Status of GlueX Particle Identification

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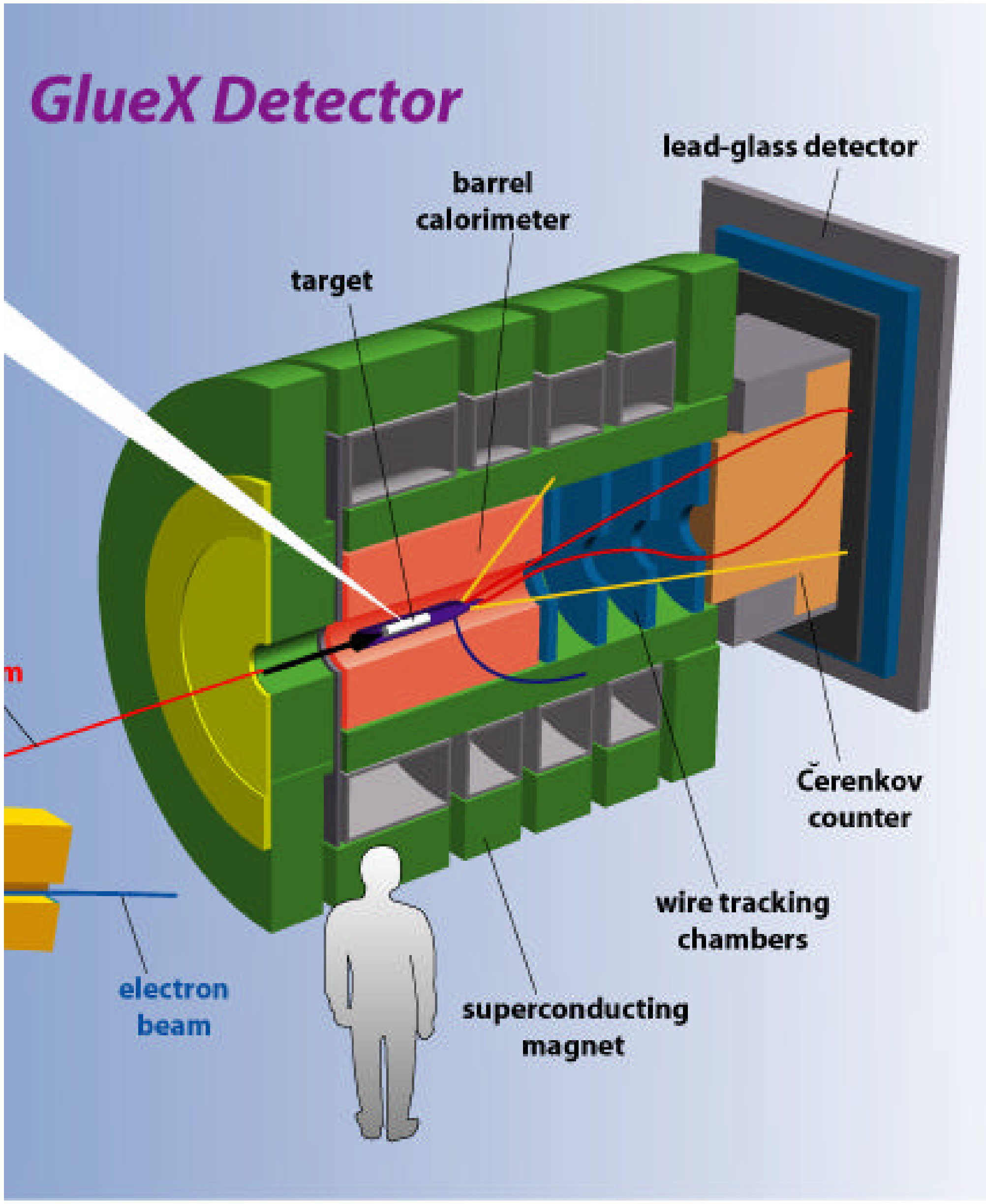
Outline

- Overview of Particle ID Components.
- Physics Examples.
- Look at each subdetector:
  - Central Drift Chamber (CDC)
  - Barrel Calorimeter (BCAL)
  - Cerenkov (CKOV)
  - Forward Time of Flight (TOF)
- Likelihoods for Particle Hypotheses.
- Angular Efficiencies.



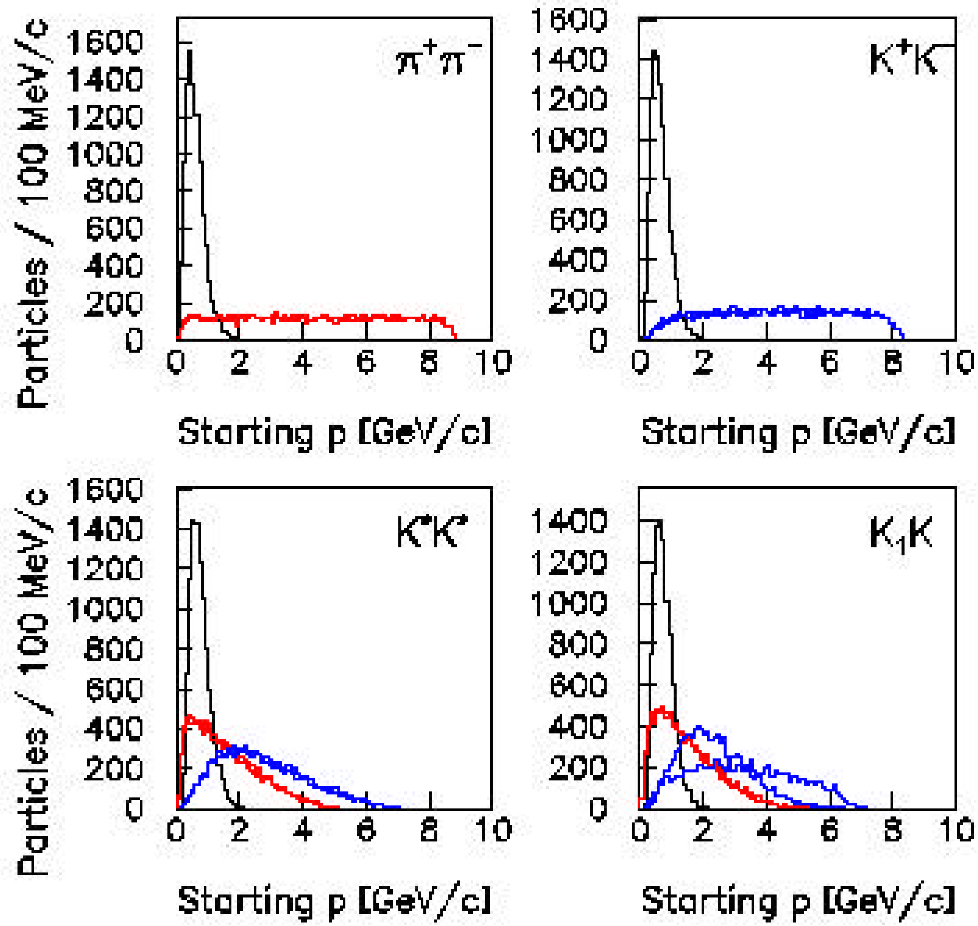
Particle ID with the GlueX Detector:

1. dE/dx from the CDC
2. Time from the BCAL
3. Photo-electrons from Cerenkov
4. Time from the TOF

Starting Momentum Spectra

Starting momenta for four reactions:

1. $\gamma p \rightarrow \pi^+\pi^- p$
2. $\gamma p \rightarrow K^+K^- p$
3. $\gamma p \rightarrow K^*K^* p$
   $\rightarrow K^+\pi^- K^-\pi^+ p$
4. $\gamma p \rightarrow K_1 K^- p$
   $\rightarrow K^+\rho K^- p$
   $\rightarrow K^+\pi^+\pi^- K^- p$



