SOMETHING IS (NOT) UP AT XENON1T

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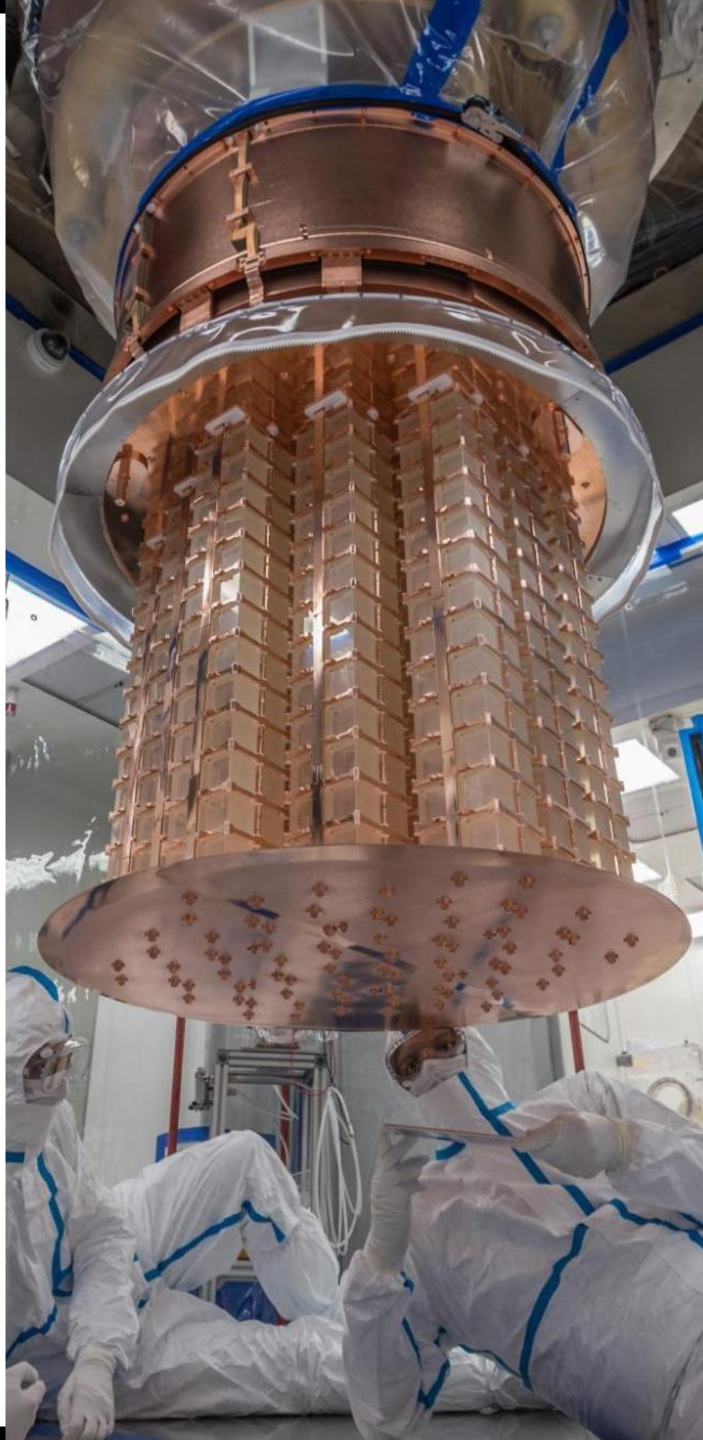
GRADUATE SYMPOSIUM 15/03/2021

UNIVERSITY OF OXFORD



DARK MATTER

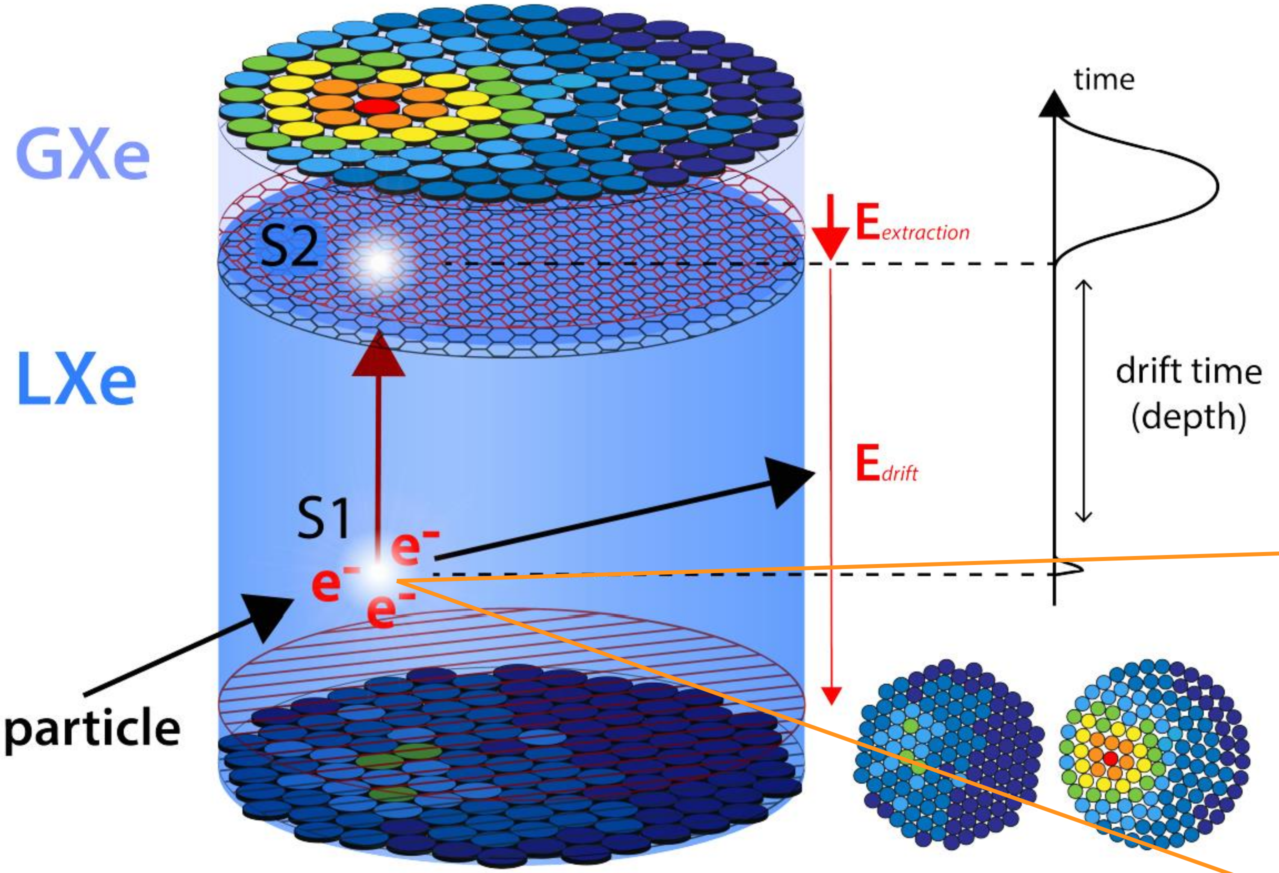
- Astrophysical and cosmological evidence suggests that most of the matter content in the Universe is made up of dark matter

