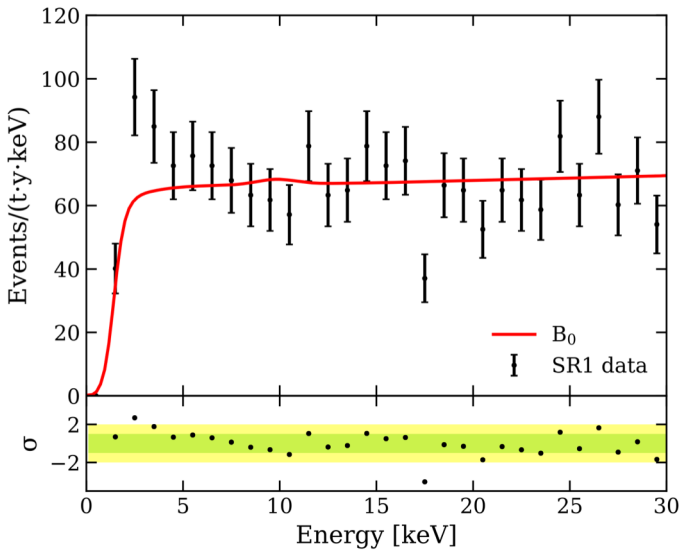
XENON1T : The Results

Observation of excess electronic events in XENON1T

arXiv : 2006.09721



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on behalf of the XENON Collaboration

+ X. Mougeot

XENON Collaboration

XENON1T facility

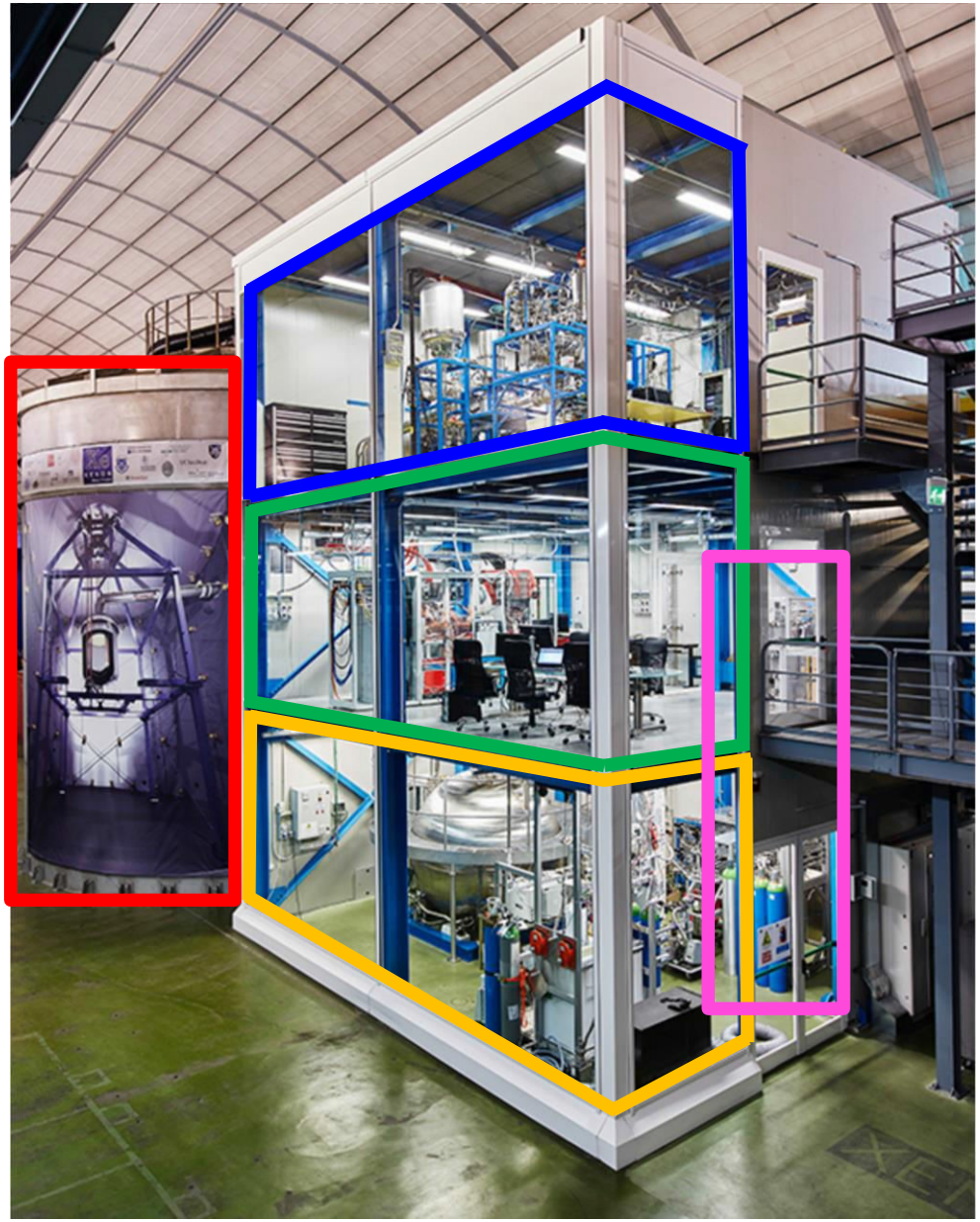
Water shield: deionized water as passive radiation shield
Muon veto: Active muon veto against muon induced neutrons (84 PMTs)

Cryogenics: Stable conditions (3.2 LXe)
Purification: LXe flow through getters, remove impurities

DAQ: Each channel has its own threshold, Flexible software algorithms
Readout: Up to 300MB/s for high rate calibrations

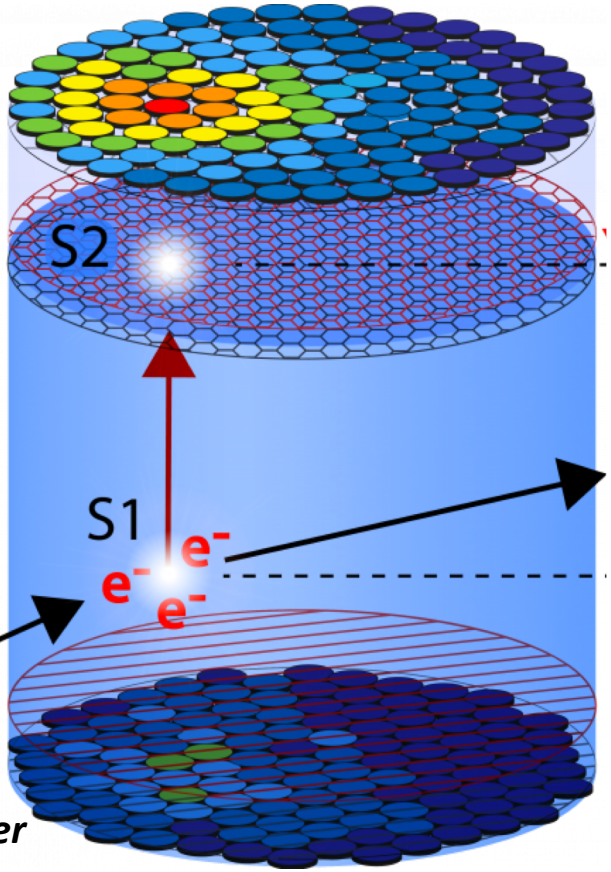
ReStoX: Emergency recovery up to 7.6 tons of LXe
Passive: No active cooling required to keep Xe contained

Kr Distillation: Remove Kr from system during fill or online
Rn Distillation: Initial tests show promising reduction for Rn

