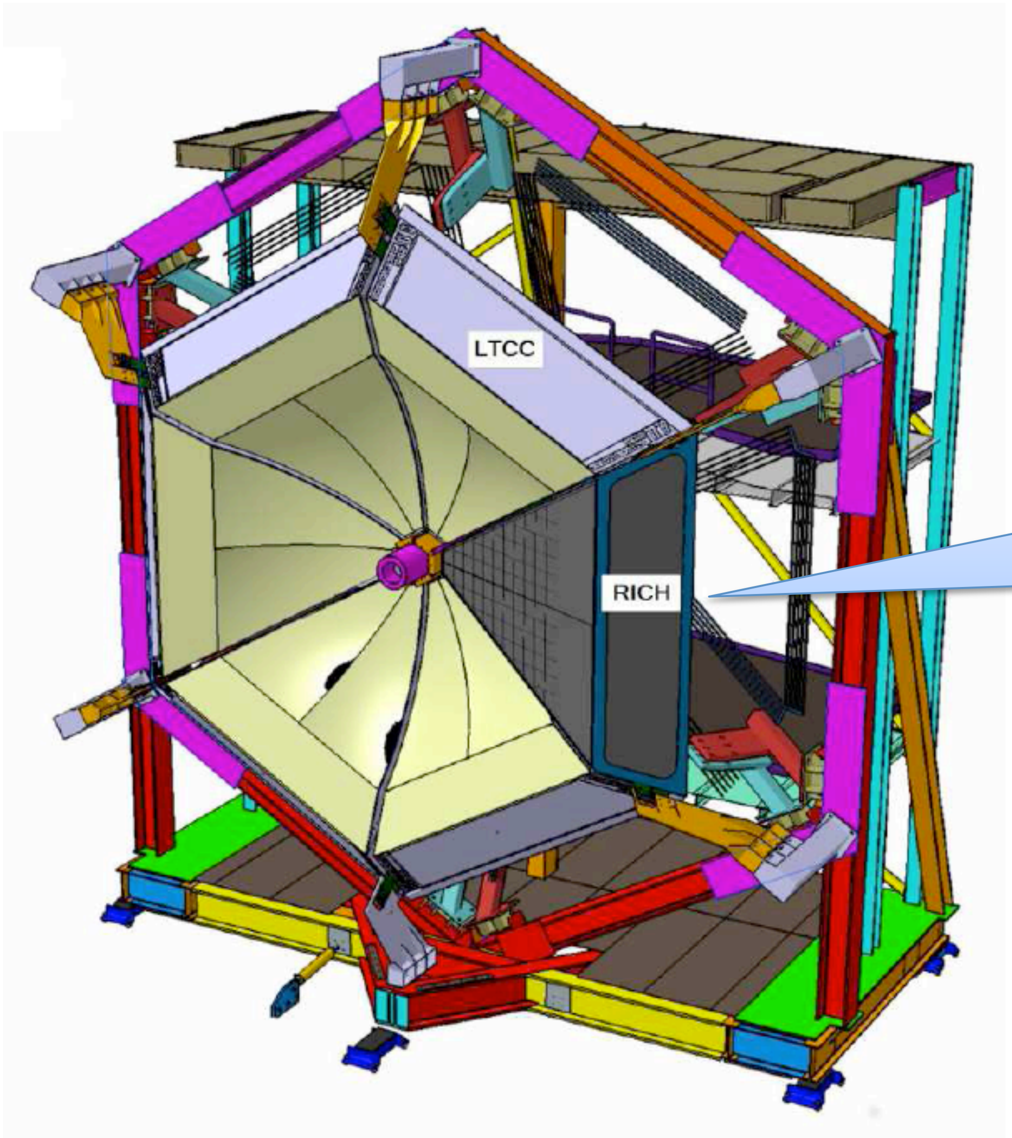
RICH INTEGRATION IN CLAS12

Contalbrigo Marco
INFN Ferrara

Rich Technical Review, 5 September 2013

RICH Project Goal

1st sector ready for physics run in 2016



Designed to fit into the LTCC clearance on the same joints of the forward carriage

Commissioning & Calibration

Use no-track events:

- Internal trigger on SPE dark-counts for digital threshold setting
- Random trigger for dark-count (no beam) and background (with beam) studies
- Vary beam intensity for occupancy studies
- Pedestal stability & Common noise studies with analog readout

Use Electron Tracks:

- Mimic pion signal (almost saturated at 4-5 GeV/c)
- Alignment (i.e. with drift-chambers and among mirrors)
- Aerogel refractive index map
- Mirror aberration corrections
- Tune of the patter-recognition and reconstruction algorithms
- Efficiency and mis-identification probability

Use meson and hyperon decays to validate RICH performances:

- K_S for pions
- ϕ for kaons
- Λ for protons

Operation

Gas system (standard solutions exist):

- Dry atmosphere for the hydrophilic aerogel preservation
- Slight overpressure to prevent contamination

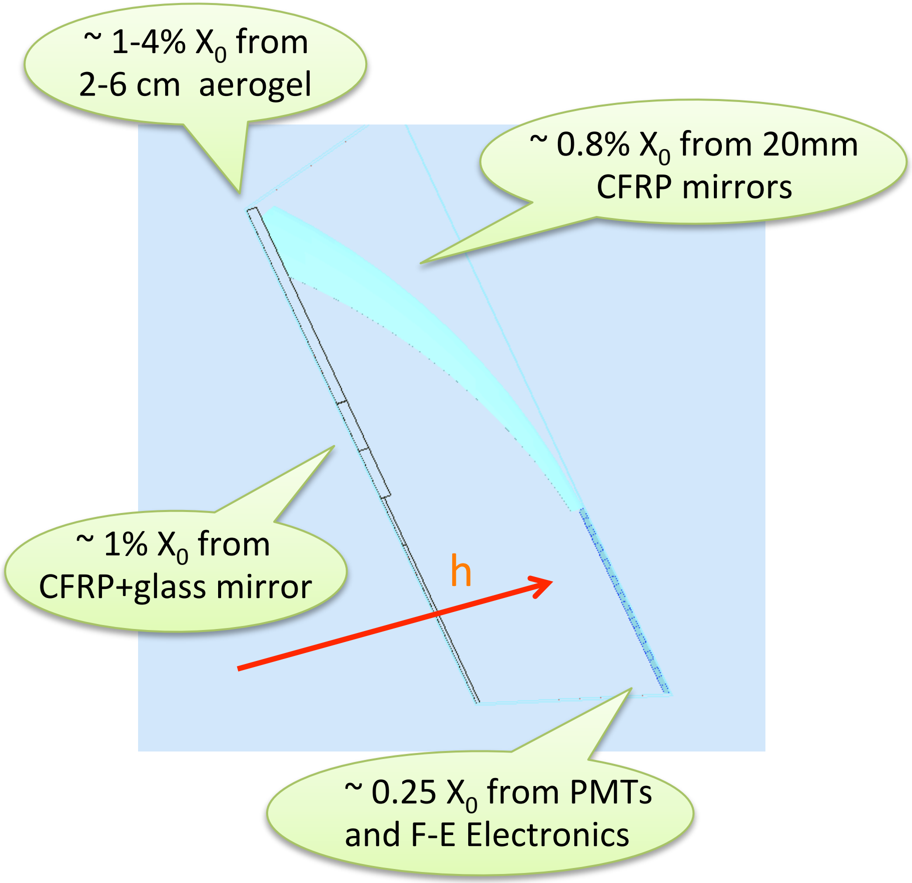
Slow Control (part of the general CLAS12 design):

