Radiogenic neutron background predictions in DEAP-3600 and in situ measurements

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TAUP 2017
Sudbury, Canada

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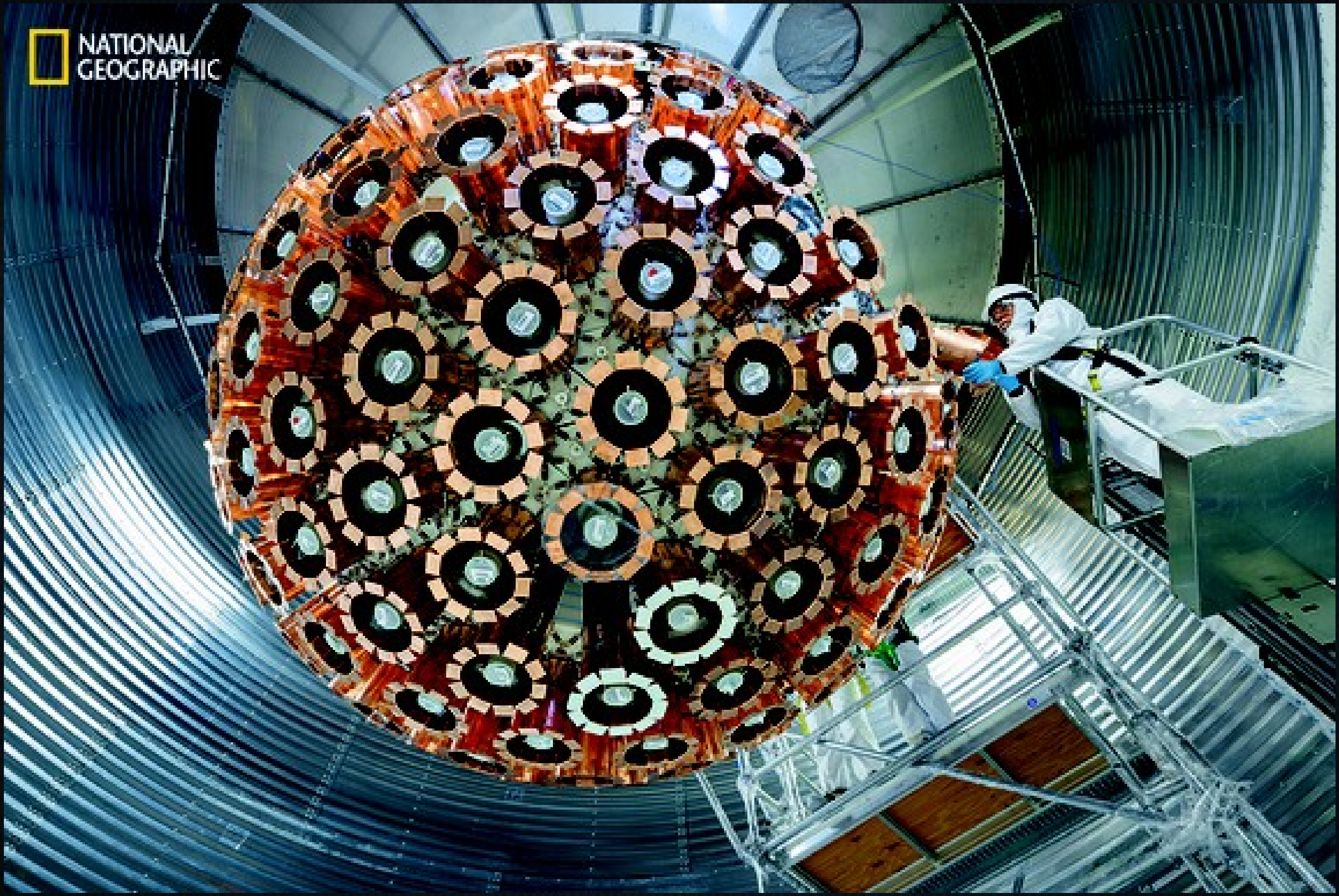
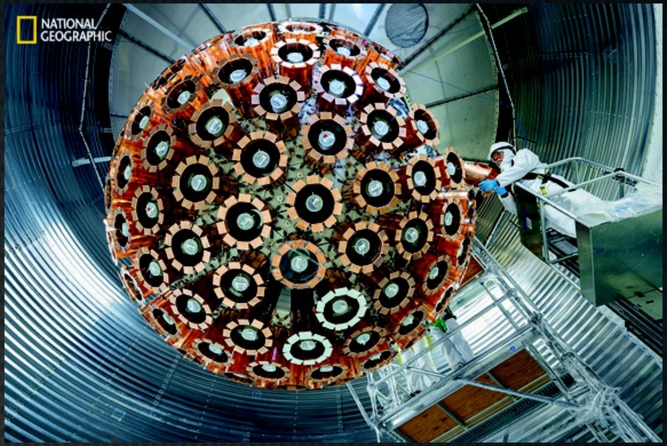
DEAP-3600



DEAP-3600

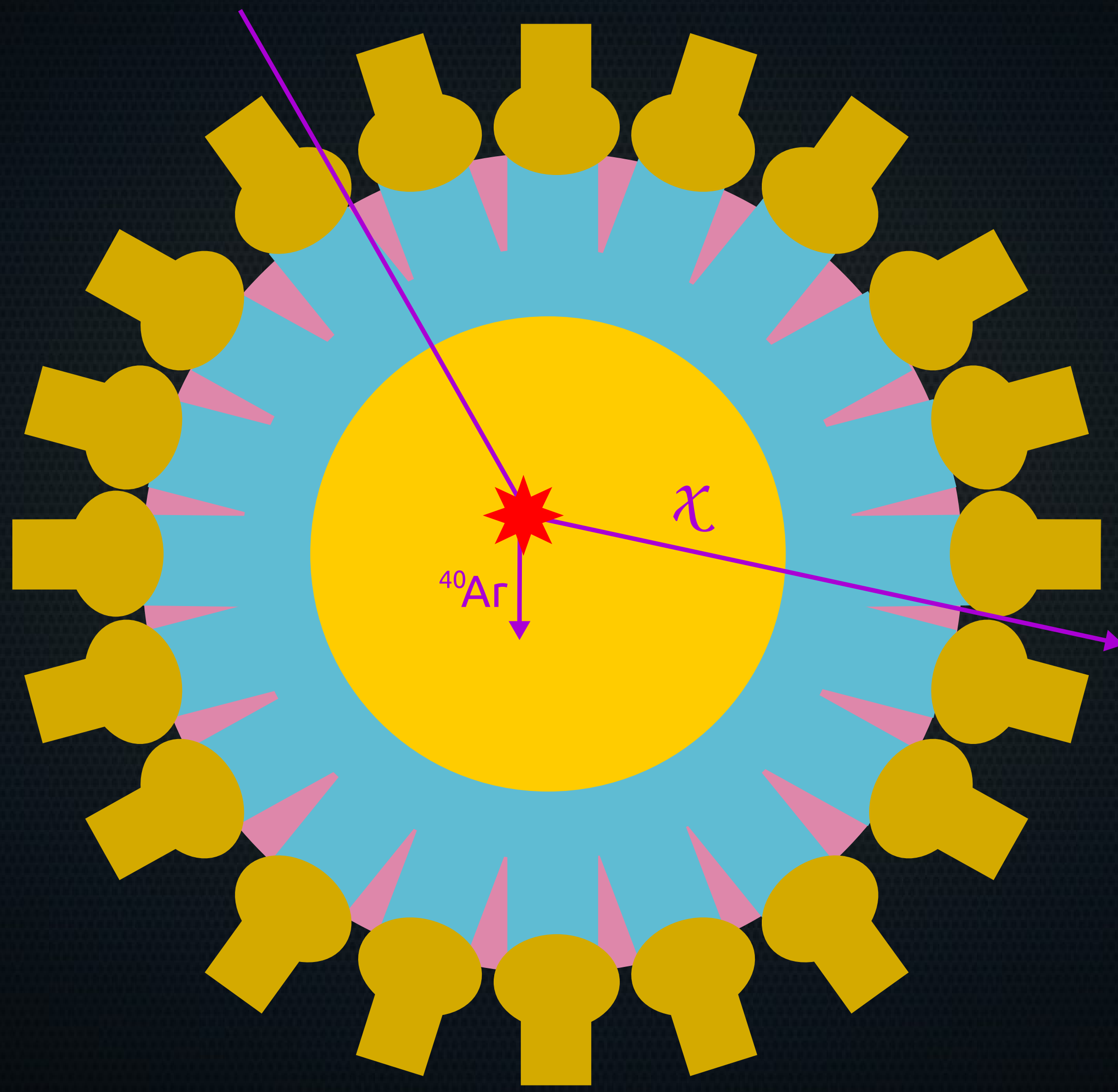
- Located at SNOLAB
- 3.3 tonnes of LAr
- 255 PMTs
- 50 cm acrylic light guides
- Insulation and filler foam between light guides



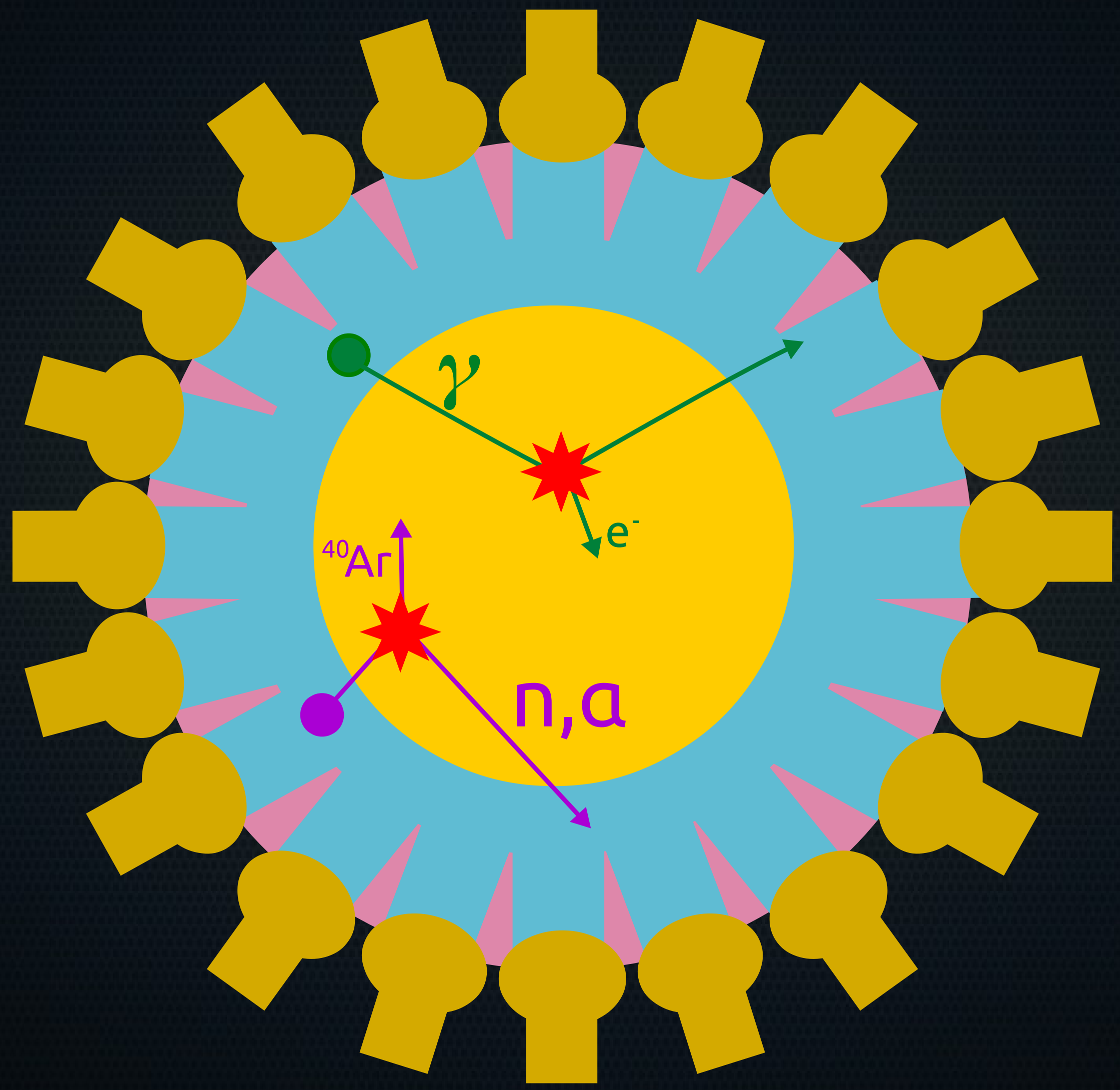
See also:

- General talk by M. Boulay (Tues. 9:30am)
- Energy reconstruction talk by S. Langrock (Mon 2:00pm)
- Overall backgrounds talk by B. Lehnert (Mon. 2:15pm)

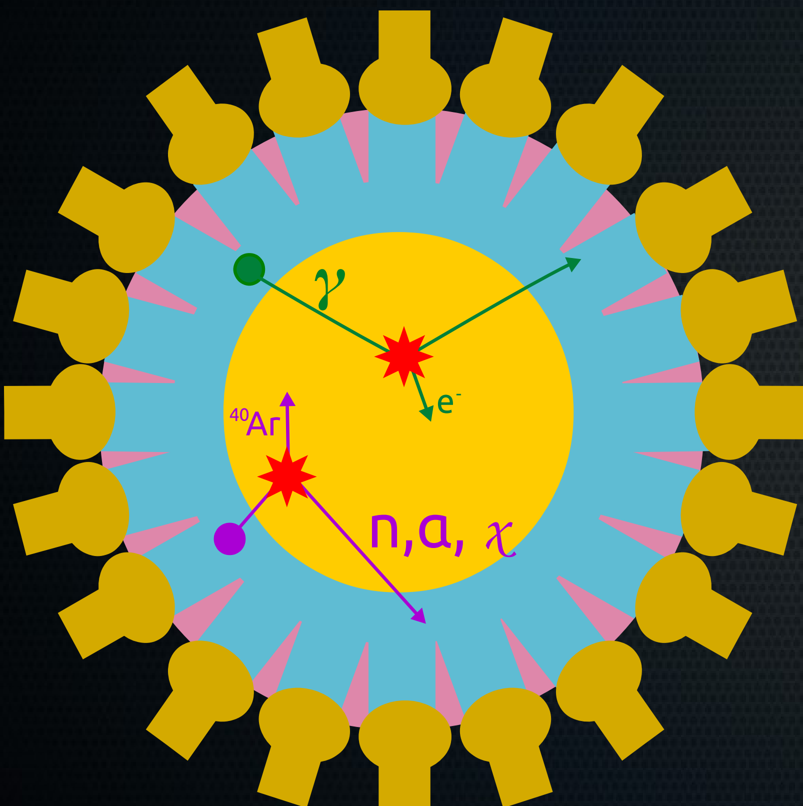
Looking for WIMPs

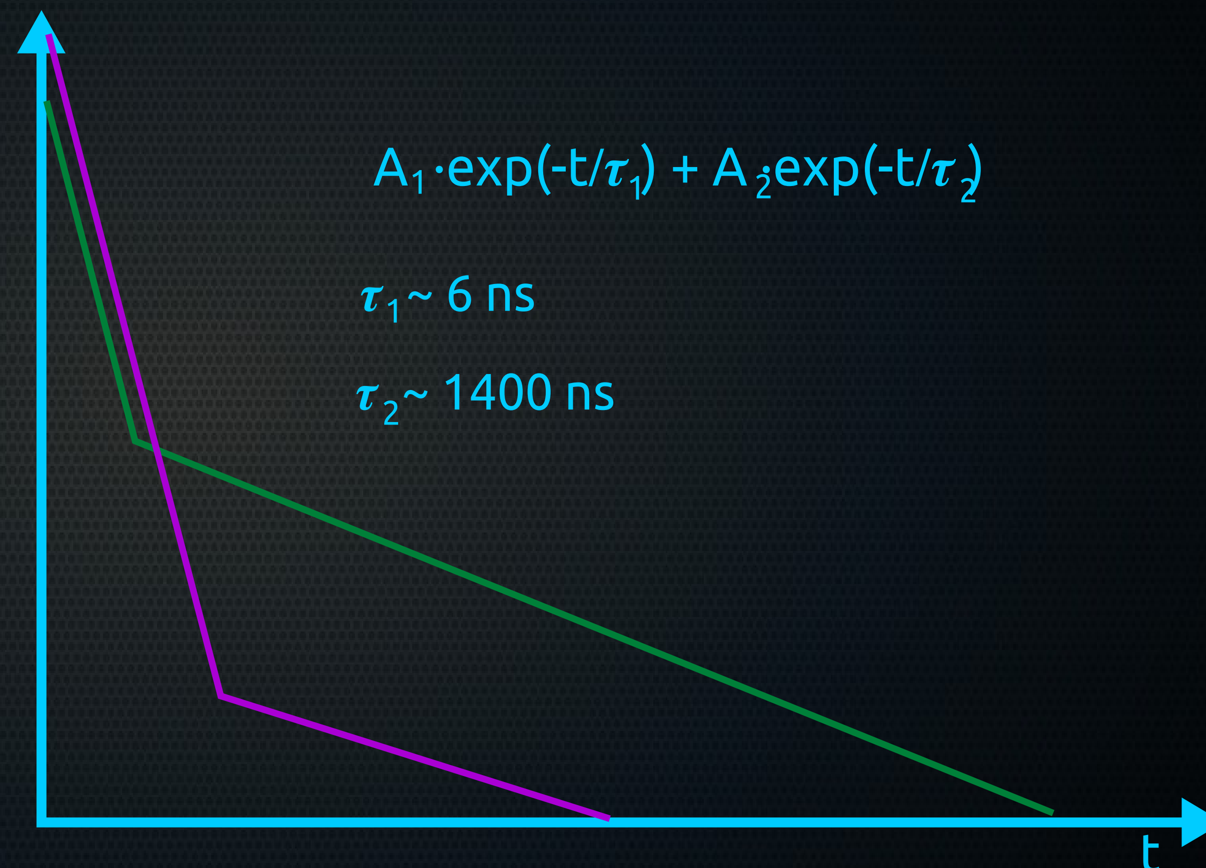


Some things are not WIMPs

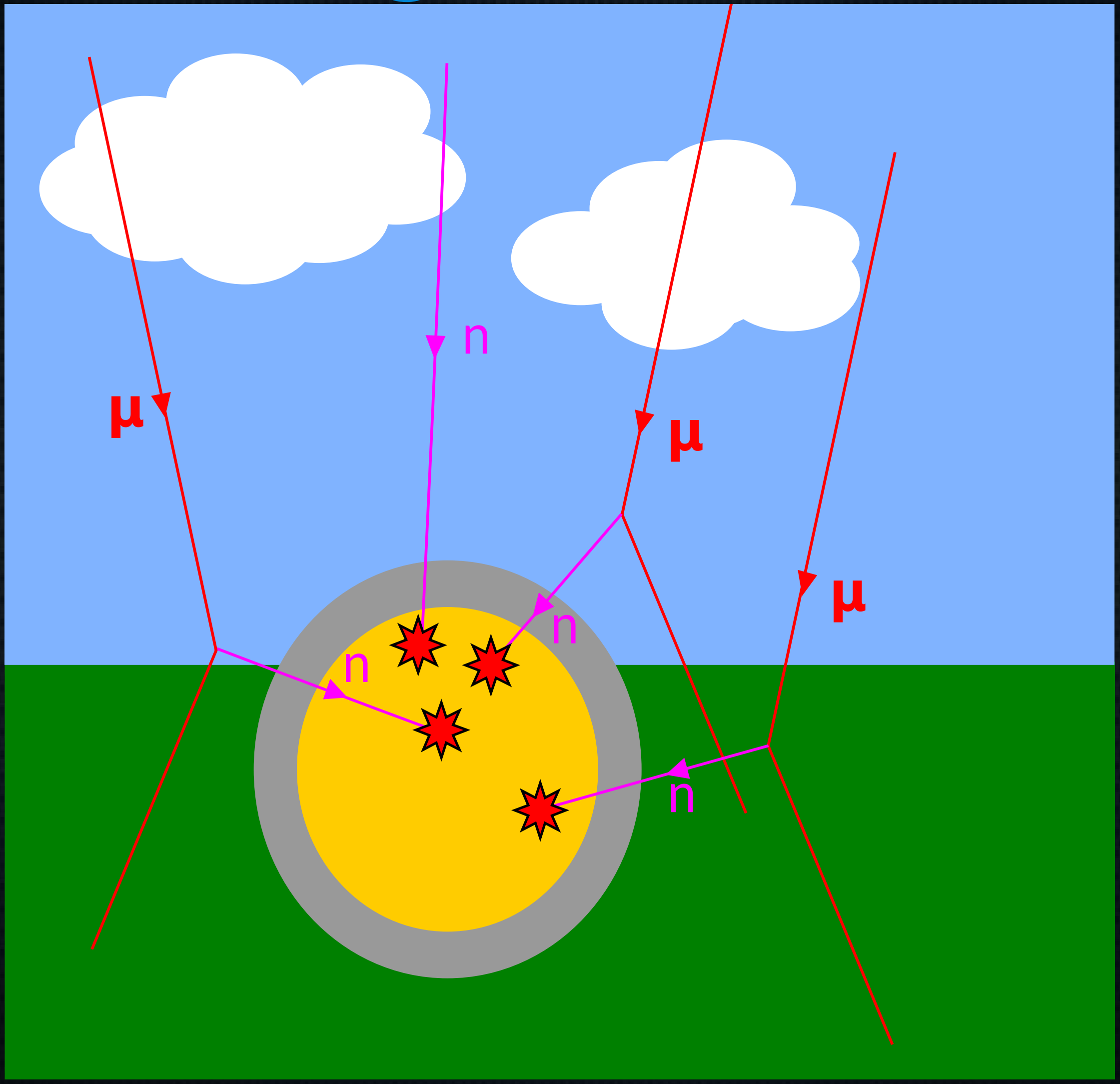


PSD eliminates many of them, but nuclear recoils remain

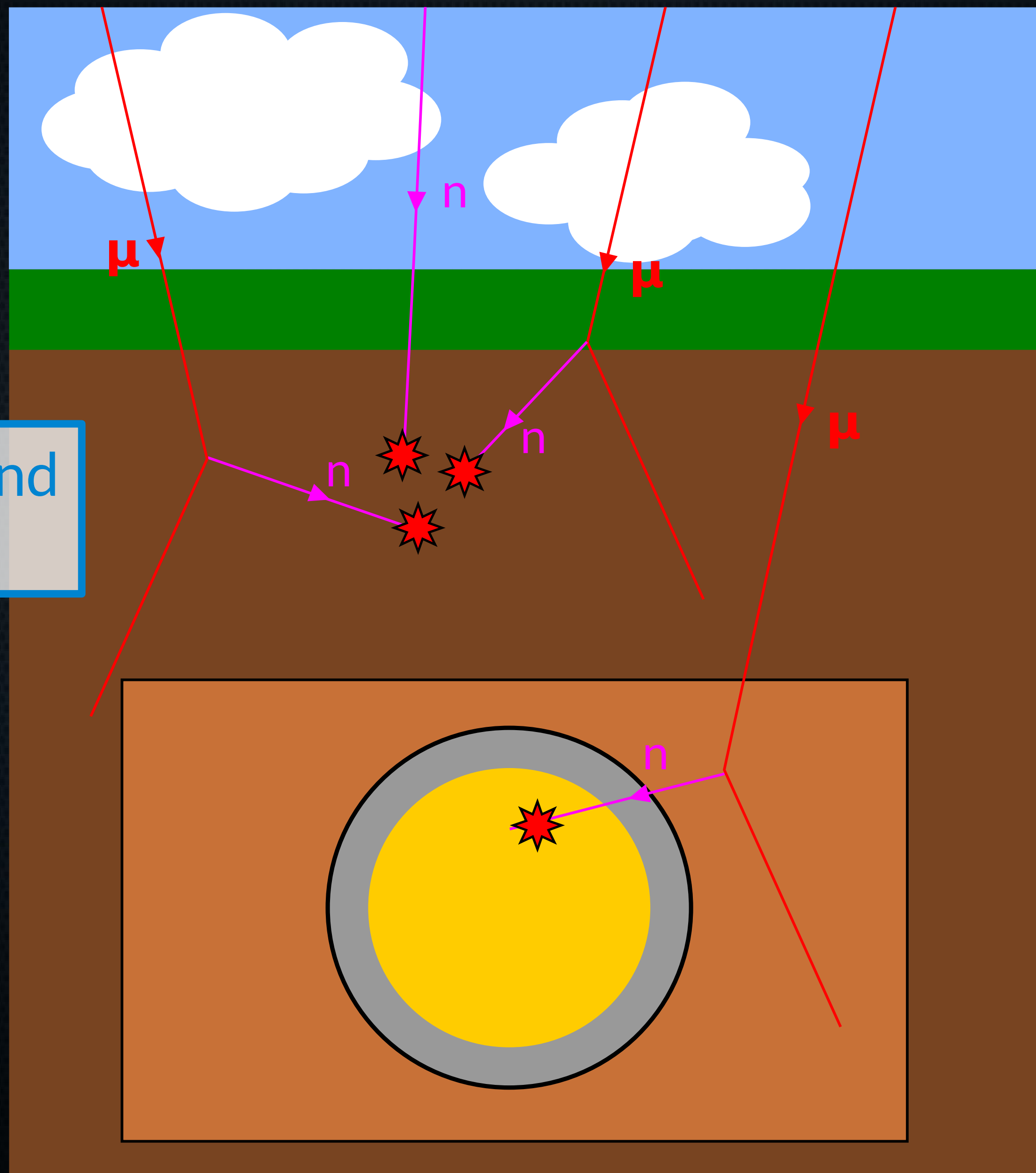




Too many cosmogenic neutrons above ground

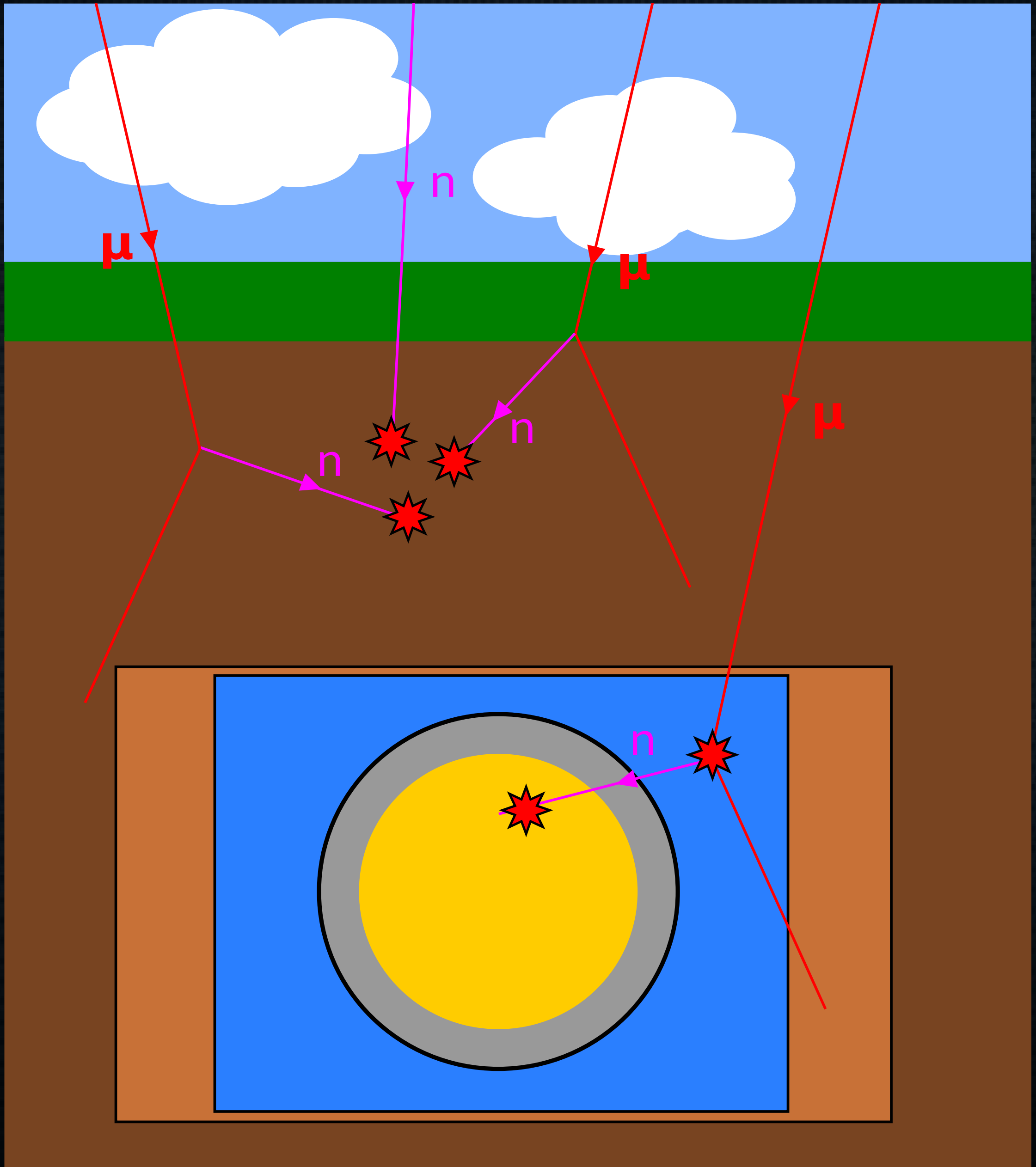


So we hide from them underground

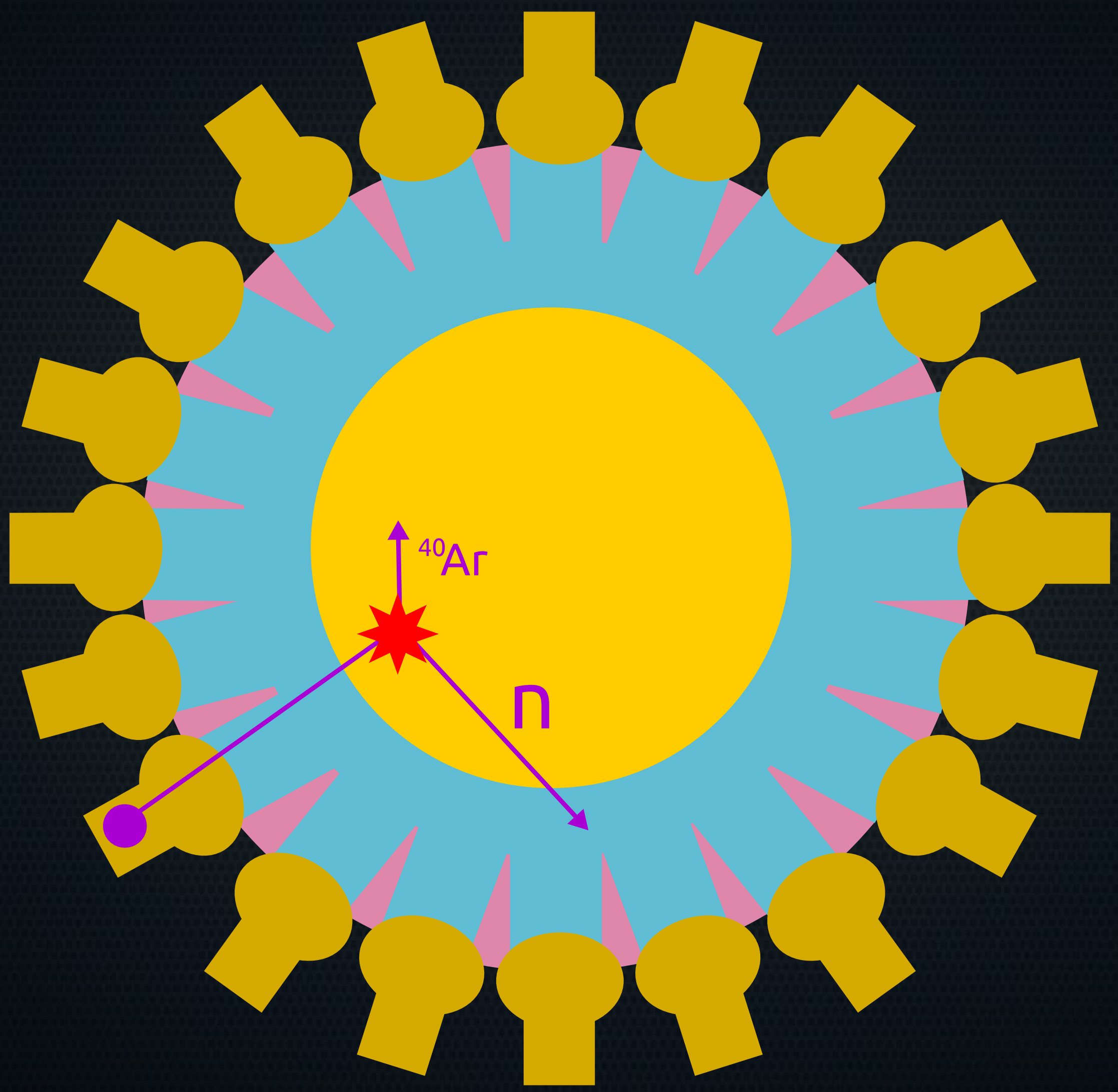


2 km underground
6 km.w.e

A water Cherenkov muon detector helps us veto them

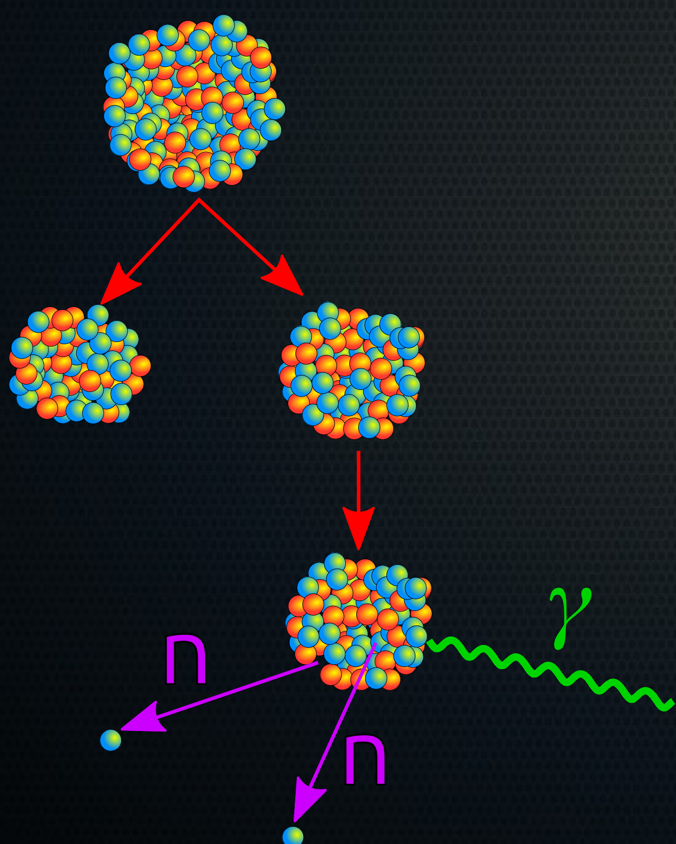


Radiogenic neutrons may still be there

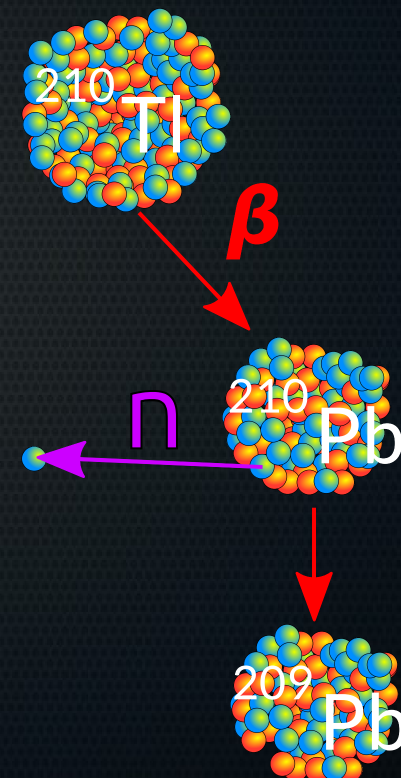


Sources of Radiogenic Neutrons (2/3)

^{238}U Fission:
1.1×10^{-6} n/s/Bq

