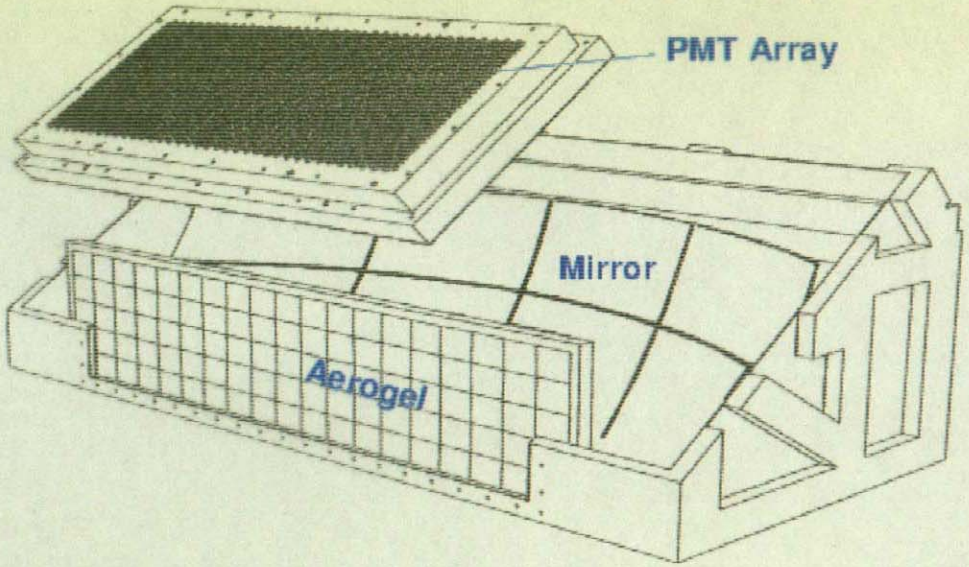
The HERMES RICH aerogel radiator



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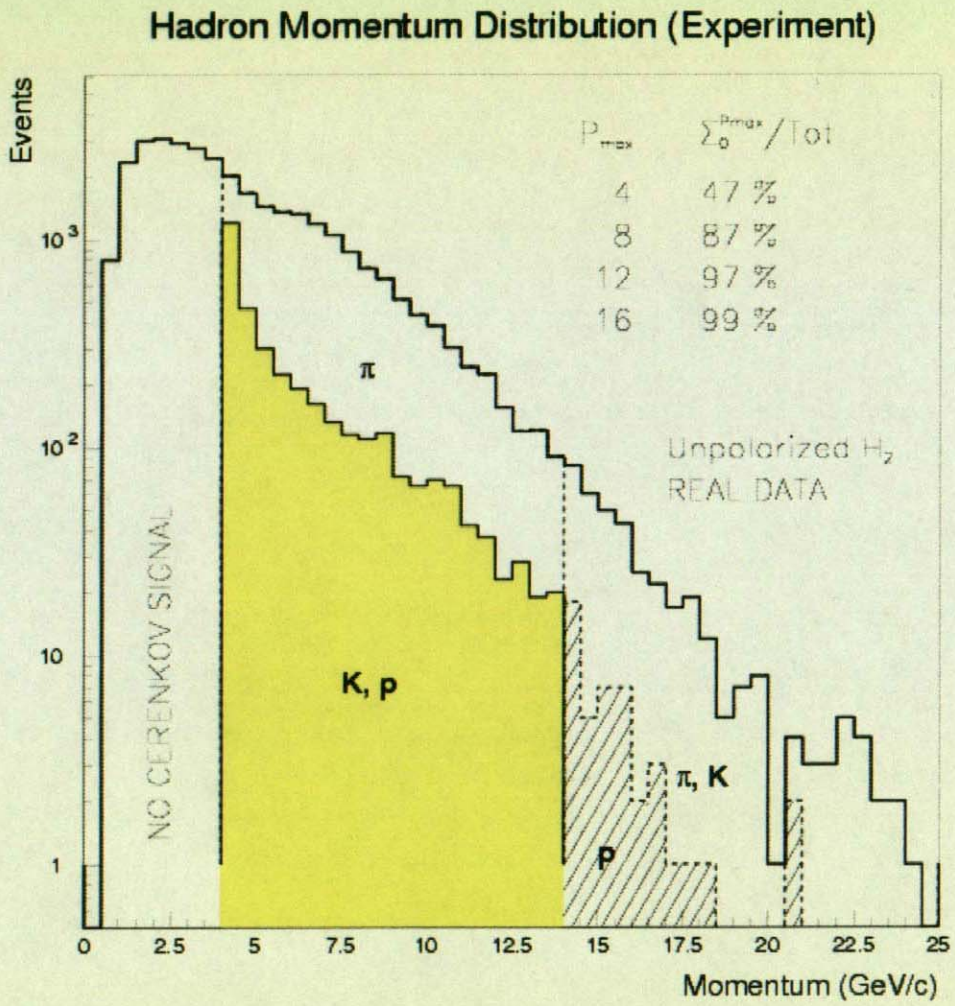
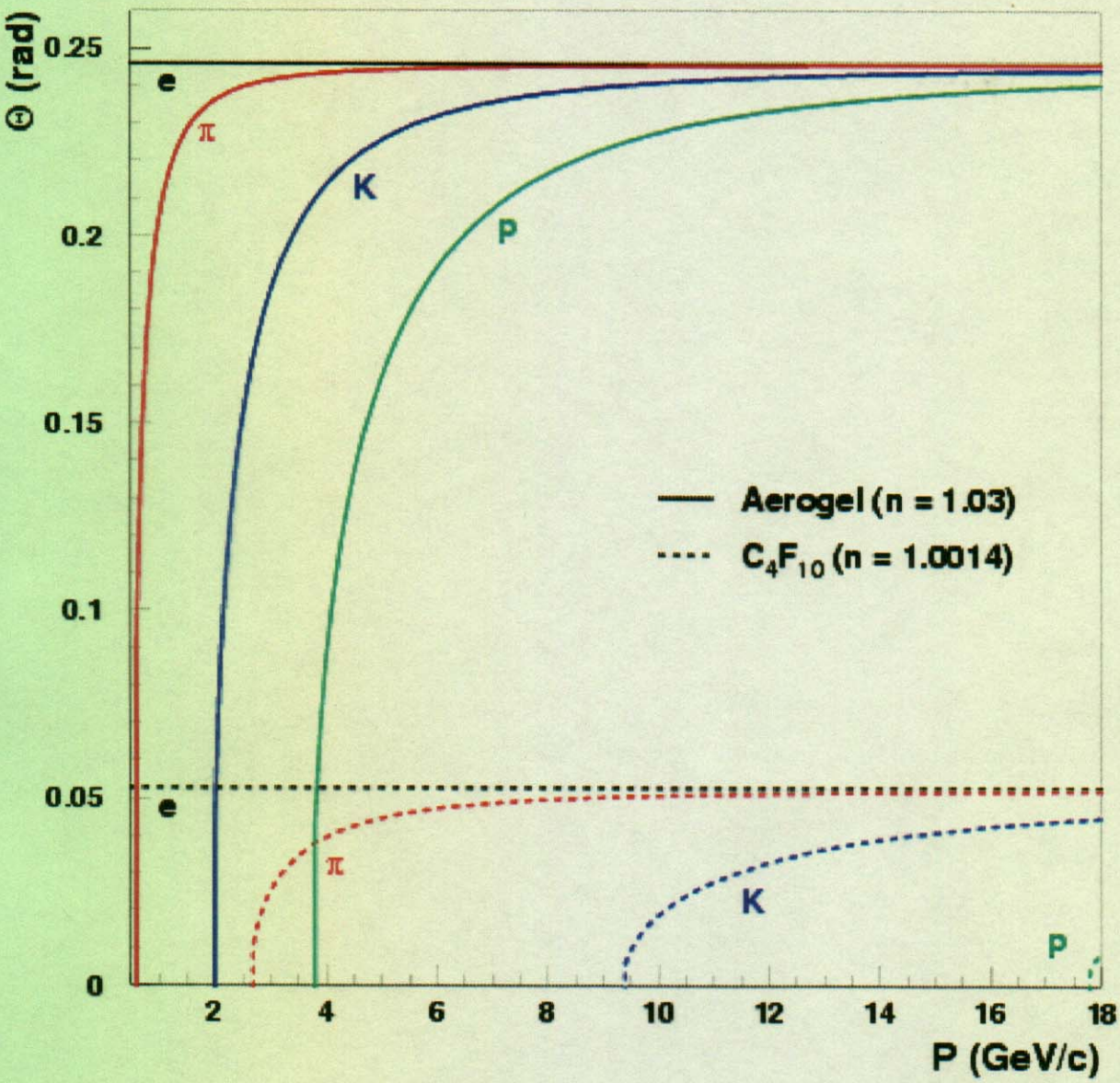
Forth Workshop on RICH Detectors at the NESTOR Institute, 5-10 June 2002, at PYLOS
Yoshiyuki Miyachi, Tokyo Institute of Technology

