The HERMES Dual-Radiator Ring Imaging Cerenkov Detector

N.Akopov et al.,

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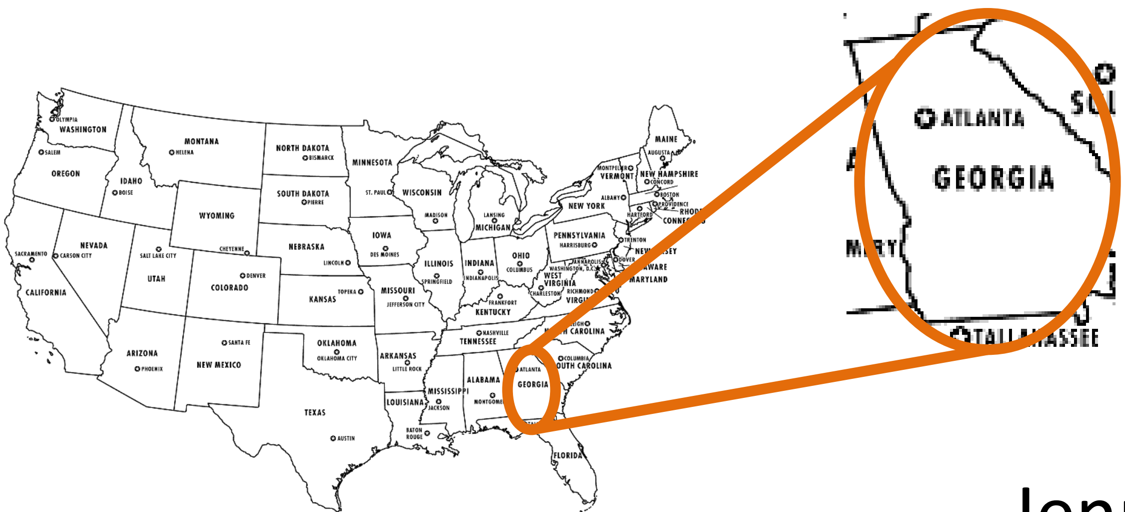

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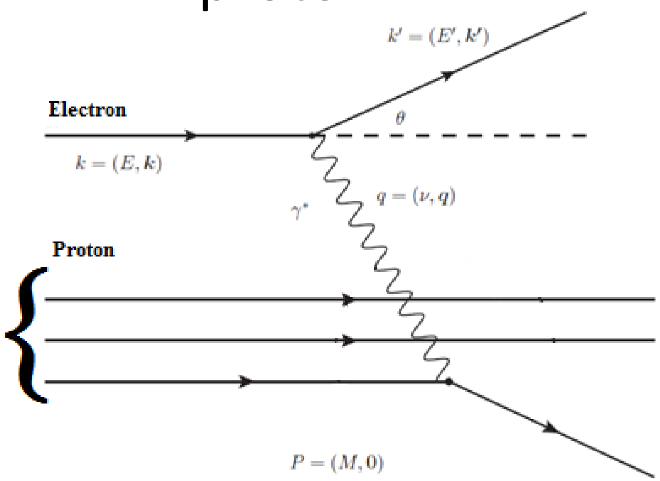
1. Introduction

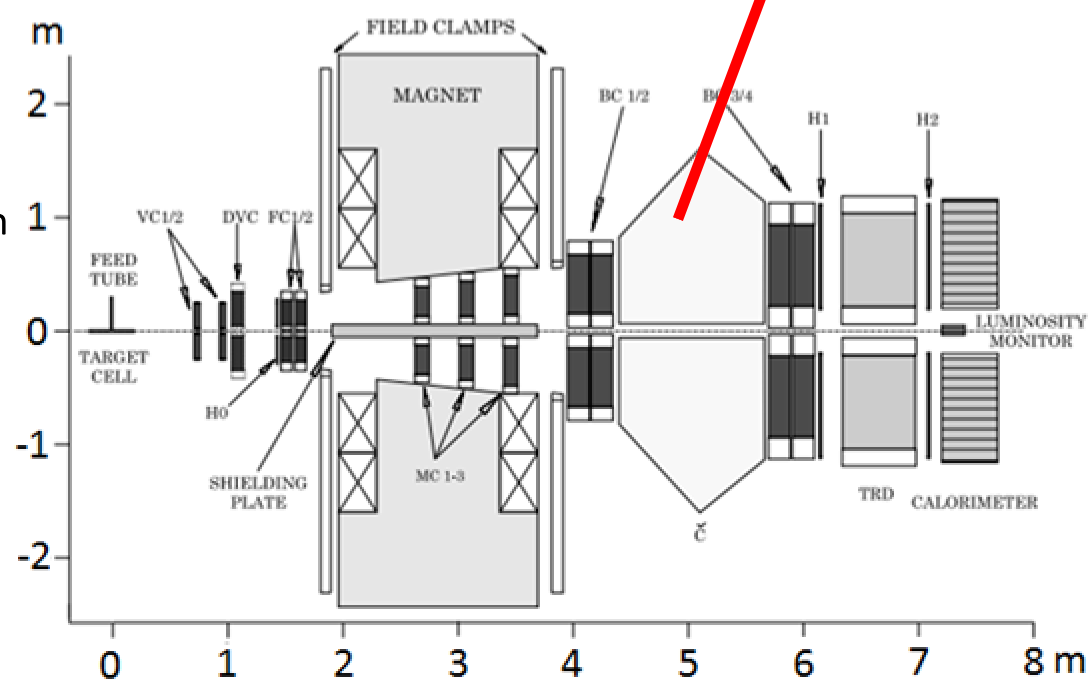
- HERMES experiment at DESY, Hamburg, Germany
  - Electron-proton deep inelastic scattering
  - Beam energy-27.5 GeV
  - Study spin structure of the proton

