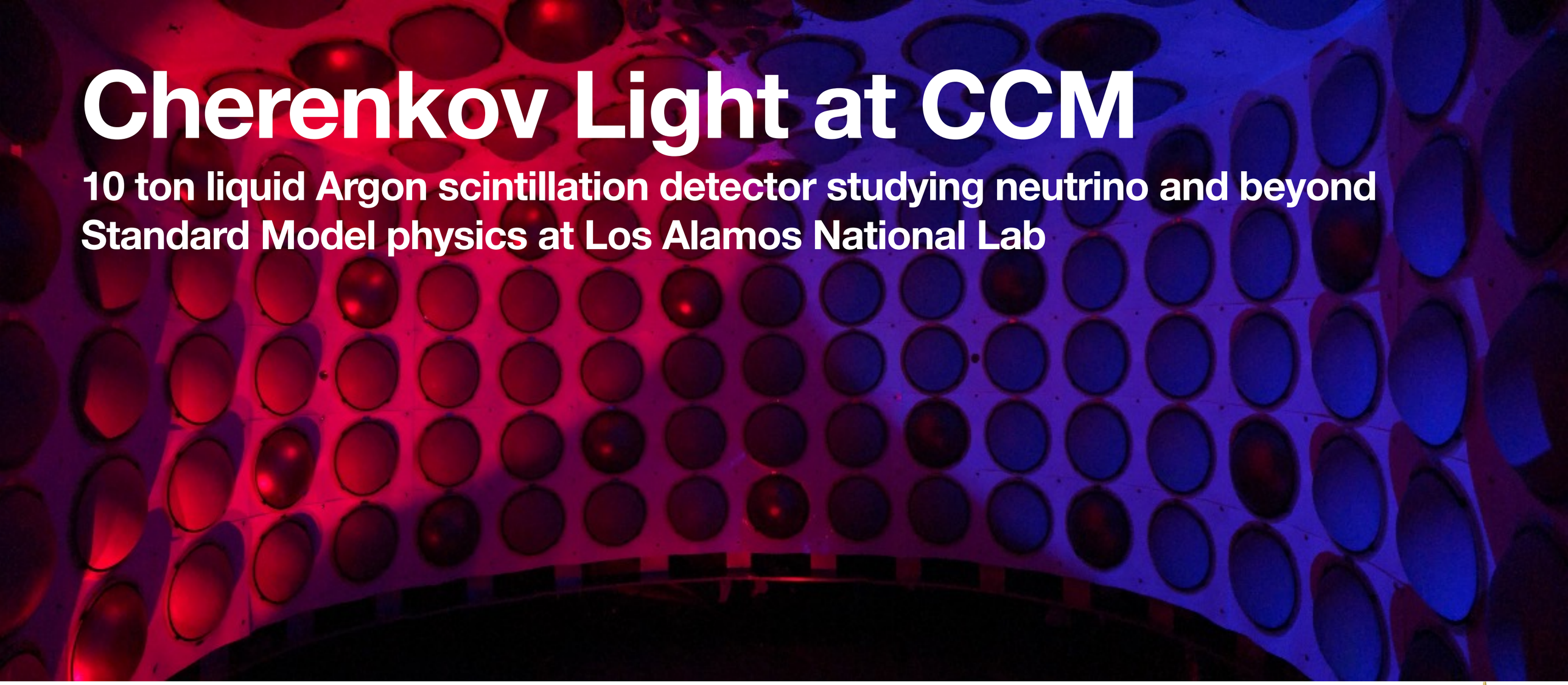

# Cherenkov Light at CCM

## 10 ton liquid Argon scintillation detector studying neutrino and beyond Standard Model physics at Los Alamos National Lab

**LIght Detection In Noble Elements Conference**
**22 September 2023**

**Darcy Newmark** ***on behalf of the CCM Collaboration***

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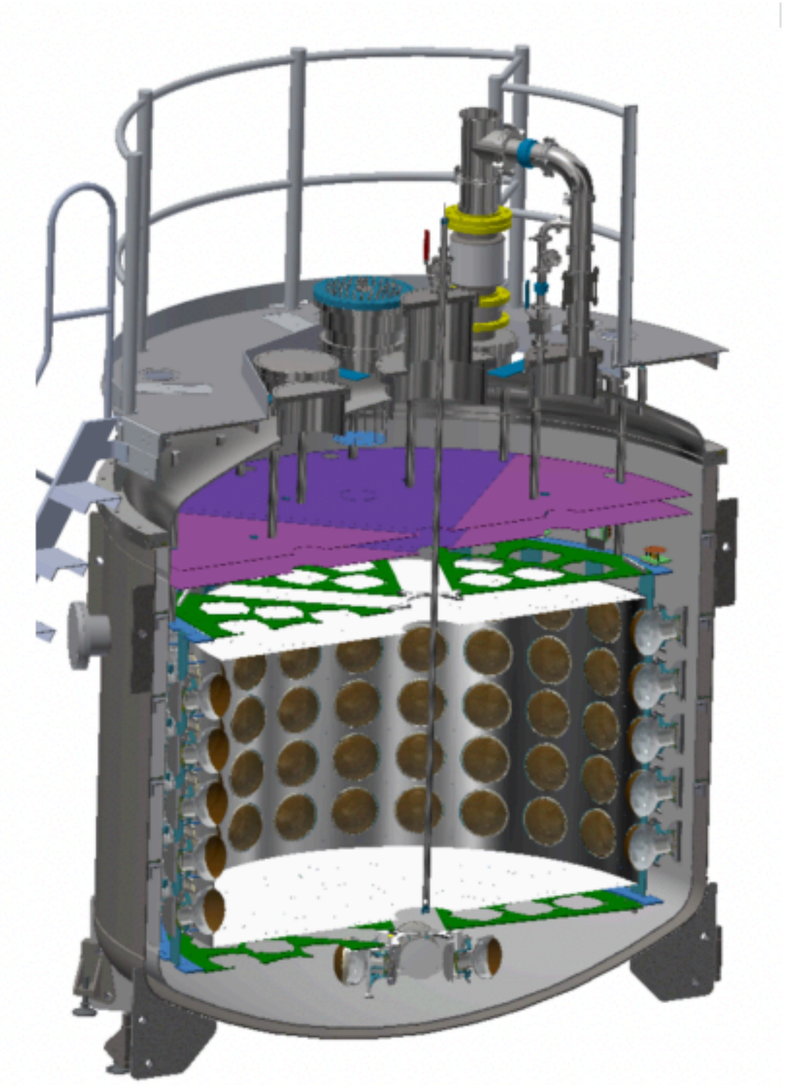
# Outline

