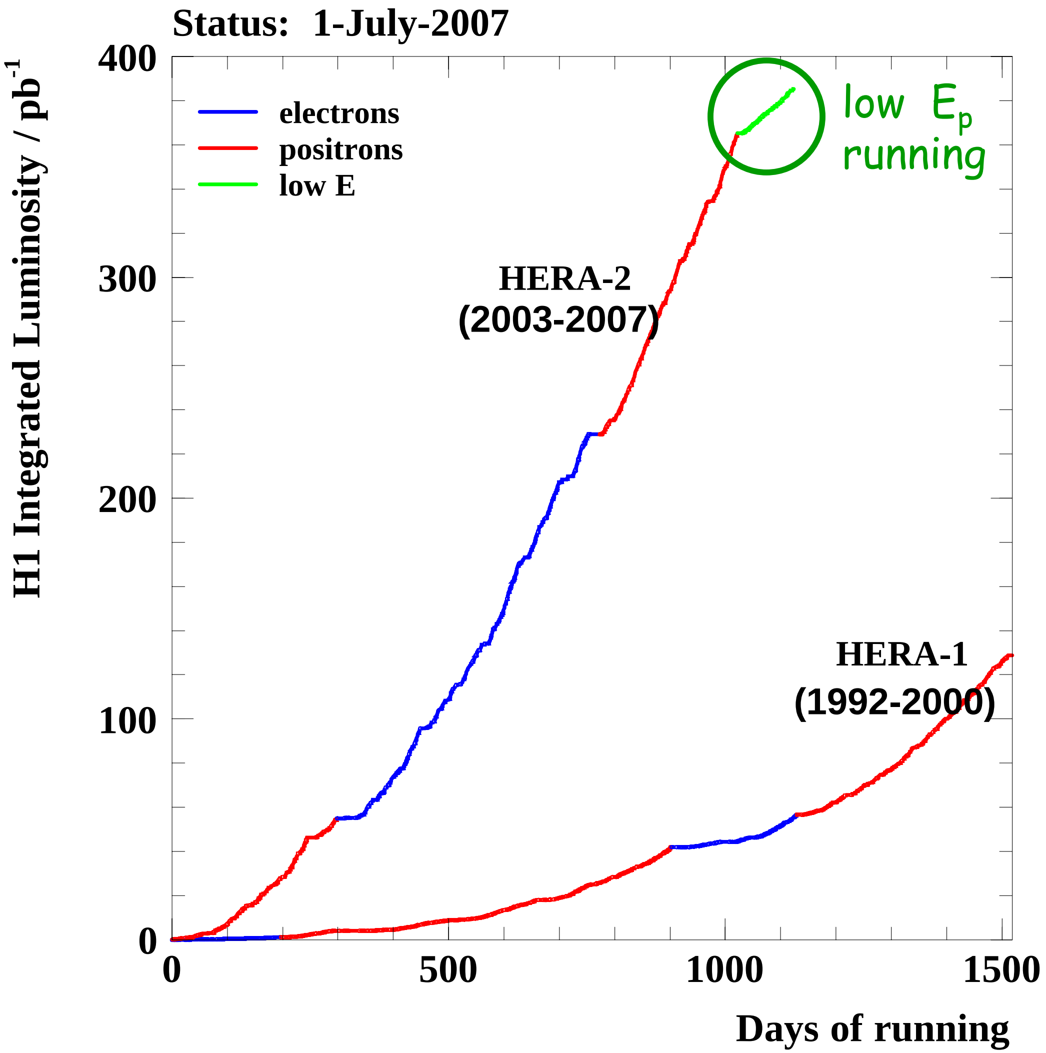
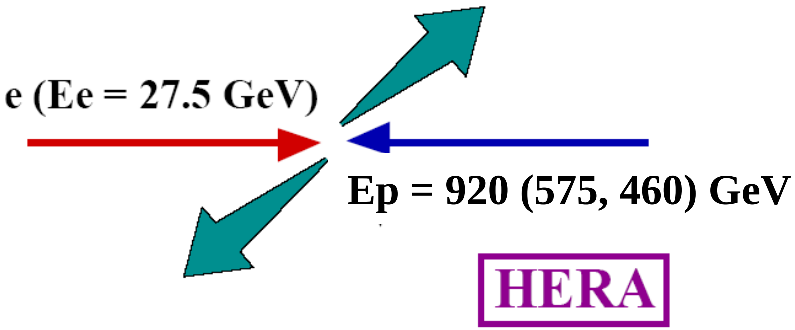
# H1/ZEUS Project Review 2008

Vladimir Chekelian (MPI for Physics, Minich)


- HERA ep collider 1992-2007
- H1/ZEUS MPI group members
- MPI hadware responsibilities
- Physics analyses
- Outlook

# HERA ( May 1992 – June 2007)




peak luminosity $5\ 10^{31}\ cm^{-2}\ sec^{-1}$
$Q^2_{max} = 10^5\ GeV^2$
$\lambda_{max} \sim 1/1000\ r_{proton}$
longitudinal e-beam polarisation

in total $\sim 1\ fb^{-1}$

about equally shared between

- H1 and ZEUS
- $e^+$ and $e^-$,
- positive and negative polarisation of the lepton beam $P_e$

# H1 & ZEUS MPI Group Members

Responsible director
- A. Caldwell

Staff scientists
- I. Abt (ZEUS Physics Coordinator, PL)
- C. Kiesling (Project Leader)
- V. Chekelian
- G. Grindhammer (QCD convener)

Post-docs
- B. Reisert (ZEUS, FL convener)
- D. Kollar (ZEUS, left 31.08.2008)
- W. Schmidke (ZEUS)
- B. Olivier (left 30.09.2008)
- A. Raspereza

Guest scientists
- A. Levy (ZEUS)
- H. Abramowiz (ZEUS)
- A. Dubak /Behrendt/

PhD students
- A. Liptaj (disputation today in Hamburg)
- R. Kogler
- A. Dossanov
- S. Shushkevich
- P. Devgun (Punjab U., ZEUS)
- I. Singh (Punjab U., ZEUS)
- V. Drugakov (Minsk/DESY, ZEUS)

Engineers
M. Fras, W. Haberer,
M. Modjesch, A. Wassatsch

Support
F. Rudert, M.Schaber

In cooperation with former
MPI PhD students and post-docs
A. Nikiforov, R. Placakyte,
B. Antunovich, Z. Rurikova,
J. Bracinik

# The (past) MPI Hardware Responsibilities

Dismantling of the detectors is finished in Febrary 2008

H1 ( C. Kiesling, A. Dubak, B. Olivier, A. Nikiforov,
R. Placakyte, B. Antunovich + engeneers)

- LAr trigger
- Neural Network Trigger (L2NN)
- Jet trigger

ZEUS ( W. Schmidke, V. Drugakov, A. Caldwell )

- Photon spectrometer, lumi measurements

Many thanks to MPI engeneers & technicians !!!

