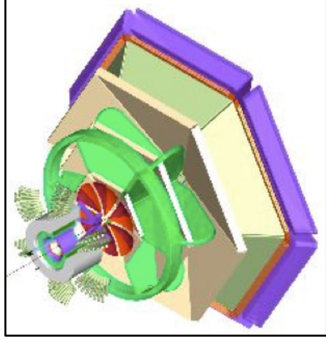
Jefferson Lab
Thomas Jefferson National Accelerator Facility



Particle Identification in CLAS12

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CLAS12 RICH Technical Review
Jefferson Lab, June 26, 2013

CLAS12

Luminosity 10^{35} cm ^{2} s^{-1}

Forward Detector

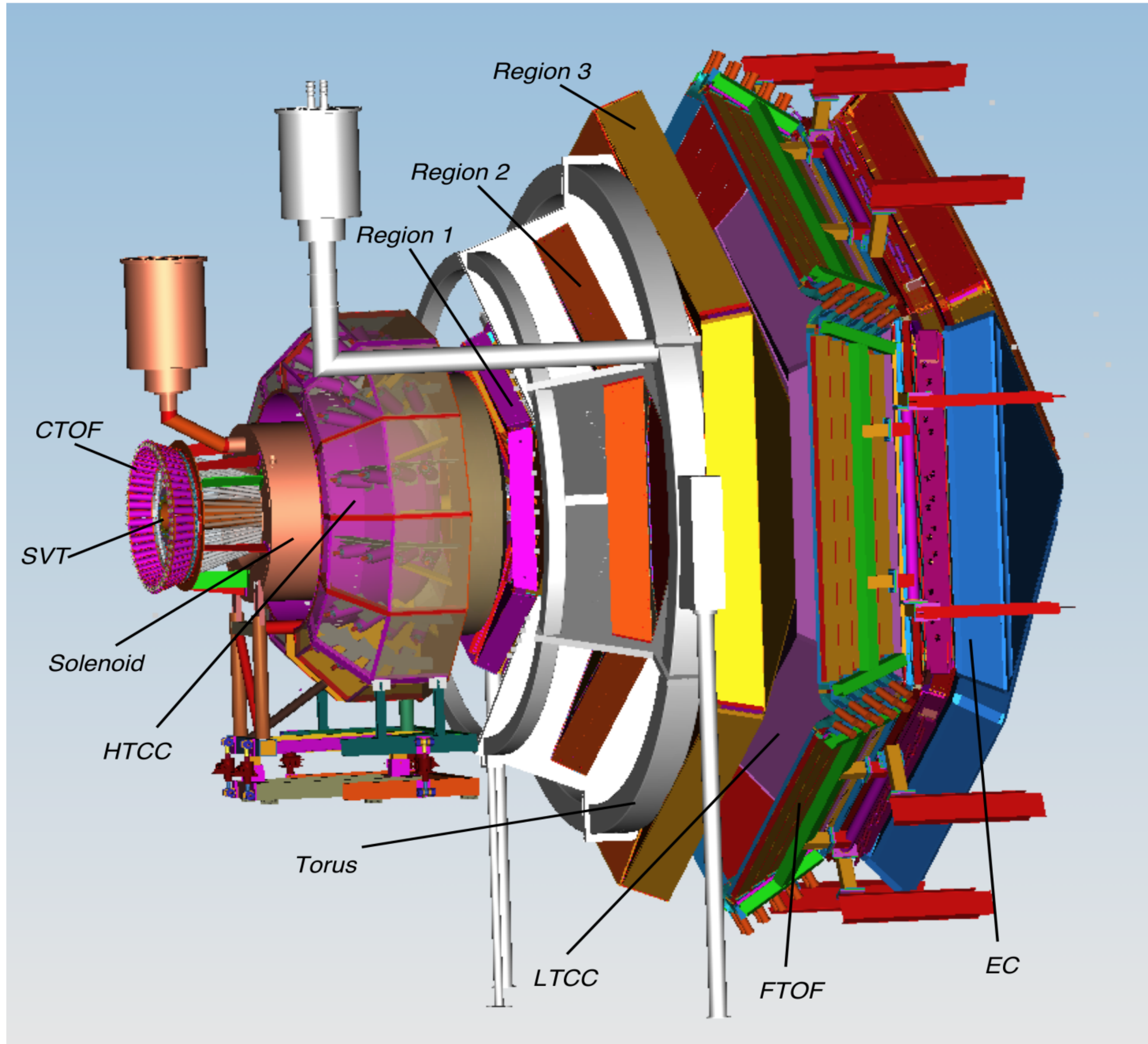
- TORUS magnet
- Forward SVT tracker
- HT Cherenkov Counter
- Drift chamber system
- LT Cherenkov Counter
- Forward ToF System
- Preshower calorimeter
- E.M. calorimeter

Central Detector

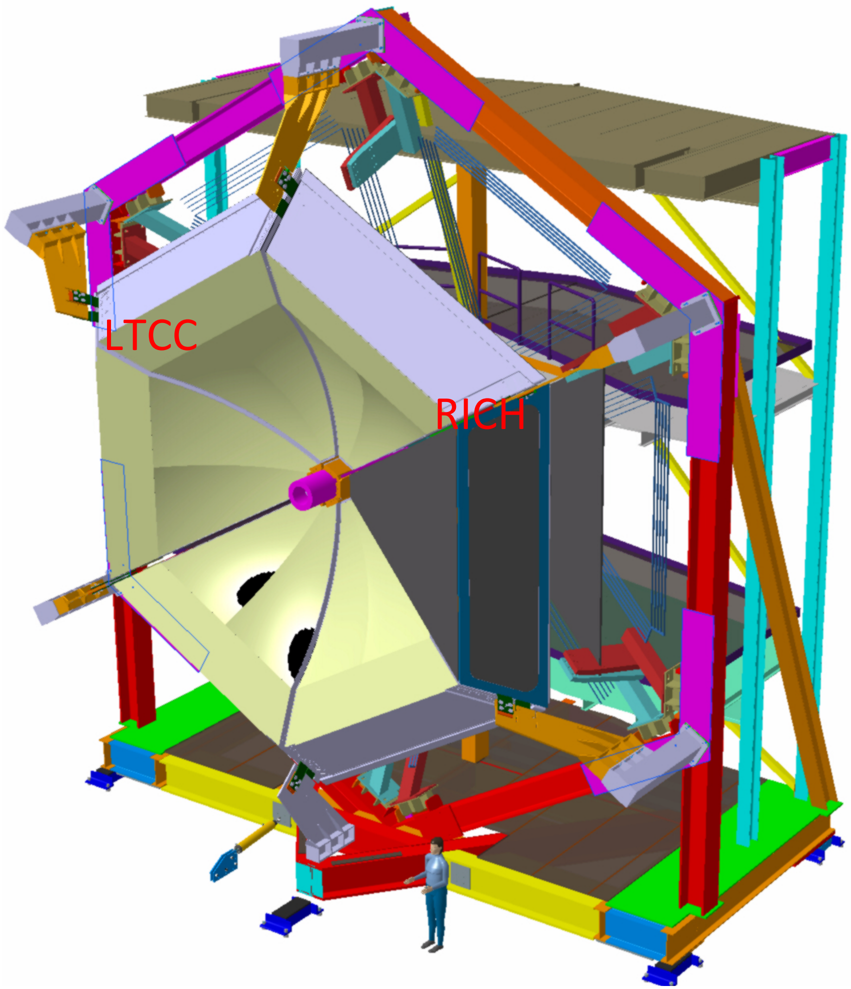
- SOLENOID magnet
- Barrel Silicon Tracker
- Central Time-of-Flight
- Polarized target (NSF)

