Soft pomeron in AdS/QCD

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Work with A. Bayona, M. Djuric, R. Quevedo

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Regge behaviour in QCD

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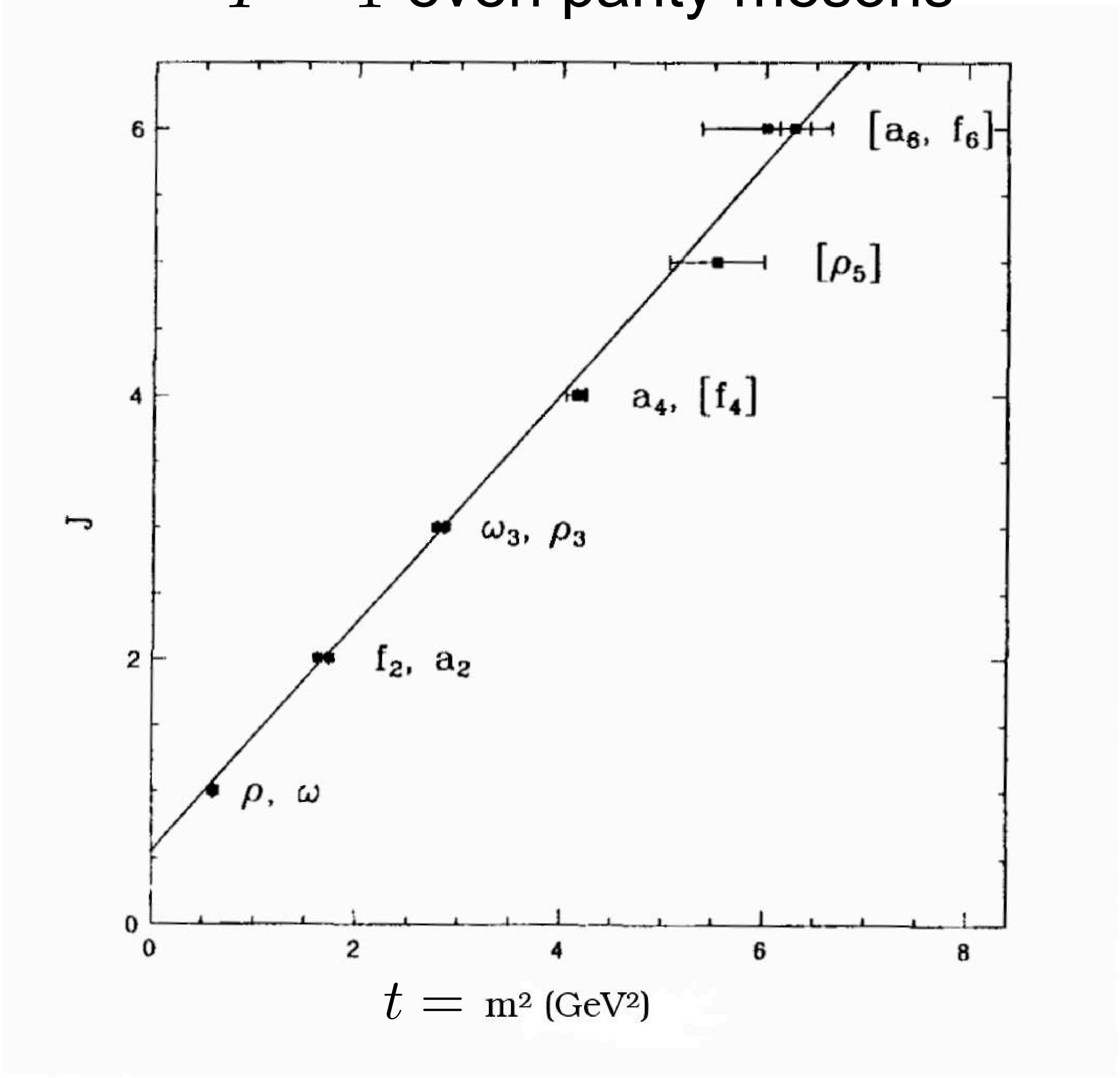
- Hadronic resonances fall in linear trajectories

$I = 1$ even parity mesons



$$J = j(t) = j(0) + \alpha' t$$

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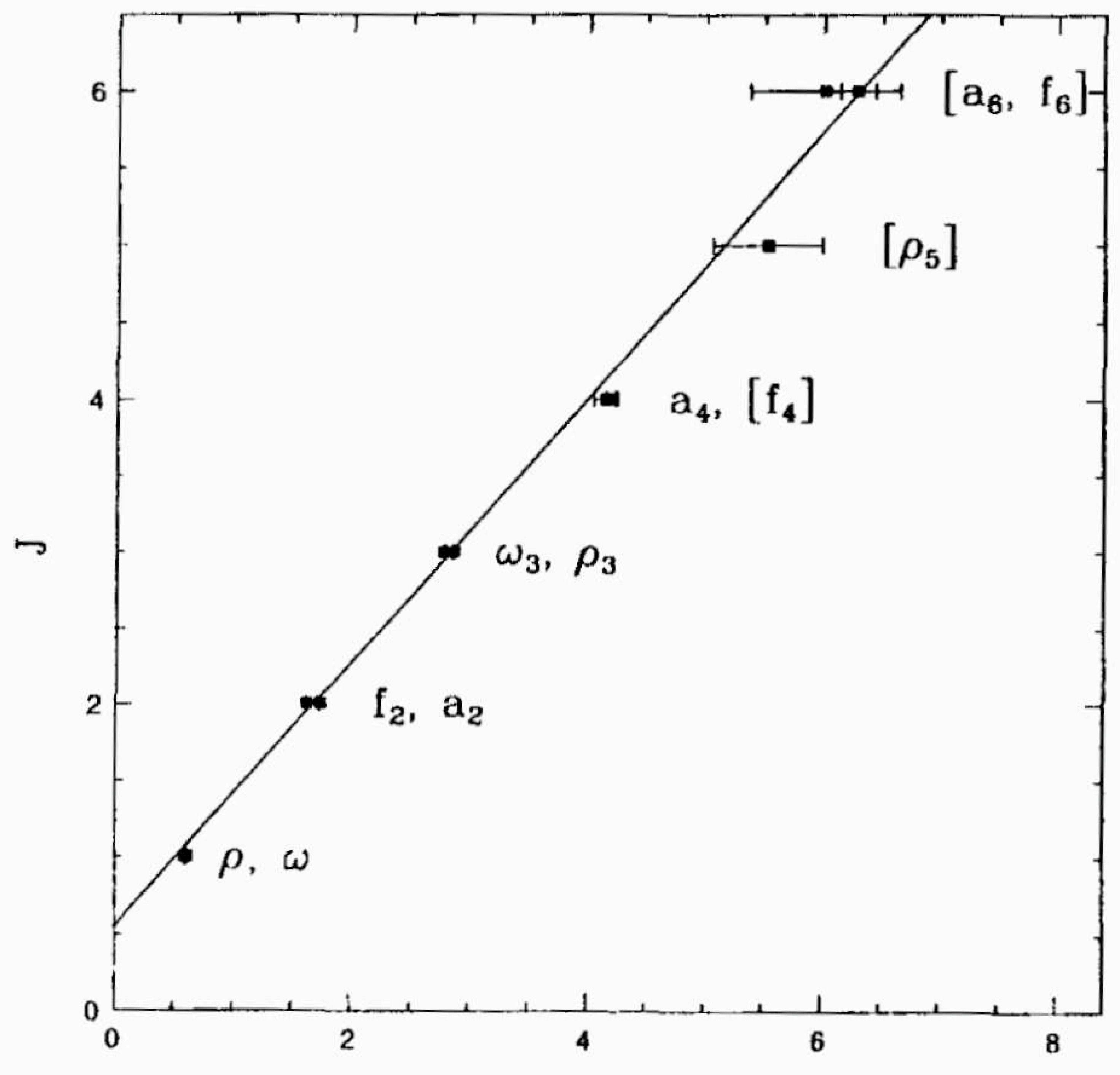


$t = $ m² (GeV²)

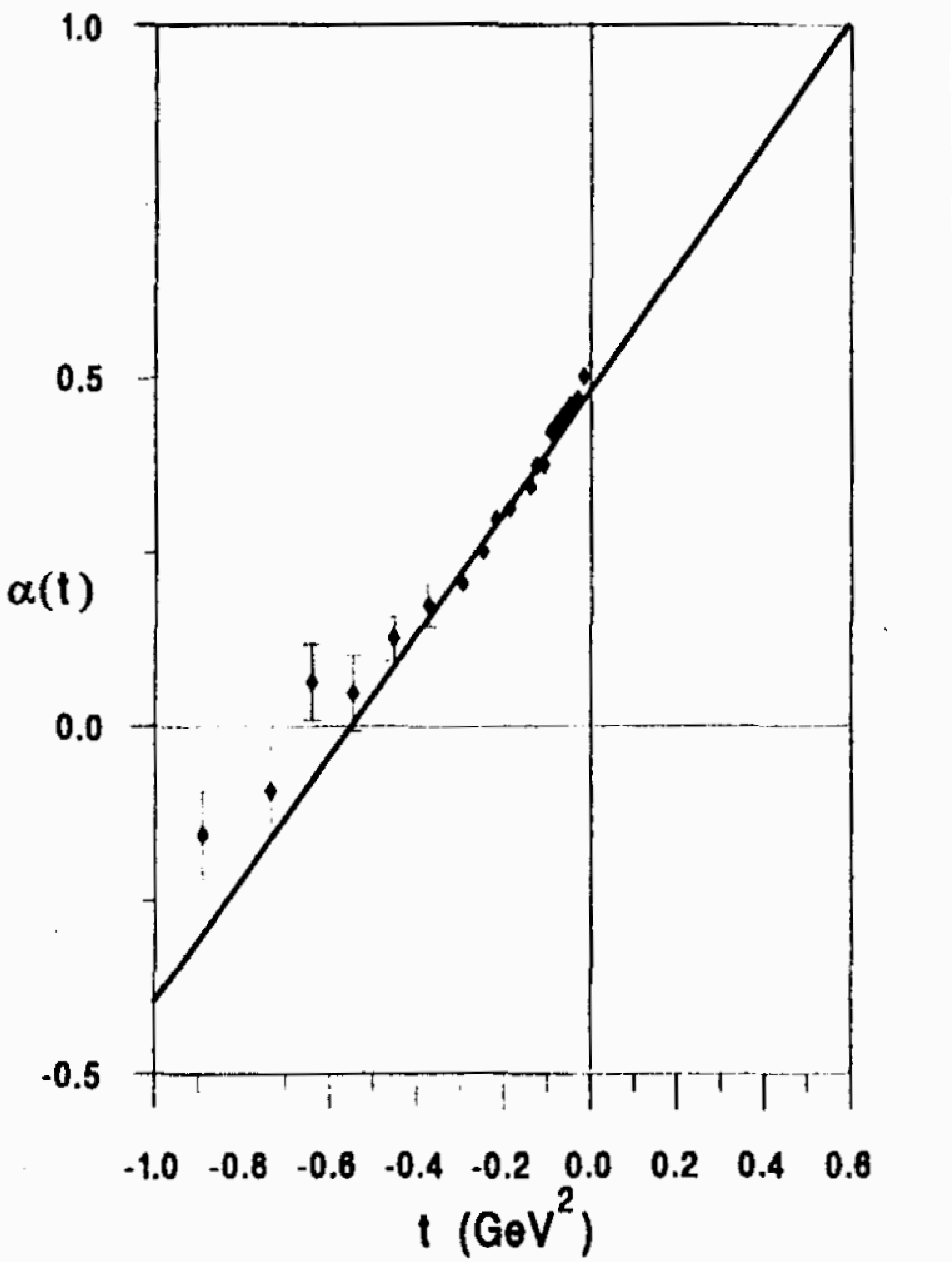
$$J = j(t) = j(0) + \alpha' t$$

$$A(s,t) \sim \beta(t) s^{j(t)}$$
$$(s \gg t)$$

Total cross section

$$\sigma \sim s^{j(0)-1}$$

$$\pi^- + p \to \pi^0 + n$$



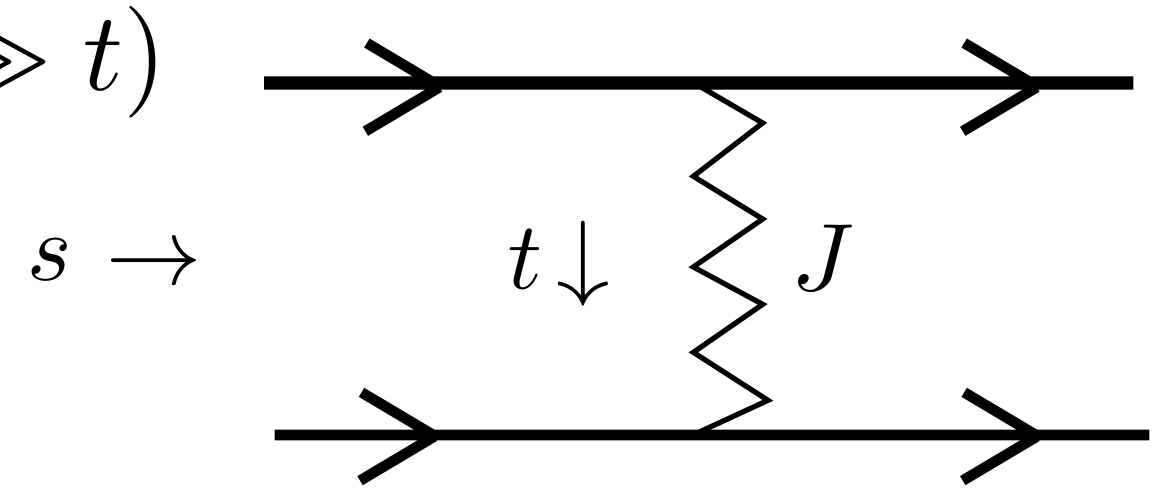
Regge theory

Regge theory

- Scattering dominated by t-channel exchange of a Regge trajectory

$$A(s,t) \approx \sum_J g_J \frac{s^J}{t - m^2(J)} \sim \sum_J g_J \frac{s^J}{J - j(t)}$$

$(s \gg t)$



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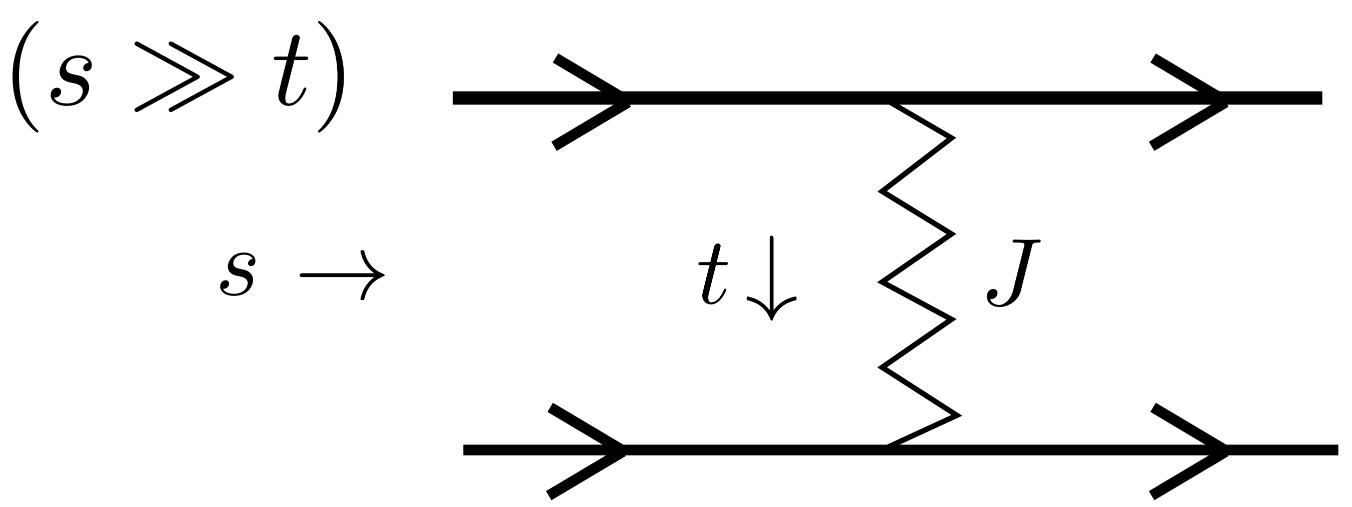
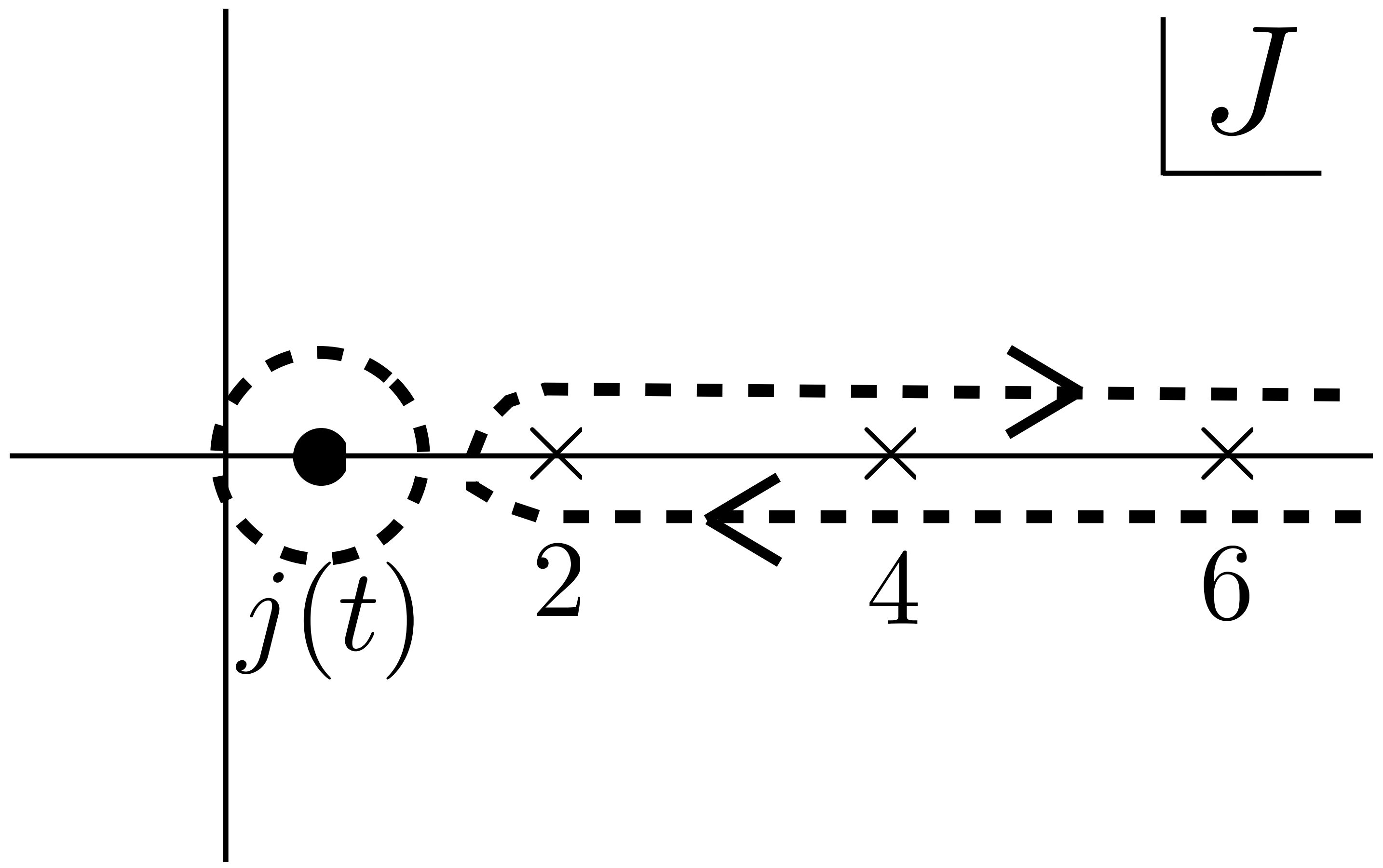


