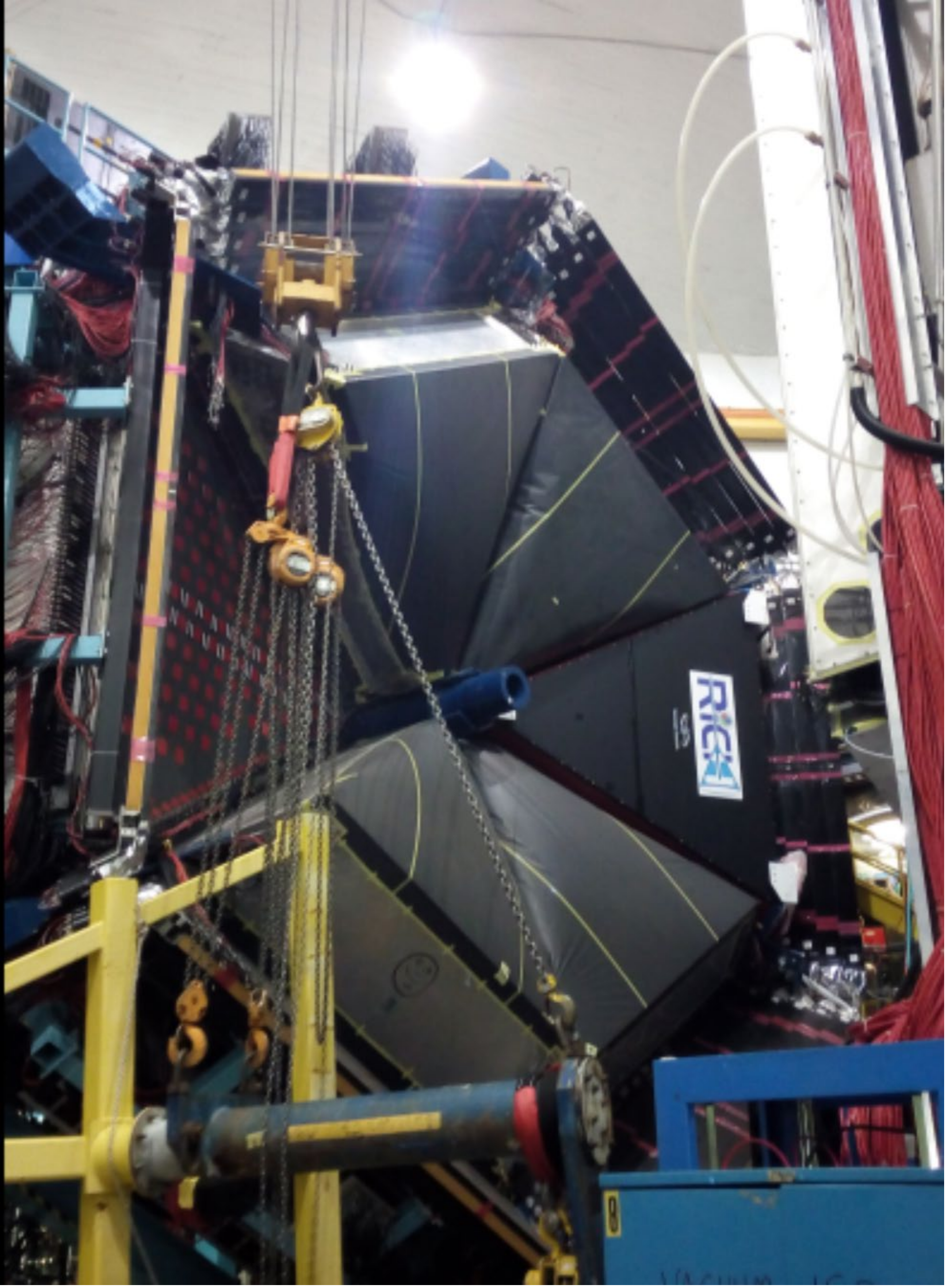


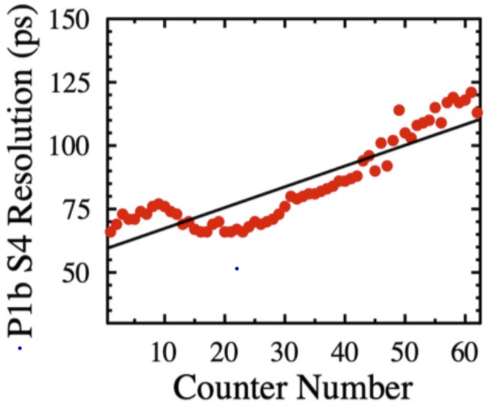
CLAS12 Kaon Detection with RICH

Marco Mirazita – INFN Frascati

Kaon ID in CLAS12

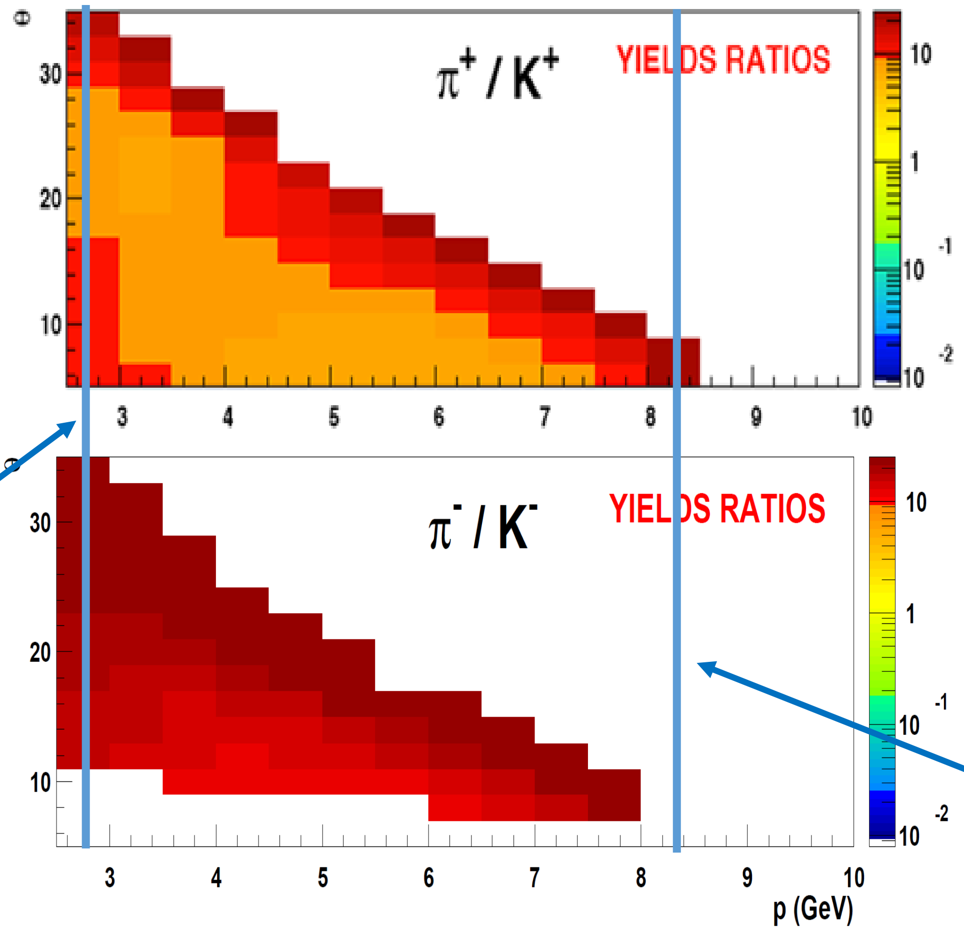
Relative yield production require ~4σ pion-kaon separation and ~3σ proton-kaon separation

Time-of-flight



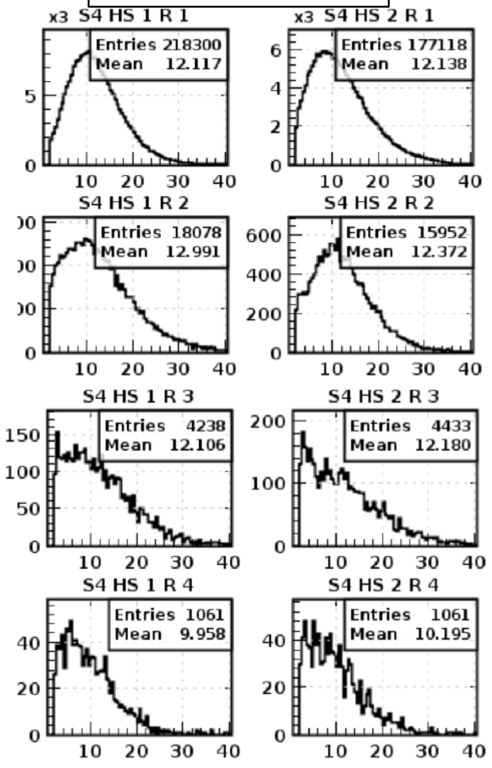
4σ separation up to 2.8 GeV with σ_{TOF} = 80 ps
→ only for paddle>30

RICH TDR (2013)



High threshold Cherenkov

“effective” npe



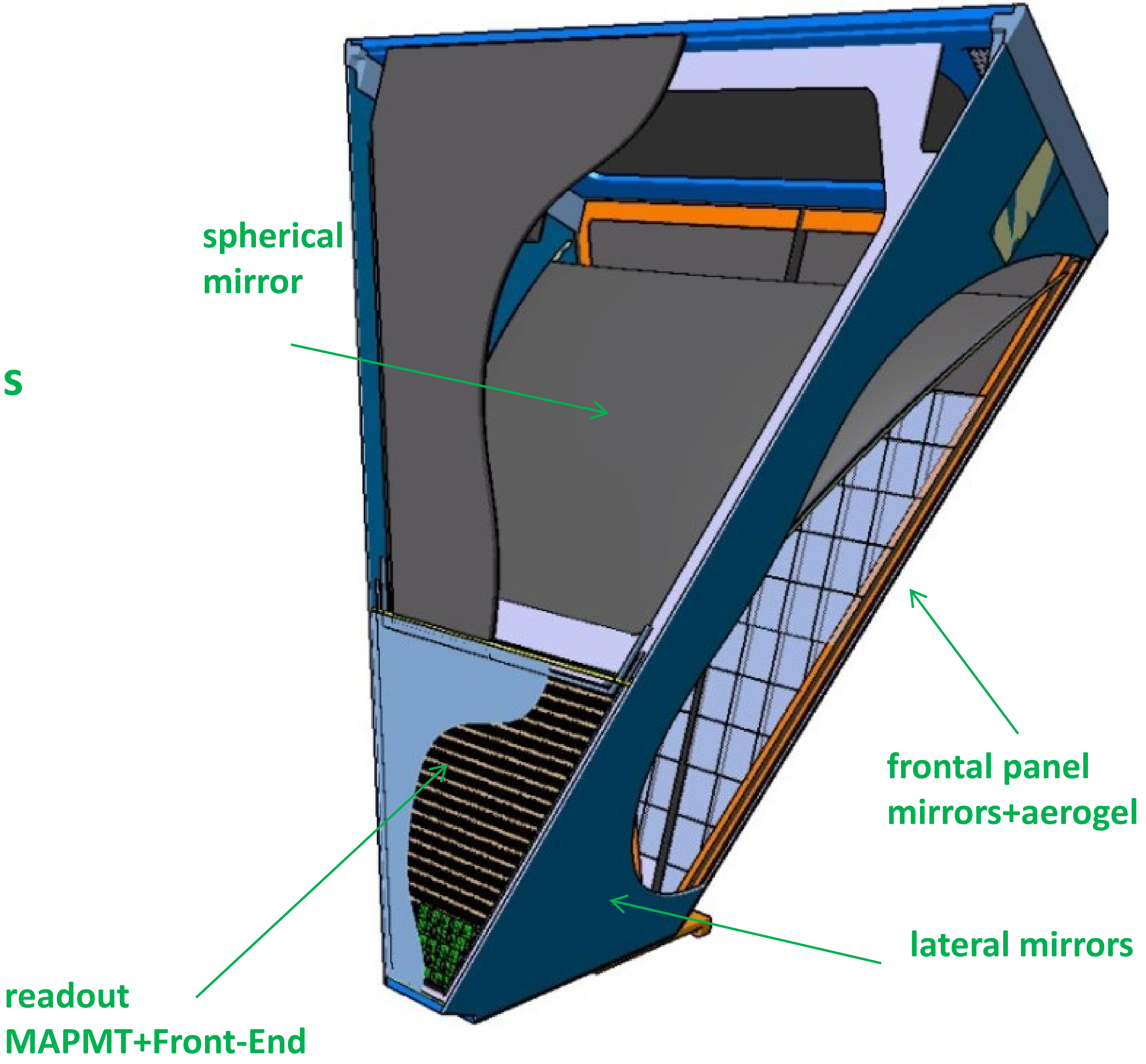
4σ separation only above 8 GeV/c with <npe>=12

The RICH design

Hybrid design with proximity and mirror focusing imaging

1. **Aerogel to match the momentum range**
2. **Photomultipliers to detect visible photons**
3. **Mirrors to reduce the detection area**

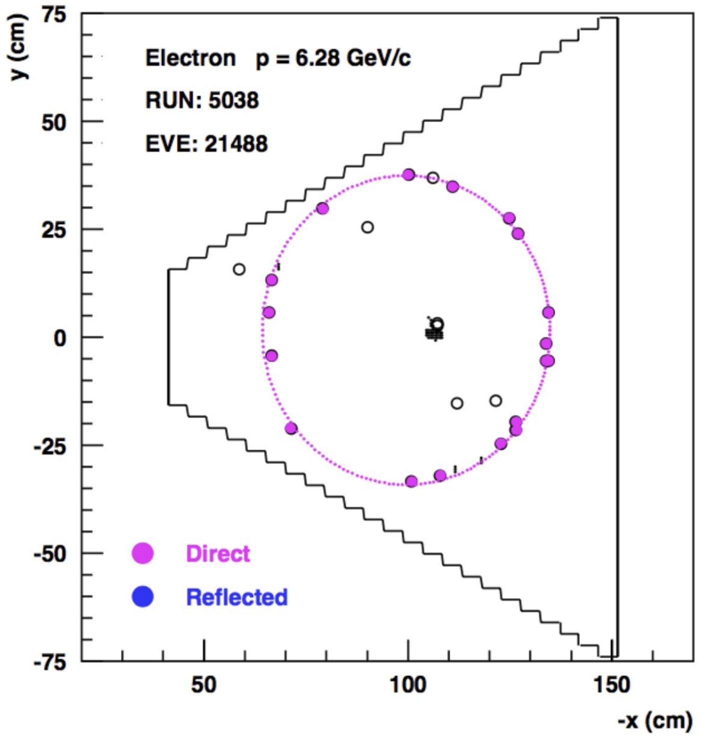
- **102 aerogel tiles in three layers**
- **391 MAPMTs with 25024 independent readout channels**
- **7 planar mirrors**
- **10 spherical mirrors**

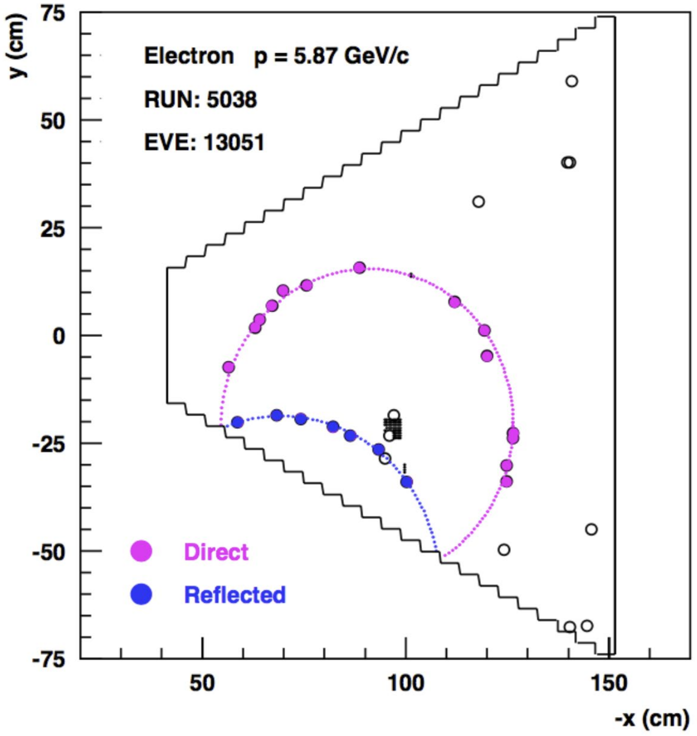


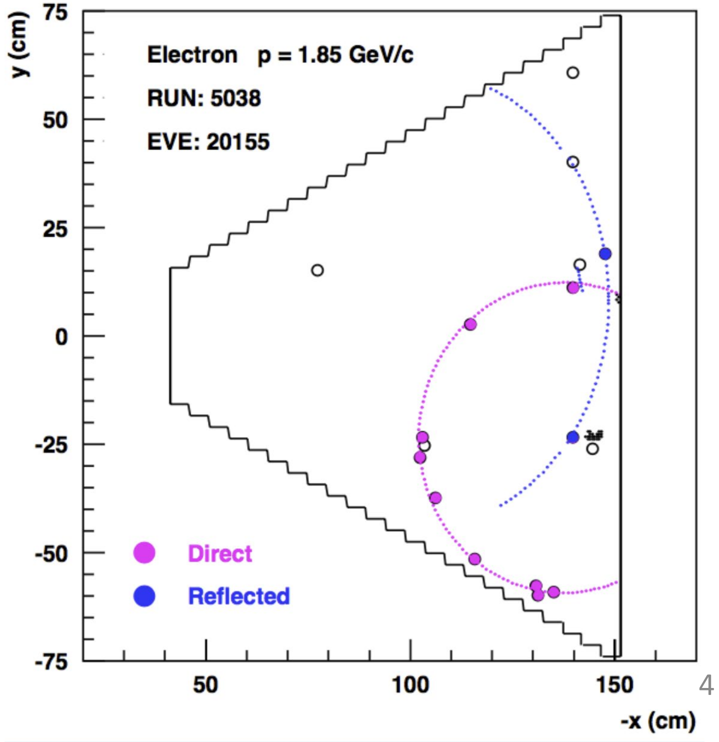
RICH reconstruction

Goals:

1. **estimate the Cherenkov angle for all the hits in the MAPMT plane**
   → Ray tracing of Cherenkov photons inside the RICH, based on:
   - **the geometry of the detector**
   - **the charged particle trajectory from CLAS12**
2. **perform the particle ID of each charged track in the detector (likelihood approach)**
   - **prior knowledge of the refractive index**







RICH cooked data

An effort has been done in 2019 in order to have the RICH ready for the pass1 massive cooking of RG-A and RG-B data

- **implementation and updates of the RICH reconstruction in coatjava**
- **revision of the reconstruction banks**
- **completion of the time calibration suite**
- **alignment of the RICH module with respect to CLAS12**
- **relative alignment between the aerogel radiator and the MAPMT plane**

Time calibration results

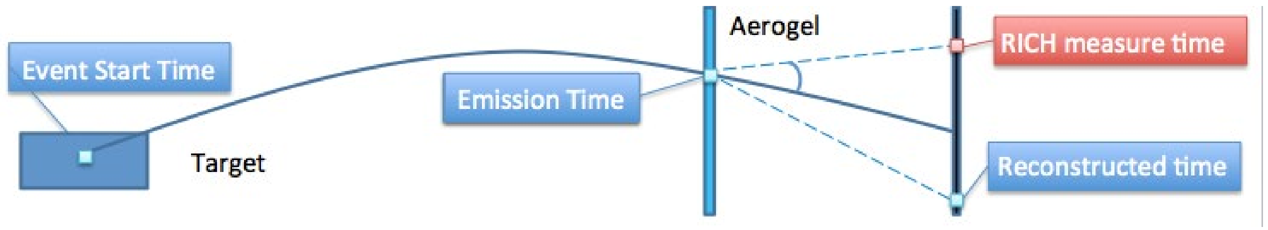
https://github.com/JeffersonLab/clas12calibration-rich