Proposed upgrades

- Micromegas (CD)
- Neutron detector (CD)
- RICH detector (FD)
- Forward Tagger (FD)



RICH for CLAS12



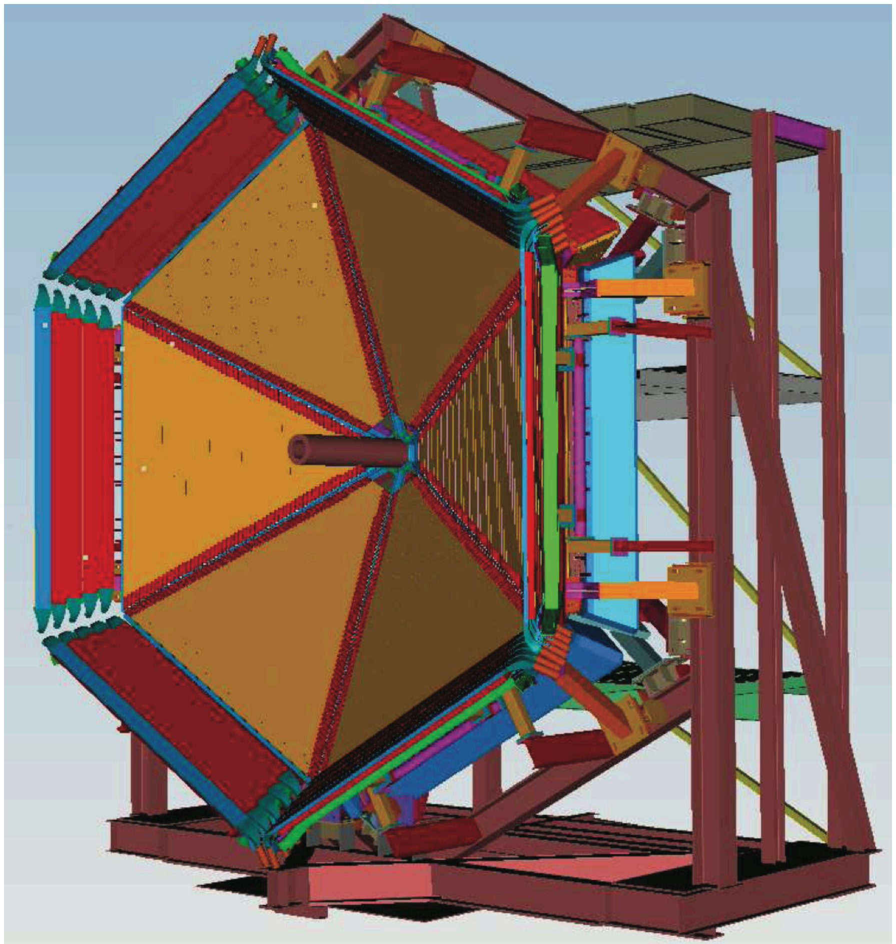
Our goal is to build one sector Ring Imaging Cherenkov Counter for particle ID in the Forward direction to achieve π/K/p separation with at least 3σ separation in a momentum range up to 8 GeV

D. Orecchini, S. Tomassini

Detectors used for Charged Particles ID in the Forward Detector

- Forward Time of Flight system FTOF
- High Threshold Cherenkov Counter HTCC
- Low Threshold Cherenkov Counter LTCC

Forward TOF

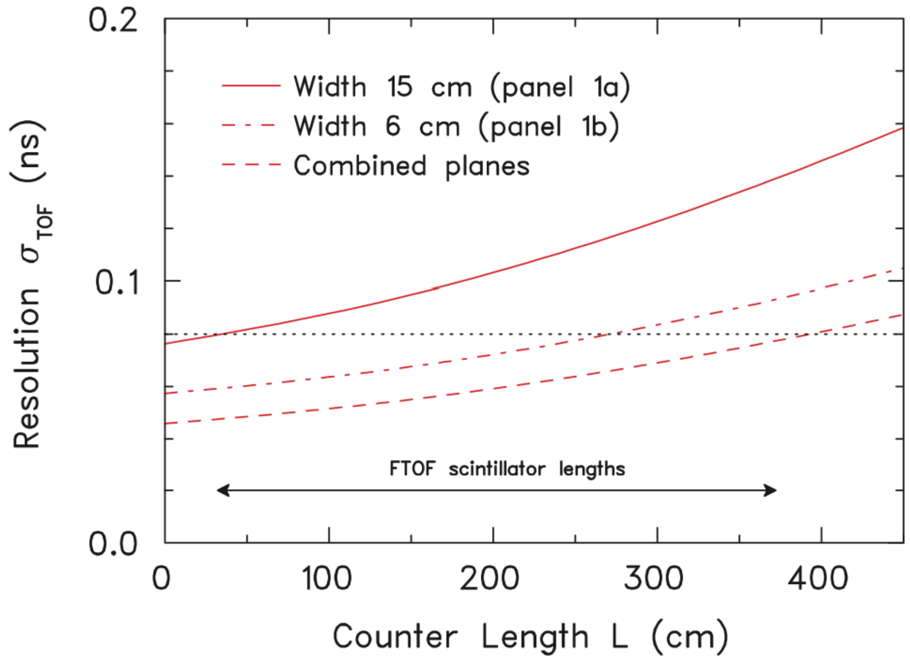


CLAS12 TOF system includes hodoscopes with 5.08 cm thick scintillators: Panel 1a, Panel 1b and Panel 2.

In addition to the existing Panel 1a one more plane of counter will be added in the forward direction – Panel 1b.

- Panel 1a: 15 cm wide, length 32-375 cm
- Panel 1b: New, 6 cm wide

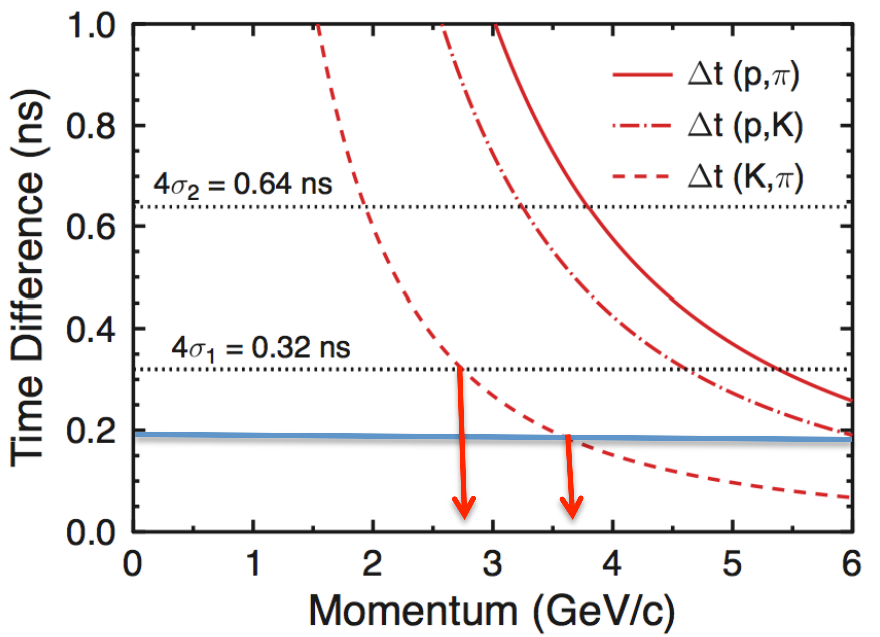
Expected Time Resolution of the Forward TOF System



σ_{TOF}<80 ps (1a+1b)

