J/ψ photoproduction – new results and future plans

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- **New results (preliminary!)** :
  - Including 2018 data batch 1-3
  - Analysis launch with tight timing cuts and $M_{measured}(e^+e^-)>2$ GeV
  - Same method of extracting cross-sections
  - Except BH in 2.1<M<2.5 GeV - very different kin. region than 1.2-2.5 GeV before
  - BH now dominates stat. error
  - $d\sigma/dt$ extracted for much wider t-range
  - MC for 2017 used for the 2018 data
- Future plans:
  - Aim for new results from 2016-2018 by the end of the year
  - Would like to initiate discussions about the position of the coherent peak in case there's an experimental issue or compelling physics case
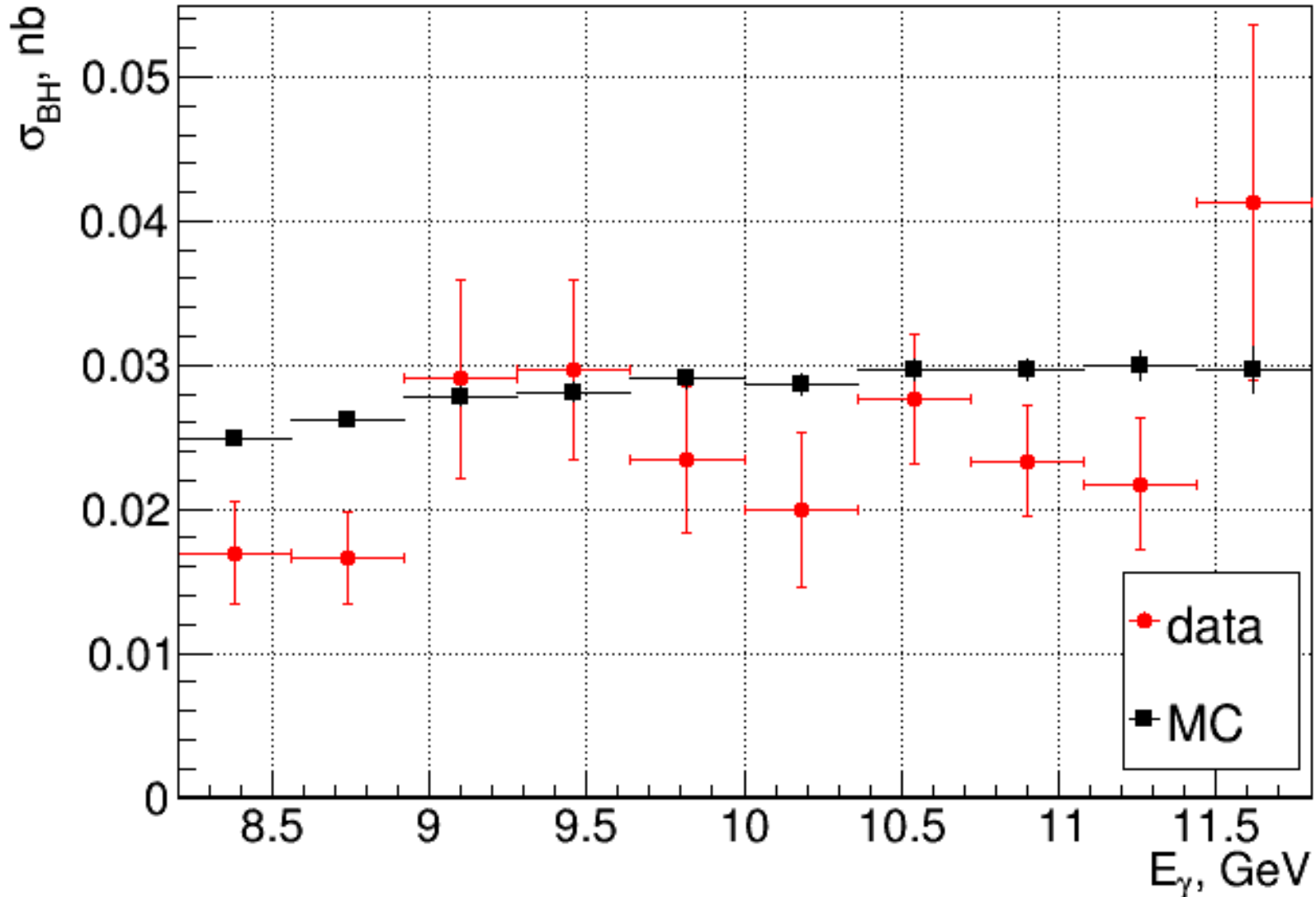
2018 data batch 1-3

χ^2 / ndf	75.97 / 55
p0	77.64 ± 7.02
p1	−23.22 ± 2.23
p2	57.8 ± 4.4
p3	3.095 ± 0.001
p4	0.01178 ± 0.00077
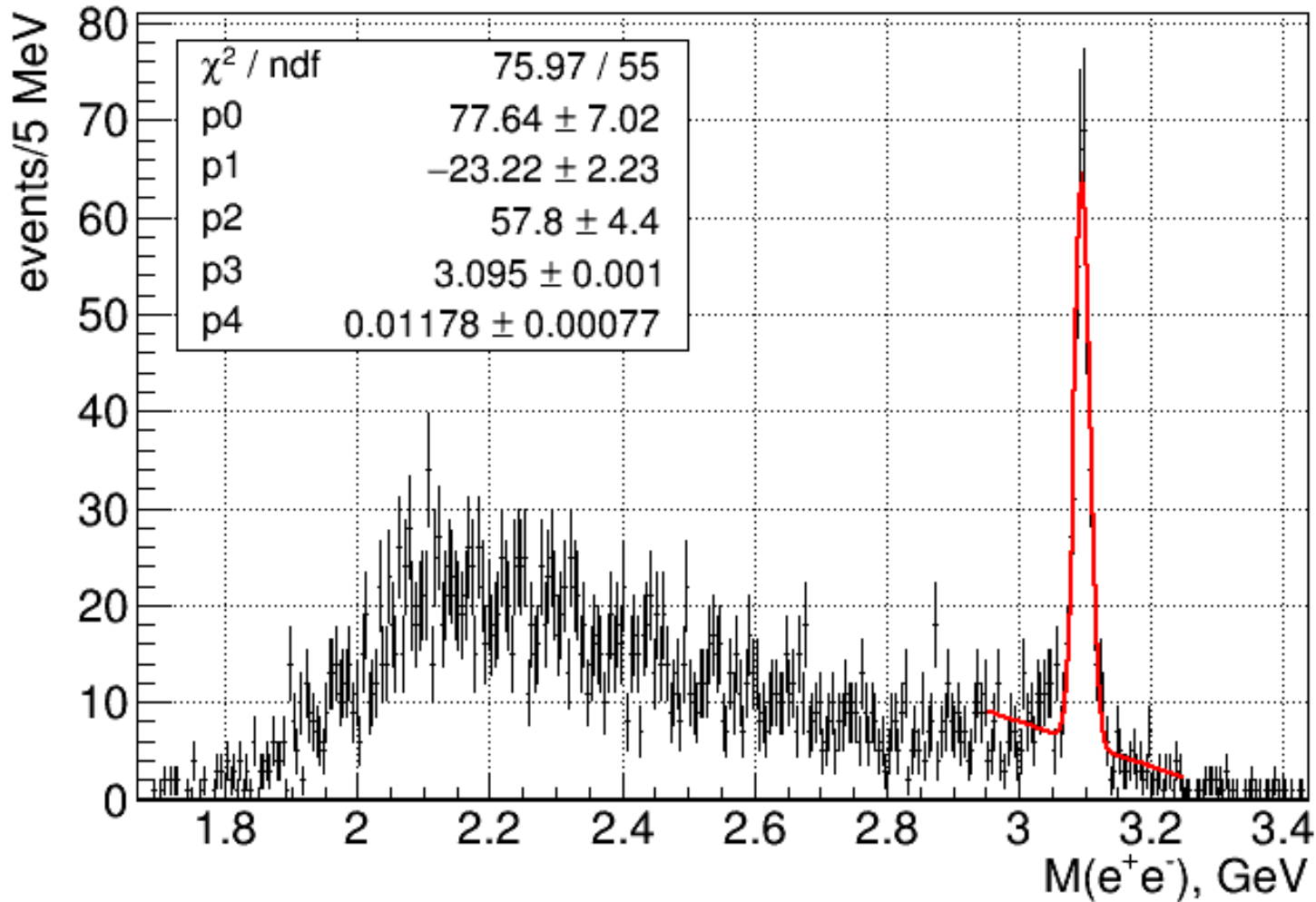
349 ± 19 J/ψ's

