

# Recent R&D for Theia

Tanner Kaptanoglu  
for the **Theia** collaboration

## XIX International Workshop on Neutrino Telescopes

2/24/2021

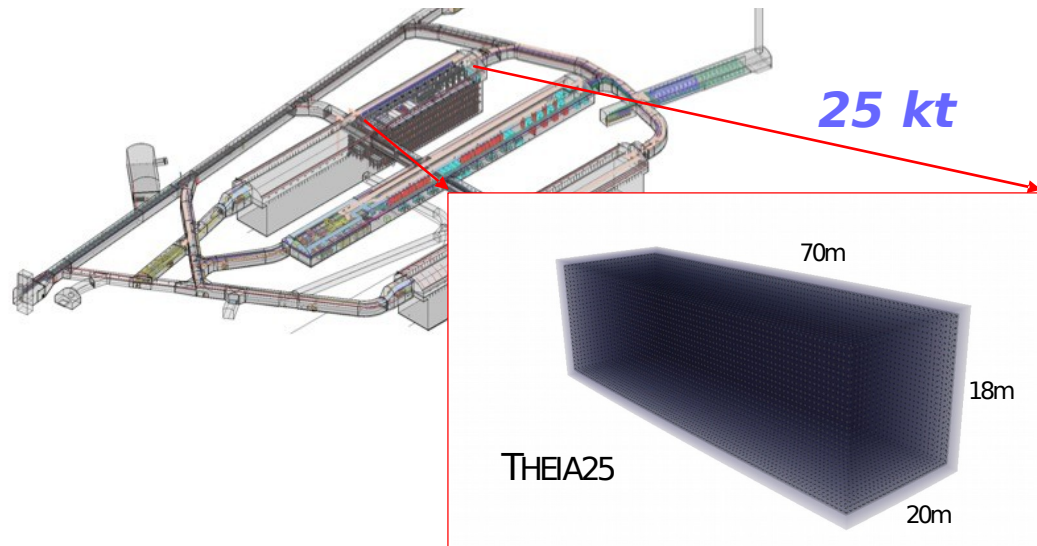
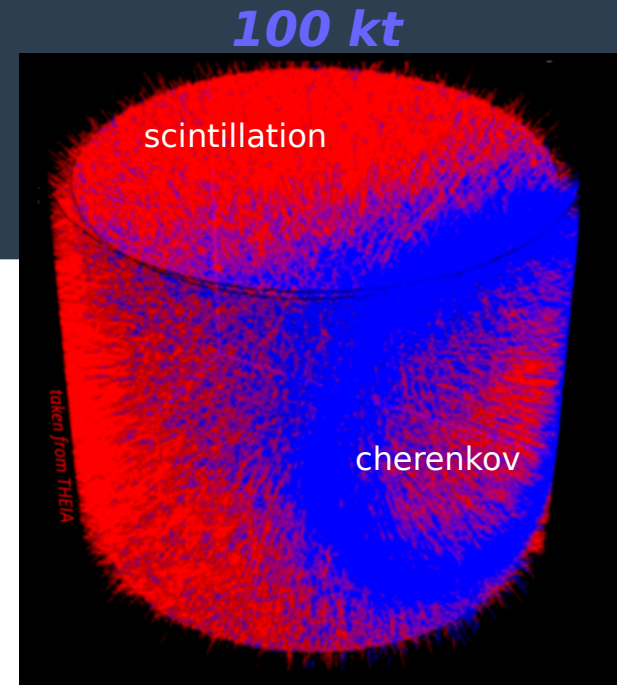


**Berkeley**  
UNIVERSITY OF CALIFORNIA

# Theia Program

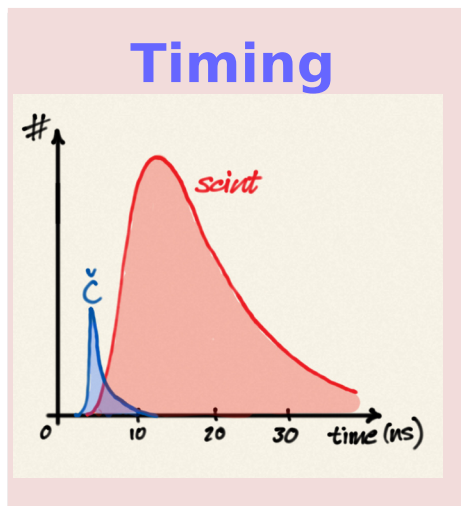
*Very large volume scintillation-based detector with the ability to utilize both the Cherenkov and scintillation signals, allowing for a broad physics program:*

- Long baseline oscillations
- Solar neutrinos
- Supernova neutrinos
- DSNB
- Geo and reactor neutrinos
- $0\nu\beta\beta$
- Nucleon decay

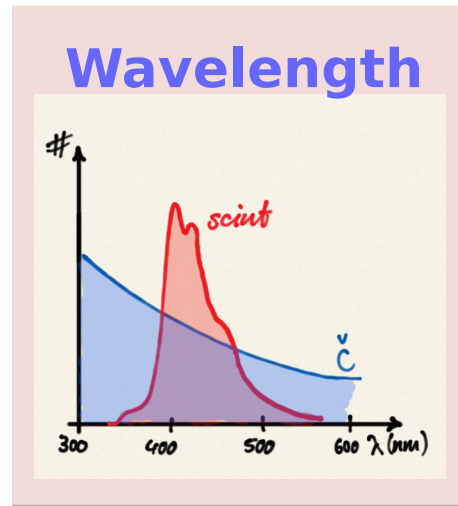


# Chererkov/Scintillation Separation

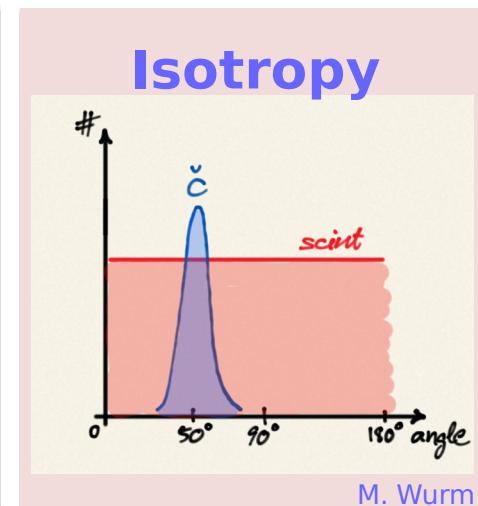
Challenge: Separate Cherenkov & scintillation despite overwhelming scintillation light yield



- LAPPDs
- Fast PMTs
- WbLS
- Slow scint.



