Measurements of VM production at HERA

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HERA

- Electron(positron) – proton collider in DESY
- Electron beam energy 27.5GeV and the protons were at 820GeV or 920GeV
- In its second, higher-luminosity phase (HERA-II, 2002–2007), the electrons remained at the same energy, but were longitudinally polarized
- Two main experiments, H1 and ZEUS, with an ep center-of-mass energy $\sqrt{s} \leq 318\text{GeV}$.

Kinematics and Experimental Selection

- Quasi-elastic vector meson production and DVCS are the simplest diffractive processes that can be studied at HERA.
- For a fixed final state vector meson or photon, they are usually described in terms of the kinematic variables, Q^2, W and t.
- Distributions in all three of these variables have been measured in analyses covering the vector meson species, ρ, ω, ϕ, ρ′, J/ψ, ψ′ and Υ
- No evidence has been found for the exclusive production at the photon vertex of particles with non-1^{--} quantum numbers such as the π^0
- The most precise vector meson data are obtained by reconstructing two-prong decays via charged decay products (notably $\rho^0 \rightarrow \pi^+\pi^-$, $\phi \rightarrow K^+K^-$ and $J/\psi \rightarrow e^+e^-$ or $\mu^+\mu^-$) and requiring no further activity beyond the noise levels in the detector

General Characteristics of Vector Meson Production

- Vector meson production has emerged as a sensitive probe of the transition from the soft diffractive dynamics which are familiar from hadronic scattering experiments to a harder regime which may be calculated perturbatively.
- Under such circumstances, the energy dependence of the photon–proton process is in good agreement with the form predicted by Regge asymptotics

$$\sigma^{\gamma p \to V p} \propto (W^2)^{2\alpha_{I\!P}(t)-2}$$

- where the pomeron trajectory

$$\alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P} t$$

- assumed to be linear and its intercept

$$\alpha_{I\!P}(0) \simeq 1.085$$

General Characteristics of Vector Meson Production

- This has been found to work well for ρ0 photoproduction data, though interestingly, the slope of the pomeron trajectory has been found to be significantly smaller than the value of $\alpha_P \sim 0.25$ obtained from soft pp and p anti-p scattering
- A possible explanation for this may be found in process-dependent absorptive corrections, which are absent in DIS, present to some extent in photoproduction and to a larger extent in fully hadronic scattering.
- Further characteristics of this soft regime are a skewed line shape for the ρ meson due to its interference with non-resonant π+π− production and a large value, $B \sim 10\ \mathrm{GeV}^{-2}$, of the slope parameter describing the t dependence according to

$$\frac{\mathrm{d}\sigma^{\gamma p \to V p}}{\mathrm{d}t} = \left(\frac{\mathrm{d}\sigma^{\gamma p \to V p}}{\mathrm{d}t}\right)_{t=0} e^{Bt}$$