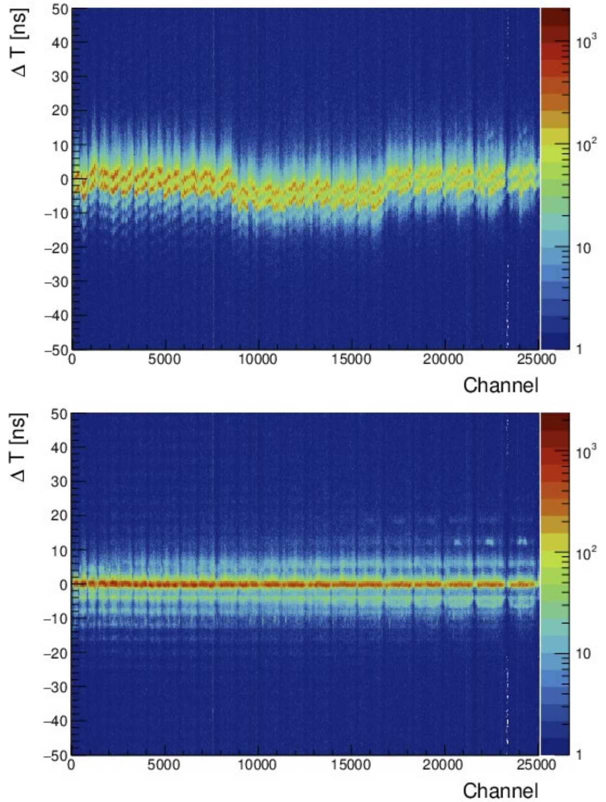
Alignment of the measured time to the one provided by CLAS12:

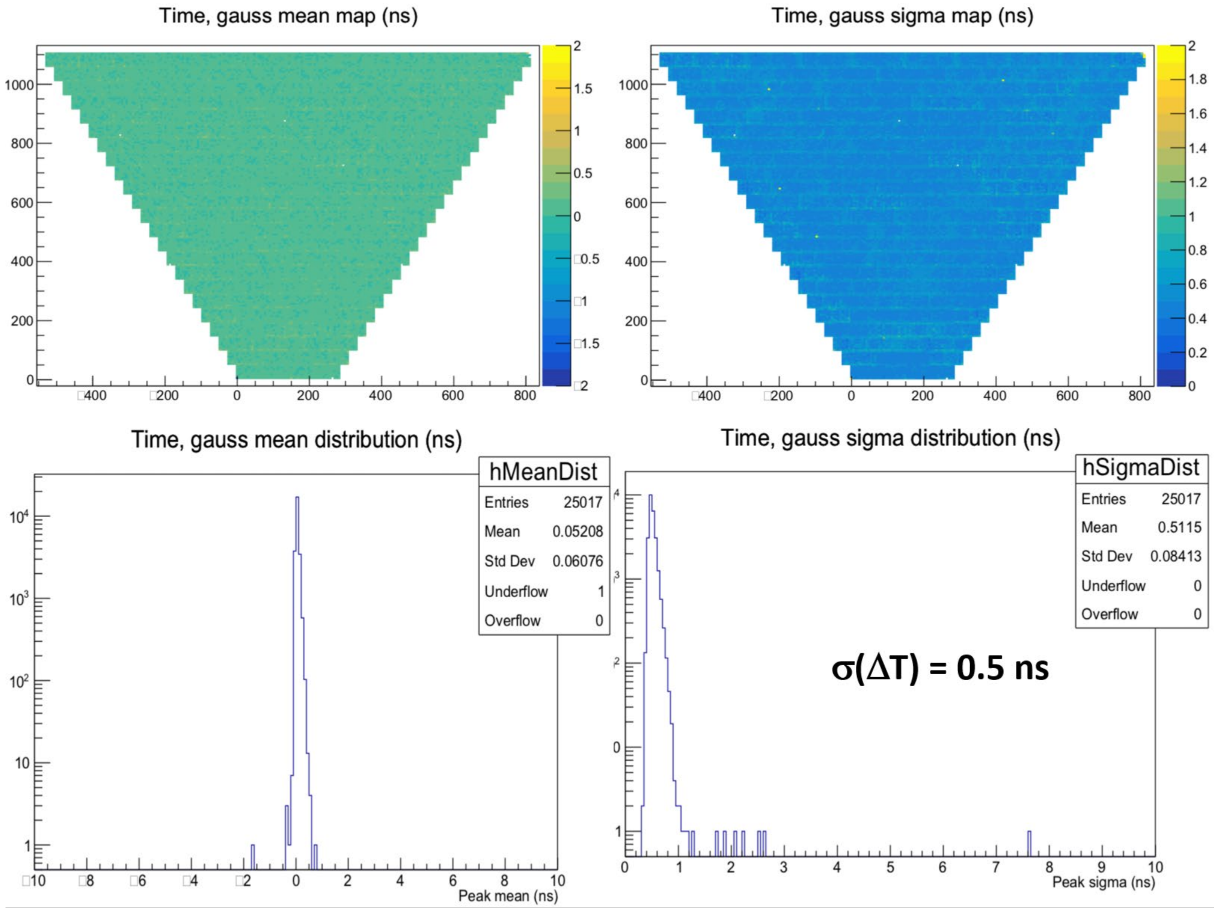
$$\Delta T = T_{meas,corr} - T_{start} - T_{rec}$$

- **25024 time offsets**
- **391 time walk functions (4 parameters each)**

➢ **goal: time resolution < 1 ns**

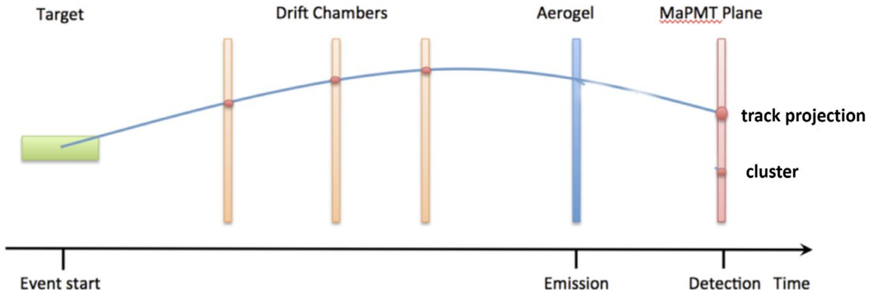




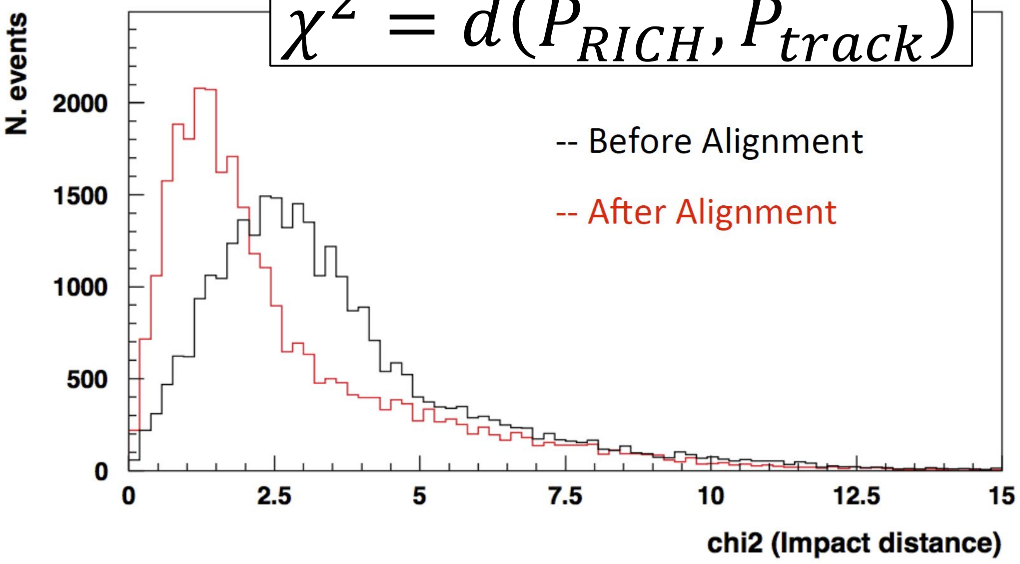


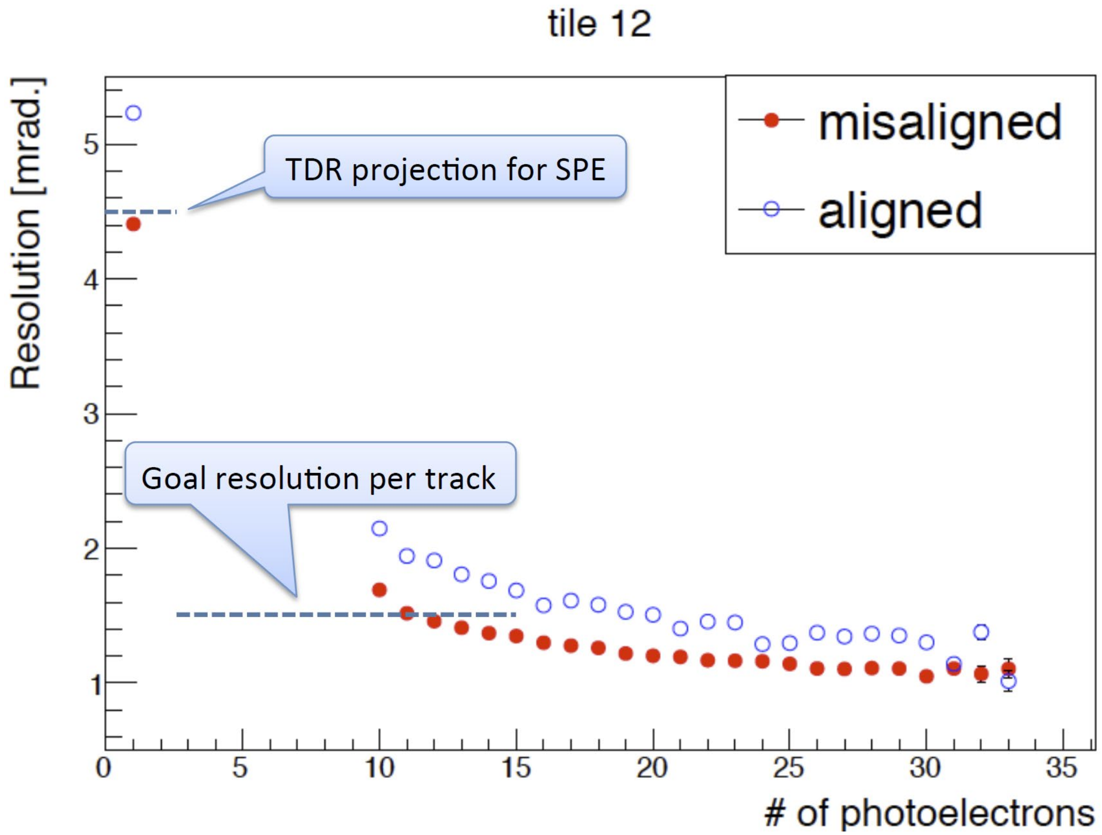
RICH alignment with respect to CLAS12

- Alignment of the RICH module with respect to CLAS12 comparing the projection of the DC trajectory to the RICH MAPMT plane and the position of the track cluster
- Relative alignment between the aerogel and the MAPMT

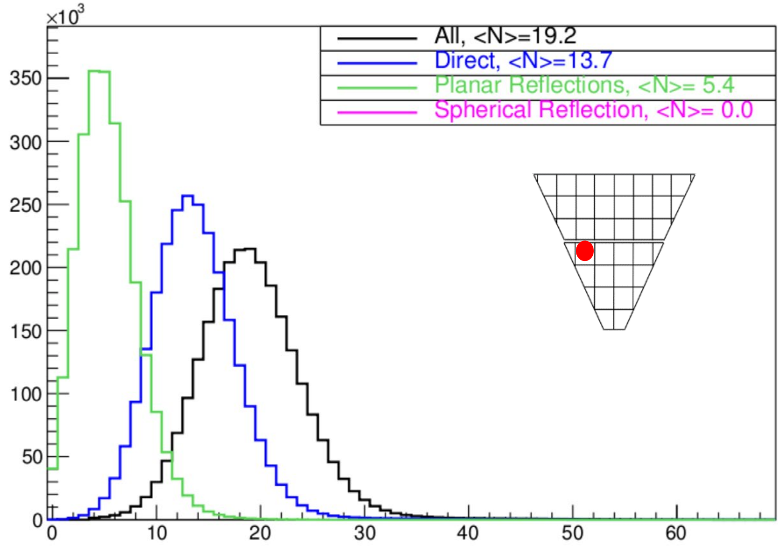


$$\chi^2 = d(P_{RICH}, P_{track})$$



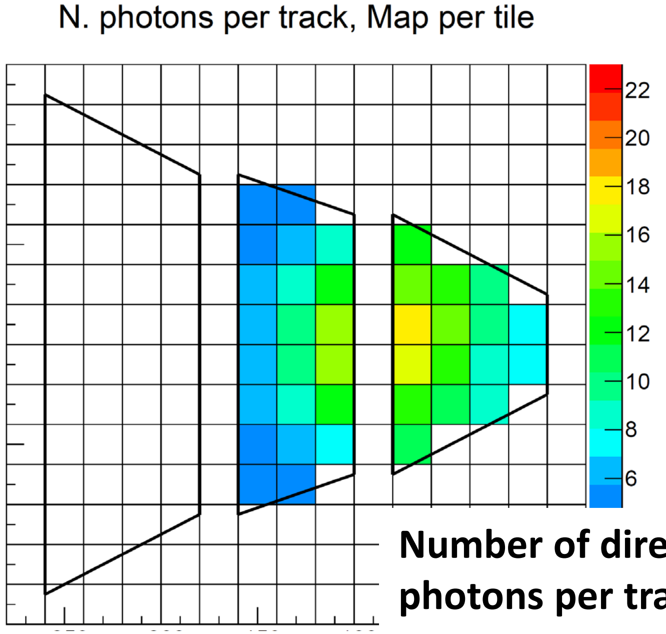


RICH performance using e-: Number of p.e. per track



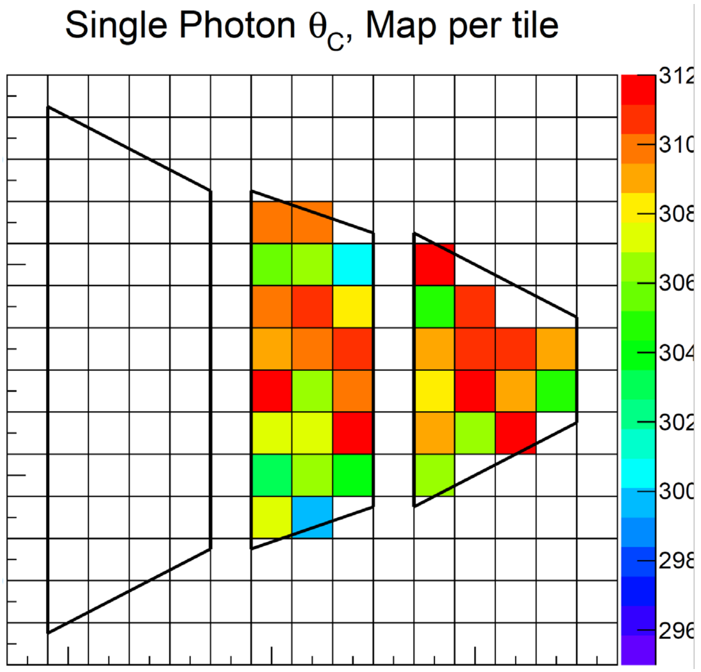
RG-A inbending – pass1

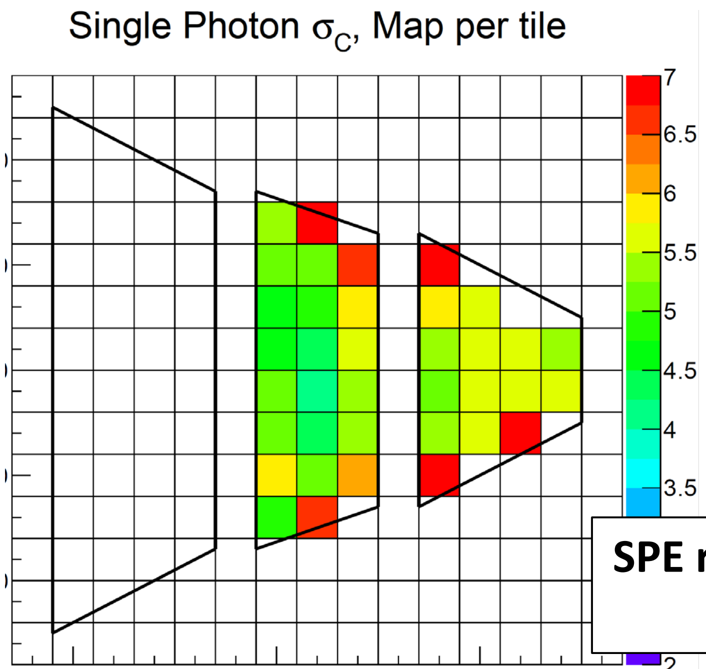
TDR:
Npe~17-19 p.e. in forward polar angles and central detector



