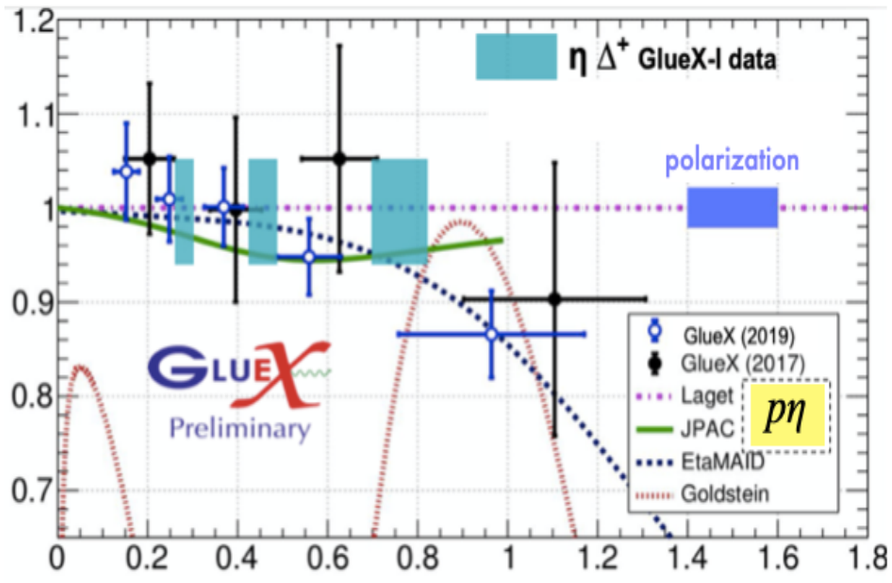
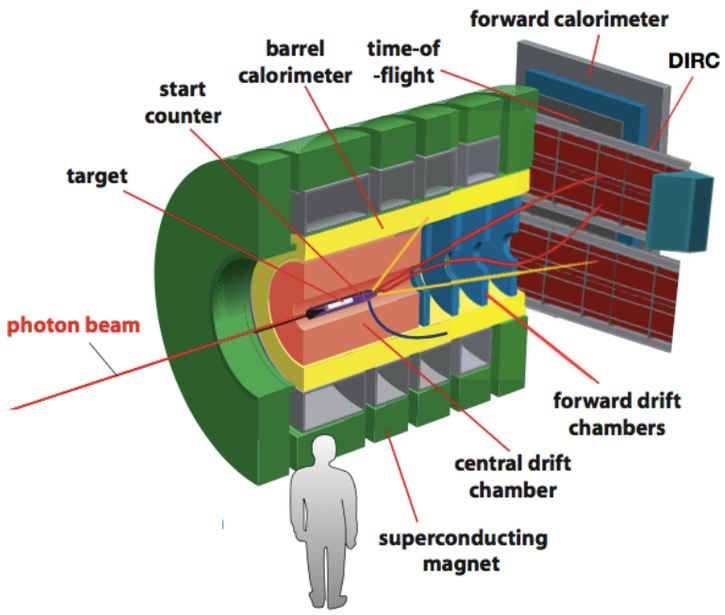
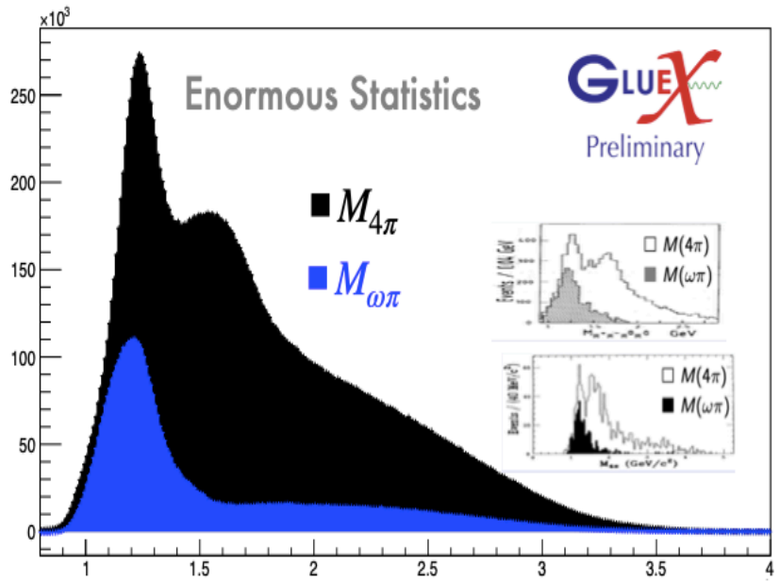






Light Exotic Mesons in the GlueX Experiment

Z. Papandreou, V. Neelamana, A. Foda

CAP Congress, June 9, 2021

University of Regina | Faculty of Science

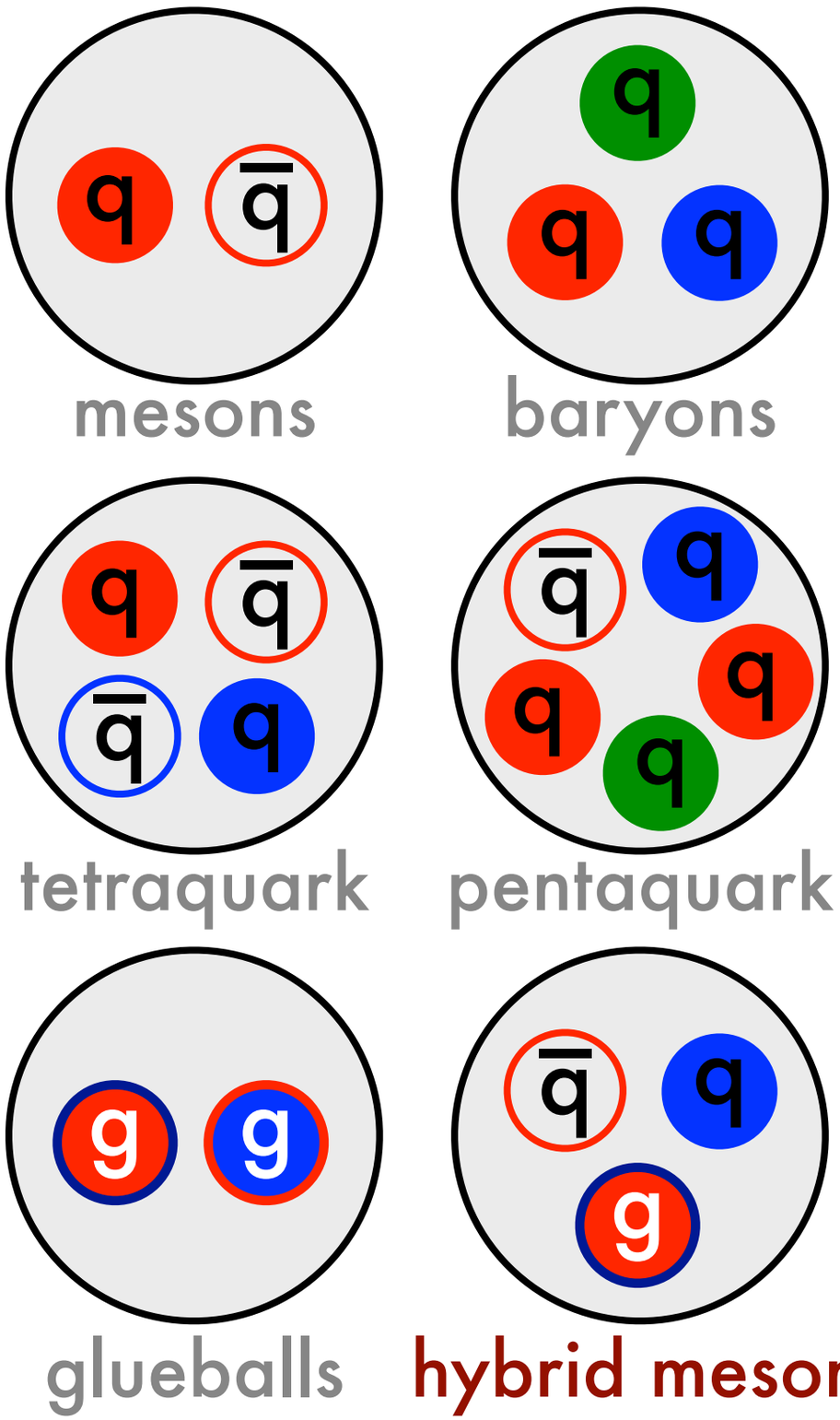
Physics Motivation

Beam Asymmetry

The Experiment

Cross Sections

Confined States of Quarks and Gluons



QCD predicts more types of states than just mesons & baryons

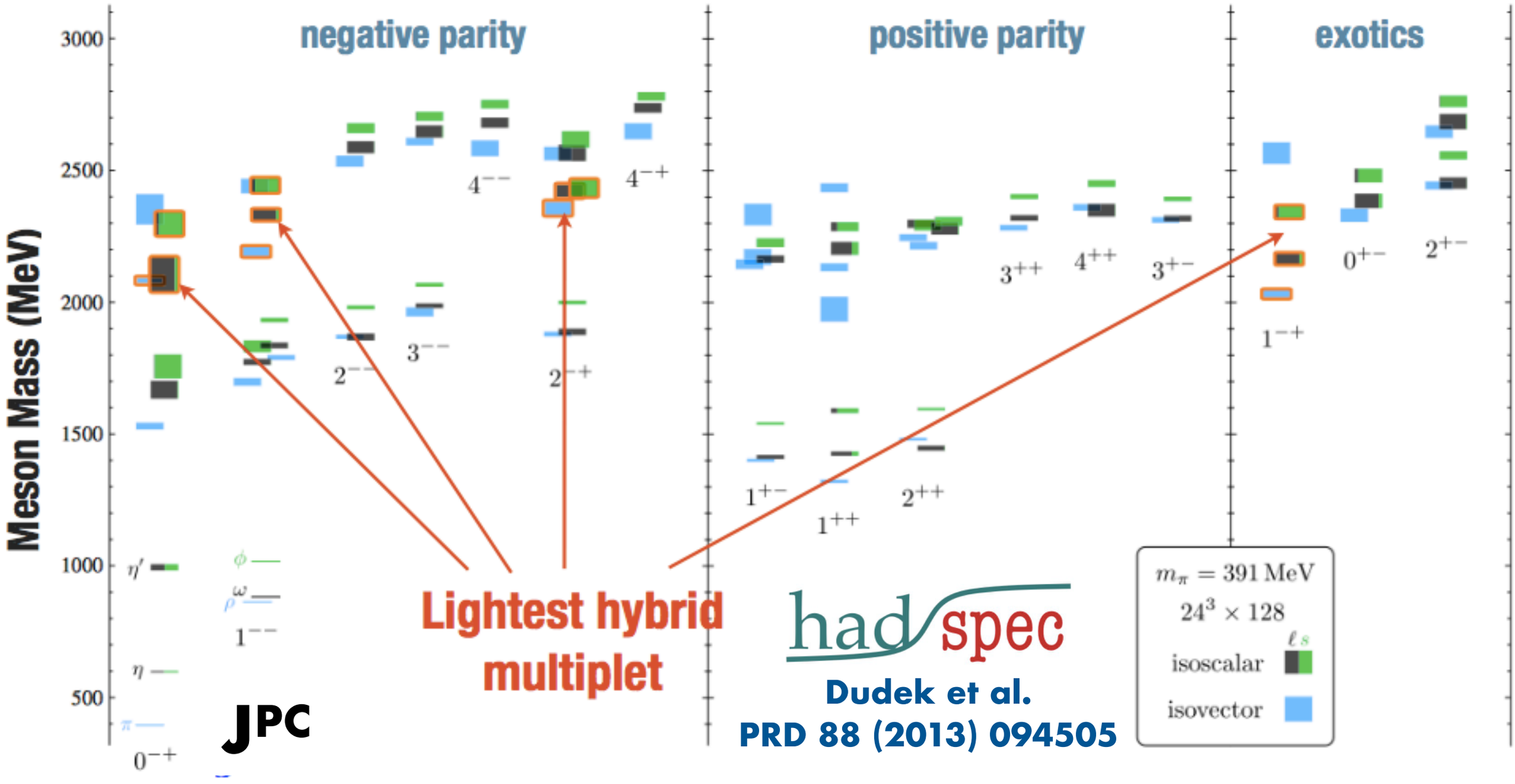
A SCHEMATIC MODEL OF BARYONS AND MESONS *

