Vector Meson Production from Gauge/Gravity Duality

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work with Miguel S. Costa and Nick Evans

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- More specifically, a recent conjecture by Maldacena relating string theory on $AdS_5 \times S_5$ to $\mathcal{N} = 4SYM$ allows us to study QCD at strong coupling.

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

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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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where

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

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  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:

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

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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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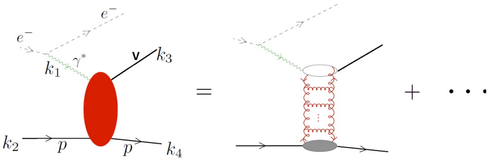

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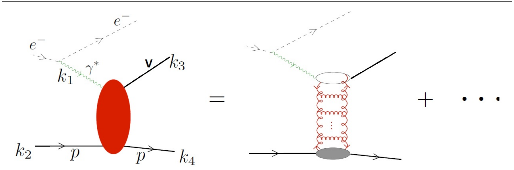

The vector mesons consist of a quark-antiquark pair, and have the same quantum numbers as the photon, $J^{PC} = 1^{--}$. The production of the ρ^0, ω, ϕ and J/Ψ was measured at HERA.

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

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$$W = 2isQQ' \int dl_\perp\, e^{iq_\perp \cdot l_\perp} \int \frac{dz}{z^3}\,\frac{d\bar{z}}{\bar{z}^3}\,\Psi(z)\,\Phi(\bar{z})\,\left[1 - e^{i\chi(S,L)}\right] .$$

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- In this analysis we use

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

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- 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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- 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, Brower Moriond 2011], 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, MD Moriond 2012].

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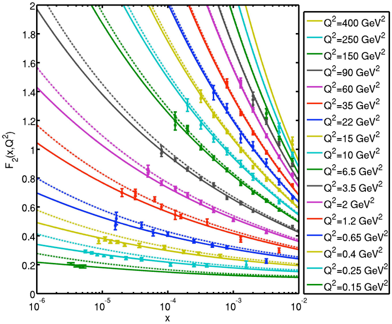
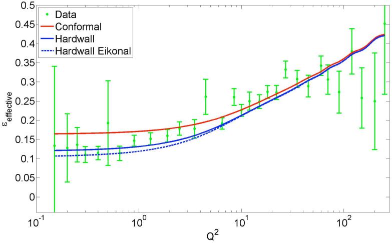
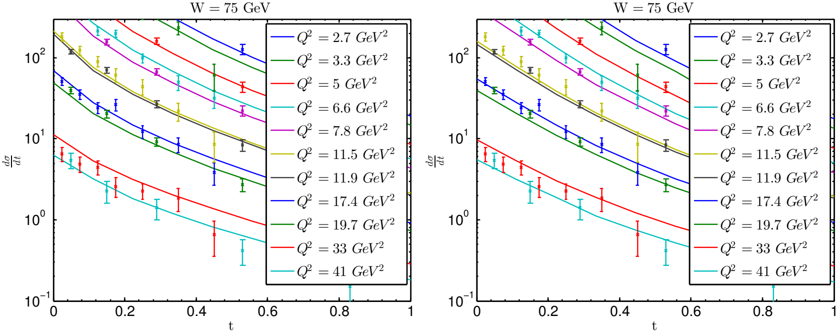


