The HERMES Dual-Radiator Ring Imaging Cherenkov Detector

HERMES実験で用いられる、2重発光体リングイメージングチェレンコフ検出器について

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Contents

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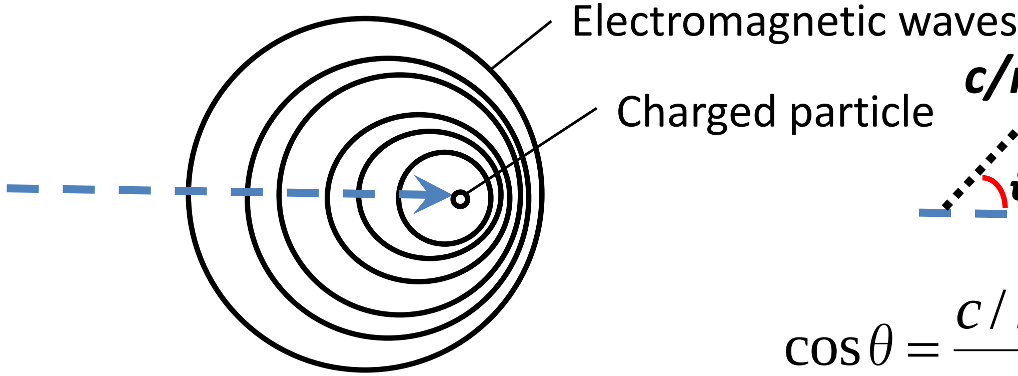
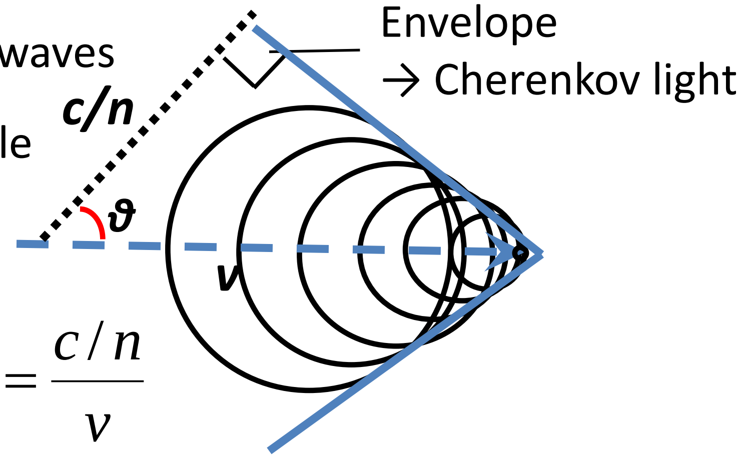
Cherenkov Radiation

- Polarization of molecule
- De-excitation to ground state
- Emission of electromagnetic waves

$v < c/n$: No interference



$v > c/n$: Interference

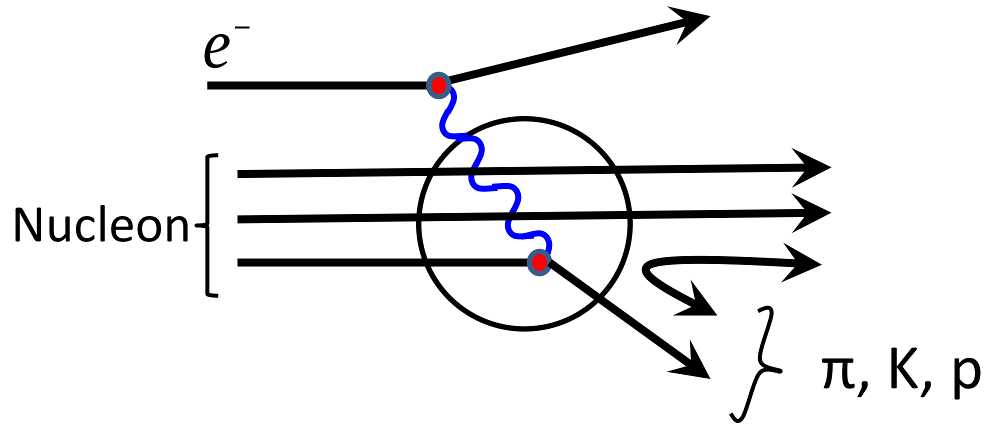


$$\cos\theta = \frac{c/n}{v}$$

HERMES Experiment

- Beam : polarized electron/positron of 27.6 GeV
- Target : polarized nucleon
  - π, K, p (95% : momentum 2-15 GeV)

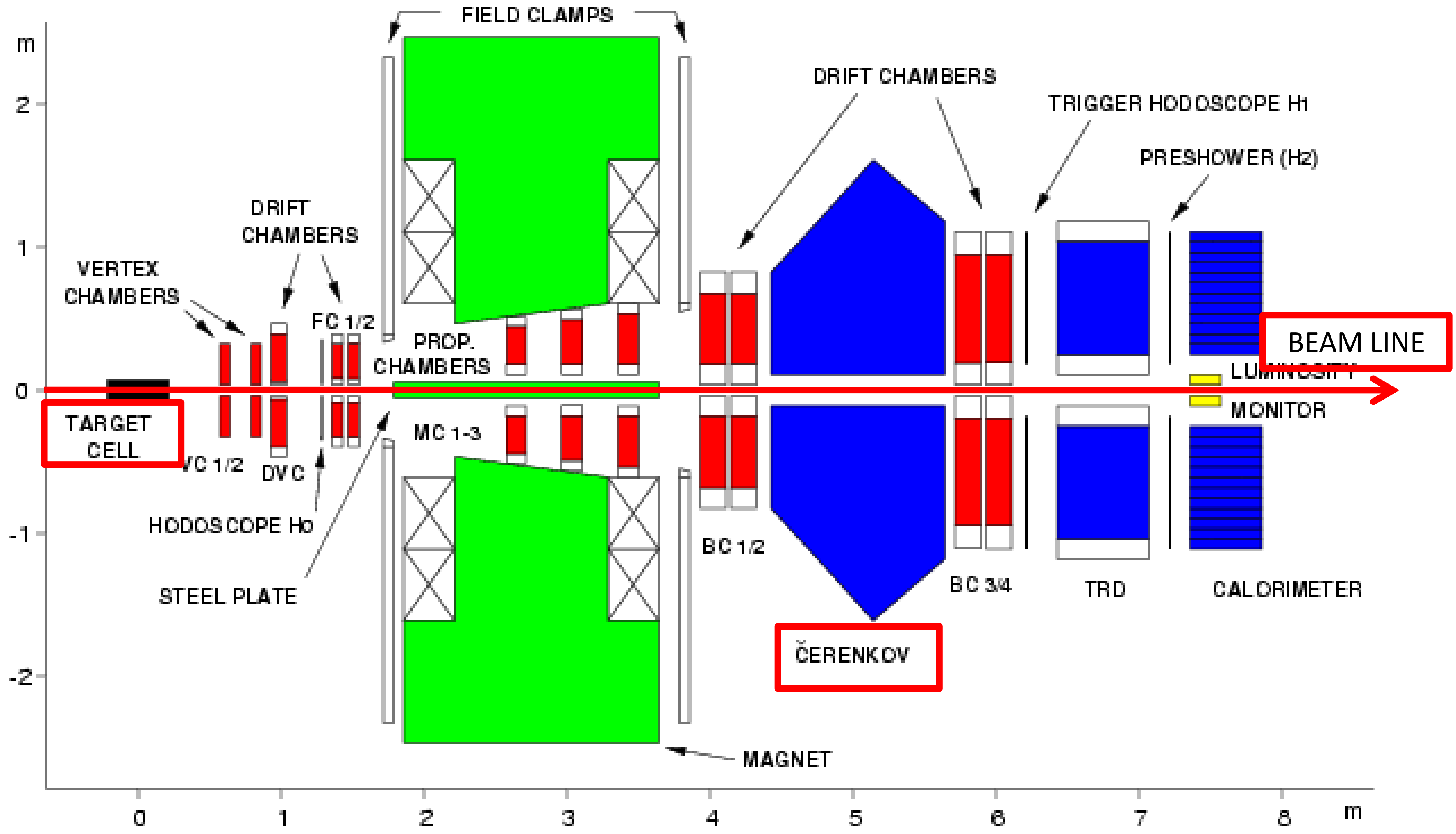
Deep inelastic electron-nucleon scattering



