第二届强子与重味物理理论与实验联合研讨会　兰州大学

Near-threshold photoproduction of J/ψ in two-gluon exchange model

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based on: Fancong Zeng, Xiao-Yun Wang*, Li Zhang, Ya-Ping Xie, Rong Wang and Xurong Chen. Eur. *Phys. J. C 80 (2020) 1027*. (arXiv:2008.13439)

Outline

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Recently, the first measurement of the near-threshold cross-section of the reaction $\gamma p \to J/\psi p$ has been reported.

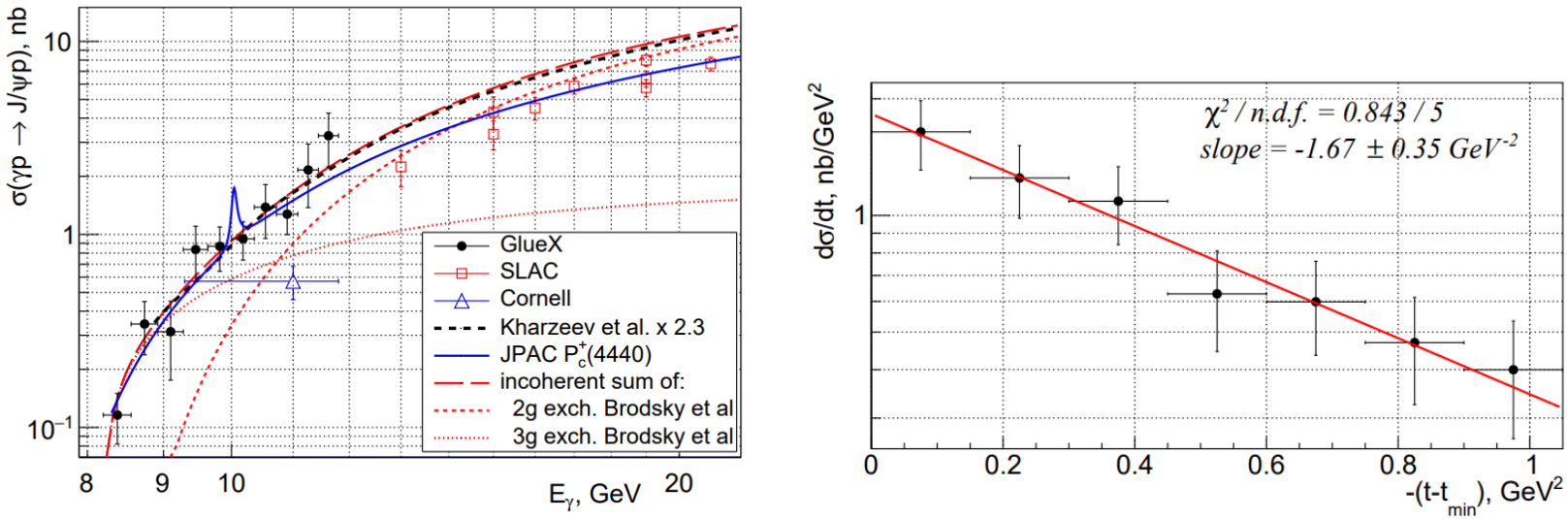


图: GlueX results for the J/ψ total cross-section vs beam energy and differential cross section for J/ψ photoproduction as a function of $-(t - t_{min})$ for $10.00 < E_\gamma < 11.80$ GeV.

[A. Ali et al. Phys. Rev. Lett. **(2019) 123(7), 072001**]

The near-threshold photoproduction of $\gamma p \to J/\psi p$ is a key experimental channel widely discussed to investigate the pentaquark photoproduction. Moreover, the near-threshold photoproduction of J/ψ also plays an important role in probing the nucleon mass structure.

