Reconstructing multi-particle final states with GlueX

Decay modes of Gluonic excitations

GlueX Experiment

Reconstruction of photons

Reconstruction of charged particles

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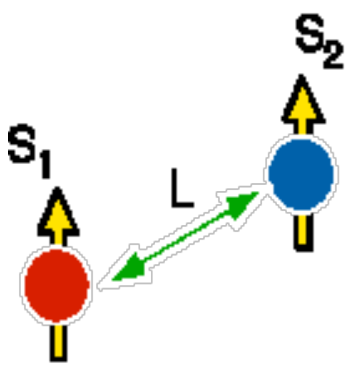
for the GlueX Collaboration

Workshop on Hadron Spectroscopy, INT 09-3

Normal Mesons – $q\bar{q}$ color singlet bound states

Spin/angular momentum configurations & radial excitations generate the known spectrum of light quark mesons.

Starting with u - d - s we expect to find mesons grouped in nonets - each characterized by a given J, P and C.

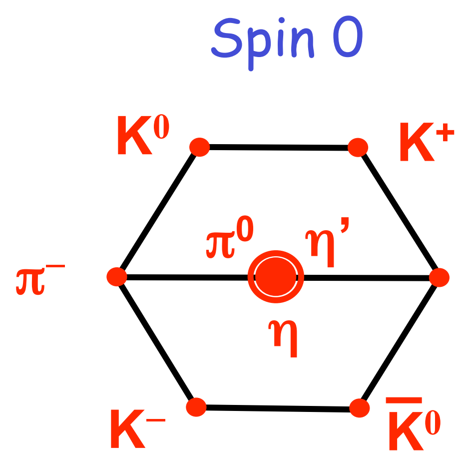


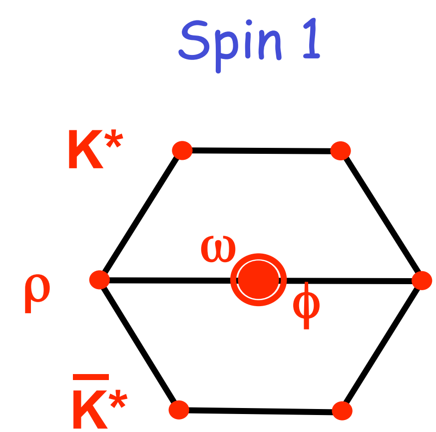
$S = S_1 + S_2$

$J = L + S$

$P = (-1)^{L+1}$

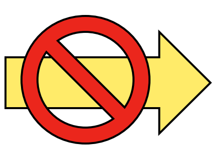
$C = (-1)^{L+S}$





$J^{PC} = 0^{-+} \ \ 0^{++} \ \ 1^{--} \ \ 1^{+-} \ \ 2^{++} \ldots$

Allowed combinations



$J^{PC} = 0^{--} \ \ 0^{+-} \ \ 1^{-+} \ \ 2^{+-} \ldots$

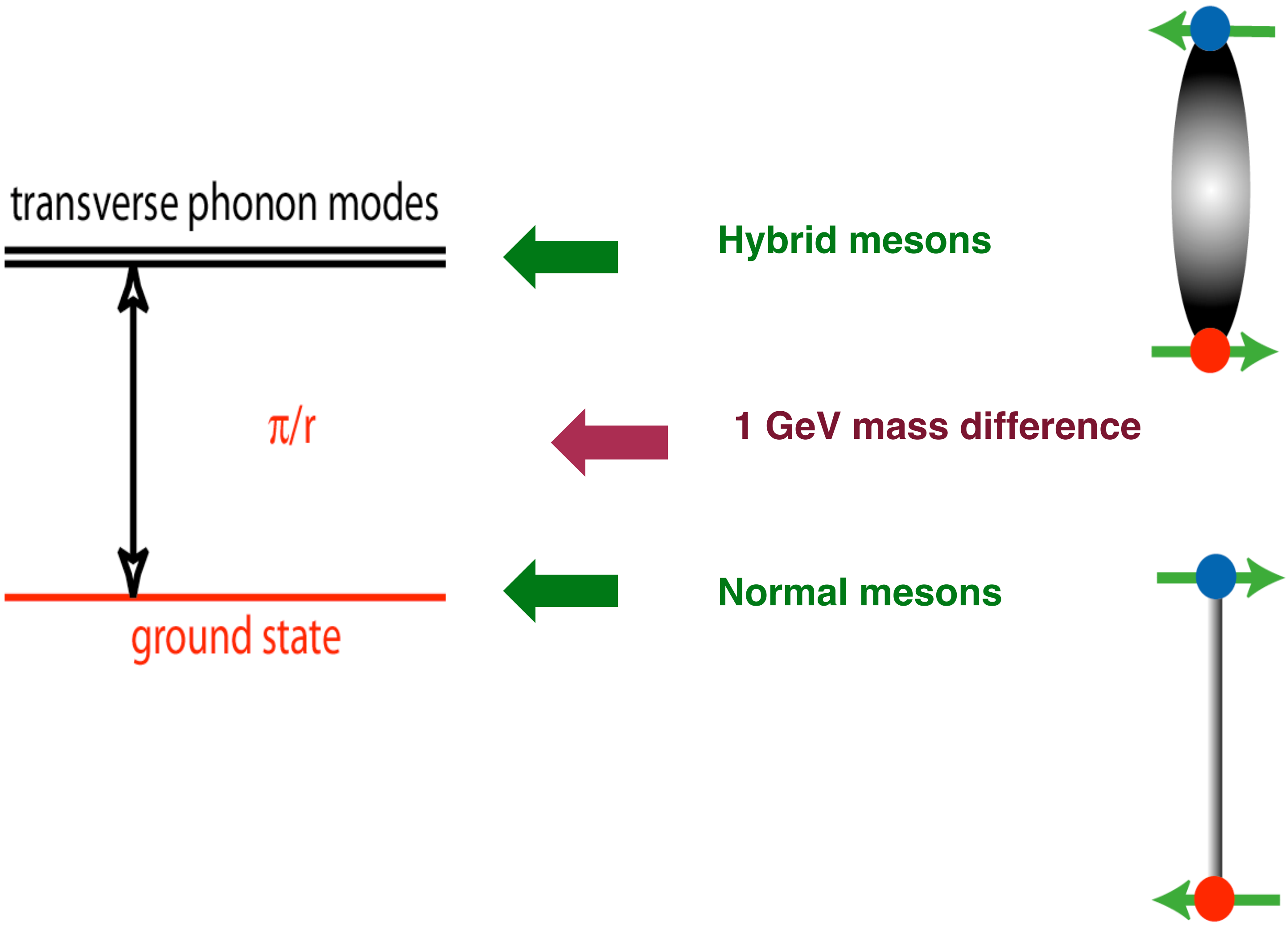
Not-allowed: exotic

Naming Scheme for u,d Mesons

Name (I=1, I=0)	L	S	J^{PC}	$^{2S+1}L_J$	Examples
π, η	0	0	0^{-+}	$^1S_0$	π, η
ρ, ω	0	1	1^{--}	$^3S_0$	$\rho(770), \omega(782)$
b, h	1	0	1^{+-}	$^1P_1$	$b_1(1235), h_1(1170)$
a, f	1	1	0^{++}	$^3P_0$	$a_0(980), f_0(980)$
a, f	1	1	1^{++}	$^3P_1$	$a_1(1260), f_1(1285)$
a, f	1	1	2^{++}	$^3P_2$	$a_2(1320), f_2(1270)$
π, η	2	0	2^{-+}	$^1D_2$	$\pi_2(1670)$
ρ, ω	2	1	1^{--}	$^3D_1$	$\rho_1(1700), \omega_1(1600)$
ρ, ω	2	1	2^{--}	$^3D_2$	
ρ, ω	2	1	3^{--}	$^3D_3$	$\rho_3(1670)$
b, h	3	0	3^{+-}	$^1F_3$	
a, f	3	1	2^{++}	$^3F_2$	
a, f	3	1	3^{++}	$^3F_3$	
a, f	3	1	4^{++}	$^3F_4$	

$$P = (-1)^{L+1}$$
$$C = (-1)^{L+S}$$
$$PC = (-1)^{S+1}$$

Hybrid Mesons

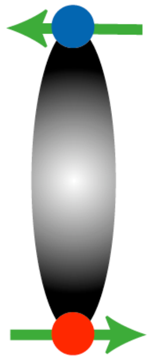


Quantum Numbers of Hybrid Mesons

Quarks $\oplus$ **Excited Flux Tube** → **Hybrid Meson**

$S = 0$
$L = 0$
$J^{PC} = 0^{-+}$

like π, K

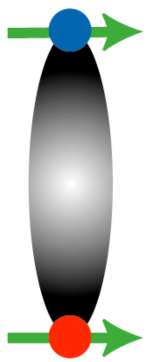


$$J^{PC} = \begin{cases} 1^{+-} \\ 1^{-+} \end{cases}$$

$$J^{PC} = \begin{cases} 1^{--} \\ 1^{++} \end{cases}$$

$S = 1$
$L = 0$
$J^{PC} = 1^{--}$

like γ, ρ



$$J^{PC} = \begin{cases} 1^{+-} \\ 1^{-+} \end{cases}$$

Exotic

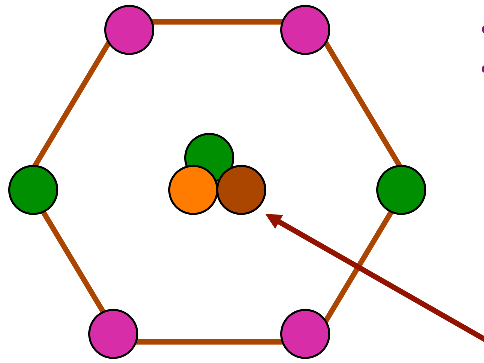
$$J^{PC} = \begin{cases} 0^{-+} \quad 1^{-+} \quad 2^{-+} \\ 0^{+-} \quad 1^{+-} \quad 2^{+-} \end{cases}$$

Flux tube excitation (and parallel quark spins) lead to exotic J^{PC}

Families of Exotics

$K_1 \quad I^G(J^{PC}) = \frac{1}{2}\,(1^-)$

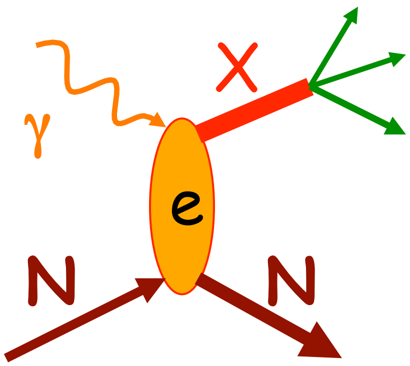
$\pi_1 \quad I^G(J^{PC}) = 1^-(1^{-+})$



1^{-+} nonet

$\eta'_1 \quad I^G(J^{PC}) = 0^+(1^{-+})$

$\eta_1 \quad I^G(J^{PC}) = 0^+(1^{-+})$



$\gamma \Leftrightarrow \rho, \omega, \phi$

Couple to vector meson
+ exchanged particle

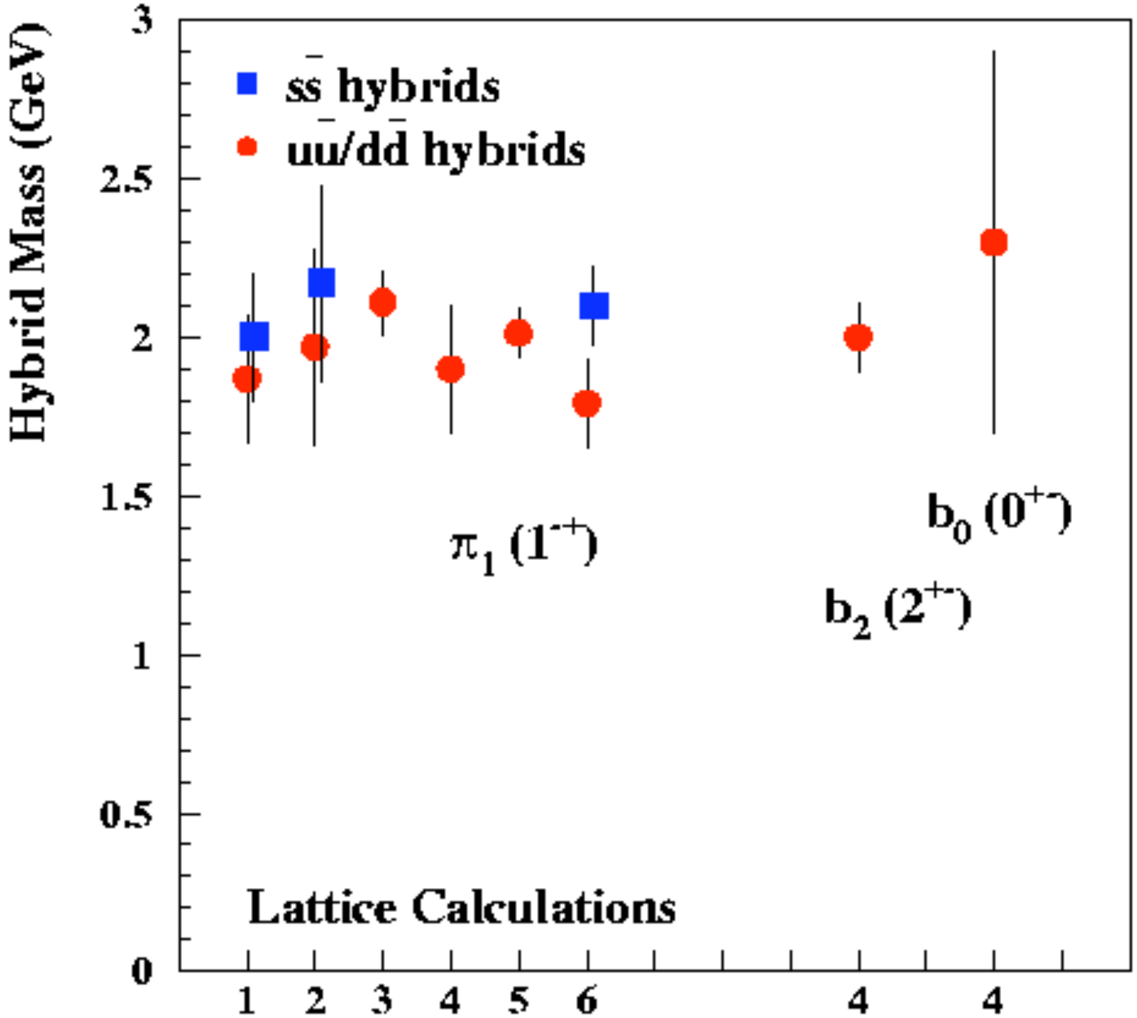
$\pi_1 \Leftrightarrow \rho\pi$

$\eta_1 \Leftrightarrow \rho b_1\,,\ \omega\phi$

$\eta'_1 \Leftrightarrow \phi\omega$

Mass Predictions

Lowest mass expected to be $\pi_1(1^{-+})$ at 1.9±0.2 GeV



Lattice

1^{-+} 1.9 GeV

2^{+-} 2.1 GeV

0^{+-} 2.3 GeV

Selection Rules

- Decays of $J^{PC}=0^{+-}$, 1^{-+}, 2^{+-},…. exotic hybrids to pseudoscalar mesons vanish.
  - Hybrids do not decay to $\eta\pi$.
  - Hybrids decays to $\pi\pi$, $\rho\rho$, KK are forbidden.
- Decays of hybrids to s-wave mesons highly suppressed.
  - Hybrid decay to $\rho\pi$ is suppressed.

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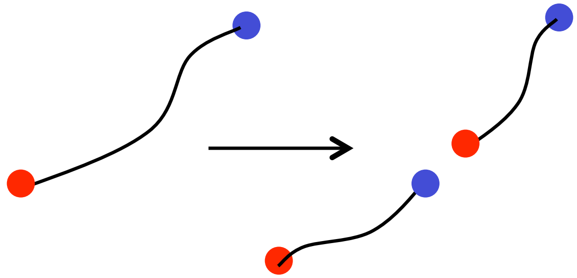
How do exotics decay?



Possible daughters:

L=1: a,b,h,f,...
L=0: π,ρ,η,ω,...

The angular momentum in the flux tube stays in one of the daughter mesons (L=1) and (L=0) meson, e.g:

flux tube L=1 quark L=1

Example: $\pi_1 \to b_1\pi$

$\hookrightarrow \omega\pi \to (3\pi)\pi$

or $\omega\pi \to (\pi\gamma)\pi$

simple decay modes such as $\eta\pi,\rho\pi$, ... are suppressed.