- Sommerfeld-Watson transform:

$$\sum_J \rightarrow \int \frac{dJ}{\sin \pi J}$$

$$A(s,t) \sim \beta(t) s^{j(t)}$$



Soft Pomeron trajectory [Donnachie, Landshoff]

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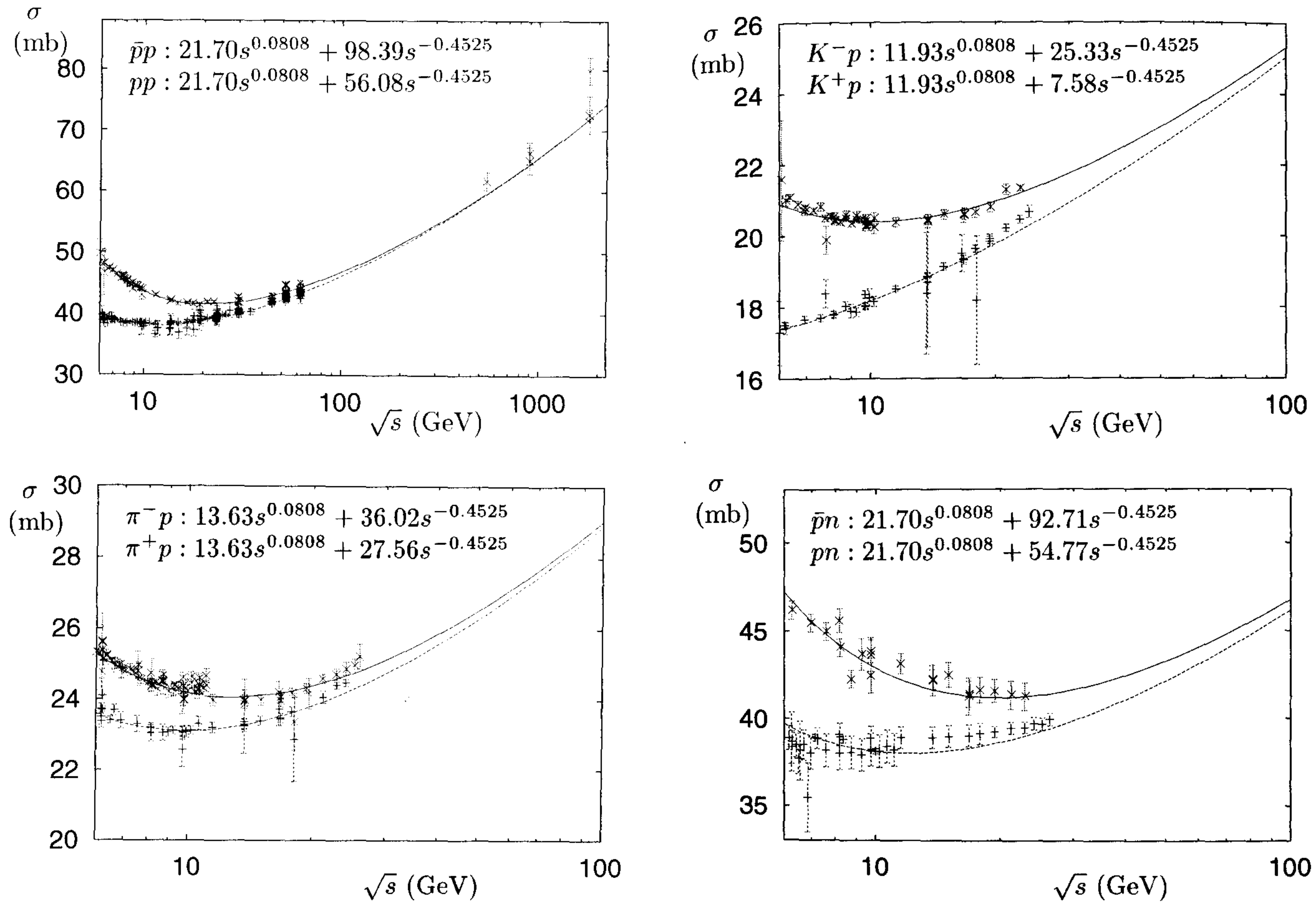
- Trajectory selected by exchanged quantum numbers. For elastic scattering these are the vacuum quantum numbers.

$$j_P(t) \approx 1.08 + 0.25t \quad \text{(GeV units)}$$

Elastic cross sections in QCD

$$\sigma \sim s^{j_P(0)-1} \sim s^{0.08}$$



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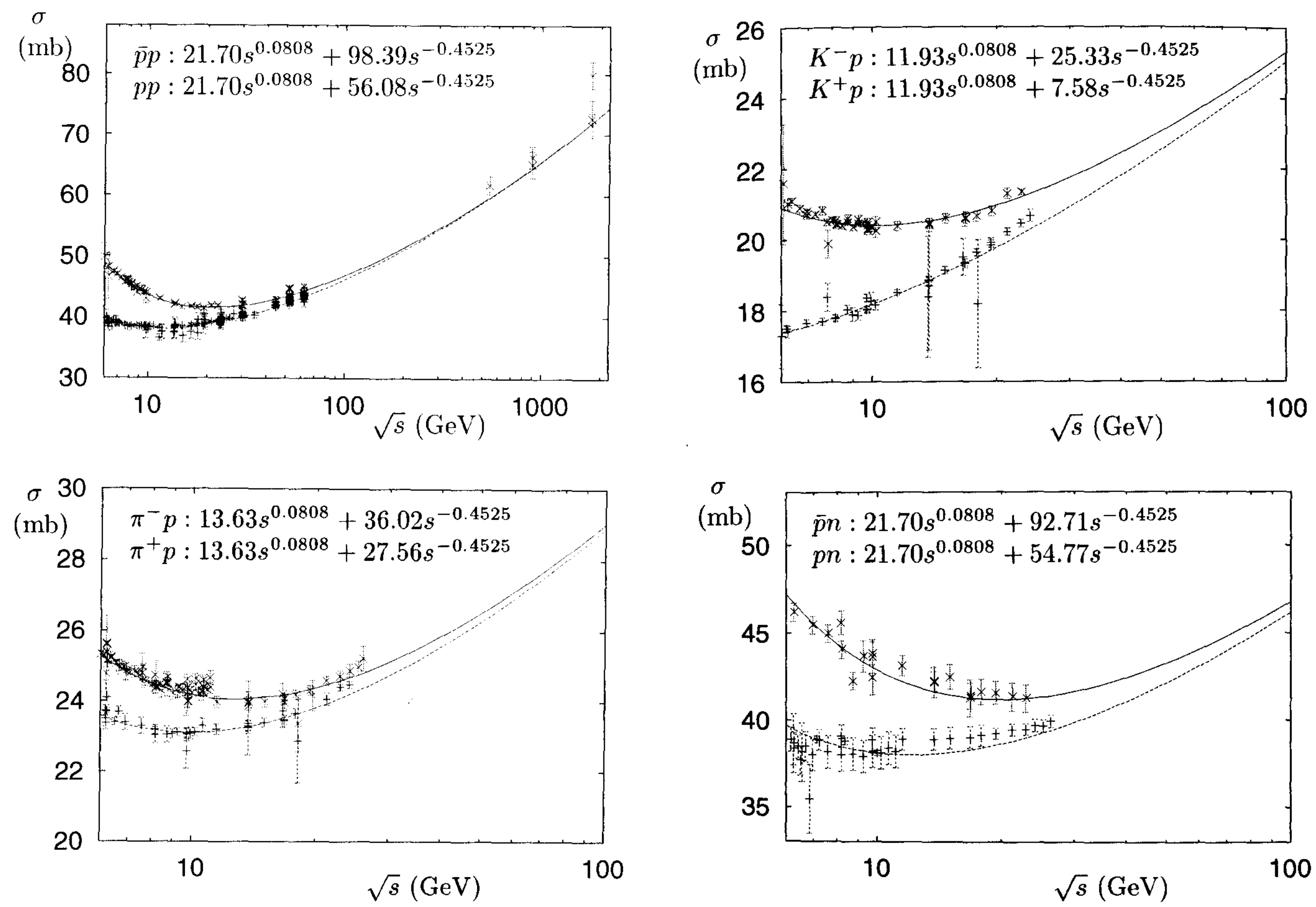
Exchange of even spin glueballs $(J \geq 2)$

$$\mathcal{O}_J \sim F_{\alpha[\beta_1} D_{\beta_2} \dots D_{\beta_{J-1}} F_{\beta_J]}{}^{\alpha}$$



Deep Inelastic Scattering

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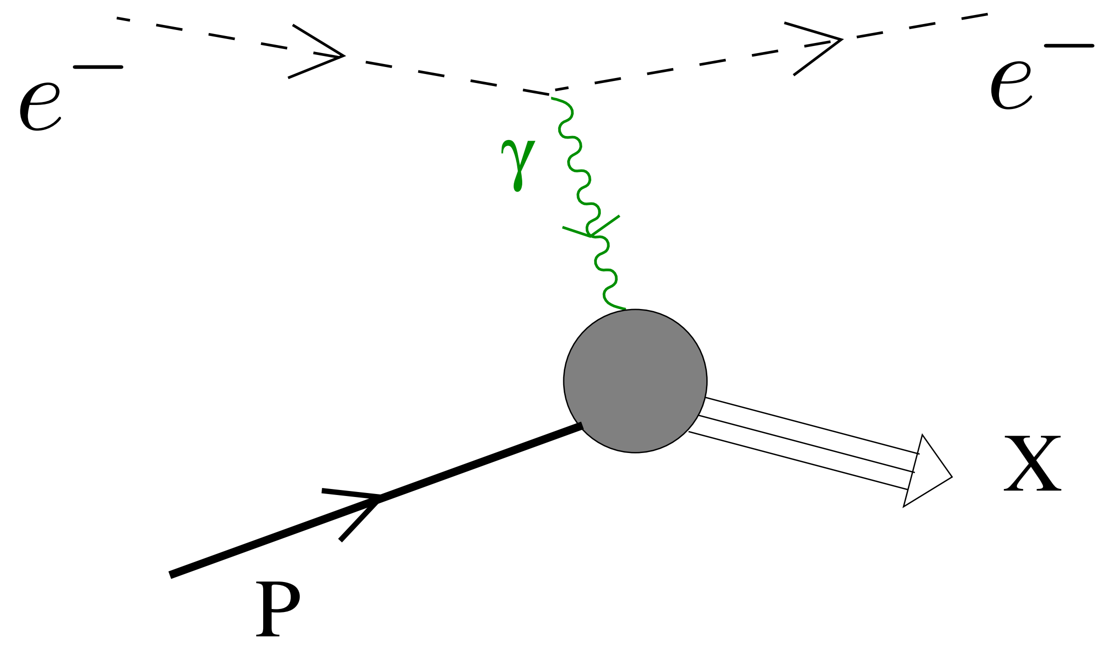
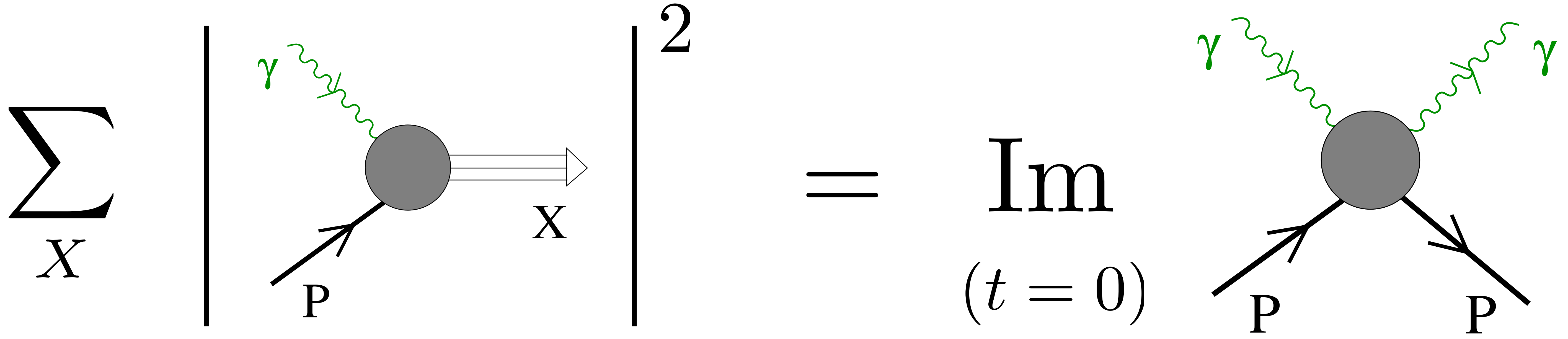


- Pomeron enters also in diffractive processes. For example DIS, where electron interacts with proton via exchange of off-shell photon

- Optical theorem



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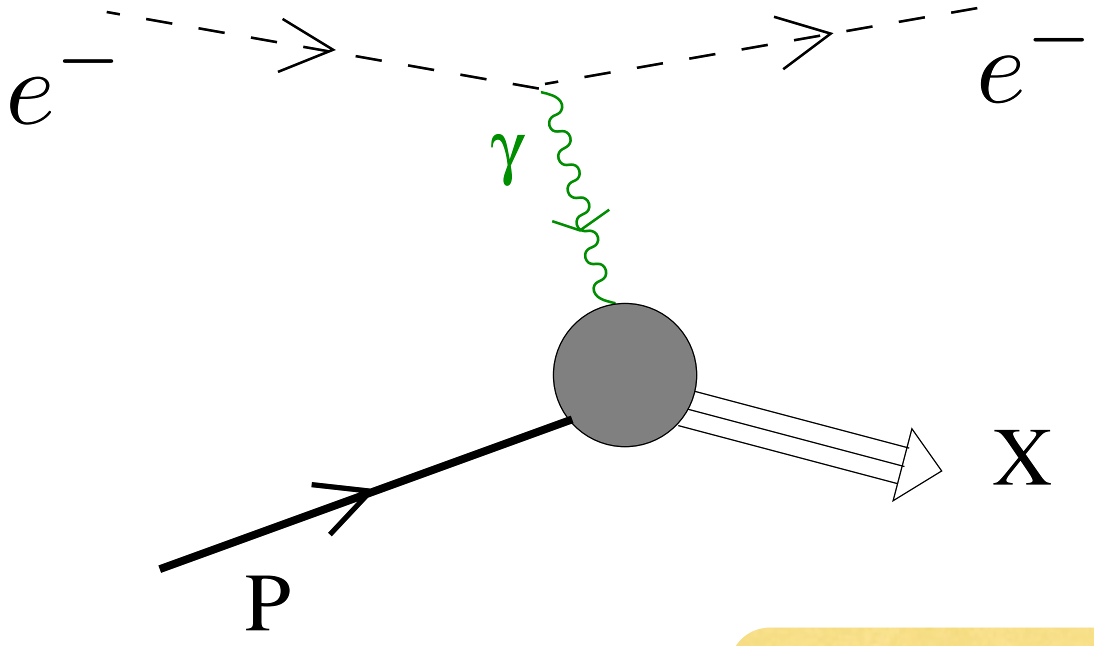
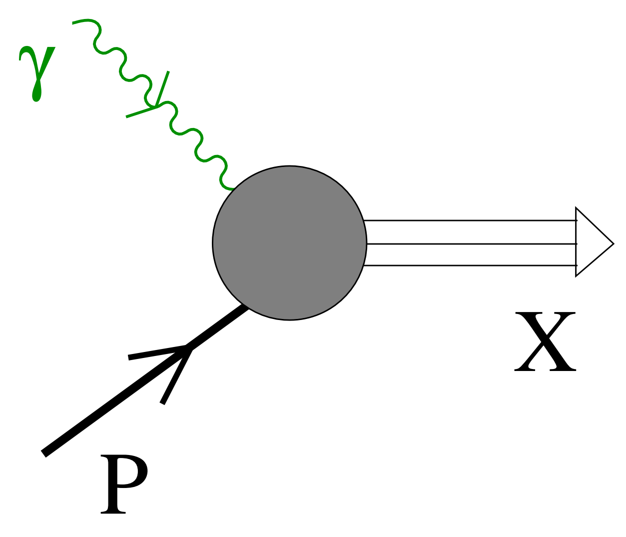
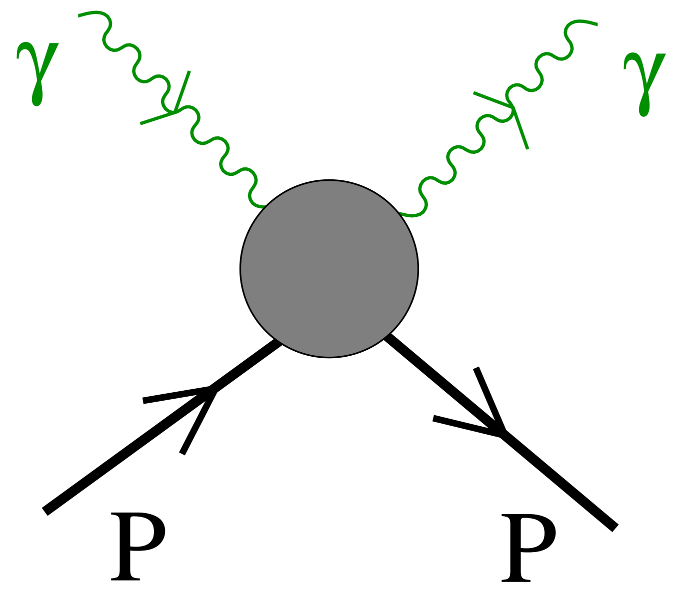


