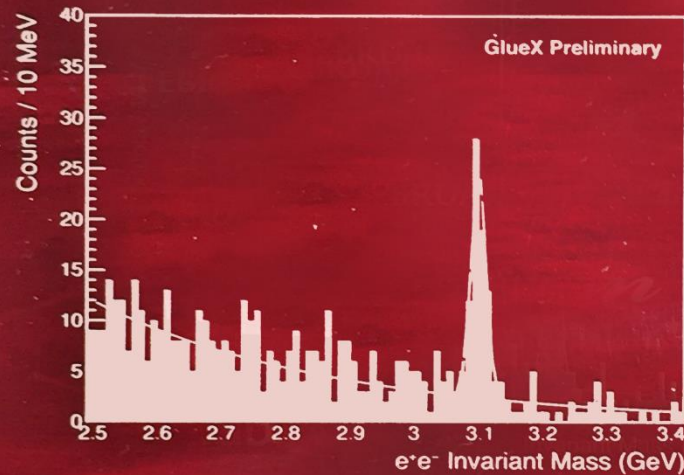


# Threshold $J/\psi$ production at GlueX

PRESENTED TO

*The GlueX Collaboration*

IN RECOGNITION OF  
THE FIRST OBSERVATION OF CHARMONIUM



Lubomir Pentchev  
for the GlueX  
collaboration

WITH THE UPGRADED 12 GEV CEBAF BEAM AT JEFFERSON LAB

FEBRUARY 16, 2017

*Jefferson* Lab

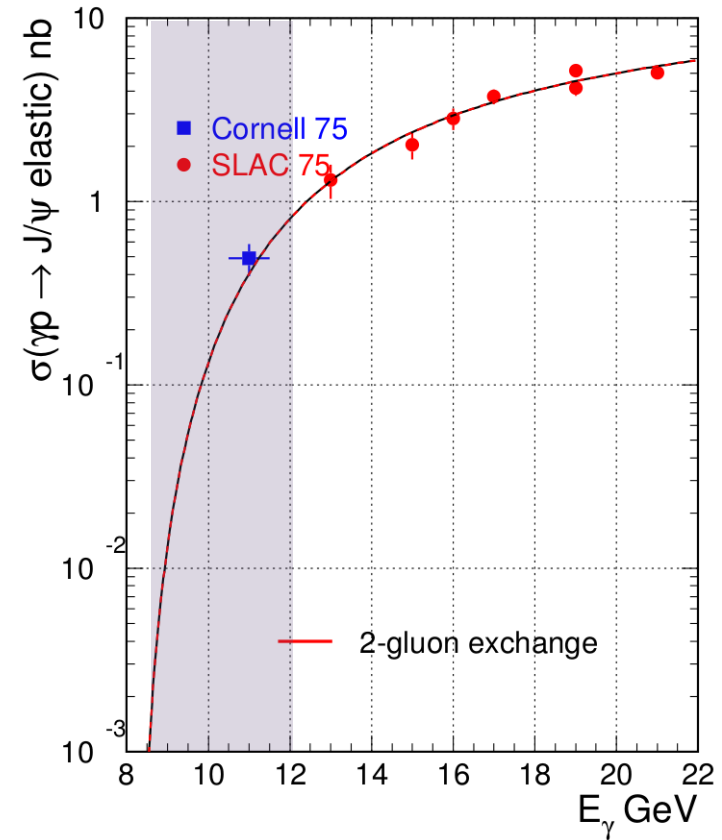
*Robert D. McKeown*

DEPUTY DIRECTOR FOR SCIENCE AND TECHNOLOGY  
THOMAS JEFFERSON NATIONAL ACCELERATOR FACILITY

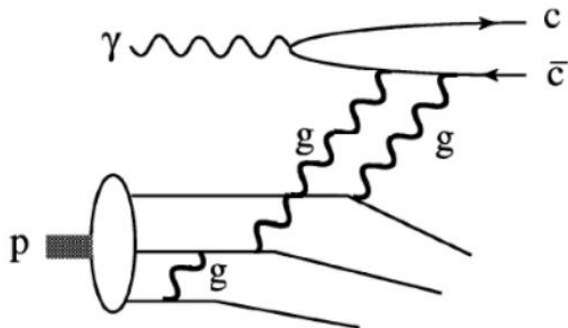
# Why study $J/\psi$ near threshold photo-production

- $J/\psi$  photo-production near threshold poorly covered by previous old measurement
- Look for threshold enhancement: sensitive to proton gluonic content (high  $x$ ); other interesting effects expected near threshold
- Hall D is the only hall with  $E_\gamma > 11$  GeV – needed to allow continuity from the high energy data; only in 2016 we had  $> 11.5$  GeV
- GlueX coherent peak right above the threshold – improved statistics at the very important point

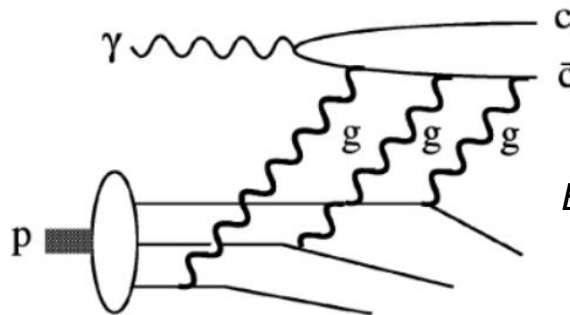
GlueX



two-gluon exchange



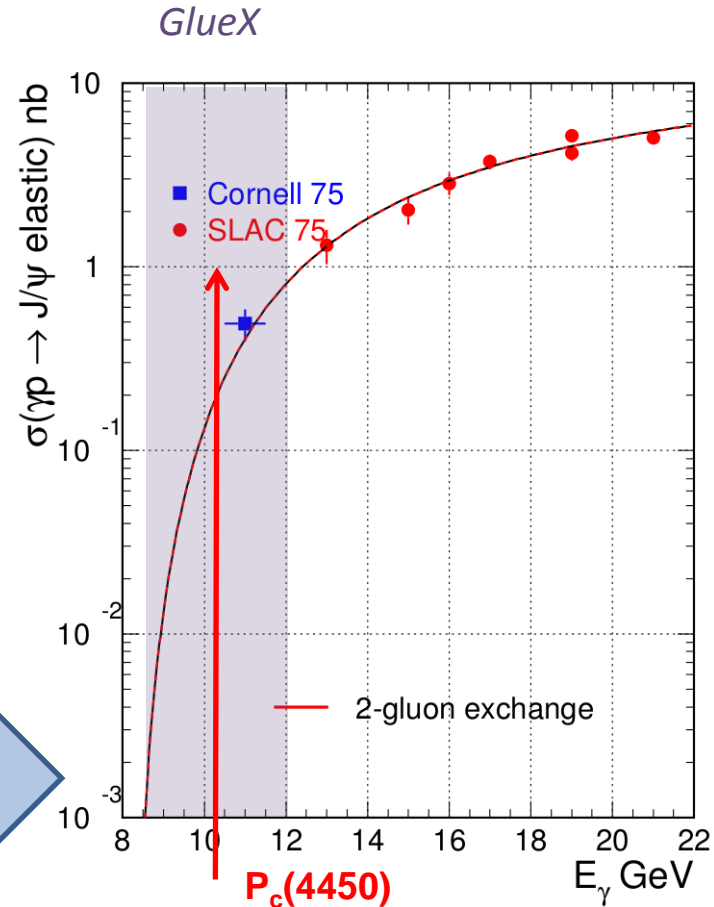
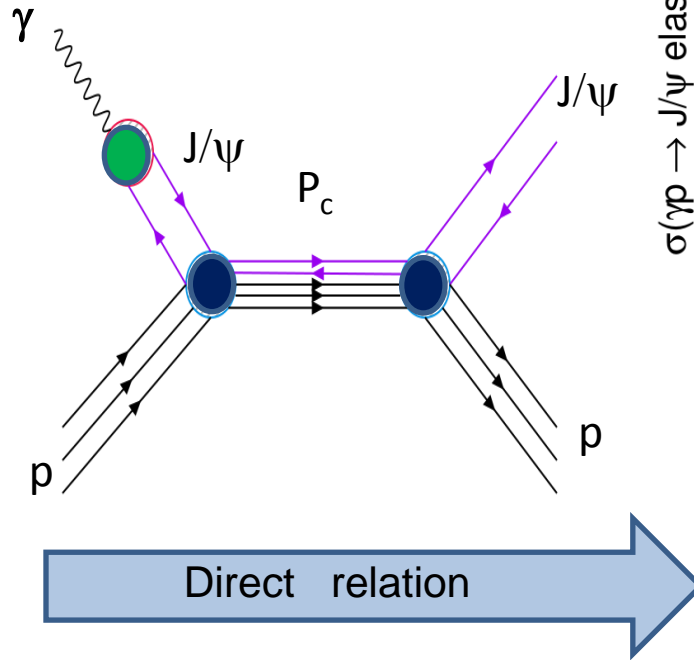
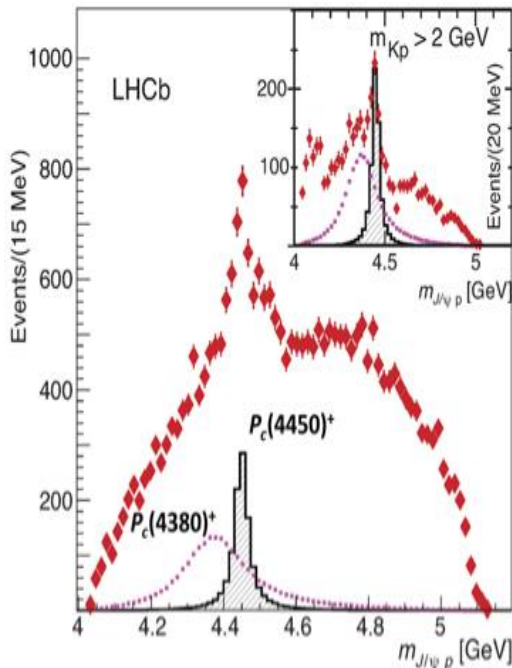
three-gluon exchange



Brodsky et al. PLB 498, 23 (2001)

