

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

Abhijit Garai on behalf of DEAP-3600 collaboration

May 27, 2026

SNOLAB Users Meeting, Sudbury, Ontario

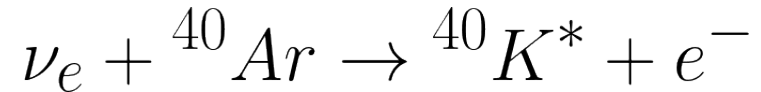


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Executive summary

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



- Observed **6** candidate events

- Background expectation $0.48_{-0.15}^{+0.16}$ events



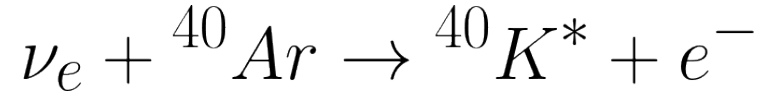
4 σ significance

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

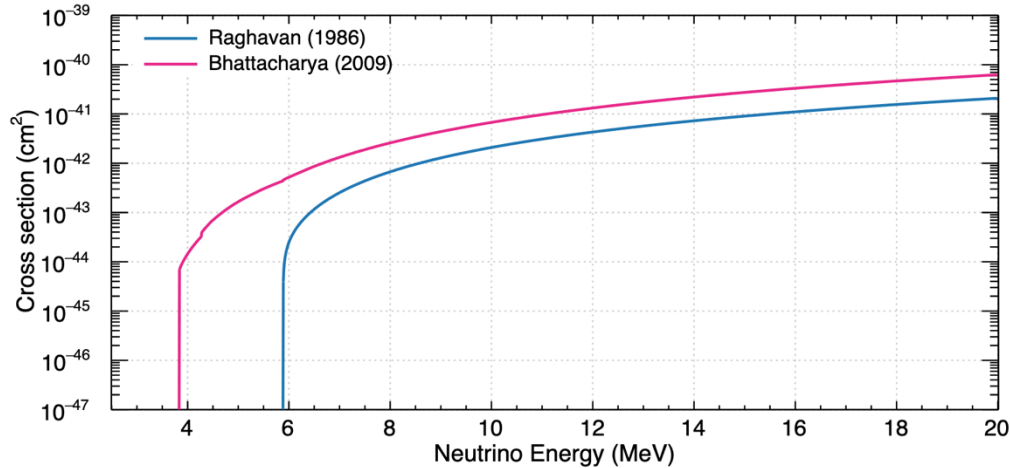
[arXiv:2605.12769](https://arxiv.org/abs/2605.12769)

Submitted to PRL on May 14, 2026

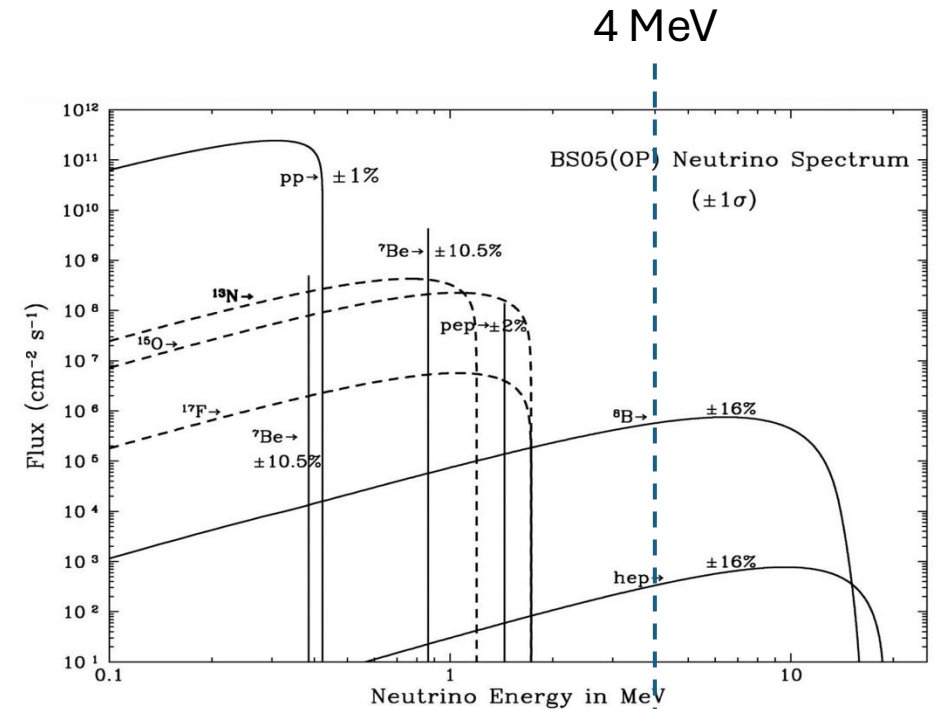
Neutrino charge-current interaction in argon



- First proposed by R. S. Raghavan (1986)
- Not yet observed R. S. Raghavan Phys. Rev. D 34, 2088 (1986)
- Would be first observation of charged-current neutrino interactions in a dark matter detector
- **Fundamental process for future multi-tonnes liquid Argon dark matter and neutrino detectors!**



- M. Bhattacharya et al. measured Gamow-Teller (GT) strengths for transitions from ${}^{40}\text{Ar}$ to ${}^{40}\text{K}$ Bhattacharya, et al., Phys.Rev. C 80, 055501 (2009)
- Energy threshold decreased from 5.9 MeV (Fermi) to 3.9 MeV (GT)
- Cross-section enhanced by a factor 3

