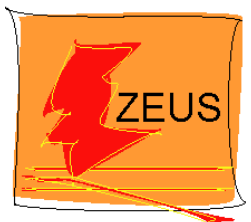


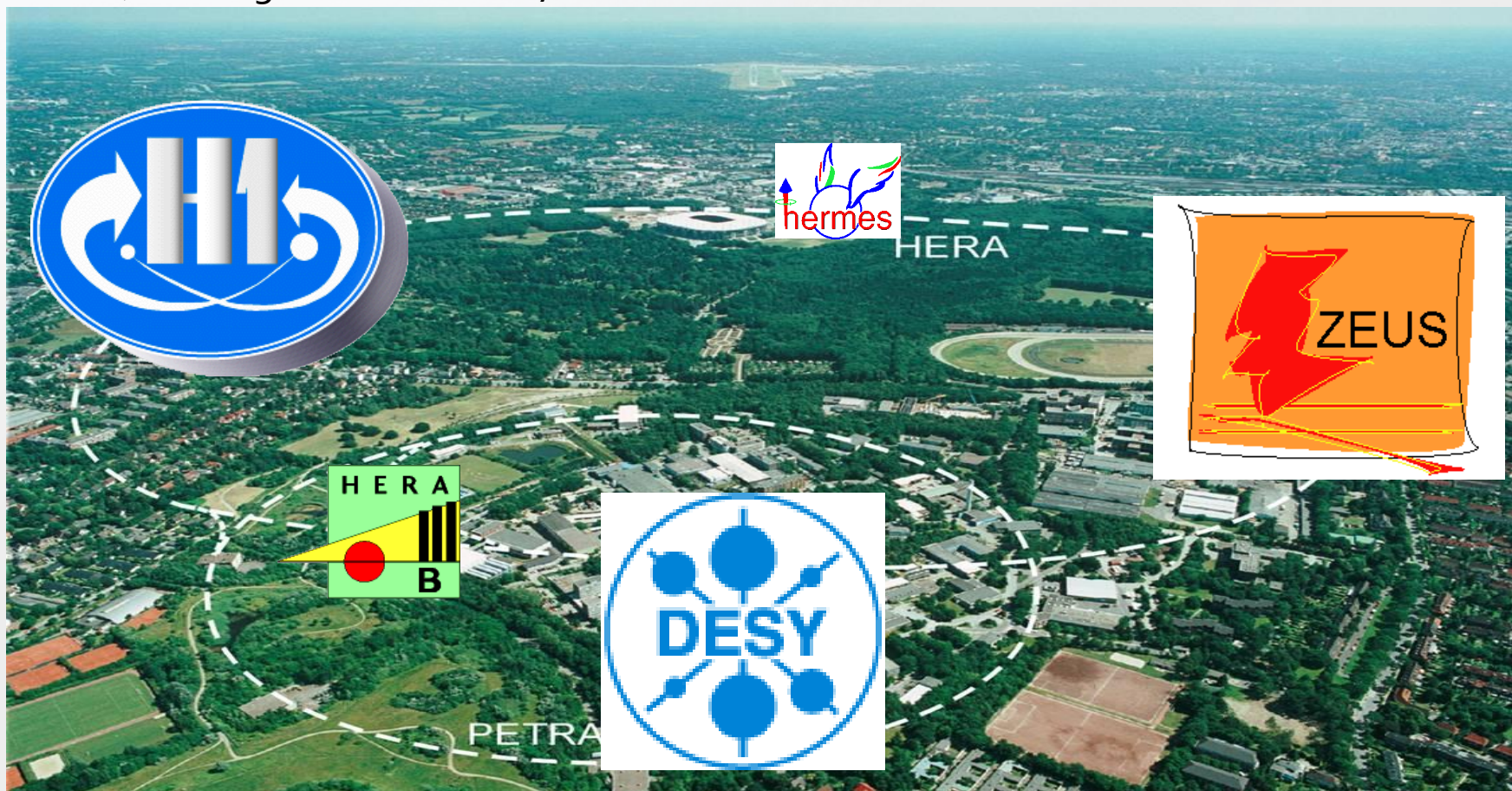
# Measurement of the $t$ dependence in exclusive photoproduction of Upsilon ( $1S$ ) mesons at HERA