Black = proton, Blue = Kaons, Red = Pions

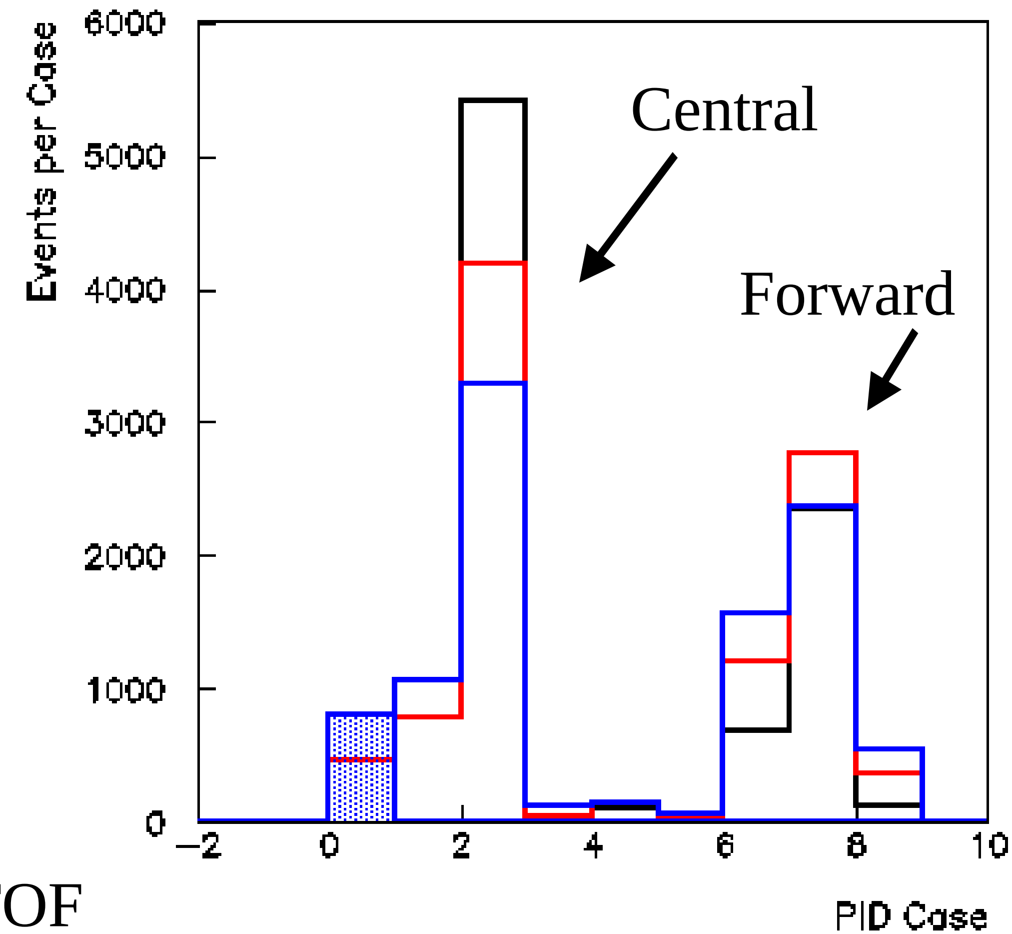
PID Cases ($\gamma p \rightarrow K^* K^* p$)

