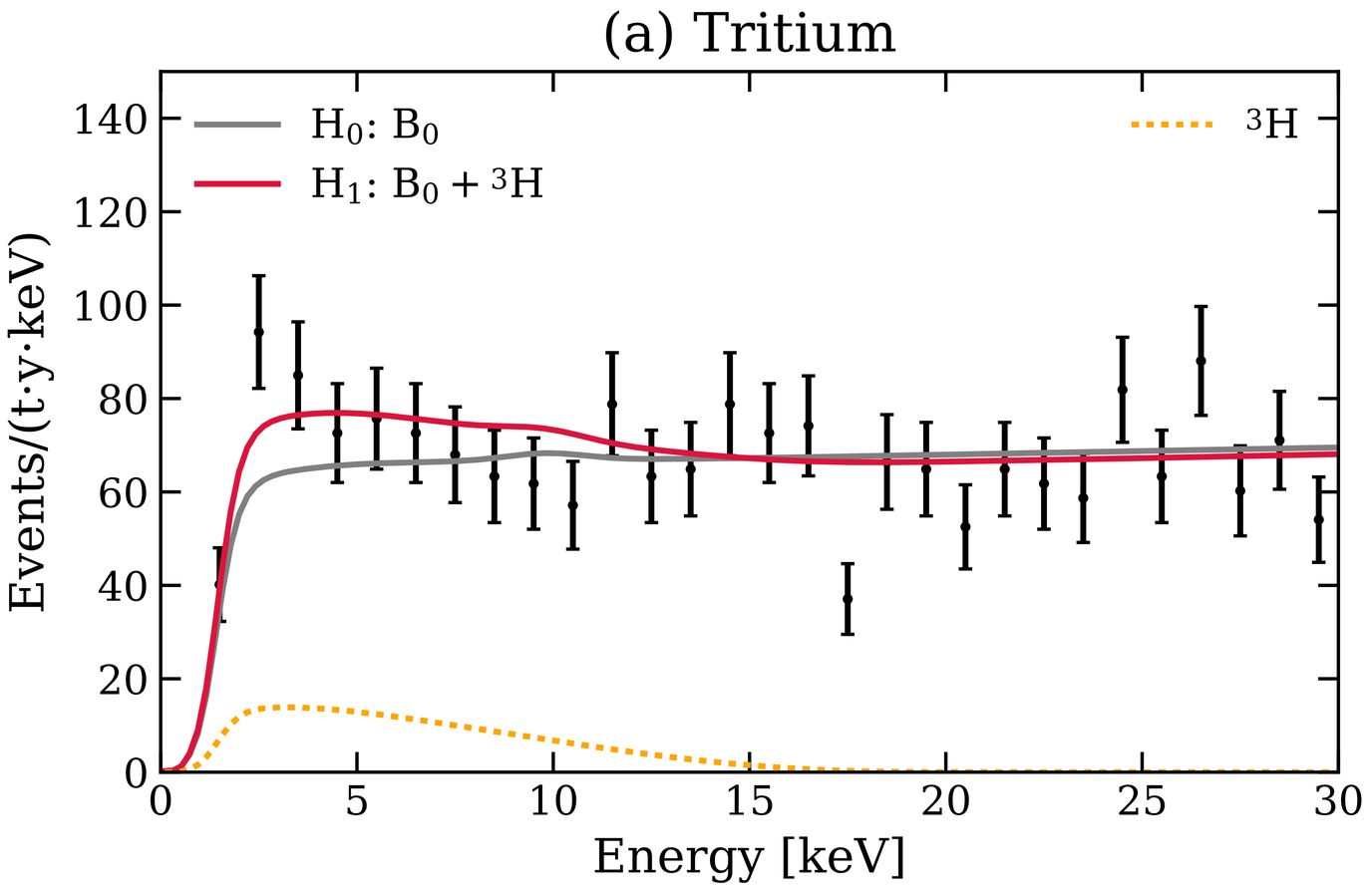
(159 ± 51) ev/keV/t/yr

< 3 atoms ^{3}H / kg Xe

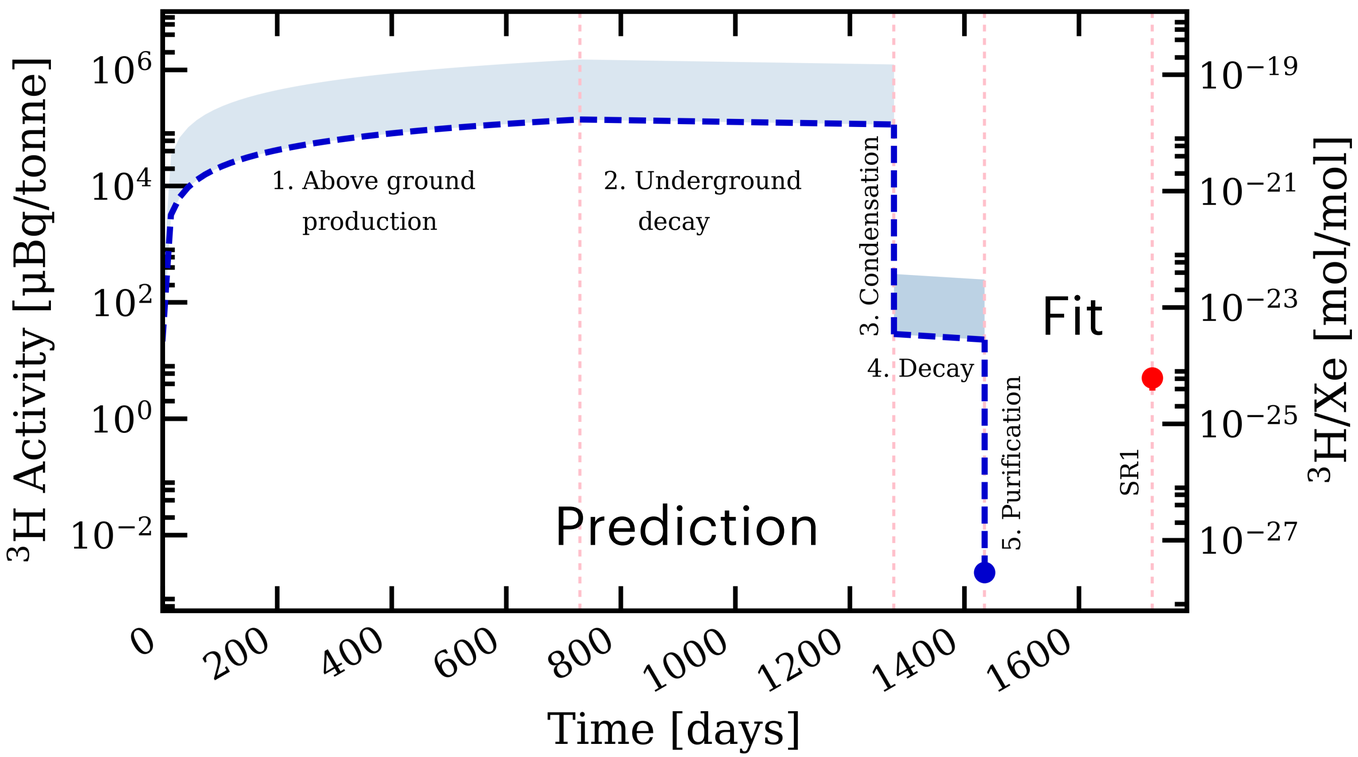
Beta decay

Q value 18.6 keV

Half life 12.3 years



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

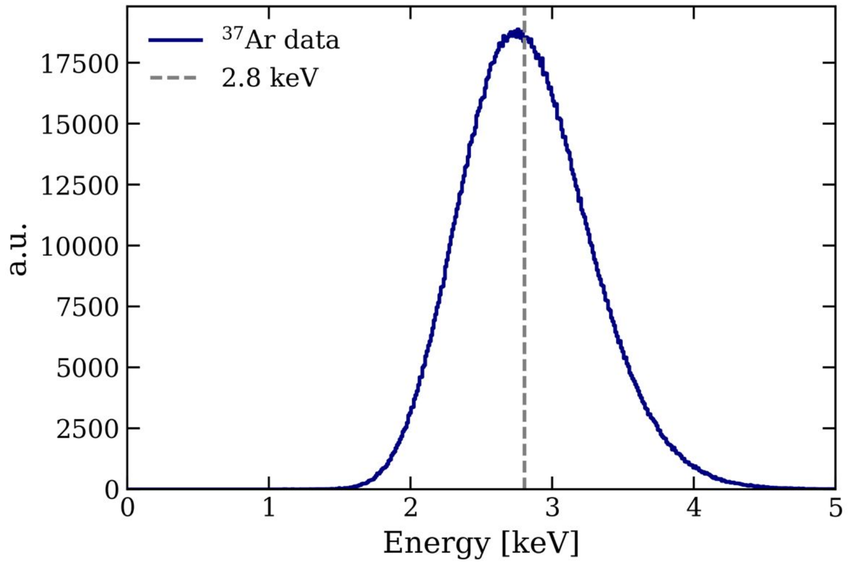
$\Longrightarrow$ < ppb O_2-equivalent impurities

Argon-37

2.8 keV energy released after EC

X-rays / Auger electrons

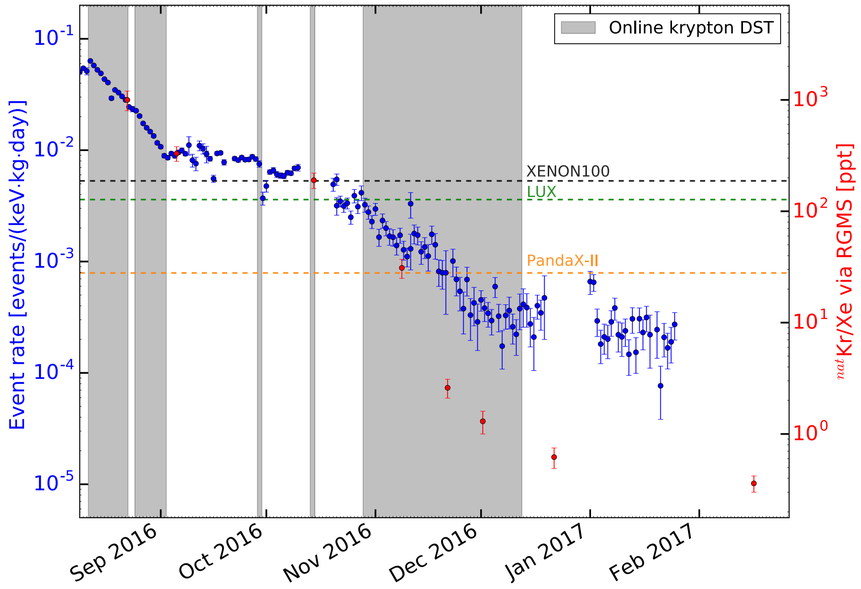
Tested as calibration source



Where from?

Always present? No, removed by distillation

Air leak? Would also introduce Kr



