RICH GEMC Simulations

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Standard set-up

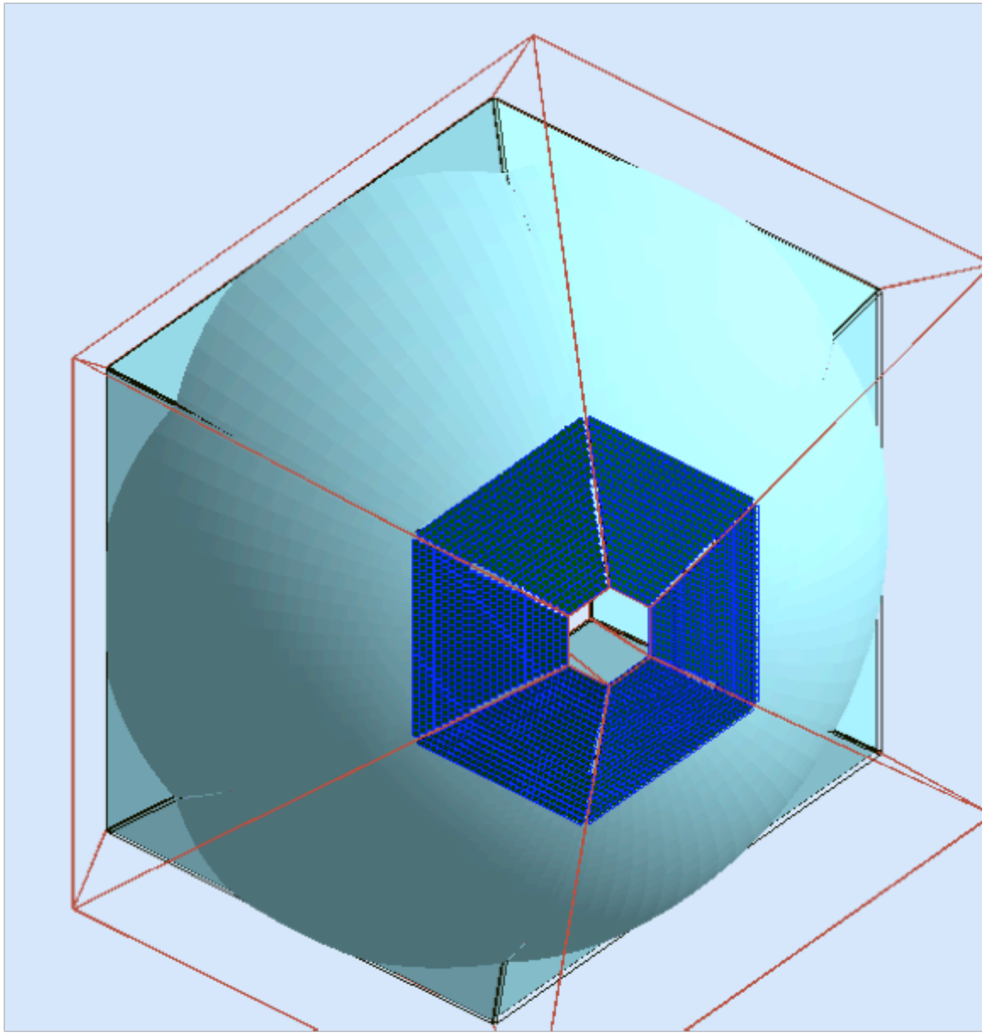
Geometry:

rich_build_radtrap_mirror35_default.pl

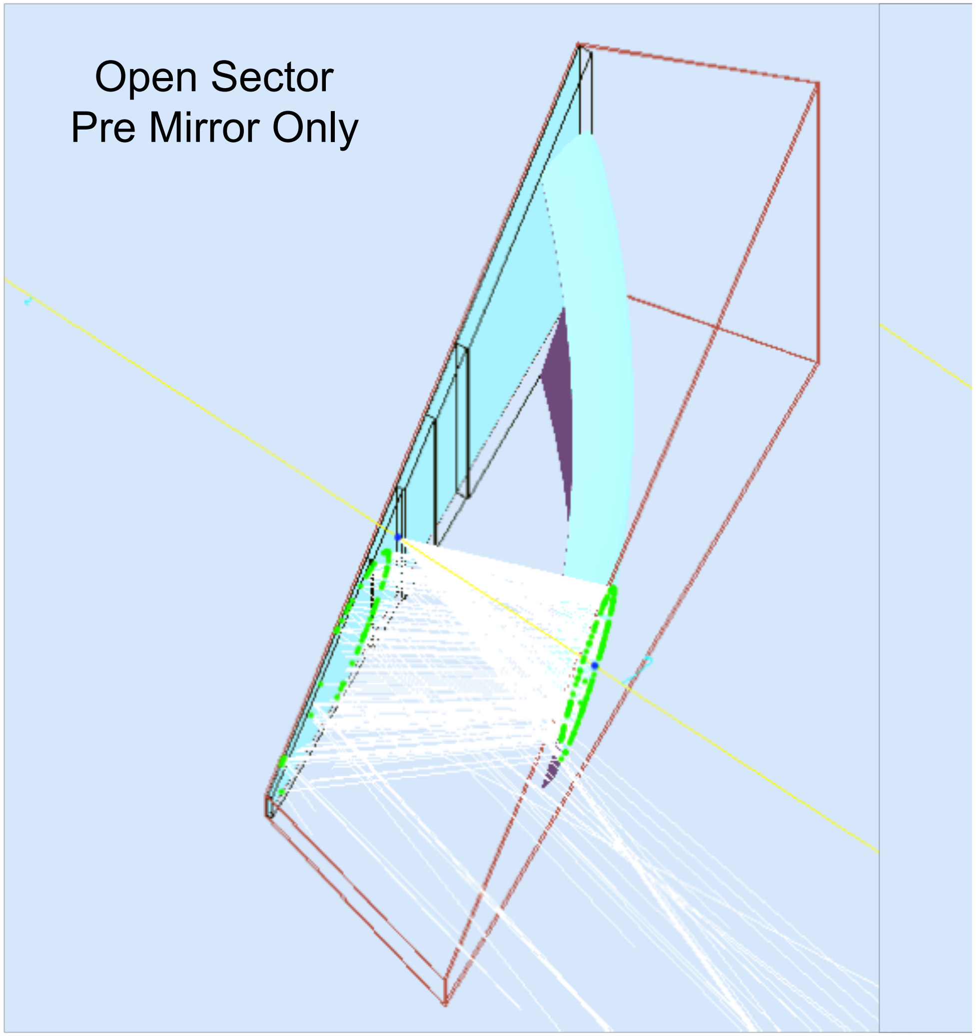
On the Jlab GEMC database

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

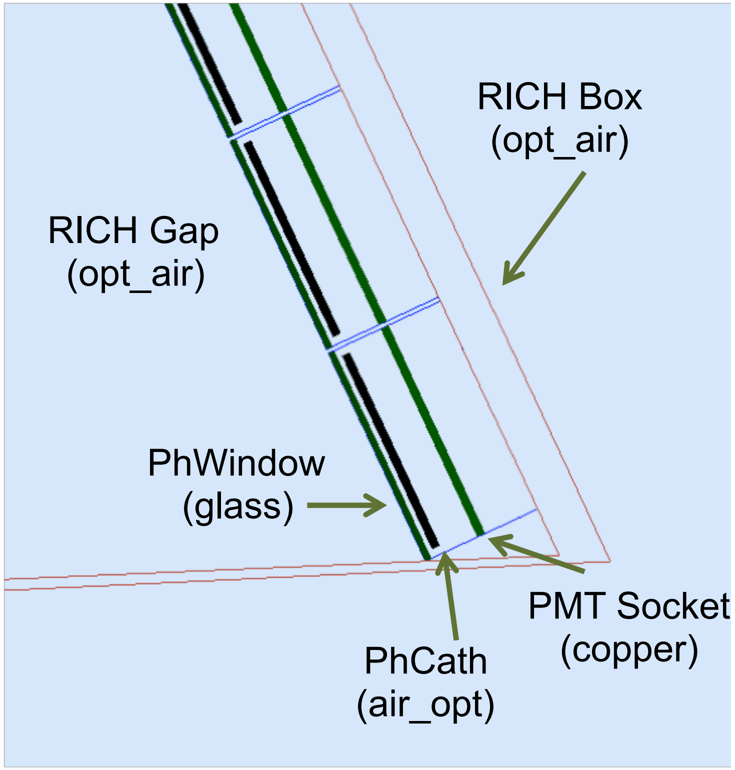
Material:

Mmaterials.cc
MDetectorConstruction.cc

On the Jlab GEMC database

Validation:

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



Standard set-up

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 %

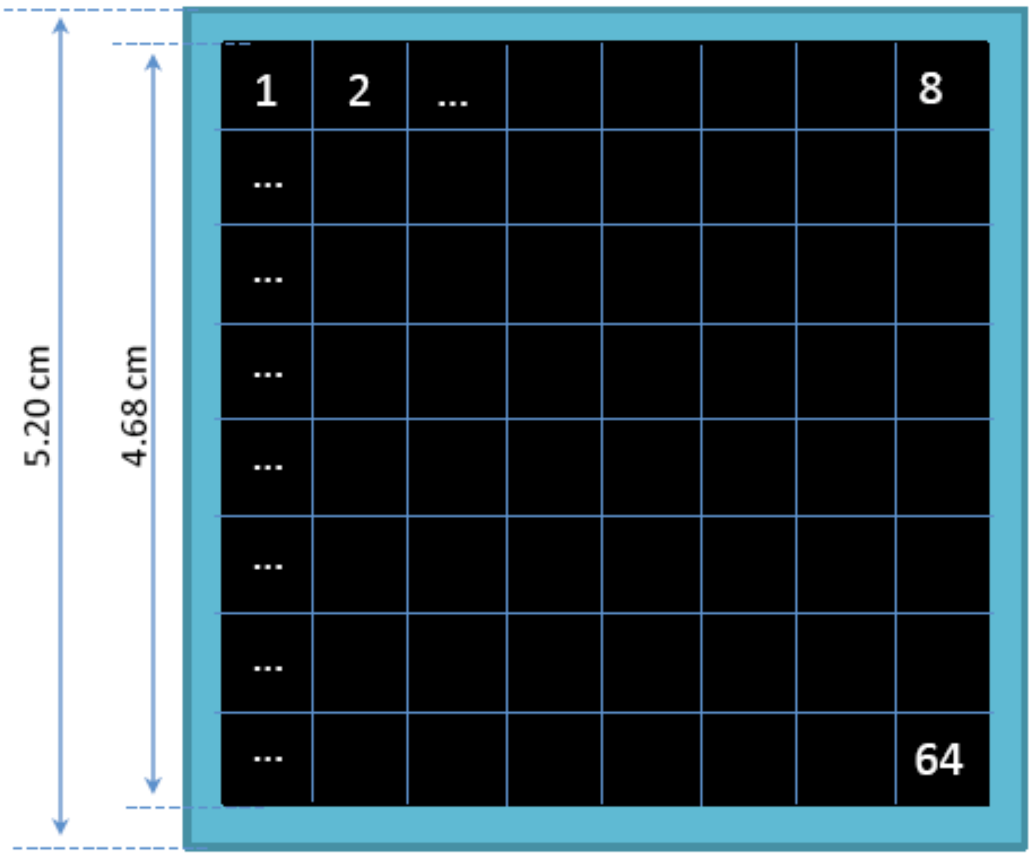
Digitalization:

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 ?



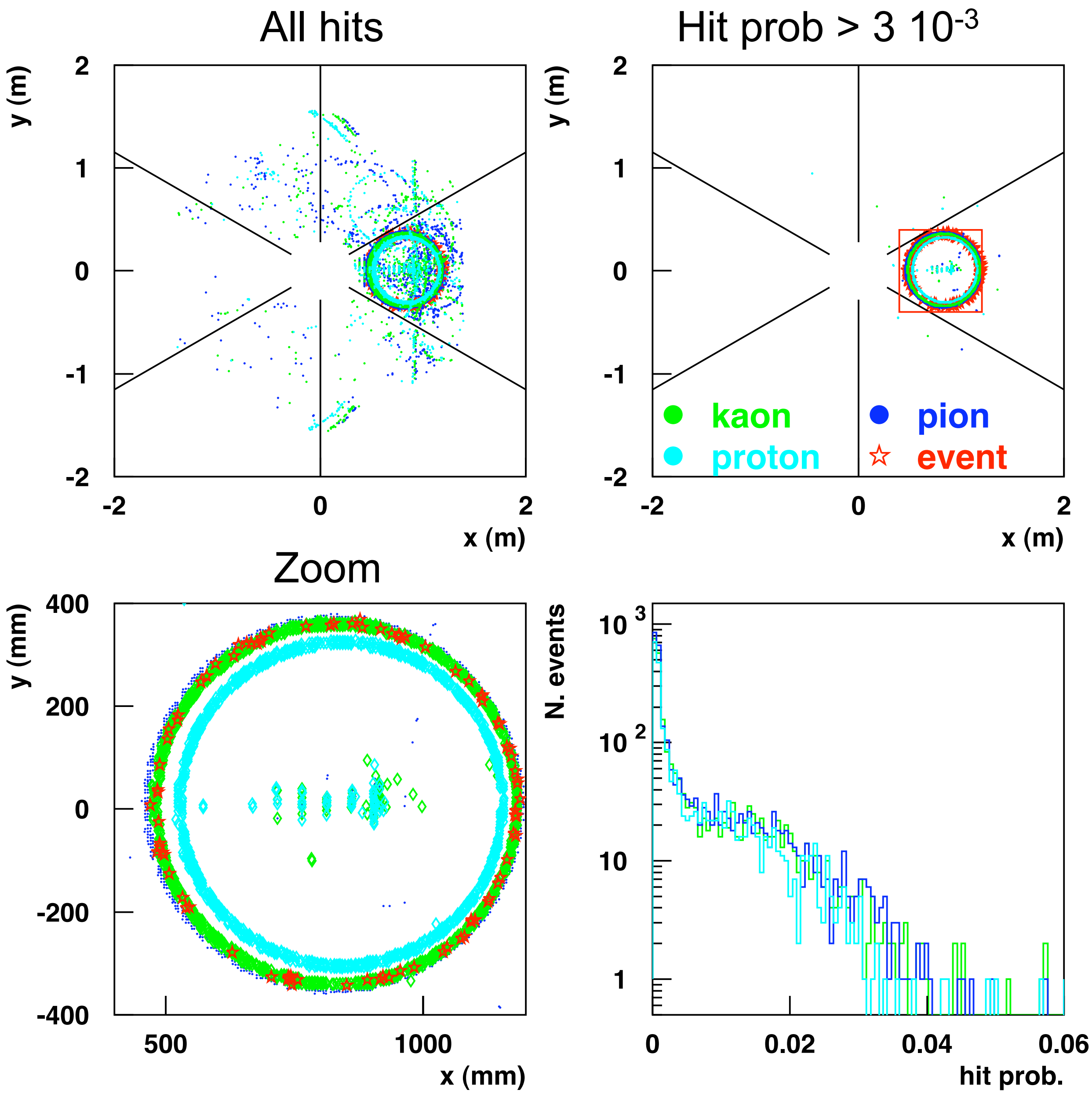
Reconstruction:

Private codes

Likelihood based on direct ray tracing

Validation:

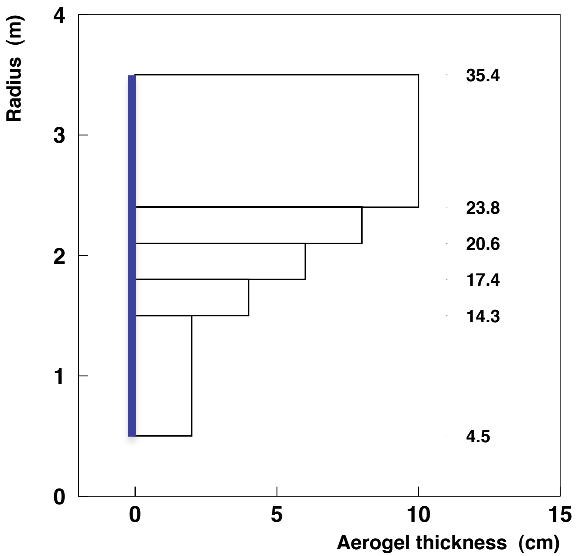
- ☐ benchmark events
- ☐ x-check
- ☐ Cherenkov light from MA-PMT window
- ☐ Resolution on charged track impact parameters
- ✔ Performances and limits
- ✔ Background (Rayleigh)

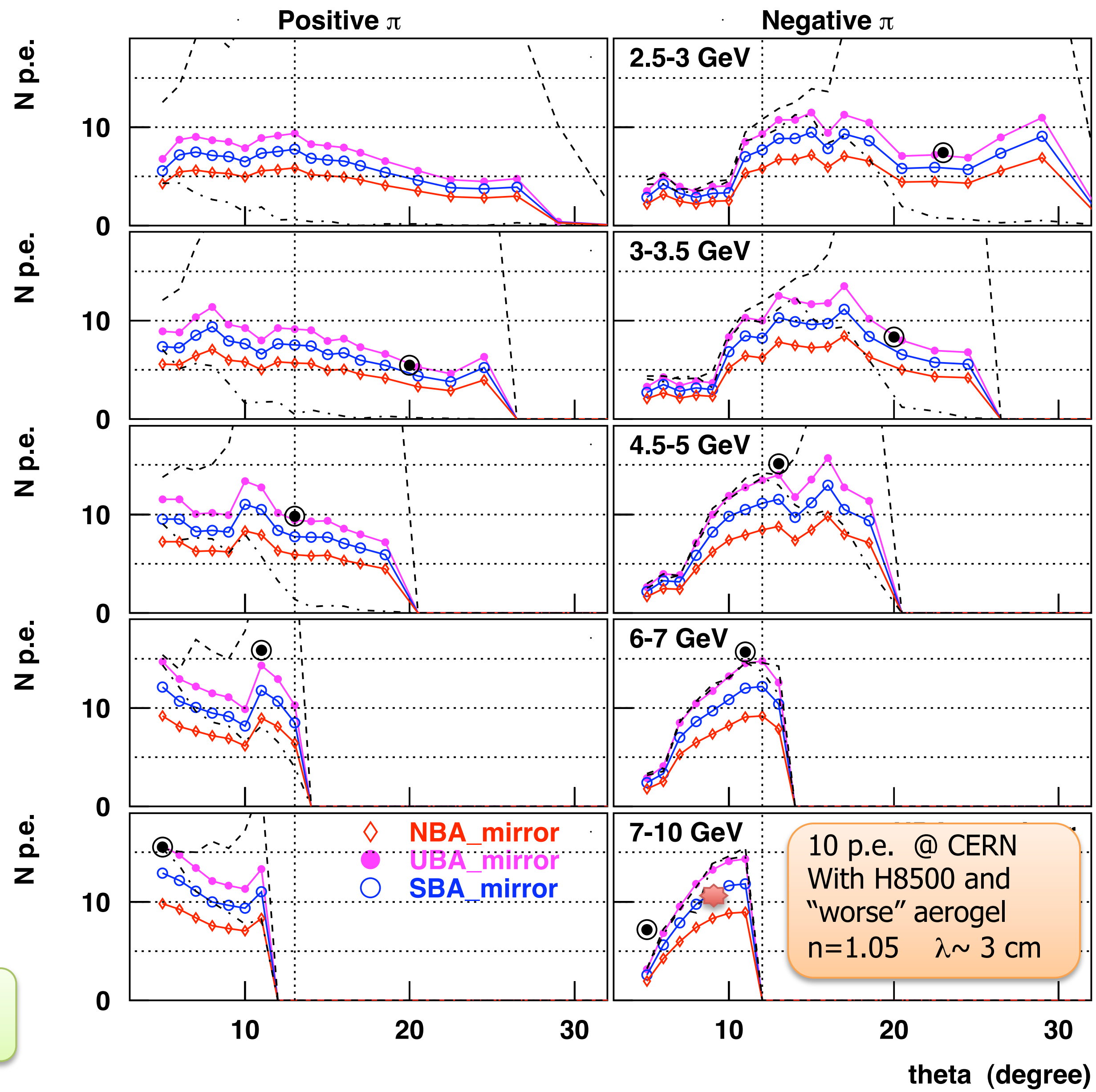


Average N p.e.: NBA ?

