SNeND Measurements: "Supernova Neutrino constrained by Neutrino Data" for DUNE

Yun-Tse Tsai, Gianluca Petrillo

Future Planning Meeting@SLAC

July 16th 2024

Supernova Neutrino Flux

Pinched-thermal form: to fit simulated flux

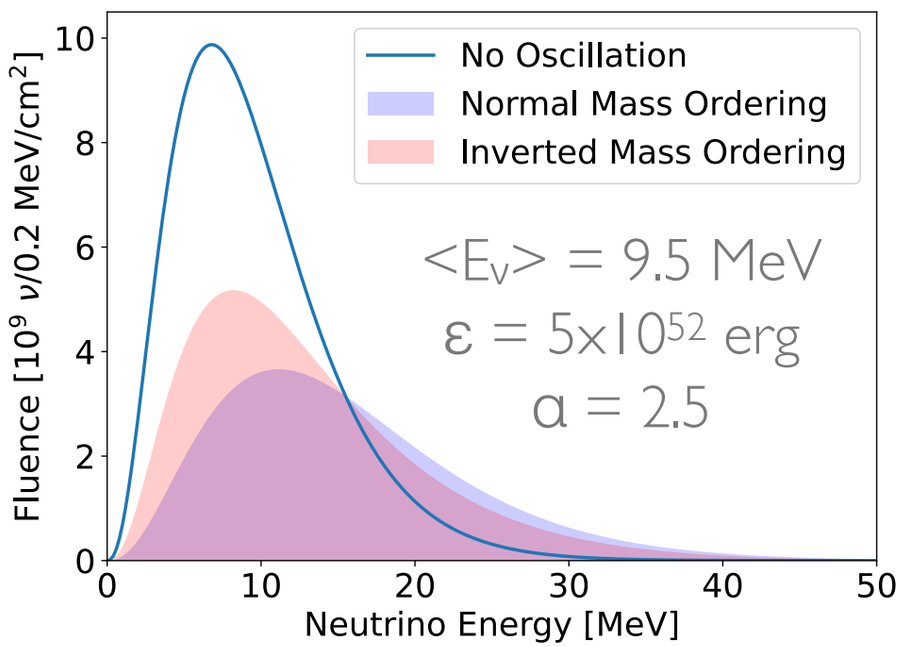
$$\phi(E_\nu) = \mathcal{N}\left(\frac{E_\nu}{< E_\nu >}\right)^{\alpha} \exp\left[-(\alpha+1)\frac{E_\nu}{< E_\nu >}\right]$$

