GlueX Particle Identification

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Detector Review, October 2004

Outline

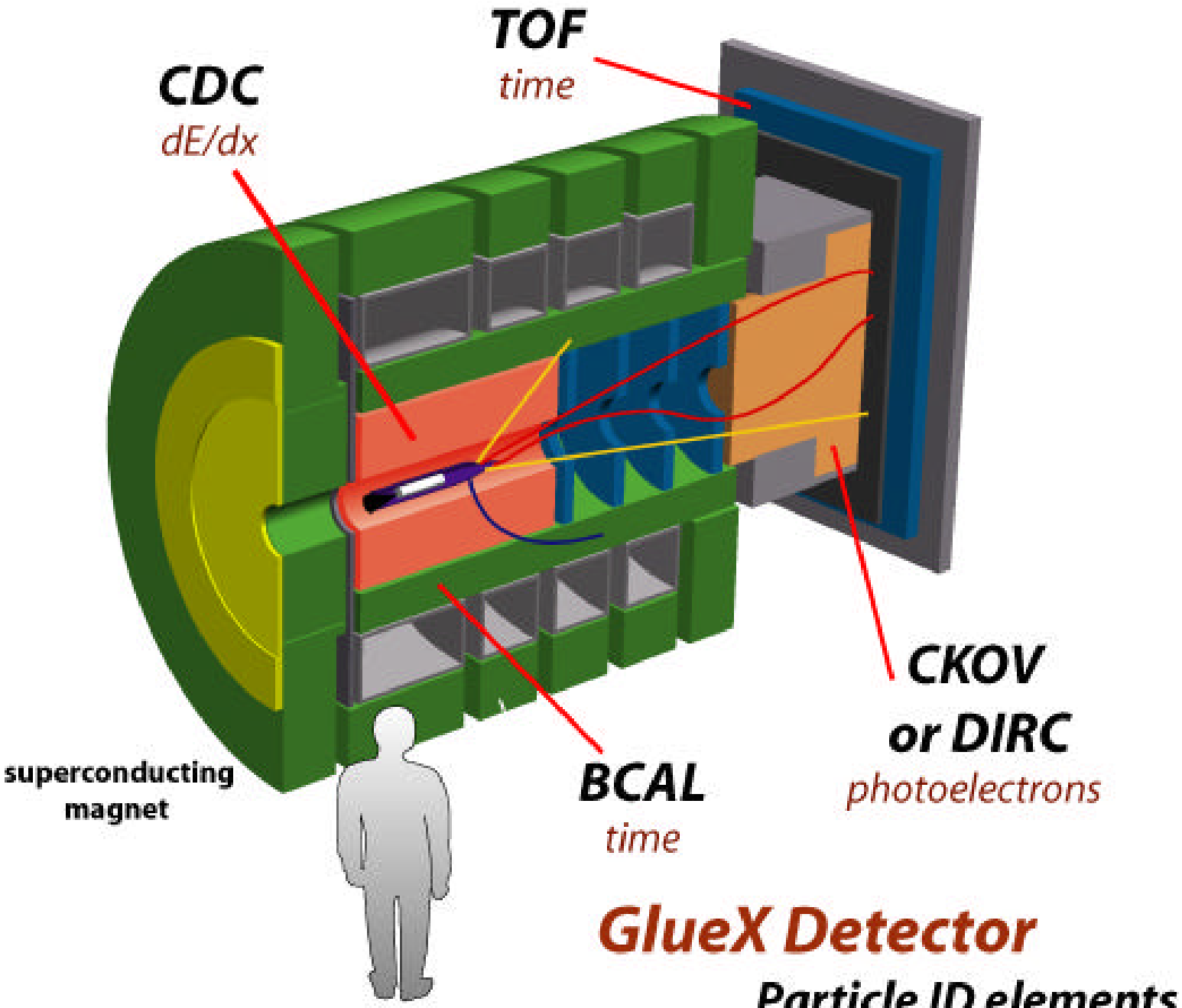
I. Introduction to each of the four particle identification components.

II. General characteristics of GlueX physics events and the match between physics and detectors.

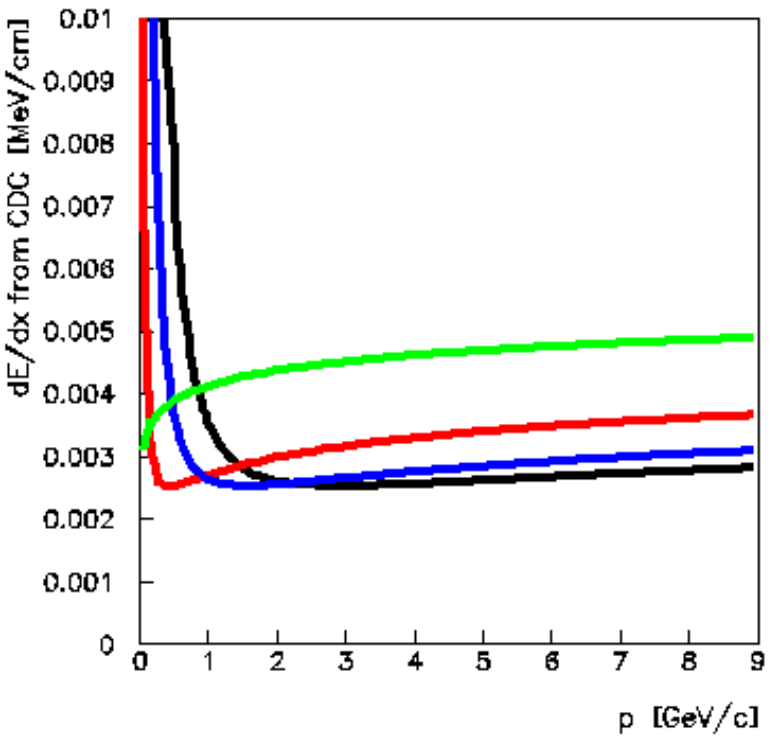
III. The likelihood method as a unified way of making decisions.

