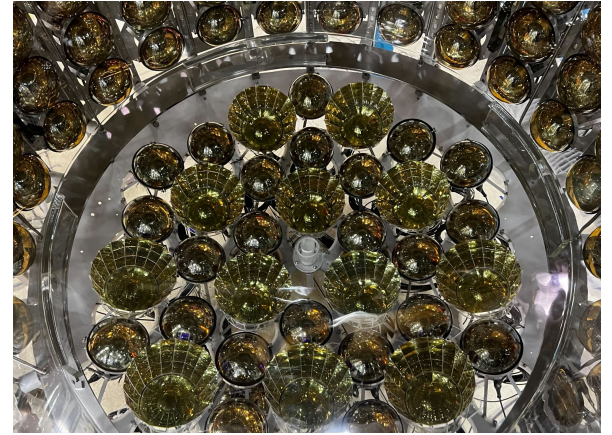
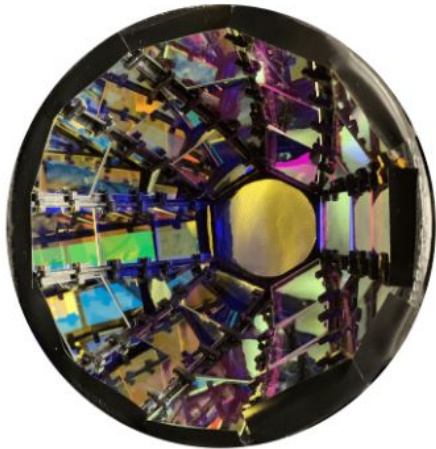


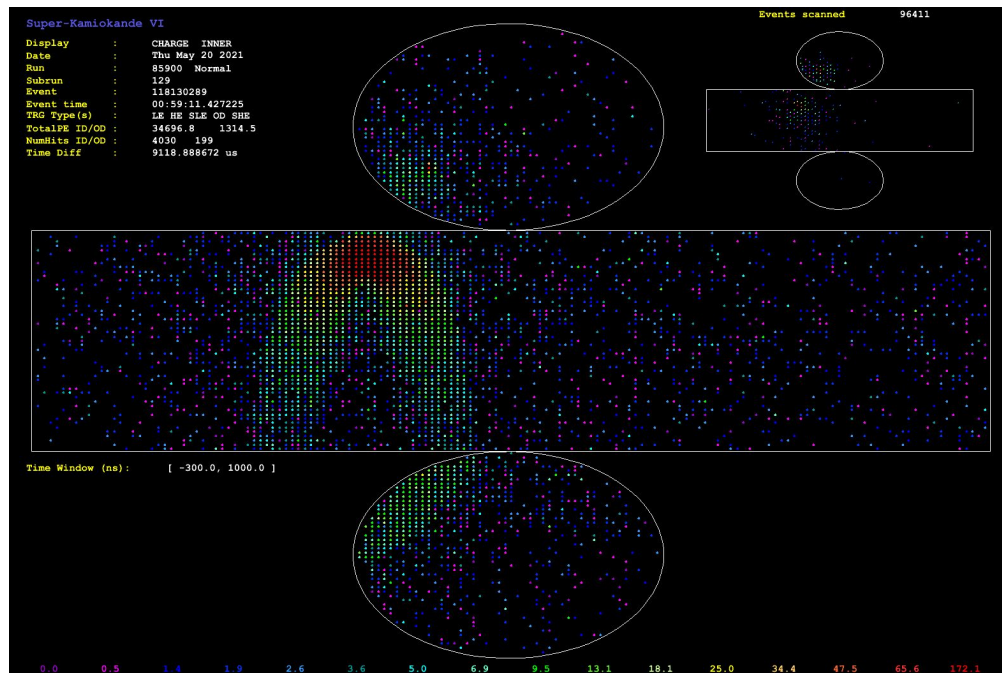
Dichroicons in Eos and Beyond

Samuel Naugle



Particle Detectors

- Optical detectors have a long history of important discoveries
 - SNO, Borexino, etc...
- Generally utilize one type of light
 - Scintillation or Cherenkov light
- Could both be utilized?
 - Increases particle ID and background rejection capabilities
 - Improves reconstruction

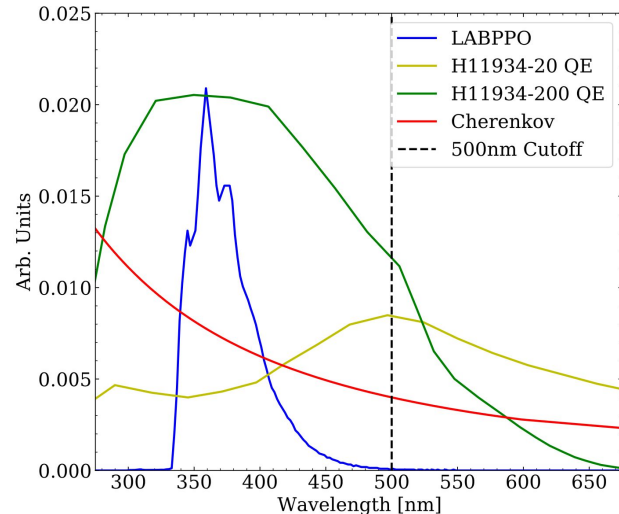
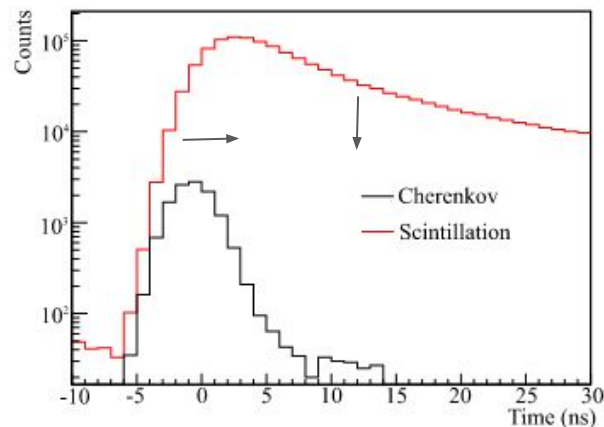


<http://www-sk.icrr.u-tokyo.ac.jp/realtimeonitor/>



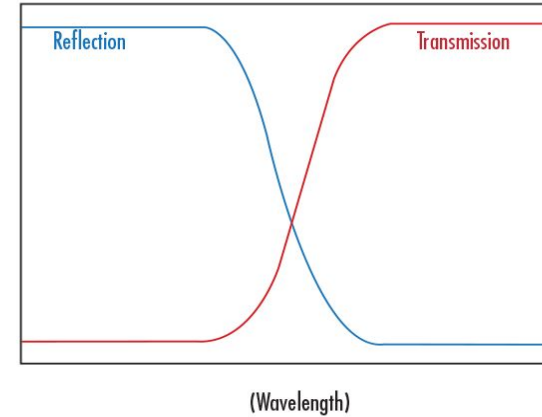
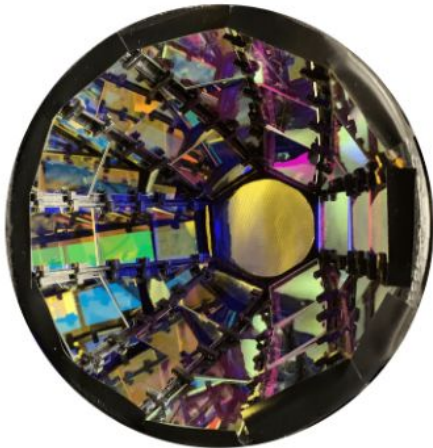
Hybrid Cherenkov and Scintillation Detectors

- A hybrid detector provides many advantages, but with some difficulties
- Four distinct approaches to hybrid detection
 - Reduce intensity of scintillation light (WbLS)
 - Utilize arrival times of Cherenkov and scintillation light (fast sensors/slow scintillators)
 - Use the angular distribution of Cherenkov photons
 - **Use wavelength information (dichroicons)**

