High $|t|$ Diffractive Photoproduction of ρ Mesons

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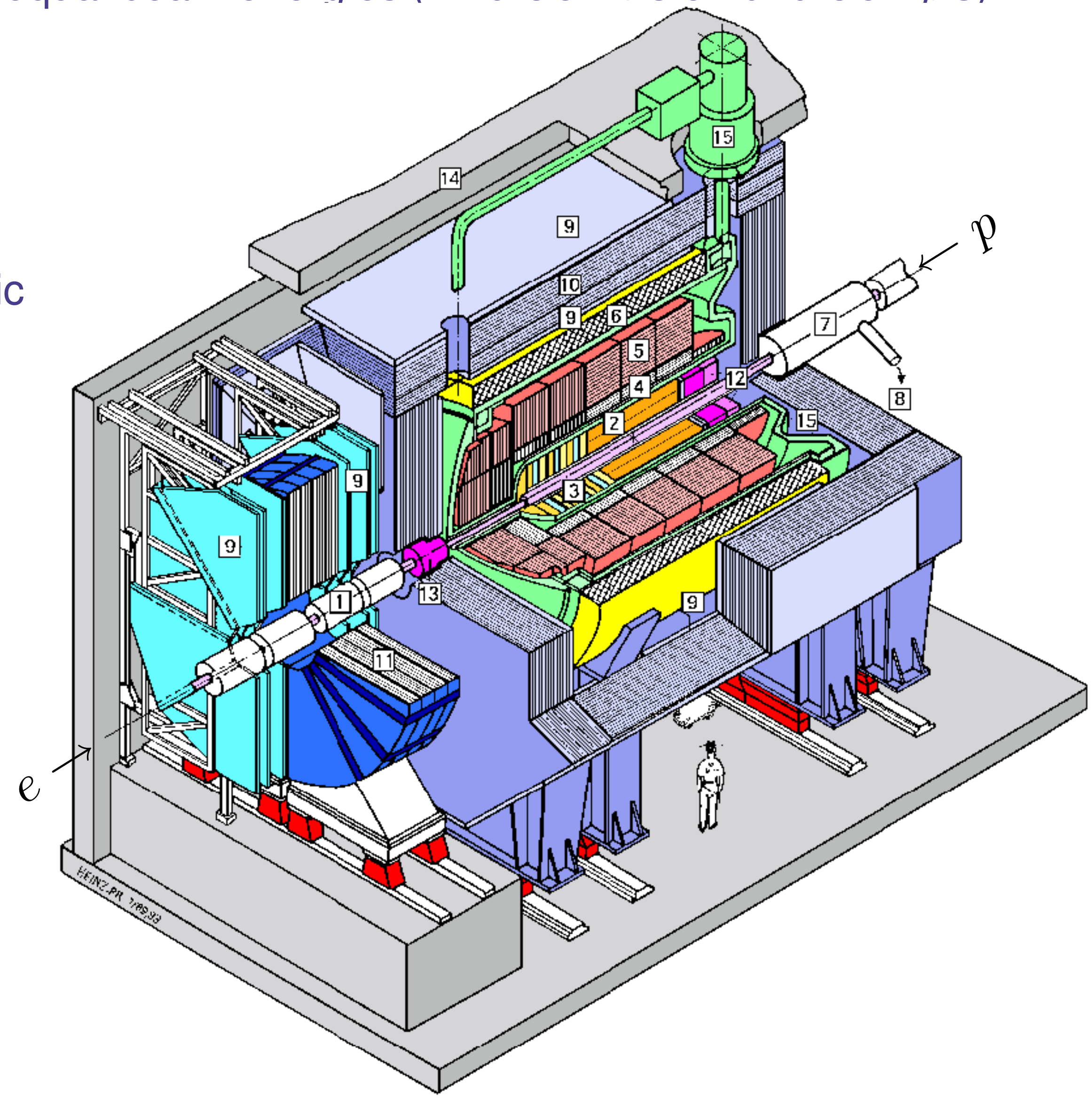
H1 Detector

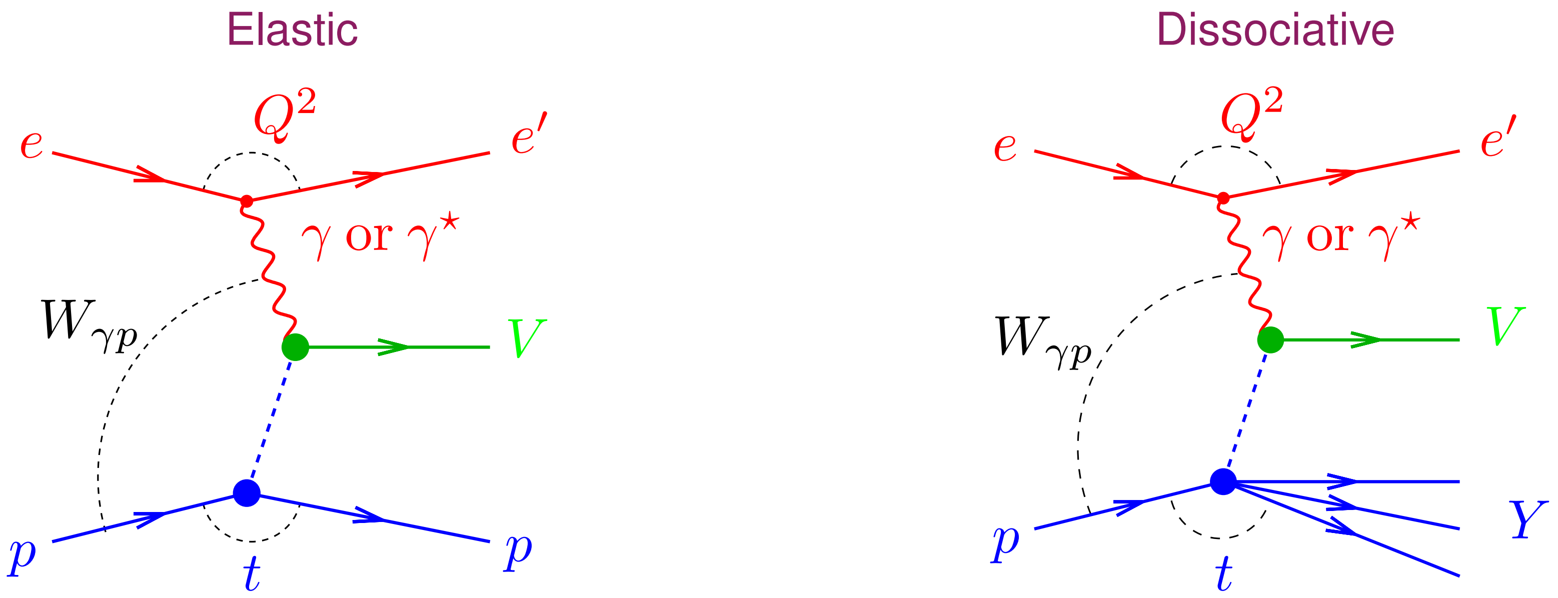
Asymmetric detector due to unequal beam energies (27.6 GeV e's on 920 GeV p's)

