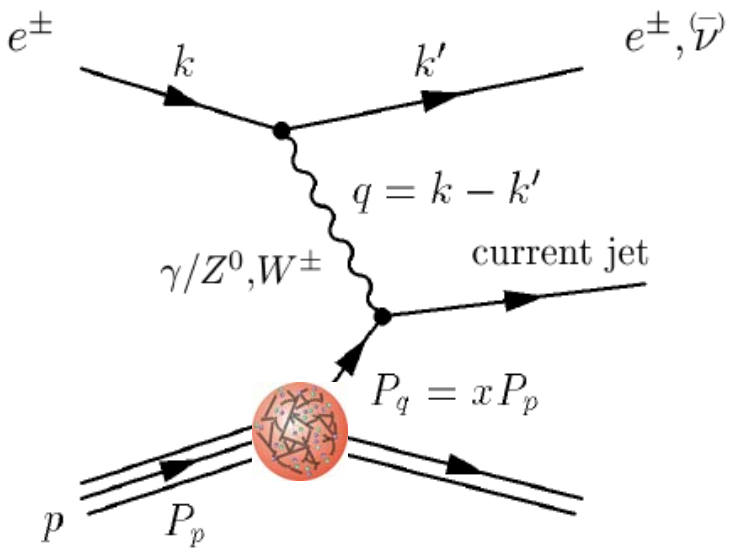
ZEUS high-y cross section measurement and preparation for low energy running

Shima Shimizu
(University of Tokyo)
on behalf of ZEUS collaboration

Deep Inelastic Scattering



- DIS cross section can be described by
  - Q^2: Virtuality → probing power
  - x : Bjorken scaling variable
    - → momentum fraction of struck quark
  - y : Inelasticity

$$Q^2 = -q^2 = -(k - k')^2 \qquad x = \frac{Q^2}{2p \cdot q} \qquad y = \frac{p \cdot q}{p \cdot k}$$

$$Q^2 = sxy$$

$\sqrt{s}$ = center of mass energy

- DIS cross section can be written with structure functions.

$$\frac{d^2\sigma}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4}(1+(1-y)^2)\left[F_2(x,Q^2) - \frac{y^2}{Y_+}F_L(x,Q^2)\right]$$

Low Q^2

$\tilde{\sigma}$: Reduced cross section ← what we measure

Structure functions; F_2, F_L

F_2 ⟶ Total number of quarks.

$$F_2 = \sum A_q x(q + \bar{q})$$

F_L ⟶ Direct sensitivity to gluon dynamics.

$$F_L = \frac{\alpha_s}{4\pi} x^2 \int_x^1 \frac{dz}{z^3} \left[\frac{16}{3} F_2 + 8 \sum_q e_q^2 \left(1 - \frac{x}{z} \right) z g(z) \right]$$

$\tilde{\sigma}$ measurement so far;

- Sensitive to F_2.
  - Extraction of sum of quark PDFs.
  - Gluon PDF extraction from scaling violation of F_2

$$\frac{\partial F_2}{\partial \ln Q^2} \propto xg$$

- F_L is sizable only at high-y → rely on theory assumption

Motivation for high-y at HERA

- HERA: World's only e-p collider
  Up to Mar/2007 with;

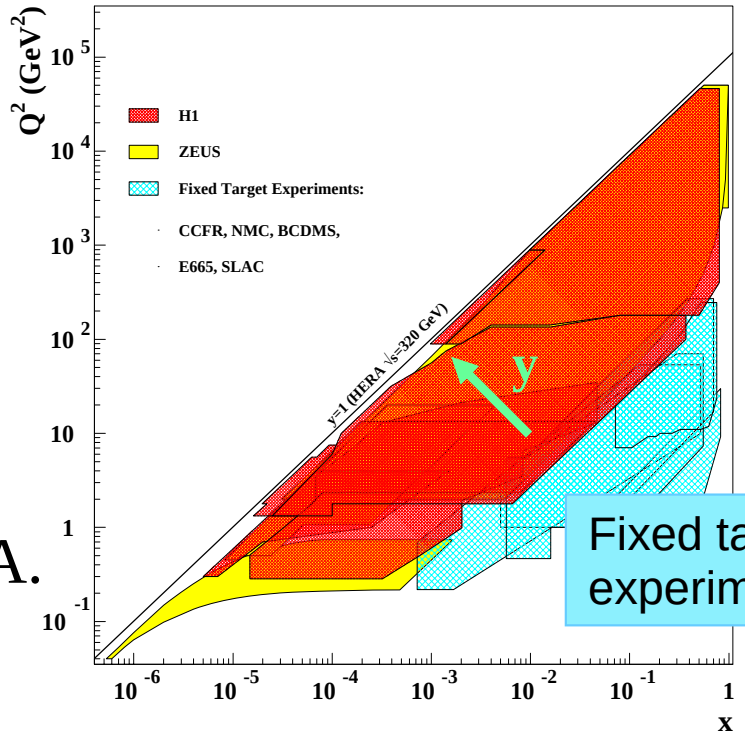
  p 920 GeV

  e^+/e^- 27.5 GeV

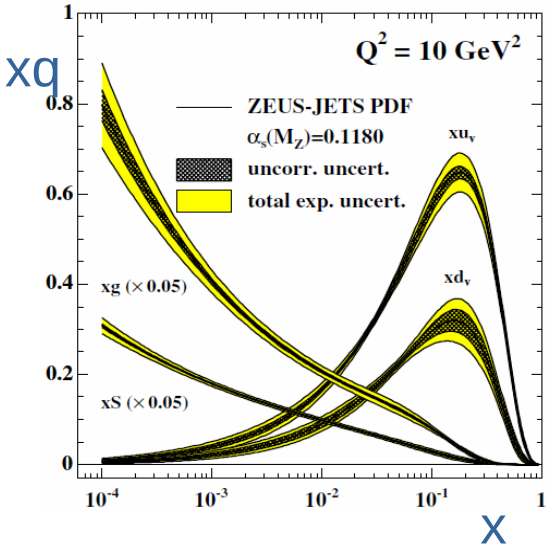
  $\longrightarrow \sqrt{s} = 318\,\mathrm{GeV}$

- Low-x physics can be accessed by HERA.
  Sea quarks and gluons are dominant.
  ← Determined by HERA
- High-y = lowest x
  - Sizeable F_L with gluon dominance

  ➔ Dynamics of gluons.
  Good test of our current understanding of proton structure.



Fixed target experiments



ZEUS New measurement @ high-y

ZEUS performed a new DIS measurement which is optimized for high-y.

- Previous measurement: 1996-97 data (HERA-I).
- New trigger was developed.