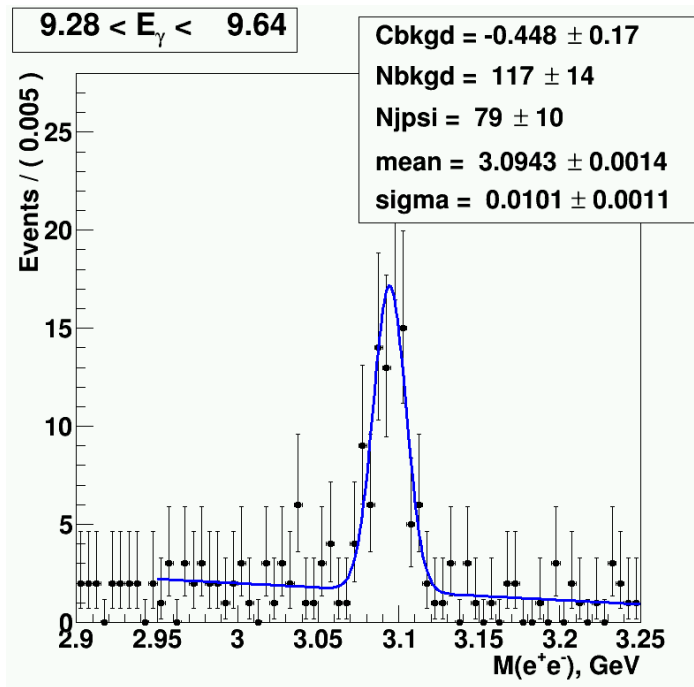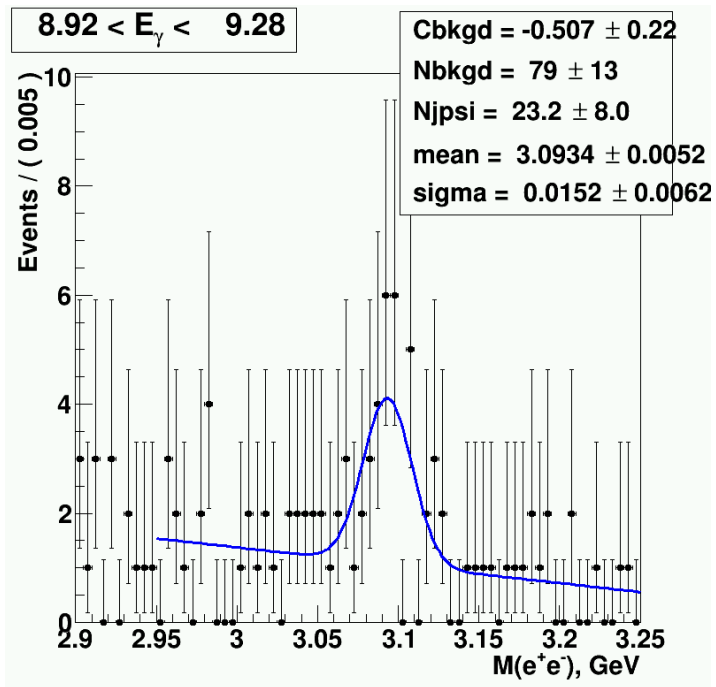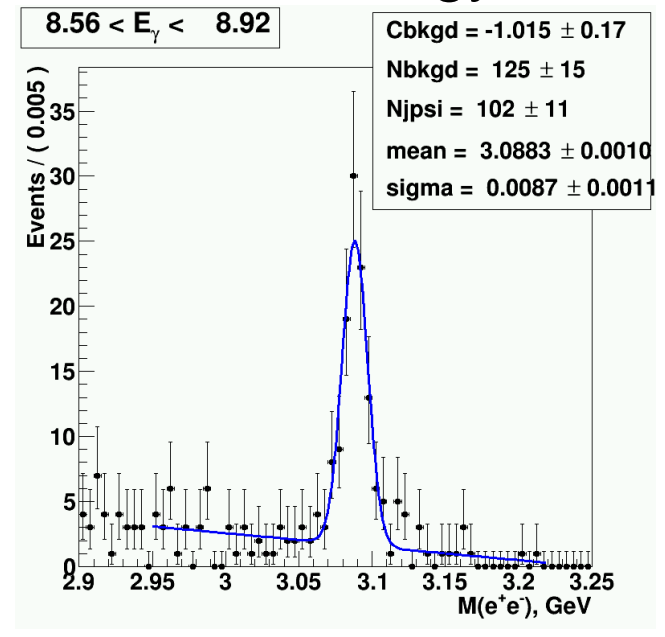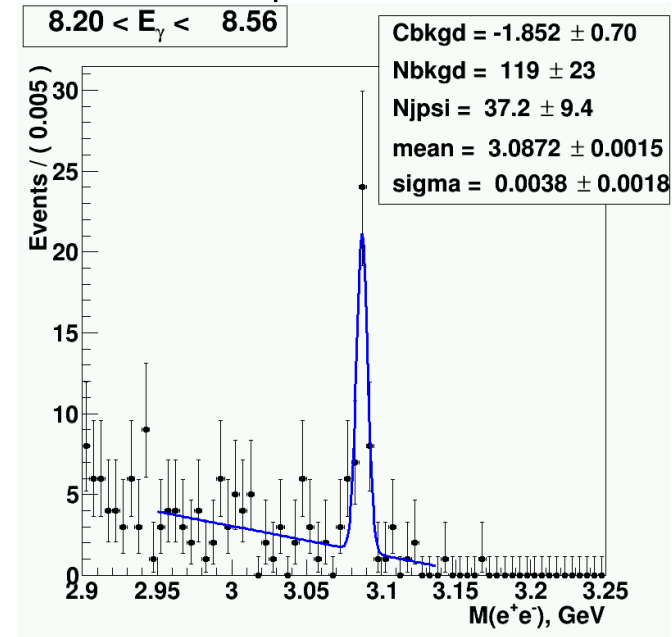about same number of events in 2017

BH in 2.1<M<2.5 GeV all data

Includes 2016+2017+2018(1-3),
2017 flux doubled, just for comparison

J/ψ all data – fits in bins of beam energy

$8.20 < E_\gamma < 8.56$

Cbkgd = -1.852 $\pm$ 0.70
Nbkgd = 119 $\pm$ 23
Njpsi = 37.2 $\pm$ 9.4
mean = 3.0872 $\pm$ 0.0015
sigma = 0.0038 $\pm$ 0.0018

$8.56 < E_\gamma < 8.92$

Cbkgd = -1.015 $\pm$ 0.17
Nbkgd = 125 $\pm$ 15
Njpsi = 102 $\pm$ 11
mean = 3.0883 $\pm$ 0.0010
sigma = 0.0087 $\pm$ 0.0011

$8.92 < E_\gamma < 9.28$

Cbkgd = -0.507 $\pm$ 0.22
Nbkgd = 79 $\pm$ 13
Njpsi = 23.2 $\pm$ 8.0
mean = 3.0934 $\pm$ 0.0052
sigma = 0.0152 $\pm$ 0.0062