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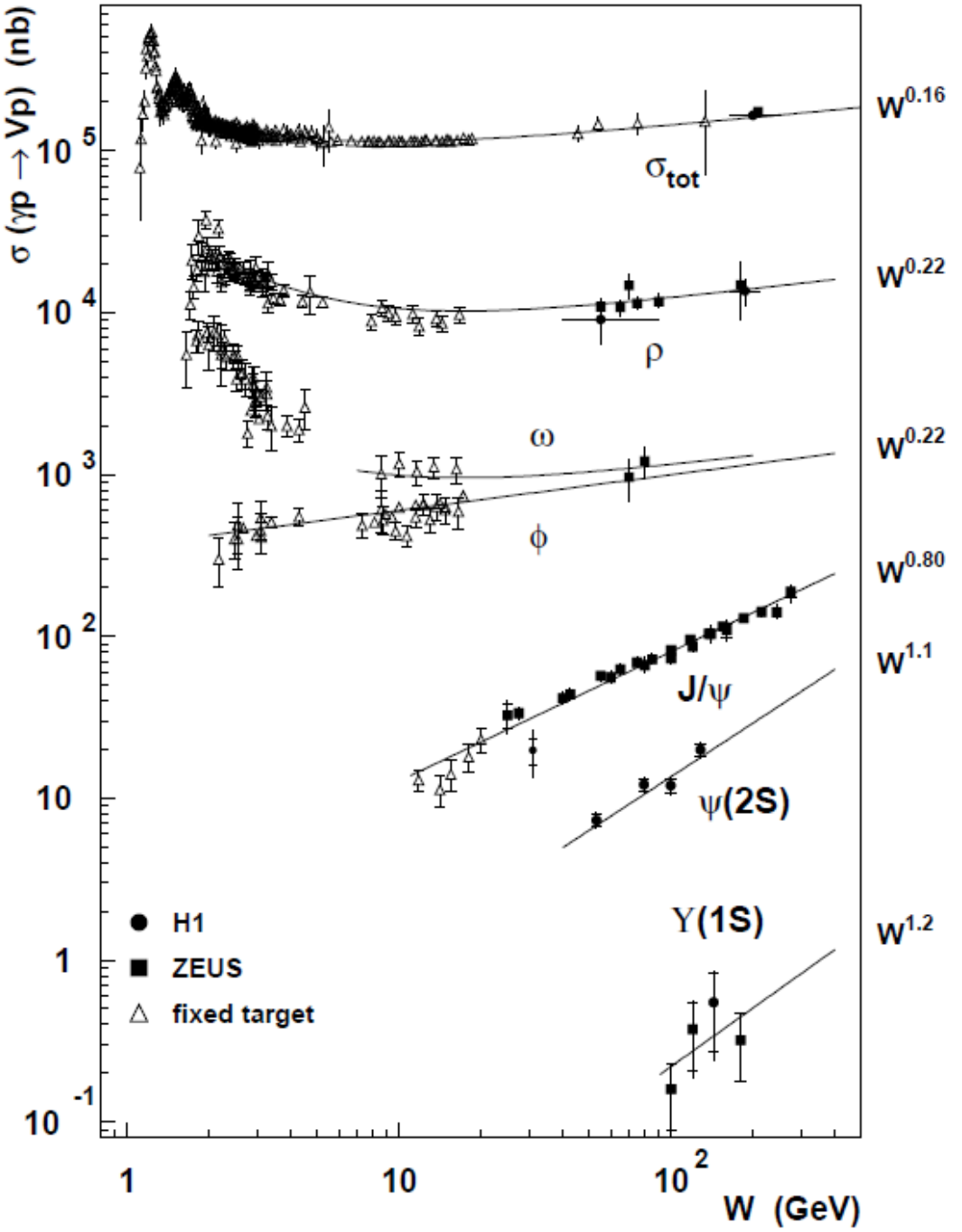
- Wherever hard scales are present, usually provided either by heavy quarks in the vector meson or by large Q^2, but sometimes also by large $|t|$, the qualitative picture changes
- The energy dependence becomes progressively steeper, such that the W dependence yields an increased effective value of $\alpha_P(0)$.
- The steepening of the dependence on W for the heaviest vector mesons can be interpreted in terms of the scale dependence of the proton gluon density at low x



