Simulations of Exotic Mesons in GlueX: Past, Present, Future

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Simulations of Exotic Mesons in GlueX

Why Physics Simulations?

- ... for the preparation of GlueX analysis tools.
- ... for the optimization of the detector design.
- ... to show the community the capabilities of GlueX.

This Talk:

- Key channels for the observation of exotic mesons.
- The evolution of GlueX exotic meson simulations.
- Next steps towards modernizing the simulations.

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, 2πη, and 2πω.

PLUS:

$\pi_1 \rightarrow \eta\pi$

$\rightarrow \eta'\pi$

AND A LITTLE HARDER:

$\pi_1 \rightarrow f_1\,\pi$;

$f_1 \rightarrow a_0\,\pi$;

$a_0 \rightarrow \eta\,\pi$.

(i.e., **3πη**)

(Do these need revisiting?)

Follow the simulation of a few of these channels through time....

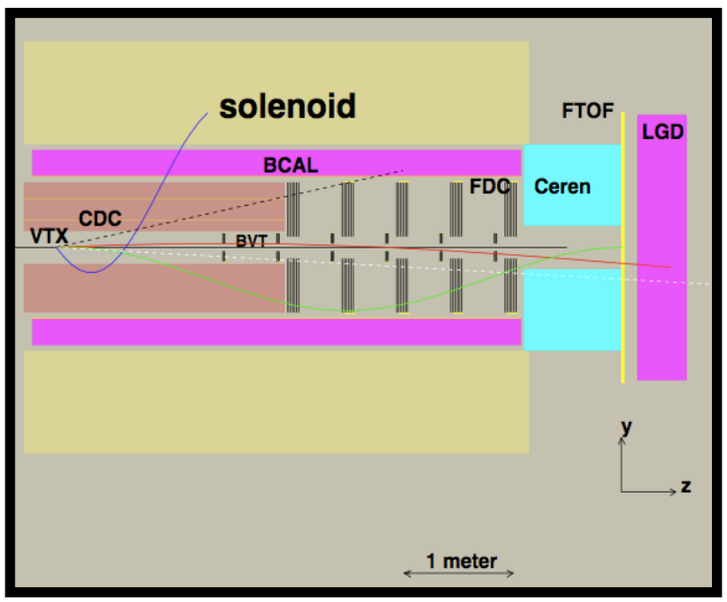
GlueX-doc-16 (May 1999): A Very Early Look at Acceptances

"HDFast" Parametric MC.

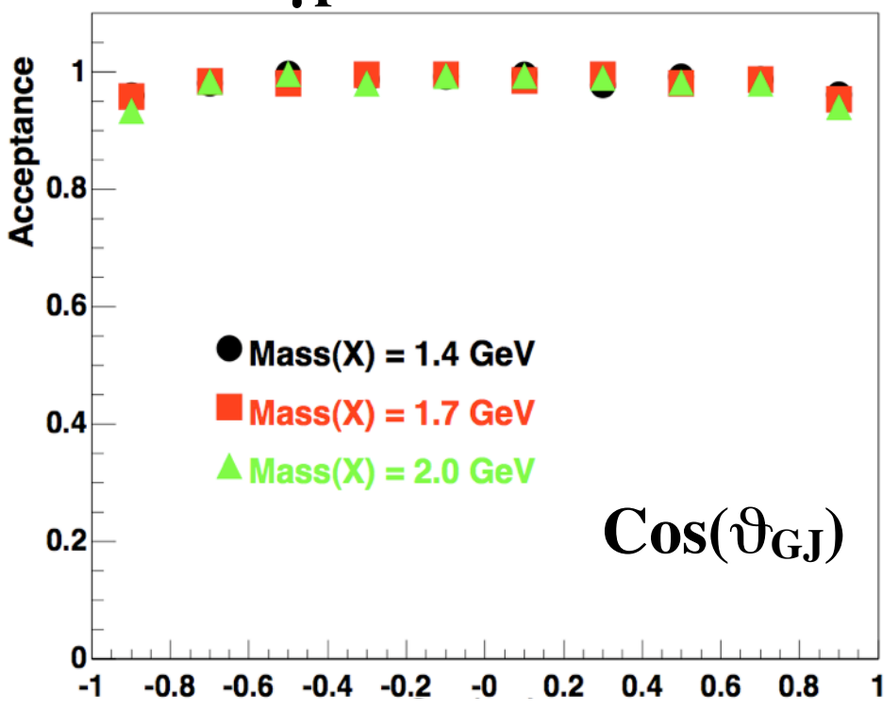
Acceptance Criteria:

