The tensor-pomeron model

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1 Introduction

We are interested in high-energy diffractive reactions, that is, processes with small momentum transfers.

Examples:

$$p + p \longrightarrow p + p,$$

$$\pi^{\pm} + p \longrightarrow \pi^{\pm} + p,$$

$$\gamma + p \longrightarrow V + p, \qquad V = \rho^0, \omega, \phi, J/\psi,$$

$$\gamma^* + p \longrightarrow \gamma^* + p, \qquad \text{DIS structure functions,}$$

$$p + p \longrightarrow p + X + p, \qquad \text{central exclusive production, CEP.}$$

These reactions can be described with the help of

<u>exchange objects</u>:

$\mathbb{P}$ $(C = +1)$ pomeron, should dominate at large energies,

$\mathbb{O}$ $(C = -1)$ odderon (?)

$\mathbb{R}$: f_{2R}, a_{2R} $(C = +1)$ } reggeons

ω_R, ρ_R $(C = -1)$

γ $(C = -1)$ photon

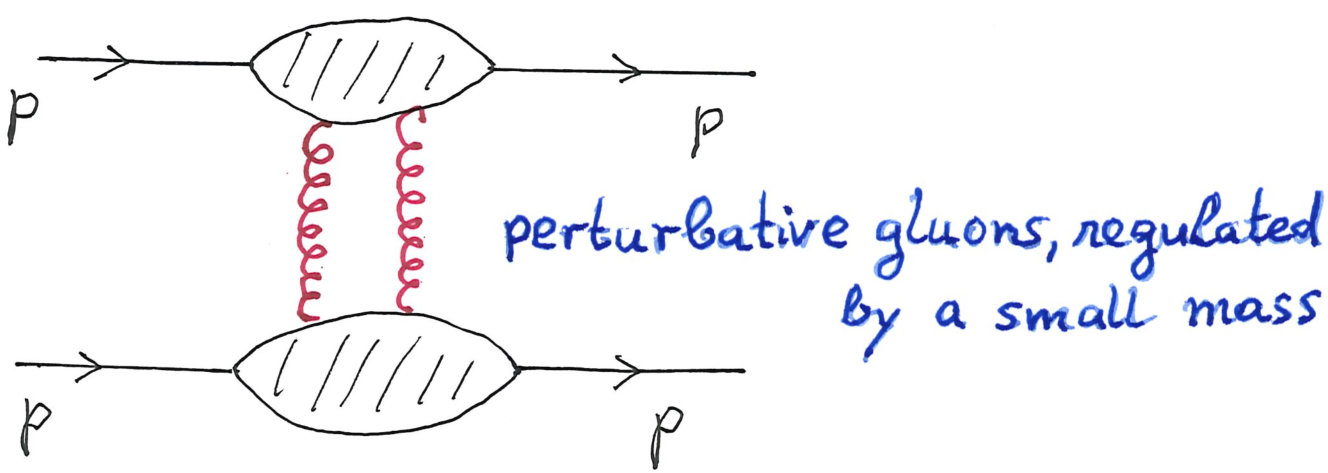
2 QCD, the pomeron and the odderon

Theoretical ideas on the pomeron in QCD were first put forward by

F. E. Low, PR D12 (1975) 163,

S. Nussinov, PRL 34 (1975) 1286.

They calculated the exchange of two gluons between colour singlet hadrons, e.g. protons.



Studies of the pomeron in QCD perturbation theory with correct massless gluons have become a big industry starting from the famous works

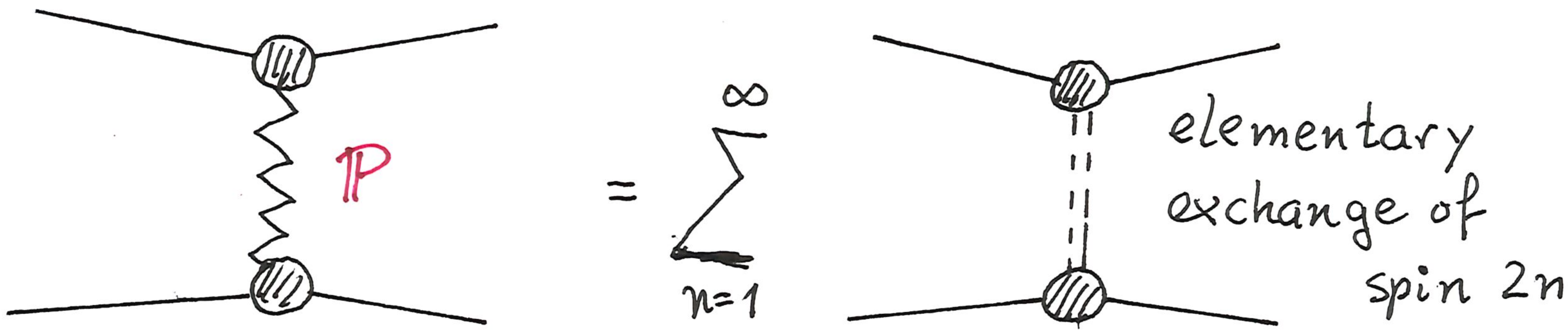
E.A. Kuraev, L.N. Lipatov, V.S. Fadin, Sov. Phys. JETP 45 (1977) 199,
I.I. Balitsky, L.N. Lipatov, Sov. J. Nucl. Phys. 28 (1978) 822.

But there are obvious problems applying perturbation theory, pQCD, to soft hadronic processes, like $p + p \to p + p$.

Peter Landshoff and myself asked ourselves if we could understand the soft pomeron in nonperturbative QCD. We investigated a toy model in Z. Phys. C35 (1987) 405. Then I tried to extend this approach to real QCD using functional techniques

O. N., Ann. Phys. 209 (1991) 436

In this approach the pomeron could be written as the coherent exchange of elementary exchanges of spin 2 + 4 + 6 + ...



Note that this series starts with spin 2 and that spin 0 is missing. This is a direct consequence of the vector nature of the basic quark-gluon coupling in QCD. We also found an odderon with vector character.

In our present tensor-pomeron model we have incorporated exactly these structures for $\mathbb{P}$ and $\mathbb{O}$ giving it a good basis in QCD.

Investigations of the pomeron using the methods of AdS/CFT correspondence also prefer a tensor nature of the pomeron:

Domokos, Harvey, Mann, PR D 80 (2009) 126015

Iatrakis, Ramamurti, Shuryak, PR D 94 (2016) 045005

3 Tensor pomeron and vector odderon

Our tensor-pomeron model originated from discussions with André Schöning from the H1 group. We asked him if he could look for odderon effects in $\pi^+\pi^-$ photoproduction. There we have (among others) two processes with $\mathbb{P}$ and $\mathbb{O}$ exchange, respectively,

$$\gamma + p \longrightarrow \rho + p, \quad \rho \to \pi^+ \pi^- \qquad \mathbb{P} \text{ exchange}$$

$$\gamma + p \longrightarrow f_2 + p, \quad f_2 \to \pi^+ \pi^- \qquad \mathbb{O} \text{ exchange}$$

There will be interference between these processes and as a consequence $\pi^+ \pi^-$ charge asymmetries.

Charge asymmetries as a signal for odderon exchange were first discussed by

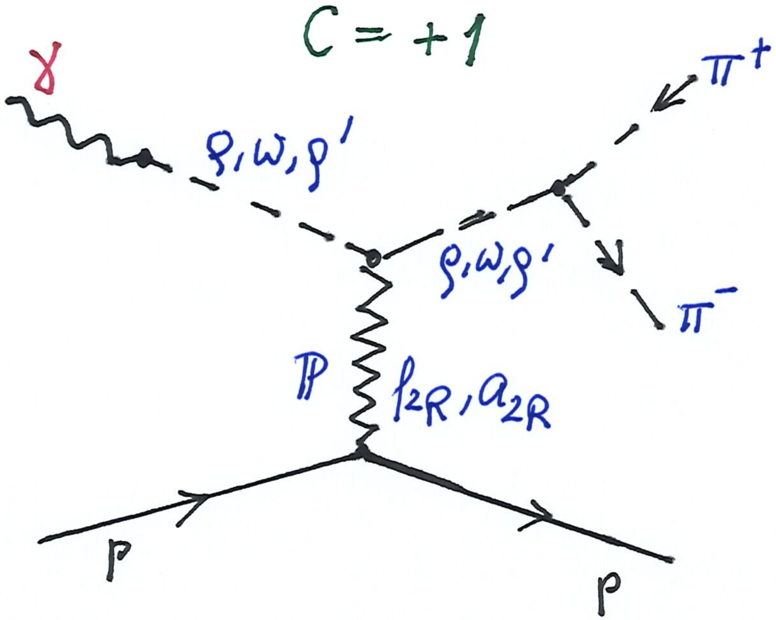
Brodsky, Rathsman, Merino, P. L. B 461 (1999) 114,

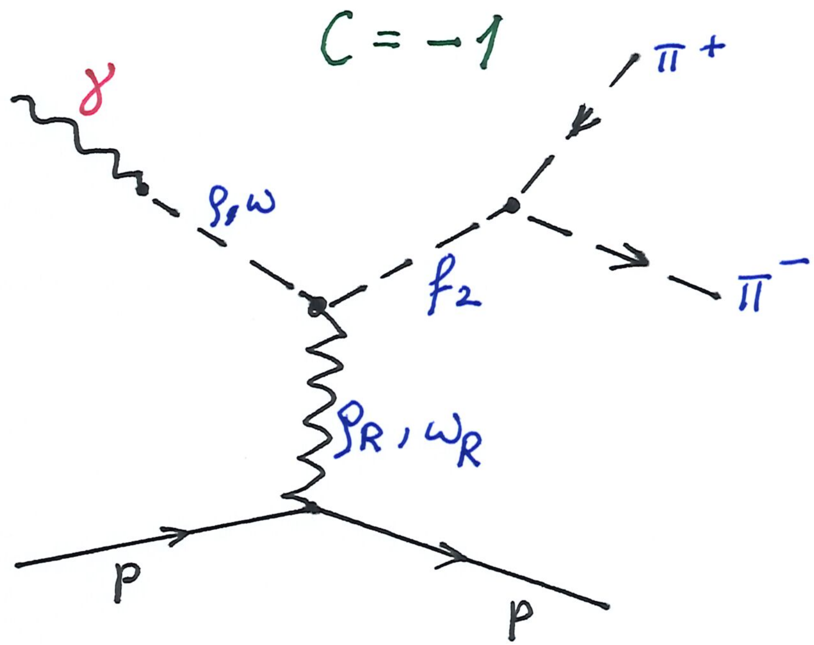
Ivanov, Nikolaev, Ginzburg, Proc. DIS 2001, hep-ph 0110181.

