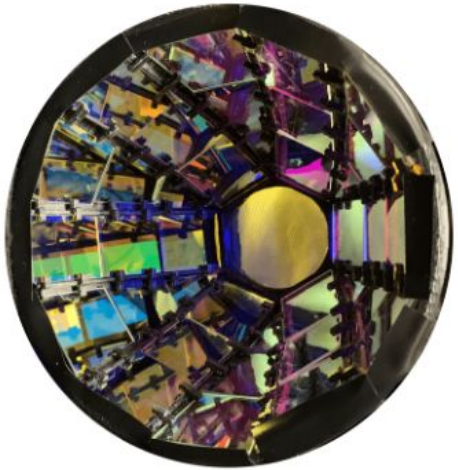
The Dichroicon:
A Spectral Photon Sorter



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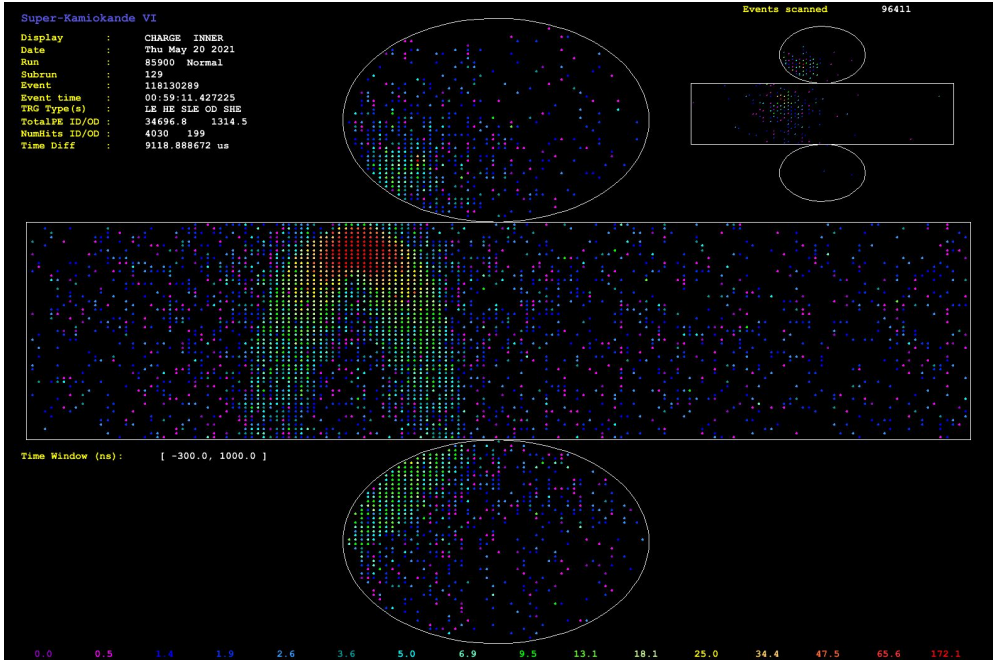
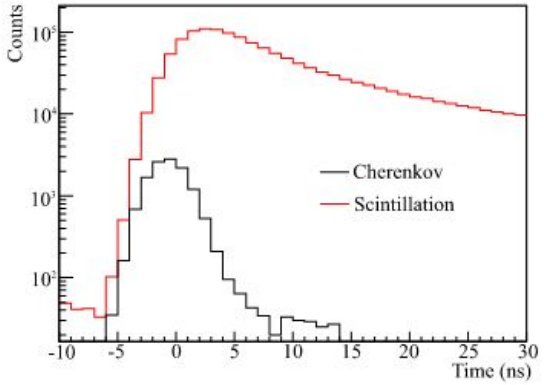
Particle Detectors

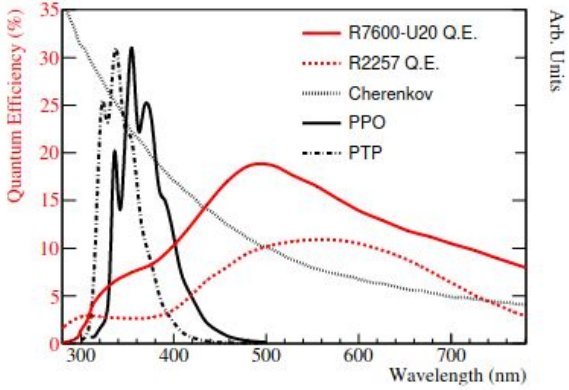
- SNO, SNO+, Super-K, etc.
  - All large neutrino detectors
  - Detect light from neutrino interactions
- Measured properties
  - Arrival times
  - Number of photons
- Ignored information
  - Wavelength
  - Polarization