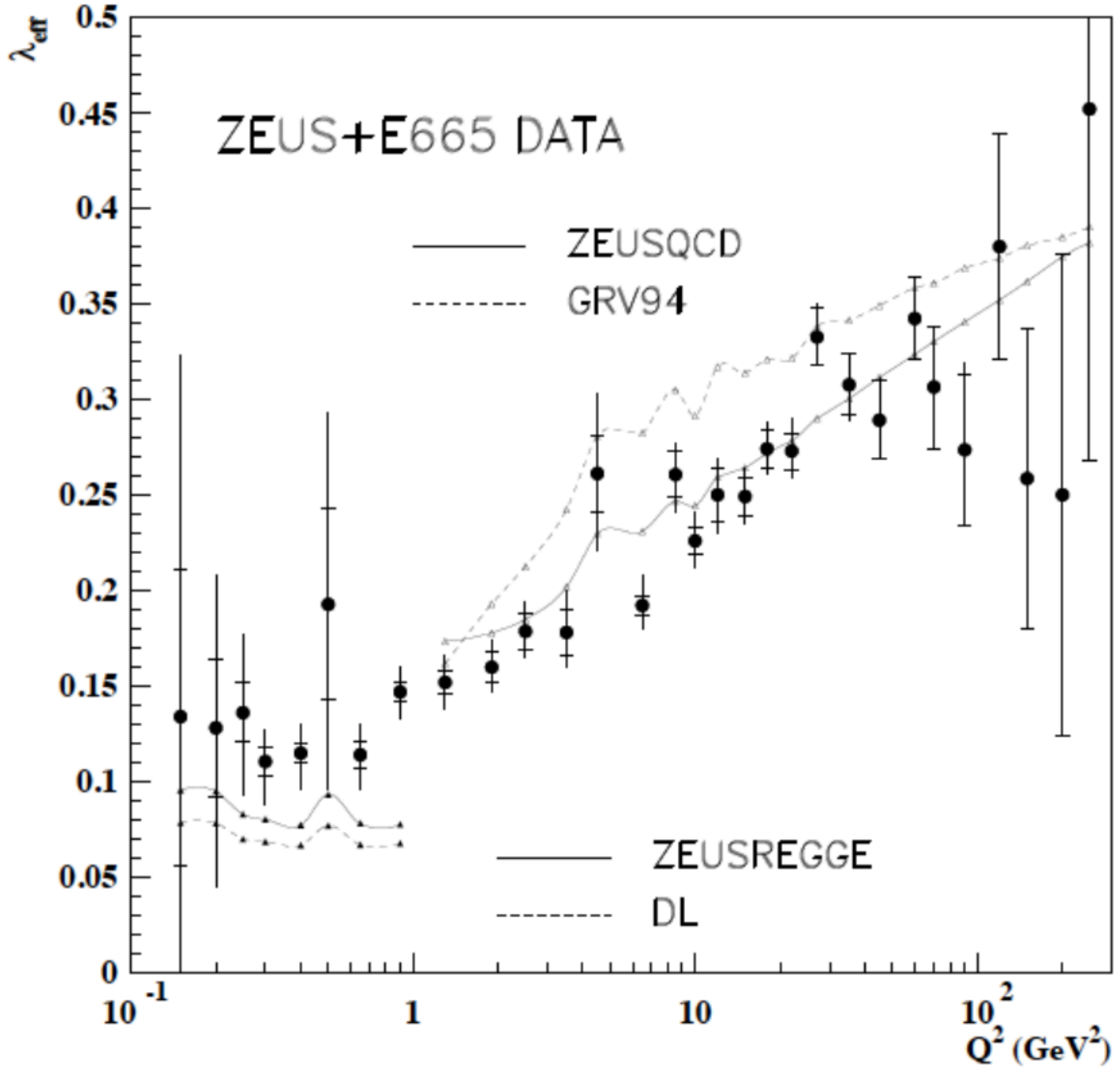
- Optical theorem

$$\sum_X \Bigg|$$


$$\Bigg|^2 = \underset{(t=0)}{\text{Im}}$$


- Regge limit corresponds to low x $\quad (s \sim Q^2/x)$

$j_0 \sim 1.1 - 1.4$



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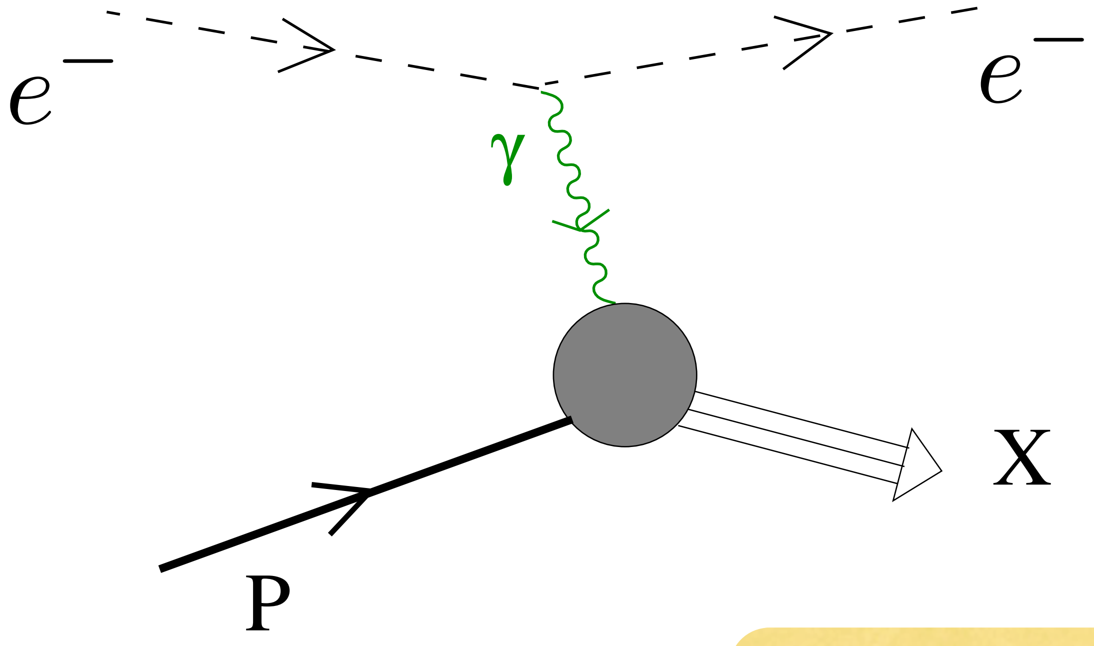

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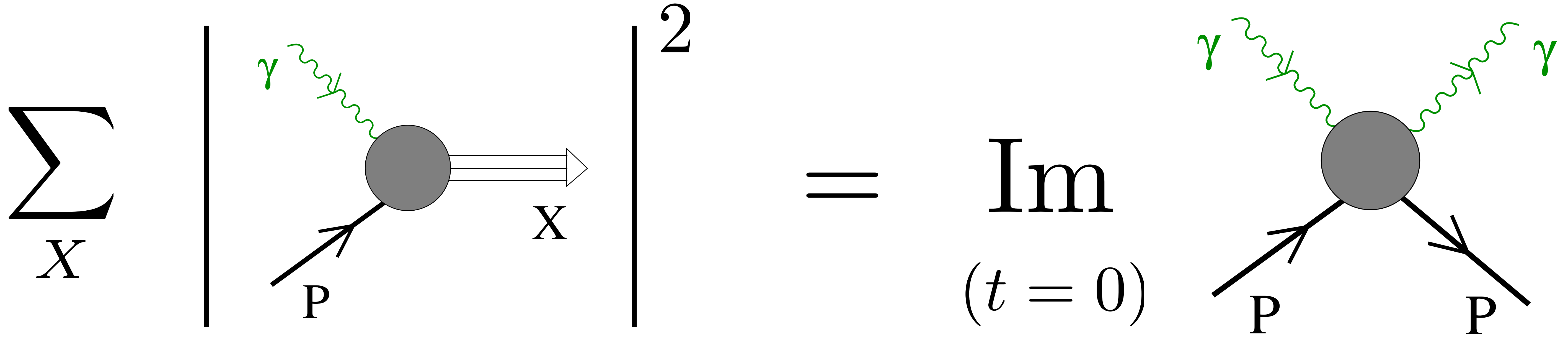

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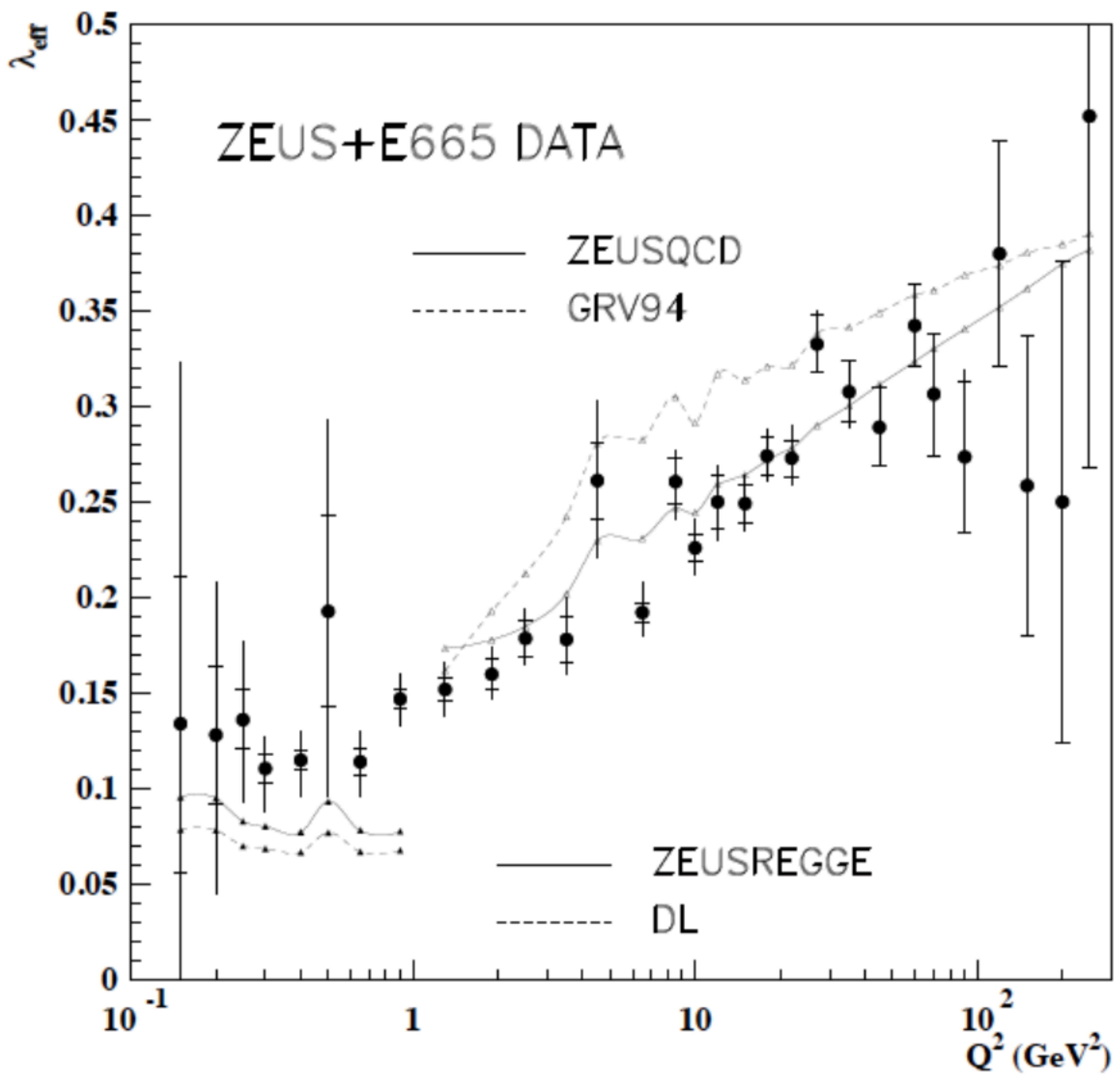

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Is it the same Regge trajectory?
One or two pomerons (soft and hard)?

Hard Pomeron [BFKL - Balitsky, Fadin, Kuraev & Lipatov]

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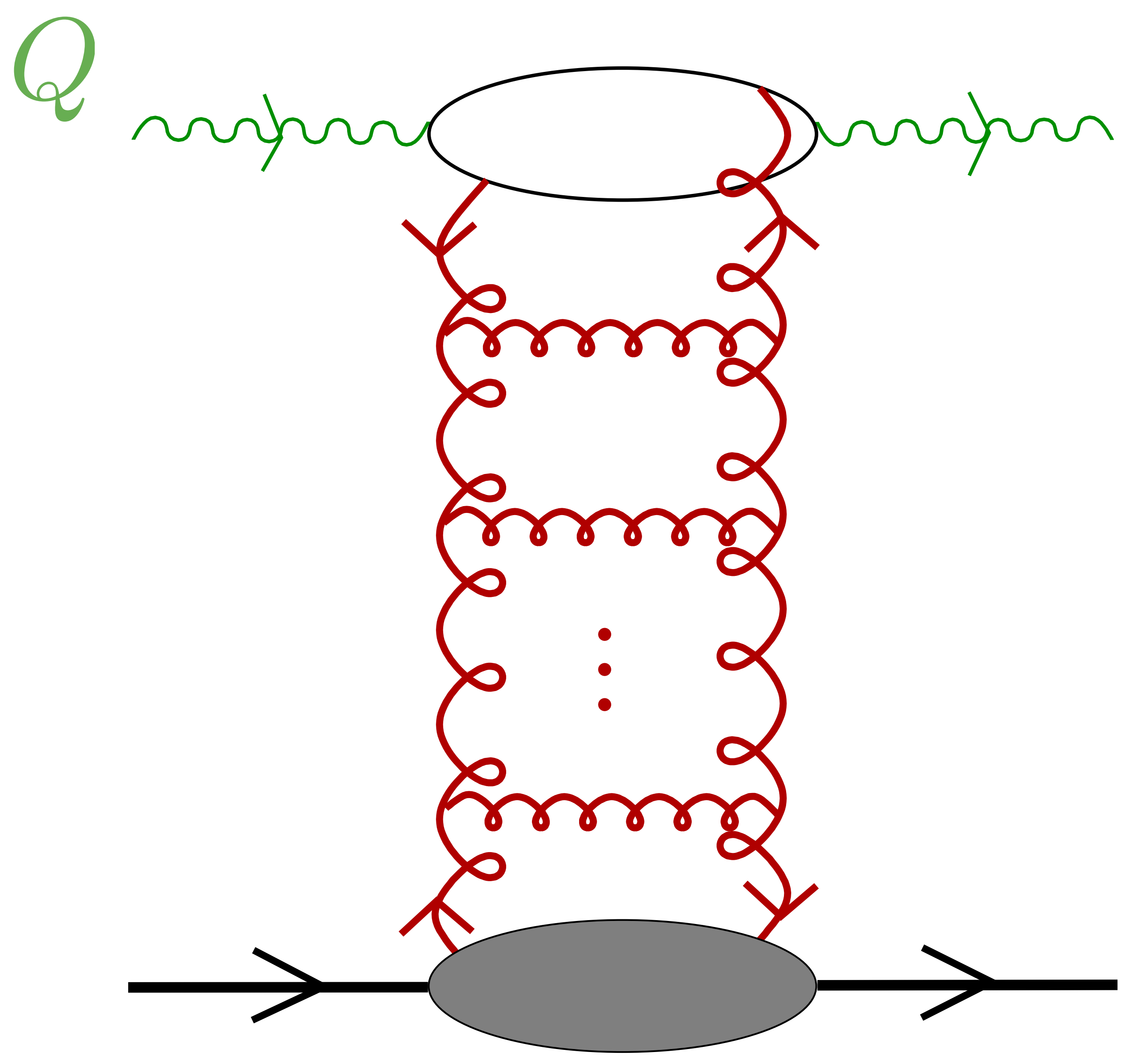


