

Toward ν_μ CC η Meson Cross Sections on Argon with SBND

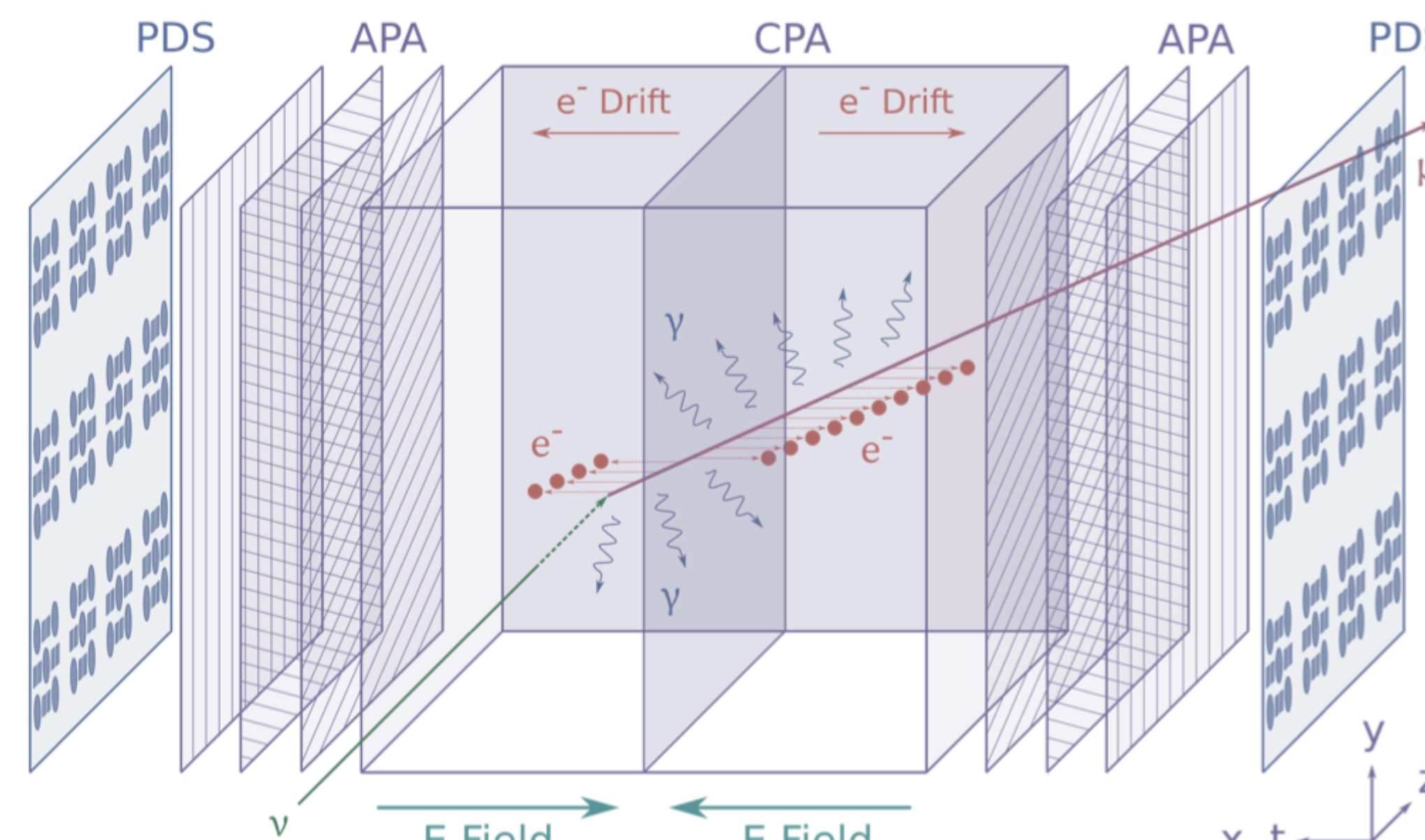
Alexander Antonakis (UC Santa Barbara) on behalf of the SBND Collaboration