Cherenkov and Scintillation Light

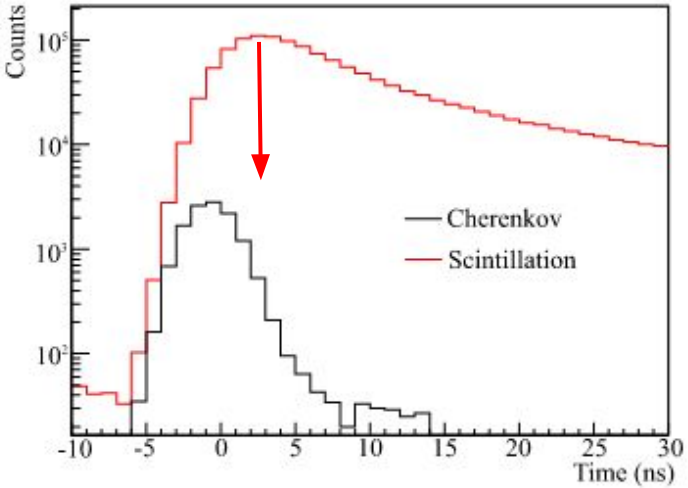
- Detectors often use water or scintillator
  - Must decide between increased energy resolution and light yield vs direction information.
- Difficult to utilize both Cherenkov and scintillation light in a detector
  - Detectors do not measure wavelength
  - Traditional PMTs are cannot resolve the fine time structure that separates the two kinds of light.

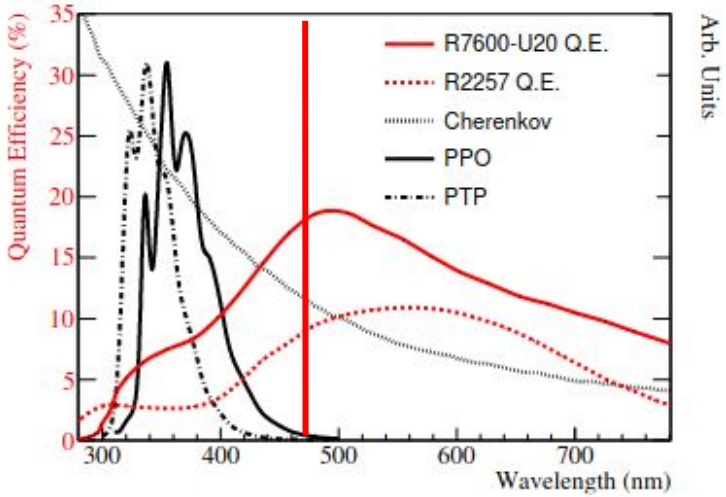




Best of Both Worlds

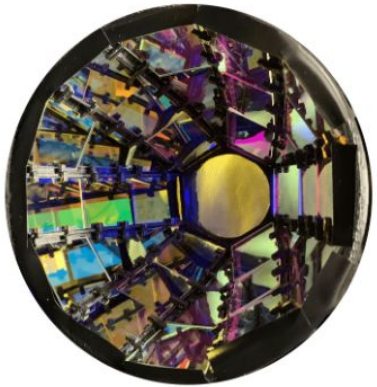
- Is it possible to retain benefits of a water detector within a scintillation detector?
  - Some proposed methods involve decreasing the light yield of the scintillator.

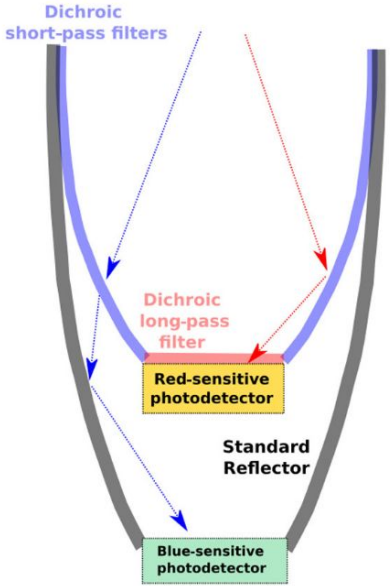


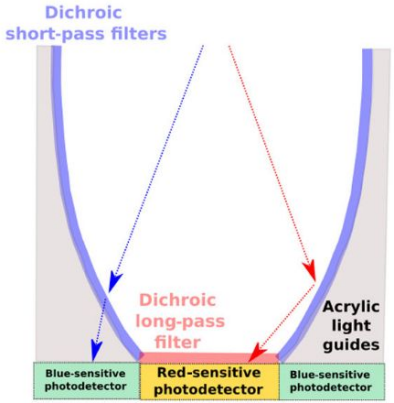


The Dichroicon

- Dichroic filters can be used to sort photons by wavelength
  - Separate Cherenkov and scintillation light decreasing the light yield of the scintillator.