Number of direct photons per track

Direct photons reconstruction

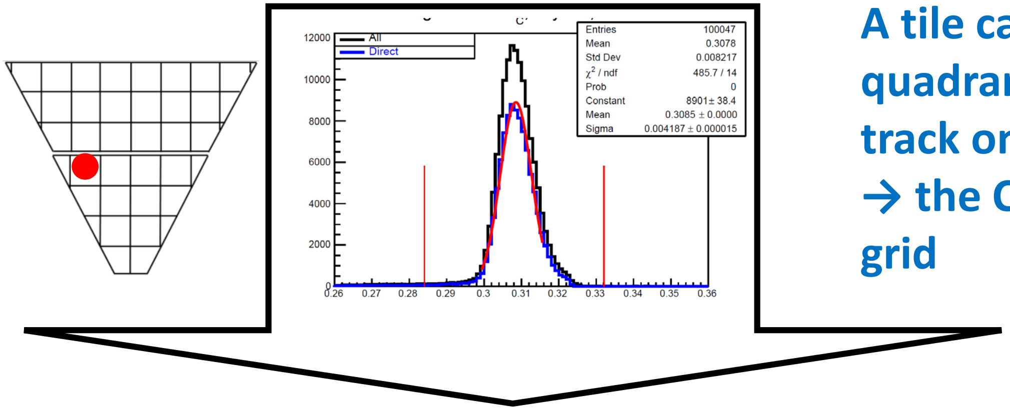




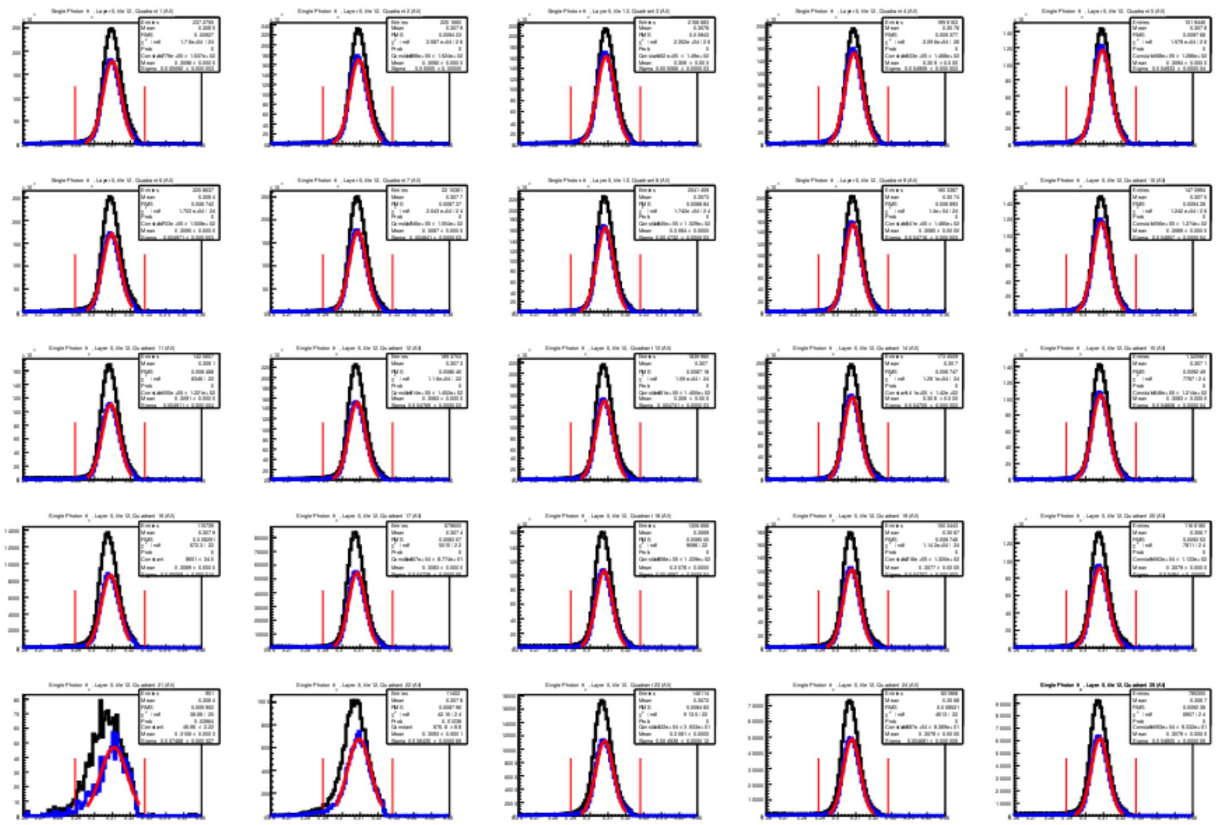
SPE resolution spec.
4.5 mrad

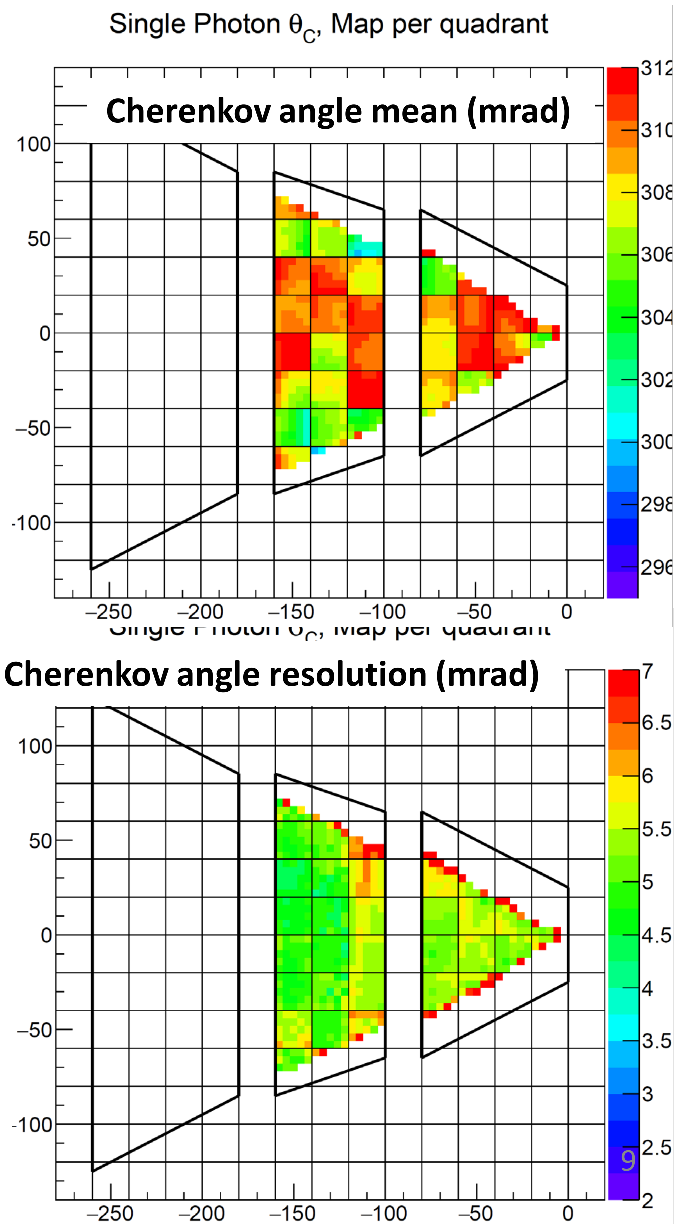
Mapping the aerogel tile

Direct photons
Electrons



A tile can be subdivided in small quadrants using the projection of the track on the aerogel plane
→ the CCDB can allocate up to a 15x15 grid





Alignment refinement

The precise alignment of the RICH internal element must follow a step by step procedure:

1. **position of the aerogel planes: two rotation angle, one offset**
    - **relative angular distance between electrons and hadrons**
    - **inbending vs outbending data**
2. **tuning of the aerogel refractive index**
    - **electrons in CLAS12**
3. **alignment of each mirror: two rotation angles, one offset per mirror**
    - **direct vs reflected photons**

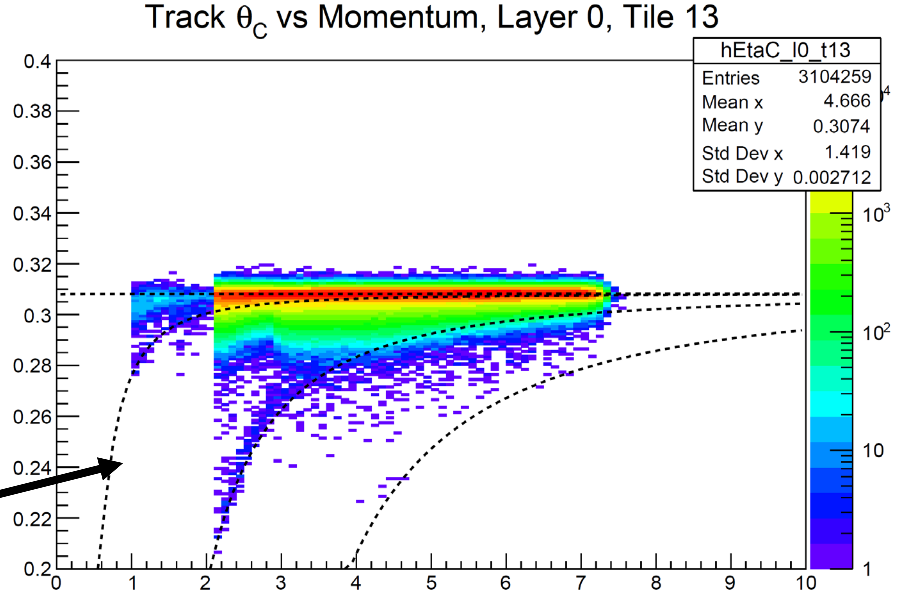
Studies for RG-A inbending, pass1 cooking will be shown

Distance between aerogel and MAPMT plane

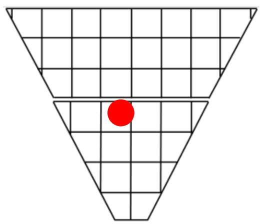
Electrons

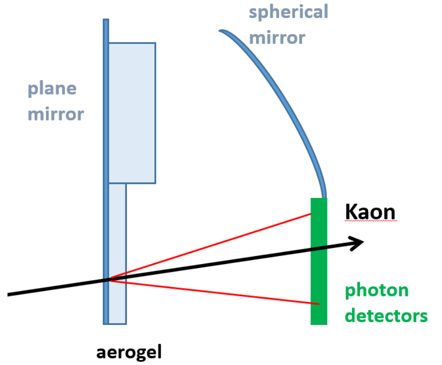
$n = 1 / \cos\theta_C$

lines from the electron Cherenkov angle



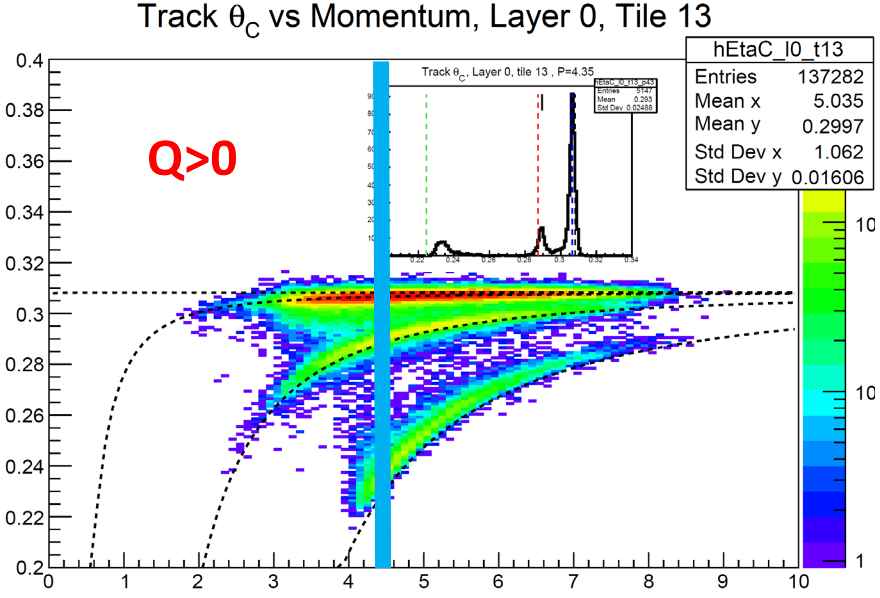
Direct photons

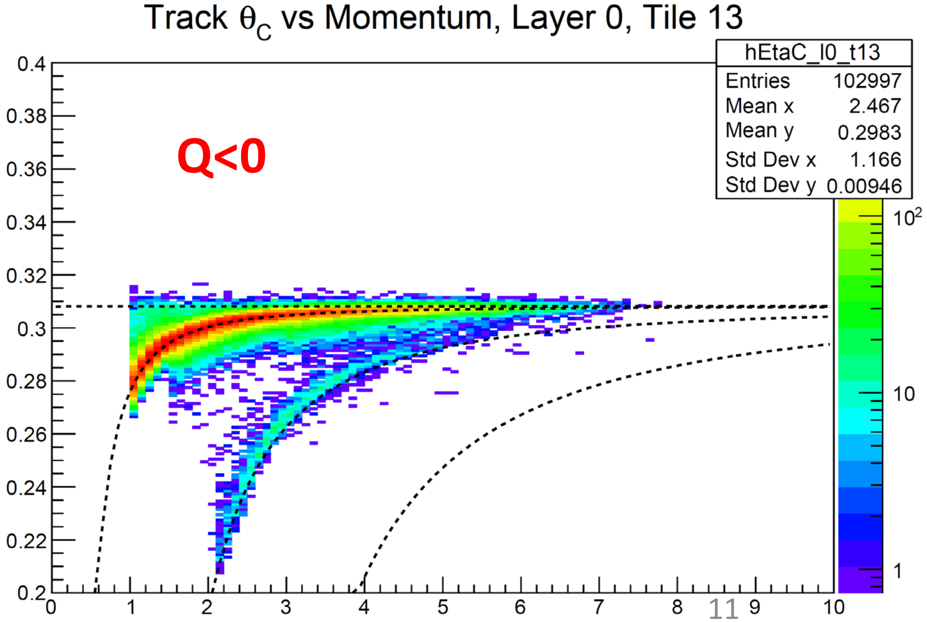




Hadrons

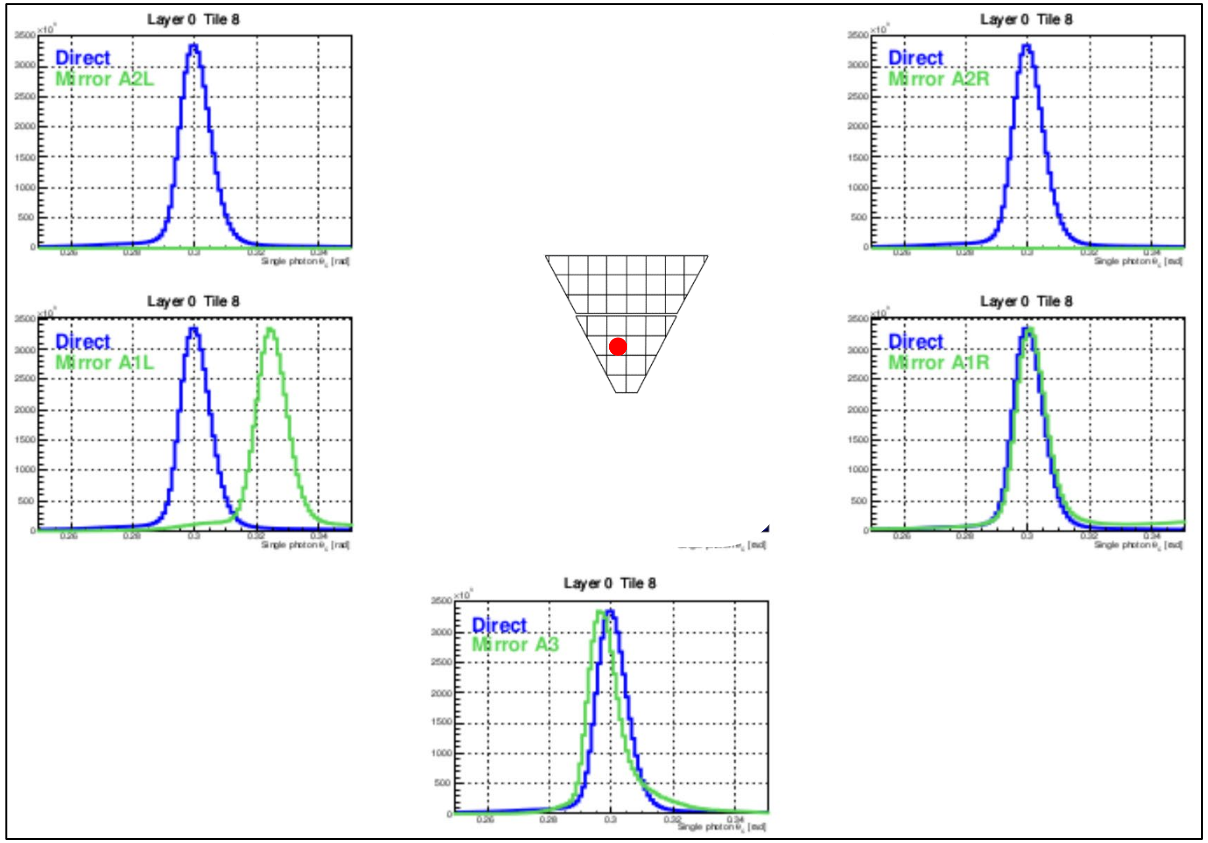
- **Wrong gap length leads to a shift of the expected angle from the reconstructed one**
- **Higher the mass, bigger the shift**

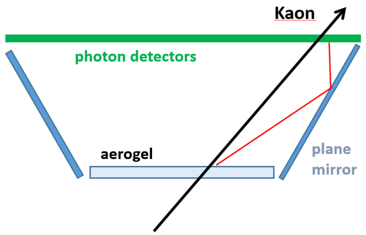


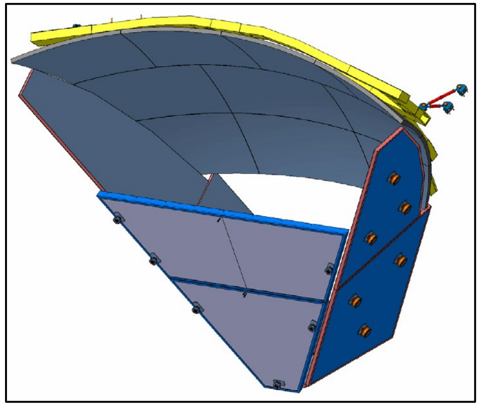


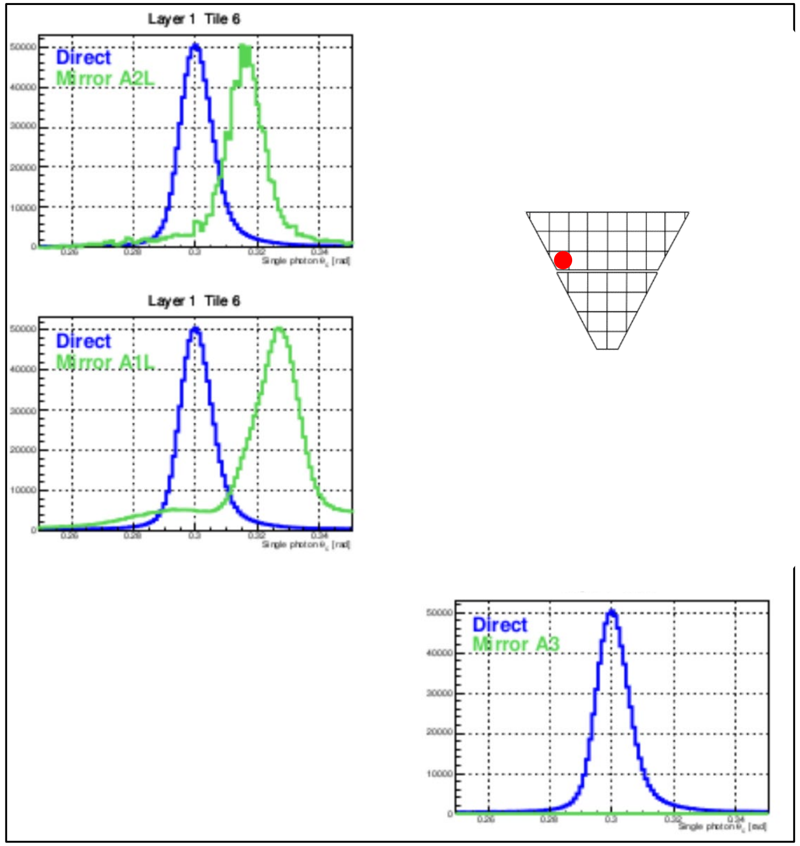
Reflected topologies: Planar mirrors

Data analyzed per tile and per mirror



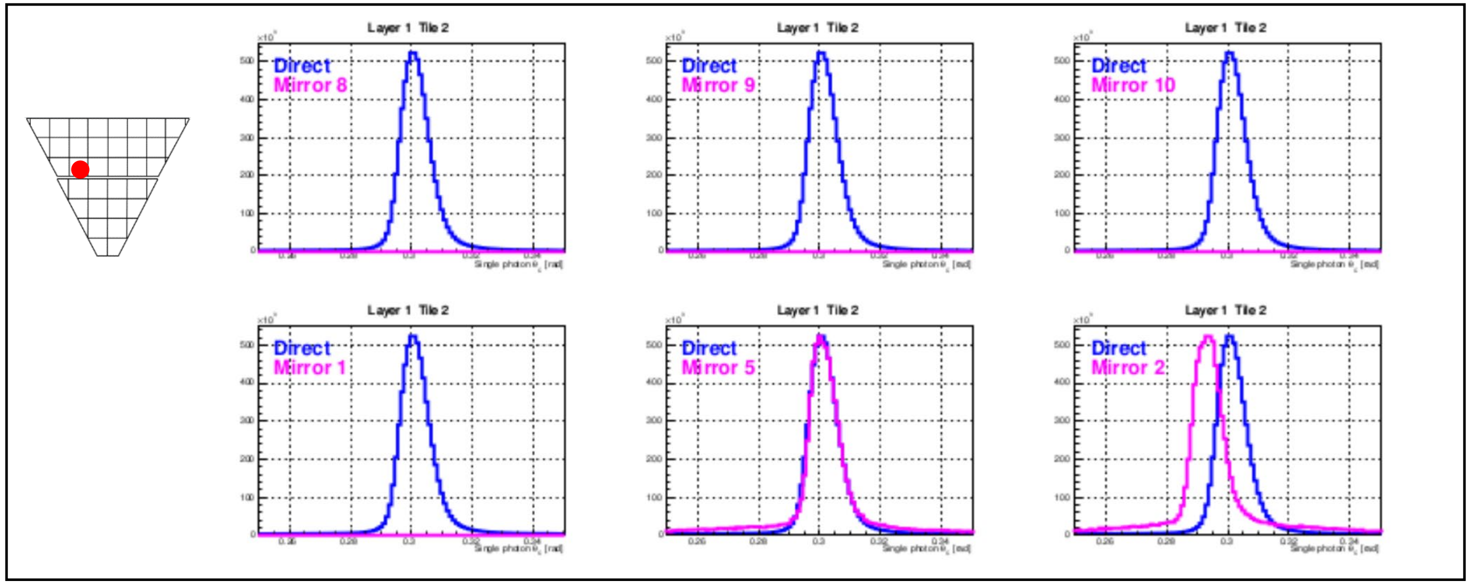


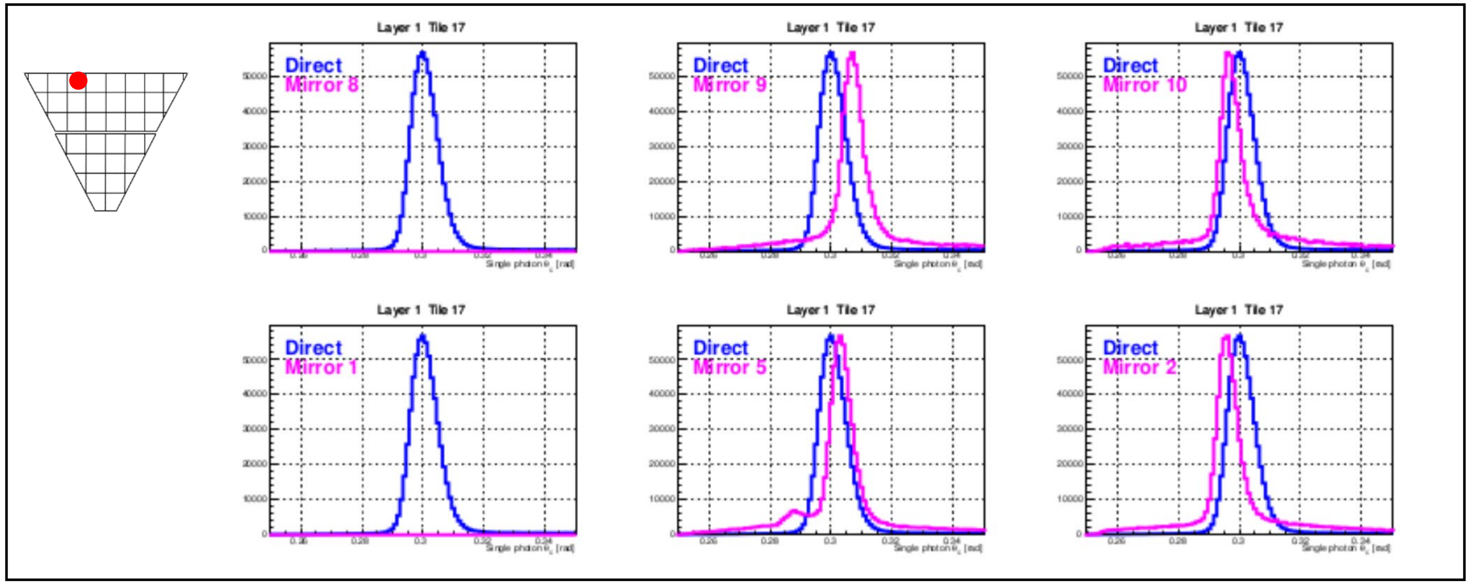




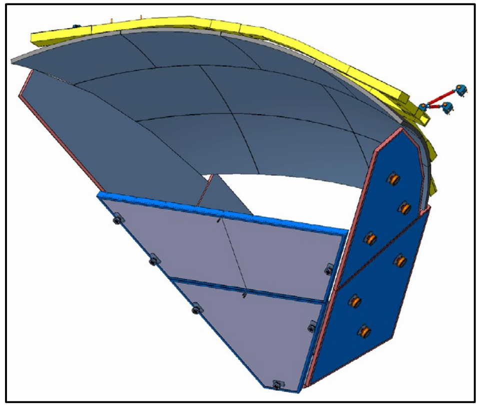
- ➢ Clear signal in all the tile-mirror combination
- ➢ Resolution similar to the direct photons
- ➢ The shift in the peak position due to misalignment

