Beam-Asymmetry Measurement in a photo-produced η' at GlueX

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(On behalf of the GlueX Collaboration)

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(November 5-6,2020)

Motivation-GlueX

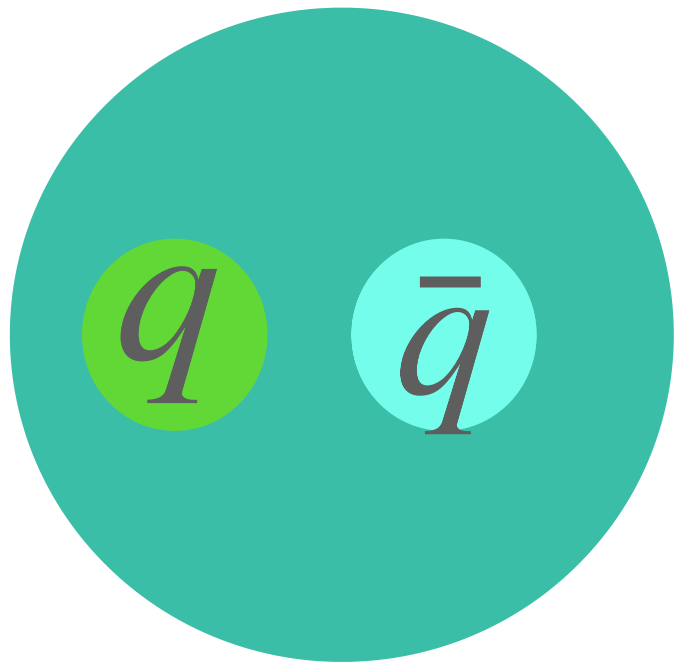
- To map out spectrum of light hybrid mesons/in particular exotics

- Mesons: particles with quark antiquark pair

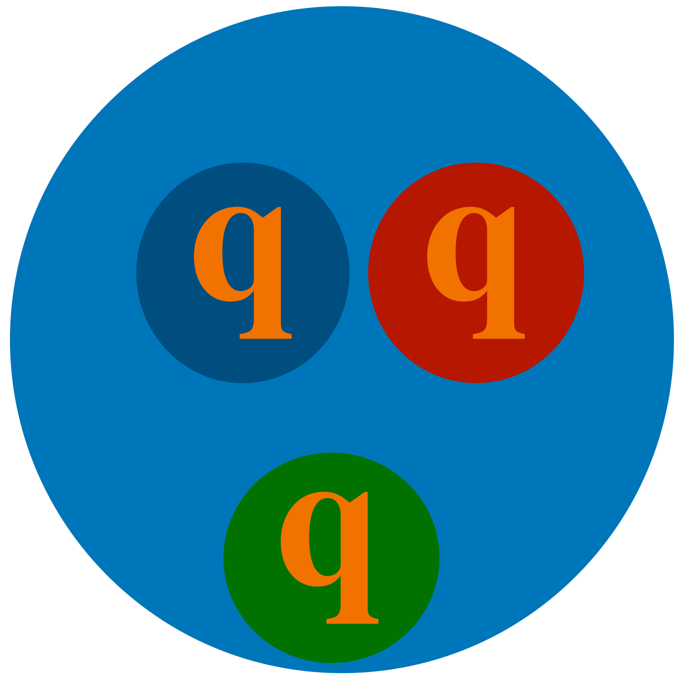
Hybrid Mesons: Quark antiquark pair with gluons which carry angular momentum

Exotic mesons are hybrids with explicitly exotic quantum numbers which are not possible in quark model*. $\pi_1(1600)\ J^{PC}:\ 1^{-+}$:J = L+S

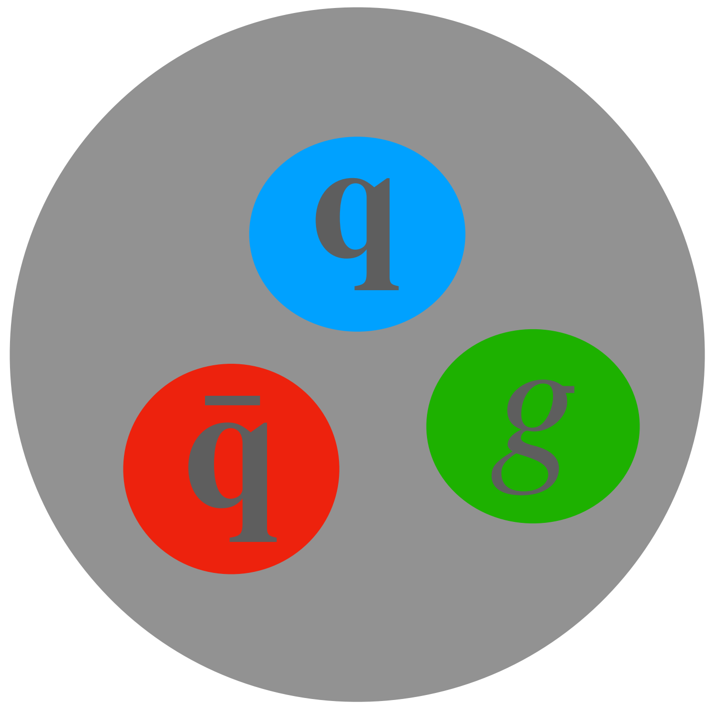
*classification scheme of hadrons in terms of their valence quarks