M. GELL-MANN
California Institute of Technology, Pasadena, California

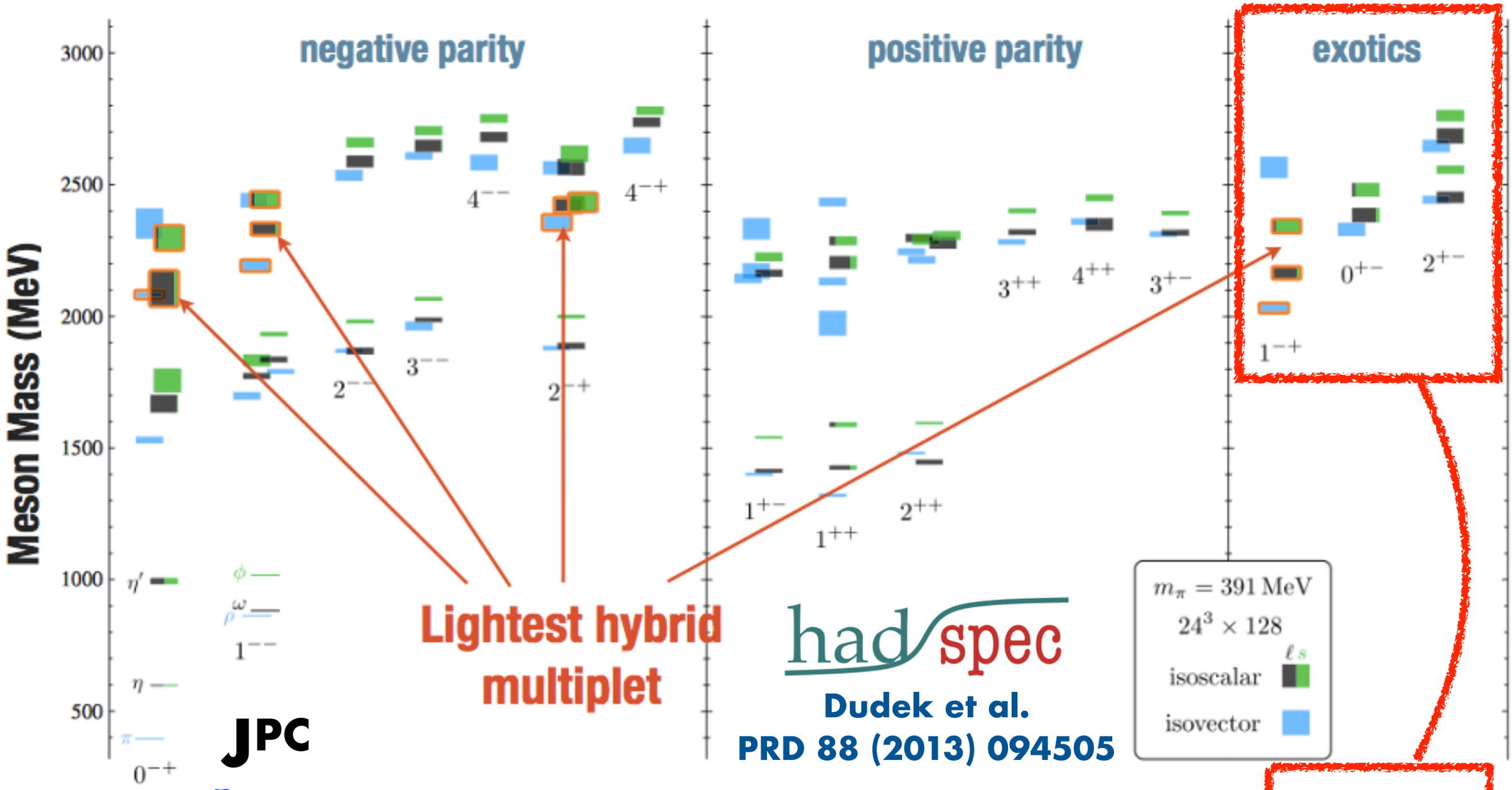
... Baryons can now be constructed from quarks by using the combinations $(q\,q\,q)$, $(q\,q\,q\,q\,\bar{q})$, etc., while mesons are made out of $(q\,\bar{q})$, $(q\,q\,\bar{q}\,\bar{q})$, etc. ... **Phys.Let.8 (1964) 214**

Can we observe explicit gluonic degrees of freedom in nature's bound states?

LQCD Full Spectrum



LQCD Full Spectrum

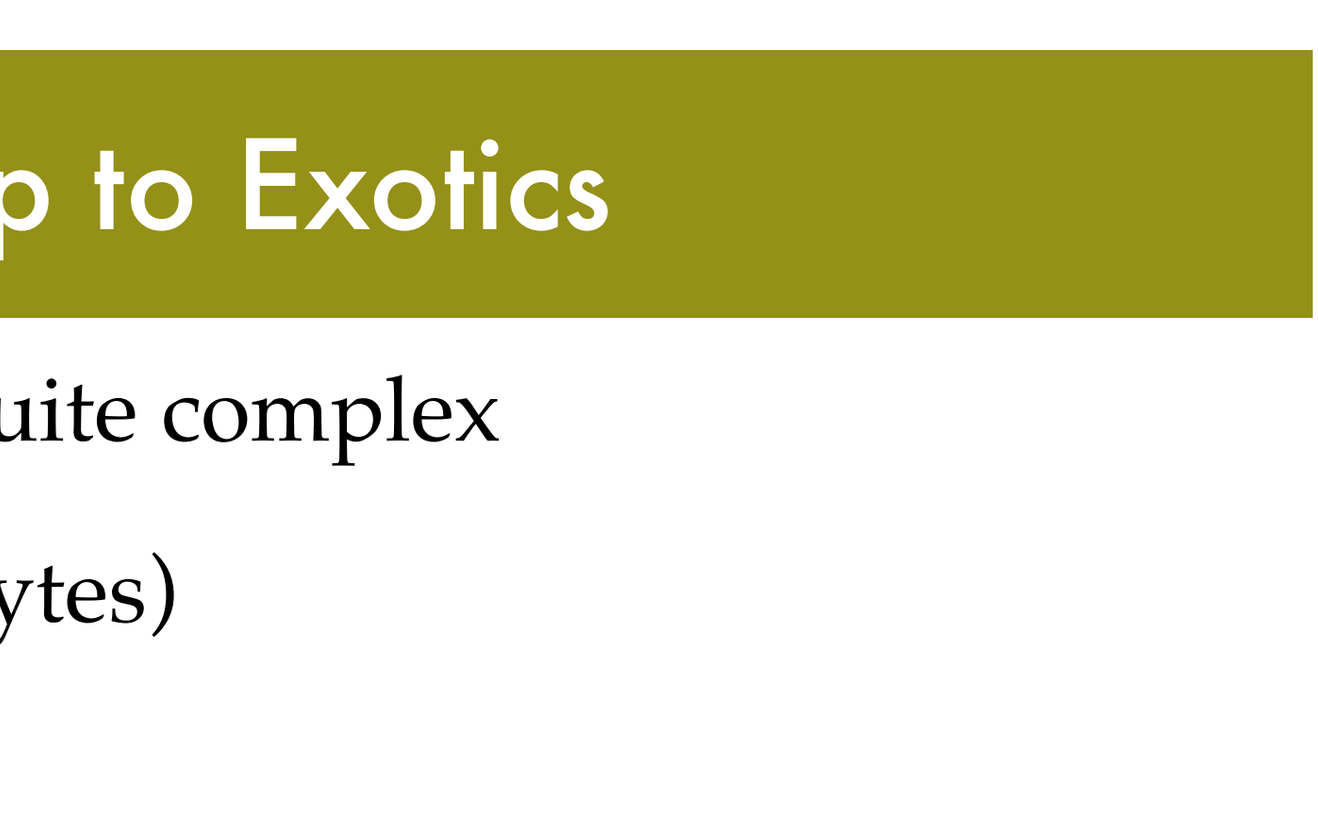


GlueX goal: look for hybrid patterns incl. exotics

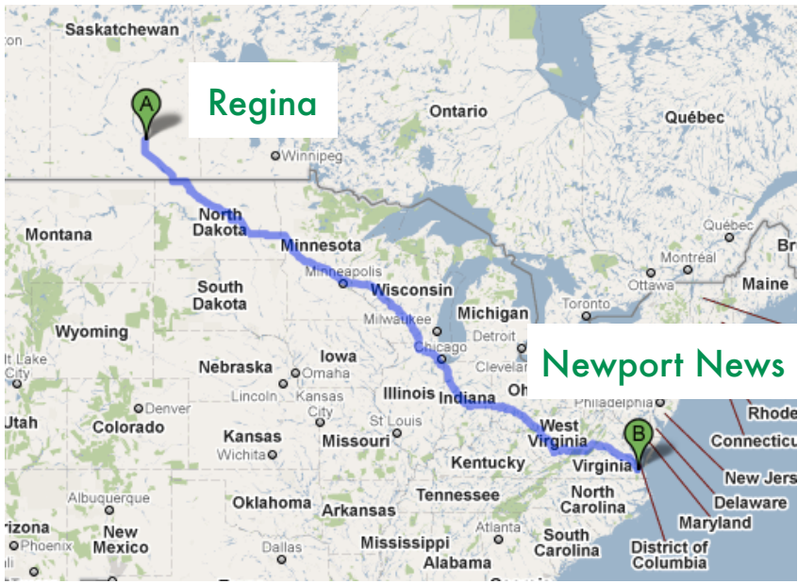
Roadmap to Exotics

- The path to exotics is quite complex
- Data processing (petabytes)
- **Roadmap** includes:

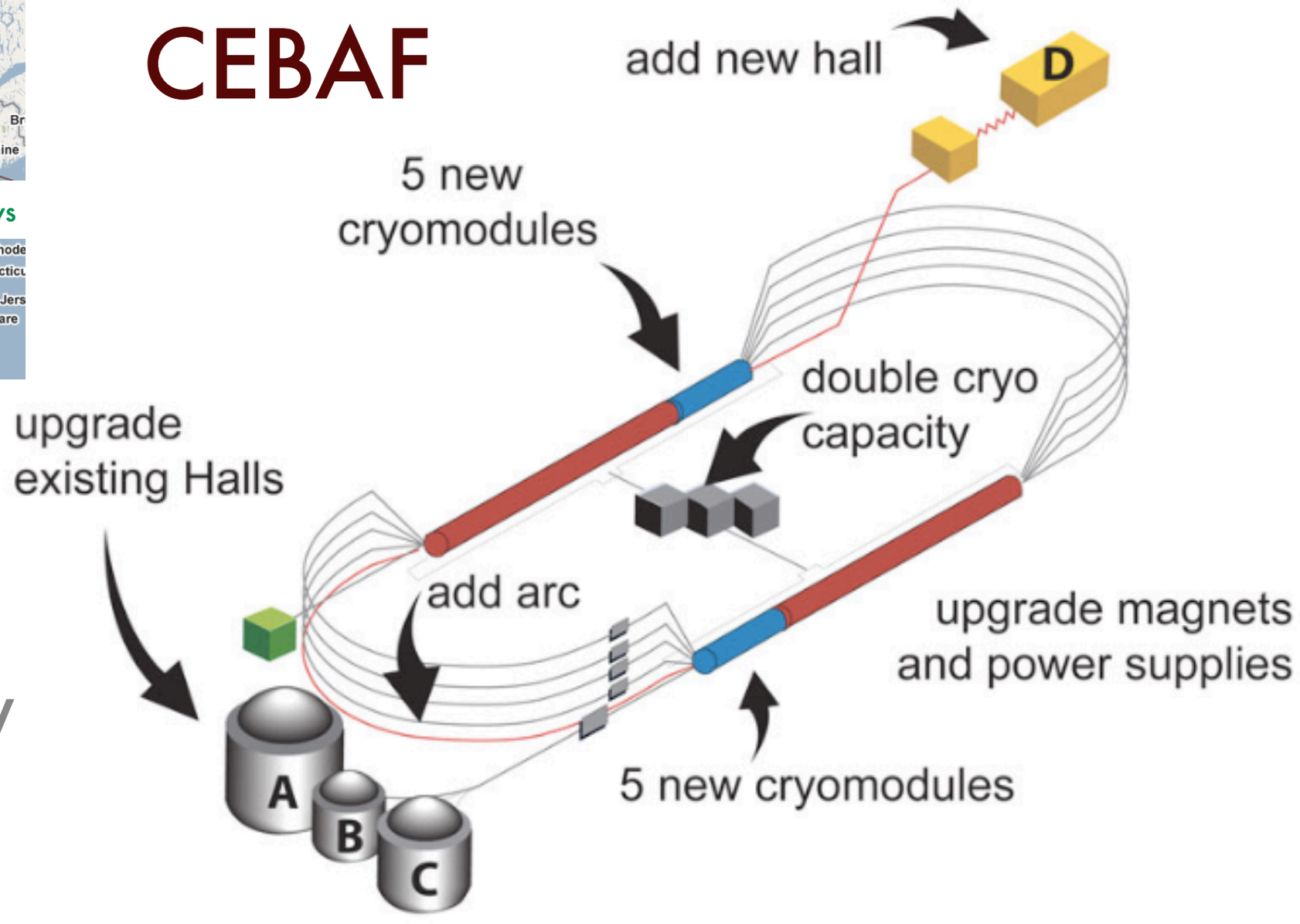
1. Beam Asymmetries
2. Detector Acceptance
3. Extraction of SDMEs
4. Cross Sections
5. Partial waves



