Differential η photoproduction cross sections off the proton from the GlueX experiment

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On behalf of the GlueX Collaboration

Outline

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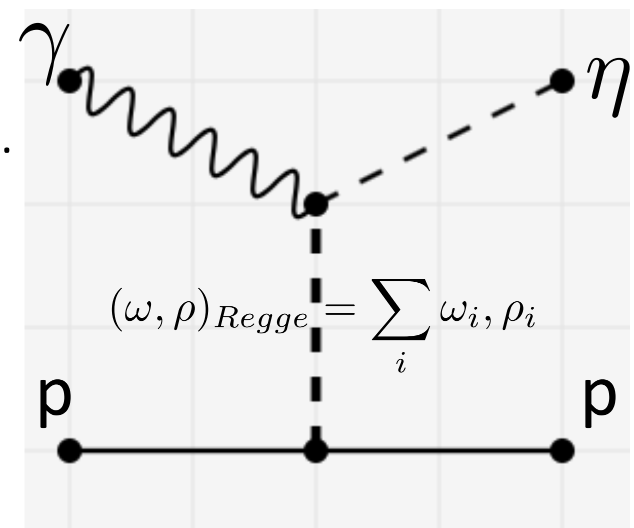
- GlueX detector and data selection
- η Differential cross section in low t-range
- η Differential cross section in low u-range
- η Differential cross section in the intermediate region (Large t and u)
- Summary

Introduction

- GlueX studies the light meson spectrum and searches for exotic and hybrid mesons. The production of the lightest multiplet of exotic mesons involves the same Regge exchanges that occur in the pseudoscalar mesons production like $\eta^{(')}$ (Mathieu et al., *Physics Letters B, 774 (2017) 362-367)*.

- The chosen reaction is one of the simplest final states in the GlueX experiment to test the Regge theory for s and t dependence.



- The forward cross section peak is due to mesons exchange ($S^{2\alpha(t)-2}$), while the backward cross section peak is due to baryons exchange ($S^{2\alpha(u)-2}$), where $\alpha(t)$ and $\alpha(u)$ are the exchanged Regge trajectories (M. Guidal, J.M.Laget and M. Vanderhaeghen*: Nucl.Phys.A 627 (1997) 645-678*).

- Previous cross section measurements are scarce for beam energies above 4.5 GeV. GlueX will provide the most extensive high statistics measurements currently available.

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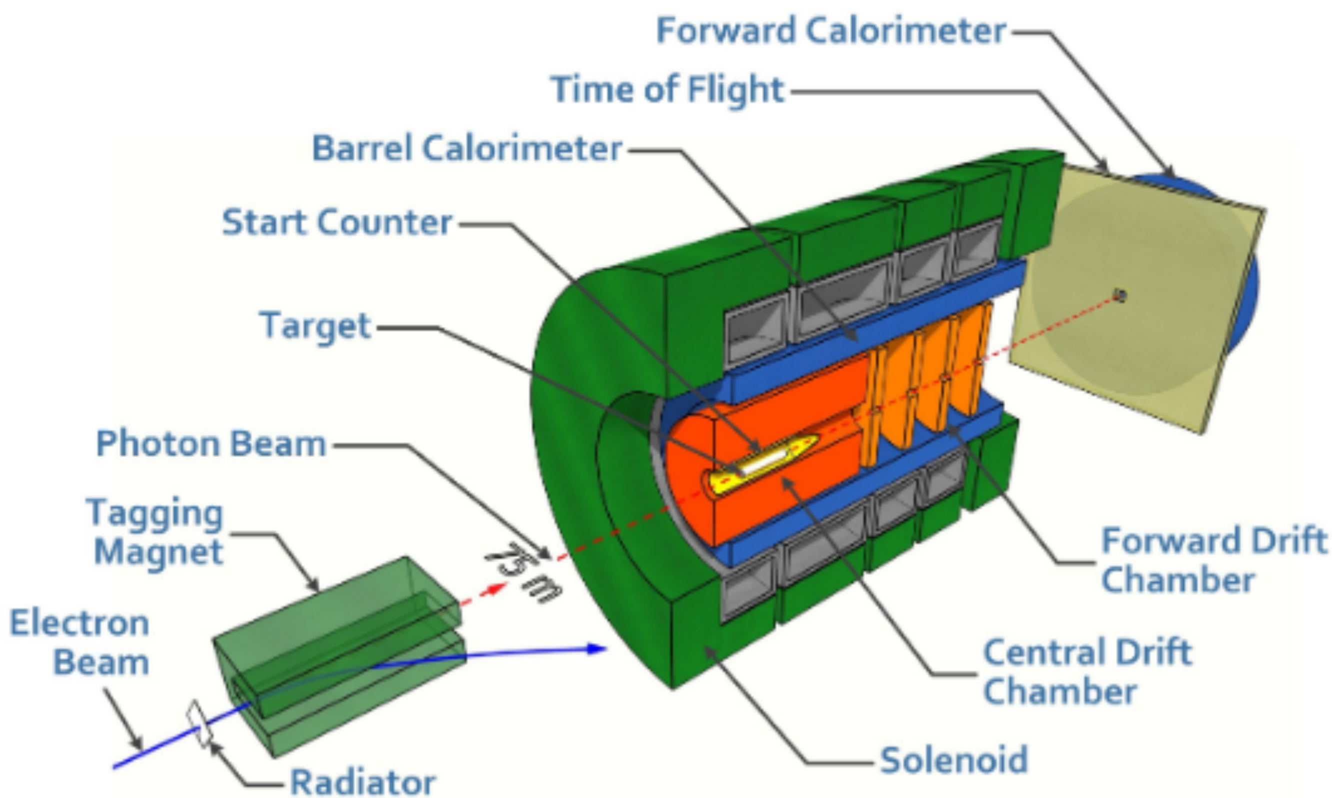
Introduction

GlueX data tests many theoretical models in the full t-range such as :

- EtaMAID2018 (L. Tiator et al. 2018), *Eur. Phys. J. A 54, 210 (2018),*
    - 21 N^* nucleon resonance states and Regge background
- JPAC (Nys et al. 2017), *Nys et al.,PhysRevD.95.034014, 2017*
- Laget Model (Laget 2006, Simon 2015), *Laget J. M., Phys. Rev. C73:044003,2006*
- *Handbag model (P. Kroll and P. Passek 2018),* *P. Kroll and P. Passek, PhysRevD.97.074023, 2018*
    - Handbag model studies the patron distribution functions and its cross section predictions valid for large s, t, and u >> conventional hadron scale 1 GeV^2

GlueX Detector

- GlueX detector located at Hall-D in Jefferson lab.
- Designed to detect charged particles and neutrals that are byproducts of possible exotic states.
- Linearly polarized photon beam interacts with a 30 cm liquid Hydrogen target in the middle of the GlueX detector.



Data Selection

$$\gamma + p \rightarrow \eta + p$$

- 39.41 % $\pm$ 0.20 $\eta \rightarrow \gamma\gamma$ neutral mode

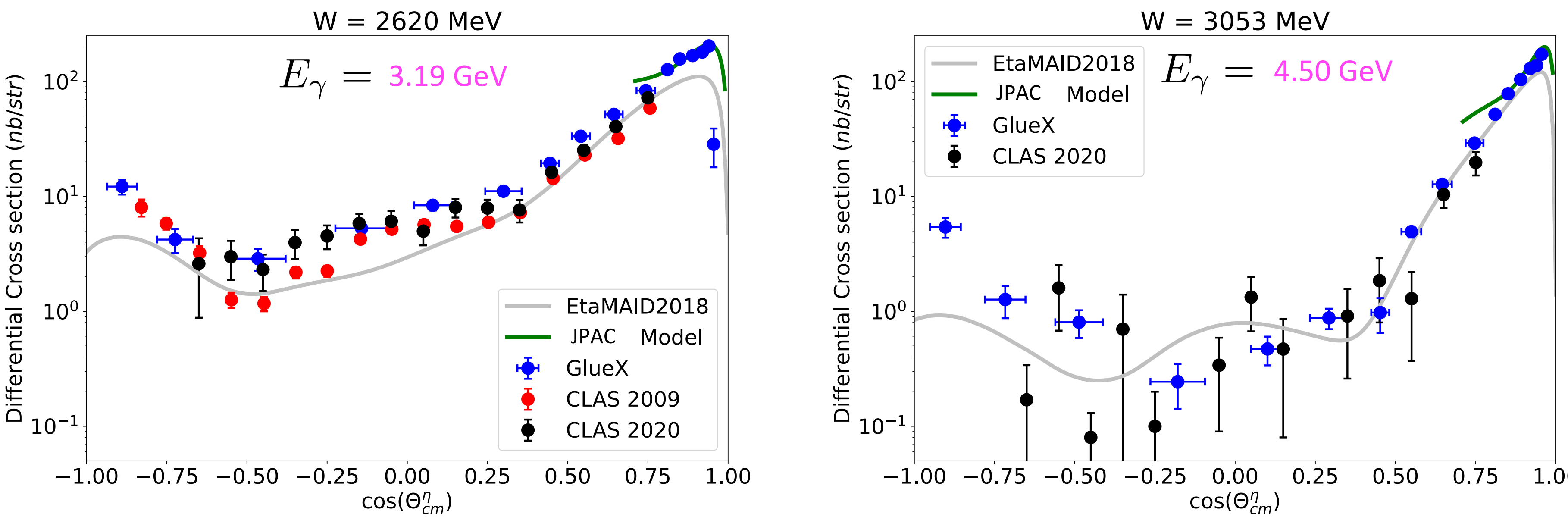
OR

- 22.92 % $\pm$ 0.28 $\eta \rightarrow \pi^+\pi^-\pi^0$ charged mode
- Most of the differential cross section results that will be shown today are from the neutral mode.