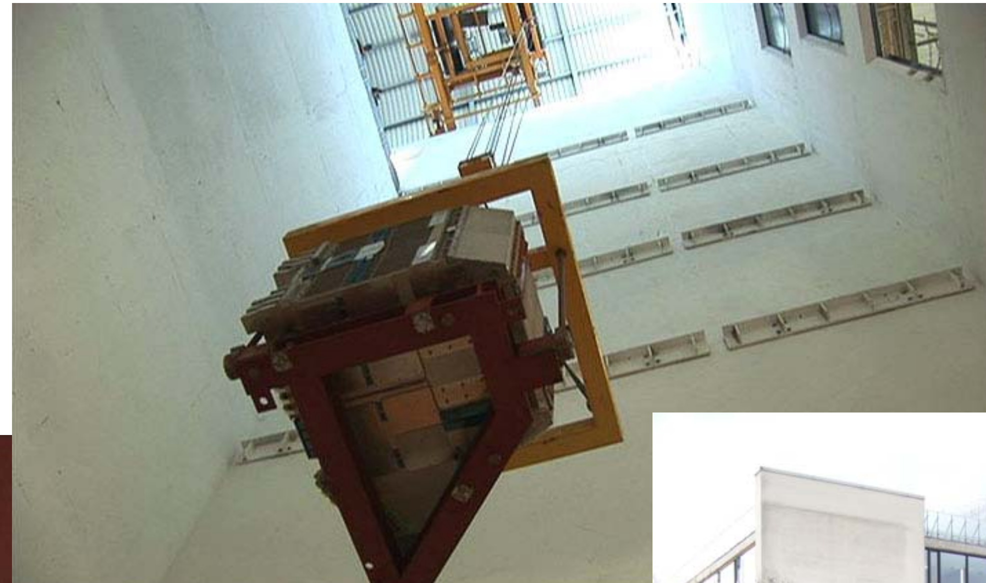
# Dismantling: LAr Calorimeter

Main component of the H1 detector

FB1H/FB2H/OF1H/OF2H are assembled in the house

45000 readout cells
65000 electronic channels

# FB1 Octant for MPI Museum


in front of the MPI building

# Dismantling: LAr trigger

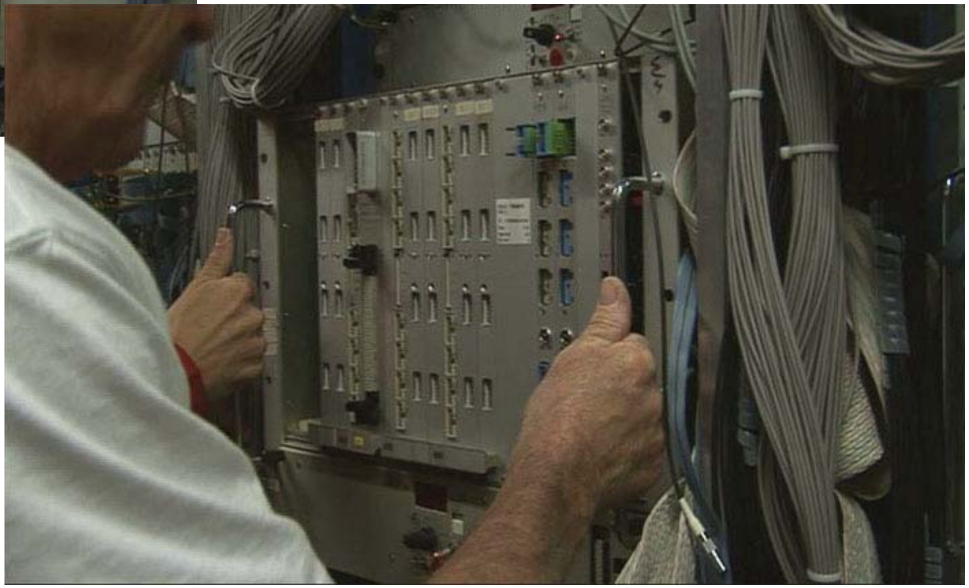
Main trigger for NC/CC at high $Q^2$

6 racks of analog electronics
2 racks for the digital part

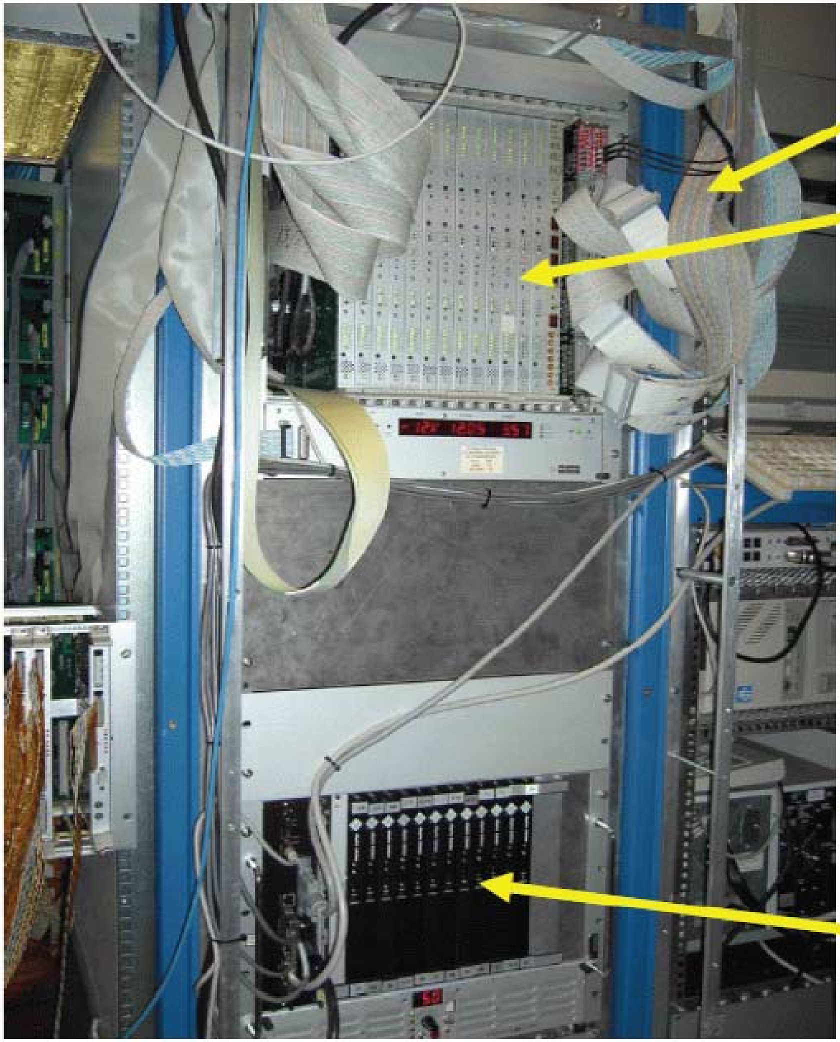
5000 Trigger cells (analog signal)
1300 Trigger Towers (em+had)
480 FADC for Big Towers (em+had)

**59 trigger elements at L1**
( 96 ns, pipelined for ~2.5 μs):

- two threshoulds for el. id
- transverse energy
- missing transverse energy
- topological energy sums
- event timing (t0)
- track-validated big towers

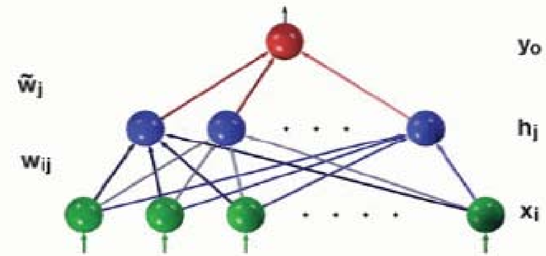


# Dismantling: Neural Network Trigger (L2NN)



data from the level 1 processors

selection & preprocessing of input data

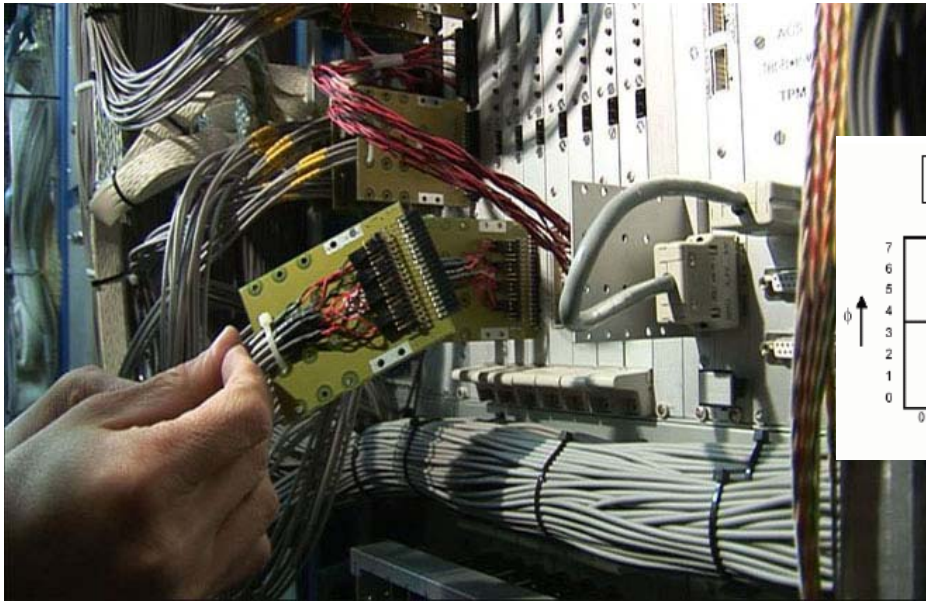



12 networks for specific physics, e.g.

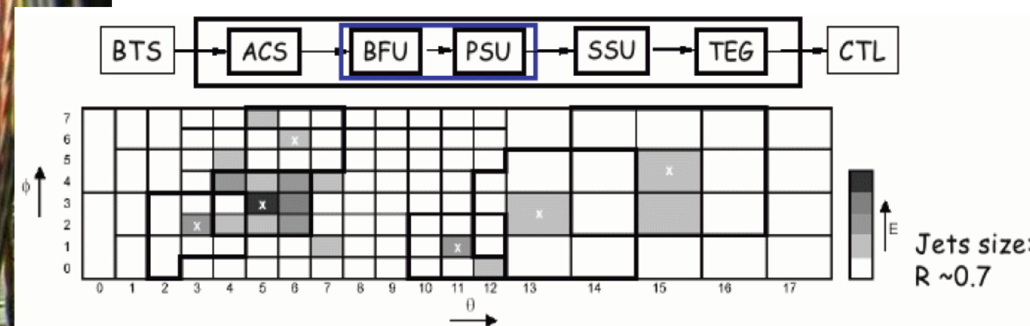
- untagged and tagged D*
- DVCS
- elastic $J/\Psi$ and $\Upsilon$ production
- photoproduction dijets

neural network processors

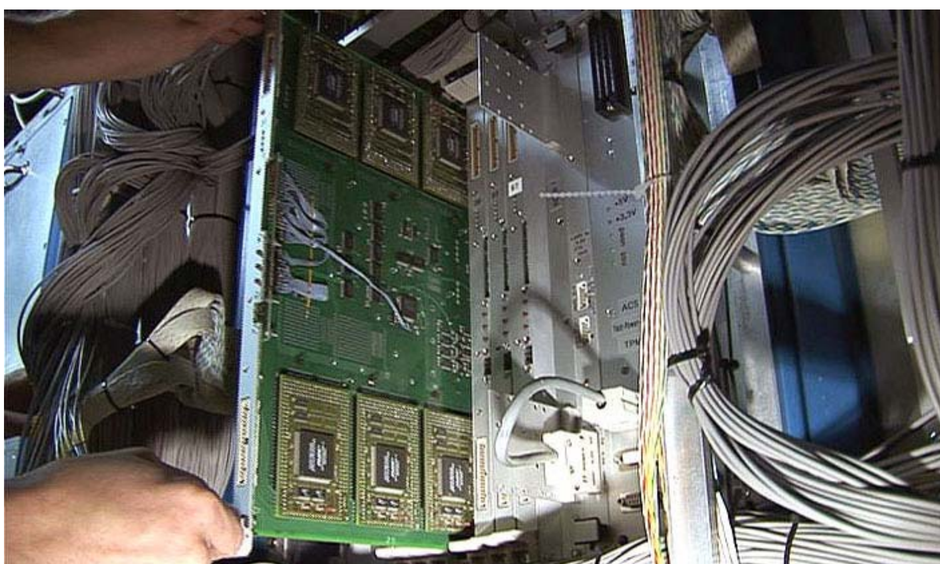
# Dismantling: Jet Trigger

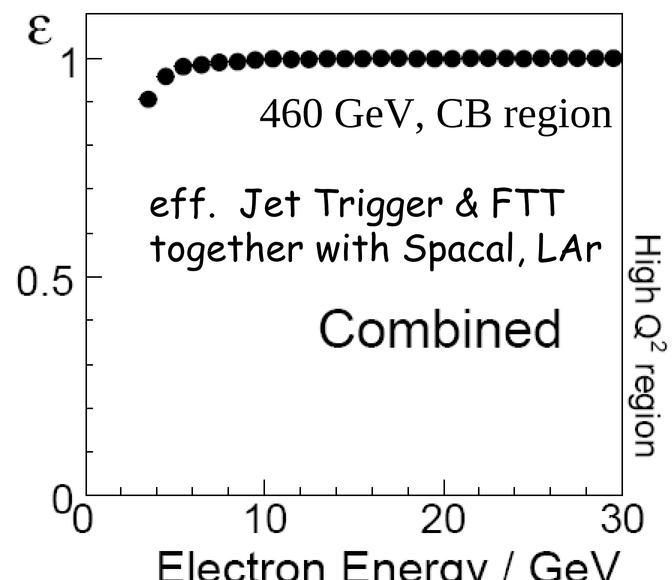


in operation from summer 2006
→ real time jet finding at L1

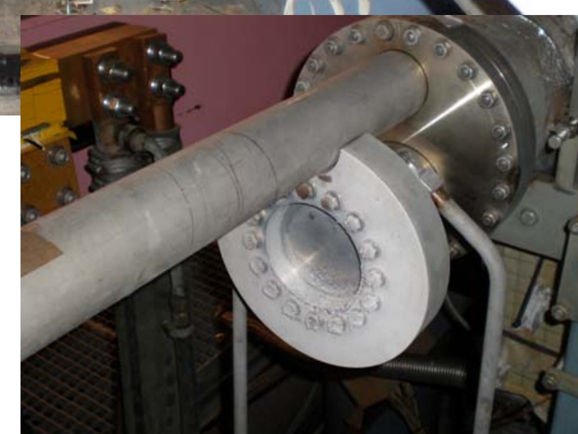



→ collect data with low $E_e'$
for $F_L$ measurement





# Dismantling: Photon Spectrometer (ZEUS)



in operation 2002-2007
- energy calibration of the lumi system
- lumi measurements