Meson



Baryon



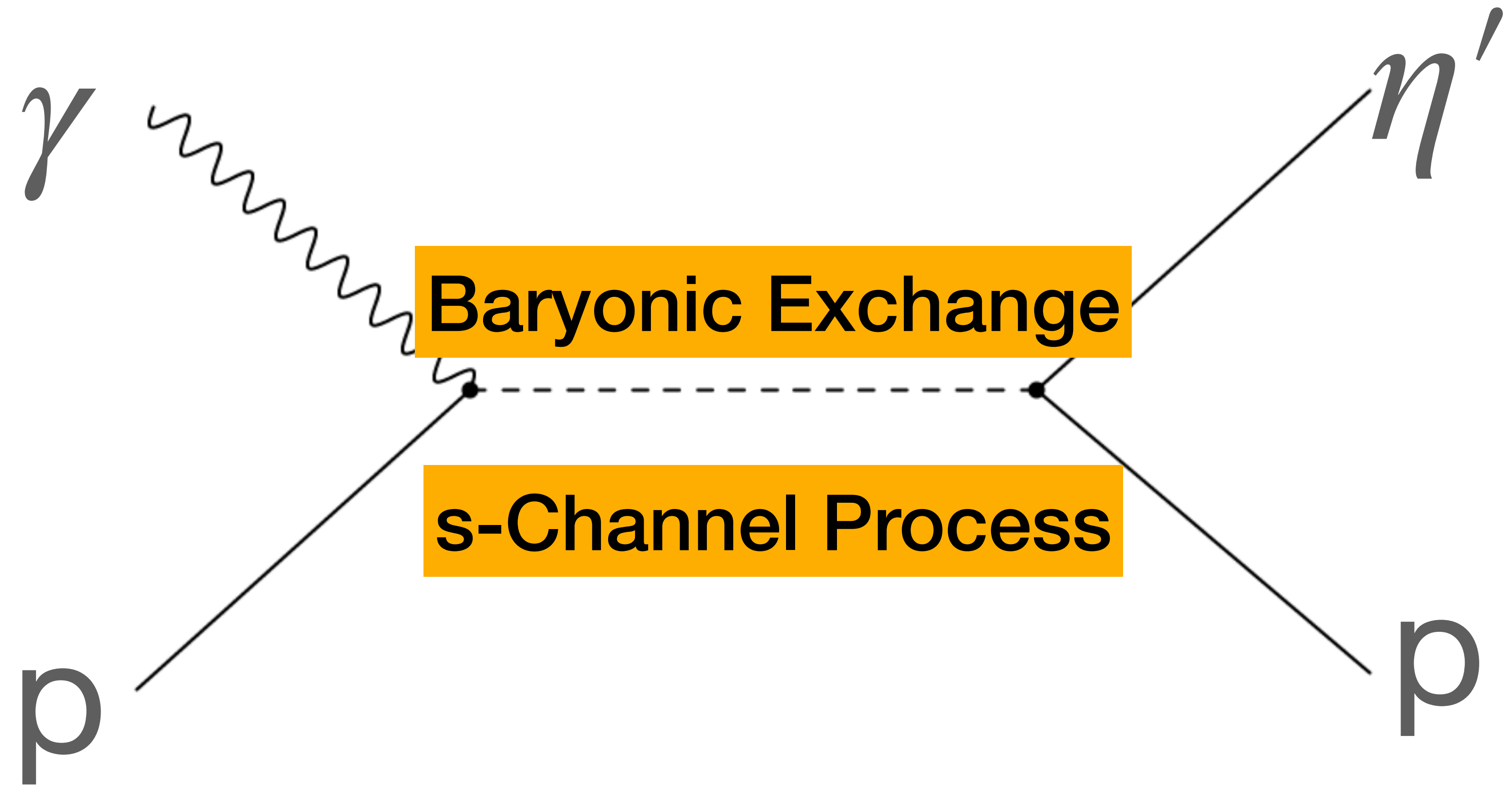
Hybrid mesons

Beam Asymmetry (Σ) Motivation at GlueX

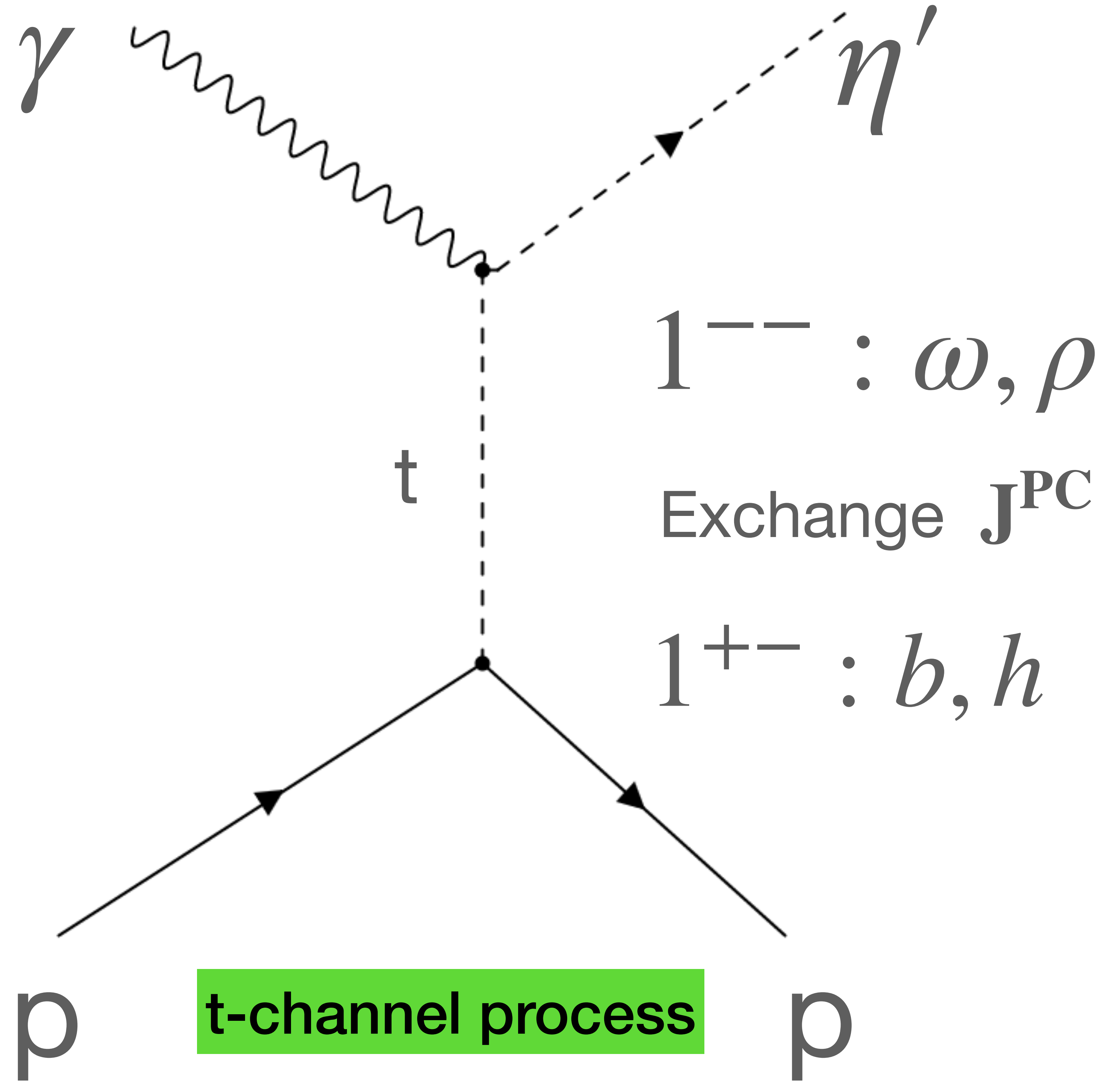
Common Regge Exchanges: Production of lightest multiplet of exotics with $\mathbf{J^{PC} = 1^{-+}}$ $(\pi_1(1600))$ and production of some of pseudoscalars mesons such as η', η and π^0 $\mathbf{P(-)^J = \pm 1}$

Finding new resonances involves requiring quantum numbers first, perform amplitude analysis to know quantum states, which constrains decays & production mechanism

Beam Asymmetry is an appropriate observable sensitive to these production mechanism (Exchange Processes)

