First Detection of CEvNS on Argon with the CENNS-10 Liquid Argon Detector

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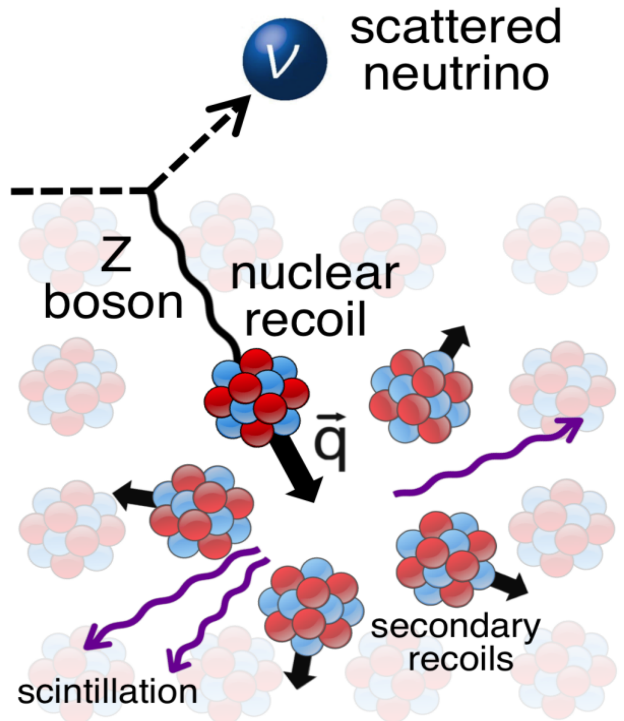
Coherent Elastic Neutrino-Nucleus Scattering (CEvNS)

- Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) was first predicted in 1974[1,2]
  - >40 years until first detection!
  - Need low-threshold, low-background detectors
  - Cleanly predicted in Standard Model (SM)
- Largest neutrino cross section at low energies
  - Nucleons in nucleus recoil "in phase", leading to N^2 dependence of CEvNS cross section

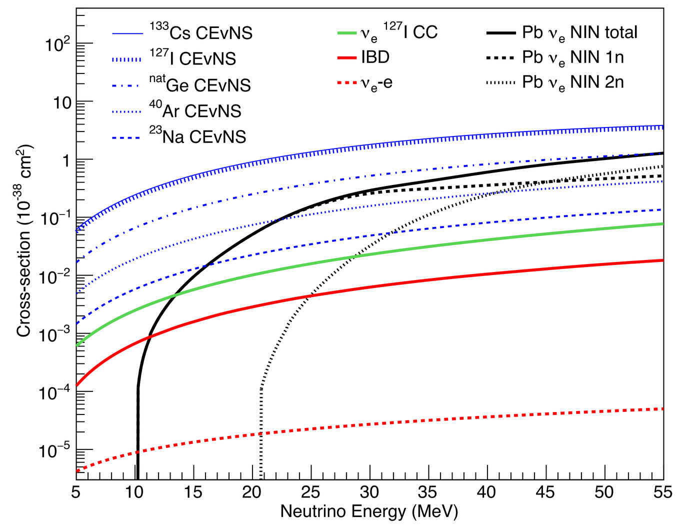


$$\sigma \approx \frac{G_F^2 N^2}{4\pi} E_\nu^2$$

- Signal is low-energy nuclear recoil

$$E_r^{max} \simeq \frac{2E_\nu^2}{M} \simeq 50\ \mathrm{keV}$$

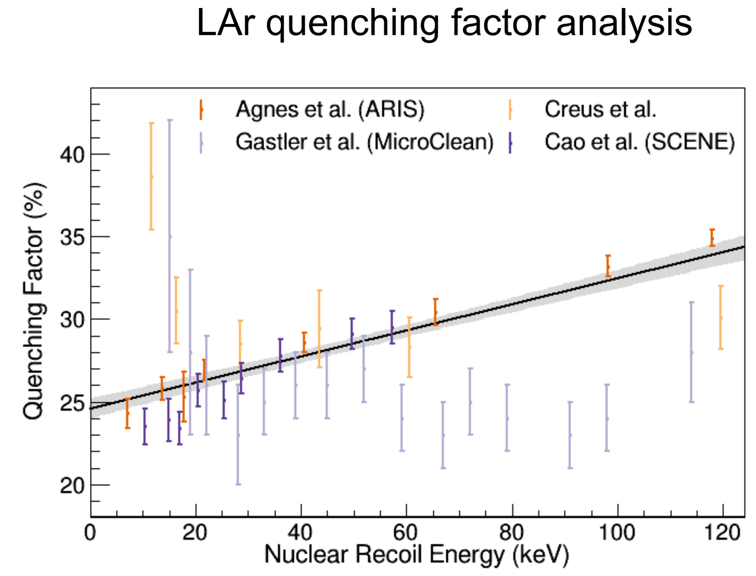
- CEvNS provides access to a host of physics including neutrino non-standard interactions (NSI)



