Exclusive and Inclusive Photoproduction of XYZ Mesons

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JPAC

Joint Physics Analysis Center

Outline

XYZ mesons

Estimated cross sections of photoproduction of XYZ mesons

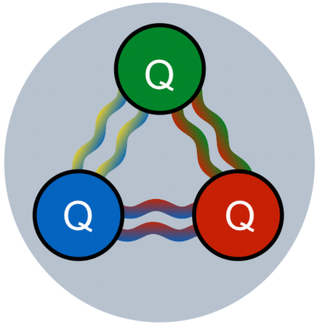
Based on
Albaladejo, Hiller-Blin, Pilloni, Winney, Fernández-Ramírez,VM, Szczepaniak (JPAC)
Phys. Rev. D102 (2020) 114010

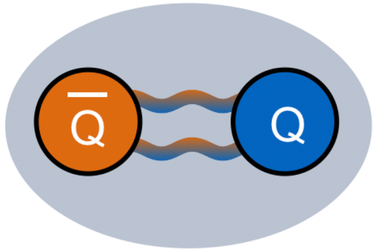
Generalisation to inclusive processes

Based on
JPAC, to appear

Exotic mesons

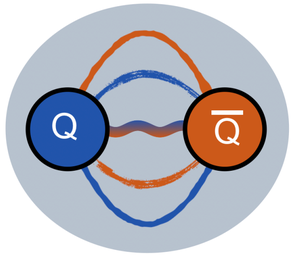
Ordinary baryons and mesons:





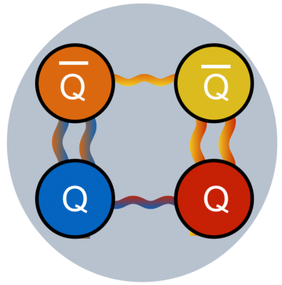
Exotic hadrons:

hybrid mesons

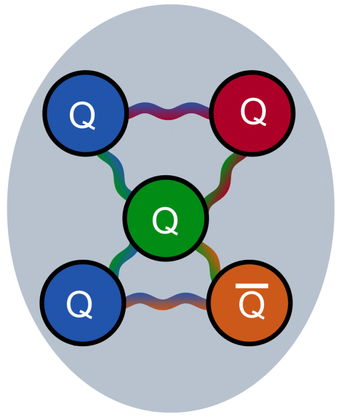


tetraquarks

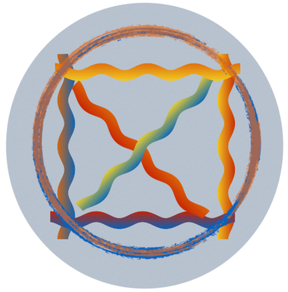
molecules



pentaquarks

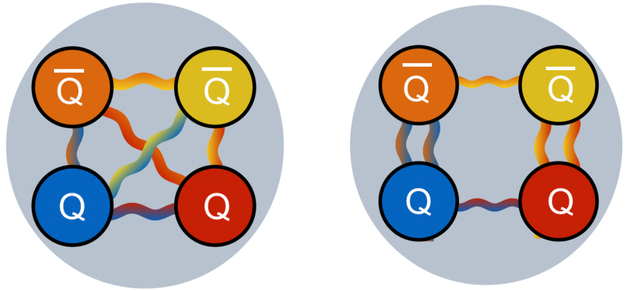


glueballs



XYZ mesons

(most of) XYZ hadrons: tetraquarks or molecules candidates with heavy quarks?

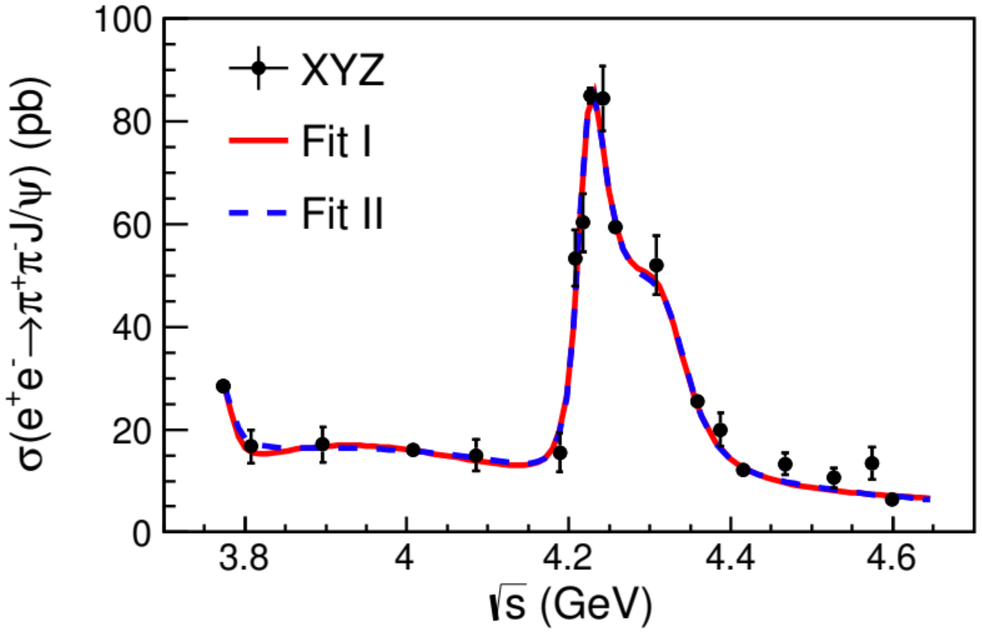


$X(3872)$ X for other states

$Y(4260)$ Y for Vector states 1^{--}

$Z_c(3900)^+$ Z for Charged states

BESIII PRL118 (2017) 092001



See talk by W. Imoehl (BESIII coll.)

XYZ mesons

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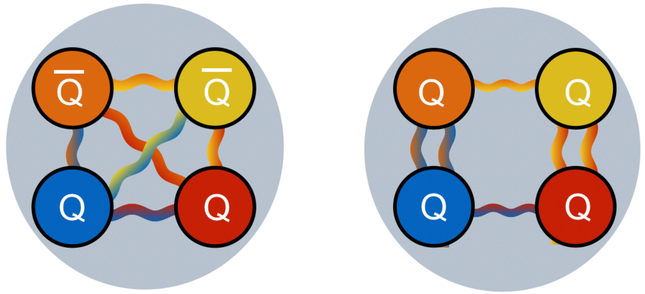

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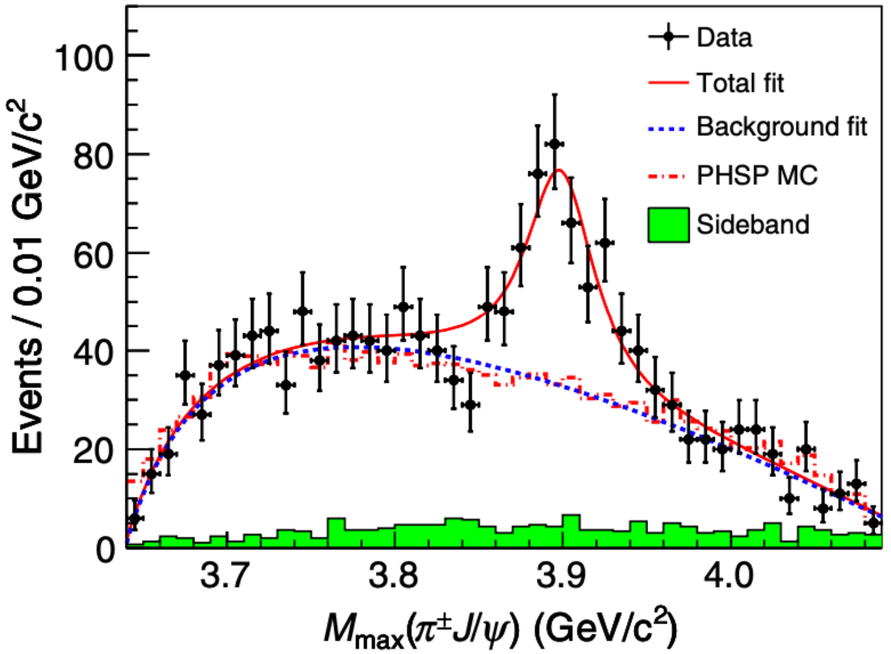
BESIII PRL110 (2013) 252001



XYZ mesons

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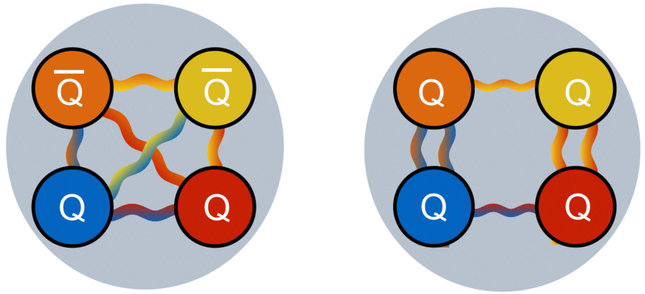

