UNIVERSITÄT DORTMUND
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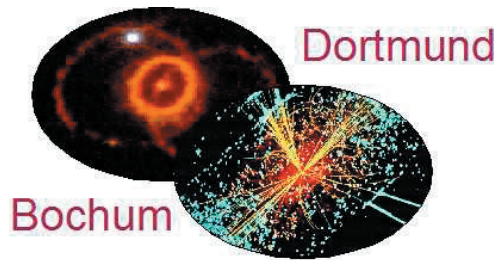
H1 Collaboration

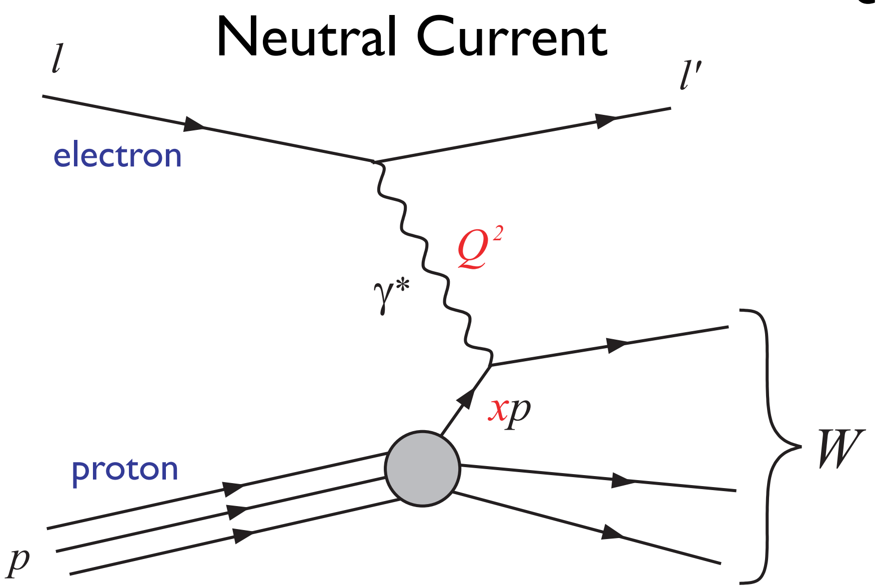
Measurement of the Proton Structure Function F_2 at Low Q^2 at HERA

- Deep Inelastic Scattering at HERA
- Experimental Techniques at Low Q^2
- Details of the Analysis
- Systematic Errors



Workshop "Hard Processes"
Universität Dortmund
13.10.05

Deep Inelastic Scattering



cms energy $\sqrt{s} = \sqrt{(l+p)^2} \approx 320\,\mathrm{GeV}$

Photon virtuality $Q^2 = -(l-l')^2$

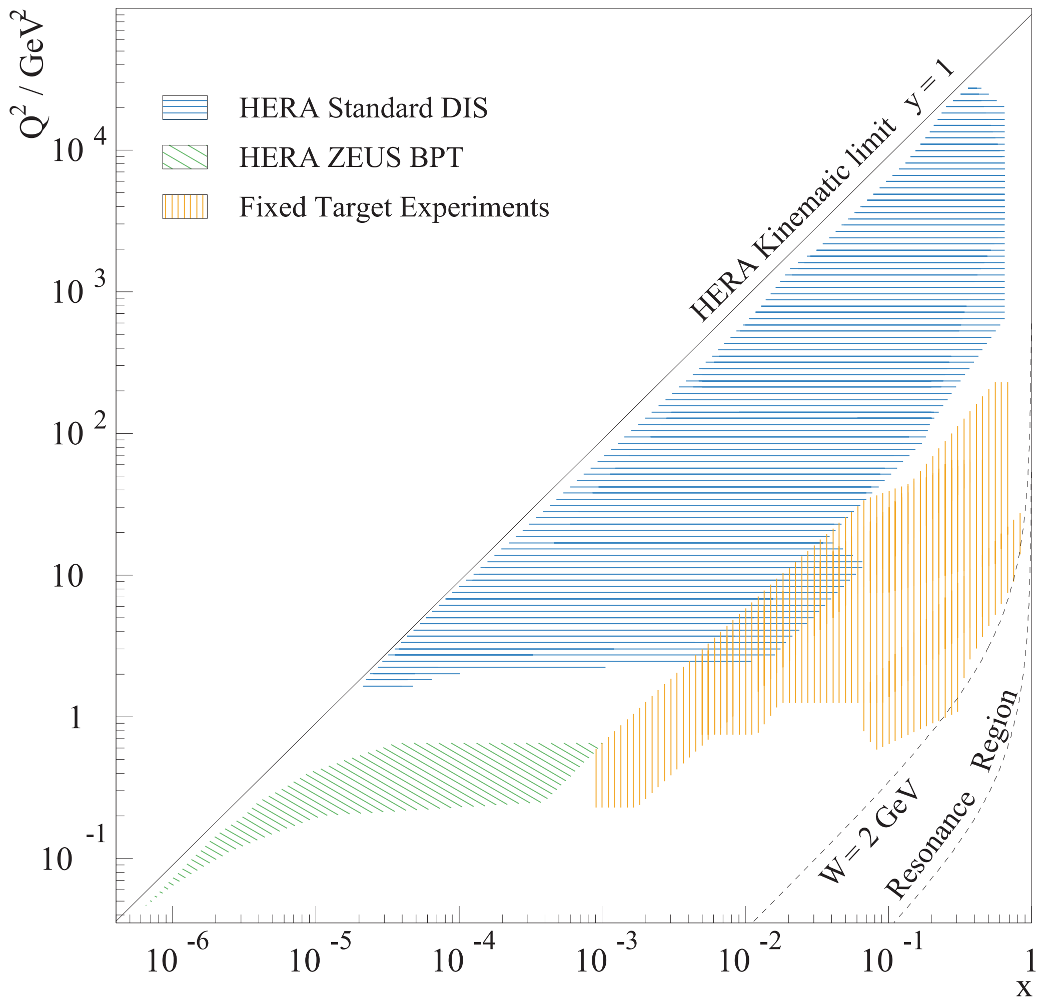
Bjorken variable $x = \dfrac{Q^2}{2p\cdot(l-l')}$