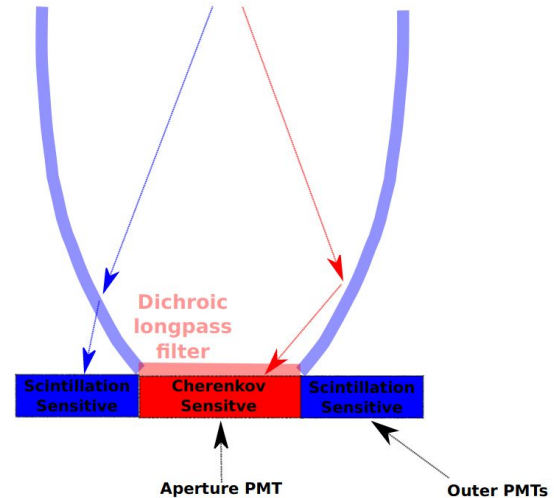


The Dichroicon

- Dichroic filters sort photons by wavelength
 - Sort Cherenkov and scintillation light to detect both simultaneously and separately

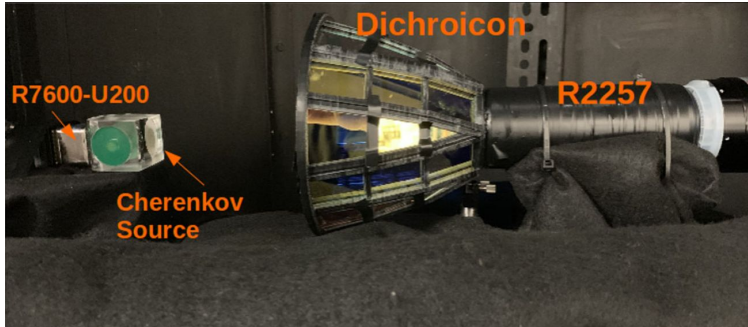
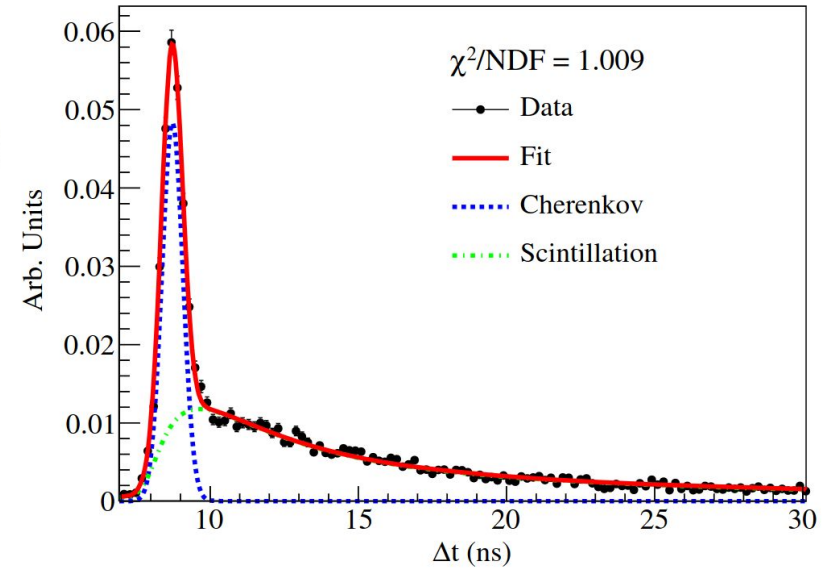
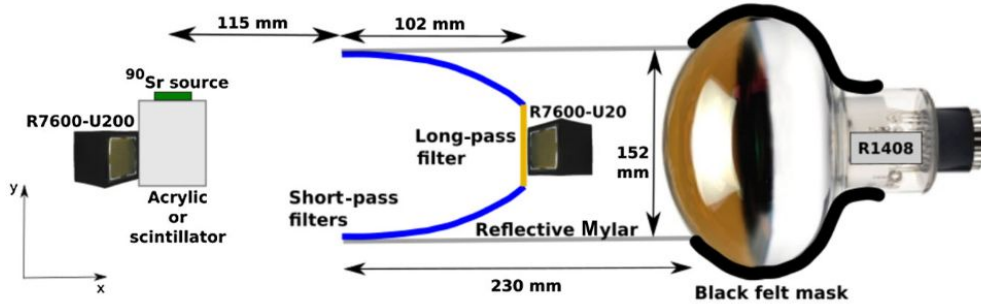


Long concentrating



First Demonstration

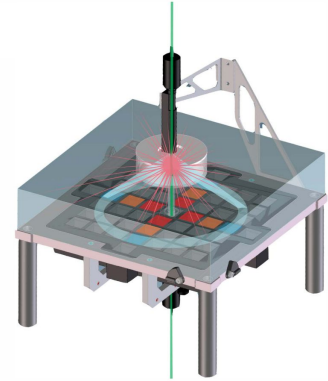
- First demonstrations showed clear separation of Cherenkov and scintillation light



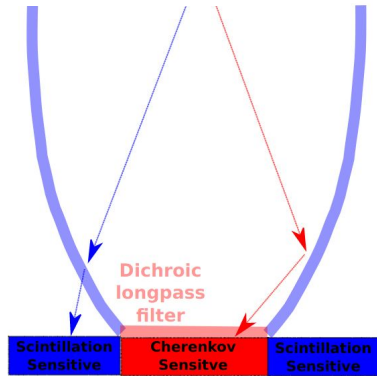
Benchtop Scale Testing of the Dichroicon

– The performance of the dichroicon was measured at the CHESS experiment

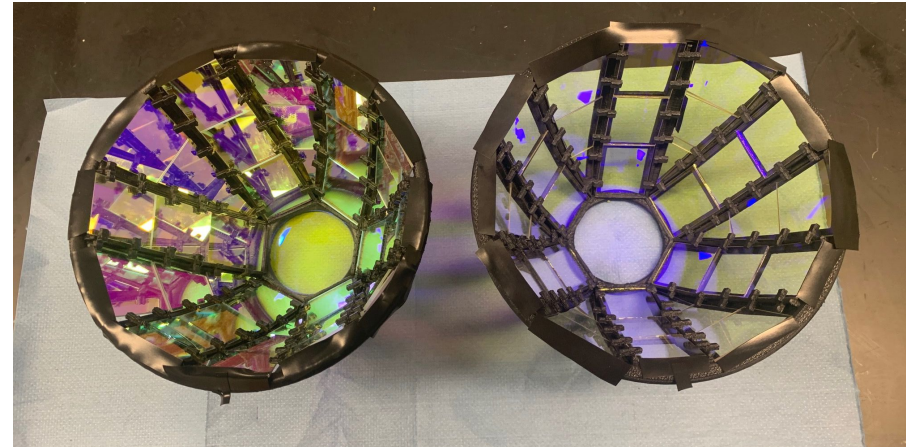
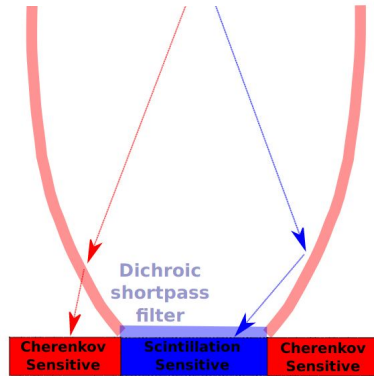
- Sources: Atmospheric muons, ^{60}Co , ^{90}Sr , and ^{210}Po
- Targets: Water, 10% WbLS, LAB with 2 g/L PPO
- Two dichroicon layouts: Long and short concentrating