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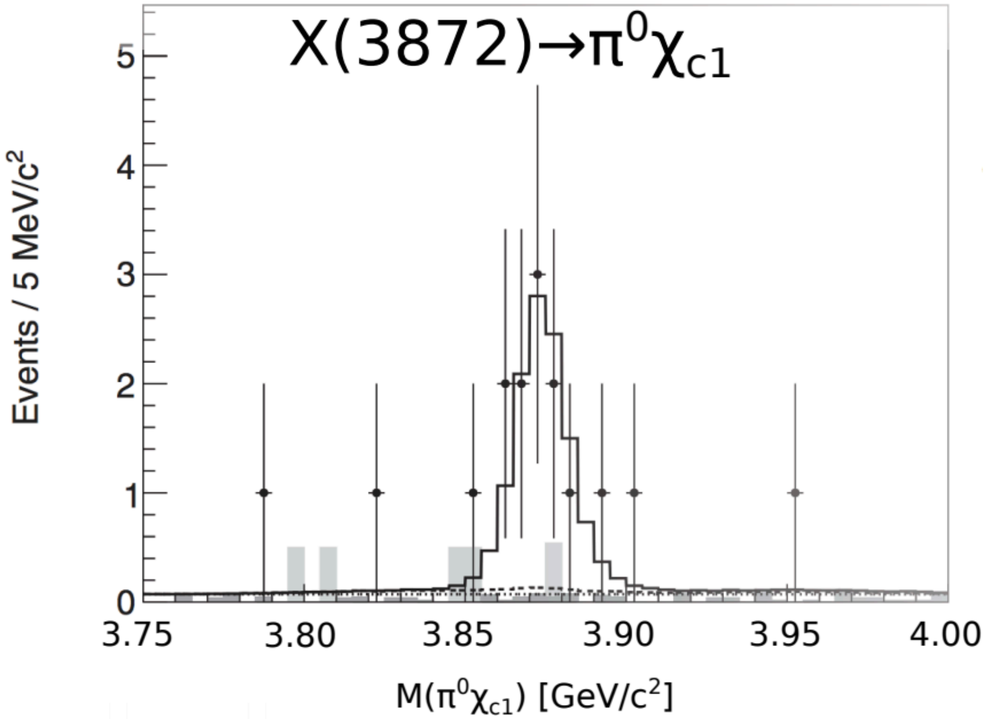
BESIII PRL122 (2019) 202001



High energy photoproduction

Electron-ion collider (EIC)

EIC Yellow Report arXiv:2103.05419

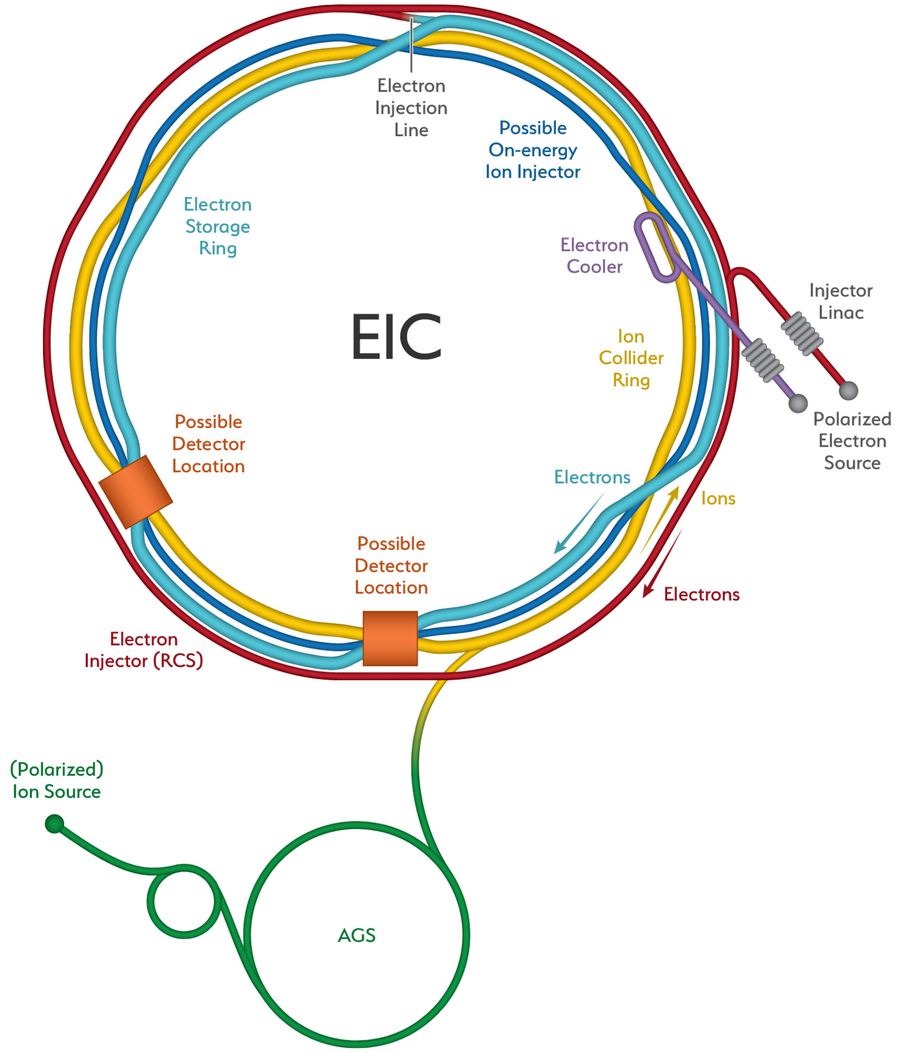
Wide range of ions, including proton

Center-of-mass energy: 20 - 140 GeV

Electron-ion collider in China (EicC)

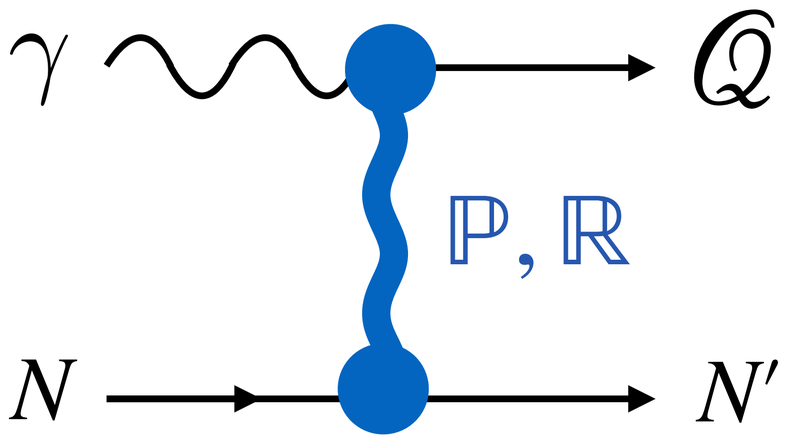
EicC arXiv:2102.09222

Center-of-mass energy: 15 - 20 GeV



Photoproduction Cross section

$s = (p_\gamma + p_N)^2 \qquad t = (p_\gamma - p_{\mathcal{Q}})^2$



Production amplitude factorised into:

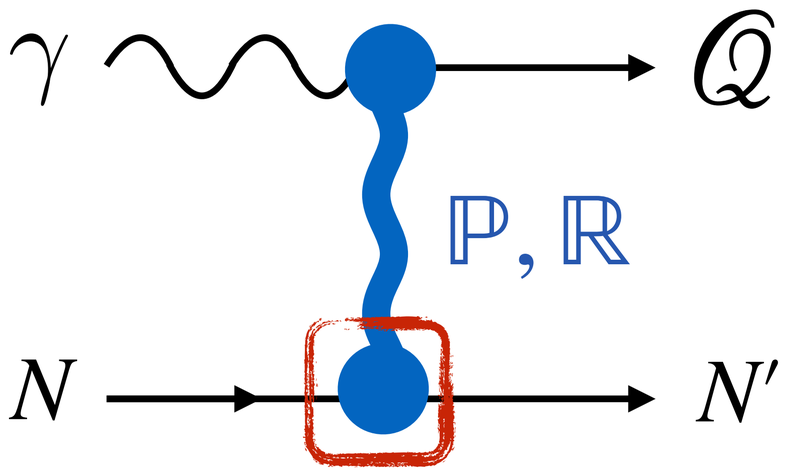
Known Reggeon-nucleon couplings

Known Reggeon propagators

Estimated Reggeon-XYZ photo couplings

Photoproduction Cross section

$s = (p_\gamma + p_N)^2 \qquad t = (p_\gamma - p_{\mathcal{Q}})^2$



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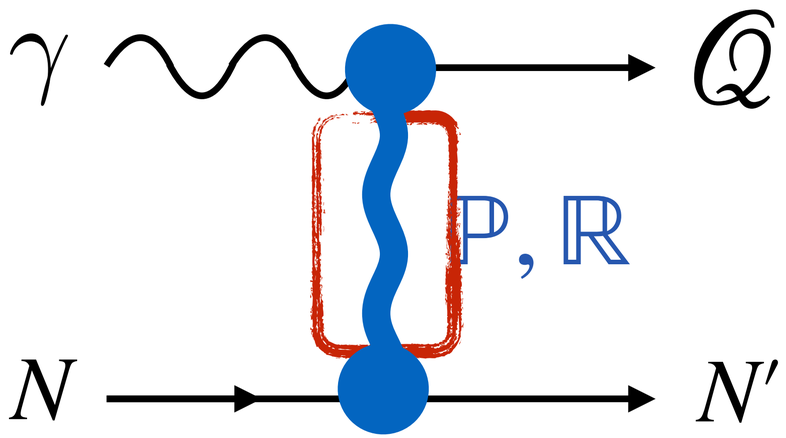

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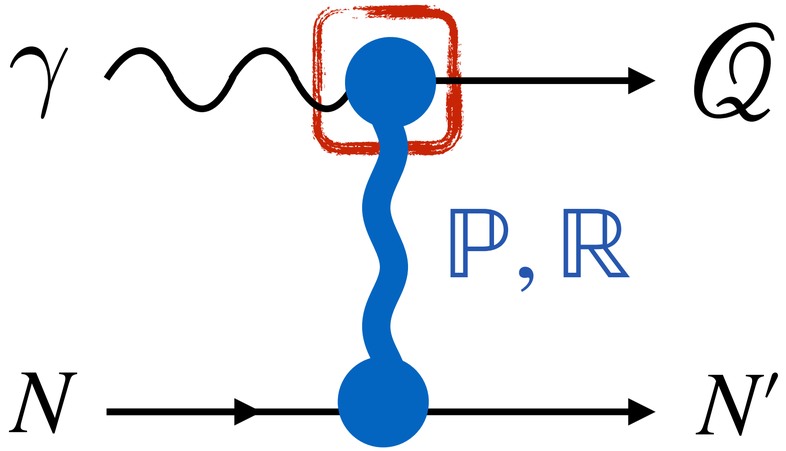