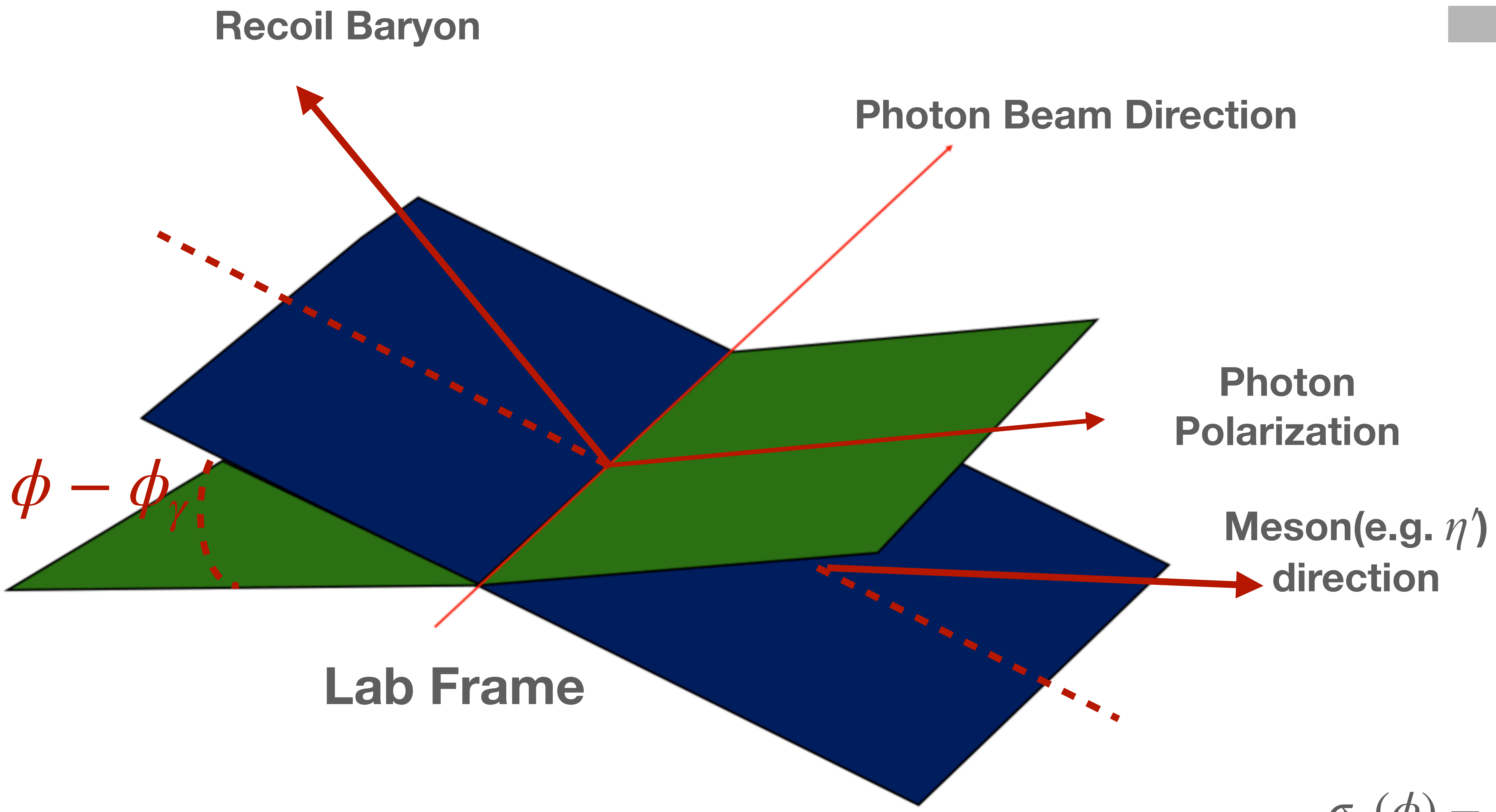


- Putting new constraints to Regge models
- Understanding resonance production mechanisms for pseudoscalar mesons.



FIU

Observable of interest: Beam Asymmetry(Σ)



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

Natural Parity Exchange | Unnatural Parity Exchange

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

Σ = 1 : Vector meson dominance

Σ =-1: Axial vector mesons

$$\Sigma = \frac{\sigma_\perp(\phi) - \sigma_\parallel(\phi)}{\sigma_\perp(\phi) + \sigma_\parallel(\phi)} \ (\approx \frac{\sigma_{\mathbf{nat}} - \sigma_{\mathbf{unnat}}}{\sigma_{\mathbf{nat}} + \sigma_{\mathbf{unnat}}})$$

Reaction Channels

$\gamma p \rightarrow \eta' p$

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

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

$\eta \rightarrow \gamma\gamma$

$\pi^0 \rightarrow \gamma\gamma$

$\pi^{\mathbf{0}} \rightarrow \gamma\gamma$

(η, π^0 mass unconstrained)

Mass: 957.78±0.06 (**MeV/c^2**)
(PDG average)

