RICH GEMC GEOMETRY

Contalbrigo Marco & Luciano Pappalardo
INFN Ferrara

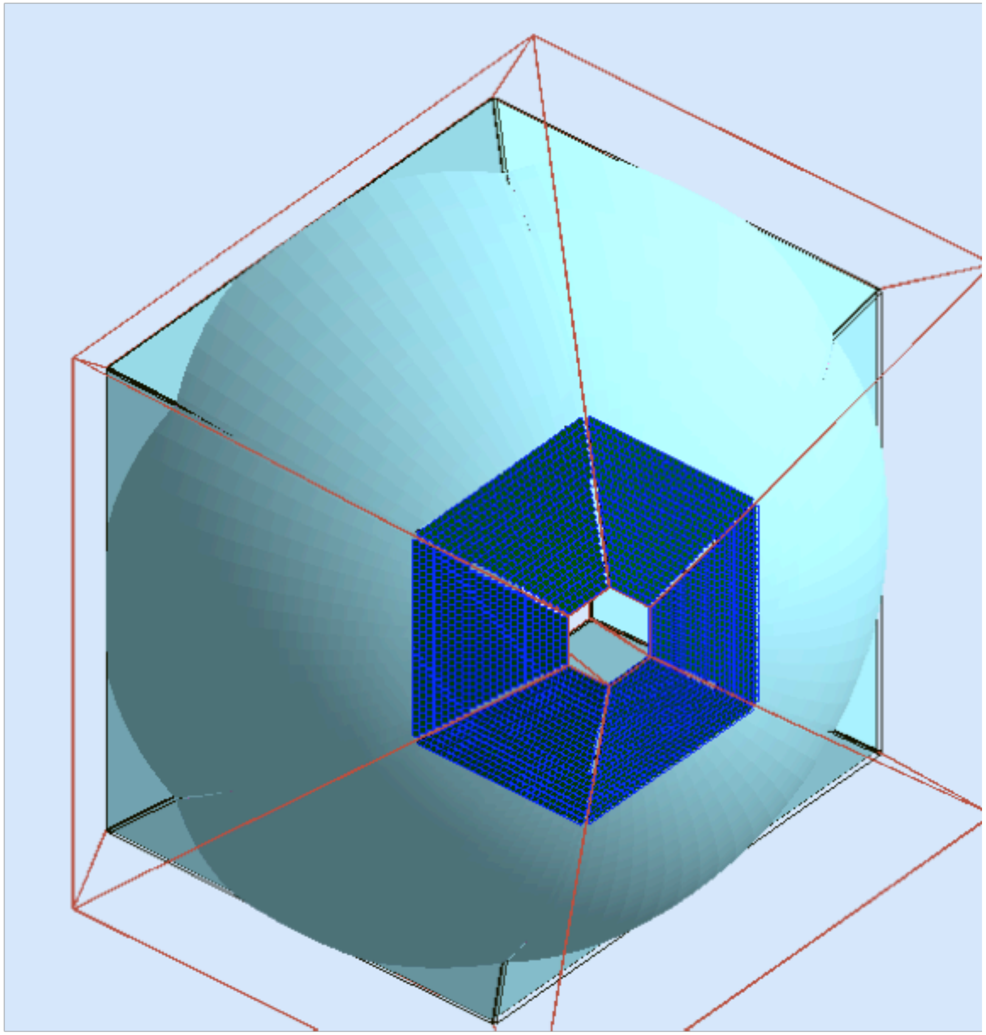
Rich Meeting, 13 January 2012

Standard set-up

Geometry:

rich_build_radtrap_mirror35_default.pl

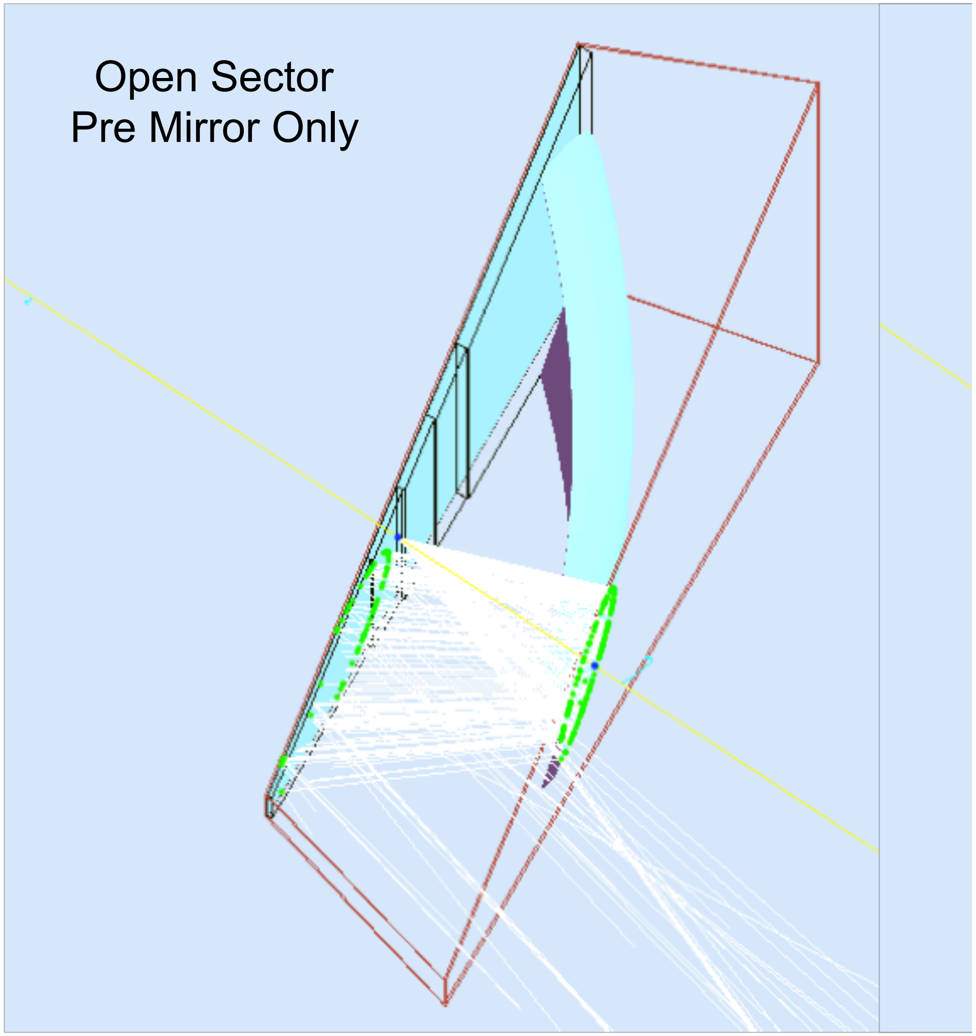
On the Jlab GEMC database

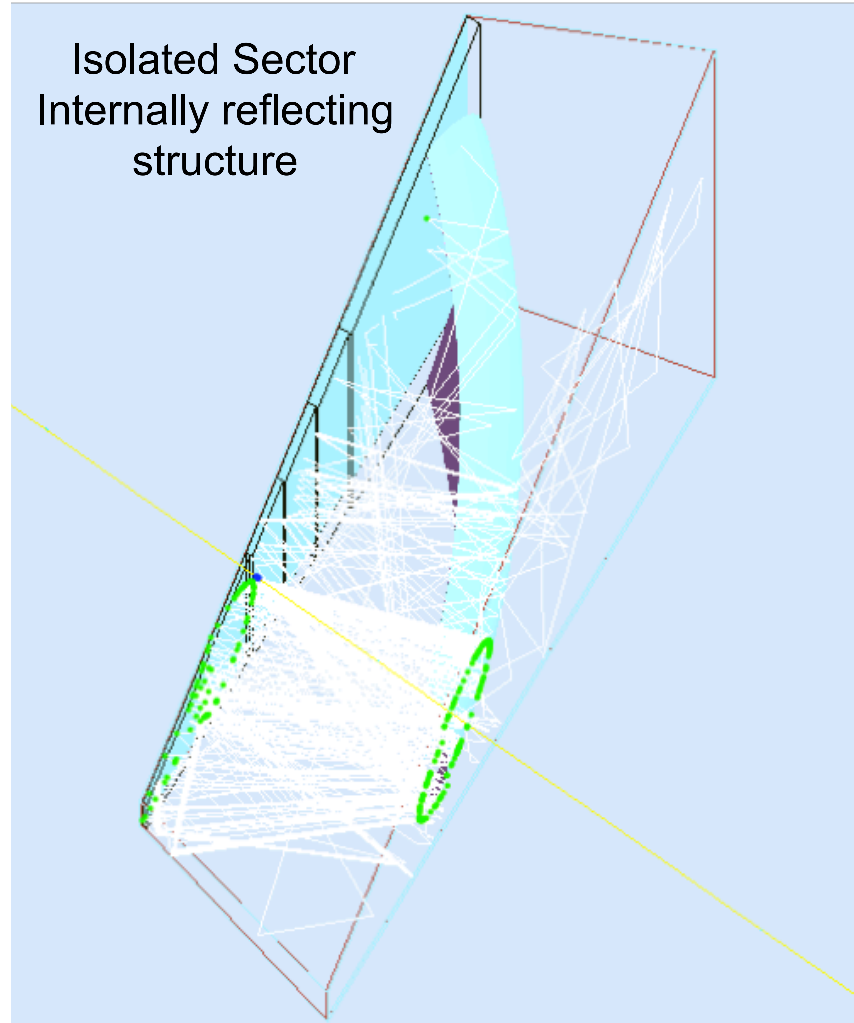


Validation:

- ✔ handle of MA-PMT copies
- ✔ volume overlaps
- ✔ refine materials
  (to match aerogel transmission)
- ☐ user friendly layout

The Open or Isolated Sector





Standard set-up

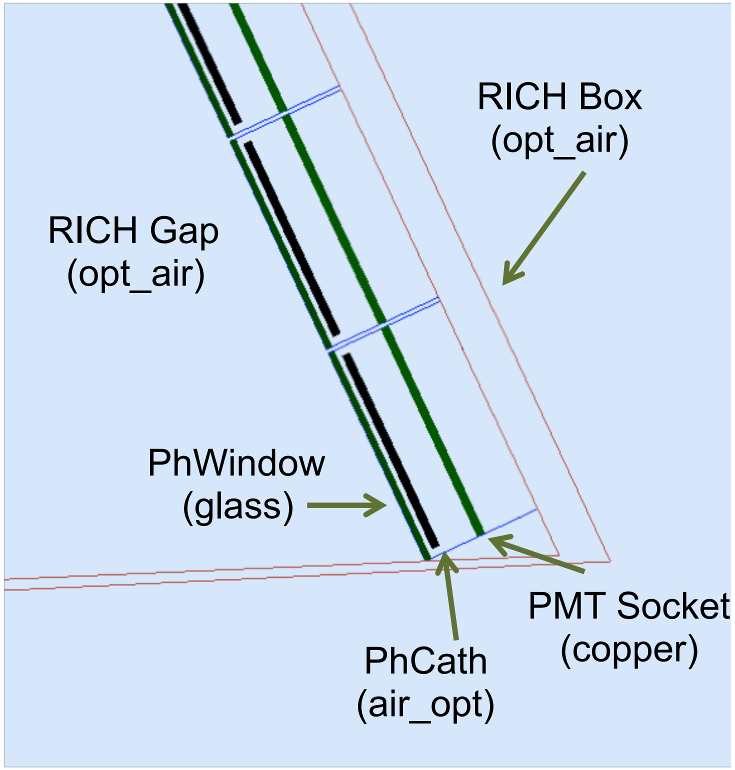
Material:

Mmaterials.cc
MDetectorConstruction.cc

On the Jlab GEMC database

Validation:

- ✔ match aerogel transmission
- ✔ MA-PMT window
- ✔ aerogel transmission (BELLE/Novosibirsk values)
- ☐ Mirror imperfections/diffusion ?
- ☐ Lucite wrap ?