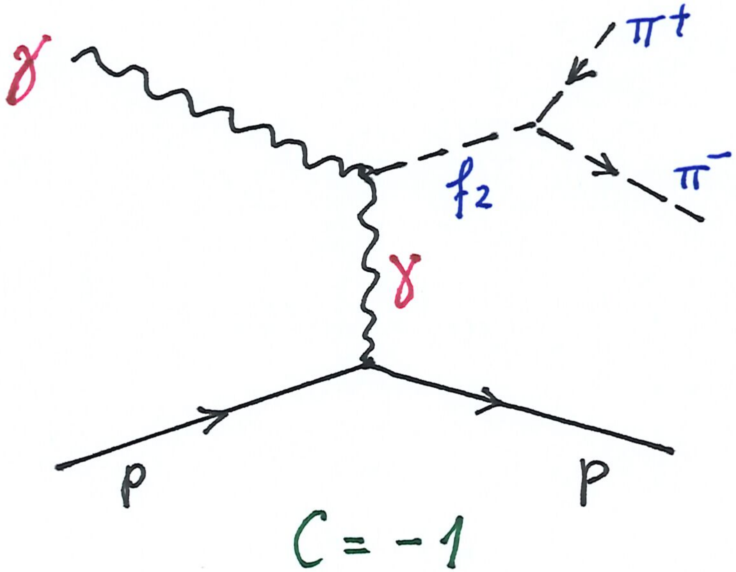
André asked us three typical questions:

- How large is the effect? Do you have a theretical model allowing to make predictions?
- Is there a background and how large is it?
- Is there a corresponding event generator?

To answer André's questions we drew all the diagrams for high energy $\pi^+ \pi^-$ photoproduction we could think of. There is a great number of such diagrams and it was clear that we needed some effective model in order to treat them all. At first we tried to use the Donnachie - Landshoff ansatz for the pomeron $\mathbb{P}$ where effectively it is treated as a vector exchange. But this led to unsurmountable problems with gauge invariance.


C = +1
γ
ρ, ω, ρ'
ρ, ω, ρ'
π+
π−
ℙ
f2R, a2R
p
p


C = −1
γ
ρ, ω
f2
π+
π−
ρR, ωR
p
p


γ
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γ
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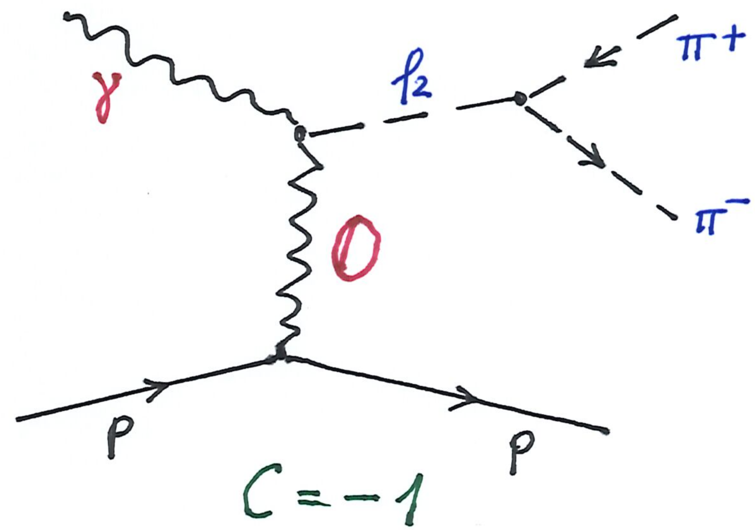
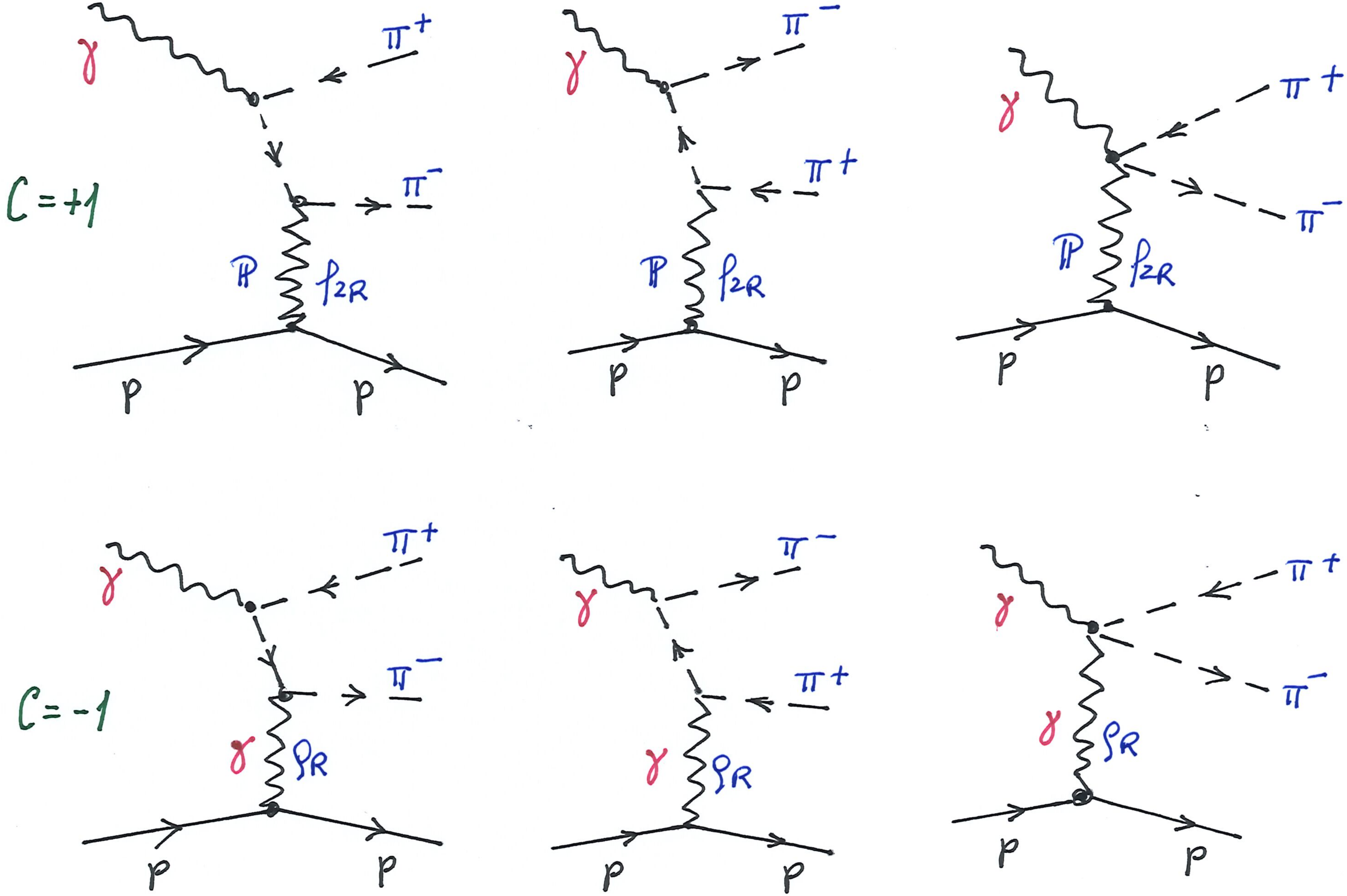
C = −1


γ
f2
π+
π−
O
p
p
C = −1



C = +1
γ
π+
π−
P
f2R
p
p
C = −1
γ
π+
π−
γ
ρR
p
p

Our solution to these problems was to construct an effective theory for high-energy diffractive reactions where

- all $C=+1$ exchanges, $\mathbb{P}$, f_{2R}, a_{2R} are treated as effective spin 2 symmetric tensor exchanges,
- all $C=-1$ exchanges, $\mathbb{O}$, ω_R, ρ_R are treated as effective vector exchanges.

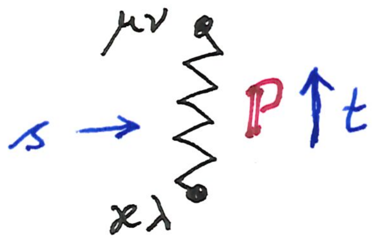
C. Ewerz, M. Maniatis, O. N., Ann. Phys. 342 (2014) 31

The theory is formulated in terms of propagators and vertices. The vertices are derived from Lagrangians for the couplings. In this way inclusion of photons is straight forward and gauge invariance is guaranteed. The Regge factors are incorporated in the effective propagators.

