Photoproduction of the $b_1(1235)$ Meson off the proton at $E_\gamma = 6$-12 GeV

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Acknowledgements:
gluex.org/thanks

University of Regina

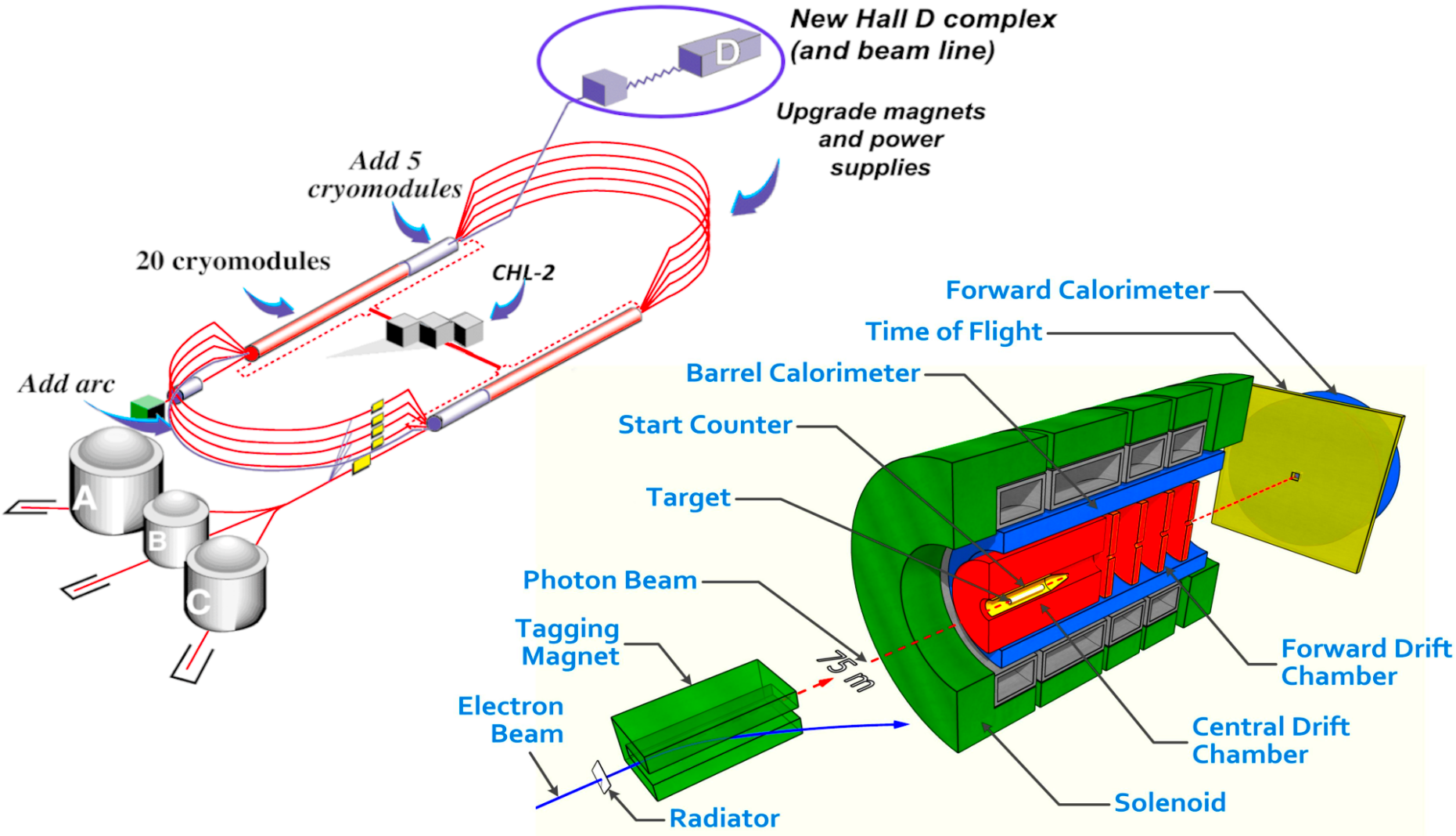
Faculty of Science

Outline

Jefferson Lab - Experimental Hall D

12 GeV Upgrade

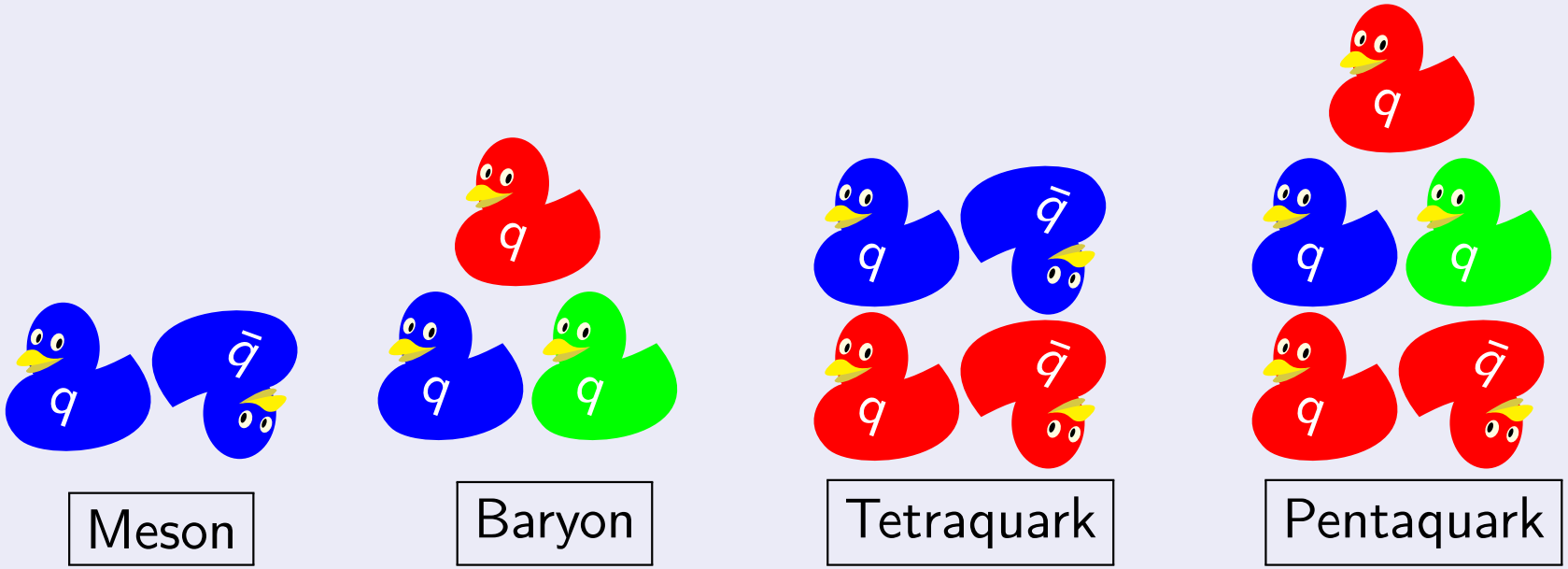
Main Goal: Map meson spectrum



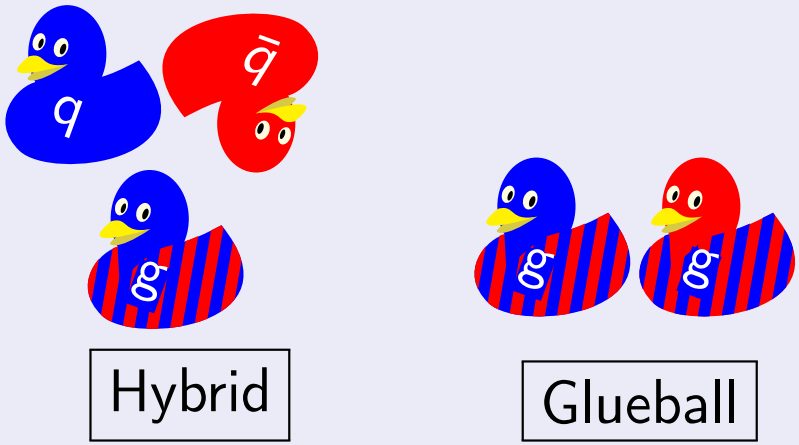
GlueX-I data collected over 2017, 2018