Production amplitude factorised into:

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Estimated Reggeon-XYZ photo couplings

Photoproduction Cross section

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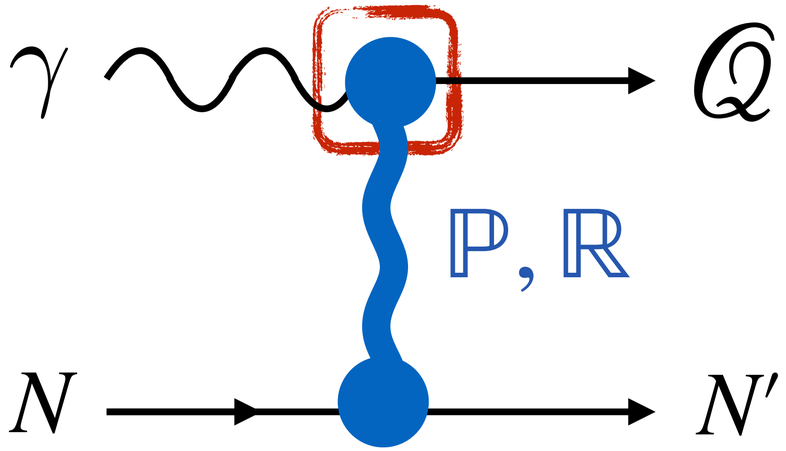


Production amplitude factorised into:

Known Reggeon-nucleon couplings

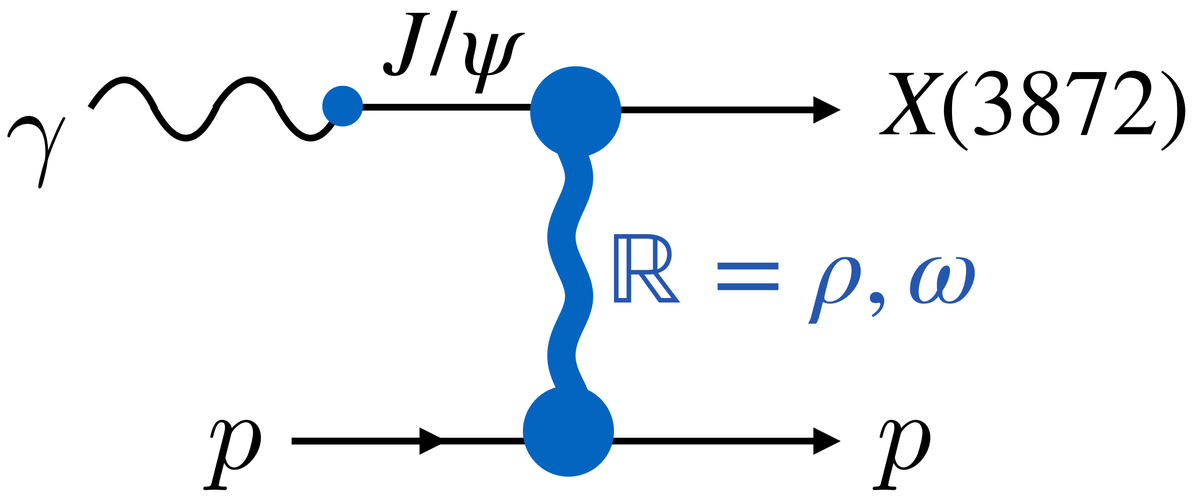
Known Reggeon propagators

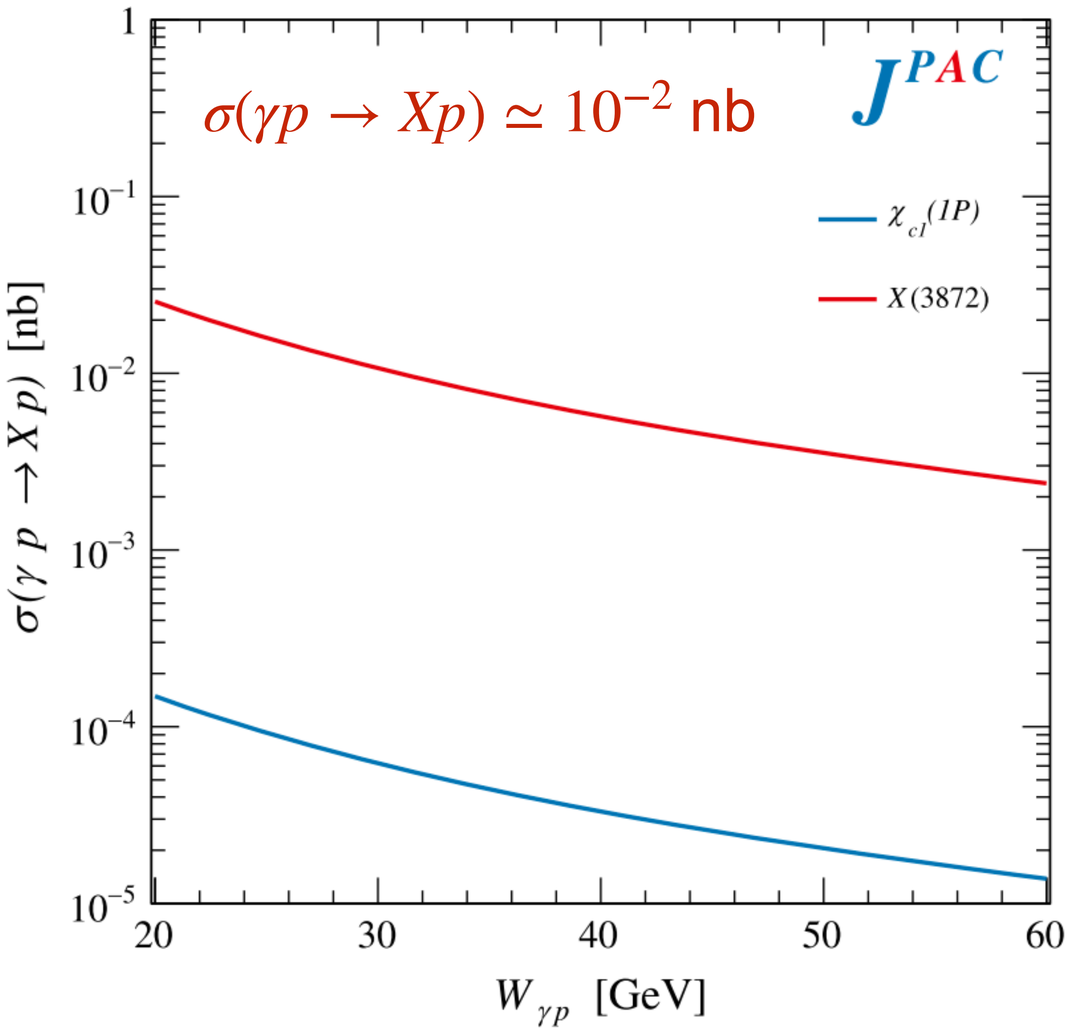
Estimated Reggeon-XYZ photo couplings

Production amplitude factorised into:

$$\frac{\mathrm{d}\sigma}{\mathrm{d}t} \propto \sum_{\lambda_\lambda, \lambda_{\mathcal{Q}}} |\beta^{\mathbb{R}}_{\lambda_\lambda, \lambda_{\mathcal{Q}}}(t)|^2 \left(\frac{s}{1\,\mathrm{GeV}^2}\right)^{2\alpha_{\mathbb{R}}(t)} \sum_{\lambda_N, \lambda'_N} |\beta^{\mathbb{R}}_{\lambda_N, \lambda'_N}(t)|^2$$

$X(3872)\ 1^{++}$





Couplings estimated using:

vector meson dominance (VMD) and branching fraction:

$$B(X \to J/\psi\,\omega) = 4.4\,\%$$

$$B(X \to J/\psi\,\rho) = 4.1\,\%$$

(strong isospin violation)

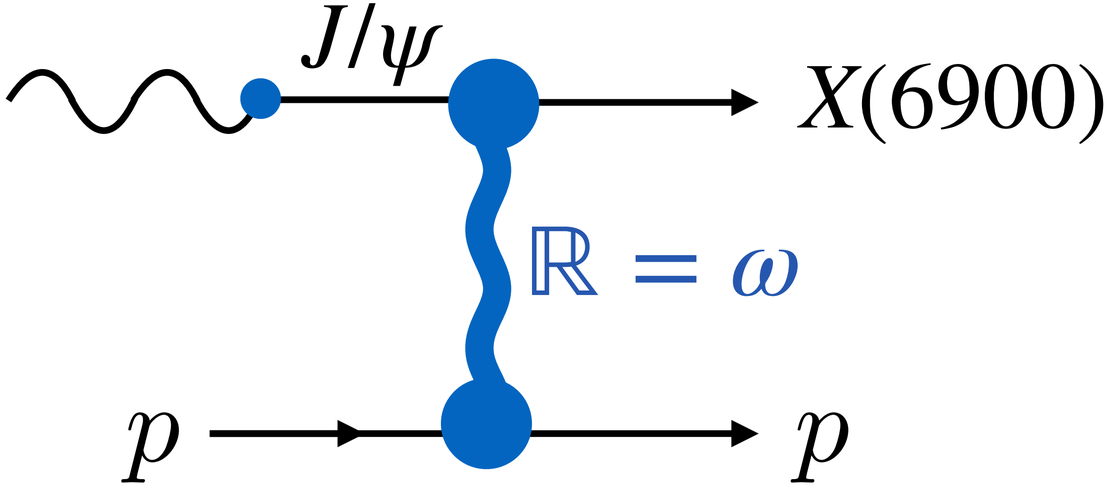
Centre-of-mass energy

Benchmark with $\chi_{c1}(1P)$ using $B(\chi \to J/\psi\,\omega)$, $B(\chi \to J/\psi\,\rho)$,…