Example: effective $\mathbb{P}$ propagator and $\mathbb{P}pp$ coupling

Pomeron field: $\mathbb{P}^{\mu\nu}(x) = \mathbb{P}^{\nu\mu}(x)$, $\mathbb{P}^{\mu\nu}(x)\, g_{\mu\nu} = 0.$

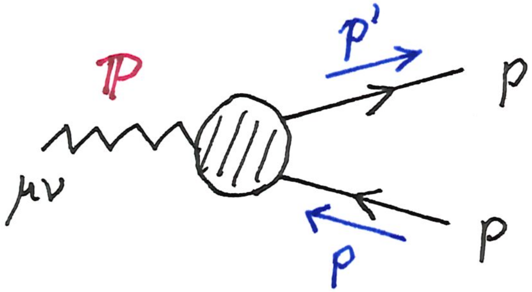
- effective propagator



$$i\Delta^{(\mathbb{P})}_{\mu\nu,\kappa\lambda}(s,t) = \frac{1}{4s}\left(g_{\mu\kappa}g_{\nu\lambda} + g_{\mu\lambda}g_{\nu\kappa} - \frac{1}{2}g_{\mu\nu}g_{\kappa\lambda}\right)\left(-is\alpha'_{\mathbb{P}}\right)^{\alpha_{\mathbb{P}}(t)-1}$$

$$\alpha_{\mathbb{P}}(t) = 1 + \varepsilon_{\mathbb{P}} + \alpha'_{\mathbb{P}}t\,, \quad \varepsilon_{\mathbb{P}} = 0.0808\,, \quad \alpha'_{\mathbb{P}} = 0.25\ \mathrm{GeV}^{-2}$$

- pomeron - proton vertex



$$i\Gamma^{(\mathbb{P}pp)}_{\mu\nu}(p',p) = -i3\beta_{\mathbb{P}NN}F_1\left[(p'-p)^2\right]\left\{\frac{1}{2}\gamma_\mu(p'+p)_\nu + (\mu\leftrightarrow\nu) - \frac{1}{4}g_{\mu\nu}(\not{p}'+\not{p})\right\}$$

$\beta_{\mathbb{P}NN} = 1.87\ \mathrm{GeV}^{-1}$, F_1 : form factor

All parameters are here determined from pp elastic scattering

Now we were equipped with a model allowing us to calculate all diagrams for $\pi^+\pi^-$ photoproduction and our experimental friends also produced an event generator for it.

Bolz, Ewerz, Maniatis, O. N., Sauter, Schöning, JHEP 01 (2015) 151

I shall show you results for

- total cross section $\sigma(\gamma p \to \pi^+\pi^- p)$,
- charge asymmetry of π^+, π^- in the proton-Jackson system,
- a detailed preliminary study from H1 of the shape of the ρ resonance.

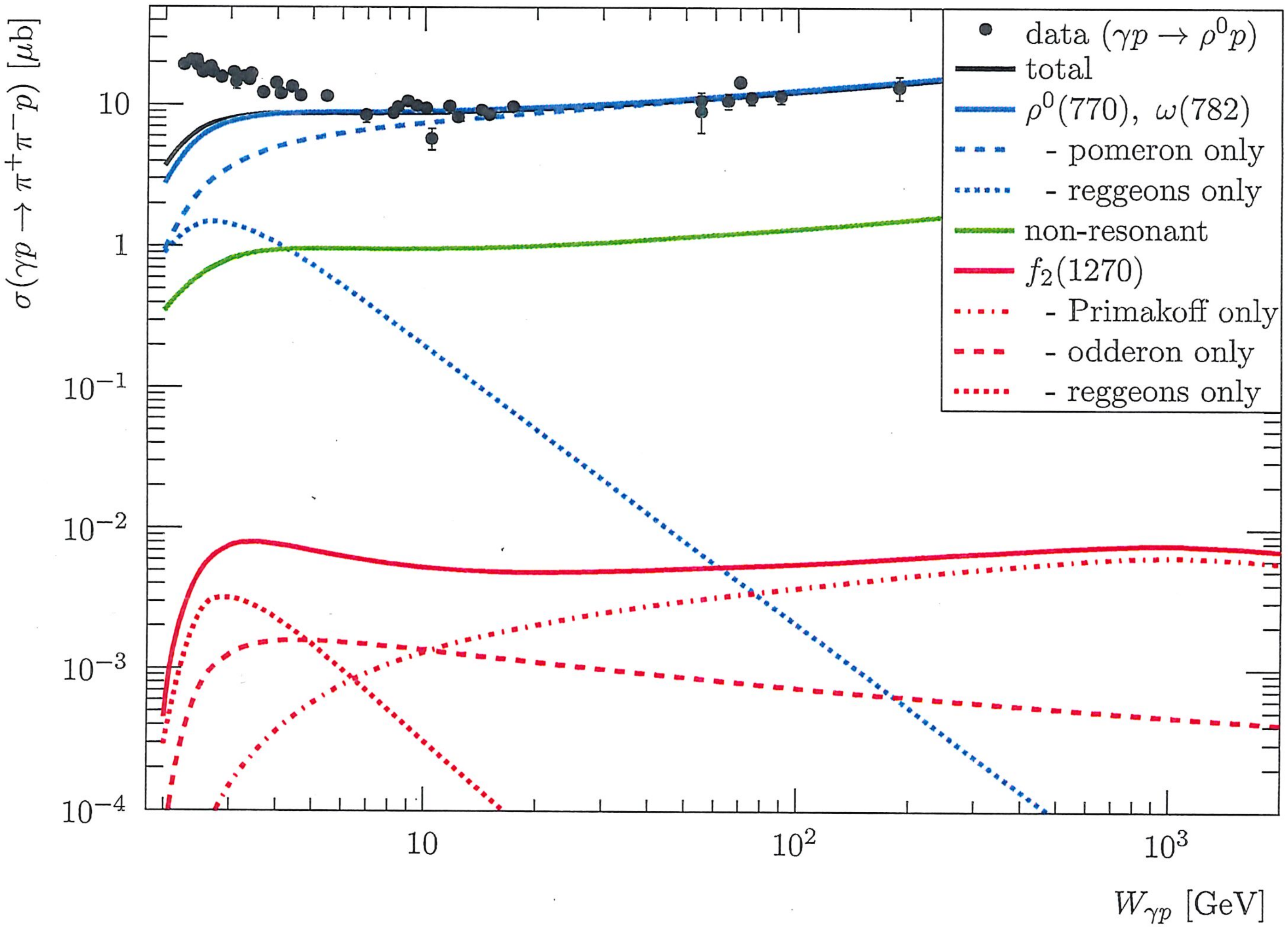
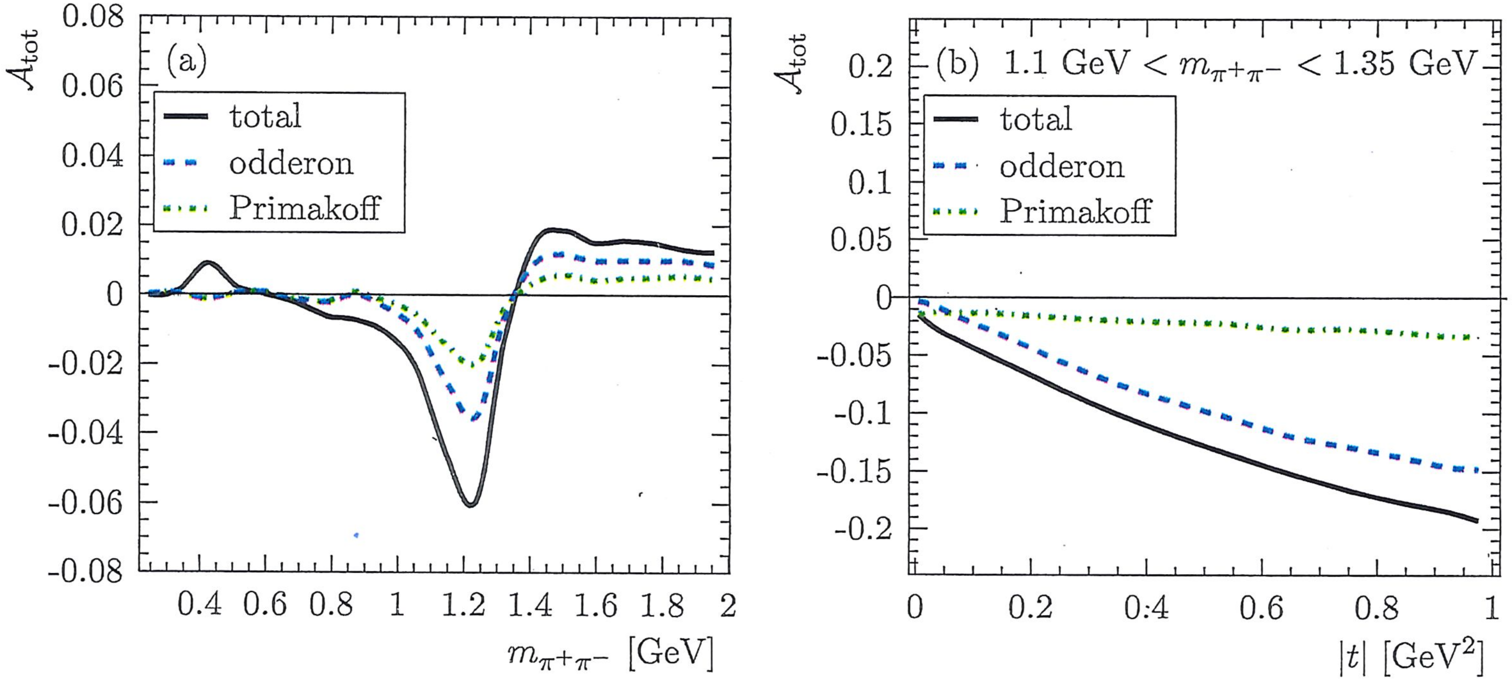
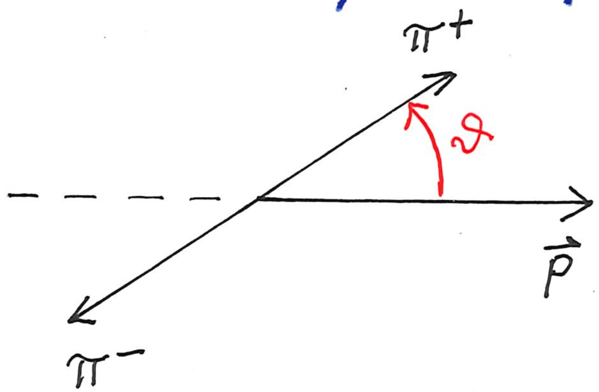


Figure 3. The total cross section $\sigma(\gamma p \to \pi^+\pi^- p)$ as a function of the center-of-mass energy $W_{\gamma p}$. The cross section is integrated over $2m_\pi \leq m_{\pi^+\pi^-} \leq 1.5\,\text{GeV}$ and $-1\,\text{GeV}^2 \leq t \leq 0$. The full model and individual contributions from vector meson production, non-resonant processes, and f_2 production are shown. The reggeon contributions comprise f_{2R} and a_{2R} in case of vector meson, and ρ_R and ω_R in case of f_2 production. High energy data for $\sigma\left(\gamma p \to \rho^0 p\right)$ from H1 [17] and ZEUS [16, 18] at HERA as well as fixed target data, referenced in [18], are shown for illustration.