0. No PID Info

1. CDC
2. CDC, BCAL

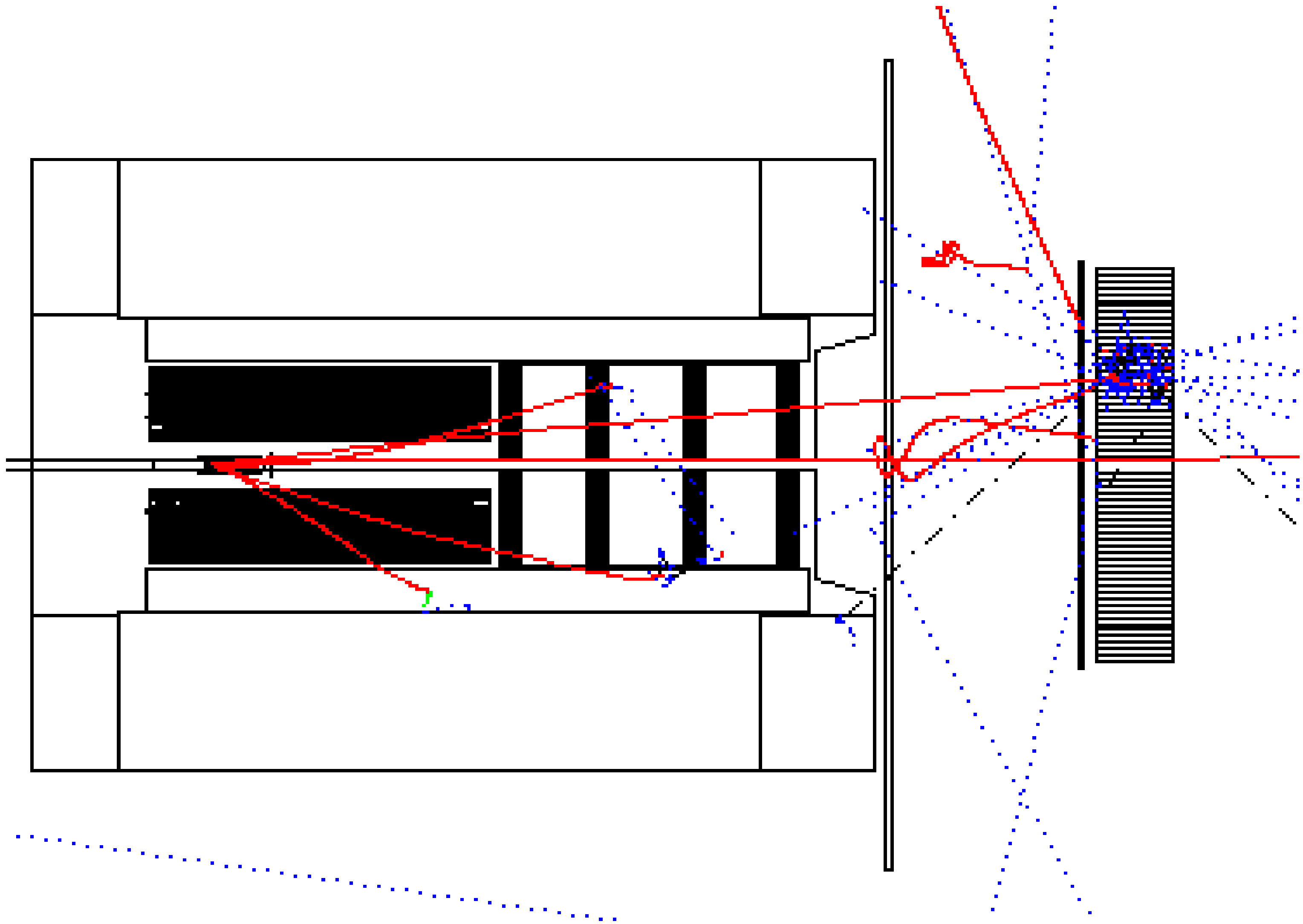
3. CKOV
4. CDC, CKOV
5. CDC,BCAL,CKOV

6. CKOV,TOF
7. CDC,CKOV,TOF
8. CDC,BCAL,CKOV,TOF

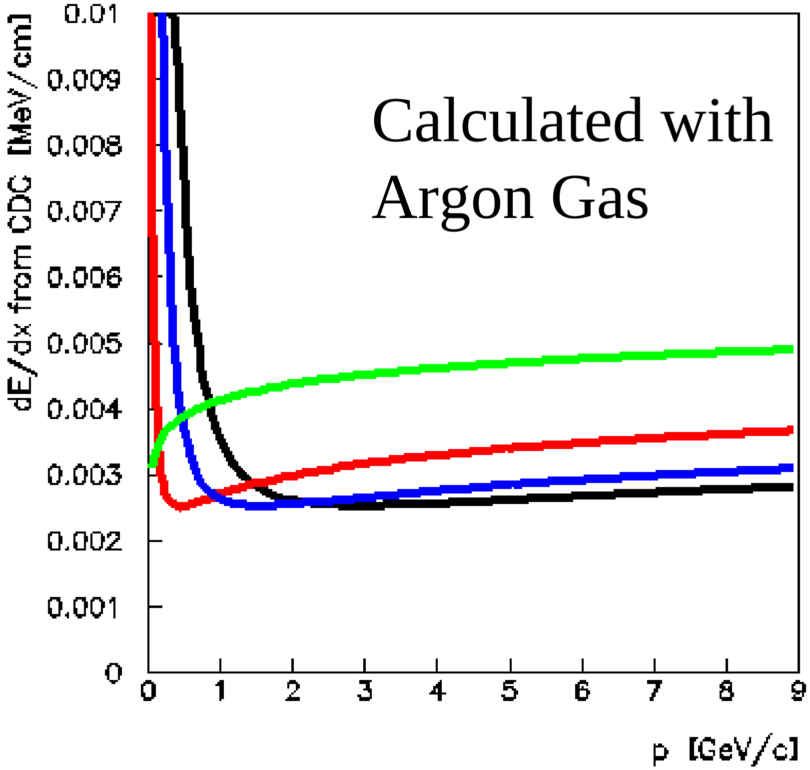


Black = proton, **Blue = Kaons**, **Red = Pions**

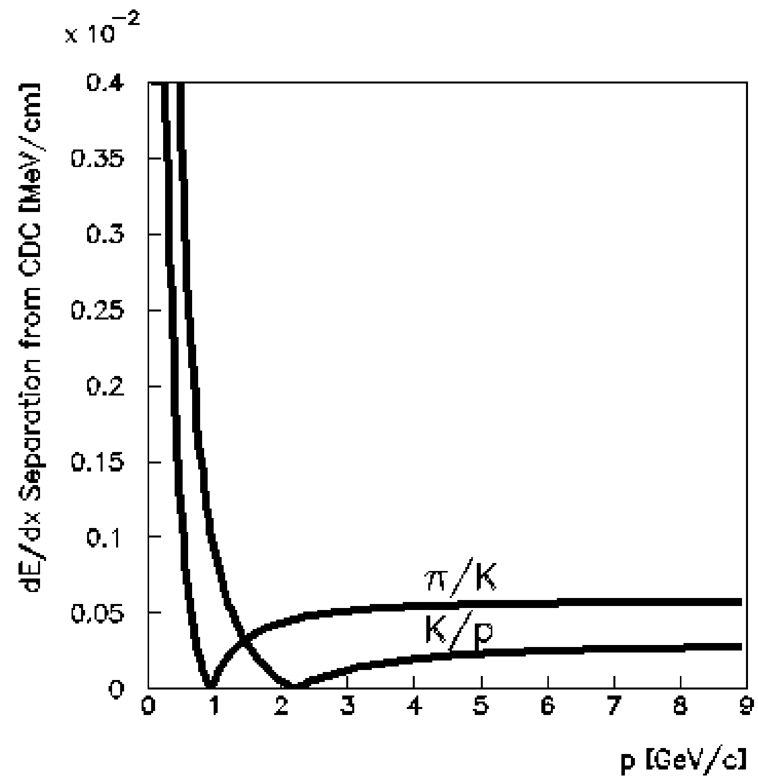
An Example From GEANT
($\gamma p \rightarrow K^*K^*p$)



dE/dx from the CDC



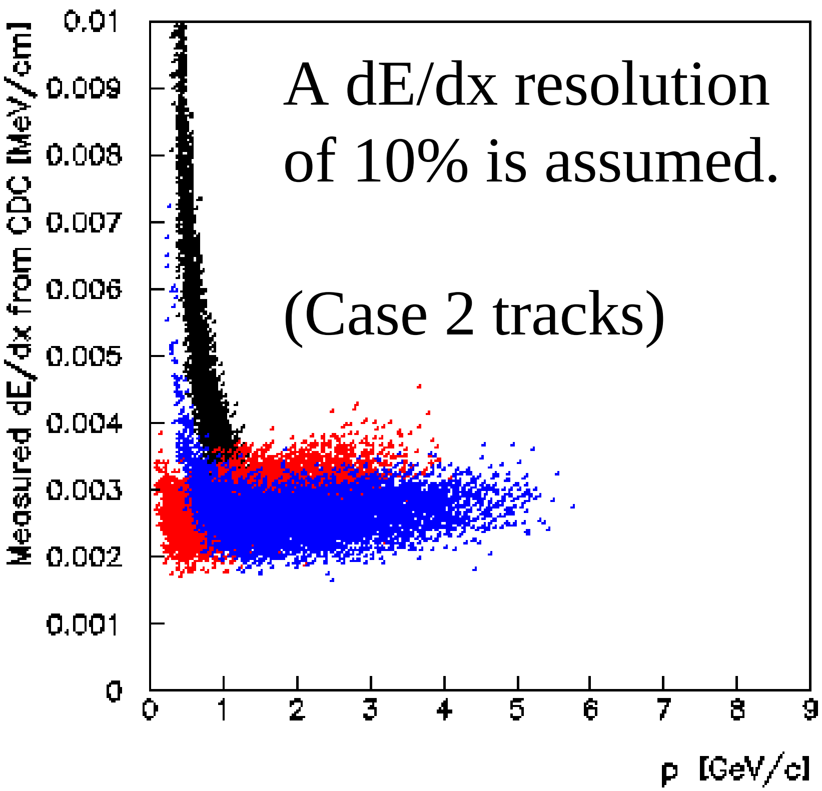
Good K/p separation below ~2 GeV/c.



Black = Proton
Blue = Kaon
Red = Pion
Green = Electron

Measured dE/dx in the CDC

Measurements for
$\gamma p \rightarrow K^{*}K^{*}p$.



Black = proton, **Blue = Kaons**, **Red = Pions**

Calculating Likelihoods:

Given a track with momentum p hitting the CDC,

$$^{CDC}L_i = 1/\sigma_i(2\pi)^{1/2}\exp(-(x-x_i)^2/\ 2\sigma_i)$$

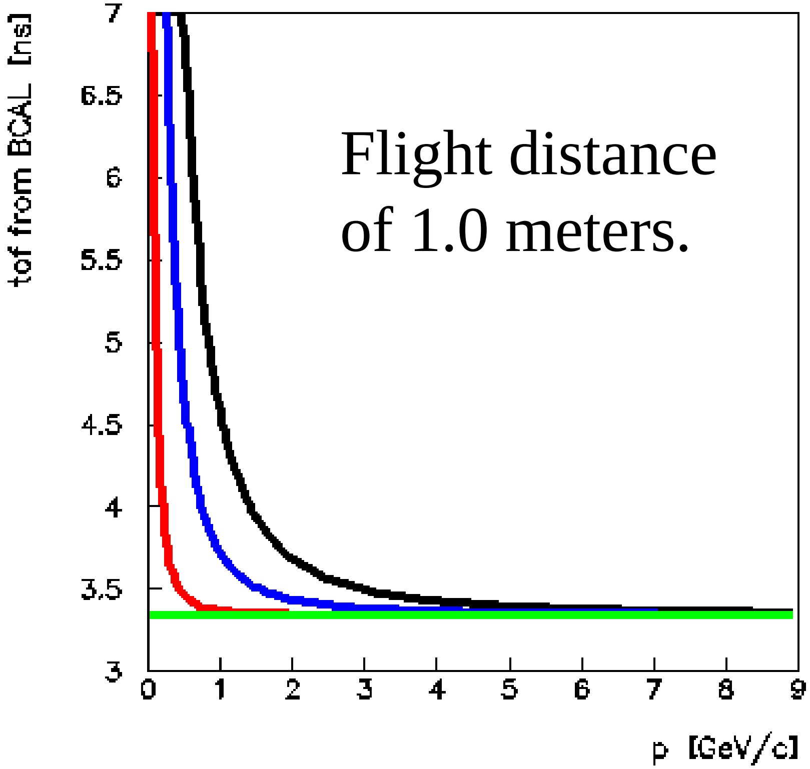
i = particle hypothesis

x_i = predicted measurement

σ_i = predicted error (10%)

x = actual measurement

Time of Flight from BCAL



Black = Proton

Blue = Kaon

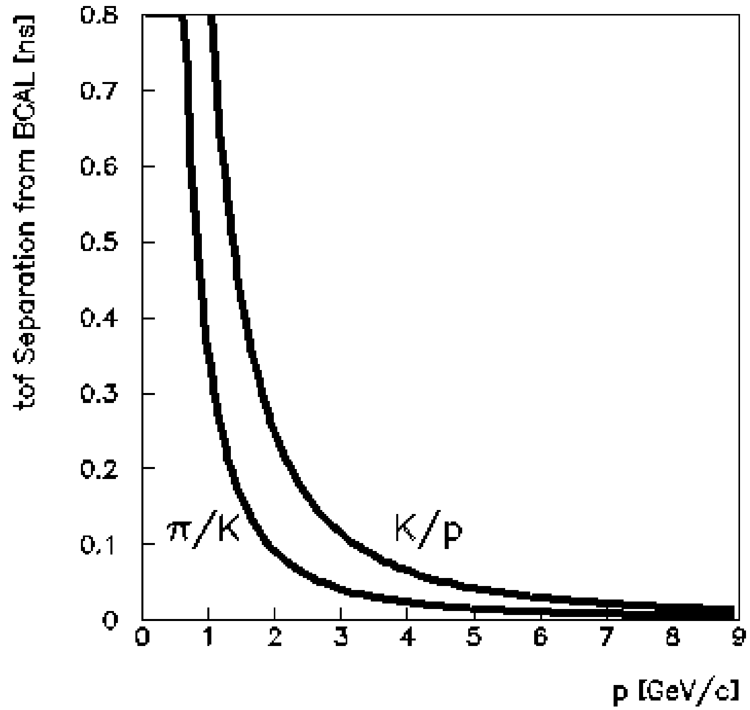
Red = Pion

Green = Electron

With 200 ps resolution, resolve:

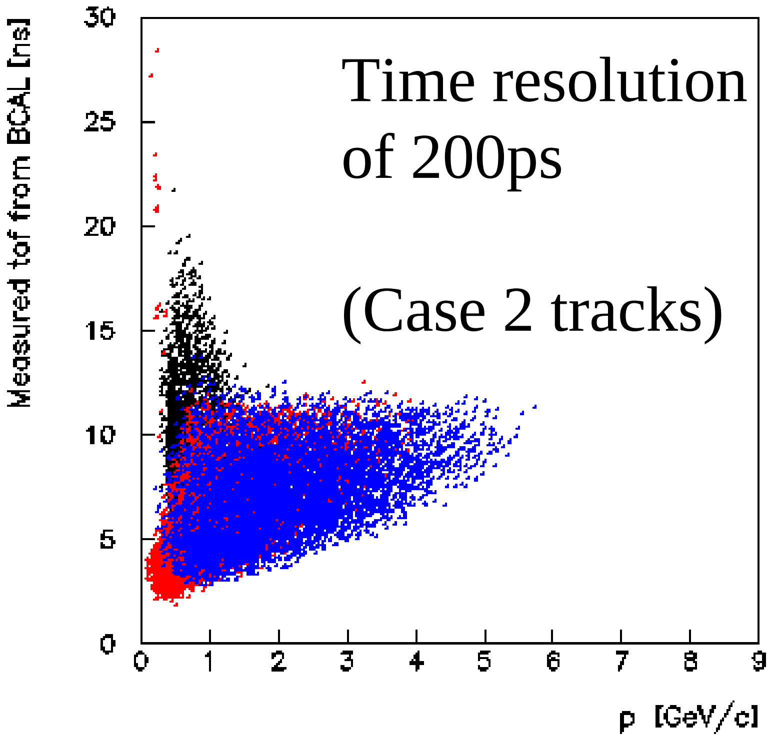
-- π/K up to ~1 GeV/c

-- K/p up to ~2 GeV/c



Measured Time from BCAL

Measurements for
$\gamma p \rightarrow K^* K^* p$.



Black = proton, **Blue = Kaons**, **Red = Pions**

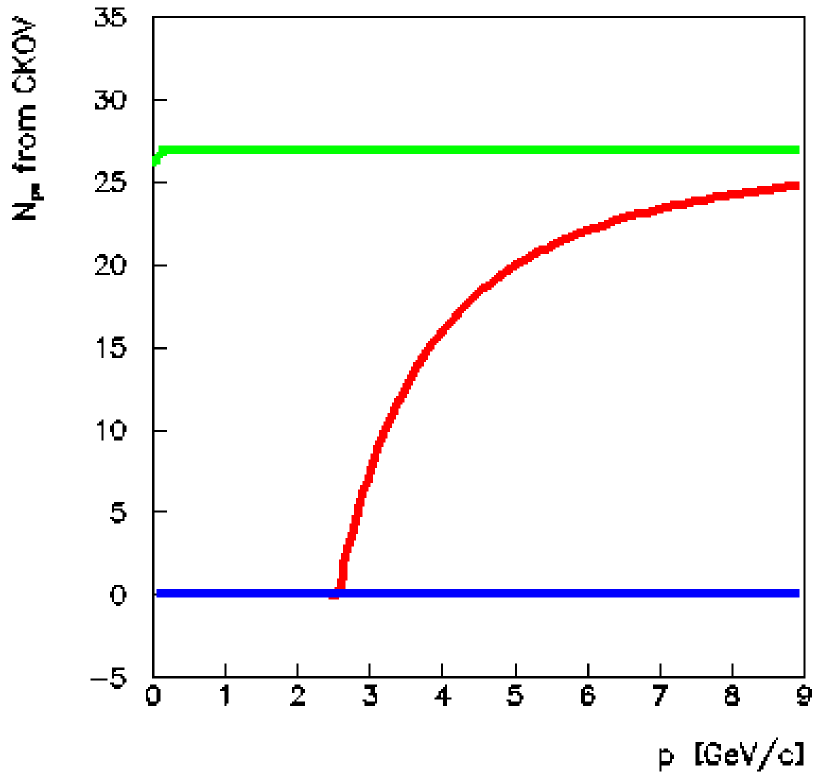
Calculating Likelihoods:

Given a track with momentum p and pathlength L hitting the BCAL,

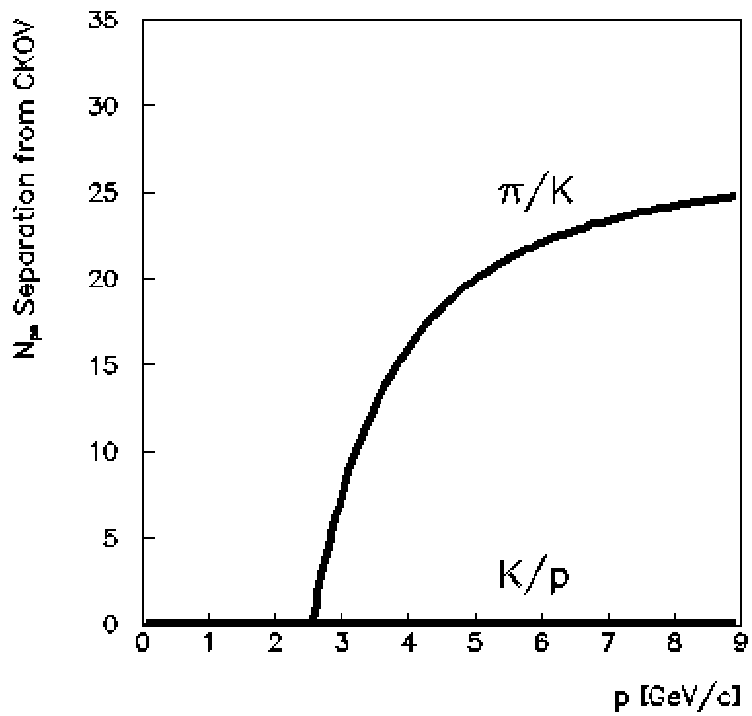
$^{BCAL}L_i = 1/\sigma_i(2\pi)^{1/2}\exp(-(t-t_i)^2/\ 2\sigma_i)$

i = particle hypothesis
t_i = predicted measurement
σ_i = predicted error
(200ps time resolution,
1% momentum res.,
1% length res.)
t = actual measurement

CKOV Photo-Electrons



The CDR design:
Index of Refraction = 1.0015
Length = 1.0 meters
Efficiency = 90 cm^{-1}.



Black = Proton
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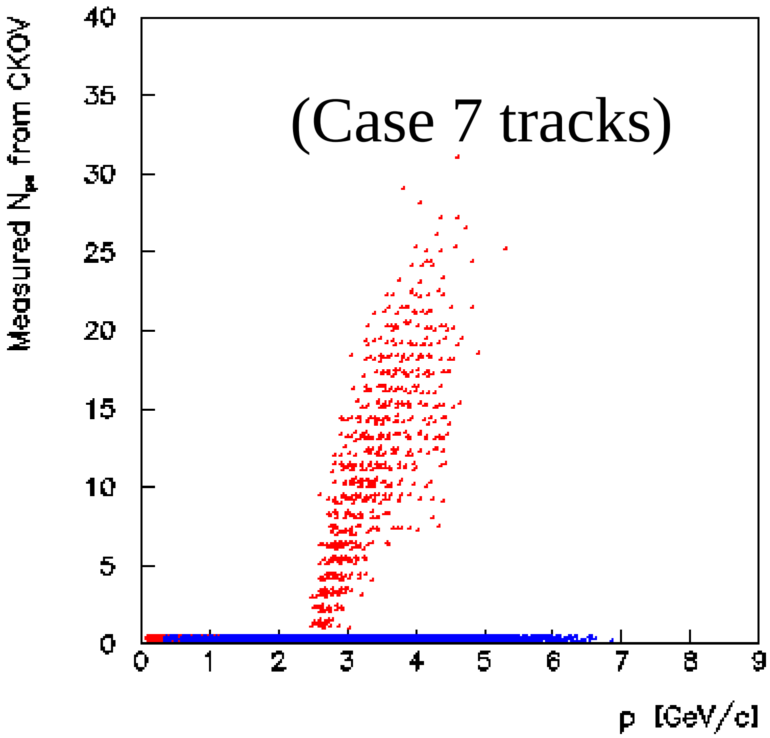
Red = Pion
Green = Electron

Measured CKOV N_{PE}

Measurements for $\gamma p \rightarrow K^* K^* p$.