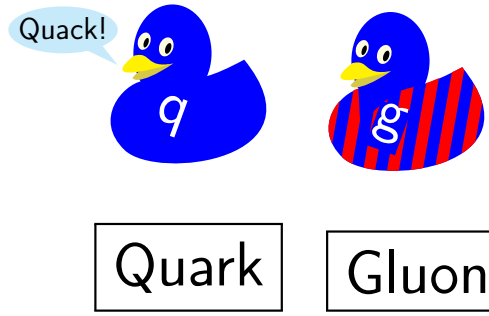
"Almost" full 4π coverage

Quark Model

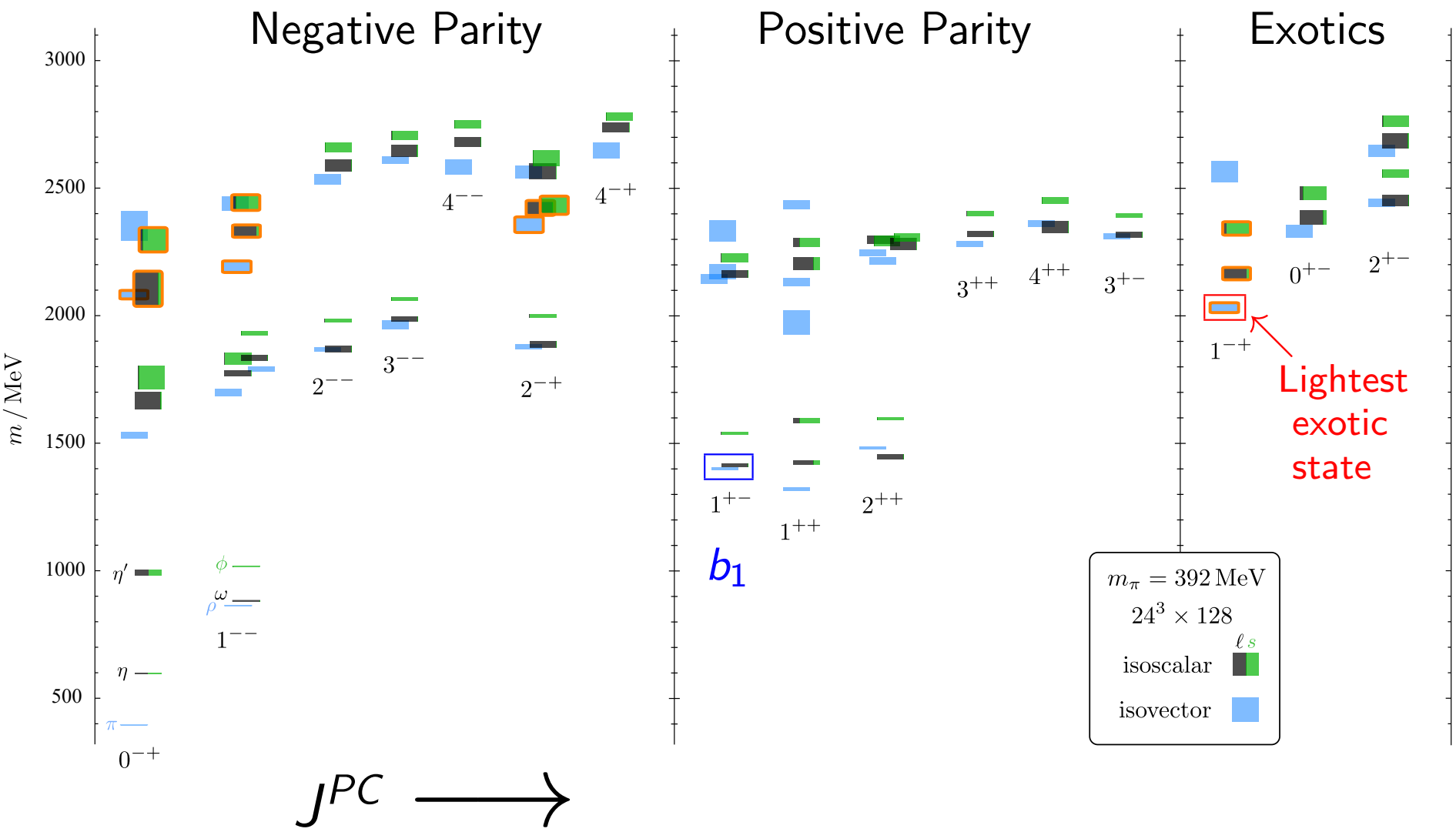


Exotics





Lattice QCD



J.J. Dudek, R.G. Edwards, P. Guo, and C.E. Thomas, Phys. Rev. D88 094505 (2013)

Exotic Meson Production

- GlueX aim: light meson spectrum. Validation for a QCD model with gluonic degrees of freedom.
- Preliminary evidence exists for the 1^{-+} exotic meson. (VES, E852, COMPASS) Many of these suffer low statistics.

