SIDIS
(Light) Gas Cerenkov

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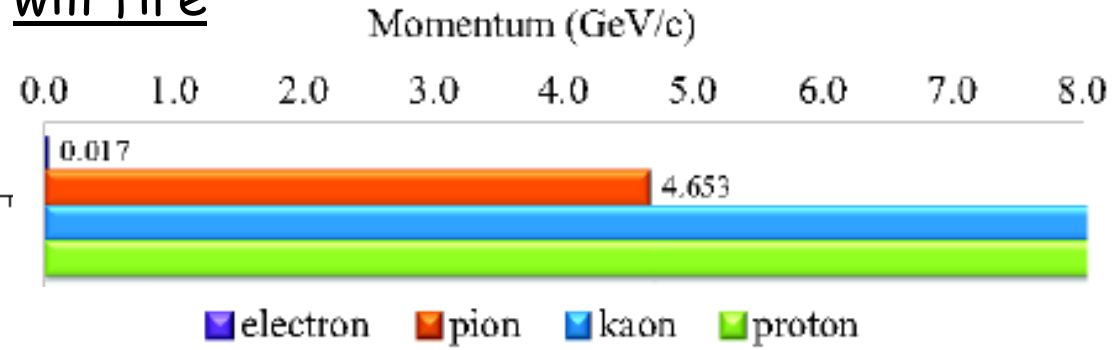
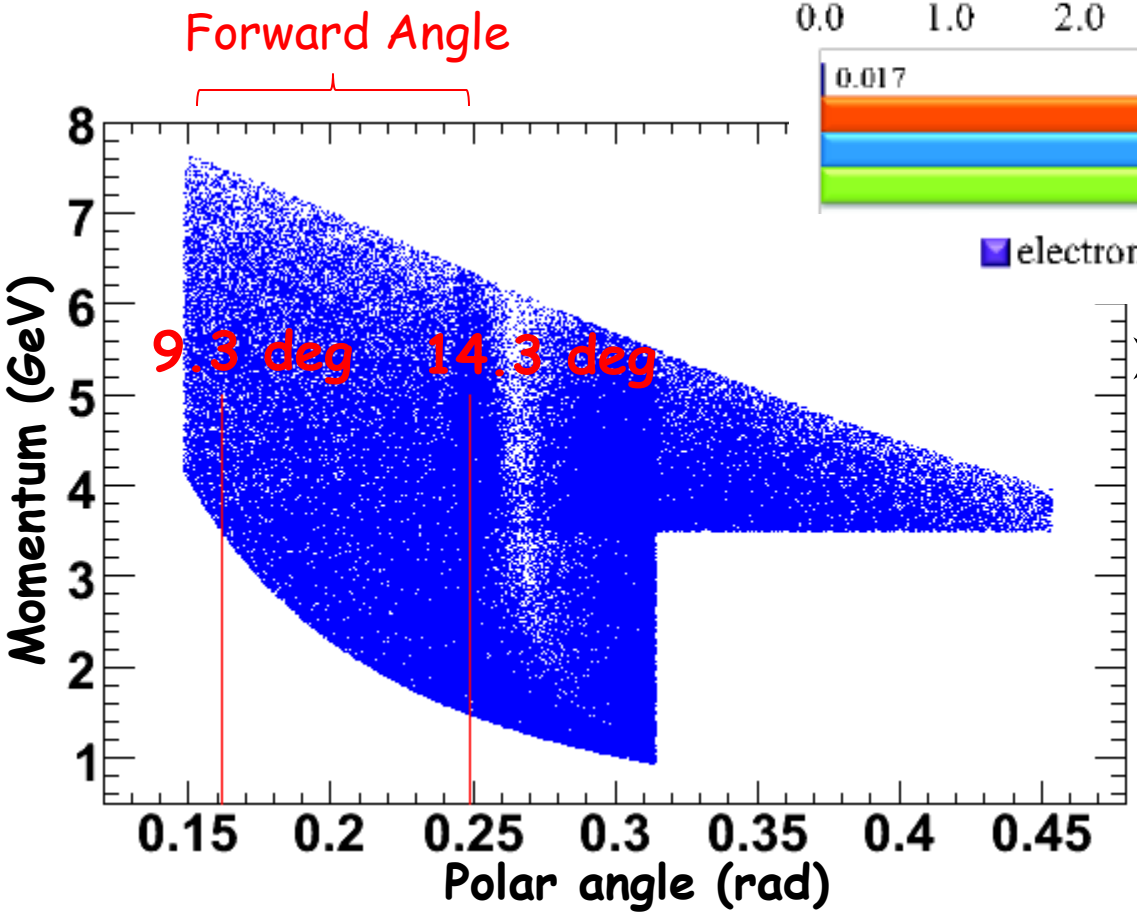
Outline

- Why SIDIS needs a light gas Cherenkov?
- Initial design idea (Yi Qiang)
- Current design:
  - Design concept: the mirrors
  - Focusing: efficiency no magnetic field
  - Focusing: efficiency with magnetic field (BaBar), positive and negative particles
- Light Gas Cherenkov: electron identification
  - Collection efficiency with cones: how small of a PMT could we use? Probably 3 inch … (work in progress)
  - Quick and rough estimation of number of photoelectrons (work in progress)
- Few thoughts on the heavy gas Cherenkov (work in progress)

Light Gas Cerenkov: Purpose

- Electron identification at forward angle
  - The Light Gas Cerenkov: CO_2 @ 1 atm, n = 1.00045
    - Electrons with p > 0.017 GeV will fire
    - Pions with p > 4.653 GeV will fire

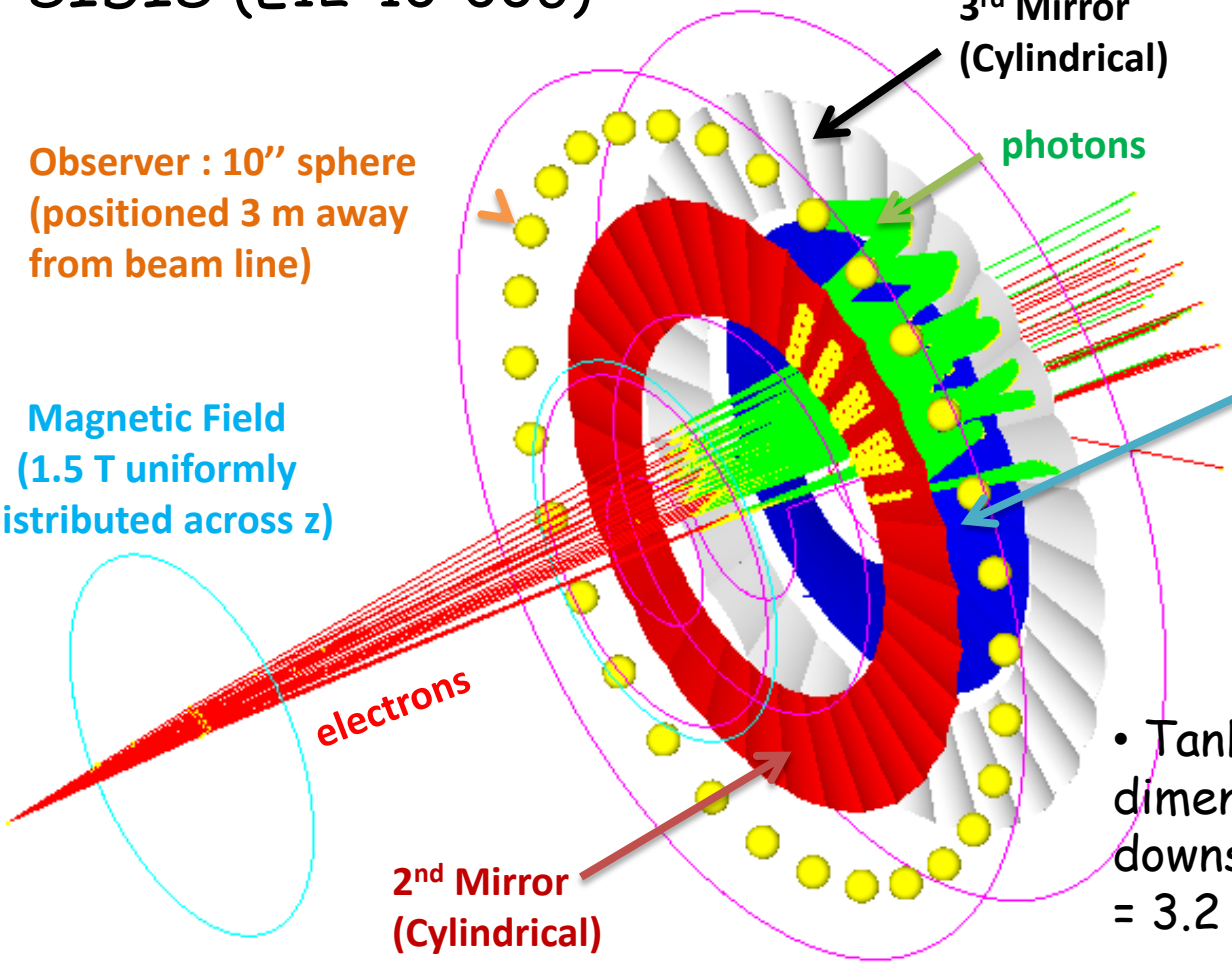




- With the BaBar magnet:
  - Identification of electrons with polar angle ~ (9.3, 14.3) deg and momentum ~ (2, 5) GeV
  - Pion—proton/kaon separation at high momentum bonus but not strictly required

Initial Design: 3-Mirror System

➢ Developed by Yi Qiang in Geant4: a viable optical system with optimal focusing for the polar angle and momentum range required by SIDIS (E12-10-006)



• Tank size followed the dimensions of the CDF original downstream yoke (outer radius = 3.2 m)