Ruled out

COULD IT BE NEW PHYSICS?

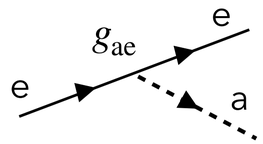
Solar axions

Production

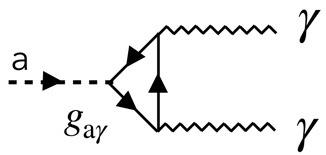
Solar physics

1. ABC

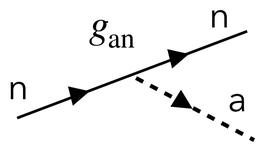
(atomic recombination and de-excitation, bremsstrahlung and Compton)



2. Primakoff

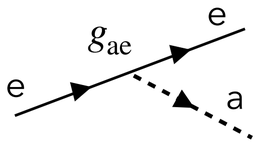


3. ^{57}Fe



Detection

Axioelectric effect

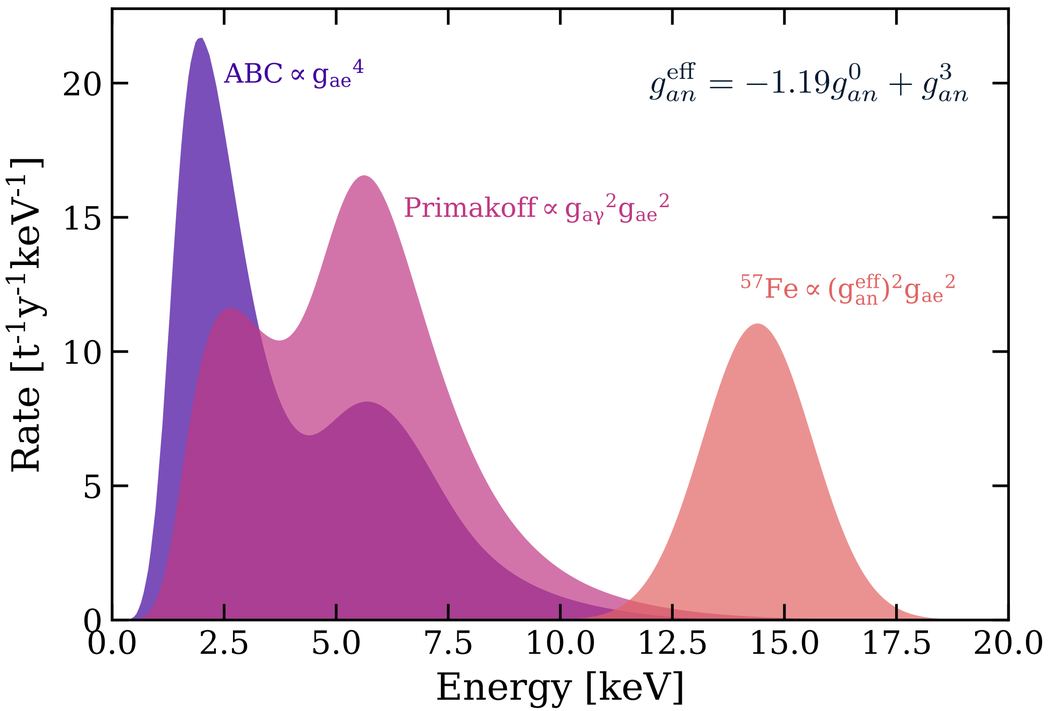


$$\sigma_{ae} = \sigma_{pe} \frac{g_{ae}^2}{\beta} \frac{3E_a^2}{16\pi\alpha m_e^2} \left(1 - \frac{\beta^{2/3}}{3}\right)$$