- Requirement :
  - π/K/p identification in 2-15 GeV

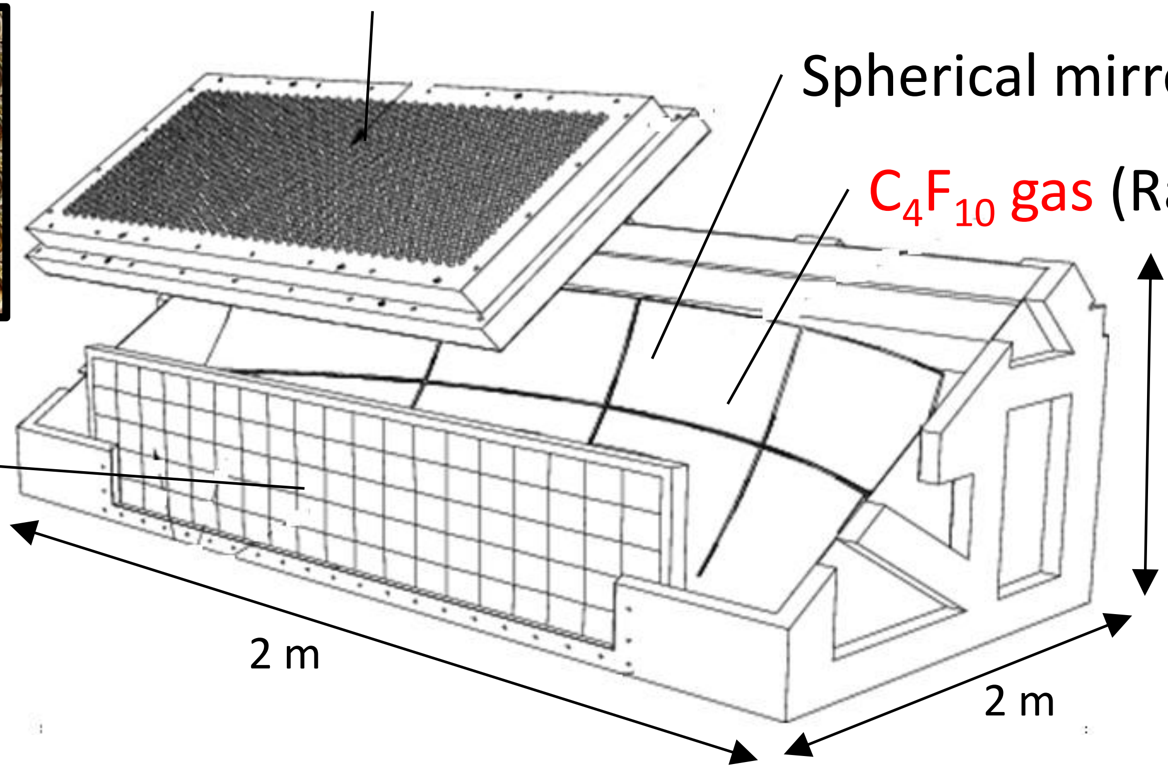
  → Ring Imaging Cherenkov (RICH) detector

