Beam Asymmetry(Σ) |-t| dependence in a photo-produced η' at GlueX off the proton

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(On behalf of the GlueX Collaboration)

eHUGS-2021

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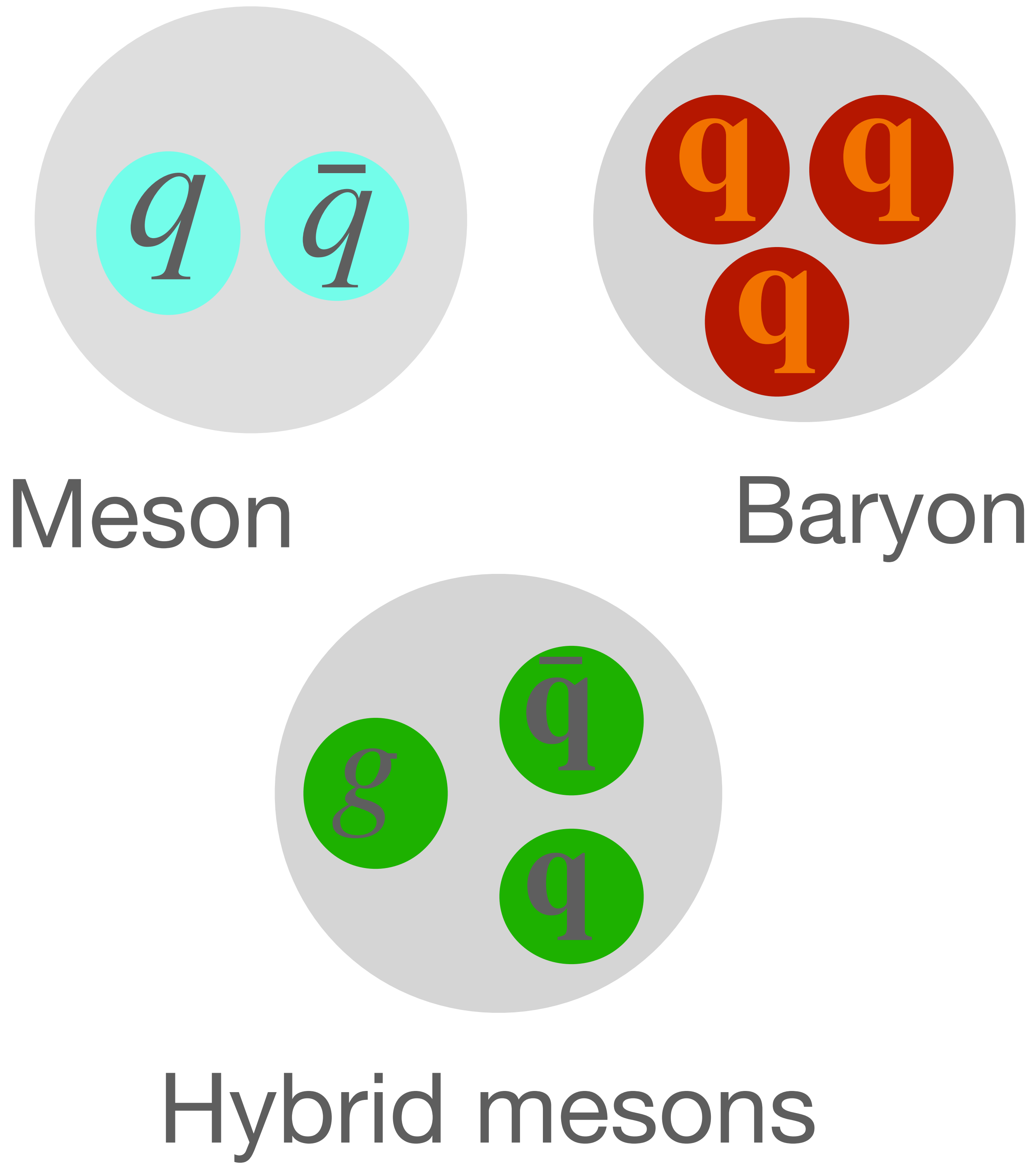
Introduction/Beam Asymmetry

- To map out spectrum of light hybrid mesons/ exotics
- Exotic mesons are hybrids with explicitly exotic quantum numbers which are not possible in quark model. $\pi_1(1600)\ J^{PC}:\ 1^{-+}$
- Putting new constraints to Regge models
- Understanding production mechanisms for pseudo-scalar mesons.



$$\Sigma_{\eta'} = \frac{\mathbf{d}\sigma_\perp - \mathbf{d}\sigma_\parallel}{\mathbf{d}\sigma_\perp + \mathbf{d}\sigma_\parallel}$$

$$\mathbf{d}\sigma_{\perp,\parallel} \equiv \frac{\mathbf{d}\sigma_{\perp,\parallel}(\mathbf{s},\mathbf{t})}{\mathbf{dt}}$$

Differential cross-section for the photons polarized perpendicular or parallel to the reaction plane, s and t are Mandelstam variables.

(Reaction Channels, η' decay modes for $\Sigma_{\eta'}$)

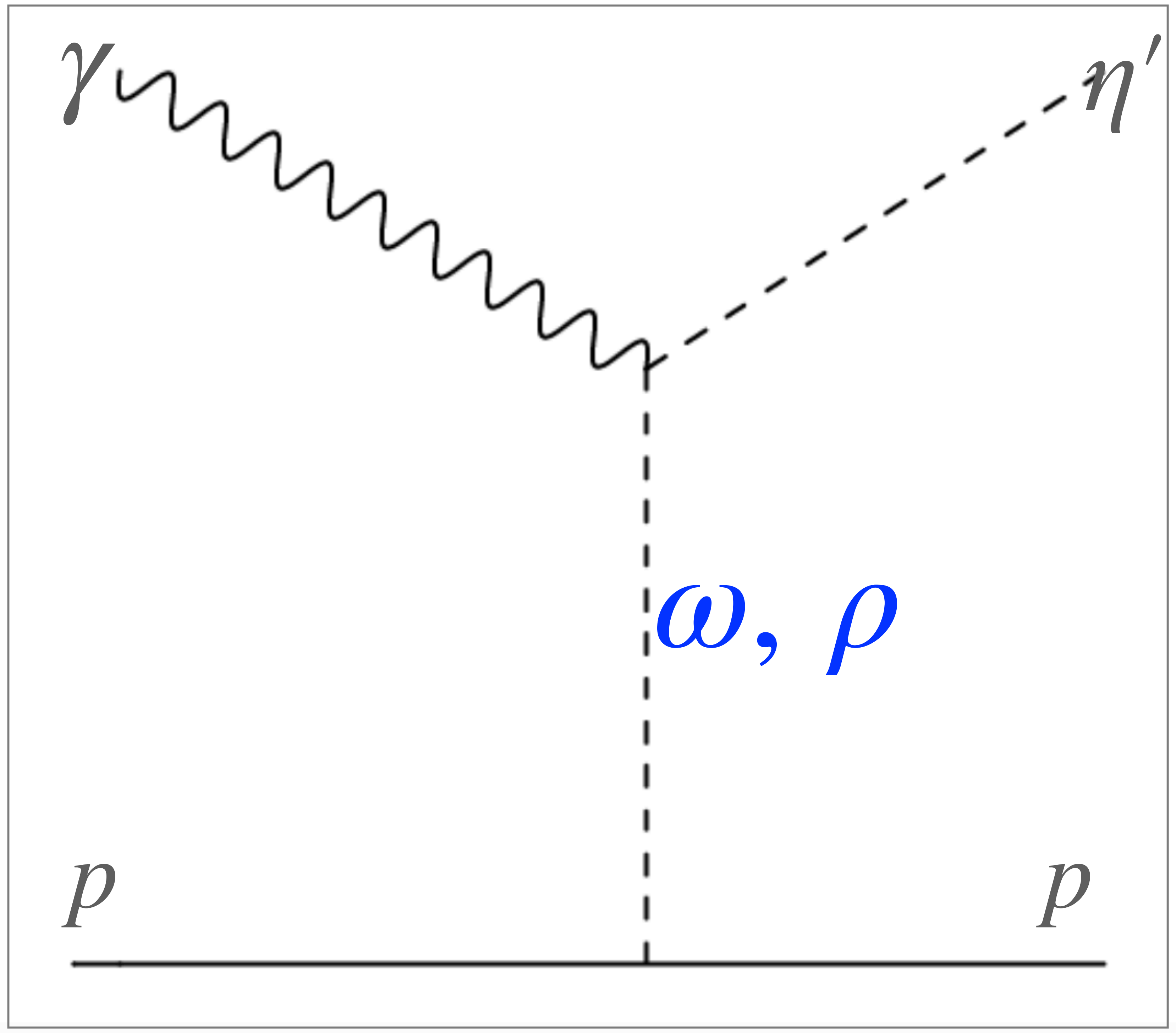
$\gamma p \rightarrow \eta' p$ $\quad \eta' \rightarrow \pi^+\pi^-\eta, \eta \rightarrow \gamma\gamma$ $\quad \Gamma_1{}^* \rightarrow (42.6 \pm 0.7)\,\%$