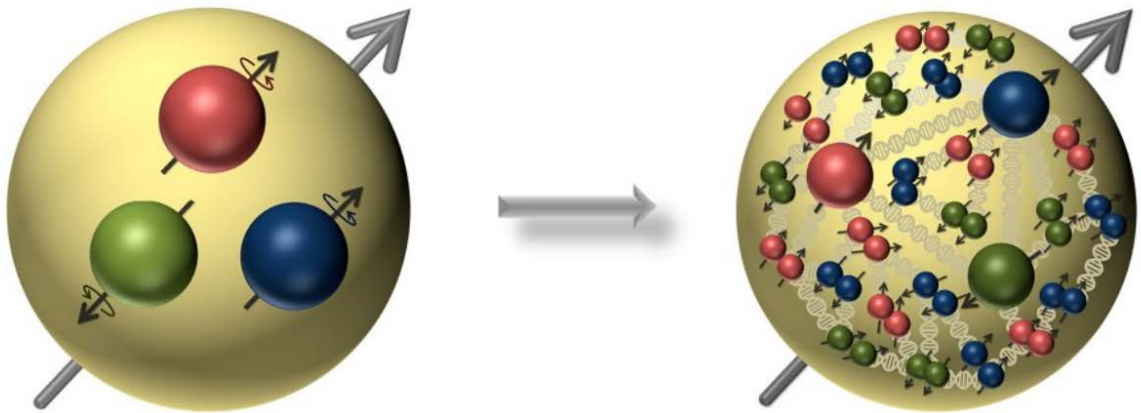


图: Three valence quarks needed to define quantum numbers contribute only 9% of its mass.

Including the photon-gluon fusion model (PGF) has been demonstrated to be applicable to explain the heavy quarkonia photoproduction in a wide energy range.

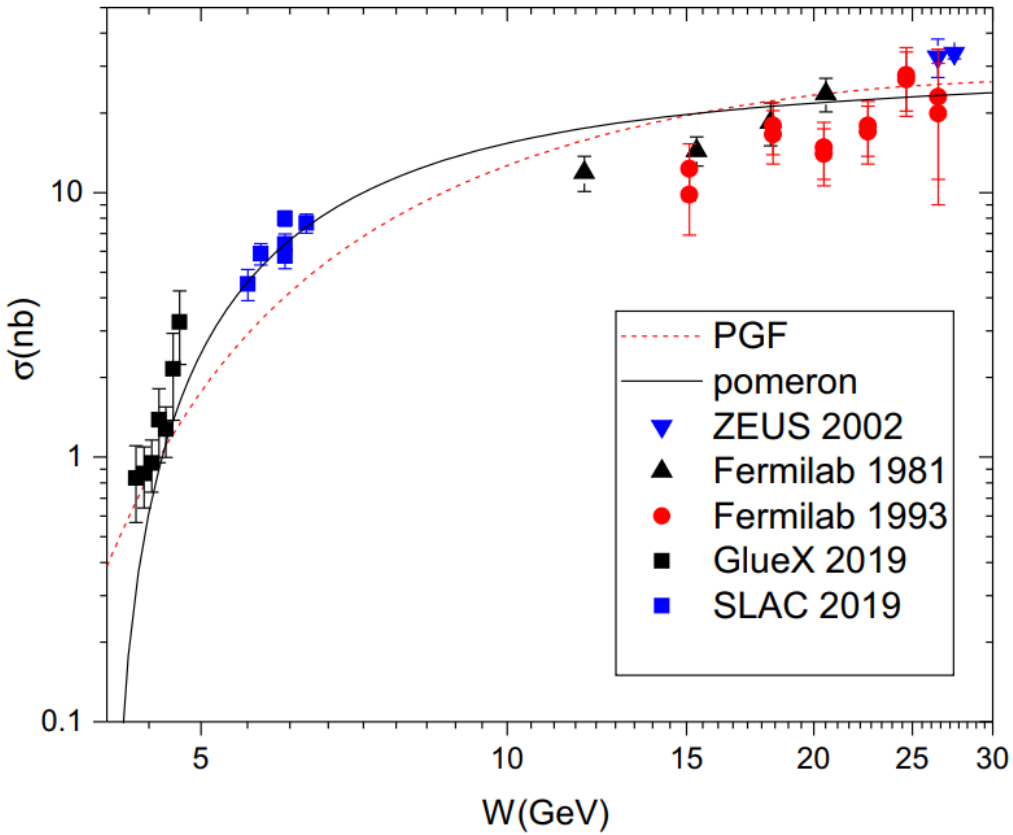
$$\sigma_{\gamma p\to pJ/\Psi} = f\int_{4m_c^2}^{4m_D^2}\frac{d\bar{s}}{\bar{s}}\sigma_{\gamma g\to c\bar{c}g}\left(x=\frac{\bar{s}}{s},m_{J/\Psi}^2\right)$$