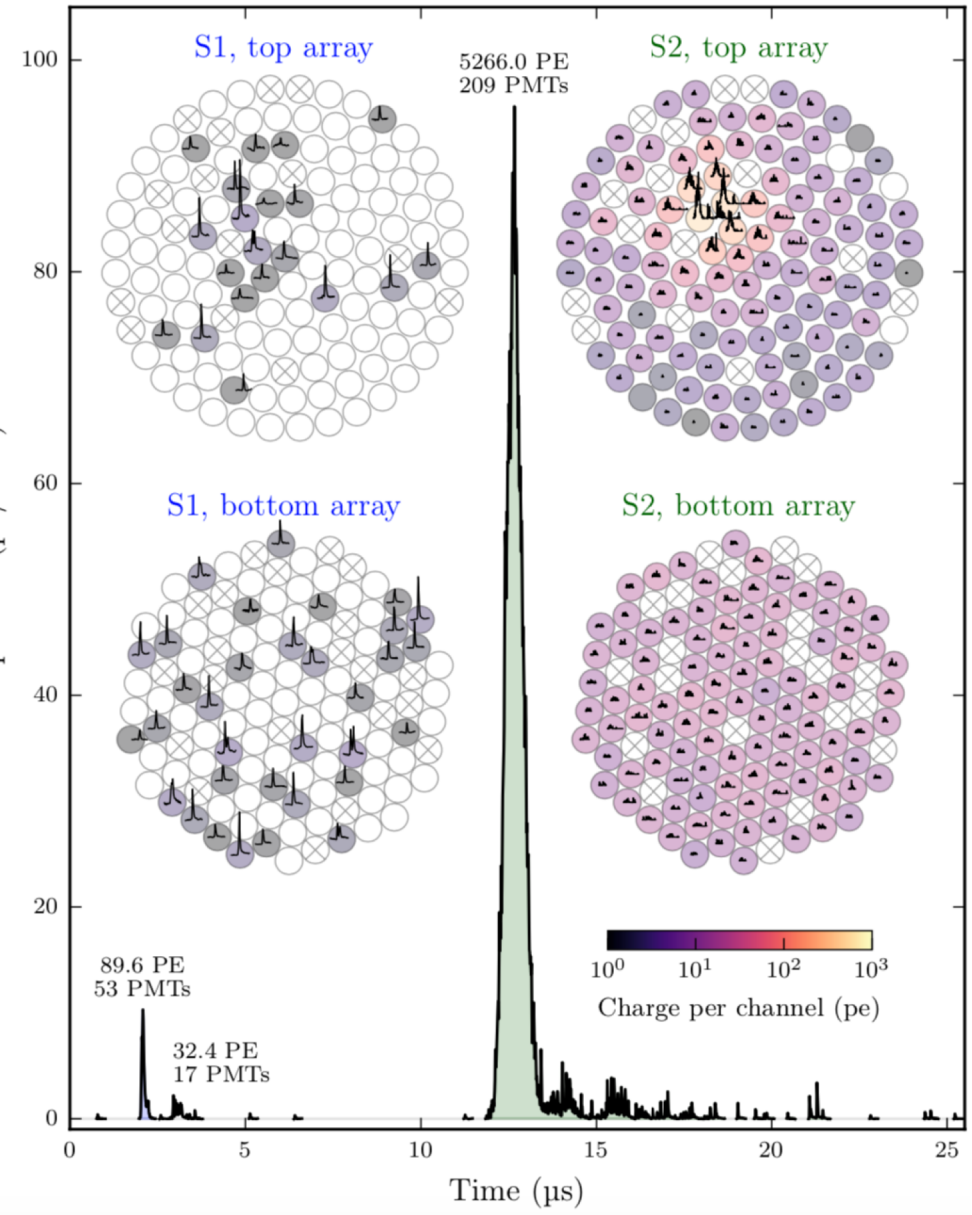


Dual phase TPC: principle

TPC = Time Projection Chamber

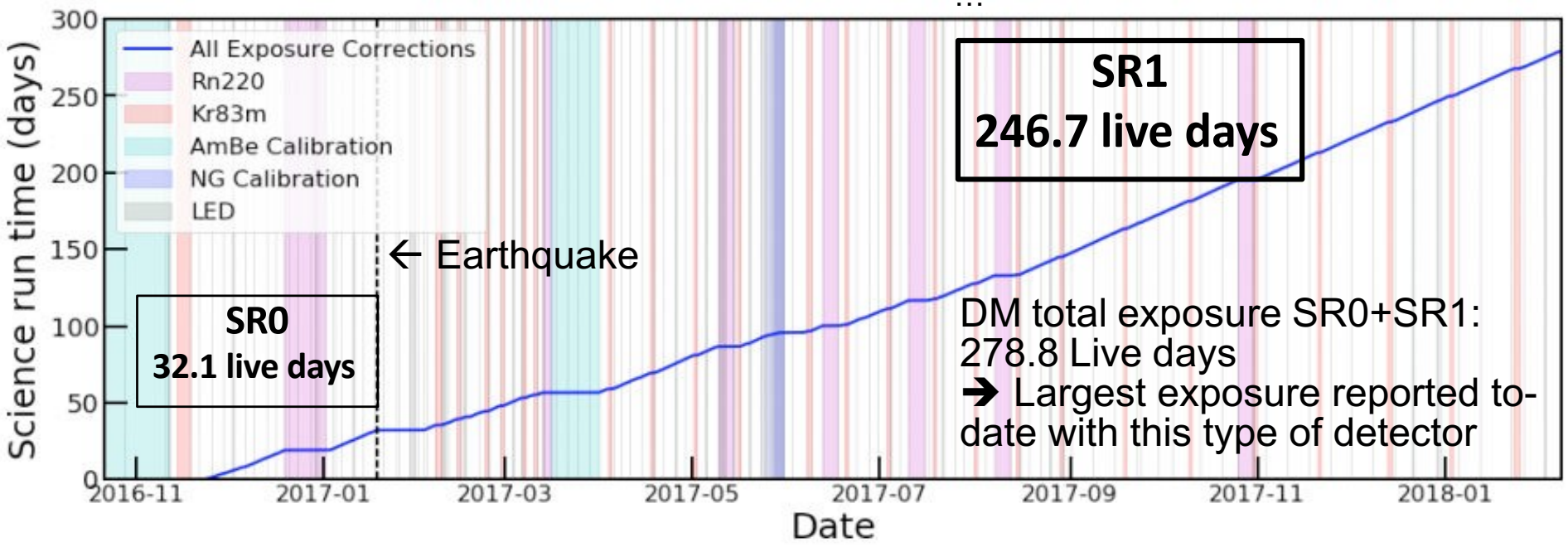


particle
=
Dark matter
Neutron
Electron
…

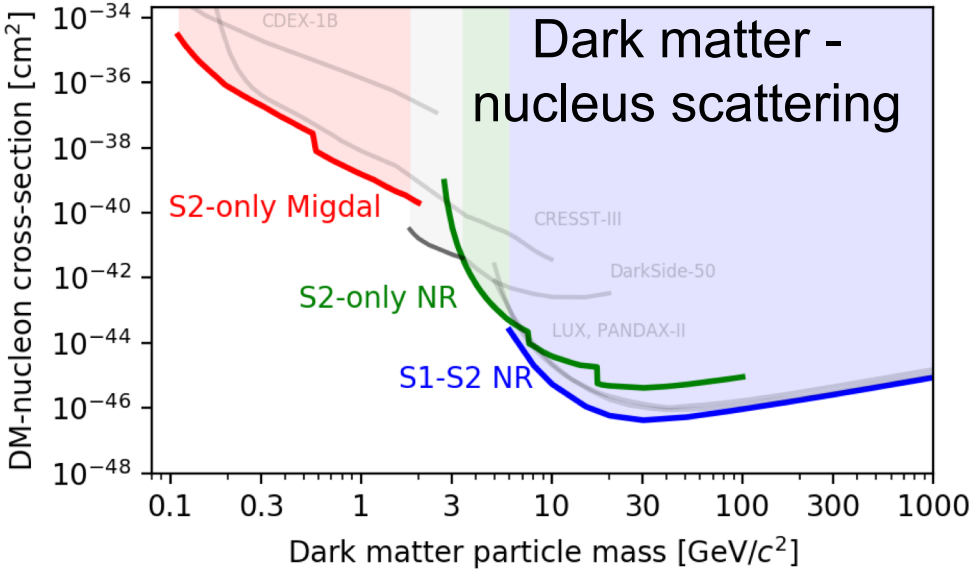


Uses of S1 & S2 with data

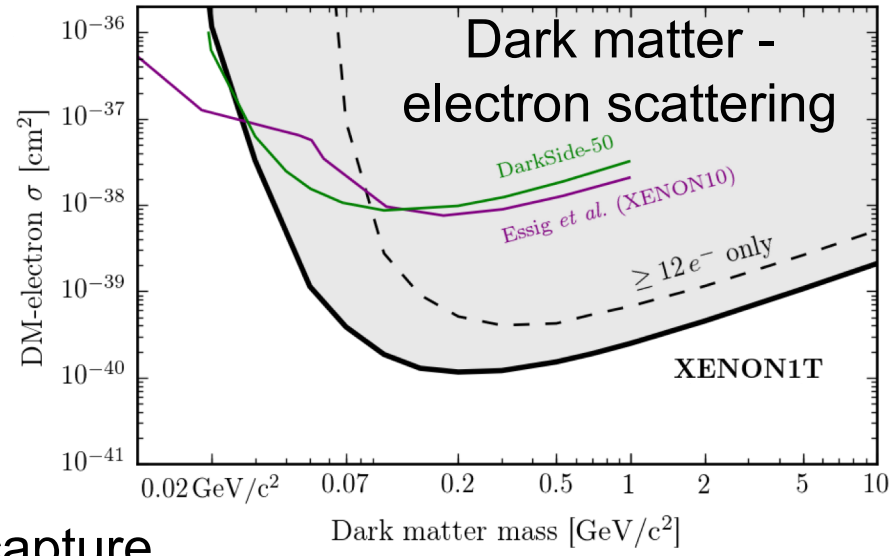
- "Standard" nuclear recoil WIMPs models:
  - SI WIMP-nucleon interactions
  - SD WIMP-nucleon interactions
  - Low mass WIMPS
  - …
- DM-electron scattering:
  - Solar axions
  - Axion-like particles (ALPs)
  - …
- Leptophilic models:
  - Annual modulation
  - Exotic models: WIMP axial-vector coupling to electrons, mirror dark matter, luminous dark matter
  - …
- Neutrino physics:
  - 0νββ decay with 136Xe
  - 2ν double electron capture with 124Xe
  - …



XENON1T previous results - main publications

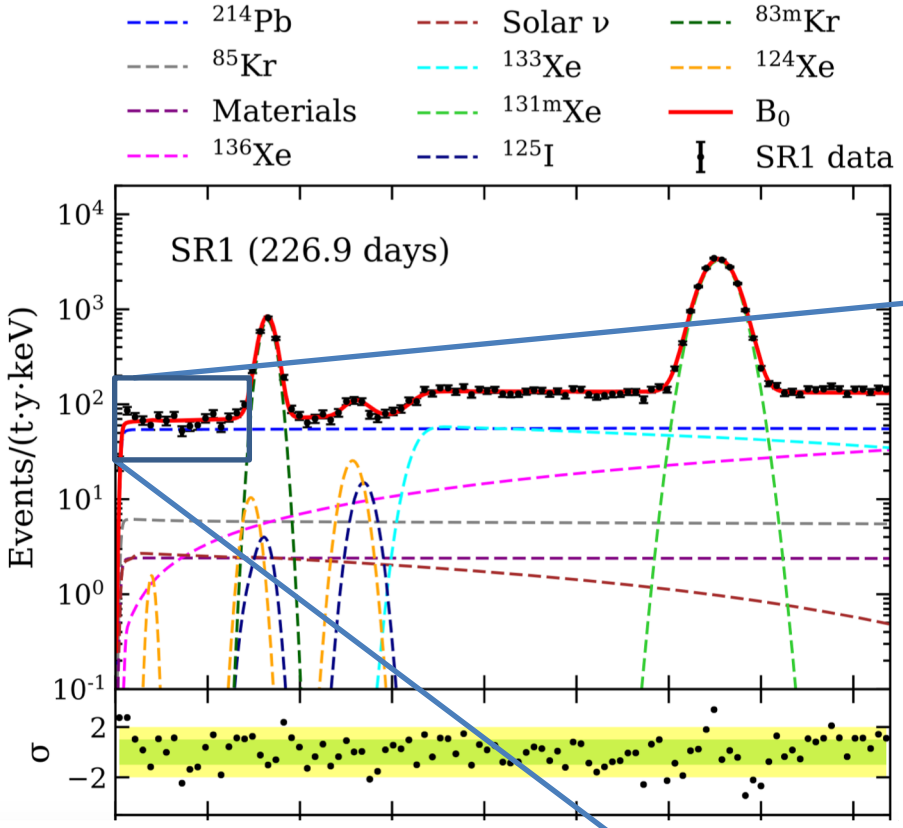


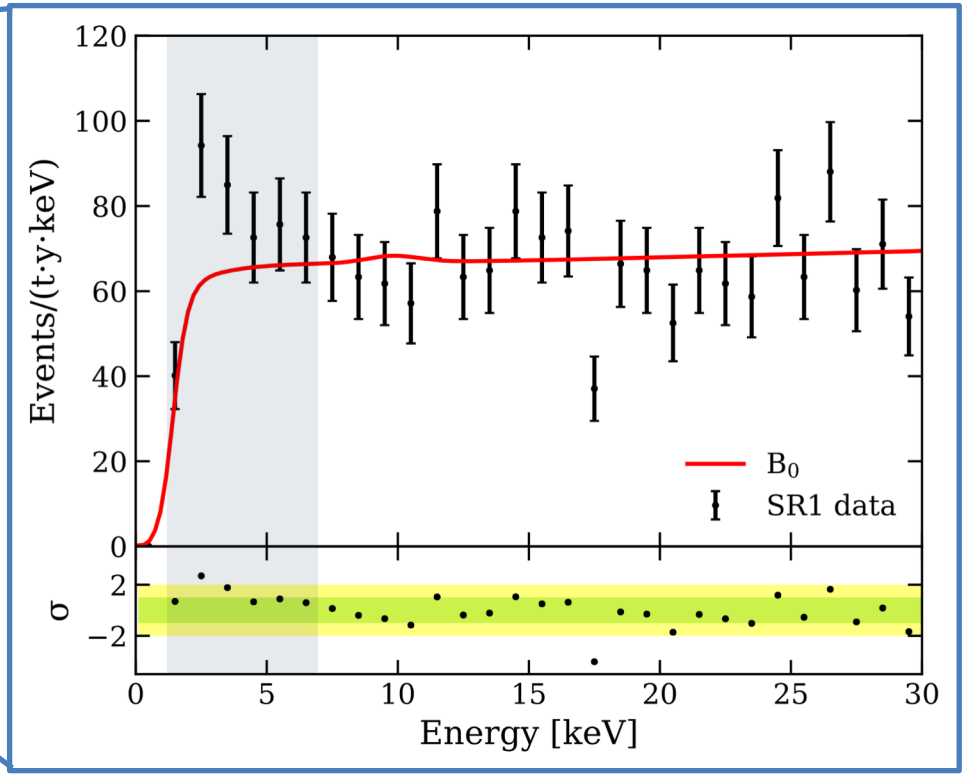
PRL 119, 181301 - First results
PRL 121, 111302 - Main WIMP search
PRL 122, 141301 - Spin-dependent WIMPs
PRL 122, 071301 - WIMP-pion interaction



PRL 123, 251801 - Light dark matter
PRL 123, 241803 - Migdal effect
Nature 568, 532–535 - ^{124}Xe double e$^-$ capture