# MPI Physics Activities

**H1**

- Inclusive NC/CC cross sections, structure functions $F_2$, $xF_3$, $F_L$
  V. Chekelian, S. Shushkevich, A. Dubak,
  A. Nikiforov, R. Placakyte, C. Kiesling
- Inclusive jets in DIS and photoproduction
  G. Grindhammer, J. Bracinik, A. Dossanov, R. Kogler
- Combination of HERA-I inclusive data & QCD fit
  V. Chekelian
- Charm fragmentation functions
  G. Grindhammer, Z. Rurikova, A. Liptaj, J. Bracinik

**ZEUS**

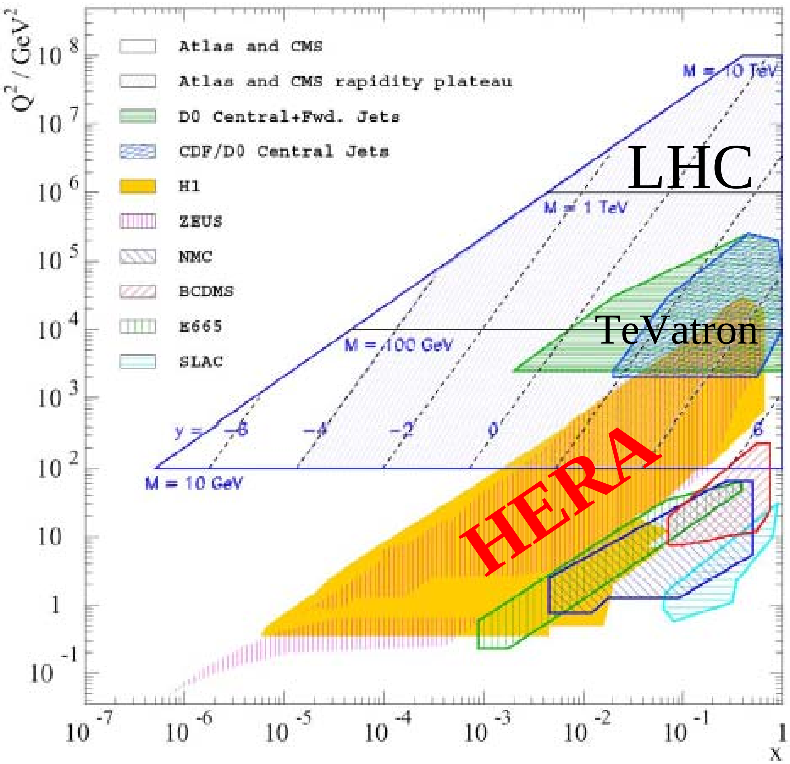
- Longitudinal structure function $F_L$ (B. Reisert, D. Kollar, P. Devgun)
- $\gamma p$ total cross section (W. Schmidke)

- ZEUS Physics Coordination by I. Abt

# Inclusive DIS cross sections

$$\frac{d^2\sigma^{e^\pm p}_{NC}}{dx\,dQ^2} = \frac{2\pi\alpha^2 Y_+}{xQ^4}\sigma_r^\pm = \frac{2\pi\alpha^2 Y_+}{xQ^4}\left[F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2) \mp \frac{Y_-}{Y_+}xF_3(x,Q^2)\right]$$

$$Y_\pm = 1 \pm (1-y)^2$$




unpolarised NC/CC inclusive cross section
- proton structure function $F_2$
- low x physics
- QCD analysis, pdfs

electron and positron beams:
- $xF_3$ : valence quarks
- sensitivity to different flavors in CC

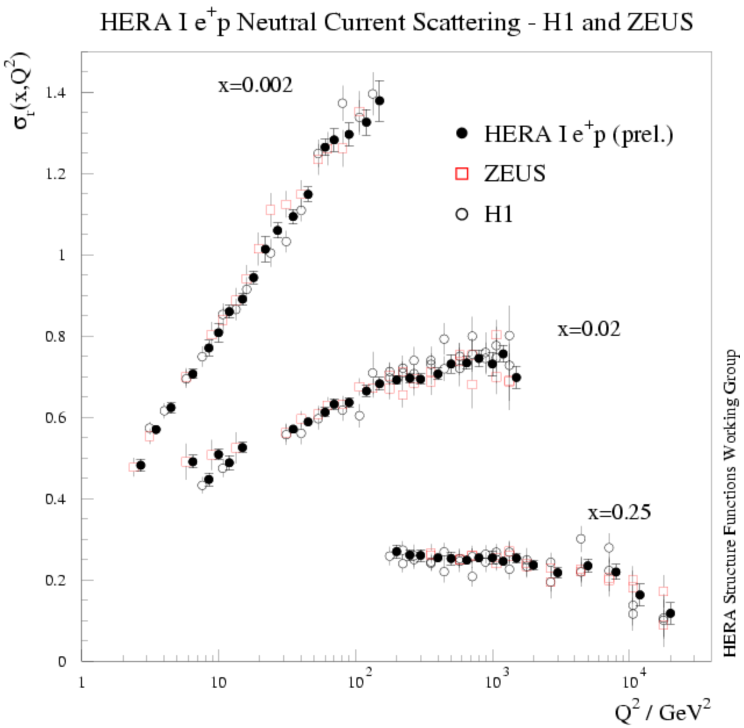
polarisation of the lepton beam:
- (V-A) structure of CC at high $Q^2$
- couplings of the light quarks to Z bozon

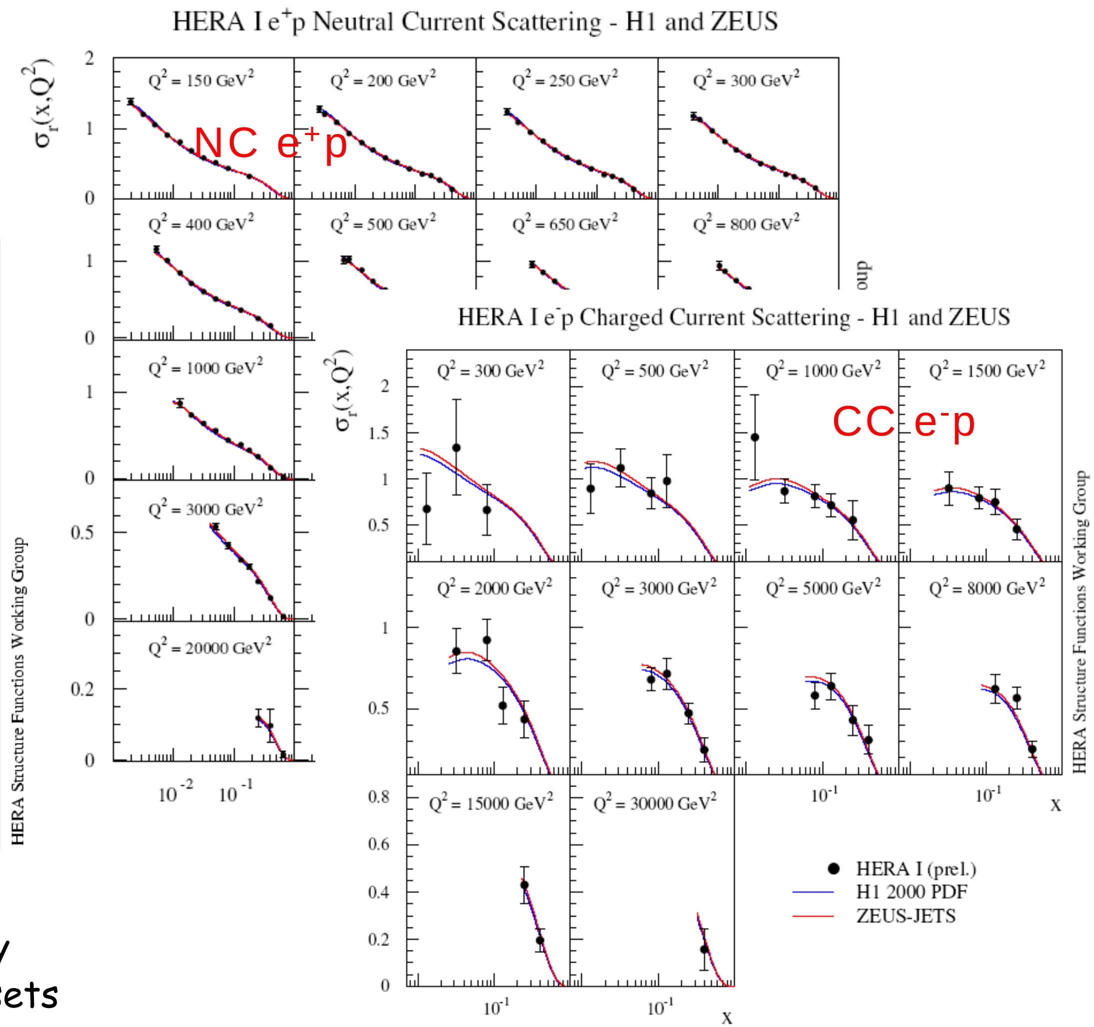
different proton beam energies
- longitudinal structure function $F_L$

