Opportunities at ORNL Spallation Neutron Sources/COHERENT

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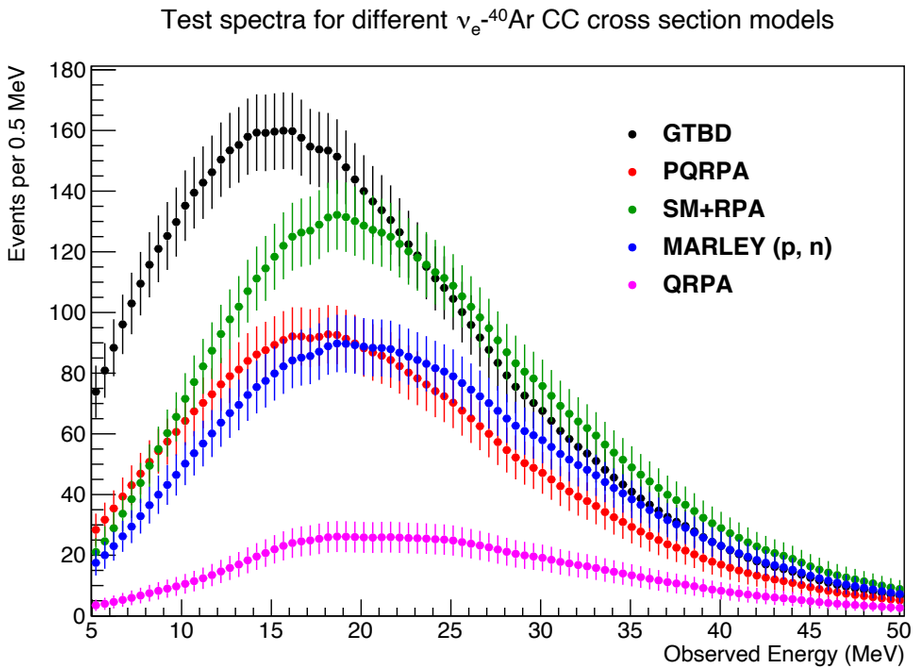
SLACmass Retreat

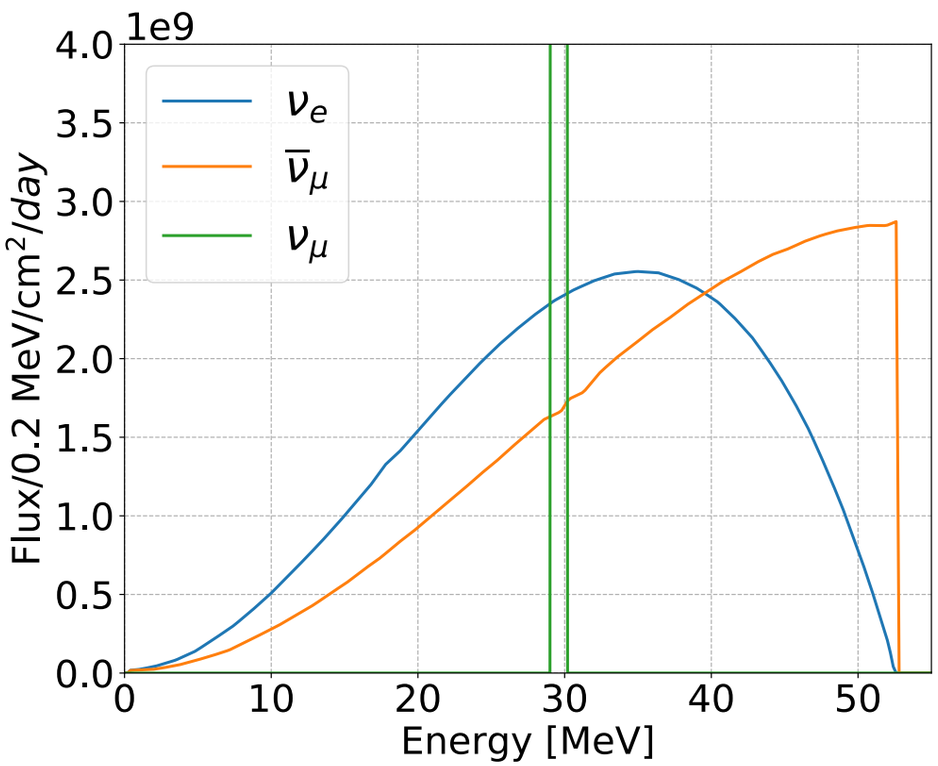
May 12th, 2022

Snowmass Activities

- The COHERENT Experimental Program (arXiv: 2204.04575)
- Physics Opportunities in the ORNL Spallation Neutron Source Second Target Station Era (not yet released)
- Neutrinos at ORNL (workshop, white paper not yet released)
- Details of this effort presented at SLAC HEP retreat in February 2021
- SNS = Spallation Neutron Source at Oak Ridge National Laboratory (ORNL)