1. The Detector
2. Cherenkov Light Identification
3. Physics Program



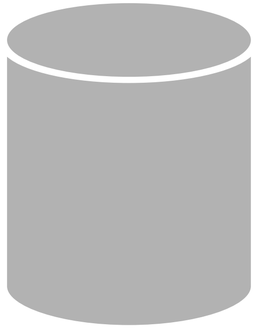
# The Detector

# Timeline

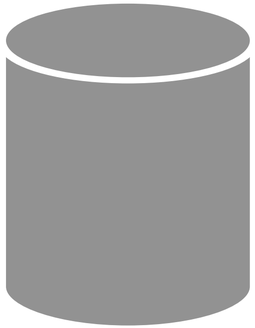
**Starting year 2 of data collection imminently!**



**CCM120 Engineering Run**
- Prototype detector
- Testing 120 PMTs for SBND
- Produced physics results



**CCM200 Engineering Run**
- Upgraded detector to 200 8” PMTs
- Doubled veto PMT coverage
- Increased forward shielding

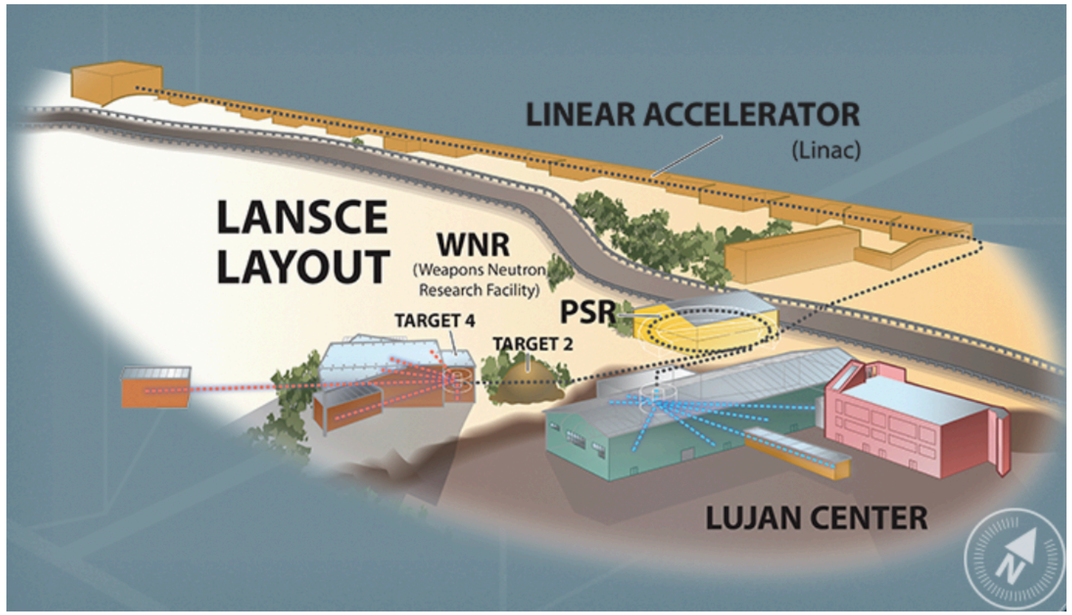


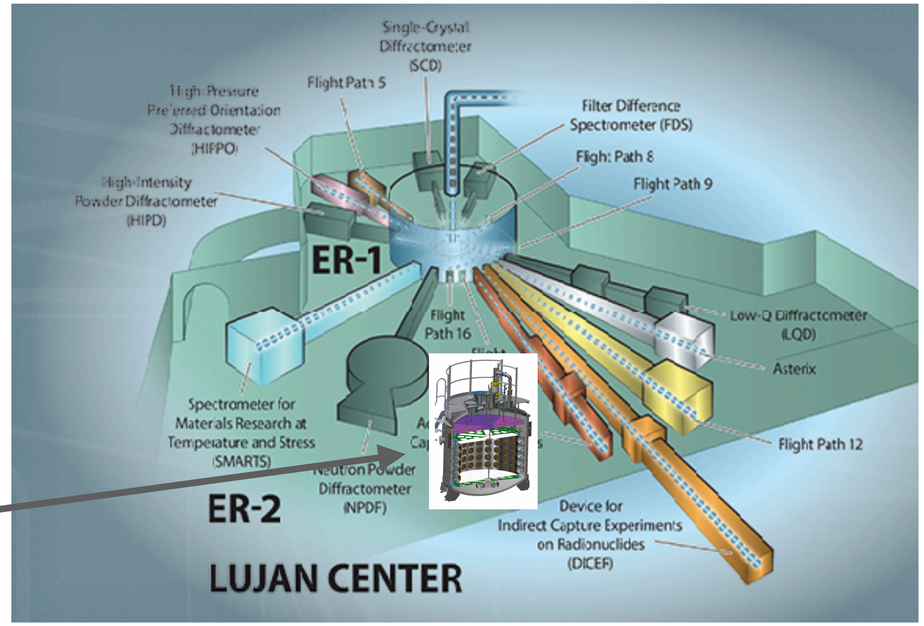
**CCM200 Physics Run (2022-2025)**
- Improved DAQ to handle more calibration streams
- Installed additional top-shielding
- Higher energy calibration sources

# Experimental Facilities

## Los Alamos Neutron Science Center (LANSCE)

- **800 MeV proton beam** bunched in the proton storage ring (PSR) and pulsed at 20 Hz with 100 $\mu$Amp current and 290 nsec beam spill
- Protons incident on tungsten target in Lujan Center, pion decay at rest creates **prompt** flux of 30 MeV $\nu_\mu$, e$^-$, $\gamma$, $\pi^0$
- Host to above ground detectors —> use beam timing for background rejection