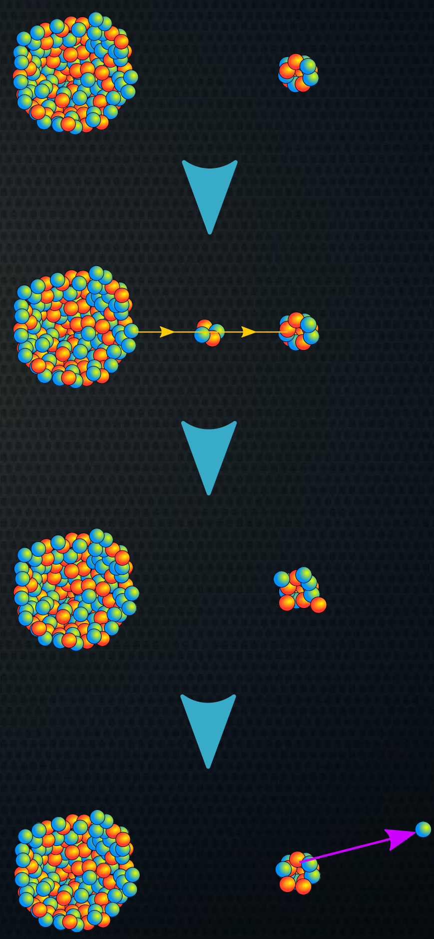


^{210}Tl Direct Neutron Emission:
1.5×10^{-8} n/s/Bq



Sources of Radiogenic Neutrons: The (α,n) Reaction

- Rate depends on concentration of all α-emitting contaminants in decay chains
- Depends on composition of material
- Need to calculate (α,n) yield of each material



To perform a sensitive WIMP search, we must understand these neutron backgrounds

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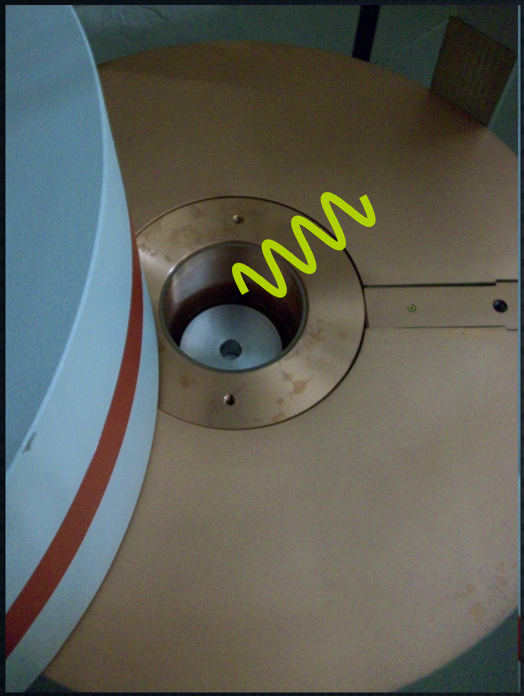
γ-counted all major detector components



PMT Borosilicate Glass

^{238}U Decay Chain
- ^{238}U to ^{230}Th : ~920 mBq/kg
- ^{226}Ra to ^{206}Pb : ~225 mBq/kg

^{235}U Decay Chain
- Full chain : ~25 mBq/kg

^{232}Th Decay Chain
- Full chain : ~140 mBq/kg

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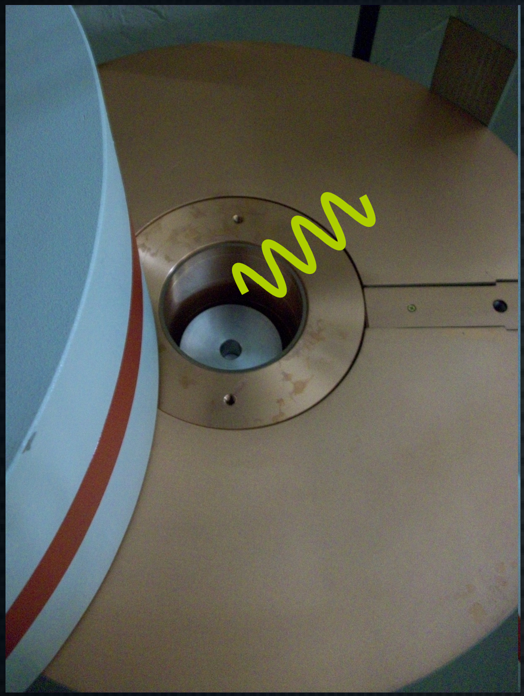

SNOLAB Ge well detector