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





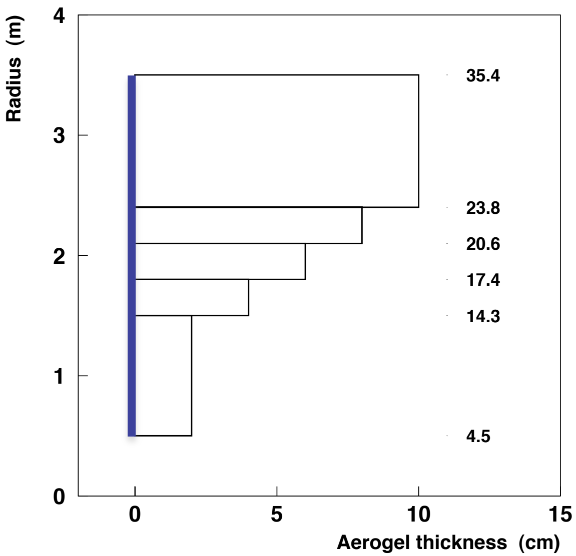
Challenging with normal bi-alkali
N_{pe} a bit higher with standard set-up

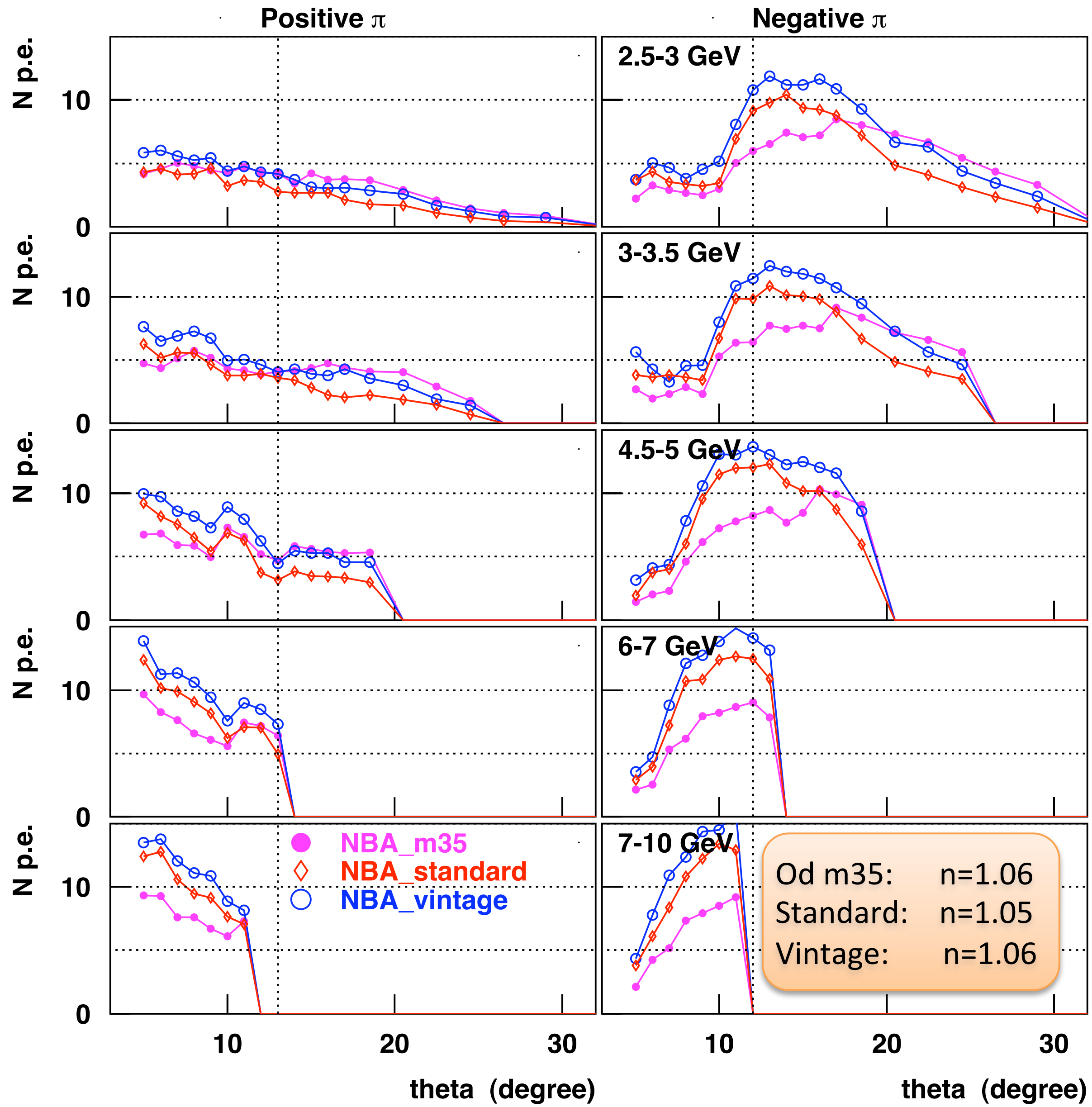
Average N p.e.: NBA ?

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





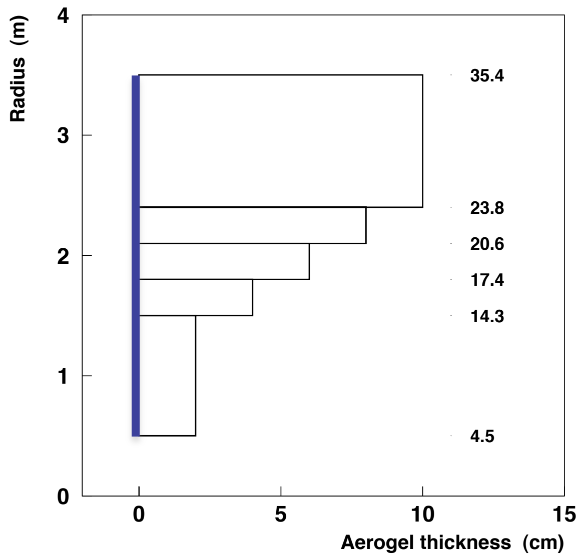
Increase of direct photons due to MA-PMT window ?
Differences to be investigated

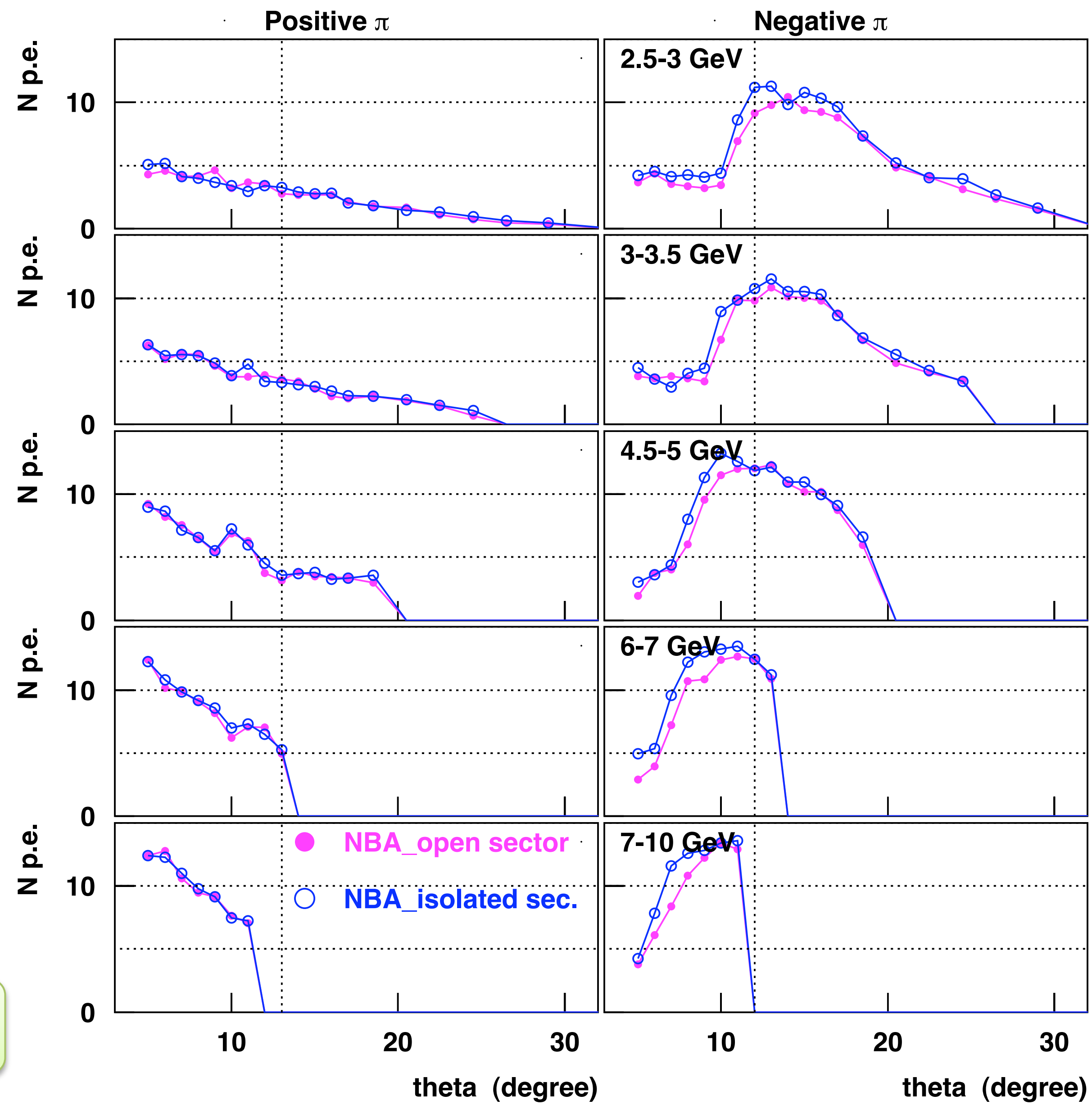
Average N p.e.: NBA ?

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

Mirror: 14° - 35°
- 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 $\mathbf{L^{(h,t)}}$ 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

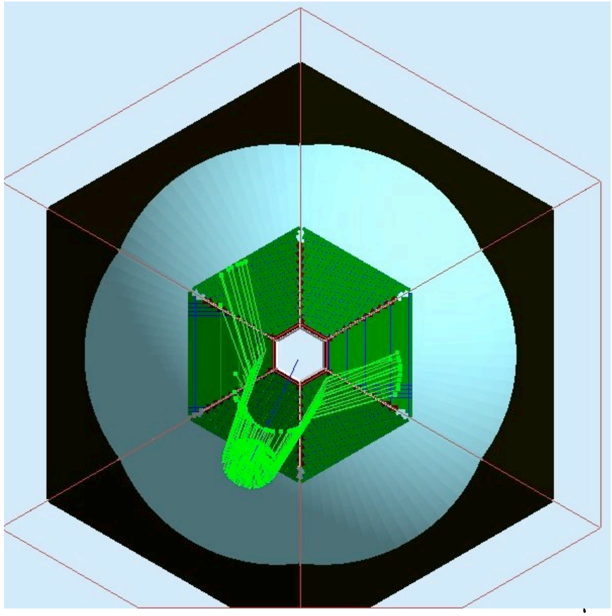
$B(i)$ is a background term (assumed to be 10^{-4}, fine with prelim. studies)

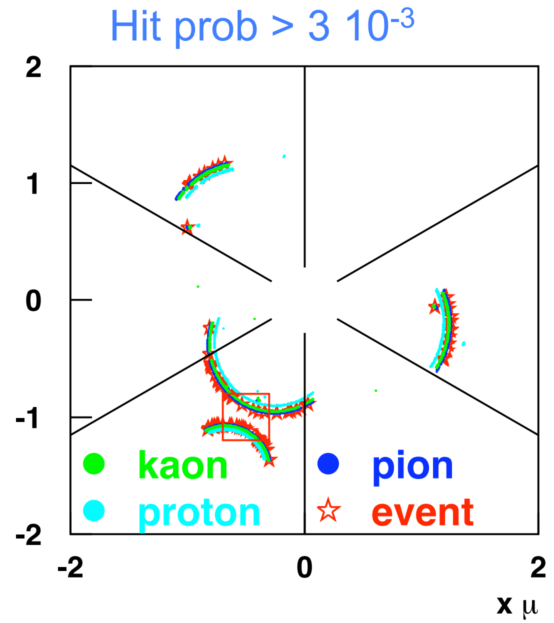
The pattern recongnition

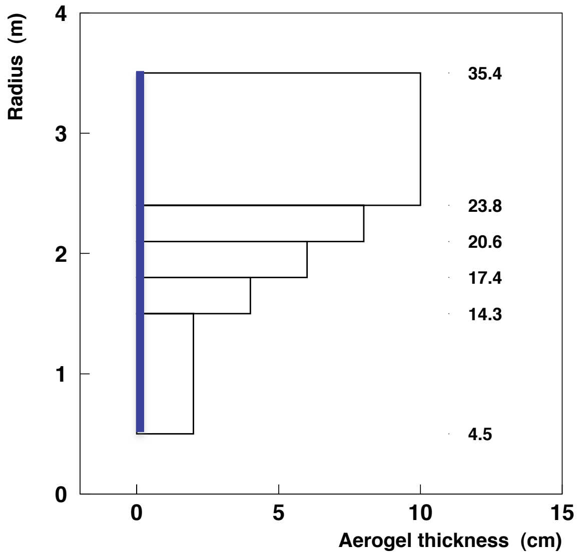
200 trials per point

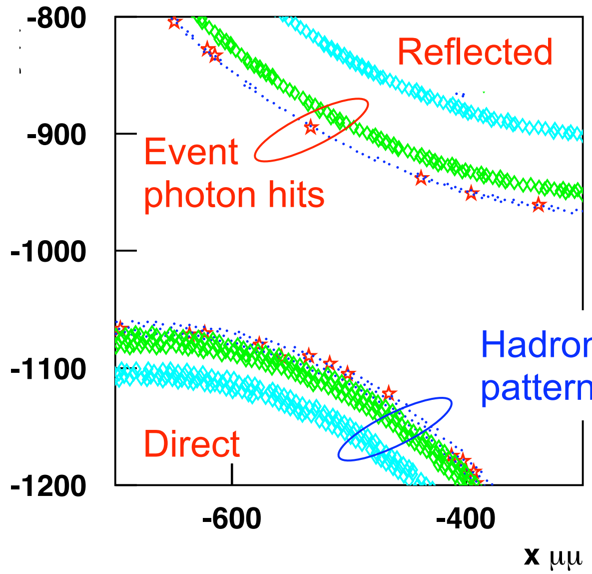
Aerogel:
- n=1.06
- thick. increasing with radius: 2-4-6-8-10 cm