Main Components (2000):

- Tracking provided by 2 concentric drift chambers (CJC1 and 2)
- LAr calorimeter with lead (EM) or steel (Had) showering plates
- Instrumented iron (CMD) & drift chambers (FMD) to detect μ's
- Taggers for low Q^2 physics at 8, 33 and 44 m in e direction



Diffractive Vector Meson Production at HERA



Proton dissociation dominates at large $|t|$

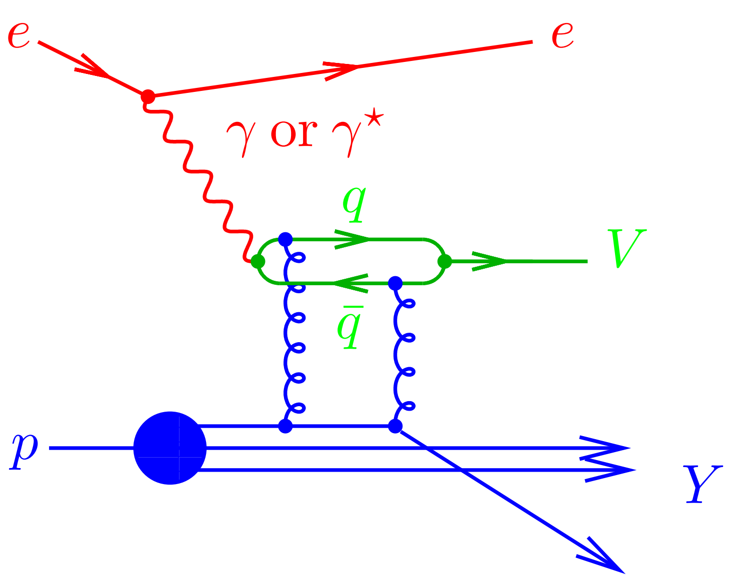
Q^2	Virtuality of the $\gamma^\star$	$\sim 0 < Q^2 < 100\ \mathrm{GeV}^2$
$W_{\gamma p}$	CoM energy of the γp system	$20 < W_{\gamma p} < 290\ \mathrm{GeV}$
y	Fraction of E_e taken by $\gamma^{(\star)}$	$\sim 0 < y = W_{\gamma p}^2/s < 0.84$
t	(4 momentum transfer at the p vertex)^2	$\sim 0 < \|t\| < 30\ \mathrm{GeV}^2$
V	Vector meson	$\rho^0, \omega, \phi, J/\psi, \psi(2s), \Upsilon(1s)$

$\Rightarrow$ Simultaneous probe of several different kinematical quantities

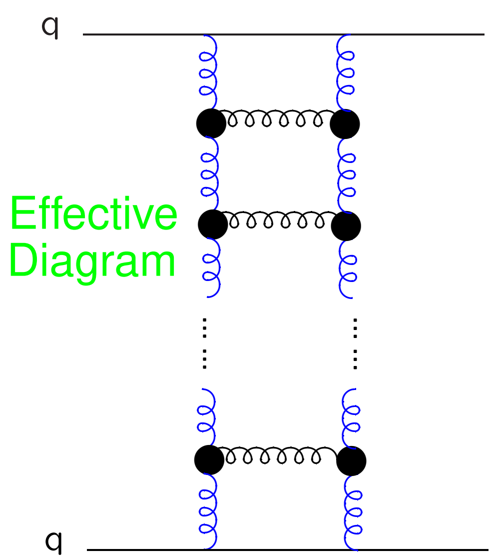
Perturbative QCD

Calculations require hard scale $\Rightarrow$ possibilities are: M_V^2, Q^2, $|t|$

Lowest Order Exchange



Higher Order Exchange



1. Photon fluctuates into $q\bar{q}$ pair
2. Lowest order exchange = 2 gluons
3. Meson wavefunction is needed to form V

Evolution: a. DGLAP $\Rightarrow \sum_n \alpha_s^n \log^n(Q^2)$

b. BFKL $\Rightarrow \sum_n \alpha_s^n \log^n(1/x)$

$\Rightarrow$ Effective gluon ladder ("QCD Pomeron")

High $|t|$ vector mesons $\Rightarrow$ ideal place to study BFKL dynamics

High $|t|$ Vector Meson Photoproduction

Two prong vector meson decay signature

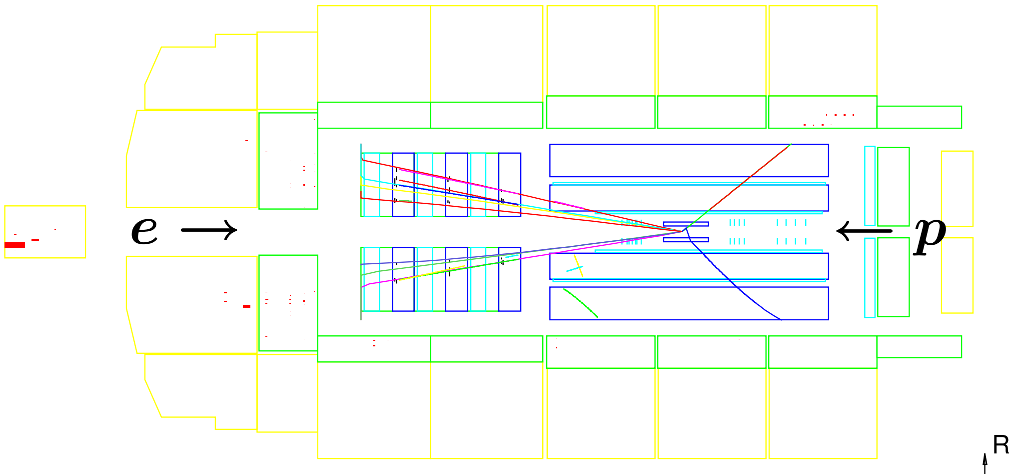
$\Rightarrow$ reconstruct $|t|$ from P_T of tracks