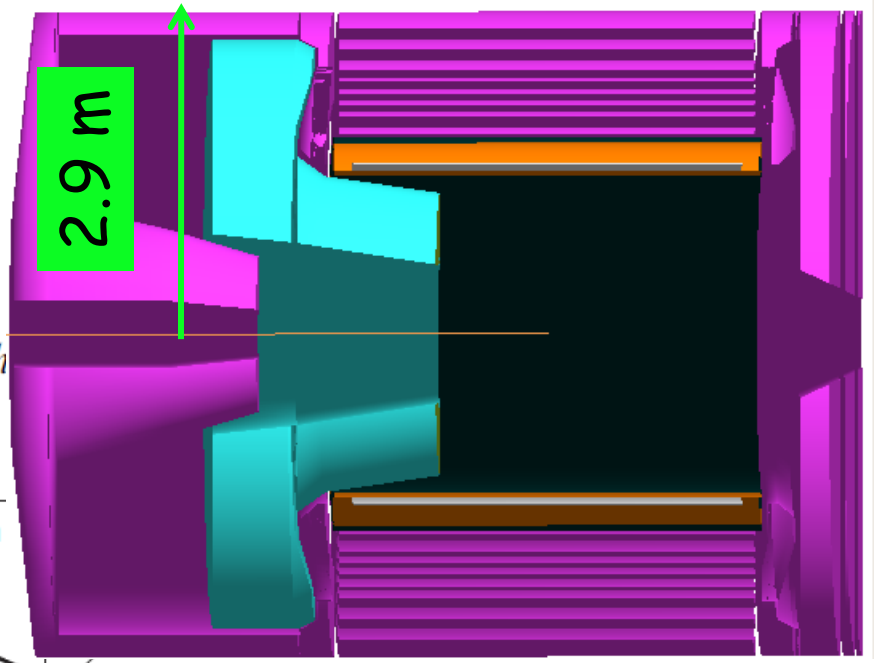
picture from Yi Qiang

Light Gas Cherenkov in SoLID

- Limited space in the hall (beam line – floor clearance) => smaller tank (and simpler design) would be more practical

+

1-mirror system has not been tested before



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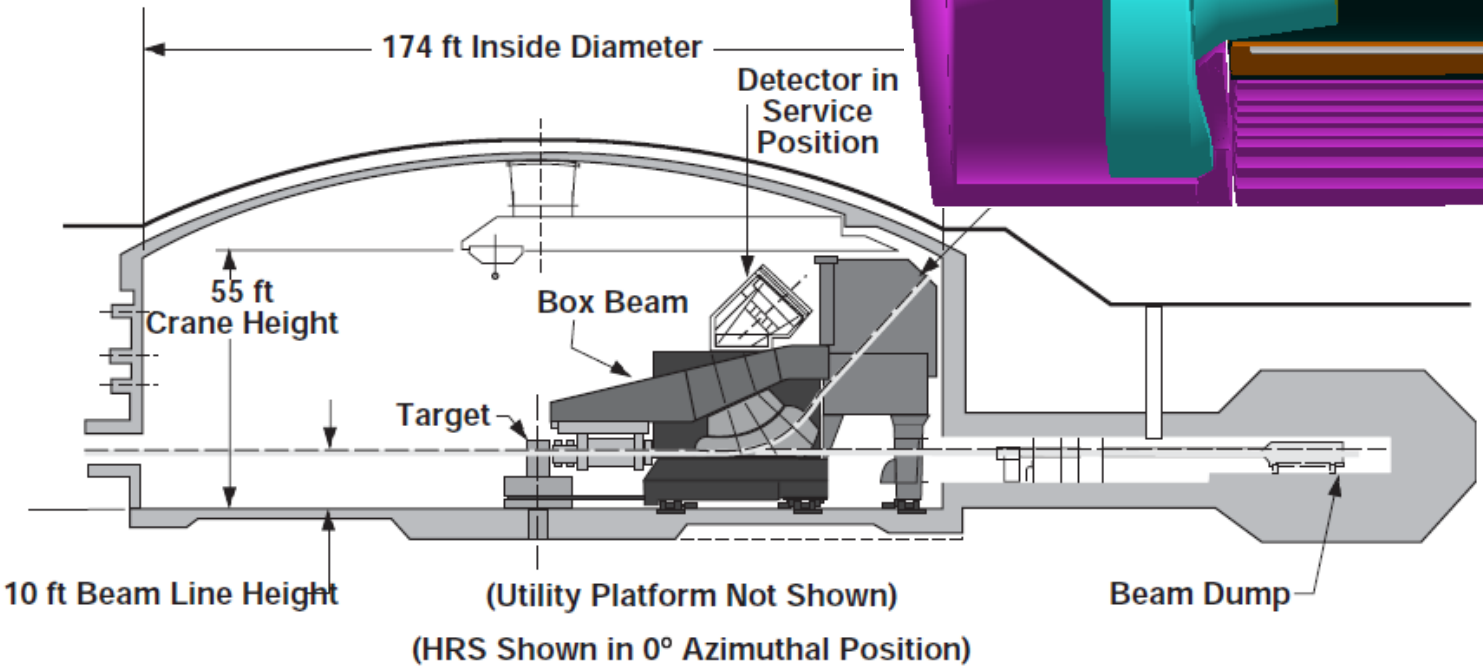
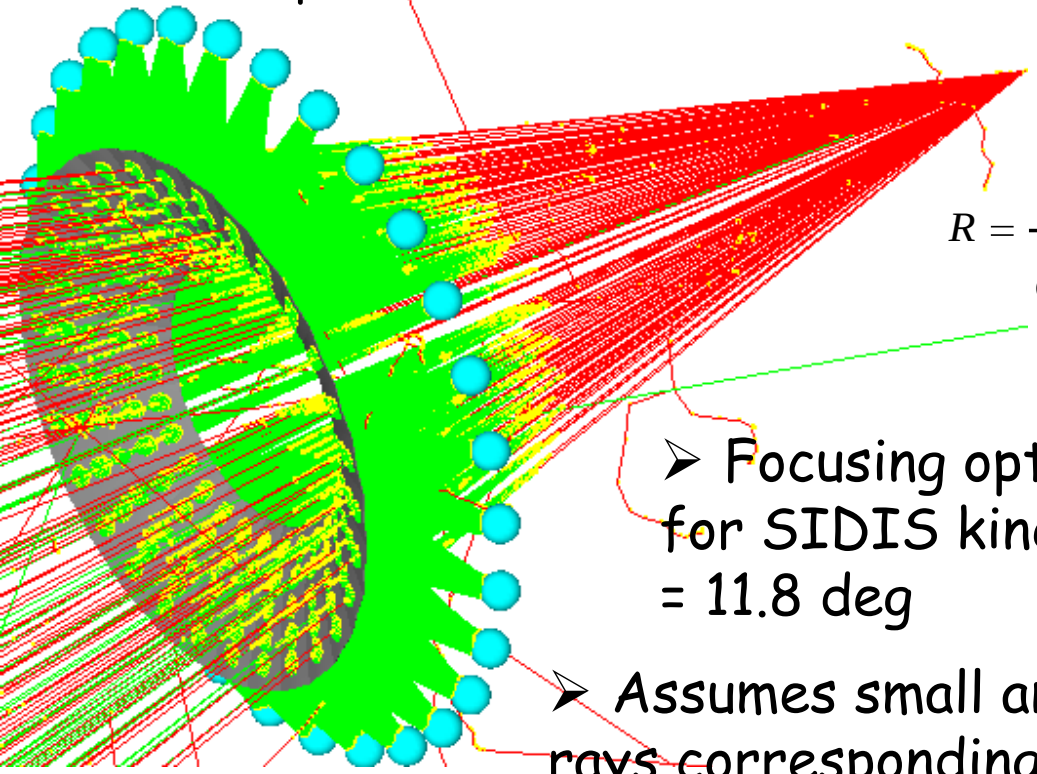


. Schematic cross section of Hall A with one of the HRS spectrometers in the (fictitious) 0° positic

Current Design: 1-Mirror System

- Use only one spherical mirror to focus the Cherenkov light onto PMTs
- If it works, it has practical advantages over the 3-mirror system:
  - Bounce off 1 mirror instead of 3 => fewer losses of Cherenkov light
  - Simpler => cheaper, easier to build/install/maintain
  - More space in the tank => more flexibility on PMT positioning



- Spherical mirror curvature:

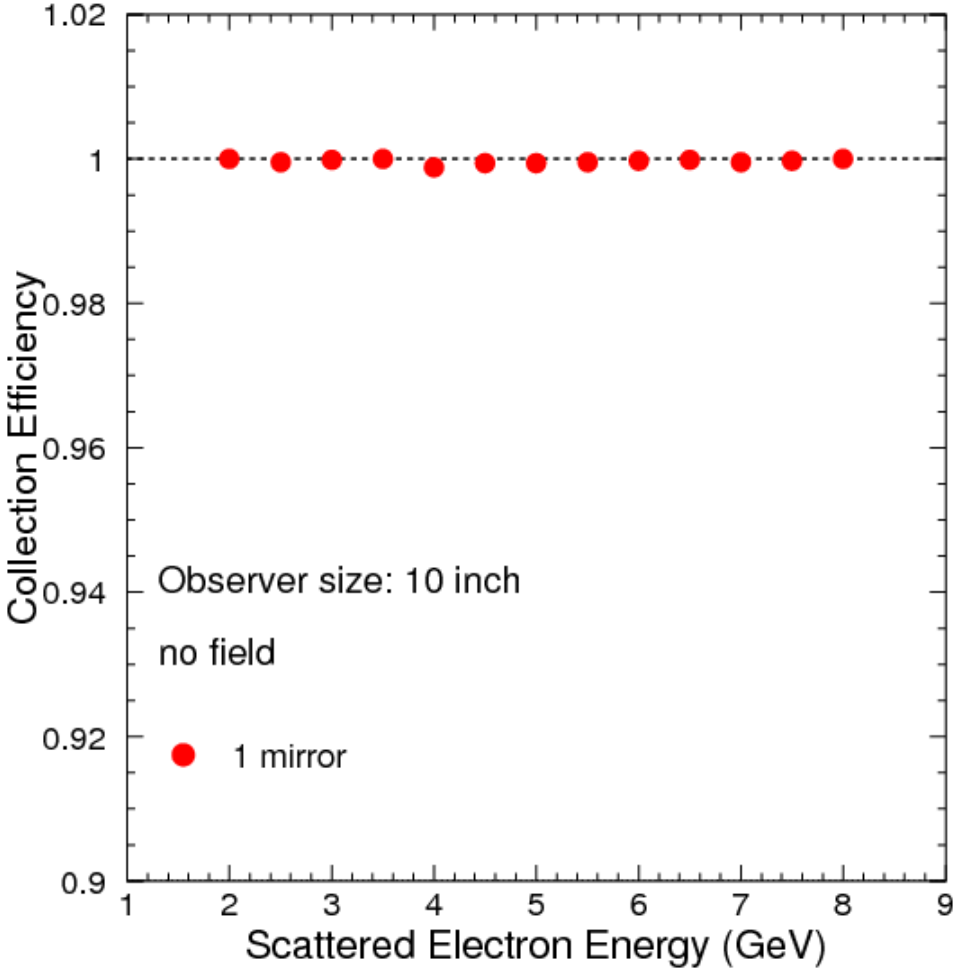
$$R = \frac{2}{\cos\theta\left(\frac{1}{x_i} + \frac{1}{x_r}\right)}$$

