Towards A RICH Detector for CLAS12 Spectrometer

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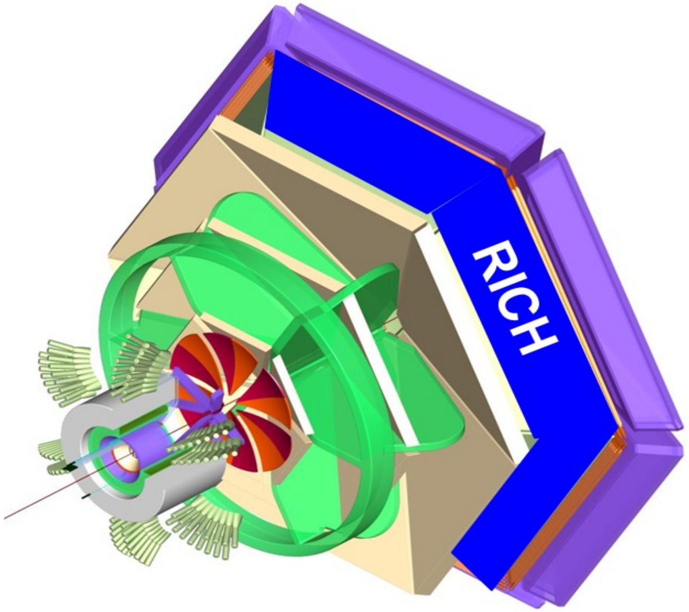
TIPP2011 Conference, Chicago, June 9-14, 2011



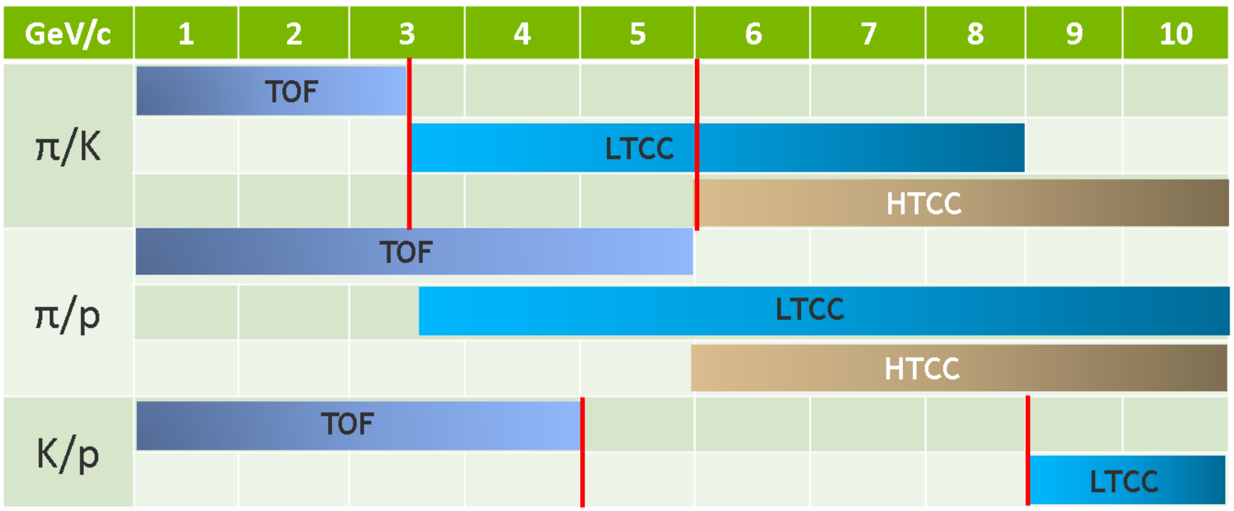
Outline

- Motivation
- CLAS12 Spectrometer
- Simulation Detail
- Reconstruction Code
- Conclusion and Outlook

Motivation

- The feasibility of the Jlab physics programs dealing with kaons in the final state requires a good detection system capable of identifying kaons with high efficiency and low contamination in a broad momentum range.

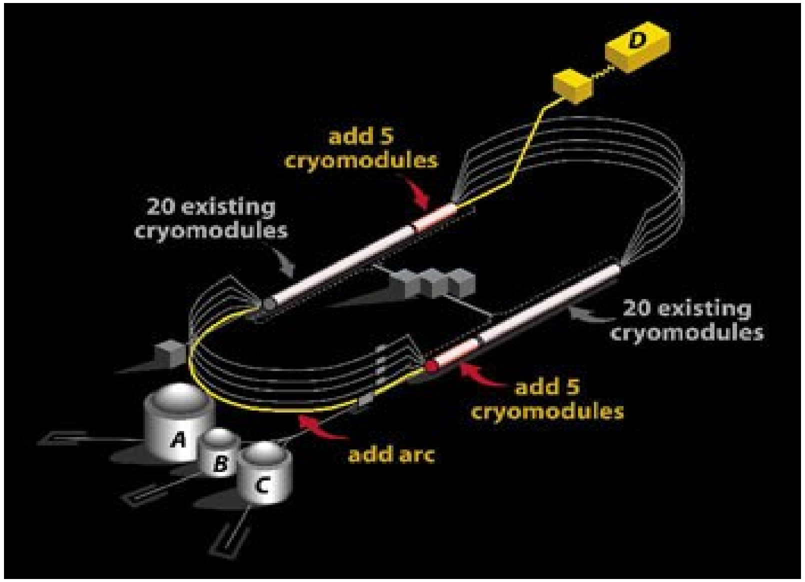
- Particle Identification system used by CLAS12 (TOF, LTCC, HTCC) does not allow for a good identification/separation between π/K/p in the whole 2.5-10 GeV/c momentum range

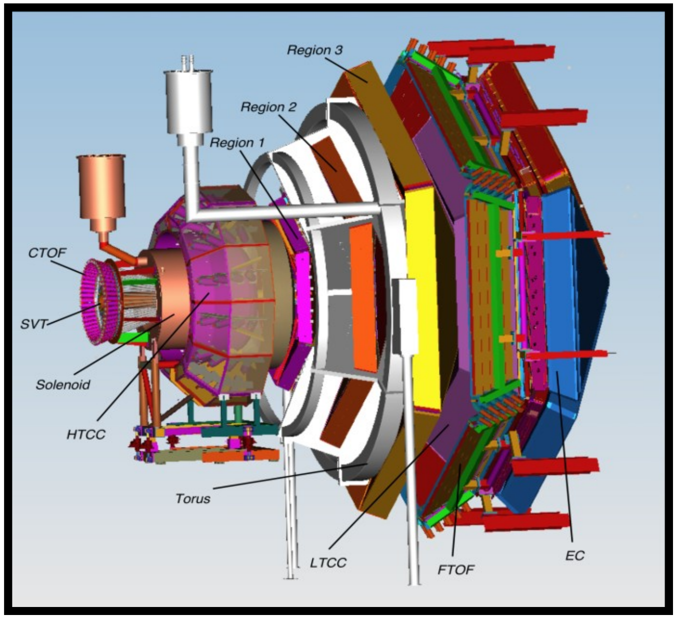


- Reliable kaon identification is only possible for momentum up to 2.5 GeV
- For momentum range 2.5-5 GeV/c kaon identification depends on LTCC performance
- In the momentum region 4-8 GeV/c it is not possible to separate between kaons and protons

→ **RICH detector is needed to improve CLAS12 PID**

Particle Identification at CLAS12



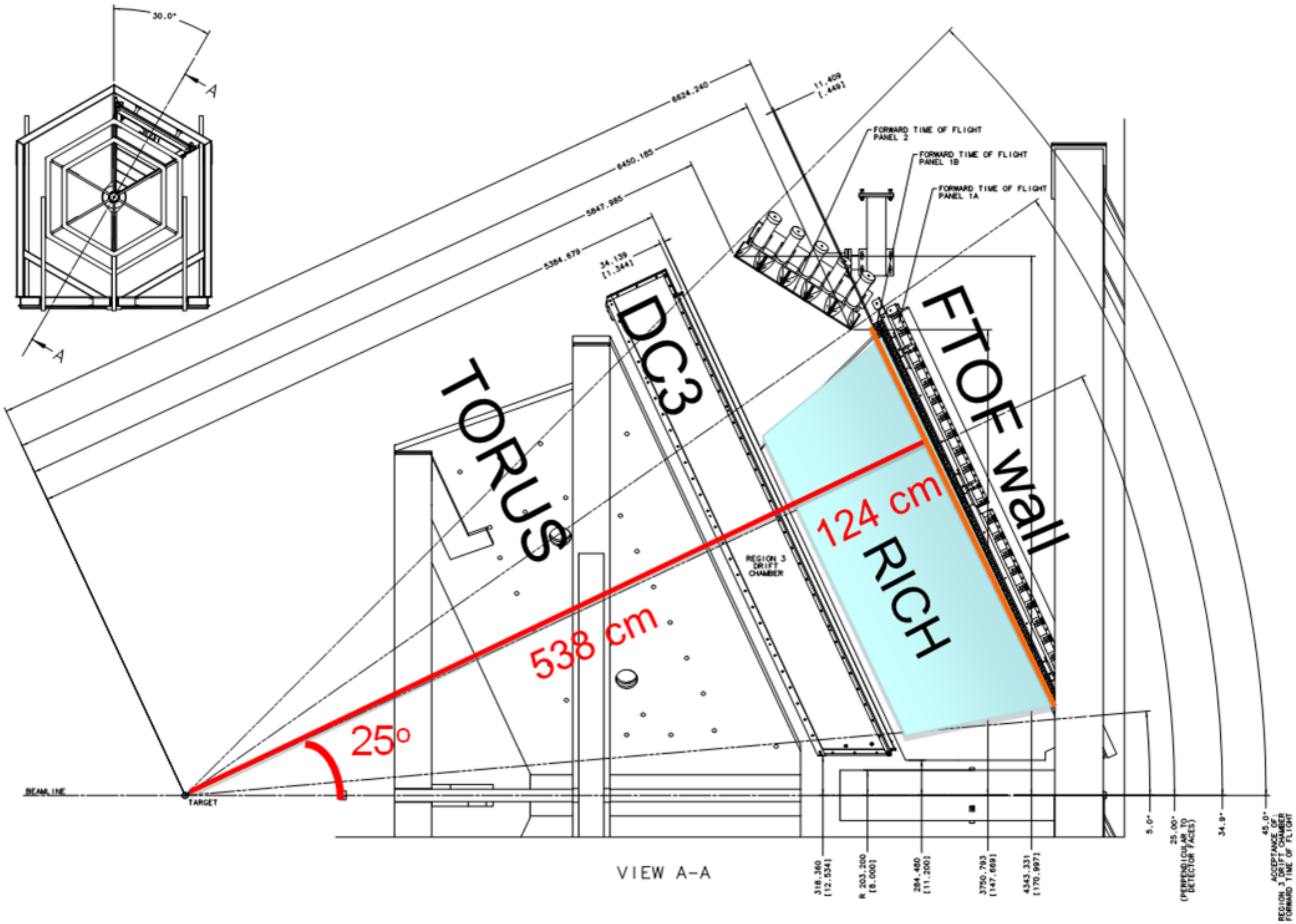


Forward Detector:
- *TORUS magnet*
- *Forward SVT tracker*
- *HT Cherenkov Counter*
- *Drift chamber system*
- *LT Cherenkov Counter*
- *Forward ToF System*
- *Preshower calorimeter*
- *E.M. calorimeter (EC)*