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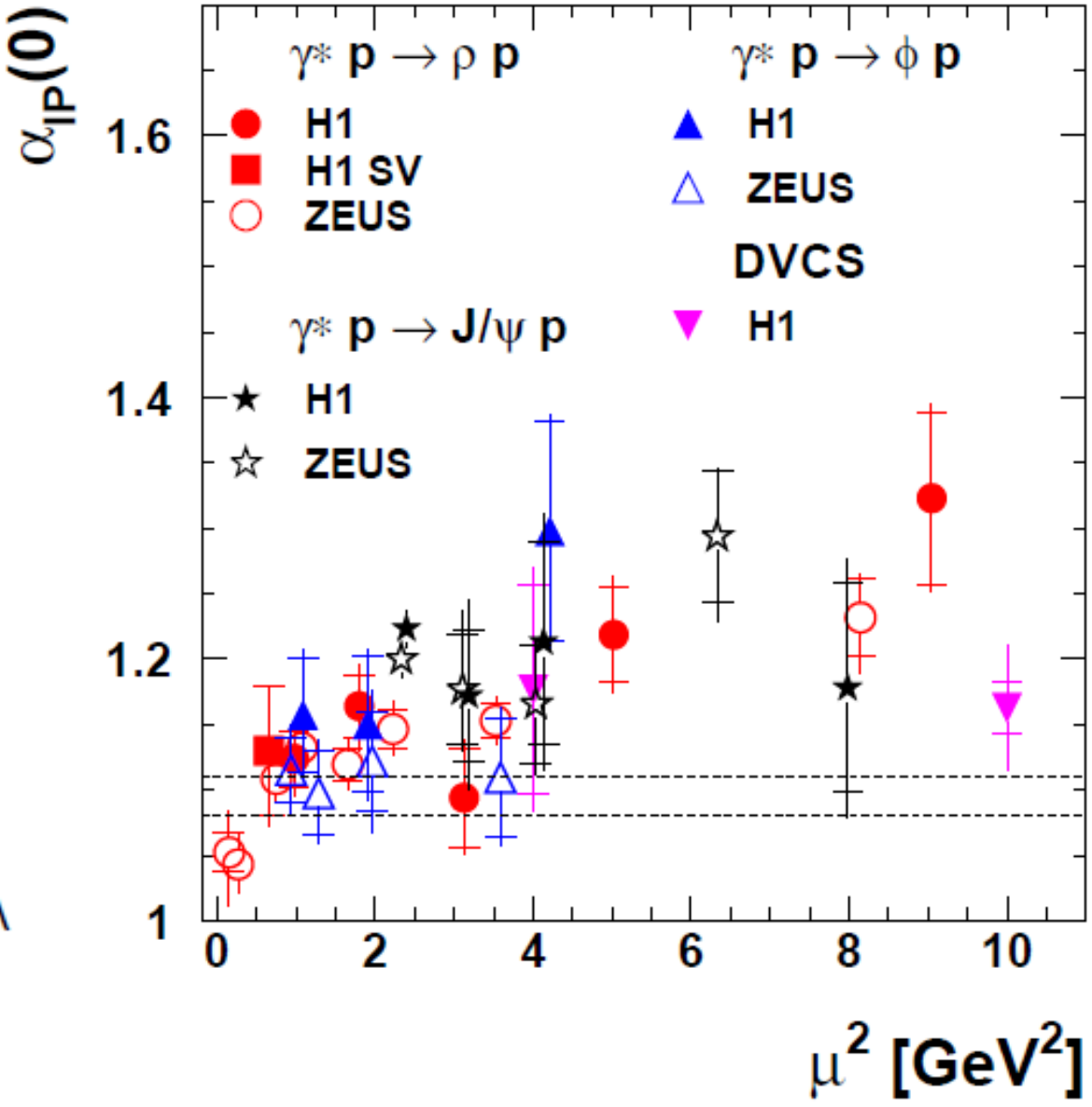
- The transition from soft hadronic to perturbative behavior is neatly mapped out in a single process in ρ^0 electro-production data.
- As Q^2 increases, the t slope parameter B decreases, the W dependence becomes steeper and the line shape skewing disappears
- As the scale increases, the effective pomeron intercept shifts from values typical of soft hadronic scattering to values which are compatible with results for the equivalent quantity $\alpha_{I\!P}(0) = 1 + \lambda$
- in fits of inclusive low-x HERA data to the form $F_2(x, Q^2) \propto x^{-\lambda(Q^2)}$