Flux Tube Expectations for $\pi_1(2000)$

Decay Mode	Final state	Partial Width PSS (MeV)	Partial Width IKP (MeV)
$b_1(1235)\,\pi$	$\omega\pi\,\pi$	43	58
$K_1(1400)\,K$	$K\pi\pi\,K$	33	75
$\eta(1295)\,\pi$	$\eta\pi\pi\,\pi$	27	21
$\rho\pi$	$\pi\pi\,\pi$	16	16
$\rho(1450)\,\pi$	$\pi\pi\,\pi$	12	12
$f_1(1285)\,\pi$	$\pi\pi\pi\pi\,\pi$	10	38
$a_1(1260)\,\eta$	$\rho\pi\,\eta$	7	13
$K_1(1270)\,K$	$K\rho\,K$	7	19
Total		> 155	> 252

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Partial width dependence on hybrid mass

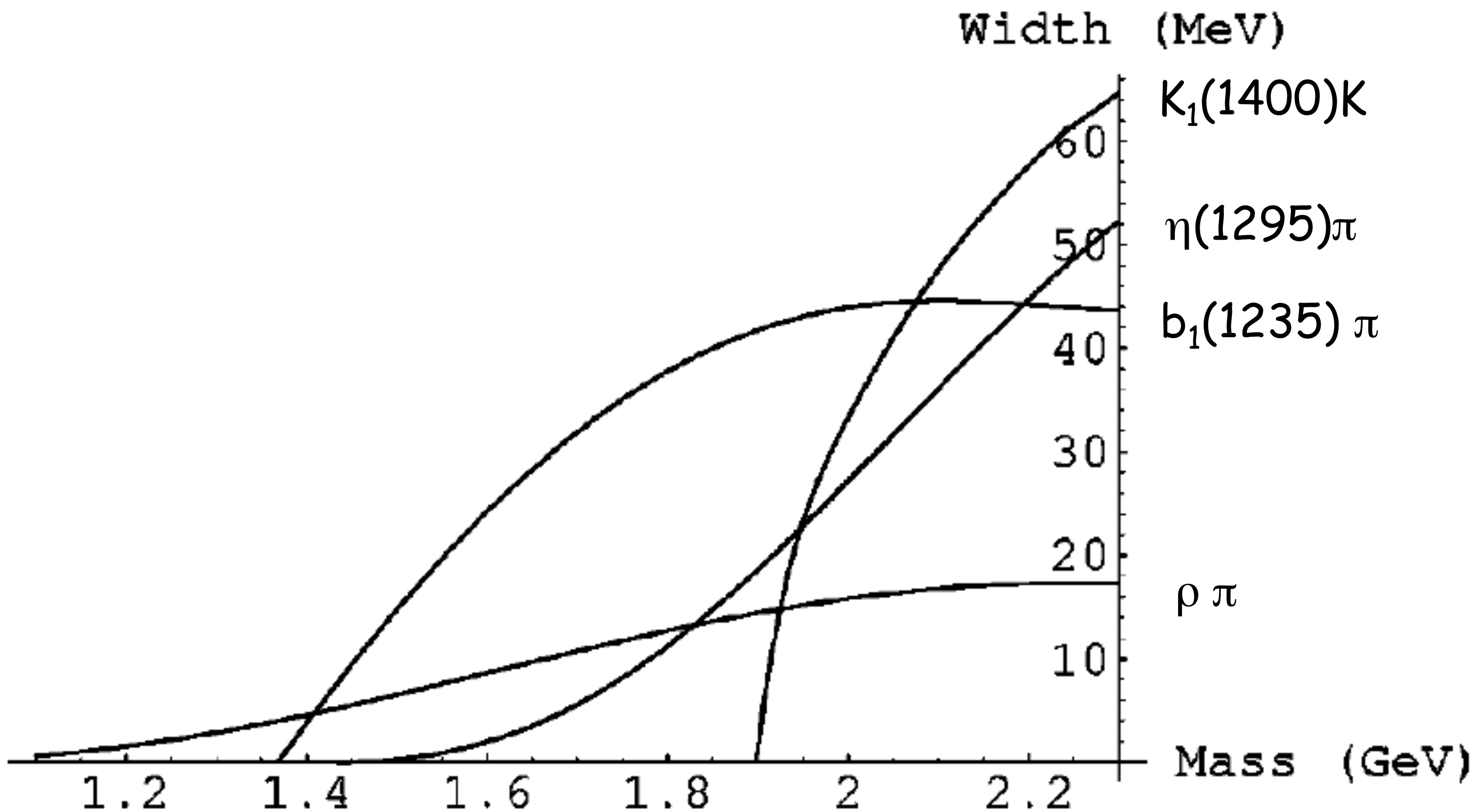

FIG. 1. Dominant partial widths of a 1^{-+} isovector hybrid at various hybrid masses. The partial widths to $K_1(1400)K$, $\eta(1295)\pi$, $b_1\pi$ and $\rho\pi$ correspond to the highest to the lowest intersections with the vertical axis.

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Strategy for Exotic Meson Search

- Use 8 – 9 GeV polarized photons (12 GeV electron beam)
  - Expect production of hybrids to be comparable to normal mesons
  - Dearth of experimental data
- Use hermetic detector with large acceptance
  - Decay modes expected to have multiple particles
  - hermetic coverage for charged and neutral particles
  - high data acquisition rate to enable amplitude analysis
- Perform partial-wave analysis
  - identify quantum numbers as a function of mass
  - check consistency of results in different decay modes

Exotic Meson Decay Channels

Our "Golden" Channels:

TABLE VI: Possible Decay Modes for Exotic Hybrids

Particle	J^{PC}	I	G	Possible Modes[a]
b_0	0^{+-}	1	$+$	
h_0	0^{+-}	0	$-$	$b_1\pi$
π_1	1^{-+}	1	$-$	$\rho\pi$, $b_1\pi$
η_1	1^{-+}	0	$+$	$a_2\pi$
b_2	2^{+-}	1	$+$	$a_2\pi$
h_2	2^{+-}	0	$-$	$\rho\pi$, $b_1\pi$

[a] Assuming the $G = +$ channel $2\pi\eta$ or the $G = -$ channels 3π or $2\pi\omega$.

***... resulting in* 3π, $2\pi\eta$, *and* $2\pi\omega$.**

PLUS:

$\pi_1 \to \eta\pi$

$\to \eta'\pi$

AND A LITTLE HARDER:

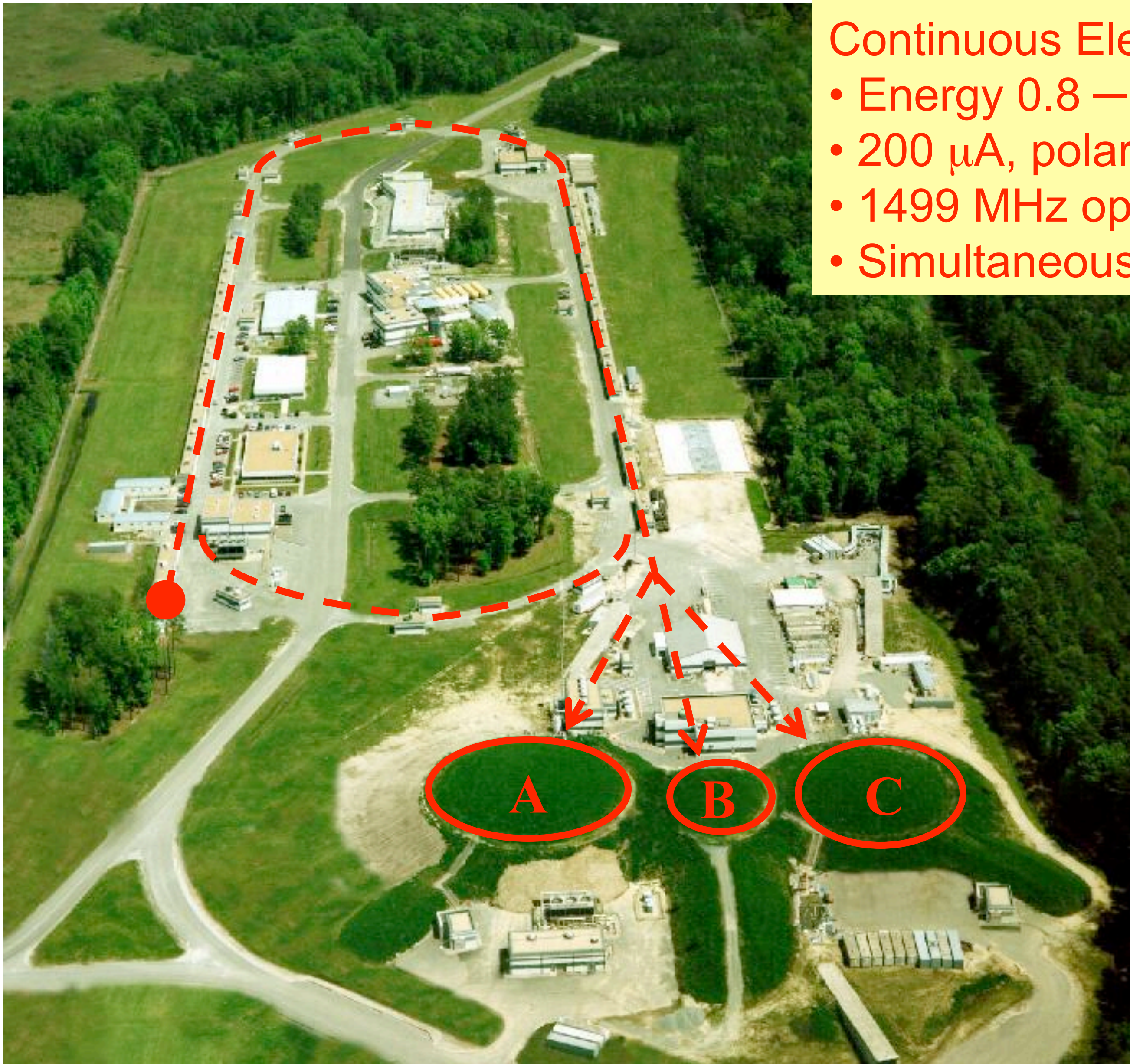
$\pi_1 \to f_1\,\pi$;

$f_1 \to a_0\,\pi$;

$a_0 \to \eta\,\pi$.

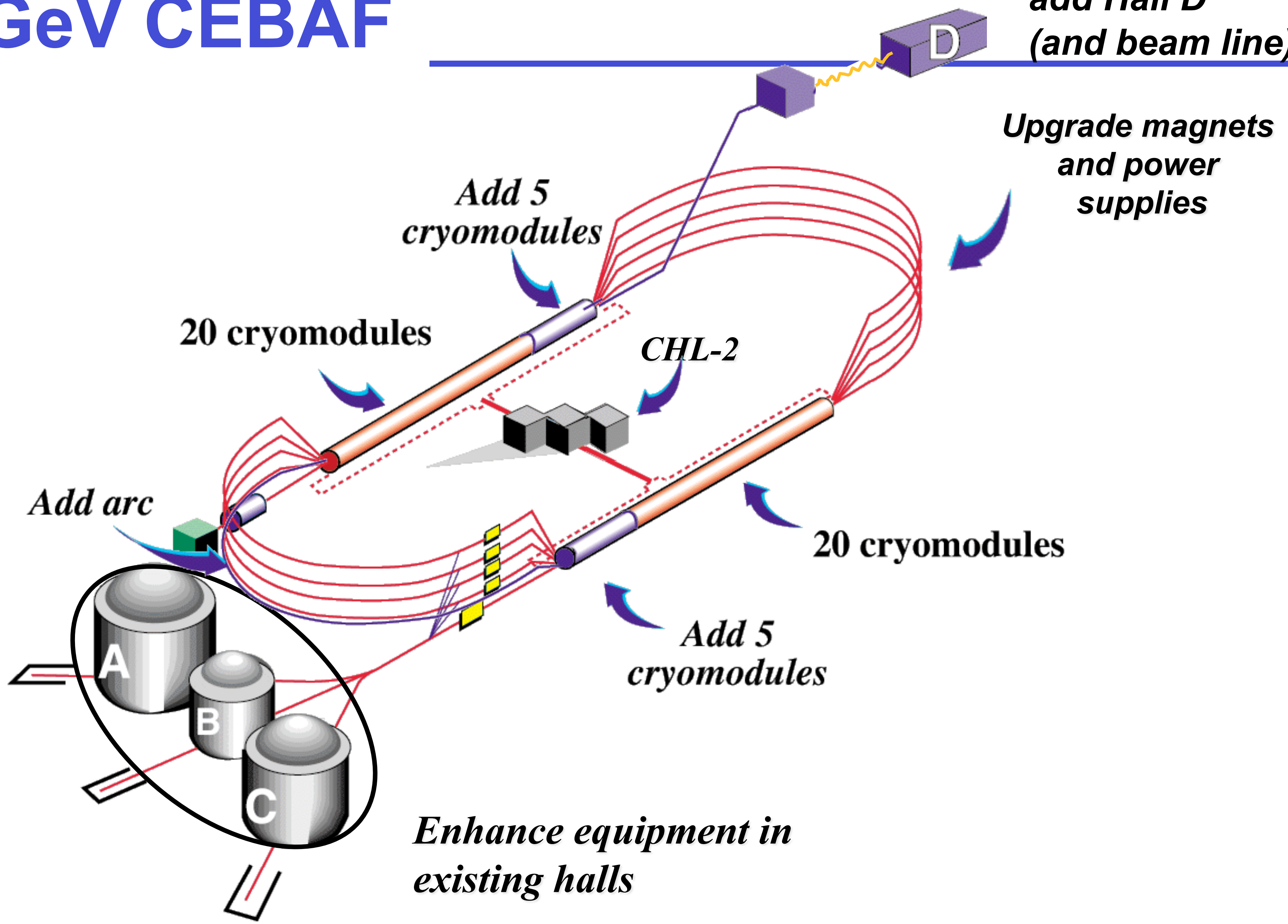
(i.e., $3\pi\eta$)

JLab accelerator CEBAF

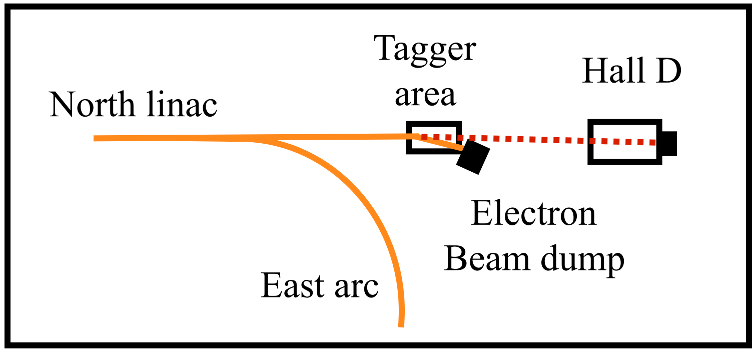


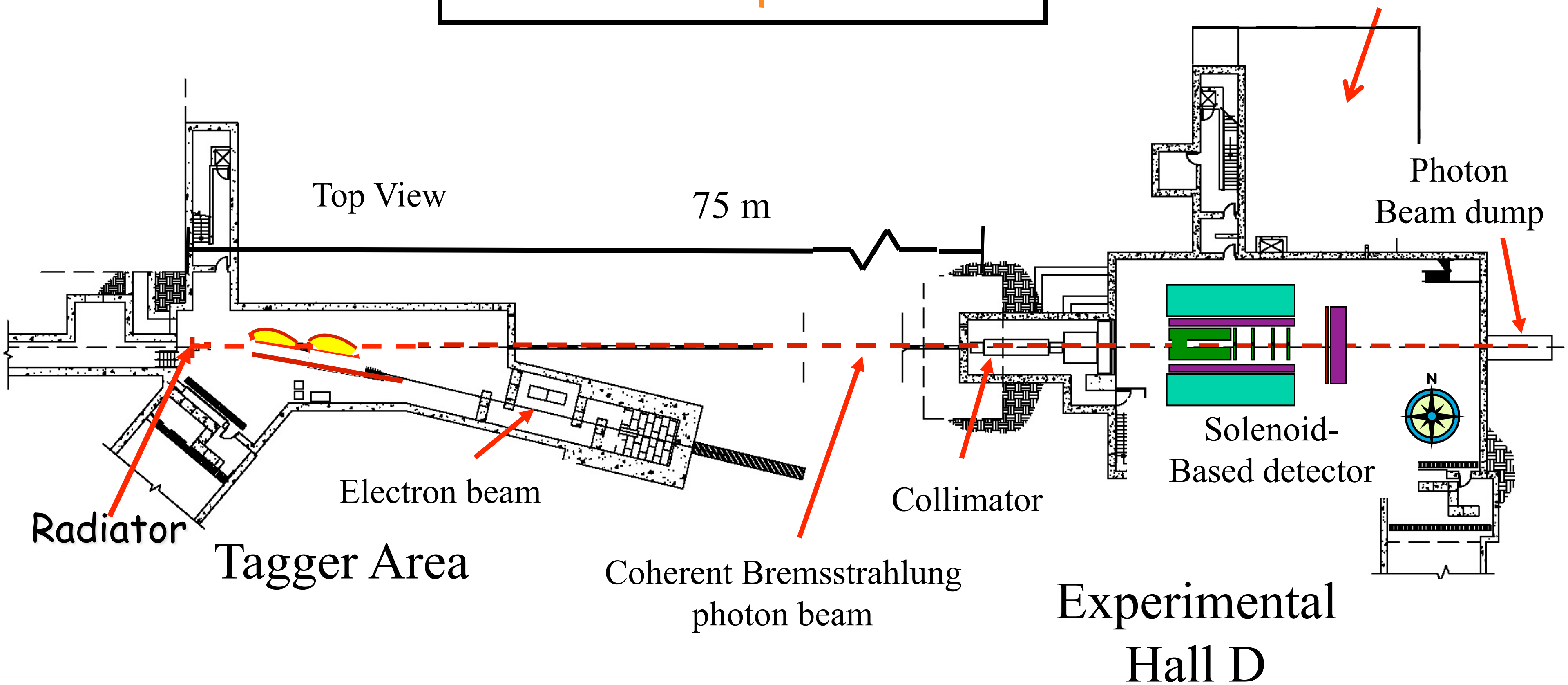
Continuous Electron Beam
- Energy 0.8 – 5.7 GeV
- 200 μA, polarization 75%
- 1499 MHz operation
- Simultaneous delivery 3 halls

