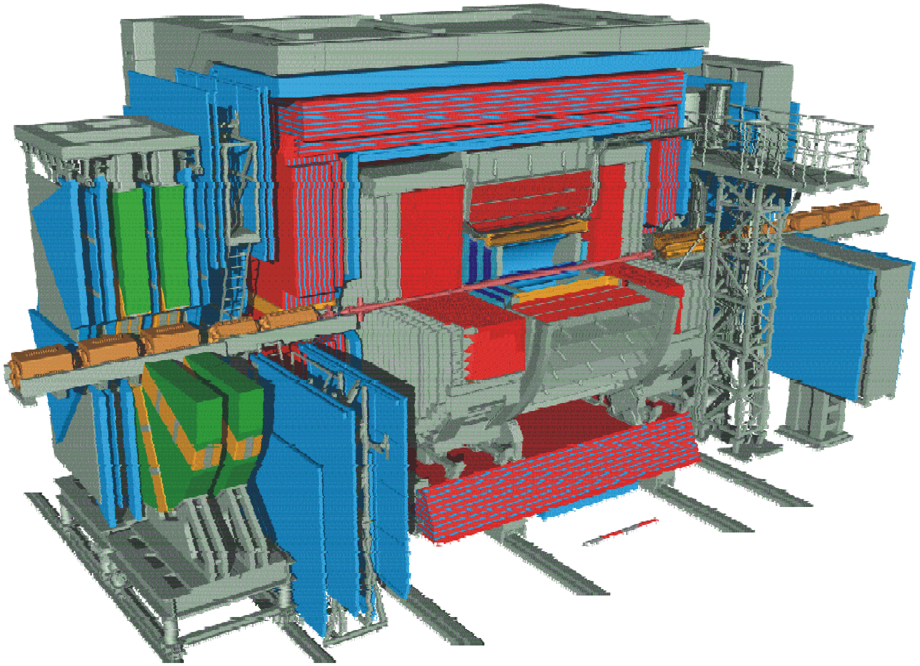
Prospects for a measurement of F_L with the ZEUS detector



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On behalf of ZEUS Collaboration

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F_L in theory

ZEUS experiment measures cross-section

$$\frac{d^2\sigma}{dx\,dQ^2}(x,Q^2)=\frac{2\pi\alpha^2}{xQ^4}[Y_+F_2(x,Q^2)-y^2F_L(x,Q^2)] \qquad Y_+=1+(1-y)^2$$

(at low Q^2 $\Rightarrow$ xF_3 neglected)

F_2 – dominant contribution to cross section

F_L – related to cross section of longitudinally polarised photon $\quad F_L=\frac{Q^2}{4\pi^2\alpha}\sigma_L$

– in Quark-Parton Model (QPM): $\sigma_L = 0 \Rightarrow F_L = 0$

– F_L nonzero in **pQCD**, in LO

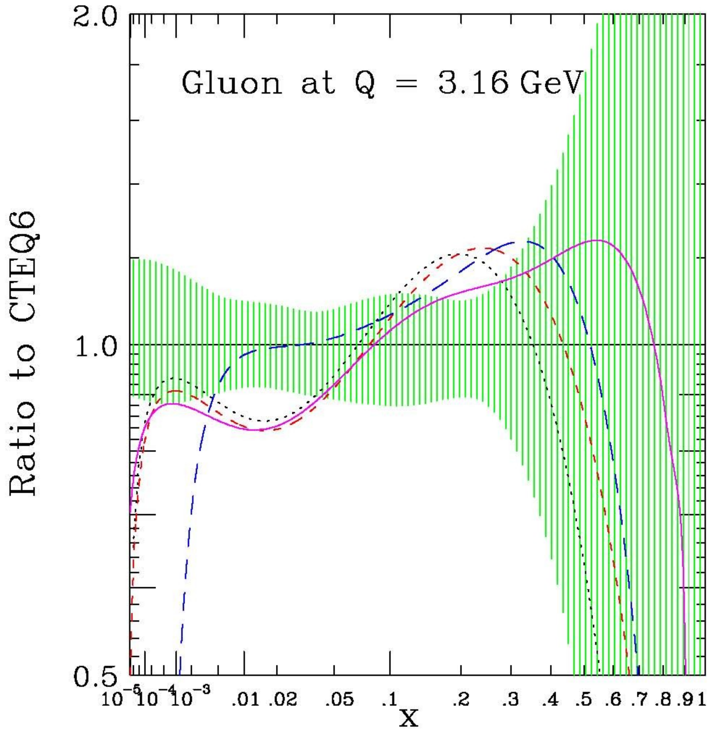
$$F_L=\frac{\alpha_s}{4\pi}x^2\int_x^1\frac{dz}{z^3}\left[\frac{16}{3}F_2+8\sum e_q^2\left(1-\frac{x}{z}\right)zg\right]$$