IV. A detailed simulation of the reaction:

$$\gamma p \rightarrow K^{*}K^{*}p \rightarrow (K^{+}\pi^{-})(K^{-}\pi^{+})p.$$

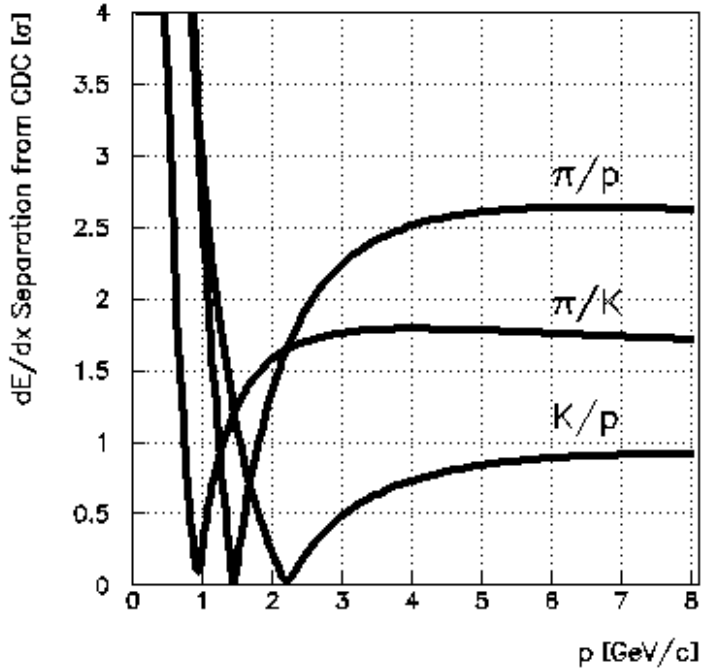

TOF
time
CDC
dE/dx
CKOV
or DIRC
photoelectrons
BCAL
time
superconducting
magnet
GlueX Detector
Particle ID elements

dE/dx from the CDC

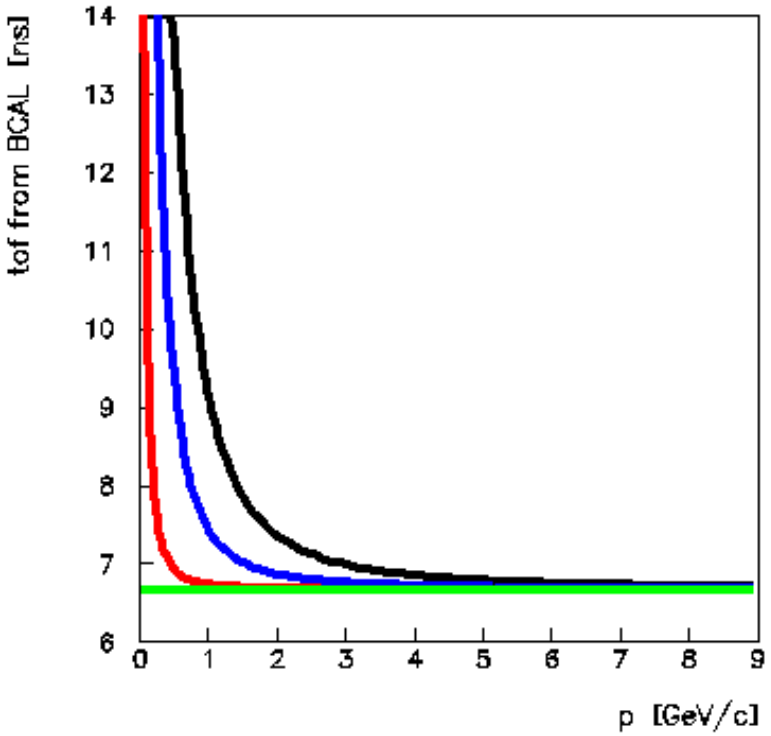


-- Argon-based gas.
-- Estimated 10% dE/dx resolution.
-- 3σ proton separation below 1 GeV/c.
-- 3σ kaon separation below 500 MeV/c.
-- Some separation in relativistic rise.

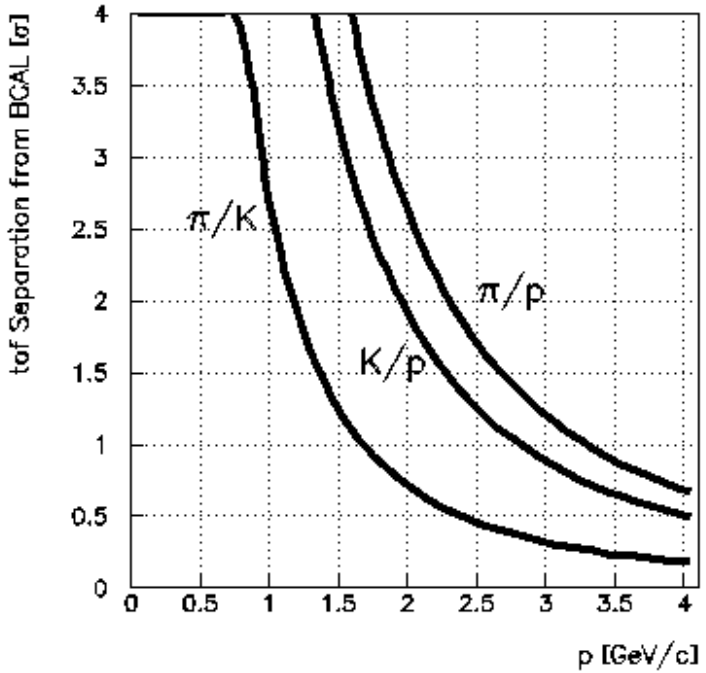
Black = Proton
Blue = Kaon
Red = Pion
Green = Electron



Time of Flight from BCAL

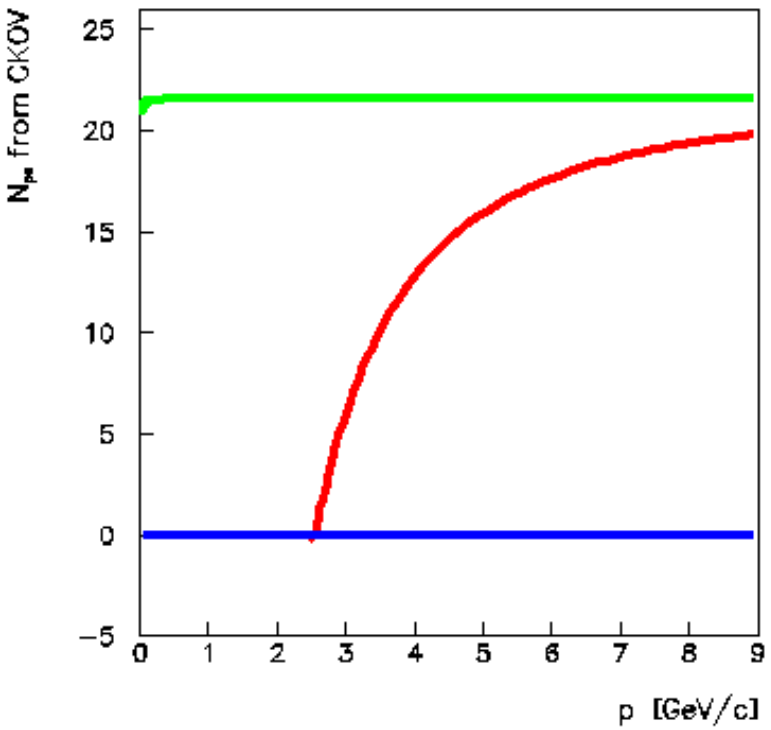


-- Estimated 250 ps resolution.
-- Plus 1% momentum and length resolutions.
-- 3σ protons below 1.5GeV/c.
-- 3σ kaons below 1.0GeV/c.