Phase	Run period	Raw Data(PB)
GlueX I	Spring 2017	0.9
	Spring 2018	1.9
	Fall 2018	1.1
GlueX II	Spring 2020	2.8
	Summer 2020	1.7

- The GlueX beam energy ($6.0 < E_\gamma < 11.5$ GeV).
- 50 % of GlueX-I data were used in the η photoproduction differential cross section measurements. The luminosity in the bin of $E_\gamma =$ 8.25 $\pm$ 0.25 GeV is 44 pb^{-1}.
- Short dedicated run for low energy data ($3 < E_\gamma < 5.5$ GeV) during the Fall 2018 run period.

Differential cross section comparisons with previous measurements



- Short dedicated run for low energy data $3 < E_\gamma < 5.5$ GeV.
- GlueX has better coverage than CLAS in low t, and u kinematic regions.
- At higher energies, the statistics are not limited in the GlueX compared to CLAS2020 results.

Williams et al., Phys. Rev. C, 80(4):045213,2009

Hu et al., arXiv:2006.01361, 2020

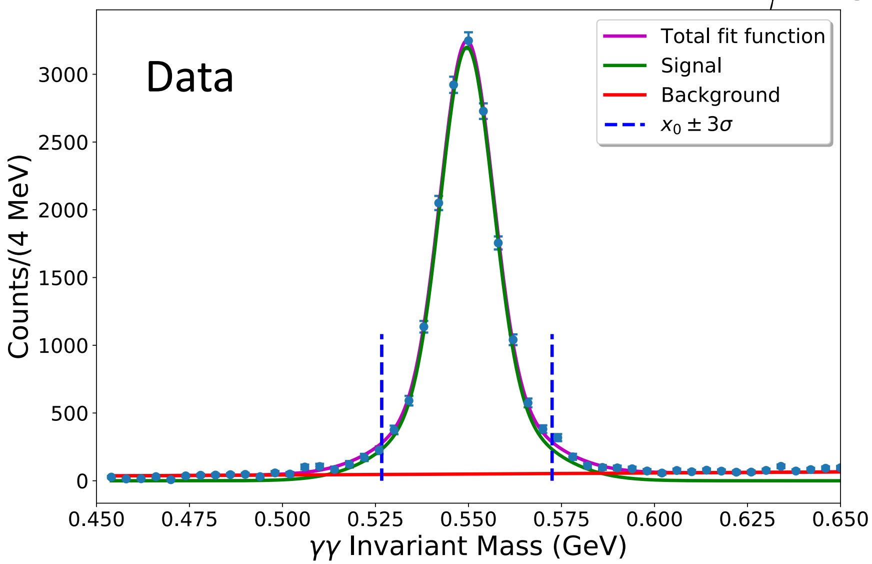
Tiator et al., *arXiv:1806.04525, 2018*

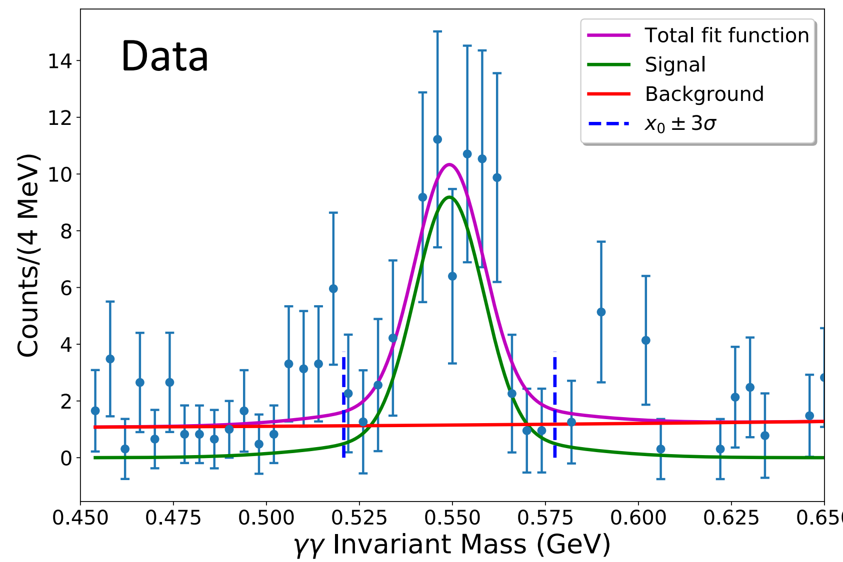
Nys et al.,PhysRevD.95.034014, 2017

http://cgl.soic.indiana.edu/jpac/EtaPhot.php,

GlueX-I data
Yield Extraction

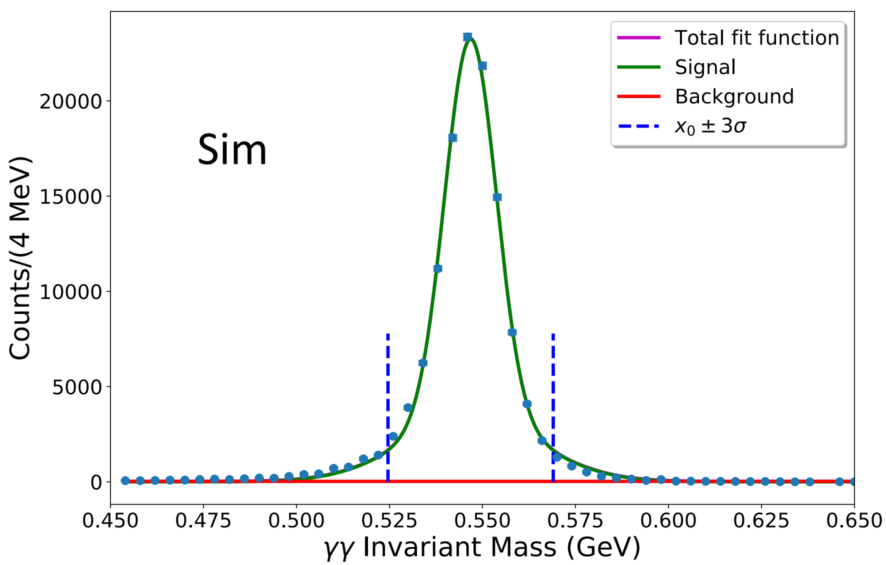
$E_\gamma = 8.25 \pm 0.25$ GeV

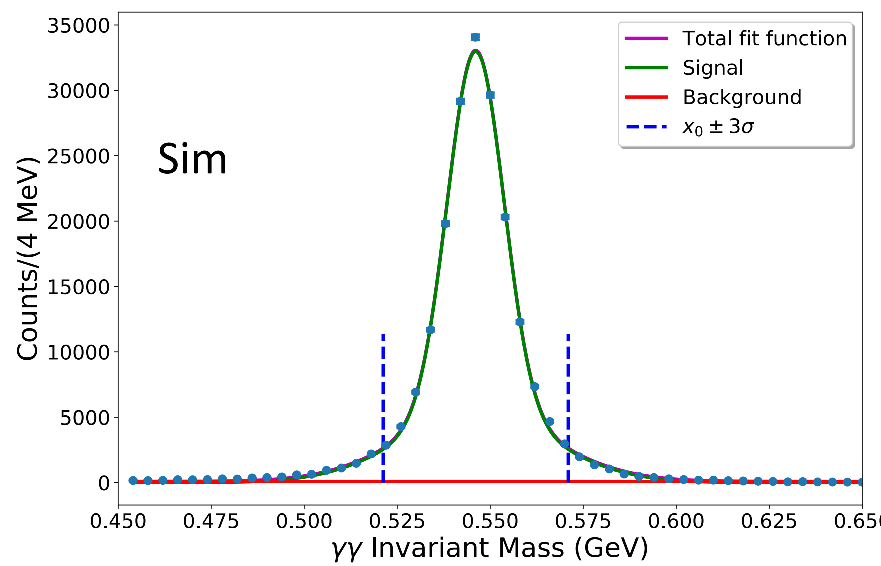




t =0.55 GeV^2

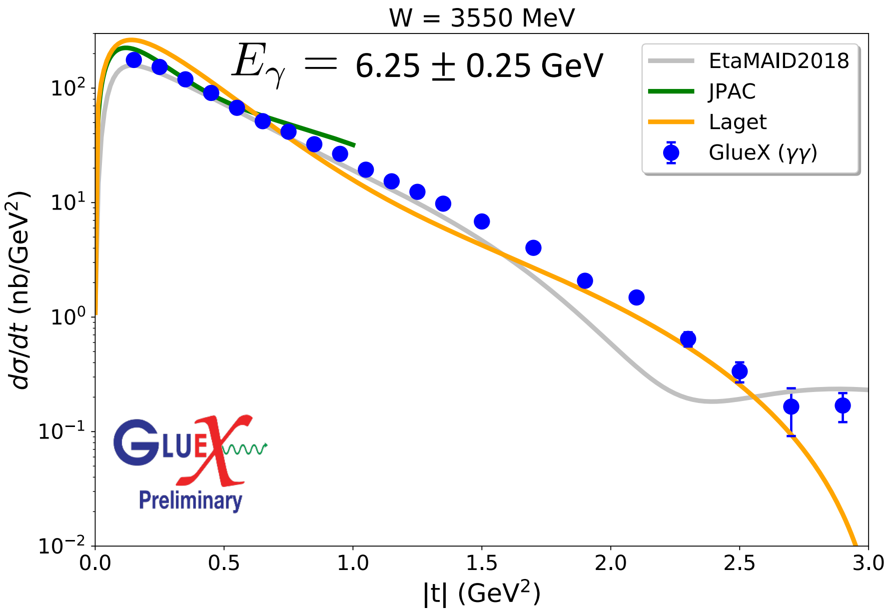
t =2.7 GeV^2

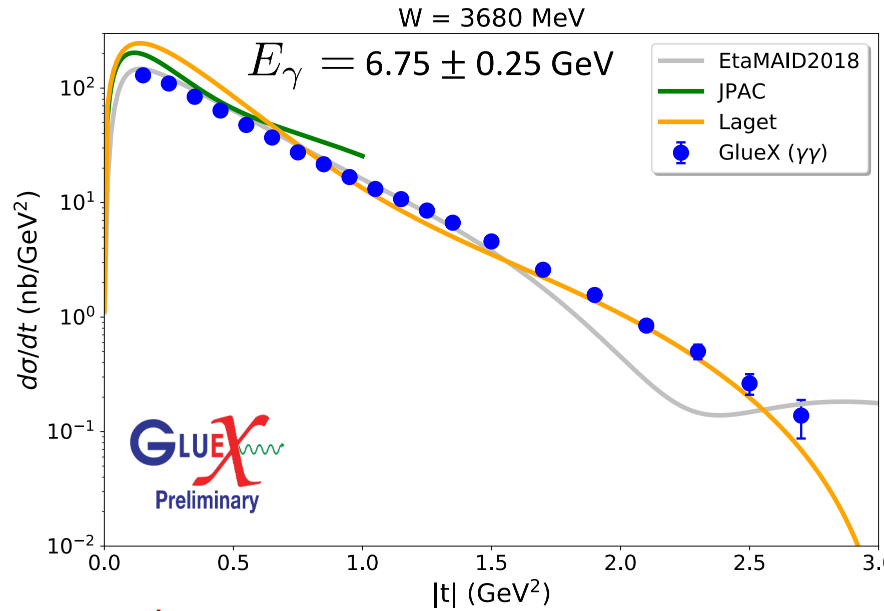




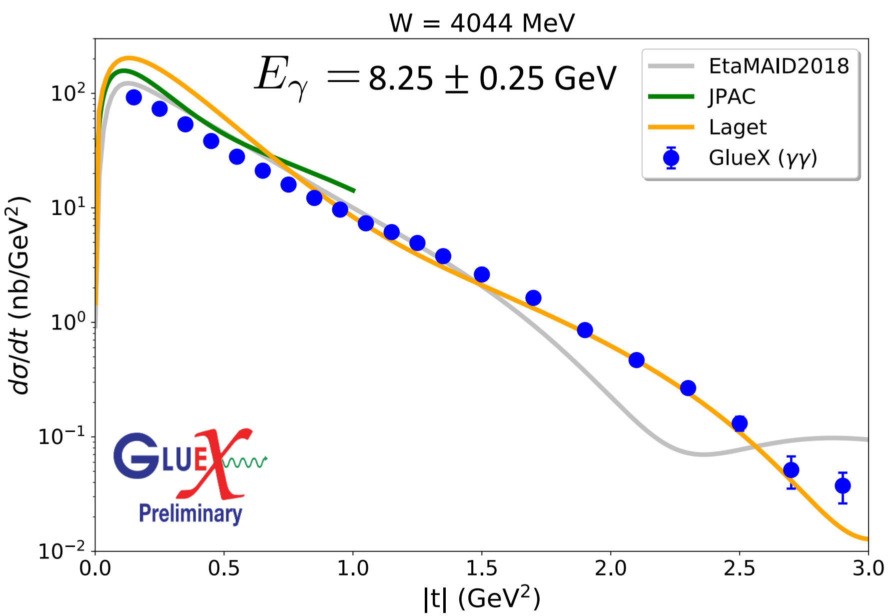
- Good fits and agreement between data and simulation

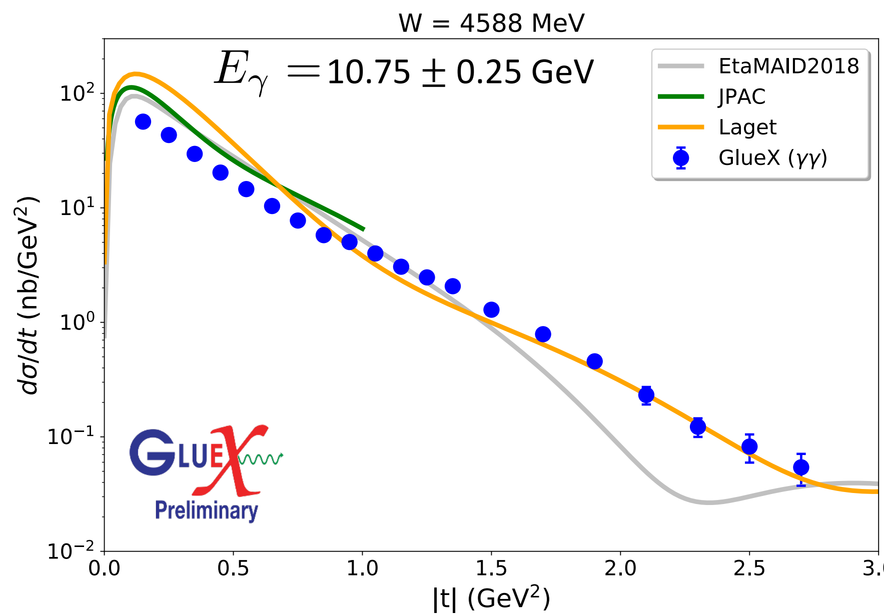
Differential Cross Section Results for the t-range [0, 3.0] GeV^2



