

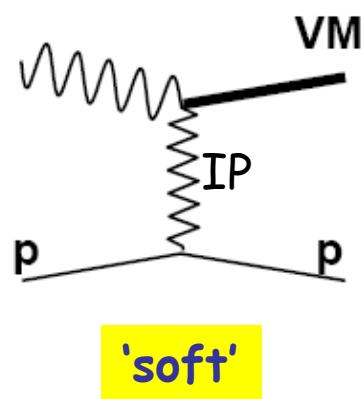
# Exclusive $\rho^0$ electroproduction

$$\gamma^* p \rightarrow \rho^0 p$$

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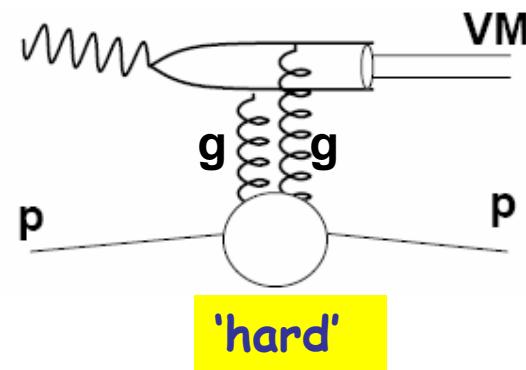
on behalf of  
the ZEUS Collaboration

# Why are we measuring



$$\sigma(W) \propto W^\delta$$

$$\frac{d\sigma}{dt} \propto e^{-b|t|}$$



- Expect  $\delta$  to increase from soft ( $\sim 0.2$ , from 'soft Pomeron' value) to hard ( $\sim 0.8$ , from  $xg(x, Q^2)^2$ )
- Expect  $b$  to decrease from soft ( $\sim 10 \text{ GeV}^{-2}$ ) to hard ( $\sim 4-5 \text{ GeV}^{-2}$ )

# $\mathcal{M}(\pi\pi)$ - all

Data collected during  
1996-2000,  $\mathcal{L} \sim 120 \text{ pb}^{-1}$

$2 < Q^2 < 160 \text{ GeV}^2$

$32 < W < 160 \text{ GeV}$

For analysis:

$0.65 < M(\pi\pi) < 1.1 \text{ GeV}$

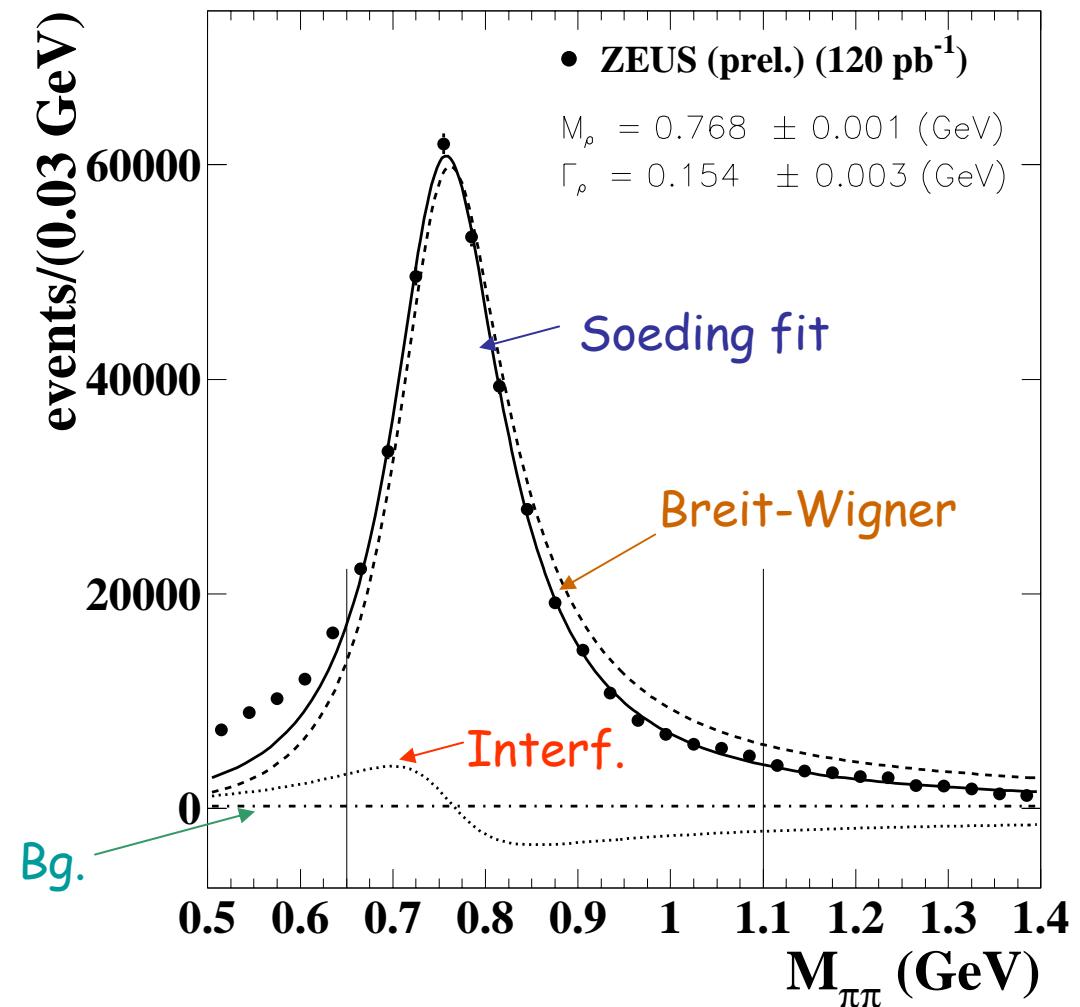
$|t| < 1 \text{ GeV}^2$

71,700 events

For cross sections:

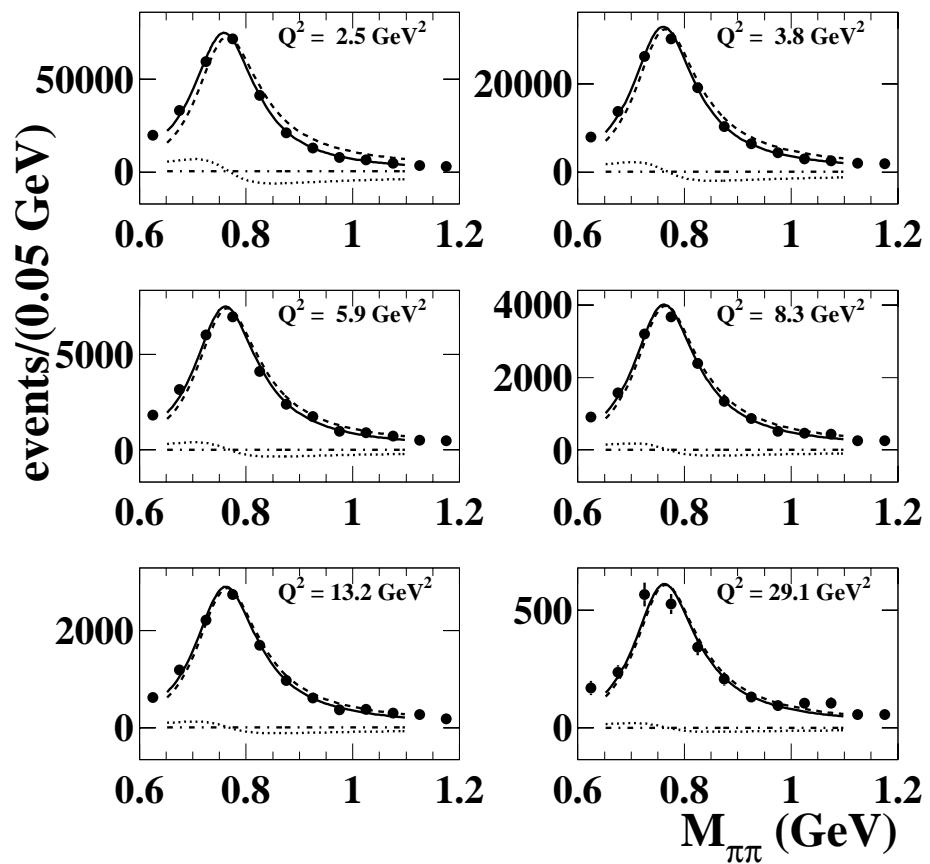
integrated over whole  $t$  and  
 $p^0$  mass

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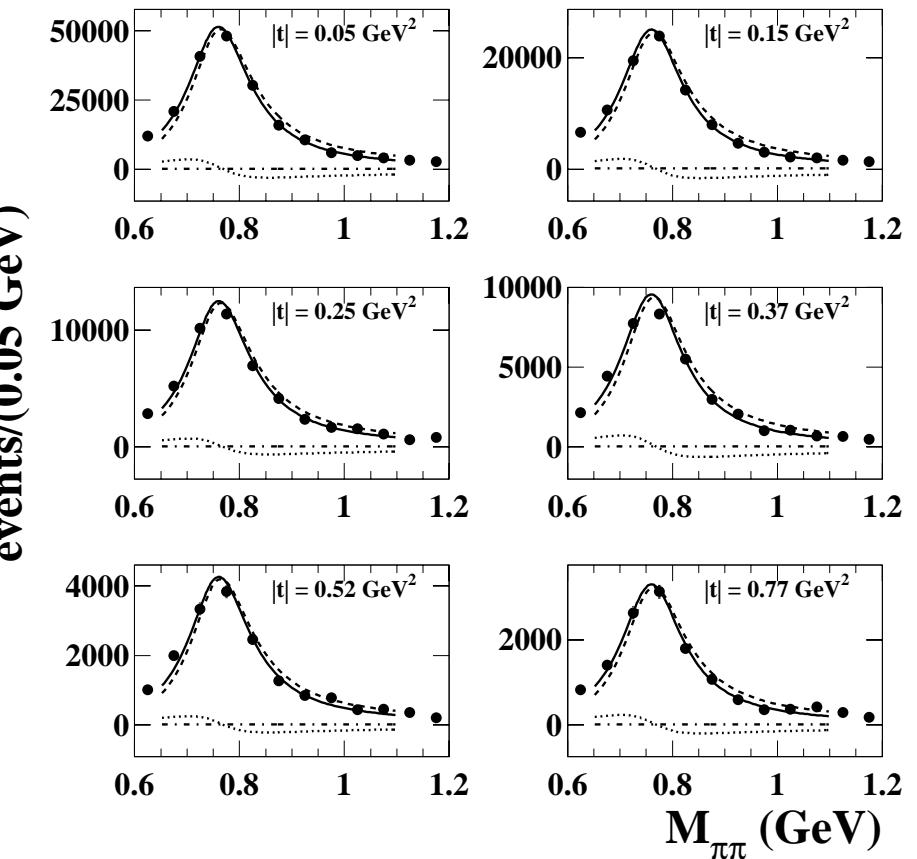


# $\mathcal{M}(\pi\pi) - Q^2, t$

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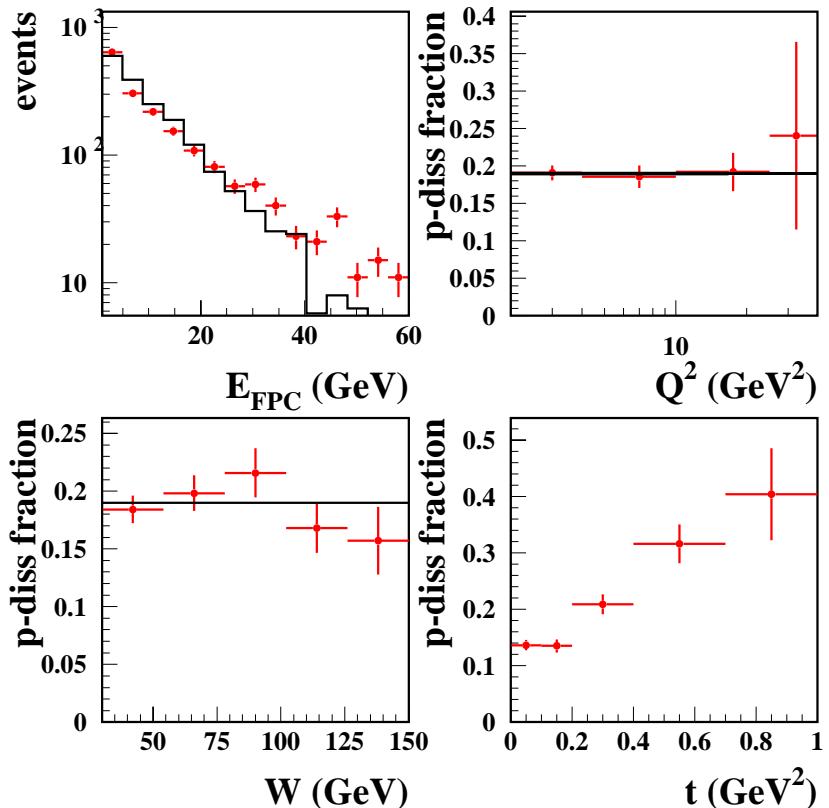
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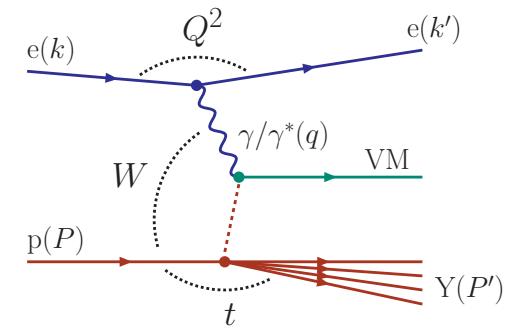
$\rho^0$  mass shape not dependent on  $Q^2$  and  $t$ .  
As  $Q^2$  increases, interference term decreases - as expected.