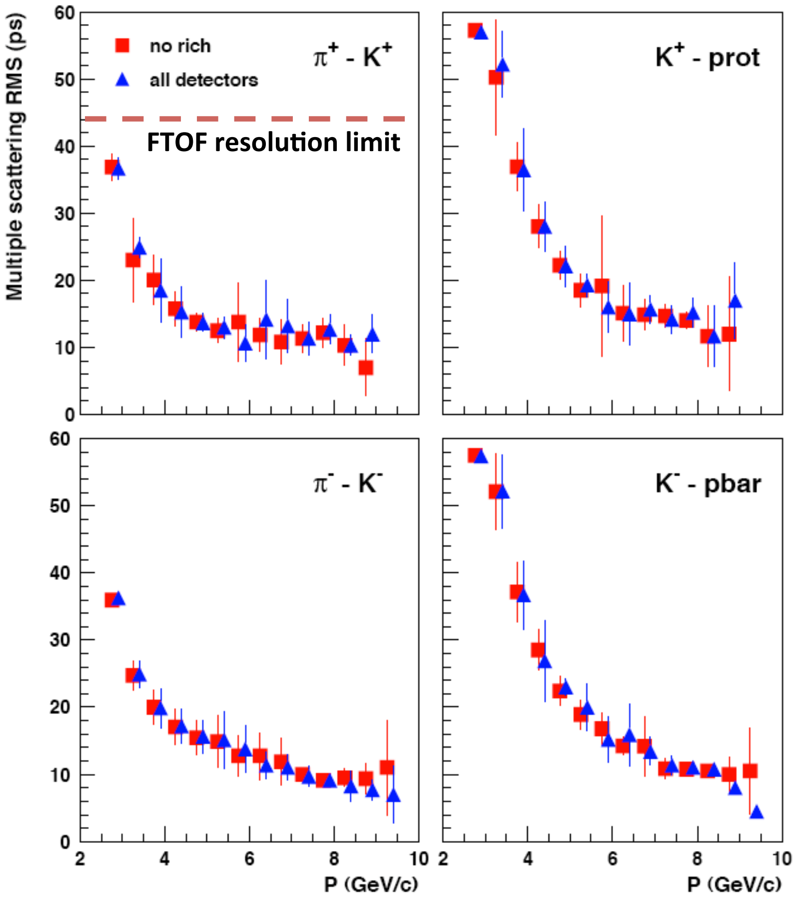
- HV and LV power supply monitor
- Gas monitor: temperature, pressure, humidity
- RICH stability monitor (i.e. on pedestals, occupancy, basic signals like high-energy electrons)

Interference with Other Detectors

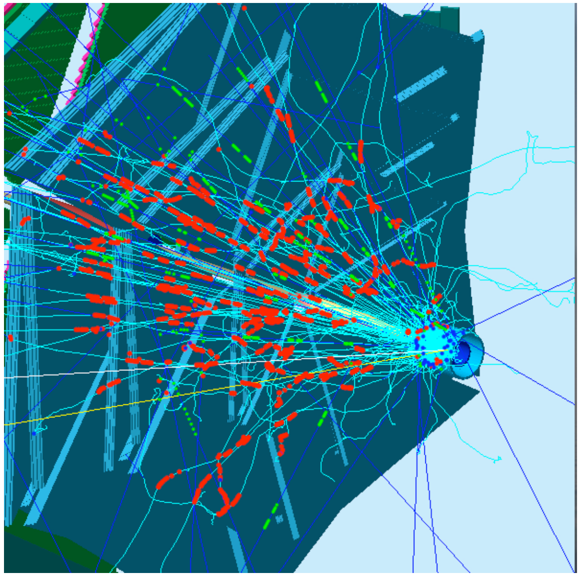
RICH material budget:

- ✓ Just in front of FTOF wall:
  multiple scattering spread << of the FTOF time resolution
- ✓ comparable with ~0.26 X_0 of FTOF and much less than preshower ~5 X_0
  energy spread << 10%/√E sampling calorimeter resolution