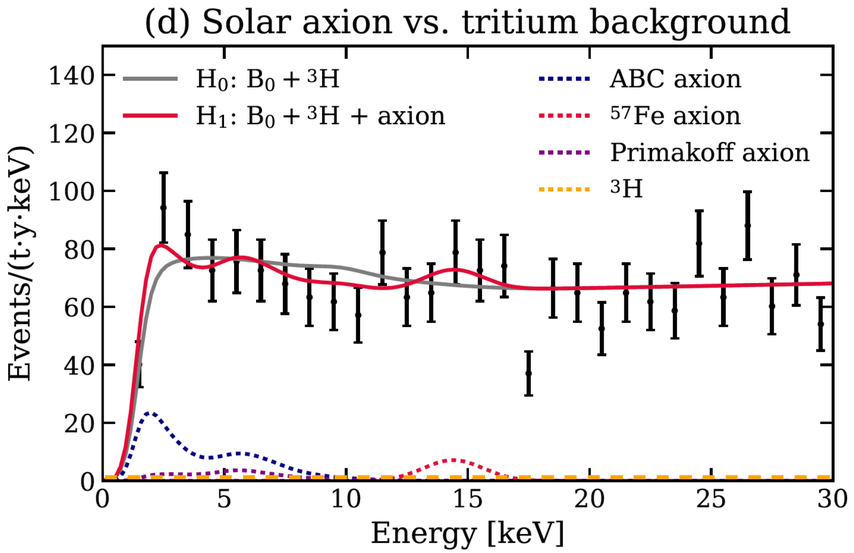
Like the photo-electric effect for axions