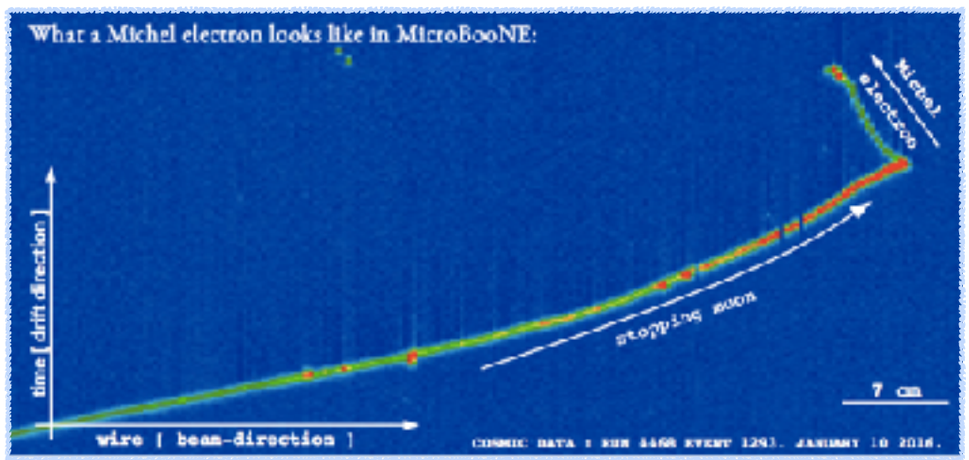
Supernova Neutrino & SNS

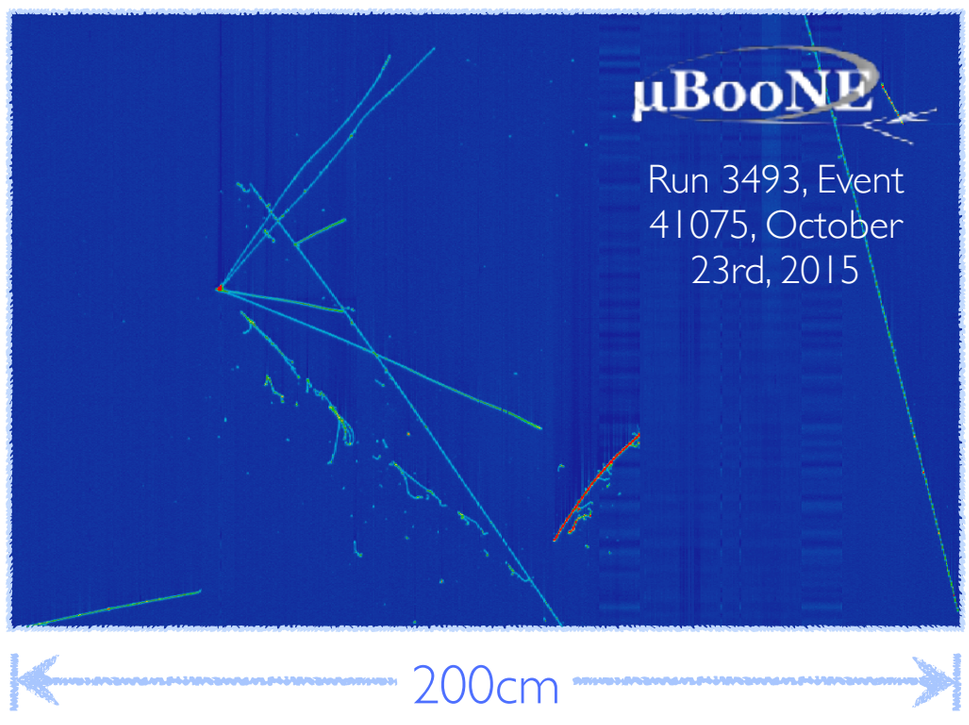




- Core-collapse supernova neutrinos: E_ν = O(1-10)MeV
- DUNE has unique sensitivity to ν_e via charged-current ν_e-Ar interactions
- Most relevant uncertainty: ν_e-Ar cross section models
- ν_e-Ar cross section measurements desired
- SNS produces neutrinos from π^+ decays at rest, E_ν<53 MeV
- Power upgrade ~2024, Second target station ~2032

LArTPC at SNS





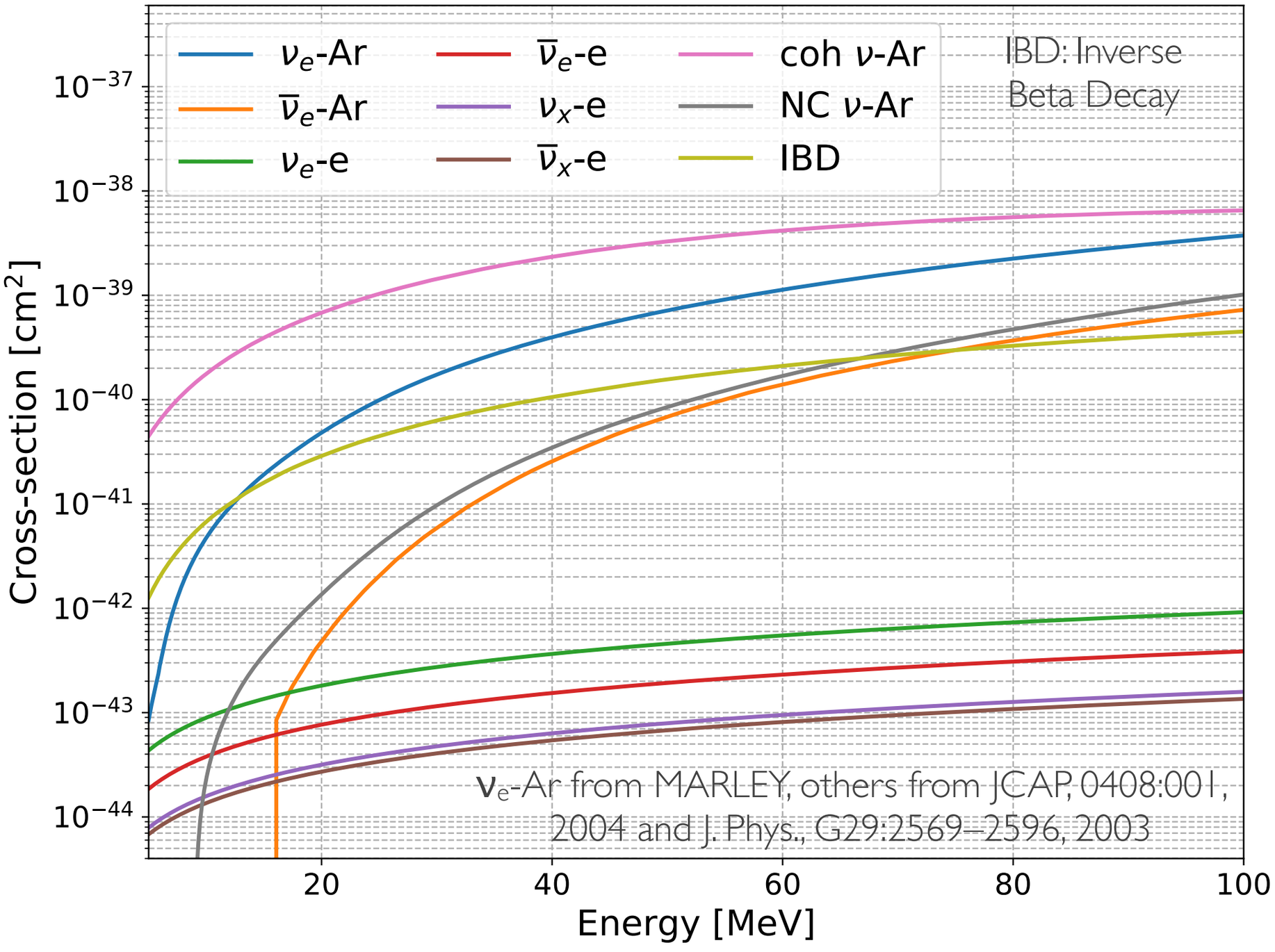
- Argon target
- Technology for DUNE far detector
  - Study detector response in the MeV regime
- Modular TPCs with pixelated charge readout for MeV-scale particles in busy environments
- Synergies with SLAC involvements in DUNE ND-LAr and **γ** TPCs