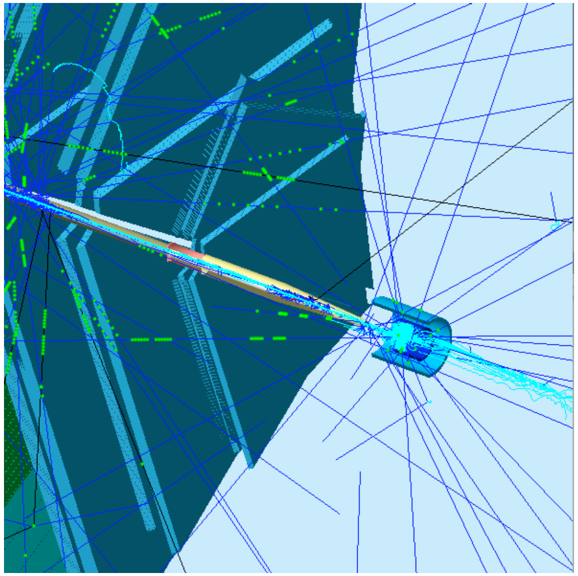




Drift Chamber Occupancy



No target field



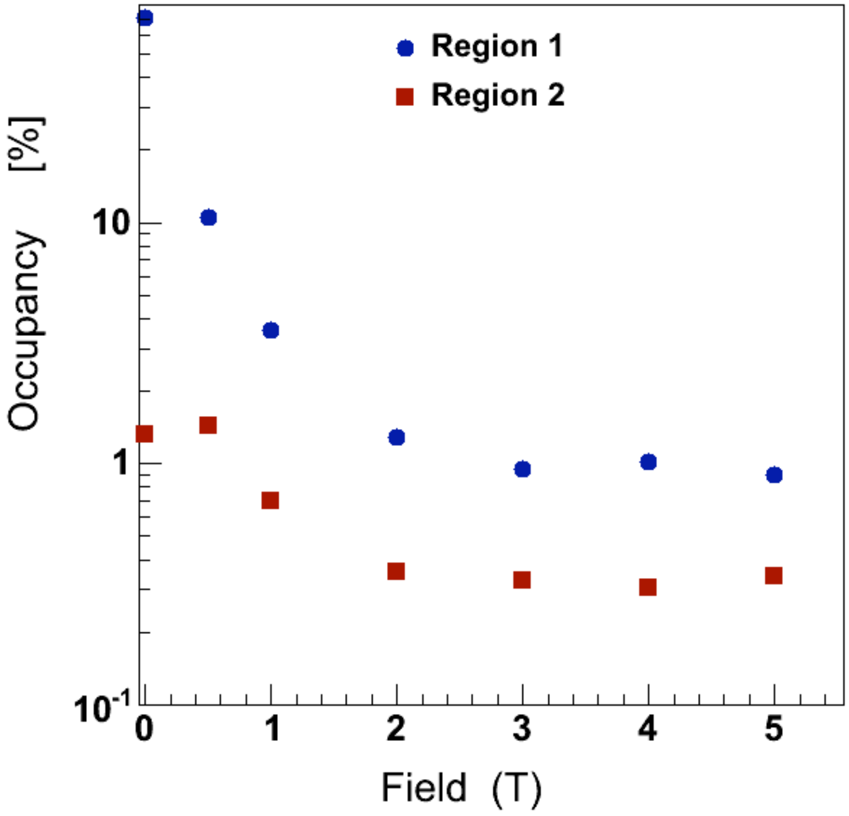
With target field

L = 10^{35} cm^{-2} s^{-1}

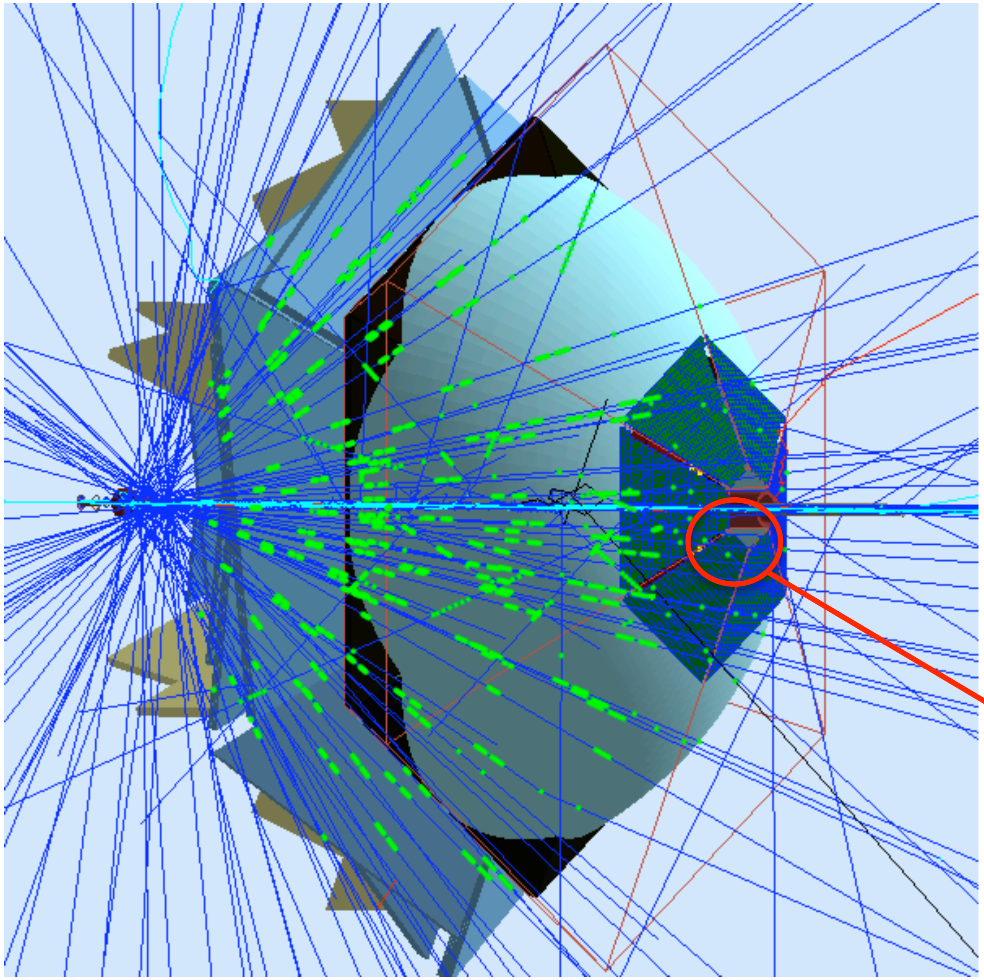
DIS rate: 1-10 kHz

Severe Moeller background

- *10-100 k within 250 ns*
- contained by central solenoid
- showering into long-range photons

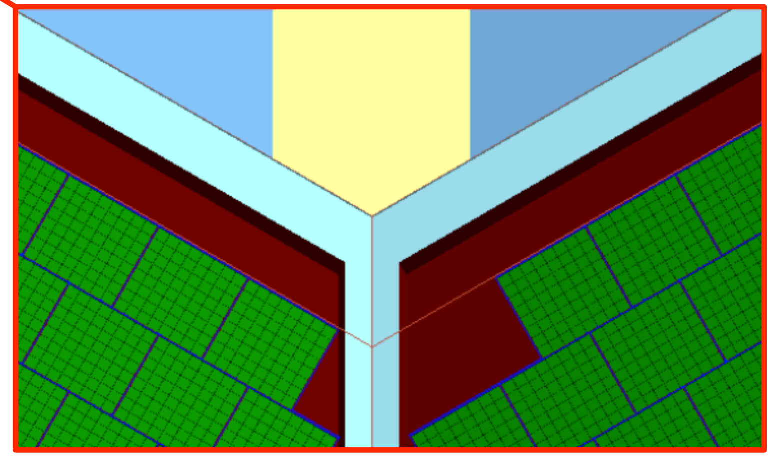


The RICH Background



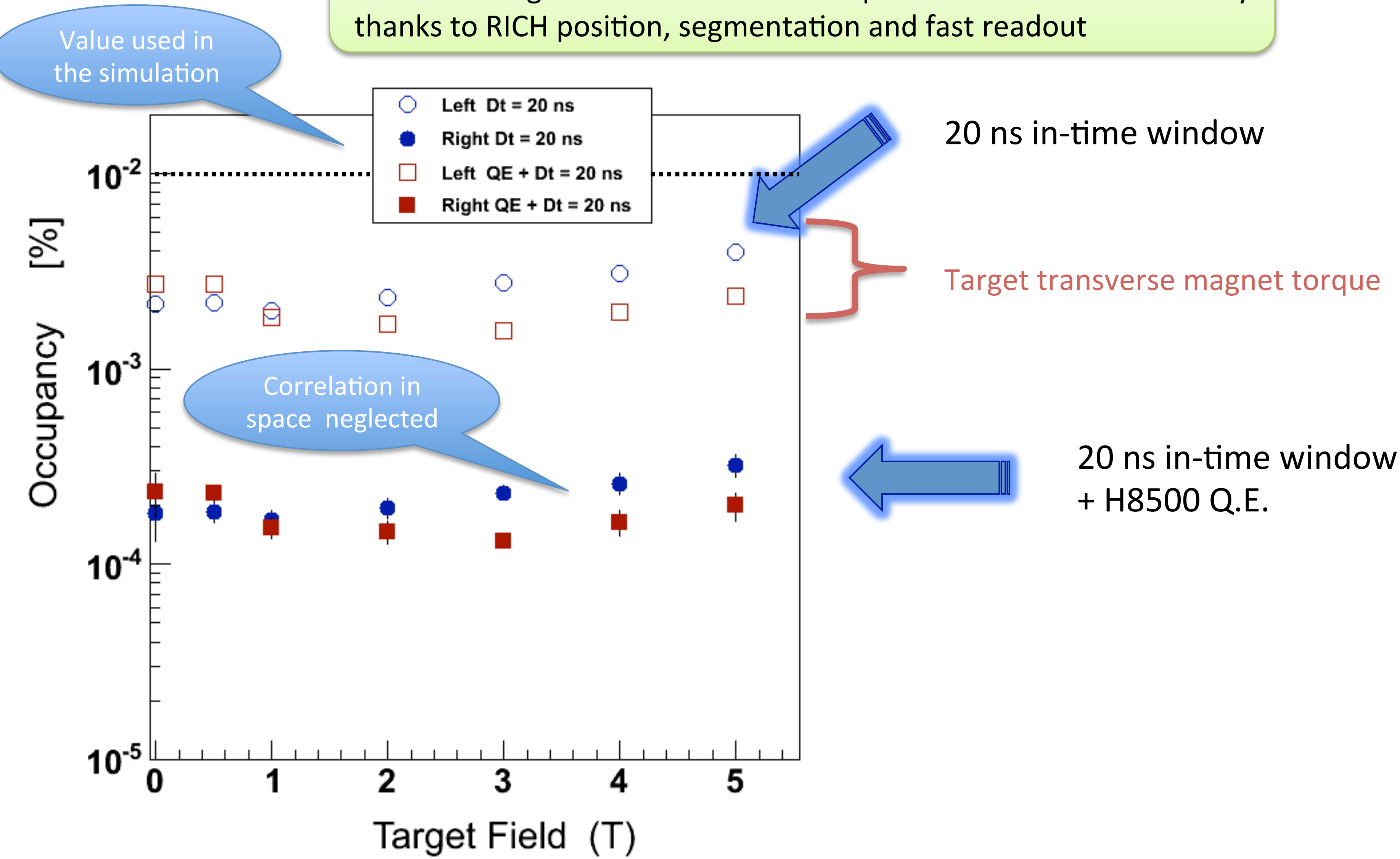
Major source of backgrounds

Photons conversions into the aerogel or in the PMT glass window producing Cerenkov light