Janusz Tomasz Malka (DESY)  
on behalf of the ZEUS Collaboration



# HERA and ZEUS

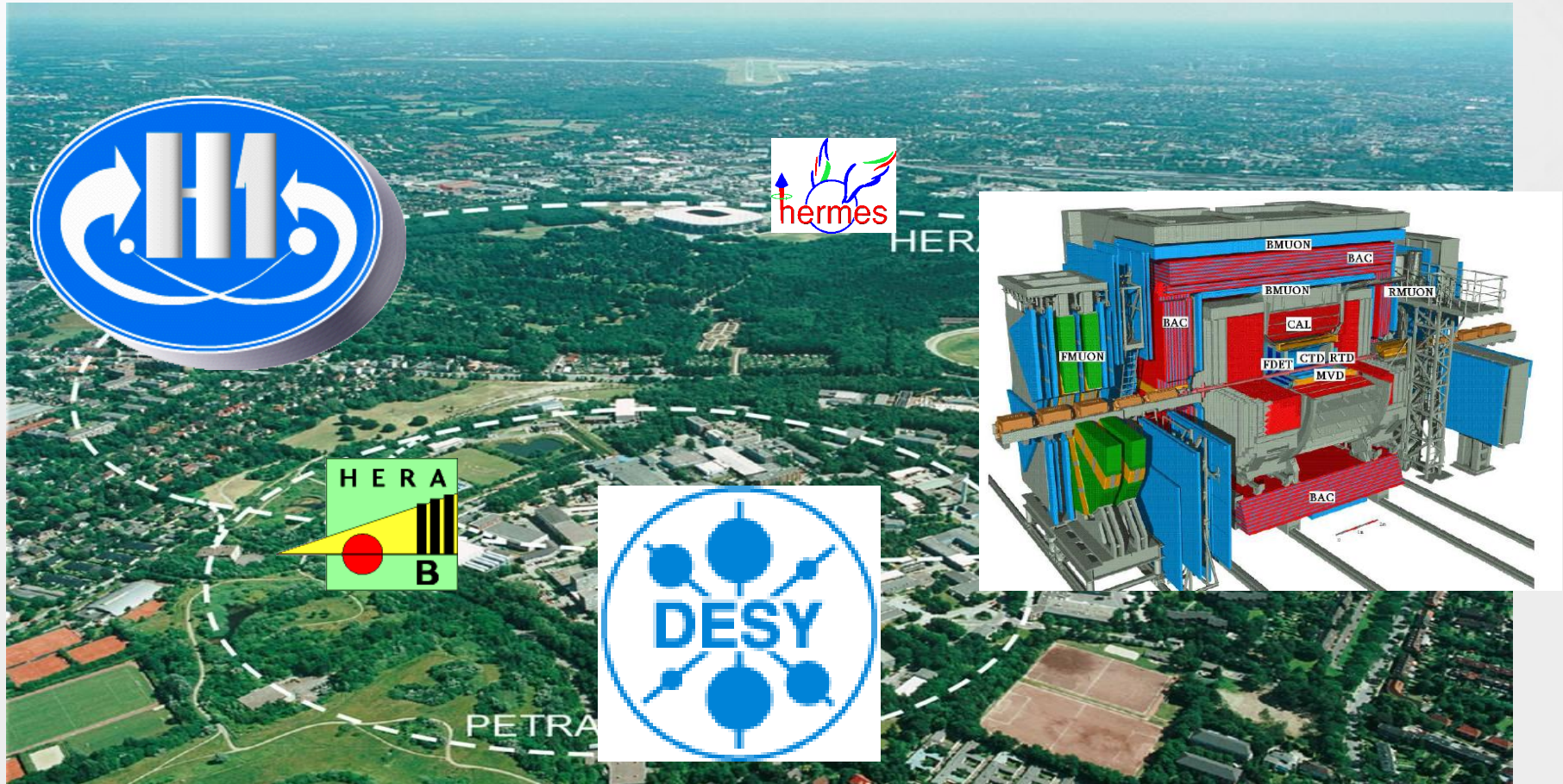
HERA was an  $ep$  collider, ( $27.5\text{ GeV}$  electrons/positrons ,  $920\text{ GeV}$  protons beam , CMS energy  $318\text{ GeV}$ ) running ended mid 2007





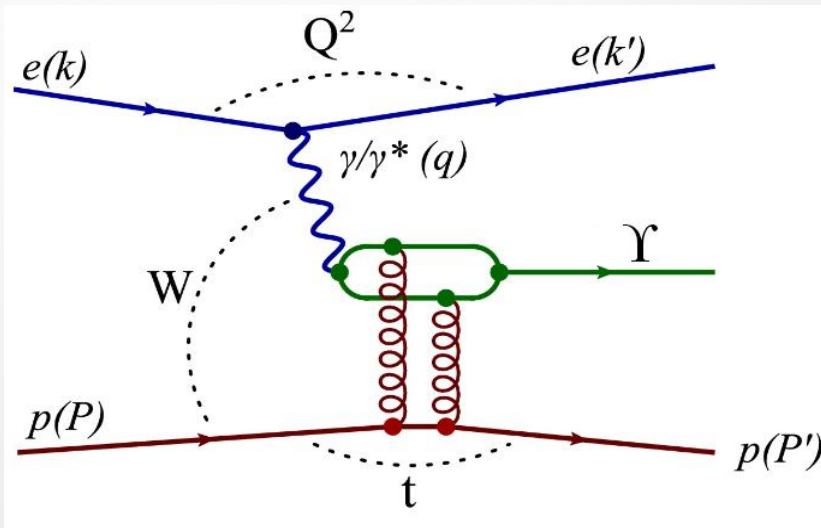
# HERA and ZEUS

ZEUS was a large multipurpose experiment, integrating all the data taken since 1996: 11 years of activity and  $468 \text{ pb}^{-1}$  of integrated luminosity