Long concentrating



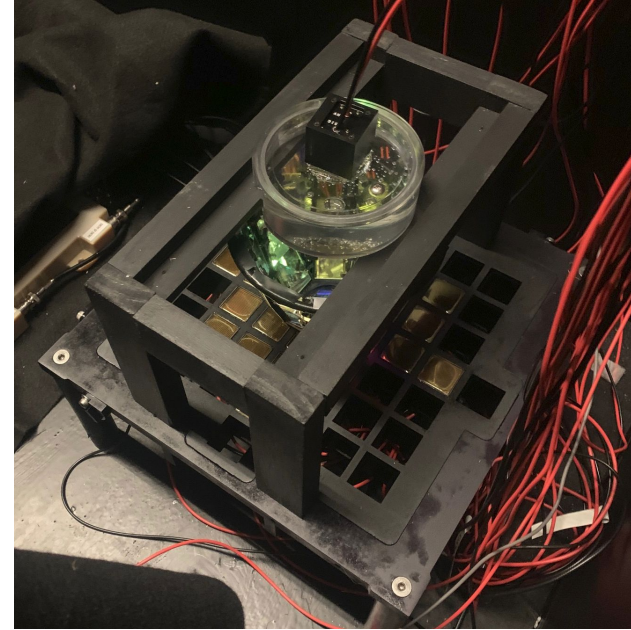
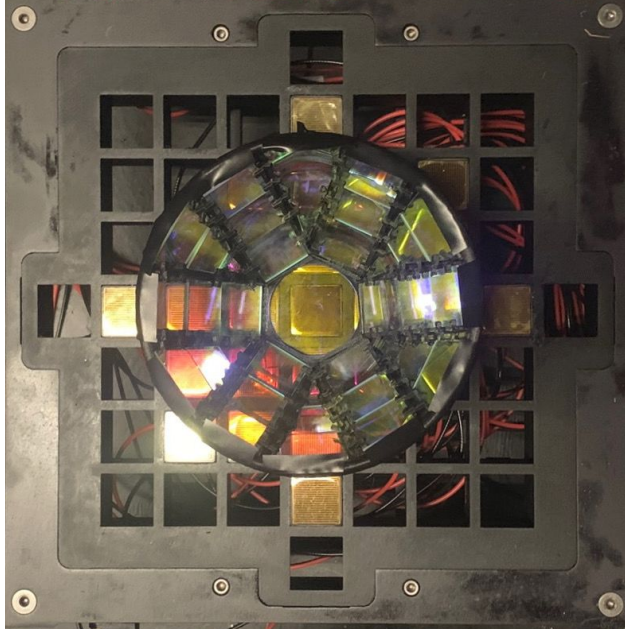
Short concentrating



Aperture PMT

Outer PMTs

Benchtop Scale Testing of the Dichroicon

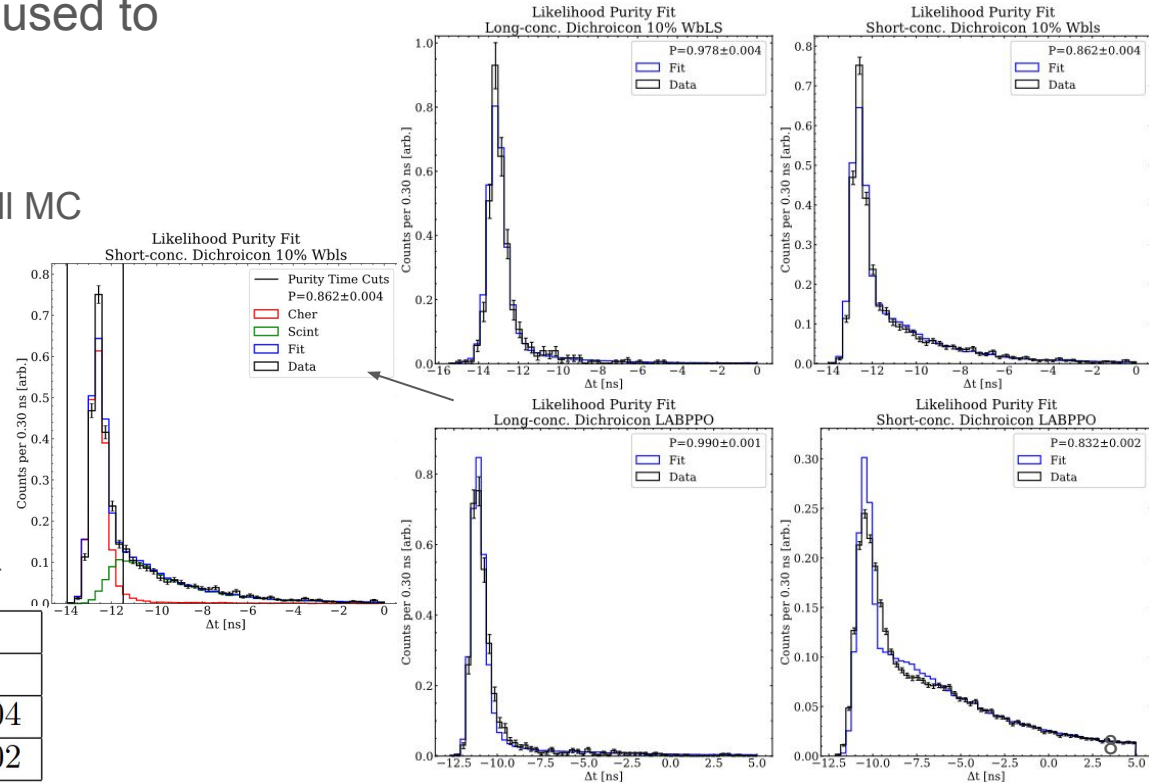
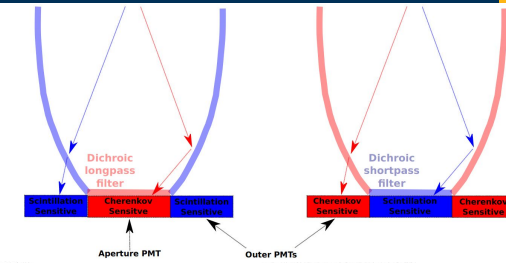


Benchtop Scale Testing of the Dichroicon

– Cosmic muon datasets were used to estimate the Cherenkov and scintillation contributions

– Measure the “**purity**” using a full MC model

– The purity is the ratio of Cherenkov photons to all photons in a prompt window

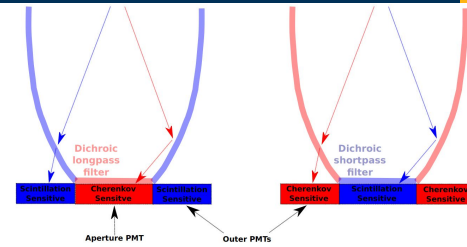


Purities		
	Long-conc.	Short-conc.
10% WbLS	0.978 ± 0.004	0.862 ± 0.004
LABPPO	0.990 ± 0.001	0.832 ± 0.002