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

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

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

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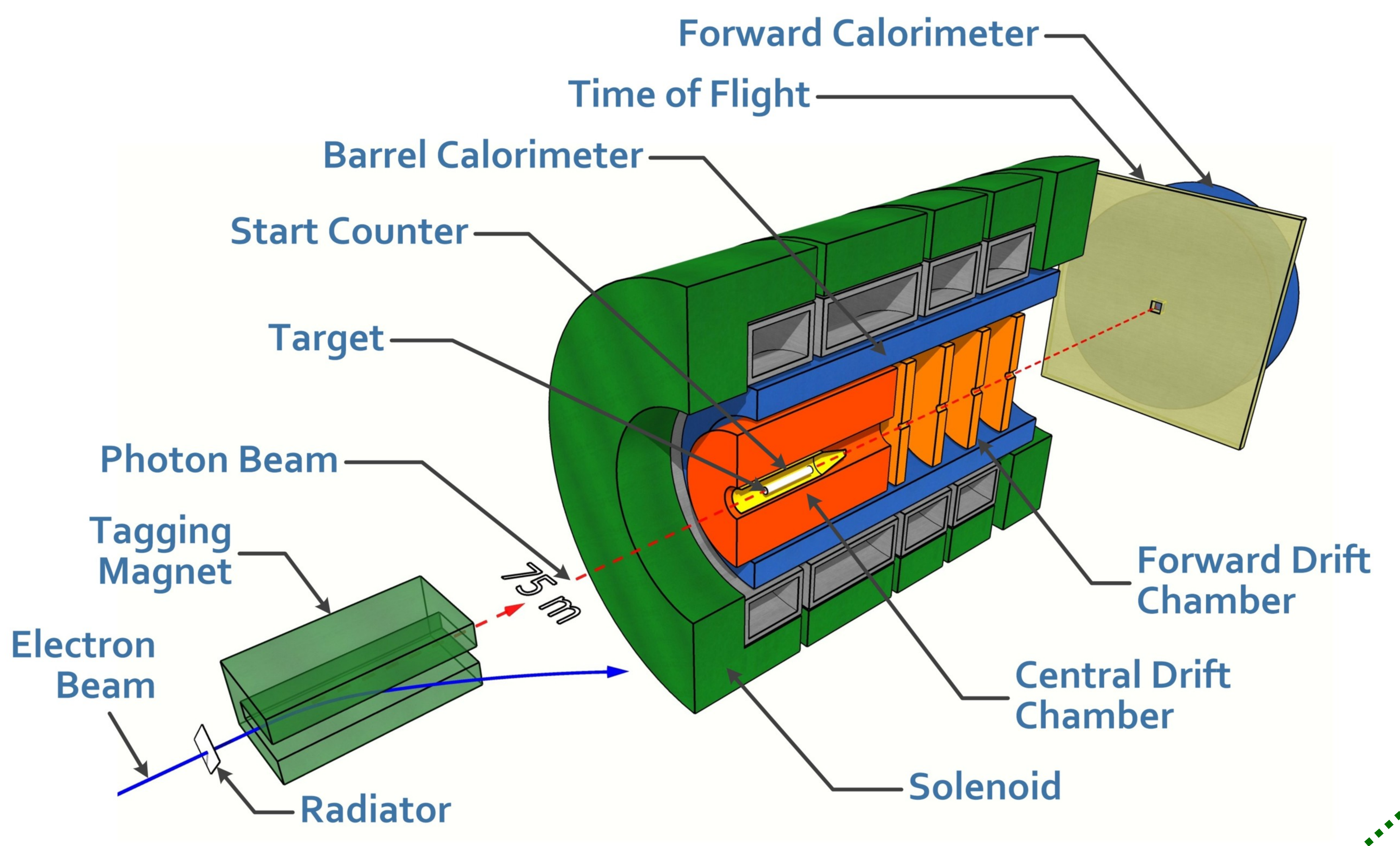
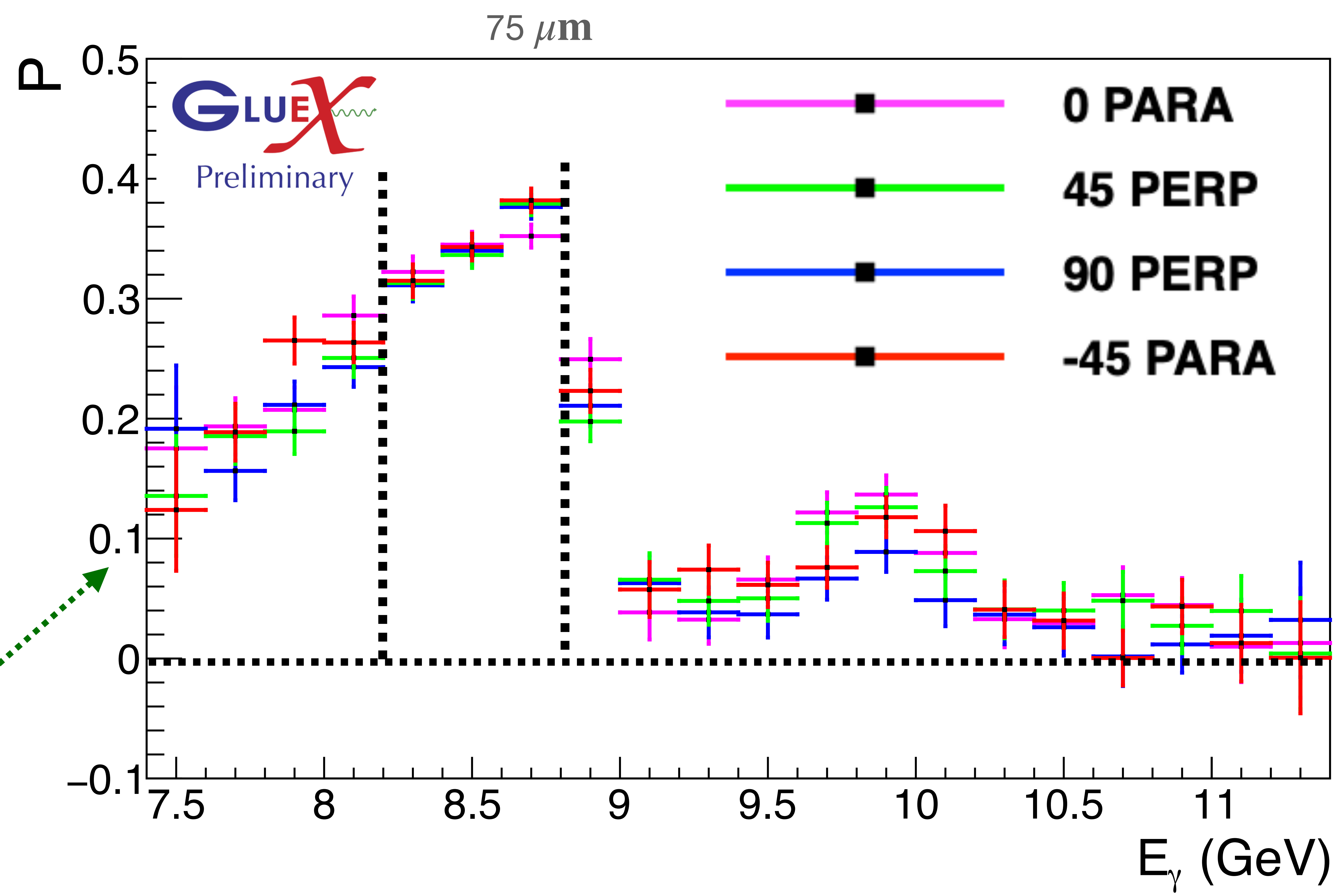
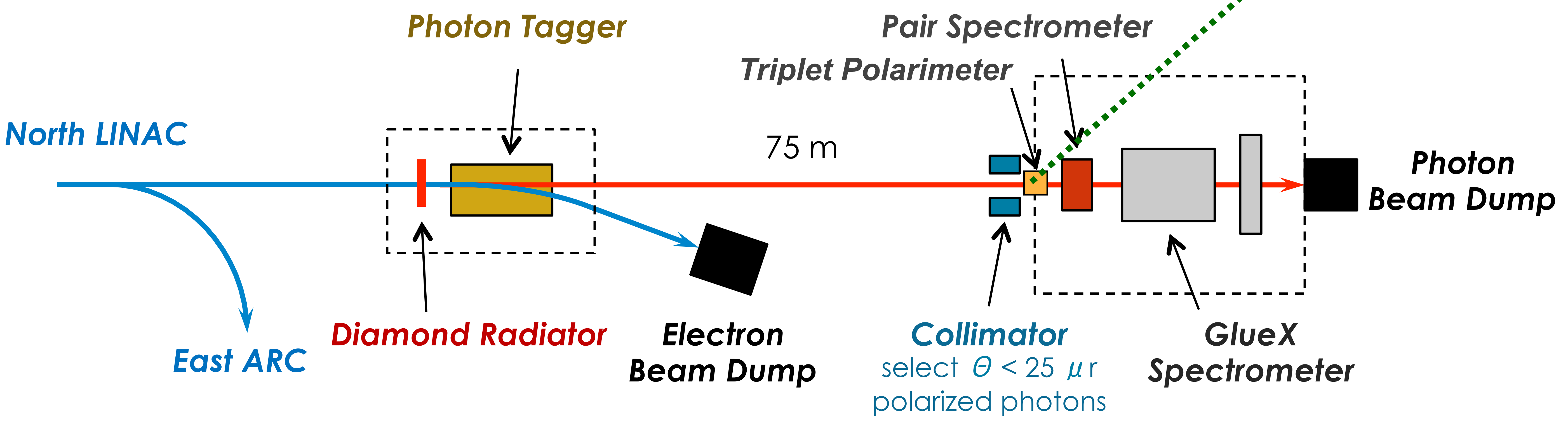
GlueX Detector, Beamline & Polarization







