

Measurement of the energy dependence of $\sigma_{\text{tot}}(\gamma p)$ at HERA

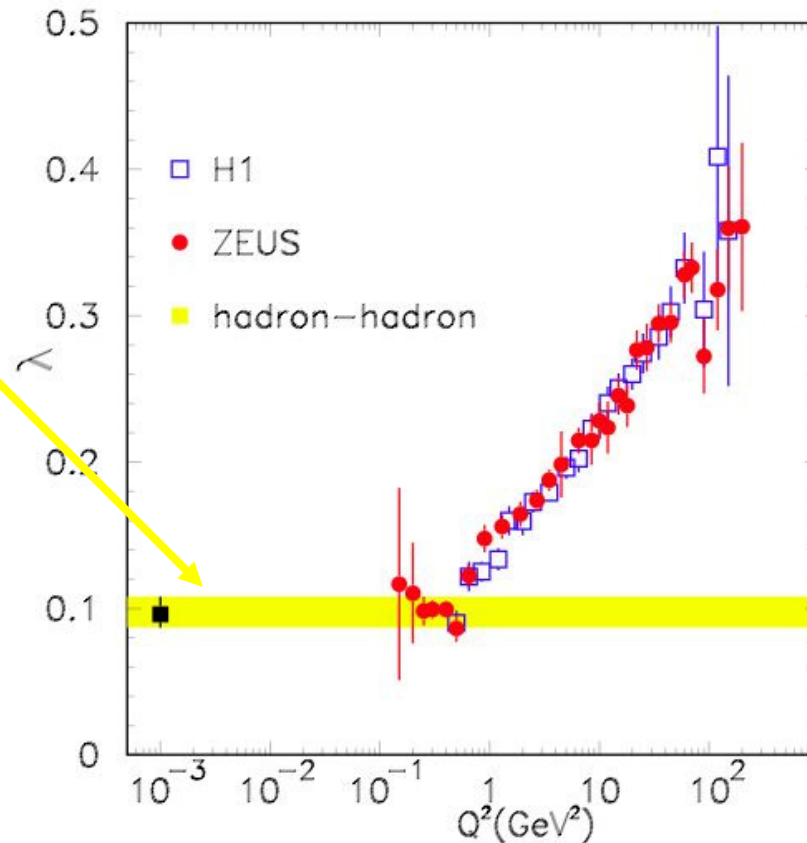
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On behalf of the ZEUS
collaboration

soft \rightarrow hard

λ HERA

$$\sigma \propto s^{0.096}$$

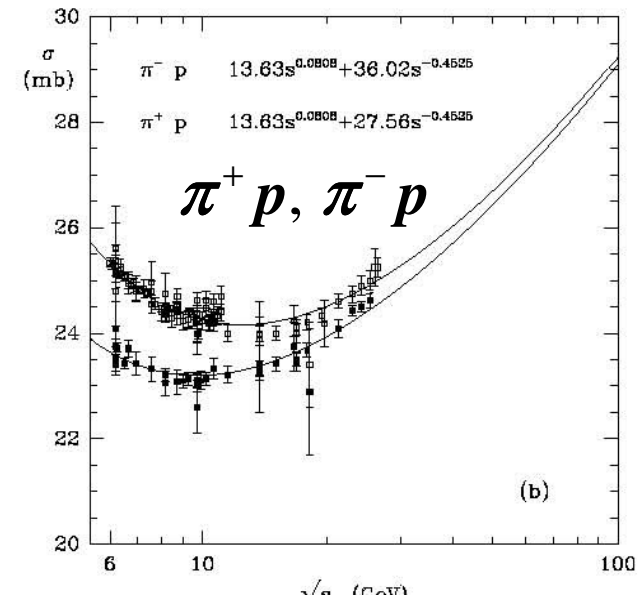
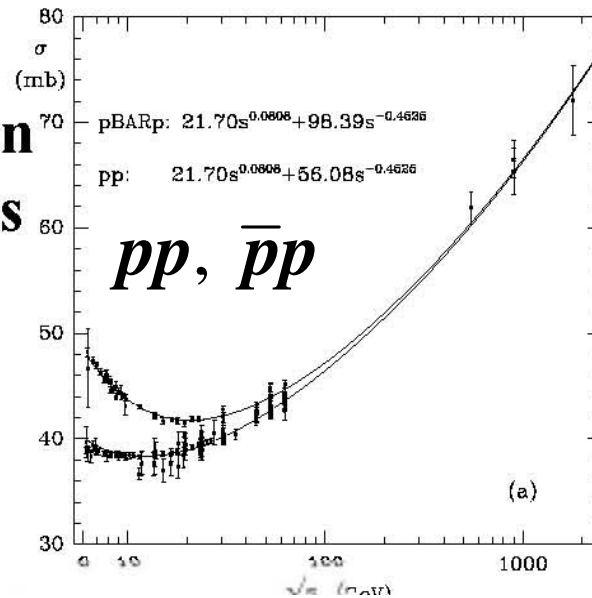