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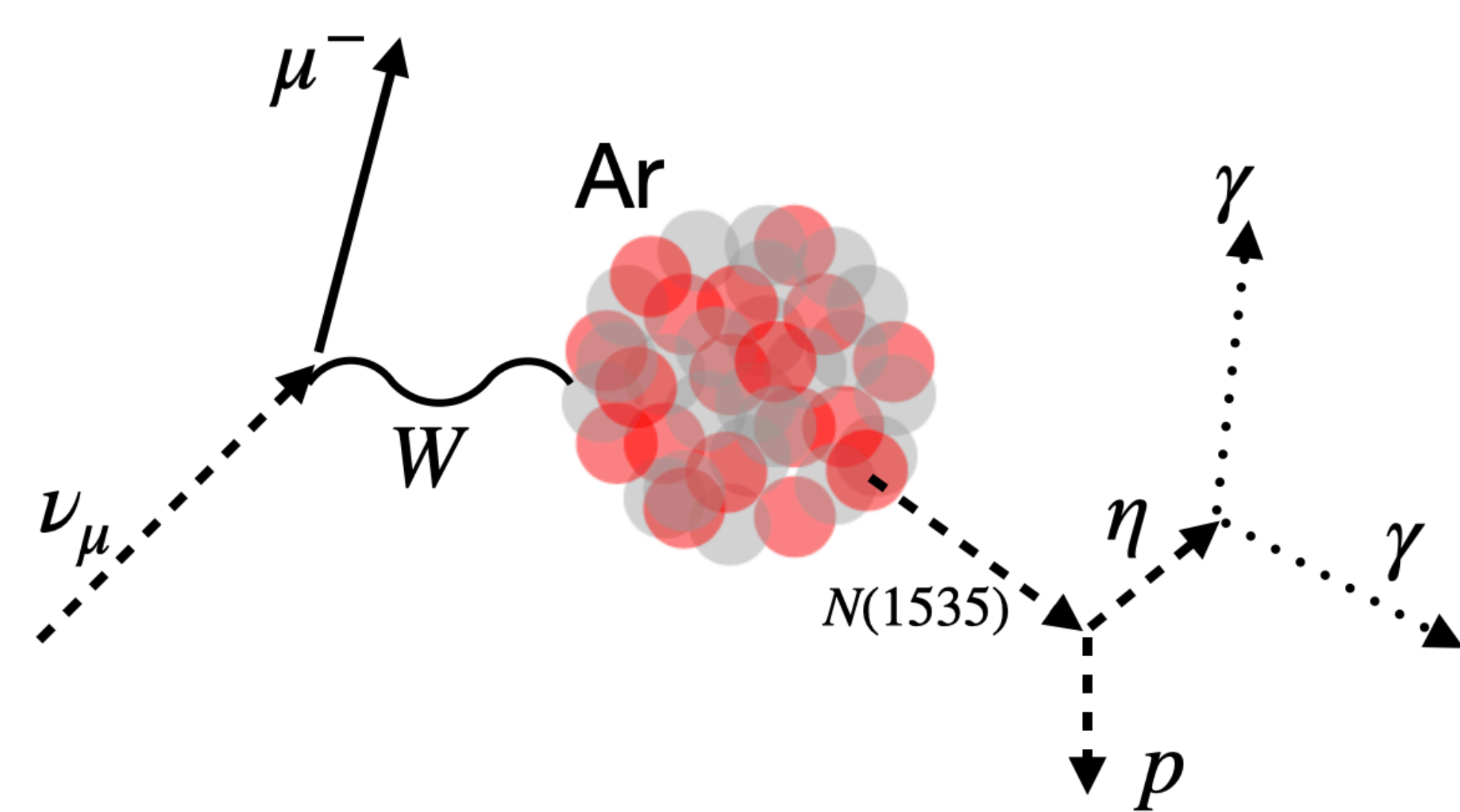
Introduction & Motivation

- Current and future neutrino oscillation experiments such as the SBND Program and DUNE require precise models of neutrino-argon interactions to achieve their physics goals [1, 2].
- Resonant interactions are an important interaction channel at GeV energies and contribute significantly to the DUNE event rate. Their modeling remains a substantial source of uncertainty.
- Production of the η mesons provides a unique probe of higher-mass baryon resonances beyond the $\Delta(1232)$ baryon, particularly the $N(1535)$, $N(1650)$, and $N(1710)$, which have large branching fractions to η mesons [3].