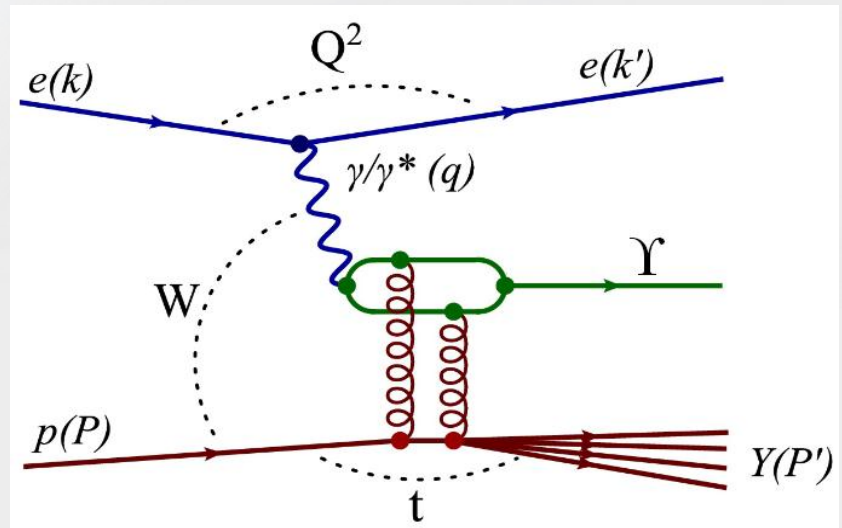


# Diffractive $\Upsilon$ production

exclusive



proton-dissociative



$Q^2$  - photon virtuality

$$Q^2 = -q^2 = -(k - k')^2$$

( $Q^2 \approx 0$  – photoproduction,  $Q^2 > 0$  – electroproduction)

$W$  - c.m. energy of  $\gamma p$  system

$$W = (q + p)^2$$

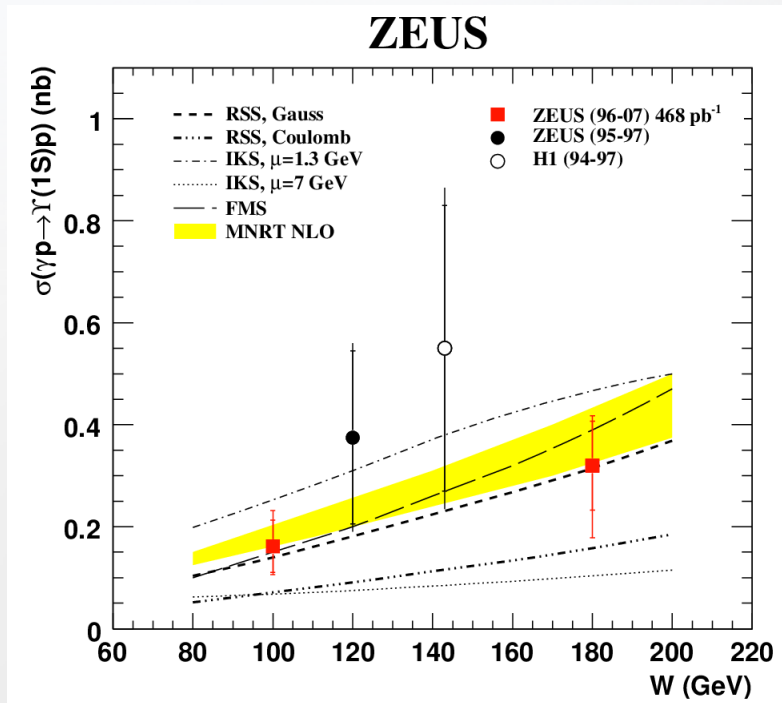
$t$  - ( $4$ -mom. transfer) $^2$  at  $p$ -vertex