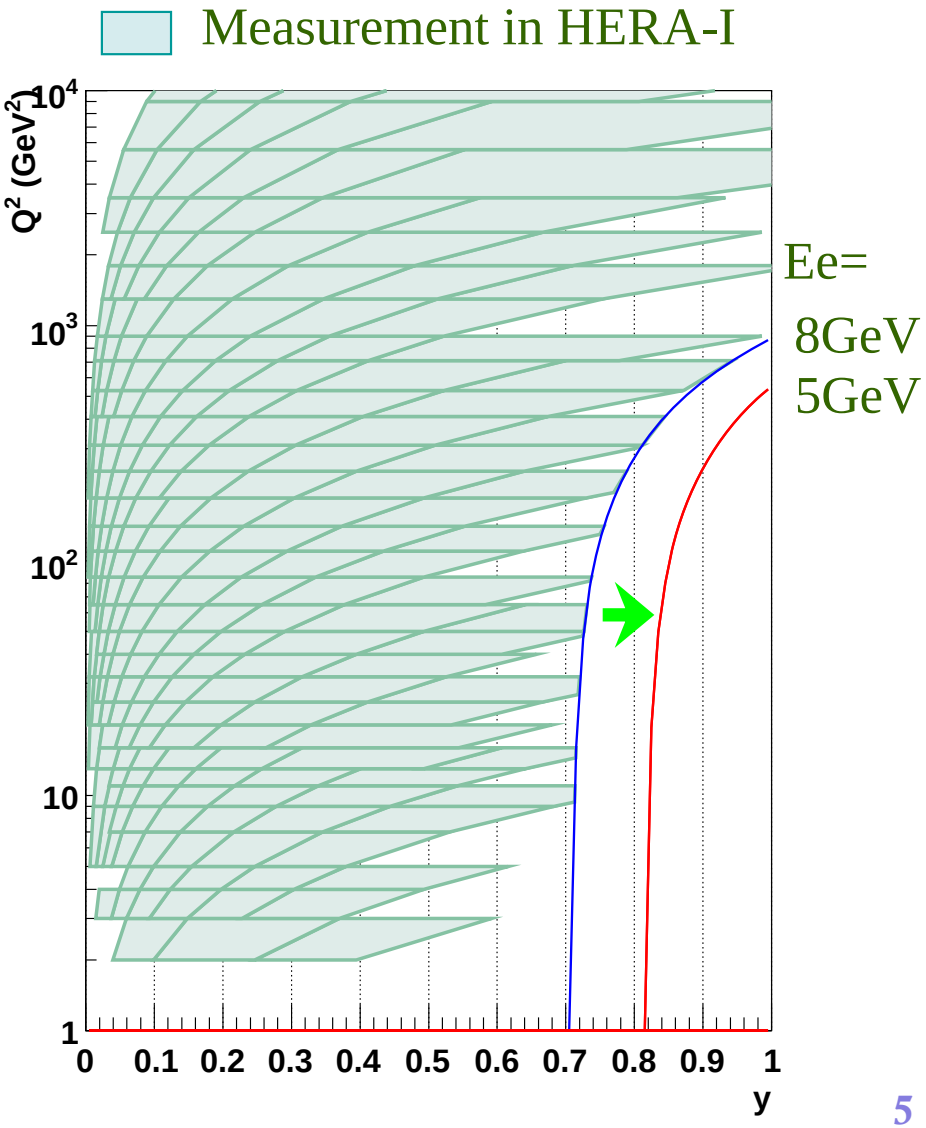
  → It allows to go to lower electron energy.

  8GeV → 5GeV

  New kinematic region at high-y

- High-y = Low Ee;
  - Ee should be well understood.
  - Severe background contamination.

  The same analysis method can be also used in F_L measurement.



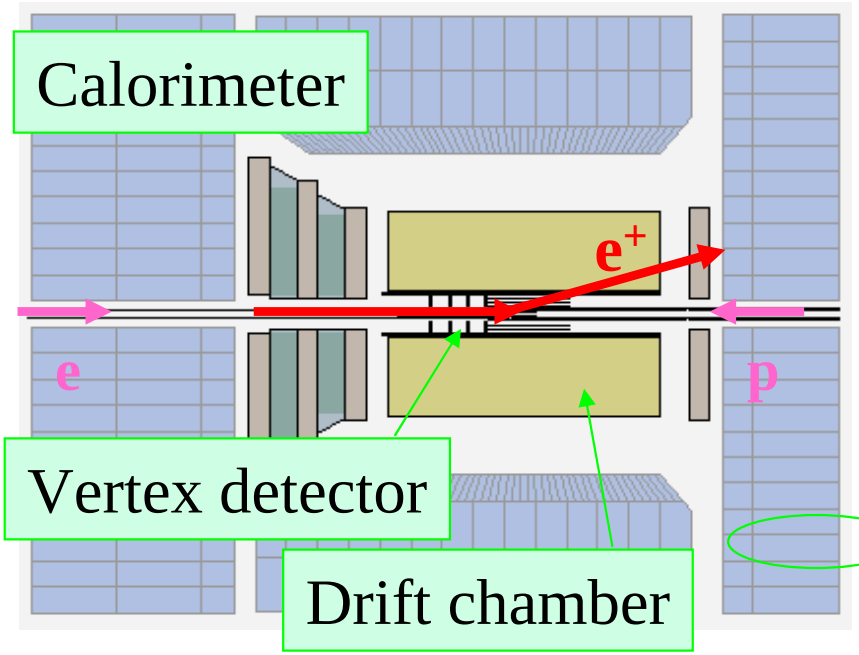
Data Selection

- Special trigger for high-y (since summer 2006)
  - Two independent logics.
    - Electron finding filter (Ee>4GeV)
    - Σ(E-pz) inclusive filter

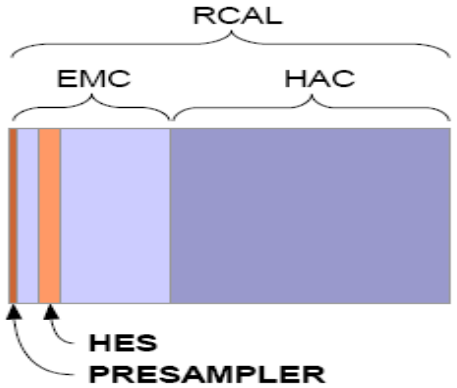
      In DIS;
      Σ(E-pz) ~2*Electron beam energy

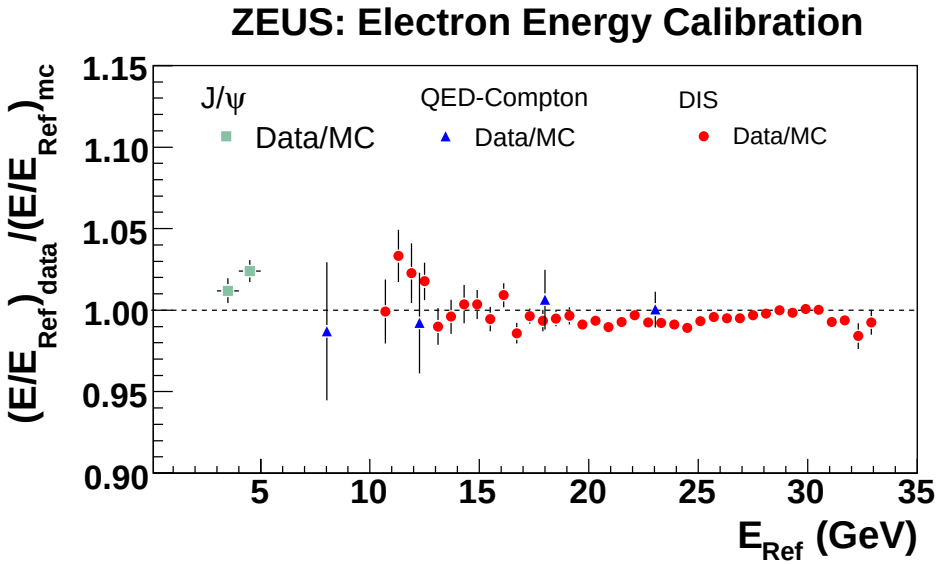
    → Cross check can be done for each other.
- Offline selection
  - Electron candidate with Ee>5GeV
    - With track requirement for θ e>~151^o
  - Σ(E-pz)>38GeV
  - Radius on RCAL > 28cm (θ e>~170^o)

Electron reconstruction in ZEUS detector



- Electrons are reconstructed based on calorimeter, together with
  - HES（silicon pad）
  - Presampler（scintillator tile）





- Electron energy scale and dead material correction is well understood with;
  - J/ψ
  - QED compton
  - DIS

→ Ee scale uncertainty: +-2%

Background estimation

Main background : Photoproduction (PHP) events.

- Electron goes through beampipe but hadron is misidentified as electron.

  → Mis-reconstruction of the event as DIS.

  Severe at high-y region (=low Ee).

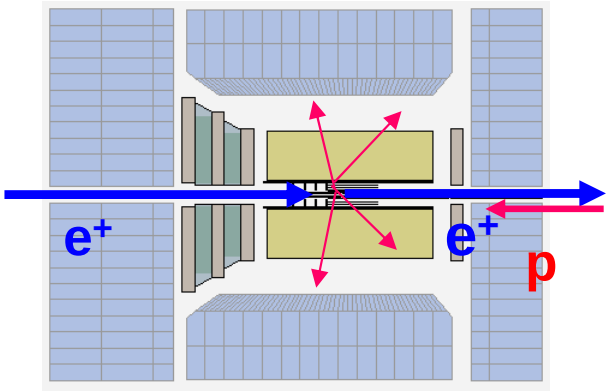
- Good understanding is needed.

