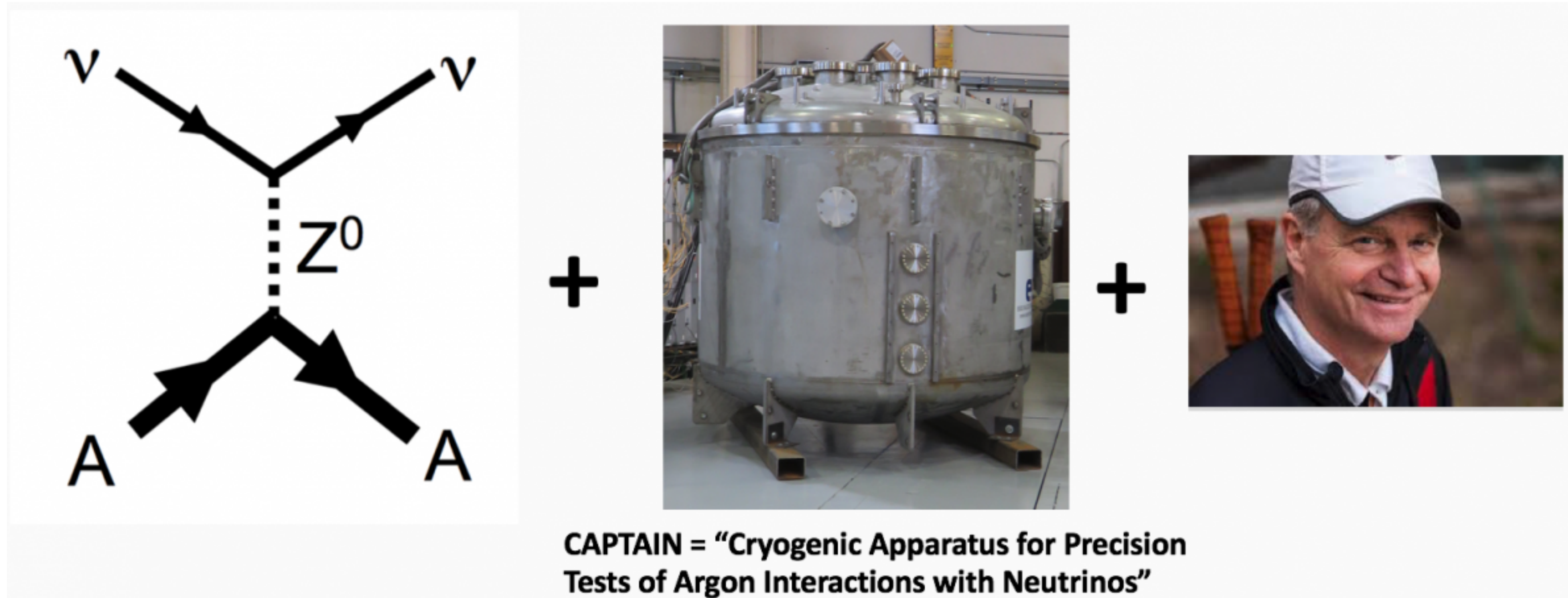


Coherent CAPTAIN-Mills

LANSCCE Intense Pulsed Proton Source Search for Dark Sector Particles



International Conference on High Energy Physics

9 July 2022

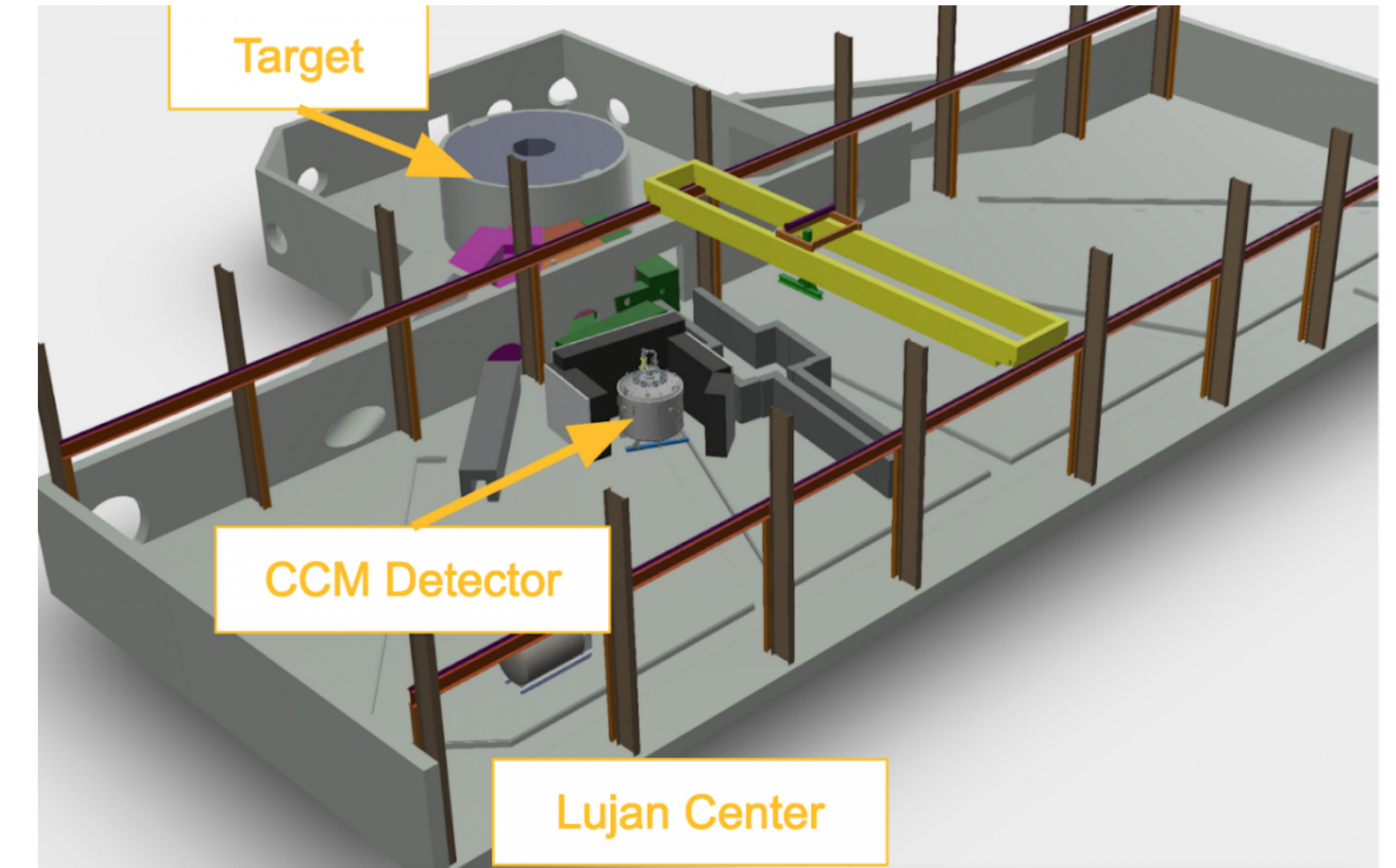
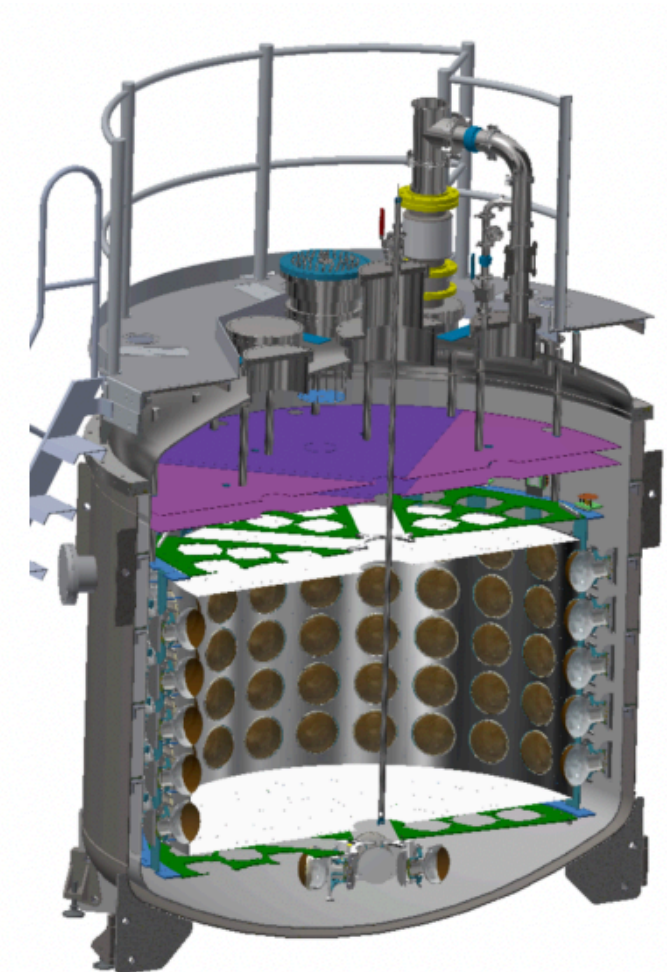
Darcy Newmark *on behalf of the CCM Collaboration*

dnewmark@mit.edu

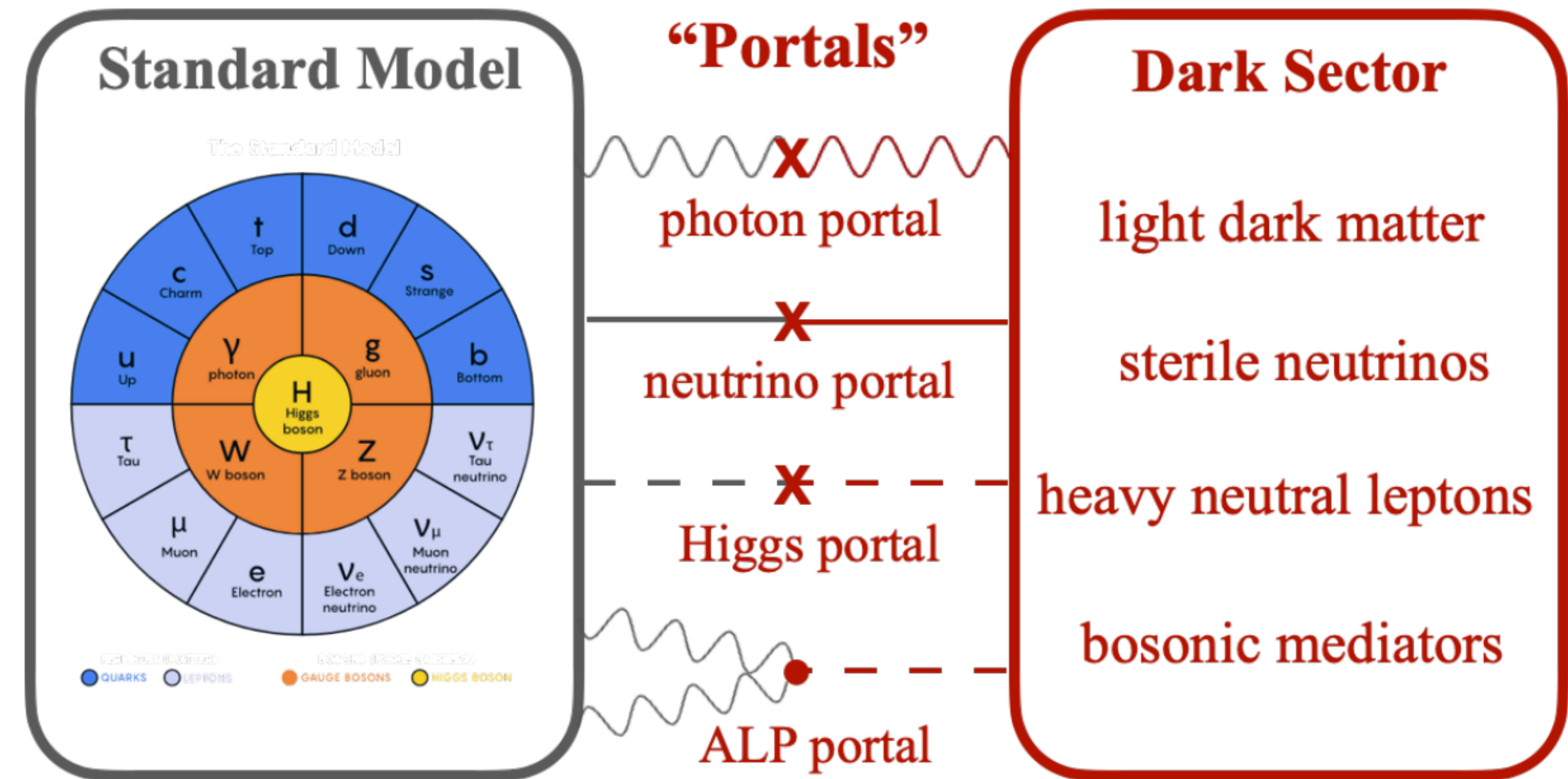
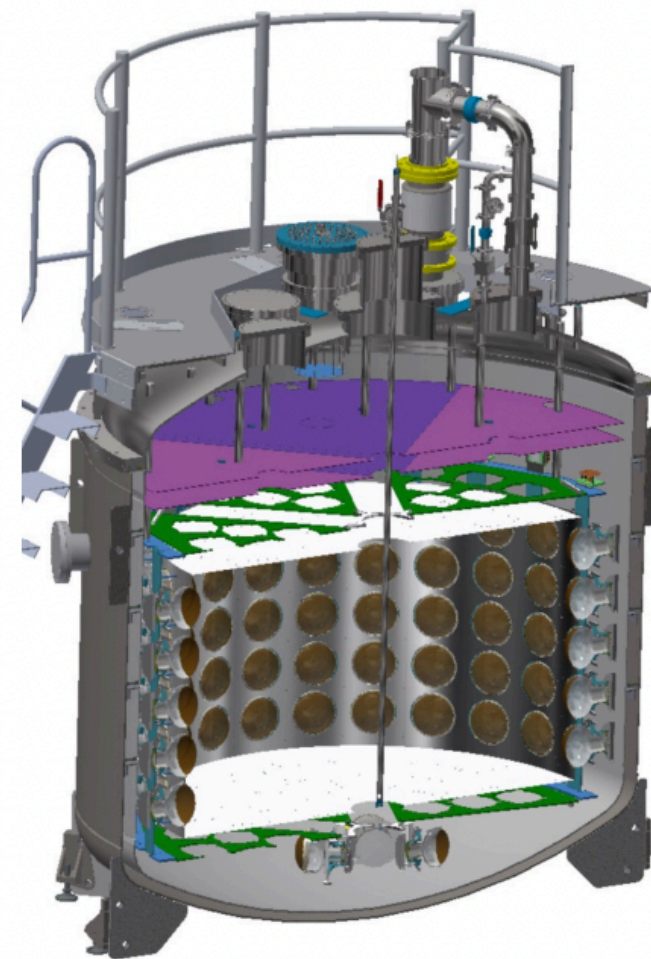
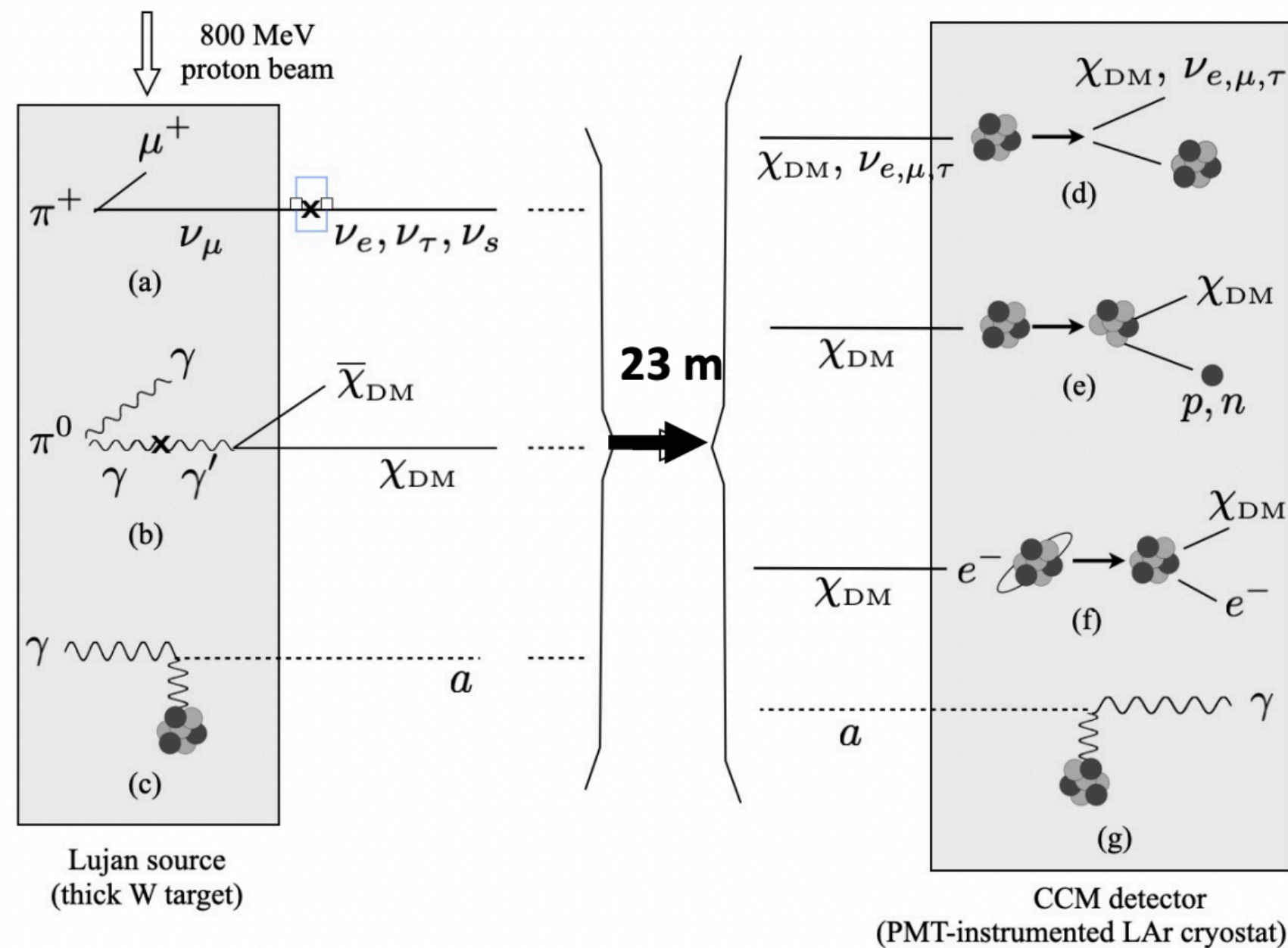