(1) tracks have at least 4 hits

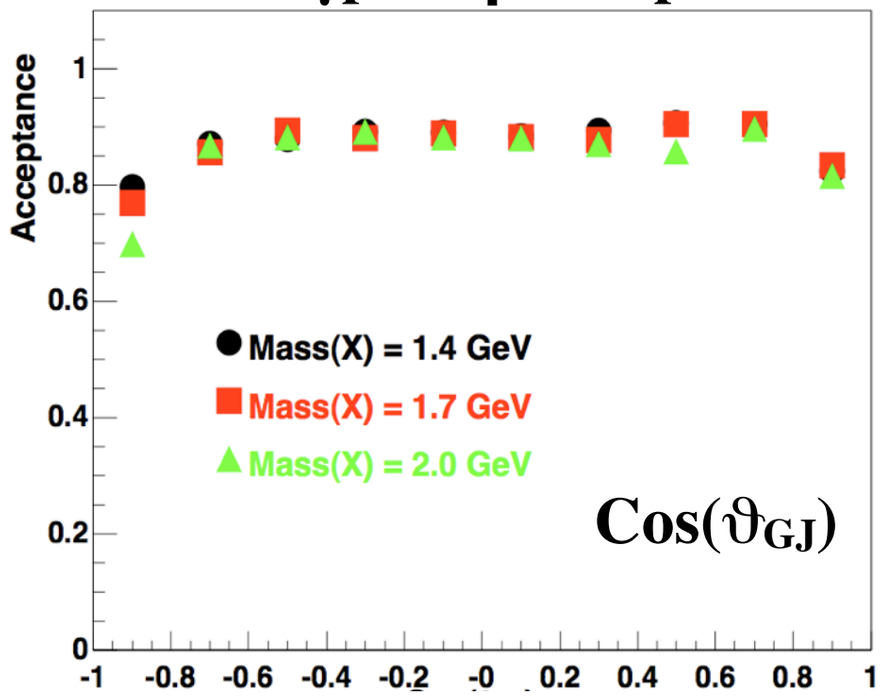
(2) photons hit the BCal or FCal



$\gamma p \rightarrow \pi^+ \pi^+ \pi^- n$



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



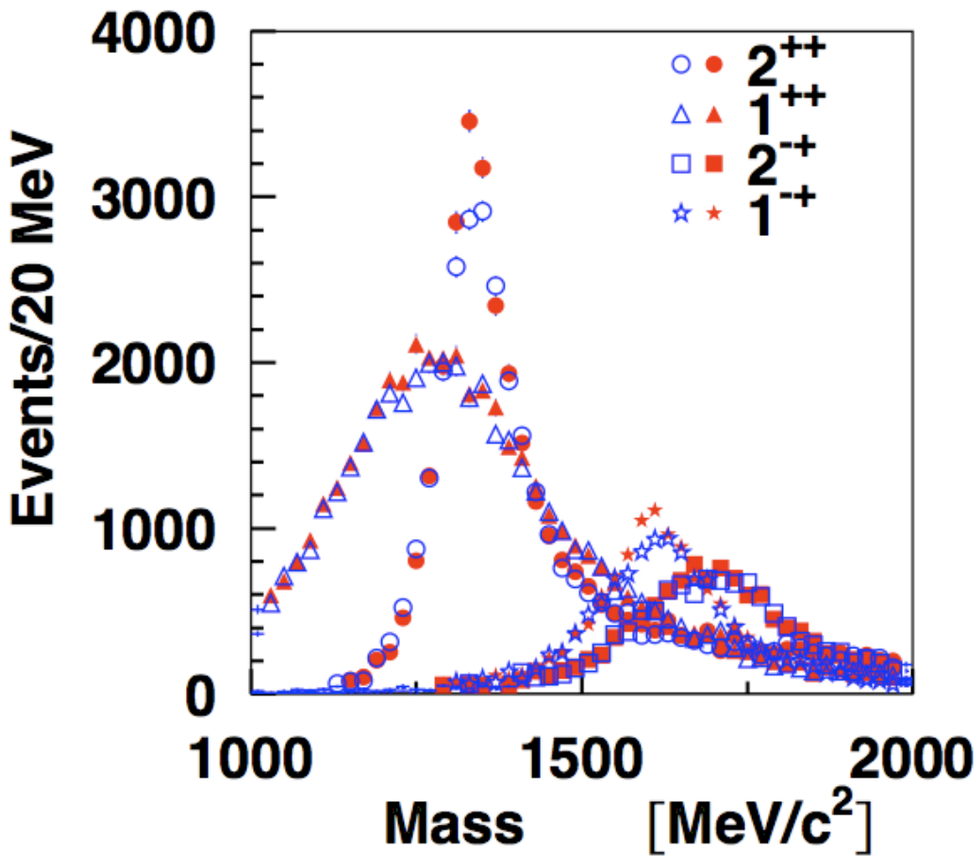
Charged Final States:
> 90% Acceptance

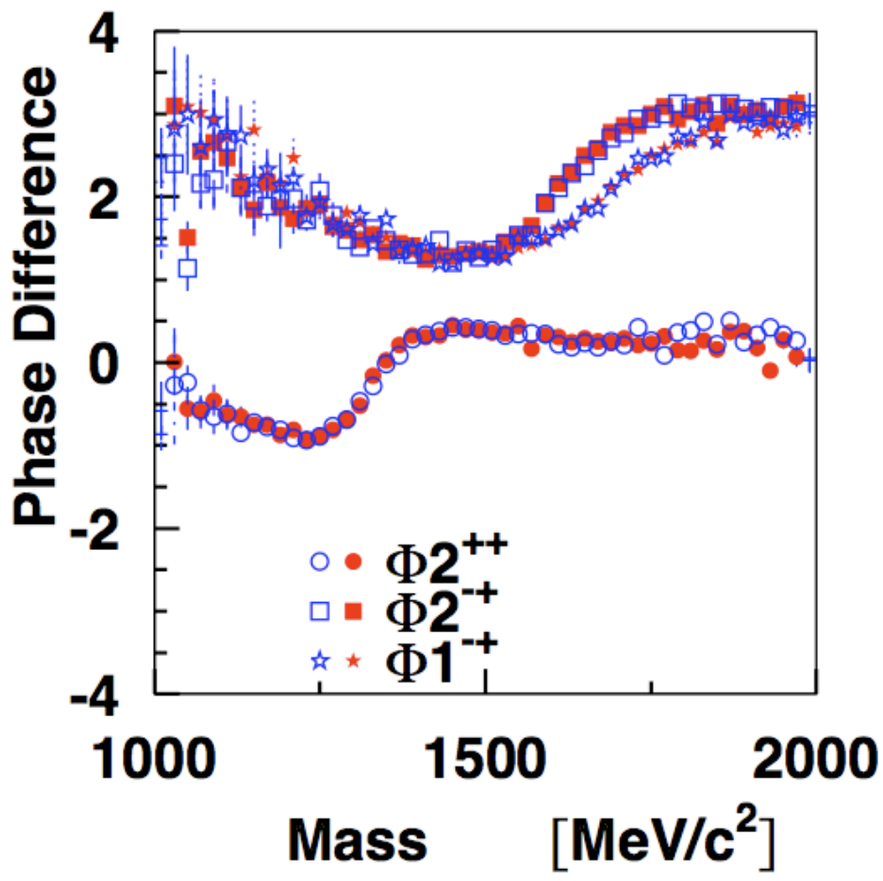
Neutral Final States:
> 80% Acceptance

GlueX-doc-44 (CDRv3, Dec. 2000): A Toy PWA Exercise

1. Generate $\gamma p \rightarrow \pi^+ \pi^+ \pi^- n$ with
   6 partial waves (a_1, a_2, π_2, π_1,...).
2. Send through the detector MC (HDFast).
3. Do a Toy PWA.