Jefferson Lab

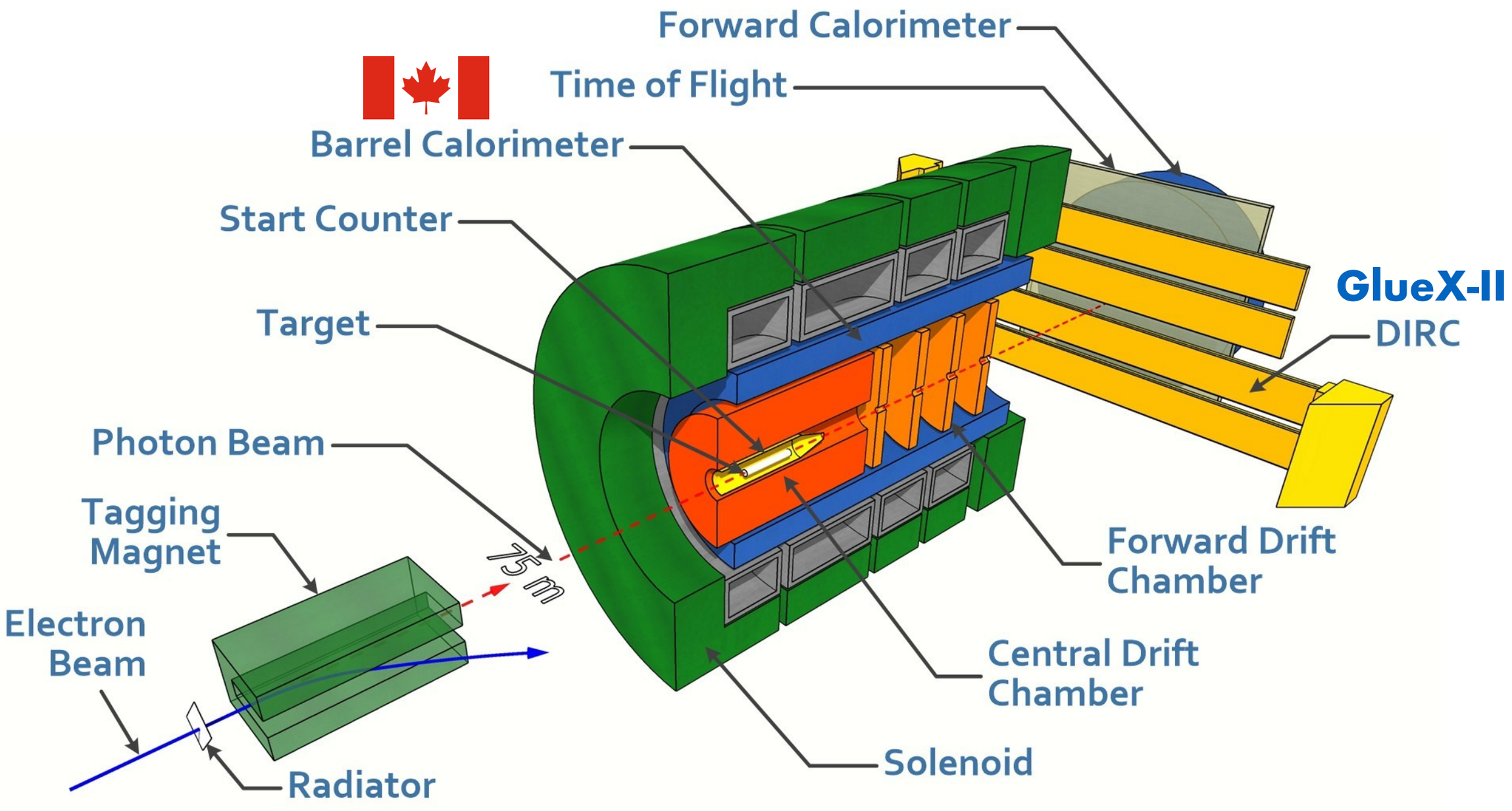


CEBAF



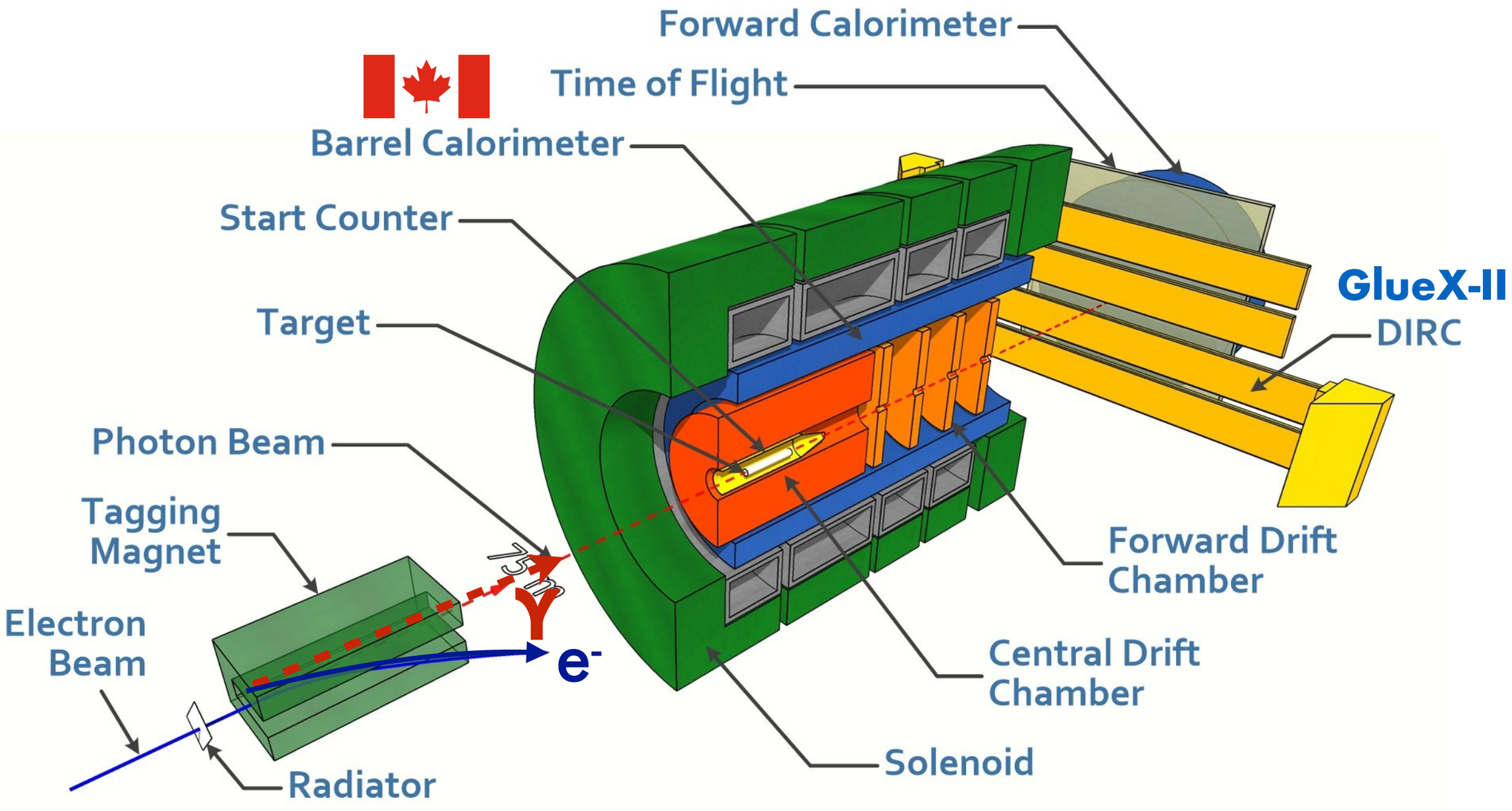
Upgraded: 12 GeV
4th Hall: GlueX

The GlueX Experiment



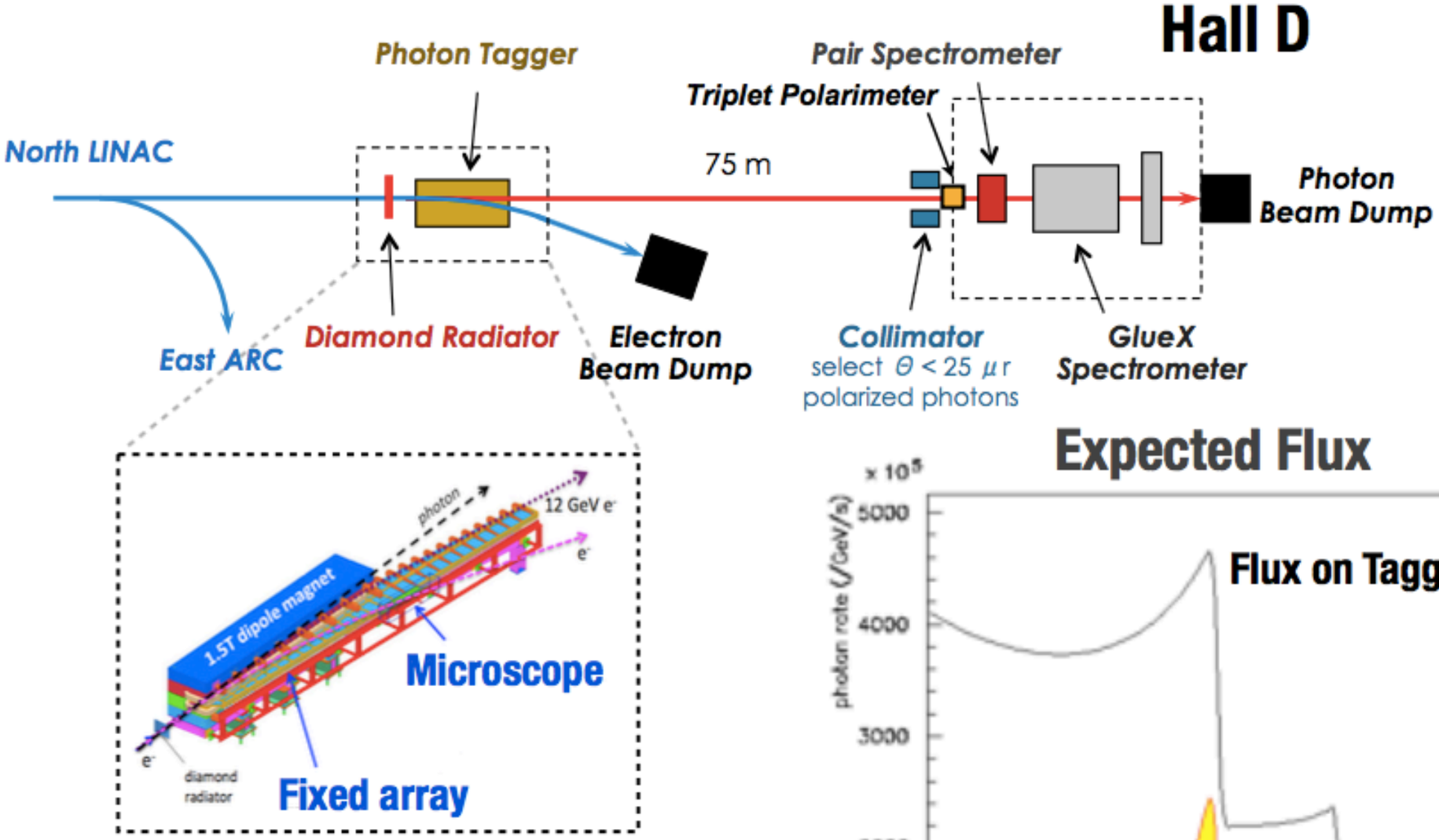
$E_\gamma = 6\text{-}12$ GeV

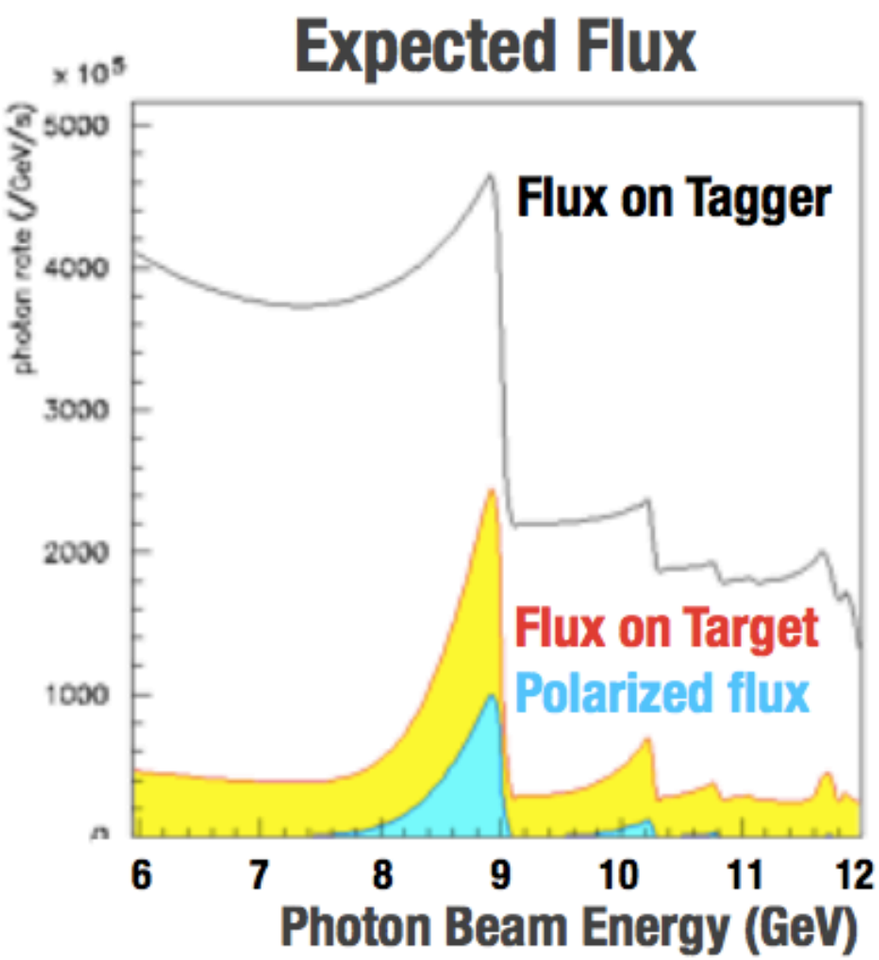