Summary

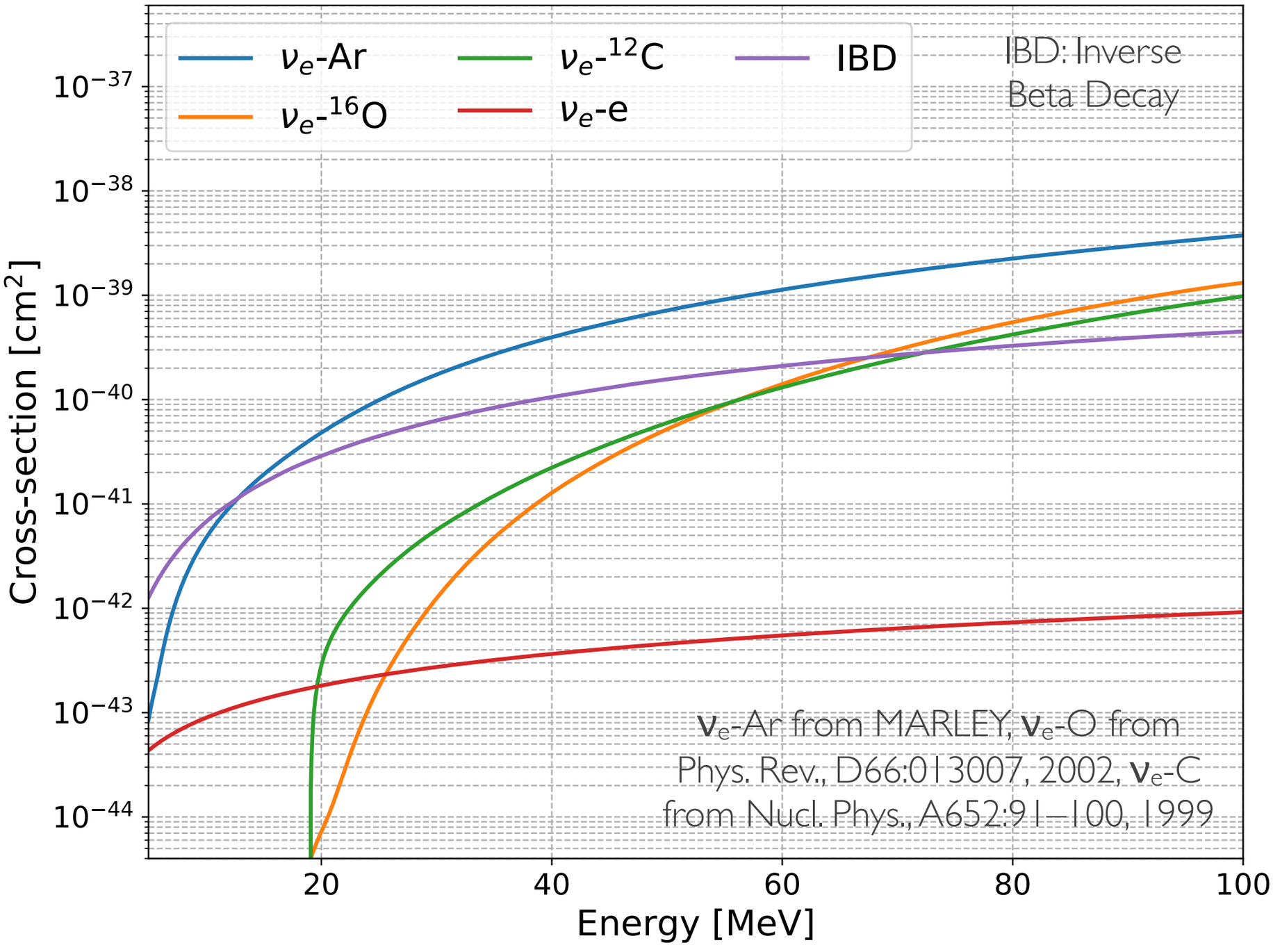
- Important to have supporting experiments for DUNE physics
- Crucial to measure ν_e-Ar CC cross sections for supernova neutrino studies in DUNE
- SNS and COHERENT provide opportunities for such measurements and other interesting physics
- Synergy with other SLAC neutrino efforts with LArTPCs: DUNE, SBN, theory group

Backup

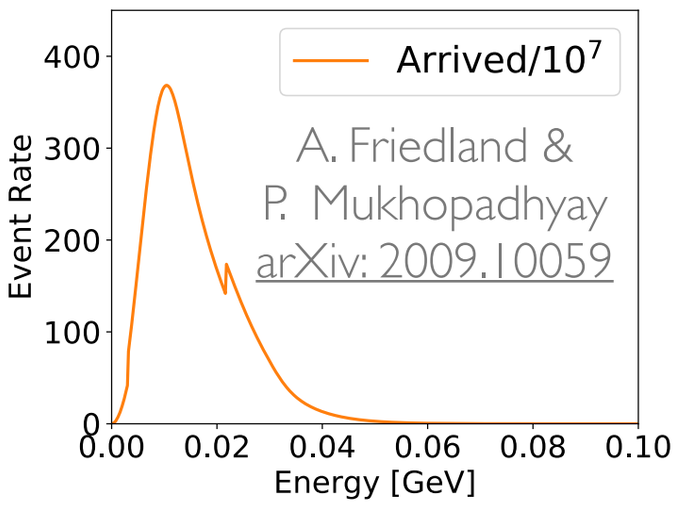
ν_e-Ar Cross Sections



ν_e Cross Sections



SN Neutrino Detection



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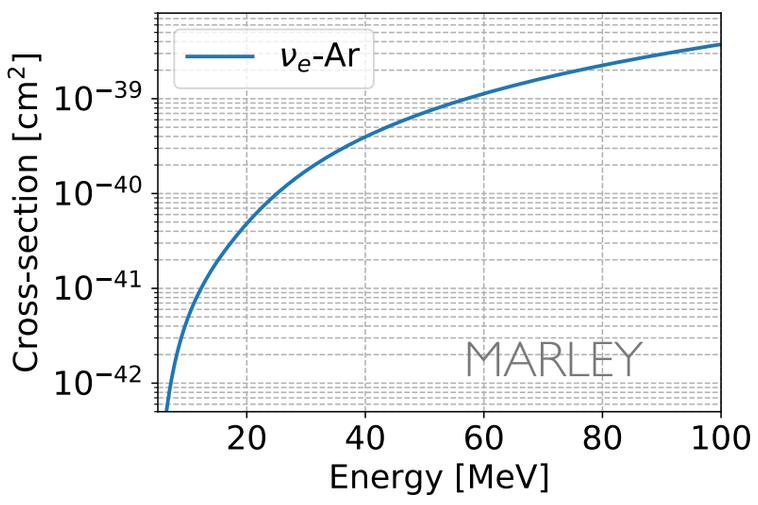