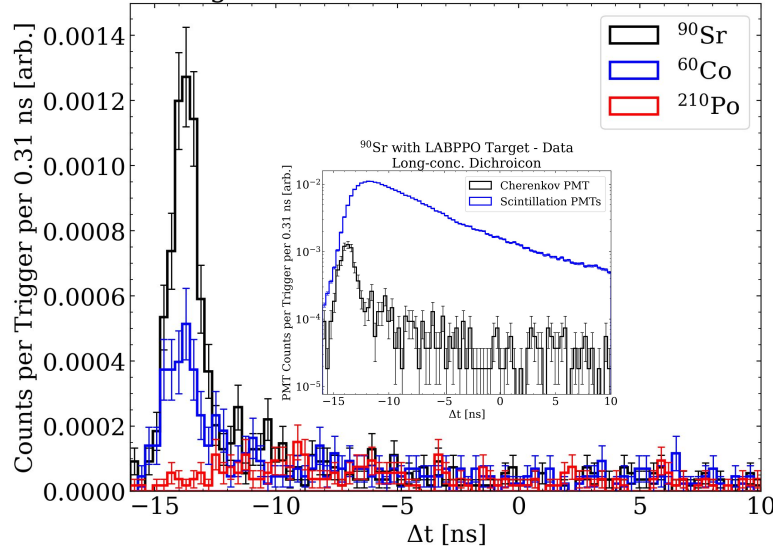


Benchtop Scale Testing of the Dichroicon

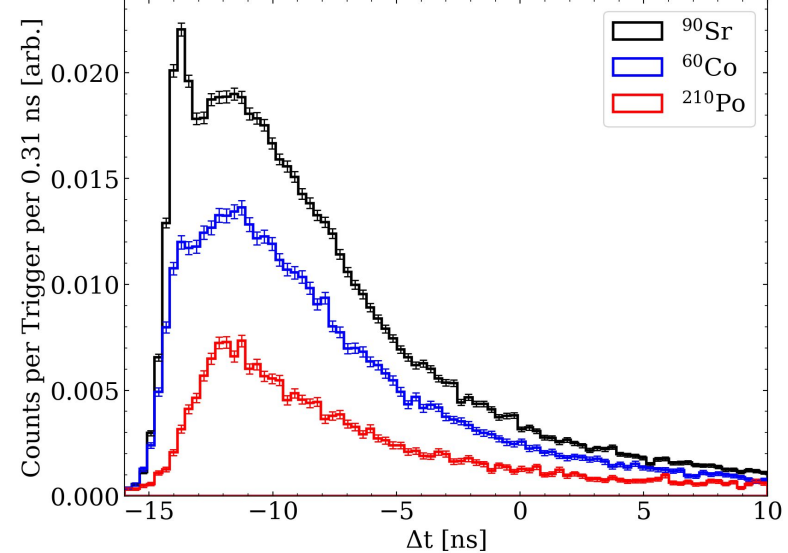
- Deployed source demonstrate particle ID capabilities of the dichroicon



Sources with LABPPO Target - Data
Long-conc. Dichroicon Cherenkov PMTs

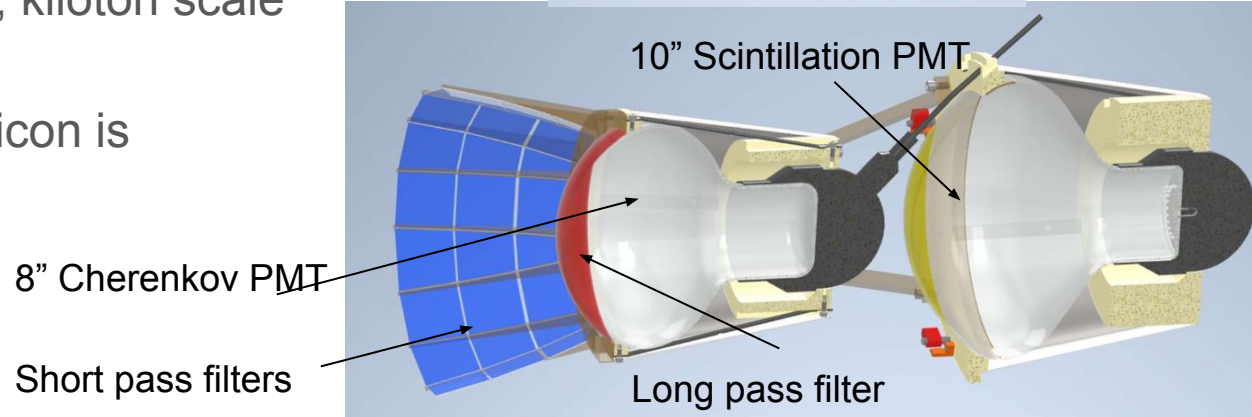
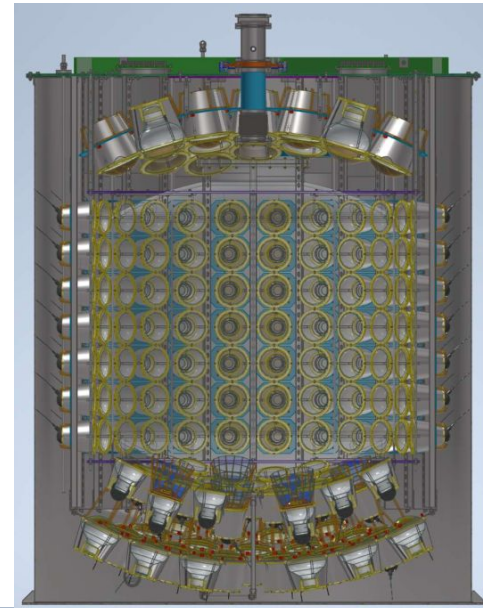


Sources with LABPPO Target - Data
Short-conc. Dichroicon Cherenkov PMTs

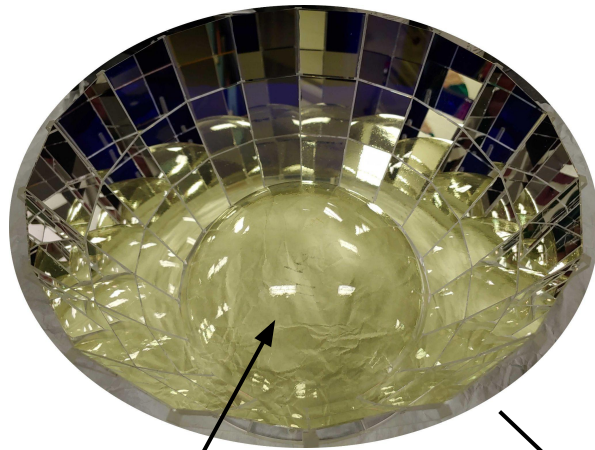


Eos Deployment

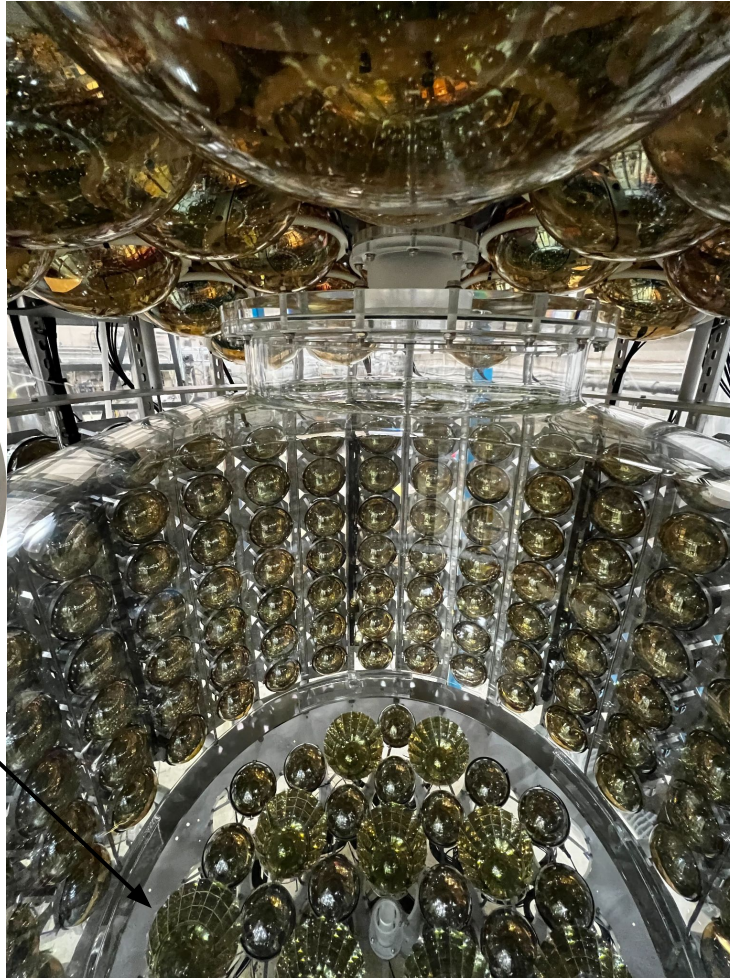
- 12 monolithic dichroicons deployed in the Eos detector
 - Eos is a 20 ton hybrid scintillation-Cherenkov detector
 - Involves many new technologies and multiple target mediums
- First test of a monolithic, kiloton scale dichroicon design
- Cost of filters per dichroicon is ~\$2000