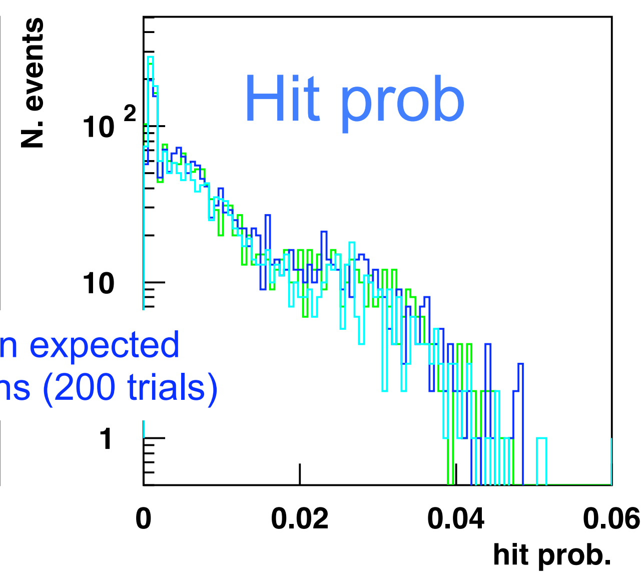
Mirror: 14º - 25º
MA-PMTs: UBA











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 → 1 good ID

LH performances for outbending particles

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

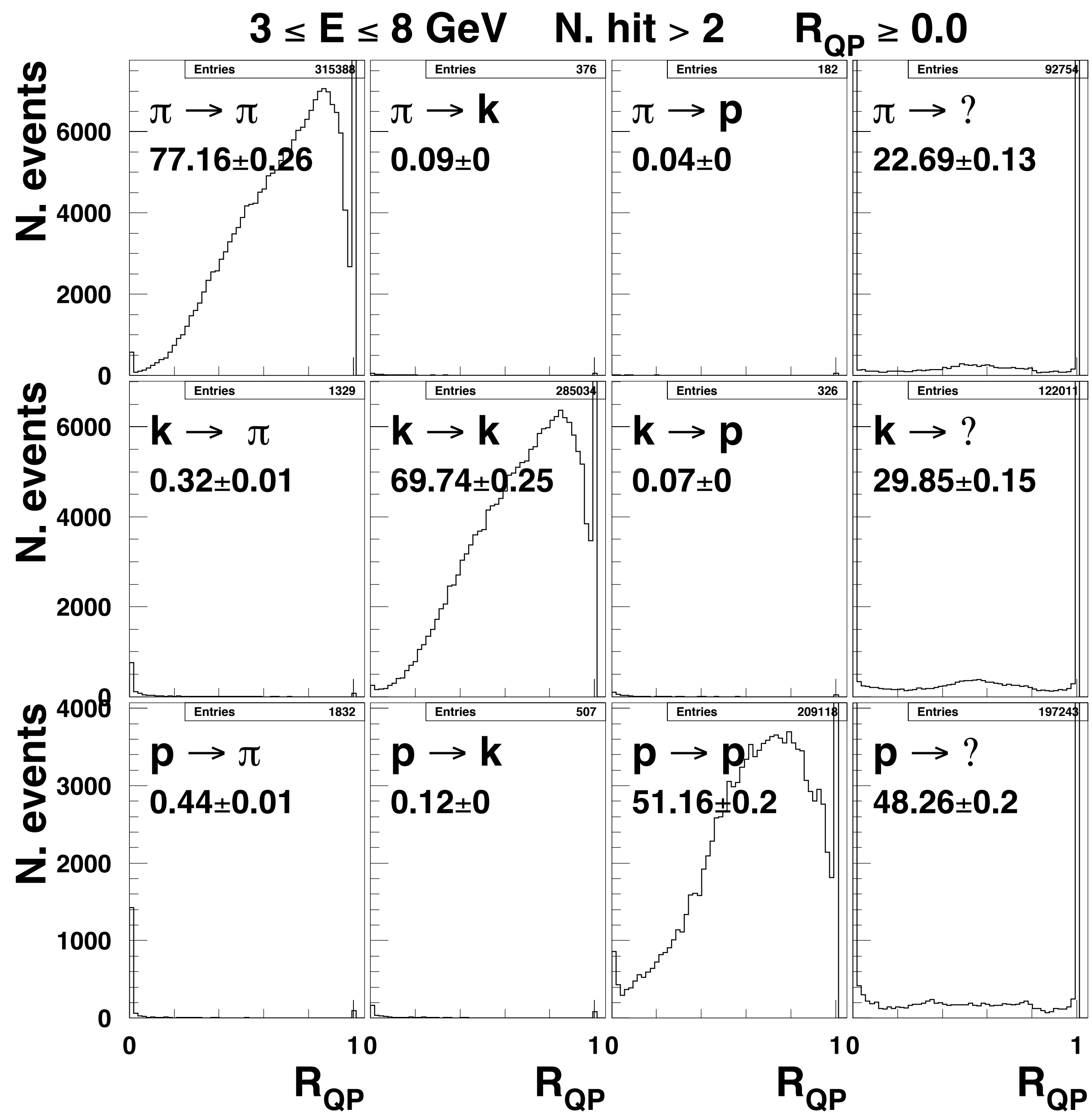
Mirror: 14º - 35º
- 90% reflectivity

MA-PMTs: H8500 eff=0.65

Contamination ~ few per mill

Efficiency ~ 70 % for kaons

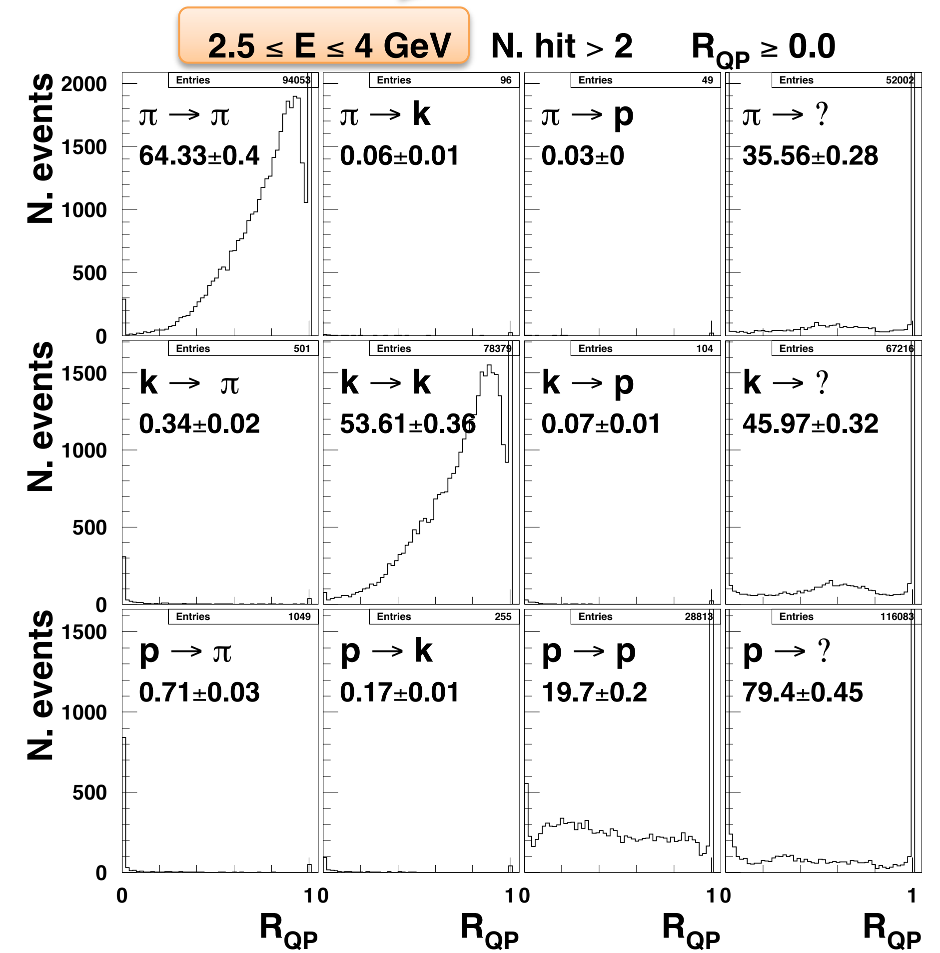
Identification quality: in average good

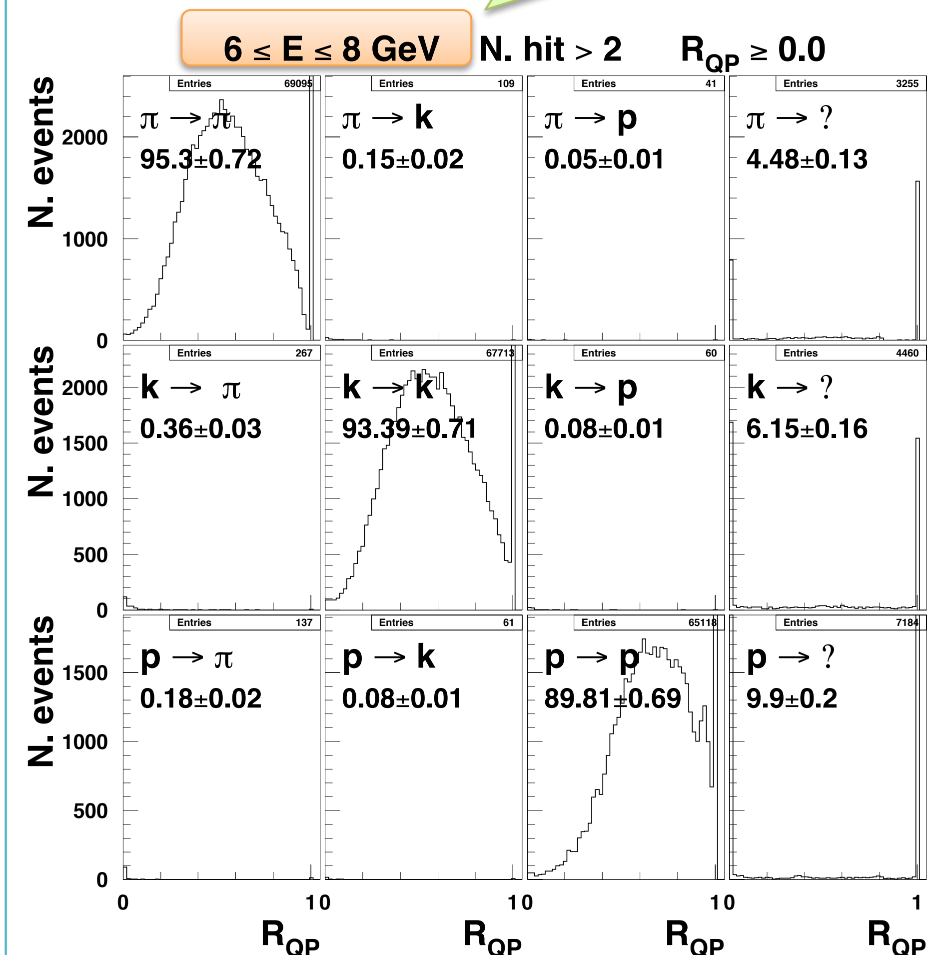


LH performances vs momentum

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

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

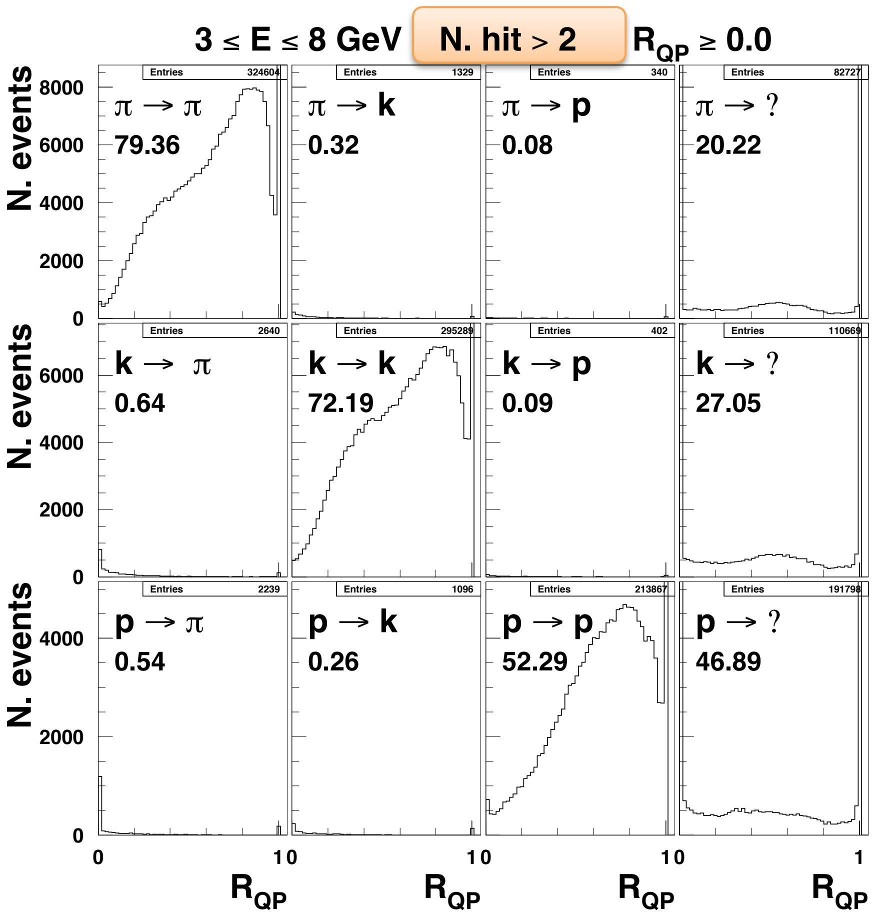


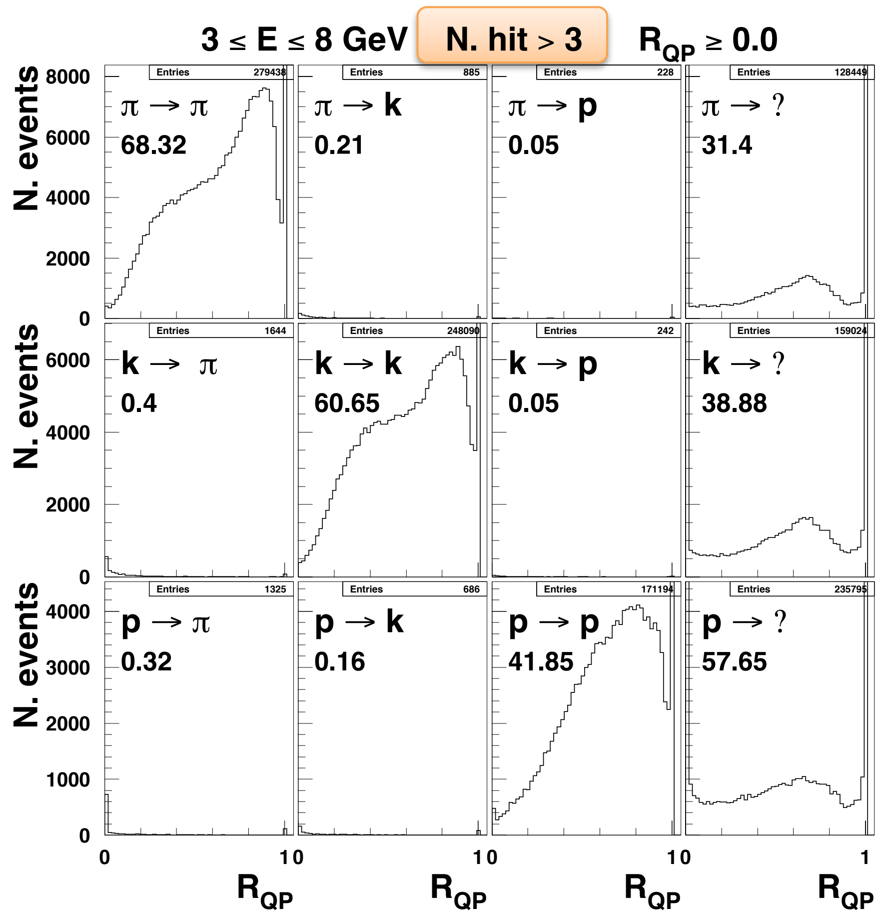


LH performances vs N. hits

Up to 2 hits the RICH response is almost random

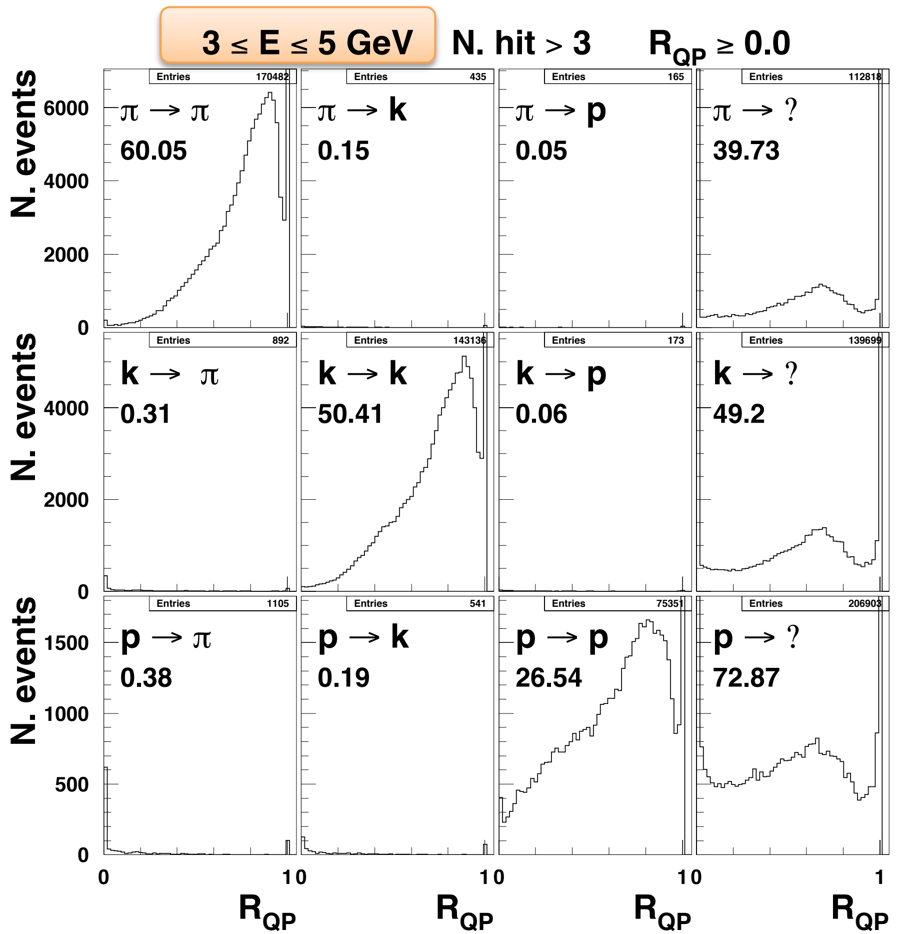
With 3 hits the identification start to be validated by R_{QP} goodness parameter

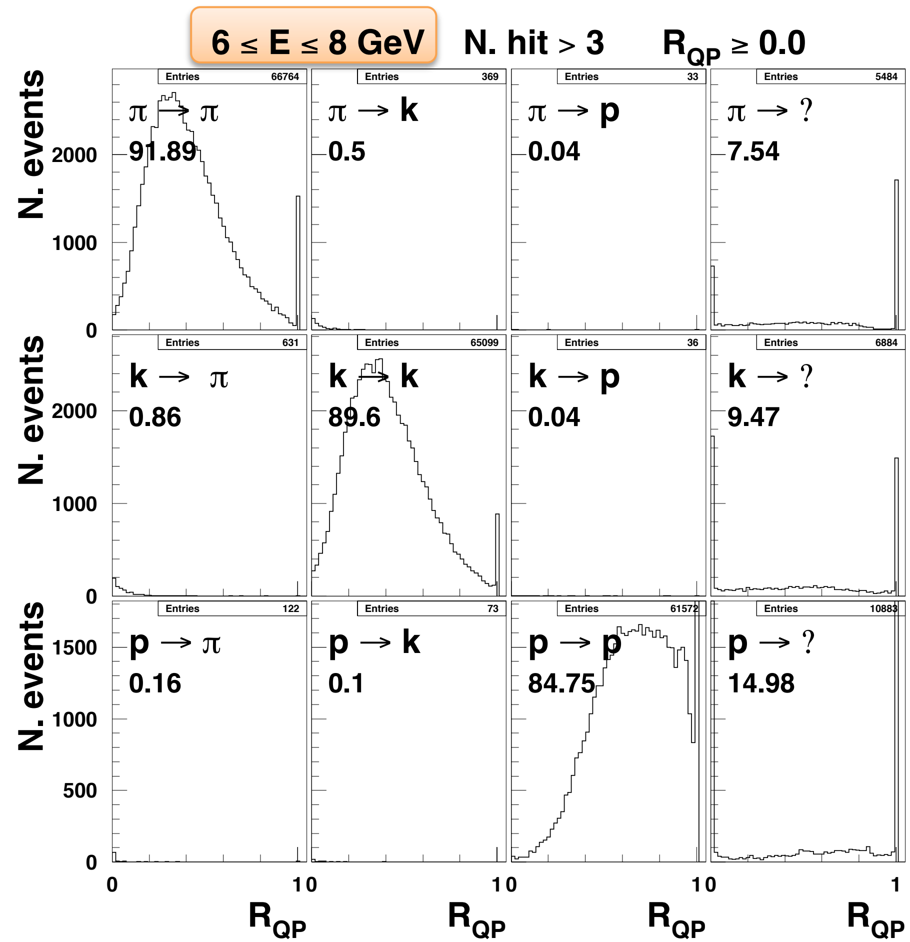




LH performances vs N. hits

At high momentum 3-hit event are not really useful: there best separation power is needed but RICH gets higher average number of photon hits