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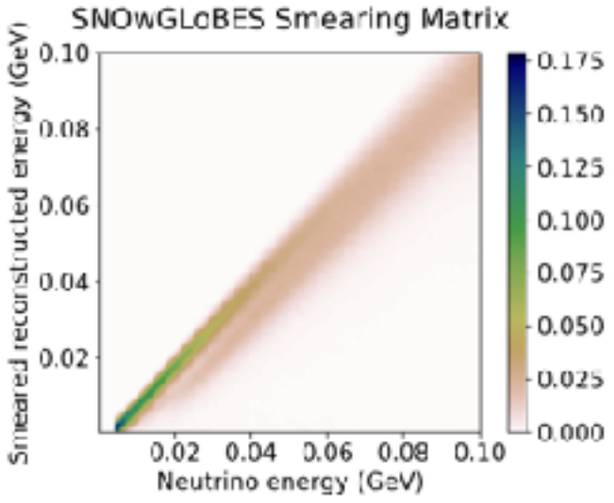
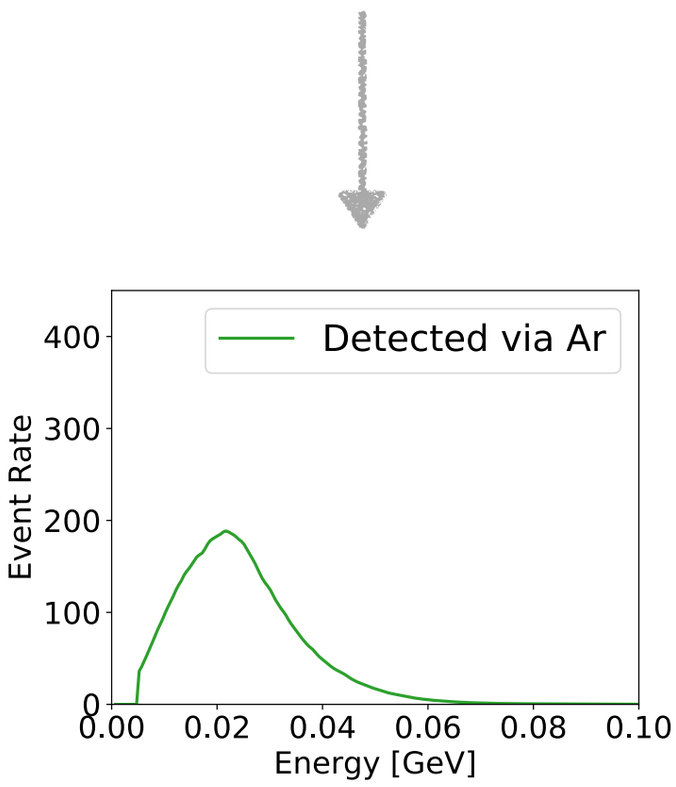




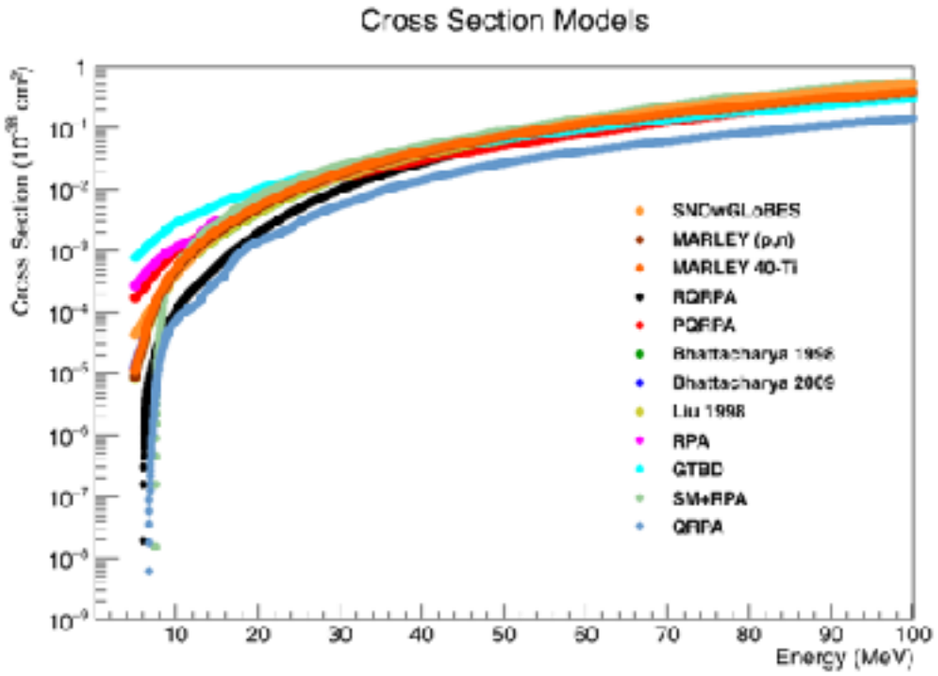
- Detect convolved **ν** flux and interaction cross sections
- Disentangled **ν** fluxes are desired
- These ν_e-Ar CC cross sections have never been measured
  - Uncertainties from cross section models are relevant

Impact from ν_e-Ar σ

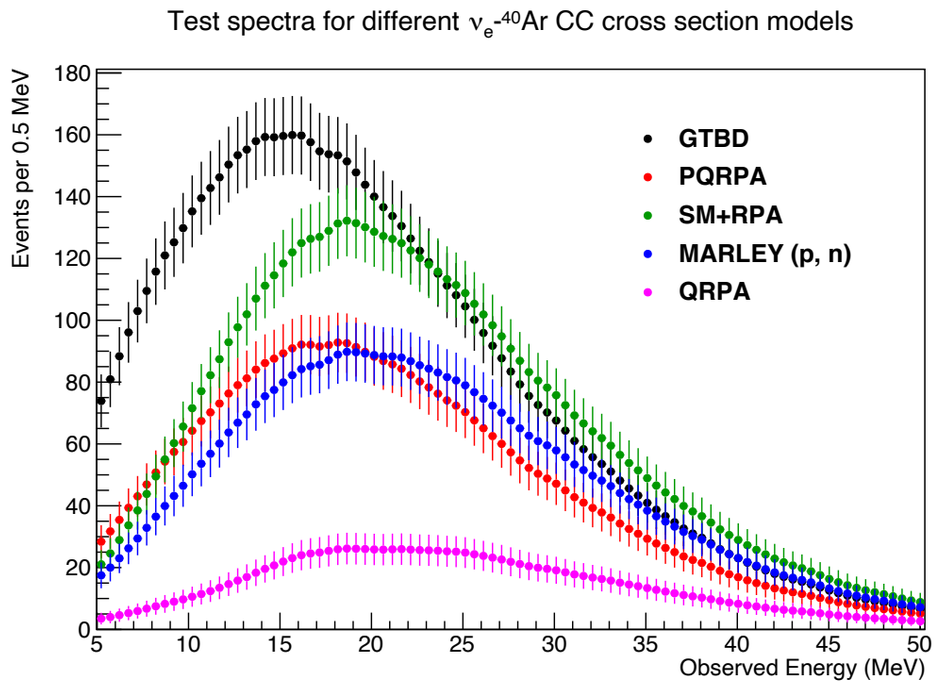
- Pinched-thermal form of supernova neutrino flux

$$\phi(E_\nu) = \mathcal{N}\left(\frac{E_\nu}{< E_\nu >}\right)^\alpha \exp\left[-(\alpha+1)\frac{E_\nu}{< E_\nu >}\right]$$

- E_ν: neutrino energy
  $<E_\nu>$: average E_ν
  $N \propto \nu$ luminosity, ε
  α: pinching parameter
- ν_e-Ar cross section models vary > O(10%)
- Impacts from ν cross section models particularly on ε, varying from -94% to 1400%