12 GeV CEBAF


add Hall D
(and beam line)
D
Upgrade magnets
and power
supplies
Add 5
cryomodules
20 cryomodules
CHL-2
Add arc
20 cryomodules
Add 5
cryomodules
A
B
C
Enhance equipment in
existing halls

Photon beam and experimental area





Linearly Polarized Photon Beam

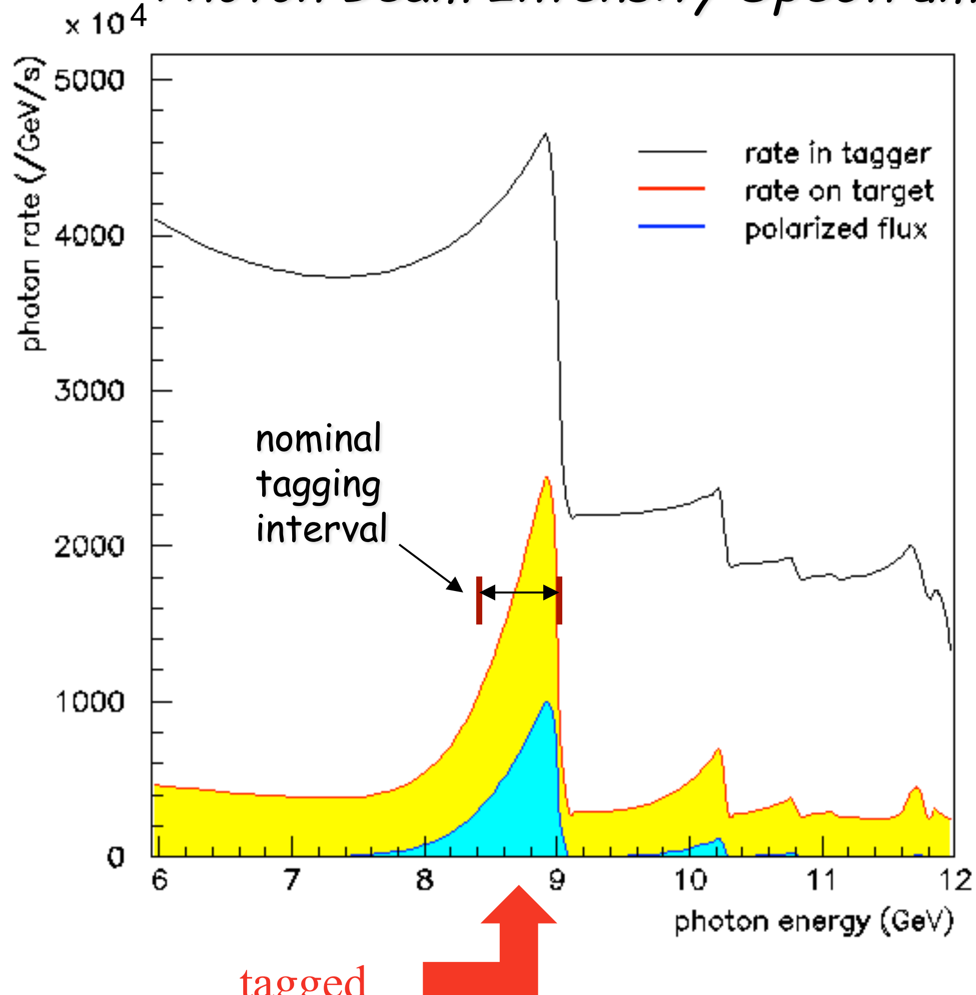
Rates are based on

- 12 GeV electron beam
- 20 μm diamond crystal
- 300 nA electron beam
- Rad-collimator: 76 m
- Collimator diameter: 3.5mm

Leads to $10^7 \gamma$/s on target

Design is expandable to $10^8 \gamma$/s

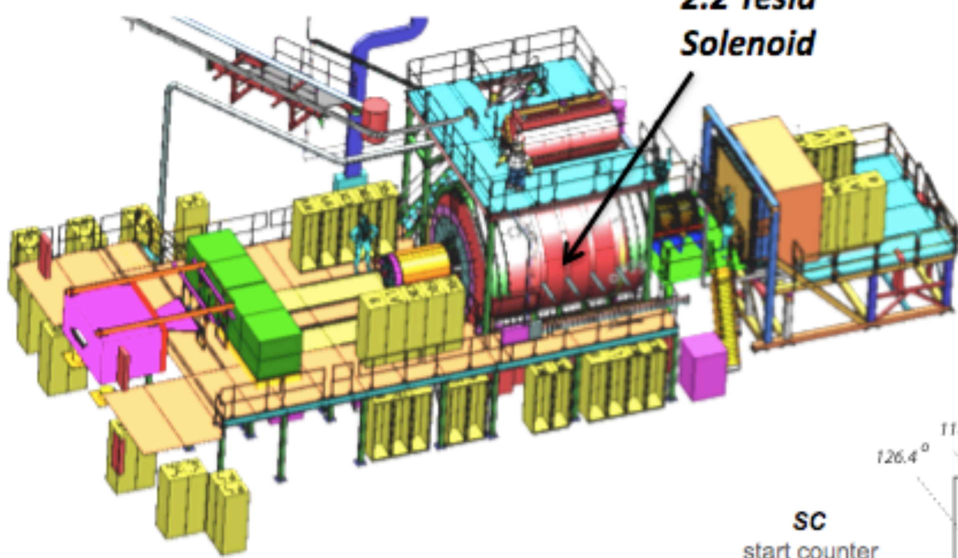
Photon Beam Intensity Spectrum



δE/E = 0.1%
Pol = 40%

photon energy (GeV)

Hall D Detector

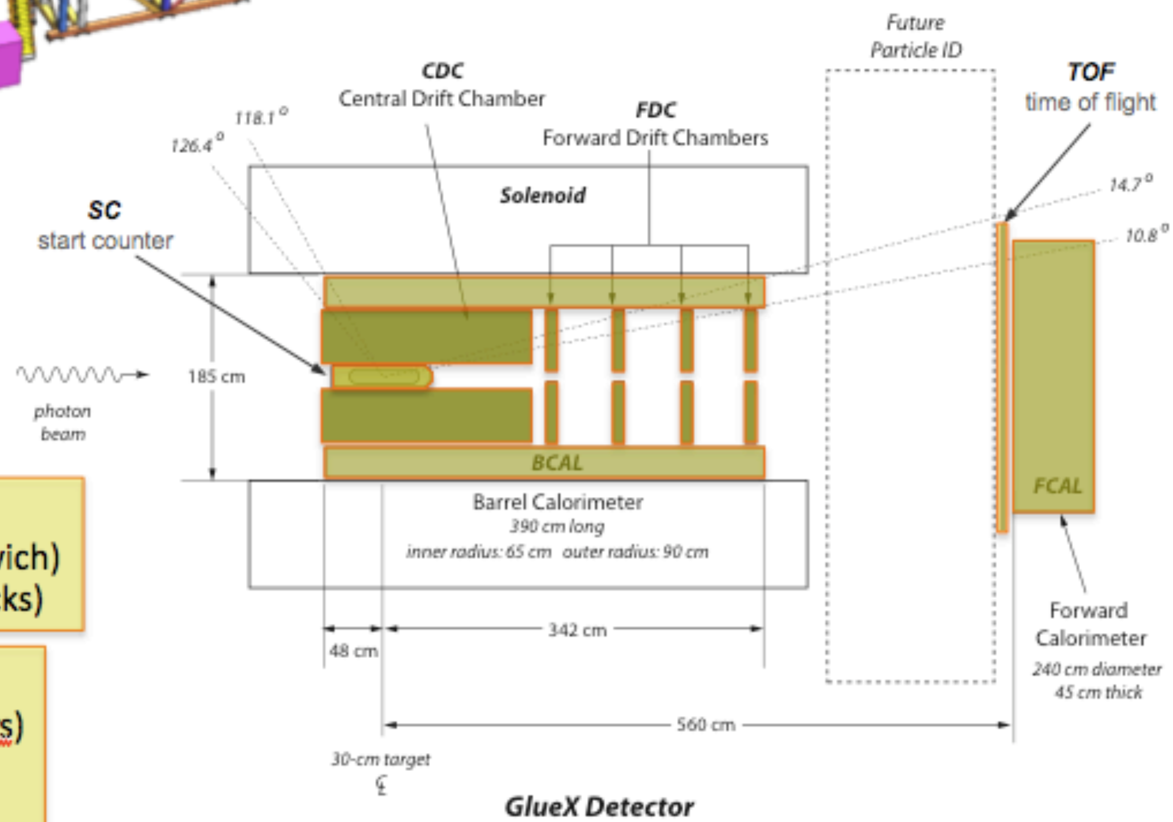


- 2.2T superconducting solenoidal magnet
- Fixed target (LH_2)
- 10^8 tagged γ/s (8.4-9.0GeV)
- hermetic

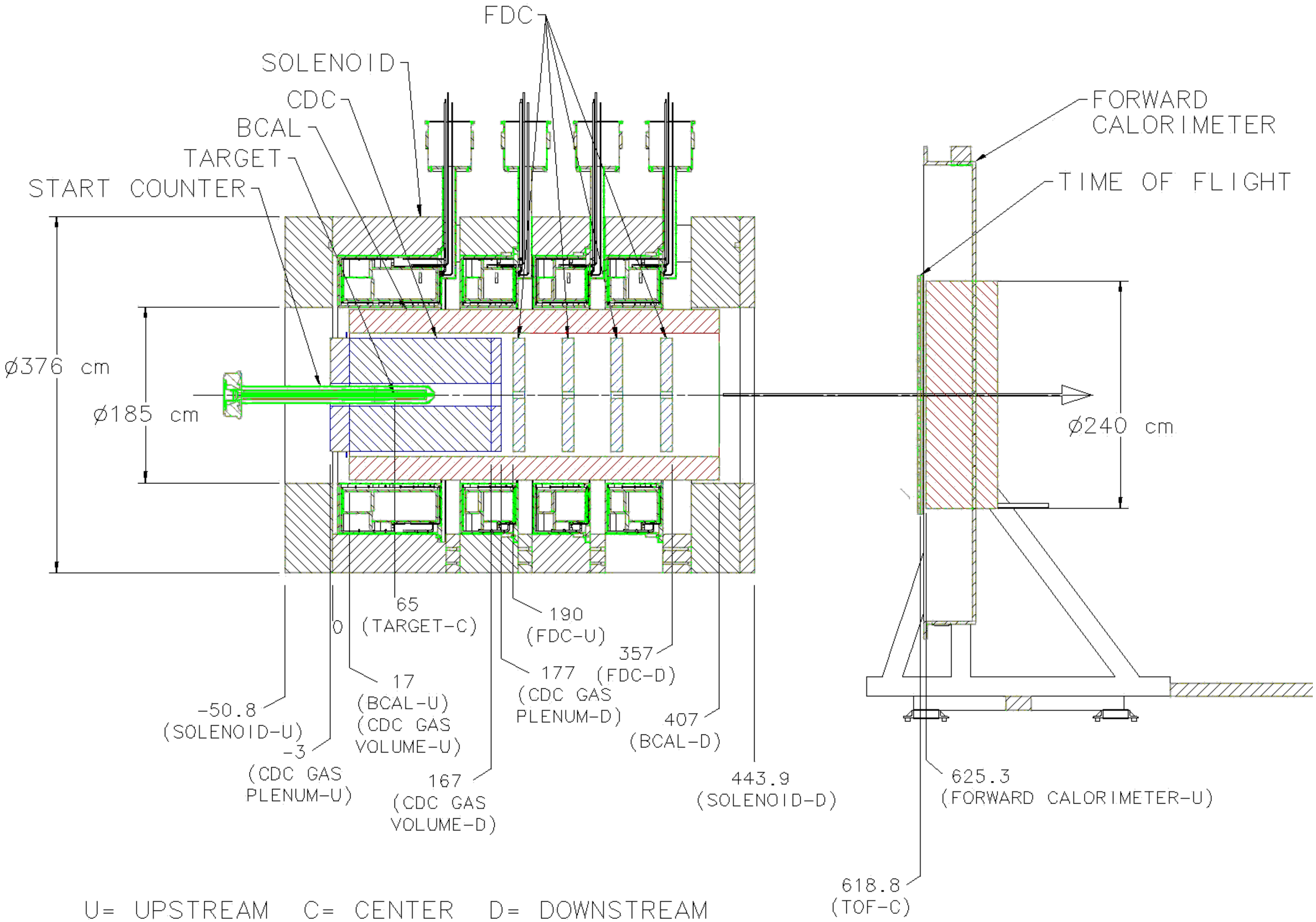
Charged particle tracking
- Central drift chamber (straw tube)
- Forward drift chamber (cathode strip)

Calorimetry
- Barrel Calorimeter (lead, fiber sandwich)
- Forward Calorimeter (lead-glass blocks)

PID
- Time of Flight wall (scintillators)
- Start counter
- Barrel Calorimeter



Hall D Detector



Hall D: Detector Design Parameters

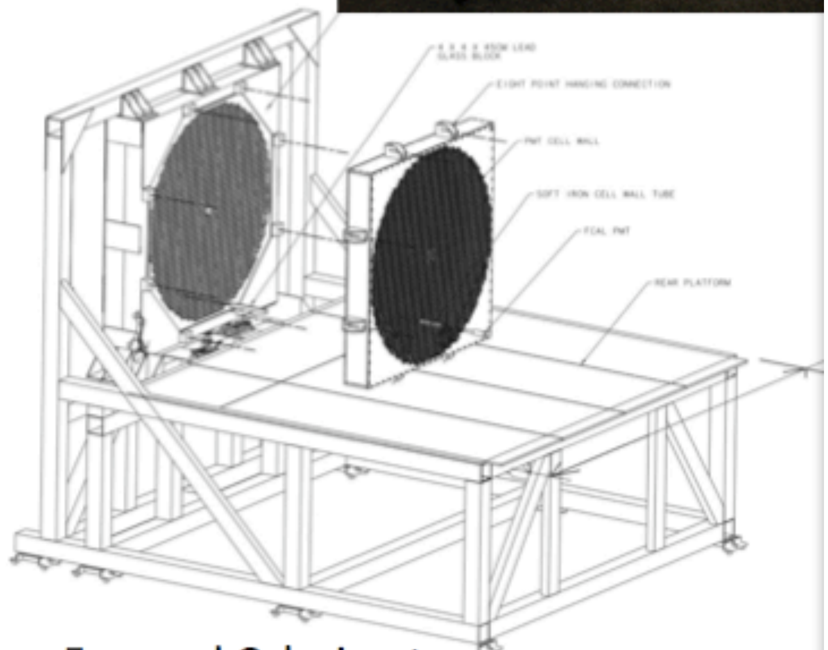
Capability	*Quantity*	*Range*
Charged particles	Coverage	$1^o < \theta < 160^o$
	Momentum Resolution (5^o-140^o)	$\sigma_p/p = 1 - 3\%$
	Position resolution	$\sigma \sim 0.15$-0.20 mm
	dE/dx measurements	$20 < \theta < 160^o$
	Time-of-flight measurements	$\sigma_{ToF} \sim 60$ ps; $\sigma_{BCal} \sim 200$ps
	Barrel time resolution	$\sigma_t{}^g < (74/\sqrt{E} \oplus 33)$ ps
Photon detection	Energy measurements	$2^o < \theta < 120^o$
	FCAL energy resolution (E > 60 MeV)	$\sigma_E/E = (7.3/\sqrt{E} \oplus 3.5)\%$
	BCAL energy resolution (E > 40 MeV)	$\sigma_E/E = (5.54/\sqrt{E} \oplus 1.6)\%$
	FCAL position resolution	$\sigma_{x,y,} \sim 0.64$ cm/$\sqrt{E}$
	BCAL position resolution	$\sigma_z \sim 0.5$cm $/\sqrt{E}$
DAQ/trigger	Level 1	< 200 kHz
	Level 3 event rate to tape	~ 15 kHz
	Data rate	300 MB/s
Electronics	Fully pipelined	250 / 125 MHz fADCs, TDCs
Photon Flux	Initial: 10^7 γ/s for 8.4<E<9.0 GeV	Final: 10^8 γ/s

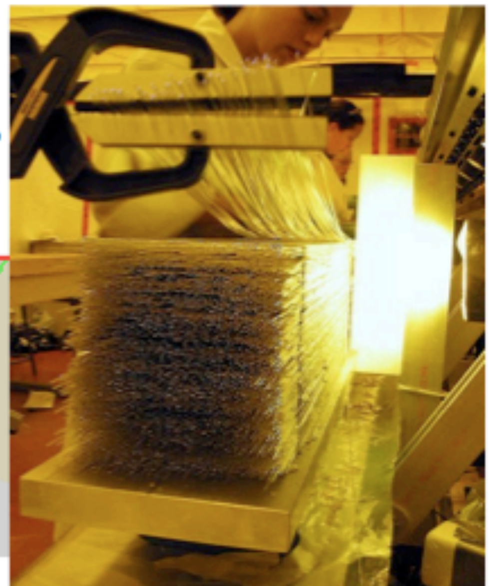
Calorimetry

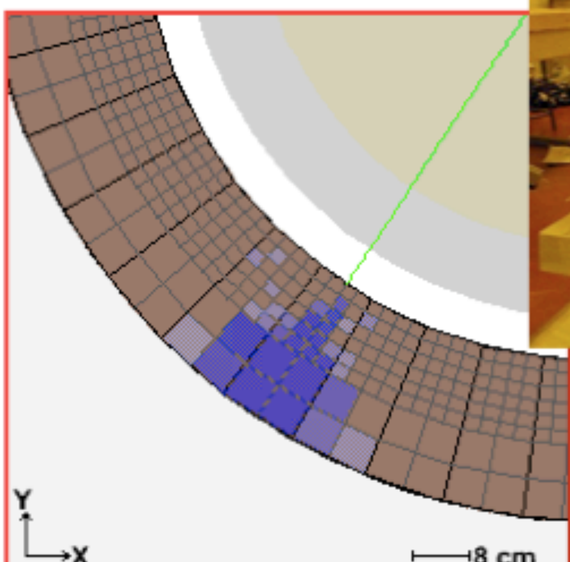
Detector Region	$\sigma(M_{\gamma\gamma})$ for π^0 [MeV/c^2]
FCAL	5.4
BCAL	9.2
FCAL + BCAL	7.6

