Eos

A 20-tonne demonstrator for hybrid detector technology

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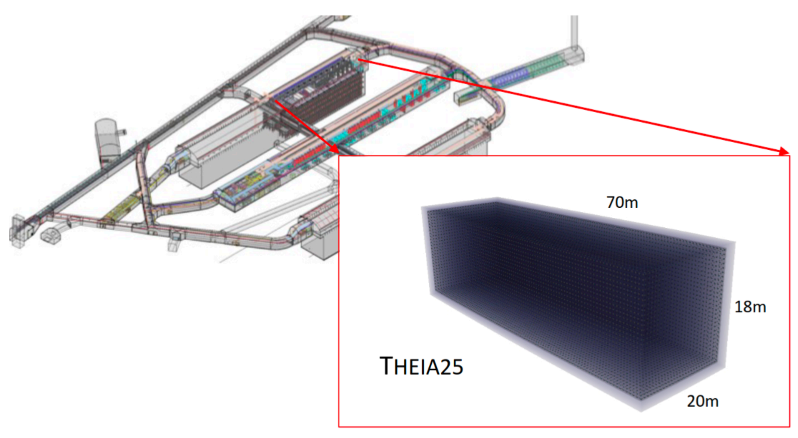
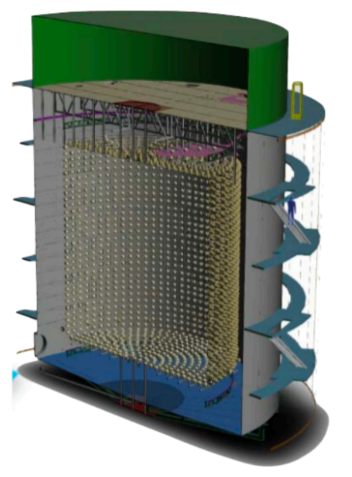
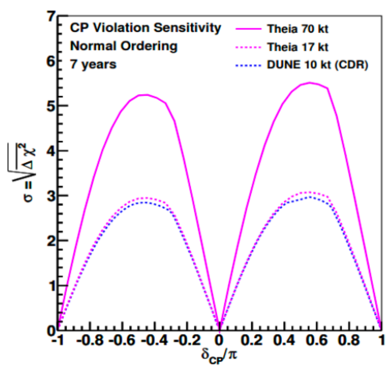
Motivation

Future ktonne scale detector, such as Theia [1], plan to leverage hybrid detector technology to provide a broad physics program that includes low-energy solar neutrinos, long-baseline oscillations, supernova neutrinos, and geo neutrinos.

Hybrid technology may have applications within nuclear test site transparency and maritime sensing.







Hybrid Detector Concept

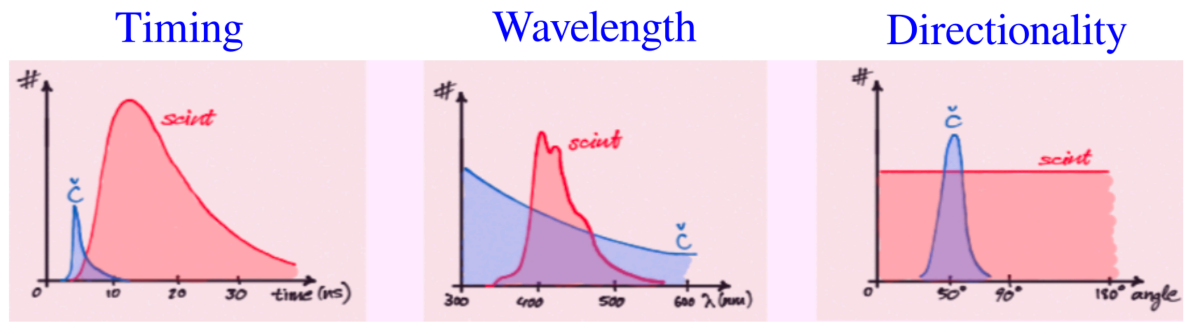
Charged particles traveling through liquid scintillator create scintillation and Cherenkov light. The Cherenkov photons are difficult to detect because of high light yield.