Requirements and Limitations

- Lepton / Hadron for DIS event
  - 98% lepton identification
  - Hadron contamination < 1%
- **Hadron identification**
  - **π, K, p from 2 to 15 GeV/c** required
- Limited Space (upgrade the HERMES original threshold type Čerenkov counter)
- As little material as possible

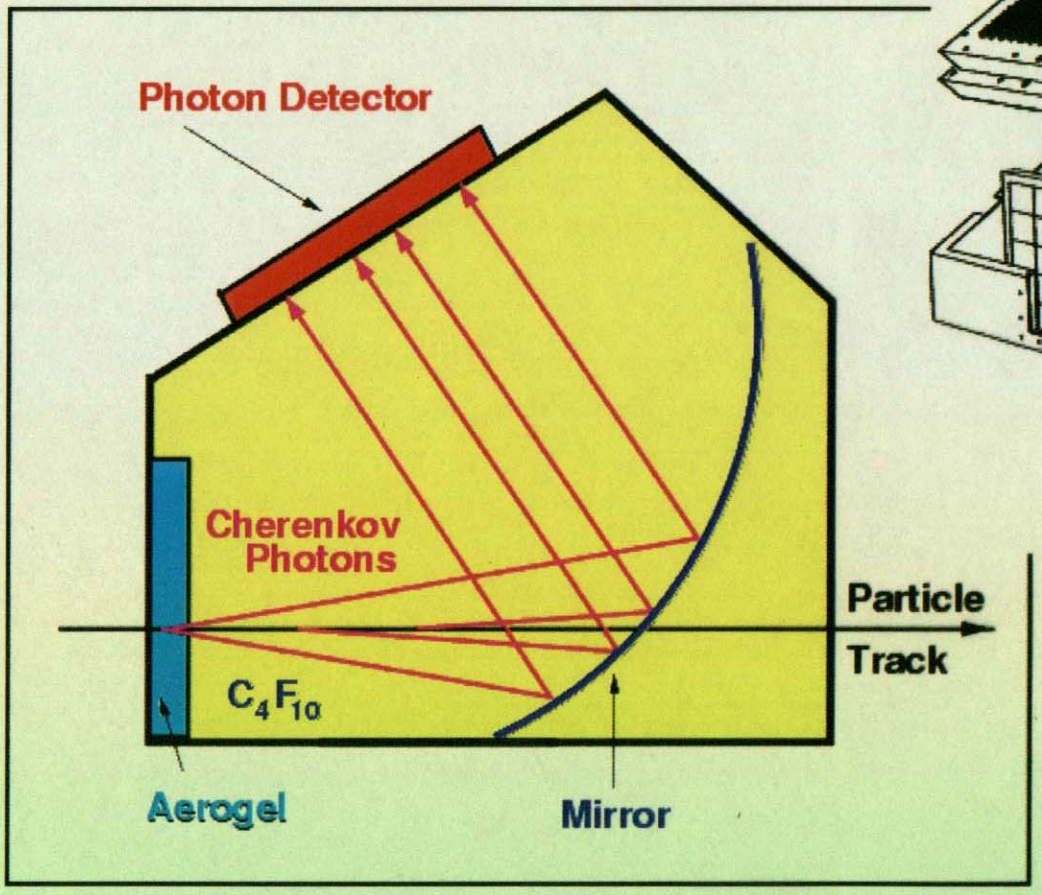


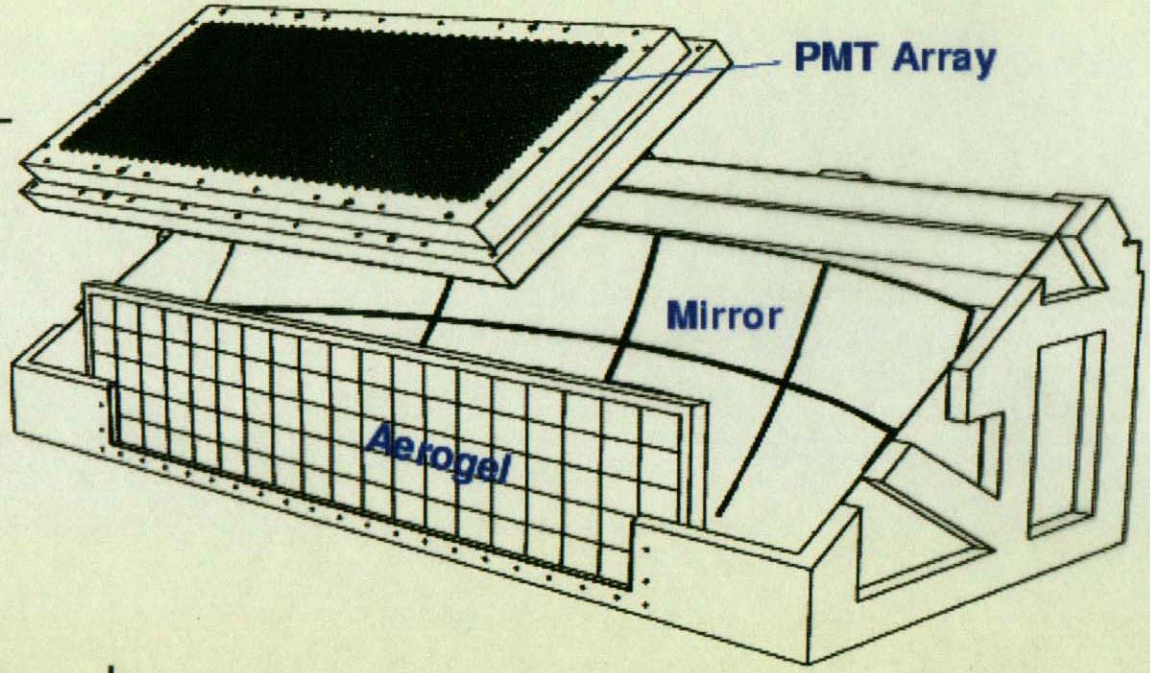
Čerenkov angle for aerogel and C_4F_{10}



- Dual radiators:
  - Higher momentum:
    - C_4F_{10} (n~1.0014)
  - Lower momentum:
    - Silica Aerogel (n~1.0304)