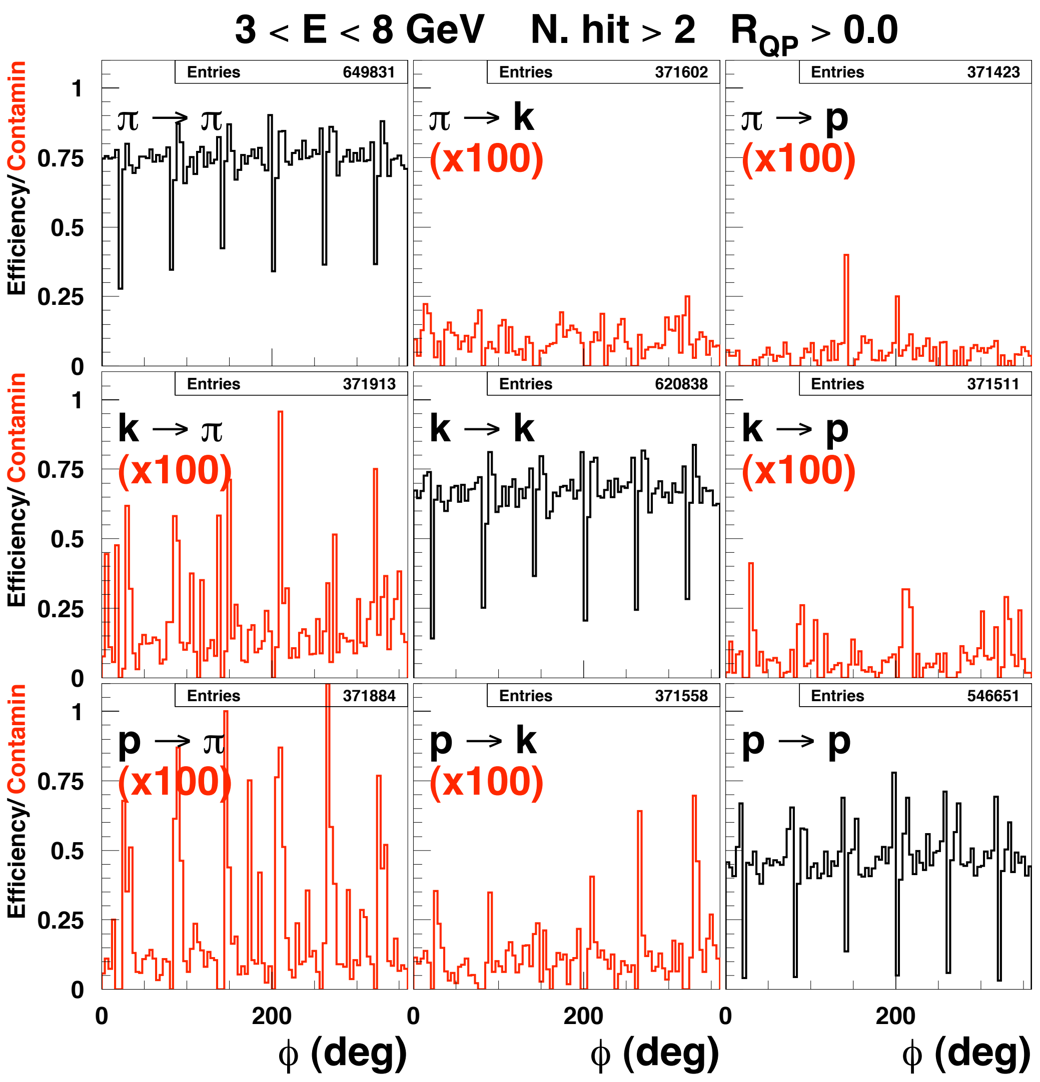




Hadron ID vs azimuthal angle

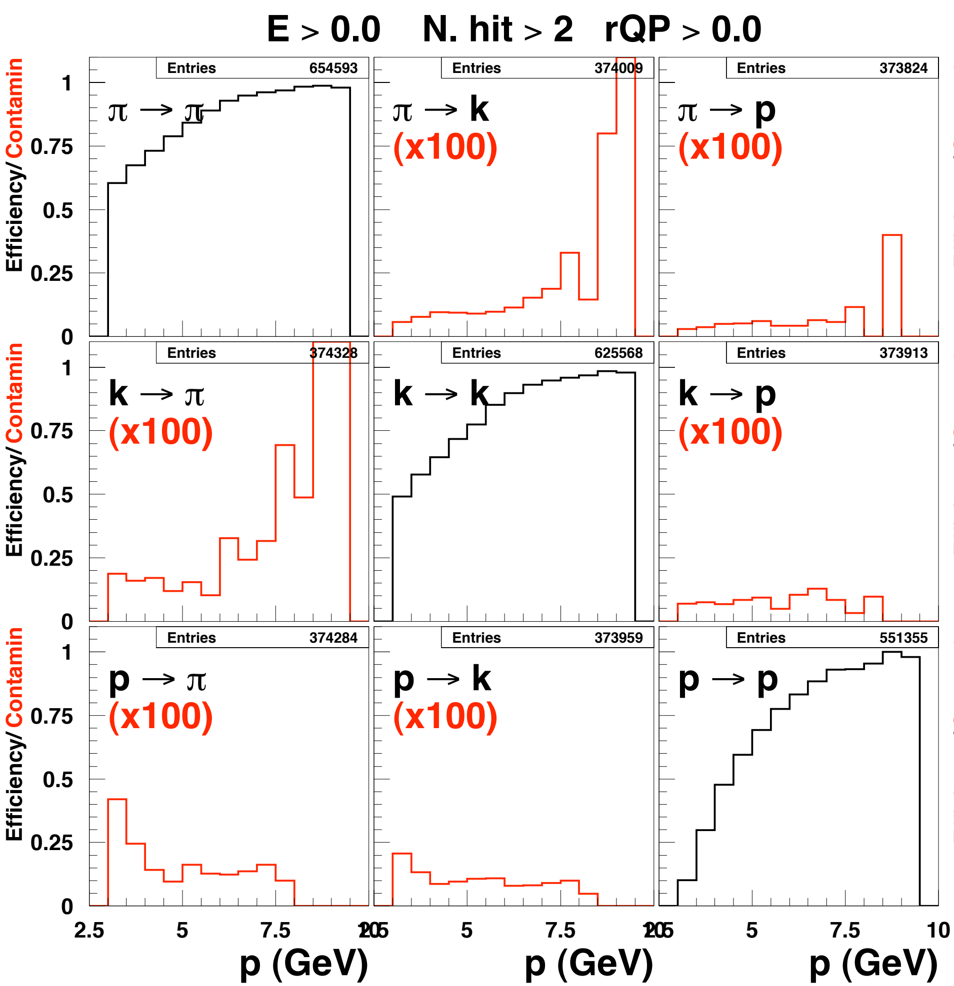
Almost uniform within a sector

Drop in performances at the sector edge due to acceptance

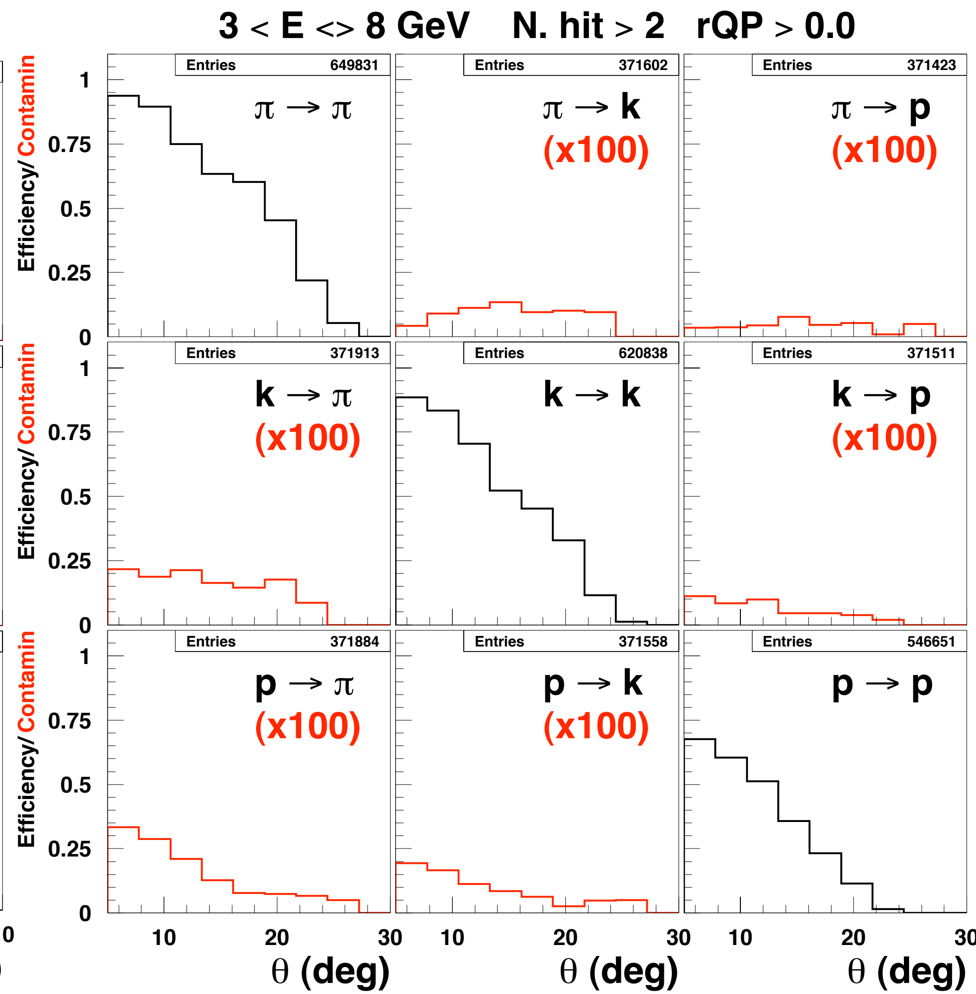


Hadron ID vs momentum/polar angle

Performances vs momentum



Performances vs polar angle



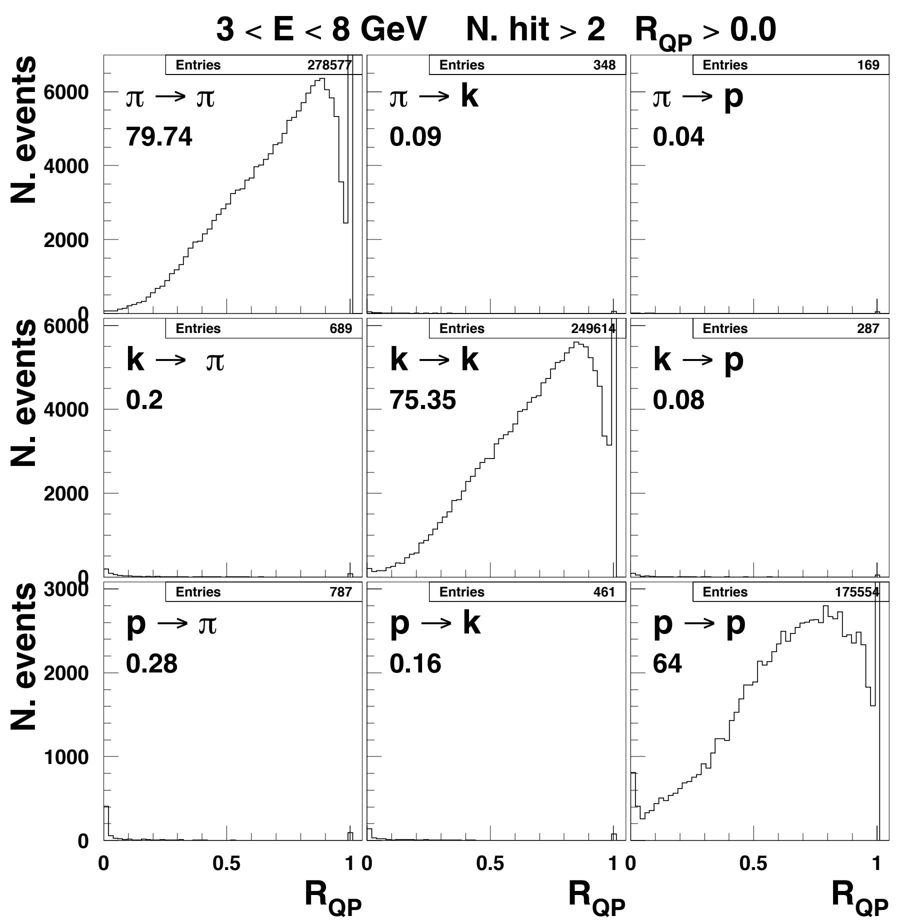
Contamination diverges above 8 GeV
At small momenta correlation with polar angle

At large polar angle too few photon hits

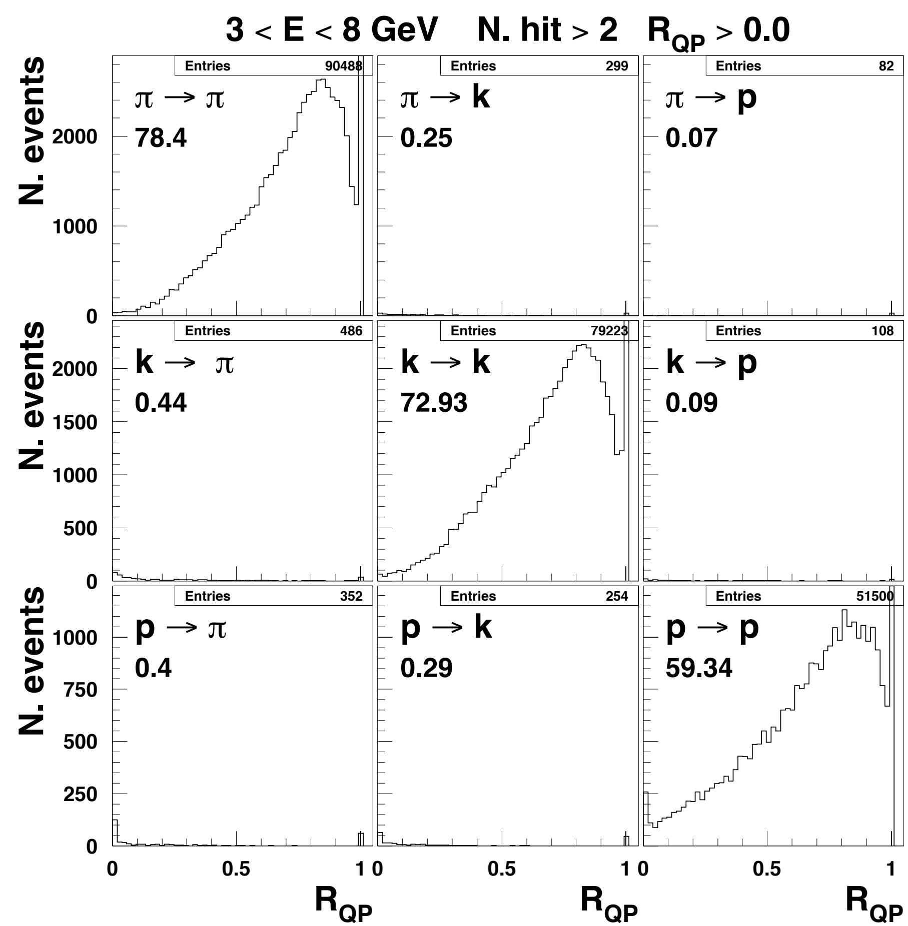
Open vs isolated sectors

Isolated sectors show slightly worse performances

Open sector



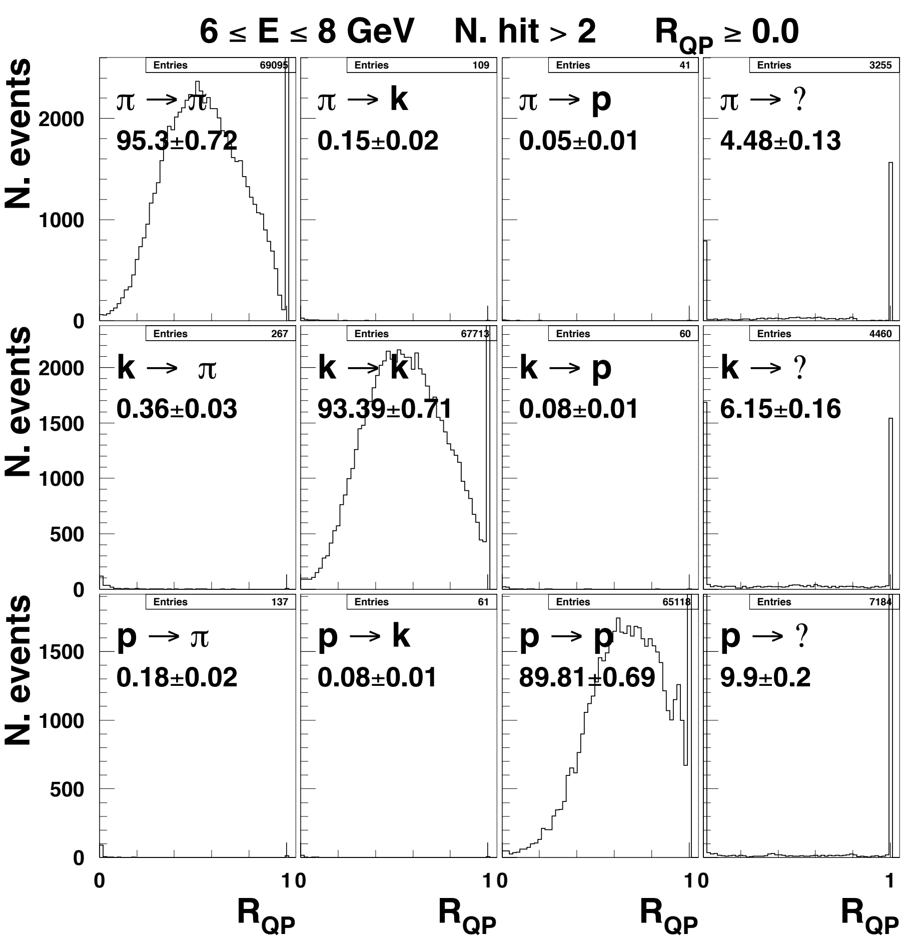
Isolated sector



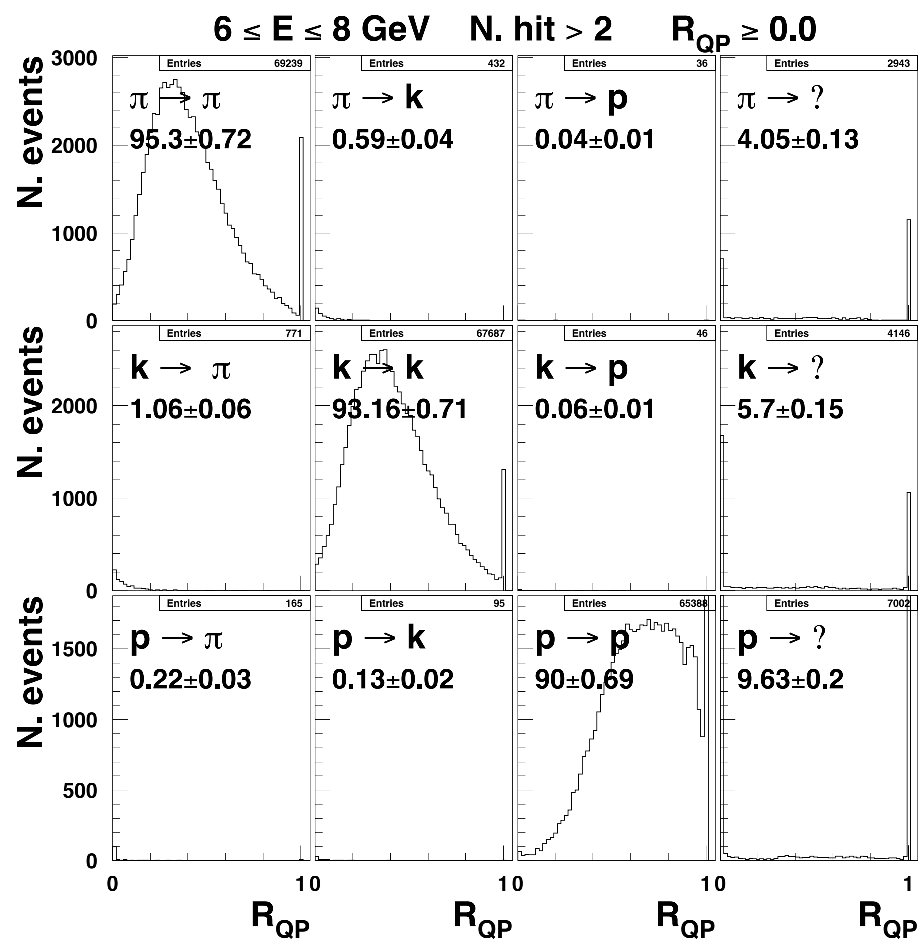
Dispersion law at n=1.05 (High P)