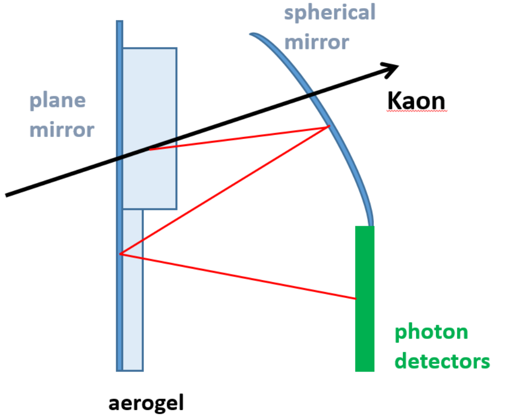
Reflected topologies: spherical mirrors





Data analyzed per tile and per mirror



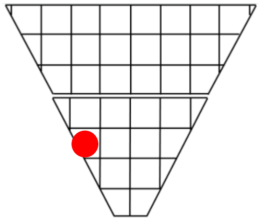


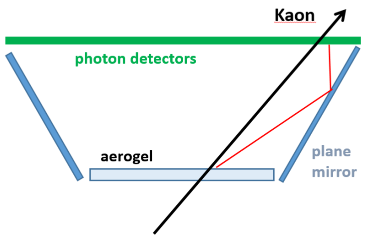
- Clear signal in all the tile-mirror combination
- Resolution similar to the direct photons
- The shift in the peak position due to misalignment

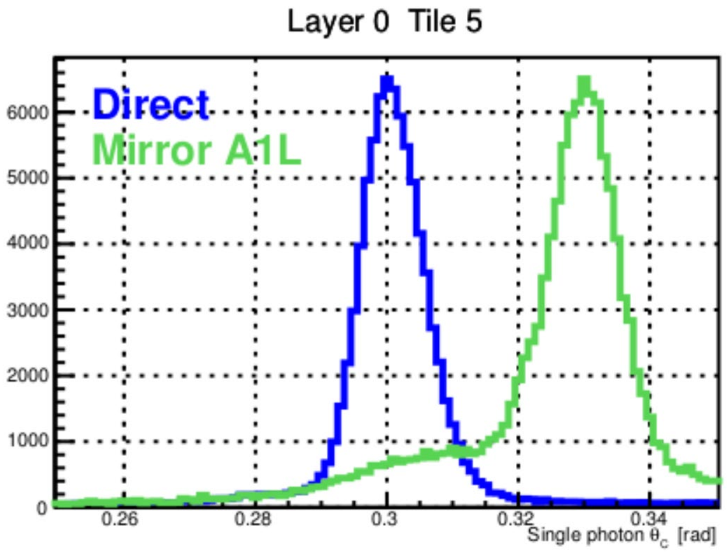
Alignment survey: planar mirror A1L

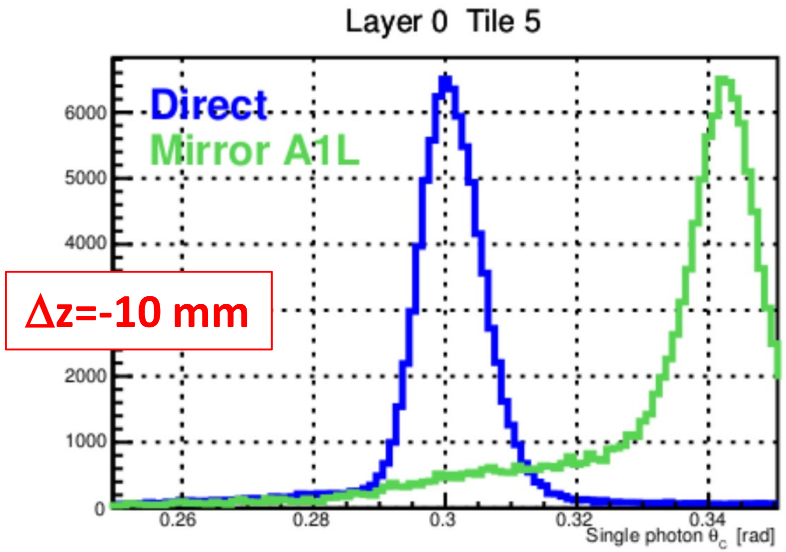
One tile and one lateral mirror

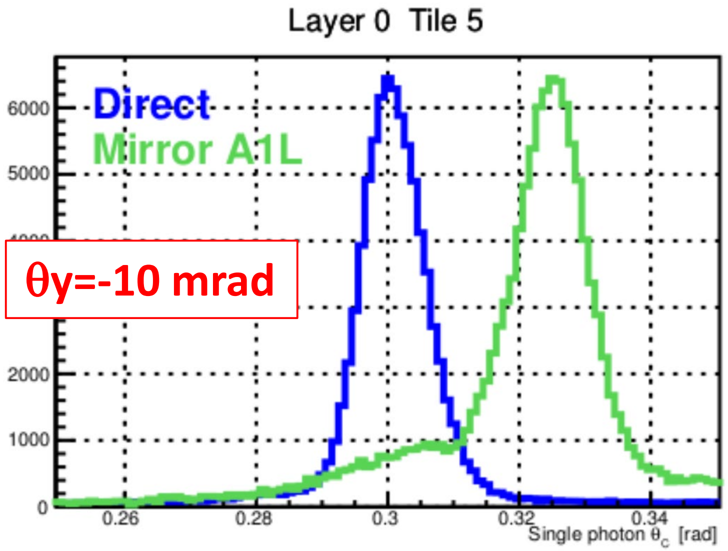
3 alignment parameters

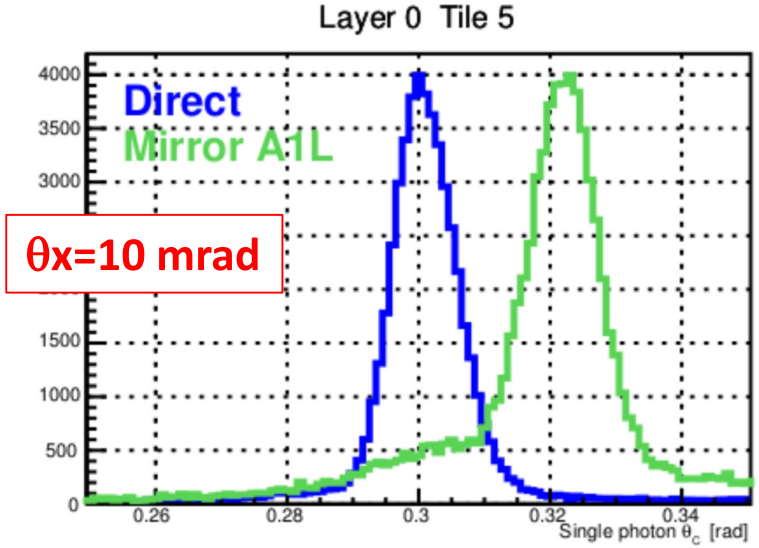


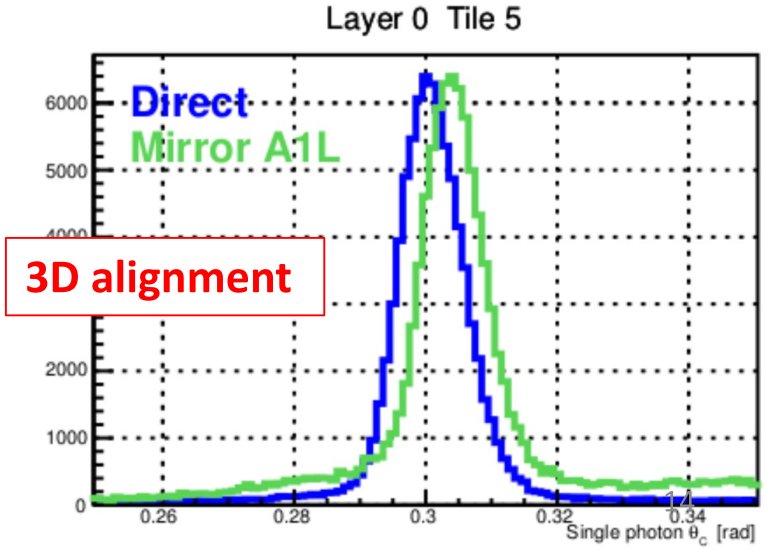










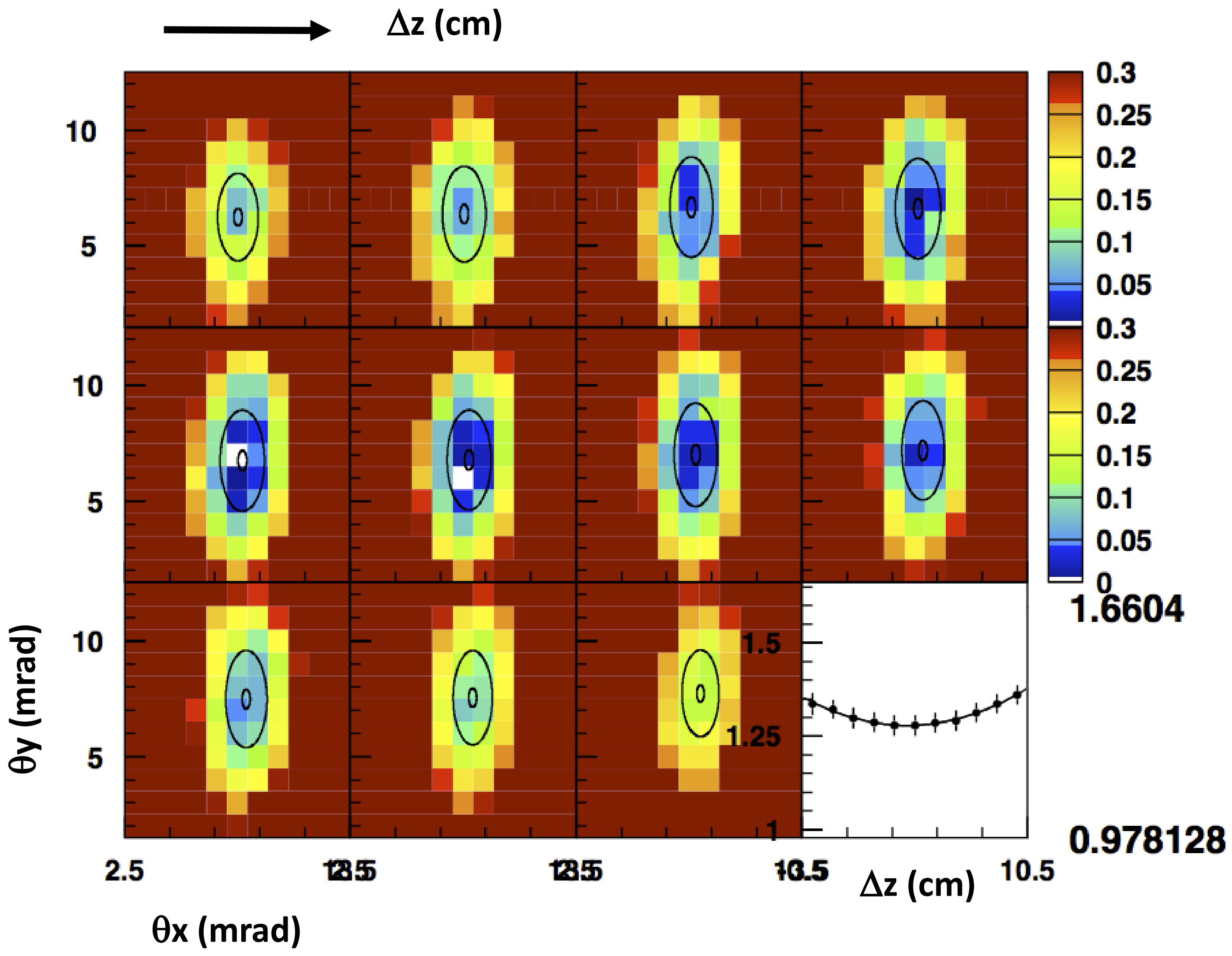


Alignment procedure: minimization algorithm

- **Two alignment angles θx, θy**
- **One position shift Δz**
- **Quality parameter**

$$\chi^2 = \sum_{j=1}^{N_{AERO}} \sum_{i=1}^{N_{PHO}} \frac{(\theta_{i,j}^{REF} - \theta_{i,j}^{MEAS})^2}{\left(\sigma_{i,j}^{REF}\right)^2}$$

- **3D scan, minimize $\Delta\chi^2 = \chi^2 - \chi^2_{min}$ in each 1D slice**



RICH PID studies: RG-A pass1 data

- **The available RG-A (and RG-B) pass1 data allows preliminary PID studies with the RICH**
  - **only direct photons**
  - → **limited angular coverage, reduced number of p.e.**

- **Relative hadron production**
  - **Select all hadrons with a given charge**
  - **Estimate events in the RICH Cherenkov angle peaks**
  - → **tuning of the k/pi ratio in CLASdis**

- **Particle contamination**
  - **Select one particle species from CLAS12 EB**
  - **Look at the RICH response**
  - → **only upper limits at present, comparison with SIDIS analysis s**

K/pi relative yield extraction

Inbending data

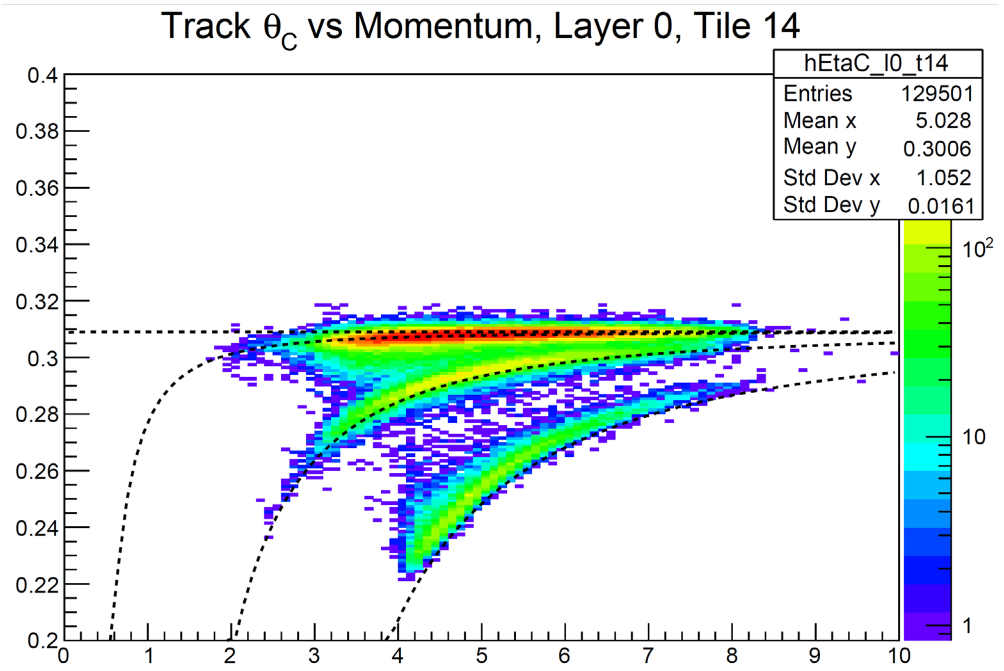
1. Select DIS inclusive e h X final state with EB
2. Look at the RICH Cherenkov angle for the hadron in the RICH

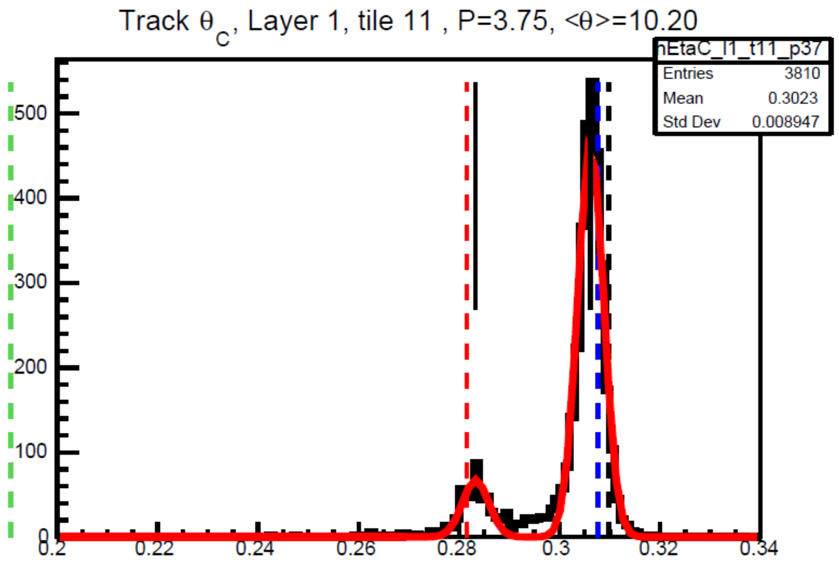
- Fit with the sum of two Gaussians with the same σ

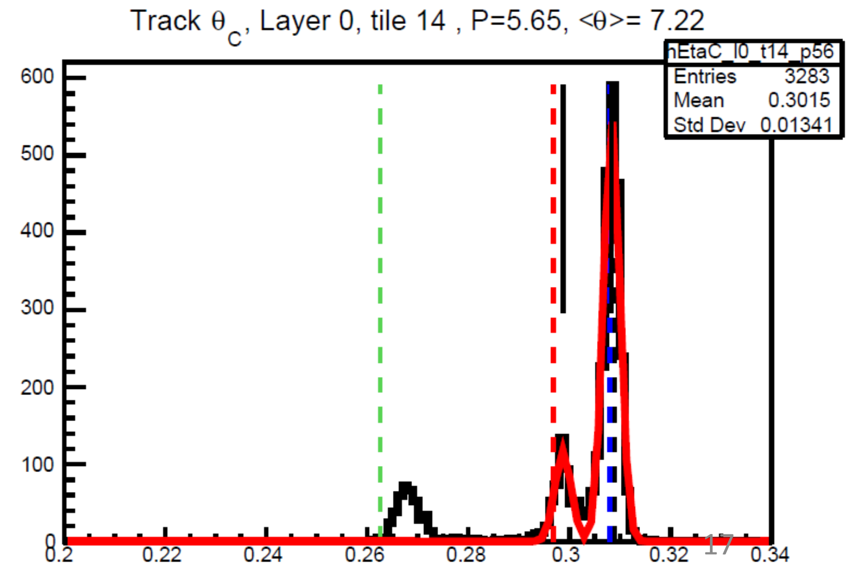
$$f(\theta) = Gaus_{\pi}\,(N_{\pi},\theta_{\pi},\sigma) + Gaus_{K}\,(N_{K},\theta_{K},\sigma)$$