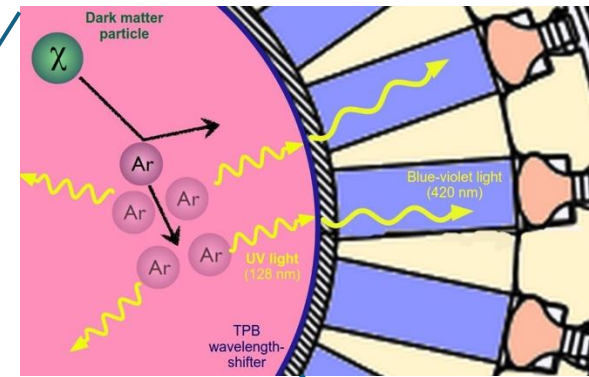
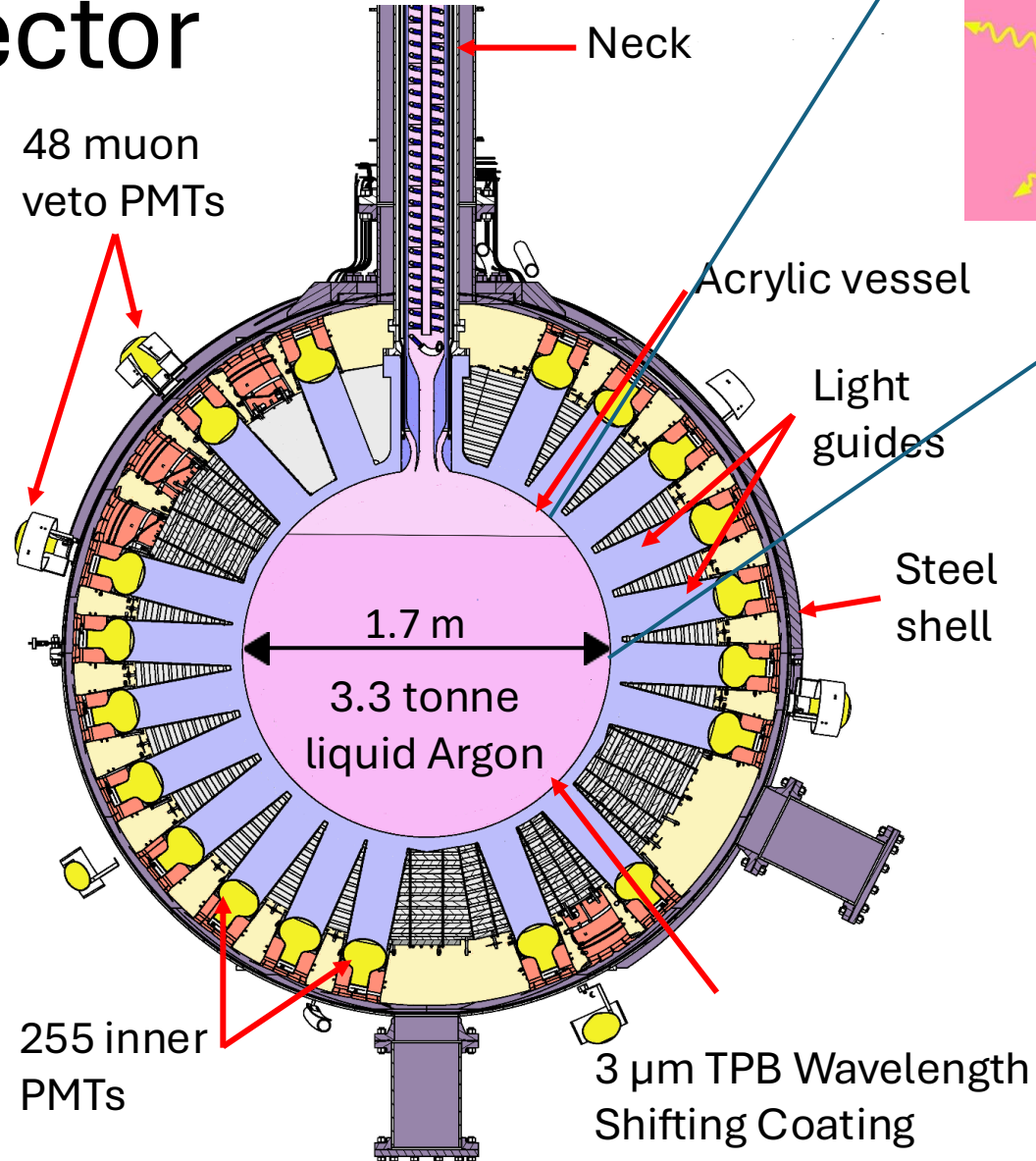


J. N. Bahcall, A. M. Serenelli, and S. Basu. New Solar Opacities, Abundances, Helioseismology, and Neutrino Fluxes. *ApJL*, 621(1):L85–L88, 2005.

DEAP-3600 detector

Dark matter Experiment using Argon
Pulse shape discrimination

- Located ~2 km underground at SNOLAB.
- Single phase liquid scintillator detector with 3.3 tonne of liquid Ar
- 255 Hamamatsu PMTs
- Water veto with 48 PMTs
- Pulse shape discrimination for background rejection ($\sim 10^{-8}$)
- Strongest limit on WIMP-nucleon cross-section on Ar in 2019



Datasets and exposure

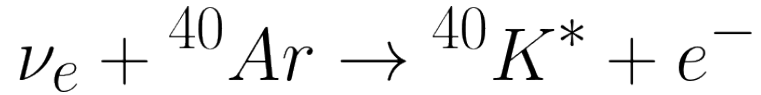
- Data used : November 4, 2016 and March 27, 2020
- Total exposure = **(7.29 ± 0.05) tonne·years**
- Other recent physics results from this dataset:
 - ^{39}Ar activity Eur. Phys. J. C 83, 642 (2023) arXiv:2302.14639
 - ^{39}Ar Half-Life Eur. Phys. J. C 85, 728 (2025) arXiv:2501.13196
 - Quenching factor of α -particles in LAr: Eur. Phys. J. C 85, 87 (2025) arXiv:2406.18597
 - Dark Matter Search with using the Profile Likelihood Ratio Method: arXiv:2603.13965