$9.28 < E_\gamma < 9.64$

Cbkgd = -0.448 $\pm$ 0.17
Nbkgd = 117 $\pm$ 14
Njpsi = 79 $\pm$ 10
mean = 3.0943 $\pm$ 0.0014
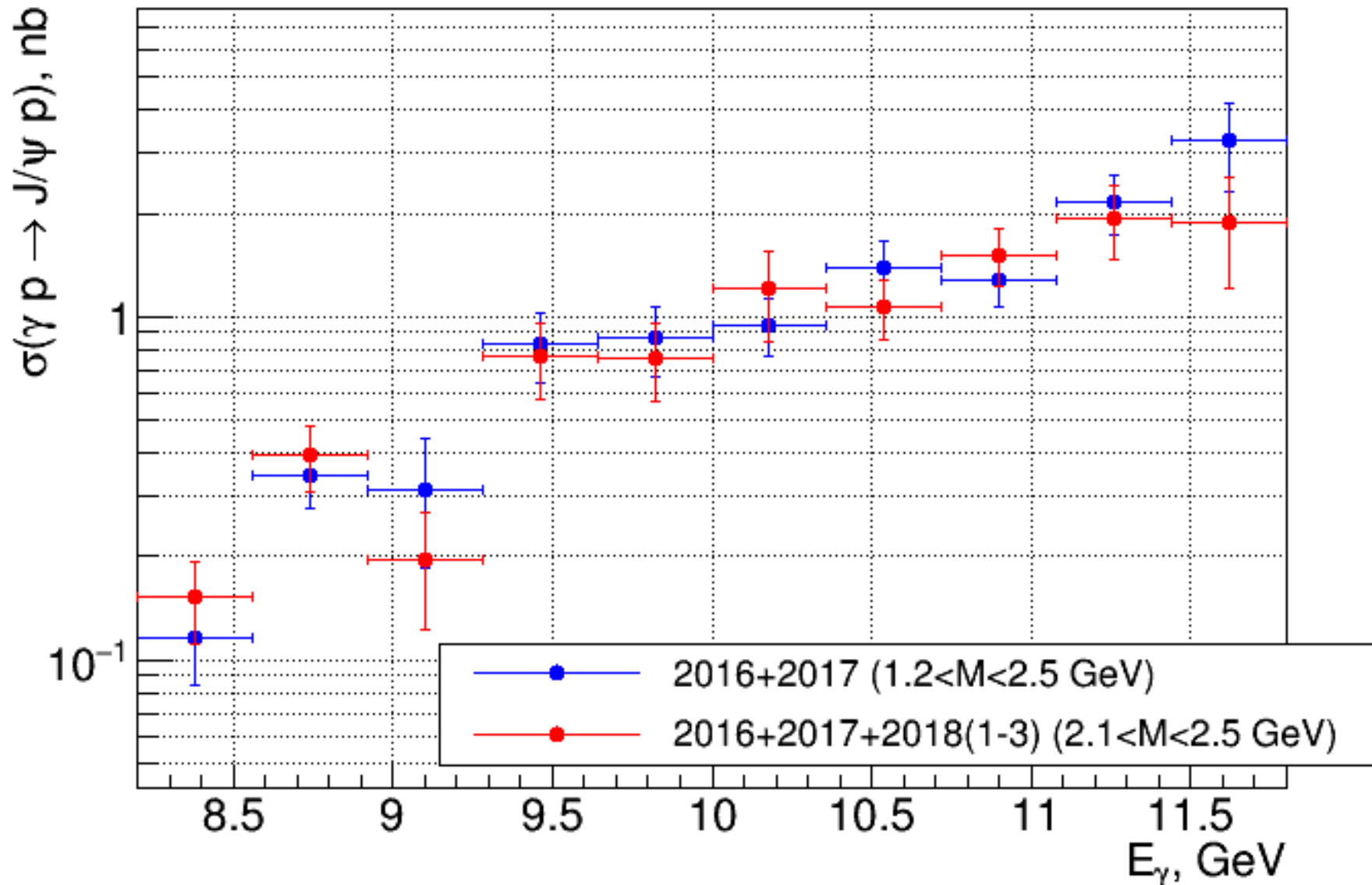sigma = 0.0101 $\pm$ 0.0011
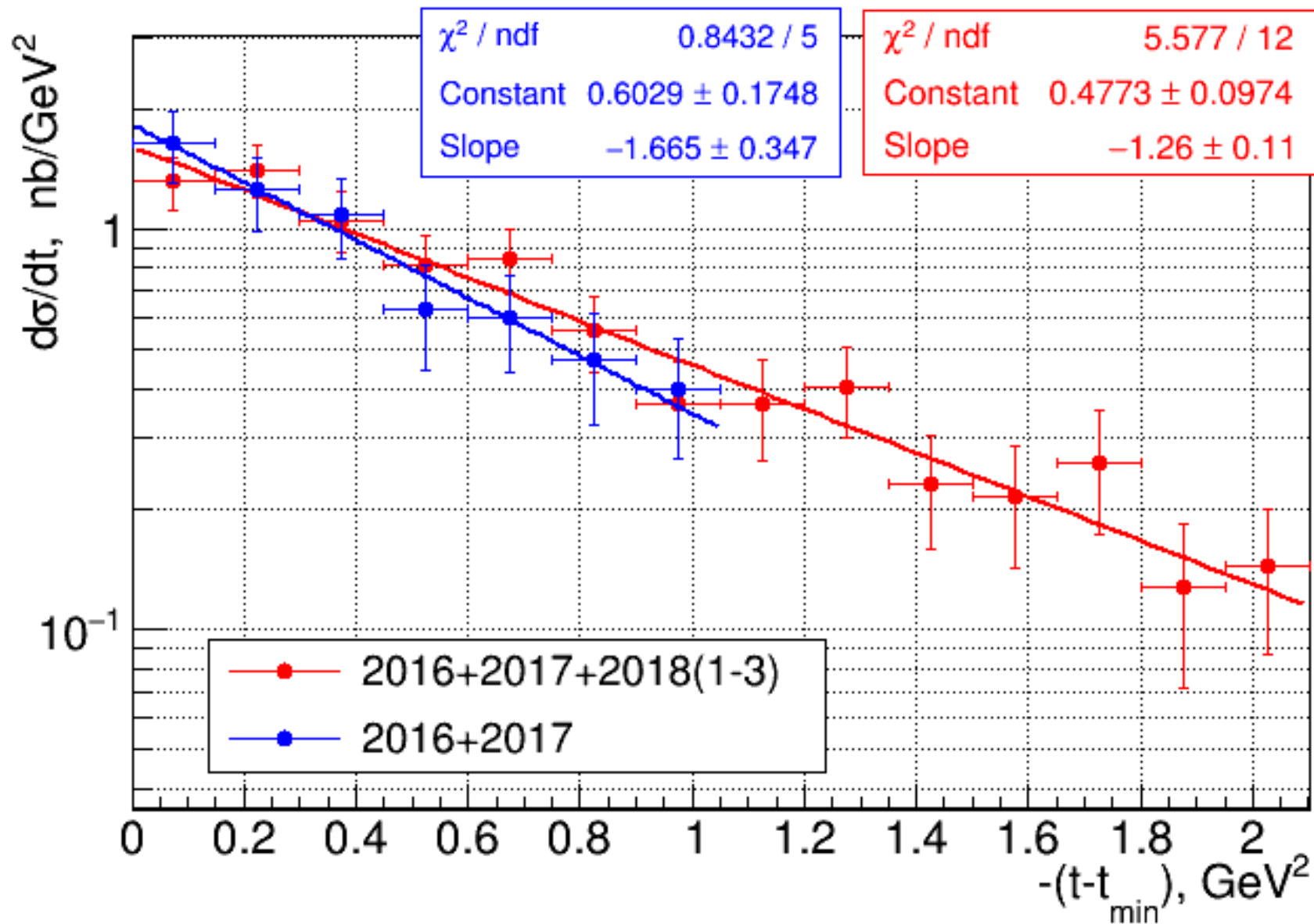
J/ψ all data – fits in bins of beam energy