$X(6900)$

$c\bar{c}c\bar{c}$ candidate in $J/\psi J/\psi$ final states

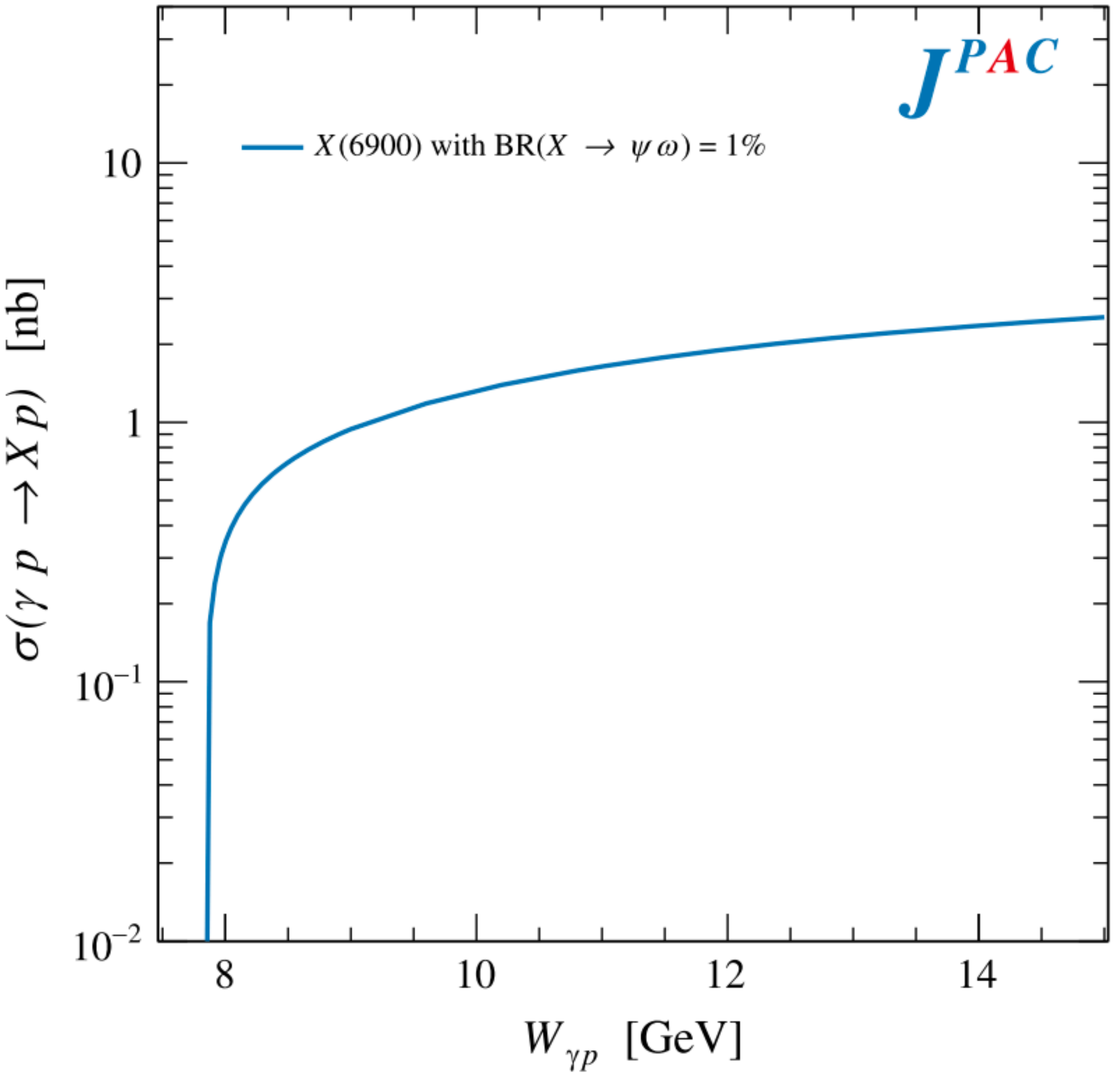
LHCb, arXiv:2006.16957



Couplings estimated using:

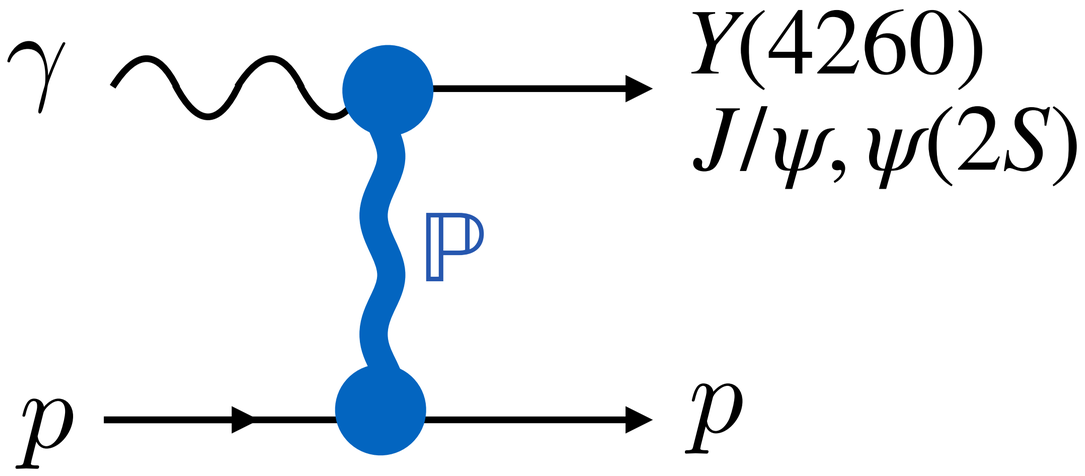
vector meson dominance (VMD) and branching fraction:

$$B(X \to J/\psi\,\omega) = 1\,\%$$



Centre-of-mass energy

$Y(4260)\ 1^{--}$



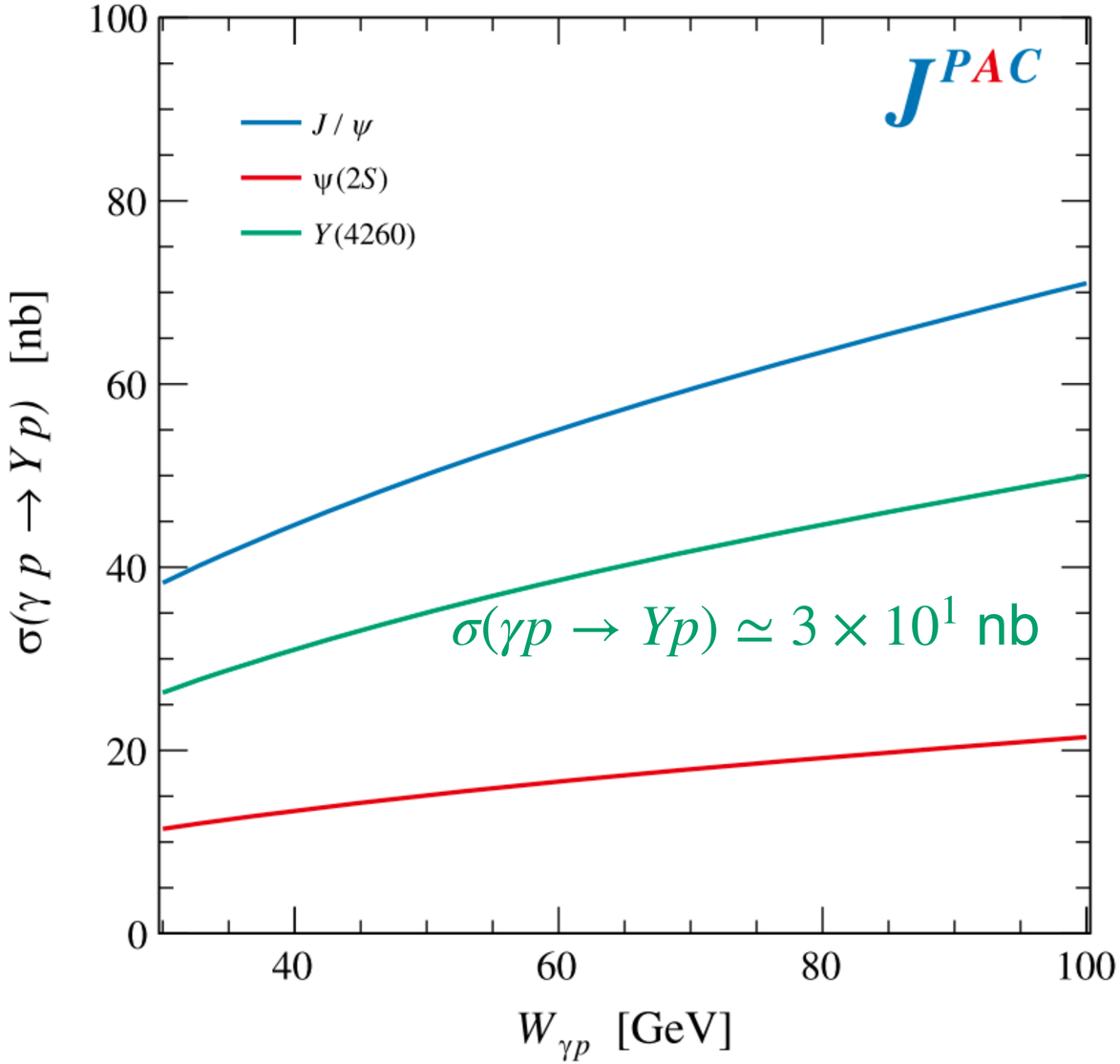
Model the photoproduction of J/ψ first

Extraction of the ratio by CLEO PRD78 (2008)