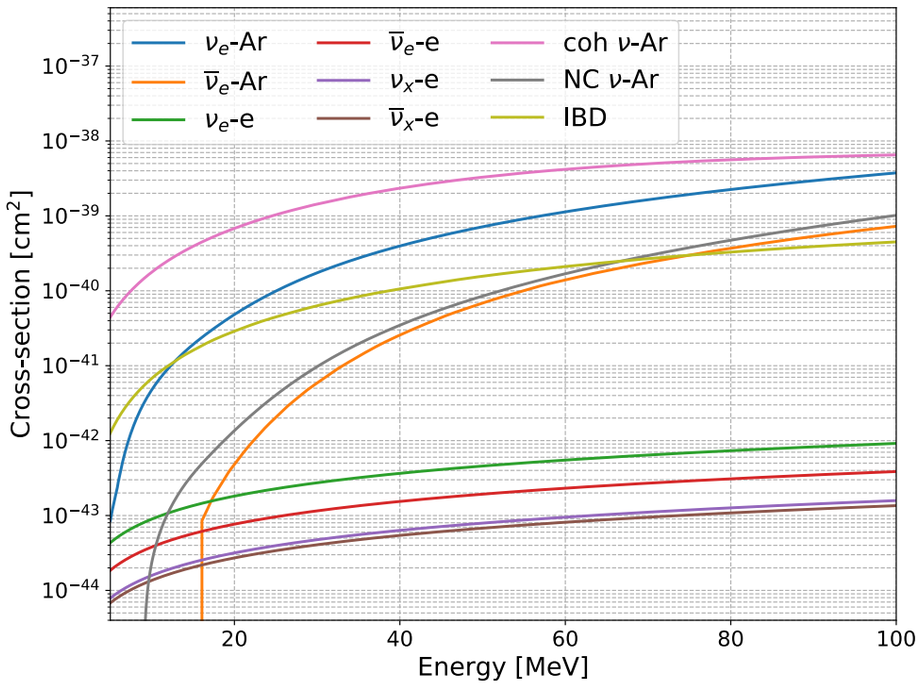


E. Conley, DUNE note 14068, paper in preparation



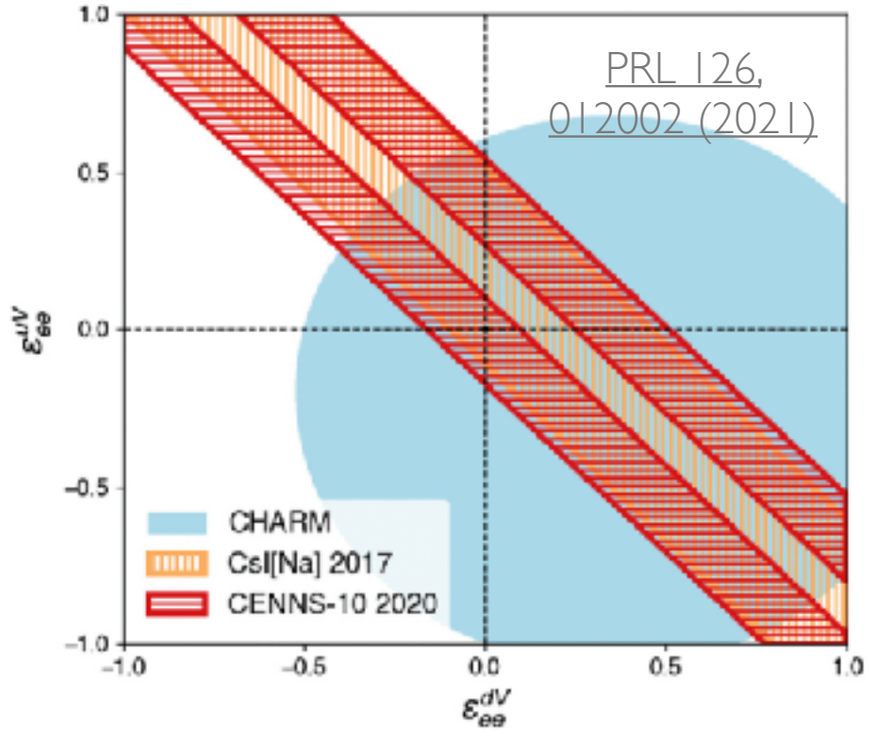
CEvNS

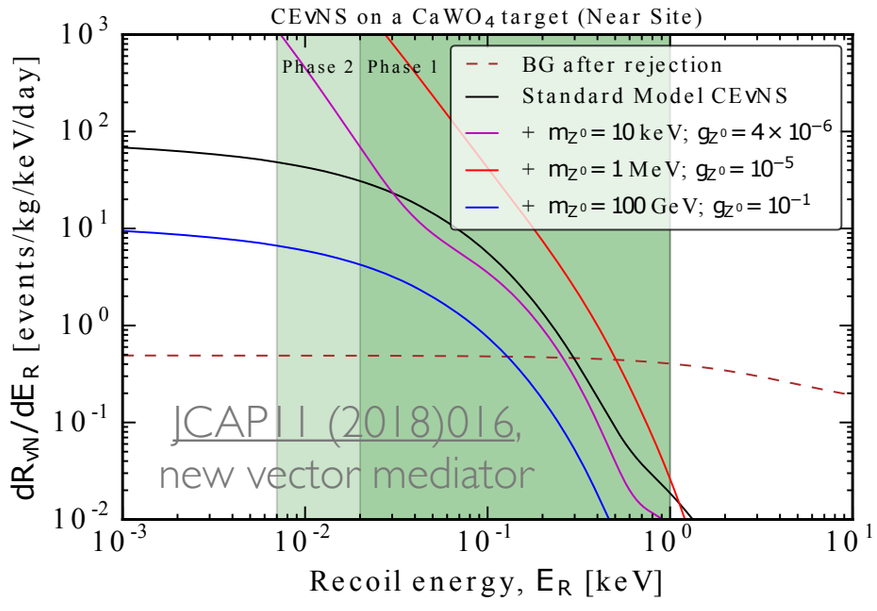
- Neutral-current scattering, predicted in 1974
- Small momentum transfer (qR<1) to the nucleon so that the nucleus recoils as a whole
  - q: momentum transfer; R: nuclear radius
- Dominant cross section when $E_\nu < 50$ MeV; $\propto N^2$
- Observable: nucleus recoils with O(10 keV) energy
- Background events for WIMP search
- First observed in 2018 by COHERENT using SNS