Notes:
- *Results look good.*
- *Finite resolution is apparent.*
- *Acceptances likely overestimated.*
- *No background is included.*





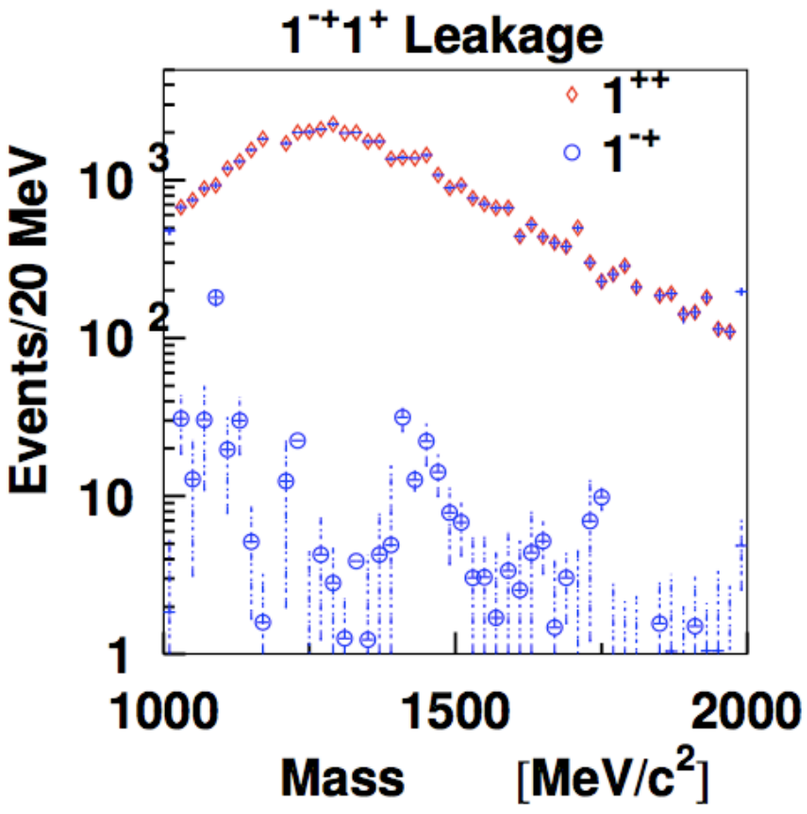
solid: generated

open: mc corrected results

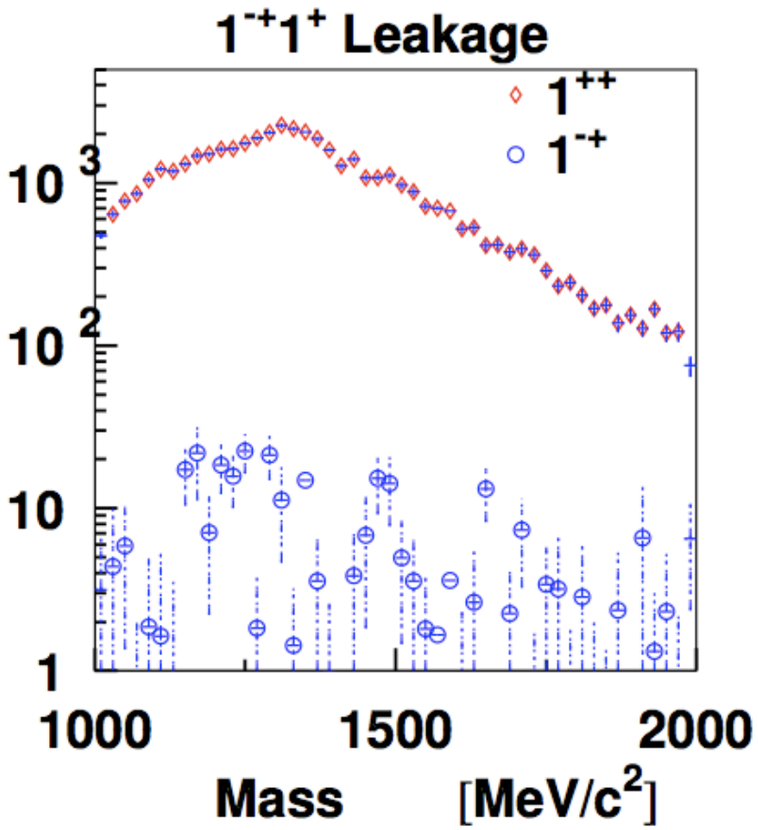
GlueX-doc-51 (Dec. 2001): A Toy PWA Leakage Study

- Generate $\gamma p \rightarrow \pi^+\pi^+\pi^-n$ and send through the detector MC, as before.
- Do the PWA with a different, *distorted* detector MC.
- Leakage into the exotic wave is less than 1%.

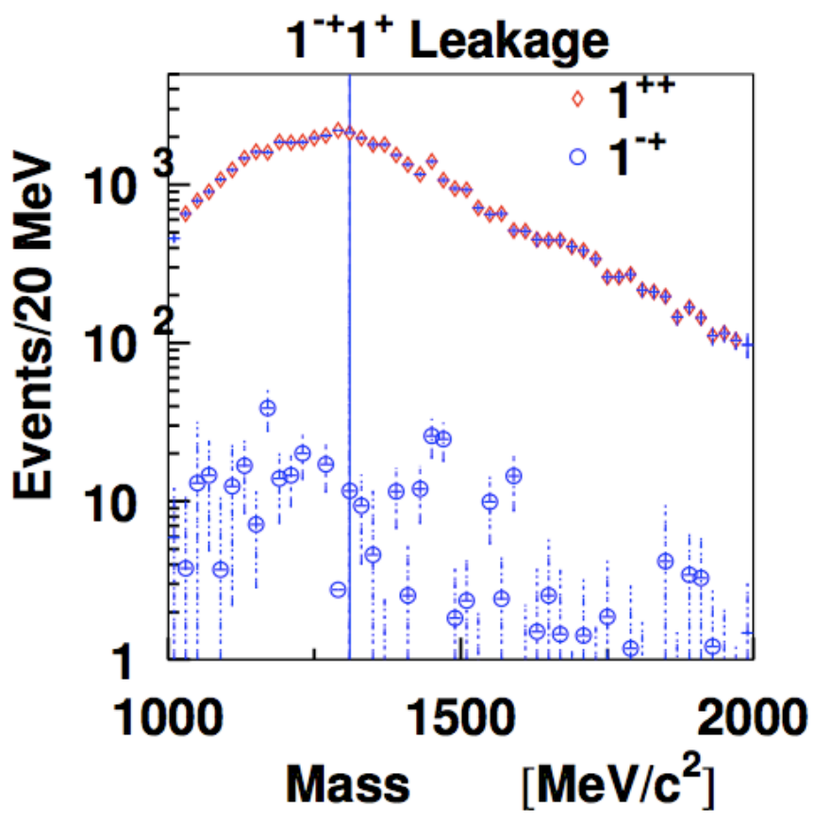
Distorted B Field



Wrong FDC Hole Size



Wrong FDC Resolution



A similar study for $\gamma p \rightarrow \pi^+\pi^0\pi^0 n$ has similar conclusions.