Panel 1a: 80-300 ps
Panel 1b: 60-100 ps
Combined: 45- 80 ps

K-π, p-K p-π Δt over L=650 cm from target to FTOF



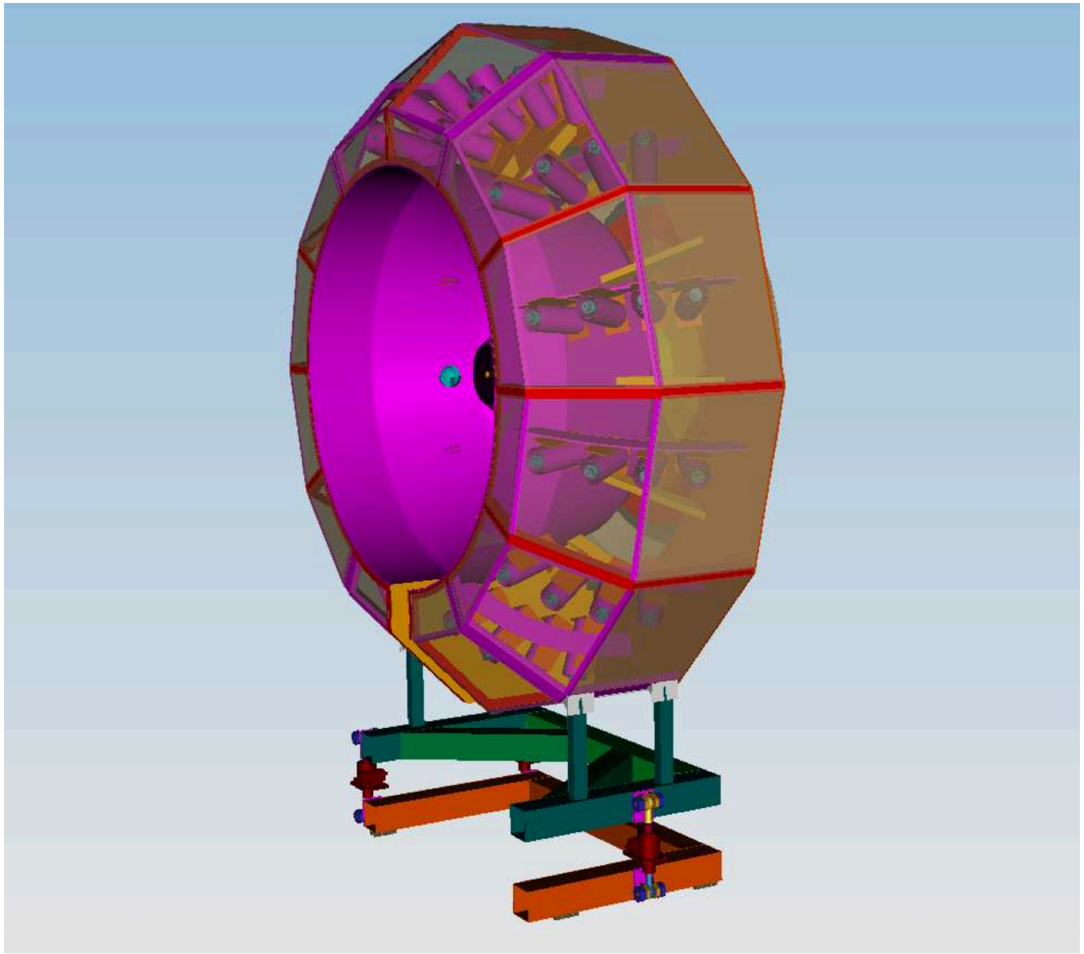
0.32 ns (36 degrees)

0.18 ns (5 degrees)

<u>*4σ pion-kaon separation*</u>

- Up to 2.8 GeV (θ = 36 degrees)
- Up to 3.6 GeV (θ = 5 degrees)
- 90% kaon efficiency