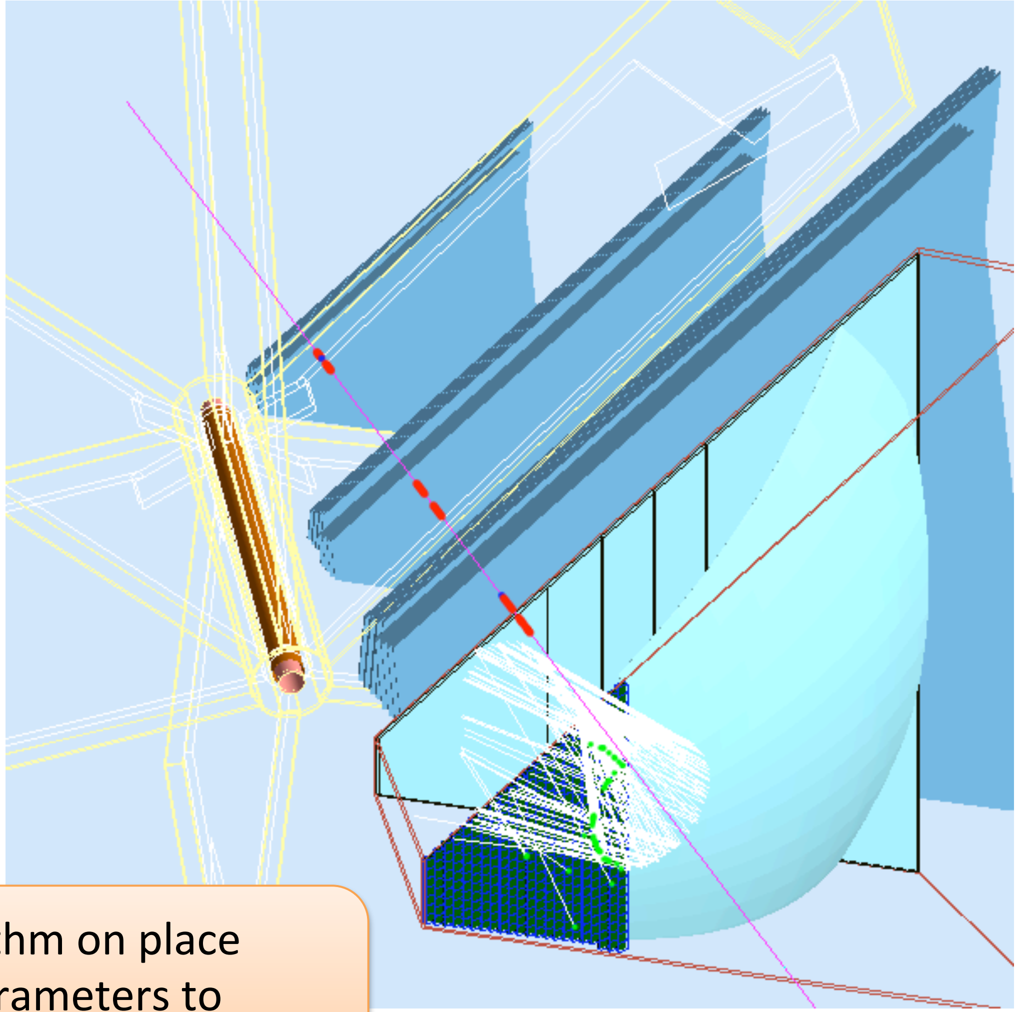
The RICH Occupancy @ L=10^{34}

Studies done for the physics run with transverse target indicates the Moeller background is under control up to the maximum luminosity thanks to RICH position, segmentation and fast readout



RICH Reconstruction

Verify and optimize the performances



Reconstruction algorithm on place
Ongoing: tuning of parameters to optimize the performances

The Likelihood Method

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:

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

(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

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

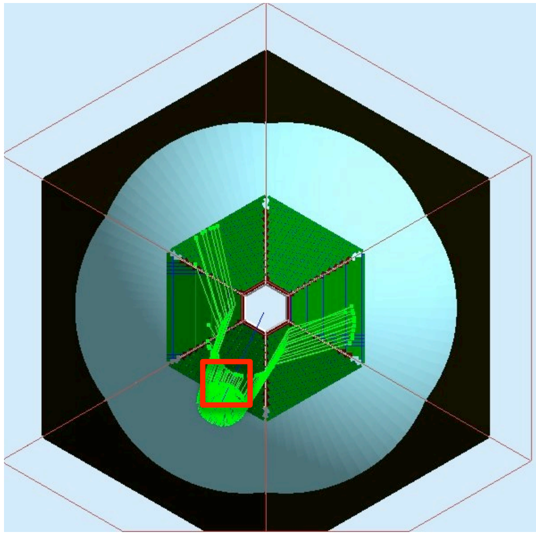
$$P^{(h,t)}_{PMT}(i) = 1 - exp(-\frac{N^{(h,t)}(i)}{\Sigma_i N^{(h,t)}(i)} n^{(h,t)} - B(i))$$

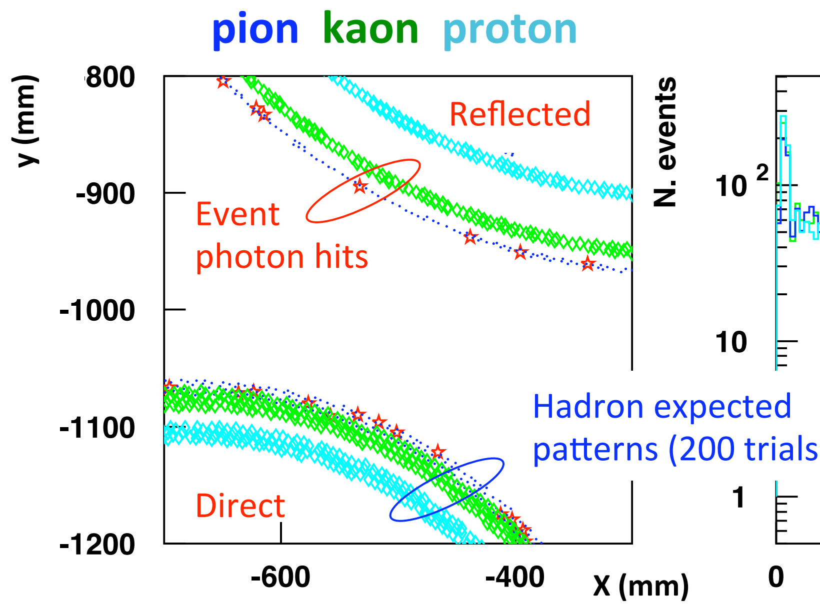
$\overline{P}^{(h,t)}_{PMT}(i) = 1 - P^{(h,t)}_{(PMT)}$ is the probability of no hit

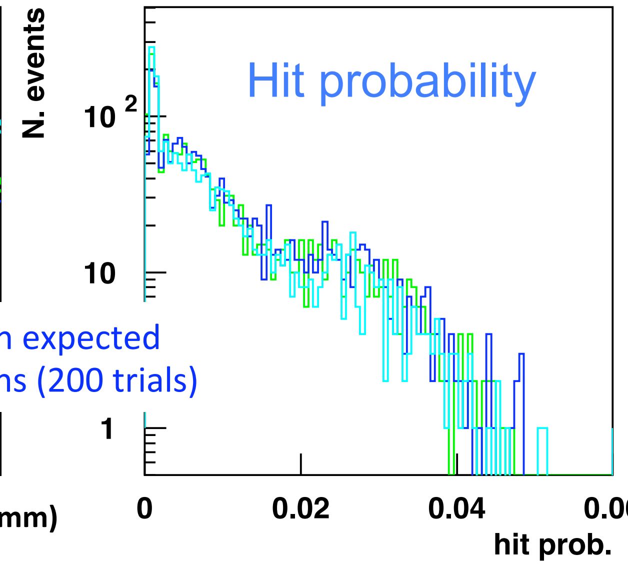
$n^{(h,t)}$ is the total number of expected PMT hits