RICH Detector
Ring Imaging Cherenkov Detector

Side View



Electron Beam



Hadrons are produced (π, K, p,…)

Identification of these particles is important for the determine spin structure

2. Particle Identification

- Momentum (p) is determined from the magnet and drift chambers

$$p = \frac{mv}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$$

- Velocity determined by cherenkov radiation angle

$$E = \frac{mc^2}{\sqrt{1-\left(\frac{v}{c}\right)^2}}, \quad p = \frac{mv}{\sqrt{1-\left(\frac{v}{c}\right)^2}} \longrightarrow E = \frac{p\,c^2}{v}$$

- Using Einstein's relation mass can be calculated

$$E^2 = (pc)^2 + (mc^2)^2$$

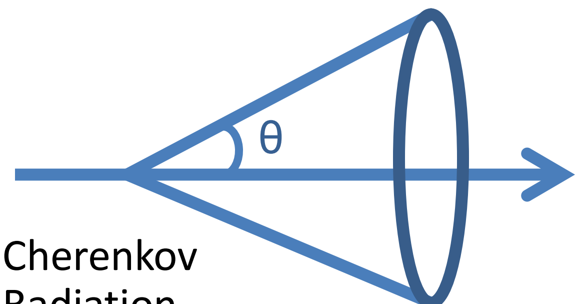
- Once the mass is determined, the particle type is known (π,K,p,…)

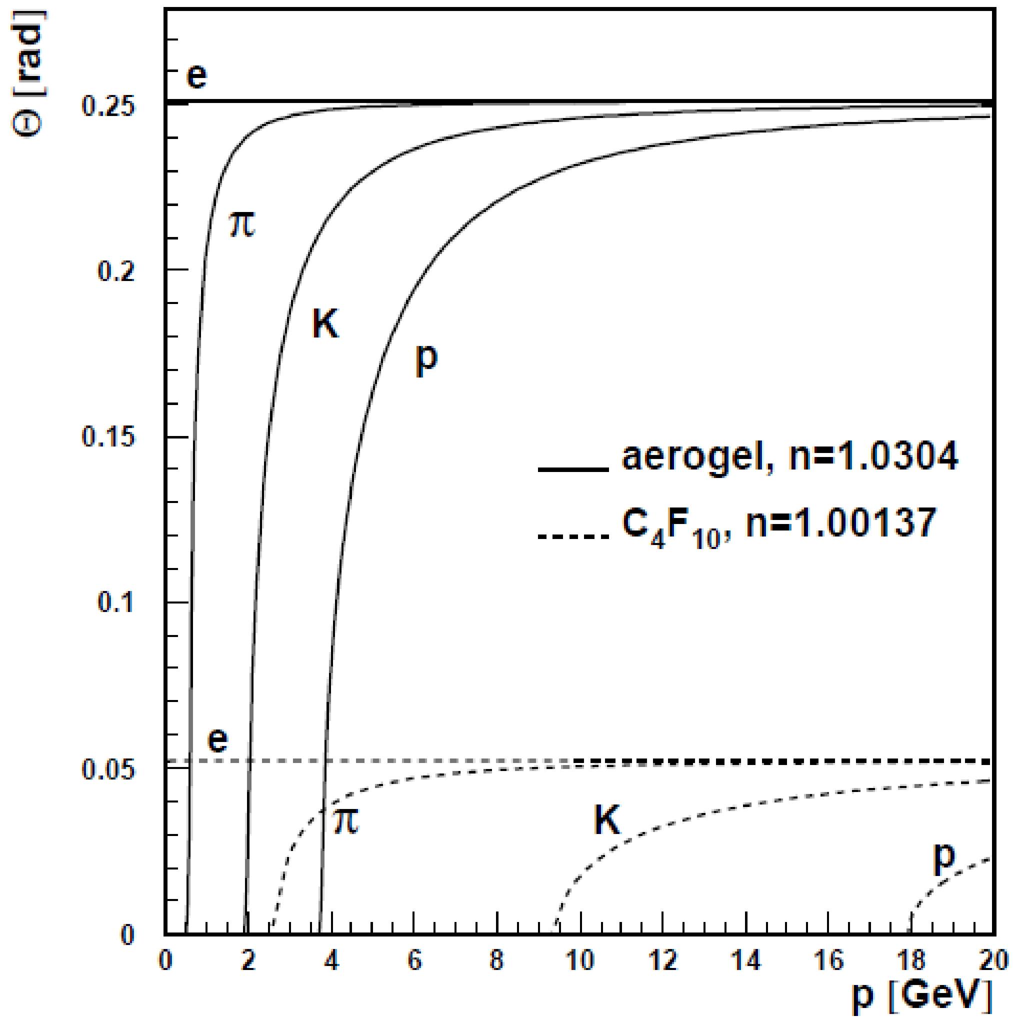
Cherenkov Radiation

- Particle emits radiation when traveling faster than the speed of light in the medium