# Combination of H1 and ZEUS
# HERA-I inclusive DIS cross section data

The goal → "the HERA data set"

expert knowledge in the treatment of correlations between individual data sets



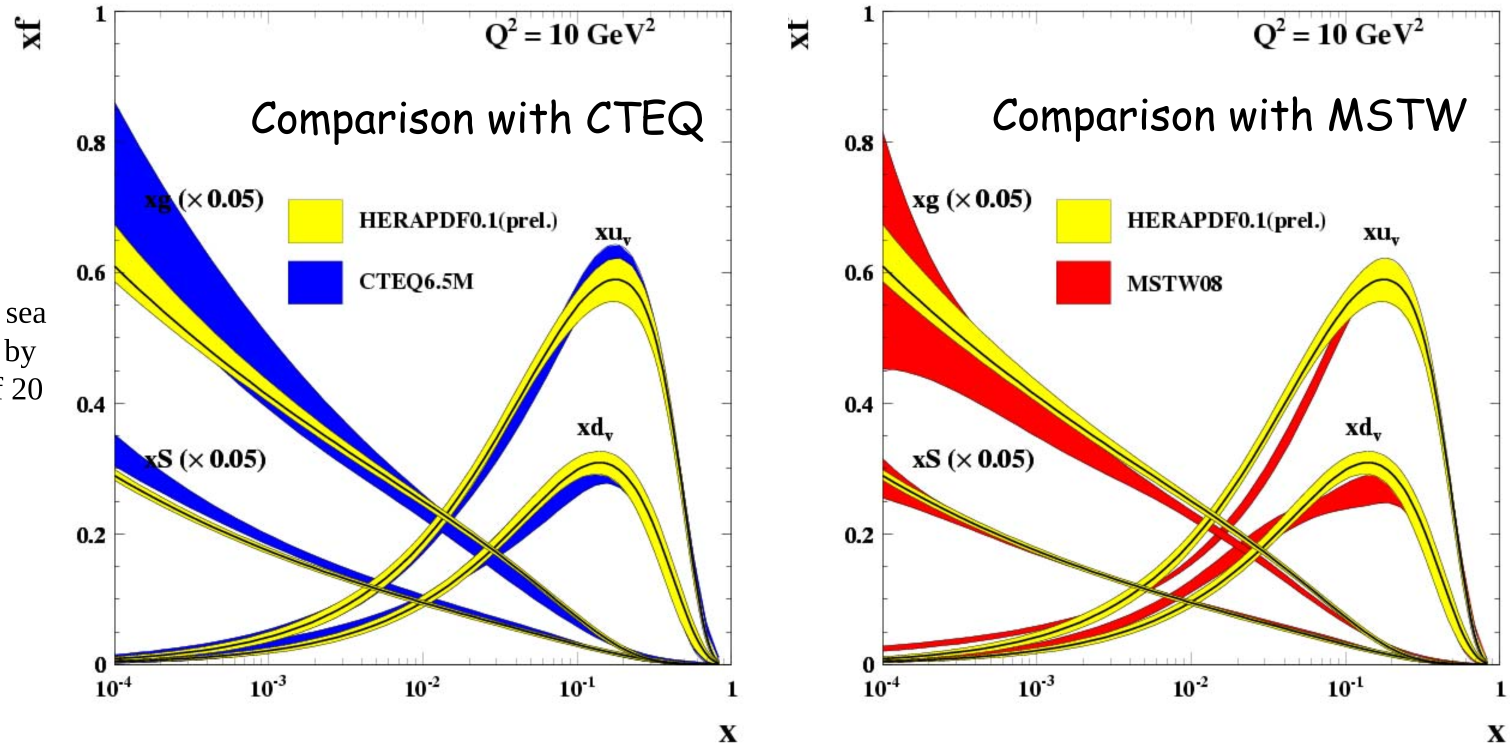

→ significant reduction of uncertainty by cross calibrating the various data sets

For the moment combine published NC,CC HERA I results (H1 & ZEUS) 1.5< $Q^2$< 30000 GeV$^2$

# HERAPDF0.1 - PDFs from HERA

NLO QCD PDF fit using the combined $e^{\pm}p$ NC/CC HERA-I data set used as a sole input

Gluon and sea are devide by a factor of 20



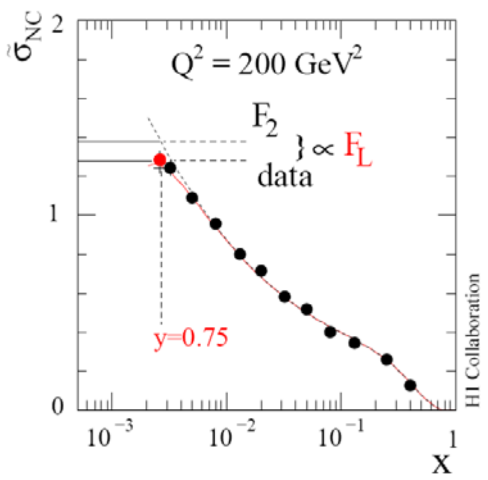

→ impressive precision compared to present global fits

→ HERAPDF0.1 is released on LHAPDF (5.6.0 23.10.2008)

# Measurement of Longitudinal Str. Function $F_L$

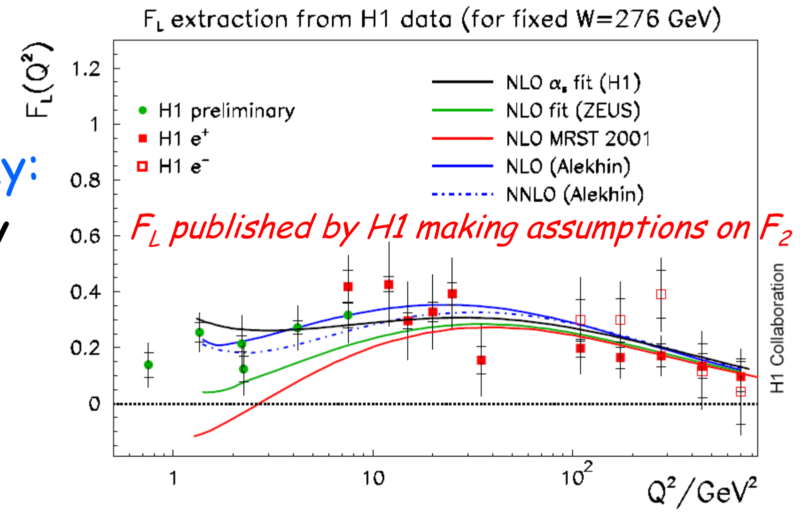
$$\tilde{\sigma}_{NC} = \frac{d^2\sigma^{ep}_{NC}}{dx\,dQ^2} \Big/ \left(\frac{2\pi\alpha^2}{xQ^4} Y_+\right) = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

sensitivity to $F_L$ only at high y



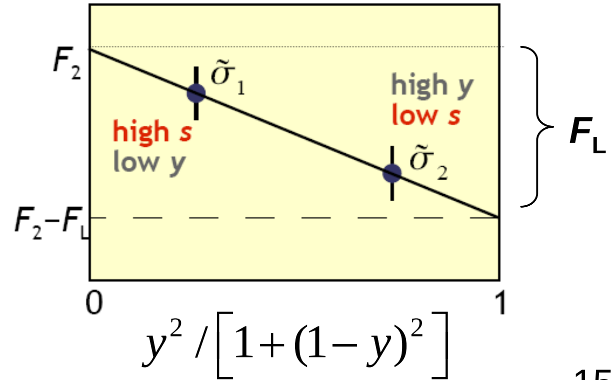

→ one possible way:

**measure σ at high y and assume $F_2$**



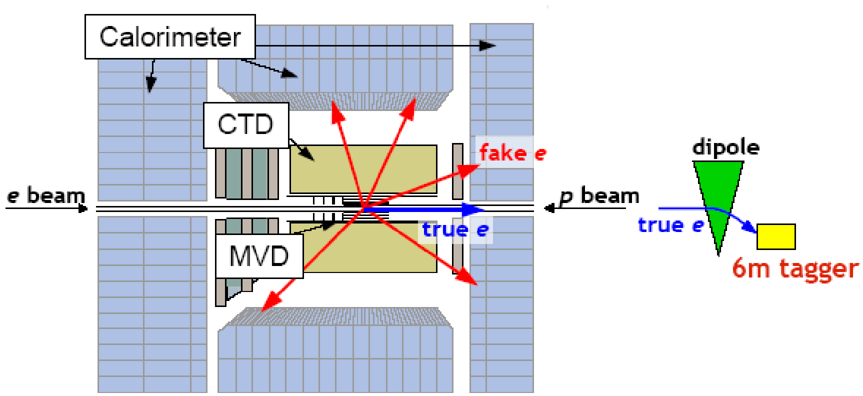

→ *free from theoretical assumption:*

measure σ at the same x & $Q^2$ and different y by changing the proton beam energy ($y = Q^2/sx$)

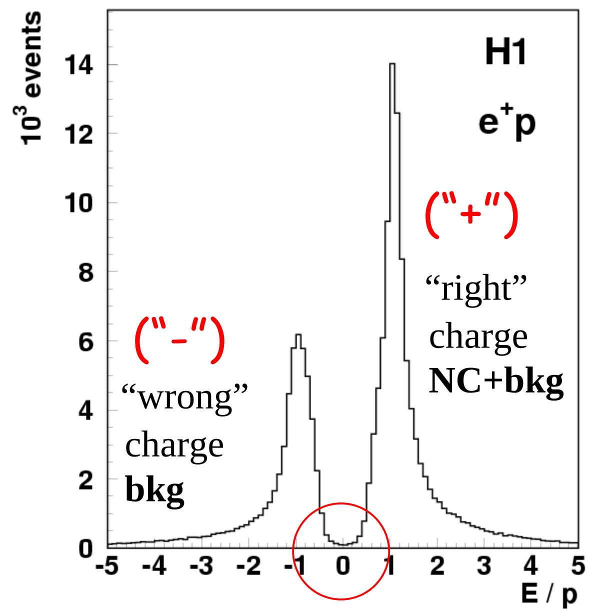


# Experimental challenge: $\gamma p$ background ($Q^2 \approx 0$)

ZEUS




H1




- **in photoproduction ($Q^2 \approx 0$) electron** with reduced energy travels along the e beam direction, bends in the dipole magnet and hits the *electron tagger* located at 6 m

- **quasi-real photon** interacts with the proton and a final state hadron is misidentified as **a fake electron** in the *main detector*

→ **$\gamma p$ events measured with signal in 6 m tagger are used to normalize PYTHIA $\gamma p$ MC for each $E_p$ period**

