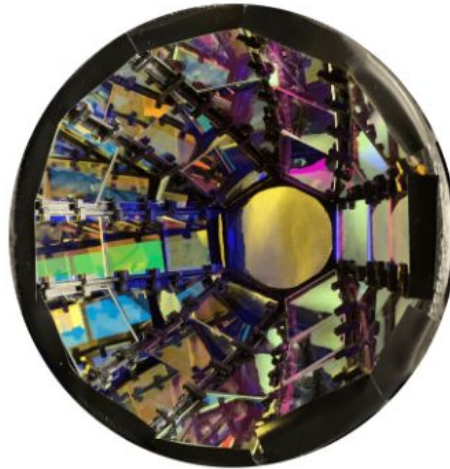


The Dichroicon: Dichroic Filters in Optical Neutrino Detectors



Samuel Naugle

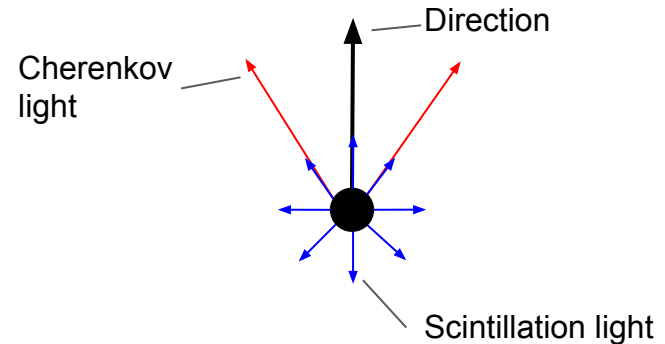
smnaugle@sas.upenn.edu

Outline

1. Brief overview of physics motivations
2. Long term goals for dichroicons
 - a. Theia
3. Near term deployments
 - a. Eos
 - b. R&D at UPenn and other institutions

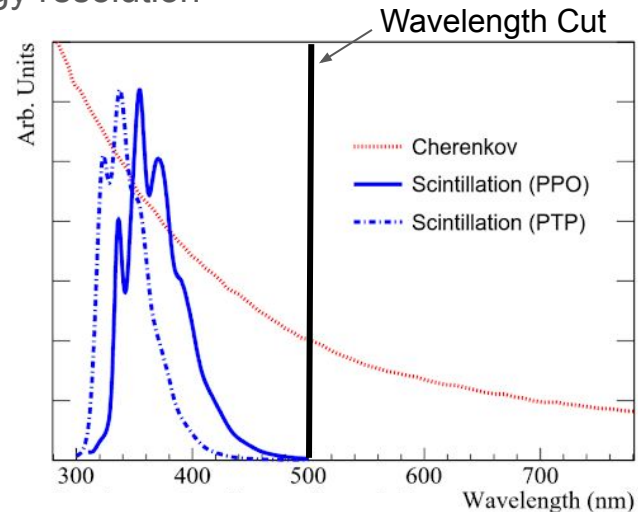
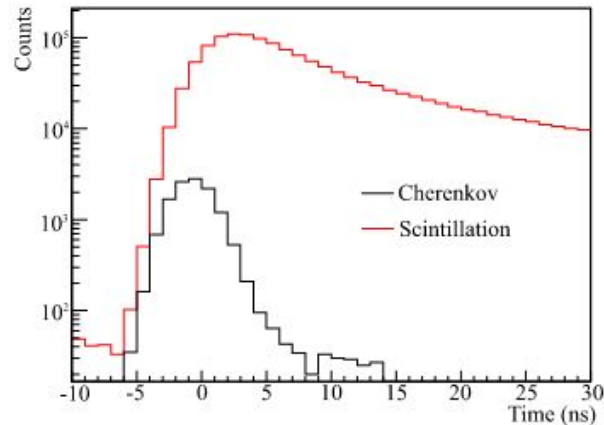
Optical Neutrino Detectors

- Optical neutrino detectors generally come in two classes
 - Scintillator and water Cherenkov detectors
- Water Cherenkov detectors
 - Cherenkov light is pointed in the direction the particle is going
 - Good directional resolution (direction the particle was going)
 - Relatively poor position (where the particle was in the detector) and energy resolution
- Scintillator detectors
 - Scintillation light is emitted isotropically
 - Good position and energy resolution
 - No direction resolution as scintillation light saturates the Cherenkov light