GlueX-doc-58 (CDRv4, Nov. 2002): A Double-Blind Exotic Search

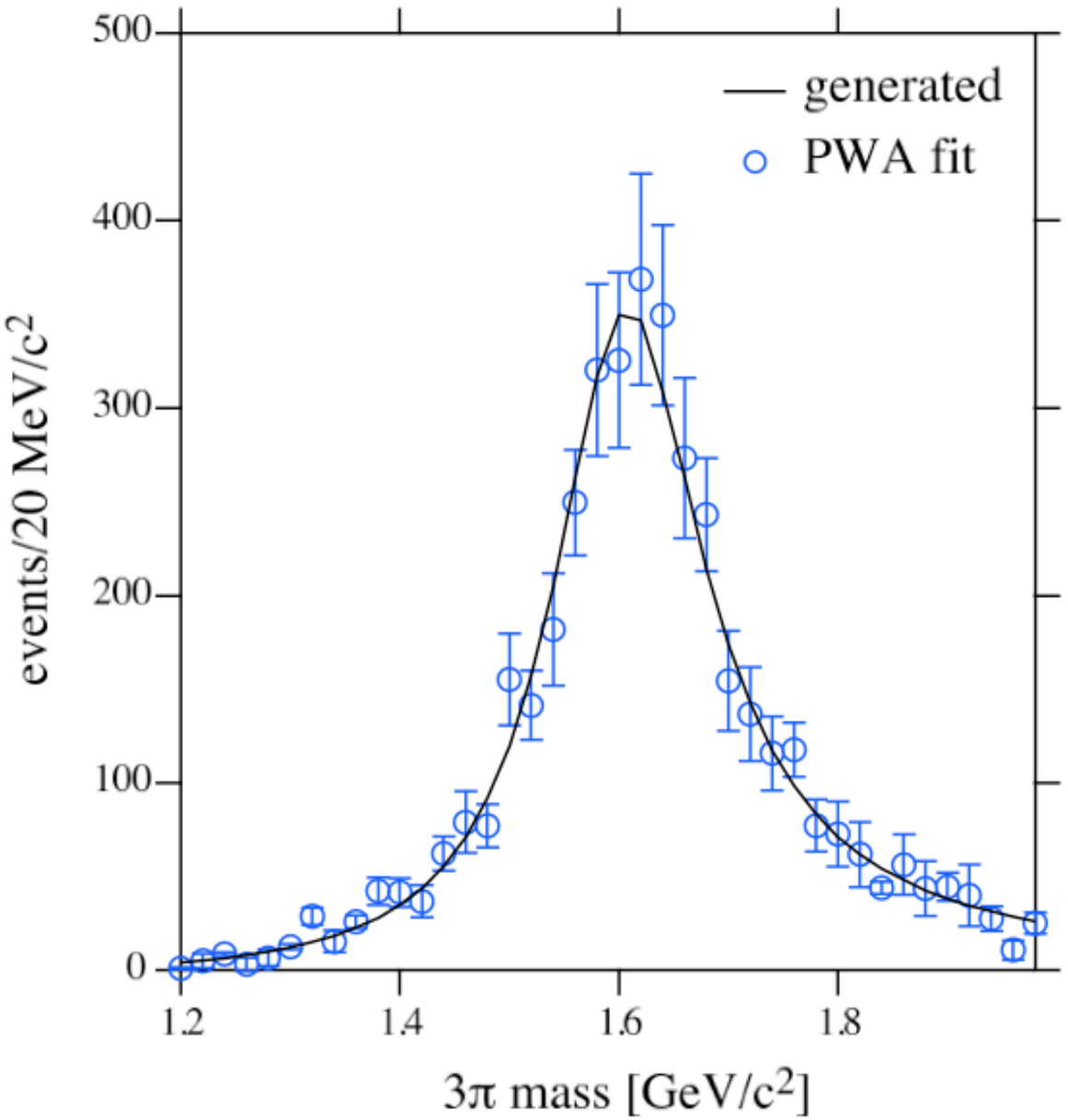
Generate an unknown set of waves for $\gamma p \rightarrow \pi^+\pi^+\pi^-n$.

Include an unknown fraction of exotic $\pi_1 \rightarrow \varrho\pi$ decays.

Use an unknown mass and width for the π_1.

Send through the detector MC.

The PWA returned:
... the right fraction of π_1 (2.5%).
... the right π_1 mass and width.



GlueX-doc-264 (Sep. 2004): Expanded Acceptance Studies

<u>"HDFast" Parametric MC.</u>

Acceptance Criteria:

(1) tracks have at least 4 hits

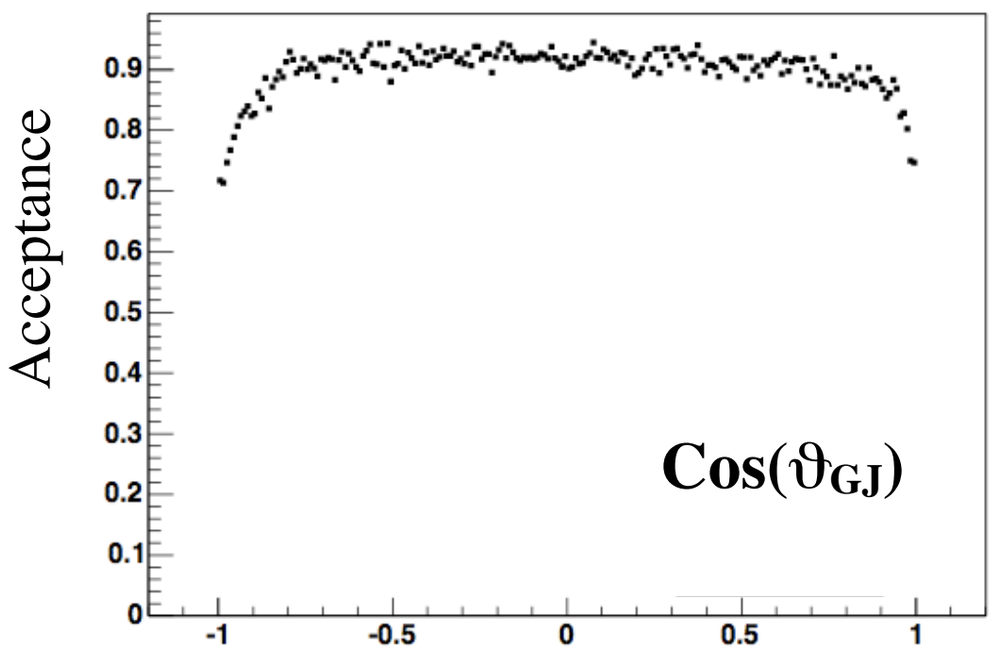
(2) photons hit the BCal or FCal

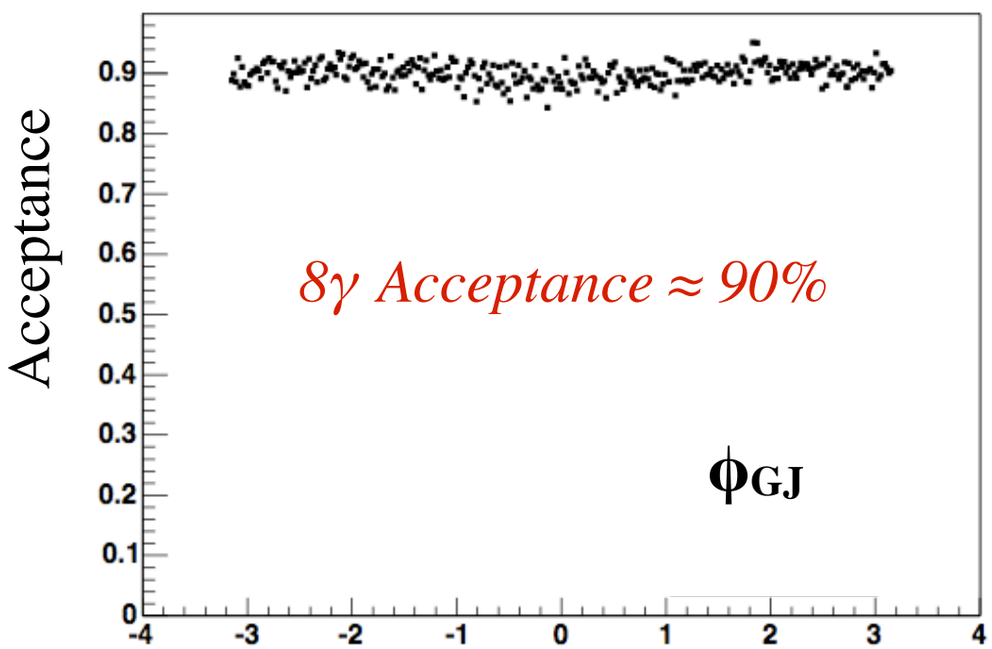
(3) photon minimum energy is:
20 MeV (BCal), 100 MeV (FCal)

New Modes:

#	*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: $\pi_1(1700) \to f_1(1285)\pi^0 \to 8\gamma$





GlueX-doc-787 (March 2007): A First Look at FCal Reconstruction

Generate single photons.

Spread photons uniformly over FCal angles.

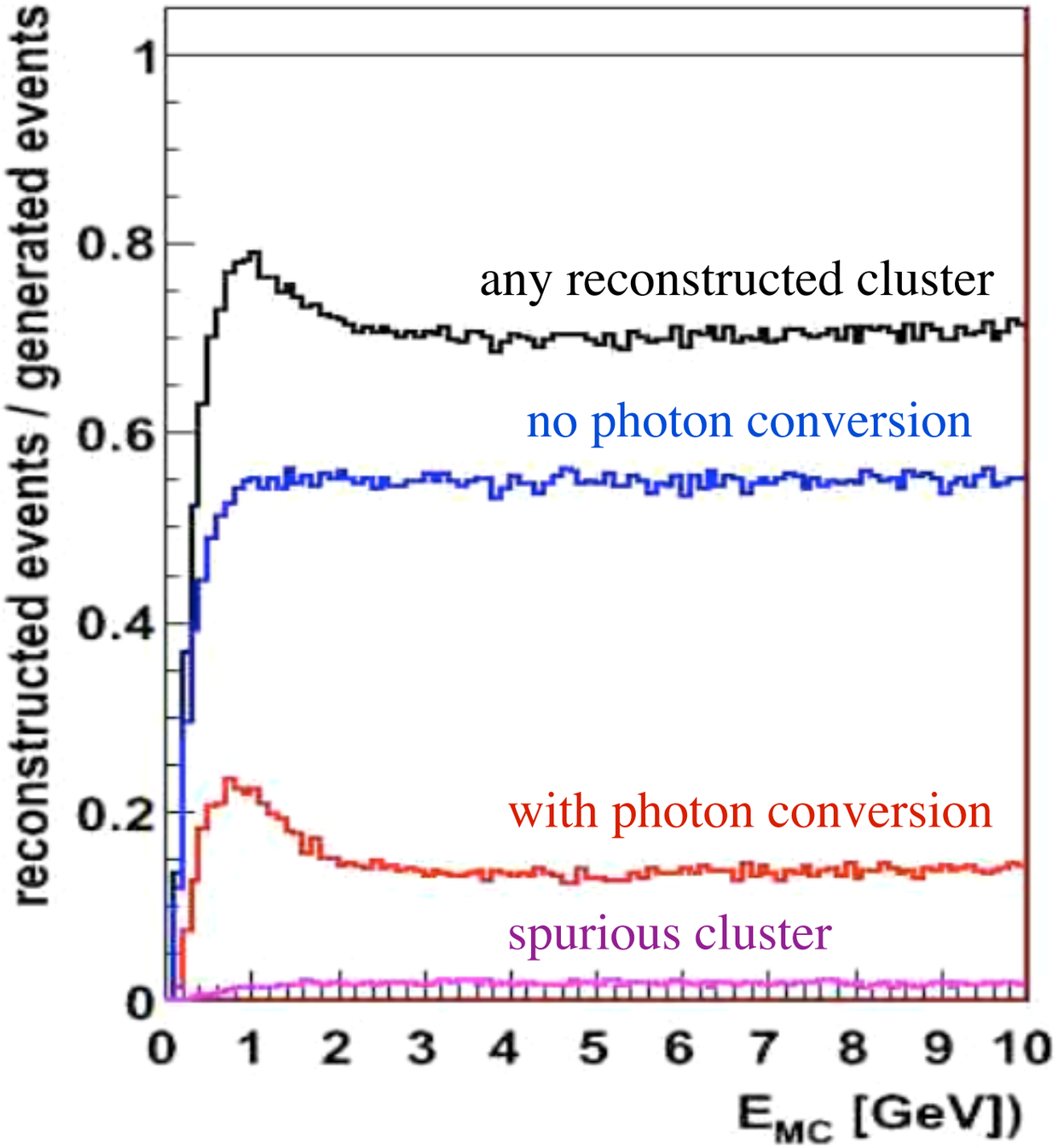
Perform full reconstruction.