Name	$(I)^G J^{PC}$	Allowed Decay Modes
π_1^0	$(1)^-1^{-+}$	$\rho^\pm\pi^\mp$, $\eta'\pi^0$, $f_1\pi^0$, $b_1^\pm\pi^\mp$, $\rho^0\omega$, $a_1^0\eta$, $b_1^0\omega$
$\pi_1^\pm$	$(1)^-1^-$	$\rho^\pm\pi^0$, $\rho^0\pi^\pm$, $\eta'\pi^\pm$, $f_1\pi^\pm$, $b_1^\pm\pi^0$, $b_1^0\pi^\pm$, $b_1^\pm\omega$, $\rho^\pm\omega$, $a_1^\pm\eta$
η_1	$(0)^+1^{-+}$	$\eta'\eta$, $f_1\eta$, $f_2\eta$, $\omega\omega$, $\rho^0\rho^0$, $\rho^\pm\rho^\mp$, $a_2^\pm\pi^\mp$, $a_2^0\pi^0$, $b_1^0\rho^0$
b_2^0	$(1)^+2^{+-}$	$\omega\pi^0$, $\rho^0\eta$, $a_2^\pm\pi^\mp$, $\rho^\pm\rho^\mp$, $b_1^0\eta$, $f_1\rho^0$, $a_1^\pm\pi^\mp$
$b_2^\pm$	$(1)^+2^+$	$\omega\pi^\pm$, $\rho^\pm\eta$, $a_2^\pm\pi^0$, $a_2^0\pi^\pm$, $b_1^\pm\eta$, $b_1^0\rho^\pm$, $b_1^\pm\rho^0$, $f_1\rho^\pm$, $a_1^\pm\pi^0$, $a_1^0\pi^\mp$
h_2	$(0)^-2^{+-}$	$\rho^0\pi^0$, $\omega\eta$, $b_1^\pm\pi^\mp$, $b_1^0\pi^0$, $f_1\omega$
b_0^0	$(1)^+0^{+-}$	$f_1\rho^0$, $b_1^0\eta$, $h_1\pi^0$
$b_0^\pm$	$(1)^+0^+$	$\pi^\pm\pi^0$, $f_1\rho^\pm$, $b_1^\pm\eta$, $b_1^0\rho^\pm$, $b_1^\pm\rho^0$, $h_1\pi^\pm$
h_0	$(0)^-0^{+-}$	$b_1^\pm\pi^\mp$, $b_1^0\pi^0$, $h_1\eta$

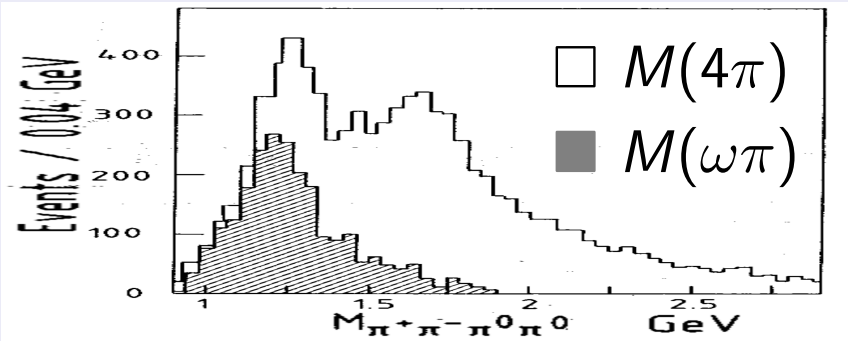
C. A. Meyer, "The Production and Decay of Normal and Exotic-Hybrid Mesons in GlueX", GlueX DocDB:4788

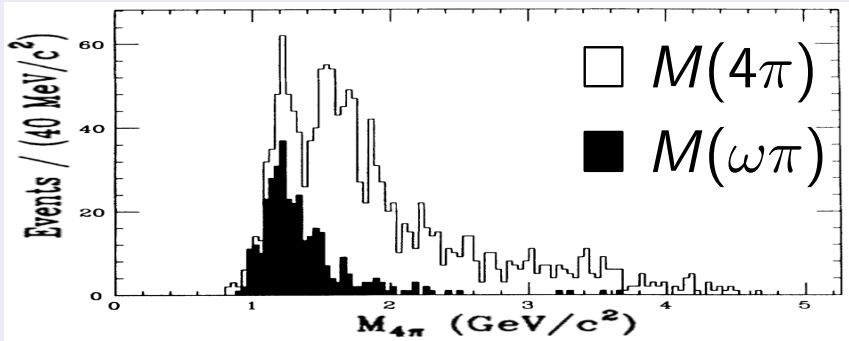
Motivation & History for the b_1 meson

Exotics $\pi_1(1600)^a$, $\pi_1(2015)^b$, h_0, b_2 could potentially decay to $b_1\pi$ which decays dominantly through $b_1 \to \omega\pi$. Precise measurement of the π_1 requires understanding the decay of the b_1 meson.

[a] Reported by E852, VES, COMPASS and CBAR
[b] Reported by E852

History of the $b_1(1235)$ Photoproduction (from the 1980s)

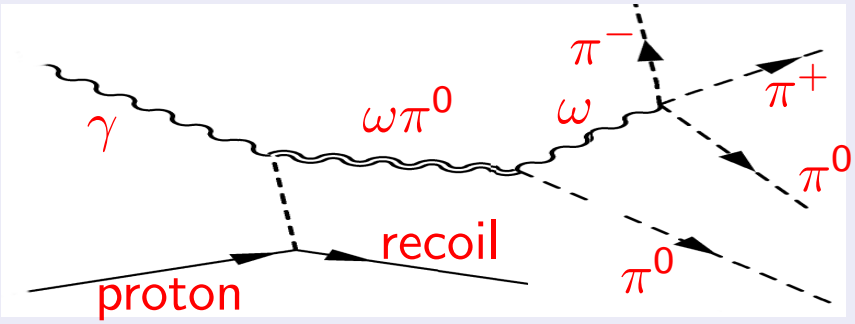




➢ (left) M. Atkinson *et al.* [Omega Photon],"A Spin Parity Analysis of the $\omega\pi^0$ Enhancement Photoproduced in the Energy Range 20-{GeV} to 70-{GeV}," Nucl. Phys. B **243**, 1-28 (1984). ➢ (right) J. E. Brau *et al.* [SLAC Hybrid Facility Photon],"Production and Decay Properties of the $\omega\pi^0$ State at 1250-{MeV}/c^2 Produced by 20-{GeV} Polarized Photons on Hydrogen," Phys. Rev. D **37**, 2379 (1988)