$$t = (P - P')^2$$

The proton can stay intact  $p(P')$  or dissociate  $Y(P')$

# W – dependence

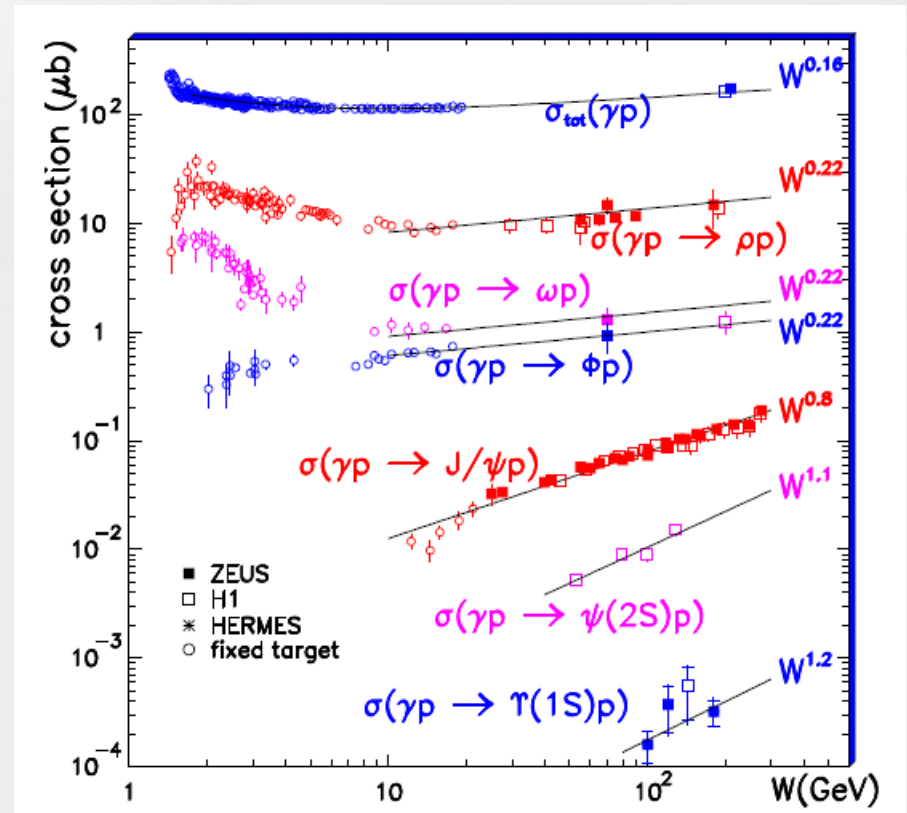
Upsilon PHP



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

$$\delta = 1.2 \pm 0.8$$

Compilation PHP



$\delta$  increases with the mass of vector meson



# Motivation for t-dependence (exponential slope)

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

$$b = b_V + b_p$$

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

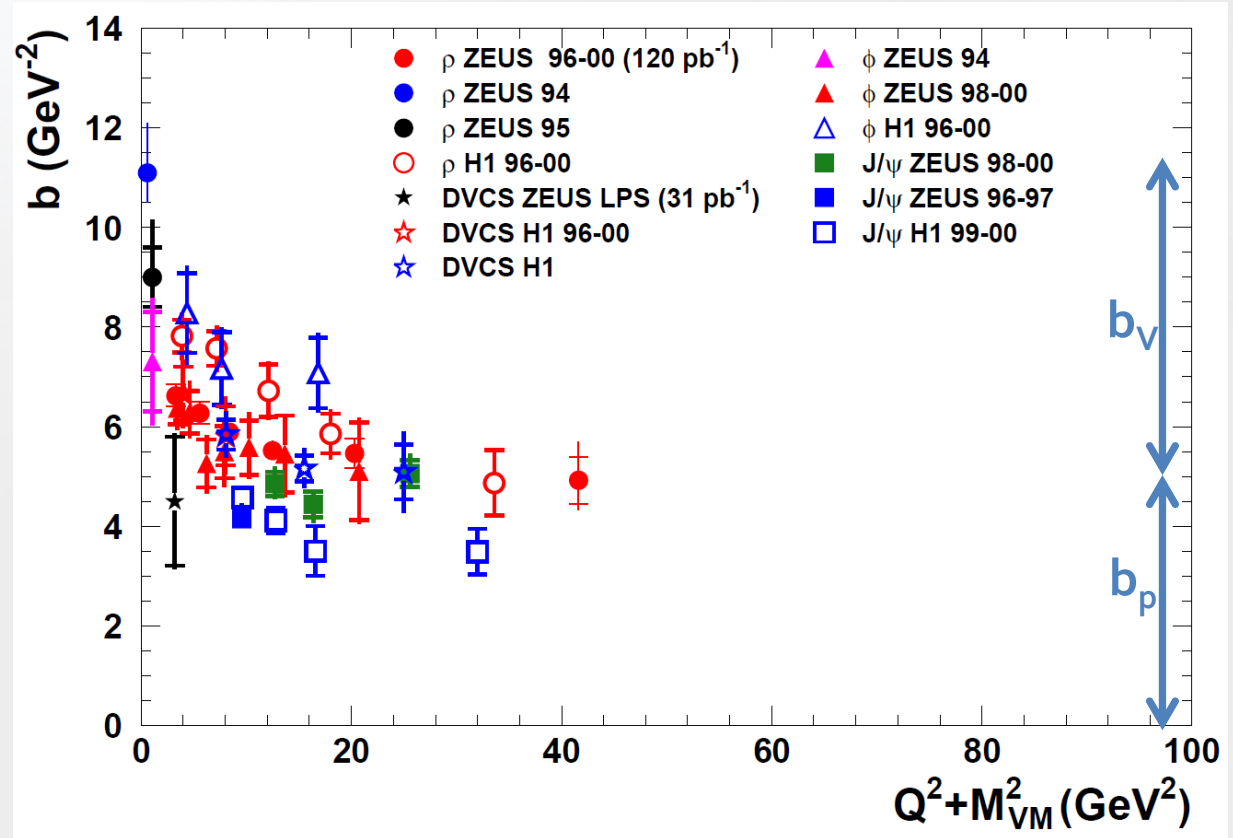
$$\rightarrow b \sim b_p \sim 5 \text{ GeV}^{-2}$$

Relation to transverse size of the interaction region,  $R_T$ :