Barrel Calorimeter:

- 191 layer Pb-scintillating fiber sandwich ($15.5X_o$)
- 12.5% sampling fraction
- 1152 + 192 = 1344 readout sections/end
- $\sigma_E/E = (5.54/\sqrt{E} \oplus 1.6)$ %
- $\sigma_z = 5mm/\sqrt{E}$
- $\sigma_t = 74ps/\sqrt{E} \oplus 33ps$
- angular coverage $11^o < \theta < 120^o$







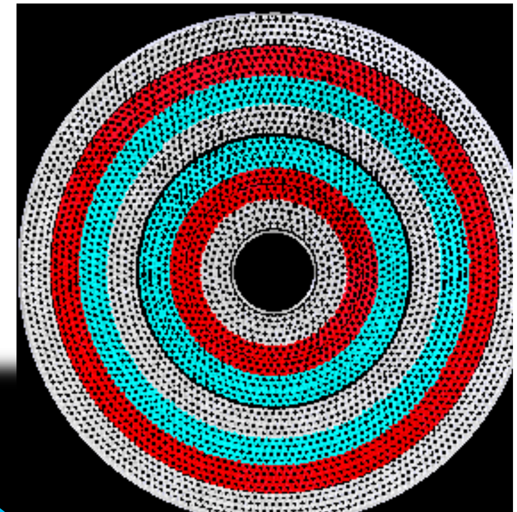
Forward Calorimeter:

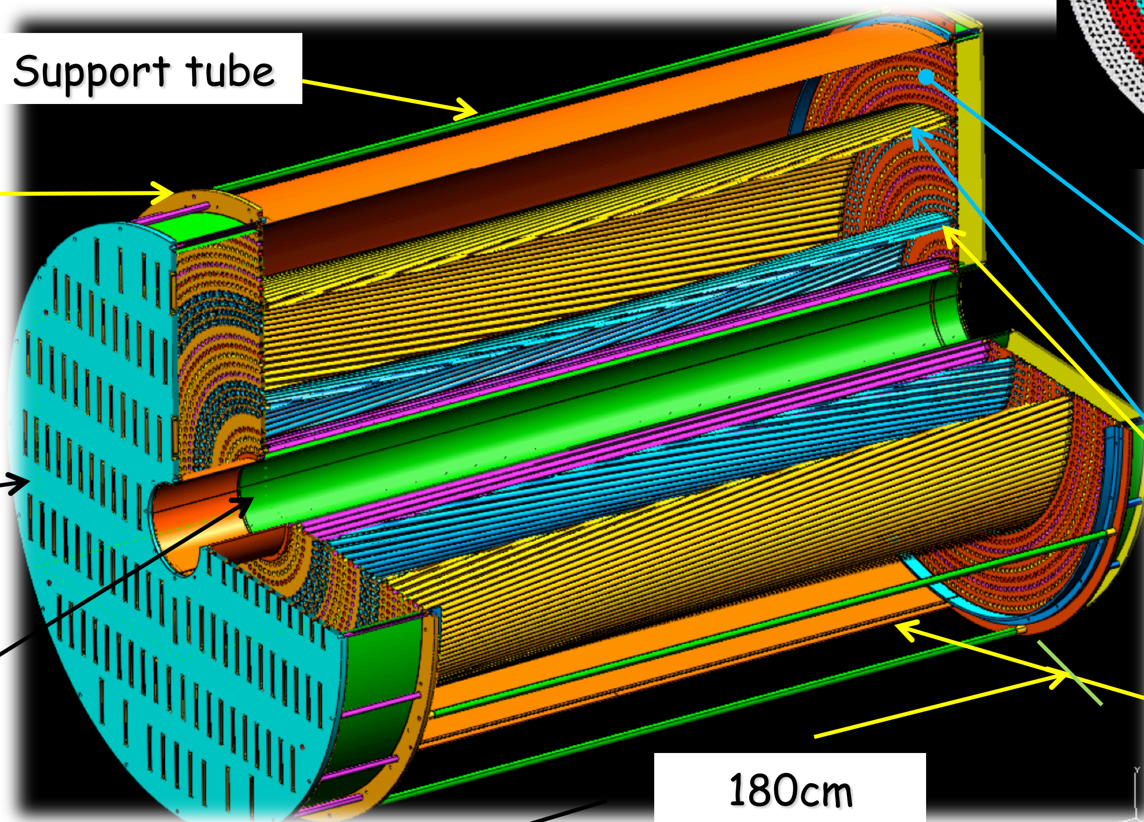
- 2800 F8-00 and F108 (center) Pb-glass blocks
- 4cm x 4cm x 45cm
- $\sigma_E/E = (5.7/\sqrt{E} \oplus 2.0)$ %
- $\sigma_{xy} = 6.4mm/\sqrt{E}$
- angular coverage $2^o < \theta < 11^o$

Central Drift Chambers

dE/dx for p < 450 MeV/c
Gas mixture: ~60/40 Ar/CO_2
Angular Coverage: 6°-155°
Resolution:
$\sigma_{r\phi}$ ~ 150 μm, σ_z~1.5 mm

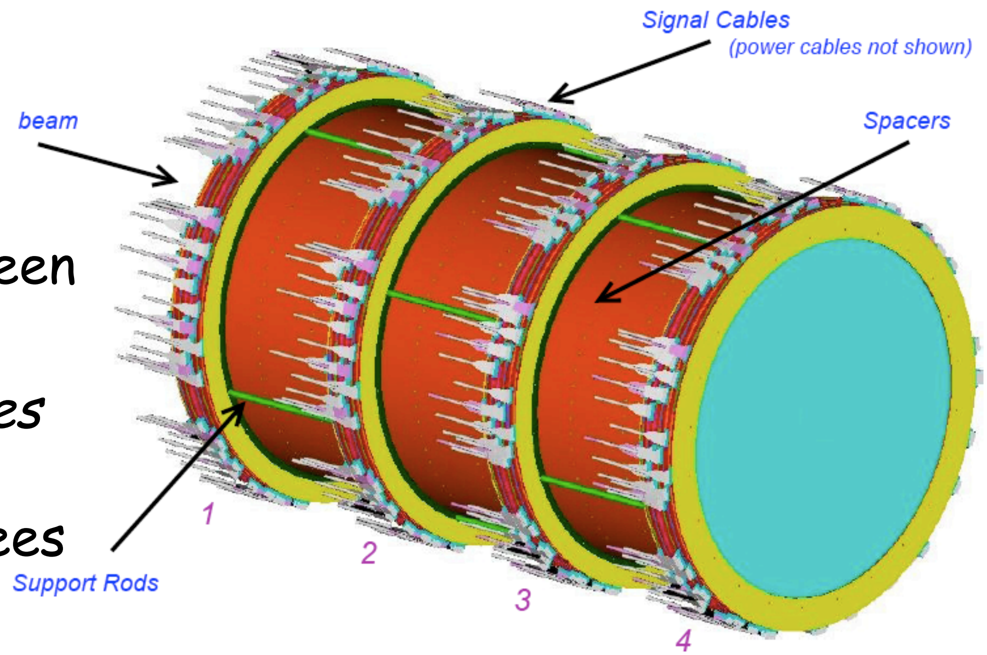
Developed at CMU, JLab

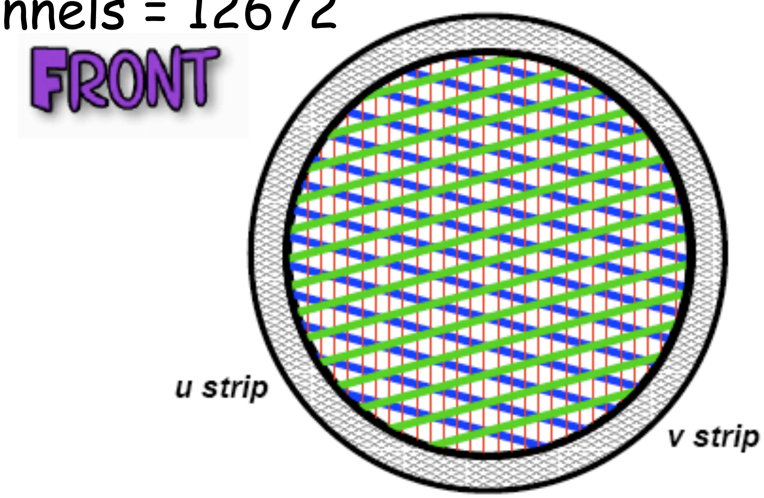


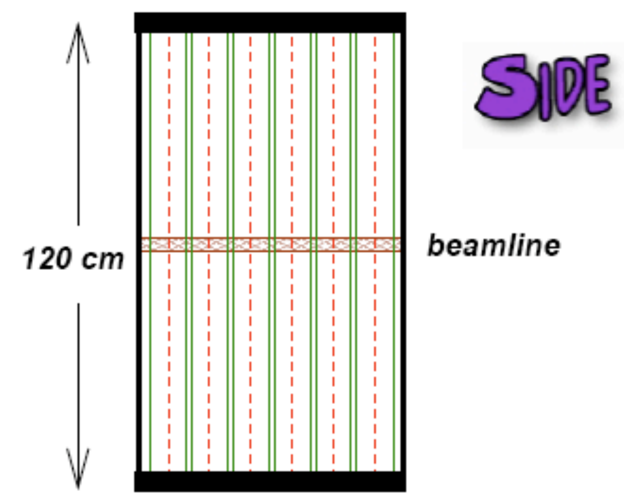


Forward Drift Chambers

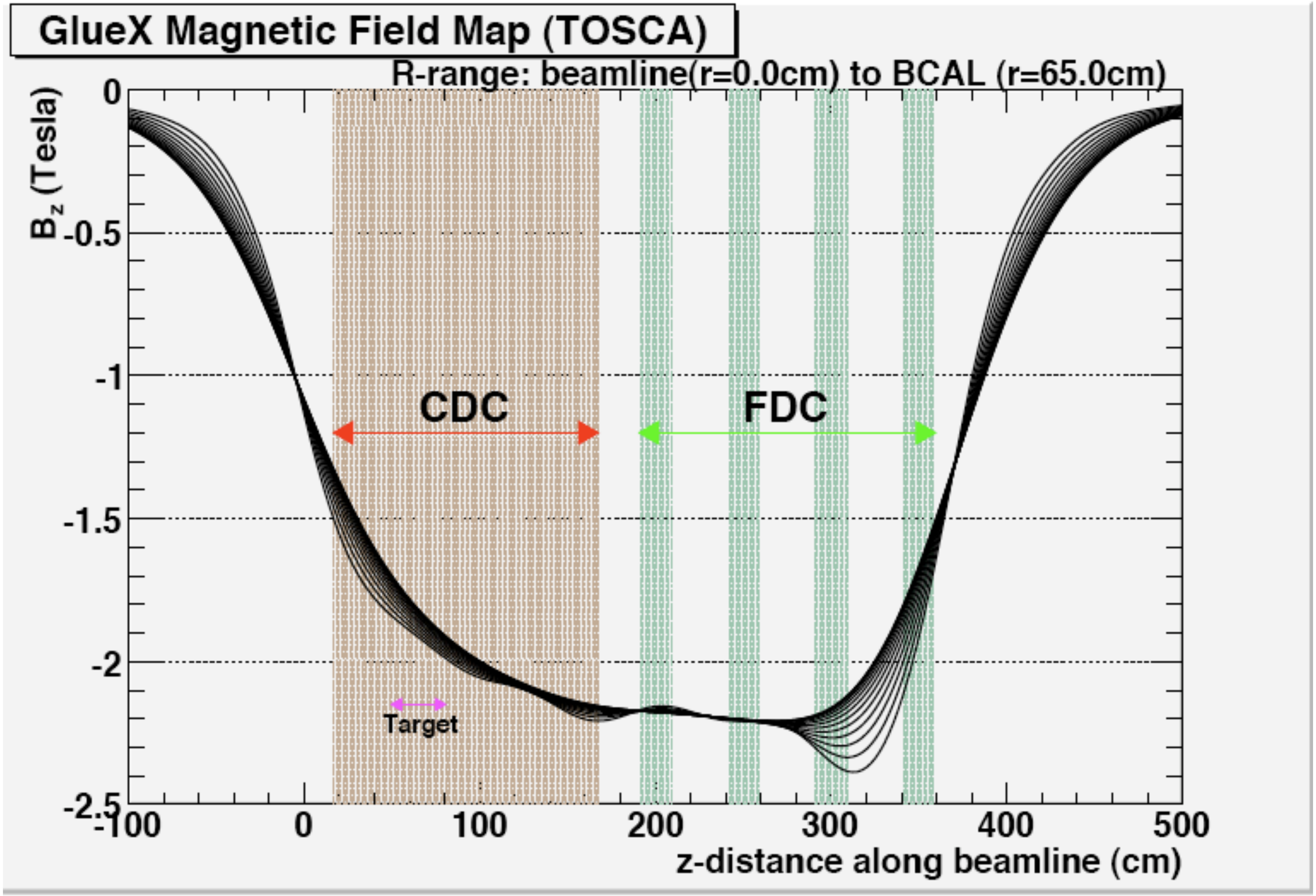
- Four packages
- Six cathode-wire-cathode sandwiches per package
- Wire planes sandwiched between U & V cathode strip planes.
  - *Strips at ±75degrees to wires*
  - Neighboring layers within package rotated by 60 degrees
  - *96 anode wires/plane*
  - *216 cathode strips/plane*
- Number of channels = 12672