$$F_2 \propto x^{-\lambda(Q^2)}$$

Where exactly is the band? How narrow can one make it? Need to have a precise determination of W dependence of σ_{TOT} .

Hadron-hadron: DL

**Hadron-hadron
scattering cross
section versus
CM energy**



**Donnachie and Lanshoff (DL) - universal behavior of
total hadron-hadron cross section :**

$$\begin{aligned}\sigma_{tot}(h-h) &= A s^{\alpha_{IP}(0)-1} + B s^{\alpha_{IR}(0)-1} \\ &= A s^{0.0808} + B s^{-0.4525}\end{aligned}$$

Hadron-hadron: DL

How was the DL fit done?

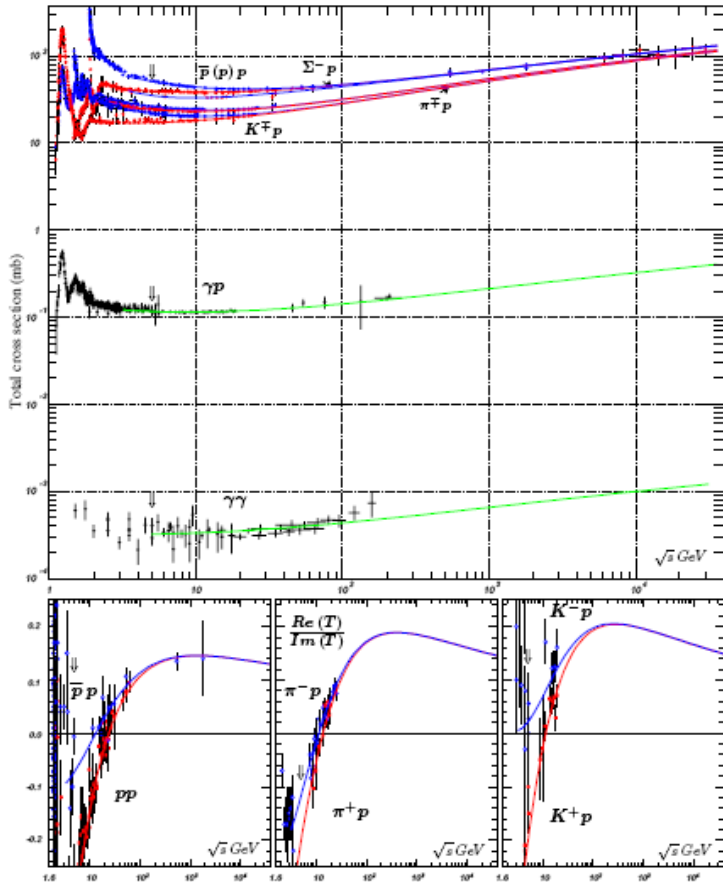
Fit the two powers only from pp and $p\bar{p}$ data above $W=10$ GeV

Get $\chi^2/df=410/130=3.16 \Rightarrow$ do not give uncertainties on parameters

“Notice also that the quality of the data is such that **the precise values of our parameters should not be taken too seriously**”
(Phys. Lett. B296, 227 (1992))

After fixing the 2 parameters find A, B for other reactions.

Cudell (CKK)



Cudell, Kang, Kim (PL B395, 311 (1997))

Repeat DL analysis, data only if 1σ or 2σ from average. Use also data on ρ (real/imaginary part of amplitude). Add separate intercepts of the $C=+$ and $C=-$ meson trajectories.

