SoLID: Transversity Light Gas Cerenkov Study

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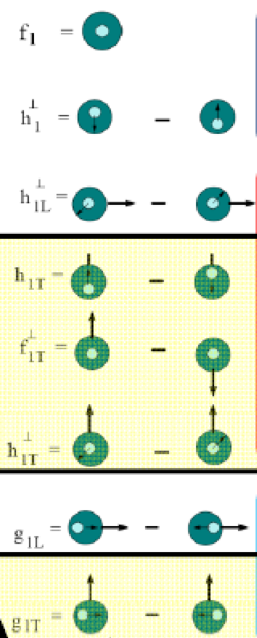
E12-10-006: Physics Goal

- Access TMDs through Semi-Inclusive DIS

$$\frac{d\sigma}{dx\,dy\,d\phi_S\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{xyQ^2}\,\frac{y^2}{2(1-\varepsilon)}\cdot$$



	$\{F_{UU,T} + \ldots$	**Unpolarized**
Boer-Mulder	$+\,\varepsilon\cos(2\phi_h)\cdot F_{UU}^{\cos(2\phi_h)} + \ldots$	
	$+\,S_L[\varepsilon\sin(2\phi_h)\cdot F_{UL}^{\sin(2\phi_h)} + \ldots]$	**Polarized Target**
Transversity	$+\,S_T[\varepsilon\sin(\phi_h+\phi_S)\cdot F_{UT}^{\sin(\phi_h+\phi_S)}$	
Sivers	$+\sin(\phi_h-\phi_S)\cdot(F_{UL}^{\sin(\phi_h-\phi_S)} + \ldots)$	
Pretzelosity	$+\,\varepsilon\sin(3\phi_h-\phi_S)\cdot F_{UT}^{\sin(3\phi_h-\phi_S)} + \ldots]$	
	$+\,S_L\lambda_e[\sqrt{1-\varepsilon^2}\cdot F_{LL} + \ldots]$	**Polarized Beam and Target**
	$+\,S_T\lambda_e[\sqrt{1-\varepsilon^2}\cos(\phi_h-\phi_S)\cdot F_{LT}^{\cos(\phi_h-\phi_S)} + \ldots]\}$	

S_L, S_T: Target Polarization; λ_e: Beam Polarization

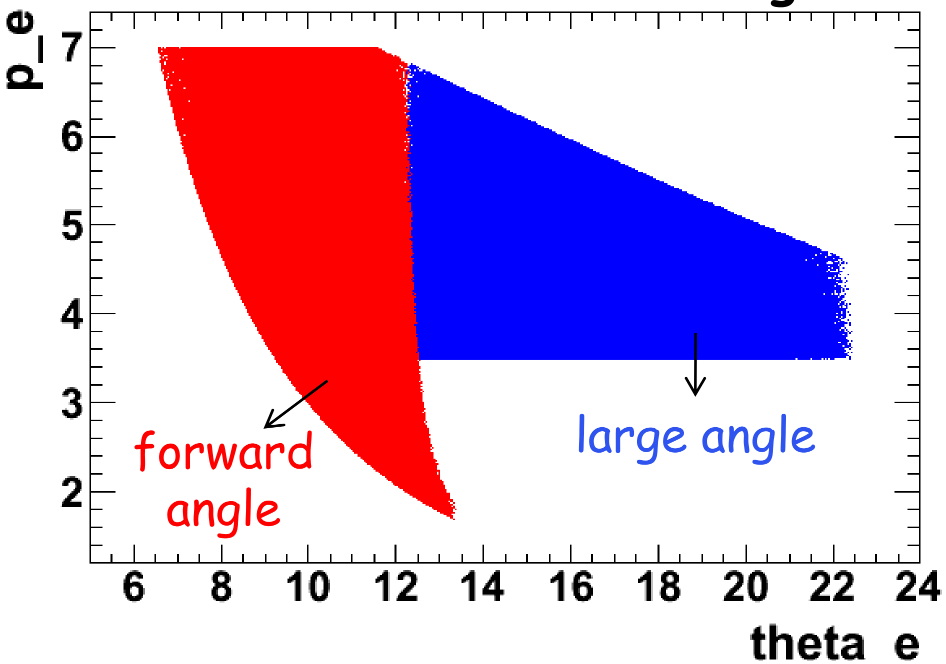
The proposed measurement in this proposal will access these terms.

