Small-x Scattering and Gauge/Gravity Duality

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work with
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Miguel S. Costa [DVCS]
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- This perturbative QCD approach works at high Q^2, and the goal is to extend it as much as possible into the low Q^2 region, typically up to somewhere of the order $Q^2 = 1 - 4GeV^2$.

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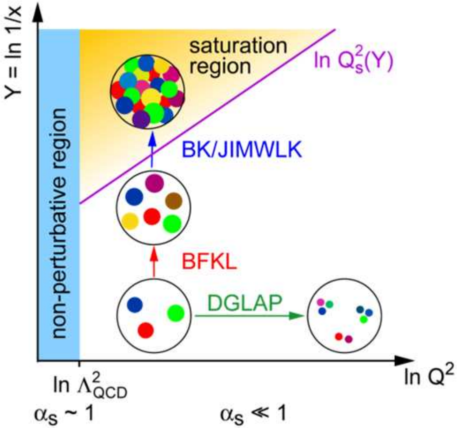

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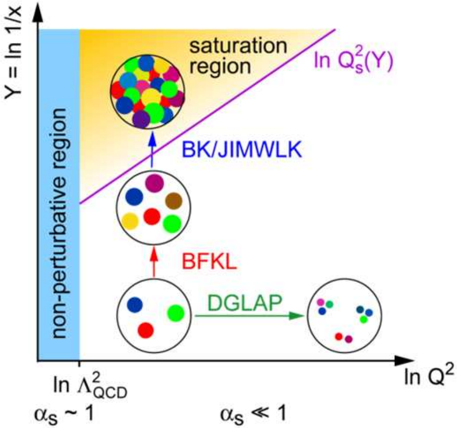

- Our goal is to apply an alternative method to study the non-perturbative and saturation regions, and also see how much can they be applied to the higher Q^2 region as well.

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- In perturbative QCD, the propagation of the Pomeron is given by the BFKL equation.

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$$ds^2 = e^{2A(z)} \left[-dx^+ dx^- + dx_\perp dx_\perp + dz dz \right] + R^2 d^2 \Omega_5 .$$

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- Correspondence works in the limit

$$N_C \to \infty, \quad \lambda = g^2 N_C = R^4/\alpha'^2 \gg 1, \text{fixed}$$

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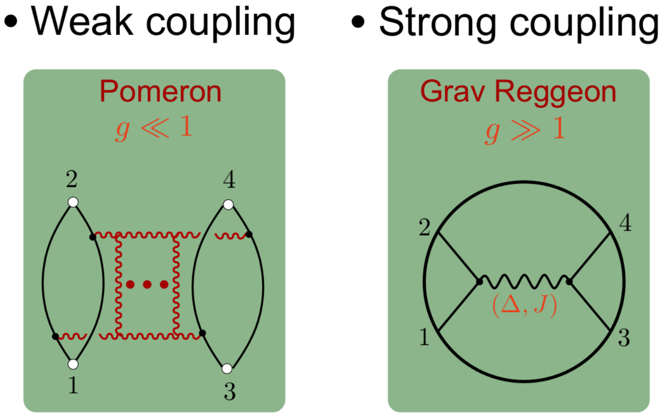

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- Similar procedure can be applied for other trajectories (e.g. for the Odderon [Brower, MD, Tan, 2008])

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- At $t = 0$
  Weak coupling:

$$\mathcal{K}(k_\perp, k'_\perp, s) = \frac{s^{j_0}}{\sqrt{4\pi\mathcal{D}\log s}} e^{-(\log k_\perp - \log k'_\perp)^2/4\mathcal{D}\log s}$$

$$j_0 = 1 + \frac{\log 2}{\pi^2}\lambda, \quad \mathcal{D} = \frac{14\zeta(3)}{\pi}\lambda/4\pi^2$$

  Strong coupling:

$$\mathcal{K}(z, z', s) = \frac{s^{j_0}}{\sqrt{4\pi\mathcal{D}\log s}} e^{-(\log z - \log z')^2/4\mathcal{D}\log s}$$

$$j_0 = 2 - \frac{2}{\sqrt{\lambda}}, \quad \mathcal{D} = \frac{1}{2\sqrt{\lambda}}$$