$\eta' \rightarrow \pi^0\pi^0\eta$ $\quad \eta \rightarrow \gamma\gamma$ $\quad \pi^0 \rightarrow \gamma\gamma$ $\quad \Gamma_2{}^* \rightarrow (22.8 \pm 0.8)\,\%$

Mass: 957.78±0.06 ($\mathbf{MeV/c^2}$) *

$I^G(J^{PC}) = 0^+(0^{-+})$

$\eta' : \frac{1}{\sqrt{(3)}}(u\bar{u} + d\bar{d} + s\bar{s})$



Natural Parity Exchange

Unnatural Parity Exchange

$$\Sigma = \frac{|\omega + \rho|^2 - |\mathbf{h} + \mathbf{b}|^2}{|\omega + \rho|^2 + |\mathbf{h} + \mathbf{b}|^2}$$

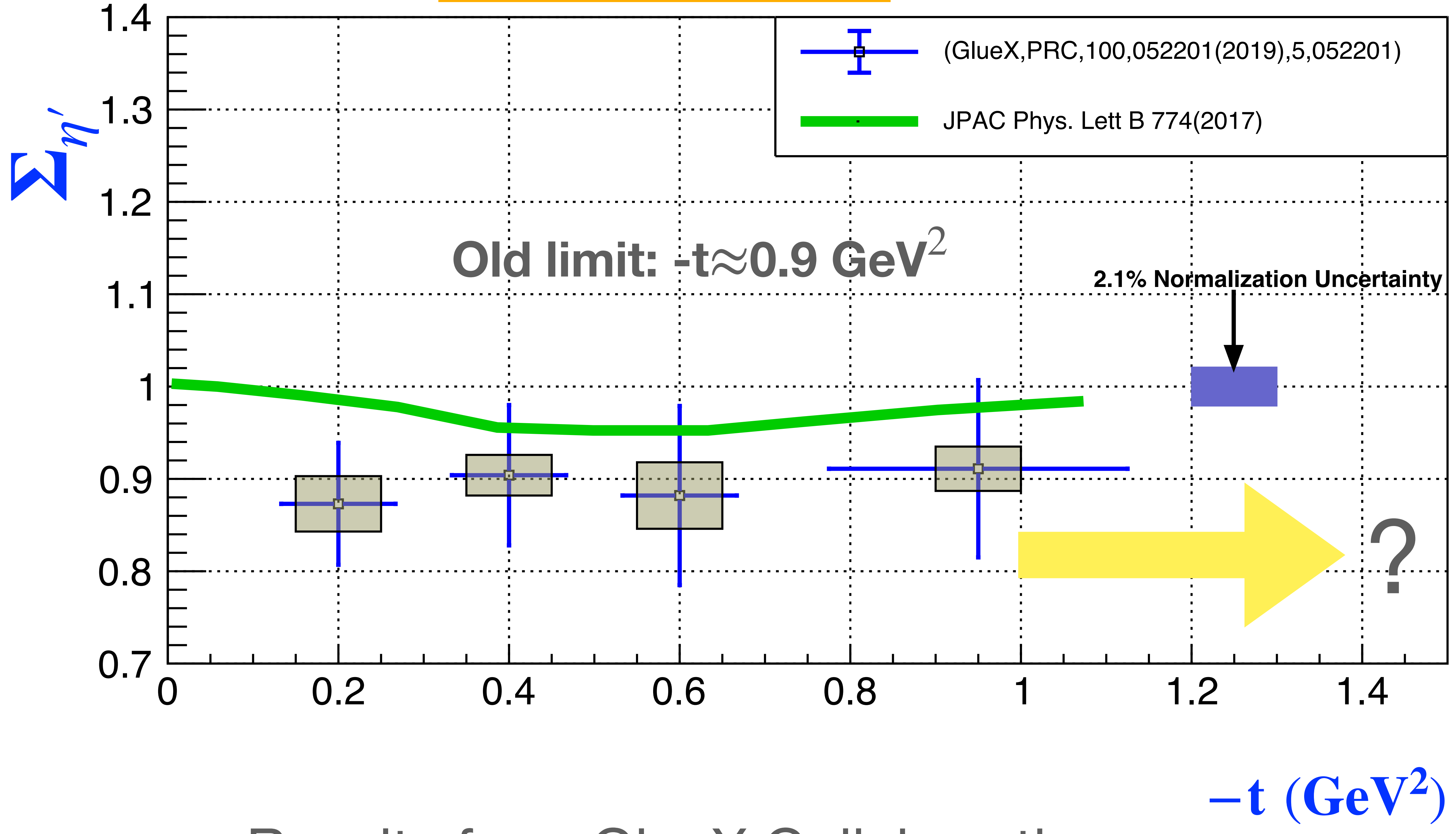
Σ =± 1 indicates vector meson/axial vector meson dominance

*M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98, 030001 (2018)

Past Analysis, Models (What was old limit?)

$$\gamma \mathbf{p} \rightarrow \eta' \mathbf{p},\ \eta' \rightarrow \pi^+\pi^-\eta, \eta \rightarrow \gamma\gamma$$