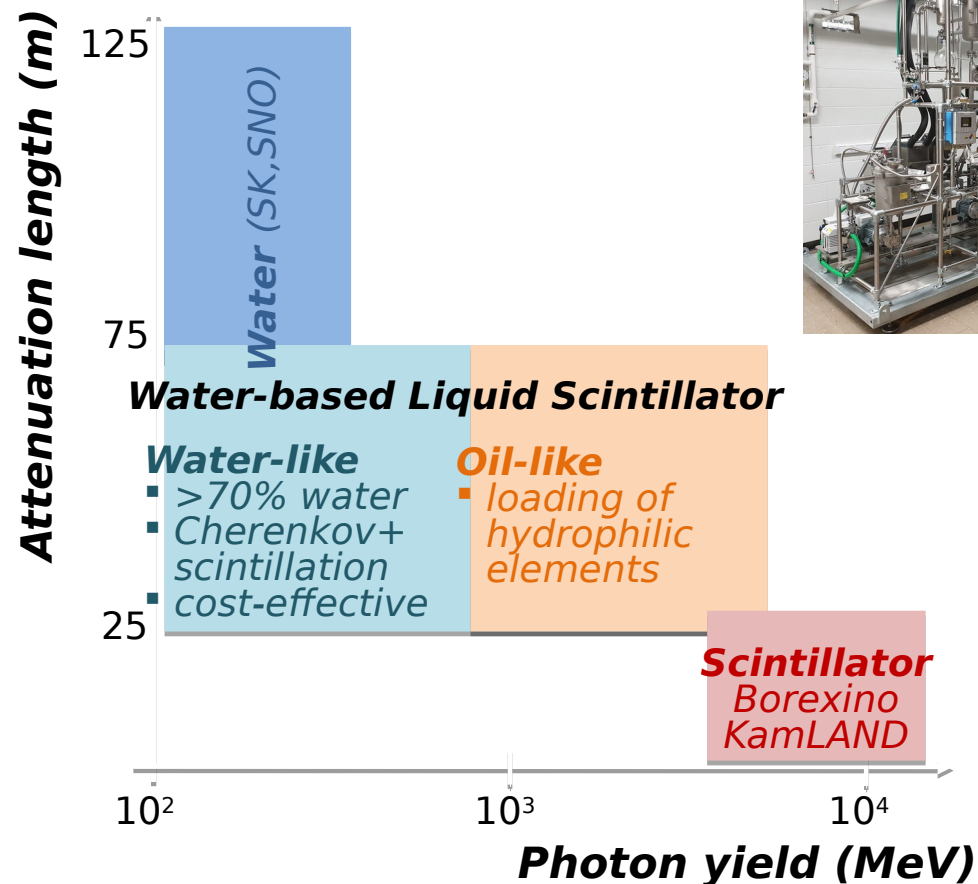
- Dichroicons
- Red-sensitive PMTs
- Filtering