Conceptual diagram of the SBND detector

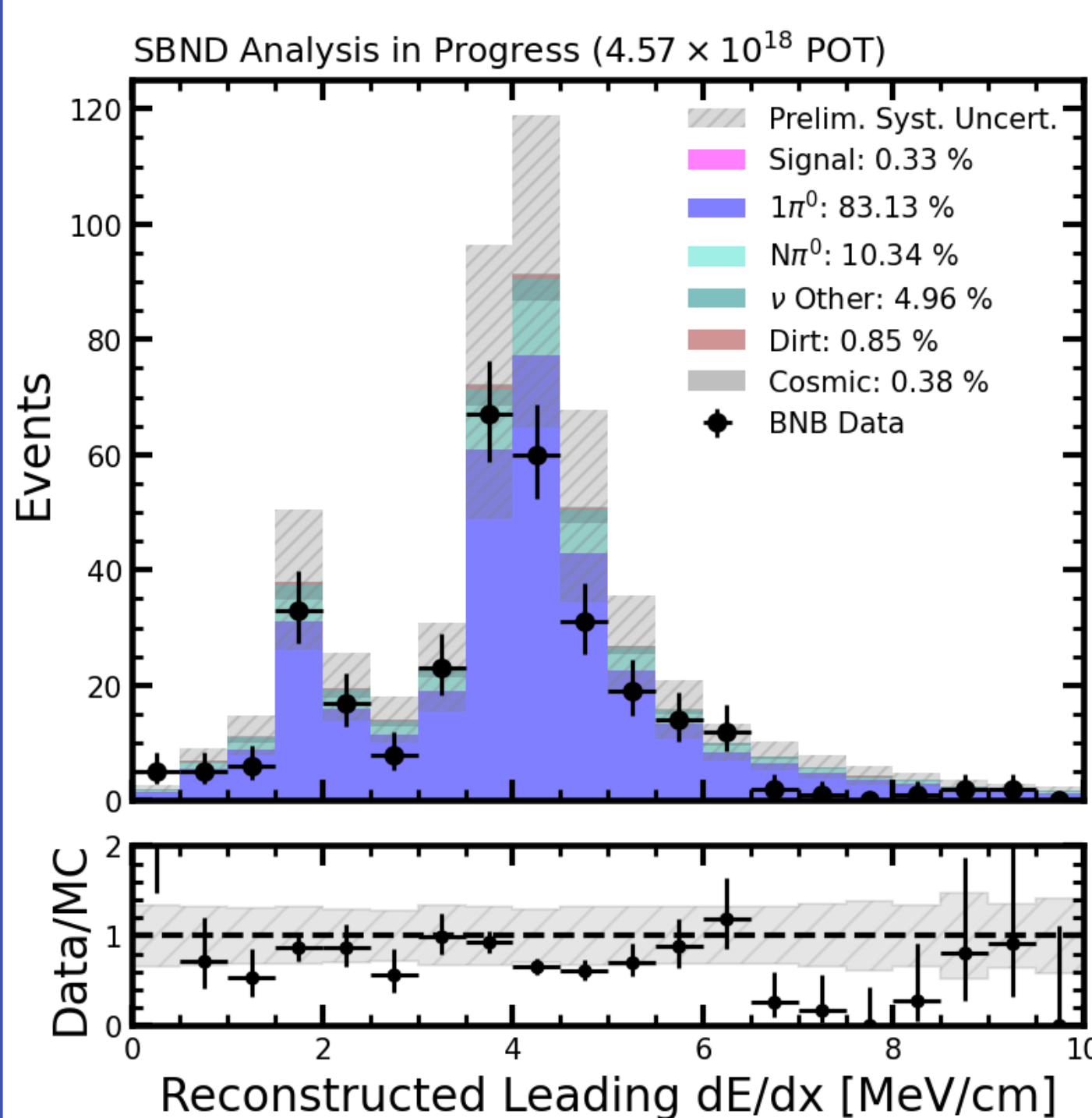
- The decay mode $\eta \rightarrow \gamma\gamma$ (BR $\approx 40\%$) produces two energetic electromagnetic showers and provides a clean experimental signature.
- MicroBooNE performed the first measurement of neutrino-induced η production on argon [4], observing fewer than 50 signal events.
- The Short-Baseline Near Detector (SBND) is expected to collect **~1400 selected signal events in Run 1**, enabling the first differential and exclusive measurements of this process.
- **The results shown in this poster come from only ~3 days of data taking**



Charged-Current interaction on argon which excites a $N(1535)$ resonance that decays to a proton and η