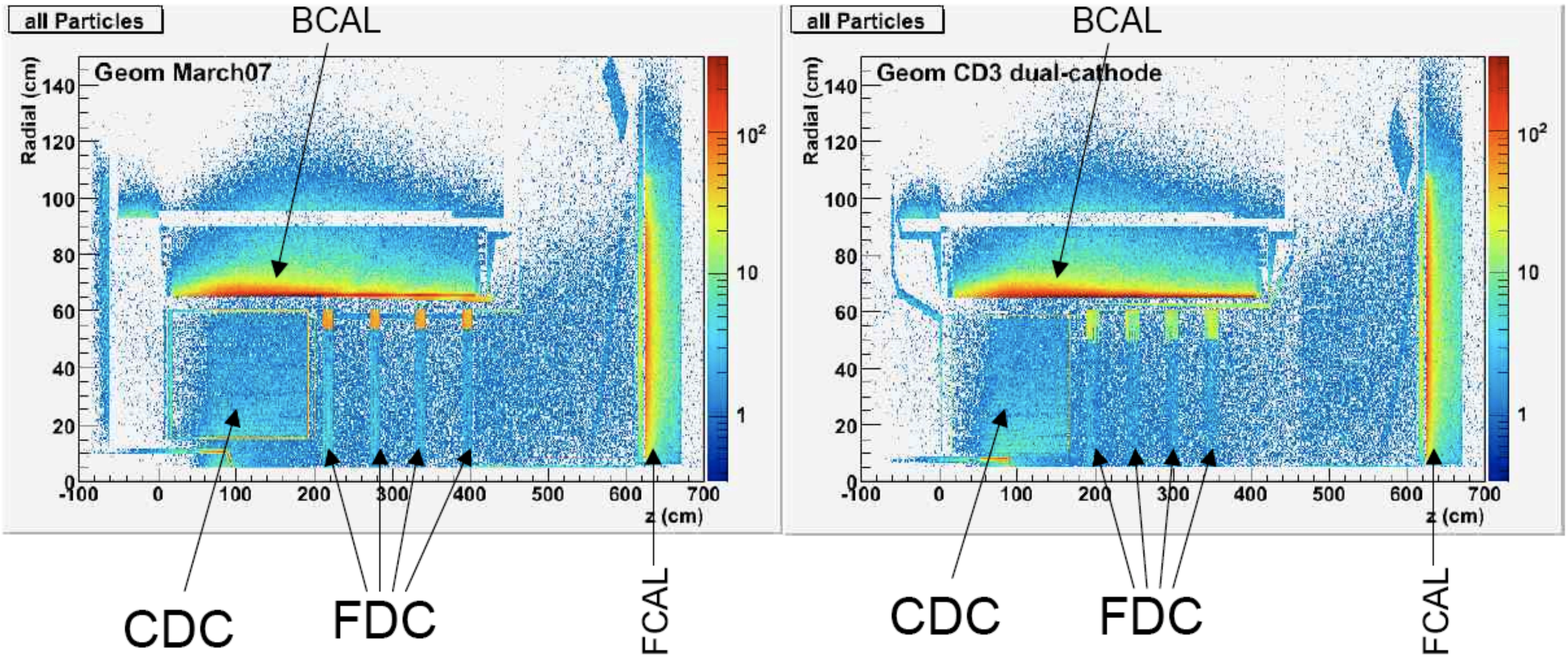




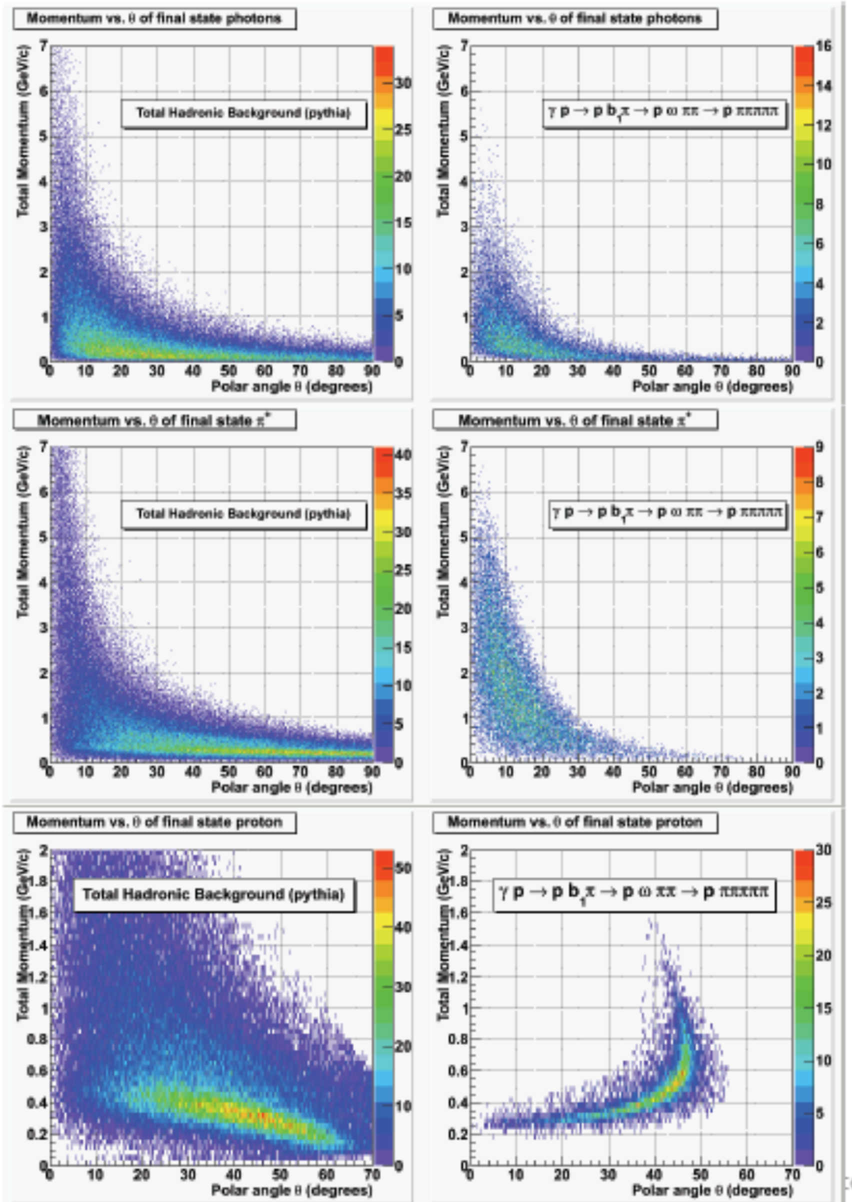
Magnetic field and chamber location



Radiation length scan



Particle kinematics



The GlueX Experiment

Goal: map the spectrum of exotic hybrid mesons

Method: Photo-produce hybrids off proton target and identify the quantum states using Partial Wave Analysis of decay product distributions

detectable final state

$\vec{\gamma} + p \rightarrow p + X$ ↳ $b_1\pi$ ↳ $\omega\pi$ ↳ $\pi\pi\pi$ — $5\pi + 1p$

9GeV linearly polarized

hybrid meson

(mixed charged and neutral)

$\vec{\gamma} + p \rightarrow p + X$ ↳ $f_1\pi$ ↳ $\eta\pi$ ↳ $\pi\pi\pi$ — $5\pi + 1p$

te -- GlueX Collab. Mtg. 13

Comments on acceptance

- Single particle acceptance
  - Geometrical
  - Thresholds
  - Energy loss, absorption and scattering by material in the detector
  - Detector efficiencies
  - EM background (uncorrelated)
- Environment
  - Other tracks or particles in the same event (confusion)
  - Particles from other interactions (accidentals)
- These considerations affect both photons and charged particles but in different ways, and have been studied to different degrees for each
- Full event reconstruction is a work-in-progress, but partial answers can be found with simpler (parametric) tools

Parametric Monte Carlo

New Modes:

"HDFast" Parametric MC.

Acceptance Criteria:

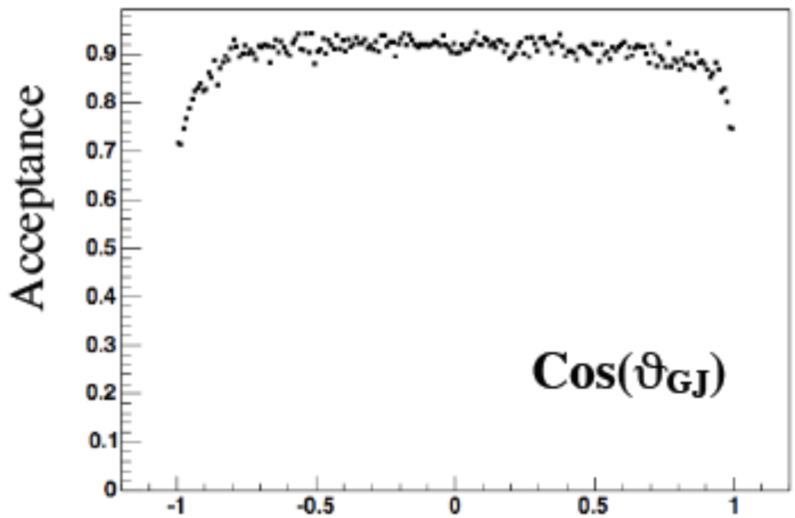
(1) tracks have at least 4 hits

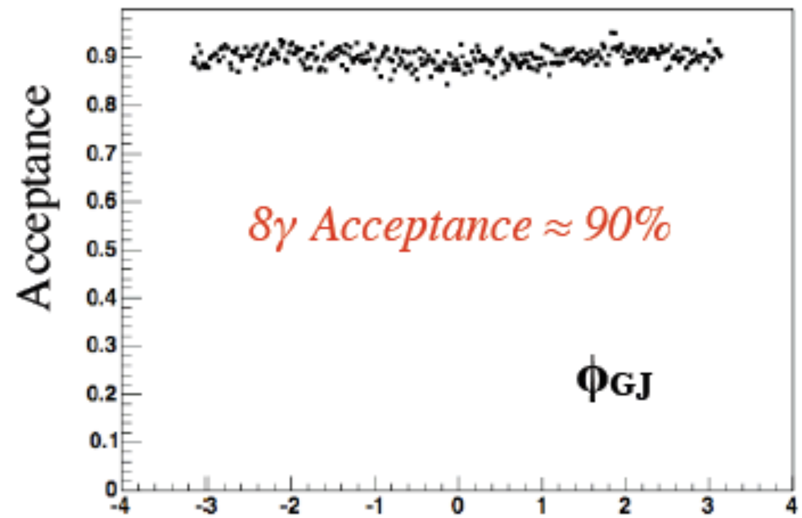
(2) photons hit the BCal or FCal

(3) photon minimum energy is:
20 MeV (BCal), 100 MeV (FCal)

#	State	Mass	Width	Decay
1	η_1	1800	300	$a_1(1260)^-\pi^+ \to [\rho^\circ\pi^-]\pi^+ \to [(\pi^+\pi^-)\pi^-]\pi^+$
2	η_1	1800	300	$a_1(1260)^-\pi^+ \to [\rho^-\pi^\circ]\pi^+ \to [(\pi^-\pi^\circ)\pi^\circ]\pi^+$
3	π_1°	1700	400	$f_1(1285)\pi^\circ \to [a_0(980)\pi^\circ]\pi^\circ \to [(\pi^\circ\eta)\pi^\circ]\pi^\circ$
4	π_1°	1700	400	$a_1(1260)^\circ\eta \to [\rho(770)^+\pi^-]\eta \to [(\pi^+\pi^\circ)\pi^-]\eta$
5	b_2^+	2000	300	$a_1(1260)^+\pi^\circ \to [\rho(770)^+\pi^\circ]\pi^\circ \to [(\pi^+\pi^\circ)\pi^\circ]\pi^\circ$
6	π_1^+	1700	400	$b_1(1235)^+\pi^\circ \to [\omega(782)\pi^+]\pi^\circ \to [(\pi^+\pi^-\pi^\circ)\pi^+]\pi^\circ$
7	h_2	2000	300	$b_1(1235)^-\pi^+ \to [\omega(782)\pi^-]\pi^+ \to [(\pi^+\pi^-\pi^\circ)\pi^-]\pi^+$

Mode 3: $\pi_1(1700) \to f_1(1285)\pi^0 \to 8\gamma$





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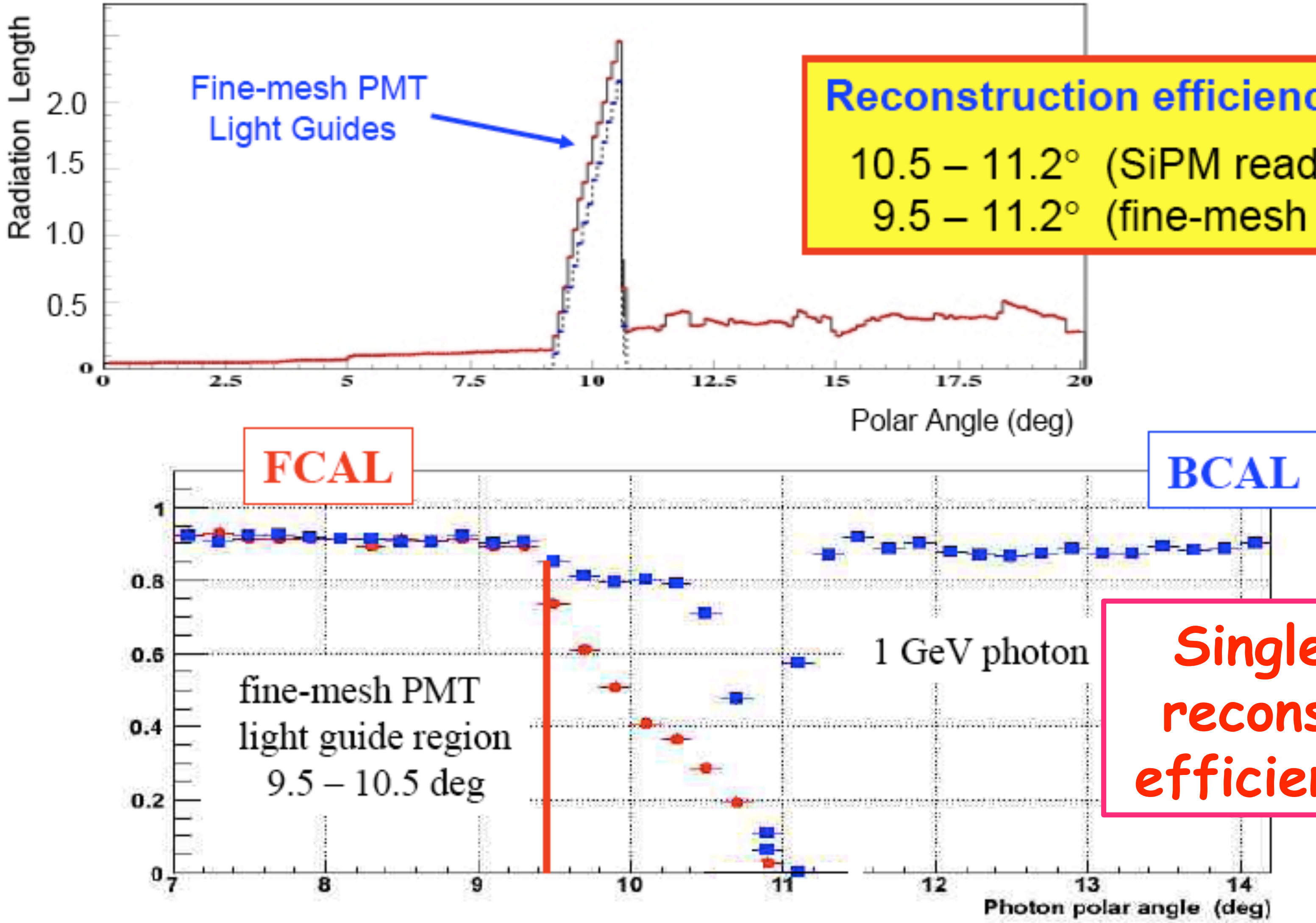
Reconstruction of single photons



Reconstruction efficiency gaps:

10.5 – 11.2° (SiPM readout)

9.5 – 11.2° (fine-mesh PMT readout)

Single photon reconstruction efficiency ~ 90%

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Realistic Geometry (Parametric)

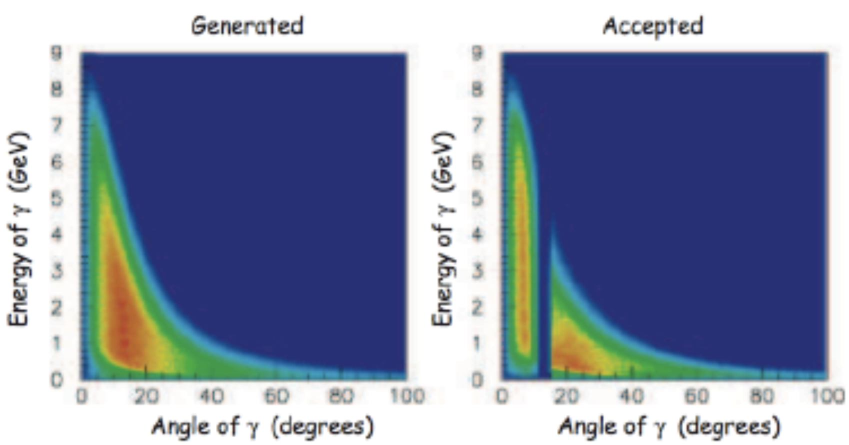
The realistic FCal acceptance has a big effect on some channels, for example:

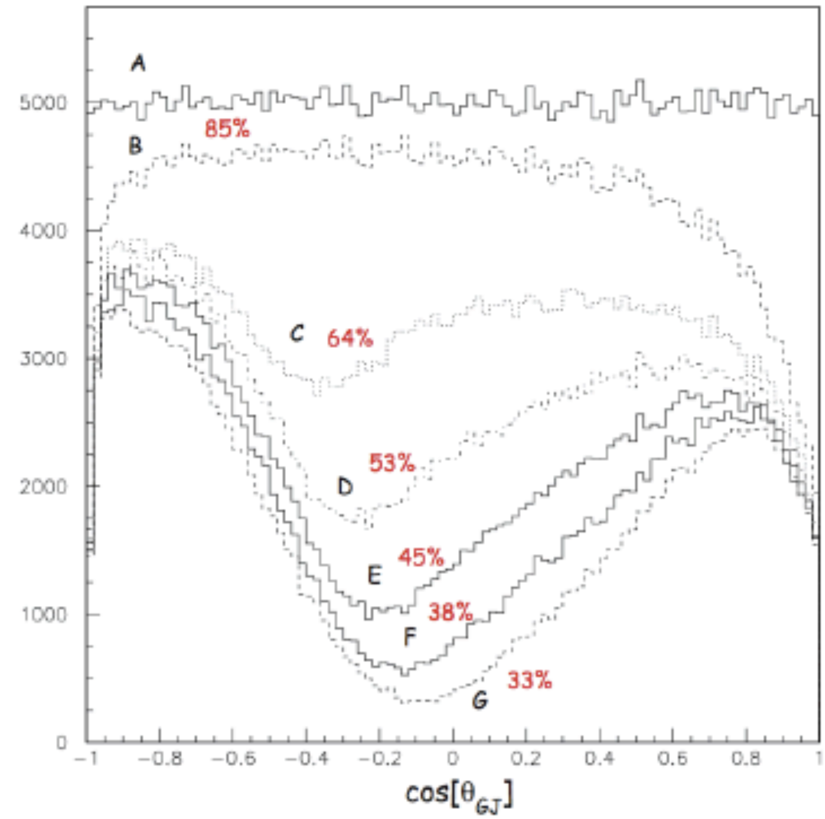
$\gamma p \rightarrow \eta\pi^0 p$

Look at stand-alone MC.

Acceptance criteria:

- photons hit the FCal or BCal
- use FCal reconstruction efficiencies
- minimum energies are 40 MeV (BCal), 100 MeV (FCal)





A. Generated distribution

B. Geometry (96%) + E_{min} Cuts

C. FCal Reconstruction Efficiencies

D-G. Reject BCal-FCal transition region from 11 to 12, 13, 14, 15 degrees.