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

CKOV Photo-Electrons



Black = Proton

Blue = Kaon

Red = Pion

Green = Electron

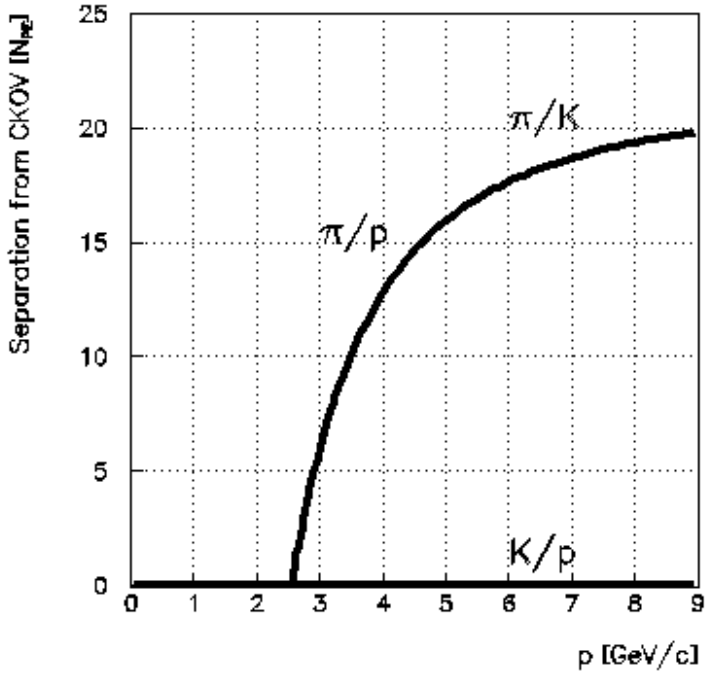
The CDR design (C_4F_{10}):

Index of Refraction = 1.0015

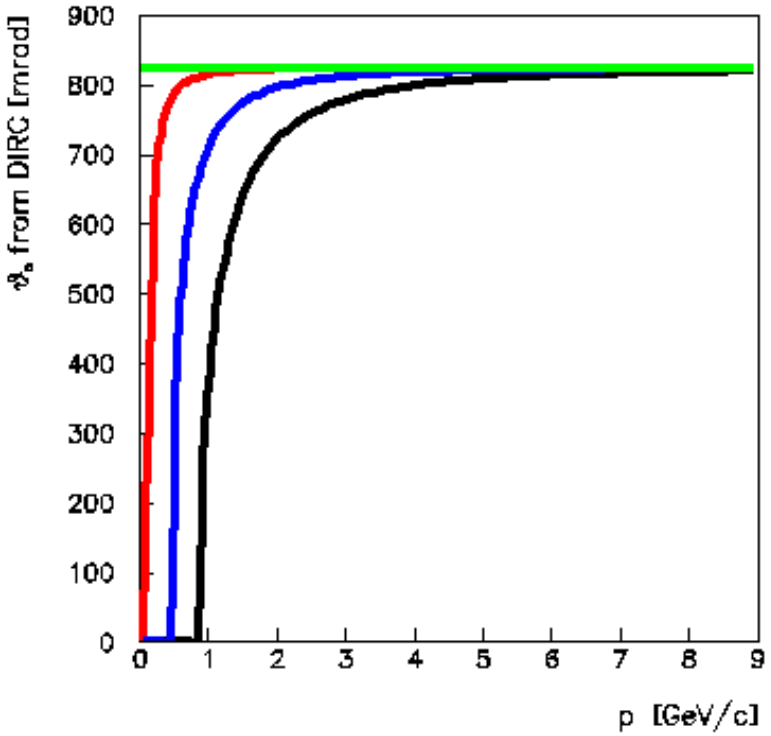
Length = 80 cm

Efficiency = 90 cm^{-1}.

Pion Threshold = 2.5GeV/c



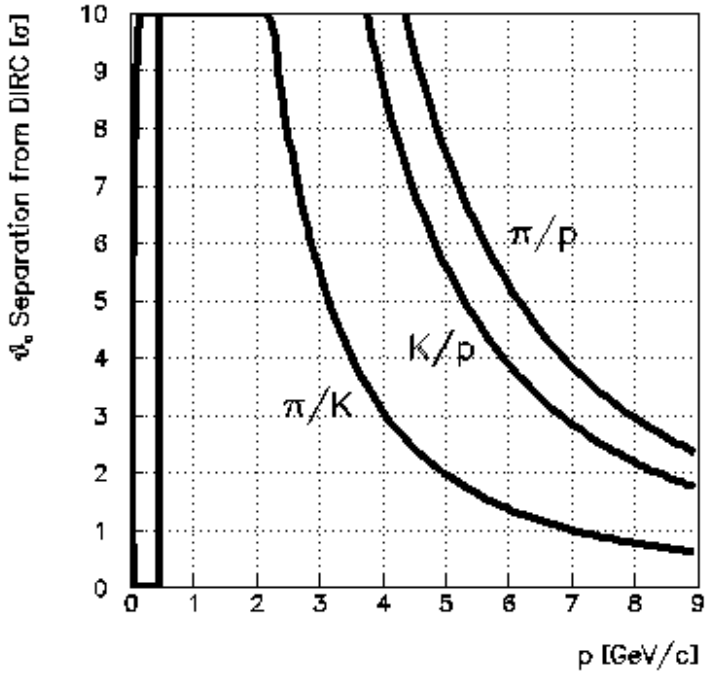
DIRC Cerenkov Angle



-- Estimated 2.1 mrad resolution.

-- 3σ protons between
450MeV/c and 6.8GeV/c.

-- 3σ kaons between
130MeV/c and 4.0GeV/c.



