SIDIS Cherenkov Detectors

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SoLID Collaboration Meeting, October 14-15 2011, JLab

Outline

→ Requirements: 2 Cherenkov detectors for positive identification of electrons and pions

→ Design

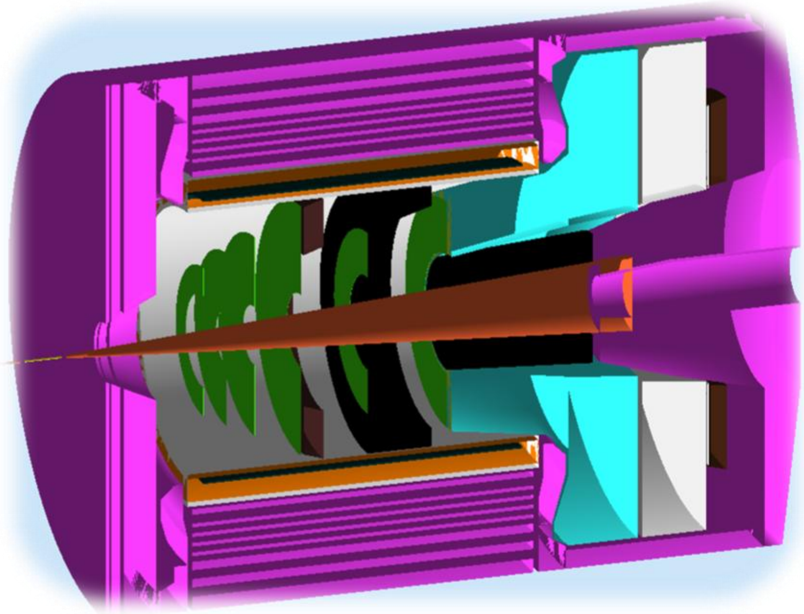
→ Mirrors
→ Photon detector options: GEMs + CsI , PMTs

→ Detectors performance

→ The electron Cherenkov: collection efficiency and signal
→ The pion Cherenkov: work in progress

Requirements

➡ Threshold Cherenkov:
- electron-pion separation
- pion-kaon/proton separation



SIDIS electron Cherenkov: 1.5 – 4.5 GeV

- positive identification of electrons
- don't care about performance below 1.5 GeV
- CO_2, CF_4 would work as radiator
- gas length available: ~ 2 m (kinematics dependent)

SIDIS pion Cherenkov: 2.5 – 7.5 GeV

- positive identification of pions
- C_4F_8O at 1.5 atm would work as radiator
- gas length available: ~ 0.9 m (kinematics dependent)

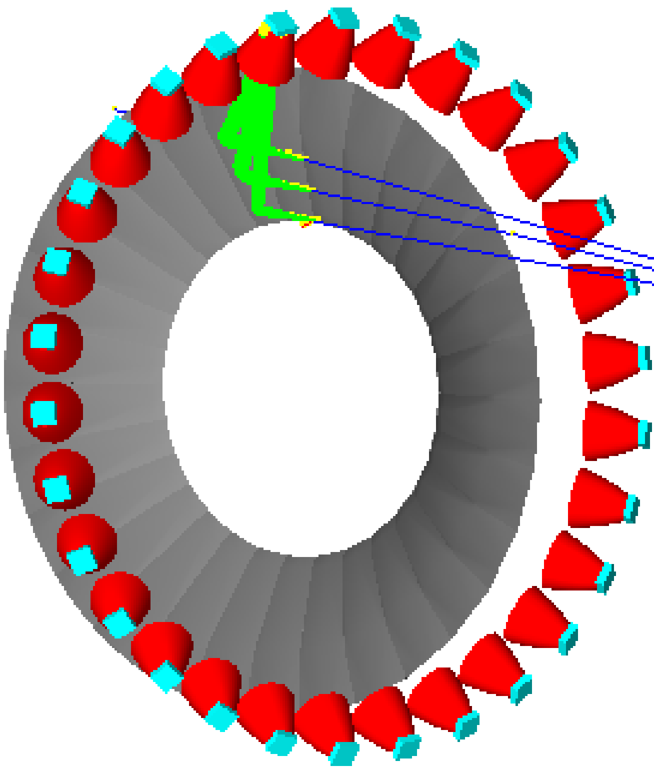
➡ 2π coverage (SIDIS)

➡ Perform in non-negligible magnetic field environment

➡ Simple design: cost effective, easy to install, operate

Optics: Spherical Mirrors

➡ Purpose: focus on small size photon detectors + ensure good 2π coverage



How we “make” them: using the “small spread around the central ray” approximation

- Input: x_i (central ray) and x_r (the photon detector coordinates)
- Output: radius of sphere (mirror curvature) and position of its center

$$R = \frac{2}{\cos\theta\left(\frac{1}{x_i} + \frac{1}{x_r}\right)}$$

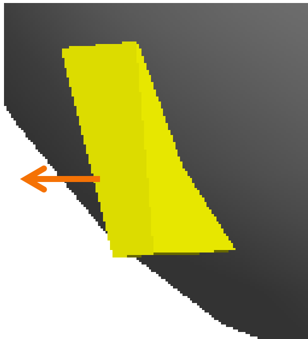
x_i = incident ray on mirror

x_r = reflected ray

θ = angle between incident ray and normal to the mirror

The mirror size is defined by the polar angular acceptance that needs to be covered and number of sectors (30)*

Cone section with size defined by the min and max polar angles intersects sphere of radius R to cut out one of the 30 spherical mirrors



*SIDIS doesn’t need sectoring but PVDIS does

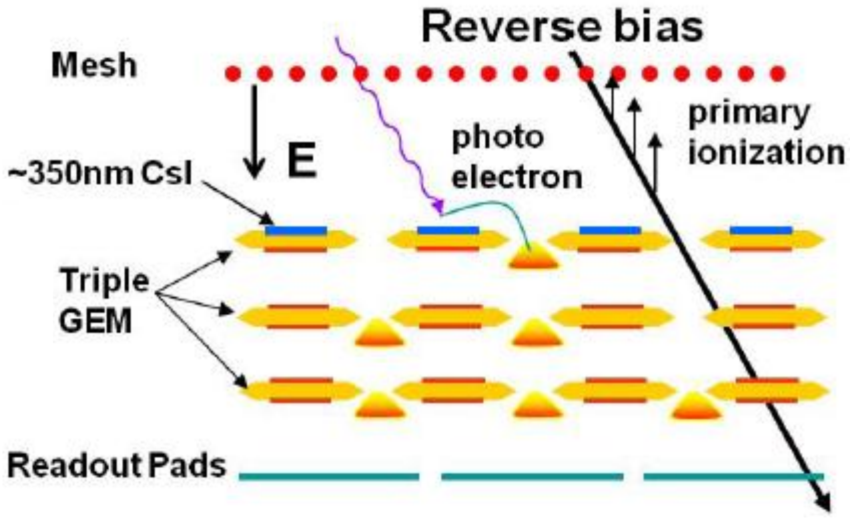
Photon Detectors

GEMs + CsI (used by PHENIX)

→ Insensitive to magnetic field

→ CsI: sensitive to deep UV light, high quantum efficiency (up to 60-70% at 110 nm)

We need:
- Pure gas transparent to UV light
- Mirrors with good reflectivity in deep UV



PMTs

→ Sensitive to magnetic field

→ Photocathodes typically sensitive to visible light mostly

We need PMTs:
- Resistant in SoLID magnetic field
- Suitable for tilling

H8500C-03

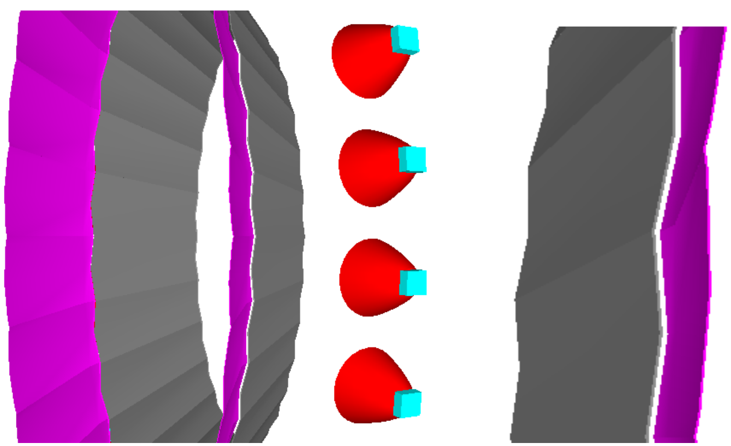
Other: we 'll keep looking

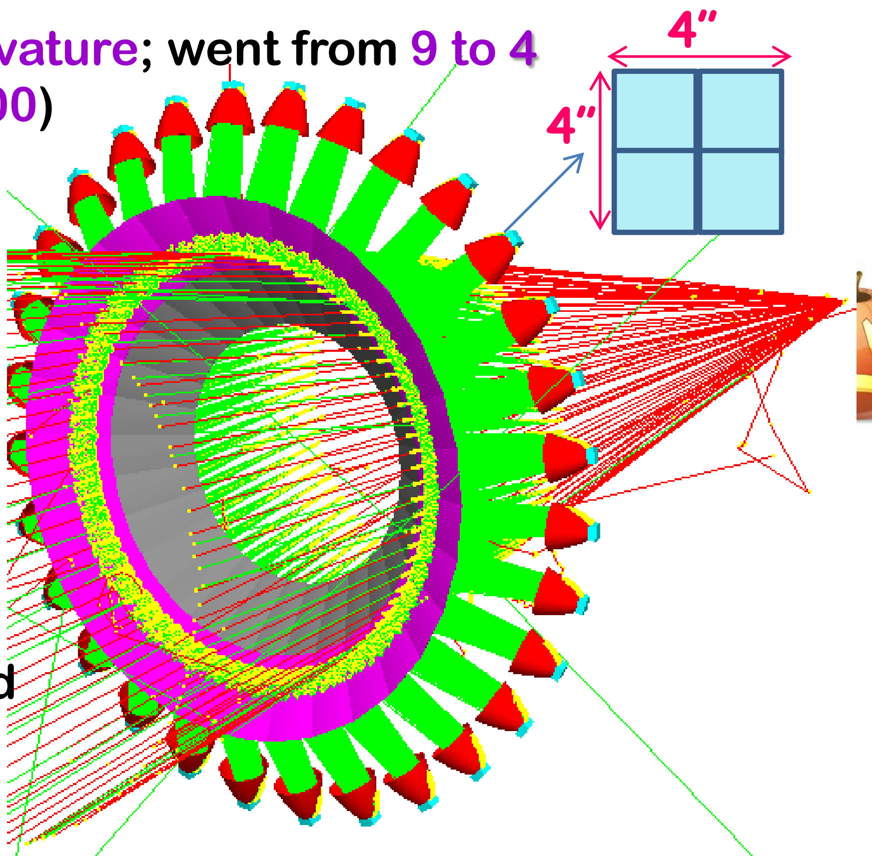
The Electron Cherenkov (PMTs): Design

- **Radiator**: CO_2
- **Mirror**: 30 spherical mirrors in 2 parts each* → 2 rings of mirrors: inner and outer
- **Photon detector**: now 4 2” H8500C-03 per sector in 2 by 2 arrays
- **Winston cones**

*mirror splitting for manufacturing & coating purposes (see Eric’s talk)

→ benefit: make each part of different curvature; went from 9 to 4 PMTs per sector (saves cost: 1 PMT = $3000)