The phenomenological pomeron exchange model is used to describe the cross section of $\gamma p \to Vp$.

$$\sigma(\gamma p\to Vp)=\sigma_p\left[1-\frac{(m_p+m_V)^2}{W_{\gamma p}^2}\right]^2 W_{\gamma p}^{\epsilon} \qquad (1)$$

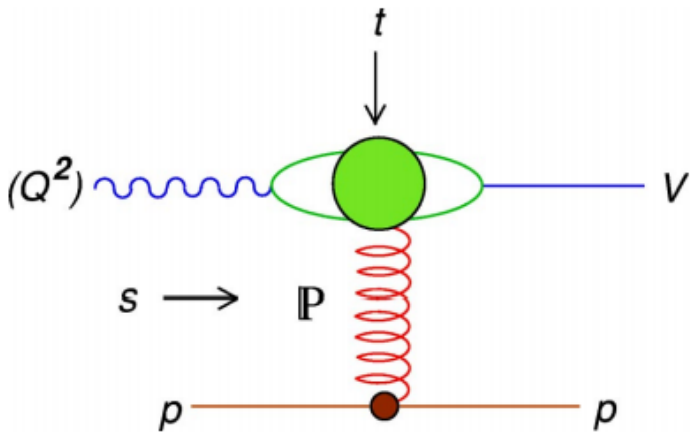
[Y.Xu, Y.Xie, R.Wang, X.Chen, Eur.Phys.J.C **80(3), 283(2020)**]

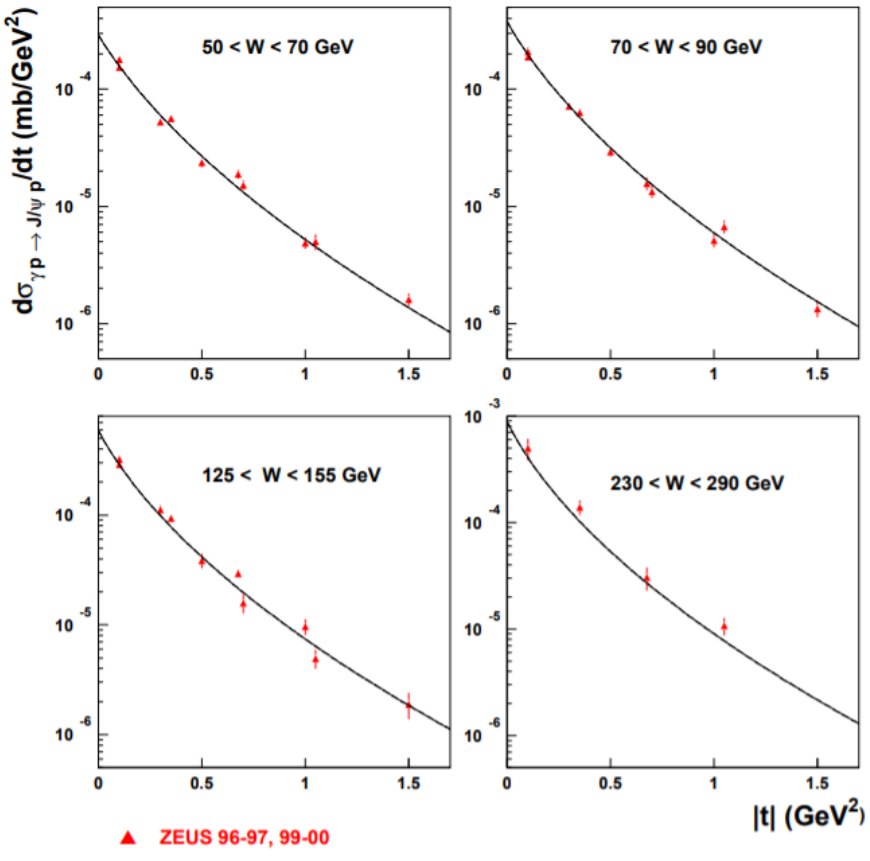
Both models give explanations for the J/Ψ photoproduction near the threshold. Unfortunately, it is difficult for these models to give the differential cross-section at the production threshold.