$$\cos(\theta) = \frac{\frac{c}{n}}{v}$$

n is index of refraction



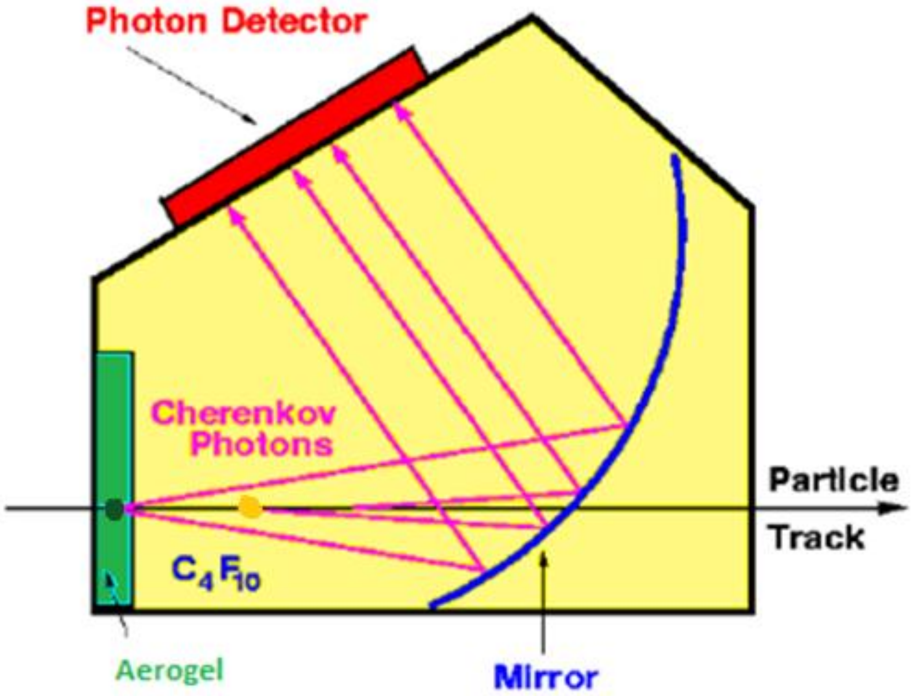


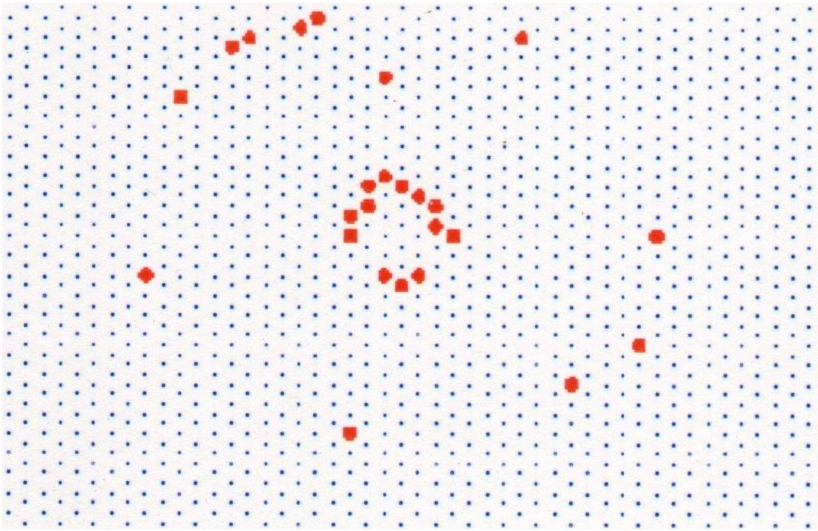
- Two radiators in the detector

3. Detector Overview

- Two radiators, one common mirror, and one common photon detector
- Separation possible due to new aerogel
  - n is larger than the Gas value but smaller than other radiator materials
- First application of aerogels as a RICH radiator