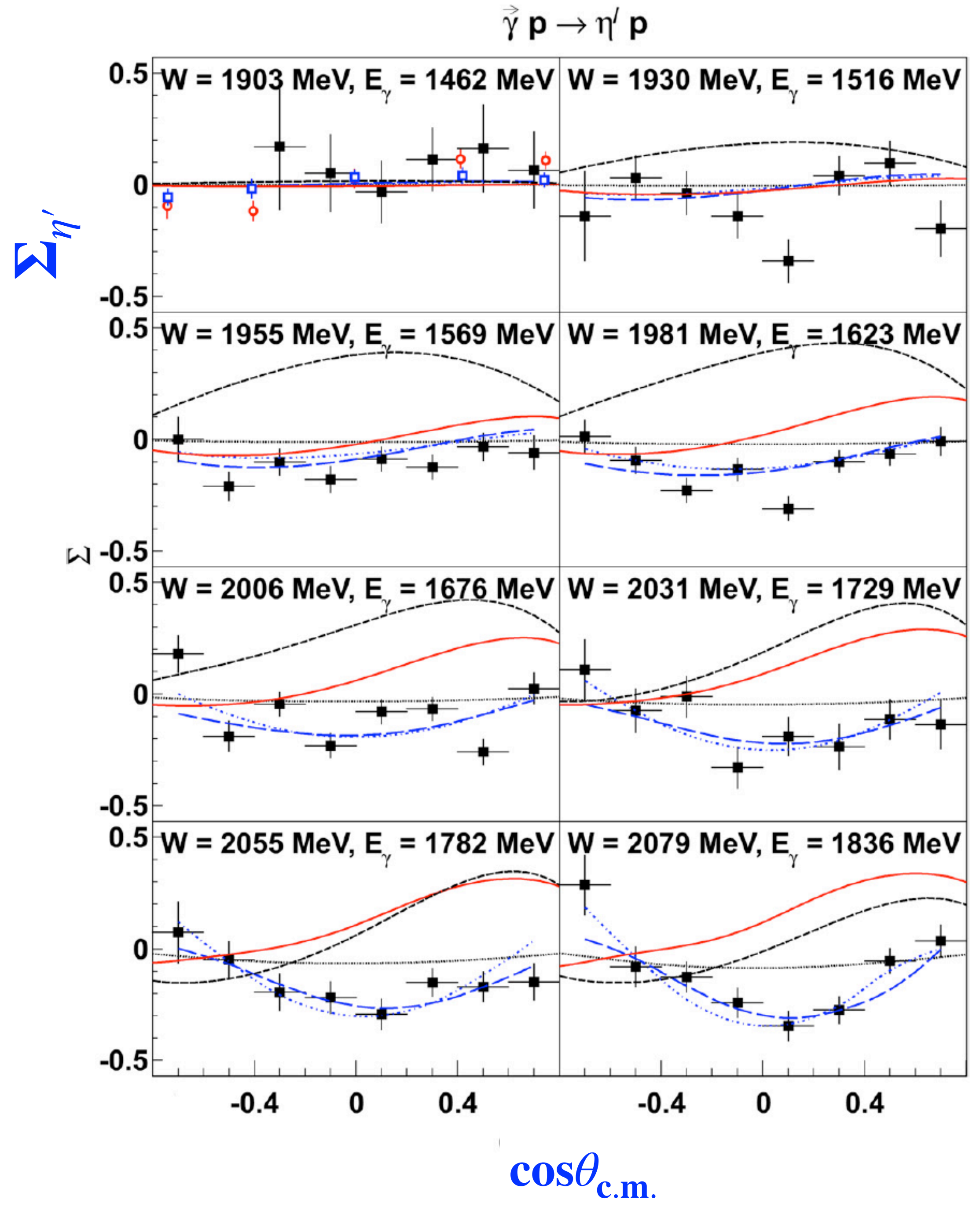
18% of GlueX-I



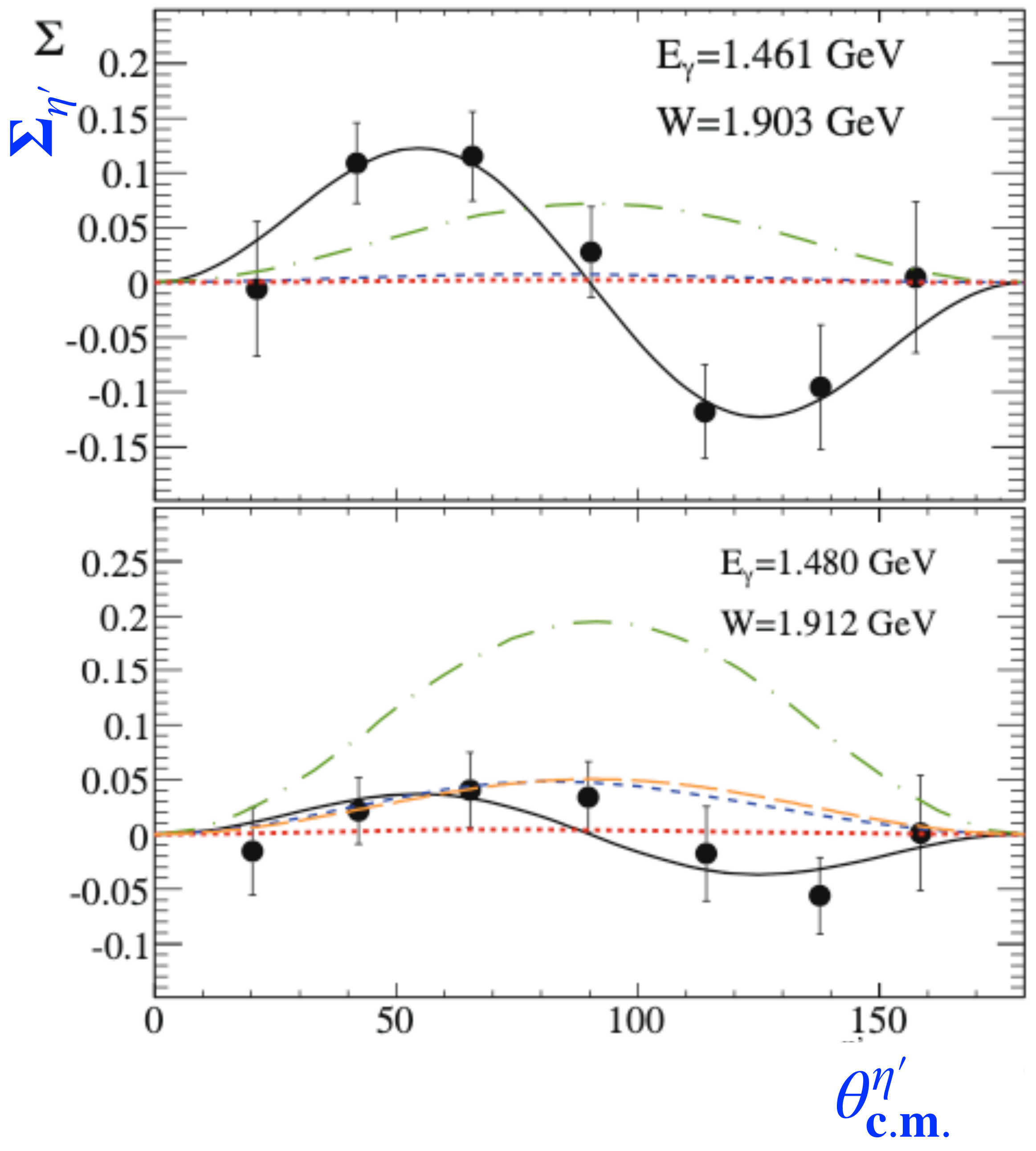
Results from GlueX Collaboration

(PRC,100,052201(2019),5,052201)