Standard set-up

Digitalization:

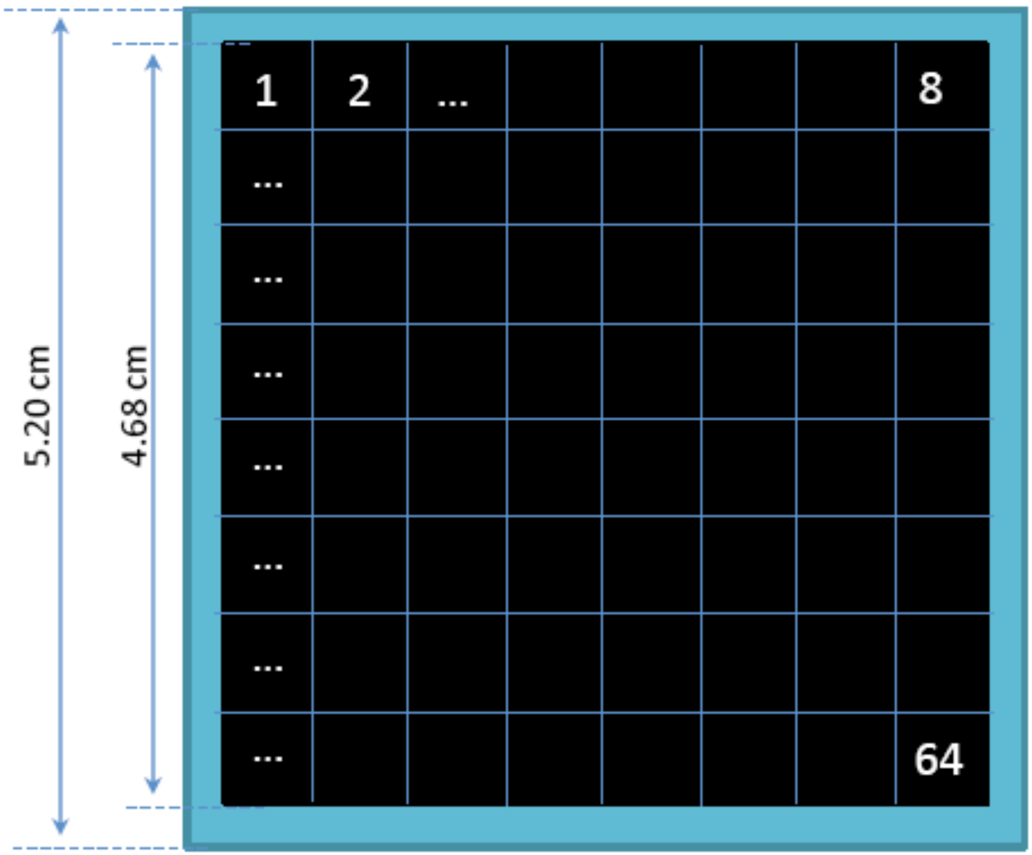
RICH_hitprocess.cc
RICH.bank
user_hits_def.txt

On the Jlab GEMC database

Validation:

- ✔ match geometry
- ✔ QE energy range
- ✔ add to output
- ☐ QE curve ?

Number of anode pixels: 64 (8x8 matrix)
Pixel size / Pitch at center: 5.8 x 5.8 / 6.08 mm
Effective area: 49 x 49 mm
Dimensional Outline: 52 x 52 x 28 mm
Packing density (Effective Area / Esternal Size) : 89 %



Standard set-up

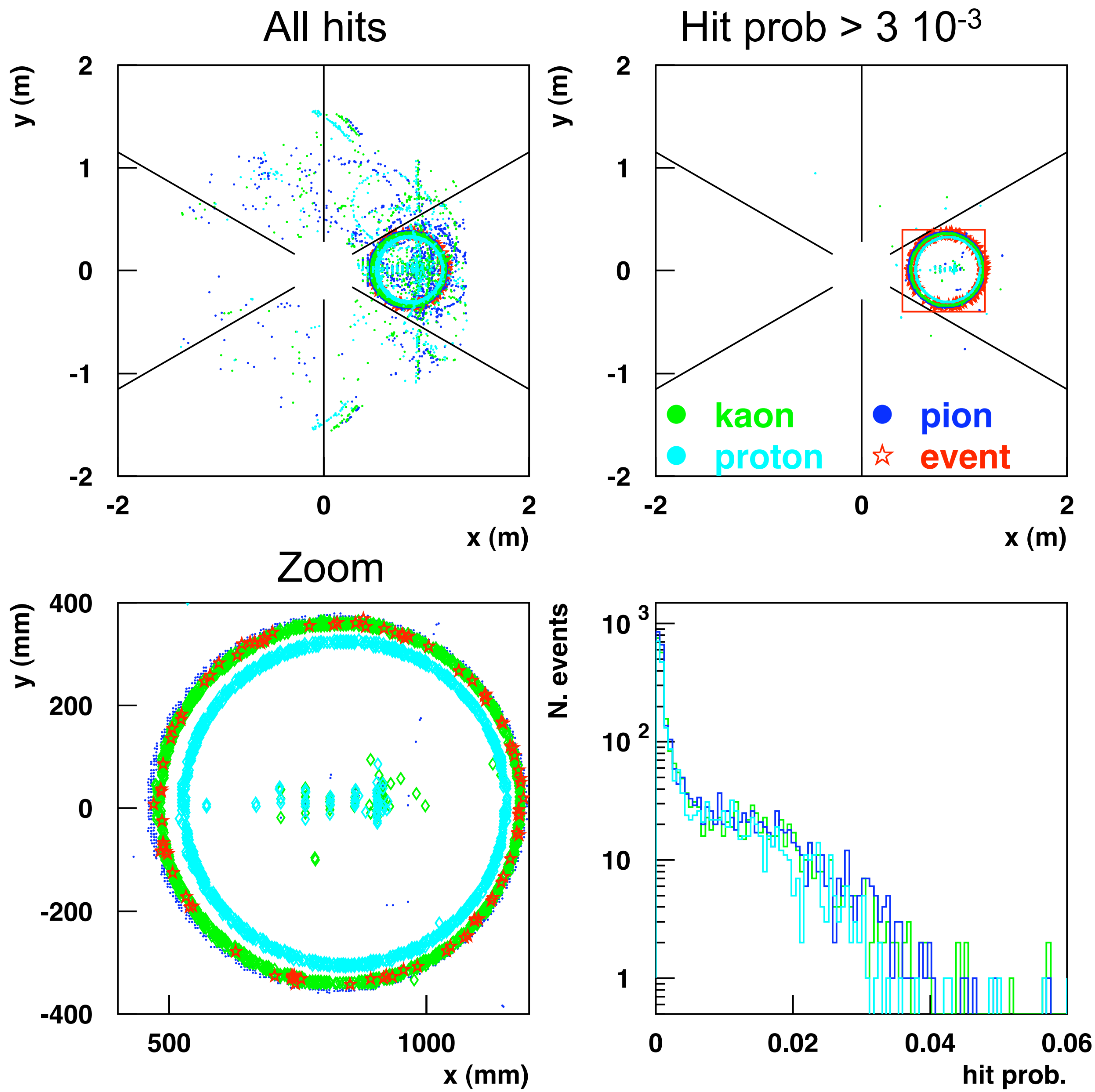
Reconstruction:

Private codes

Likelihood based on direct ray tracing

Validation:

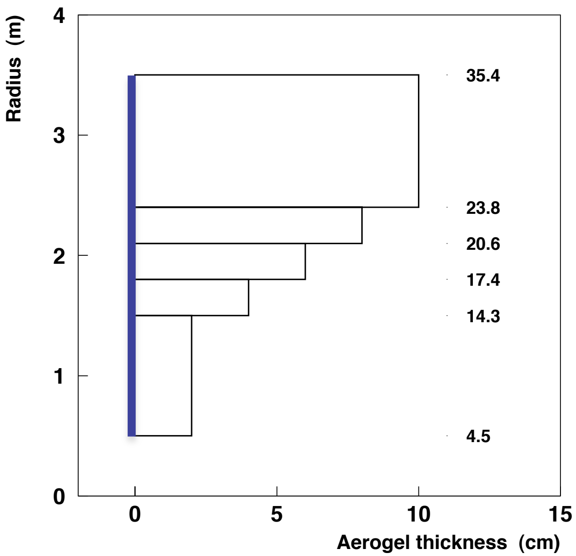
- ✔ benchmark events
- ☐ x-check
- ☐ Cherenkov light from MA-PMT window
- ☐ Resolution on charged track impact parameters
- ☐ Background (Rayleigh)