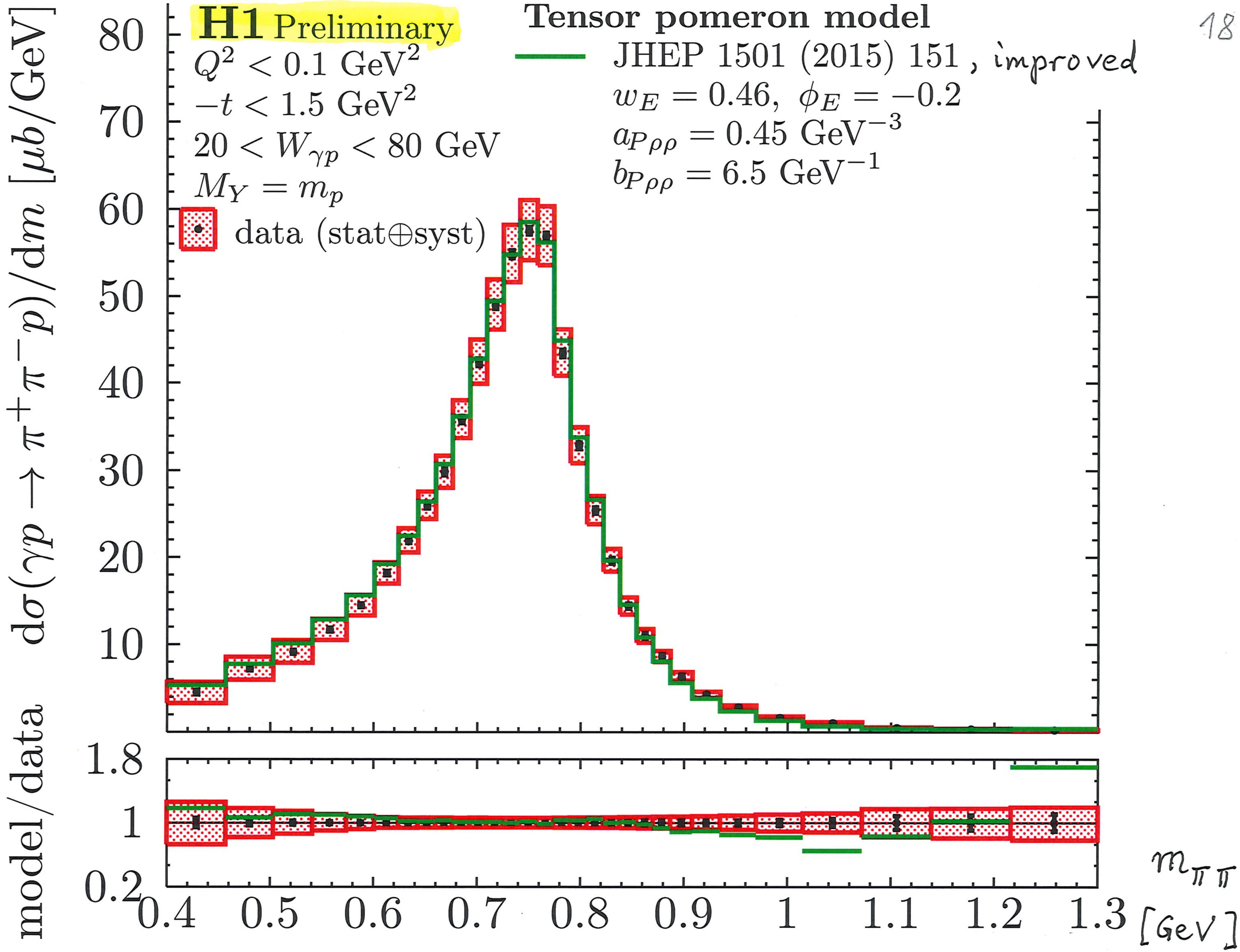


Go to the rest system of $\pi^+\pi^-$



Charge asymmetry:

$$A = \frac{\sigma(\cos\vartheta > 0) - \sigma(\cos\vartheta < 0)}{\sigma(\cos\vartheta > 0) + \sigma(\cos\vartheta < 0)}$$


H1 Preliminary
$Q^2 < 0.1$ GeV^2
$-t < 1.5$ GeV^2
$20 < W_{\gamma p} < 80$ GeV
$M_Y = m_p$
data (stat⊕syst)
Tensor pomeron model
JHEP 1501 (2015) 151 , improved
$w_E = 0.46,\ \phi_E = -0.2$
$a_{P\rho\rho} = 0.45$ GeV^{-3}
$b_{P\rho\rho} = 6.5$ GeV^{-1}
$d\sigma(\gamma p \to \pi^+\pi^- p)/dm$ [μb/GeV]
model/data
$m_{\pi\pi}$ [GeV]
18

Conclusions on $\pi^+\pi^-$ photoproduction:

- We have a theoretically rather satisfactory model. Some improvements have been made, giving then a nice description of the ρ shape. A further improvement may be the inclusion of the $\rho(1700)$ in addition to the $\rho(1450)$ alredy considered in the model.
- The model gives predictions for all possible distributions, e.g. $\pi^+\pi^-$ angular distributions in the $\pi^+\pi^-$ rest frame.
- A search for an odderon contribution in f_2 production could be made.
- The extension of the model to $\pi^+\pi^-$ electroproduction is straightforward.
- A main physics issue, besides the odderon, is the determination of the couplings of the pomeron to ρ, $\rho(1450)$, and $\rho(1700)$.

From the experimental side I see the following issues:

- The existing event generator would need, as far as I understand, some polishing. The extension to electroproduction would be welcome.
- It would be nice if there could be a serious comparison of the HERA data on $\pi^+\pi^-$ production with the model.
- At LHC there will soon be data on our reaction from CEP of $\pi^+\pi^-$ pairs in Ap collisions.
- In the future the $\pi^+\pi^-$ photo- and electroproduction can and will be studied at the EIC.
- We think that it would be worthwhile if somebody, maybe from the xFitter group, could develop the model into a tool easily useable by experimentalists for fitting their data.

4 Applications of the tensor-pomeron model

$\gamma p \to \pi^+ \pi^- p$ Bolz, Ewerz, Maniatis, O.N., Sauter, Schöning, JHEP 01 (2015) 151

$pp \to pp$, spin dependence: Ewerz, Lebiedowicz, O.N., Szczurek, PL B763 (2016) 382

CEP, X, Lebiedowicz, O.N., Szczurek

η, η', f_0	Ann. Phys. 344 (2014) 301
ρ_0	P.R. D91, 074023 (2015)
$\pi^+\pi^-, f_0, f_2$	P.R. D93, 054015 (2016)
$\pi^+\pi^-\pi^+\pi^-$	P.R. D94, 034017 (2016)
ρ^0 with proton diss.	P.R. D95, 034036 (2017)
$p\bar{p}$	P.R. D97, 094027 (2018)
K^+K^-	P.R. D98, 014001 (2018)

CEP X

$p\bar{p}$ in ultraperipheral heavy ion collisions — Klusek-Gawenda, Lebiedowicz, O.N., Szczurek, PRD 96 (2017) 094029

$K^+K^-K^+K^-$ via $\phi\phi$ — Lebiedowicz, O.N. Szczurek, PRD 99 (2019) 094034,

$f_2 \to \pi^+\pi^-$ — arXiv: 1901.07788 (2019),

$\phi \to K^+K^-$, $\mu^+\mu^-$ — arXiv: 1911.01909 (2019),

Photoproduction and low x DIS — Britzger, Ewerz, Glazov, O.N., Schmitt, arXiv: 1901.08524 (2019) PRD 100 (2019) 114007

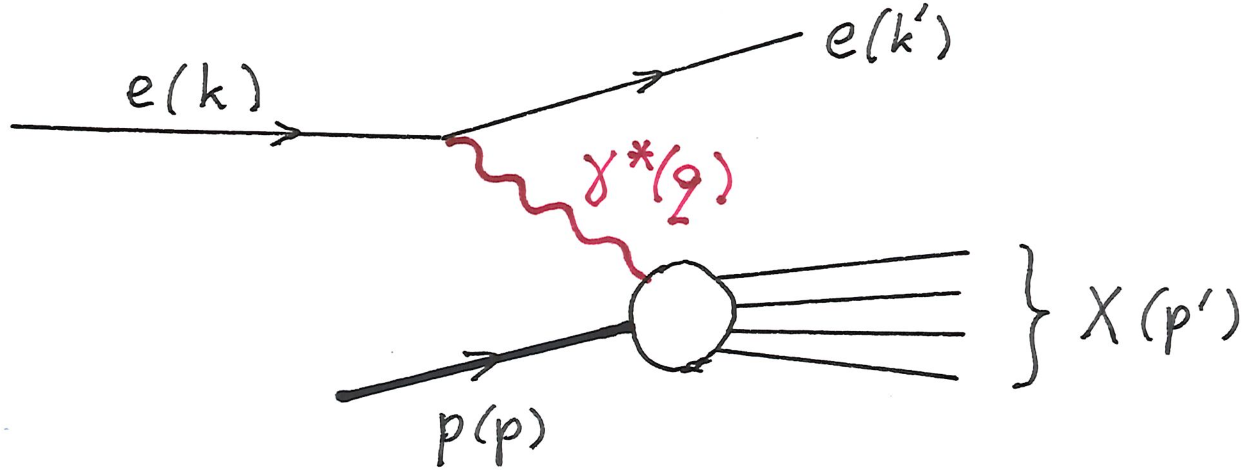
Many thanks go to all with whom I had the pleasure to collaborate on these projects.