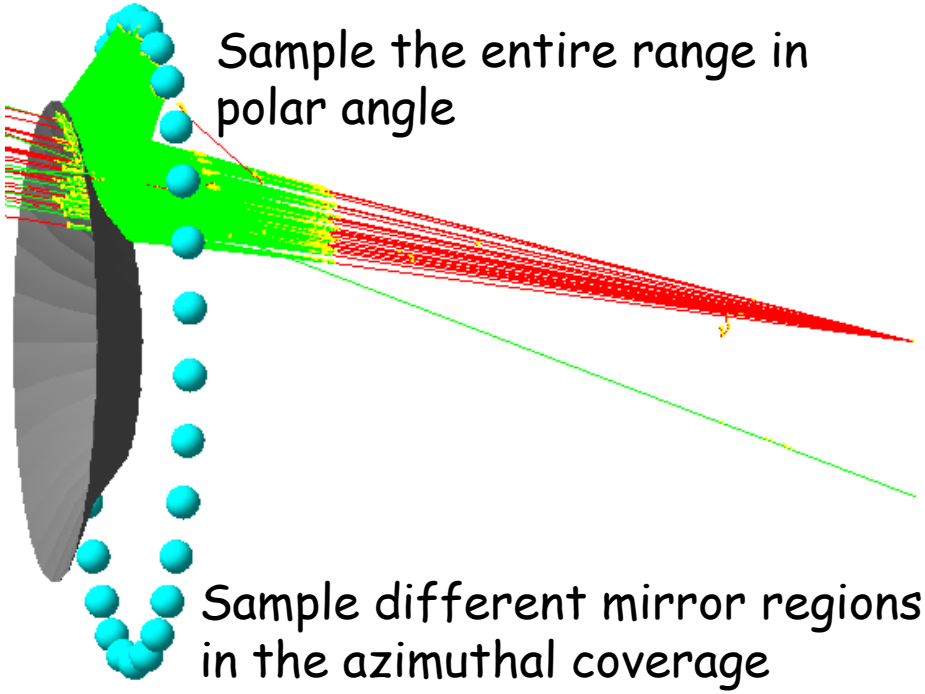
x_i = incident ray on mirror
x_r = reflected ray
θ = angle between incident ray and normal to the mirror

- Focusing optimized for central ray: for SIDIS kinematics (BaBar) => (9.3 + 14.3)/2 = 11.8 deg
- Assumes small angle between central ray and rays corresponding to min and max polar angles

1-Mirror System: Collection Efficiency

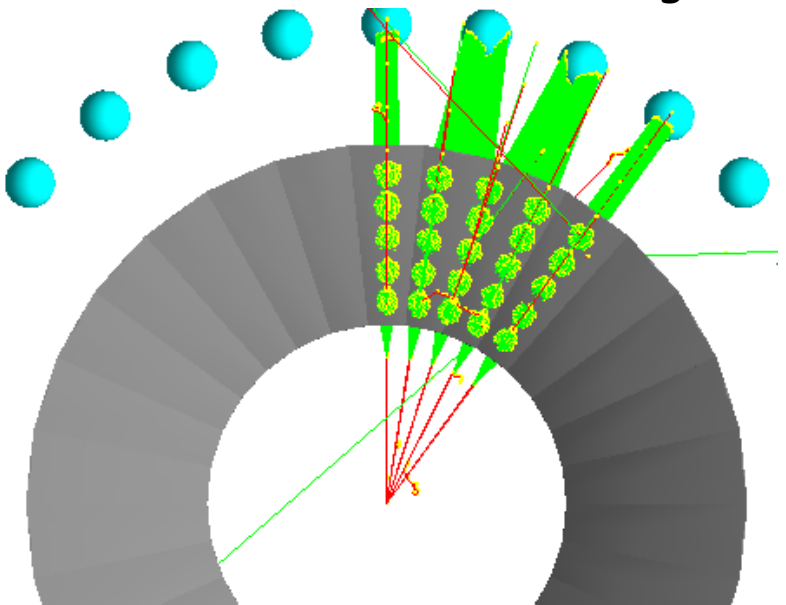
➢ **No magnetic field:**





Sample the entire range in polar angle

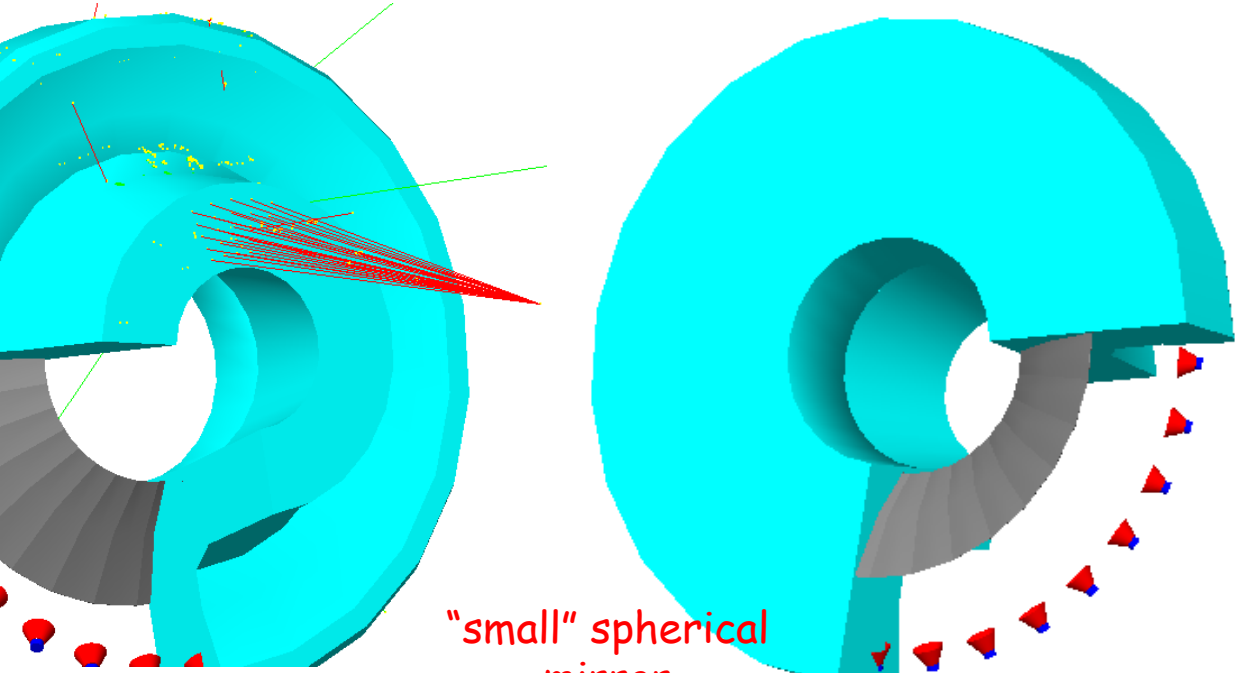
Sample different mirror regions in the azimuthal coverage