Black = proton, **Blue = Kaons**, **Red = Pions**

Calculating Likelihoods:

Given a particle of momentum p, calculate the expected number of photoelectrons under different particle hypotheses:

$$\mu = N_0 \lambda \sin^2\theta_c.$$

If cerenkov "fires":

$$^{CKOV}L_i = (1-e^{-\mu}) + a - a(1-e^{-\mu})$$

If cerenkov is quiet:

$$^{CKOV}L_i = e^{-\mu}(1-a)$$

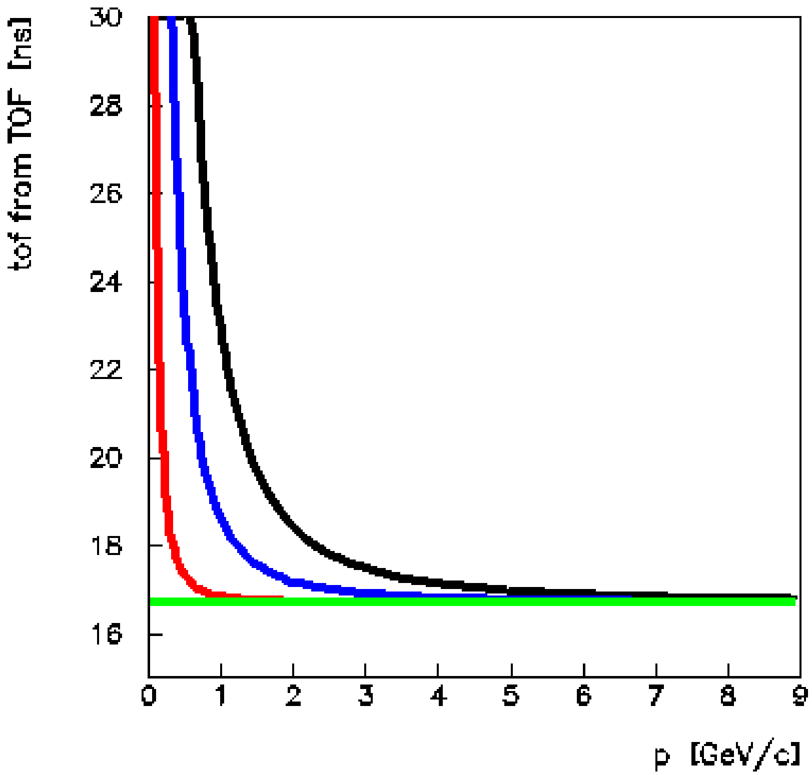
N_0 = cerenkov efficiency

λ = length of cerenkov

θ = cone of radiation angle

a = accidental rate

Time from the TOF Wall



Black = Proton

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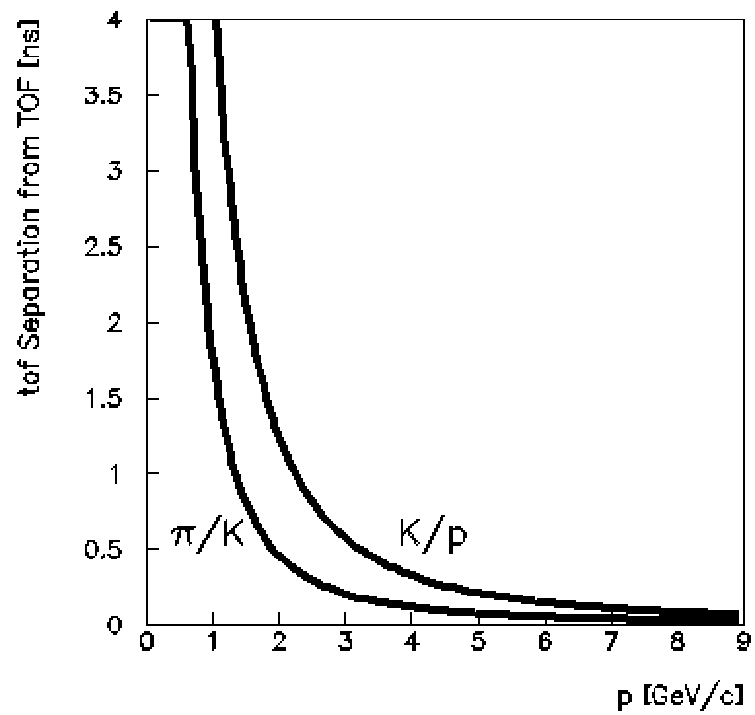
Green = Electron

With 100 ps resolution, resolve:

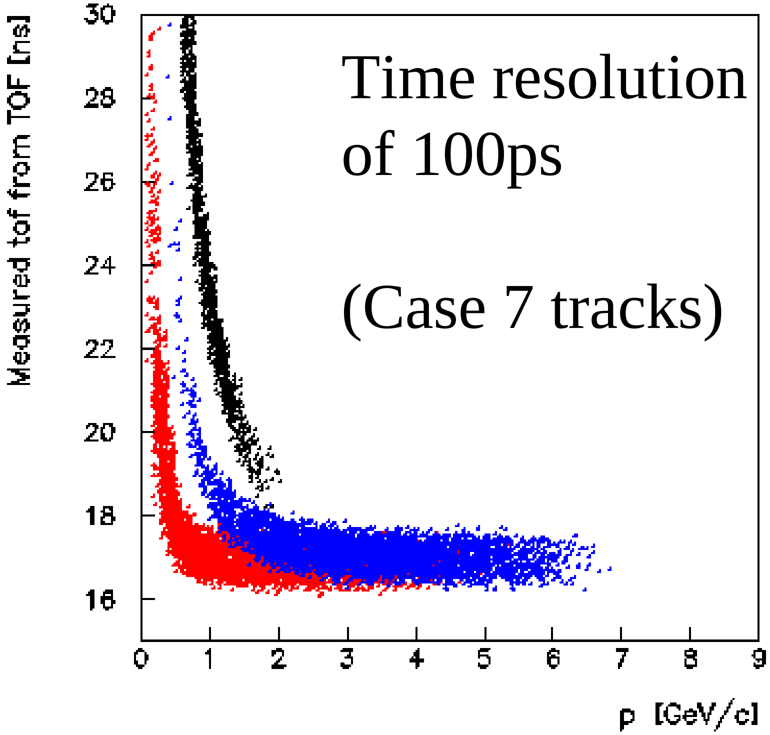
-- π/K up to ~2.5 GeV/c

-- K/p up to ~4.0 GeV/c



Measured TOF from the TOF Wall

Measurements for $\gamma p \rightarrow K^{*}K^{*}p$.



Black = proton, **Blue = Kaons**, **Red = Pions**

Calculating Likelihoods:

Given a track with momentum p and pathlength L hitting the TOF,

$${}^{TOF}L_i = 1/\sigma_i(2\pi)^{1/2}\exp(-(t-t_i)^2/\ 2\sigma_i)$$

i = particle hypothesis

t_i = predicted measurement

σ_i = predicted error

(100ps time resolution,

1% momentum resolution,

1% length resolution)

t = actual measurement

Likelihoods

- Combine the likelihoods from all the detectors into a single likelihood, e.g.,

  $$L_K = L_K^{CDC} L_K^{BCAL} L_K^{CKOV} L_K^{TOF}$$

- Make decisions based on likelihood ratios. For now, use:

  π/K separation $= 2\ln(L_\pi/L_K)$

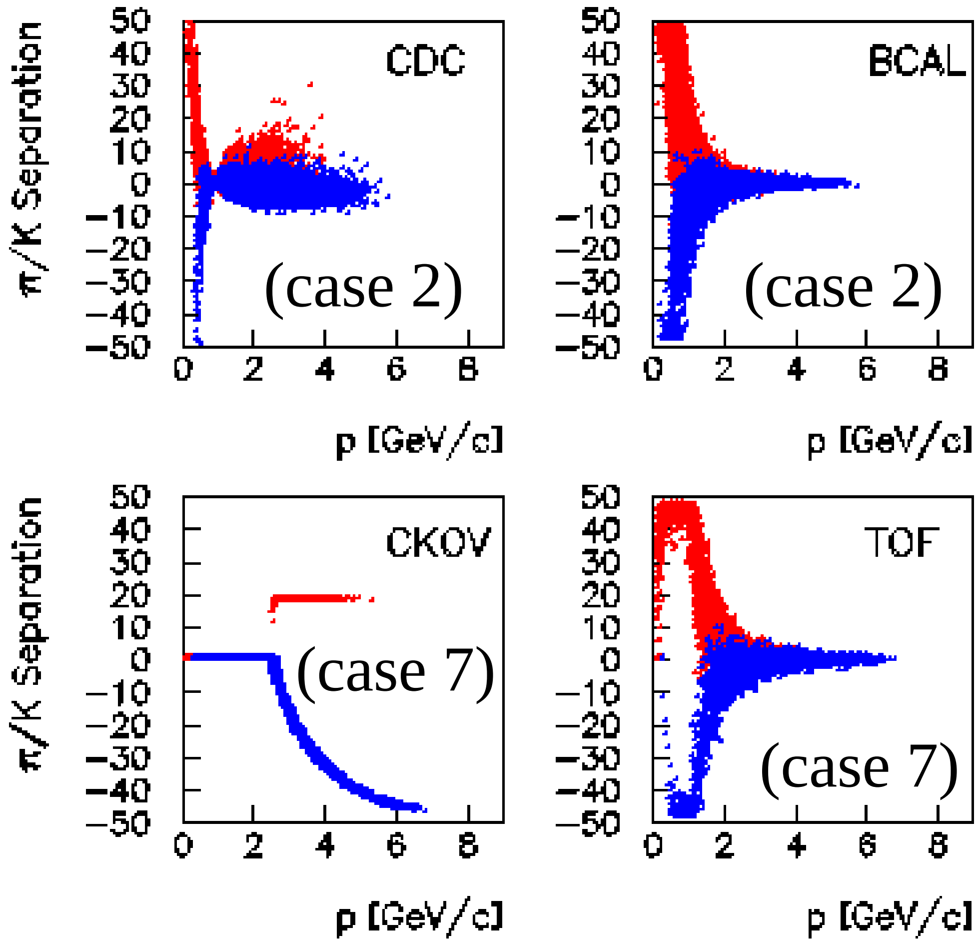
  K/π separation $= 2\ln(L_K/L_\pi)$

  p/K separation $= 2\ln(L_p/L_K)$

π/K Separation

π/K separation
$= 2\ln(L_\pi/L_K)$
for $\gamma p \rightarrow K^* K^* p$

Look at the ratio for each detector individually.

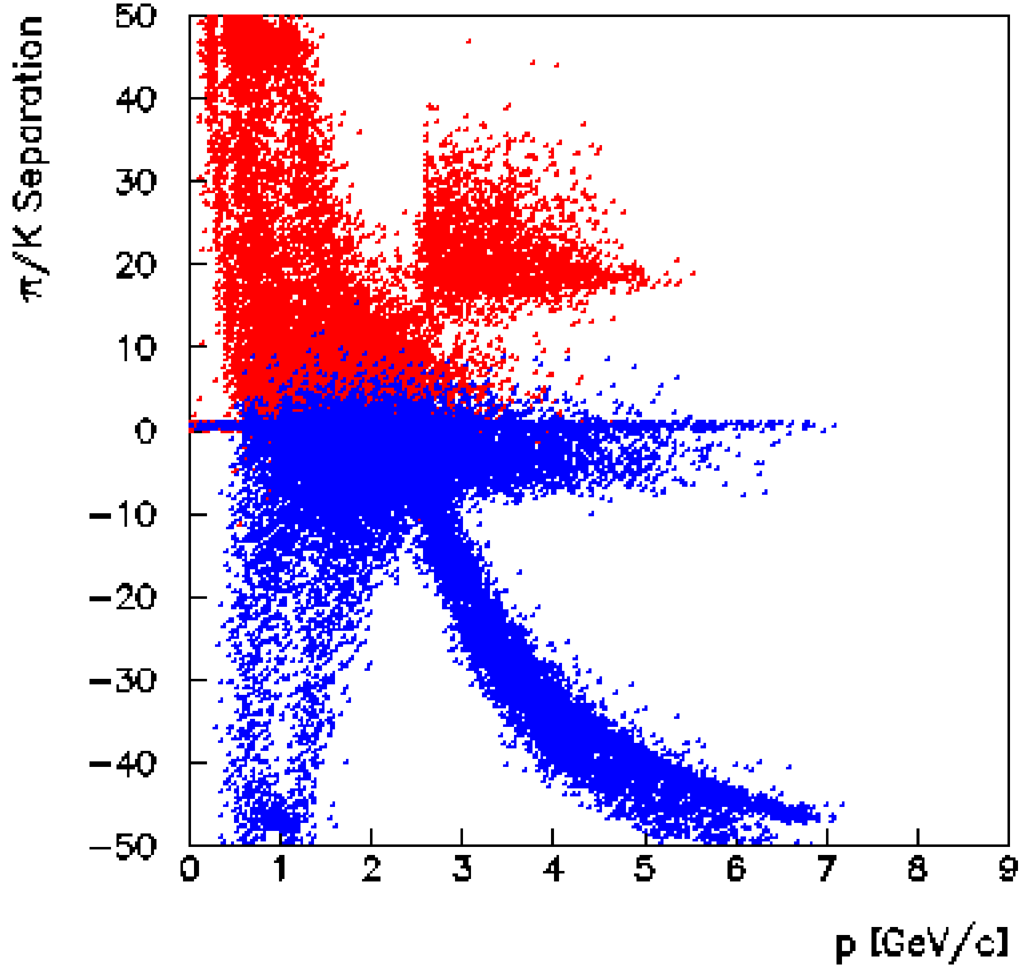


Blue = Kaons, **Red = Pions**

π/K Separation

Combine likelihoods into an overall likelihood.

Now look at the π/K separation.

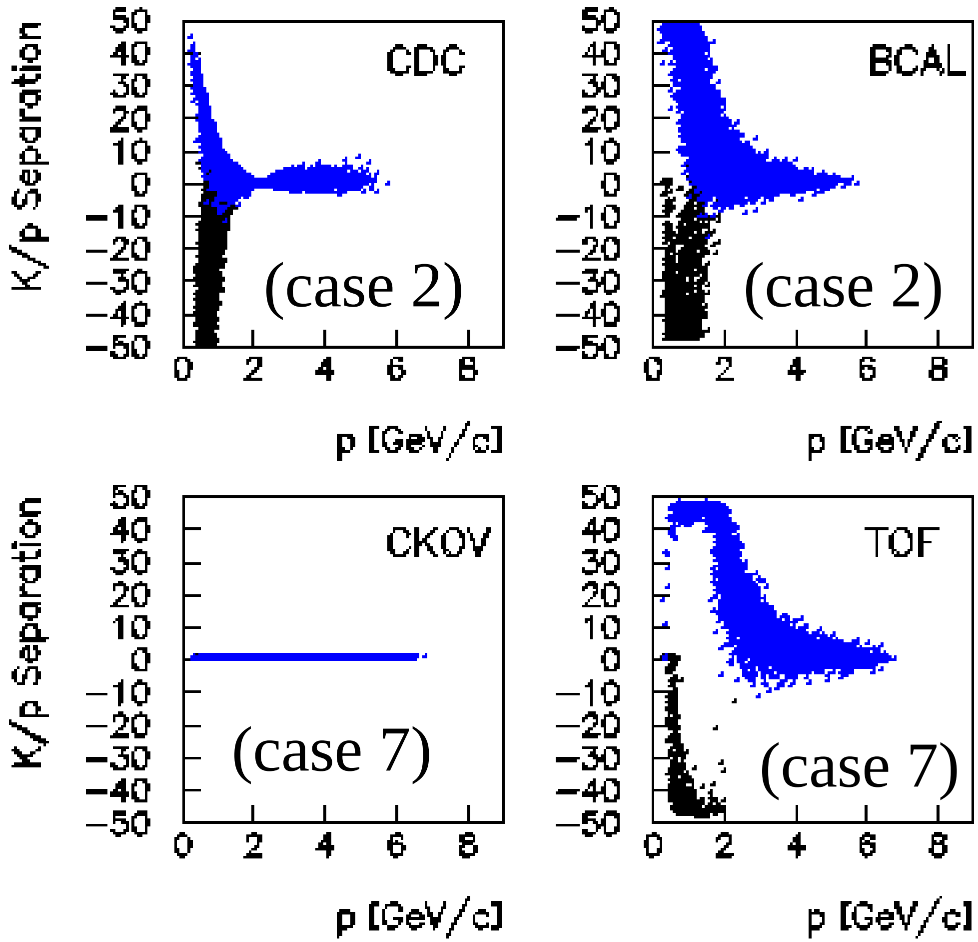


Blue = Kaons, **Red = Pions**

K/p Separation

K/p separation
= $2\ln(L_K/L_p)$
for $\gamma p \rightarrow K^* K^* p$

Look at the ratio
for each detector
individually.