Two (reggeized) gluon exchange with ladder interactions

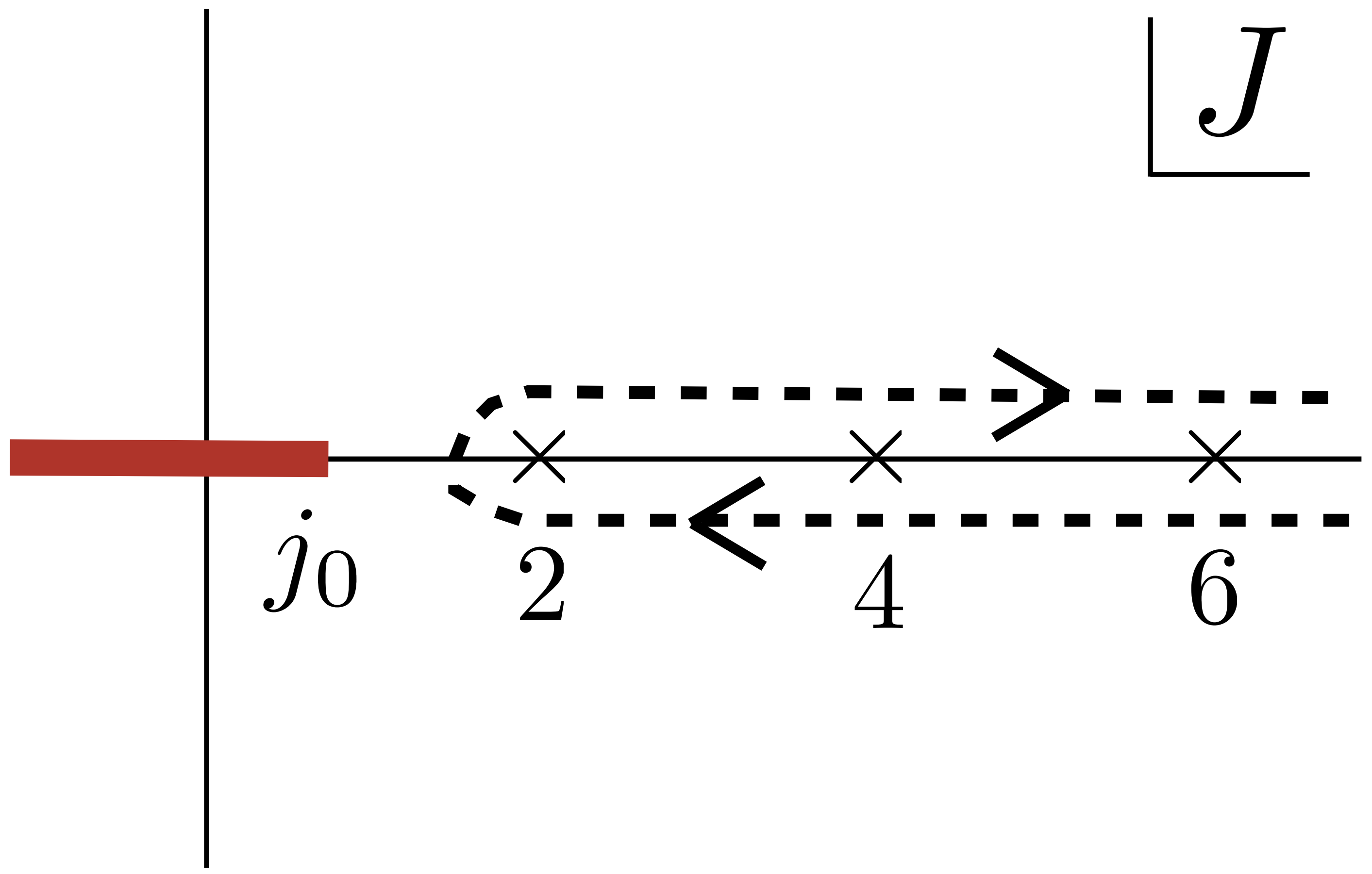
Resums $(\alpha_s \ln 1/x)^n$ contributions

Valid for hard probes $Q \gg \Lambda_{QCD}$

Exhibits conformal symmetry, hard pomeron is a cut in J-plane starting at

$$j_0 = 1 + \frac{12 \ln 2}{\pi} \alpha_s$$

2.65



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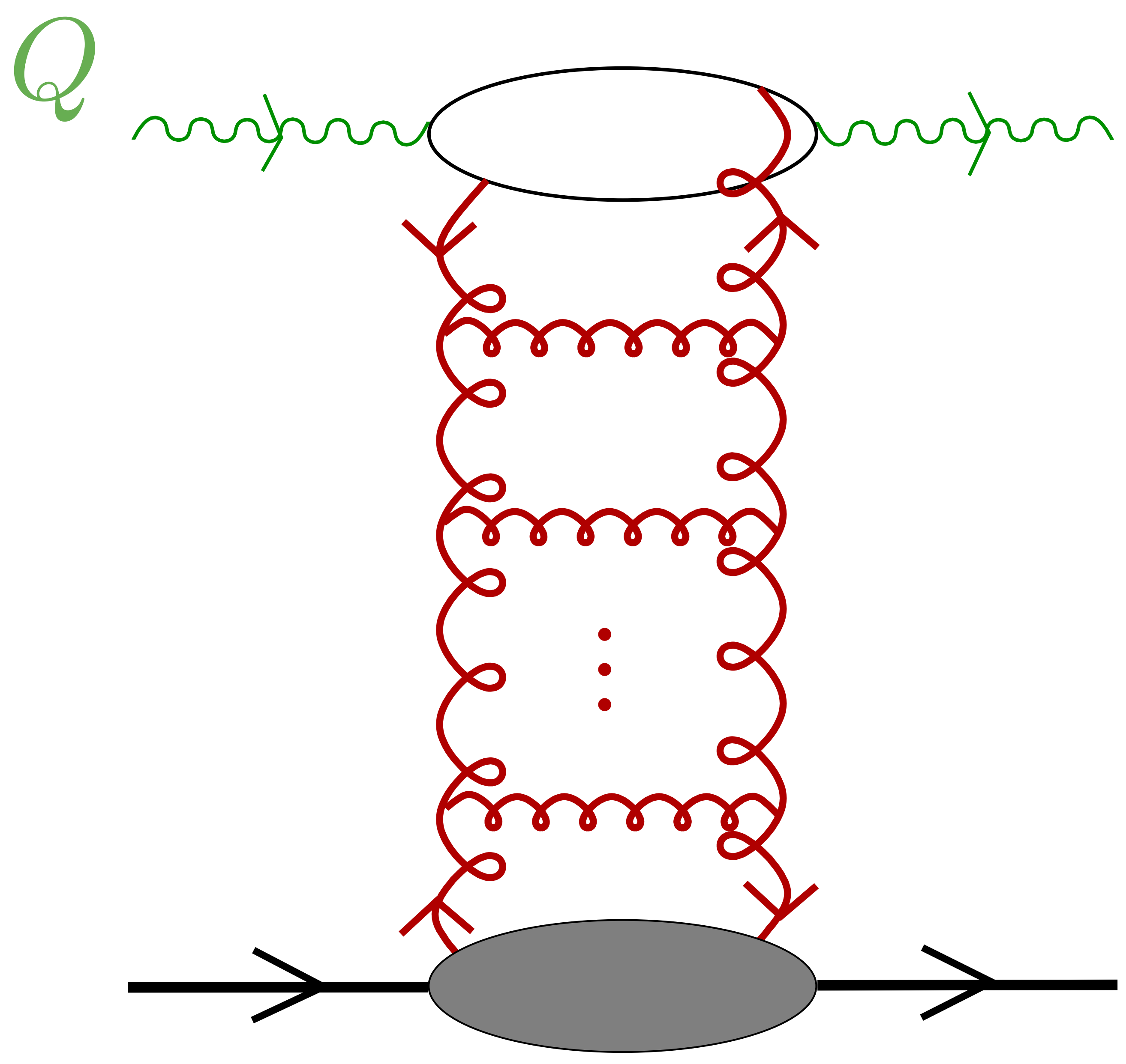

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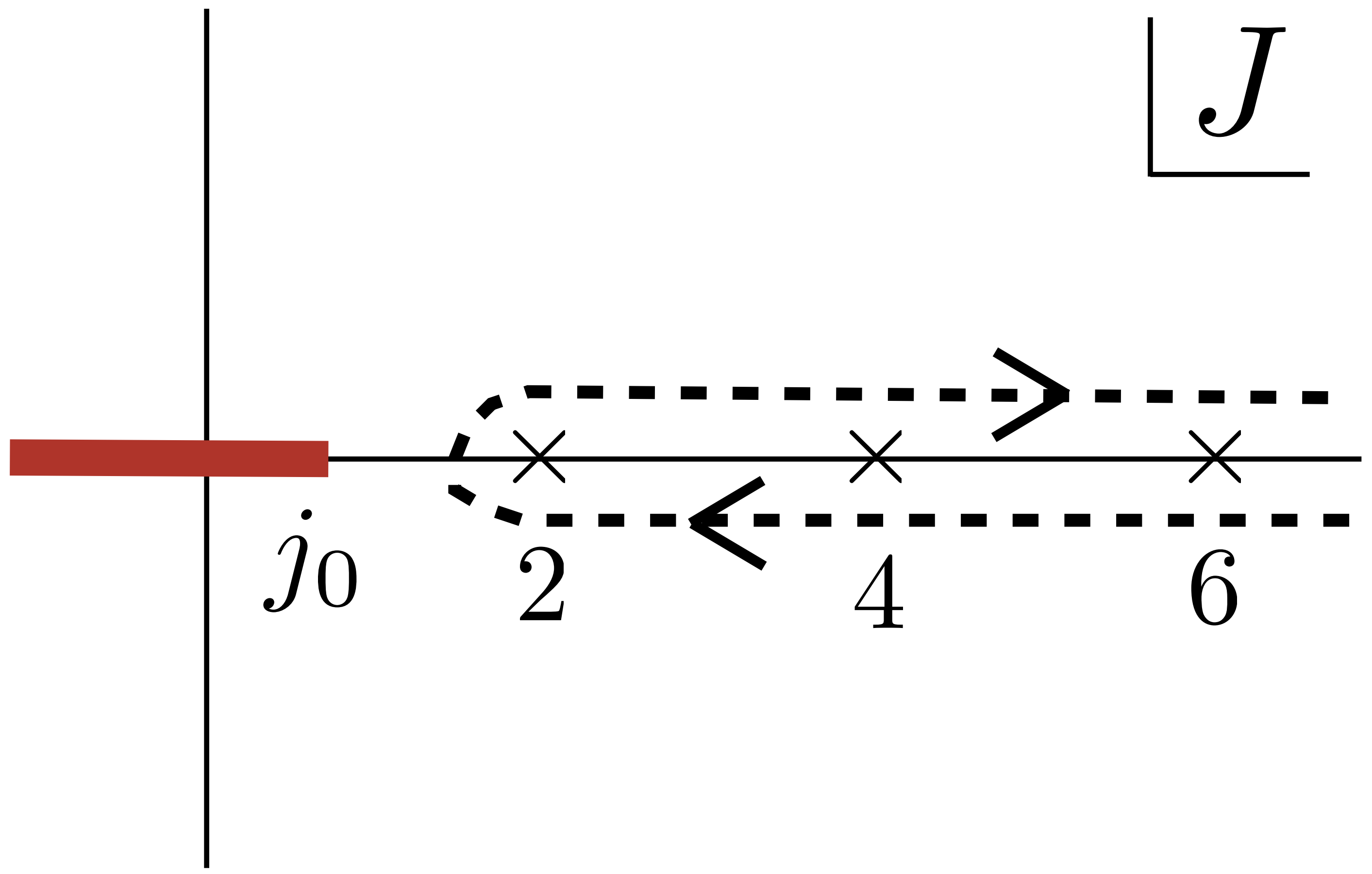


- Breaking conformal symmetry, explains well DIS data outside the confining region $Q \sim \Lambda_{QCD}$

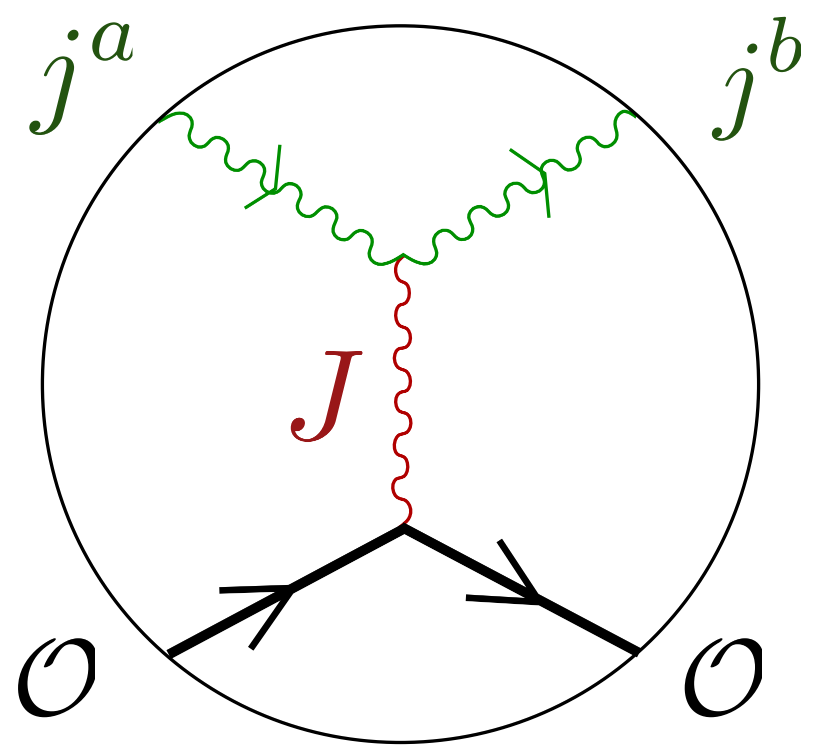
[Kowalski, Lipatov, Ross, Watt 10]

Graviton/Pomeron Regge trajectory [Brower, Polchinski, Strassler, Tan 06]

• At strong coupling pomeron trajectory described by string theory graviton Regge trajectory in Anti-de Sitter space (large N, conformal theory $\mathcal{N}=4\ SYM$)

$$\left(D^2 - m^2\right) h_{a_1 \ldots a_J} = 0$$

with $m^2 = \Delta(\Delta - 4) - J$



Again a cut in J-plane, starting at

$$j_0 = 2 - \frac{2}{\sqrt{\lambda}} \qquad \lambda = \frac{R^4}{\alpha'^2}$$

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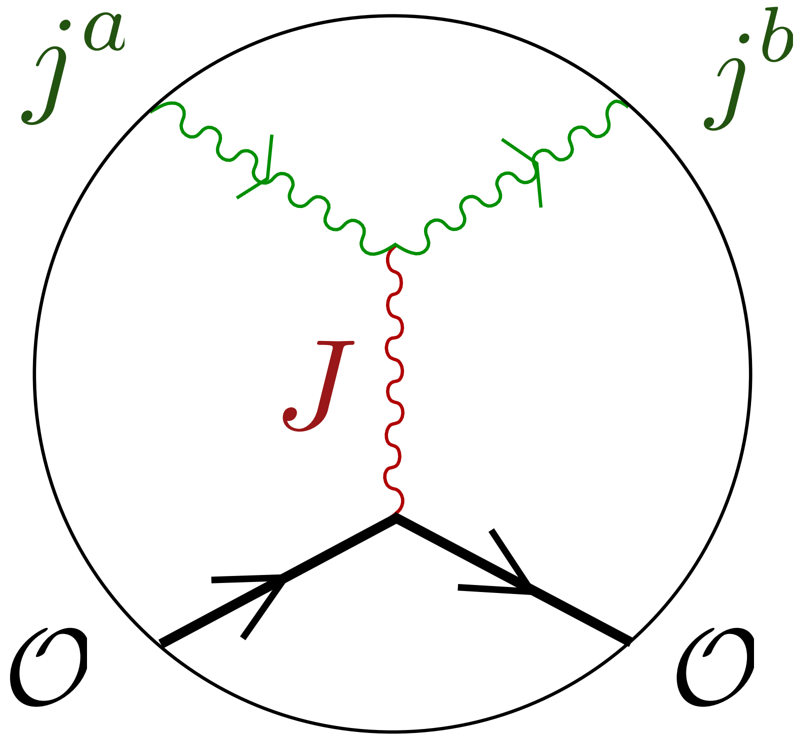


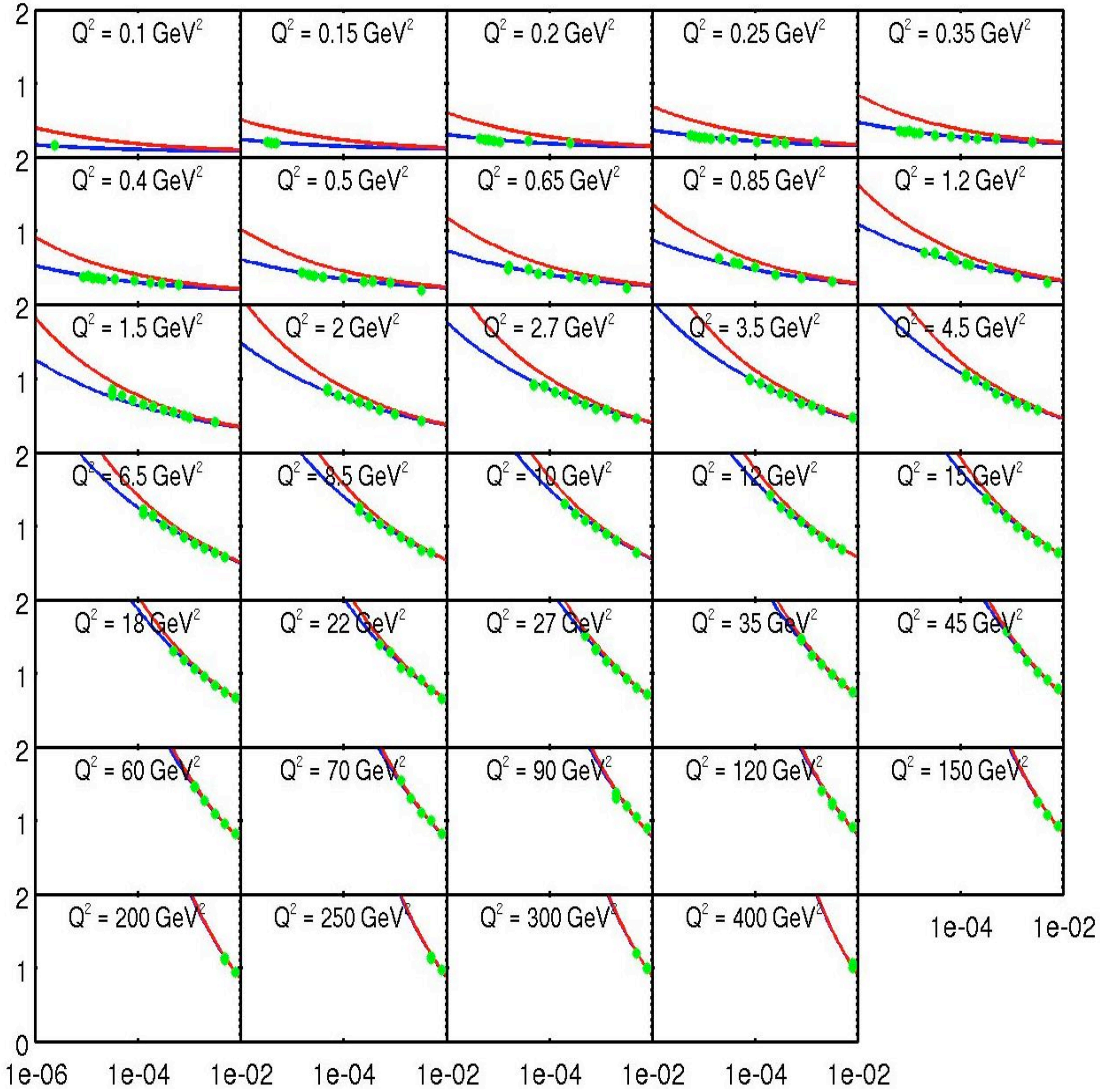
Again a cut in J-plane, starting at

$$j_0 = 2 - \frac{2}{\sqrt{\lambda}} \qquad \lambda = \frac{R^4}{\alpha'^2}$$

• Explains well low x data for DIS, DVCS, VMP including inside confining region $Q \sim \Lambda_{QCD}$