Cherenkov and Scintillation Light

- Hard to utilize both Cherenkov and scintillation light in large neutrino detectors
 - Scintillation light is typically orders of magnitude more intense
- The spectral photon sorting abilities of the dichroic filters allows for new hybrid Cherenkov-scintillator detector
 - Directional resolution with good position and energy resolution

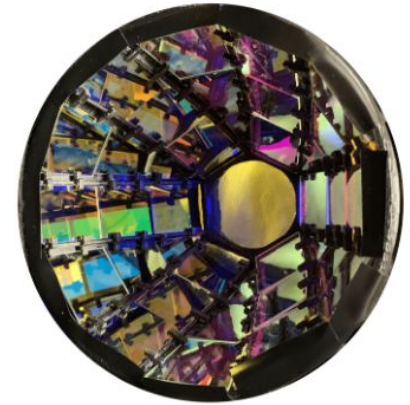
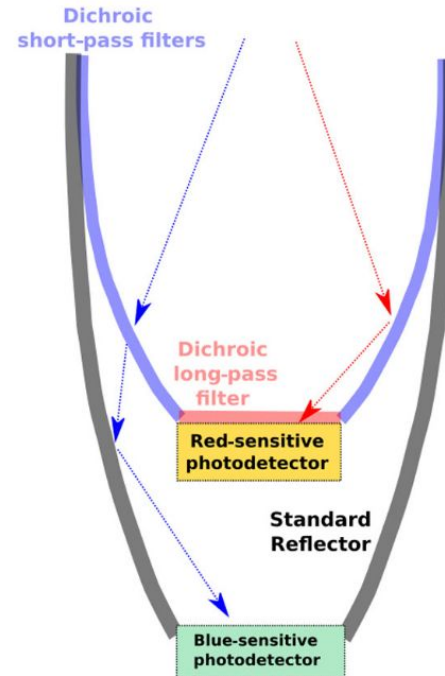


Cherenkov and Scintillation Light

- Being able to leverage both kinds of light would allow for a very broad physics program in a single detector
- Advantages:
 - Increased particle ID capabilities
 - New background rejection strategies
 - Increased sensitivities to new physics processes
- There are additional applications in optical neutrino detectors besides Cherenkov scintillation sorting
 - Correction for dispersion in large detectors
 - And more...
- How do we actually do the sorting?

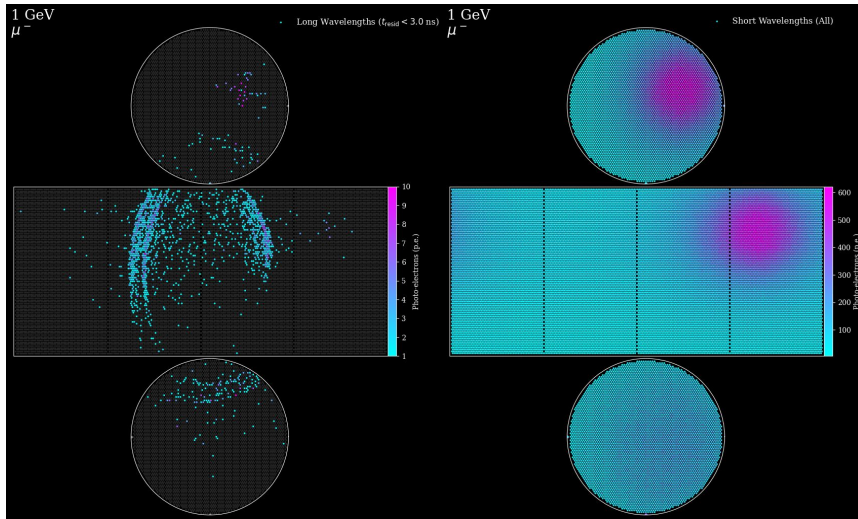
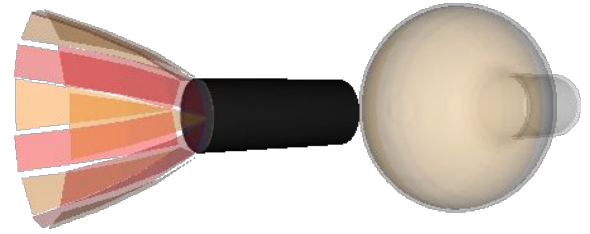
The Dichroicon

- Winston cone of dichroic filters coupled to two PMTs
 - Winston cone is optimal concentrator
- One PMT at the aperture of the Winston cone
 - Collects Cherenkov light
- One PMT behind the barrel of the Winston cone
 - Collects scintillation light