  Two analyses were done; (→ See next slides)

  – 6m tagged sample

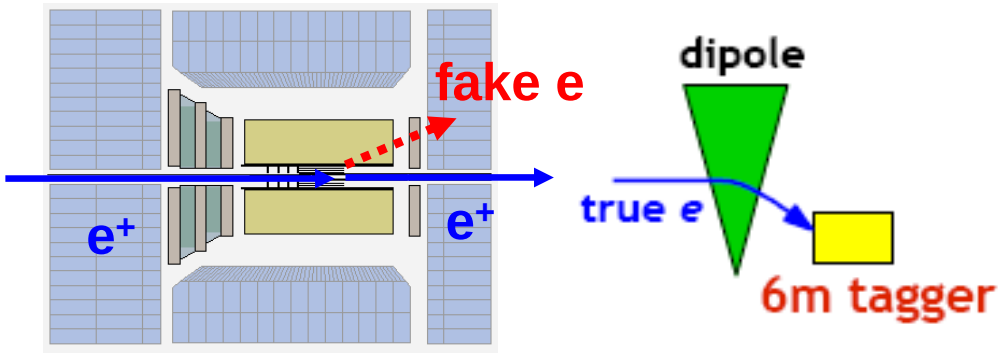
  – PHP enriched sample

  → cross check of 6m tagged sample.

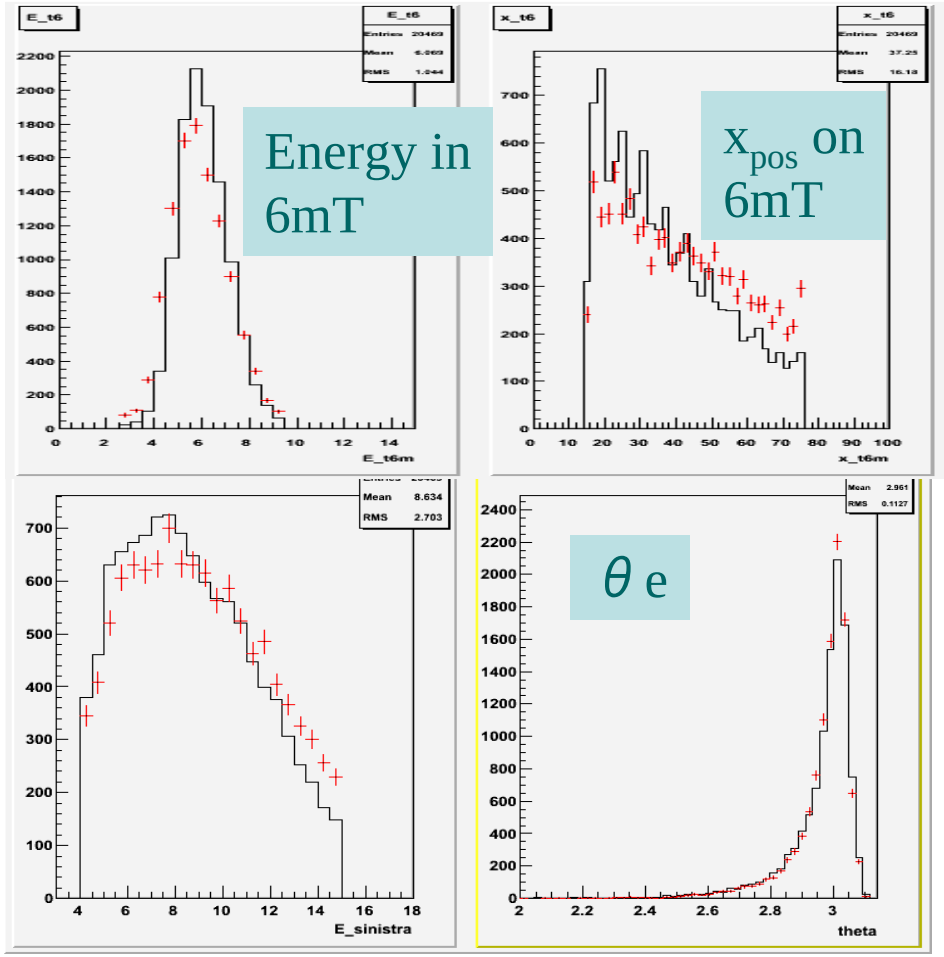


6m tagged sample

- 6m tagger located downstream of electron beam.
- Direct detection of PHP events with good acceptance.



Energy of misidentified electron in CAL



- Not perfect, but reasonable description of distribution shape by PHP MC.

\+ data
– PHP MC (PYTHIA)

Normalized by Nevents

PHP enriched sample - cross check

- Trigger without electron finding → PHP events are also taken.
  - Sample with clear electron candidate : DIS sample
  - Sample with unclear electron candidate: PHP enriched sample

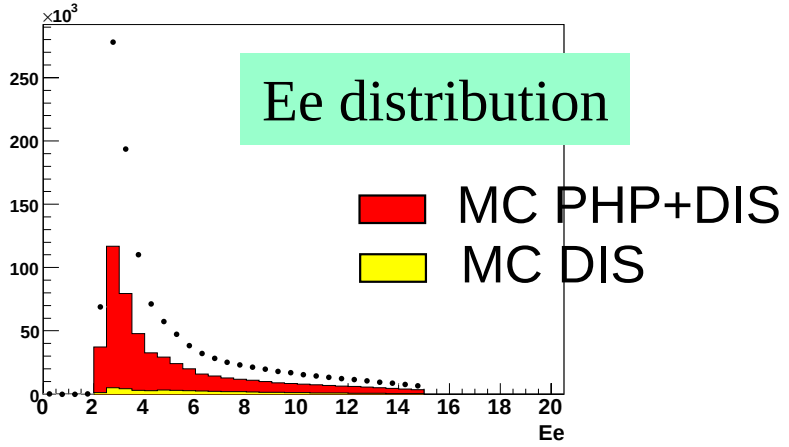
- The difference between data and MC shows scaled behaviour of PHP MC.

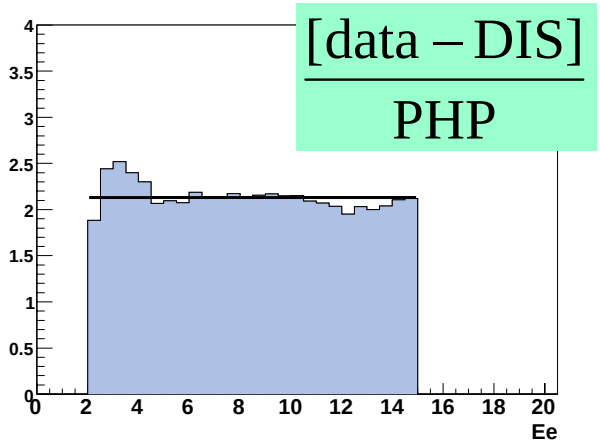
PHP MC is normalized by a factor.

- 6m tagged sample
- PHP enriched sample

⟶ Factors agree within 5%

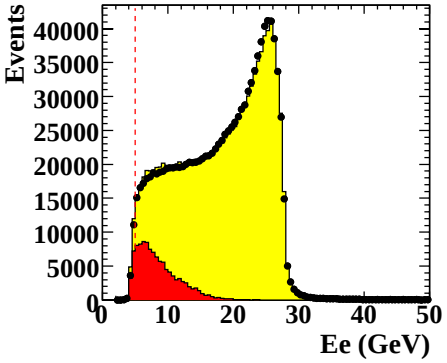
Considering imperfection of the description of MC, we assign 10% uncertainty on the factor.