Acceptance **>99%** for non-converting photons.

Material has a big effect (**77%** total efficiency, c.f. GlueX-doc-823).

NB. FDC has since reduced its material budget.

This is a more realistic picture.



GlueX-doc-817 (May 2007): Study of $\eta\pi^0$ with FCal Reconstruction

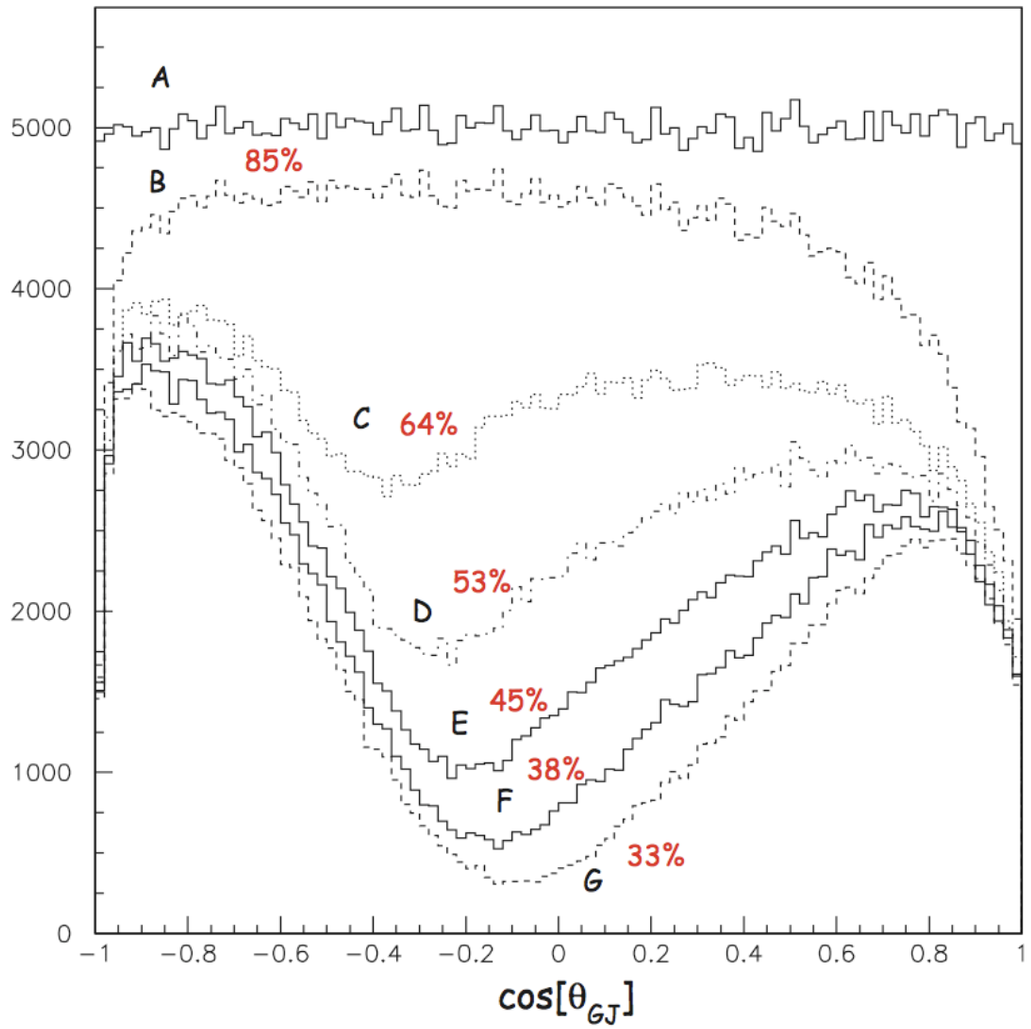
The realistic FCal acceptance has a big effect on some channels, for example:

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

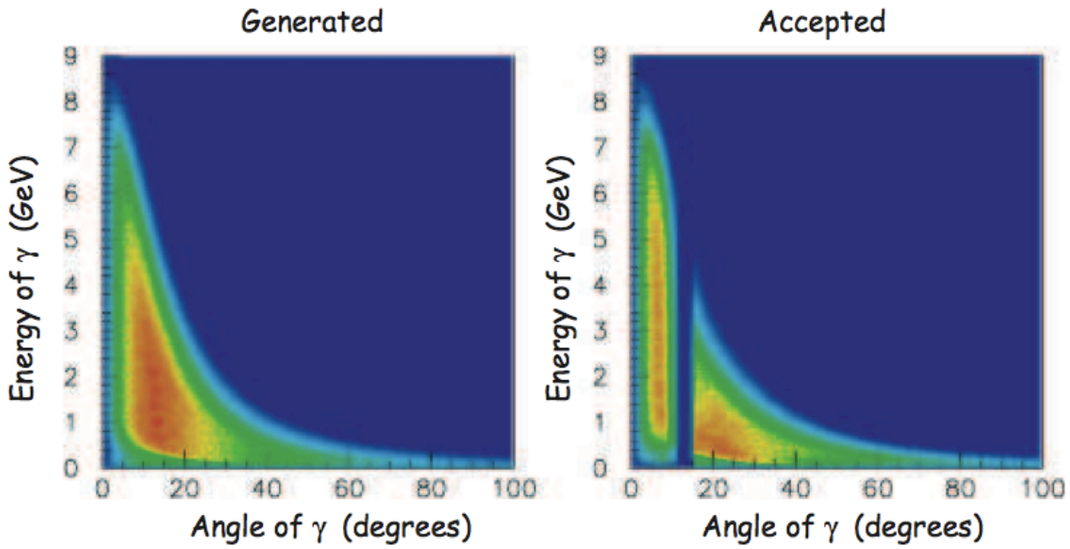
Look at stand-alone MC.