# Proton dissociation

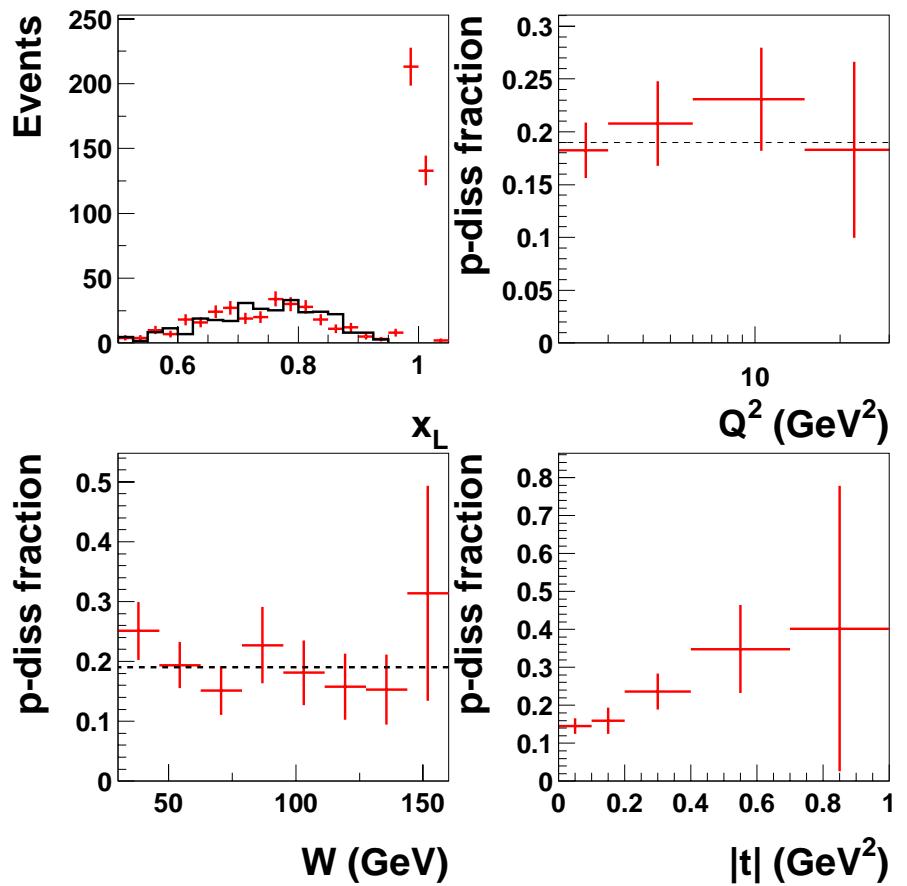
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MC: PYTHIA



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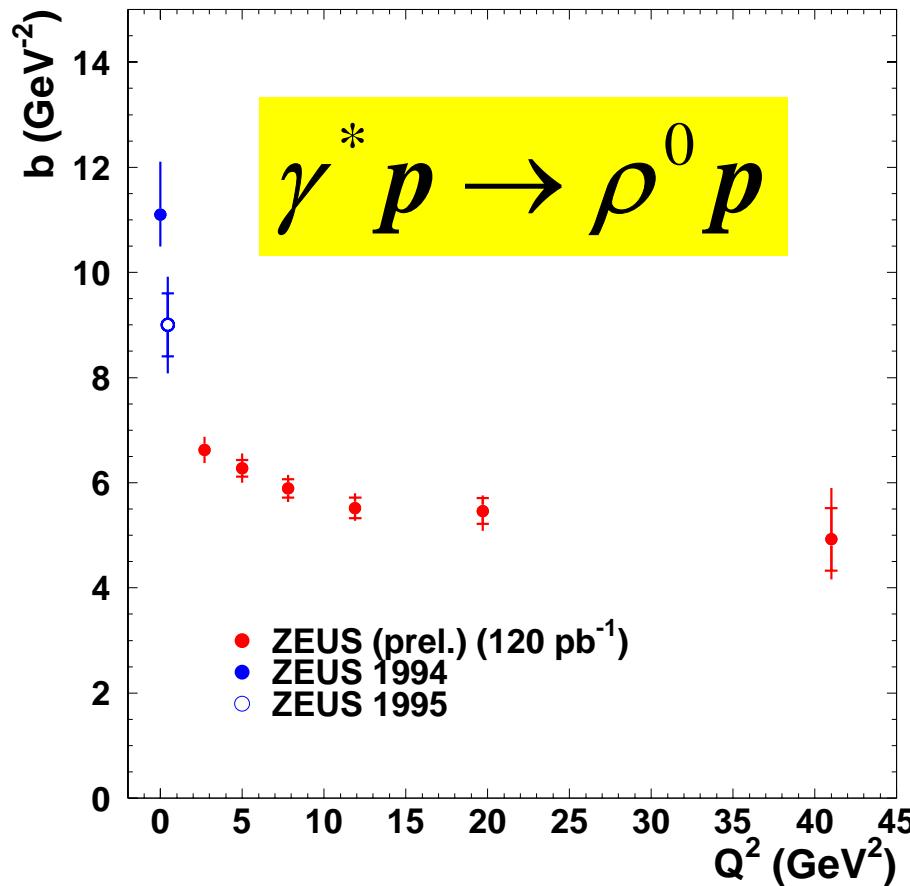


$$\text{pdiss: } 19 \pm 2(\text{st}) \pm 3(\text{sys}) \%$$

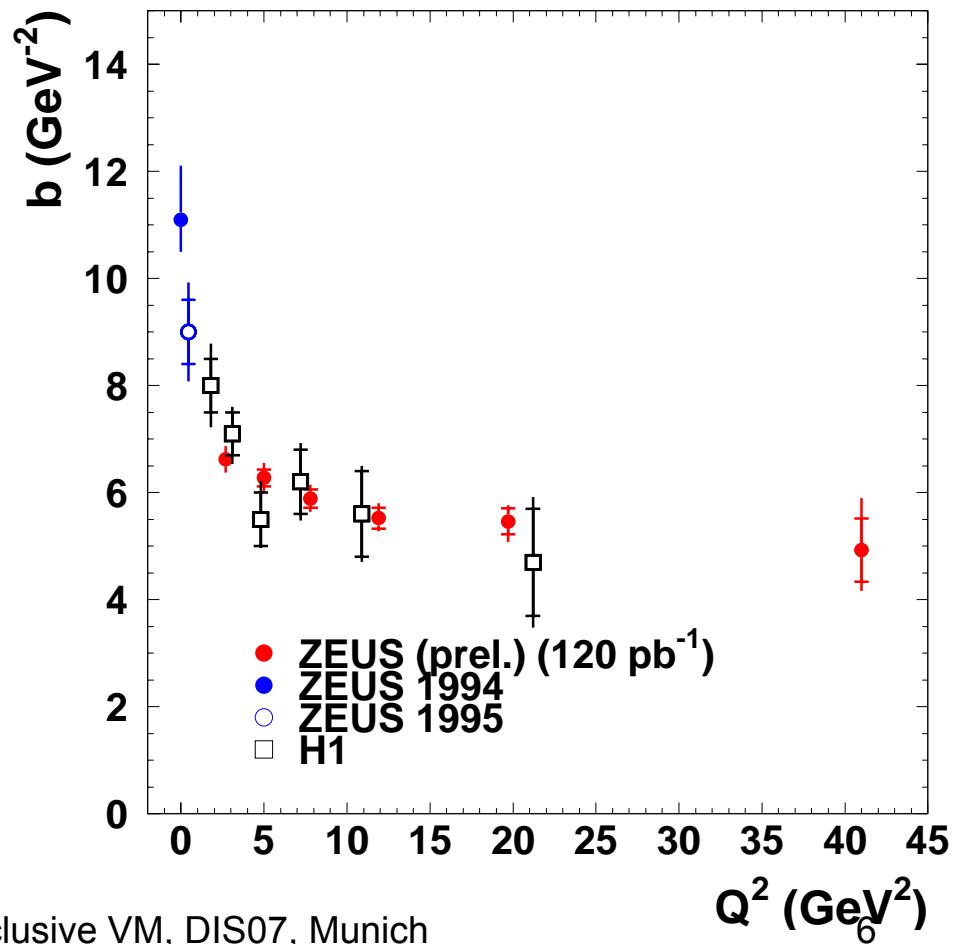
# b( $Q^2$ )

Fit  $\frac{d\sigma}{dt} \propto e^{-b|t|}$  in different  $Q^2$  bins:

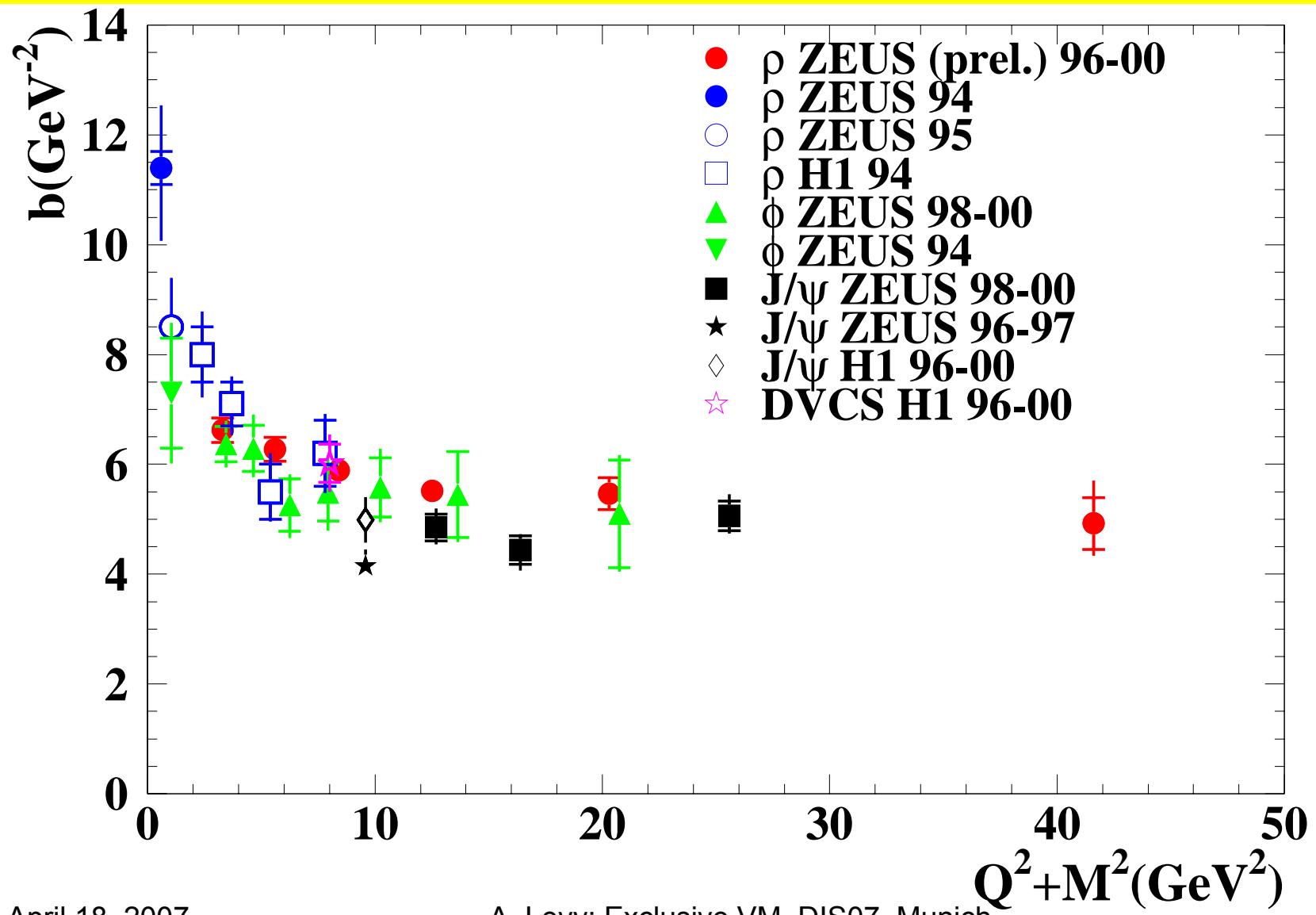
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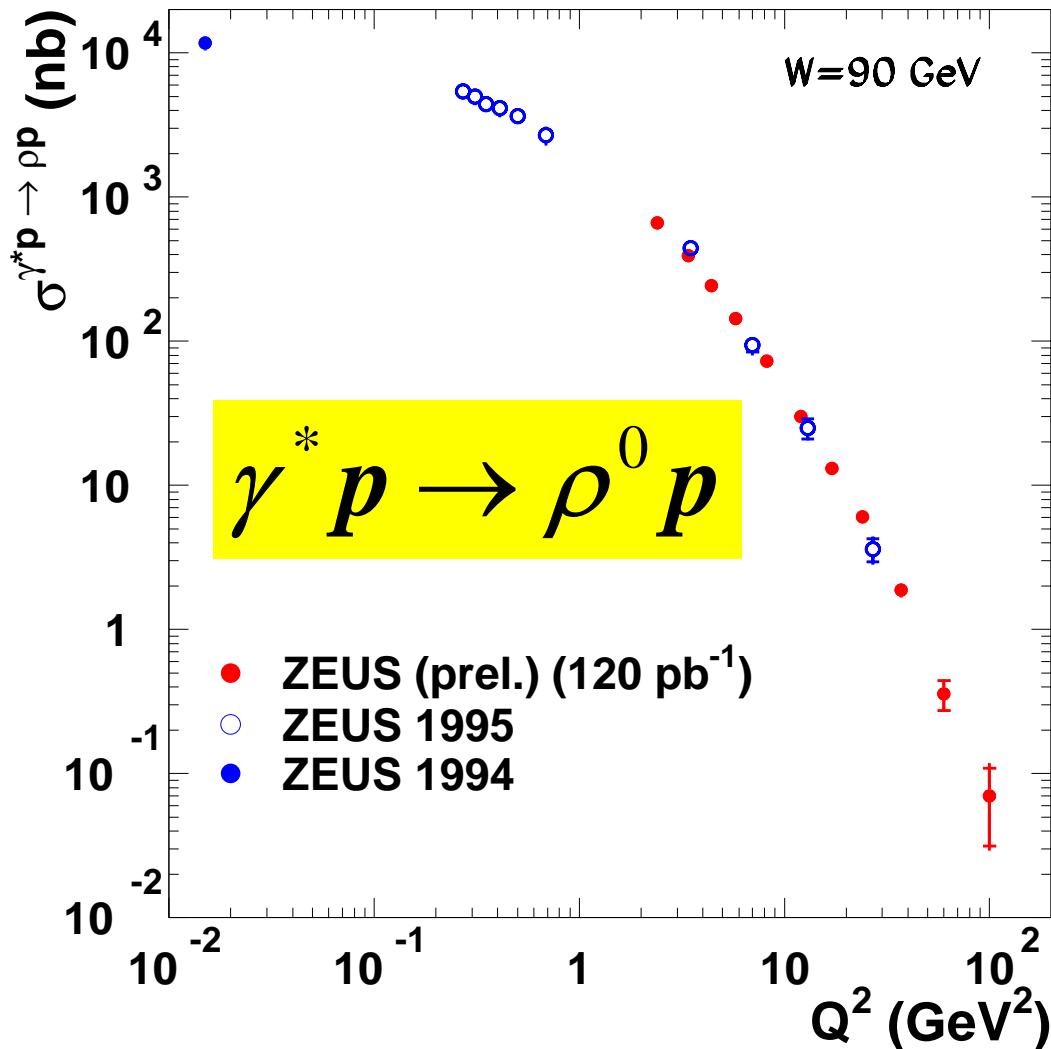