Inelasticity $y \approx \dfrac{Q^2}{xs}$

Invariant mass of the hadronic final state $W = \sqrt{Q^2\dfrac{1-x}{x} + m_p^2}$

$$\frac{d^2\sigma}{dx\,dQ^2} = \frac{2\pi\alpha^2}{Q^4 x}\left(Y_+ F_2(x,Q^2) - \underbrace{y^2\cdot F_L(x,Q^2)}_{\text{negligible at low y}}\right) \qquad Y_+ = 1+(1-y)^2$$

Accessible Phase Space



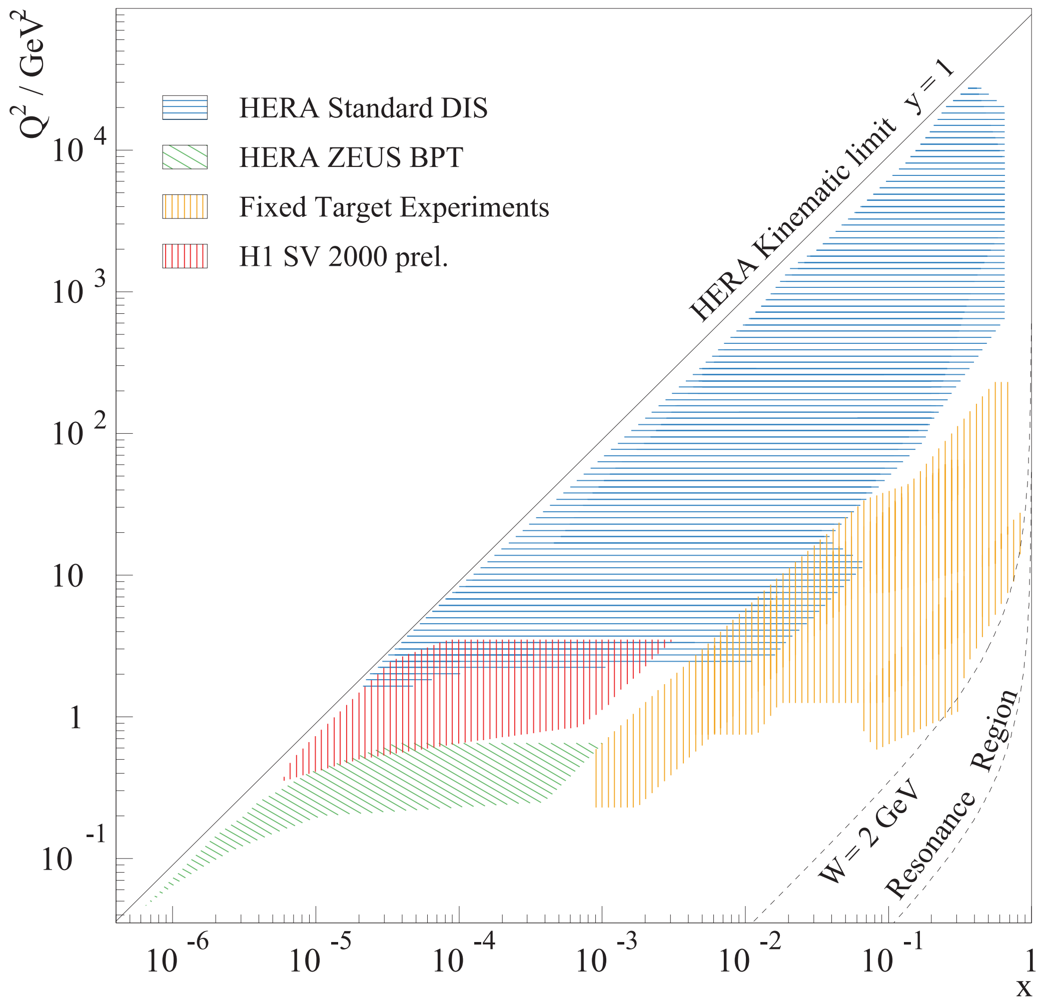
Medium - high Q^2:

- asymptotic freedom
- perturbative QCD

Low Q^2:

- transition to soft hadronic physics
- $\alpha_s(Q^2)$ becomes large
- phenomenological models

Accessible Phase Space



Medium - high Q^2:

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Low Q^2:

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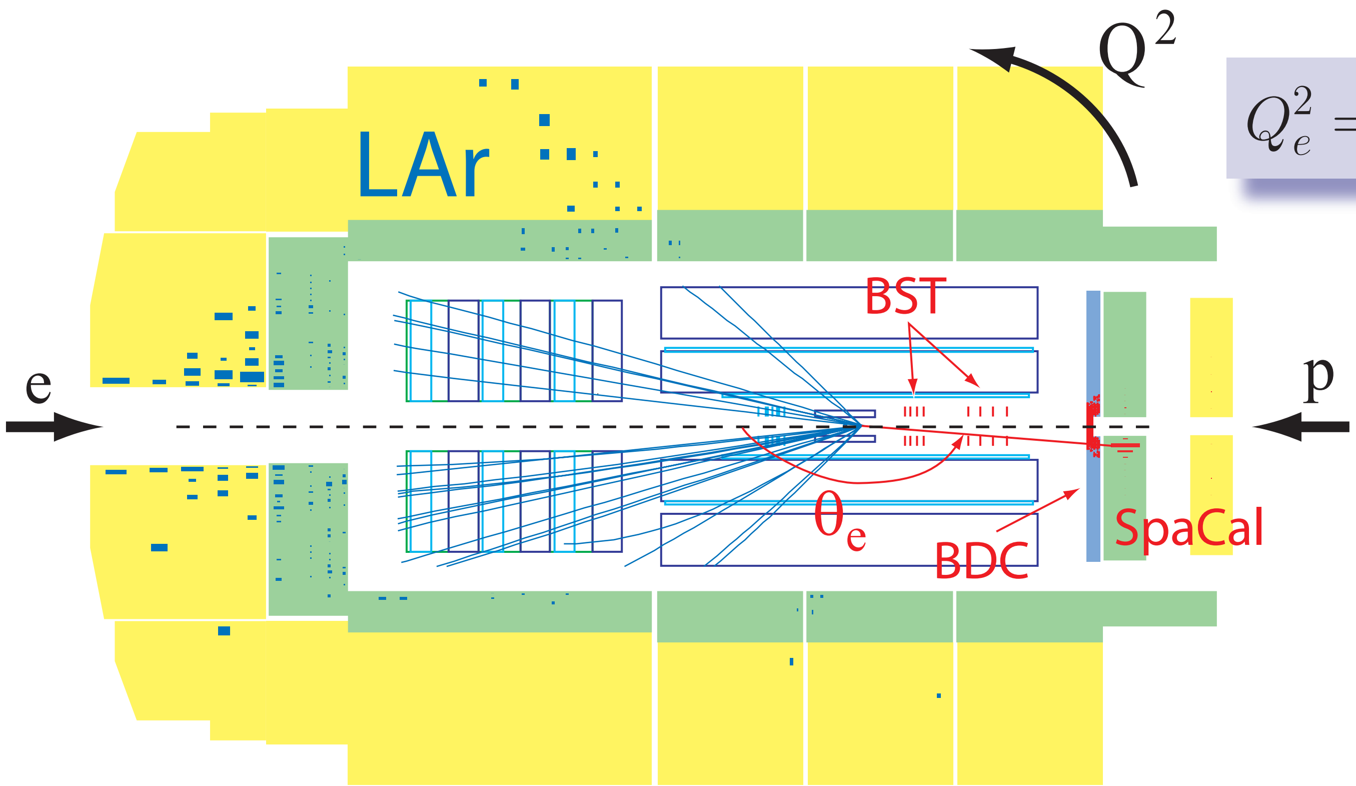
Experimental Techniques to Access Low Q^2