from PAC35 talk

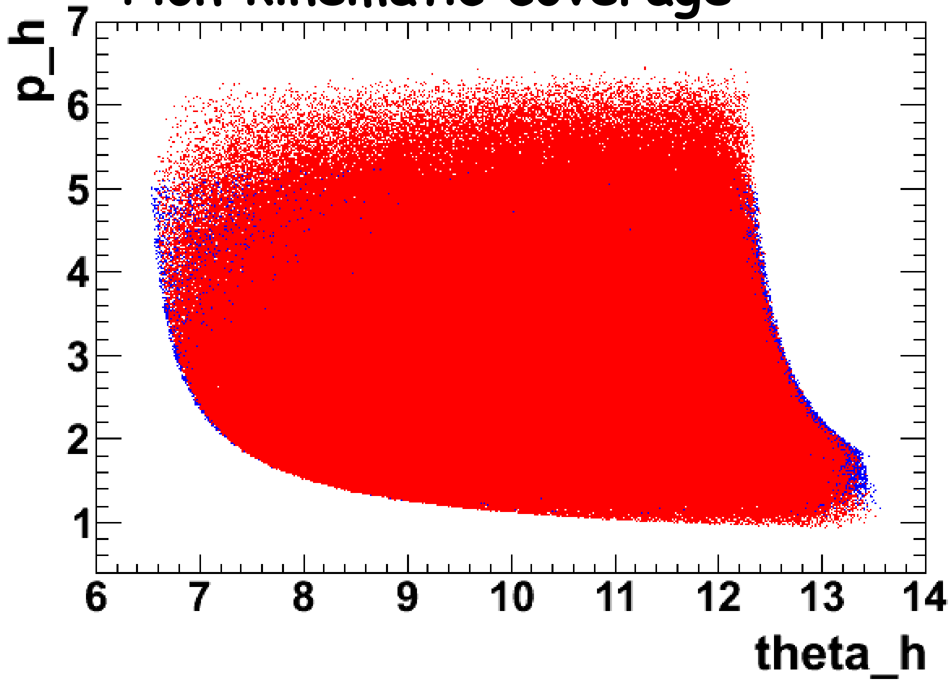
E12-10-006: Kinematics

➢ Coincidence experiment in Hall A with SoLID: $(e^-, \pi^{+,-})$

Electron kinematic coverage



Pion kinematic coverage

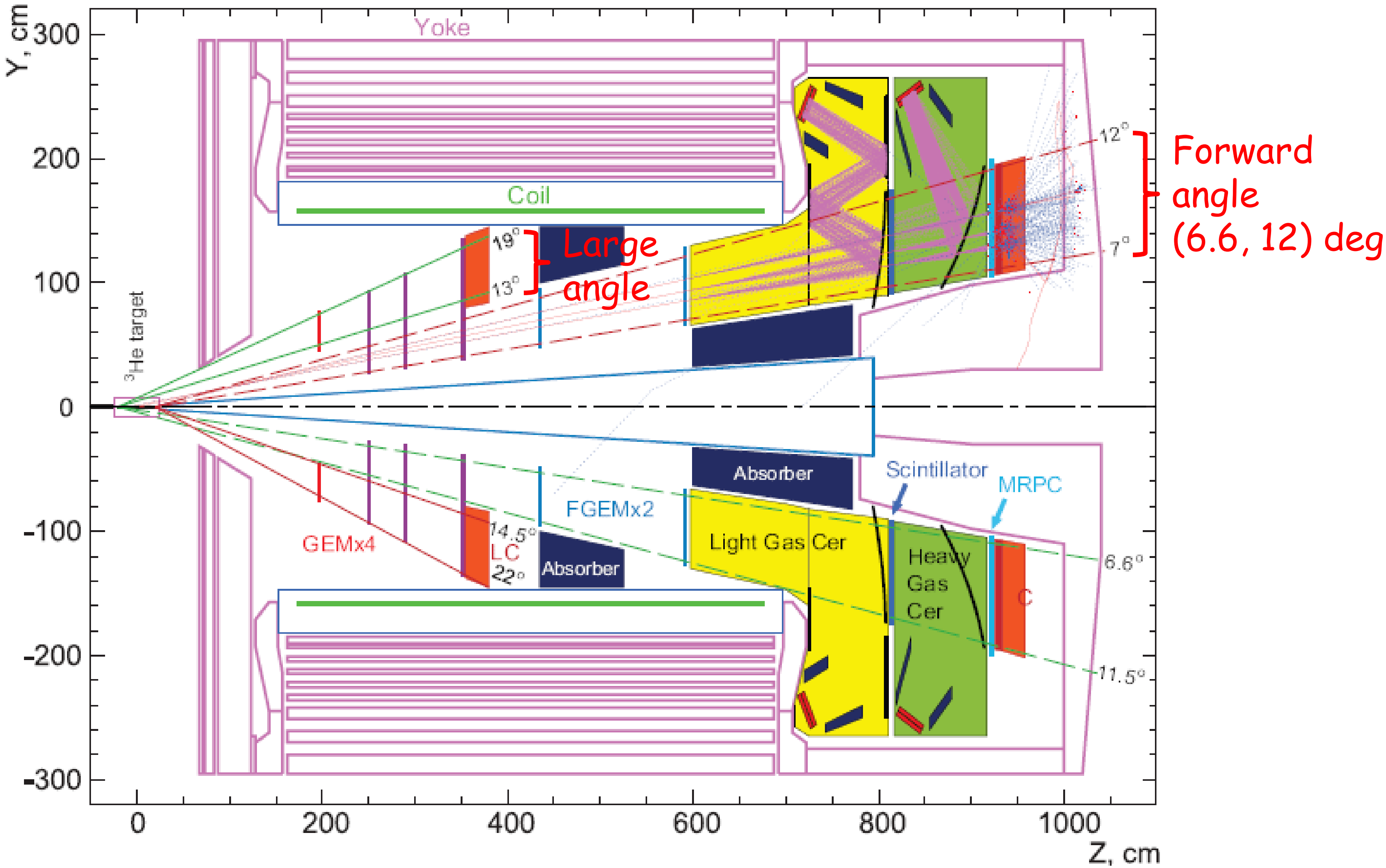


- Q^2 coverage: (1, 8) GeV^2
- W coverage: (2.3, 4) GeV
- x coverage: (0.05, 0.65)
- z coverage: (0.3, 0.7)