Central Detector:
- *SOLENOID magnet*
- *Barrel Silicon Tracker*
- *Central Time-of-Flight*

Proposed upgrades:
- *Micromegas (CD)*
- *Neutron detector (CD)*
- ***RICH detector (FD)***
- *Forward Tagger (FD)*

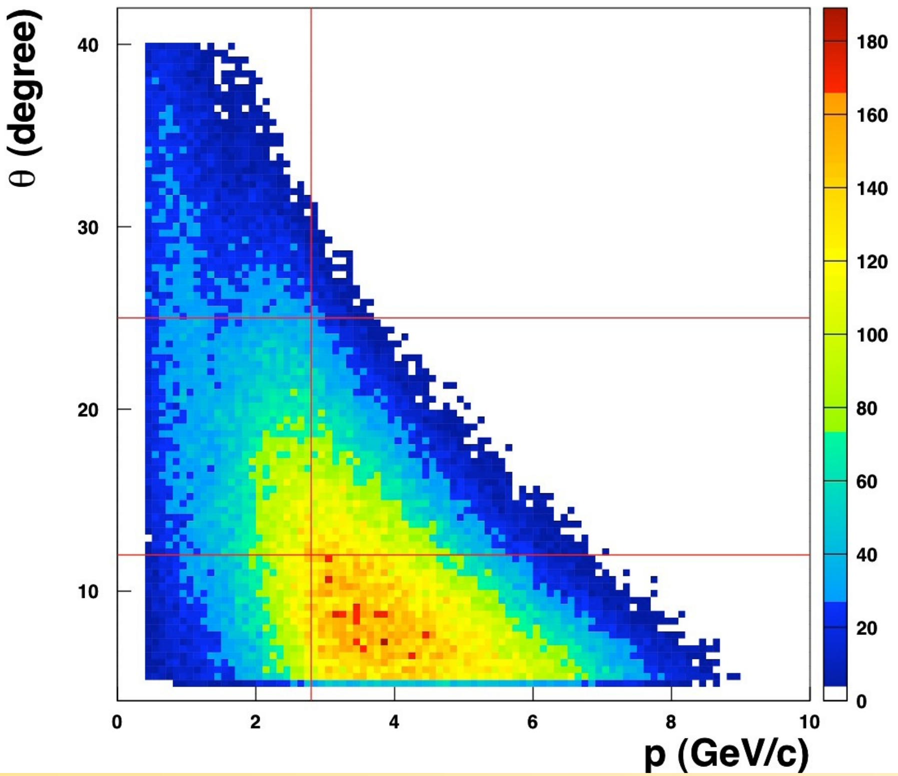
RICH Layout



Kaon momentum/angular distribution

In order to determine the momentum and angular distributions of kaons, pythia generator was used to generate semi-inclusive events by scattering an 11 GeV electron beam off a proton target

Q^2>1GeV^2, W^2>4GeV^2, y<0.85, z>0.2, pdf cteq6m



Most kaons are produced between 5-40 degrees and with momentum up to 8 GeV

RICH Performance

The angular resolution per photon:

$$\sigma_{\theta_C} = \sqrt{\sigma_{rad}^2 + \sigma_{PD}^2 + \sigma_{geom}^2 + \sigma_{tr}^2}$$

The ring resolution:

$$\sigma_{ring}(\theta_C) = \frac{\sigma_{\theta_C}}{\sqrt{N_{pe}}}$$

The separating power:

$$N_\sigma = \frac{\left(m_1^2 - m_2^2\right)}{2p^2\sqrt{n^2-1}\,\sigma_{\theta_C}}$$

The number of photo-electrons N_{pe}:

$$\boxed{N_{pe} = 370\,L\int \varepsilon \sin^2\theta_c\,dE = L\,N_0 \sin^2\theta_c}, \quad N_0 = N\int(QTR)dE$$

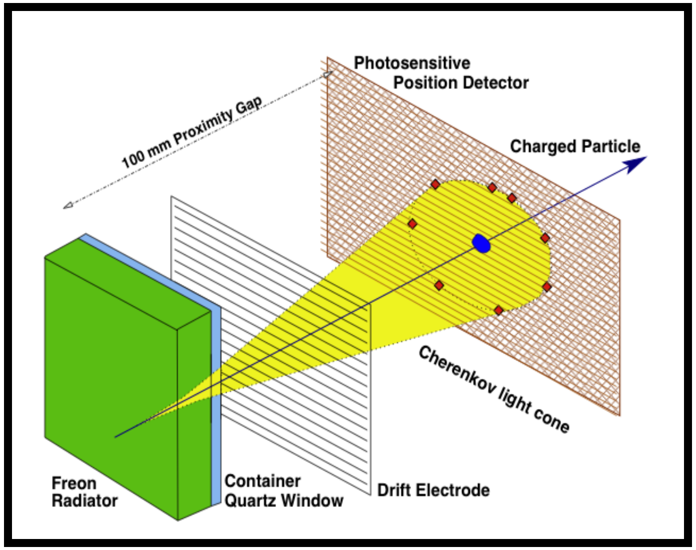
Usually N_o between ~ 20 and 100

<u>General rule</u>: **minimize σ_{θ_C} and maximize N_{pe}**

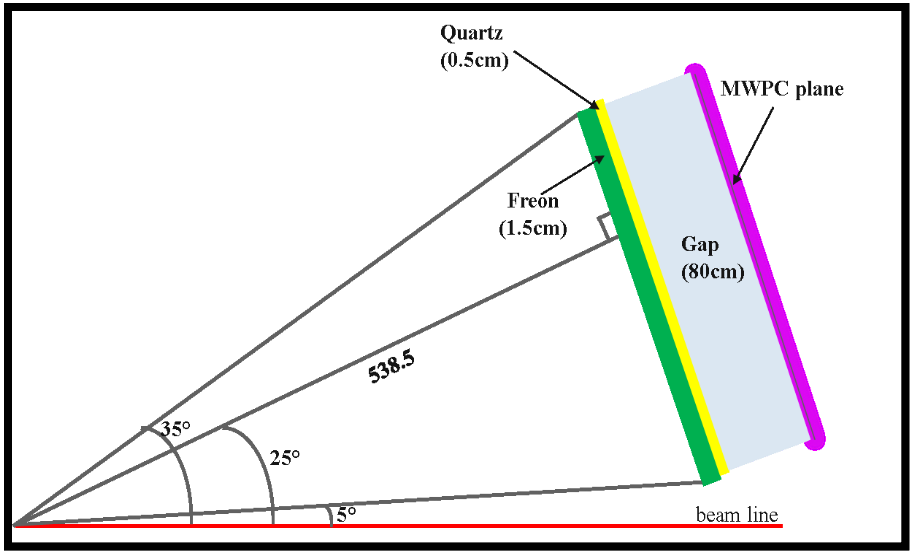
Proximity Focusing RICH Detector

Requirements:

- Fit inside the available Area (124 cm)
- Should be able to operate in a high rate environment and in a Magnetic field
- Reasonable cost
- Material budget(impact on CLAS12 perferformance)



A proximity focusing RICH detector similar to the one used in Hall A Hyper Nuclei experiment *(Garibaldi et al., NIM A502:117, 2003)* was choosen as a starting point for the simulation because it fulfills the above requirements.