GlueX-doc-817 2007

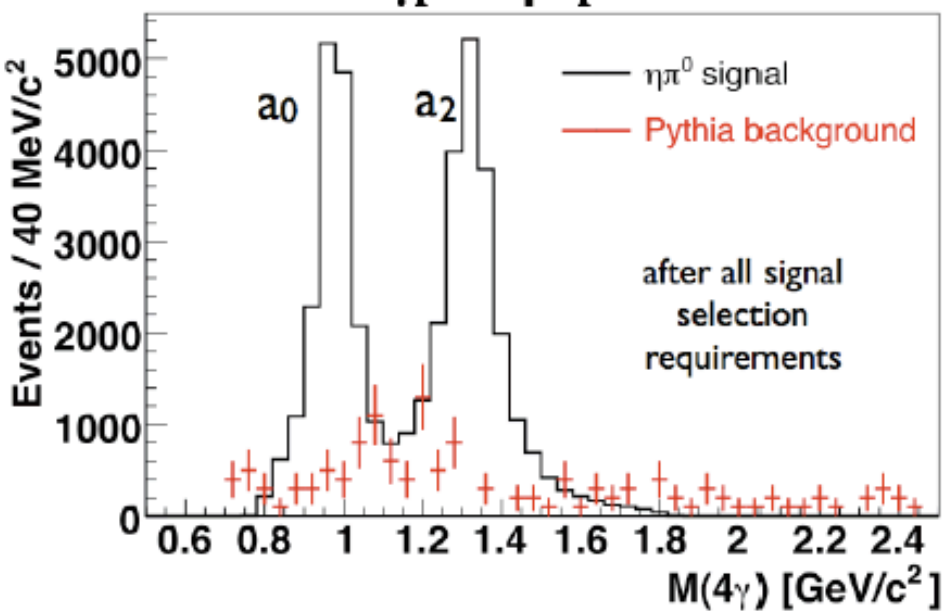
Realistic Reconstruction (first attempt)

- Generate $\gamma p \to \eta\pi^0 p$ and $\gamma p \to \eta 3\pi^0 p$.
- Generate Pythia background using Pythia-predicted $\eta\pi^0$ and $\eta 3\pi^0$ rates.
- Do full calorimeter reconstruction.
- Assume 100% efficiency for recoil proton.
- Balance initial and final 4-momenta.

Notes:

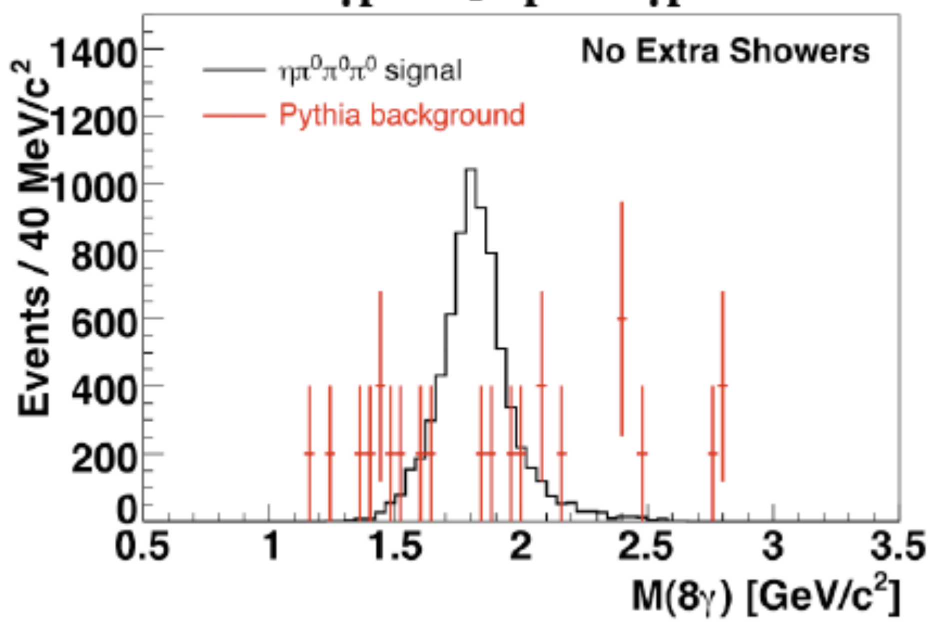
- *Efficiencies are lower than "HDFast"*
- *Signal to background is still quite good.*
- *More background MC would help.*
- *a_0 and a_2 are correctly identified in PWA.*
- *Most realistic picture to date… promising…*

$\gamma p \to \eta\pi^0 p$



Acceptance ≈ 45%

$\gamma p \to f_1\pi^0 p \to 8\gamma p$



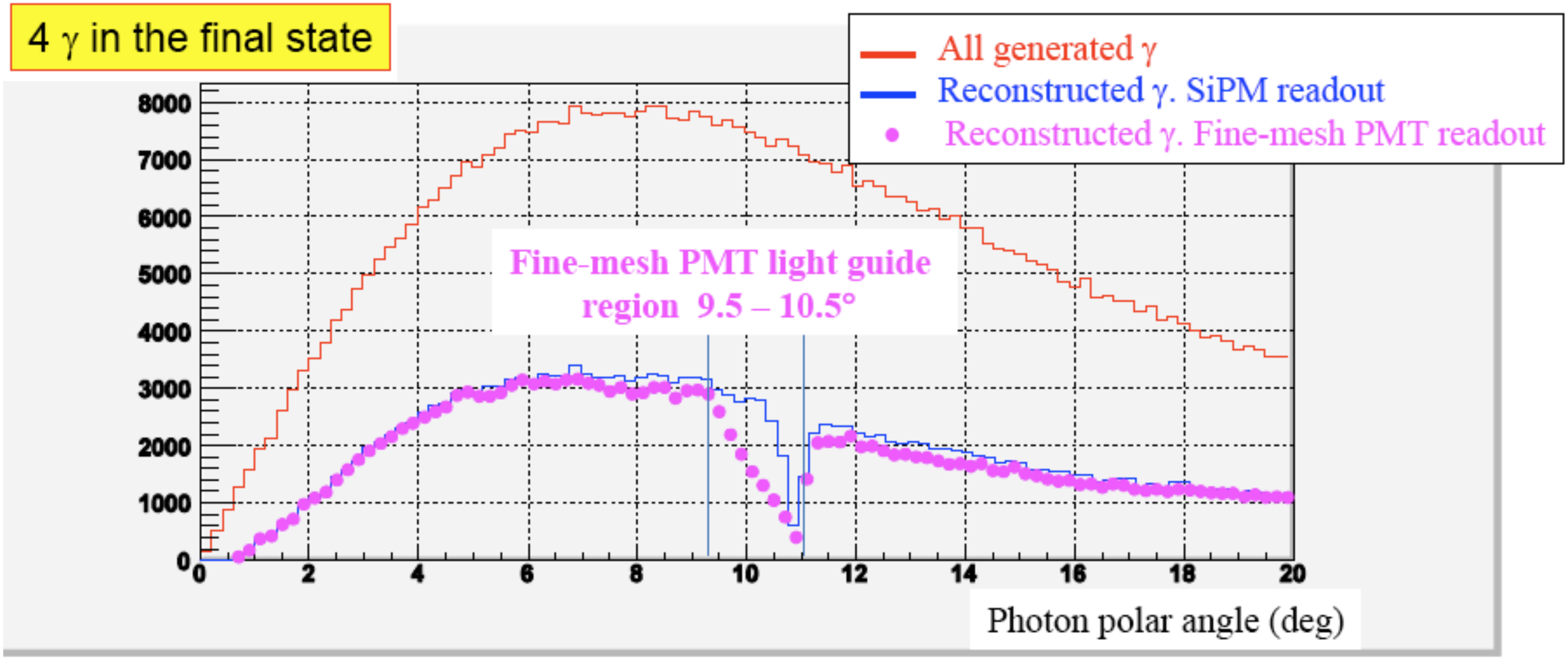
Acceptance ≈ 8-10%

GlueX-doc-898 2008

Acceptance for $\gamma p \rightarrow Xp \rightarrow \eta\pi^0 p$

Polar angle distribution of all photons

4 γ in the final state



- Significant population of final state photon in the efficiency gap region
- Reconstruction efficiency of four photons in the calorimeters:

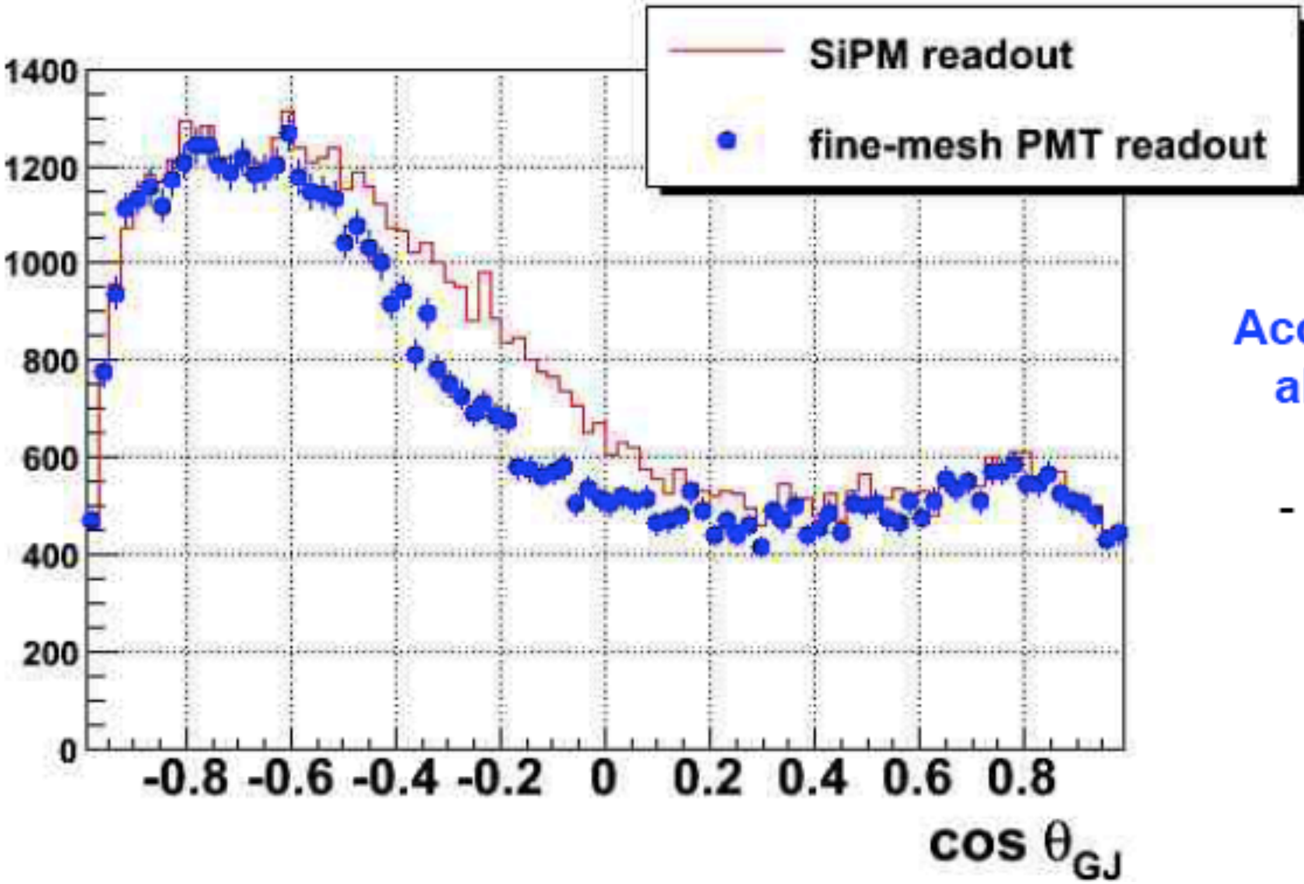
35.5 % for the SiPM readout

32.2 % for the fine-mesh PMT readout

GlueX-doc-1316 2009

Acceptance for $\gamma p \rightarrow Xp \rightarrow \eta\pi^0 p$

Angular distributions in the Gottfried-Jacksone frame



4 γ in the final state

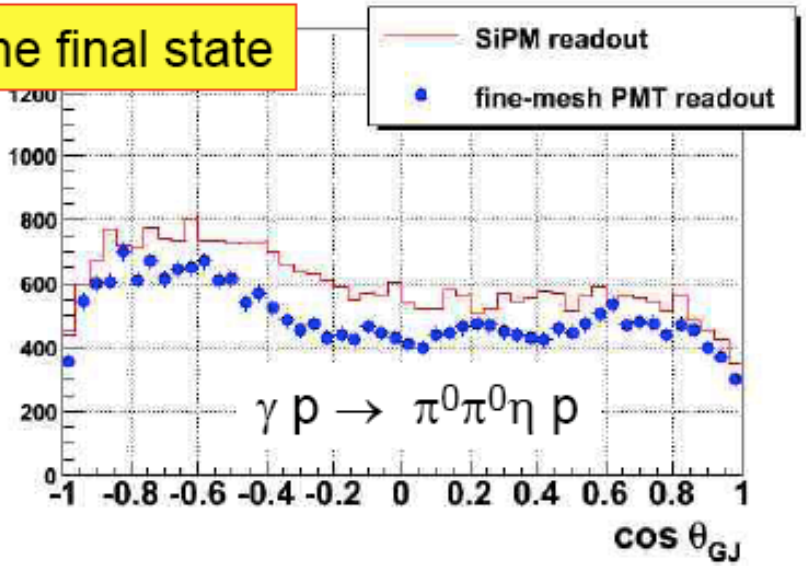
Acceptance for events with all reconstructed photons

- slightly larger acceptance for the SiPM readout in the cos θ region -0.6 – 0.2

GlueX-doc-1316 2009

Decays with charged and neutrals

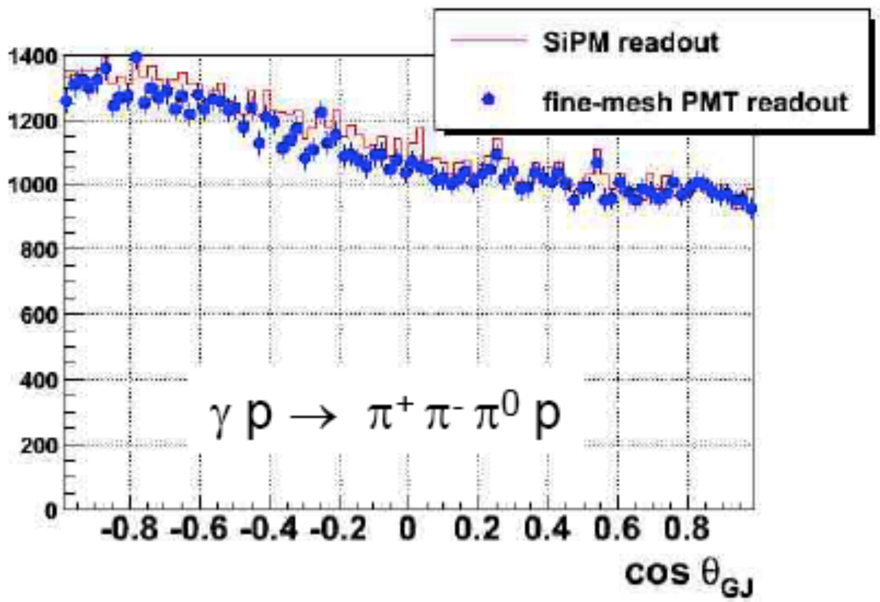
6 γ in the final state



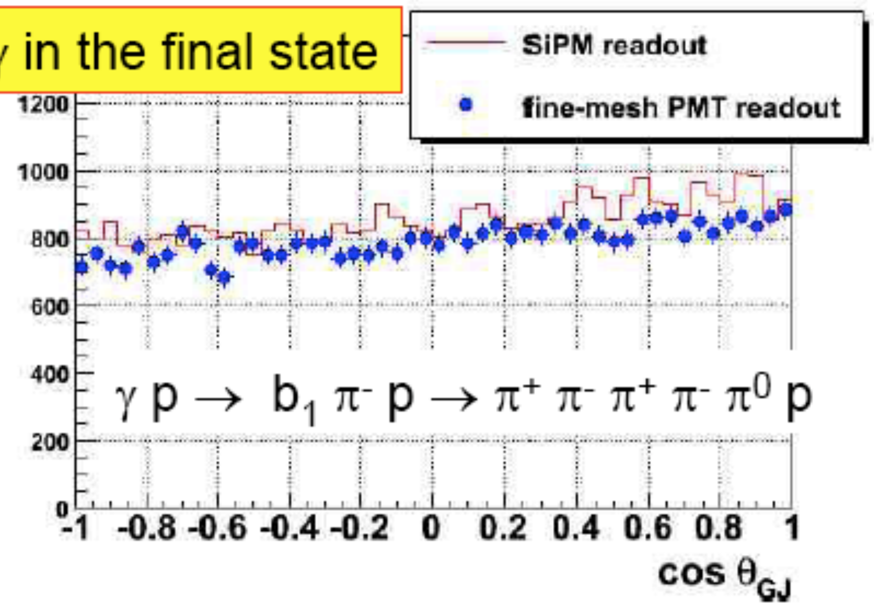
Reconstruction efficiency of all photons in the event

Decay	SiPM	Fine-Mesh PMT
$\pi^0\pi^0\eta$	19.9%	16.5%
$\pi^+\pi^-\pi^0$	53.7%	50.0%
$b_1\pi^-$	53.6%	49.6%

Note: Charged particles in fiducial volume, but not actually reconstructed.