[Y.Xu, Y.Xie, R.Wang, X.Chen, Eur.Phys.J.C **80(3), 283(2020)**]

Soft dipole Pomeron model has a perfect quality of fitting to both the total and the differential cross−sections in the high energy region. However, there is an inconsistency for the differential cross−section near the threshold.



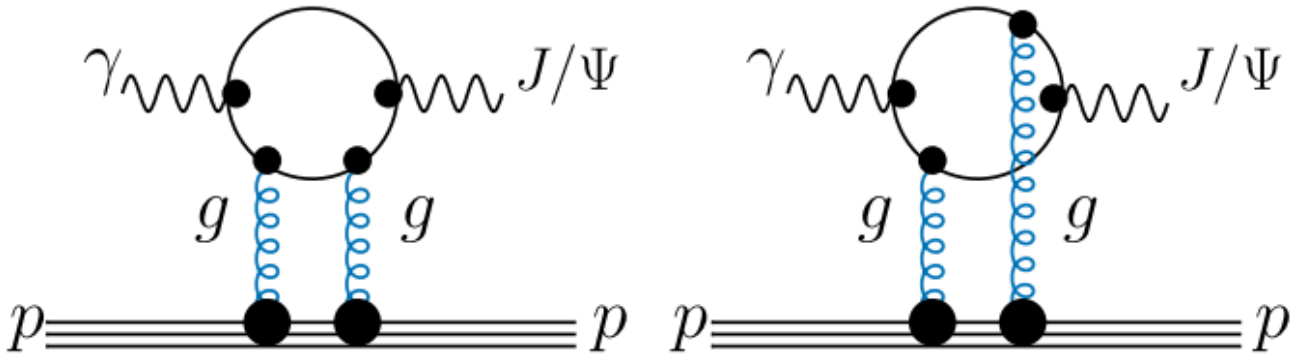


[E.Martynov, E.Predazzi, A.Prokudin, Phys.Rev.D**67, 074023(2003)**.]

Outline

two-gluon exchange model

The two-gluon exchange model is based on the photon fluctuation into the quark-antiquark pair ($\gamma \to q + \bar{q}$) and the picture of the double gluon exchange between the nucleon state and the quark-antiquark pair.
In a word, the two-gluon exchanging process is dominant in J/Ψ production near threshold.



The two-gluon exchange amplitude can be written as

$$\mathcal{T} = \frac{i\sqrt{2}\pi^2}{3} m_q \alpha_s e_q f_V F_{2g}(t)[\frac{xg\left(x, Q_0^2\right)}{m_q^4} + \int_{Q_0^2}^{+\infty} \frac{dl^2}{m_q^2\left(m_q^2 + l^2\right)} \frac{\partial xg\left(x, l^2\right)}{\partial l^2}].$$

The amplitude is normalized and $\frac{d\sigma}{dt} = \alpha|\mathcal{T}|^2$. In the lowest order, the J/Ψ photoproduction differential cross-section is given as,

$$\frac{d\sigma}{dt} = \frac{\pi^3 \Gamma_{e^+e^-} \alpha_s}{6\alpha m_q^5} \left[xg\left(x, m_J^2\right)\right]^2 \exp(bt) \qquad (2)$$

$x = m_J^2/W^2 (W = 4.59 GeV)$, the W-dependence of the slope $b = \frac{d}{dt} In[\frac{d\sigma}{dt}]$

The $xg(x, m_J^2)$ is the gluon distribution function at $Q^2 = m_J^2$, and in this work it is parameterized using a simple function form $xg(x, m_J^2) = A_0 x^{A_1}(1-x)^{A_2}$. The parameters A_0, A_1, A_2 can be fixed by the experimental data.
The total cross-section is obtained by integrating the differential cross-section over the allowed kinematical range from $|t_0|$ to $|t_1|$,