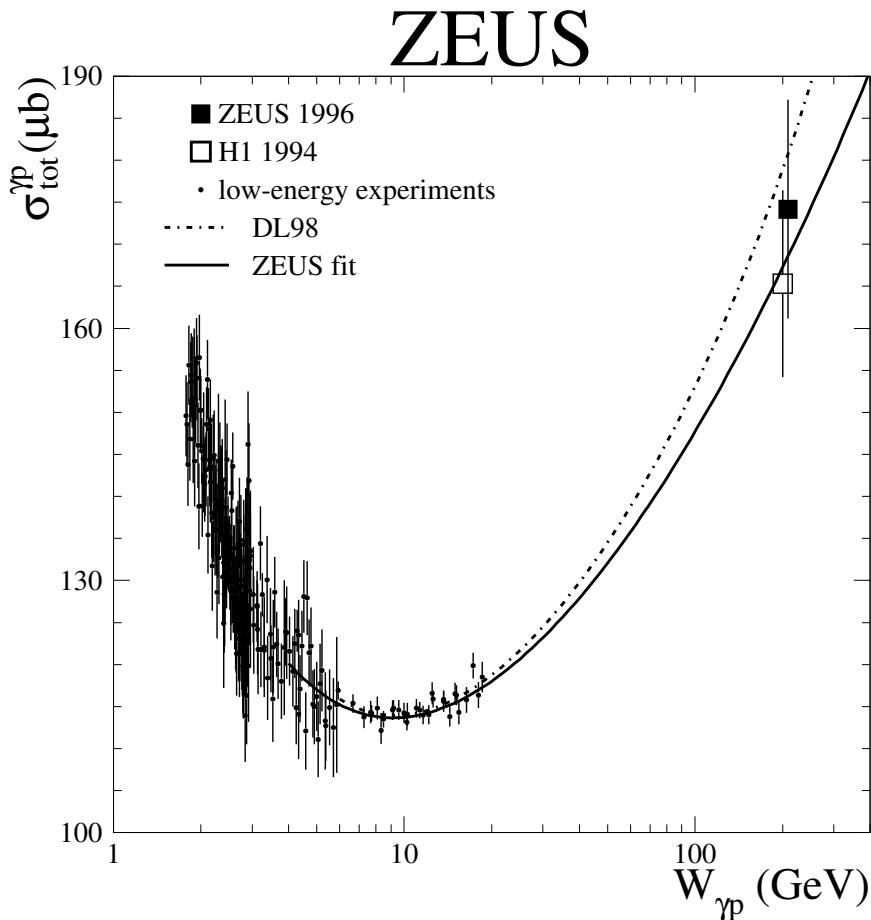
Get:

$$\varepsilon = 0.096^{+0.012}_{-0.009}$$

but

“feel that intercepts as high as 1.11 and as low as 1.07 are possible”

$\sigma_{\text{TOT}}(\gamma p)$ at HERA



At HERA:

H1 ($W=200$ GeV), $165 \pm 2 \pm 11 \mu\text{b}$

ZEUS ($W=209$ GeV), $174 \pm 1 \pm 13 \mu\text{b}$

Large systematic uncertainties
from 35m tagger acceptance
and Calorimeter acceptance.

Want to reduce the
large systematic error
on total cross section
by measuring ratios at
different W in a single
experiment.

Concept of measurement

Change W by changing only proton energies, take ratios of cross sections

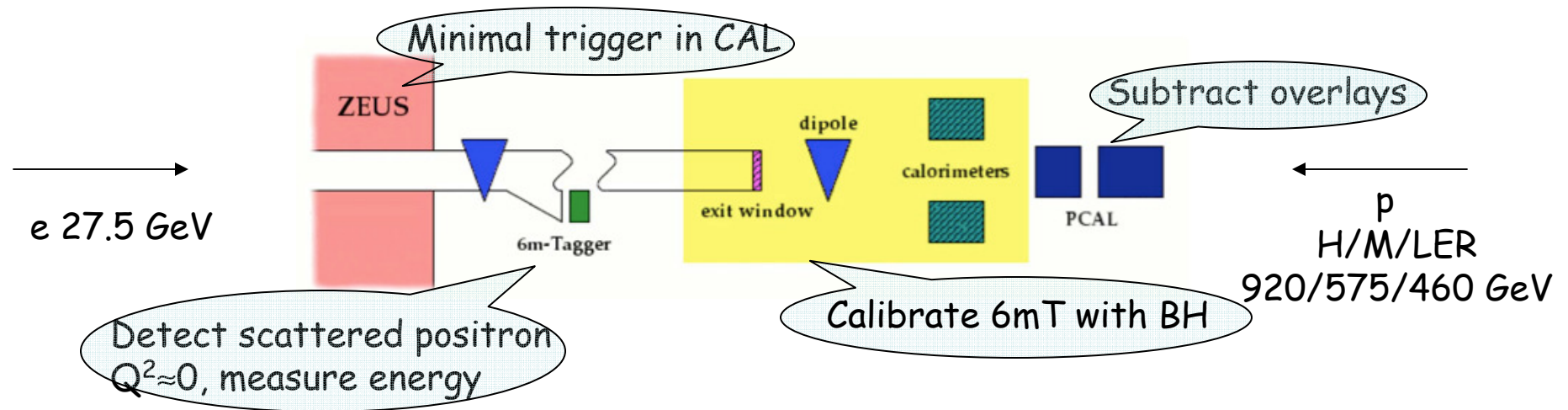
Assuming $\sigma \sim W^{2\varepsilon}$, ε can be extracted from the ratio R of cross sections probed at different W values.