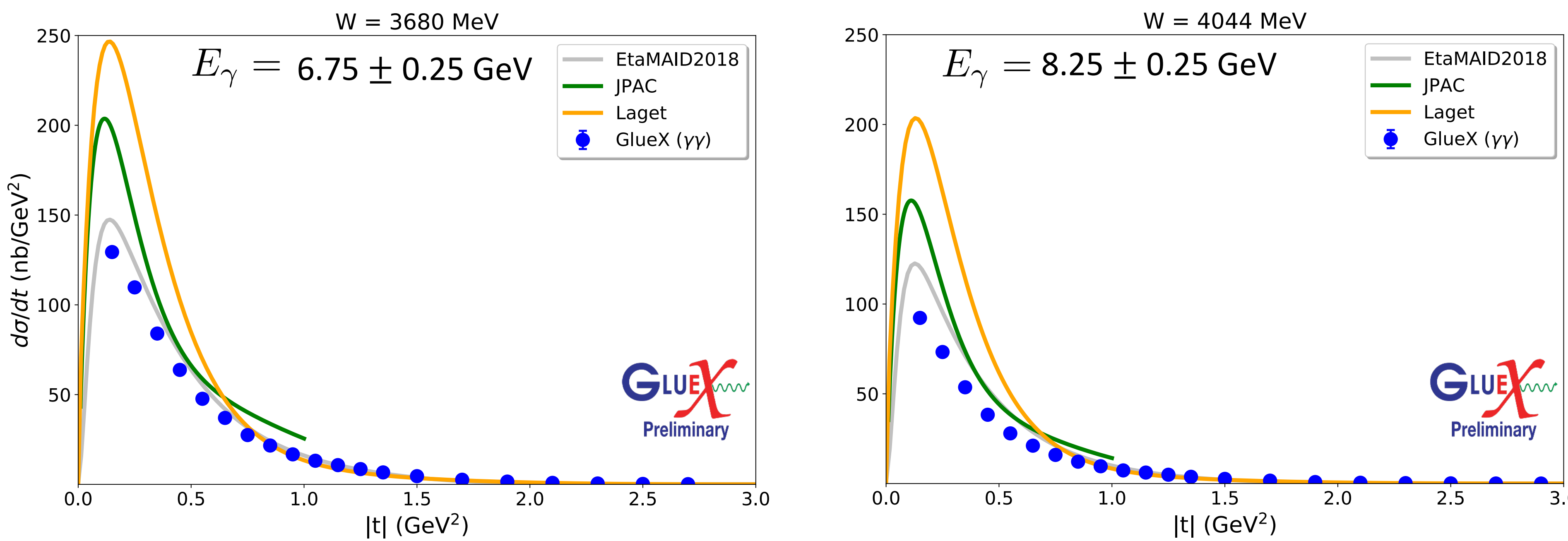


Errors are statistical





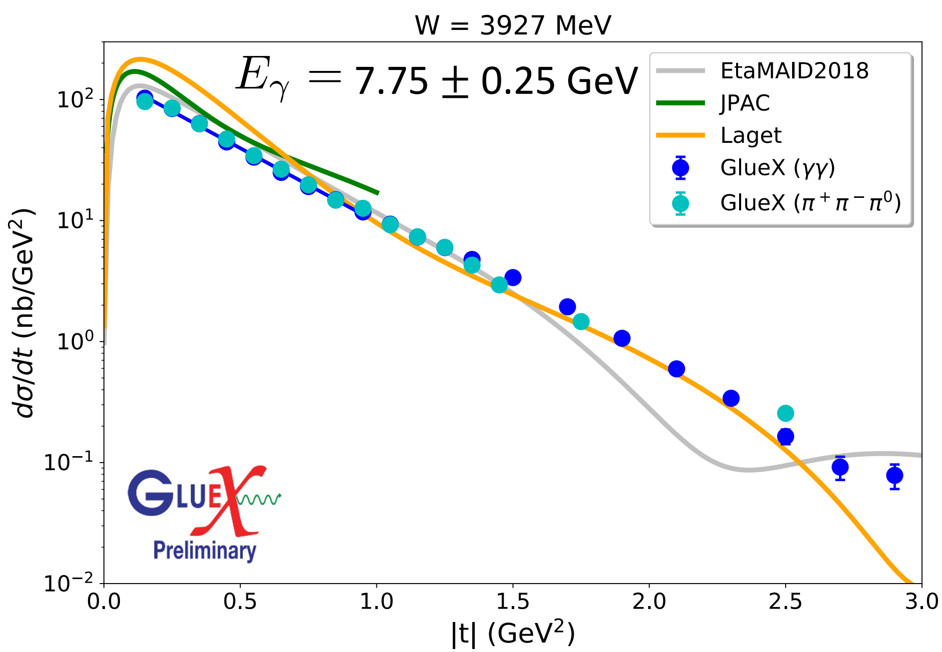
Differential Cross Section Results for the t-range [0, 3.0] GeV^2

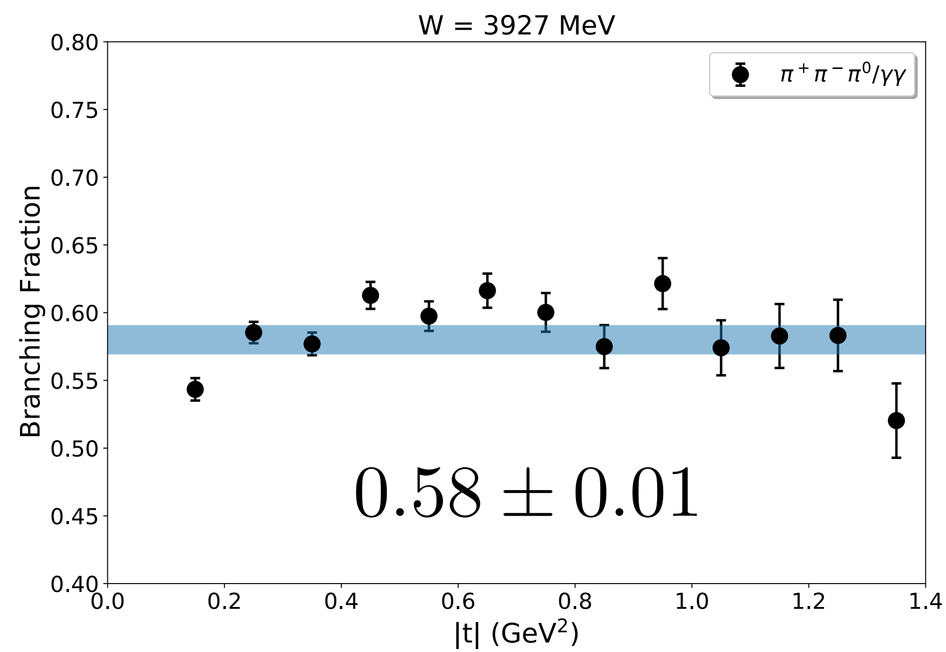


- EtaMAID2018 has similar pattern as data at |t| < 1.5 GeV^2, while Laget model has similar pattern as the data at |t| > 1.5 GeV^2.
- EtaMAID2018 has better agreement with the data at low energies.

Differential Cross Section Results for the t-range [0, 3.0] GeV^2

Compare to charged decay mode

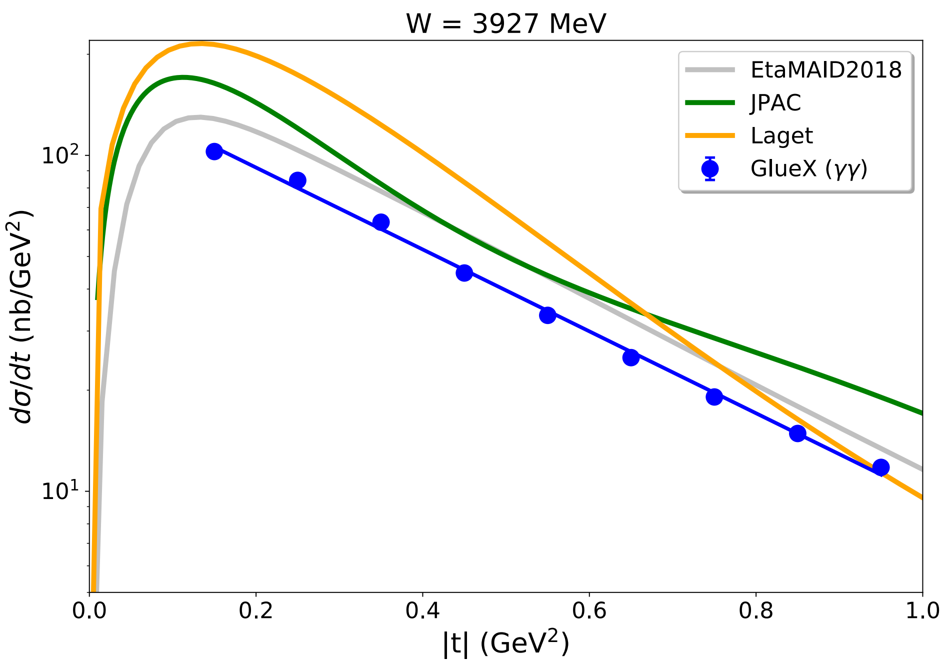


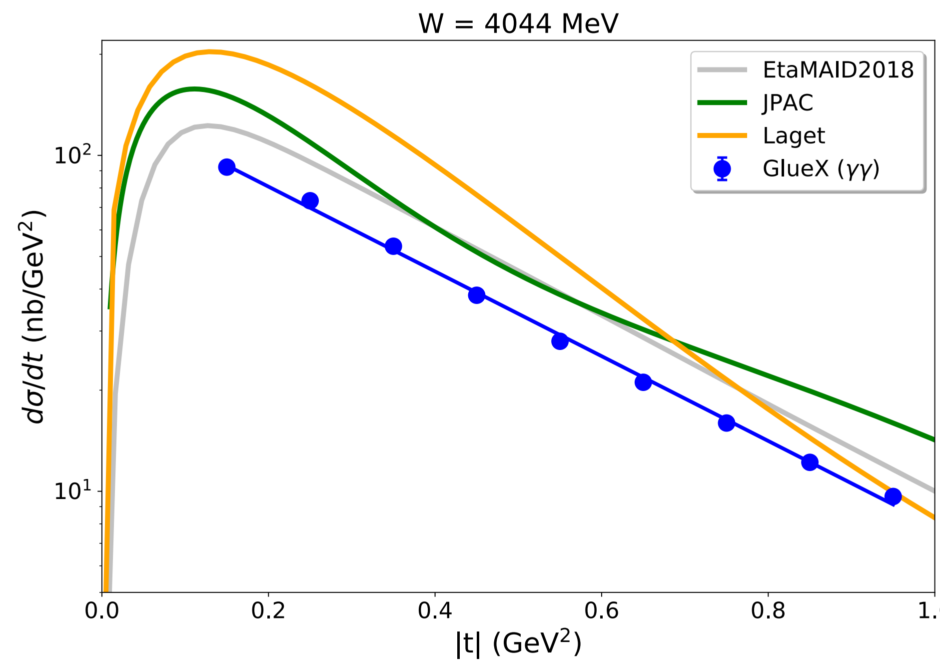


- Good agreement with the PDG branching fraction of the two decay-branching ratios