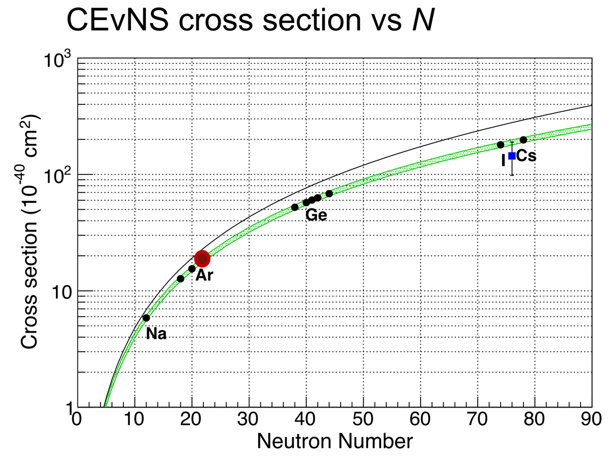
Liquid Argon for CEvNS Detection

- Low N nuclei (N = 22) to map out N^2 dependence of CEvNS cross section
- High scintillation yield of 40 photons/keVee
- Well measured quenching factor
- Pulse shape discrimination (PSD) capabilities to further remove electron recoil backgrounds

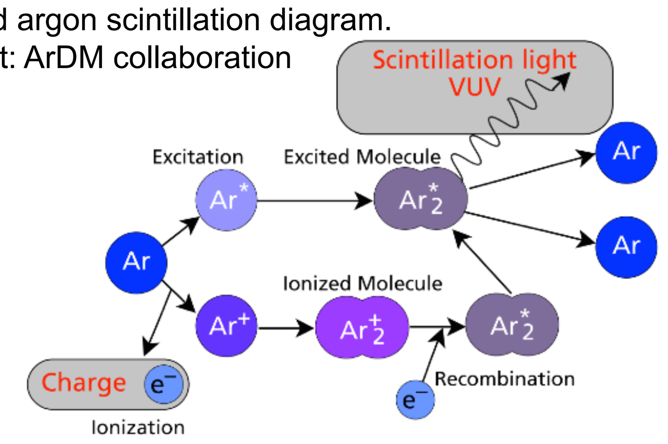
LAr quenching factor analysis



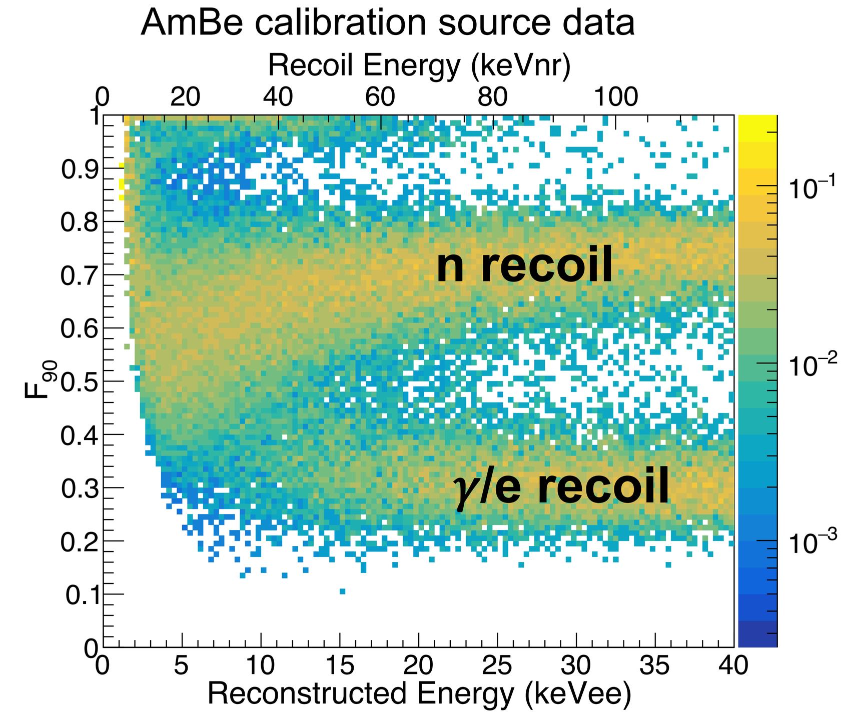
CEvNS cross section vs N



Liquid argon scintillation diagram. Credit: ArDM collaboration



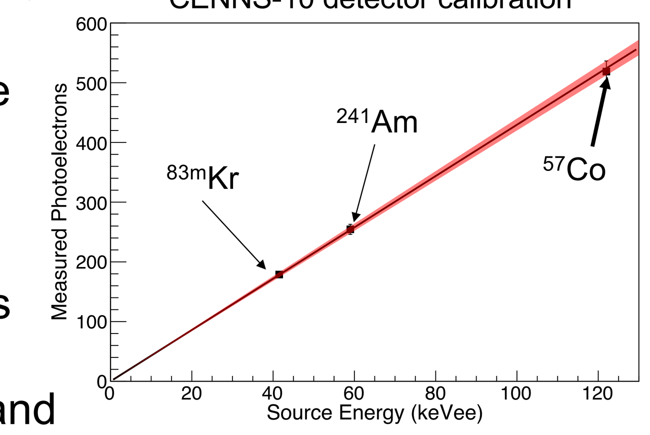
AmBe calibration source data



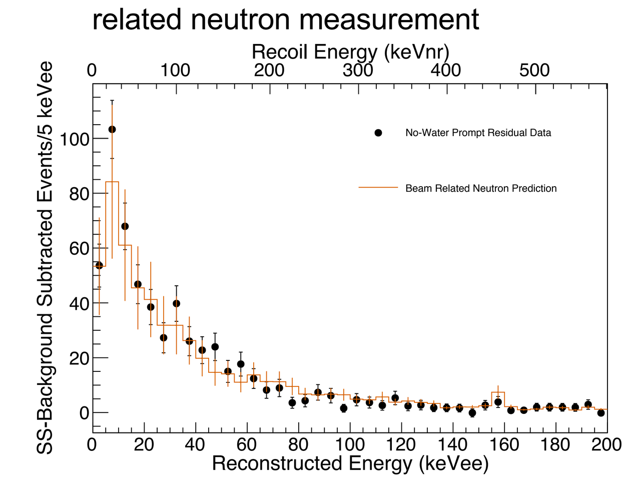
CENNS-10 Analysis

- Calibrate detector using variety of gamma and neutron sources
  - Designed and implemented ^{83m}Kr source for low energy calibration
- Measure steady-state backgrounds using separate off-beam trigger
- Measure beam-related neutron backgrounds with no-water shielding runs
  - In agreement with prior measurements and simulations
- Full 3D binned likelihood fit performed in energy/PSD/time
  - Input PDFs into likelihood fit from SM CEvNS prediction, measured/simulated beam-related neutrons (BRN) and measured steady-state backgrounds
- 2 independent analyses performed on first production data