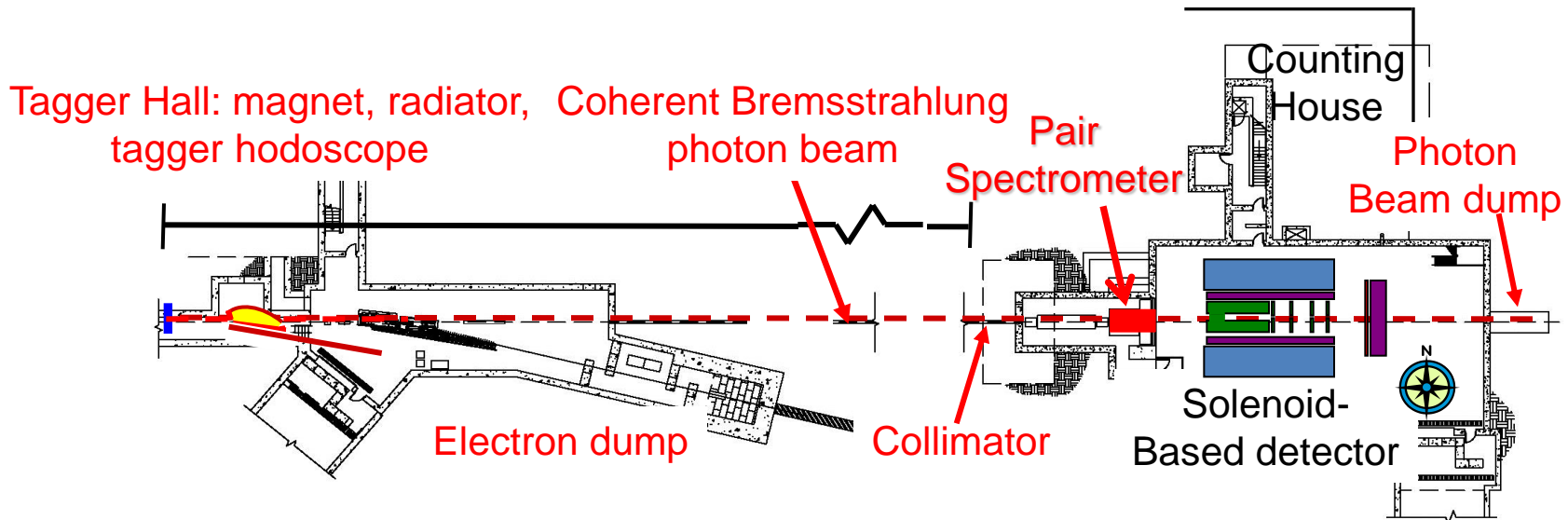
# Why study $J/\psi$ near threshold photo-production

- Also because of the LHCb pentaquarks - DIRECT relation – if they exist they should be seen in s-channel photoproduction:



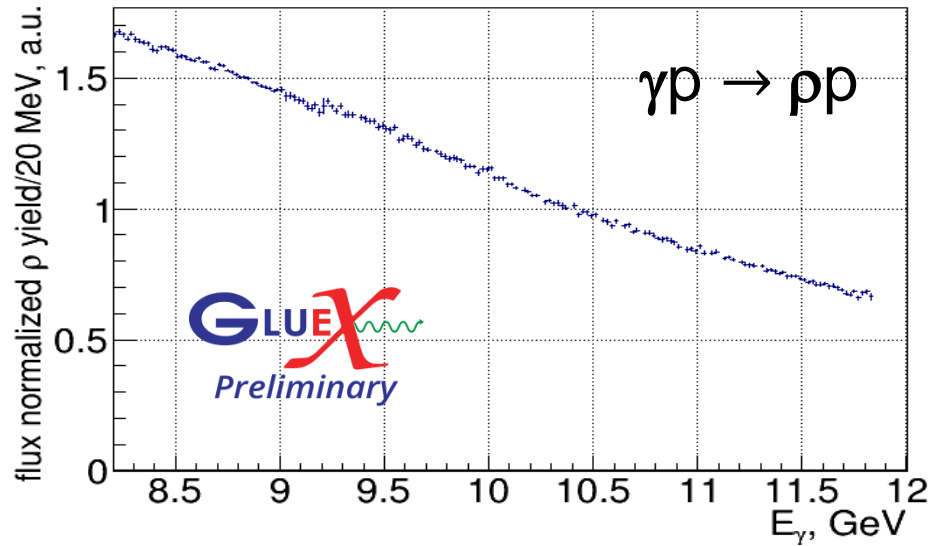
- V.Kubarovsky and M.B.Voloshin, PRD 92.031502 (2015).
- M.Karliner and J.Rosner, arXiv: PLB 752, 329 (2016).
- A.Blin, C.Fernandez-Ramirez, A.Jackura, V.Mathieu, V.Mokeev, A.Pilloni, and A.Szczepaniak, PRD 94,034002 (2016).

# Hall D layout

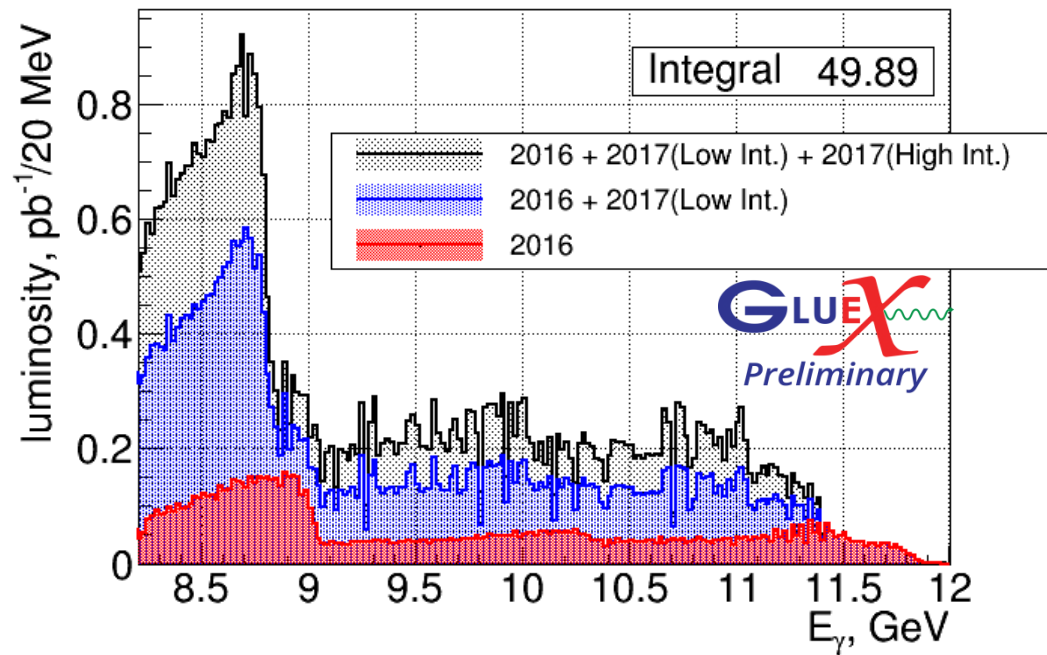


- Photon energy tagged by scattered electron  $\sim 0.1\%$  resolution
- Photon beam collimated at 75m,  $<25 \mu\text{rad}$
- Intensity:  $\sim 2 \cdot 10^7 - 5 \cdot 10^7 \gamma/\text{sec}$  above  $J/\psi$  threshold (8.2 GeV) – total  $\sim 50 \text{ pb}^{-1}$  in 2016-2017 runs

# Tagged fluxes



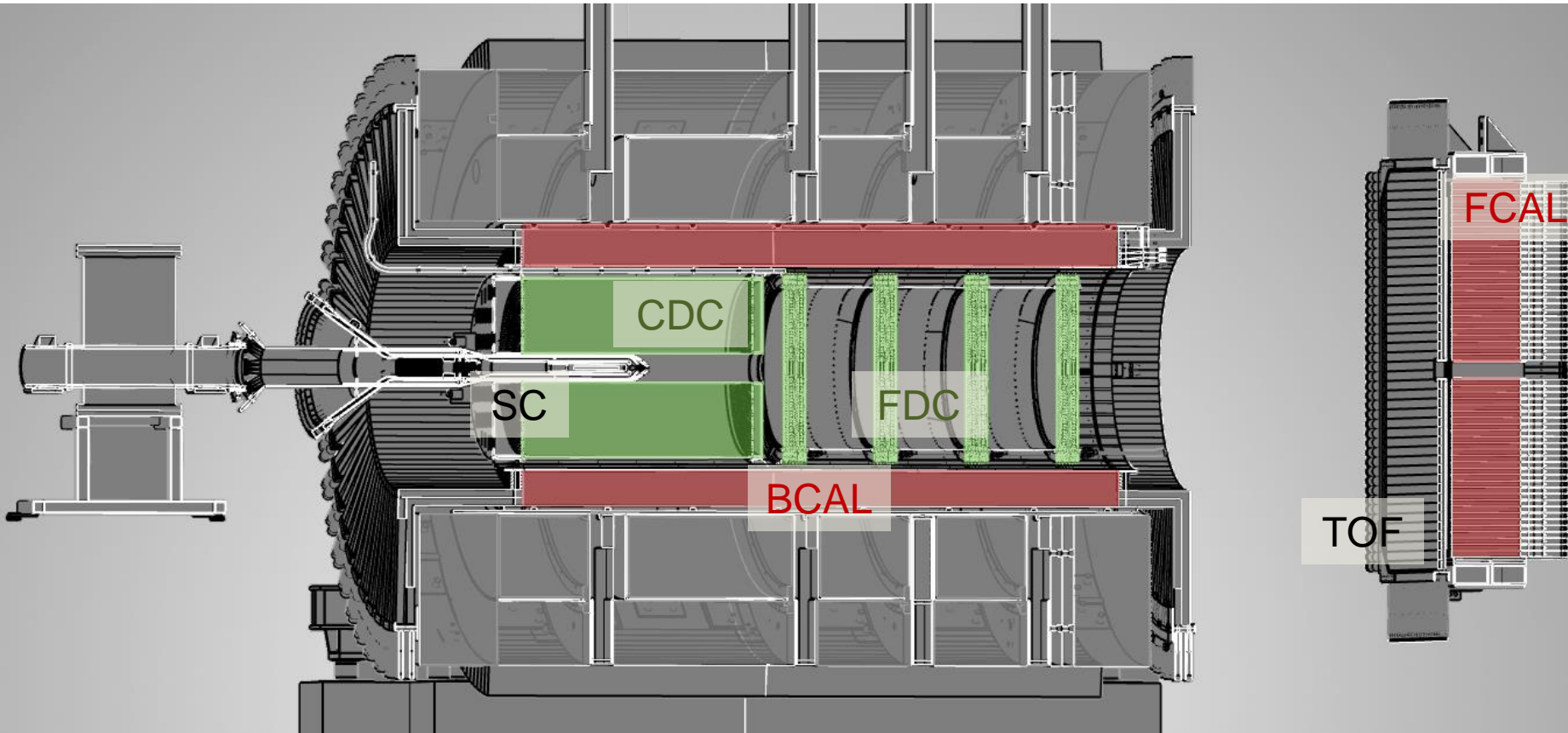
Fluctuations in flux coming from tagger efficiency, but canceled in normalized yields