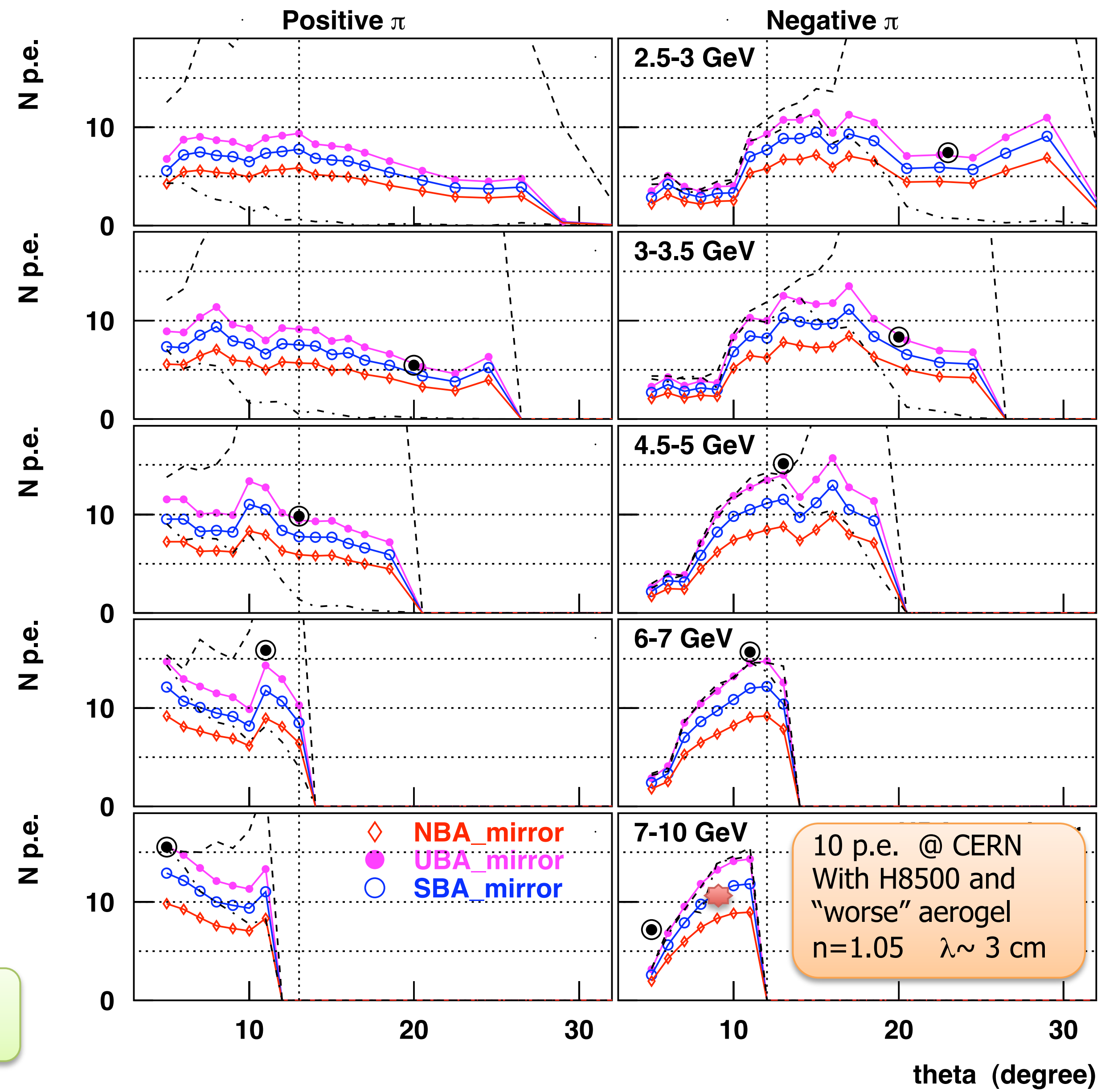
Average N p.e.: NBA ?

Aerogel:
- n=1.06, λ=5.5 cm
- thick. increasing with radius: 2-4-6-8-10 cm

Mirror: 14º - 25º
MA-PMTs: various eff=0.65



Challenging with normal bi-alkali



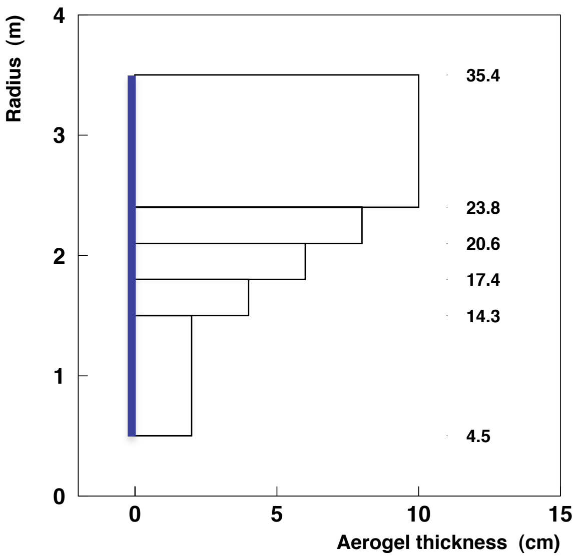
10 p.e. @ CERN
With H8500 and "worse" aerogel
n=1.05 λ~ 3 cm

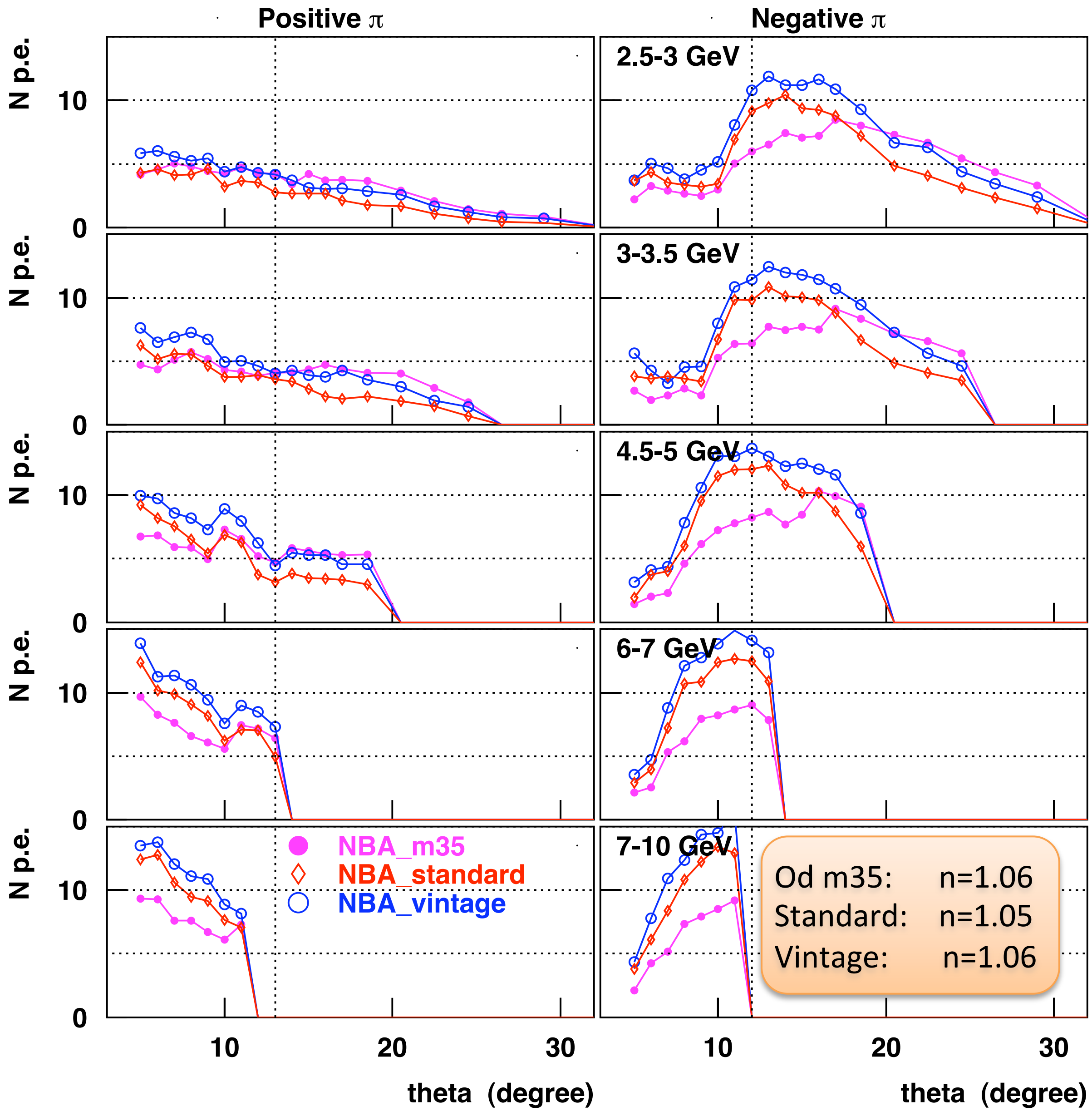
Average N p.e.: NBA ?

Aerogel:
- n=1.05, λ=5.5 cm
- thick. increasing with radius: 2-4-6-8-10 cm

Mirror: 14° - 35°
- 90% reflectivity

MA-PMTs: H8500 eff=0.65





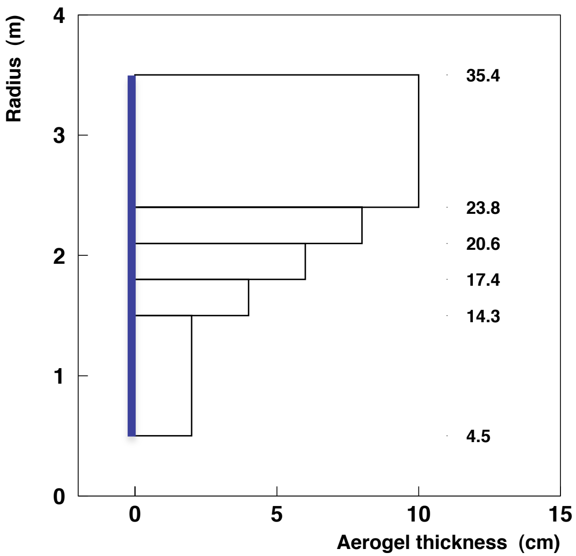
Increase of direct photons due to MA-PMT window ?
Differences to be investigated