E_ν: neutrino energy

$<E_\nu>$: average E_ν

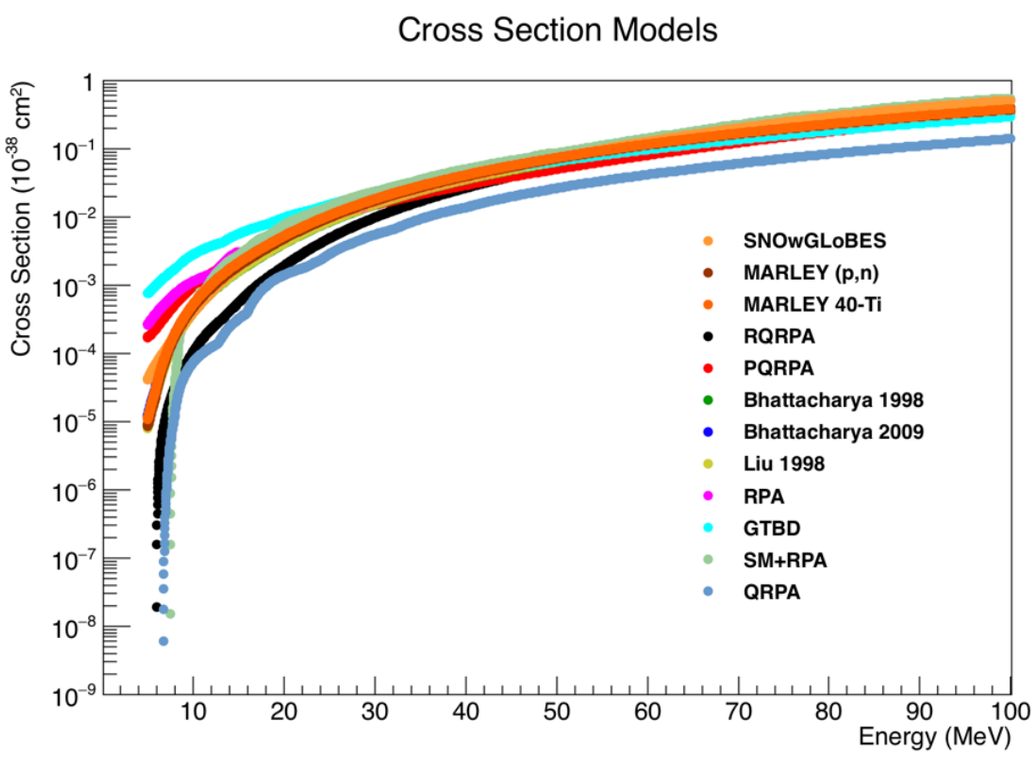
$N \propto \nu$ luminosity, ε

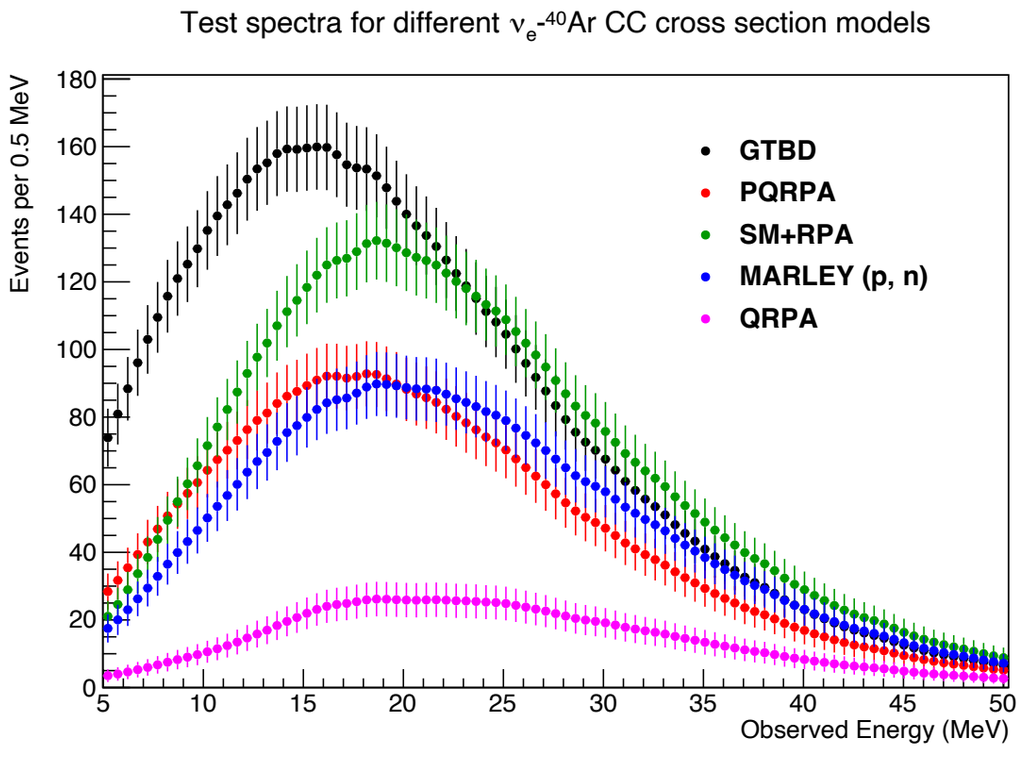
α: pinching parameter



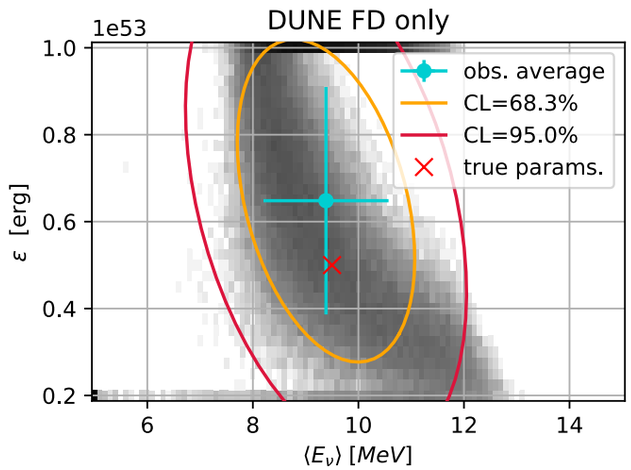
Impact from ν_e-Ar σ

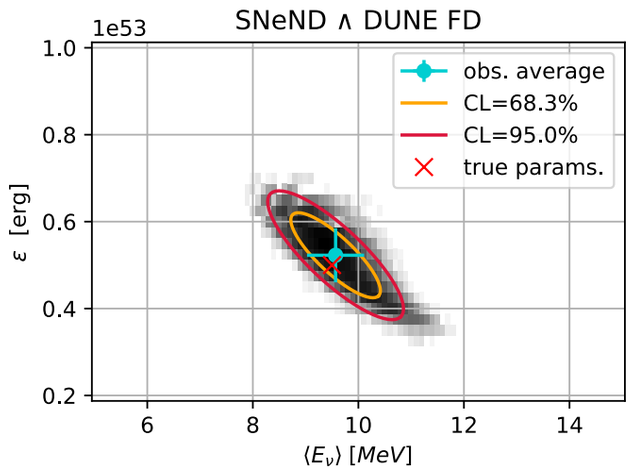
- ν_e-Ar charged-current (CC) interaction cross section with E_ν<100 MeV has never been measured
  - Theoretical models vary > O(10%)
- Highly significant impacts on DUNE SN ν measurements, particularly on ε, biased from -94% to +1400% in extreme scenarios (PRD 107, 112012 (2023))