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

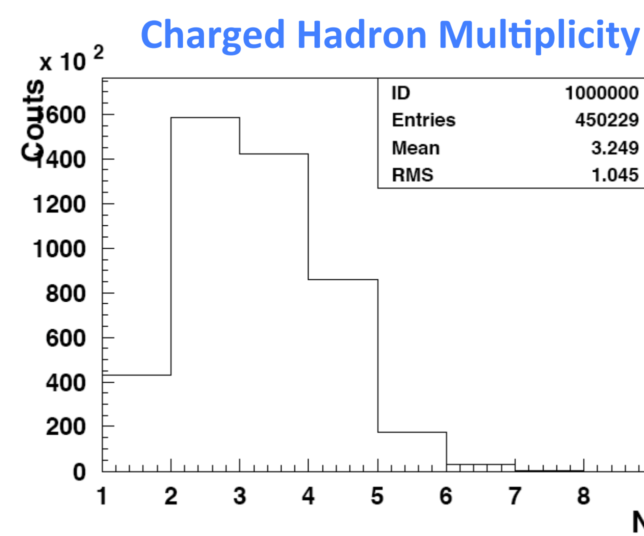
The RICH Reconstruction Algorithm







Standard techniques available but important to optimize:
Geometry together with Likelihood parameters
(background, time coincidence window, p.d.f precision)