Distinguishing the Cherenkov and scintillation photons will:

a) Improve energy/vertex resolution, relative to water Cherenkov detector

b) Allow directional reconstruction using Cherenkov light

c) Enhance signal sensitivity and background rejection through particle ID



Hybrid Detector Technology

A. Novel liquid scintillator (WbLS and slow LS)

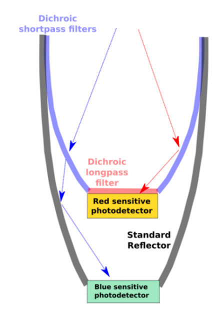
Novel scintillators such as water-based LS (WbLS) [3, 4] and slow LS help enhance the Cherenkov signal. These materials have several advantages, such as tunable optics (e.g. light yield and rise-time), that make detecting the Cherenkov light easier.

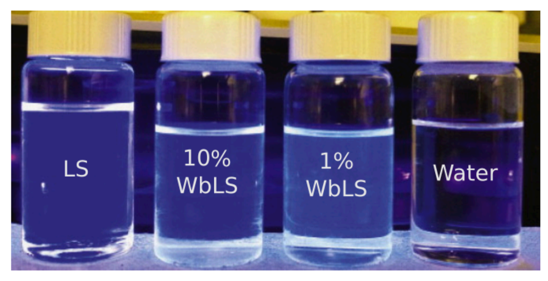
B. Spectral sorting with dichroicons

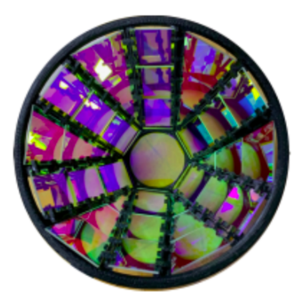
The dichroicon [5] is a Winston cone concentrator built from dichroic filters that sorts photons towards two different PMTs, one which detects the long-wavelength (Cherenkov-rich) photons and the other which detects the short-wavelength (scintillation-rich) photons.

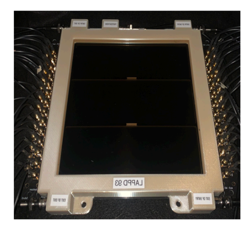
C. Fast-timing photodetectors

Large-area photodetectors with extremely precise timing (<1 ns jitter) and high quantum efficiency (>25%), such as LAPPDs [6] and the Hamamatsu R14688-100 PMT [7], can be used to identify early Cherenkov photons.







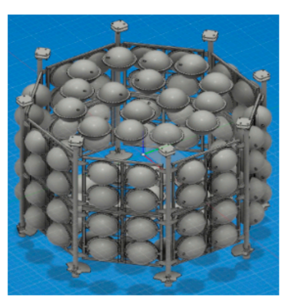


Eos Detector

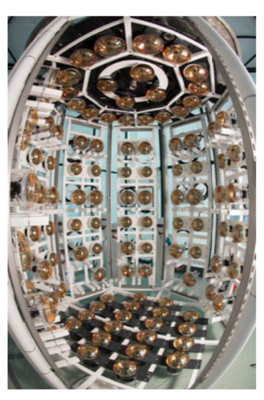
- Eos is constructed at UC Berkeley.
- The detector consists of a 4-tonne acrylic inner vessel (IV) filled with novel LS.
- The IV is contained in a 20-tonne stainless steel outer vessel (OV) filled with water.
- Commissioning underway.
- First data has been taken!