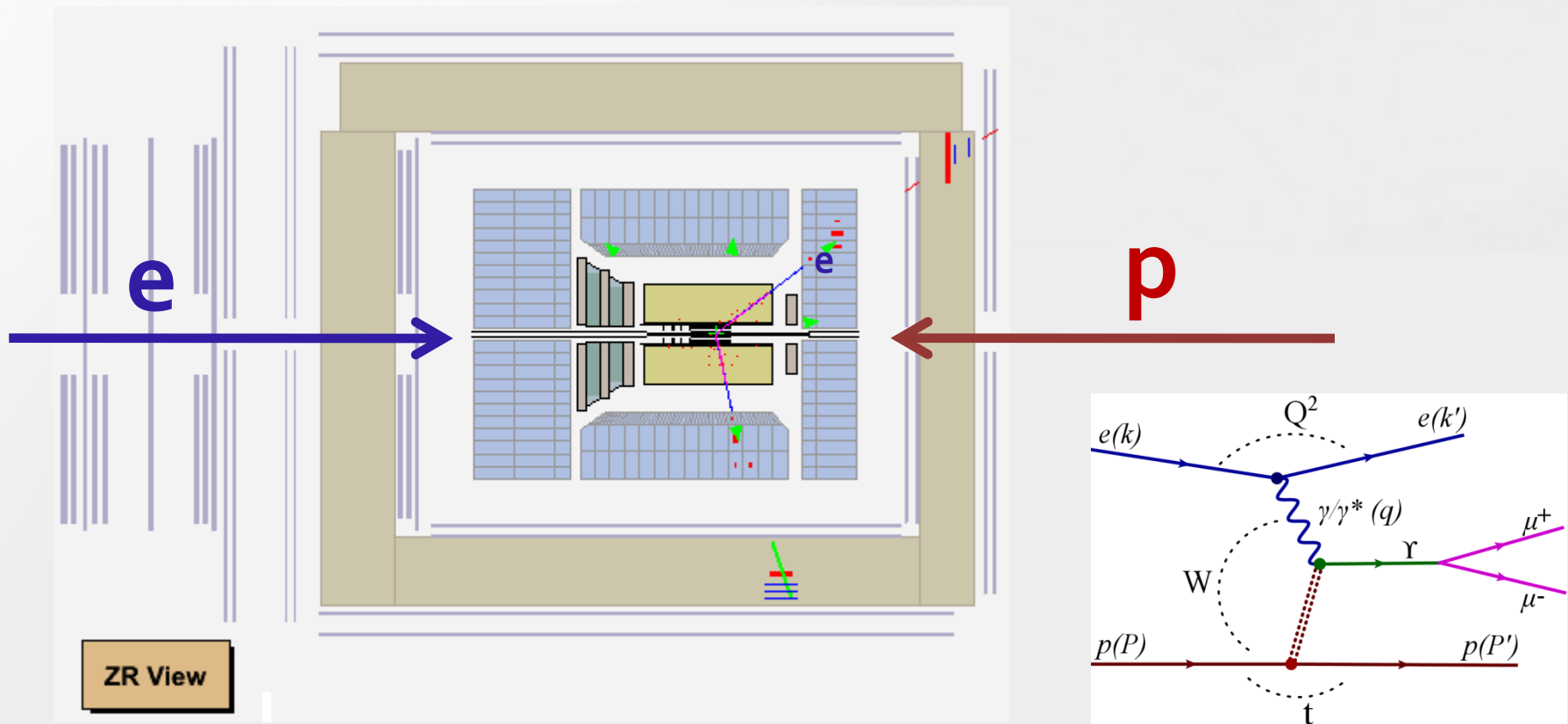
$$b_p = R_T^2/2$$

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

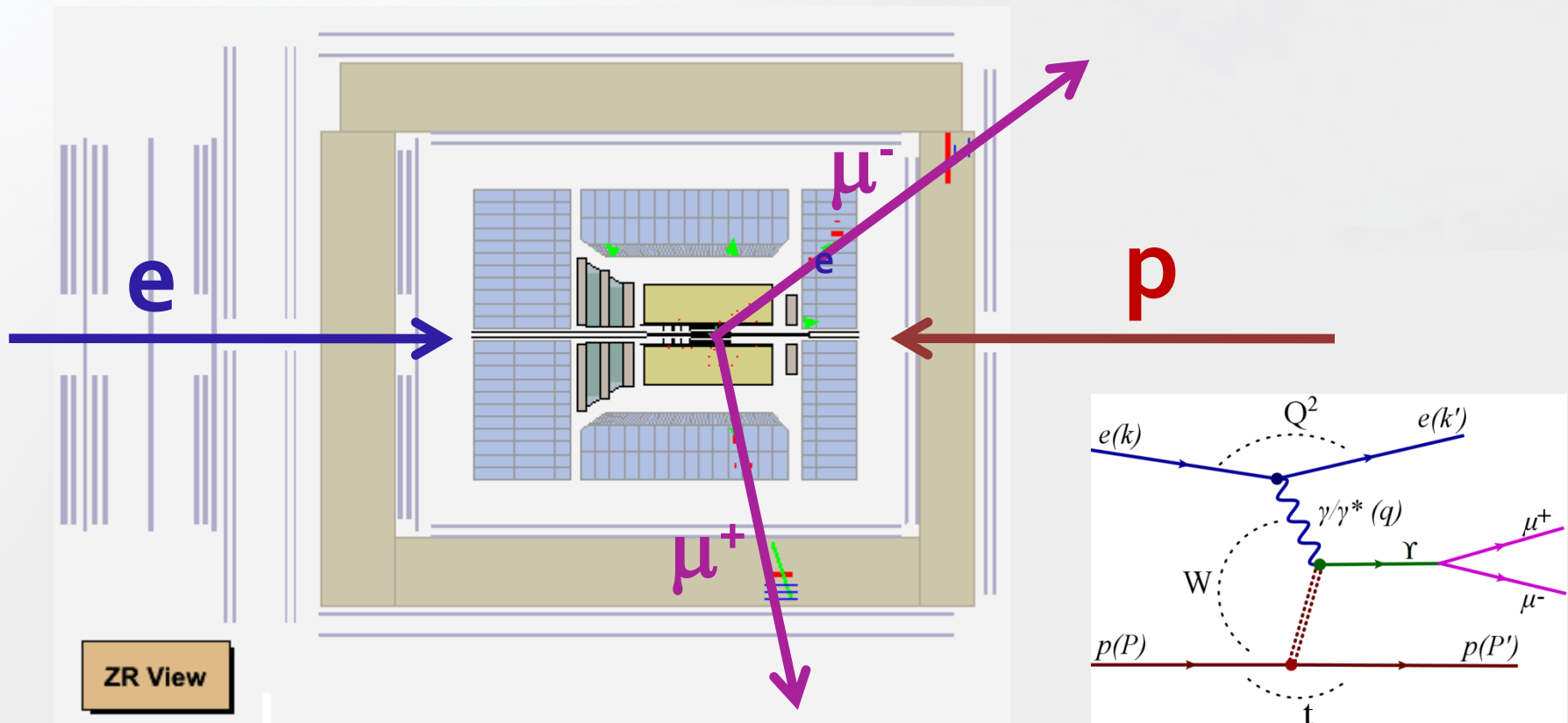
Gluon radius of the proton



# Elastic $\Upsilon$ event as seen in the ZEUS detector



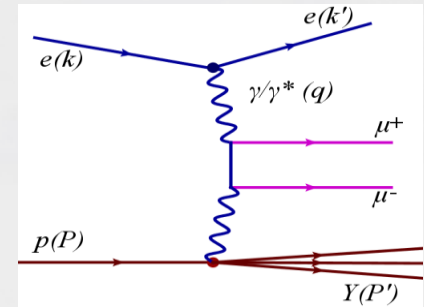
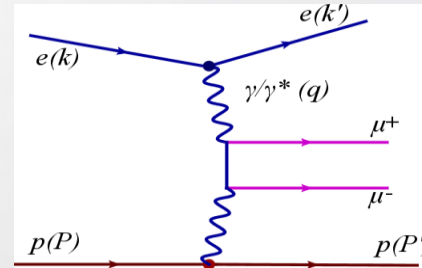
# Elastic $\Upsilon$ event as seen in the ZEUS detector



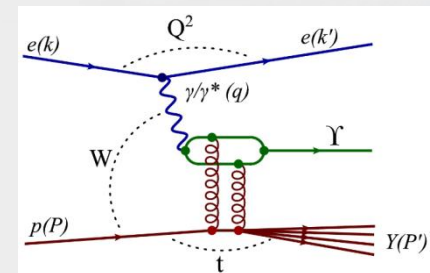


# Background processes

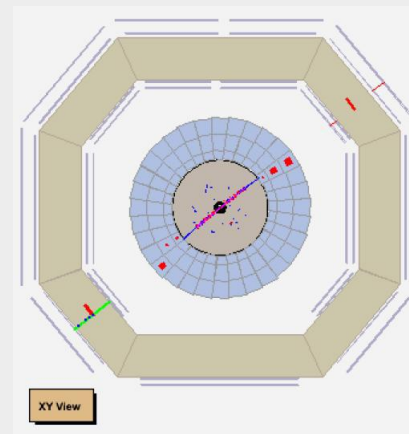
- Bethe-Heitler  $\gamma\gamma \rightarrow \mu^+ \mu^-$



- Upsilon production with proton dissociation



- Cosmic muons passing near to the interaction point



# 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  $J/\psi$ );

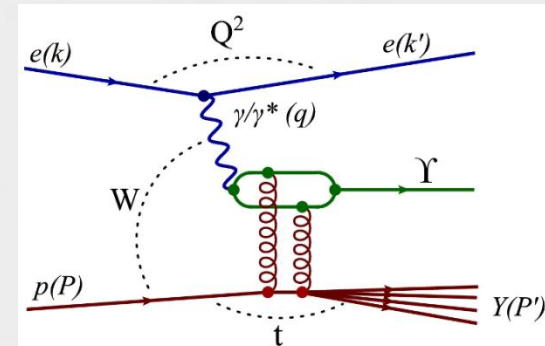
$\sigma(\gamma p) \sim W^{1.2}$

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

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

# Proton dissociation contribution

- Definition of the fraction:  
 $f_{pdiss} = N_{pdiss} / (N_{elastic} + N_{pdiss})$
- Small statistics for a standalone measurement of  $f_{pdiss}$  in this analysis