$$R = \frac{\sigma(W_1)}{\sigma(W_2)} = \left(\frac{W_1}{W_2} \right)^{2\varepsilon}$$

Experimentally, $\sigma = \frac{N}{A \cdot \mathcal{L}}$ and therefore $R = \frac{N_1}{N_2} \cdot \frac{A_2}{A_1} \cdot \frac{\mathcal{L}_2}{\mathcal{L}_1}$.

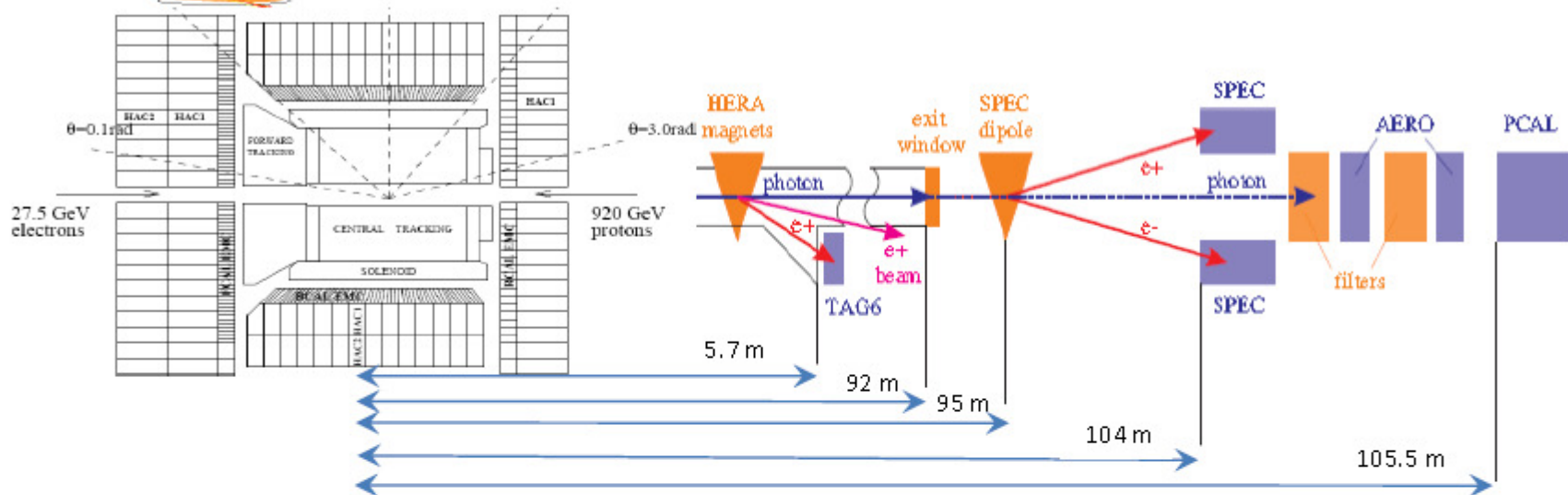
The acceptance is expected to be the same for the three energy setups as the photon energy is the same and RCAL covers the fragmentation region of the photon \rightarrow the ratio of acceptances will be canceled.

W dependence of $\sigma_{\text{tot}}(\gamma p)$



Expect CAL acceptances at different W to be same - (checked with PYTHIA). Tagger acceptance under control.