Event Selection

$$\gamma p \rightarrow p\,\omega\pi^0 \rightarrow p\,\pi^+\pi^-\pi^0\,\pi^0$$



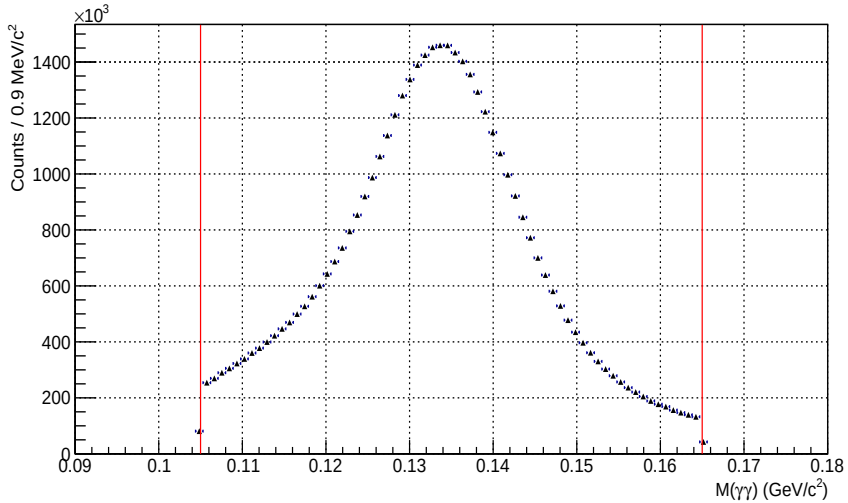
All Particles Detected

π^0 formed in the range [0.105,0.165] GeV.

47% of GlueX-I Data

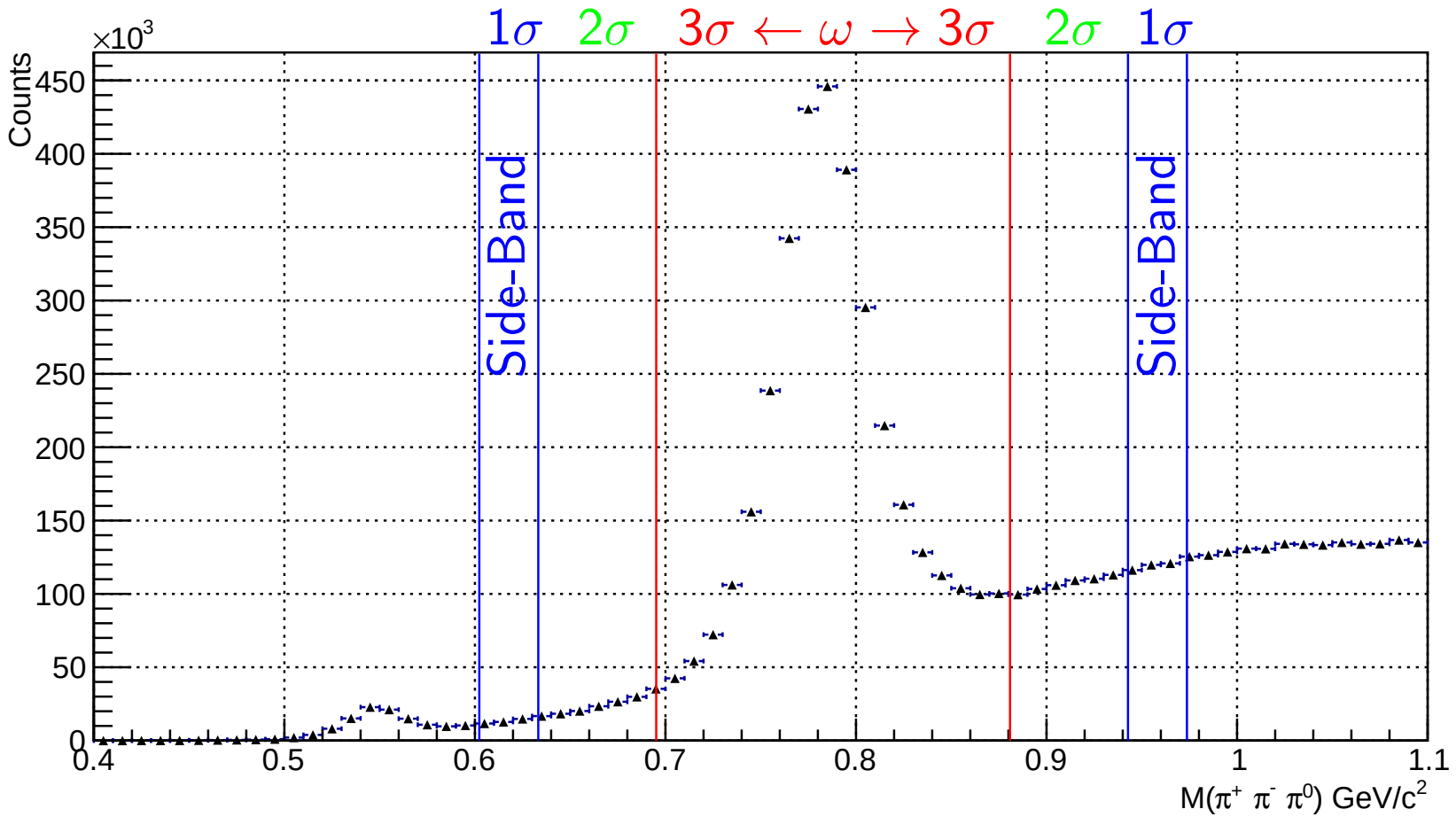
Selection Cuts

- ➢ PID Cuts (dE/dx & Time of flight).
- ➢ Invariant mass of π^0 & ω.
- ➢ Missing mass cut.
- ➢ Kinematic fit.
- ➢ Beam Energy cut.
- ➢ Fiducial & vertex cut.