Low Energy: S-Channel Exchange Dominance



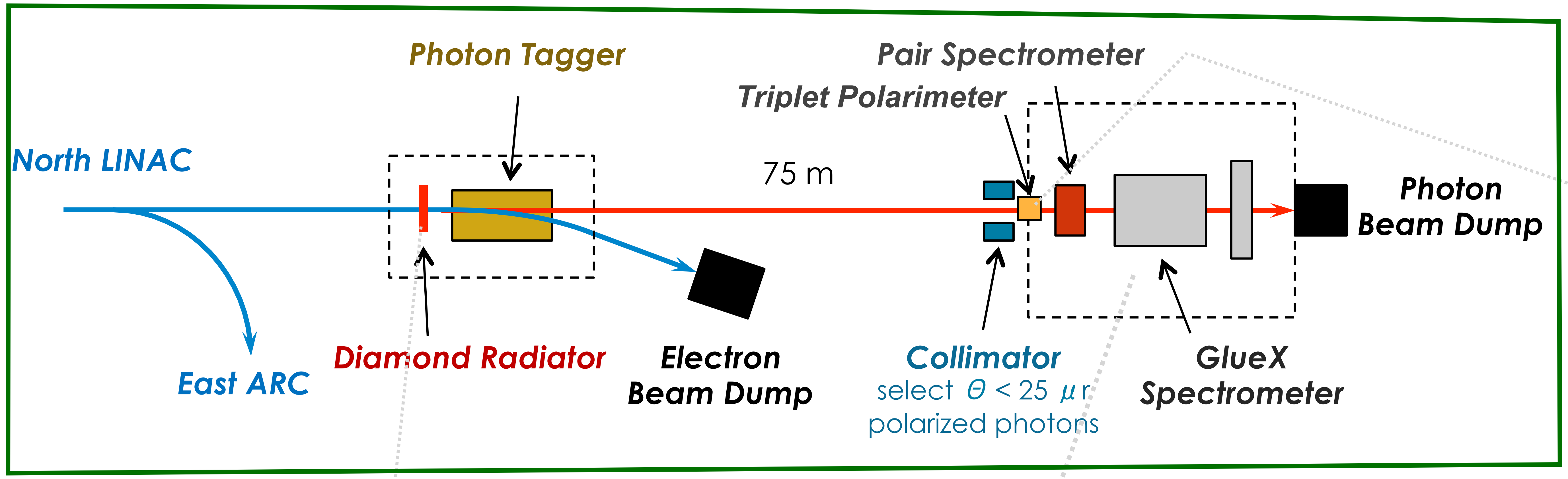
Physics Letters B 771 (2017) 213–221 (*CLAS collaboration*)