# GlueX detector

2T-solenoid, LH target

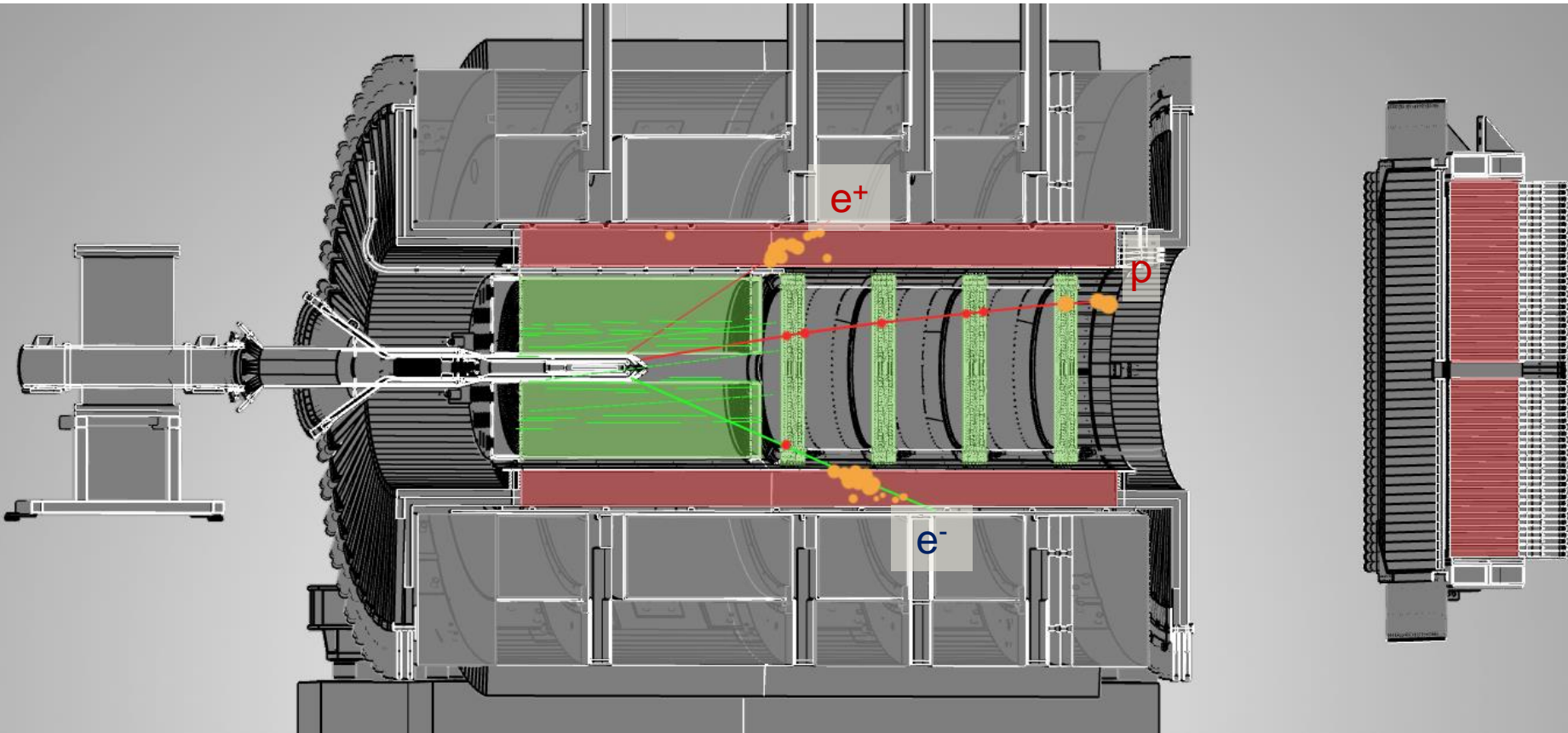
Tracking (FDC,CDC) , Calorimetry (BCAL,FCAL) , Timing (TOF,SC)



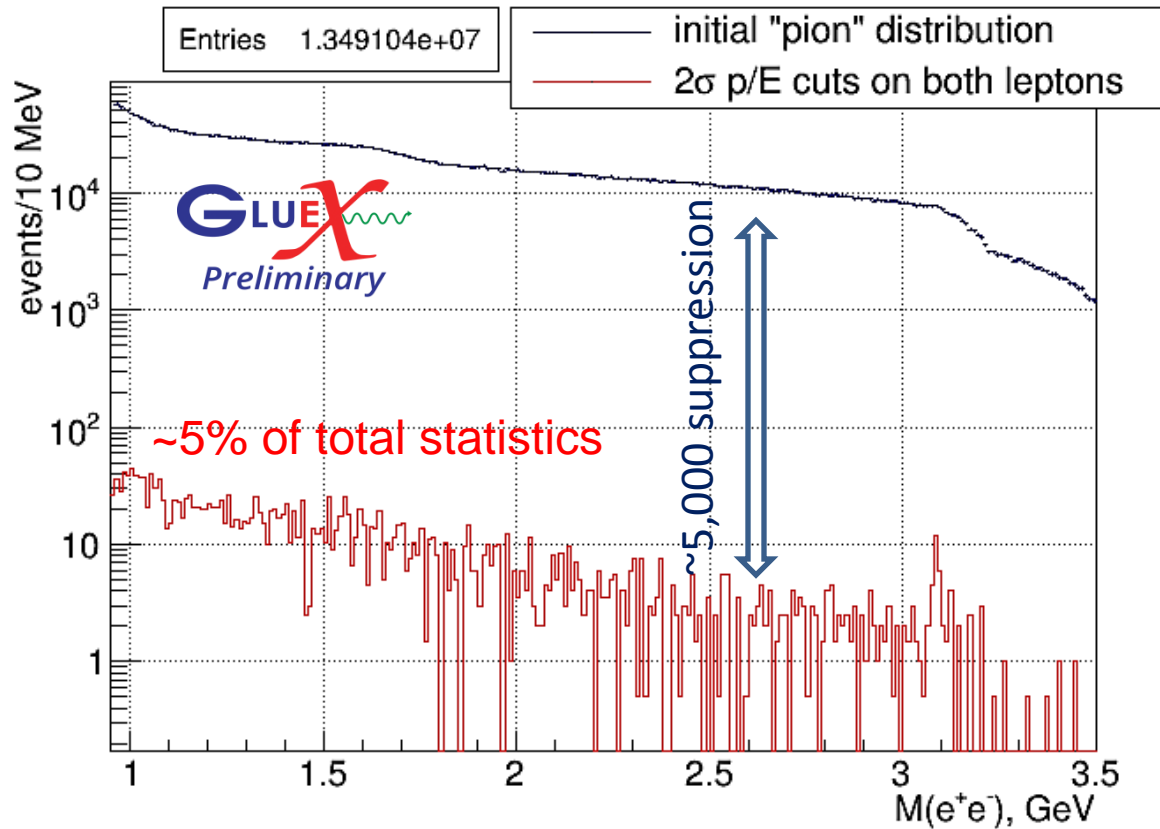
- Hermetic detector:  $1 - 120^\circ$  polar and full azimuthal acceptance
- Tracking:  $\sigma_p/p \sim 1 - 5\%$
- Calorimetry:  $\sigma_E/E \sim 6\%/\sqrt{E} + 2\%$

# $J/\psi$ event

Exclusive reaction  $\gamma p \rightarrow J/\psi p \rightarrow e^+e^-p$



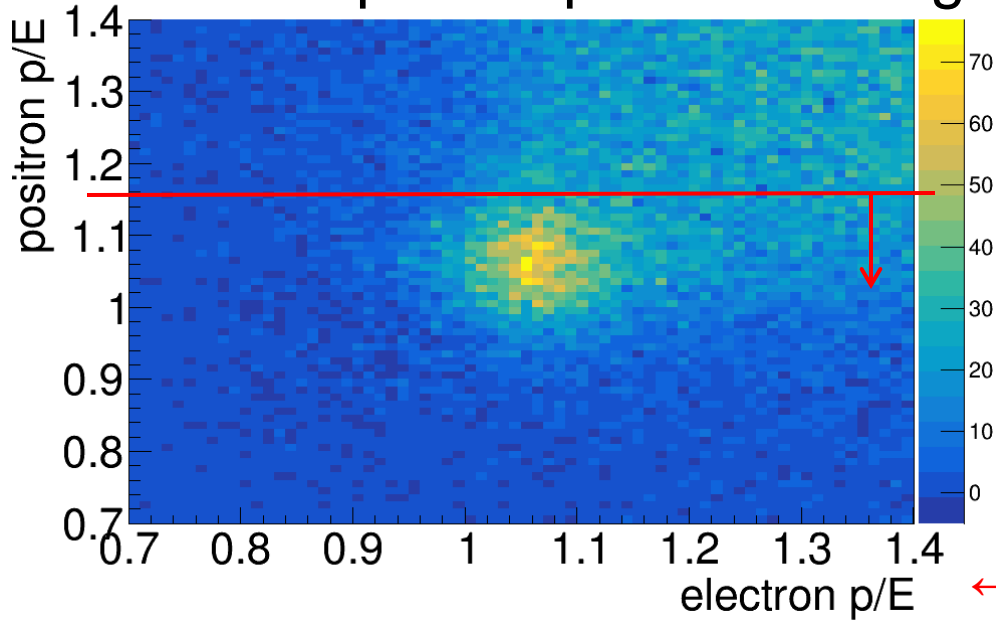
# Electron/proton separation using E(calorimetry)/p(tracking)