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Additionally α-counted ashen acrylic samples to measure ^{210}Pb

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Need to predict neutron production rate, given this radioactivity

- Fission and direct neutron emission rates depend only on the isotope emitting the neutron
- The (α,n) reaction depends on the energies of all α decays and the material composition

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- Fission and direct neutron emission rates depend only on the isotope emitting the neutron
- The (α,n) reaction depends on the energies of all α decays and the material composition

→ Need to know the (α,n) yield of each material, given exposure to a decay chain

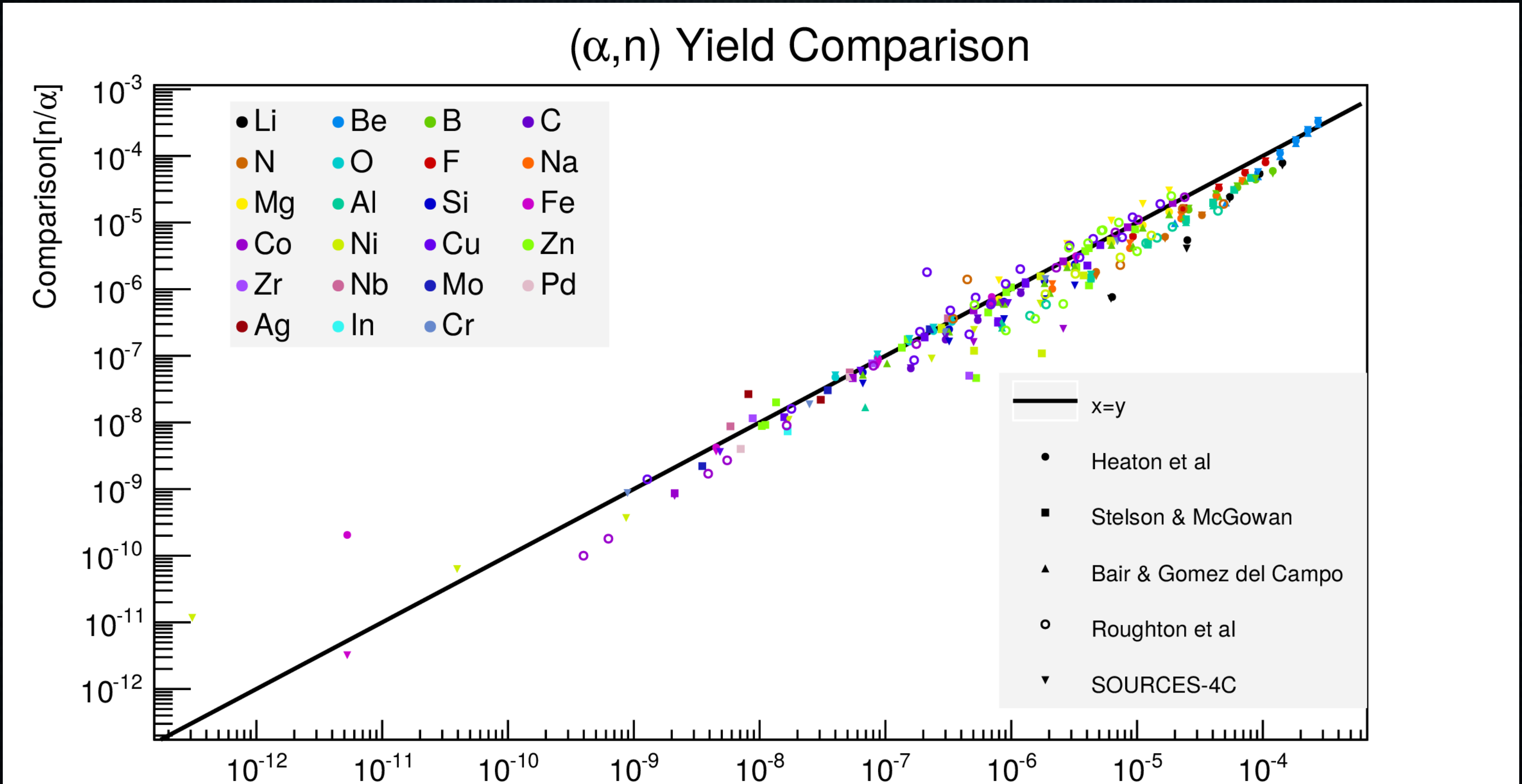
Neutron Calculator Based On TALYS

See paper at arXiv:1702.02465 (Submitted to NIM A)
Download: github.com/shawest/neucbot