DIS - [Cornalba, MSC 08; Levin, Potashnikova 10; Brower, Djuric, Sarcevic, Tan 10]
DVSC - [MSC, Djuric 12]
VMP - [MSC, Djuric, Evans 13]

DIS - AdS Pomeron [Brower, Djuric, Sarcevic, Tan 10]



HERA combined data by H1 and ZEUS experiments [Aaron et al 10] with

$$0.10 < Q^2 < 400\ GeV^2,\ x < 10^{-2}$$

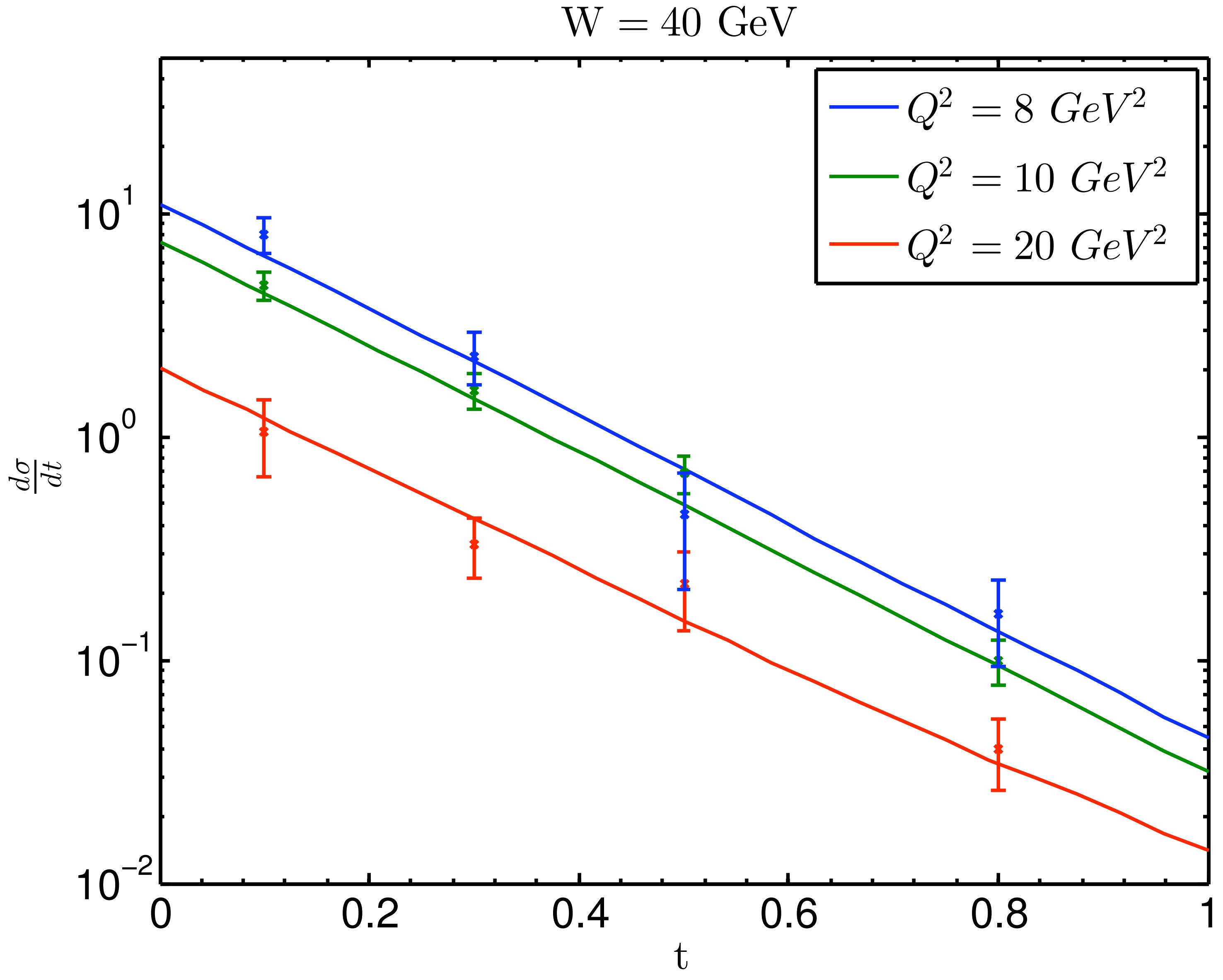
For hard wall model obtained excellent fit with (249 points)

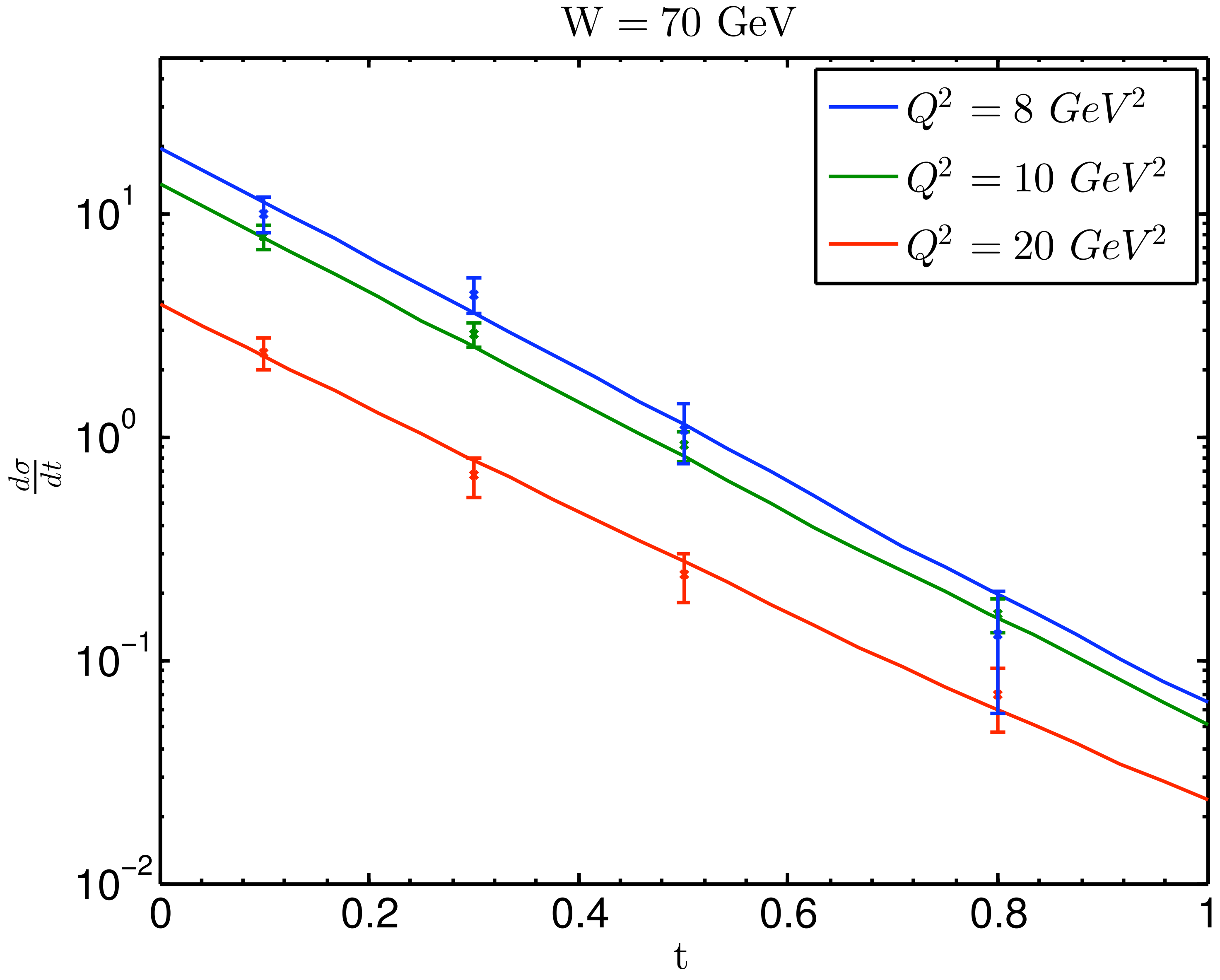
$$\chi^2_{d.o.f.} = 1.07$$

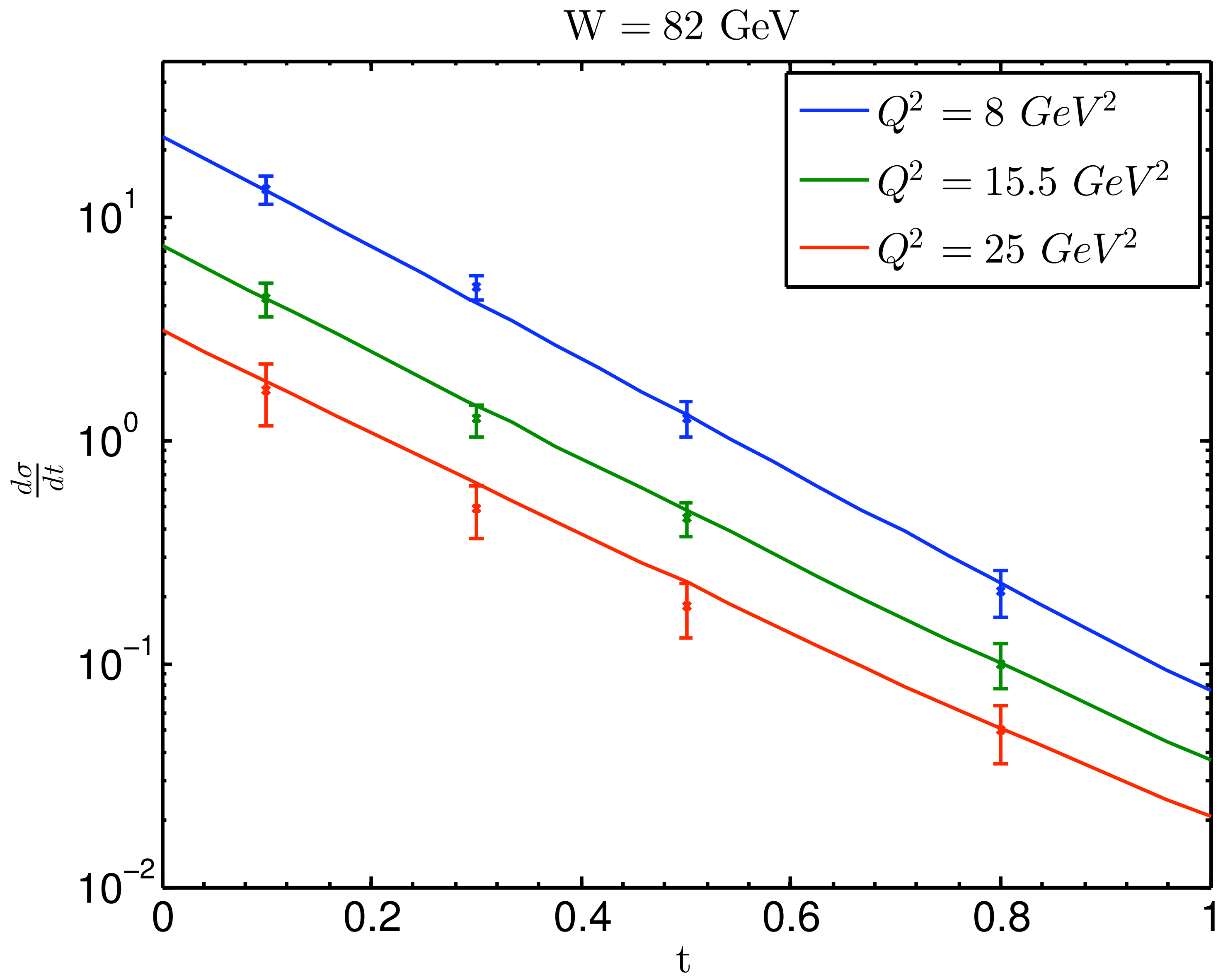
DVSC (differential cross section) [MSC, Djuric 12]

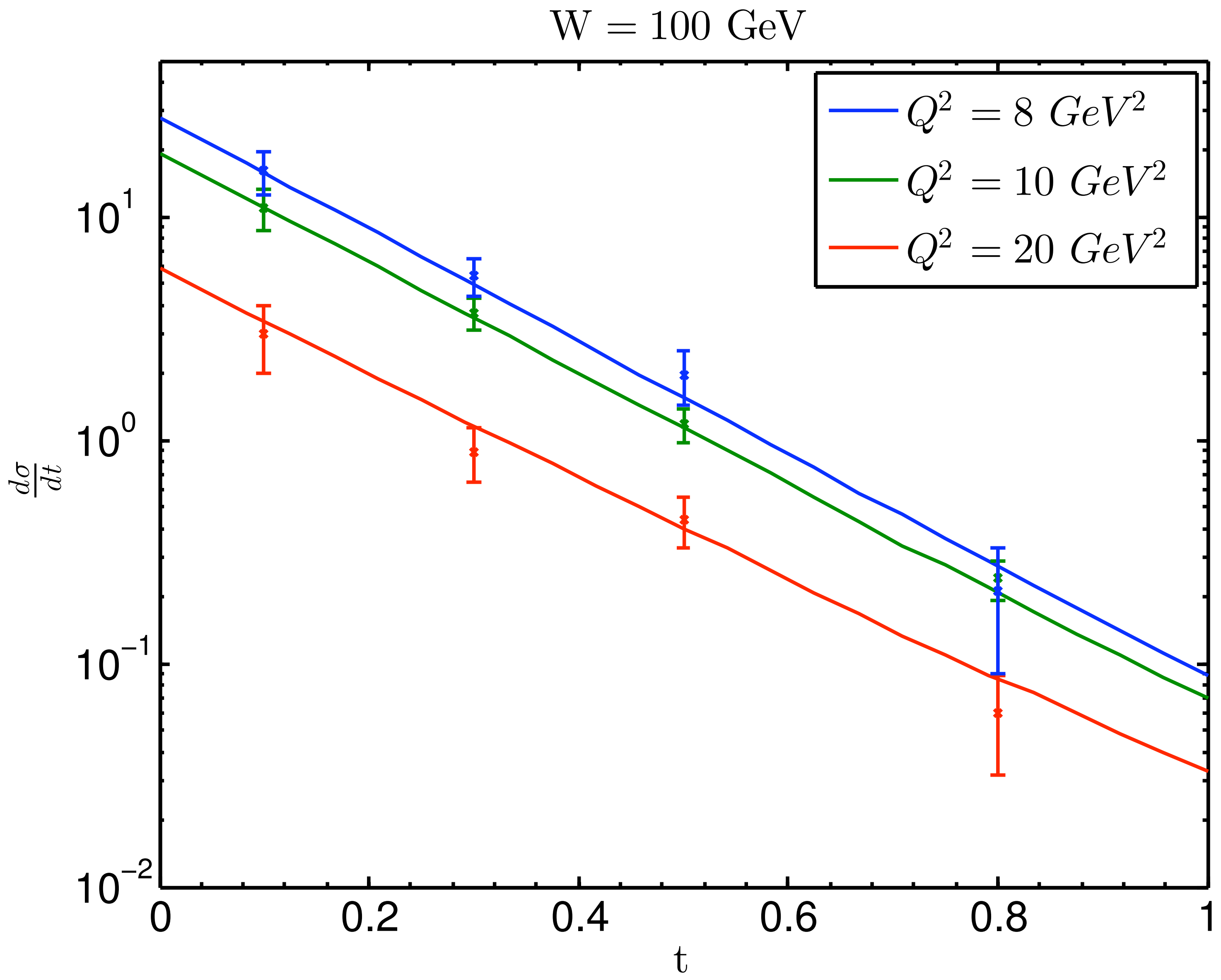
All data (52 points)