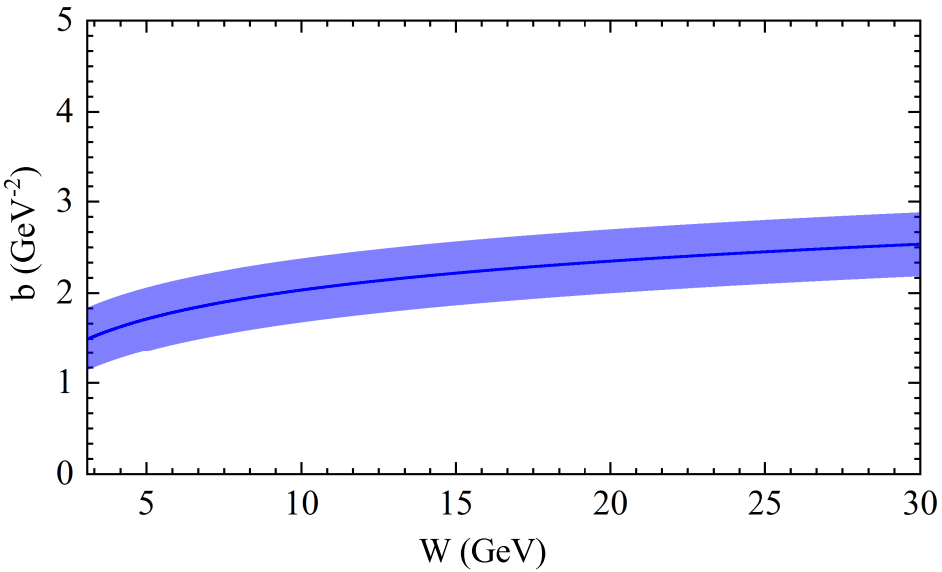
$$\sigma = \int_{|t_0|}^{|t_1|} \frac{\pi^3 \Gamma_{e^+e^-} \alpha_s}{6\alpha m_q^5} \left[xg\left(x, m_J^2\right)\right]^2 \exp(b(W)t)dt$$

[A.Sibirtsev et al. J. Phys. G **30, 1427–1444 (2004)**]

The exponential slope b(W) has little vary with the energy W.

$$b(W) = b_0 + 0.46 \mathrm{In}(W/W_0)$$

It is precisely because the value of b changes very slowly with energy that even after we consider the error of b, the value of b is still between $1 \sim 2\mathrm{GeV}^2$ near the energy threshold.



[S.Chekanovetal., ZEUS. Eur. Phys. J. C **24, 345–360 (2002).**]

The exclusive electroproduction of J/ψ is closely connected J/ψ photoproduction, as in the electron scattering process, the J/ψ vector meson is generated from the virtual photon exchanged between the electron and the hadron.

$$\sigma(\mathrm{ep} \to \mathrm{eJ}/\psi\mathrm{p}) = \int \mathrm{dkdQ}^2 \frac{\mathrm{dN}^2(\mathrm{k}, \mathrm{Q}^2)}{\mathrm{dkdQ}^2} \sigma_{\gamma^*\mathrm{p}\to \mathrm{J}/\psi\mathrm{p}}(\mathrm{W}, \mathrm{Q}^2), \quad (3)$$

The connection between the cross-section induced by a real photon and that induced by a virtual photon is governed by,

$$\sigma_{\gamma^*\mathrm{p}\to \mathrm{J}/\psi\mathrm{p}}(\mathrm{W}, \mathrm{Q}^2) = \sigma_{\gamma\mathrm{p}\to \mathrm{J}/\psi\mathrm{p}}(\mathrm{W}, \mathrm{Q}^2 = 0) \left(\frac{\mathrm{M}_\mathrm{V}^2}{\mathrm{M}_\mathrm{V}^2 + \mathrm{Q}^2} \right)^\eta. \quad (4)$$