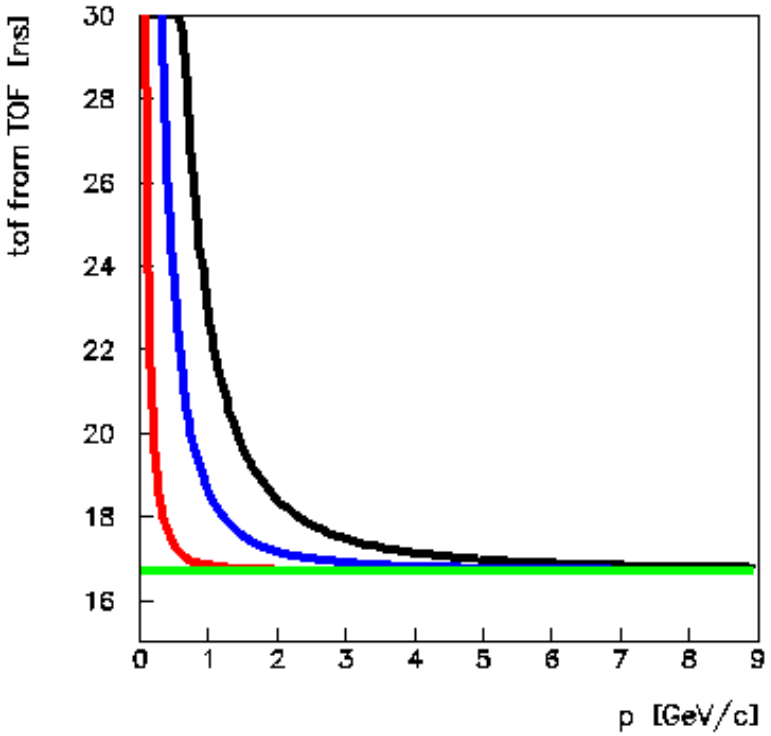
Black = Proton

Blue = Kaon

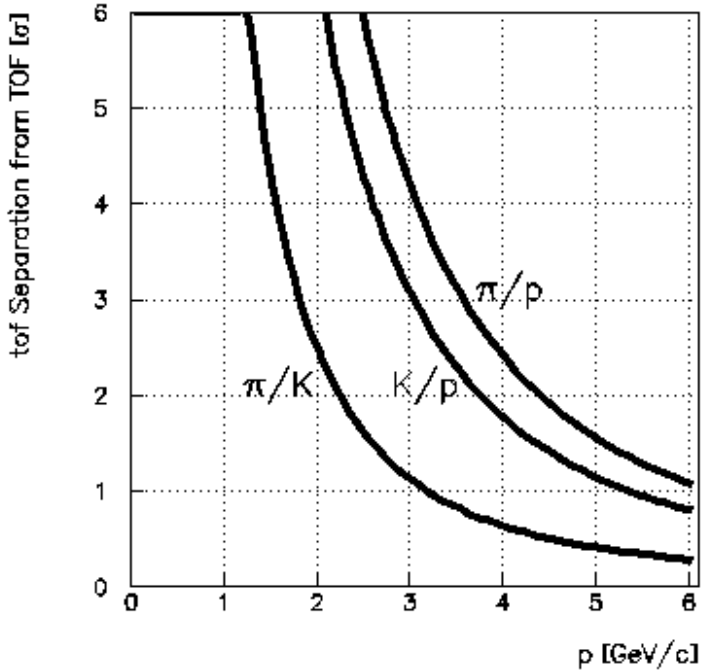
Red = Pion

Green = Electron

Time from the TOF Wall



-- Estimated 70 ps resolution.
-- Plus 1% momentum and length resolutions.
-- 3σ protons below 3.0GeV/c.
-- 3σ kaons below 1.8GeV/c.