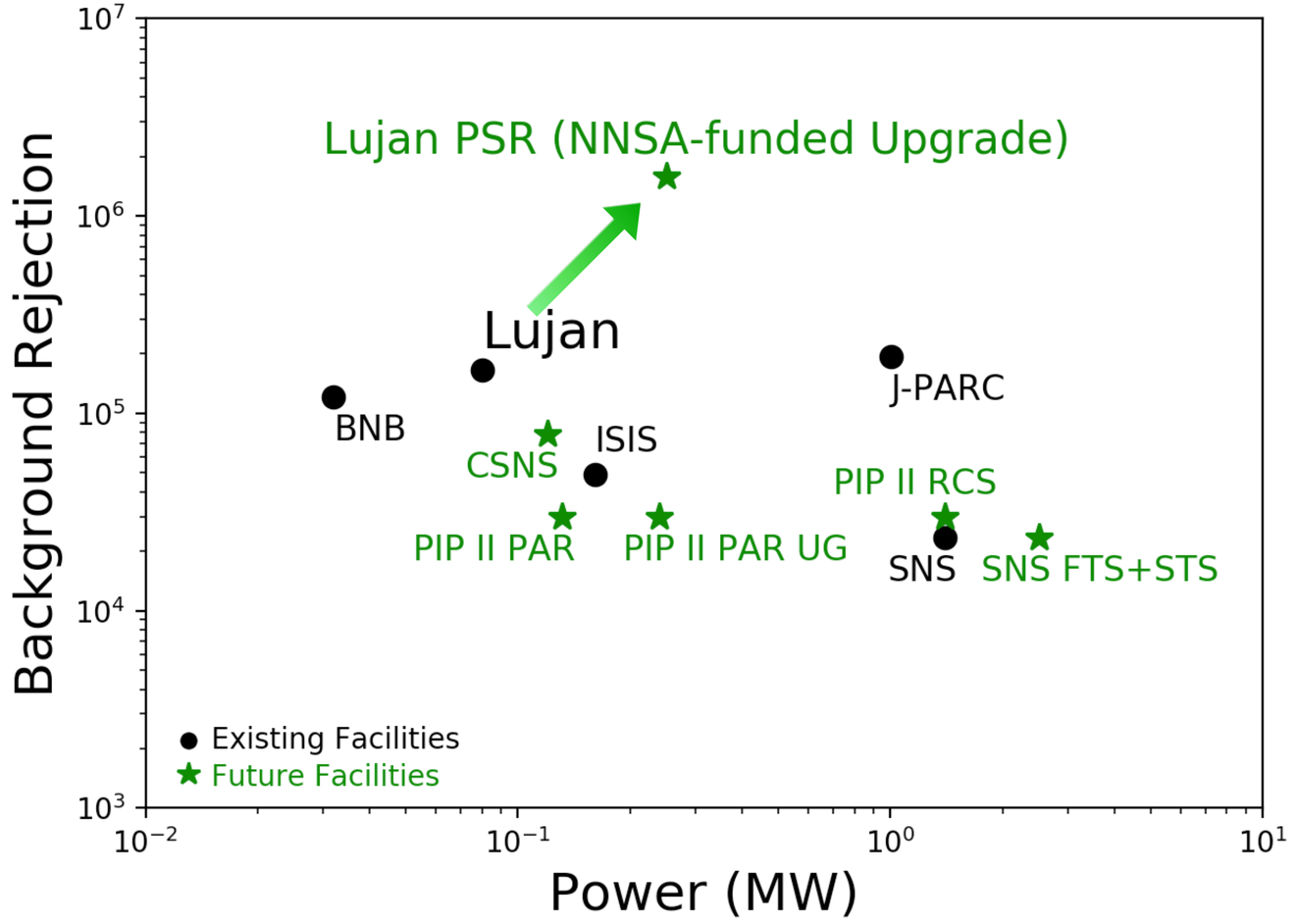



CCM Detector

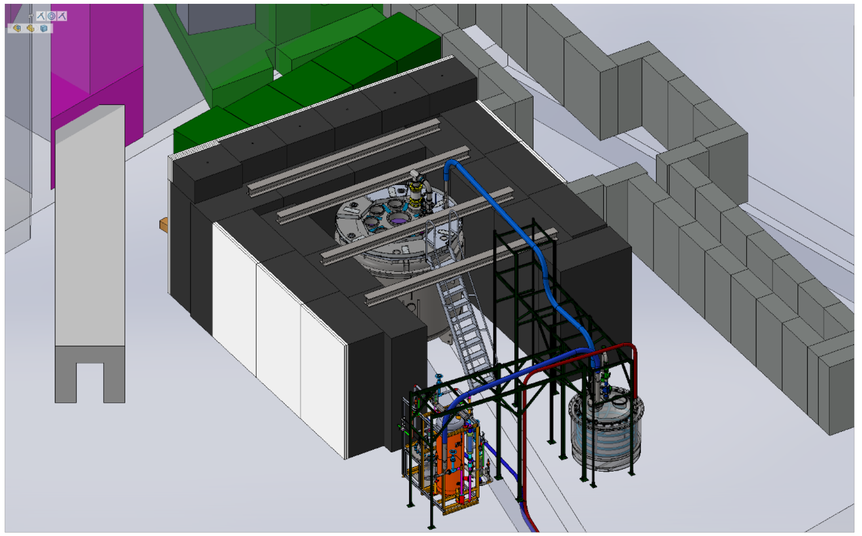
# Lujan Facility Capabilities

- Lujan Facility upgrades focusing on **background rejection**, lower power can be compensated with larger detector
- 10 year upgrade to increase background rejection by an order of magnitude through shortening beam spill window from 290 ns to 30 ns



# CCM at Lujan

- Detector positioned 90˚ off axis from the proton beam and 23m from tungsten target
- ~2.5m diameter and ~2m tall cylindrical cryostat contains 200 8” photomultiplier tubes (PMT) for **5 ton fiducial LAr volume, 50% photocoverage**
- **5 ton optically isolated active veto region** surrounding fiducial volume with 40 1” veto PMTs
- The Lujan facility will receive $2.25 \cdot 10^{22}$ POT in the ongoing 3 year run cycle, producing flux of $5.28 \cdot 10^{5}\ \nu$ /cm$^2$/s