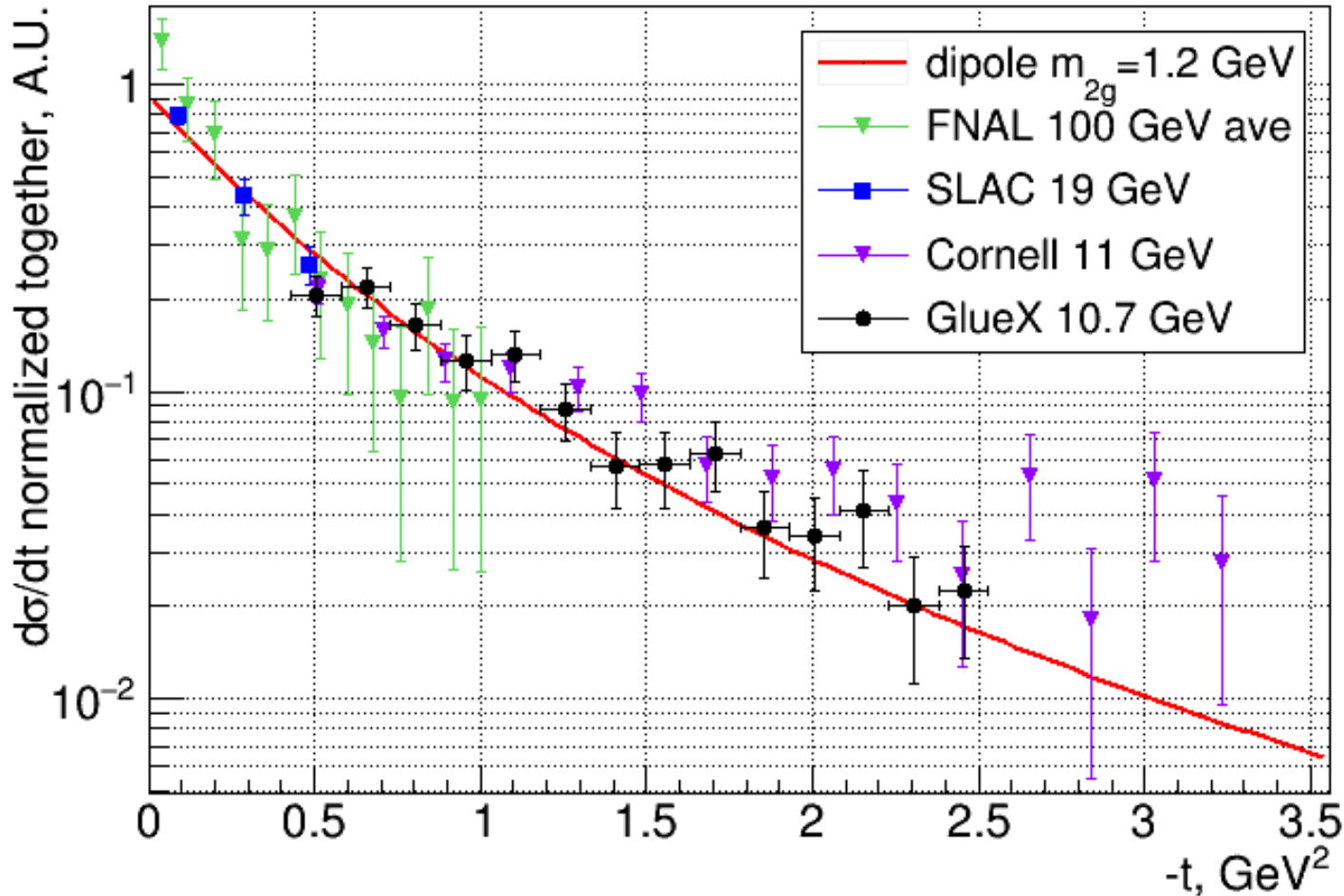# J/ψ all data – fits in bins of beam energy
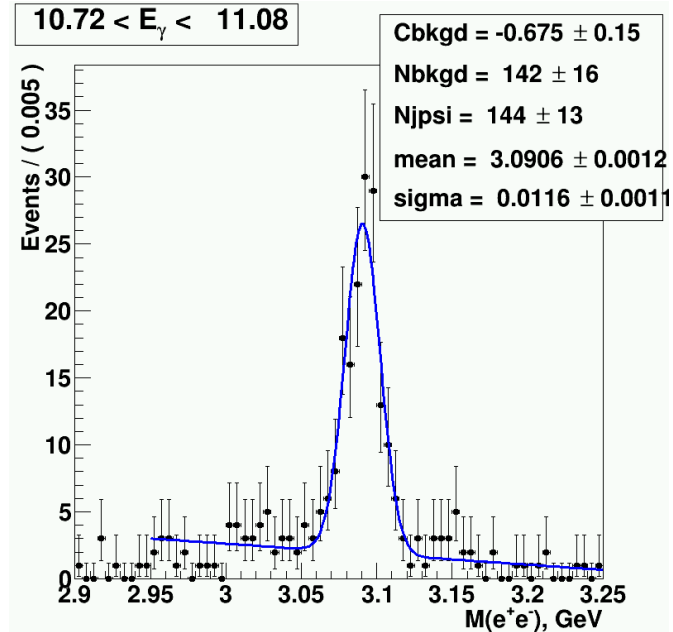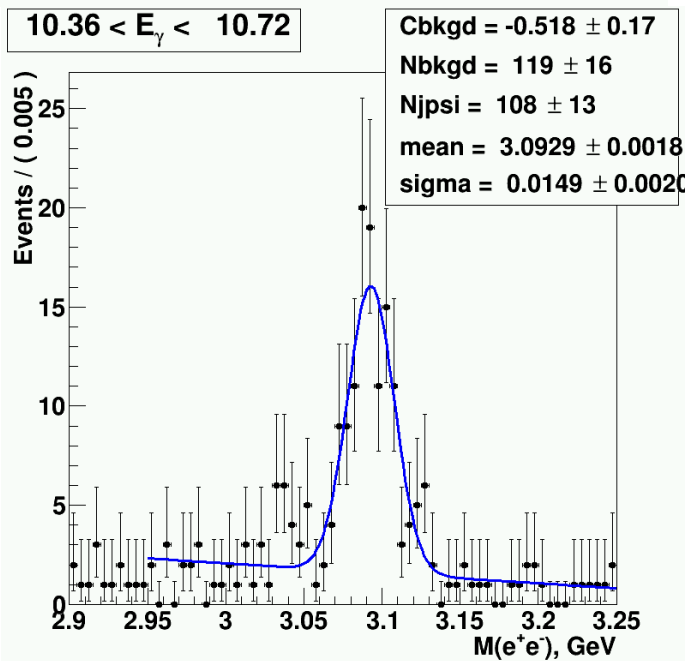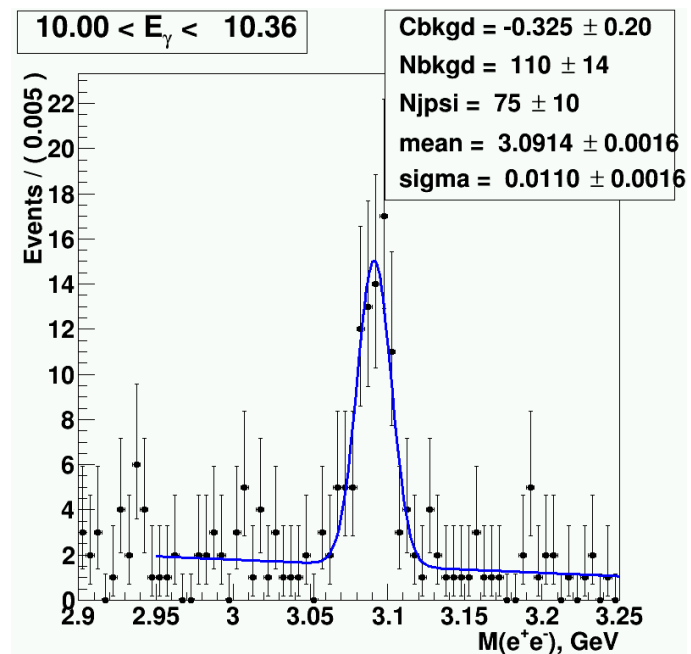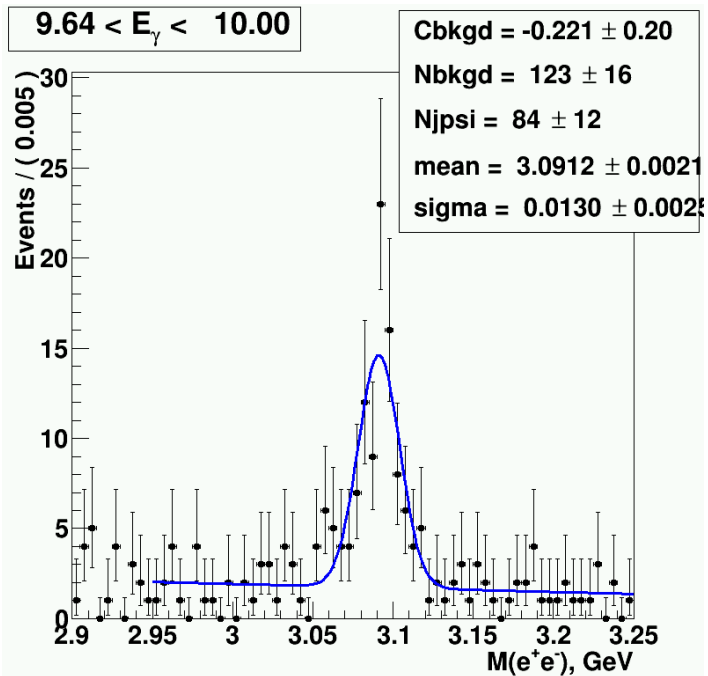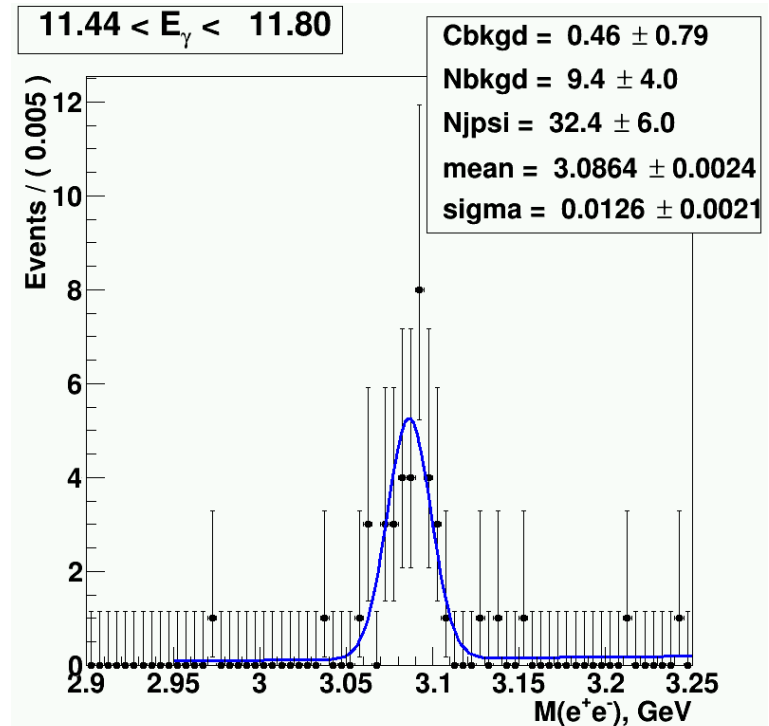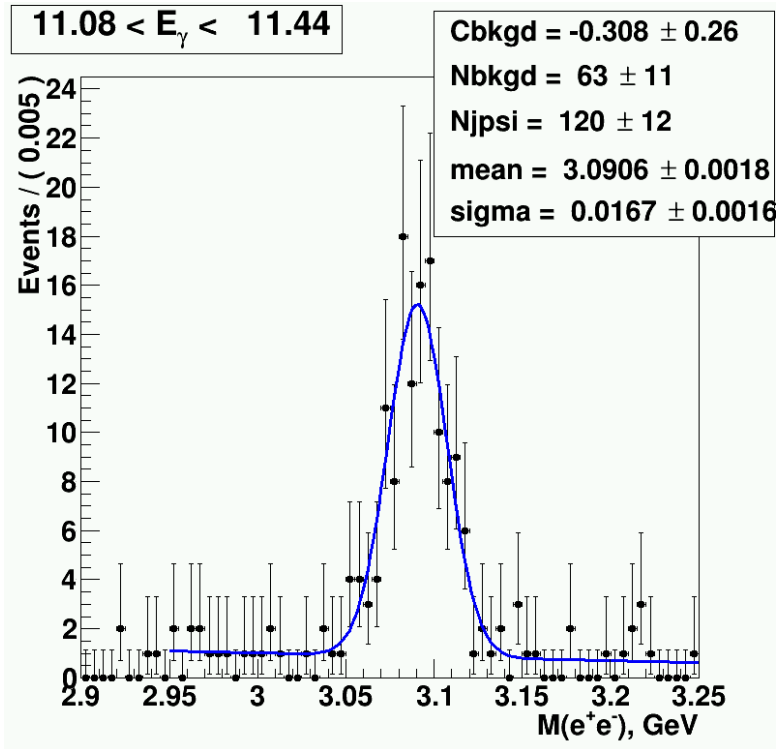
J/ψ total cross-section – all data so far

