

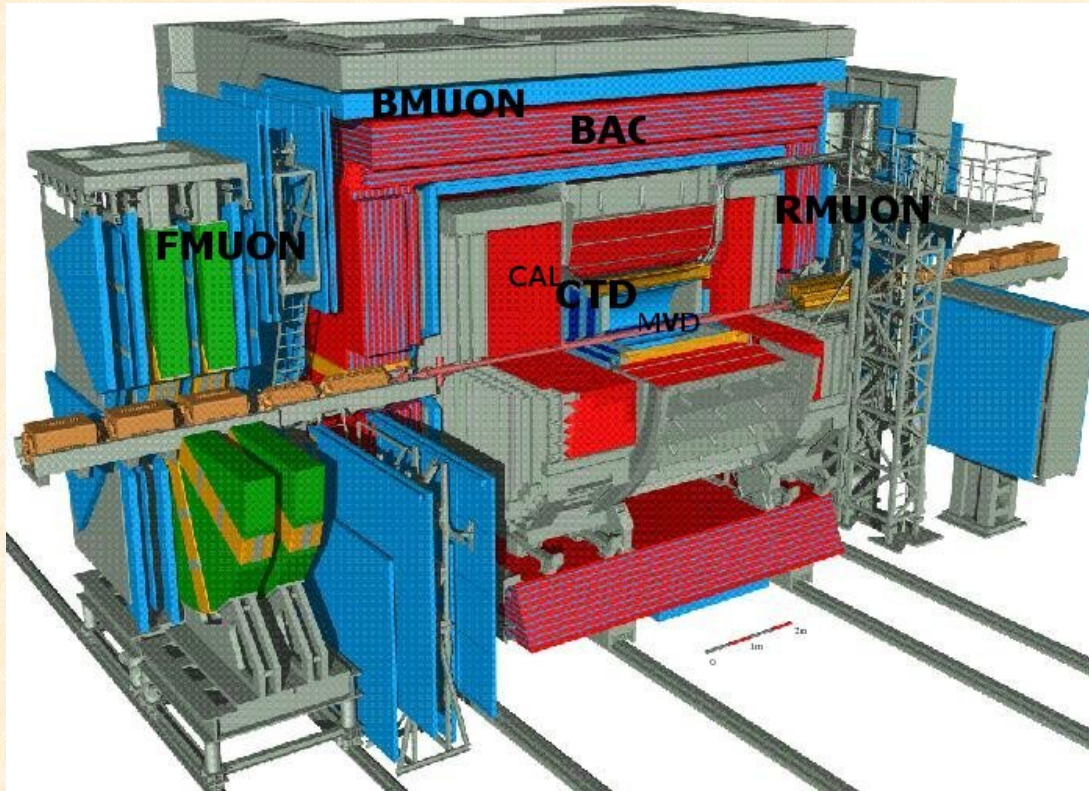
Measurement of the t -dependence in exclusive photoproduction of Upsilon ($1S$) mesons at HERA



Jacek Ciborowski
Warsaw University

on behalf of the ZEUS Collaboration

Detector and beam conditions



e : 27.5 GeV p : 820,920 GeV

$\sqrt{s} = 300, 318$ GeV

Integrated lumi: 468 pb⁻¹

(1996 - 2007)

Muons tracked in:

MicroVertex Detector

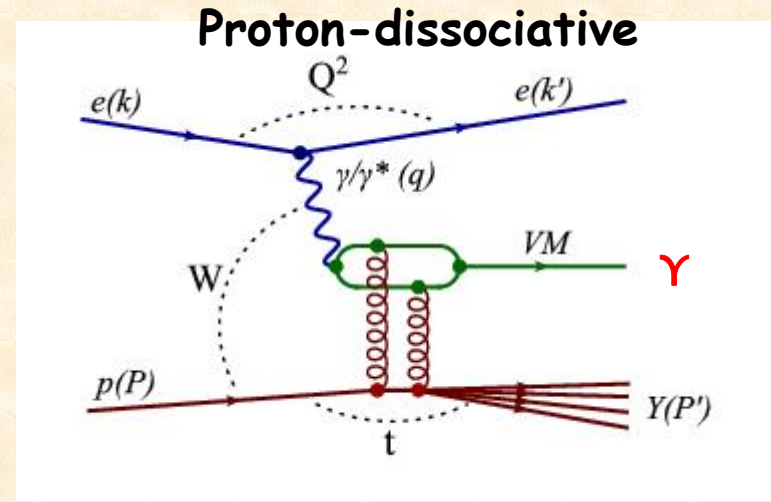
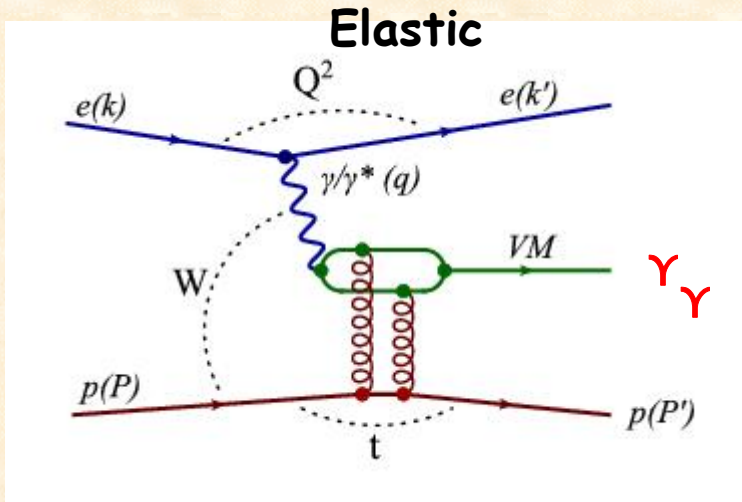
Central Tracking Detector,

F/B/R MUON chambers,

BAcking Calorimeter

+ mip identification in CAL

Graphs, kinematics



W - energy of the γp system

Q^2 - negative 4 mom. transfer squared at the electron vertex
(γ virtuality); here ~ 0 (PHP)

$t = (p-p')^2$ - 4-momentum transfer squared at the proton vertex

VM - vector meson; here Υ (Upsilon) QCD scales: Q^2 , t , M_{VM}

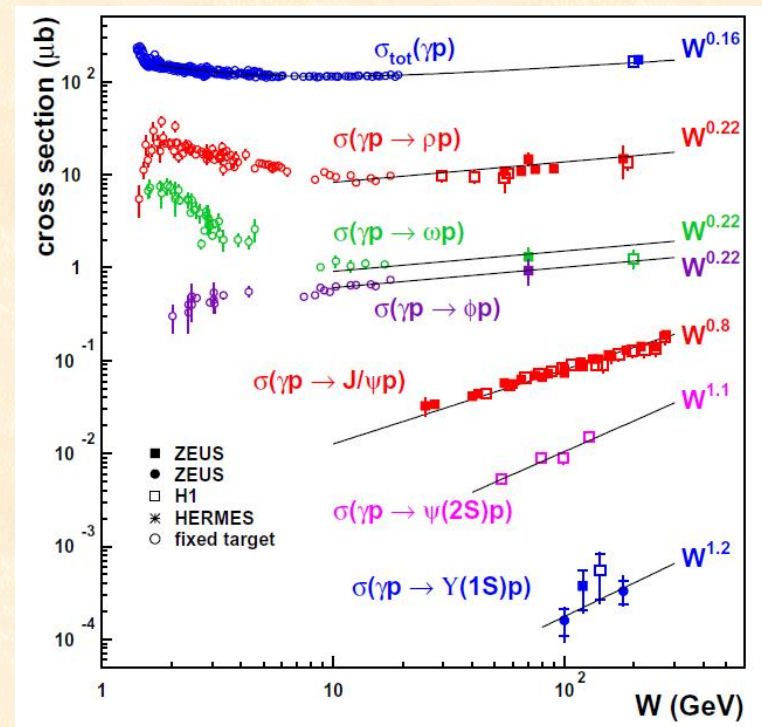
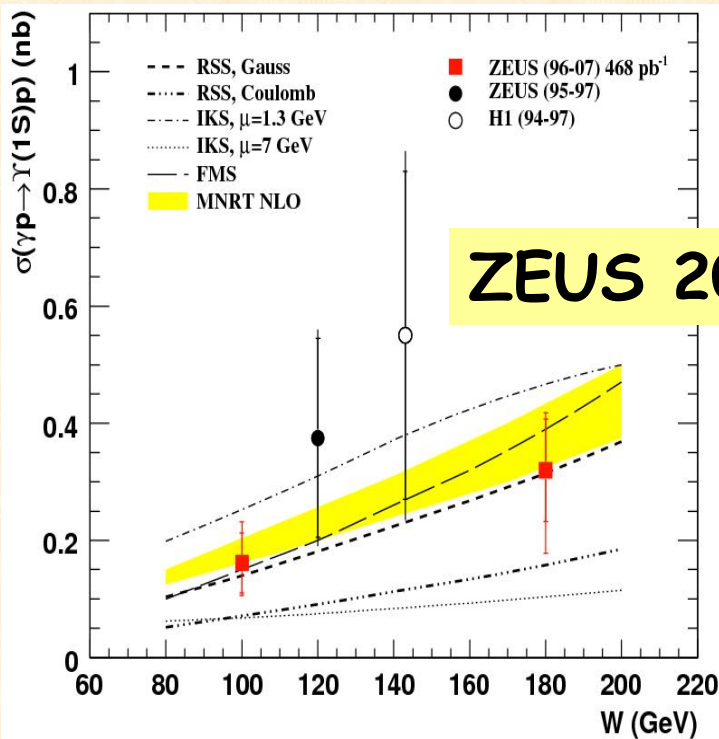
W - dependence (summary)