Focus on the excess

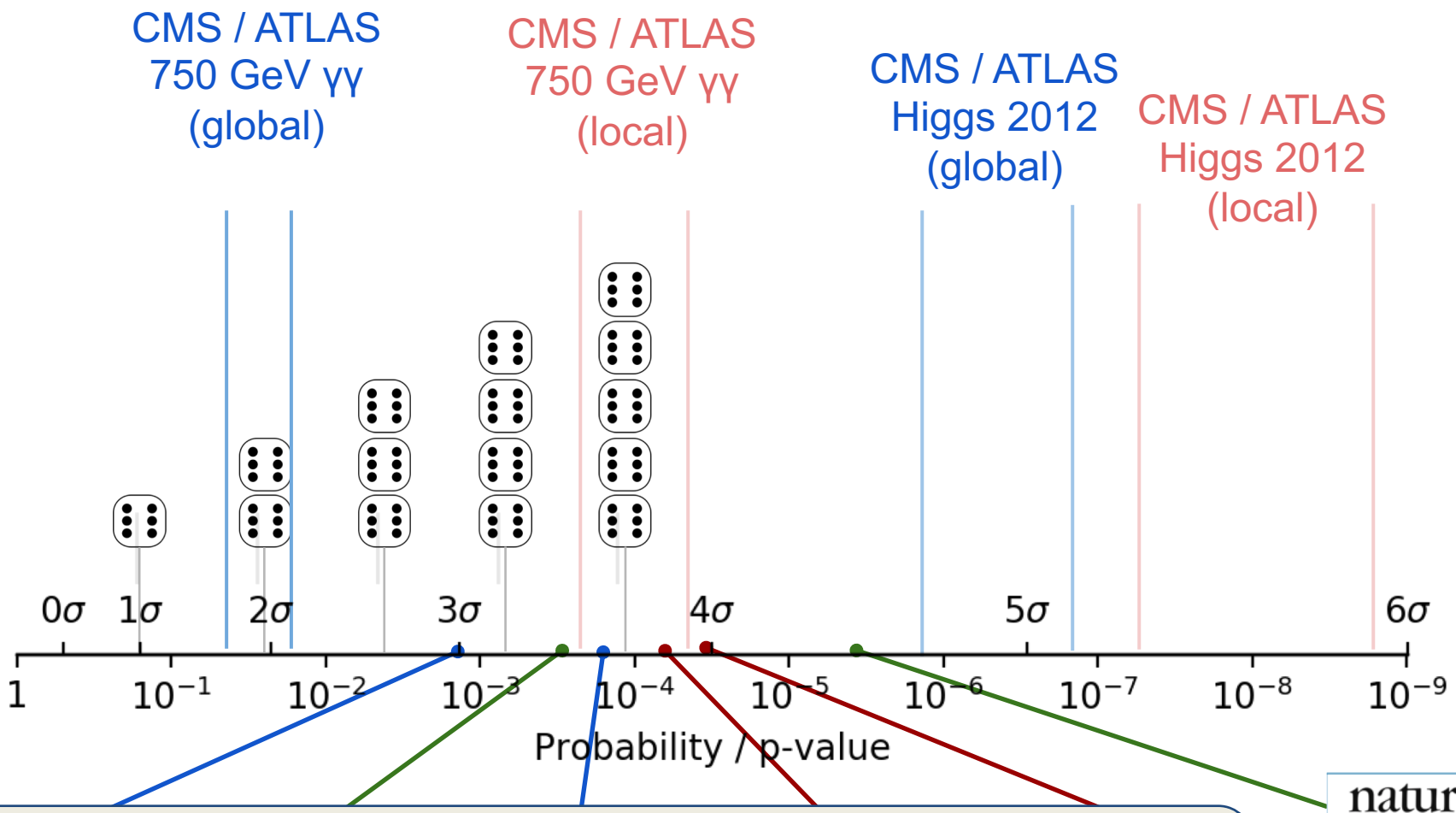




(76 +/- 2) events/(t·y·keV) in [1, 30] keV

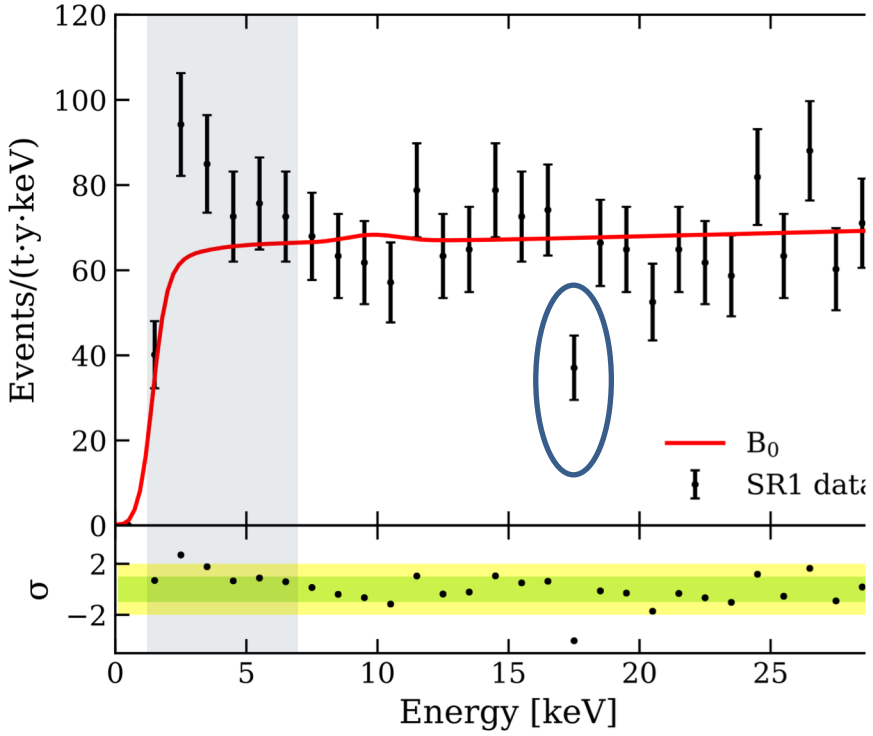
Lowest background rate ever achieved in this energy range!

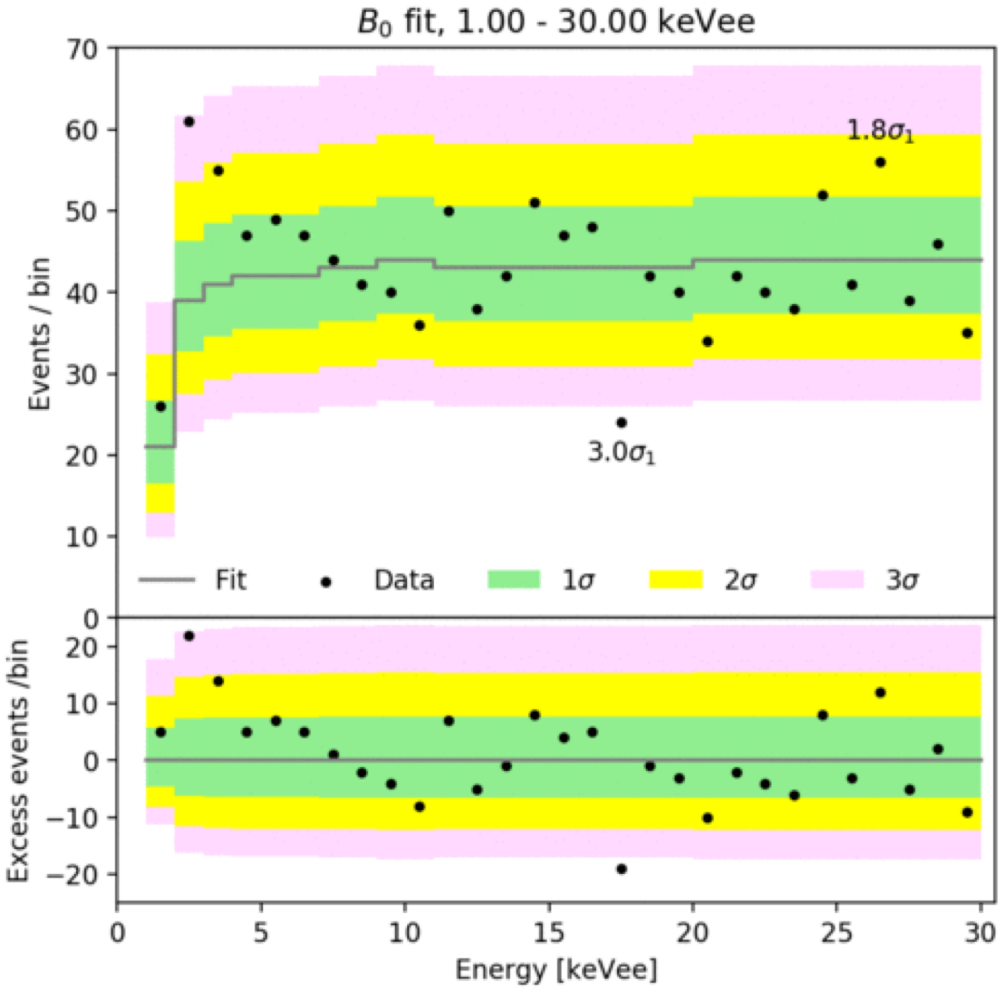
Probabilities



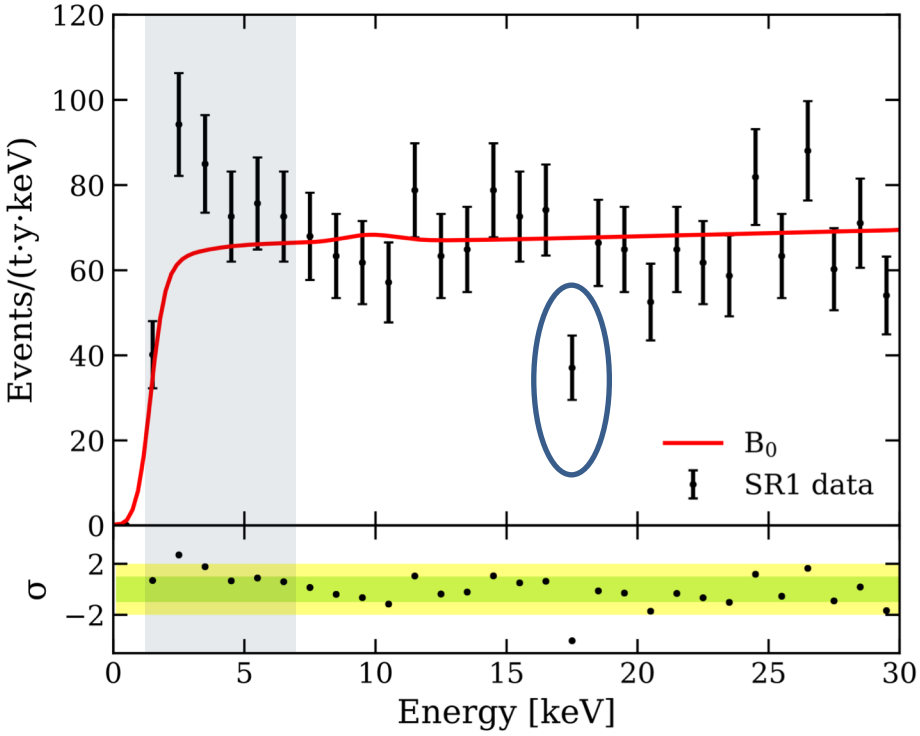
Bosonic DM (global) | **Tritium / Magnetic neutrinos** | **Solar Axions (global)** | **Solar Axions (ABC only)** | **Bosonic DM (~2.3 keV)**