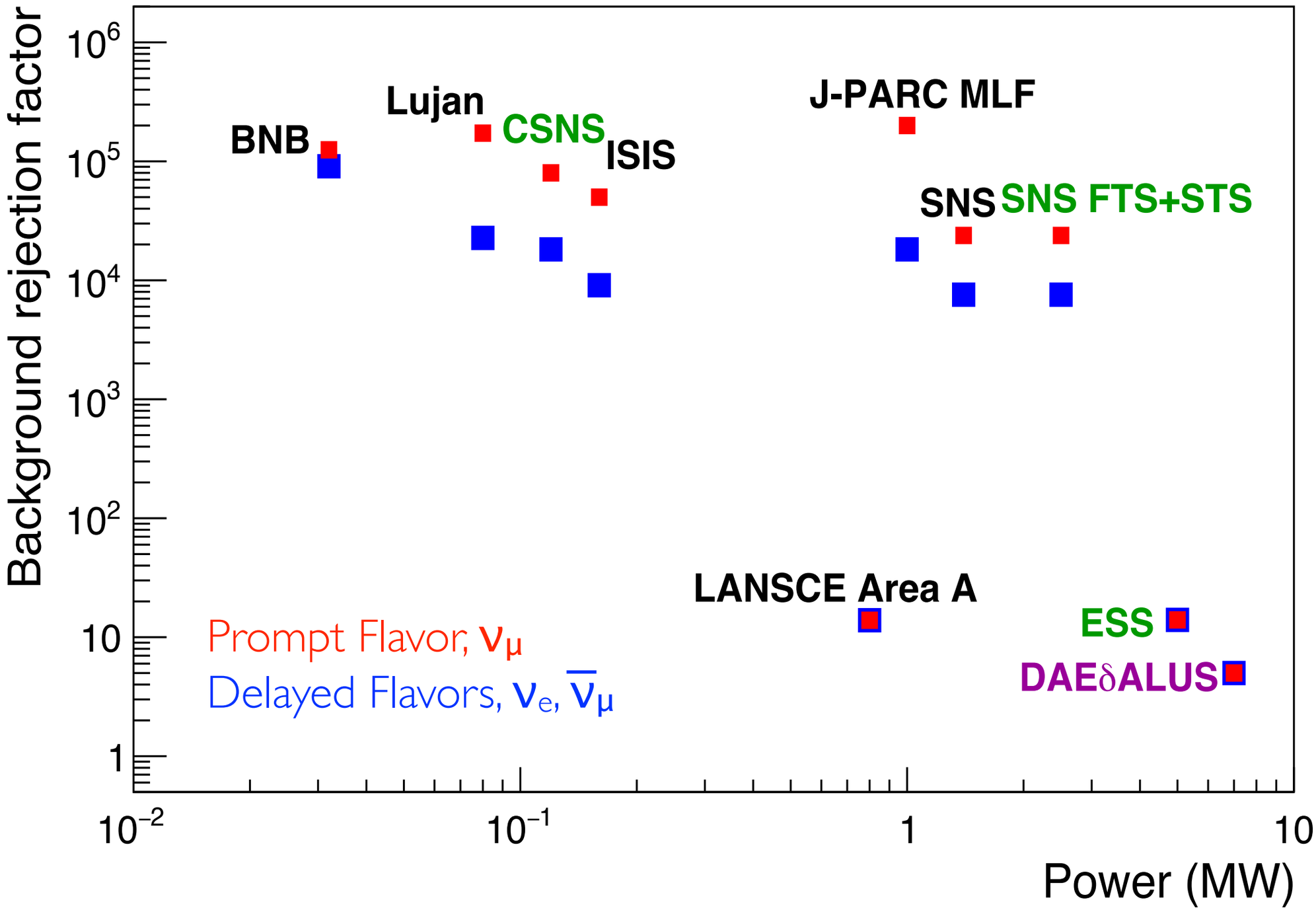
SM & BSM Physics Probe

- Physics probed by CEvNS
  - Non-standard interaction
  - Dark scalar and vector mediators
  - Weak mixing angle
  - Neutrino magnetic moment
  - Effective neutrino charge radius
- BSM physics changes the cross sections
- Low threshold detector