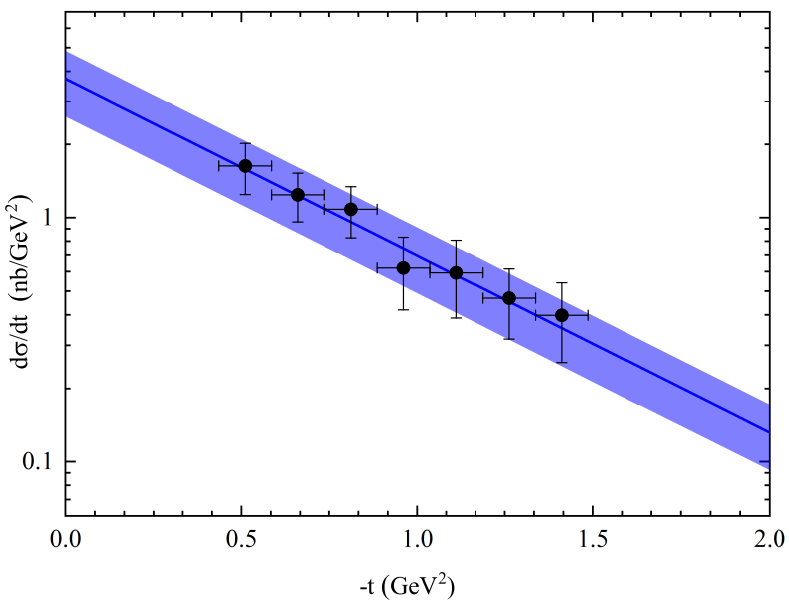
[S.R.Klein, Y.P.Xie, Phys. Rev. C **100(2), 024620 (2019).**]

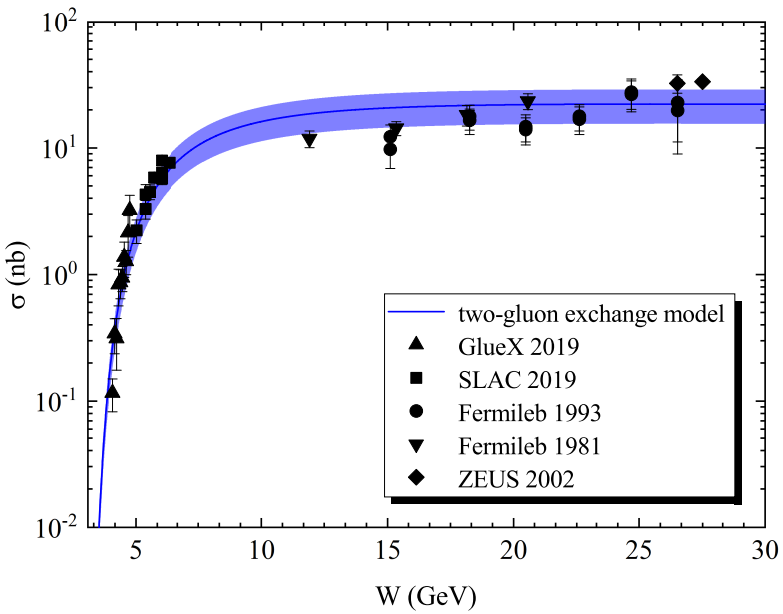
Outline

The free parameters A_0, A_1, A_2 are fixed by a global analysis.

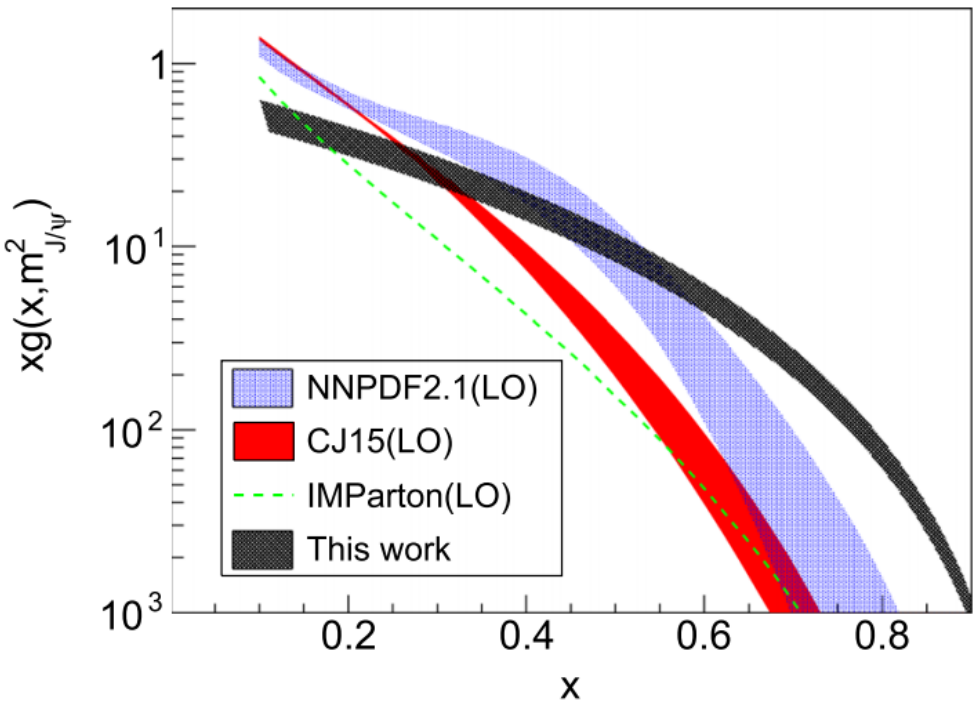
A_0	A_1	A_2	χ^2/d.o.f.
0.71 ± 0.12	-0.00061 ± 0.00045	2.83 ± 0.26	0.20