Control with
Goodness Estimator

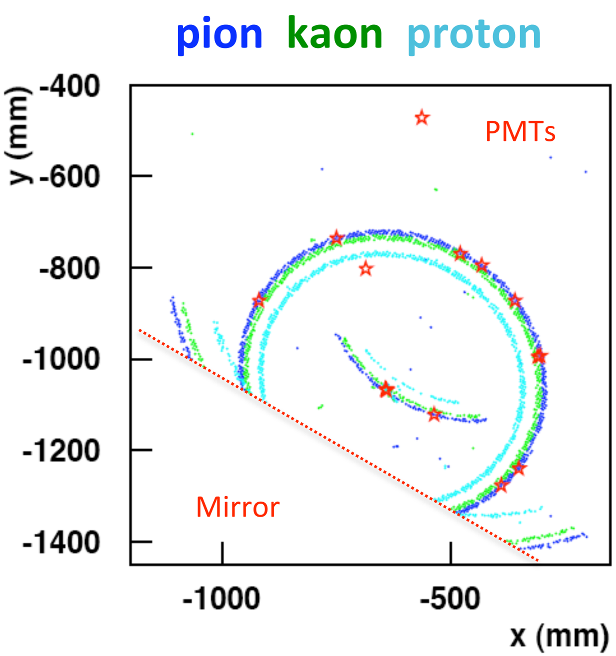
Poor ID confidence Good

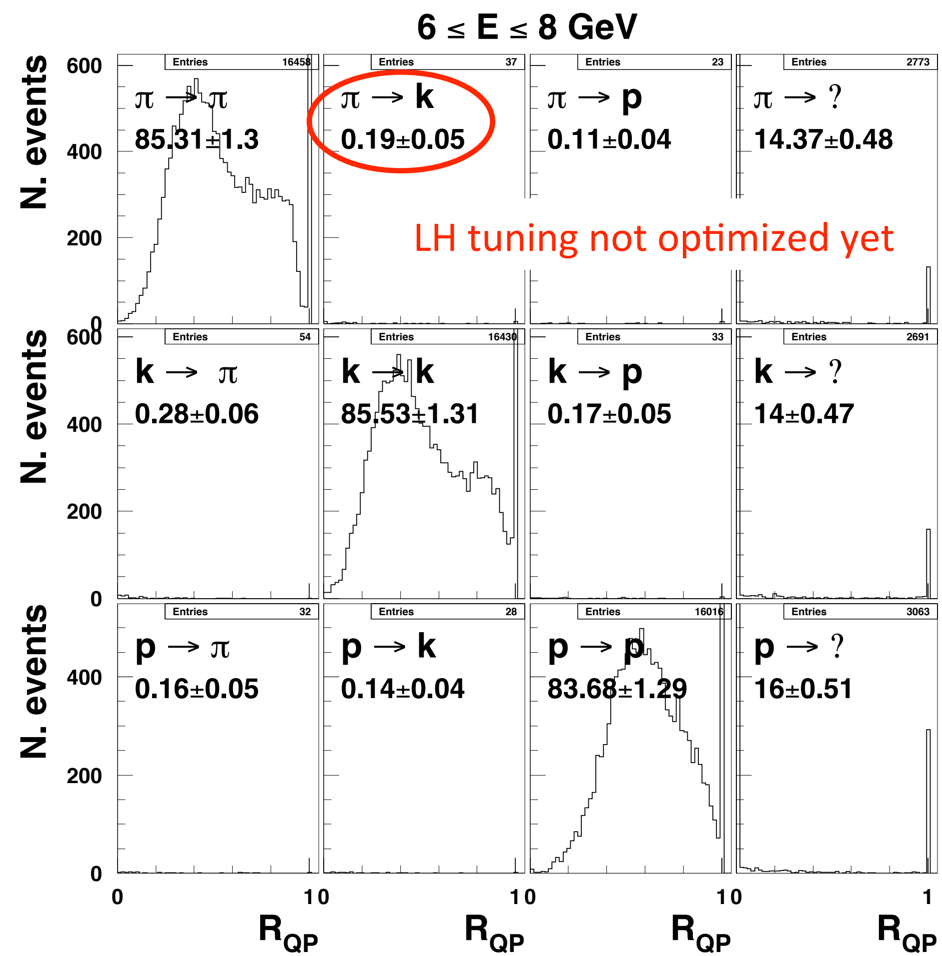
0 → 1

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

Events in CLAS12

P = 6.3 GeV/c θ = 6 degrees R_{QP} = 0.59

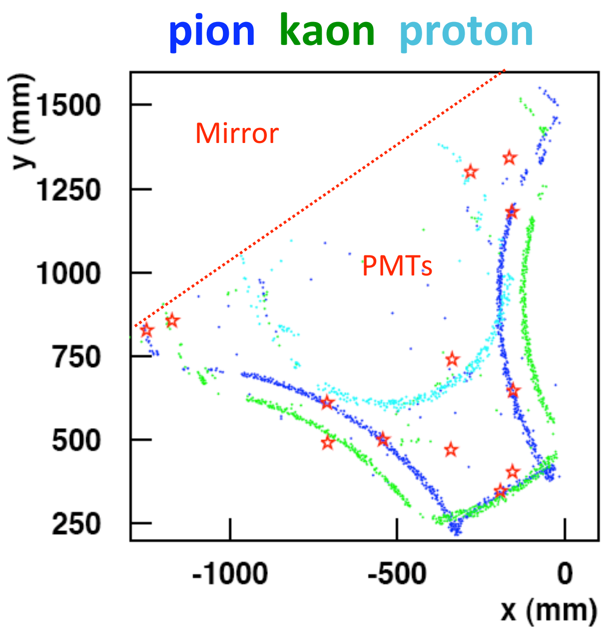




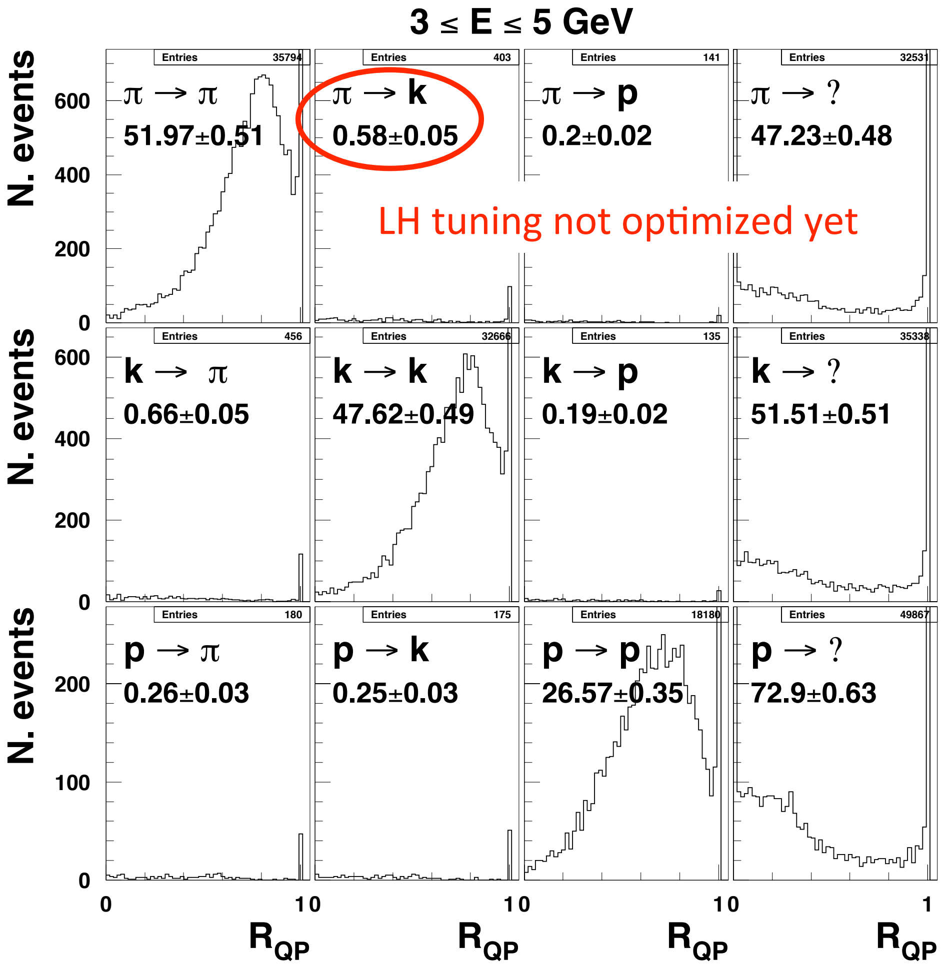
Good ID thanks to high photon yield
R_{QP} reflects close Cherenkov rings

Events in CLAS12

P = 3.7 GeV/c θ = 22 degrees R_{QP} = 0.98



Good ID thanks to separate patterns
Un-identifications reflect photon yield



CLAS12 Combined PID

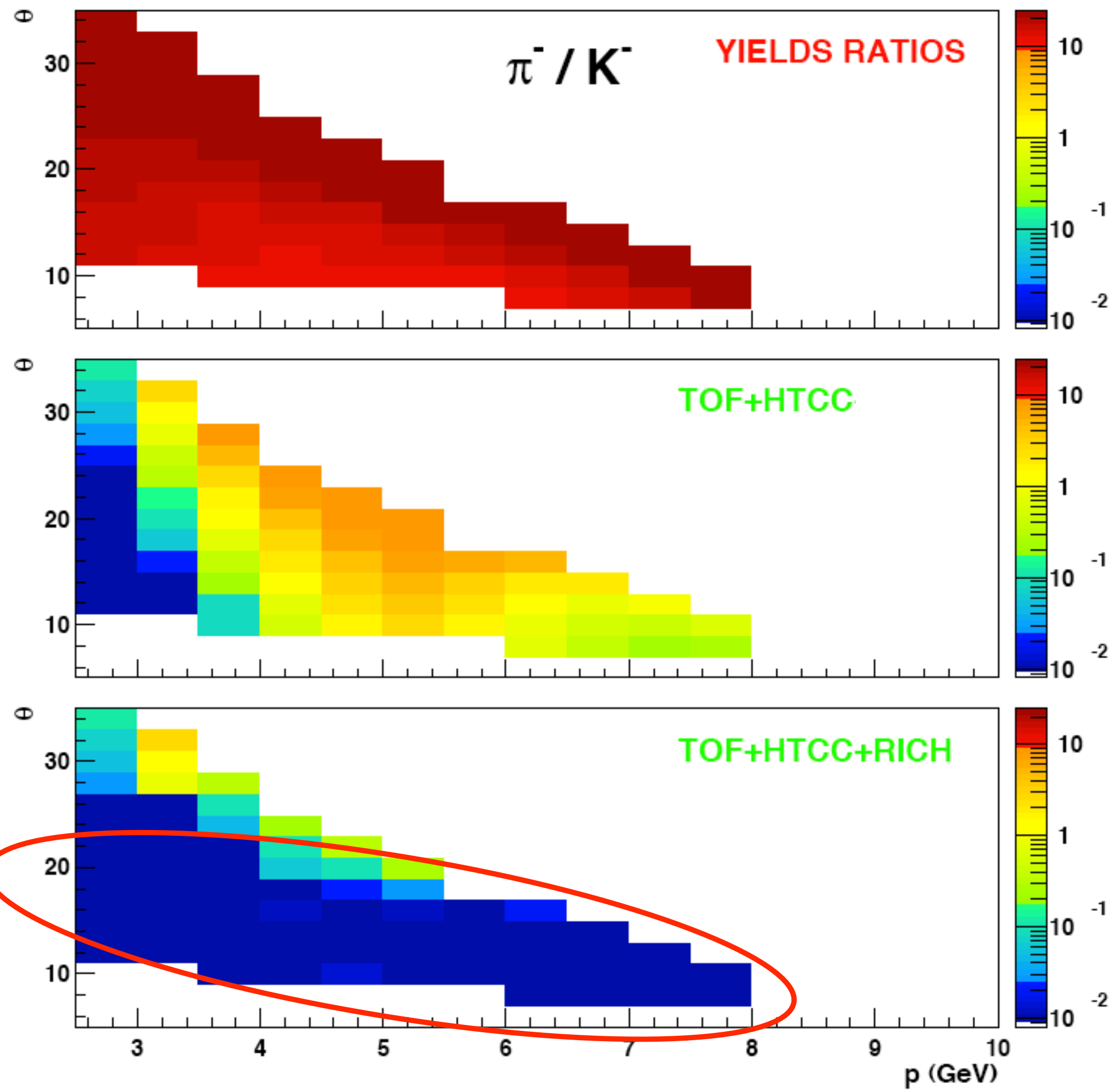
Pion contamination in the kaon sample for In-bending Particles