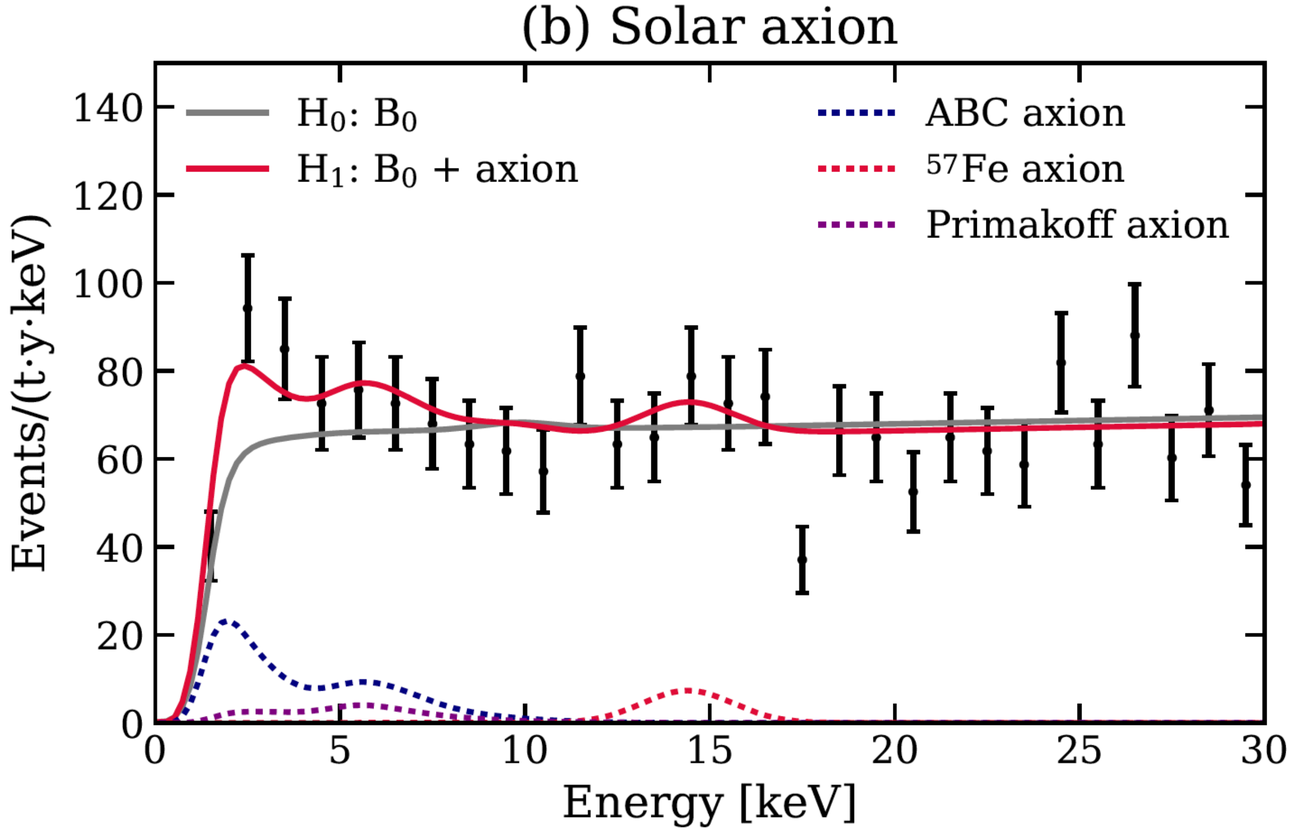
Reconstruction

XENON1T resolution, efficiency



Solar axions

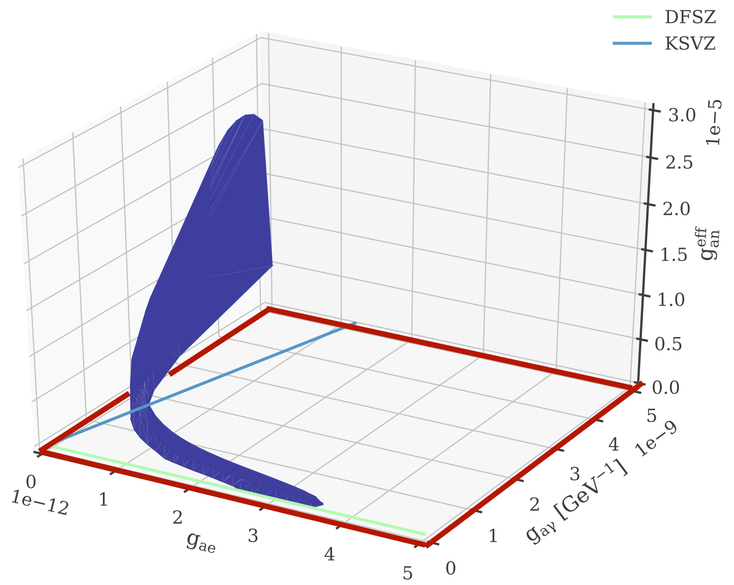


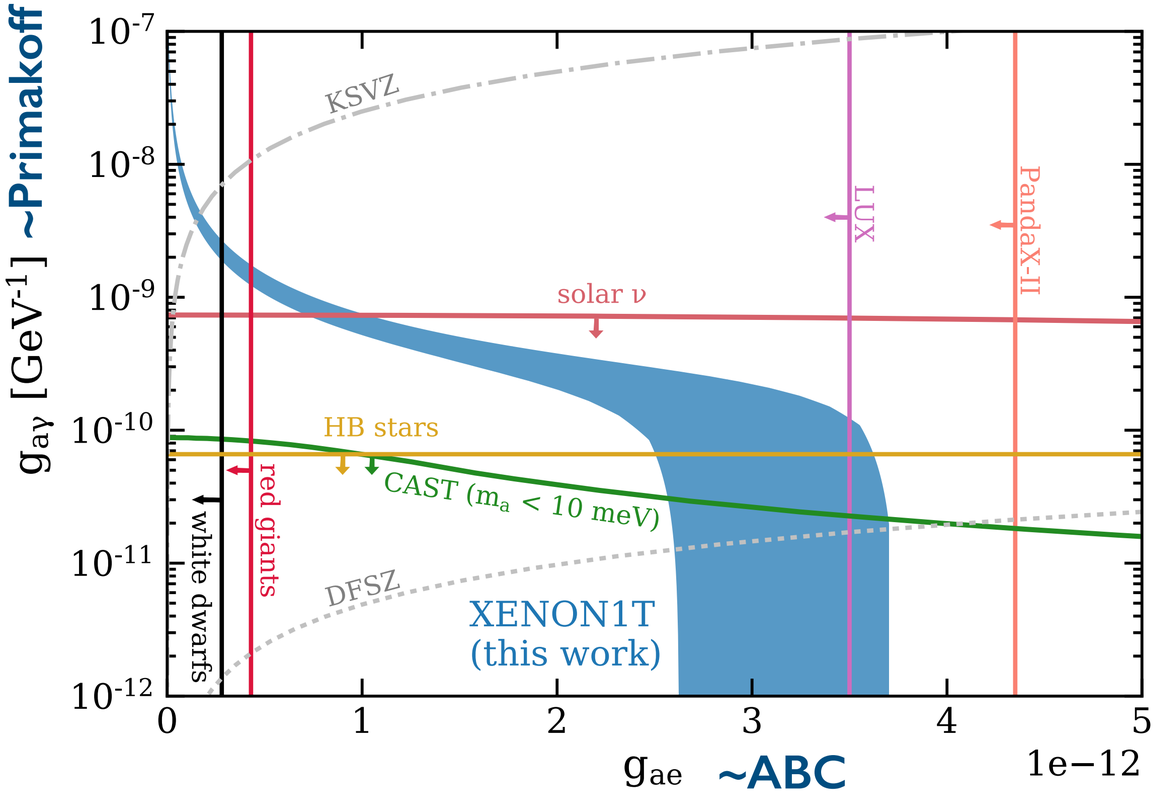


Solar axions only: 3.4σ over background
Axions + ^{3}H: 2.0σ over background + ^{3}H

Solar axions

3D allowed region for the three parameters





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

(arXiv 1708.02111)

At least one of ABC and Primakoff non-zero

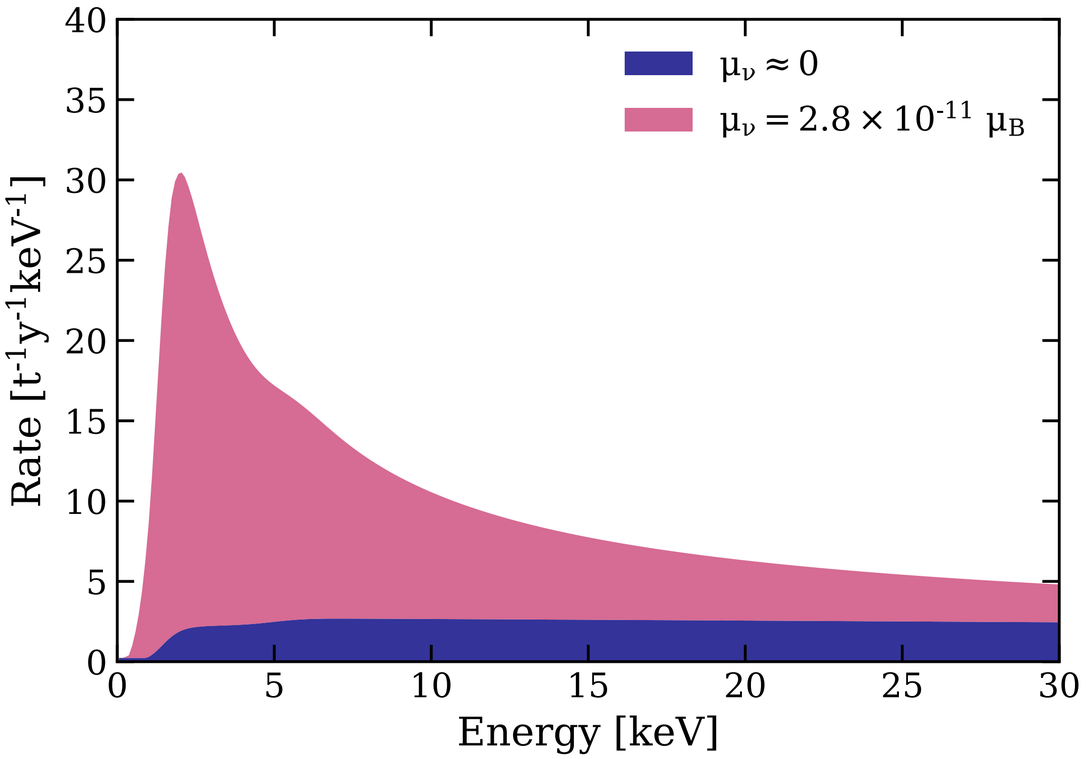
Neutrino magnetic moment

Massive neutrinos have magnetic moment

$$\mu_\nu \approx 3 \cdot 10^{-19} \left(\frac{m_\nu}{\mathrm{eV}} \right) \mu_\mathrm{B}$$

A larger value $\left(\gtrsim 10^{-15} \mu_\mathrm{B} \right) \Longrightarrow$ Majorana neutrinos