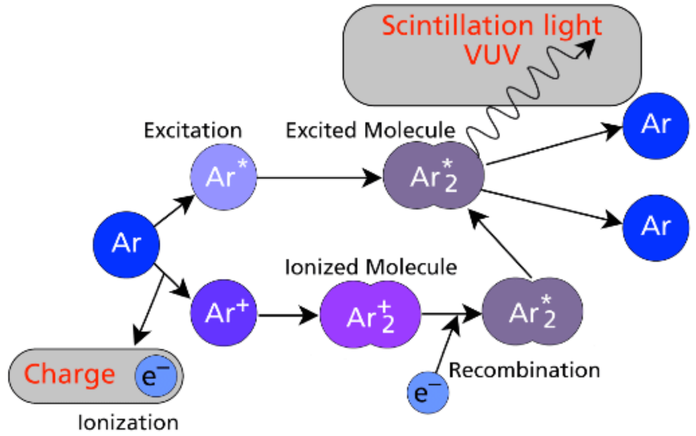

# CCM200 Detector

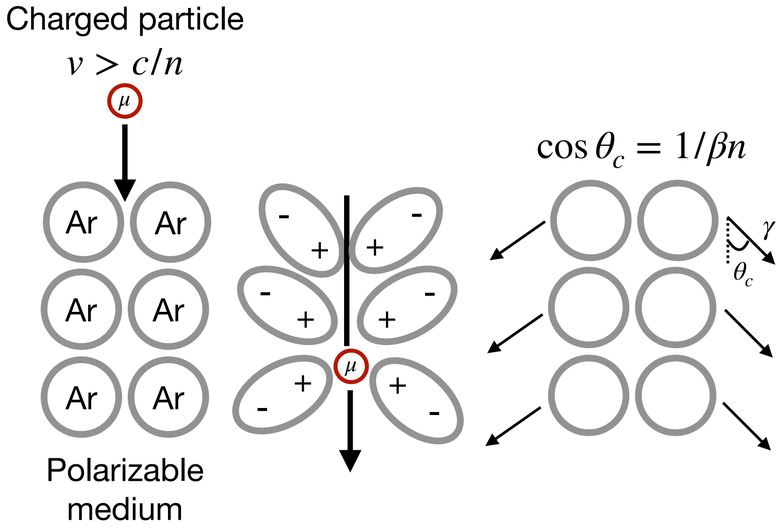
- 80% of PMTs coated in 1,1,4,4-Tetraphenyl-1,3-butadiene (TPB) to **wavelength shift LAr scintillation light**
- TPB foils on walls of the detector **(efforts led by Andrzej Szelc's group)**
- Electronics have **2ns** sampling time
- Energy detection range from ~100 keV to ~200 MeV

# Cherenkov Light Identification

# Light in Liquid Argon

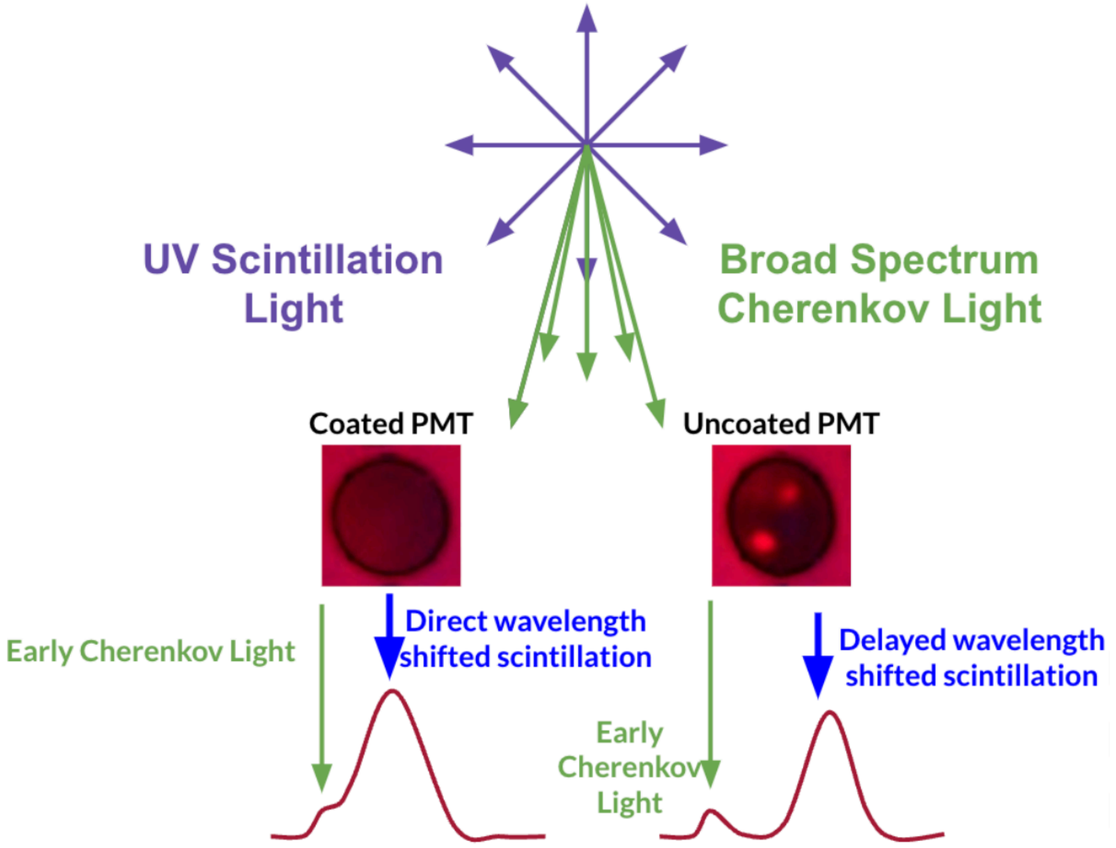
| Quality | Scintillation Light | Cherenkov Light |
|---|---|---|
| Intensity (for a MIP) | ~40,000 photons/MeV | ~ 700 photons/MeV (wavelength > 100nm) |
| Direction | Isotropic | Directional |
| Timing | Fast component (nsec) and slow component (usec) measured by DEAP collaboration | Prompt (psec start) |
| Photon Wavelength | Spectrum peaks at 128 nm | $dN/d\lambda \propto \lambda^{-2}$ |