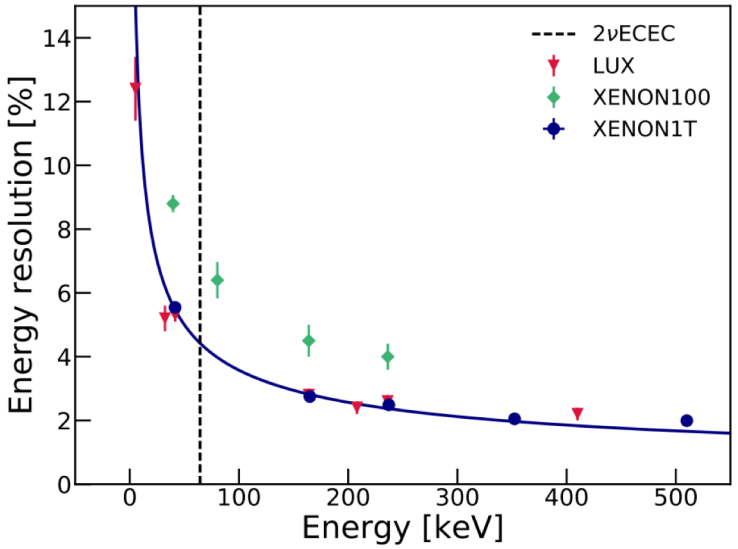
Focus on the excess

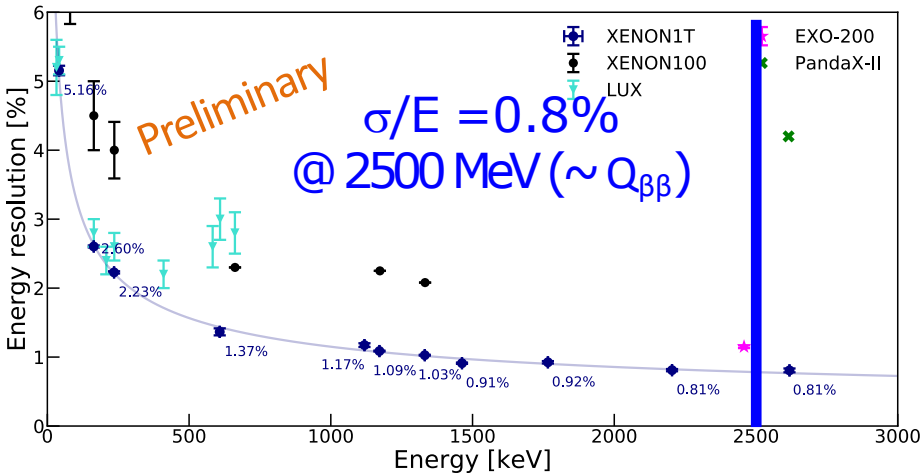




Energy reconstruction

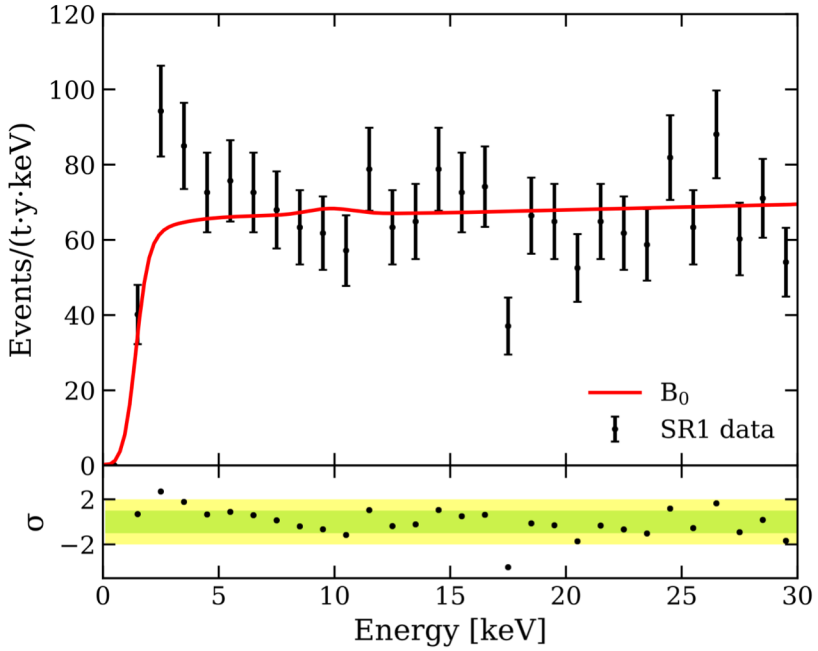






World best energy resolution in a LXe detector

Mismodeling



Excess **is not at our threshold fall-off**

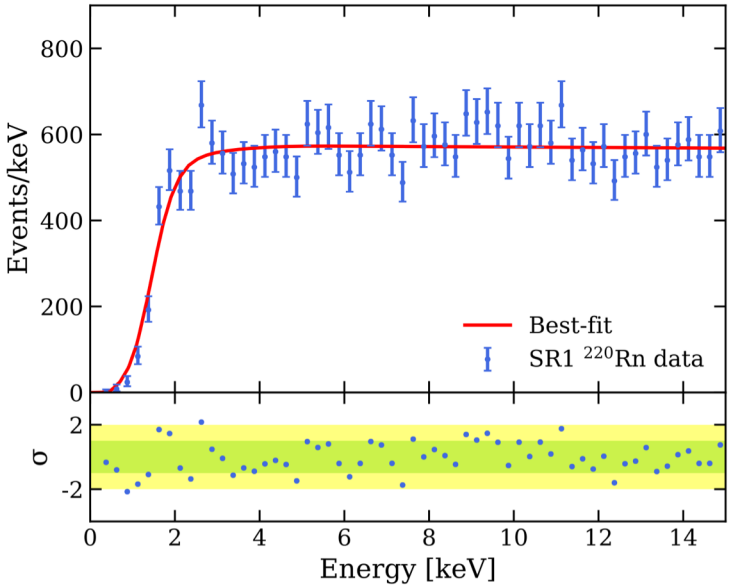
Persists if we would:

… double the analysis threshold post-hoc

… fix efficiency at +-1 sigma

… use different software versions

… do a (cS1, cS2) profile likelihood

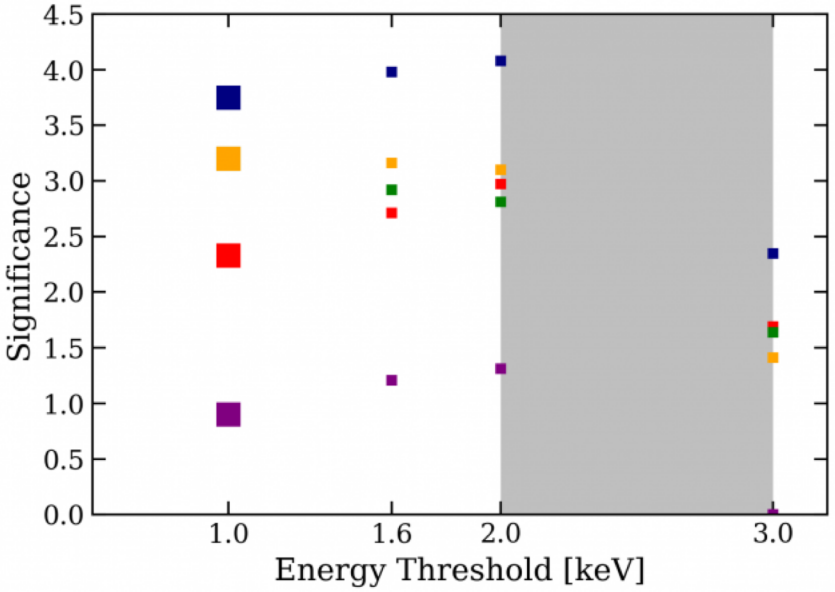


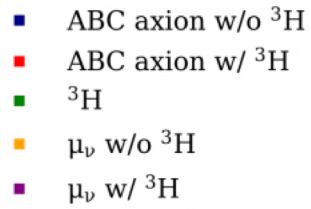
^{220}Rn calibration data validates our model

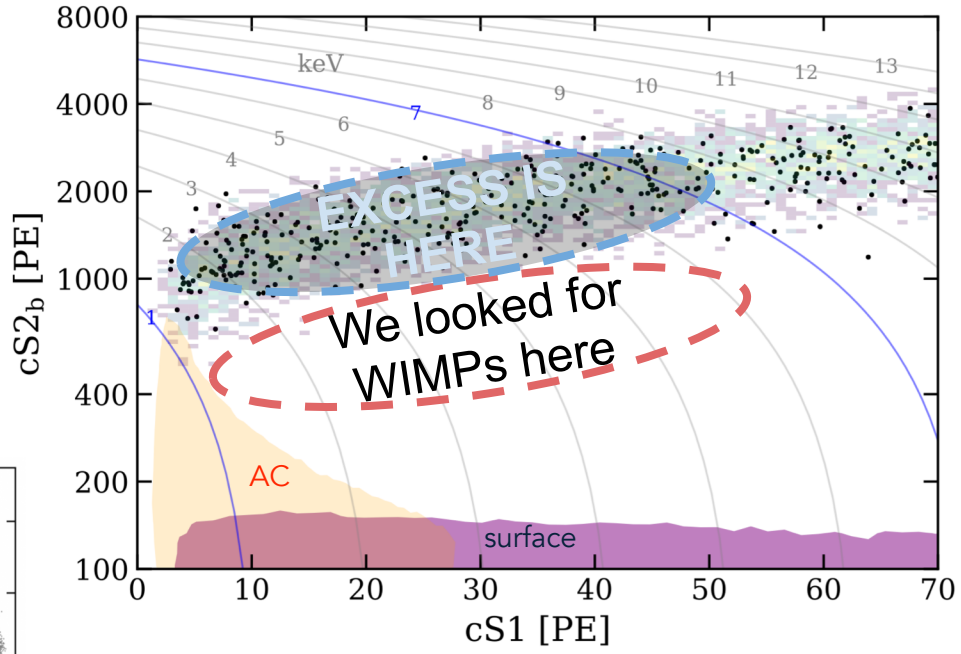
To explain the excess, you need:

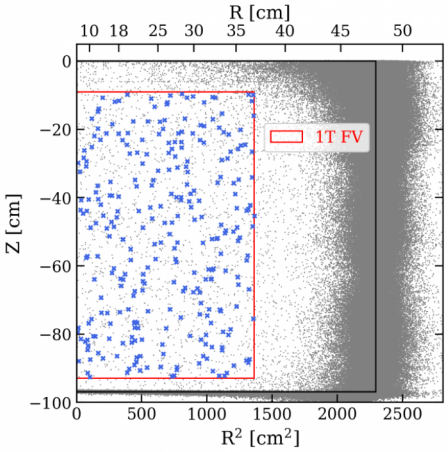
- a large systematic
- that is absent when we calibrate