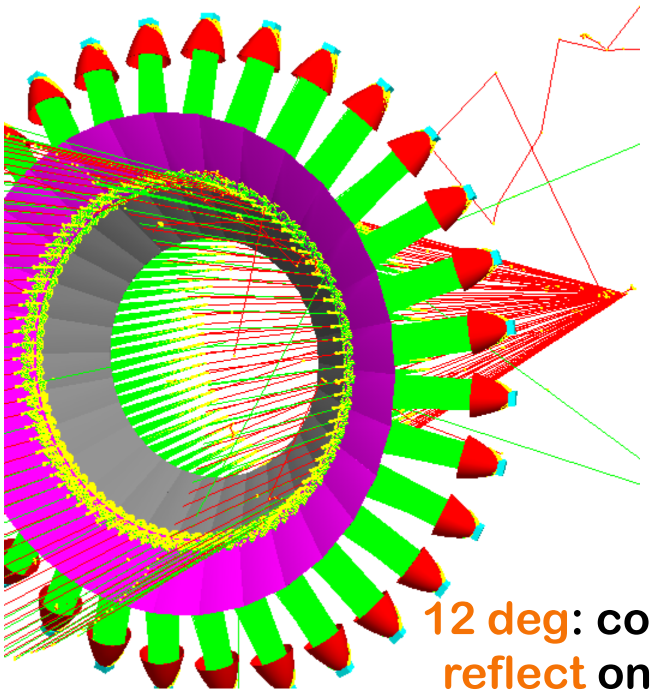


→ “exciting opportunity”: make them of light and rigid material to remove the need for double edge support

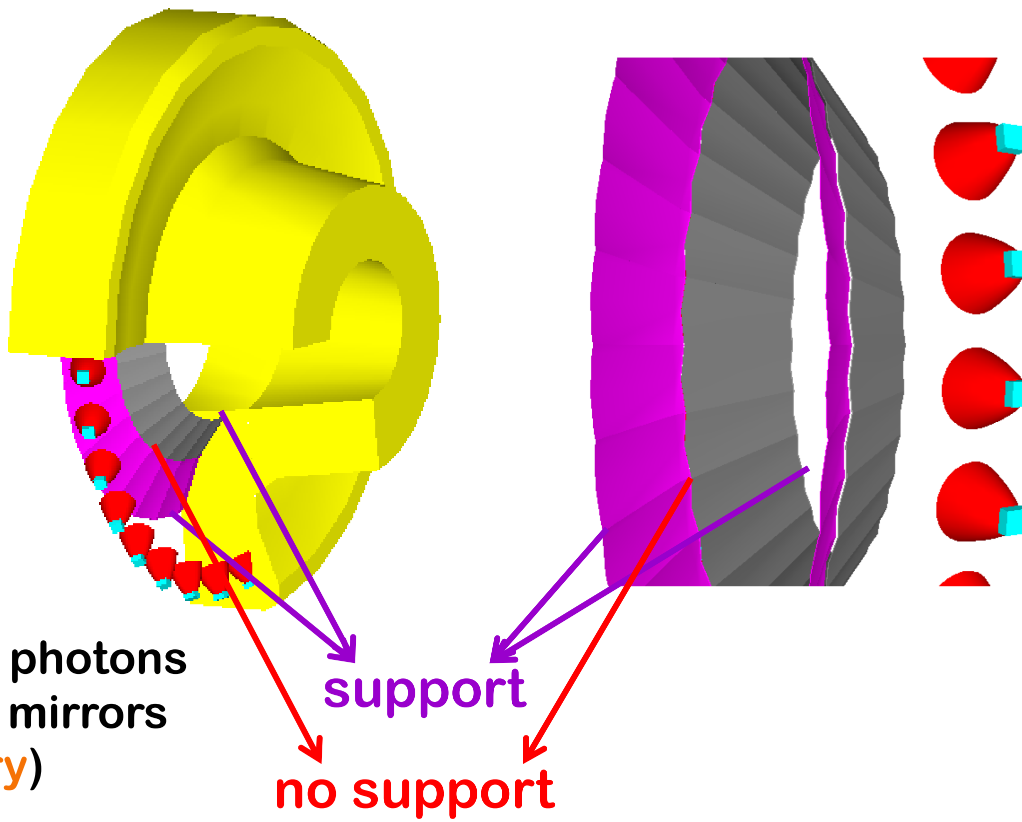
→ No impact on physics phase space

Cherenkov Mirrors: Material & Support

- Mirrors: <u>light & rigid material</u> so no double-edge support would be needed



12 deg: cone of photons reflect on both mirrors (boundary)



- Options: glass-coated beryllium technology & carbon fiber technology
  - Both extensively studied/tested at CERN for the RICH LHCb (the carbon fiber was chosen: delivery time and cost)

Cherenkov Mirrors: Material & Support

Mirrors: glass-coated beryllium

Nuclear Instruments and Methods in Physics Research A 595 (2008) 197–199

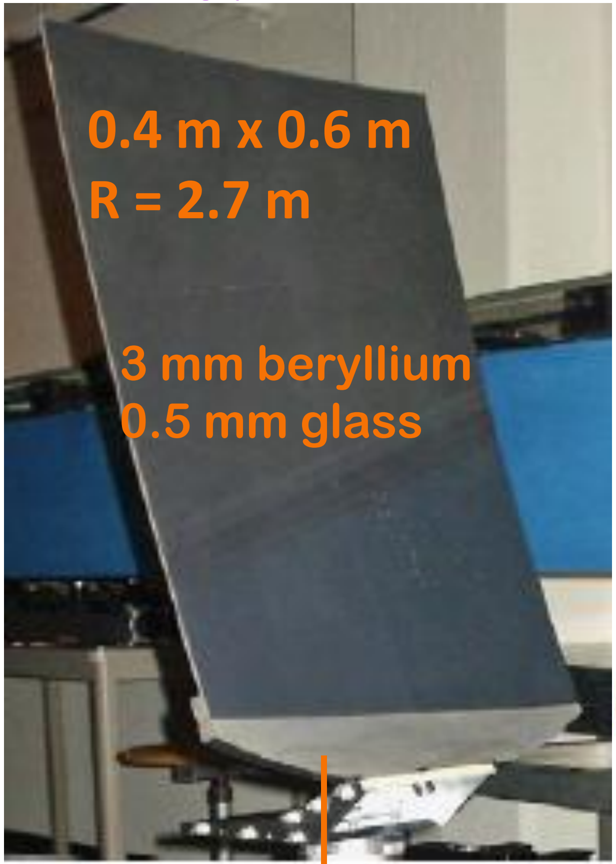
Advantages: radiation hard, fluorocarbon compatibility, non-magnetic, light-weight, good rigidity

→Without glass (+ Al) coating, poor reflectivity in visible and UV: 50%; with glass (+ Al) coating: 90% for λ > 200 nm

LHCb prototype (made in Russia): central point support on the beryllium rim (single bolt) → maximum deflection of the mirror due to gravity = 160μm

Disadvantages: high manufacturing costs + high toxicity (requires special safety measures during manufacturing and handling)

Prototype for LHCb



20 mm thick beryllium rim at one edge to support it

Cherenkov Mirrors: Material & Support

Mirrors: carbon fiber reinforced polymer (CFRP)

70% carbon-fiber (reinforcement material) +
30% resin (binds the fibers together)

Nuclear Instruments and Methods in Physics Research A 593 (2008) 624– 637

Advantages: same as glass-coated beryllium + considerably cheaper, with no safety implications

LHCb mirrors (made by CMA, US):

→ sandwich honeycomb structure: two outer CFRP layers (1.5 mm) + core cells in-between as reinforcement

→ reflectivity with Al + MgF_2 coating: ~90% for λ > 200 nm

May be a good choice for SoLID Cherenkovs

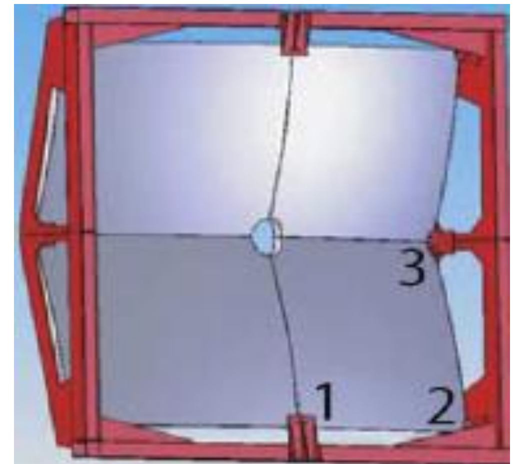
We need to:

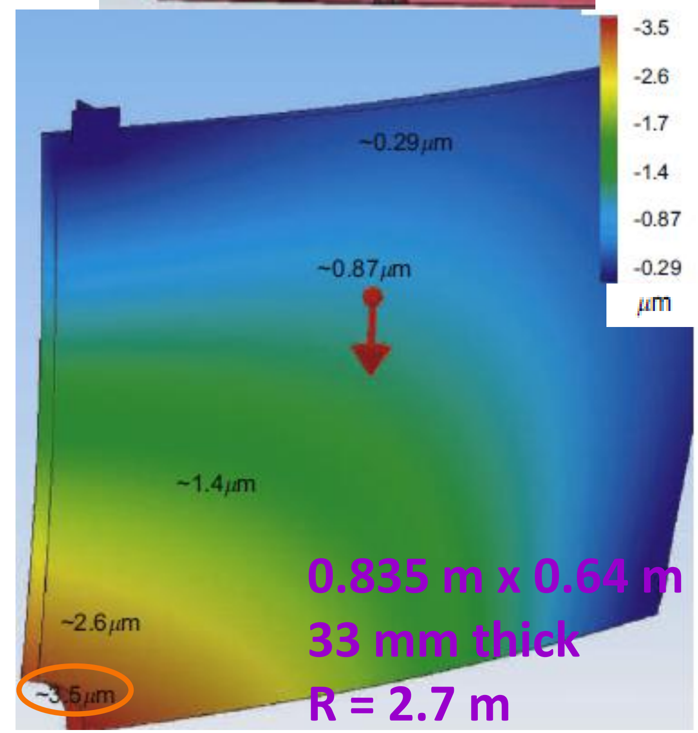
→ Find best way of supporting CFRP mirrors (Gary)

→ Ask CMA (for example) for a quote

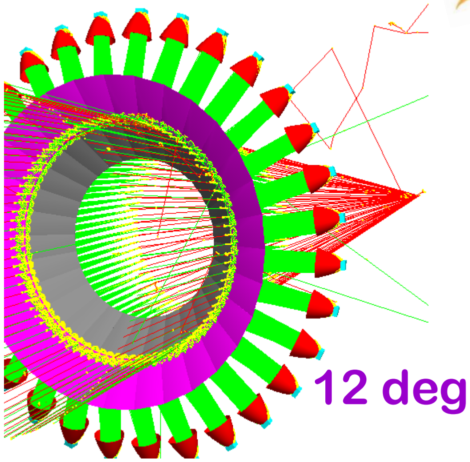
→ get good reflectivity below 200 nm as well