Position of RICH

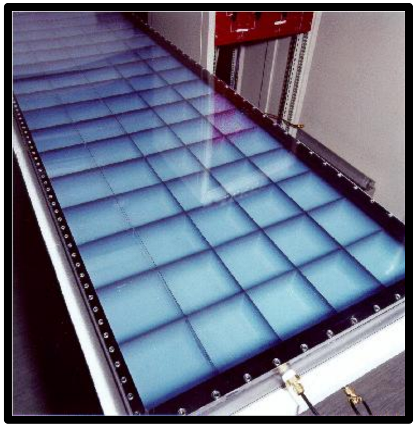


RICH Detector

Photon detector (1934 PMTs) : Hexagonal close packed



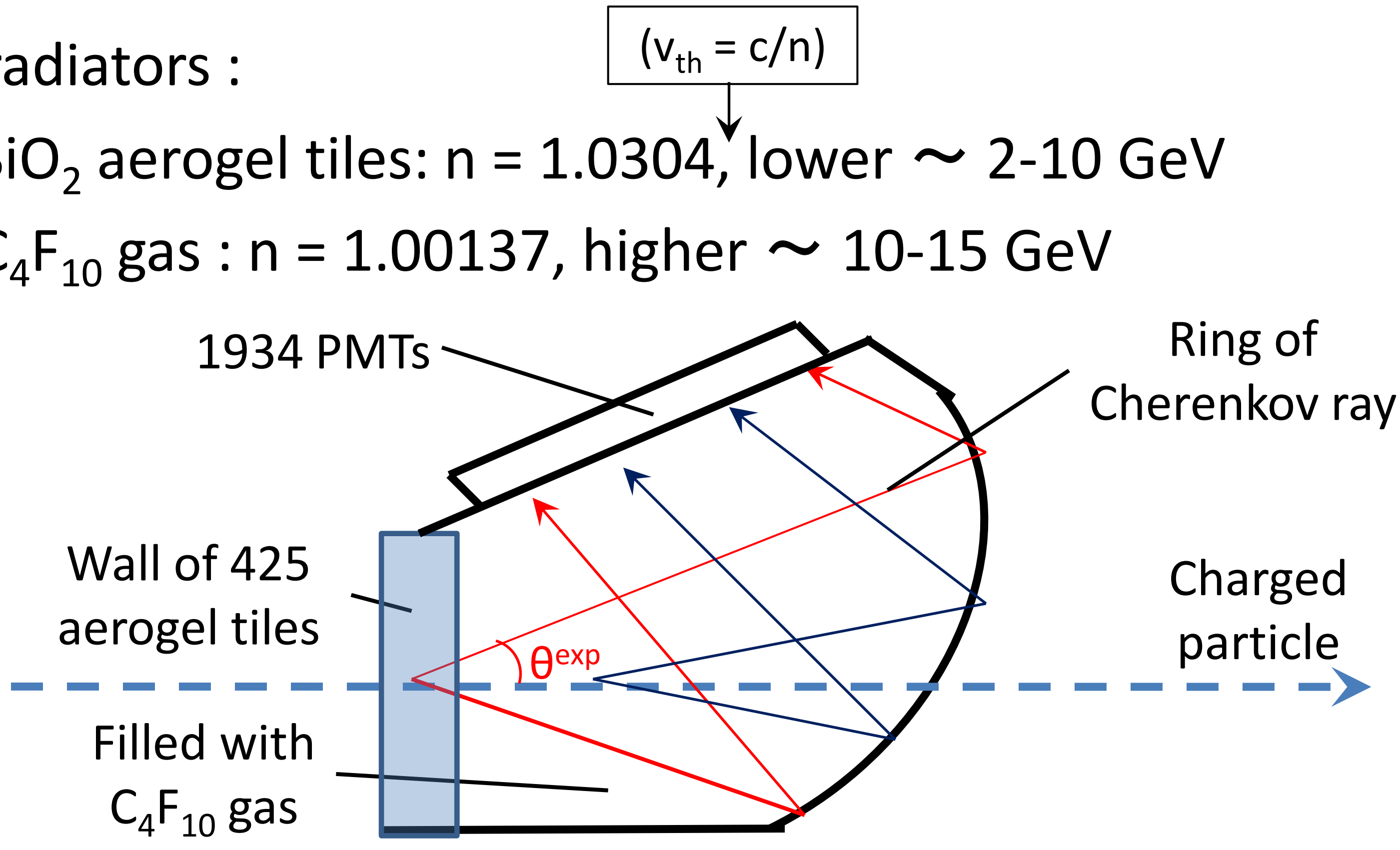
425 aerogel tiles
(Radiator)



- The first successful use of aerogel as RICH radiator
- Aerogel tiles were manufactured in Japan and tested at Tokyo Tech

Inverse Ray Tracing

- 2 radiators :
  - SiO_2 aerogel tiles: n = 1.0304, lower ~ 2-10 GeV
  - C_4F_{10} gas : n = 1.00137, higher ~ 10-15 GeV

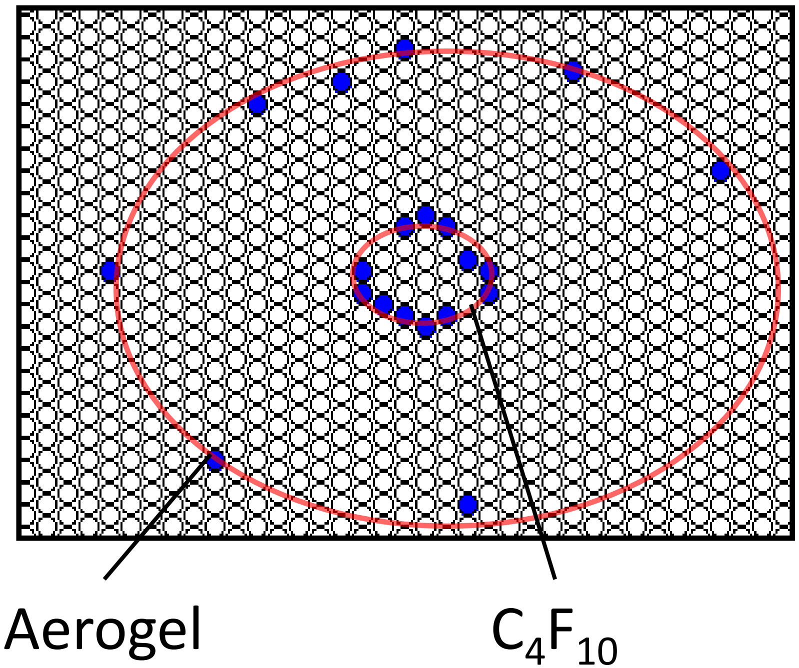


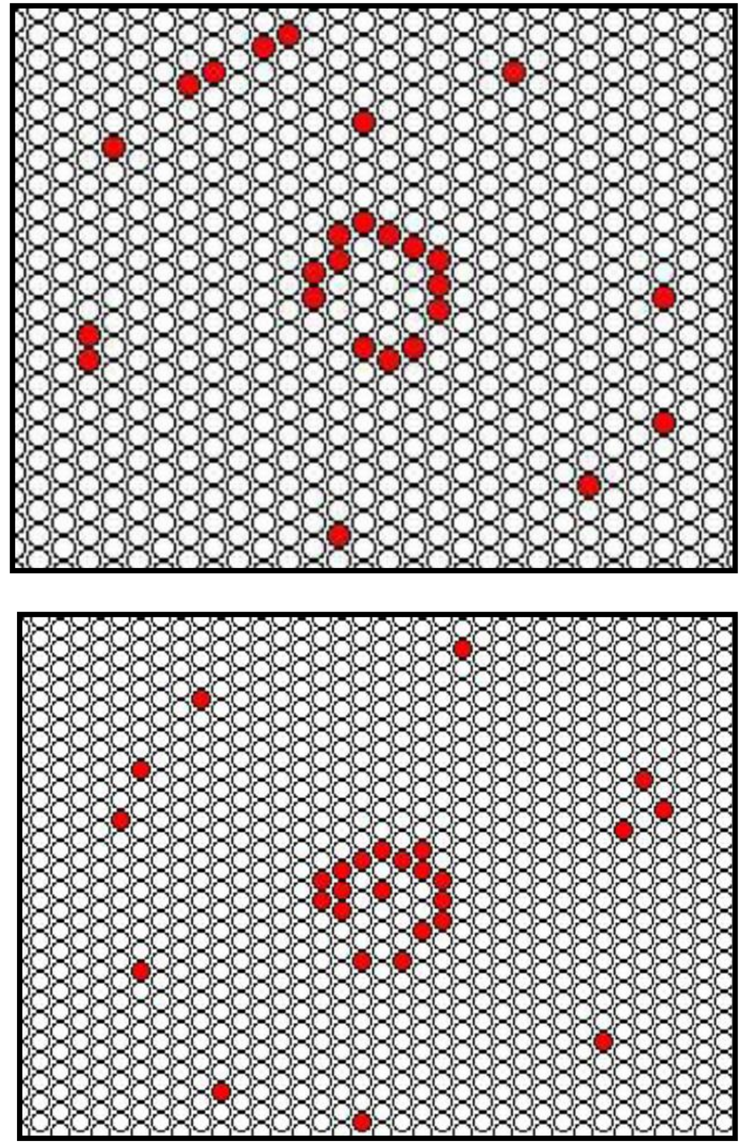
- Which PMT detected a photon?