At small x the gluon density dominates

→ **F_L has never been measured at small x**

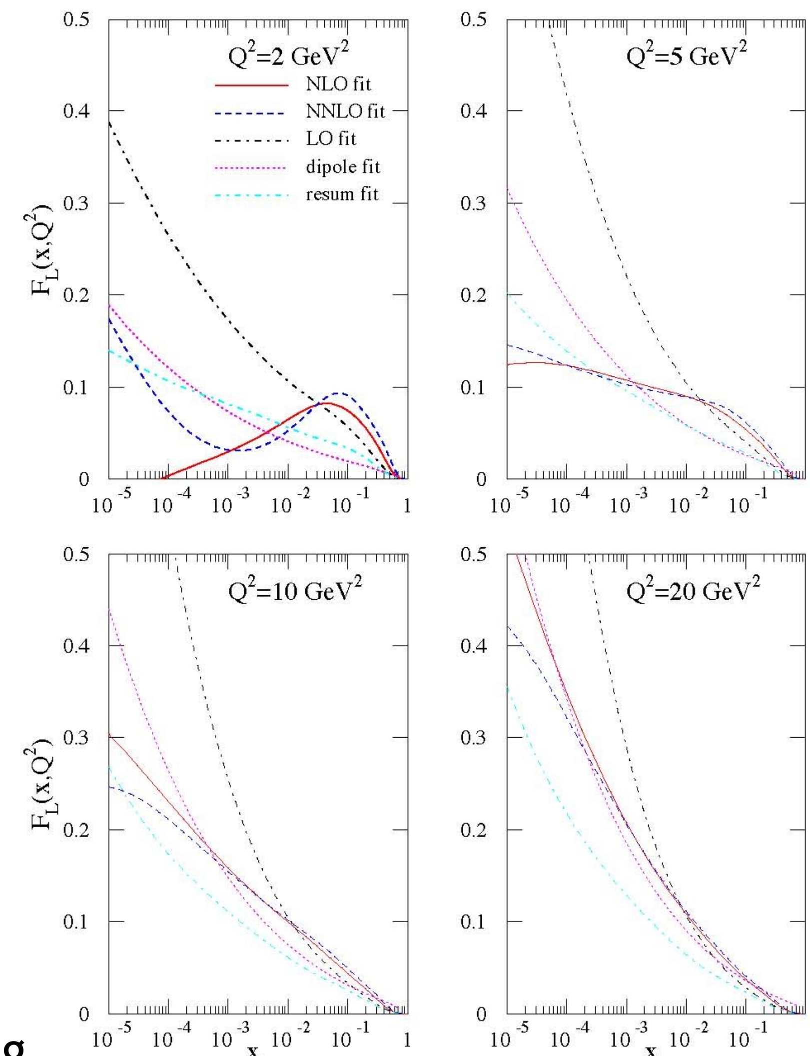
→ measurement of F_L would provide direct access to gluon densities

Status of F_L and gluon densities



mrst2001, mrst2002, mrst2003, mrst2004

MRST predictions: F_L at LO, NLO, NNLO



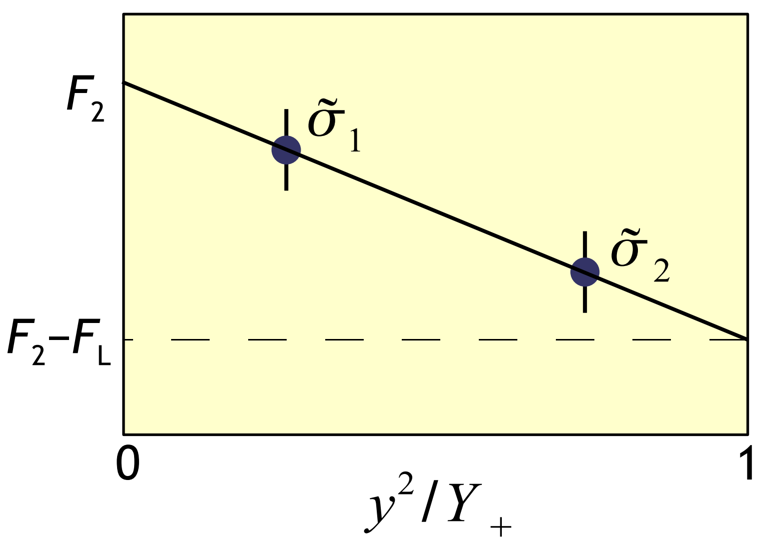
- Relatively large uncertainties in gluon densities at small ***x***
- ***F_L* is poorly constrained by present data**
  $\rightarrow$ different theoretical predictions
- Measurement of F_L $\rightarrow$ test of our QCD understanding
  $\rightarrow$ important input to QCD fits of PDF's

F_L measurement with two beam energies

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

$\tilde{\sigma}$ → reduced cross section

To separate F_2 and F_L one needs to measure the cross section at the same x and Q^2 but different values of y ⇒ different **s** (different beam energies)



$$F_L(x,Q^2) = \frac{\tilde{\sigma}_1(x,Q^2,y_1) - \tilde{\sigma}_2(x,Q^2,y_2)}{\frac{y_2^2}{Y_{2+}} - \frac{y_1^2}{Y_{1+}}}$$

larger y difference
more points (beam energies)
⇒ **higher accuracy of F_L measurement**

Possible running scenarios

3 months of HERA running at lower proton beam energy:

→ 2 vs. 3 energy points

SCENARIO	E_p = 920 GeV	E_p = 460 GeV	E_p = 690 GeV
1	30 pb^{-1}	10 pb^{-1}	0 pb^{-1}
2	30 pb^{-1}	5 pb^{-1}	5 pb^{-1}

→ lower energy ⇒ higher precision on F_L (350 GeV ?)

→ to consider – uncertainties with HERA setup times
– lower luminosity at lower beam energy

→ **we assume two beam energies** (scenario 1)