LHCb mirrors

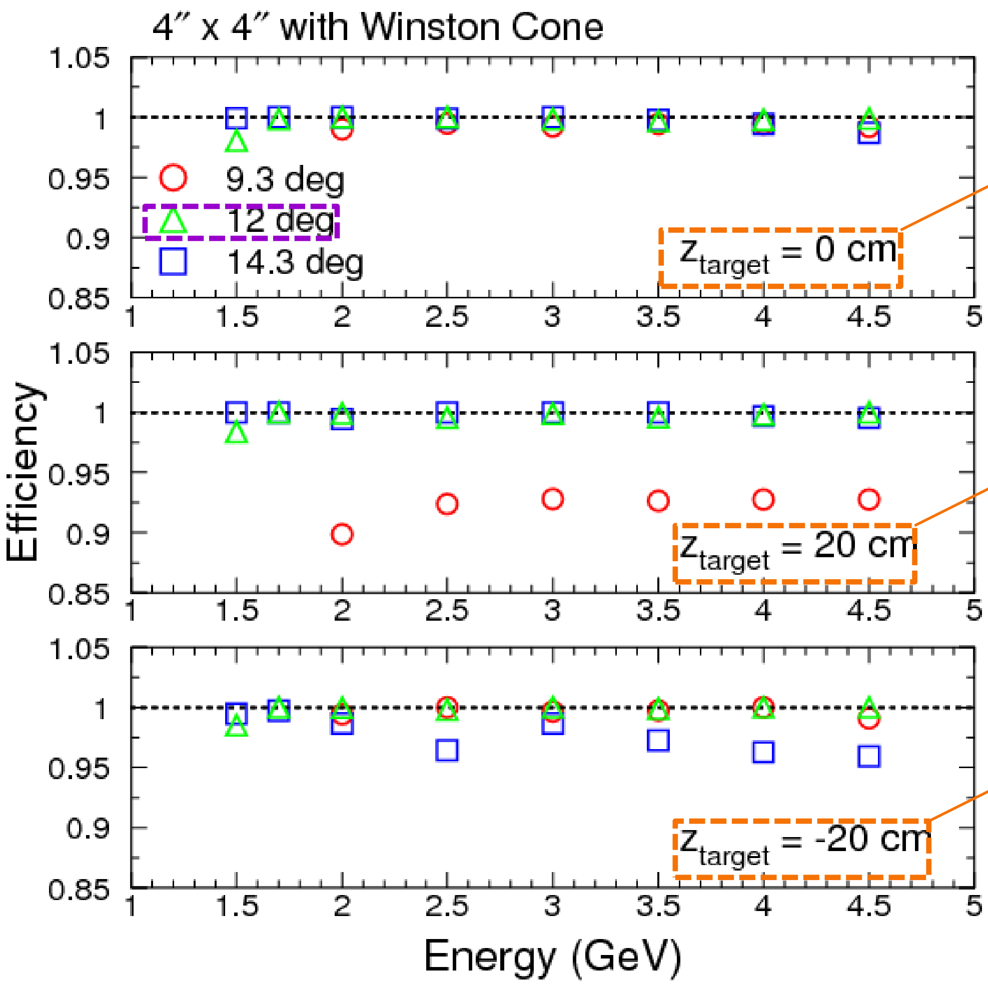




The Electron Cherenkov (PMTs): Collection Efficiency



- Good collection efficiency with 4 PMTs per sector + no support between the 2 mirror rings



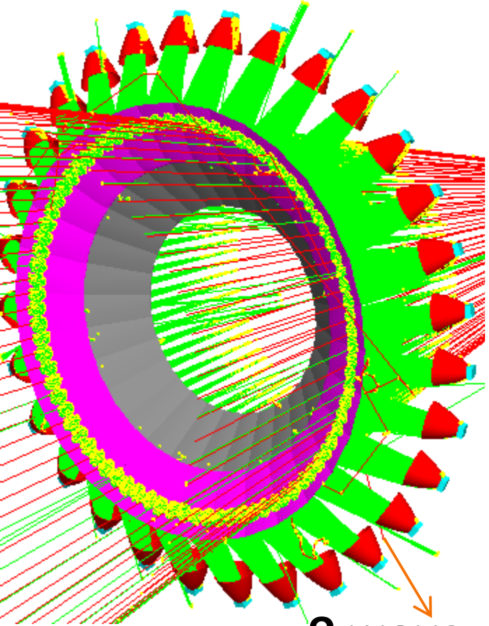
Over 98% regardless of the kinematics

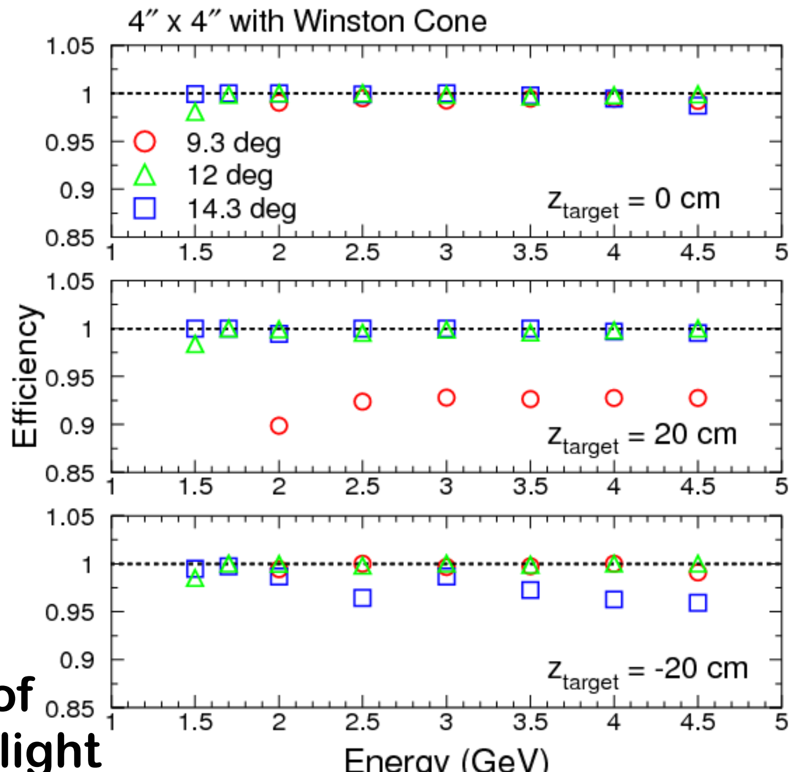
Over 98% at most kinematics; **~90%** at the lowest polar angle

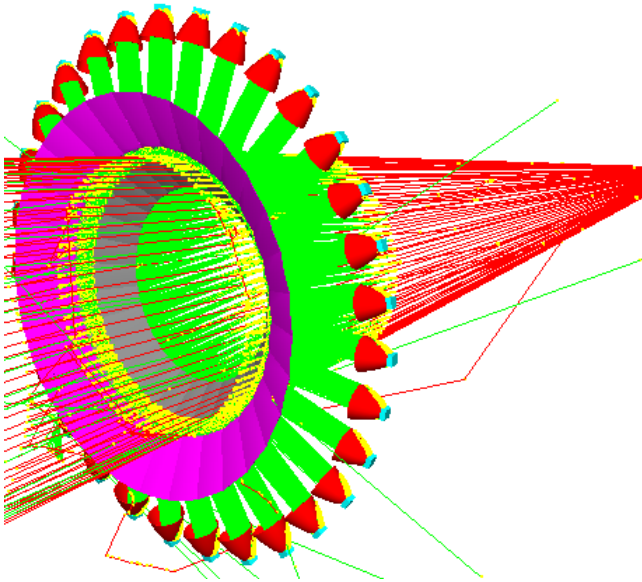
Over 98% at most kinematics; **over 95%** at the highest polar angle