Coherent CAPTAIN-Mills (CCM) Overview

- 10 ton liquid argon (LAr) scintillation detector located at Los Alamos National Laboratory
- 200 8" photomultiplier tubes (PMT) for 50% coverage of 5 ton fiducial volume
- Positioned 90° off axis and 23m from stopped pion and muon source
- $2.25\text{E}22$ POT/3 years for $5.28\text{E}5$ neutrinos/cm²/s



CCM Physics Program Overview



Below ~ 1 MeV:

- Dark matter production and detection via vector (and pseudo)-scalar portals

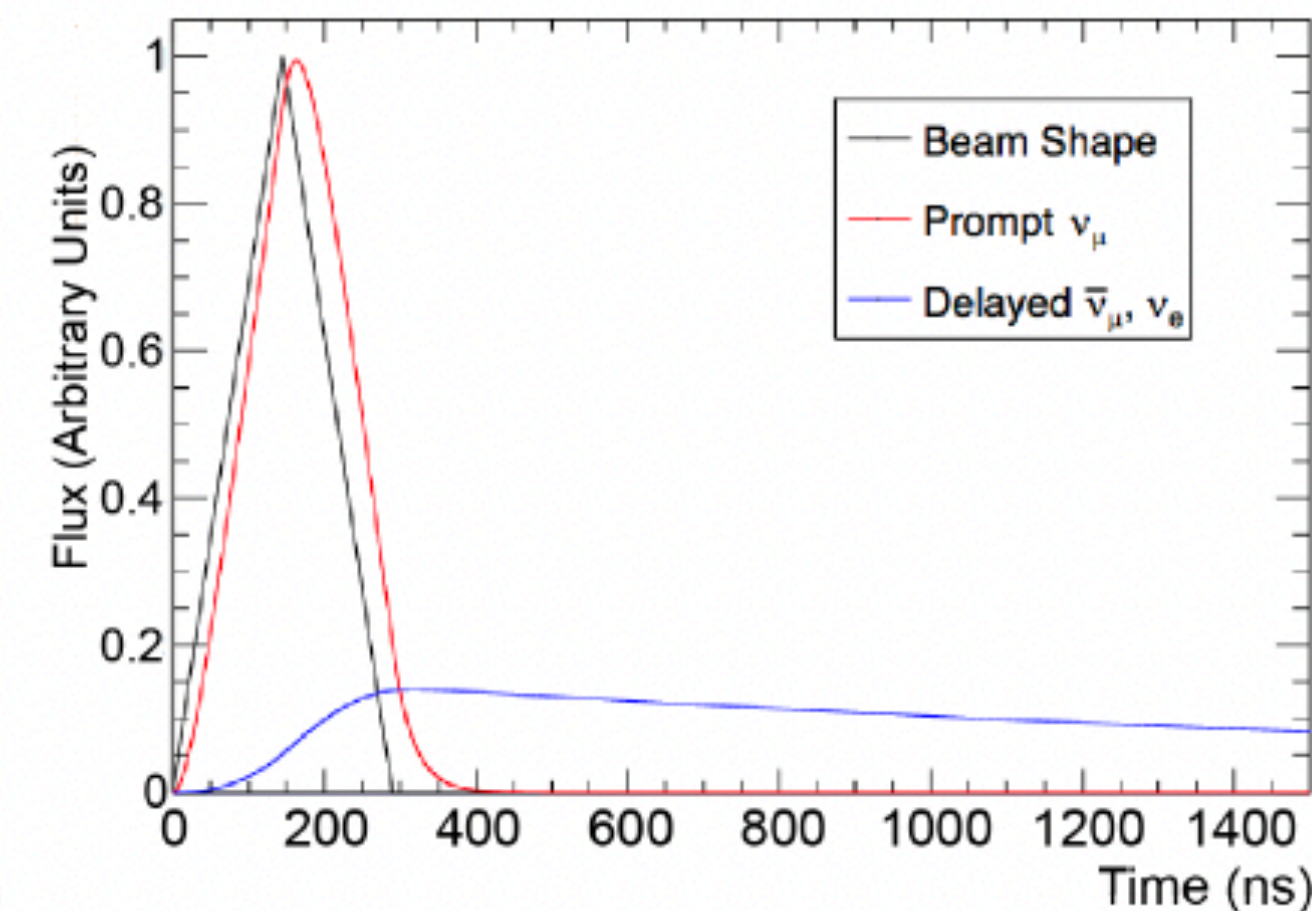
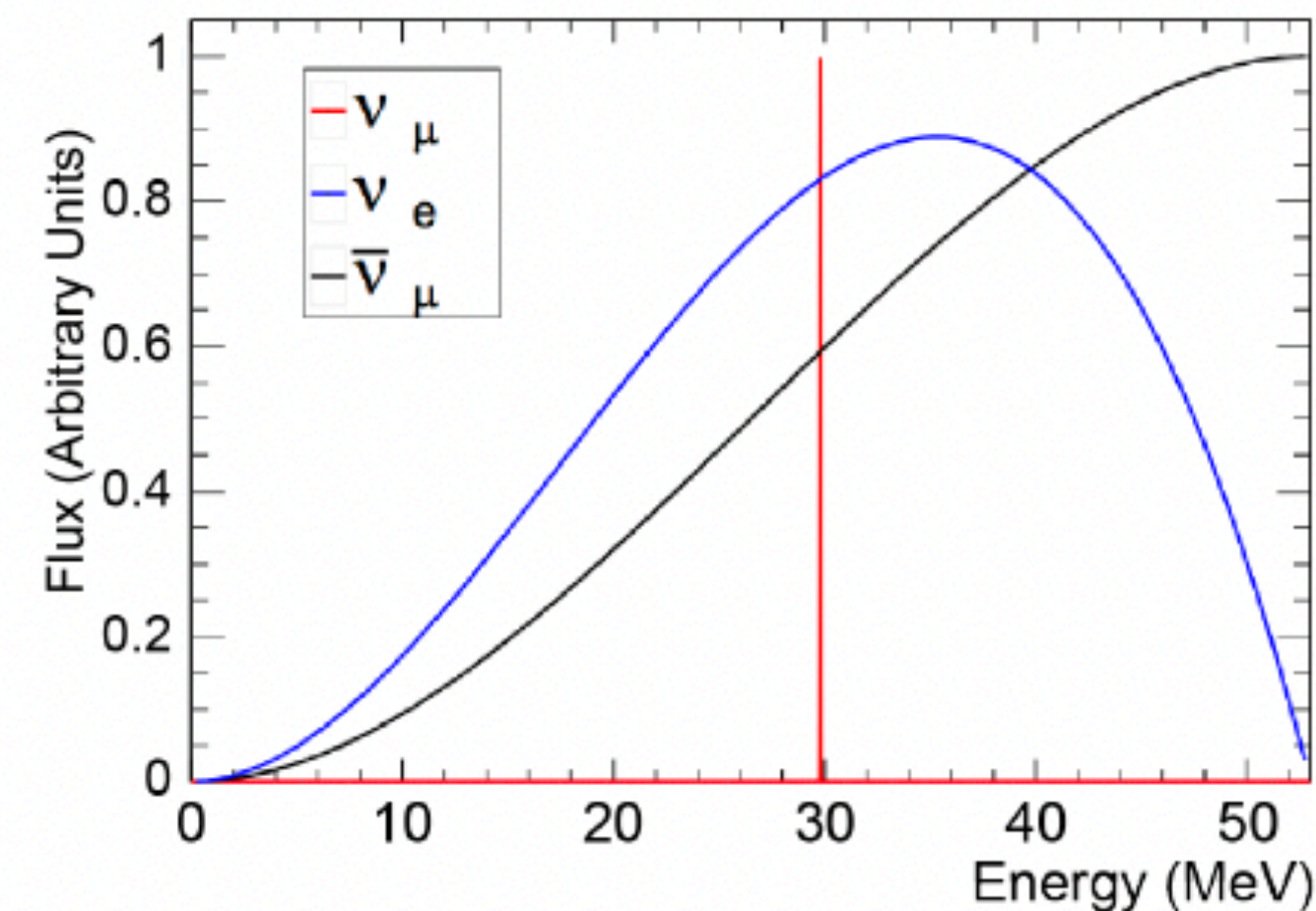
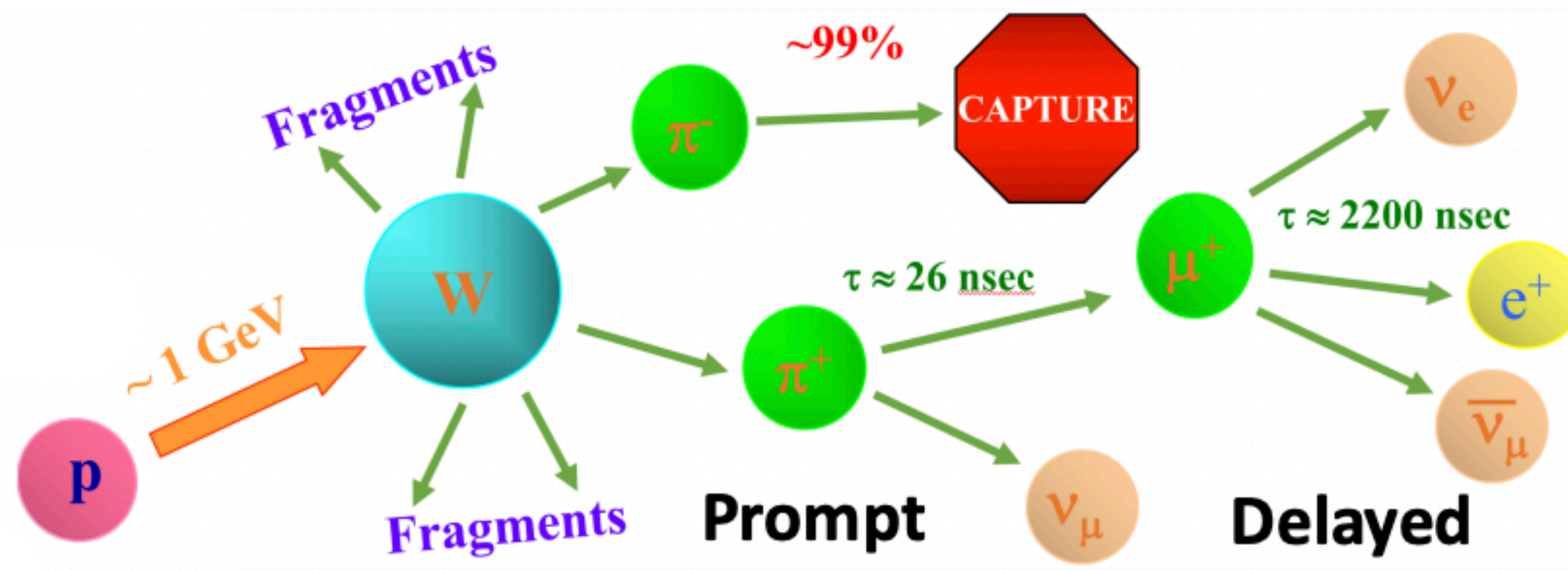
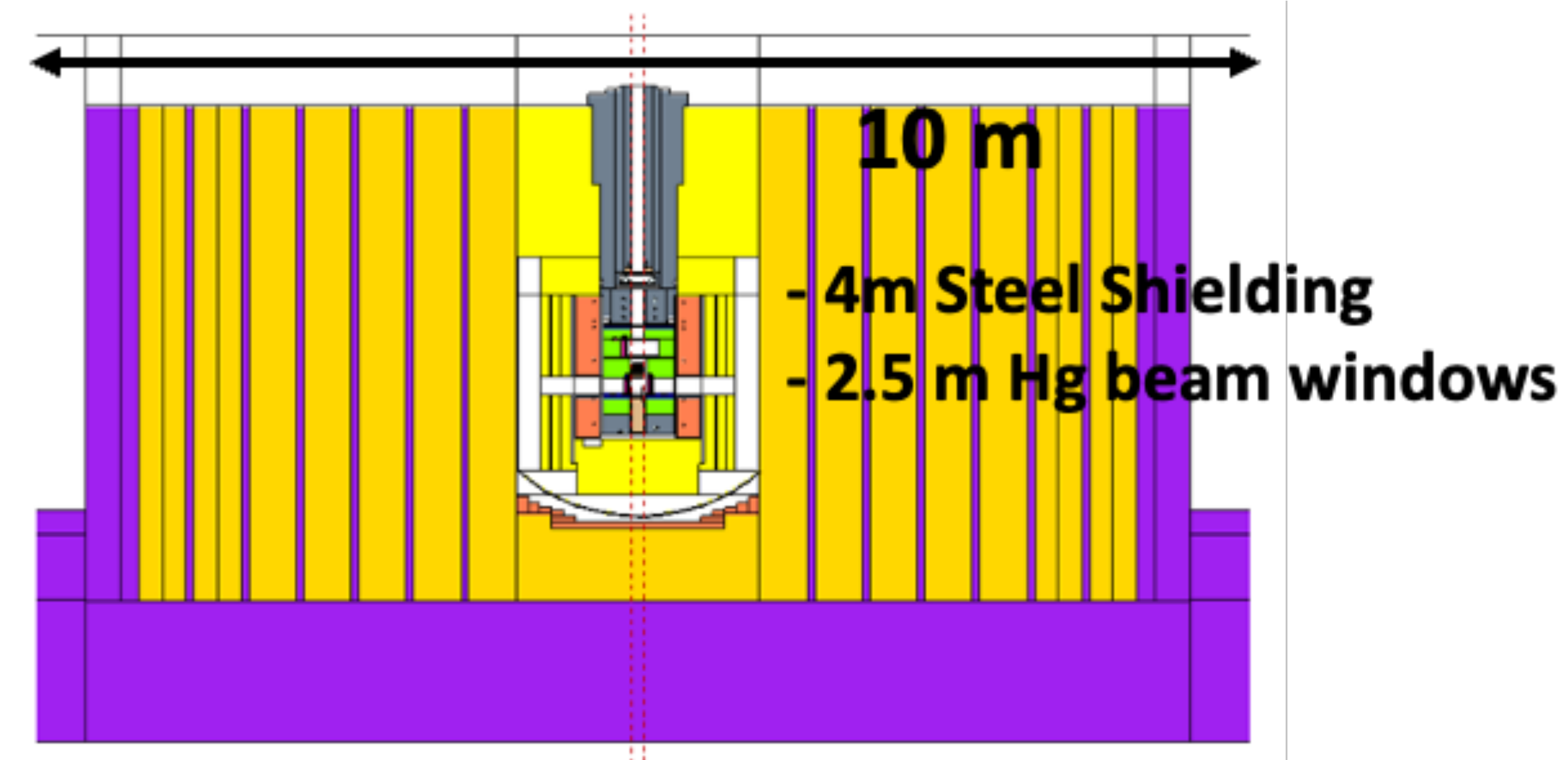
Above ~ 1 MeV:

- Neutrino portals (sterile neutrinos, heavy natural leptons)
- Dark sector mediators (ALPs, dark vectors, dark higgses)

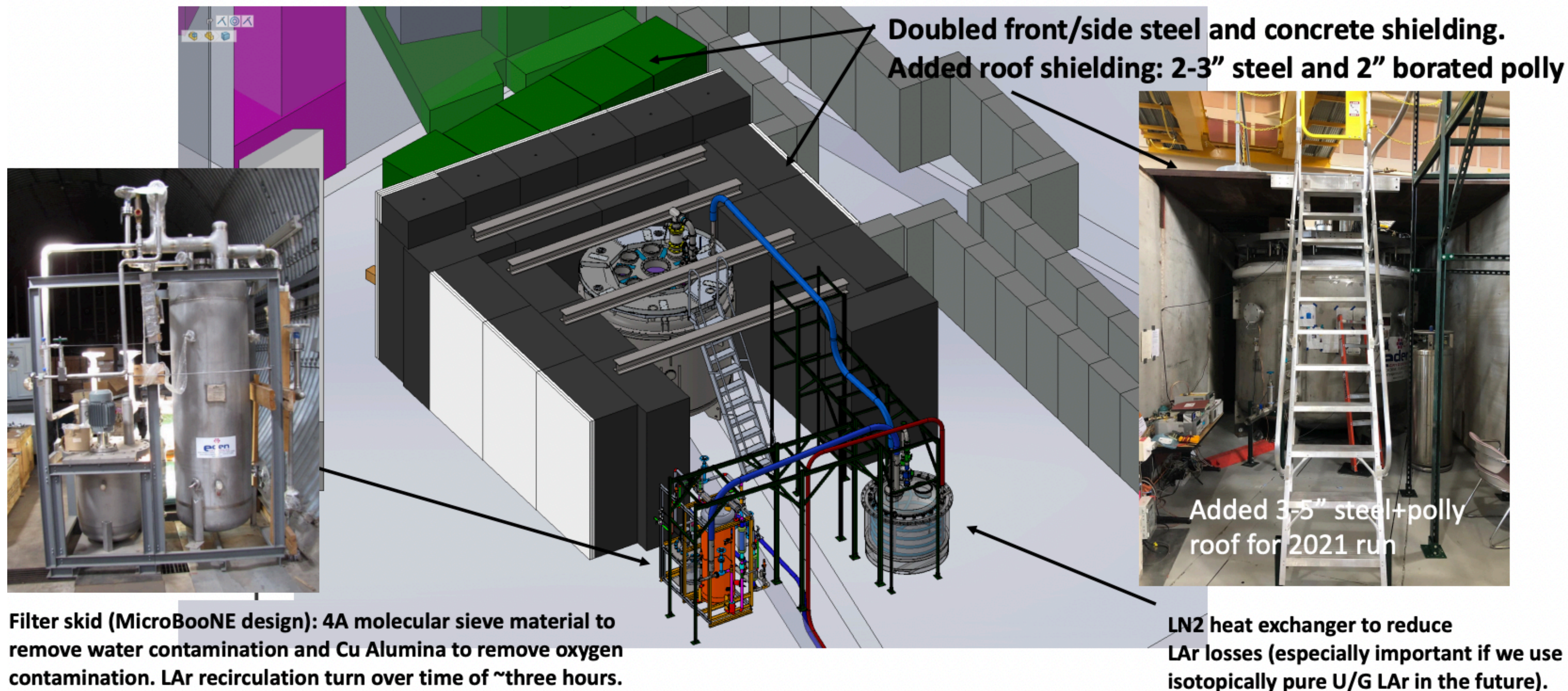
Lujan Facility

Lujan Target

- 800 MeV proton beam, 100 μA current, 290 nsec pulse at 20 Hz
- Protons incidence on tungsten target creates prompt flux of 30 MeV ν_μ and delayed flux of $\bar{\nu}_\mu$ and ν_e

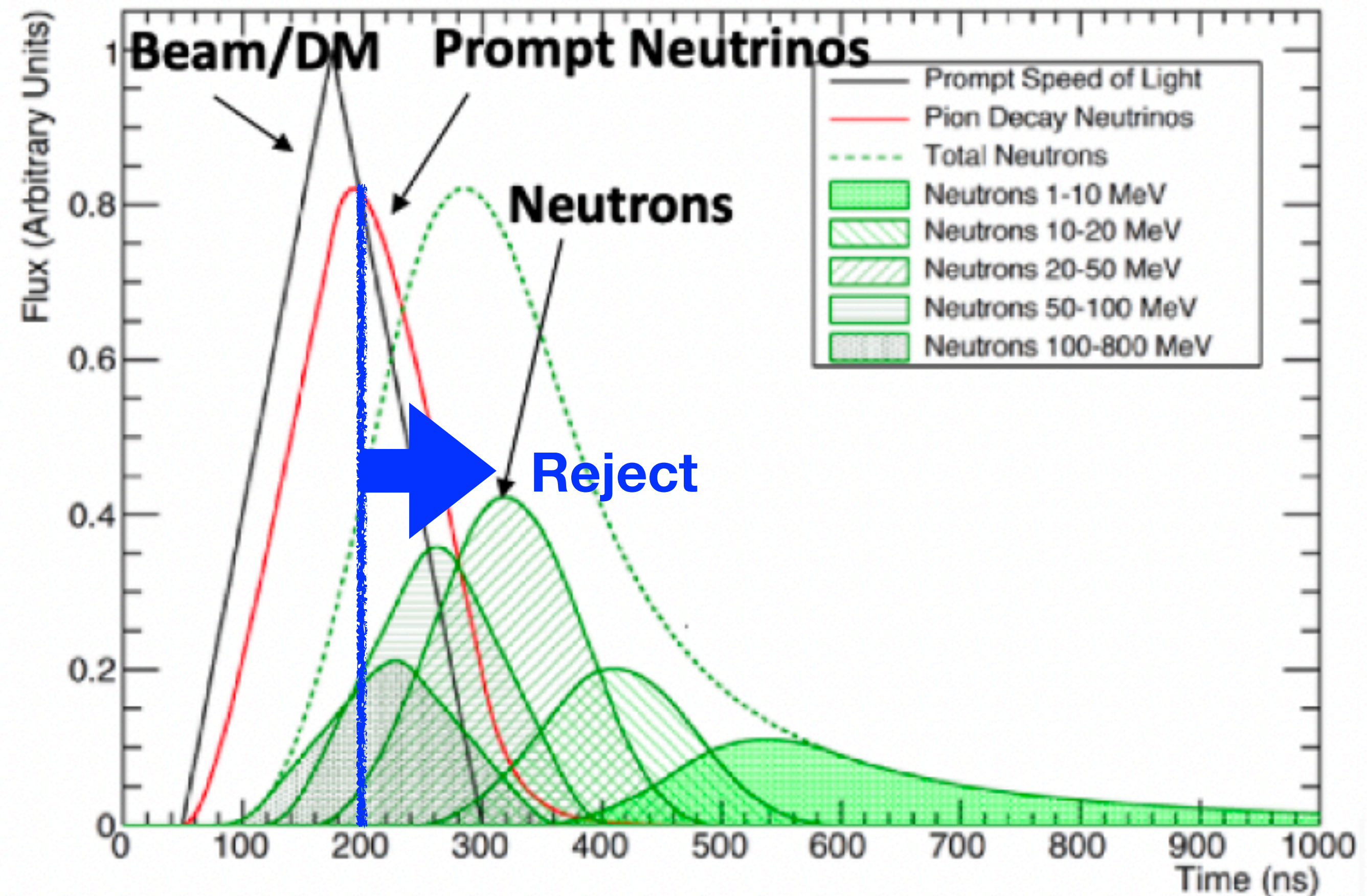


CCM200 Layout at Lujan (L = 23m)



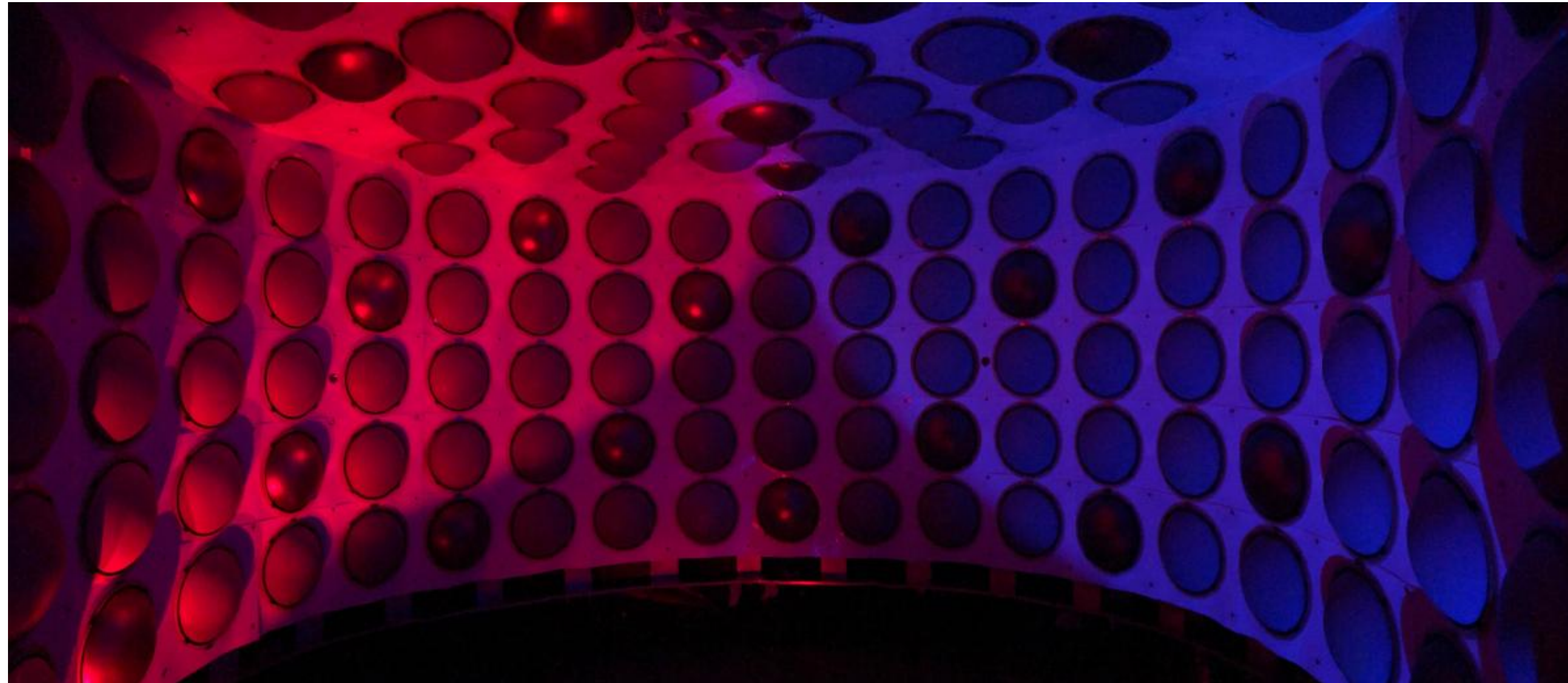
Backgrounds

- Use 190nsec timing cut to isolate prompt ν_μ
- Primary neutron background with $E_n \approx 20\text{-}50$ MeV reduced by timing cut, fast neutrons absorbed by shielding (see [arXiv:2105.14020](https://arxiv.org/abs/2105.14020) for discussion of timing cuts)
- Shielding
 - 2m concrete
 - 5m of steel