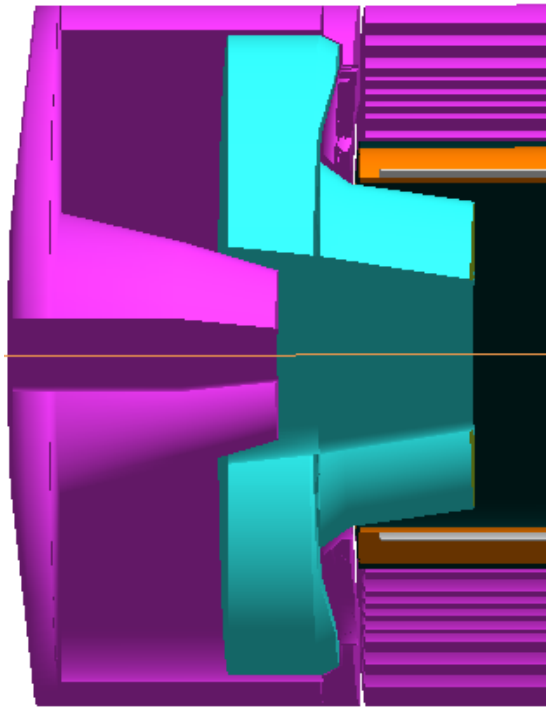


➢ Very good focusing for the whole kinematic range

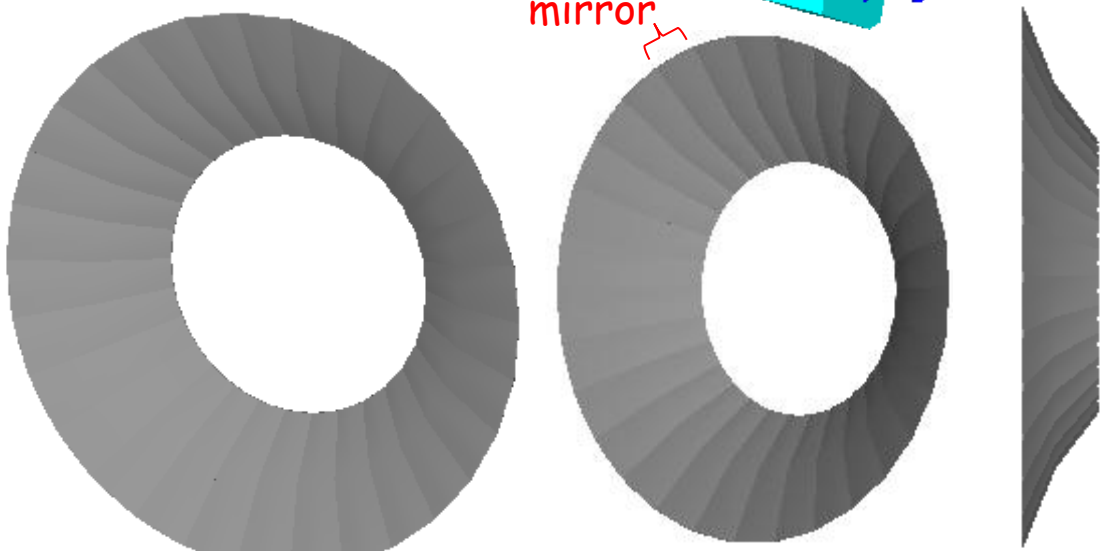
Tank and Mirror

- Tank: same dimensions as in the Geant3 simulation (proposal)



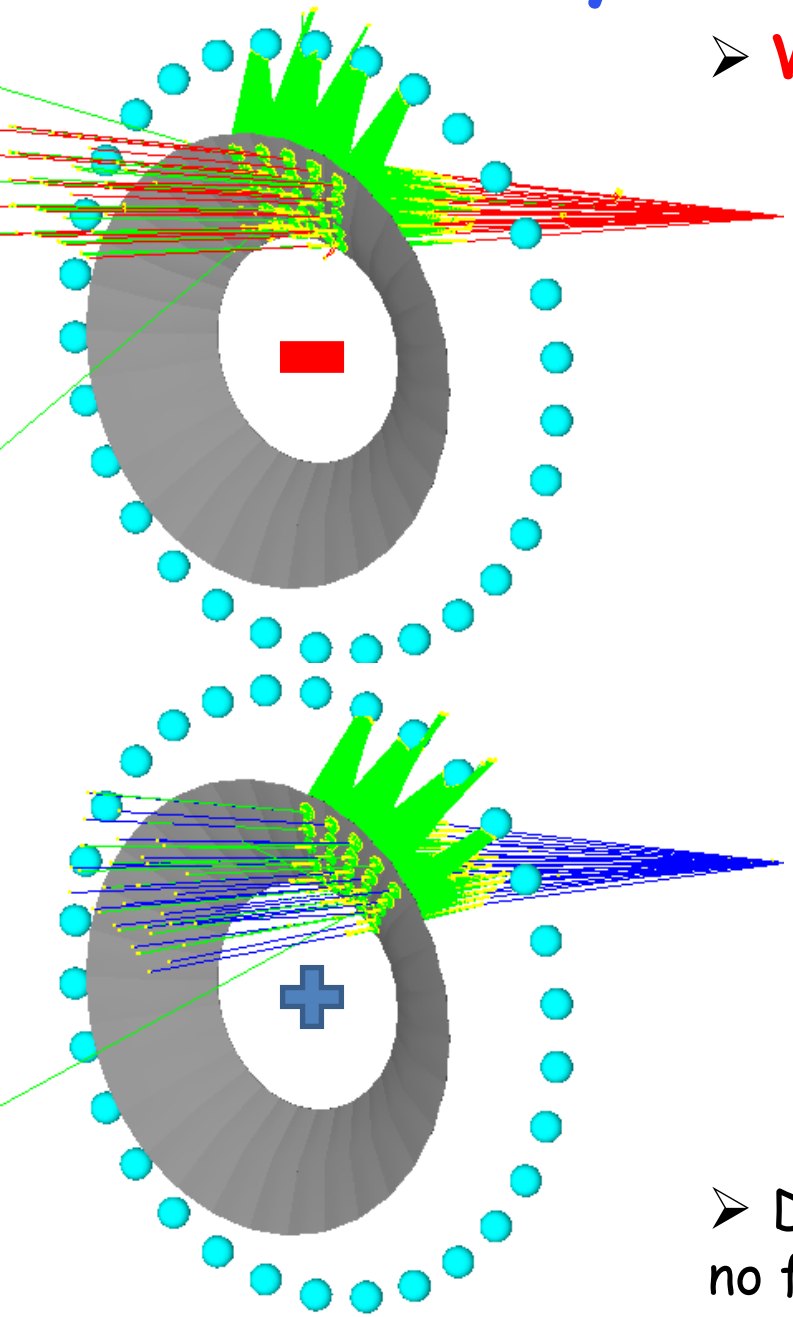


"small" spherical mirror

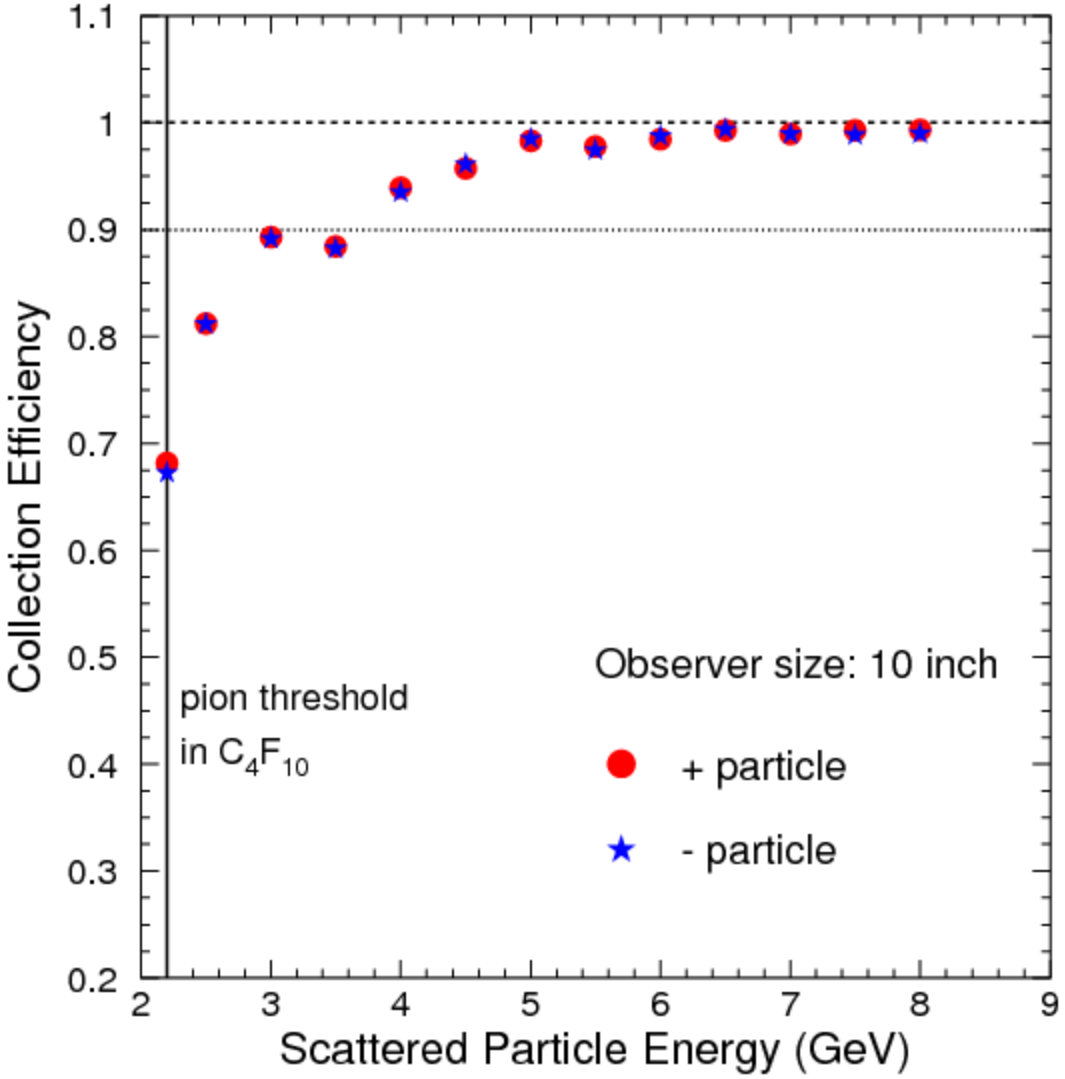


- Mirror: "big" mirror made of 30 "small" spherical mirrors (30 sectors)