# $b(Q^2 + M^2) - VM$



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## $\sigma(Q^2)$

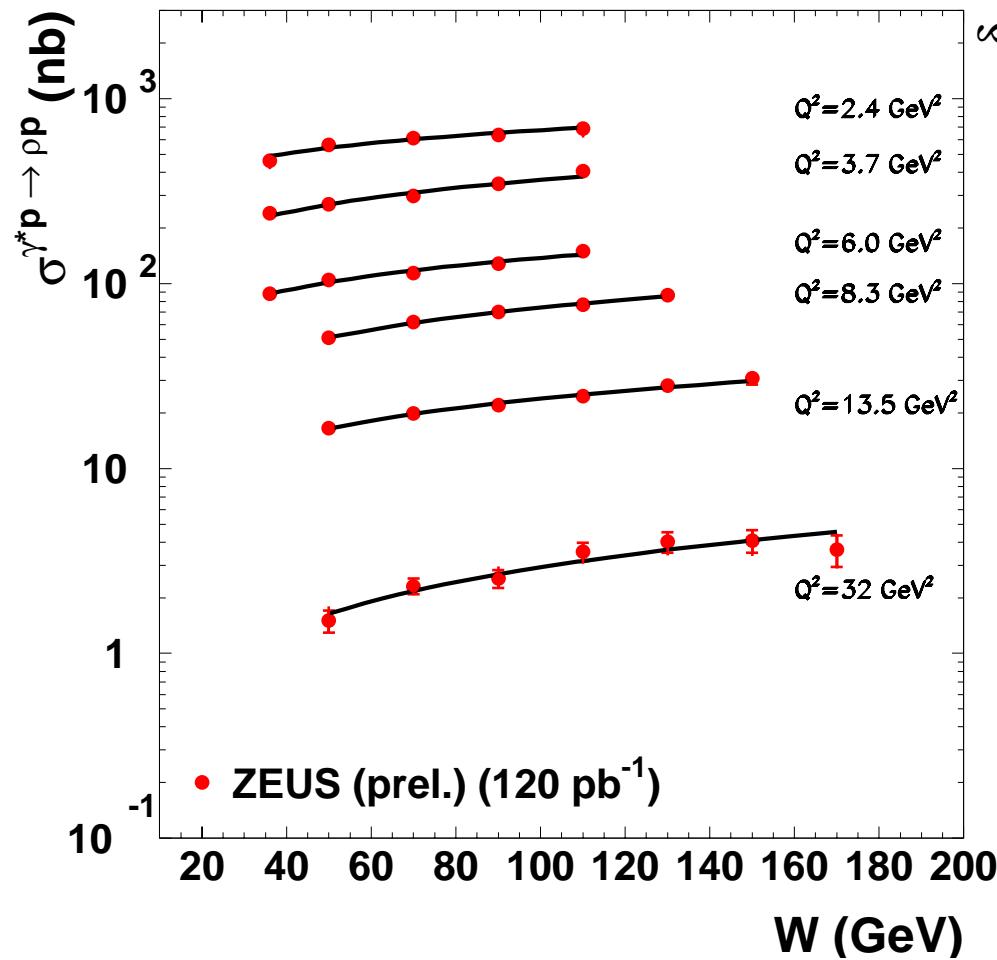


$$\sigma \propto (Q^2 + M^2)^{-n}$$

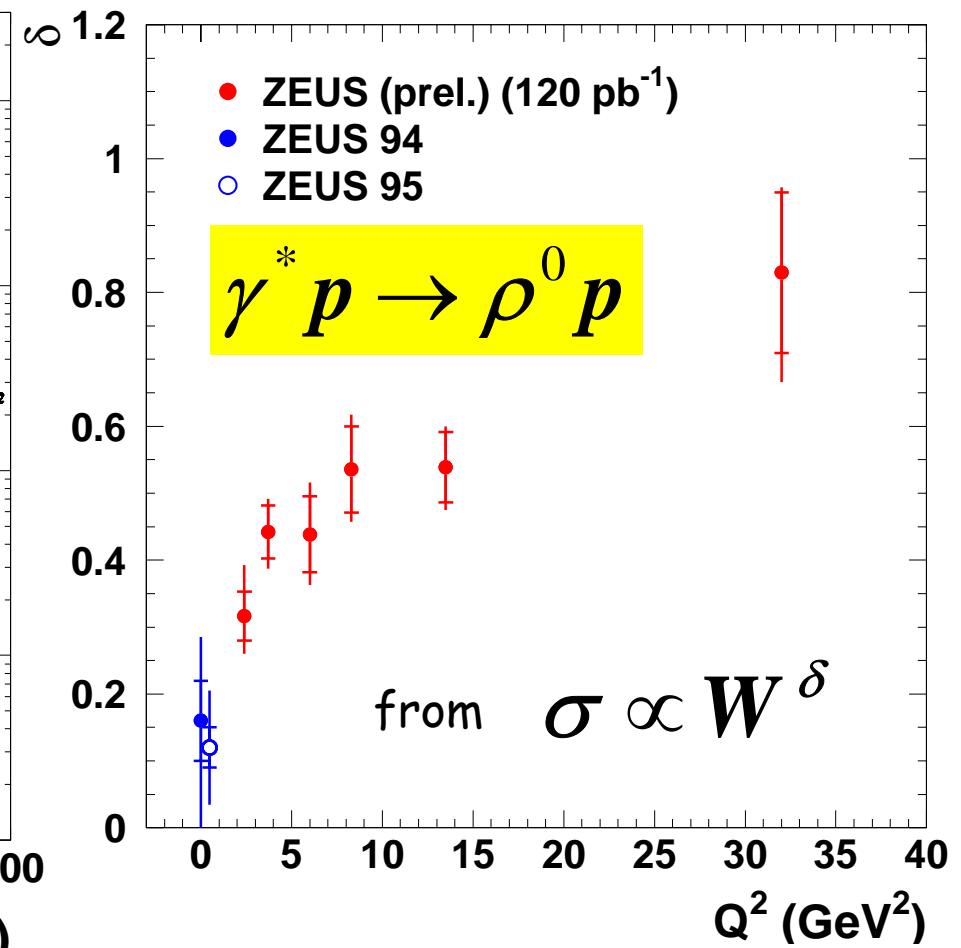
Fit to whole  $Q^2$  range  
gives bad  $\chi^2/\text{df} (\sim 70)$