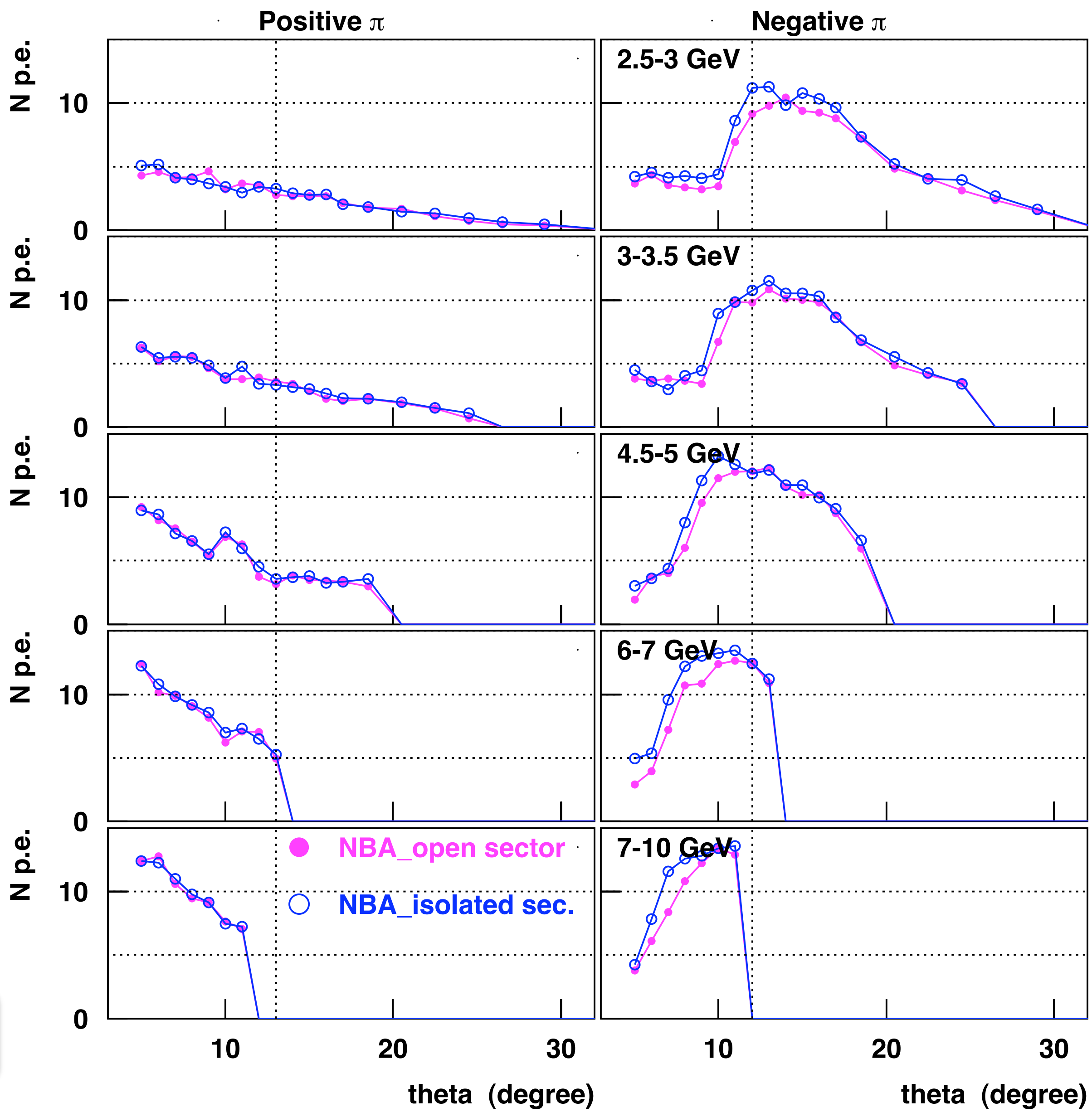
Average N p.e.: NBA ?

Aerogel:
- n=1.05, λ=5.5 cm
- thick. increasing with radius: 2-4-6-8-10 cm

Mirror: 14º - 35º
- 90% reflectivity

MA-PMTs: H8500 eff=0.65





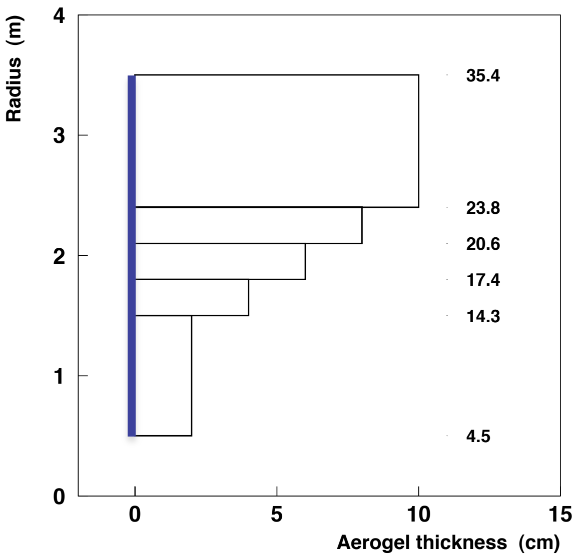
Minor difference on the number,
Major on the hit pattern

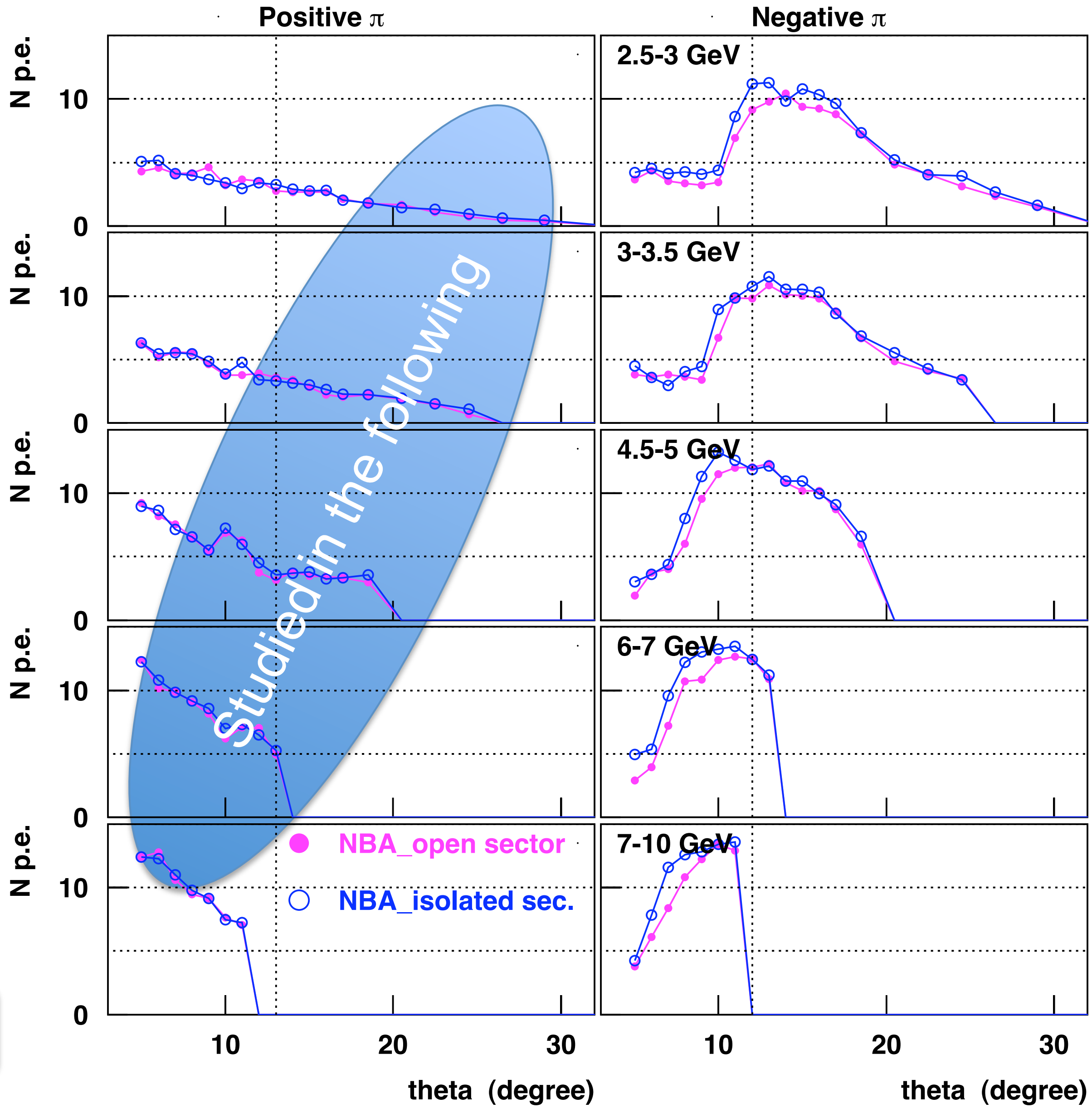
Average N p.e.: NBA ?

Aerogel:
- n=1.05, λ=5.5 cm
- thick. increasing with radius: 2-4-6-8-10 cm

Mirror: 14º - 35º
- 90% reflectivity

MA-PMTs: H8500 eff=0.65





Minor difference on the number,
Major on the hit pattern

The likelihood

For a given track t and particle hypothesis h $(=\pi, K, p)$ use **direct ray tracing** for a large number of generated photons to determine the **hit probability for each PMT**

The **measured hit pattern** is compared to the hit **probability densities** for the different hypotheses through a likelihood function:

$$L^{(h,t)} = \Sigma_i log[P_{PMT}^{(h,t)}(i) C_{PMT}(i) + \overline{P}_{PMT}^{(h,t)}(i)(1 - C_{PMT}(i))]$$

(the hypothesis that maximizes $\mathbf{L}^{(\mathbf{h},\mathbf{t})}$ is assumed to be true)

$C_{PMT}(i)$ is the hit pattern from data
- = 1 if the ith PMT is hit
- = 0 if the ith PMT is not hit

$P_{PMT}^{(h,t)}(i)$ is the probability of a hit given the kinematics of track t and hypothesis h

$$P_{PMT}^{(h,t)}(i) = 1 - exp(-\frac{N^{(h,t)}(i)}{\Sigma_i N^{(h,t)}(i)} n^{(h,t)} - B(i))$$

$\overline{P}_{PMT}^{(h,t)}(i) = 1 - P_{(PMT)}^{(h,t)}$ is the probability of no hit

$n^{(h,t)}$ is the total number of expected PMT hits

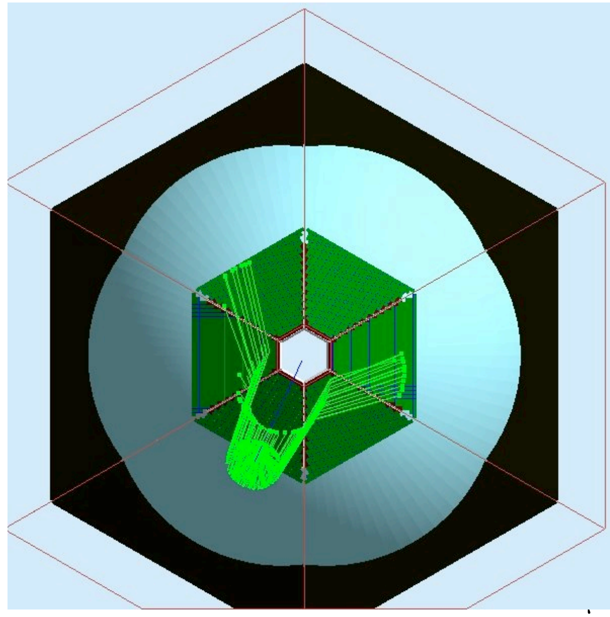
$B(i)$ is a background term (assumed to be 10^{-4}, fine with prelim. studies)