- p_T coverage: (0, 1.6) GeV^2
- 2π coverage in the azimuthal angle

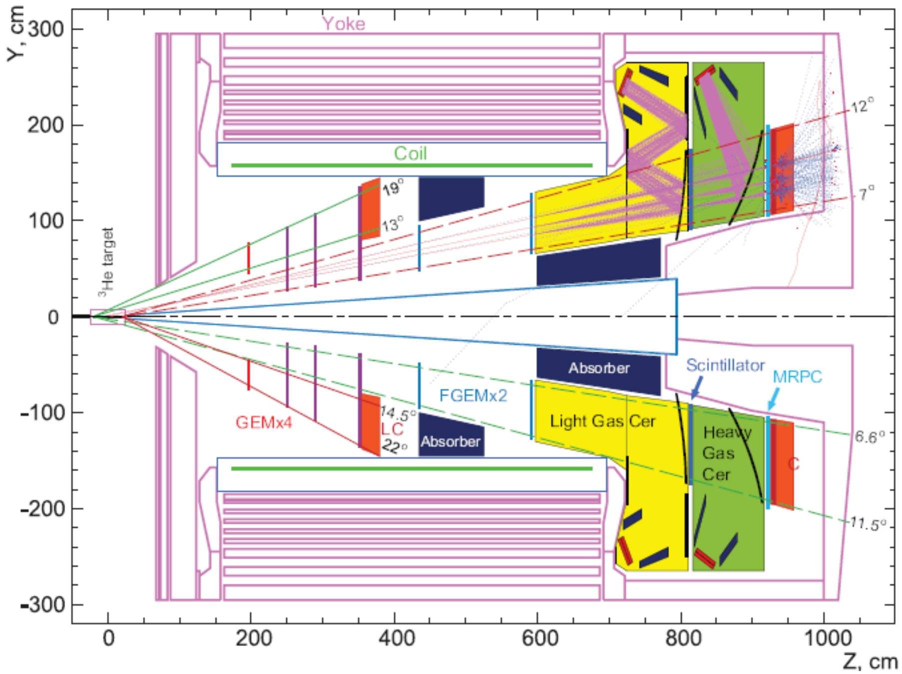
E12-10-006: SoLID Detector

- **Coincidence** experiment in Hall A with SoLID: $(e^-, \pi^{+,-})$



E12-10-006: SoLID Detector

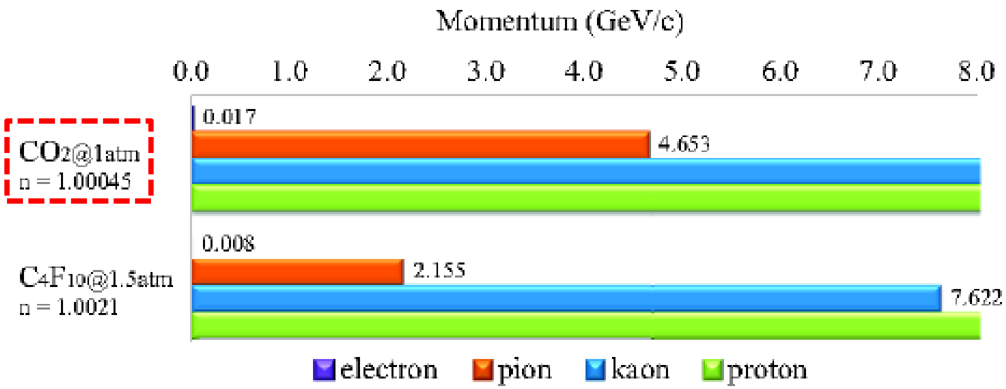
- **Coincidence** experiment in Hall A with SoLID: **$(e^-, \pi^{+,-})$**



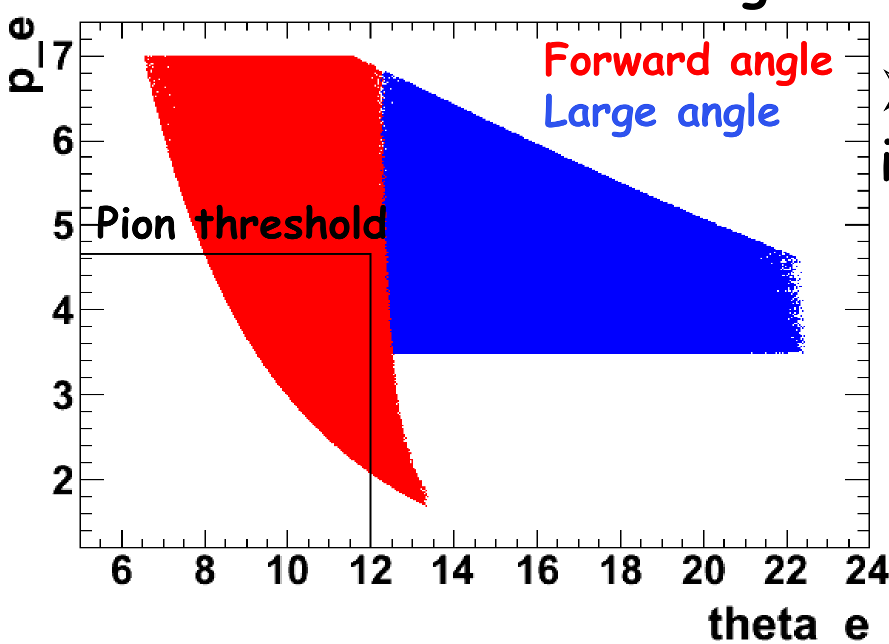
- Large angle detectors: **e^-**
  - GEMs (4 layers)
  - Shashlyk-type Calorimeter
- Forward angle detectors: **$e^-, \pi^{+,-}$**
  - GEMs (5 layers): tracking
  - **Light Gas Cerenkov**: e^- identification mainly
  - Scintillator: used to form hadron trigger
  - Heavy Gas Cerenkov: $\pi^{+,-}$ identification
  - MRPC: timing info to form coincidence
  - Calorimeter: **e^-, π** separation at high momentum

