

First evidence of neutrino absorption on argon
using ^8B solar neutrinos in DEAP-3600

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on behalf of the DEAP collaboration

CAP Congress 2026
23rd June 2026

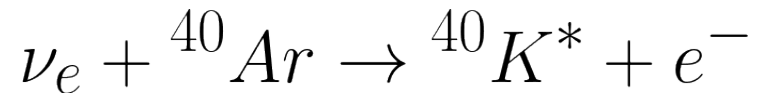


Carleton
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Key results



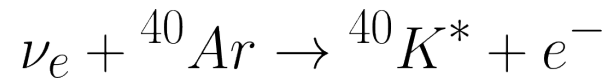
- First evidence for charged-current solar neutrino absorption (ν_e CC) on argon



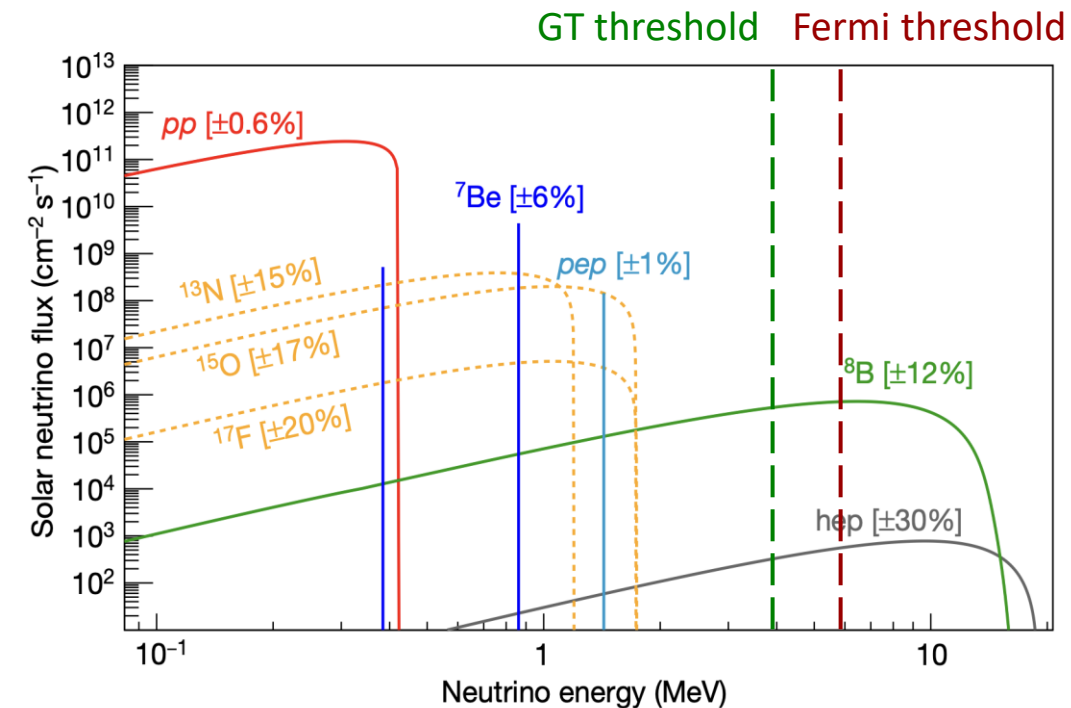
- Observed 6 candidate events in 10.5 – 13 MeV ROI
- Background expectation $0.48_{-0.15}^{+0.16}$ events $\Rightarrow 4\sigma$ significance
- Measured cross-section $\langle \sigma_{CC}^{ROI} \rangle = 4.0_{-1.7}^{+2.2} \times 10^{-41} \text{cm}^2$
 - Bhattacharya et al. (2009) $\langle \sigma_{CC}^{ROI} \rangle = (1.67 \pm 0.05) \times 10^{-41} \text{cm}^2$

[arXiv:2605.12769](https://arxiv.org/abs/2605.12769) Submitted to PRL

Neutrino CC interaction in argon



- First proposed by Raghavan ([1986](#))
- Bhattacharya et al. ([2009](#)) measured Gamow-Teller (GT) transition strengths from ${}^{40}\text{Ar}$ to ${}^{40}\text{K}$
- Energy threshold decreased from 5.9 MeV (Fermi) to 3.8 MeV (GT)
- Cross-section enhanced by a factor of 3
- Fundamental process for future multi-tonne liquid argon dark matter and neutrino detectors
- Unobserved (until now)



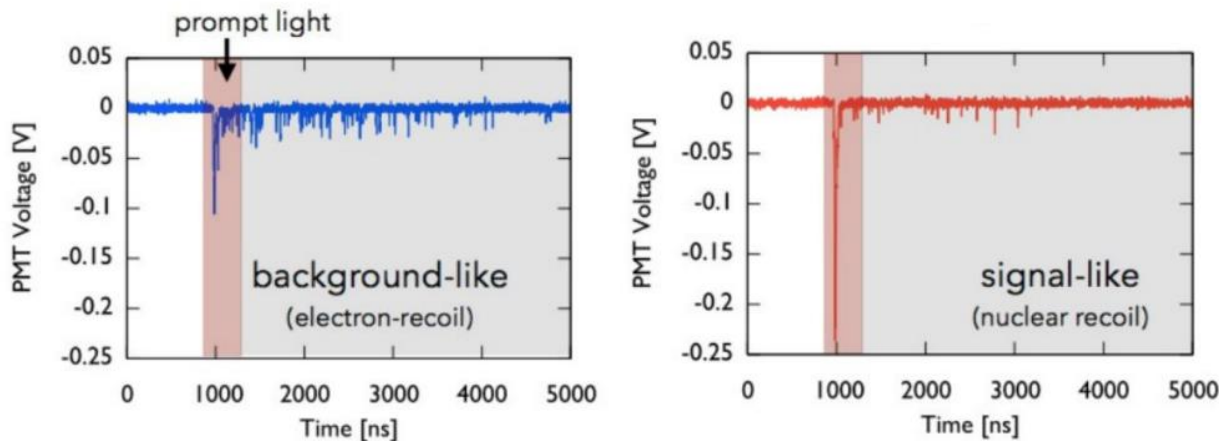
Borexino Collaboration,
Nature **562**, 505–510 (2018)