Ongoing physics analyses:

- Muon flux measurement with DEAP-3600
- GW-coincident neutrino search
- Boosted dark matter
- $0\nu\text{ECEC}$ on ^{36}Ar

More: Michela Lai's talk yesterday

ν_e CC Signal in DEAP-3600



Single-Pulse Events

- De-excitation does not go through metastable state
- Event only has one pulse

$$E_{single} = E_e + \sum E_\gamma$$

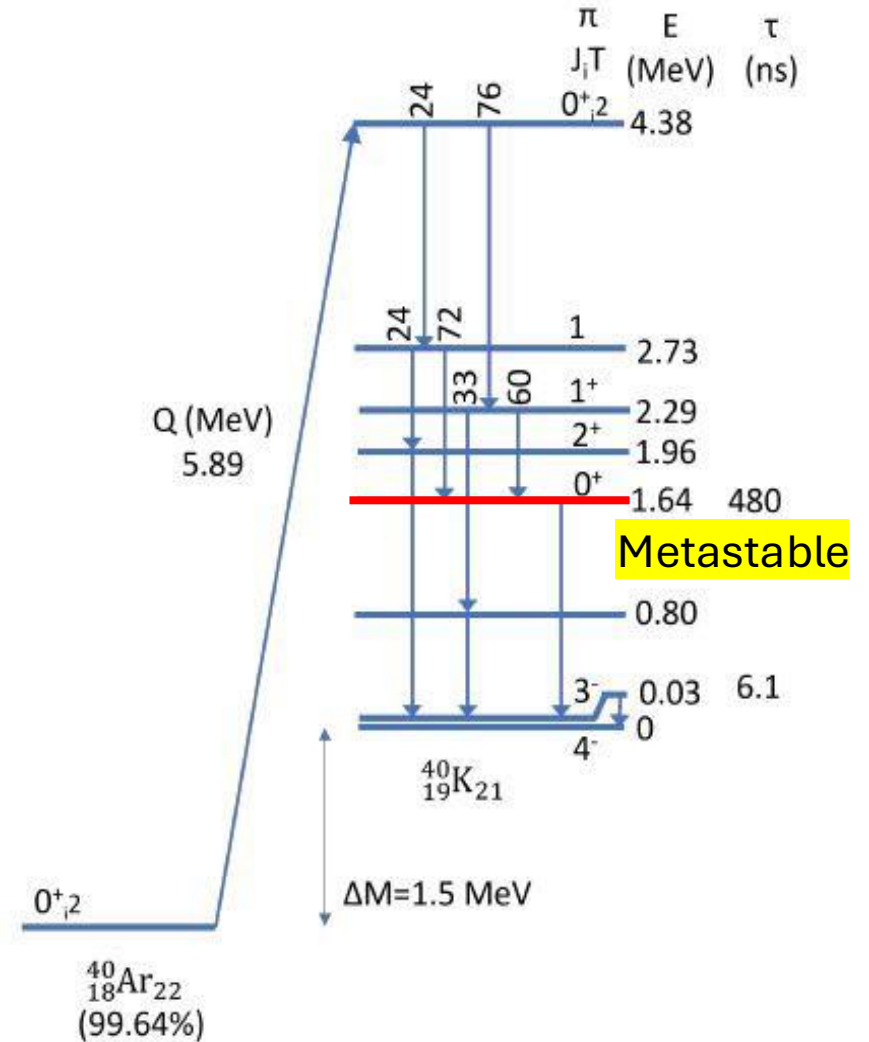
Delayed Coincidence Events

- De-excitation goes through the metastable state
- Event has two pulses

$$E_{prompt} = E_e + \sum E_{\gamma,1}$$

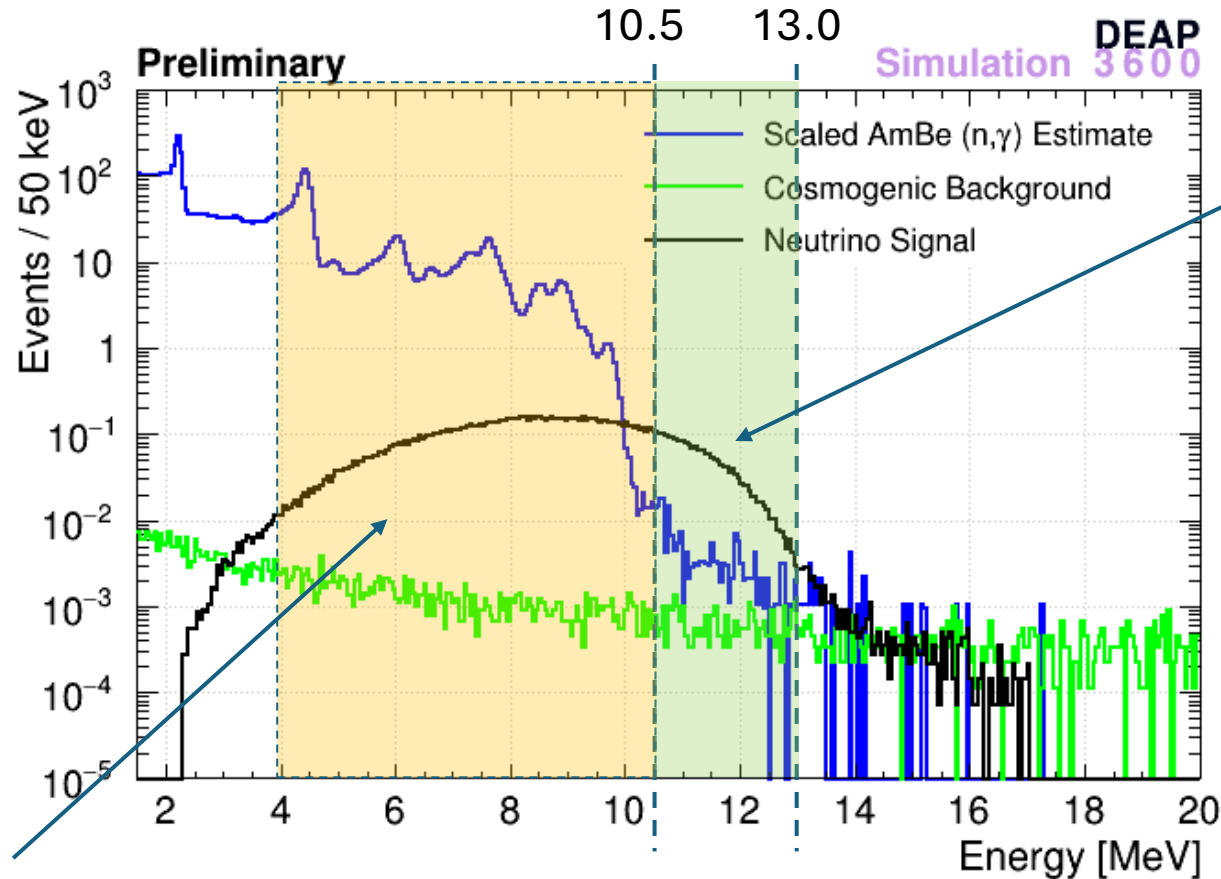
$$E_{delayed} = \sum E_{\gamma,2} = 1.64 \text{ MeV}$$

From excitation level to 1.64 MeV metastable state



~30% of de-excitations through **metastable** state

Region of Interest (ROI)



ROI for this analysis

- Counting experiment
- Neutrino signal > background
- Accurate background model

10.5 MeV to 13.0 MeV reconstructed energy
12.0 MeV to 14.5 MeV incident neutrino energy

Lower bound: driven by radiogenic background
Upper bound: driven by cosmogenic background