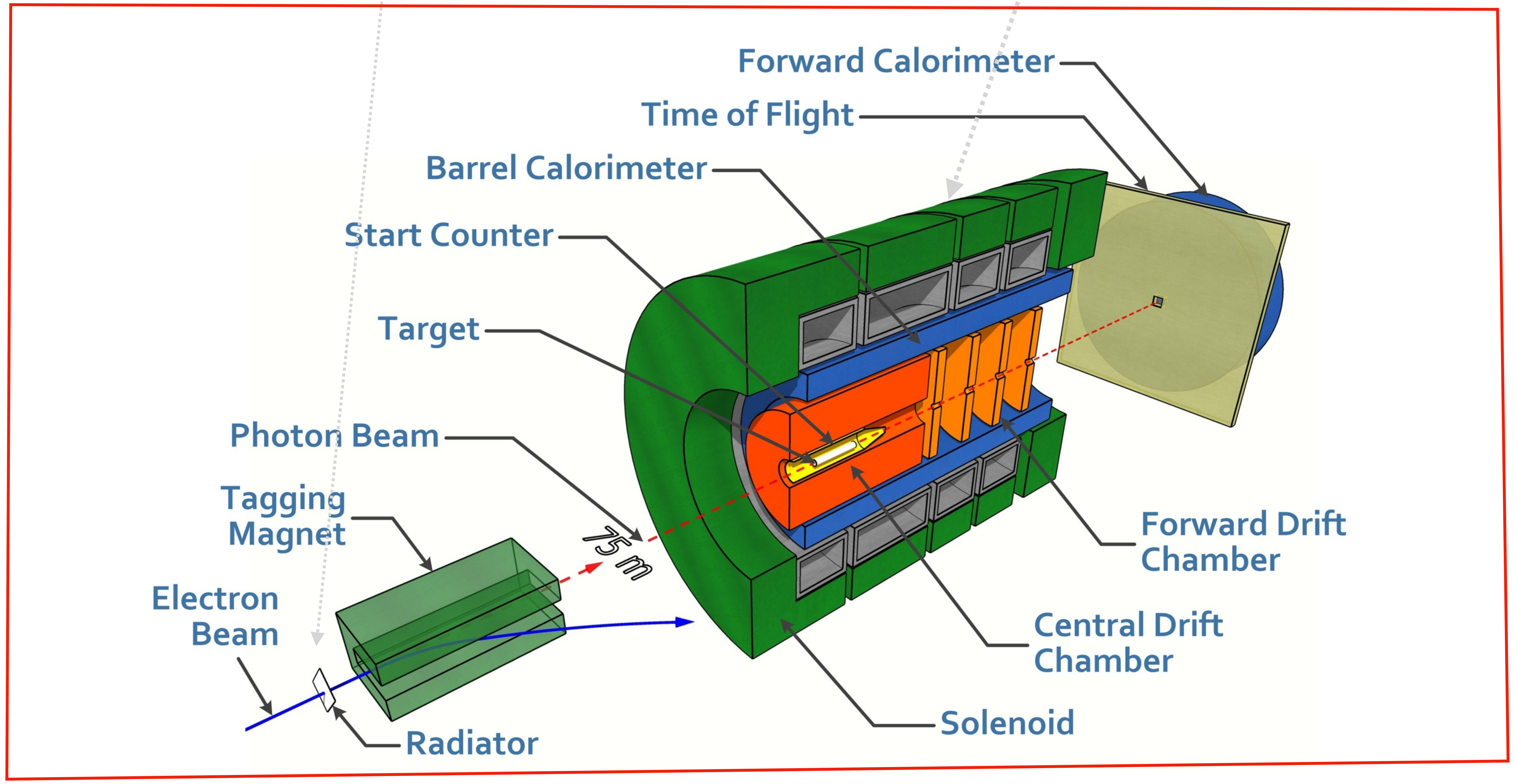


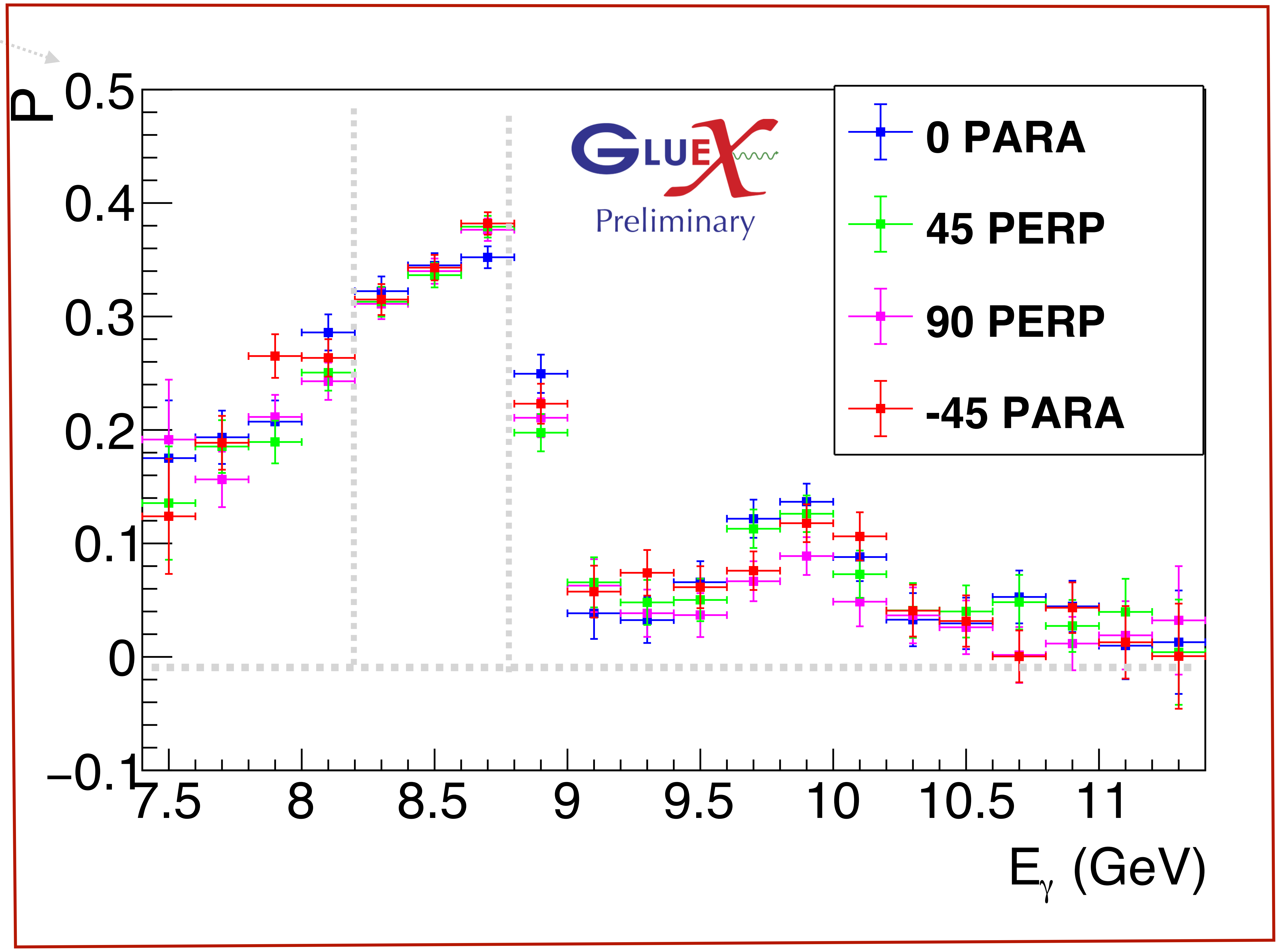
Eur. Phys. J.A **51 (2015) 7, 77**

(From GrAAL Collaboration)

GlueX Beamline, Detector & Polarization







Nucl.Instrum.Meth.A 987 (2021) 164807

Beam Asymmetry Method

Photoproduction of pseudoscalar mesons: Linearly polarized photon beam and an unpolarized target, the polarized cross-section σ_{pol} is related to the beam asymmetry via the following equation:

$$\sigma_{pol}(\phi, \phi_\gamma) = \sigma_{unpol}[1 - P_\gamma \Sigma cos(2(\phi - \phi_\gamma))]$$

$$\Sigma = \frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel}$$

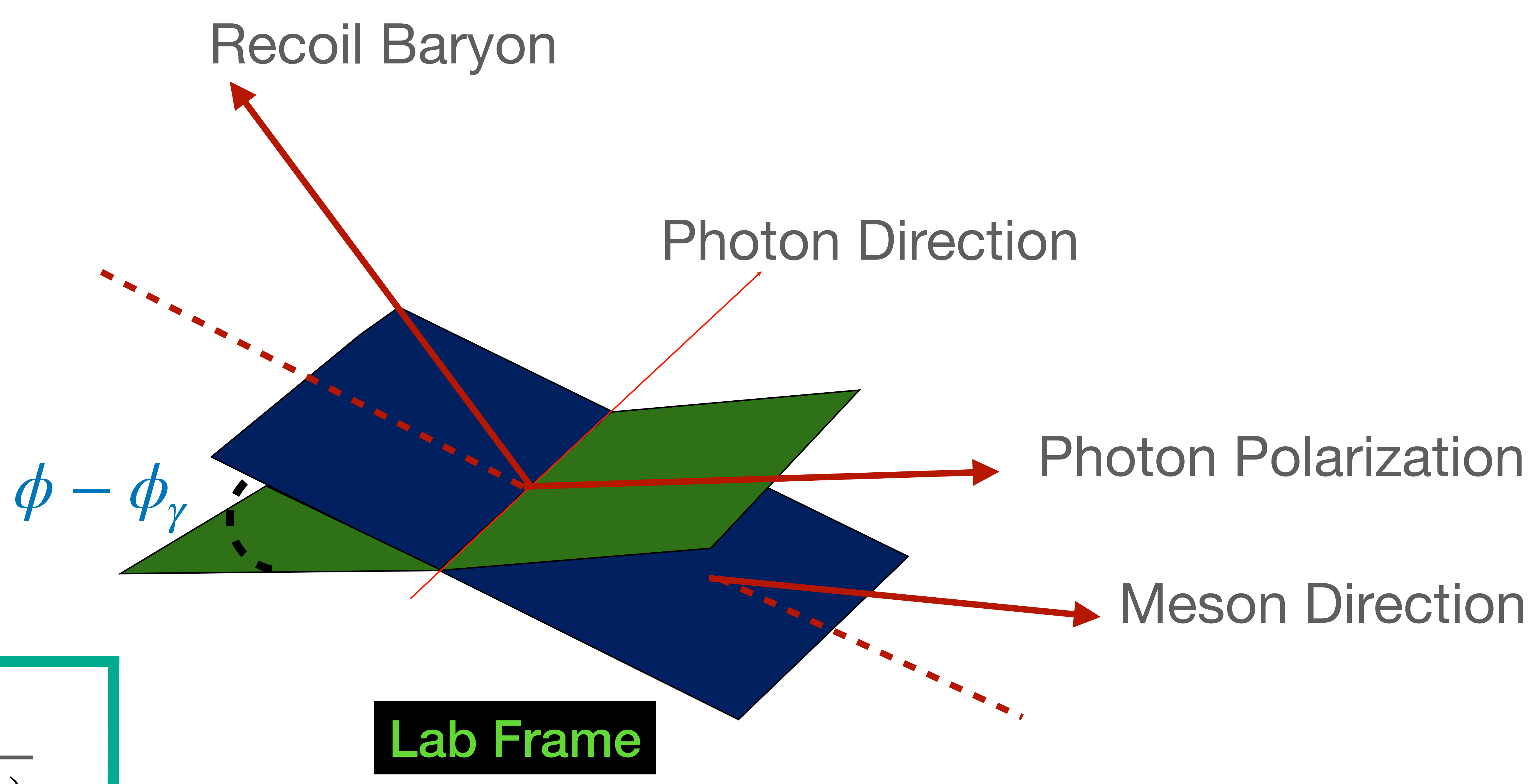
$$Y_\parallel(\phi, \phi_\gamma = 0)\ \alpha N_\parallel[\sigma_0 A(\phi)(1 - P_\parallel \Sigma cos2\phi)]$$

$$Y_\perp(\phi, \phi_\gamma = 90)\ \alpha N_\perp[\sigma_0 A(\phi)(1 + P_\perp \Sigma cos2\phi)]$$

$$\text{Yield Asymmetry (YA)} = \frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel)\Sigma cos2(\phi - \phi_0)}{2 + (P_\perp - P_\parallel)\Sigma cos2(\phi - \phi_0)}$$