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$$A(s,t) = 2is \int d^2 l e^{-i\mathbf{l}_\perp \cdot \mathbf{q}_\perp} \int dz d\bar{z} \, P_{13}(z) P_{24}(\bar{z})(1 - e^{i\chi(s,b,z,\bar{z})})$$

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- We can study different scattering processes by supplying P_{13} and P_{24}.
- For example, already applied to DIS [Brower, MD, Sarčević,Tan; Cornalba, Costa, Penedones], and DVCS [Costa, MD].

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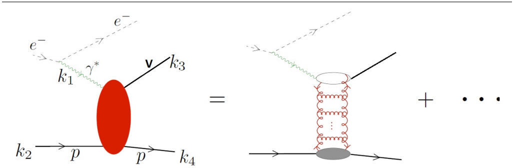

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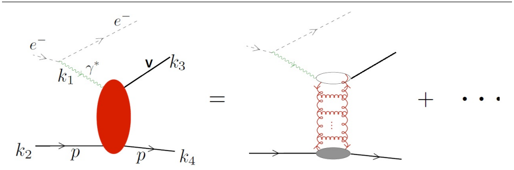

The vector mesons consist of a quark-antiquark pair, and have the same quantum numbers as the photon, $J^{PC} = 1^{--}$. The production of the ρ^0, ω, ϕ and J/Ψ was measured at HERA.

- We are interested in calculating the differential and exclusive cross sections

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- In this analysis we use

$$\Psi_n(z) = -(\sqrt{C \, \frac{\pi^2}{6}} \, z^2 \, K_n(Qz))(\frac{\sqrt{2}}{\xi J_1(\xi)} z^2 J_n(mz)), \;\; \Phi(\bar{z}) = \bar{z}^3 \, \delta(\bar{z} - z_\star)$$

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Conformal Pomeron

- We start with the conformal pomeron, with

$$1 - e^{i\chi} \approx -i\chi = -i(\cot(\frac{\pi\rho}{2}) + i) g_0^2 e^{(1-\rho)\tau} \frac{L}{\sinh L} \frac{\exp(\frac{-L^2}{\rho\tau})}{(\rho\tau)^{3/2}}$$

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- C is the aforementioned normalization, and g_0^2 is related to the coupling of the external states to the pomeron.

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- Similarly, the $t = 0$ result for the hard-wall model can also be written explicitly

$$\chi_{hw}(\tau, t=0, z, \bar{z}) = \chi(\tau, 0, z, \bar{z}) + \mathcal{F}(\tau, z, \bar{z})\, \chi(\tau, 0, z, z_0^2/\bar{z})\,.$$

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- When $t \neq 0$, we will use an approximation

$$\chi_{hw}(\tau, l, z, \bar{z}) = C(\tau, z, \bar{z})\, D(\tau, l)\, \chi_{hw}^{(0)}(\tau, l, z, \bar{z})$$

- The function

$$\mathcal{F}(\tau, z, \bar{z}) = 1 - 4\sqrt{\pi\tau}\, e^{\eta^2}\, \mathrm{erfc}(\eta)\,, \qquad \eta = \frac{-\log(z\bar{z}/z_0^2) + 4\tau}{\sqrt{4\tau}}$$

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- Varies between -1 and 1, approaching -1 at either large z, which roughly corresponds to small Q^2, or at large τ corresponding to small x.
- It is therefore in these regions that confinement is important!

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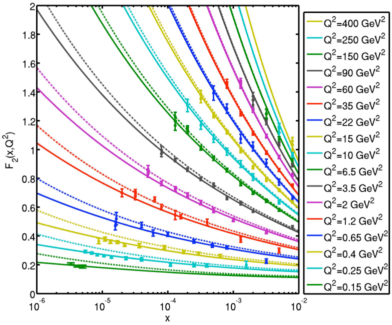
- We will look at both the differential and total exclusive cross sections.