The two-gluon exchange model is valid to describe the J/Ψ photoproduction near the production threshold!

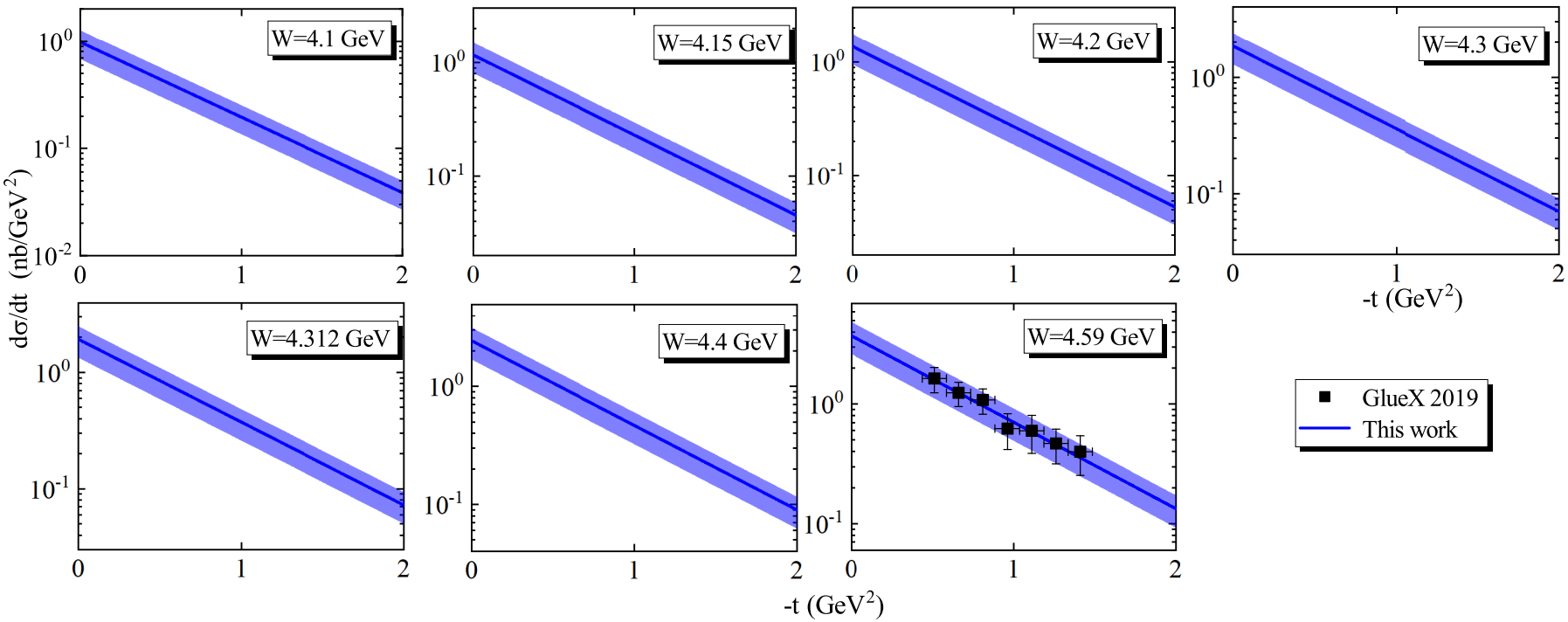




It is found that the gluon distributions determined by different groups are more or less consistent with each other in the low x range of $x < 0.3$. On the other side, our obtained gluon distribution is higher than other predictions when $x > 0.6$.