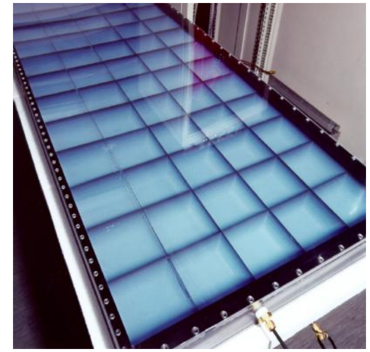
Top Half

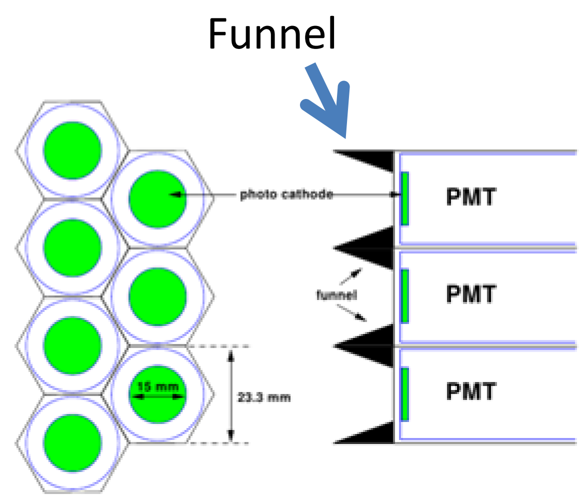




4. Dual RICH Radiator Components

- Radiators
  - Aerogel (SiO_2) n=1.0304
    - 114mm , 114mm, 11.3mm
    - 391 titles, 5 rows, 17 col., 5 layers
  - C_4F_{10} (g) n=1.00137
- Mirror
  - 8 segments
  - Radius 2.2m, focal length 1.1 m
- Photo–Multiplier Tube (PMT) Array
  - 1934 Tubes
  - 15mm active diameter
  - Total 0.75 inch diameter PMT

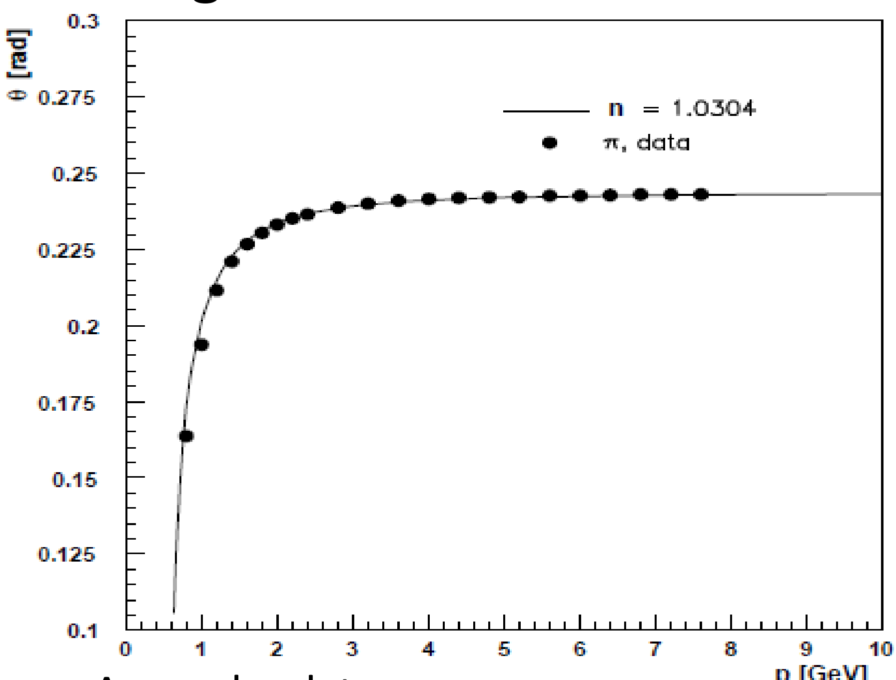




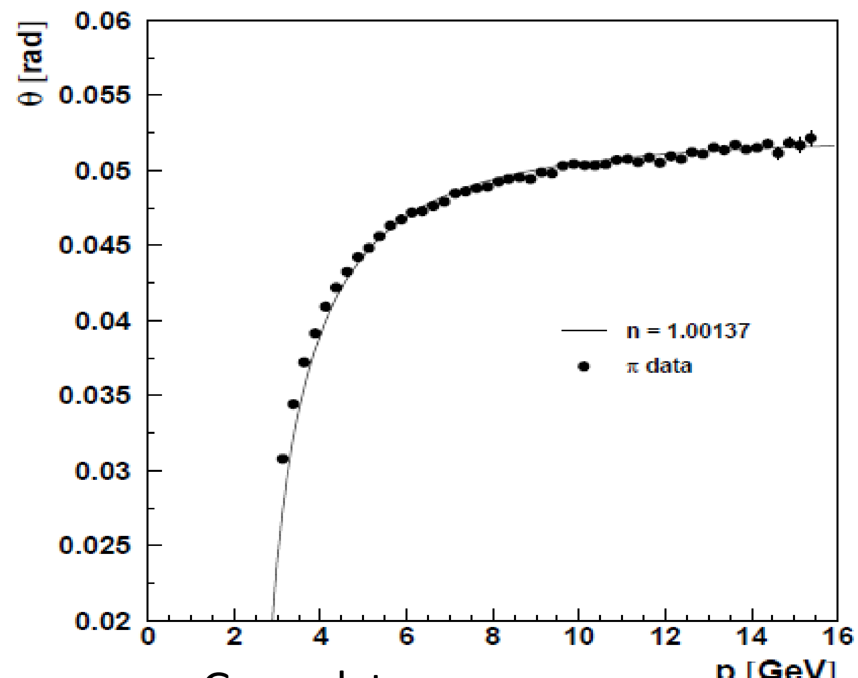
5. Performance

- Efficiency was measured using these decay processes
- Detection efficiency
  - π 90%
  - K 75%
  - p 72%
- Angles match theoretical values