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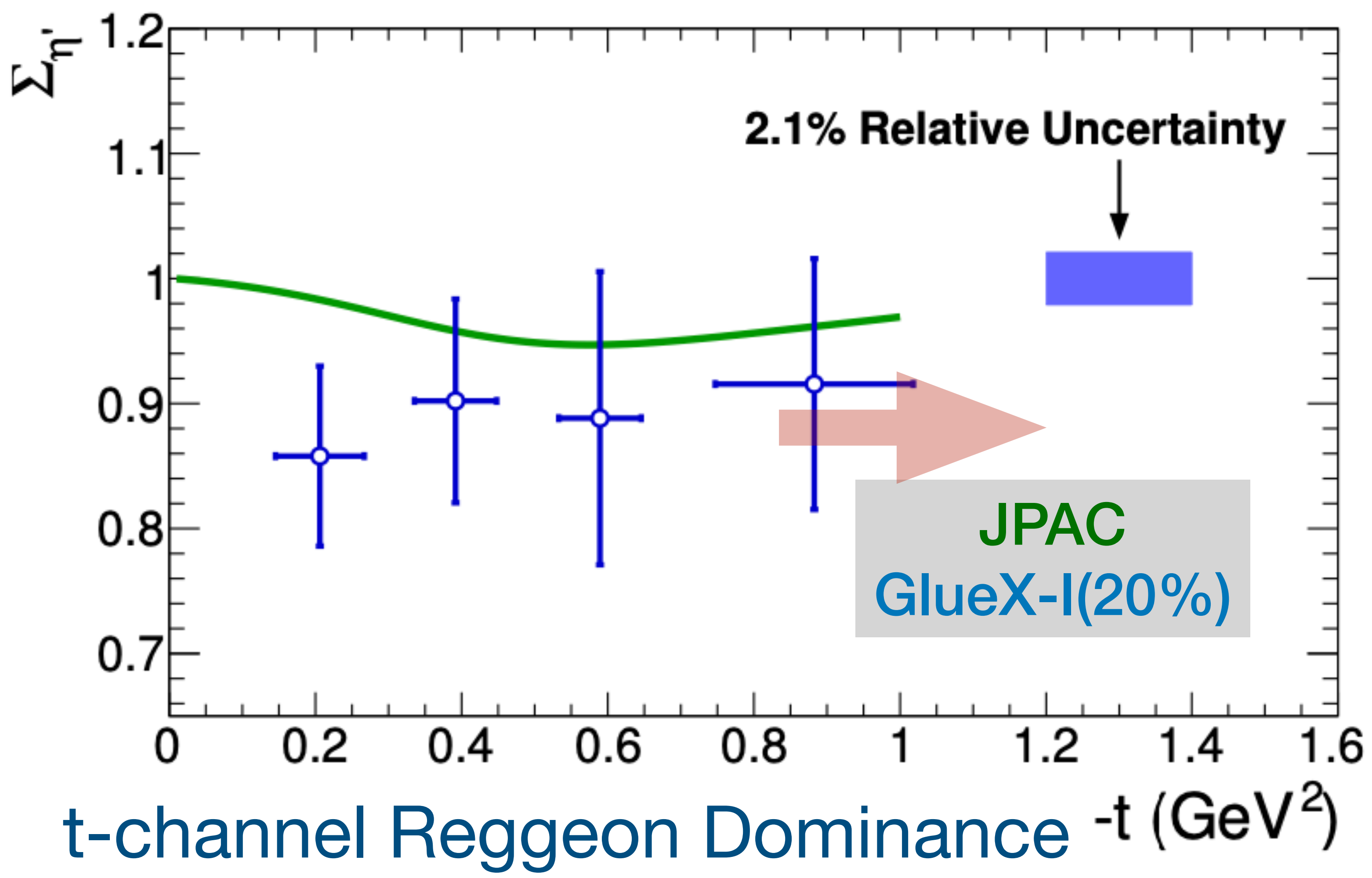
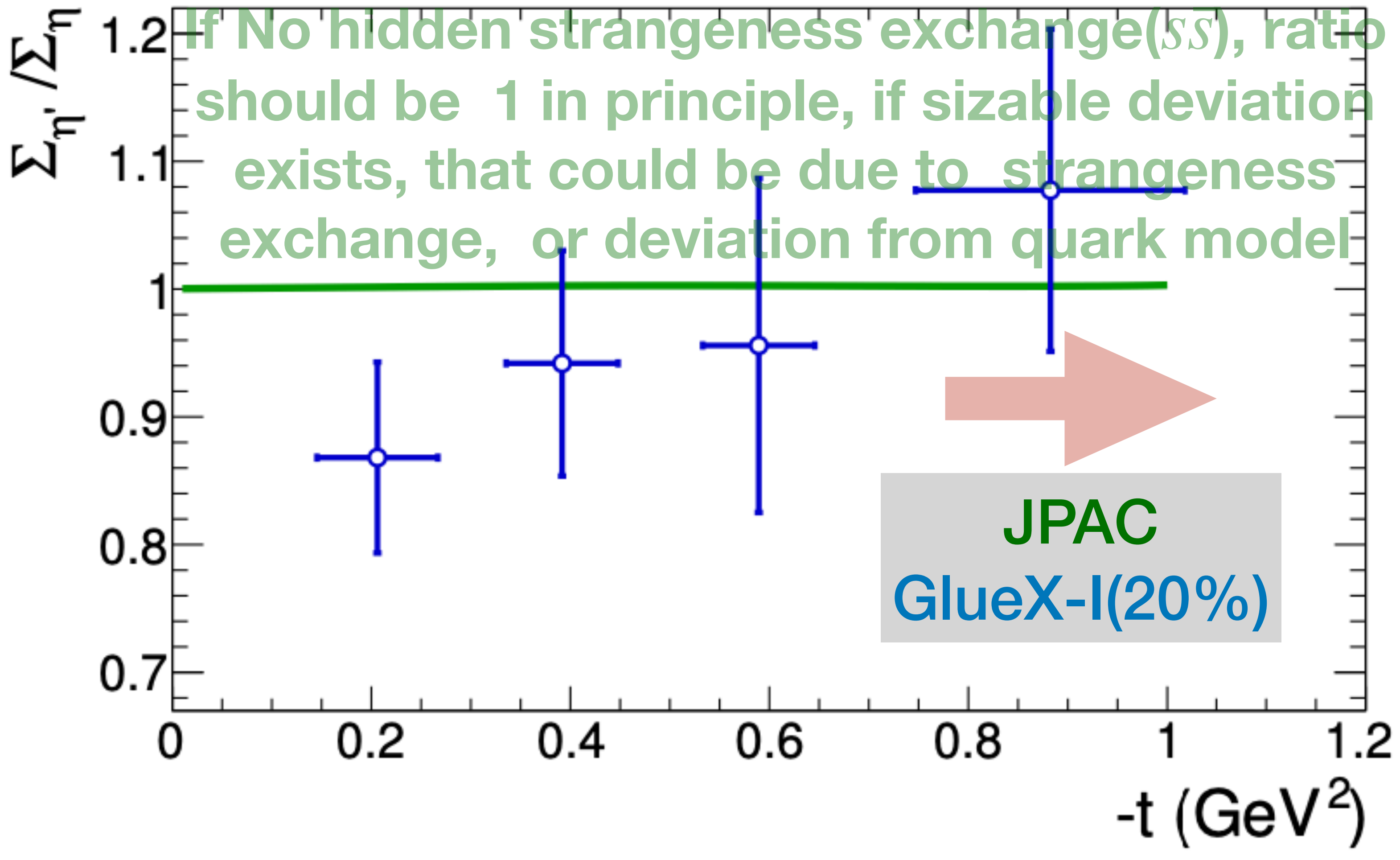
Prior Measurements & Models:

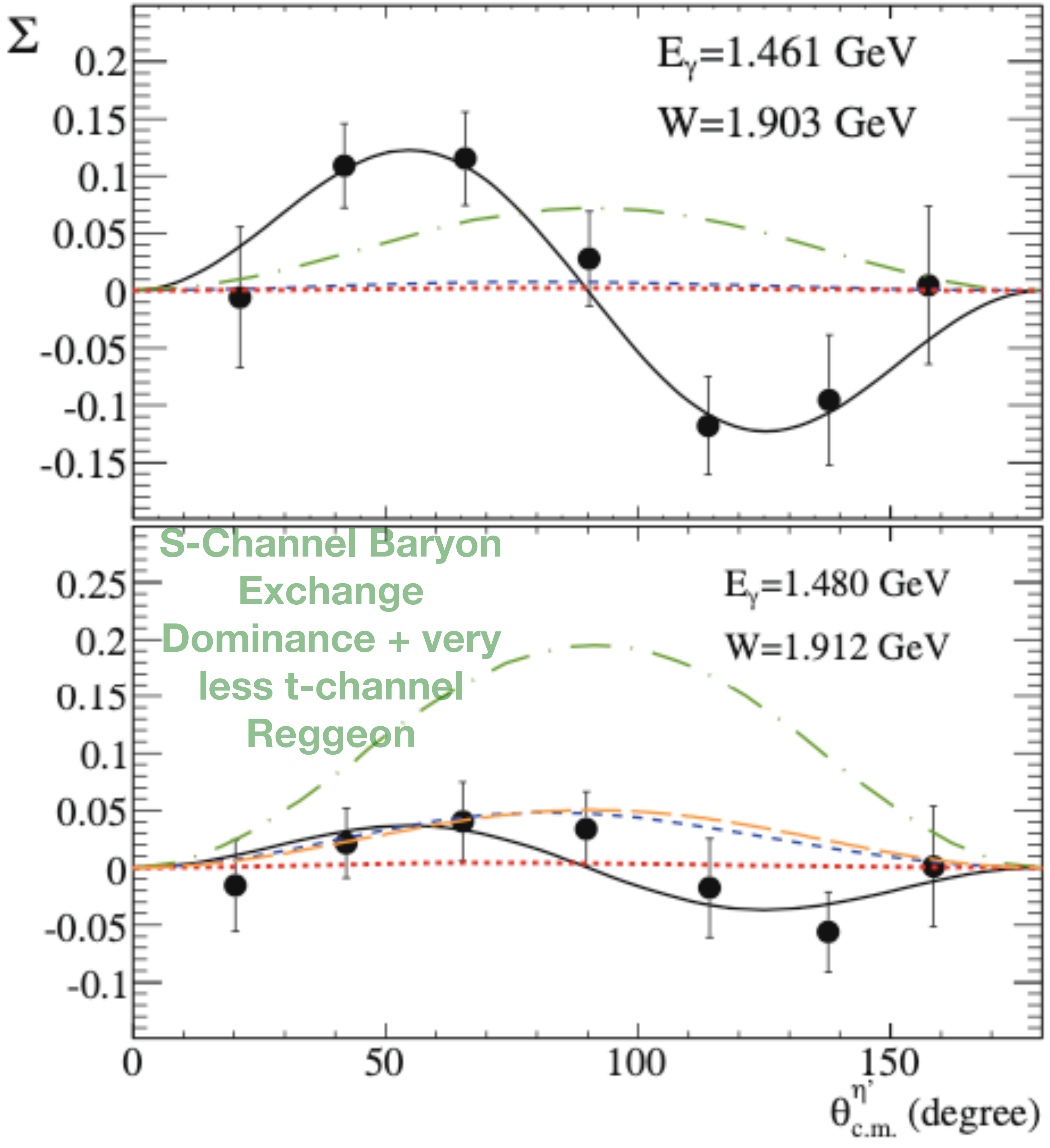


t-channel Reggeon Dominance



Phys. Rev. C **100**, 052201(R)

(From GlueX Collaboration)



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

(From GrAAL Collaboration, CLAS results were similar to this.)

....Eta-MAID(EtaPrime -MAID) (Phys. Rev. C 68, 045202 (2003))

....Nakayama & Haberzettl(Phys.Rev.C87,054004 (2013))

.....(V. A. Tryasuchev) Part. Nucl. Lett. 10, 315 (2013)

....Chiral-Quark Model (Phys. Rev. C 84, 065204 (2011))

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Invariant Mass

- Inner product of four-momentum vectors

- $\mathbf{M}^2 = (\Sigma\ \mathbf{P})^2 = (\Sigma\ \mathbf{E})^2 - (\Sigma \vec{\mathbf{p}})^2$

- $\mathbf{M}^2 = (\mathbf{E}_{\pi^+} + \mathbf{E}_{\pi^-} + \mathbf{E}_{\gamma_1} + \mathbf{E}_{\gamma_2})^2 - (\vec{\mathbf{P}}_{\pi^+} + \vec{\mathbf{P}}_{\pi^-} + \vec{\mathbf{P}}_{\gamma_1} + \vec{\mathbf{P}}_{\gamma_2})^2$
- $\mathbf{M}^2 = (\mathbf{E}_{\gamma_1} + \mathbf{E}_{\gamma_2} + \mathbf{E}_{\gamma_3} + \mathbf{E}_{\gamma_4} + \mathbf{E}_{\gamma_5} + \mathbf{E}_{\gamma_6})^2 - (\vec{\mathbf{P}}_{\gamma_1} + \vec{\mathbf{P}}_{\gamma_2} + \vec{\mathbf{P}}_{\gamma_3} + \vec{\mathbf{P}}_{\gamma_4} + \vec{\mathbf{P}}_{\gamma_5} + \vec{\mathbf{P}}_{\gamma_6})^2$