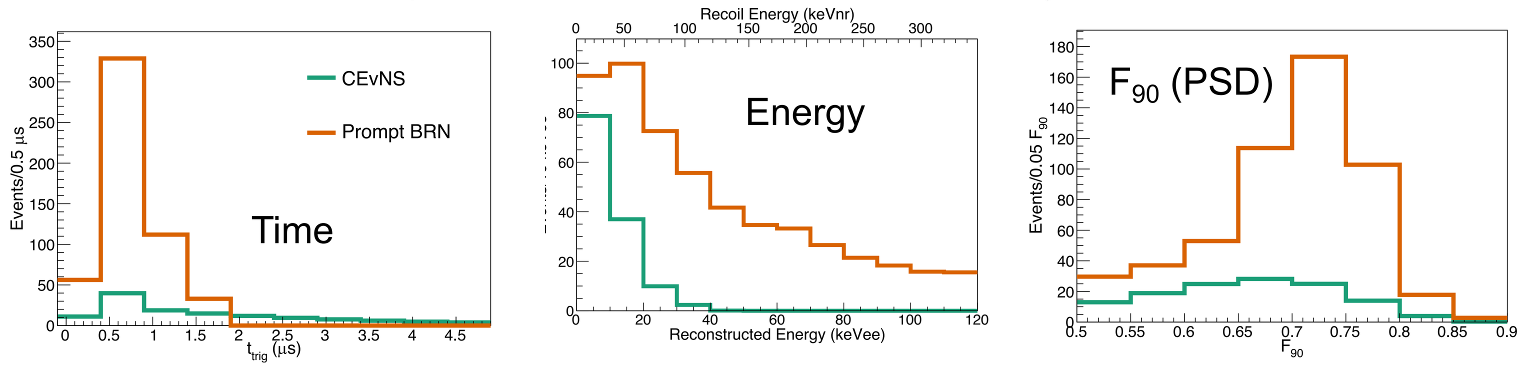
CENNS-10 detector calibration



Production data no-water beam-related neutron measurement



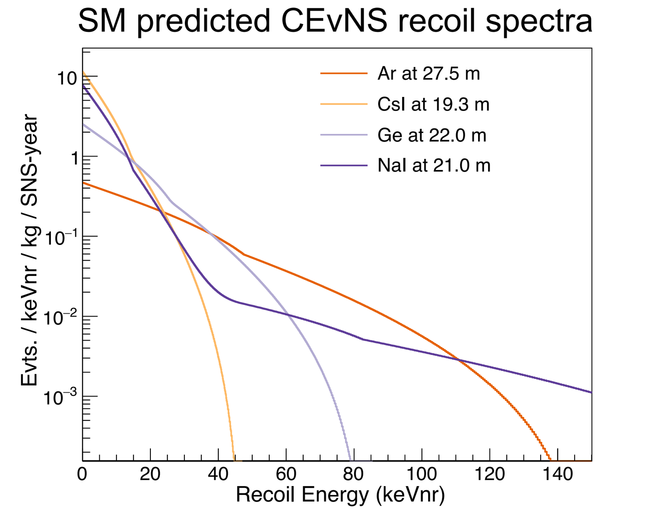
Input PDFs to 3D binned likelihood analysis



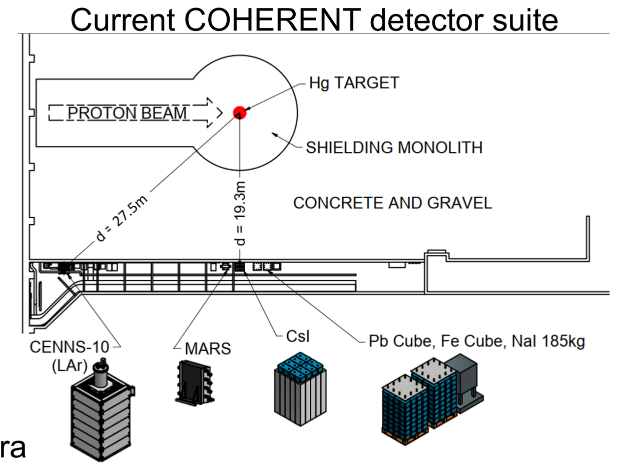
The COHERENT Experiment

- First goal to observe CEvNS and measure N^2 dependence of CEvNS cross section
  - First observation of CEvNS in August 2017 with 14.6 kg CsI[Na] crystal![3]
    - Placed further bounds on neutrino non-standard interactions (NSI)
- Located at the Spallation Neutron Source (SNS) at ORNL
  - World's most powerful pulsed proton source
  - ϕ_ν = 4.3 x 10^7 ν/cm²/s at 20 m
  - Neutrons produced by SNS largest beam-related background
- Neutrinos produced through π-decay at rest
- Steady-state background rejection through pulsed beam