- Several dark matter particle candidates have been proposed but all have thus far eluded direct detection.

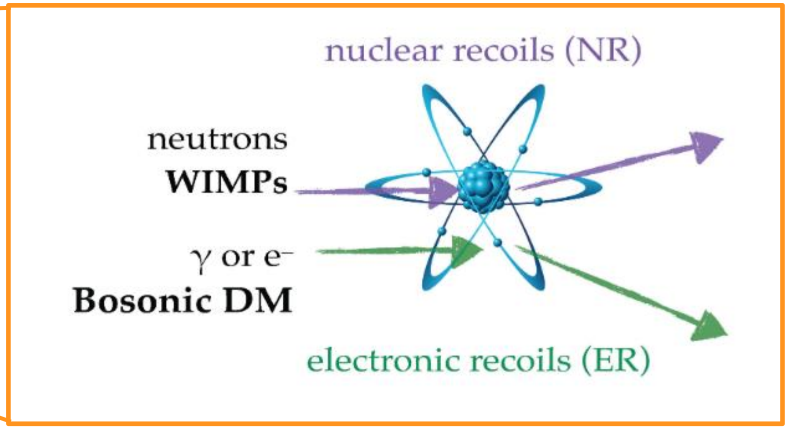
WHAT IS XENON1T

- XENON1T experiment operated underground at the INFN Laboratori Nazionali del Gran Sasso (LNGS) from 2016 to 2018
- Primarily designed to detect weakly interacting massive particle (WIMP) dark matter.
- Also sensitive to alternative dark matter candidates and other BSM