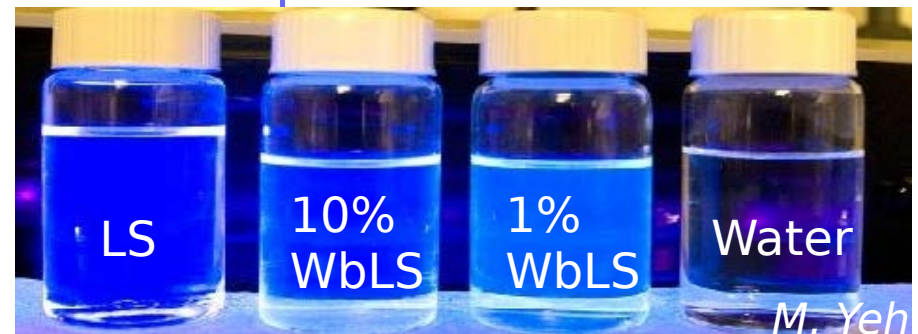
- LAPPDs
- Improved recon. methods

# Water-based Liquid Scintillator

*Novel target medium: water-based liquid scintillator*



Development at Brookhaven

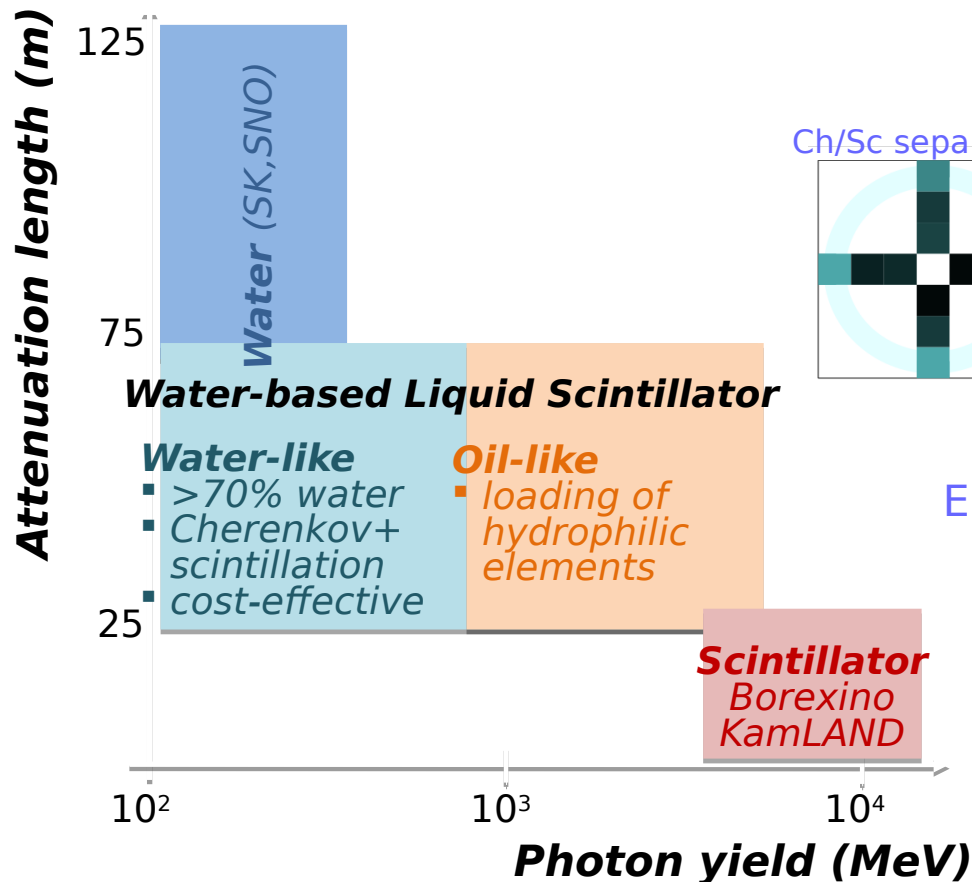


# Water-based Liquid Scintillator

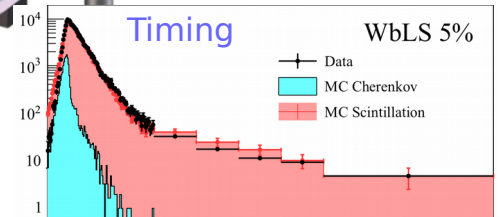
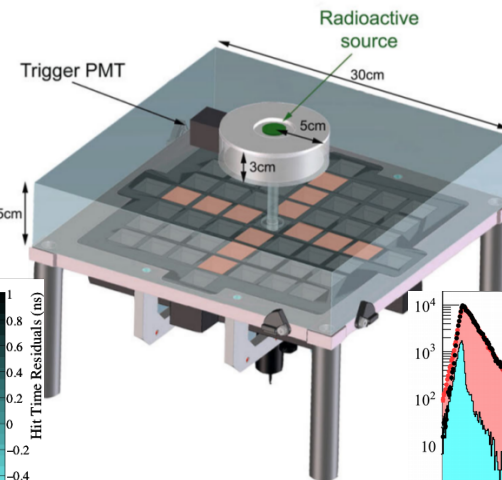
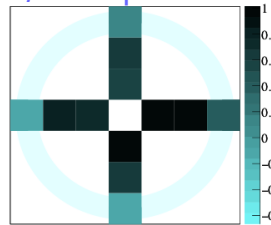
Characterization in **CHES** at LBNL

Light yield [photons/MeV]

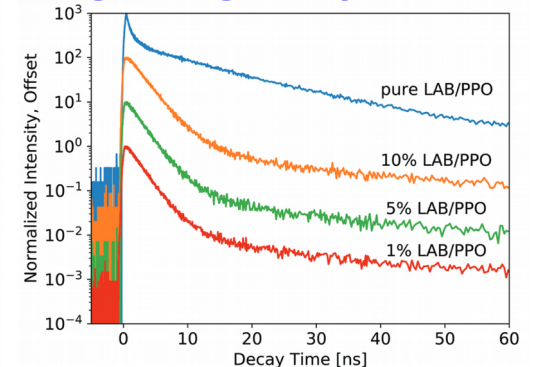
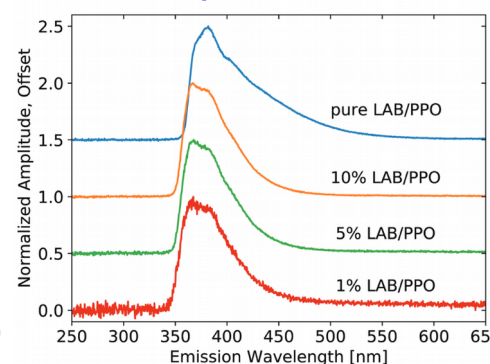
1% WbLS  $234 \pm 30$   
 5% WbLS  $770 \pm 72$   
 10% WbLS  $1357 \pm 125$