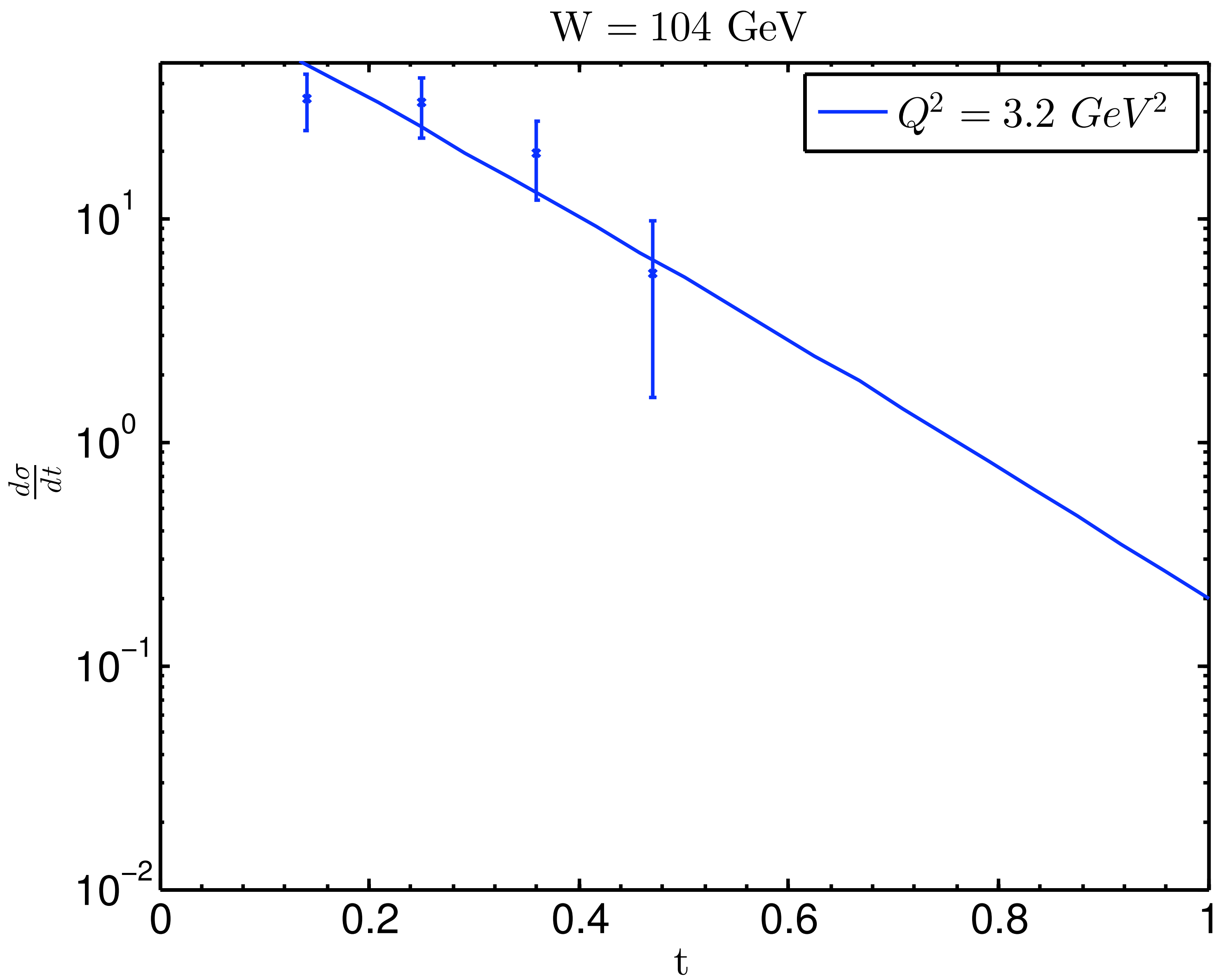
$$\chi^2_{d.o.f.} = 0.51$$



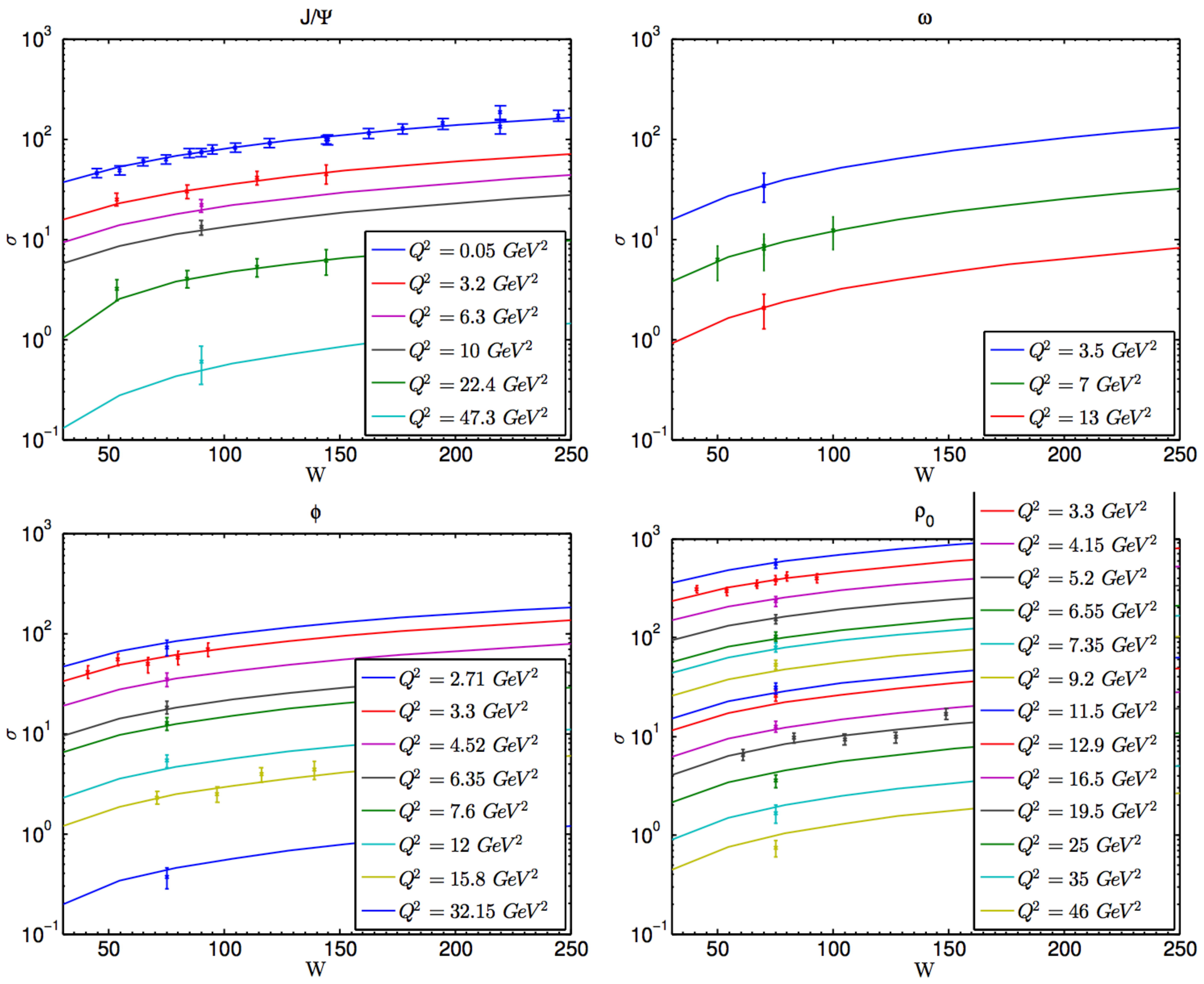








VMP ($J/\Psi,\ \omega,\ \phi,\ \rho_0$) [MSC, Djuric, Evans 13]



AdS/QCD [Gursoy, Kiritsis, Nitti 07]

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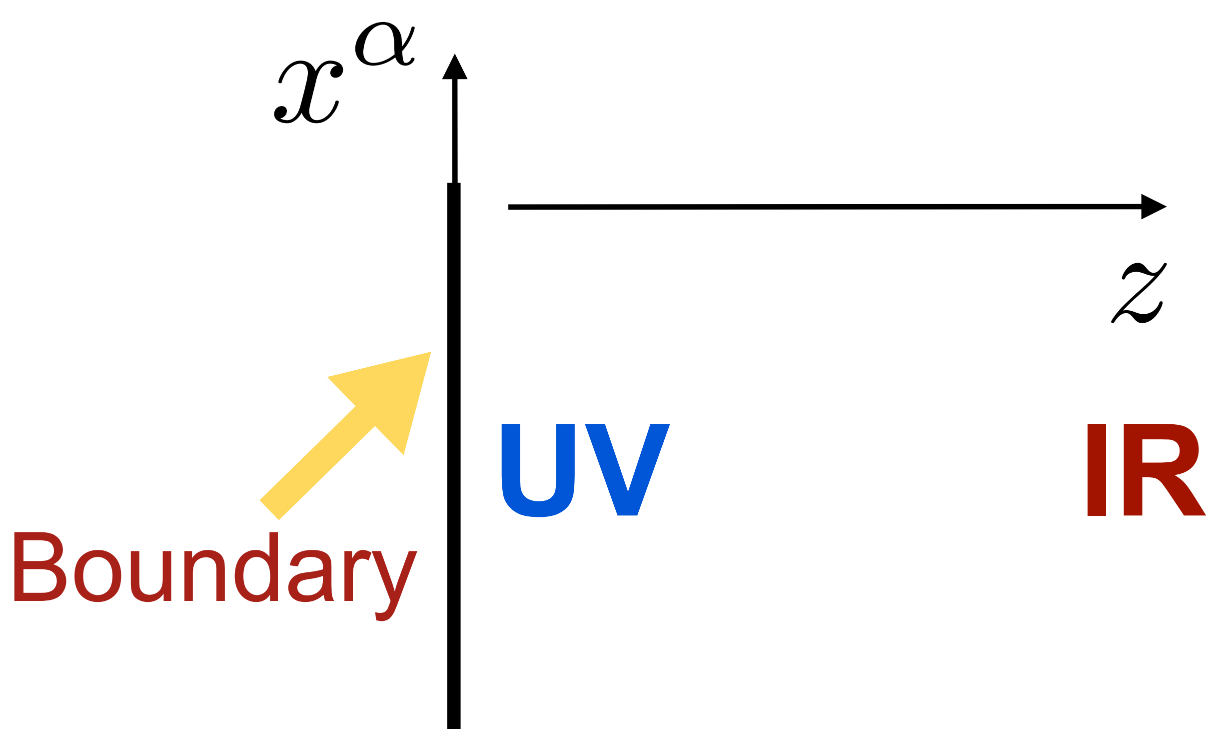
- 5D dilaton-gravity phenomenological model constructed to reproduce QCD

$$S = \frac{1}{2\kappa^2} \int d^5x \sqrt{-g} \left[R - \frac{4}{3}(\partial\phi)^2 + V(\phi) \right]$$



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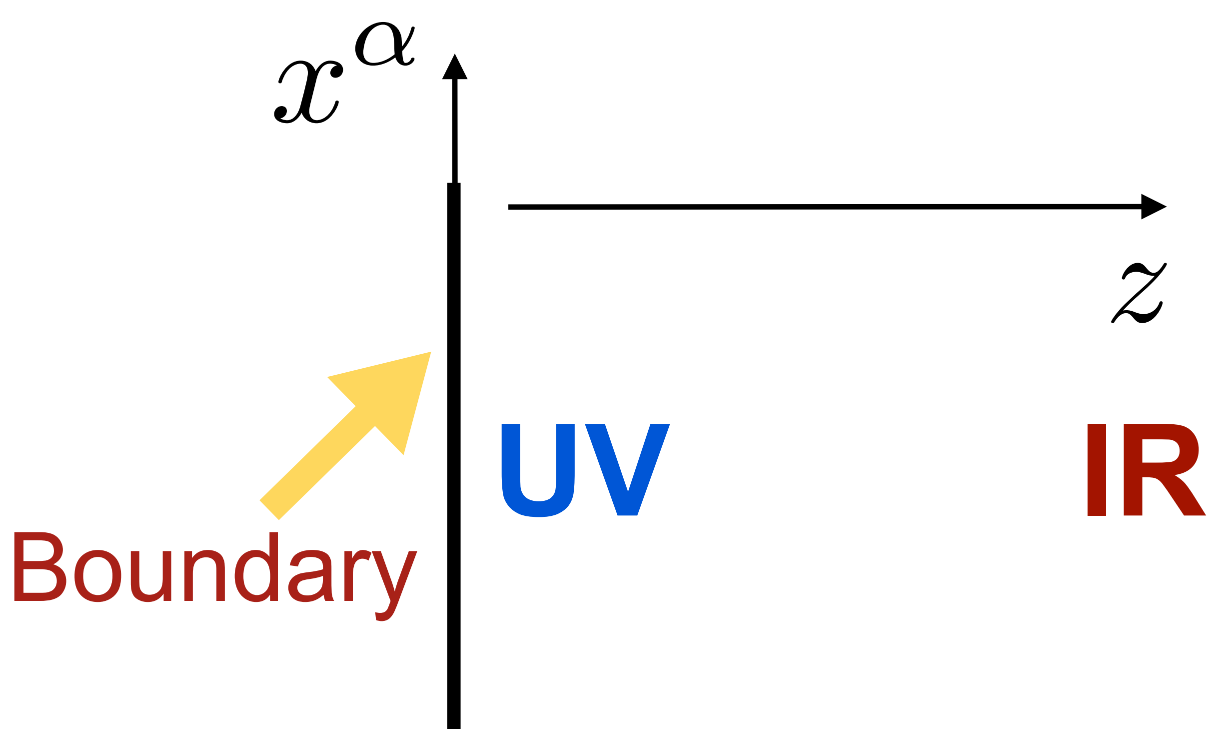
Judicious choice of potential with only 2 free parameters!



Constructed to match QCD perturbative beta function

Reproduces: - heavy quark-antiquark linear potential

- glueball spectrum from lattice simulations

- thermodynamic properties of QGP (bulk viscosity, drag force and jet quenching parameters)

Graviton/Pomeron Regge trajectory [Brower, Polchinski, Strassler, Tan 06]

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$$\mathcal{O}_J \sim F_{\alpha[\beta_1} D_{\beta_2} \dots D_{\beta_{J-1}} F_{\beta_J]}{}^{\alpha}$$

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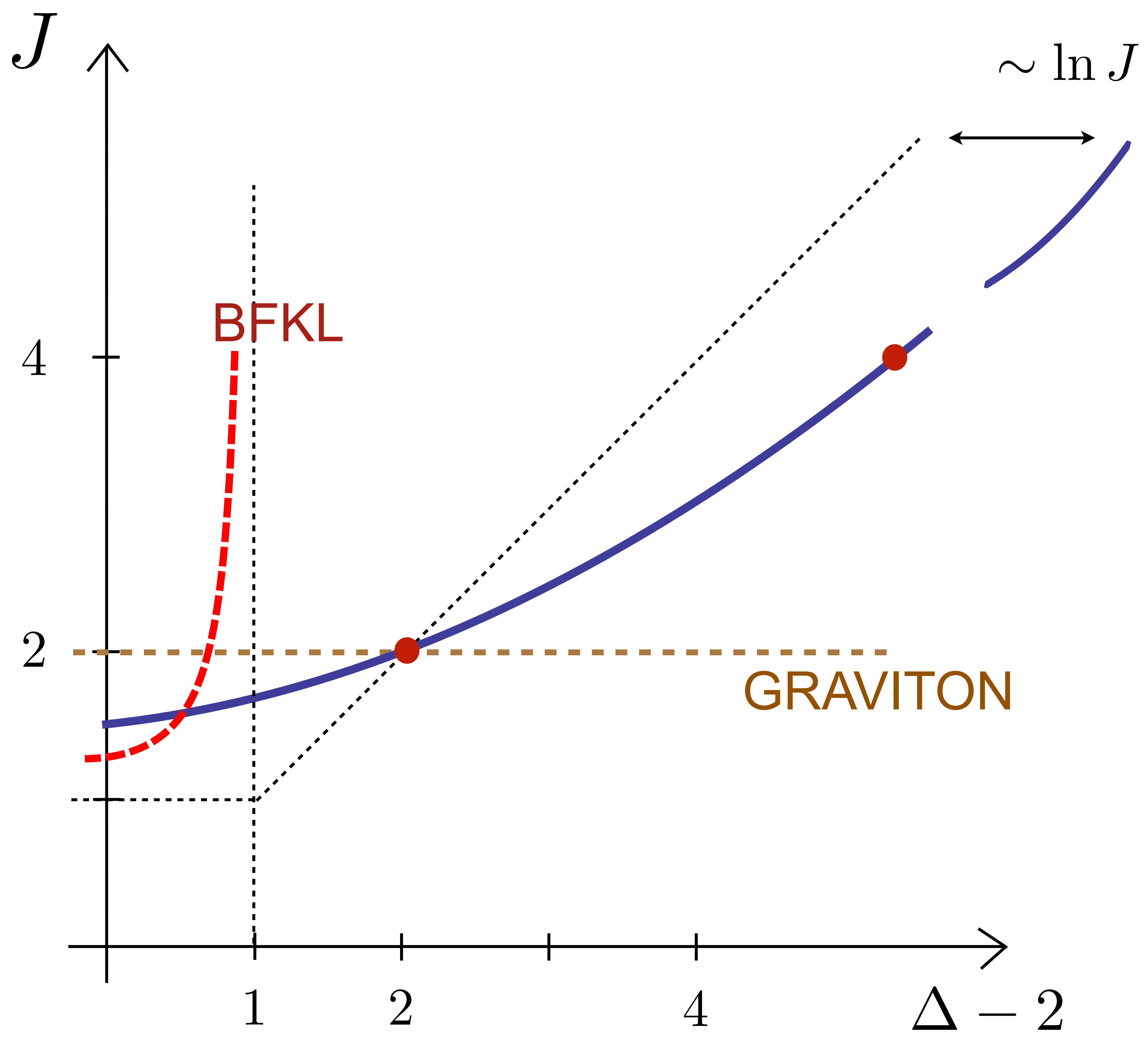

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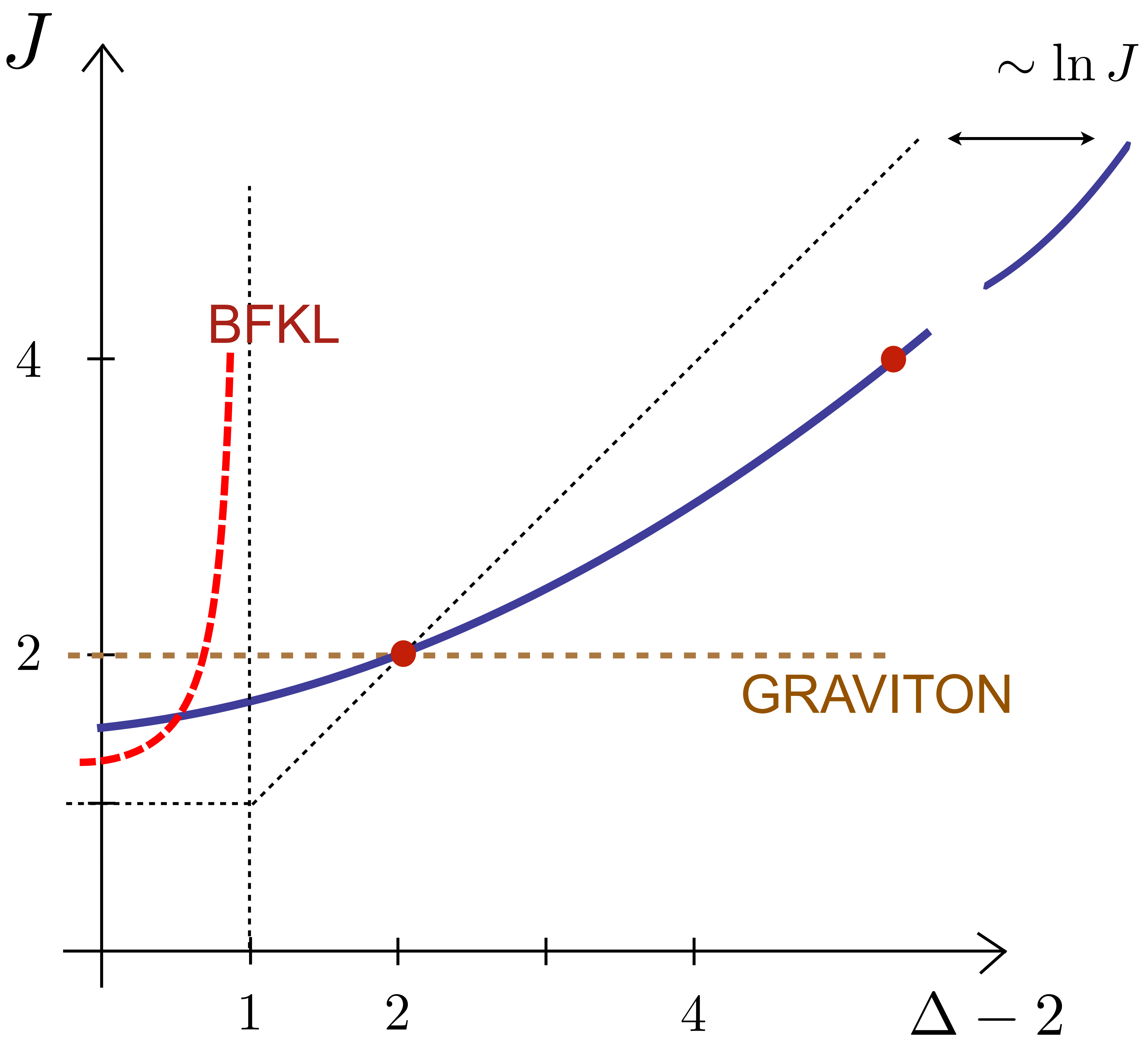
- Diffusion limit

$$J(\Delta) = J_0 + \mathcal{D}\,(\Delta - 2)^2 \;\Longrightarrow\; m^2 = \frac{2}{\alpha'}(J-2) - \frac{J}{L^2}$$



