

From Tons to Kilotons: Hybrid Scintillation–Cherenkov Detection in Liquid Argon

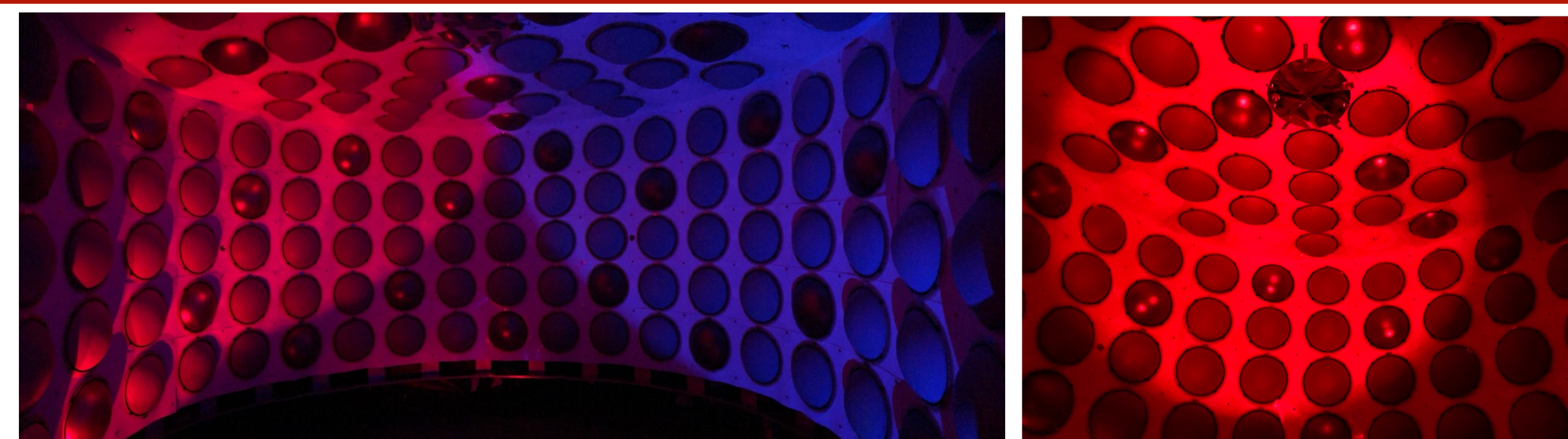
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Hybrid Optical Detectors