Upsilon PHP

$$\sigma(\gamma p) \sim W^\delta$$

$$\delta = 1.2 \pm 0.8$$

Compilation PHP



Motivation for t -dependence (exponential slope)

$$d\sigma/d|t| \sim \exp(-b|t|)$$

$$b = b_V + b_p$$

$$b_V \sim 1/(Q^2 + M_{VM}^2) \sim 0$$

$$\rightarrow b \sim b_p \sim 5 \text{ GeV}^{-2}$$

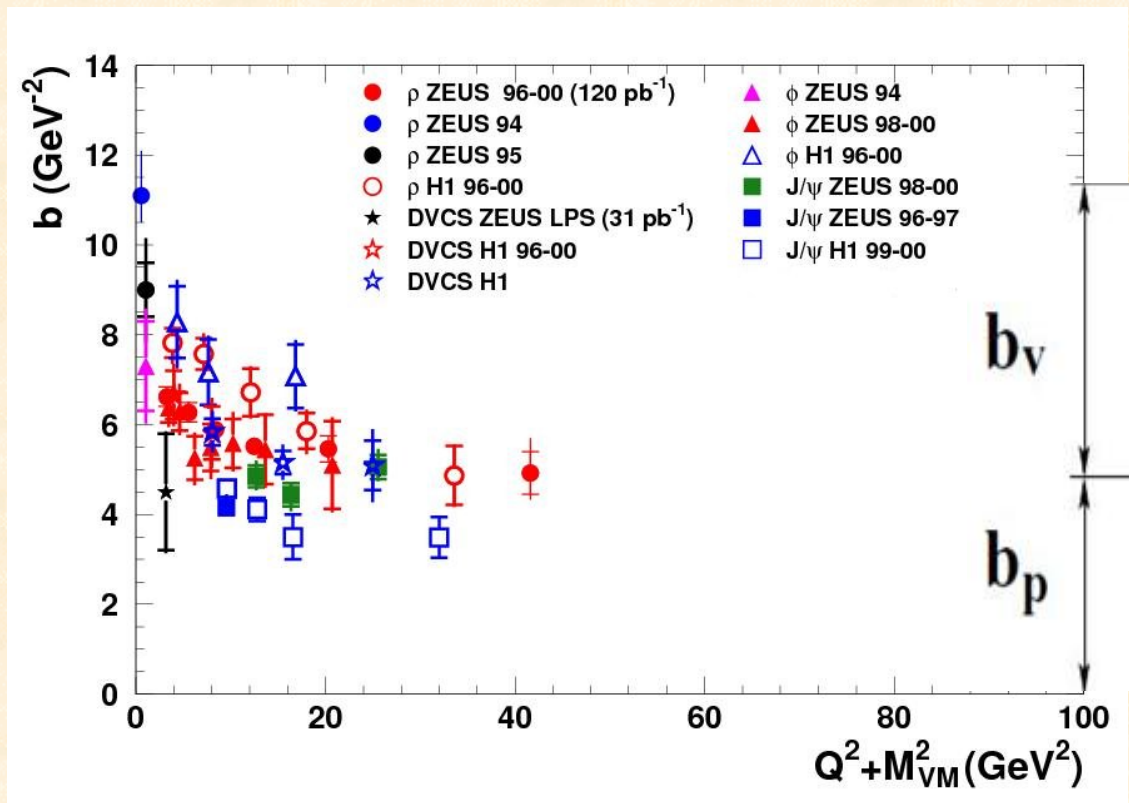
Relation to transverse
size of the interaction
region, R_T :