Would lead to enhanced neutrino-electron scattering cross-section



Neutrino magnetic moment

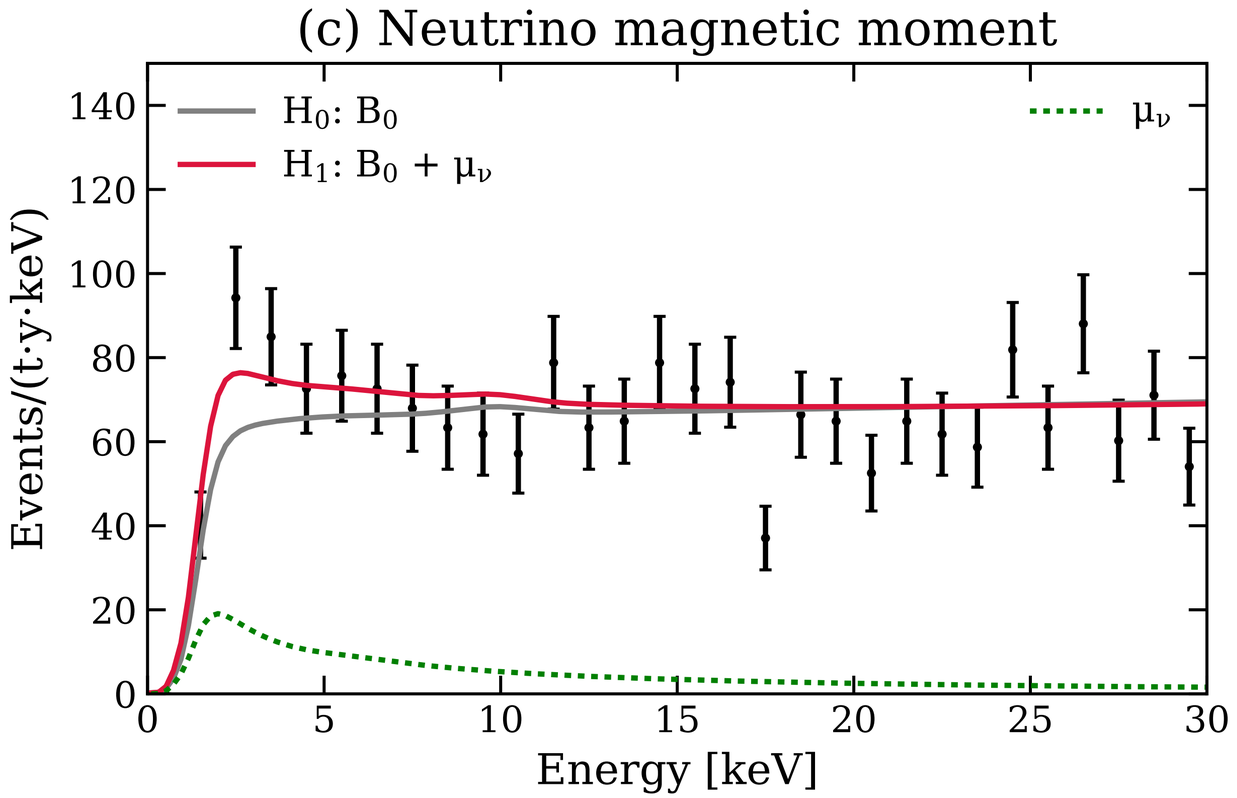
Mag. Moment: 3.2σ over background

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

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

Compatible with other experiments

In tension with astrophysical constraints



arXiv 1910.10568

arXiv 1907.00115

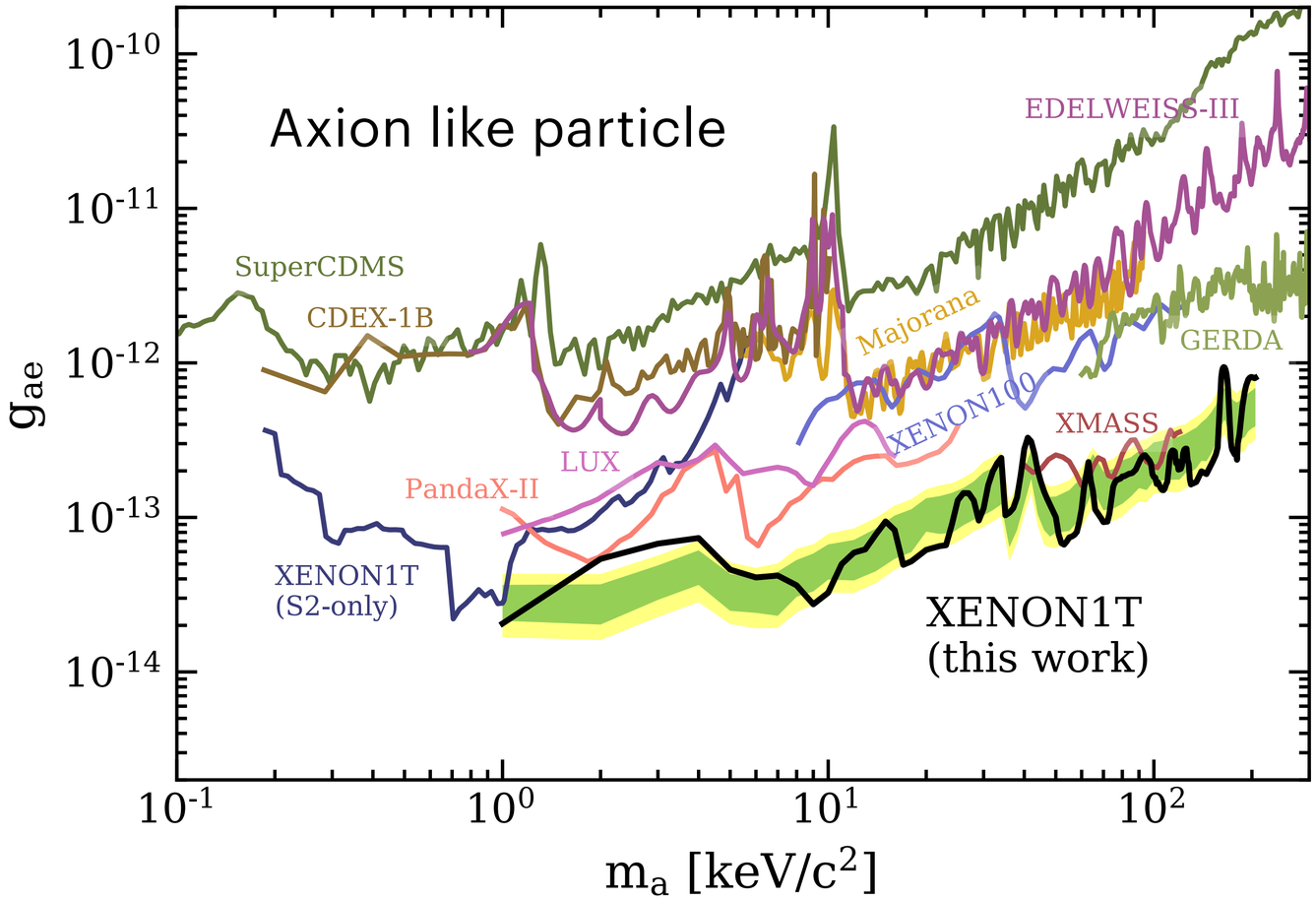
Bosonic dark matter

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