Other efforts in tonne-scale hybrid detectors

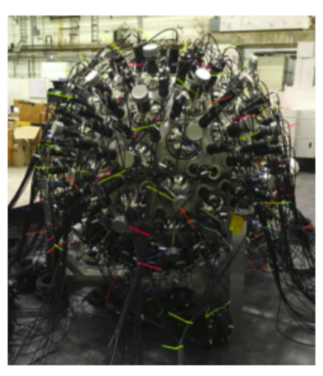
Brookhaven 1t and 30t Tanks (stability/optics)



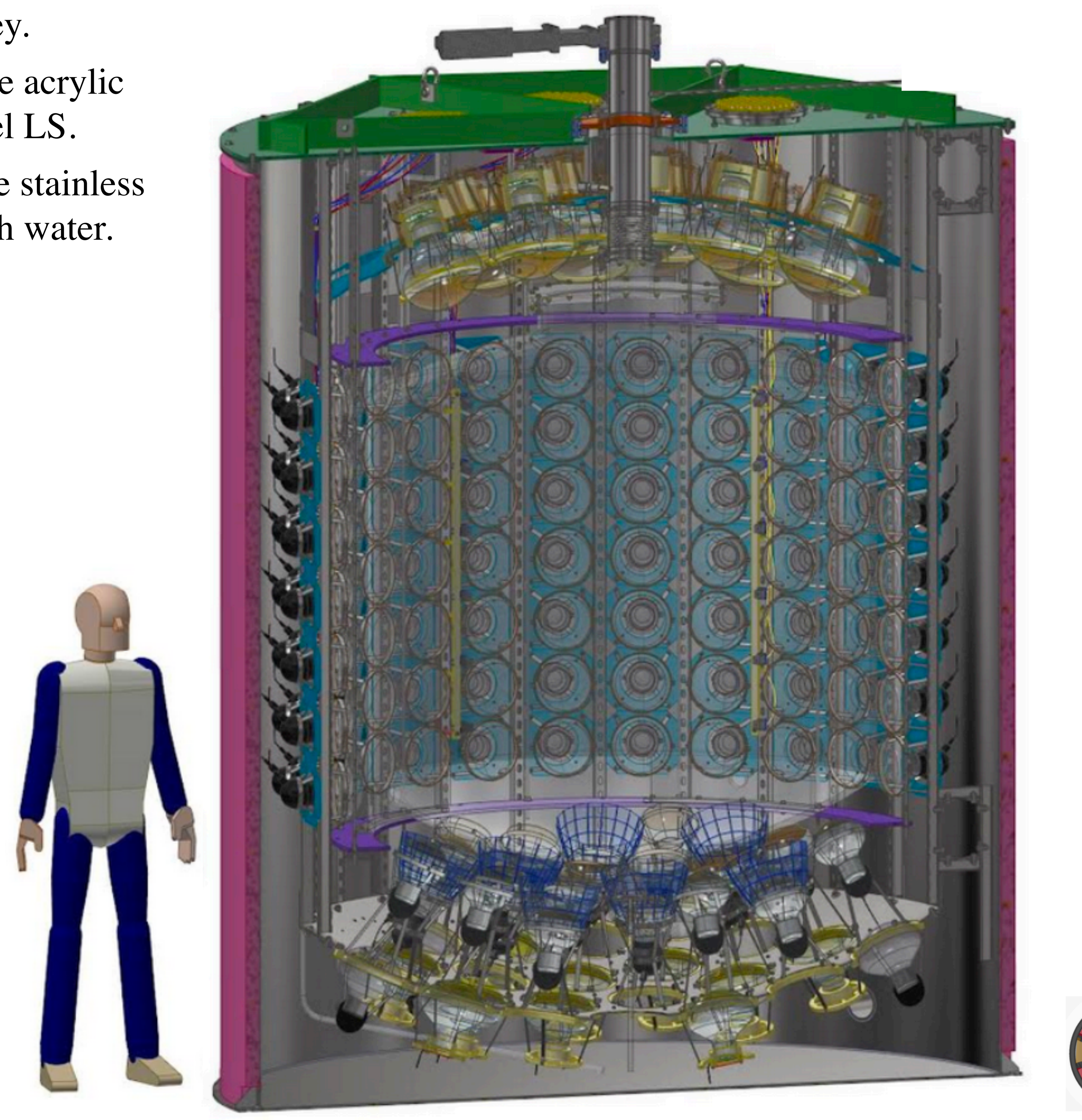
BUTTON (low background characterization)



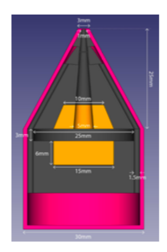
ANNIE (high energy) [12]



NuDot (fast timing, pure LS) [13]



EOS is a *flexible* testbed for hybrid detection technology, readout solutions, and analysis techniques.