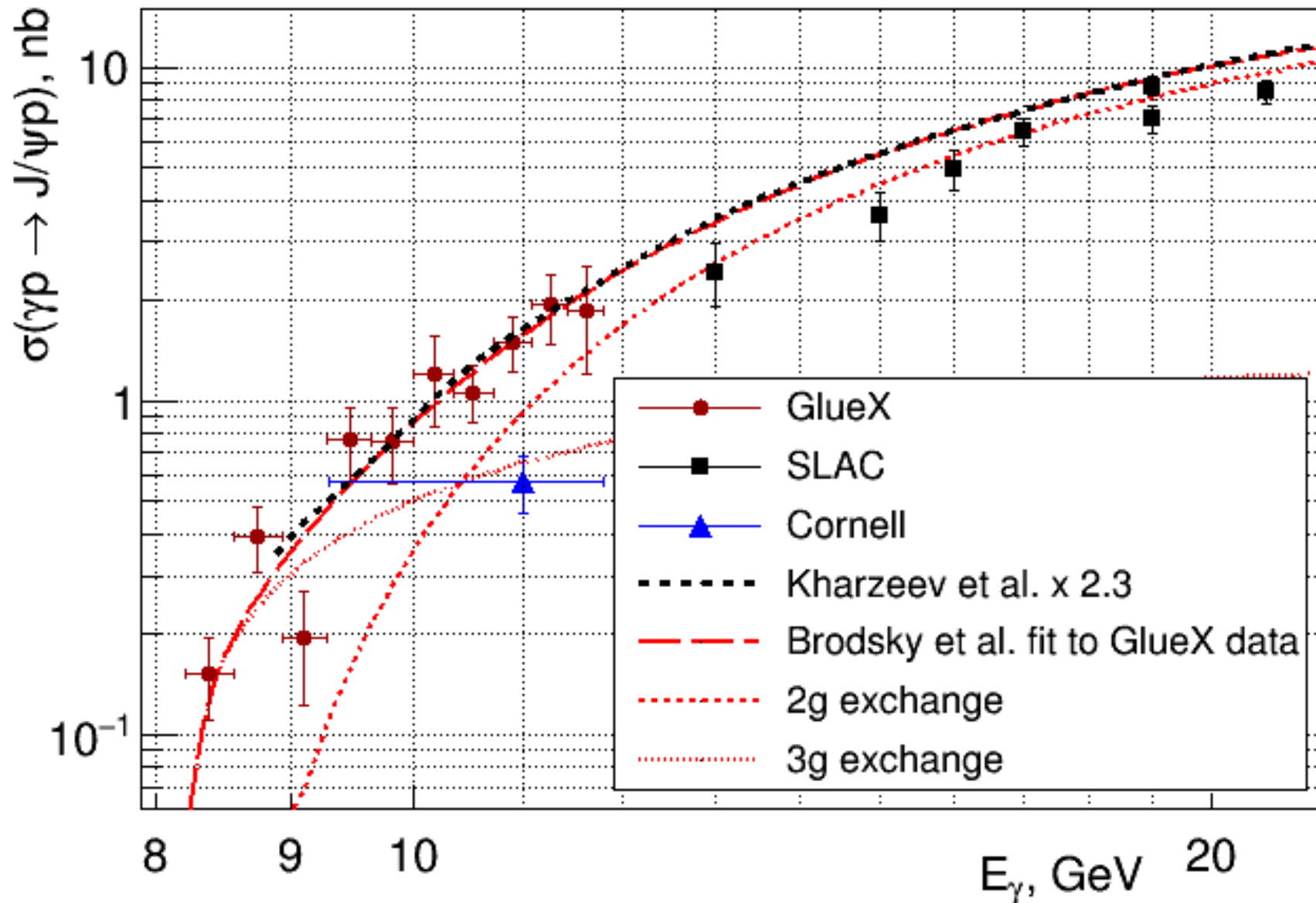Differential cross-section – all data
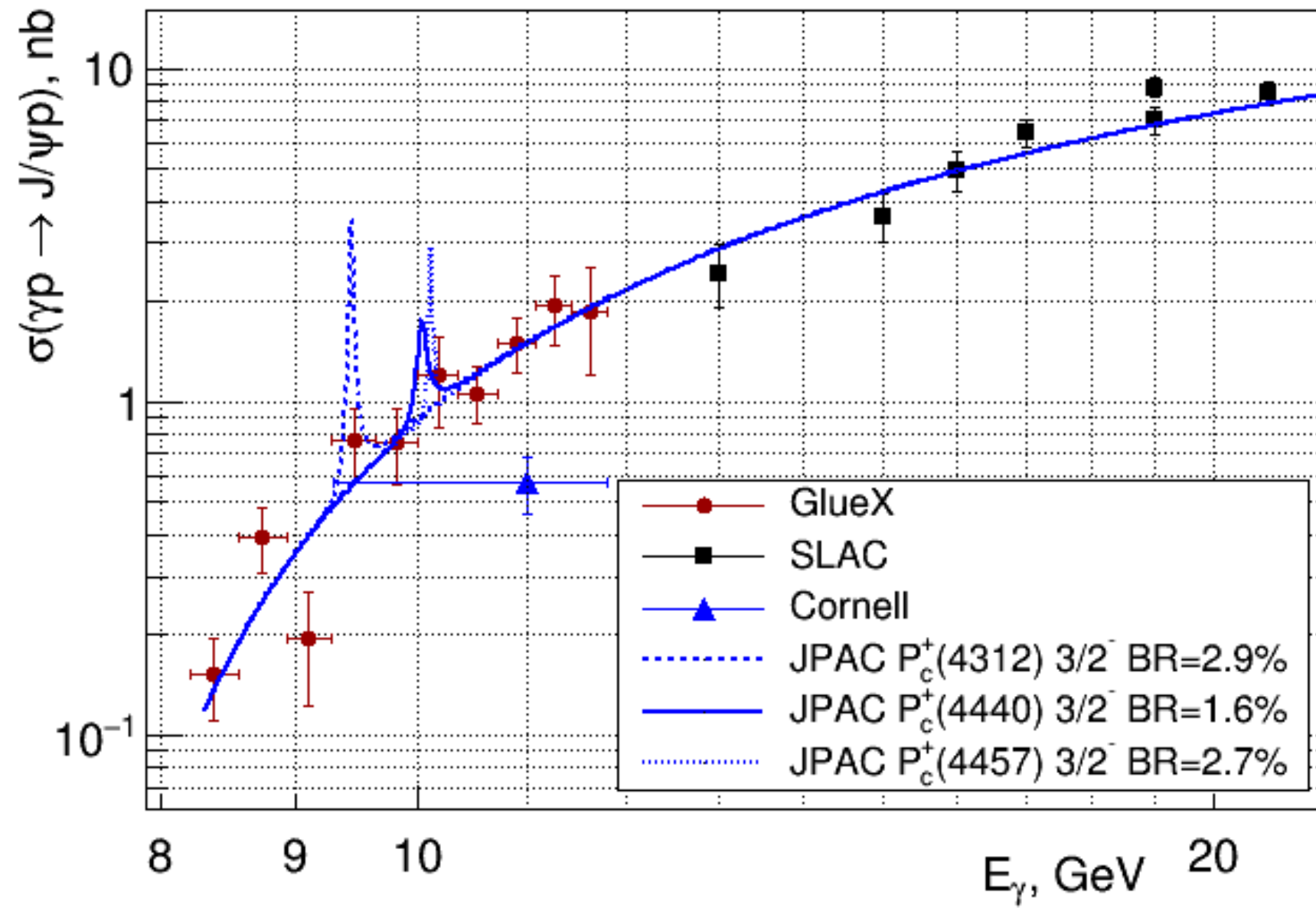
Proton Gluonic Form Factor

- *Frankfurt and Strikman PRD66 (2002)* suggested t-dependence defined by the proton gluonic FF
- Explains t-slope change with energy (due to t_{min} and t-range dependence) in wide energy range