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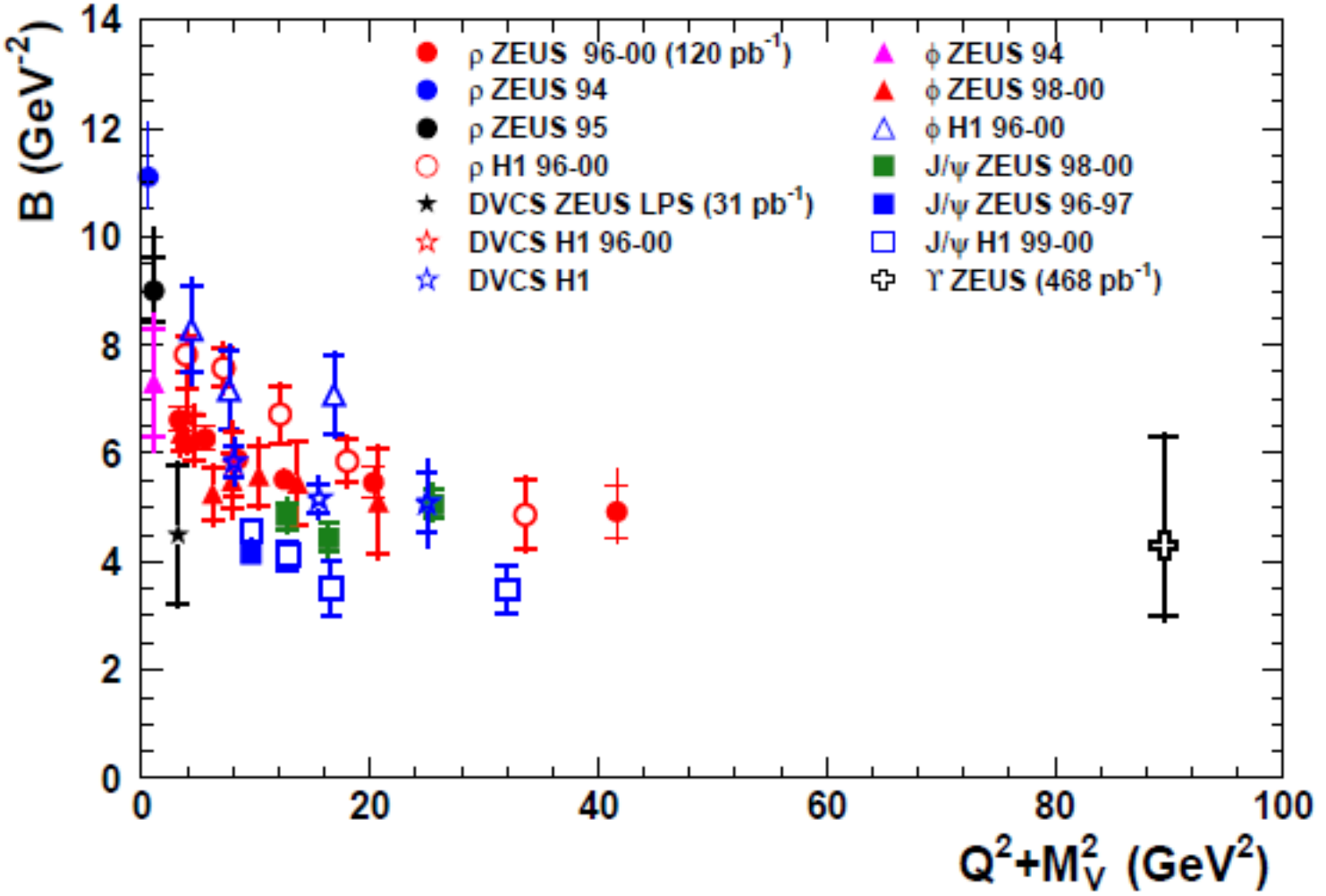
- The exponential t slopes of vector meson production processes are also found to vary systematically with scale and are approximately invariant in $Q^2 + M^2$
- Although the uncertainties are often large and there is some scatter, the data suggest a convergence towards an asymptotic value of $B \sim 5 GeV^{-2}$



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- In optical models, this can be interpreted as the point at which the physics is entirely short-distance in nature, the size of the probe becomes negligible and the slope parameter measures the size of the proton.
- Quantitatively, this indicates an effective proton size of around 0.6 fm, which is interestingly smaller than the value of ~ 0.8 fm which is well measured using electromagnetic probes.
- Interpreting vector meson production in terms of gluon exchange, this suggests that the gluon radius of the proton may be smaller than its quark radius.