HERMES RICH Design





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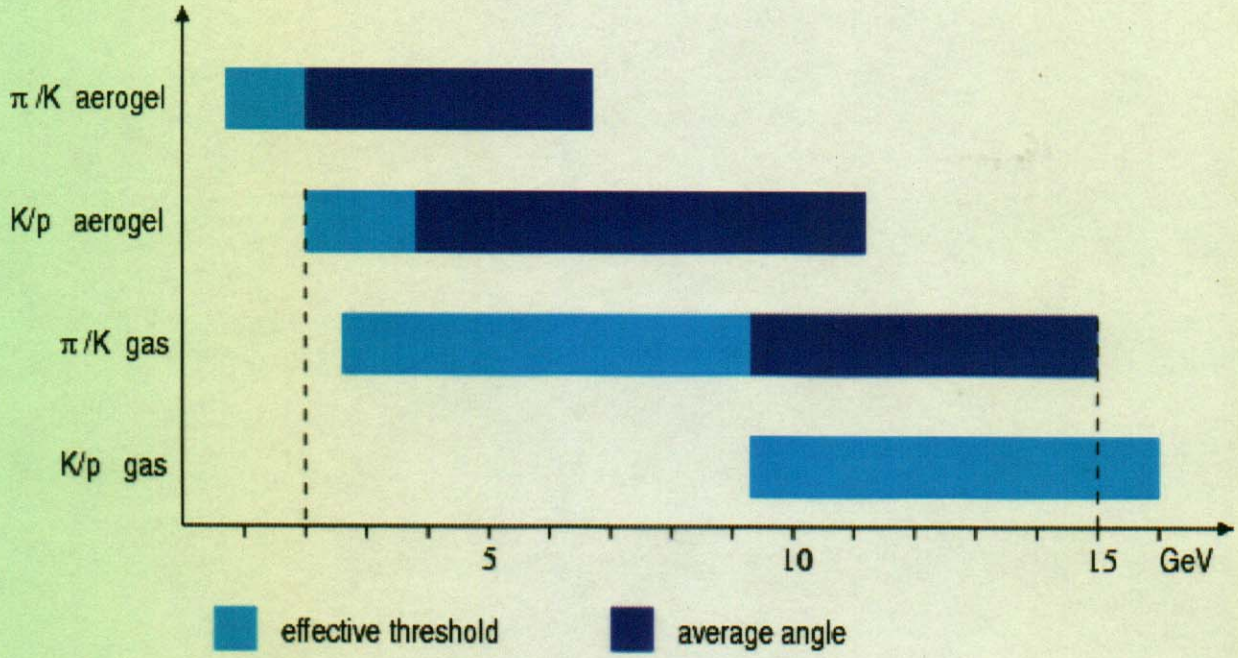
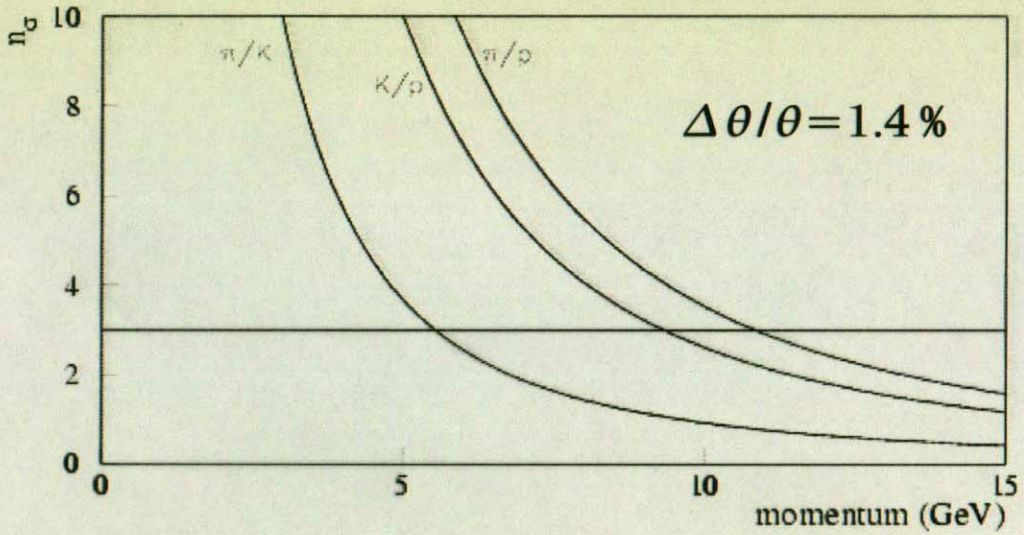
Particle Identification Scheme



- **Below 3 GeV/c**
  - Aerogel as "Threshold": π / K
- **3 to 9.3 GeV/c**
  - Aerogel as "**RICH**": K / p
  - Gas as "Threshold": π / K
- **Above 9.3 GeV/c**
  - Gas as "Threshold": K / p
  - Gas as "**RICH**": π / K

Required Reconstruction Resolution



$$n_\sigma^{p/K} = \frac{|\theta_p - \theta_K|}{\sqrt{d\theta_p^2 + d\theta_K^2}}$$