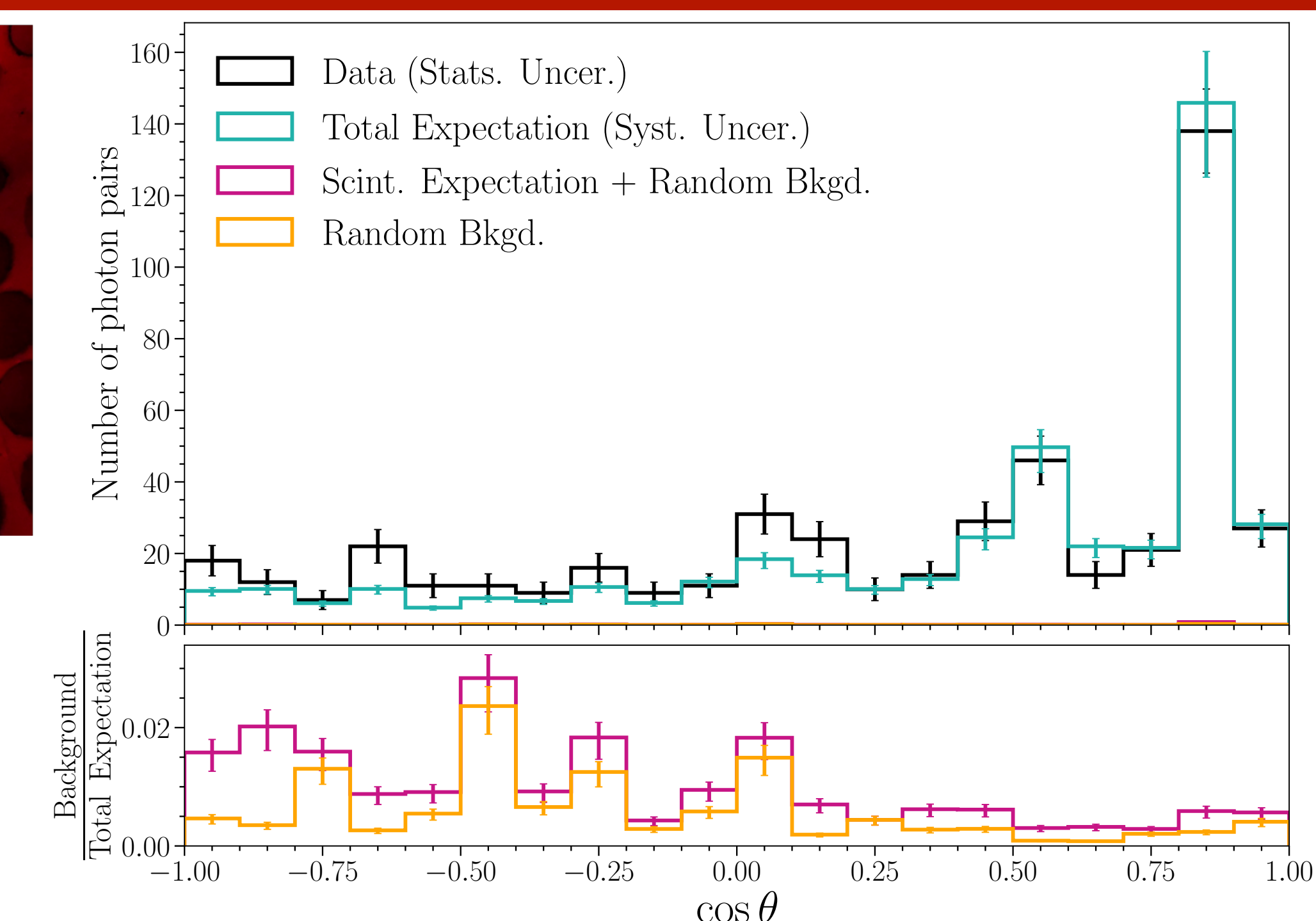
Quality	Scintillation Light	Cherenkov Light
Intensity	~10 ⁴ photons/MeV	~ 10 ² photons/MeV
Direction	Isotropic	Directional
Timing	Typically ~nsec	Prompt (psec start)
Photon Wavelength	Narrow emission spectrum	$dN/d\lambda \propto \lambda^{-2}$

- Hybrid optical detectors resolve **both** scintillation and Cherenkov light
 - Combining both signals allows for excellent energy resolution and direction reconstruction / particle identification
 - Typically separate two signals based on timing and wavelength
- Major goal of 2021 Snowmass instrumentation frontier working group to advance weakly interacting physics searches