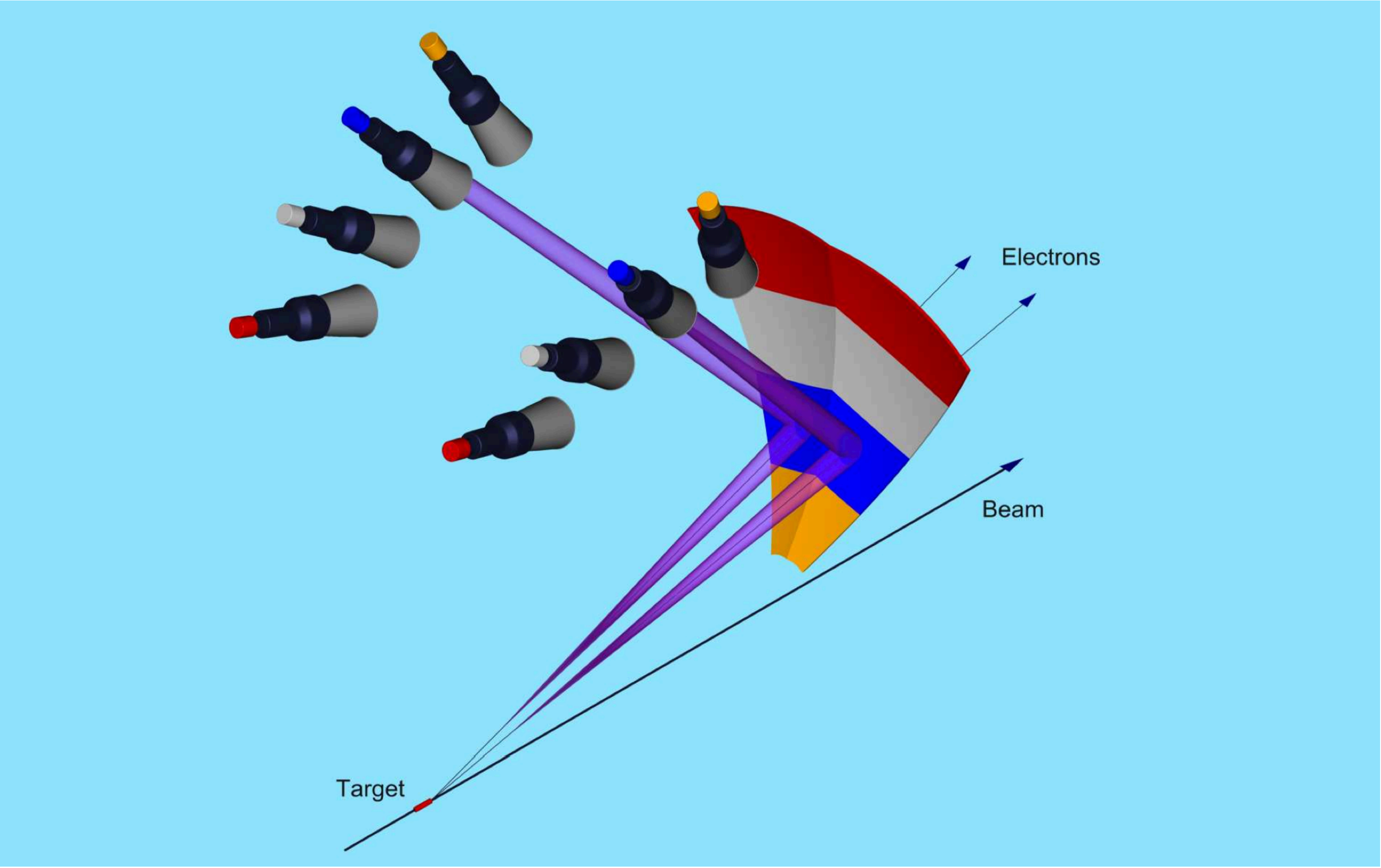
High Threshold Cherenkov Counter



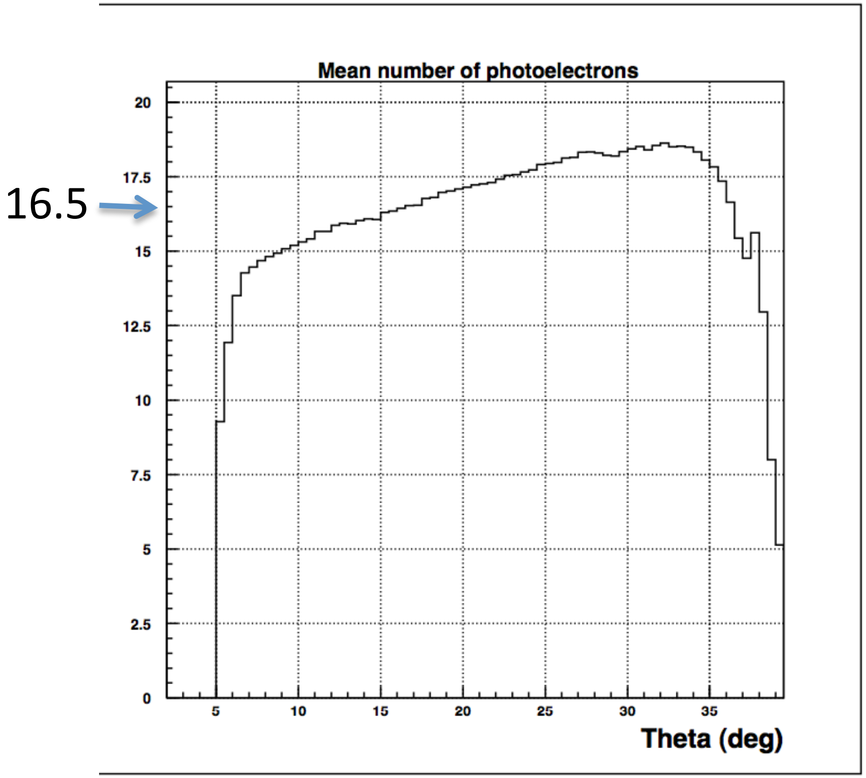
- New CLAS12 detector
- Designed to separate electrons from pions
- High efficiency
- Hermetic, no dead zones

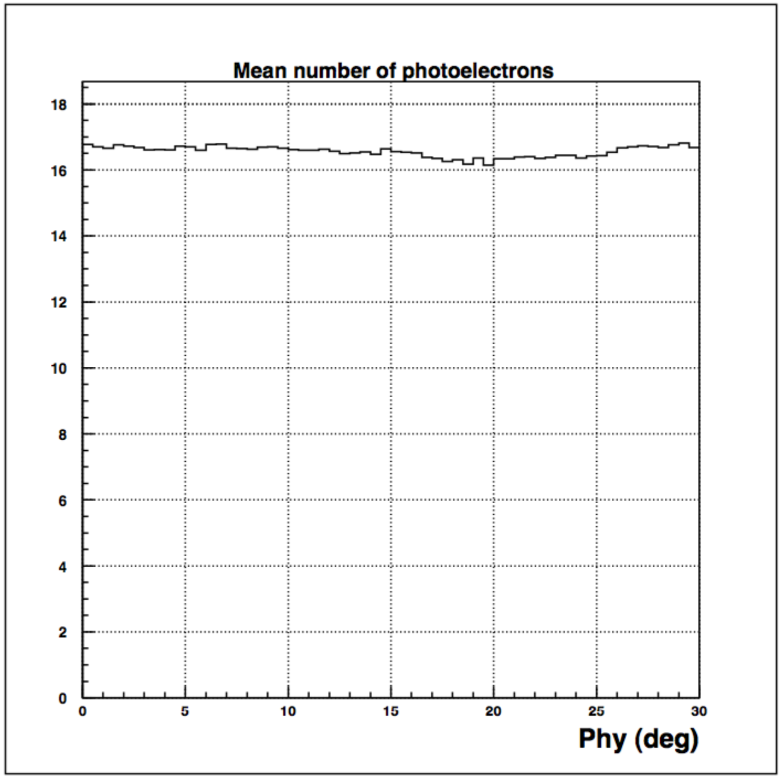
- Radiator: CO_2
- 48 5" PMTs with quartz window
- Expected number of the photoelectrons >16

HTCC 3D View



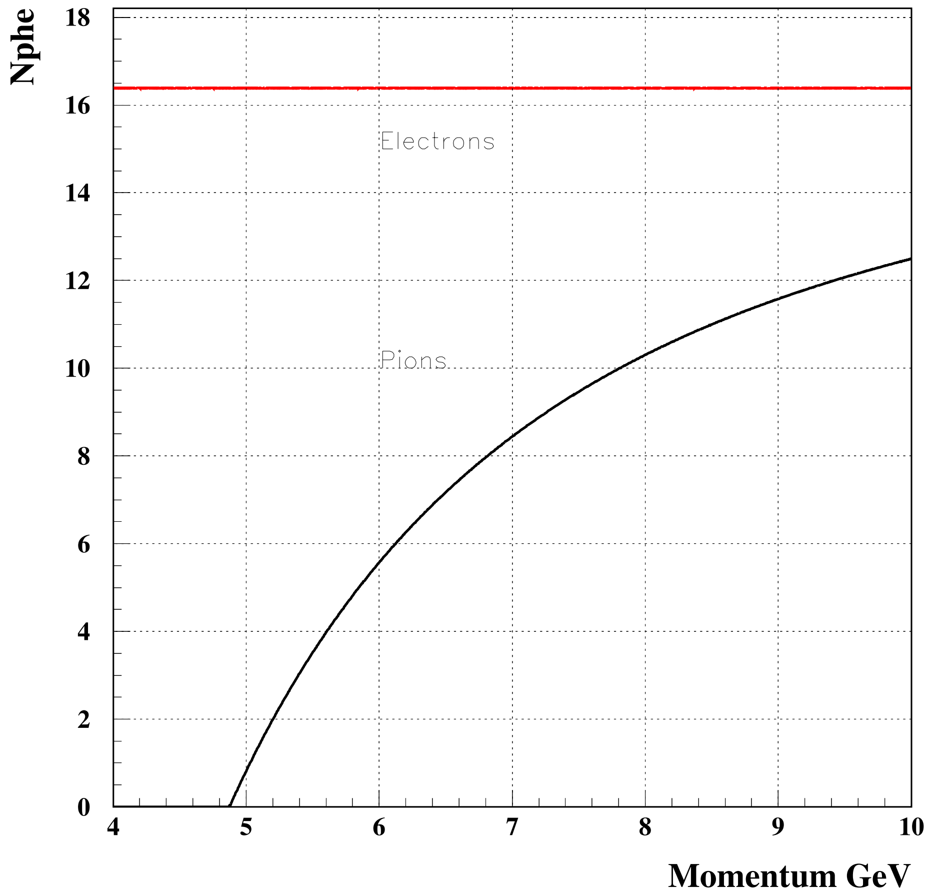
HTCC: Number of Photoelectrons for electrons





The average number of photoelectrons almost independent of theta and absolutely independent of phi. The hermeticity of HTCC is 100%, no dead zones.