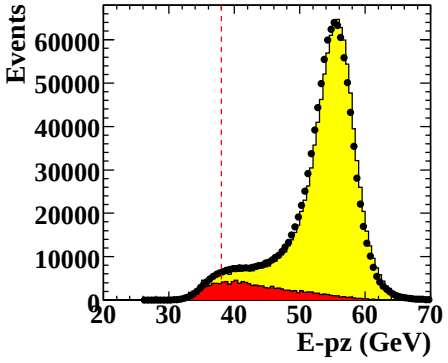


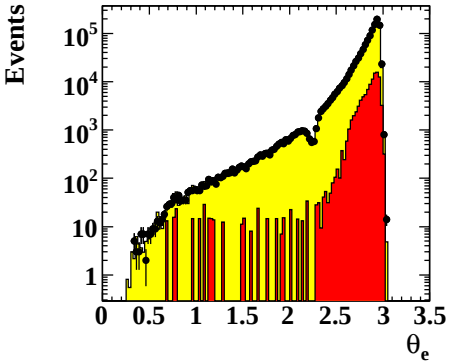


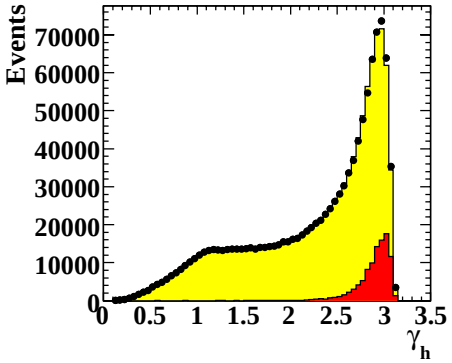
Control plots for high-y analysis

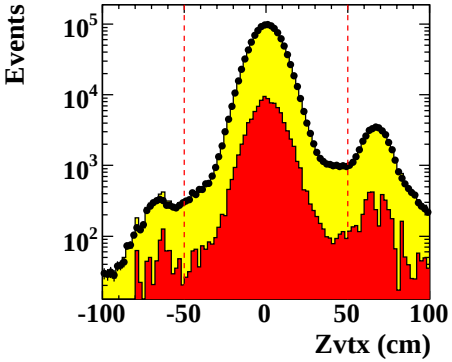
ZEUS





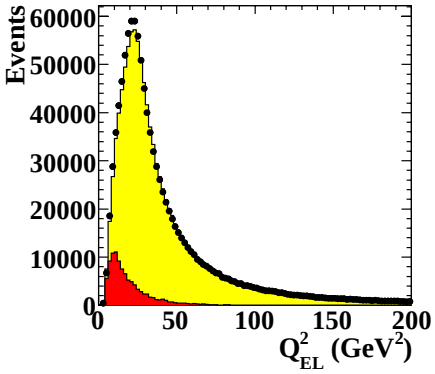


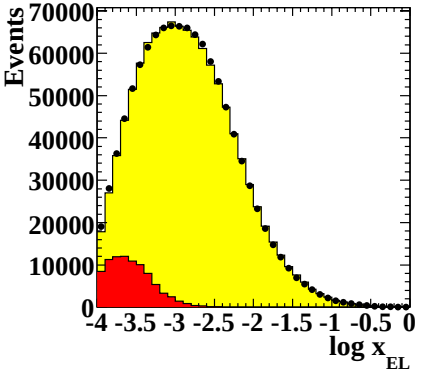


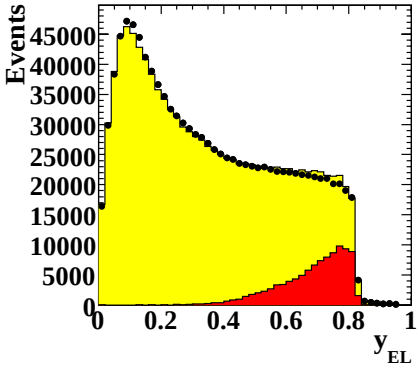


- ZEUS (prel.)
  06e+p (29pb-1)
  MC DIS+γp
  MC γp

ZEUS







- ZEUS (prel.)
  06e+p (29pb-1)
  MC DIS+γp
  MC γp

e+p data from 2006: L=29.4 pb^{-1}

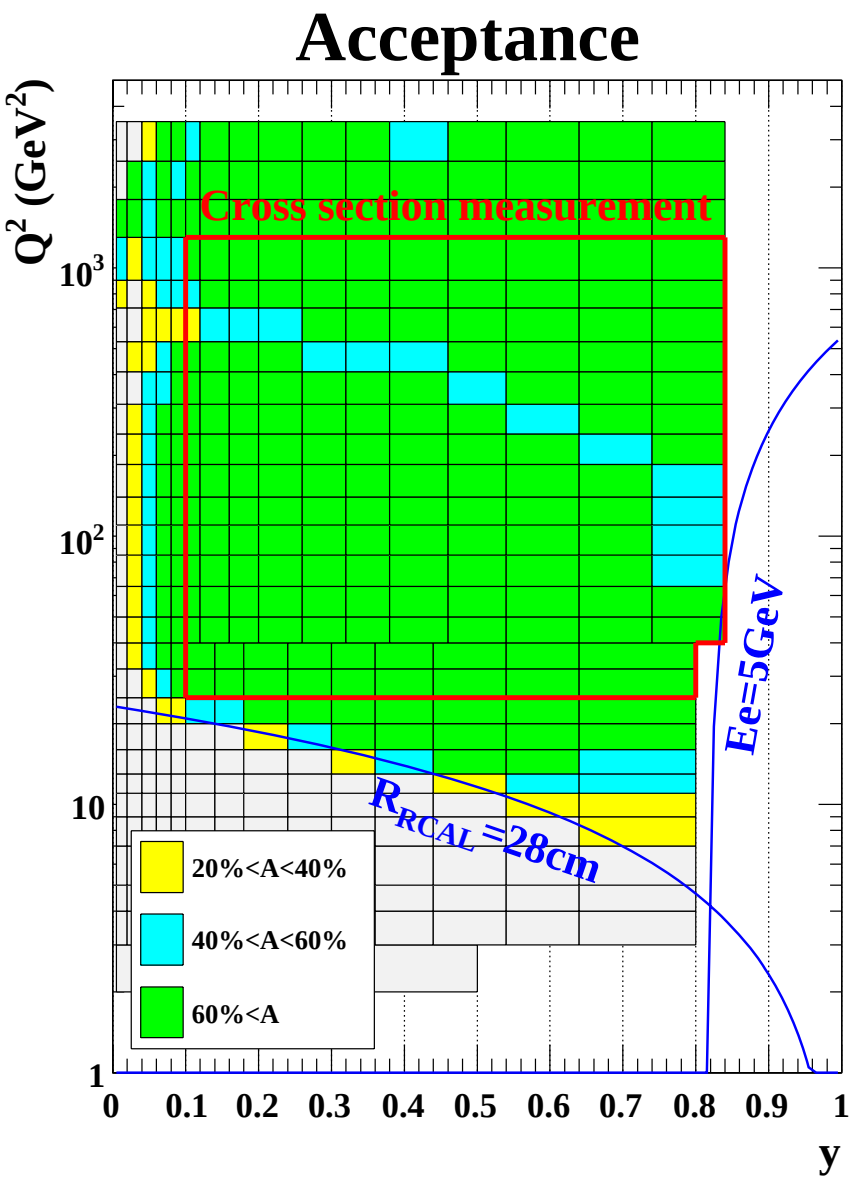
MC describes data well.