The Electron Cherenkov (PMTs): Focusing

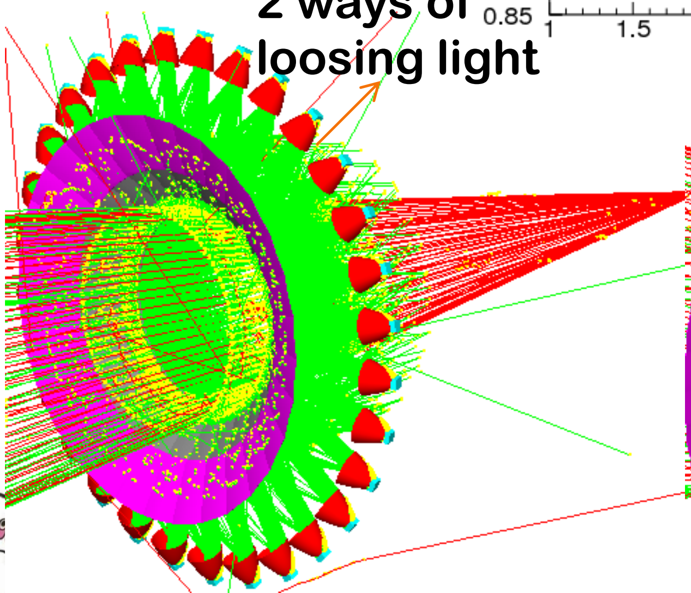
➡ **Examples**

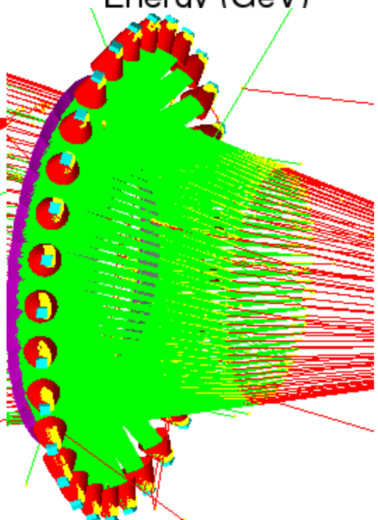


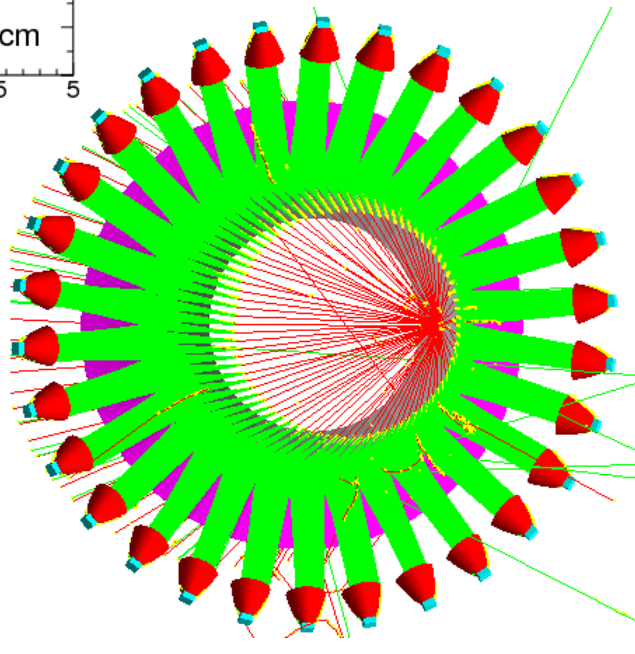




2 ways of loosing light



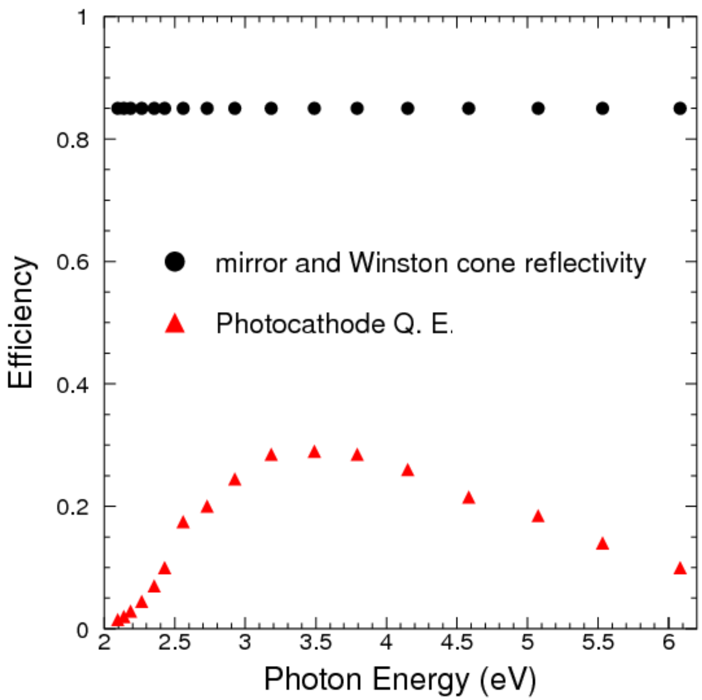


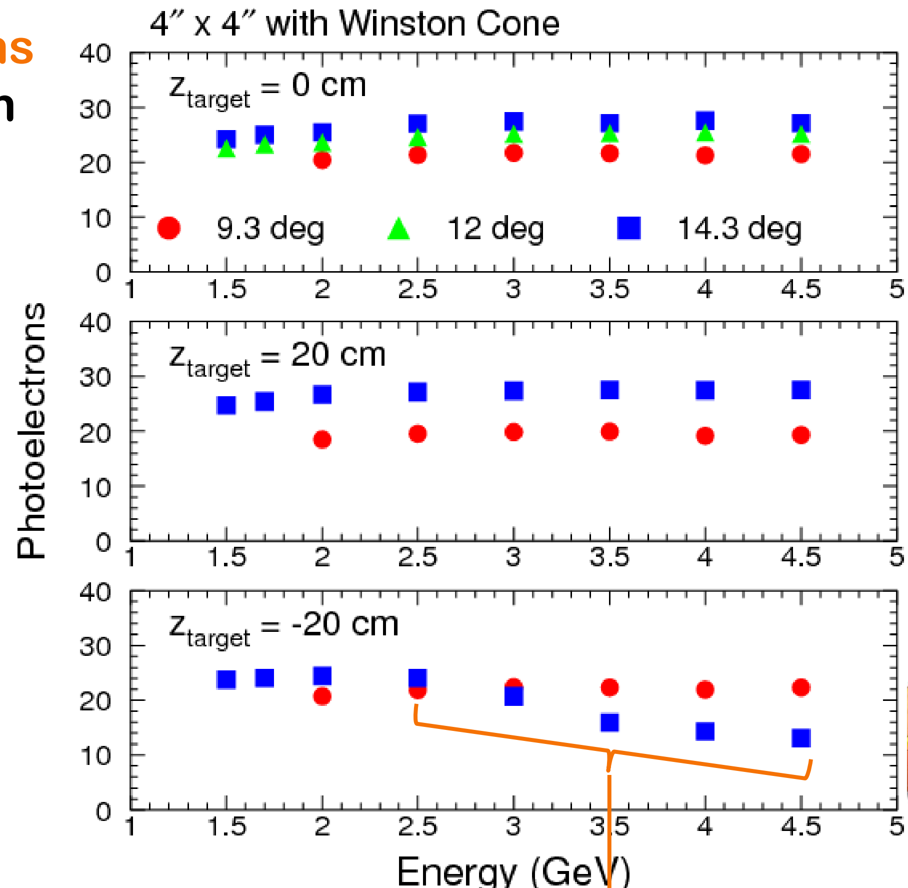


The Electron Cherenkov (PMTs): Signal

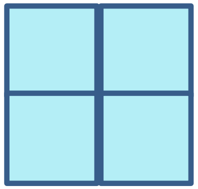
➡ **Estimates include:**

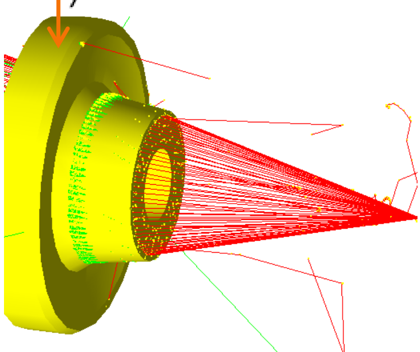
→ **wavelength dependent corrections** **(Q.E. of H8500C-03 + mirror/Winston cone reflectivity)**
→ **effect of PMT window (Eric implemented that)**





tile

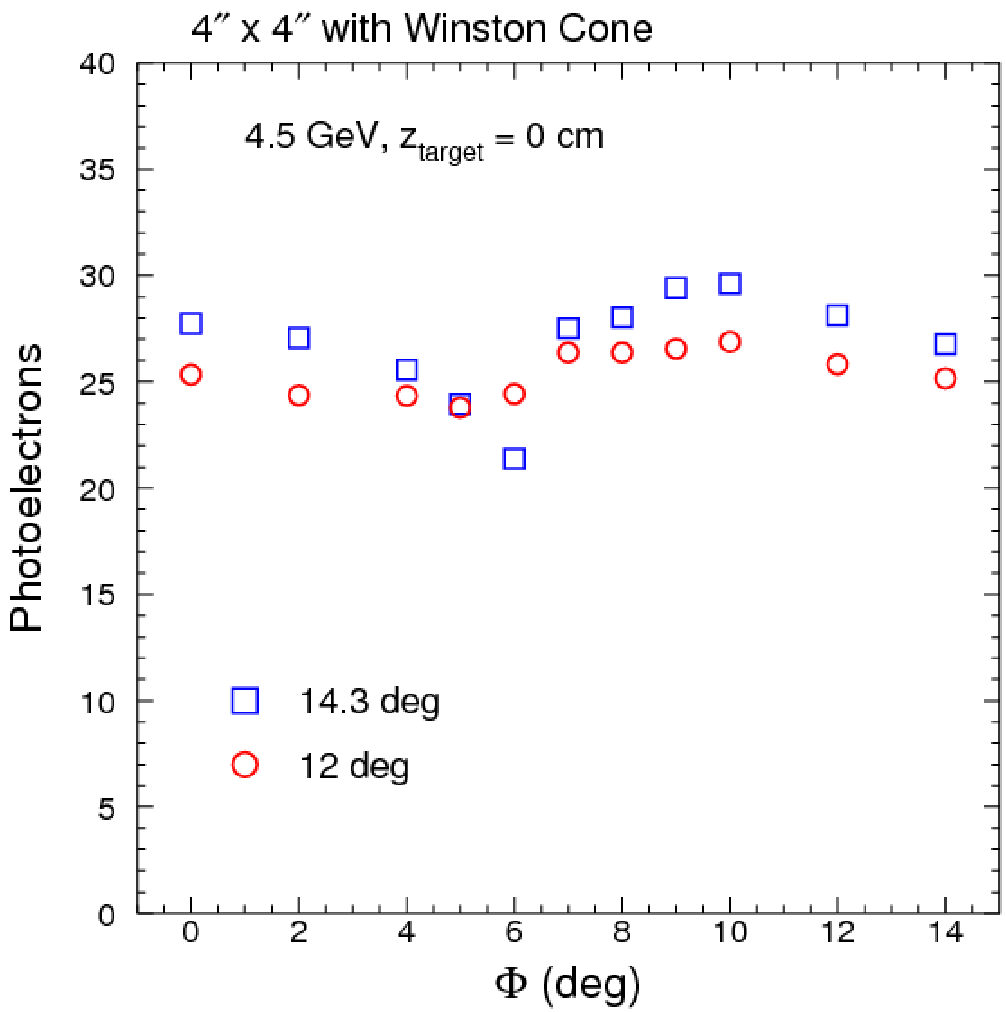


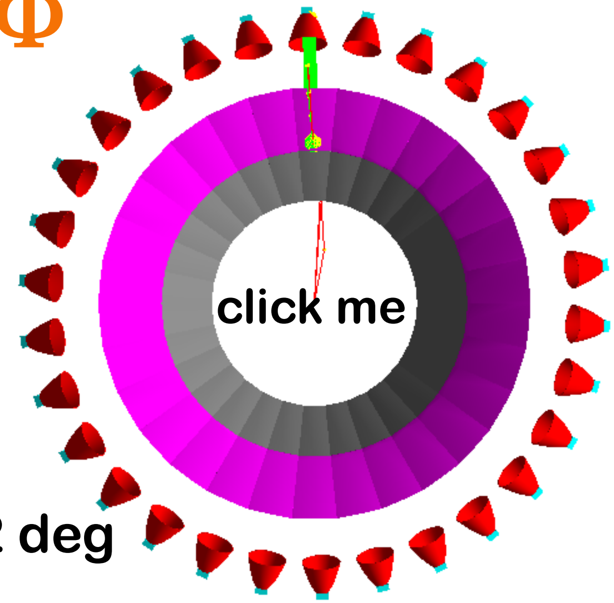


→ **additional overall reduction of 0.7 (accounts for dead zone that result from tiling +…)**

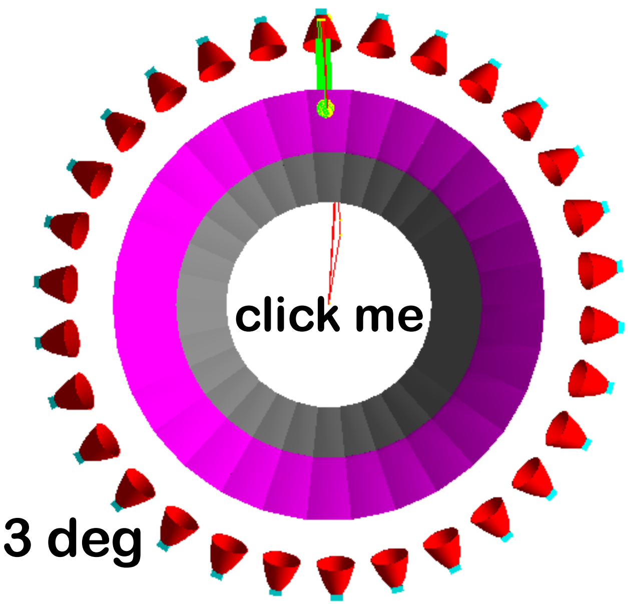
The Electron Cherenkov (PMTs): Performance vs. Φ

- Fairly small effect at the “edge” of angular acceptance





12 deg



14.3 deg

H8500C-03 in SoLID Magnetic Field

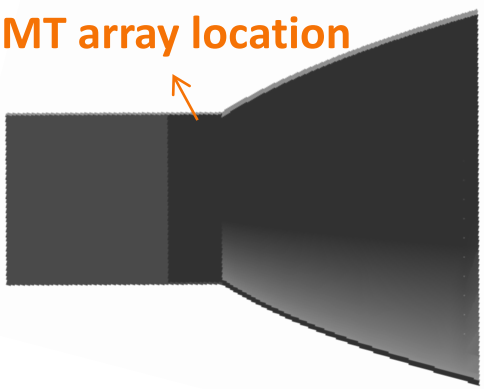
➡ **From H8500C field tests at Temple U.**

→ at 20 G (longitudinal field): < 10% signal loss
→ at 70 G: 30%

Request sent to Amuneal for "ideal" shield which will incorporate the Winston cones

- longitudinal component of the magnetic field from 150 G to < 20 G
- transverse component of the magnetic field from 70 G to 0 G

Dark area inside the shield = PMT array location



Estimates based on BaBar v4 field map

Ideal *could be higher* though (< 50 G)