Small impact on the efficiency
Significant increase of the contamination to a still manageable level

Dispersion as 1.03



Dispersion as n-1

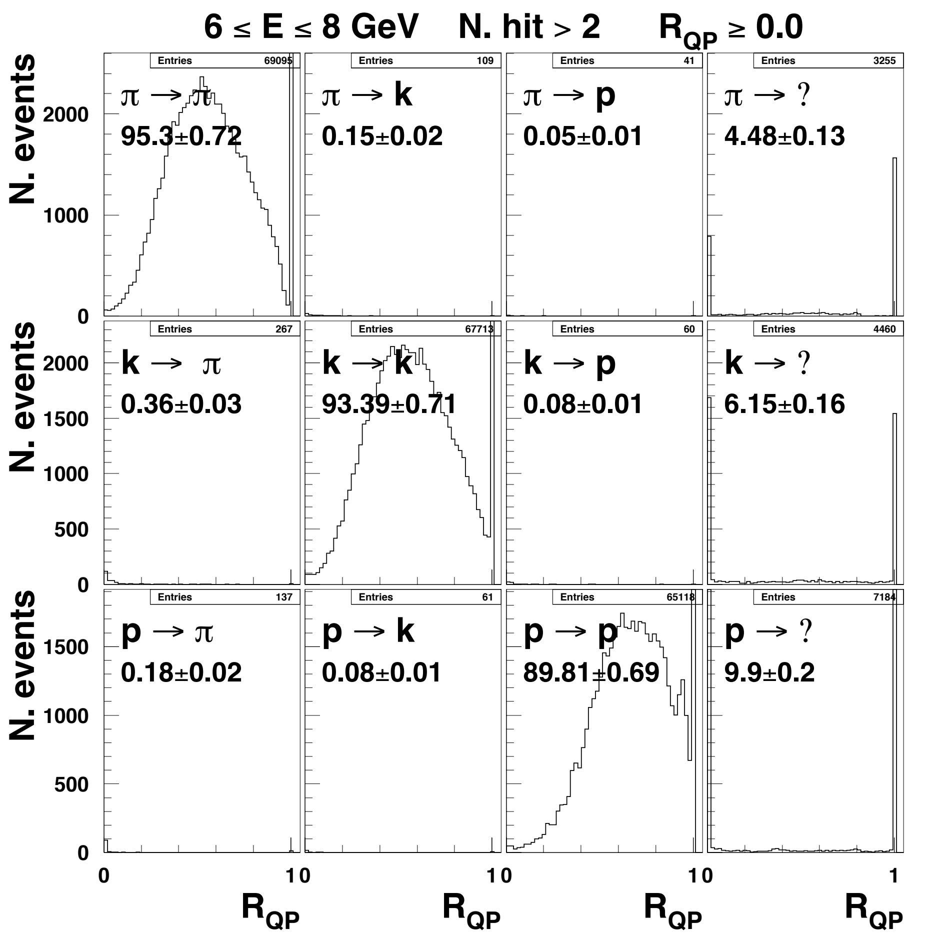


+ Rayleigh scattering (High P)

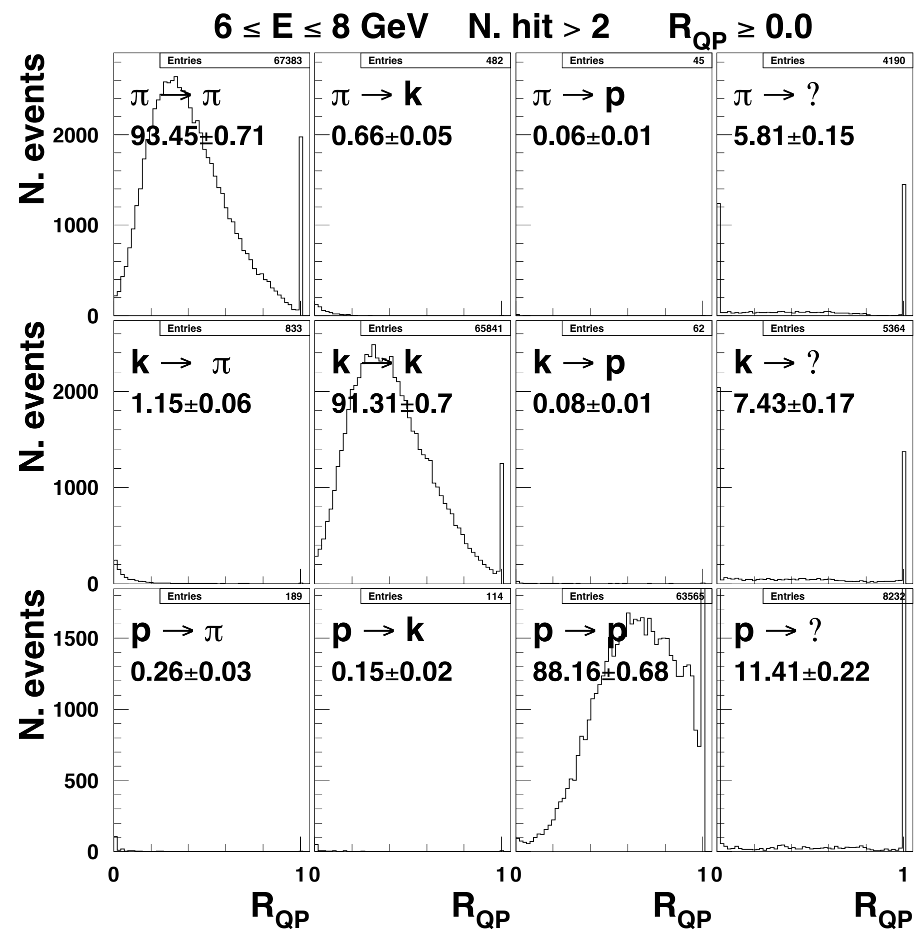
In the LH, Rayleigh scattering is treated as background

Small worsening of the performances

Rayleigh as absorption



Rayleigh scattering

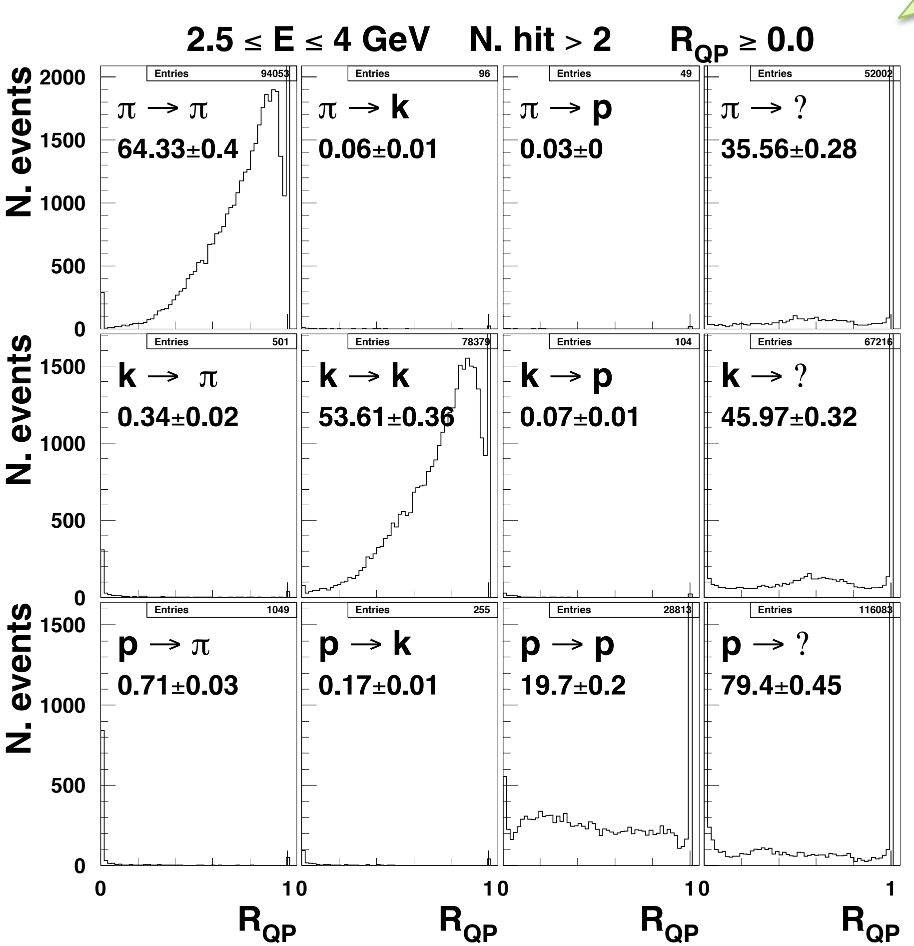


+ Rayleigh scattering (Low P)