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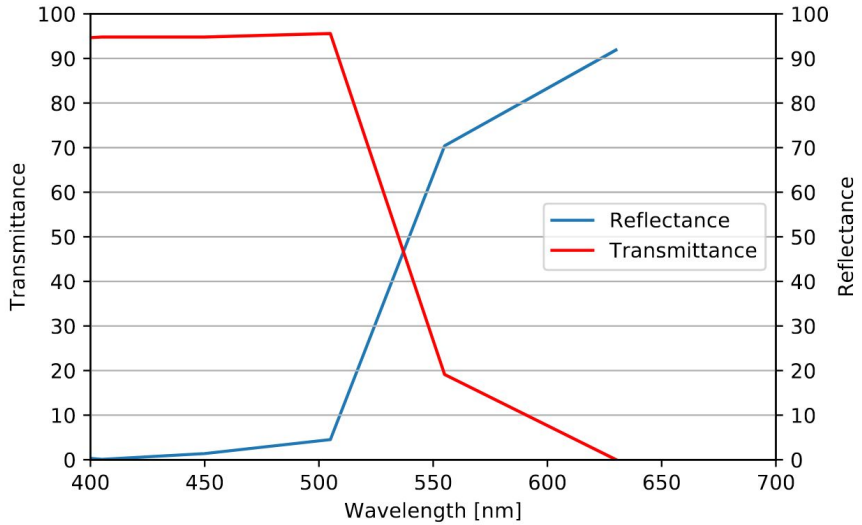
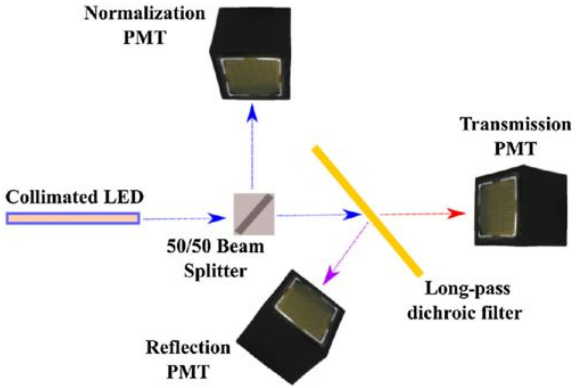
Dichroic Filters

- The dichroic filters act as long or shortpass filters
  - But reflect rather than absorb the rejected light.