The GlueX Experiment



E_γ = 6-12 GeV

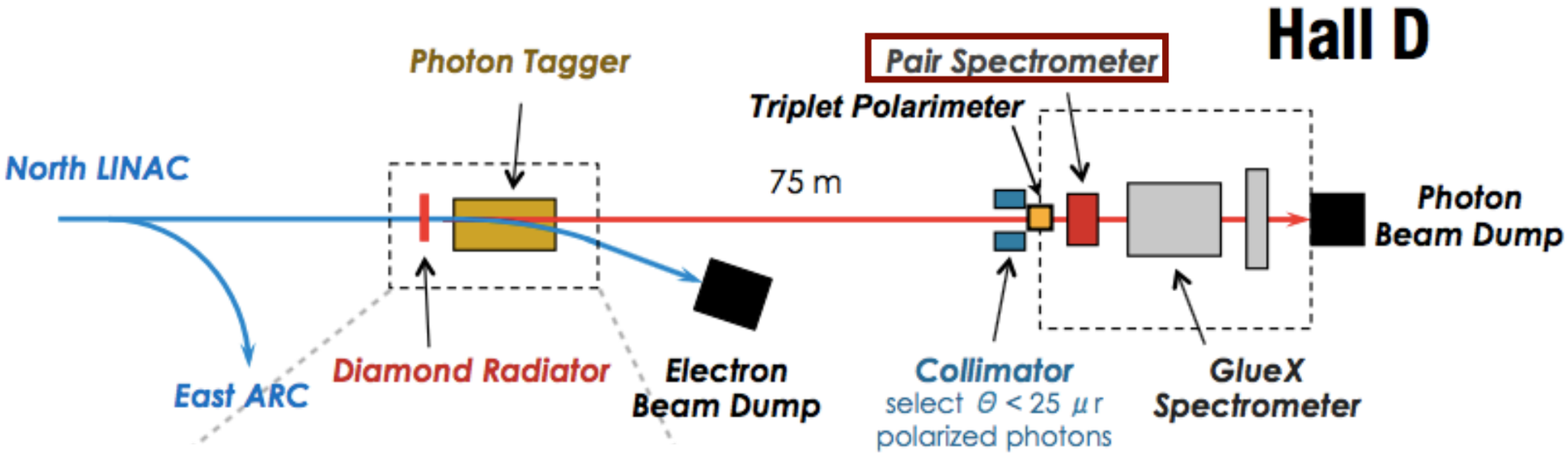
The Photon Beam



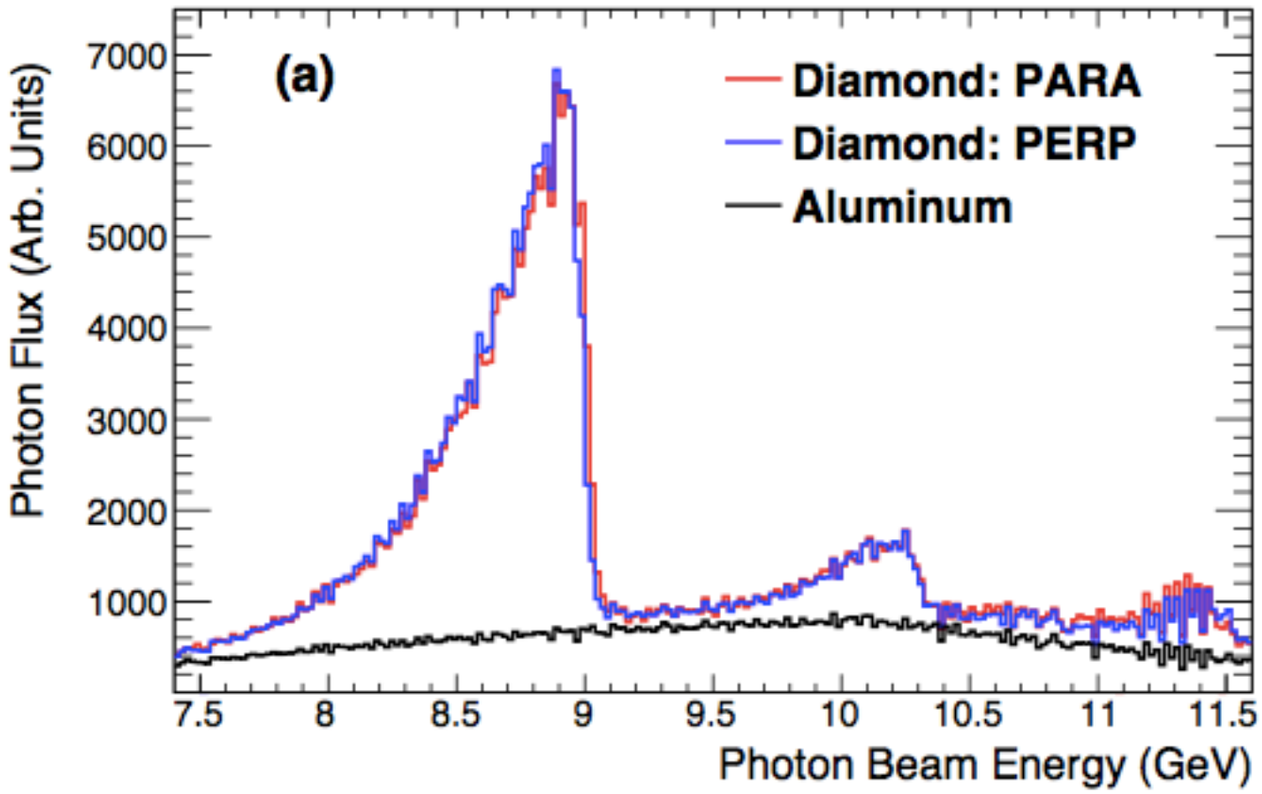


- Linearly polarized photons via coherent bremsstrahlung from diamond radiator
- Design intensity of 10^8 γ/s in coherent peak between E_γ = 8.4 and 9 GeV