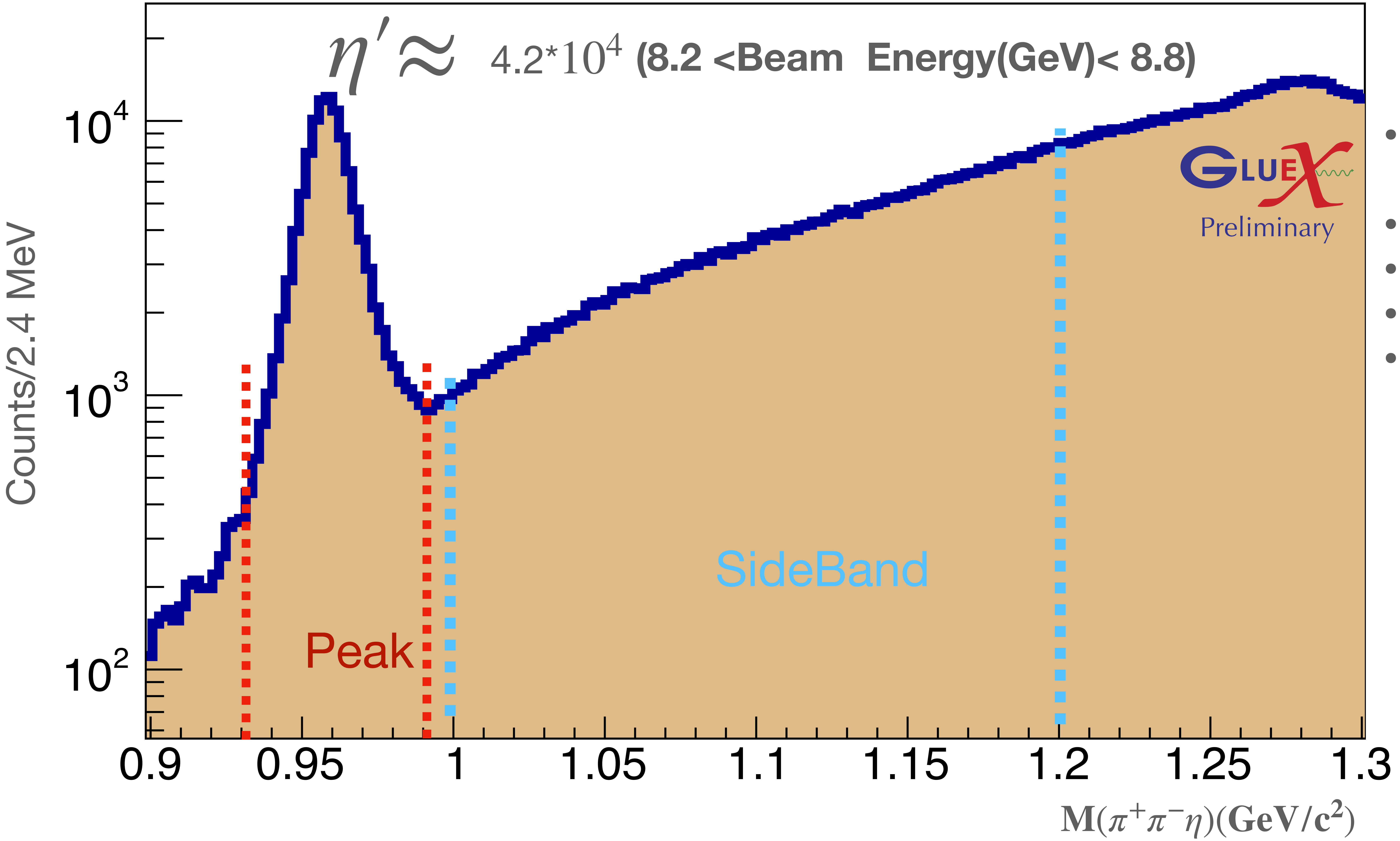
$$F_R = \frac{N_\perp}{N_\parallel}$$

ϕ_0 is the diamond misalignment offset



Two orthogonal polarizations combined appropriately result in a cancellation of acceptance & detector inefficiencies in principle

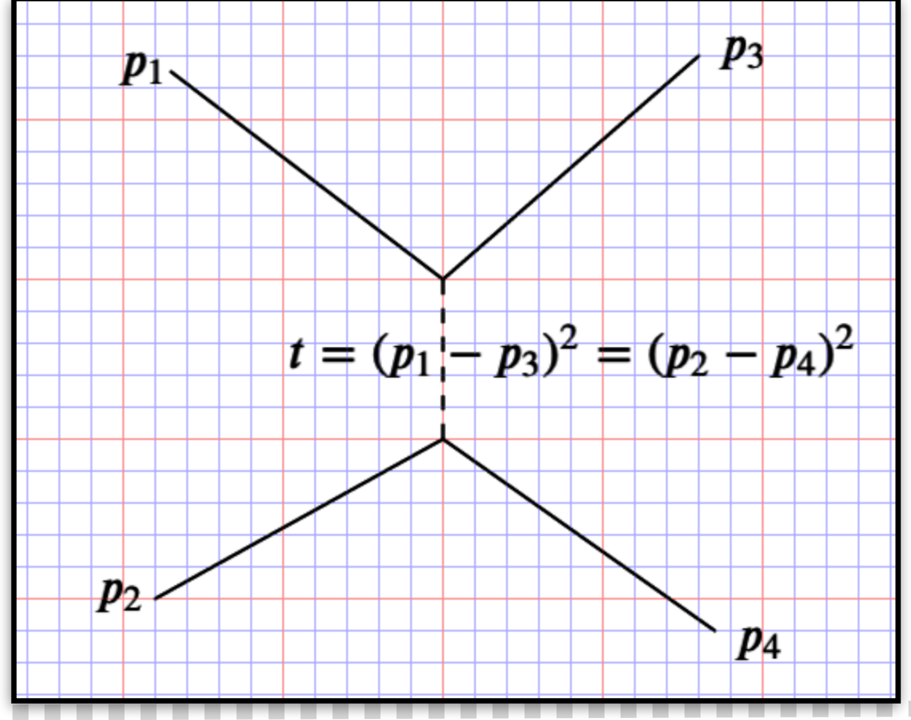
$\eta\pi^+\pi^-$ invariant mass spectrum: GlueX-I



Event Selections via:

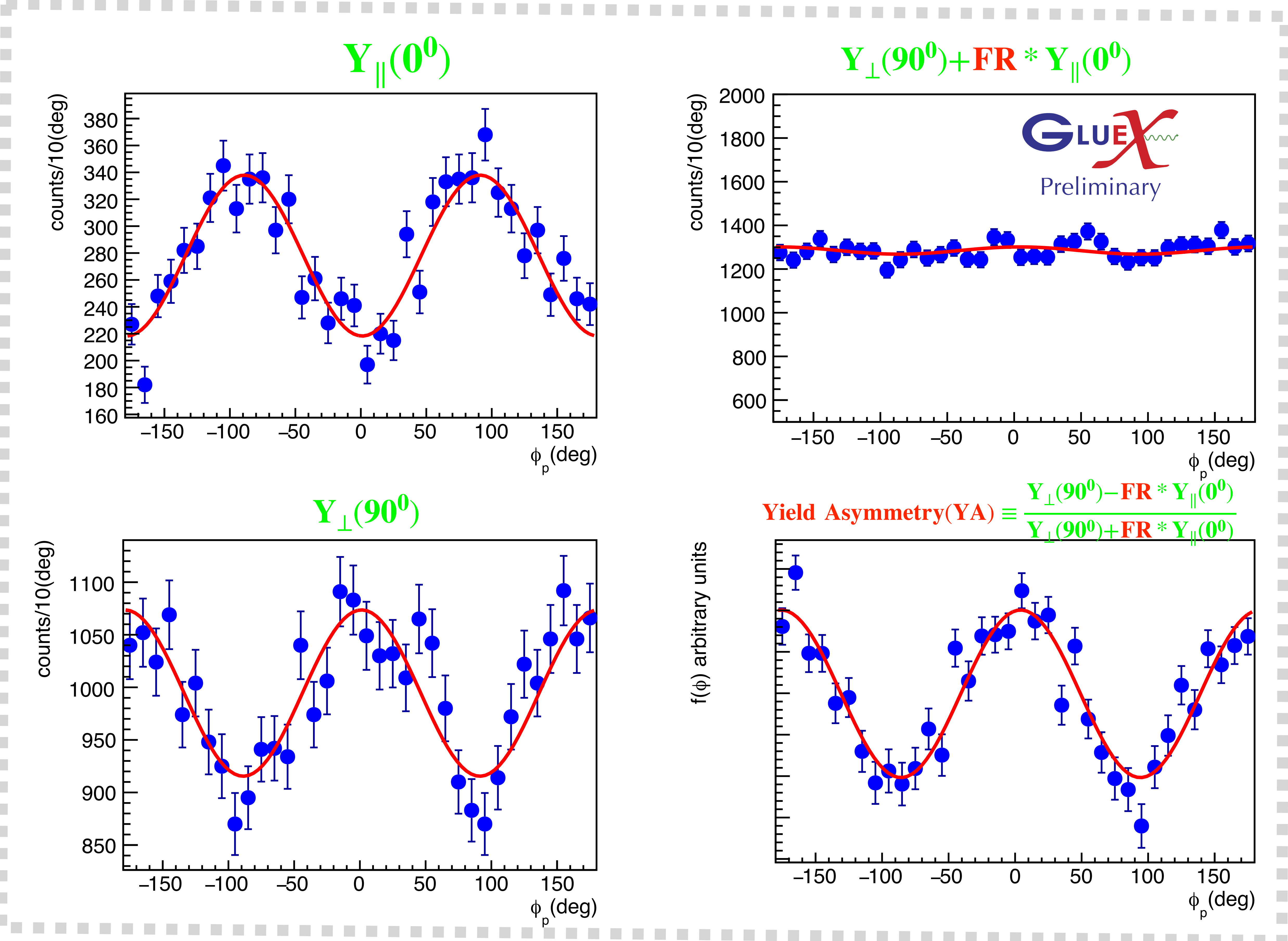
- Chi-squared per degree of freedom
- Recoil Proton Momentum
- Vertex R
- Vertex Z
- Missing Mass Squared

Angular Distributions :low and high |-t| examples

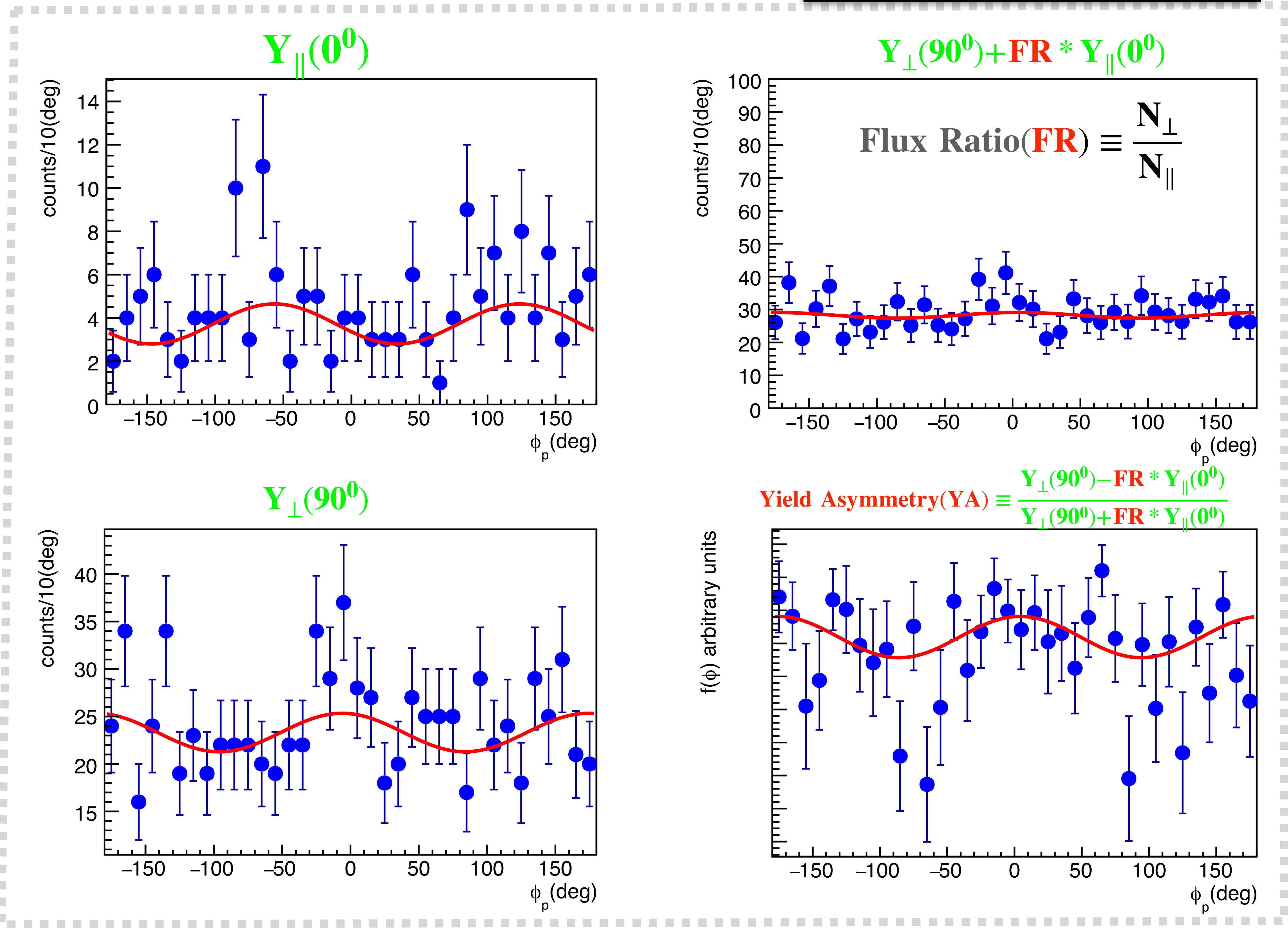


ϕ **distributions** ϵ $|\mathbf{M}_{\eta'}| < 3\sigma$

(0.1<|-t|<0.3 : Low |-t|)