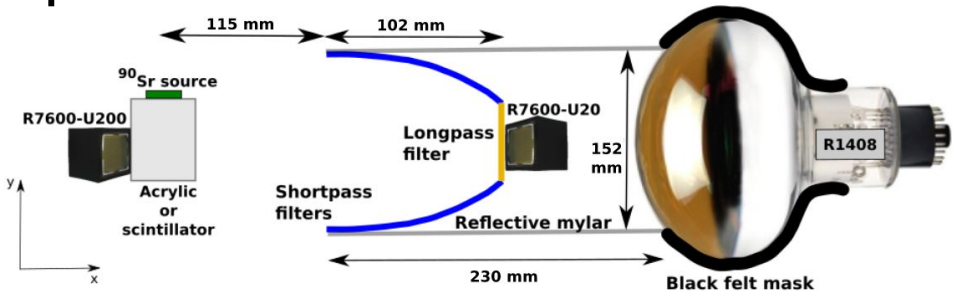


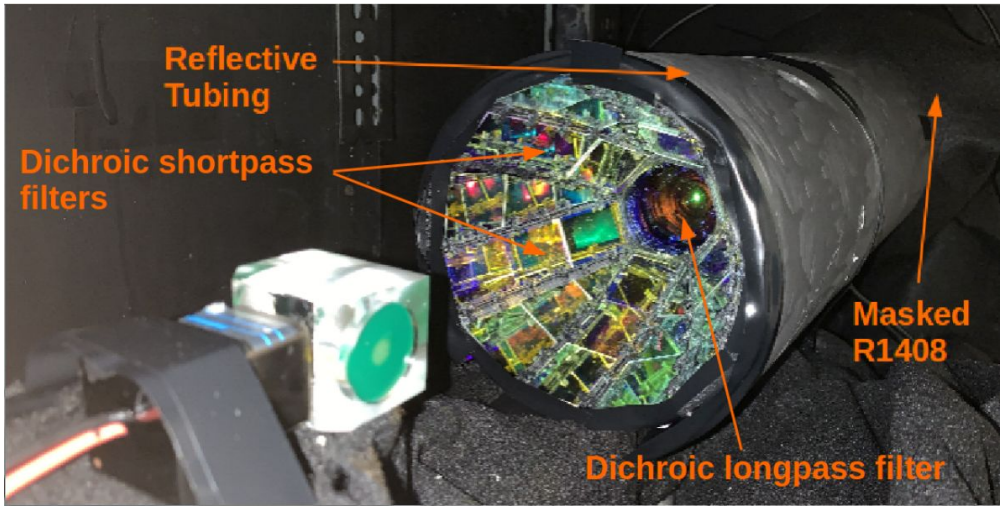


  - Transmittance at 0° incidence and reflection at 15° incidence

Testing the Dichroicon - Setup

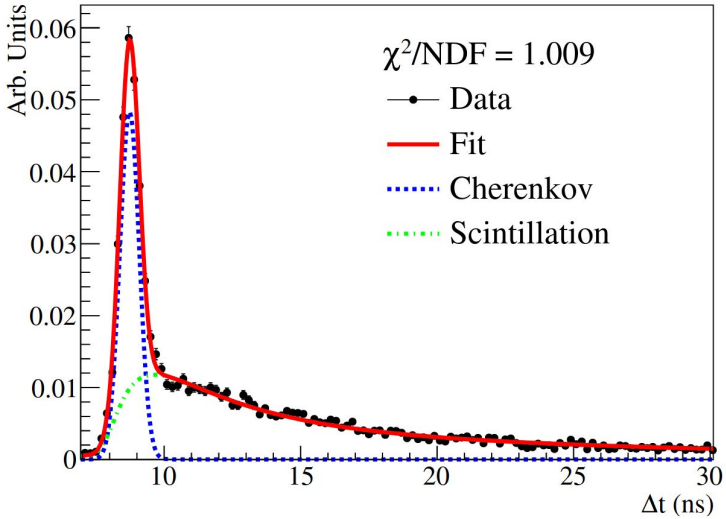
- Initial testing of the dichroicon used a Sr90 source and target of LAB + 2g/L PPO
  - Measured the efficiency of the dichroicon's ability to separate scintillation and Cherenkov light.





Testing the Dichroicon - Results

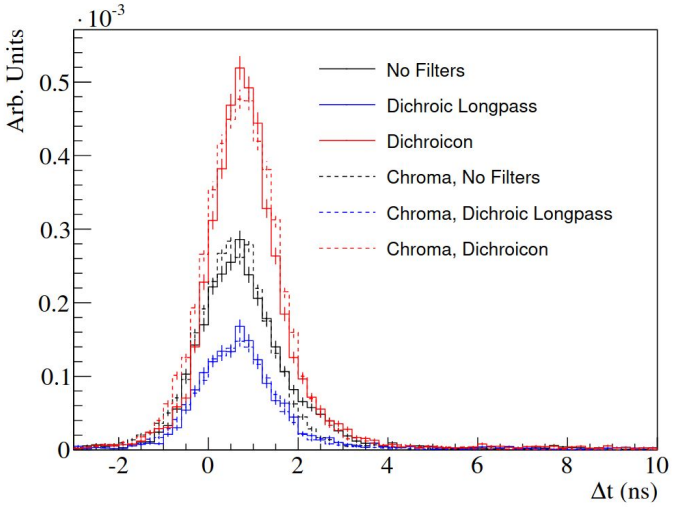
– A fit combining the two time distributions can be used to find the relative concentrations of each kind of light on the aperture PMT.

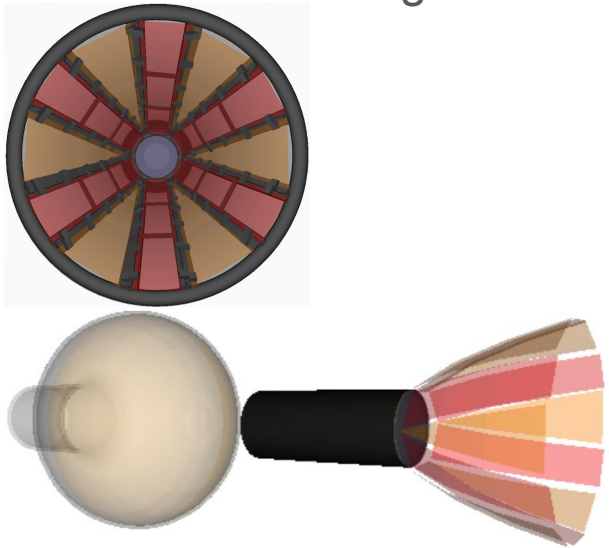


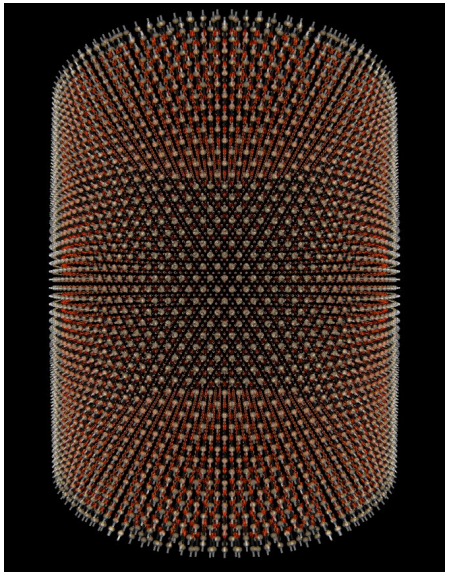
➔ In a prompt time window, Cherenkov photons can be detected with a **purity of over 90%.**

Modeling the Dichroicon

– To understand the impact of the dichroicon in large scale scintillation detectors, the fast optical photon simulation Chroma is being used.