DEAP-3600

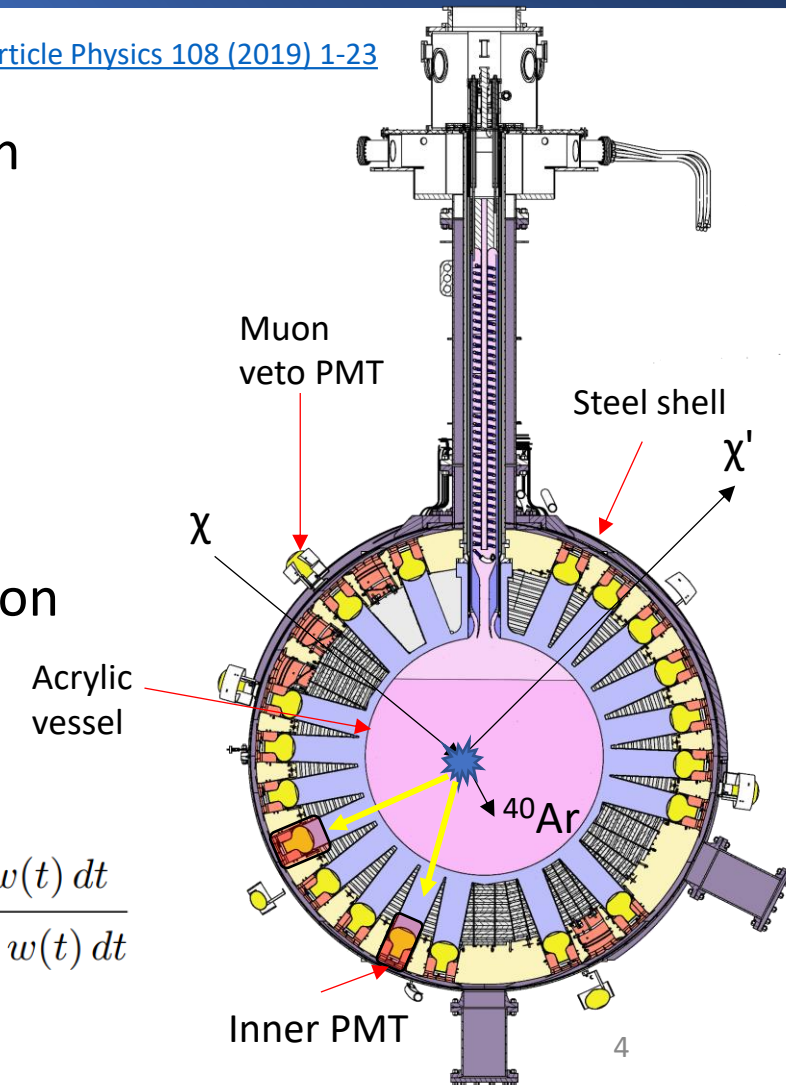


[Astroparticle Physics 108 \(2019\) 1-23](#)

- Single phase liquid argon based dark matter detector located 2km underground at SNOLAB
- Dark matter Experiment using Argon Pulseshape discrimination
- (3269 ± 24) kg of LAr target mass in acrylic vessel
- Pulse shape discrimination for background rejection ($\sim 10^{-8}$)
- 4.8 kBq americium-beryllium (AmBe) neutron source for calibration



$$F_{\text{prompt}} = \frac{\int_{-28 \text{ ns}}^{150 \text{ ns}} w(t) dt}{\int_{-28 \text{ ns}}^{10000 \text{ ns}} w(t) dt}$$

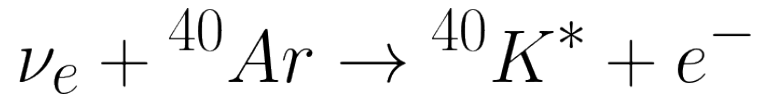


Dataset and other updates



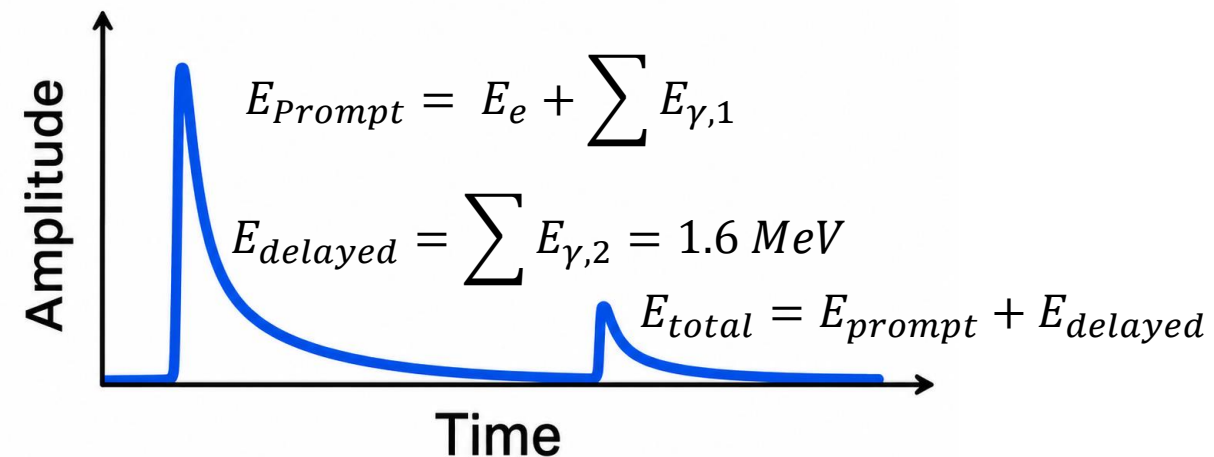
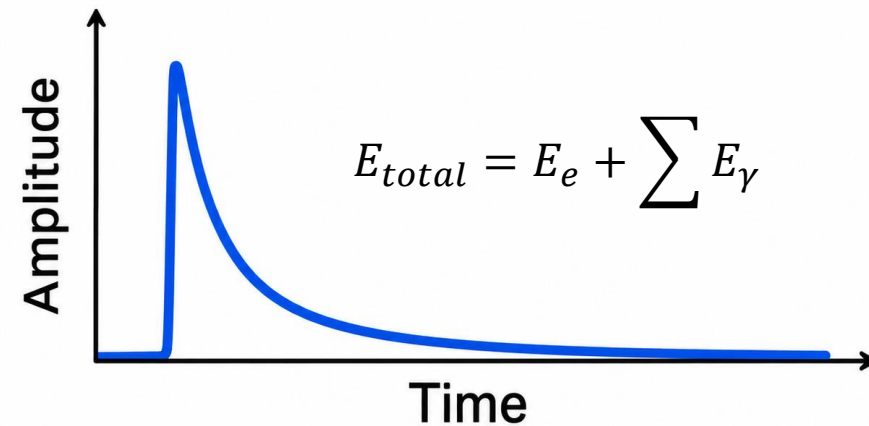
- Data used in this analysis - November 4, 2016 – March 27, 2020
- Total exposure = (7.29 ± 0.05) tonne·years
- Recent physics results from DEAP
 - Dark Matter Search using the Profile Likelihood Ratio Method - arXiv:2603.13965
 - Position reconstruction in DEAP - JINST **20** P07012 (2025)
 - ^{39}Ar Half-Life - Eur. Phys. J. C 85, 728 (2025)
 - Quenching factor of α -particles in LAr - Eur. Phys. J. C 85, 87 (2025)
- Hardware upgrades implemented (post-2020)
 - Pyrene-coated flow guides installed
 - Dust removal pipe inserted