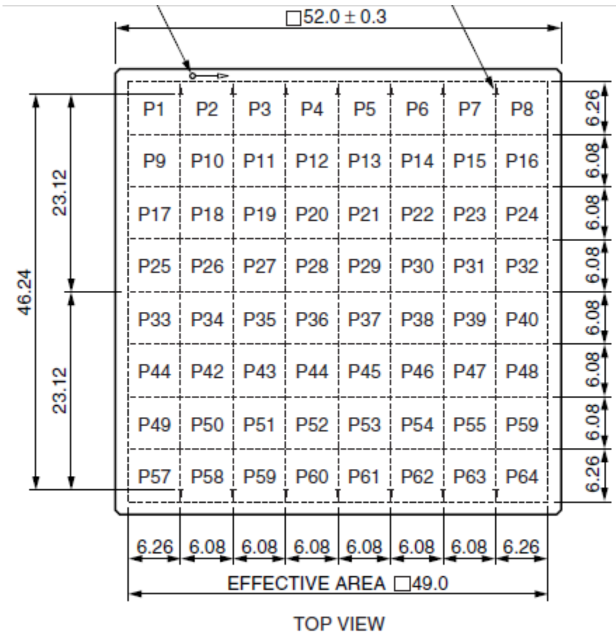
Amuneal:
→possible with a 2 layer shield
- → inner: Amumetal 0.04"
- → outer: 1008 carbon steel 1/8"
- → mylar in between 0.062"

→ Winston cone substantially more expensive than straight cone ($1350 per cone)

Need to check with simulation if we could use straight cones

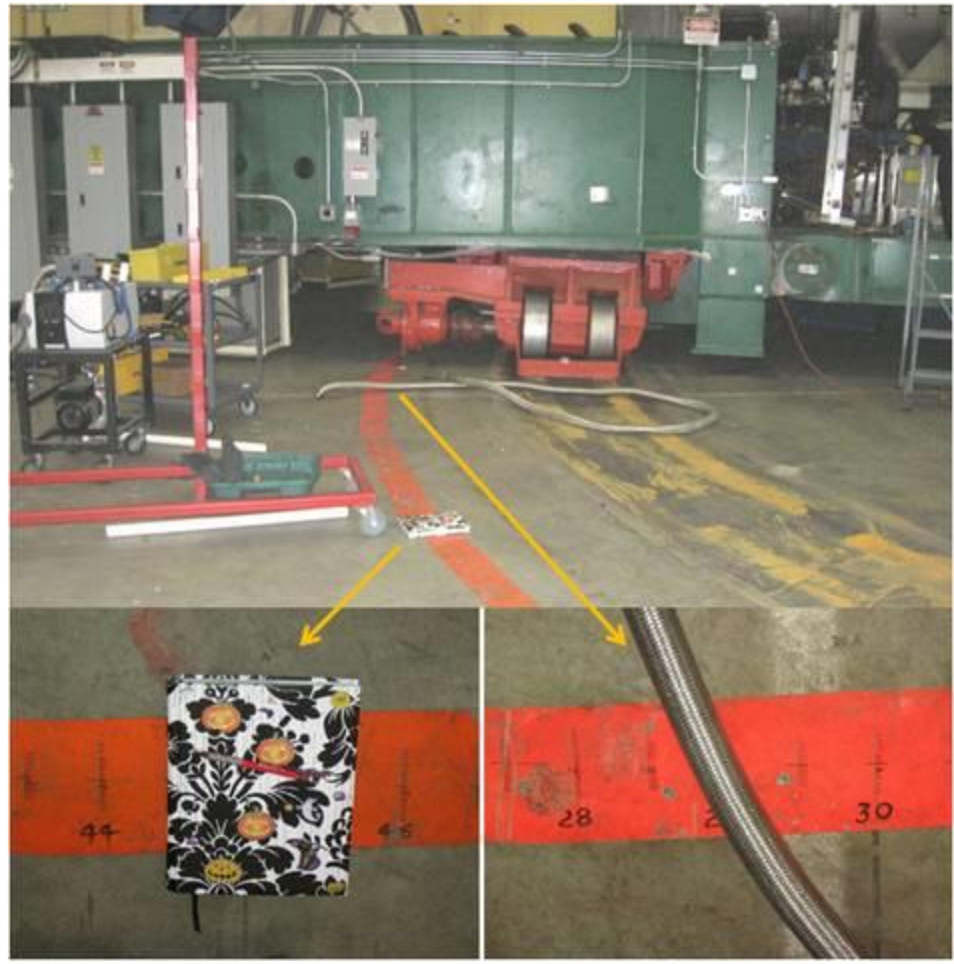
H8500C-03: Tentative Plan for Test in Hall A

➡ Background on PMT window of concern



→ sum over all anodes would be fine but we could also take advantage of the pixeling and use coincidence between pixels to "cut" background

→ would like to test this approach during g_2^p

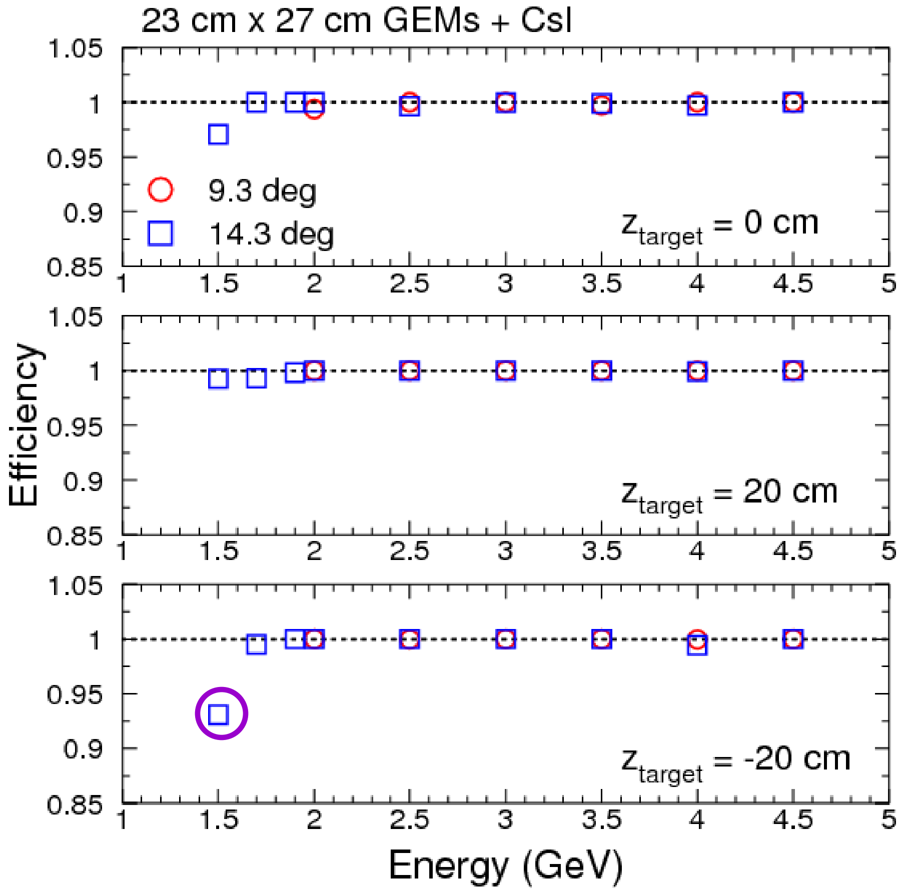


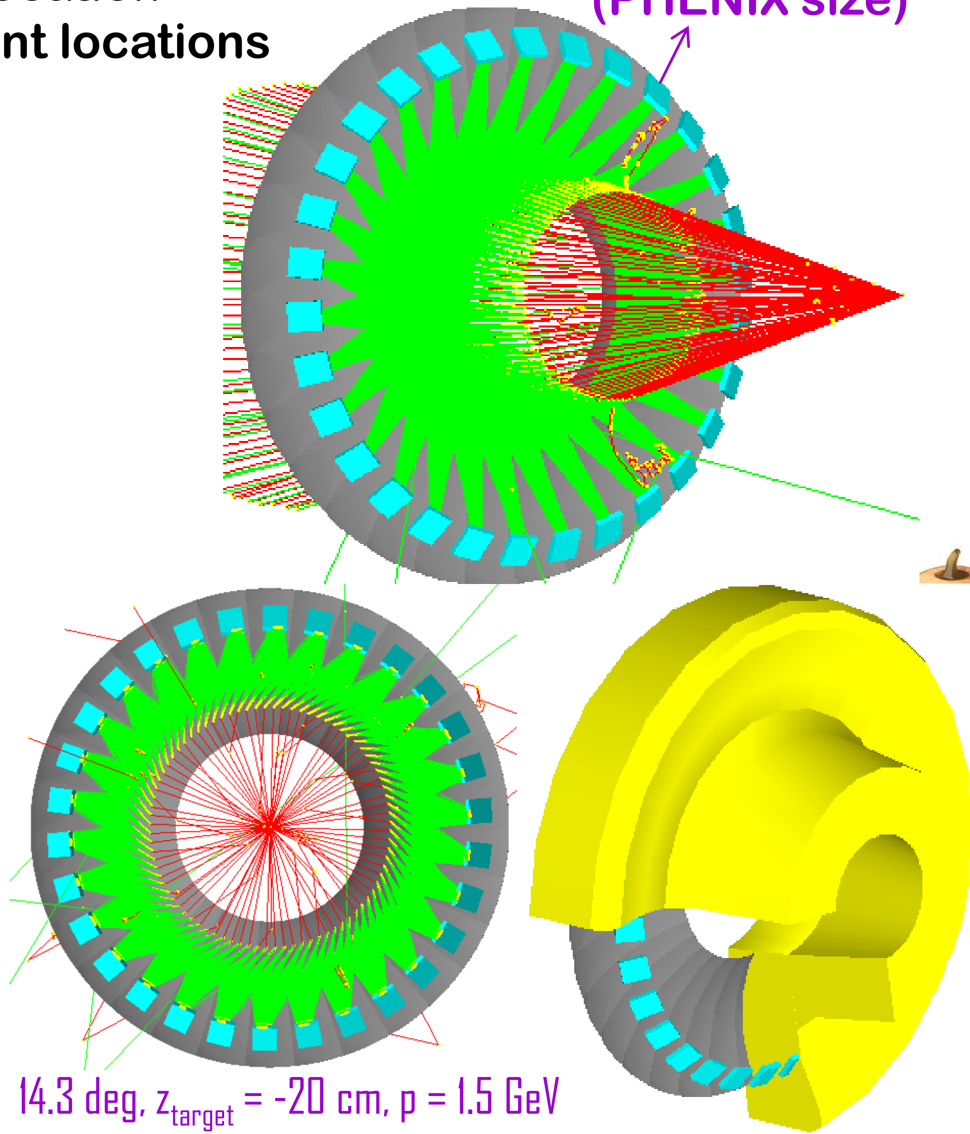
Place the PMT in a dark box with some shielding somewhere between 29 and 45 deg