Decay	Efficiency
$\rho^0 \to \pi^+\pi^-$	$\varepsilon_\pi = 0.915 \pm 0.024$
$K_s \to \pi^+\pi^-$	$\varepsilon_\pi = 0.900 \pm 0.005$
$\phi \to K^+K^-$	$\varepsilon_K = 0.750 \pm 0.007$
$\Lambda \to p\pi^-$	$\varepsilon_p = 0.726 \pm 0.010$ $\varepsilon_\pi = 0.890 \pm 0.011$



Aerogel π data



Gas π data

6. Conclusion

- Allows identification of pions, kaons, and protons in the 2-10 GeV/c range
- This is almost the whole momentum range for the hadrons produces in the HERMES experiment
- Design can be improved by using larger tiles.
- Having smaller PMT tubes will reduce error

7. Summary

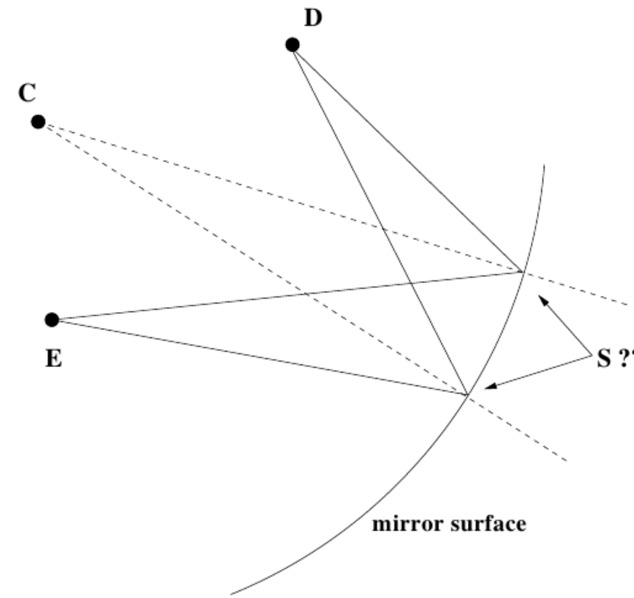
- HERMES is electron-proton deep inelastic scattering experiment
- Particle identification uses a combination of momentum and velocity
- Velocity is determined by cherenkov radiation angle
- Uses two separate radiators
- First application of the aerogel as a RICH radiator material

Performance Detail

- Yield
  - Aerogel average hits 10->8
- Background
  - Ring-less tracks, multiple tracks per event, ring-less PMT hits, electronic Noise - 1 PMT hit per 5 events
- Average Angle and Resolution
  - Aerogel 7.6 mrad, Gas 7.5mrad

Angle Determination

- Inverse Ray Tracing
  - Determines the angle of Cherenkov Radiation
    - Known emission and detection point
    - Assume the emission point



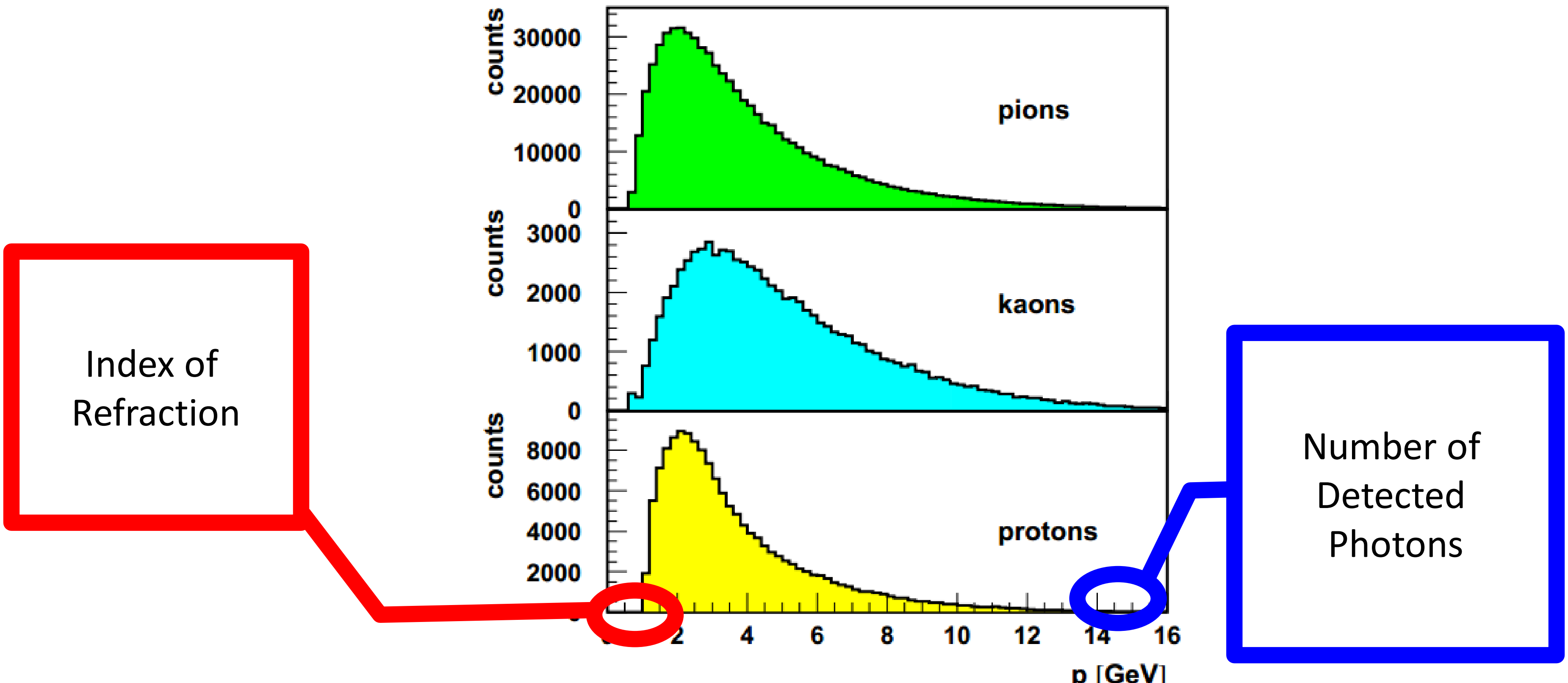
- Likelihood Analysis
  - Determines particle type
    - Use average angle of the PMT hits per particle
    - Creates a distribution