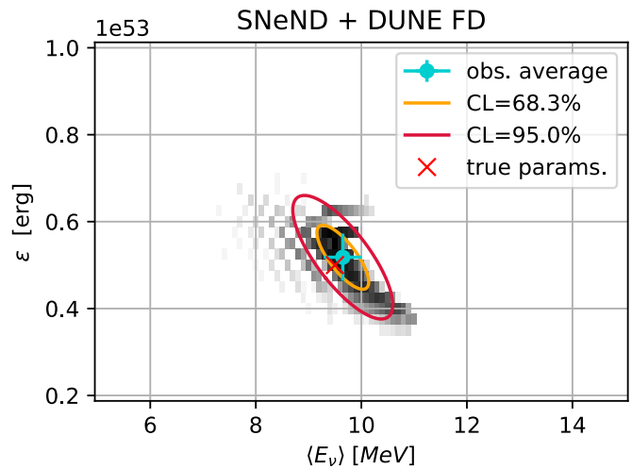


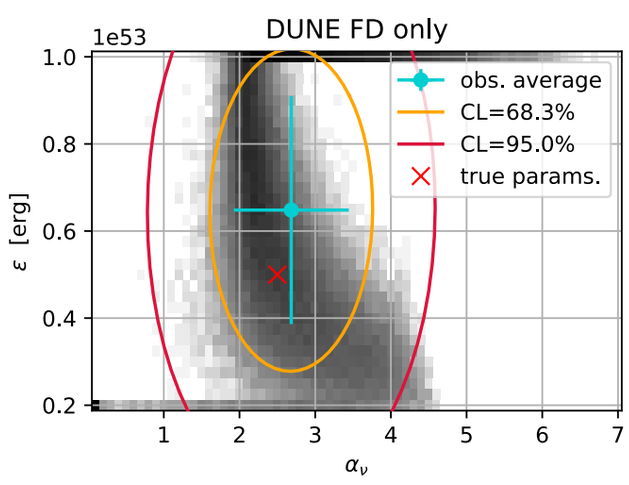


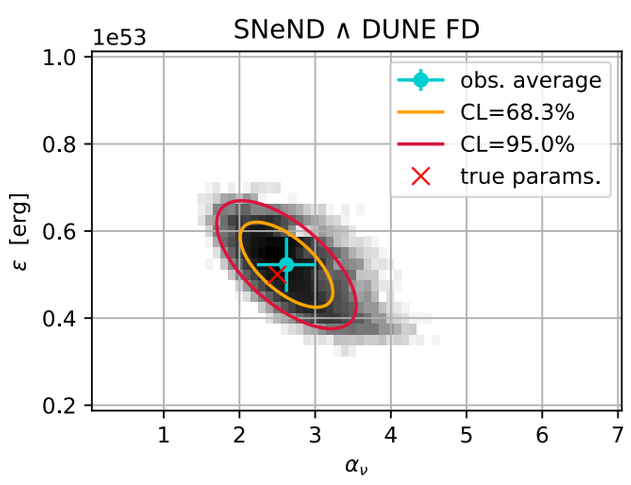
20% Uncertainty on σ

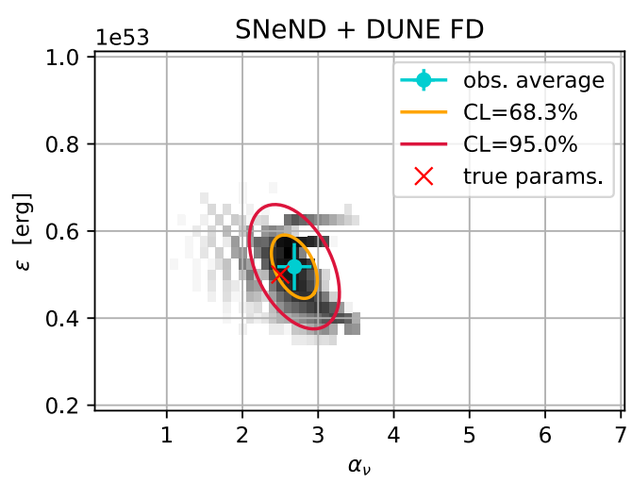


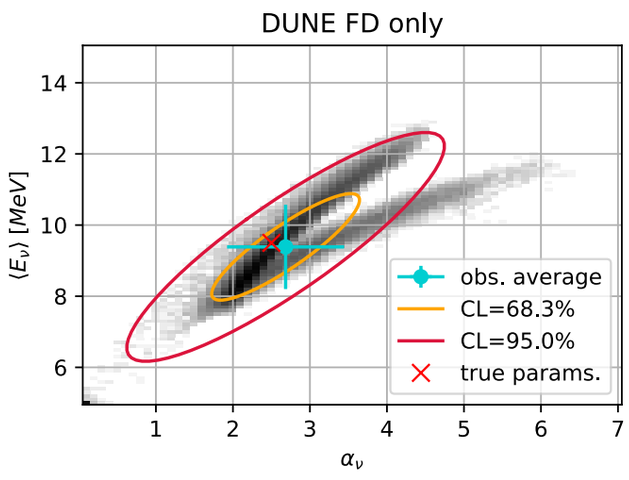


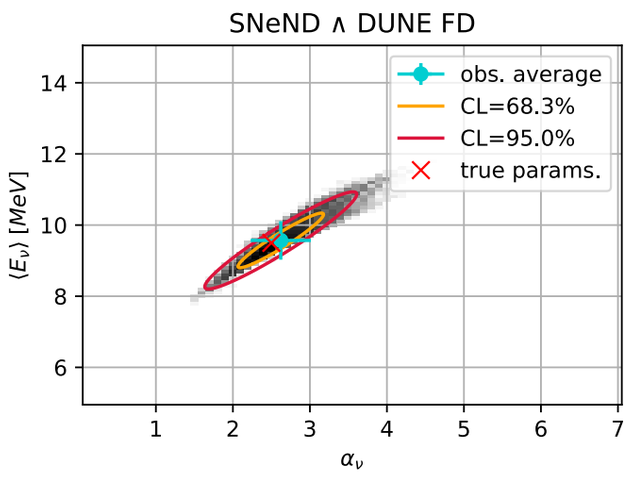


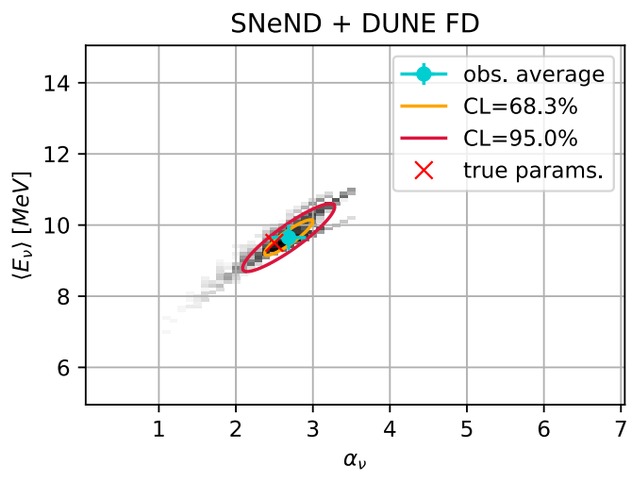






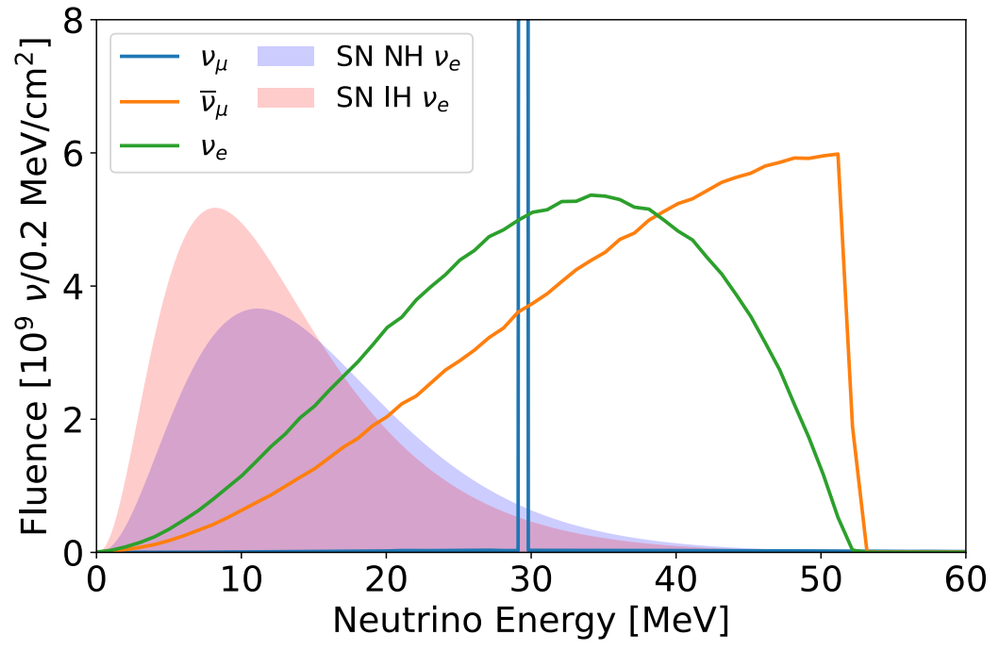


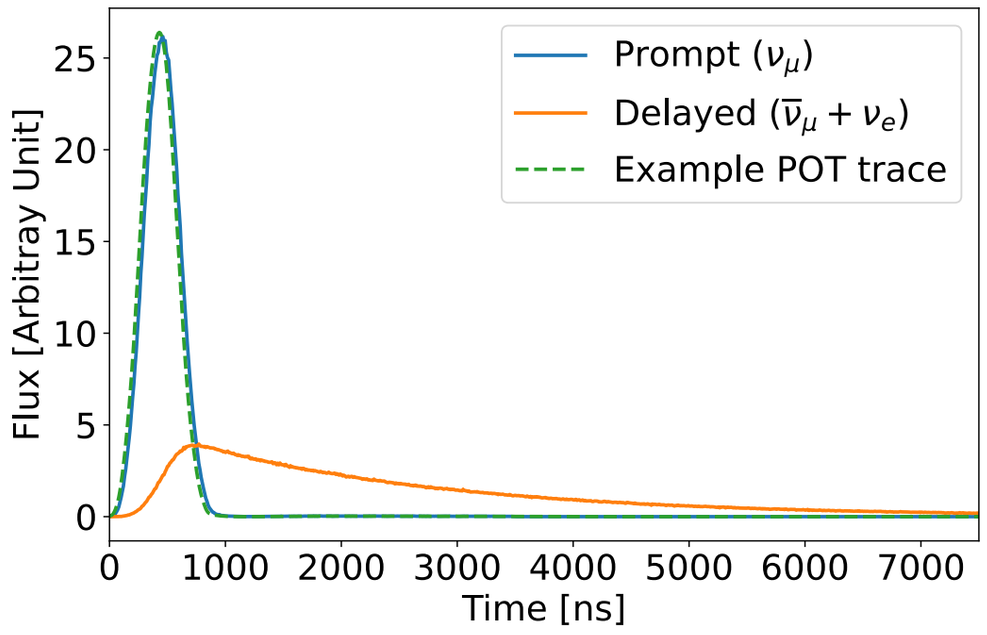




Measure ν_e-Ar CC σ@SNS

- Neutrinos produced from π^+ decay at rest, $E_\nu \sim O(10MeV)$