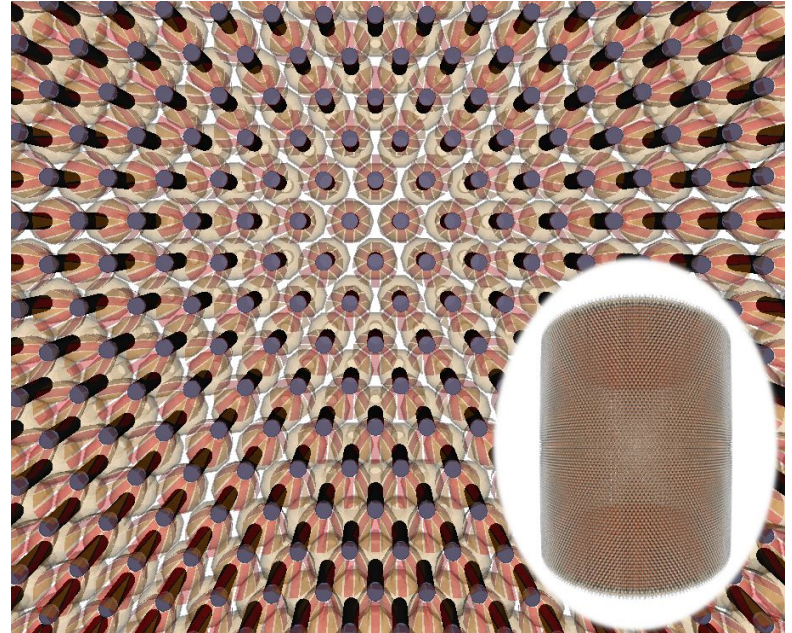
Long Term Goal

- 50 kT neutrino detector called “Theia”
- Could contain up to ~30,000 dichroicons