$$Q_e^2 = 2E_eE'_e(1+\cos\theta_e)$$

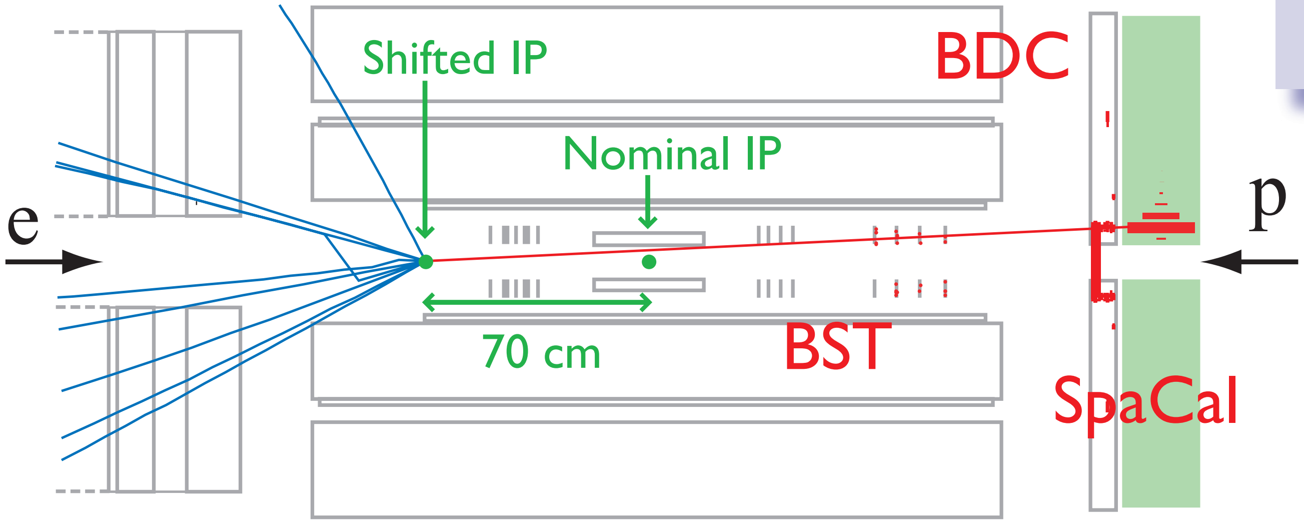
- standard DIS in main detector:

  $Q^2 > 2\ \mathrm{GeV}^2$

Possibilities to access lower Q^2:

- larger polar angles
- lower initial electron energy

Shifted Vertex Run



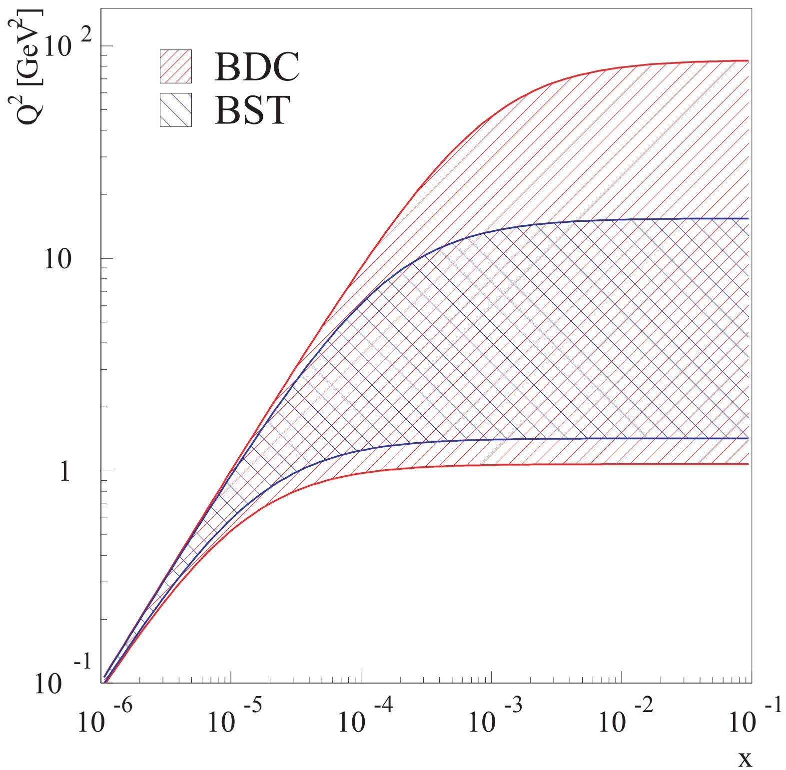
- special data taking period in the year 2000
- interaction vertex shifted by 70 cm