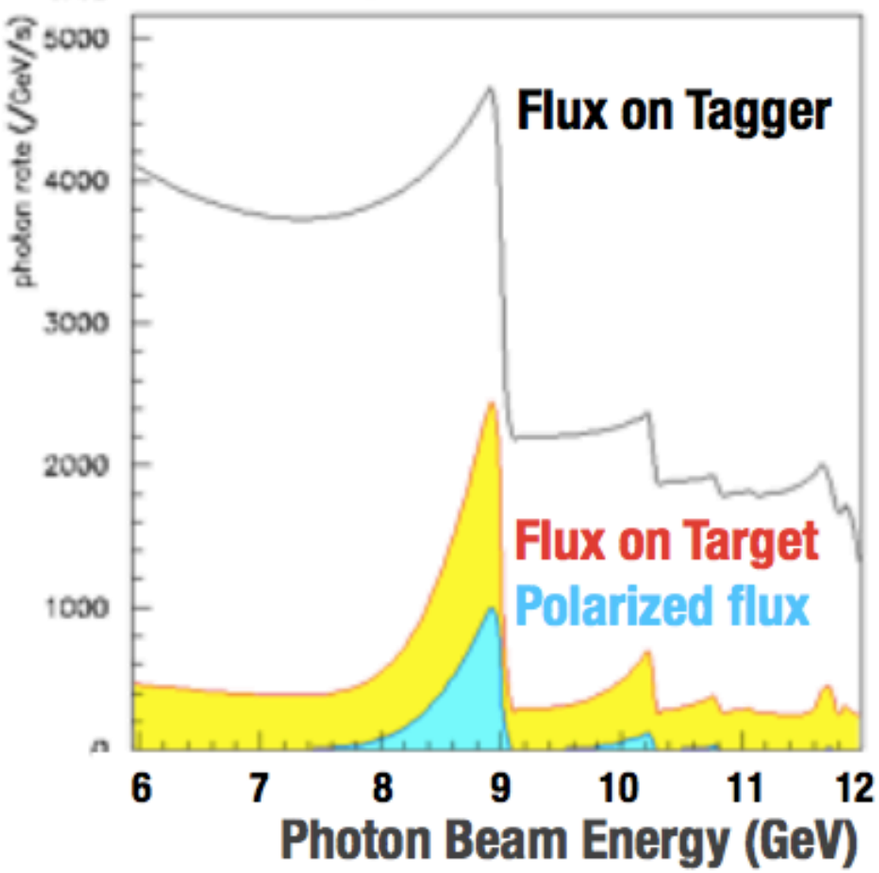
The Photon Beam



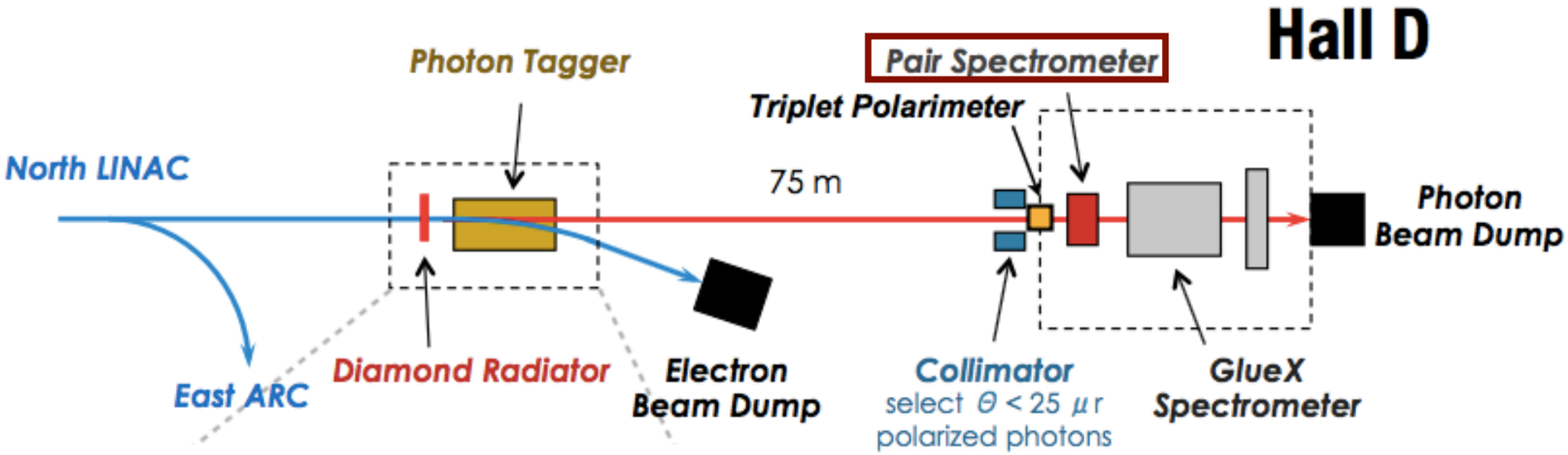
Measured Flux



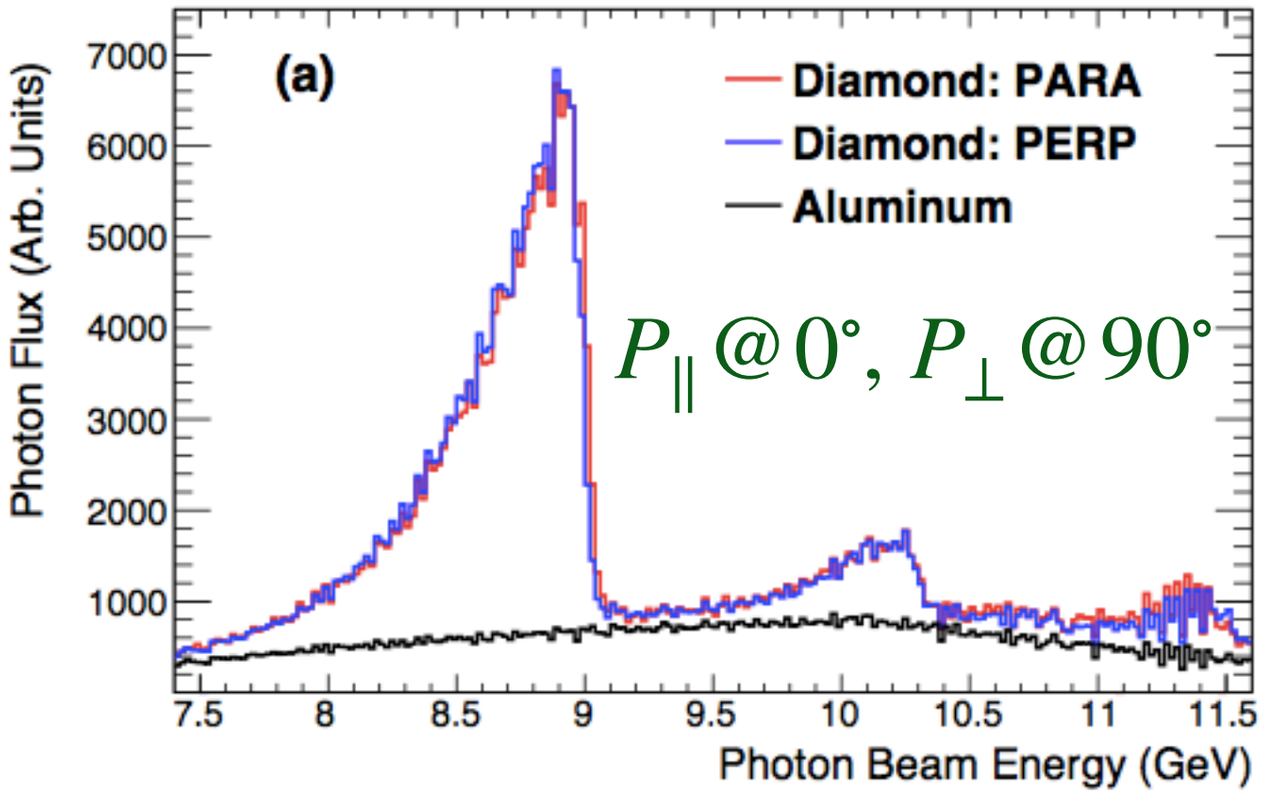
Expected Flux



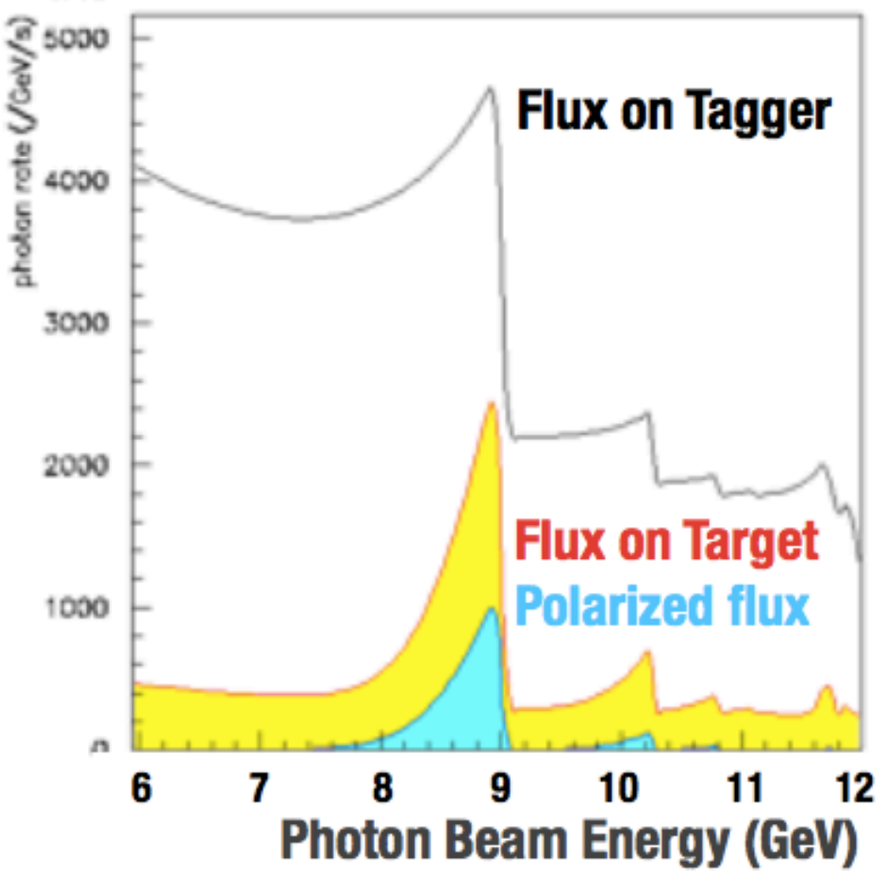
The Photon Beam



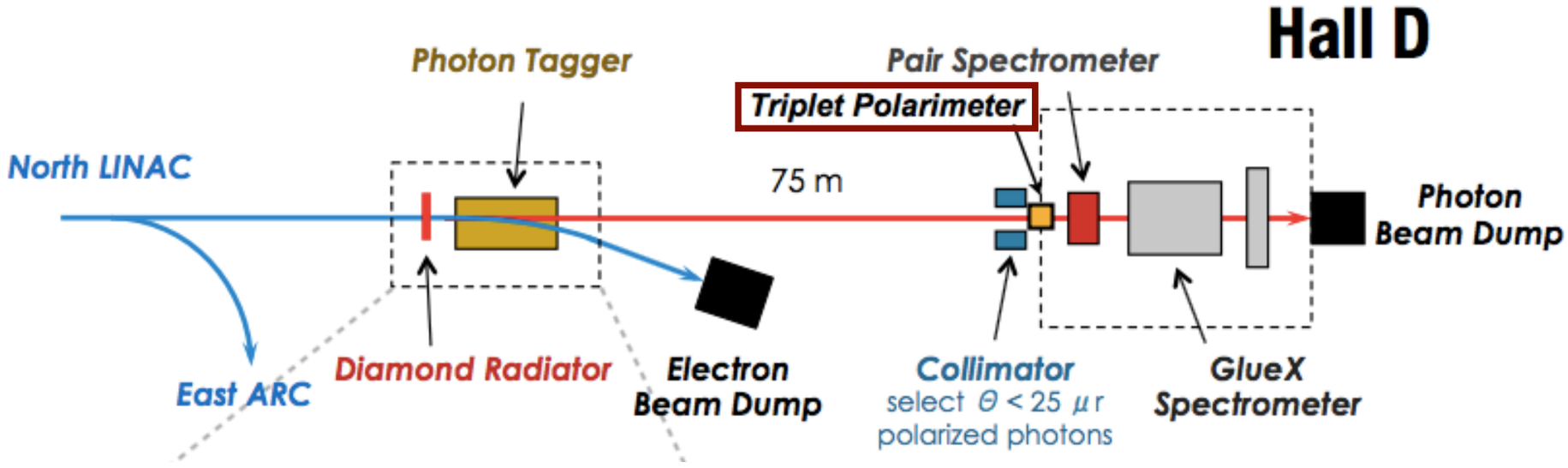
Measured Flux



Expected Flux



The Photon Beam



- **Triplet production**

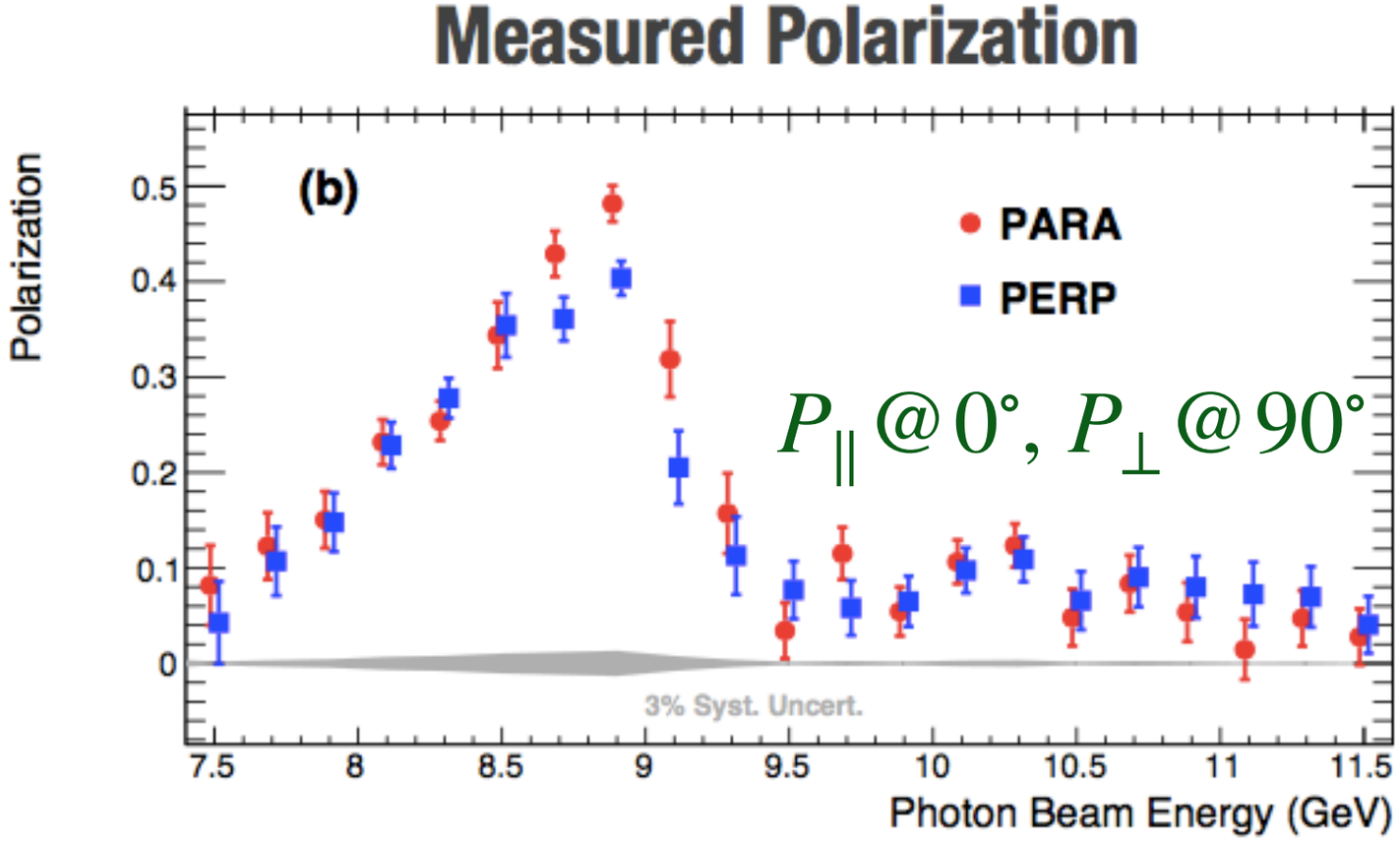
$$\gamma e^- \rightarrow e^- e^+ e^-$$

  - Known analyzing power

$$d\sigma \sim 1 \pm P\Sigma cos(2\phi_{e^-})$$

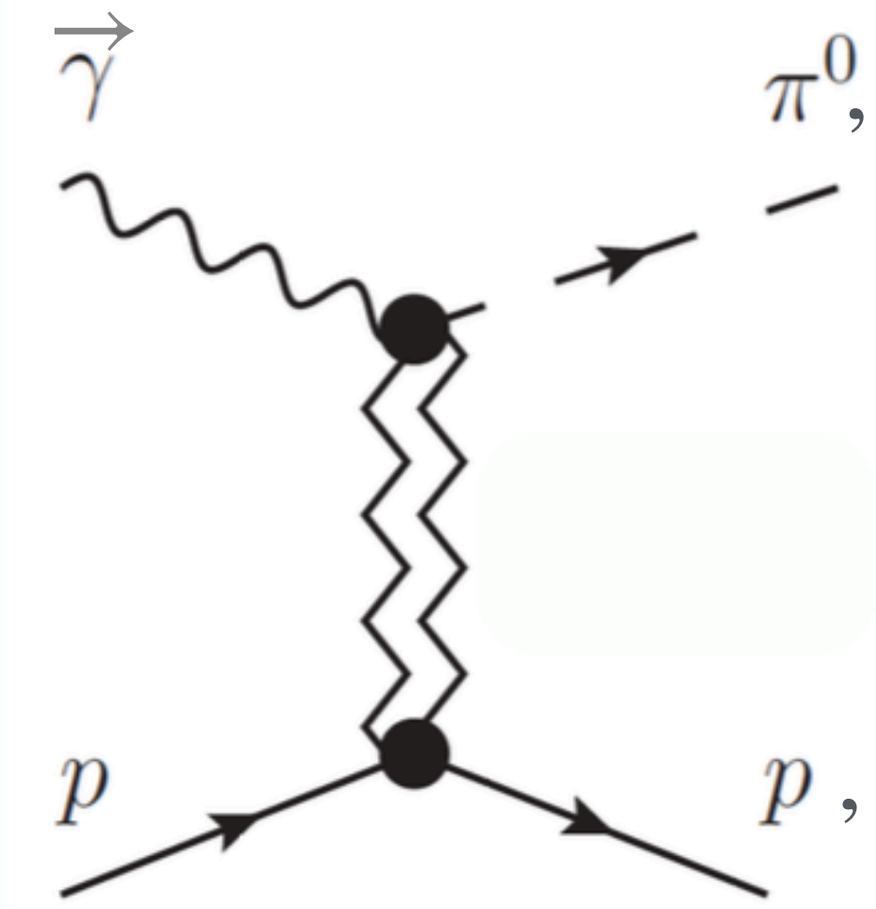
  - Measure beam polarization independent of spectrometer

arXiv:1703.07875



Reaction Mechanism

linear polarization



Exchange J^{PC}

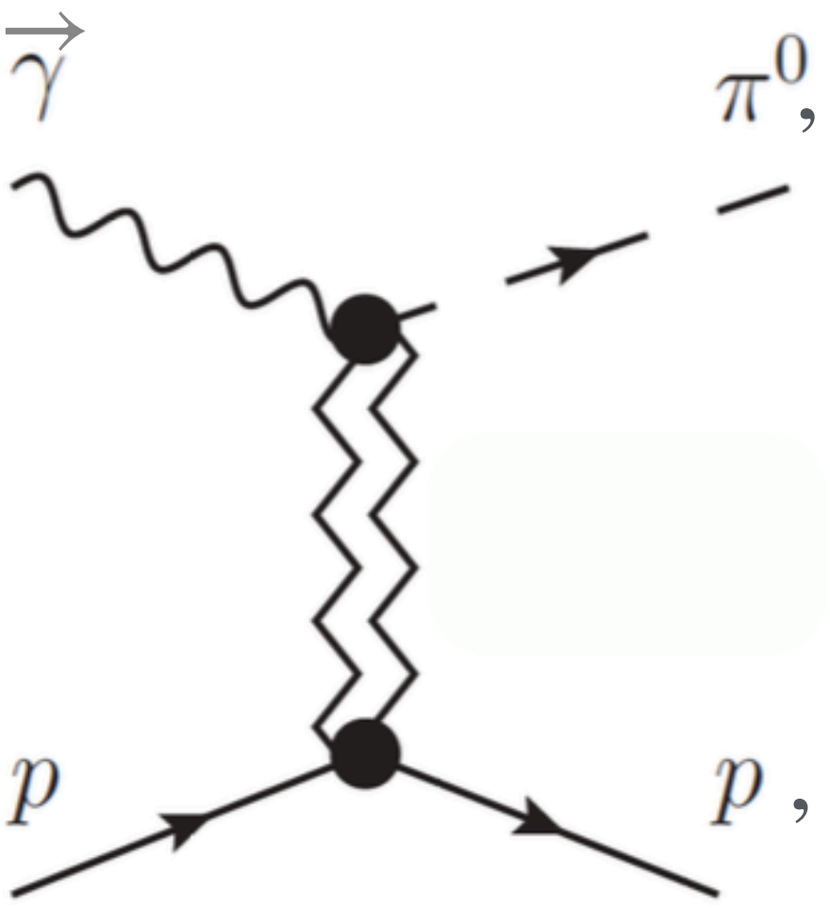
$1^{--} : \omega, \rho$ natural, $\Sigma = +1$

$1^{+-} : b, h$ unnatural, $\Sigma = -1$

- Photon beam polarization filters the "naturality" of the exchange particle
- Reaction mechanism knowledge needed for PWA
- **Beam Asymmetry, Σ**: "low-hanging fruit"; detector acceptance cancels

Reaction Mechanism

linear polarization



- Photon beam polarization filters the "naturality" of the exchange particle