- Production rate:

$$R(K/\pi) = N_{\pi} \,/\, N_{K}$$



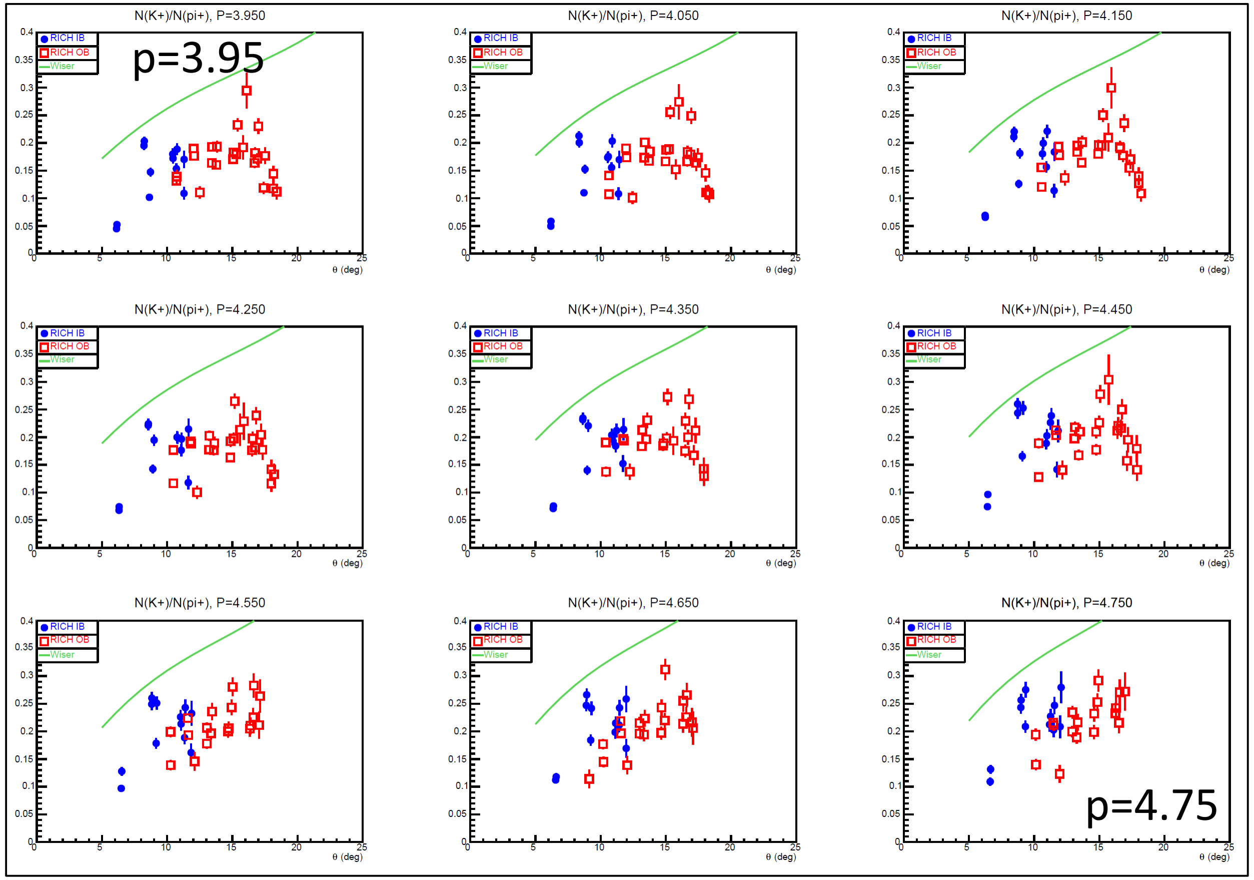




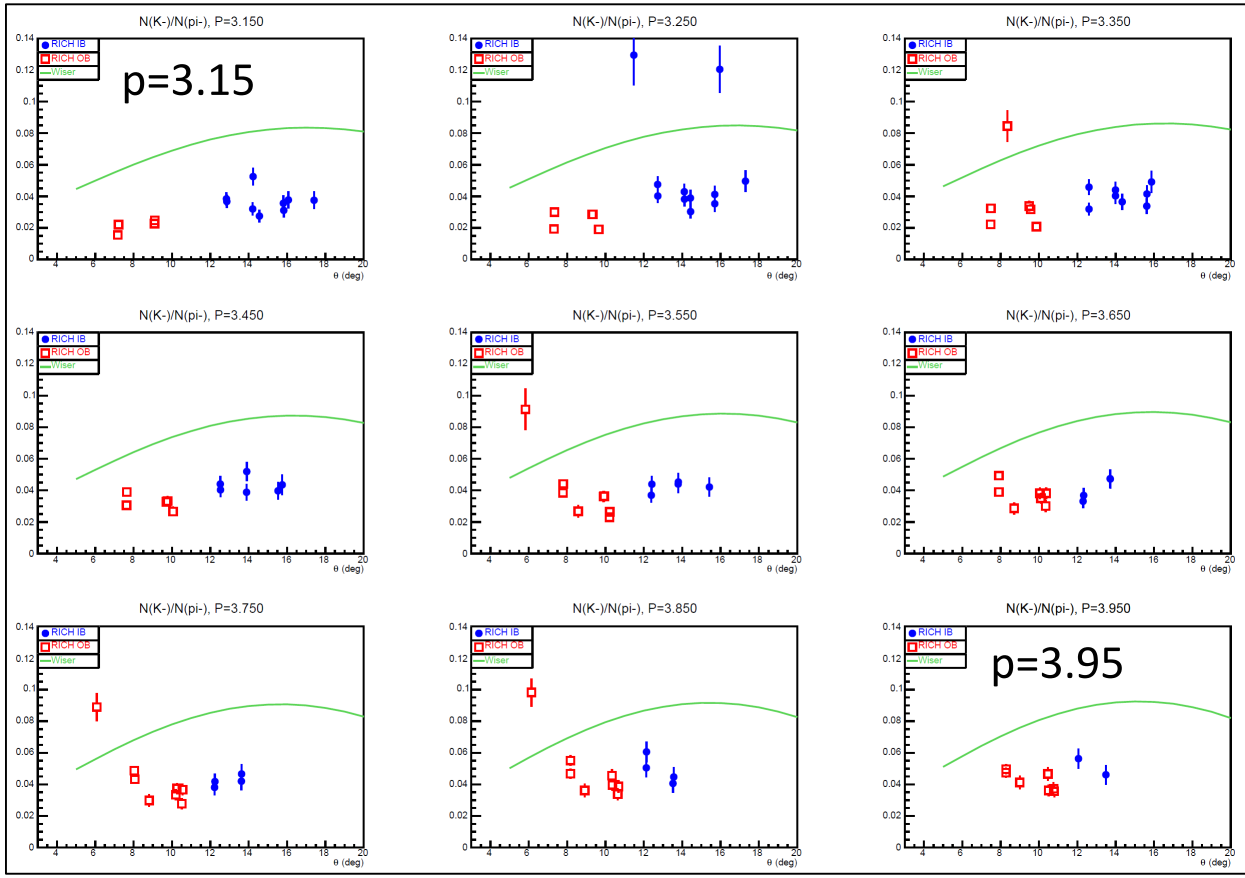
K/pi production yield

blue: RICH inbending
red: RICH outbending
green: Wiser fits

positive hadrons

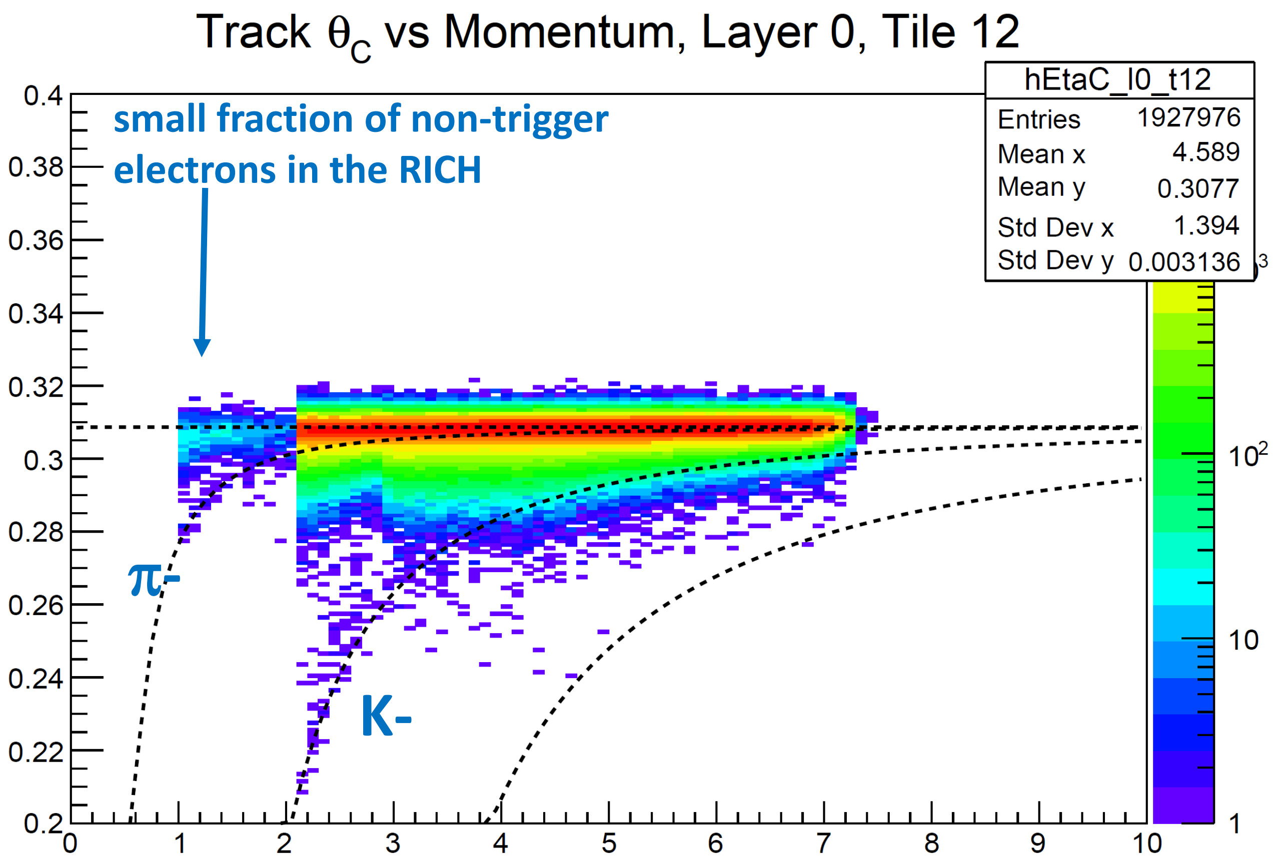


negative hadrons

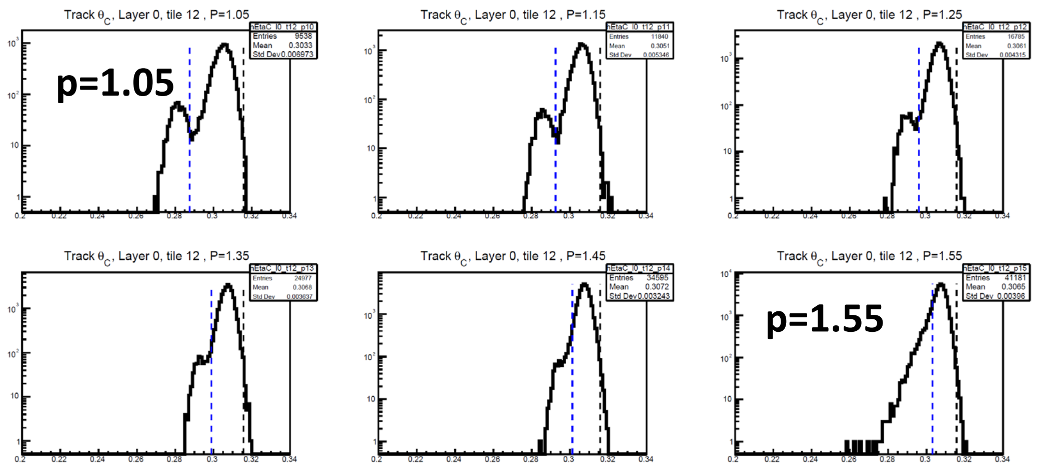


Electron ID contamination

1. Select DIS inclusive e X final state with EB
2. Look at the RICH Cherenkov angle for the electron in the RICH



Inbending data



- Contamination estimate is possible only for p < 1.4 GeV/c
- The momentum range of sensitivity could be slightly extended with better alignment (i.e. more photons)
- Too low momenta for SIDIS kinematics

Pion ID contamination

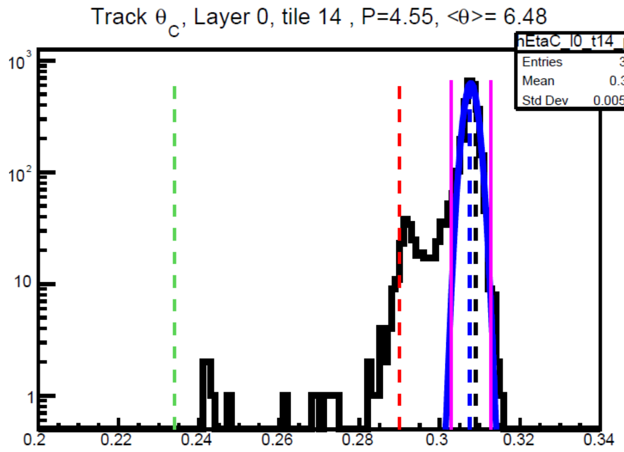
Inbending data

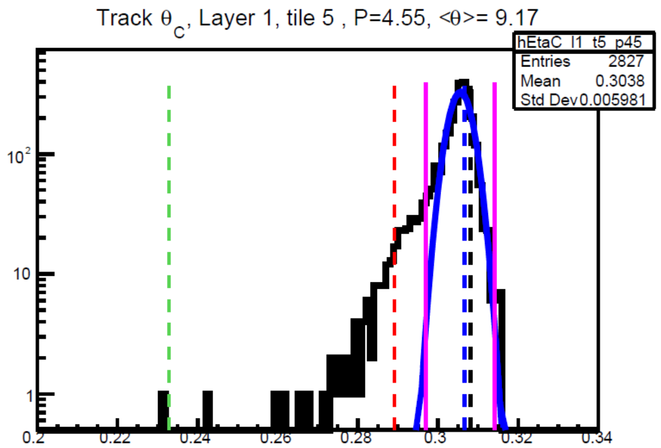
1. Select DIS inclusive e pi X final state with EB
2. Look at the RICH Cherenkov angle for the pion in the RICH

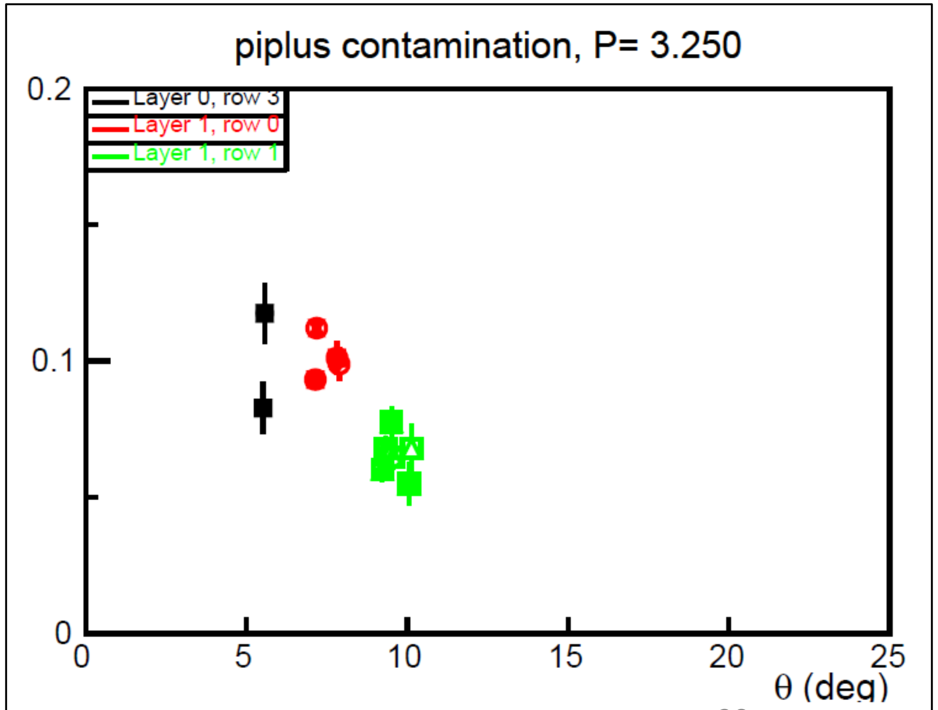
- Fit with the pion peak with a Gaussian
- Count the number of events out from the peak+/-3sigma region (pink lines)
- Contamination:

$$C = \frac{N(\theta < \theta_{min}) + N(\theta > \theta_{max})}{N_{tot}}$$

→ **the present estimate can be considered only an upper limit**

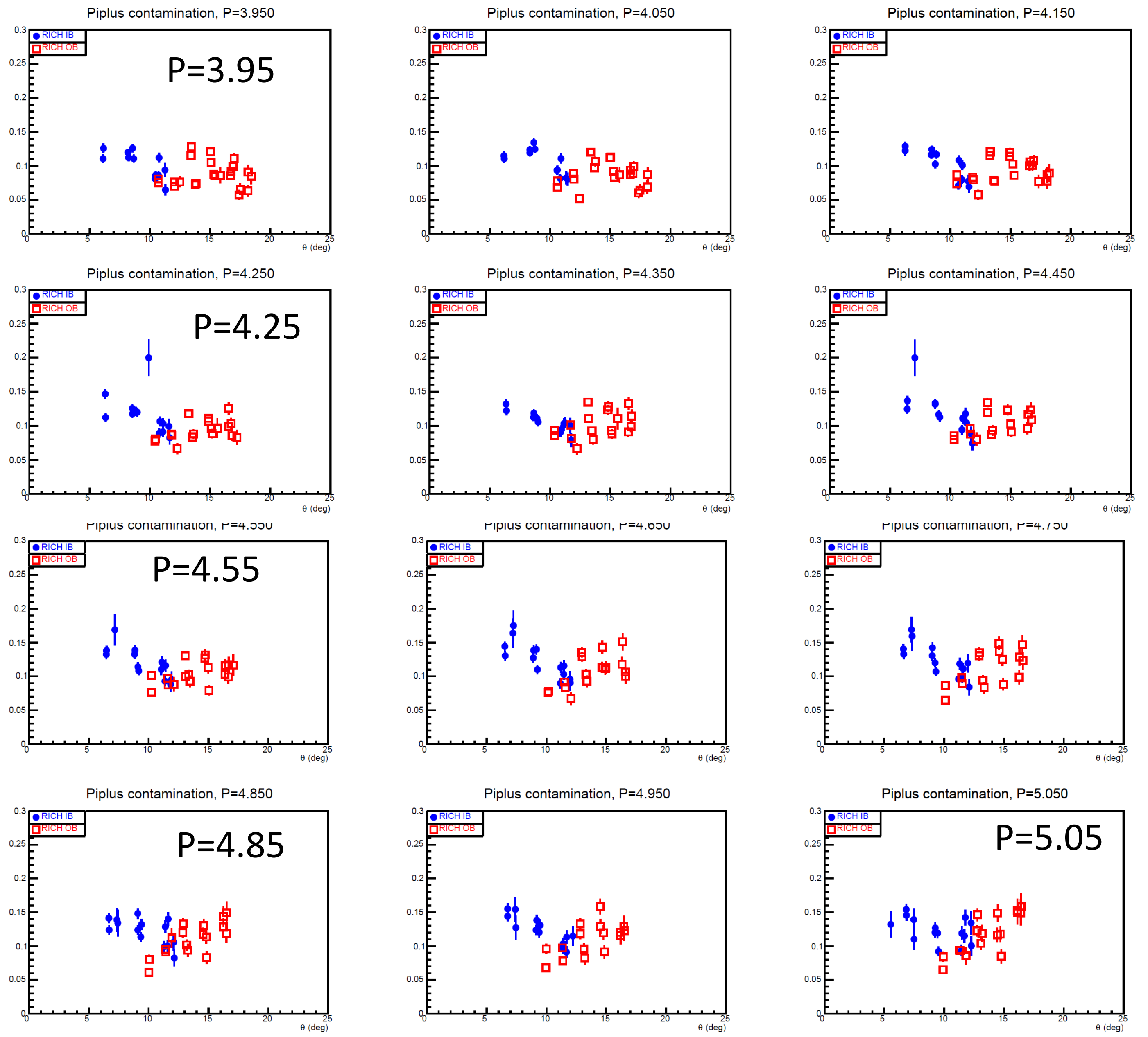






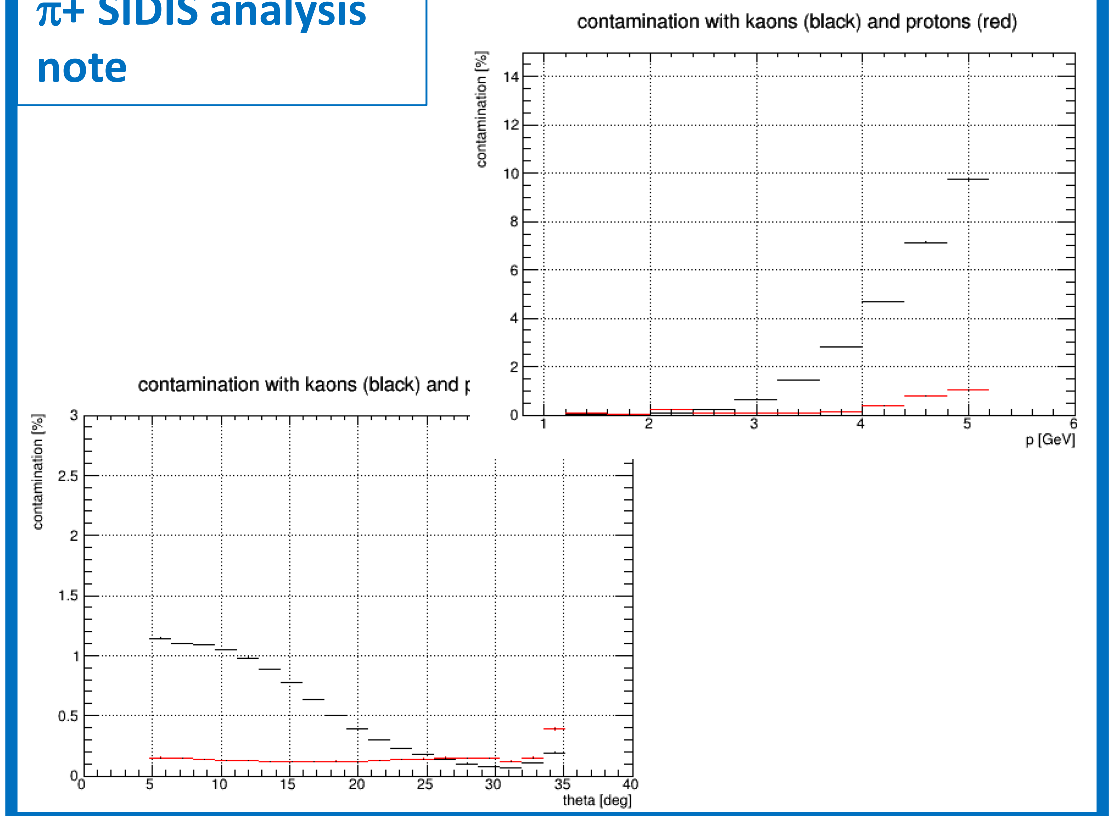
Pi+ contamination vs theta at fixed P

blue: RICH inbending
red: RICH outbending

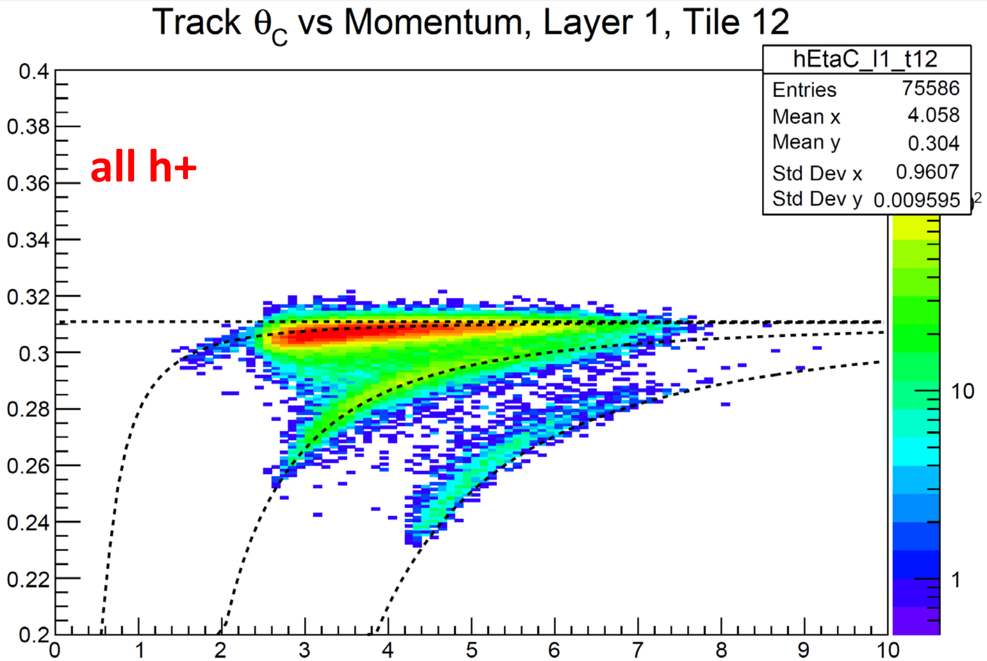


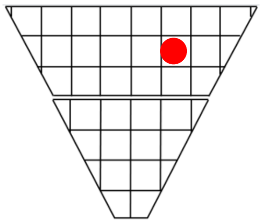
- **Overall current contamination estimate around 10-15%**
- **Real contamination could be lower due to tails in the pion peak**

π+ SIDIS analysis note

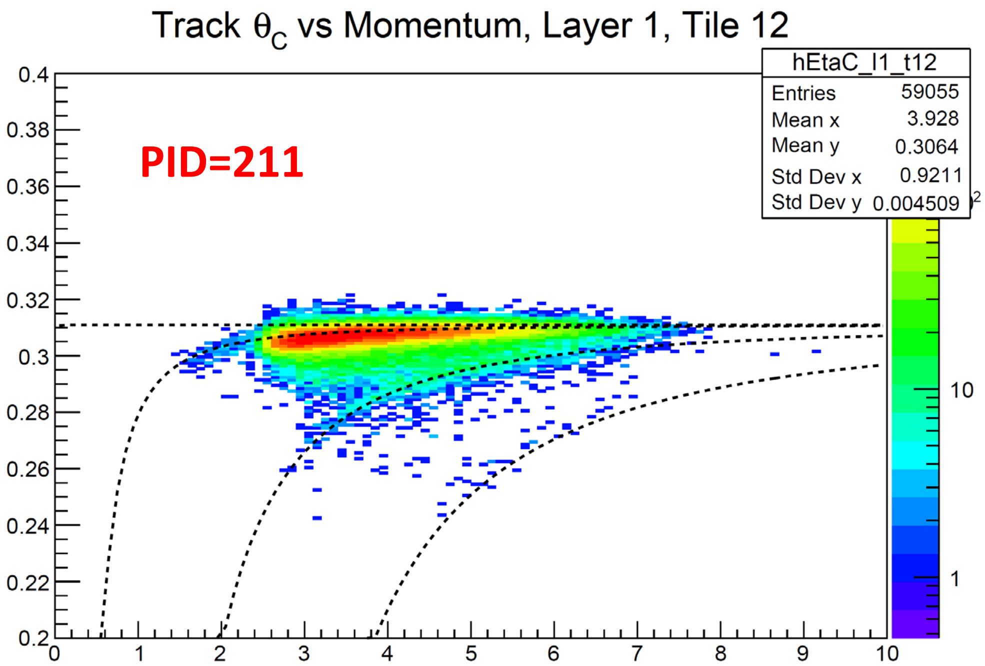


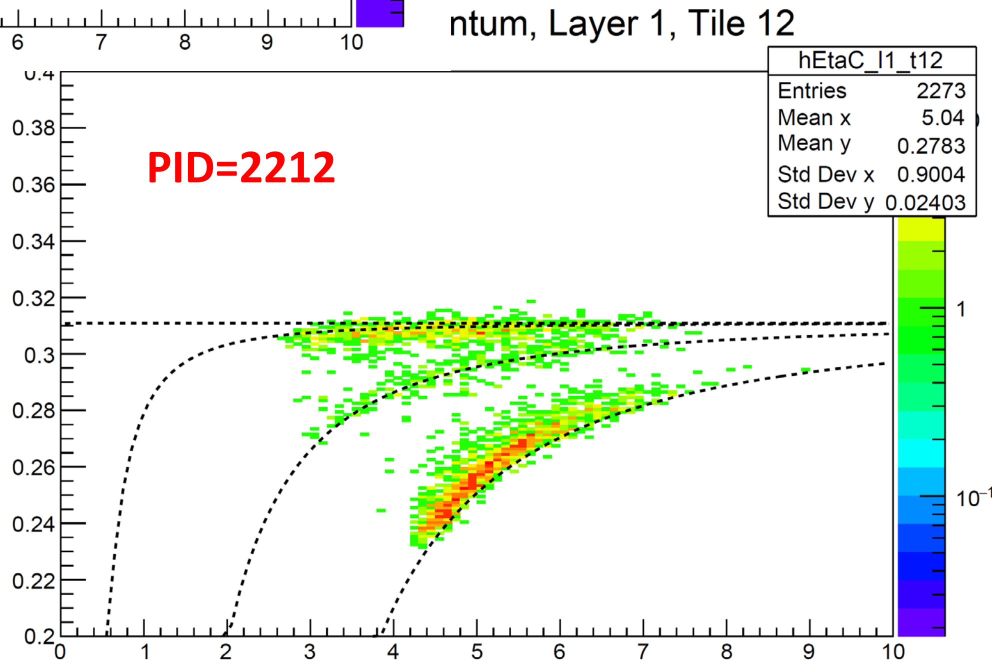
Positive hadron misID

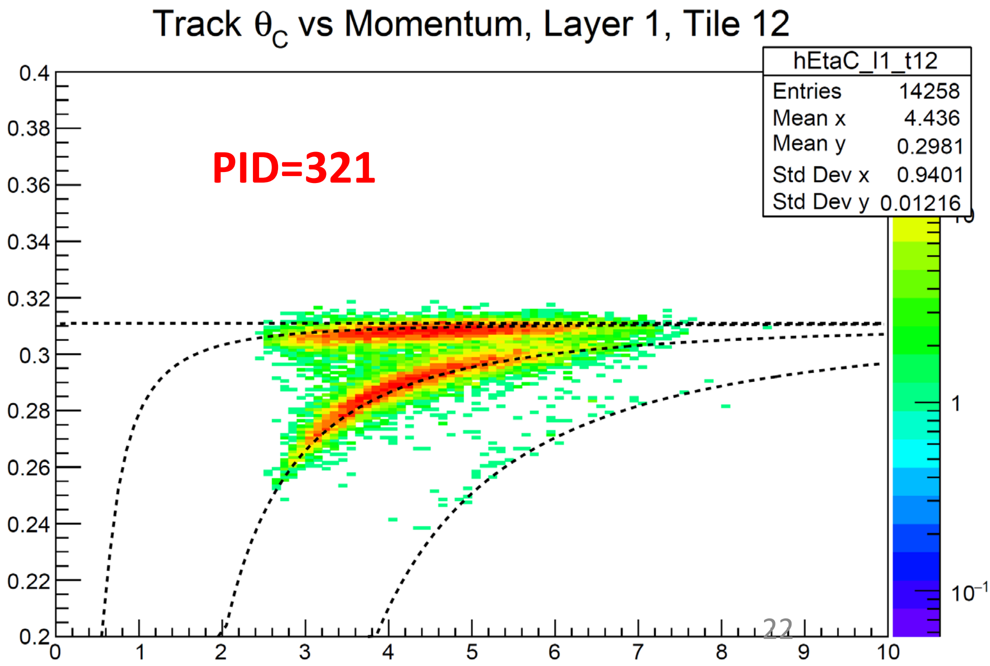




Layer 1
Tile 12
row 1



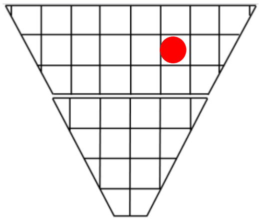




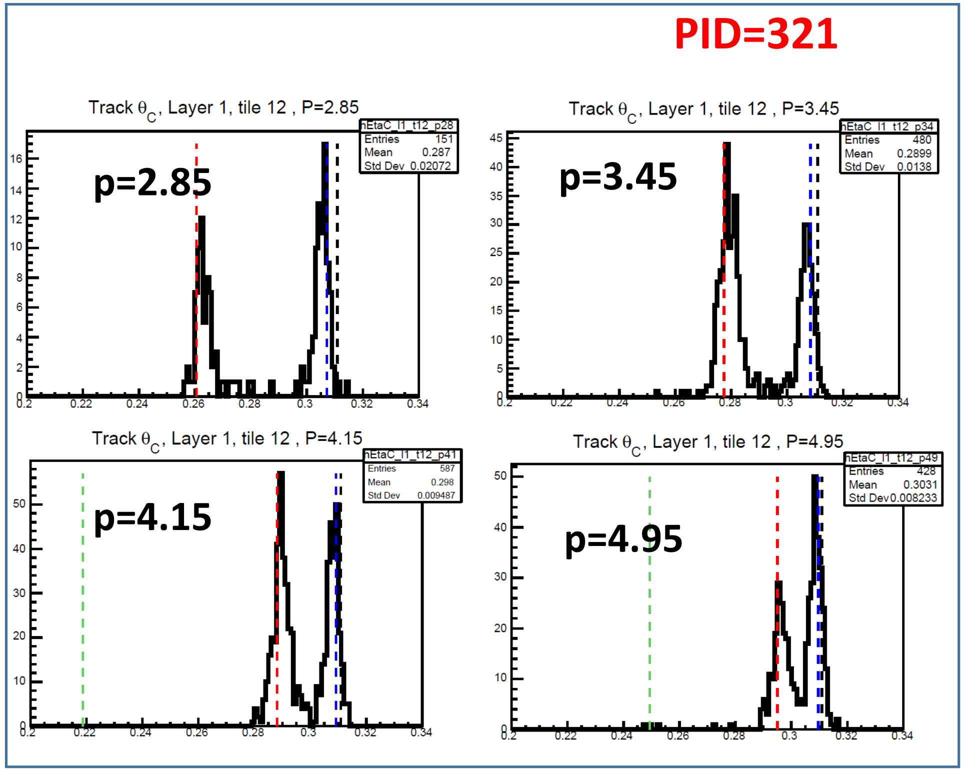
Thresholds:

- ***above 2 GeV for K***
- ***above 4 GeV for p***

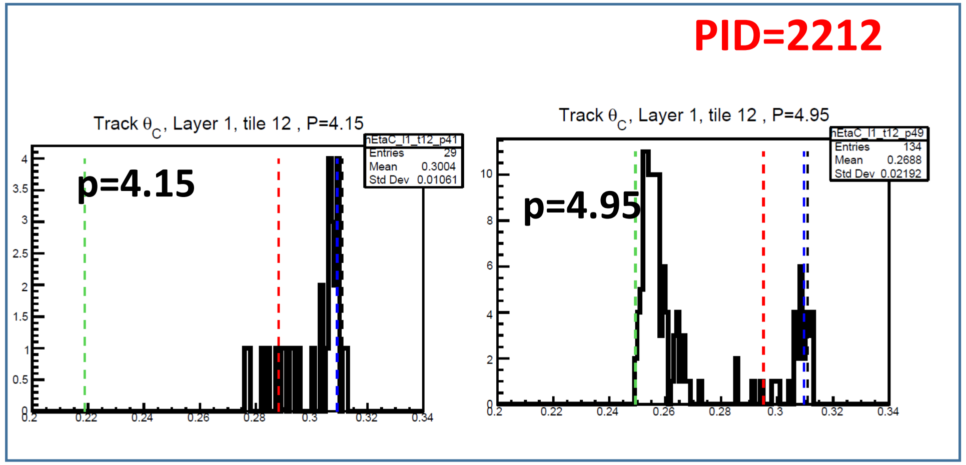
K+ and proton ID contaminations



Layer 1
Tile 12
row 1



θ ~ 9 deg



1. Contamination to K+ is large, around 50% already at 3 GeV/c
2. Contamination to p is also significant
   → cross check with TOF resolution vs angles

Summary and outlook

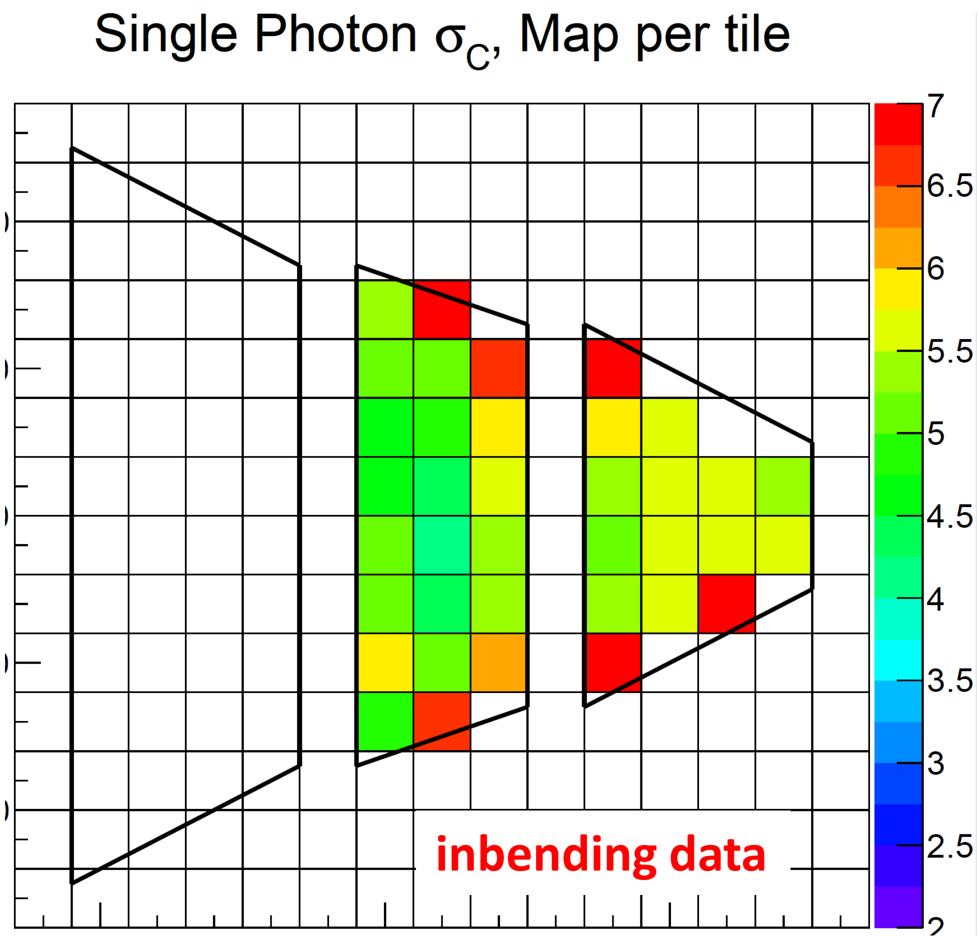
1. **The present RICH reconstruction relies only on the direct photons**
   - **limited angular coverage and number of p.e.**
   - **results presently affected by asymmetric Cherenkov angle distribution shape due to misalignments**
2. **Preliminary PID studies have been started using the RG-A pass1 data to provide feedbacks for the first publications**
   - **estimate of the K/pi production ratio, tuning of the clasDIS event generator**
   - **upper limit on the contamination in the pi+ ID around 10%**
   - **indication of high contamination in the Kaon ID already around 3 GeV/c**
   - **need completion of the alignment to get more precise estimations**