Number of Photoelectrons



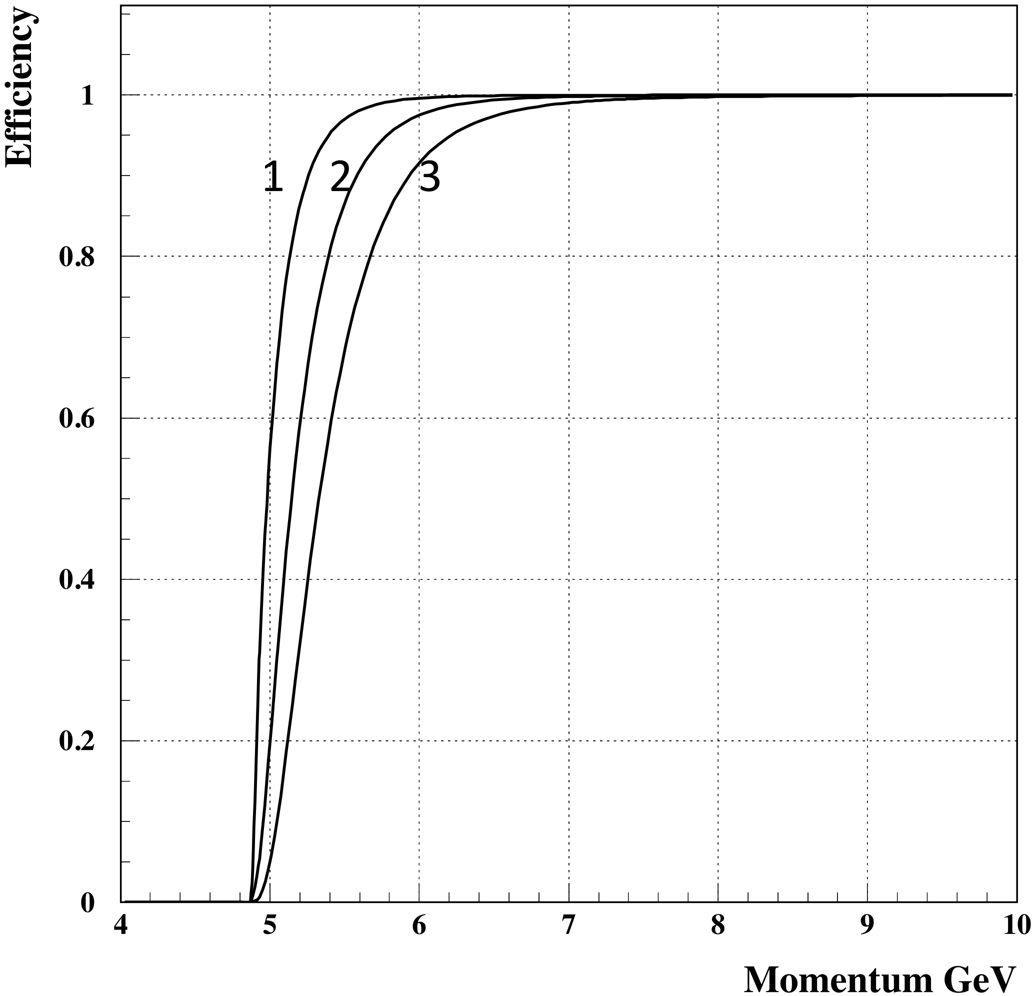
Electrons

Pions

$$N^{\pi}_{Nphe} = N^{e}_{Nphe} \frac{Sin^2\theta^{\pi}}{Sin^2\theta^{e}}$$

The number of the photoelectrons goes up from 0 at the threshold (~5 GeV) to 12 at P=10 GeV. These estimations are very robust in my opinion.

Pions efficiency for minimum Nphe=1,2 and 3

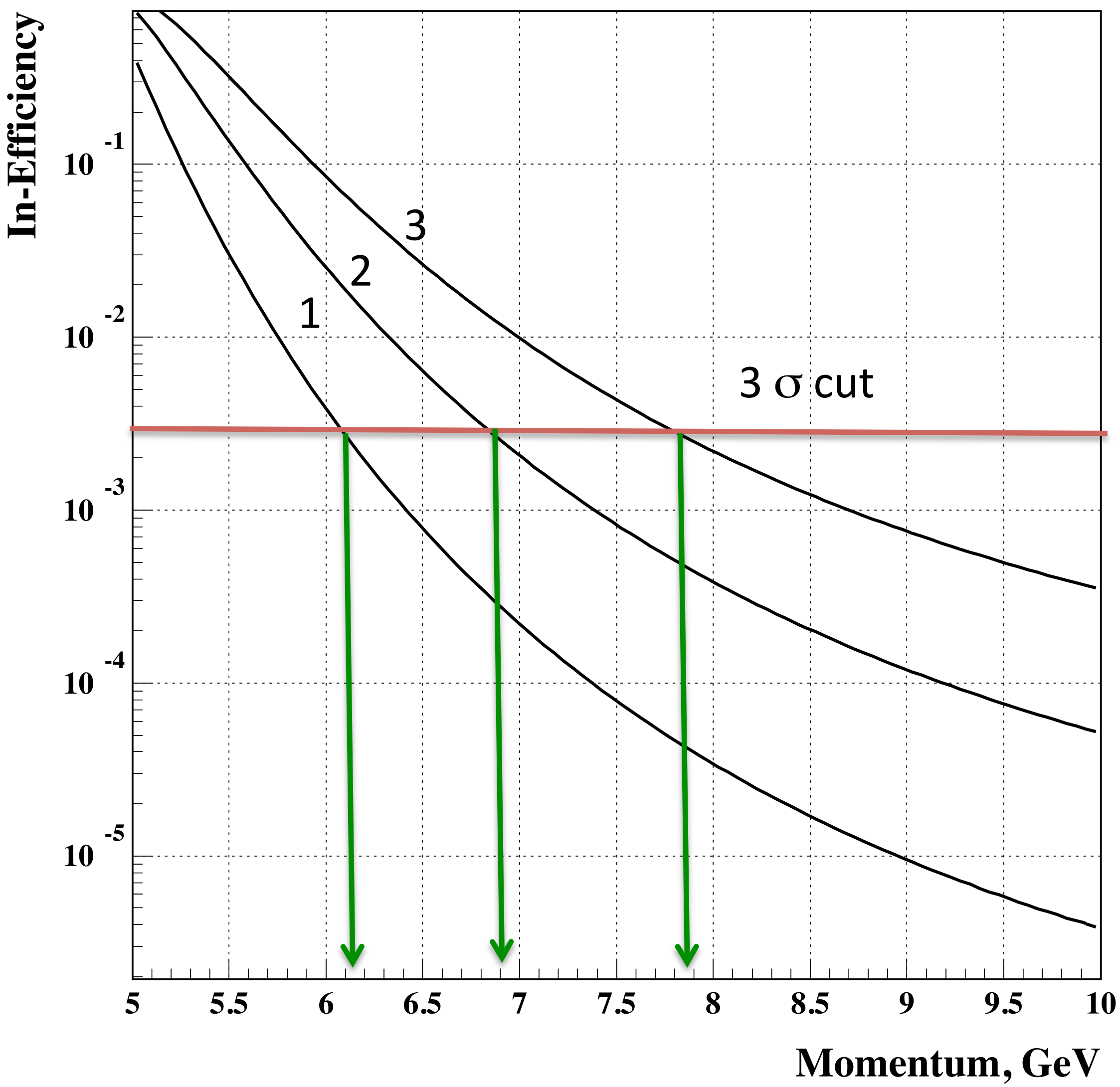


The efficiency was calculated using the Poisson distribution with average given in the previous slide.

The exact cut (1,2 or 3) on the minimum number of the photoelectrons will be established after the commissioning of the High Threshold Cherenkov Counter

Nphe=3 is the conservative cut.