The ZEUS detector and trigger



During few months before HERA shutdown, it was running **27.5 GeV** positrons and protons of three different energies:
 High Energy Run (HER) - **920 GeV**
 Medium Energy Run (MER) - **575 GeV**
 Low Energy Run (LER) - **460 GeV**

The luminosity collected in the ZEUS detector was determined in two independent ways (photon calorimeter and spectrometer) by measuring the rate of the Bethe-Heitler (BH) process

$$e^+p \rightarrow e^+\gamma p$$

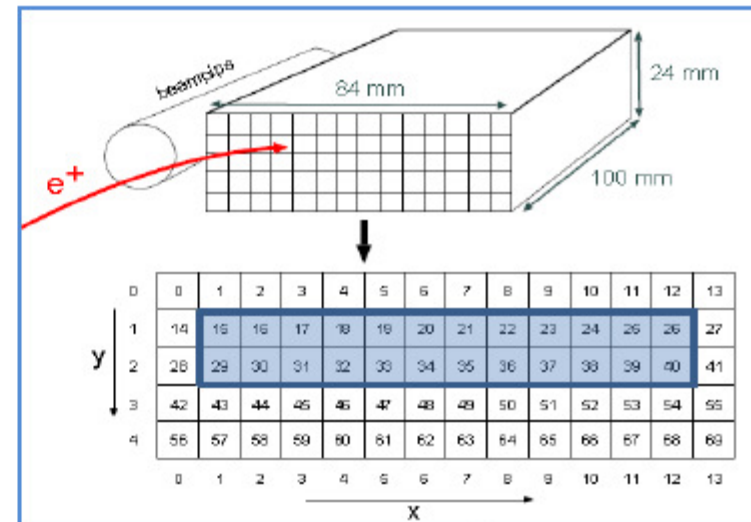
Required a **hit in the 6m Tagger (TAG6)** and **energy deposition in the rear part of the calorimeter**. In addition, $E_{PCAL} < 14 \text{ GeV}$.

The 6m tagger was calibrated with the spectrometer: $E_{6mT} = E_e - E_{spec}$.

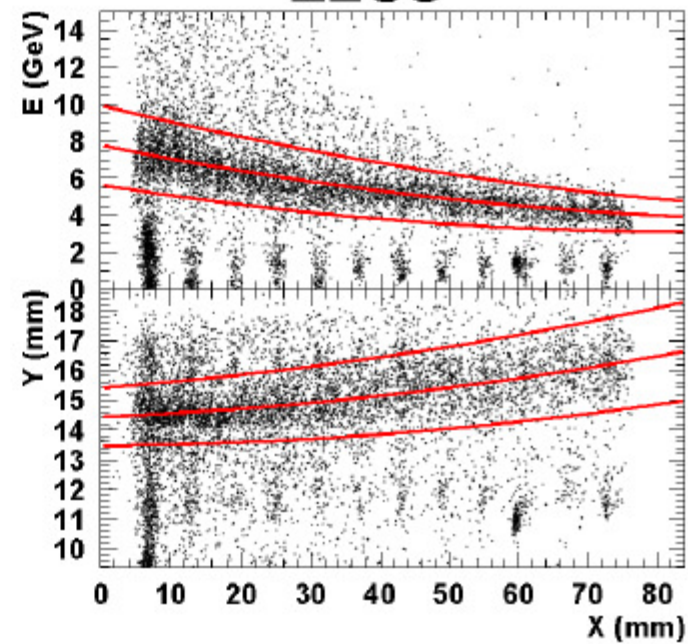
Event selection

TAG6

- clean hit in TAG6- highest cell not at the edge of the detector, energy sharing between cells around highest energy cell.
- The positron position was reconstructed using a neural network trained on the MC.
- Neural network was also used to correct the energy of positrons for a small number of noisy cells which were excluded.
- The energy (E) and the vertical position (Y) were determined as a function of the horizontal position (X) and cuts were made to reject off-momentum beam positrons and background from beam-gas interactions.