Di-Photon Event Selections

	Cut	Efficiency [%]	Purity [%]
Neutrino Selection	ν score > 0	98.3	0.05
	FV: $ x < 190, y < 190, z \in [10, 490]$ cm	96.6	0.086
	Barycenter Flash Match Score > 0.05	83.9	0.2
Photon Selection	Track Score < 0.5	-	-
	Energy > 50 MeV	-	-
	Conversion Gap > 2 cm	-	-
	$\cos\theta_{\nu\gamma} > 0.9$	-	-
η Selection	$N_\gamma = 2$	38.3	2.96
	$250 < M_{\gamma\gamma} < 750$ MeV	36.6	28.3
	$M_{max} > 400$ MeV	33.2	41.8
	$\cos\theta_{\gamma\gamma} < 0.5$	31.8	45.98



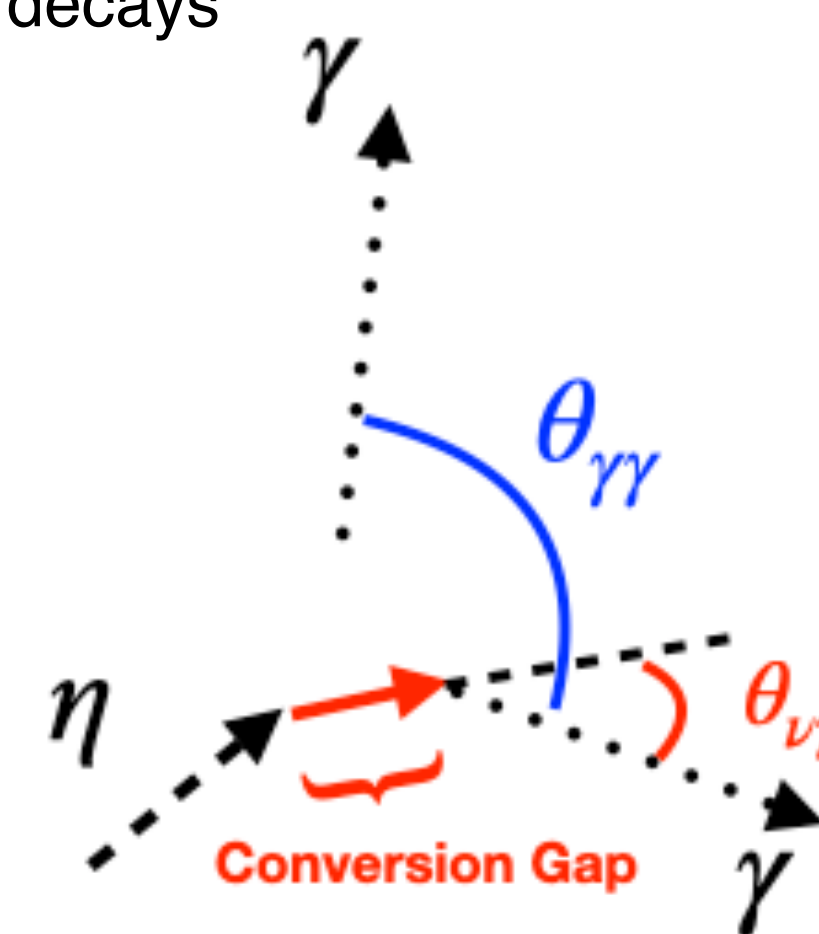
- The selection proceeds in 3 stages to tag η meson decays to two photons

 - 1. Neutrino Selection:** Basic topology, fiducial volume requirements, and charge-to-light matching are used to reject cosmic-ray backgrounds and neutrino interactions originating outside the detector
 - 2. Photon Selection:** Require two reconstructed electromagnetic shower candidates displaced from the neutrino interaction vertex.
 - 3. η Meson Selection:** Kinematic cuts separate η mesons from π^0 backgrounds.