1-Mirror System: Collection Efficiency



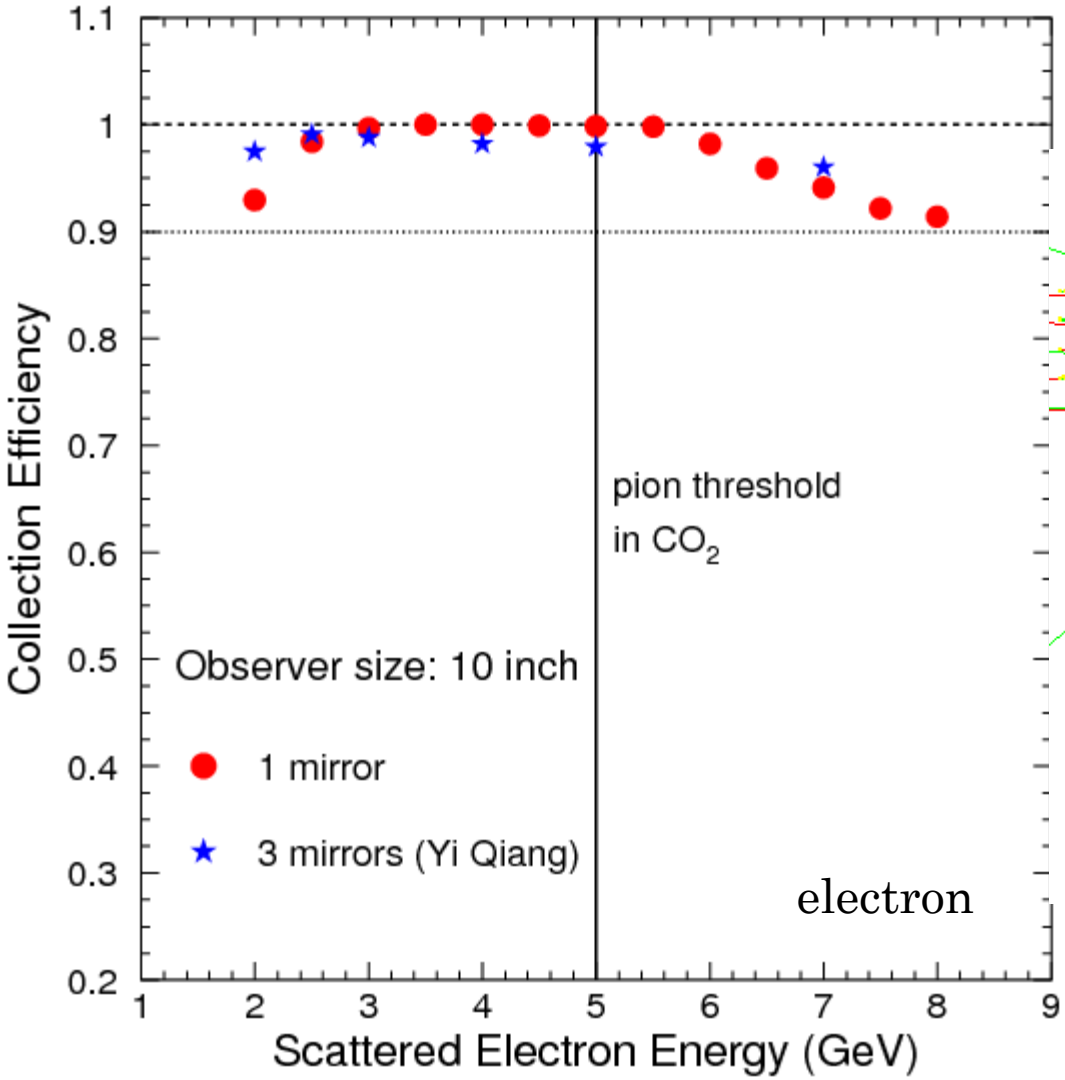
- With magnetic field (BaBar):



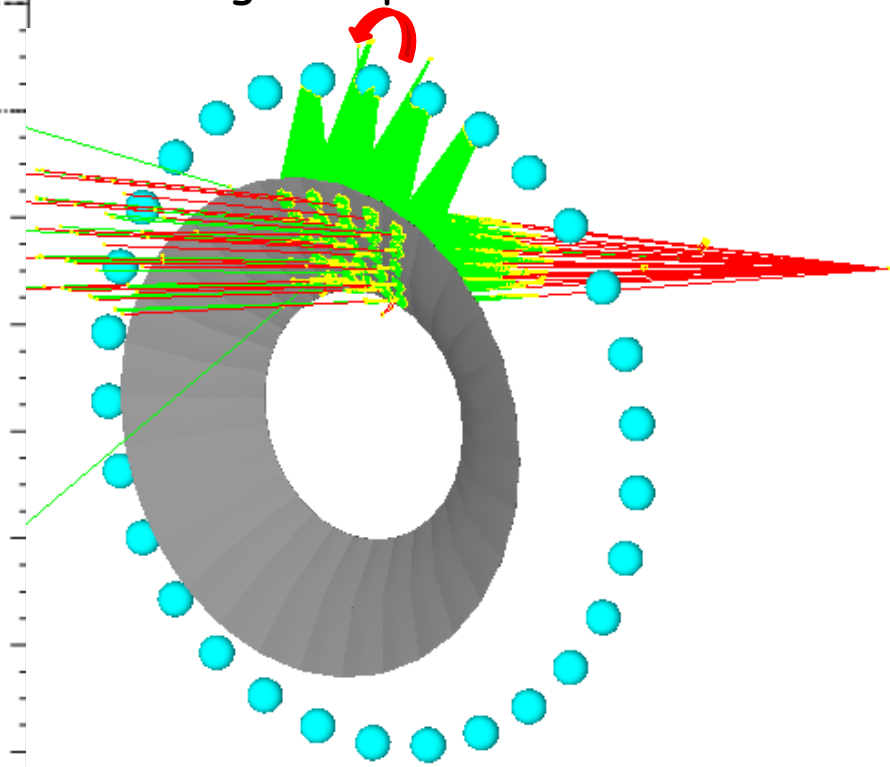
- Drop in efficiency at low momentum w.r.t. no field case but still pretty good

Electron Collection Efficiency

➢ For now (reminder of talk) focus on electron detection: **Light Gas Cherenkov**

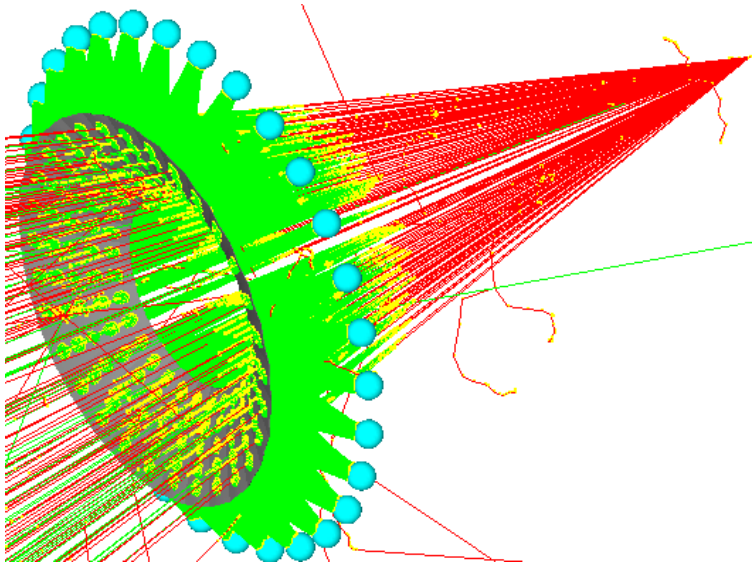


Slightly rotate Observers to favor negative particles



➢ Good efficiency in the kinematic region of interest (same as for the 3-mirror)

Focusing onto PMTs



- Cherenkov light spot size at PMTs ~10 inch (all kinematics)

↓

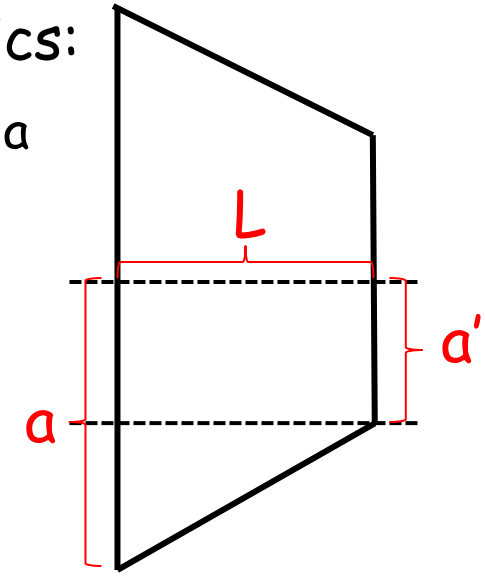
Need to reduce it to 3 inch (at least) if we want to avoid bunching PMTs

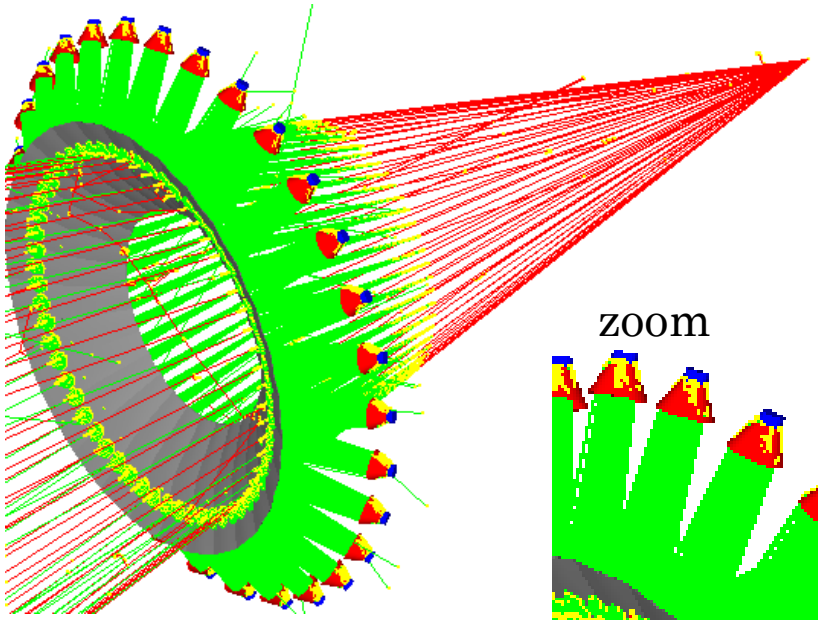
↓

use cones

- Cone characteristics:
  - Entrance aperture: 2a
  - Exit aperture: 2a′
  - Length: L