Energy dependence

Energy dependence
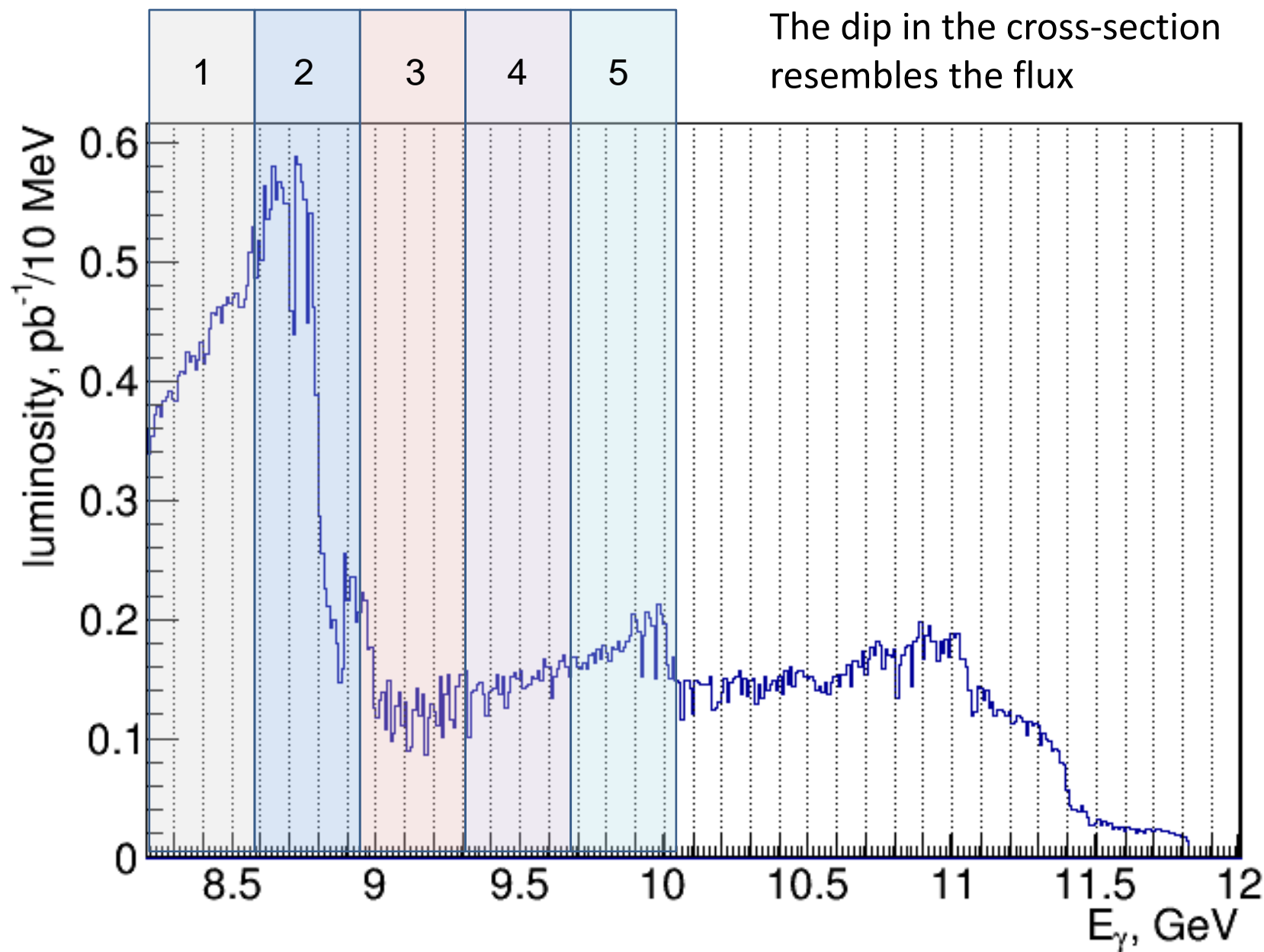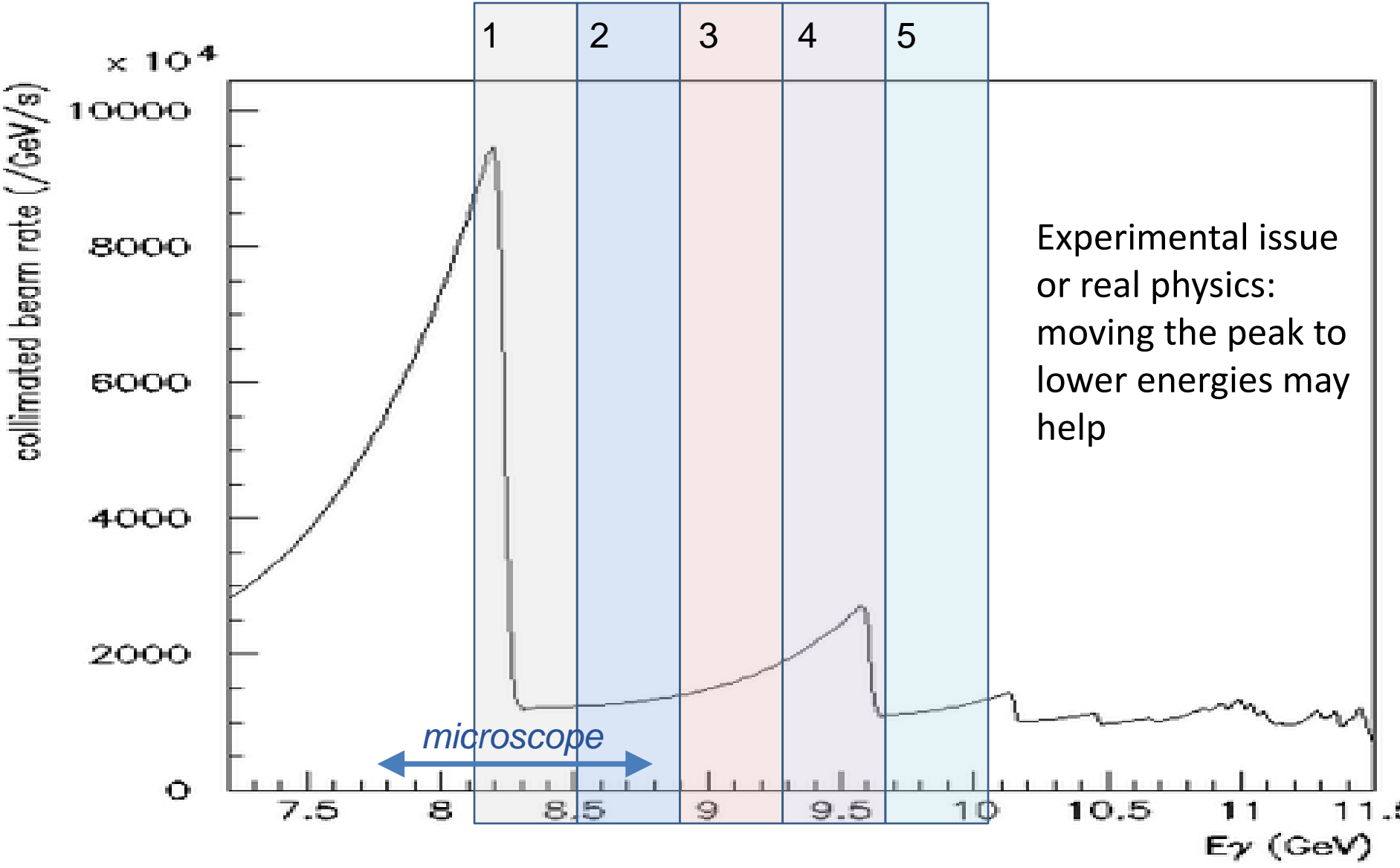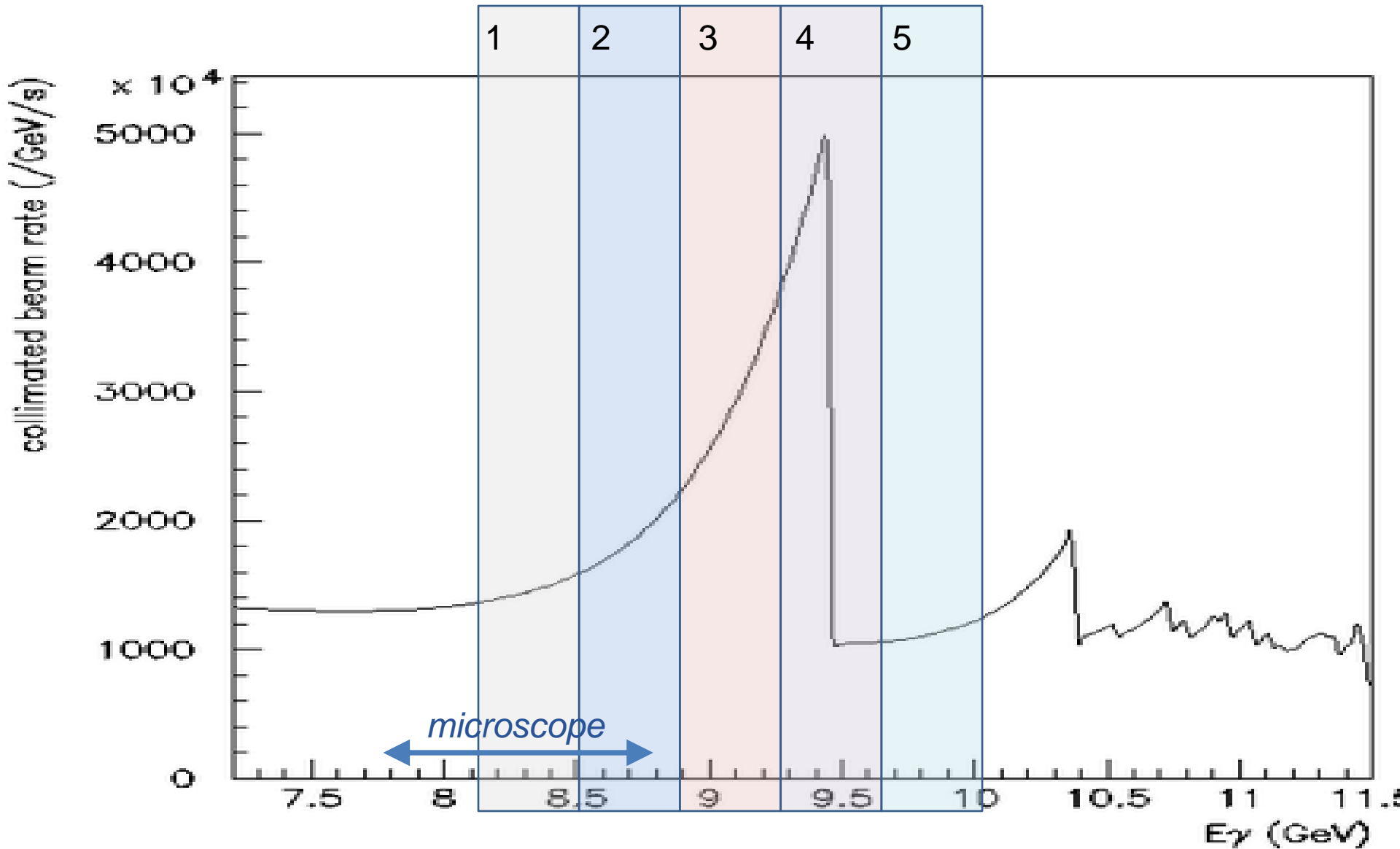
Photon spectrum 2016+2017