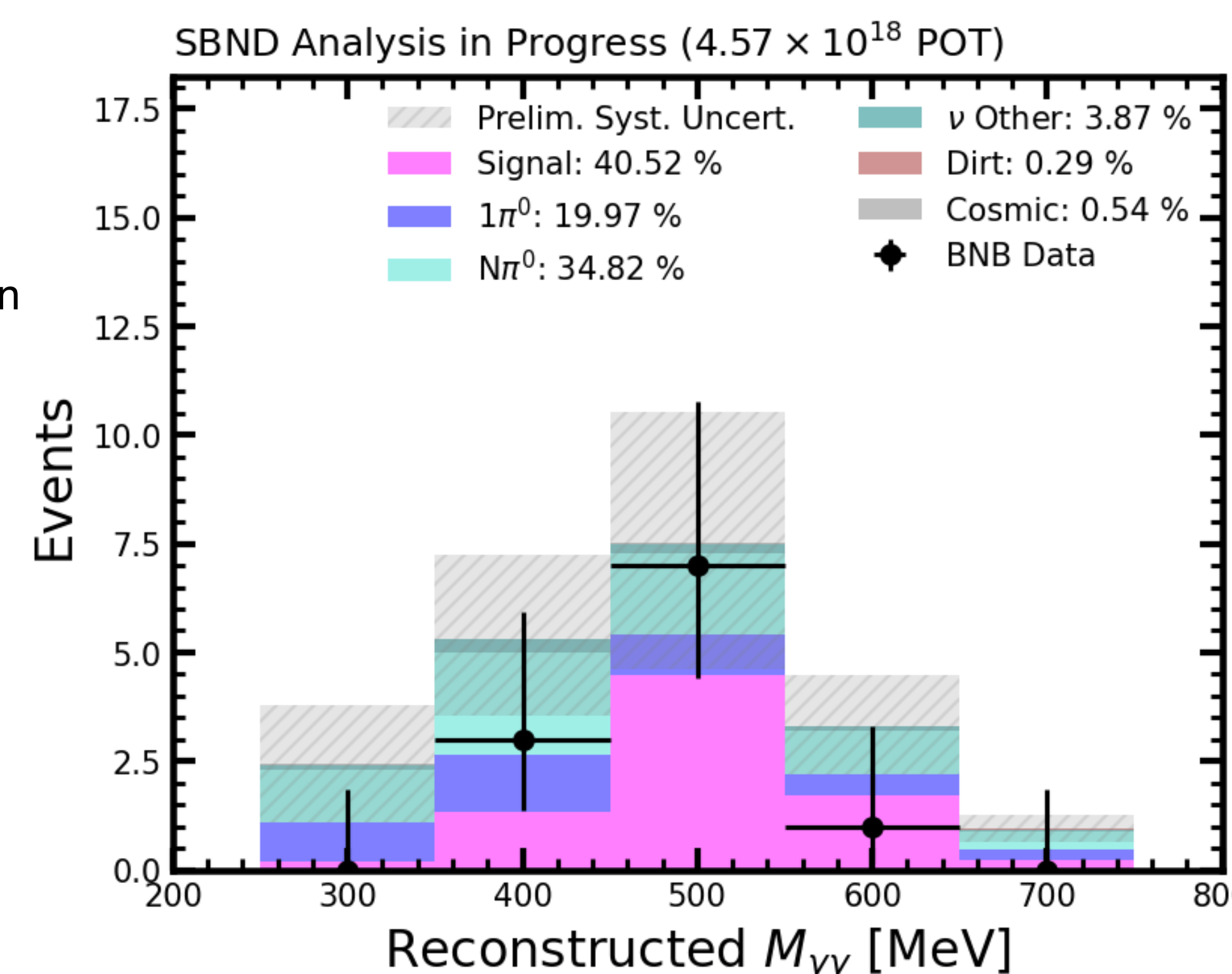
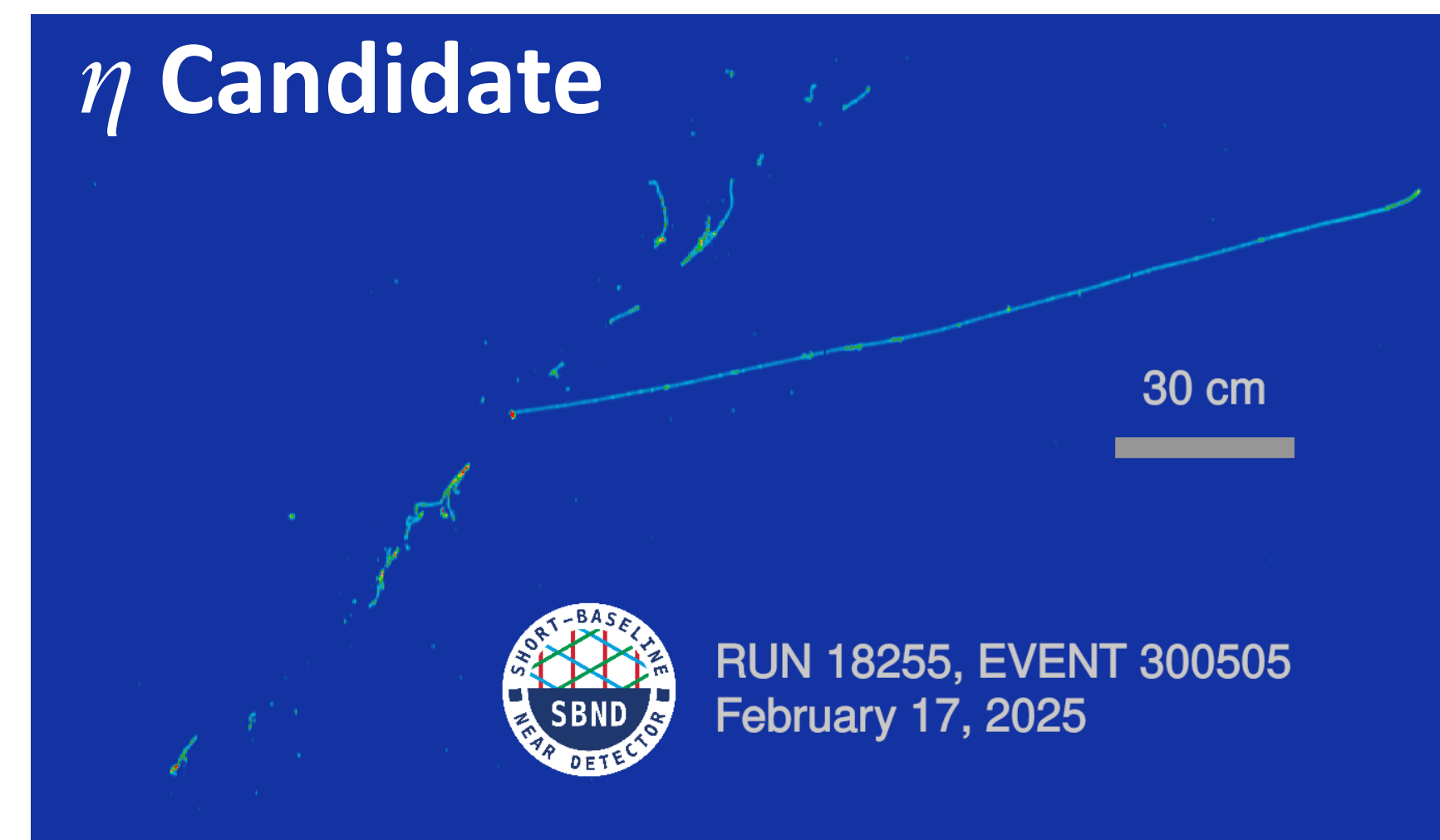
- Left: the dE/dx distribution of photon candidates shows a strong peak at ~ 4 MeV/cm as expected.