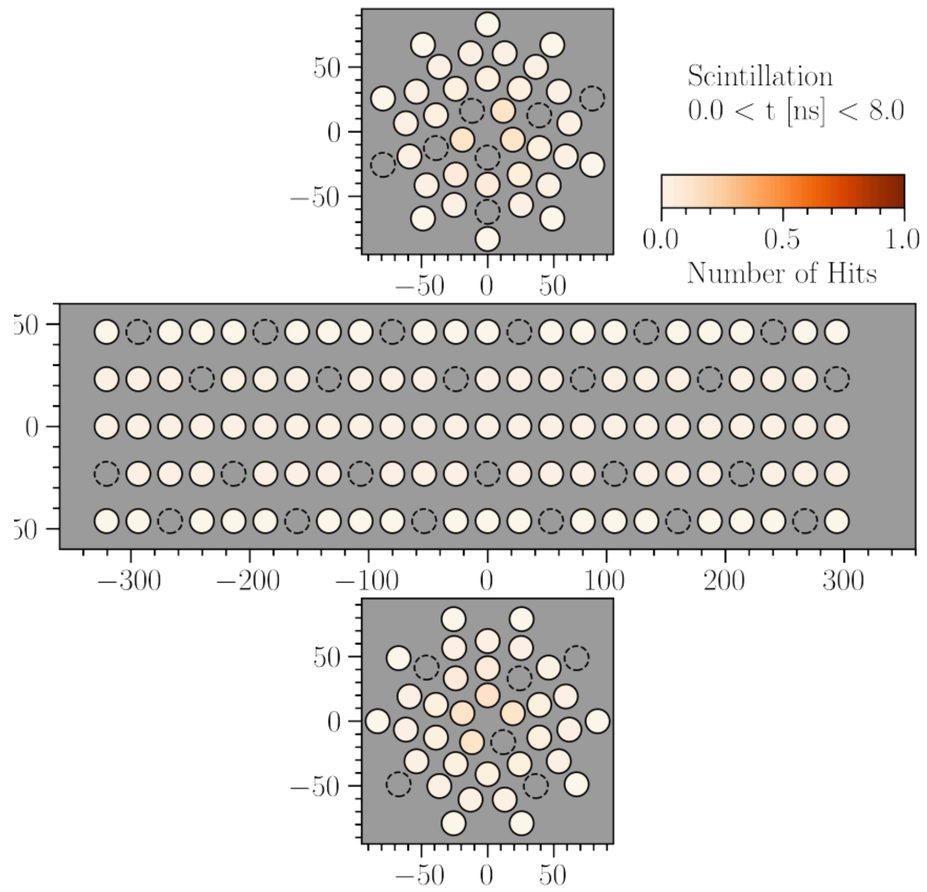
# Light Collection in CCM

- UV scintillation light can be **directly absorbed by coated PMTs** or absorbed and remitted by TPB on the walls of the detector (delayed scintillation can be absorbed by uncoated PMTs)
- Broad spectrum Cherenkov light can be **directly absorbed by uncoated PMTs** (visible component) or coated PMTs (UV component)
- 2nsec timing resolution and combination of coated and uncoated PMTs gives us a handle on **timing** and **wavelength** of light