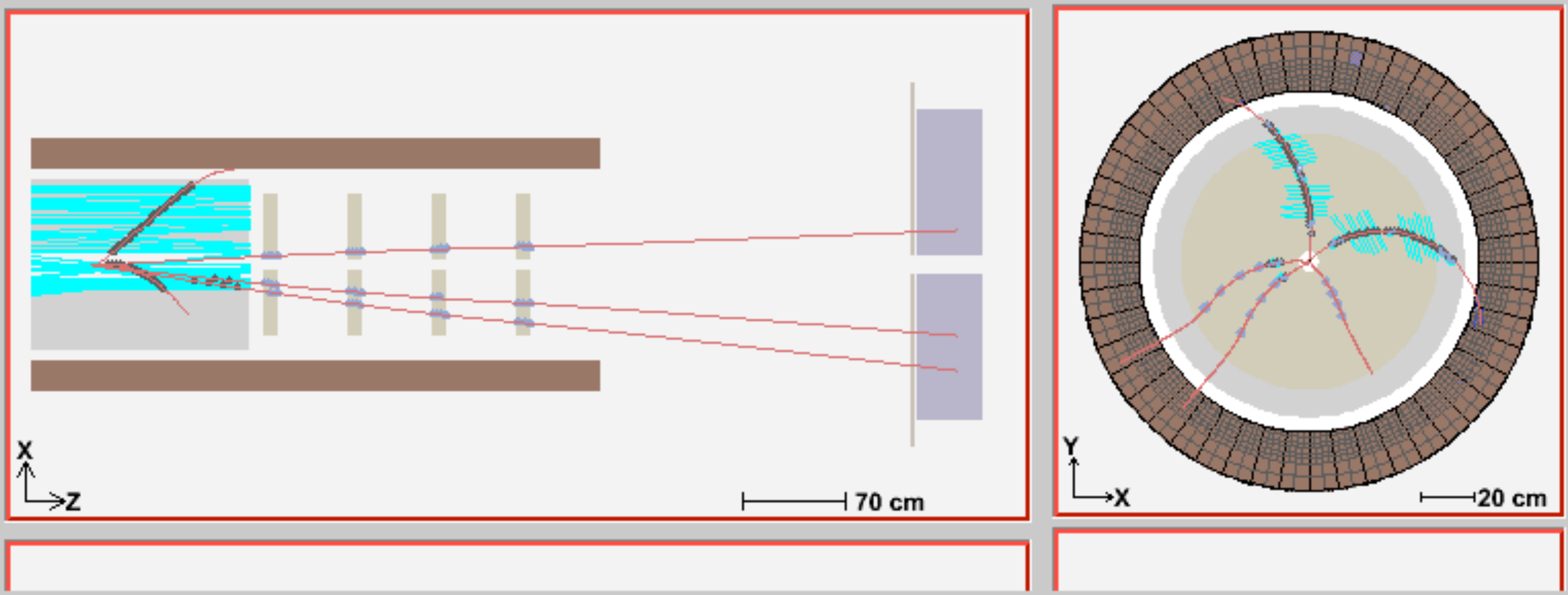
2 γ in the final state



Reconstruction of charged particles

- Momentum reconstruction uses central (CDC) and forward drift chambers (FDC)
  - Low-energy particles can either stop in the target, or spiral multiple times confusing event reconstruction
  - Trajectories in the transition between CDC and FDC is a challenge
- Particle identification
  - Energy loss in CDC to tag protons
  - Time-of-flight measurements in barrel calorimeter and forward scintillator array used to easily separate pions from protons
  - Kaon identification limited to $p < 1.5$ GeV for $\theta<10$ deg.
  - BUT at present, we usually make simplifying assumptions about the particle identification in the event analysis.
- Comments
  - All hadronic interactions turned on for signal particles.
  - BUT: no electromagnetic background, no random noise, no out-of-time interactions.

“typical” $\gamma p \rightarrow 2\pi^+ 2\pi^- p$



Track Info

Thrown

trk:	type:	p:	theta:	phi:	z:
1	pi+	2.618	7.888	4.209	60.35
2	pi+	1.897	8.863	3.071	60.35
3	pi-	0.3495	42.6	0.7796	60.35
4	pi-	3.98	4.834	5.499	60.35
5	proton	0.4812	50.14	1.409	60.35
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Reconstructed

trk:	type:	p:	theta:	phi:	z:	chisq/Ndof:	Ndof:
1	pi+	1.868	8.71	3.052	58.58	3.132	33
2	pi-	3.962	4.827	5.497	60.17	2.466	39
3	pi+	2.517	7.476	3.569	60.92	3.159	33
4	pi-	0.3503	42.47	0.7583	60.44	0.9394	25
5	proton+	0.4691	49.85	1.393	60.1	1.652	23
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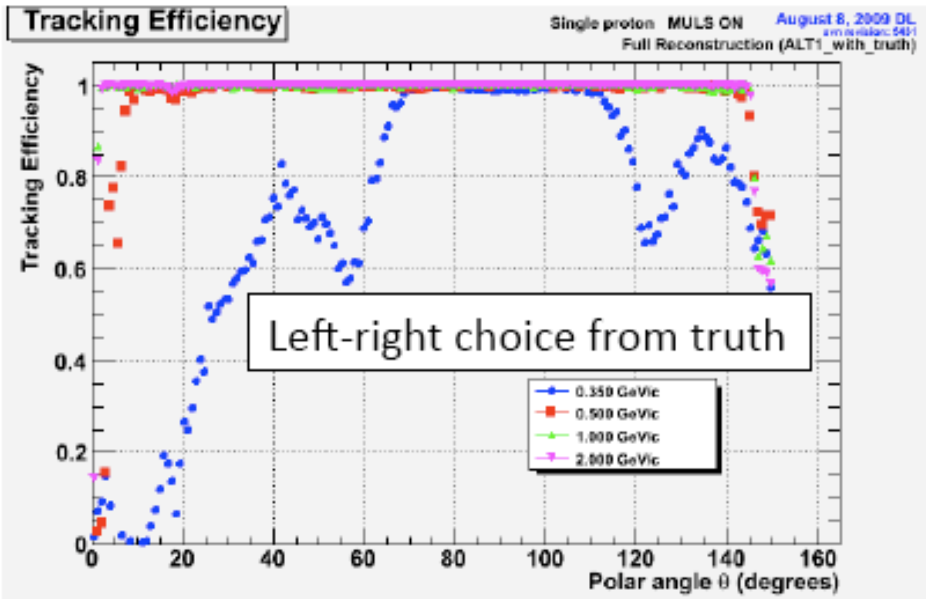
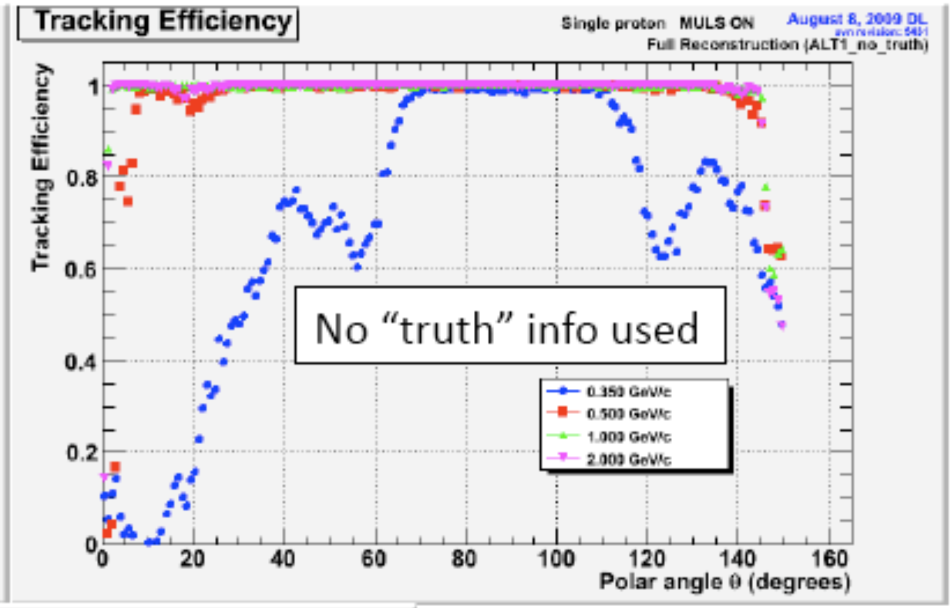
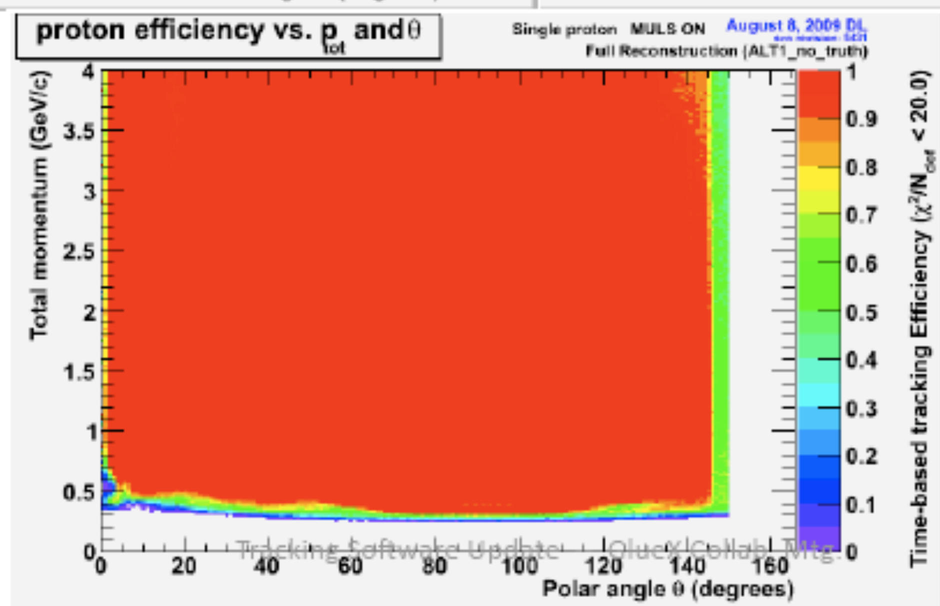
Single track proton tracking efficiency





preliminary

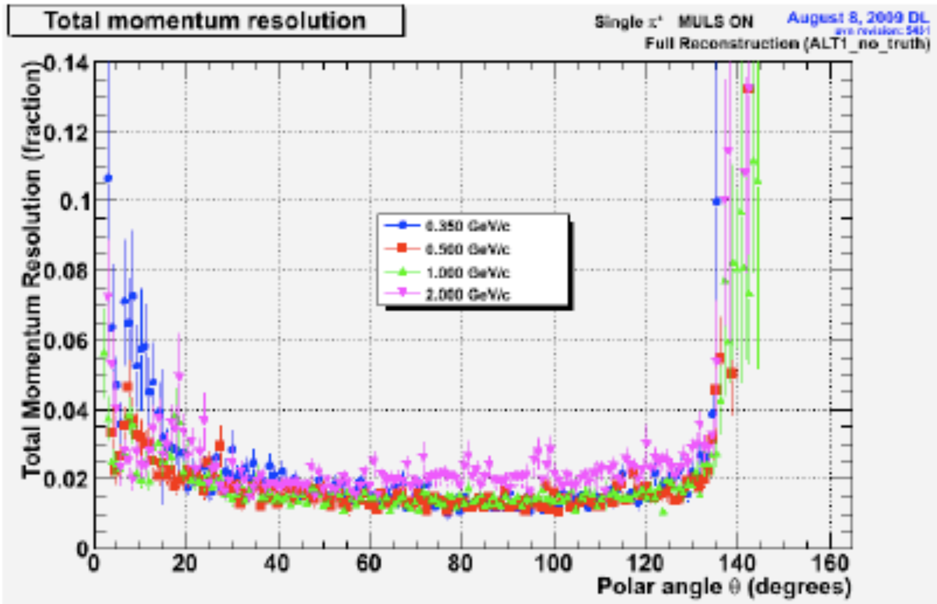


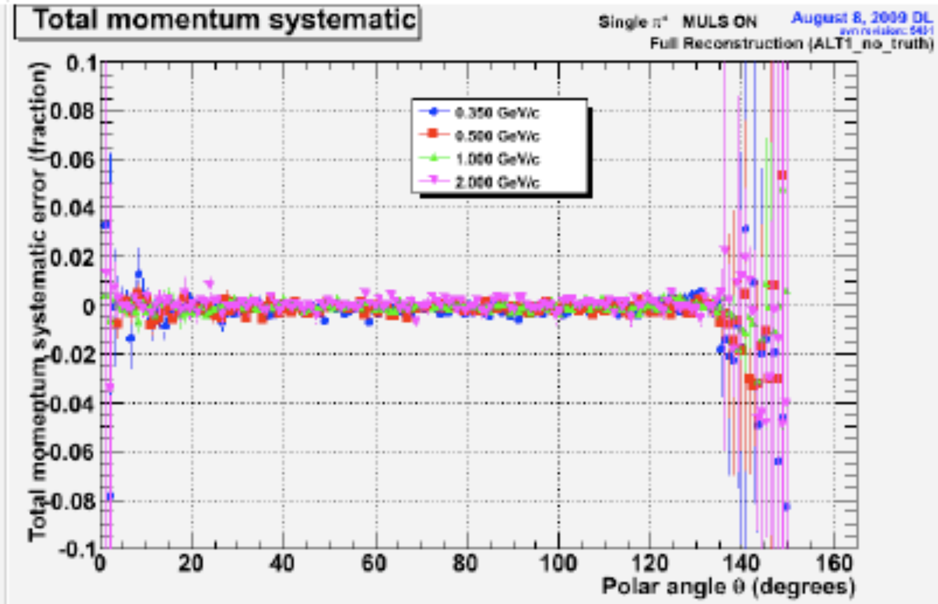
Tracking efficiency based on chi-sq/ Ndof cut of 20

9/11/09

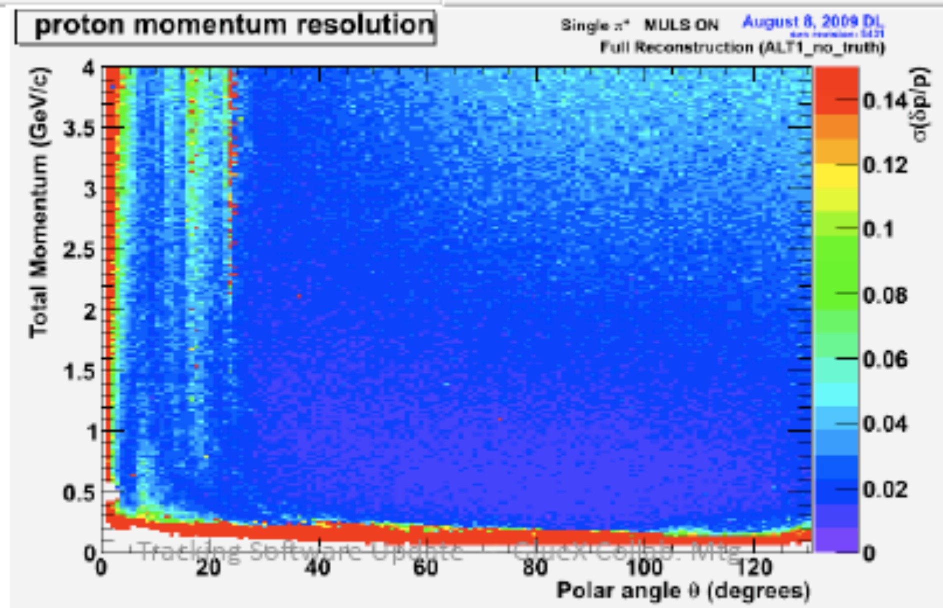
GlueX-doc-1335 2009

π^+ momentum resolution



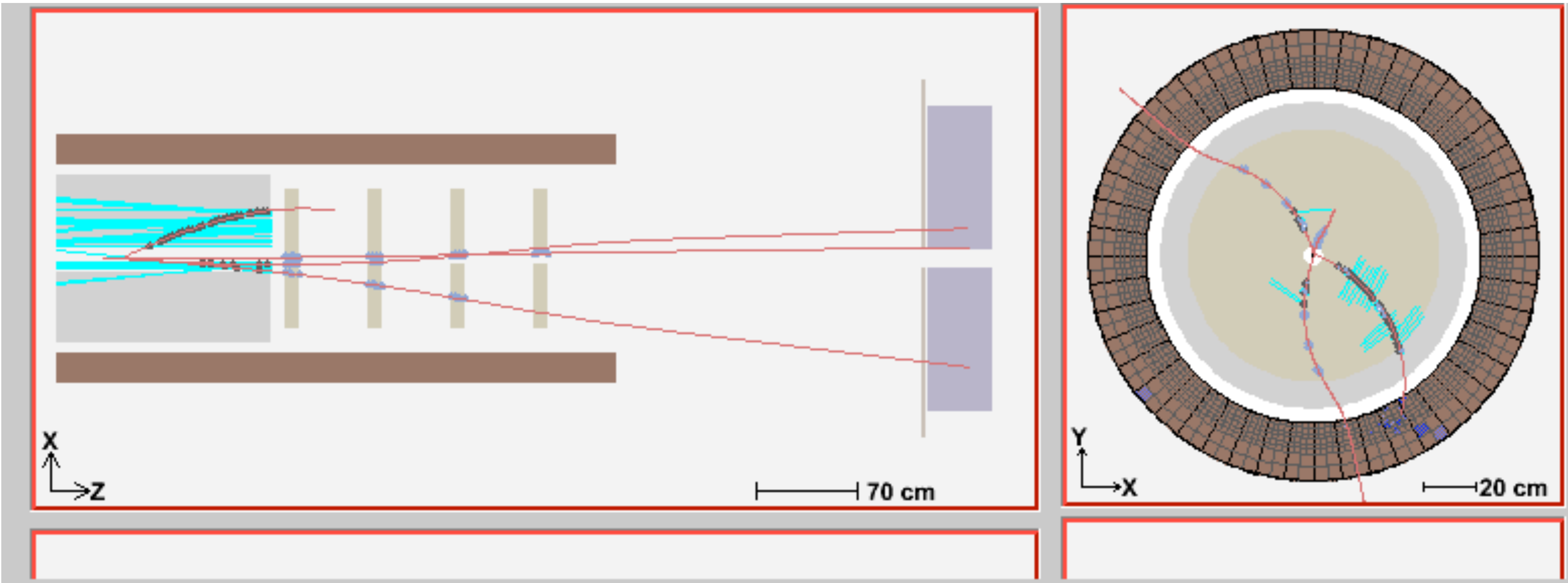


preliminary



GlueX-doc-1335 2009

"typical" $\gamma p \rightarrow 2\pi^+ 2\pi^- p$



Track Info

Thrown

trk:	type:	p:	theta:	phi:	z:
1	pi+	2.027	11.29	4.374	62.22
2	pi+	1.859	10.62	1.862	62.22
3	pi-	0.7483	27.51	5.894	62.22
4	pi-	4.308	1.923	1.378	62.22
5	proton	0.2482	29.66	2.85	62.22
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Reconstructed