5 Photoproduction and low x DIS in the two-tensor-pomeron model

What can we say in the tensor-pomeron approach when going from soft to hard reactions?

We investigate this for DIS:

$$e(k) + p(p) \longrightarrow e(k') + X(p')$$



kinematic variables:

$$s = (p+k)^2 \,, \quad q = k - k' \,, \quad Q^2 = -q^2 \,,$$

$$W^2 = p'^2 = (p+q)^2 \,, \quad \nu = p\cdot q / m_p = \frac{W^2 + Q^2 - m_p^2}{2m_p}$$

$$x = \frac{Q^2}{2m_p \nu} = \frac{Q^2}{W^2 + Q^2 - m_p^2} \,, \quad y = \frac{p\cdot q}{p\cdot k}$$

We follow in our work Donnachie & Landshoff, PL B 437 (1998) 408, and assume that there are two pomerons, but of tensor type:

hard pomeron $\mathbb{P}_0$

soft pomeron $\mathbb{P}_1$

Our aim is to develop a model describing in one framework

- the hard regime of low x DIS, that is, HERA data for $x \leq 0.01$, $Q^2 \leq 50\ \mathrm{GeV}^2$;
- the soft regime, $Q^2 \lesssim 1\ \mathrm{GeV}^2$, in particular photoproduction, $Q^2 = 0$.

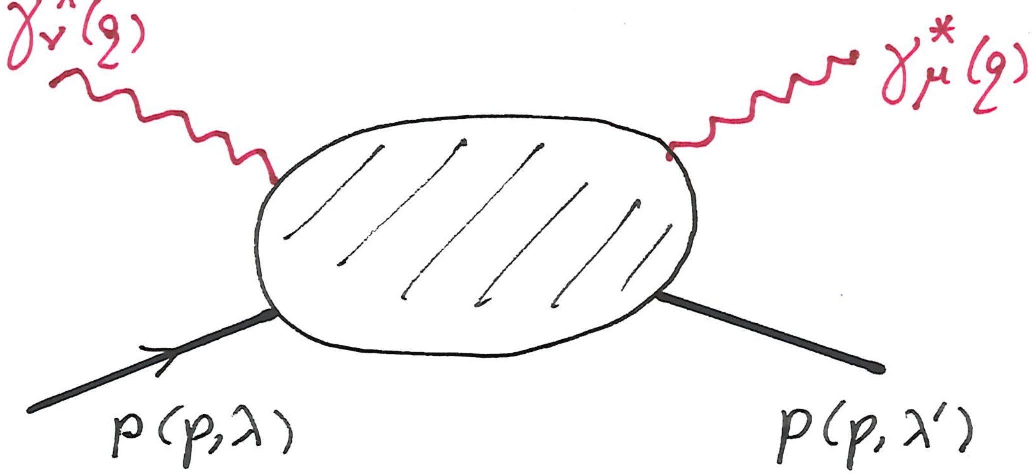
D. Britzger, C. Ewerz, S. Glazov, O.N., S. Schmitt, arXiv:1901.08524, PRD 100 (2019) 114007

The two-tensor-pomeron model

The reaction we study as theorists is forward real and virtual Compton scattering

$$\gamma_\nu^{(*)}(q) + p(p,\lambda) \longrightarrow \gamma_\mu^{(*)}(q) + p(p,\lambda')$$

$$\lambda, \lambda' \in \{1/2, -1/2\}$$



$$\mathcal{M}^{\mu\nu}_{\lambda'\lambda}(p,q)$$

Hadronic tensor of DIS:

$$W^{\mu\nu}(p,q) = \sum_{\lambda',\lambda} \frac{1}{2}\delta_{\lambda\lambda'} \frac{1}{2i}\left[\mathcal{M}^{\mu\nu}_{\lambda'\lambda}(p,q) - \left(\mathcal{M}^{\nu\mu}_{\lambda\lambda'}(p,q)\right)^*\right]$$

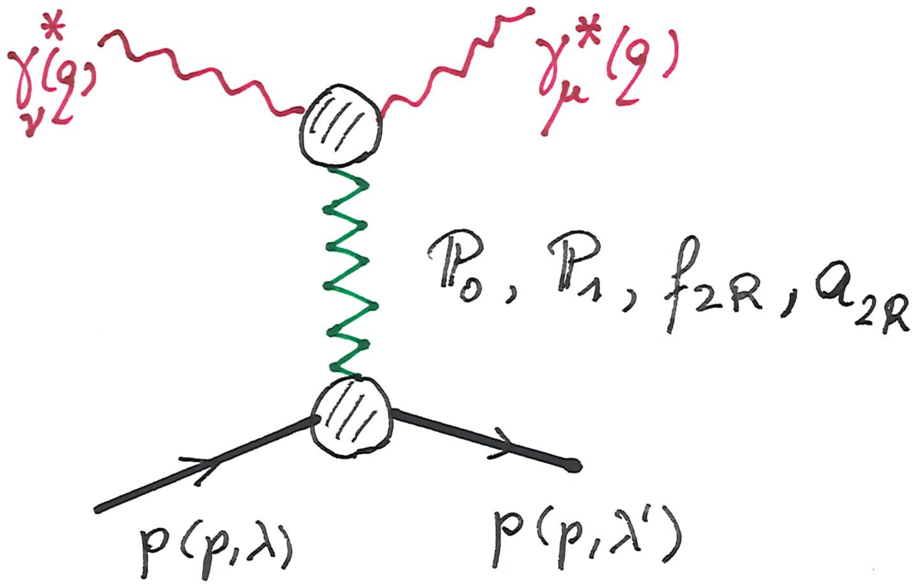
From this we get in the usual way the cross sections for absorption of transverse and longitudinal virtual photons on the proton

$$\sigma_T(W^2, Q^2) \quad , \quad \sigma_L(W^2, Q^2).$$

The photoabsorption cross section for real photons is

$$\sigma_{tot,\gamma p}(W^2) = \sigma_T(W^2, 0).$$

In our model we describe the virtual Compton amplitude at high energies by exchange of hard and soft pomeron. In addition we consider reggeon exchange, relevant for lower W: f_{2R}, a_{2R}.



Exchange diagrams for

$$\mathcal{M}^{\mu\nu}_{\lambda'\lambda}(p,q)$$

The main parameters of the model are the intercepts of $\mathbb{P}_0, \mathbb{P}_1, f_{2R}, a_{2R}$ and their couplings to $\gamma^*\gamma^*$.

$\mathbb{P}_j\gamma^*\gamma^*$ coupling functions: $\hat{a}_j(Q^2)$, $\hat{b}_j(Q^2)$.

Theoretical results, neglecting for this presentation terms of order m_p^2/W^2 and Q^2/W^2:

$$\sigma_{tot,\gamma p}(W^2) = \sigma_T(W^2, 0) = 4\pi\alpha \sum_{j=0,1} 3\beta_j (W^2\tilde{\alpha}_j')^{\varepsilon_j} \cos\left(\frac{\pi}{2}\varepsilon_j\right) \hat{b}_j(0)$$