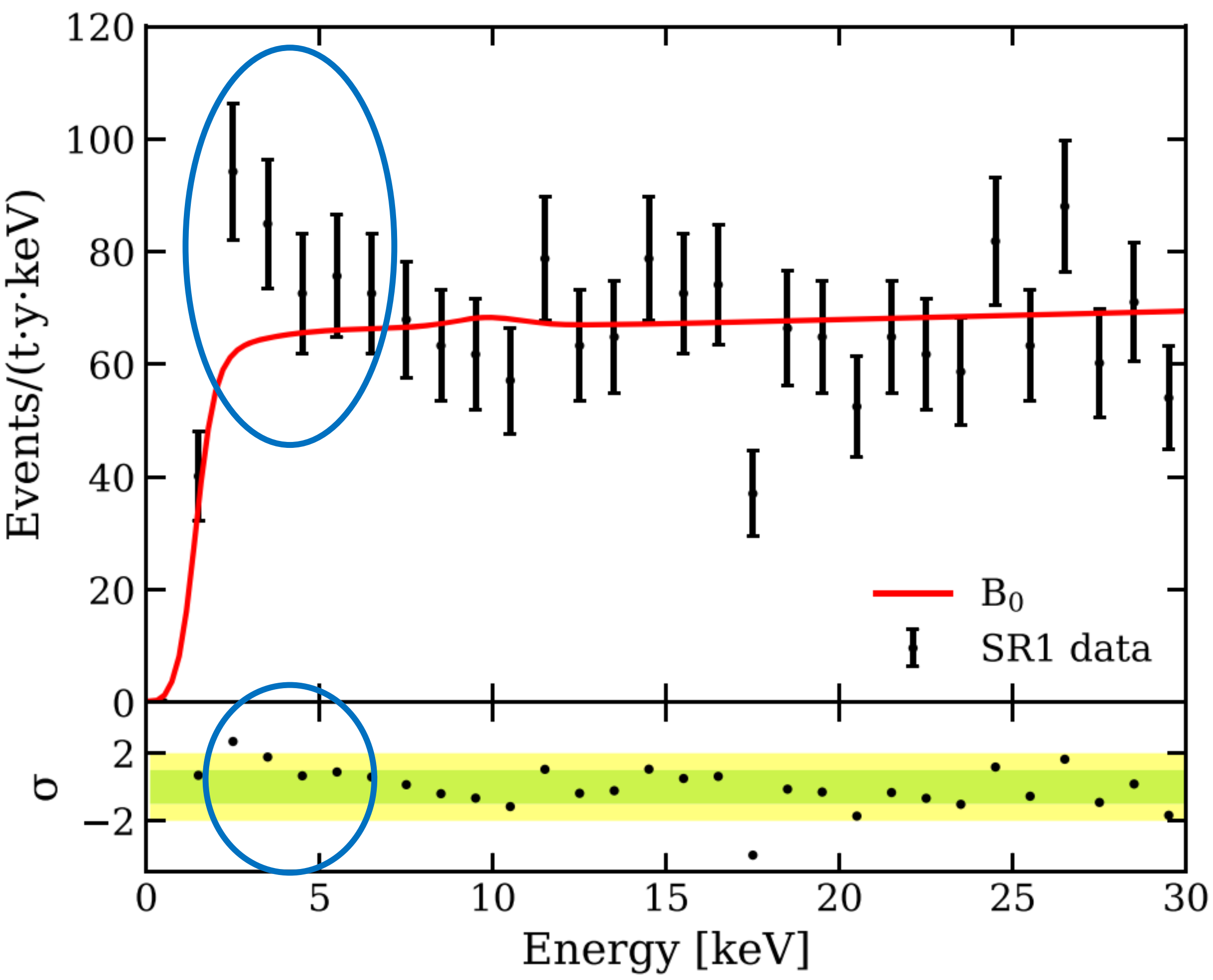
WHAT XENON1T WAS BUILT FOR

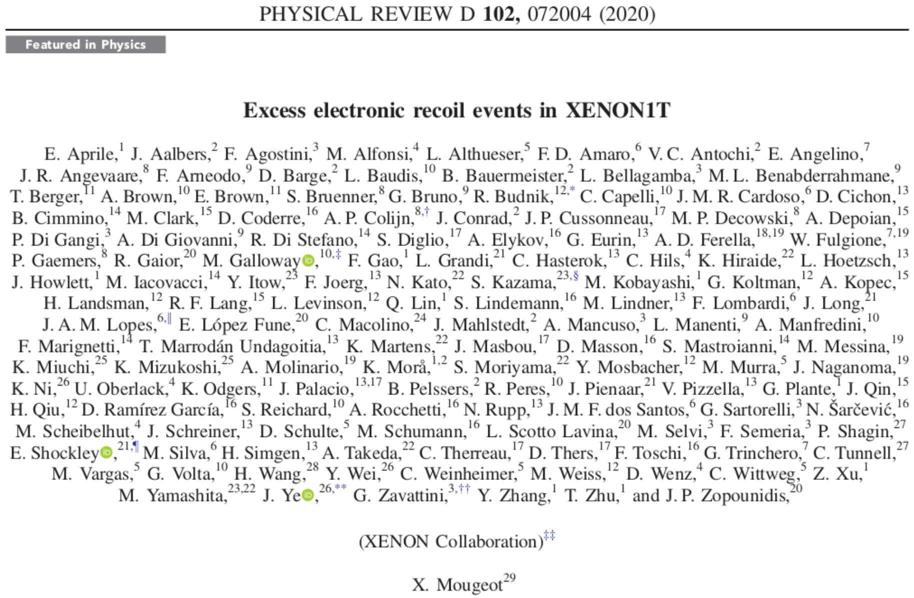


- Dual-phase TPC: liquid xenon 2.0-tonne active target with a gaseous phase on top + 2 arrays of PMTs
- Signal: prompt scintillation (S1) and delayed electroluminescence (S2)
- S2/S1 ratio used to distinguish nuclear recoils (NRs) from electronic recoils (ERs)



AN ELECTRON RECOIL ECCESS





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Featured in Physics

Excess electronic recoil events in XENON1T

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(XENON Collaboration)[‡‡]

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- 1–7 keV: 285 ER events observed in the data VS expected 232 ± 15 events from background only (3.3σ Poisson fluctuation)

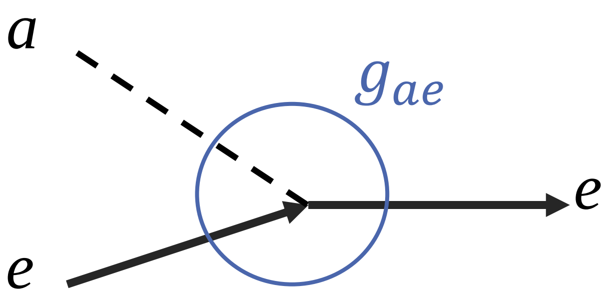
WHAT'S HAPPENING?

Four hypothesis consistent with signal type:

1. Solar Axions
2. Solar Neutrinos with anomalous magnetic moment
3. Dark matter bosons (Heavy axions or Dark photons)
4. Tritium background

SOLAR AXIONS

- 1977 Peccei and Quinn: postulate new field as solution to the strong CP problem
- Wilczek-Weinberg realize Peccei-Quinn field gives rise to new boson they call axion
- Axions produced in the Sun could produce electron recoil signal with energies in the keV range via axio-electric effect