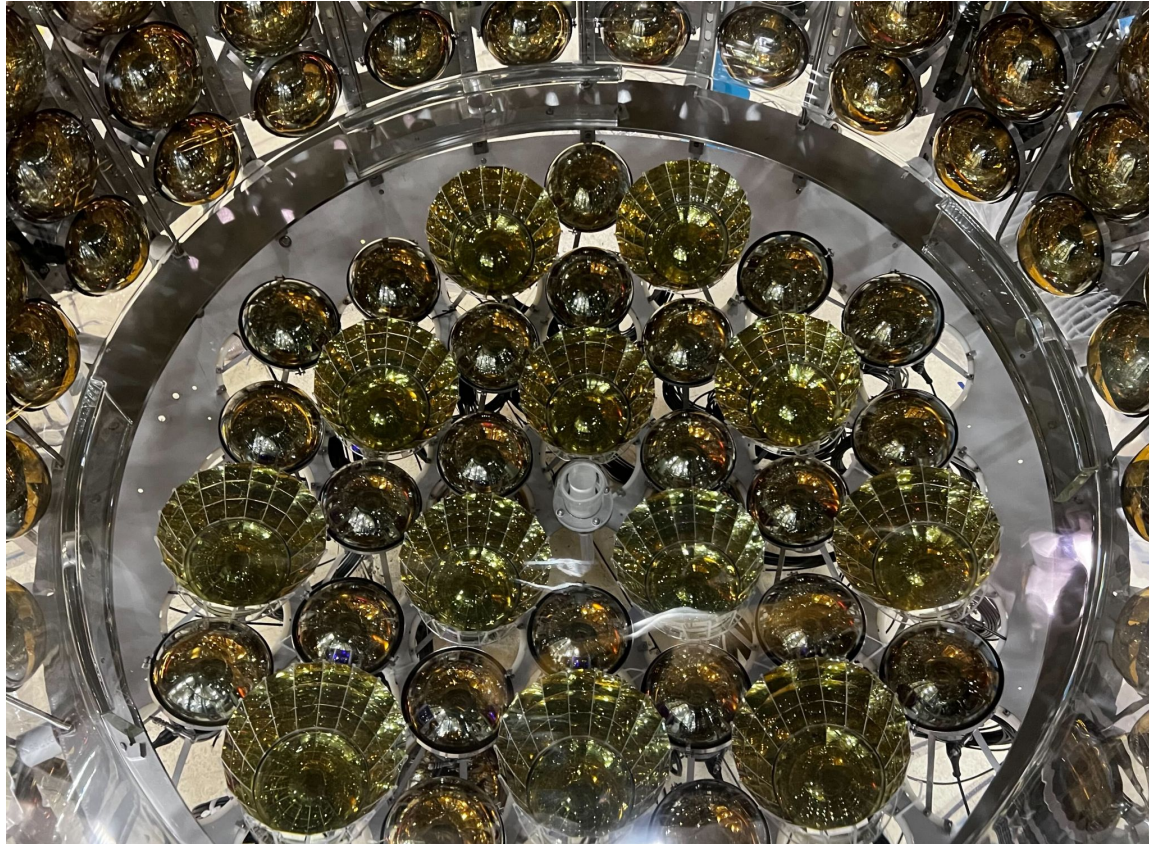
Eos Deployment



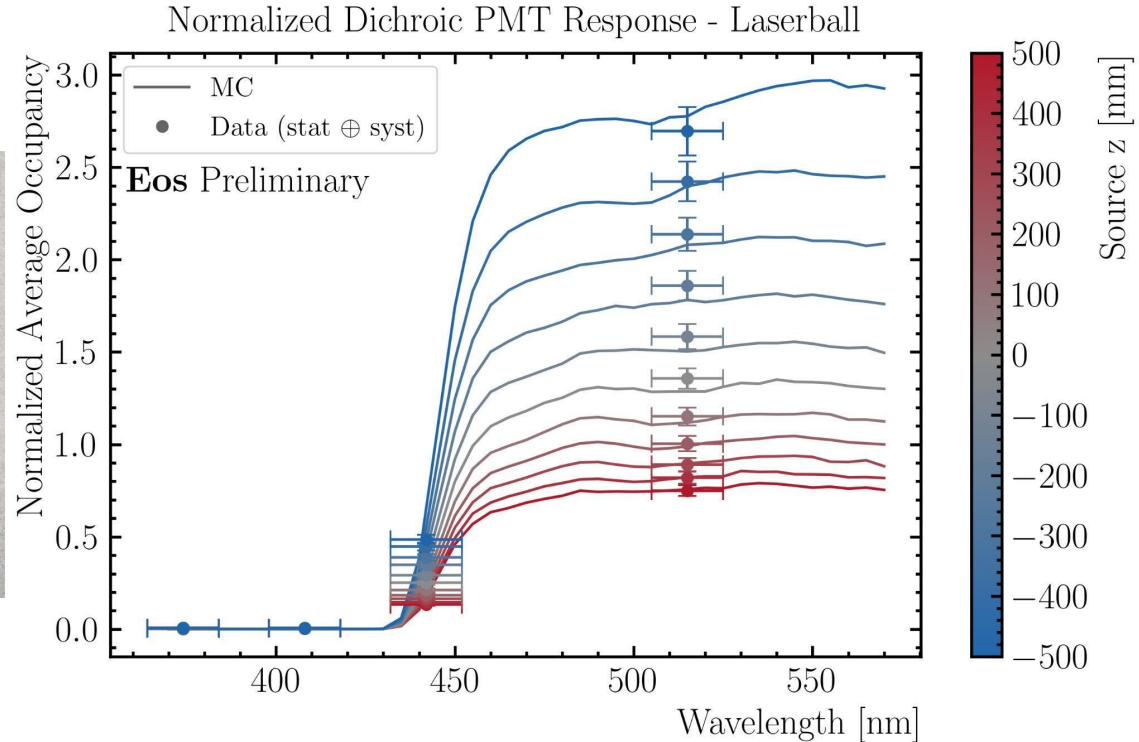
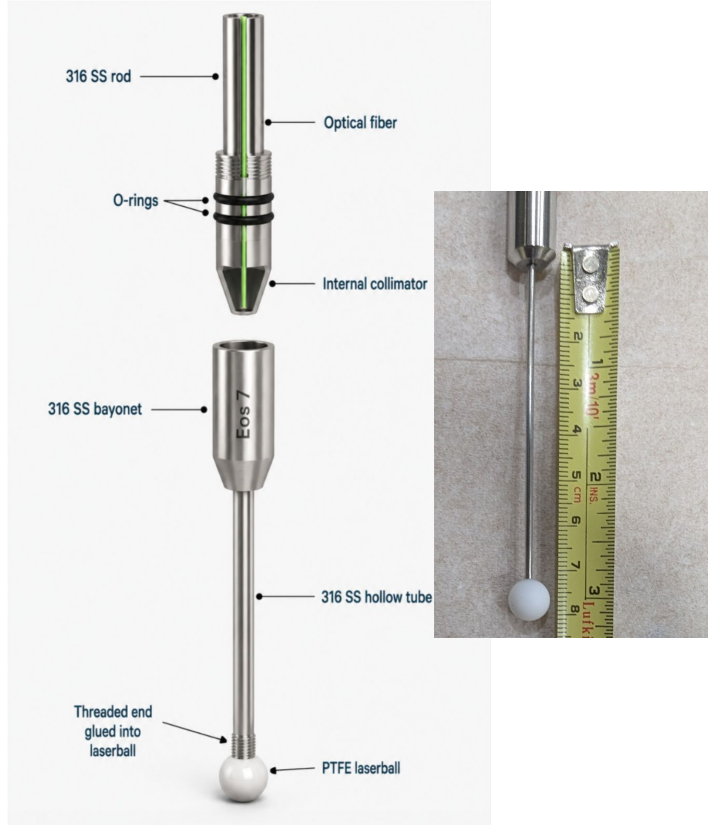
Curved
Longpass Filter