trk:	type:	p:	theta:	phi:	z:	chisq/Ndof:	Ndof:
1	pi+	1.966	11.31	4.37	64.67	1.956	24
2	pi+	1.852	10.61	1.851	60.31	3.125	30
3	pi-	3.913	1.922	1.426	50.03	2.408	39
4	pi-	0.7611	27.13	5.892	61.52	1.416	21
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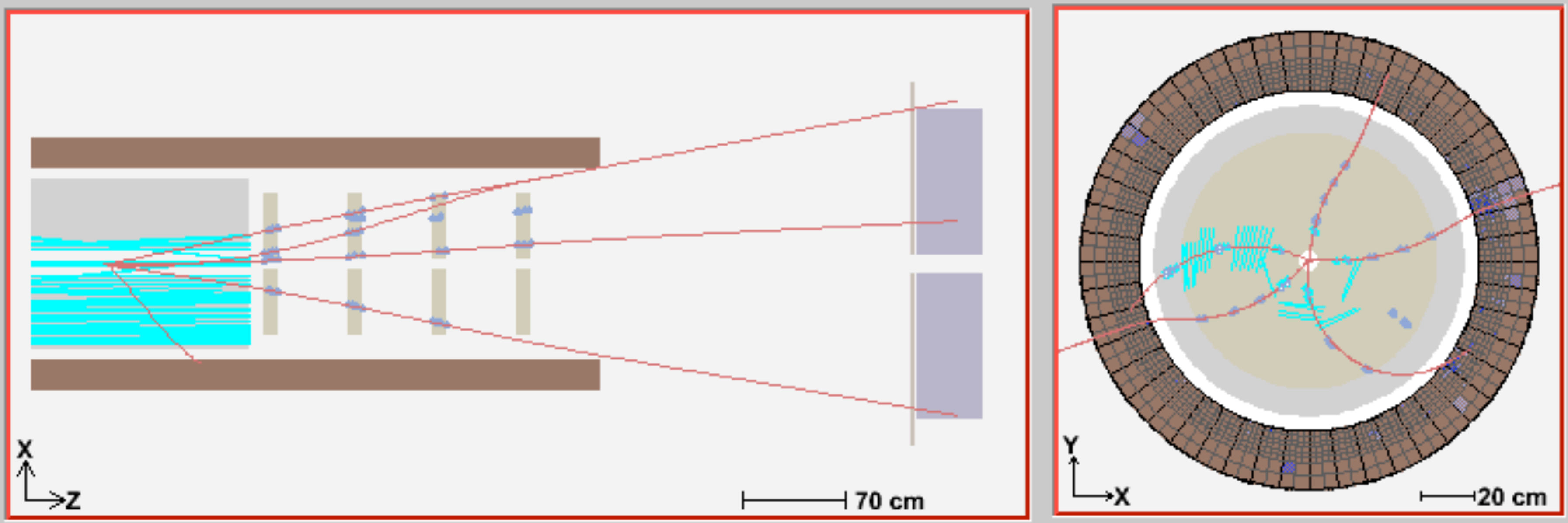
“typical” $\gamma p \rightarrow 2\pi^+ 2\pi^- p$



Track Info

Thrown

trk:	type:	p:	theta:	phi:	z:
1	pi+	2.722	12.07	6.203	69.55
2	pi+	0.8265	16.36	4.532	69.55
3	pi-	3.31	7.836	1.476	69.55
4	pi-	2.021	11.76	4.005	69.55
5	proton	0.4386	49.02	2.71	69.55
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Reconstructed

trk:	type:	p:	theta:	phi:	z:	chisq/Ndof:	Ndof:
1	pi-	3.267	7.771	1.494	67.3	1.935	31
2	pi-	1.985	11.69	4.021	69.56	3.604	31
3	pi+	2.753	11.96	6.191	68.38	3.65	20
4	pi+	0.8488	17.04	4.588	72.81	8.872	21
5	pi+	0.4221	50.56	2.703	69.18	11.66	27
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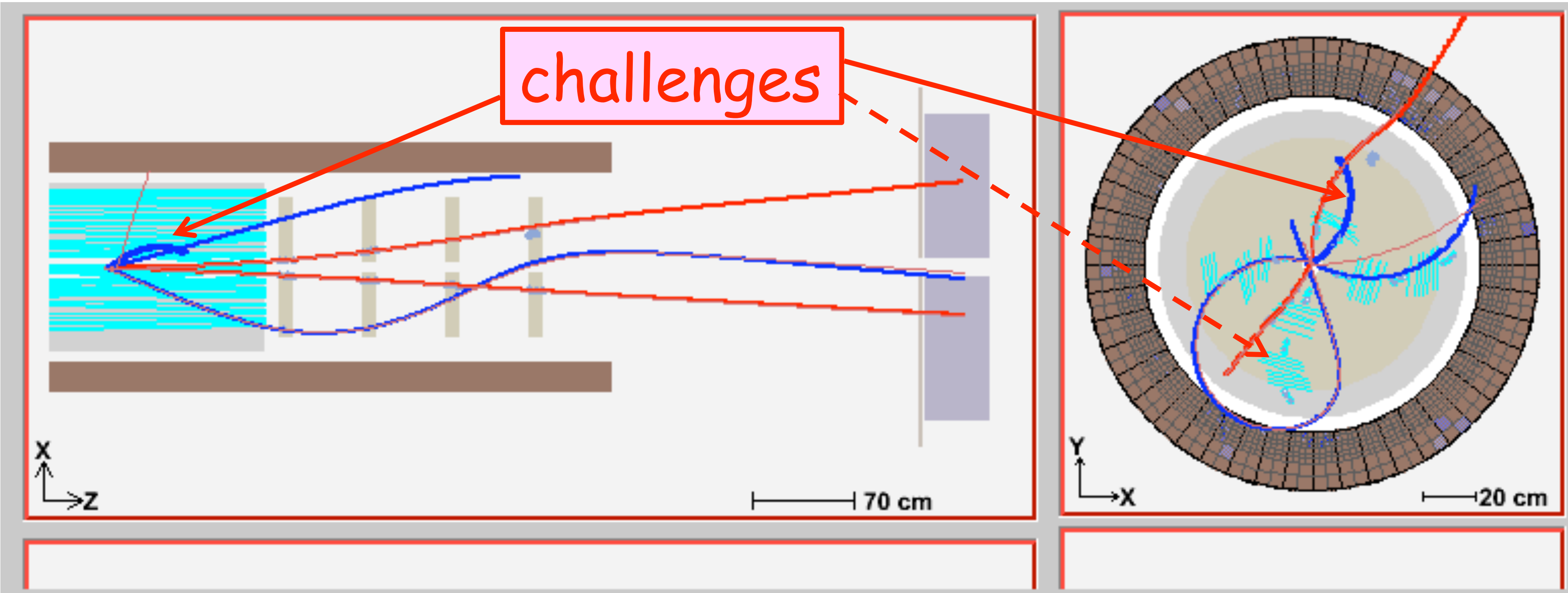
Generated event 52 $\gamma p \rightarrow 2\pi^{+}2\pi^{-}\ p$



Track Info

Thrown

trk:	type:	p:	theta:	phi:	z:
1	pi+	0.5565	23.41	2.87	57.4
2	pi+	1.038	16	5.786	57.4
3	pi-	5.322	5.324	4.267	57.4
4	pi-	1.999	11.88	1.557	57.4
5	proton	0.31	40.65	0.5825	57.4
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Reconstructed

trk:	type:	p:	theta:	phi:	z:	chisq/Ndof:	Ndof:
1	pi-	2.235	11.99	1.52	56.22	4.313	18
2	pi-	6.06	5.306	4.223	59.3	3.739	39
3	pi+	0.5574	22.81	2.858	56	0.5777	15
4	proton+	0.6791	73	0.04931	64.06	153.7	11
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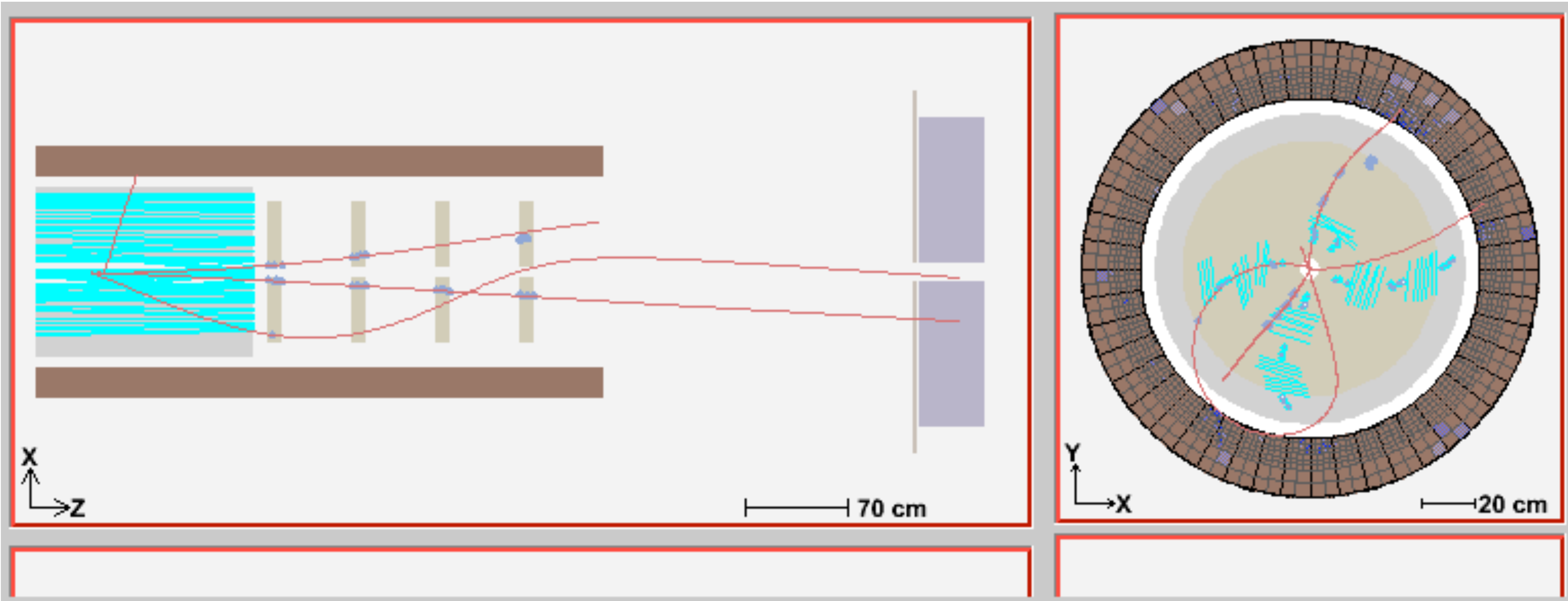
Kalman Filter fit event 52 $\gamma p \rightarrow 2\pi^+ 2\pi^- p$



Track Info

Thrown

trk:	type:	p:	theta:	phi:	z:
1	pi+	0.5565	23.41	2.87	57.4
2	pi+	1.038	16	5.786	57.4
3	pi-	5.322	5.324	4.267	57.4
4	pi-	1.999	11.88	1.557	57.4
5	proton	0.31	40.65	0.5825	57.4
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Reconstructed

trk:	type:	p:	theta:	phi:	z:	chisq/Ndof:	Ndof:
1	pi-	2.235	11.99	1.52	56.22	4.313	18
2	pi-	6.06	5.306	4.223	59.3	3.739	39
3	pi+	0.5574	22.81	2.858	56	0.5777	15
4	proton+	0.6791	73	0.04931	64.06	153.7	11
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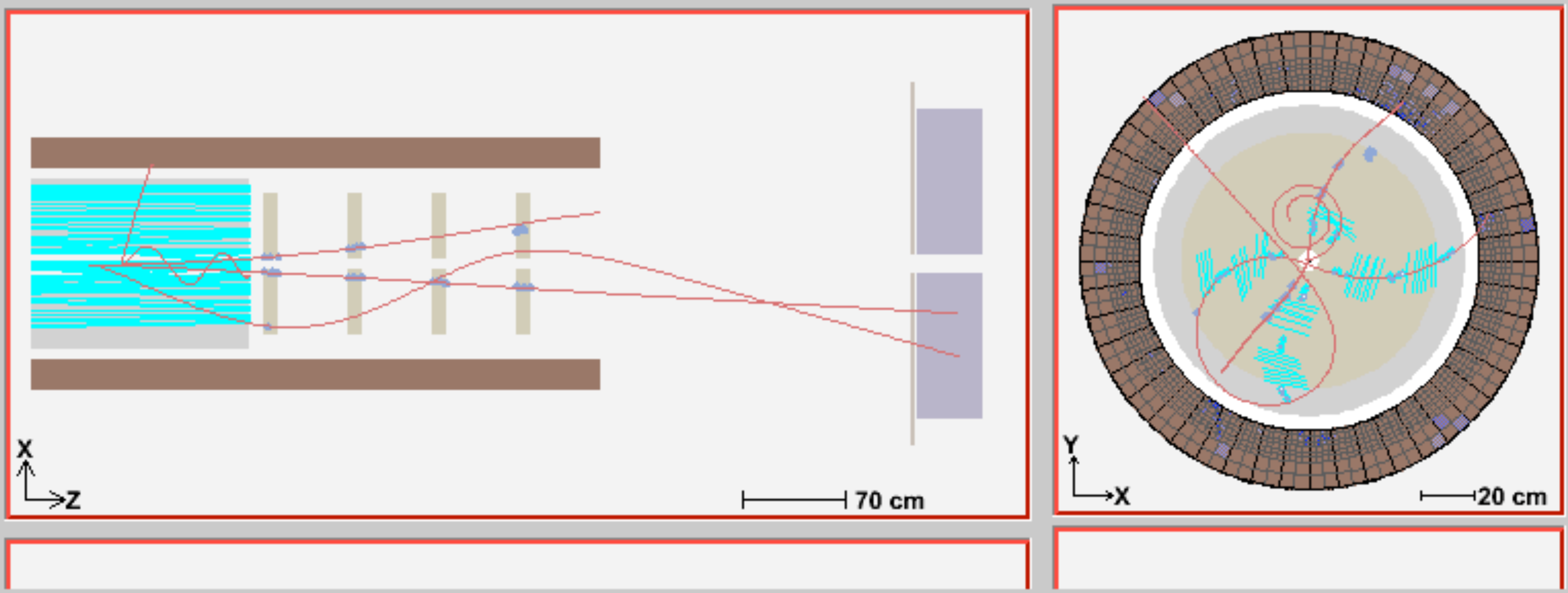
Least-square fit event 52 $\gamma p \rightarrow 2\pi^+ 2\pi^- p$



Track Info

Thrown

trk:	type:	p:	theta:	phi:	z:
1	pi+	0.5565	23.41	2.87	57.4
2	pi+	1.038	16	5.786	57.4
3	pi-	5.322	5.324	4.267	57.4
4	pi-	1.999	11.88	1.557	57.4
5	proton	0.31	40.65	0.5825	57.4
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Reconstructed

trk:	type:	p:	theta:	phi:	z:	chisq/Ndof:	Ndof:
1	pi-	2.109	12.01	1.541	56.63	0.6547	18
2	pi-	5.495	5.317	4.242	60.67	5.938	31
3	pi+	0.4593	24.09	2.727	63.53	3.268	16
4	pi+	0.3298	74.15	5.817	78.18	17.06	20
5	pi+	0.109	52.83	0.1346	80	60.83	3
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Summary

- Model expectations
  - In photoproduction, gluonic excitations will be produced with roughly the same cross sections as normal mesons.
  - Gluonic excitations are expected to decay preferentially to multi-particle final states
- The GlueX detector has been designed to have high acceptance for both neutral and charged particles
  - Studies are underway to understand the detailed acceptance of many photoproduction reactions at high intensity and with many particles in the final state.
  - Full event reconstruction with charged and neutrals with all backgrounds included is a work-in-progress