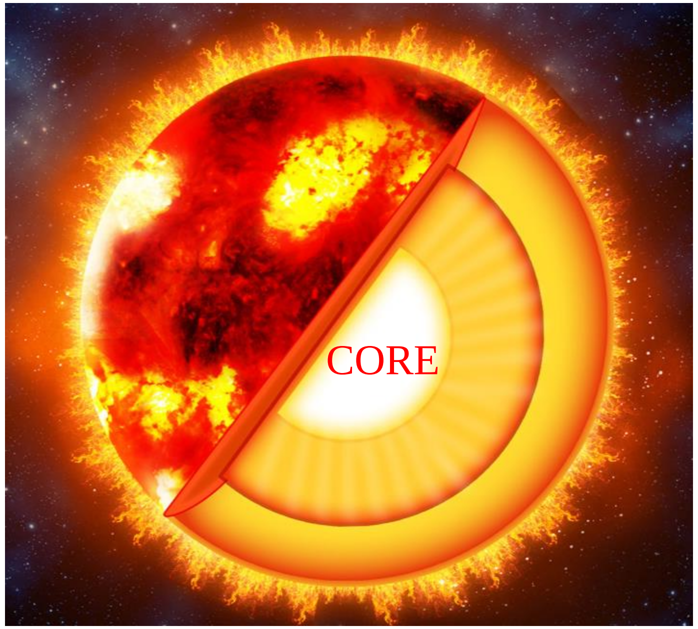
AXIO-ELECTRIC EFFECT

Peccei

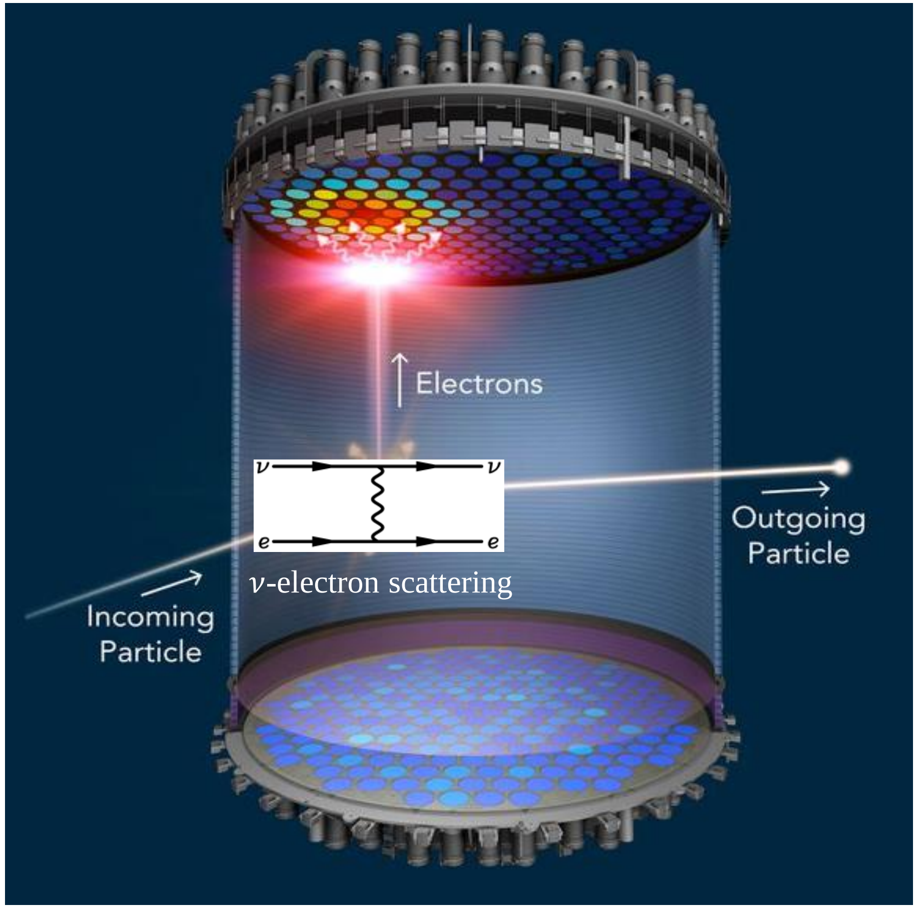
Quinn

ENHANCED MAGNETIC MOMENT SOLAR NEUTRINOS

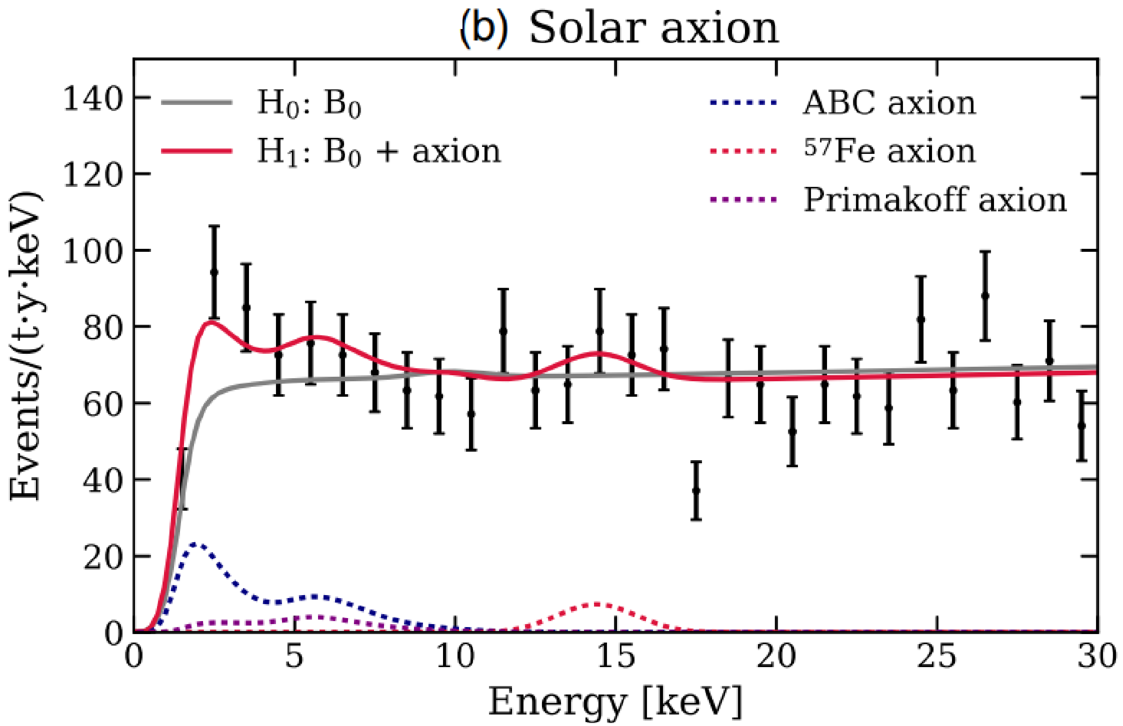
- Enhanced magnetic moment would increase the neutrino scattering cross sections at low energies
- $\mu_\nu \sim 7 \times 10^{-11} \times \mu_B$
- SM $\mu_\nu \sim 10^{-20} \times \mu_B$ for massive neutrinos (10^{10} times smaller)