- Reaction mechanism knowledge needed for PWA
- **Beam Asymmetry, Σ**: "low-hanging fruit"; detector acceptance cancels

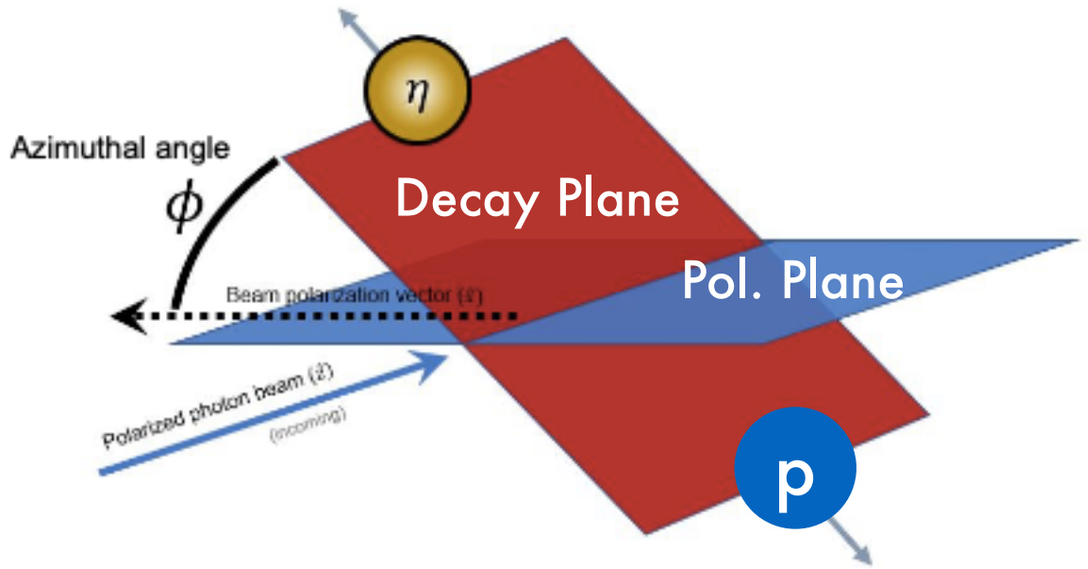
Beam Asymmetry, Σ

Direct-Fit Method $\vec{\gamma}p \rightarrow p(\pi^0, \eta, \eta')$

pure sample of events, fit $\cos(2\Delta\phi)$ distribution

$$\frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel)\Sigma cos(2(\phi - \phi_0))}{2 - (P_\perp + P_\parallel)\Sigma cos(2(\phi - \phi_0))}$$

$P_{\perp,\parallel}$ polarization values 0°/90°, -45°/45°, F_R - flux ratio



Phys. Rev. C95, 042201(R) (2017) Phys. Rev. C100, 052201(R) (2019)

Beam Asymmetry, Σ

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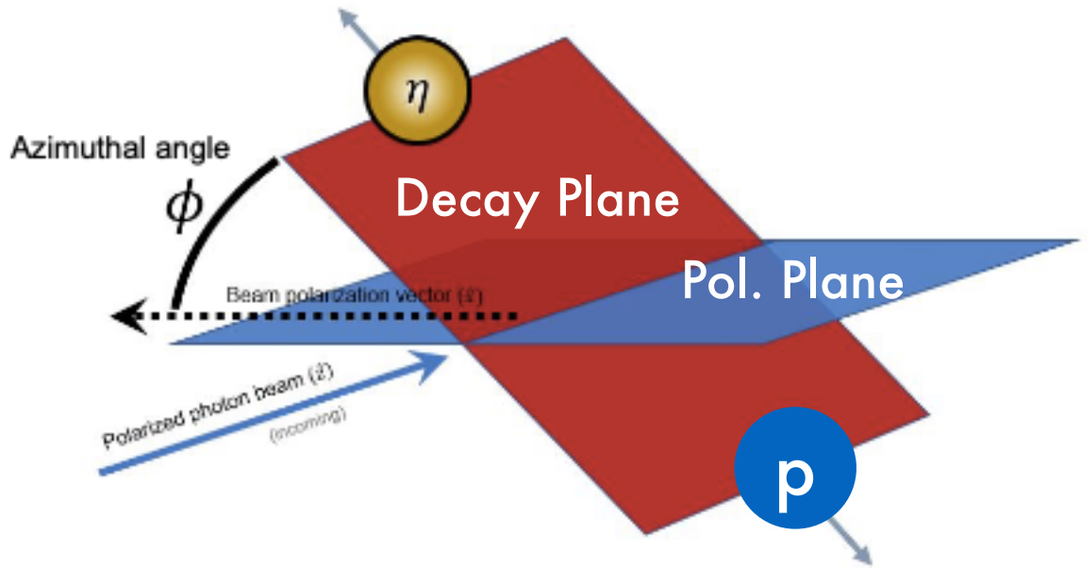


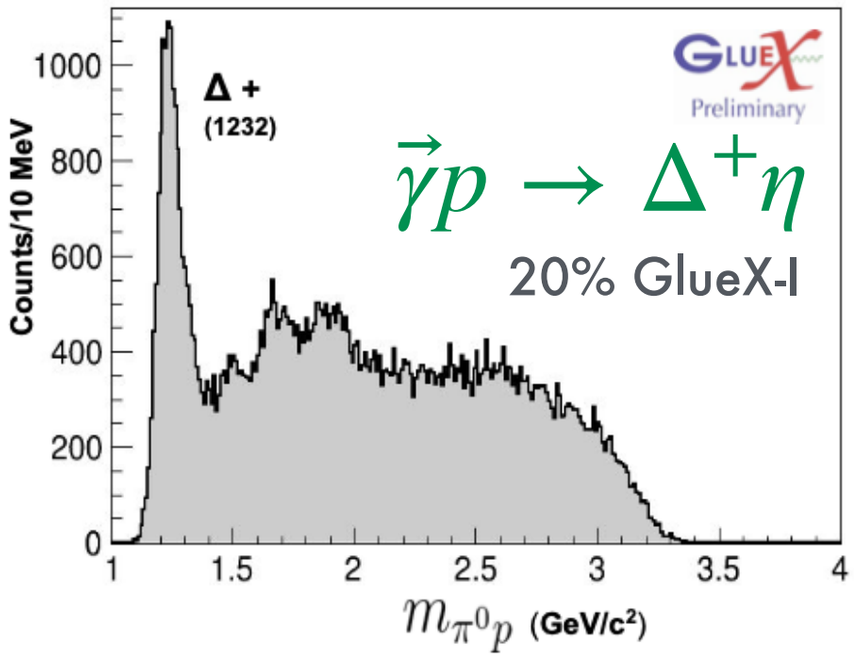
Phys. Rev. C95, 042201(R) (2017) Phys. Rev. C100, 052201(R) (2019)

Moment-Yield Method $\vec{\gamma}p \rightarrow \Delta^{++}\pi^-$

project the cos(2Δϕ) component, then isolate the Δ++ contribution by its known line shape

$$\Sigma = \frac{Y_2^\perp - Y_2^\parallel}{\frac{P_\parallel}{2}(Y_0^\perp + Y_4^\perp) + \frac{P_\perp}{2}(Y_0^\parallel + Y_4^\parallel)}$$