Delayed Coincidence (Ongoing analysis)

- Unique neutrino signature
- Neutrino signal << background

Expected Neutrino Signal

- Expected neutrino rate :

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

Number of ^{40}Ar nuclei in the detector

- Depends on detector mass, ^{40}Ar abundance

$$\begin{aligned} \Gamma &= 2.2 \pm 0.2_{sys} \text{ events}/(\text{tonne} \cdot \text{year}) \\ &= 16.1 \pm 1.5_{sys} \text{ events in } 7.3 \text{ tonne} \cdot \text{year} \end{aligned}$$

Oscillated ^8B + *hep* neutrino flux

Cross-section model

Bhattacharya, *et.al.*, Phys.Rev. C 80, 055501 (2009)

Total expected neutrinos in the ROI : **$2.3 \pm 0.4_{sys}$**

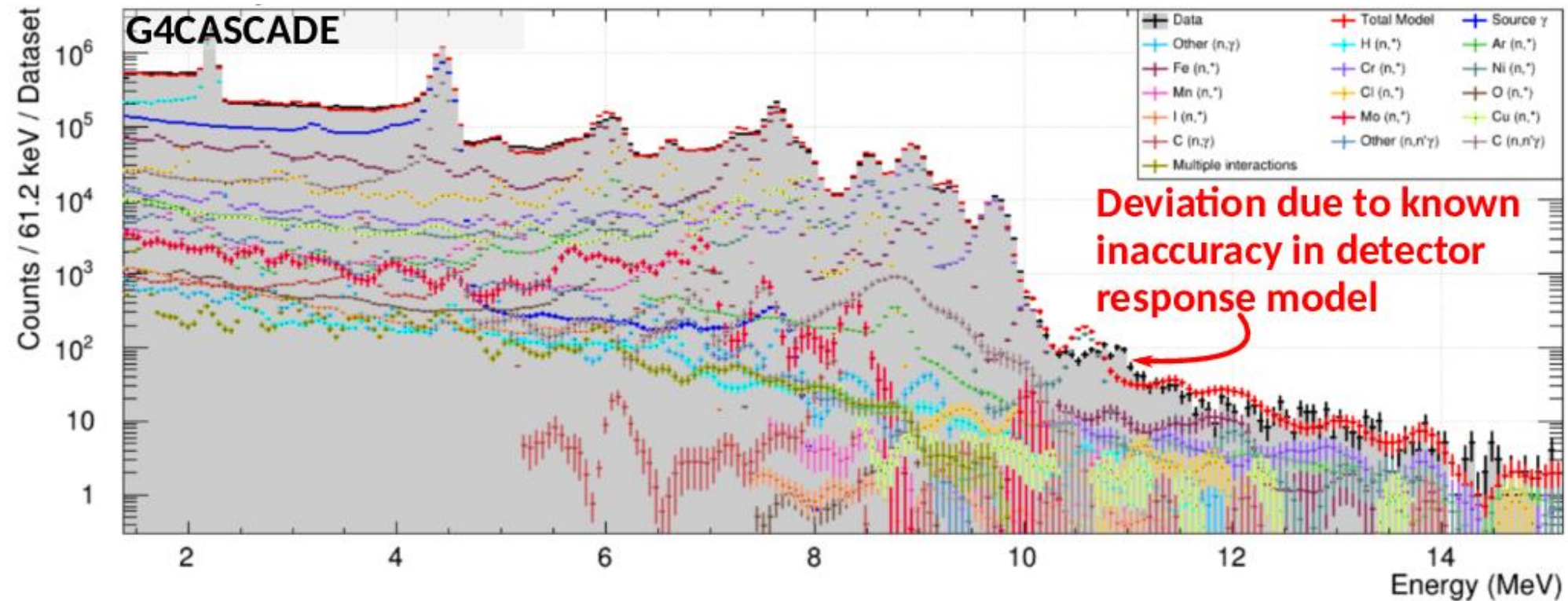
Detection efficiency: 92%

ROI: 10.5-13 MeV reconstructed energy

2.3 ± 0.4 events from ^8B neutrinos

0.03 ± 0.01 events from *hep* neutrinos

Energy calibration



- 4.8 kBq AmBe neutron source
- Calibrate charge response of the individual PMTs
- sum of PMT charges in units of single photoelectrons
- correct for light yield changes over time on a run-by-run (\sim daily,