Zoom In Differential Cross Section Results for the t-range [0, 1.0] GeV^2

- Linear Fit for $\ln(\frac{d\sigma}{dt})$ for |t| < 1 GeV^2
- Determine Regge parameters





- The slope from the data is very similar to the EtaMAID2018

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Extracted Regge Trajectories

A Regge trajectory can be expressed as

$$\alpha(t) = \alpha' t + \alpha_0 \,,$$

where the differential cross section in the t-channel exchange is proportional to :

$$\frac{d\sigma}{dt} \propto \left(\frac{s}{s_0}\right)^{2(\alpha' t + \alpha_0) - 2}$$

s_0 = 1 GeV^2 (Conventional hadronic scale)

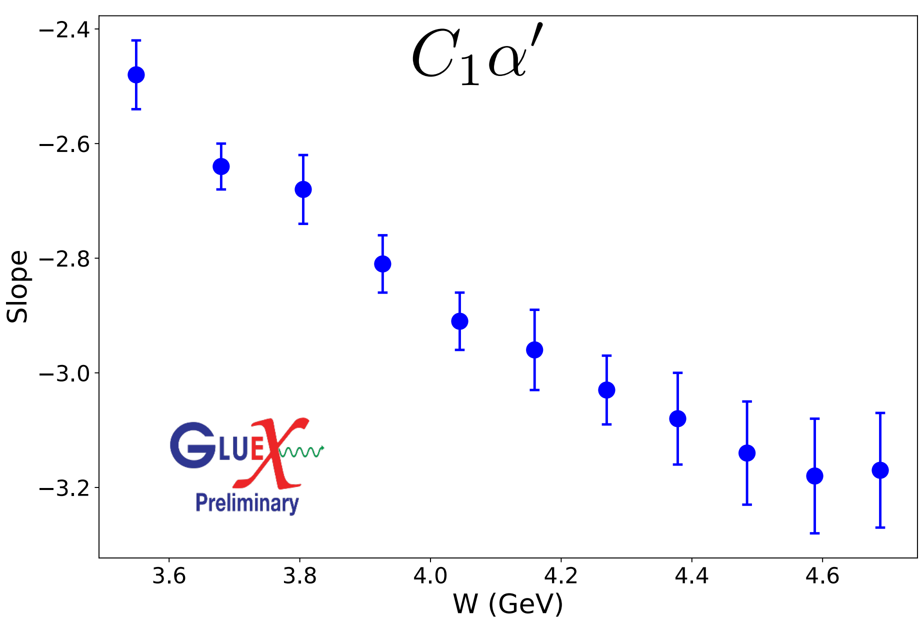
$$\ln\left(\frac{d\sigma}{dt}\right) \propto C_0 + C_1 \alpha' t,$$

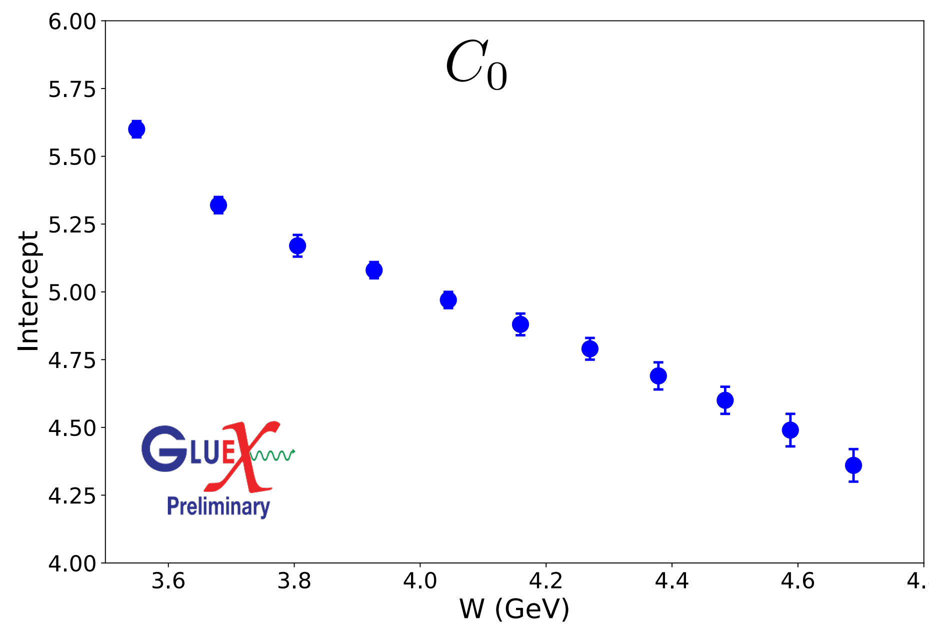
where

$$C_1 = 2 \ln\left(\frac{s}{s_0}\right)$$

$$C_0 = C_1(\alpha_0 - 1) + \ln \Lambda,$$

Where Λ is the proportionality constant





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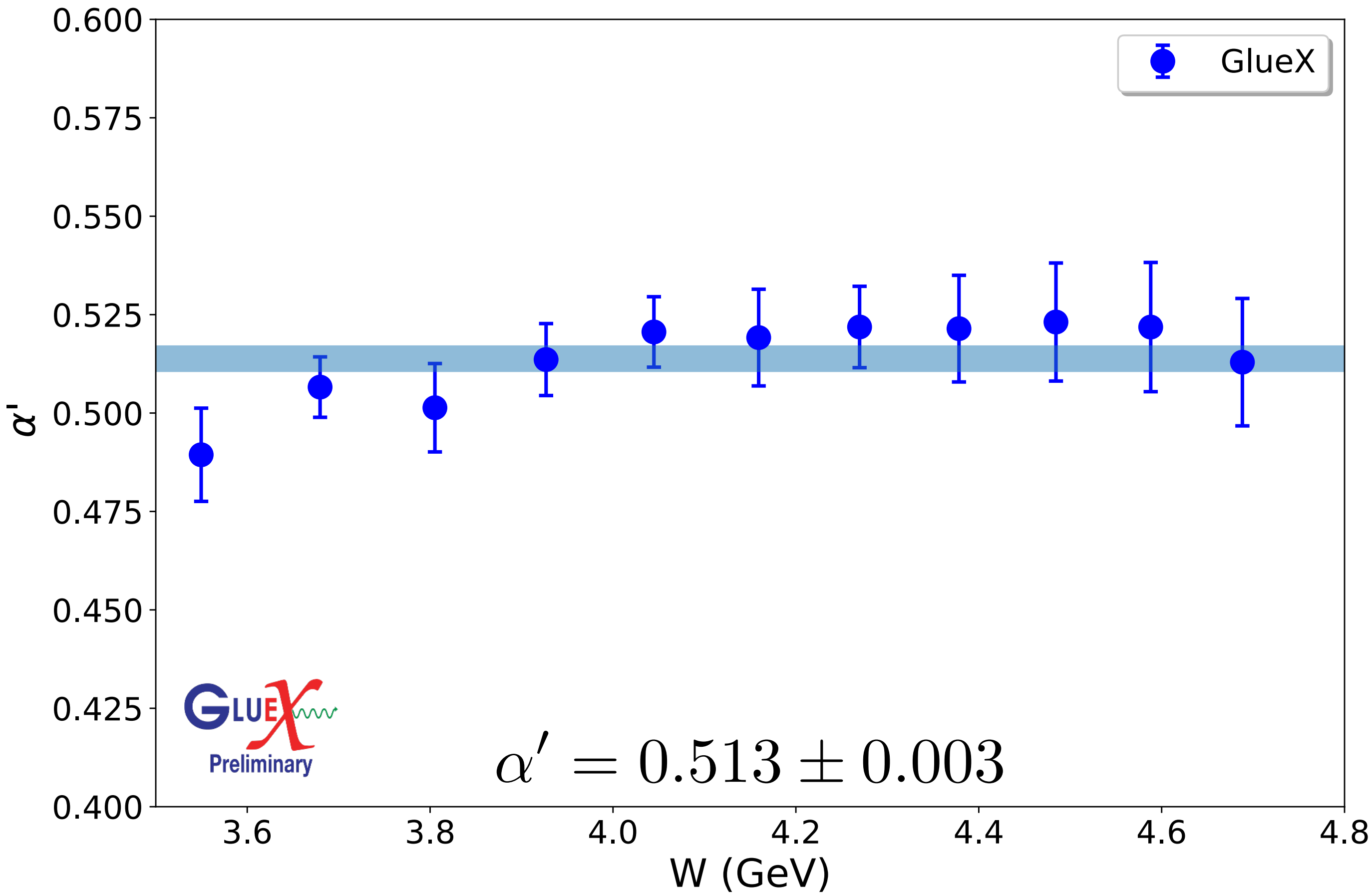
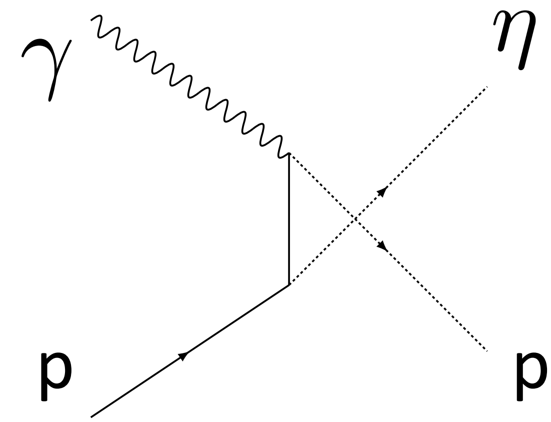
Extracted Regge Trajectories