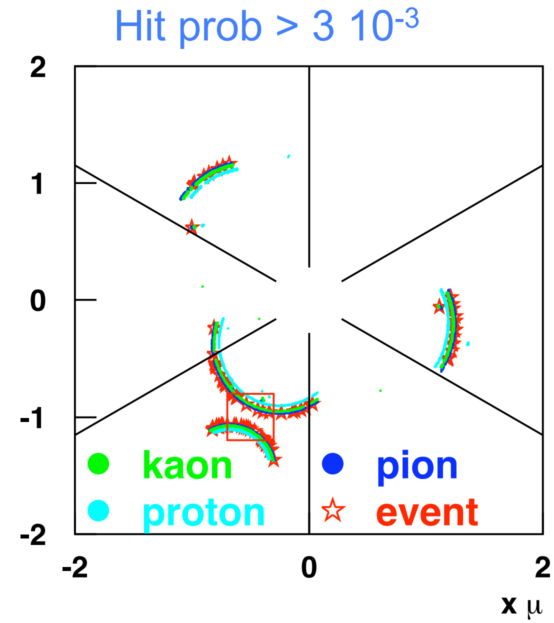
The pattern recongnition

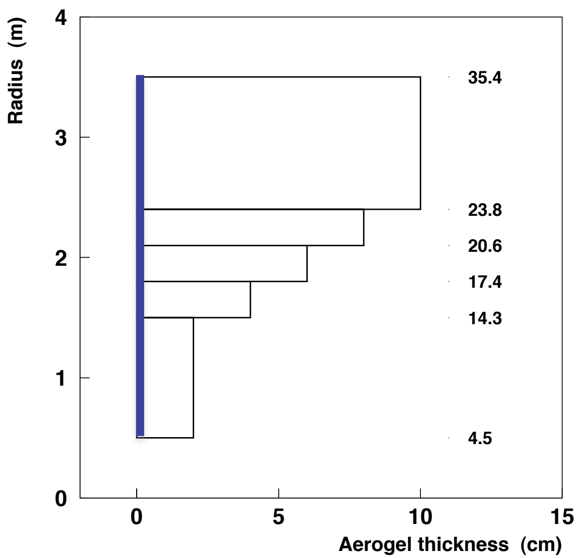
200 trials per point

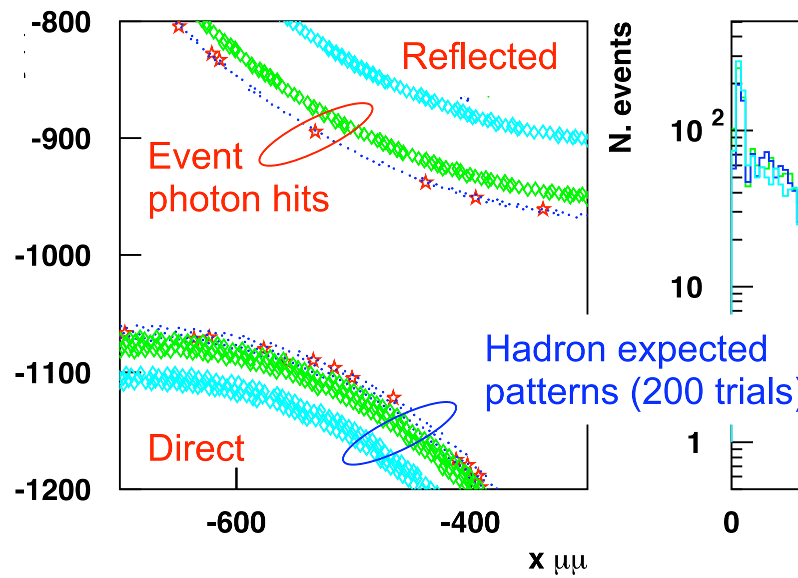
Aerogel:
- n=1.06
- thick. increasing with radius: 2-4-6-8-10 cm

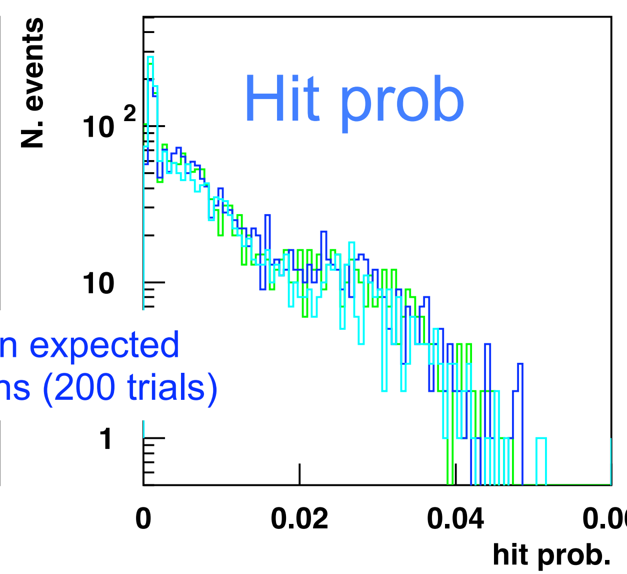
Mirror: 14º - 25º
MA-PMTs: UBA











The goodness parameter

For a given track t and particle hypothesis h $(=\pi, K, p)$ use **direct ray tracing** for a large number of generated photons to determine the **hit probability for each PMT**

The **measured hit pattern** is compared to the hit **probability densities** for the different hypotheses through a likelihood function:

$$L^{(h,t)} = \Sigma_i log[P^{(h,t)}_{PMT}(i) C_{PMT}(i) + \overline{P}^{(h,t)}_{PMT}(i)(1 - C_{PMT}(i))]$$

Sum on all PMTs: it depends on the total number of readout channels and the background level

$$LH = L^{(h,t)} - L^{(h,t)}_{MIN}$$

L minimum: no signal, hits where only background is expected

$$R_{QP} = 1 - \frac{LH^{2st}}{LH^{1st}}$$

Quality parameter:

0 ambiguity $\longrightarrow$ 1 good ID

LH results for positive hadrons

Aerogel:
- n=1.05, λ=5.5 cm
- thick. increasing with radius: 2-4-6-8-10 cm

Mirror: 14^o - 35^o
- 90% reflectivity

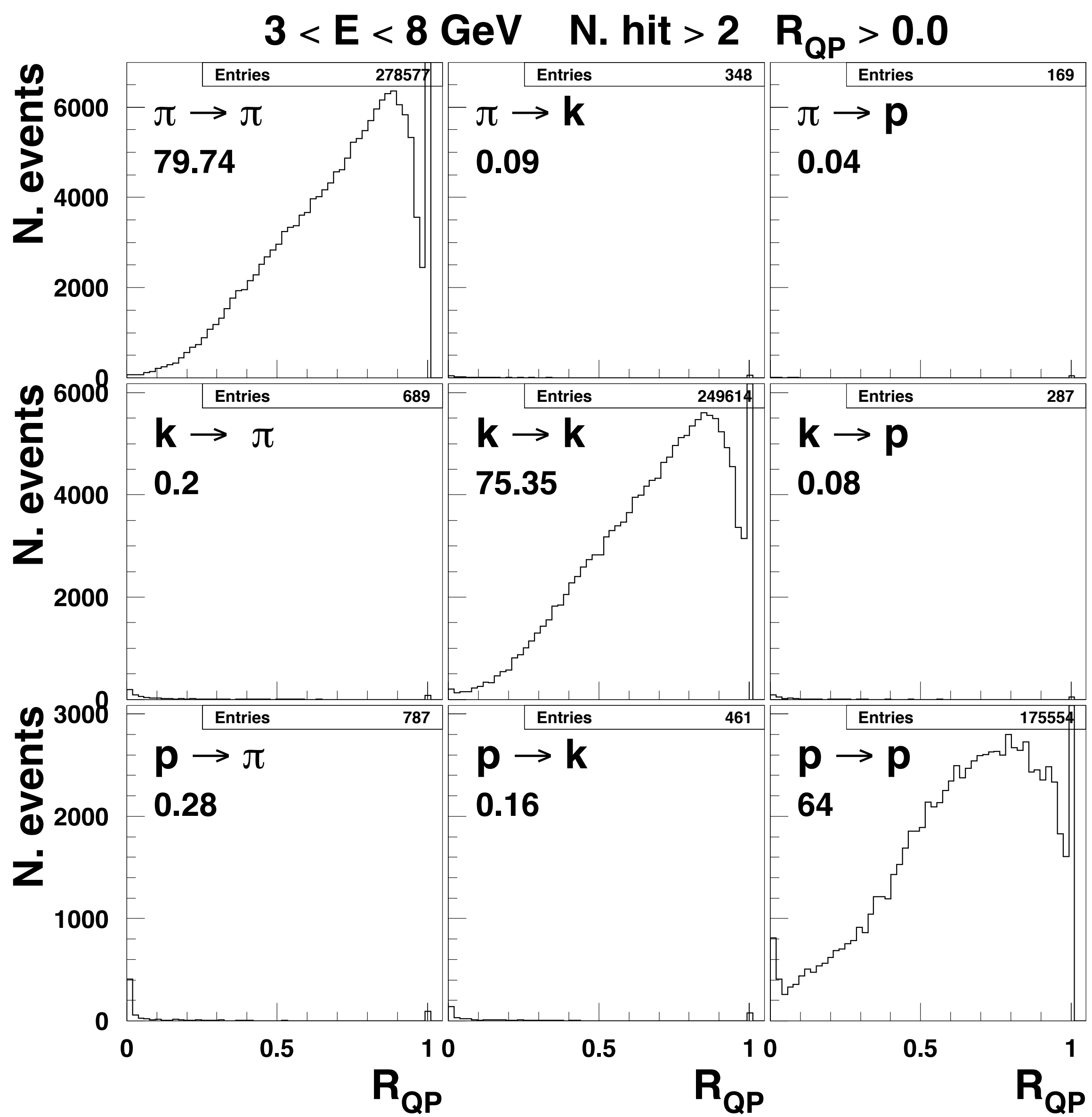
MA-PMTs: H8500 eff=0.65

Contamination ~ few per mill

Efficiency ~ 80 %

previous tables based on ***only*** events with nhit > 2

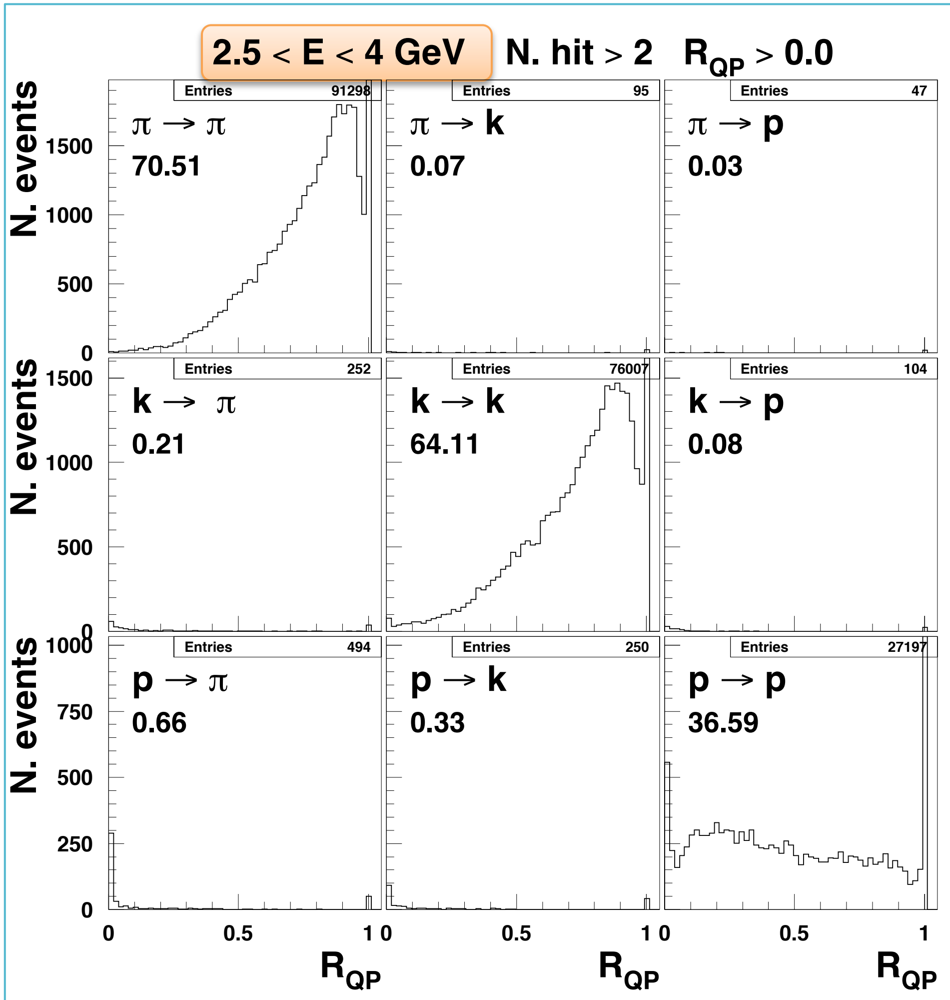
Identification quality: in average good

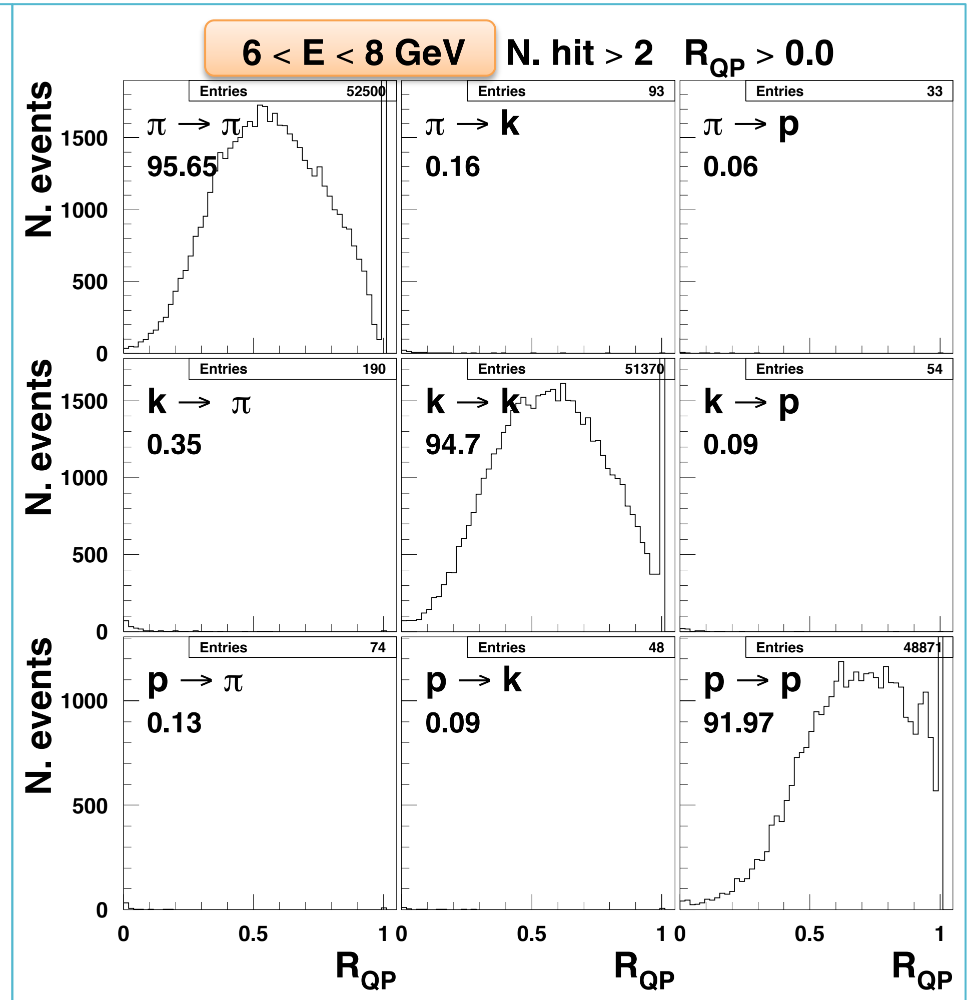


LH performances

Low momentum: smaller efficiency due to angular spread and small $N_{q.e.}$

High momentum: high uniform efficiency, ID more challenging (broader R_{QP})