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

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

Non-linear detector response and ROI

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

- double-peaked neutrino event with 13.0 MeV (1.64 + 11.36) total energy
- PE (1.64 MeV) = 11.8×10^3 PE
- PE (11.36 MeV) = 76.0×10^3 PE
- Sum = 87.8×10^3 PE

- $\text{PE}^{-1}(87.8 \times 10^3 \text{ PE}) = 13.2 \text{ MeV}$

- Upper bound for double-peaked events reconstructed with single-peak calibration: 13.2 MeV

Event selection

	Event selection cut	Live time	ROI Events
Select electron recoil physics events	→ Low-level cuts	817.9 d	12
Veto muon induced background	→ Muon veto cut	814.7 d	12
	Event selection cut	Acceptance	ROI Events
Remove Scintillation in neck veto fibers	→ Neck veto cut	1.00	6
Remove events outside of liquid argon	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
Allow delayed coincidence events	→ Pile-up cut	0.95	6
Remove instrumental events	→ Scintillation waveform cut	0.92	6

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

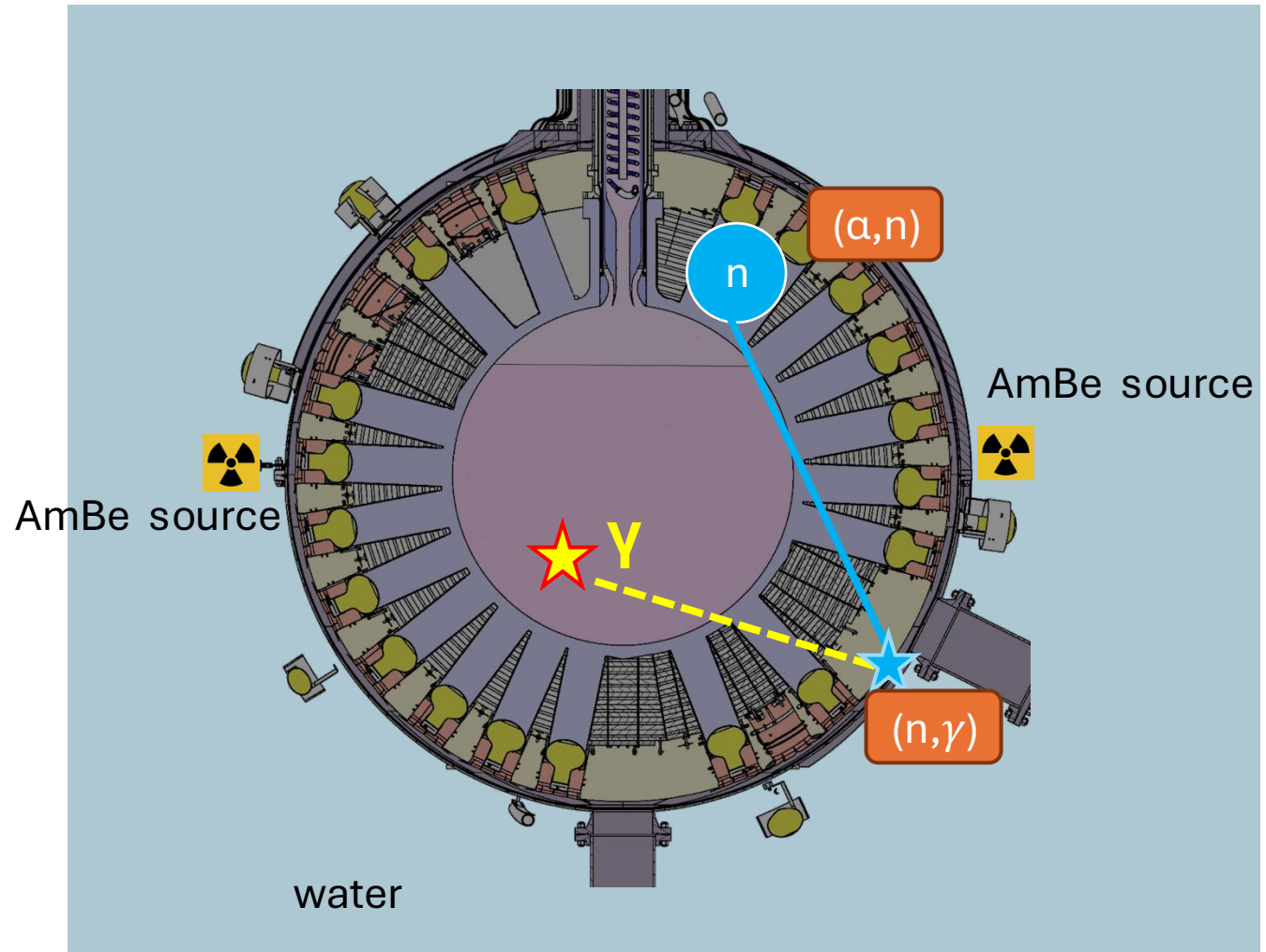
- Dominant sources of neutrons: PMTs, stainless steel shell and the water tank
- Neutron captured by detector materials
- de-excites through a series of gamma rays