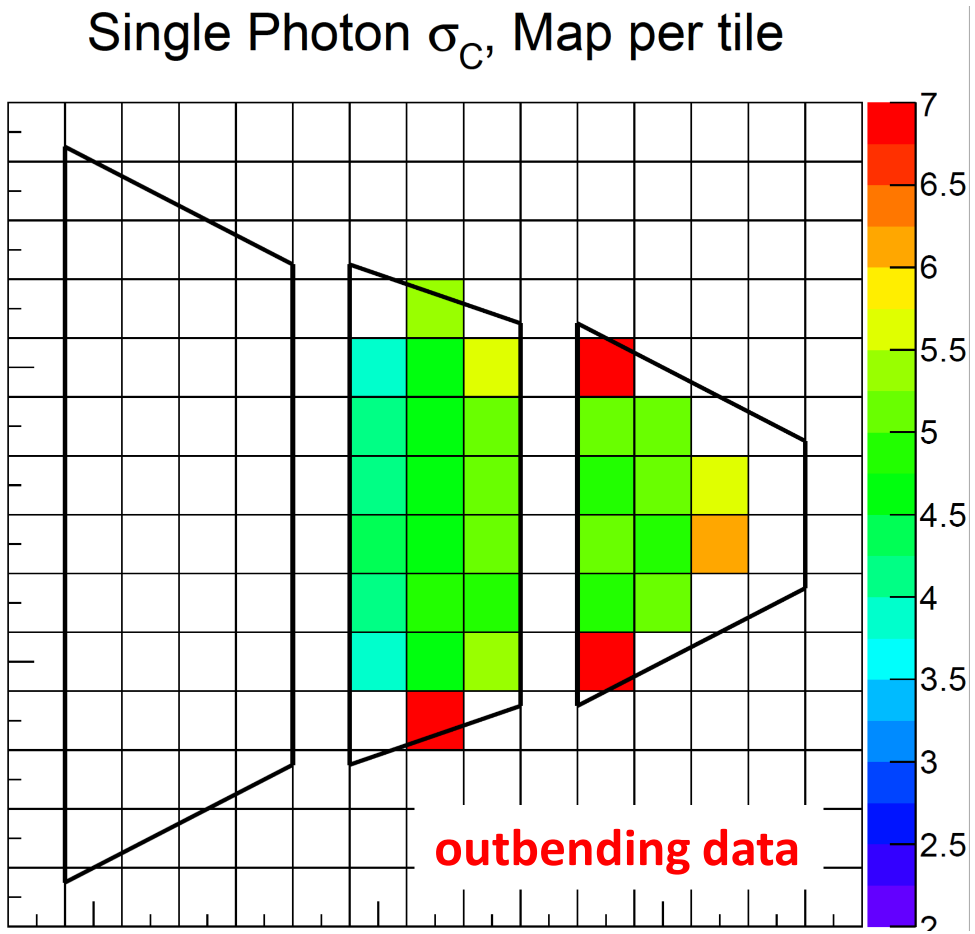
- **Tools to extract the alignment parameters of the RICH internal elements have been developed**
- **The tools have been tested using the RG-A pass1 cooking data**
- **We are now ready to start the alignment process in a systematic way**
  - **reprocessing of the RICH data will be necessary**

→ The goal is to complete the task by the end of the year, in time for the pass2 cooking

backup

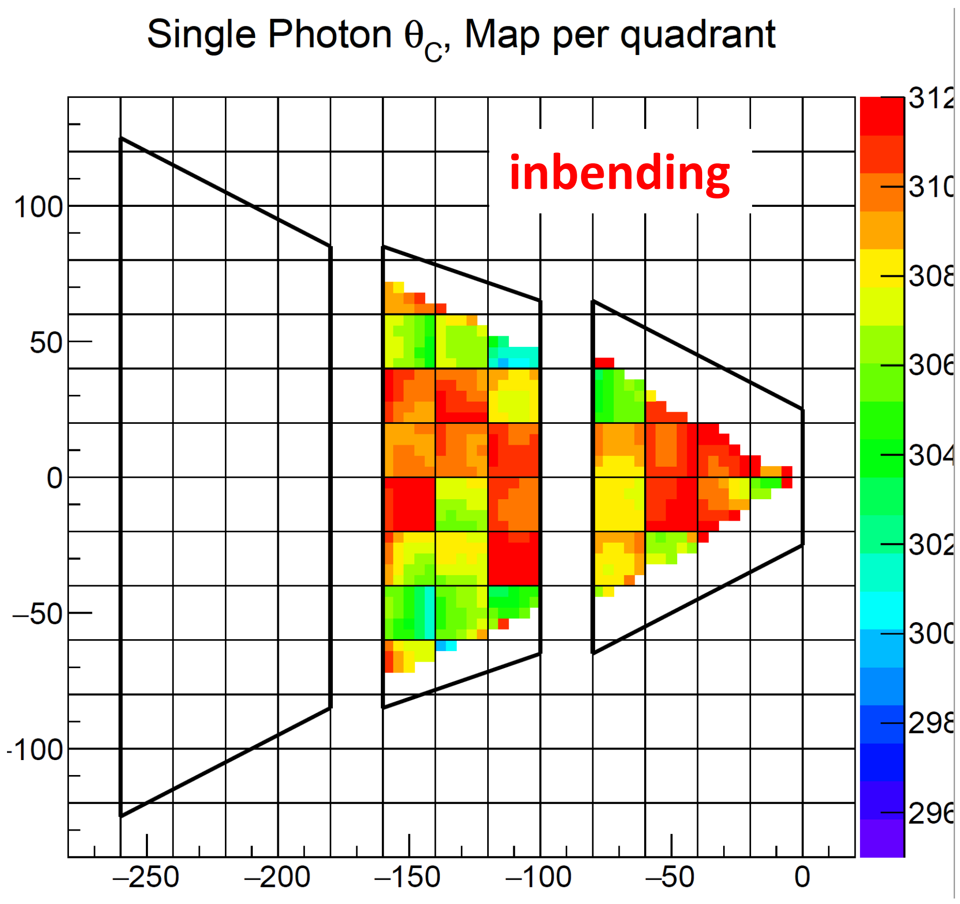
RICH performance with e-: Single photon resolution

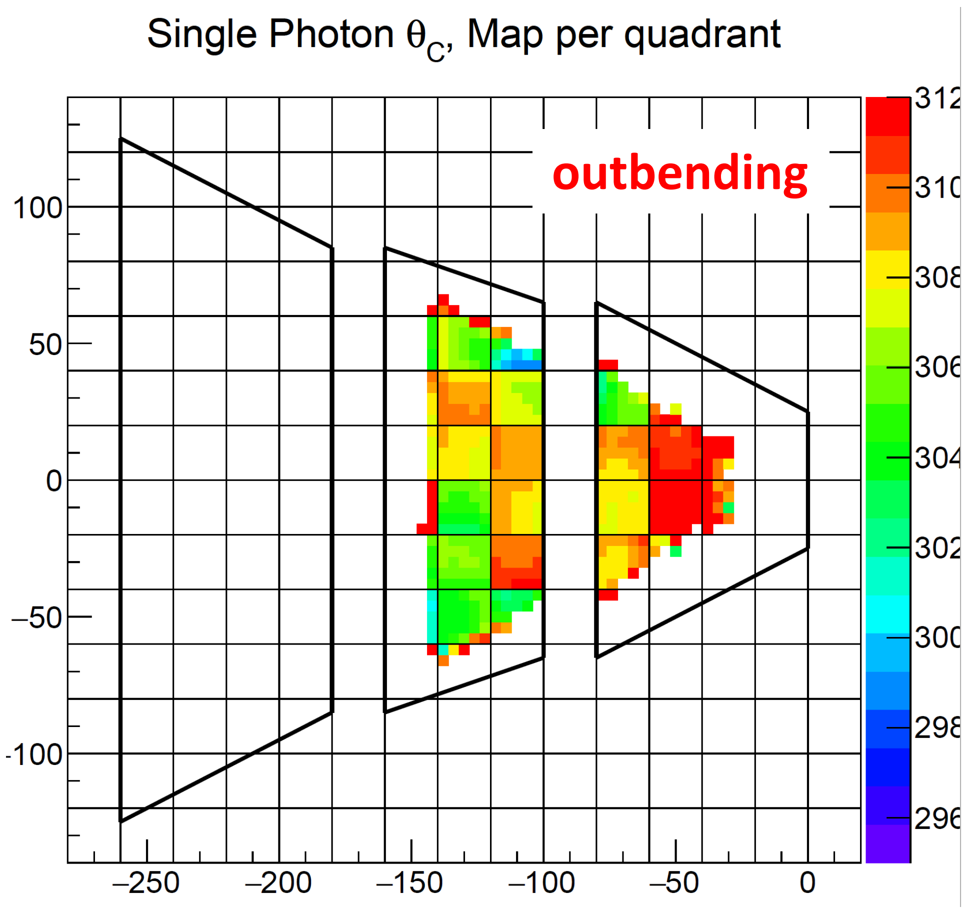




SPE resolution spec.
4.5 mrad

Inbending vs outbending electrons

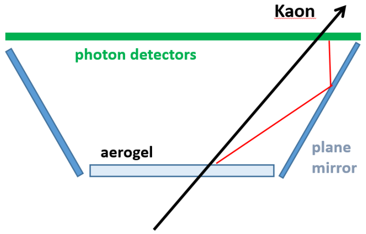


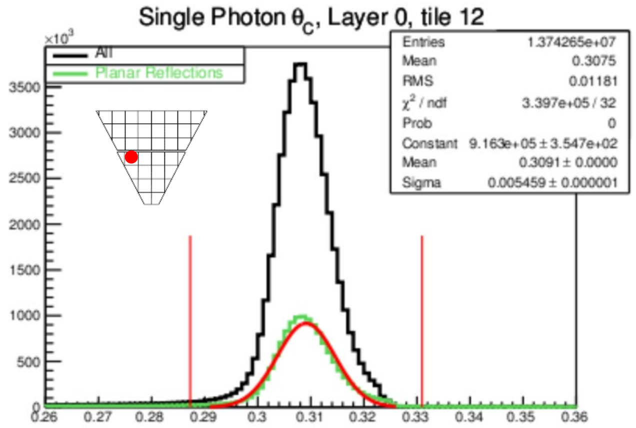


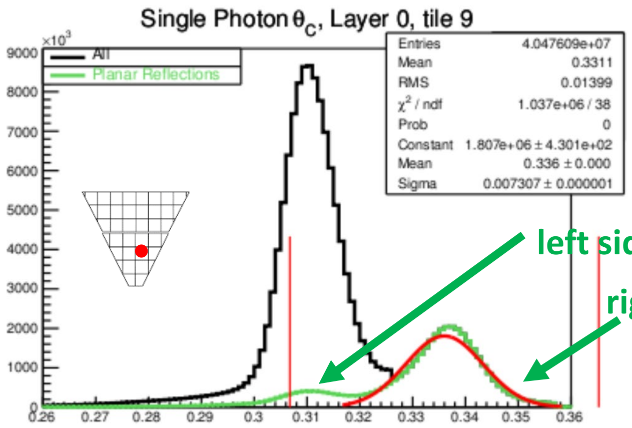
- **Same relative color pattern from inbending to outbending data**
- **shift of the mean angle from in- to out-bending due to wrong gap length**

Reflected photon topologies

- One reflection on a planar mirror

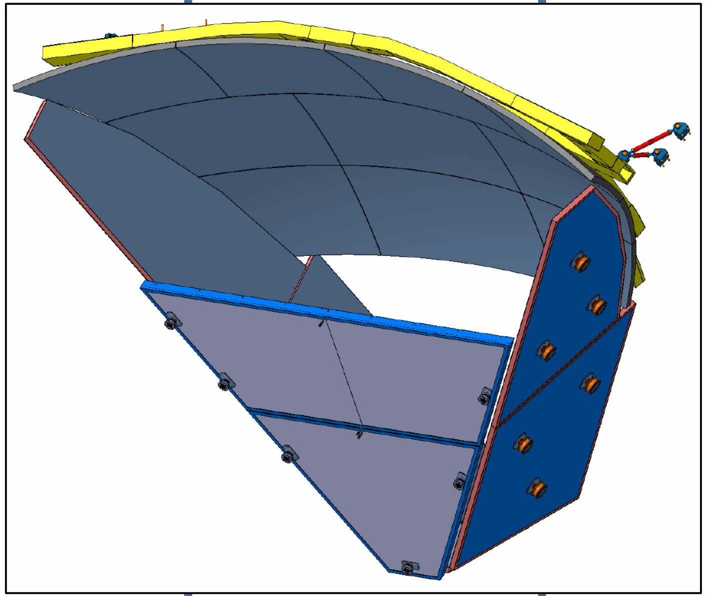




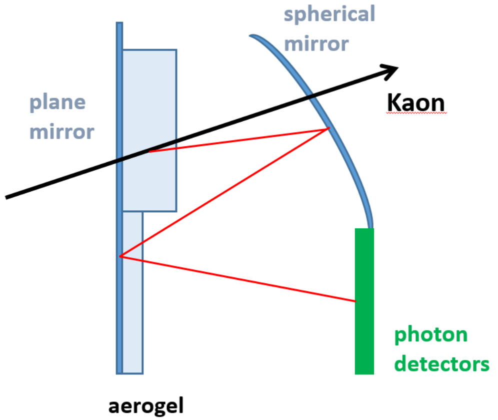


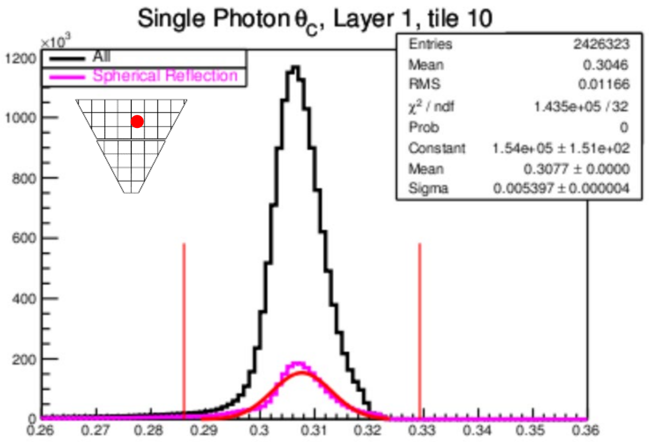
left side reflection

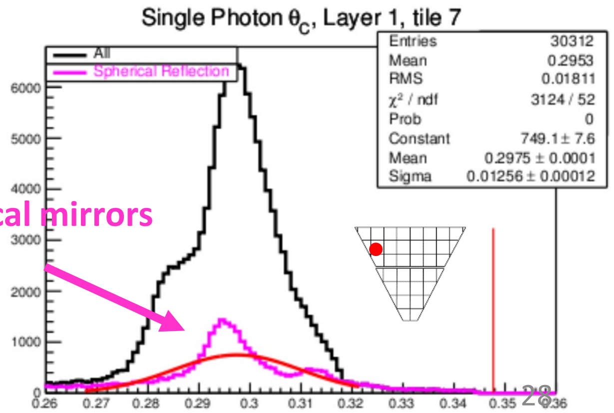
right side reflection



- Two reflections
- First reflection on a spherical mirror

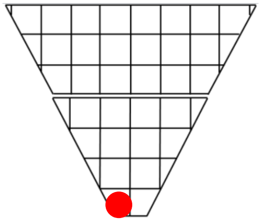




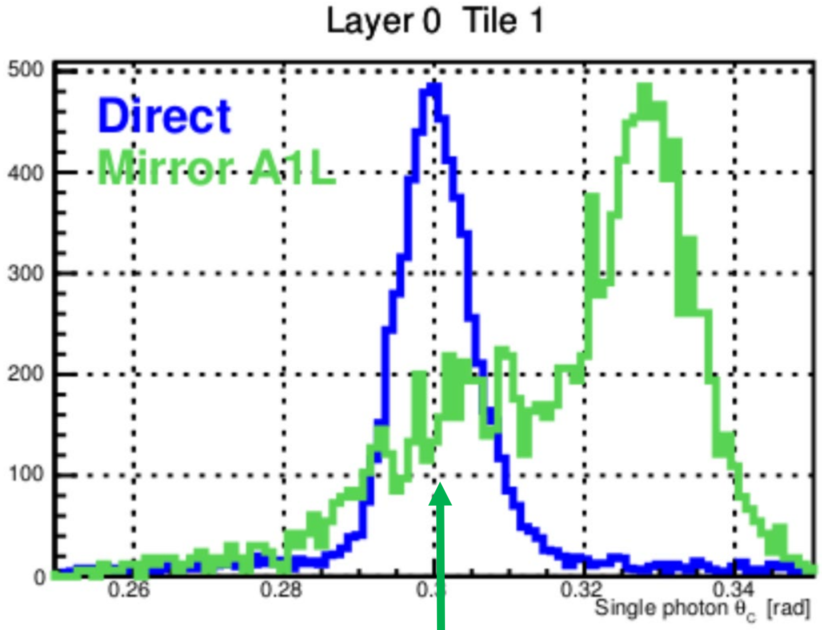


various spherical mirrors

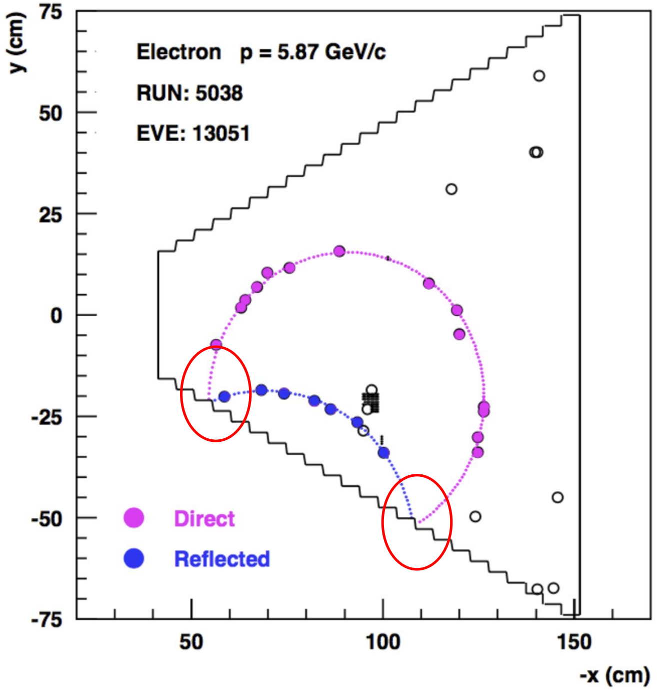
Alignment survey: planar mirror A1L



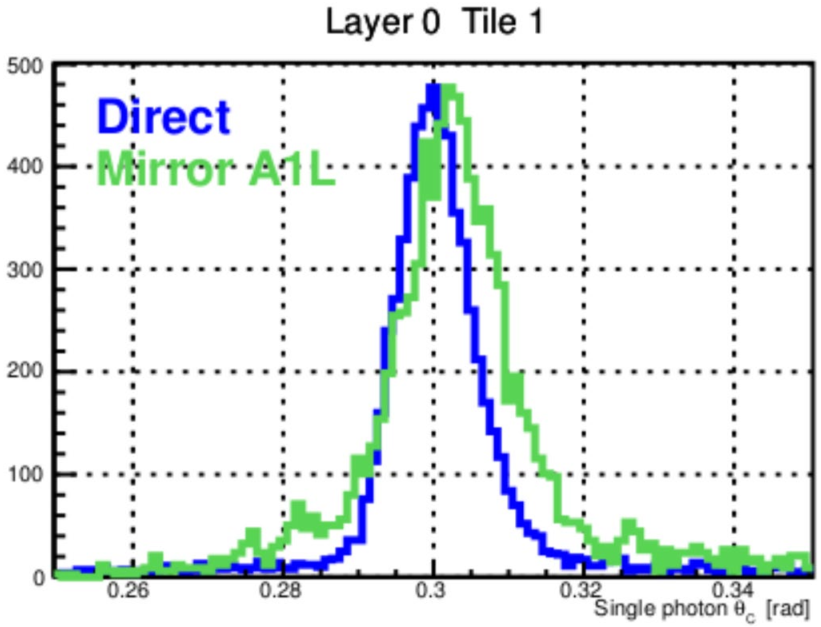
Before alignment



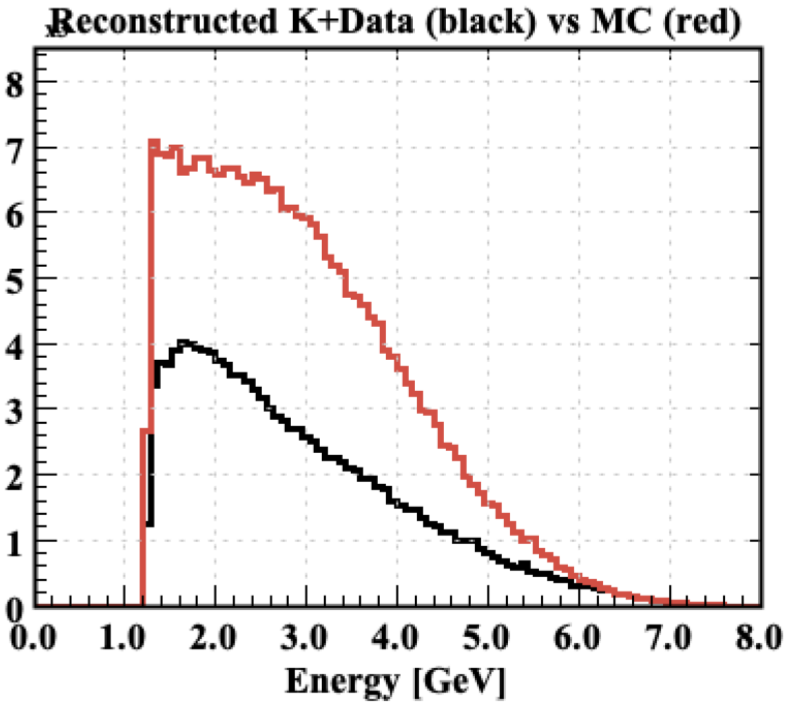
Wrong Cherenkov angle reconstruction due to misaligned geometry