Cross section measurement

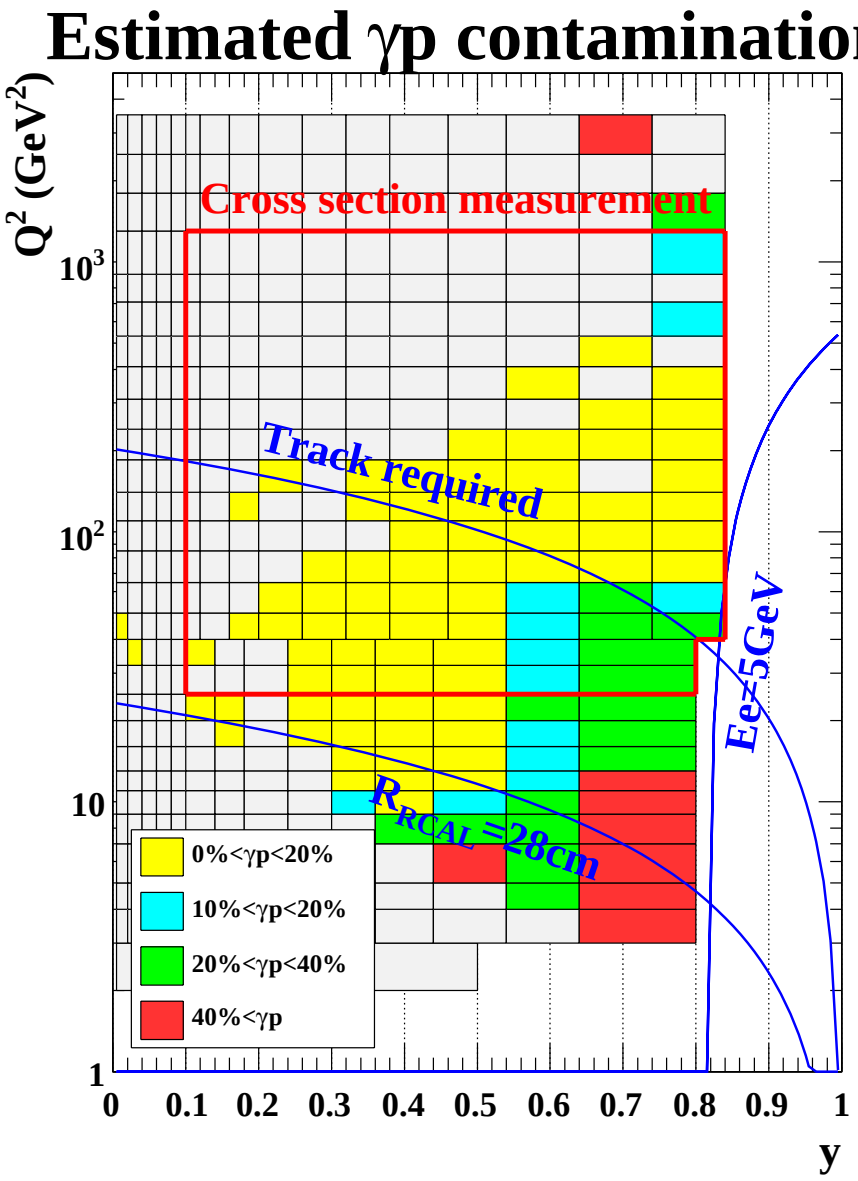
- Kinematic reconstruction is done by Ee, θ_e.
  (Electron method)
  Good resolution at high-y region.

- Bins are defined in (y,Q^2) plane.
  → Good coverage of high-y region.

- Most of bins have acceptance above 60%.
  → Good acceptance for overall region of cross section measurement.

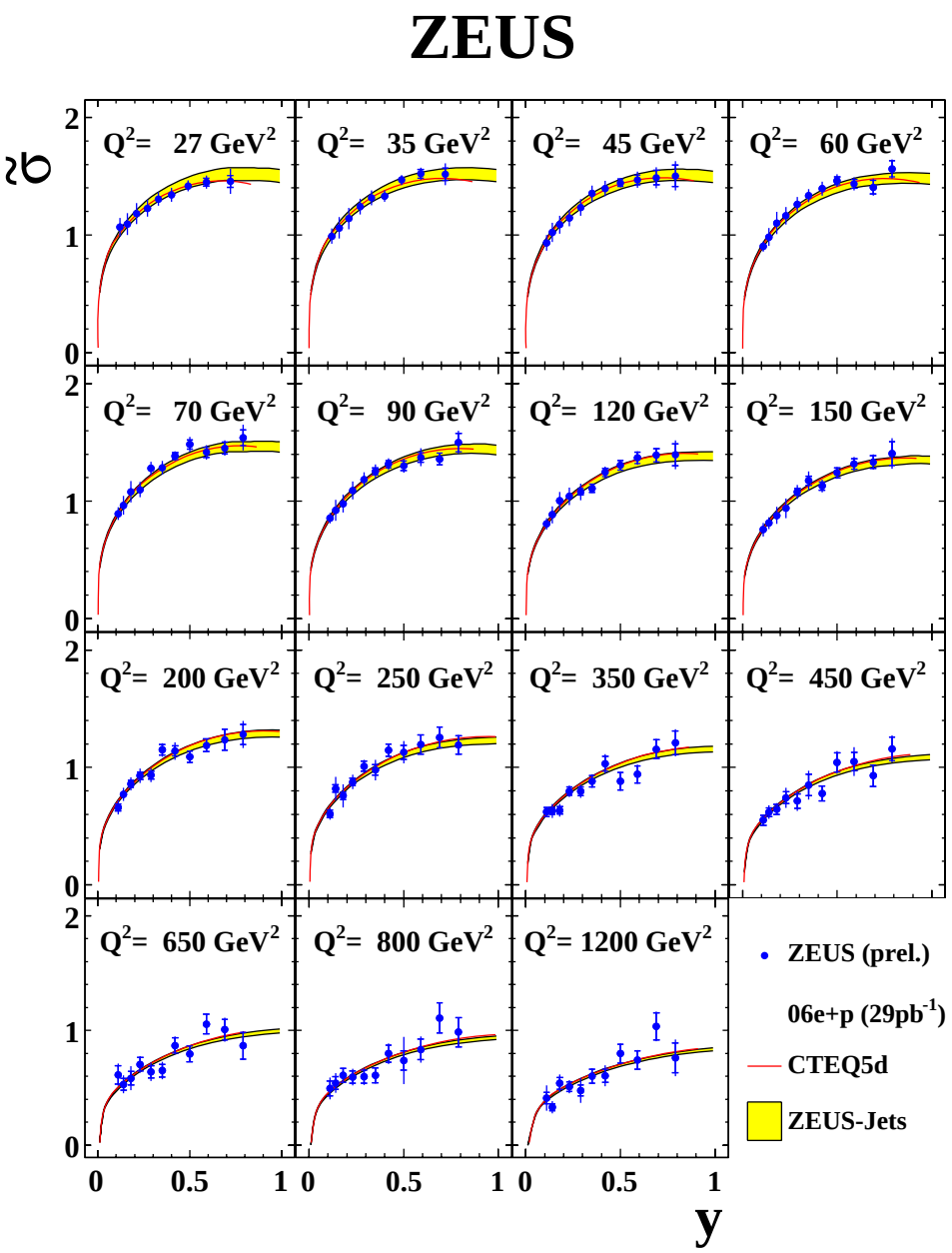


Background contamination



- Estimated PHP contamination is less than 40% in cross section measurement.

Reduced cross section



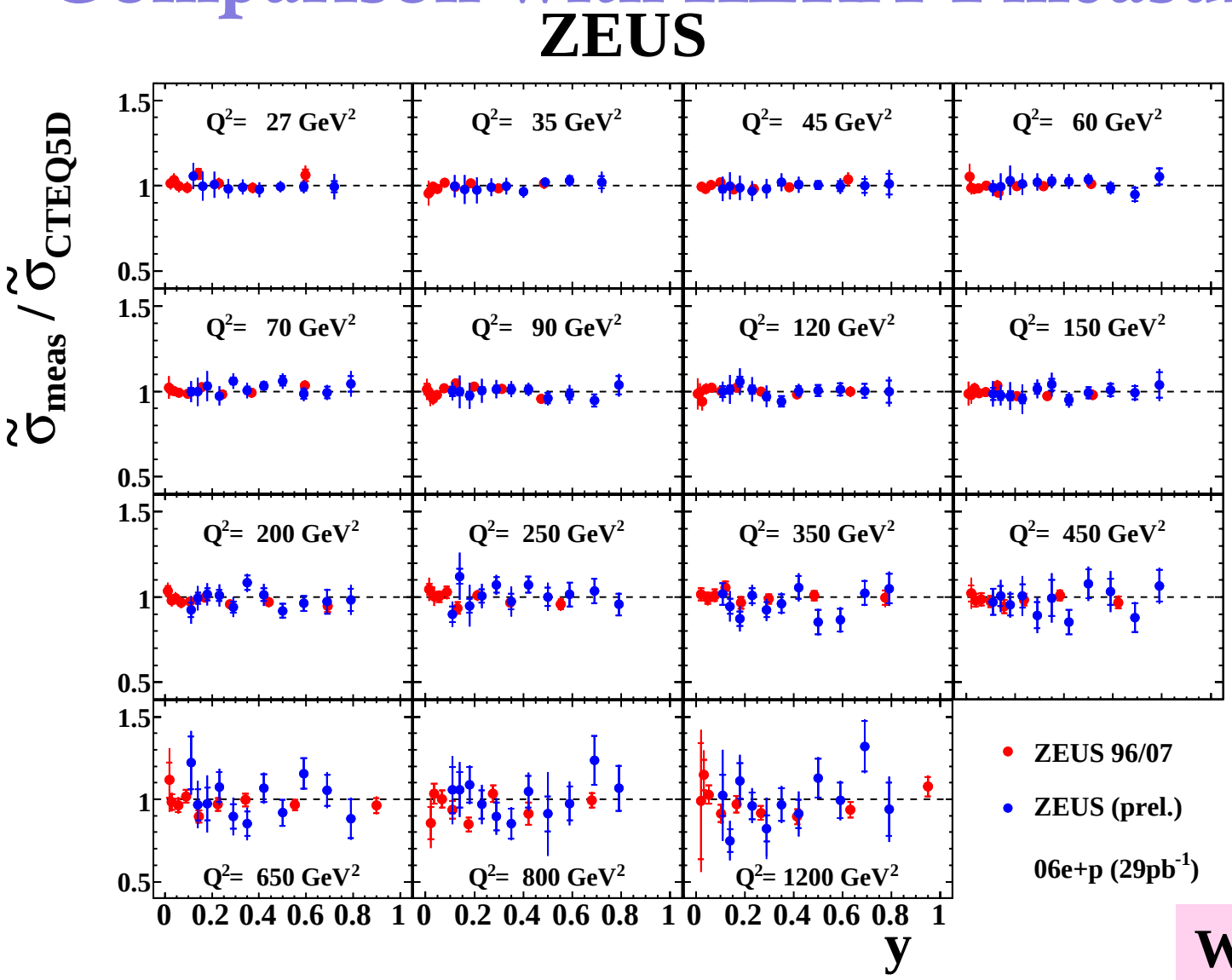
- Measured reduced cross sections are compared to SM predictions with
  - CTEQ5D
  - ZEUS-Jets PDF