$$+ \text{ reggeon term},$$

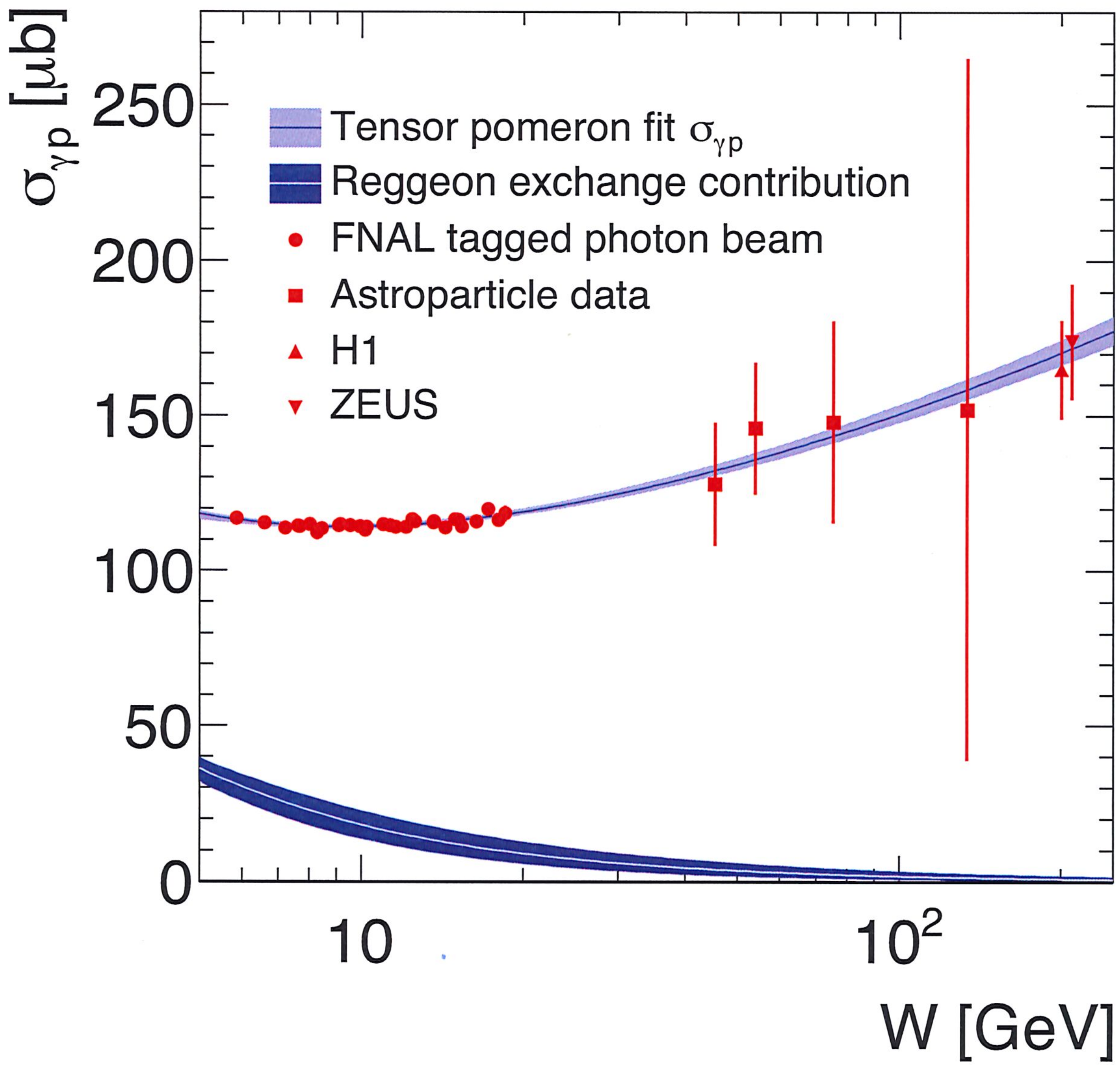
$$\sigma_T(W^2, Q^2) + \sigma_L(W^2, Q^2) = 4\pi\alpha \sum_{j=0,1} 3\beta_j (W^2\tilde{\alpha}_j')^{\varepsilon_j} \cos\left(\frac{\pi}{2}\varepsilon_j\right) \hat{b}_j(Q^2),$$

$$\sigma_L(W^2, Q^2) = 4\pi\alpha Q^2 \sum_{j=0,1} 3\beta_j (W^2\tilde{\alpha}_j')^{\varepsilon_j} \cos\left(\frac{\pi}{2}\varepsilon_j\right) 2\hat{a}_j(Q^2).$$

All gauge invariance relations are satisfied, in particular,

$$\sigma_L(W^2, Q^2) \propto Q^2 \quad \text{for} \quad Q^2 \longrightarrow 0.$$

Fit results: photoproduction



For real photoabsorption, a soft reaction, we find dominance of the soft pomeron $\mathbb{P}_1$. The hard pomeron, $\mathbb{P}_0$, contribution is compatible with zero. At $W = 200$ GeV, for instance, we find the following contributions to $\sigma_{tot,\,\gamma p}$:

soft pomeron	$\mathbb{P}_1$	$170.4^{+4.2}_{-4.0}$	μb,
hard pomeron	$\mathbb{P}_0$	$0.002^{+0.086}_{-0.002}$	μb,
reggeon		$0.84^{+0.99}_{-0.58}$	μb.

For DIS the directly measured quantity is the reduced cross section:

$$\sigma_r(W^2, Q^2, y) = \frac{Q^4\, x}{2\pi\alpha^2[1+(1-y)^2]} \frac{d^2\sigma(ep \to eX)}{dx\, dQ^2}$$

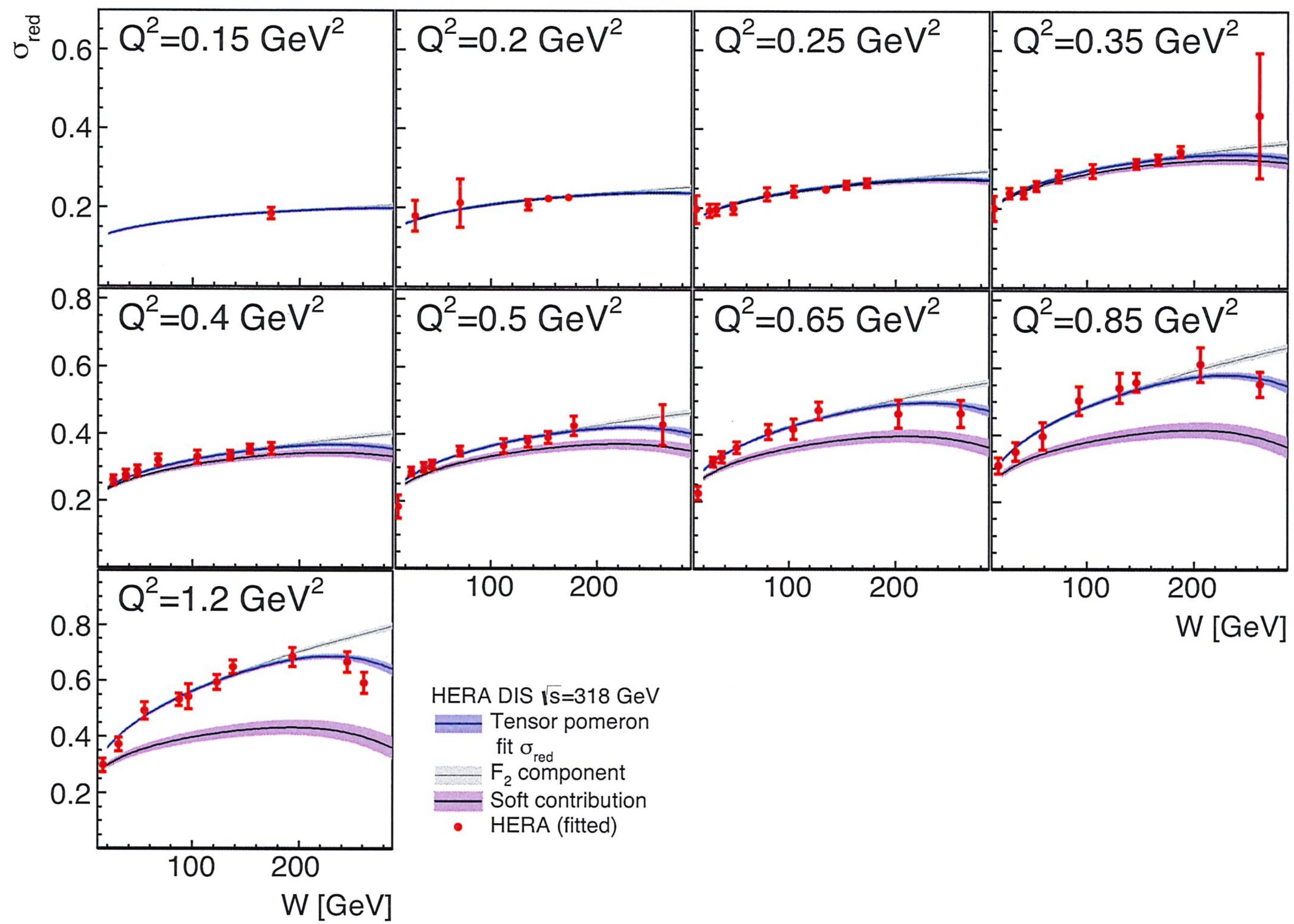
$$= \frac{Q^2}{4\pi^2\alpha}(1-x)\left[\sigma_T(W^2, Q^2) + \sigma_L(W^2, Q^2) - \frac{y^2}{1+(1-y)^2}\sigma_L(W^2, Q^2)\right]$$

As an example we show our fit to the HERA data at $\sqrt{s} = 318$ GeV. The fits at the other values of $\sqrt{s} = 225$, 251, and 300 GeV are similar.

Fit results: DIS (5)