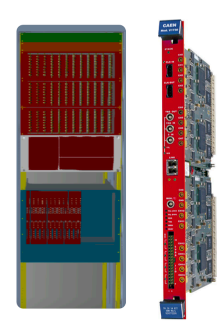


Directional electron source: Deployed through a calibration source port at the top of the detector. Provides a source of events with a known direction to demonstrate direction reconstruction. Other potential sources include higher energy gamma-rays or neutrons.

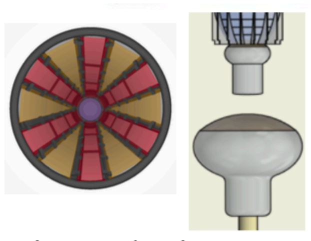
Novel LS: EOS will first fill with water for calibrations before injecting LS to create WbLS. We will study the detector response as a function of scintillator fraction and ultimately fill with pure LS.

204 R14688-100 PMTs: State-of-the-art timing 8" PMTs with TTS of 900 ps (FWHM).

24 R11780 PMTs: High quantum efficiency 12" PMTs with fast timing and excellent charge response [14].

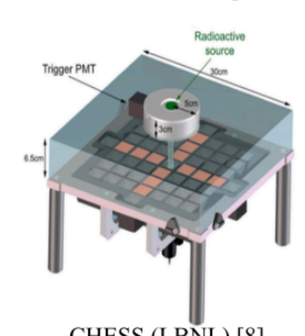


CAEN V1730S: Fast waveform digitizers allow for precise timing and charge measurements with no deadtime. Will be readout by custom DAQ.



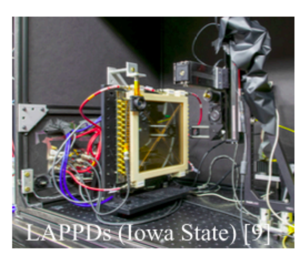
Dichroicons: placed at the bottom of the detector to take advantage of directional source pointing downward.

Lots of exciting hybrid detector R&D at the bench-top scale

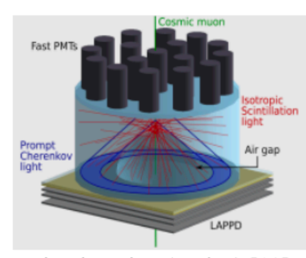


CHESS (LBNL) [8]

Dichroicons (UPenn) [5]

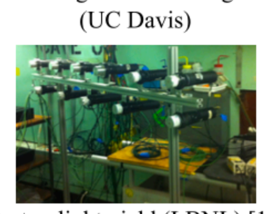


LAPPDs (Iowa State) [9]



Ring imaging (Mainz) [10]

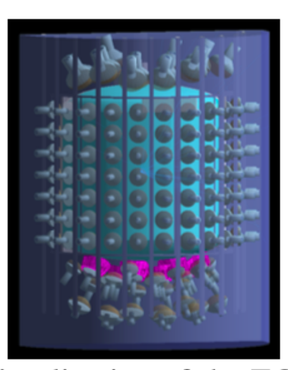
Long-arm scattering (UC Davis)



Proton light yield (LBNL) [11]

Eos Goals

- **Cherenkov and scintillation separation at the multi-ton scale**
- **Improved vertex and energy resolution, relative to water Cherenkov**
- **Direction reconstruction against scintillation light background**
- **Performance testing for range of detector configuration**
- **Validate WbLS model at tonne-scale**
- **Future deployments near reactor core or test beam**



Visualization of the EOS geometry in RAT-PAC

References and Acknowledgements

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