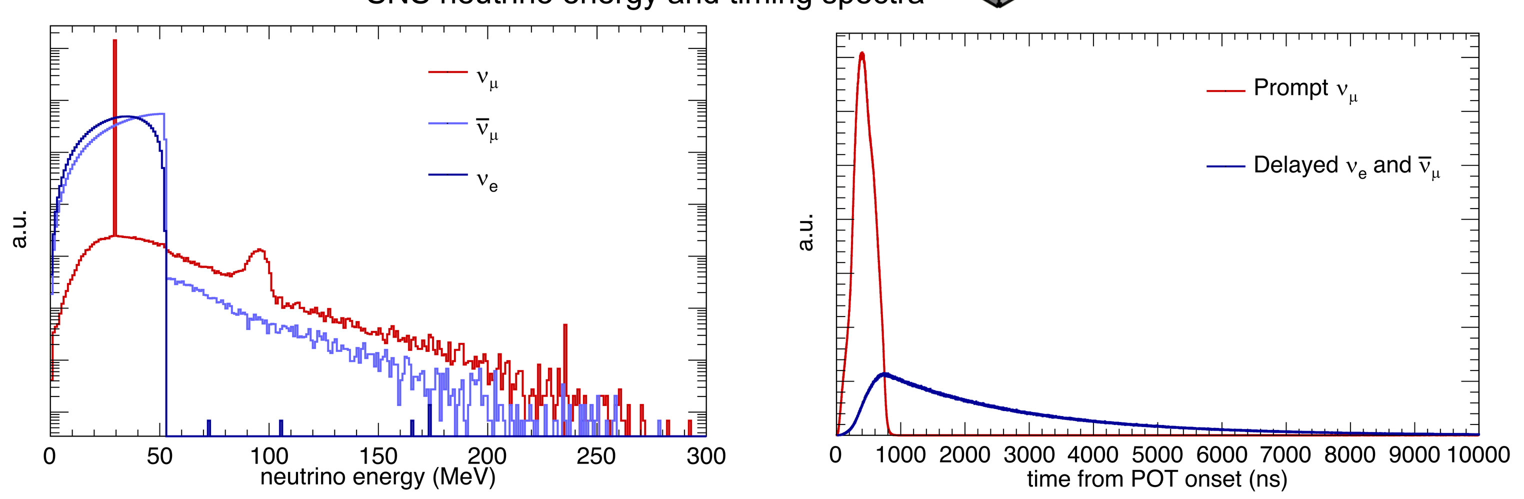
SM predicted CEvNS recoil spectra



Current COHERENT detector suite

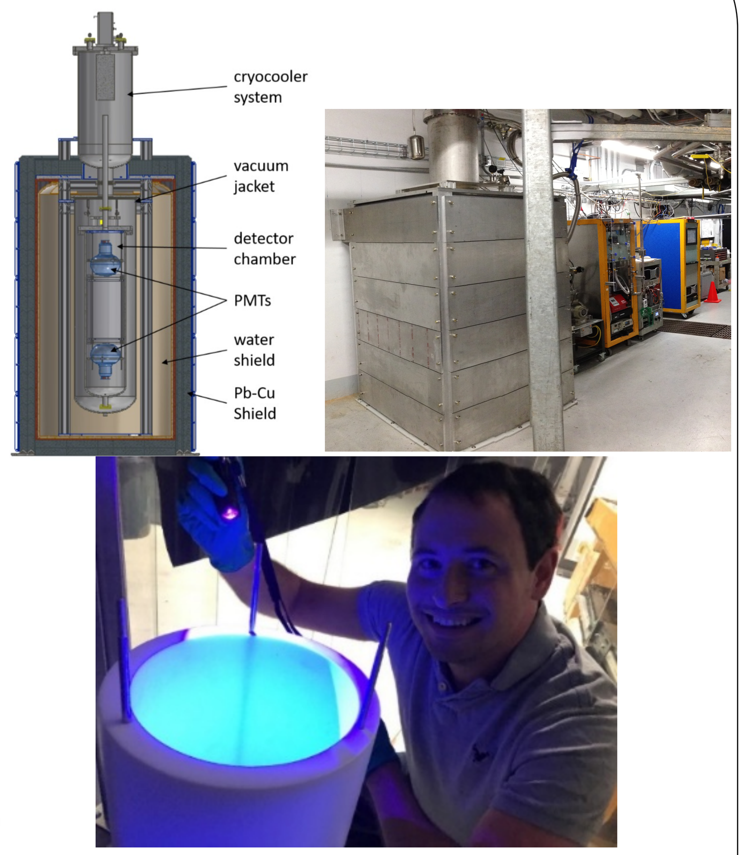


SNS neutrino energy and timing spectra

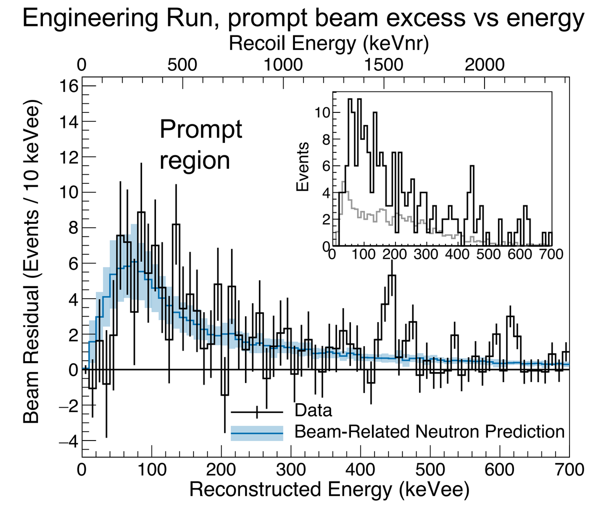


The CENNS-10 Detector

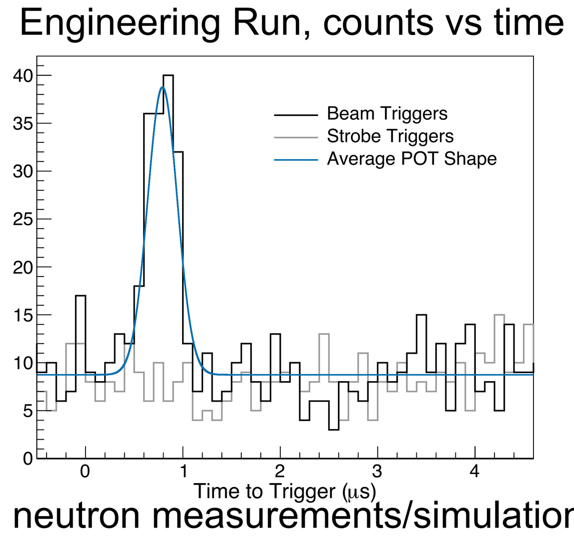
- Single-phase liquid argon calorimeter
- 24 kg fiducial volume
- 2x Hamamatsu R5912-02MOD PMTs
- TPB-coated Teflon sides and PMTs for wavelength shifting of liquid argon scintillation
- 20 cm H_2O, 1.25 cm Cu, 10 cm Pb shielding for background reduction