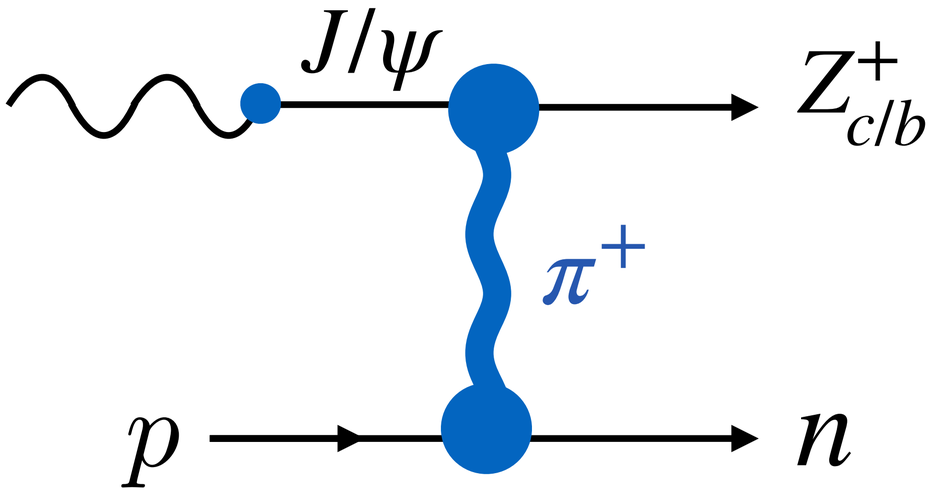
$$\frac{\sigma_{\psi'}}{\sigma_{J/\psi}} = \frac{B(\psi' \to \gamma gg)}{B(J/\psi \to \gamma gg)} \simeq 30\,\%$$

Using HERA data $R_{\text{HERA}} = 6.5\,\%$

$$\frac{\sigma_Y}{\sigma_{\psi'}} = \frac{B(Y \to J/\psi\pi\pi)}{B(\psi' \to J/\psi\pi\pi)} \longrightarrow \frac{\sigma_Y}{\sigma_{J/\psi}} \simeq 70\,\%$$



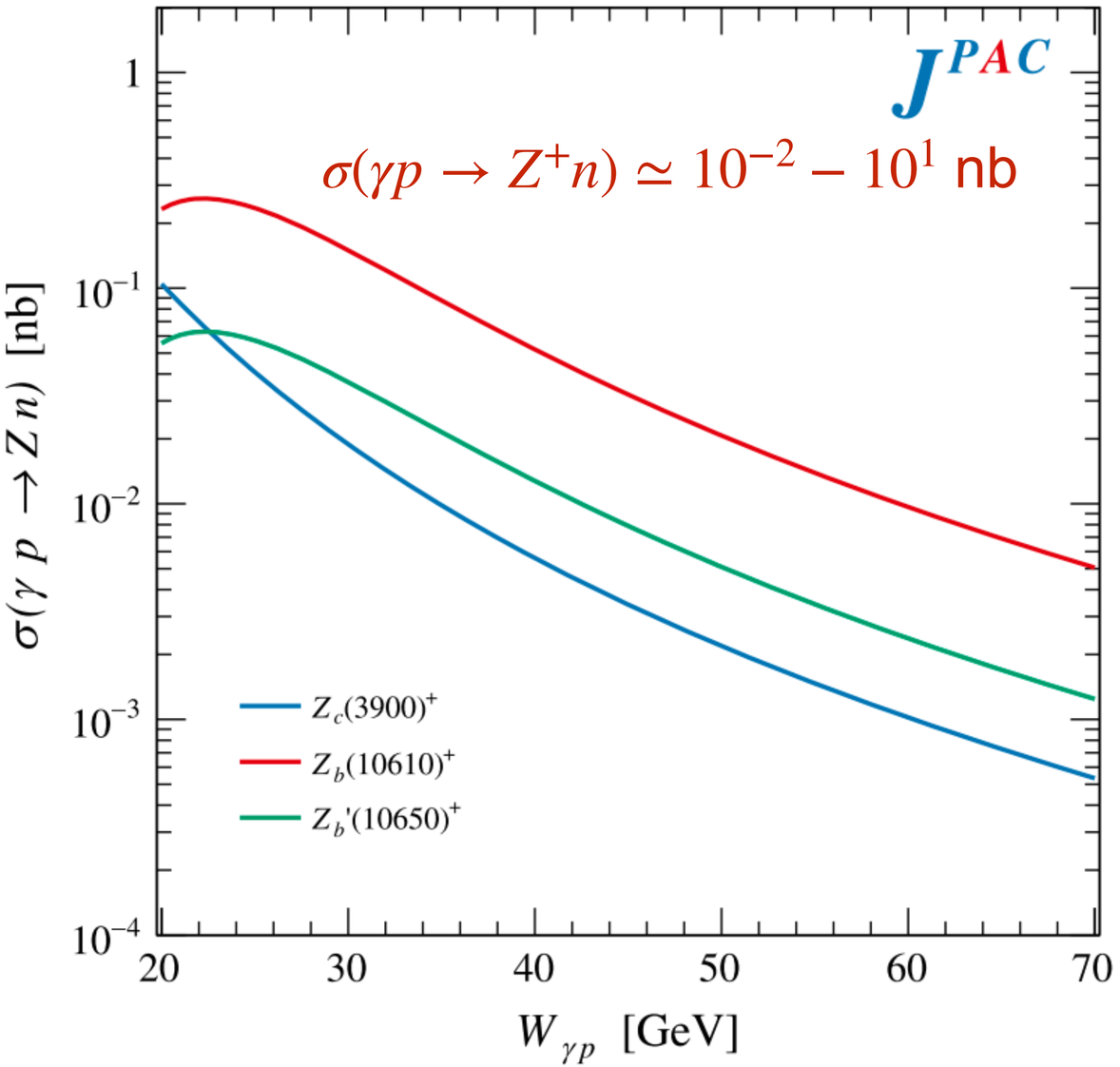
Centre-of-mass energy



Couplings estimated using:

vector meson dominance (VMD) and branching fraction:

$$B(Z_c^+(3900) \to J/\psi\,\pi^+) = 10.5\,\%$$



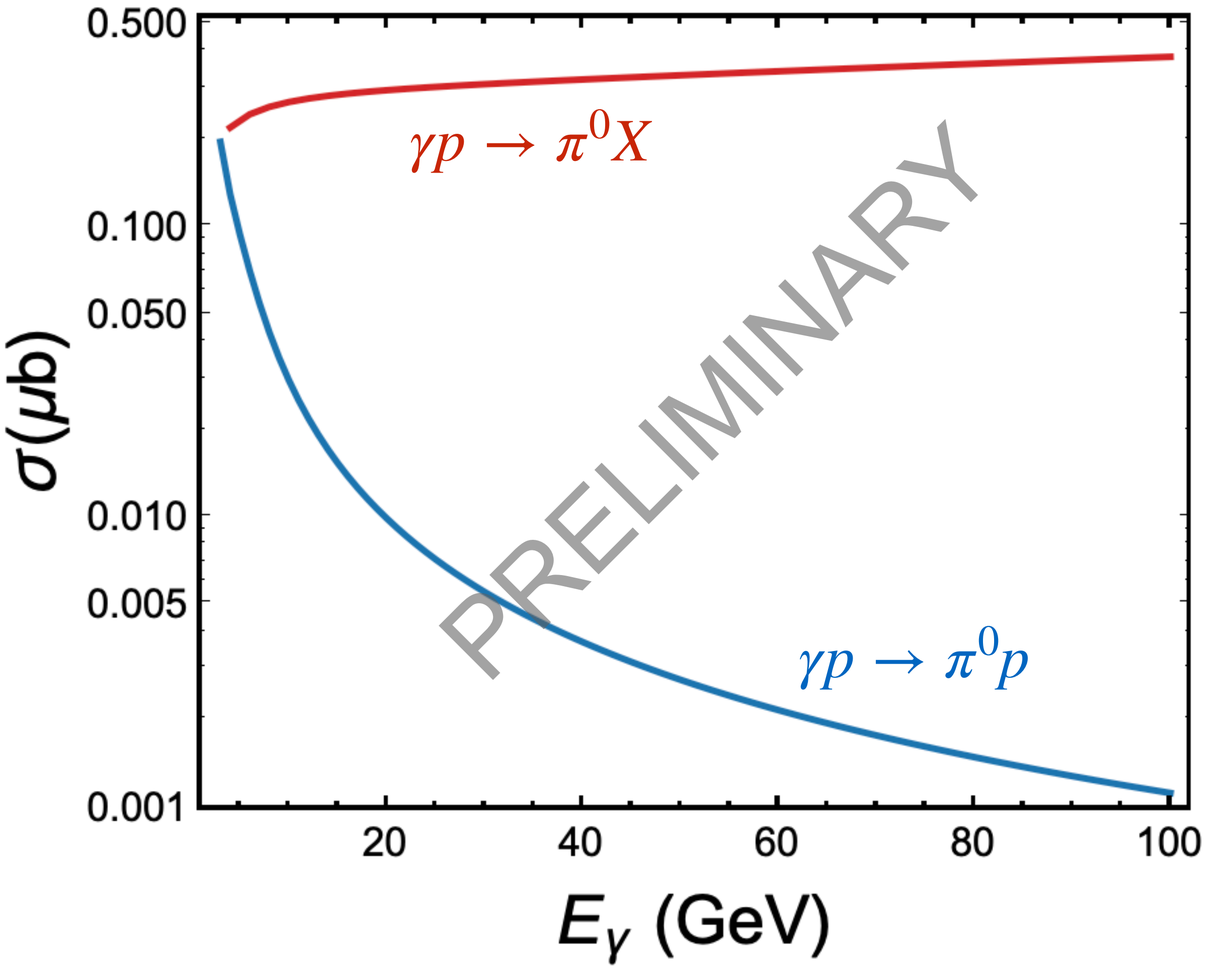
Centre-of-mass energy

Why inclusive reactions?