η Meson Selections

- Kinematic requirements are used to separate η mesons from π^0 backgrounds
- Events are selected in the η mass region, near $M_{\gamma\gamma} \sim 548$ MeV
- The maximum mass a di-photon pair can originate from, M_{max} , is leveraged to select heavier mesons
- Because π^0 's are much lighter, they are often more boosted and their decay photons tend to be more collimated, producing larger values of $\cos\theta_{\gamma\gamma}$
- The η mass peak provides a valuable benchmark for shower reconstruction, extending calibration and reconstruction-performance studies to higher energy than the π^0 decays

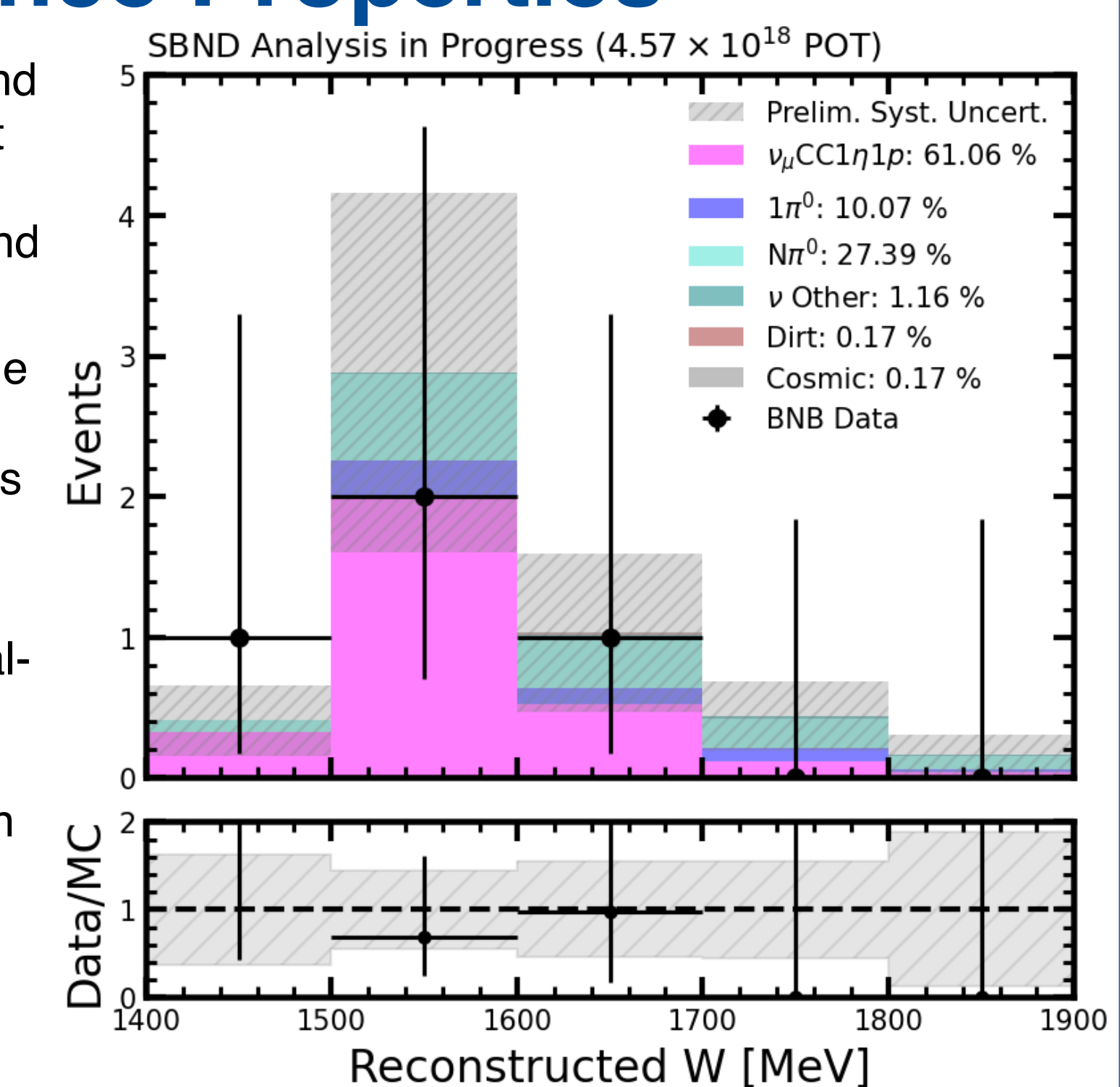


η Candidate



Probing Resonance Properties

- We additionally select for a muon and proton candidate using the excellent calorimetry of the SBND detector to study properties of the resonance and boost our signal purity.
- Reconstructing the 4-momenta of the proton and η allows us to measure center-of-momentum frame variables such as the invariant mass of the resonance, W .
- These variables are sensitive to final-state interactions (FSI) within the nucleus [4] and provide a powerful probe of neutrino-nucleus interaction modeling, helping to distinguish between competing theoretical predictions.



Summary & Outlook

- The measurement of η production helps us to better understand the the modeling of neutrino interactions on argon that produce higher resonance states beyond the $\Delta(1232)$ baryon
- We have demonstrated selections in SBND to tag η mesons as well as final state topologies consistent with higher mass resonance states
- We aim to boost our efficiency and purity with more advanced selection methods in future iterations of this work.



References:

- [1] R. Acciarri et al. *A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam*. 2015. arXiv: 1503.01520
- [2] B. Abi et al. *Deep Underground Neutrino Experiment (DUNE), Far Detector Technical Design Report, Volume II: DUNE Physics*. 2020. arXiv: 2002.03005
- [3] P. Abratenko et al. *First Measurement of η Meson Production in Neutrino Interactions on Argon with MicroBooNE*. Phys. Rev. Lett. 132 (15 Apr. 2024)
- [4] R. K. Pradhan, R. Lalnuntluanga, and A. Giri. *Centre-of-momentum frame analysis of η production in DUNE*. The European Physical Journal C 85.10 (Oct. 2025)

Acknowledgements:

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