Acceptance criteria:

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



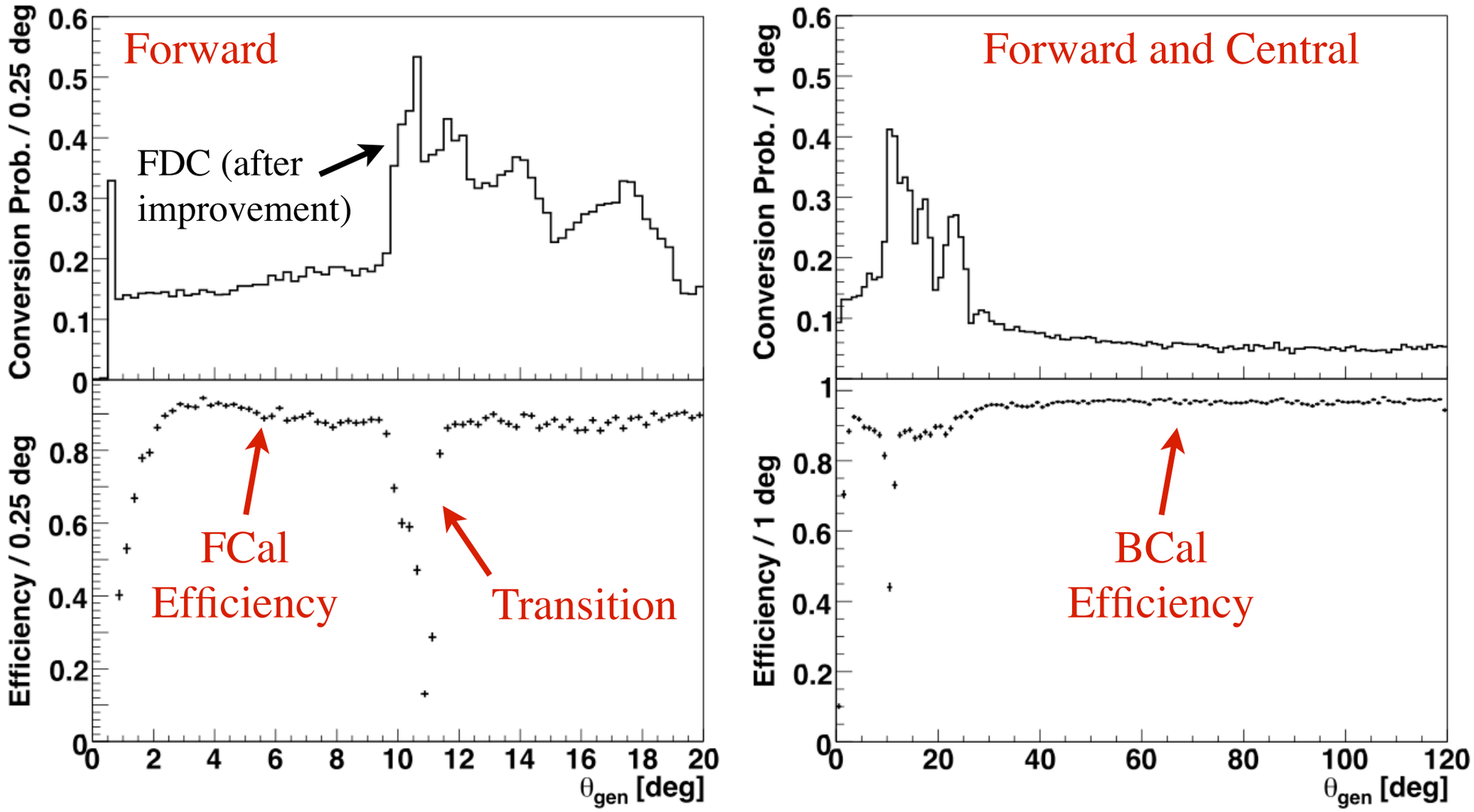
A. Generated distribution
B. Geometry (96%) + E_{min} Cuts
C. FCal Reconstruction Efficiencies
D-G. Reject BCal-FCal transition region from 11 to 12, 13, 14, 15 degrees.