The Electron Cherenkov (GEMs+CsI): Design

➡ **Very similar configuration possible for SIDIS and PVDIS**

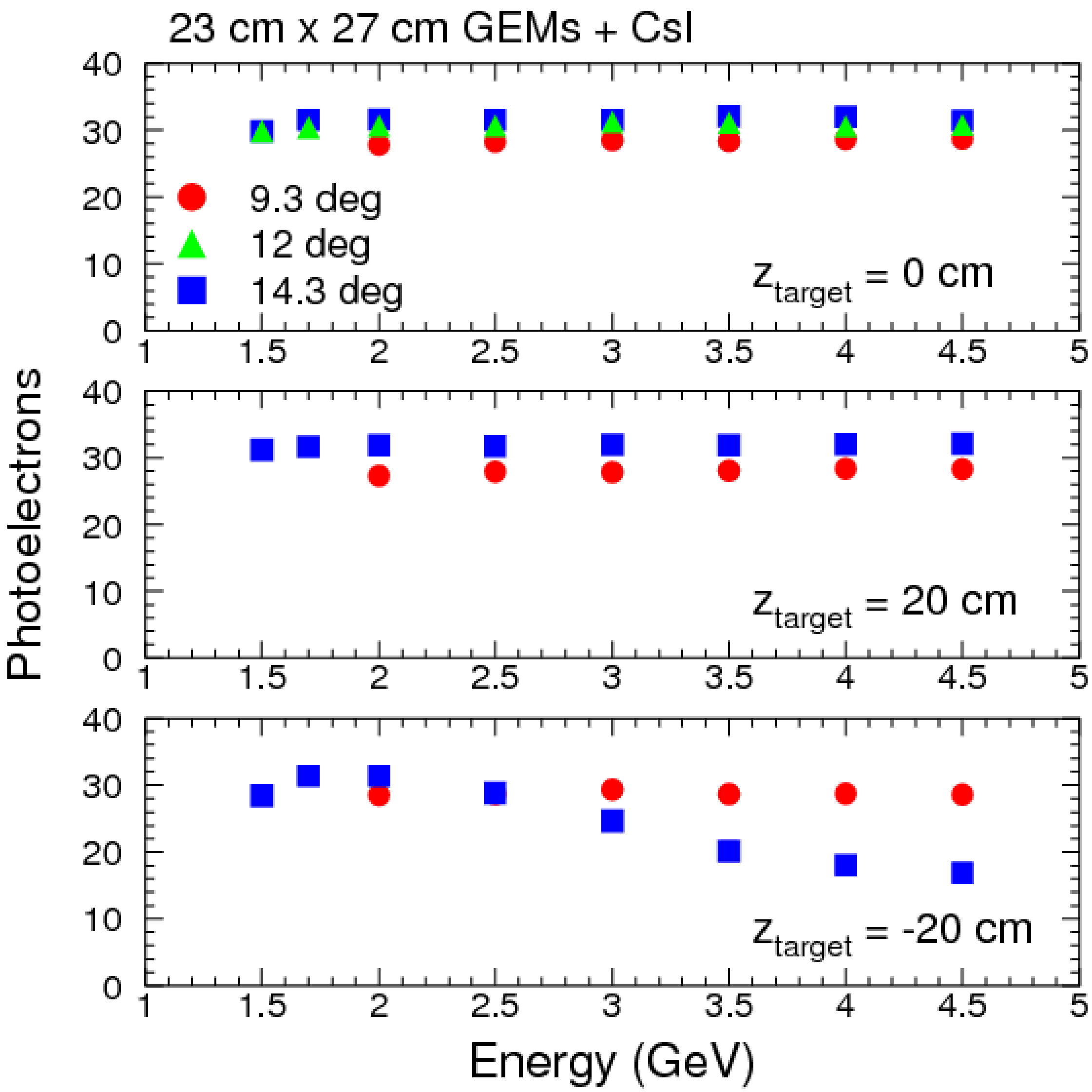
- **same tank except for additional piece for SIDIS**
- **same mirrors, mounted at the same location**
- **same GEMs + CsI, mounted at different locations**
- **same gas: CF_4**





Not cost efficient to make mirrors of different curvatures

The Electron Cherenkov (GEMs+CsI): Signal

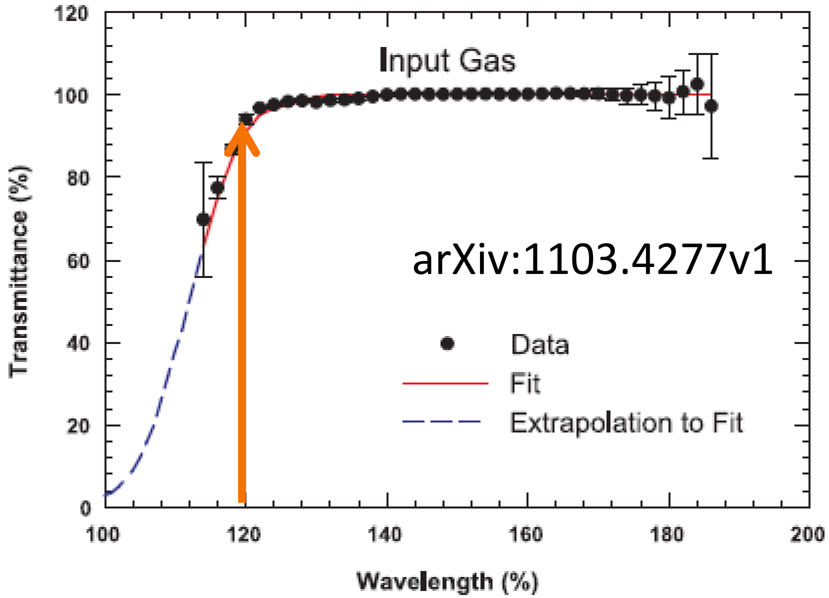


Takes into account wavelength dependent corrections (mirrors reflectivity, gas absoption, Q.E. of CsI)

+

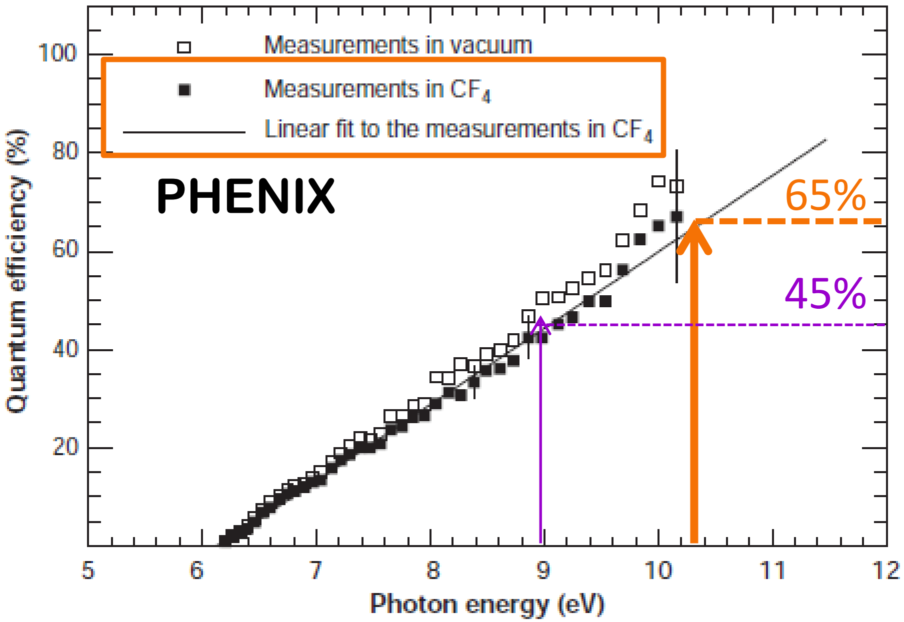
an additional multiplicative correction of 0.5 – the PHENIX factor - (optical transparency of mesh and photocathode, radiator gas transparency, transport efficiency etc.)

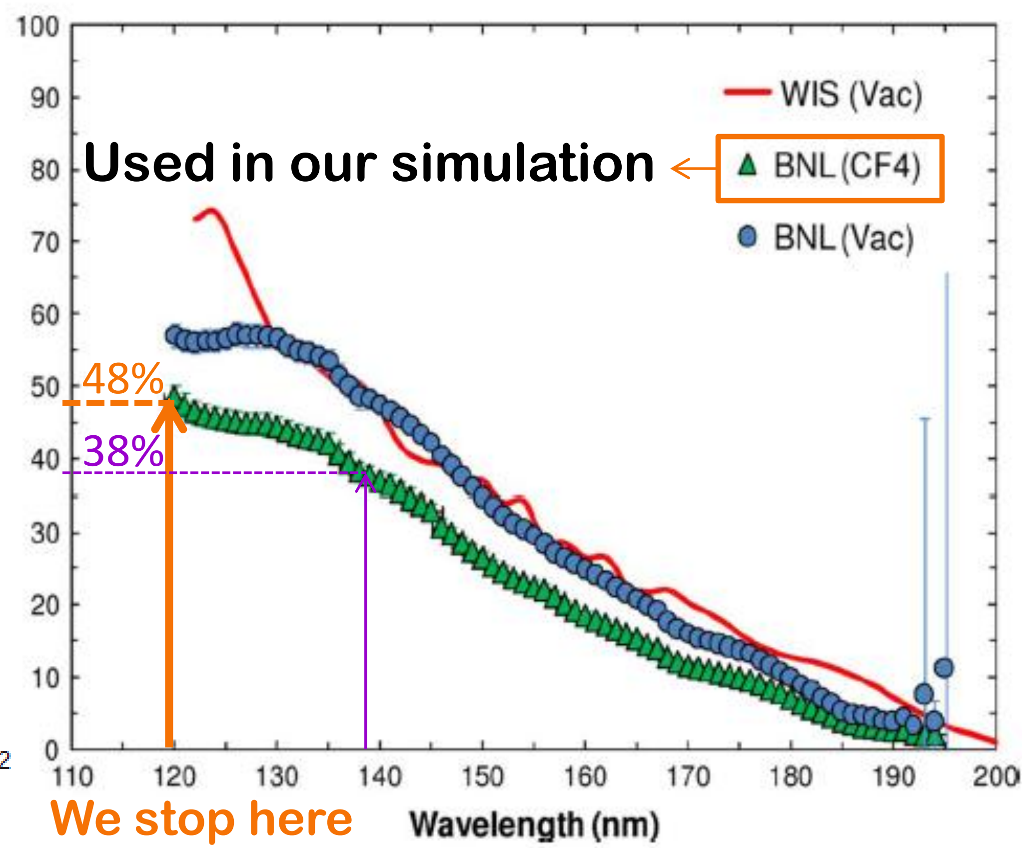
The Electron Cherenkov (GEMs+CsI): CsI Q.E.