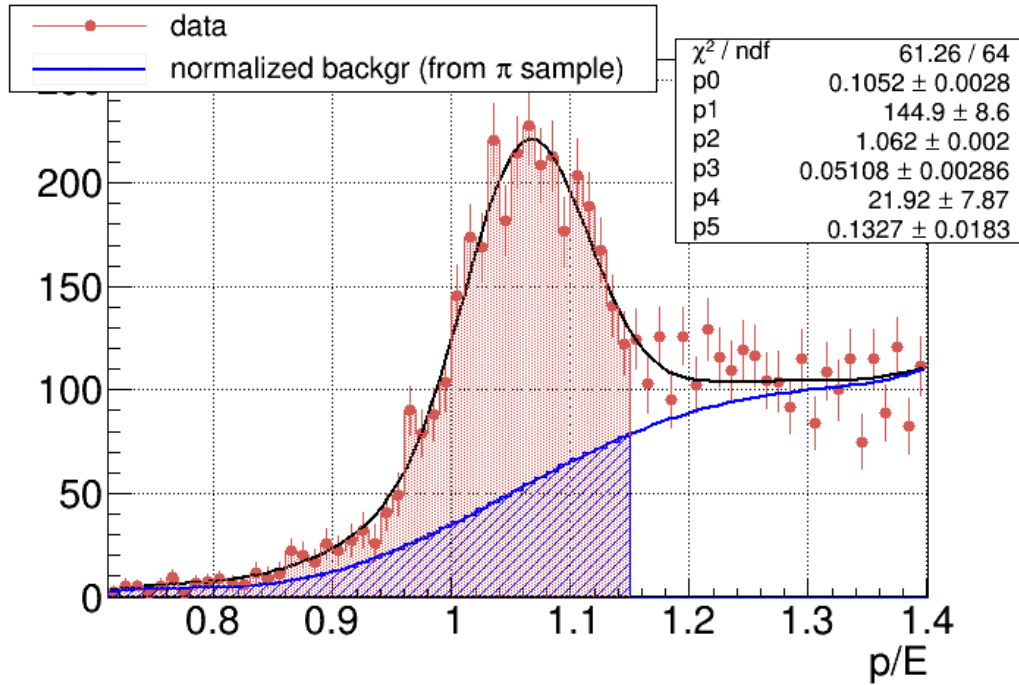
Suppression factor of  $\sim 5000$  by E/p cuts ( $2\sigma$ ) on both leptons



# Electron/pion separation using E(calorimetry)/p(tracking)



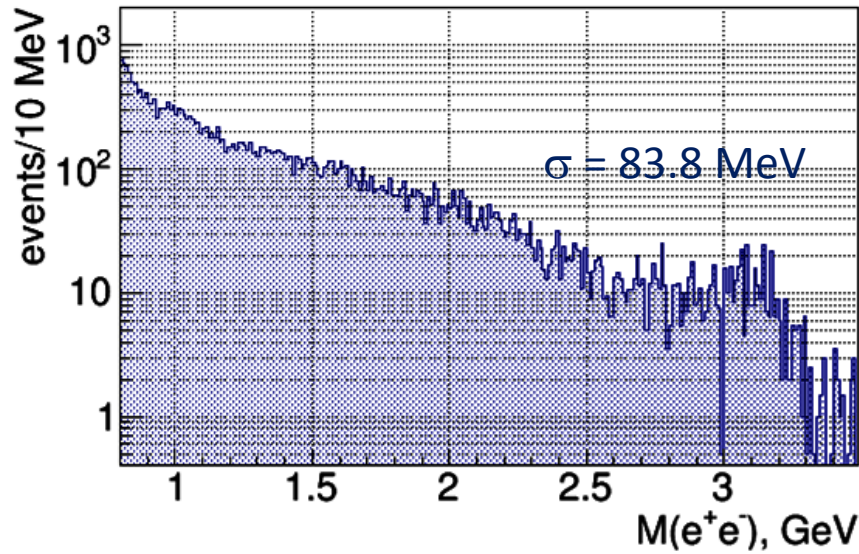
← Note p/E on plots!



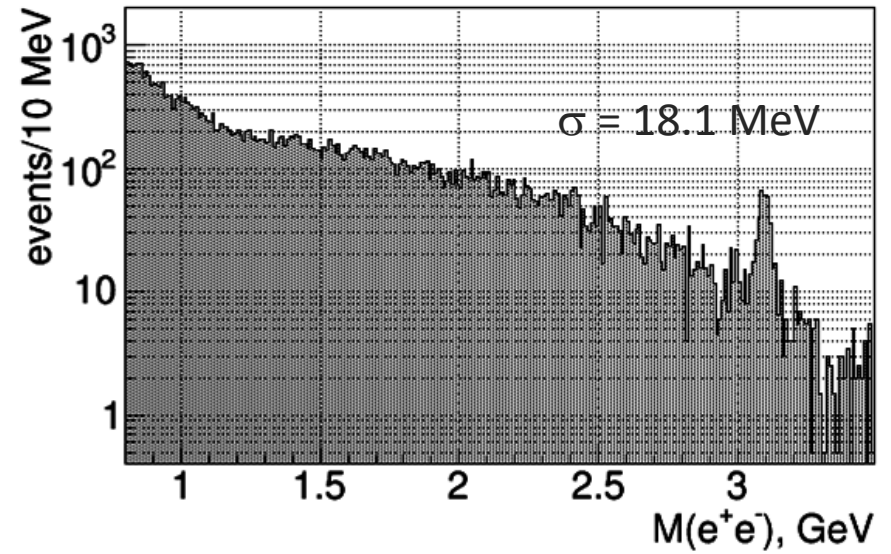
- $36 \pm 1.2\%$   $\pi$  contamination in 1.5-2.5 GeV  $M(e^+e^-)$  region with  $2\sigma$  cut on electrons
- BH yields corrected in bins of energy
- Background shape from pion sample (E / p anti-lepton cuts)

# $\gamma p \rightarrow J/\psi p \rightarrow e^+e^-p$ reconstruction methods (leptons tagged)

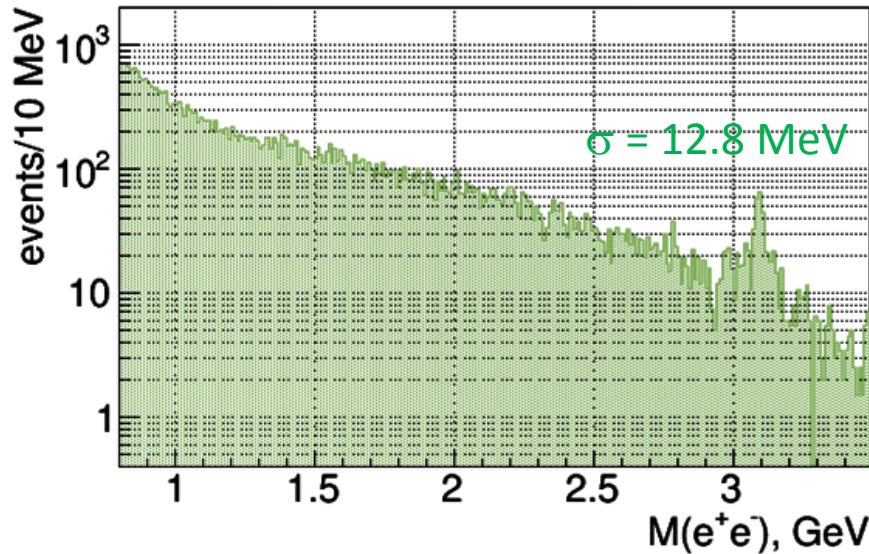
$M(e^+e^-)$  from electron and positron reconstruction



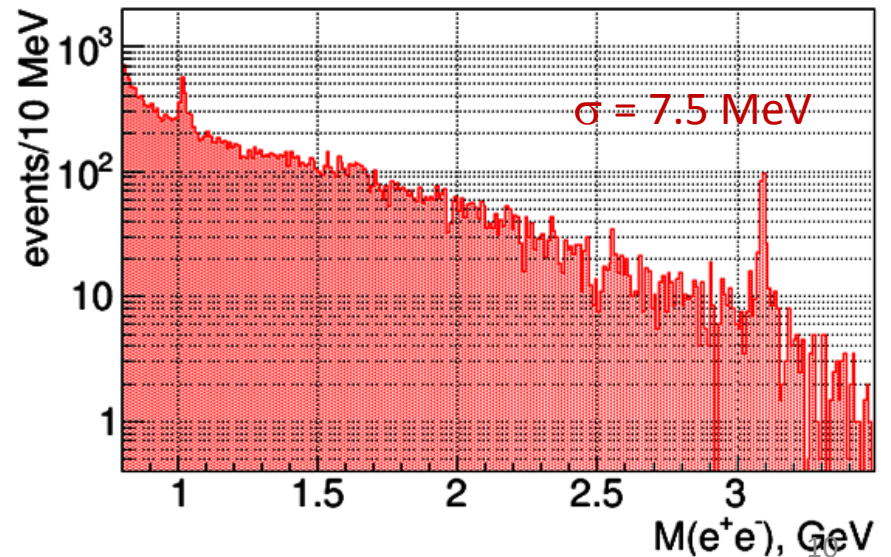
$M(e^+e^-)$  from recoil proton  $\gamma p \rightarrow pM_x$