ν_e CC Signal in DEAP-3600



$$E_\nu = E_e + E_\gamma + Q = E_{\text{vis}} + 1.5 \text{ MeV}$$

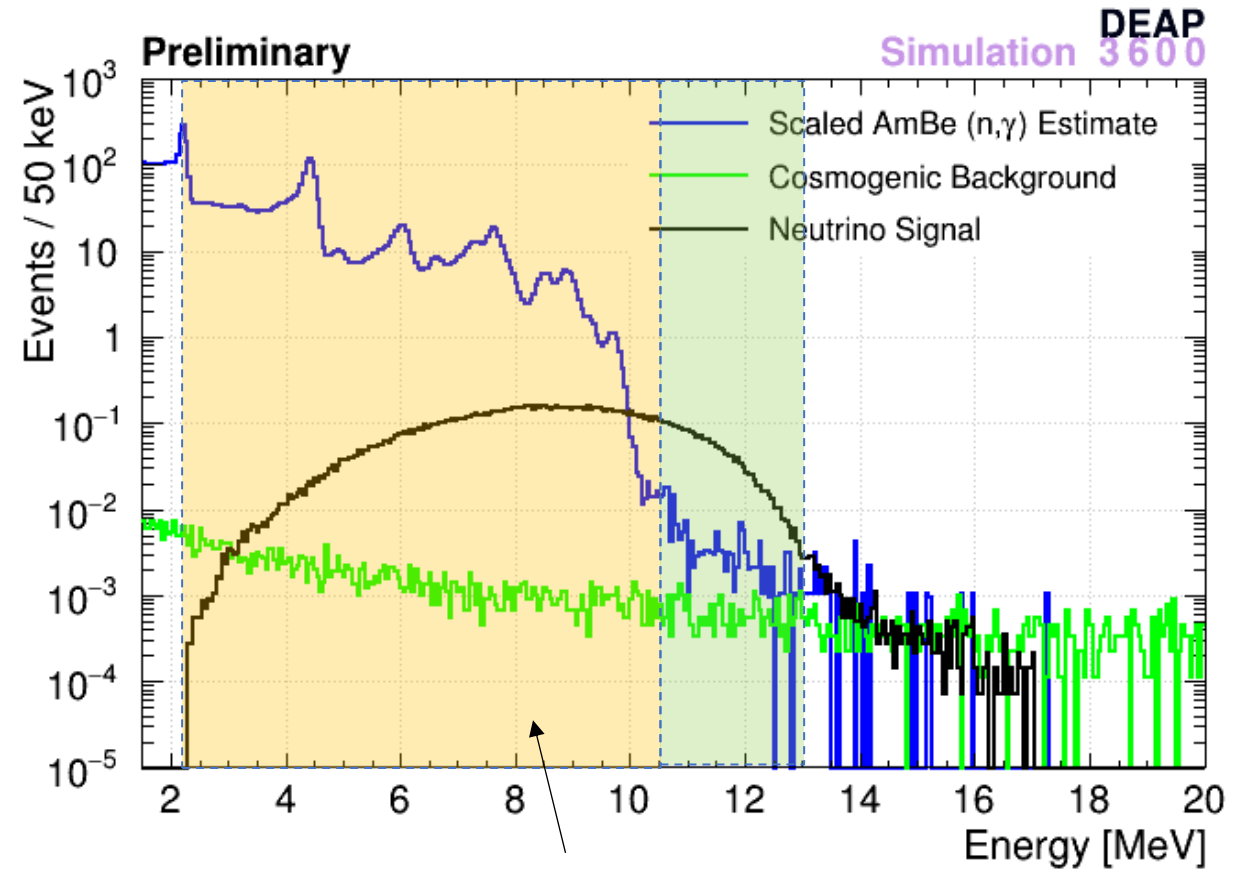
- Electron recoil events in the MeV range
- Single peak and double peak (delayed coincidence) events – branching ratio of ~29%
- Metastable state lifetime = 2nd peak delay time = 480ns



Region of Interest (ROI)



- 10.5 – 13 MeV reconstructed energy
- 12 – 14.5 MeV incident neutrino energy
- Reduces backgrounds while optimizing sensitivity to solar neutrinos
- Lower bound driven by radiogenics, upper bound driven by cosmogenics



Event selection



Select electronic recoil physics events
Veto muon induced background

Event selection cut	Live time	ROI Events
→ Low-level cuts	817.9 d	12
→ Muon veto cut	814.7 d	12

Remove scintillation in neck veto fibers
Remove events outside of liquid argon

Event selection cut	Acceptance	ROI Events
→ Neck veto cut	1.00	6
→ Reconstructed height cut	0.99	6
Event timing cut	0.98	6
Early pulse suppression cut	0.97	6
PMT charge distribution cut	0.97	6
→ Pile-up cut	0.95	6
→ Scintillation waveform cut	0.92	6

Remove pile-up while accepting prompt
and delayed gammas from neutrinos

Remove instrumental events

Expected neutrino rate



$$\Gamma = N_{nuclei} \int_{E_{min}}^{E_{max}} \frac{d\phi(E)}{dE} \sigma(E) dE$$

Cross-section model
Bhattacharya et al. (2009)

Number of ^{40}Ar
nuclei in the detector

Oscillated (NuFIT 6.1) ^8B (SNO)
+ hep (GS98) neutrino flux

$$\begin{aligned}\Gamma &= 2.2 \pm 0.2_{sys} \text{ events}/(\text{tonne} \cdot \text{year}) \\ &= 16.1 \pm 1.5_{sys} \text{ events in } 7.29 \text{ tonne} \cdot \text{year}\end{aligned}$$

Total expected neutrinos in the ROI (after
applying ROI selection cuts) : **2.3 ± 0.4**

2.3 ± 0.4 events from ^8B neutrinos
 0.03 ± 0.01 events from hep neutrinos

Backgrounds (at a glance)