$$\sqrt{s} = 318\,\text{GeV}$$

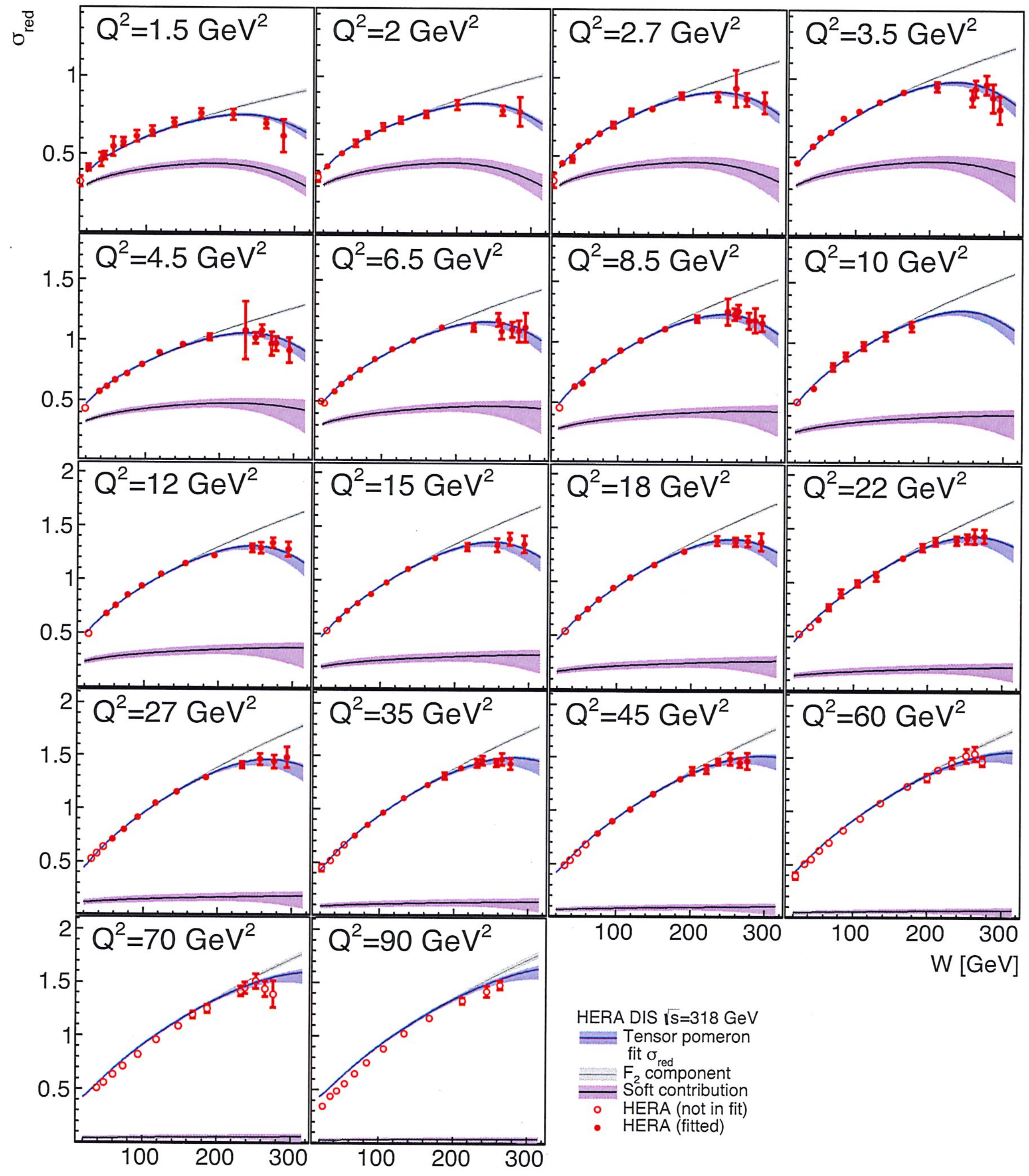
$$y = \frac{W^2 + Q^2 - m_p^2}{s - m_p^2}$$



reduced cross section

Fit results: DIS (6)

$$\sqrt{s} = 318\,\mathrm{GeV}$$



reduced cross section

Fit results:

- intercepts:

  hard pomeron $\alpha_{\mathbb{P}_0}(0) = 1 + \varepsilon_0$, $\varepsilon_0 = 0.3008\binom{+73}{-84}$

  soft pomeron $\alpha_{\mathbb{P}_1}(0) = 1 + \varepsilon_1$, $\varepsilon_1 = 0.0935\binom{+76}{-64}$

  reggeon $\mathbb{R}_+ = f_{2R} + a_{2R}$ $\alpha_{\mathbb{R}_+}(0) = 0.485\binom{+88}{-90}$

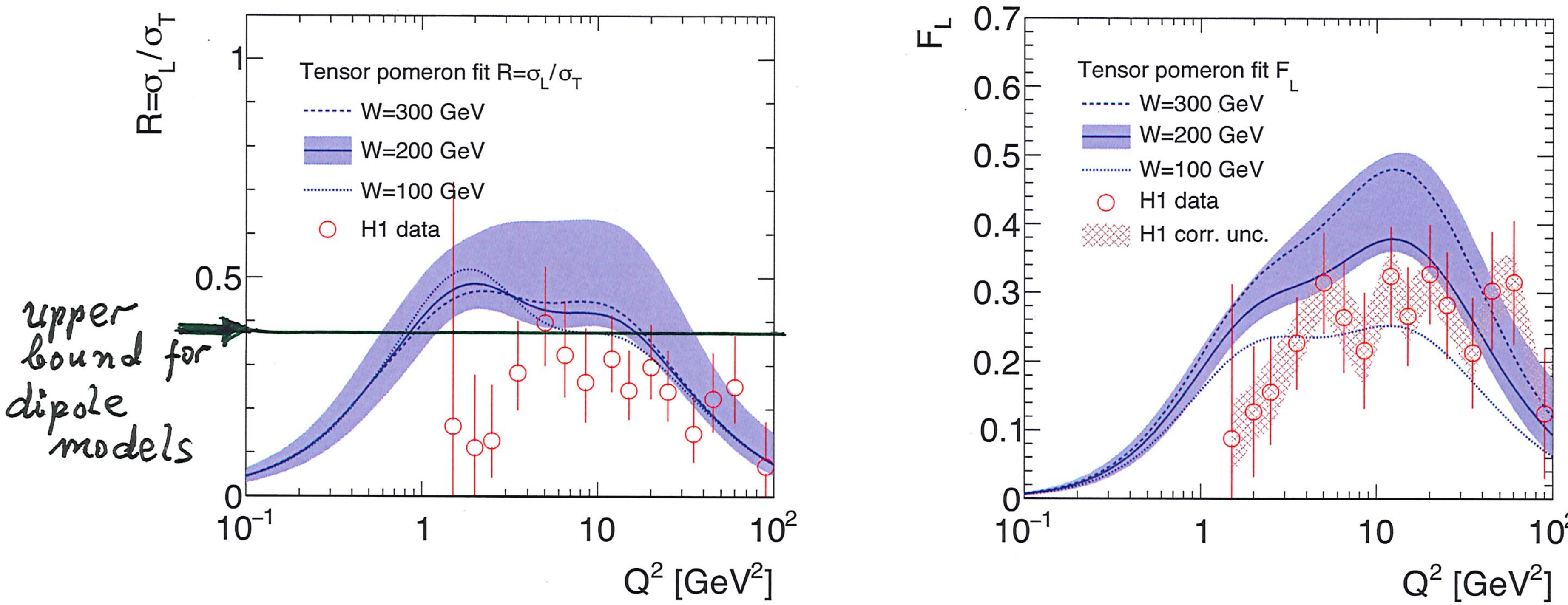
- coupling functions $\hat{a}_j(Q^2)$, $\hat{b}_j(Q^2)$.

- the fit seems to prefer rather large values for the ratio

$$R(W^2, Q^2) = \frac{\sigma_L(W^2, Q^2)}{\sigma_T(W^2, Q^2)} .$$

$R = \sigma_L/\sigma_T$ and F_L

- comparison to F_L extraction by H1 (not in fit): fit prefers relatively large R



- Future measurements of σ_L and R at an EIC would be very interesting.

Observations: R and the dipole model

- R close to upper bound from dipole model, $R_{max} = 0.37248$.
  This might indicate problems with the dipole model in the corresponding kinematical regime.

- Speaking of the dipole model … (and since we discussed photoproduction):
  One should use W instead of x_{Bj} in the dipole cross section - because of QFT, and since otherwise photoproduction is constant in energy.

Fit results, contined.

- At $Q^2=0$ and for small Q^2 soft pomeron, $\mathbb{P}_1$, exchange dominates, for high Q^2 the hard pomeron, $\mathbb{P}_0$.
  Their contributions are roughly equal for $Q^2 \approx 5\ GeV^2$.
  Soft pomeron exchange is clearly visible up to $Q^2 \approx 20\ GeV^2$.
- We see no sign of saturation in our fit to the HERA low x data.
- A pomeron coupling like a vector can be excluded.
  A vector pomeron cannot contribute to the photoabsorption cross section and to the DIS structure functions.

- The twist expansion is, in essence, an expansion in powers of $1/Q^2$. Thus, it cannot be used for $Q^2 \to 0$.
  For $Q^2 \gtrsim 10\ GeV^2$ our results are consistent with making the relations:
  - hard pomeron exchange, $\mathbb{P}_0$, $\longleftrightarrow$ leading twist $\longleftrightarrow$ QCD improved parton model,
  - soft pomeron exchange, $\mathbb{P}_1$, $\longleftrightarrow$ higher twists.

  Then our conclusion is that higher twist effects should not be neglected for $Q^2 \lesssim 20\ GeV^2$ at low x.
- The tensor-pomeron model has no problems going down to $Q^2 = 0$. We get a very satisfactory fit to the data from small Q^2, including $Q^2 = 0$, where the virtual photon behaves hadronlike, to high Q^2, the hard regime, in one framework.

6 Conclusions

- We have developed a model for diffractive high-energy phenomena. The couplings of the pomeron and the odderon to particles are like those of a second rank symmetric tensor and a vector, respectively.
- The model has already been applied to many reactions and we think that it is quite user friendly.
- We have treated many central exclusive production (CEP) reactions and we have given many predictions for the LHC experiments. A special emphasis was on reactions where one can look for possible odderon effects.

- We think that it would be very worthwhile to study photo- and electroproduction of vector mesons using our model:

$$\gamma^{(*)} + p \longrightarrow V + p,$$

$$V = \rho^0, \omega, \phi, J/\psi$$

I have talked about ρ^0 production at HERA. We also have some results for ω and ϕ photoproduction. In electroproduction we will presumably have soft and hard pomeron contributions. This should allow a determination of the trajectory of the hard pomeron, where from DIS we have the intercept $\alpha_{\mathbb{P}_0}(0) \cong 1.3$.

- Photoproduction can be studied at the LHC in ultraperipheral Ap collions. Photo- and electroproduction at the future EIC.