Typically energy deposits in fwd direction

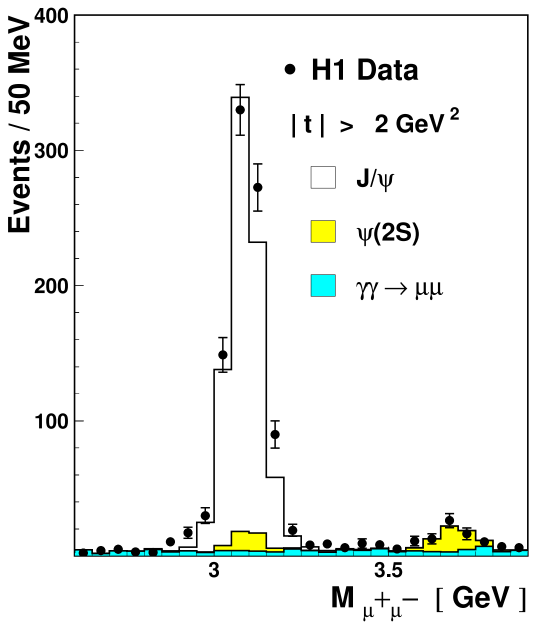
Incoming e scattered through small angle

$\Rightarrow$ Not in main detectors (can be tagged)

$\Rightarrow$ Clean experimental signature!



$\gamma p \longrightarrow \rho Y$ candidate



Non-resonant background at large $|t|$ is small

Small contribution from $\psi(2s)$ vector meson

$\Rightarrow$ Backgrounds at large $|t|$ are small!

Heavy J/ψ Photoproduction at High $|t|$

$J/\psi \to \mu^+\mu^-$ using $\mathcal{L} = 78\,\mathrm{pb}^{-1}$ with $Q^2 < 1\,\mathrm{GeV}^2$ (untagged)

$|t|$ dependence:

Probes region $|t| > M^2_{J/\psi}$ for the first time

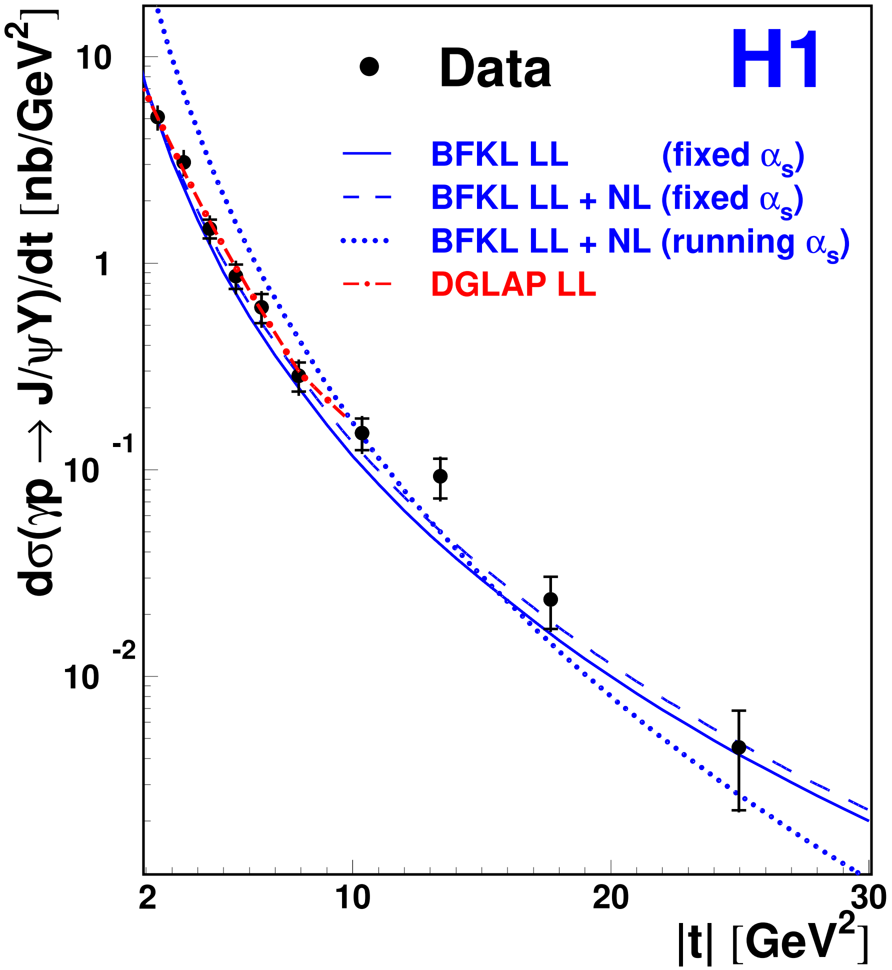
Large $|t|$ dependence: $\frac{d\sigma}{dt} \sim |t|^{-n}$

$\Rightarrow n_{J/\psi} \approx 3.00$ for $|t| > 3.5\,\mathrm{GeV}^2$

Fixed α_s BFKL models well describe the data

But prescription for running $\alpha_s \Rightarrow$ steeper $|t|$

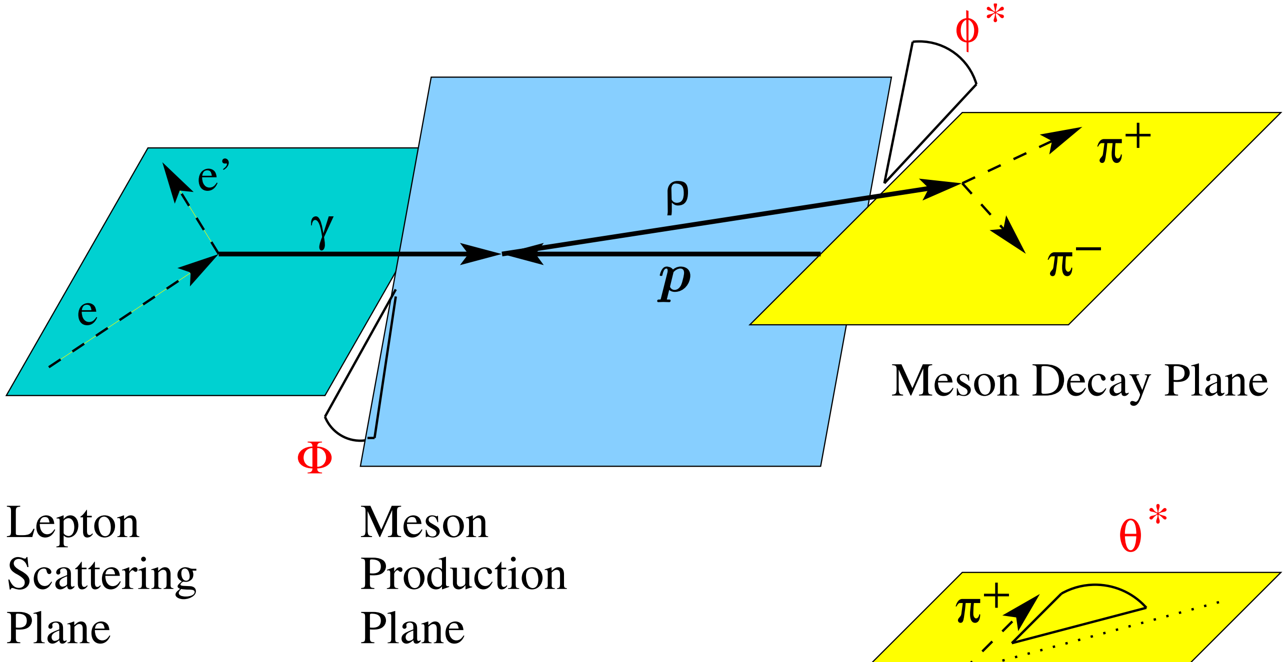
DGLAP describes data where valid $(|t| \leq M_V^2)$