- 60 live-days of neutron calibration data
- Equivalent of $\sim 10^7$ live-days of background neutrons in the physics dataset

Method

1. Normalize AmBe source neutron spectrum to 8-10 MeV in the physics dataset
2. Integrate normalized spectrum in the ROI
3. Subtract contribution from pileups
4. Apply a correction factor of 0.8 to account for systematic differences due to position and energy of neutrons

G4RiversideCASCADE for the (n,γ) simulations



Total radiogenic background in the ROI: **0.43 ± 0.05 (stat) ± 0.14 (sys)**

Backgrounds: Cosmogenics

Residual muon flux at SNOLAB : $3.3 \times 10^{-10} / \text{cm}^2/\text{s}$

- Cherenkov light in the water triggers veto PMTs
- Events in the LAr that are correlated with the muon veto triggers are vetoed
- Muons clipping/missing the veto detector are untagged
- Secondaries: neutrons, gamma-rays pions/kaons electrons/positrons mimic neutrino-like signal
- Long-lived activated isotopes may decay outside the veto window

Cosmogenic background estimated using RAT and FLUKA based MC simulation



Backgrounds: Cosmogenics

- Veto trigger efficiency as a function of Cherenkov photon production with optical simulations in RAT
- Muon veto applied based on Cherenkov photon production in FLUKA
- Systematic uncertainties:
 - PMT quantum efficiency
 - water absorption length
 - tank liner reflectivity

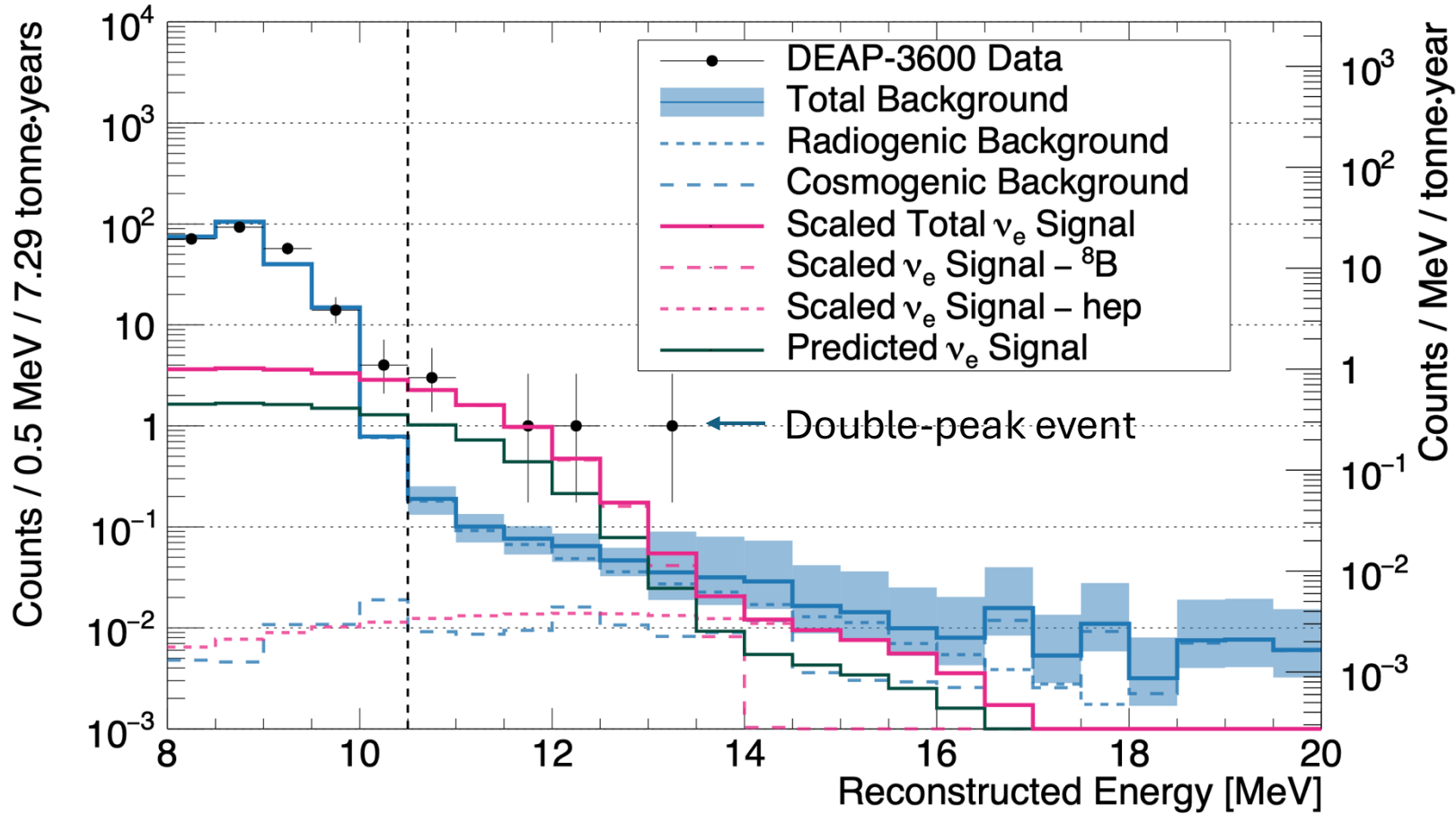
In 10–20 MeV range:

24 events tagged by muon veto in data
consistent with prediction of 20 events

Total cosmogenic background in the ROI:

0.048 ± 0.009 (stat) $+0.070 -0.025$ (sys)