SIDIS particle flux
within acceptance
pion >> kaon everywhere

TOF +HTCC pion rejection
for 90% kaon efficiency
pion >> kaon in a broad region

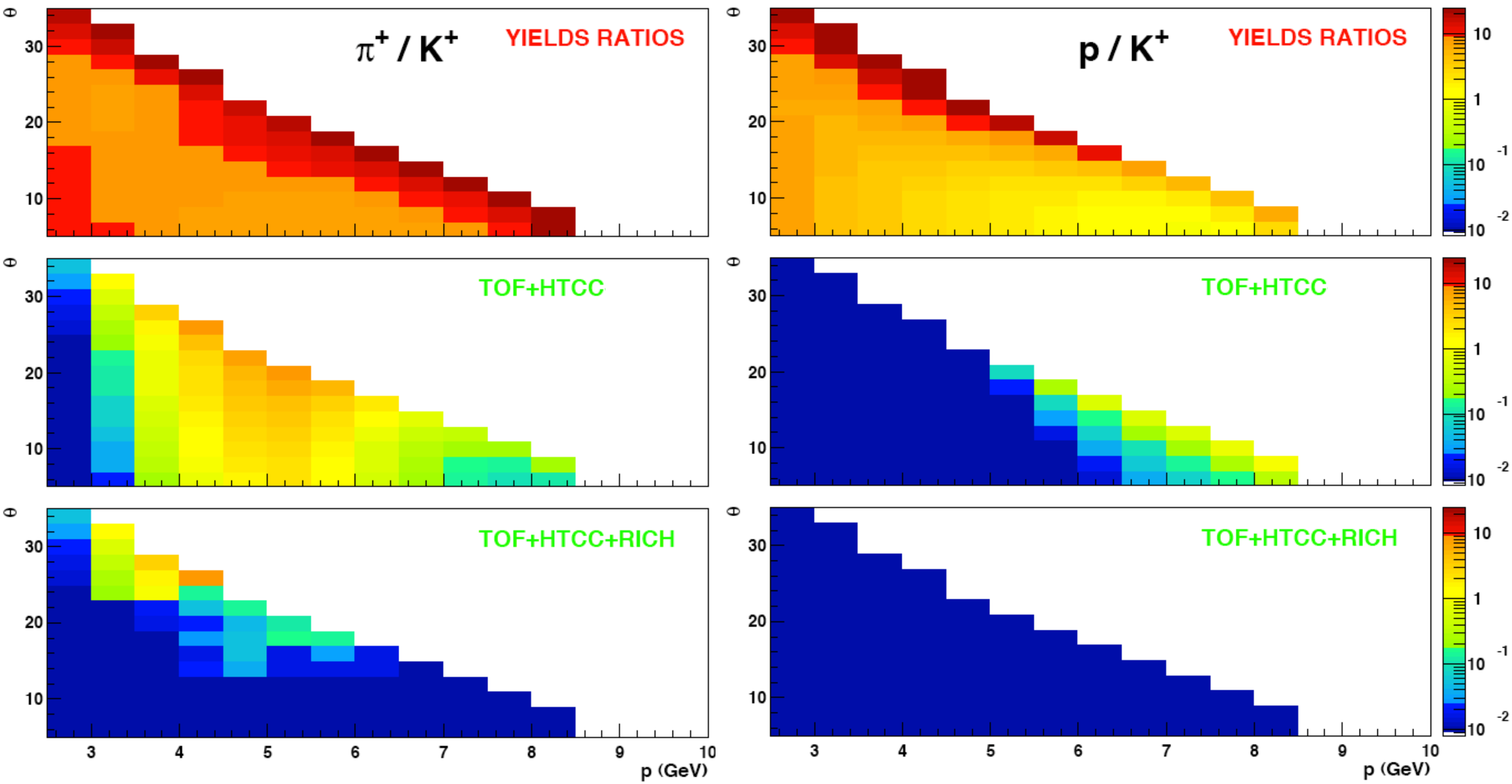
TOF+HTCC+RICH
pion rejection

Even with a tuning not yet optimized the pion contamination is of the order of 1%



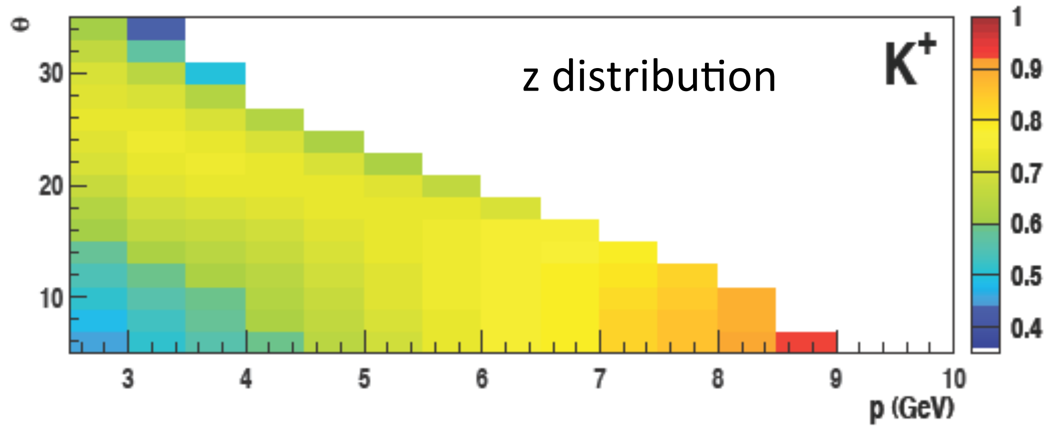
CLAS12 Combined PID

Pion contamination in the kaon sample for Out-bending Particles

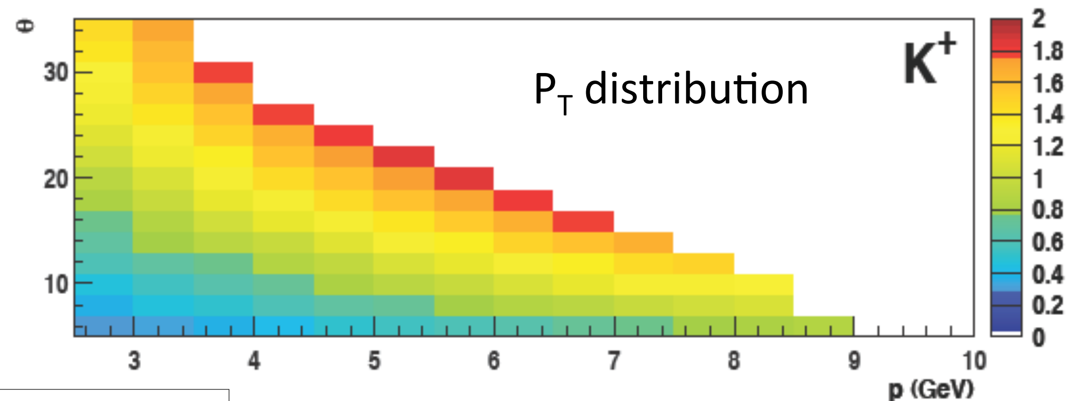


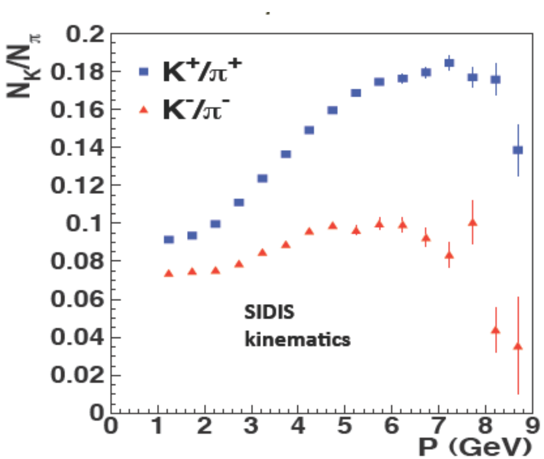
RICH Requirements

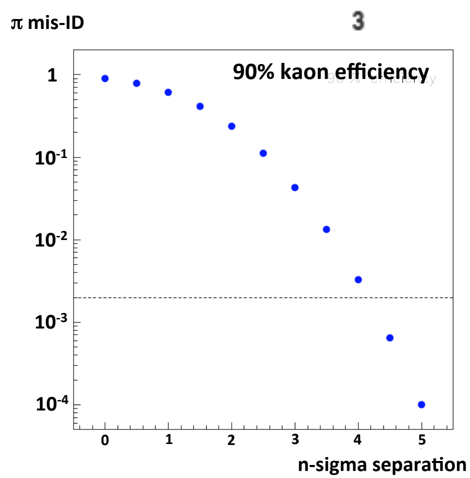
✔ Full momentum coverage up to 8 GeV/c
Pion rejection above 3 GeV/c
Proton rejection above 5 GeV/c



Angular coverage reaching
✔ above 20 and
✔ up to 25 degrees
(optimization in progress)

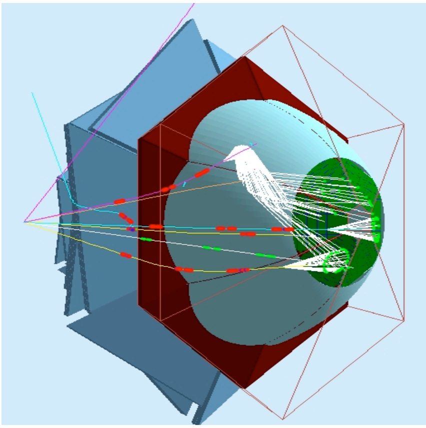




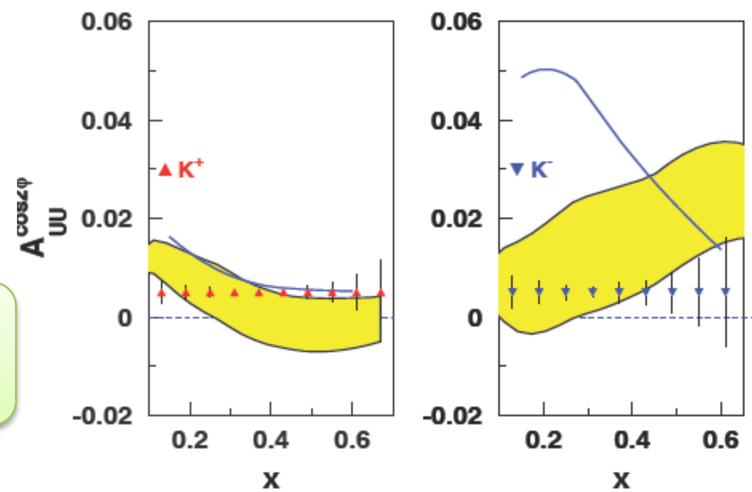


✔ Contamination limited at the few % level
Pion rejection close to 500
Proton rejection close to 100

