EXCLUSIVE VECTOR MESONS AT HERA

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In this talk I discuss a simultaneous analysis, within an impact parameter dependent saturated dipole model, of exclusive diffractive vector meson (J/ψ, ϕ and ρ) production, deeply virtual Compton scattering and the total $\gamma^* p$ cross section data measured at HERA. Various cross sections measured as a function of the kinematic variables Q^2, W and t are well described, with little sensitivity to the details of the vector meson wave functions. The analysis determines the properties of the gluon density in the proton in both longitudinal and transverse dimensions, including the impact parameter dependent saturation scale. The overall success of the description indicates universality of the emerging gluon distribution and proton shape.

In this talk I have presented an analysis of exclusive diffractive vector meson data measured at HERA within an impact parameter dependent saturated dipole ("b-Sat") model. The talk is based on the work by H. Kowalski, L. Motyka and G. Watt [1]. As a result of a lively discussion after the presentation the investigation was extended to the DVCS processes. Here a short summary of the talk:

Exclusive diffractive processes at HERA, such as exclusive vector meson production or deeply virtual Compton scattering (DVCS), are excellent probes of the proton shape in the perturbative regime. Several investigations have already shown that these processes can be well described within a QCD dipole approach with the vector meson wave functions determined by educated guesses and the photon wave function computed within QED; see, for example, Refs. [2,3,6]. It was also pointed out some time ago that the exclusive vector meson and DVCS processes provide severe constraints on the gluon density at low-x [4,5].

The vector meson and DVCS processes are measured at HERA in the small-x regime where the behaviour of the inclusive deep-inelastic scattering (DIS) cross section, or the structure function F_2, is driven by the gluon density. The dipole model allows these processes to be calculated, through the optical theorem, from the gluon density determined by a fit to the total inclusive DIS cross sections. Usually, it is assumed that the evolution of the gluon density is independent of the proton shape in the transverse plane.

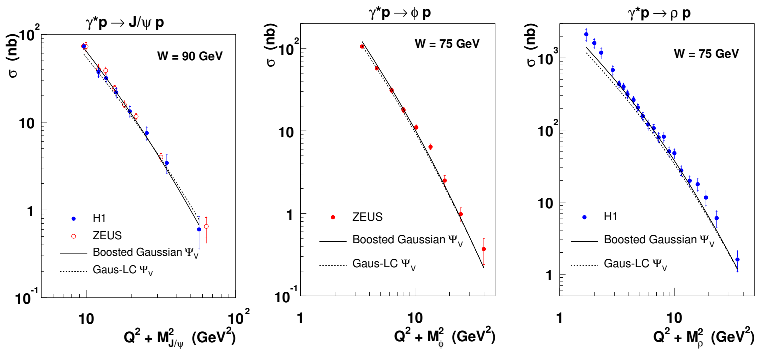

Figure 1. Total vector meson cross section σ vs. $(Q^2 + M_V^2)$ compared to predictions from the b-Sat model using two different vector meson wave functions.

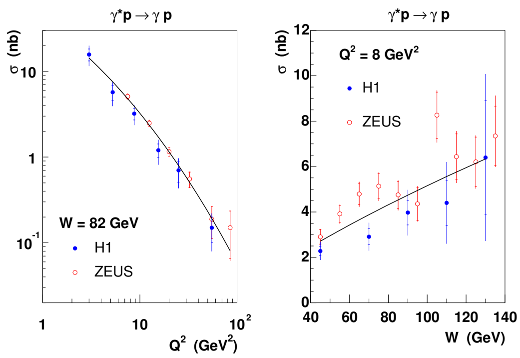

Figure 2. Total DVCS cross sections σ vs. Q^2 (left) and σ vs. W (right) compared to predictions from the b-Sat model.

In the dipole model, deep inelastic scattering is viewed as the interaction of a colour dipole, that is, mostly a quark–antiquark pair, with the proton. The transverse size of the pair is denoted by $\boldsymbol{r}$ and a quark carries a fraction z of the photon's light-cone momentum. In the proton rest frame, the dipole lifetime is much longer than the lifetime of its interaction with the target proton. Therefore, the elastic $\gamma^* p$ scattering is assumed to proceed in three stages: first the incoming virtual photon fluctuates into a quark–antiquark pair, then the $q\bar{q}$ pair scatters elastically on the proton, and finally the $q\bar{q}$ pair recombines to form a virtual photon or vector meson.