# $\sigma(W)$

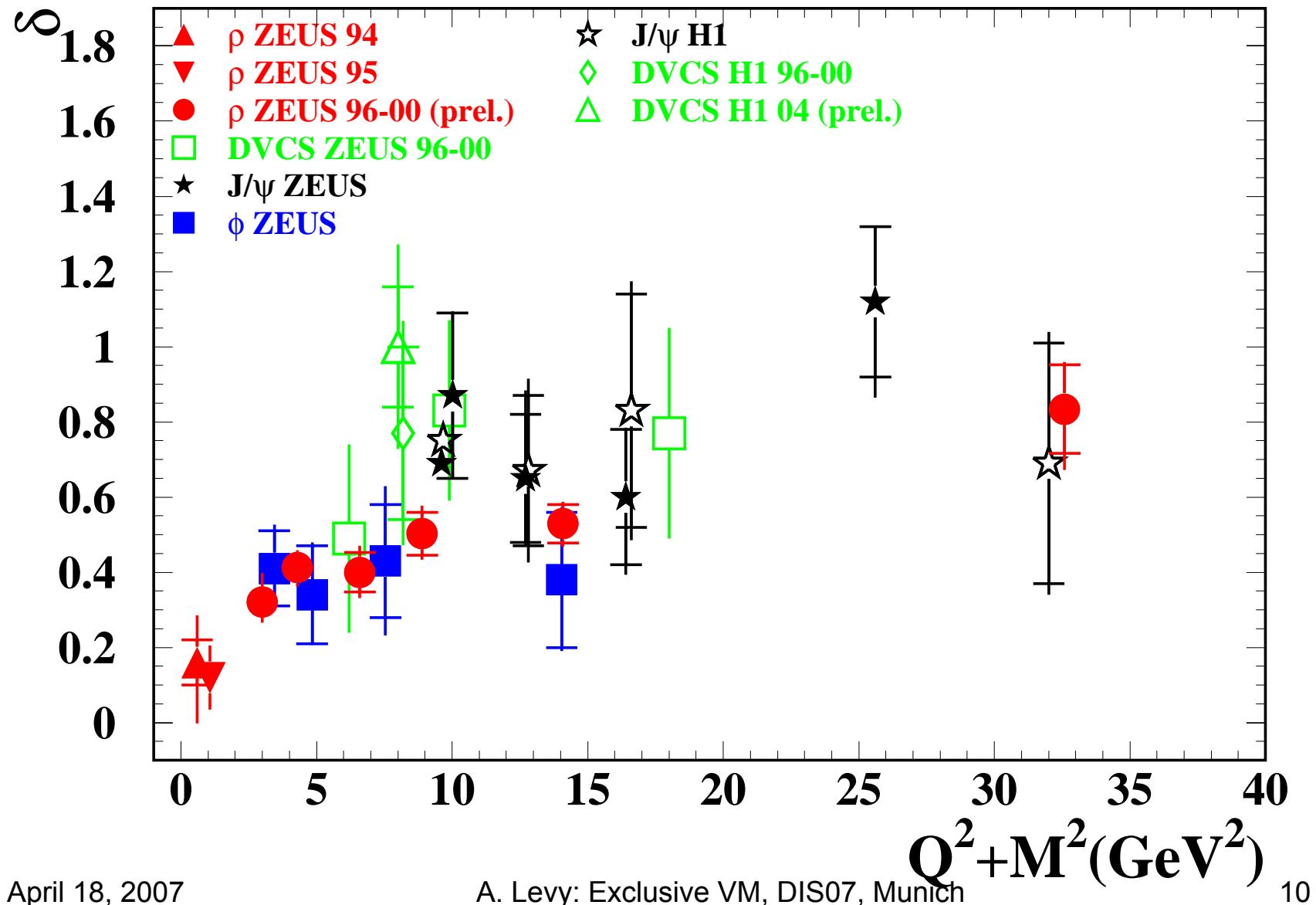
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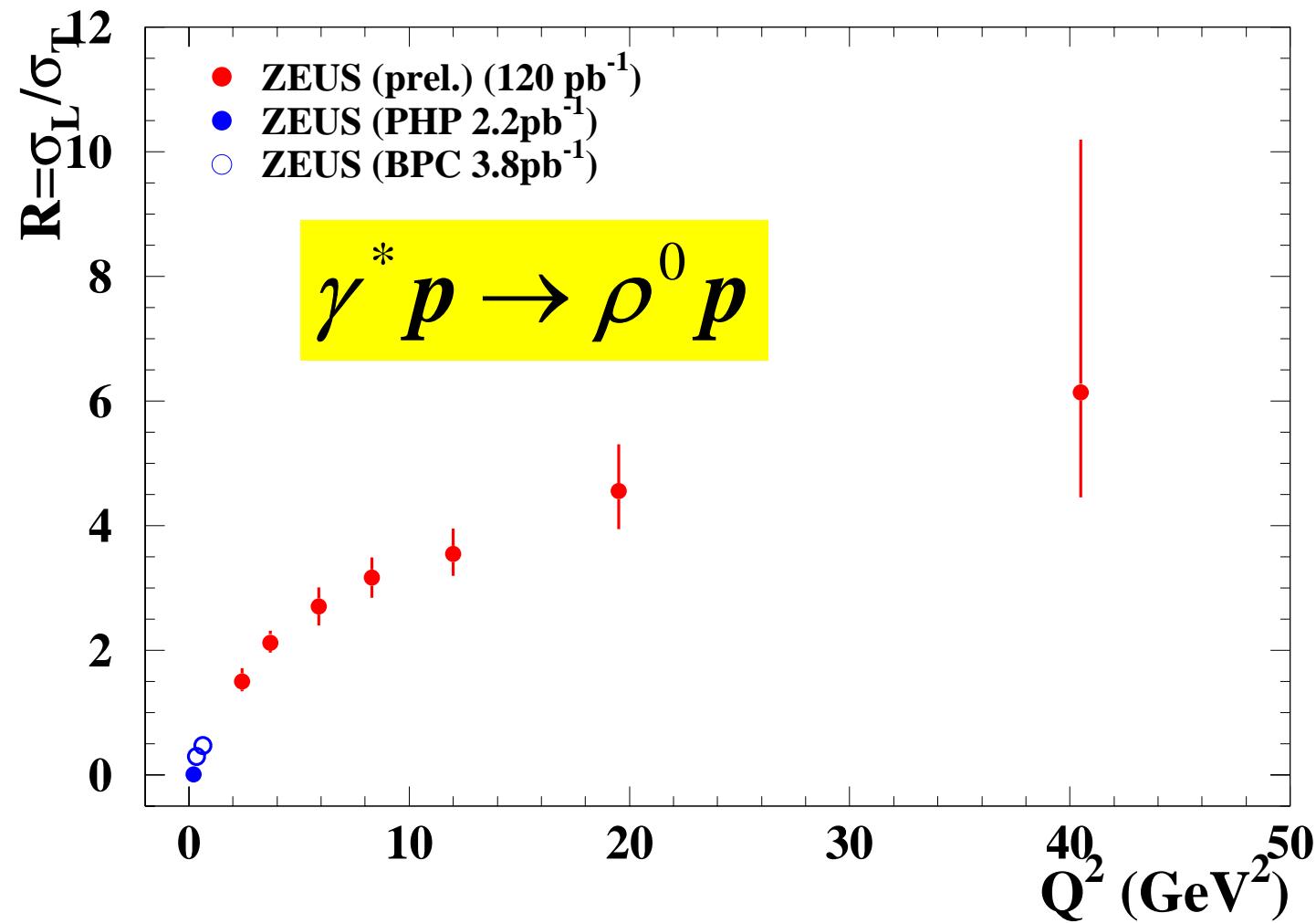


# $\delta(Q^2) - \text{VM}$

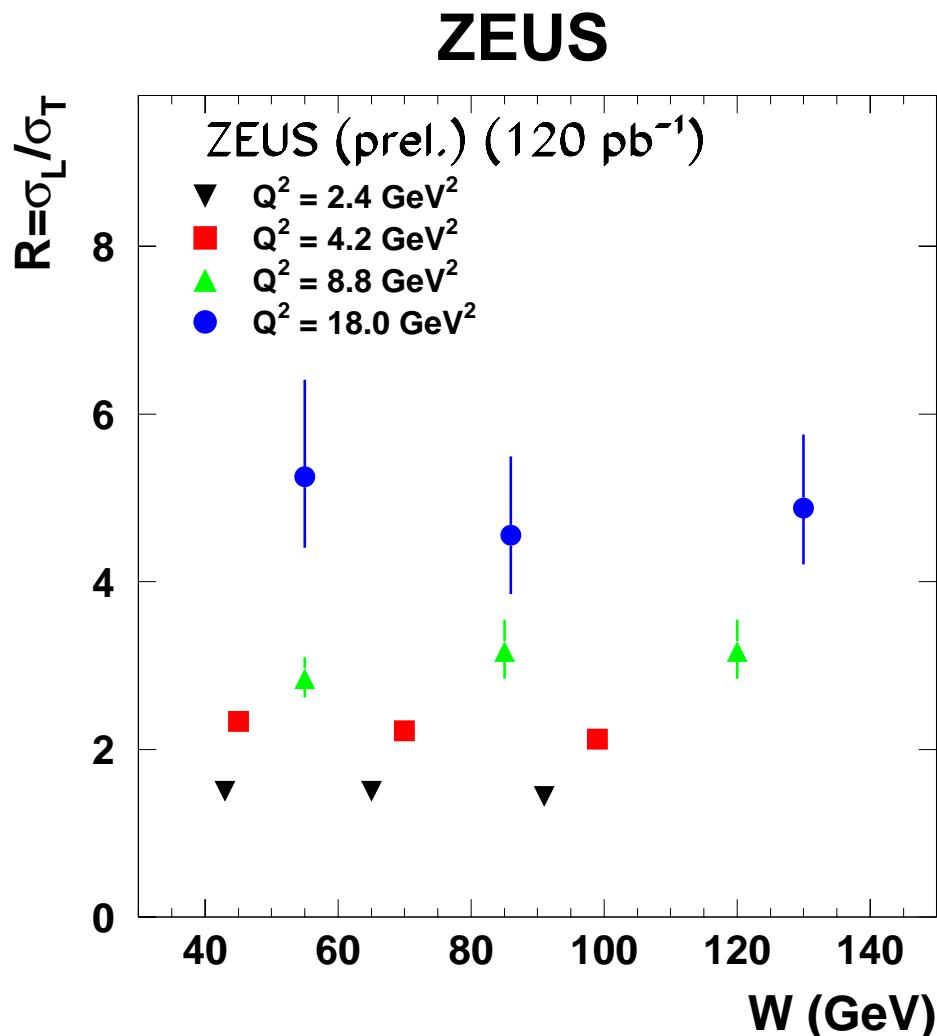


$$R = \sigma_L / \sigma_T (Q^2)$$

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# $R(W)$



$\Rightarrow \sigma_L$  and  $\sigma_T$  same  $W$  dependence

???

$\sigma_L \Rightarrow (\text{qqbar})$  in small configuration

$\sigma_T \Rightarrow (\text{qqbar})$  in small and large configurations

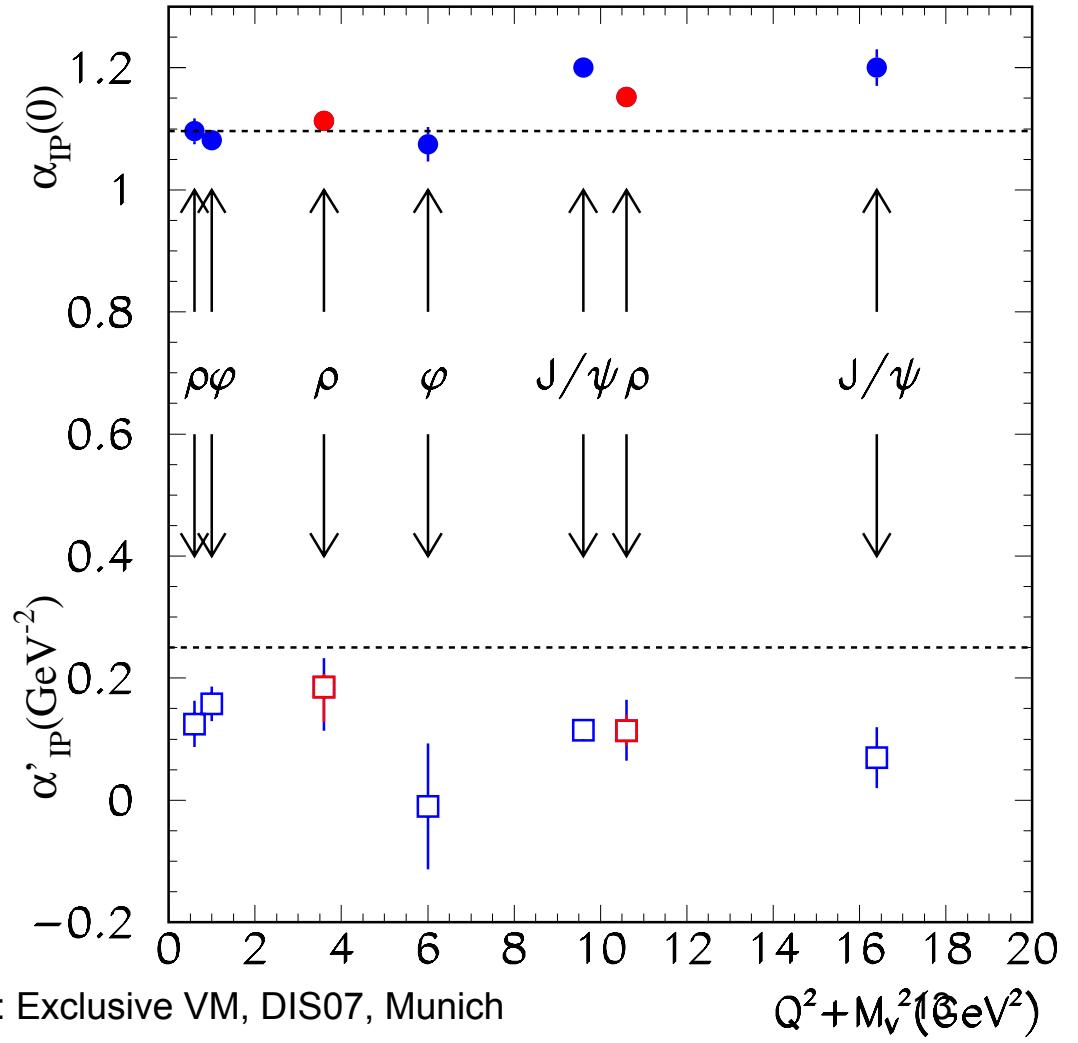
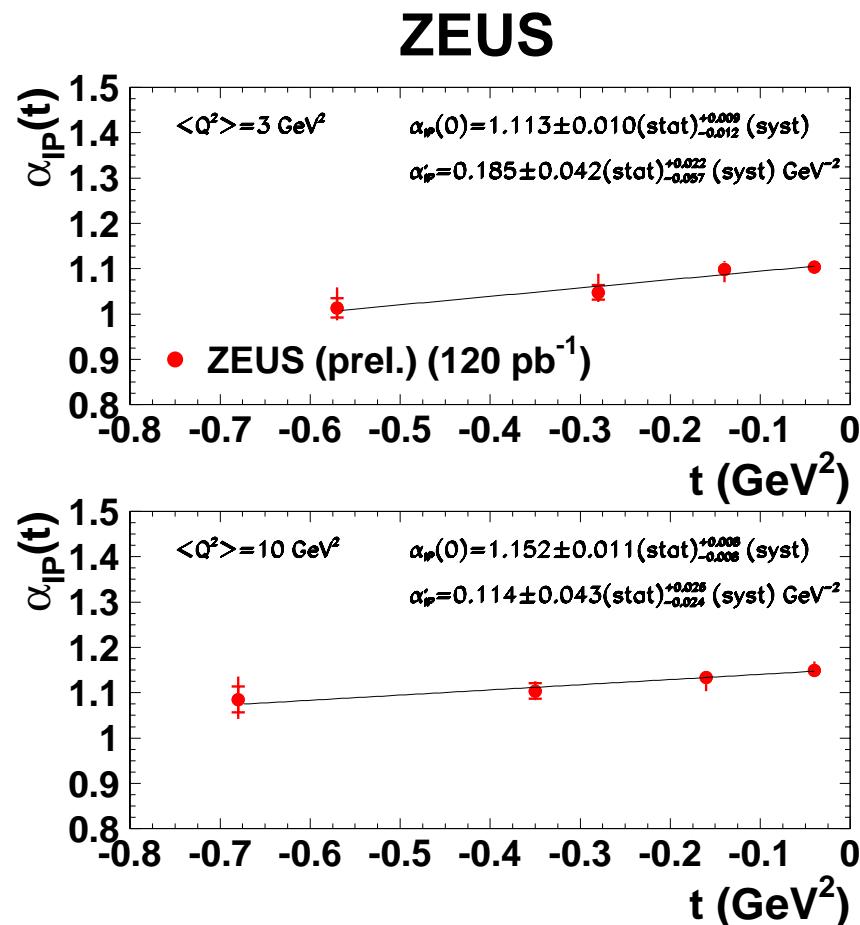
small configuration  $\Rightarrow$  steep  $W$  dep