$$\alpha' = |\text{slope}|/C_1$$

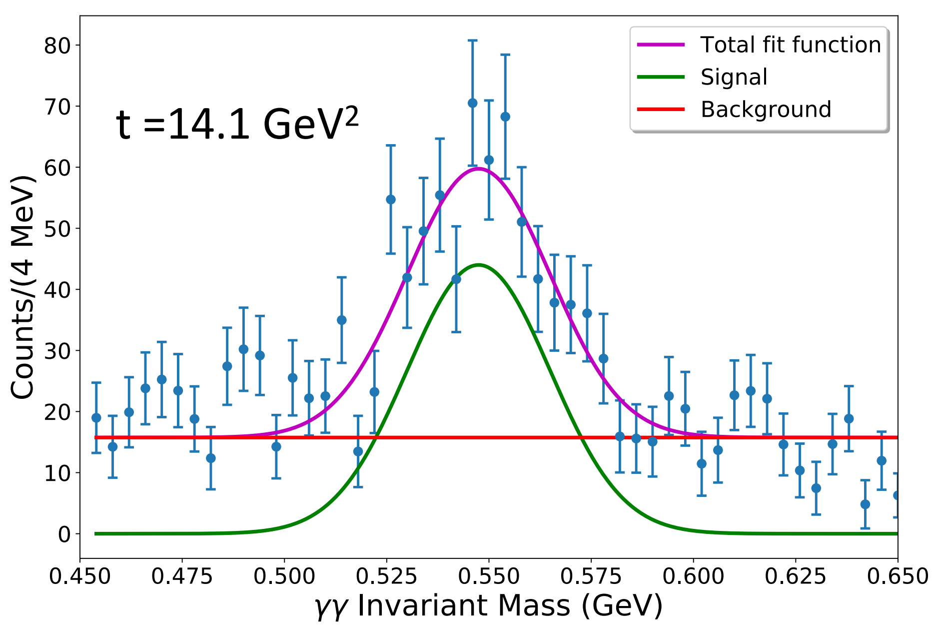


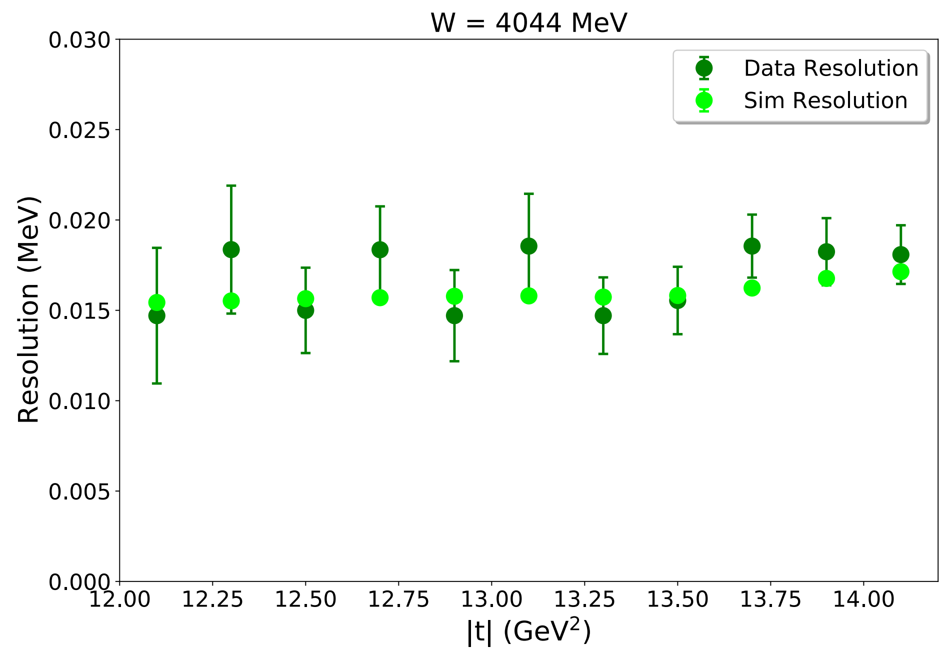
Differential cross section in the low u-range

- GlueX has a very good acceptance to measure the differential cross section in both t-channel, and u-channel exchanges.



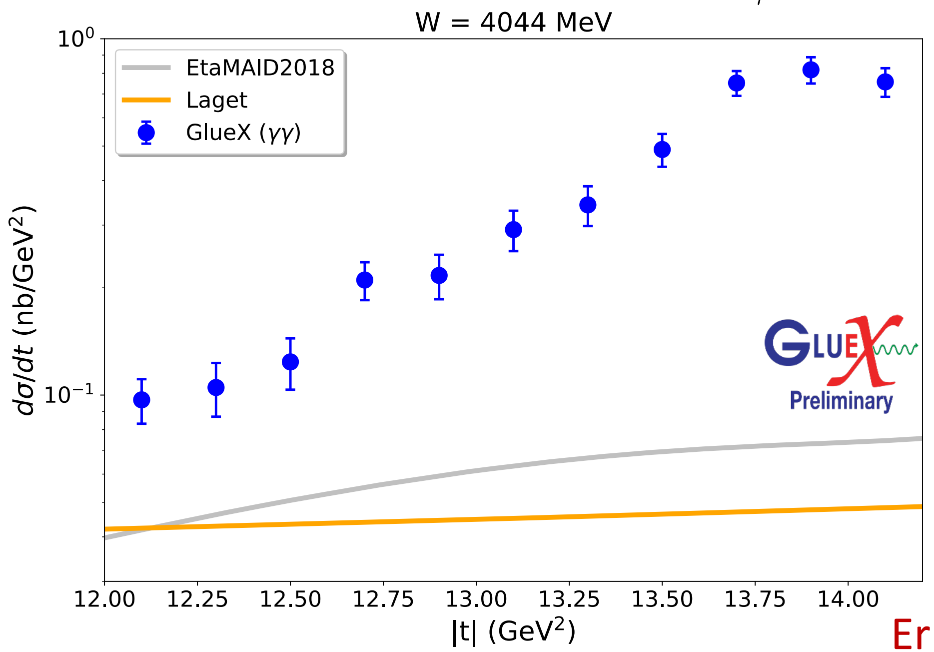
Gaussian fit + Linear background to extract the yield from each t-bin.