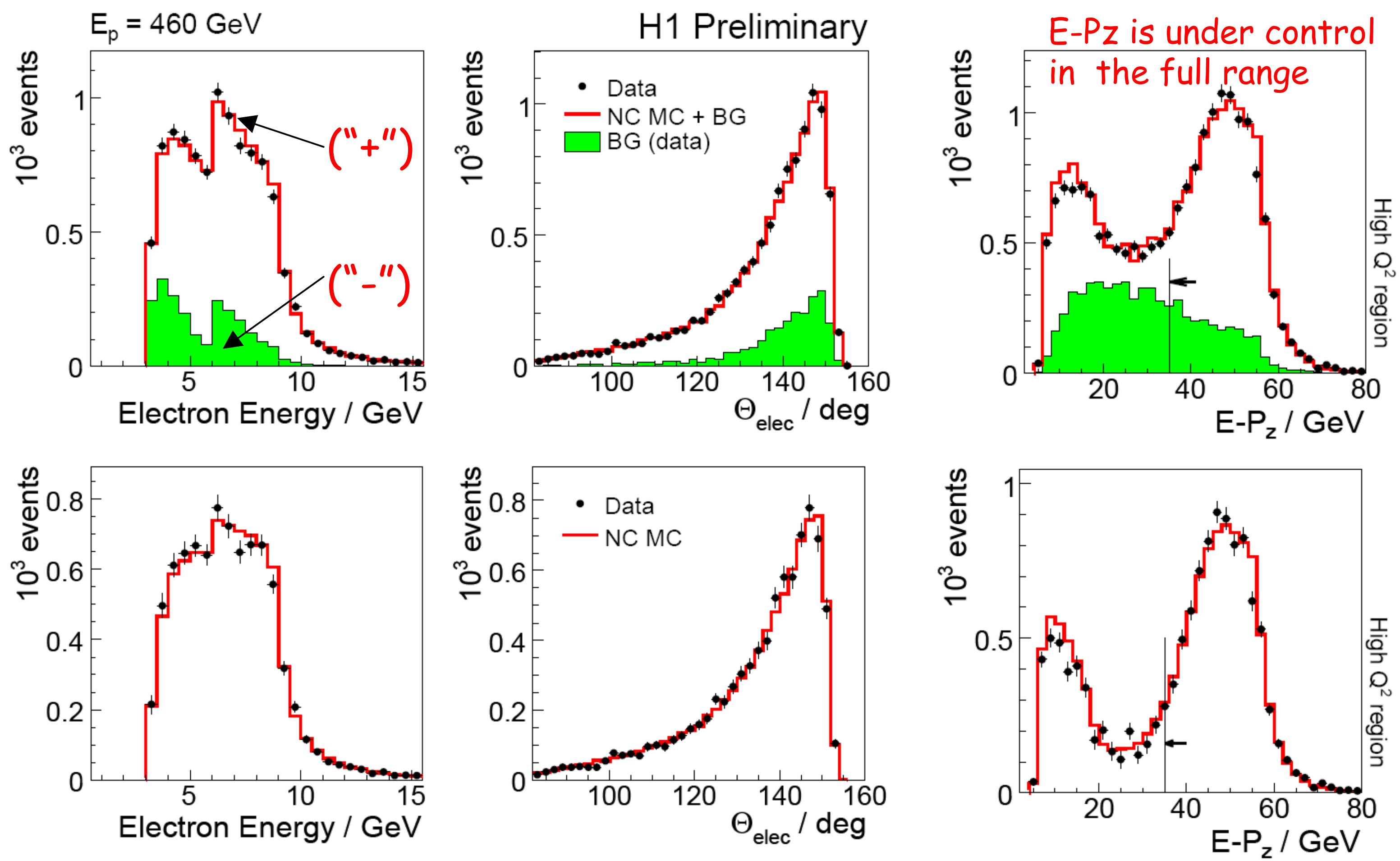
make use of **electric charge** of the scattered electron using track from the primary interaction, pointing to the electron cluster:

- **good charge measurement resolution**
- **wrong assignment of the charge < 1%**

→ **identify and exclude half of $\gamma p$ bkg require the "right" charge**

→ **estimate and subtract remaining $\gamma p$ bkg using "wrong" charge**

# High y region (0.70<y<0.90) at high $Q^2$ (H1)



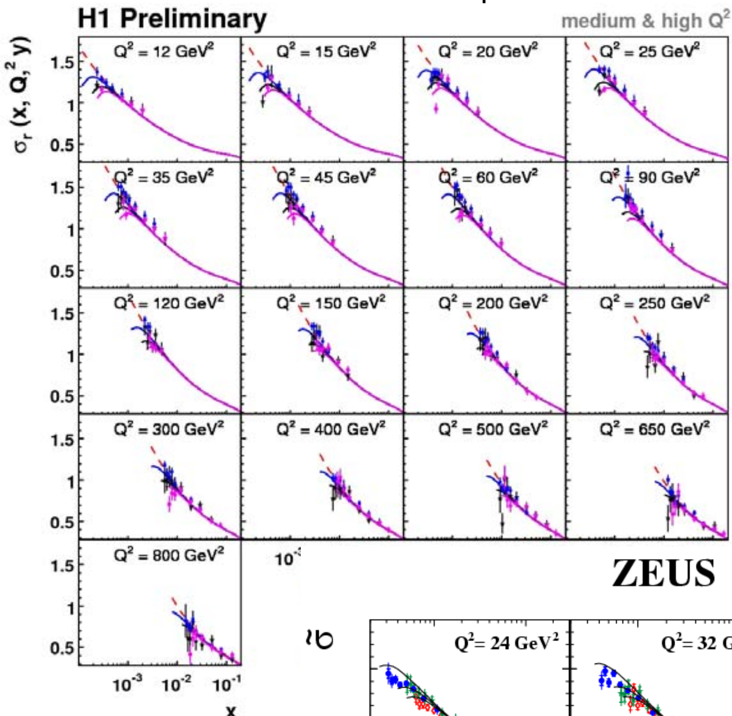

→ step at $E_e$=6 GeV is due to selection requirements

**the requirement E-Pz>35 GeV :**
- ***rejects γp background***
- ***rejects initial state radiation (ISR)***

# NC cross sections from H1 & ZEUS

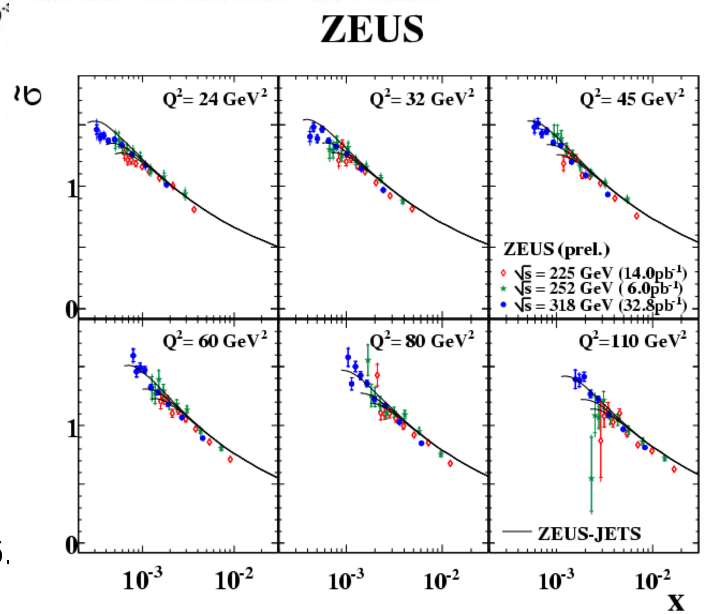
three cross section
for each $Q^2$ and $x$

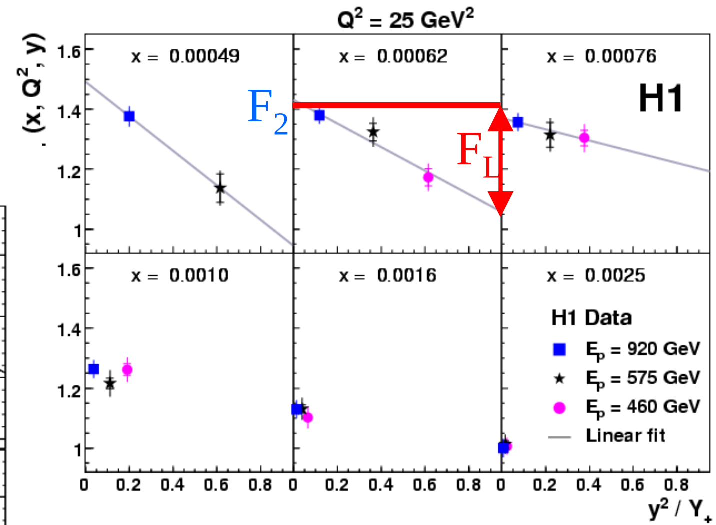
$E_p$ = 460,575,920 GeV




$$\tilde{\sigma}_{NC} = F_2 - \frac{y^2}{1+(1-y)^2} F_L$$

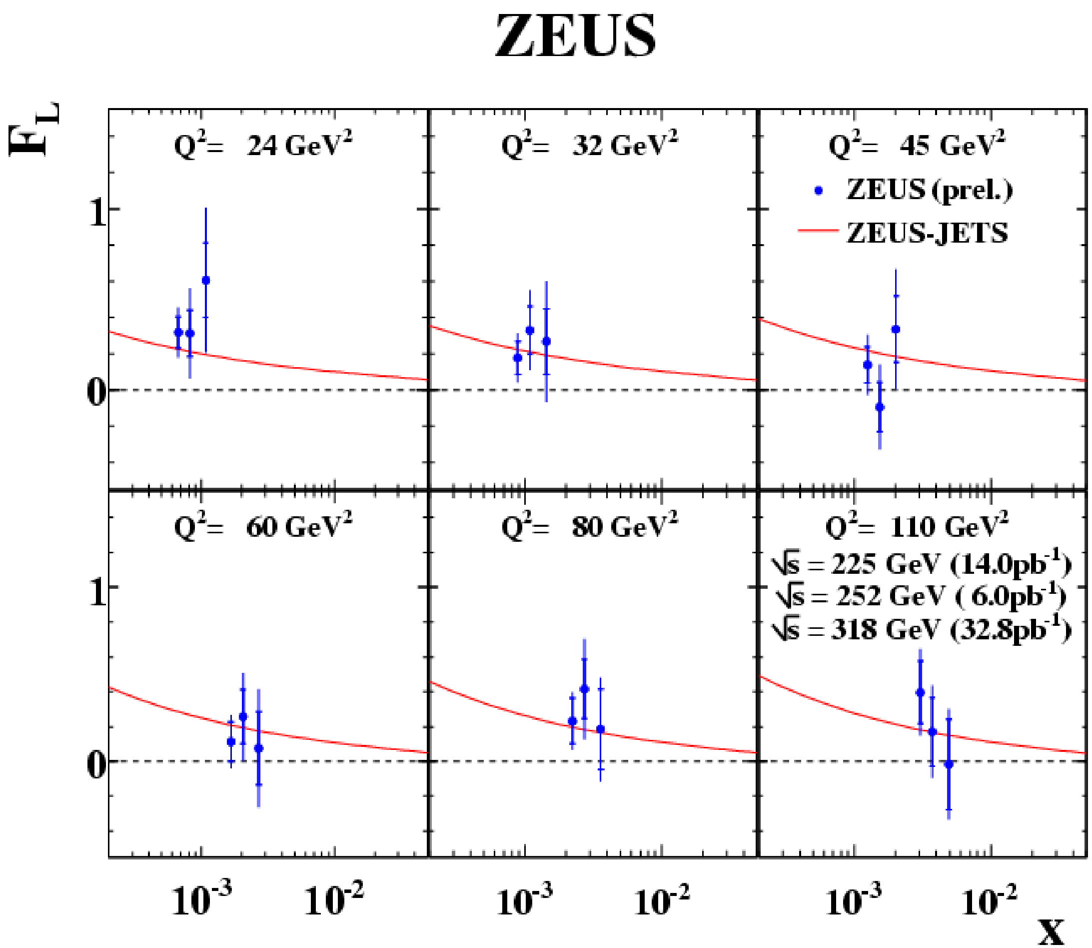
→ determine $F_L$ and $F_2$ from linear fits at each $x$ and $Q^2$