$$tg\theta = \frac{a - a'}{L}$$

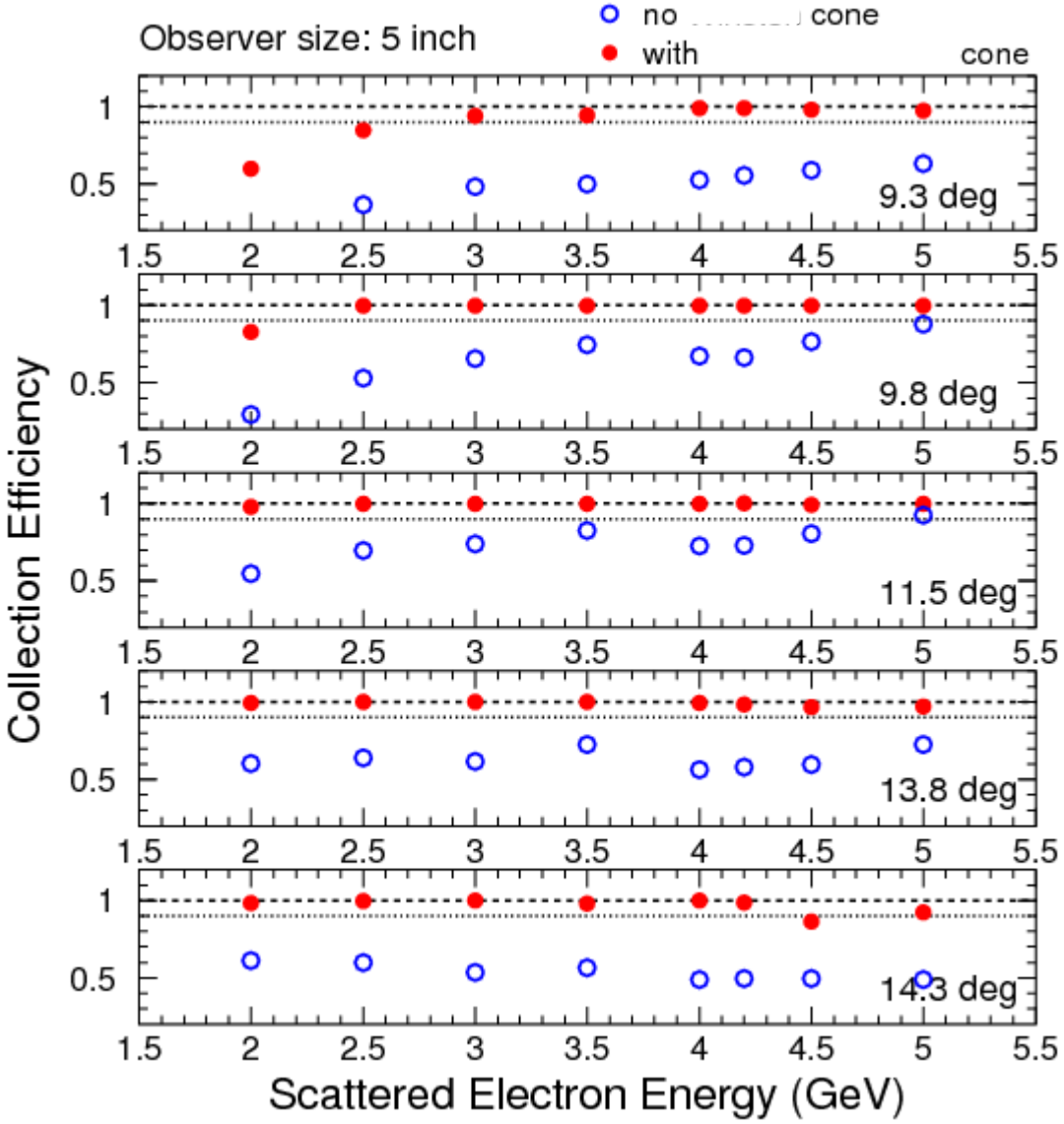


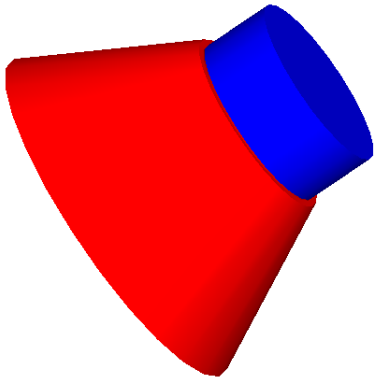


zoom

Work in Progress…

- Focusing onto 5 inch area:



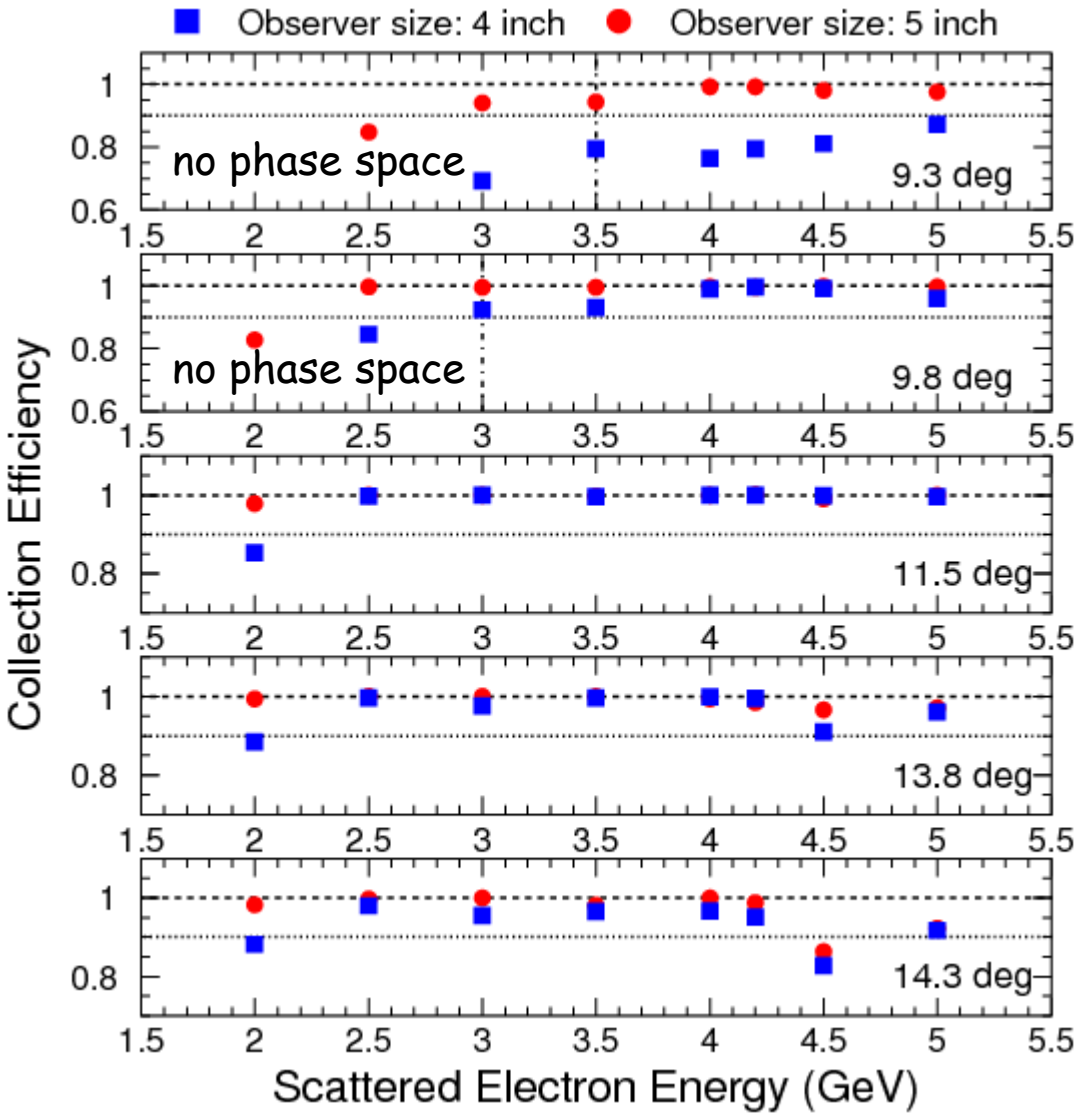


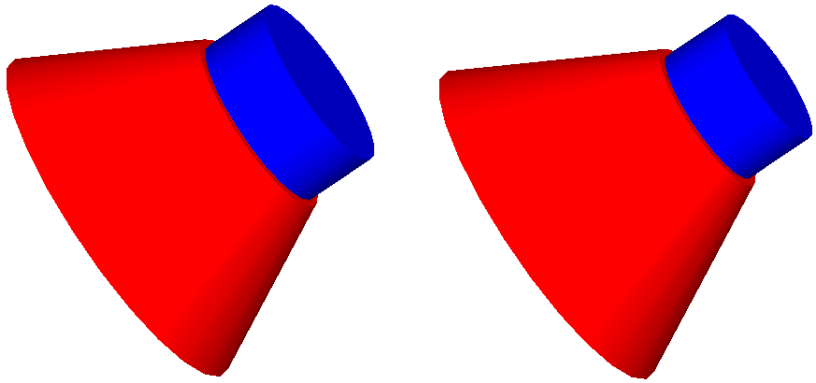
a = 5 inch
a' = 2.5 inch
L = 4.7 inch

- Good collection efficiency overall (> 90%) from 14.3 deg to 9.8 deg
- Lower efficiency at low momentum (< 3 GeV) for 9.8 deg and 9.3 deg **however** no phase space there for SIDIS

Work in Progress…

- Focusing onto 4 inch area:



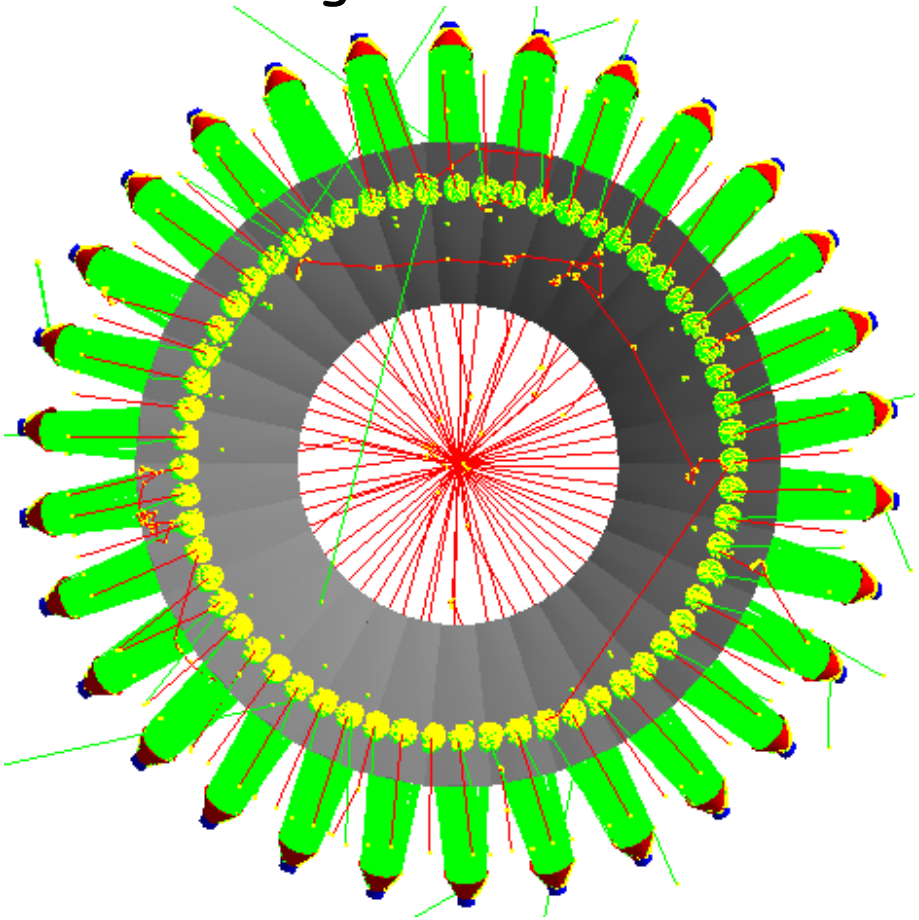


- Keep the same cone angle => make the cone longer and the entrance aperture just slightly smaller

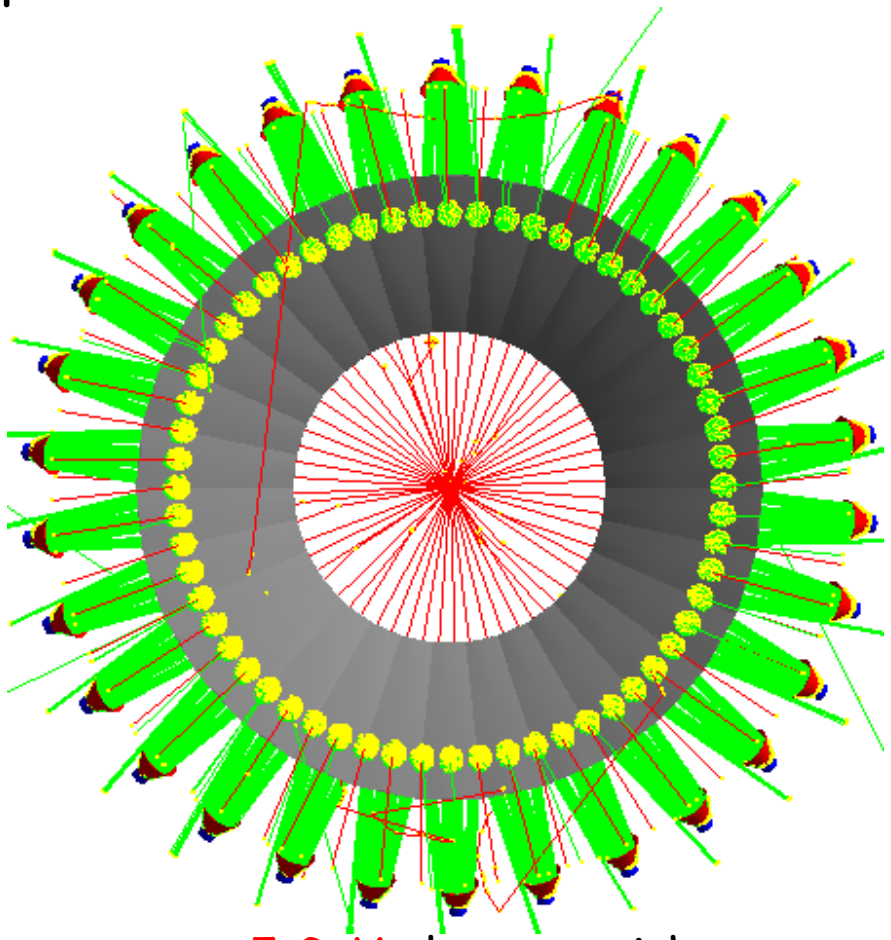
- Efficiency drops significantly (by at most 20%) only at the lowest angle – 9.3 deg

Work in Progress…

- Focusing onto 4 inch area: examples



2.5 GeV electron with
Polar angle = 13.8 deg

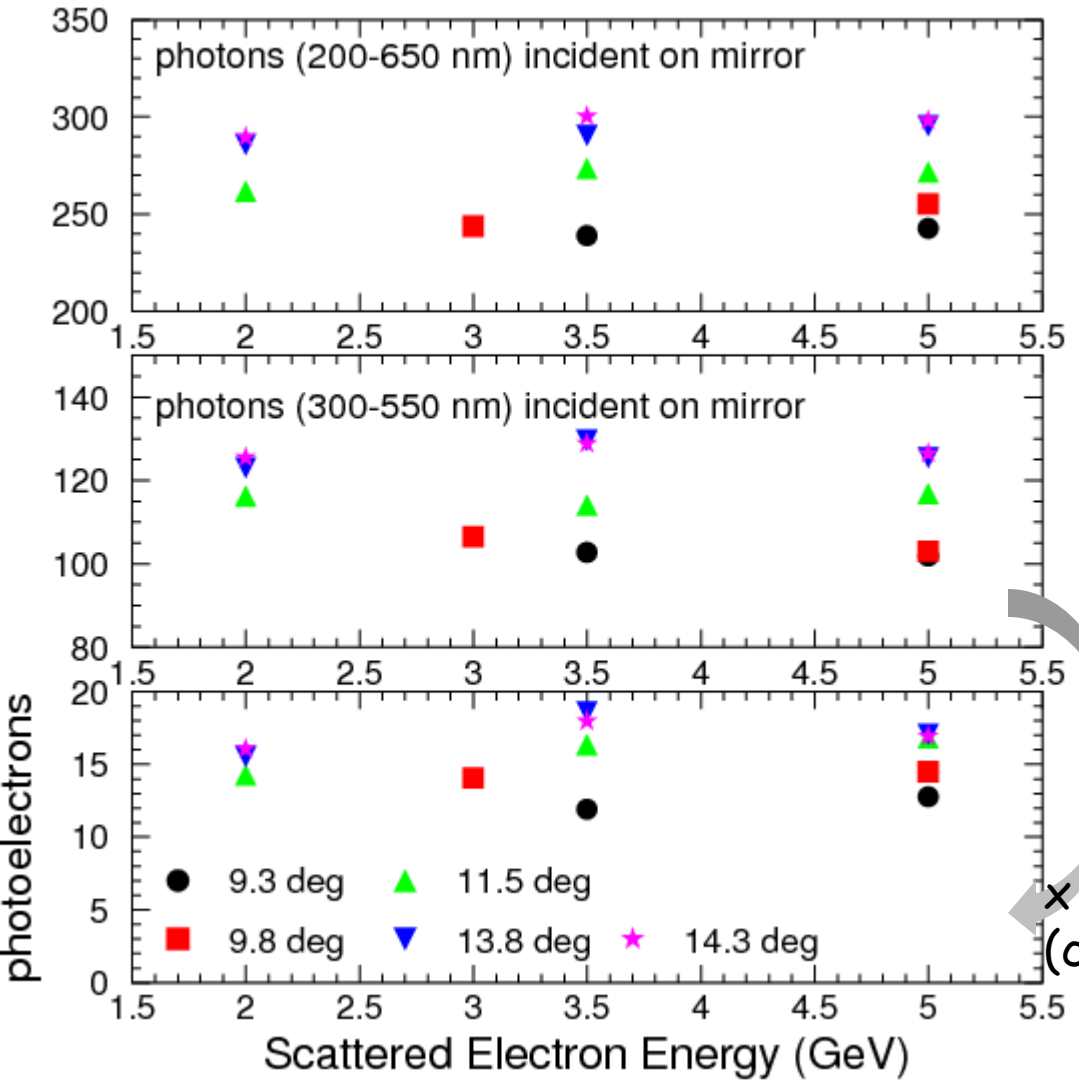


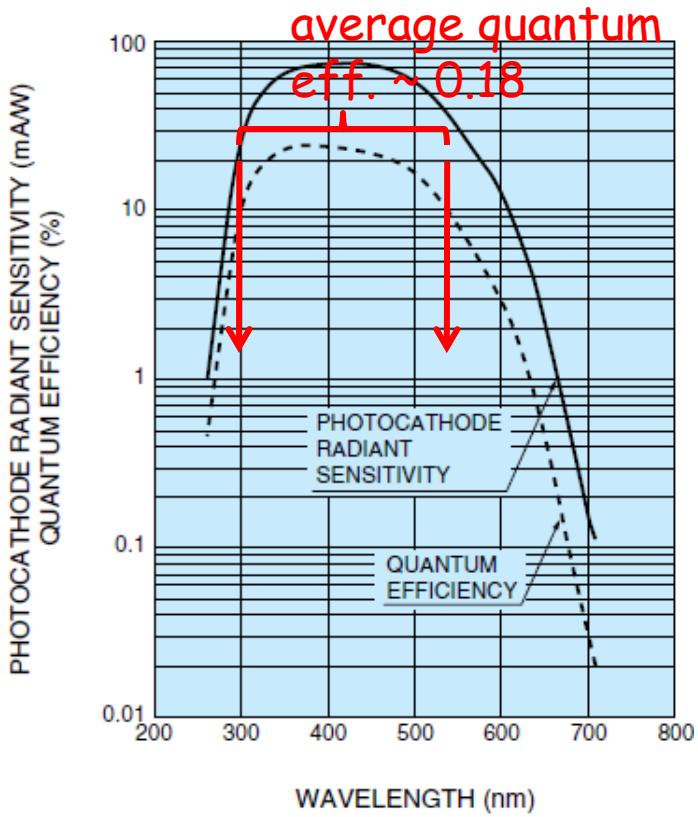
5 GeV electron with
Polar angle = 13.8 deg

- Problem at low angle, low momentum: multiple bounces off the cone

Work in Progress…

- Will try to go to 3 inch (to do) … until then:
- Quick and rough estimation of number of photoelectrons:





× 0.8 (mirror reflectivity) x (collection eff.) x 0.18 (quantum eff.)