NeuCBOT: a tool for calculating (α,n) Yields

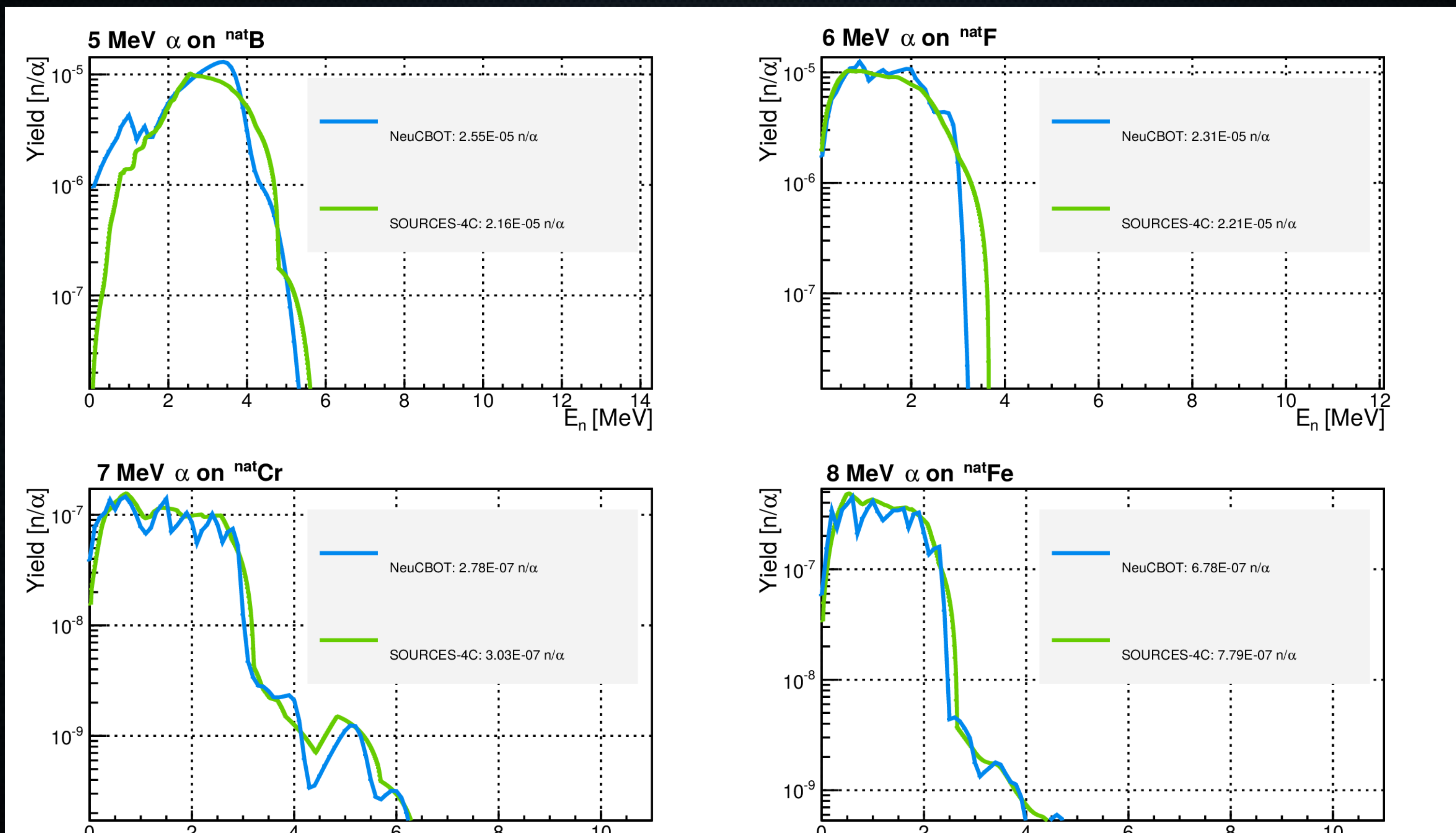
- User friendly
- TALYS-generated nuclear reaction library for all naturally occuring isotopes, α energies up to 10 MeV
  - Integrates with TALYS to expand libraries
- Simulates (α,n) reaction with stopping powers from SRIM
- Pulls α decay data from ENDF databse

General agreement with benchmarks; NeuCBOT Slightly Systematically Higher



From arXiv:1702.02465 [physics.ins-det]

NeuCBOT and SOURCES-4C spectra agree well



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DEAP-3600 Neutron Yields

NeuCBOT	n/s/Bq			
Material	U238 upper	U238 lower	U235	Th232
Borosilicate Glass	3.93E-06	1.76E-05	2.56E-05	2.43E-05
Acrylic	2.19E-07	9.72E-07	1.42E-06	1.33E-06
Invar	2.06E-12	2.58E-07	1.84E-07	1.08E-06
TPB	3.15E-07	1.35E-06	1.96E-06	1.84E-06
Polyethylene	2.52E-07	1.09E-06	1.58E-06	1.49E-06
Polystyrene	3.01E-07	1.29E-06	1.88E-06	1.77E-06
Stainless Steel	1.31E-09	5.52E-07	4.42E-07	1.96E-06
Argon	8.82E-08	1.41E-05	1.72E-05	2.64E-05

~143,000 neutrons produced/year in various components

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Dominant source : PMT Glass

Geometry and acrylic greatly suppress these neutrons

- Preliminary Geant4 simulations indicate ~19 neutrons/year produce nuclear recoil above ~11 keVee
  - Before ROI cuts and fiducialization
- Additional analysis cuts will further reduce this

Geometry and acrylic greatly suppress these neutrons

- Preliminary Geant4 simulations indicate ~19 neutrons/year produce nuclear recoil above ~11 keVee

NeuCBOT:
- 15 n/year from PMT glass
- 1 n/year from PMT ceramic
- 3 n/year from polystyrene filler foam

SOURCES-4C:
- 13 n/year from PMT glass
- 2 n/year from PMT ceramic
- 2 n/year from polystyrene filler foam

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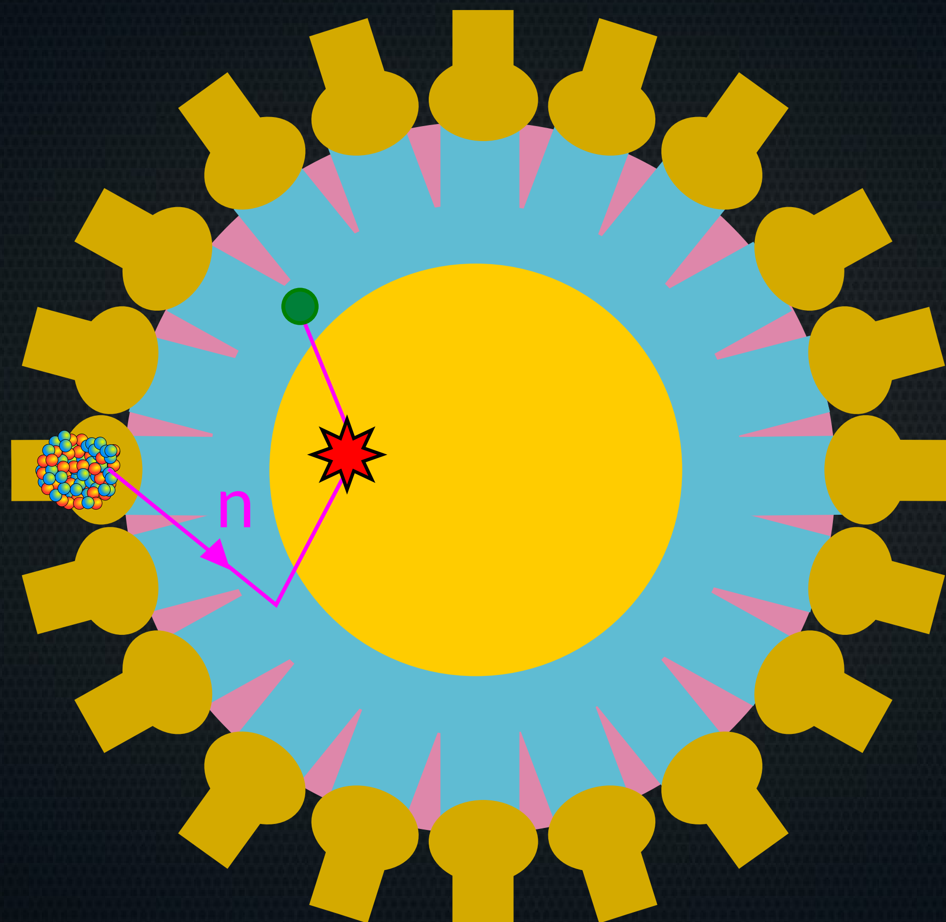
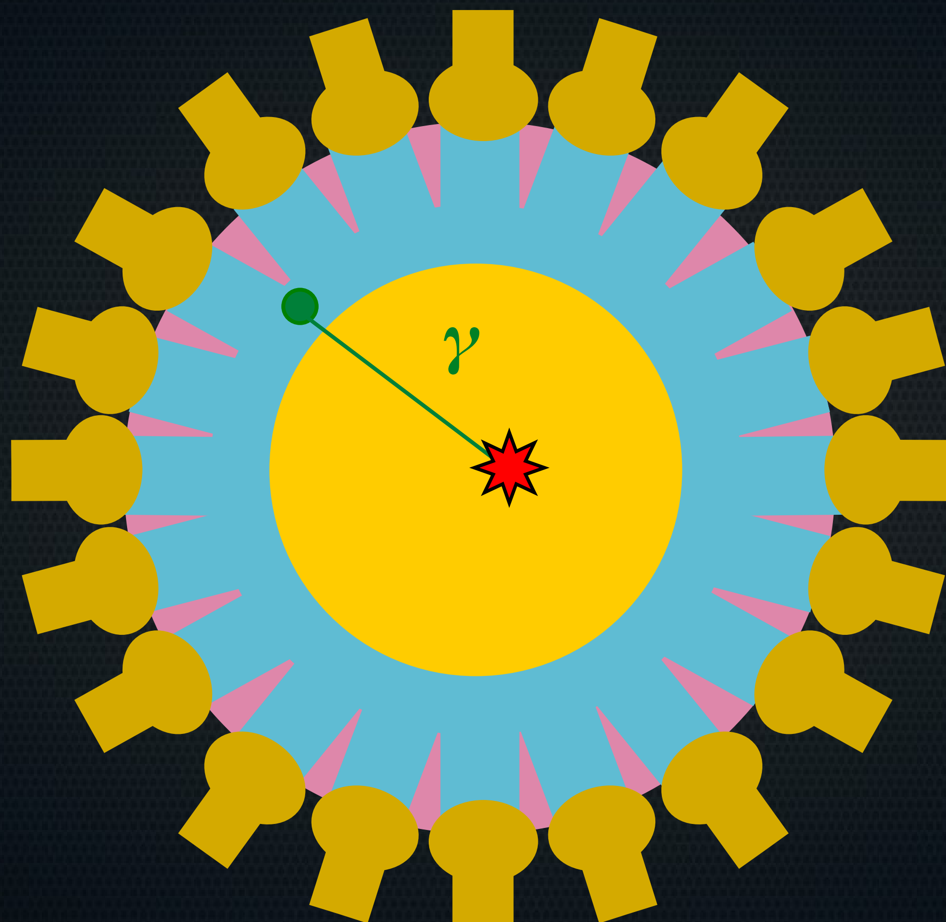
Neutrons that scatter in LAr eventually capture in LAr or acrylic