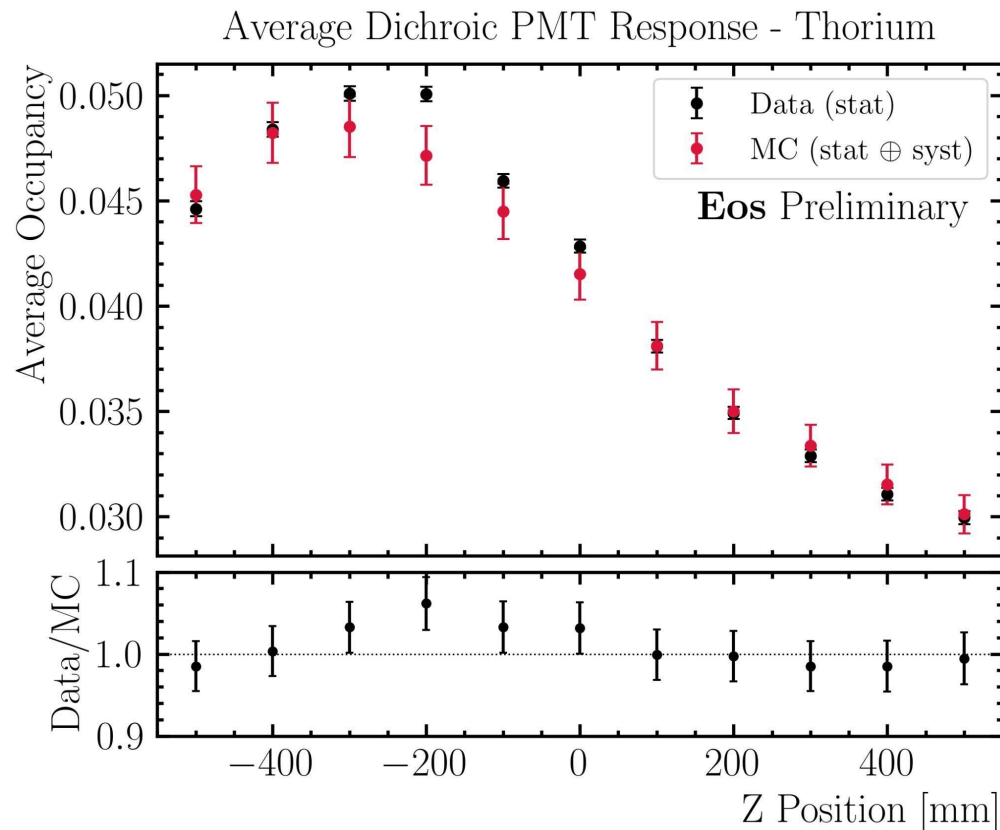
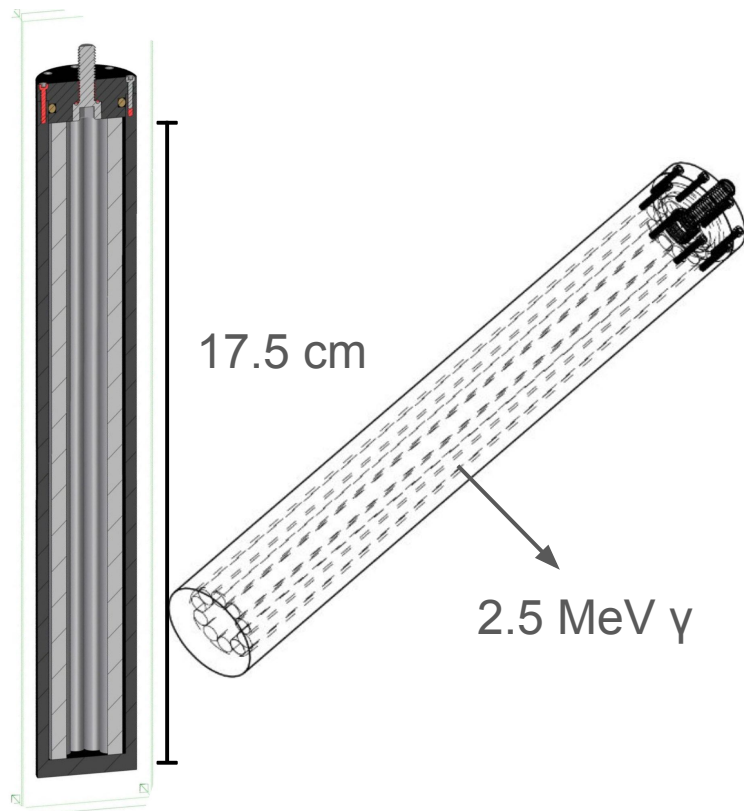
Eos Deployment



Eos Demonstrations - Laserball

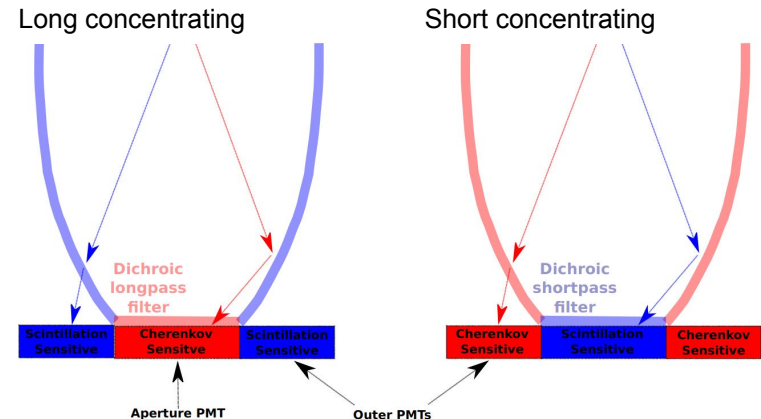
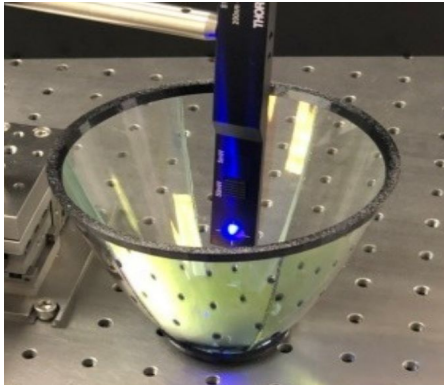


Eos Demonstrations - Thorium Source



Looking Ahead - Near Term

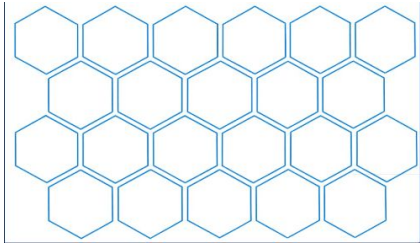
- There are many ideas that still need to be explored
 - Large scale short concentrating dichroicon
 - New photodetectors like SiPMs and LAPPDs
 - New dichroic filter technology including atomic layer deposition (ALD) techniques
 - **“Hex”-dichroicons**



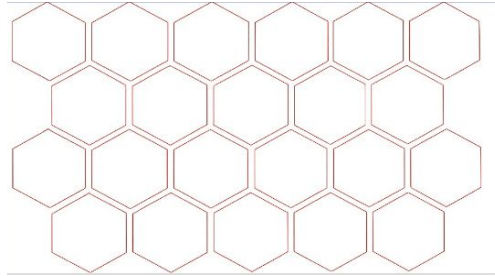
Hex-dichroicons

- In principle, the hex-dichroicon layout can provide full sorting

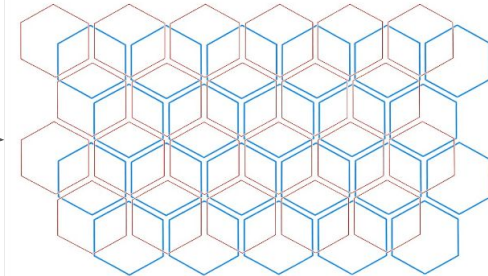
Short conc.