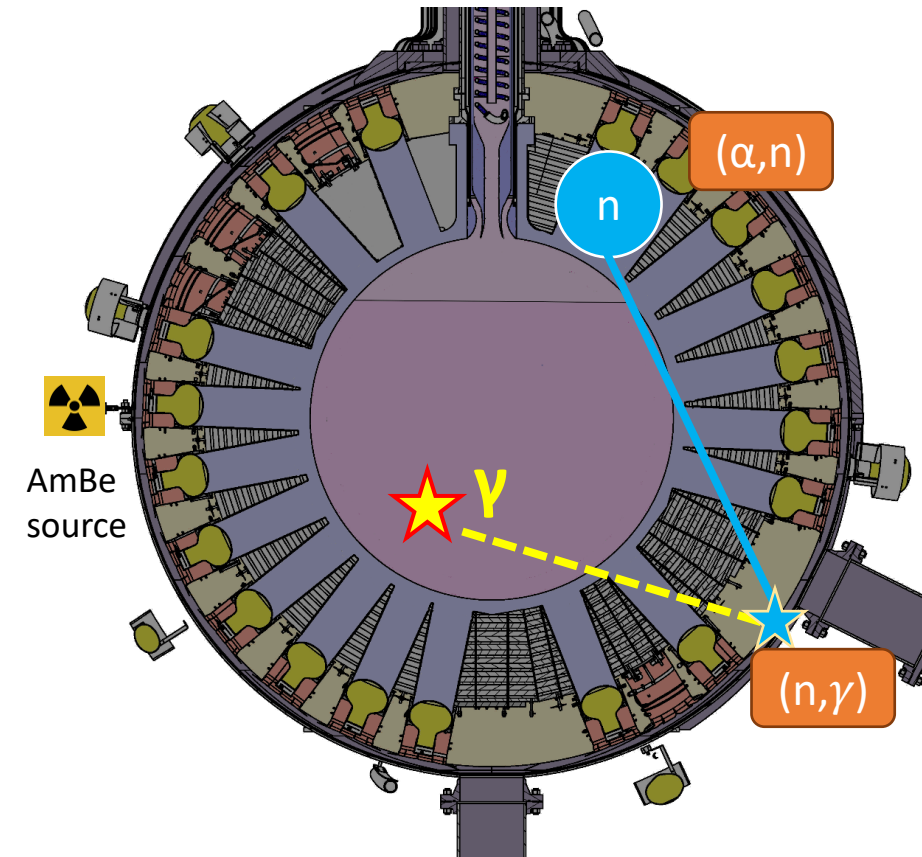
Dominant
sources of
backgrounds

Background Source	Events in ROI in 815 live-days
→ Radiogenic (n, γ)	0.43 ± 0.05 (stat) ± 0.14 (sys)
→ Cosmogenic	0.048 ± 0.009 (stat) $^{+0.070}_{-0.025}$ (sys)
Correlated $\gamma - \gamma$ pile-up	$< 10^{-3}$
Uncorrelated $\gamma - \gamma$ pile-up	$< 10^{-3}$
Correlated $\alpha - \alpha$ pile-up	$< 10^{-3}$
Uncorrelated $\alpha - \alpha$ pile-up	$< 10^{-3}$
Total Background	$0.48^{+0.16}_{-0.15}$

Backgrounds – Radiogenic neutrons



- Arises from radiative neutron capture on detector materials.
- Dominant sources of neutrons – PMTs, stainless steel vessel, and water tank
- 60 live-days of neutron calibration data using AmBe
- Equivalent of $\sim 10^7$ live-days of background neutrons in physics dataset
- To estimate background in ROI – apply cuts, scale to physics data, integrate in ROI, subtract contribution from pile-ups, apply correction factor to account for systematic differences between AmBe and physics neutrons (using RAT/GEANT4/G4RiversideCascade)
- Total radiogenic background in the ROI: **0.43 ± 0.05 (stat) ± 0.14 (sys)**



Backgrounds - Cosmogenics



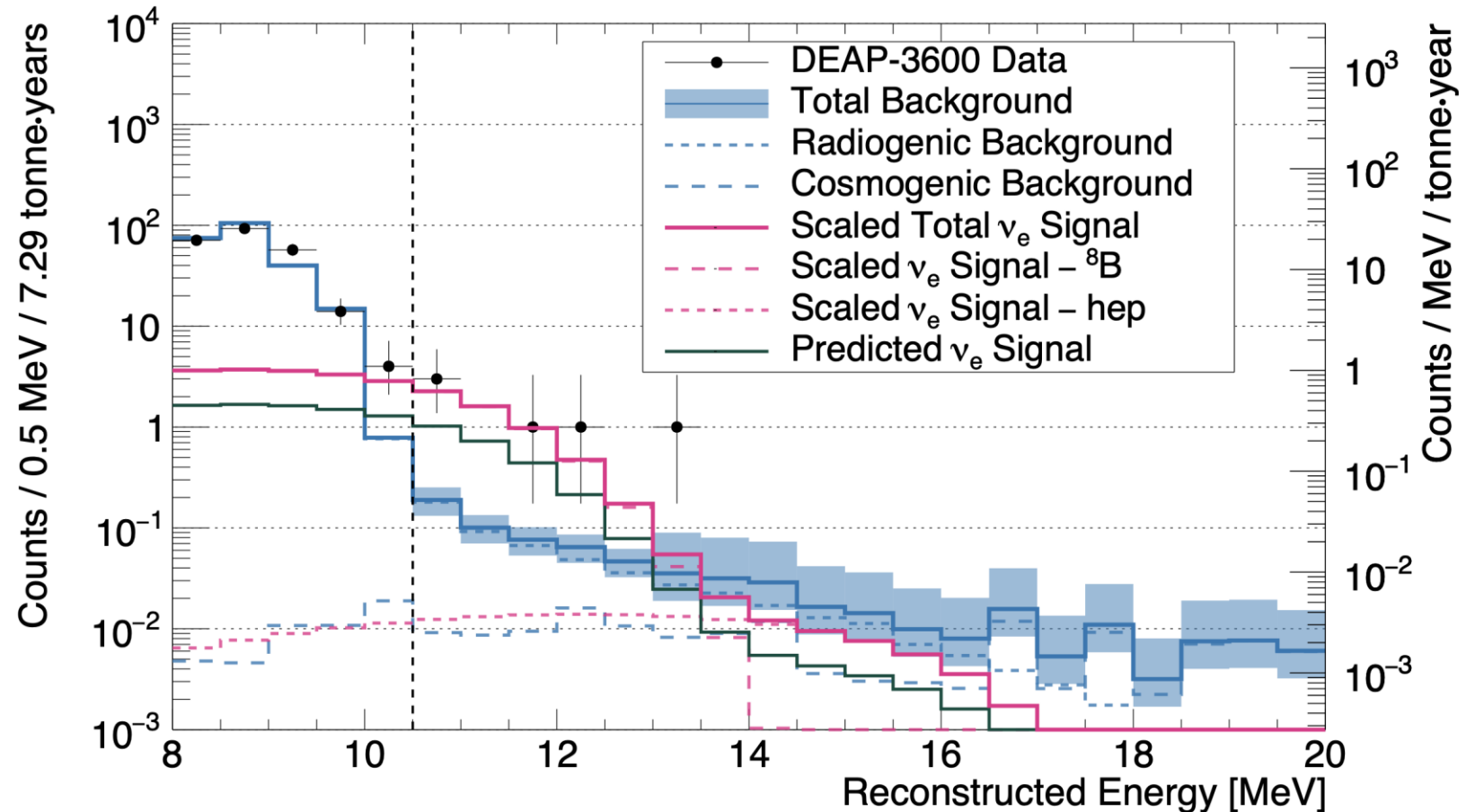
- Residual muon flux at SNOLAB : 3.31×10^{-10} muons/cm²/s
- Usually, muons induce Cherenkov light in the water tank that triggers veto PMTs
- Events in LAr correlated with the muon veto triggers are vetoed
- However, muons clipping/missing the veto detector are untagged
- Muons produce secondaries in surrounding rock and detector materials – gammas, e⁺/e⁻, neutrons, pions, kaons which can mimic neutrino-like signal
- Additionally, muon-activated long-lived isotopes may decay outside the veto window
- Cosmogenic background estimated using RAT and FLUKA based MC simulation
- Total cosmogenic background in the ROI: **0.048 ± 0.009 (stat)**
+0.070 -0.025 (sys)