$$b_p = R_T^2/2$$

$$\rightarrow R_T \sim 0.6 \text{ fm}$$

Gluon radius of the proton

Pre-Upsilon t -slope compilation



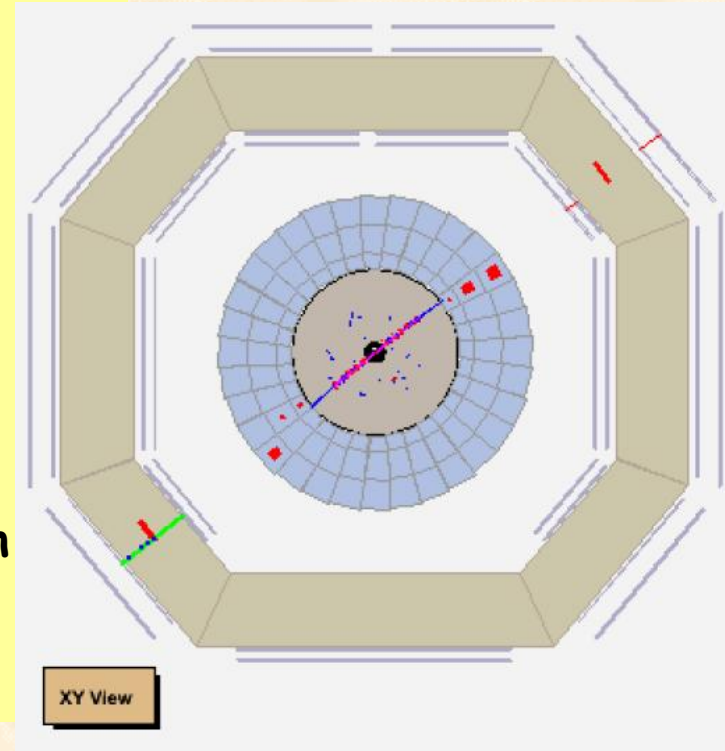
Event topology, backgrounds

Upsilons identified via $\Upsilon \rightarrow \mu^+\mu^-$ -decay channel

→ only 2 muons in the final state in the detector

Background processes:

1. Bethe-Heitler $\gamma\gamma \rightarrow \mu^+\mu^-$
2. Upsilon production with proton dissociation
3. Cosmic muons passing near/fitted to the interaction point



Event selection

Basic selections:

2 oppositely charged tracks from ep vtx, 5 CTD superlayers,
at least one identified as μ and the other at least as a mip in CAL

Each track $p_T > 1.5 \text{ GeV}$

Bethe-Heitler bgd suppression: $|\eta^+ - \eta^-| < 1.5$

Cosmic muons rejection: angle $|\pi - \alpha| > 0.1$

CAL energy not associated with tracks $< 0.5 \text{ GeV}$ ($\rightarrow Q^2 < 1 \text{ GeV}^2$)

$M_Y < 4 \text{ GeV}$ $60 < W < 220 \text{ GeV}$ $|t| < 5 \text{ GeV}^2$

Selected $> 2.7 \text{ k}$ $\mu + \mu^-$ pairs ($< 1\%$ cosmic)

Monte Carlo

$\gamma p \rightarrow \Upsilon p$ elastic and pdiss DIFFVM 2.0 (Regge + VDM)
pdiss + JETSET 7.3

SCHC (s-channel helicity conservation) assumed

$d\sigma/d|t| \sim \exp(-b|t|)$ $b=4.5 \text{ GeV}^{-2}$ (as for J/ψ); $\sigma(\gamma p) \sim W^{1.2}$