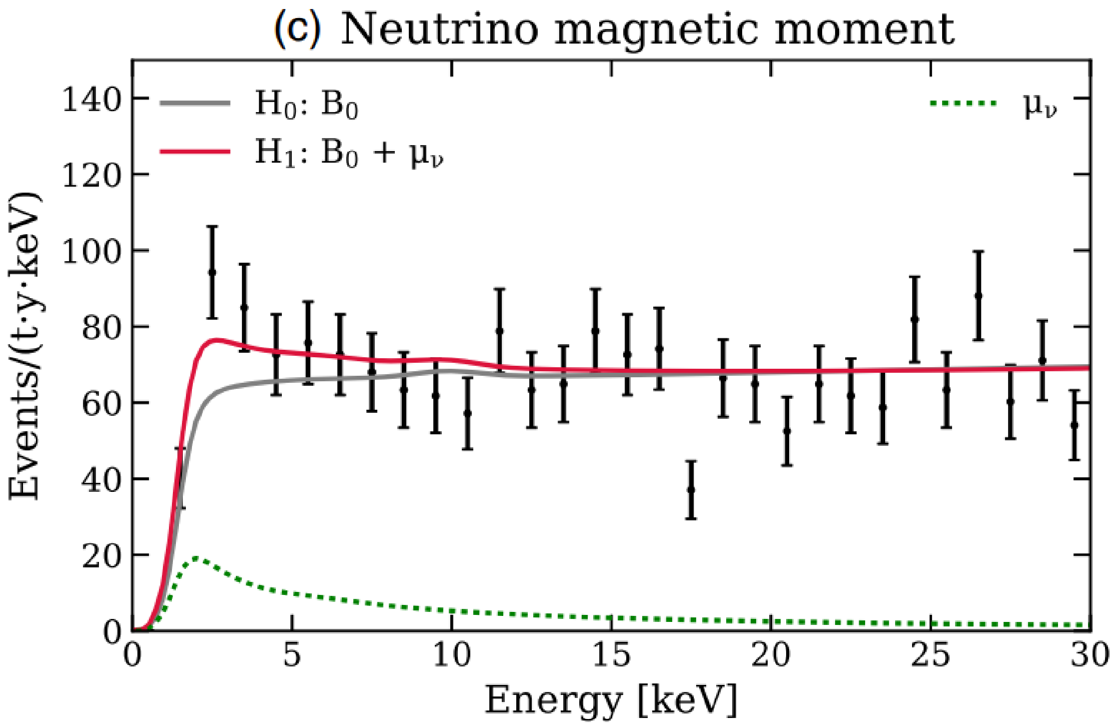


ν flux



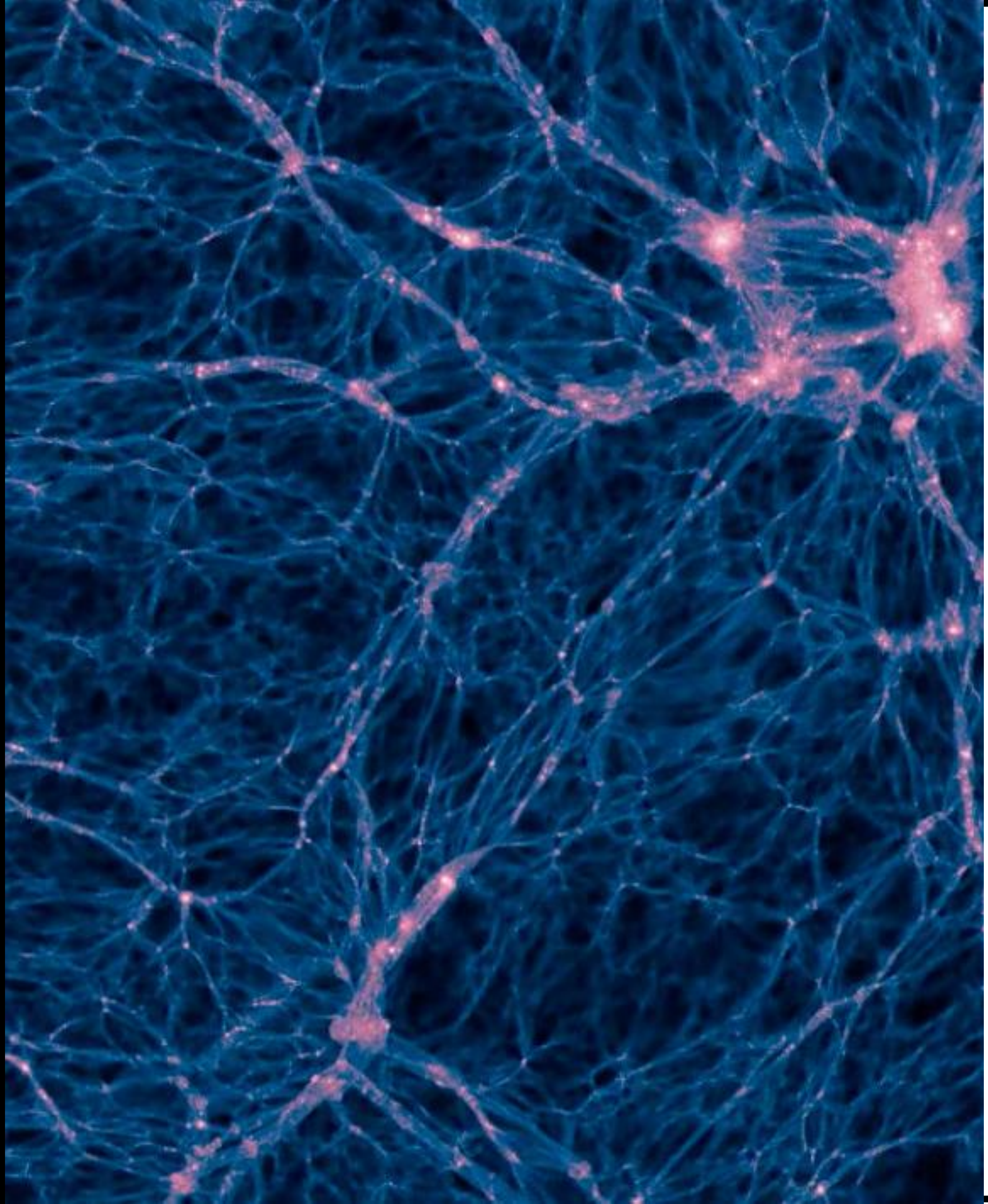
SOLAR RESULTS





- Fits over background:
  - LEFT Solar Axions: favored 3.4σ
  - RIGHT Neutrinos with enhanced magnetic moment: favored 3.1σ

- NOTE: Result is in strong tension with indirect constraints from analyses of white dwarfs and globular clusters