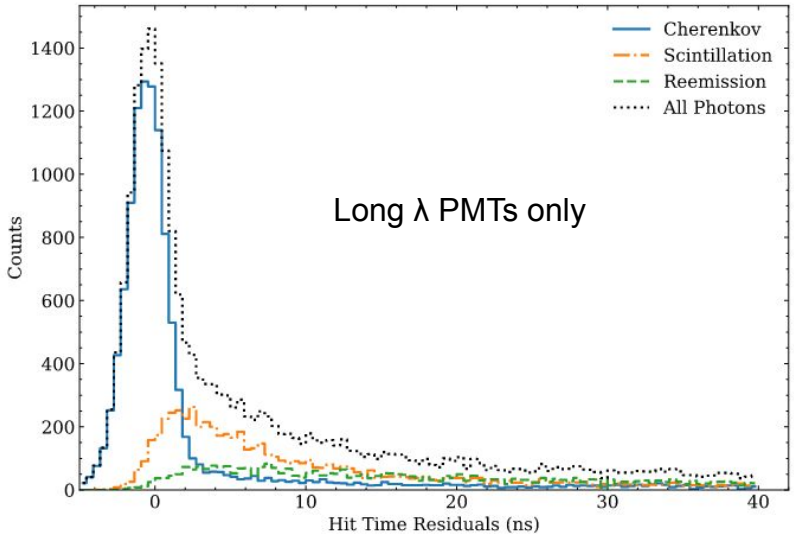
➔ Above is a visualization of a 50kT Theia detector. To the left are renderings of dichroicons in Chroma

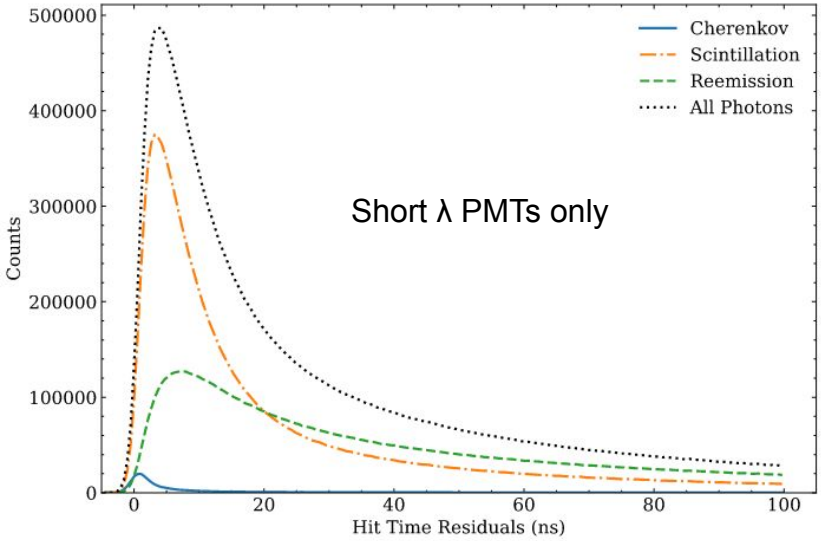
Contact us if you are interested in using Chroma!

Impact in Theia-like Detectors

– In this detector, the scintillation and Cherenkov signals can still be separated with great efficiency.

  – Even with orders of magnitude more scintillation light being produced.