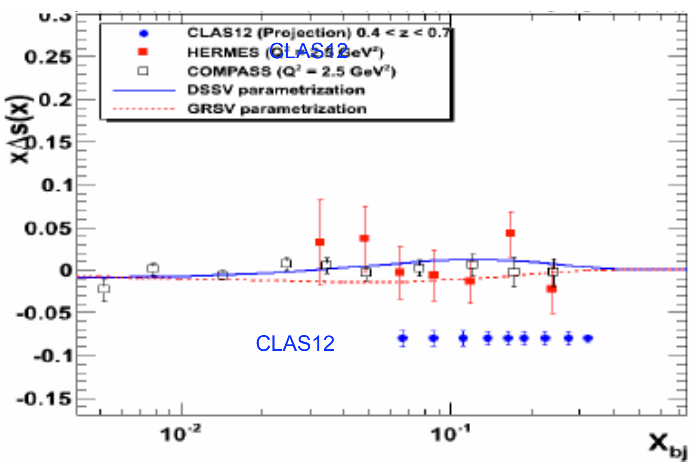
Kaon Program @ CLAS12



E12-09-08: Studies of Boer-Mulders Asymmetry in Kaon Electroproduction with Hydrogen and Deuterium Targets

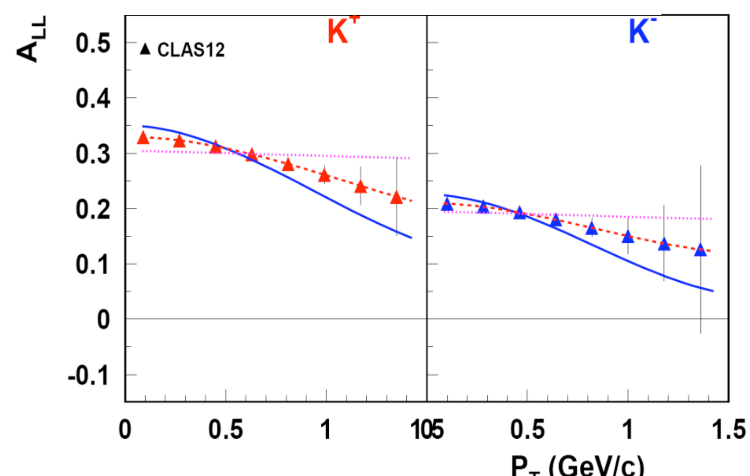


RICH detector for flavor separation of quark spin-orbit correlations in nucleon structure and quark fragmentation



E12-09-09:

Studies of Spin-Orbit Correlations in Kaon Electroproduction in DIS with polarized hydrogen and deuterium targets



E12-09-07:

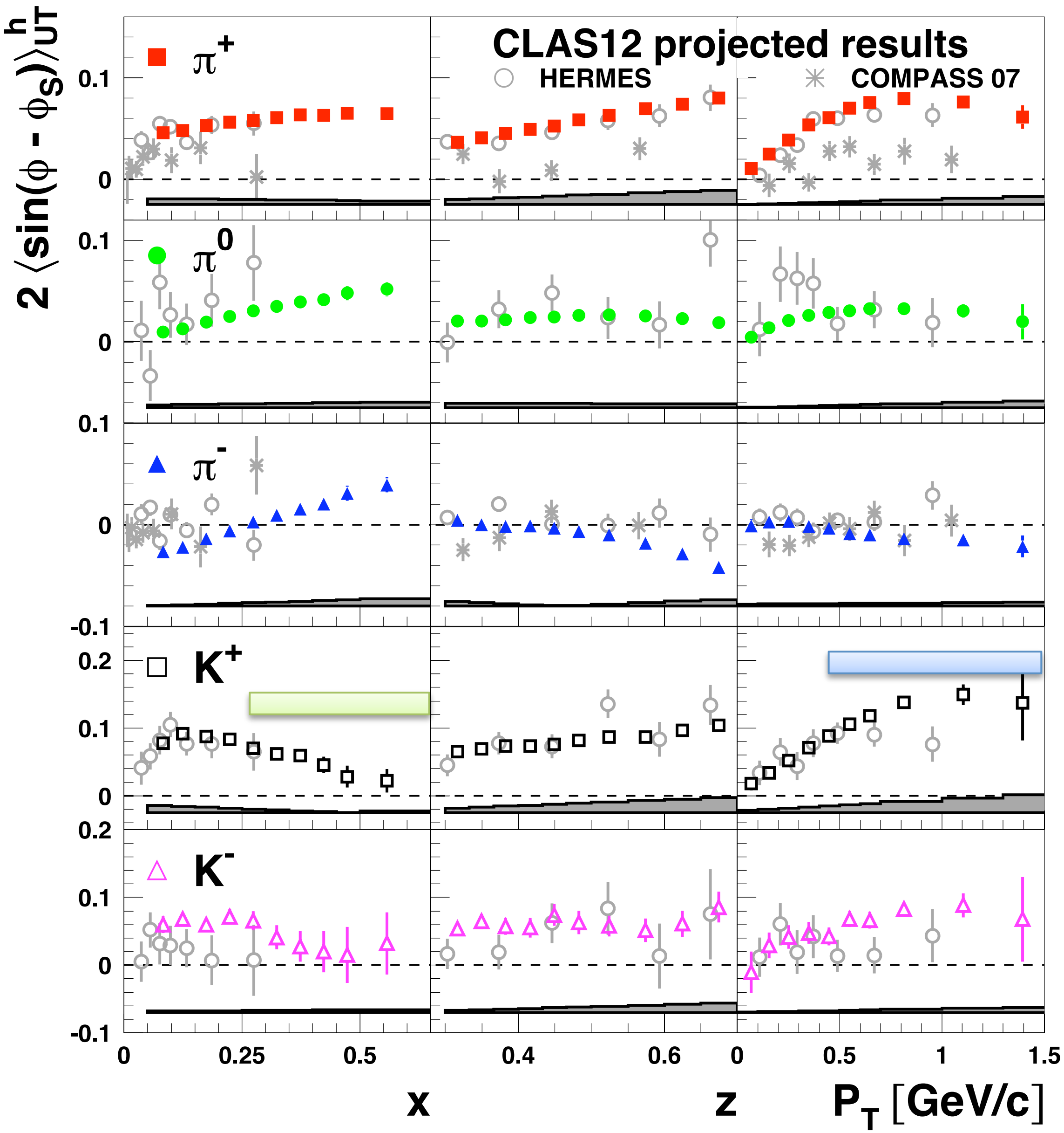
Studies of partonic distributions using semi-inclusive production of Kaons

Kaon Program @ CLAS12

C12-11-111:
Transverse spin effects in SIDIS at 11 GeV with a Transversely polarized target using the CLAS12 Detector

Covering so far unexplored quark valence region

Achieve unprecedent precision in a broad range of p_T



Conclusions

Interference with CLAS12:

- Designed to fit into the LTCC clearance
- No impact on the downstream detector performances
- Background occupancy at a manageable level

RICH Operation:

- Use physics triggers for commissioning and calibration
- Use well-known maximum-likelihood methods to
  reconstruct the not-trivial Cherenkov signal pattern
- Use CLAS12 standard solutions for gas system and slow-control

The RICH detector allows hadron ID in the full CLAS12 kinematics
ensuring the approved physics program to be accomplished