large configuration  $\Rightarrow$  slow  $W$  dep

$\Rightarrow$  large (qqbar) configuration is suppressed

# Pomeron trajectory

Get Pomeron trajectory from  $d\sigma/dt(W)$  at fixed  $t$

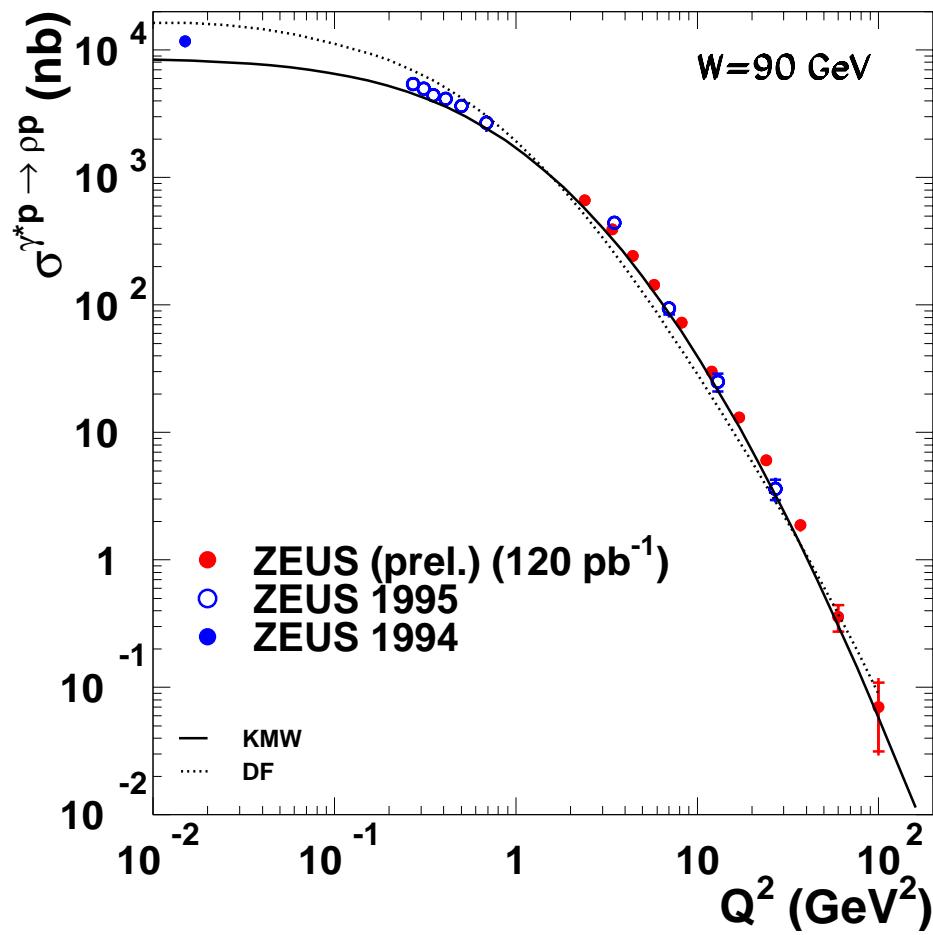


# Comparison to theory

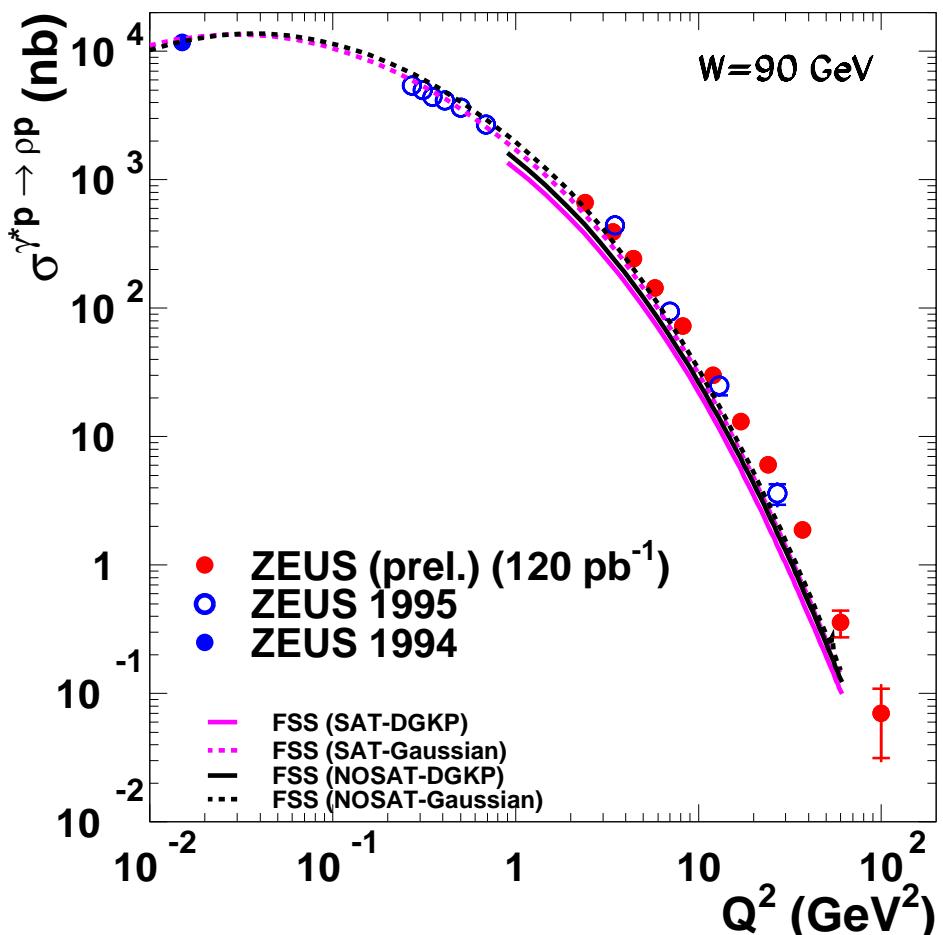
- Martin-Ryskin-Teubner (MRT) - work in momentum space, use parton-hadron duality, put emphasis on gluon density determination.  
*Phys. Rev. D 62, 014022 (2000).*
- Forshaw-Sandapen-Shaw (FSS) - improved understanding of VM wf. Try Gaussian and DGKP (2-dim Gaussian with light-cone variables).  
*Phys. Rev. D 69, 094013 (2004).*
- Kowalski-Motyka-Watt (KMW) - add impact parameter dependence,  $Q^2$  evolution - DGLAP.  
*Phys. Rev. D 74, 074016 (2006).*
- Dosch-Ferreira (DF) - focusing on the dipole cross section using Wilson loops. Use soft+hard Pomeron for an effective evolution.  
*hep-ph/0610311 (2006).*