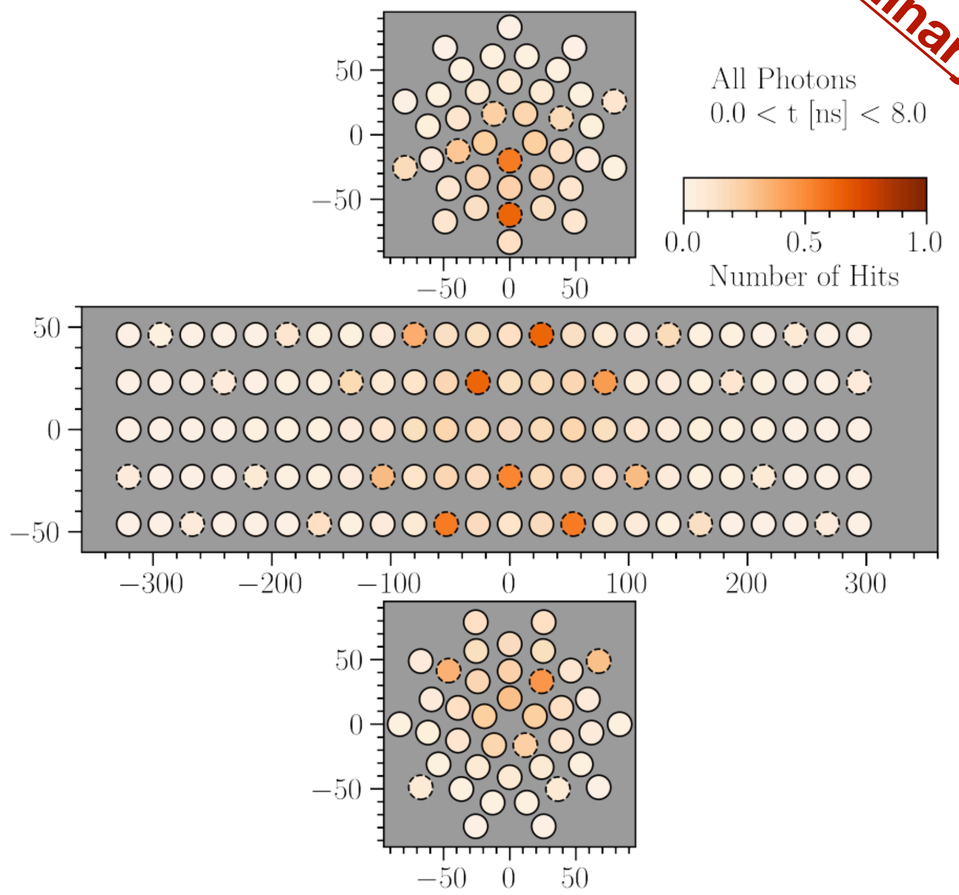
# Simulation of 5 MeV Electron in CCM

**Scintillation Photons Only**
**(No Cherenkov Light)**



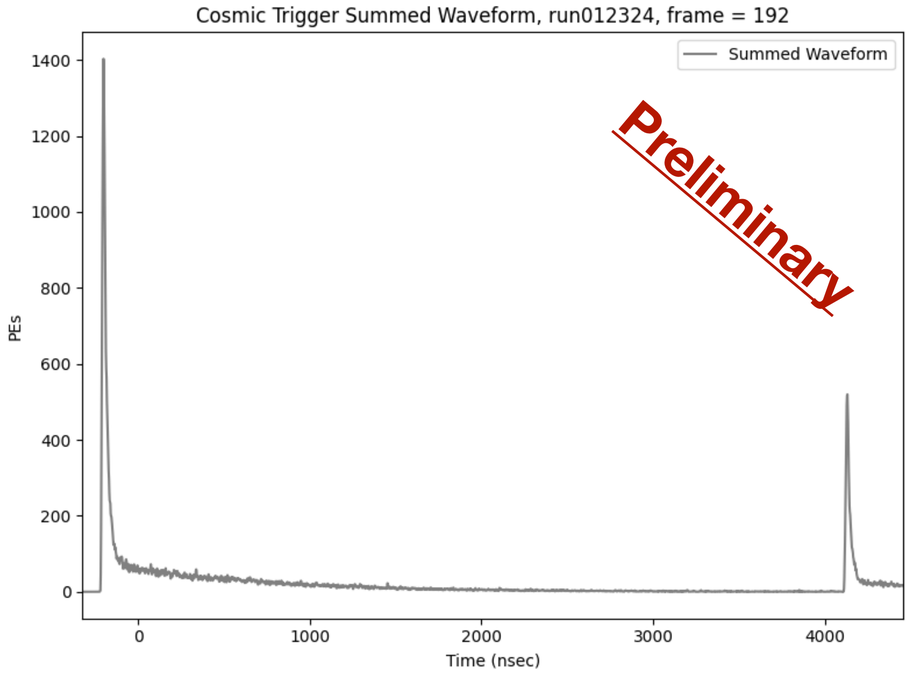

**All Photons**
**(With Cherenkov Light)**

Preliminary



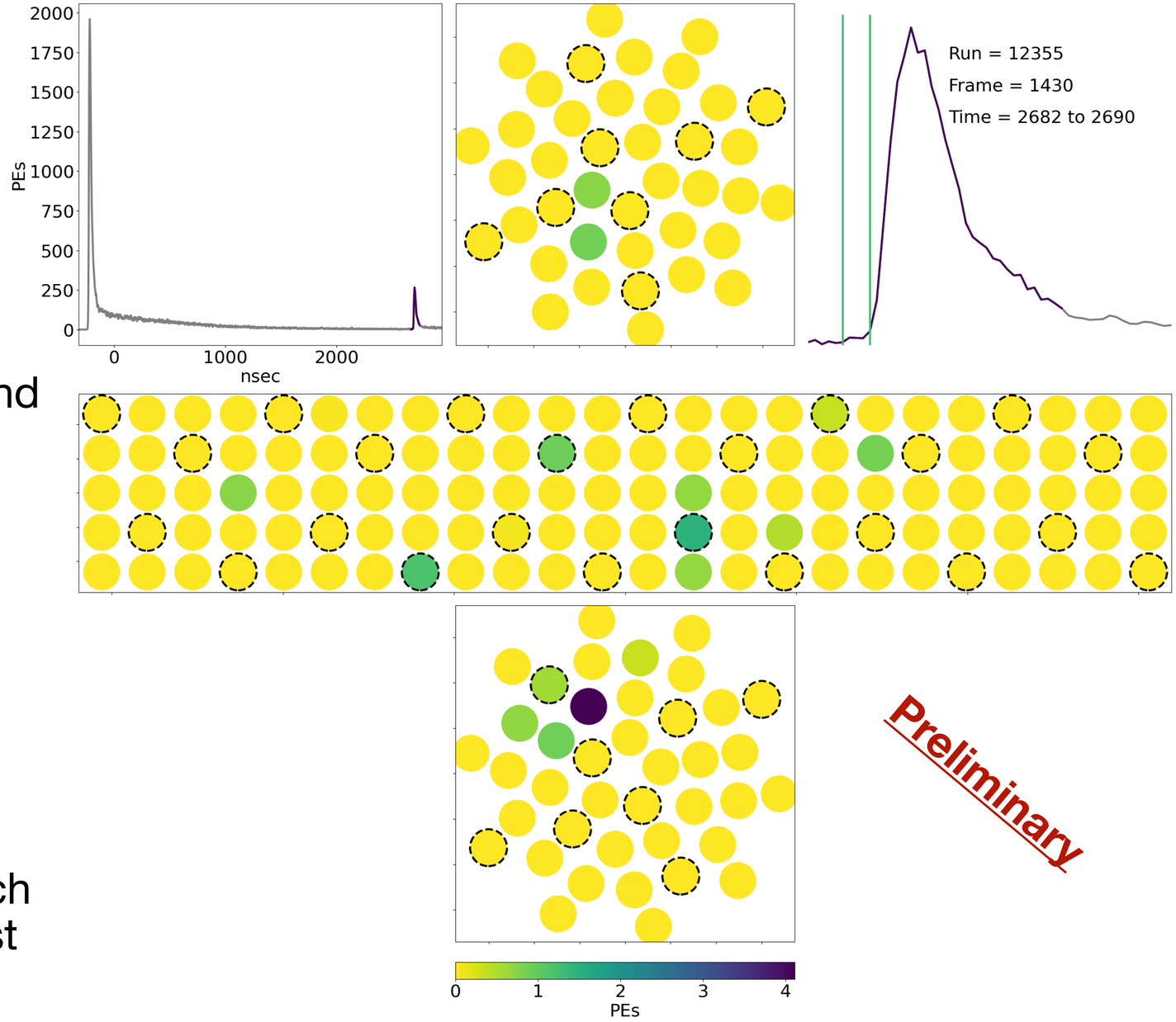
# Data Driven Search for Cherenkov Light