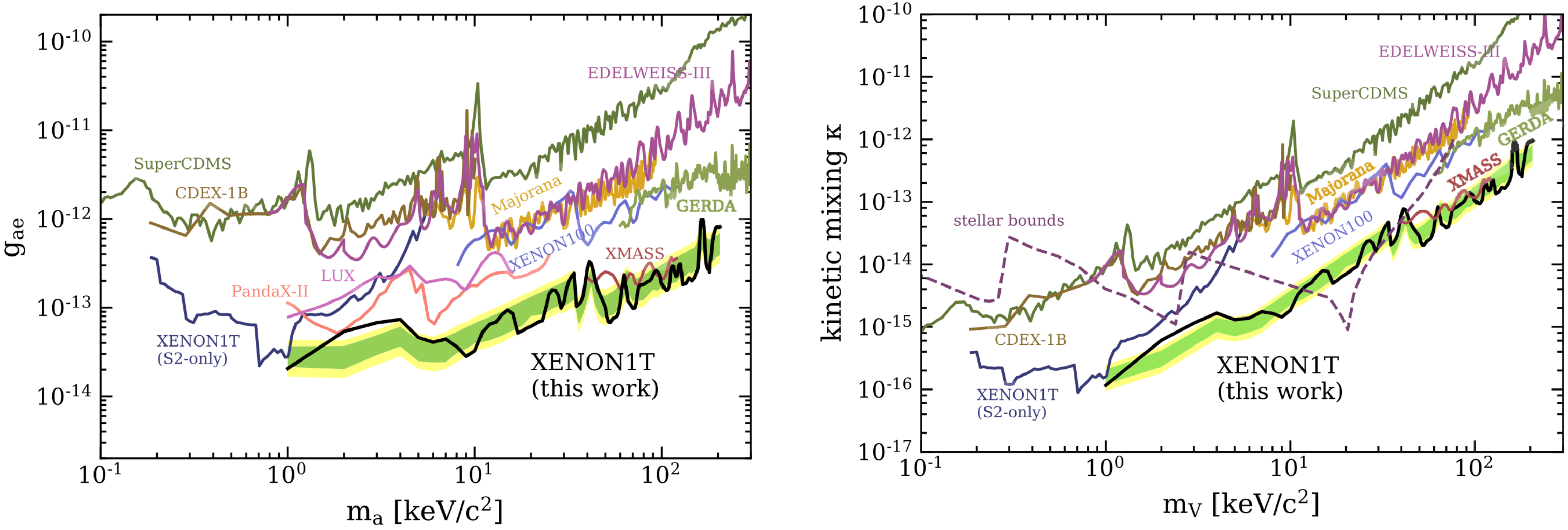
BOSONIC DARK MATTER?

1. Axion-Like Particles (ALPs)
   - Pseudoscalar bosons like QCD axions
   - Higher masses, but do not solve the strong CP problem

2. Dark photons:
   - Vector bosonic dark matter
   - Can couple weakly with SM photons through kinetic mixing

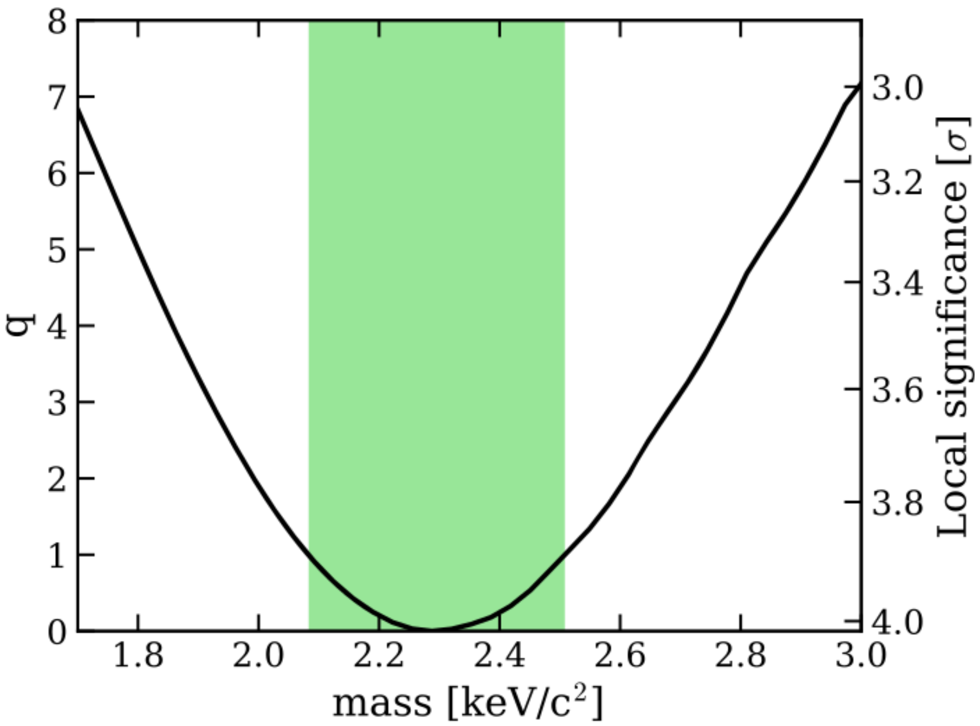
- Expected signal: mono-energetic peak at the rest mass of the particle

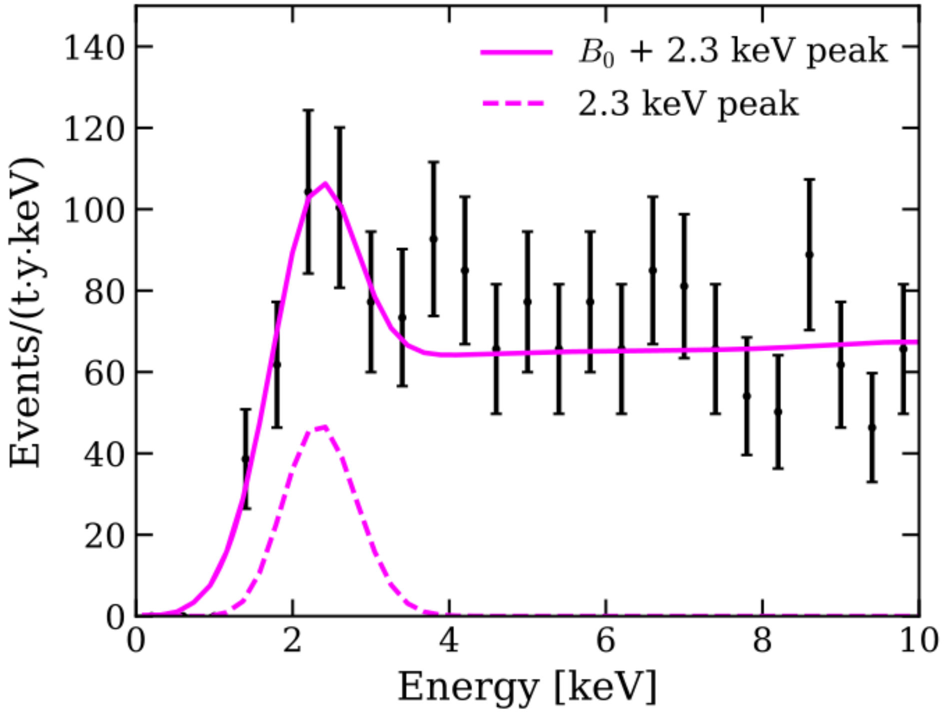
DARK MATTER RESULTS



- Masses between 1 and 210 keV/c^2 : No global significance over 3σ over the background model
- Set upper limit on the couplings g_{ae} (axion-electron coupling strength) and κ (kinetic mixing strength between photons and dark photons)
- Most stringent constraints for most mass values considered