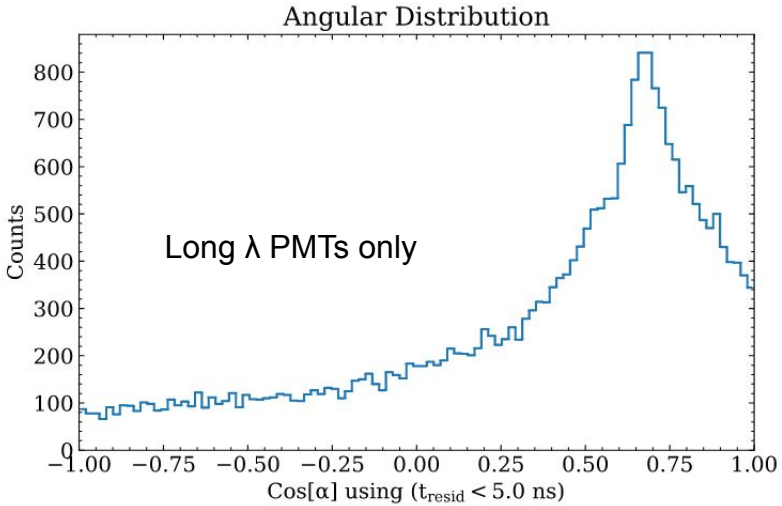


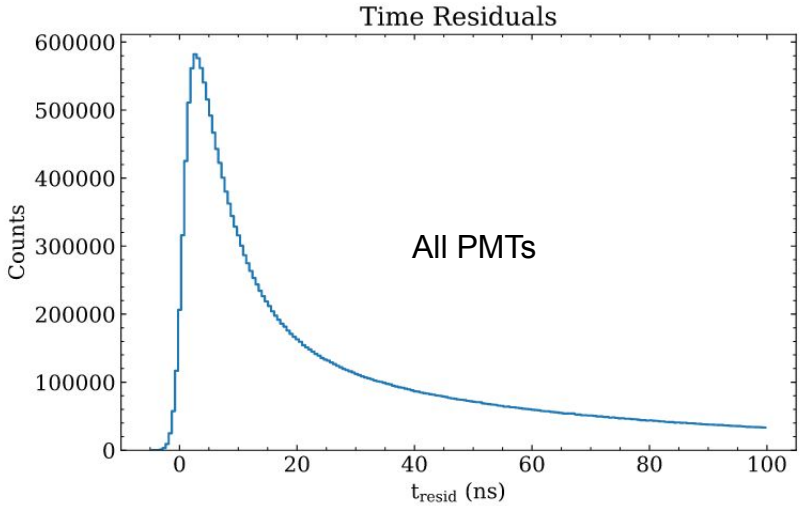


– 5MeV e^- uniformly generated within the detector

Impact in Theia-like Detectors

– The dichroicon allows detectors to separate the two signals
  – This greatly improves a detectors reconstruction ability, and increases particle ID efficiency.



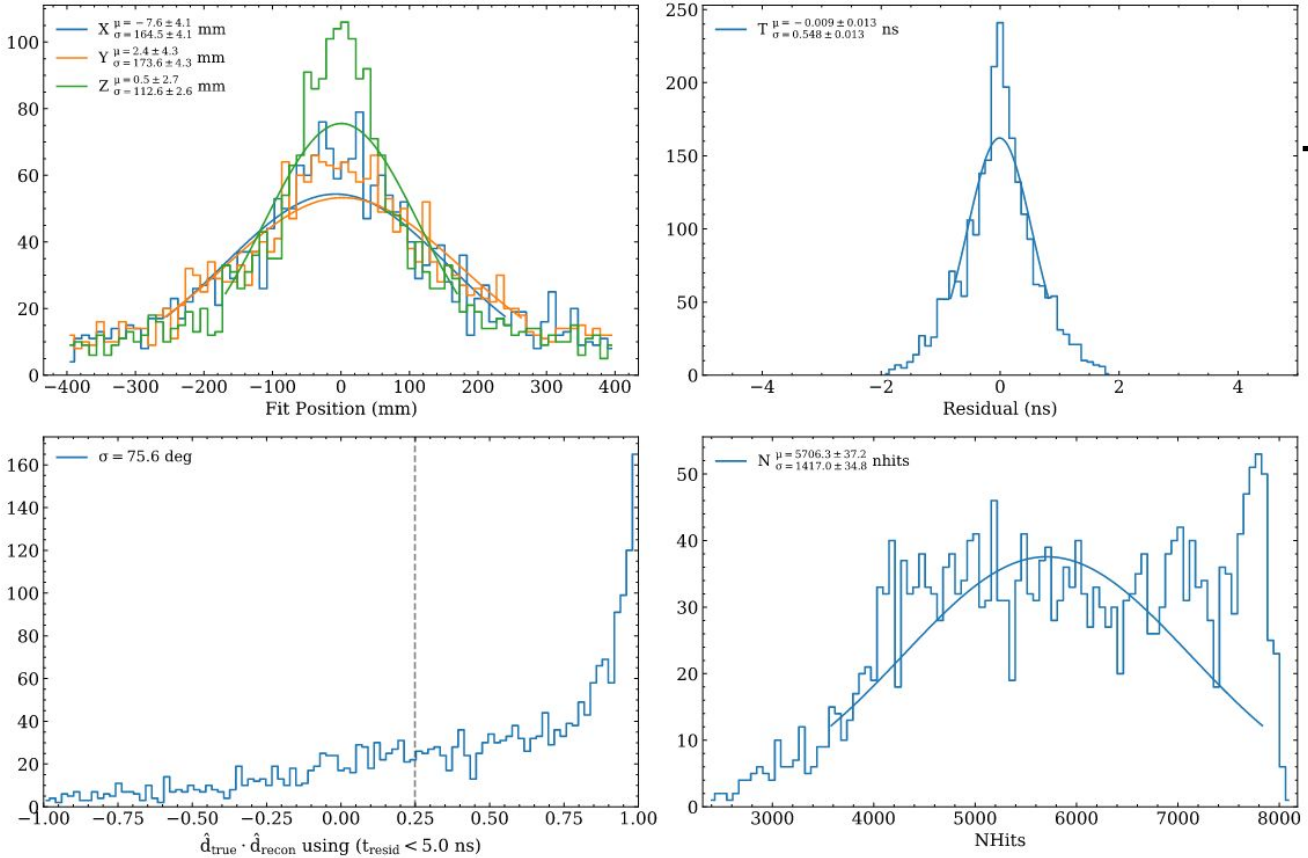


  – Cos[α] is the cosine of the emission angle of the Cherenkov light relative to the event direction
  – 5MeV e^- uniformly generated within the detector