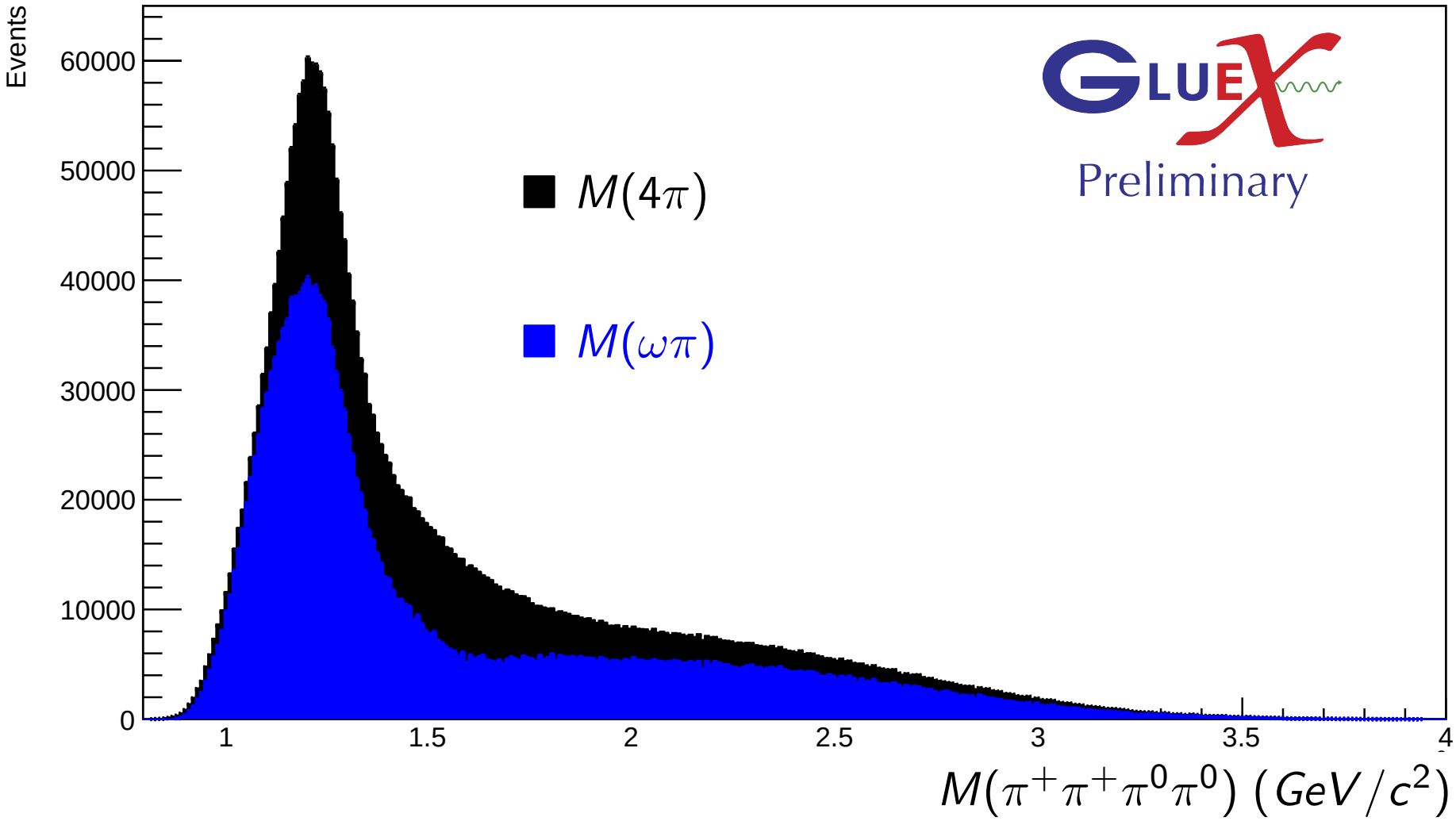


ω side-band subtraction

$$\omega \rightarrow \pi^+\pi^-\pi^0 \ (\Gamma = 89.2\%)$$



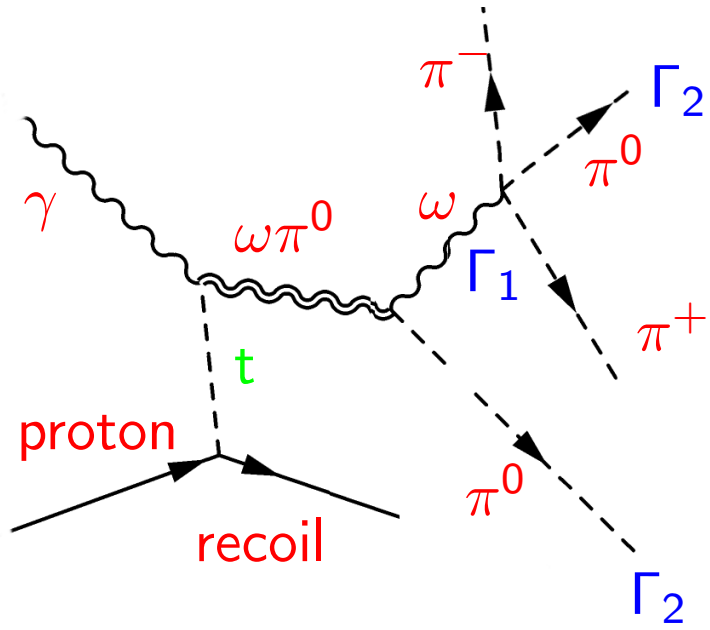
$\omega\pi^0$ Invariant Mass



Cross Section Calculation

$$\sigma_{\omega\pi} = \int_{|t|=0.25} \int \frac{d\sigma}{dt\ dM_{\omega\pi}} dt\ dM$$

- BR $= \Gamma_1 \times \Gamma_2^2$.
  - $\Gamma_1(\omega \to \pi^+\pi^-\pi^0) = 89.2\%$.
  - $\Gamma_2(\pi^0 \to 2\gamma) = 98.8\%$.
- Mandelstam-t:
  (*four momentum transferred*)^2
  beam to recoil
  $t = (p_\gamma - p_{b_1})^2 = (p_{recoil} - p_{target})^2$.



Monte-Carlo Simulation

- Moment analysis model used by previous experiments [a].
- A basis set of 25 orthogonal moments.
- A set of 22 parameters obtained by fitting the data.
- Generating resonances with $J^P = 1^{\pm}, 0^-$.
- Sample used in this report: 120M events.
- t-slope: -5 for $0.25 < |t| < 0.95\ GeV^2/c^2$
  -2 for $0.95 < |t| < 3.0\ GeV^2/c^2$.
- MC subjected to same cuts as data.