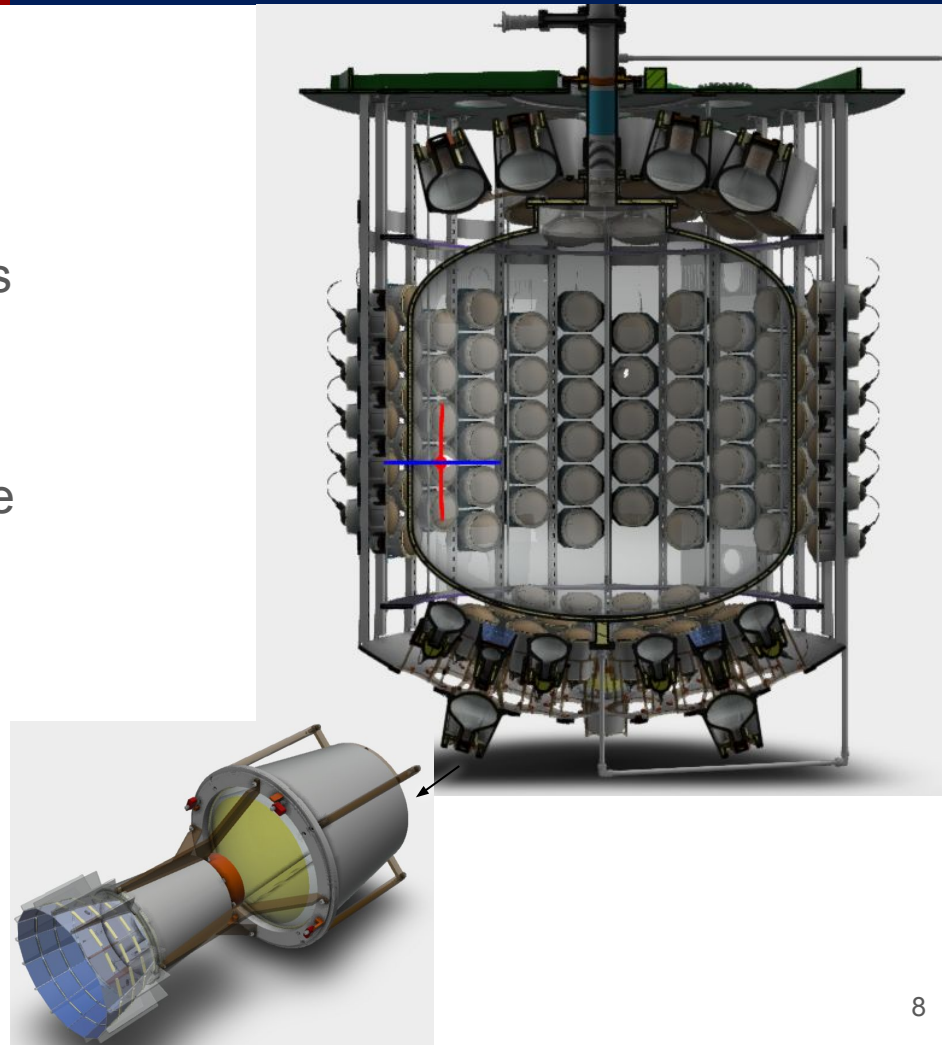
Cherenkov PMTs

Scintillation PMTs



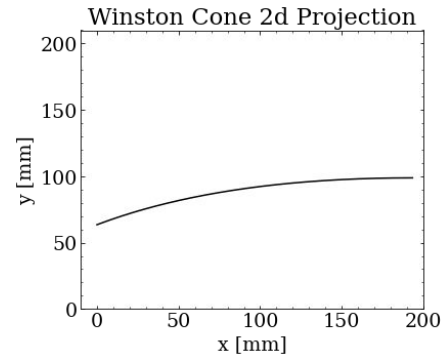
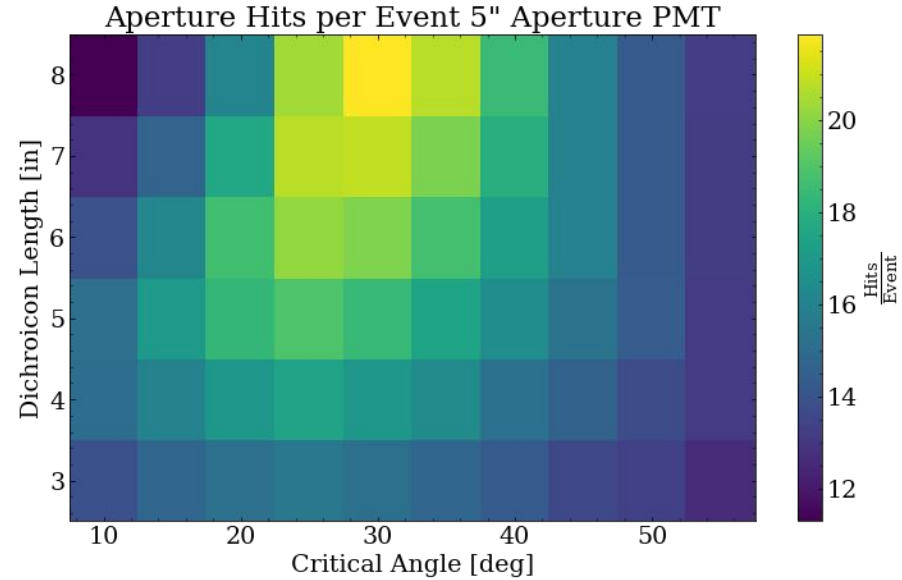
Short Term Goal

- Deployment of 4-10 dichroicons in Eos
 - Eos is a 4 ton particle detector
 - Will serve as a proof of concept for larger experiments like Theia
- Dichroicons will be at the bottom of the detector
- Much of the current optimization work is focused on this deployment
 - Most should carry over to Theia with some slight modifications
- **Deployment will be summer 2023**
 - Phased deployments after that