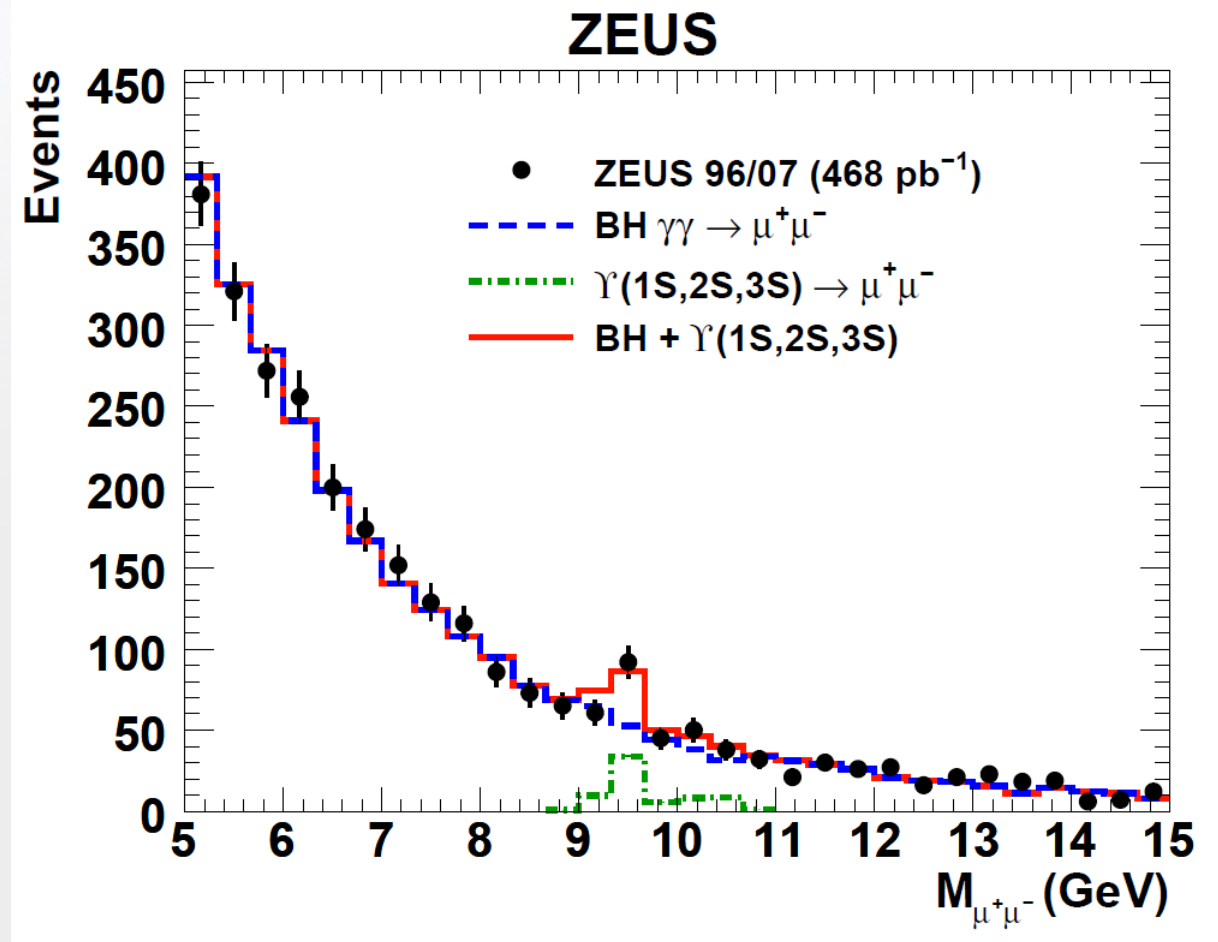


- Earlier measurements show:  $f_{pdiss}$  similar for all VM  
Justified to assume:  $f_{pdiss} = 0.25 \pm 0.05$  (result for  $J/\psi$ )
- $d\sigma/d|t| \sim \exp(-b|t|)$  contains elastic and proton diss. contributions
- Assume for  $pdiss$ :  $b_{pdiss} = 0.65 \pm 0.1 \text{ GeV}^{-2}$  (result for  $J/\psi$ )

# Invariant mass distribution

- mass range: 5-15 GeV
- BH normalised excluding 9-11 GeV mass range
- Signal mass window: 9.33-9.66 GeV (scanned–no cosmic)