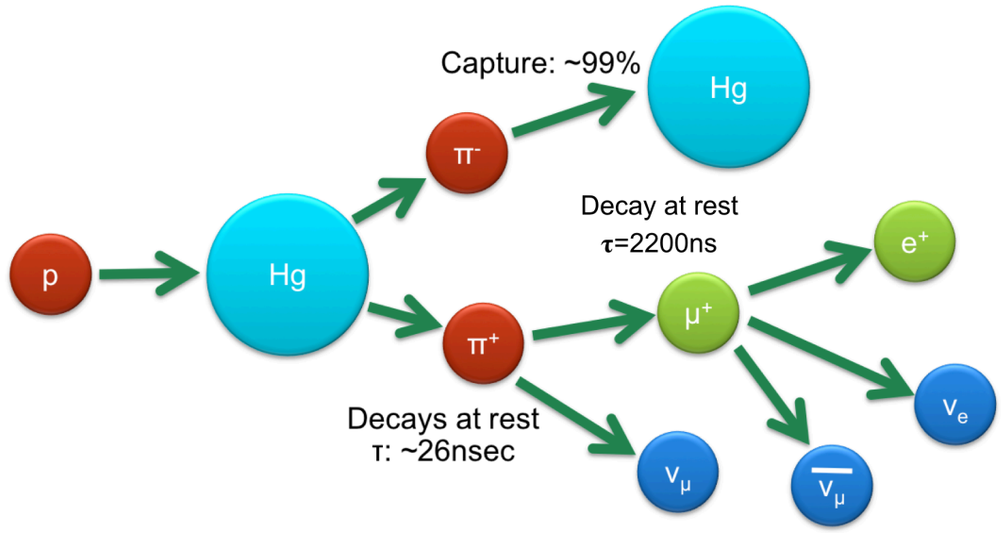


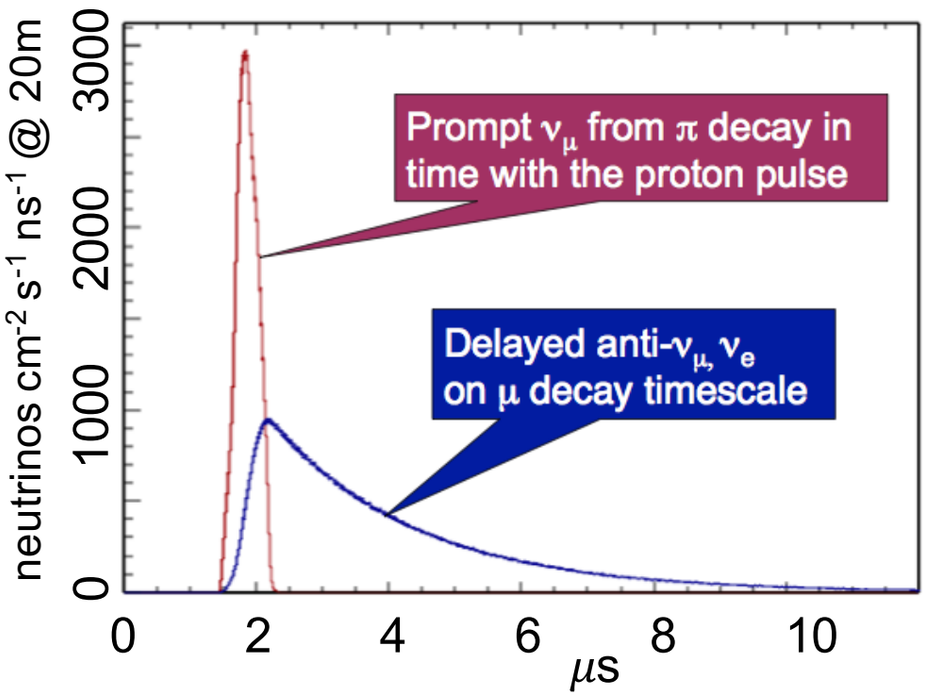
ν Sources from π DAR



Neutrino Source at ORNL

- Spallation Neutron Source (SNS)
- H^- LINAC: 1GeV @1.4MW, 60 Hz; mostly pions
- Liquid mercury target
  - Minimize pions decay-in-flight
- Operate ~5000 hours/year
- $2.81 \times 10^{14} \nu/cm^2/flavor/year$ @ 20m
- Discovery of Coherent Elastic Neutrino-Nucleus Scattering





SNS Status & Plan

2021 — 2024 — ~2032

Current SNS

- 1.4MW, 1GeV, 20mA, 60Hz
- Available for a couple of ton-scale LAr detectors
- A 750kg LAr scintillator is being discussed

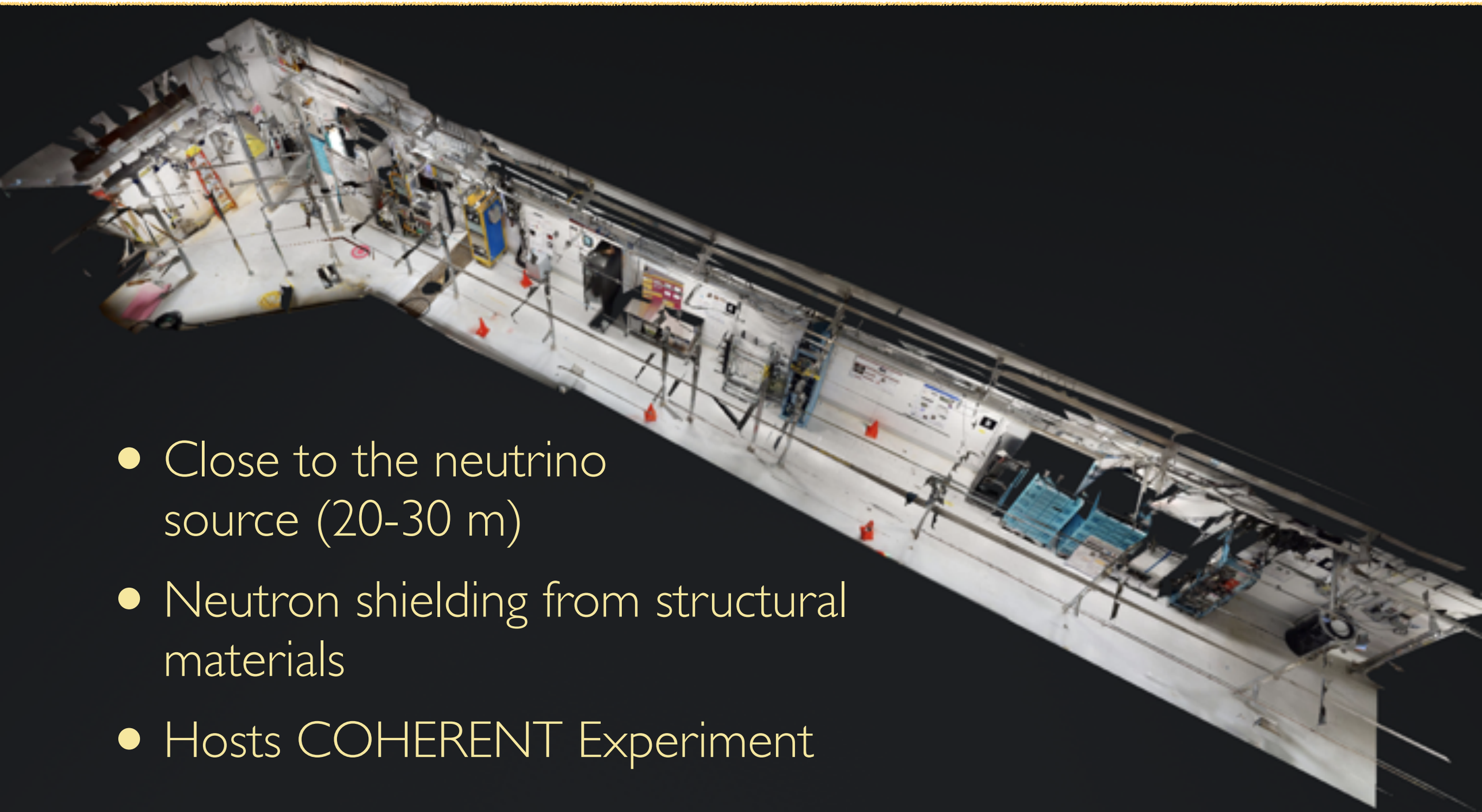
Proton Power Upgrade (PPU)

- 2MW, 1.3GeV, 27mA, 60Hz
- D_2O flux monitor

Second Target Station (STS) Project

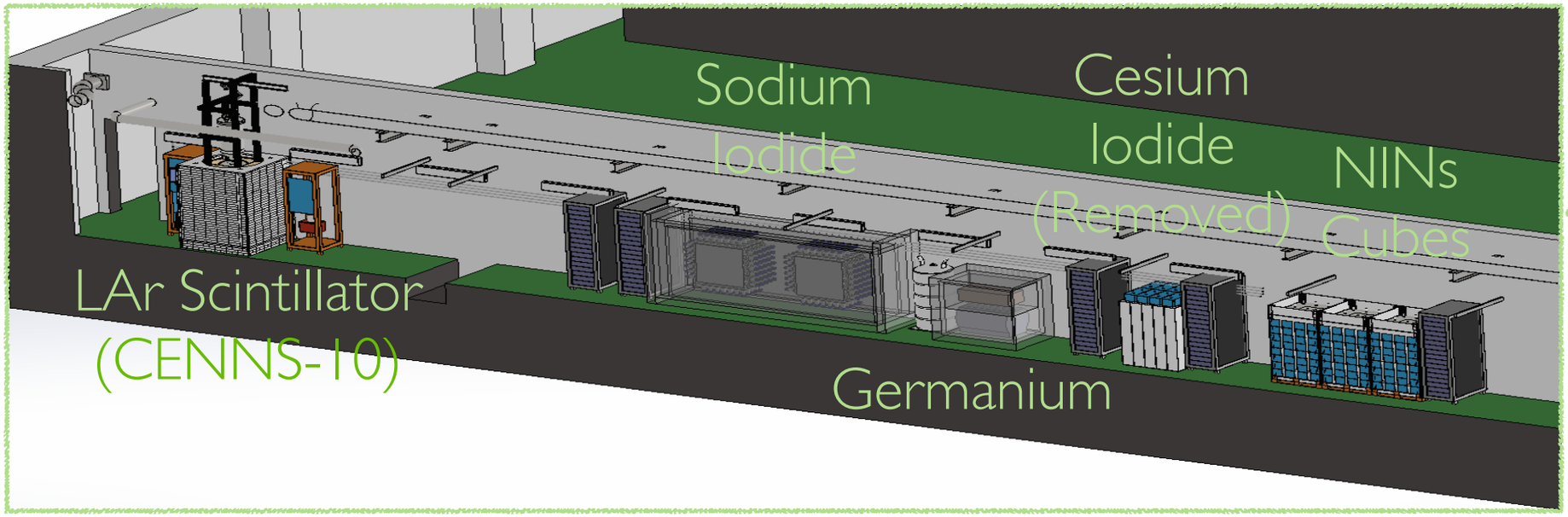
- 2.8MW, 1.3GeV, 38mA, 60Hz
- First Target Station (FTS) 2MW, 45Hz
- STS 0.7MW, 15Hz, tungsten target
- Available for 10-ton scale LAr detectors