CCM200 Detector

CCM200

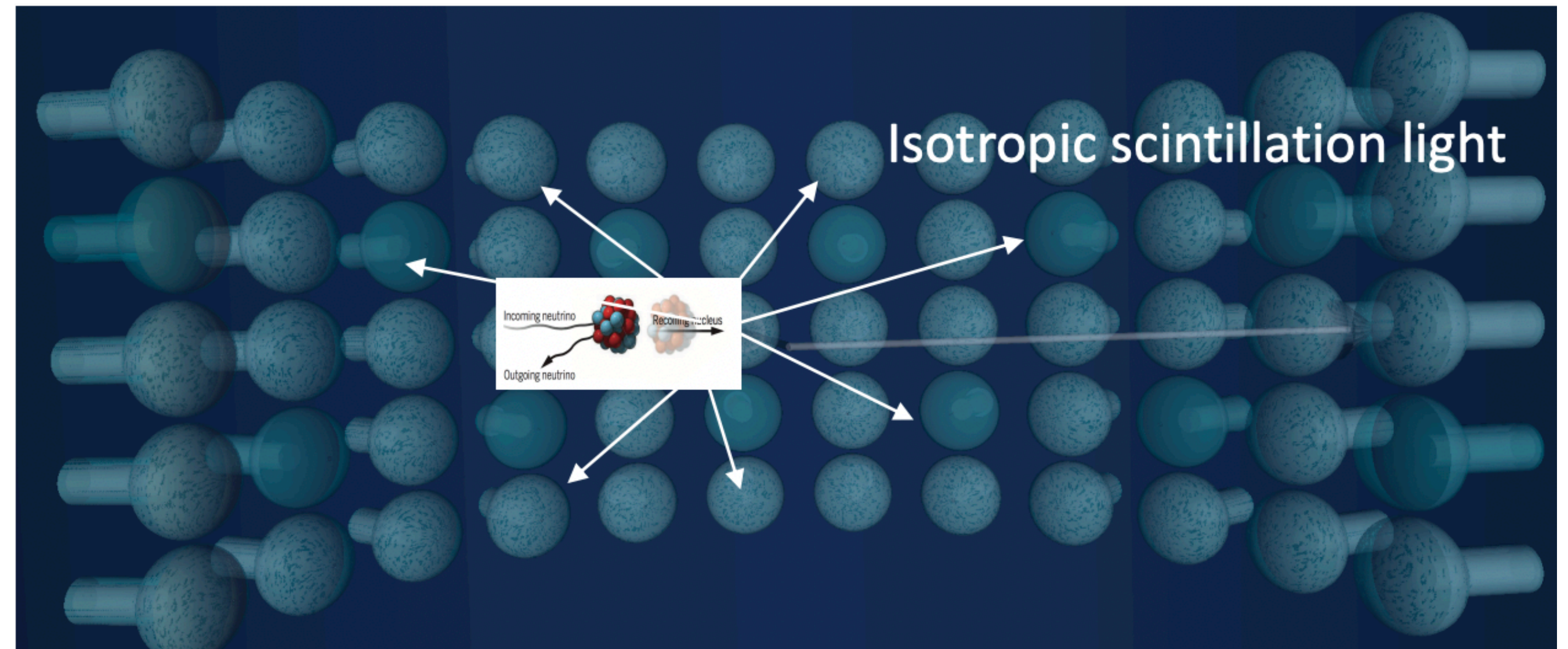
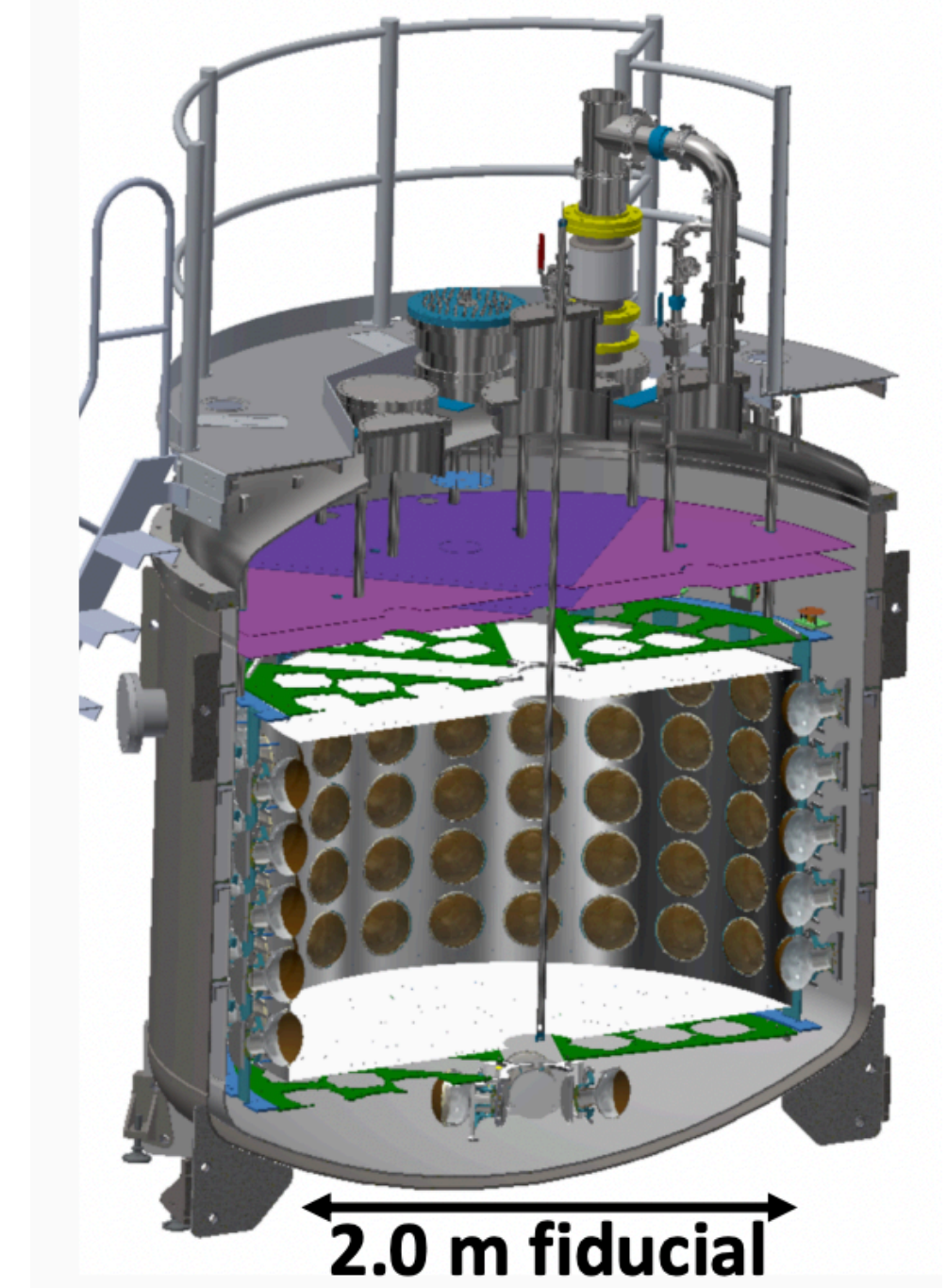


- CCM200 constructed during Covid, began running Oct 2021
- 80% of PMTs coated in 1,1,4,4-Tetraphenyl-1,3-butadiene (TPB)



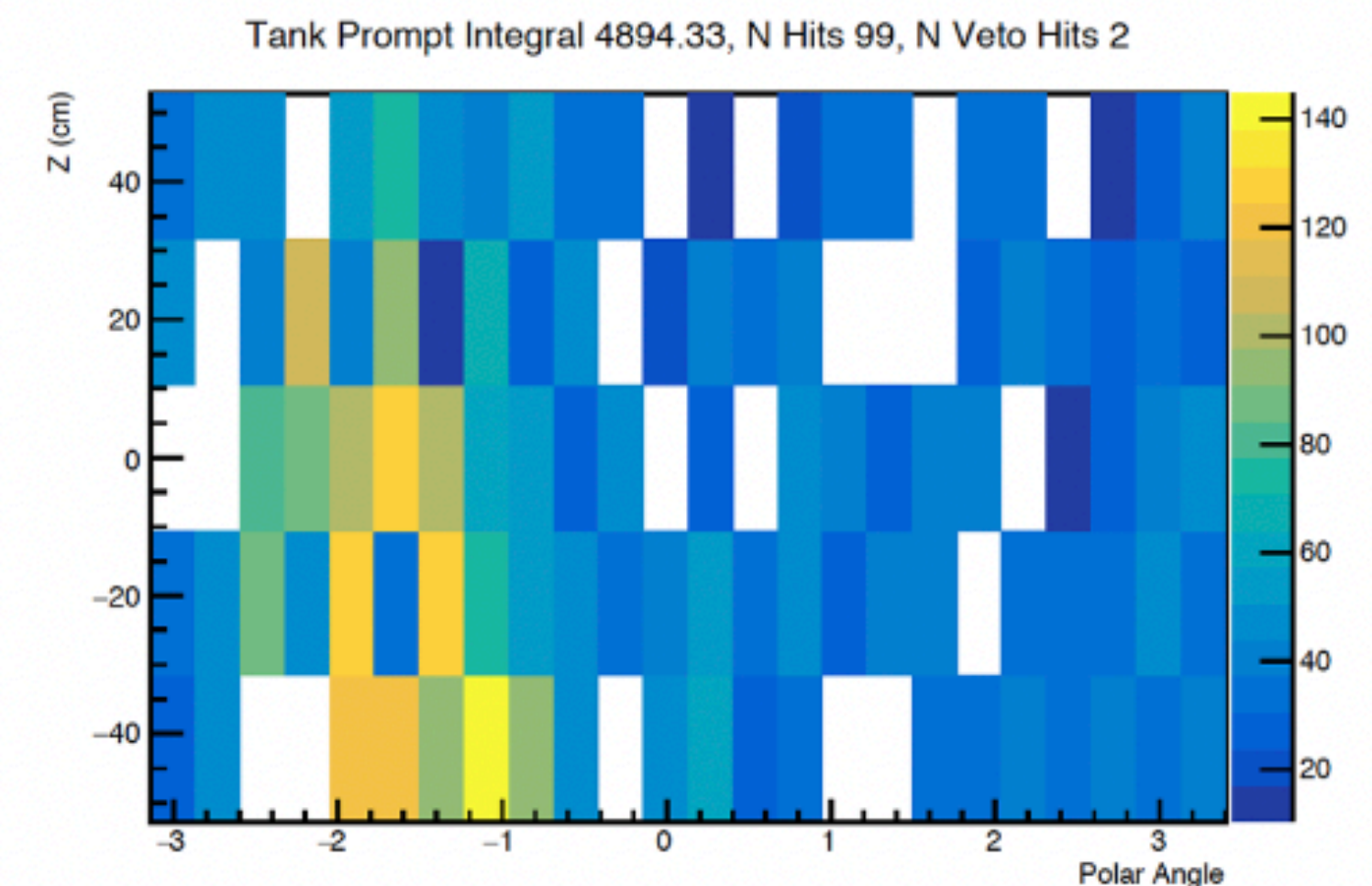
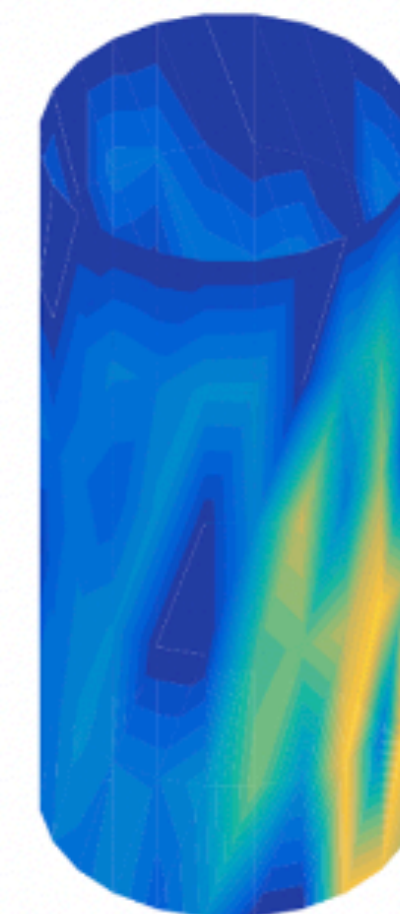
CCM Light Detection

- LAr scintillates at 128nm with 40,000 photons/MeV
 - 4x brighter than typical oil-based liquid scintillator
- TBP coating shifts UV LAr scintillation photons to visible light to penetrate PMTs
- 40 1" veto PMTs and 200 8" PMTs for event reconstruction
resolution of ~1nsec timing, ~15cm position, and ~20% energy
- Uncoated PMTs allow for unique capabilities — simultaneous scintillation and Cherenkov light detection
- Energy detection range from ~10 keV to ~200 MeV



Search for Cherenkov signal [PRELIMINARY]

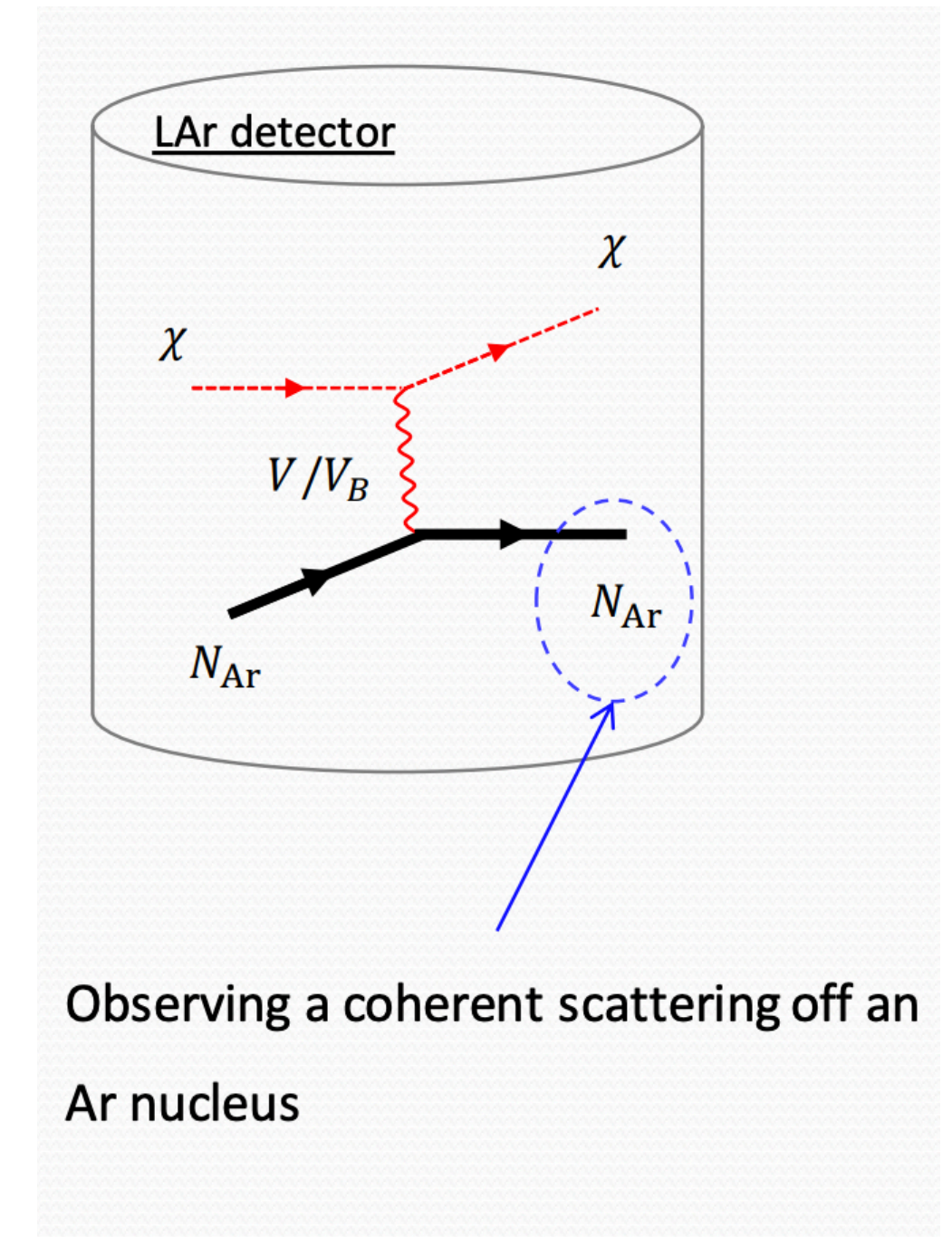
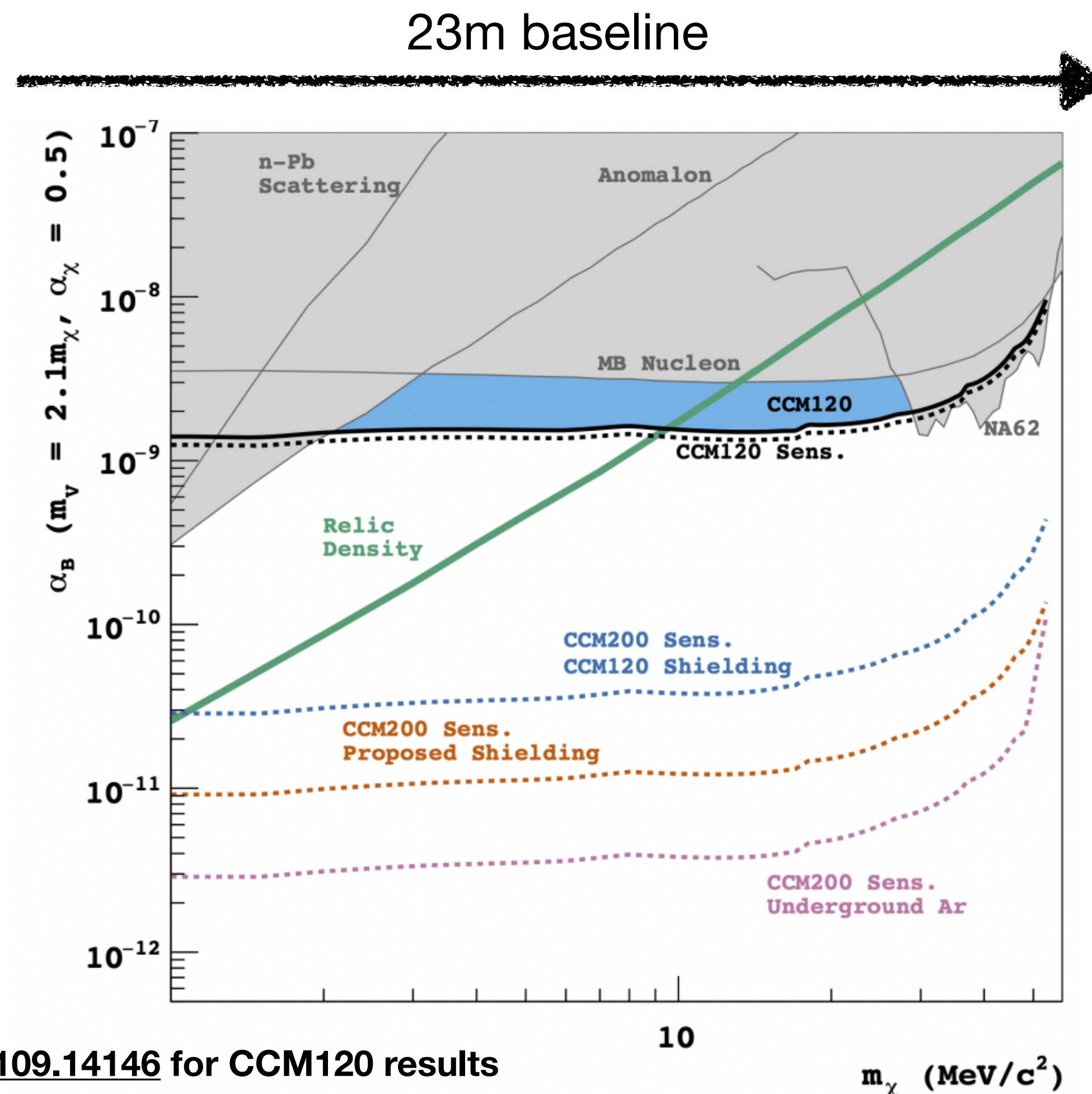
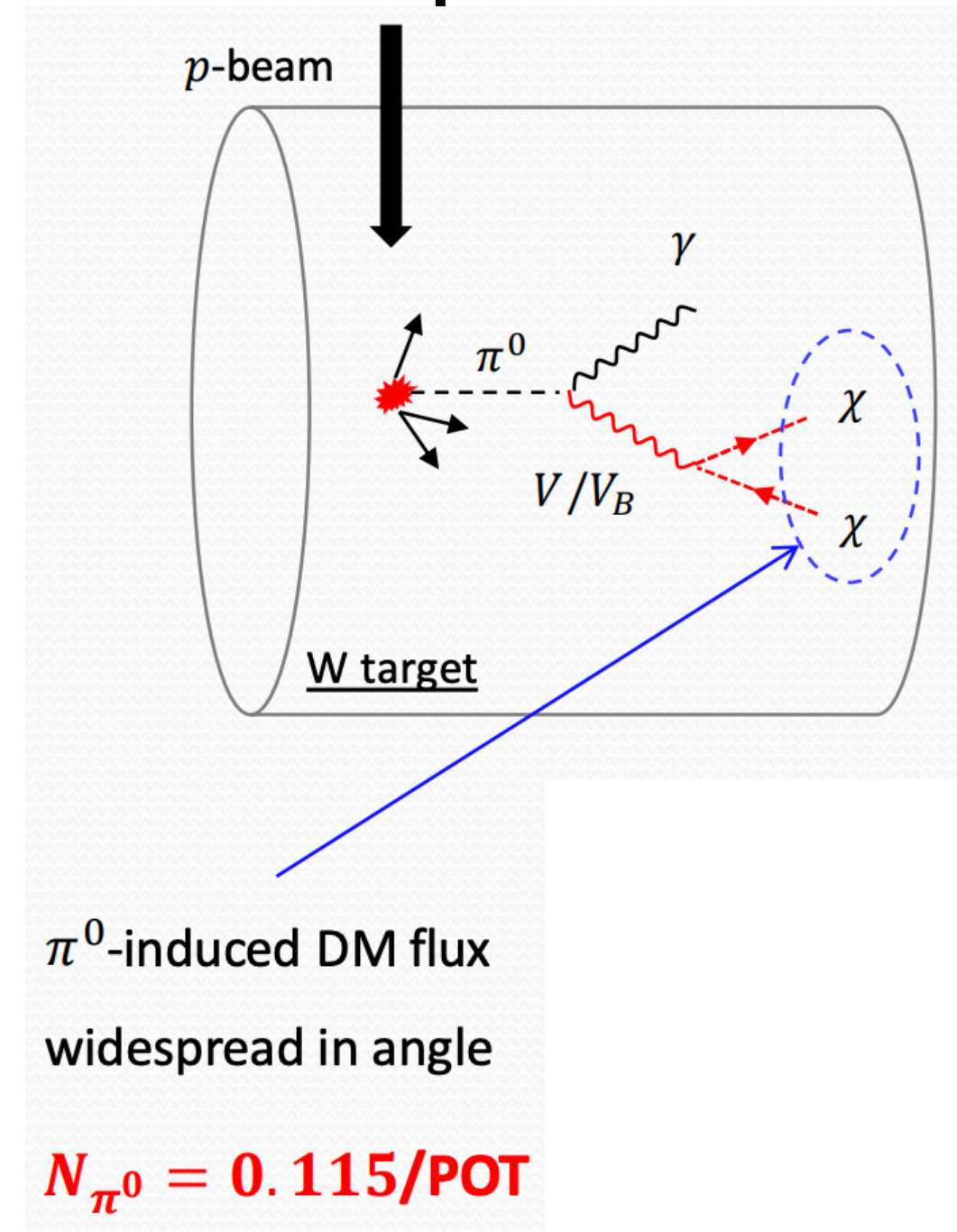
- Event-by-event ID of Cherenkov light
 - 20% uncoated PMTs isolate prompt visible light
- Reduce CCM backgrounds through pointing and PID
- Improve light simulations in LAr detectors
- Cosmic ray muon detection