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$$\Big[\big(D^2 - 2\partial^b\phi D_b - \Delta(\Delta-4)\big)g_{a_1 b}g_{a_2 c} + J R_{a_1 b a_2 c}\Big]h^{bc}{}_{a_3\ldots a_J} = 0$$

$\Delta = \Delta(J)$ e.g. in perturbation theory

$\Delta = 2 + J + \gamma_J$

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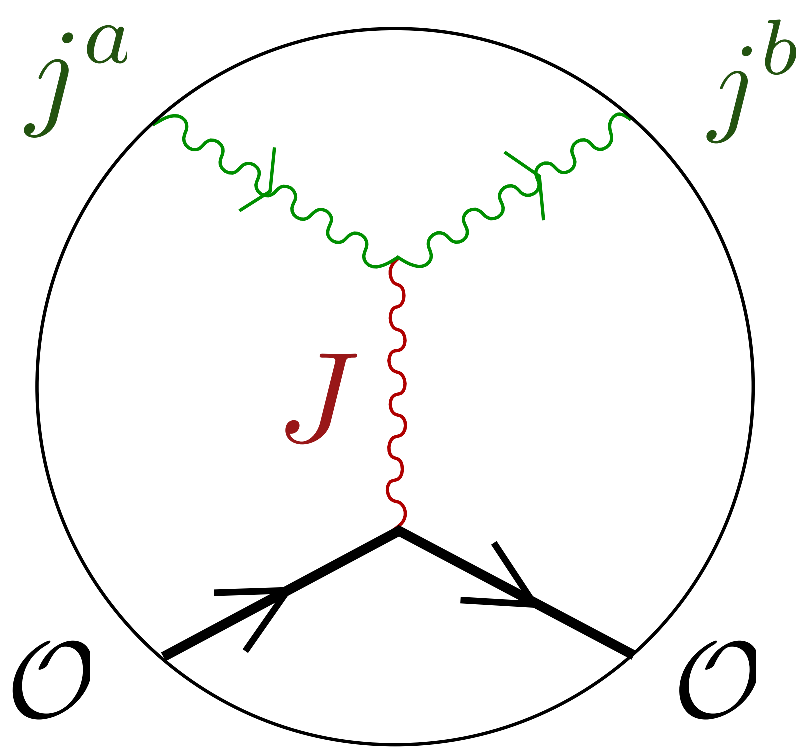
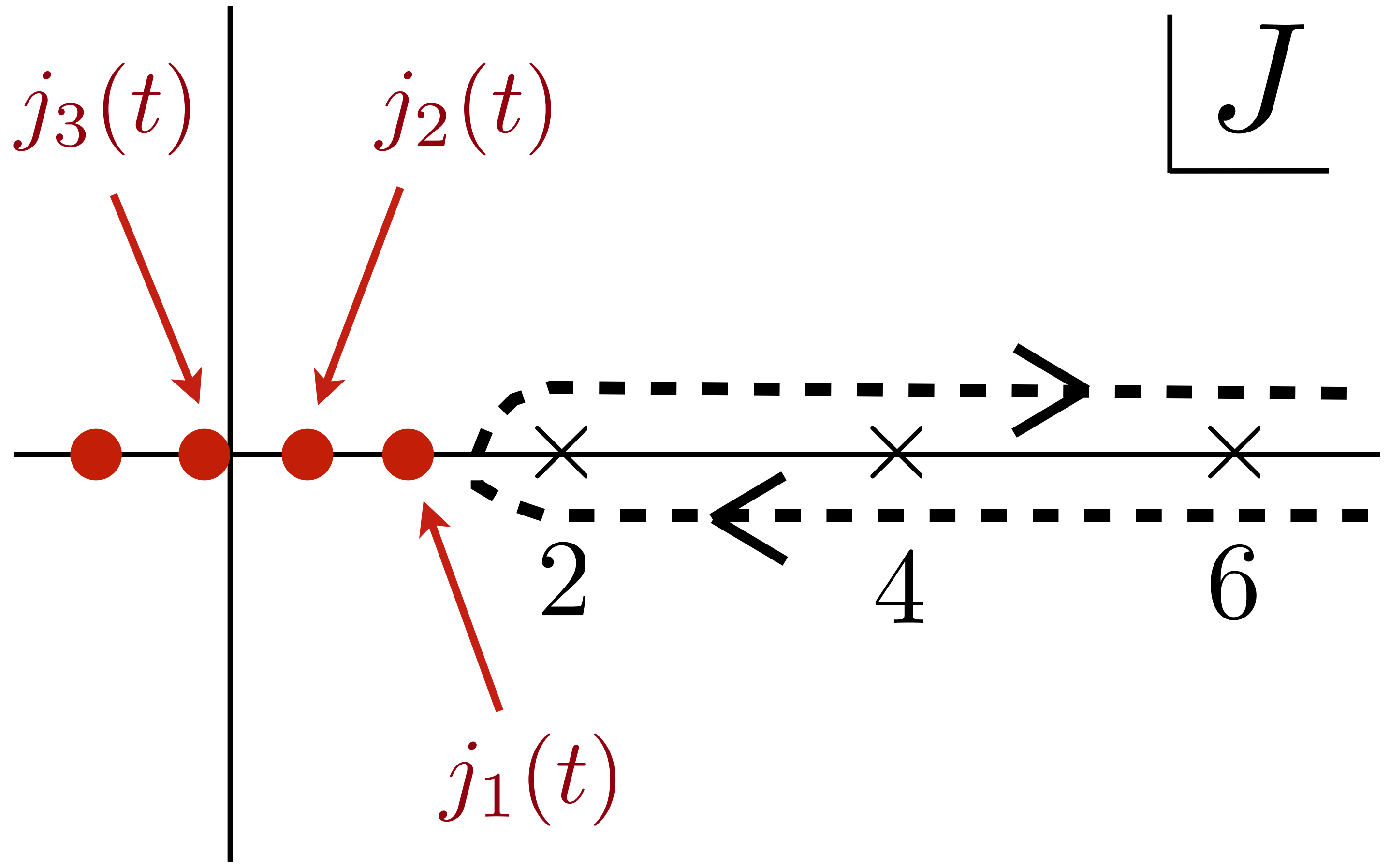
- Sum over spin J exchanges in 5D dual theory





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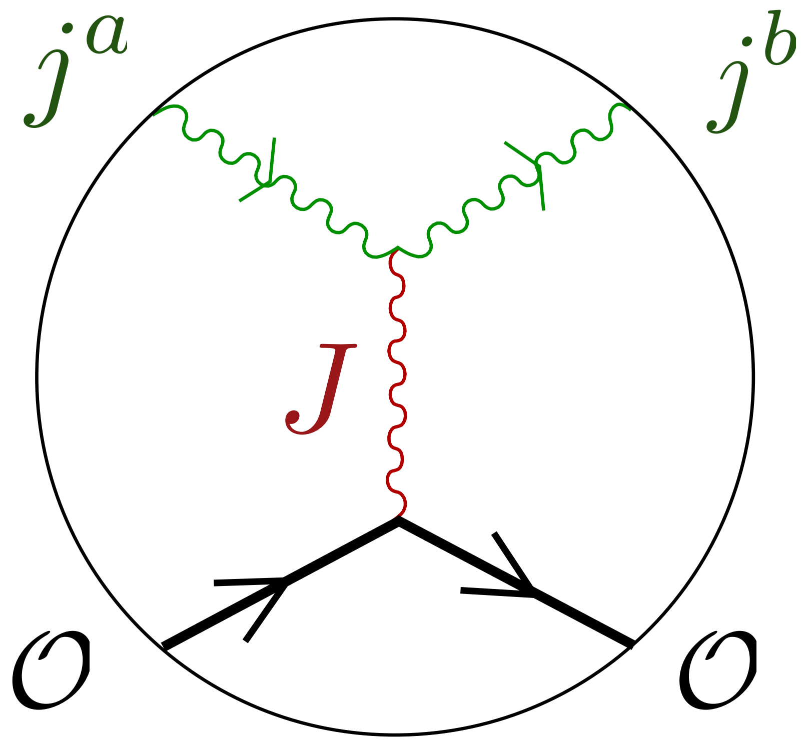

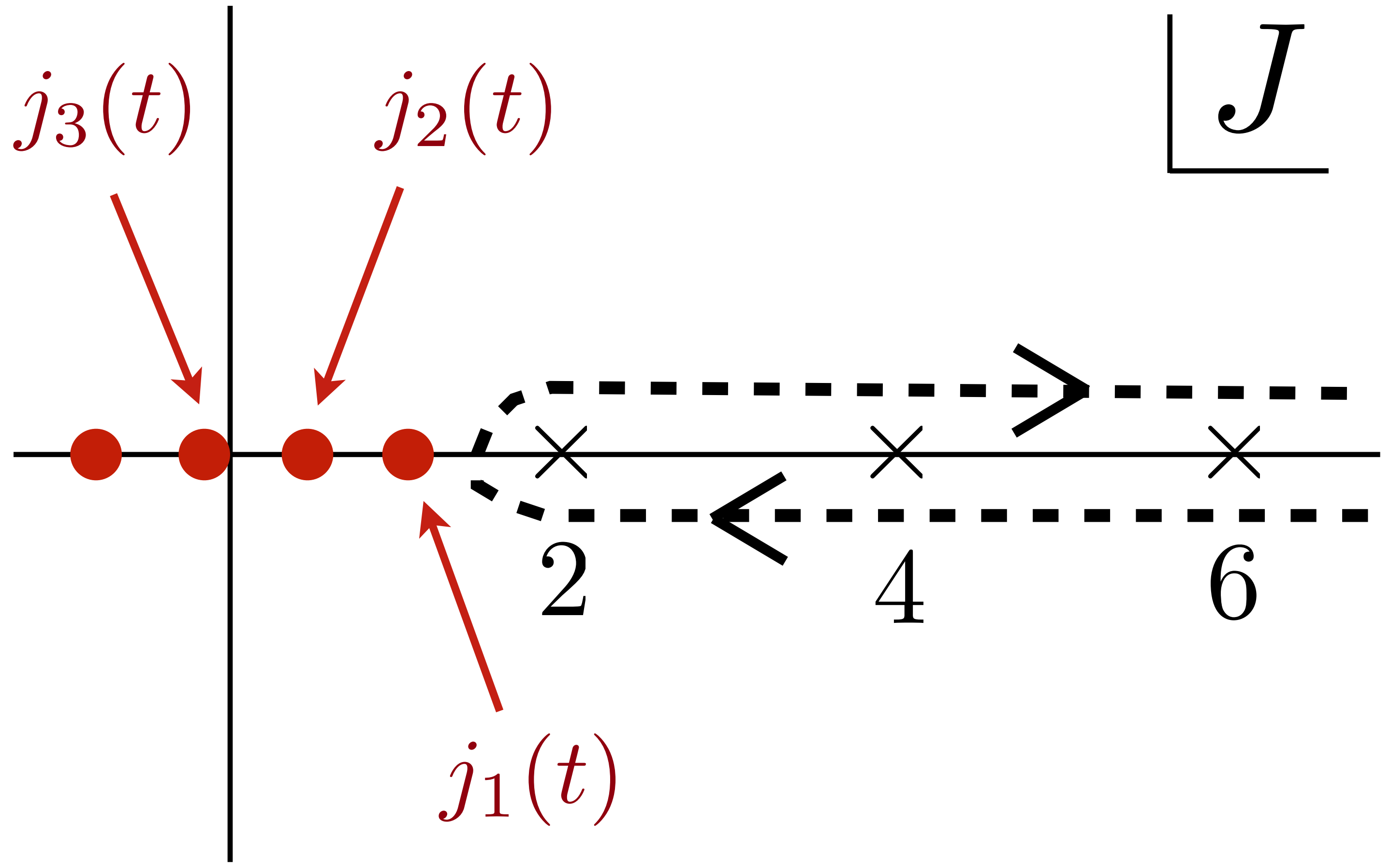

- Analytically continue using diffusion approximation for $J < J_0$ ($\Delta \in \mathbb{C}$)

$$\Delta(\Delta-4) = \frac{2}{\alpha'}(J-2)$$

Pomeron Regge trajectories

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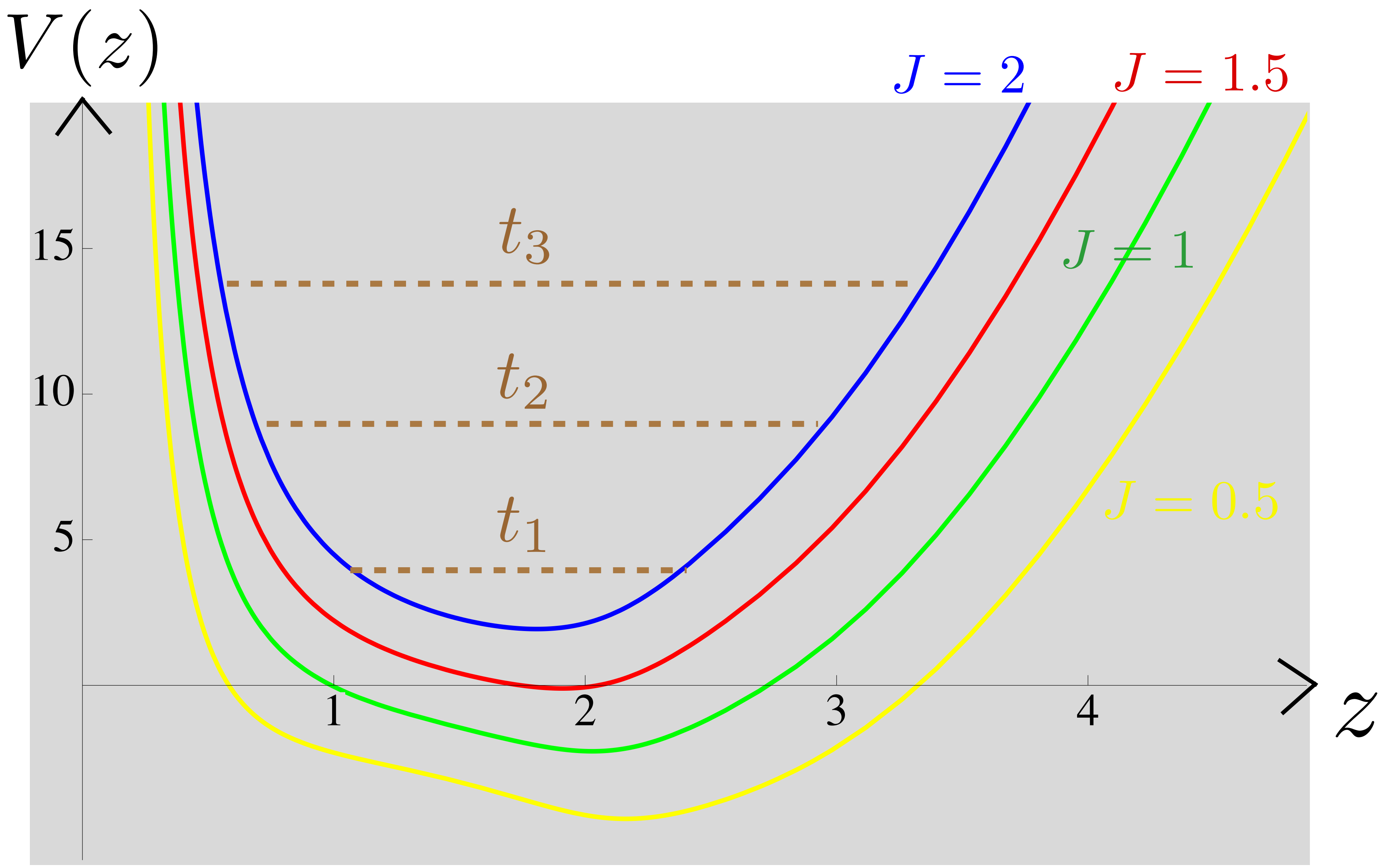
- Problem reduces to a J-dependent Schrodinger potential. Poles in J-plane at $t = t_n(J) \;\Rightarrow\; J = j_n(t)$

$$T(s,t) \sim \sum_n \left(e^{-A(z)-A(z')} s\right)^{j_n(t)} \psi_n(z)\psi_n^*(z')$$