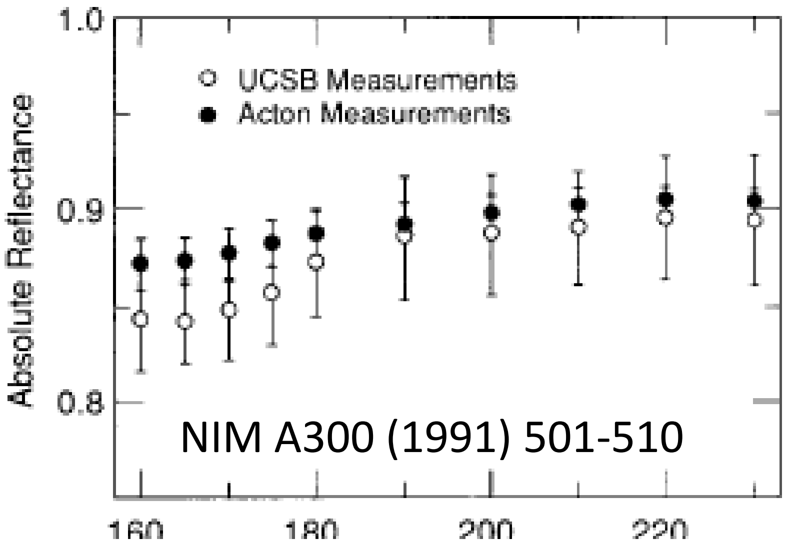
➡ **Wavelength-dependent corrections: CsI Q.E. + gas transparency**

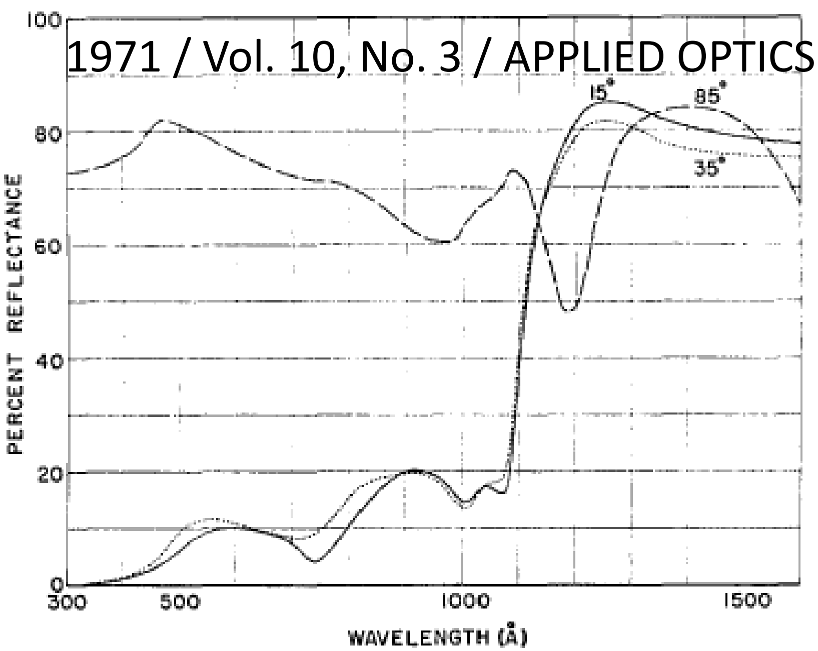
B. Azmoun *et al.*, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 56, NO. 3, JUNE 2009



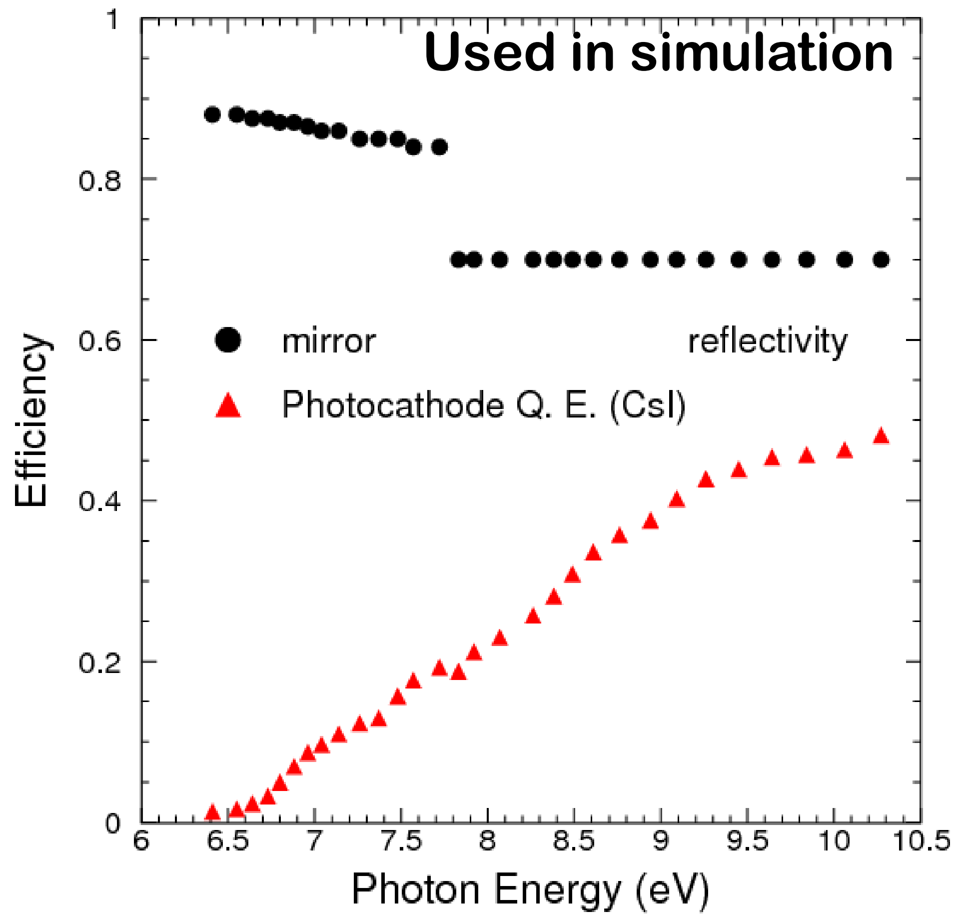


The Electron Cherenkov (GEMs+CsI): Mirror Reflectivity in far UV

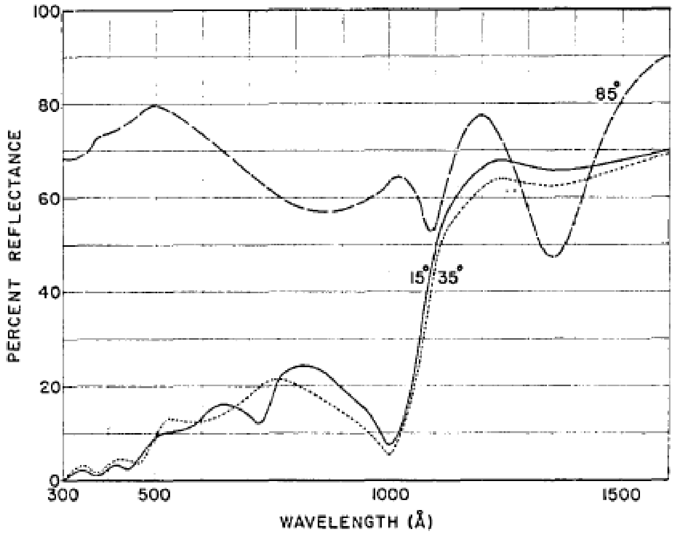




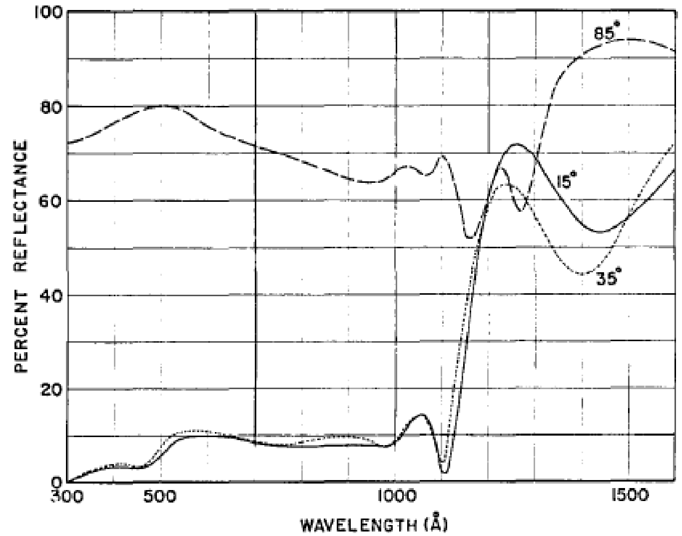
➡ **Wavelength-dependent corrections: mirror reflectivity**



Mirrors Reflectivity in far UV

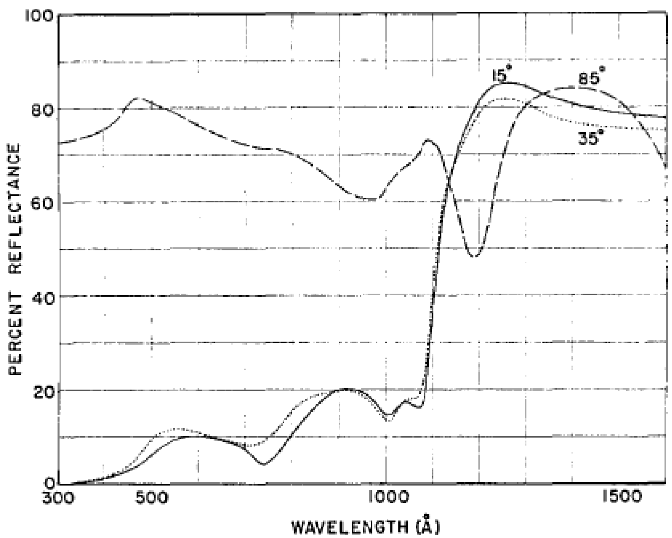


Measured reflectance of an Al + MgF_2 mirror from 300 Å to 1500 Å. The MgF_2 thickness is 150 Å.

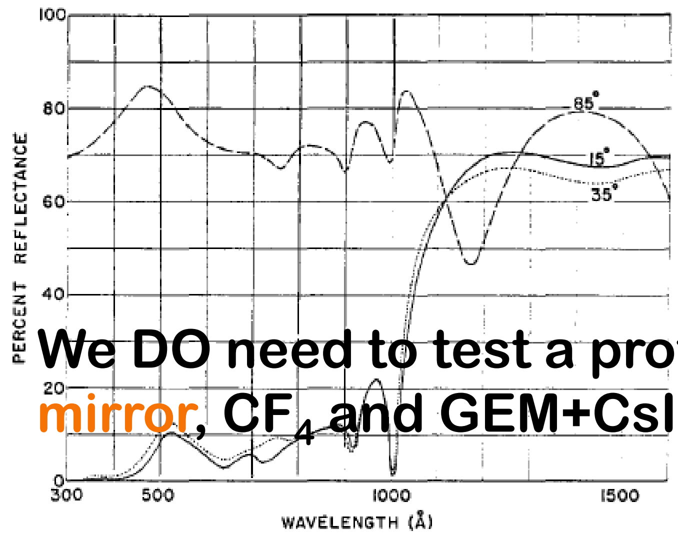


Measured reflectance of an Al + MgF_2 mirror from 310 Å to 1600 Å. The MgF_2 thickness is 620 Å.

Depends on angle of incidence and thickness of protective layer



Measured reflectance of an Al + MgF_2 mirror from 300 Å to 1600 Å. The MgF_2 thickness is 250 Å.



Measured reflectance of an Al + LiF mirror from 300 Å to 1600 Å. The LiF thickness is 250 Å.