DEAP-3600 measurement



- Observed 6 events
- Total Background $0.48^{+0.16}_{-0.15}$
- Total expected signal 2.3 ± 0.4
- Background only significance 4σ
- Background + signal significance 1.5σ



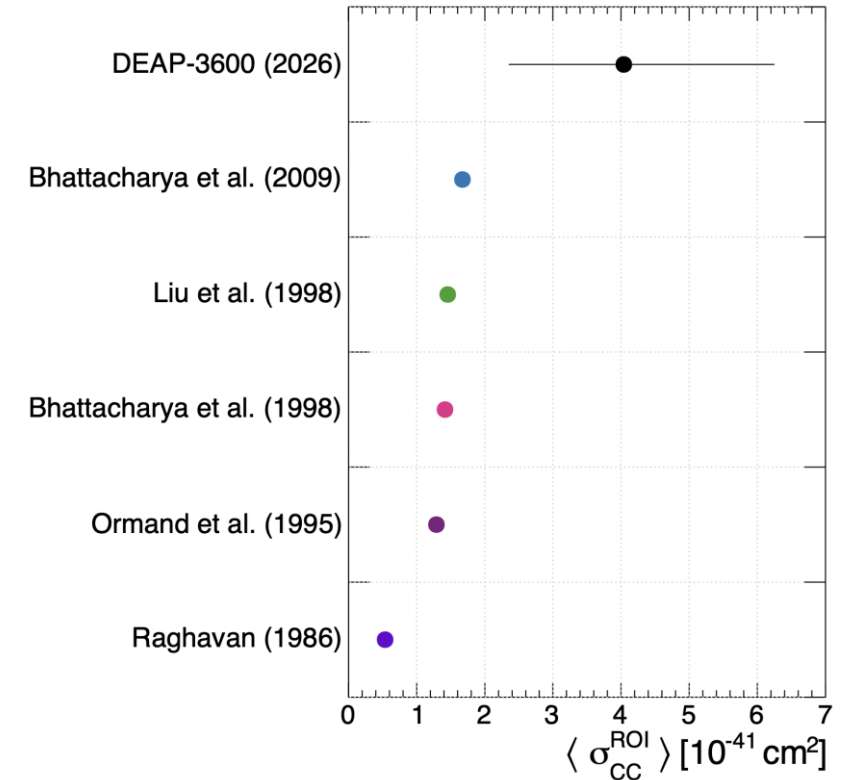
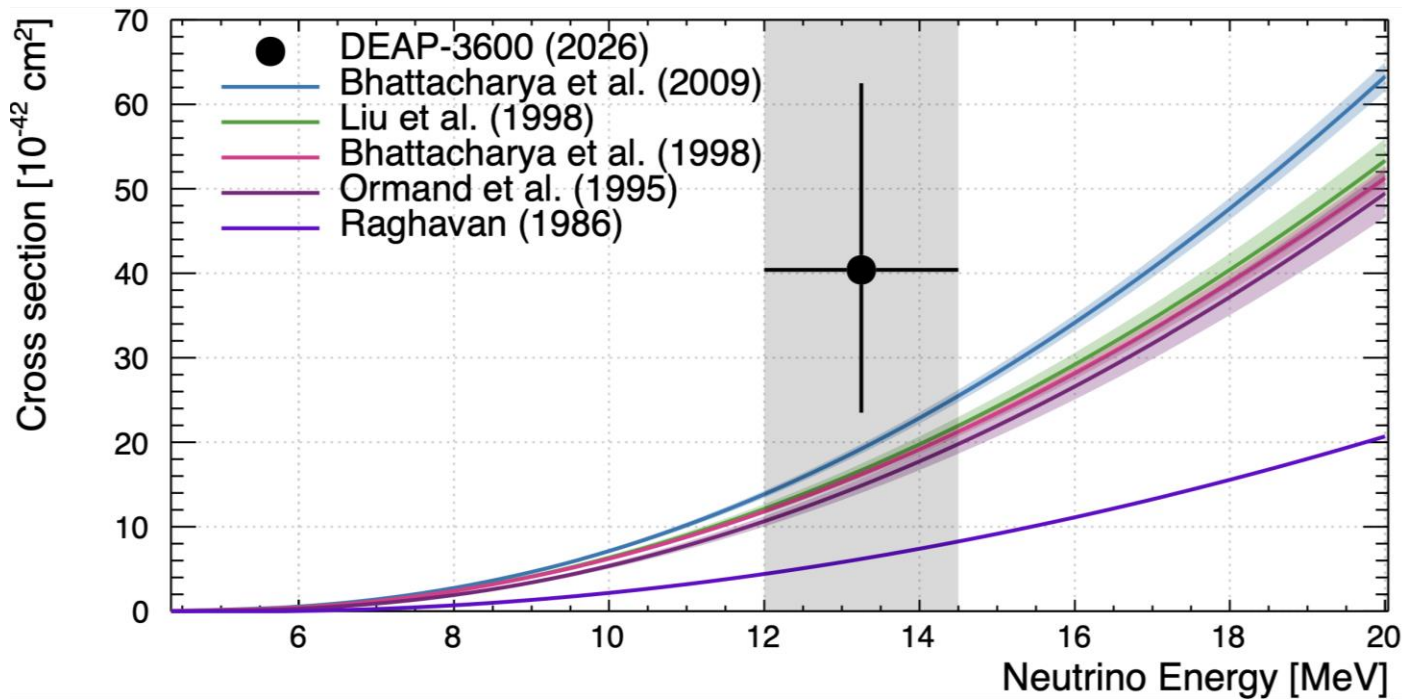
Cross-section measurement



$$\langle \sigma_{CC}^{ROI} \rangle = 4.0^{+2.2}_{-1.7} \times 10^{-41} \text{ cm}^2$$

$2.4^{+1.3}_{-1.0}$ higher than Bhattacharya et al. (2009)