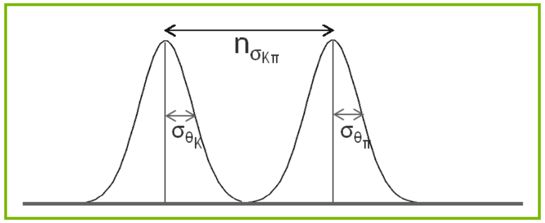


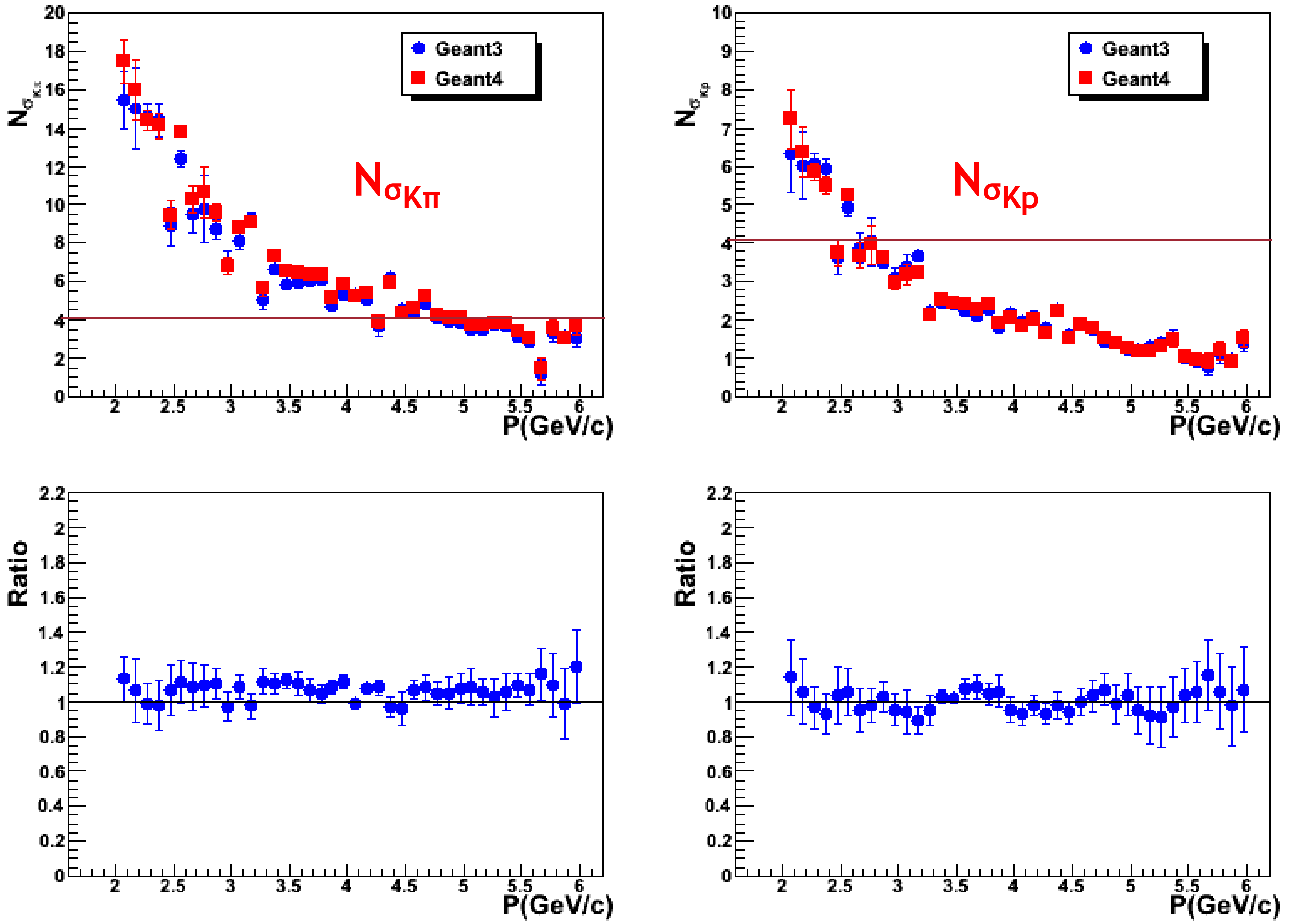
Detector Components:

- Liquid Freon Radiator C_6H_{14}, <n> = 1.28
- Quartz Window
- Proximity Gap CH_4 gaz
- Thin layer of CsI deposited on 8x8 mm^2 pad (photocathode for MWPC plane)

Separating power

$$n_{\sigma_{p1p2}} = \frac{\langle\theta_{p_1}\rangle - \langle\theta_{p_2}\rangle}{\langle\sigma_{\theta_{p1}}\rangle + \langle\sigma_{\theta_{p2}}\rangle}$$

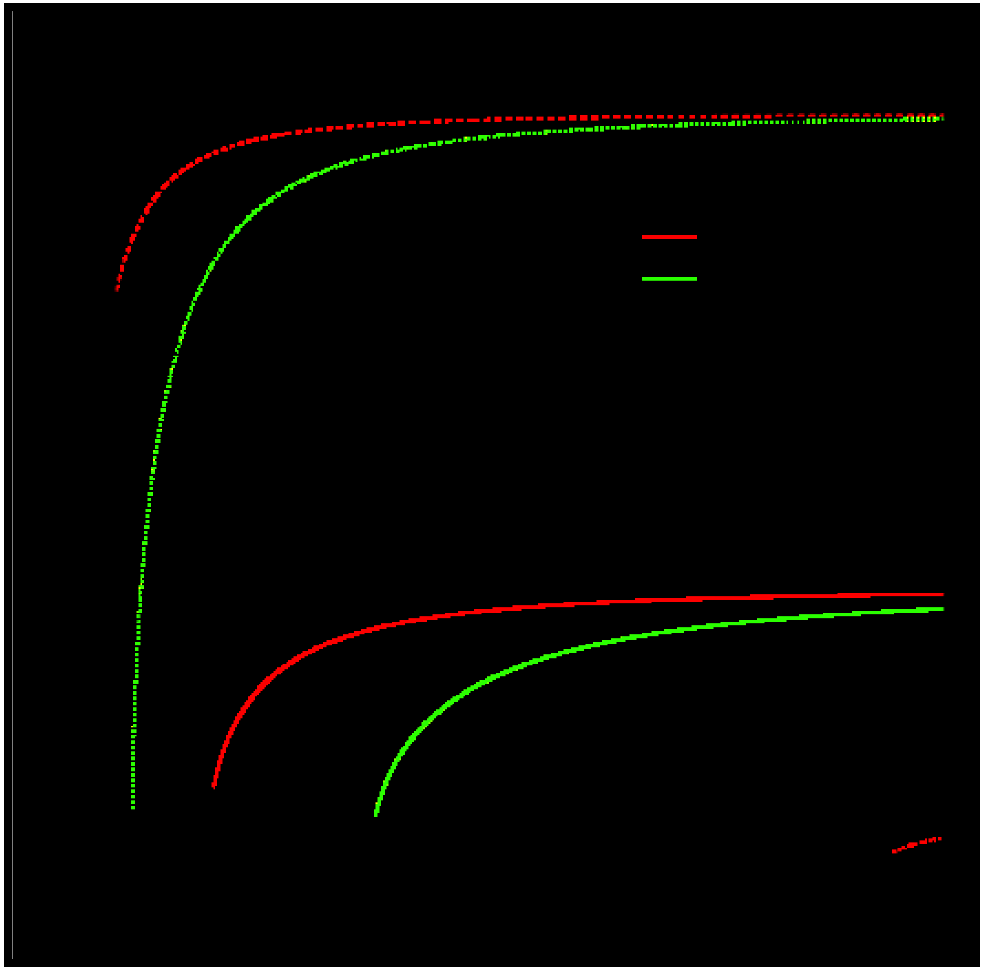


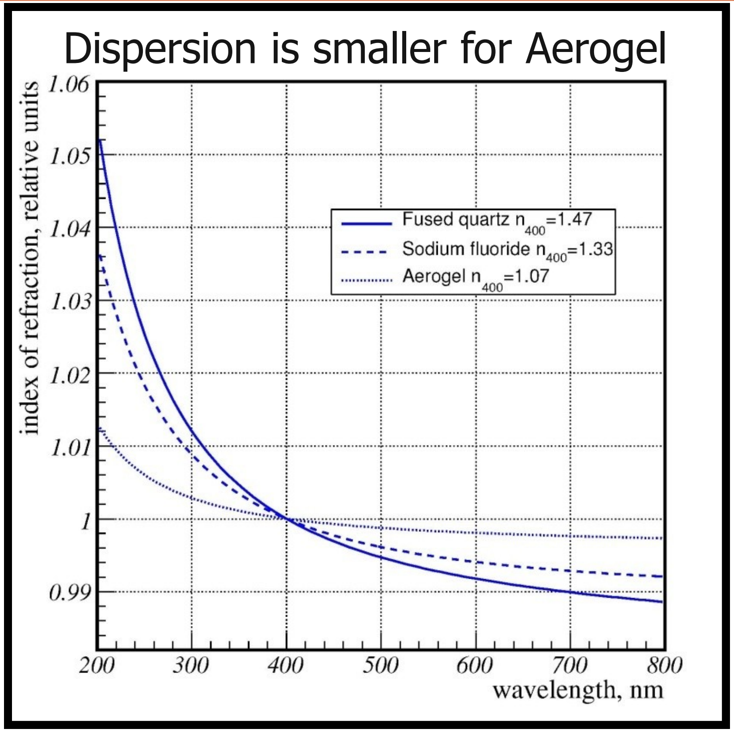


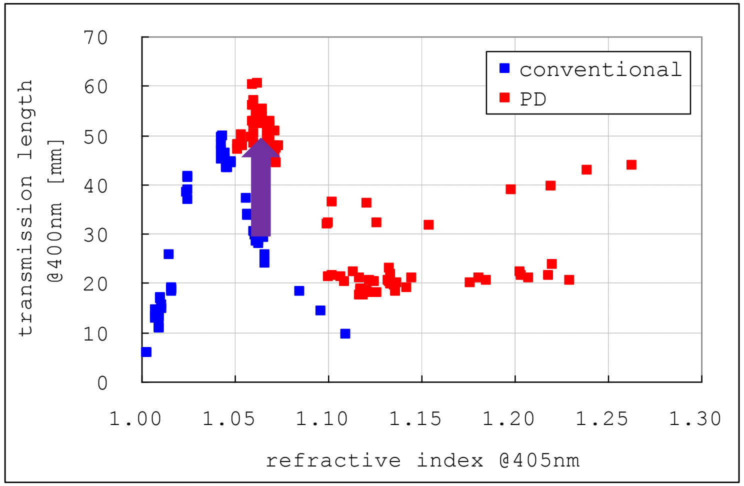
Freon+UV-light detection does not provide enough discrimination power in the 2-8 GeV/c momentum range

Use of Aerogel is mandatory to separate hadrons in the 2-8 GeV/c momentum range → collection of visible Cherenkov light → use of PMTs