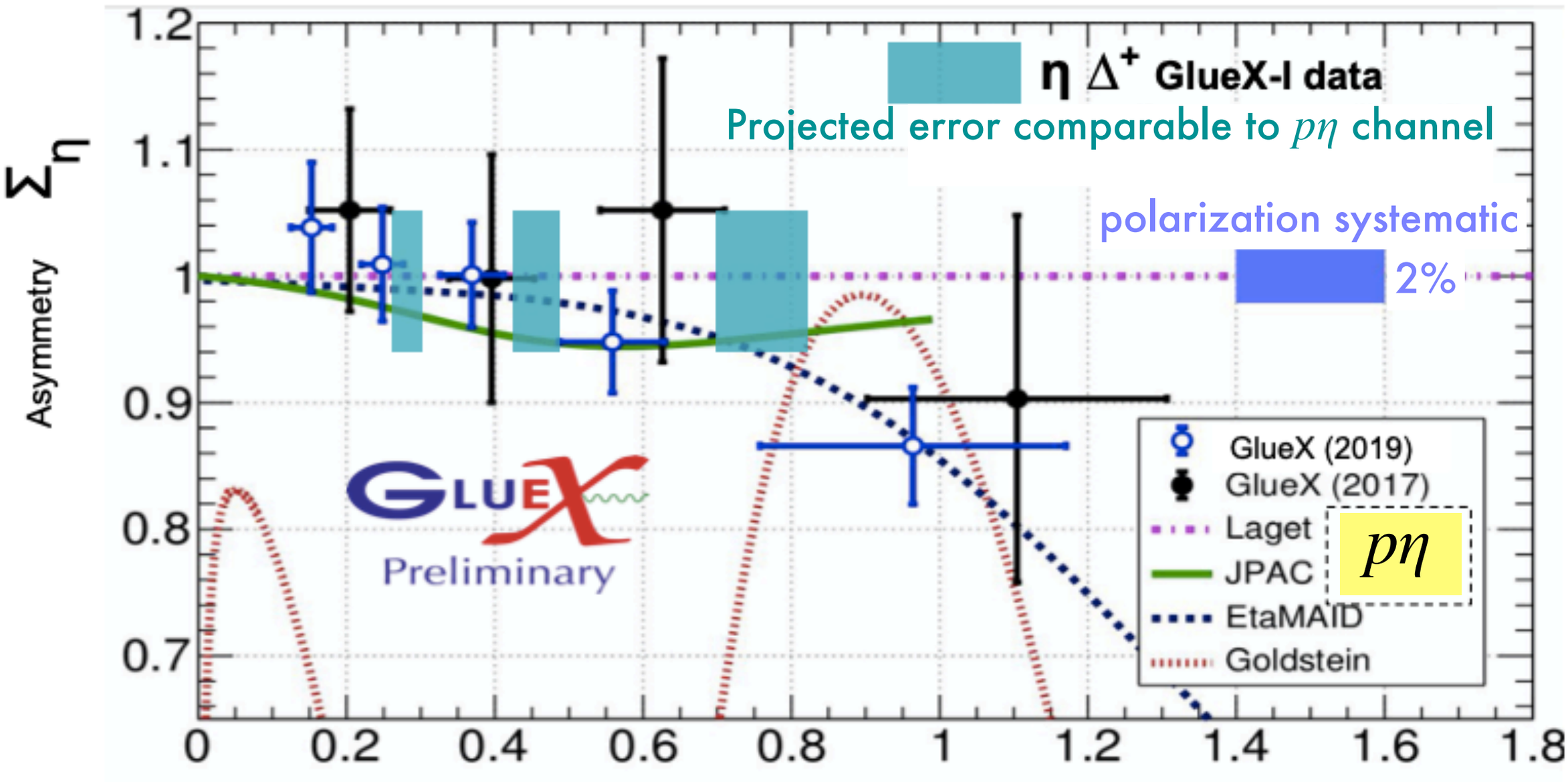
$Y_n^{\perp,\parallel}$ yields from moment-weighted cos(nϕ) histos, n=0,2,4..



Phys. Rev. C 103, L022201 (2021)

Projected ΔΣ

Reaction is dominantly natural, $\Sigma_\eta \approx 1$



Phys. Rev. C100, 052201(R) (2019)

Phys. Rev. C95, 042201(R) (2017)

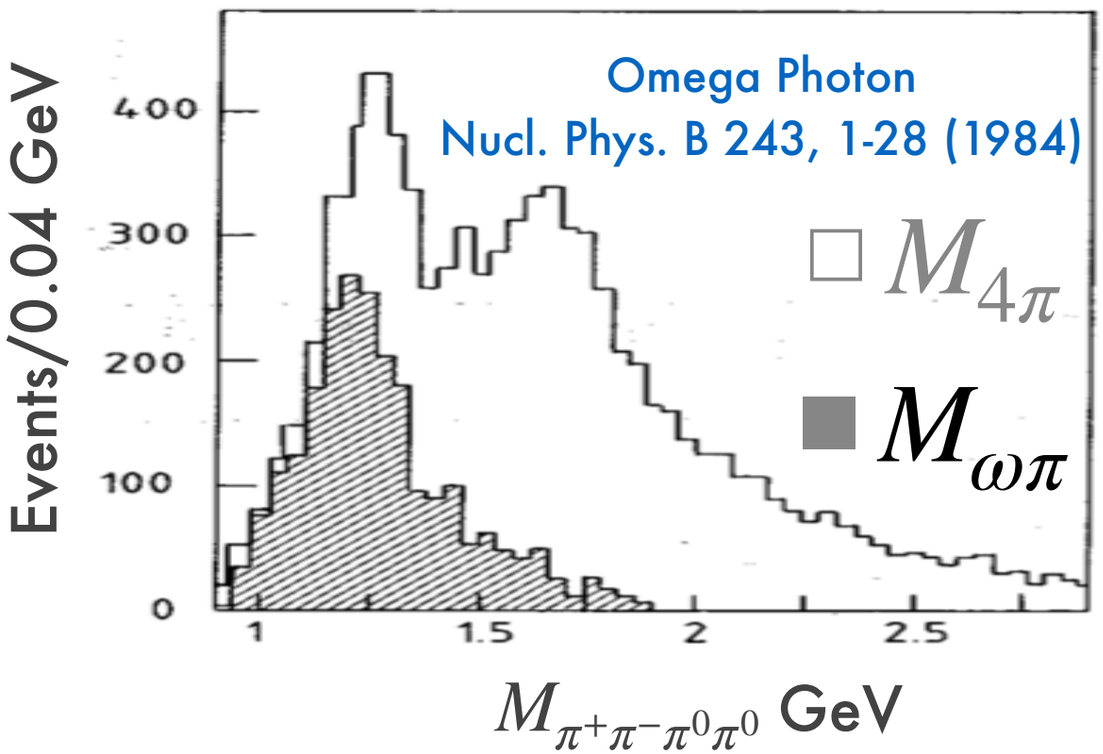
b_1 meson ($\omega\pi$ spectra)

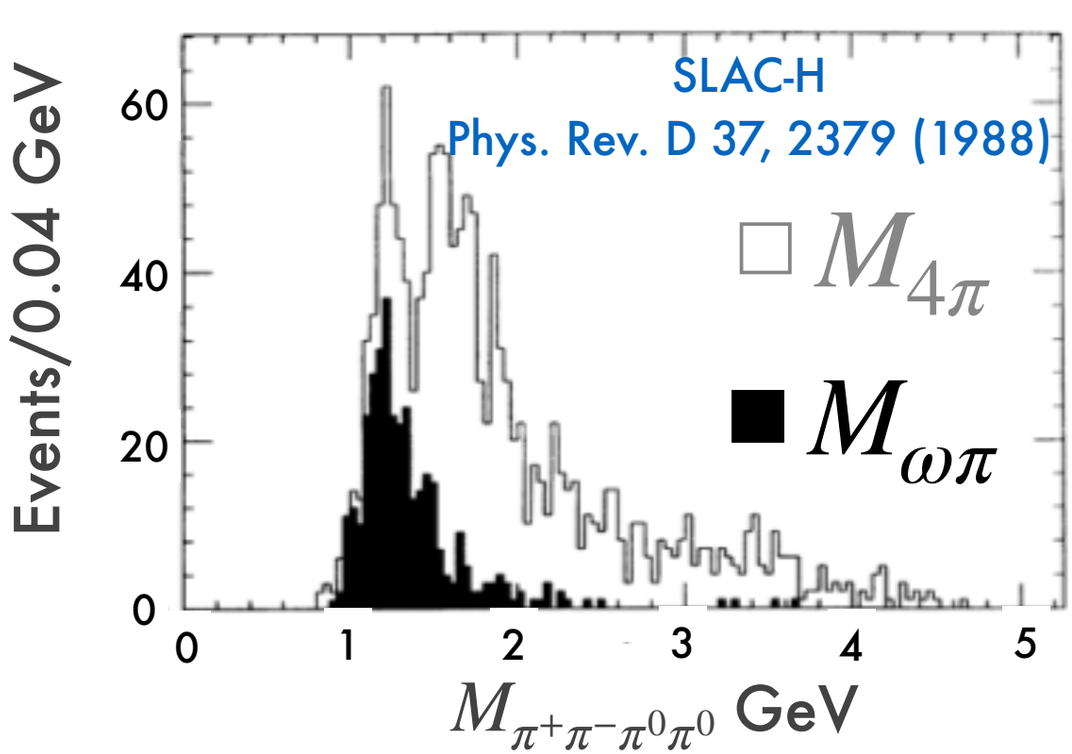
Exotics $\pi_1(1600)^a$, $\pi_1(2015)^b$, h_0, b_2 could potentially decay to $b_1\pi$ which decays dominantly through $b_1 \to \omega\pi$. Precise measurement of the π_1 requires understanding the decay of the b_1 meson.

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

$$\gamma p \to p b_1 \to p(\omega)\pi^0 \to p(\pi^+\pi^-\pi^0)\pi^0$$

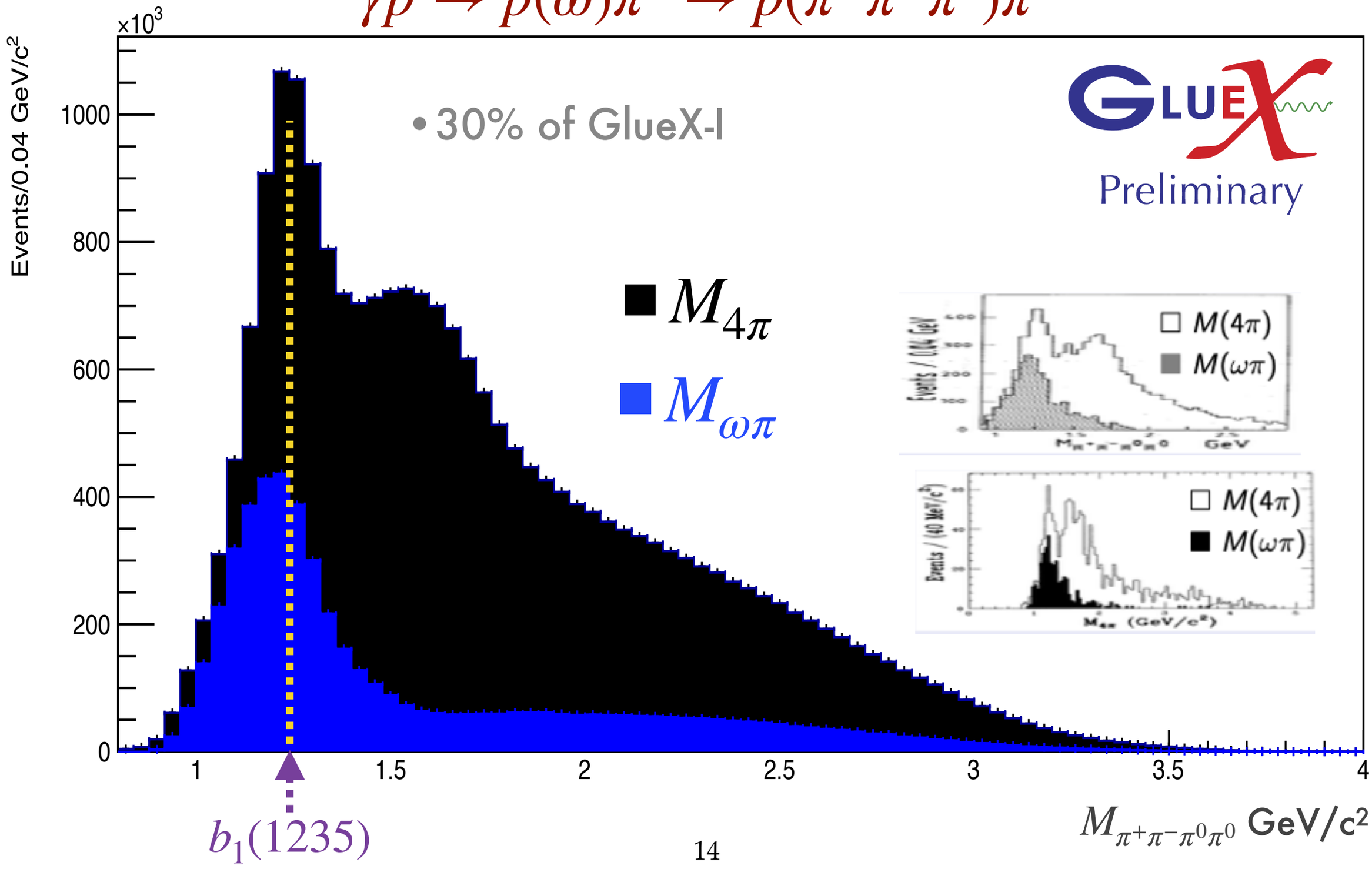
History of the $b_1(1235)$ Photoproduction (from the 1980s)