$$L = exp\left[-\frac{(\theta_{th} - \langle\theta\rangle)^2}{2\sigma_{\langle\theta\rangle}^2}\right]$$

$$\sigma_{\langle\theta\rangle} = \frac{\sigma_\theta}{\sqrt{N}}$$

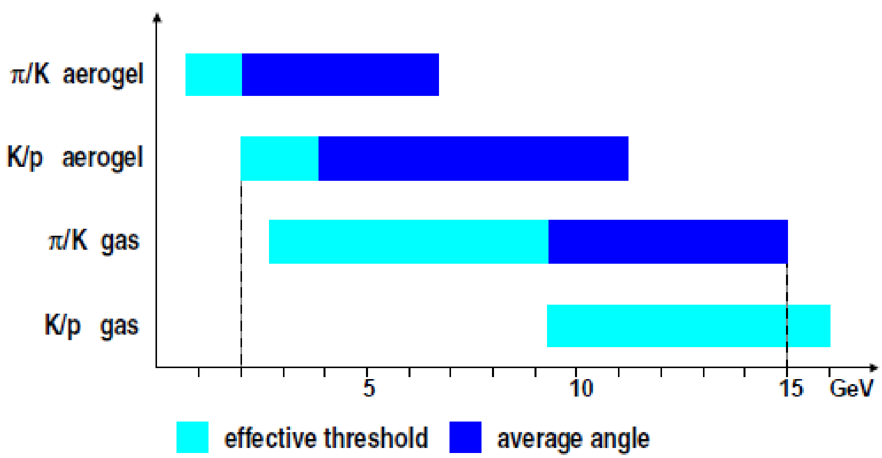
Detector Design

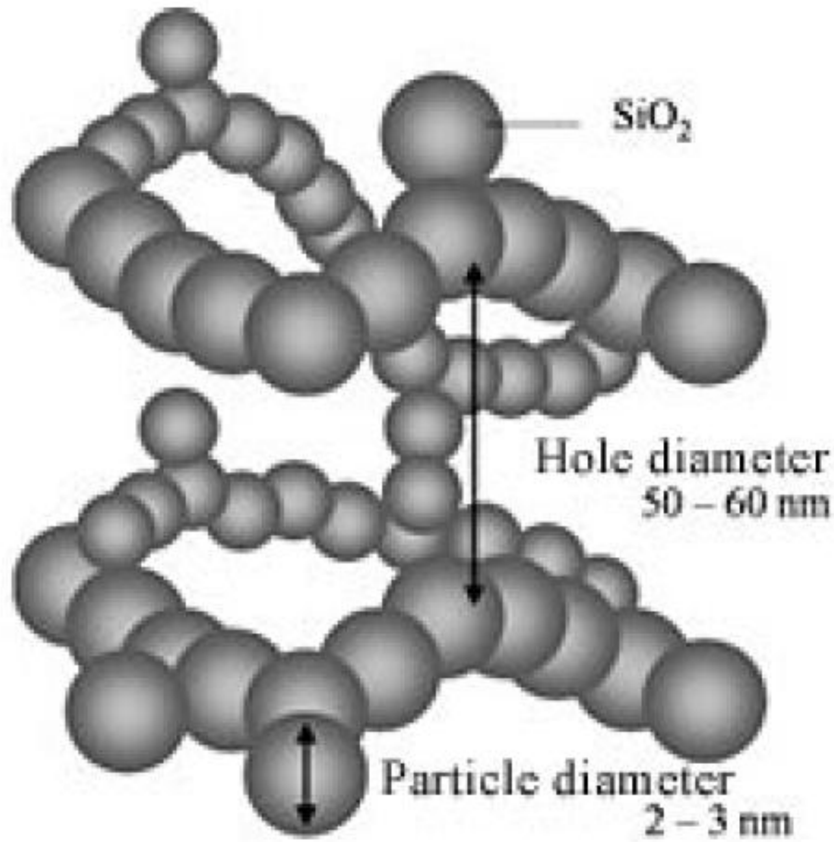
- Range determines parameters