# $Q^2$

## ZEUS

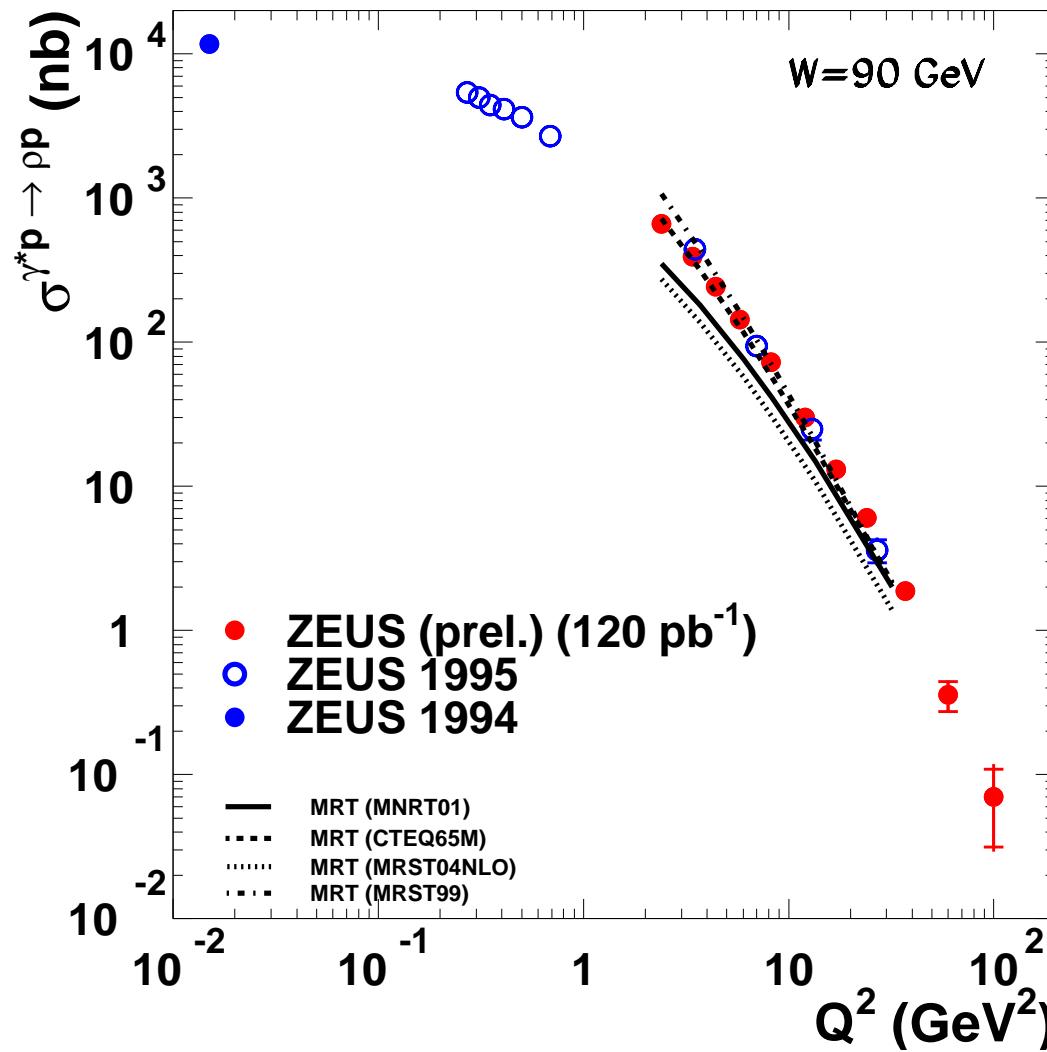


## ZEUS



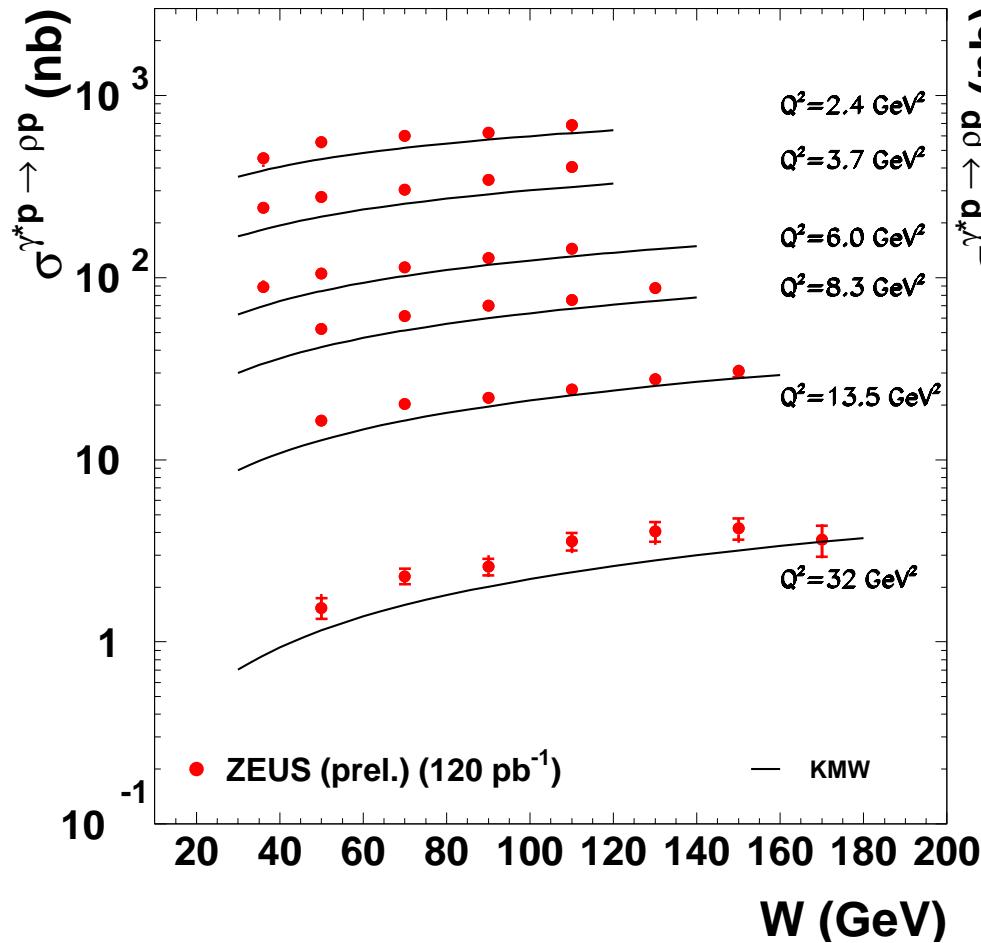
$Q^2$

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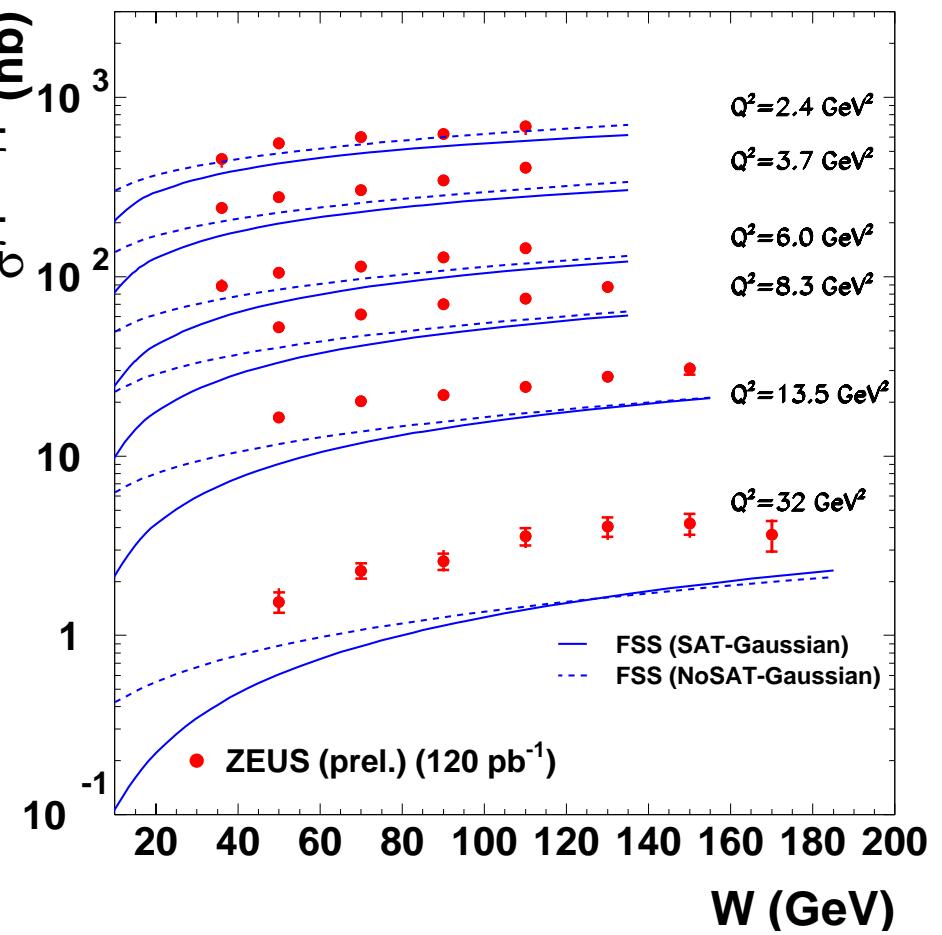


# W dependence

ZEUS

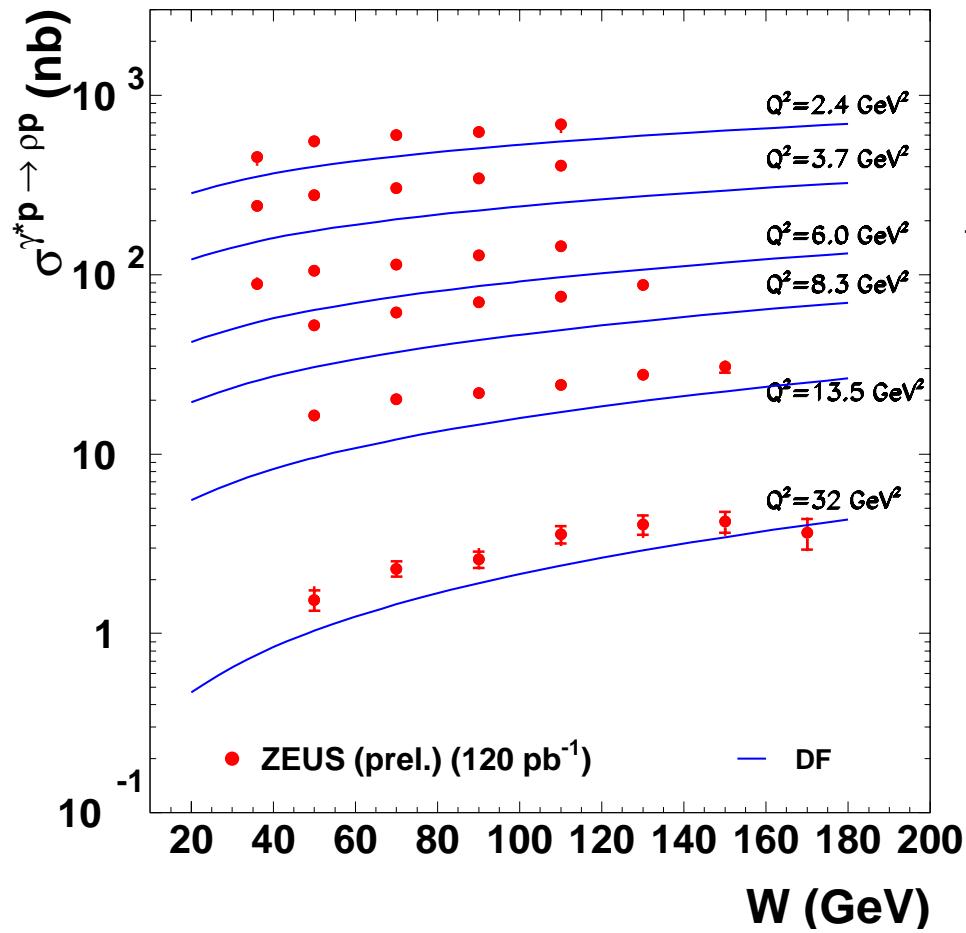


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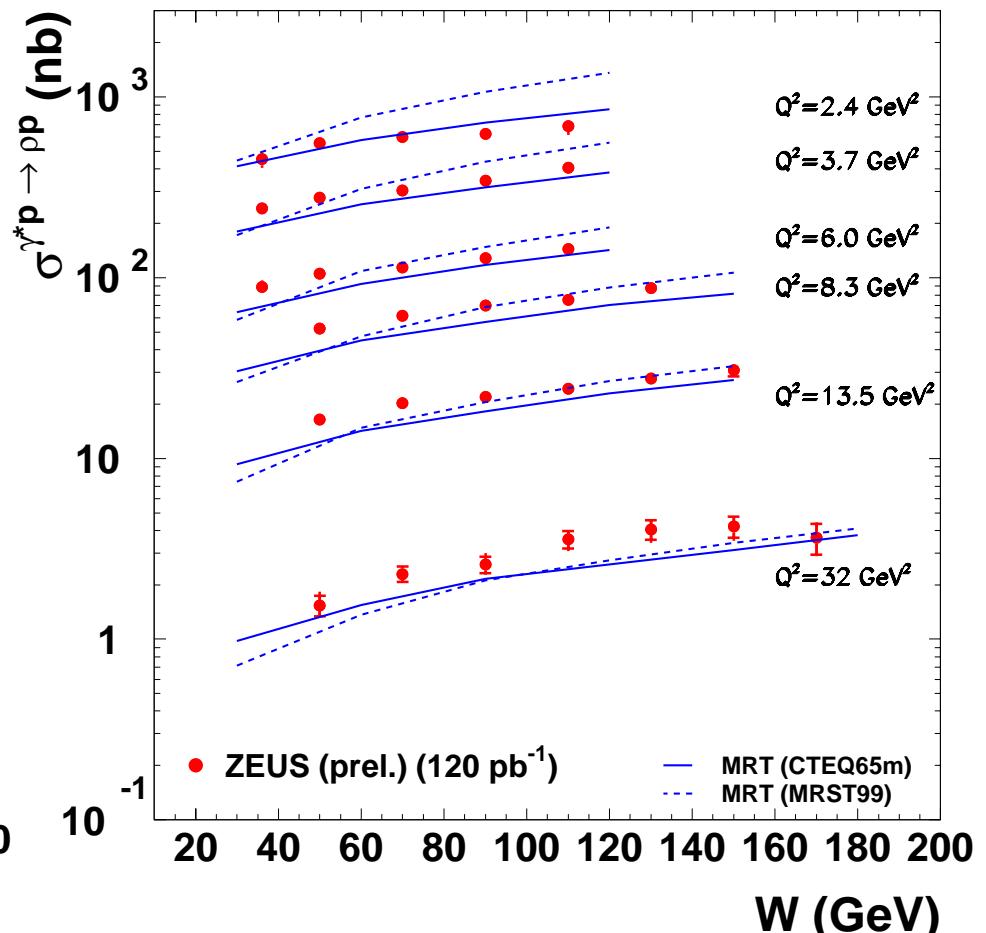