Capture γ may scatter in LAr

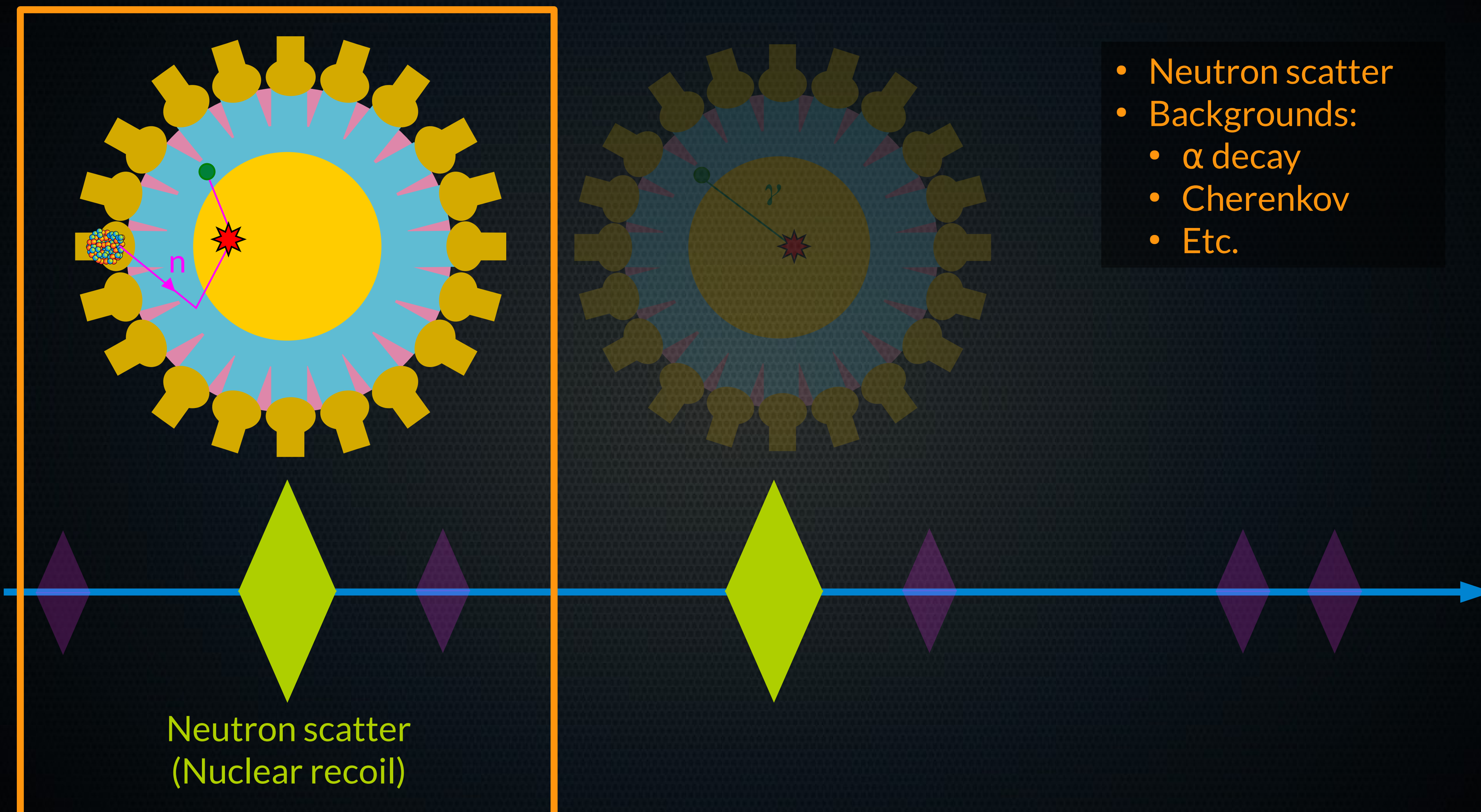


O(100 us) later

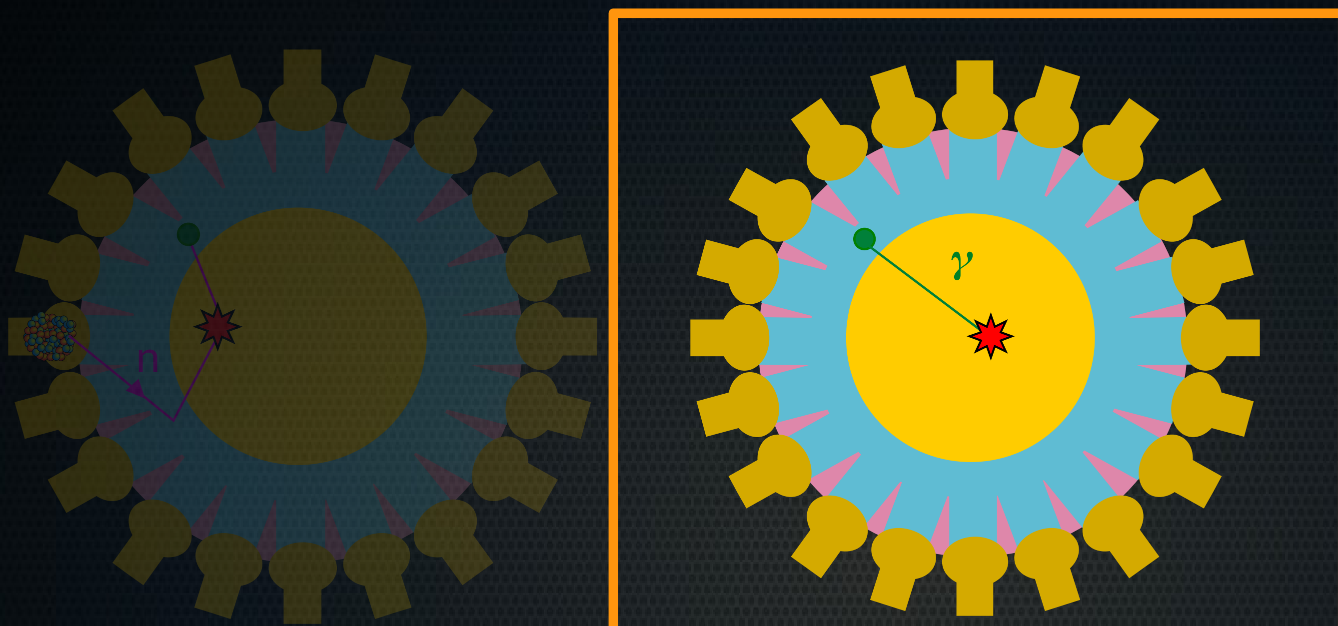
Can we use these coincidences to tag neutrons and constrain the neutron rate?

1) Identify Neutron Scatter Candidates

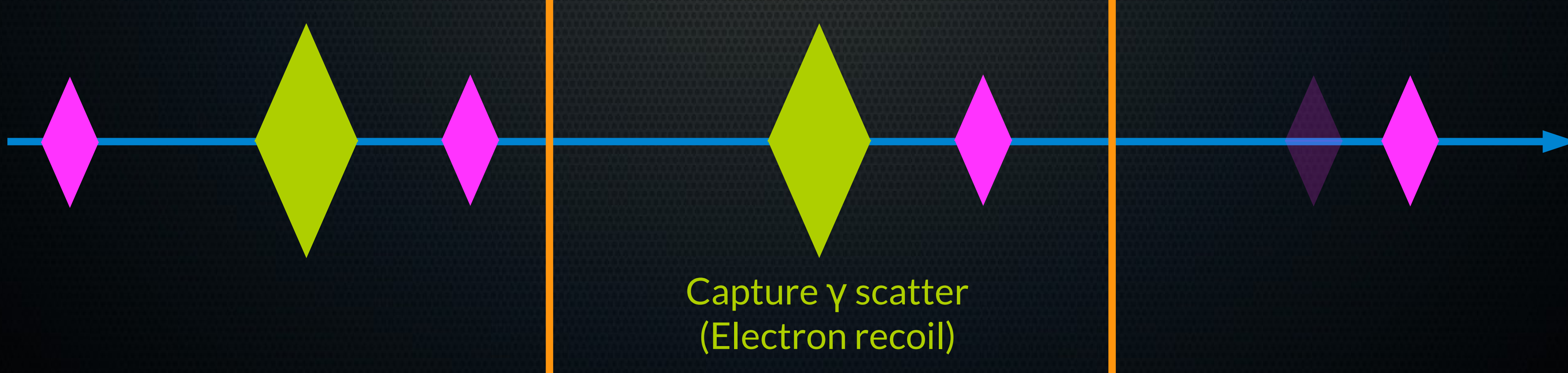
- Neutron scatter
- Backgrounds:
  - α decay
  - Cherenkov
  - Etc.