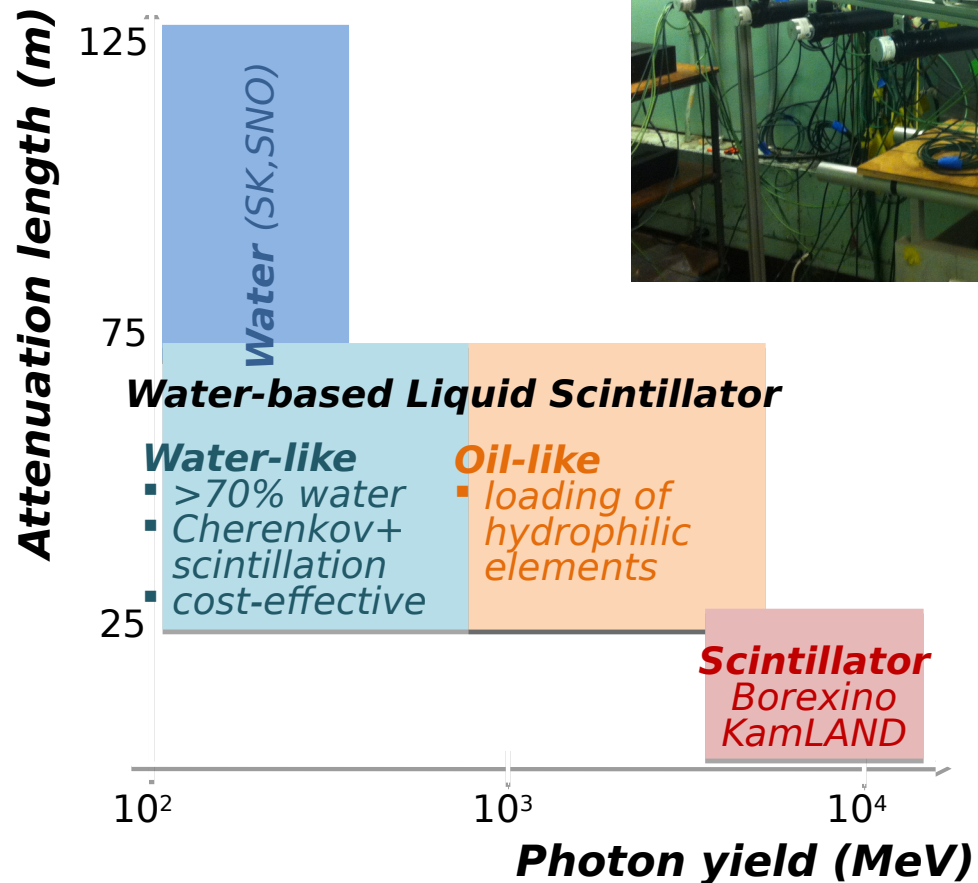
Ch/Sc separation



Emission spectrum and timing using x-ray excitation



# Water-based Liquid Scintillator



Proton light yield at LBNL



Long-arm scattering and attenuation at UC Davis

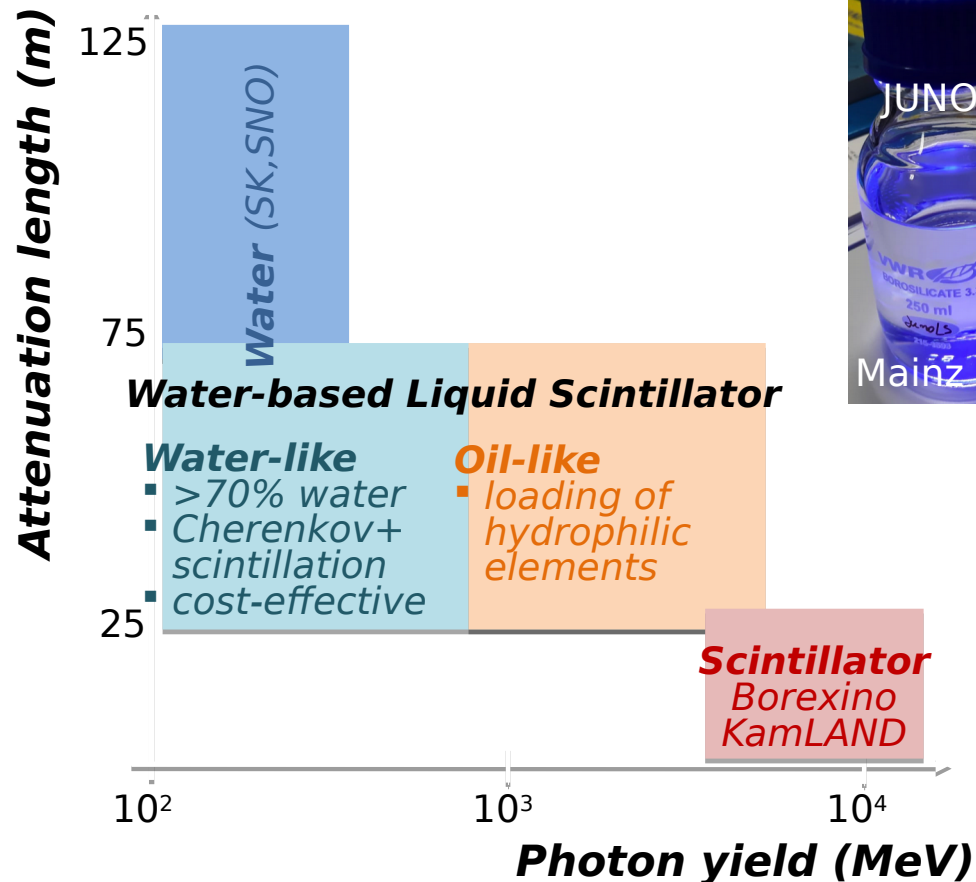


## Other important development:

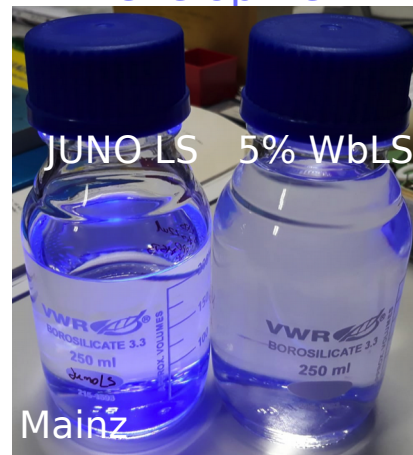
- UC Davis nanofiltration
- LLNL light yield non-linearity & long-arm scattering
- Advanced reconstruction techniques, including machine learning