Invariant mass

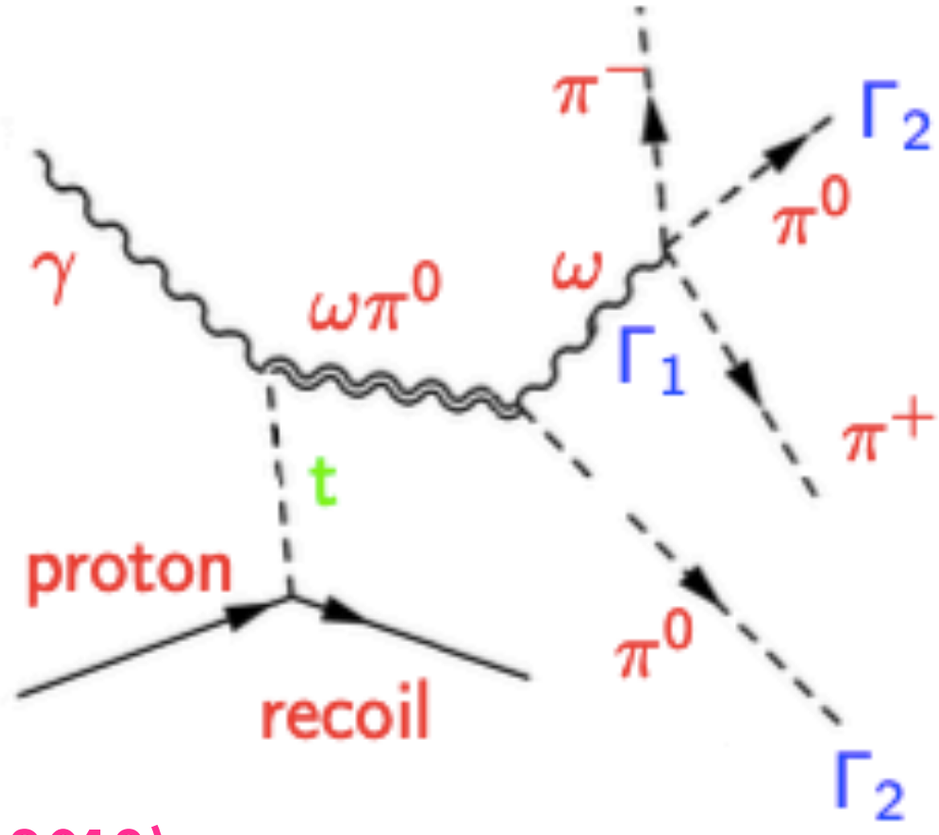
$$\gamma p \rightarrow p(\omega)\pi^0 \rightarrow p(\pi^+\pi^-\pi^0)\pi^0$$



Cross Sections: $\omega\pi$

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

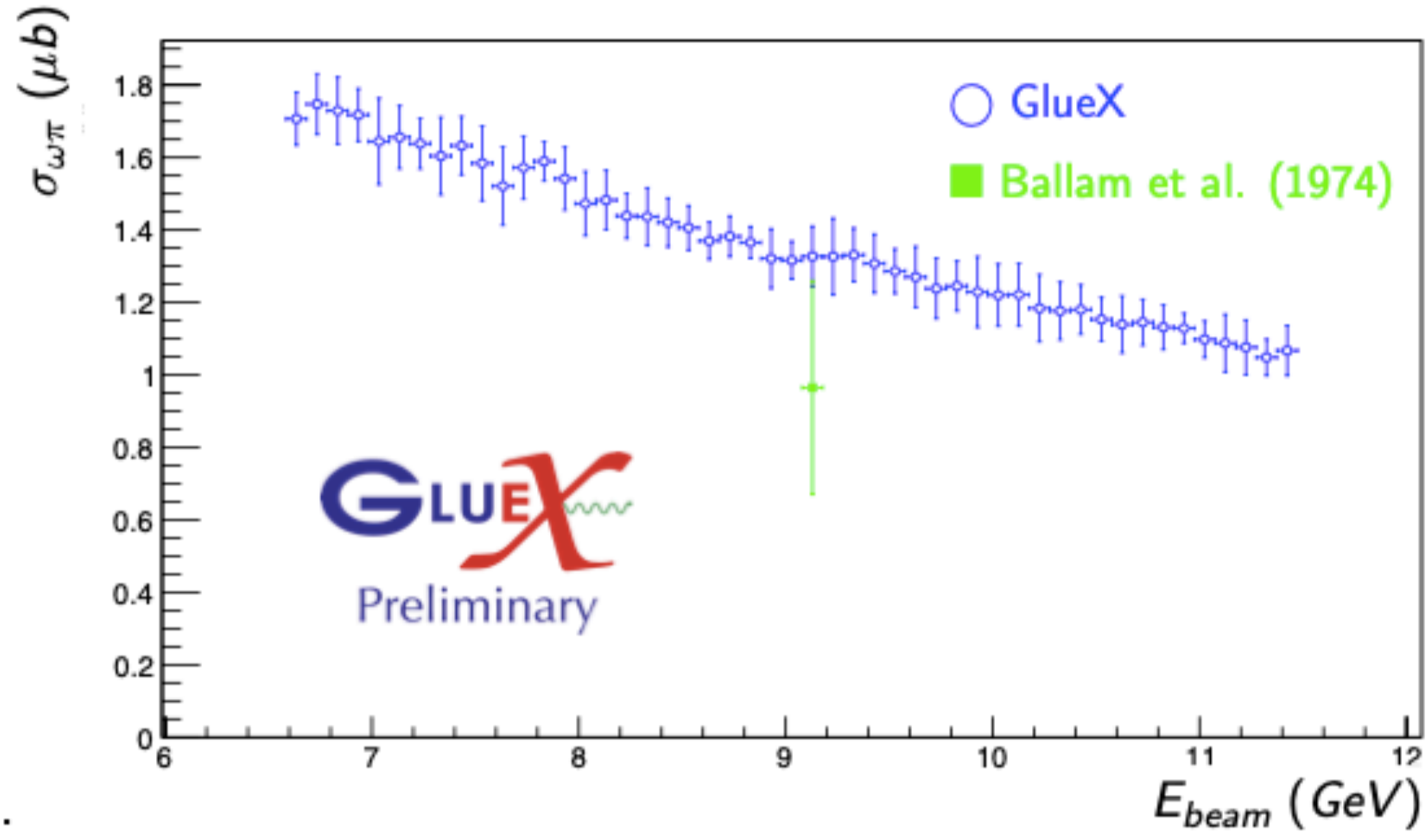
- $BR = \Gamma_1 \times \Gamma_2^2$.
  - $\Gamma_1(\omega \to \pi^+\pi^-\pi^0) = 89.2\%$.
  - $\Gamma_2(\pi^0 \to 2\gamma) = 98.8\%$.
- Mandelstam-t:
  (*four momentum transferred*)^2
  beam to recoil
  $t = (p_\gamma - p_{b_1})^2 = (p_{recoil} - p_{target})^2$.



- GlueX-I: 3 data-taking periods (2017-2018)
- this talk: preliminary total cross sections
- coming soon: differential cross sections

Total Cross Section: $\omega\pi$

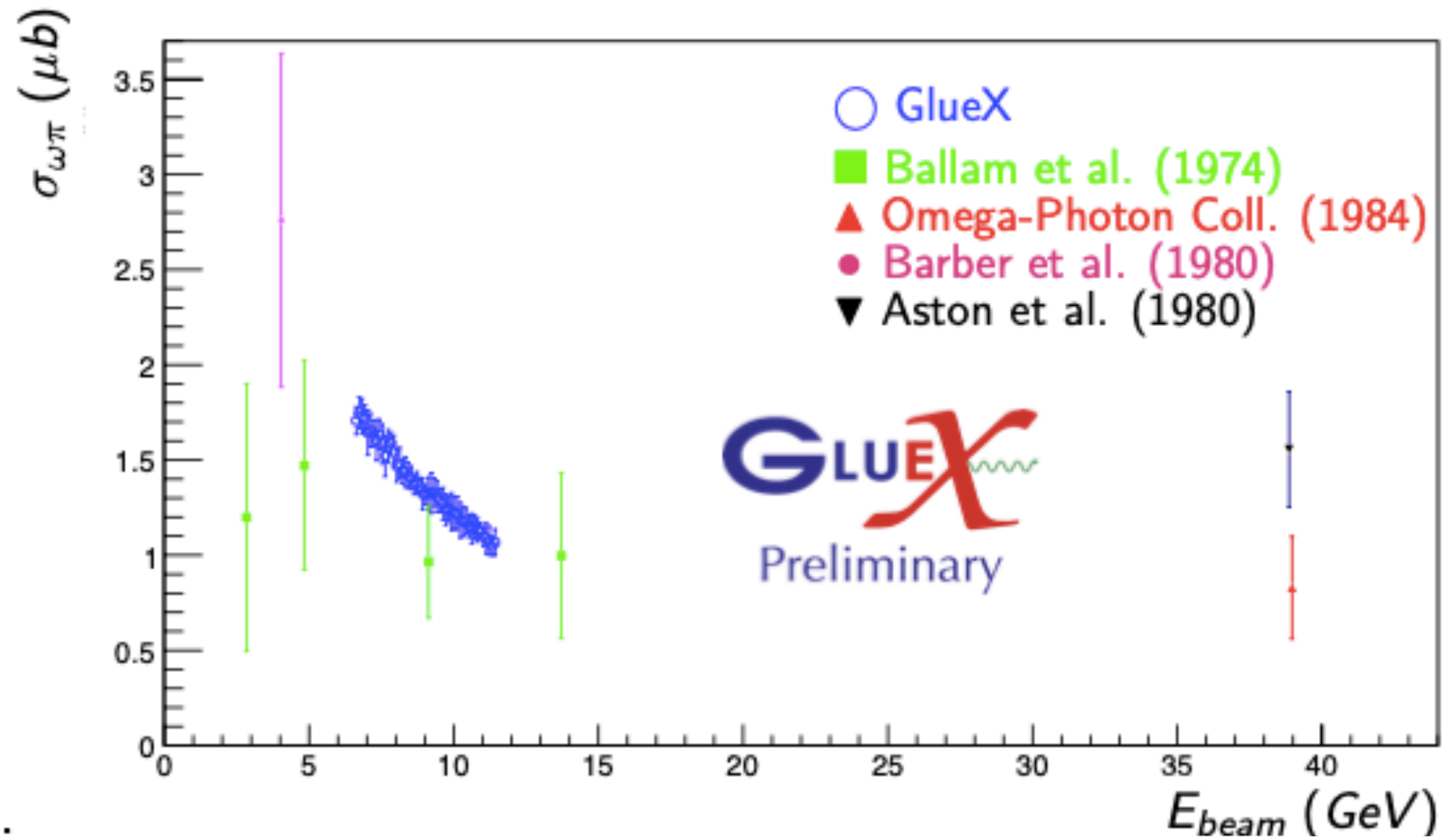
$$|t| > 0.25 GeV^2/c^2$$



Errors: Statistical (50% GlueX-I) ⊕ Systematics-Periods (~10%)

Total Cross Section: $\omega\pi$

$$|t| > 0.25 GeV^2/c^2$$



Errors: statistical (50% GlueX-I) ⊕ Systematics-Periods (~10%)

Summary & Outlook

- Gluonic-field excitation → complete spectrum of mesons.
- LQCD predicts hybrid multiplets; GlueX aims to map them.
- Channels: $\vec{\gamma}p \rightarrow$ [baryon=p, Δ, Σ][meson=$\pi, K, \eta, \eta', \phi$]...

✓ Early physics publications: beam asymmetries.

- Coming soon: SDMEs, cross sections...→ **PWA**.
  - GlueX-II: DIRC upgrade for improved K/π separation
  - Other physics: Primakoff, pion polarizability, SRC, JEF, KLF.

http://gluex.org/thanks

University of Regina | Sci Faculty of Science

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GlueXcitations periment