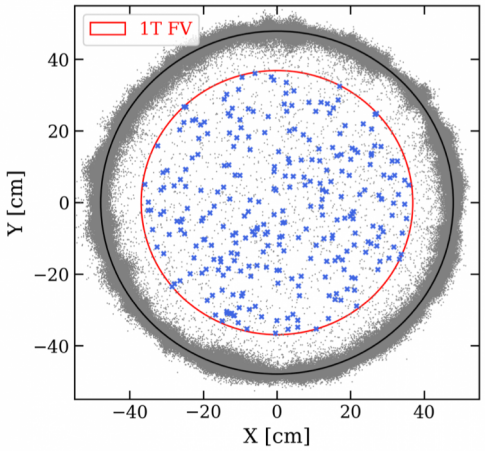
Mismodeling







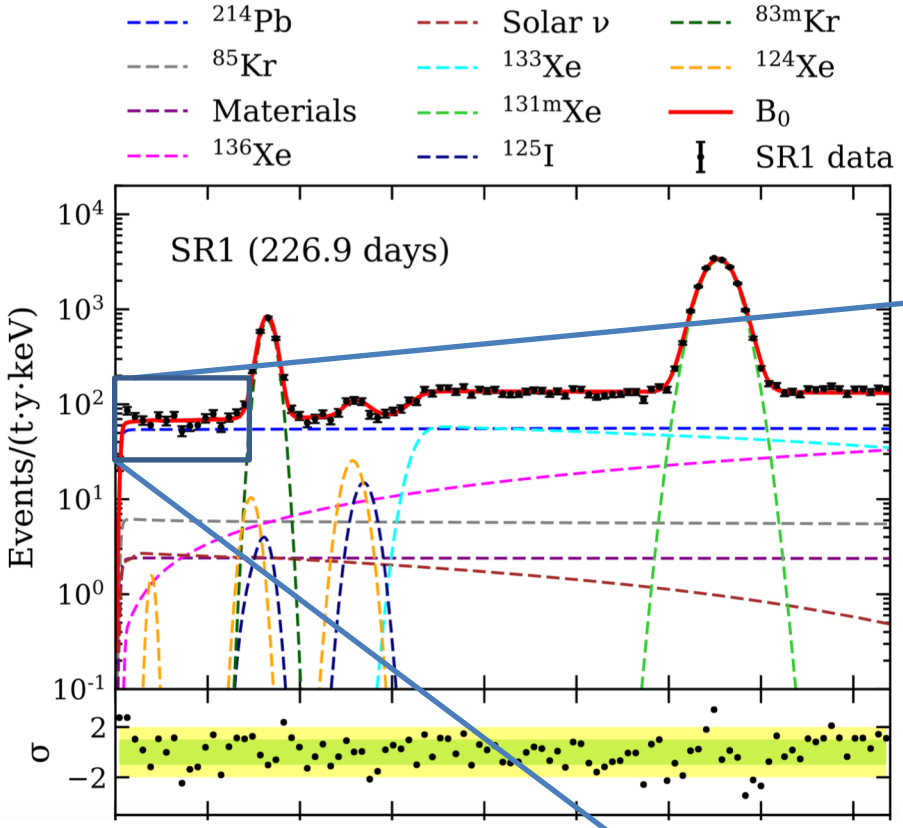


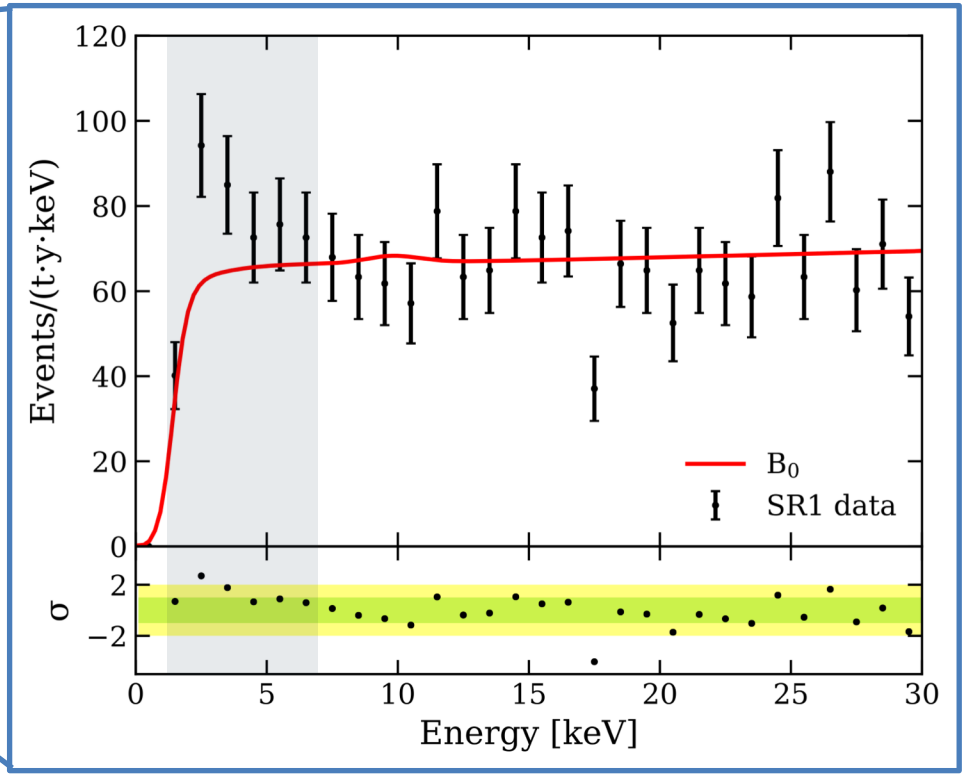


The excess is **right next to our prime WIMP search region**

No other event source relevant besides electronic recoils

Focus on the excess

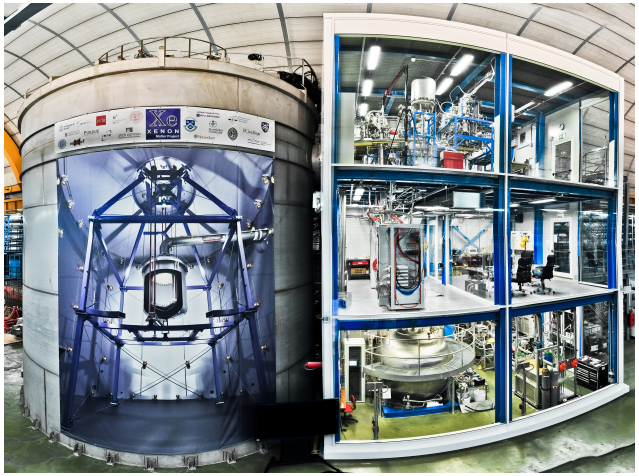




(76 +/- 2) events/(t·y·keV) in [1, 30] keV

Lowest background rate ever achieved in this energy range!