Radiator: Aerogel



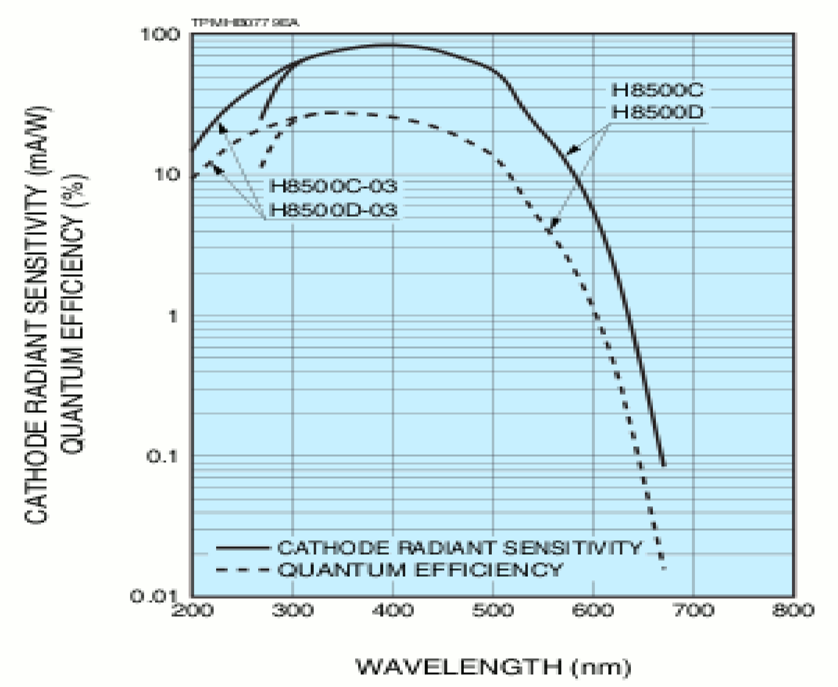




New technique "Pinhole drying (PD)" method allow the production of aerogel with high refractive index (n> 1.05) and high transparency

see talk by T. Makoto, june 09

Photon detector: MAPMT H8500C



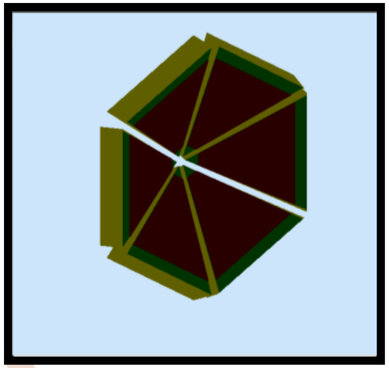
Range : 260-650 nm
30% QE @ 400 nm
packing factor: 89%

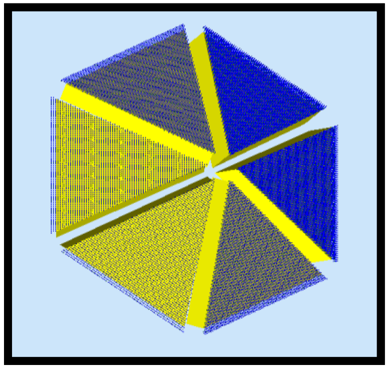
MAPMT	Dimension (mm^3)	Effective area (mm^2)	Pixel size (mm^2)
H8500-C	52x52x28	49x49	5.2x5.2 (8x8)

RICH Detector Setup

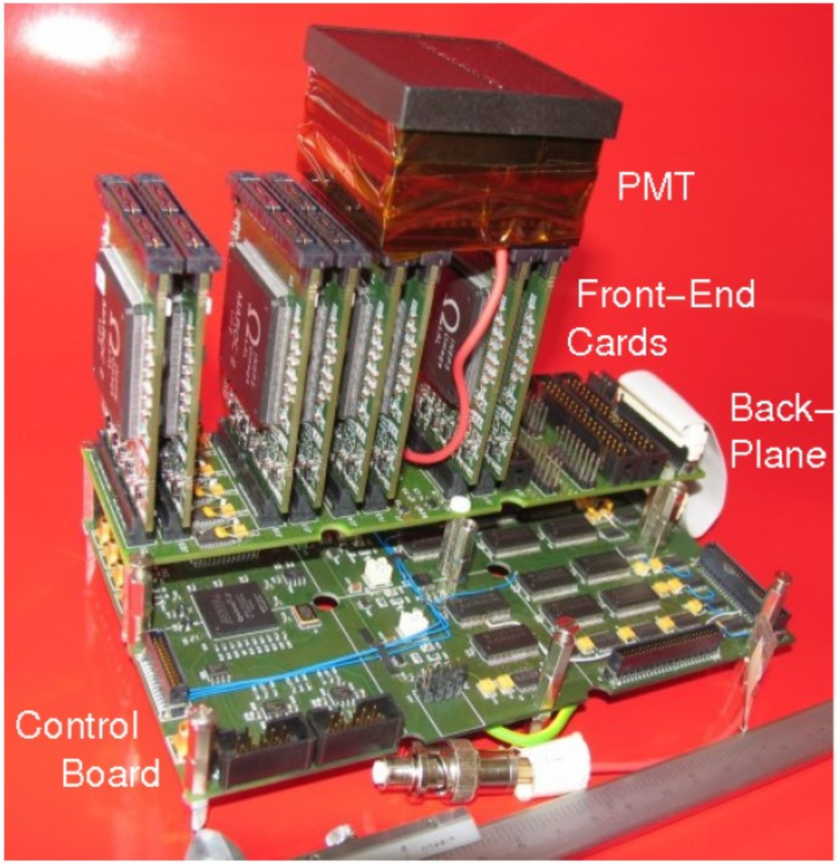
Component	Volume (cm3)	Material
Rich Body	130x460x124	Aluminum
Radiator	110x400x3	Aerogel
Gap	120x450x100	Methane
Photon Detector	5.2x5.2x2.8	MAPMT H8500-C

- Radiator: Aerogel Ref. index = 1.06
- Gap: Methane
- PMT: MAPMT H8500





A.G. Argentieri et al. NIM A 617 (2010) 348–350

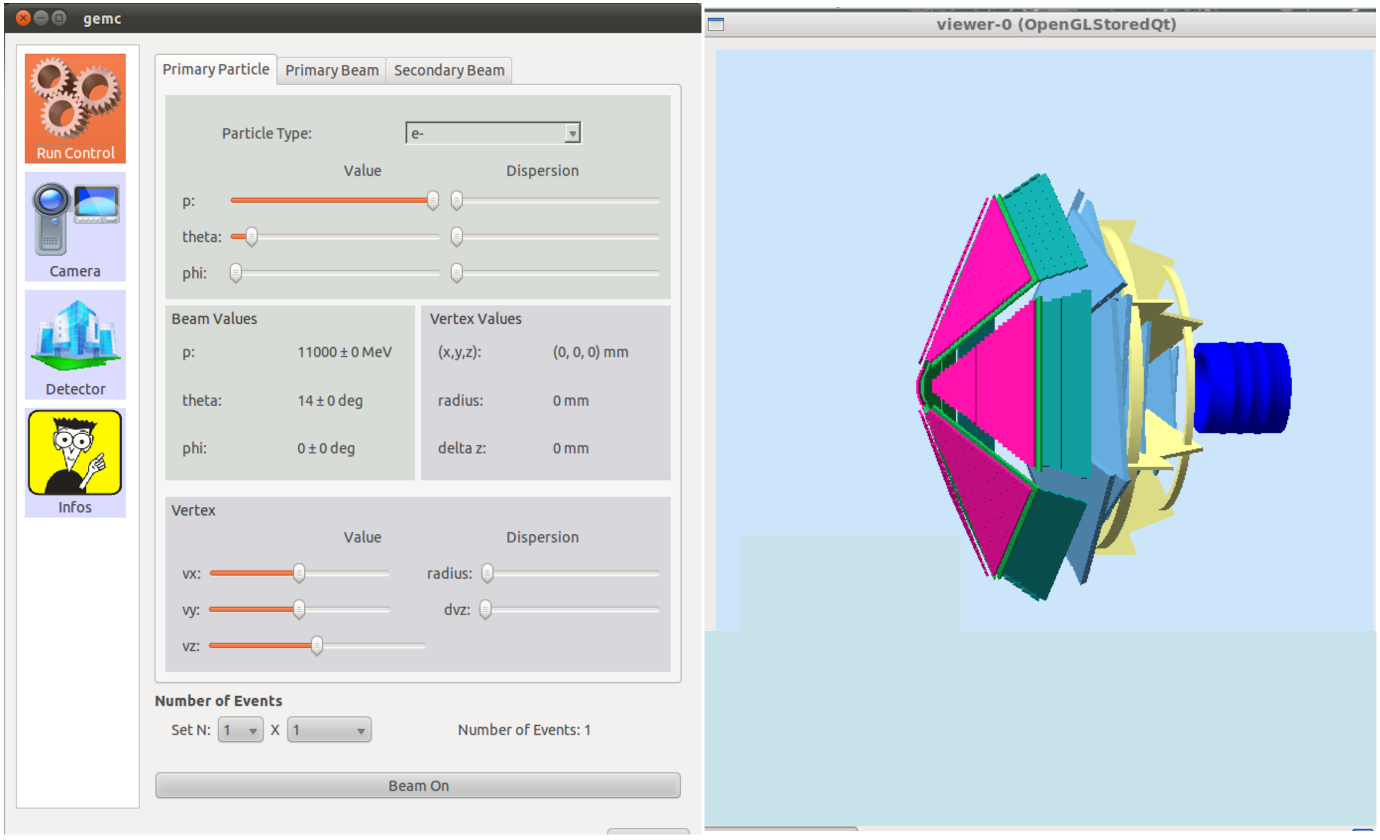


Only 17 cm space is left for electronics

Software: GEMC

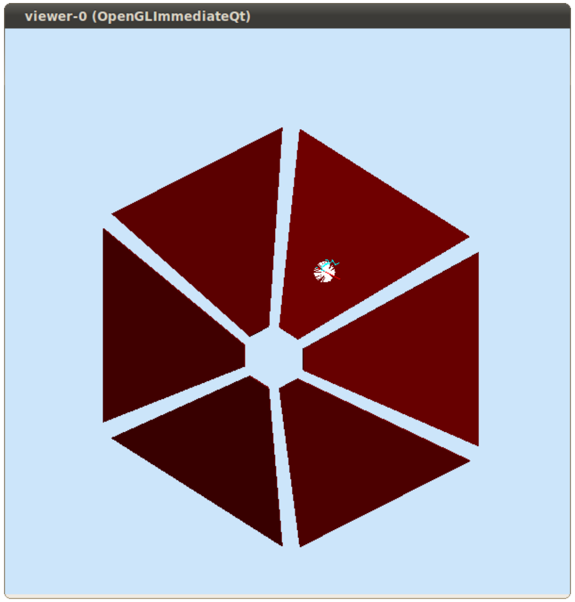
Full simulation chain
- realistic geometry
- track multiplicity / background