# Water-based Liquid Scintillator

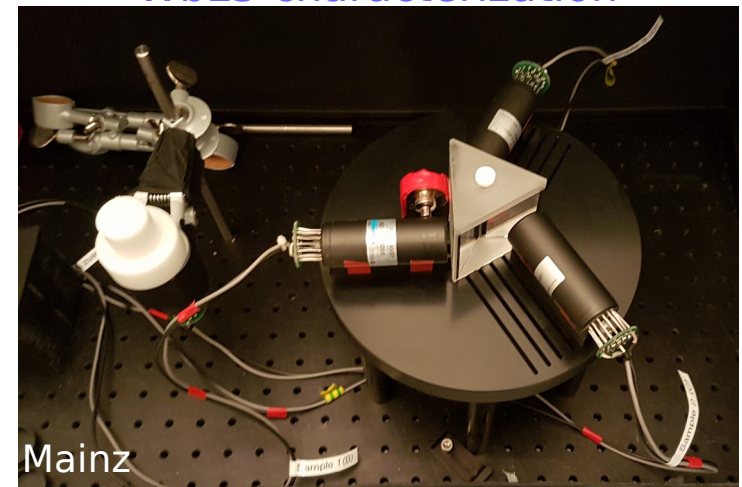
Strong European collaboration



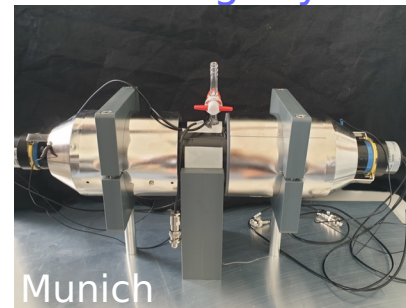
Development



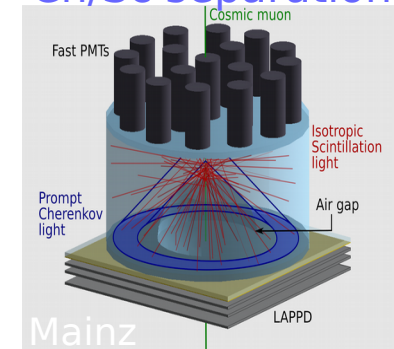
WbLS characterization



Proton light yield

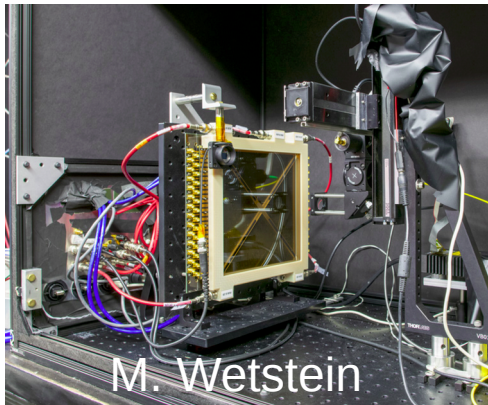


Ch/Sc separation



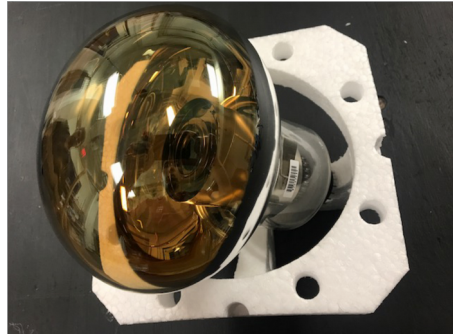
# Photodetectors & Scaling Up

## Emerging technologies



### LAPPDs

~3mm resolution  
TTS~30ps  
Q.E > 20%



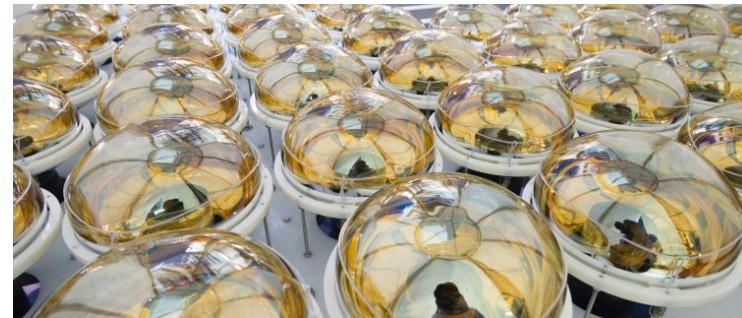
### Very fast large-area & HQE PMTs

TTS~500ps  
Q.E. > 30%



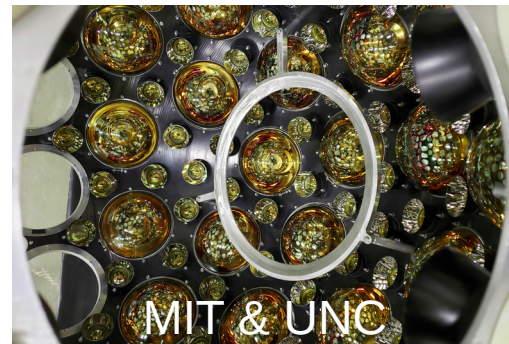