Averaged over 12–14.5 MeV neutrino energy using 8B spectrum

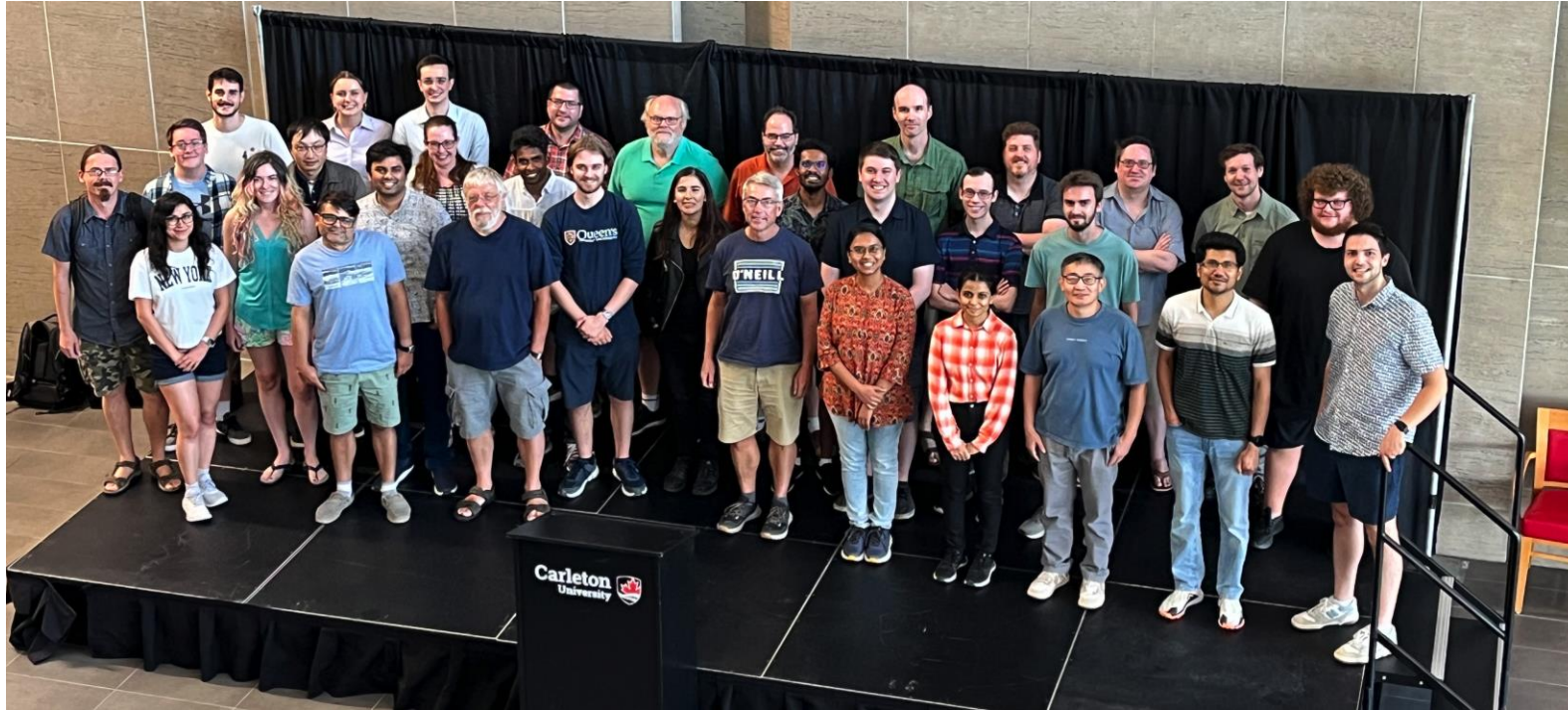
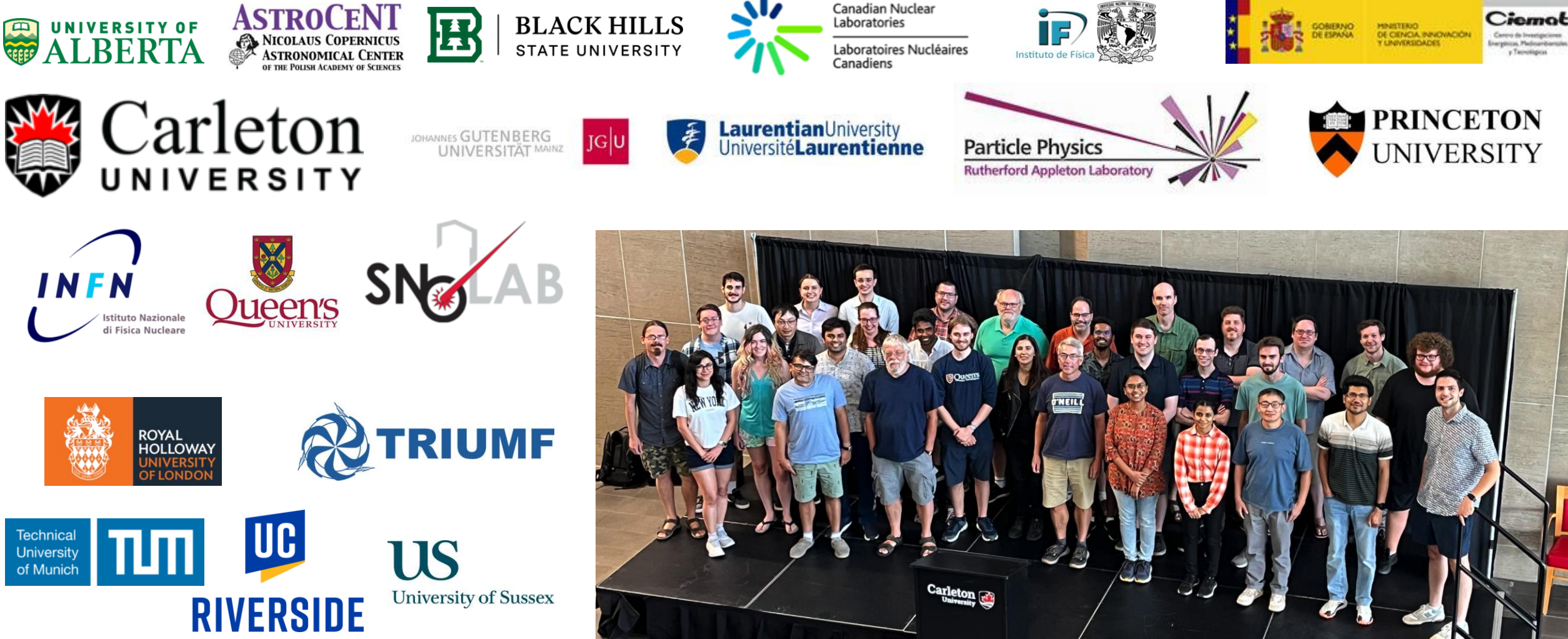


Summary and outlook



- First evidence (4σ) for CC solar neutrino absorption (ν_e CC) on argon
- $\langle \sigma_{CC}^{ROI} \rangle = 4.0_{-1.7}^{+2.2} \times 10^{-41} \text{ cm}^2$
- First observation of charged-current neutrino interactions in a dark matter detector
- Establishes liquid argon as a powerful medium for solar neutrino physics
- Upcoming from DEAP - Lower the energy threshold by using the delayed metastable transition signature + more data
- For next-gen detectors
 - Higher statistics with large-scale detectors DarkSide-20k, ARGO, DUNE
 - Improved measurement of the ^8B solar neutrino spectrum
 - Neutrino energy spectra from supernova neutrinos
 - Direct measurement of hep neutrinos