Light Gas Cerenkov

- Mainly used for electron identification at forward angle
  - The Light Gas Cerenkov: filled with CO_2 @ 1 atm, n = 1.00045
    - ○ Electrons with p > 0.017 GeV <u>will fire</u>
    - ○ Pions with p > 4.653 GeV <u>will fire</u>



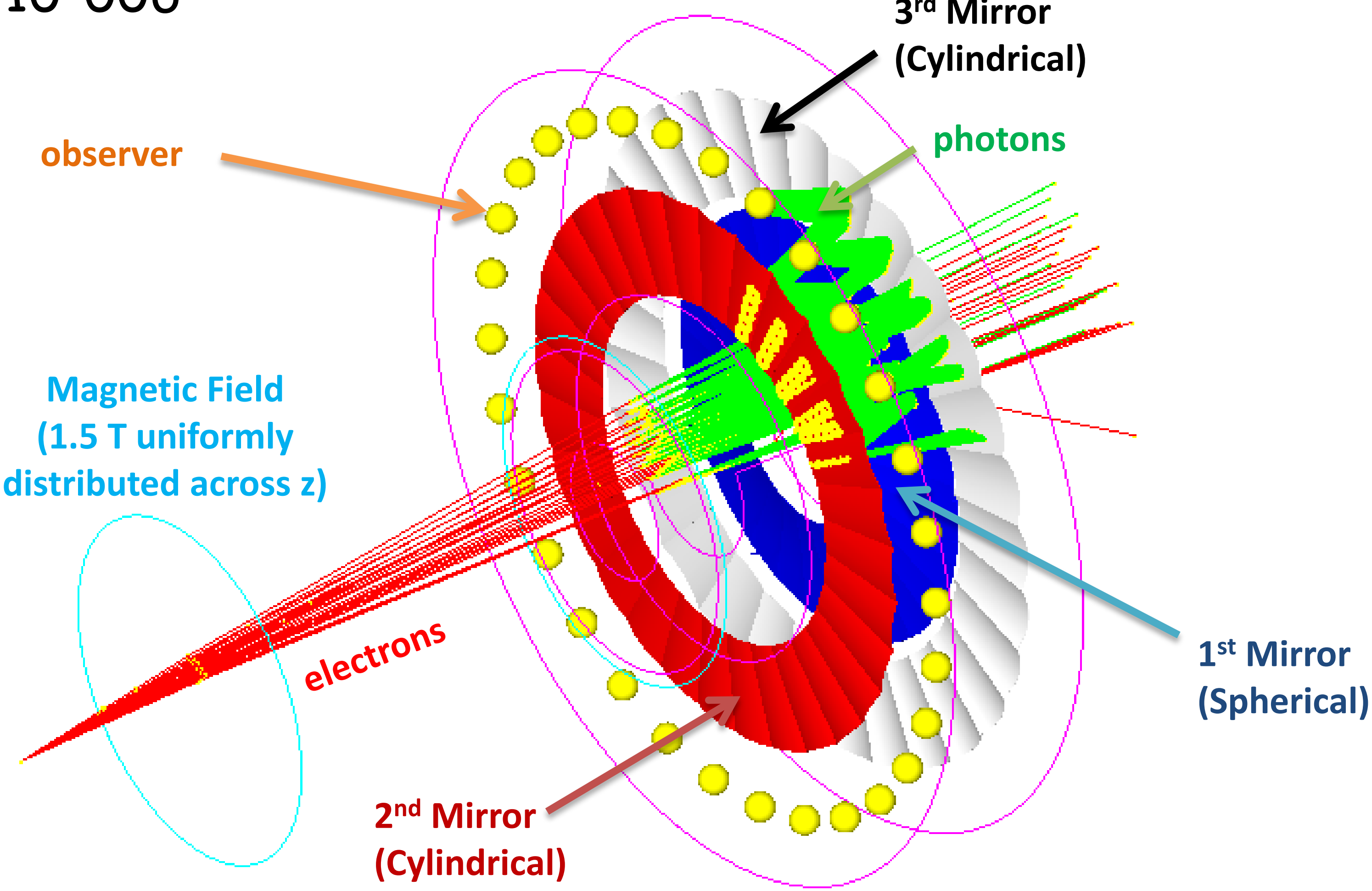
Electron kinematic coverage



- Given its properties and placement in SoLID, can be used to:
  - ○ Separate electrons with p = (0.017, 4.653) GeV from pions at forward angle
  - ○ Separate pions with p = (4.653, 8) GeV from kaons and protons