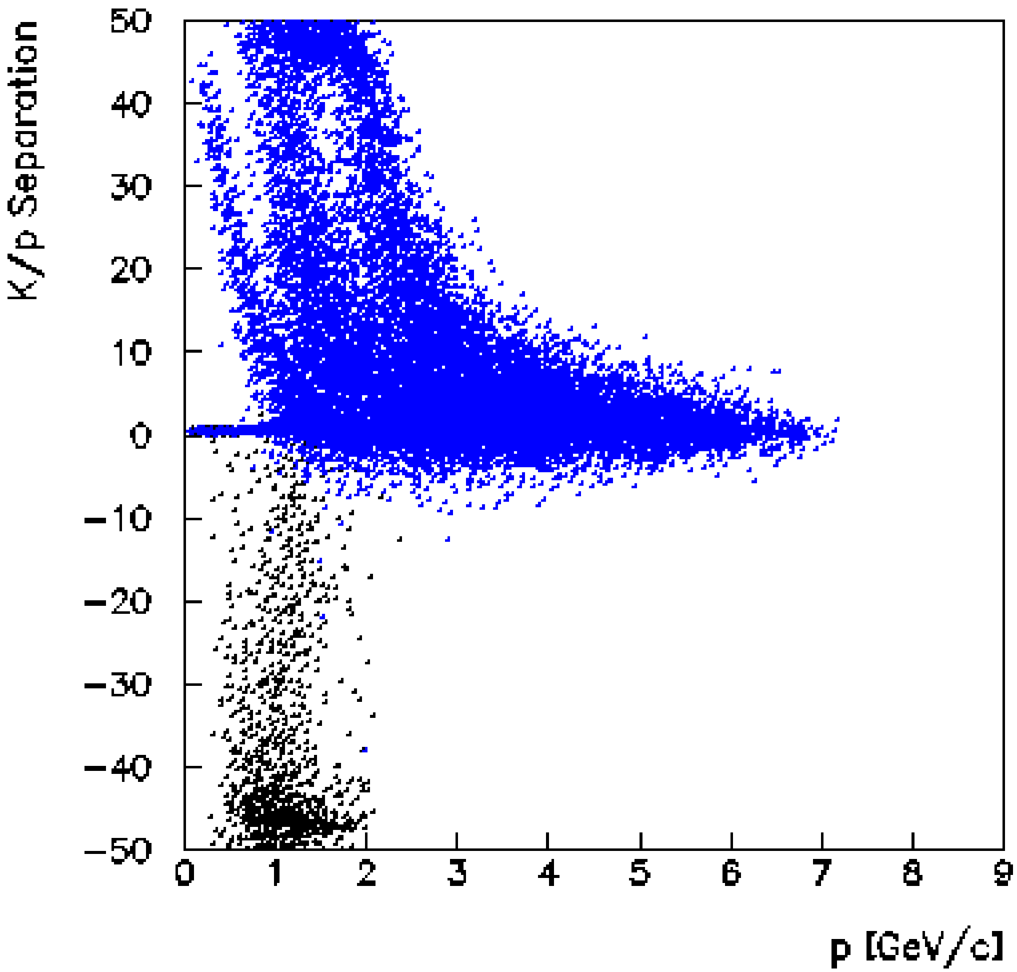


Black = proton, Blue = Kaons

K/p Separation

Combine likelihoods into an overall likelihood.

Now look at the K/p separation.



Black = proton, Blue = Kaons

Particle ID Cuts

- To get an idea of efficiencies, make the following simplifications…
- A Pion is considered identified if:

  $2\ln(L_\pi/L_K) > 2.0$
- A Kaon is considered identified if:

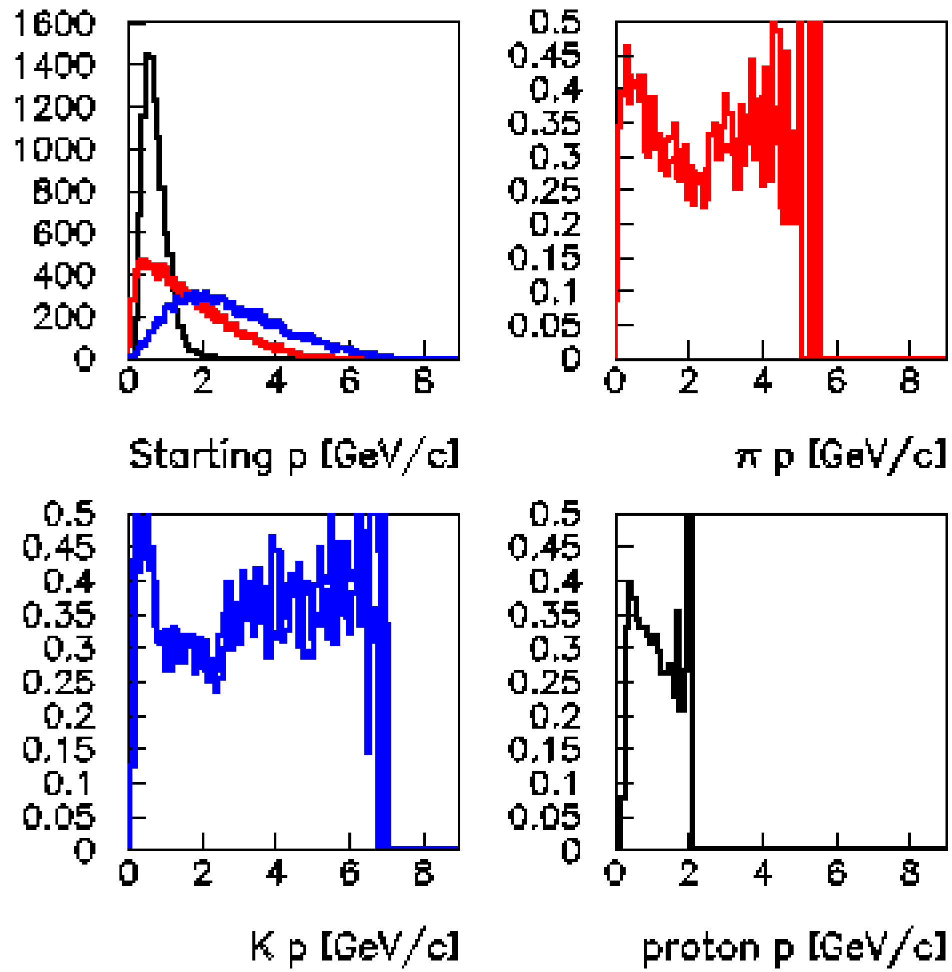
  $2\ln(L_K/L_\pi) > 2.0$
- A Proton is considered identified if:

  $2\ln(L_p/L_K) > 2.0$

Momentum Efficiencies

For $\gamma p \rightarrow K^* K^* p$, there is definite structure in momentum efficiencies…

Inefficiencies due to…
-- high momentum central tracks.
-- forward tracks from 2 to 3 GeV/c



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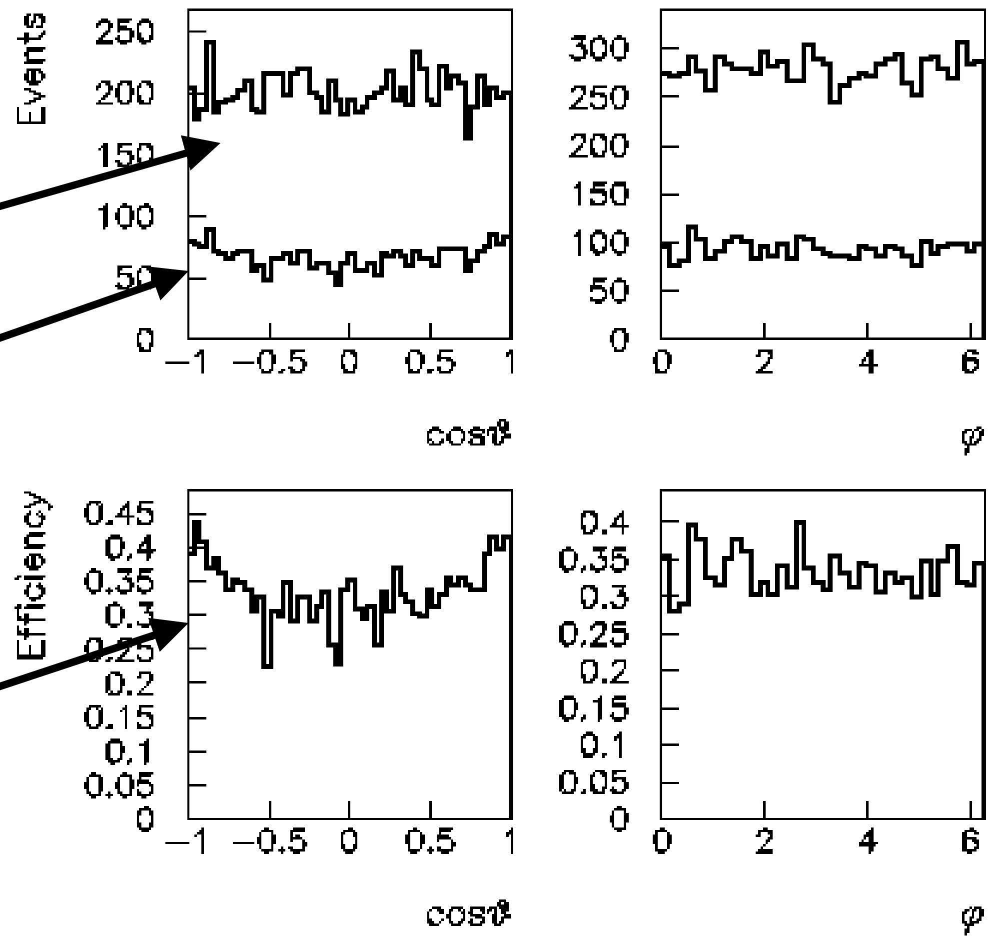
Angular Efficiencies for K^*K^*