Shape optimization

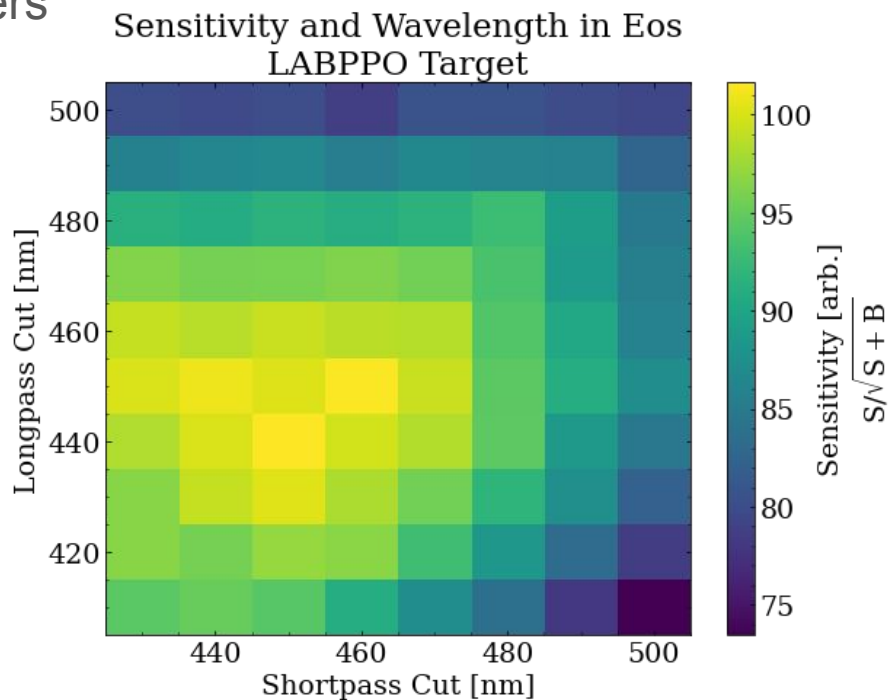
- Three parameters define Winston cone shape
 - Diameter of aperture, critical angle, and length
 - PMT size determines the aperture diameter which is 5"
 - Max length and critical angle are free to vary
- Scans over these two free parameters give optimal shape
- Tiling to approximate curve decreases efficiency
 - Continuous petals improves design!



7.61" long
1.34" wide

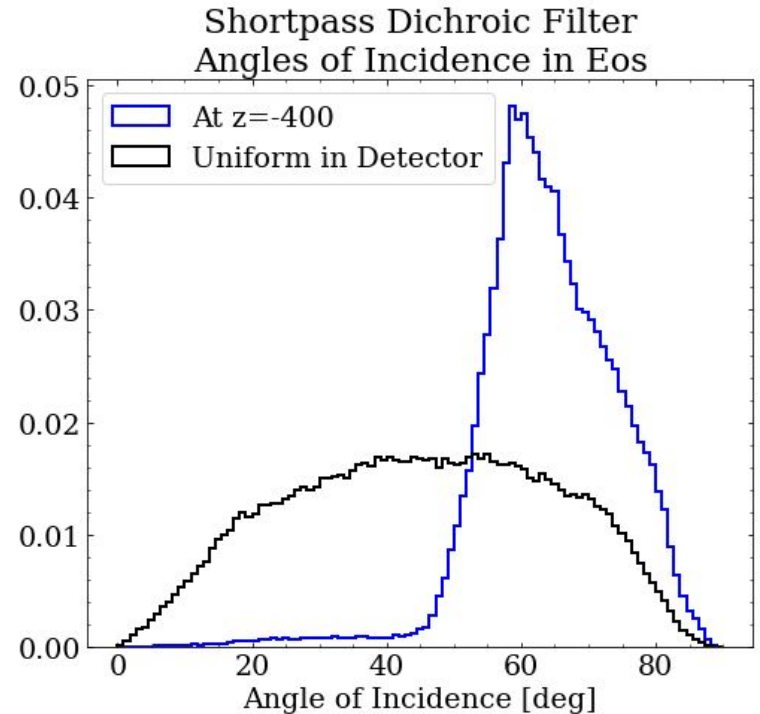
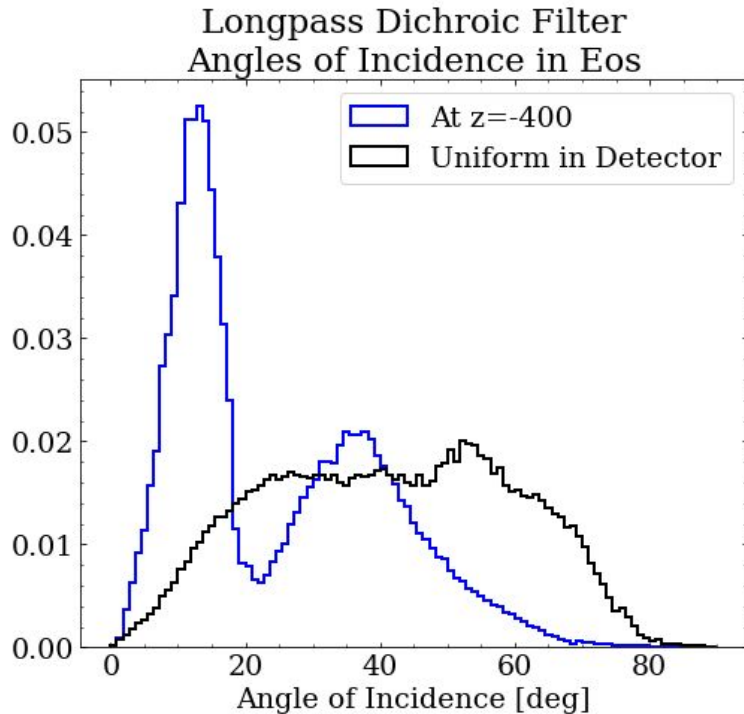
Cut on/off wavelengths