### Large-area red-sensitive PMTs

## Tonne-scale detectors



### ANNIE

~25  
tonne +  
planned  
LAPPD & WbLS  
deployment



### NuDOT

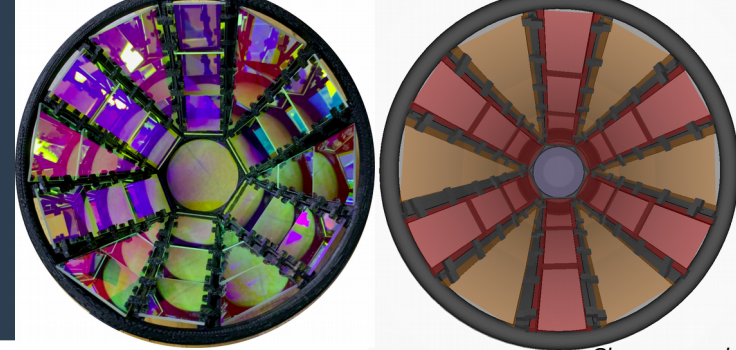
~1 tonne with  
fast PMTs

### Additional tonne-scale test-beds:

- Brookhaven
- LLNL
- University of Sheffield

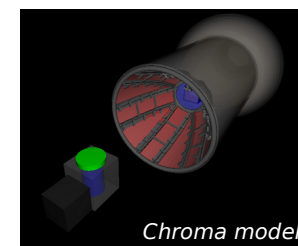
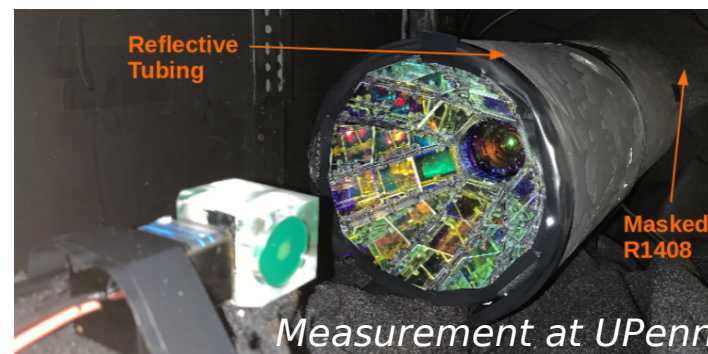
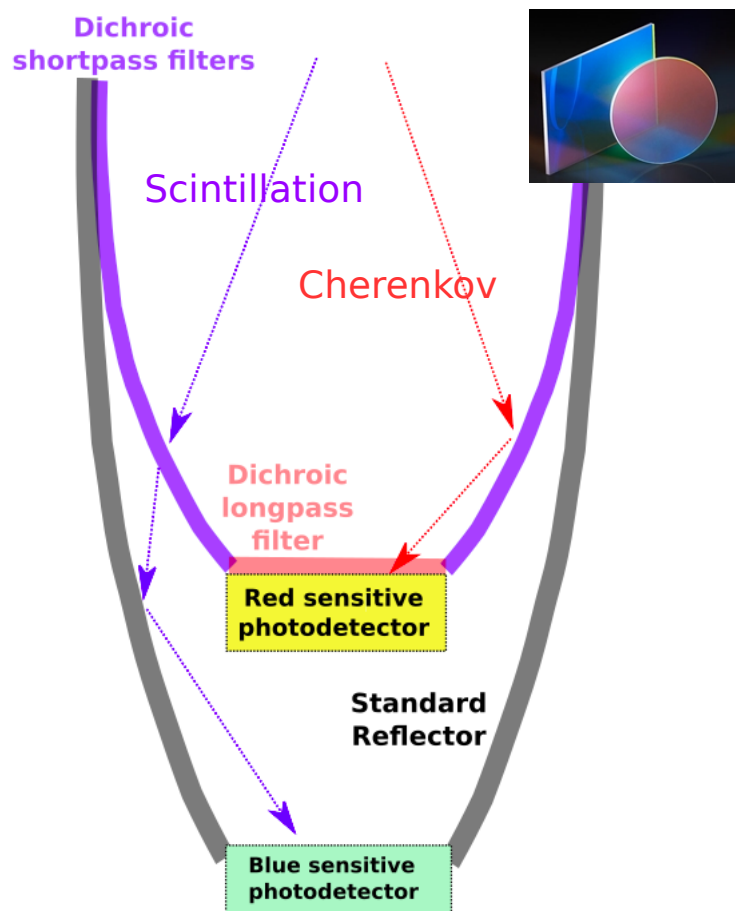


# The Dichroicon

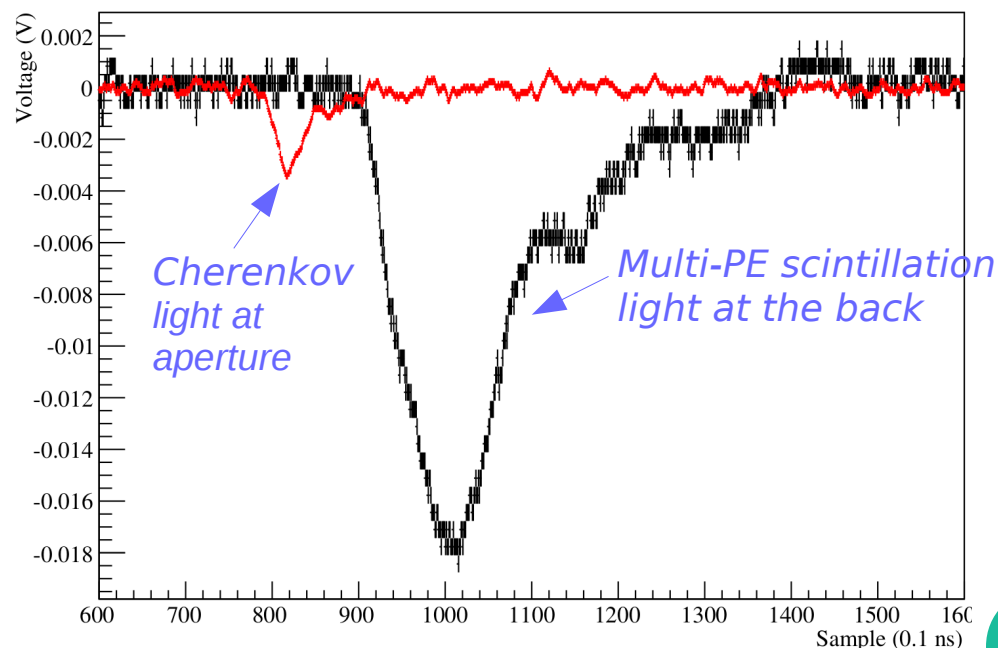


Chroma model

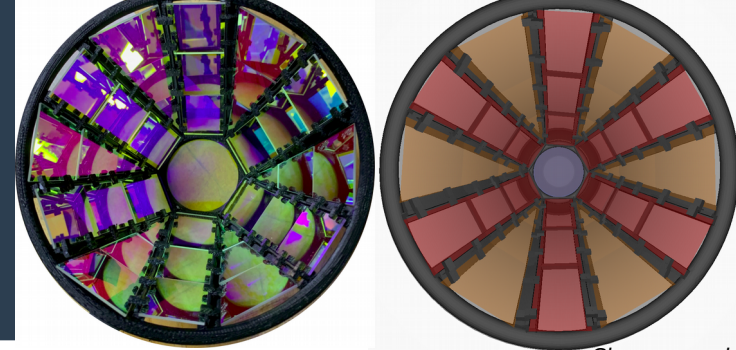
## Spectral sorting using dichroic filters