# W dependence

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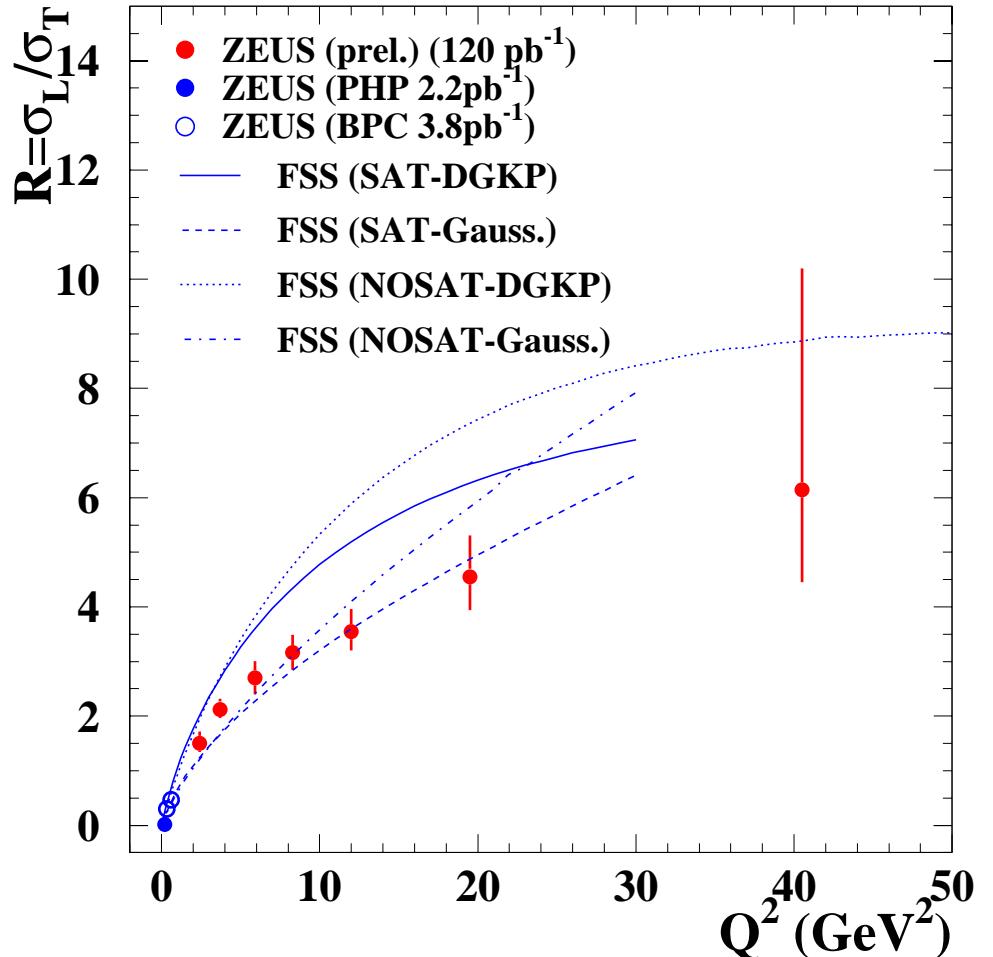
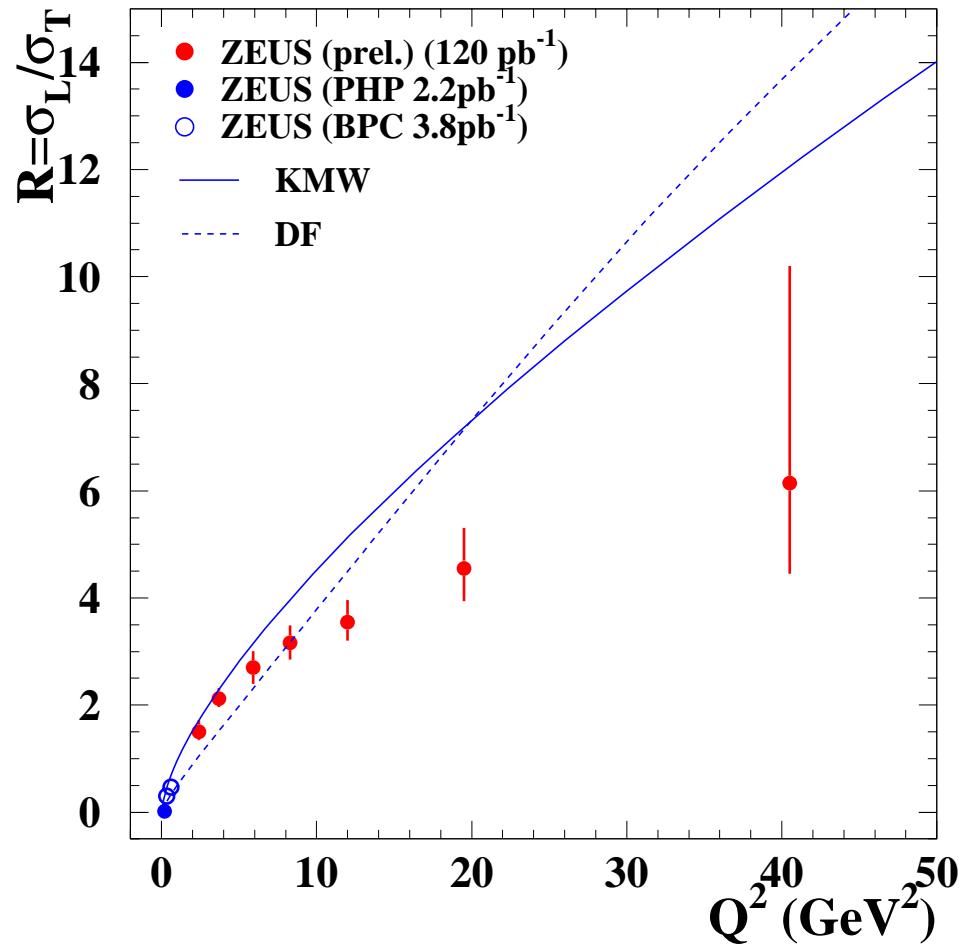
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# $R(Q^2)$

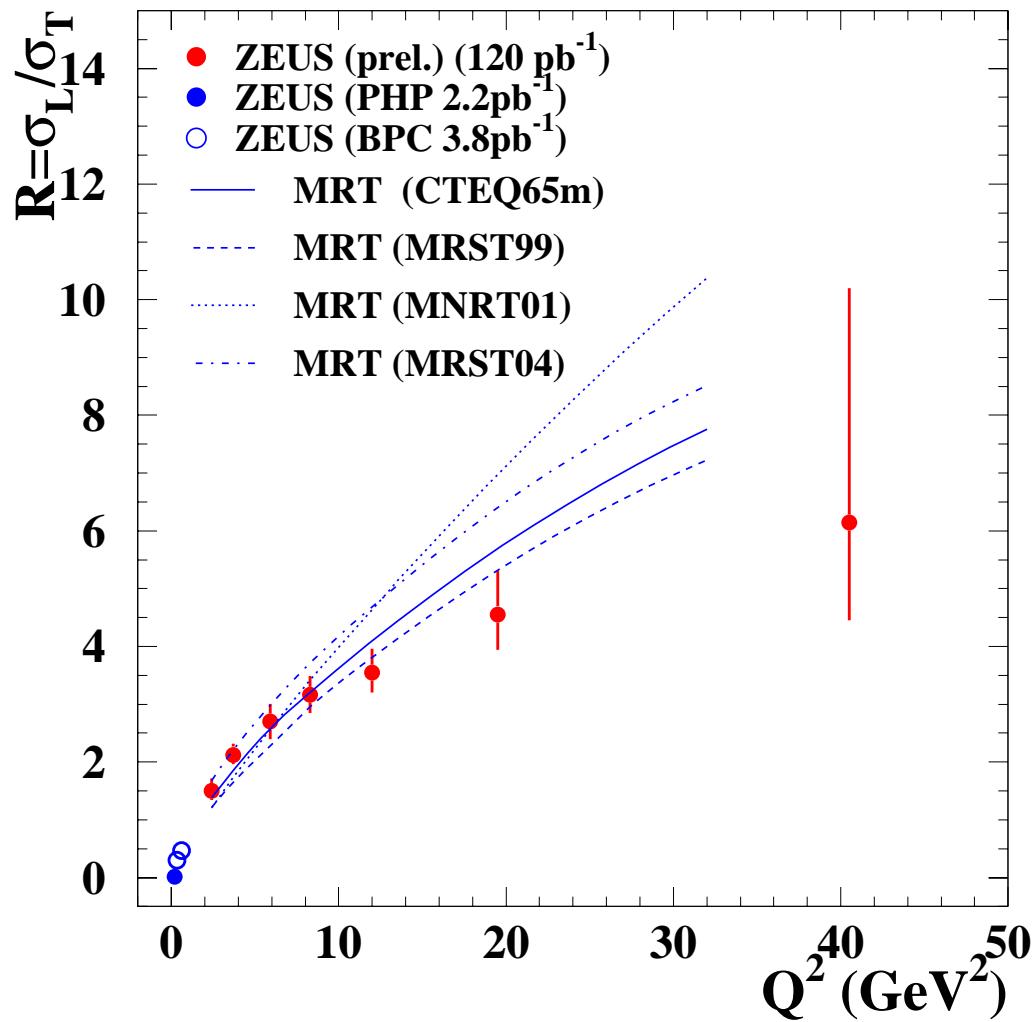
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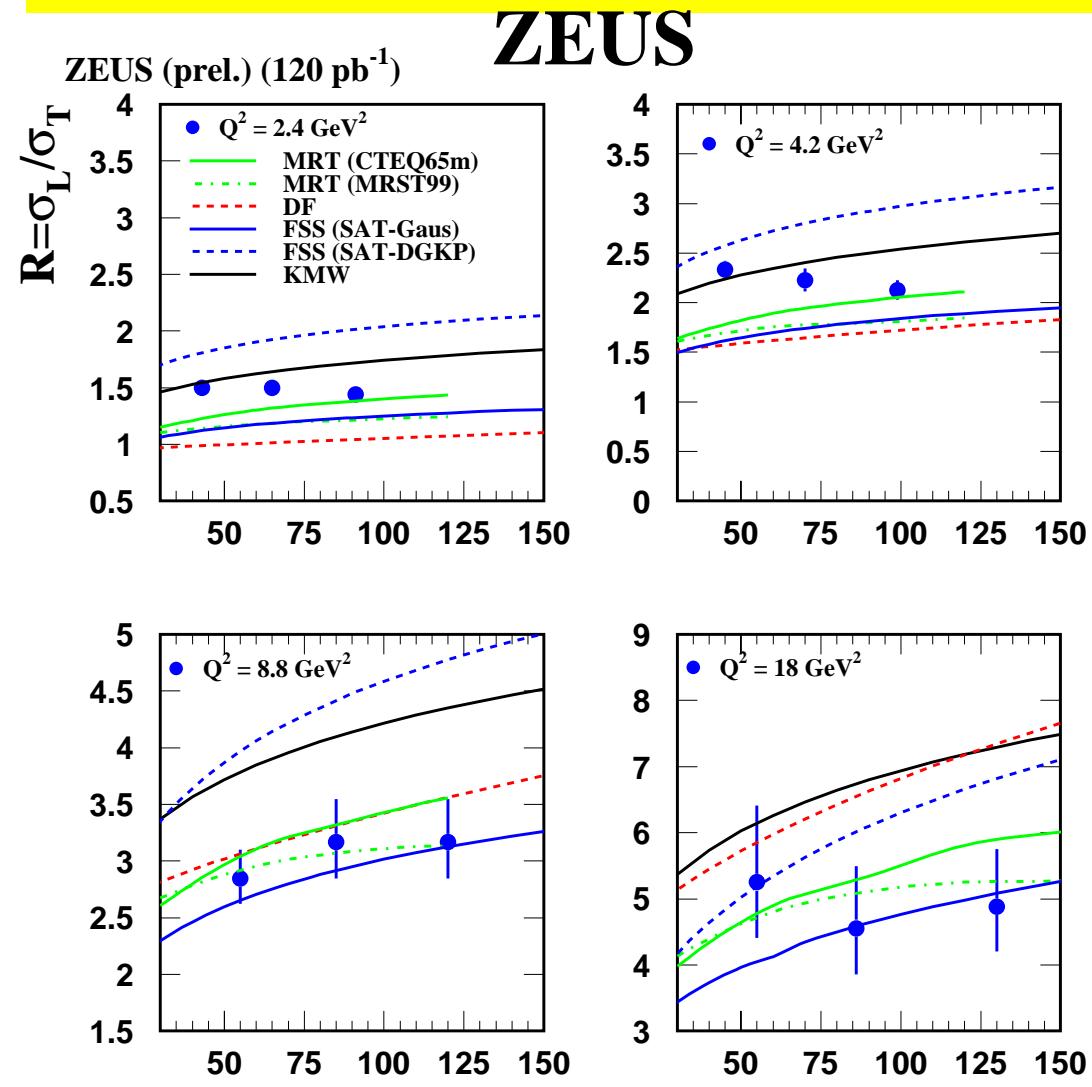


# $R(Q^2)$

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# R(W)