→ Cherenkov angle θ^{exp}: Inverse Ray Tracing (IRT)

Ring Imaging by 1934 PMTs

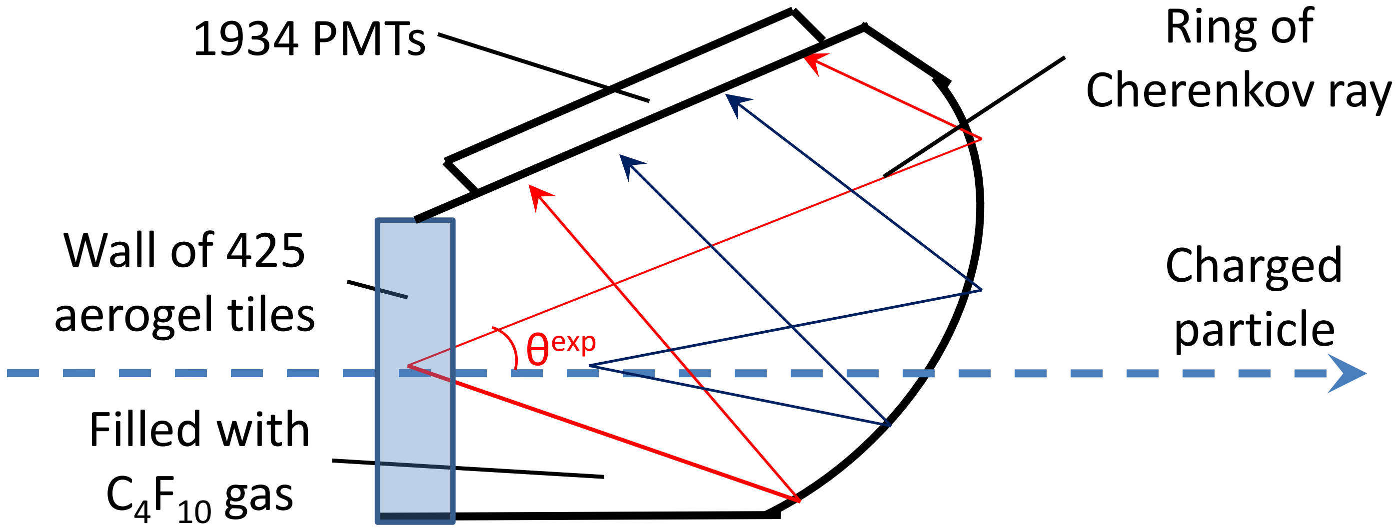
Screen : Hexagonal close packed
1934 PMTs





Inverse Ray Tracing

- 2 radiators :
  - SiO_2 aerogel tiles: n = 1.0304, lower ∼ 2-10 GeV ($v_{th} = c/n$)
  - C_4F_{10} gas : n = 1.00137, higher ∼ 10-15 GeV



- Which PMT detected a photon?

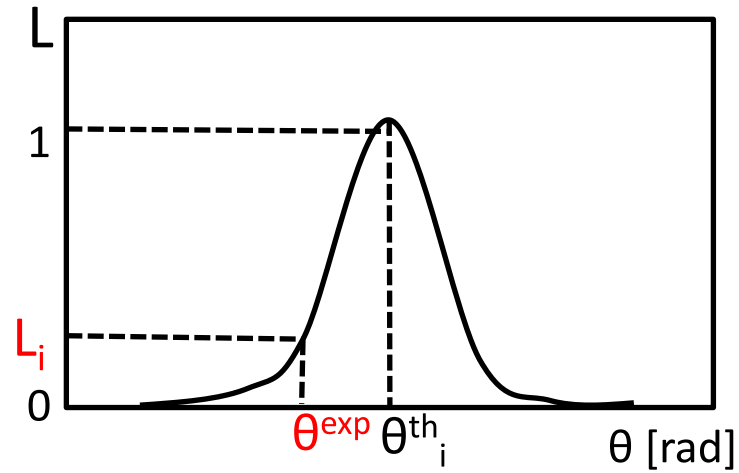
→ Cherenkov angle θ^{exp}: Inverse Ray Tracing (IRT)

Likelihood Analysis

- Theoretical Cherenkov angle θ^{th}_i (i = π, K, p)
  - $p = \dfrac{mv_i}{\sqrt{1-v_i^2}}$, $(c=1)$
  - $\cos\theta^{th}_i = \dfrac{1}{nv_i}$ $\longrightarrow$ $\theta^{th}_i = \arccos\dfrac{1}{n}\sqrt{1+\left(\dfrac{m_i}{p}\right)^2}$
- Which of θ^{th}_π , θ^{th}_K or θ^{th}_p is the most likely to θ^{exp} ?

  → Likelihood : Gaussian

  - $L_i\left(\theta^{exp}\right) = \exp\left[-\dfrac{(\theta^{exp}-\theta^{th}_i)^2}{2\sigma^2}\right]$
  - σ : from angle resolution of PMTs