What makes a signal in XENON1T

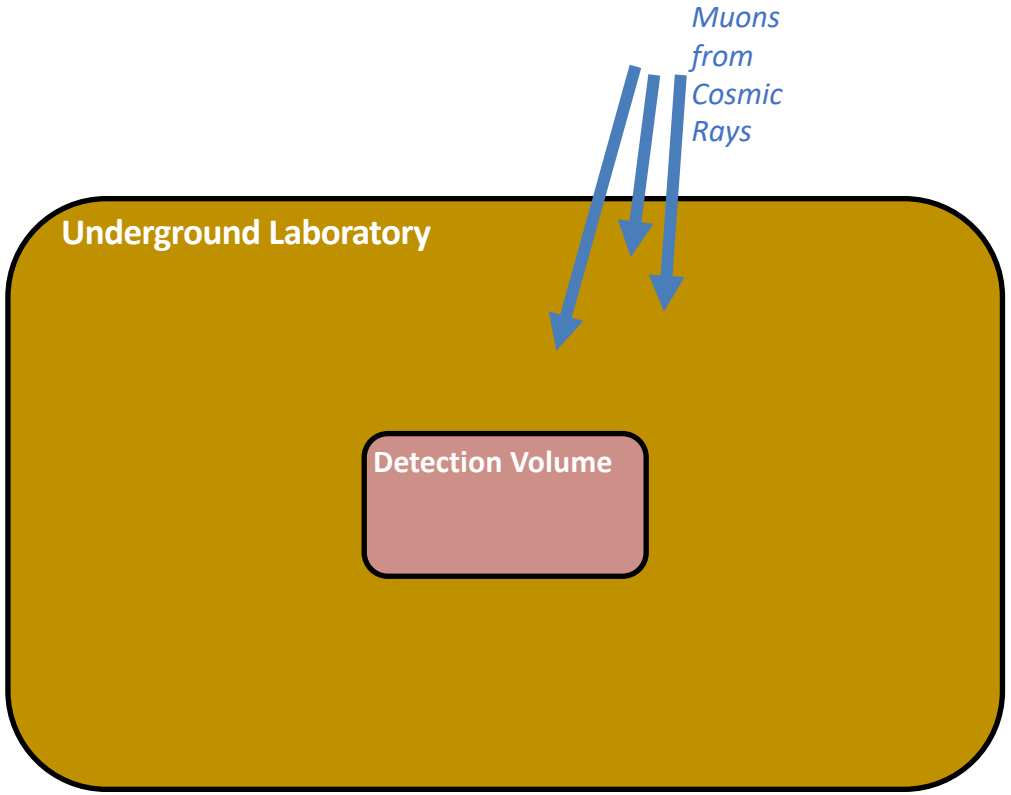


Detection Volume

What makes a signal in XENON1T

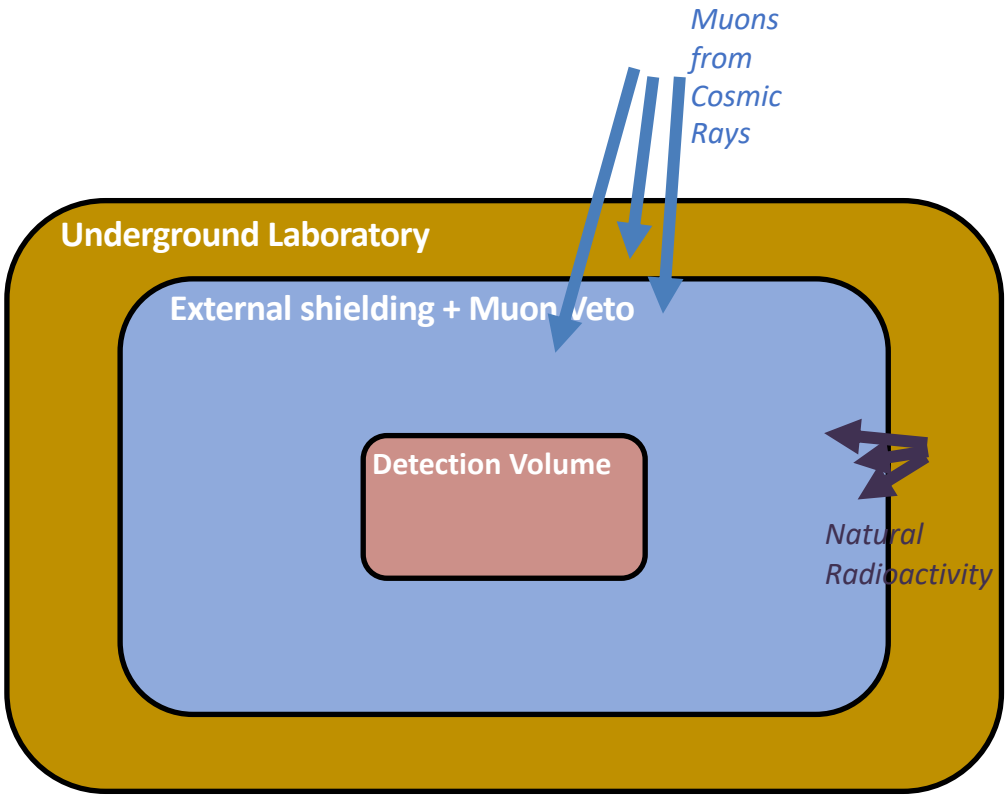
[1] Pass through > km of rock

- Cosmic Rays
- Neutrinos
- Dark Matter



What makes a signal in XENON1T

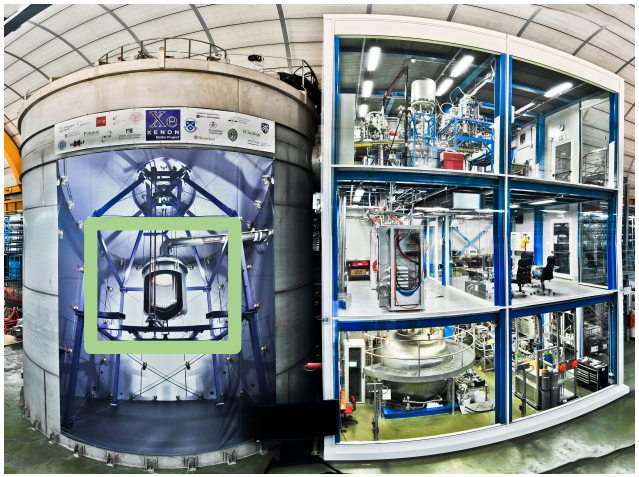
- Ambient radioactivity

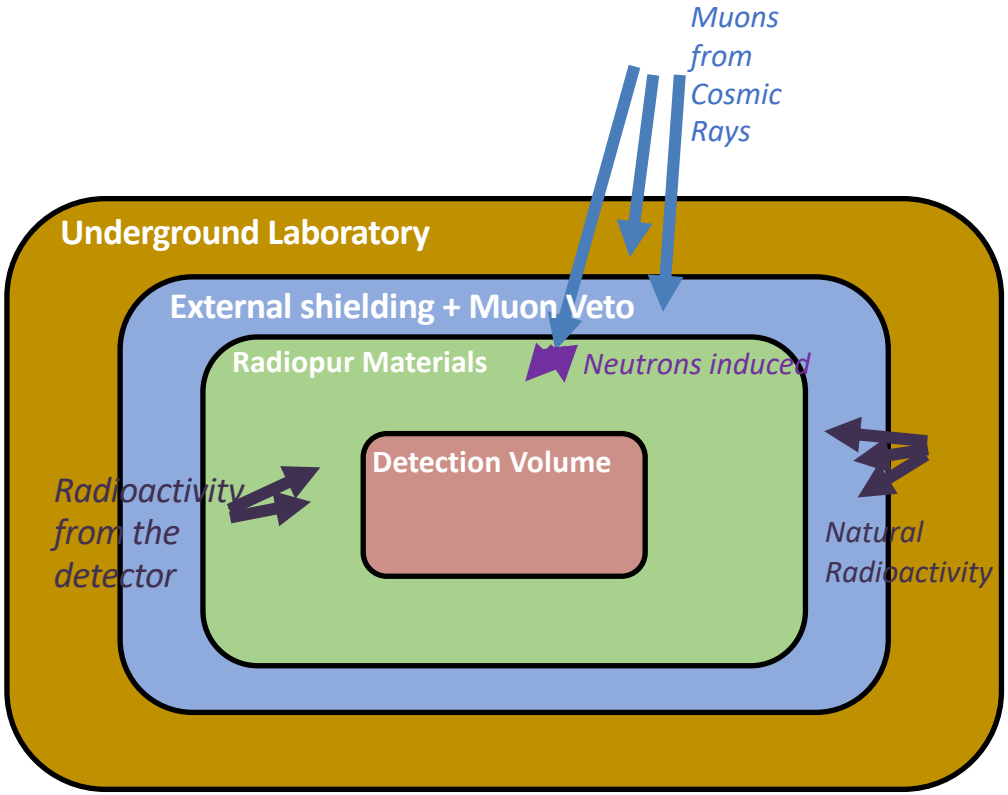


What makes a signal in XENON1T

[2] Pass through cm of metal and xenon

- Experiment radioactivity





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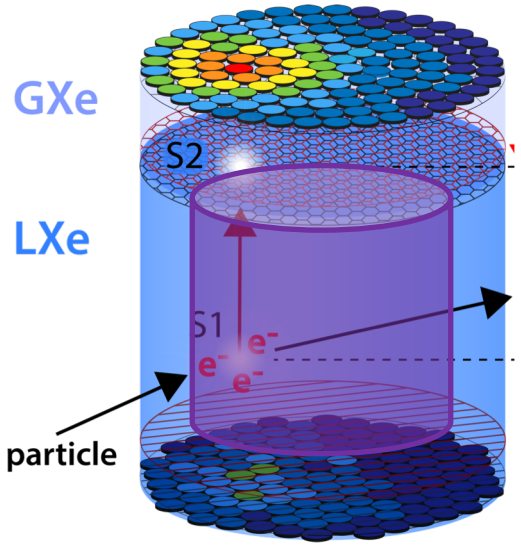
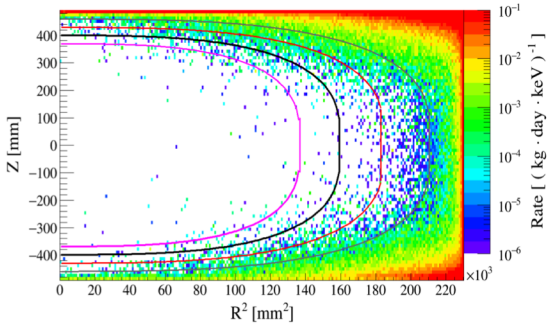
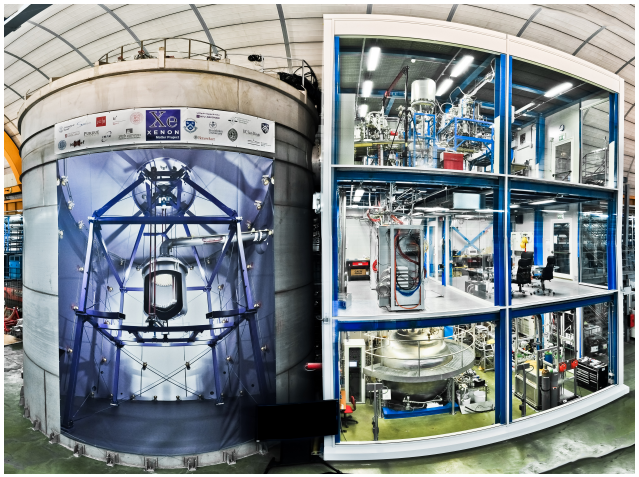
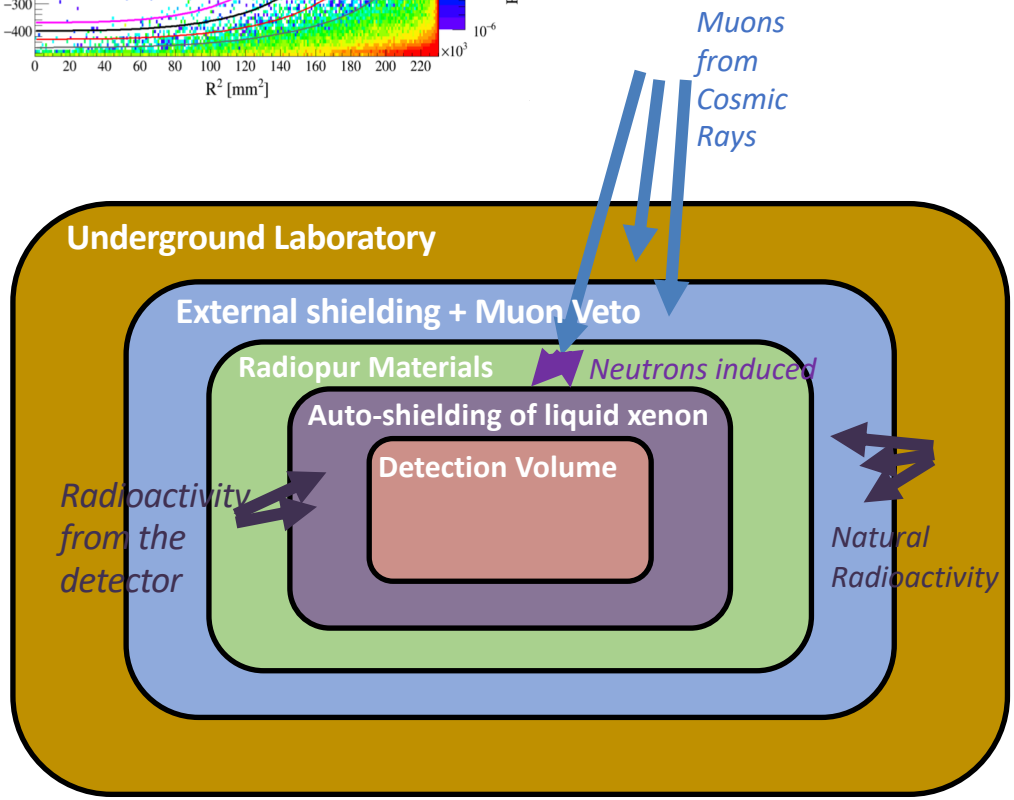


- Detector radioactivity







What makes a signal in XENON1T

- Internal radioactivity
  ^{222}Rn et ^{85}Kr
- Activation (after neutron generator data)

^{214}Pb, ^{85}Kr, ^{136}Xe, ^{133}Xe, ^{124}Xe (!)

Accounted for, different energies

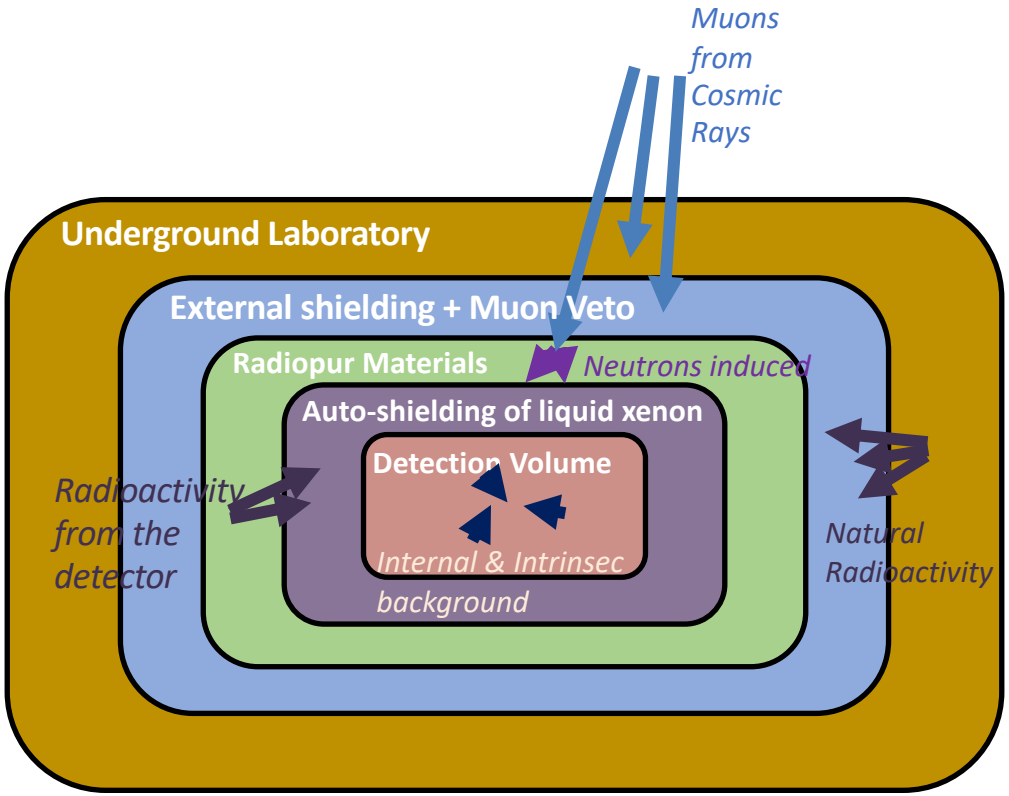
^{127}Xe, ^{37}Ar

$t_{1/2}$ ~ month, too short

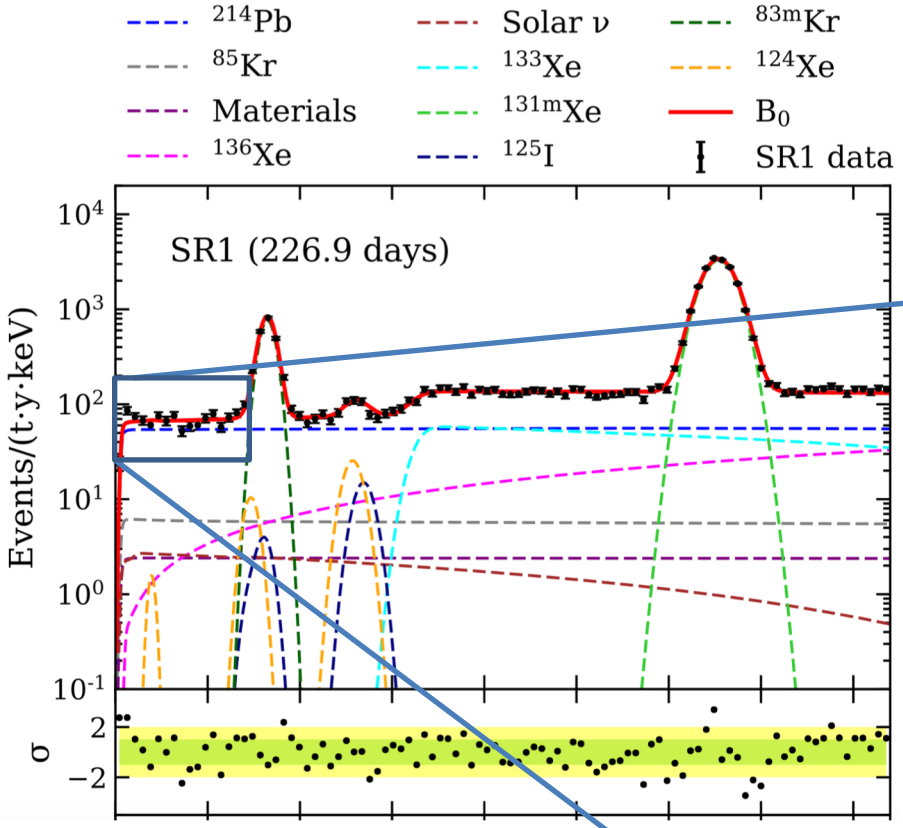
> 6L day air leak not seen

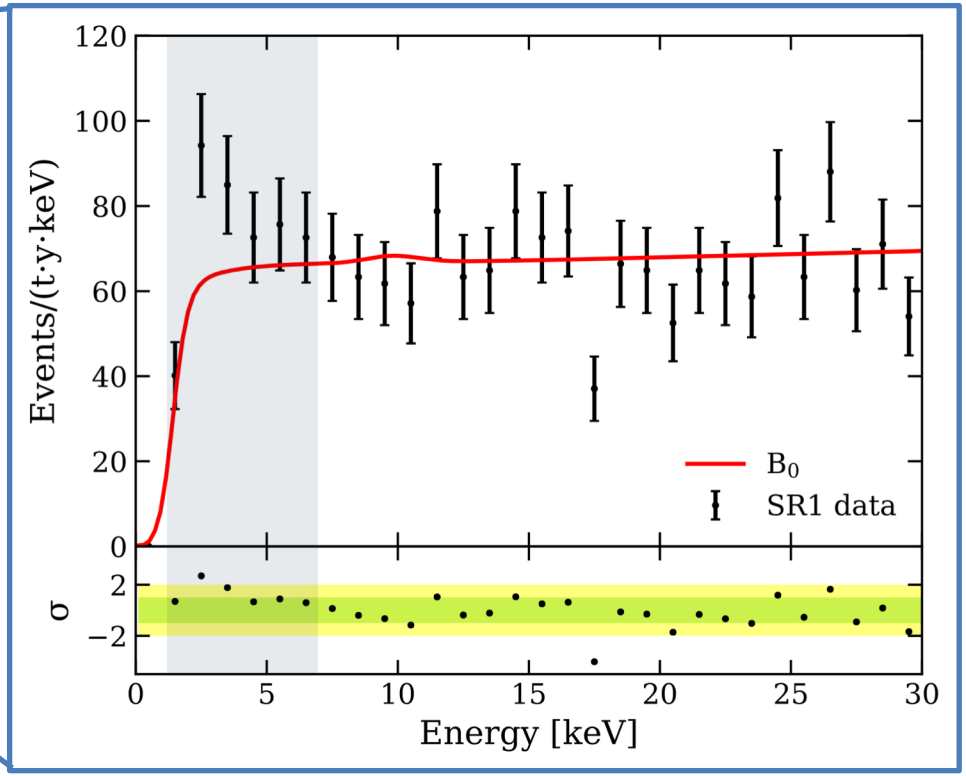
Tritium

...