The Coherent CAPTAIN-Mills Detector

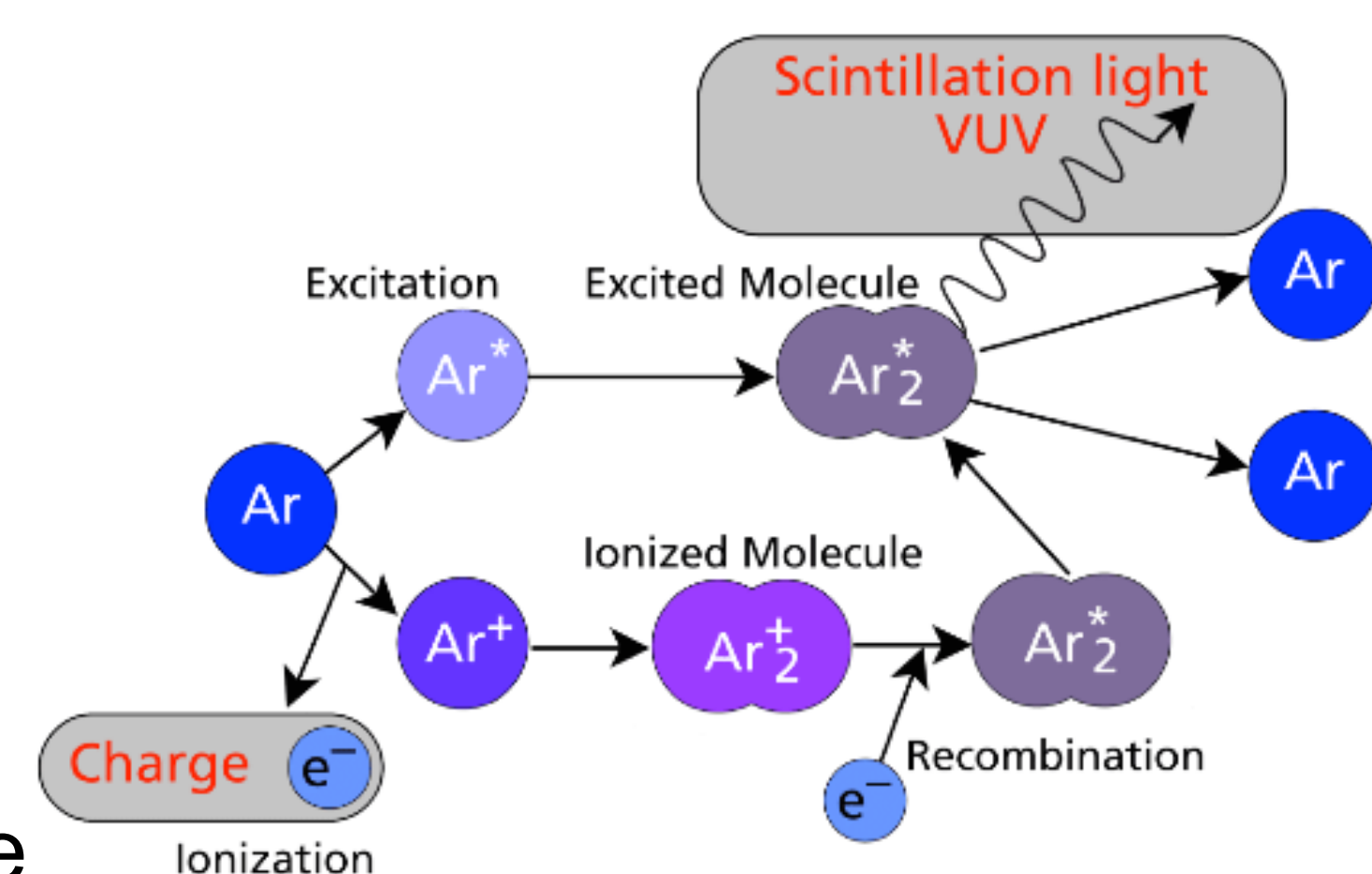


- 10-ton liquid argon detector at LANL (pion decay-at-rest source)
- Instrumented with 200 8" PMTs for light collection
 - Wavelength shifter TPB applied to 160 PMTs (leaving 40 uncoated PMTs)
 - 2 ns timing resolution
- Combination of fast timing and uncoated PMTs enables enhanced sensitivity to visible Cherenkov radiation in the very prompt time region of events
- Demonstrated first event-by-event separation of Cherenkov light from sub-MeV electrons using sodium calibration source** (*PhysRevLett.135.171804, PhysRevD.112.072010*)