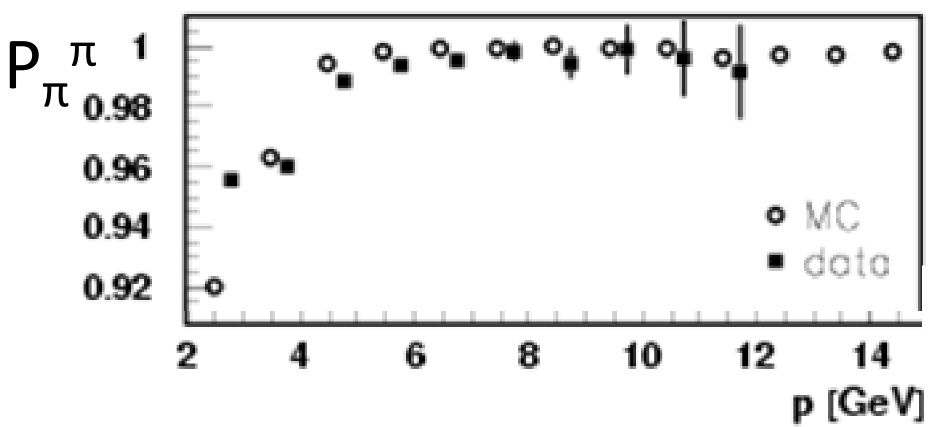


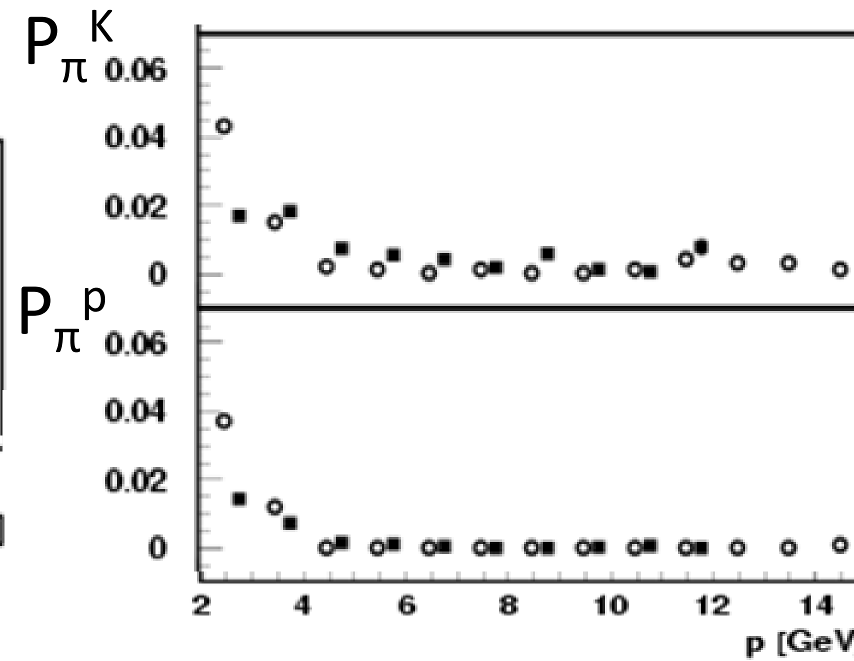
- Identified type : Highest likelihood of L_π , L_K , L_p

Efficiency

- Identification probability P_π :
  - π is identified as π (P_π^π), K (P_π^K), p (P_π^p).
- Efficiency : Higher than 92% in 2-4 GeV
  and 99% in 4-15 GeV

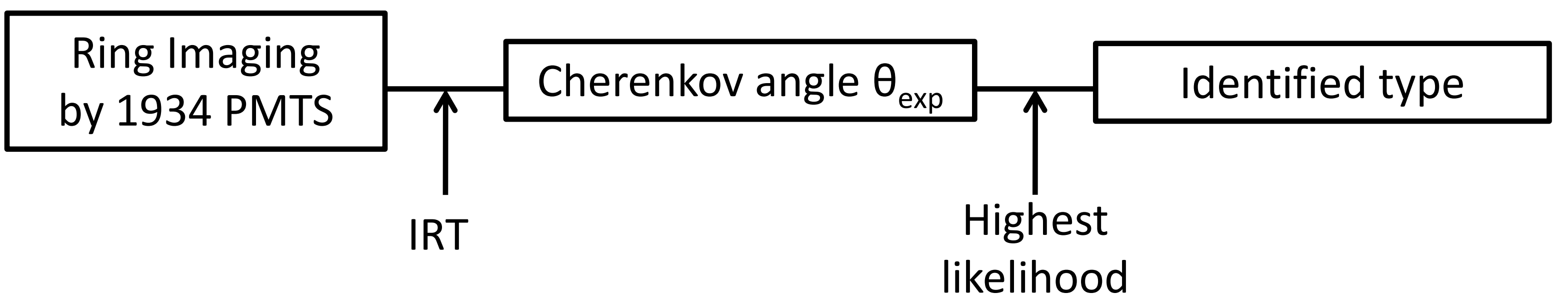
(Efficiency) = P_π^π





Summary

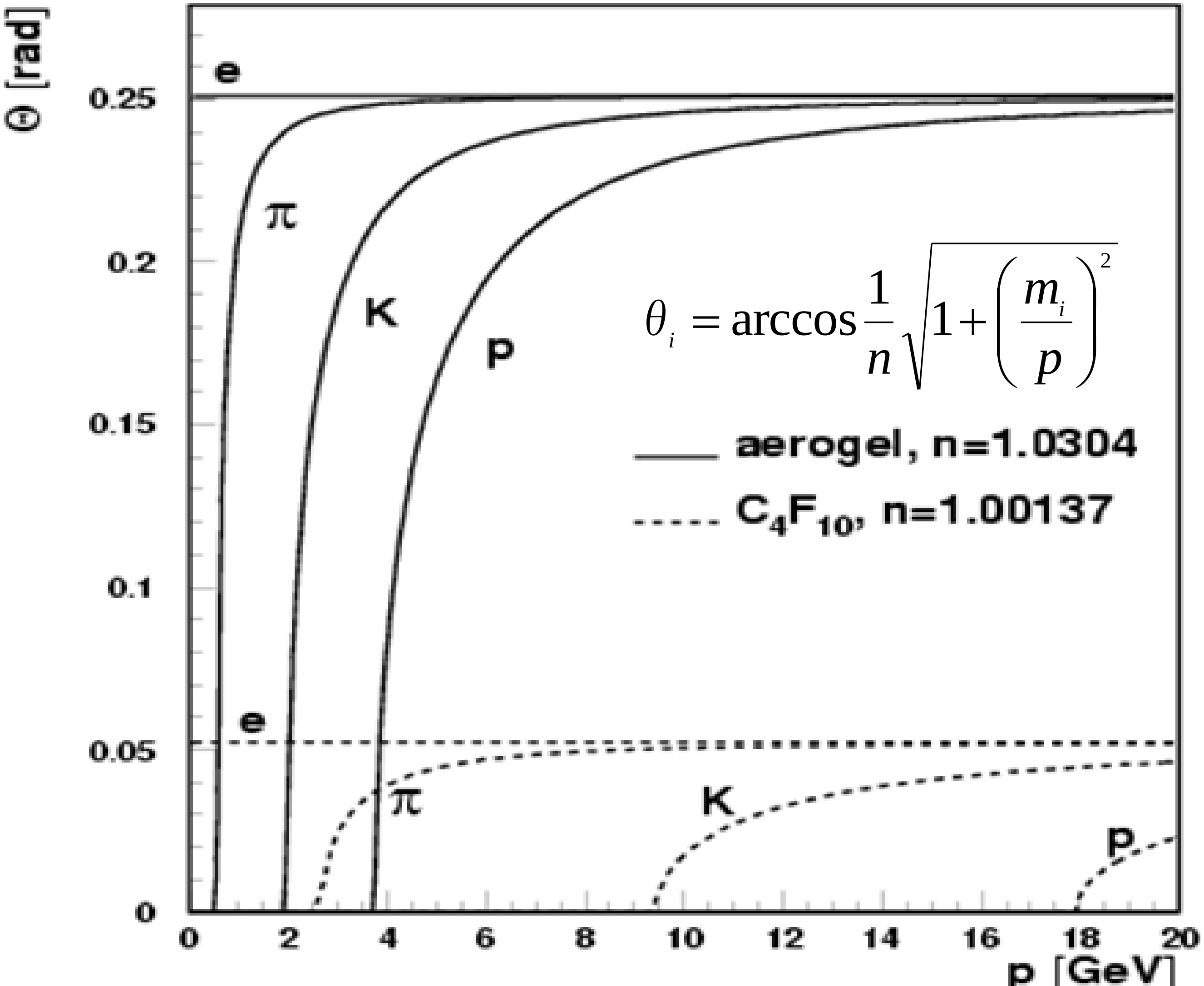
- In the HERMES experiment, dual-radiator RICH detector provides π/K/p identification in 2-15 GeV.
- <Identification chart>



- The efficiency of the RICH detector is higher than 92% in 2-4 GeV and 99% in 4-15 GeV.
- Aerogel was successfully used as a RICH radiator in an actual experiment for the first time.