- 3 σ separation of kaon and proton at 9.3 GeV/c, above which C_4F_{10} can be used as a threshold Čerenkov counter
  - **$\Delta\theta/\theta \leq 1.4\%$ is required**
  - **For aerogel $\Delta\theta/\theta \sim 0.5\%$ is required** (Others: Photo-detector pixel size, correction efficiency and so on)
- $\Delta\theta/\theta \sim 0.5\%$ corresponds
  - **$\Delta n/n \sim 1.0\ \%$**

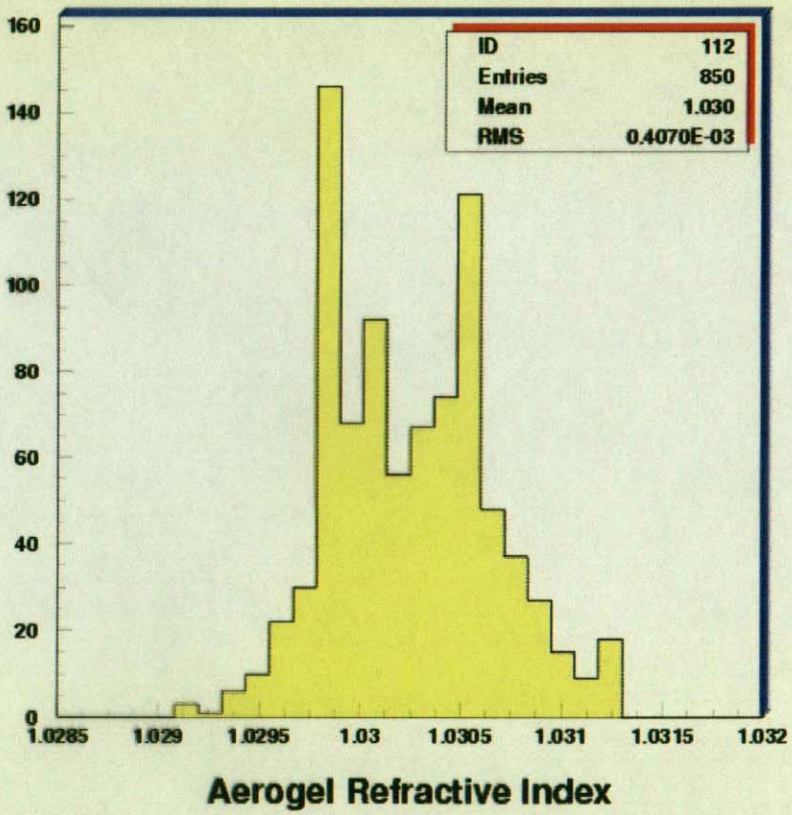
HERMES RICH Silica Aerogel

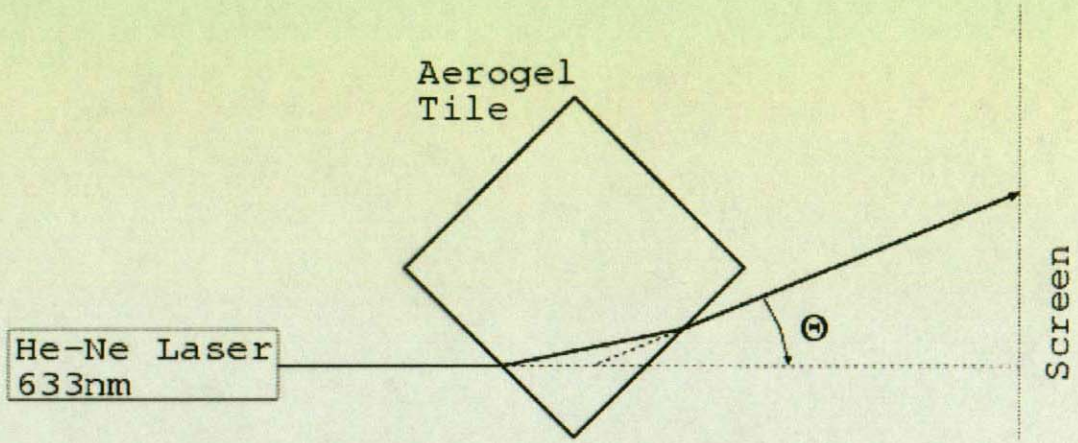
- Produced by **Matsushita Electric Works** (Osaka, Japan)
- Size: about **11×11×1 cm³**
- Refractive Index: **about 1.03**
- Total Number of Produced Tiles: 1680

Contribution to Reconstruction Resolution

- **Possible contributions to the Čerenkov angle reconstruction resolution**
  - Refractive index variation
  - Dispersion relation
  - Rayleigh Scattering
  - Deflection at the tile surface
  - Reflection inside the aerogel tile

Refractive Index Measurement

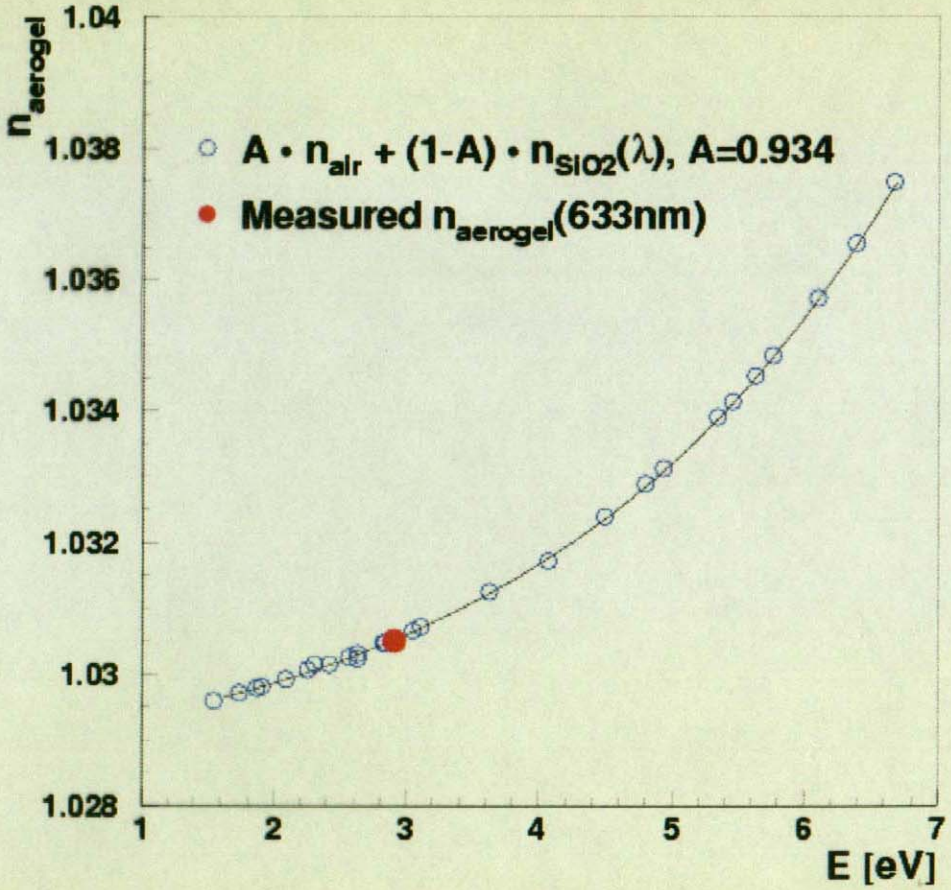




- Refractive index was measured by 633nm laser
  - $\Delta n = 4.1 \times 10^{-4}$ for selected tiles
- Position dependence of the refractive index was also measured
  - $\Delta n = 2.8 \times 10^{-4}$ (within one tile)