  → They are well described by the predictions.

- Systematic checks

• Electron energy scale	2%
• PHP norm. factor	10%
• Electron finding inefficiency	10%
• E-pz threshold	2GeV

Comparison with HERA-I measurement



- Measurement is extended to high-y region especially at low Q^2 compared to HERA-I.

We have succeeded to extend the measurement to high-y.

Low Energy Running

- HERA has finished ‘usual’ operation (HER) on 21/Mar/2007
- Since then, HERA started to deliver luminosity with lowered proton beam energy (LER) successfully. *Congratulations to HERA!*

  26/Mar → 2/Jul: 3 months of LER operation.

- Main issue in LER: F_L

$$\tilde{\sigma} = F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2)$$

  Cross sections with same (x,Q^2) but different y, i.e. Different centre of mass energy

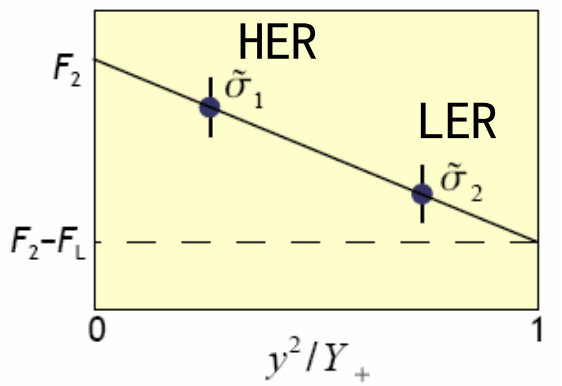
  → Direct separation of F_L from F_2 . w/o theory assumption

- F_L at low-x : legacy of HERA

Preparation in ZEUS

- Feasibility study for F_L measurement is done.
  → See talk at DIS06 given by D.Kollar.
- High-y measurement

$$\tilde{\sigma} = F_2(x,Q^2) - \frac{y^2}{Y_+} F_L(x,Q^2)$$



Higher y in LER
↓
Larger difference of y^2/Y_+
↓
Better F_L precision

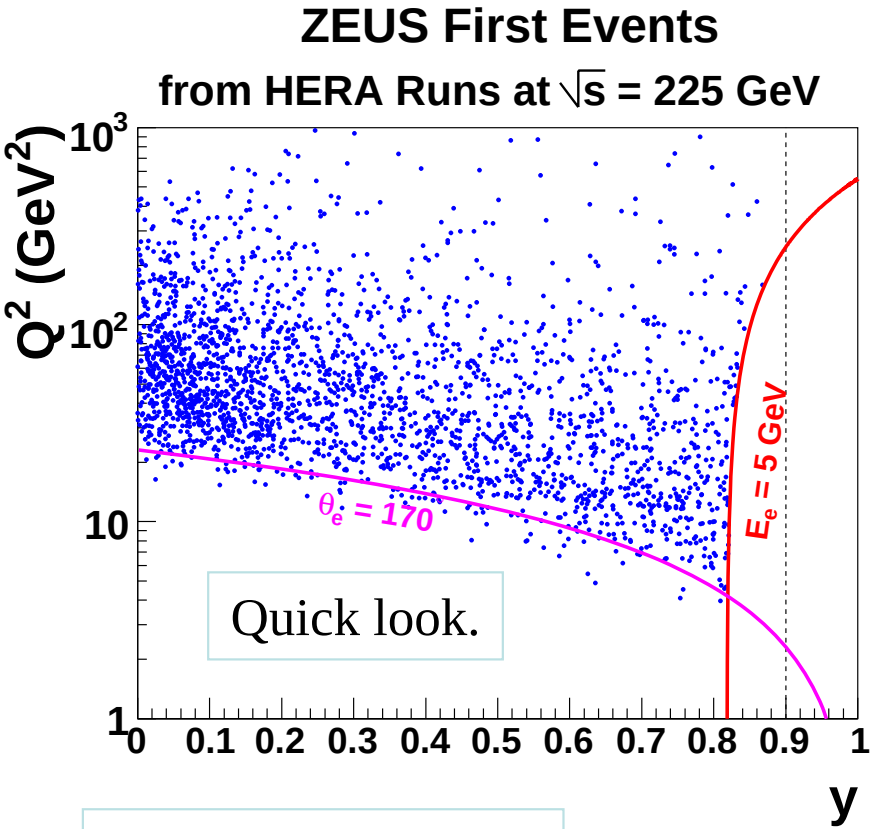
DIS measurement is already extended to high-y region.
→ We can measure high-y region also in LER.

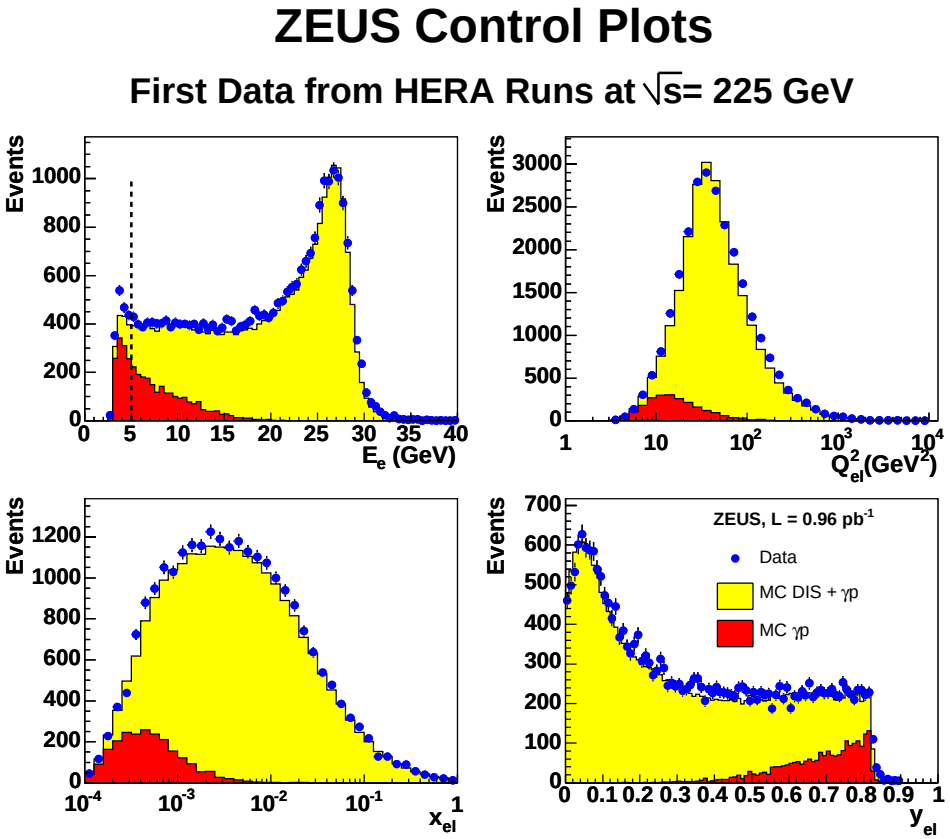
- Trigger
  - Inclusive E-pz: No electron finding done online.
- Detectors are in good condition.