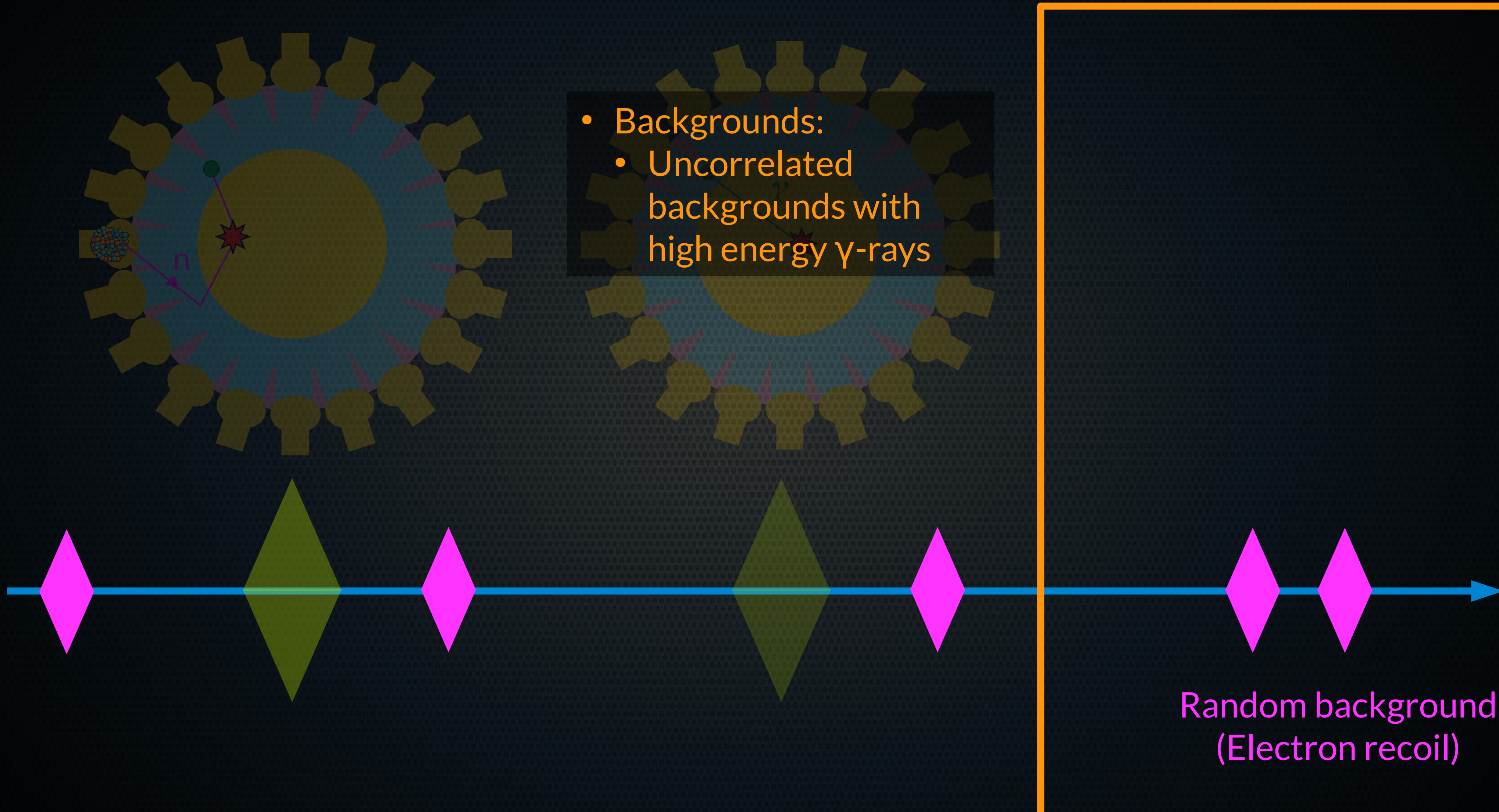
2) Identify Neutron Capture Candidates



- $^{1}H(n,\gamma)^{2}H$ (2.2 MeV)
- $^{40}Ar(n,\gamma)^{41}Ar$ (6.1 MeV)
- Backgrounds:
  - Uncorrelated backgrounds with high energy γ-rays