The dip in the cross-section resembles the flux

Photon spectrum $E_{peak} = 8.3$ GeV

Experimental issue or real physics: moving the peak to lower energies may help

Photon spectrum $E_{peak} = 9.5$ GeV

Photon beam asymmetry

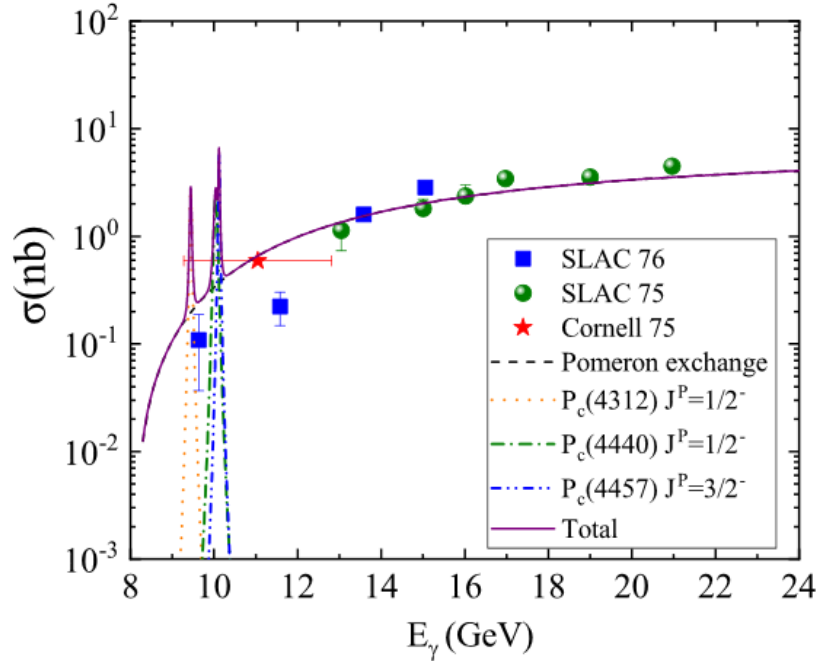*Xiao-Yun Wang, Xu-RongChen, and Jun He, arXiv:1904.11706 (Apr 26 2019)*

FIG. 2. (Color online) Total cross section for the $\gamma p \rightarrow J/\psi p$ reaction by assuming branching ratio $Br[P_c \rightarrow J/\psi p] \simeq 3\%$. The black dashed, orange dotted, green dot-dashed, blue dash-double dotted, and violet solid lines are for the Pomeron exchange, $P_c(4312)$, $P_c(4440)$, $P_c(4457)$, and total contributions, respectively. The experimental data are from Refs. [23–25].
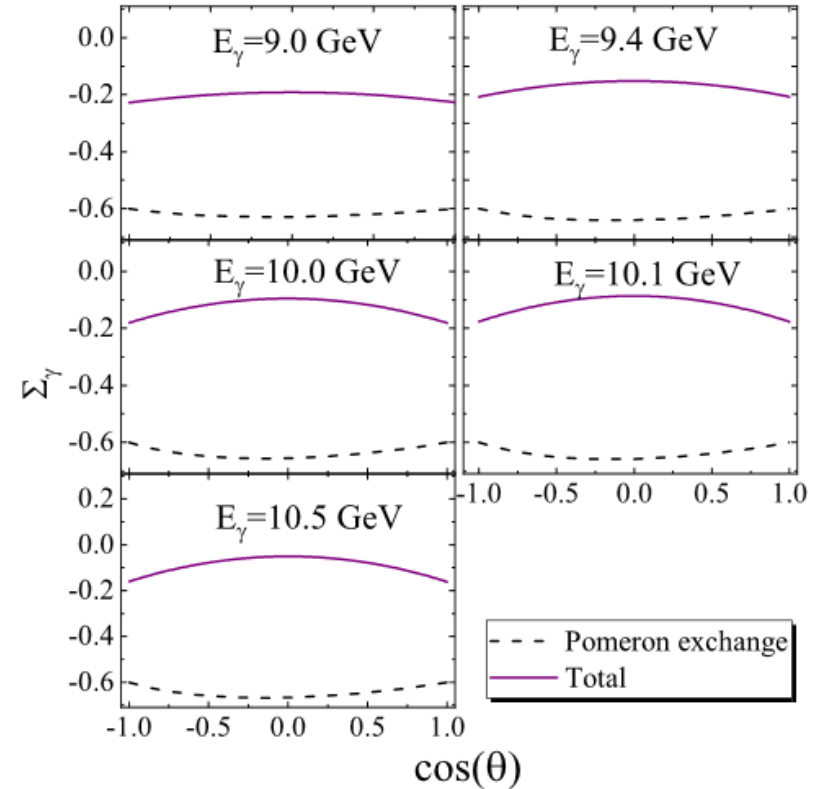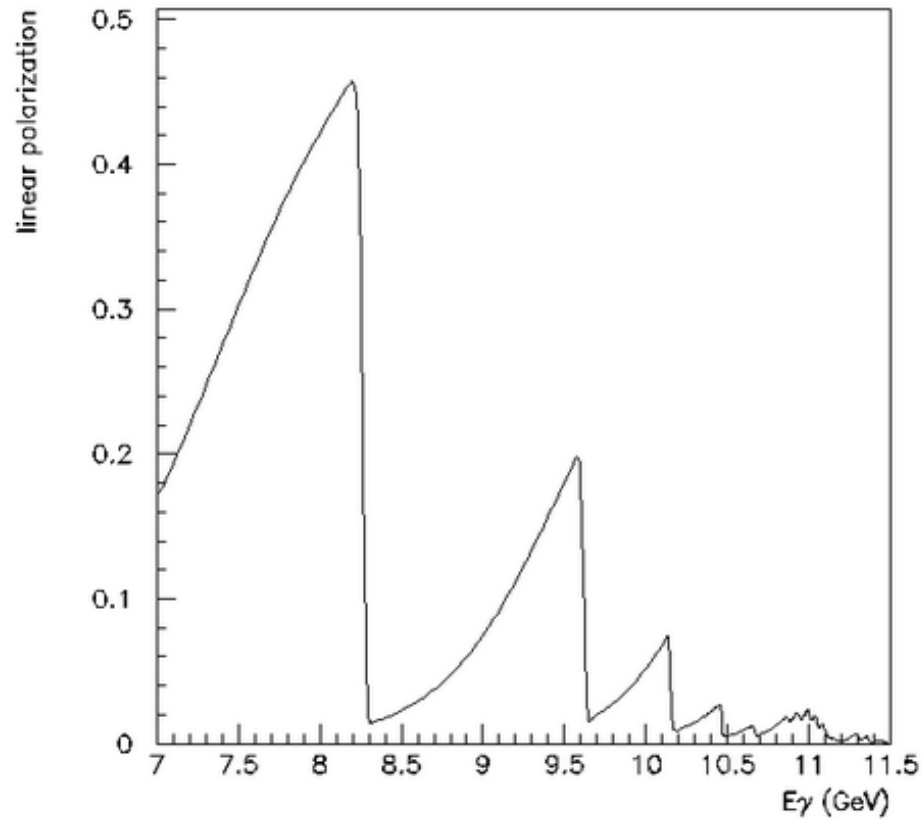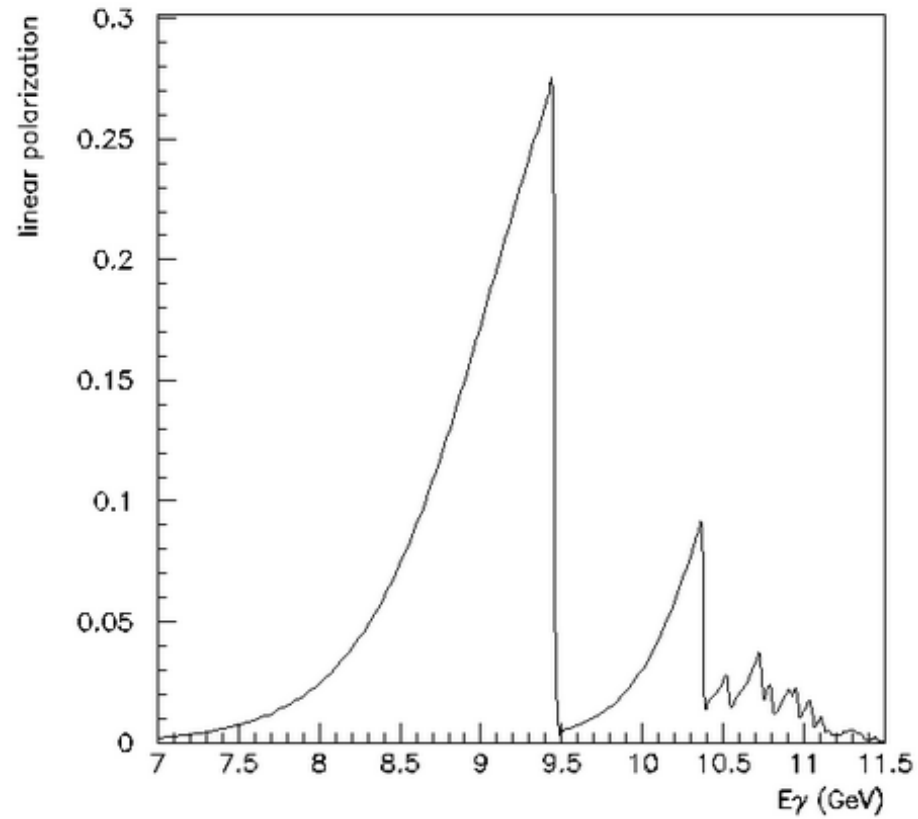
FIG. 7. (Color online) The photon beam asymmetries Σ_γ for the $\gamma p \rightarrow J/\psi p$ reaction of $E_\gamma = 9.0 - 10.5$ GeV. The violet solid curves represent the total results including the P_c states, whereas the black dashed lines only show the result of Pomeron exchange.