Light Gas Cerenkov: Simulation

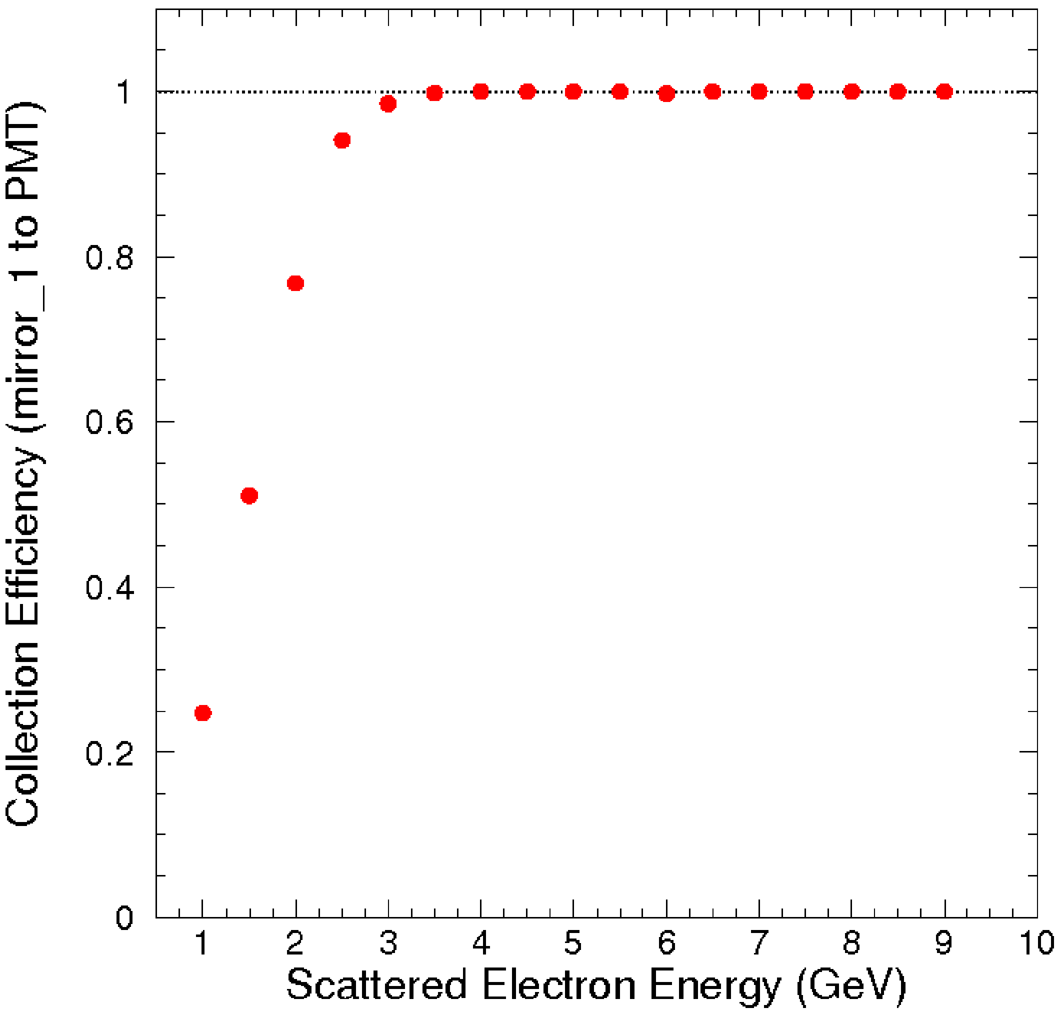
- Developed by Yi Qiang in Geant4: a viable optical system with optimal focusing for the polar angle and momentum range required by E12-10-006



picture from Yi Qiang

Light Gas Cerenkov: Collection Efficiency

➢ Of the photons that reached the first mirror, how many reached the observer (Winston cone + PMTs) assuming 100% mirror reflectivity?



- The coil's magnetic field complicates the problem: electrons with low momentum will be bent more than those with high momentum

○ The mirrors and the observer can be positioned such that:

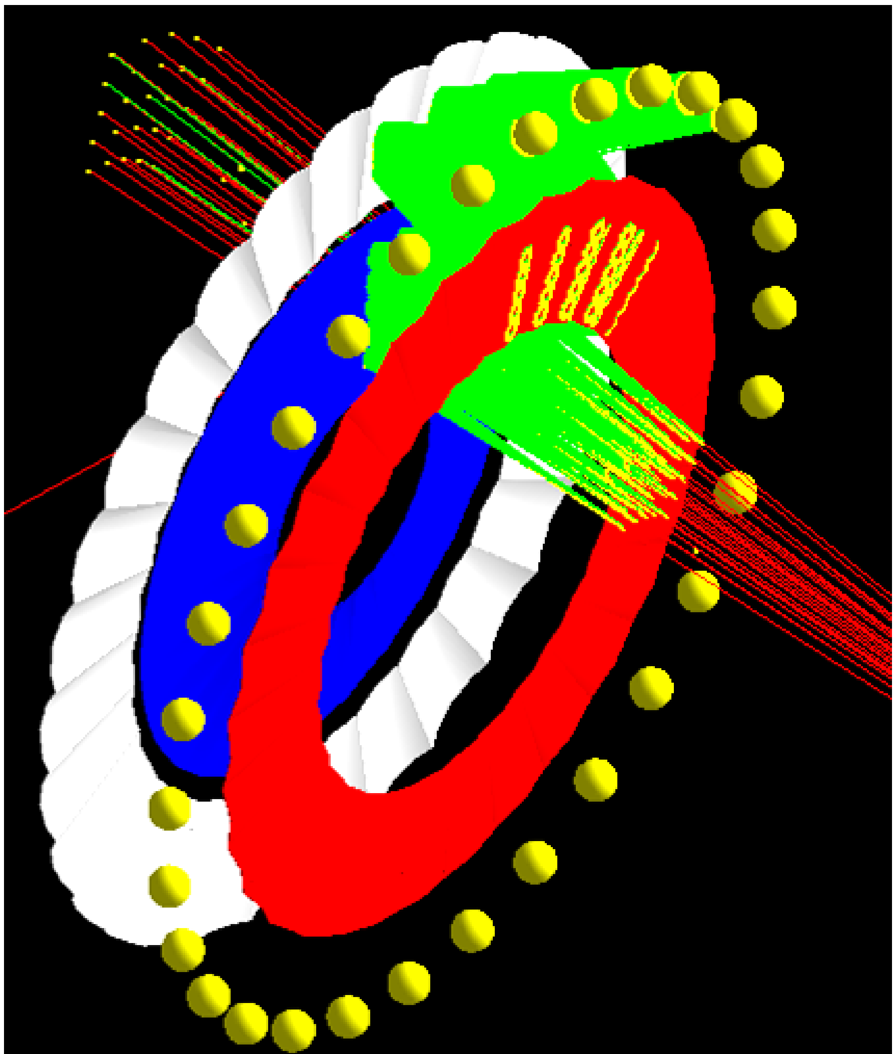
→ very good efficiency at high momentum (> 3 GeV)

→ not so good efficiency at low momentum (< 3 GeV)

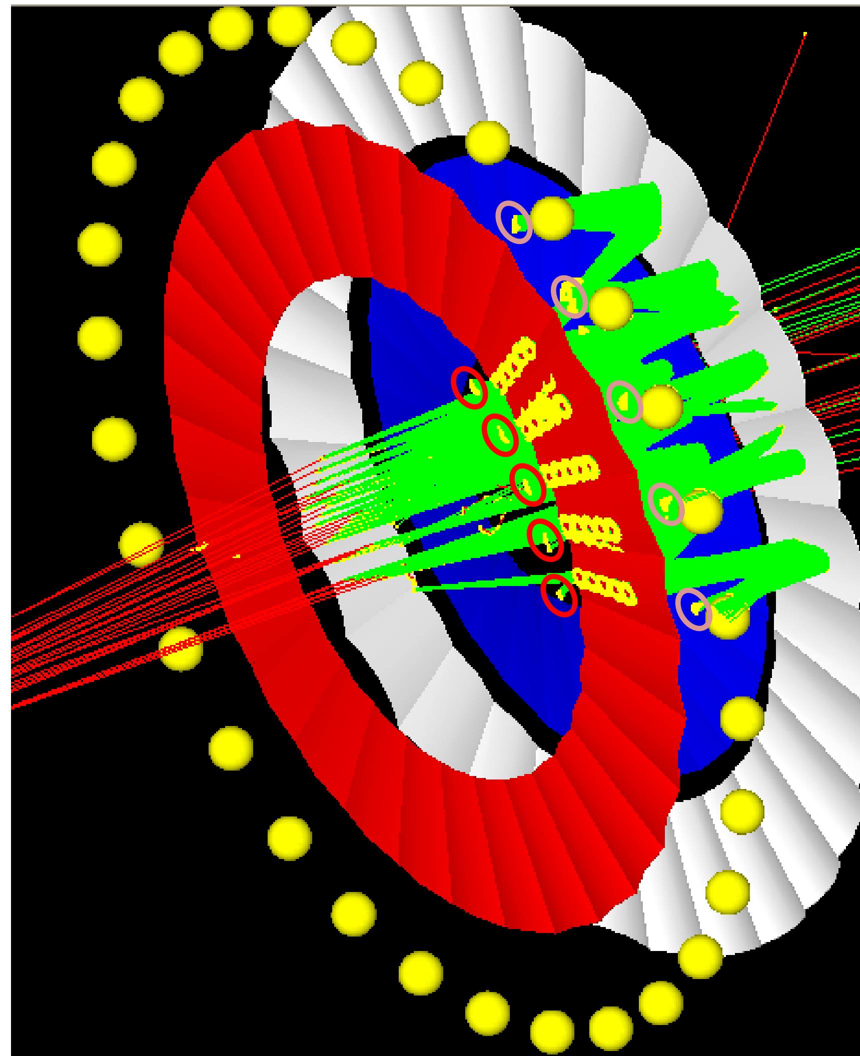
Light Gas Cerenkov: Collection Efficiency