Pions inefficiency for minimum Nphe=1,2 and 3



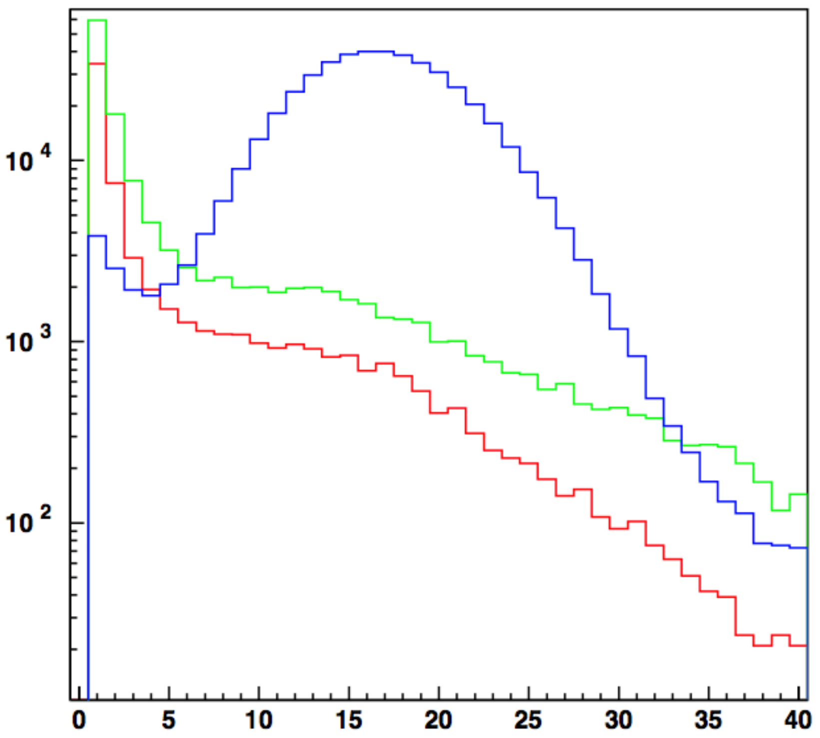
If there is no signal in HTCC :

- The charge particle is a kaon (or proton)
- The charge particle is a pion, that was not detected by HTCC due to the inefficiency

The 3 σ cut ($3\ 10^{-3}$) gives the minimum momentum of 6.1 (Nphe=1), 6.9(2) or 7.8(3) GeV

The cut on minimum number of photoelectrons will depend on the performance of HTCC and random noise in the detector

Pions and kaons below threshold



Blue-electrons
Green – pions 4 GeV
Red – pions 2 GeV

- Pions may produce Cherenkov light in HTCC even under the threshold due to the δ-electrons. However the probability of such processes is low and the amplitude of the Cherenkov light is small.

- The kaons are always below the HTCC threshold.

- Efficiency for 2 GeV pions = 0.2, 0.1, 0.08%
  Efficiency for 4 GeV pions =0.5, 0.25, 0.2%.

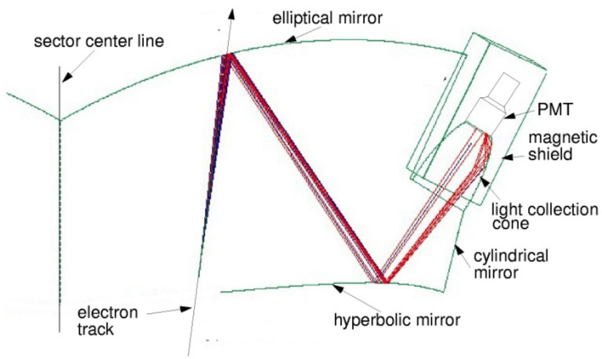
It is 1,2 or 3 minimum Nphe cut. The efficiency for kaons will be in the same percent range. It means that the kaon will be interpreted as pion at approximately one percent level.

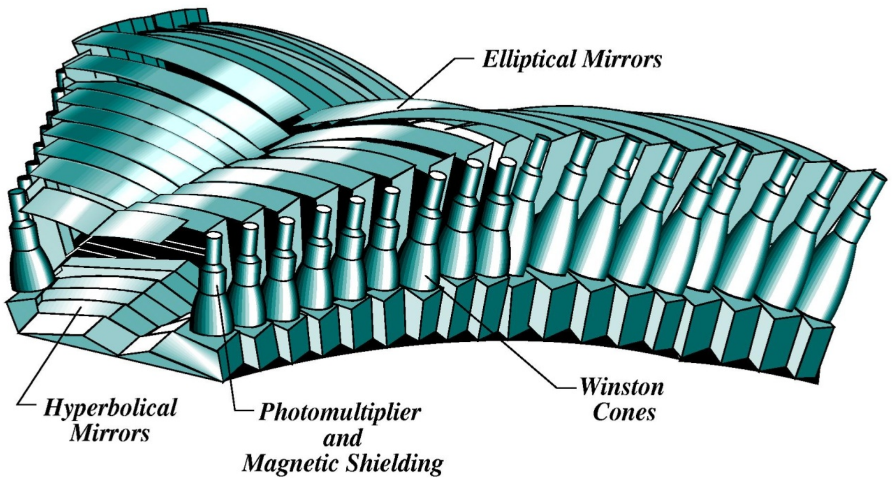
HTCC conclusion

Taking the minimum number of photoelectrons as 2-3 we can conclude

- 3σ π/K separation in the region 7-8 GeV
- In the region 6-7 GeV the pion suppression factor will be better then 10^{-1}-10^{-2} only
- The more difficult region is between 5 and 6 GeV. However even in this momentum range HTCC will help RICH to resolve pions from kaons

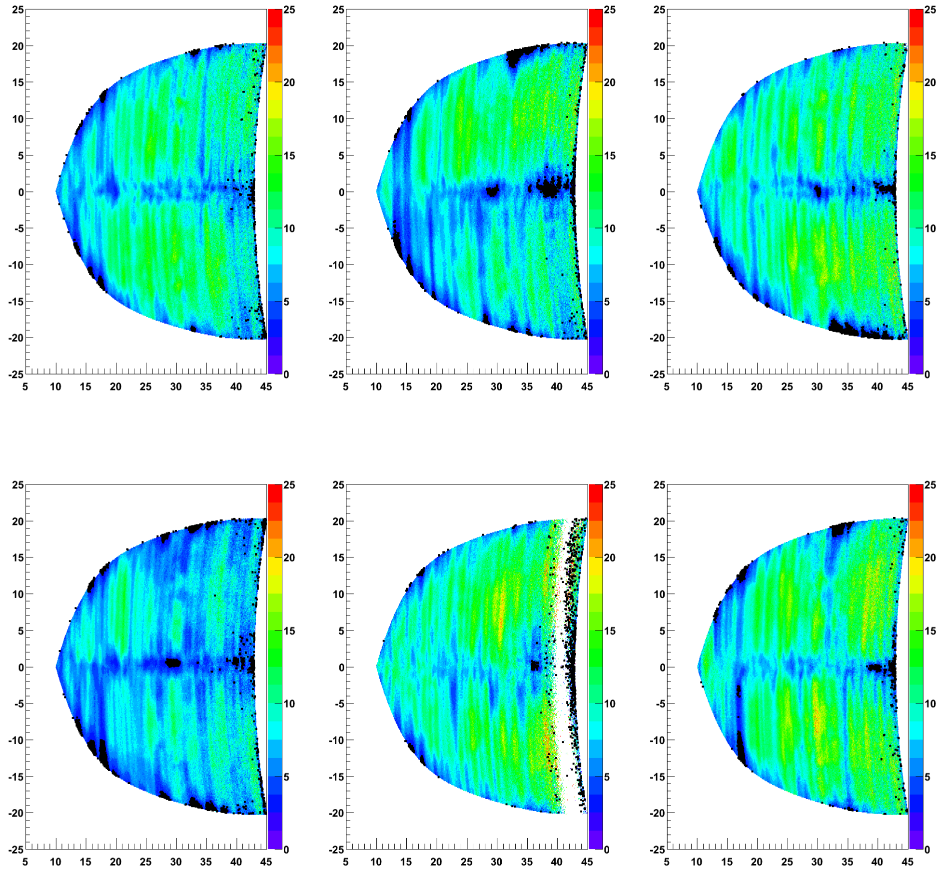
Low Threshold Cherenkov Counter





- Gas C_4F_{10} at 1 atm.
- Pion threshold p=2.7 GeV/c
- Number of photoelectrons is factor of 2 less then at HTCC
- The ϕ acceptance is limited
- The detector has irregularities (see next slide)