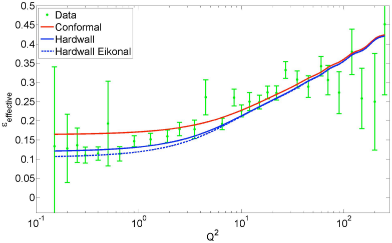
DIS

- Note that the same formalism has been applied before to DIS with good results ($\chi^2 = 1.04$ for the best model) [Brower, MD, Sarčević, Tan, 2010, Cornalba, Costa, Penedones, 2010], and DVCS ($\chi^2 = 1.00$ and $\chi^2 = 0.51$ for the best models of the cross section and differential cross section respectively) [Costa, MD, 2012].

DIS

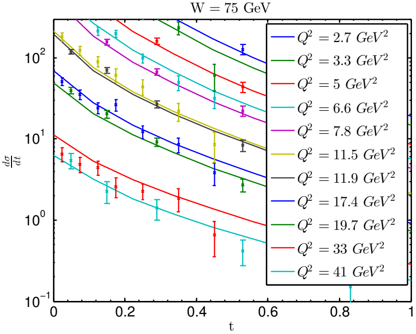
- Note that the same formalism has been applied before to DIS with good results ($\chi^2 = 1.04$ for the best model) [Brower, MD, Sarčević, Tan, 2010, Cornalba, Costa, Penedones, 2010], and DVCS ($\chi^2 = 1.00$ and $\chi^2 = 0.51$ for the best models of the cross section and differential cross section respectively) [Costa, MD, 2012].

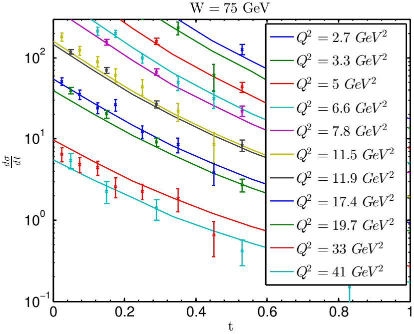




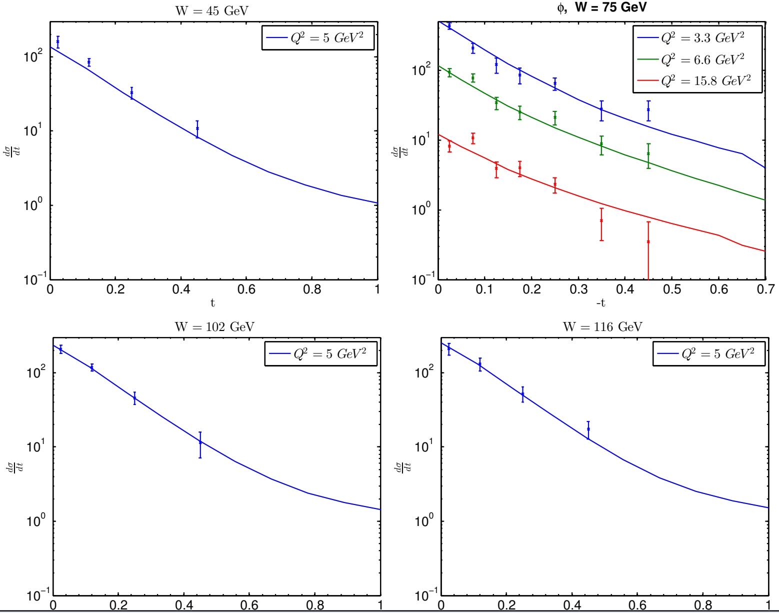
		σ [nb]				dσ/dt [nb/GeV²]		
		ρ	φ	Ω	J/ψ	ρ	φ	J/ψ
	m [GeV]	0.77549	1.019445	0.78265	3.096916	0.77549	1.019445	3.096916
	N	48	27	6	38	35	21	84
Conformal	χ^2	0.92	0.60	0.0099	0.28	1.7	1.3	2.9
	g_0^2	4.6	1.8	0.53	0.62	1.6	0.25	0.56
	ρ	0.76	0.73	0.64	0.70	0.65	0.54	0.72
	z* [GeV^{-1}]	3.4	3.0	1.8	0.98	2.1	2.5	2.2
Hardwall	χ^2	0.88	0.61	0.015	0.30	1.7	1.4	1.8
	g_0^2	4.1	1.8	0.67	0.75	2.2	0.38	0.69
	ρ	0.76	0.73	0.66	0.71	0.69	0.59	0.75
	z* [GeV^{-1}]	3.6	3.6	1.5	0.87	2.2	2.5	2.4
	z_0 [GeV^{-1}]	4.8	4.4	7.3	5.3	7.7	8.6	4.6