The total cross section for a small dipole to pass through a dilute gluon cloud is proportional to the dipole area, the strong coupling constant, and the number of gluons in the cloud, i.e the gluon density. The ikonalization of this cross section allows to relax the assumption of a dilute gluon cloud.

Various cross sections measured as a function of Q^2, W and t can be described by a dipole model with a minimal number of free parameters, namely the parameters μ_0^2, A_g and λ_g of the initial gluon distribution, $xg(x, \mu_0^2) = A_g\, x^{-\lambda_g}\, (1-x)^{5.6}$, and the proton width B_G. The wave functions of the virtual photon are known from QED, while the vector meson wave functions are assumed to have a Gaussian shape. The variable which fluctuates in the Gaussian is, of course, not known precisely. However, we have shown that the observed distributions are fairly insensitive to the particular assumptions, with possible exception of the σ_L/σ_T ratio for the ρ meson.

An important finding of this investigation is that, although the vector meson wave functions are not fully known, one obtains a good description of the measured data. The model parameters, which were fixed by the fit to the total inclusive DIS cross section and the vector meson t-distributions, describe the measured Q^2 and W dependence of vector meson production and DVCS very well, together with the absolute normalisation. The measured DVCS t-distribution agrees with the model expectation within the measurement error.

Another important finding is that the t-dependences of all three vector mesons and the DVCS process can be simultaneously described with one universal shape of the proton. The parameter characterising the size of the proton, $B_G = 4$ GeV^{-2}, determined in this investigation, corresponds to a root-mean-square impact parameter $\sqrt{\langle b^2 \rangle} = 0.56$ fm. This is rather smaller than the proton charge radius of 0.870 ± 0.008 fm. This leads to a rather surprising result that gluons are more concentrated in the centre of the proton than quarks. DVCS measurements planned at JLab should help clarify this somewhat puzzling picture.

The investigation presented here demonstrates that a wide class of high-energy scattering processes measured at HERA may be understood within a simple and unified framework. The key ingredient is the gluon density which is probed in the longitudinal and transverse directions. The success of

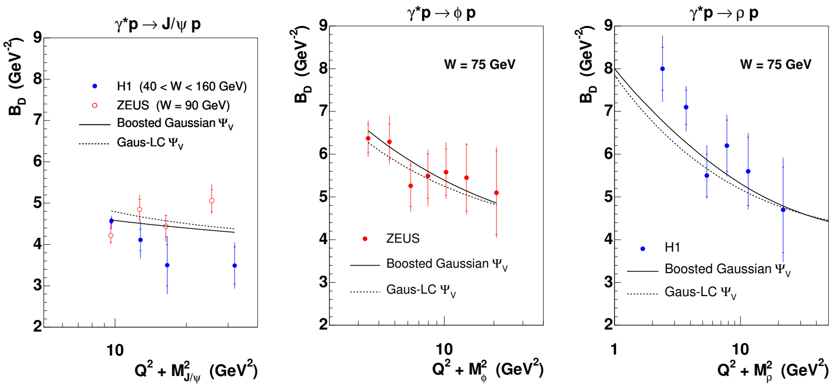

Figure 3. The t-slope parameter B_D vs. $(Q^2 + M_V^2)$, where B_D is defined by fitting $\mathrm{d}\sigma/\mathrm{d}t \propto \exp(-B_D|t|)$, compared to predictions from the b-Sat model using two different vector meson wave functions.

the description indicates the universality of the emerging gluon distribution.

Let us finish with a general remark that vector meson and DVCS processes may be used to probe the properties of nuclear matter in a new way. In measurements with polarised beams it is possible to achieve precision which would allow a holographic picture of protons and nuclei to be obtained. Such a measurement could be performed at an *ep* collider with roughly a third of the HERA centre-of-mass energy, similar to the one described in the eRHIC proposal.

Acknowledgments

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