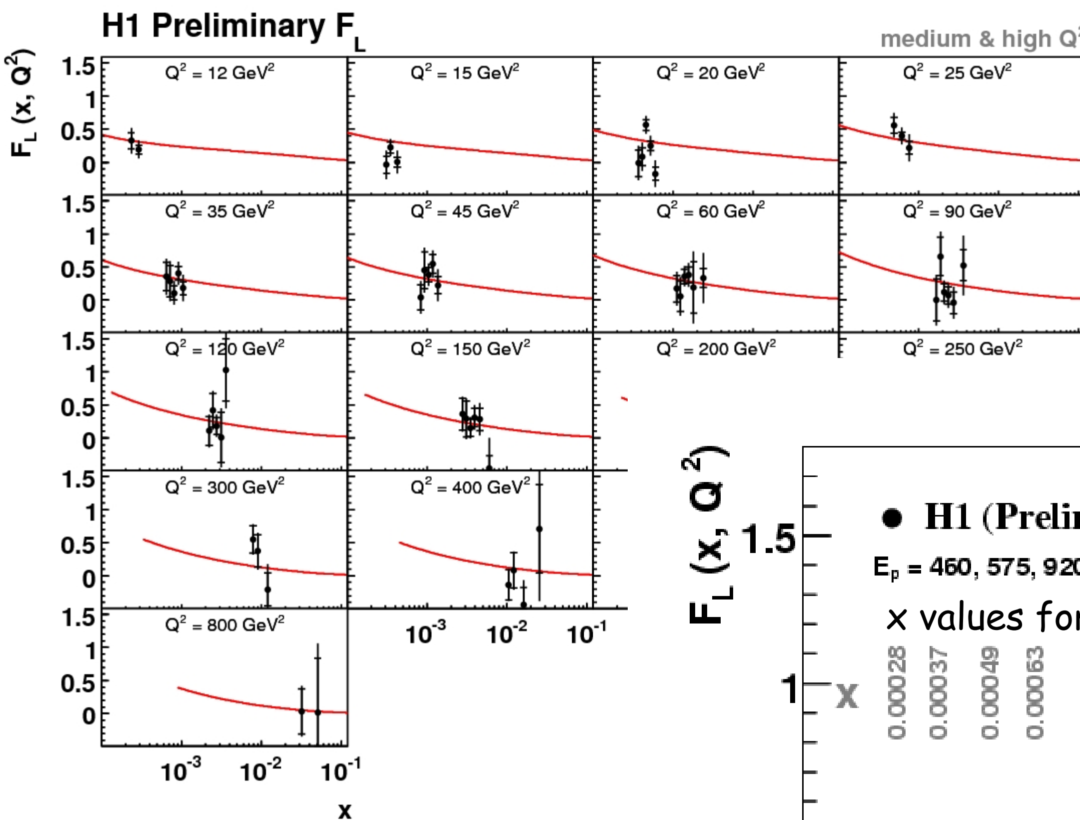

depatures of the theory curves from $F_2$ are due to $F_L$

# $F_L$ (x, $Q^2$) from ZEUS



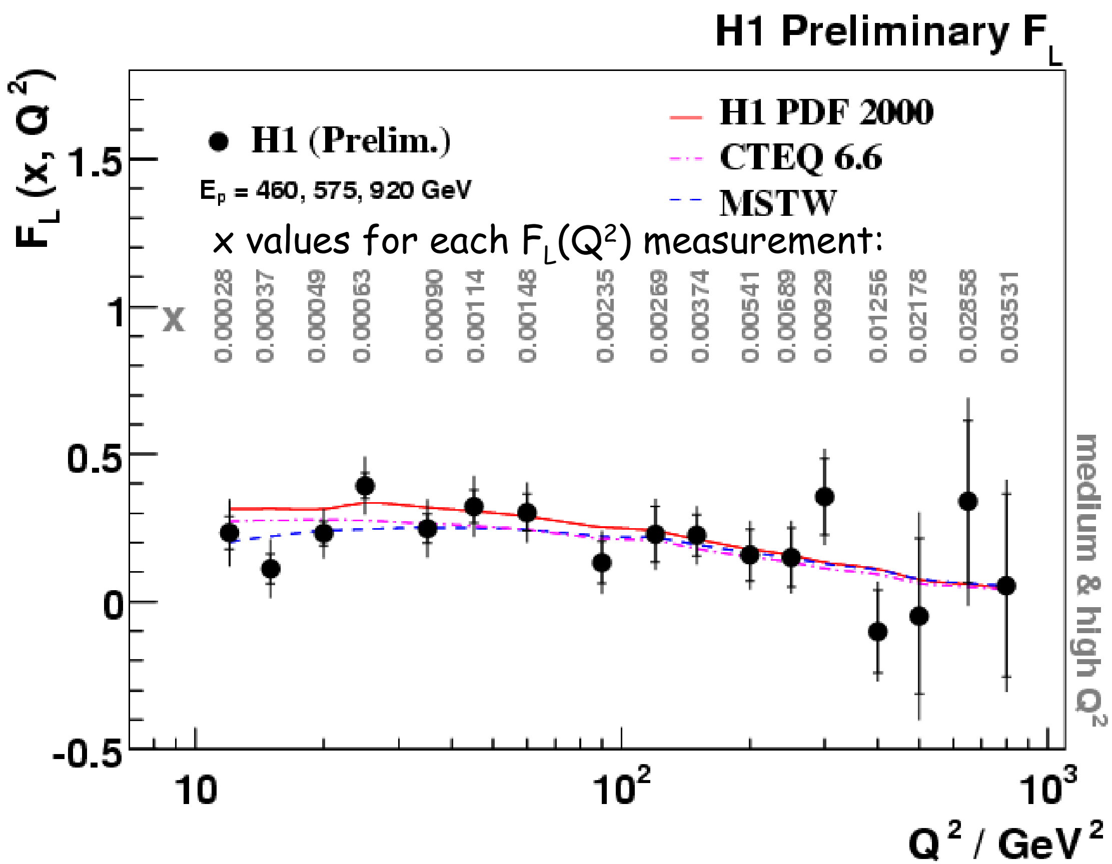

→ $F_L$ measurements are above zero and in agreement with QCD calculations

# $F_L$ (x, $Q^2$) and averaged $F_L$ ($Q^2$) from H1




individual $F_L$ are averaged in x for each $Q^2$ using total errors

→ overall correlated systematics between $F_L$ points is $\delta F_L \approx$ 0.05-0.10




→ $F_L$ measurements are in a good agreement with NLO/NNLO QCD calculations

→ **extension to $Q^2$ < 10 $GeV^2$ will provide an important constraint**

V.Chekelian, 16.12.2008

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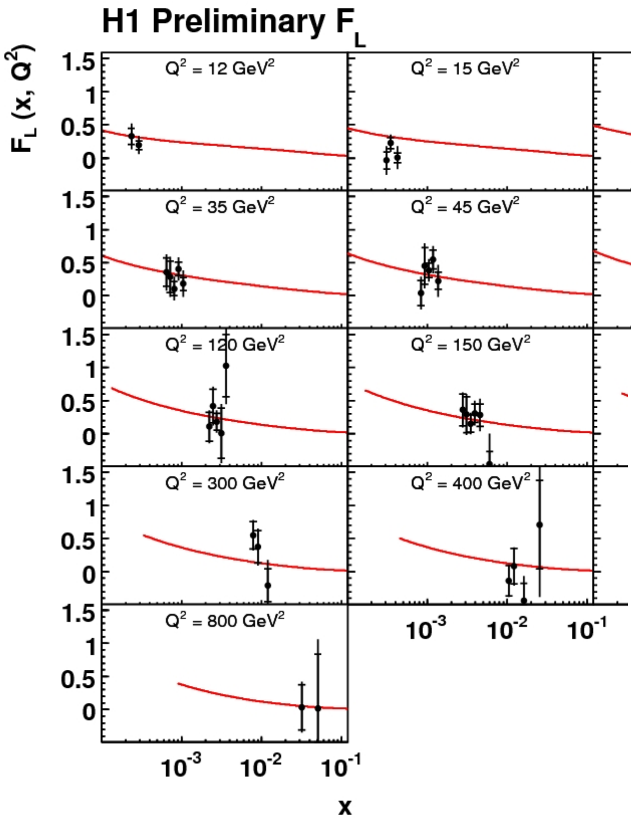