Easier to extract experimentally

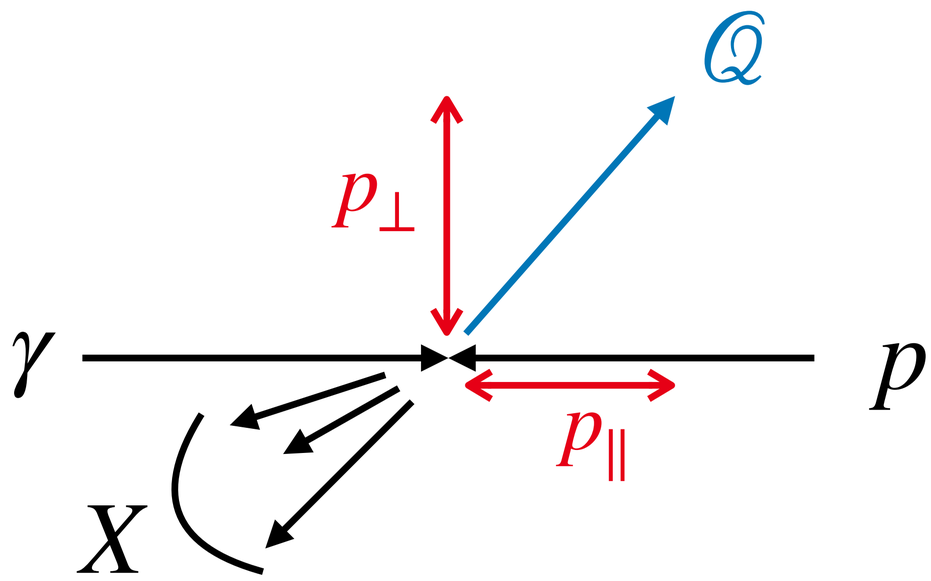
Constant cross section at high energies
Even for non-Pomeron production

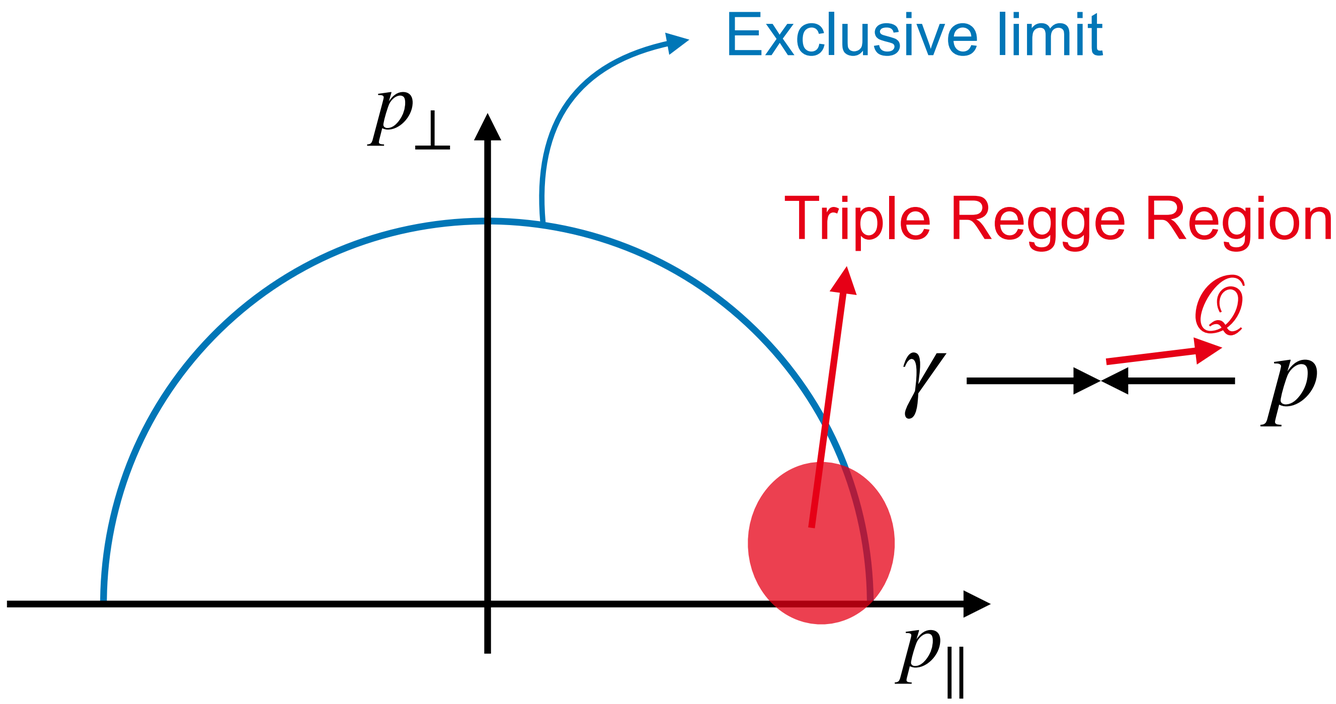
All following results are preliminary



Kinematic of Semi-Inclusive Reactions

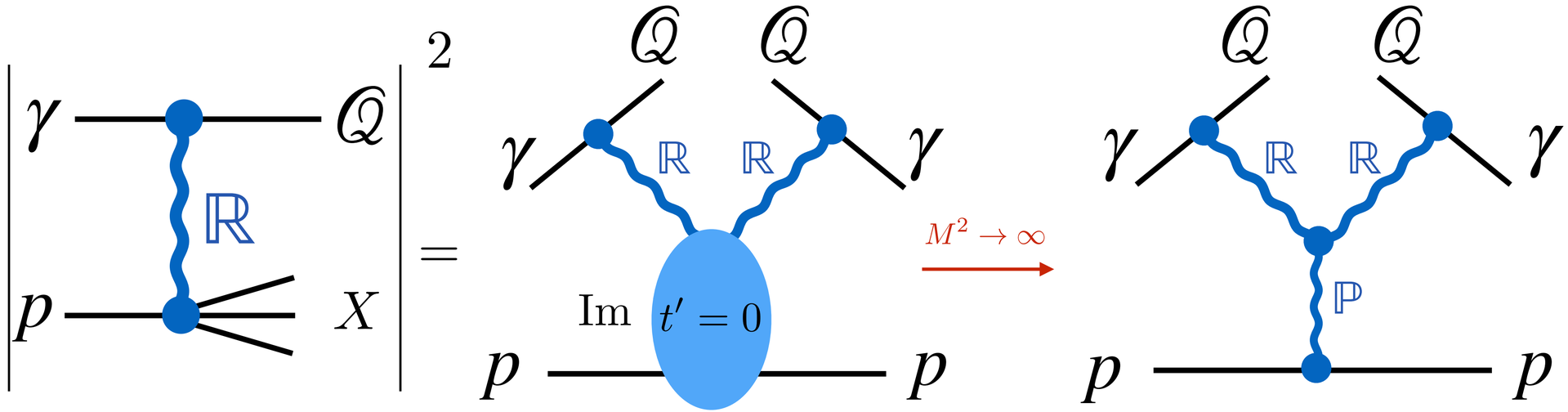
$$\gamma + p \to \mathcal{Q} + X$$





Triple Regge limit corresponds to $x = p_\parallel / p_{\parallel,\mathrm{max}} \simeq 1$

Triple Regge Region



$$E_{\mathbb{Q}} \frac{\mathrm{d}\sigma}{\mathrm{d}^3 p_{\mathbb{Q}}} = \frac{\alpha'}{\pi} \sum_{\lambda_\lambda, \lambda_{\mathbb{Q}}} |\beta^{\mathbb{R}}_{\lambda_\lambda, \lambda_{\mathbb{Q}}}(t)|^2 (1-x)^{1-2\alpha(t)} \sigma^{\mathbb{R}p}_{\mathrm{tot}}$$