Photon beam polarization

$E_{peak} = 8.3$ GeV

$E_{peak} = 9.5$ GeV

Summary

- New very preliminary results (twice more statistics) are consistent with the paper results

- Plan to have 2016-2018 combined results by the end of the year
    - Requires unified analysis of all (2016-2108) the data: reconstruction, analysis, MC, etc.
    - New unbinned analysis to set limits on the pentaquarks, that includes better(at 10 MeV level) understanding of the flux

- Some not statistically significant features at ~9.1 GeV require attention – when all 2018 data analyzed we will have statistical significance
    - Lowering the energy of the coherent peak may help - experimental problem or real physics
    - In case of compelling physics case we may decide to move to peak to higher energies
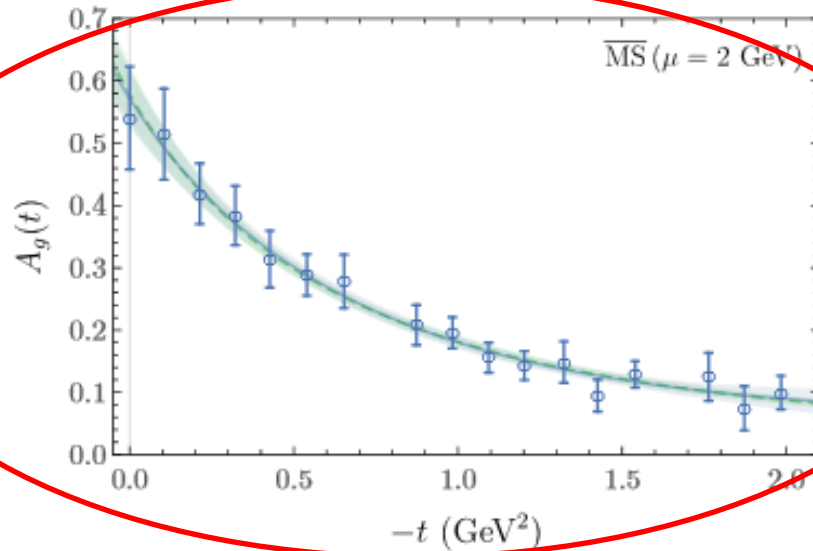
Back-ups

Proton Gluonic Form Factors: A,B,C

J/ψ p → J/ψ p:

$$\langle P'|(T_g)^{\mu}_{\mu}|P\rangle = \langle P'| \left(\frac{\beta(g)}{2g} F^a_{\mu\nu} F^{\mu\nu}_a + m\gamma_m \bar{\psi}\psi \right) |P\rangle$$

$$= \bar{u}(P') \left[A_g M + \frac{B_g}{4M}\Delta^2 - 3\frac{\Delta^2}{M}C_g + 4\bar{C}_g M \right] u(P)$$

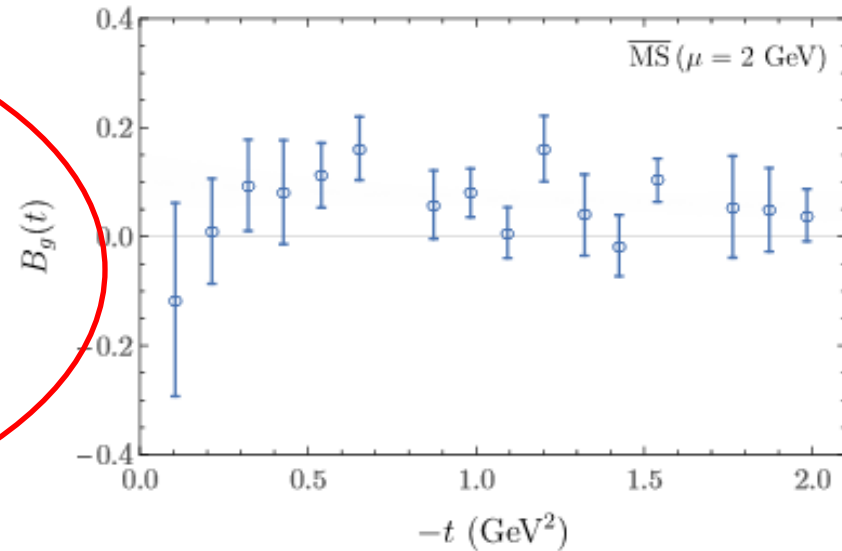- Red – maximal trace anomaly term (related to fraction of nucleon mass arising from gluons)
- Blue – no trace anomaly E_γ = 9.3 GeV

Yoshitaka Hatta and Di-Lun Yang
https://arxiv.org/pdf/1808.02163.pdf
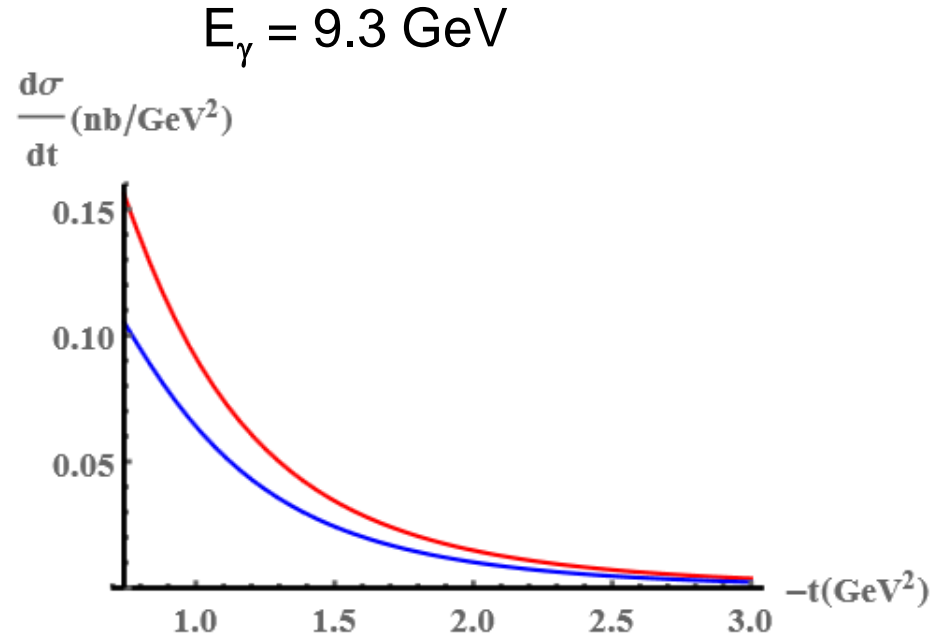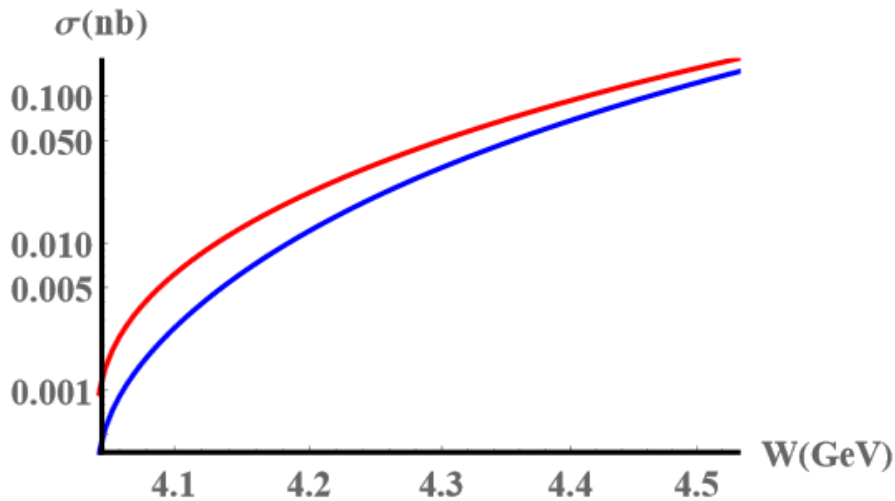
Proton Gluonic Form Factors: A,B,C (lattice calculations)

(a)

(b)

Fits in dipole form:

	m (GeV)	α
A_g	1.13(6)	0.58(5)
D_g	0.48(5)	-10(3)

P. E. Shanahan and W. Detmold
https://arxiv.org/pdf/1810.04626.pdf