$M(e^+e^-)$  from angles only



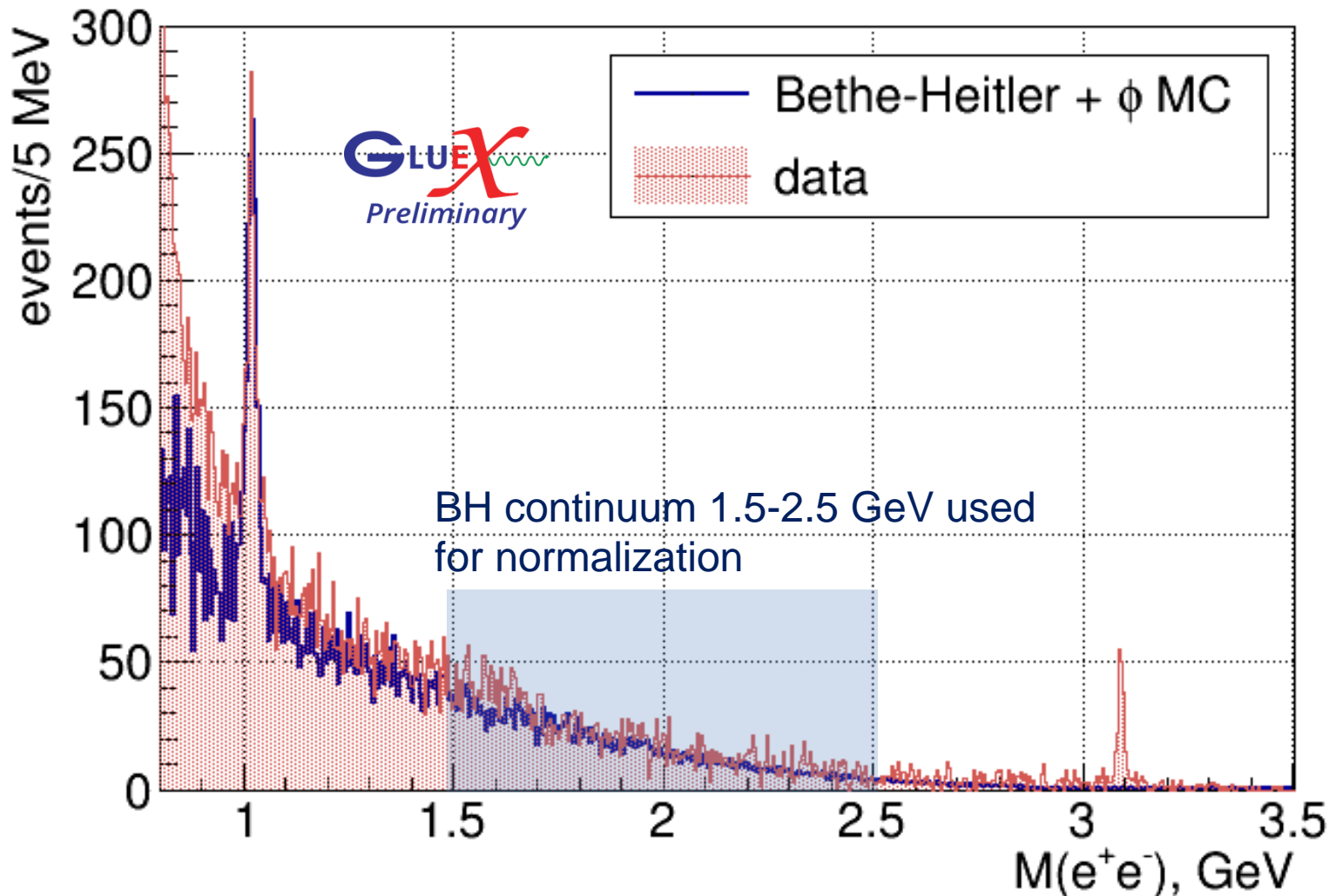
$M(e^+e^-)$  from kinematic fit



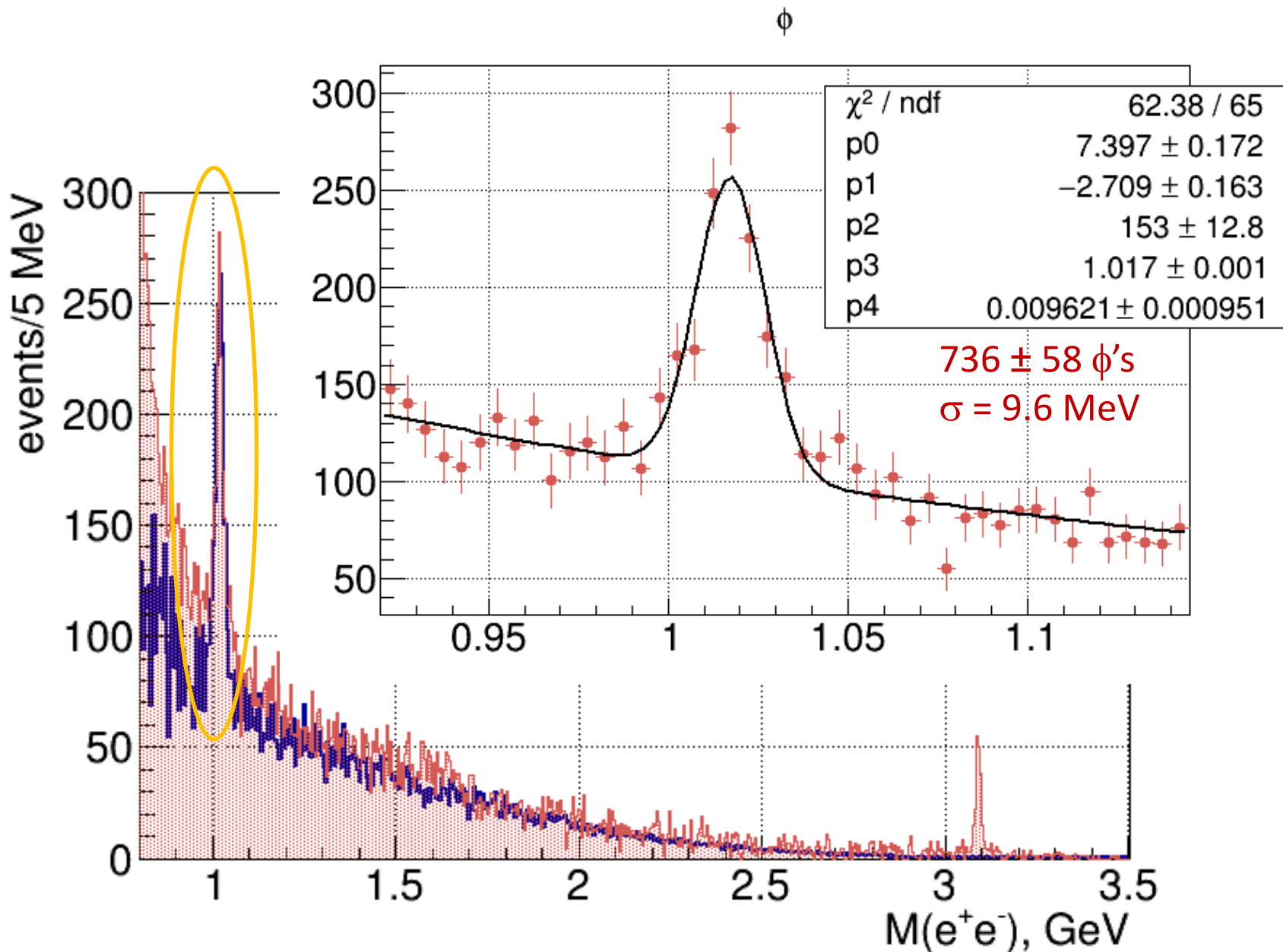
# M(e<sup>+</sup>e<sup>-</sup>) spectrum

Shown actual yields and MC -  
**NO normalization applied**

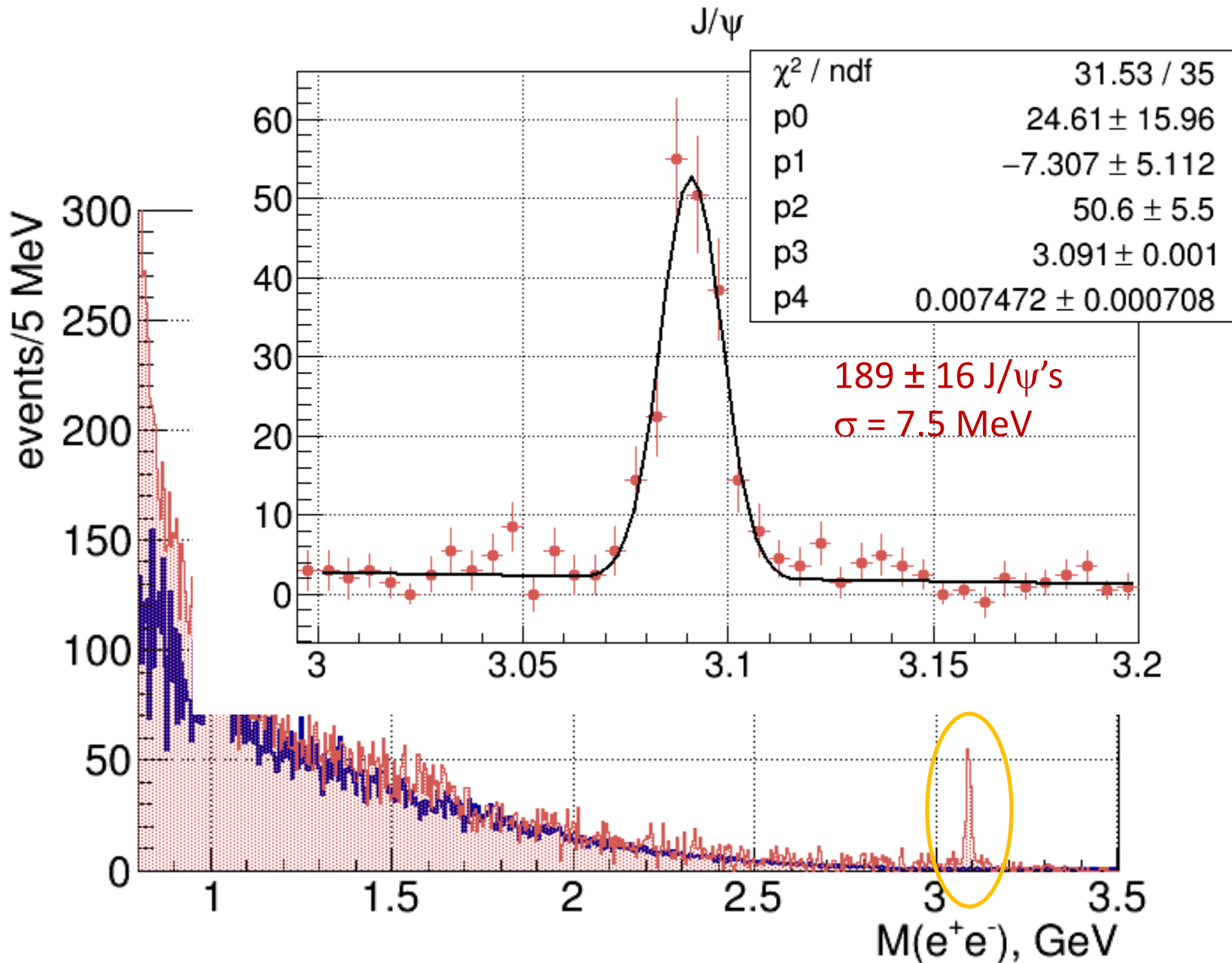
- BH simulations from R.Paremuzyan, based on:
- Berger, E., Diehl, M. & Pire, B. Eur. Phys. J. C (2002) 23: 675.