Example

All photons are collected by the observer at momentum = 4 GeV

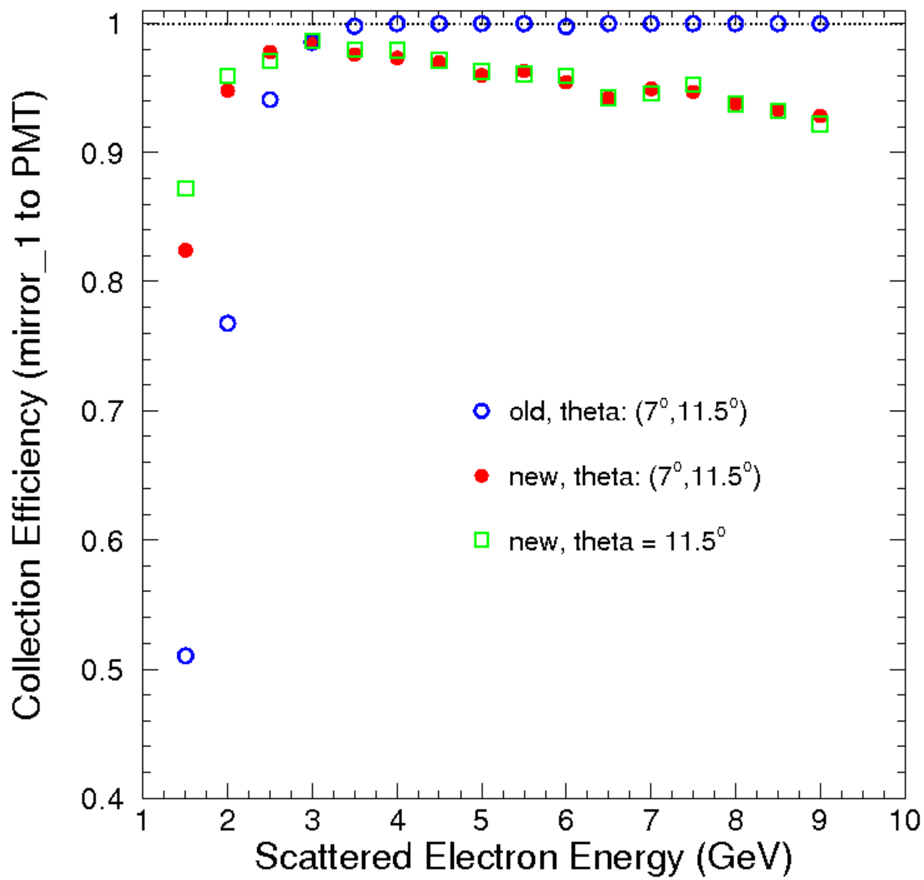


Some photons miss the observer and some photons miss the second mirror at momentum = 2 GeV



Light Gas Cerenkov: Collection Efficiency

○ **Or** … the mirrors and the observer can be positioned to optimize the efficiency at low momentum → slightly reduced efficiency at high momentum



Difference between old and new: the observer was repositioned

➢ Need to implement realistic magnetic field distribution: re-check the collection efficiency at low momentum

Light Gas Cerenkov: More Realistic Simulation

- Magnetic field:
  → Current: uniform magnetic field in the z direction (1.5 T)
  → Realistic: once we know what magnet we will use…

- Winston Cones simulation:
  → Current: the observer simulated as 10" diameter spheres
  → Realistic: need to simulate the Winston cones and their orientation to maximize light collection

- Tank simulation:
  → Current: no material for detector's walls and window (only a volume of CO_2 with optical properties for boundary assumed)
  → Realistic: introduce materials for window and walls