  $\pi^+ \rightarrow \mu^+ \nu_\mu \rightarrow (e^+ \nu_e \overline{\nu}_\mu)\nu_\mu$
- H- LINAC: 1GeV @1.4MW, 60 Hz; mostly pions
  - Will be upgraded 2024!
- Liquid mercury target
  - Minimize pions decay-in-flight
- Operate ~5000 hours/year
- $2.81 \times 10^{14} \nu/cm^2/flavor/year$ @ 20m





Proposal & Timeline

- Proposing to install a LArTPC at COHERENT
  - 50x60x60 cm^3, 250-kg LAr
  - Shorter, slimmer version of a module of DUNE ND-LAr with LArPix and ArcLight, CRT
- A scenario
  - Design ready by Spring 2025
  - Installation 2025-2026
  - Commissioning late 2026
  - 3-year of data collection
  - ν_e-Ar CC cross section measurements ready for internal review in 2029

Status & Challenges

- Status:
  - Rough designs on the LArTPC and piping
  - Preliminary studies on signal & background rates
- Challenges:
  - Funding opportunities & human resources
  - Light readout electronics for ND-LAr unclear
  - Detection threshold for MeV-scale particles not well-defined nor verified
  - Reconstruction algorithms optimizing to MeV-scale particles to be developed

Milestones

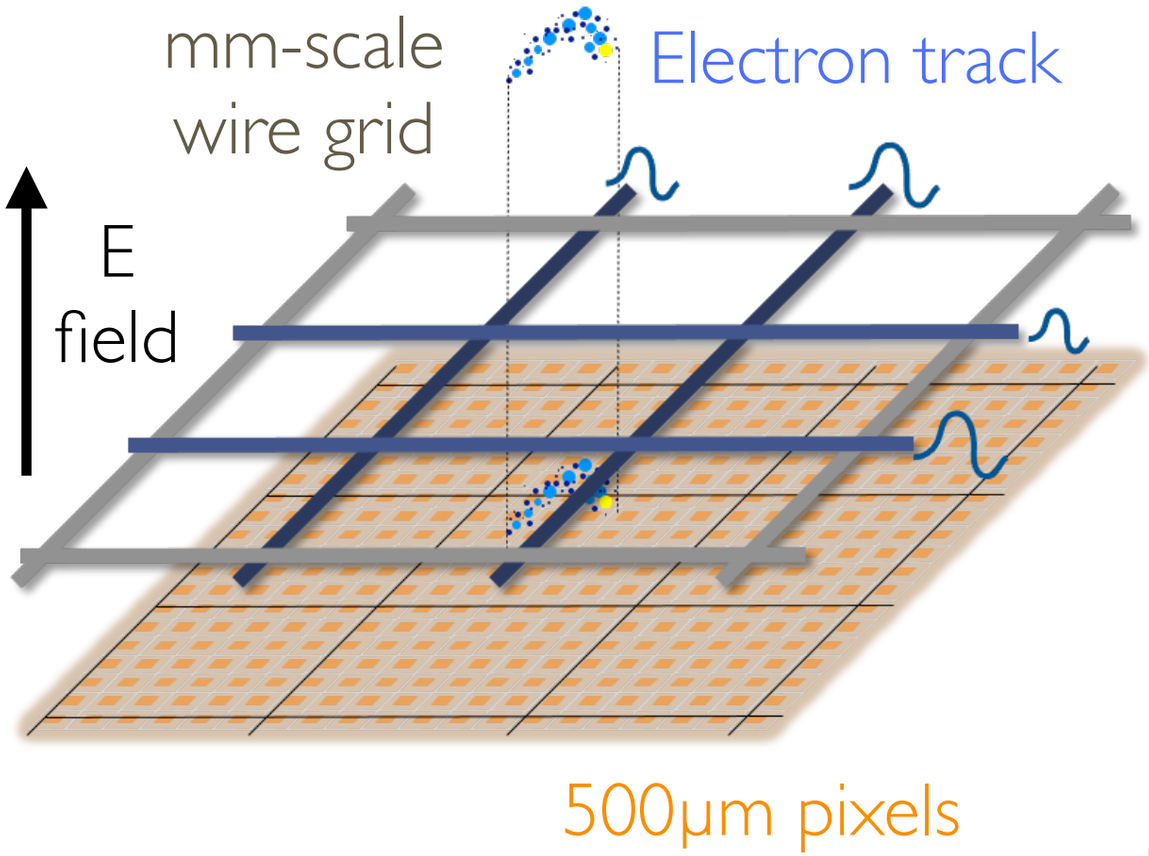
- Installation completed and commissioning started
- Detector calibration and detector characterization
- First ν_e-Ar CC cross section measurement
- Search for physics beyond SM
- Concrete proposal for future 10-ton-scale LArTPC at ORNL (ASTAE)
- Differential ν_e-Ar CC cross section measurements
- ν-Ar NC cross section measurements