ZEUS first look at LER data

- ZEUS is collecting LER data with good efficiency.
- Quick look at the first week of LER data taking (~1pb^{-1});

  → Good data quality.





We will enlarge the measurement region.

LER has just started with good condition!

Summary

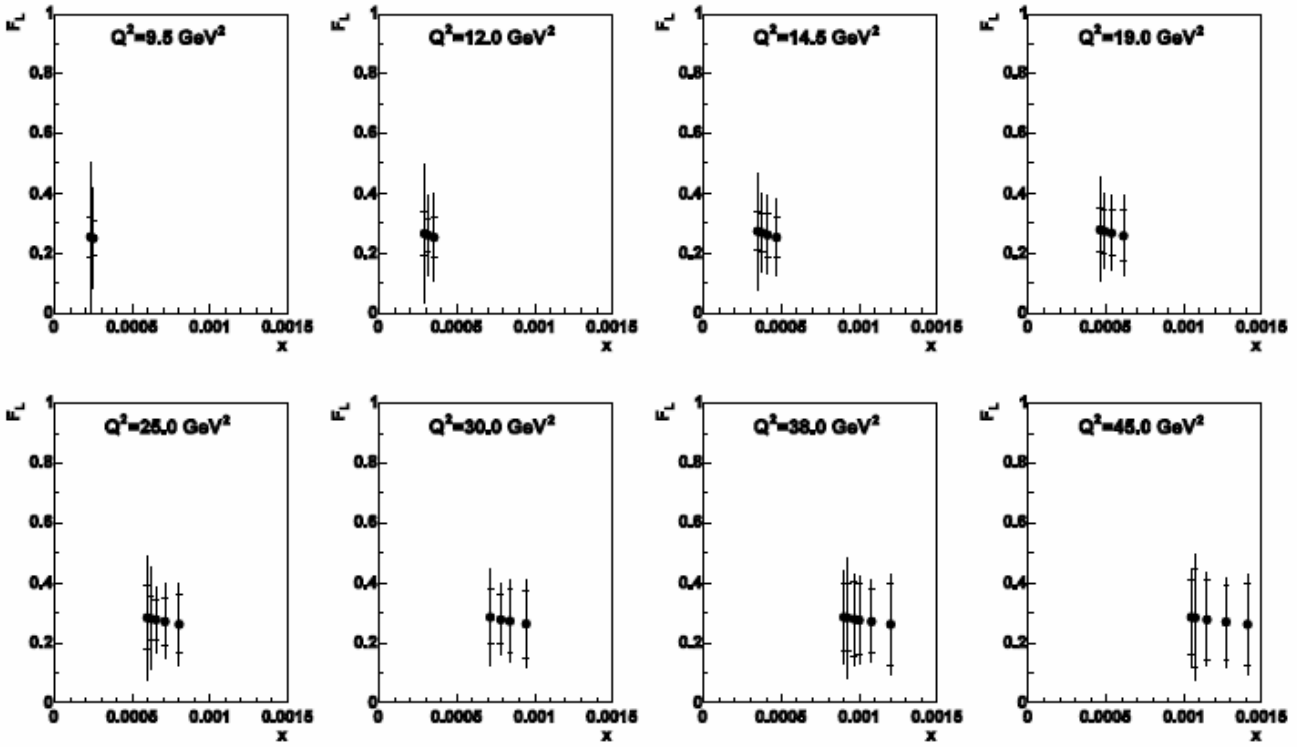
- DIS cross section is measured in the high-y region.
  - New trigger allows us to go to lower electron energy.
    - 2006 positron data: $L=29.4pb^{-1}$
  - Measurement is successfully extended to higher y compared to HERA-I result.
  - Measured cross sections are in good agreement with SM prediction. (CTEQ5d, ZEUS-Jets)
- We aim for a direct measurement of F_L.
  - HERA has started to deliver LER luminosity successfully.
  - ZEUS has started to collect data with good efficiency and good data quality.

Backups

Feasibility study using MC

Low Q^2: small stat., big syst.

Note: F_L values set to 0.2 F_2



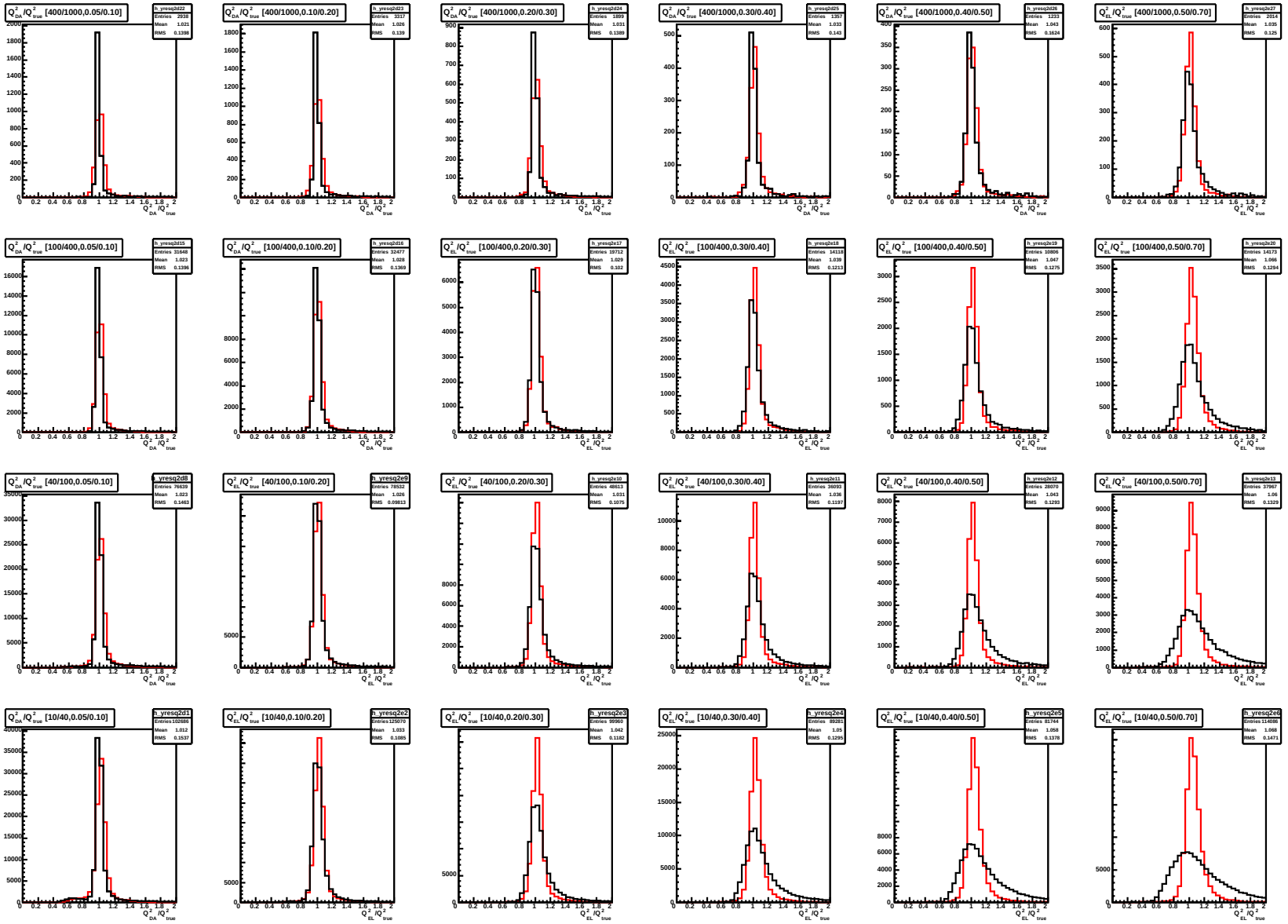
Largest systematics from:
PhP background normalization and EF inefficiency

High Q^2: big stat., small syst.

