Dichroic Approaches to Photon Collection

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Outline

1. Dichroic filters
2. Applications to photon collection
   a. ARAPUCA
   b. Dichroicon
3. Design considerations
4. Concluding remarks
Dichroic Filters

– Reflect or transmit photons by wavelength
  – With minimal absorption
– Many films of differing indices of refraction
  – Strongly angularly dependent response
  – Surrounding medium affects filter response
Applications: ARAPUCA

– Named after a hunting trap as it “traps” light
– Employs dichroic filters and wavelength shifting materials
– Trapped light then bounces around inside the “trap” until it is absorbed or detected
Applications: ARAPUCA

– Allows for a small active surface area to collect photons from a larger surface area
  – Effectively functions like a concentrator

H.V. Souza, arXiv:2112.02967
Applications: Dichroicon

– The “dichroicon” separates photons using dichroic filters
  – Many applications including Cherenkov/scintillation separation, correcting for dispersion, …
– Allows for a hybrid Cherenkov scintillation detector with a broad physics program
Applications: Dichroicon

- Benchtop measurements show 93% of photons in early time window are Cherenkov
Applications: Dichroicon

– The performance of the dichroicon was also measured using the CHESS experiment
  – Sources: Cosmic-ray muons and radioactive sources
  – Targets: Water, 10% WbLS, LAB with 2 g/L PPO
  – Dichroicon layouts: Standard and Complementary

*Paper coming soon!
Applications: Dichroicon

- Probes much higher energy regime with a pixelated array of fast PMTs
- Includes measurements taken with 10% WbLS
- Introduces complementary dichroicon design

*Paper coming soon!
Applications: Dichroicon

– Compare between set ups and target using the purity, P

Atmospheric Muons Incident on WbLS Target
Cherenkov PMT

![Graph showing comparisons with different dichroic setups.]

\[
P = \int_{\mu-3.5\sigma}^{\mu+1.5\sigma} \frac{N_{Ch}(t)}{N_{Ch}(t) + N_{Sc}(t)} dt
\]

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<thead>
<tr>
<th>Purities</th>
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<th>Complementary</th>
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<tbody>
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<td>10% WbLS</td>
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Applications: Dichroicon

– Planned future deployment of dichroicons in Eos
  – Eos is a ~4 ton demonstrator planned to be constructed in the next year
Applications: Dichroicon

– Far future goal for dichroicons is Theia
  – Monolithic kiloton-scale hybrid Cherenkov/scintillation detector
  – Could be equipped with large number of dichroicons

Design Considerations

To discuss design considerations we can revisit the CHESS deployment.

Atmospheric Muons Incident on WbLS Target
Cherenkov PMT

Why is there more scintillation light?

Why is the purity lower?

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Design Considerations: Angular Dependence

– Dichroic filters have a strongly angular dependent response
  – Due to the thin film interference that transmits and reflects photons
  – This must be considered in device design
Design Considerations: Media Dependence

– The behavior of the dichroic filters also depends on the index of refraction of the surrounding media
Concluding Remarks

– Dichroic filters have many new and exciting applications to a wide range of particle physics
  – ARAPUCAS, dichroicons
    ■ A variety of new analysis and reconstruction techniques
– Demonstrations of their utility have already been confirmed
– Still in early stages of R&D, many new and exciting possibilities still haven’t been explored
Acknowledgements

ARAPUCA information:
A.A. Machado et al 2018 JINST 13 C04026
H.V. Souza, arXiv:2112.02967

Previous dichroicon paper:
Phys. Rev. D 101, 072002 – Published 15 April 2020

More information on Eos can be found in “Future Advances in Photon-Based Neutrino Detectors: A SNOWMASS White Paper”:
https://arxiv.org/abs/2203.07479

Theia: an advanced optical neutrino detector:

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