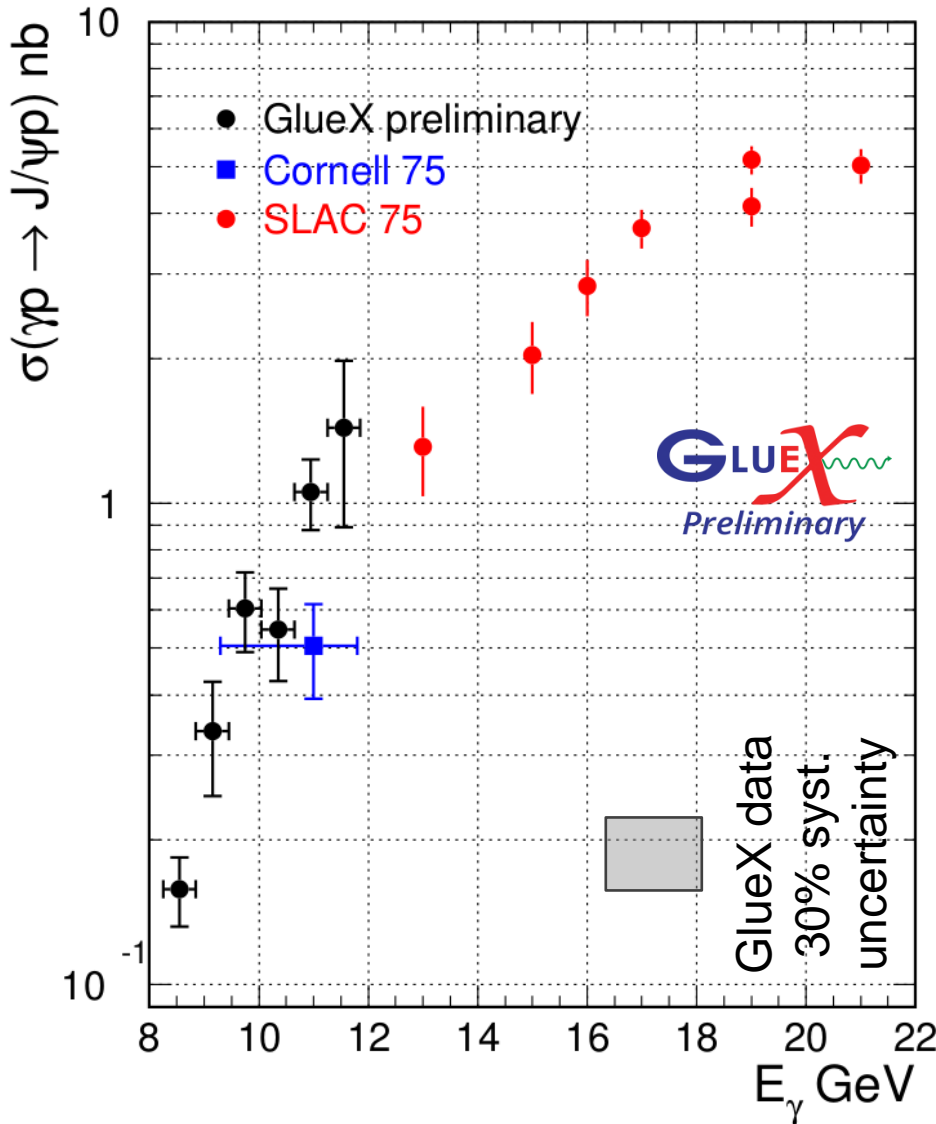
# M(e<sup>+</sup>e<sup>-</sup>) spectrum - $\phi$



# M(e<sup>+</sup>e<sup>-</sup>) spectrum – J/ψ



# J/ $\psi$ cross-section – preliminary results

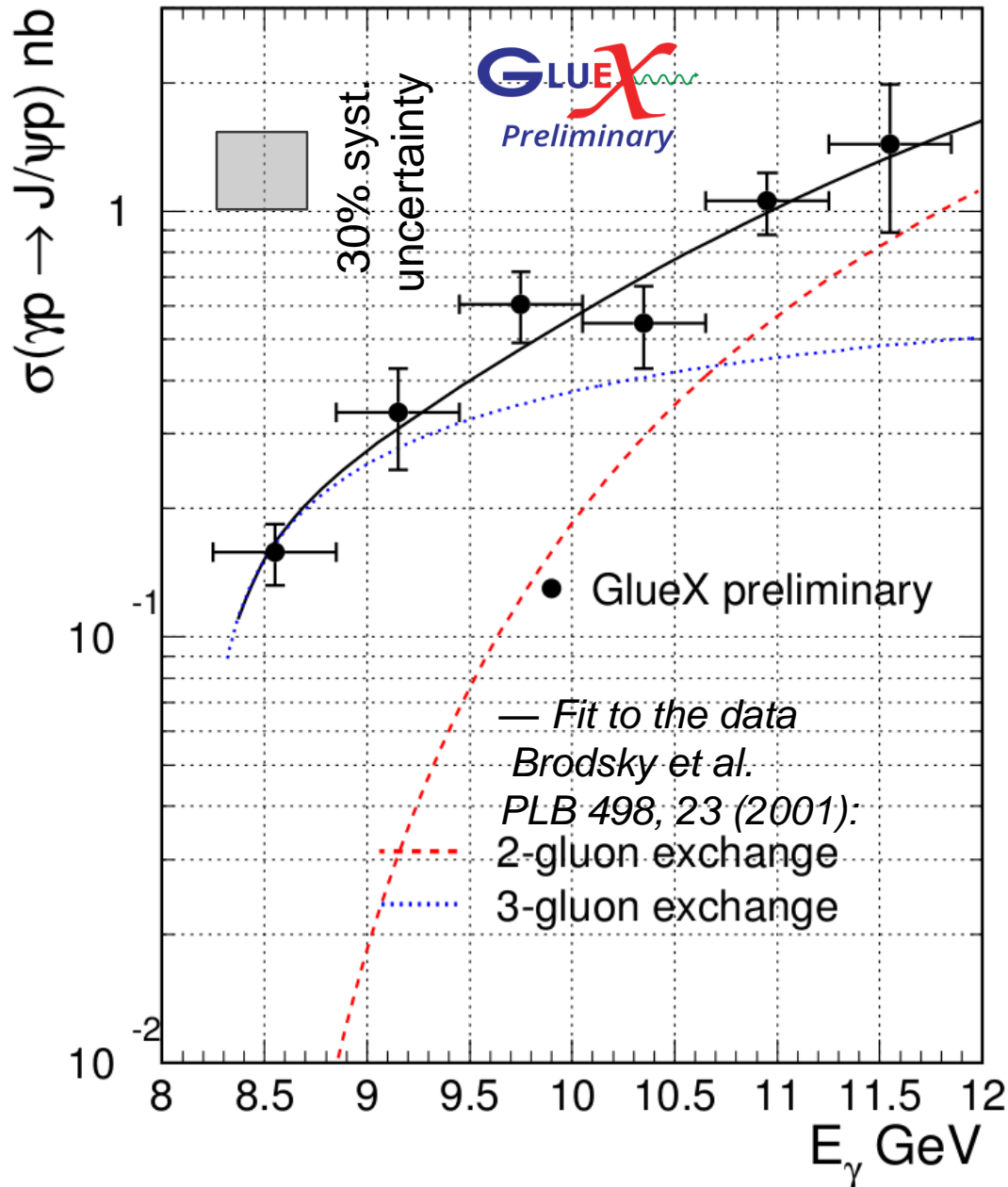


SLAC results calculated from  $d\sigma/dt(t=t_{\min})$  using  $t$ -slope of  $2.9 \pm 0.3 \text{ GeV}^{-2}$  (measured at 19 GeV)

Cornell data:

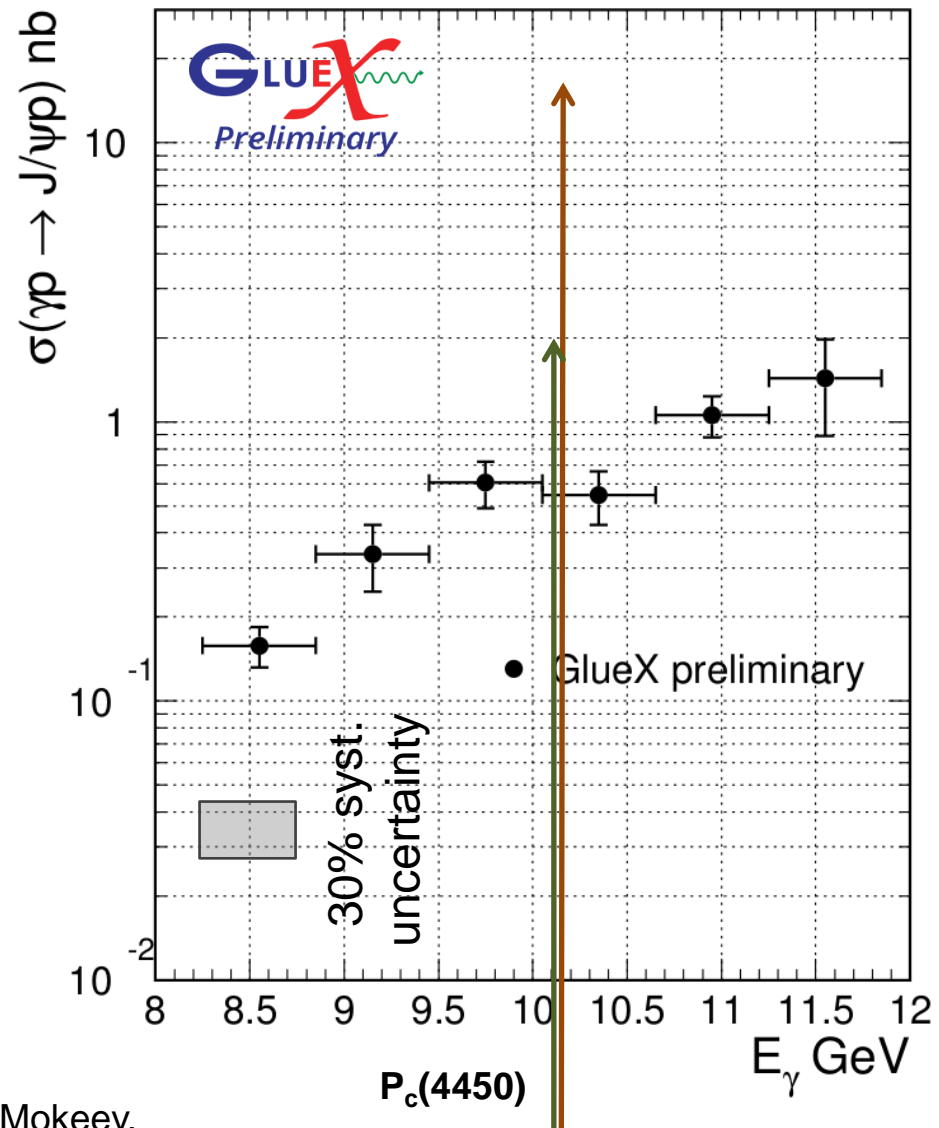
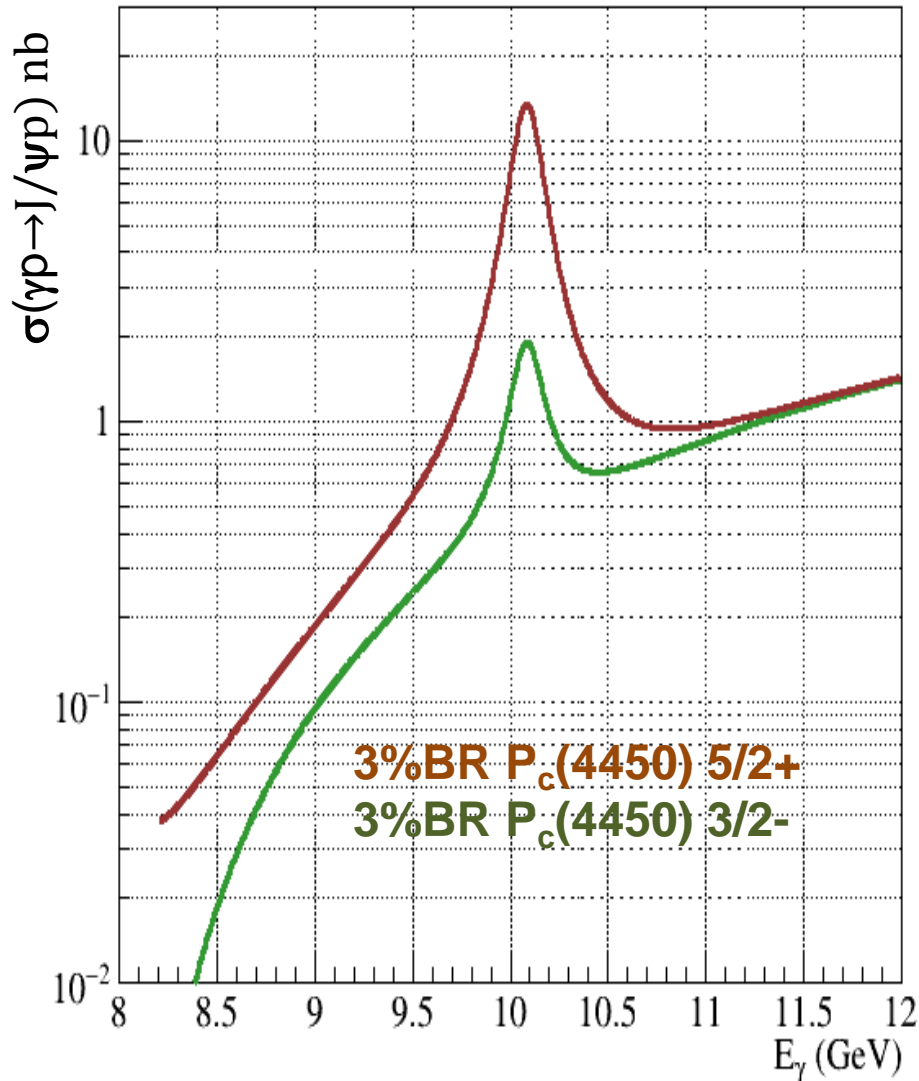
- $t$ -slope  $1.25 \pm 0.2 \text{ GeV}^{-2}$
- horizontal errors represent acceptance

# J/ψ cross-section – preliminary results



- Theory gives only shapes of the curves
- Fit to the data with two parameters - the amplitudes of 2- and 3-gluon exchange
- Data near threshold consistent with 3-gluon exchange

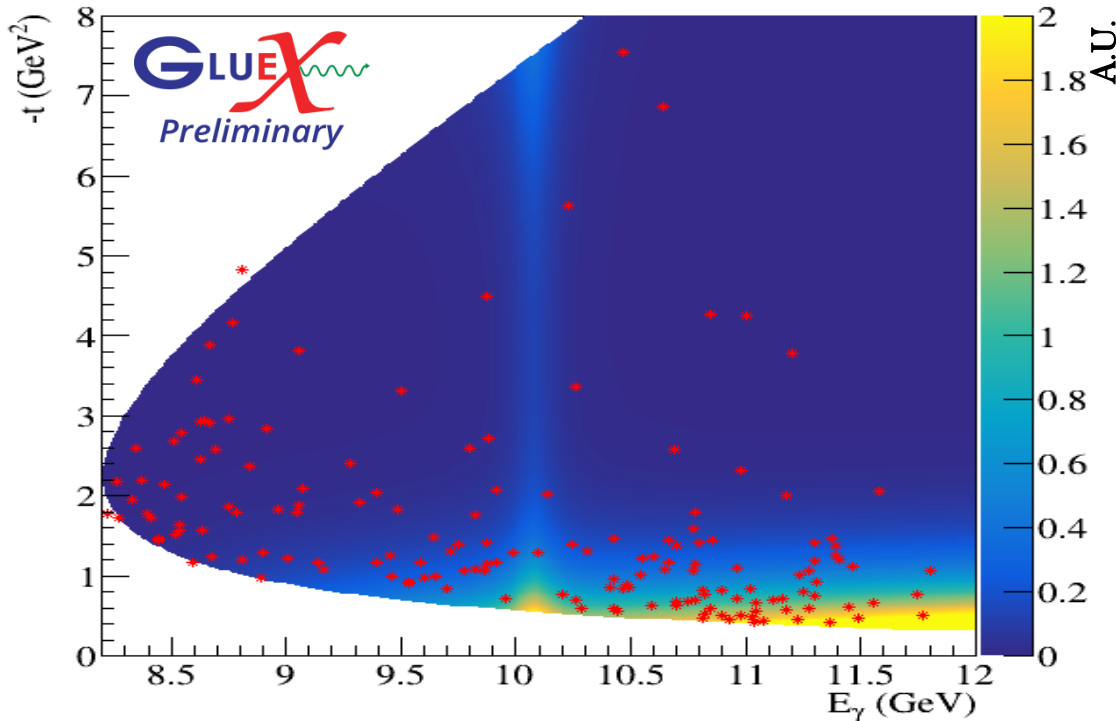
# $J/\psi$ cross-section and pentaquark predictions



A.Blin, C.Fernandez-Ramirez, A.Jackura, V.Mathieu, V.Mokeev, A.Pilloni, and A.Szczepaniak, PRD 94,034002 (2016).



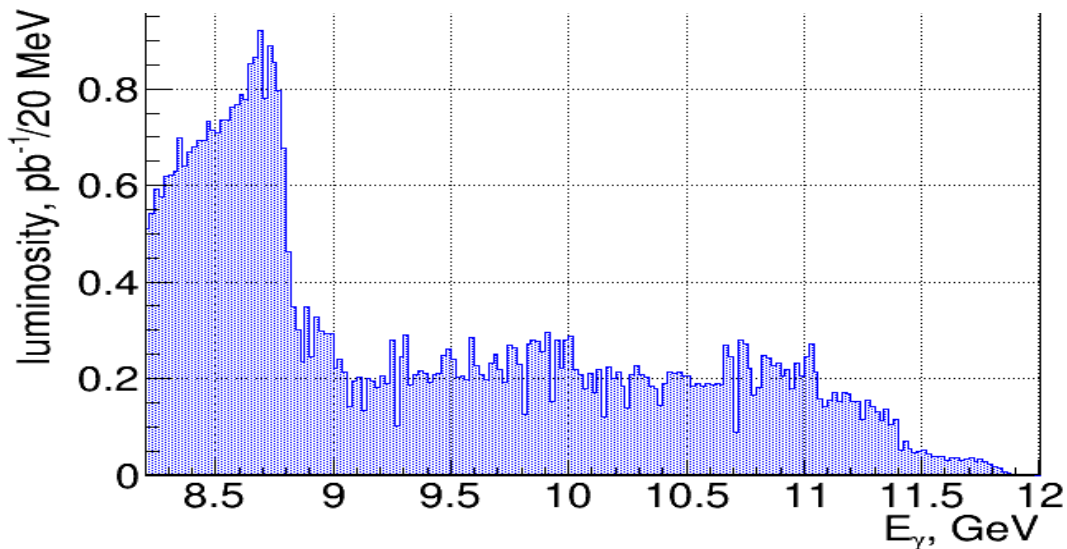
# t vs $E_\gamma$ unbinned distribution for $J/\psi$ events



**dots** – GlueX data

**color** – model prediction from JPAC for 3%BR  $P_c(4450) 5/2^+$

A.Blin, C.Fernandez-Ramirez,  
A.Jackura, V.Mathieu, V.Mokeev,  
A.Pilloni, and A.Szczepaniak,  
PRD 94,034002 (2016).