Physics Searches

Coherent Dark Matter Search

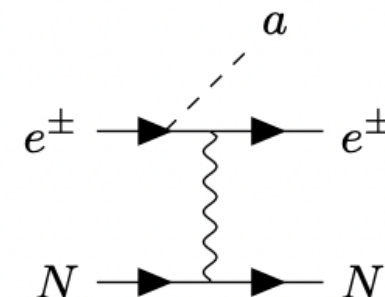
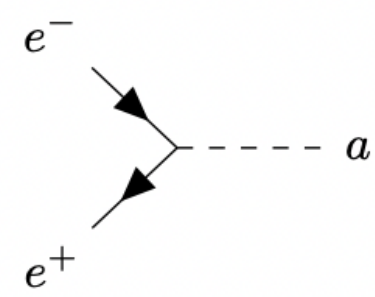
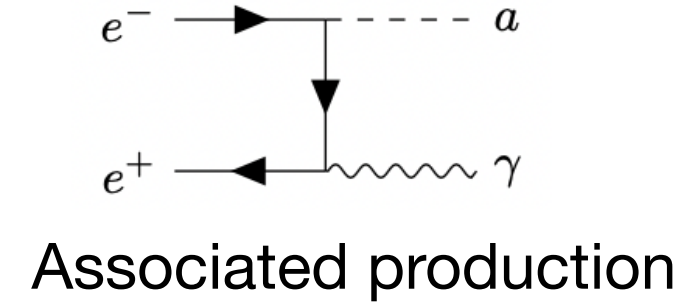
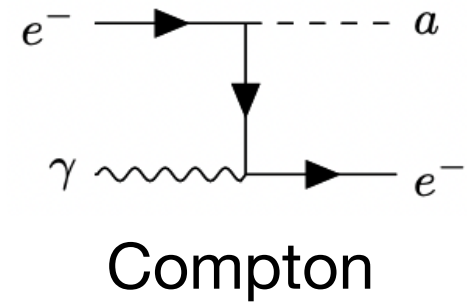
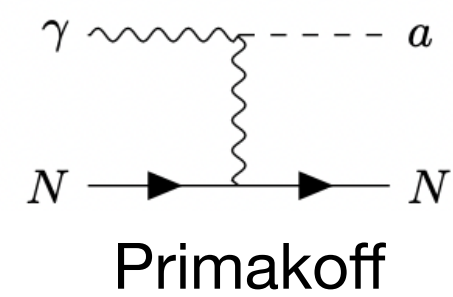
- Basic vector portal model



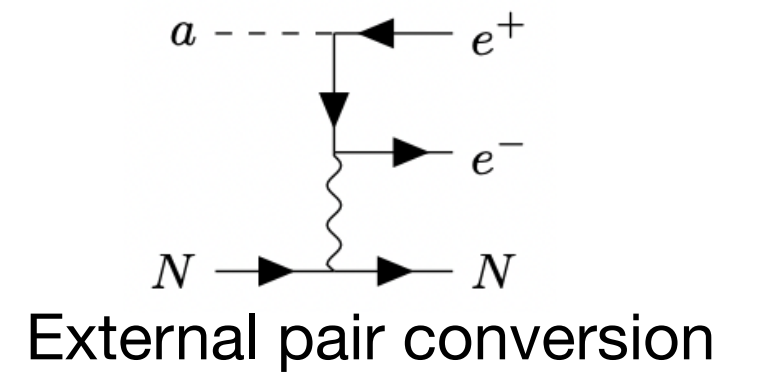
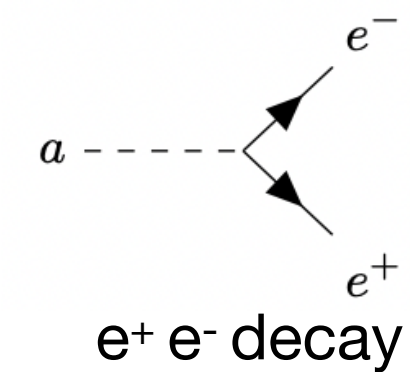
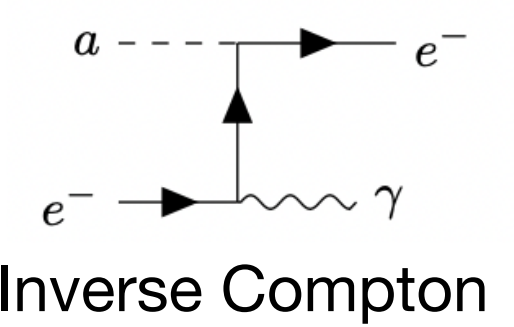
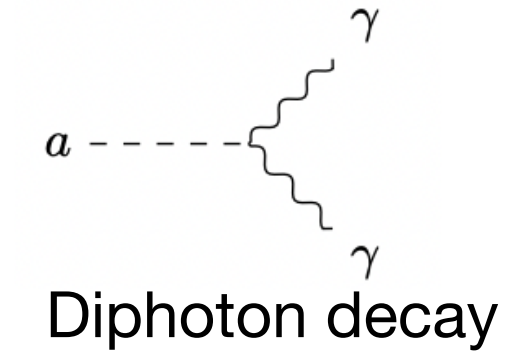
See <https://arxiv.org/abs/2109.14146> for CCM120 results

Axion-Like Particles Sensitivities

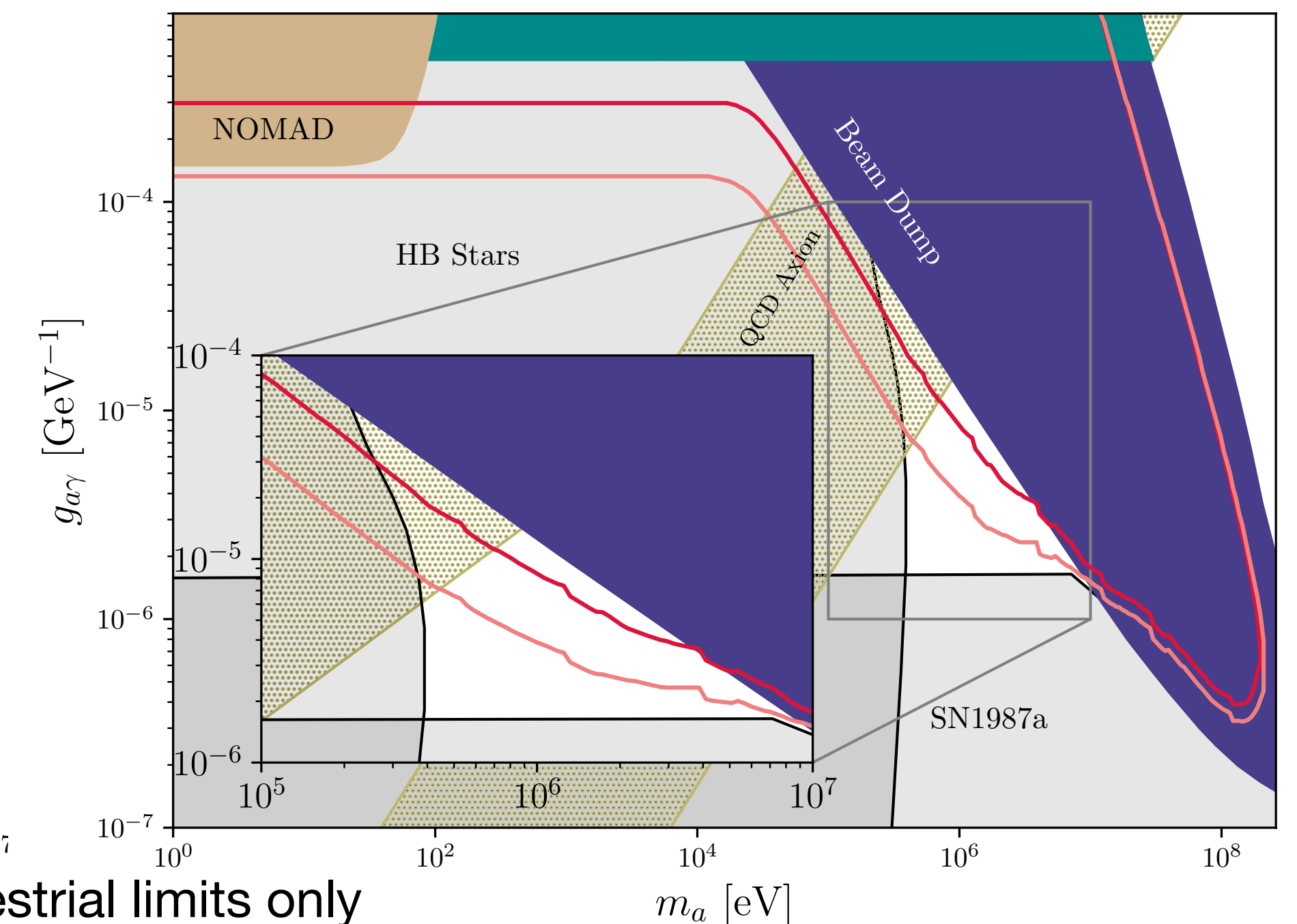
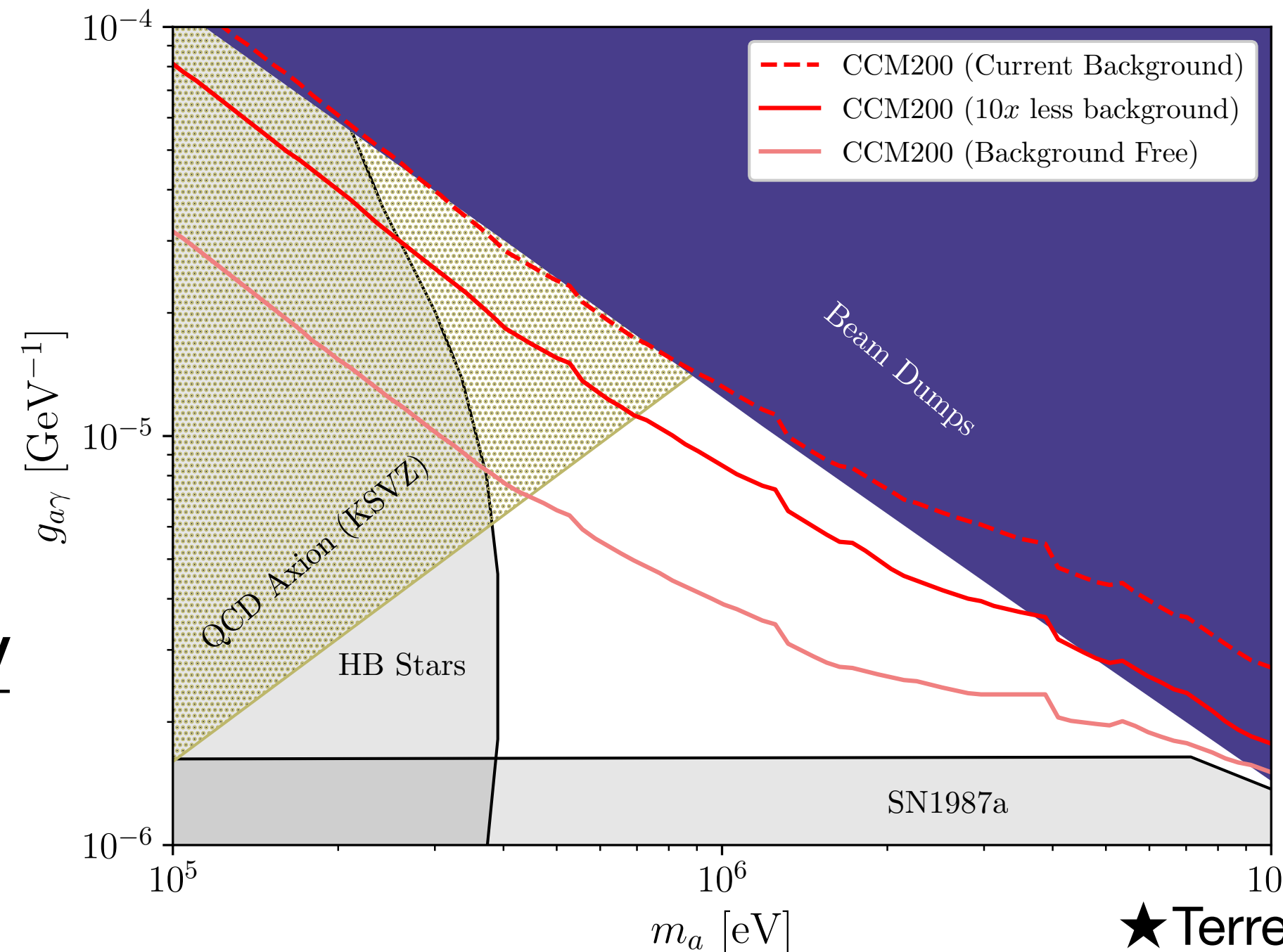
Production