Radiators

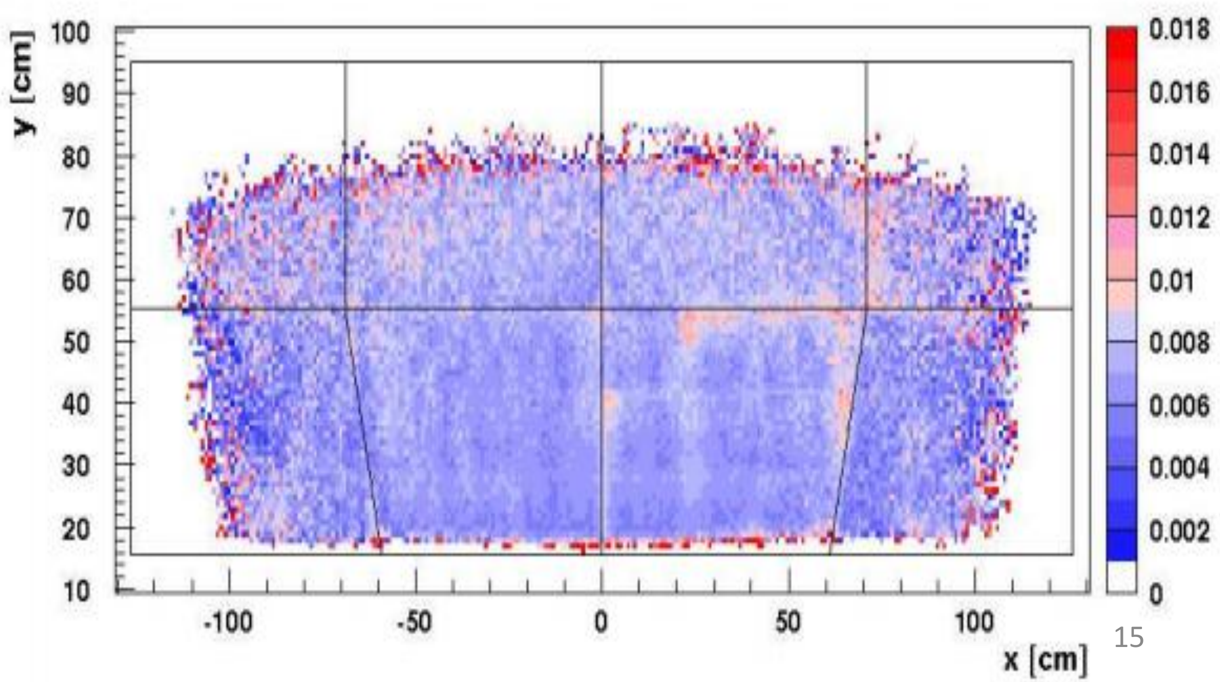
- Areogel Tiles
  - Structure
- Gas
  - 4000L





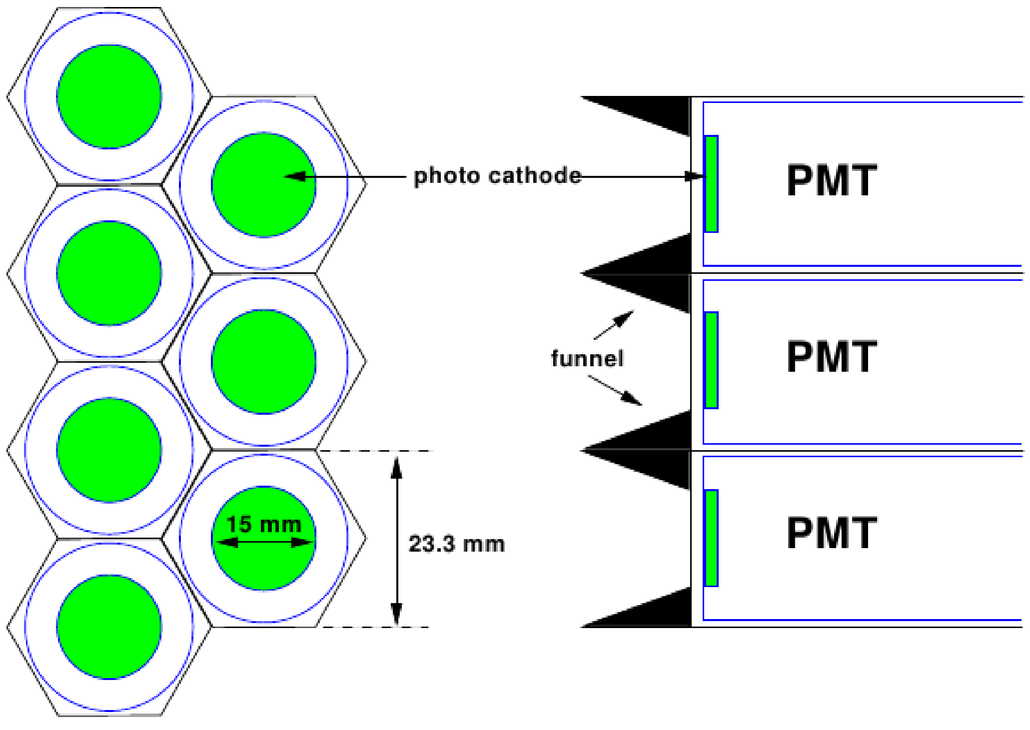
Mirror Array

- Three phase alignment
  - Set center of array
  - Orient the individual pieces
  - Further adjust from 9 segments
- Radius 2.2m
- Focal length 1.1m