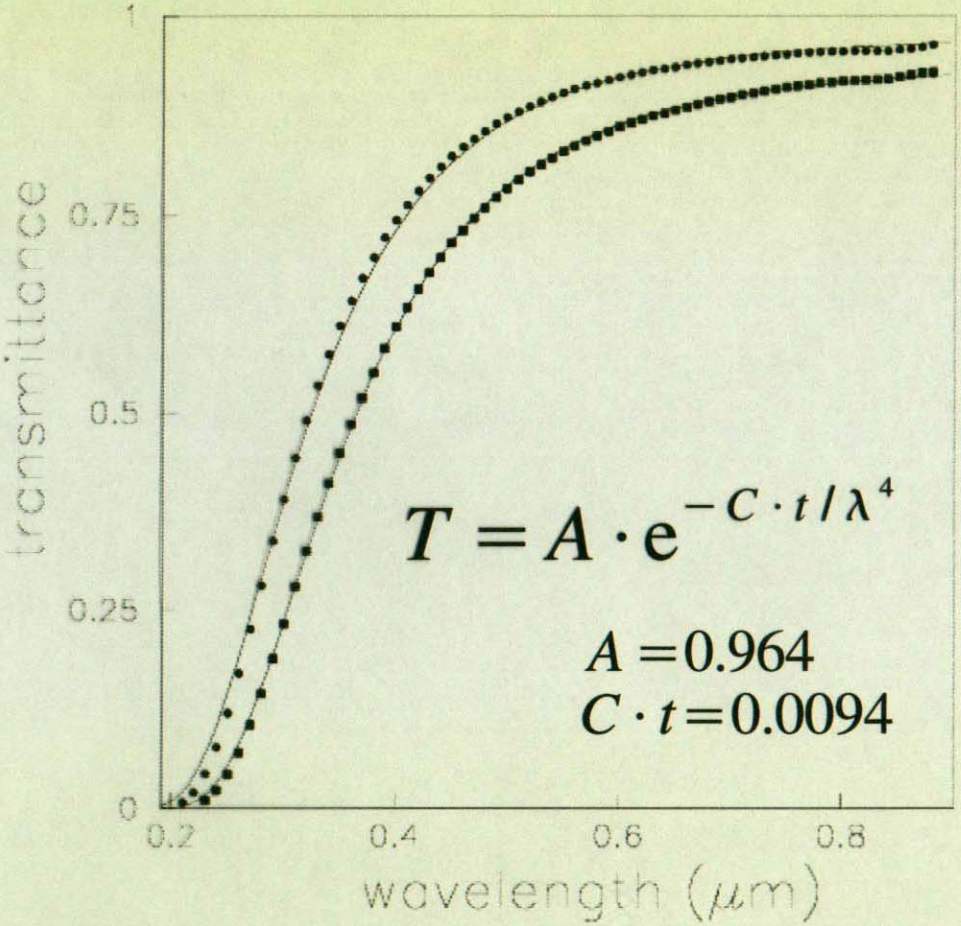
Dispersion Relation

$$n_{aerogel}(\lambda) = A \cdot n_{air} + (1 - A) \cdot n_{SiO_2}(\lambda)$$

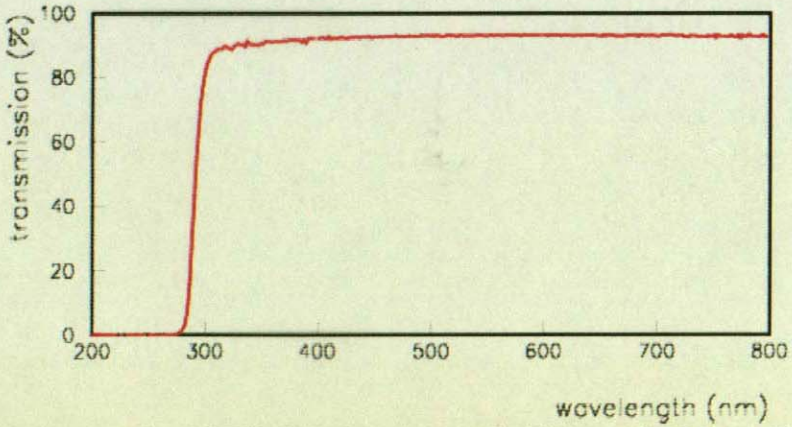


- **Dispersion relation of aerogel**
  - Air (n~1) and Silica's dispersion relation
  - Mixing Parameter A can be determined measured refractive index at 633nm
  - **$\Delta\theta/\theta \sim 0.3\%$**
    - $\Delta n = 5 \times 10^{-4}$
    - Lucite widow, light detection efficiency, and so on.