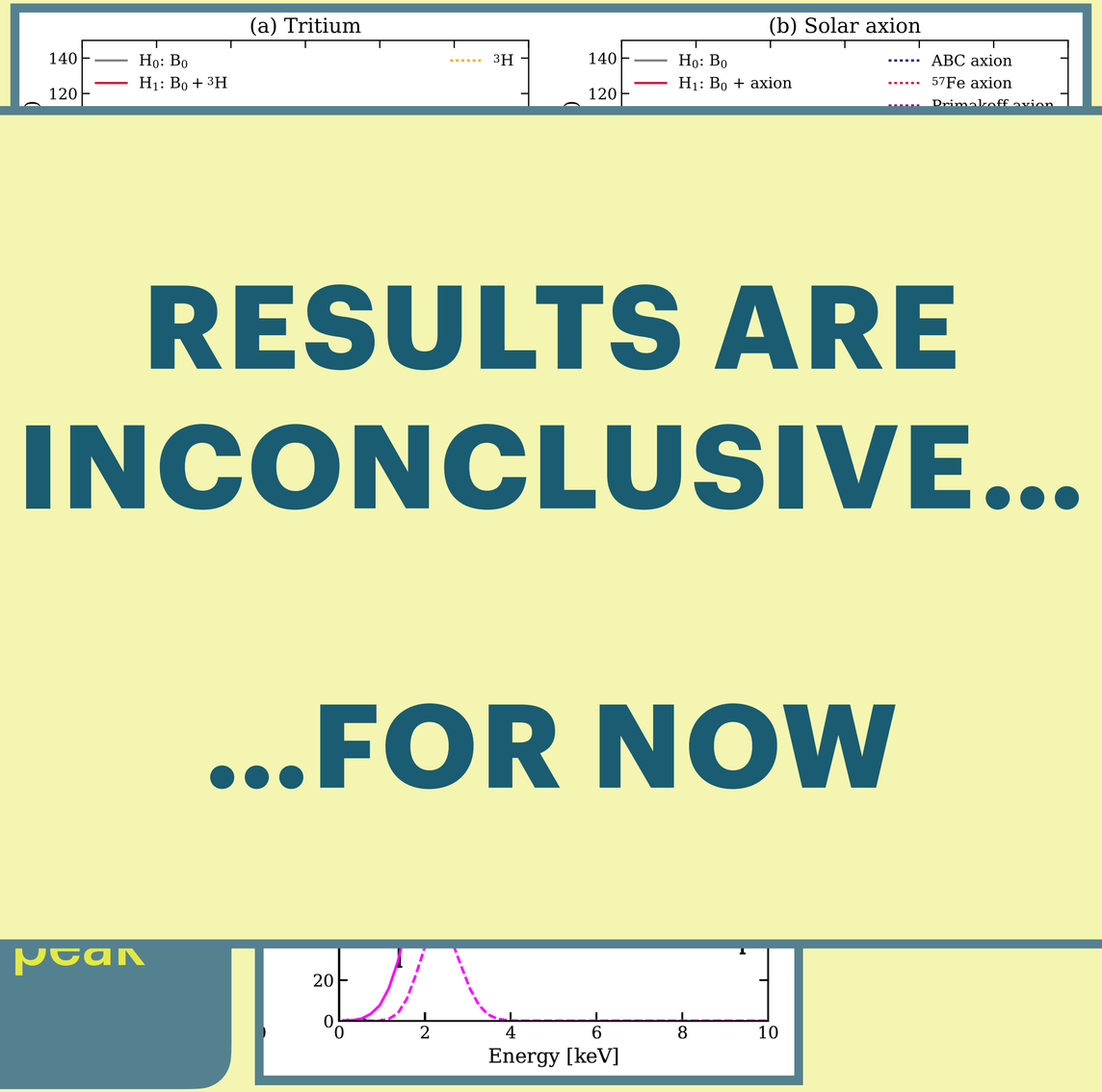
No > 3σ excess ⟹ only report limits



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

Tritium
3.2σ

Solar axions
3.4σ



RESULTS ARE INCONCLUSIVE...

...FOR NOW

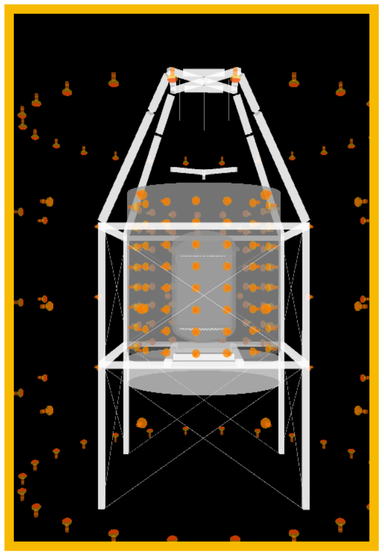
μ_ν
3.2σ

Axions + ^3H
2.0σ

Mono-energetic peak
3.0σ

XENONnT

Some of what's new in XENONnT



Neutron veto

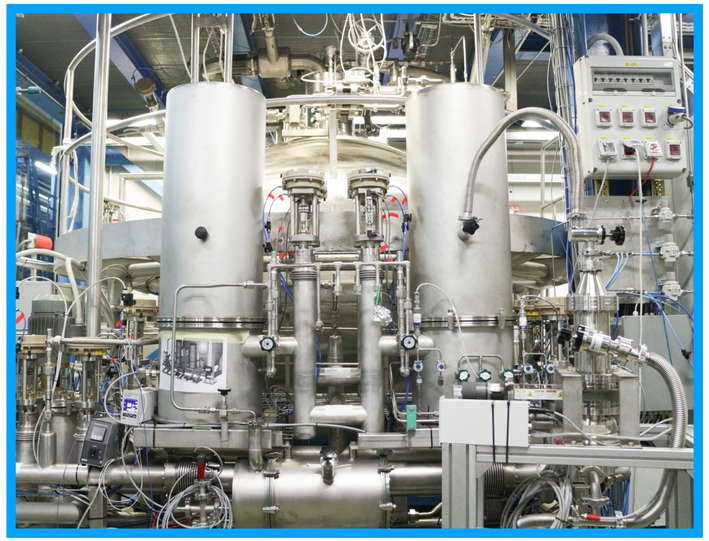
- Inner region of existing muon veto
- optically separate
- 120 additional PMTs
- Gd in the water tank
- 0.5 % $Gd_2(SO_4)_3$