Light Gas Cherenkov: Summary

- 1-Mirror design: the way to go

To do (short range plan):

Optics:

- Reduce the light spot size to 3 inch and still keep good collection efficiency

PMTs:

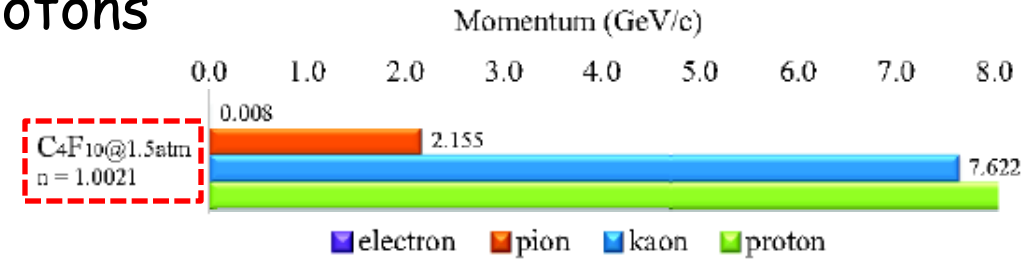
- Find out if we can get 3 inch PMTs (resistant in magnetic field; good quantum efficiency at low wavelengths)
- PMTs in magnetic field:
  - How big is the field at the current PMT position?
  - If not acceptable, find a "magic spot" to place the PMT…
- Realistic simulation of PMTs: fold in the quantum efficiency and get a more realistic estimation for the signal

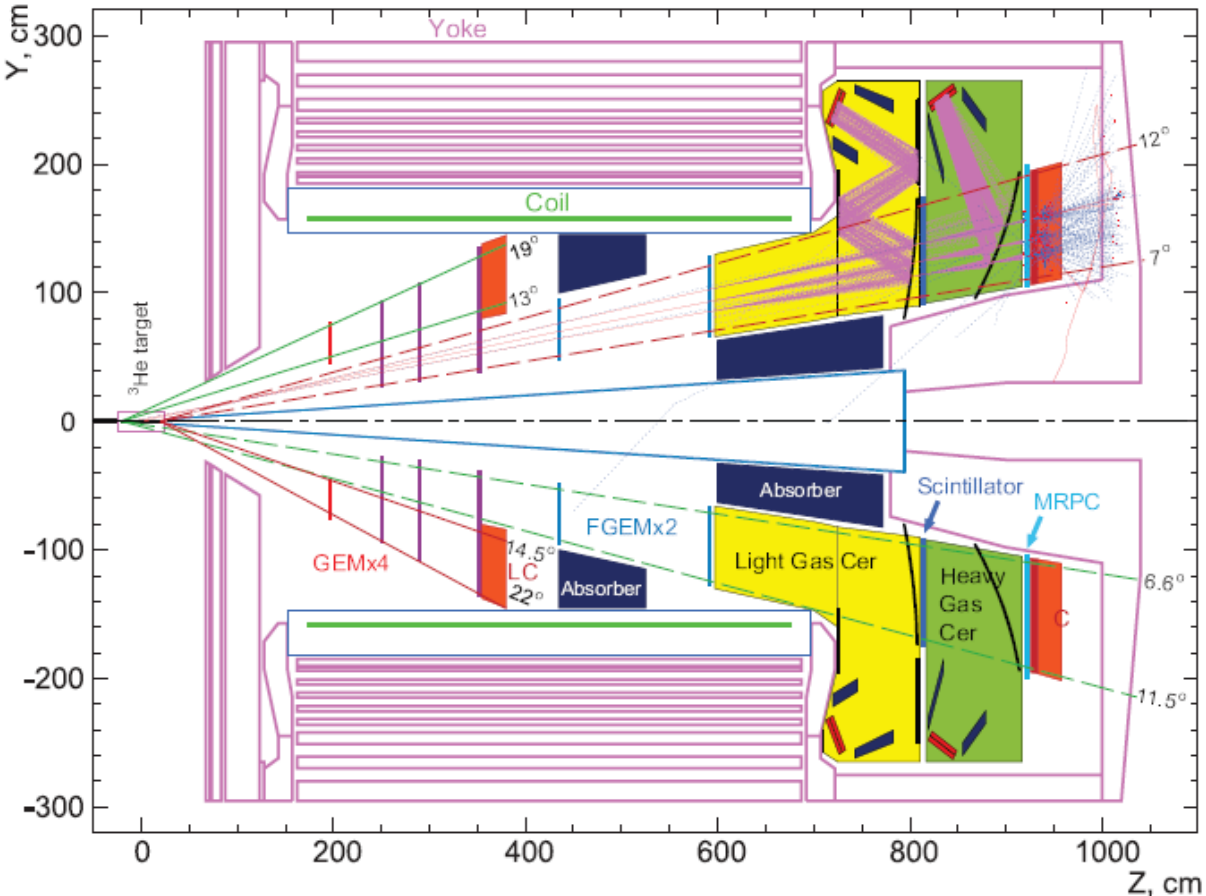
Simulation:

- Migrate to GEMC and write routines to fish out the detector response

To Do: Heavy Gas Cherenkov

- Requirements for SIDIS (E12-10-006): separate pions from kaons and protons

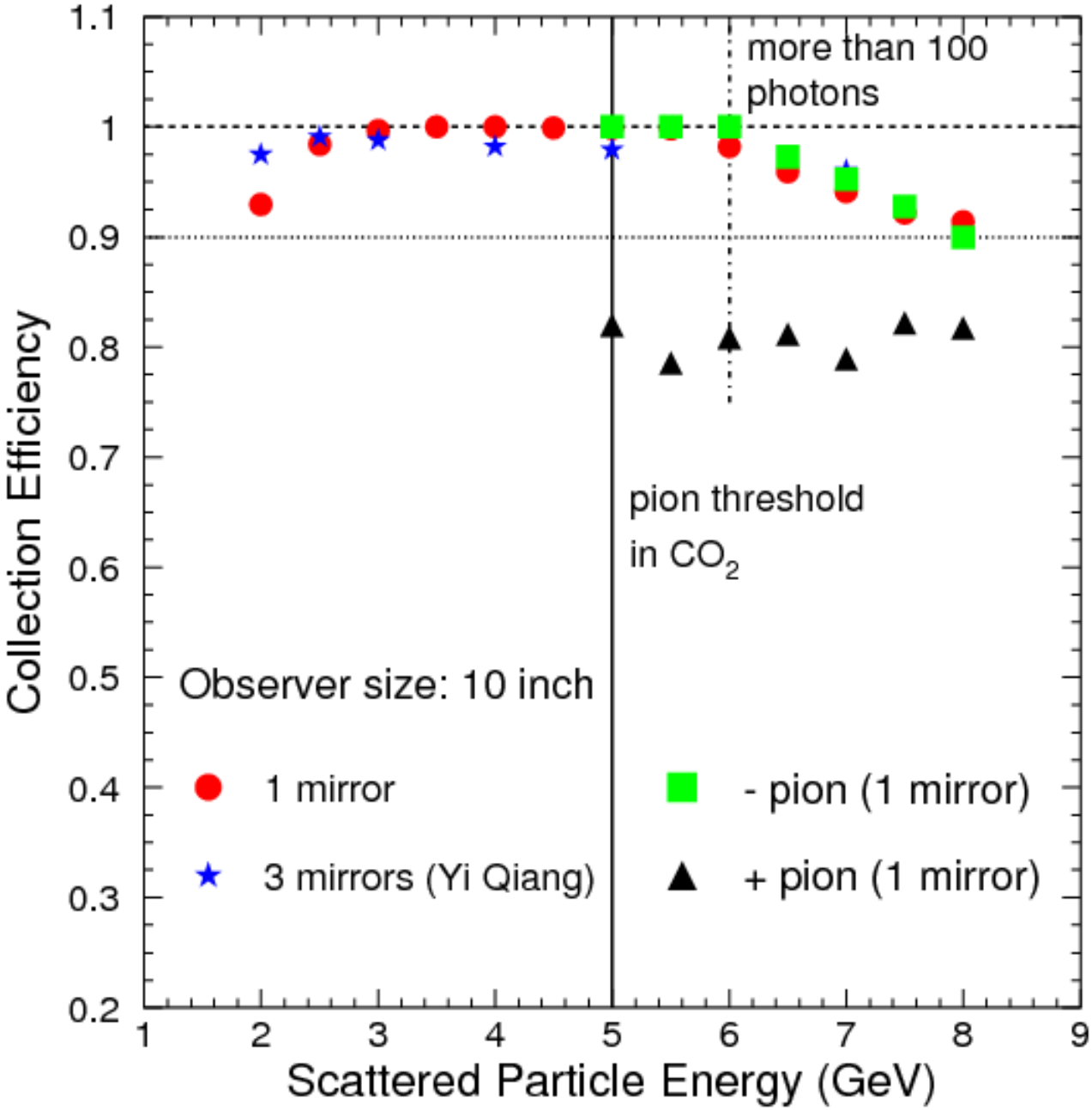




- More stringent requirements than for the light gas Cherenkov (both positive and negative particles) + less space available

Backup Slides

Light Gas Cherenkov: Efficiency



Light Gas Cherenkov: 4 inch Cone