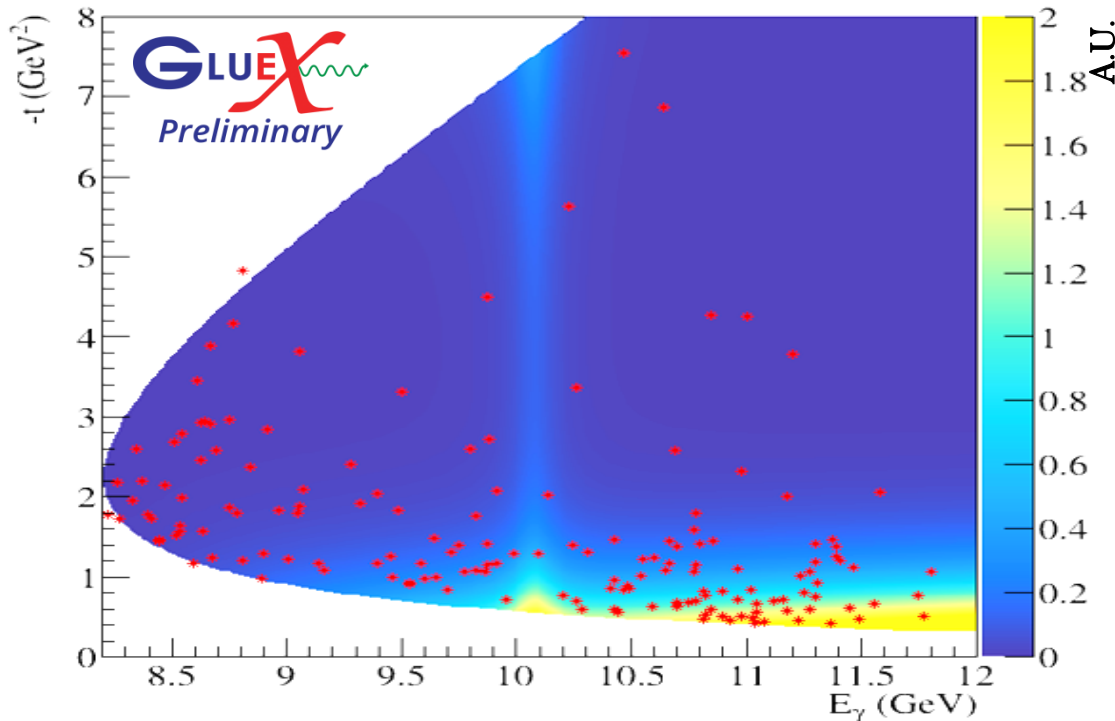
- Density of data points proportional to flux and efficiency
- No significant variations of flux ( $E_\gamma > 9$  GeV) and efficiency

# My messages to the user's community

- JLab 12GeV accelerator has UNIQUE opportunity (high intensity, correct energy, polarized beam) to study  $J/\psi$  photo-production right above the threshold ( $E_\gamma=8.2$  GeV) up to 12 GeV
- Reaching the MAXIMUM BEAM ENERGY is very important to ensure consistency with the measurements in the high energy region.
- Pion background requires at least  $10^3$  suppression and much more to study BH continuum
- Preliminary GlueX cross-sections near thresholds are higher than expected from the two-gluon exchange extrapolation of old data
- The results show domination of the t-channel and no evidence for the LHCb pentaquark. Can set a limit for  $P_c(4450) \rightarrow J/\psi p$  BR at a several percent level

# Back-ups

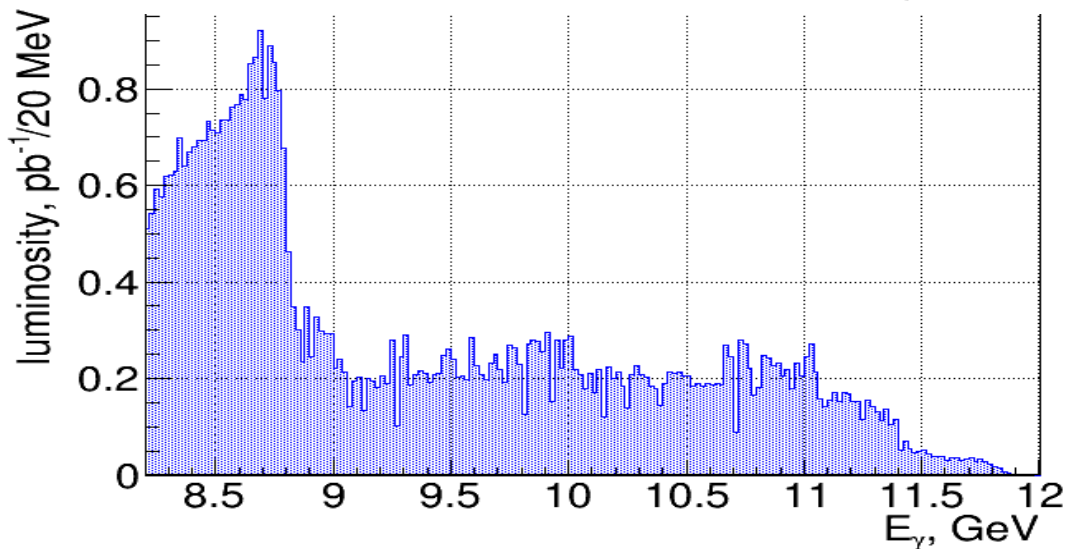
# t vs $E_\gamma$ unbinned distribution for $J/\psi$ events



**dots** – GlueX data

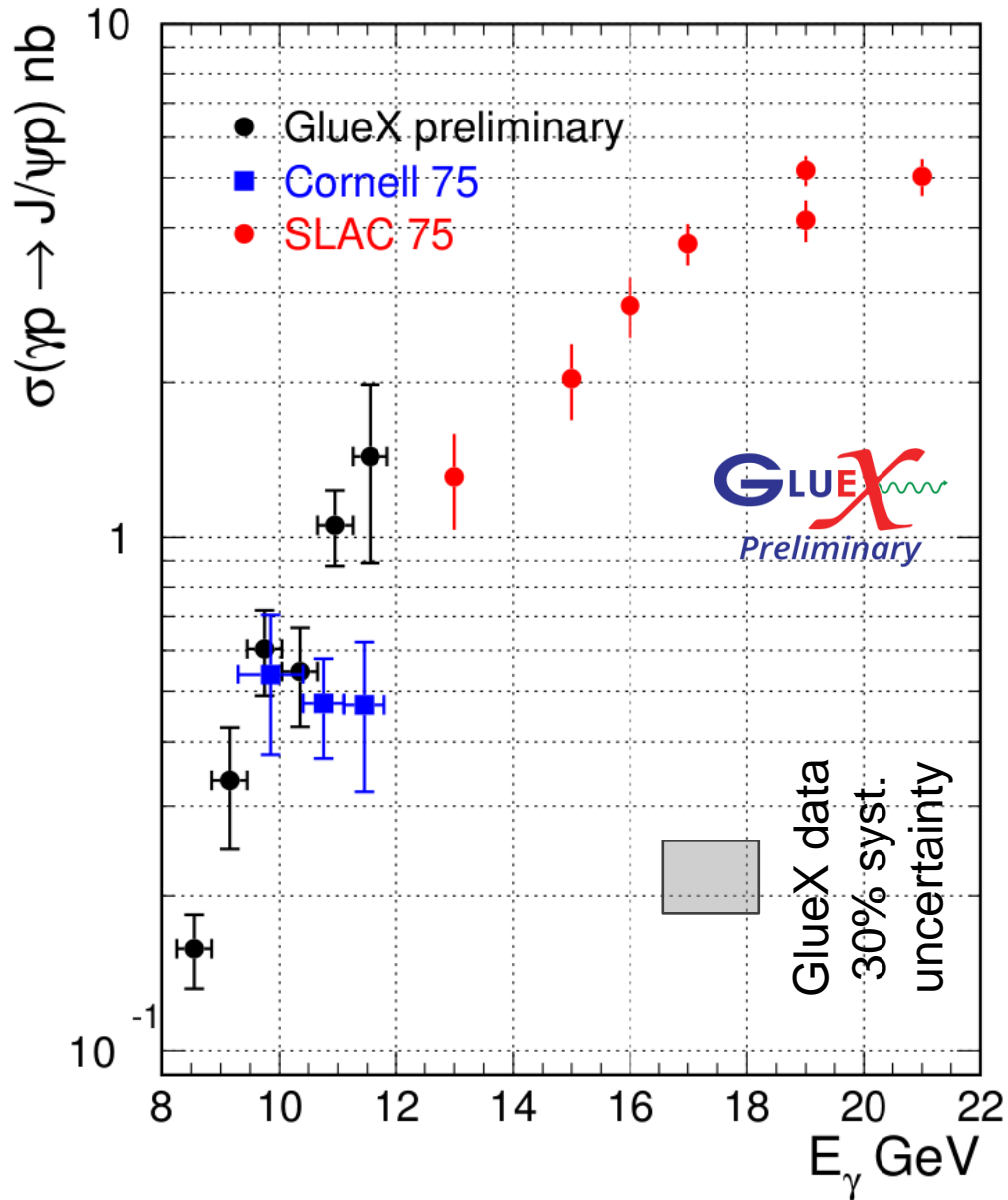
**color** – model prediction from JPAC for  $P_c(4450) 5/2^+$

A.Blin, C.Fernandez-Ramirez, A.Jackura, V.Mathieu, V.Mokeev, A.Pilloni, and A.Szczepaniak, PRD 94,034002 (2016).



- Density of data points proportional to flux and efficiency
- No significant variations of flux ( $E_\gamma > 9 \text{ GeV}$ ) and efficiency

# $J/\psi$ cross-section – preliminary results



# $M(e^+e^-)$ spectrum