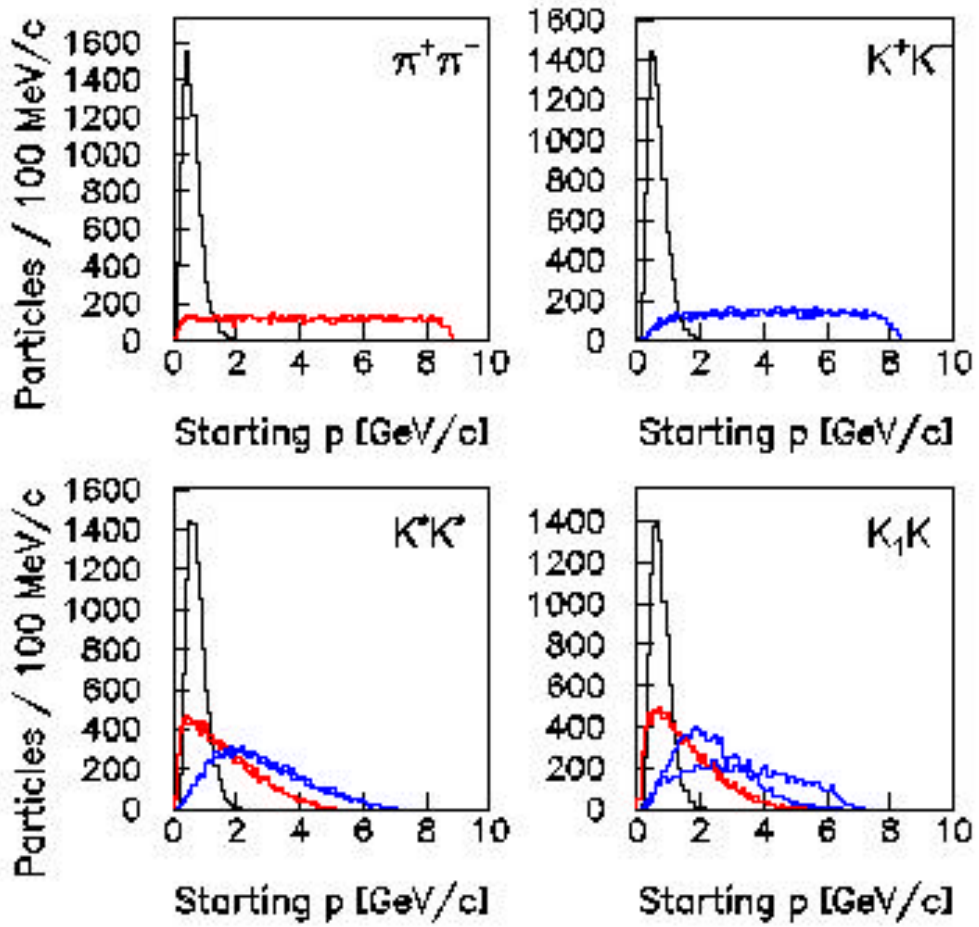


Black = Proton
Blue = Kaon
Red = Pion
Green = Electron

Starting Momentum Spectra

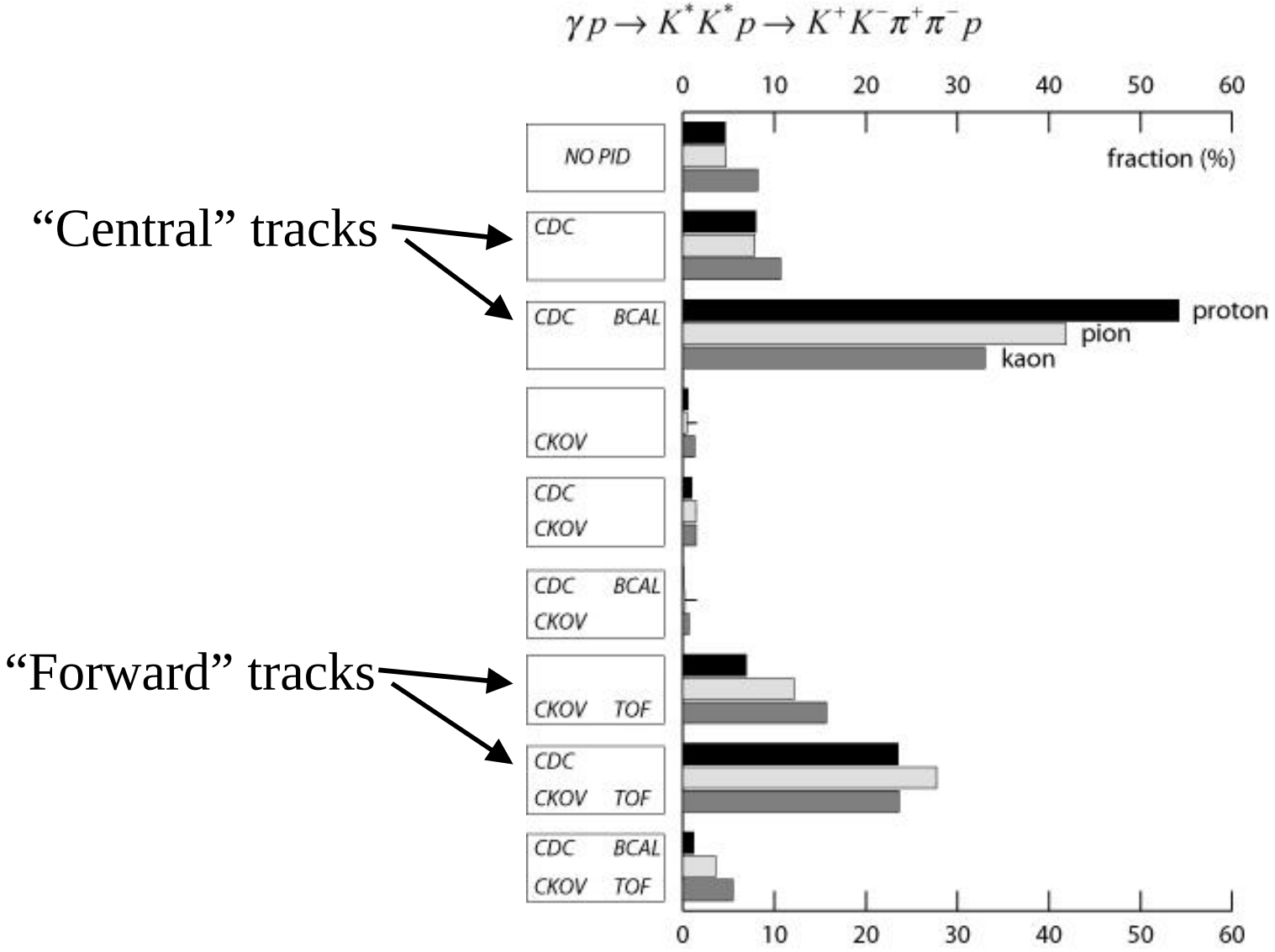
Starting momenta for four reactions:

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. $\gamma p \rightarrow K_1K^- p$
   $\rightarrow K^+\rho K^- p$
   $\rightarrow K^+\pi^+\pi^- K^- p$



Black = proton, Blue = Kaons, Red = Pions

Where do tracks go?

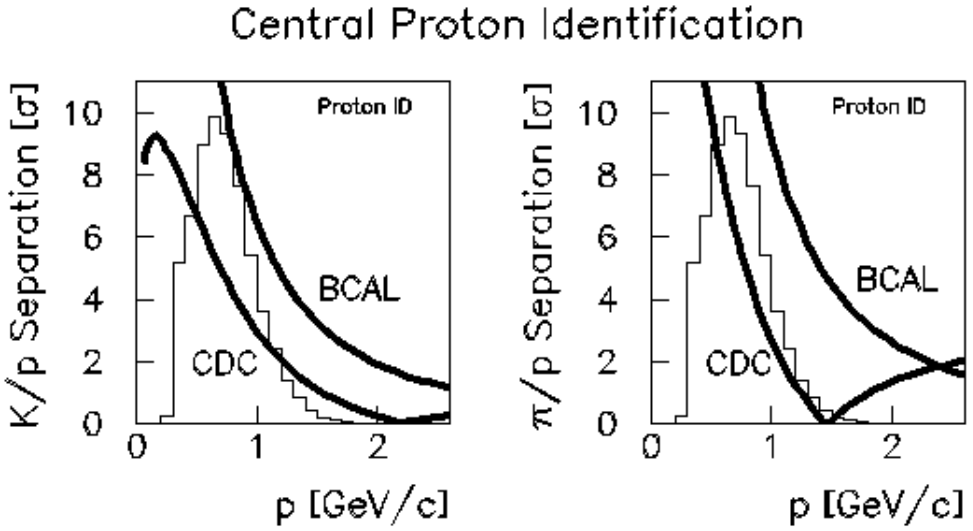


Proton Identification

Central Protons:

curves = separations (σ)
histogram = central proton momentum spectrum

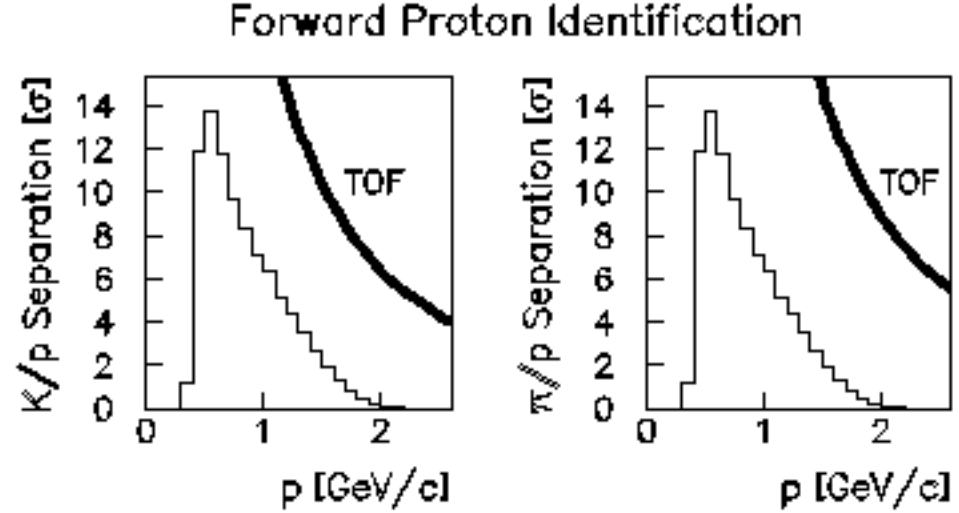
⇒**Good Separation**



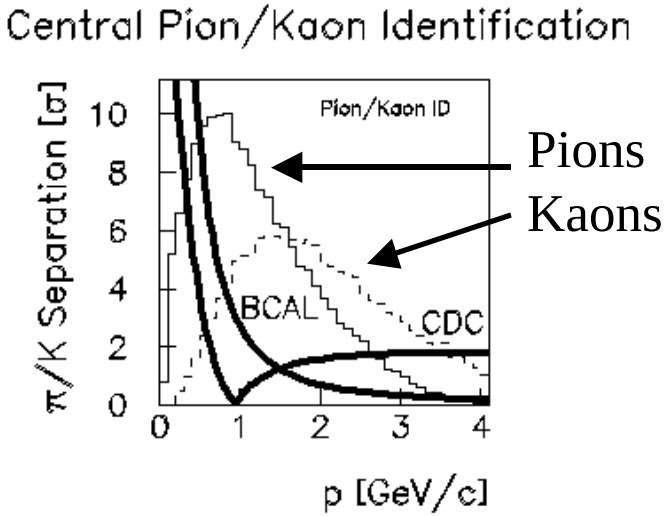
Forward Protons:

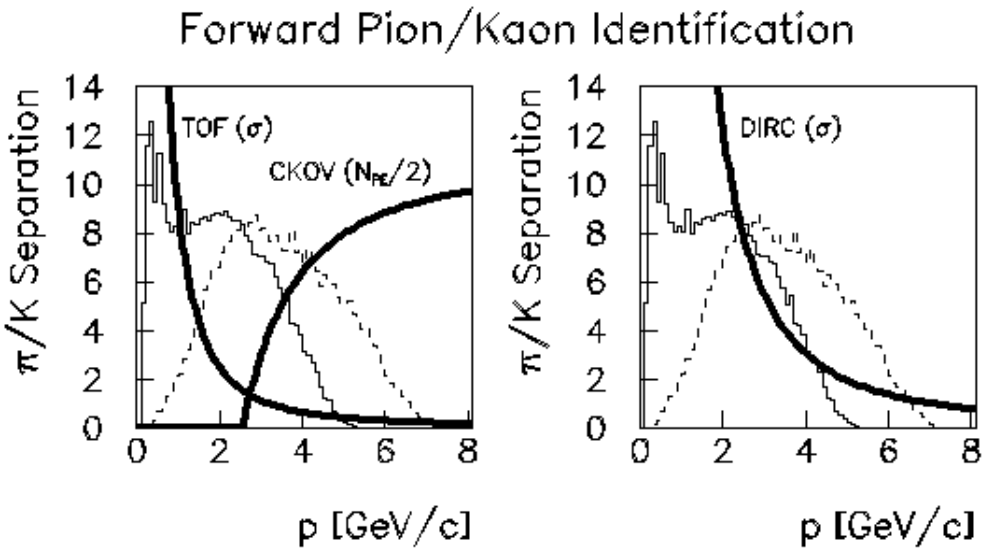
curves = separations (σ)
histogram = forward proton momentum spectrum

⇒**Even Better Separation**



Kaon Identification





Central Kaons:

-- 3σ separation
below 1 GeV/c
-- ~2σ separation
above 2 GeV/c

Forward Kaons:

Gas Option:
-- 3σ separation
below 1.8 GeV/c
-- ~5pe separation
above 3.0 GeV/c

DIRC Option:
-- 3σ separation
below 4.0 GeV/c

The Likelihood Method

- Make particle identification decisions based on calculated likelihoods for different hypotheses:

  L(i) = probability a given track is of type i, where i = π,K,p.

- A convenient way to incorporate information from a variety of different detector elements:

  $L(i) = {}^{CDC}L(i)^{BCAL}L(i)^{CKOV}L(i)^{TOF}L(i)$

Calculating Likelihoods (I)

Tracks at the TOF wall:

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

$$^{TOF}L(i) = \frac{1}{\sqrt{2\pi}\sigma_i} e^{-(t-t_i)^2/2\sigma_i}$$

i = particle hypothesis

t_i = predicted measurement

σ_i = predicted error

(70ps time resolution for TOF,
1% momentum res.,
1% length res.)

t = actual measurement

Calculating Likelihoods (II)

- Similar Gaussian calculations are used for:
  - Time of flight in the BCAL (σ_i = 250ps)
  - dE/dx in the CDC (σ_i = 10%)
  - θ_c in the DIRC (σ_i = 2.1mrad)

- Likelihoods for the gas Cerenkov are based on a Poisson distribution of the expected and measured numbers of photoelectrons.

Making a Decision

- Use a likelihood ratio test to decide between hypotheses:

$$R(i) = -2\ln\{ L(i) / (L(\pi) + L(K) + L(p)) \}$$

  is a χ^2 statistic with one d.o.f.

- The requirement:

$$R(i) > 2.7$$

  rejects hypothesis i at the 90% confidence level.