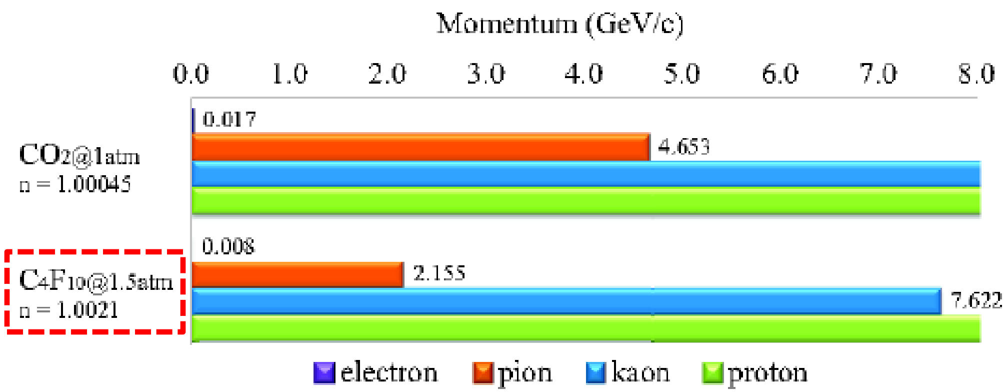
- Take into account mirror reflectivity

- Implement this simulation in GEMC

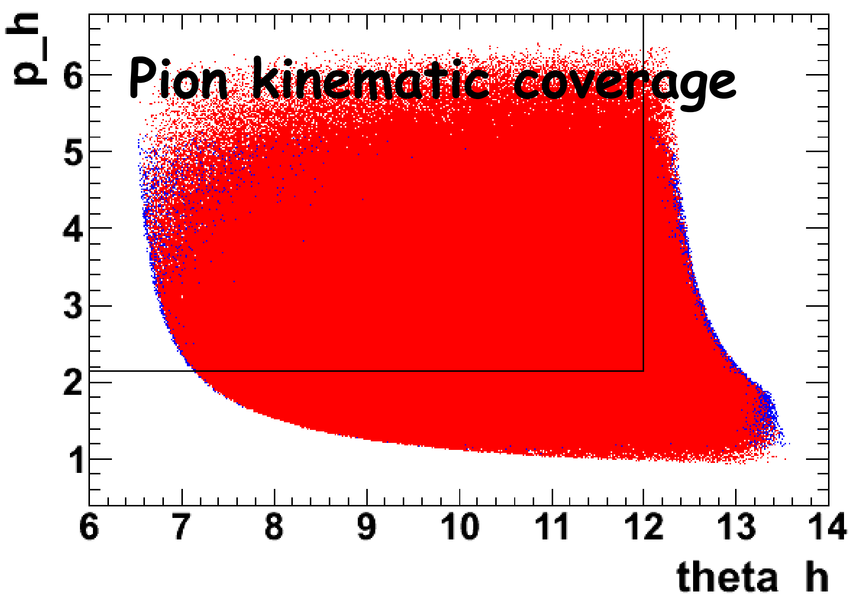
- …?

Heavy Gas Cerenkov

- Requirements for E12-10-006: separate pions from kaons and protons at forward angles, 6.6-12 deg
- The Heavy Gas Cerenkov: filled with C_4F_{10} @ 1.5 atm, n = 1.0021



- We can separate pions with momentum = (2.2, 7.6) GeV from kaons and protons



No simulation yet…

- Open question: use a similar optical design as for the **light gas Cerenkov**?

Summary

- Requirements for E12-10-006: need both **light and heavy gas Cerenkov detectors** to separate electrons from pions and pions from kaons and protons

- **Light gas Cerenkov**:

  • 3-mirrors optical system in place and working

  To do:

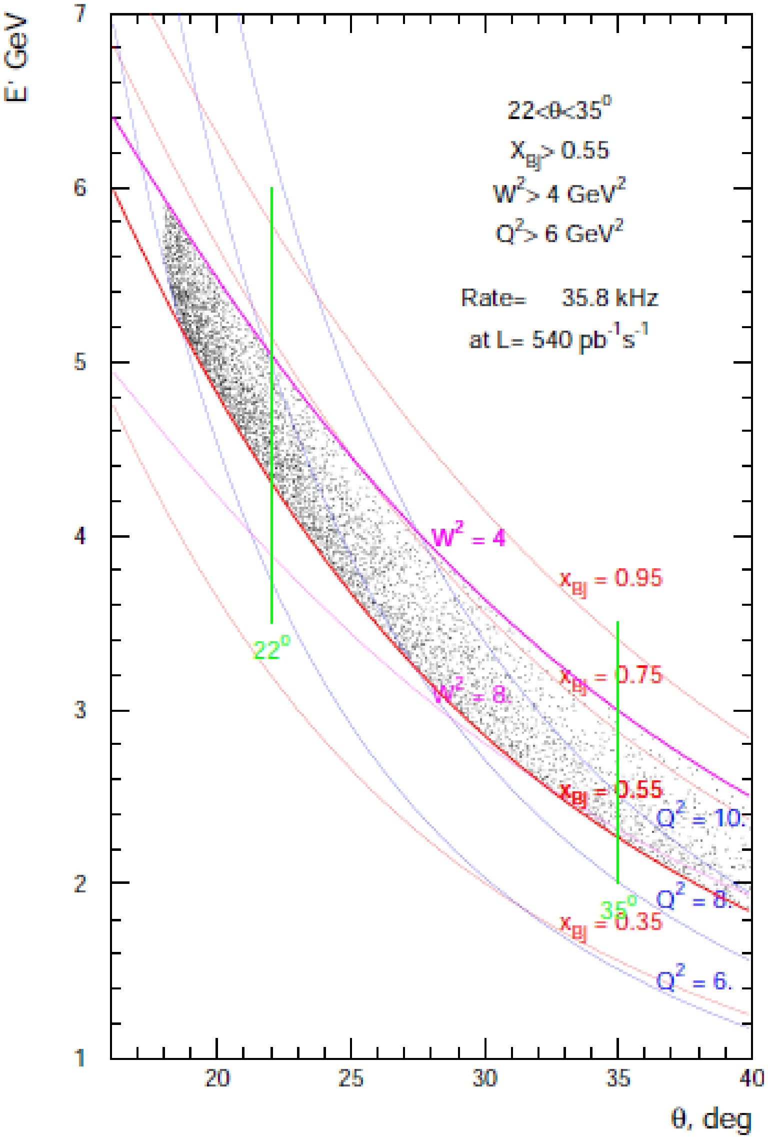
  • implement a realistic field map and re-check the collection efficiency
  • simulate the Winston cones
  • implement the simulation in GEMC

- **Heavy gas Cerenkov**:

  • no simulation yet… Use similar optical system as for the light gas Cerenkov?

Backup Slides

Open Issues



1) Adaptability of simulation (3-mirrors system) for use in PVDIS

- PVDIS: the polar angular coverage is very different than for E12-10-006

- Current Cerenkov design (placement of first mirror) is optimized for a central ray with a polar angle of 9.3 deg