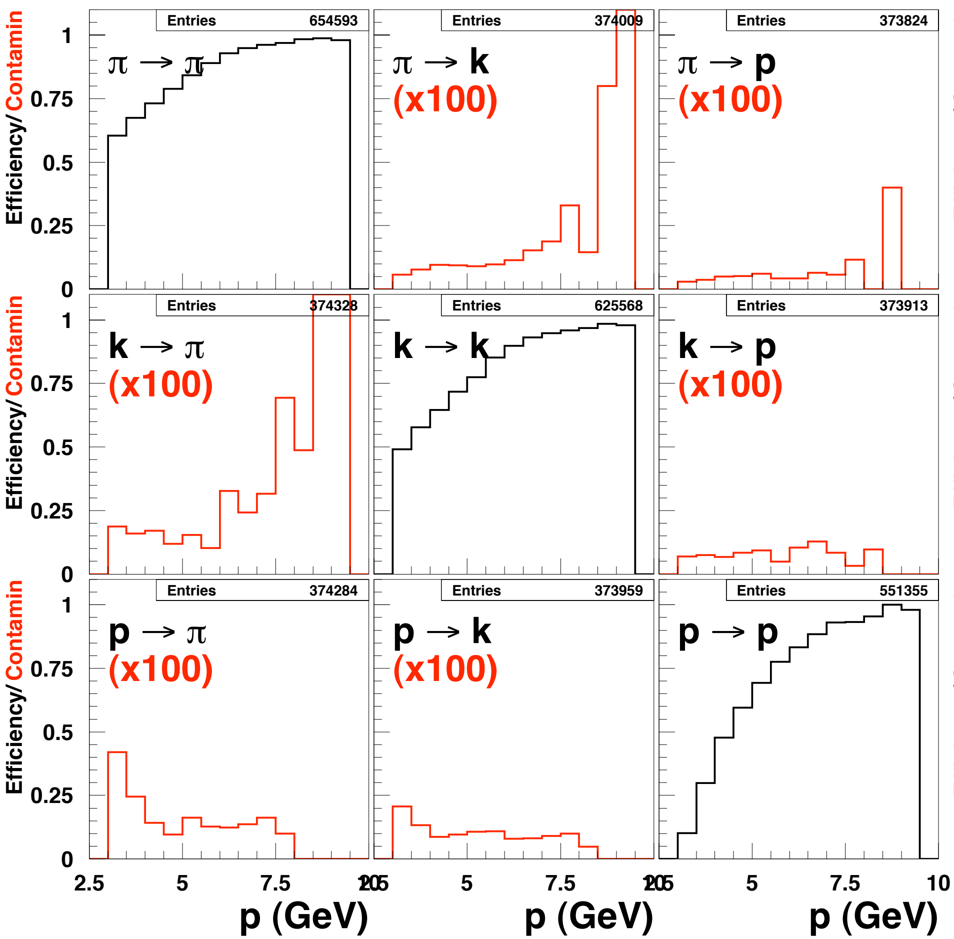




Hadron ID vs momentum/polar angle

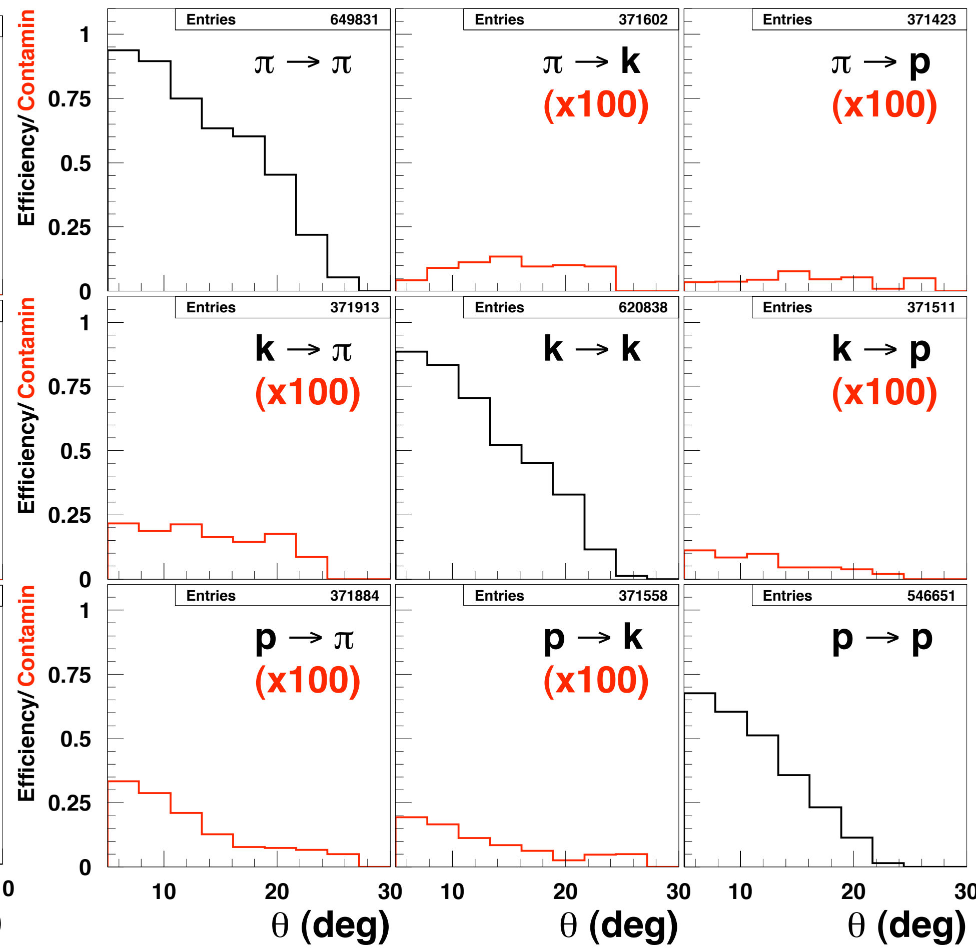
Performances vs momentum

E > 0.0 N. hit > 2 rQP > 0.0



Performances vs polar angle

3 < E <> 8 GeV N. hit > 2 rQP > 0.0



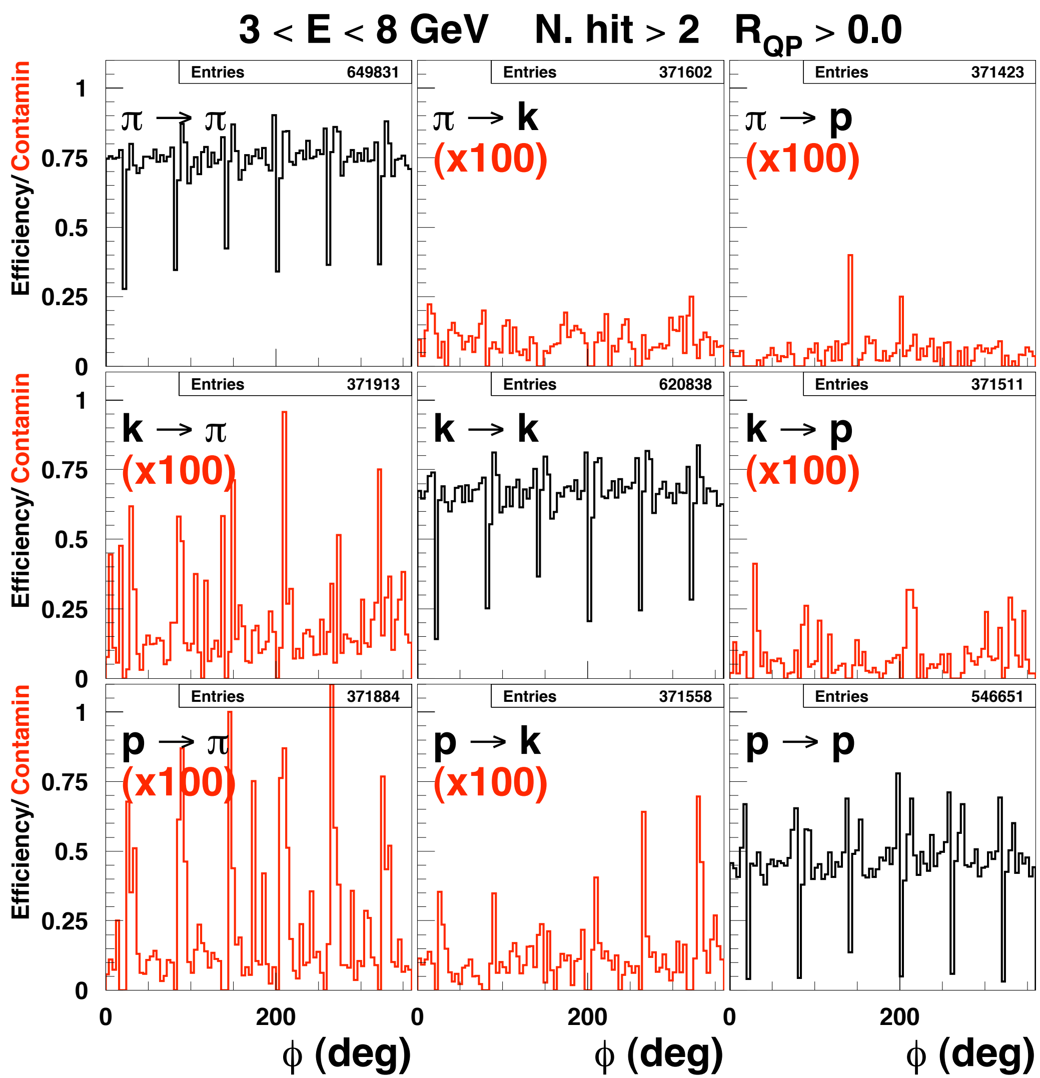
Contamination diverges above 8 GeV
At small momenta correlation with polar angle

At large polar angle too few photon hits

Hadron ID vs azimuthal angle

Almost uniform within a sector

Drop in performances at the sector edge due to the RICH structure



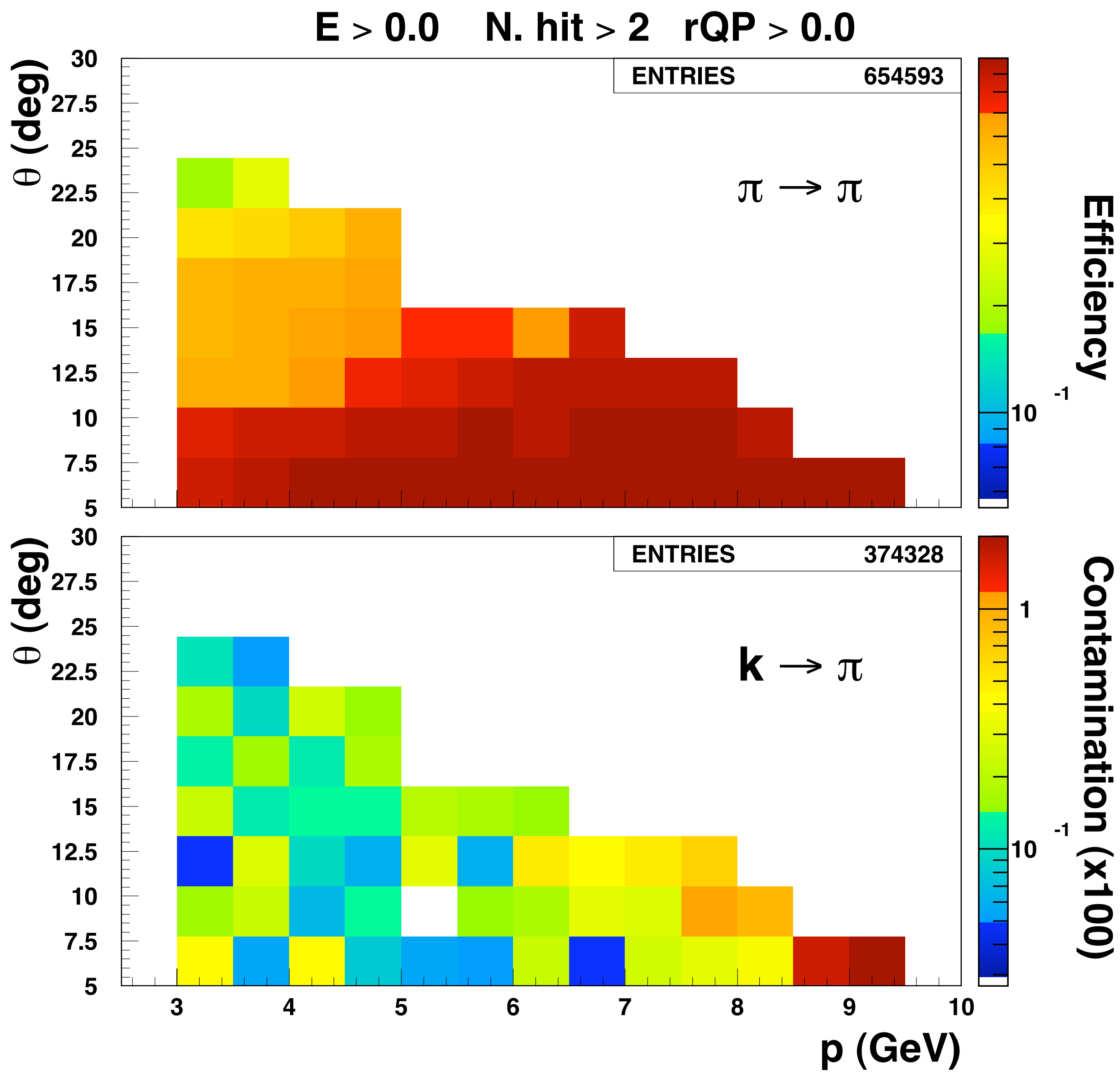
Hadron ID vs momentum/polar angle

Aerogel:
- n=1.05, λ=5.5 cm
- thick. increasing with radius: 2-4-6-8-10 cm

Mirror: 14° - 35°
- 90% reflectivity

MA-PMTs: H8500 eff=0.65

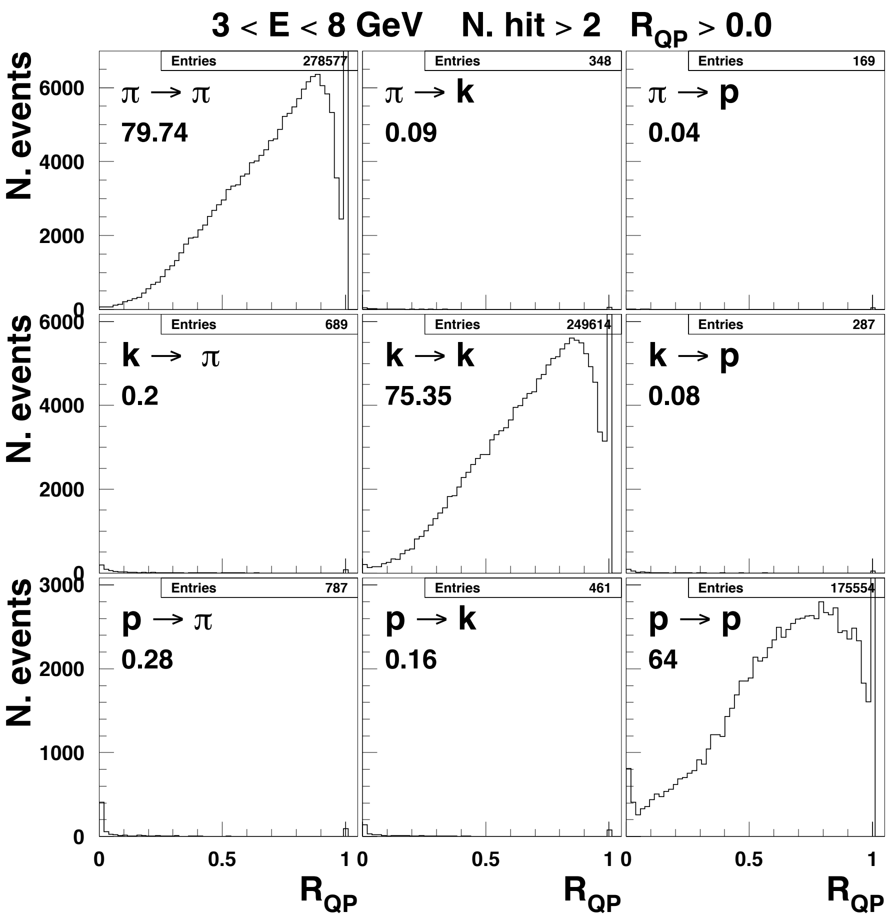
Large angles challenging for Positive charged hadrons