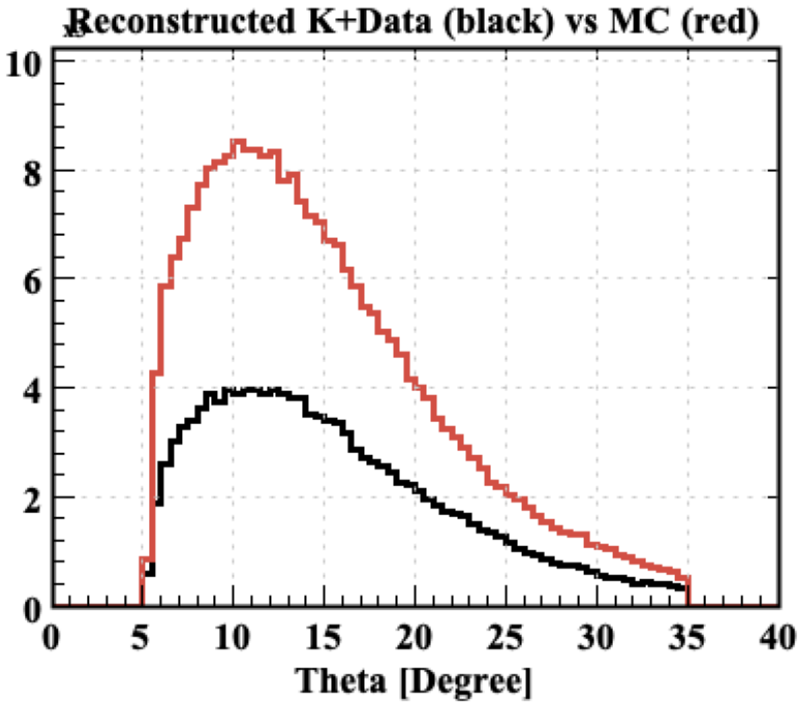


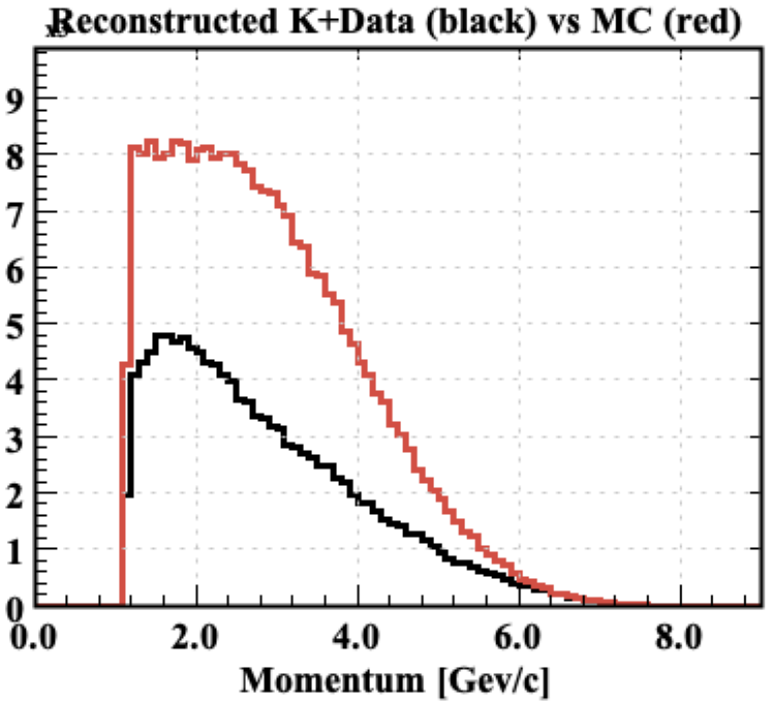
After alignment



Kaon production rate: data vs MC





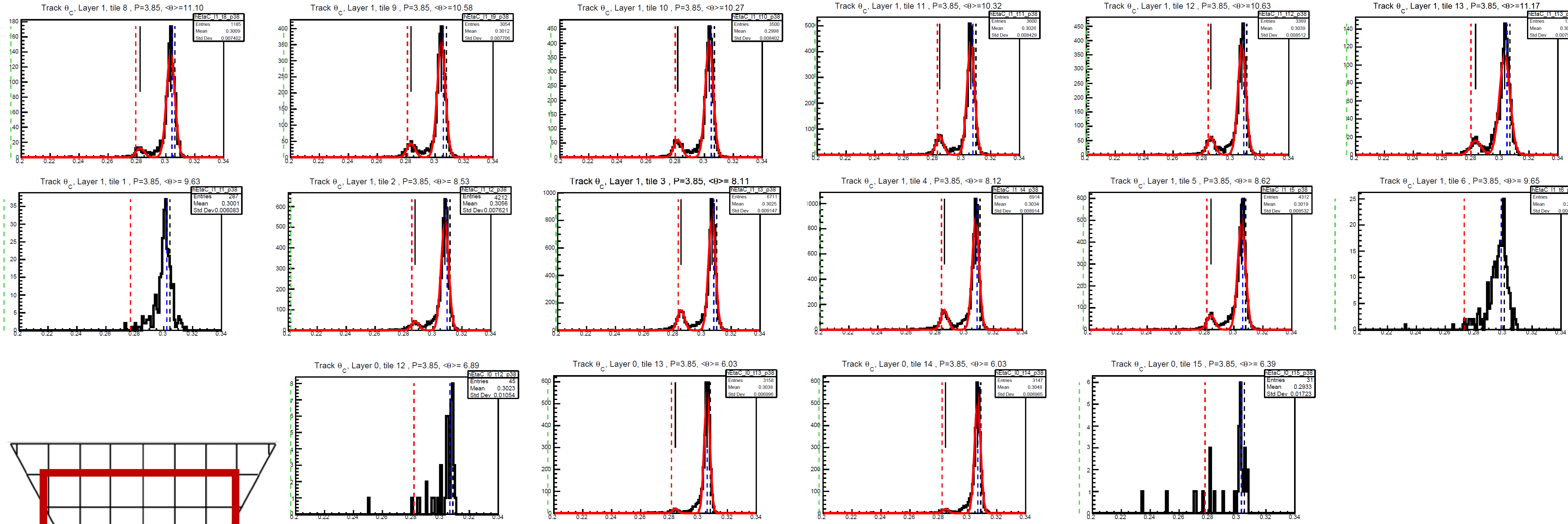


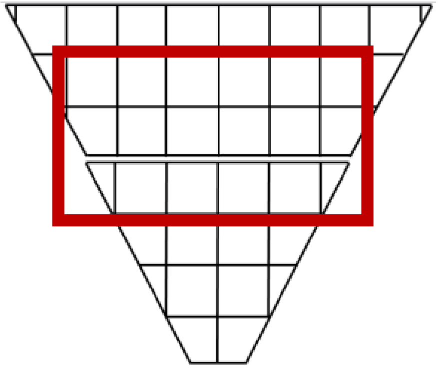
Kaon Production rate scaled by 0.4 in the latest Monte Carlo generation

Ratio vs angles (Q>0)

P=3.85 GeV/c

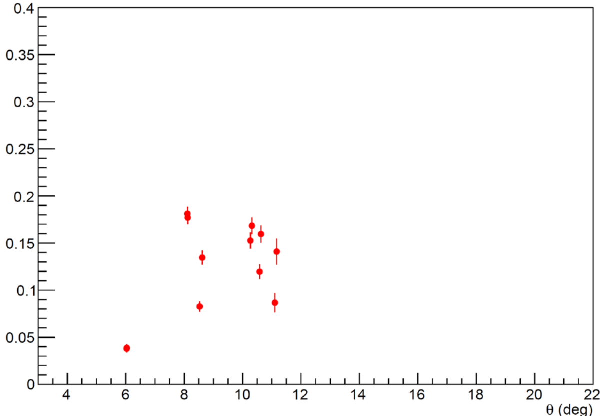
- **Inbending data**





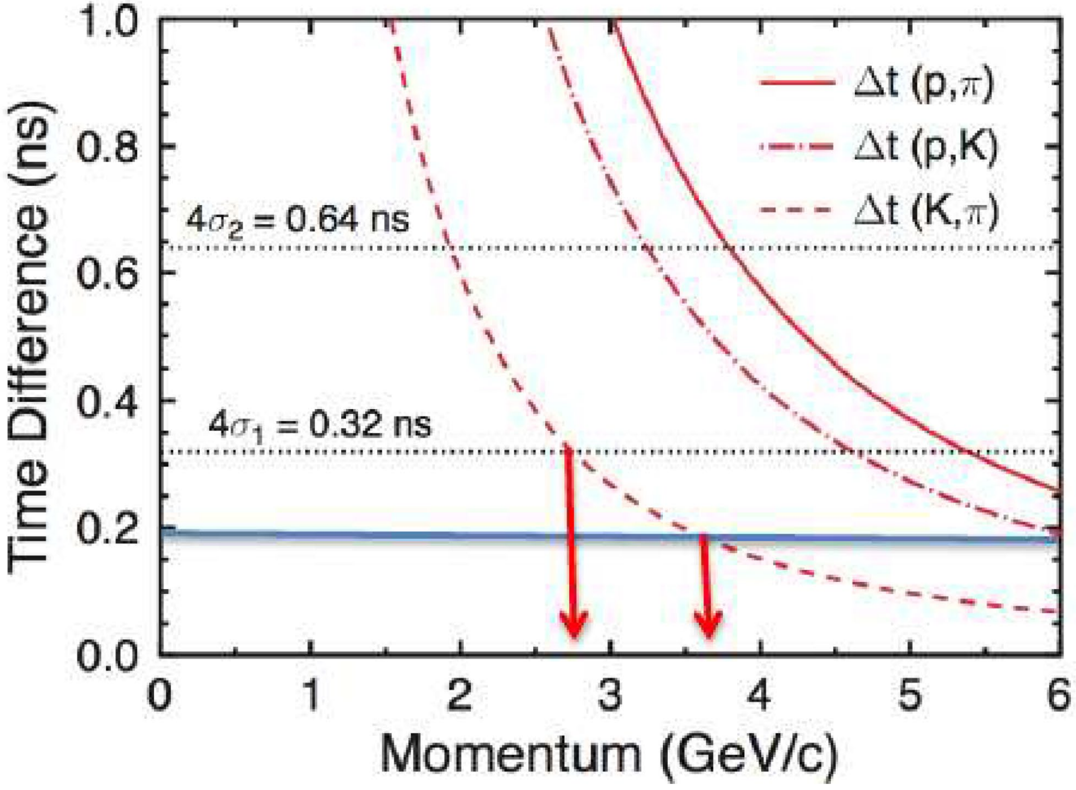
Variations among tiles with similar kinematics, most likely due to:

- **distortion in the signal shape**
- **different fractions of direct photons**

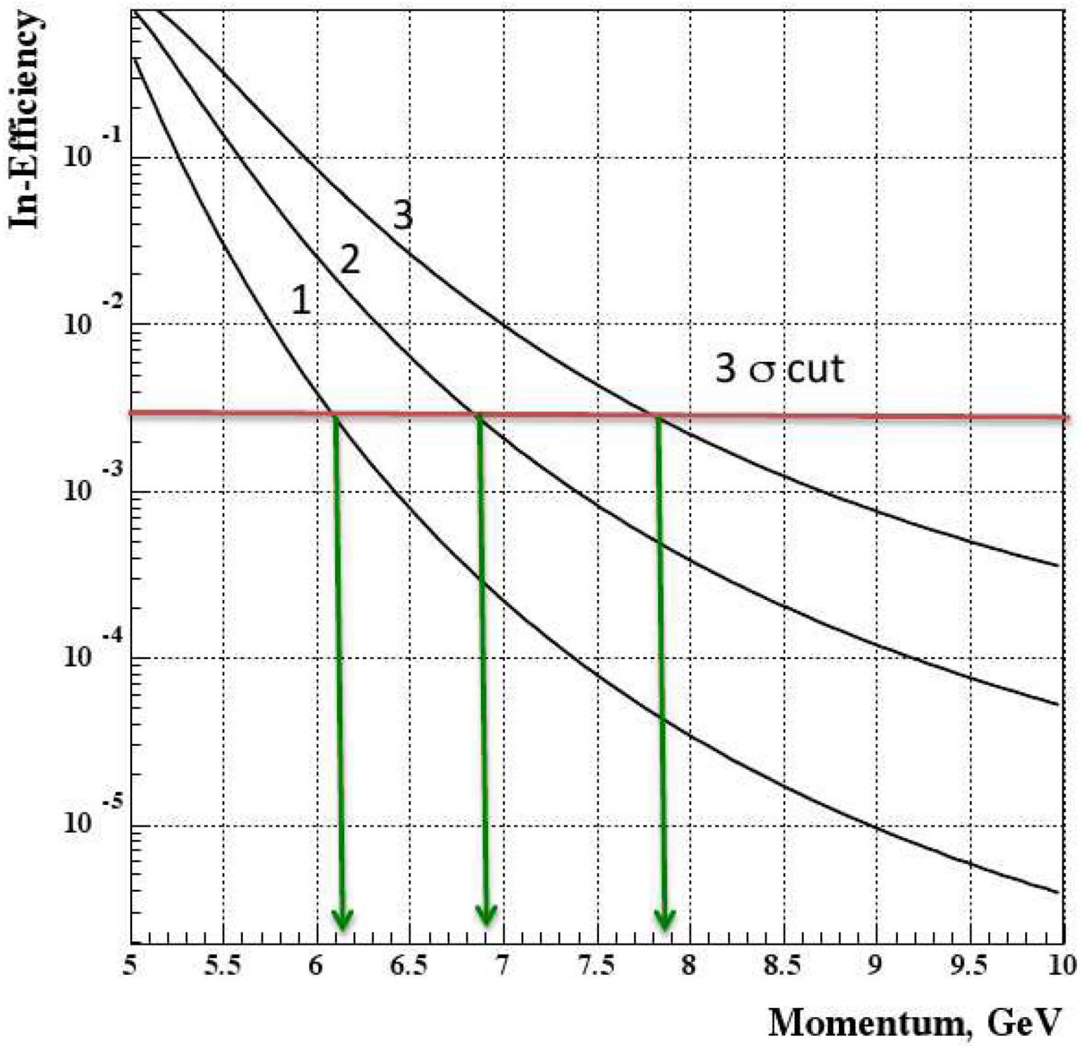


Kaon ID with CLAS12

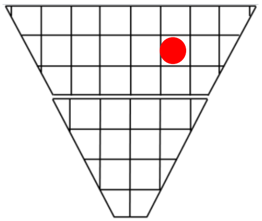
Time of flight
- **arrival time difference**



High threshold Cherenkov counter
- **pion inefficiency with <Npe>=12**

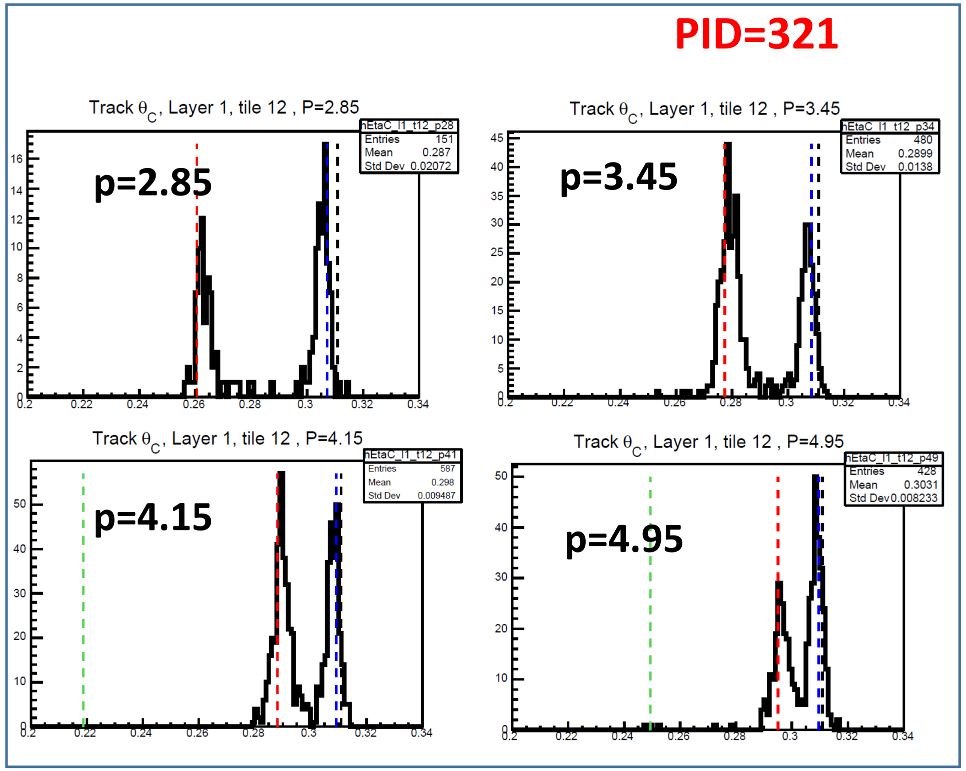


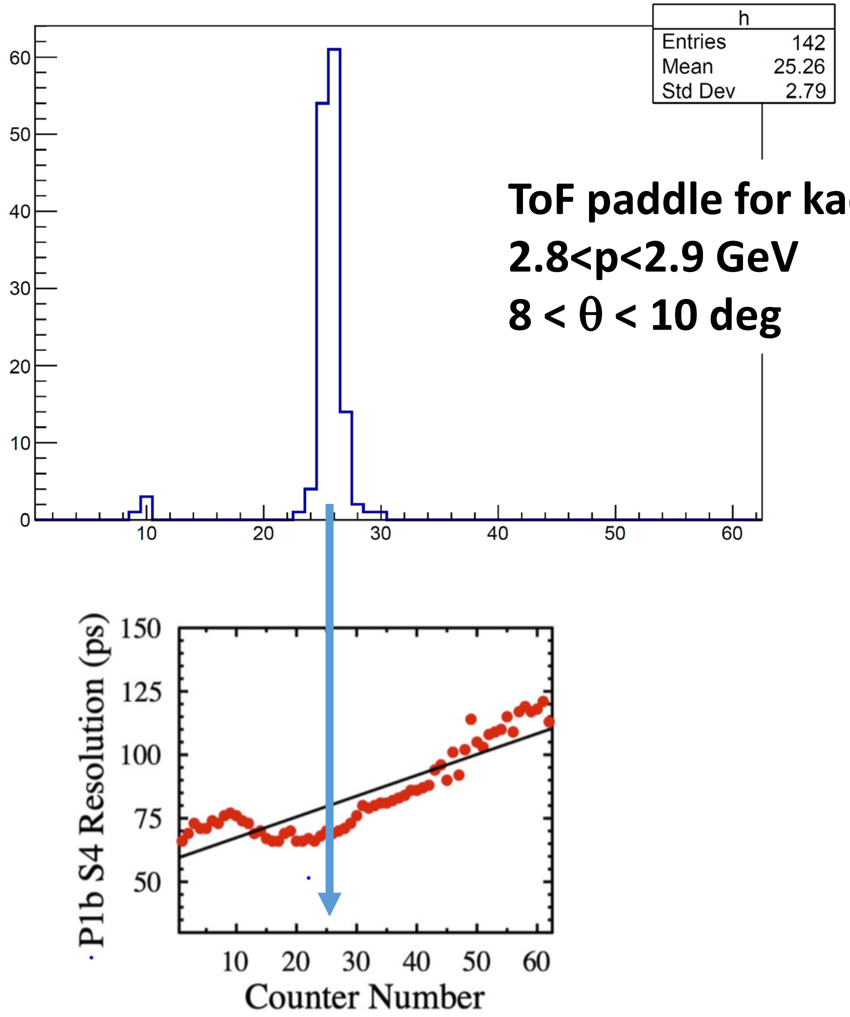
Kaon ID contaminations



Layer 1
Tile 12
row 1

θ ~ 9 deg





ToF paddle for kaons
2.8<p<2.9 GeV
8 < θ < 10 deg