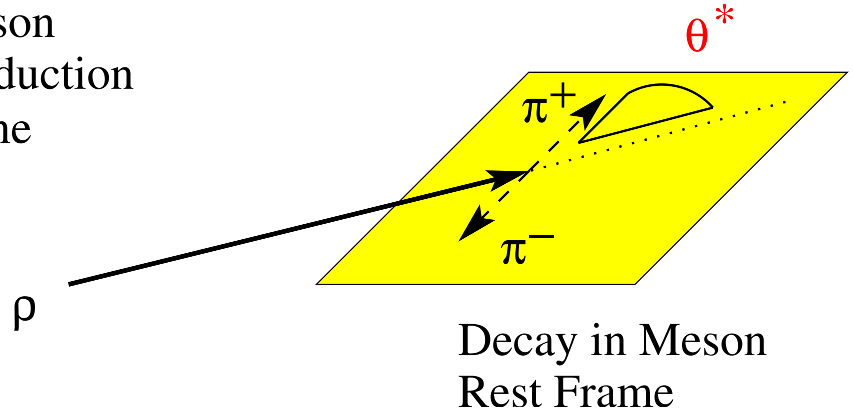
Helicity Studies: Testing the Meson WF

Perform a boost into γp CoM frame $\Rightarrow$ can measure angular decay distributions ($\theta^\star$, $\phi^\star$ & Φ)

Extracting "spin density matrix elements" (SDMEs) $\Rightarrow$ provides a test of vector meson WF!



Helicity $=$ component of spin along direction of the particle's motion

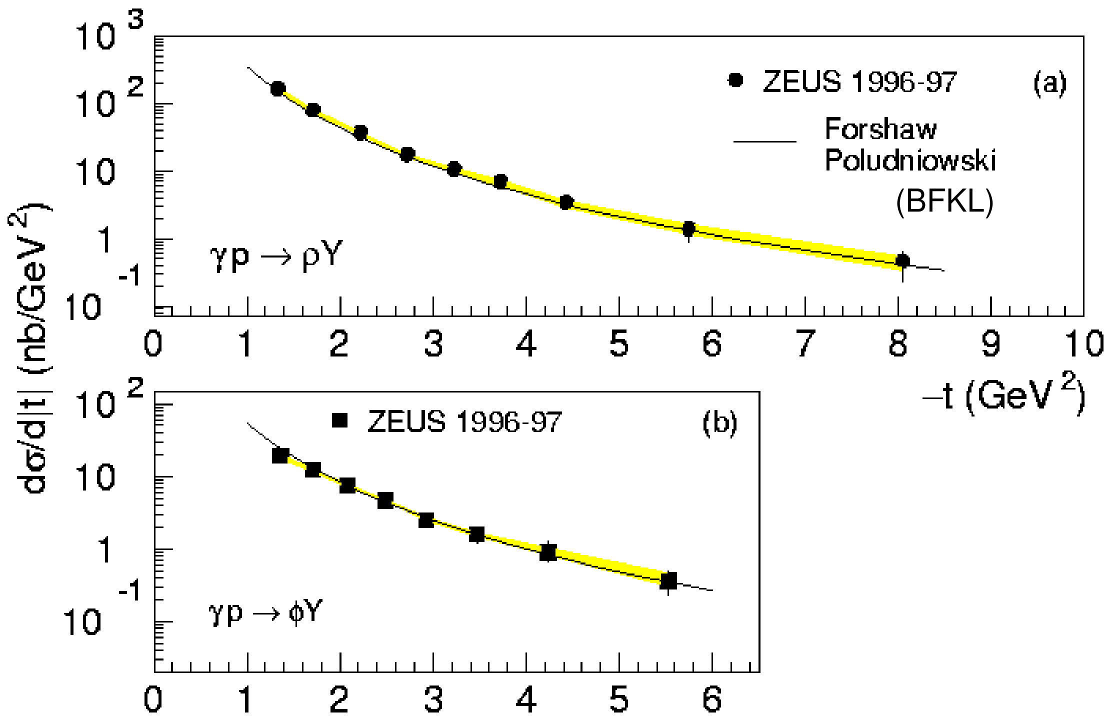


Heavy J/ψ consistent with SCHC $\Rightarrow$ Simple meson WF assumptions appear satisfactory

Lighter ρ violates SCHC (s channel helicity conservation) $\Rightarrow$ more complicated WF needed?

Light Vector Meson Photoproduction at High $|t|$

ZEUS have measured ρ & ϕ using $\mathcal{L} = 25\ \mathrm{pb}^{-1}$ with $Q^2 < 0.02\ \mathrm{GeV}^2$ (tagged)



$|t|$ dependence:

Large $|t|$ dependence: $\frac{d\sigma}{dt} \sim |t|^{-n}$

$\Rightarrow n \sim 3$ for both ρ & ϕ

BFKL describes $|t|$ dependence well

(using only simple vector meson WF)

Predictions for the full “lightcone” VM wavefunctions have recently become available

(These are necessary to simultaneously describe the high $|t|$ behaviour and SDMEs)

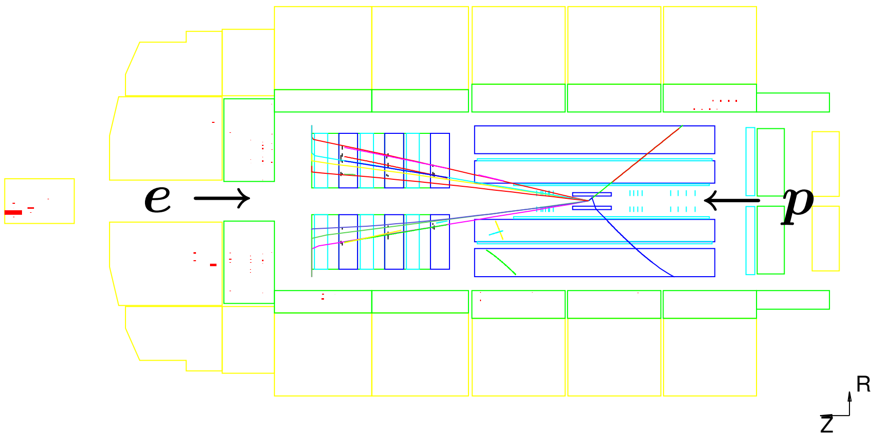
Light VMs can provide important information on these as yet unmeasured WFs!