Larger TPC

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

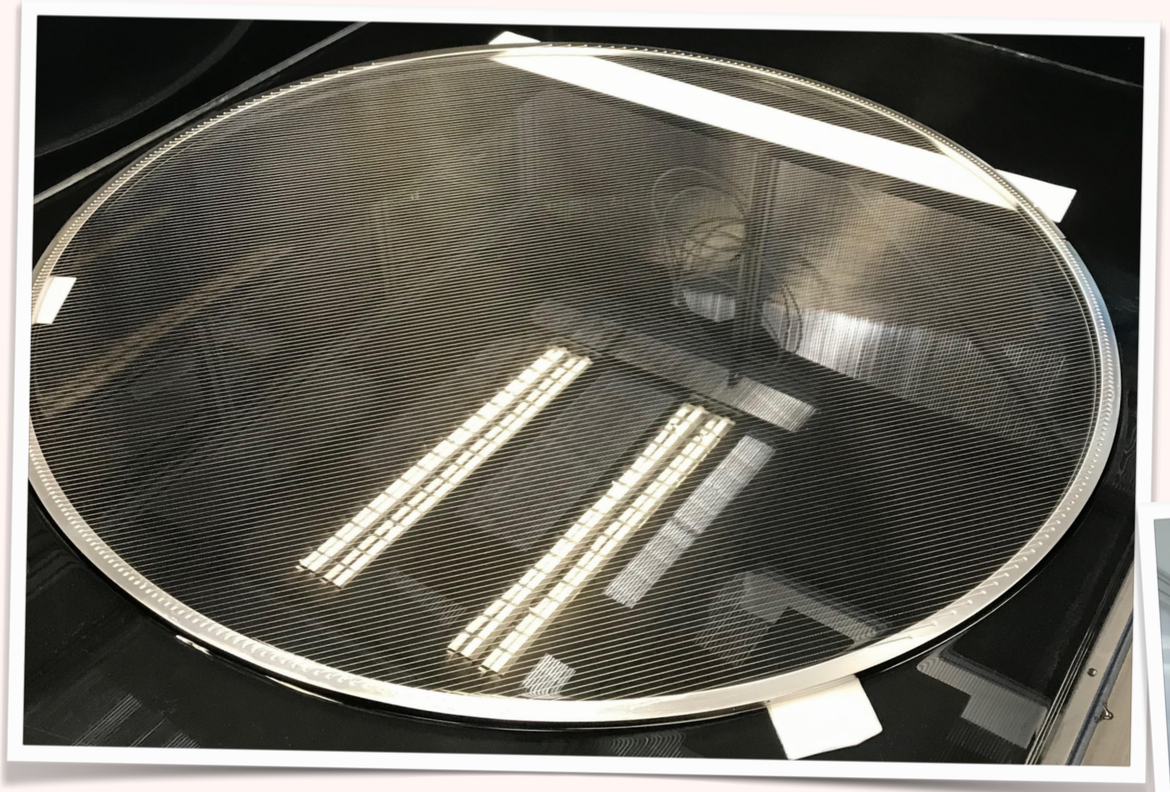
^{222}Rn distillation

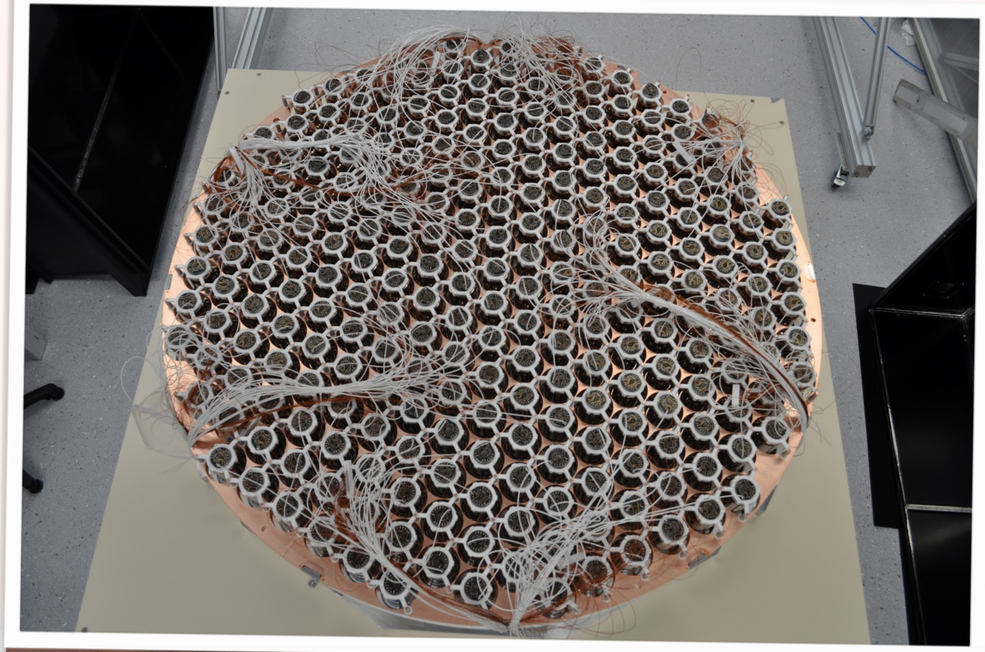
- Reduce Rn (^{214}Pb) from pipes, cables, cryogenic system
- New system, PoP in XENON1T