- Using cosmic muons to develop search for Cherenkov light
- Trigger on CosmicWatch Detectors (S. Axani et. al.) placed on top of our detector
- Using Michel electron spectrum for both sample containing Cherenkov light and energy calibration up to ~50 MeV
- In progress, planning on using machine learning to identify Cherenkov light on an event by event basis



# Cosmic Event

- Upper left plot: summed waveform for this data event
  - Cosmic muon depositing energy around around 0 nsec (relative to trigger)
  - Michel electron peak around 2.6 $\mu$sec
- Upper right plot: zoomed-in view of Michel electron peak
  - Green lines indicate 8nsec region of interest at the start of the event
- Event display shows summed charge in each PMT during our Cherenkov region of interest

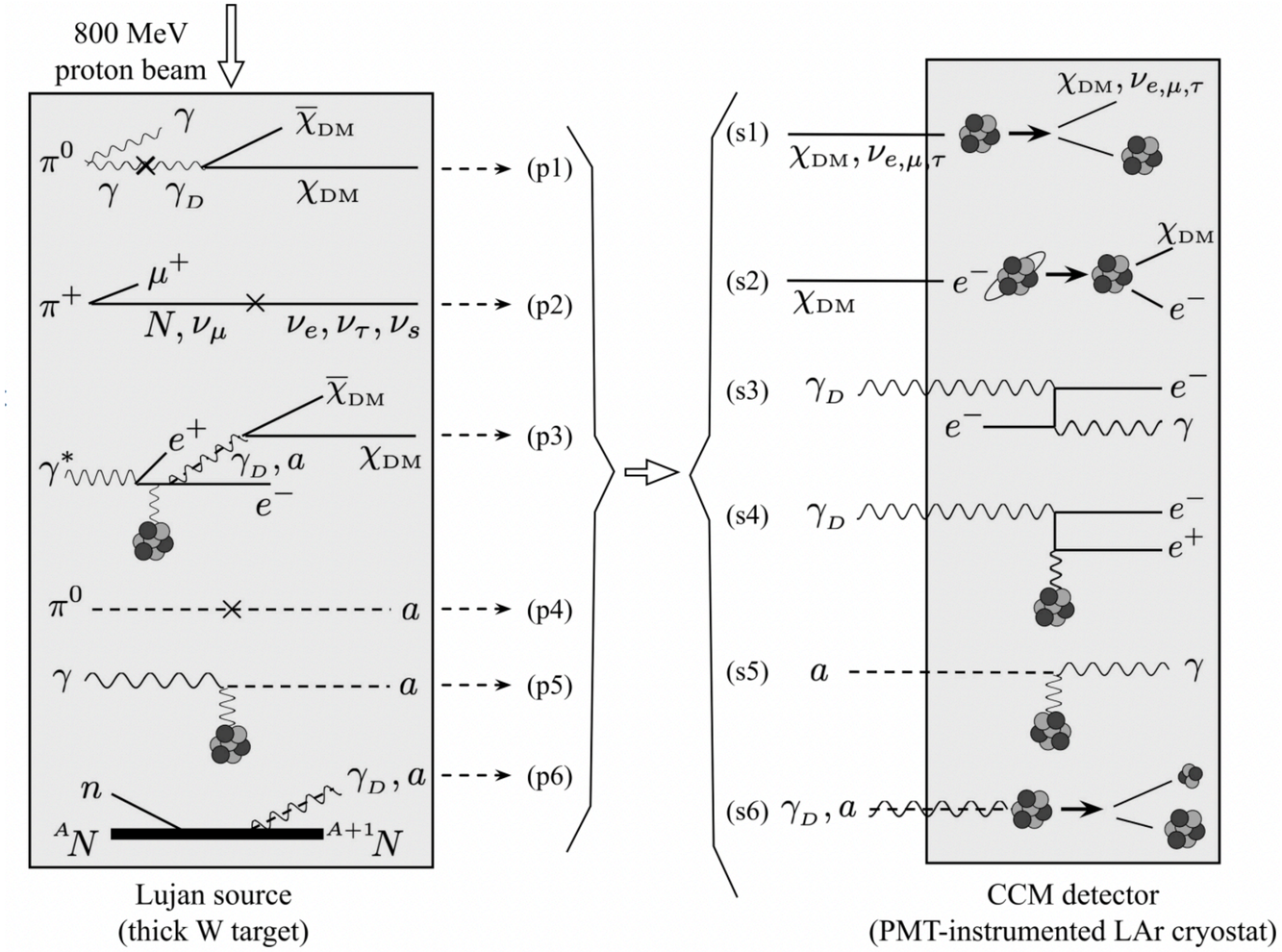


# Physics Program

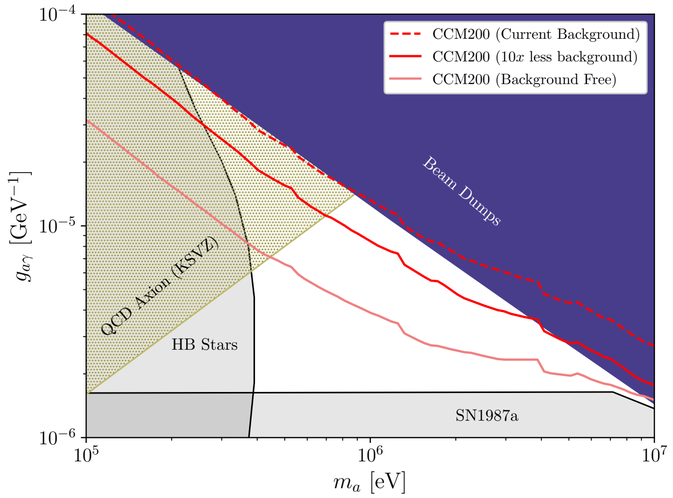
# BSM Physics Searches

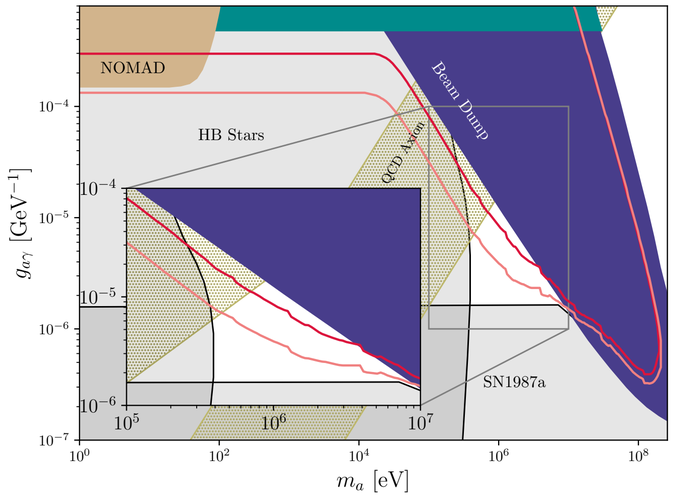