Detection

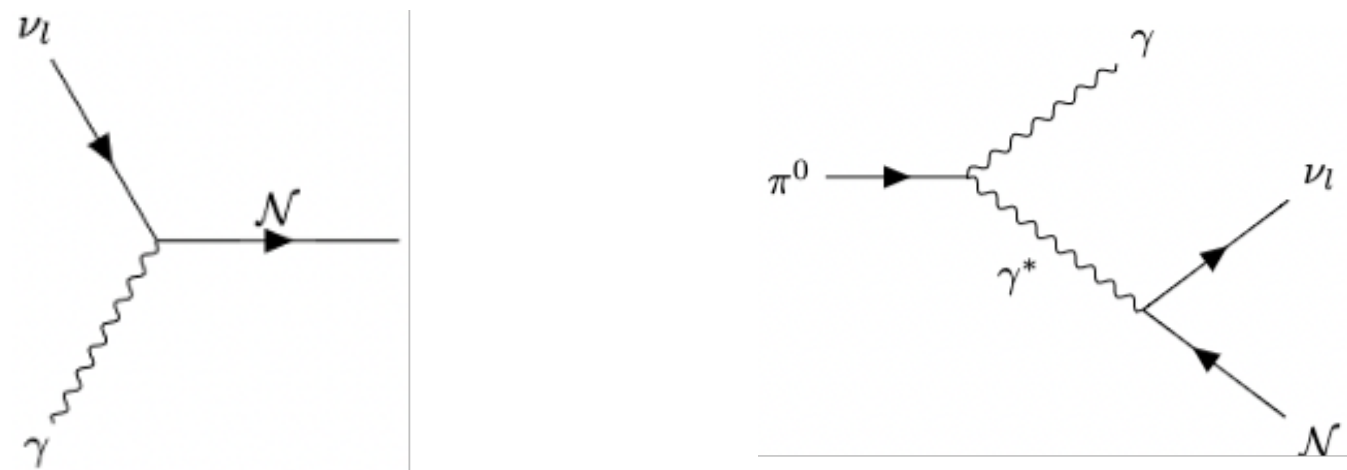


- High energy EM signals (1-10 MeV)
- Sensitivity at 90% CL
- Can probe “cosmological triangle”
- See <https://arxiv.org/abs/2112.09979> for further details

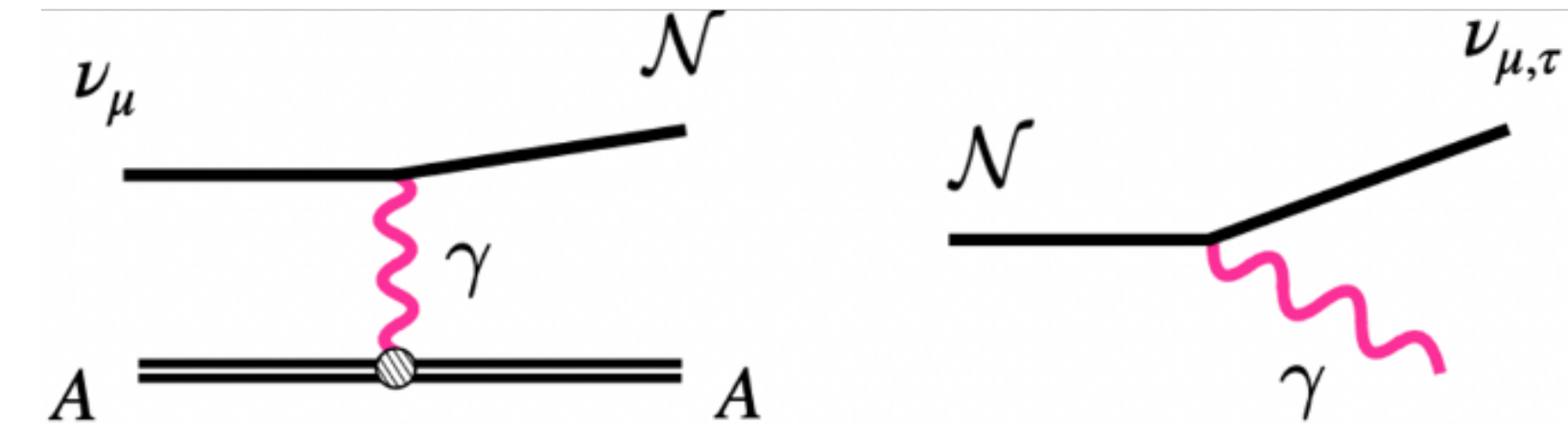


Heavy Neutral Lepton Production at CCM

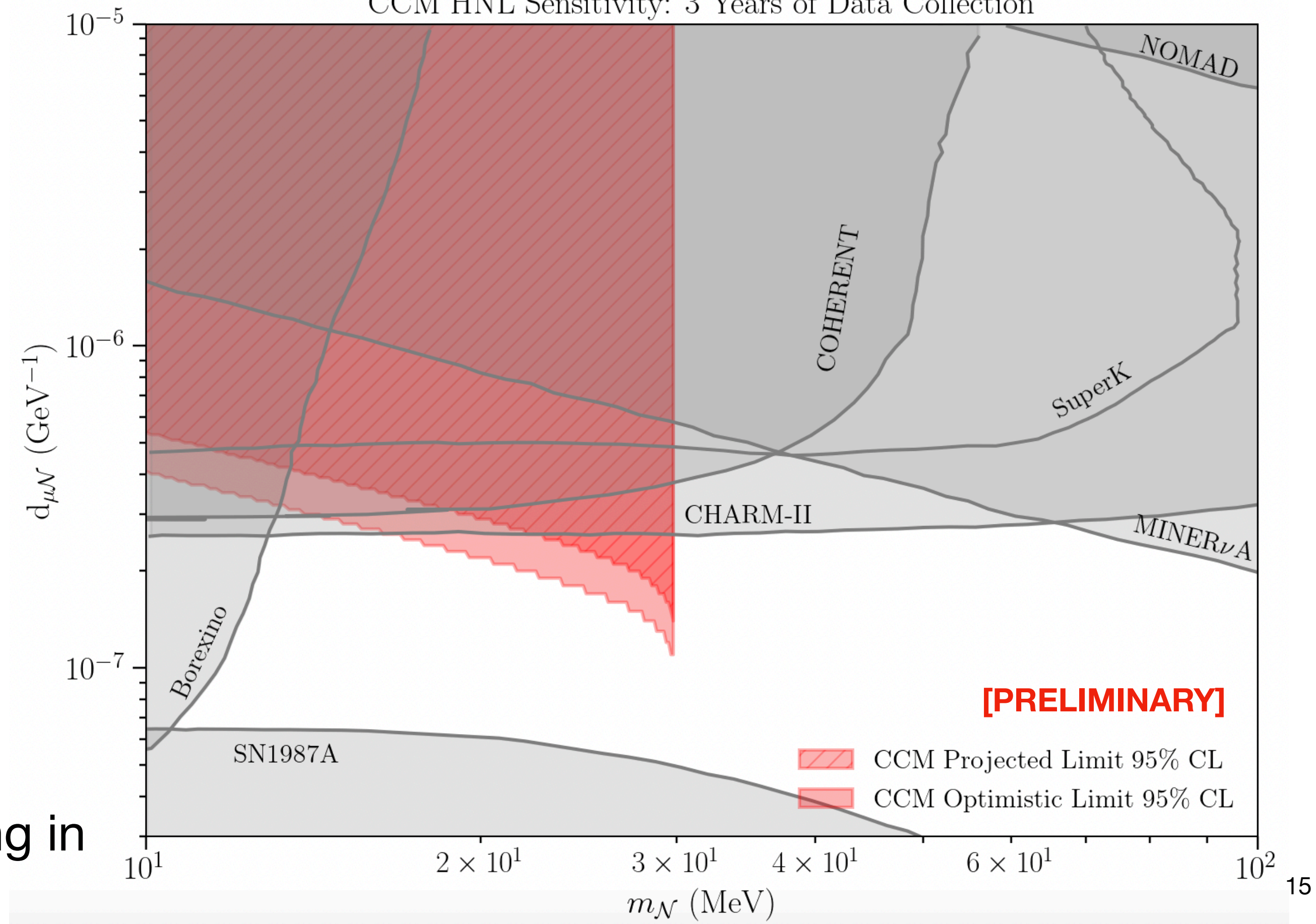
- Considering HNL production from neutrino upscattering in shielding and detector materials only
 - Potential to increase shielding if detector moved to 40m
- Projected limit for 100 background events/year, optimistic limit for 10 background events/year
- Other production channels to be considered:



- Neutrino-photon resonant HNL production
- π^0 Dalitz-like decay
- Can also search for nuclear recoil from upscattering in detector



CCM HNL Sensitivity: 3 Years of Data Collection

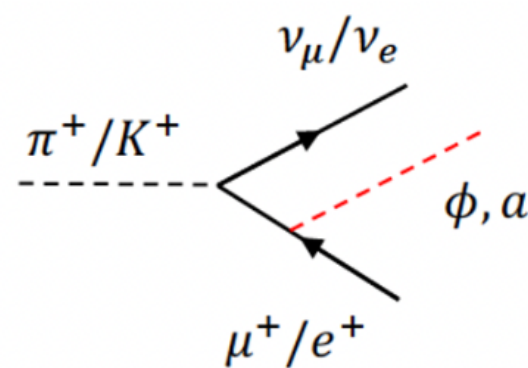


Dark Sector Coupling to Meson Decay

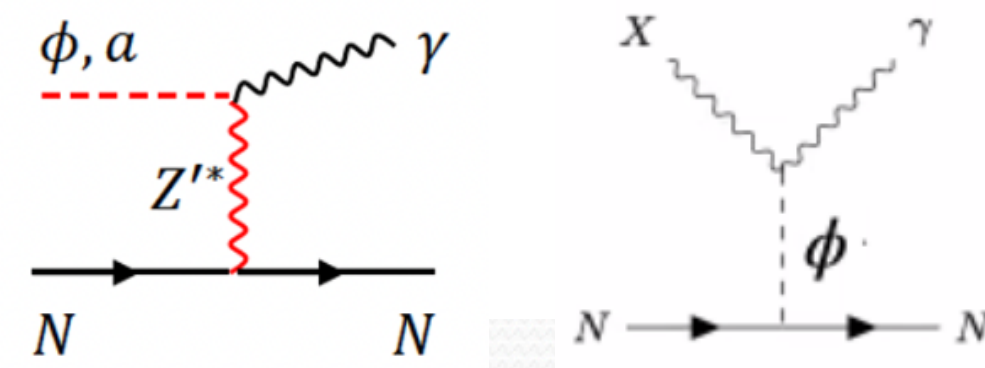
<https://arxiv.org/abs/2110.11944>

- Probe proposed explanation of MiniBooNE Low Energy Excess from 3 body meson decay producing scalar (or pseudo-scalar) particles that interact in the detector