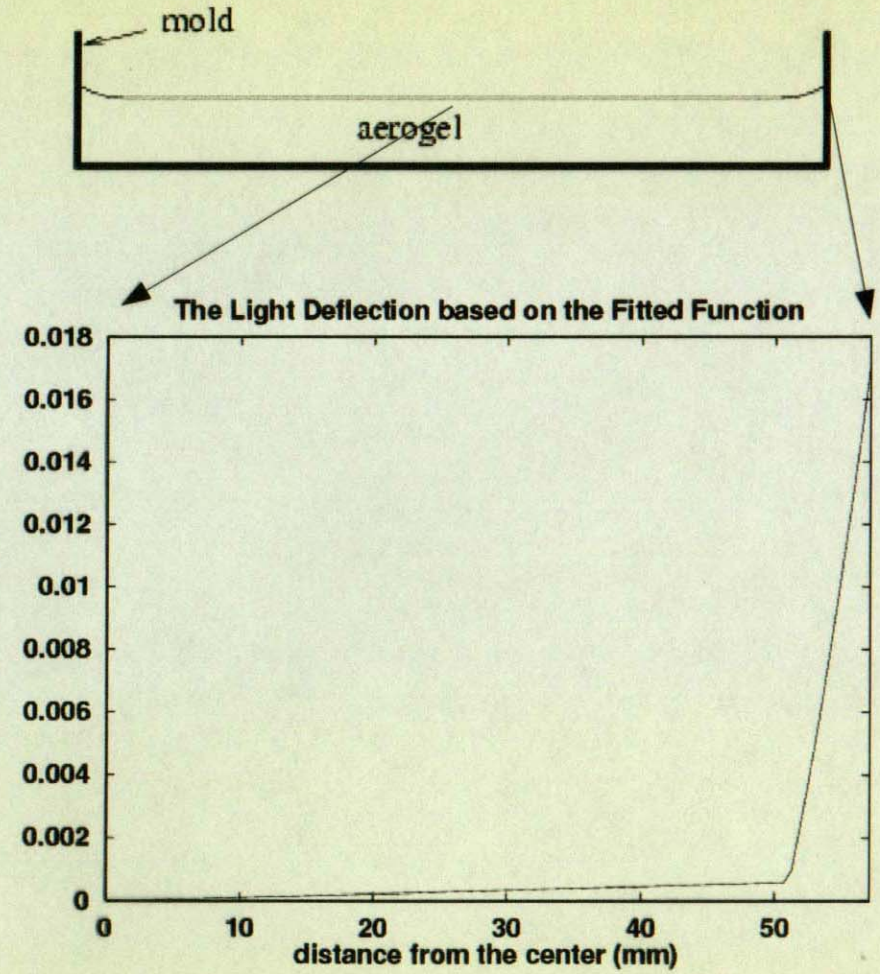
Rayleigh Scattering

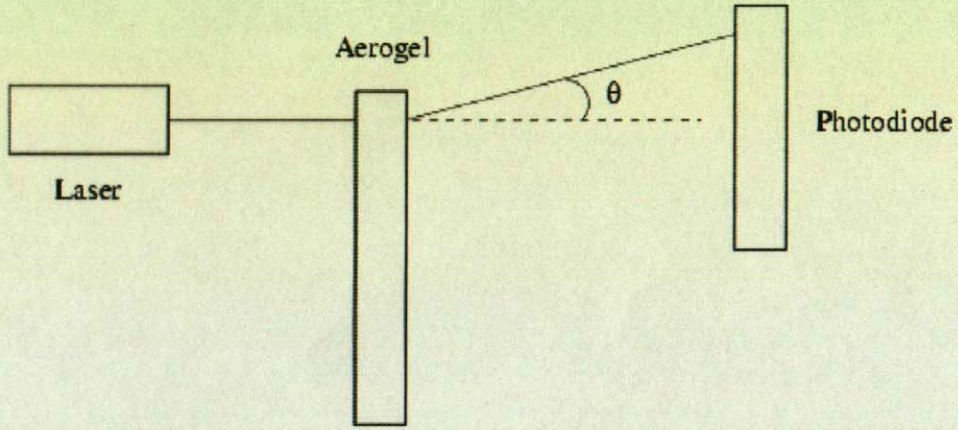


- Rayleigh Scattering is dominated below 0.3 μm
  - Estimated by measuring transmittance and determine Hunt parameter
- Exit Lucite window eliminates Rayleigh scattered radiation
  - $\Delta\theta/\theta \sim 0.1\%$



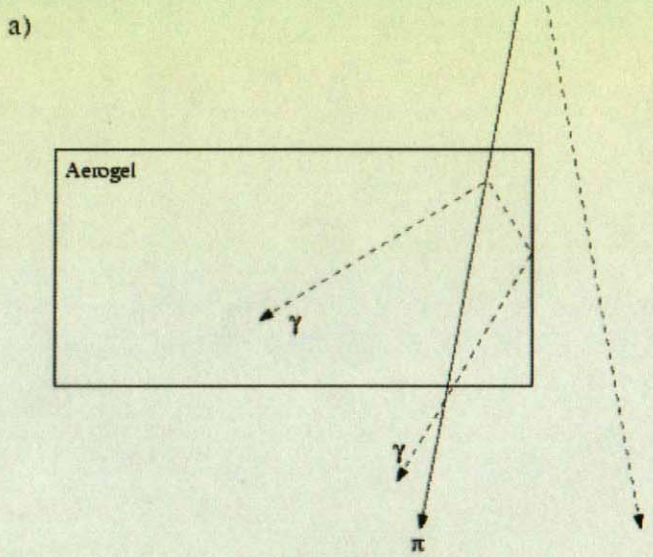
Deflection at the tile edge region

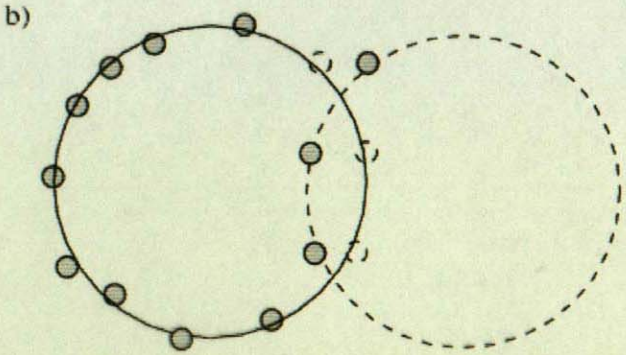


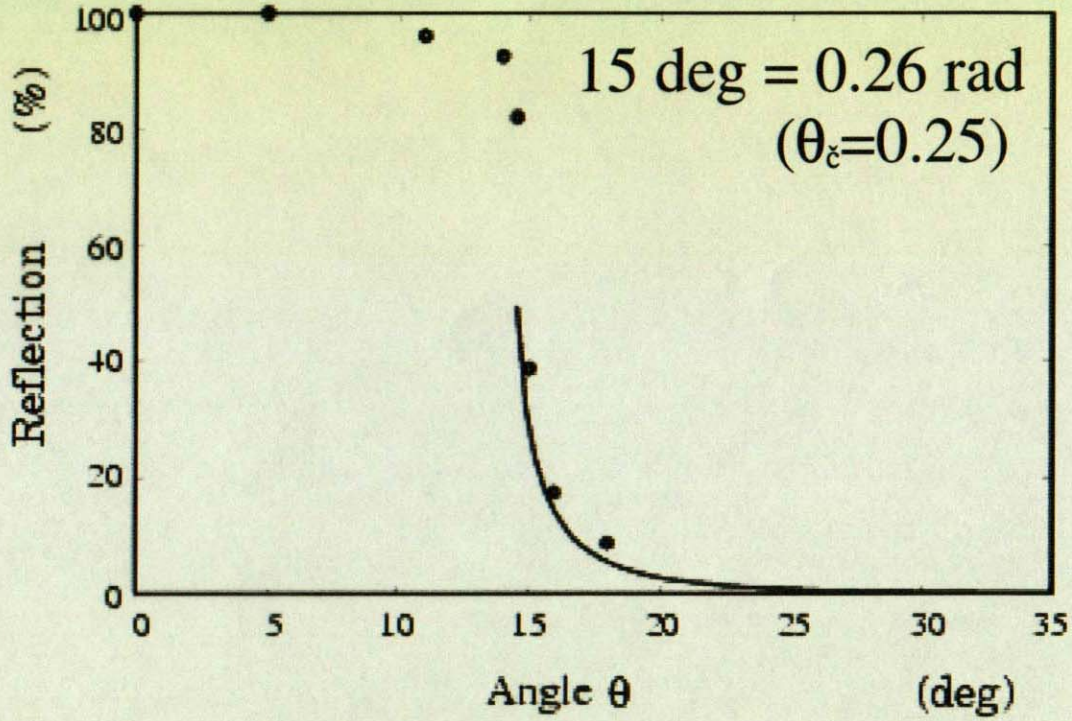


- Large deflection at the edge was found (at tile outer 5mm region)
- Non-flat tile surface
  - Consistent results tile thickness measurement