Radiative corrections $O(1\%)$ not included

Bethe-Heitler $\mu^+\mu^-$ GRAPE v1.1k

Pdiss contribution

Definition of the fraction: $f_{pdiss} = N_{pdiss} / (N_{elastic} + N_{pdiss})$

Too scarce statistics for a standalone measurement of f_{pdiss} in this analysis

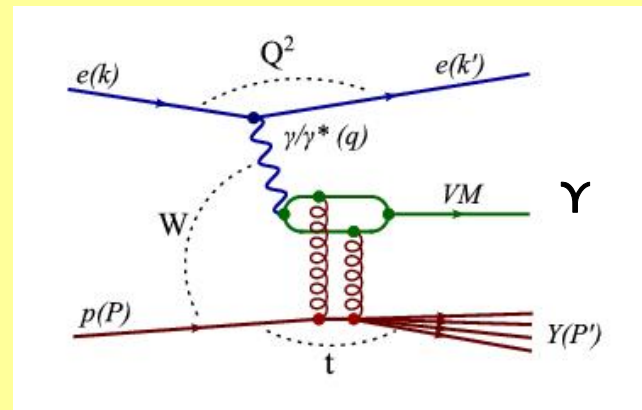
Earlier measurements show:

f_{pdiss} similar for all VM

Justified to assume: $f_{pdiss} = 0.25 \pm 0.05$ (result for J/ψ)

$d\sigma/d|t| \sim \exp(-b|t|)$ contains elastic and proton diss. contributions

Assume for pdiss: $b_{pdiss} = 0.65 \pm 0.1 \text{ GeV}^{-2}$ (result for J/ψ)