DEAP-3600 measurement



Observed: 6 events

2.3 ± 0.4 events from ^8B neutrinos

0.03 ± 0.01 events from hep neutrinos

Total Background $0.48^{+0.16}_{-0.15}$

Background only: 4σ

Background+signal: 1.5σ

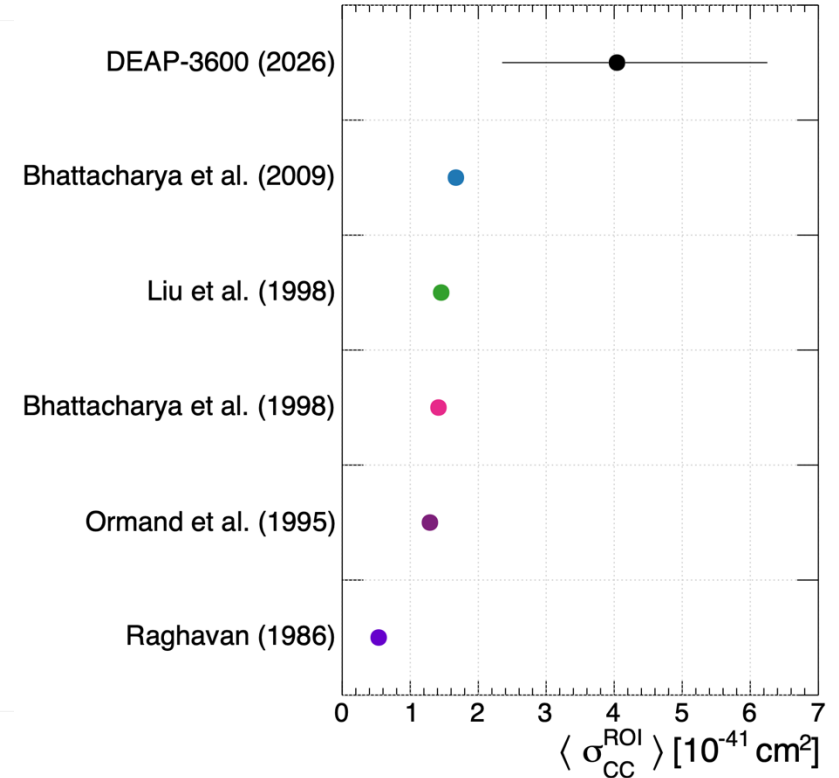
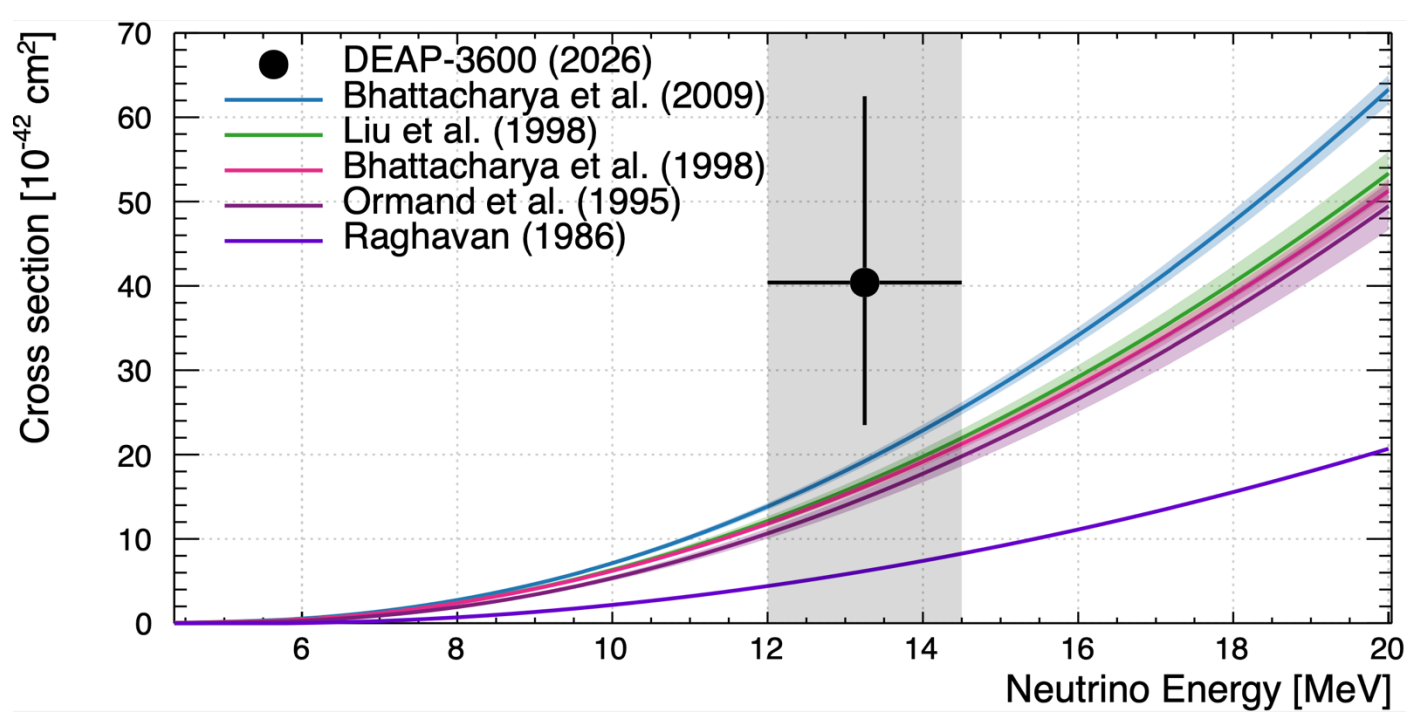
double-peak event