Reflection and Deflection at the side surface







- Install black Tedlar foil between tiles
  - Absorb randomly scattered at the side
  - Absorb diffracted radiation at the edge

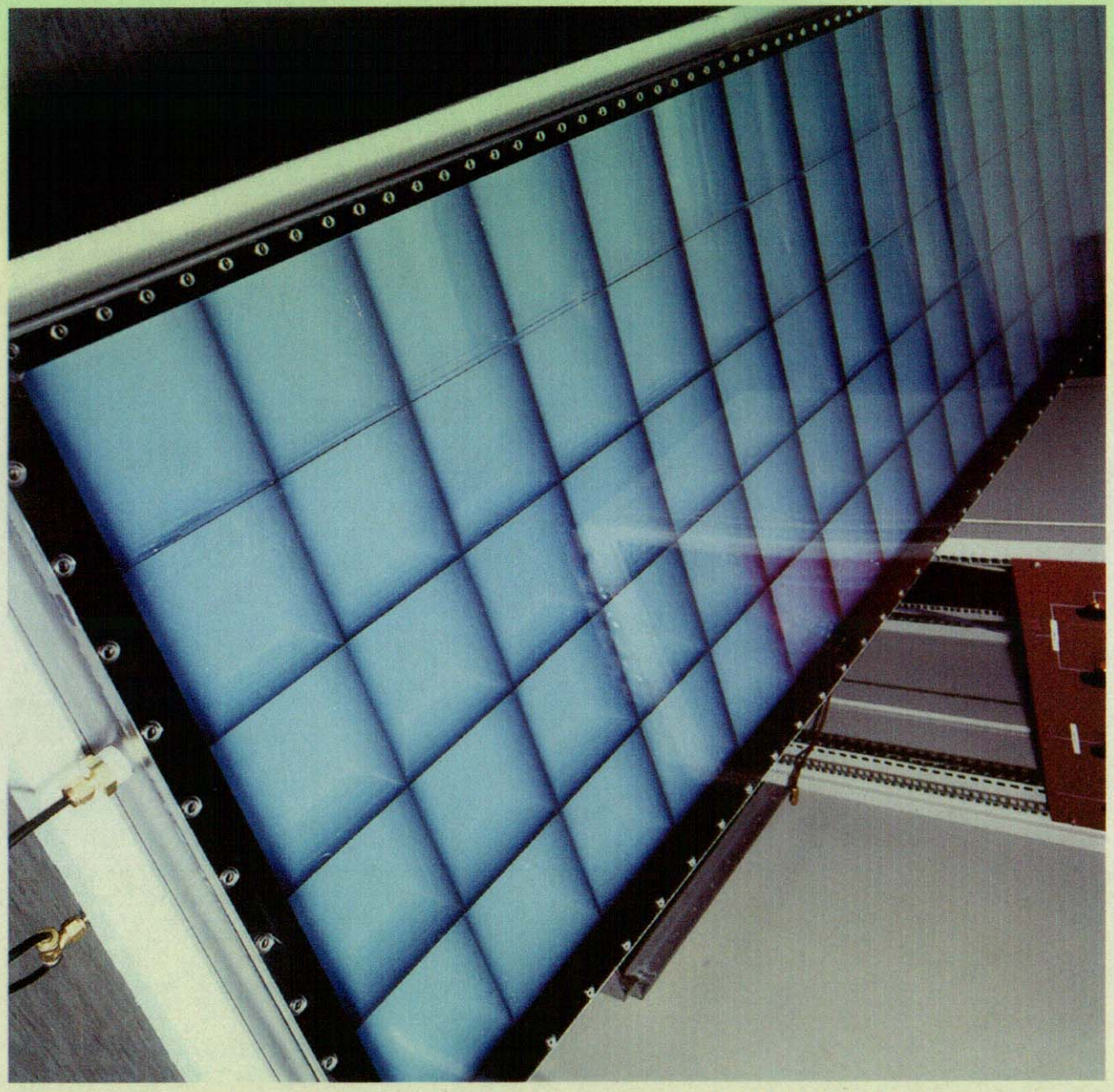
Tile Selections

- **Tile selection: 1040 out of 1680 tiles**
  - Good transparency, no visible large cracks
  - Uniform surface shape
  - Quality check
    - Tile Size: **$11.31 \leq x, y \leq 11.51$ cm, $1.025 \leq z \leq 1.225$ cm**
    - Refractive index: **$1.0290 \leq n \leq 1.0310$**
- **Select 425 × 2 tiles for top and bottom**
- **Final goal: $\Delta\theta/\theta|_{aerogel} \leq 0.5\%$**

HERMES RICH Aerogel Radiator

- **5 layers with 5×17** for top and bottom
  - Maximize unscattered / scattered radiation ratio : 5 tiles
  - Similar refractive index in one stack
  - Minimize diffraction effect at the tile edge region
    - Flat surface to the downstream
    - Photon absorbers between stacks
  - Gas shielded container + **dry N_2 gas** circulated continuously