$$\delta Acceptance = \frac{\sqrt{Thrown - Accepted}}{Thrown}$$

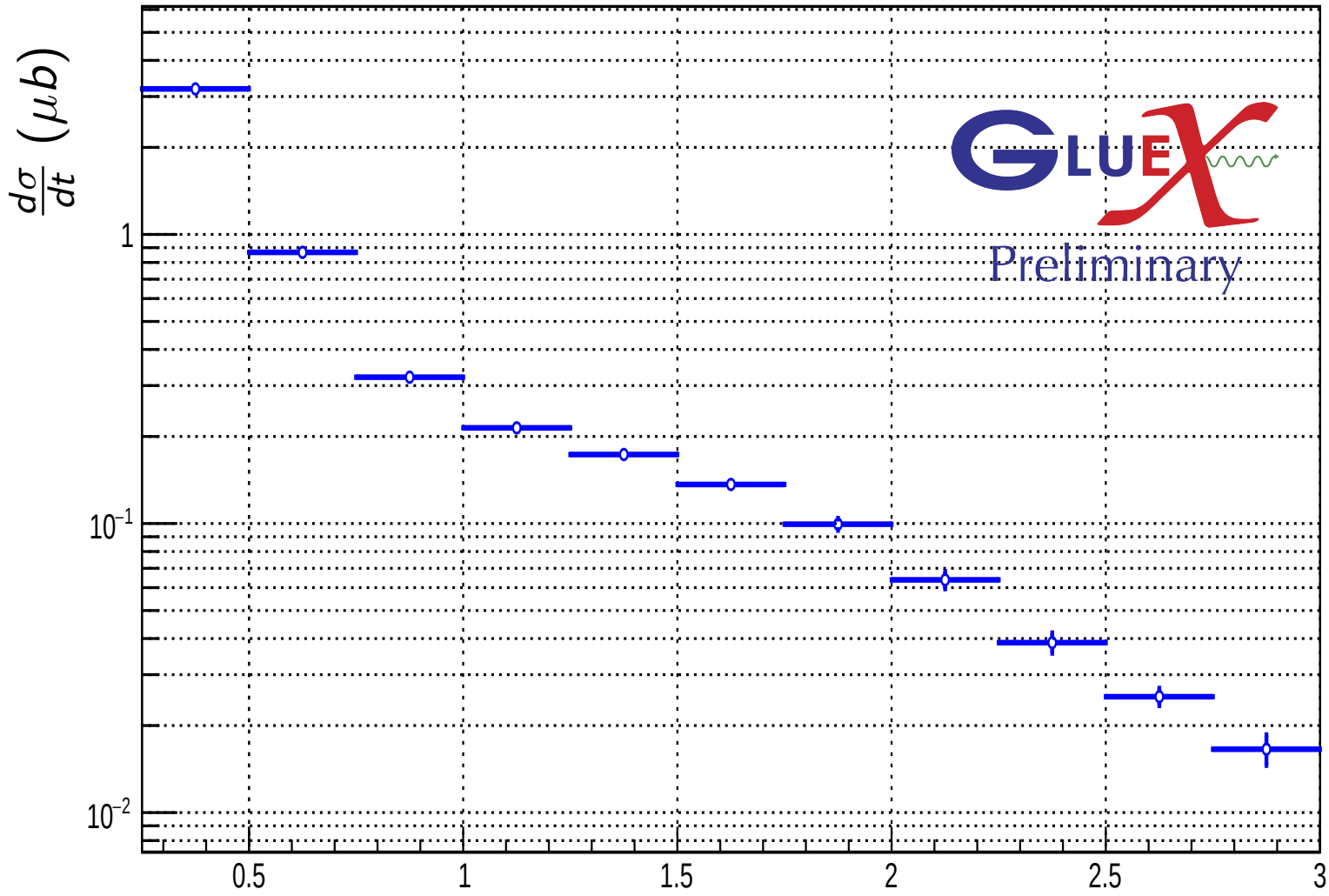
[a] Omega Photon Collab. M. Atkinson et al., Nucl.Phys. B243, 1-28, (1984).
SLAC-H Collab. J. E. Brau et al., Phys. Rev. D V37, (1988).

$\omega\pi^0$ Differential Cross Section

5 Beam Energy Bins

Slope change $|t| \sim 1 GeV^2/c^2$

$E_{beam} = 6.5 - 7.48\ GeV$

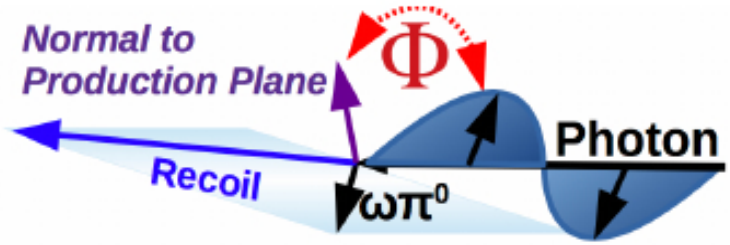


Error bars represent statistical error.

