Charged Particle Identification in GLUEX

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http://www.jlab.org/~gen/gluex/talk_pid_rev.pdf

Outline

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GLUEX and physics goals

The main goal of GLUEX: search for hybrid mesons:

- $\gamma p \rightarrow pX^{\circ}(1.8 - 2.4)$, $\gamma p \rightarrow nX^{+}(1.8 - 2.4)$
- Various decay modes to charged and neutral products
- Expected: $\frac{d\sigma}{dt} \propto e^{\beta t}$, where $\beta \sim 5\ \mathrm{GeV}^{-2}$
- Exclusivity

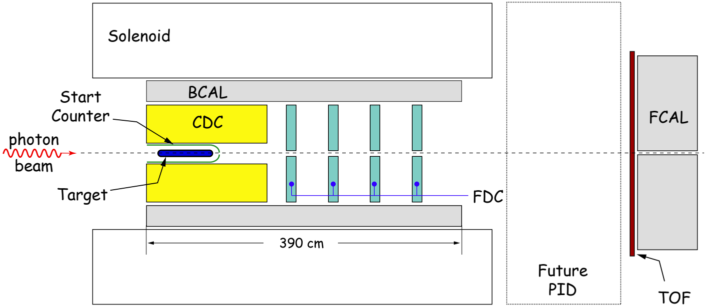
The goal of PID:

1. First stage: identify the recoil proton
2. Next stage: identify the charged kaons

PID components

1. dE/dx in CDC for $\theta > 15^\circ$ and $P < 0.6$ GeV/c;
2. *TOF* in BCAL, resolution $\sigma \approx 200$ ps;
3. *TOF* in FTOF, resolution $\sigma \approx 80$ ps;

An additional PID will be considered at the next stage.



Detector is cylindrically symmetric about the beamline

Evaluation of the PID performance

PID performance:

1. Recoil proton identification in a typical reaction
2. Charged kaon identification in a typical reaction
3. Full identification of a reaction including p, $\pi^{\pm}$,K$^{\pm}$
   - PID
   - Kinematical constraints, as $(E, \vec{P})_{total}$ in reactions with recoil protons

Reactions considered

- Recoil proton spectrum depends on M_X and β
  we should check various cases
- Reactions with $K^{\pm}$ pairs are the most promising
  in the strange sector
- Backgrounds: come from generic photoproduction
  ("minimum bias events")

Reactions

1. $\gamma p \to pX^{\circ}(2.2) \to pK^{\circ *}\overline{K}^{\circ *} \to pK^{+}\pi^{-}K^{-}\pi^{+}$ $\quad \beta = 5\ \mathrm{GeV}^{-2}$
2. $\gamma p \to pX^{\circ}(1.8) \to p\pi^{+}\pi^{-}\pi^{-}\pi^{+}$ $\quad \beta = 8\ \mathrm{GeV}^{-2}$
3. PYTHIA for simulating minimum bias events (BG)

Background simulation using PYTHIA

- PYTHIA has been tuned at higher energies $E > 20$ GeV
- At our energies $E \sim 8$ GeV PYTHIA results should be compared with measurements, in particular for strange particles.

PYTHIA vs experiment - non-strange sector

Partial cross section normalized to: $\sigma_{tot}^{\gamma p} = 120\ \mu b$

process $\gamma p \rightarrow$	via	Experiment E_γ, GeV	Experiment σ, μb	PYTHIA E_γ, GeV	PYTHIA σ, μb
1 prong		9.3	8.5±1.0	9.0	6.2
3 prong		9.3	64.4±1.5	9.0	59.0
5 prong		9.3	34.2±0.9	9.0	44.0
7 prong		9.3	6.8±0.3	9.0	8.3
$p\pi^+\pi^-$		9.3	14.7±0.6	9.0	14.5
	$p\rho^\circ$	9.3	13.5±0.5	9.0	13.0
$p\pi^+\pi^-\pi^\circ$		9.3	7.5±0.8	9.0	7.0
	$p\omega$	9.3	1.9±0.3	9.0	1.4
$p2\pi^+2\pi^-$		9.3	4.1±0.2	9.0	3.7

Reasonably good agreement!