C++, CLHEP libraries, Qt4 libraries, Geant4, Scons/Python, mysql, root, pythia

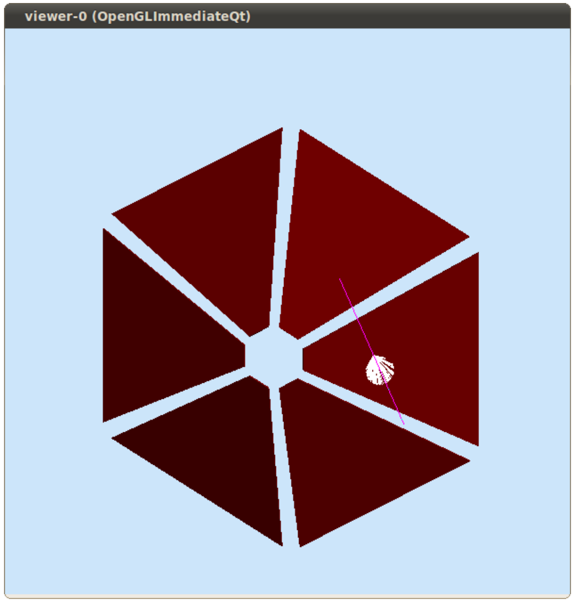


Cerenkov rings

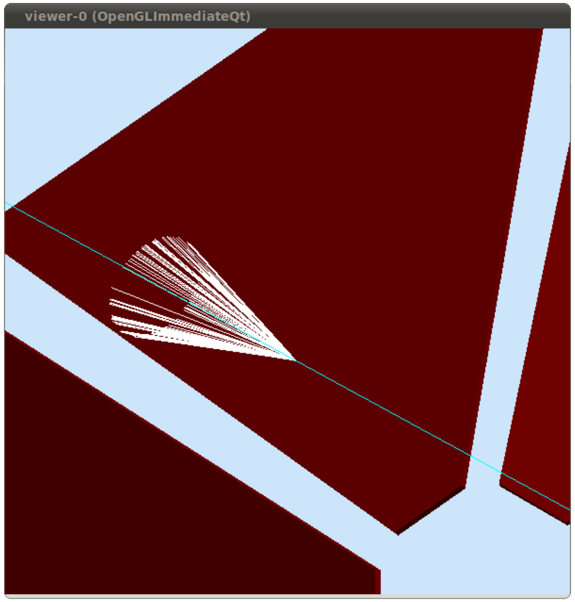
2 GeV kaon



2 GeV pion



2 GeV electron



Simulation

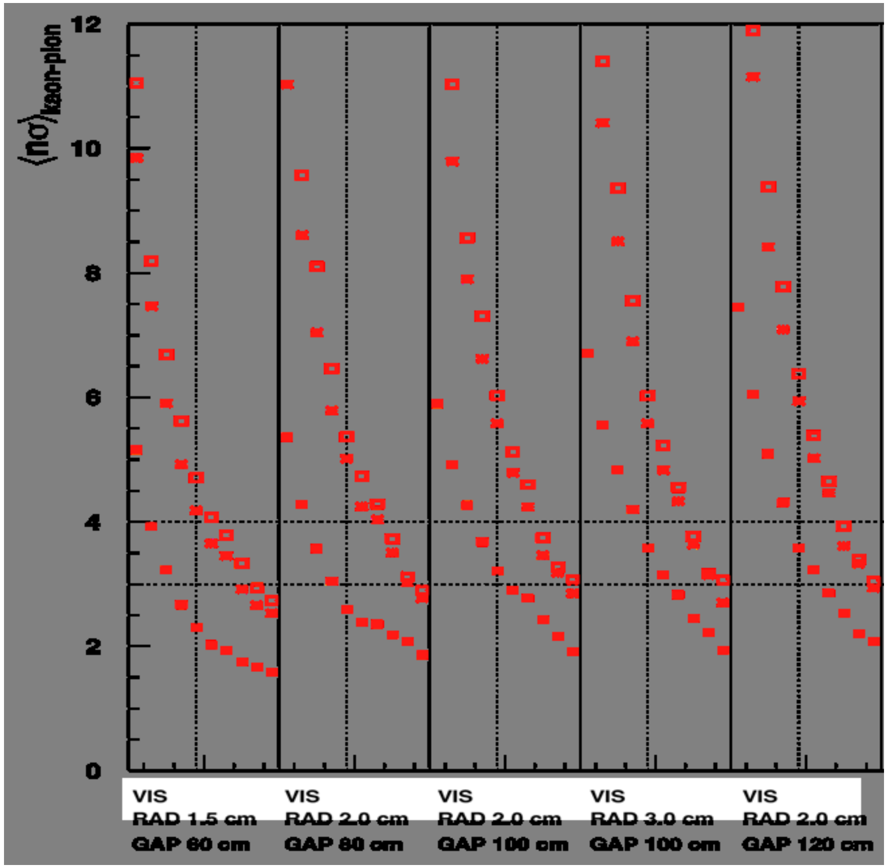
A full simulation was developed in order to optimize:

- The Aerogel thickness
- The Aerogel refractive index
- The gap length
- The pixel size

The outcome of the simulation is parameterized in term of

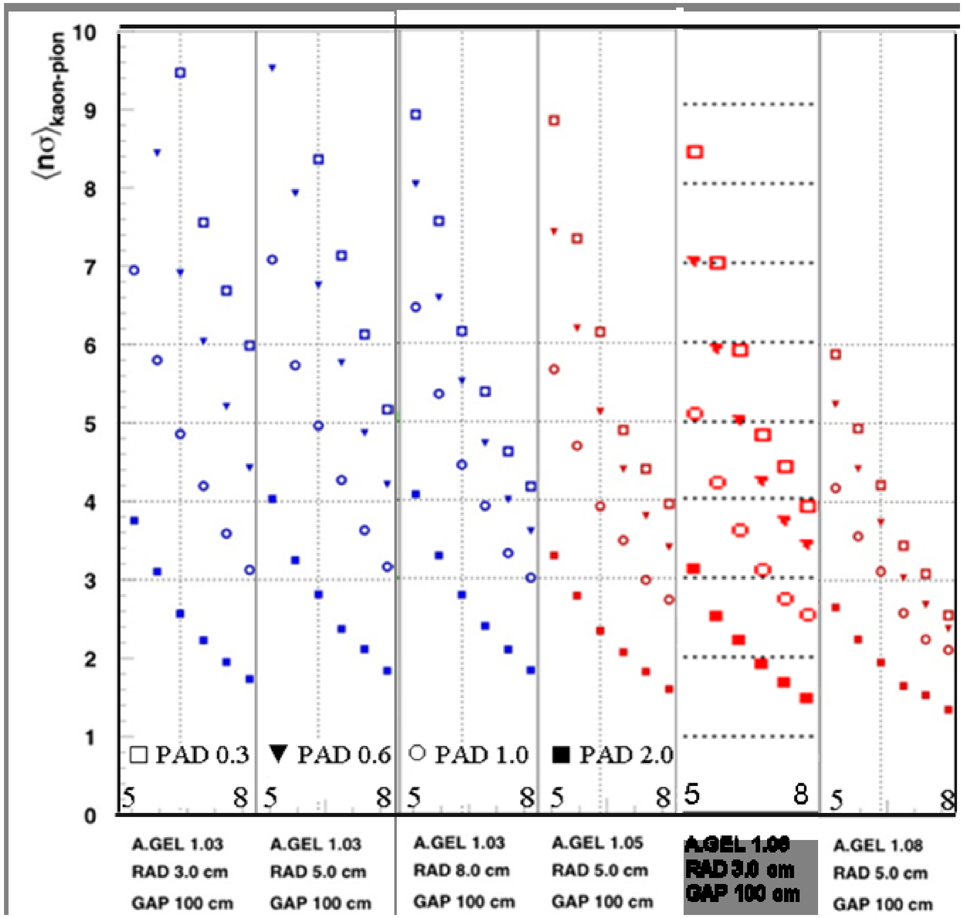
- The separation power (N_σ)
- The number of photoelectrons (Npe)

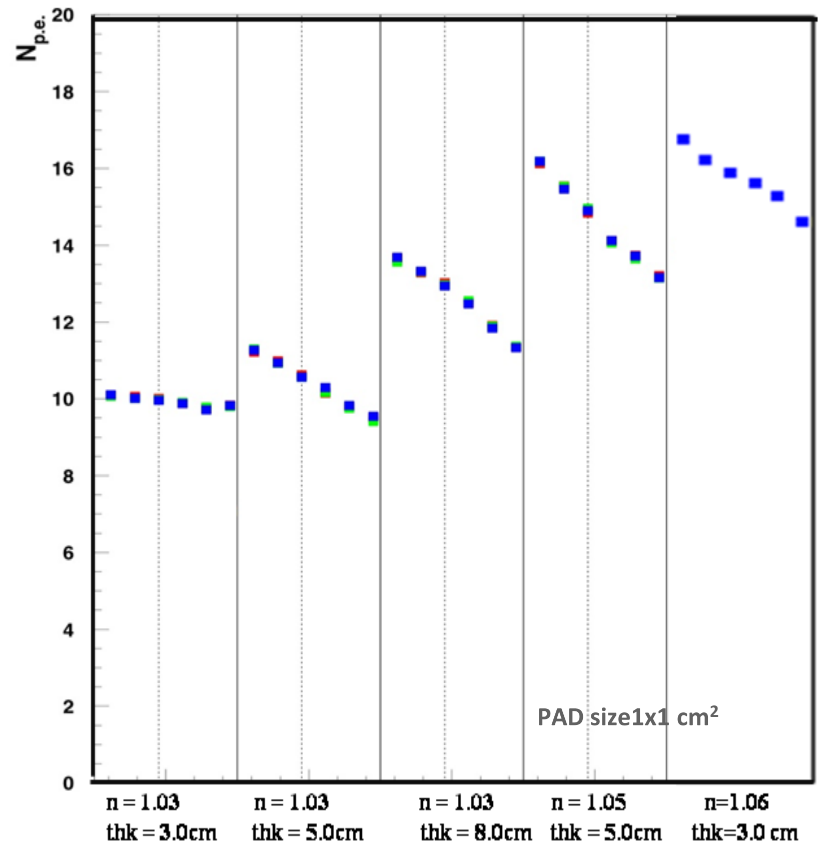
Gap length study



As expected, increasing the Gap length improve the separating power in the 5-8 GeV/c momentum range.