- Double-peak event reconstructed at 13.1 MeV applying single-peak event calibration
- Below the upper bound of 13.2 MeV for the double-peak events calibrated as single-peak event
- Second peak at 252 ns, energy 1–2 MeV: consistent with delayed neutrino event (1.64 MeV, 480 ns lifetime)
- 5 single-peak and 1 double-peak events
- branching ratio for delayed neutrino events: (3-45) % at 68% CI

DEAP-3600 cross section measurement

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

$2.4_{-1.0}^{+1.3}$ higher than Bhattacharya, Goodman and García (2009)

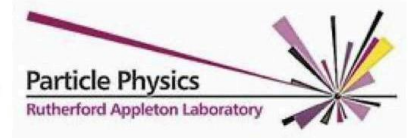


Systematics uncertainties

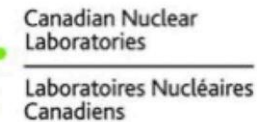
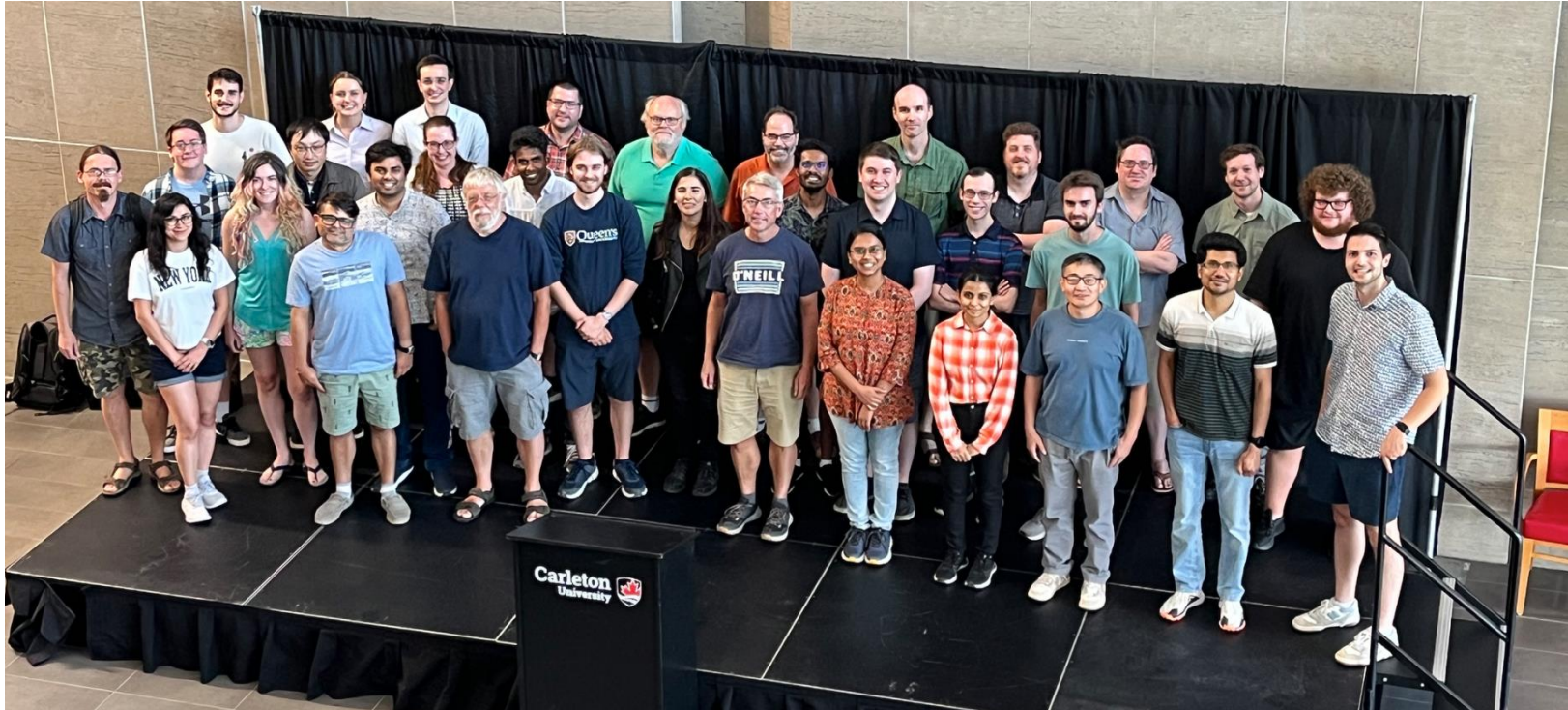
Systematic Unc.	Value	Bkg	CC ν_e
Energy Scale Bias	$0 \pm 1.5\%$	10.1%	11.7%
Energy Resolution	96 keV \pm 17 keV	0.5%	0.1%
Int./Ext. γ LY Bias	$0 \pm 1.3\%$	0.2%	12.6%
AmBe Bkg Scaling	0.8 ± 0.2	18.4%	–
AmBe Pile-up Est.	0.28 ± 0.09 events	21.9%	–
MV Cut Efficiency	$99.6\%_{-1.0\%}^{+0.4\%}$	$+14\%$ -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%

Summary and future outlook

- First evidence (**4 σ**) 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
- Lower the energy threshold by exploiting the delayed metastable transition γ -ray
- Establishes liquid argon as a powerful medium for solar neutrino physics
- Higher statistics with large-scale detectors DarkSide-20k, ARGO, DUNE
- Improved measurement of the ^8B solar neutrino spectrum
- Neutrino energy spectra from supernova neutrinos
- Future measurement of *hep* neutrinos



DEAP-3600 collaboration



~100 researchers in Canada, Germany, Italy, Mexico, Poland, Russia, Spain, UK, USA