- Cut on wavelength that maximizes sensitivity is $\sim 450\text{nm}$ for both the shortpass and longpass filters



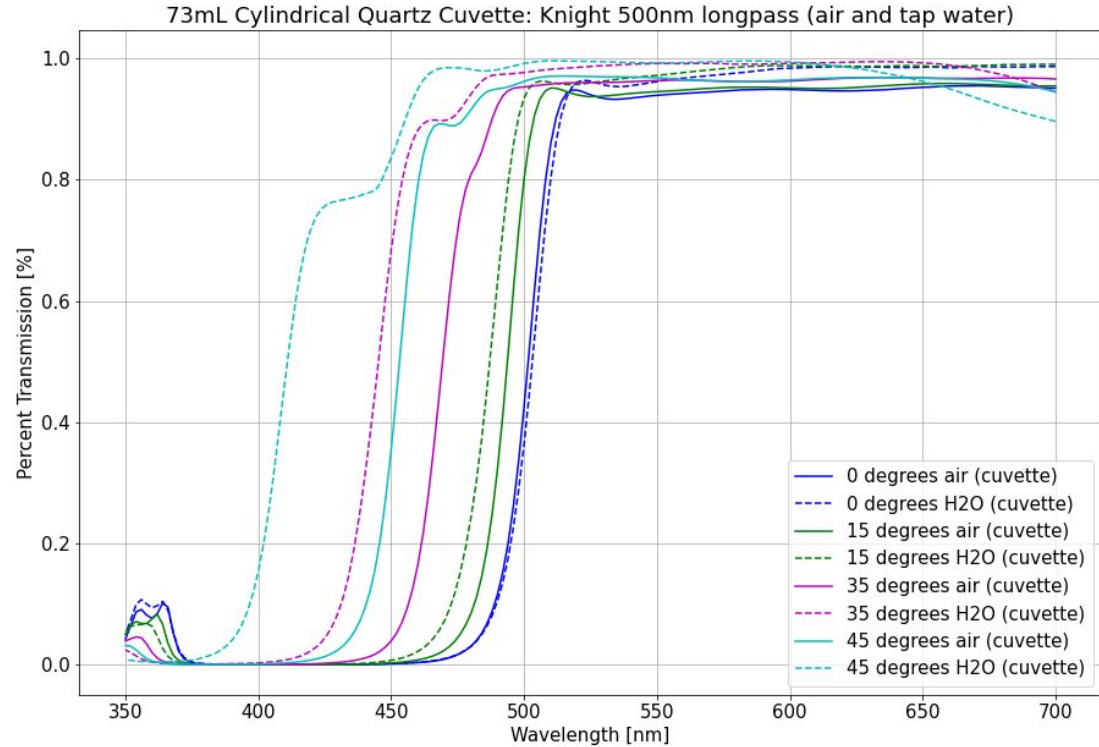
Angle of Incidence

– The angles of incidence on the dichroic filters



Current dichroic filters

- The transmission curves of filters under consideration in air and water
- Transmission > 95% for most AOI
- Reflections are 1-T
- Transmission curves shifted when placed in water
- Per dichroicon price \$3-5k
 - Estimate depends on Winston cone size and tiling strategy



Summary of requirements for Eos

- Shape is Winston cone with 2.5” aperture radius, 6-8” long, critical angle 30-40°
 - Minimize tiling along the barrel
- Cut on wavelengths near 450nm
- Angles of incidence
 - Shortpass: 40 to 75°
 - Longpass: 0 to 45°
 - Prefer minimal translation of cut on wavelength in those angles of incidence
- The filter will be **deployed in water** which will affect filter performance
- Transmissions $\geq 95\%$ for AOI of interest
- Eos will take data in phases
 - If summer timeline is unrealistic we can think about deploying these dichroic filters in later phases

R&D

- If the Eos deployment timeline is not realistic, we are still interested in purchasing dichroic filters for testing
- Specifics will be similar to those described for Eos with slight alterations
- We can add filter transmission curves into our simulations as measurements are made