Invariant mass distribution

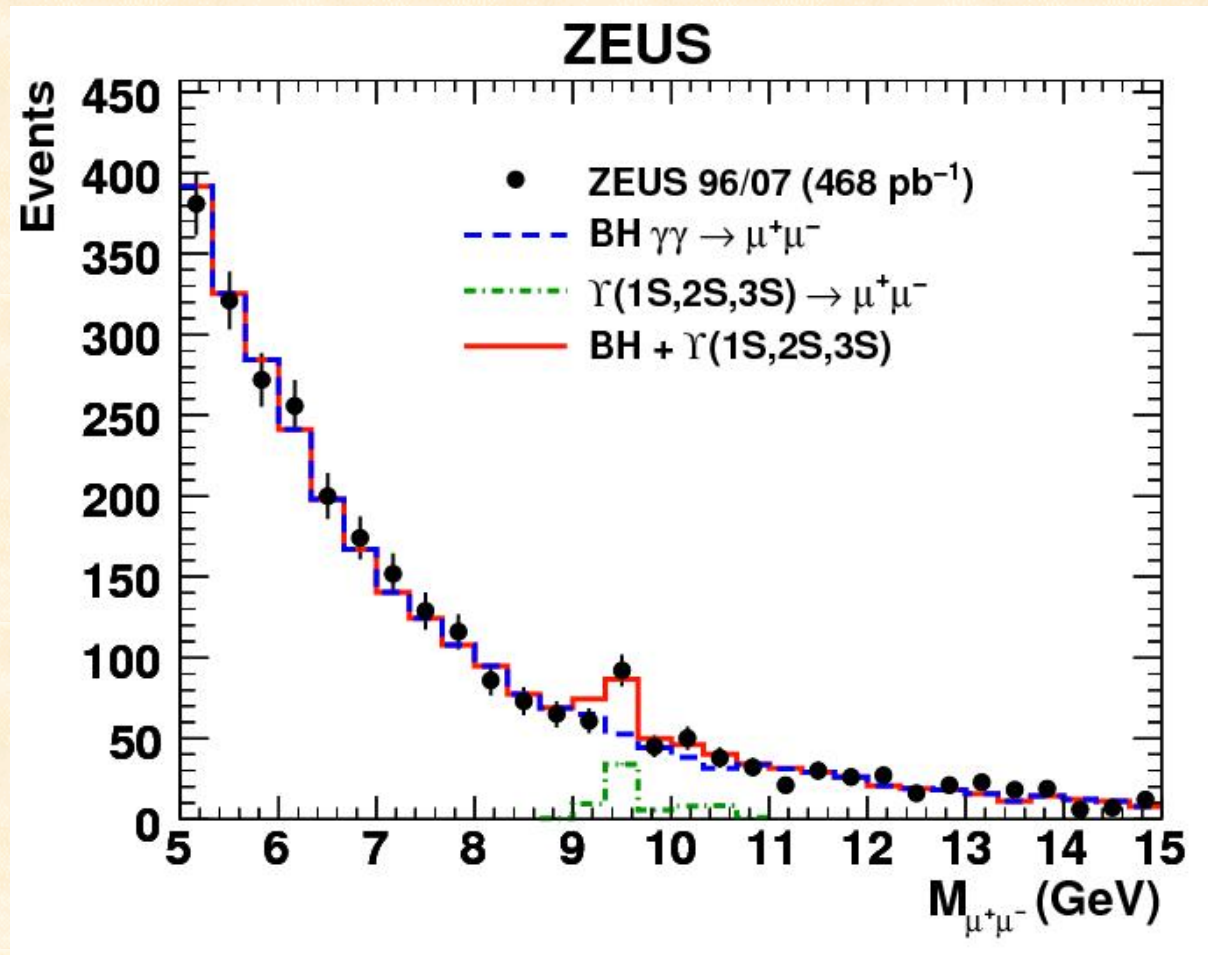
Data range: 5-15 GeV

BH normalised
excluding
9-11 GeV mass range

Signal mass window:
9.33-9.66 GeV (1 bin)
(scanned - no cosmic)

Upsilon 1S:2S:3S ratios
from CDF:

0.73 : 0.19 : 0.08



dN/d|t| and slope extraction

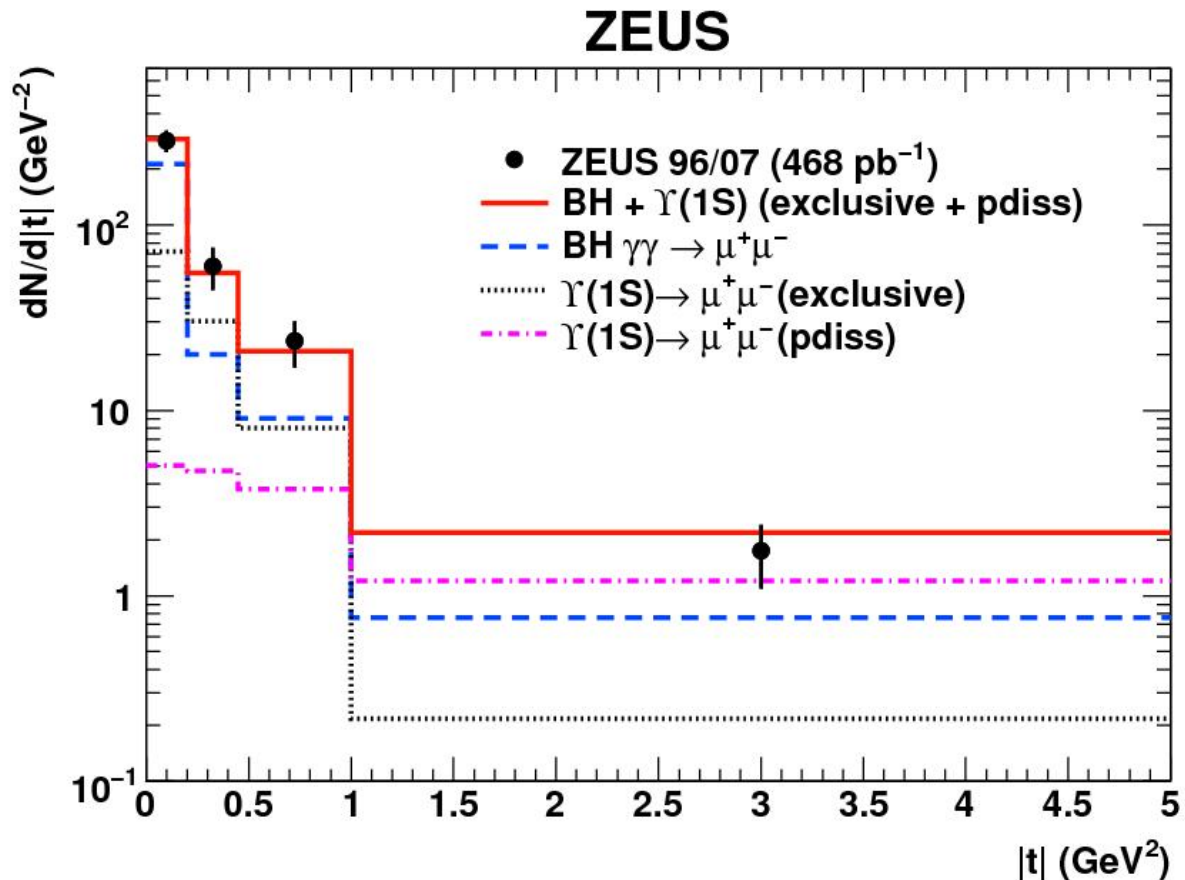
Binned Poissonian
maximum log-likelihood
fit \rightarrow elastic b, N(1S)