Backups

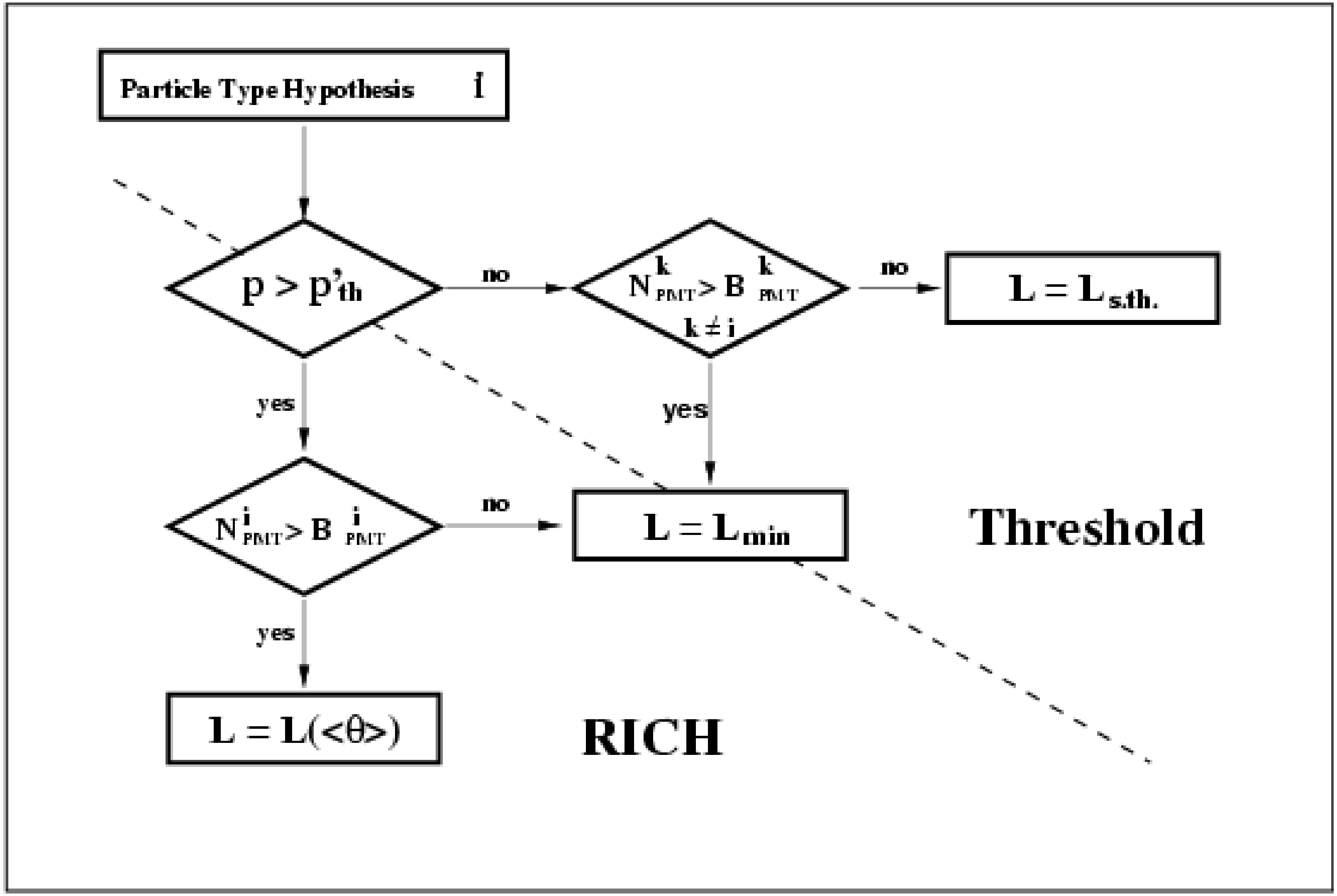
Cherenkov angle versus Momentum



Threshold Momentum

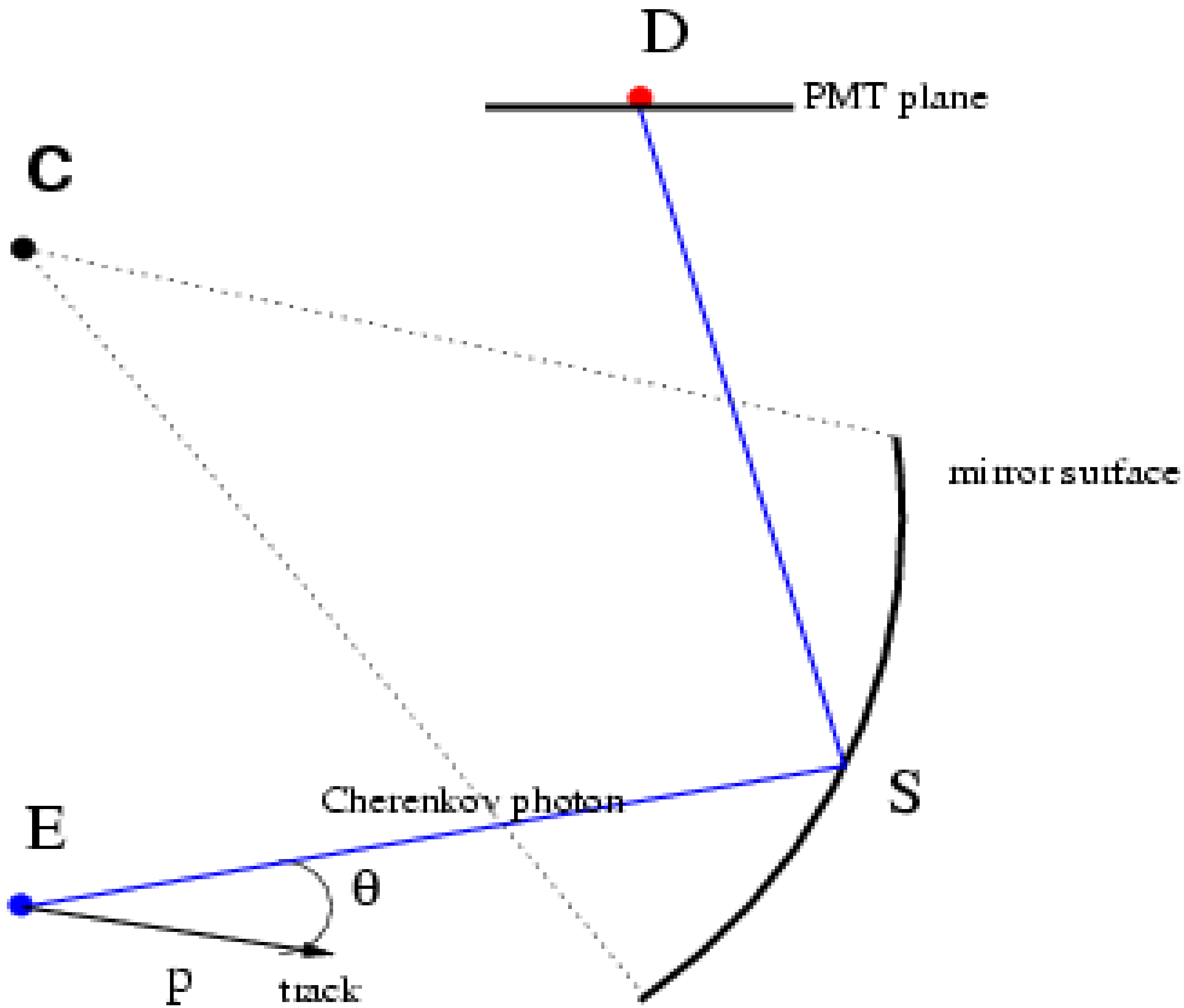
	aerogel	C_4F_{10}
n	1.0304	1.00137
$\beta_t\gamma_t$	4.03	19.10
π	0.6 GeV	2.7 GeV
K	2.0 GeV	9.4 GeV
p	3.8 GeV	17.9 GeV