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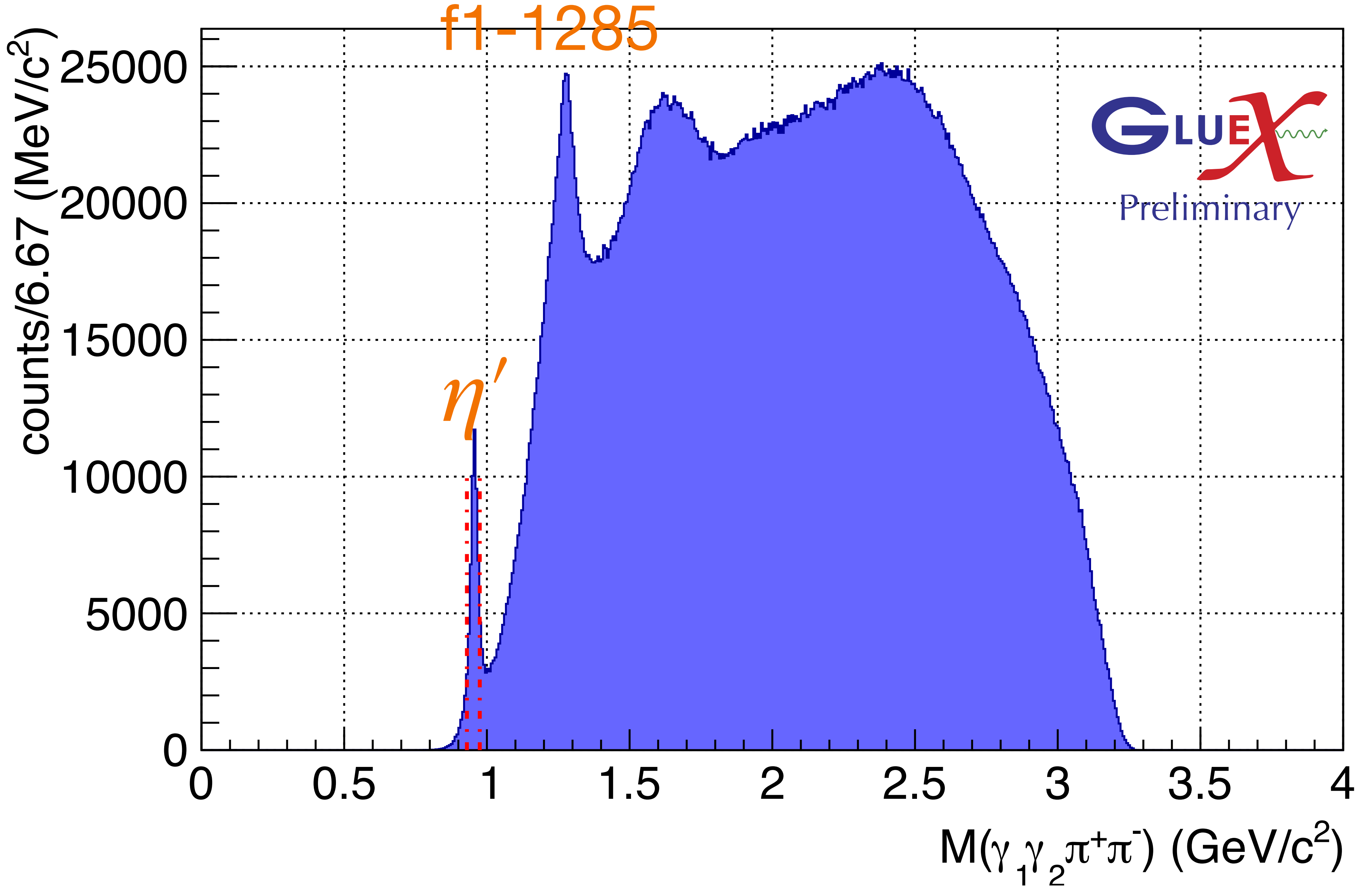
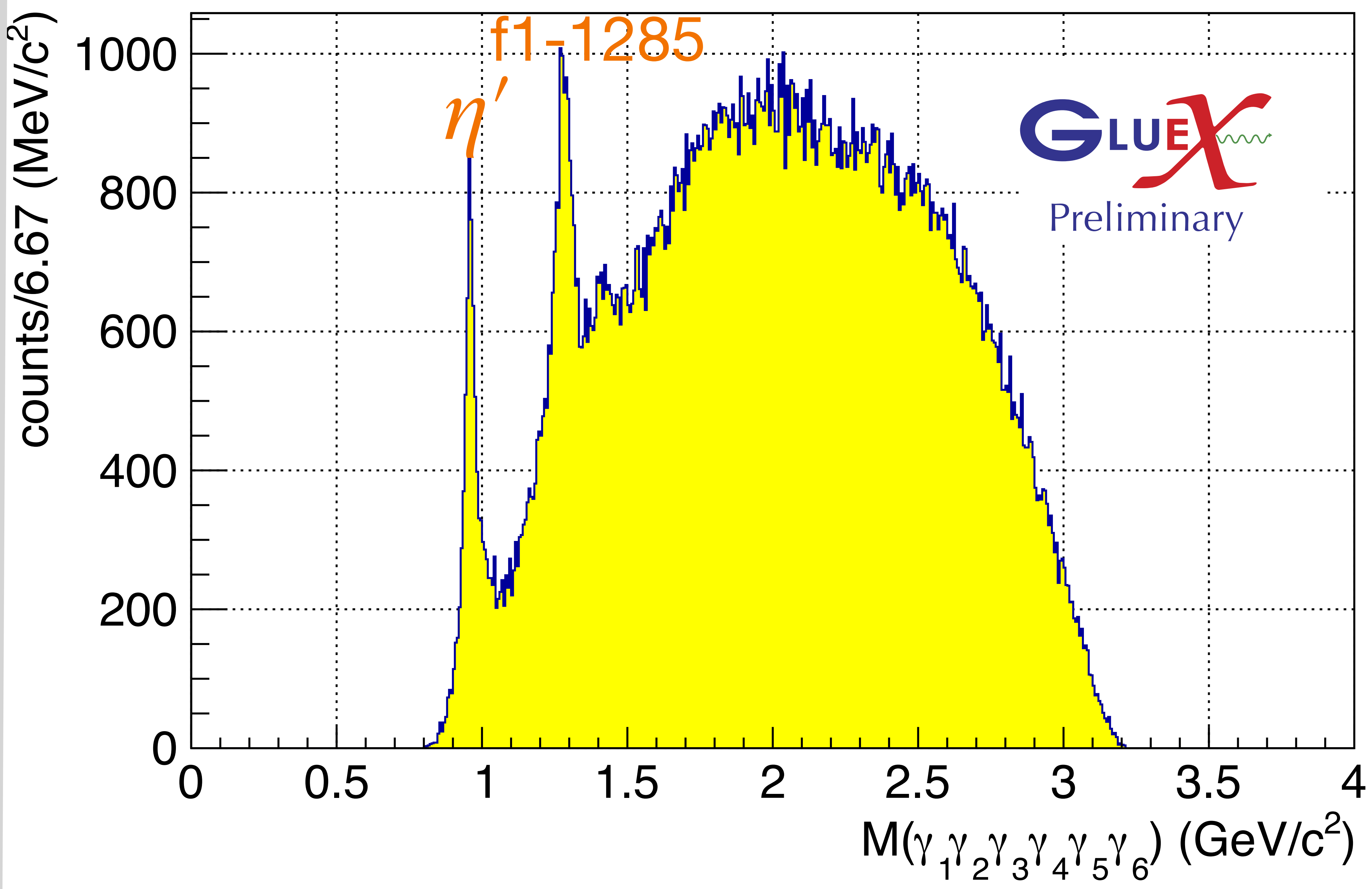
Invariant Mass Spectra

$\eta' \to \pi^+\pi^-\eta$



$\eta' \to \pi^0\pi^0\eta$



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Beam Asymmetry Method

Extract ϕ dependent yields

$$Y_{\parallel}(\phi, \phi_{\gamma} = 0, -45)\ \alpha N_{\parallel}[\sigma_0 A(\phi)(1 - P_{\parallel}\Sigma cos2\phi)]$$

$$Y_{\perp}(\phi, \phi_{\gamma} = 45{,}90)\ \alpha N_{\perp}[\sigma_0 A(\phi)(1 + P_{\perp}\Sigma cos2\phi)]$$

FORM A RATIO OF diff. & sum of YIELDS

(REDUCE SOME OF SYSTEMATICS)