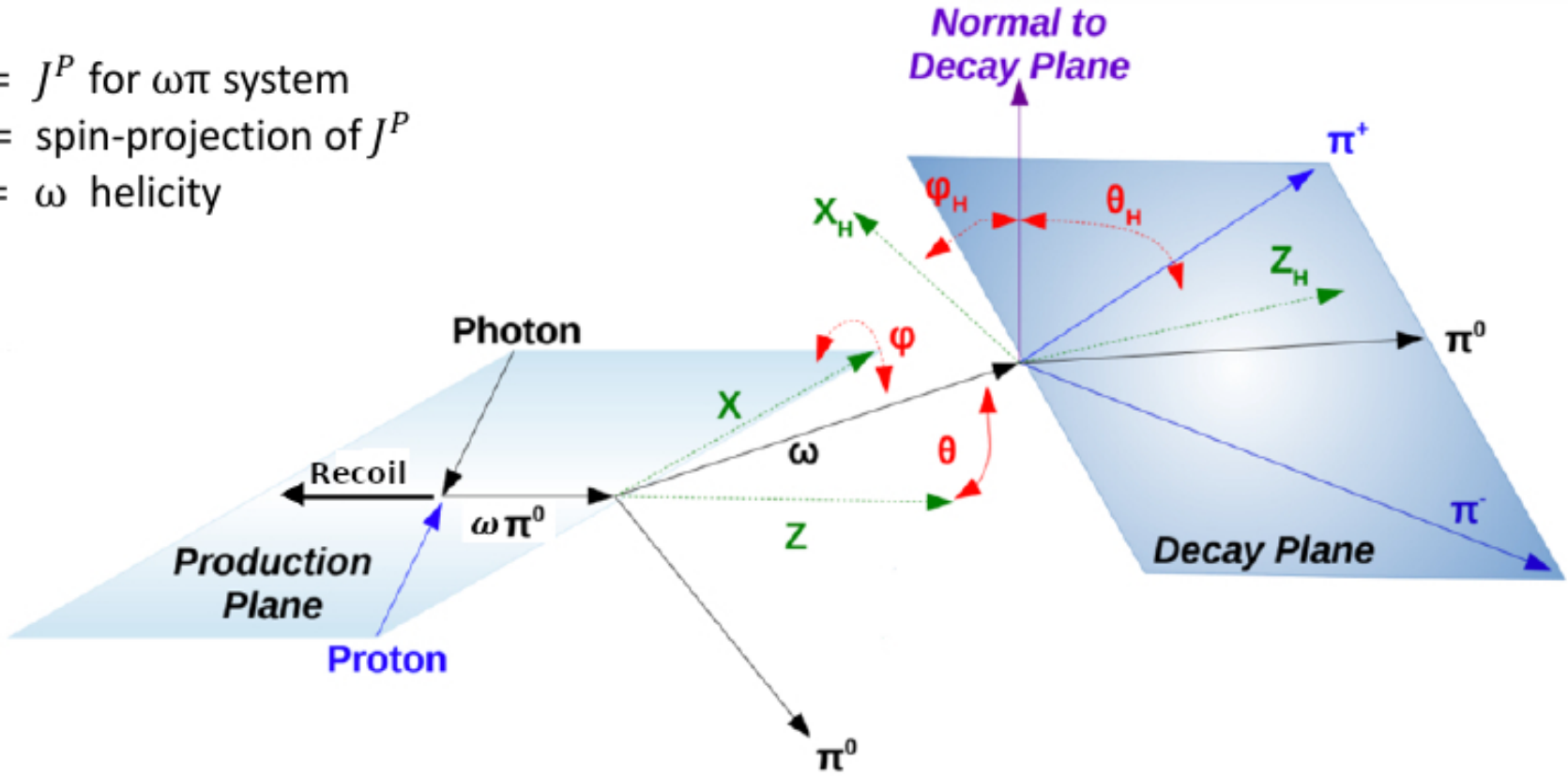
Amplitude Analysis

5-dimensional phasespace: $\Phi, \phi, \theta, \phi_H, \theta_H$

$$X^i_m(\Omega, \Omega_H) = \sum_{\lambda=-1,0,1} D^{J_i *}_{m,\lambda}(\Omega) F^i_\lambda D^{1*}_{\lambda,0}(\Omega_H) G$$



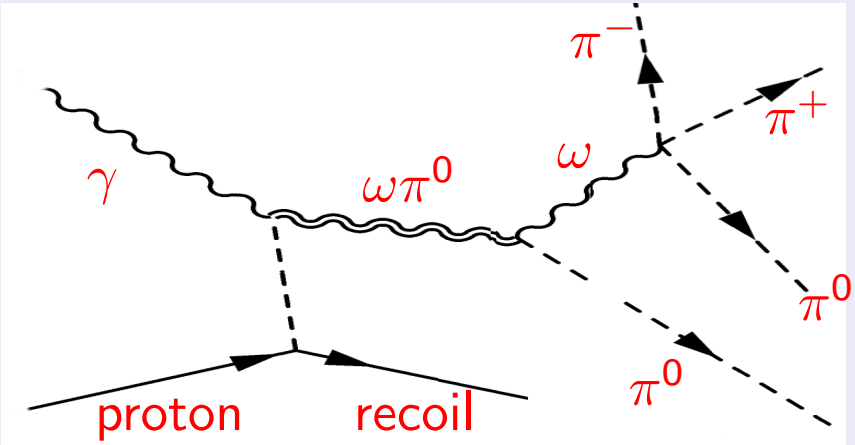
i = J^P for ωπ system
m = spin-projection of J^P
λ = ω helicity

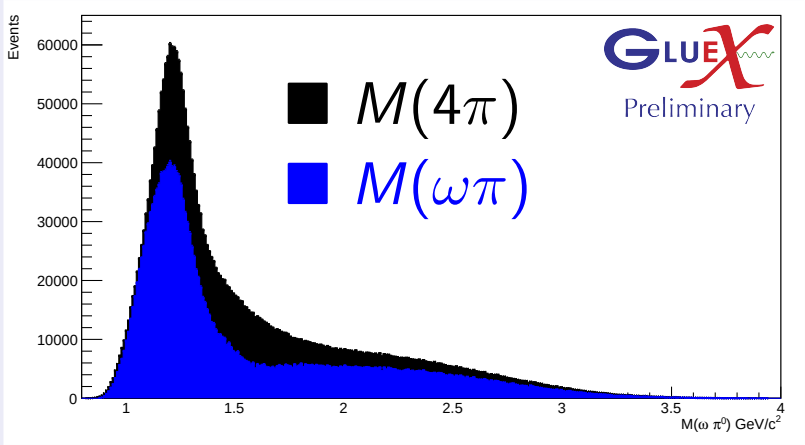


Close collaboration with JPAC (A. Szczepaniak and V. Mathieu) to develop and validate polarized amplitudes

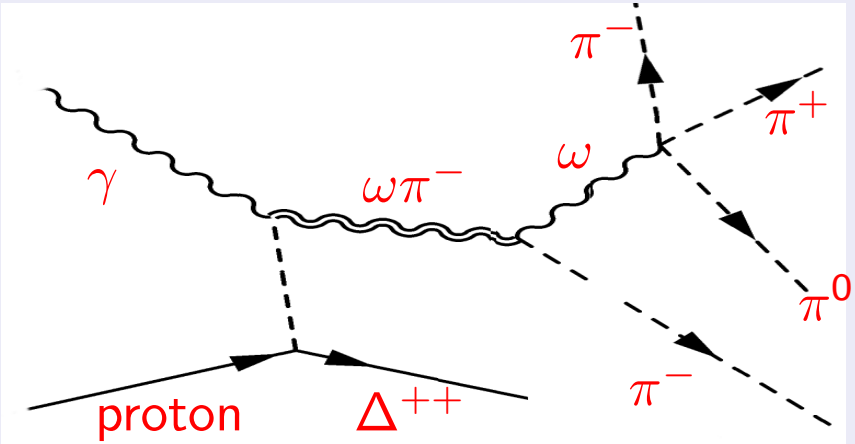
APS Tue, Apr 20th, Y12: Photo-Production of Hadrons III

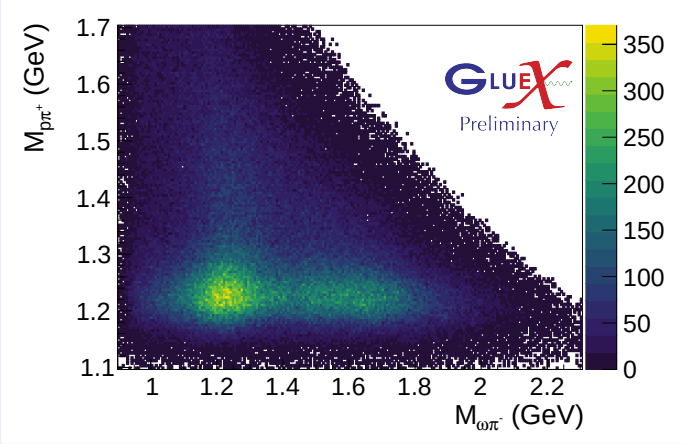
Karthik Suresh, $b_1(1235) \rightarrow \pi^+\pi^-\pi^0\pi^0$





Amy Schertz, $b_1^-(1235) \rightarrow \pi^+\pi^-\pi^0\pi^-$





Summary & Future Work

$\omega\pi^0$ Cross Section

- Differential cross sections of the $\omega\pi^0$ photoproduction indicate two production processes. $(0.25 < -t < 3.0\ GeV^2/c^2)$.
- Slopes close to previous measurements and improve their statistics.