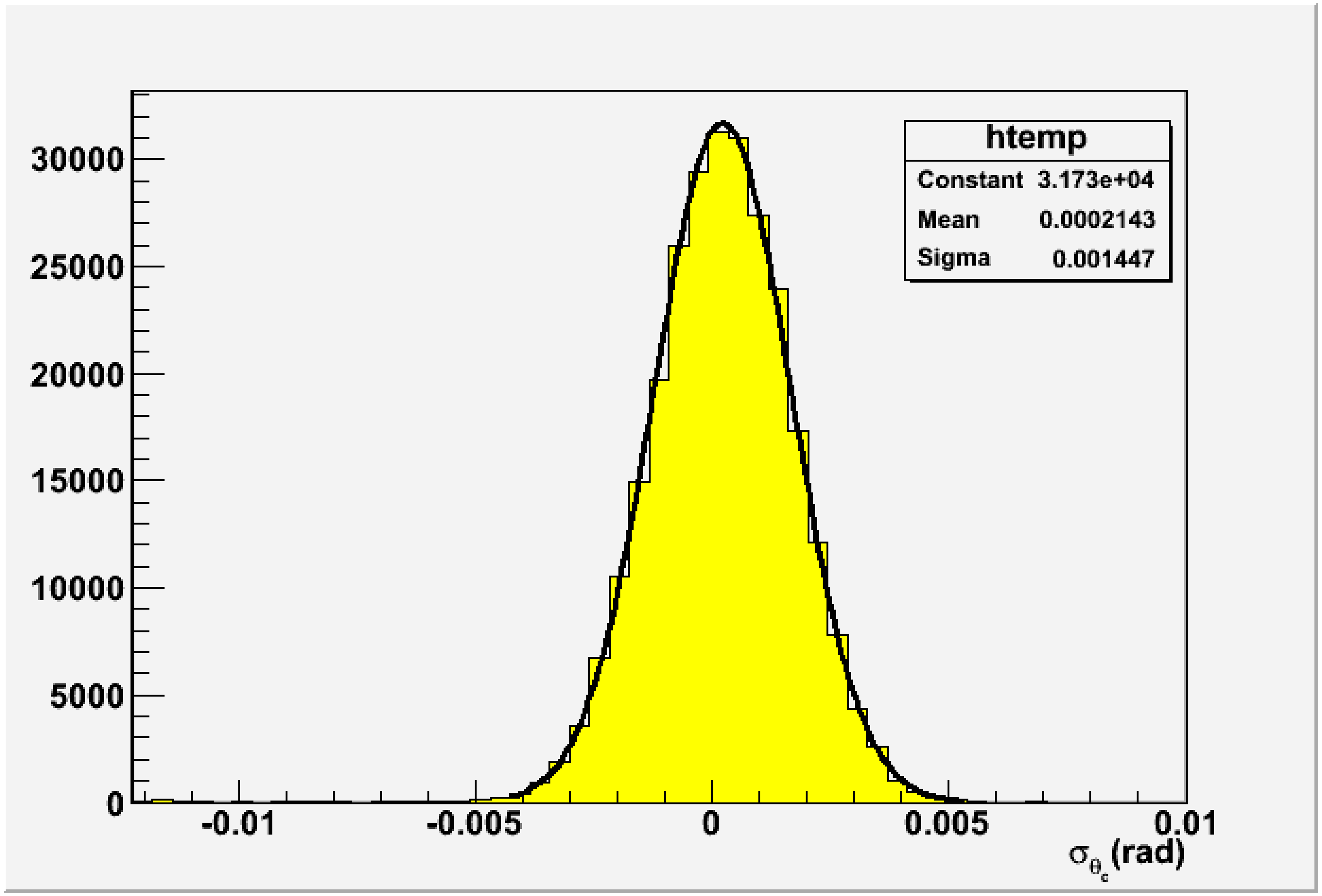
Aerogel thickness & Ref. Index Study





- Decrease of Aerogel thickness improve the small pad size response
- Increasing the refractive index reduce the separation power but on the other hand increase the number of photoelectrons

Angular resolution

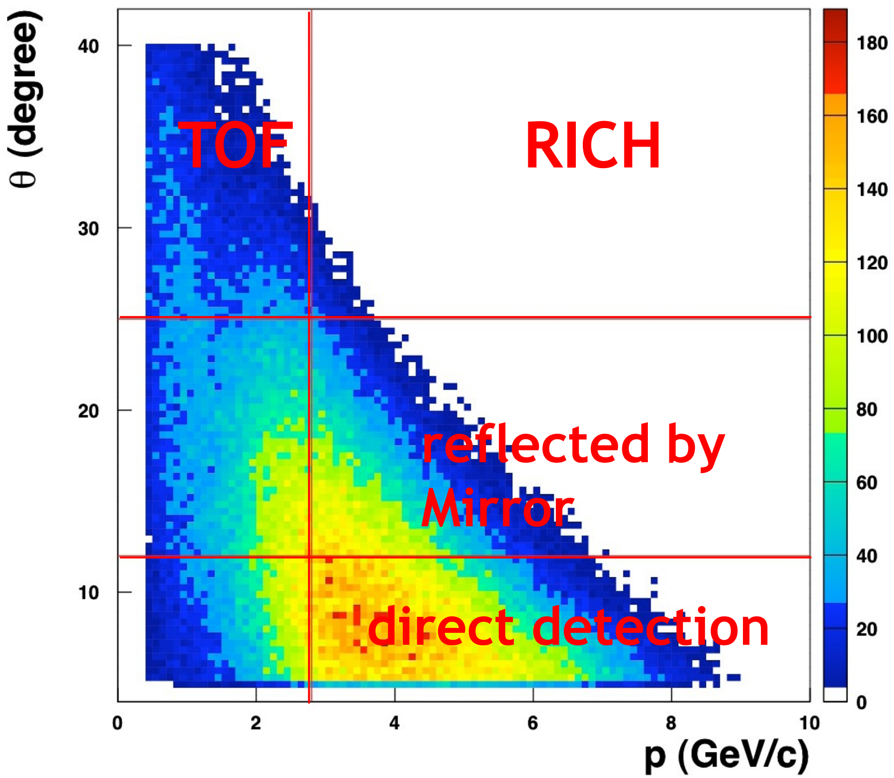


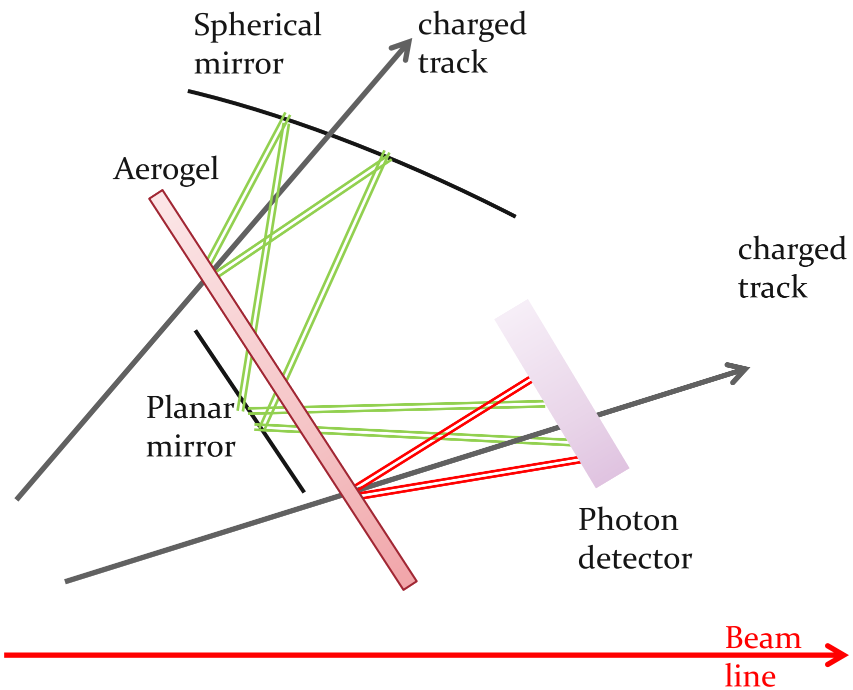
$$\Delta\sigma_{\theta_c} = 1.45 \text{ mrad}$$

New Configuration (under study)

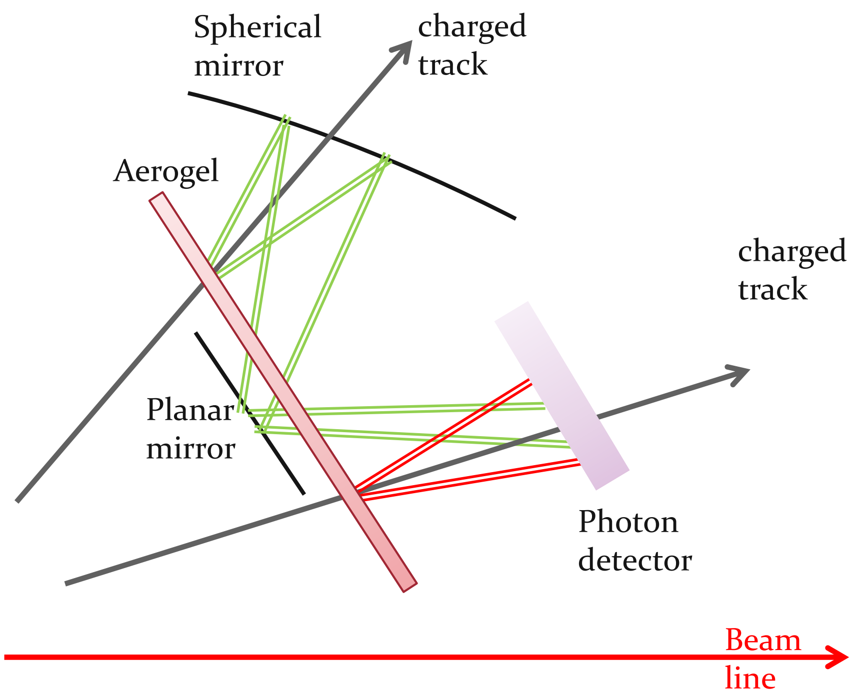
One RICH sector must span over 6 m^2 in order to cover the desired acceptance →(~12000 PMTs) →(very high cost) →use of mirrors to focus photons on small area.