- Identifying Cherenkov light on an event by event basis in LAr is worthwhile on it's own right — and **allows for tagging of backgrounds in our other physics searches**

- Our physics programs covers searching for leptophobic dark matter, axion like particles, and meson portal solutions to the MiniBooNE anomaly [PhysRevD.107.095036, PhysRevD.106.012001, PhysRevLett.129.021801, 2309.02599]

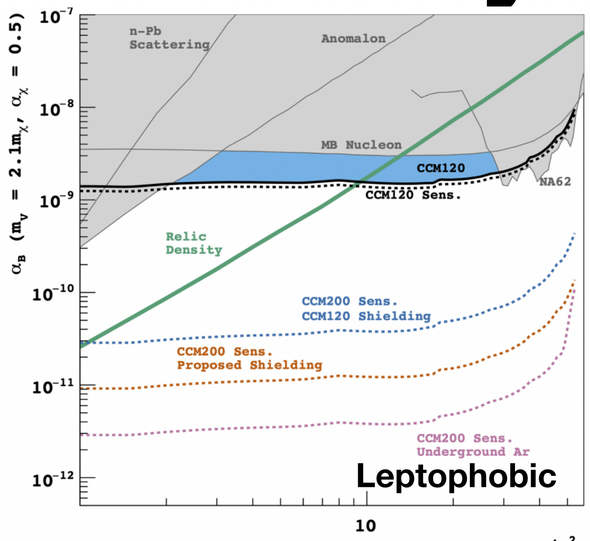


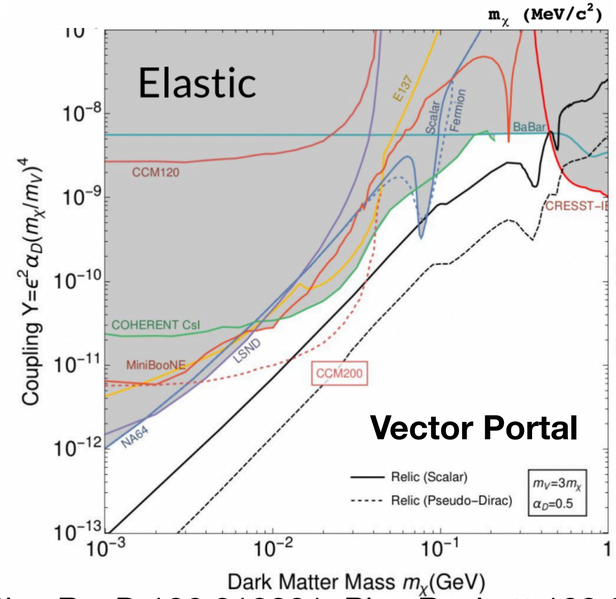
# Physics Results Summary Plots



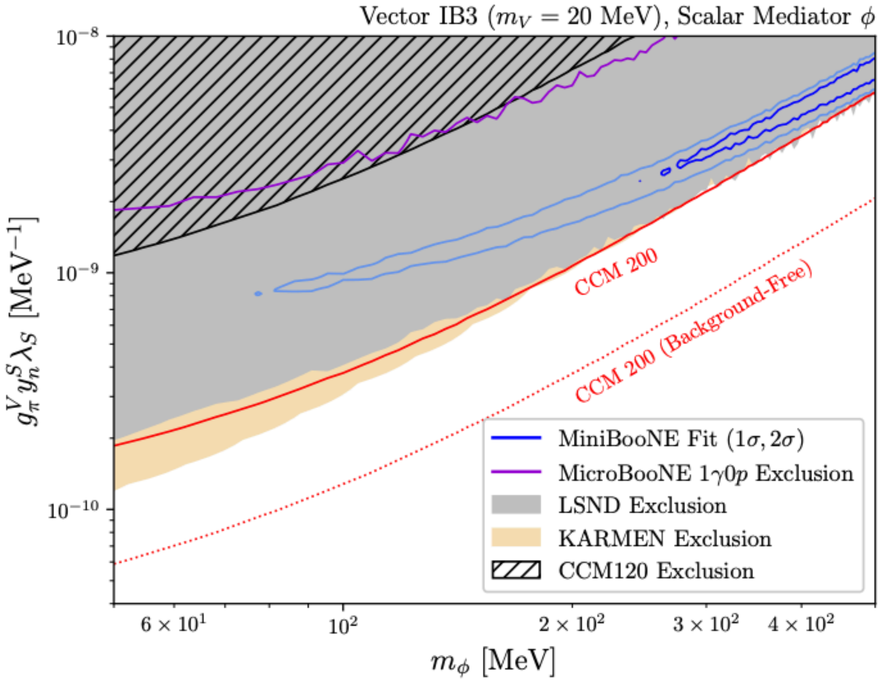




PhysRevD.107.095036




PhysRevD.106.012001, PhysRevLett.129.021801




arXiv:2309.02599

# Summary

- CCM200 is entering the second of a three year run cycle and will probe many new models/parameter space in the dark sector
- Cherenkov light separation in CCM is possible because of precision timing and combination of coated and uncoated PMTs
- Event by event identification of Cherenkov light program is ongoing and looking promising, keep an eye out on the arXiv

# Thank you for listening!