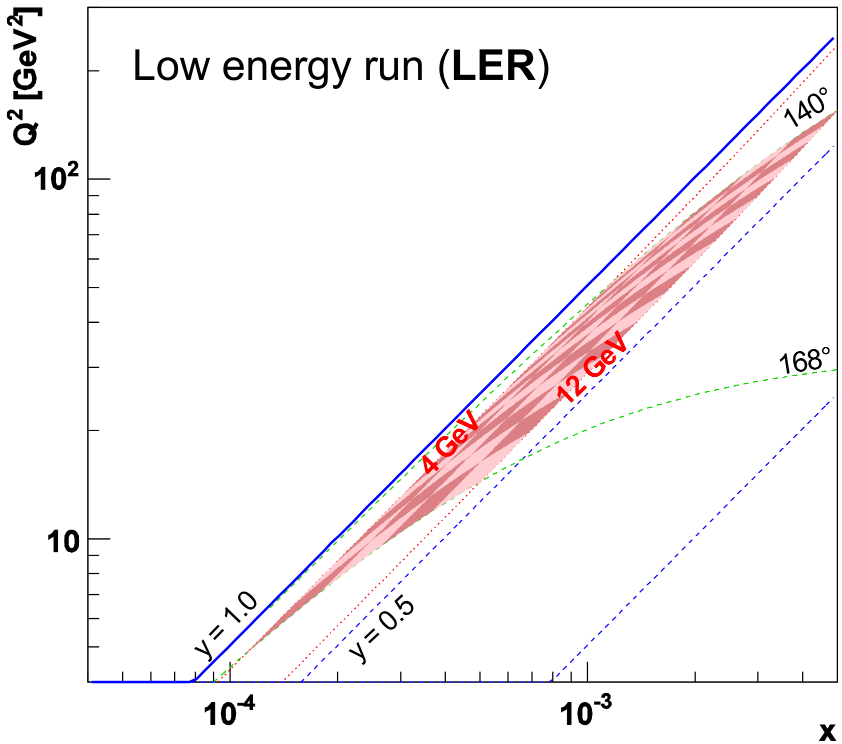
→ if accelerator setup and data taking smooth, could try third point at the end

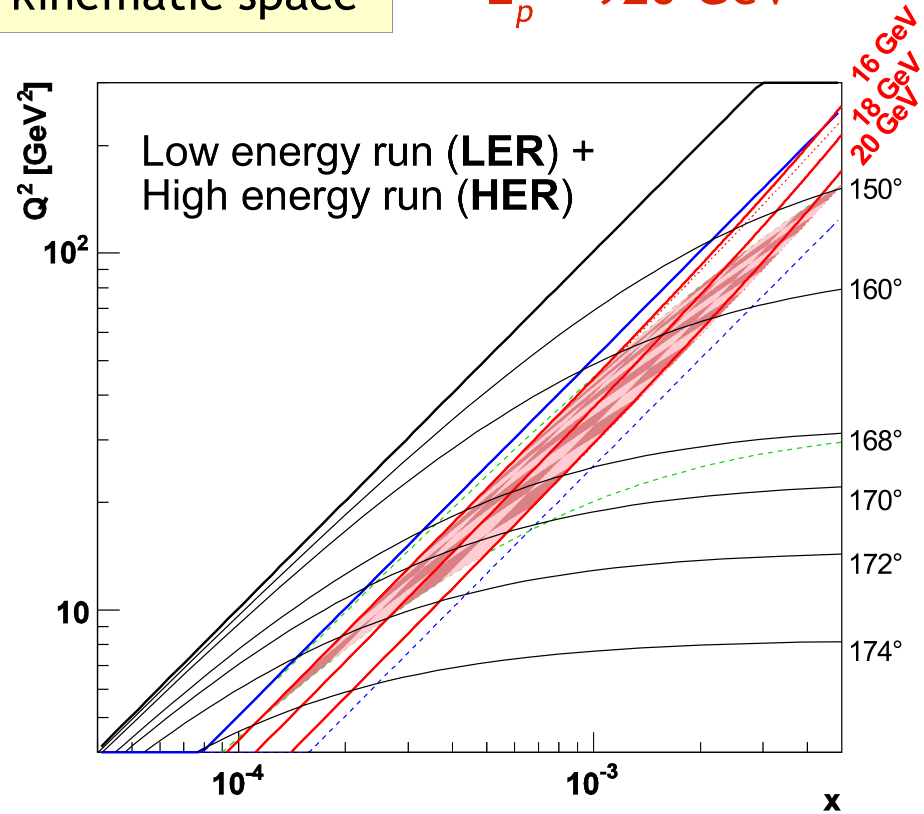
Kinematic plane for the two runs

E_p = 460 GeV

Coverage of the kinematic space

E_p = 920 GeV





4 – 12 GeV in scattered electron energy in **LER** ⇔ **16 – 20 GeV** in scattered electron energy in **HER**

Best F_L measurement ⇒ reach **highest *y*** possible
⇒ **lowest** possible **electron energy** in LER

Need to reliably recognize the scattered DIS electron down to 4 GeV

➔ Low Q^2 so electrons mostly in backward direction

Components:

RCAL:

→ looking at fraction of energy deposited in the EM part

HES + **Presampler**:

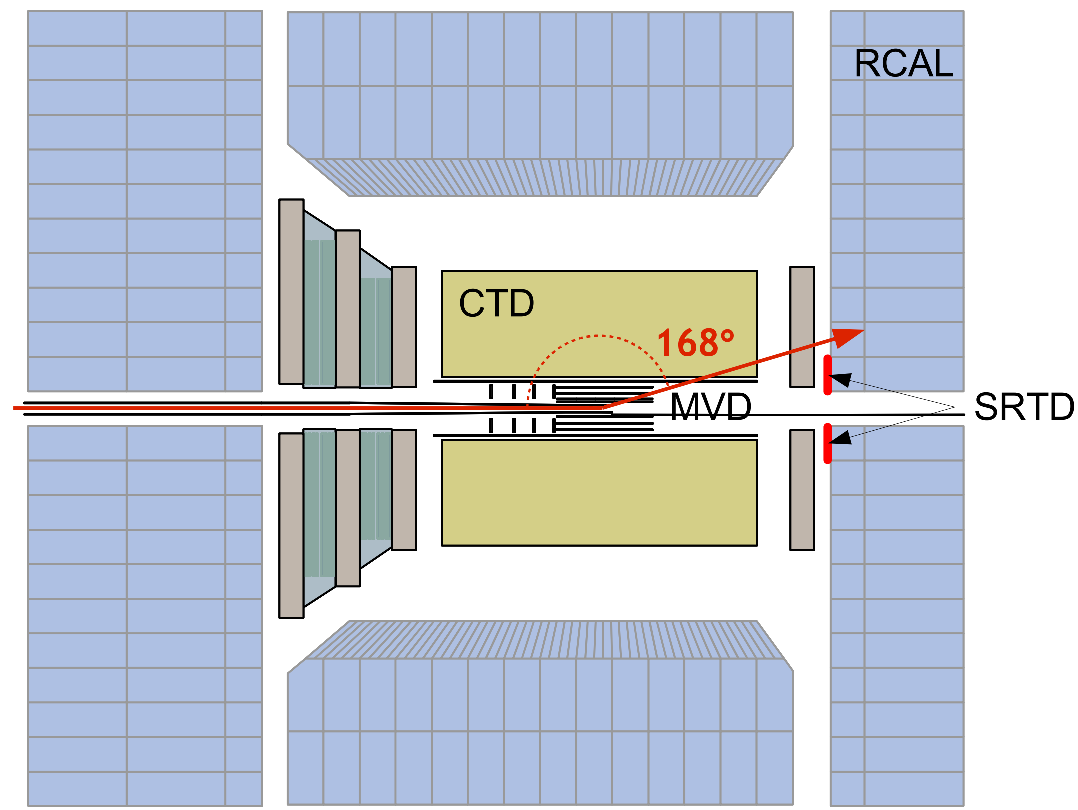
→ looking at the shape of the shower

Tracking:

→ photon-electron separation

→ central tracking using CTD and MVD has acceptance only up to ≈168°

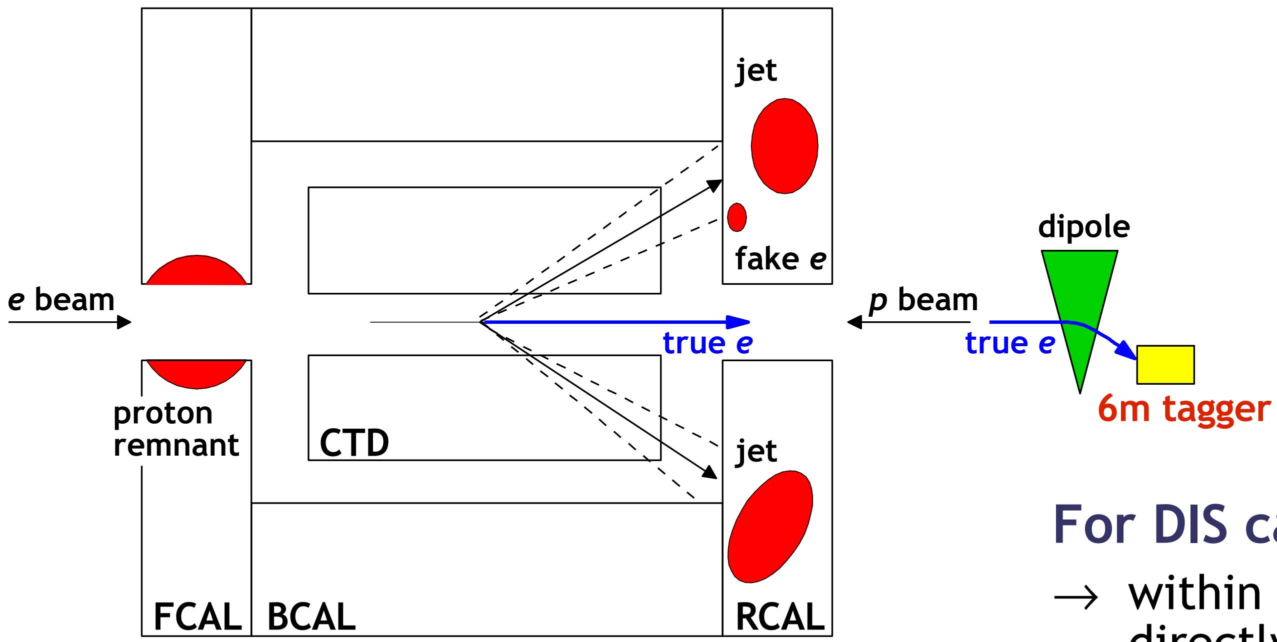
→ SRTD could help, however, behind a lot of material
$\Rightarrow$ increased $\gamma \rightarrow e^+e^-$ probability



- largest contribution to background ⇐ large cross section at low Q^2

PhP event:

→ electron irradiates almost a real photon which then interacts with the proton
→ true electron with lower energy goes down the beam pipe
→ one of the particles in the detector recognized as DIS electron