- Initial Engineering Run with high threshold placed limit on CEvNS cross section and constrained beam-related neutron (BRN) backgrounds[4]
- First production data with lower threshold from July 2017-November 2018
- Calibration shows ~4.5 photoelectrons/keVee (20 keVnr threshold)



Engineering Run, prompt beam excess vs energy



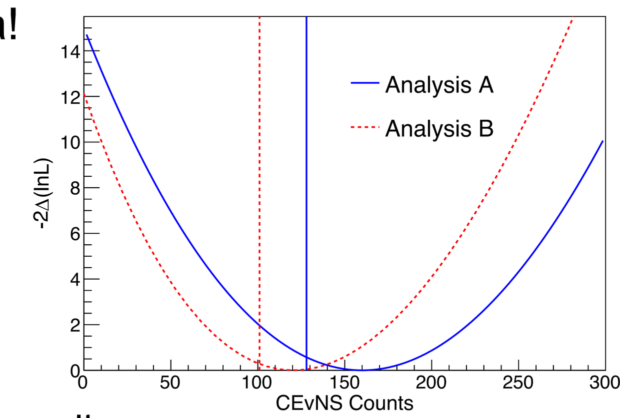
Engineering Run, counts vs time



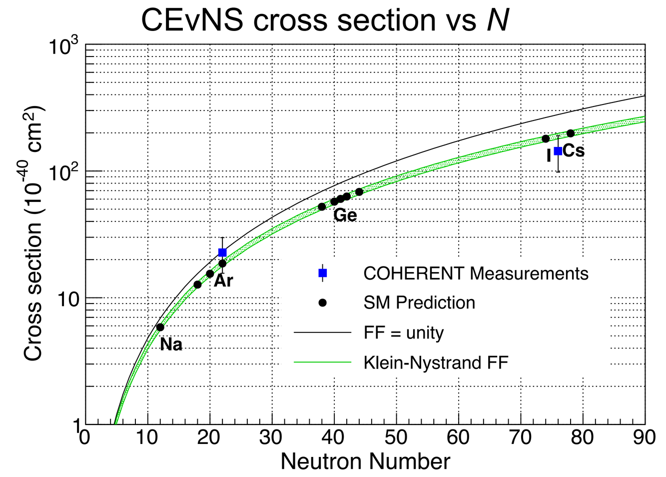
Engineering Run data agrees well with prior beam-related neutron measurements/simulations