Upsilon 1S:2S:3S ratios  
from CDF: 0.73 : 0.19 : 0.08



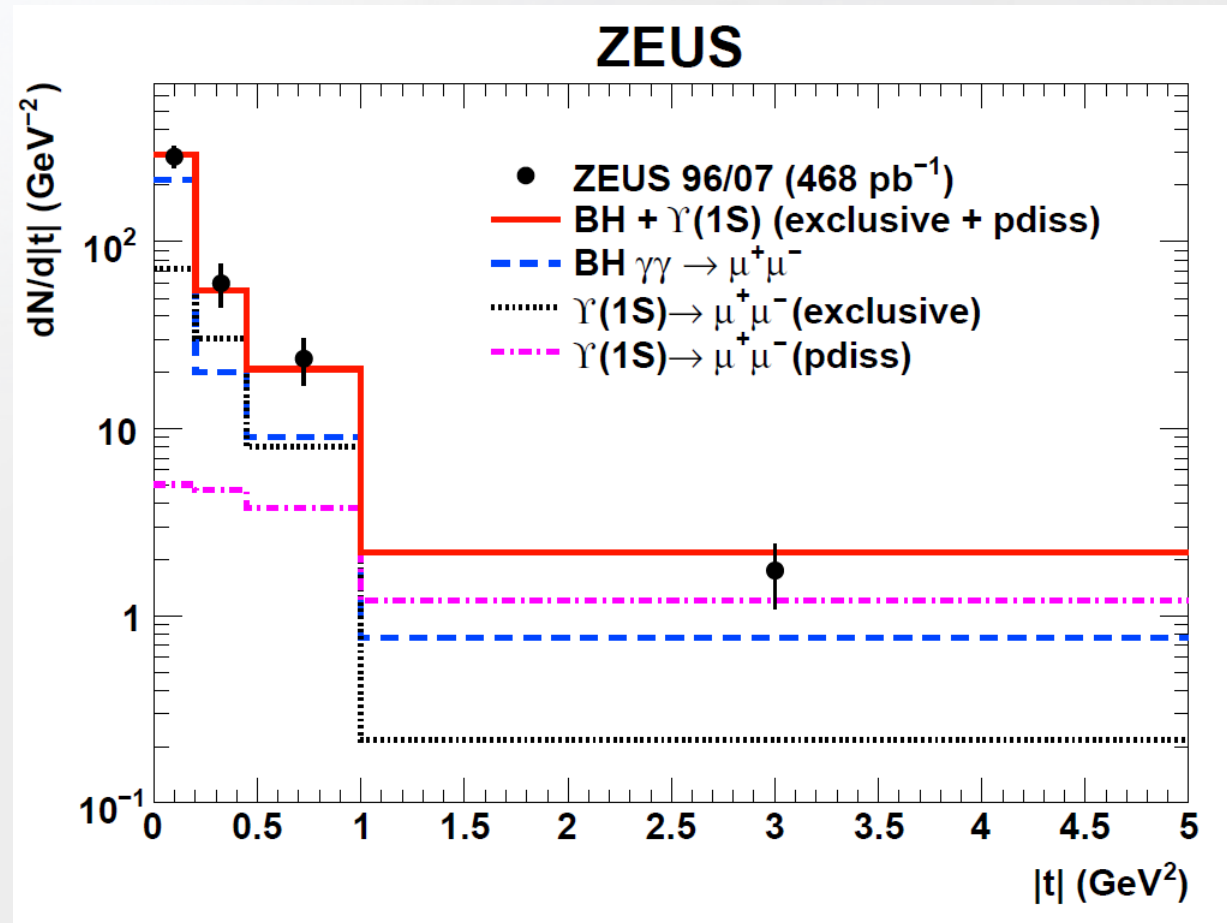


# $dN/d|t|$ and slope measurement

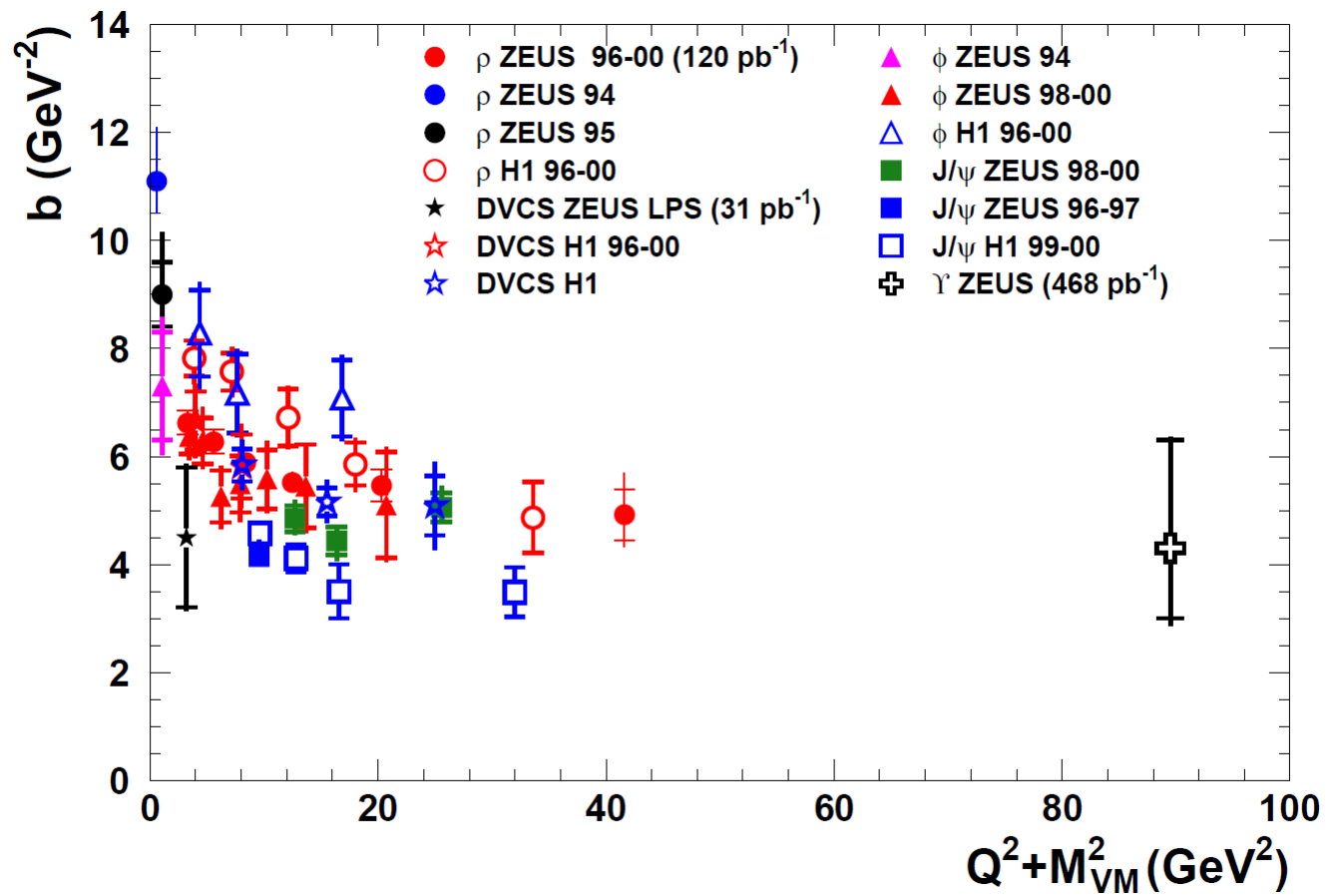
- Binned Poissonian maximum log-likelihood fit  $\rightarrow$  elastic  $b$ ,  $N(1S)$
- $N(1S) = 41 \pm 10$  events (44% of all events in the mass window)

- ZEUS RESULT:

$$b = 4.3^{+2.0}_{-1.2} {}^{+0.5}_{-0.6} \text{ GeV}^{-2}$$



# Compilation for elastic b slope



Universal behaviour observed

# Summary

- $\Upsilon(1S)$  t-slope measured for the first time
- Doubles the range of the  $Q^2+M^2$  scale
- In agreement with asymptotic behaviour
- Consistent with expectations from the proton radius and QCD