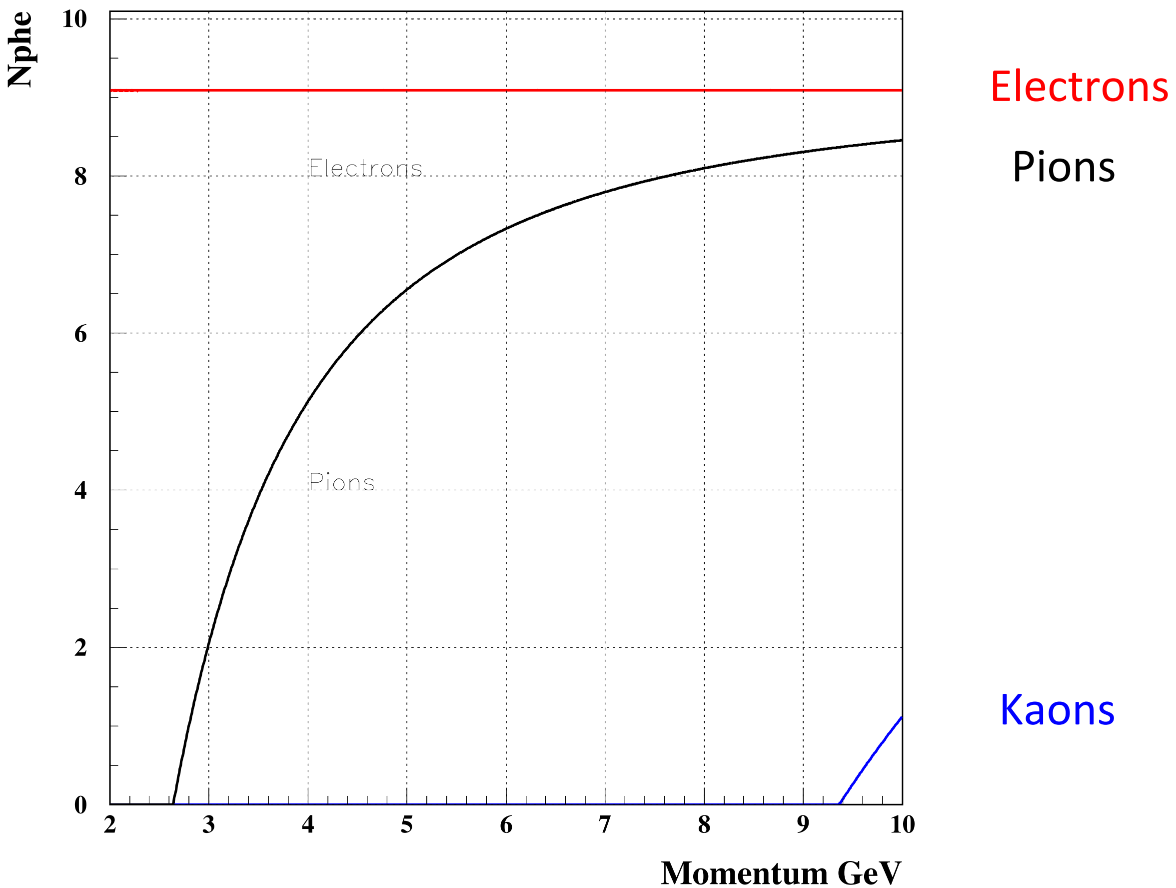
Number of Photoelectrons in LTCC



- The detector has very complicated irregular structure
- The ϕ coverage is limited
- The central region has low efficiency
- Detector can be used in particle ID only after carefully designed fiducial cuts

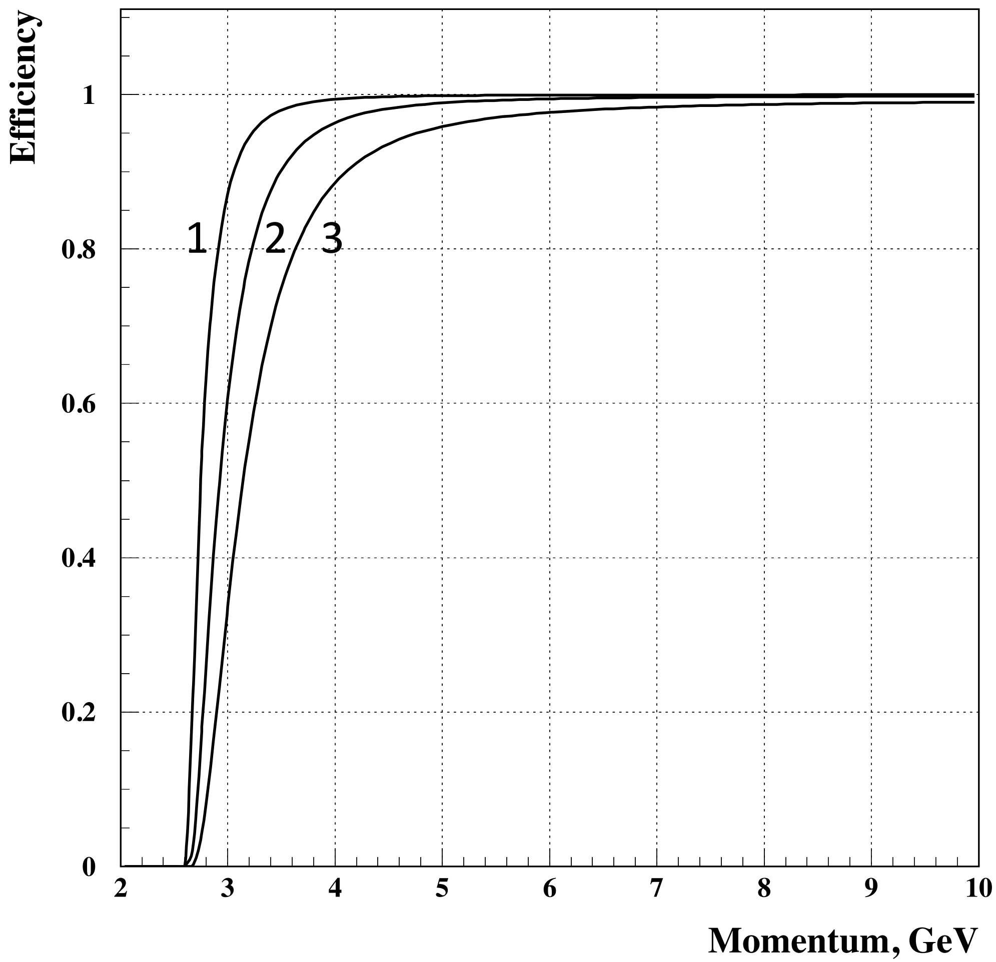
Number of photoelectrons for pions

(after fiducial cuts)



The number of the photoelectrons goes up from 0 at the threshold (~2.7 GeV) to 8.5 at P=10 GeV.