6m tagger

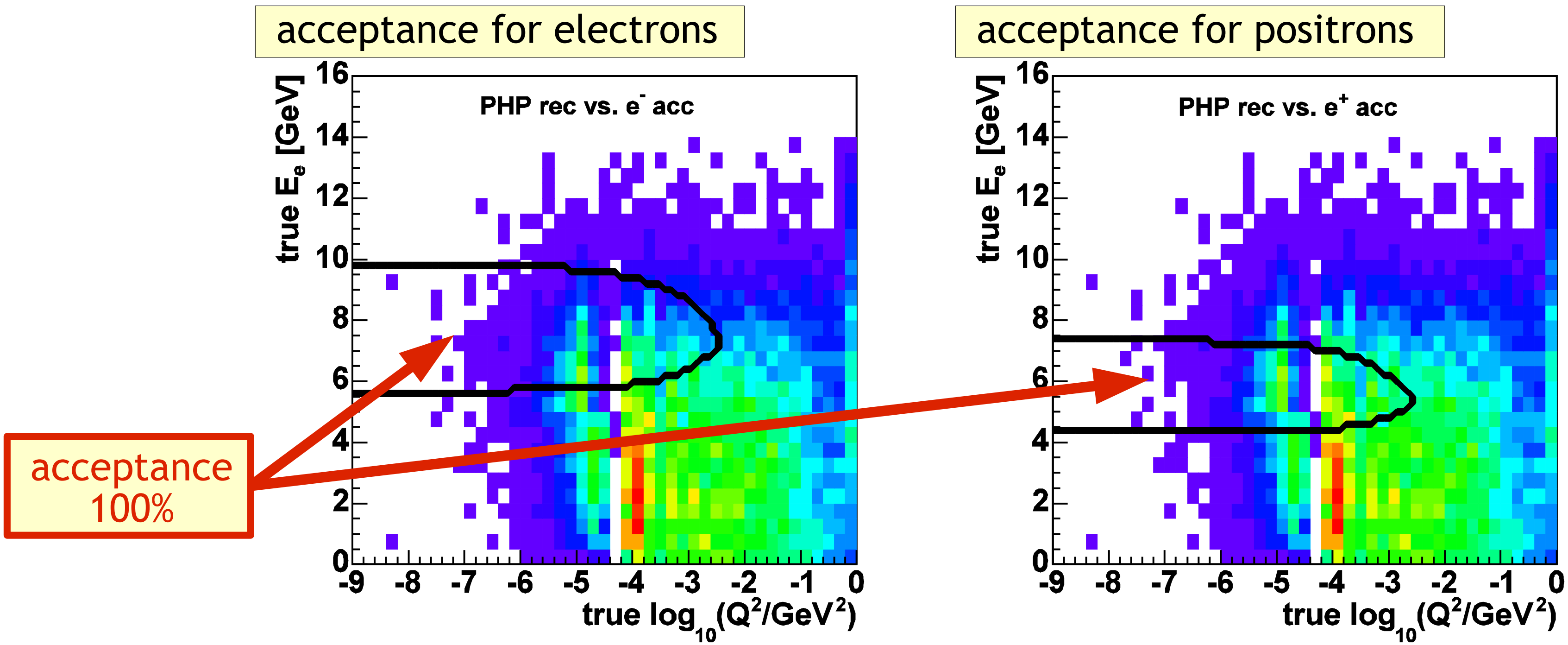
→ working fine
→ agreement with ZEUS luminosity measurement system within 2%

For DIS candidate with valid electron:

→ within acceptance window measure PhP directly
→ normalize PhP Monte Carlo

6m tagger acceptance

→ PYTHIA PhP background distribution vs. 6m tagger acceptance (reconstructed as DIS events)



- **positron running advantageous** over electron running
  → lower energy
- for e^+ running 6m tagger identifies 25% of php events
- possibly measure php and normalize MC

Details of the study

Use Monte Carlo to estimate the precision of the F_L extraction with the ZEUS detector

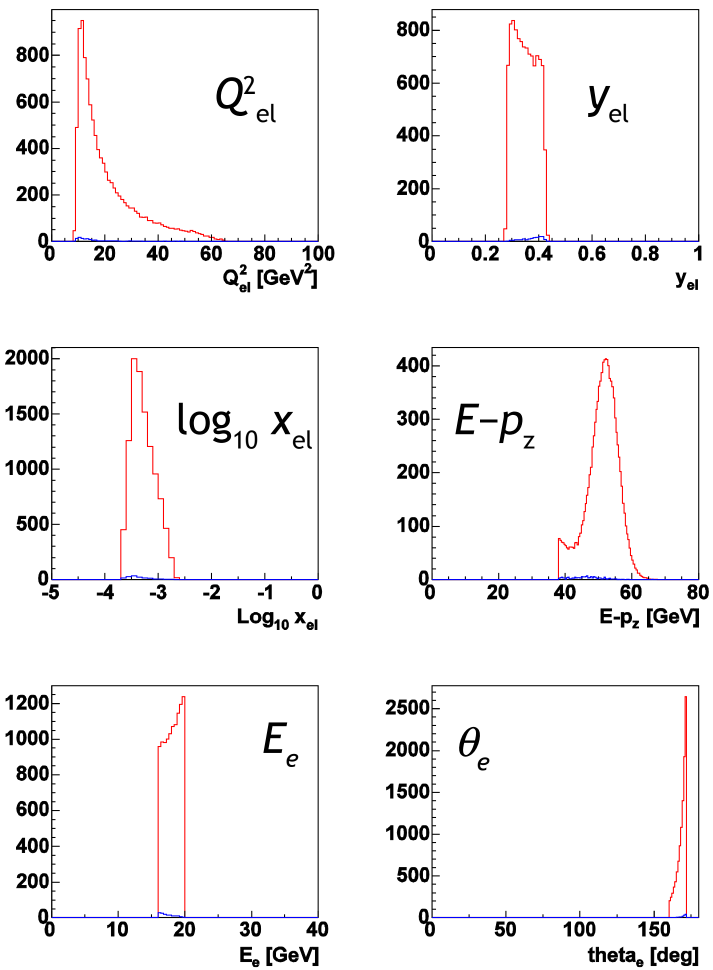
- ➔ in HER select events with electron candidate with
  $16 \text{ GeV} < E_e < 20 \text{ GeV}, \quad 160^\circ < \theta_e < 172^\circ$
- ➔ in LER select events with electron candidate with
  $4 \text{ GeV} < E_e < 12 \text{ GeV}, \quad 150^\circ < \theta_e < 168^\circ$, **require track** for $E_e < 10$ GeV
- ➔ use 6m tagger to reject PhP if within the acceptance