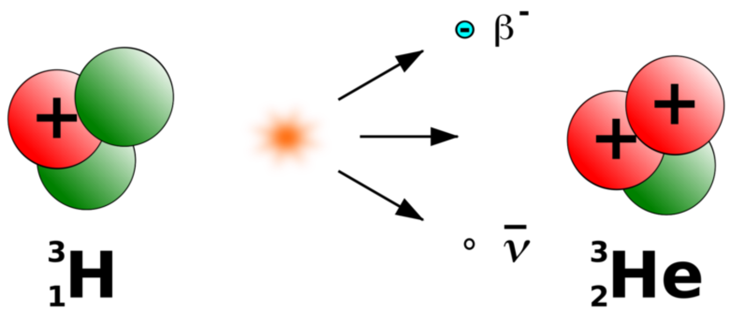
DARK MATTER RESULTS

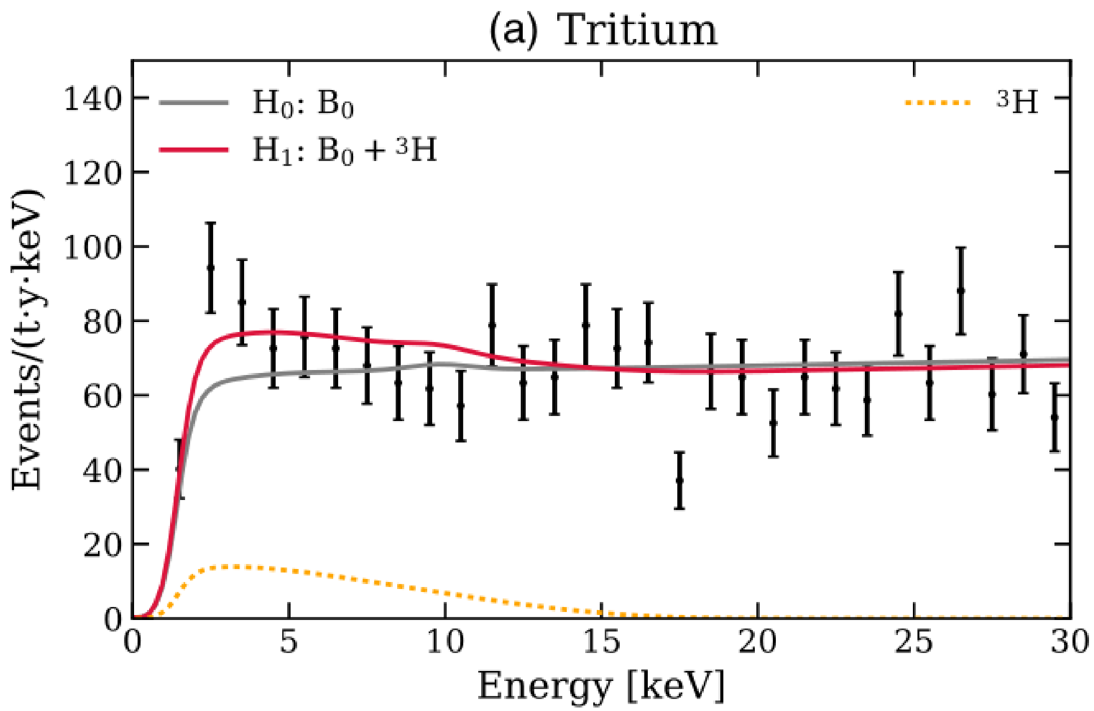




- Look for general peak not considering the type of particle
- Masses allowed to vary freely between 1.3 and 3.3 keV/c^2
- Favored mass value of 2.3$\pm$0.2 keV/c^2 (68% C.L.) with a 3.0σ global (4.0σ local) significance over background