Flow Chart

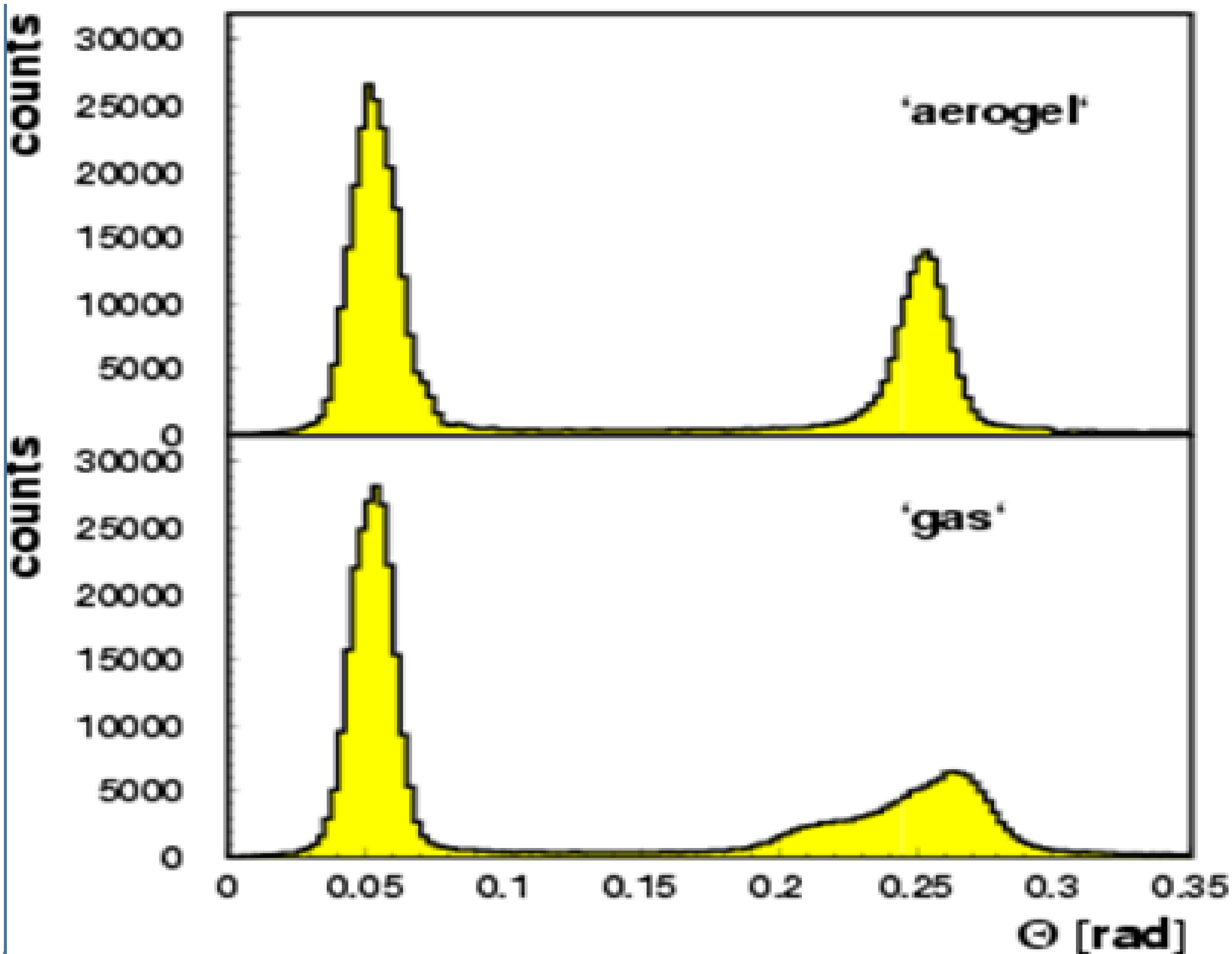


Particle Type Hypothesis i
p > p'th
no
N k PMT > B k PMT
k ≠ i
no
L = L s.th.
yes
yes
N i PMT > B i PMT
no
L = L min
Threshold
yes
L = L(<θ>)
RICH