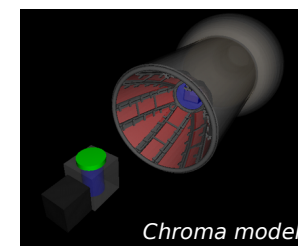
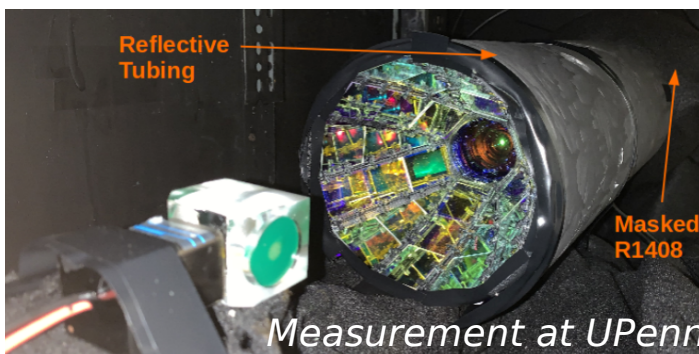
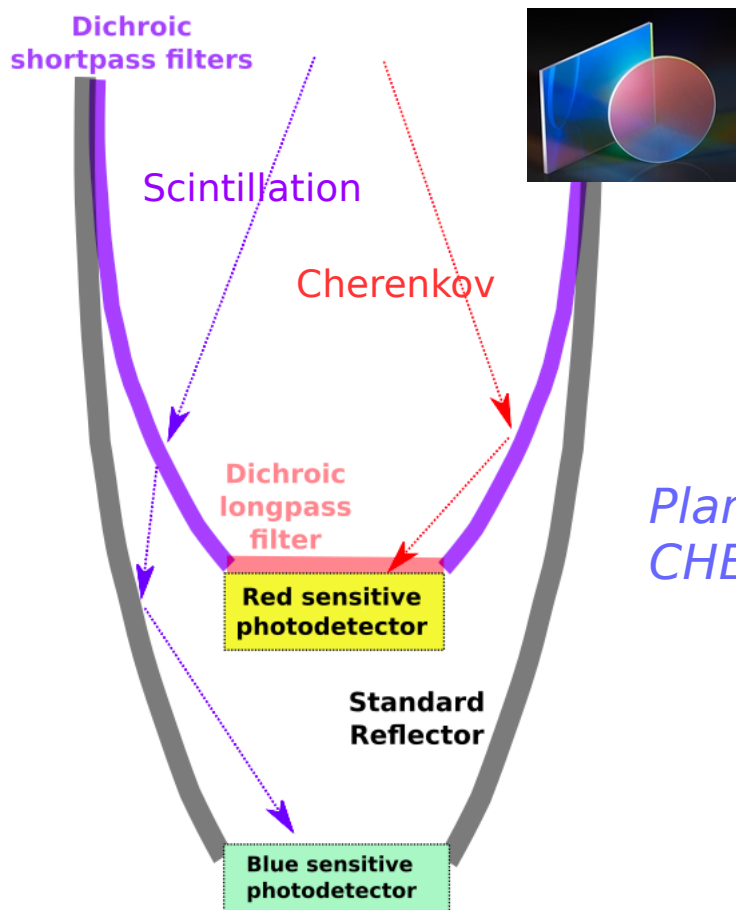
Chroma model



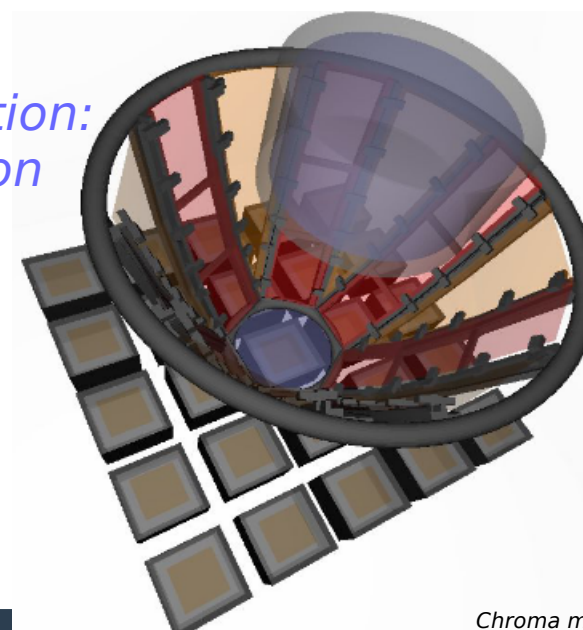
# The Dichroicon



*Spectral sorting using dichroic filters*



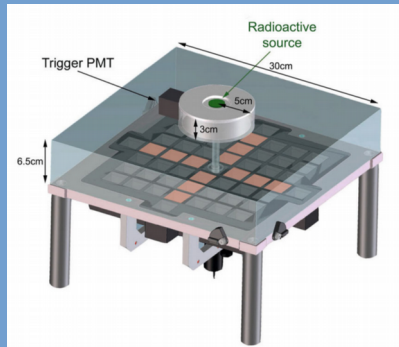
*Planned collaboration:  
CHESS + Dichroicon*