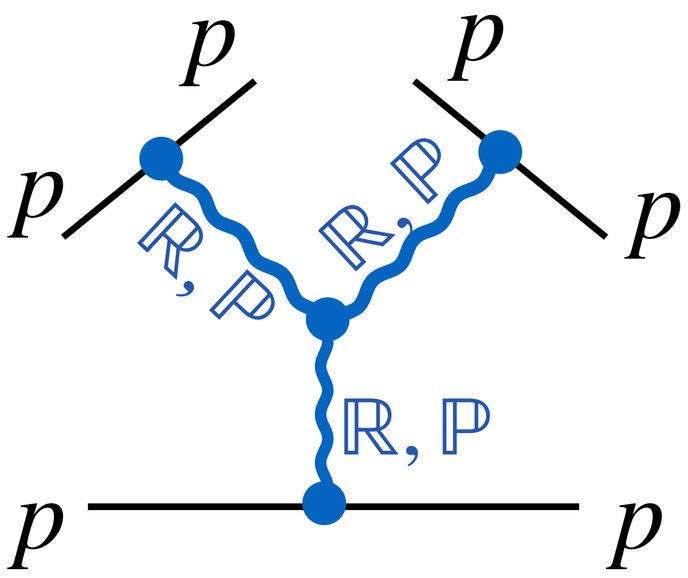
$$= G_{RRP}(t)(1-x)^{1-2\alpha(t)}$$

3 Reggeon-particle couplings and 1 Triple Reggeon coupling

Field and Fox Parametrisation

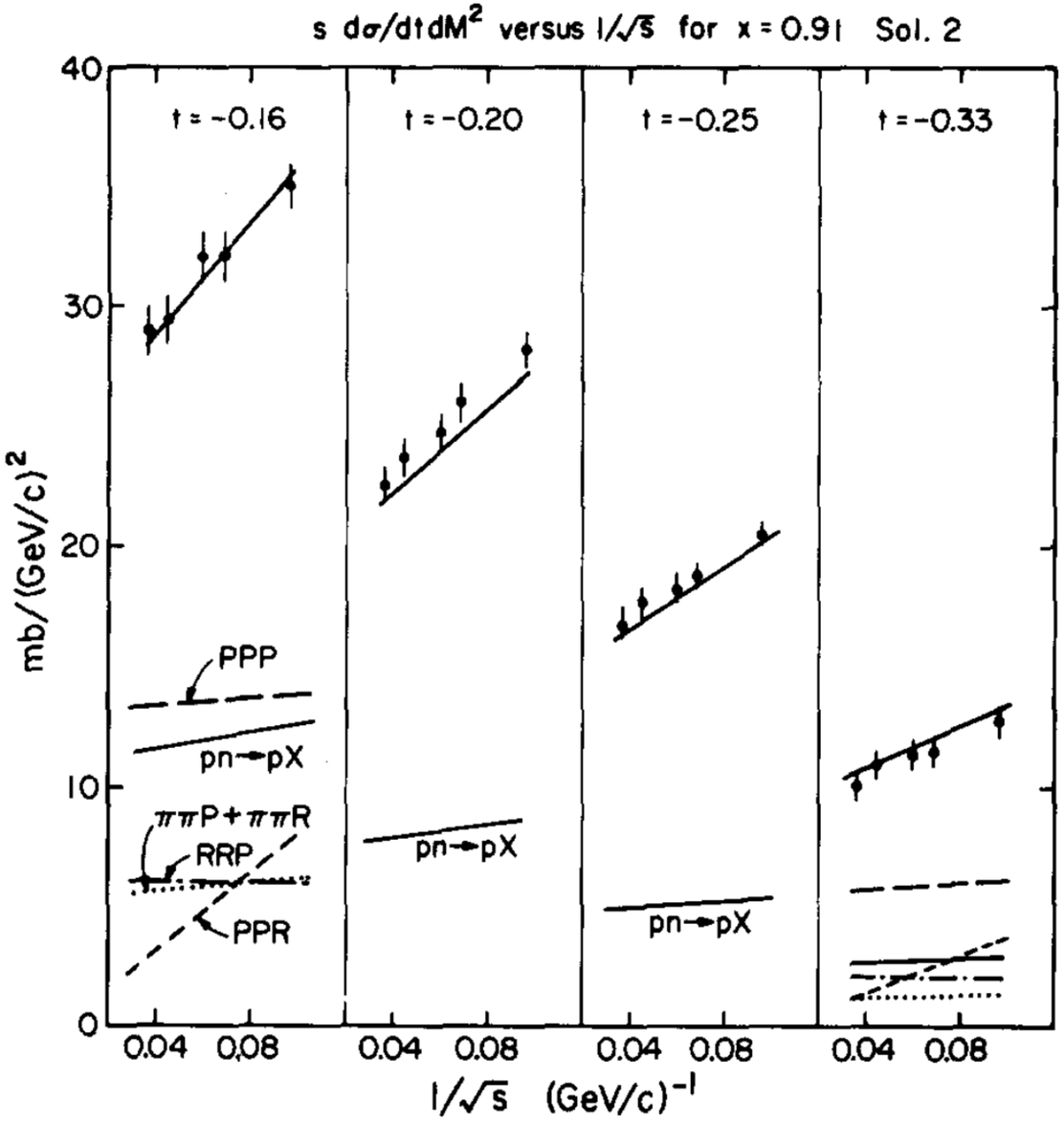
NPB102 (1974) 367

$$p + p \to p + X$$

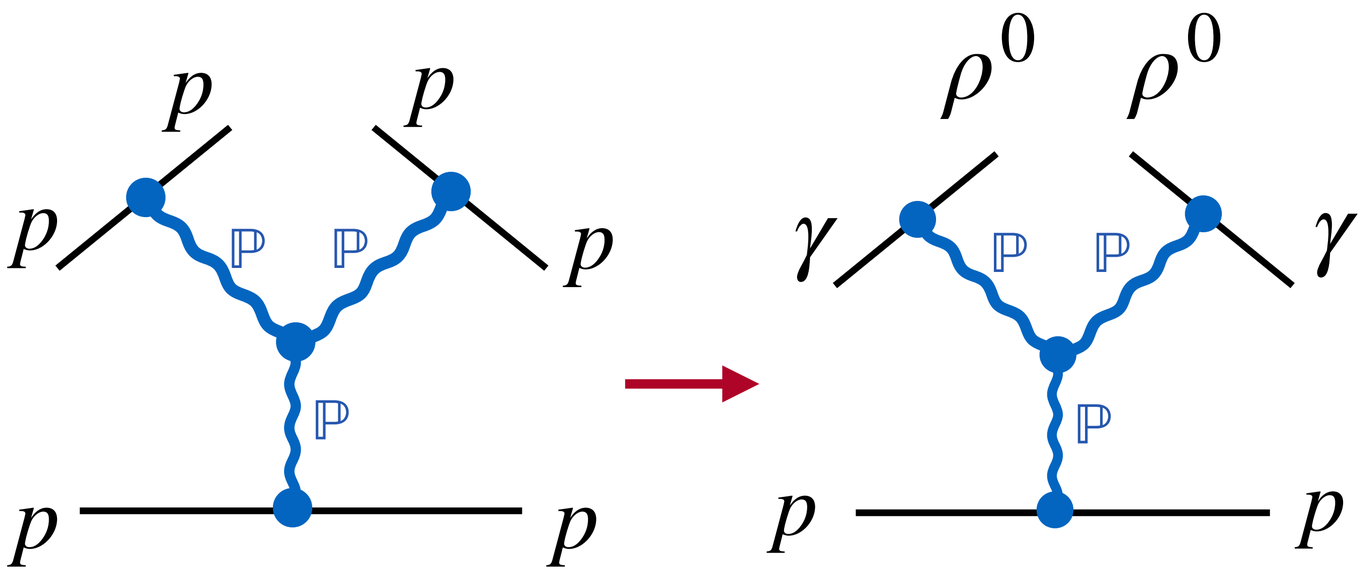


$$E_N \frac{\mathrm{d}\sigma}{\mathrm{d}^3 p_N} = \frac{1}{s} \sum_{ijk} G_{ijk}(t)(1-x)^{-\alpha_i(t)-\alpha_j(t)}(M^2)^{\alpha_k(0)}$$