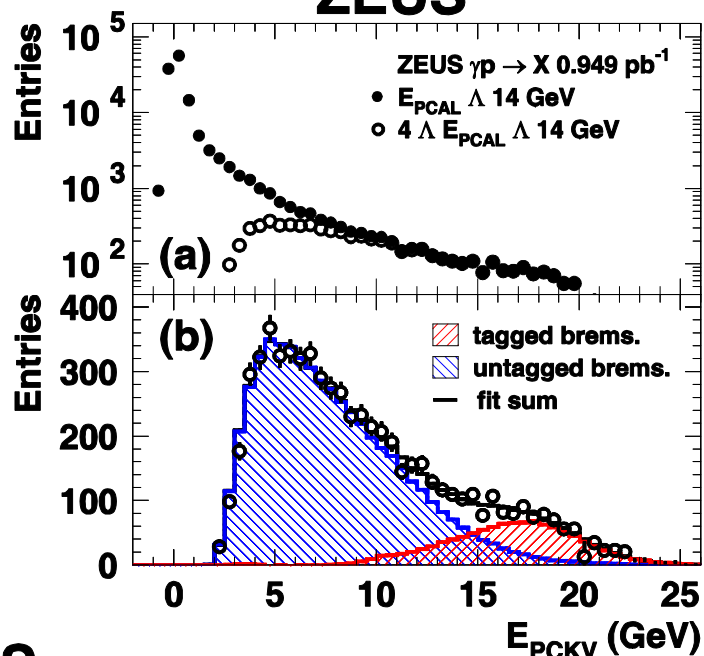
ZEUS



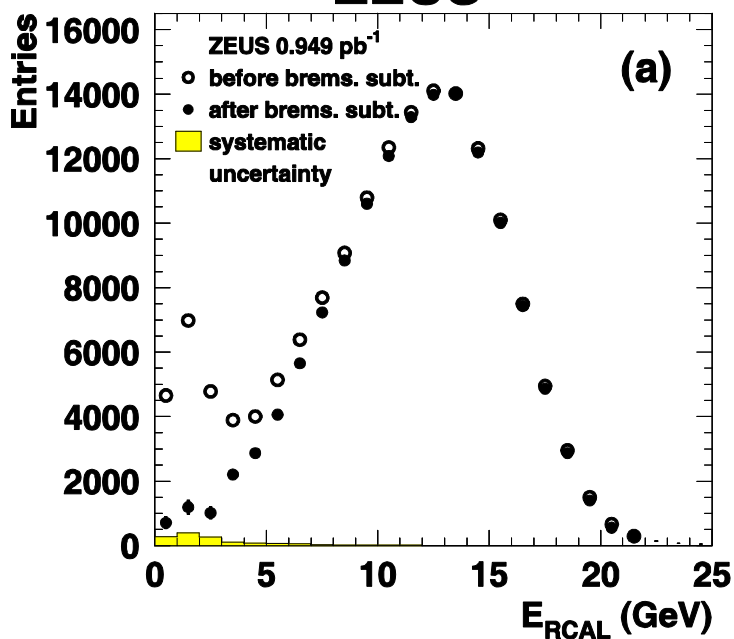
Background corrections

- background from beam-gas interactions was determined using non-colliding positron bunches and subtracted statistically (scaled to the ratio of currents).
- Photoproduction events with hit in TAG6 that occurred in coincidence with a hit in PCAL of bremsstrahlung photon with energy >14 GeV were vetoed- corrected by weighting the number of accepted events by a factor determined from the rate of overlaps at the time the event was accepted.
- Photoproduction events that satisfied the RCAL trigger but had no hit in TAG6 that occurred in coincidence with bremsstrahlung event with a hit in TAG6 that was not vetoed by the PCAL veto (due to limited acceptance and resolution of the PCAL) were subtracted.