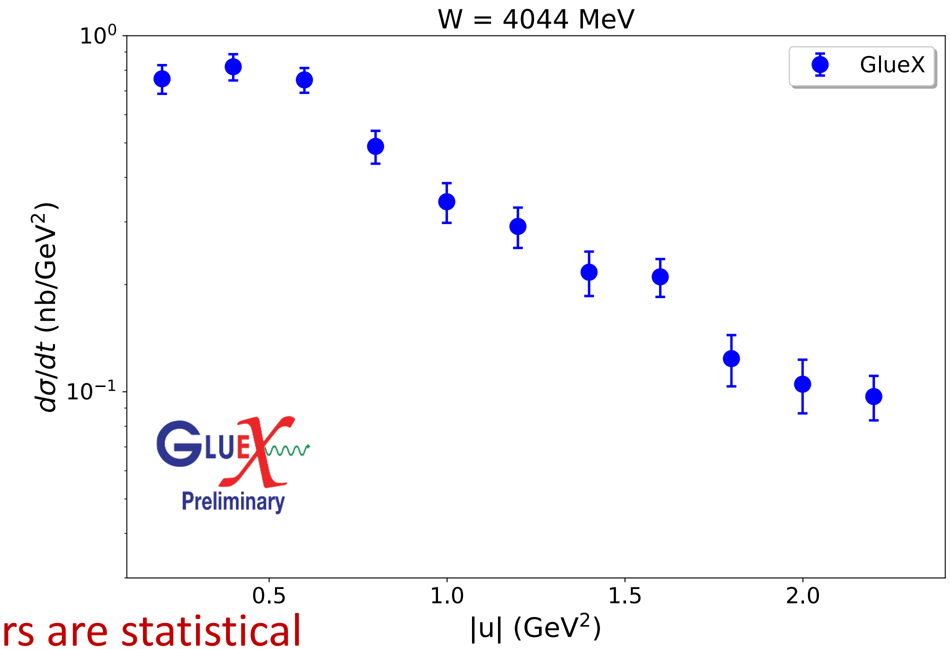




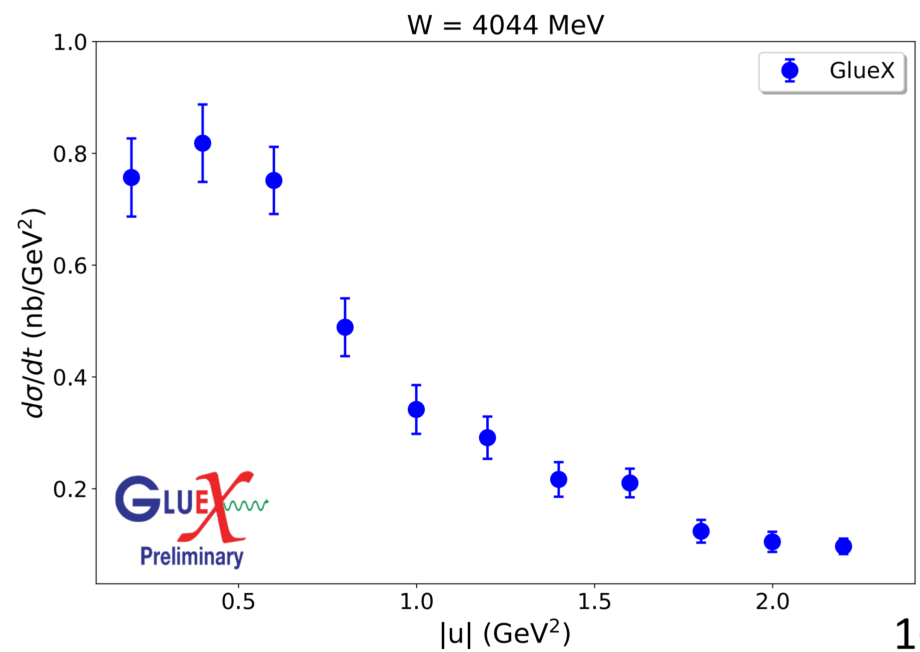
Differential cross section in the low u-range

$E_\gamma = 8.25 \pm 0.25$ GeV





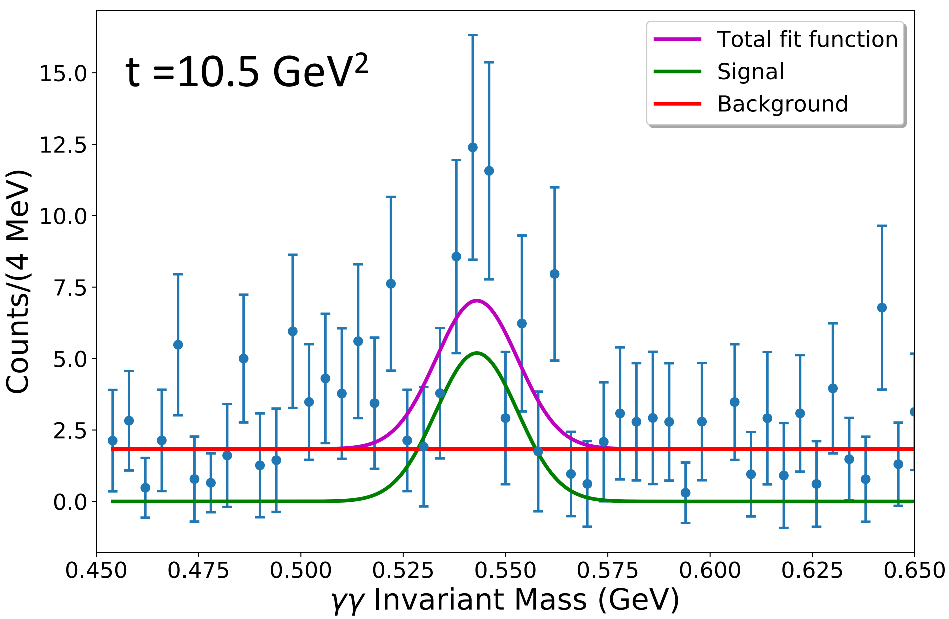
Errors are statistical

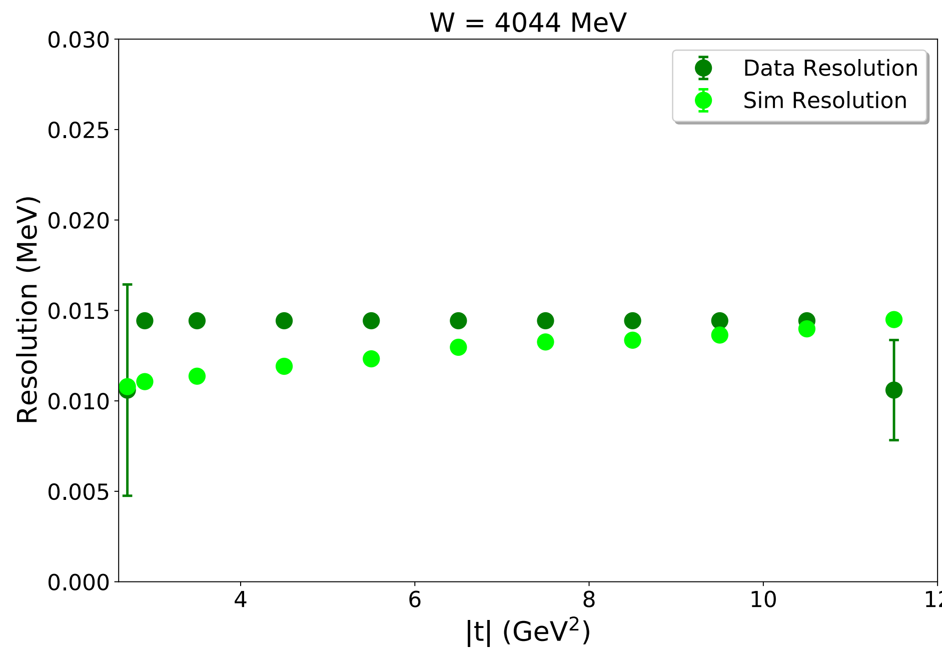


- Differential cross section peak in u-channel exchange.

Intermediate region (large t and u)

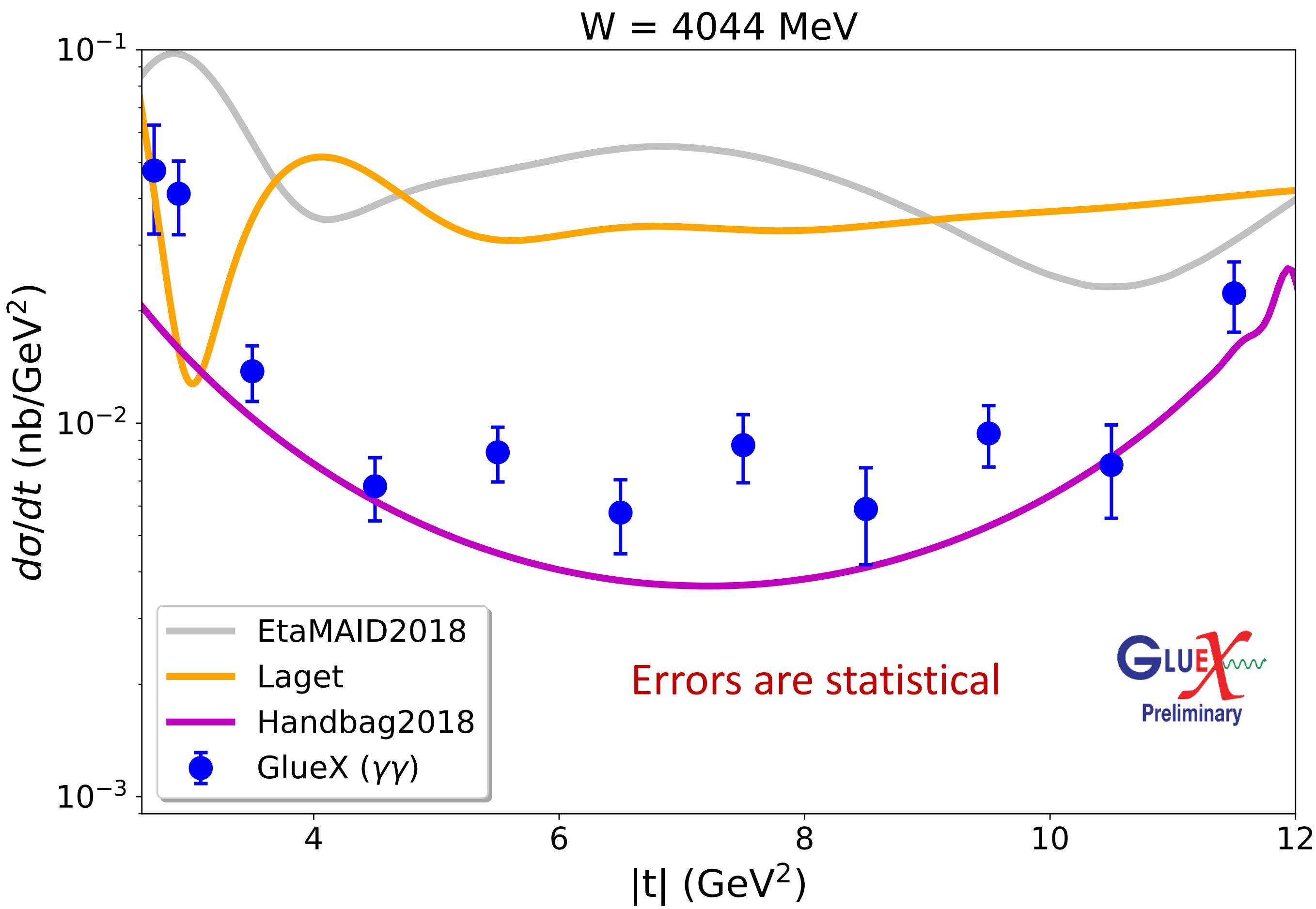
- Hard reactions, very small cross sections
- Low statistics, peak shape constrained by simulation