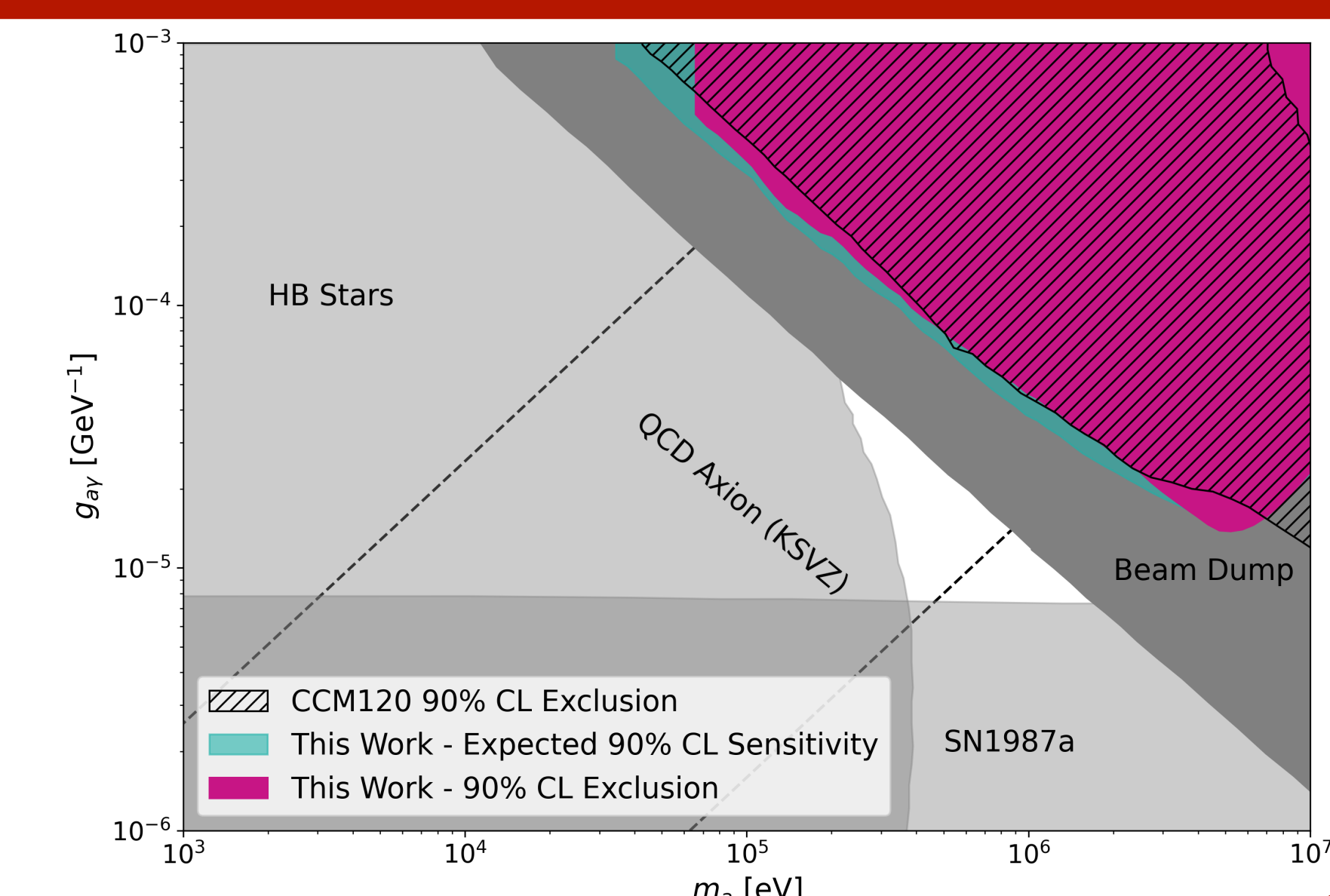
Liquid Argon for Hybrid Detection

- While many hybrid detectors use oil / water based liquid scintillators, **CCM uses liquid argon for light collection**
- Advantages of liquid argon:
 - Pure liquid argon does not absorb wavelengths greater than 113nm
 - Naturally slower scintillator than oil-based liquid scintillators
 - Cryogenic nature can suppress dark rate currents in photodetectors (e.g. SiPMs)



Axion-Like Particle Search

- Search for ALPs through photon-coupling channel
 - Production through Primakoff scattering in the target
 - Detection through inv. Primakoff scattering and diphoton decay in the CCM detector
- Leveraging Cherenkov radiation to better separate final state photon signatures from backgrounds
 - 6x improvement in background rejection** compared to previous iteration of the analysis not leveraging Cherenkov light
- Manuscript in preparation for publication



Future Ultra Large Liquid Argon Hybrid Detector

- Ongoing study of a 17-kton liquid argon hybrid scintillation and Cherenkov detector**
- 70% photocathode coverage
- Studying various wavelength shifter coating fractions to understand impact on Cherenkov light separation

