Update from the
XENON dark matter project

OBSERVATION OF EXCESS ELECTRONIC-RECOIL EVENTS IN XENON1T

PRD 102, 072004 (2020)
Laboratori Nazionali del Gran Sasso
Italy
Laboratori Nazionali del Gran Sasso
Italy
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)
This talk

Search for excess above known BGs

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

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

The excess is here

Cannot explain the excess

Adam Brown | adam.brown@physik.uni-freiburg.de
IT COULD BE A NEW BACKGROUND
Tritium

Beta decay
Q value 18.6 keV
Half life 12.3 years

3.2σ over background
(159 ± 51) ev/keV/t/yr
< 3 atoms $^3$H / kg Xe

Where from?
Emanation from detector materials neither confirmed nor ruled out
Tritium — possible origins

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

Where from?

Seems unlikely
Tritium — possible origins

Where from?

Emanation from detector materials?
Atmospheric abundance \((5-10) \times 10^{-18} \text{HTO/H}_2\text{O}\)
Best fit \(\leadsto 60-120\) ppb \(\text{H}_2\text{O}+\text{H}_2\)

Can neither confirm nor rule out tritium

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

\textbf{HTO}

Light yield \(\leadsto O(1)\) ppb \(\text{H}_2\text{O}\)

\textbf{HT}

Electron lifetime (xenon purity) \(\leadsto <\) ppb \(\text{O}_2\)-equivalent impurities
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?
Search for a mono-energetic peak
Could be dark matter, e.g. axion-like particle or dark photon
Most significant at $2.3 \pm 0.2$ keV
No $> 3\sigma$ excess $\implies$ only report limits

**Mono-energetic peak: 3.0$\sigma$ over background (global)**
Neutrino magnetic moment

Mag. Moment: $3.2\sigma$ over background
with $^3\text{H}$: $0.9\sigma$ over background + $^3\text{H}$

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

$\geq 10^{-15} \mu_B \implies$ 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

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

We ignore the inverse Primakoff effect

**Reconstruction**

XENON1T resolution, efficiency

\[
geff = -1.19g_{an}^0 + g_{an}^3
\]

Adam Brown | adam.brown@physik.uni-freiburg.de
Solar axions

Solar axions only: $3.4\sigma$ over background
Axions + $^3$H: $2.0\sigma$ over background + $^3$H

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

(arXiv 1708.02111)
Tritium 3.2\(\sigma\)

\(\mu_\nu\) 3.2\(\sigma\)

Mono-energetic peak 3.0\(\sigma\)

Solar axions 3.4\(\sigma\)

Axions + 3\(^3\)H 2.0\(\sigma\)

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 % Gd₂(SO₄)₃

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

### 222Rn distillation
- Reduce Rn (²¹⁴Pb) from pipes, cables, cryogenic system
- New

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

→ Higher exposure and lower BG

→ Better resolution

Lower thresholds
XENOnT — watch this space

Excellent xenon purity achieved

Parameters
LXe mass: 8620 kg
O$_2$ outgassing: 0.08 mg/d, $\downarrow$ as $t^{-1}$
Filter efficiency: 60%

XENONnT now being commissioned
XENOnT — watch this space

Excellent xenon purity achieved

Expect to know more with few months of data