Opportunities for SLAC

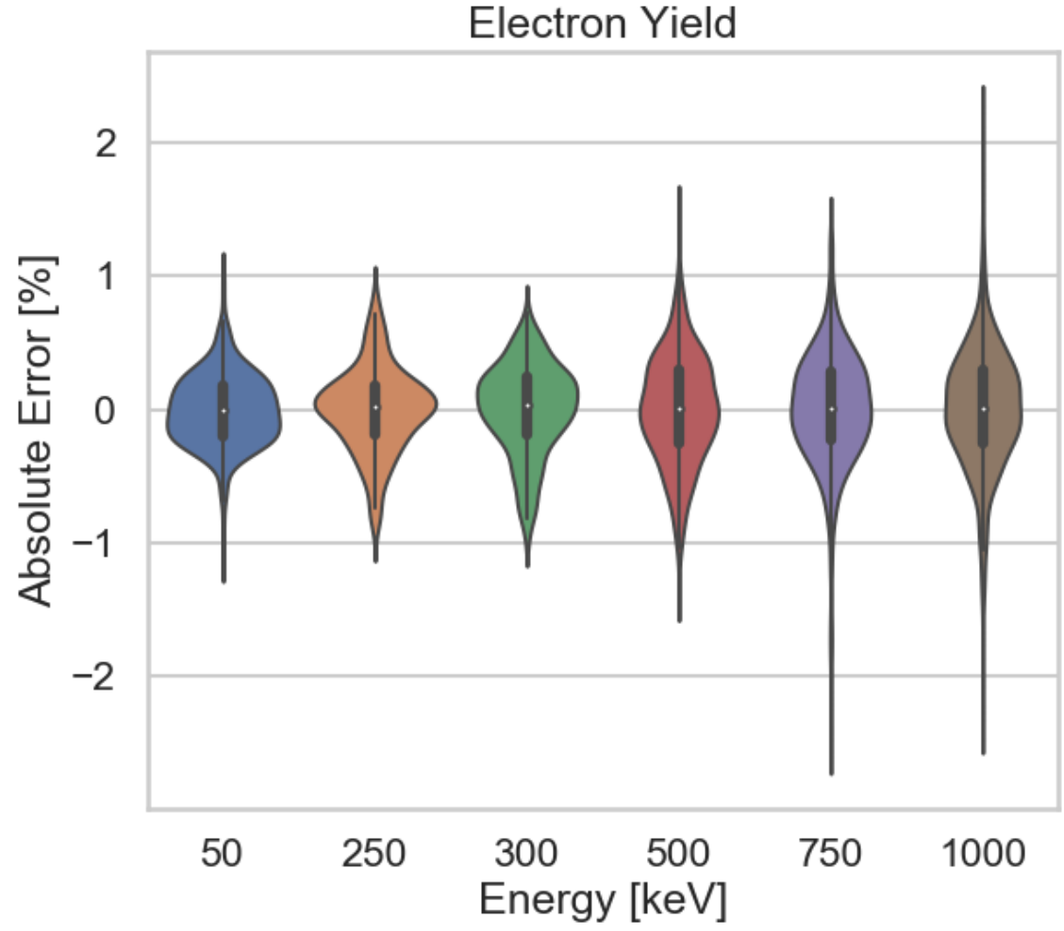
- LArTPC construction/operation at COHERENT
- Detector calibration for MeV-scale particles
- SPINE targeting MeV-scale particles
- Cross section measurement relevant to supernova neutrinos in DUNE; MeV-scale physics in LArTPCs
- Development of the future 10-ton-scale LArTPC at ORNL (ASTAE)
- Studies of the impacts on supernova neutrinos
  - Inputs from supernova experts (SLAC & ORNL), cross section experts
  - Interactions with Hyper-K collaborators through COHERENT (mini-K)