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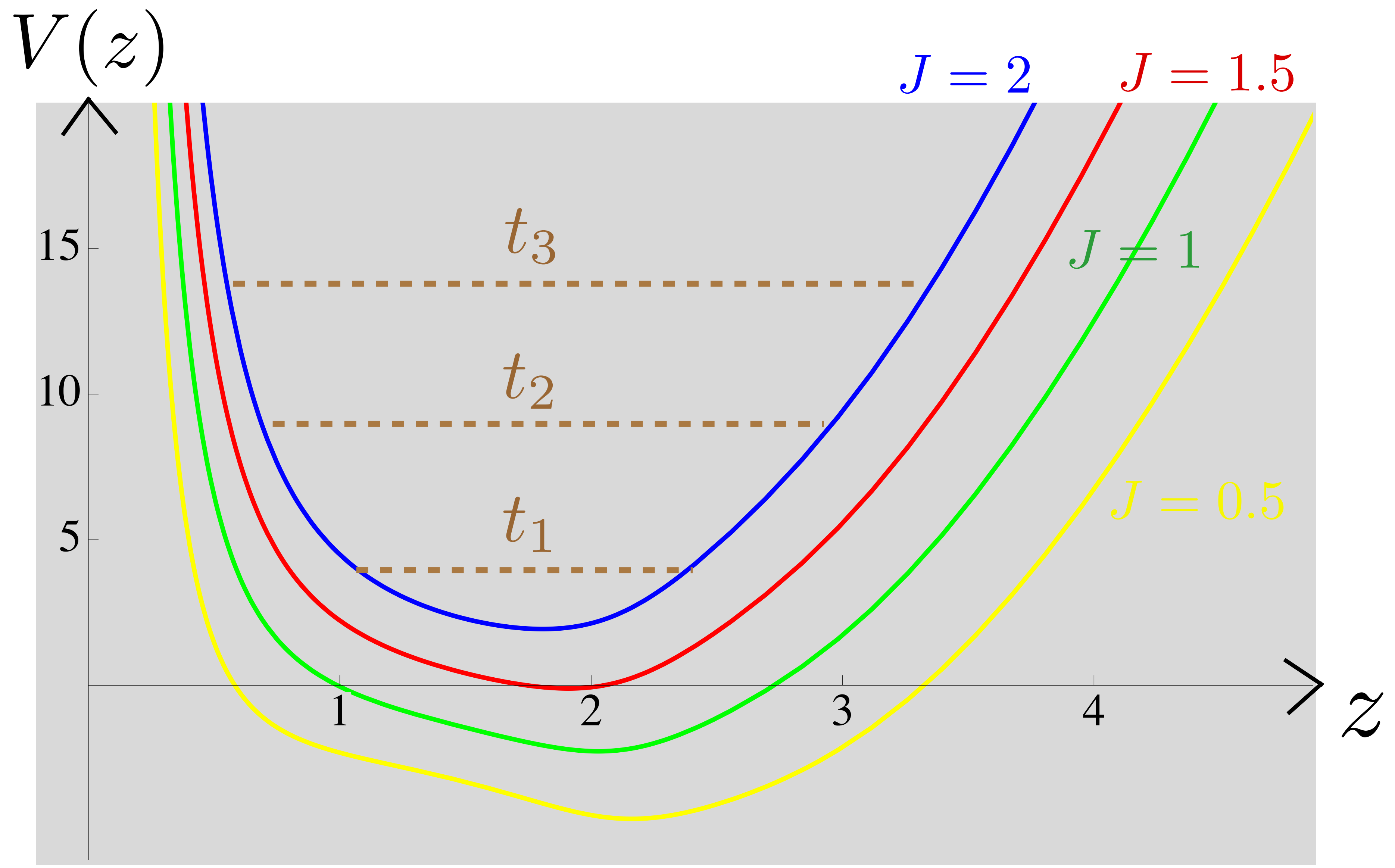
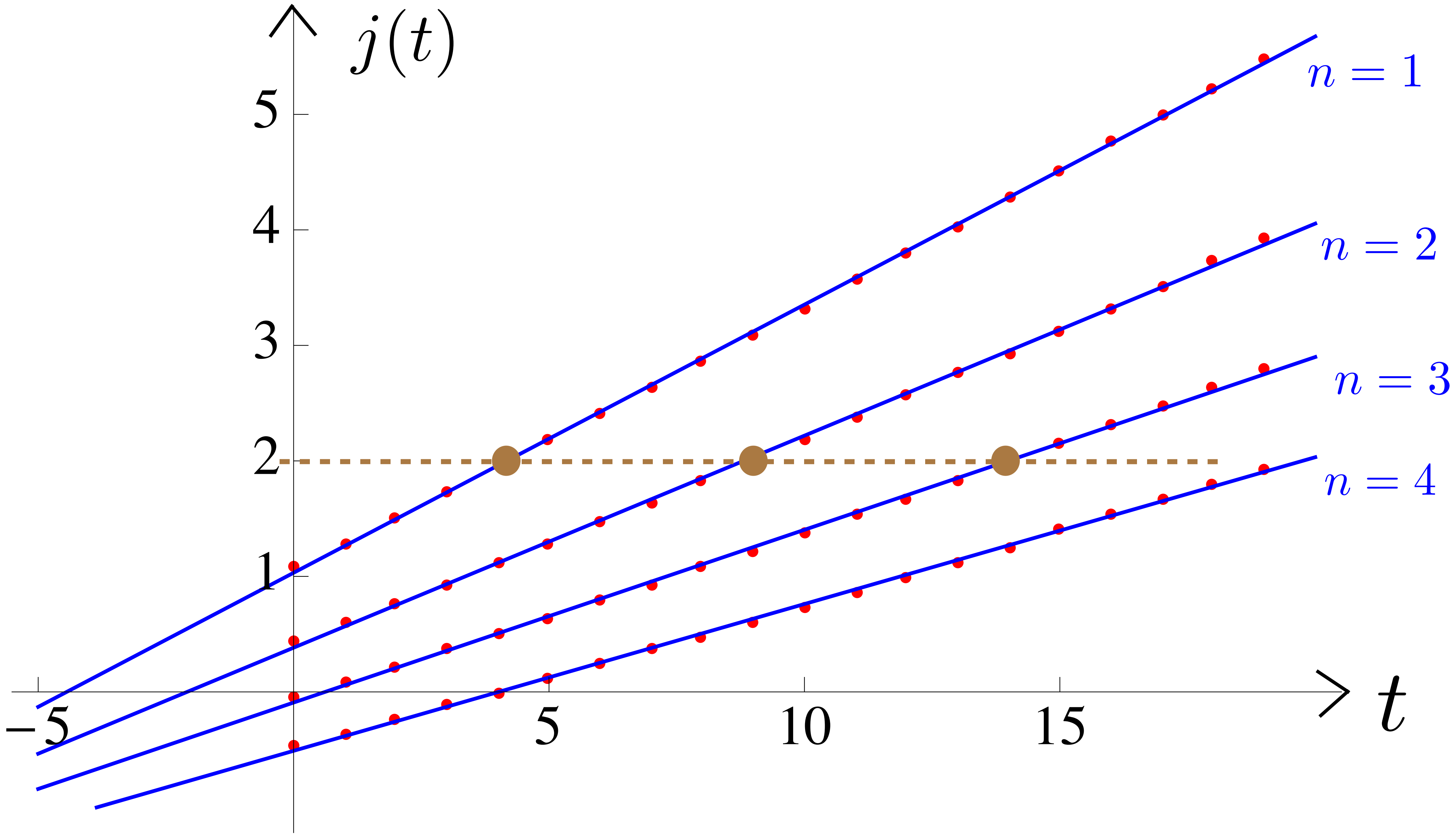


- Obtained approximate linear Regge trajectory. One free parameter to fit soft pomeron intercept and slop. E.g.

$$j_1(t) \approx 1.08 + 0.22\,t$$



Free parameter $l_s = 0.18$ consistent with value obtained for quark-antiquark potential

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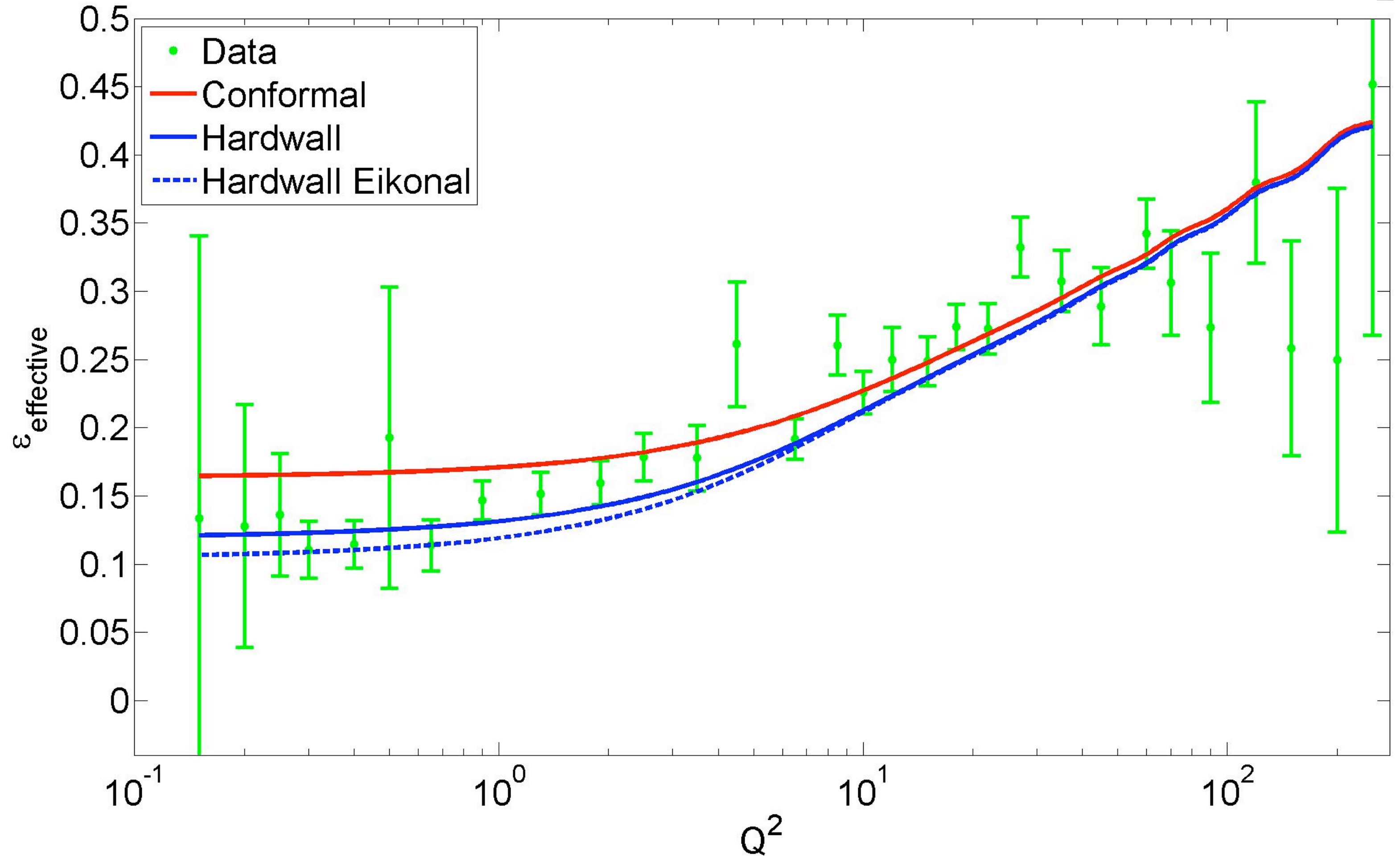
- Connection with hard-pomeron. Understand running of effective exponent

[Brower, Djuric, Sarcevic, Tan 10]



$$\sigma \sim \frac{1}{s} \text{Im}\, T(s,t=0) \sim f(Q) \left(\frac{1}{x}\right)^{\epsilon_{eff}(Q)}$$

Add next sub-leading poles and study behavior with a varying probe scale Q

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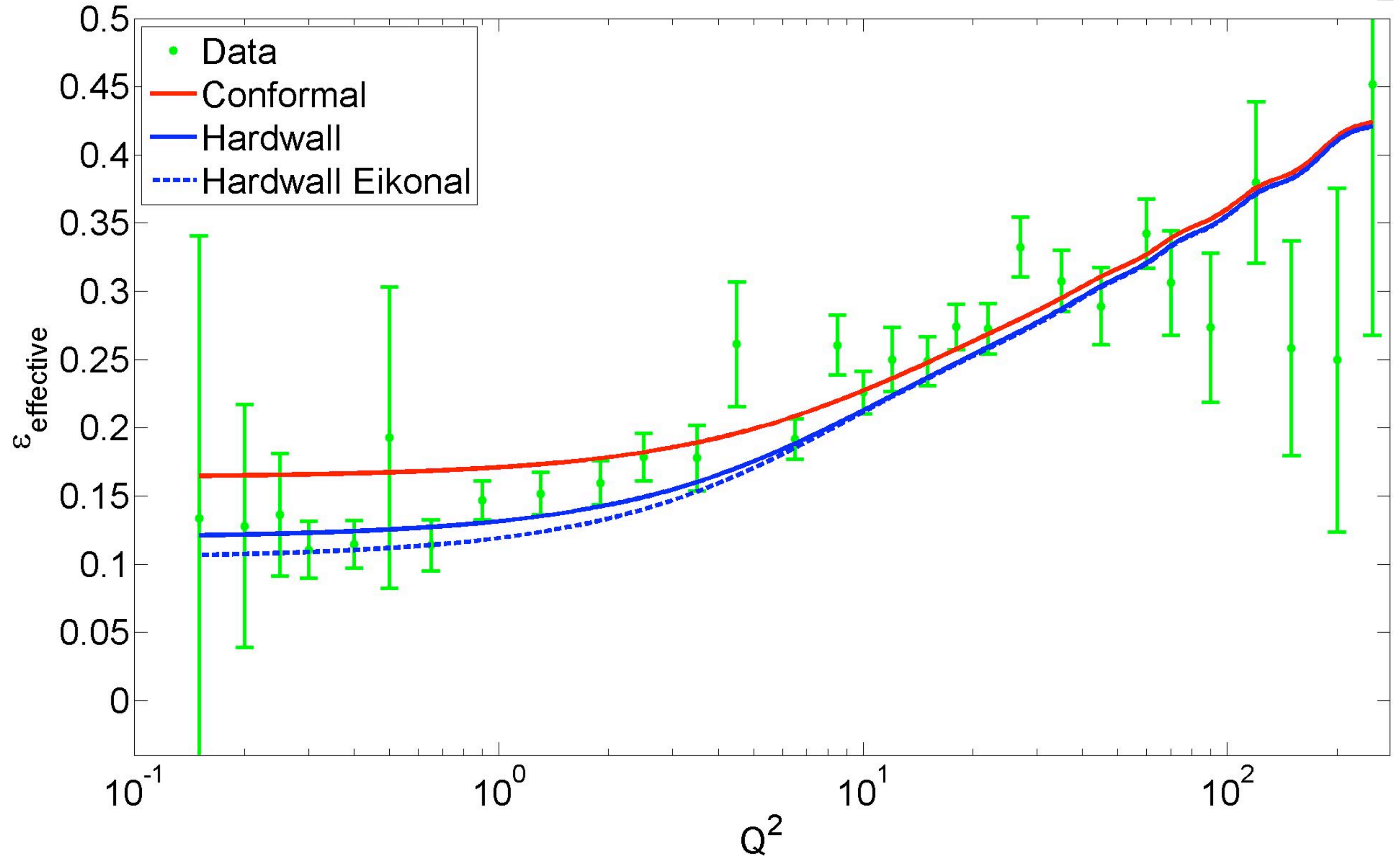
- AdS/QCD phenomenological model matches surprisingly well the intercept and slope of Donnachie-Landshoff pomeron

- Connection with hard-pomeron. Understand running of effective exponent

[Brower, Djuric, Sarcevic, Tan 10]



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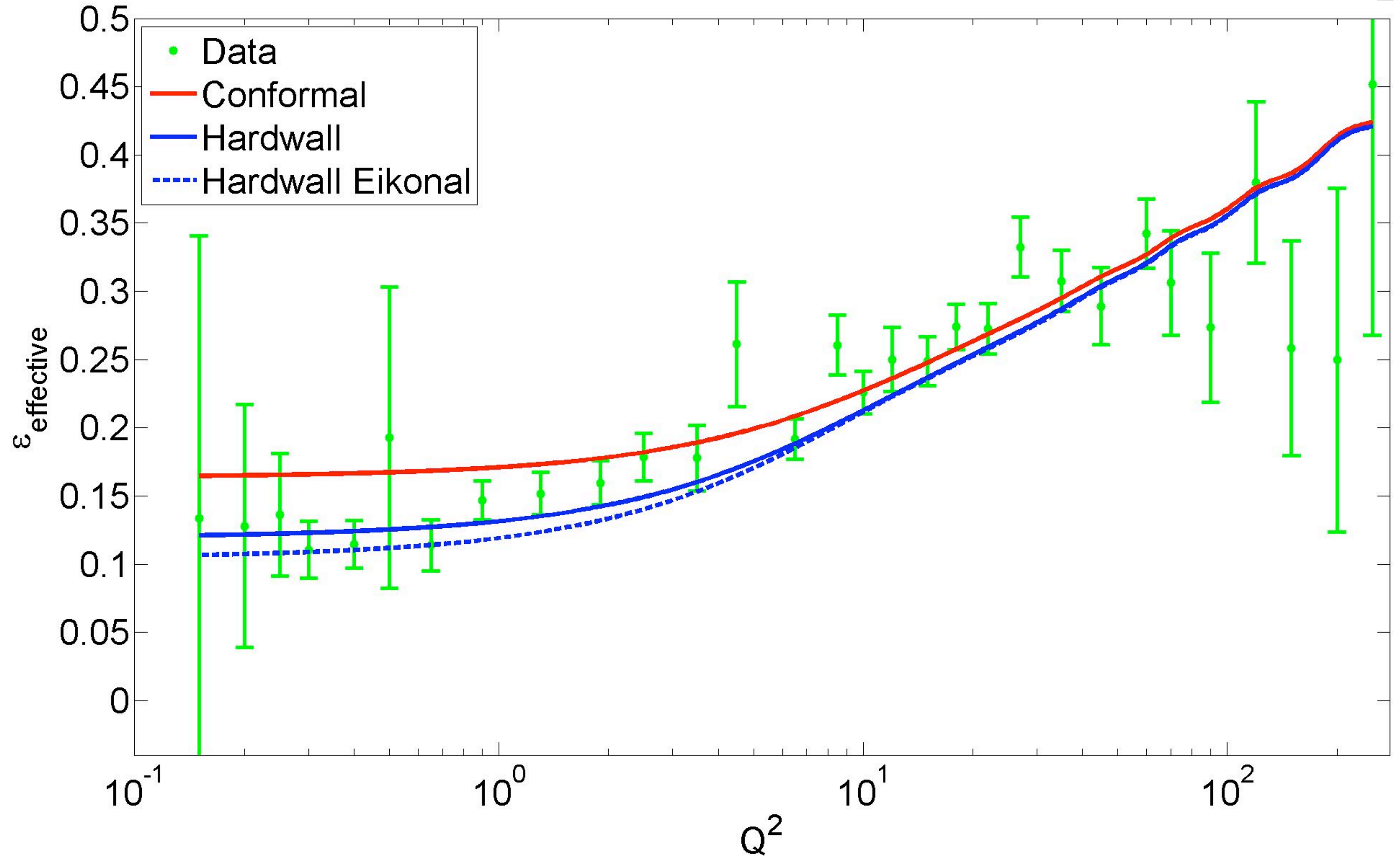

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- Make a careful analysis of data for DIS, DVSC and VMP. Goal:

unify soft and hard pomerons

THANK YOU