High $|t|$ ρ Event Selection

2000 data $\Rightarrow \mathcal{L} \approx 48\,\mathrm{pb}^{-1}$

Photoproduction: $\gamma p \rightarrow \rho Y$

Decay: $\rho \rightarrow \pi^+\pi^-$ (~100%)



Cuts:

1. Photoproduction with e' detected in 44 m tagger $\Rightarrow Q^2 < 0.01\ \mathrm{GeV}^2$
   $\Rightarrow 70 < W_{\gamma p} < 115\ \mathrm{GeV}$
2. Two good oppositely charged tracks (one with $P_t > 0.4\ \mathrm{GeV}$ to fire trigger)
3. Both must be detected within the central region ($20 < \theta < 160^\circ$)
4. $|t| > 1\ \mathrm{GeV}^2$ (dissociative) where $|t| \approx P^2_{t,\rho}$ in photoproduction
5. Require $\Delta\eta > 2$ for diffractive processes ($\eta = -\ln\left(\tan\frac{\theta}{2}\right)$)
6. No neutral cluster with energy above $0.4\ \mathrm{GeV}$ (noise level)
7. Mass cuts: $0.6 < M_{\pi\pi} < 1.1\ \mathrm{GeV}$ and $M_{KK} > 1.04\ \mathrm{GeV}$ ($\phi \rightarrow K^+K^-$)

Number of events selected ~ 21000

$M_{\pi\pi}$ *and* $|t|$ *Distributions*

Invariant mass $(M_{\pi\pi})$:

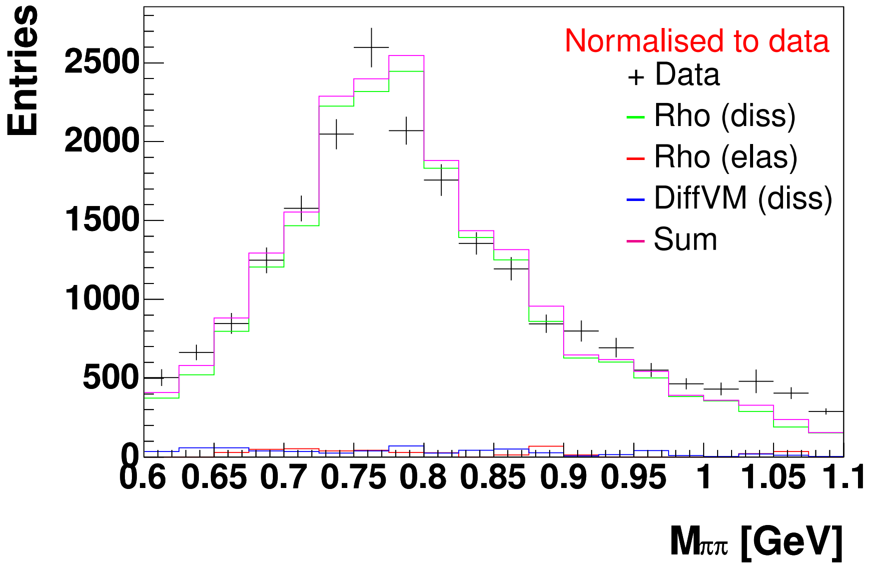
DiffVM uses a non-rel BW for ρ line shape

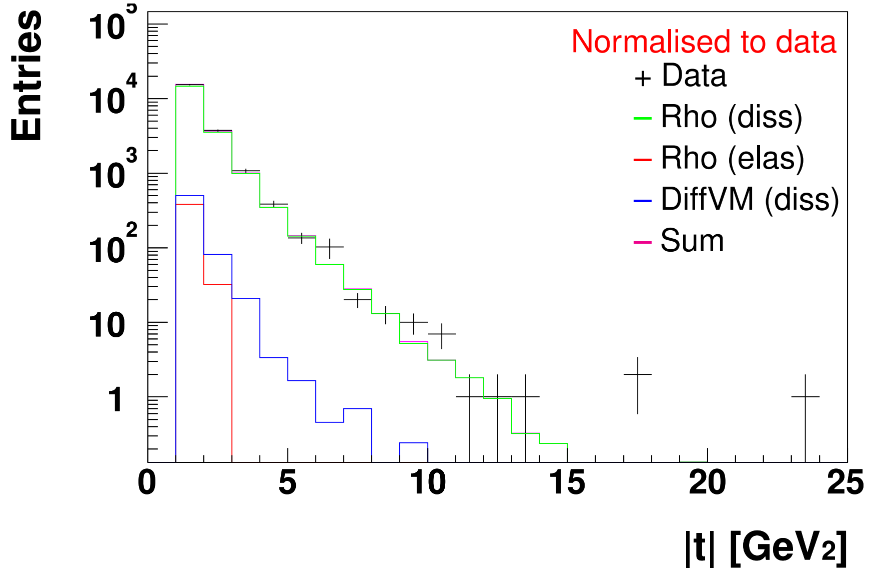
$\Rightarrow$ Convert to a relativistic BW distribution

$+$

Incorporate skewing effects (Ross-Stodolsky)

$\Rightarrow$Accounts for non-resonant π production





$|t|$ slope:

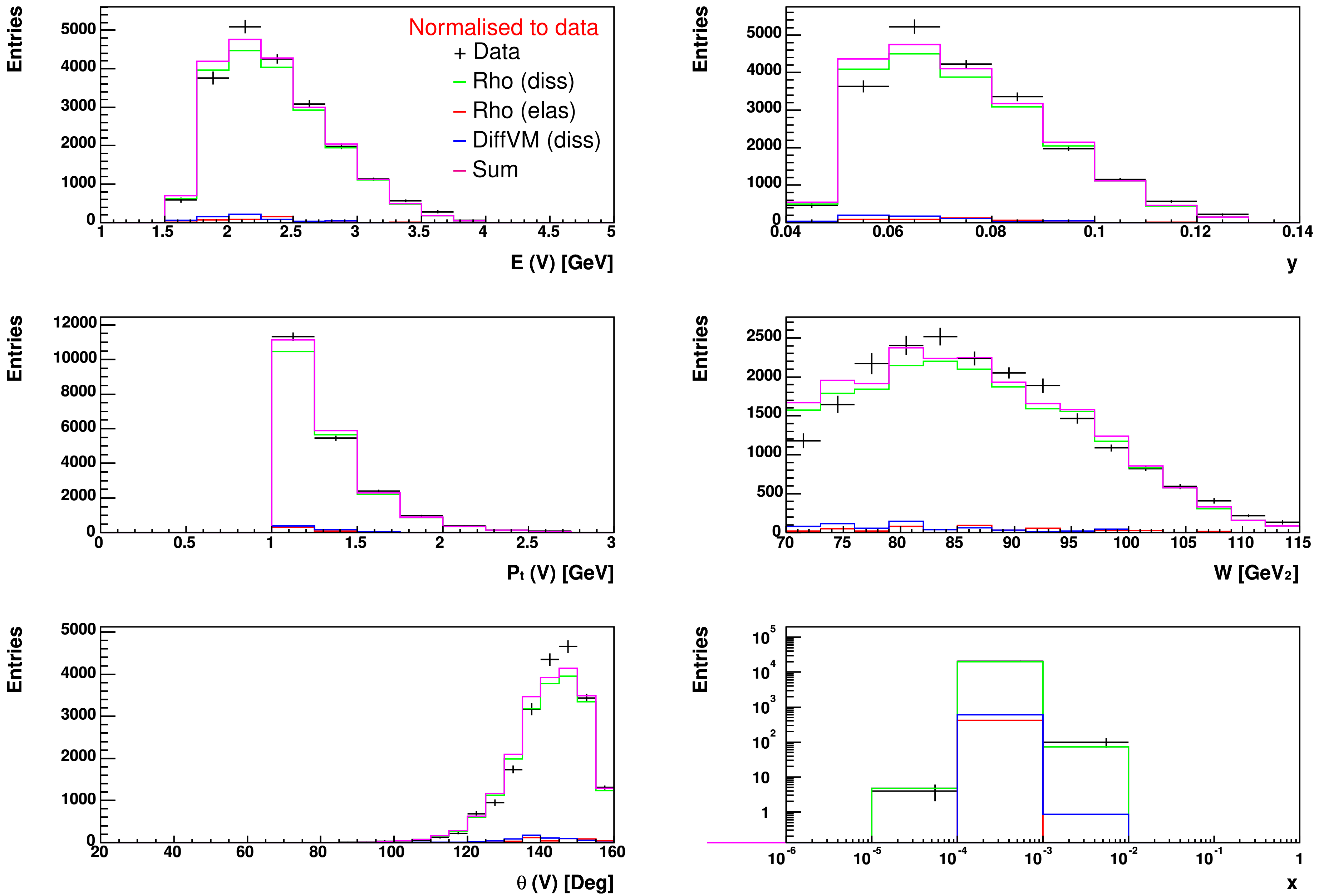
MC generated with a shallow $|t|$ slope

$\Rightarrow$Produces more statistics at high $|t|$

$\Downarrow$

Has been re-weighted to describe the observed $|t|$ distribution of the data

Control Plots



Preliminary Cross Section

γp cross section:

$$\frac{d\sigma(\gamma p \to \rho Y)}{d|t|} = \frac{1}{F(y,Q^2)} \frac{d\sigma(ep \to \rho Y)}{d|t|}$$

$$= \frac{1}{F(y,Q^2)} \frac{N_{data}(t)}{\mathcal{L} A \Delta t}$$

Weizsäcker-Williams flux:

$F(y, Q^2) =$ Correction for effective γ flux $=$

$$\frac{\alpha}{2\pi} \log\left(\frac{Q^2_{max}}{Q^2_{min}}\right) \left[1 + (1-y)^2\right] \log\left(\frac{y+dy}{y-dy}\right)$$

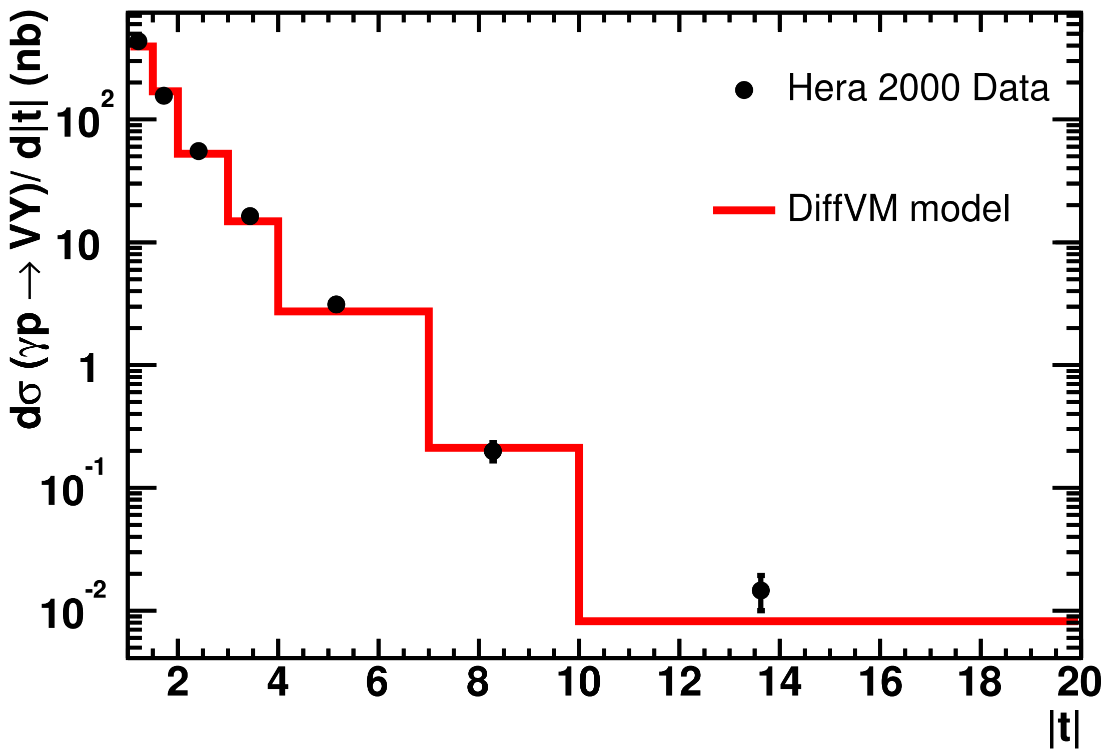
Prescaled luminosity: $\mathcal{L} \approx 23\ \mathrm{pb}^{-1}$