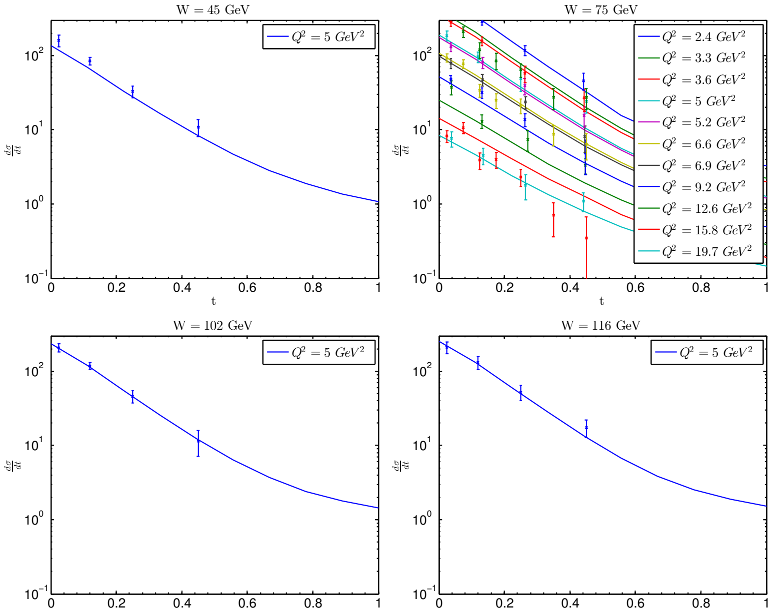


		σ				dσ/dt		
		ρ	ϕ	Ω	J/ψ	ρ	ϕ	J/ψ
	m	0.77549	1.019445	0.78265	3.096916	0.77549	1.019445	3.096916
	N	48	27	6	38	35	21	84
Conformal	χ^2	0.9234	0.6002	0.0099	0.2844	1.7387	1.2732	2.8818
	g0^2	2.29	0.5742	0.2673	0.3946	0.7814	0.0805	0.3565
	2/sqrt(λ)	0.76	0.7339	0.6416	0.697	0.6473	0.5443	0.7165
	z*	3.4074	3.0012	1.8355	0.9823	2.1453	2.5445	2.1536
Hardwall	χ^2	0.8819	0.6131	0.015	0.6285*	1.6574	1.3595	1.8442
	g0^2	2.0438	0.5559	0.3335	3.1893	24.4179	2.6638	9.6671
	2/sqrt(λ)	0.758	0.7321	0.6589	0.7396	0.6946	0.5905	0.7539
	z*	3.5947	3.6341	1.4668	2.1019	2.1847	2.5064	2.4172
	z0	4.8164	4.3625	7.2955	4.2519	7.6918	8.5684	4.6465

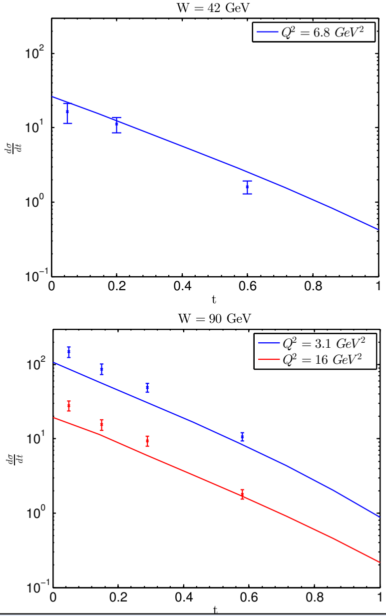
Differential cross section for the ρ meson:



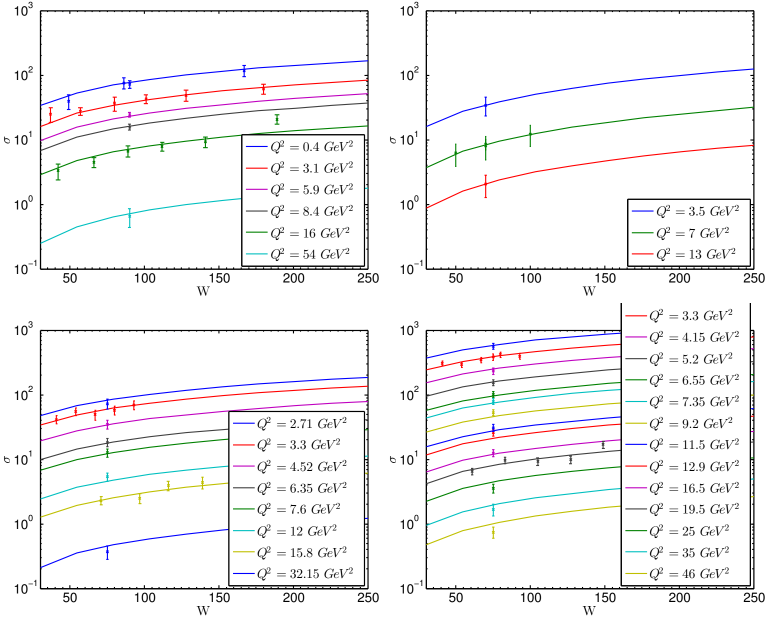
Differential cross section for the ϕ meson (hardwall model):



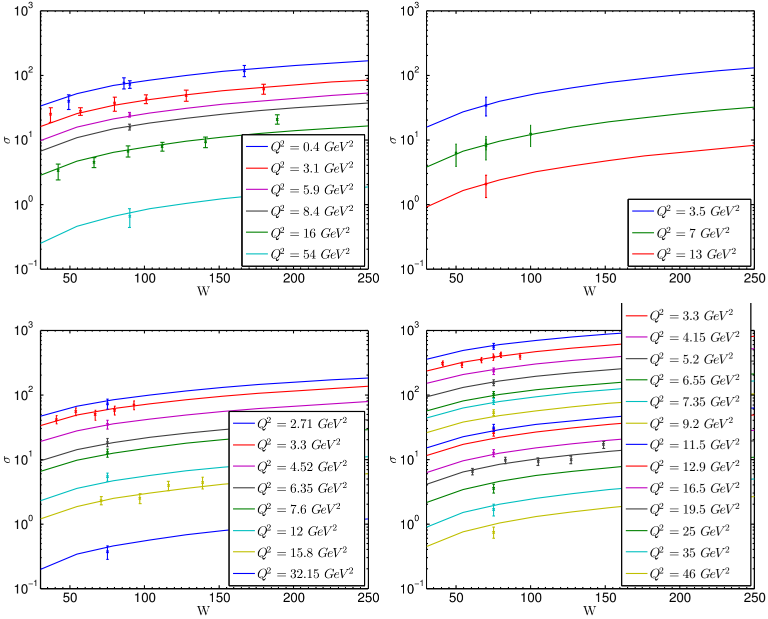
Differential cross section for the J/Ψ meson (hardwall model):



Cross sections for the conformal model:



Cross sections for the hardwall model:



Outline

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- 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) and combine our methods with work by others (for example on the vector meson wavefunctions).

Thank you!