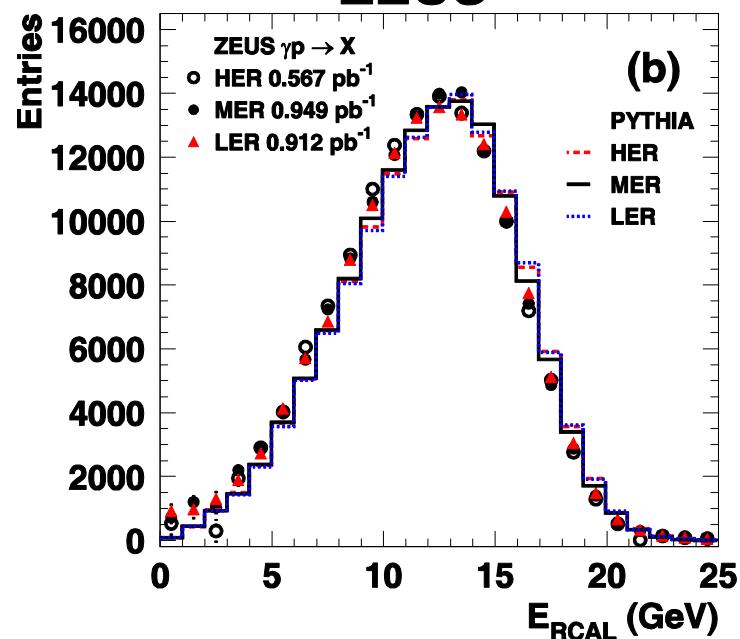
ZEUS



ZEUS



ZEUS



From e^+p cross section to γp cross section

$$\frac{d\sigma^{e^+p}(y)}{dy} = \frac{\alpha}{2\pi} \left[\frac{1 + (1-y)^2}{y} \ln \frac{Q_{max}^2}{Q_{min}^2} - 2 \frac{(1-y)}{y} \left(1 - \frac{Q_{min}^2}{Q_{max}^2} \right) \right] \sigma_{tot}^{\gamma p}(y)$$



$\sigma_{tot}(\gamma p)$ can be extracted from σ^{e^+p}

$$\sigma_{tot}(e^+p) = f \cdot \sigma_{tot}(\gamma p)$$

$$f = \int_{y_{min}}^{y_{max}} \frac{\alpha}{2\pi} \left[\frac{1 + (1-y)^2}{y} \ln \frac{(1-y)Q_{max}^2}{m_e^2 y^2} - 2 \frac{(1-y)}{y} \left(1 - \frac{m_e^2 y^2}{(1-y)Q_{max}^2} \right) \right] dy$$

$$y_{min/max} = 1 - \frac{E'_{e_{max/min}}}{E_e}$$

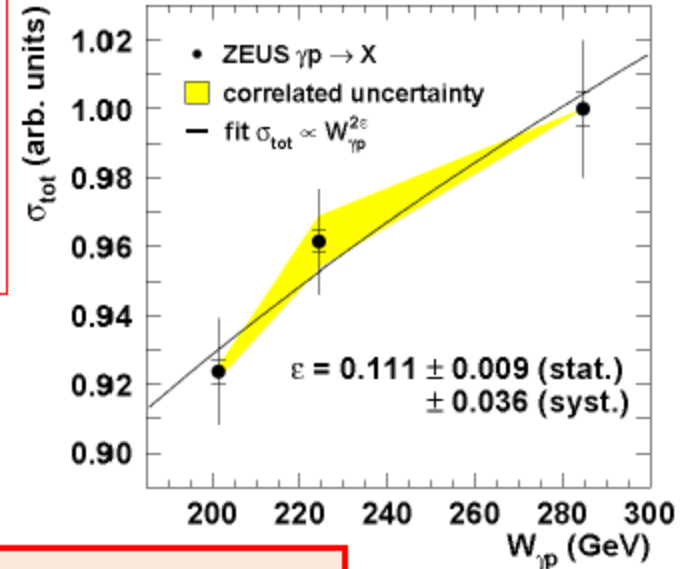
Flux uncertainty dominated by range of integral.

Results

The γp cross sections ratio

$$R = \frac{\sigma_i^{\gamma p}}{\sigma_{HER}^{\gamma p}} = \frac{N_i}{N_{HER}} \cdot \frac{A_{HER}}{A_i} \cdot \frac{\mathcal{L}_{HER}}{\mathcal{L}_i} \cdot \frac{f_{HER}}{f_i}$$

$\mathcal{L}_{LER} = 912 \text{ nb}^{-1}$	$f_{LER} = 0.877 \cdot 10^{-3}$	$N_{LER} = 116740$
$\mathcal{L}_{MER} = 949 \text{ nb}^{-1}$	$f_{MER} = 0.895 \cdot 10^{-3}$	$N_{MER} = 128954$
$\mathcal{L}_{HER} = 567 \text{ nb}^{-1}$	$f_{HER} = 0.852 \cdot 10^{-3}$	$N_{HER} = 76310$



$$\epsilon = 0.111 \pm 0.009 \text{ (stat.)} \pm 0.036 \text{ (syst.)}$$

Summary

**W dependence of $\sigma_{\text{tot}}(\gamma p)$
determined in a single experiment.**

λ HERA