Focus on the excess

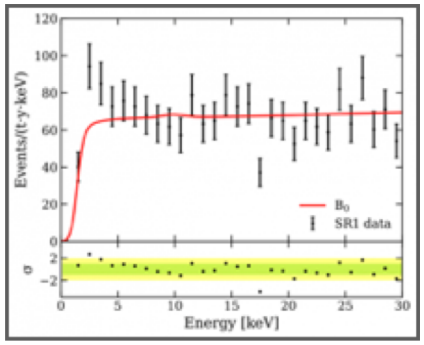


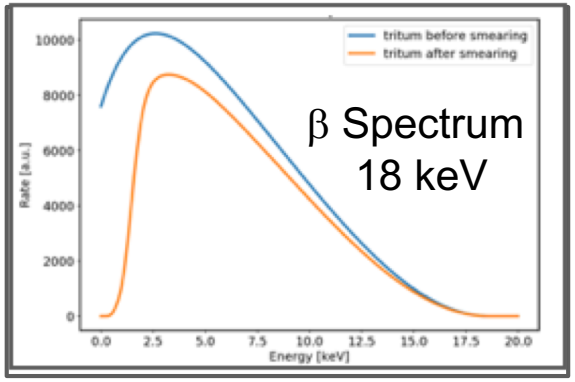


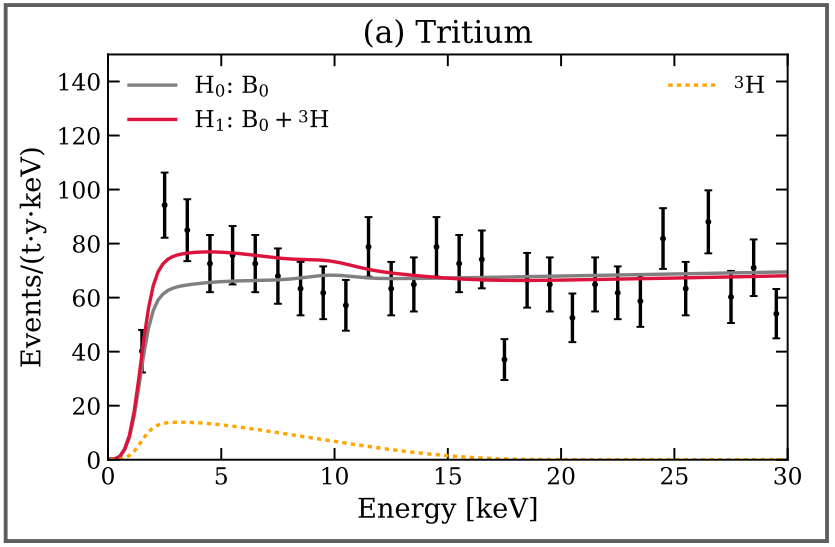
(76 +/- 2) events/(t·y·keV) in [1, 30] keV

Lowest background rate ever achieved in this energy range!

Tritium hypothesis







^{3}H half-life 12 . 3 years (too long to observe in SR1)

Best-fit tritium rate:

159 ± 51 events/(t · y · keV)

^{3}H:Xe concentration:

(6.2 ± 2.0)→ 10–25 mol/mol

fewer than 3 tritium atoms per kg of xenon!

Tritium favored over background-only at 3.2σ

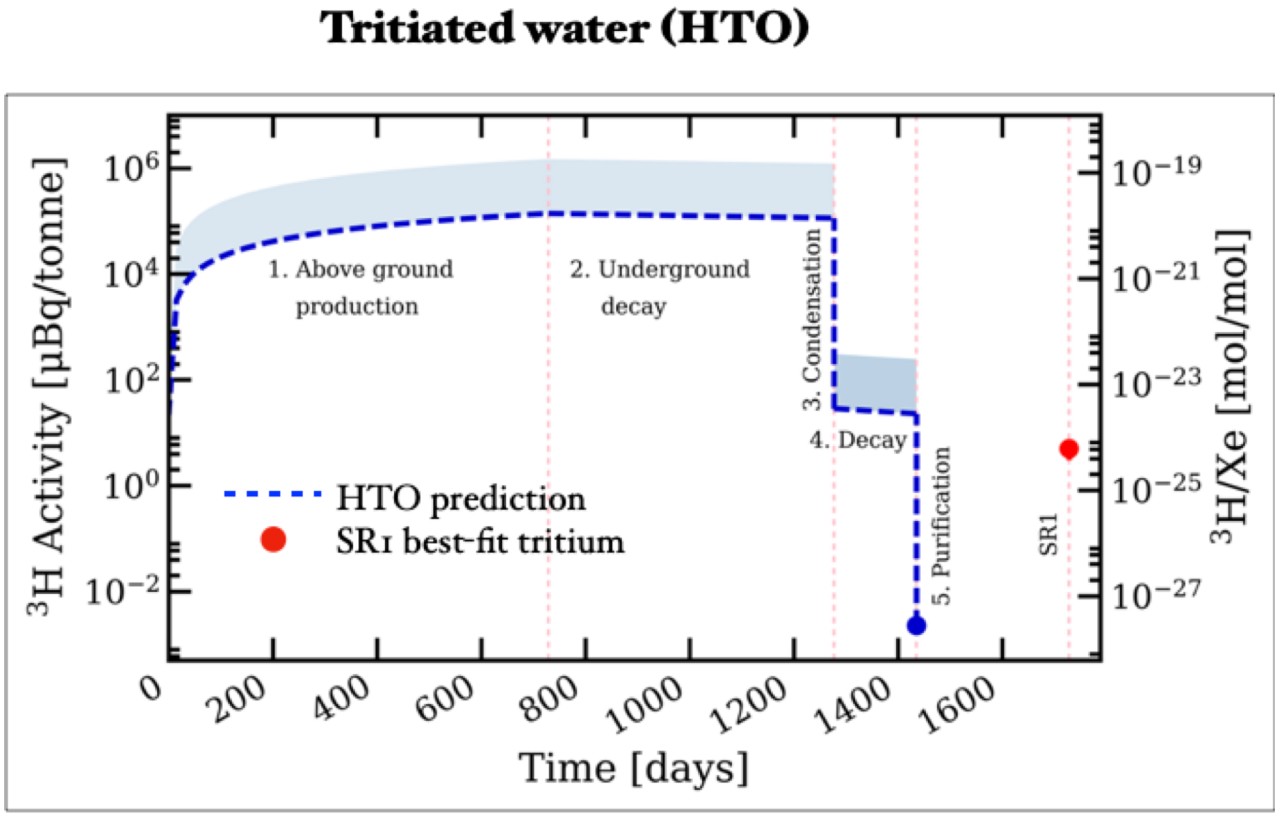
Tritium hypothesis

Cosmogenic activation of xenon: ~32 tritium atoms/kg/day (Zhang, 2016)

1 ppm water in bottles implies tritium forms predominately HTO.

Efficient removal (99.99%) in purification system (SAES getter with hydrogen removal unit)

From purification and handling, this component seems unlikely.

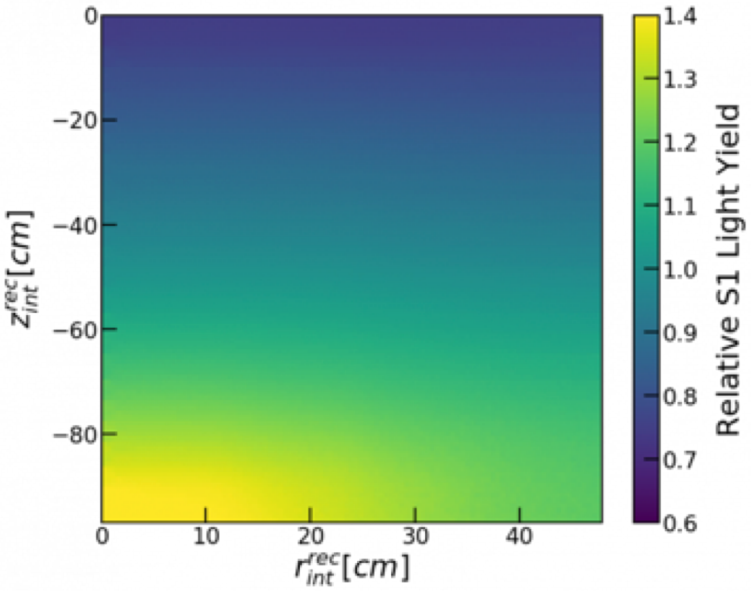


(note: tritium from activation While underground is negligible.)

Tritium hypothesis

atmospheric abundance 3H:H in H2O is 5 - 10 x 10-18 mol/mol *
Tritiated molecules can emanate into LXe target from water and hydrogen in detector materials in the form of HTO and tritiated hydrogen (HT).
emanation in equilibrium with removal.

Best-fit gives **60-120 ppb of (H_2O + H_2)** impurities



HTO

Our light yield implies **O(1) ppb H_2O**

HTO emanation seems unlikely based on LXe purity arguments.

Tritium hypothesis

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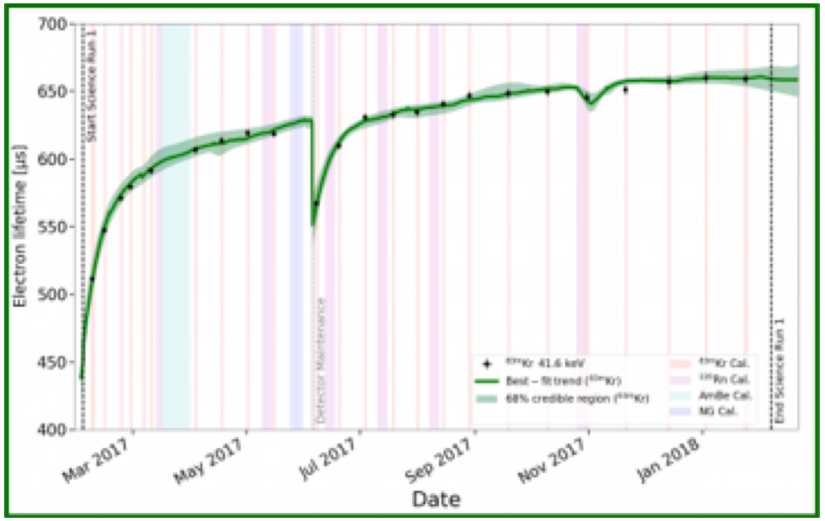
HT

- Assume same abundance HT in H2 as HTO in H2O (no direct measure)
- No direct measure, but good electron lifetime indicates O(0.1 ppb) O2-equivalent impurities

Requires 100x more H2 than other molecules

HT emanation seems unlikely based on LXe purity arguments.



Tritium hypothesis

HOWEVER

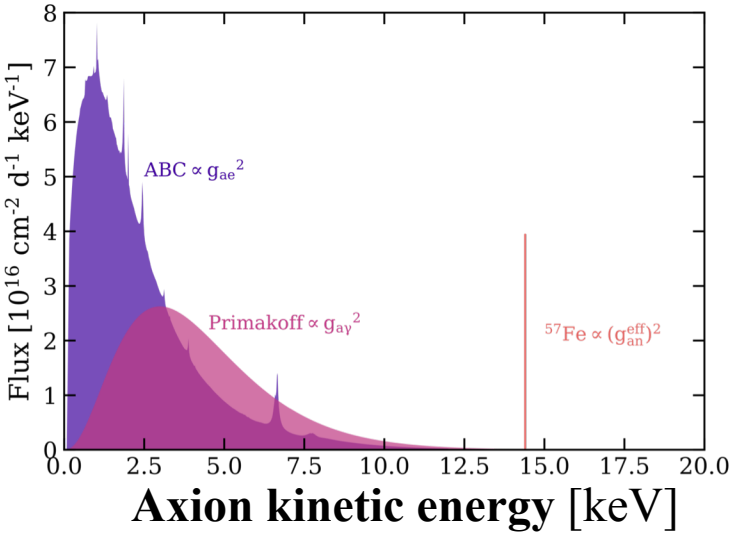
Many unknowns about tritium in a cryogenic LXe environment

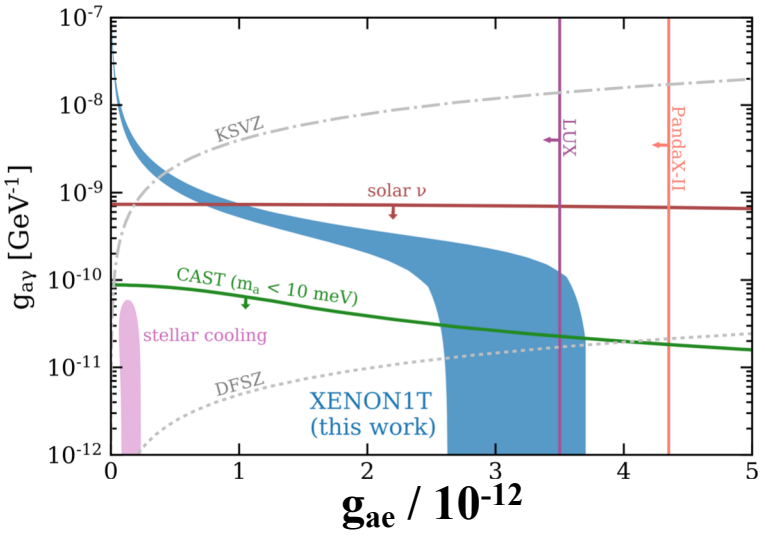
- Radiochemistry, particularly isotopic exchange (formation of other molecules?)
- Diffusion properties of tritiated molecules
- Desorption and emanation
- For HT, no direct measure of either abundance or H_2 concentration.