Reconstruction in Theia-like Detectors

– 5MeV e⁻ uniformly generated within the detector

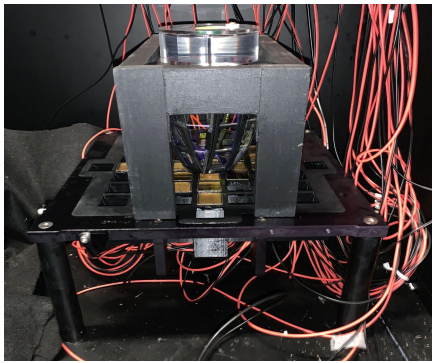
➔ 20 cm position resolution

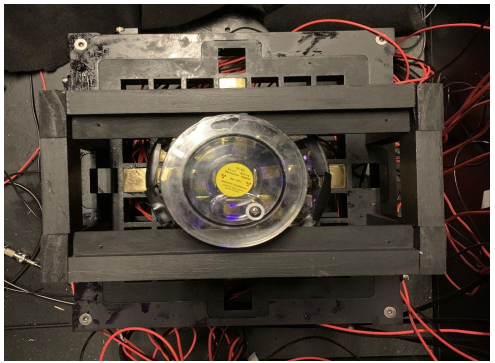


➔ Sub ns time resolution

Looking Ahead

- Work is currently being done to try and fully quantify the impact of dichroicons in large scale particle detectors
  - Through simulation and experiment.
- A dichroicon has been deployed at Berkeley Lab
  - Will probe a more high energy regime using atmospheric muons, opening the door to new applications.





Concluding Remarks

- The dichroicon is a spectral photon sorter that allows large scale particle detectors to separate scintillation and Cherenkov light without drastically reducing the scintillation light yield.

- Work is currently underway to fully characterize the impact of dichroicons in these particle detectors, but current results look promising!

Acknowledgements

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Dichroicon results:
Phys. Rev. D 101, 072002 – Published 15 April 2020

Super-K event from:
http://www-sk.icrr.u-tokyo.ac.jp/realtimemonitor/

Theia: an advanced optical neutrino detector:
Eur. Phys. J. C 80, 416 (2020)