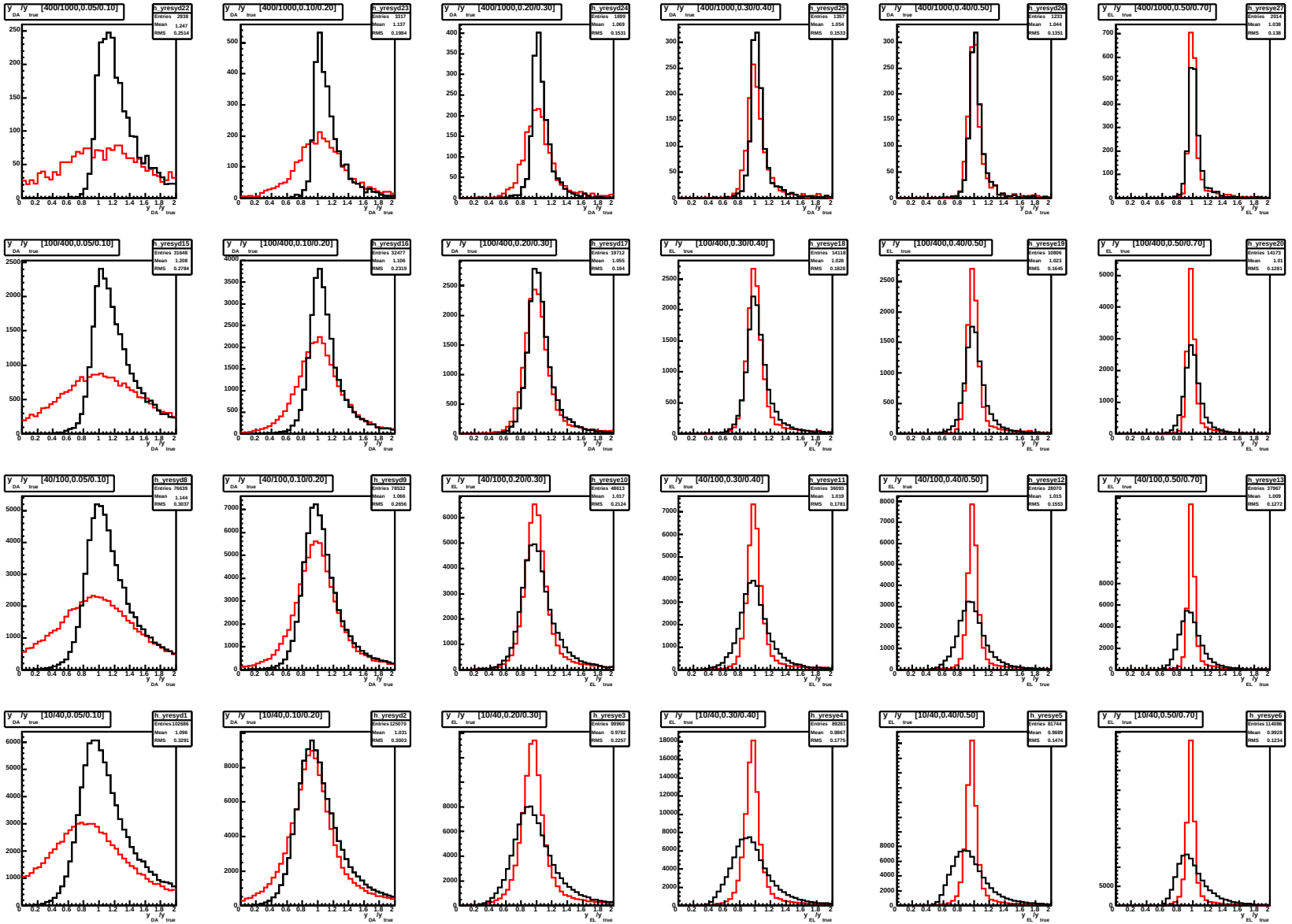
Slides from a talk given by D. Kollar at DIS2006

Systematic checks:	Varied by:
→ Photoproduction background normalization	10%
→ Electron finding inefficiency (including trigger)	10%
→ Energy scale	2% at 4 GeV → 1% at 27.5 GeV
→ Luminosity uncorrelated	1%
→ Luminosity correlated	2%

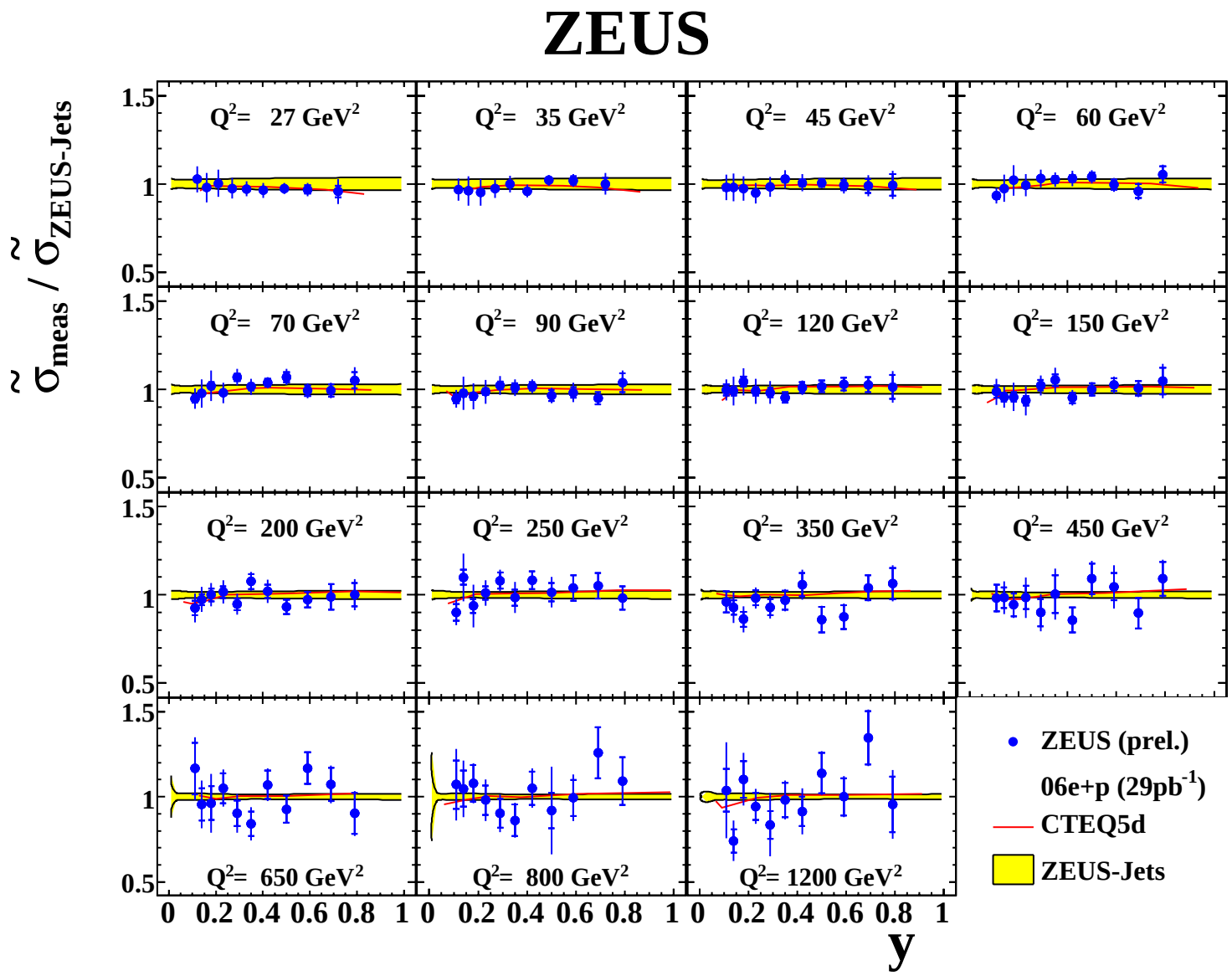
Resolution in Q^2



Resolution in y



Comparison to ZEUS Jets PDFs



Measurement is consistent with ZEUS Jets PDFs.