Included:

1. Acceptance correction (A)
2. Background subtractions
3. Bin centre corrections

MC tuned to describe $|t|$ dependence

Still to do: Trigger efficiency corrections



Summary

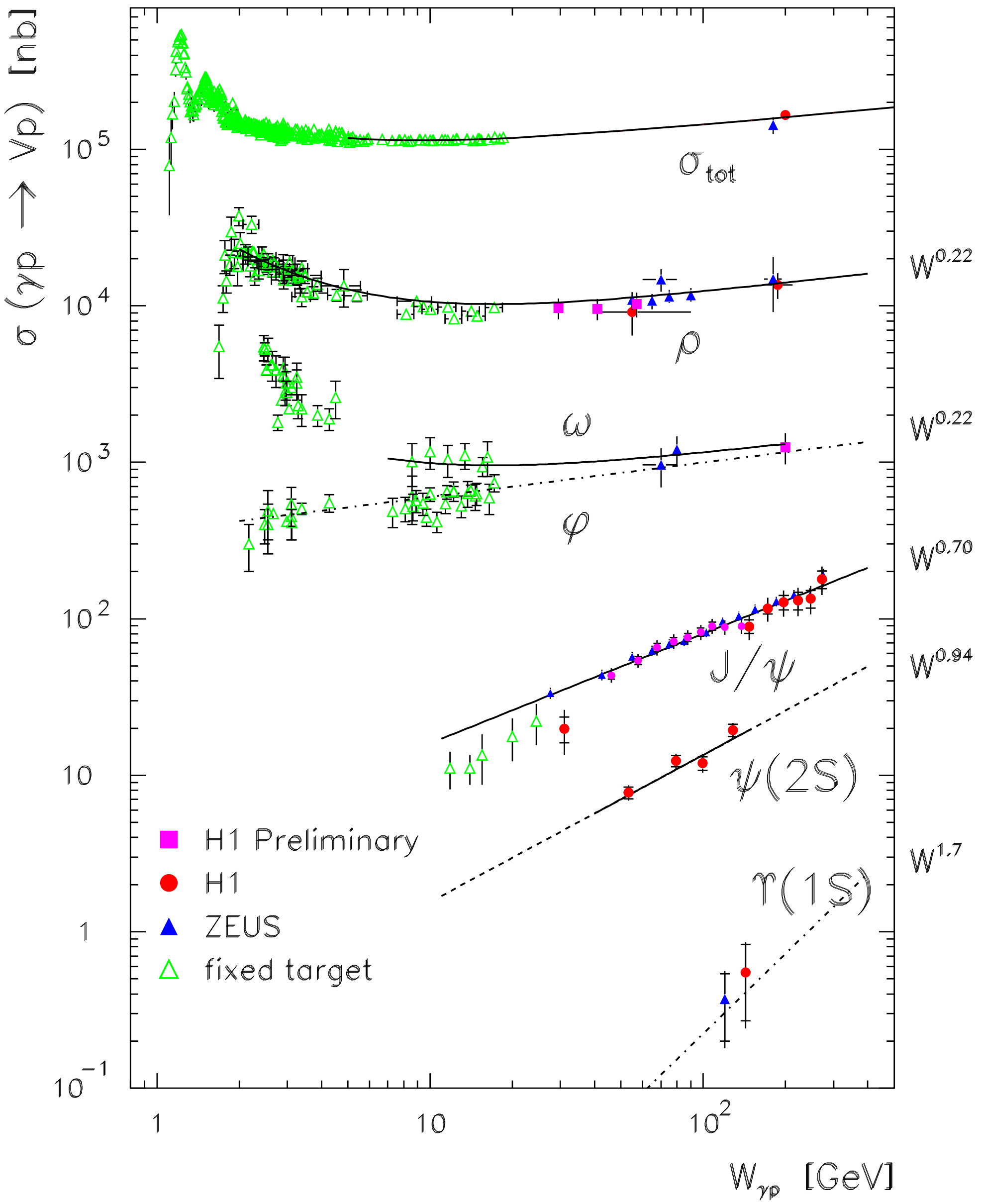
General:

- High $|t|$ VMs are the ideal place to study BFKL dynamics
- Predictions for full “lightcone” VM wavefunction now available
- Light VMs provide information on these as yet unmeasured WFs
- Clean experimental signal with low backgrounds

Analysis:

- A sample of $\sim$ 21000 ρ events $(|t| > 1\ \mathrm{GeV}^2)$ selected
- Initial measurement of differential cross section with $|t|$
- Measurement of SDMEs will test light meson WF assumptions
- Intend to extend analysis to look at ϕ mesons in addition

Elastic Vector Meson Photoproduction



Elastic and photoproduction

$\Rightarrow$ Both $|t|$ and Q^2 small

Light Vector Mesons (ρ, ω, ϕ):

Observed dependence $\sigma \sim W^{0.22}$

$\Rightarrow$ Consistent with soft $I\!P$ expectation

which comes out of Regge theory

Heavier Vector Mesons $(J/\psi, \psi(2s))$:

Steeper rise in cross section observed

$\Rightarrow$ Need something in addition to soft $I\!P$

What about QCD?