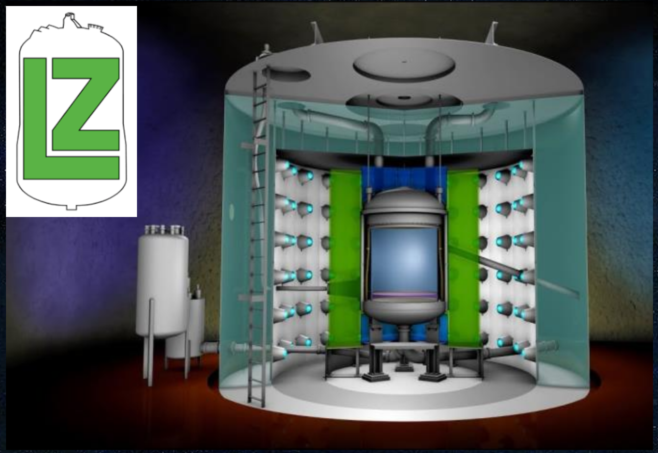
DON'T GET TOO EXCITED: IT MIGHT BE BORING TRITIUM



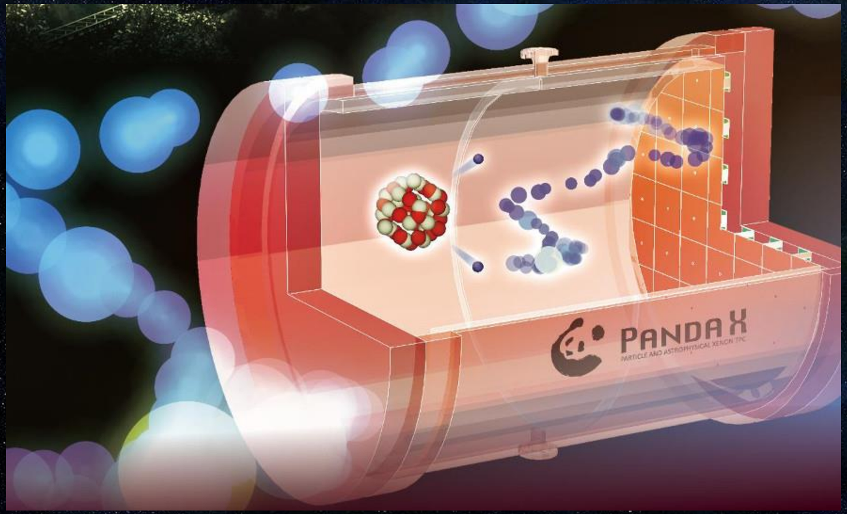


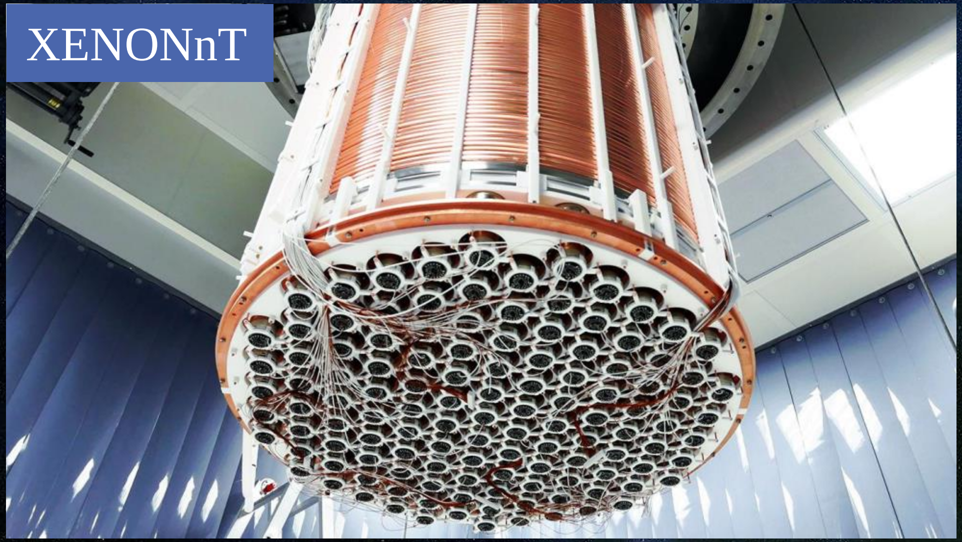
- Tritium expected to be present in the detector
- β decay of tritium has similar spectrum to that observed
- Very low concentration required to account for the excess
- $O(10^{-25} mol/mol)$ of tritium 3.2 σ favored over background
- Currently no way to discard Tritium hypothesis with current sensitivity levels

CONCLUSIONS: TOO EARLY TO TELL



- 3.3σ anomaly is interesting but no hypothesis is currently sufficiently favored to claim a discovery
- Next-generation detectors will need to investigate

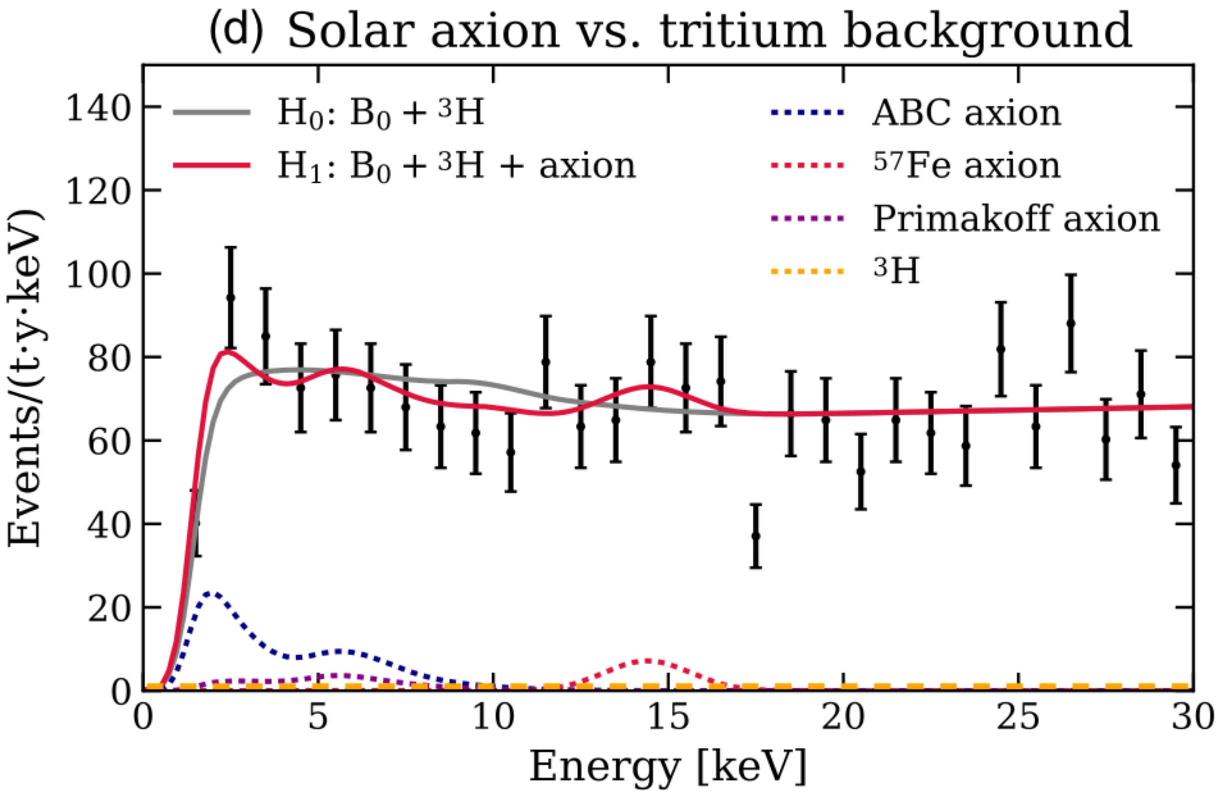




THANK YOU!

BACK-UP

NEW RESULTS (CONSIDERING TRITIUM)



- Unconstrained tritium component was added to the background model: null hypothesis is $^3H + B_0$
- Solar axion signal: still preferred in this test, but significance is reduced to 2.0σ
- Neutrino with anomalous magnetic moment: significance reduced to 0.9σ