Differential cross section results for the intermediate region

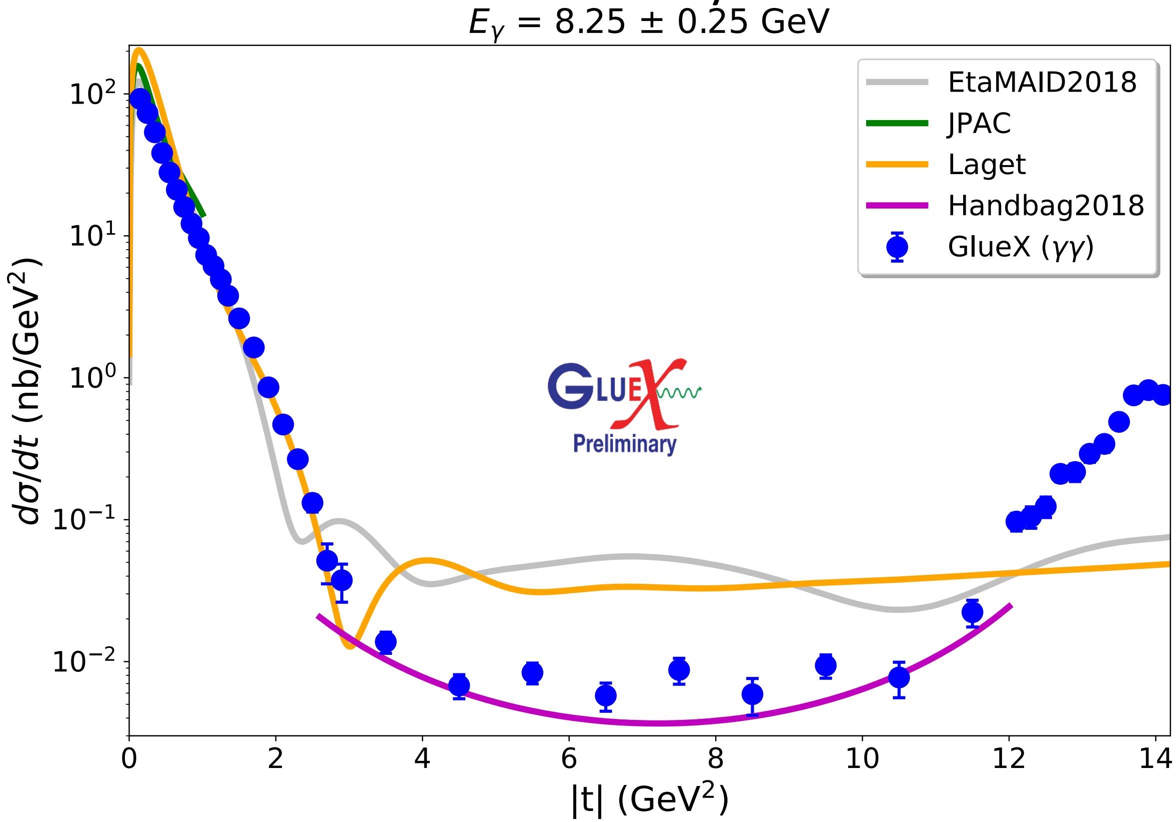
E_γ = 8.25 ± 0.25 GeV



P. Kroll and P. Passek, PhysRevD.97.074023, 2018

The general data trend is generally reproduced by the handbag model in this region.

Summary



- EtaMIAD2018 and Laget models reproduce data trend for |t| < 2-3 GeV^2.
- For the transition region (4 < |t|< 11 GeV^2), the handbag model seems to be valid.
- For |t| > 12 GeV , no current model is describing the data.

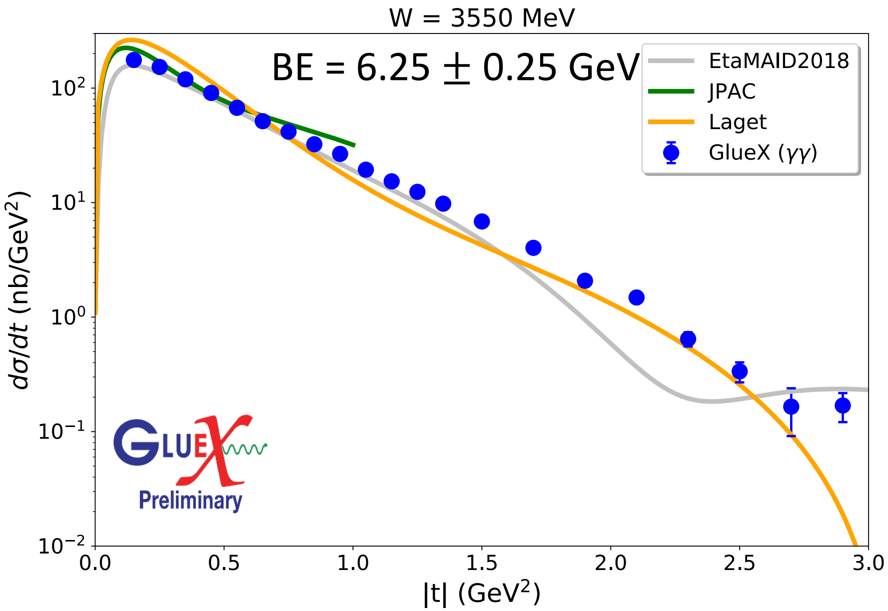
- GlueX provides η photo-production cross section in the full t-range over a very wide range of beam energies up to 11.5 GeV, that covers several physics topics and production mechanisms.
- All the η differential cross section work will be published after systematic uncertainties are calculated.

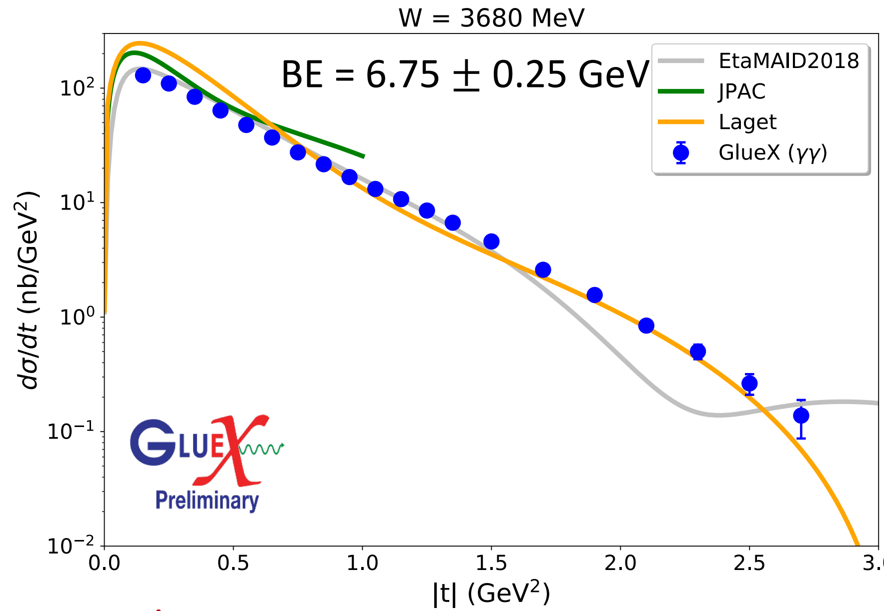
GlueX acknowledges the support of several funding agencies and computing facilities gluex.org/thanks/

This work is supported in part by the Department of Energy Contract DESC0013620

Backup

Differential Cross Section Results for the t-range [0.1, 3.0] GeV^2





Errors are statistical