Neutrino Alley at FTS



- Close to the neutrino source (20-30 m)
- Neutron shielding from structural materials
- Hosts COHERENT Experiment

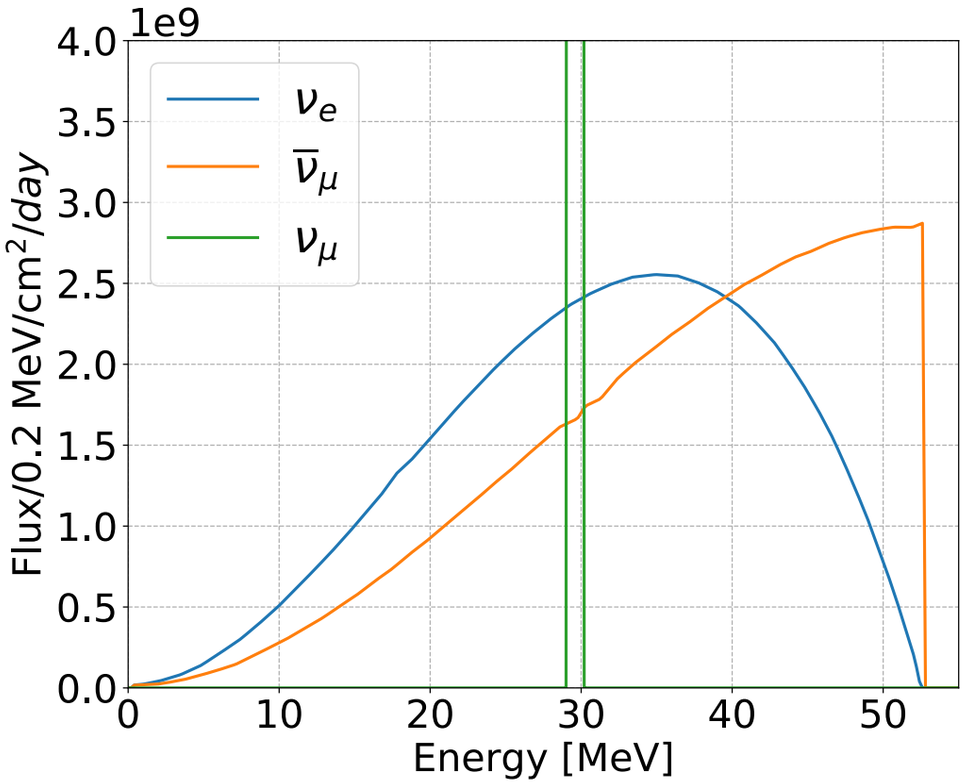
COHERENT Upgrades

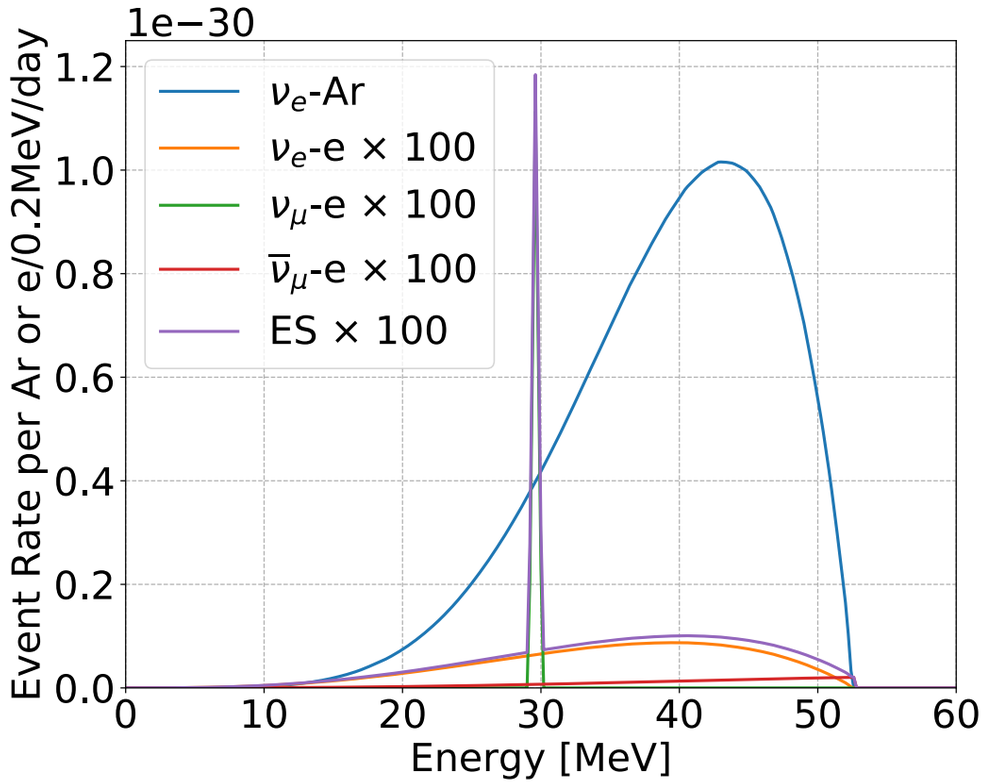


Heavy water detector

- Germanium, Sodium Iodide, Heavy water detectors
- LAr scintillator (CENNS-10) concluding soon
- Pursuing funding for 1-ton LAr scintillator (CENNS-750)
- Extended physics goals: precision measurements of SM and nuclear physics, searches for new physics, instrument R&D
- Experiments and requirements at STS under discussion

Expected ν_e-Ar CC Events





- 30m away from the target at Neutrino Alley (FTS)
- Expect ~300 ν_e-Ar CC interactions/ton/year
  - Good for inclusive cross section measurements
- Also serve as a project shifting to a potential 10-ton scale LAr detector in the future 2nd Target Station