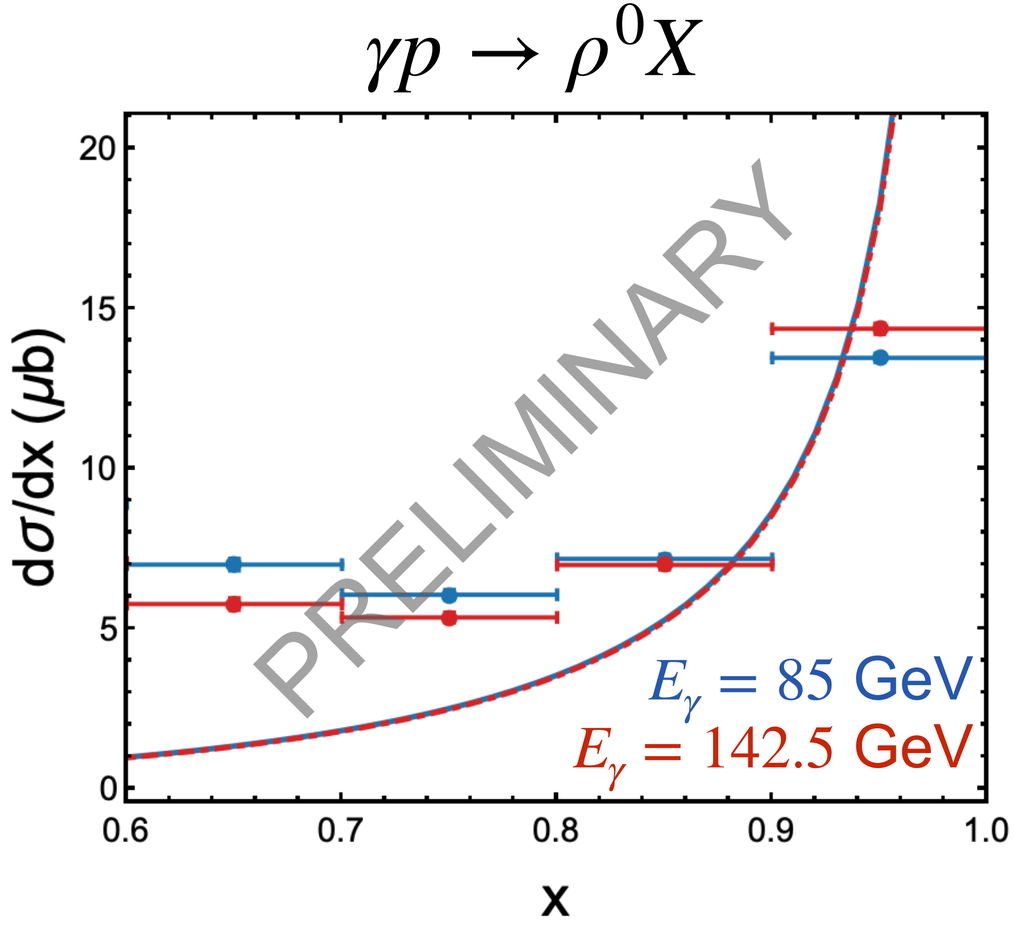
$$i, j, k = \mathbb{P}, \mathbb{R}$$



Triple Pomeron

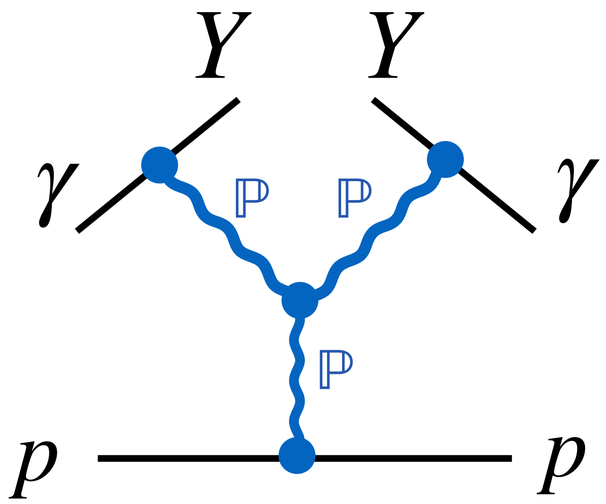


$$E\frac{\mathrm{d}\sigma}{\mathrm{d}^3p} = \left(\frac{\beta^{\mathbb{P}}_{\gamma p}}{\beta^{\mathbb{P}}_{pp}}\right)^2 G_{PPP}(t)(1-x)^{1-2\alpha_{\mathbb{P}}(t)}$$

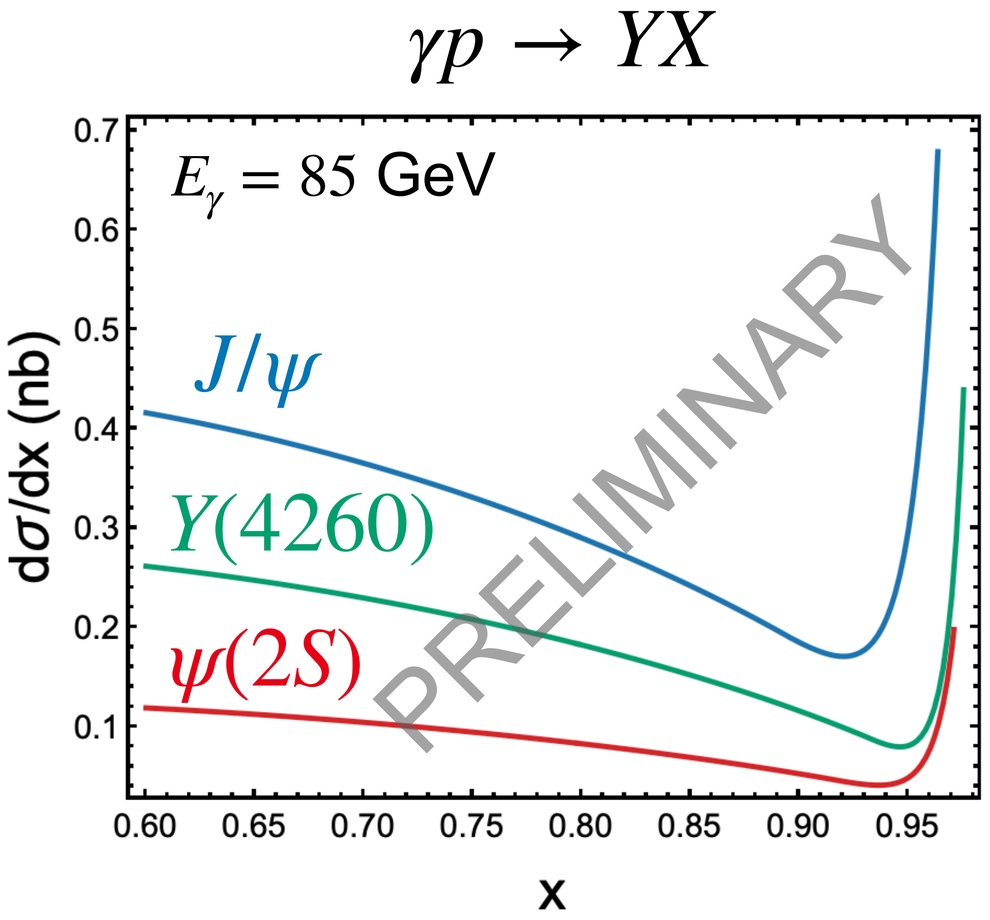


OMEGA photon ZPC53 (1992) 581

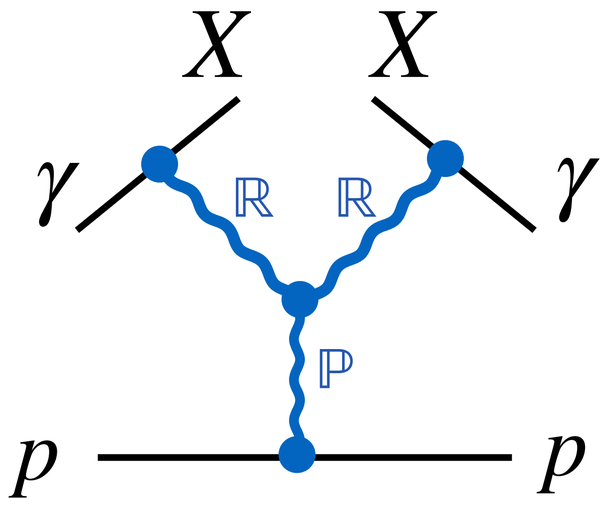
$Y(4260)\ 1^{--}$

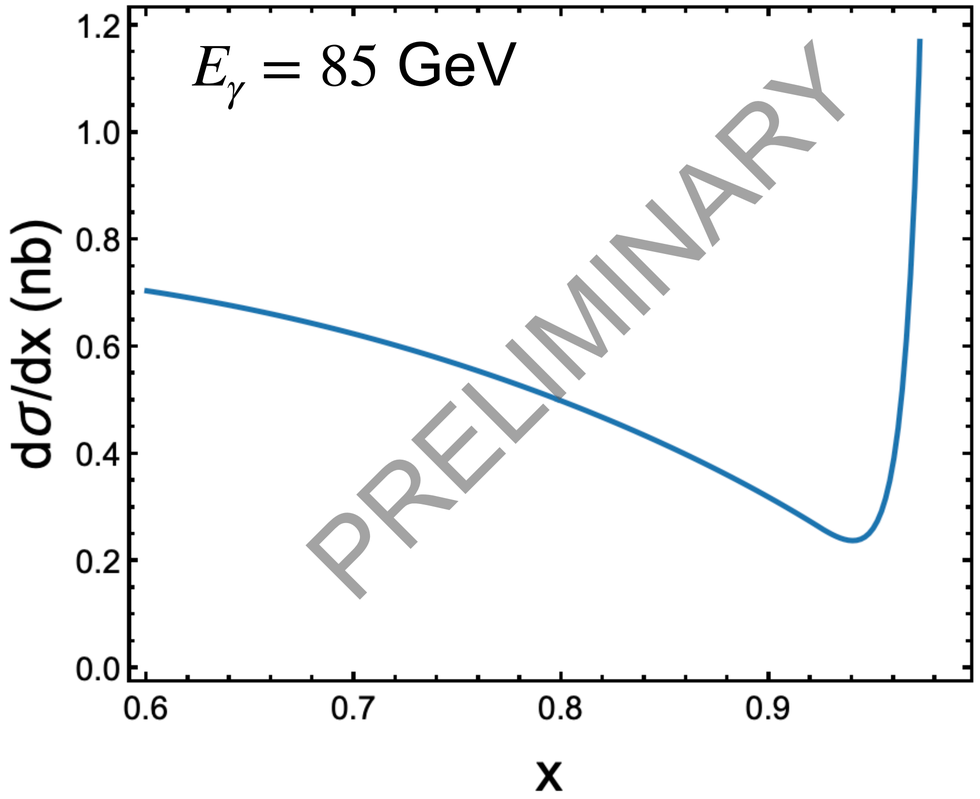


$$E\frac{\mathrm{d}\sigma}{\mathrm{d}^3p} = \left(\frac{\beta^{\mathbb{P}}_{\gamma Y}}{\beta^{\mathbb{P}}_{pp}}\right)^2 G_{PPP}(t)(1-x)^{1-2\alpha_{\mathbb{P}}(t)}$$



$X(3872)$ 1^{++}





$$E\frac{\mathrm{d}\sigma}{\mathrm{d}^3p} = \left(\frac{\beta^{\mathbb{R}}_{\gamma X}}{\beta^{\mathbb{R}}_{pp}}\right)^2 G_{RRP}(t)(1-x)^{1-2\alpha_{\mathbb{R}}(t)}$$

Conclusions

Estimate cross section for exclusive photoproduction of
$X(3872), Y(4260), Z_c(3900)^+, \ldots$

Vector states Y have large cross section at high energies, thanks to the Pomeron exchange

Estimation of inclusive cross section in progress
Benchmark on known mesons