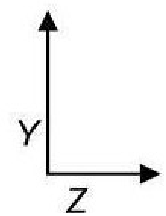
One reflection (HERMES-like) detector is not enough to cover all the acceptance → use dual mirror ("LHCb"-like) detector but with Inward reflection

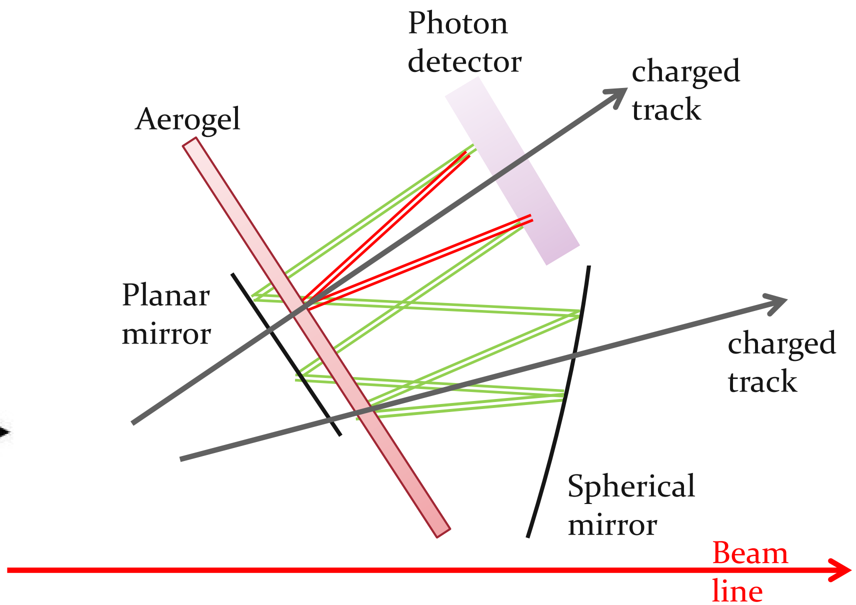




New Configuration (under study)







Inward reflection + Direct detection

- Angular coverage:
  - Direct: 5-12 deg.
  - w/ Reflections: 12-34 deg.
- Reduce the PMT plane area by a factor 3
- PMTs close to beam line Radiation damage

Outward reflection + Direct detection

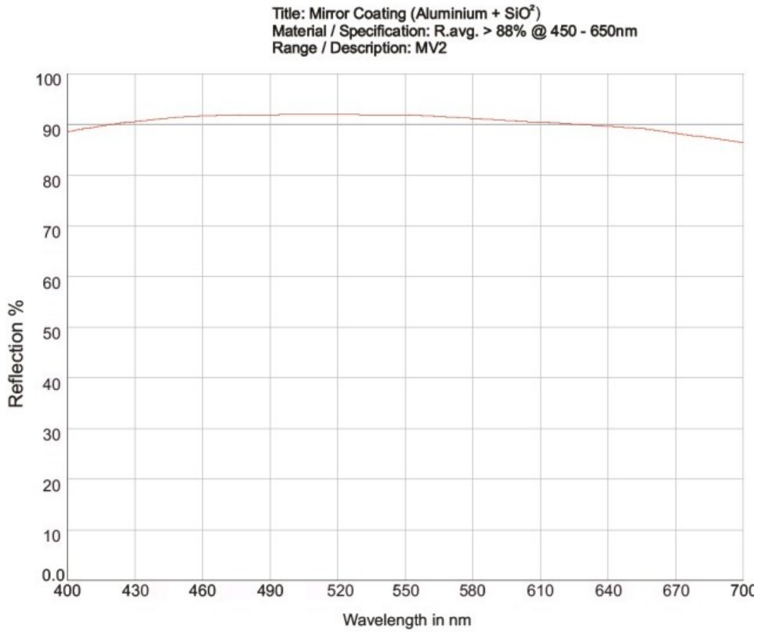
- Angular coverage:
  - Direct: 22-36 deg.
  - w/ Reflections: 5-22 deg.
- Reduce the PMT plane area by a factor 2
- Mirror close to beam line

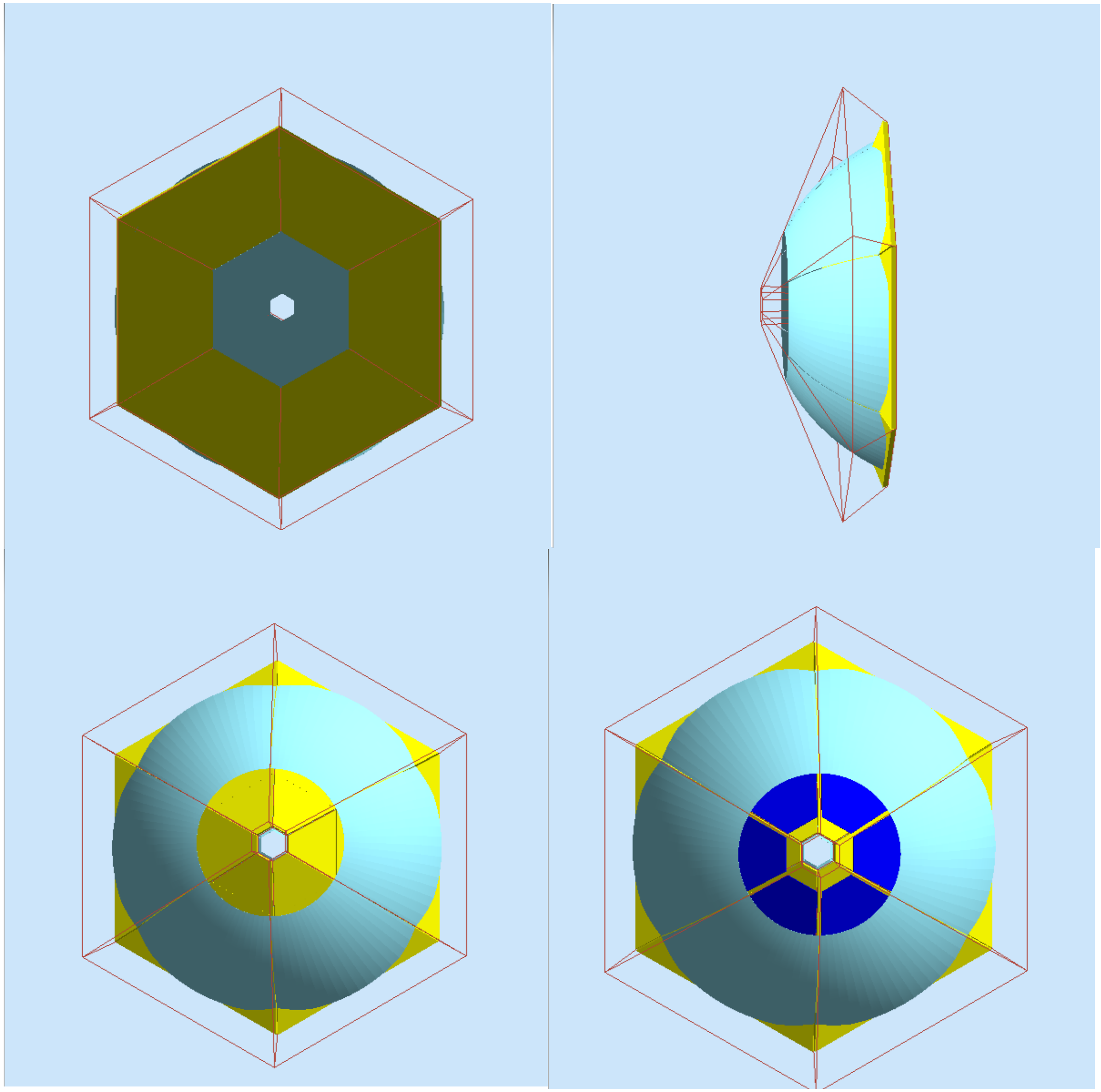
RICH New Configuration

Large Area to reduce the cost of the

Component	Volume (cm3)	Material
Rich Body	130x460x124	Aluminum
Radiator	110x400x3	Aerogel
Gap	120x450x100	Methane
Planar Mirror		SiO2 + Aluminum
Spherical Mirror		SiO2 + Aluminum
Photon Detector	5.2x5.2x2.8	MAPMT H8500-C

- Radiator: Aerogel Ref. index = 1.06
- Gap: Methane
- Mirror: Aluminum+SiO2
- PMT: MAPMT H8500-C





Study of this new configuration is in progress

Reconstruction Algorithm

The objective of this algorithm is to determine the type of the particle that produce a ring in the RICH detector plane.

T: Track table $\quad T \equiv \{(t_i), i = 1..N_{tracks}\}$

H: Hypothesis table $\quad H \equiv \{(h_j), j = e^-, \pi, K, p\}$

For each track t∊ T (having a momentum p) and for each hypothesis h∊ H

- Generate a number of Cerenkov photons around the track.
- Propagate these photons and find where they hit the photon detector plane (DRT)
- Determine $N_{PH}^{h,t}(i)$ the number of photons that hit the i^{th} PMT

The probability to hit the i^{th} PMT

$$P^{h,t}(i) = \frac{N_{PH}^{h,t}(i)}{N_{PH}^{h,t}}, \text{ where } N_{PH}^{h,t} = \sum_i N_{PH}^{h,t}(i)$$ "hit probability distribution".