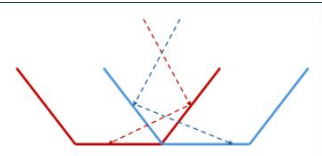
Long conc.



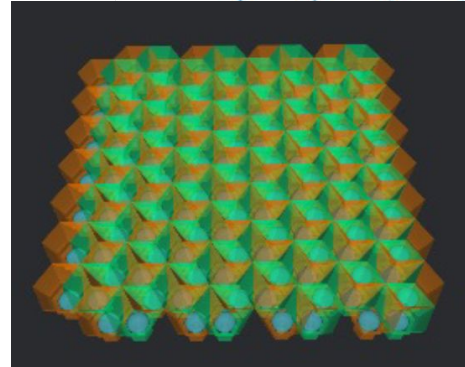
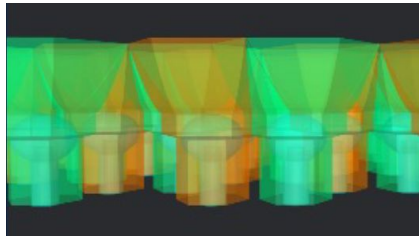
+



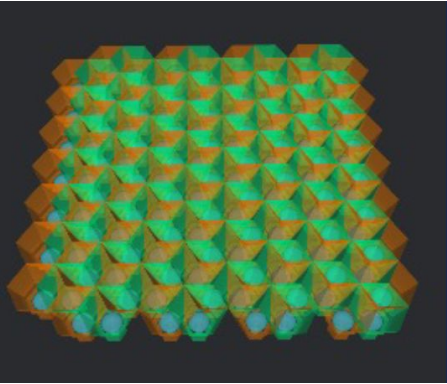
Side view



Geant4 geometry:

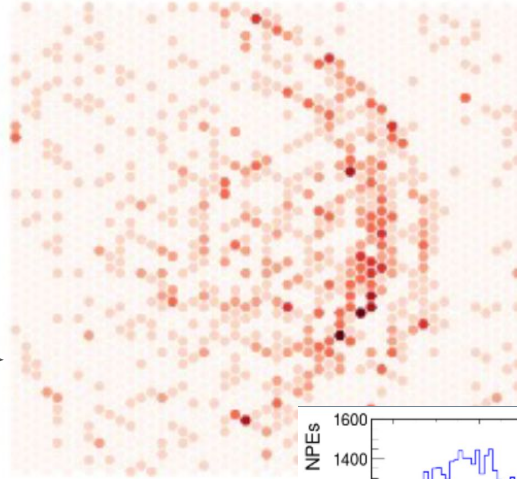


Hex-dichroicons

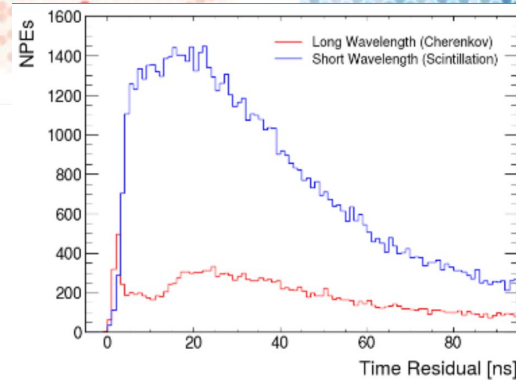
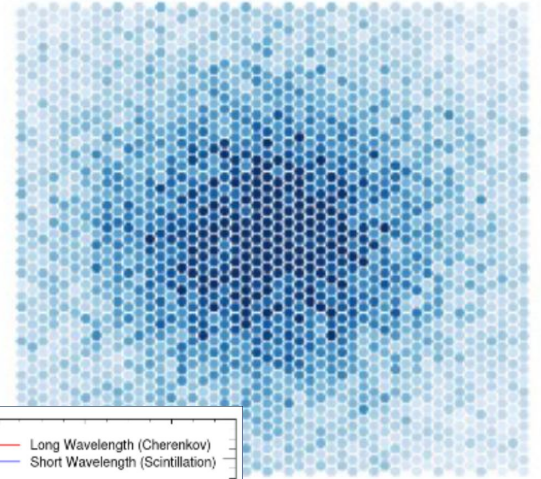


1 GeV μ

Long Wavelength (Cherenkov)

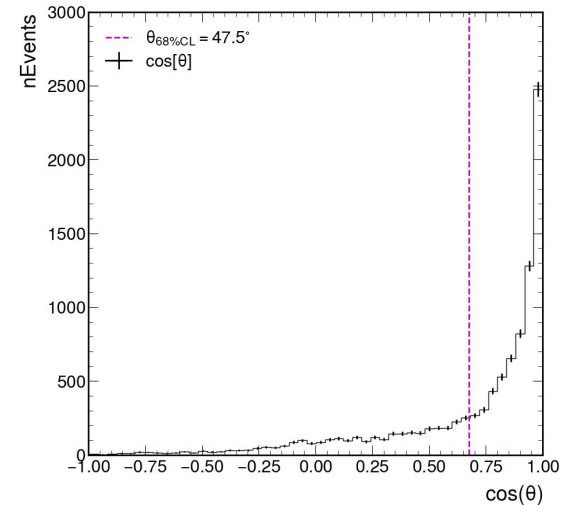
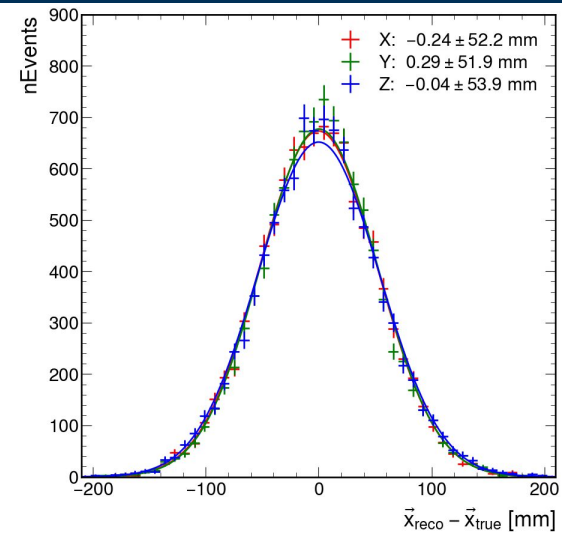
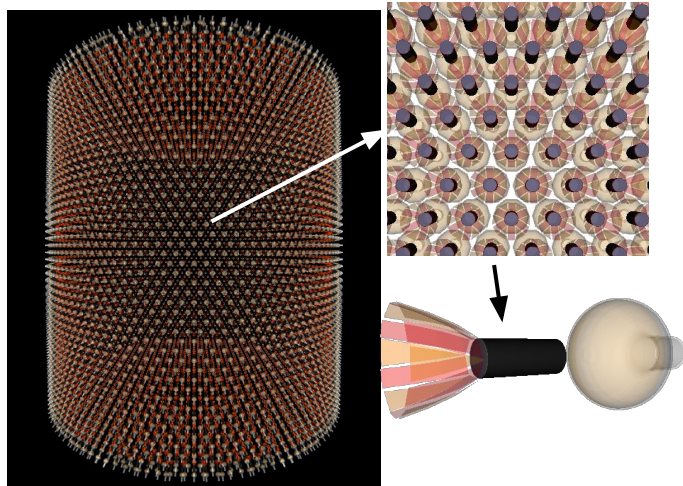