# Path to Theia

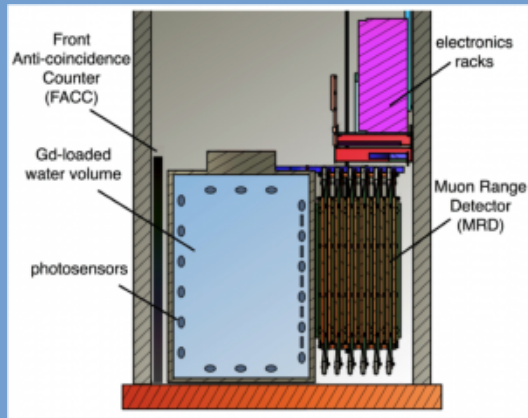
*Clear plan for technology scale up from bench-top to Theia*

**CHESS**



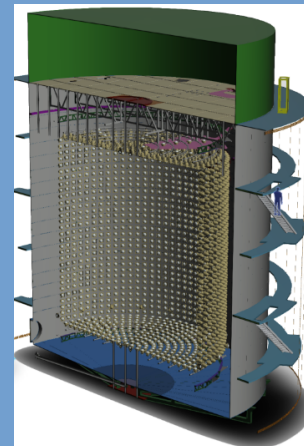
~ 1L

**ANNIE**



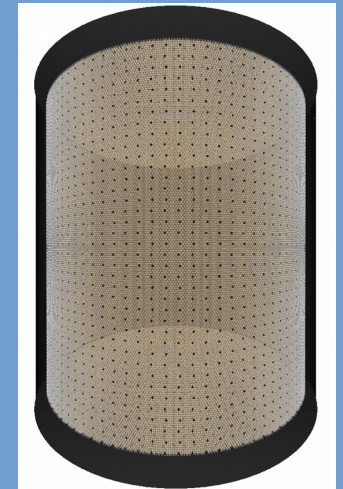
~1 tonne

**AIT/NEO**



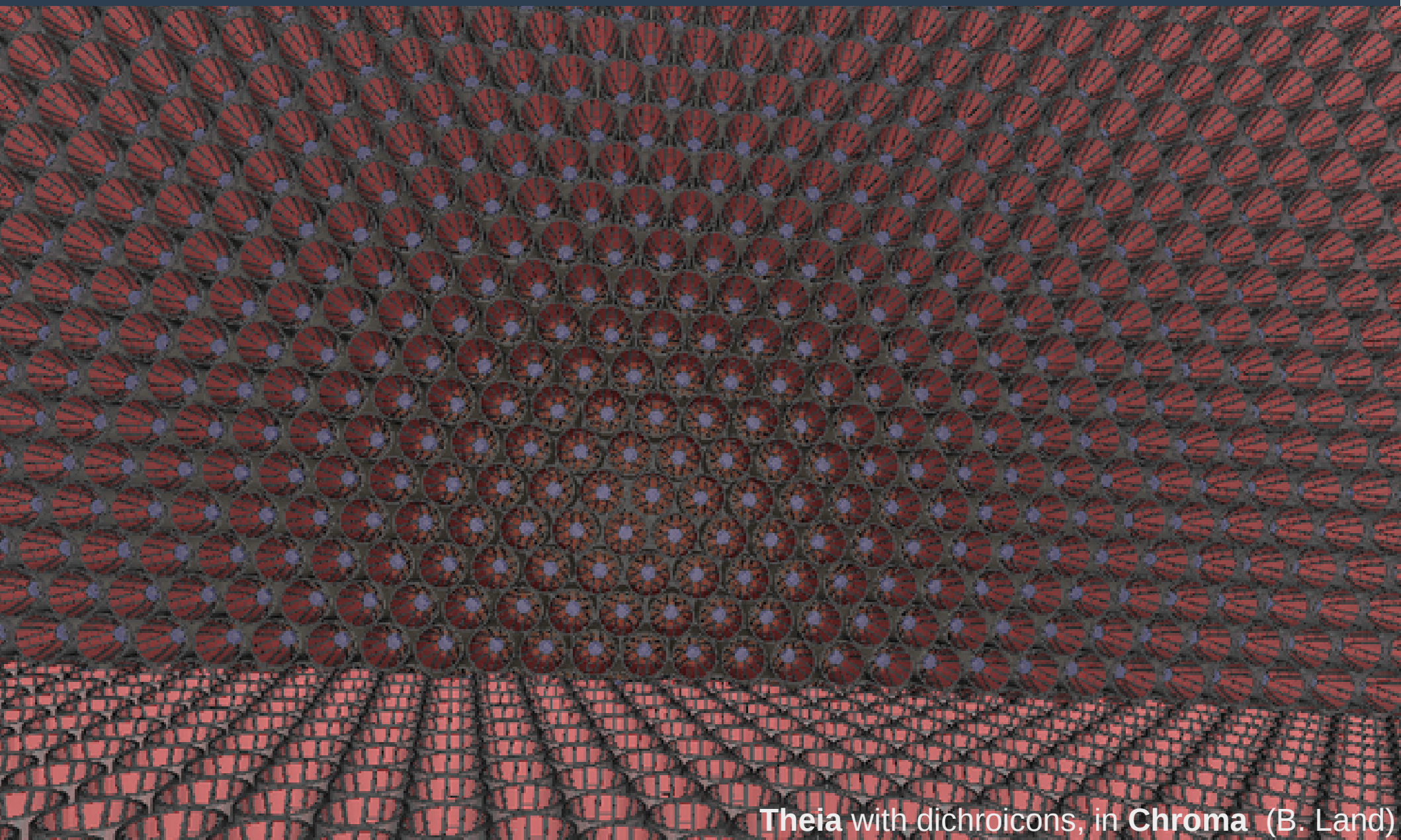
> 1 ktonne

**Theia**



25-100 ktonnes

# Thanks! Questions?



Theia with dichroicons, in Chroma (B. Land)