Depends on protective layer material

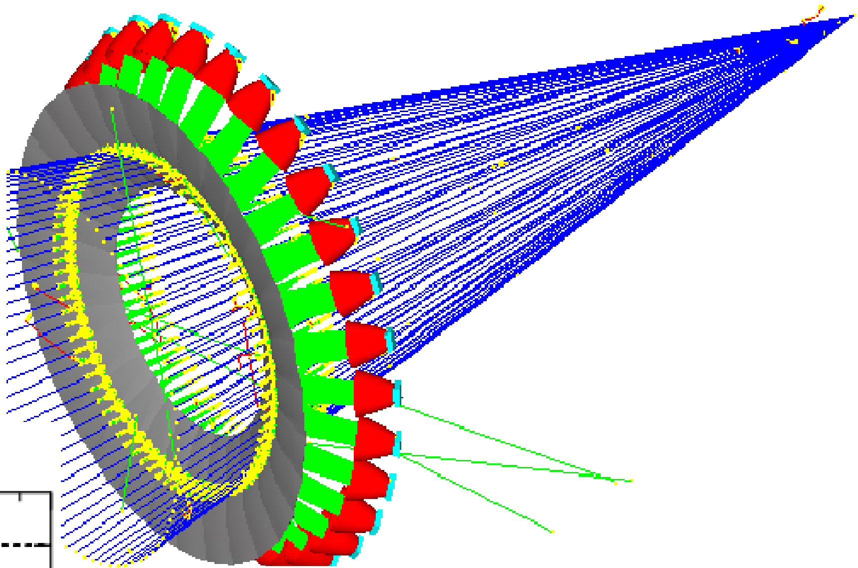
We DO need to test a prototype with mirror, CF_4 and GEM+CsI (see Eric's talk)

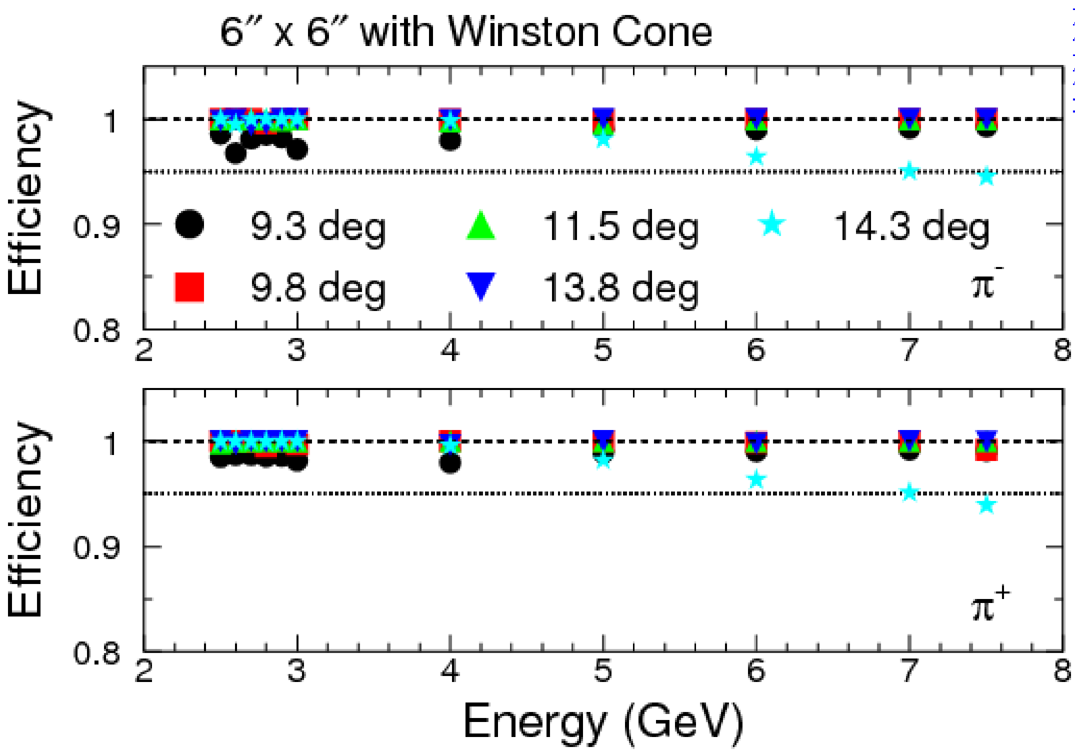
The Pion Cherenkov (PMTs): Design

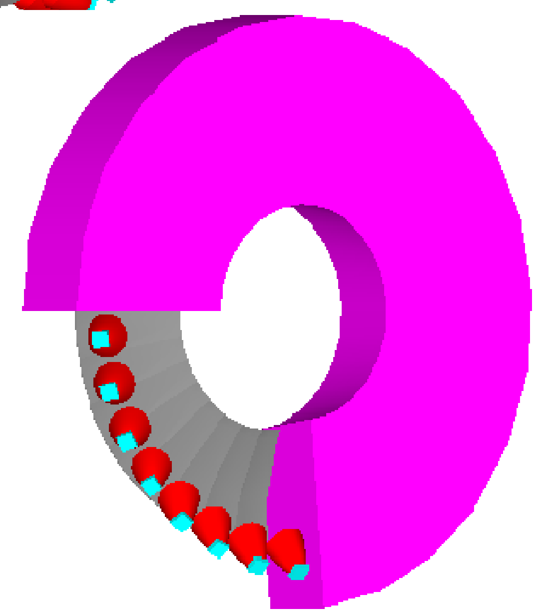
➡ **Similar design as for electron Cherenkov, the PMT option**

- gas: C_4F_8O

→ **Before we knew we have to split the mirrors: very good collection efficiency with one mirror and 9 2" PMTs per sector**



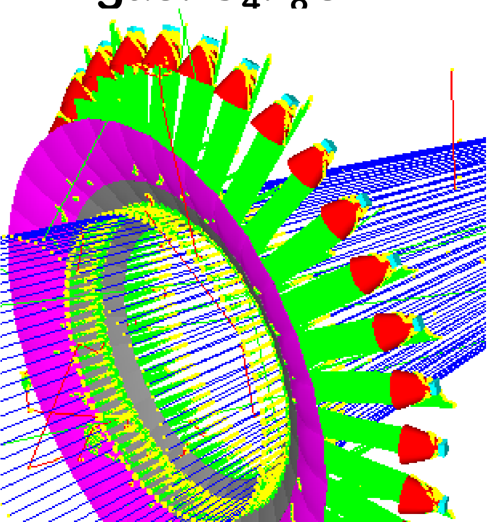




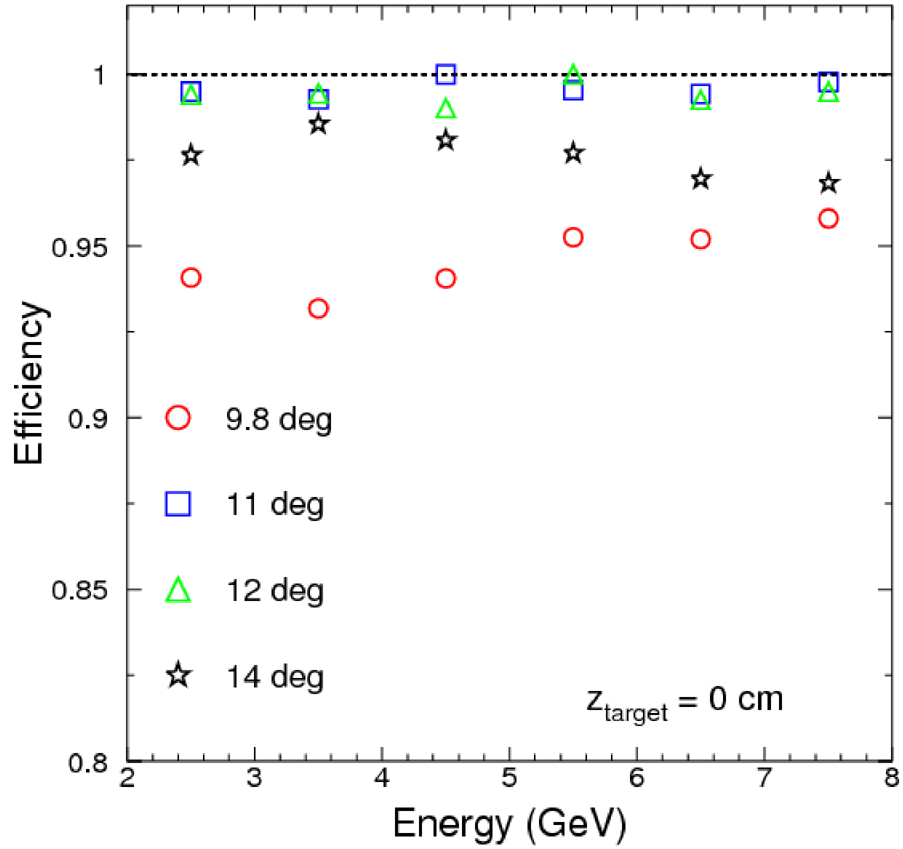
The Pion Cherenkov (PMTs): Design

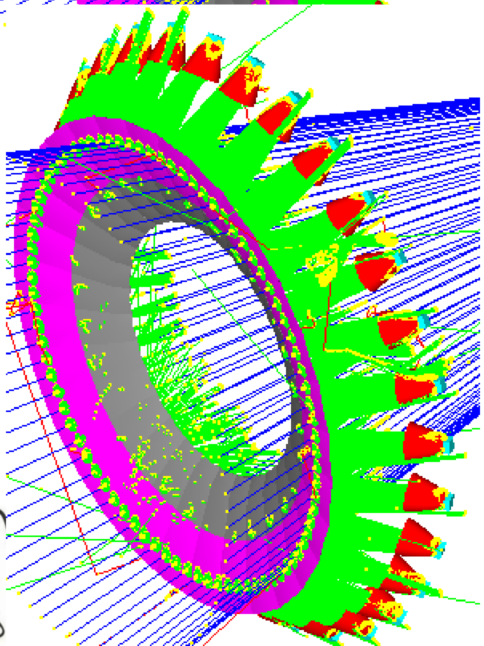
➡ **Similar design as for electron Cherenkov, the PMT option**

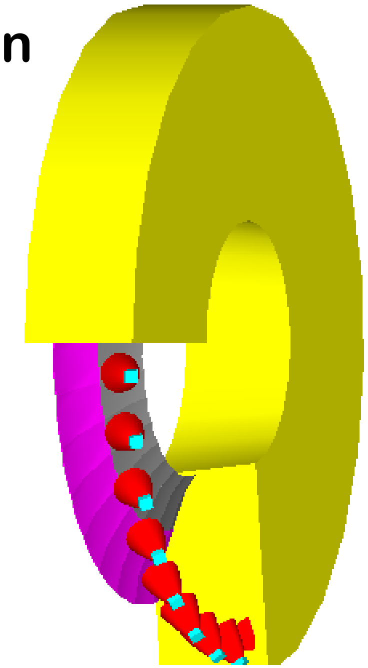
- gas: C_4F_8O

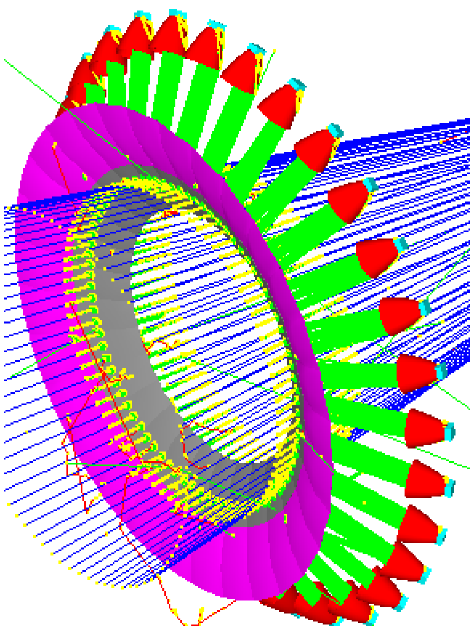


→ **We split the mirrors (different curvature) + went to 4 PMTs per sector**









Work in progress

Summary

Simulation and design: iterate!

→ "finalize" the Cherenkovs design
→ switch to CLEO when available and re-optimize
→ migrate to GEMC
→ …

Tests:

→ test H8500C-03 during g_2^p
→ test GEMs + CsI prototype during g_2^p: see next talk for details
→ …