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

ϕ_0 is the diamond misalignment offset

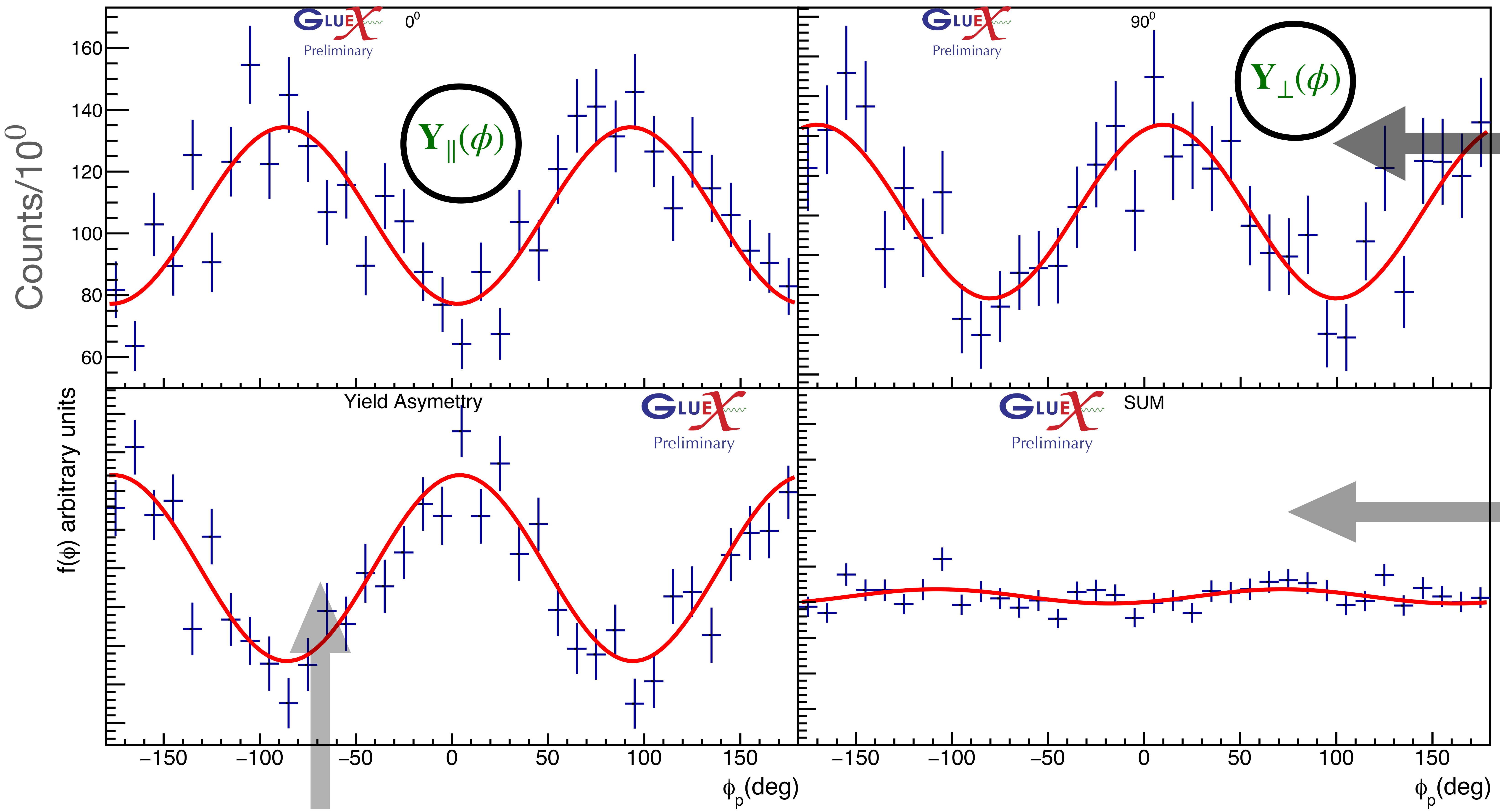
$$\mathbf{F_R} = \frac{\mathbf{N_{\perp}}}{\mathbf{N_{\parallel}}}$$

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

$$\Sigma_{\mathbf{Signal}} = \frac{\Sigma_{\mathbf{Peak}} - \delta\Sigma_{\mathbf{BG}}}{\mathbf{1} - \delta}$$

$$\delta = \frac{\mathbf{B}}{\mathbf{S + B}} \qquad \Sigma_{\mathbf{BG}} \approx \Sigma_{\mathbf{SB}}$$

Phi_Distributions for one data set, Yield Asymmetry and Sum



0.3<-t<0.5 GeV^2

$Y_{\perp} + FR * Y_{\parallel}$

$$YA = \frac{Y_{\perp} - FR * Y_{\parallel}}{Y_{\perp} + FR * Y_{\parallel}} = \frac{(P_{\perp} + P_{\parallel})\Sigma cos2(\phi - \phi_0)}{2 + (P_{\perp} - P_{\parallel})\Sigma cos2(\phi - \phi_0)}$$

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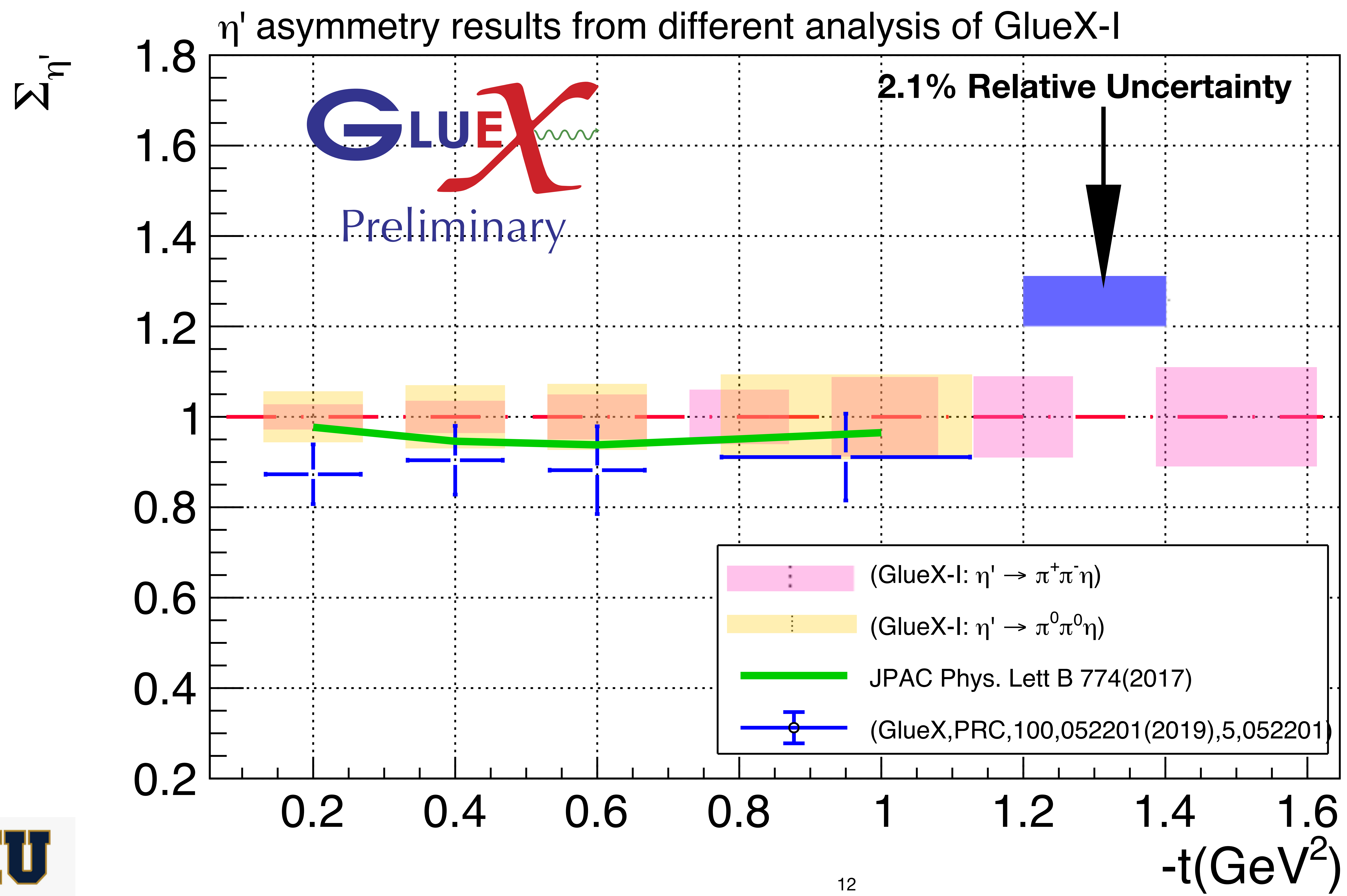
Projected Preliminary Uncertainties from GlueX-I



Outlook

- Ongoing analysis, event selections/Data Quality, invariant Masses, angular distributions etc..
- Able to see preliminary projections to see how far in -t we can access
- Get results using full data sets from GlueX-I,II
- Systematics on various aspects

Thank You so much everyone!!!

Backup

SB region selection