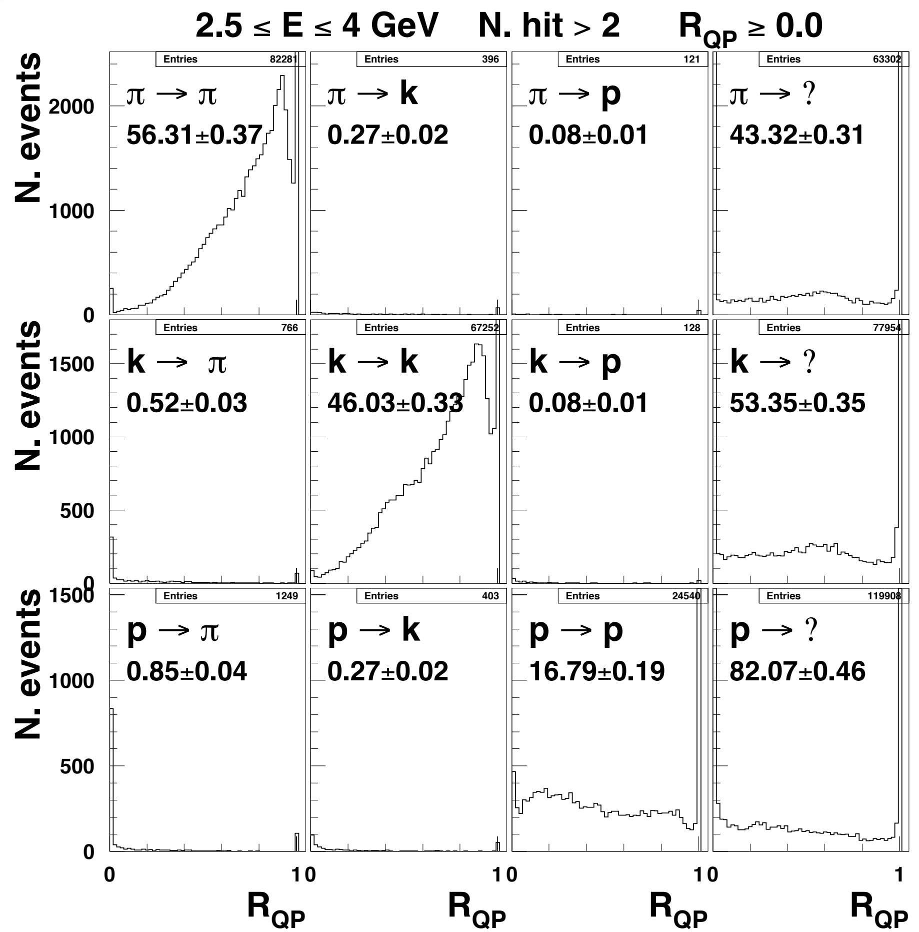
Small worsening of the performances

Significant increase of events with too few photoelectrons: to be investigated

Rayleigh as absorption



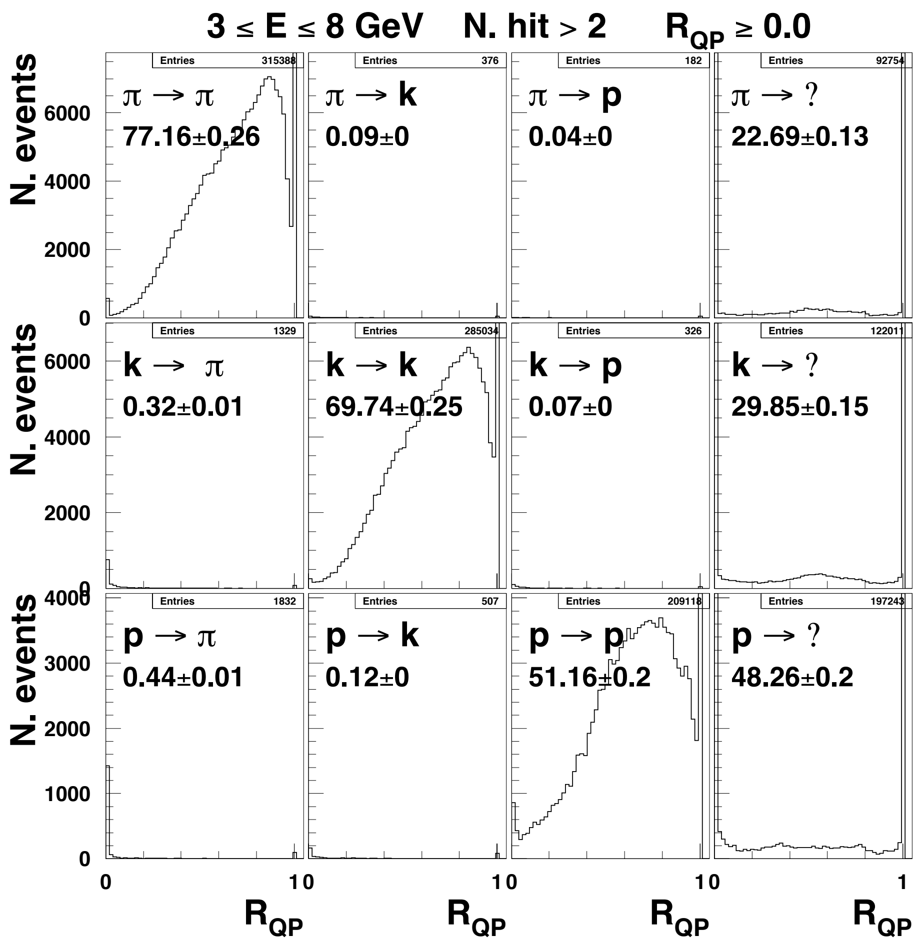
Rayleigh scattering



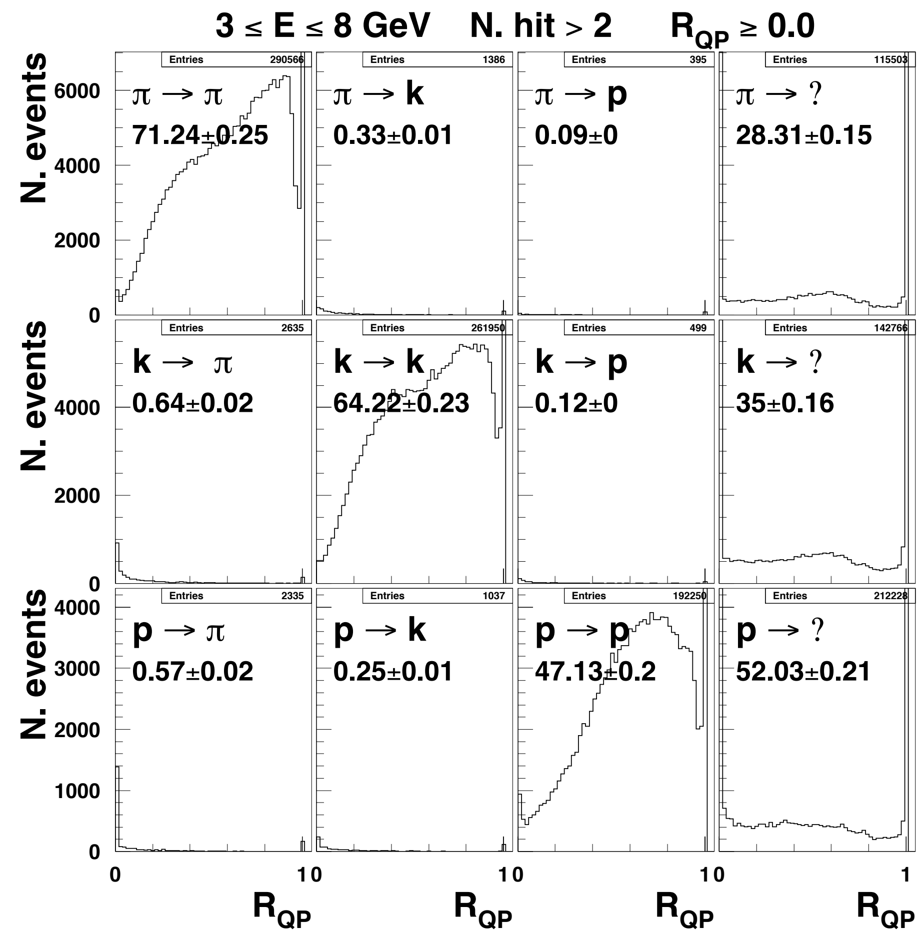
+ Rayleigh scattering

Significant increase of events with too few photoelectrons: to be investigated

Rayleigh as absorption



Rayleigh scattering

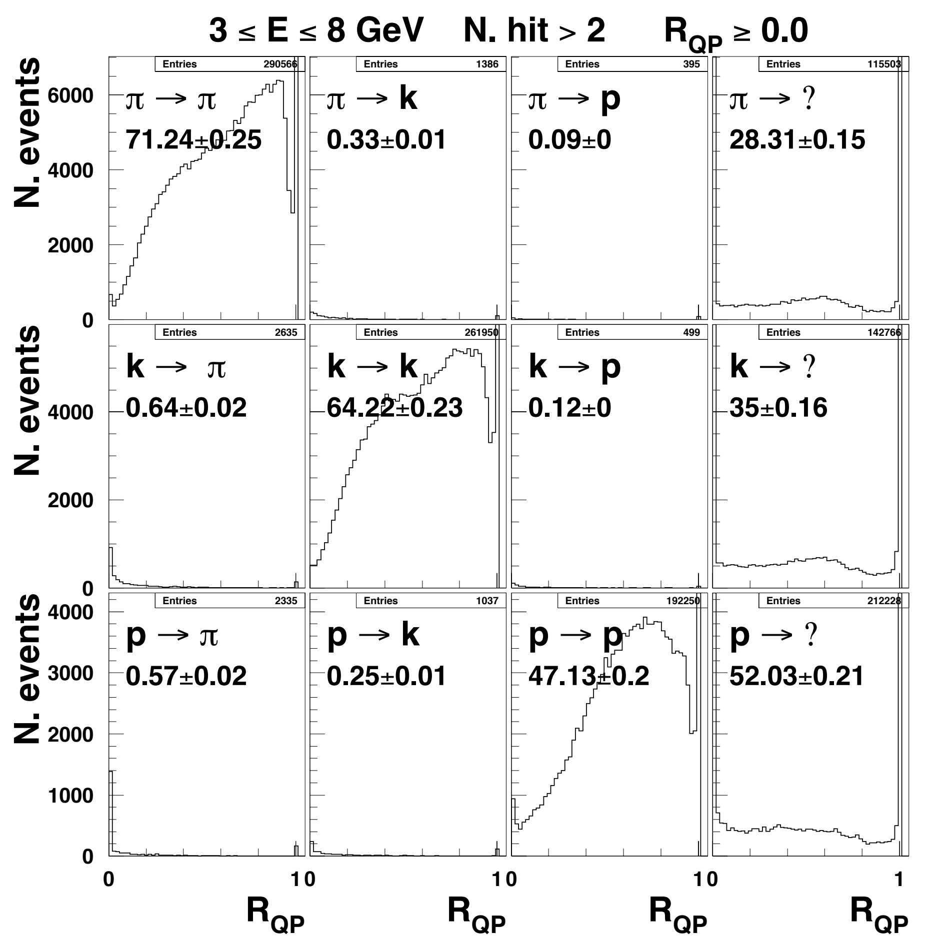


LH performances vs bending

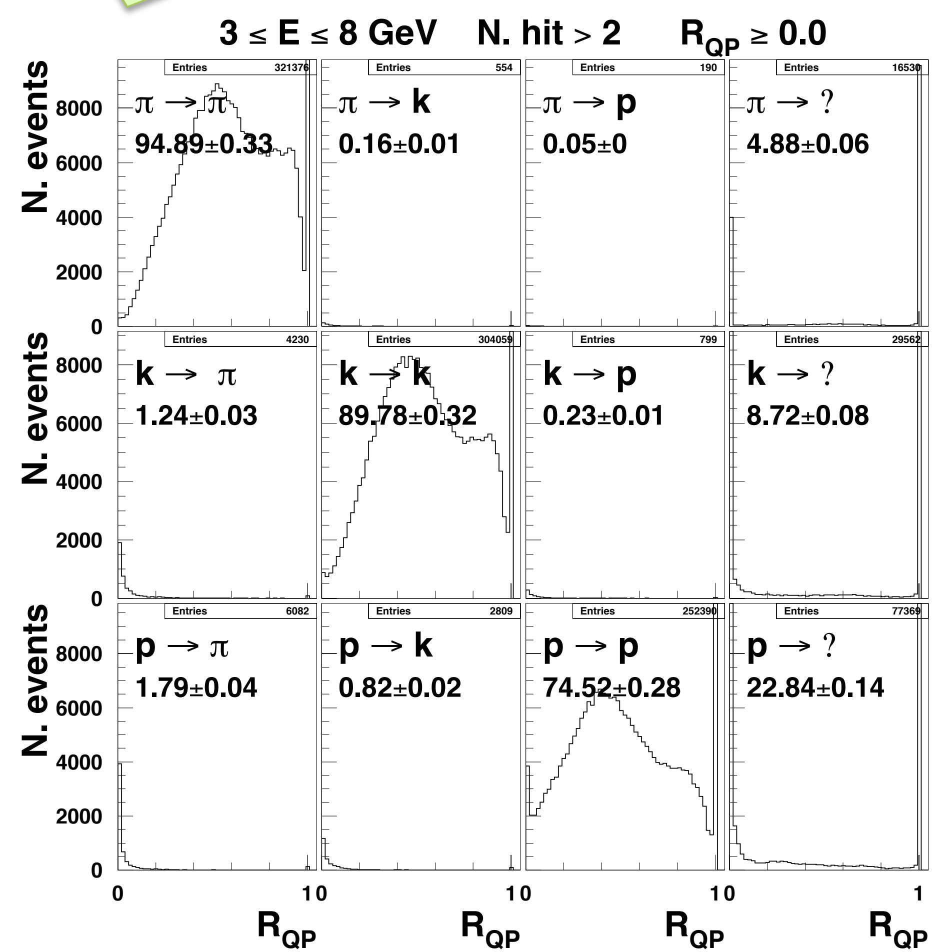
Better performance for IN-bending particles

Different R_{QP} shape

OUT-bending (positives)



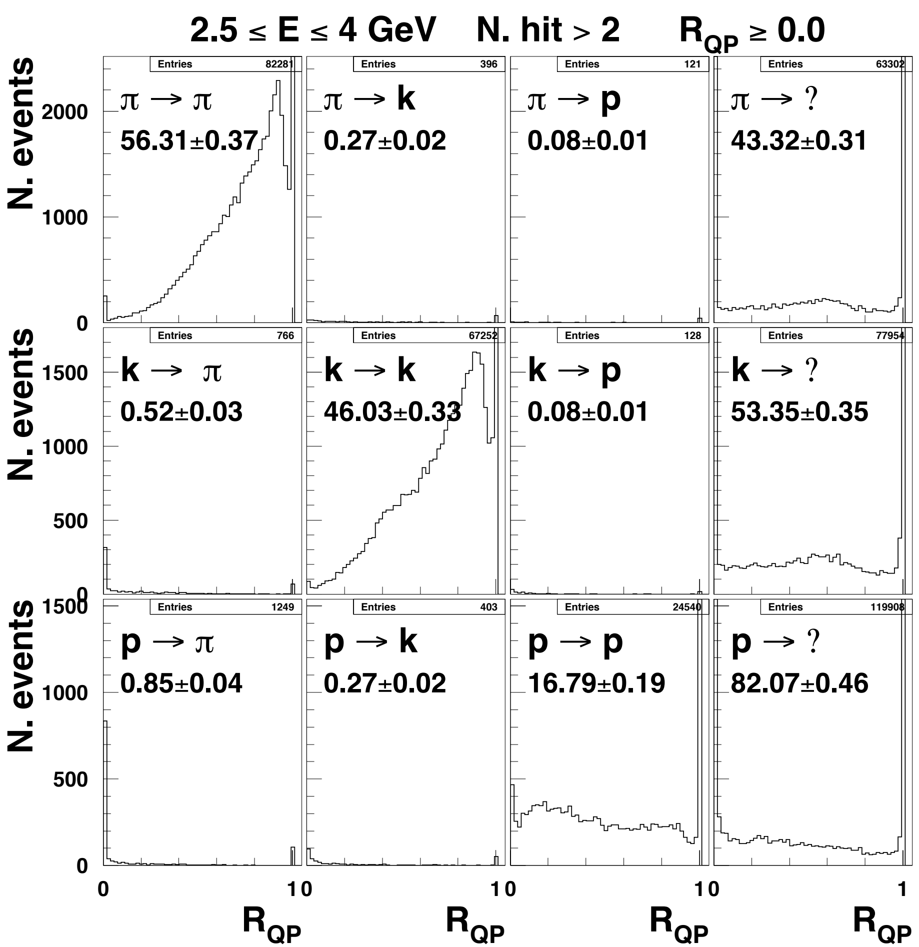
IN-bending (negatives)



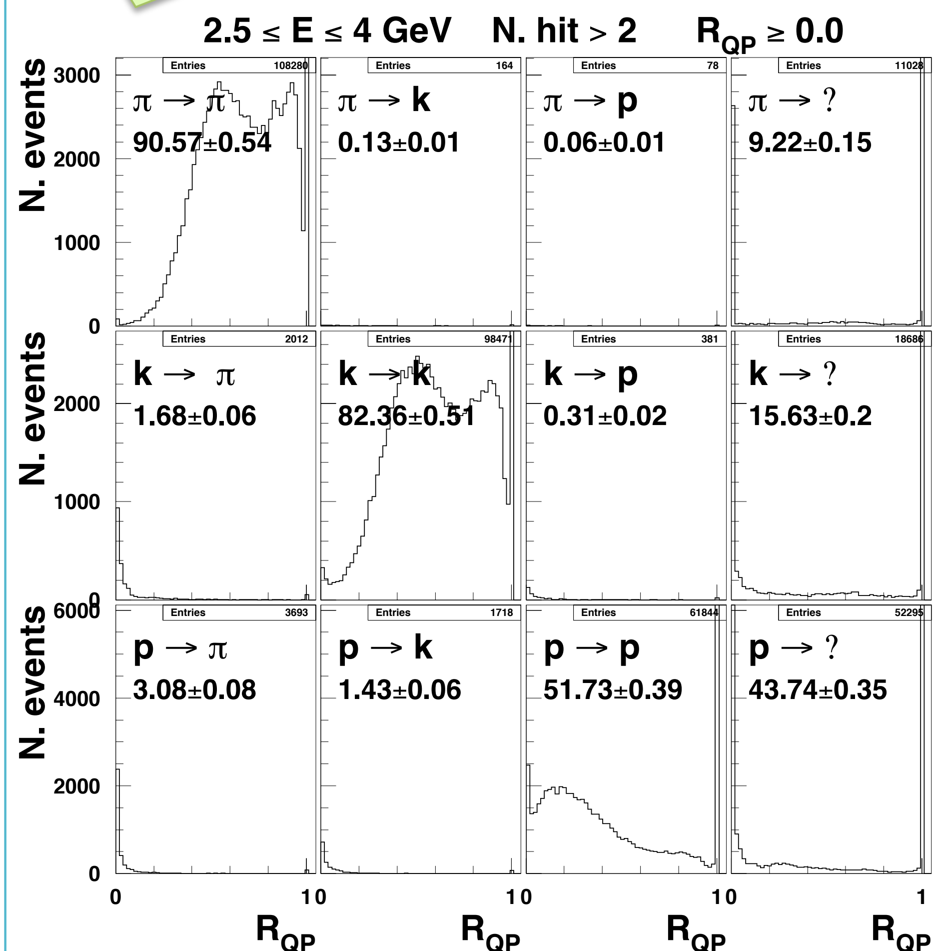
LH performances vs bending (Low P)

Different R_{QP} shape probably due to large angle, small N_{pe} events or raw fiducial volume selection

OUT-bending (positives)



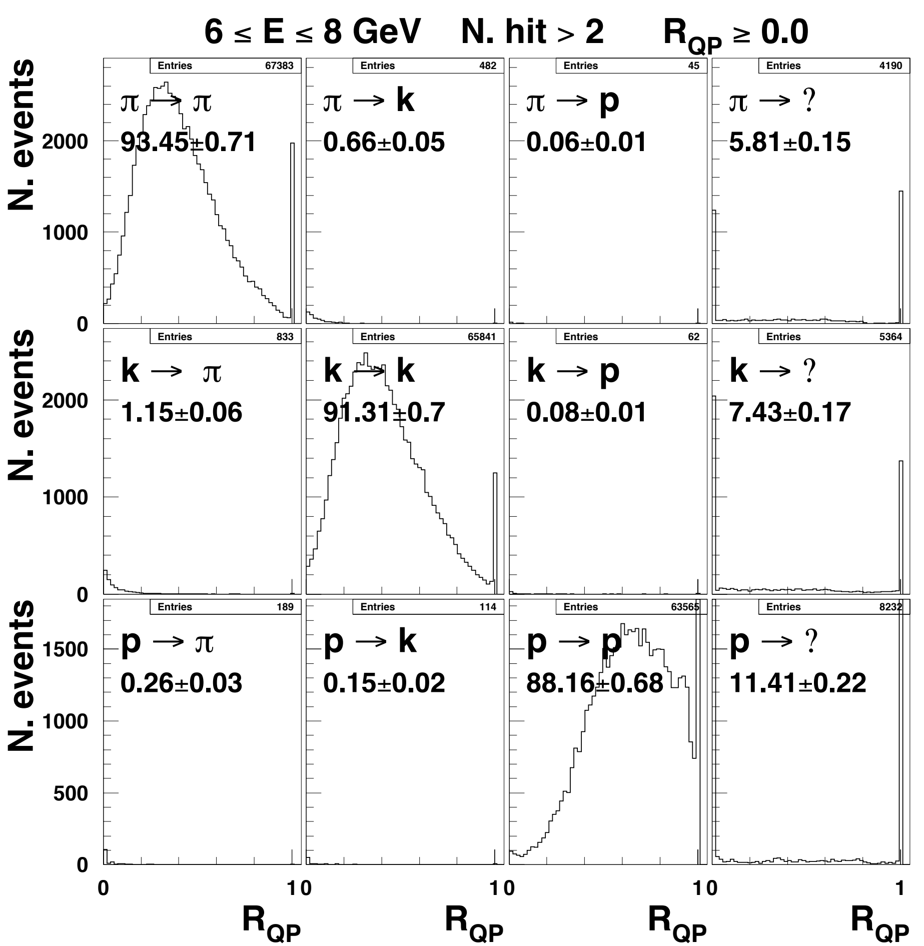
IN-bending (negatives)



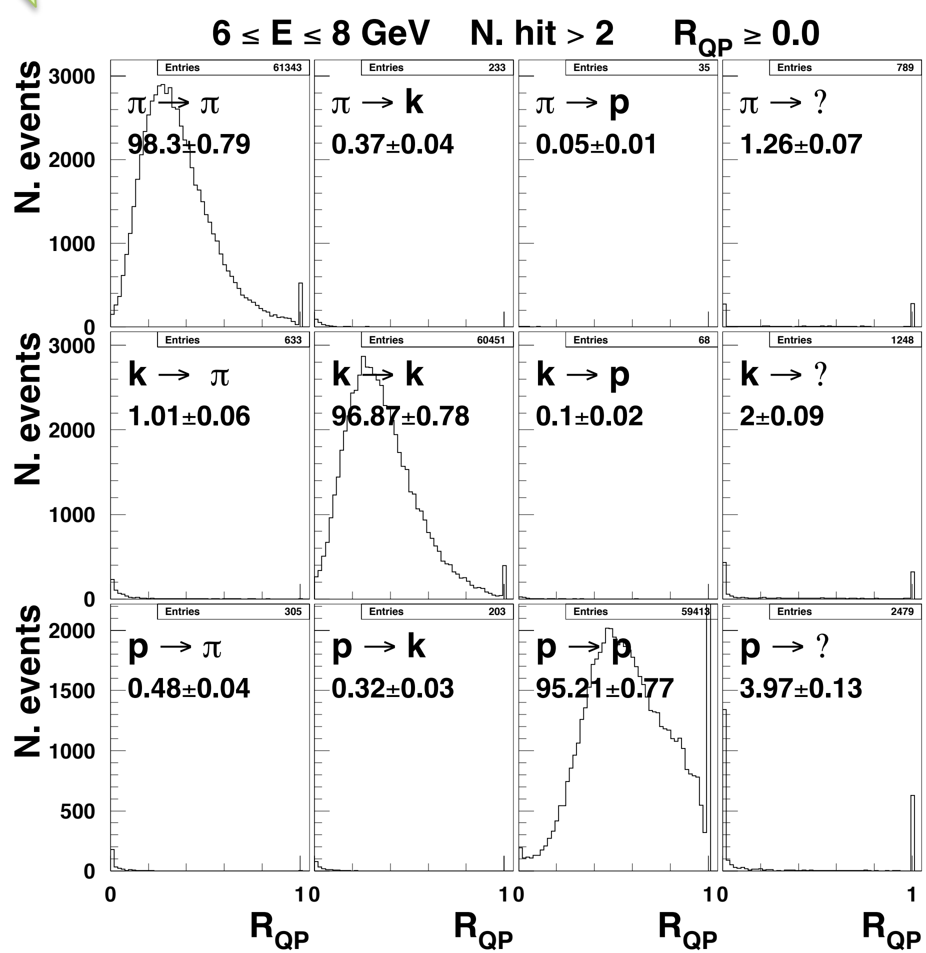
LH performances vs bending (High P)

Differences in R_{QP} shape vanish

OUT-bending (positives)



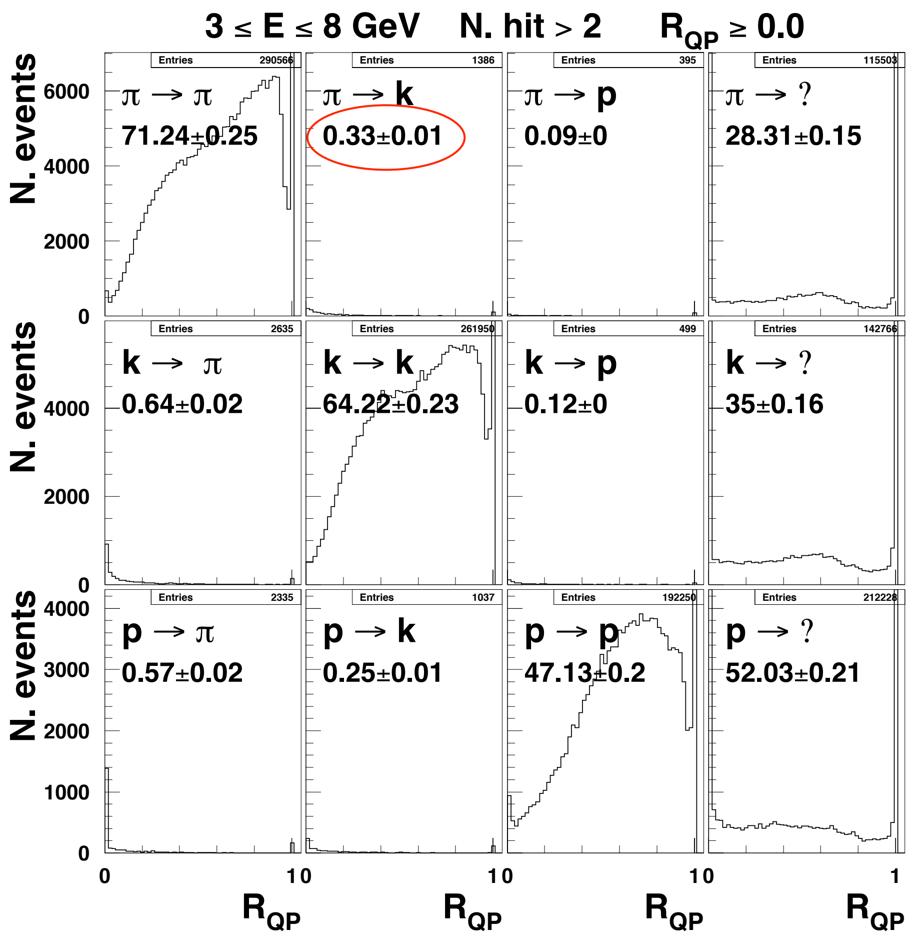
IN-bending (negatives)