Starting

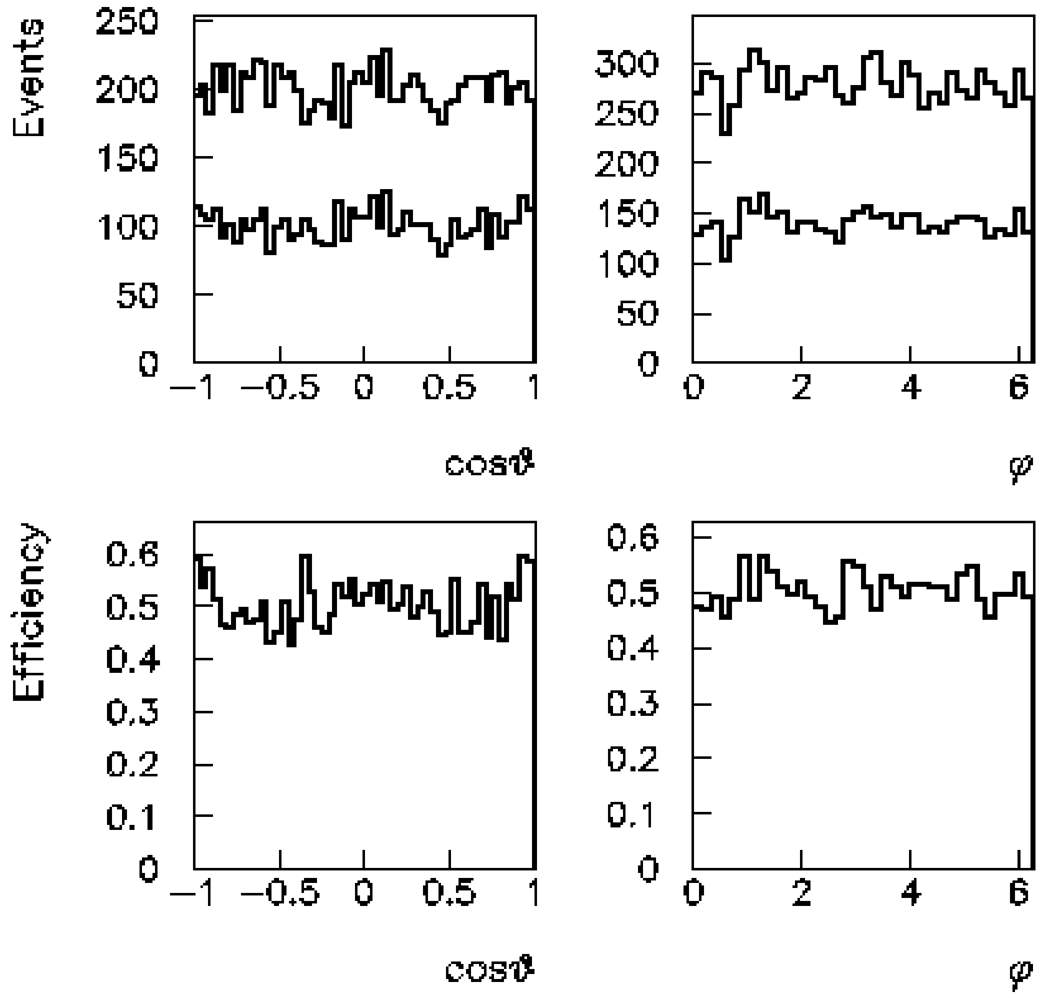
After PID



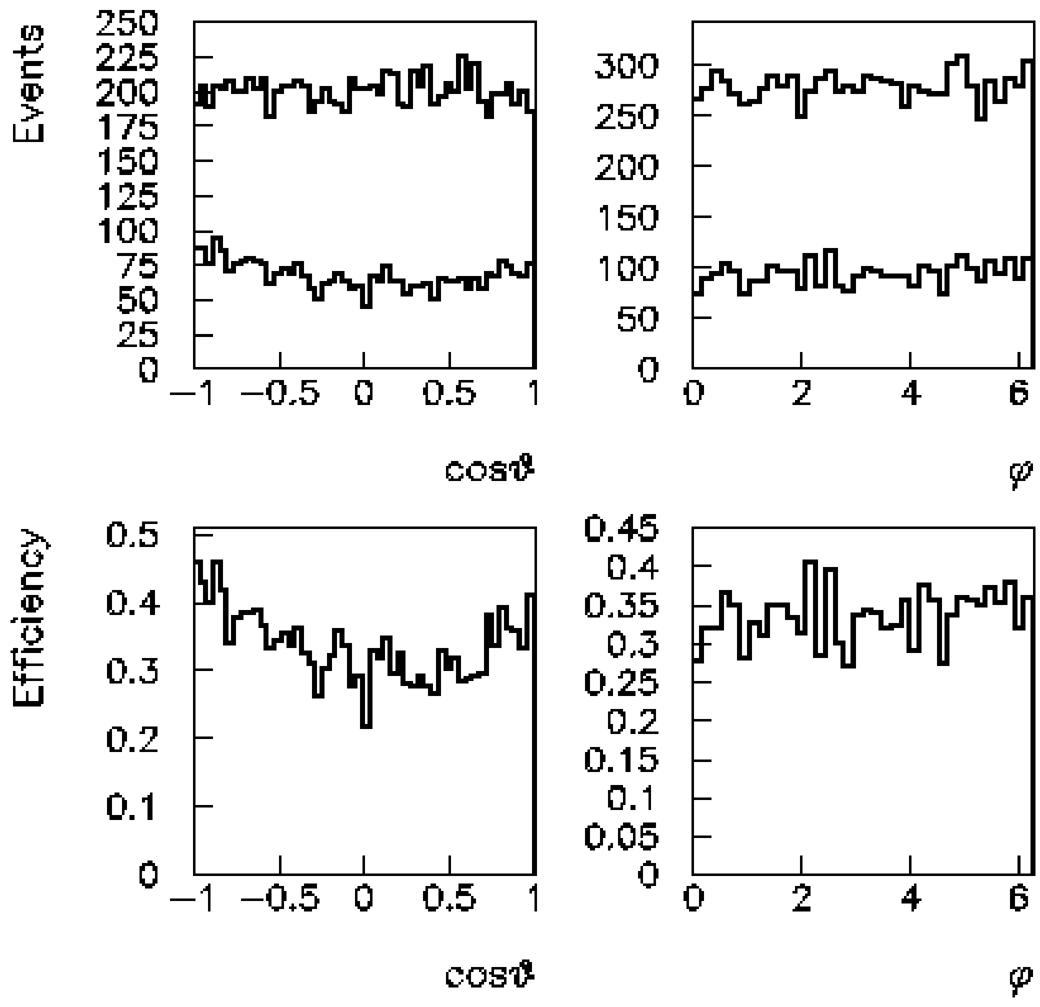
Efficiencies in Gottfried-Jackson angles.

Preference for forward-backward decays.

Angular Efficiencies for K^+K^-



Angular Efficiencies for K_1K



Conclusions

- There are no overwhelming problems in GlueX particle ID.
- In the present setup, inefficiencies occur due to:
  - High momentum central tracks
  - Forward tracks between 2 and 3 GeV/c
- These inefficiencies lead to sculpted momentum spectra, but only slight variations in angular efficiencies.