PYTHIA vs experiment - strange sector

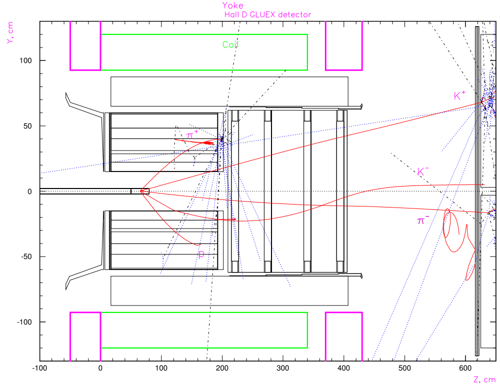
Partial cross section normalized to: $\sigma_{tot}^{\gamma p} = 120~\mu$b

process $\gamma p \rightarrow$	via	Experiment E_γ, GeV	Experiment σ, μb	PYTHIA E_γ, GeV	PYTHIA σ, μb
strange		5.6	8.7±0.9	9.0	24.0
pK^+K^-		9.3	0.58±0.05	9.0	0.47
	$p\phi$	9.3	0.27±0.03	9.0	0.26
$pK^+K^-\pi^+\pi^-$		9.3	0.46±0.05	9.0	0.60

Full strange cross section is $\times$3 larger
Partial strange cross sections are reasonable

Simulation

- Simplified model of geometry in GEANT
- GEANT: tracking, decays and interactions with the matter
- No track reconstruction
- Momentum/angular resolutions in a tabulated form



$\gamma p \rightarrow pK^+\pi^-K^-\pi^+$

Beam: coh. brem. 7.5-9.5 GeV

Acceptance:

Track requirement:
hits CDC or BCAL or TOF
Accept.: $\varepsilon \sim 50\%$
Losses: decays, interactions

Simulation of TOF

$$t_{measured} = t_{RF} + \frac{z_\circ}{c} + \frac{L_{trajectory}}{c\beta}$$

Simulated TOF

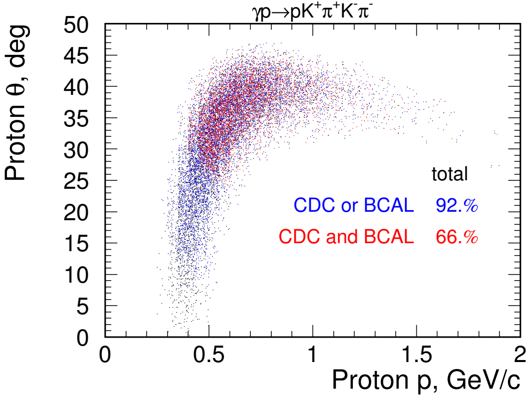
- MC: track origin $\vec{x}_o$
- MC: hit coordinates $\vec{x}_h$
- Trajectory length $L^2 = (\vec{x}_h - \vec{x}_o)^2$
- TOF randomized due to the basic resolution

"Reconstructed" TOF

- MC: reconstructed vertex $\vec{x}_v$
- MC: hit coordinates $\vec{x}_h$
- Trajectory length $(\vec{x}_h - \vec{x}_v)^2$
- Trajectory length randomized
- "Measured" momenta used

detector	basic σ_T	additional resolution: trajectory σ_L	vertex $\sigma_{X,Y,Z}$, cm	momentum resolution	total for π
BCAL	200 ps	2 cm	$2 \times 0.1, 1.0$	yes	$\sim$70 ps
2 FTOF	60 ps	1 cm	same	yes	$\sim$50 ps