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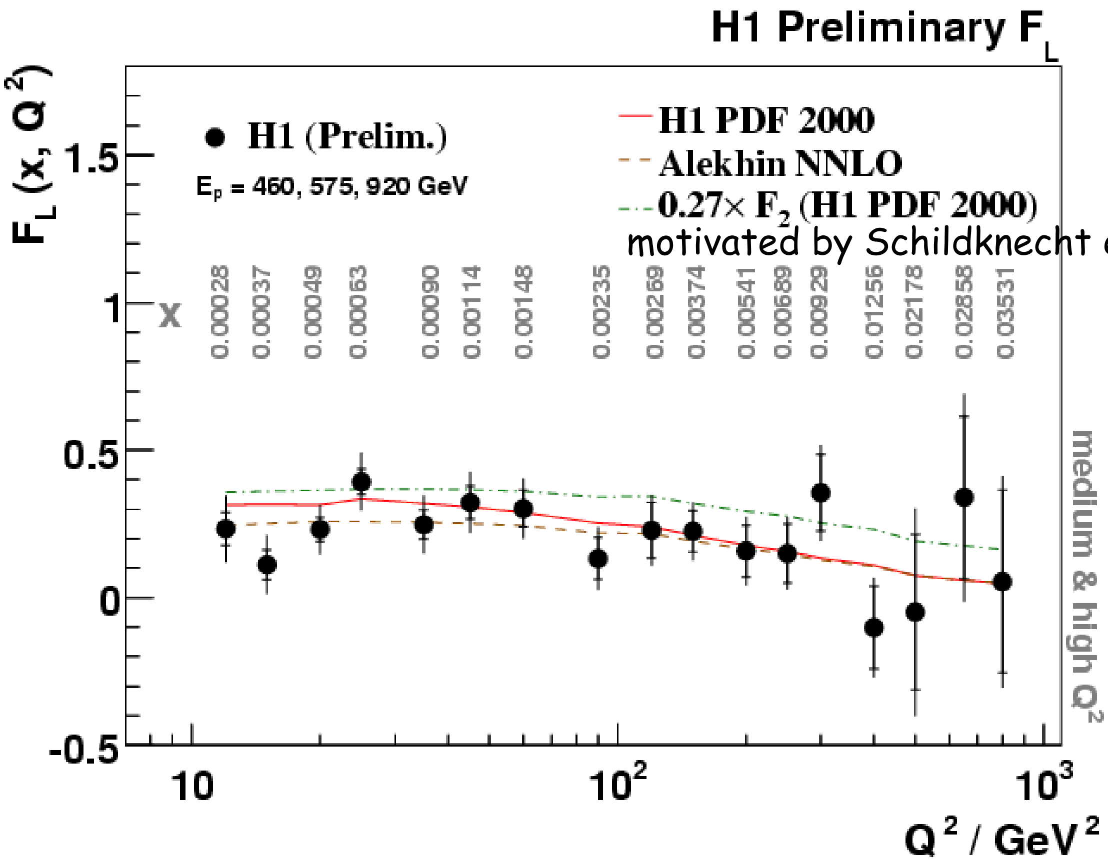


→ $F_L$ measurements are in a good agreement with NLO/NNLO QCD calculations

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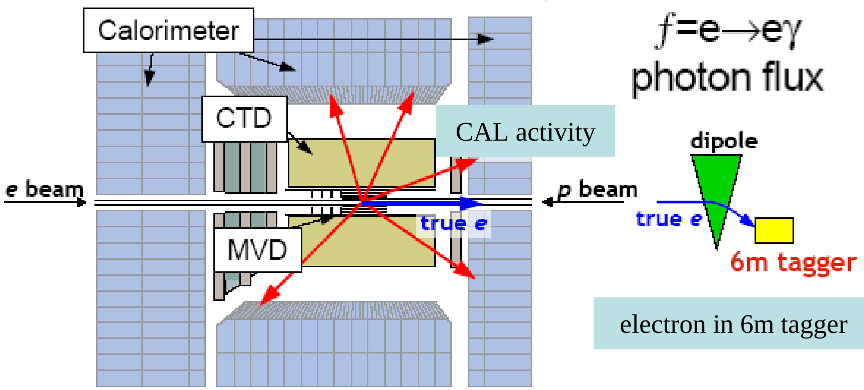
# Energy dependence of $\sigma_{tot}(\gamma p)$ (ZEUS)




**trigger:** electron in 6m tagger + CAL activity

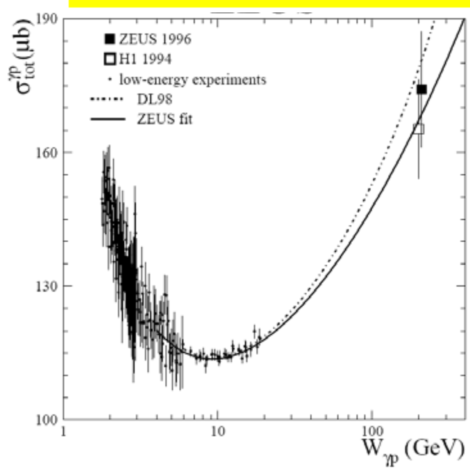
$$R = \frac{\sigma^{\gamma p}_{HER}}{\sigma^{\gamma p}_{LER}} = \frac{N^{HER}_{evt}}{N^{LER}_{evt}} \cdot \frac{L_{LER}}{L_{HER}} \cdot \frac{f_{LER}}{f_{HER}}$$

Uncertainties: $\pm 0.52\%(\text{stat.}) \pm 1.05(\text{sys.}) \pm 1\% \pm 3.5\%$

from: signal measurement LUMI tag6 (to be improved)

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

$$\sigma_{tot}(h-h) = As^{\alpha_{IP}(0)-1} + Bs^{\alpha_{IR}(0)-1}$$
$$= As^{0.0808} + Bs^{-0.4525}$$




**CAL acceptance** at different W is expected to be the same (checked with PYTHIA)

$\sigma_{tot}(\gamma p) \sim W^{2\varepsilon}$, $W^2_{Ep=920}/W^2_{Ep=460} = 2$

$$R = 1.050 \pm 0.005(\text{stat}) \pm 0.040(\text{syst})$$

$$\varepsilon = 0.070 \pm 0.007(\text{stat}) \pm 0.021(\text{syst}) \pm 0.050(6\,\text{mT})$$

consistent with high energy power obtained from pp and ppbar data: $\varepsilon$=0.08-0.096

# Charm fragmentation function (H1)

Production cross-section for inclusive process ep->H+X:

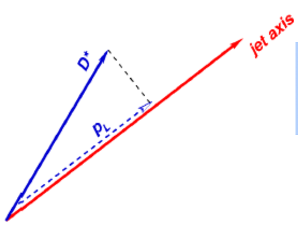
$$\sigma_H = \sum_i \sum_k f_{i/p}(x,\mu_f) \otimes \hat{\sigma}_{i\gamma\to kX}(\alpha_s(\mu_r),\mu_r,\mu_f) \otimes D_k^H(z,\mu_f)$$

***Parton Density Function*** — ***Hard Scattering (perturbative)*** — ***Fragmentation Function***

Peterson parameterisation:

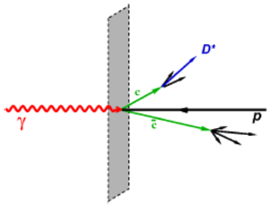
$$D_Q^H(z) \propto \frac{1}{z[1-(1/z)-\varepsilon/(1-z)]^2}$$

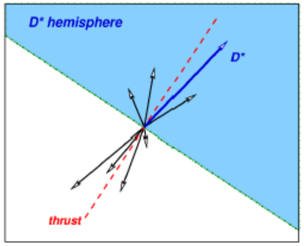
**Understanding of the charm fragmentation is crucial for high precision measurements in charm sector at HERA**

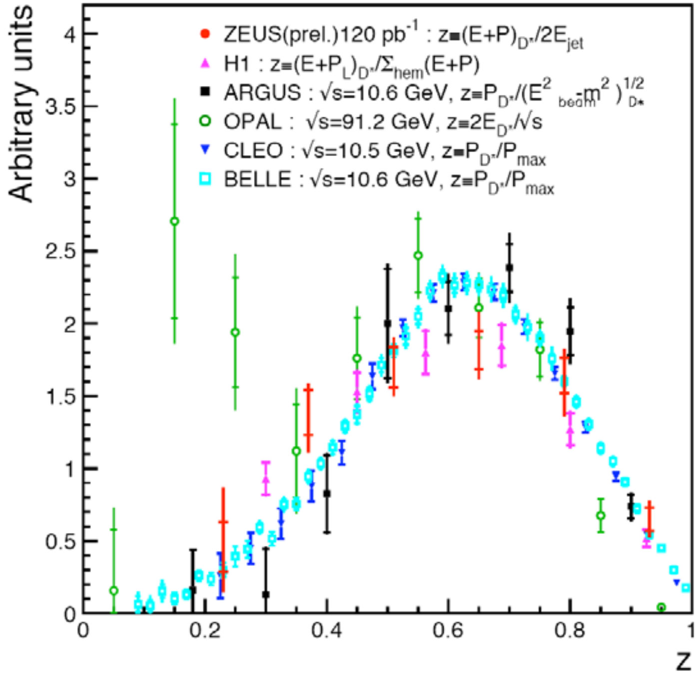



$$z_{jet} = \frac{(E+p_L)_{D^*}}{(E+p)_{jet}}$$

$$z_{hem} = \frac{(E+p_L)_{D^*}}{\sum_{hem}(E+p)_i}$$




universality of fragmentation function

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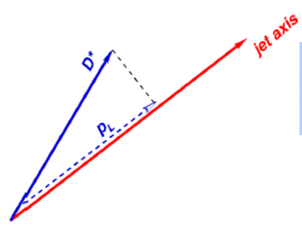


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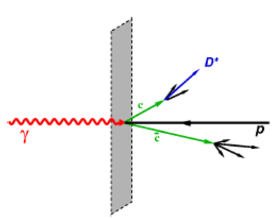
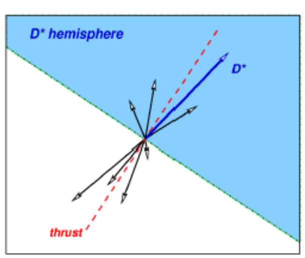
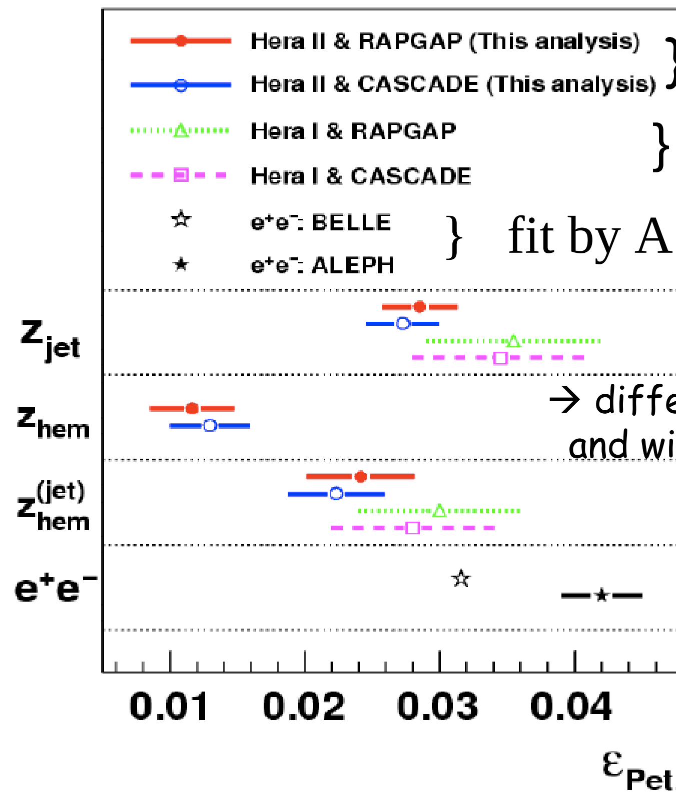