BFKL & DGLAP Evolution

1. DGLAP LL: sums terms in $\alpha_s^n \log^n(Q^2)$

Strong k_T ordering: $k_{T,i}^2 \ll k_{T,i+1}^2 \ll \ldots \ll Q^2$

Weak long. mom ordering: $x_i > x_{i+1} > \ldots > x$

Used to evolve quark and gluon PDFs in Q^2

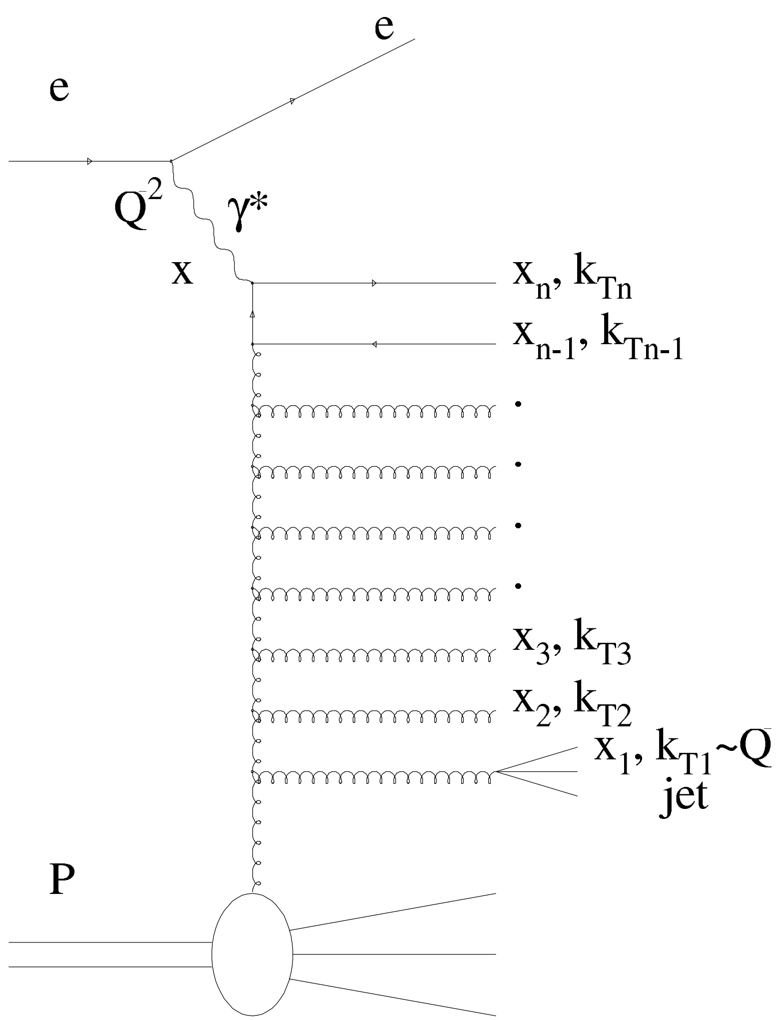
Fails at low x!

2. BFKL LL: sums terms in $\alpha_s^n \log^n(1/x)$

No ordering in $k_T \Rightarrow$ "random walk" . . . but . . .

Strong long. mom ordering: $x_i \gg x_{i+1} \gg \ldots \gg x$

Both predict fast rise in cross section with W



High $|t|$ vector mesons $\Rightarrow$ ideal place to test BFKL dynamics

Helicity in High $|t|$ J/ψ Photoproduction

Untagged electron:

Can only measure 2 angular distributions $\theta^\star$ & $\phi^\star$

$\Rightarrow$ Provides access to 3 indep linear combos

of "spin density matrix elements (SDMEs)"

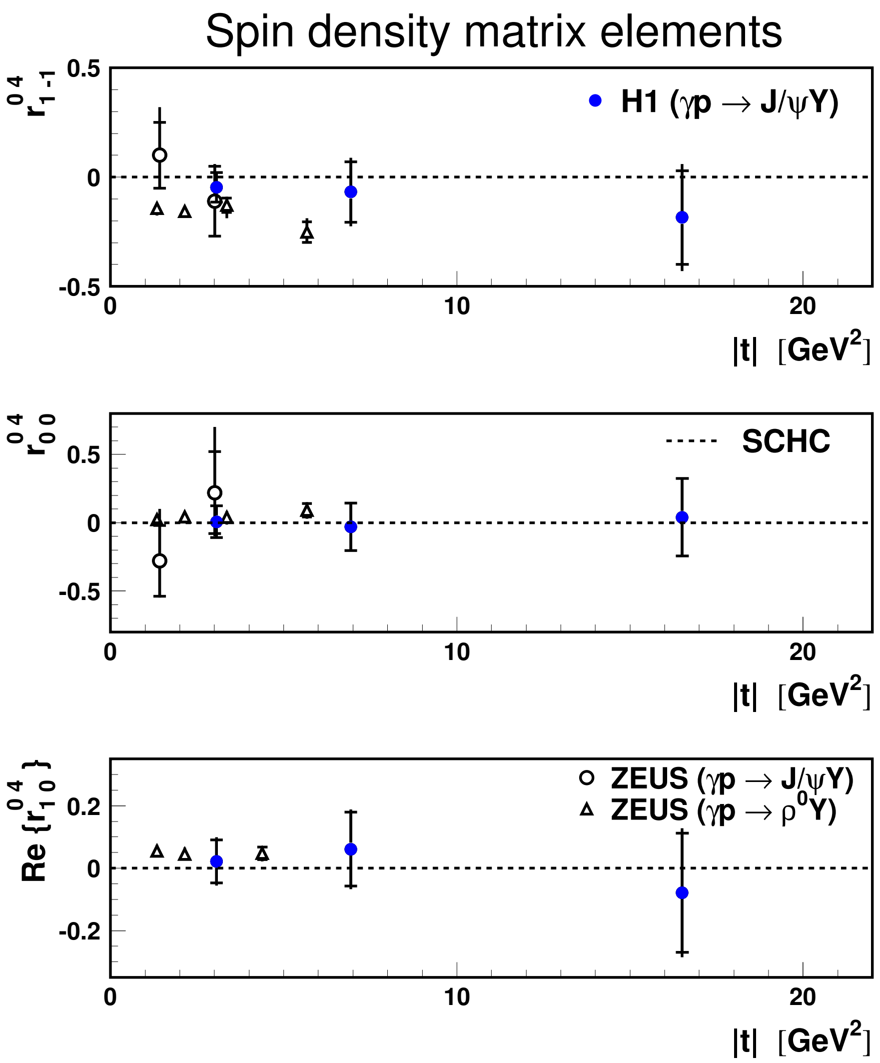
s channel helicity conservation (SCHC)

$\Rightarrow$ Vector meson retains helicity of photon

$\Rightarrow$ All 3 combos of SMDEs predicted to be zero

J/ψ data consistent with zero & therefore SCHC

$\Rightarrow$ Simple WF assumptions appear satisfactory



In contrast ρ is not consistent with zero $\Rightarrow$ SCHC is violated $\therefore$ more complicated WF needed?

Background Processes

Several possible processes can fake a signal of two oppositely charged tracks:

$\phi \rightarrow K^+K^-$	Two charged kaons fake pions and therefore ρ
$\omega \rightarrow \pi^+\pi^-\pi^0$	Neutral pion undetected & charged pions fake ρ
$\rho' \rightarrow \rho^\pm\pi^\mp\pi^0$	Opp charged pions from two-stage decay fake ρ
$\hookrightarrow \pi^\pm\pi^0$	and both neutral pions remain undetected

Also treating small ($|t| \leq 3$) elastic ρ contribution as a background