Chroma github repository:
https://github.com/BenLand100/chroma

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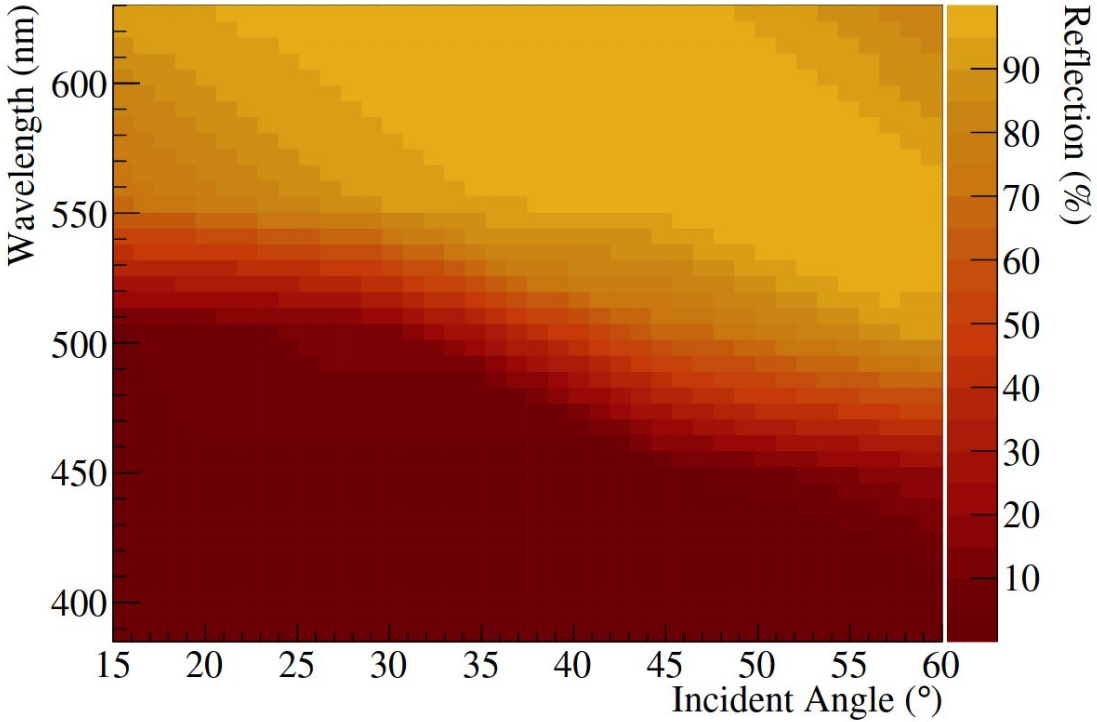
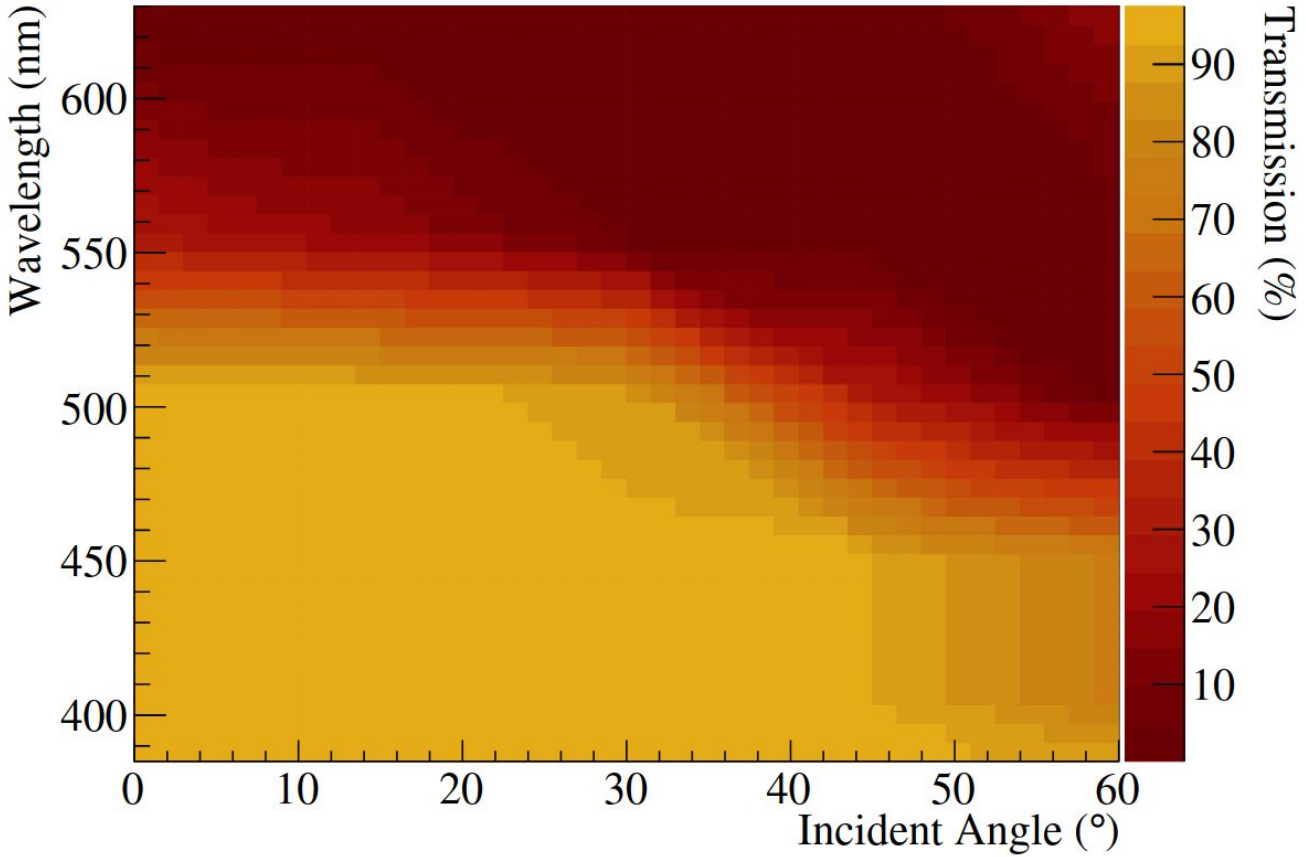
Feel free to email me with any additional questions at smnaugle@sas.upenn.edu and thanks for listening!

Back ups


Wavelength (nm)
600
550
500
450
400
15
20
25
30
35
40
45
50
55
60
Incident Angle (°)
Reflection (%)
90
80
70
60
50
40
30
20
10


Wavelength (nm)
600
550
500
450
400
0
10
20
30
40
50
60
Incident Angle (°)
Transmission (%)
90
80
70
60
50
40
30
20
10