LH performances vs R_{QP} cut

With R_{QP} it is possible to reduce by a factor 2 the contamination with small impact on the efficiency

OUT-bending (positives)



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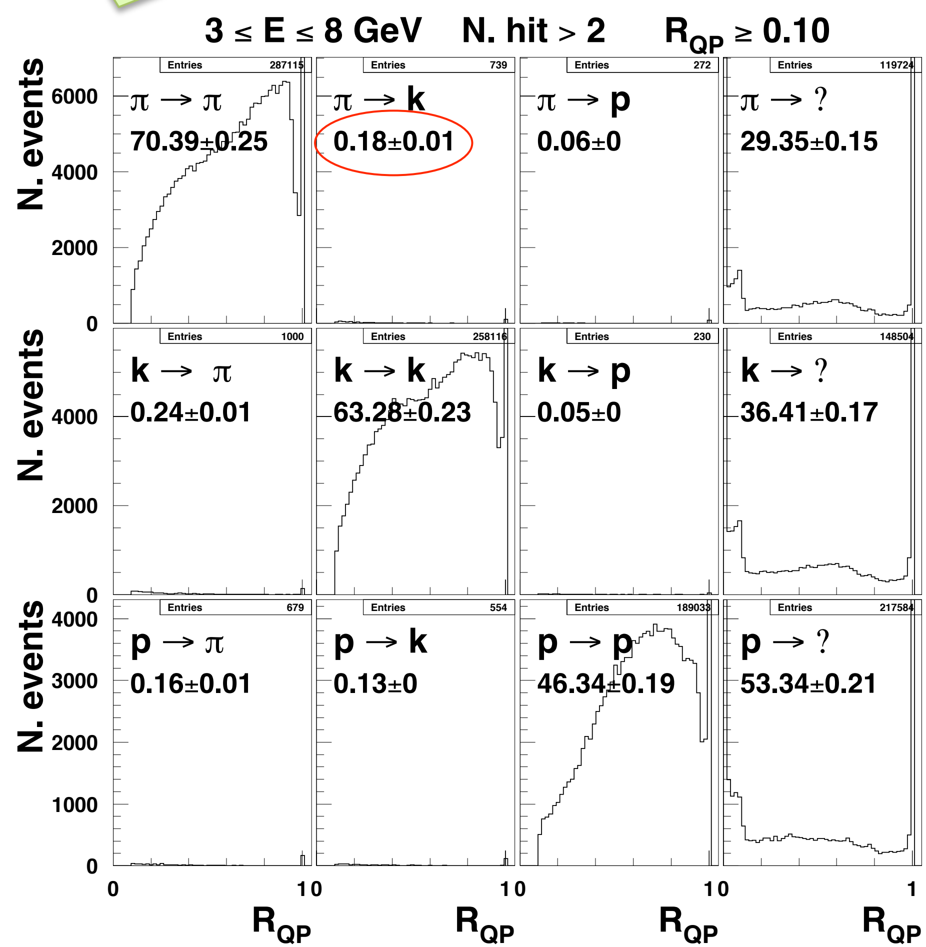

LH performances vs R_{QP} cut

With R_{QP} it is possible to reduce by a factor 2 the contamination with small impact on the efficiency

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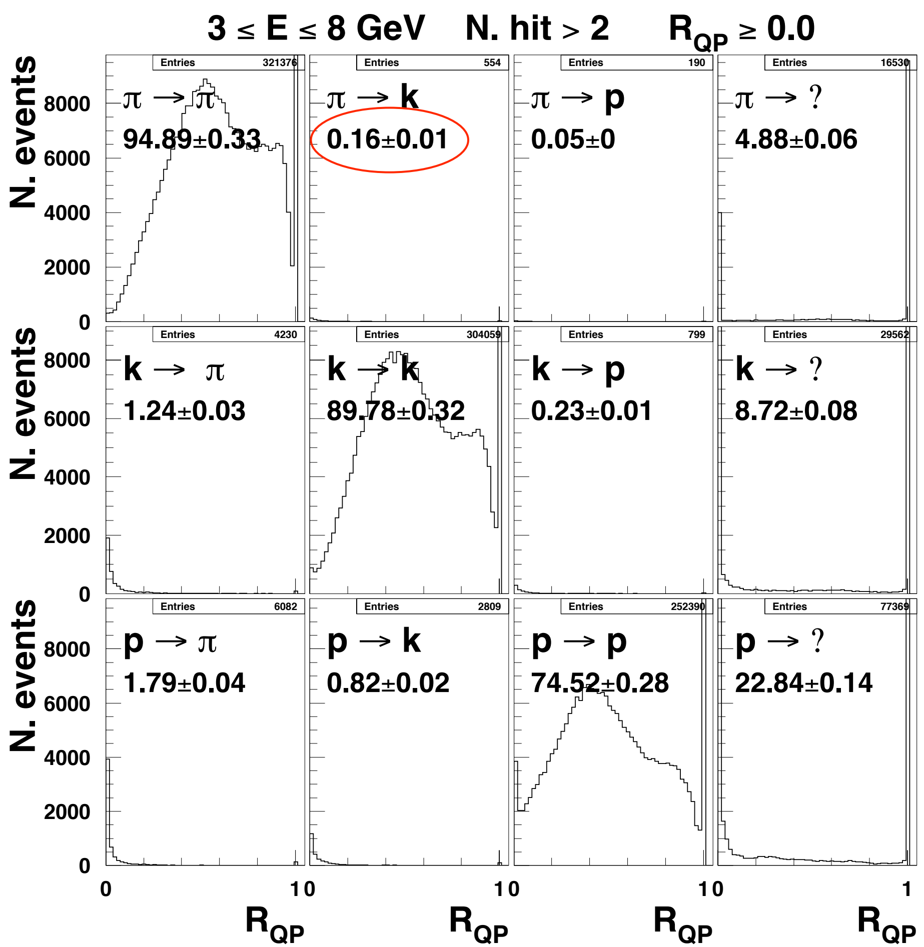
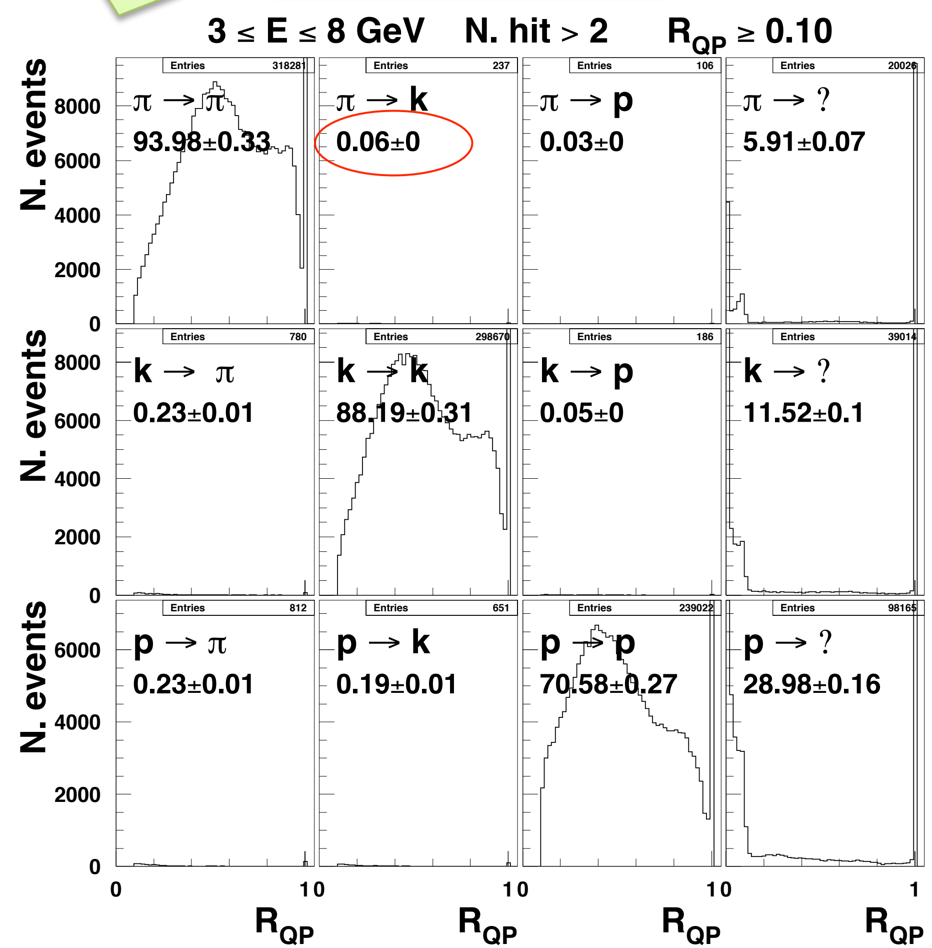
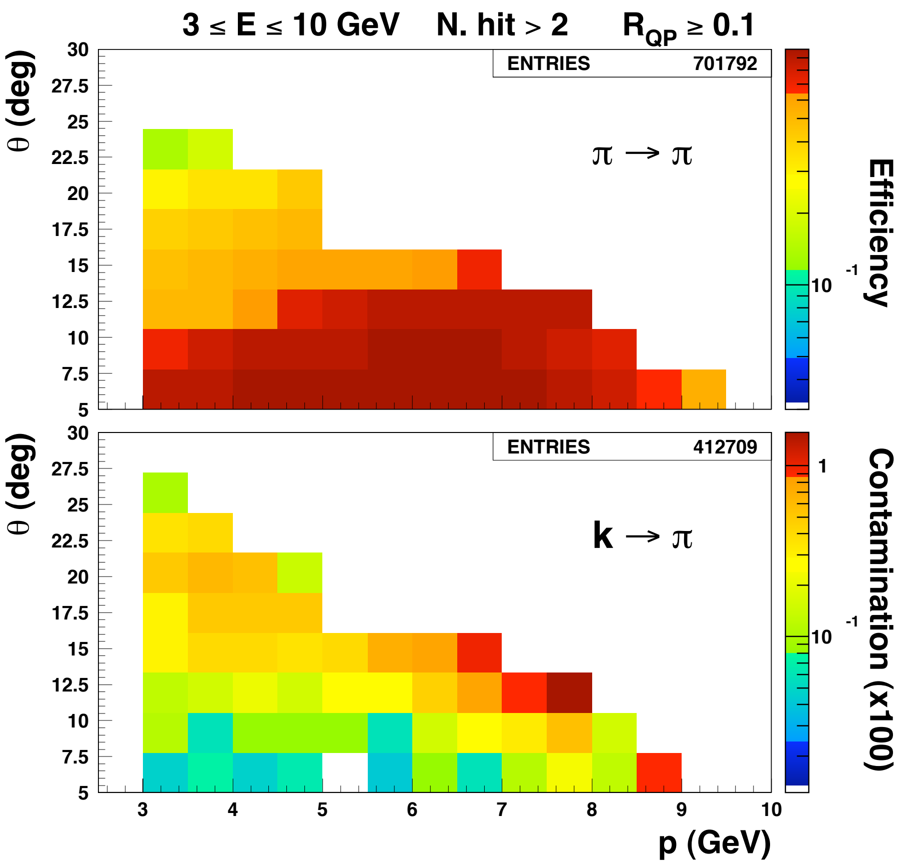


IN-bending (negatives)

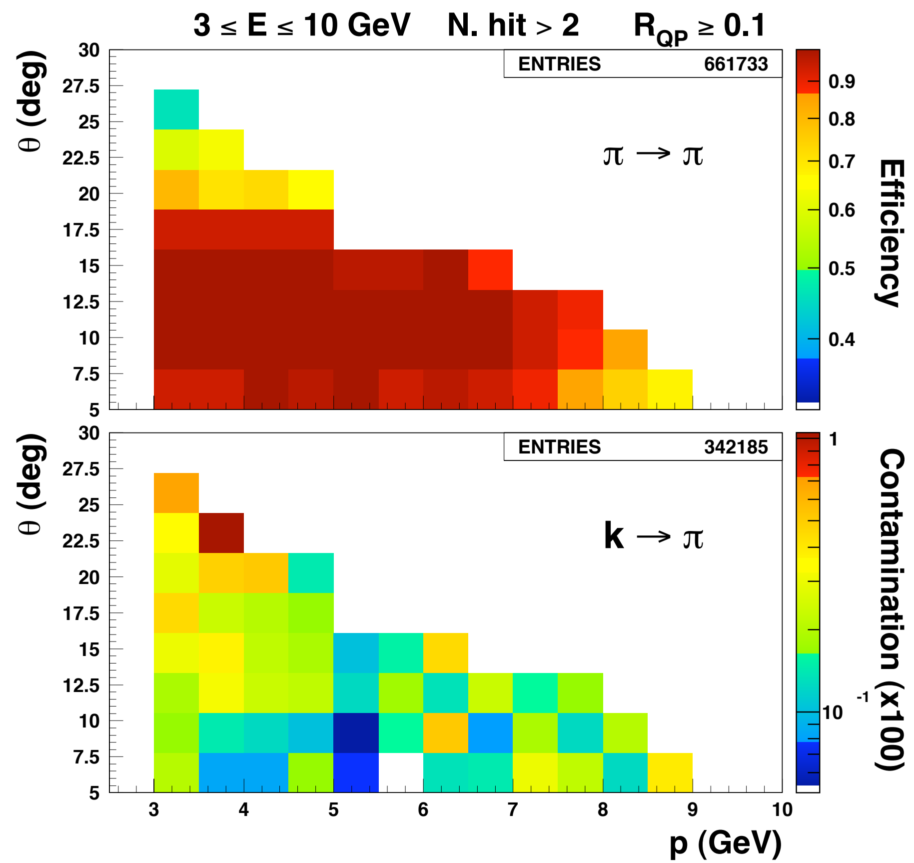


LH performances in 2D

OUT-bending (positives)



IN-bending (negatives)



Prototype for standard set-up

Geometry:

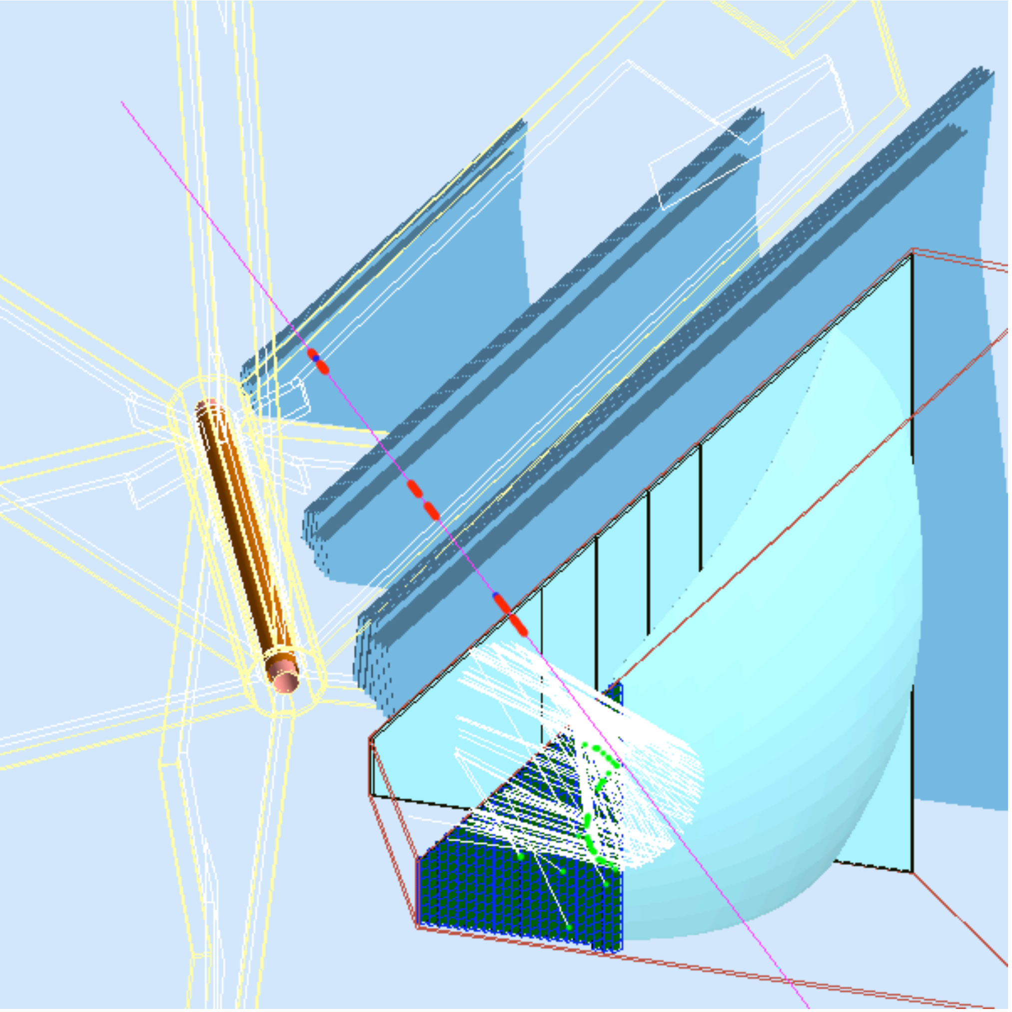
rich_build_radtrap_mirror35_default.pl

On the Jlab GEMC database

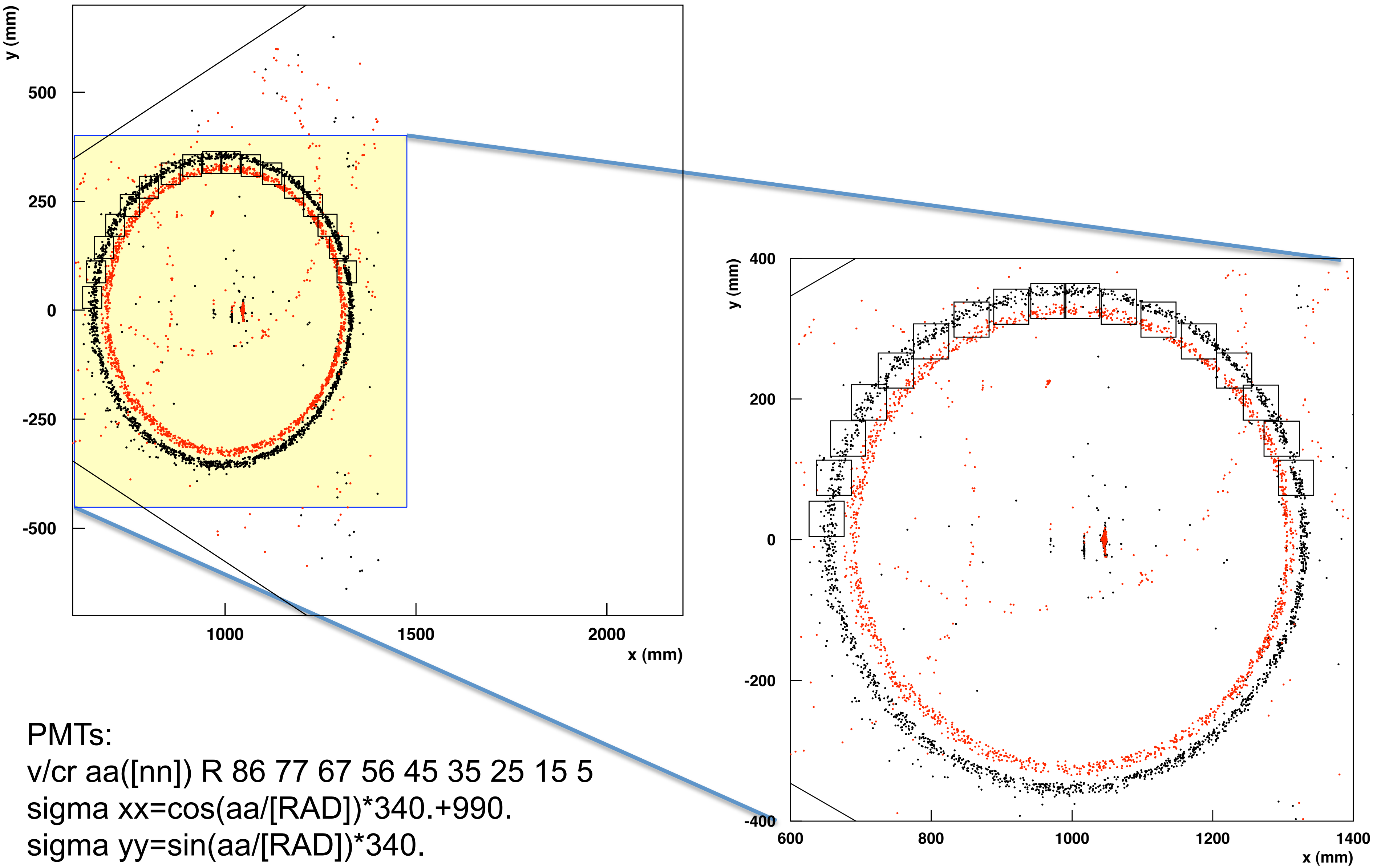
Only one isolated sector

No magnetic field

Aerogel & PMTs as in CLAS12



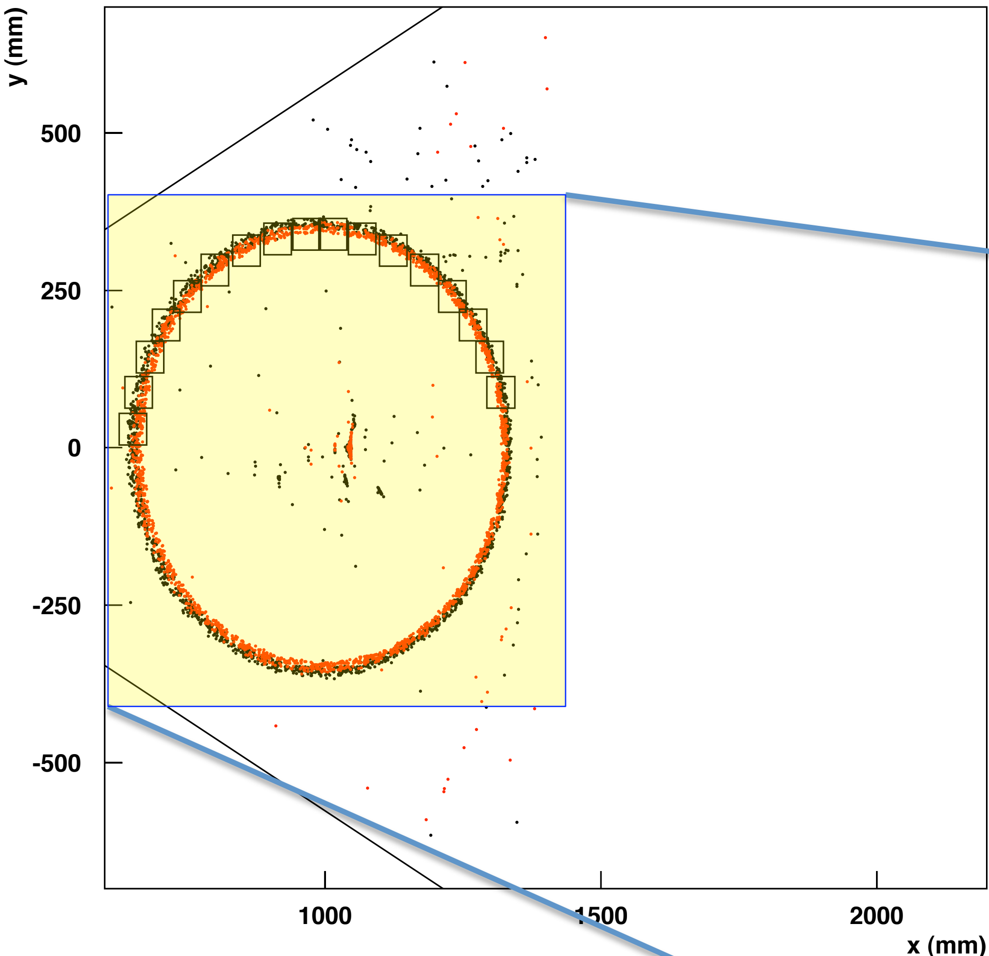
9° degrees, 4 GeV/c

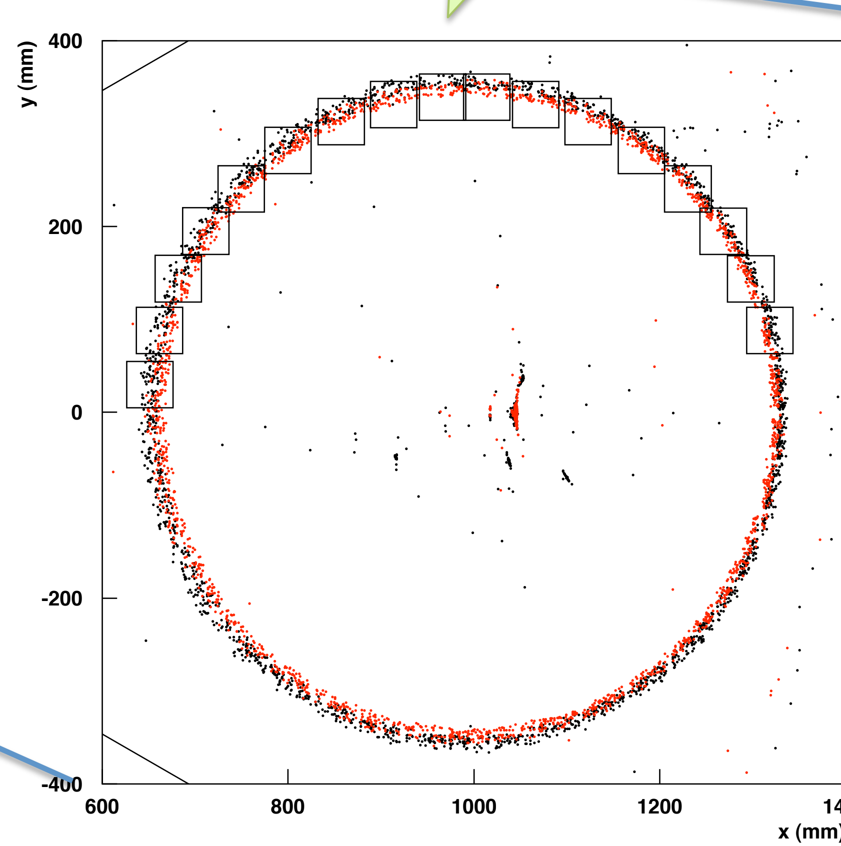


PMTs:
v/cr aa([nn]) R 86 77 67 56 45 35 25 15 5
sigma xx=cos(aa/[RAD])*340.+990.
sigma yy=sin(aa/[RAD])*340.

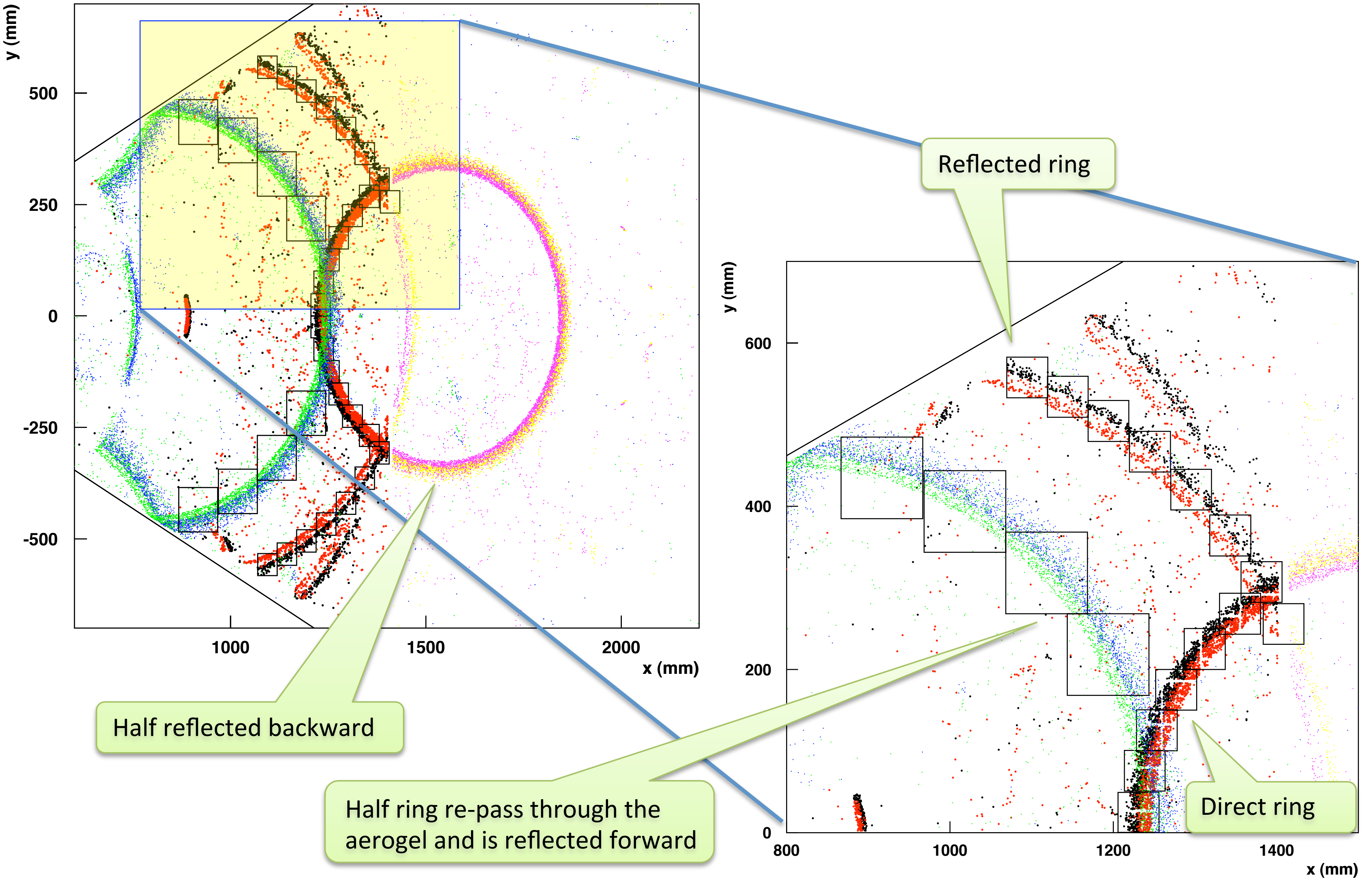
9º degrees, 8 GeV/c

Simple configuration to test the pion-kaon separation at the upper limit in momentum

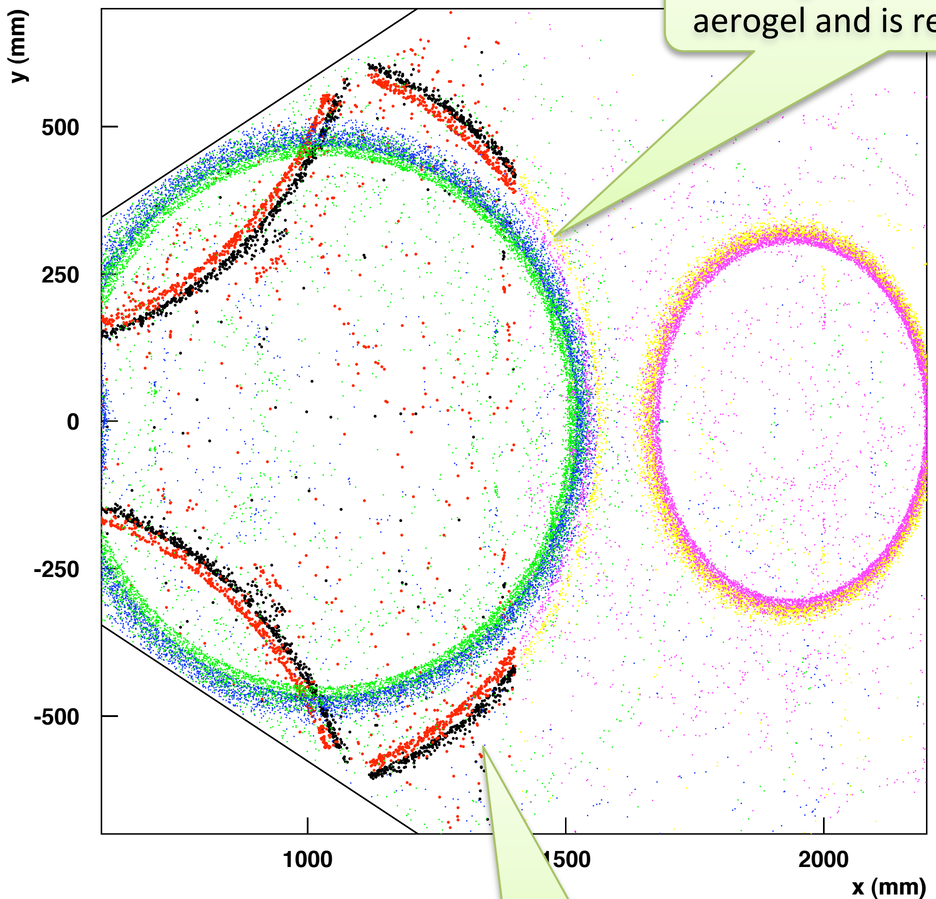




14° degrees, 6 GeV/c



18° degrees, 6 GeV/c



Full ring re-pass through the aerogel and is reflected forward

Full ring reflected backward

Only reflected ring

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**

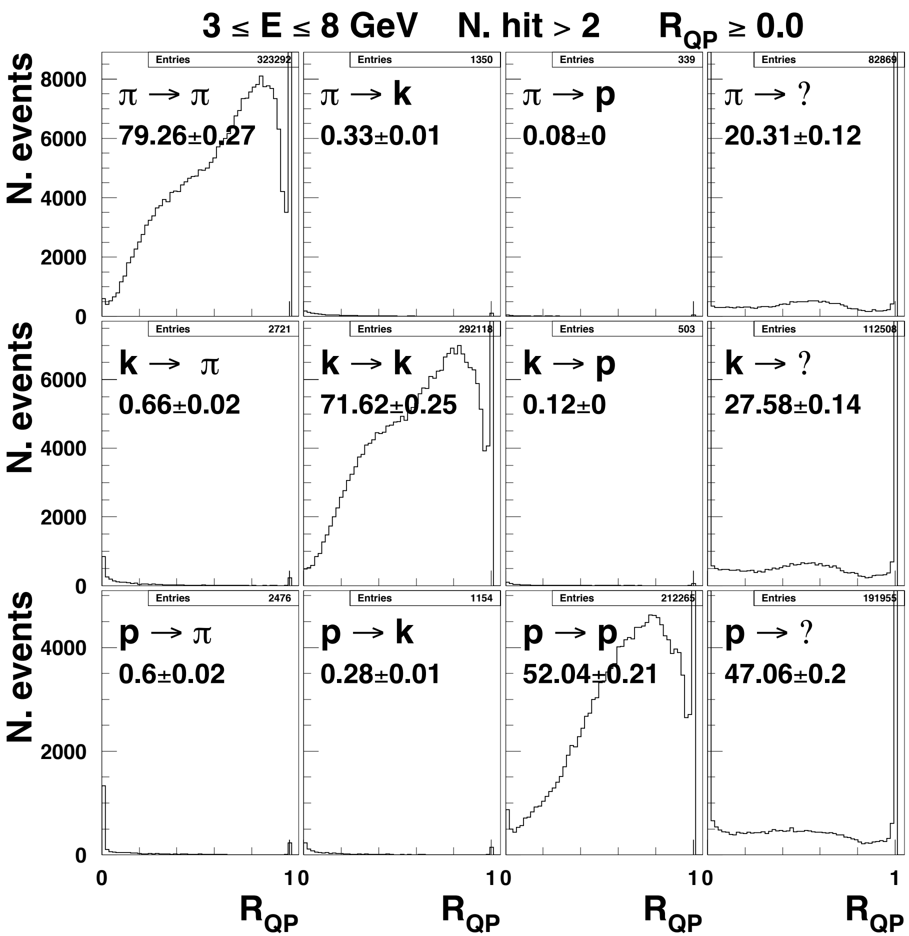
- **GEMC (GEANT4-based) simulation + reconstruction available**
  - ✔ *Detailed geometry (aerogel in tiles)*
  - ✔ *Optical effects (mirror reflectivity and quality)*
  - ✔ *Digitalization*
  - ✔ *Background (Rayligh)*
  - ✔ *Realistic components characteristics*
  - ✔ *Likelihood based on direct ray-tracing*
  - * *Validation of the preliminary results ongoing*
  - * ***Optimal compromise to be found***

- **Proof of principle with a realistic prototype:**
  - * ***Performances at upper momentum limit (up to 8 GeV/c)***
  - * **Double reflection concept**
  - * **Hardware components**

TEST

In the LH, Rayleigh scattering is treated as background
Significant increase of events with too few photoelectrons: to be investigated

Iside rayleigh



Anubis rayleigh