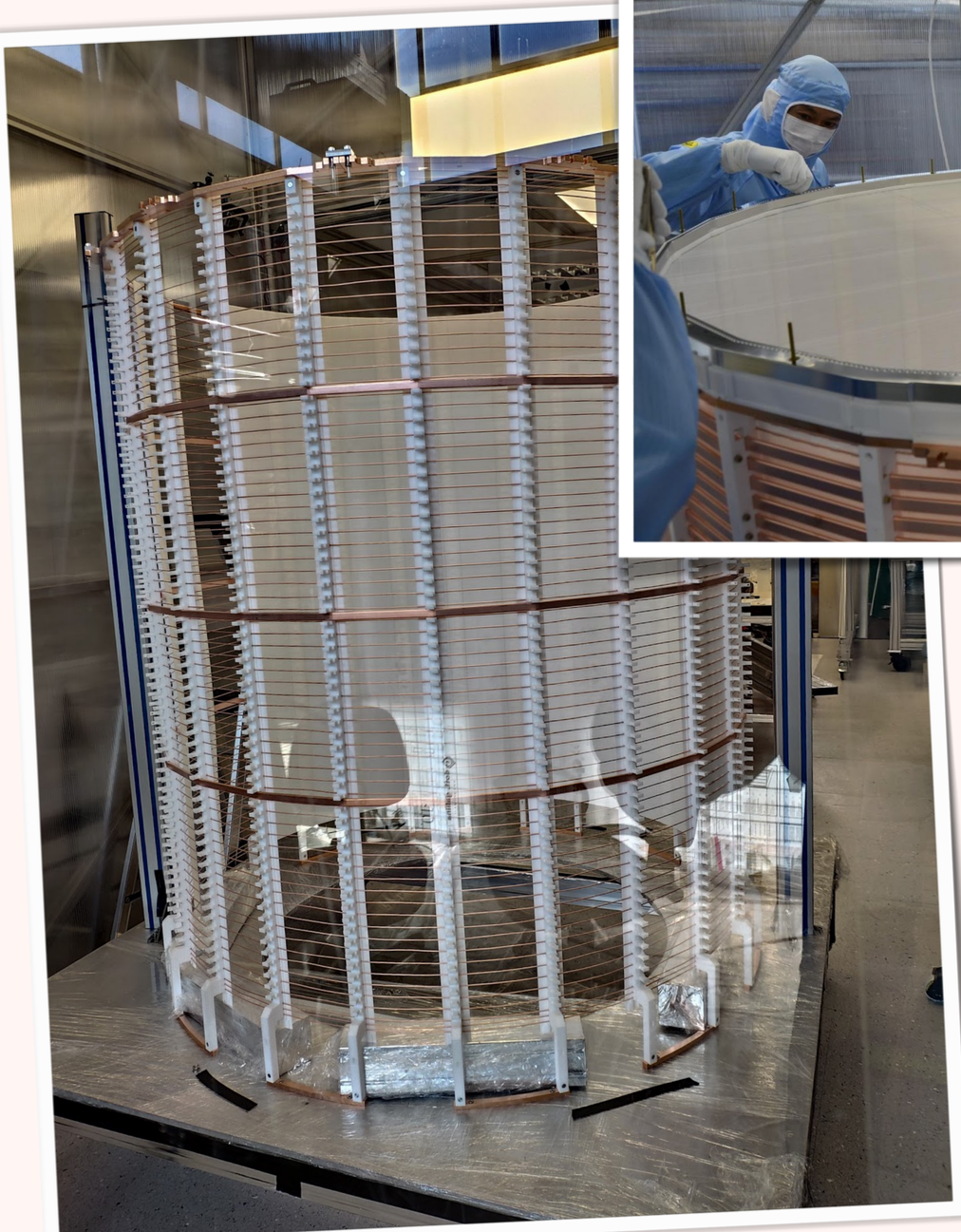


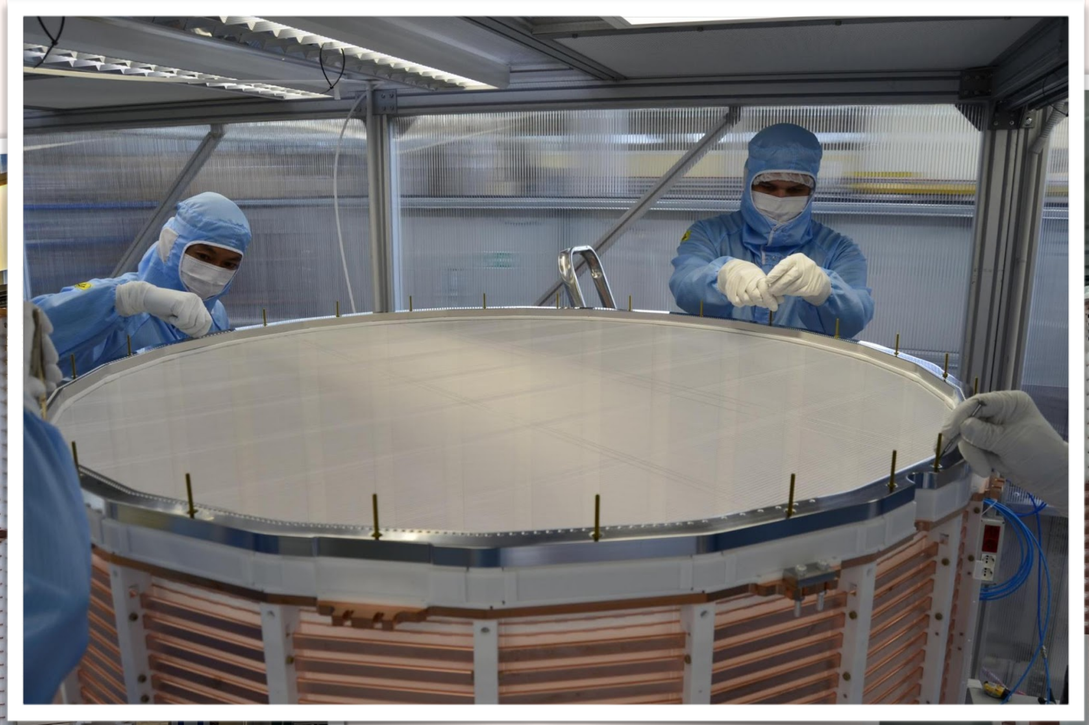
LXe purification

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







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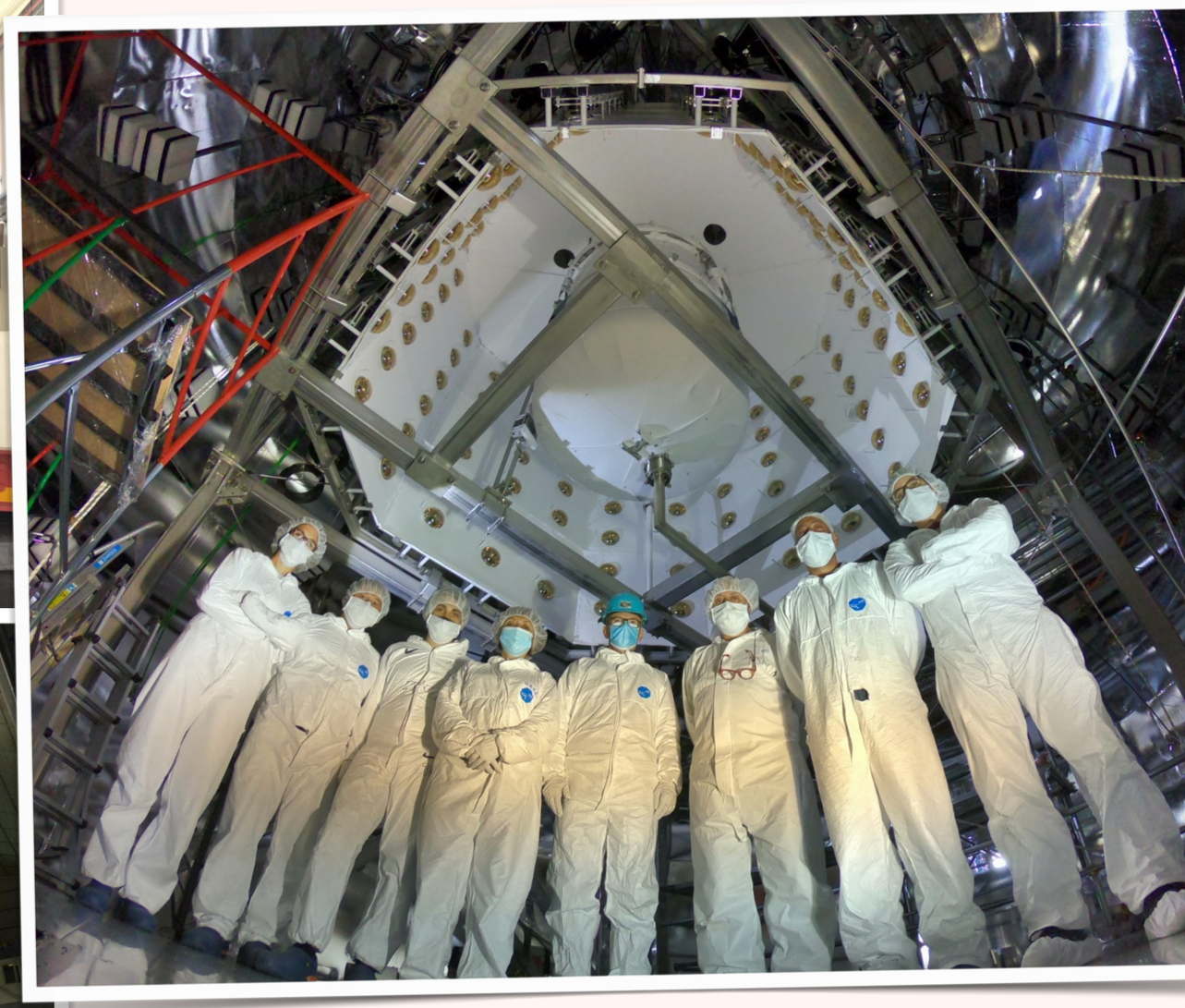
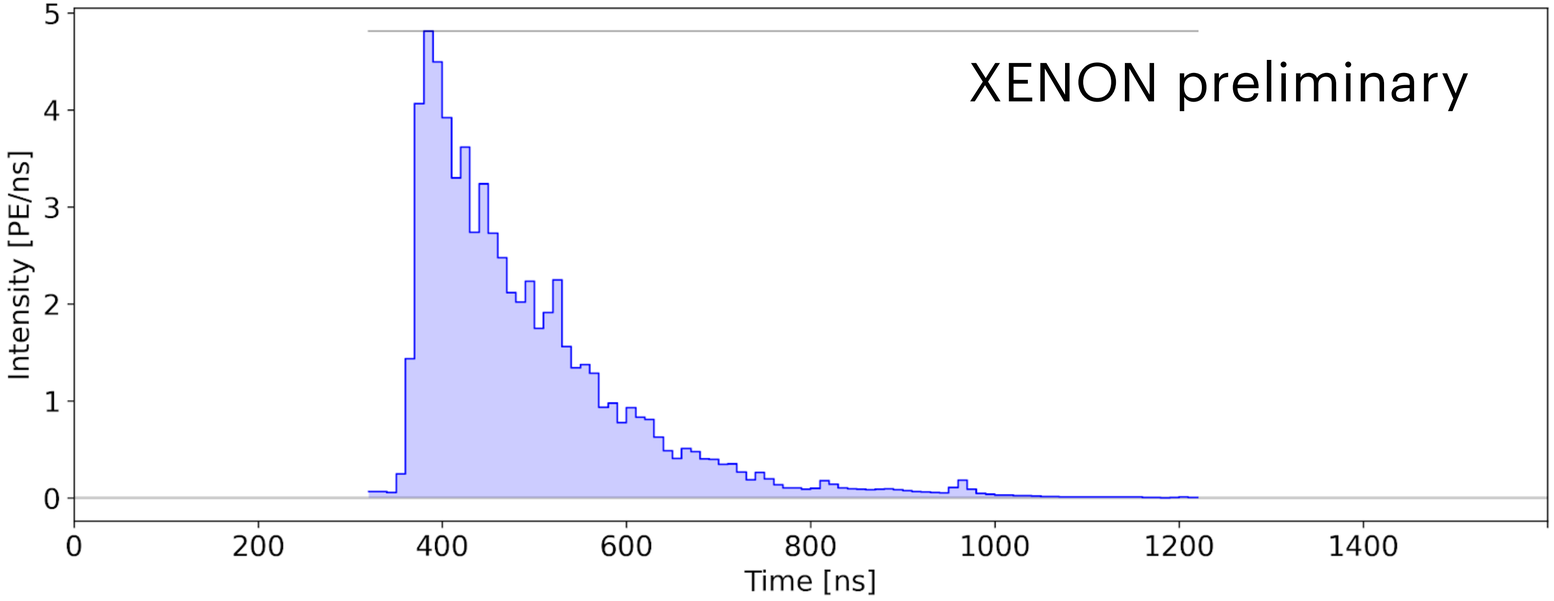


XENOnT — watch this space

Cryostat has been closed for several months

Just recently started filling it with liquid xenon

First scintillation light already seen (in gas xenon):



THANK YOU FOR LISTENING

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