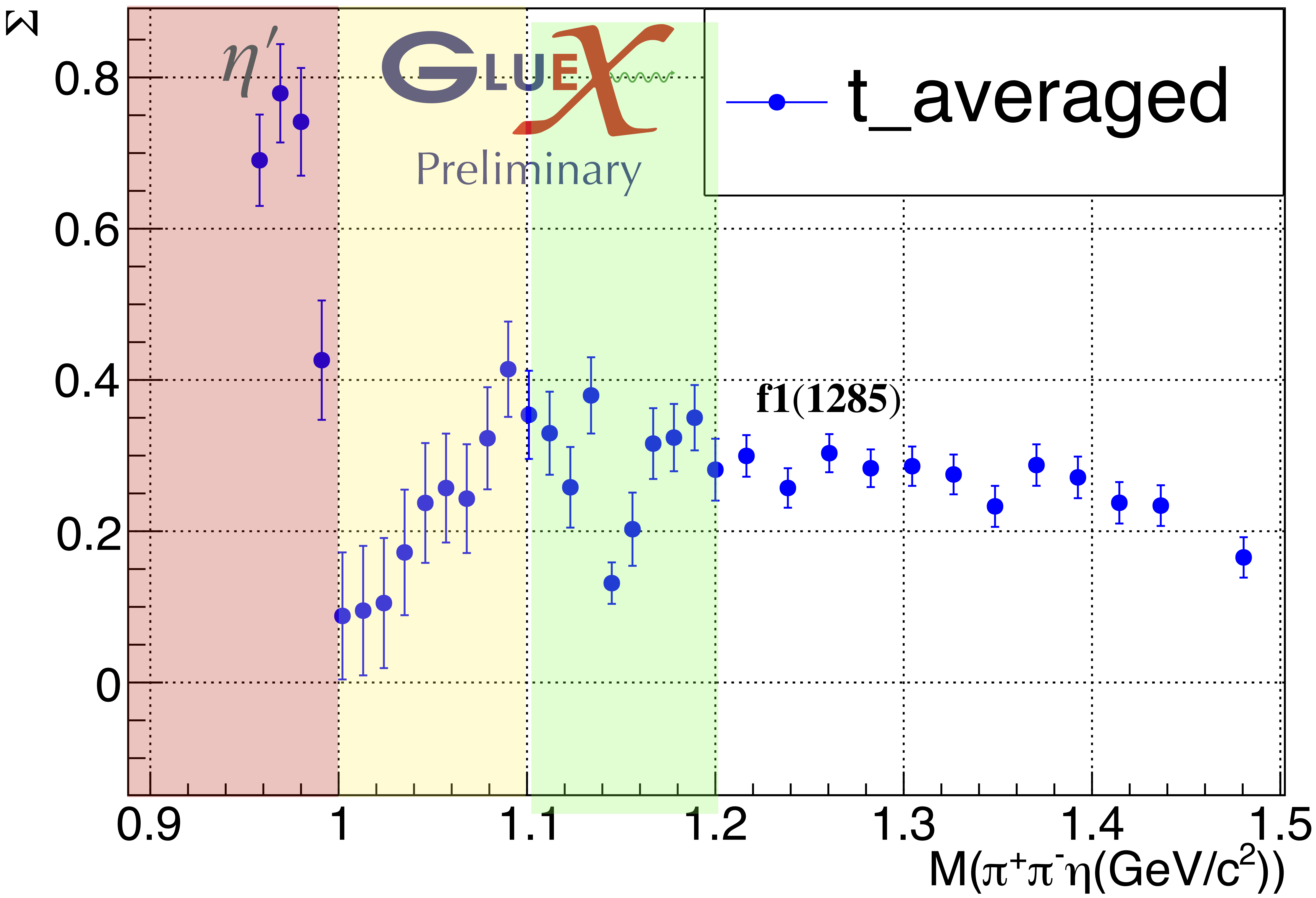


(1.7<|-t|<2.1 :High |-t|)

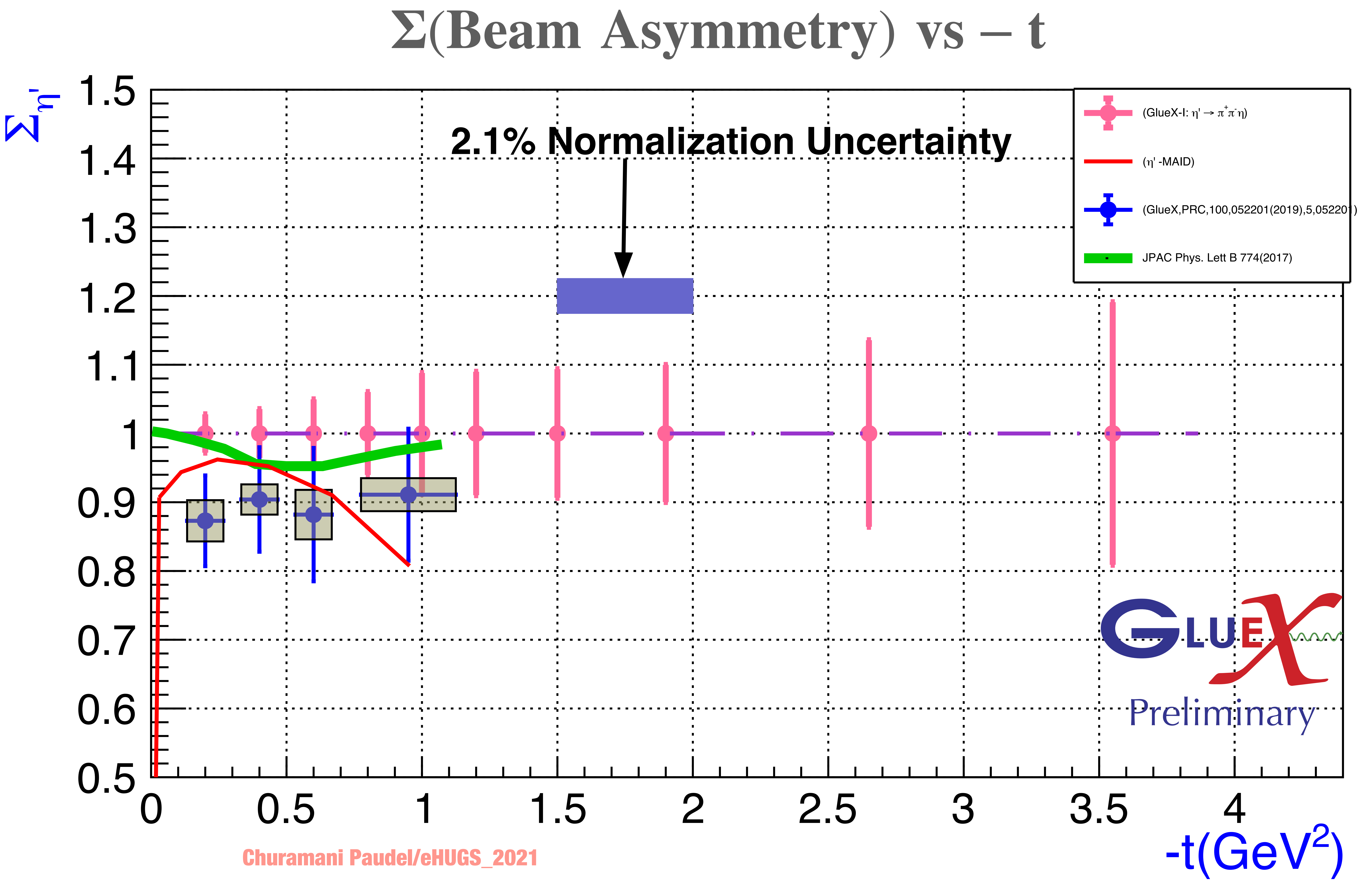


Σ vs M in finer mass bins

53%(2018) GlueX-I $\pi^+\pi^-\eta$



Projected Preliminary Uncertainty GlueX-I



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Summary & Future works

- Ongoing analysis
- $\eta' \rightarrow \eta\pi^0\pi^0$ decay mode
- $\Sigma_{\eta'}$ vs $\mathbf{M}$ (Mass dependency further being studied)
- $\Sigma_{\eta'}$ vs $|-\mathbf{t}|$
- Data/Monte Carlo Study
- Different theory models

(Accessible via this QR)

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BACKUP