Short Wavelength (Scintillation)



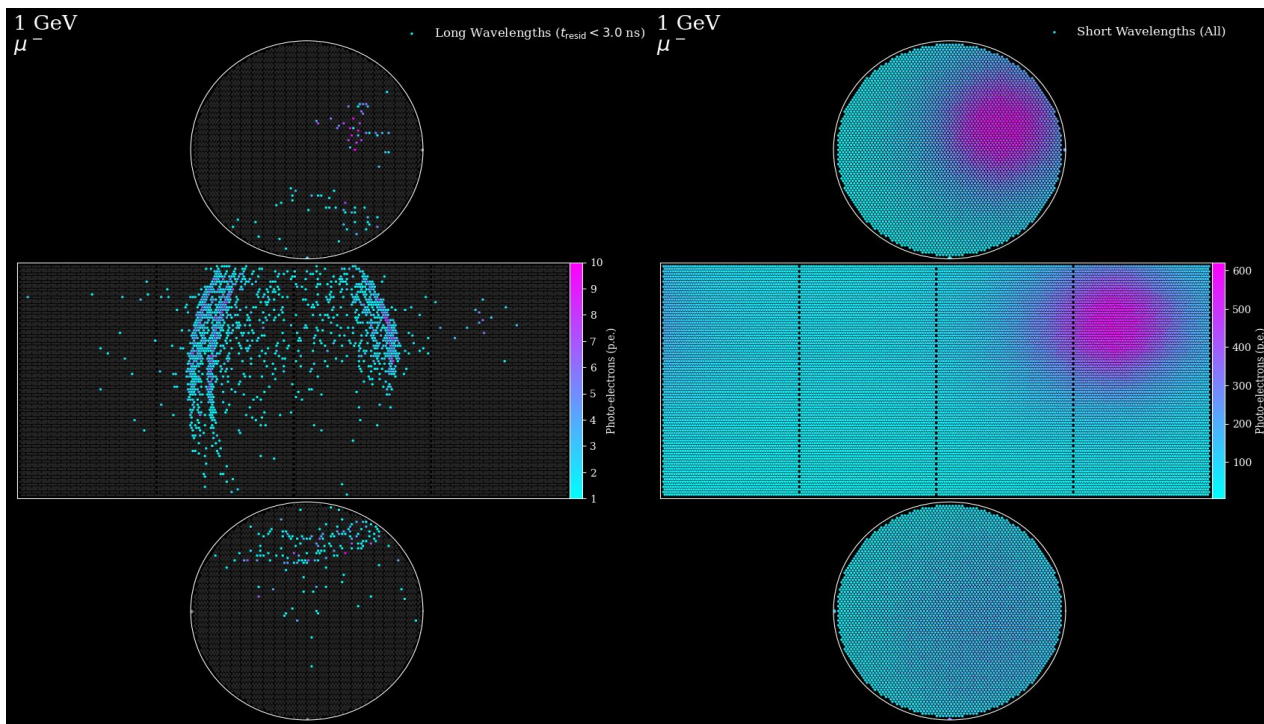
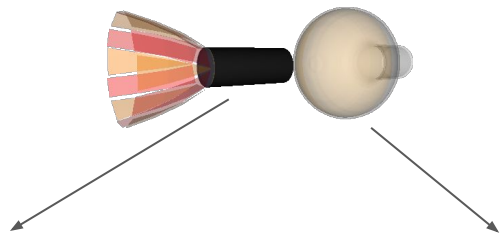
Looking Ahead - Long Term

- This is all working towards a dichroicon filled next generation kiloton-scale neutrino detector, ie Theia, a 50kT detector
 - Below are preliminary simulation results of 5 MeV electrons in a detector filled with 2g/L LABPPO



Questions?

Thanks for listening!



Backup



Benchtop Scale Testing of the Dichroicon

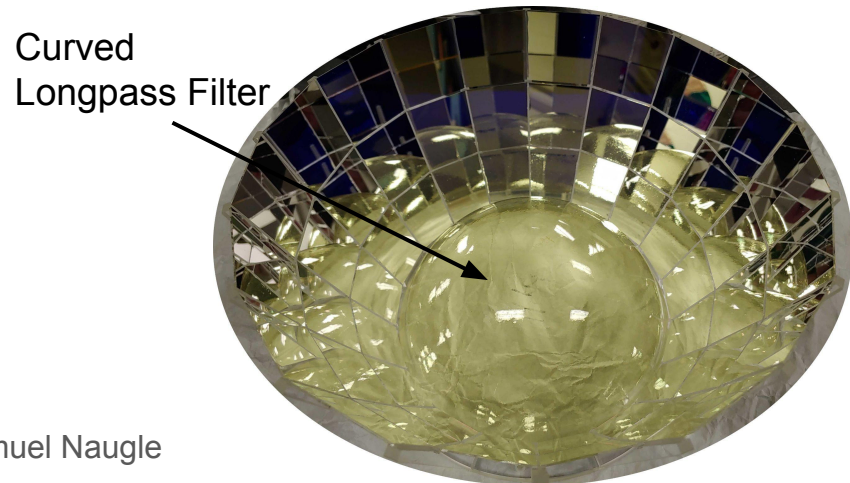
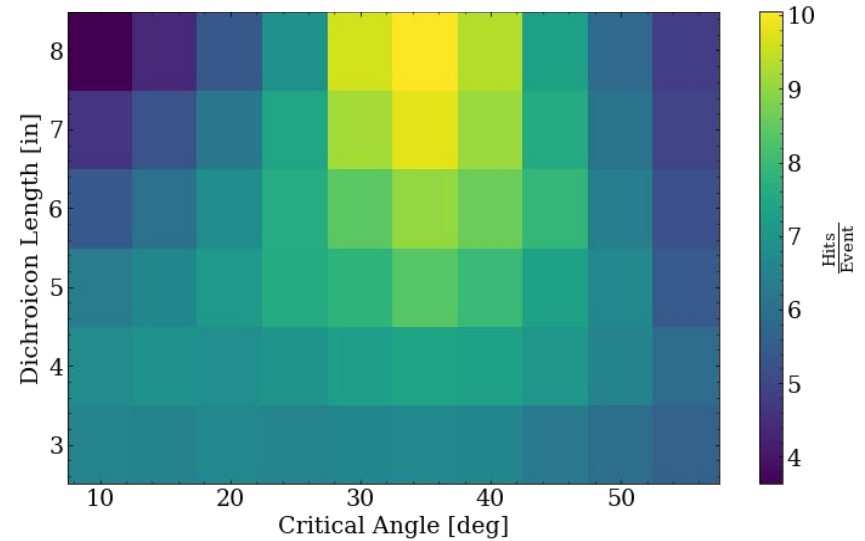
- Charge collection measurements show that the advantage of the Winston cone for photon collection

	Scintillation Yield	Cherenkov Yield
	Charge/Event/PMT [pC]	C_{hits}/PMT
Aperture Filter	10.2 ± 0.1	0.023 ± 0.007
Long-conc. Dichroicon	4.35 ± 0.04	0.066 ± 0.009
Short-conc. Dichroicon	19.2 ± 0.3	0.077 ± 0.002

- The dichroicon is not filtering light, rather it **sorts** the photons
- Non-optimal experimental setup with close photon sources
 - Expect larger yields in large detectors

Eos Considerations

- A large amount of effort was put into optimizing this new, larger dichroicon design
- Simulated various Winston cone shapes to find maximum collection efficiency
- Custom molded longpass filters also improve collection efficiency by ~50%
 - Relative to a flat longpass filter design



Angular dependence