GAMPix: Low Noise

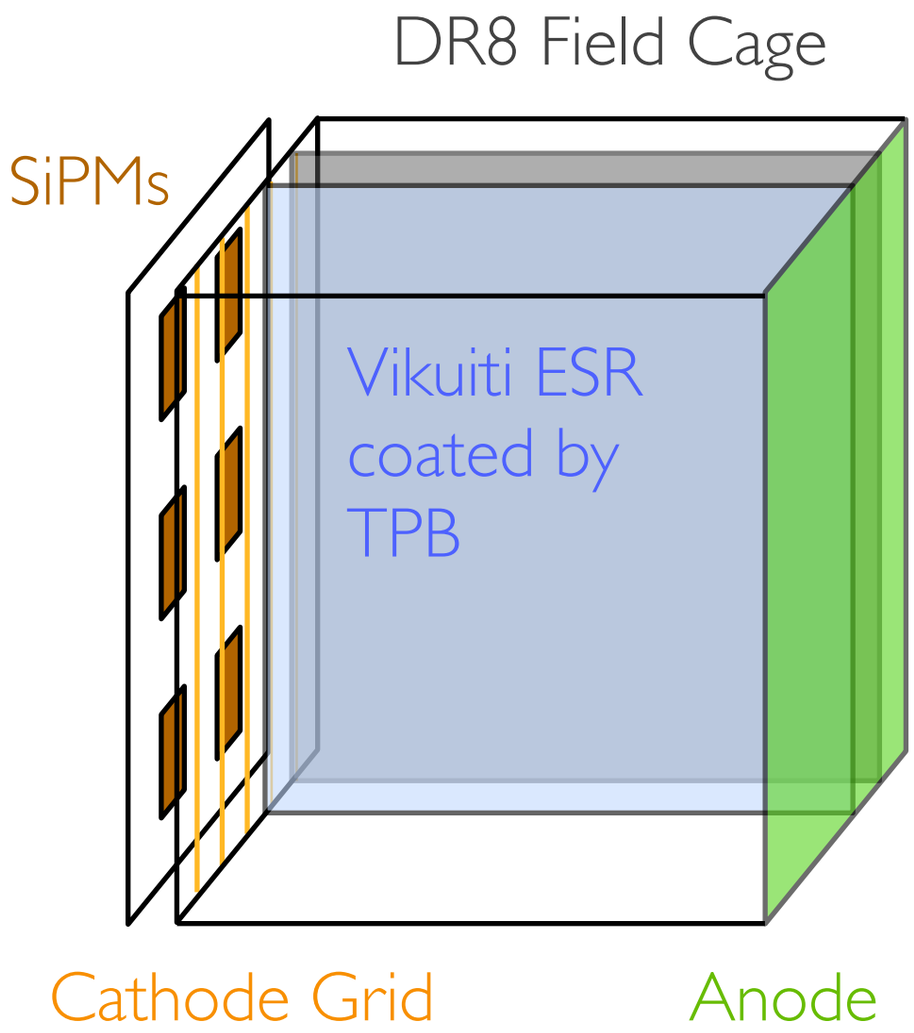
500μm-pixels triggered by mm scale wire readout. Low noise level (50e^-) for MeV γ detection; important for $\sigma_{\nu\text{-}Ar}$ studies



Combine the signals on wires and pixels to obtain fine tracking, calorimetry, drift distance, etc.



Light Detector R&D



- Play with configurations of the light collection system for modular, pixelated LArTPCs, targeting MeV-scale particles
- Inspired by the liquid-noble TPC dark matter/0νββ experiments
- Light sensors on cathode, reflective foil+wavelength shifters on the field cage
- Aim for the light detection efficiency of O(5%)
- Constructing a 5x5x5cm^3 LArTPC, SLArPAAS, to verify simulation