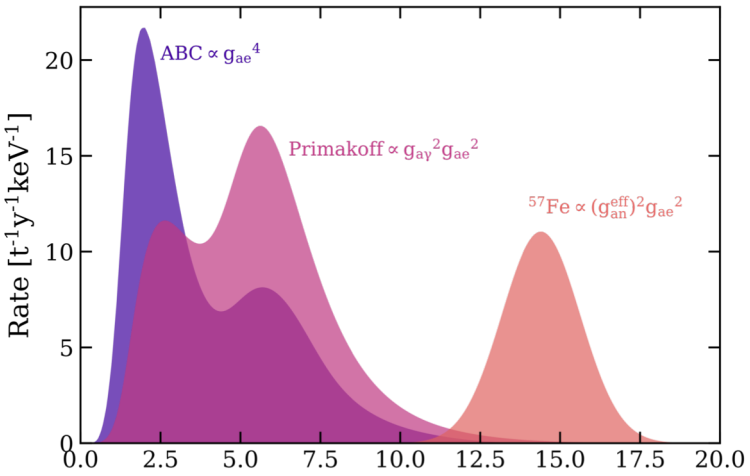
We can neither confirm nor exclude the presence of tritium.

- We consider it an hypothesis, but don't include it in the background model.
- Report additional σ results (but not constraints on signal parameters) with tritium included as a background component.

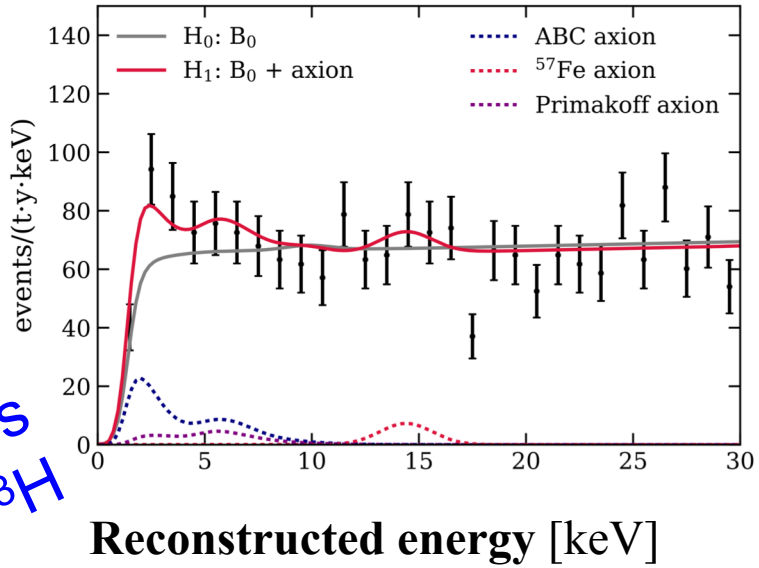
Solar Axion



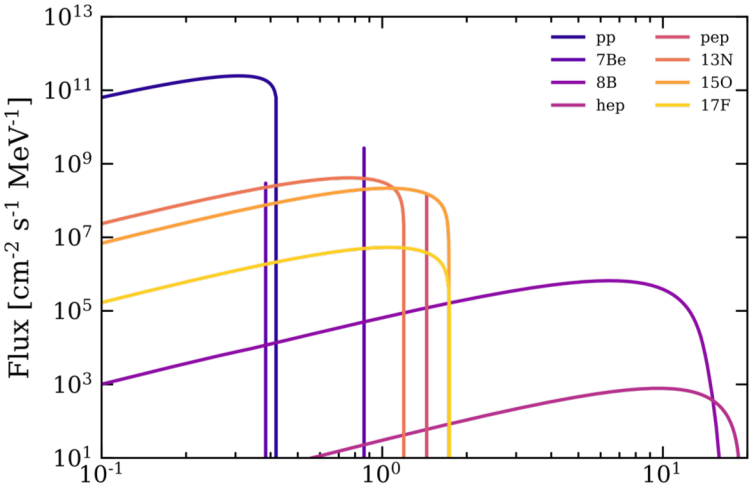




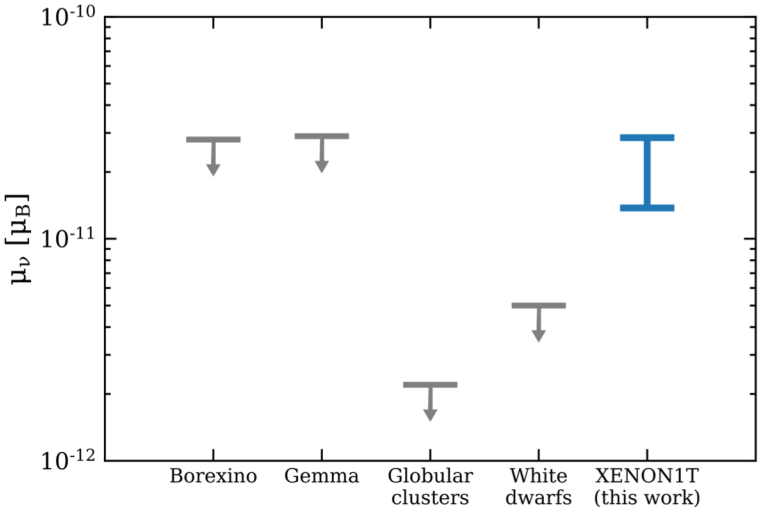
3.5 σ excess
2.1 σ with ^{3}H

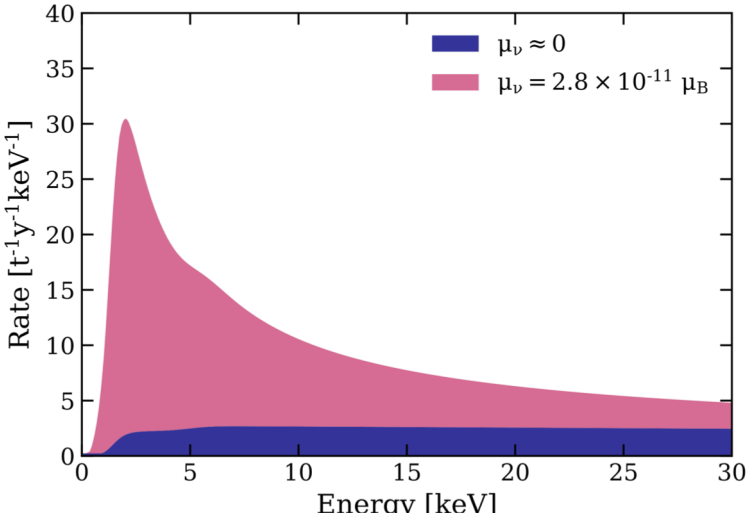


Neutrino Magnetic Moment



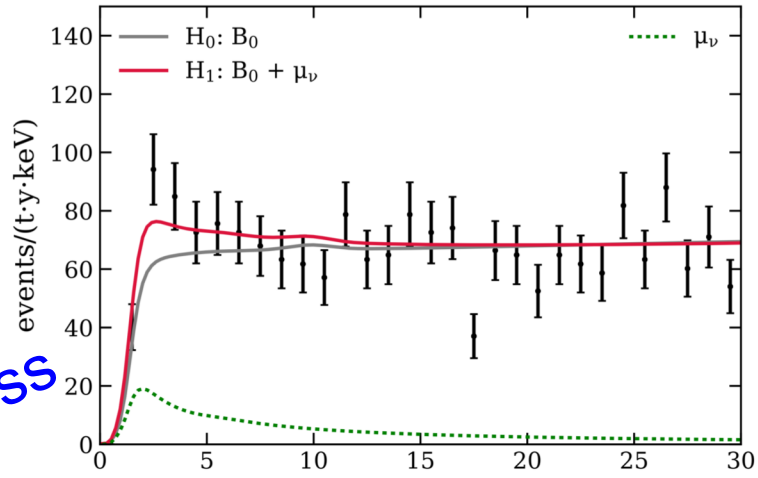
Neutrino kinetic energy [MeV]





Reconstructed energy [keV]

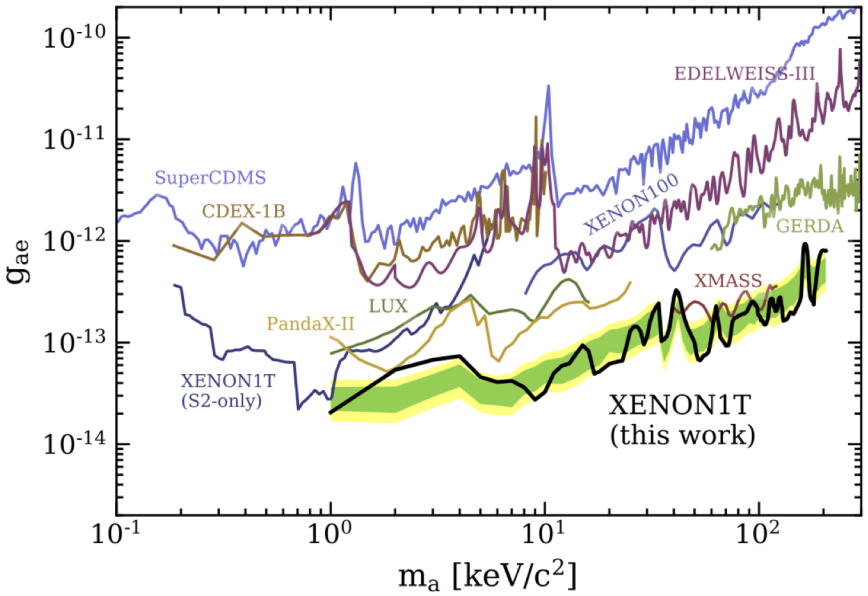
3.2 σ excess



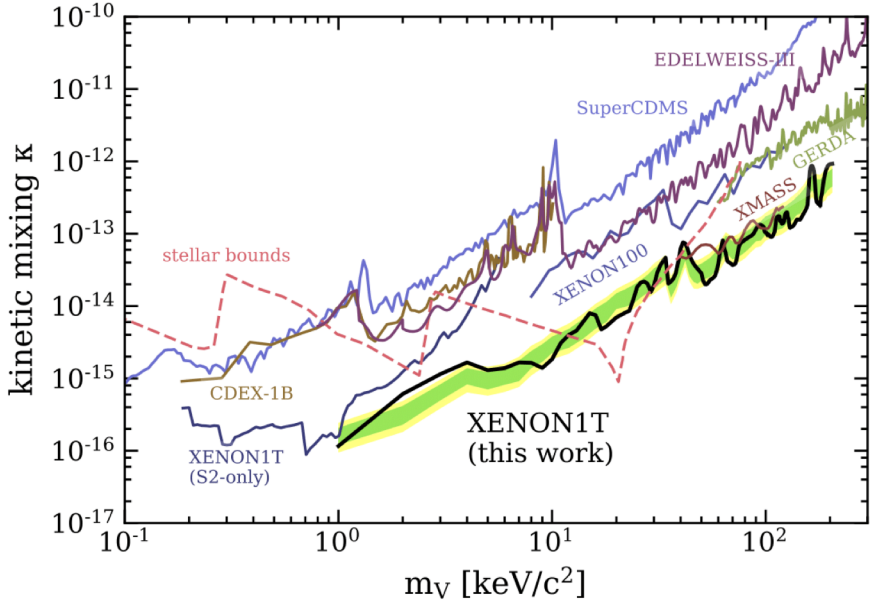
Reconstructed energy [keV]

Bosonic dark matter

Axion-like particle



Dark photon



XENONnT is coming !

x3

Active volume

1/6

Background

commissioning ongoing

It will be interesting to see what XENONnT and others find!

XENONnT is coming !

XENONnT will discriminate axions from tritium with
~ few months of data