A realistic probability should take into account detector efficiency, detector acceptance,…

$$N_{PE}^{h,t}(i) = n^{h,t} P^{h,t}(i)$$

Reconstruction Algorithm

Where $n^{h,t}$ is the total number of photoelectrons expected for the (h,t) ring and $N_{PE}^{h,t}(i)$ is the mean number of photoelectrons in the i[th] PMT

$$n^{h,t} = n_0^{h,t} \frac{1 - \frac{1}{\beta^2 n^2}}{1 - \frac{1}{n^2}}, \qquad n_0^{h,t} \approx 8$$

Assuming a Poisson distribution of the photoelectrons $N_{PE}^{h,t}(i)$ the probability that the i[th] PMT will respond can be evaluated as:

$$P_{PMT}^{h,t}(i) = 1 - \exp(-N_{PE}^{h,t}(i) - B(i))$$

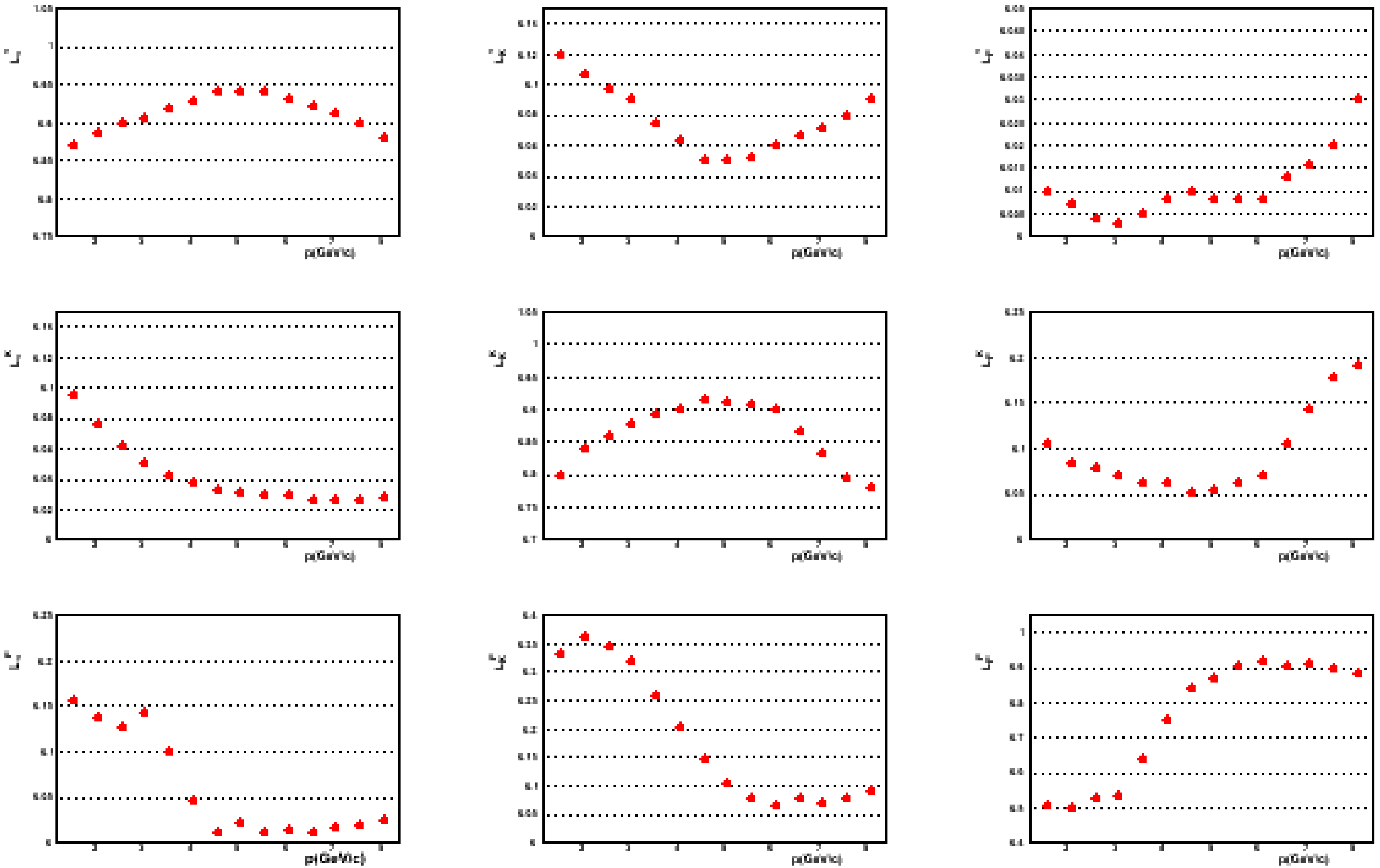
and finally the probability that the hypothesis h is true can be estimated as

$$\boxed{L^{h,t} = \sum_i \log\left(P_{PMT}^{h,t}(i) C_{PMT}(i) + \overline{P}_{PMT}^{h,t}(i)(1 - C_{PMT}(i))\right)}$$

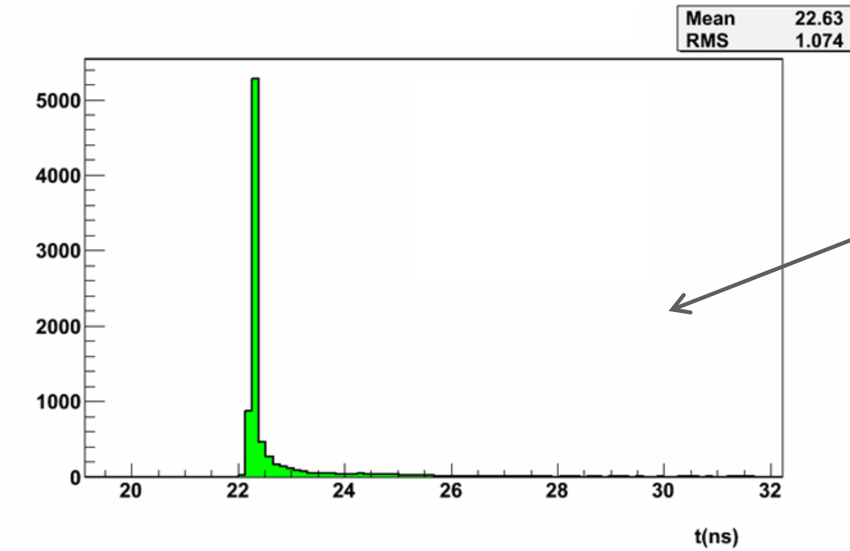
$C_{PMT}(i)$ is 1(0) if the i[th] PMT did(did not) respond in the observed hit pattern (MC)

The hypothesis which maximizes the likelihood $L^{h,t}$ will be considered as particle identification.

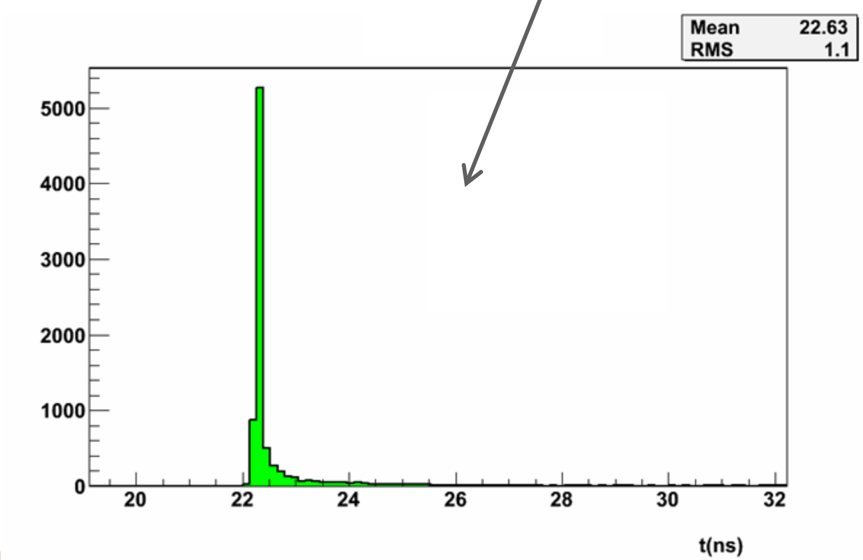
Normalized Likelihood for direct detection

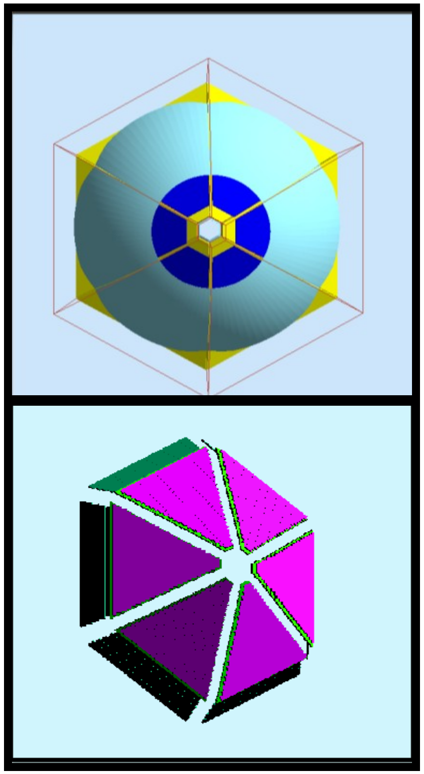


Impact of RICH Material on TOF



TOF distribution for 2.5 GeV pions
Without and with RICH





No significant difference between both plot

The effect of RICH material on TOF distribution is negligible

Collaborators

26 collaborators are participating to is project

INSTITUTIONS	Researchers
ARGONNE IL	3
INFN Bari, Ferrara, Genova, Frascati, Roma/ISS	13
GLASGOW U.	2
JLAB	2
U. CONN	3
UTFSM (Chile)	3

Conclusion

- Simulation has showed that a 3 cm thick Aerogel with a refractive index of n=1.06, a 100 cm length gap and a pixel size less than 1x1 cm^2 offers an acceptable separating power and a large number of photoelectrons

- The Reconstruction Algorithm seems to work very well. Its generalization to the dual mirror case is in progress

- Test of various types of MAPMT is underway (Glasgow, INFN-Frascati)

  - Uniformity of the pixel-to-pixel gain
  - Uniformity of the gain within the pixel
  - Study of the single photon response
  - Gain with non perpendicular light
  - Magnetic field effect

  see talk by B. Seitz, june 11

Thank you !

CLAS12 Physics Program

Study of Boer-Mulders effect with kaons

Studies of Kotzinian-Mulders effect with kaons

Studies of partonic distributions using semi inclusive production of kaons

One reflection case