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%

Reconstructed kinematic variables

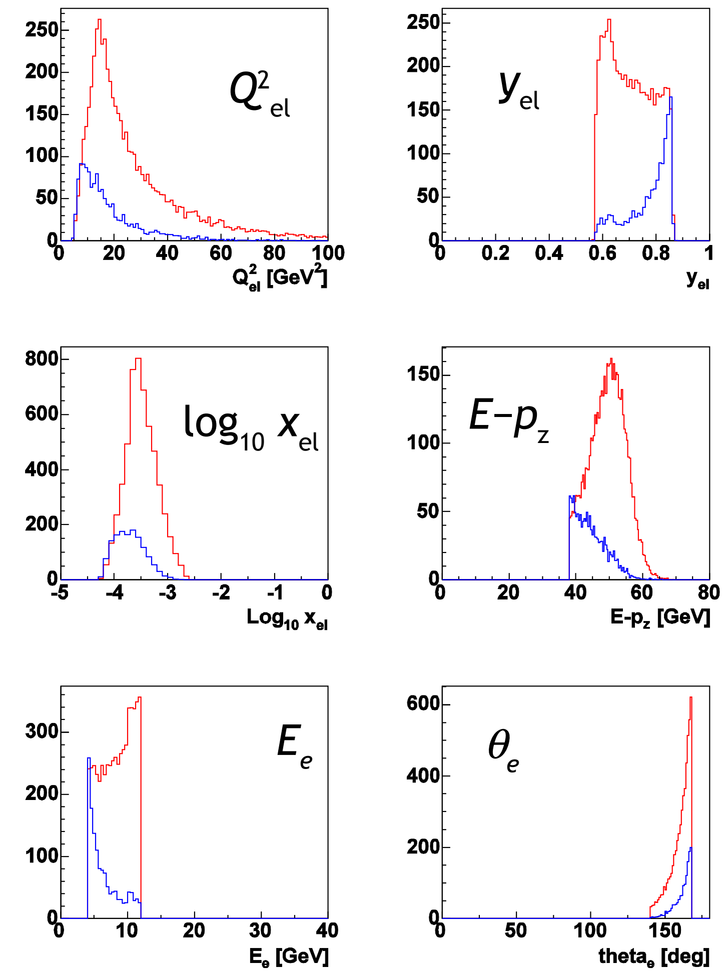
(normalized to 1 pb^{-1})

High energy run



16 GeV < $\boldsymbol{E_e}$ < 20 GeV
160° < $\boldsymbol{\theta_e}$ < 172°

Low energy run



4 GeV < $\boldsymbol{E_e}$ < 12 GeV
150° < $\boldsymbol{\theta_e}$ < 168°

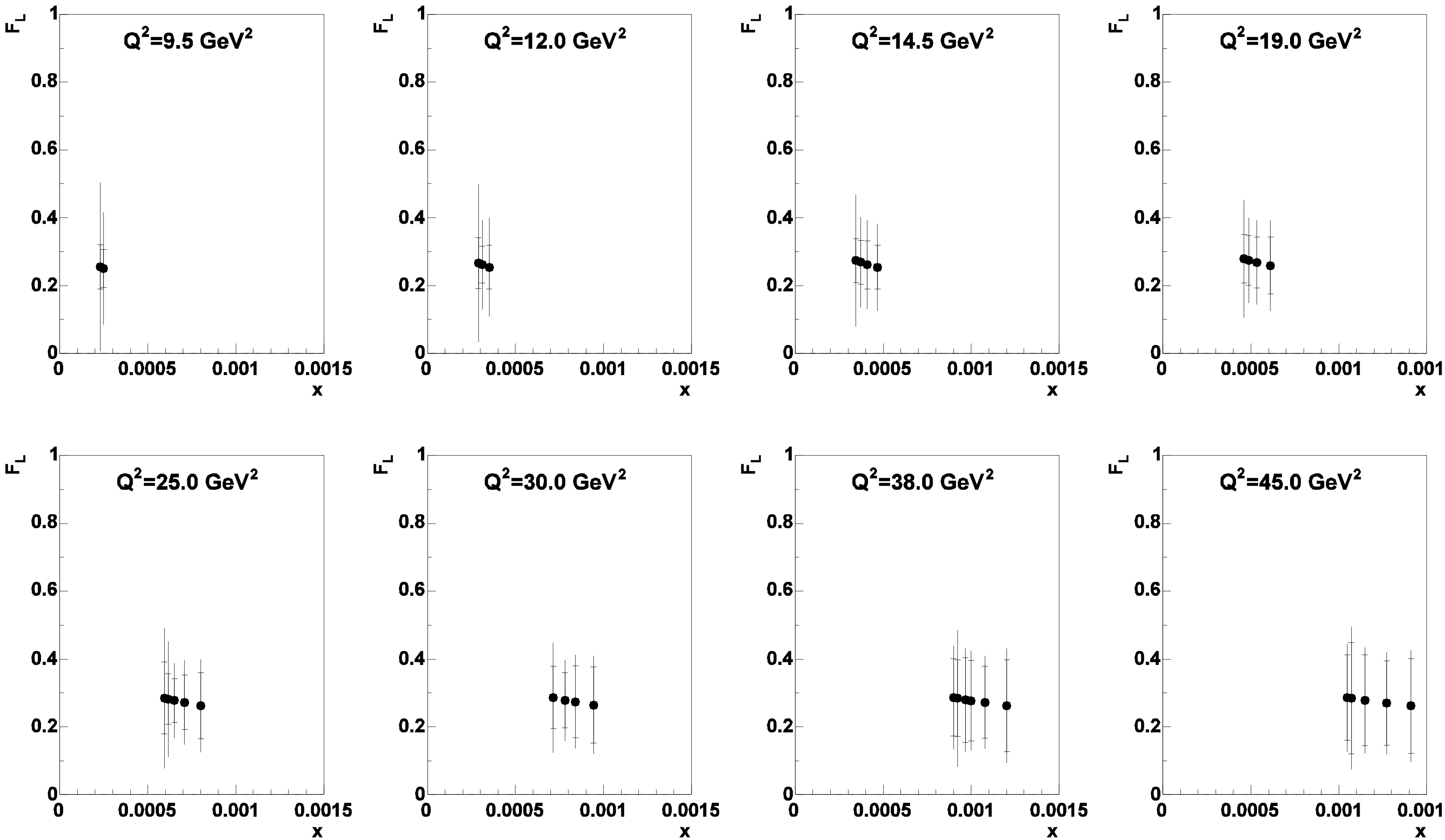
PhP background is a problem for Low energy run (for low energy electrons)