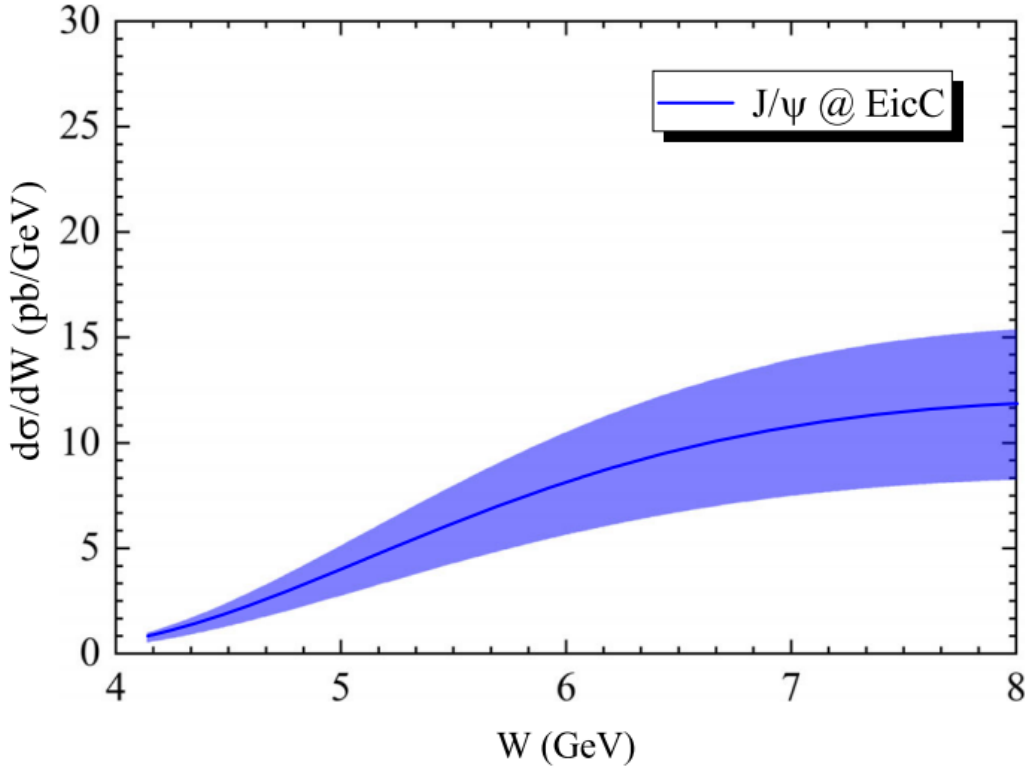


The J/Ψ photoproductions near the threshold at more different energies are predicted by the two-gluon exchange model J/Ψ in the energy range 4.1GeV < W < 4.6GeV.



[Fancong Zeng, Xiao-Yun Wang*, et al. Eur. Phys. J. C 80 (2020) 107227.]

In order to investigate the opportunity of EicC in J/ψ study, we calculate the differential cross-section of J/ψ electroproduction as a function of the c.m. energy of the system. The cross-section is around a doze of pb, which suggests a high yield rate at the high luminosity EicC.



Outline

Summary

1. We have reproduced the total and differential cross-section of the reaction $\gamma p \to J/\psi p$ near the production threshold with two-gluon exchange model.

2. The gluon distribution does not go down quickly when x approaches one.

3. On EicC, the low energy EIC, the J/ψ production cross-section is around 10 pb based on our model, hence EicC will be an important and interesting future machine to collect the J/ψ data and to explore the exotic hadrons in the charm sector and the nucleonic mass structure.

Thanks for your attention!

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