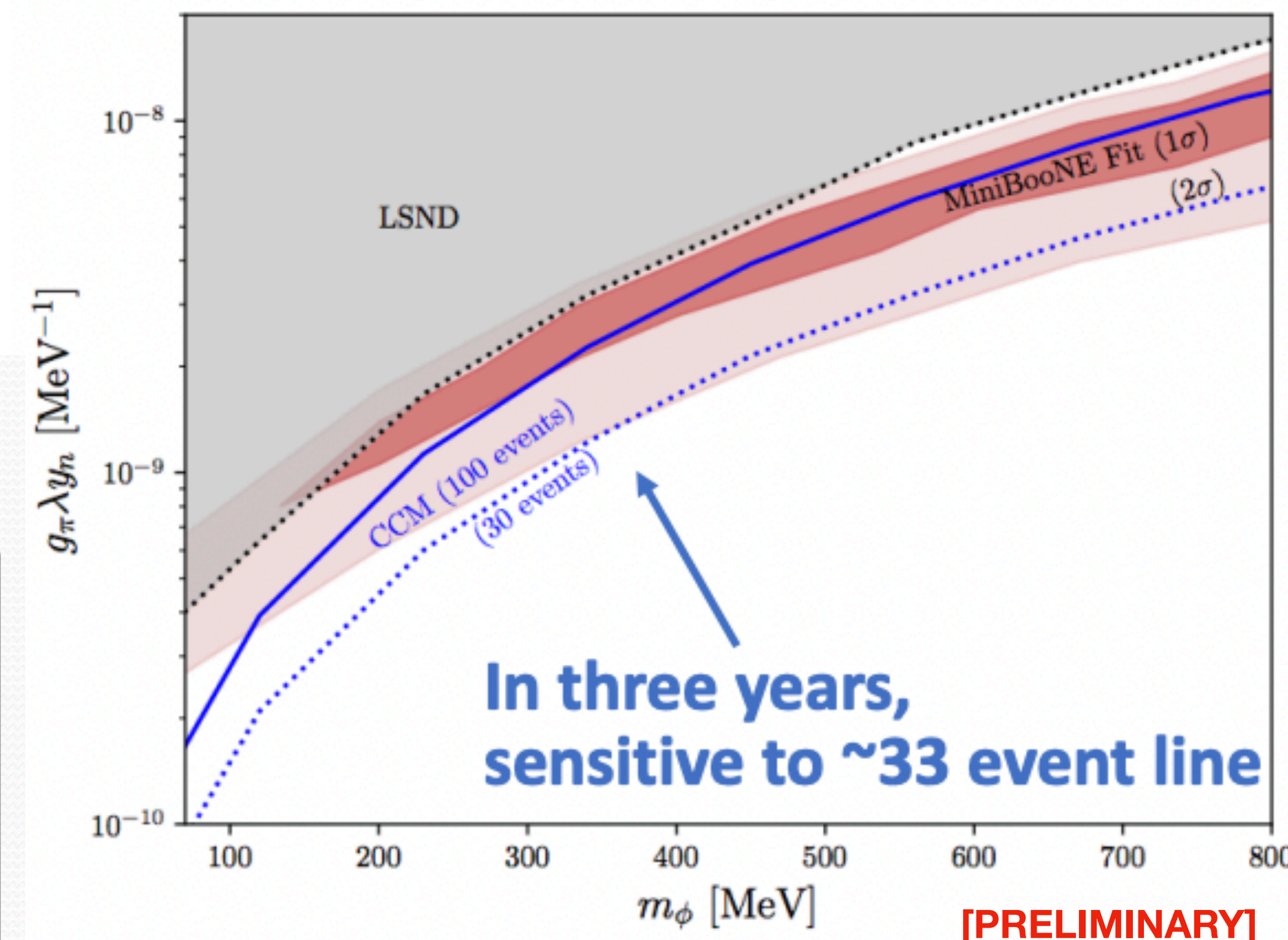
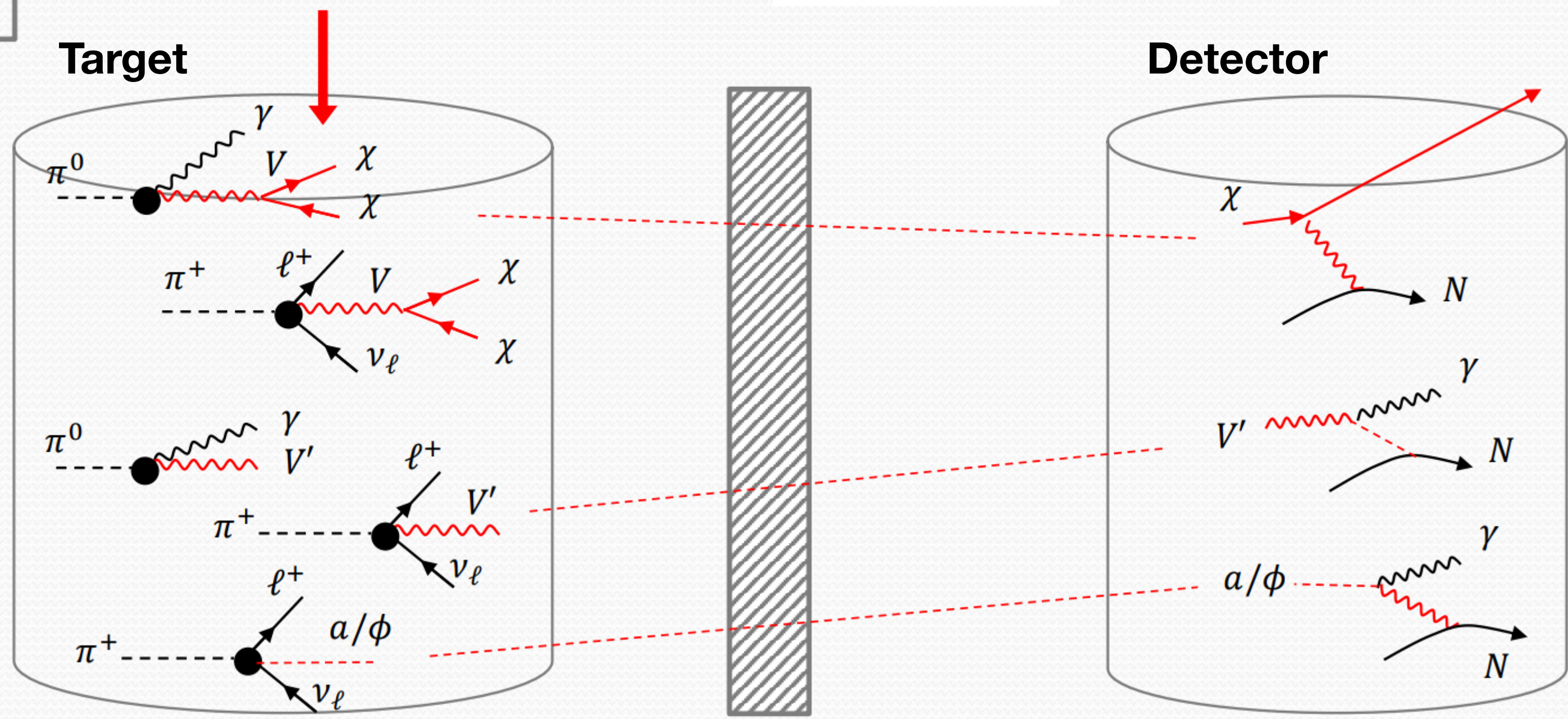
Production



Detection



CCM



[PRELIMINARY]

New Results Out!

First Leptophobic Dark Matter Search from the Coherent CAPTAIN-Mills Liquid Argon Detector (10.1103/PhysRevLett.129.021801)

First dark matter search results from Coherent CAPTAIN-Mills (10.1103/PhysRevD.106.012001)

Up next:

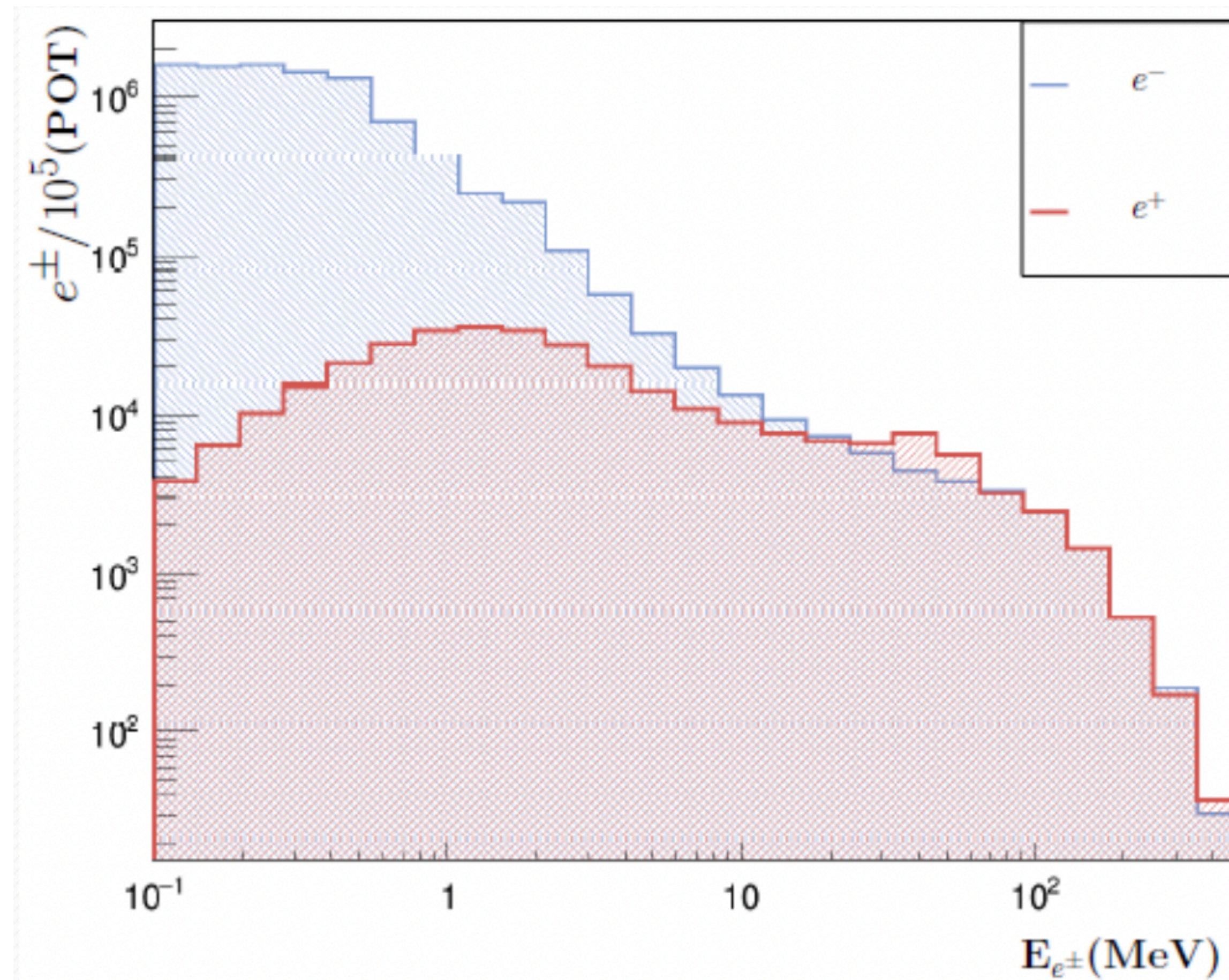
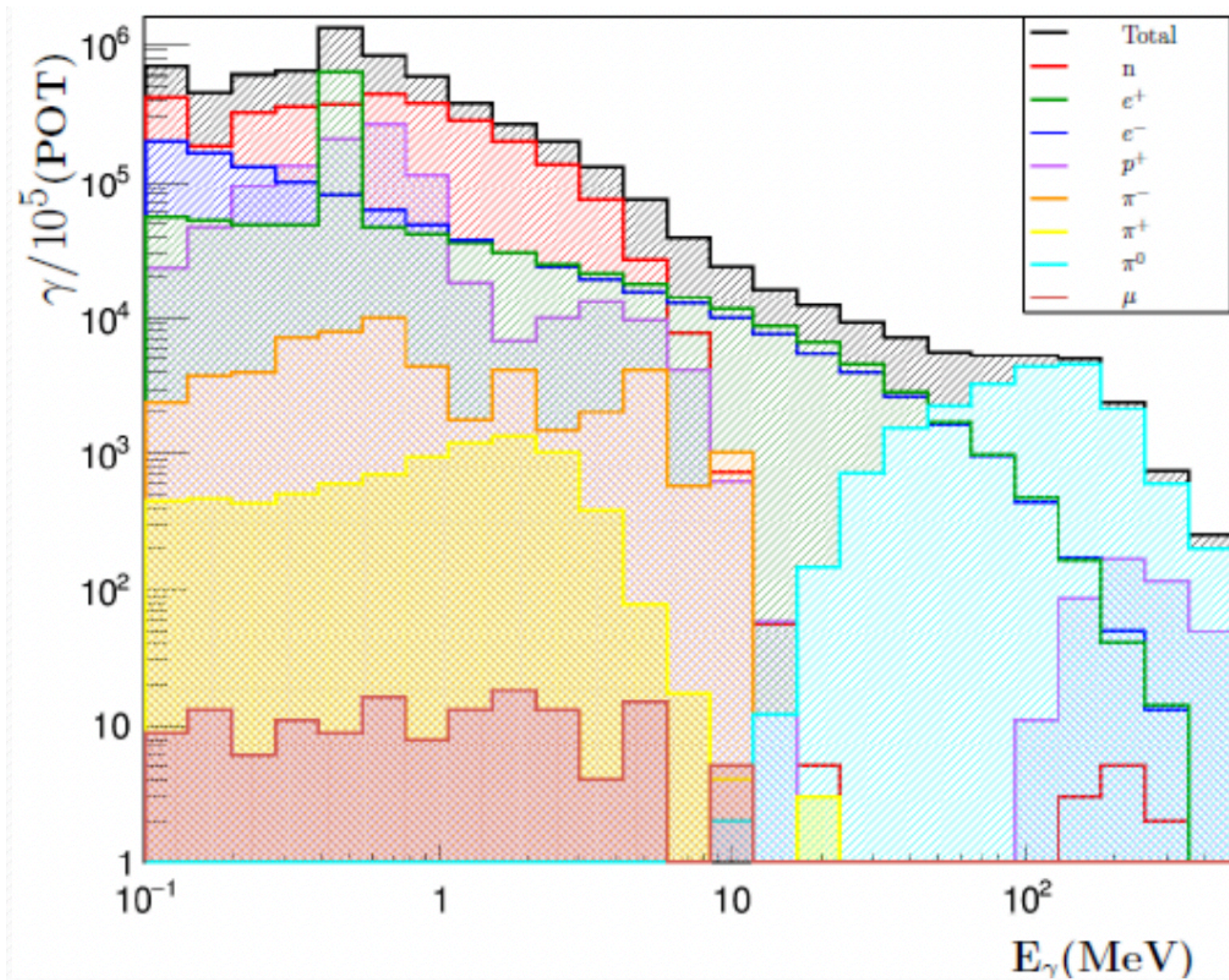
- CCM200 is starting 3 year data collection run
- Wide capabilities to test many models, results within a few years
- Interested in probing short baseline anomalies through dark sector coupling models