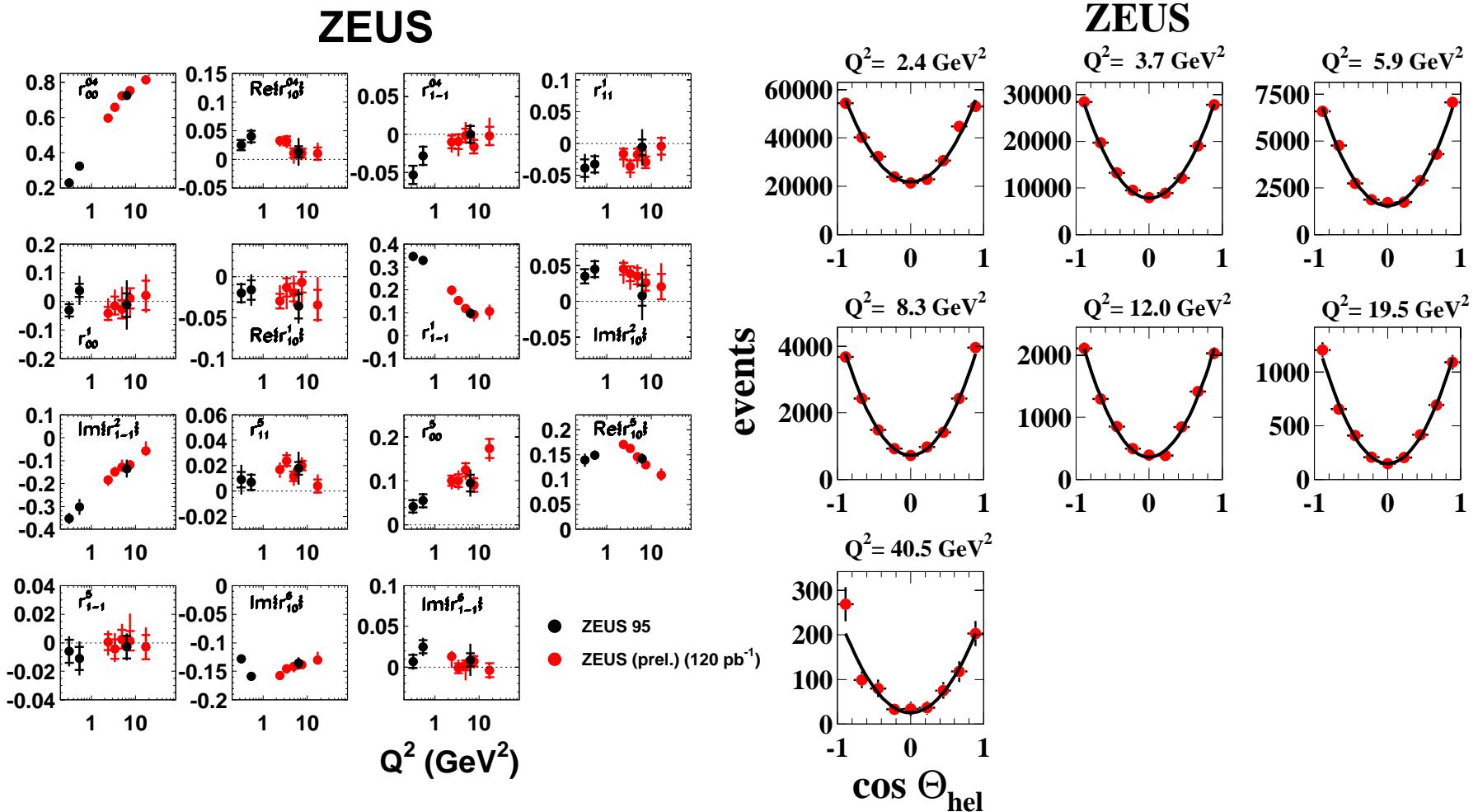


# Summary and conclusions

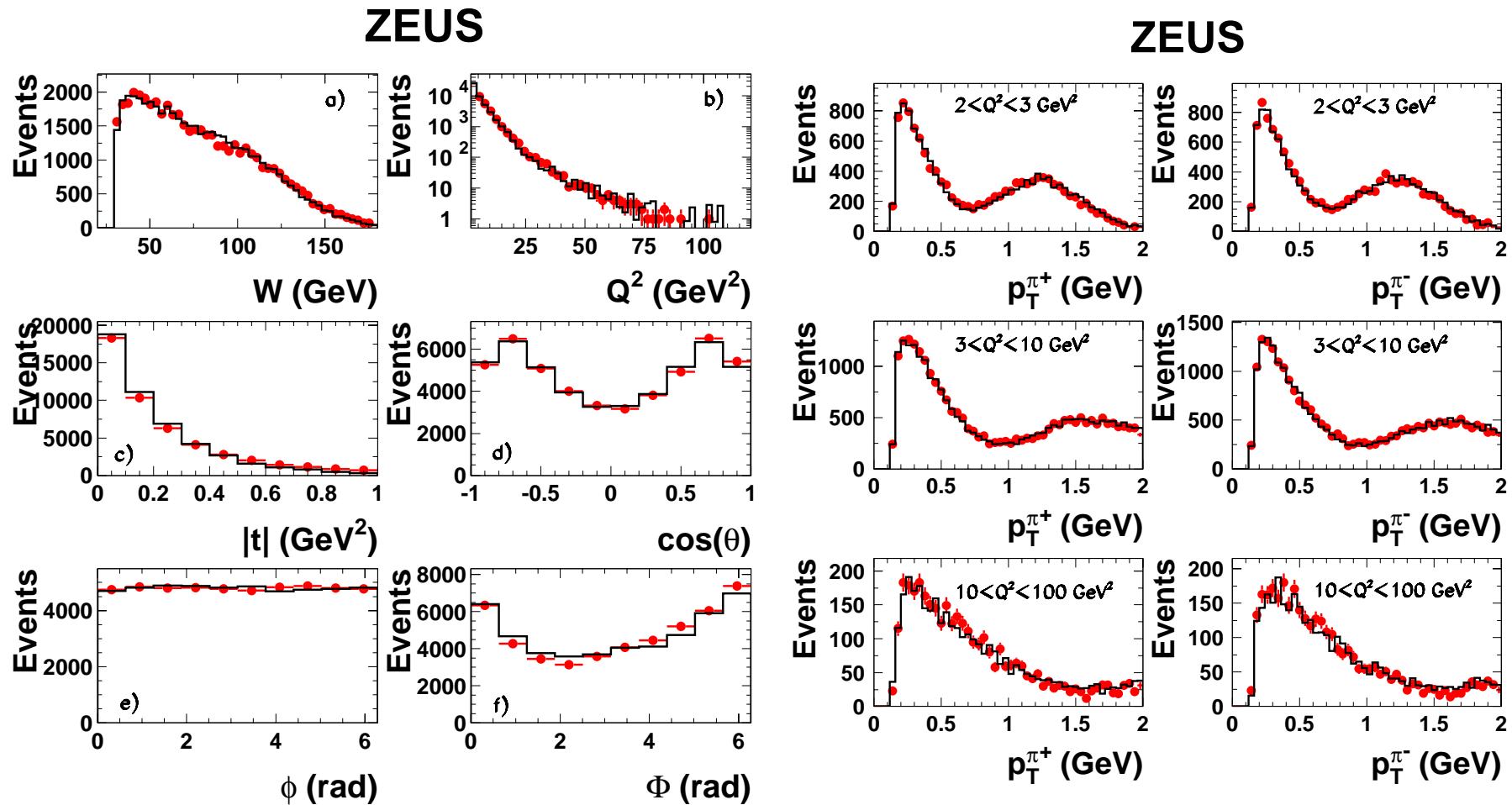
- The  $Q^2$  dependence of  $\sigma(\gamma^* p \rightarrow pp)$  cannot be described by a simple propagator term.
- The cross section is rising with  $W$  and its logarithmic derivative in  $W$  increases with  $Q^2$ .
- The exponential slope of the  $t$  distribution decreases with  $Q^2$  and levels off at about  $b = 5 \text{ GeV}^{-2}$ .
- The ratio of cross sections induced by longitudinally and transversely polarised virtual photons increases with  $Q^2$ , but is independent of  $W$ .
- The effective Pomeron trajectory has a larger intercept and smaller slope than those extracted from soft interactions.
- All these features are compatible with expectations of perturbative QCD.
- None of the models which have been compared to the measurements are able to reproduce all the features of the data.

# Backups

# Density matrix elements



# Control plots

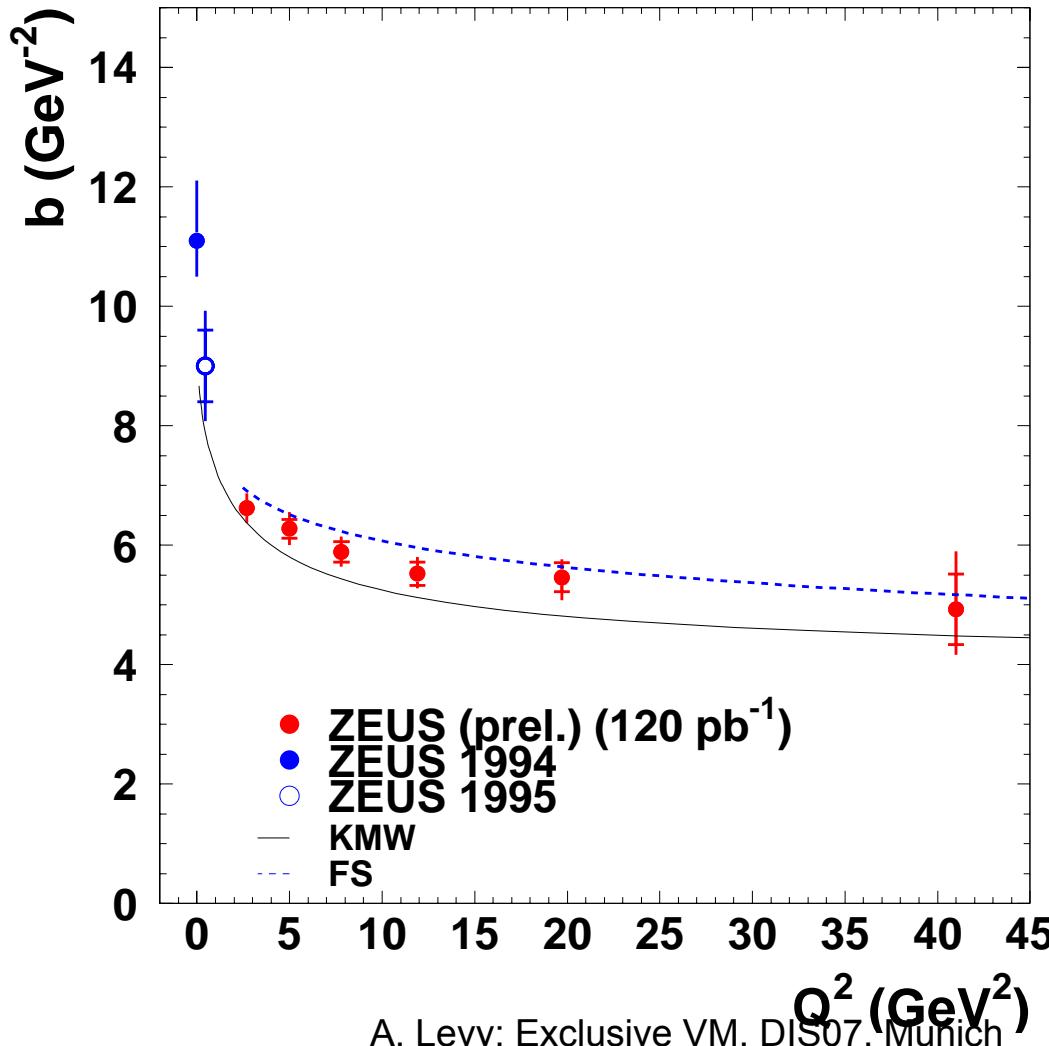


# Systematics

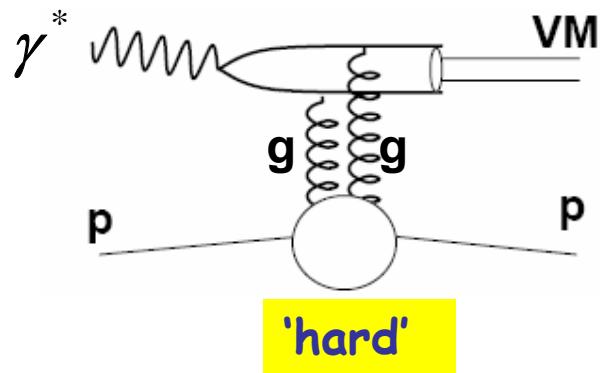
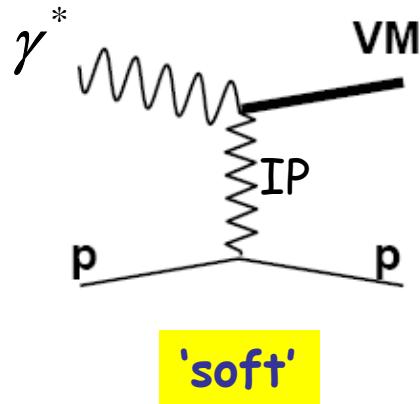
- $E - P_Z$  cut (default 45 GeV) was changed to 42 and 48 GeV
- $p_T$  of the pions (default 0.15 GeV) was changed to 0.2 GeV
- elasticity cut. The energy of unmatched island (default 0.3 GeV) was changed to 0.25 and 0.35 GeV
- elasticity cut. The distance of closest approach of island and extrapolated track was changed from 30cm (default) to 20cm
- Z-vertex cut (default  $|Z| < 50\text{cm}$ ) was varied from 40 to 60 cm
- Reconstruction position of electron shifted wrt MC by  $\pm 1\text{mm}$  - alignment check
- Electron position resolution in MC varied by  $\pm 10\%$
- Box cut (default 13.2X8 cm) was increased by 0.5 cm
- $\pi\pi$  mass window (default 0.65-1.1 GeV) was changed to 0.65-1.2 GeV
- generated W dependence in MC was reweighed by  $W^n$ , ( $n = \pm 0.03$ )
- generated t in MC was reweighed by  $\exp(bt)$   $b = \pm 0.5 \text{ GeV}^{-2}$
- angular distributions in MC were reweighed according SCHC. Default reweighing comes from 15 matrix element fit.
- generated  $Q^2$  in MC was reweighed by  $(Q^2 + M_p^2)^k$ , where  $k = \pm 0.05$

# b-slope

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# Comparison to theory



- All theories use dipole picture
- Use QED for photon wave function
- Use models for VM wave function - usually take a Gaussian shape (some take a  $q\bar{q}$  bound state - "Cornell model")
- Use gluon density in the proton
- Some use saturation model, others take sum of nonperturbative + pQCD calculation, and some just start at higher  $Q^2$
- Most work in configuration space, MRT works in momentum space. Configuration space - puts emphasis on VM wave function. Momentum space - on the gluon distribution.
- **W dependence** - information on the gluon
- **$Q^2$  and  $R$**  - properties of the wave function