GlueX-doc-989 (Feb. 2008): Contemporary Calorimetry

Realistic calorimeter efficiencies after BCal and FCal full reconstruction…

Single 1 GeV Photons



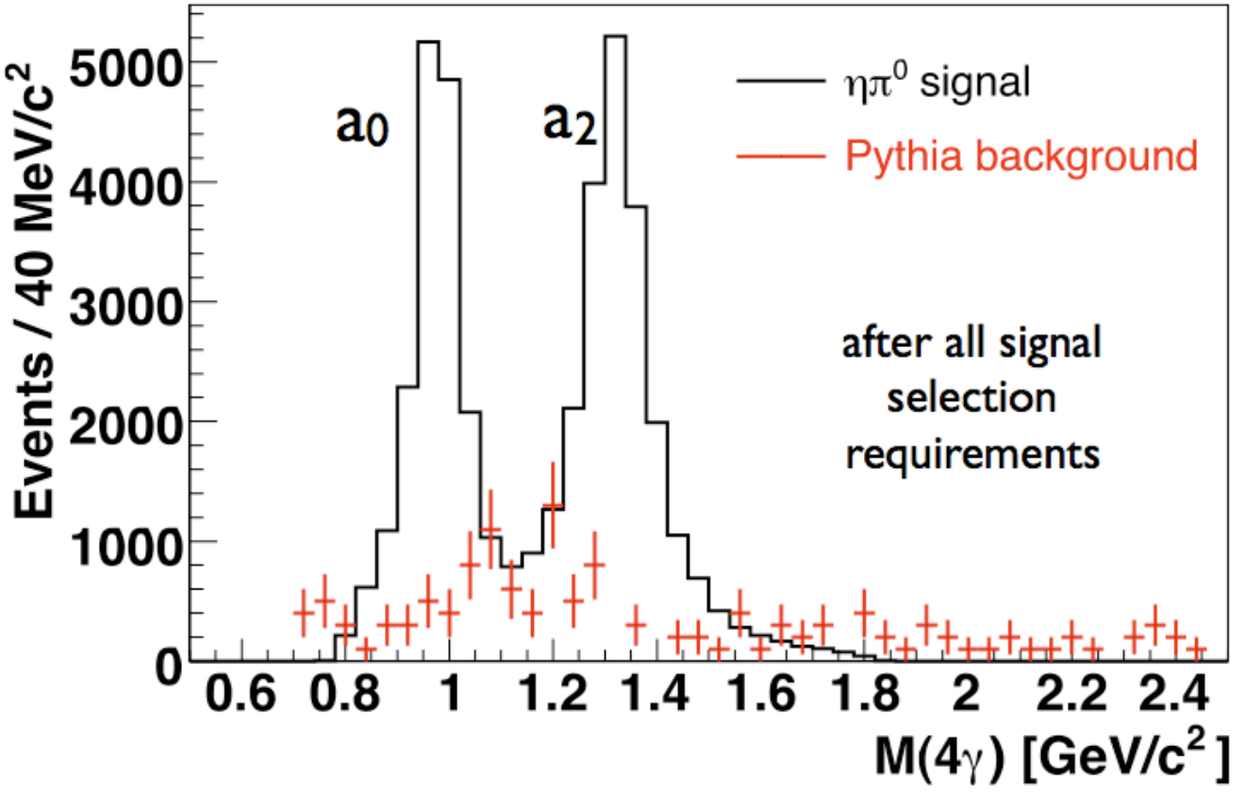
GlueX-doc-989 (Feb. 2008): Physics Channels with Background

- Generate $\gamma p \rightarrow \eta\pi^0 p$ and $\gamma p \rightarrow \eta 3\pi^0 p$.
- 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:

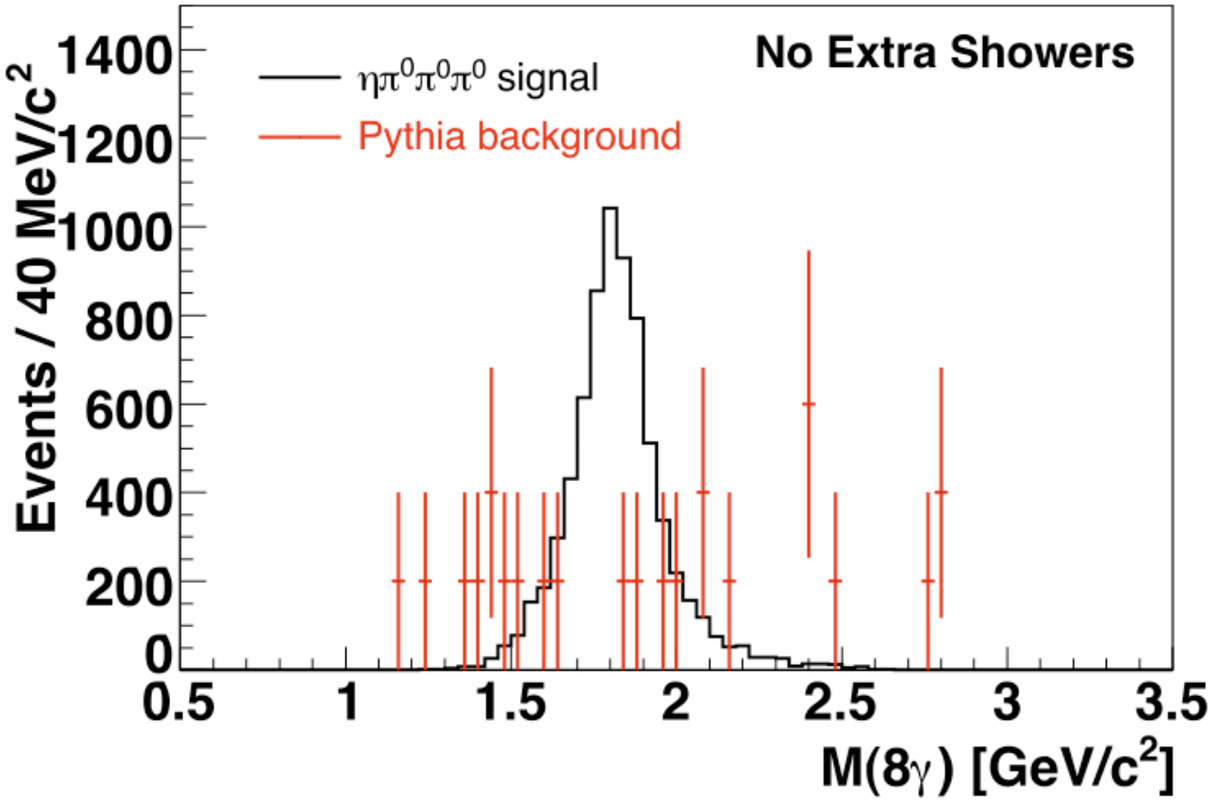
- *Efficiencies are lower than "HDFast"*
- *Signal to background is still quite good.*
- *More background MC would help.*
- *a_0 and a_2 are correctly identified in PWA.*
- *Most realistic picture to date… promising…*

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



Acceptance ≈ 45%

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



Acceptance ≈ 8-10%

Next Steps

- Blake and U. Regina are continuing to expand the studies on the previous slide while also working on calorimetry reconstruction.
- Simulations have come a long way since 1999.
- GlueX is ready for more realistic physics simulations:
  - Photon reconstruction is in place.
  - Single track resolutions and efficiencies are coming together.
  - A parametric MC exists combining tracking and calorimetry.
  - We should update our physics simulations with our latest knowledge of the detector.
- We should have a new set of baseline simulations for conferences, etc.
- Consistency is important. There should no longer be a reason to resort to 1999 efficiencies.
- There are many opportunities for new exotic meson simulations!