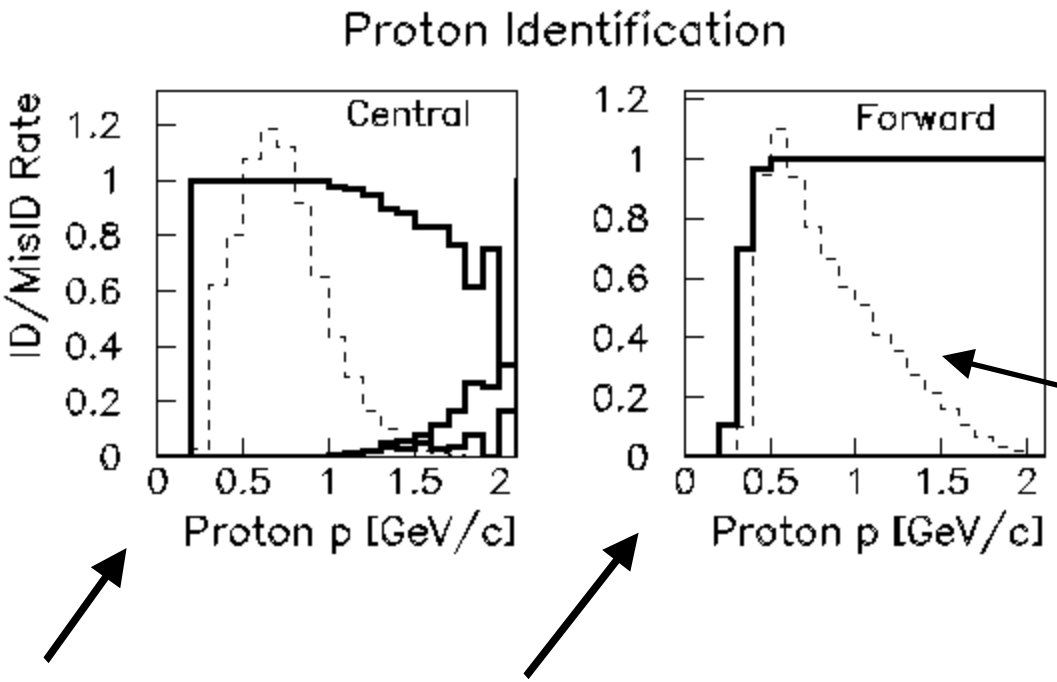
A First Algorithm

- Pion Identification:
  - -- Reject kaons: R(K) > 2.7
  - -- Don't reject pions: R(π) < 2.7
- Kaon Identification:
  - -- Reject pions: R(π) > 2.7
  - -- Don't reject kaons: R(K) < 2.7
- Proton Identification:
  - -- Reject pions: R(π) > 2.7
  - -- Reject kaons: R(K) > 2.7
  - -- Don't reject protons: R(p) < 2.7
- There is a lot of room for innovation (for example, incorporating strangeness conservation).

A Simulation of $\gamma p \rightarrow K^{*}K^{*}p$

- Generate events with:
  - -- a beam energy of 9GeV
  - -- $K^{*}K^{*}$ mass between threshold and 3GeV/c^2
  - -- t' distributed as $e^{-10t'}$.
- Put the events through a GEANT simulation recording hits at each of the detector elements.
- Smear the particle identification measurements by the expected resolutions.
- Calculate likelihoods and make particle id decisions.

Proton Results



Central Protons:
(62.58% of total)
ID Rate: 99.2%
MisID: 0.6%

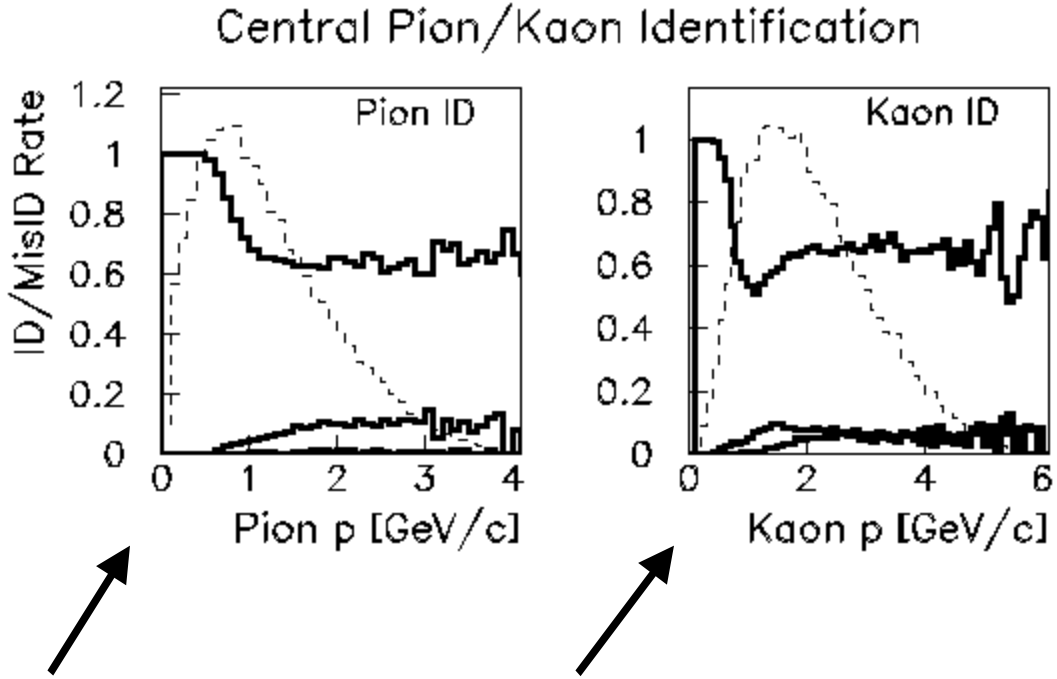
Forward Protons:
(30.27% of total)
ID Rate: 99.1%
MisID: 0.0%

Overall:
ID Rate: 94.3%
MisID: 0.4%

Central Pions and Kaons

Good identification below ~1GeV/c.

Above ~1GeV/c ID rates drop to around 60%.



Central Pions:
(50.4% of total)
ID Rate: 76.4%
MisID: 5.6%

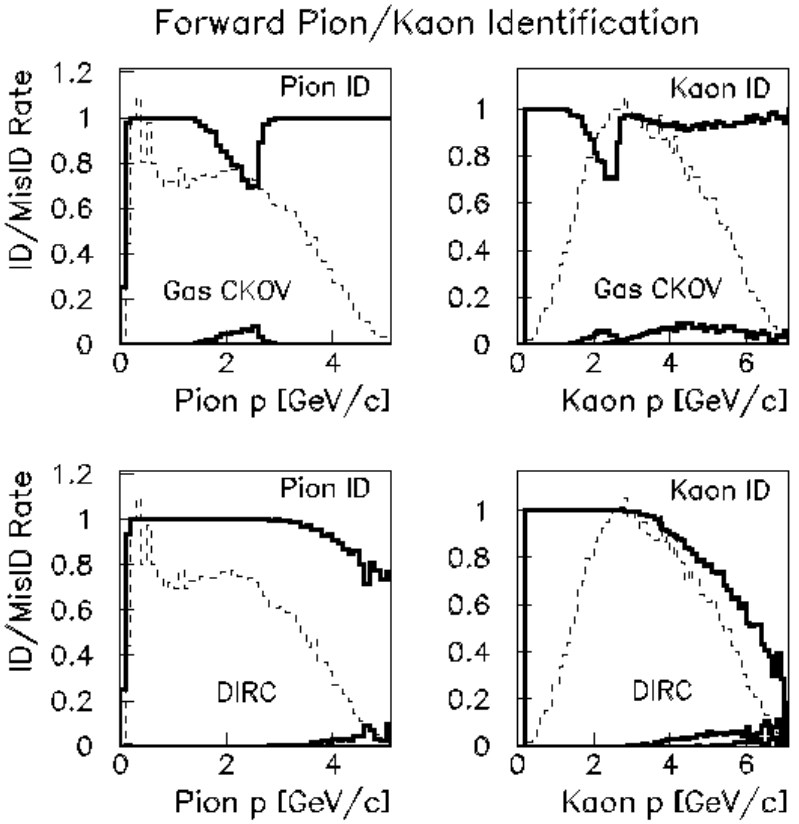
Central Kaons:
(43.7% of total)
ID Rate: 64.0%
MisID: 10.1%