Recoil proton: kinematics and tracking



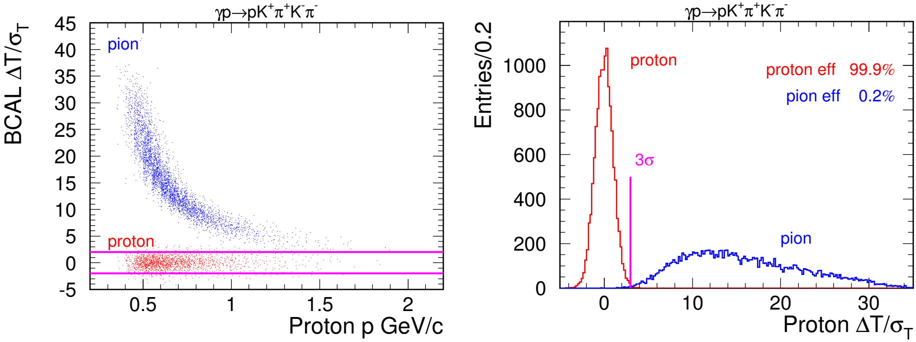
Reaction: $\gamma p \to pK^+\pi^-K^-\pi^+$

MC results:

detector	of all protons
CDC	92%
CDC and BCAL	66%
BCAL only	0%

CDC requirement
trajectory in gas $\ell_{gas} > 20$ cm

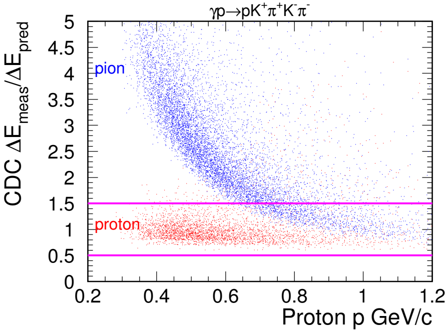
Recoil proton in TOF (BCAL)

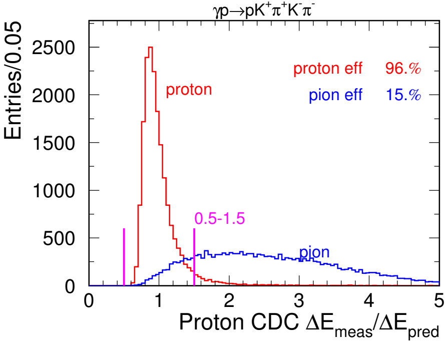


3σ cut for proton hits:

assumed	accepted
proton	99.8%
pion	0.2%

Recoil proton in CDC





$\frac{dE}{dx}$ simulation

- routines from GEANT (Landau theory)
- ideal detector

$$0.5 < \frac{\Delta E_{meas}}{\Delta E_{pred}} < 1.5 \text{ cut}$$

for proton hits:

assumed	accepted
proton	95%
pion	15%

Summary on recoil proton PID

The results may depend on:

- t-distribution
- Mass M_X, via t_{min}

Reactions tried:

a) $\beta = 5$ GeV^{-2} γp$\rightarrow$ pX(2.2) "harder" proton
b) $\beta = 8$ GeV^{-2} γp$\rightarrow$ pX(1.8) "softer" proton

c) PYTHIA for minimum bias

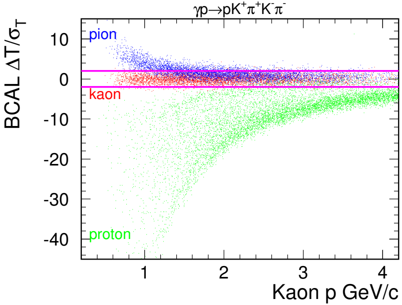
Combined TOF (BCAL) and CDC:

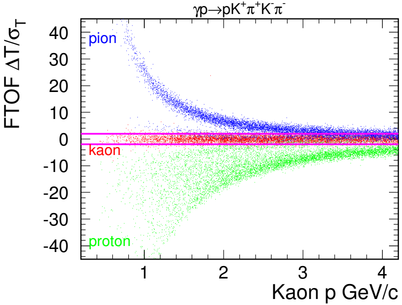
assumed	a) in PID	a) accepted by PID	b) in PID	b) accepted by PID
proton	$\sim$ 92%	$\sim$ 95%	$\sim$ 76%	$\sim$ 97%
pion	-	$\sim$ 0.4%	-	$\sim$ 0.2%

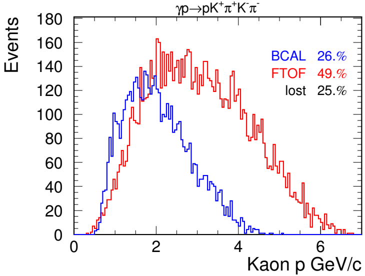
PYTHIA: p enrichment $\times$10 to p/π=3/1

A good performance!