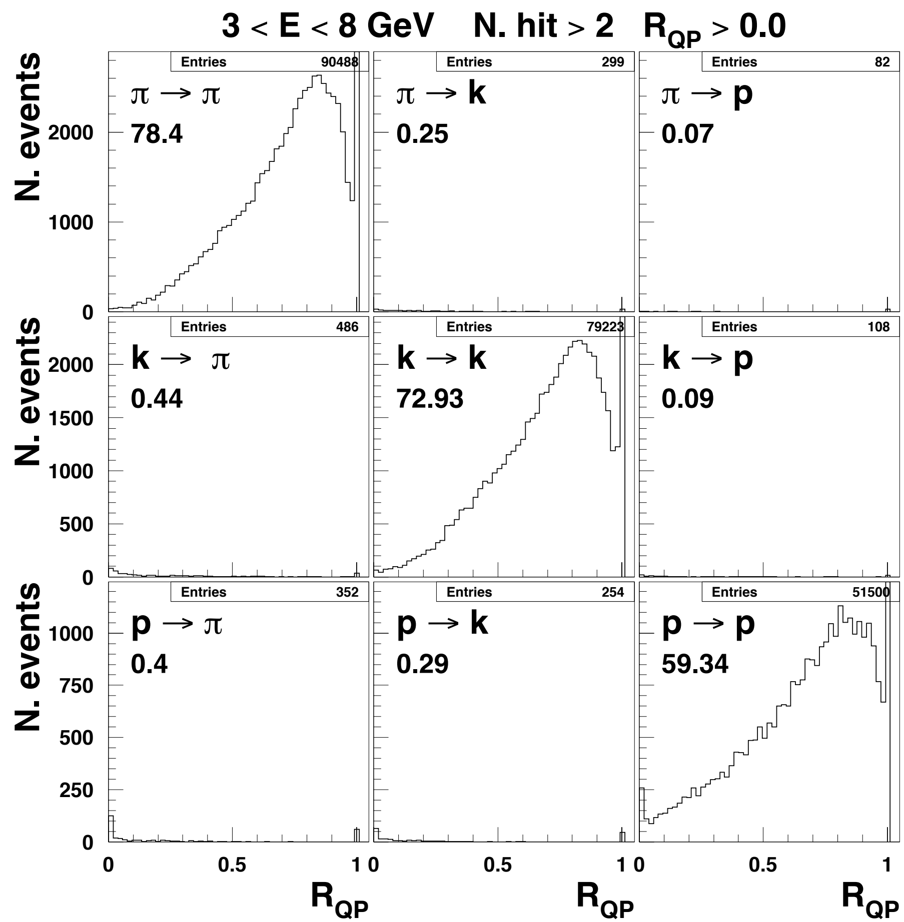
Open vs isolated sectors

Isolated sectors show slightly worse performances

Open sector

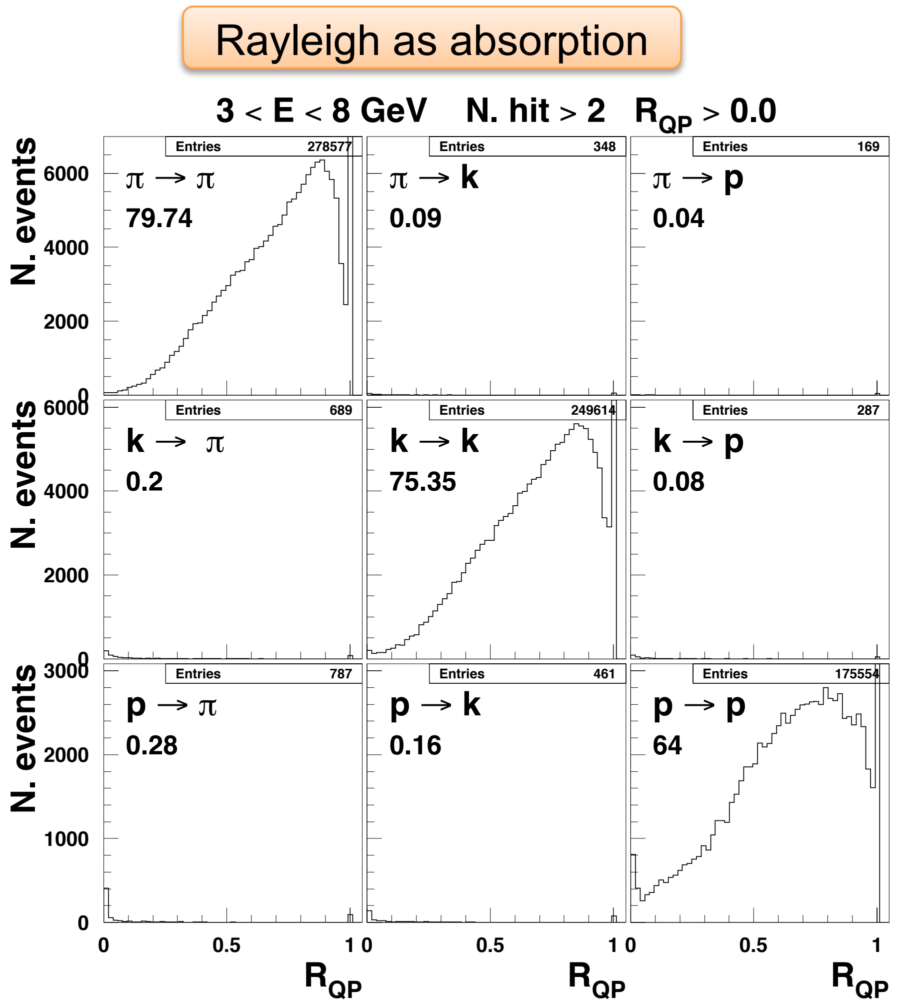


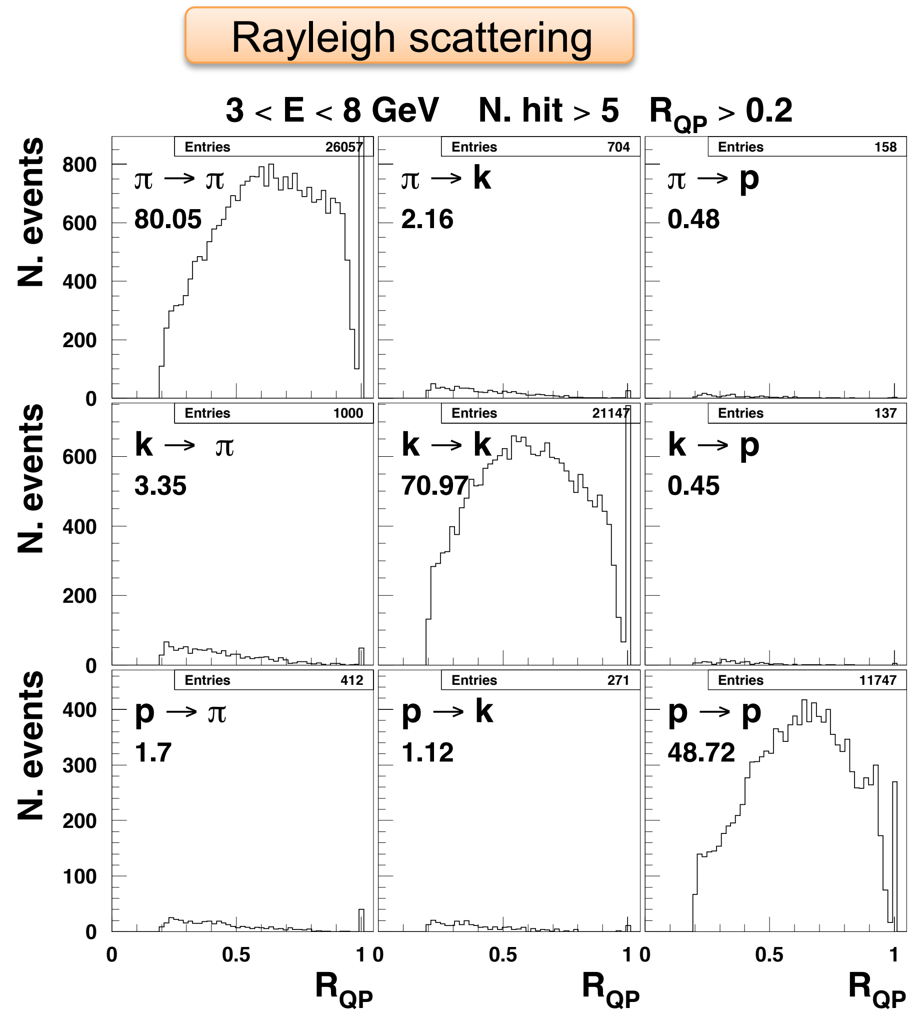
Isolated sector



Rayleigh scattering

Just a first blind look shows a potential issue
Benefit of lucite wrap to be investigated





Conclusions

Aerogel provides in principle a good pion/kaon separation up to 8 GeV/c

- **Systematic studies performed with a GEANT3-based simulation indicate a suitable configuration for the RICH in terms of pions/kaons separation is achievable**

- **Standard GEMC setup (GEANT4-based)**
  - ✔ *Detailed geometry*
  - ✔ *Optical effects (Rayleigh + mirror reflectivity)*
  - ✔ *Realistic components characteristics*
  - ✔ *Digitalization*
  - * ***Validation of the preliminary results ongoing***
  - * ***Optimal compromise to be found***

- **A reconstruction algorithm for quantitative studies under test:**
  - * ***Looking for the limiting cases***
  - * *CPU time consuming (**need optimization**);*

- ***First estimate of Background***
  - * *Coming mainly from photon conversions in the aerogel (from Moeller showering)*
  - * ***The level seems acceptable** (**spatial distribution to be tested**)*