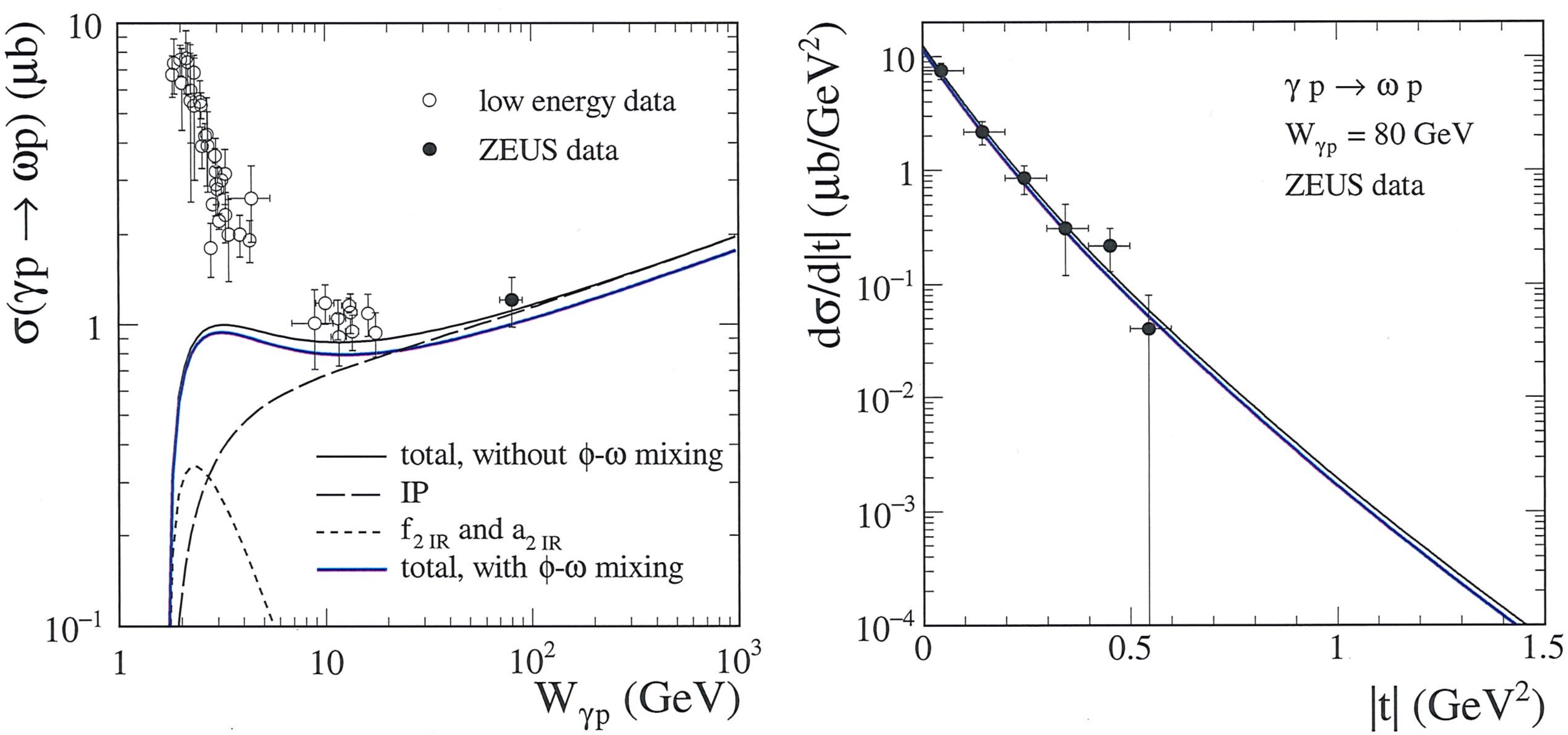


FIG. 30: Left panel: The elastic ω photoproduction cross section as a function of the center-of-mass energy $W_{\gamma p}$. Our results are compared with the ZEUS data [87] (at γp average c.m. energy $\langle W_{\gamma p} \rangle = 80$ GeV) and with a compilation of low-energy experimental data (open circles; see the caption of Fig. 2 of [18] for more references). The black solid line corresponds to results with both the pomeron and reggeon ($f_{2\mathbb{R}}$, $a_{2\mathbb{R}}$) exchanges. The black long-dashed line corresponds to the pomeron exchange alone while the black short-dashed line corresponds to the reggeon term. In the calculation we used the parameters of the coupling constants given by (B1), (B2) and (B4). The blue solid line corresponds to the complete result including the ϕ-ω mixing effect (for the $\mathbb{P}$ exchange) with the parameter set A (B5). Right panel: The differential cross section for the $\gamma p \to \omega p$ reaction at $W_{\gamma p} = 80$ GeV. Our complete results, without (the black line) and with (the blue line) the mixing effect, are compared to the ZEUS data [87].

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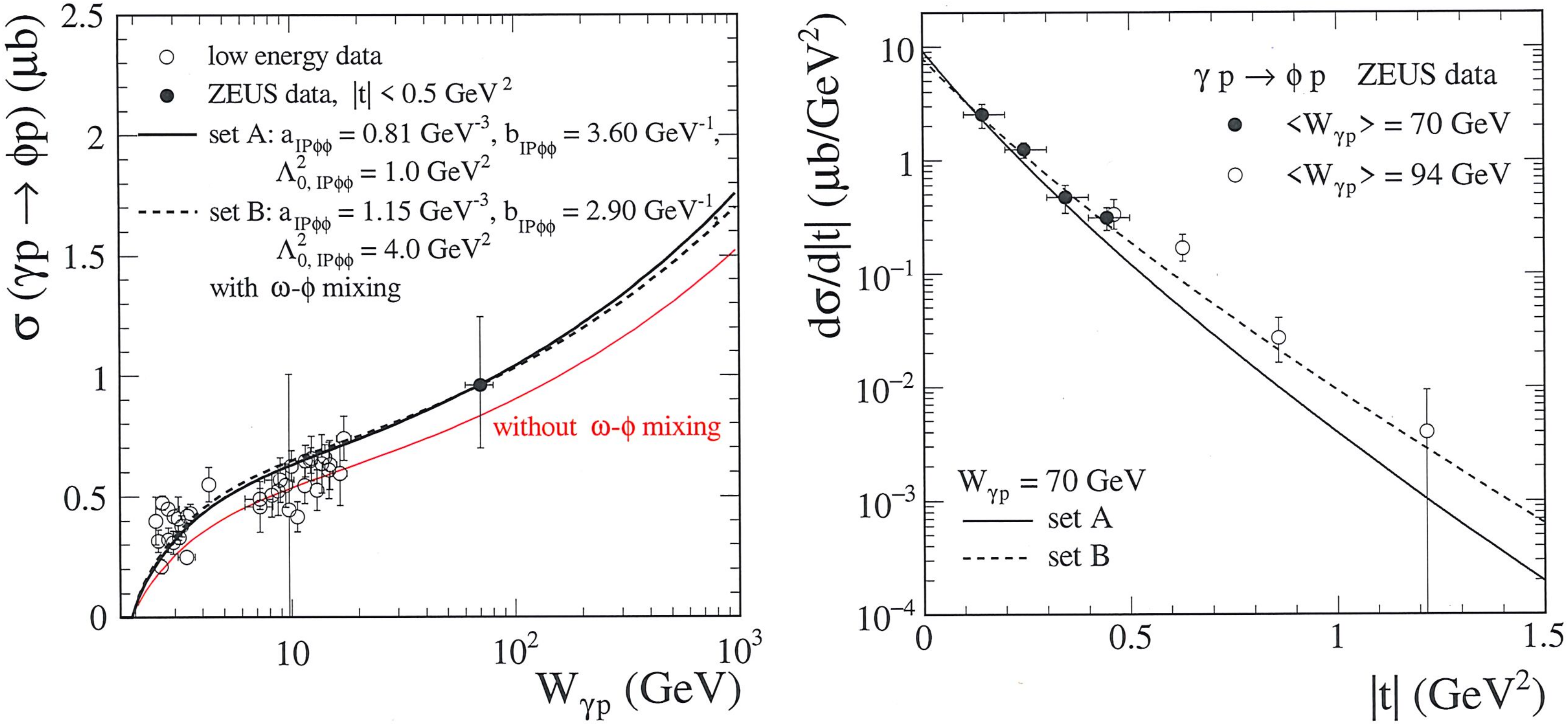

FIG. 32: Left panel: The elastic ϕ photoproduction cross section as function of the center-of-mass energy $W_{\gamma p}$. Our results are compared with the HERA data [73] at $W_{\gamma p} = 70$ GeV and with a compilation of low-energy experimental data (see the caption of Fig. 6 of [51] for references). The upper lines represent results for two parameter sets, set A and set B, including the $\omega \to \phi$ transition terms with (B9), (B10), (B11). Here we take in (2.19), in set A (B7), $\Lambda^2_{0,\mathbb{P}\phi\phi} = 1.0\ \mathrm{GeV}^2$ and, in set B (B8), $\Lambda^2_{0,\mathbb{P}\phi\phi} = 4.0\ \mathrm{GeV}^2$. The lower red line represents the result for the diagram (a) of Fig. 31 only with the parameter set (B7). Right panel: The differential cross section $d\sigma/d|t|$ for the $\gamma p \to \phi p$ process. We show the ZEUS data at low $|t|$ (at $W_{\gamma p} = 70$ GeV and the squared photon virtuality $Q^2 = 0\ \mathrm{GeV}^2$, solid marks, [73]) and at higher $|t|$ (at $W_{\gamma p} = 94$ GeV and $Q^2 < 0.01\ \mathrm{GeV}^2$, open circles, [74]). Again, the results for the two parameter sets, set A (B7) and set B (B8), are presented.

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Thank you for
your attention!

Additional Material

A Effective propagators and vertices of the Tensor Pomeron Model

B Helicity in pp elastic scattering and the spin structure of the pomeron

C Photoproduction and low x DIS in the two-tensor-pomeron model

D Various CEP reactions in the tensor-pomeron model. Single ϕ CEP: a "smoking gun" for odderon exchange?