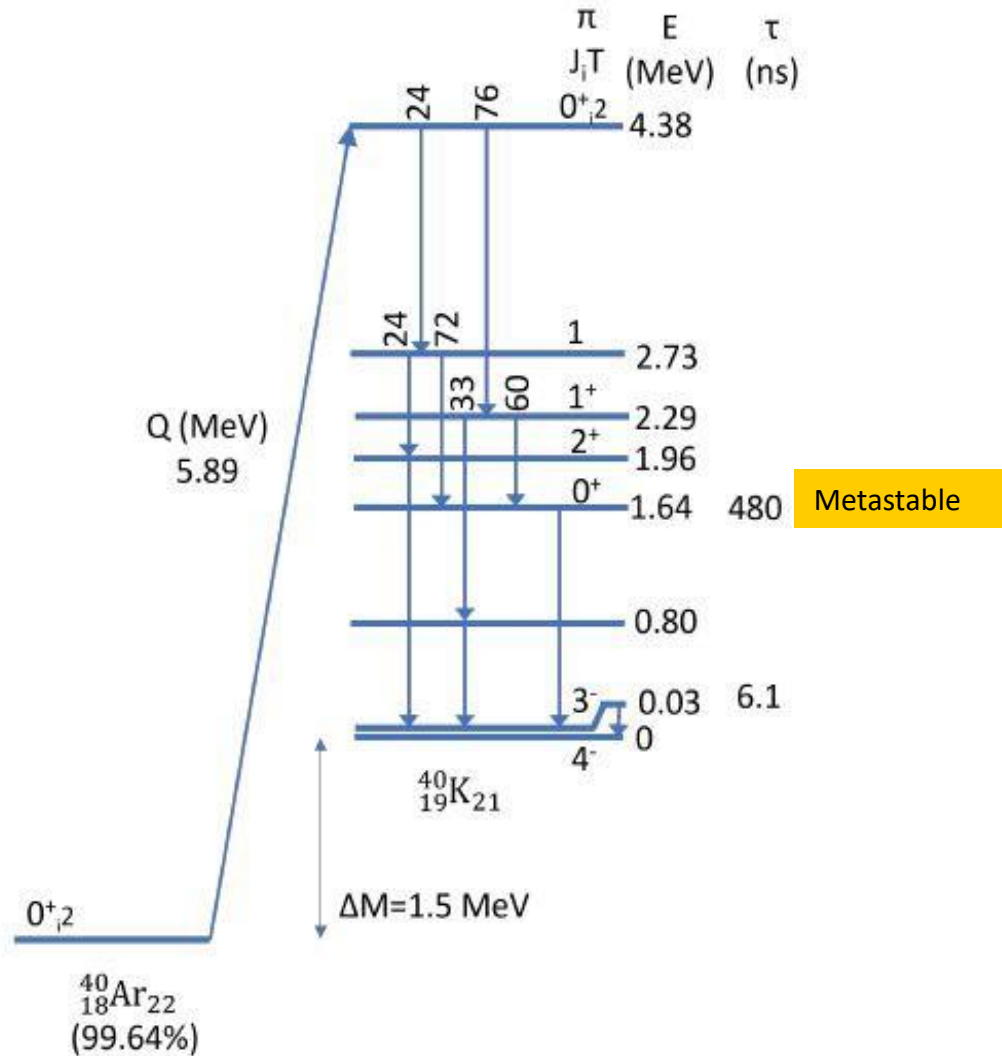
The DEAP collaboration



Backup slides



Energy levels in ^{40}K



Energy calibration



- 4.8 kBq AmBe neutron source - used to calibrate charge response of PMTs in the MeV range
- Sum of PMT charges expressed in units of single photoelectrons, corresponds to number of photoelectrons (PE)
- Corrected for light yield changes over time on a run-by-run basis
- For $E_{\text{vis}} > 2.5$ MeV, the number of PE and energy resolution σ related to E_{vis} using quadratic model