Future Work

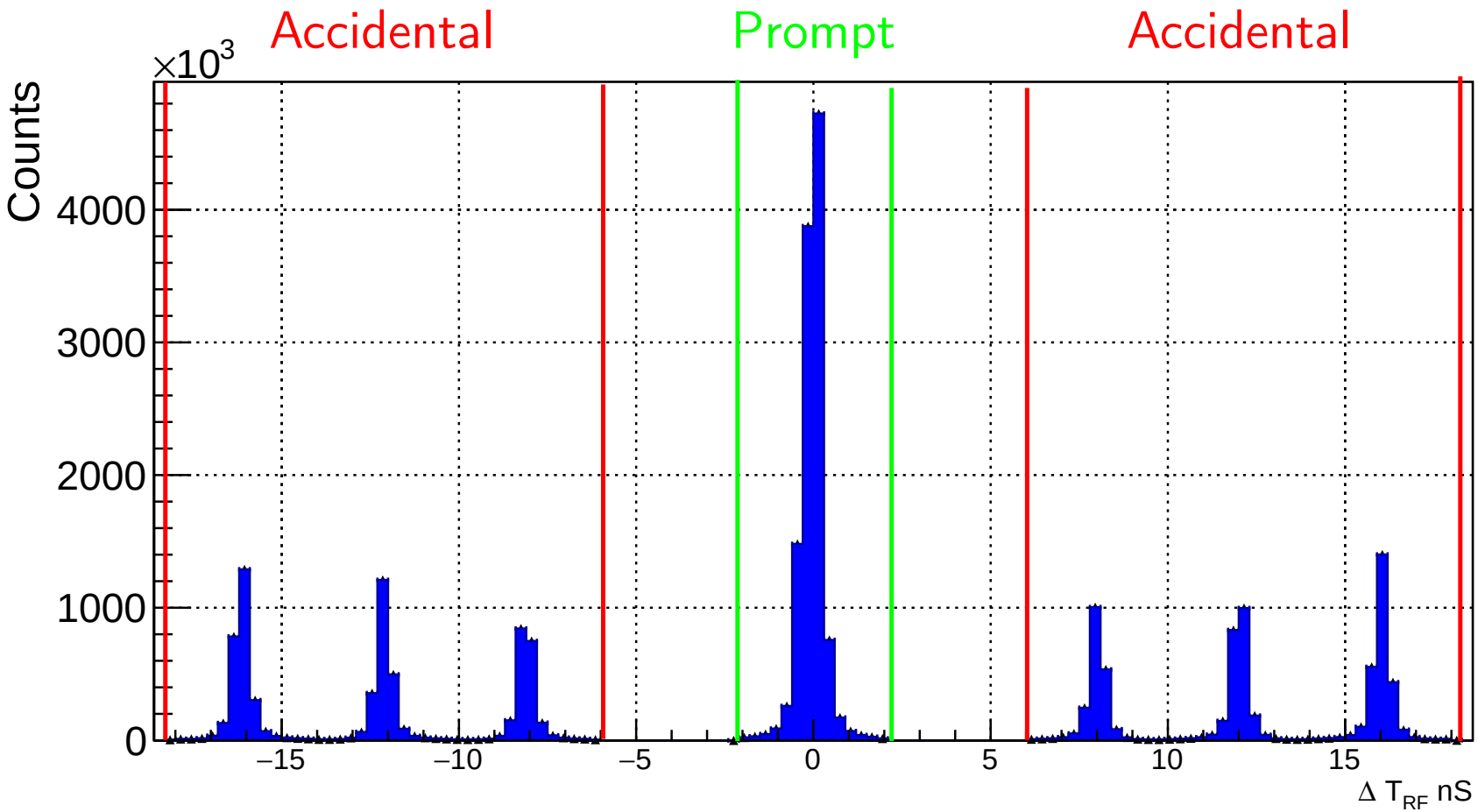
- Include 53% GlueX-I & GlueX-II data set to increase statistics.
- Systematic studies are underway.
- PWA of the $\omega\pi^0$ would allow extracting the $b_1(1235)$ total and differential cross section.

GlueX Acknowledgements:

gluex.org/thanks

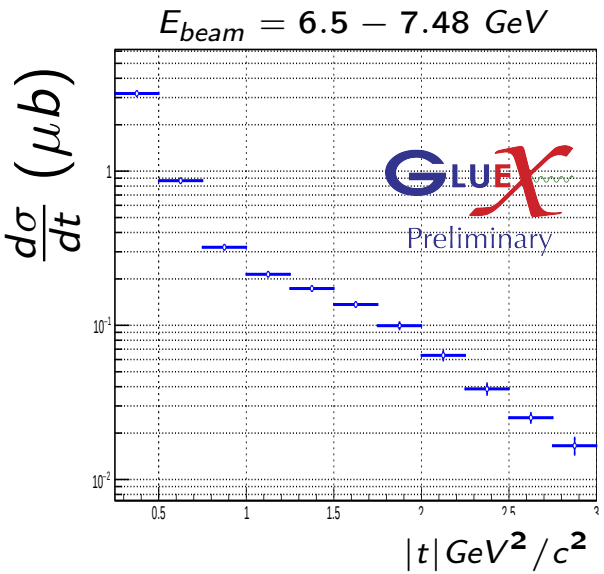
Backup

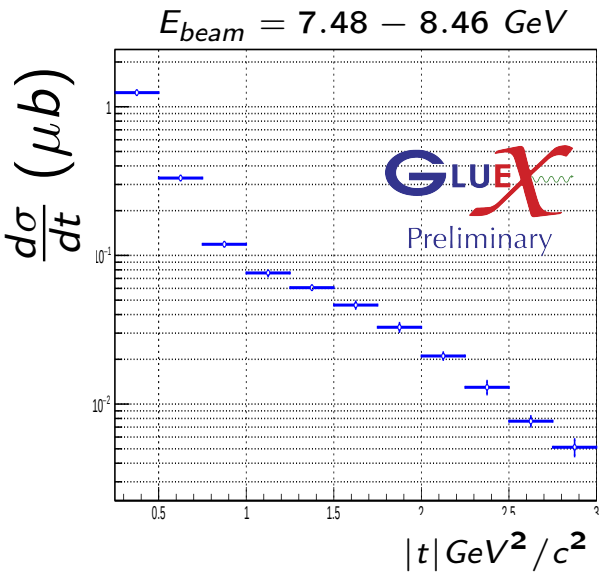
Accidental Subtraction



All distributions shown are 'accidental-subtracted'.

$\omega\pi^0$ Differential Cross Section





Slope change

at $|t| \sim 1 GeV^2/c^2$