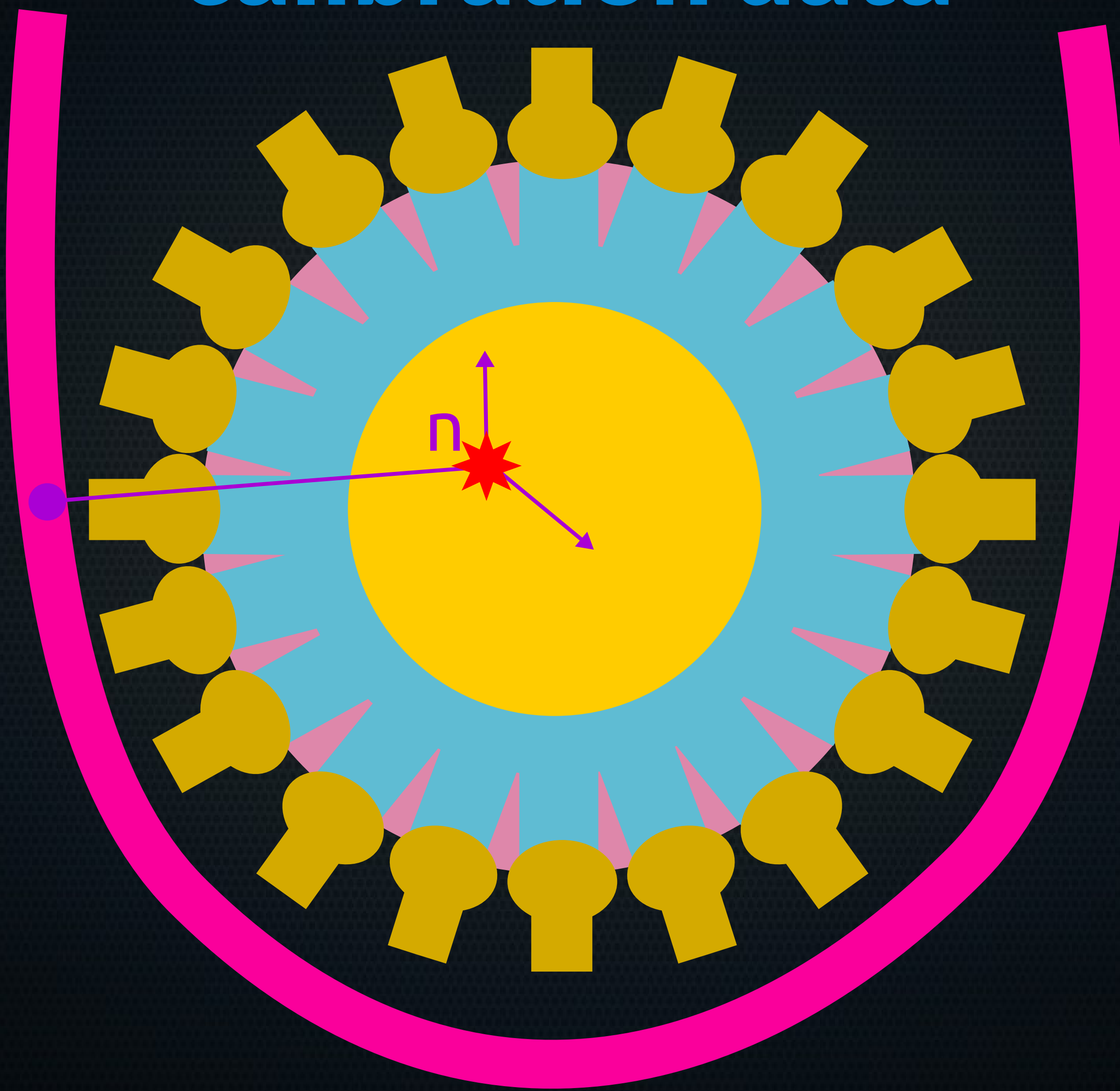


3) Measure Uncorrelated ER Rate

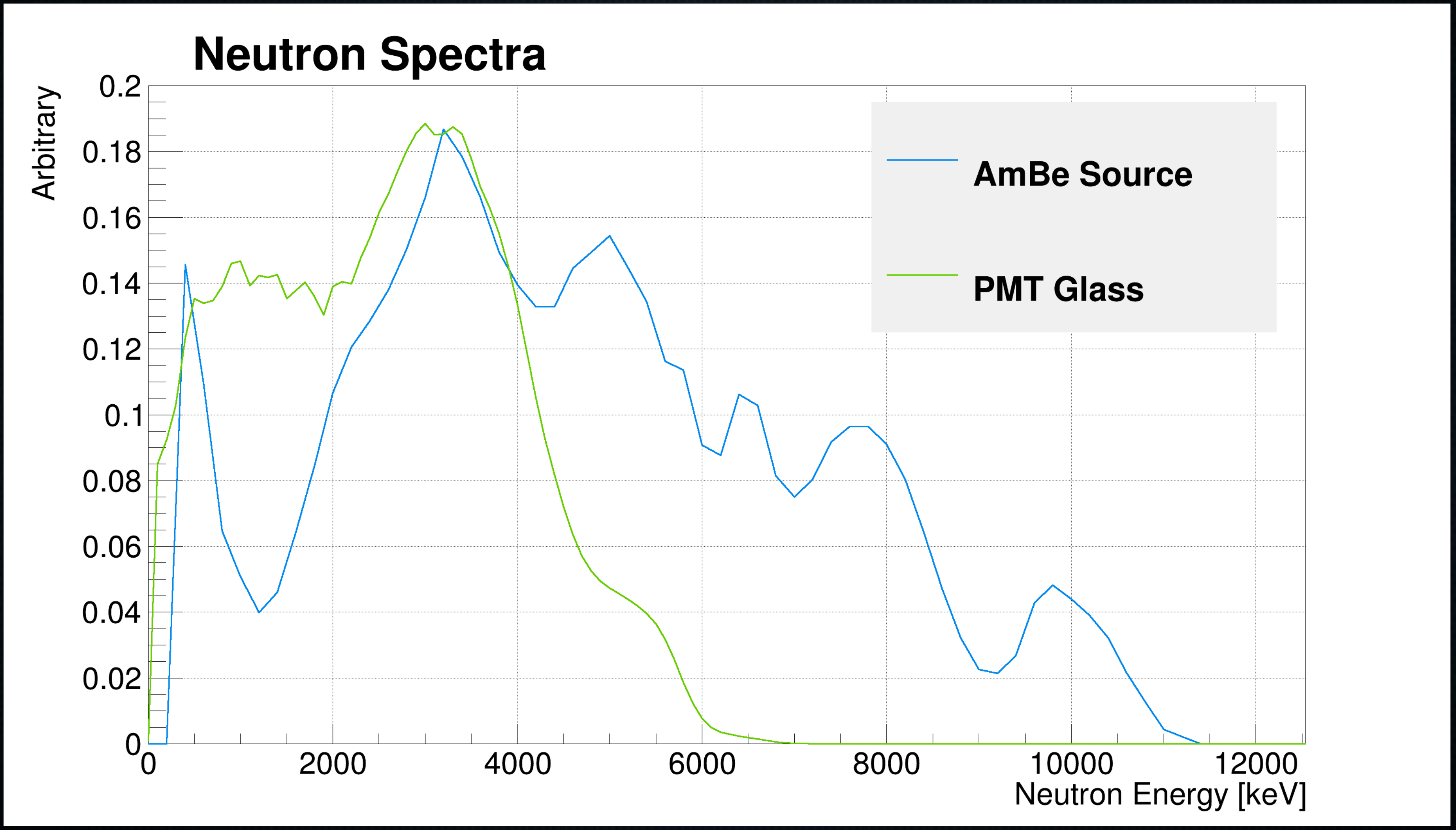


- Backgrounds:
  - Uncorrelated backgrounds with high energy γ-rays

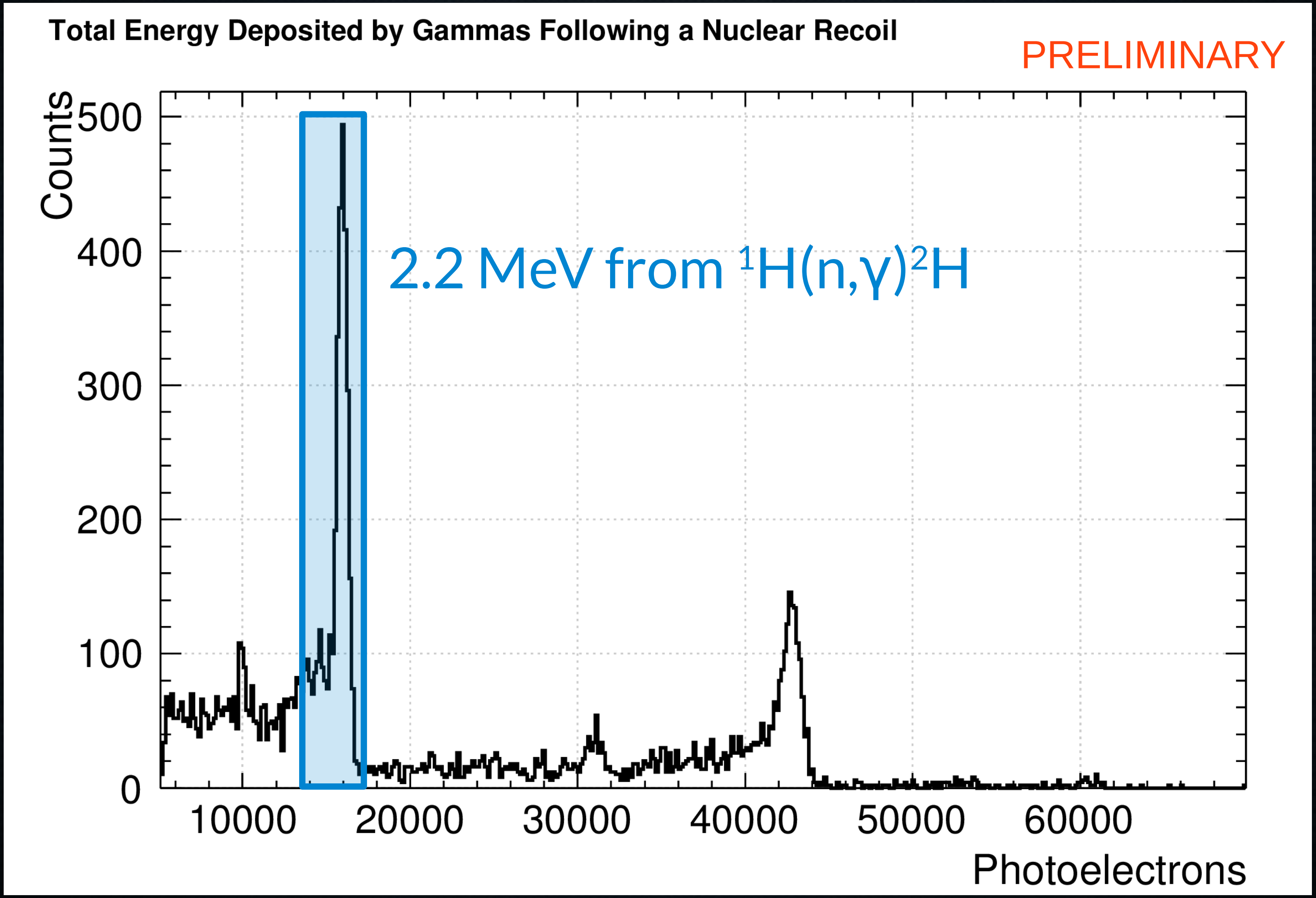
Measured efficiency with AmBe calibration data



Can approximate PMT glass neutrons with AmBe neutrons



AmBe Calibration: Clear Neutron Capture Signals



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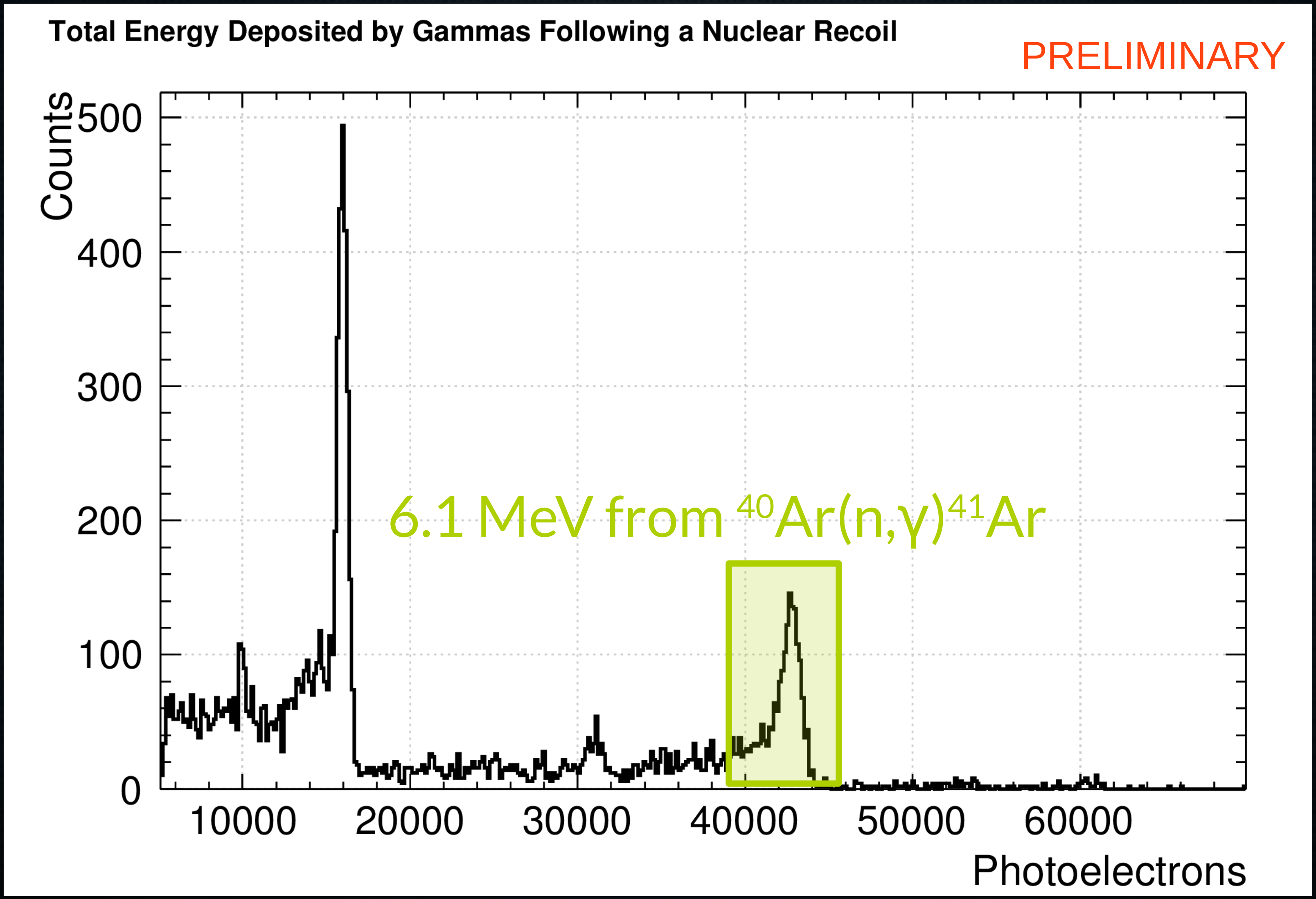
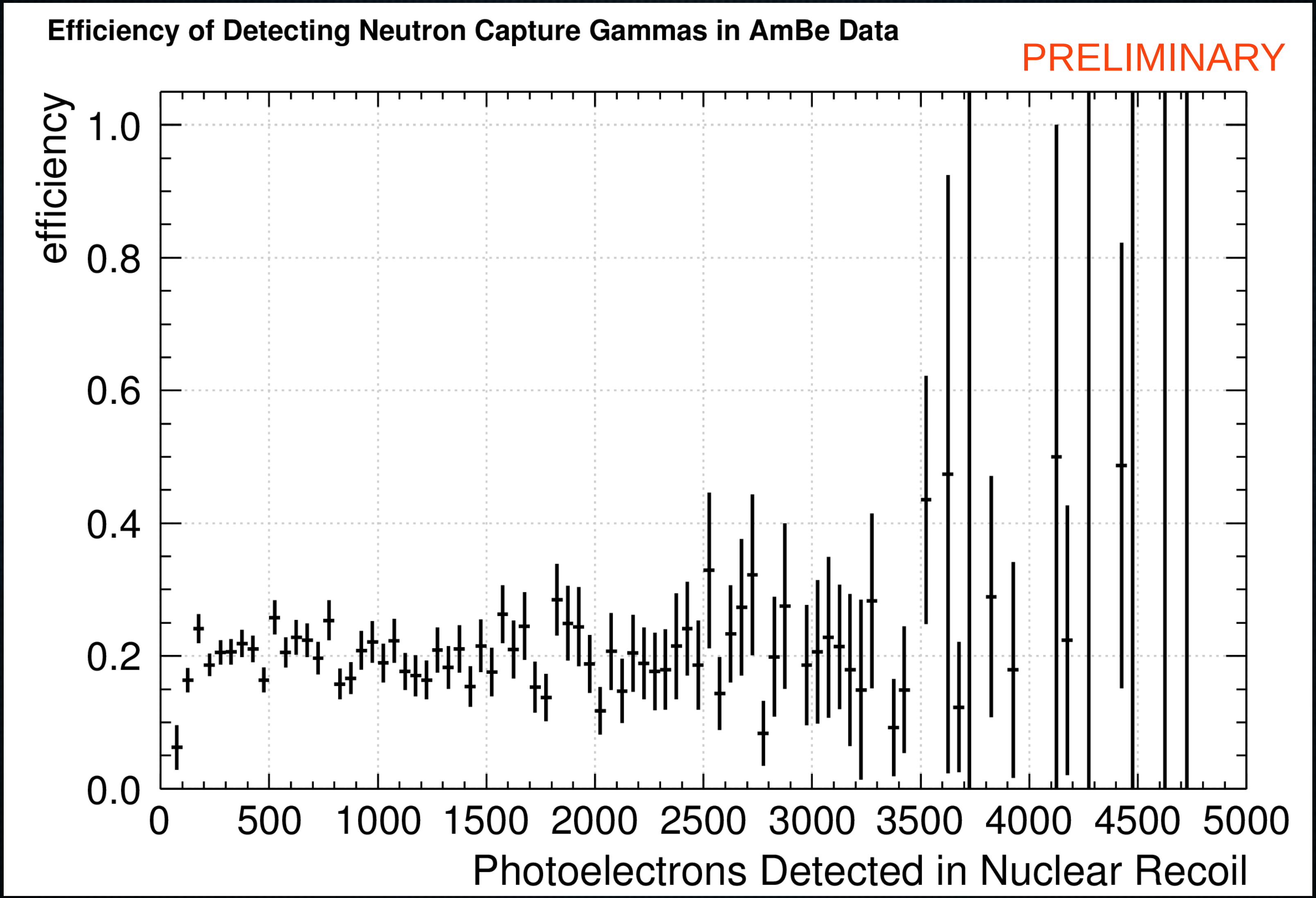


AmBe Calibration: Detect NR-ER Coincidence was 19.3% Efficiency



In Situ Neutron Search: Saw no neutron captures

- In ~5 live days of data, 0 NR-ER pairs
  - Require: NR above 11 keVee
  - Require: ER abve 1.9 MeV
- Preliminary projections to 109 live days of data will allow us to limit the rate to < 26 per year
  - Currently ongoing analysis

Conclusion

- We performed a detailed assay of detector components
- Used NeuCBOT to predict the neutron flux from these components
  - Expect ~19 events/year before fiducial and ROI cuts
- Search for neutron capture signal allows us to measure this background in-situ
  - Upcoming analysis with larger dataset will give us more interesting constraints

END