DIS
PhP

Uncertainties of F_L extraction

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

Note: F_L values set to 0.2 F_2



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

Largest systematics from:
PhP background normalization and EF inefficiency

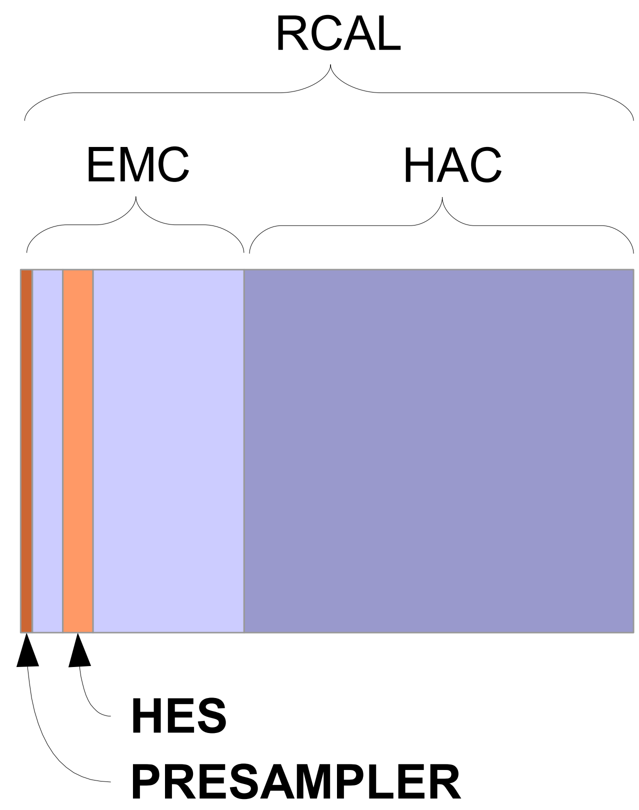
Hadron-electron separation using shower size in the calorimeter

HES:

- → Silicon diodes at $4X_0$ in the EMC
- → ~ shower maximum for several GeV electrons
- → small interaction probability for hadrons

PRESAMPLER:

- → Scintillator tiles covering EMC
- → energy correction for showers developed in the dead material before reaching cal
- → small output for hadrons



Using HES and Presampler to improve electron finding outside the tracking acceptance.

Under study...

Extraction of F_L/F_2

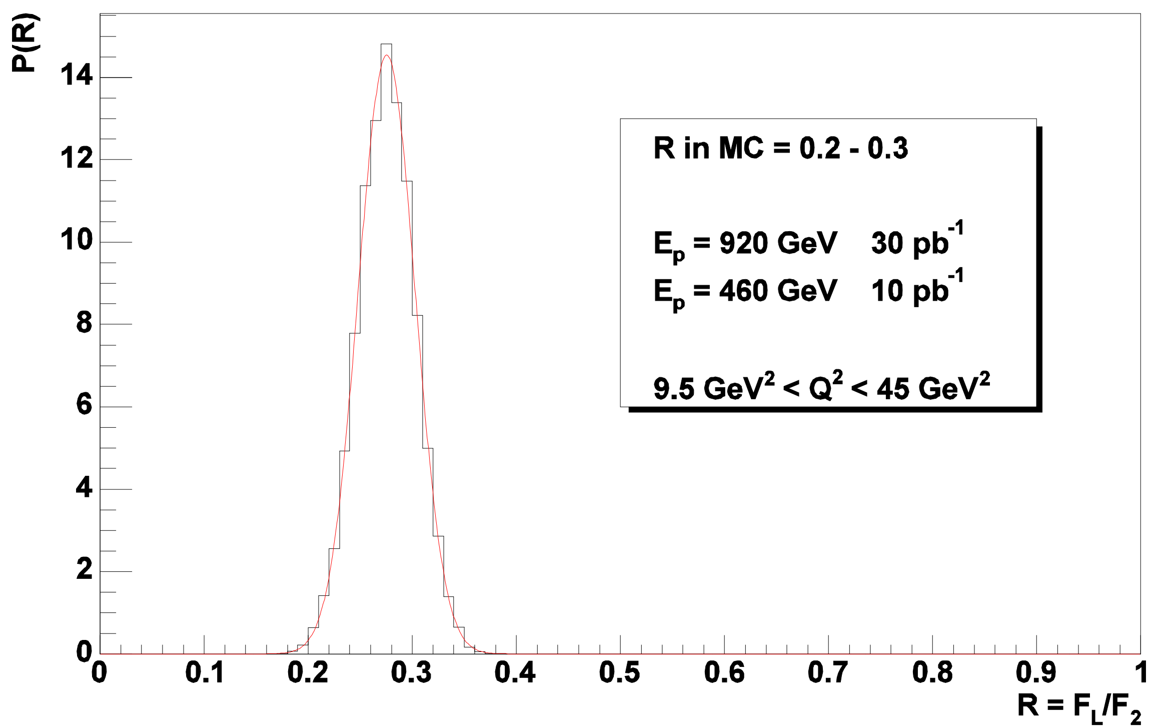
Use Bayesian approach to extract $$R = \frac{F_L}{F_2}$$