Differential cross section for the ρ meson:

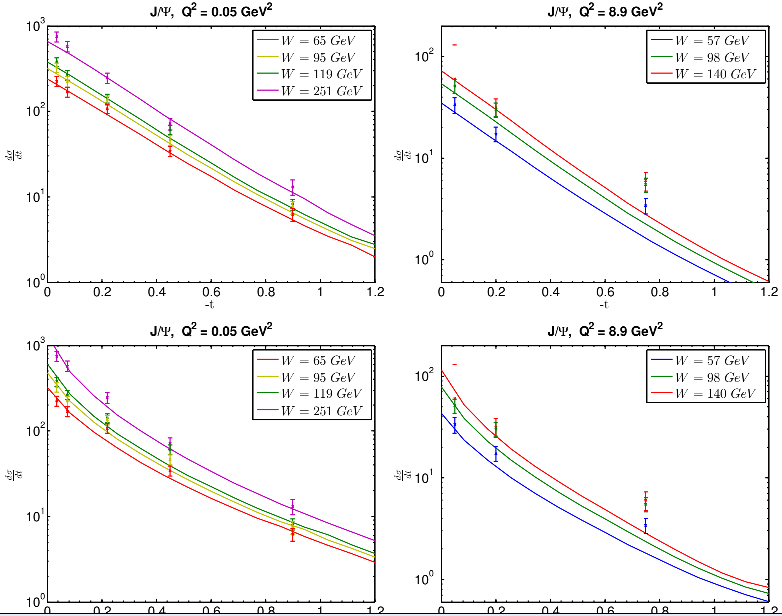




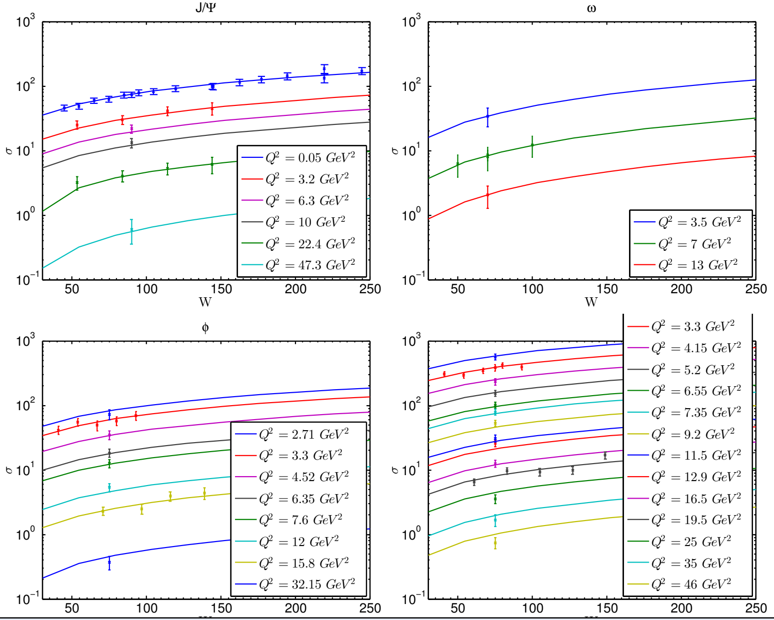
Differential cross section for the ϕ meson (hardwall model):