Collaboration

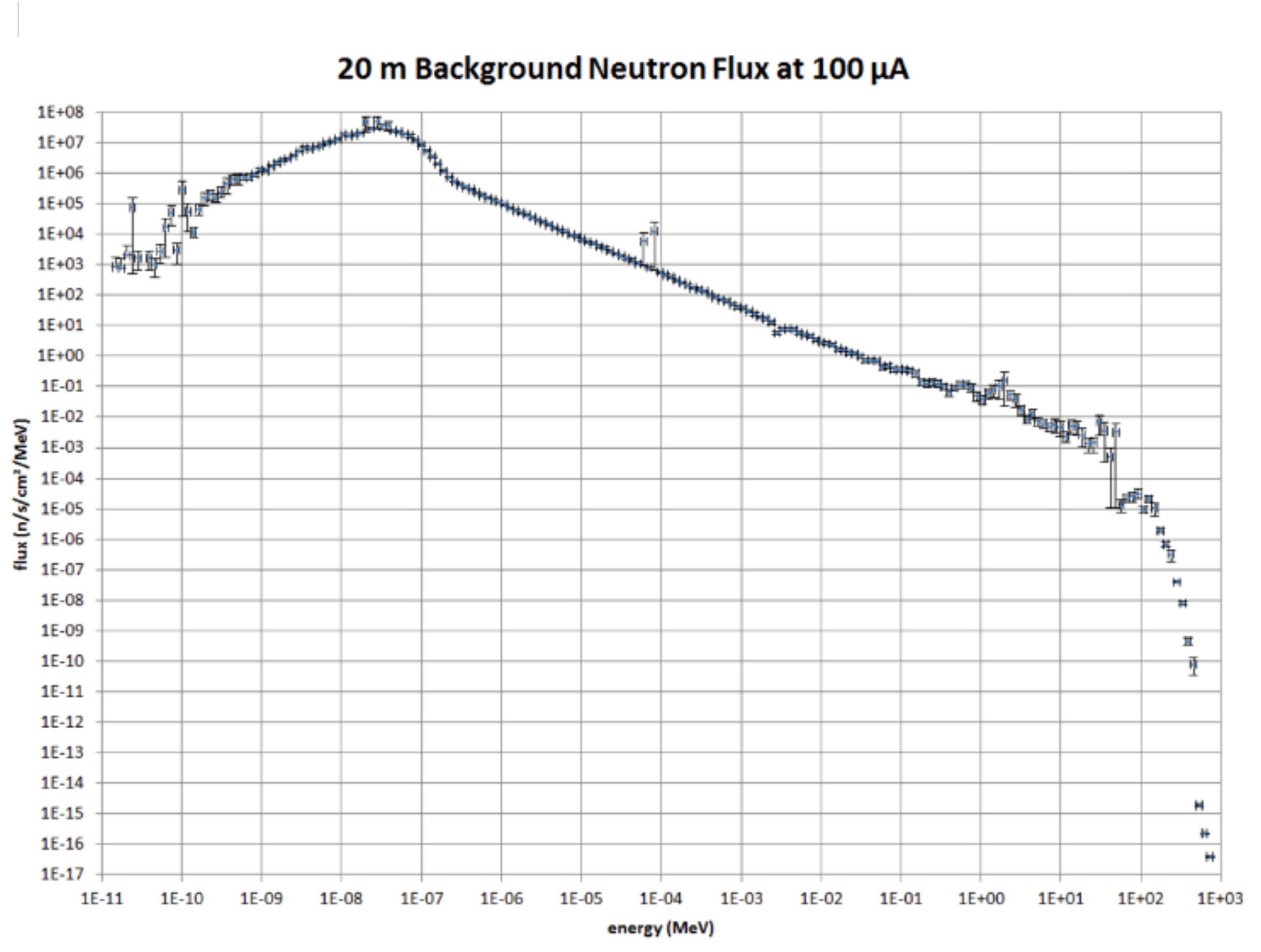
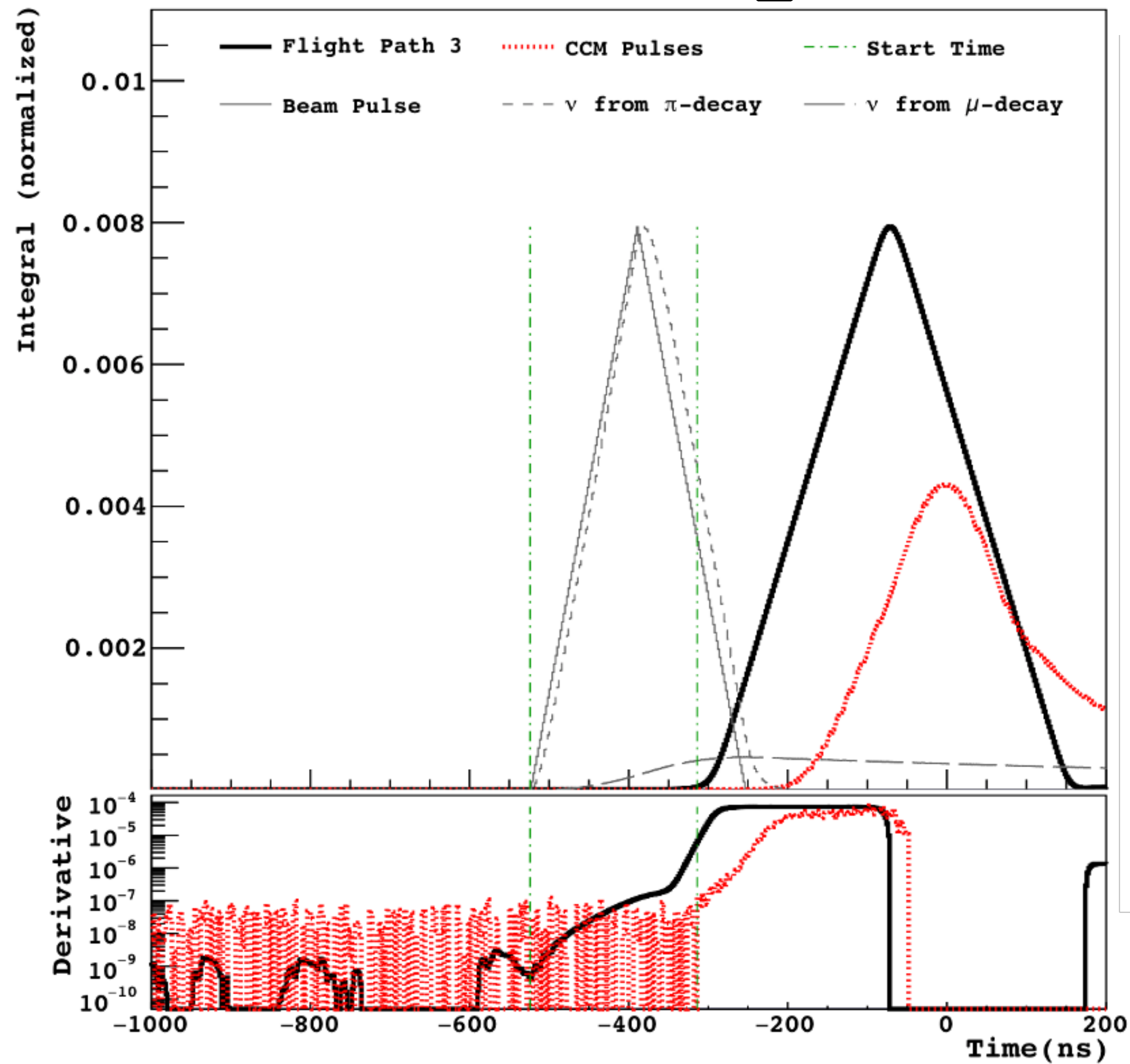


Backup slides

γ/e Flux



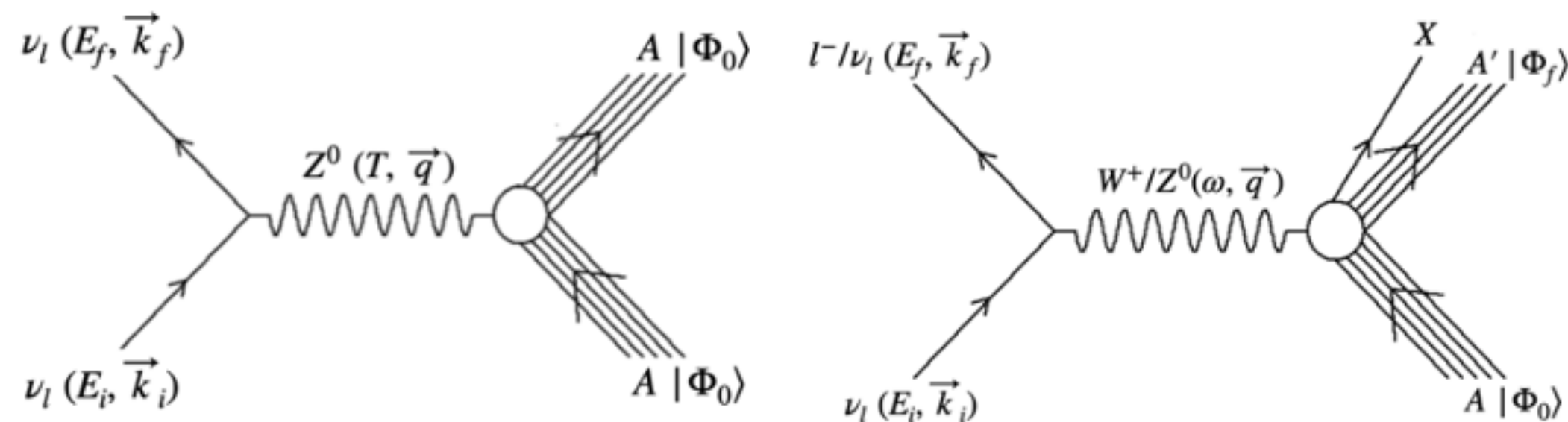
Neutron Background



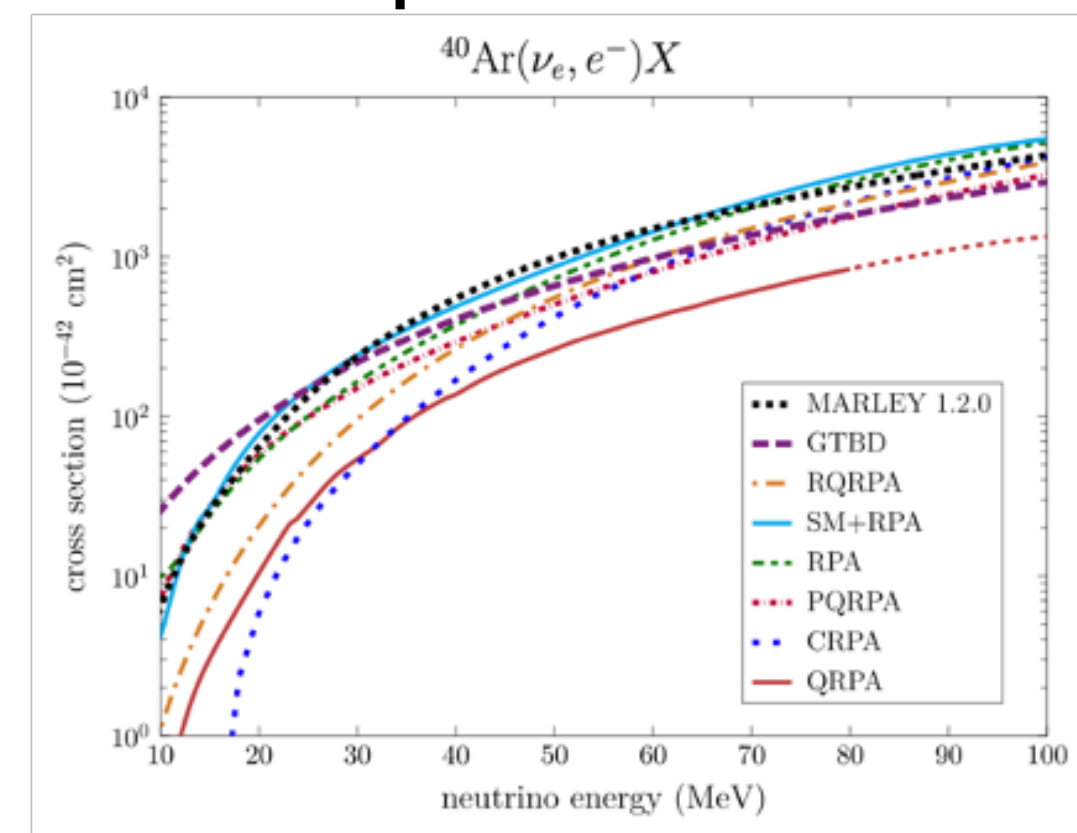
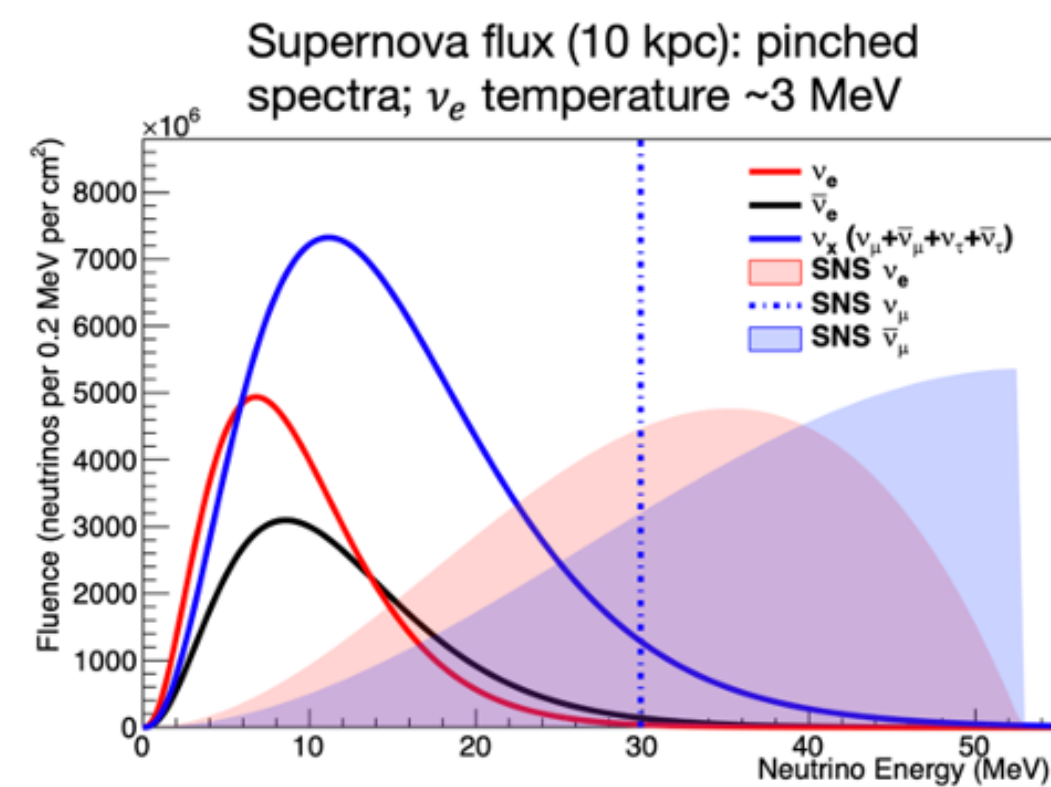
CEvNS, SN, Gallium anomalies

Need to first observe CEvNS before embarking on sterile neutrino search

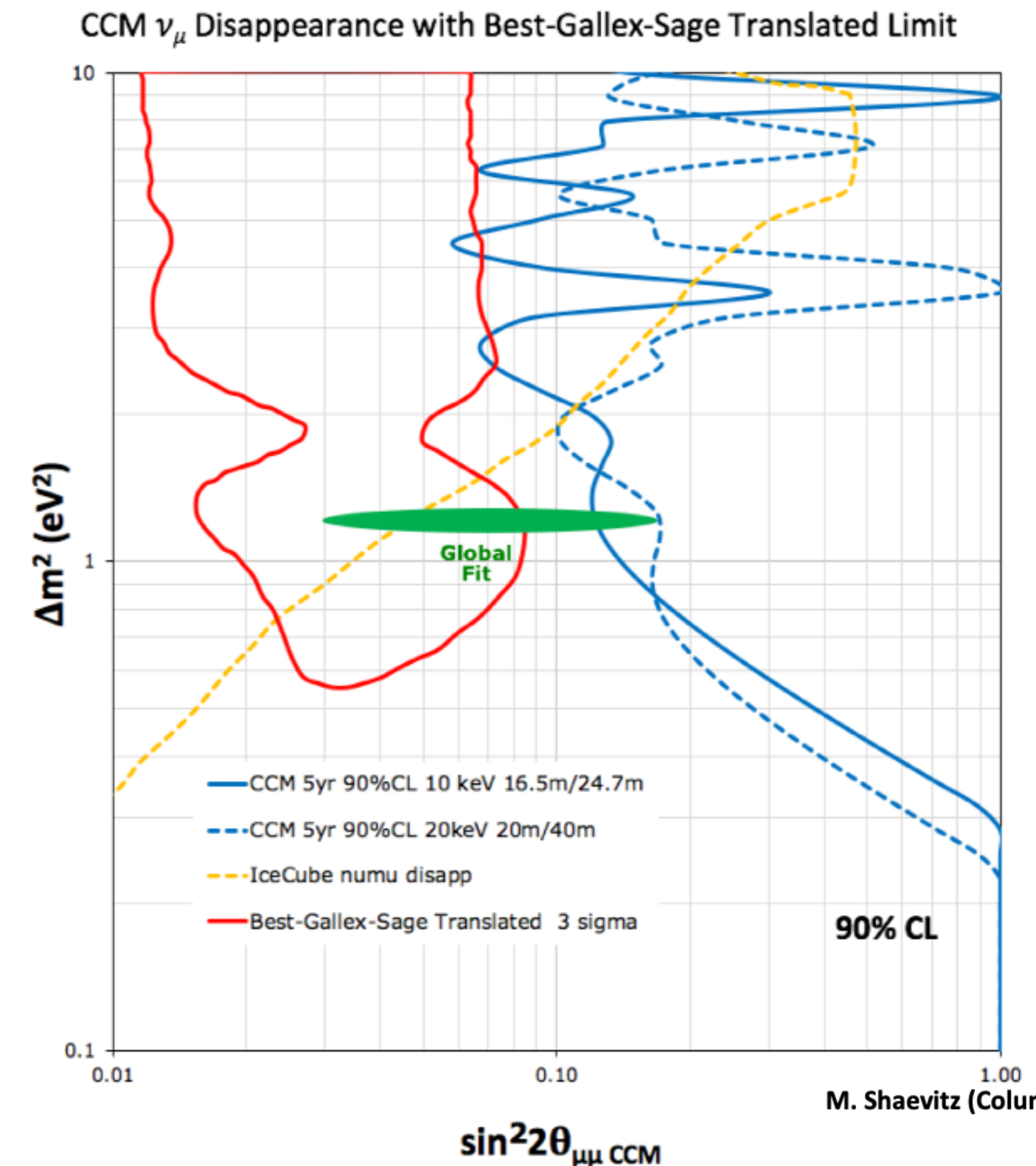
Limited data on Argon CEvNS and CC/NC cross sections



~25% spread on CC models



DUNE SN physics requires CC/NC on Argon measurements



M. Shaevitz (Columbia)