→ suppose ***R*** is a constant, i.e. we can combine all bins

→ include all uncertainties

→ MC sample had a value of ***R*** = 0.2 – 0.3

→ **extracted *R* uncertainty ≈0.027**



Average F_L/F_2 from theoretical predictions:

CTEQ5D	0.25
MRST2002 LO	0.3
MRST2004 NLO	0.18
MRST2004 NNLO	0.18

Summary

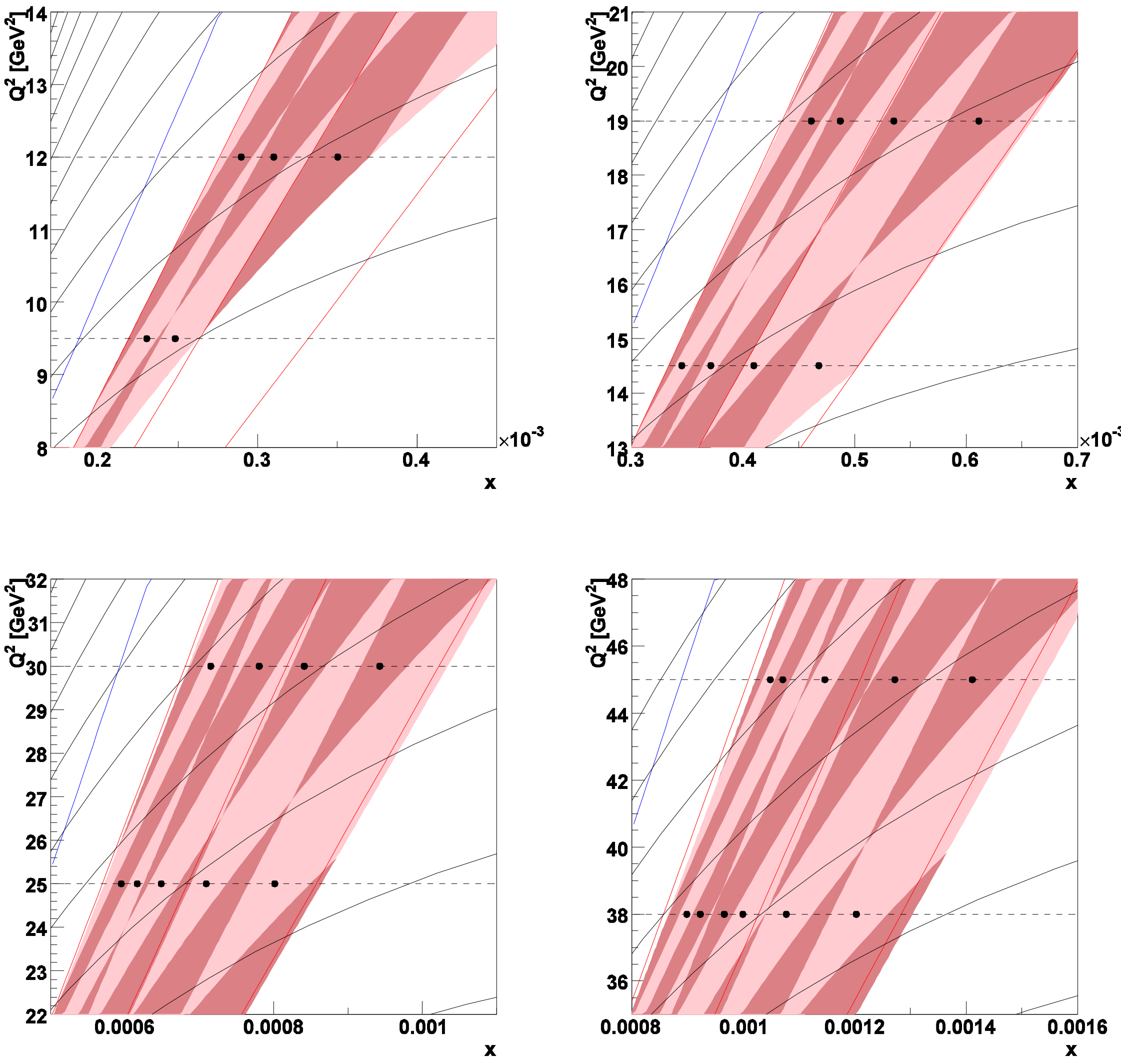
- F_L should be measured
  - basic ingredient in the cross section
  - test of perturbative QCD at small x
  - would bring information on gluon density
- kinematic range and precision of F_L measurement with ZEUS is moderate
- however, there is room for improvement
  - extending Q^2 and x range
  - better electron finding with HES and Presampler
  - better understanding of the PhP background using 6m tagger
    $\rightarrow$ reduction of the PhP normalization systematics

ZEUS Collaboration has expressed interest in low energy running to the DESY PRC (will be meeting in May)

BACKUP SLIDES

(x,Q^2) points for F_L extraction

Q^2 = 9.5, 12, 14.5, 19, 25, 30, 38, 45 GeV^2



→ 2-6 x points/Q^2 point

→ Limitation at low Q^2 is tracking requirement

→ Limitation at high Q^2 is statistics

Cross-section measurement at high *y*

→ clearly, **electron finding at low energies is a challenge**

→ the ZEUS detector is not the ideal device

⇒ we want to perform a NC cross-section measurement at high ***y*** with current beam energy

→ this will allow to prepare and test detectors and techniques for electron finding and background rejection

New territory for ZEUS F_2 measurement