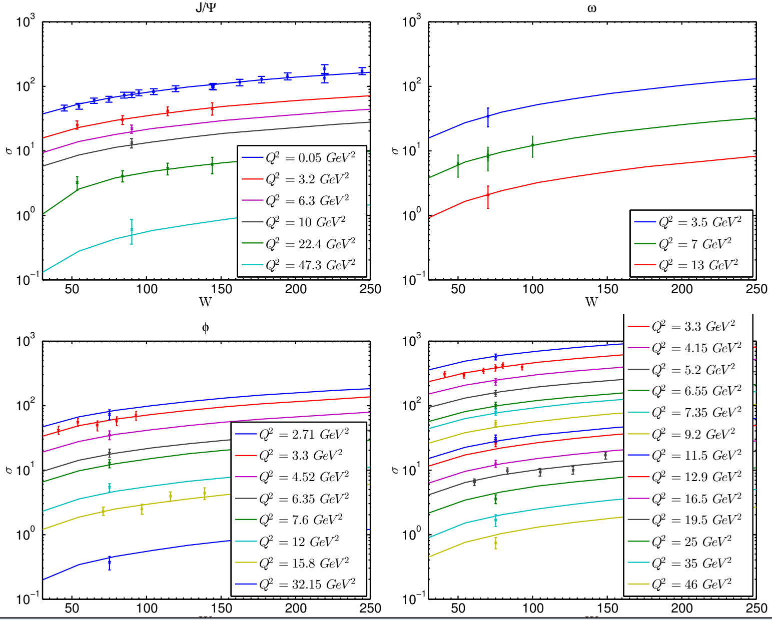
Differential cross section for the J/Ψ meson (hardwall model):



Cross sections for the conformal model:



Cross sections for the hardwall model:



Outline

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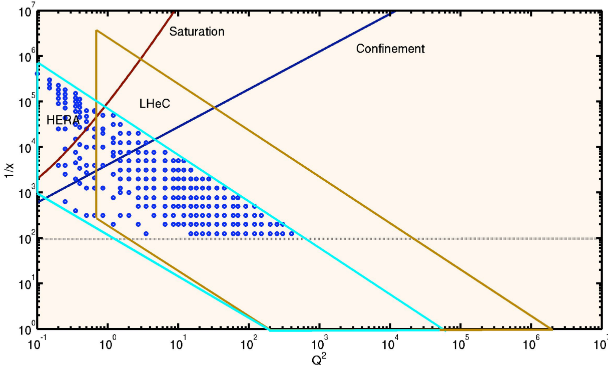

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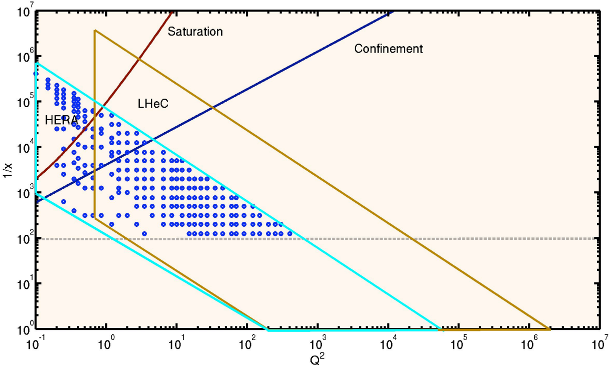

The above order of lines is the opposite of what is generally thought. Is it an artifact of our model?

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- It might therefore be possible to extend some of the insights we gain even into the weak coupling regime.
- The hard wall model, although a simple modification of AdS, seems to capture effects of confinement well. Interesting to repeat some of the calculations using a different confinement model to identify precisely what features are model independent.

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- Eventually it would be good to have a single set of parameters that fits several different processes.
- We can also try to use a different AdS model of confinement (for example the soft wall model [Brower, MD, Raben, Tan, in preparation]) and combine our methods with work by others (for example on the vector meson wavefunctions).

Thank you!