Pions inefficiency for minimum Nphe=1,2 and 3



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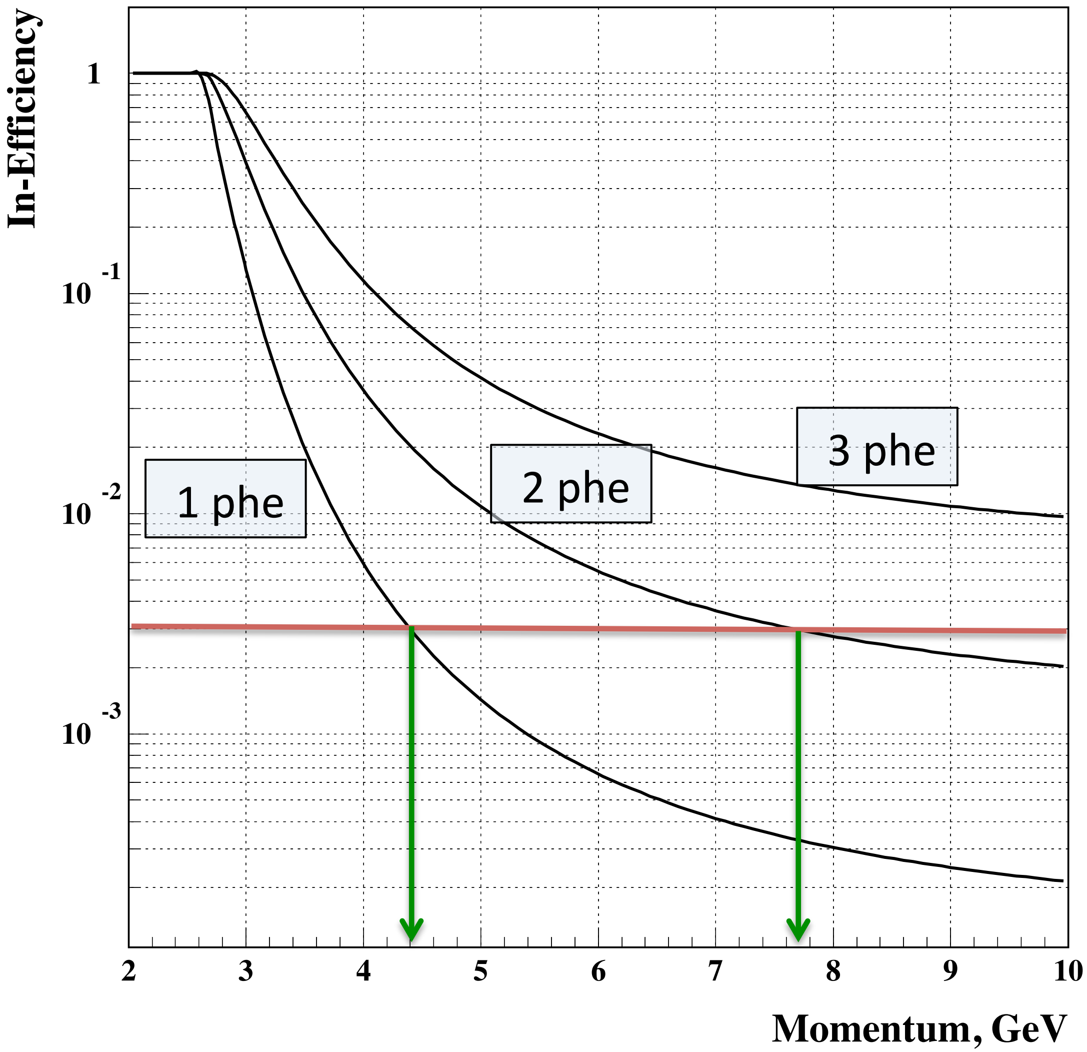
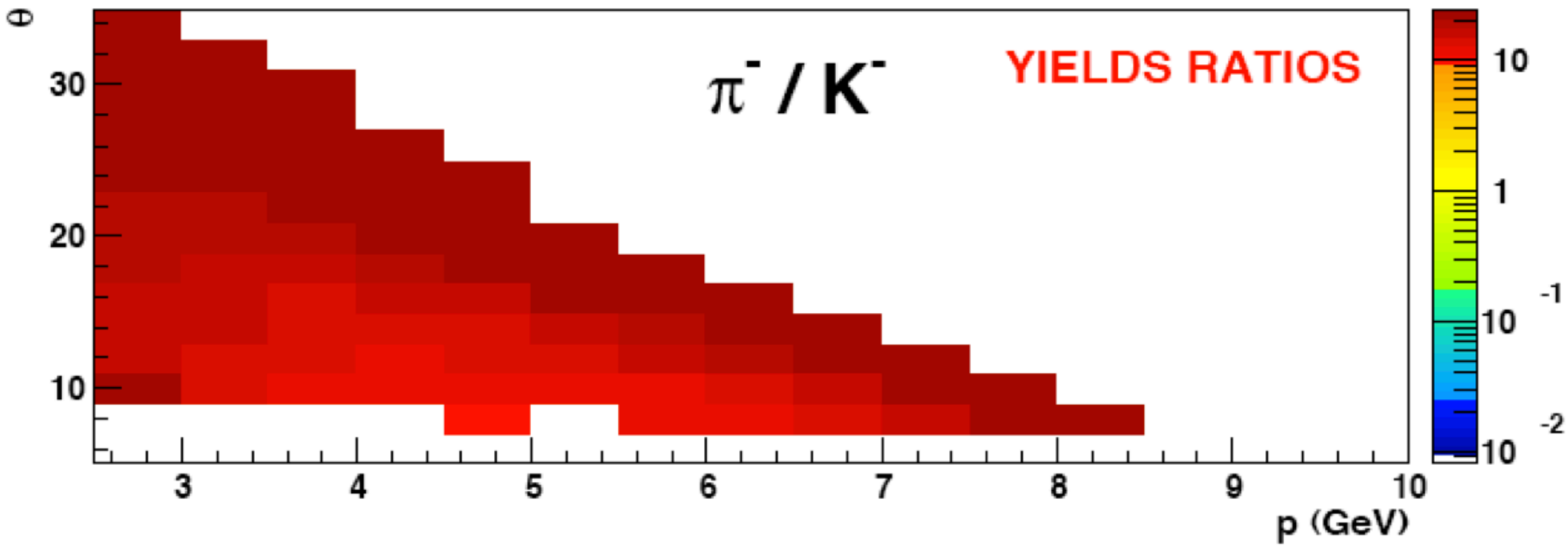
Pions inefficiency for minimum Nphe=1,2 and 3



- In CLAS analysis the cut on number of photoelectrons must be at least 2-3
- We can reach 3σ separation only for N_{phe}=2 at 7.7 GeV

- The rejection factor in the momentum range 4-10 GeV is from 10^{-1} up to 10^{-2} for conservative cut N_{phe}=3

SIDIS π/K Ratio



The π/K ratio is in the range 10-20 for SIDIS. To have a pion contamination at the level of 5% we need rejection factor at least $3\ 10^{-3}$ what corresponds to more then 3σ separation.

Summary of CLAS12 PID

- Forward TOF will achieve 4σ π/K separation up to momentum 2.8-3.6 GeV depending on the production angle
- HTCC covers momentum range 5-10 GeV but achieves 3σ separation only for particles with momentum greater then 7-8 GeV depending on the minimum number of the photoelectrons cut
- LTCC has limited acceptance and irregular average number of photoelectrons along it's area. The 3σ separation can be reached only for particles with p> 7.7 GeV
- RICH detector can cover the gap from 3.6 up to 7 GeV to achieve the designed π/K separation