Kaon identification with TOF in BCAL and FTOF







Efficiency for kaon hits

	accepted			
	BCAL		FTOF	
	3σ	2σ	3σ	2σ
kaon	99%	95%	99%	95%
pion	83%	63%	51%	34%

PYTHIA: K enrichment $\times 3$ to K/π=1/5

Event Reconstruction

Global event $(E, \vec{P})$ resolution (true combinations):

	final				initial
	p_X	p_Y	p_Z	E	tagger
σ, MeV	15	15	150	150	10

Kinematic fitting

Global event fitting using constraints:

- high precision initial parameters $(E, \vec{P})_{total}$
- secondary particle masses

4C fits for $(E, \vec{P})_{total}$

1. 30% better accuracy for track parameters
2. Strongly improved ΔE separation $\Rightarrow$ PID

Reaction

Process: $\gamma p \rightarrow pX^{\circ}(2.2) \rightarrow pK^{\circ}(890)\overline{K}^{\circ}(890) \rightarrow pK^{+}\pi^{-}K^{-}\pi^{+}$
A large background can be expected:

- events with no strangeness dominate by a factor of $\times 10$
- 12 mass combinations per event

Event identification with kinematic fitting

1. 3-momentum balance $\Delta\vec{P}$ $CL(\chi^2) > 0.01$
2. 4C fit with the given mass assignment $CL(\chi^2) > 0.01$
3. PID:
   - *TOF* protons: $\Delta T < 3\sigma$, kaons/pions: $\Delta T < 2\sigma$
   - *CDC* $0.5 < \frac{\Delta E_{meas}}{\Delta E_{pred}} < 1.5$

Signal and background from PYTHIA

combinations	cuts					
	kinem.		PID			all
	3-mom	4C	p	K	both	
efficiency	0.99	0.99	0.80	0.84	0.67	0.65
BG suppression	10.	20.	6.0	13.	80	16000
(true ID)/comb	0.01	0.20	-	-	0.93	0.93

Kinematic fitting is the key element in PID!

Without fitting, the BG is about 5 times worse

Robustness of the method

Checks for robustness:

- Slow dependence on the track variances:

all errors	BG/total
$\times 1$	0.07
$\times 2$	0.30
$\times 4$	0.70

- Additional ways to increase the BG suppression have been investigated:
  - stronger CL cuts
  - checking other mass asignments
  - selecting the best combination in the event

Possible limitations against large suppression factors:

- non-Gaussian errors, long tails in the residuals, or flat backgrounds (coming from pattern recognition)
- poor understanding of the track covariances

Used by many at $E \sim$10 GeV: bubble chmbs. $\Rightarrow$ CLEO/BaBar etc...

Summary

1. The first stage of GLUEX: non-strange mesonic resonances
   The first-stage PID is very good for the recoil protons:
   - efficiency to protons $\sim 90\%$
   - pions suppression factor ~ 200
   - pion BG from PYTHIA events $\sim 4\%$ (recoil range)
     $\sim 30\%$ (all positive tracks)
2. The next stage of GLUEX may involve strange resonances.
   - Overdefined kinematics (all final particles detected):
     Kinematic fitting with the PID appear to be sufficient for identification of events with $K^{\pm}$, to BG$< 10\%$.
   - Missing particles:
     1C fit for the recoil: kaon events: BG$> 80\%$
     An additional PID will be required for physics with $K^{\pm}$
3. The combination of kinematic fitting with the simple PID allows to carry out the first stage and a part of the second stage program.