N(1S) = 41 ± 10 events
(44% of all events in
the mass window)

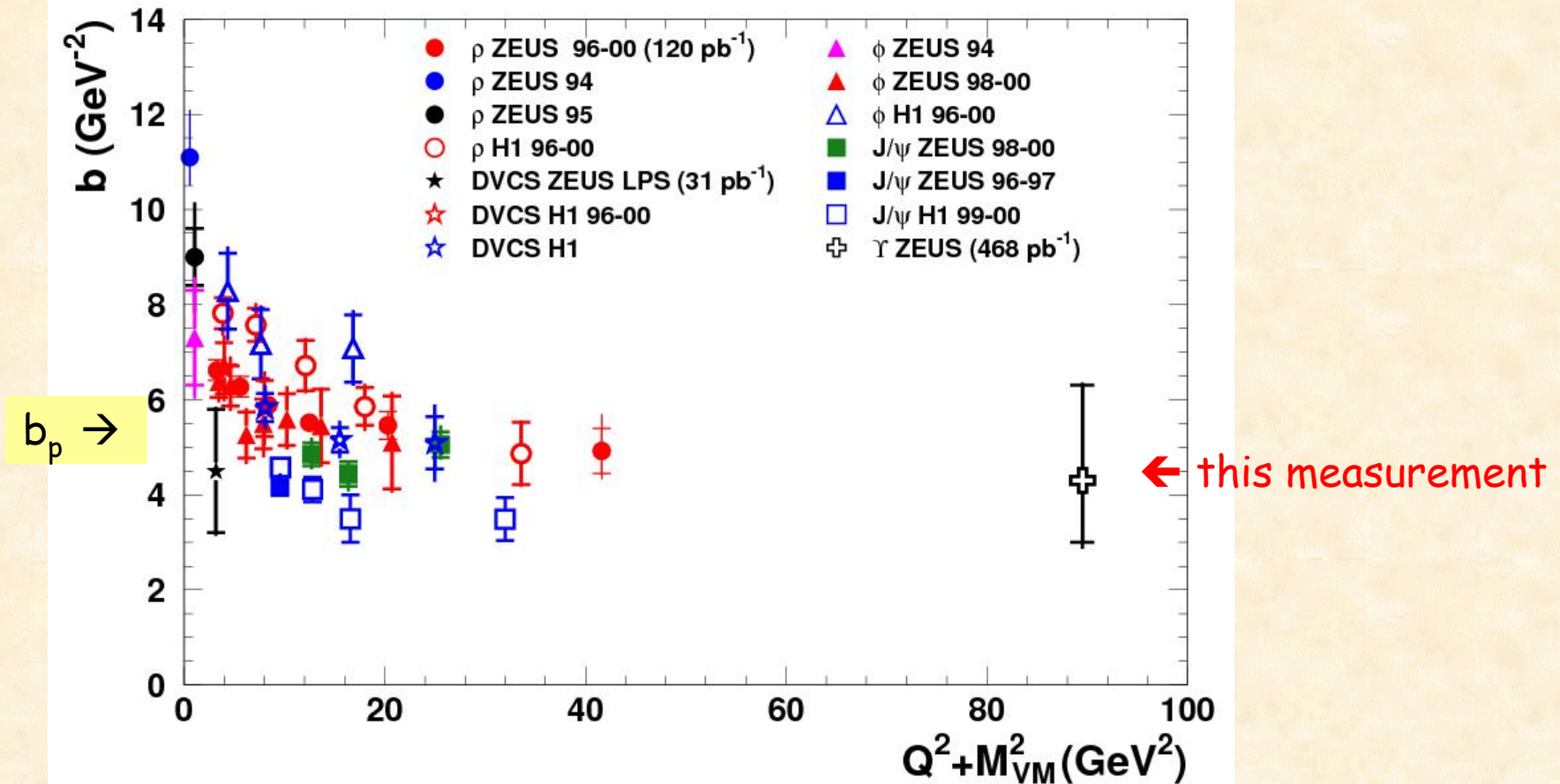
ZEUS RESULT:

$$b = 4.3^{+2.0}_{-1.3} \quad ^{+0.5}_{-0.6}$$

GeV⁻²



Compilation for elastic b



By the way

Cox, Forshaw, Sandapen
(2004, 2009)

predict:

$$b=3.7 \text{ GeV}^{-2}$$

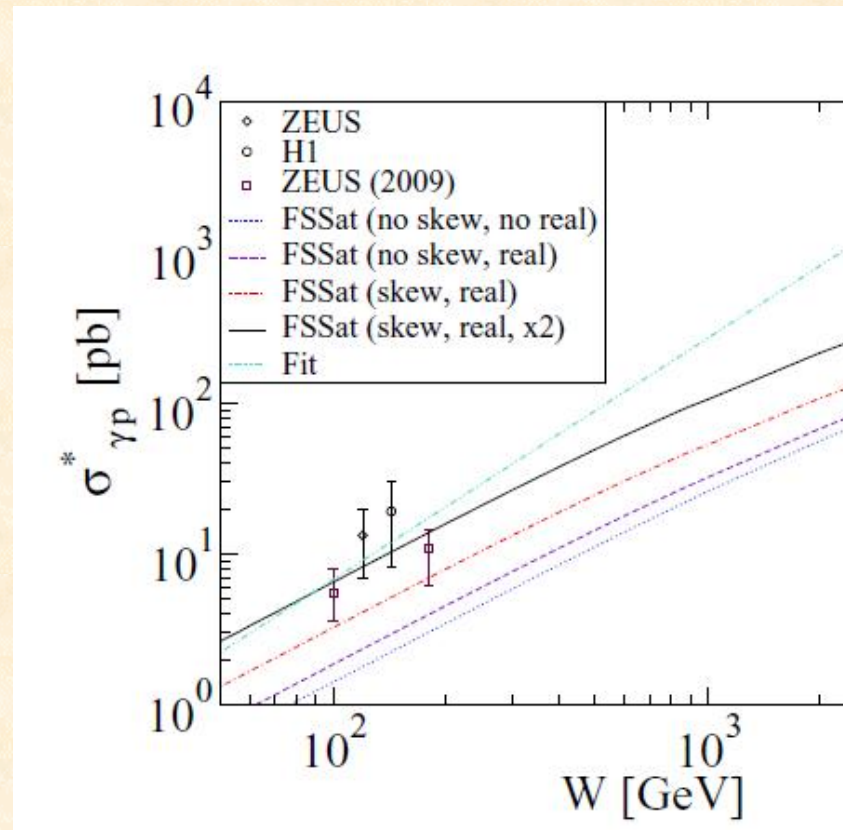
for $\gamma p \rightarrow \Upsilon p$ ($pp \rightarrow \Upsilon pp$)

at LHC

JHEP 0906 (2009) 034

A tool to look for
saturation in the proton

CFS predictions (2009) for W^δ at HERA



Summary and conclusions

- W dependence of $\sigma(\gamma p \rightarrow \Upsilon(1S) p) \sim W^\delta$
 $\delta = 1.2 \pm 0.8$
- $\Upsilon(1S)$ t -slope measured for the first time
- $b = 4.3^{+2.0}_{-1.3} {}^{+0.5}_{-0.6} \text{ GeV}^{-2}$
- Doubles the range of the $Q^2 + M^2$ scale
(now up to 90 GeV^2)
- In agreement with asymptotic behaviour
- Consistent with expectations from the proton radius and QCD