Forward Pions and Kaons

Forward Pions:
(38.8% of total)

With Gas
ID Rate: 94.4%
MisID: 1.5%

With DIRC
ID Rate: 98.6%
MisID: 0.3%



Forward Kaons:
(38.8% of total)

With Gas
ID Rate: 91.4%
MisID: 4.8%

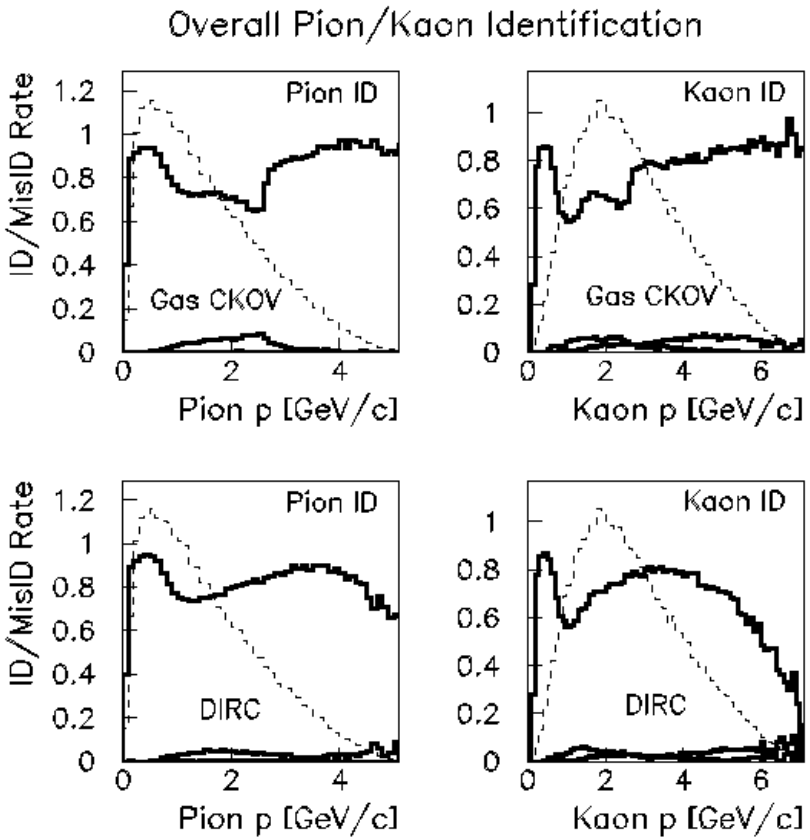
With DIRC
ID Rate: 90.3%
MisID: 2.0%

Overall Identification

Overall Pions:

With Gas
ID Rate: 80.4%
MisID: 3.5%

With DIRC
ID Rate: 82.9%
MisID: 2.9%



Overall Kaons:

With Gas
ID Rate: 71.2%
MisID: 6.8%

With DIRC
ID Rate: 71.9%
MisID: 5.3%

Angular Acceptances

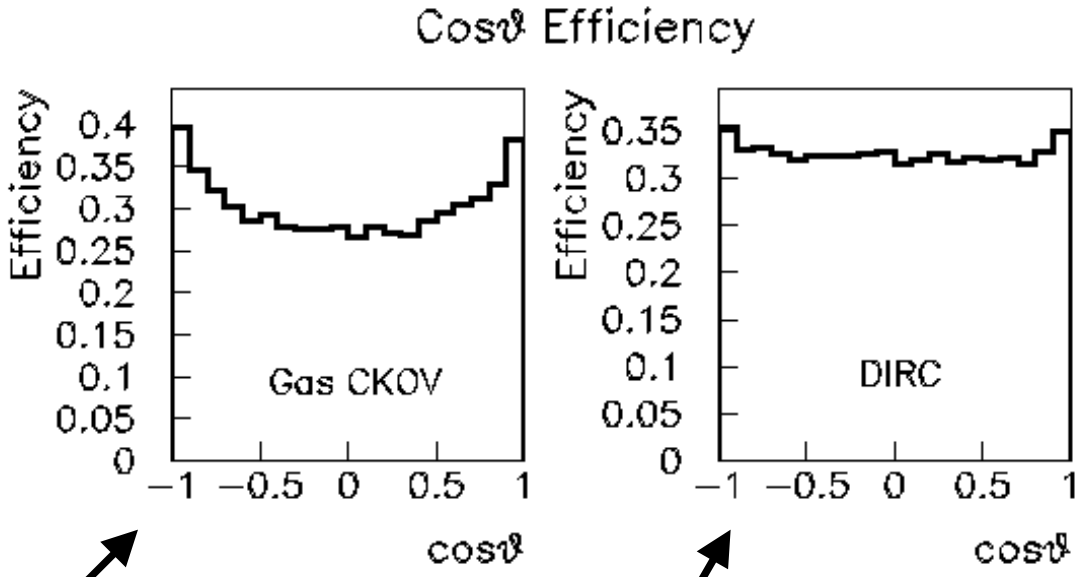
- One of the central physics goals of GlueX is to perform angular analyses of resonance decays.

- In order to do this with confidence, it is crucial to have well-understood and nearly uniform acceptances in the decay angles.

- In fact, this is at least as important as overall rates and efficiencies.

Gottfried-Jackson cosθ Acceptances ($\gamma p \rightarrow K^{*}K^{*}p$)

Cosθ is defined between the direction of one of the K* and the direction of the beam in the K*K* rest frame.



Gas option:
Preference for forward-backward decays due to the hole in the forward acceptance.

DIRC option:
Very flat acceptance.

Summary

- The CDC and BCAL will identify low momentum central tracks.
- The forward TOF and either a gas CKOV or a DIRC will identify forward tracks.
- Using a likelihood method in a typical reaction like $\gamma p \rightarrow K^{*}K^{*}p$, we identify:

  -- ~94% of all protons

  -- ~80% of all pions

  -- ~70% of all kaons