**Results: Summary for $\varepsilon_{Pet.}$**




} A. Liptaj theses

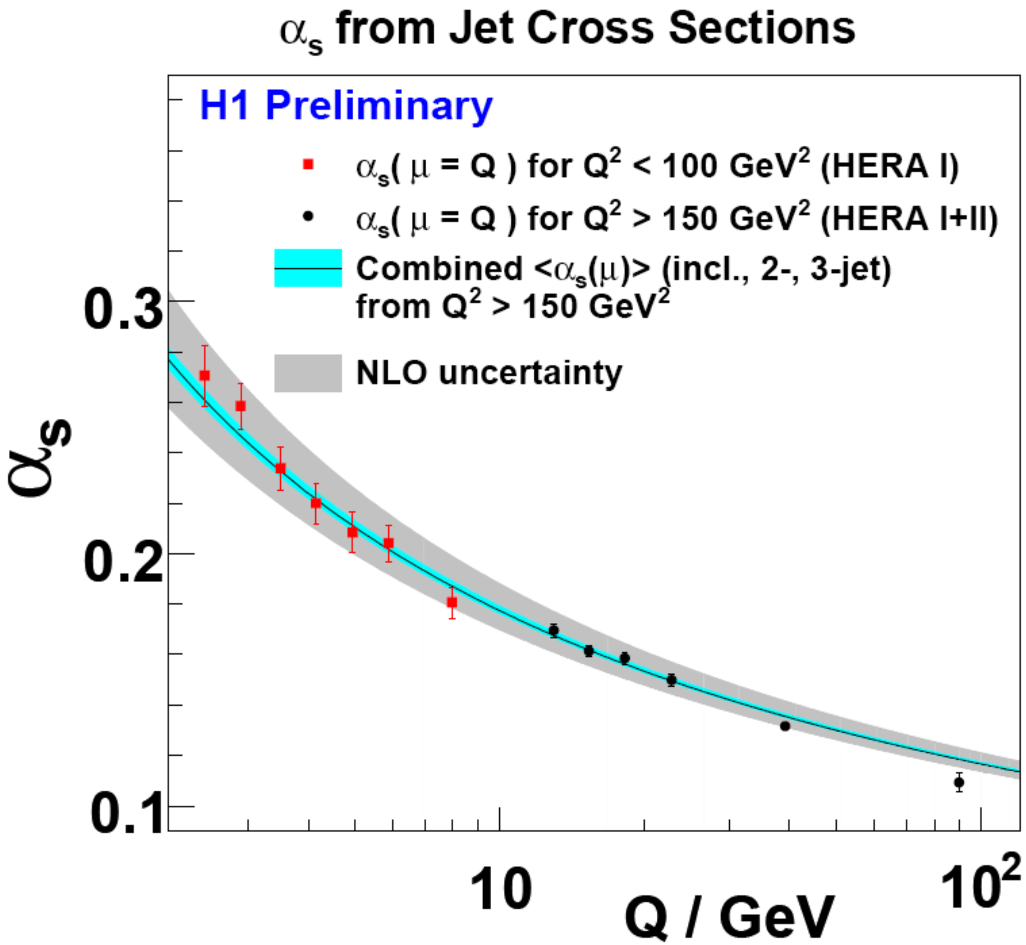
} H1 publication

} fit by A.Liptaj (PYTHIA)

→ difference for events with and without identified jets

→ in agreement with $e^+e^-$ Belle

# Normalised jets cross section and $\alpha_s$ (H1)




normalised cross sections

$$\frac{\sigma_{1JET}}{\sigma_{DIS}}, \frac{\sigma_{2JET}}{\sigma_{DIS}}, \frac{\sigma_{3JET}}{\sigma_{DIS}}$$

HERA I+II :

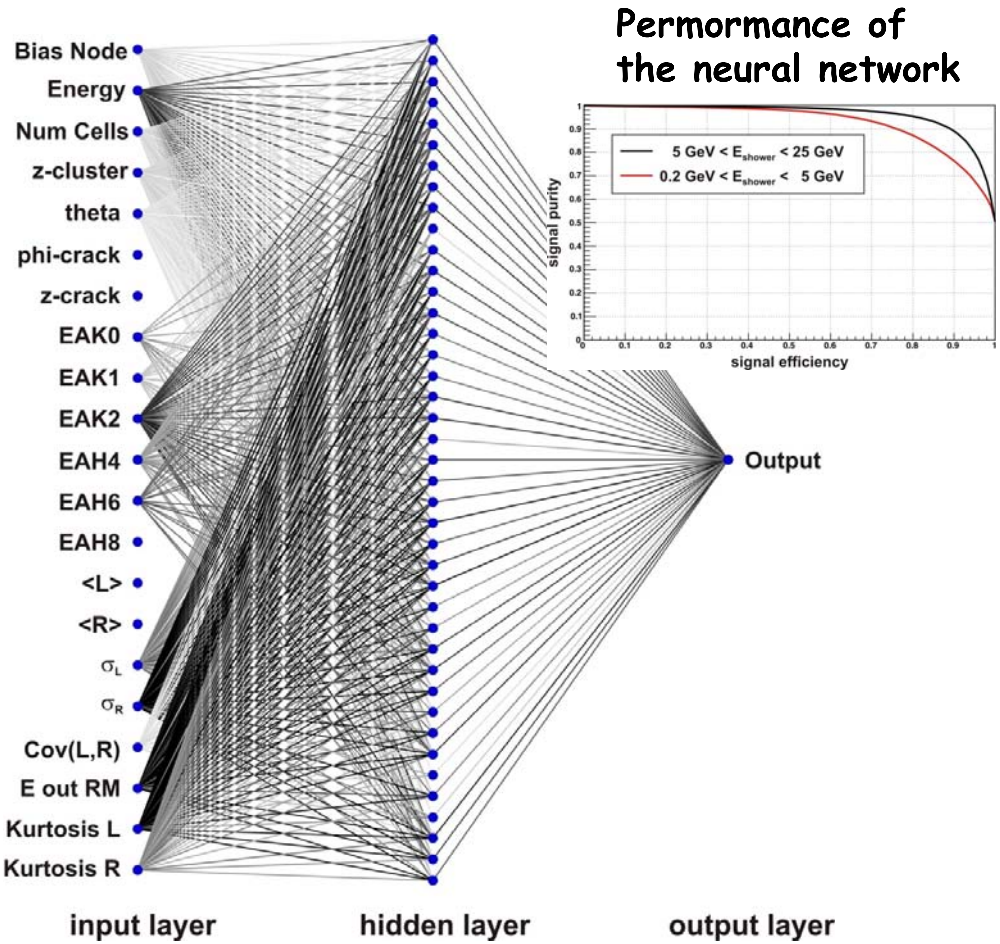
6 times more statistics w.r.t. HERA I
improved hadronic energy scale 2% → 1.5%

at NLO

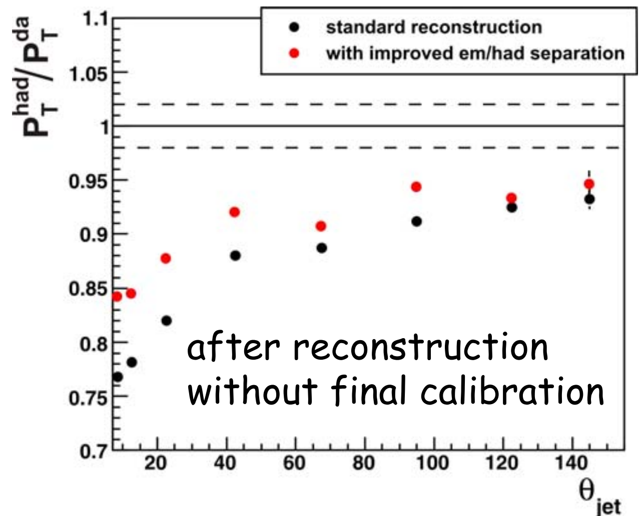
$$\alpha_s(M_Z^2) = 0.1182 \pm 0.0008(\text{exp}) \, {}^{+0.0041}_{-0.0031}(\text{scale}) \pm 0.0018(\text{pdf})$$

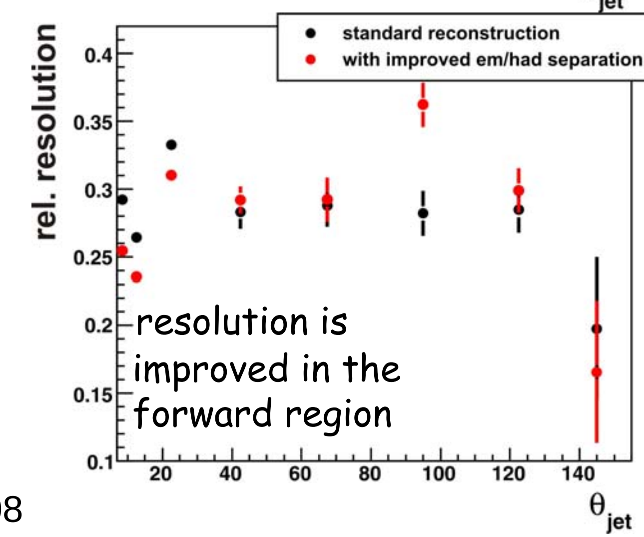
next goals :
- also absolute jet cross section
- common binning with ZEUS
- improvement of jet energy scale

# Improvement of jet energy measurement by identification of em clusters using neural network




DIS $Q^2 > 100$ GeV$^2$ with jets



# Outlook

H1

- Inclusive DIS cross section and SF ($F_2$, $xF_3$, $F_L$)
- Inclusive jets cross section in DIS and photoproduction
- Combination of the final H1 & ZEUS inclusive (and jets) data
- QCD fits (NLO/NNLO) of inclusive (and jets) data

ZEUS

- NC cross section at high x
- Longitudinal structure function $F_L$ (extention to low and high $Q^2$)
- $\gamma p$ total cross section

- ZEUS Physics Coordination by I. Abt till summer 2009