First Detection of CEvNS on Ar target

- Detect CEvNS at >3σ with first production data!
- Result agrees within 1σ with SM
- Parallel analyses consistent
- Place further bounds on neutrino NSI
  - Overlap between CsI and LAr bounds, no joint analysis performed



CEvNS cross section vs N



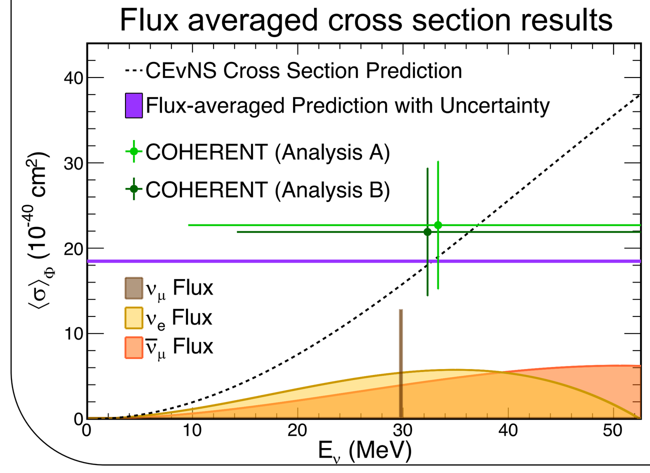
"Analysis A" results

Predicted CEvNS	128 ± 17
Fit CEvNS	159 ± 43 (stat.) ± 14 (syst.)
2Δ(-lnL)	15.0
Null Rejection Significance	3.5σ (stat. + syst.)

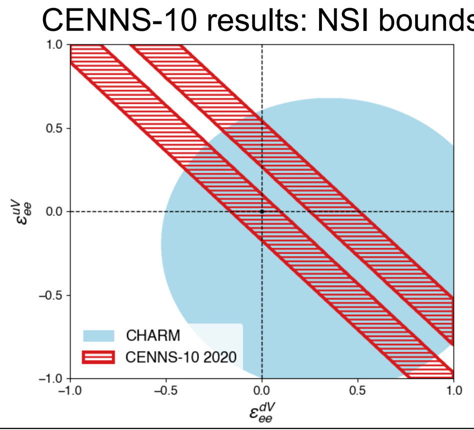
"Analysis B" results

Predicted CEvNS	101 ± 12
Fit CEvNS	121 ± 36 (stat.) ± 15 (syst.)
2Δ(-lnL)	12.1
Null Rejection Significance	3.1σ (stat. + syst.)

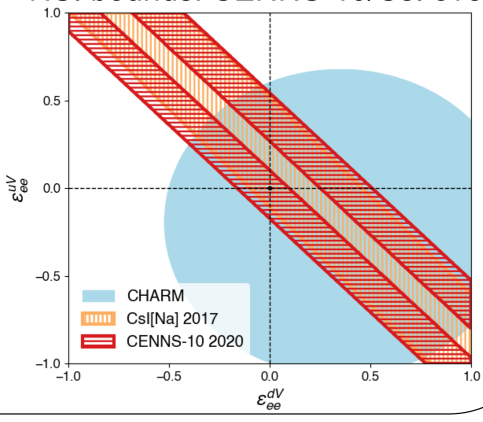
Flux averaged cross section results



CENNS-10 results: NSI bounds



NSI bounds: CENNS-10/CsI overlap



Acknowledgements

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References

[1]D.Z. Freedman, Phys. Rev. D9 (1974)
[2]V.B. Kopeliovich and L.L. Frankfurt, ZhETF Pis. Red. 19 (1974)
[3]D. Akimov et al. (COHERENT). Science 357, 1123–1126 (2017)
[4]D. Akimov et al. (COHERENT). Phys. Rev. D100 (2019) no.11, 115020