HERMES RICH Aerogel Radiator



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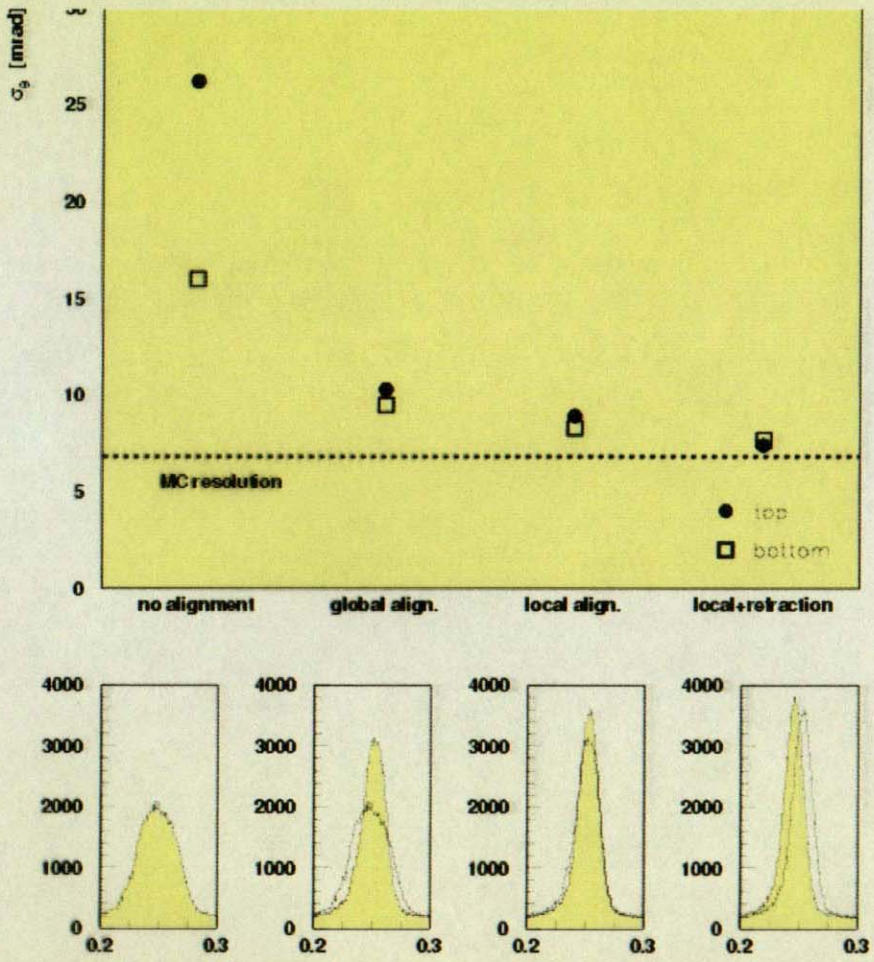
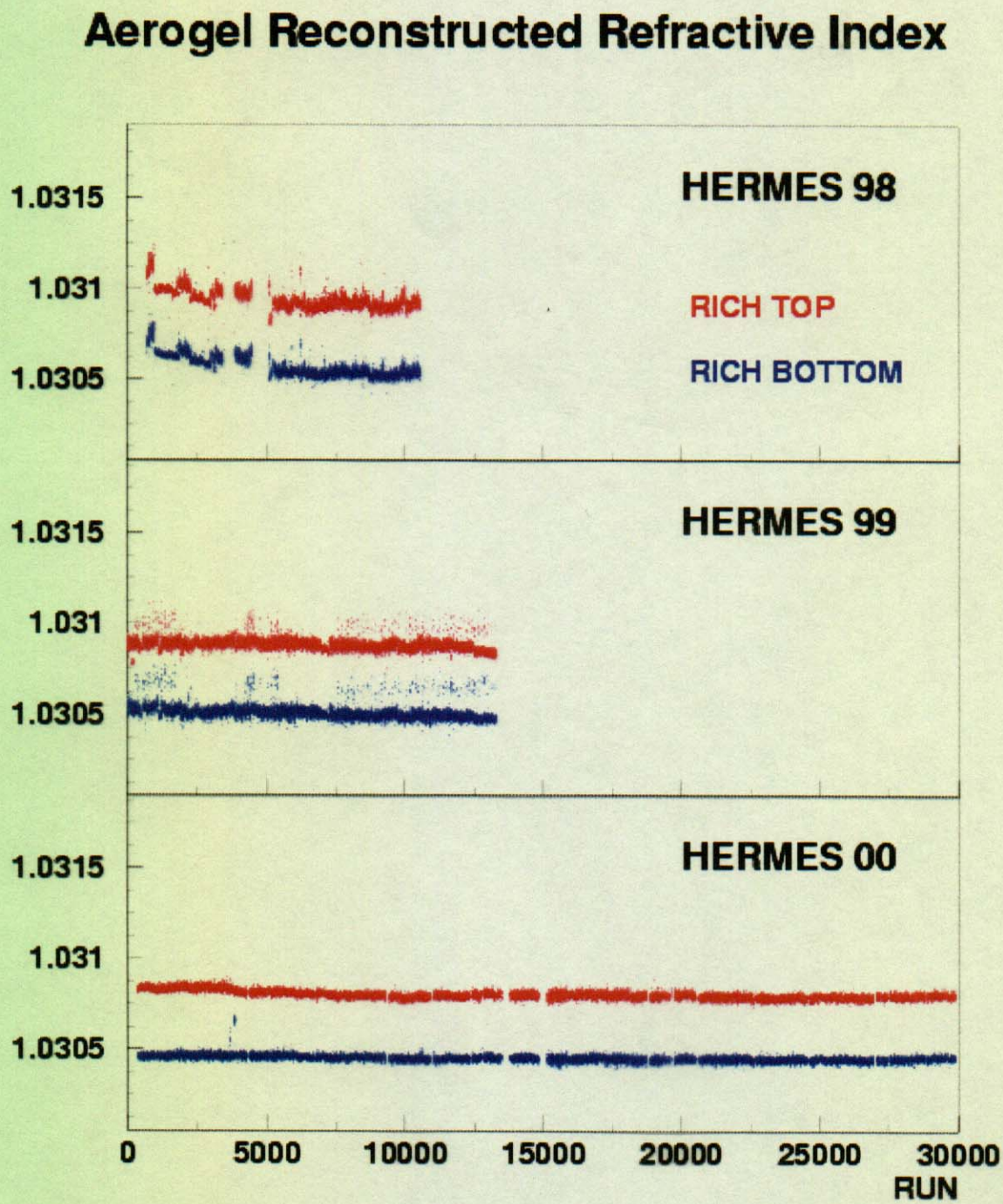
Single Photon Resolution



- Achieved single photon resolution: $\Delta\theta_{single} \sim 7.6$ mrad
  - Global + local alignment, boundary corrections....
  - Small background
    - Lucite exit window
    - Absorber between tiles

$$\frac{\Delta\theta}{\theta} = \frac{\Delta\theta_{single}}{\theta} \cdot \frac{1}{\sqrt{N_{aero} \approx 10}} \approx 1\% \qquad (\theta \approx 0.25)$$

Longterm stability



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Summary

- HERMES uses aerogel and C_4F_{10} radiators to identify π, K, p from 2 to 15 GeV/c.
- Select 850 aerogel tiles for RICH
  - 1680 Tiles were produced by Matsushita Electric Works
- Stable RICH operation over three years since 1998
- Single Photon Resolution : $\Delta\theta \sim 7.6$ mrad
  - Allow us to study a lot of physics topics; quark flavor decomposition by measuring spin asymmetries of π and K ...