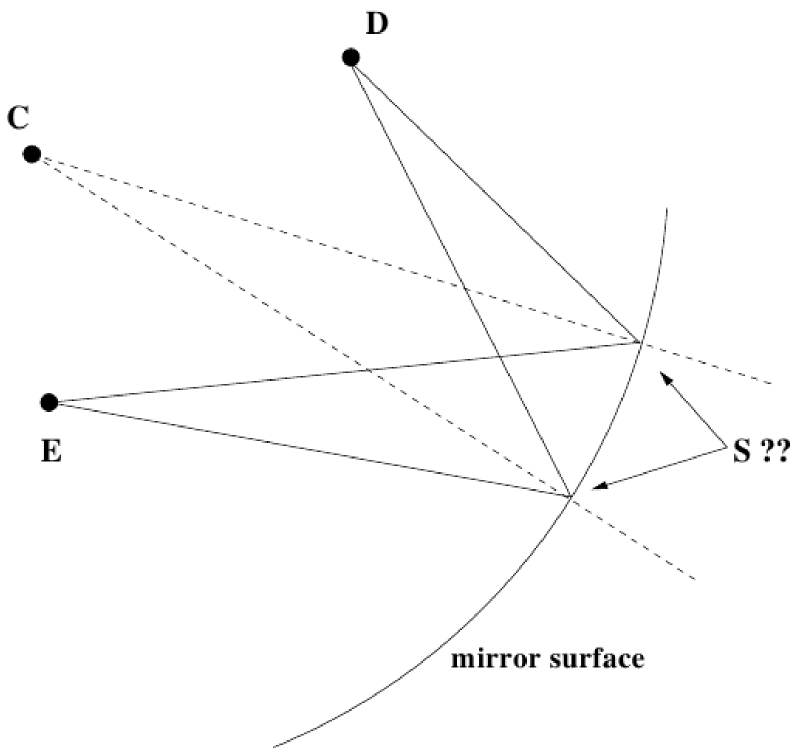


Photon Detector

- Array of Photon-to-electron photocathodes
  - Minimum diameter of 15mm
  - Funnels
  - Pixel 23.3mm



Inverse Ray tracing



- Determines the angle of Cherenkov Radiation
  - Known emission and detection point
  - Assume the emission point

$$\vec{S} = \vec{C} + \left(\frac{R\cos\beta}{a} - \frac{R\sin\beta \cdot \cos\alpha}{a \cdot \sin\alpha}\right) \cdot \vec{CE} + \frac{R\sin\beta}{d\sin\alpha} \cdot \vec{CD}$$

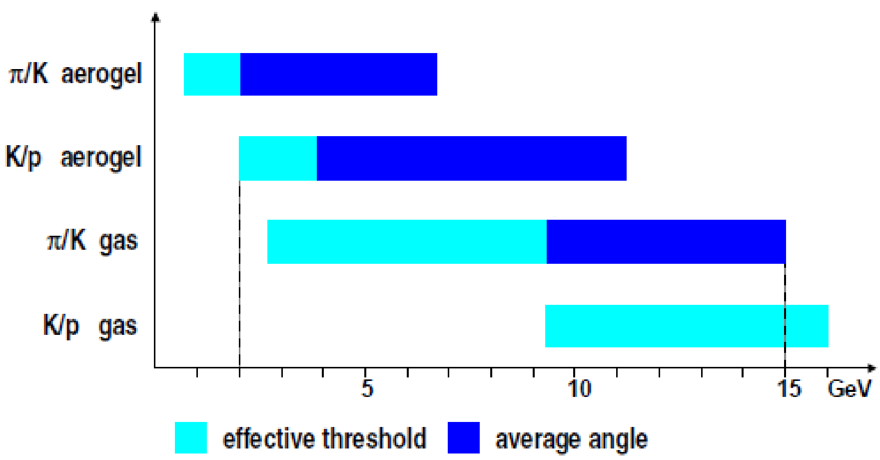
Likely-Hood Analysis

- Determines particle type
- Method
  - Use average angle of the PMT hits per particle
  - Creates a distribution

$$L = exp\left[-\frac{(\theta_{th} - \langle\theta\rangle)^2}{2\sigma_{\langle\theta\rangle}^2}\right] \qquad \sigma_{\langle\theta\rangle} = \frac{\sigma_\theta}{\sqrt{N}}$$

Error

- The error is low for protons and kaons because of the edges of the momentum have lower efficiency then the mids-range momentum
- Algorithm slightly different for the protons



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Structure Information from Hadron Separation

- Electron beam and proton are polarized
- Picks quirk flavor
- Then the contribution of the identified quark to the spin can be calculated