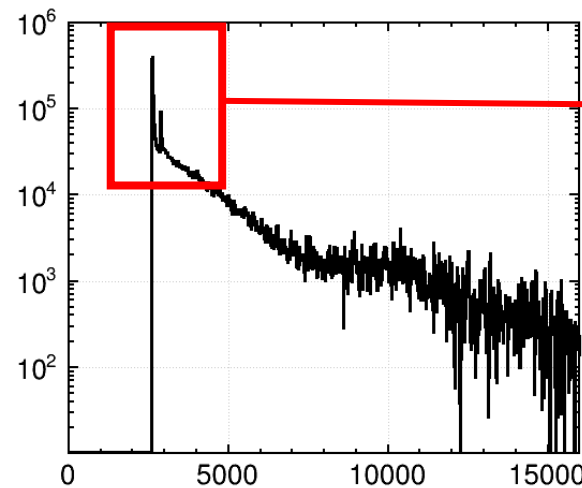
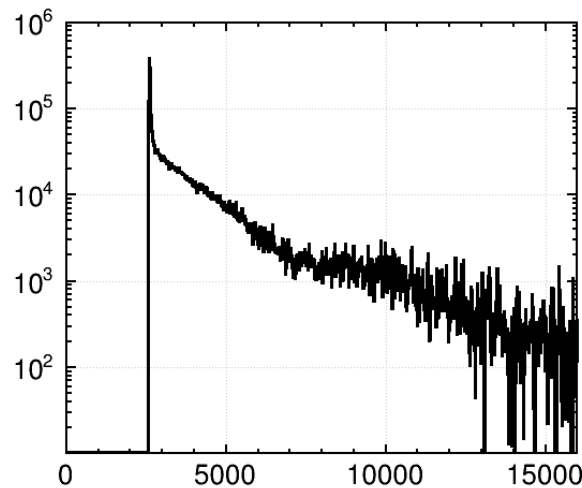
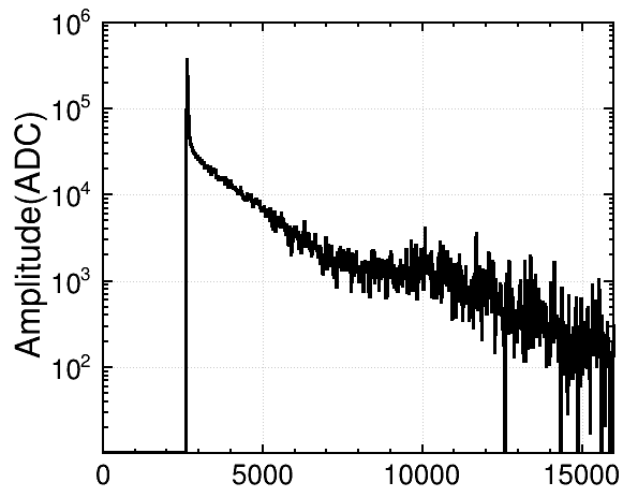
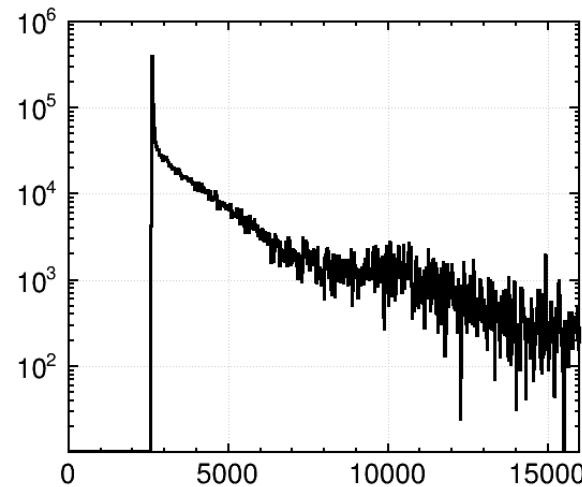
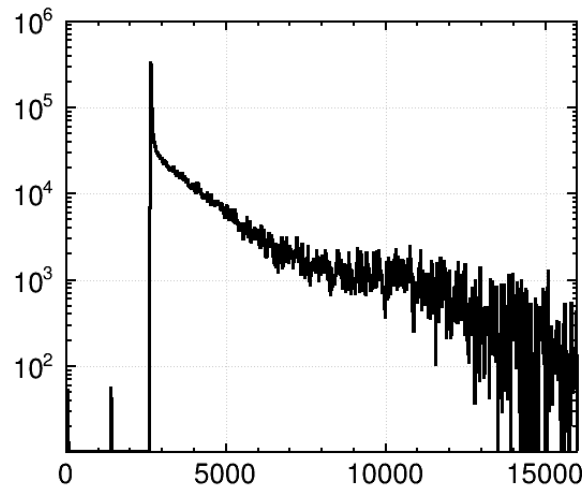
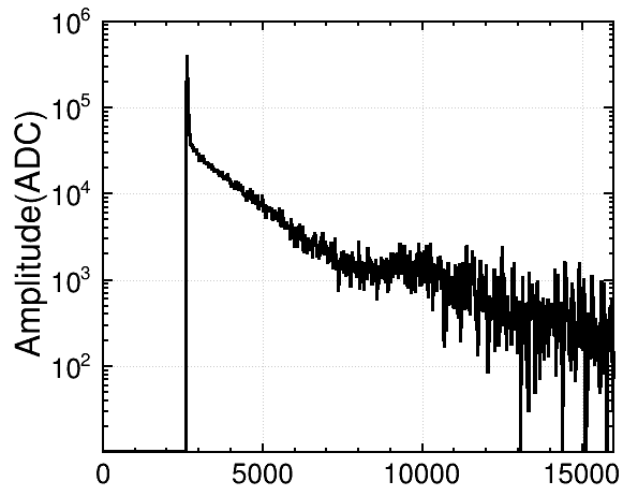
$$\text{PE}(E_{\text{vis}}) = C + B \cdot E_{\text{vis}} + A \cdot E_{\text{vis}}^2,$$

$$\sigma^2 = (1 + \sigma_{\text{PE}}^2) \cdot \text{PE} + \sigma_{\text{rel, LY}}^2 \cdot \text{PE}^2$$

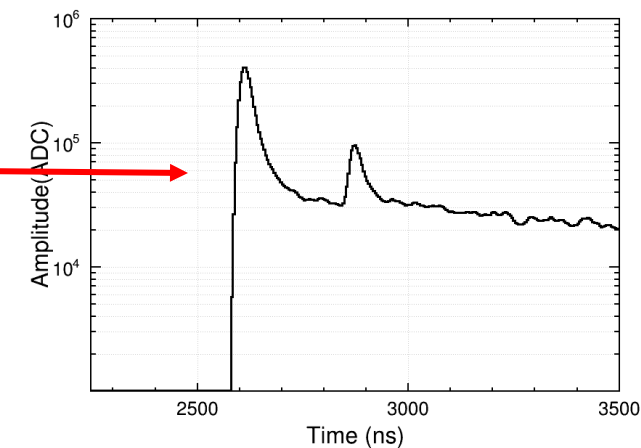
L. Weimer et al. arXiv:2408.02774



6 neutrino-like event waveforms



Delayed coincidence event
2nd peak energy = 1-2 MeV
2nd peak time delay = 252 ns
Consistent with transition
signature from ^{40}K
metastable state.



Single peaks vs. double peaks



- Energy response function, calibrated on single-peak events, systematically reconstructs double-peak events at higher energies.
- For example – for double-peak event with 13MeV (= 1.64MeV + 11.36MeV) total energy
 - PE(13MeV) = 86.6e3 PE
 - For individual peaks - PE(1.64 MeV) = 11.8e3 PE, PE(11.36 MeV) = 76.0e3 PE
 - If considering these individual peaks, total PE = 87.8e3 PE
 - $PE^{-1}(87.8e3 \text{ PE}) = 13.2 \text{ MeV}$
- Upper bound for double-peak events reconstructed with single-peak calibration = 13.2 MeV

$$PE(E_{\text{vis}}) = C + B \cdot E_{\text{vis}} + A \cdot E_{\text{vis}}^2$$

Delayed coincidence event



- Double-peak event reconstructed at 13.1 MeV applying single-peak event calibration
- Second peak at 252 ns, energy 1–2 MeV: consistent with metastable ^{40}K decay signature (1.64 MeV, 480 ns lifetime)
- 5 single-peak and 1 double-peak events
- Branching ratio for delayed coincidence neutrino events: (3-45) % at 68% CI

Systematic uncertainties



Systematic Unc.	Value	Bkg	CC ν_e
Energy Scale Bias	$0 \pm 1.5\%$	10.1%	11.7%
Energy Resolution	96 keV \pm 17 keV	0.5%	0.1%
Int./Ext. γ LY Bias	$0 \pm 1.3\%$	0.2%	12.6%
AmBe Bkg Scaling	0.8 ± 0.2	18.4%	—
AmBe Pile-up Est.	0.28 ± 0.09 events	21.9%	—
MV Cut Efficiency	$99.6\%_{-1.0\%}^{+0.4\%}$	$+14\%$ -4.4%	—
^8B solar ν_e flux	$(5.2 \pm 0.2) \times 10^6 \text{ cm}^{-2} \text{ s}^{-1}$	—	3.9%
<i>hep</i> solar ν_e flux	$(0.8 \pm 0.2) \times 10^4 \text{ cm}^{-2} \text{ s}^{-1}$	—	0.4%
Expected $\langle \sigma_{\text{model}} \rangle$	$(1.67 \pm 0.05) \times 10^{-41} \text{ cm}^2$	—	3.0%
Total	—	$+33\%$ -31%	18%