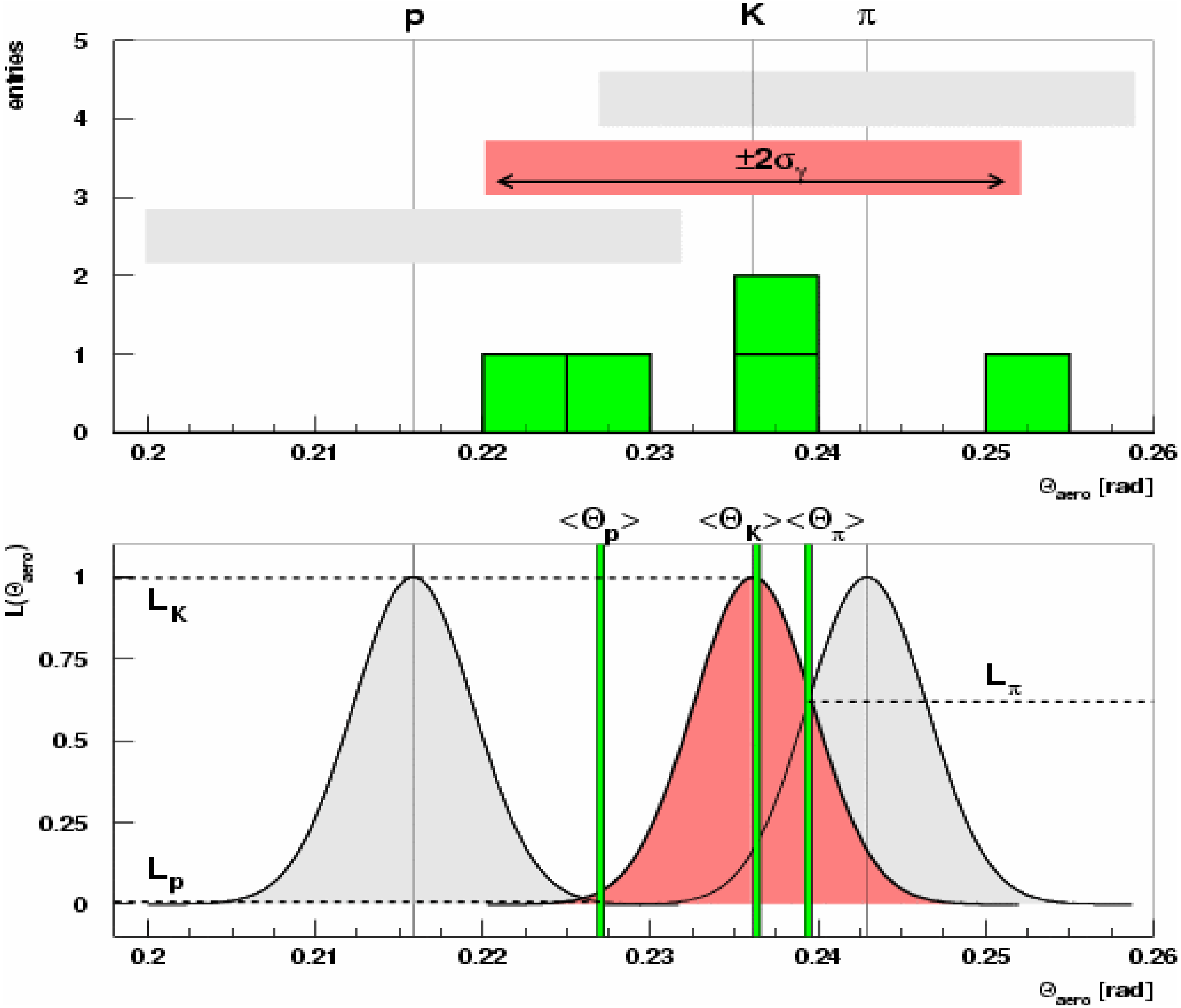
Inverse Ray Tracing



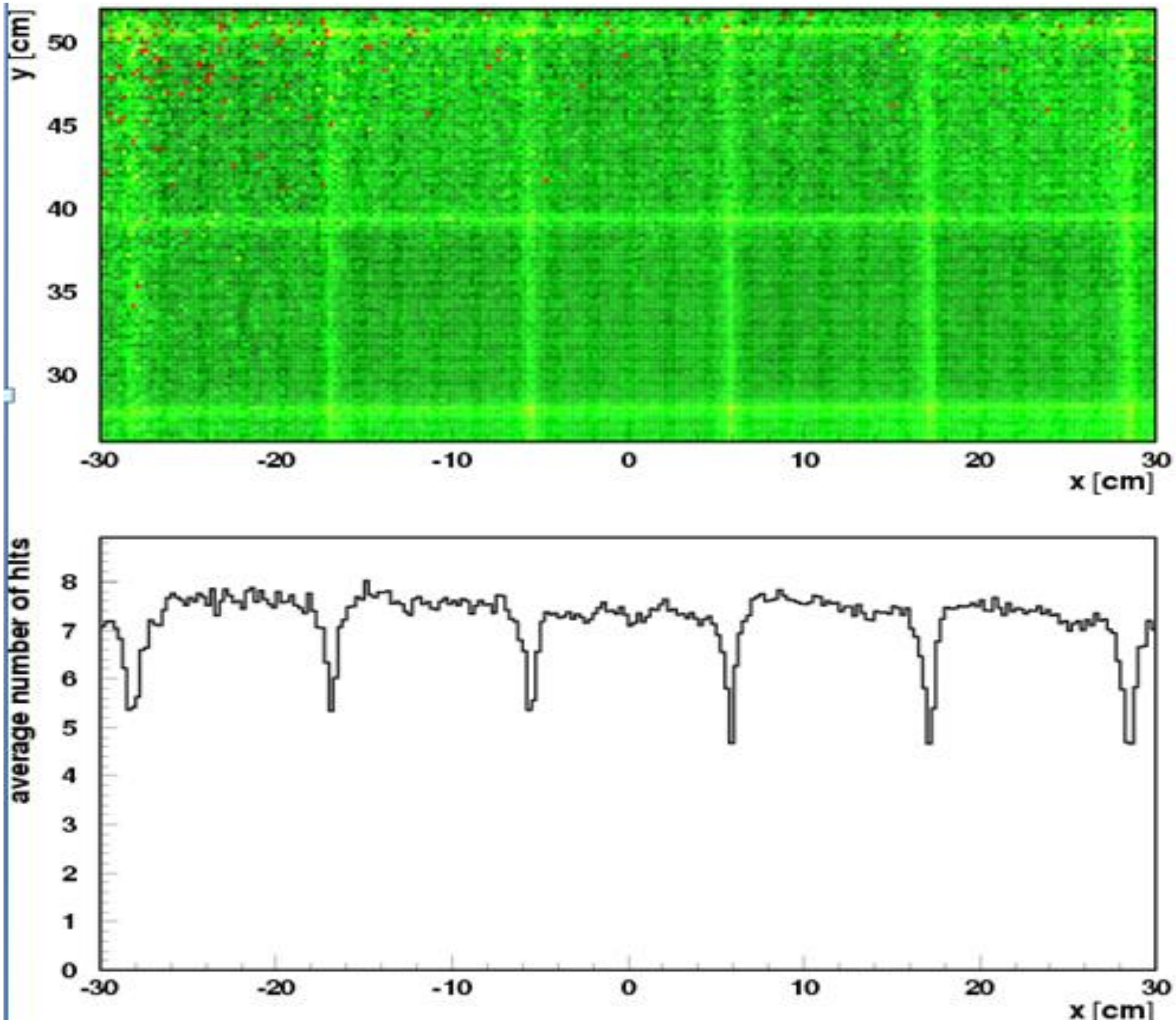
From which Radiator?



$\theta^{exp, i}$ (i = π, K, p)



Tile Structure



Efficiency

- Identifidation probabilities P_{π} :
- π is identified as π (P_{π}^{π}), K (P_{π}^{K}), p (P_{π}^{p}) or not identified (P_{π}^{X})
- Misidentification : lower than 8% in 2-4 GeV and 1% in 4-15 GeV