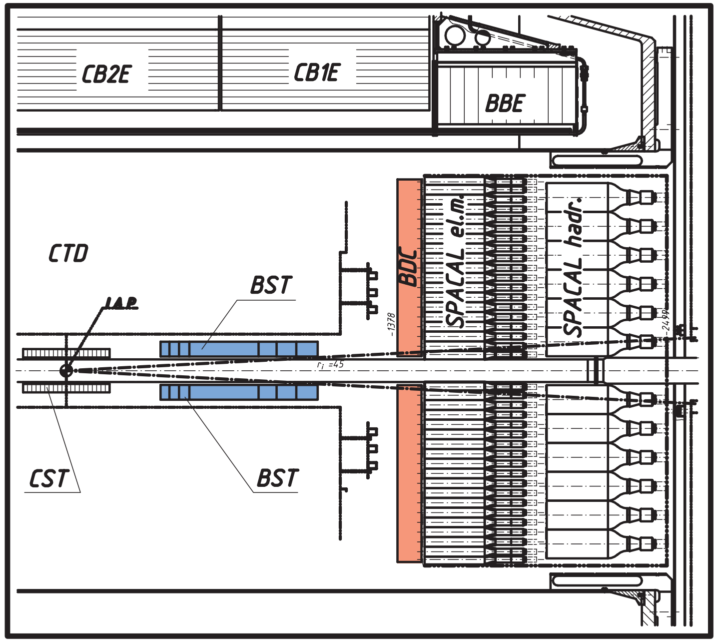
- 4-fold increase in statistics w.r.t. previous shifted vertex run (1995)
- preliminary analysis using the BST already exists

Other Possibilities:

- detectors mounted close to the beam pipe (ZEUS BPT)
- radiative events

Aim of the Analysis



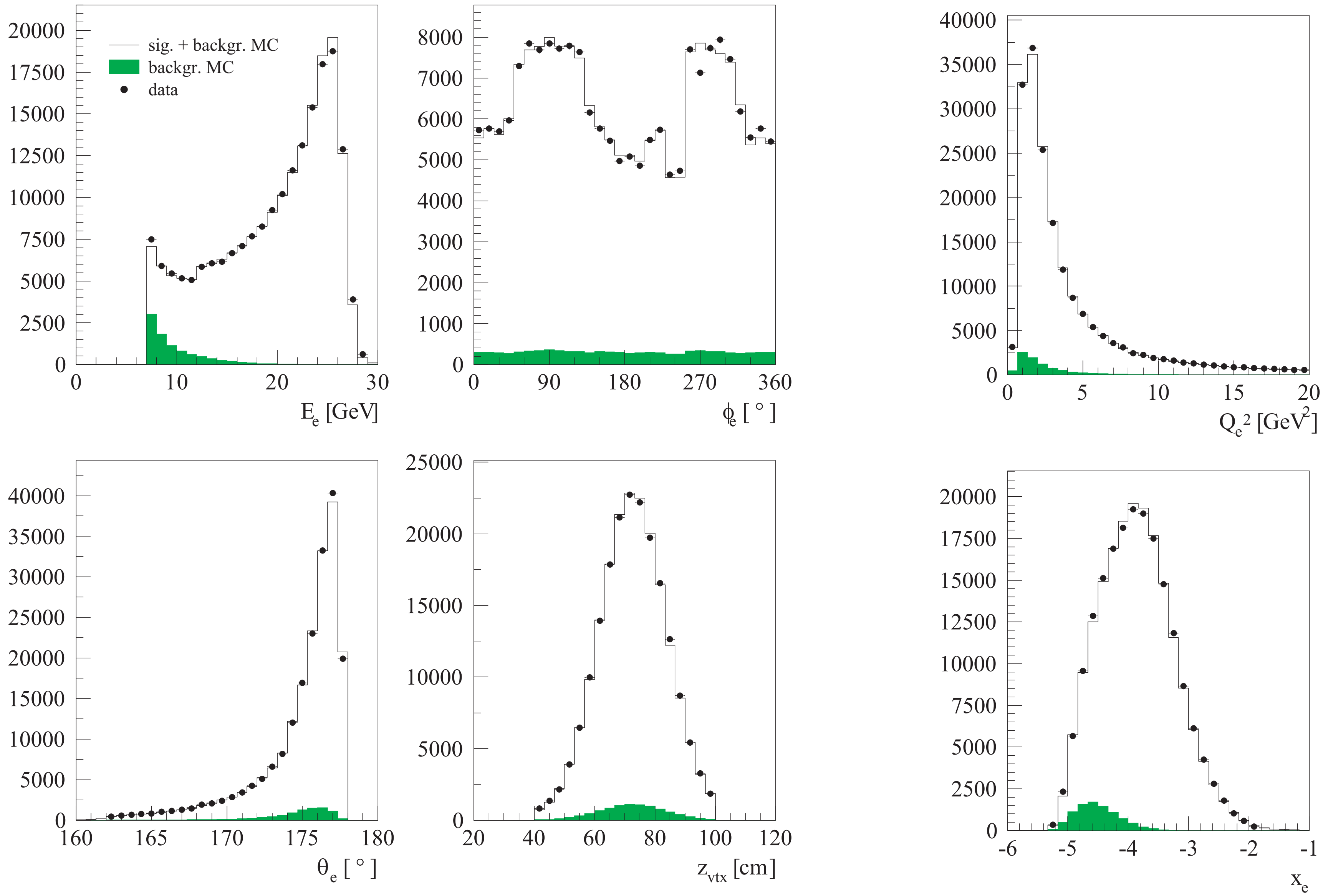


- cross-check of the preliminary results based on the BST
- BDC to reconstruct the polar angle of the electron
  - further cross-check
  - complementation of the accessible phase space

Preparation of Data and MC Samples

- alignment (SpaCal, BDC)
- calibration (SpaCal, LAr)
- MC models
  - reconstruction efficiencies [vertex, BDC]
  - acceptance
- Background [hadron fakes scattered electron]
  - normalisation of the background MC
- detailed systematic studies of the hadronic final state

Control Distributions



Systematic Error

Question:

- Can we benefit from the increased statistics w.r.t. the previous shifted vertex run in 1995?

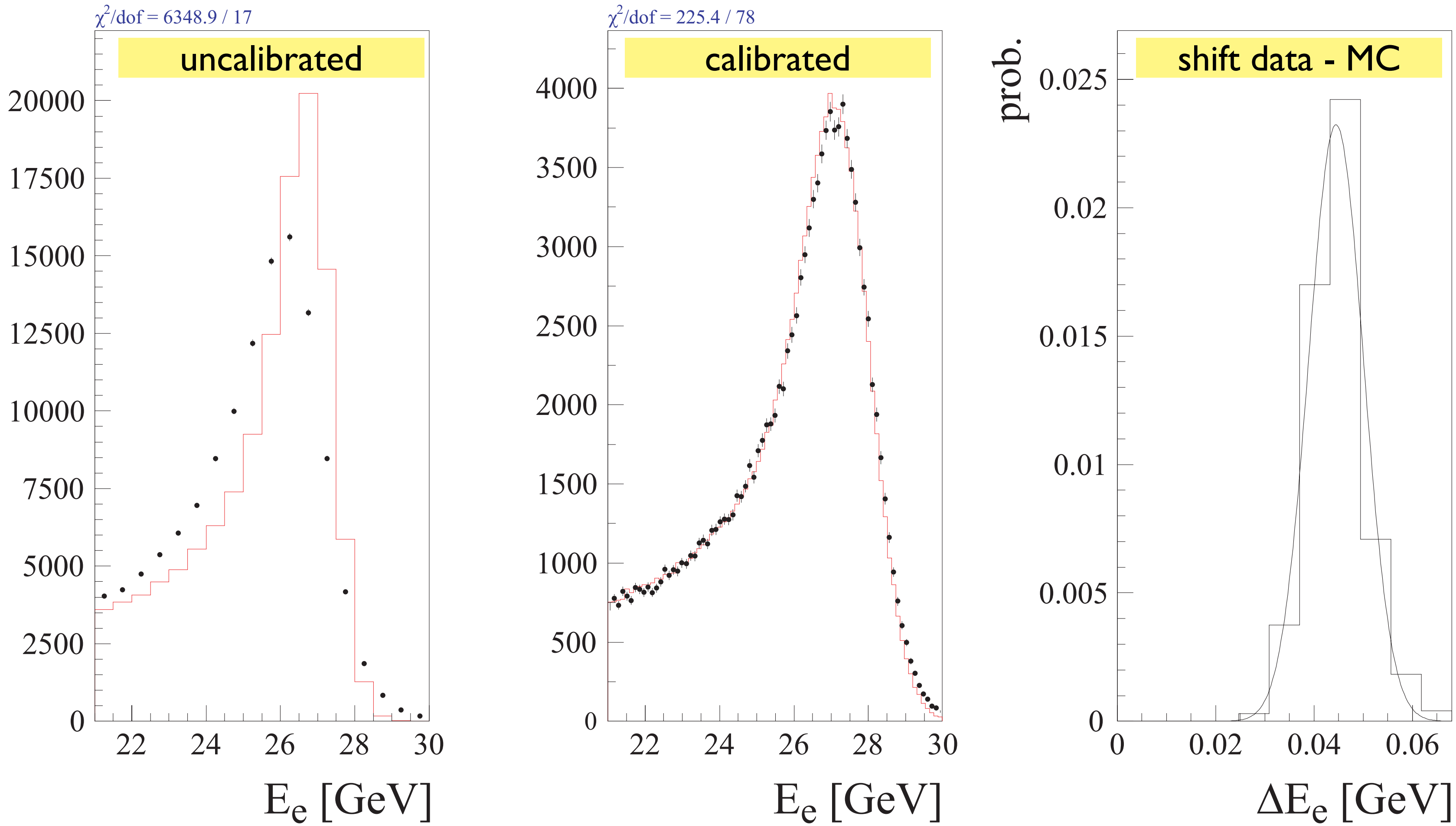
Answer:

- look at the systematic error of the measurement

Task:

- identify and quantify systematic uncertainties
- study their influence on the F_2 measurement

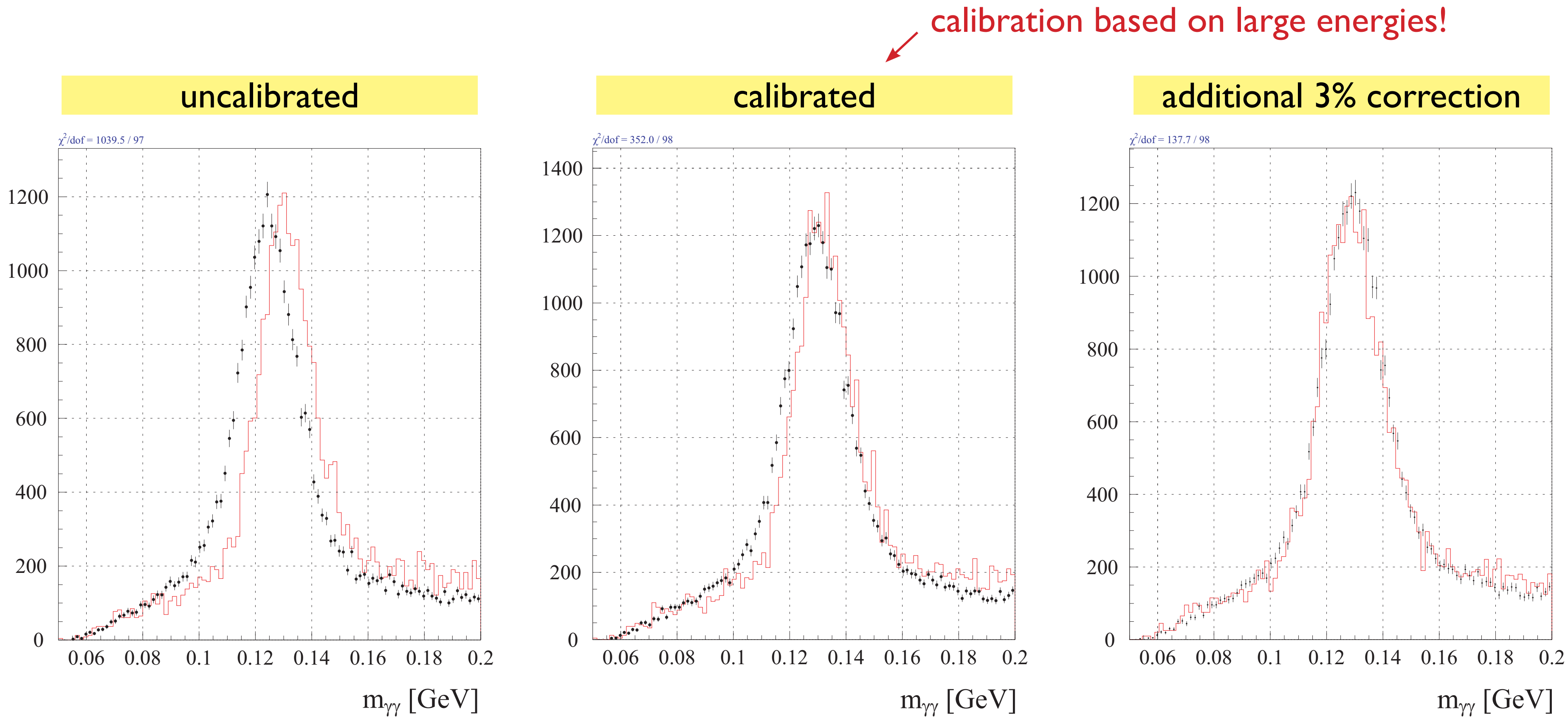
Energy Scale of the Scattered Electron



- check of the result of the SpaCal calibration at the kinematic peak

  ⇒ systematic uncertainty on the relative energy scale: 0.2%

Energy Scale of the Scattered Electron

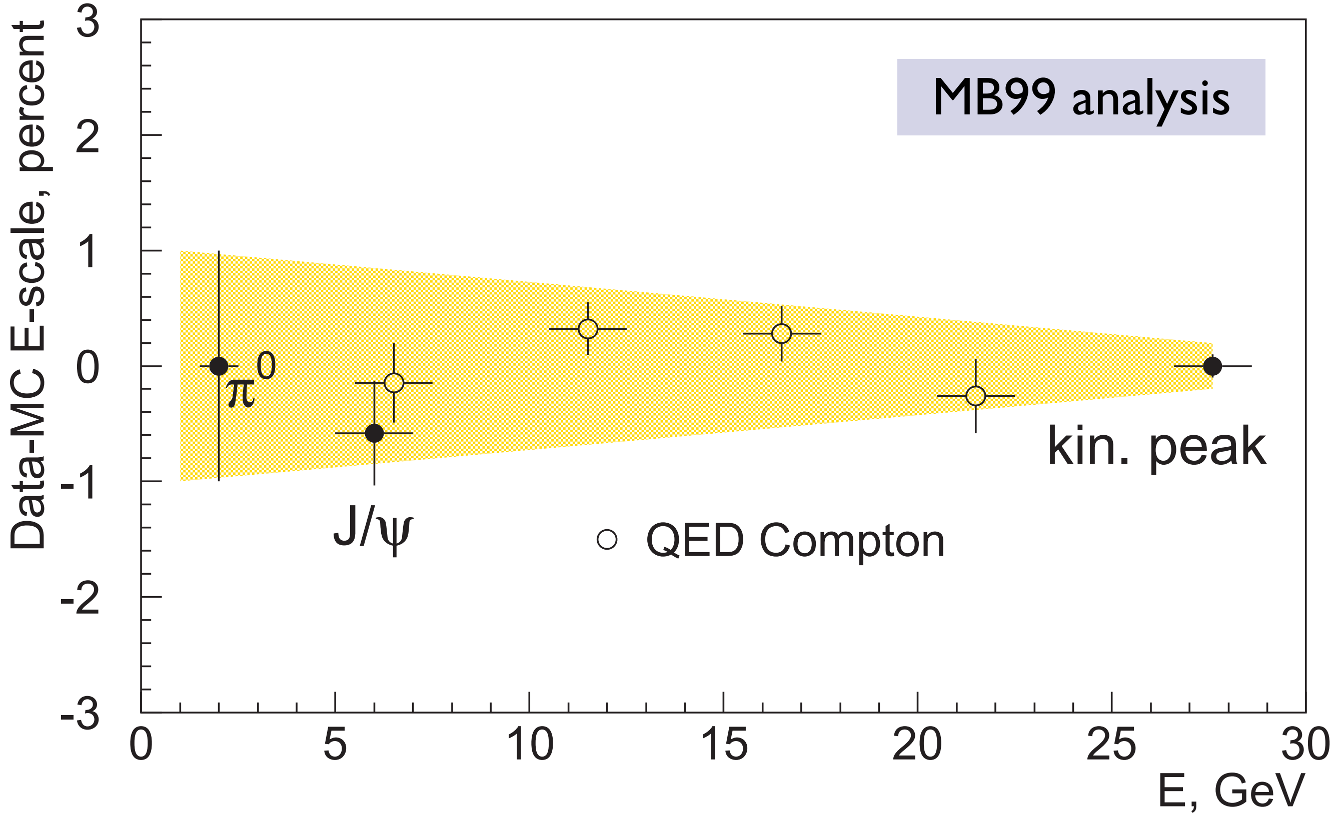


check of the SpaCal linearity at E ≈ 2 GeV with π^0 mesons:

- additional correction of 3% necessary
- remaining uncertainty: 1%

$$\pi^0 \rightarrow \gamma\gamma$$
$$m_{\pi^0} = 135\,\mathrm{MeV}$$

Energy Scale of the Scattered Electron



- at $E_e \approx 2$ GeV: 1%
- kinematic peak: 0.2%

Cross-check of the scale uncertainty:

- J/Ψ mesons: $J/\Psi \rightarrow e^{+} + e^{-}$
- QEDC events: $e + p \rightarrow e + \gamma + X$

Systematic Uncertainties

source	uncertainty	
trigger efficiency	0.5%	normalisation error
luminosity measurement	1.8%	
signal MC statistics	$\sqrt{N_{MC}}$	uncorrelated error
background MC statistics	$\sqrt{N_{MC,bg}}$	
radiative corrections	1%	
scattered electron energy scale	0.2% at E_e = 27.5 GeV 1% at $E_e \approx$ 2 GeV	correlated error
scattered electron angle	0.5 mrad	
hadronic energy scale LAr	2%	
hadronic energy scale SpaCal	500 MeV	
LAr noise	10%	
normalisation of background MC	15%	

- contributions to the correlated error are determined by shifting the variables in MC by the uncertainties in both directions

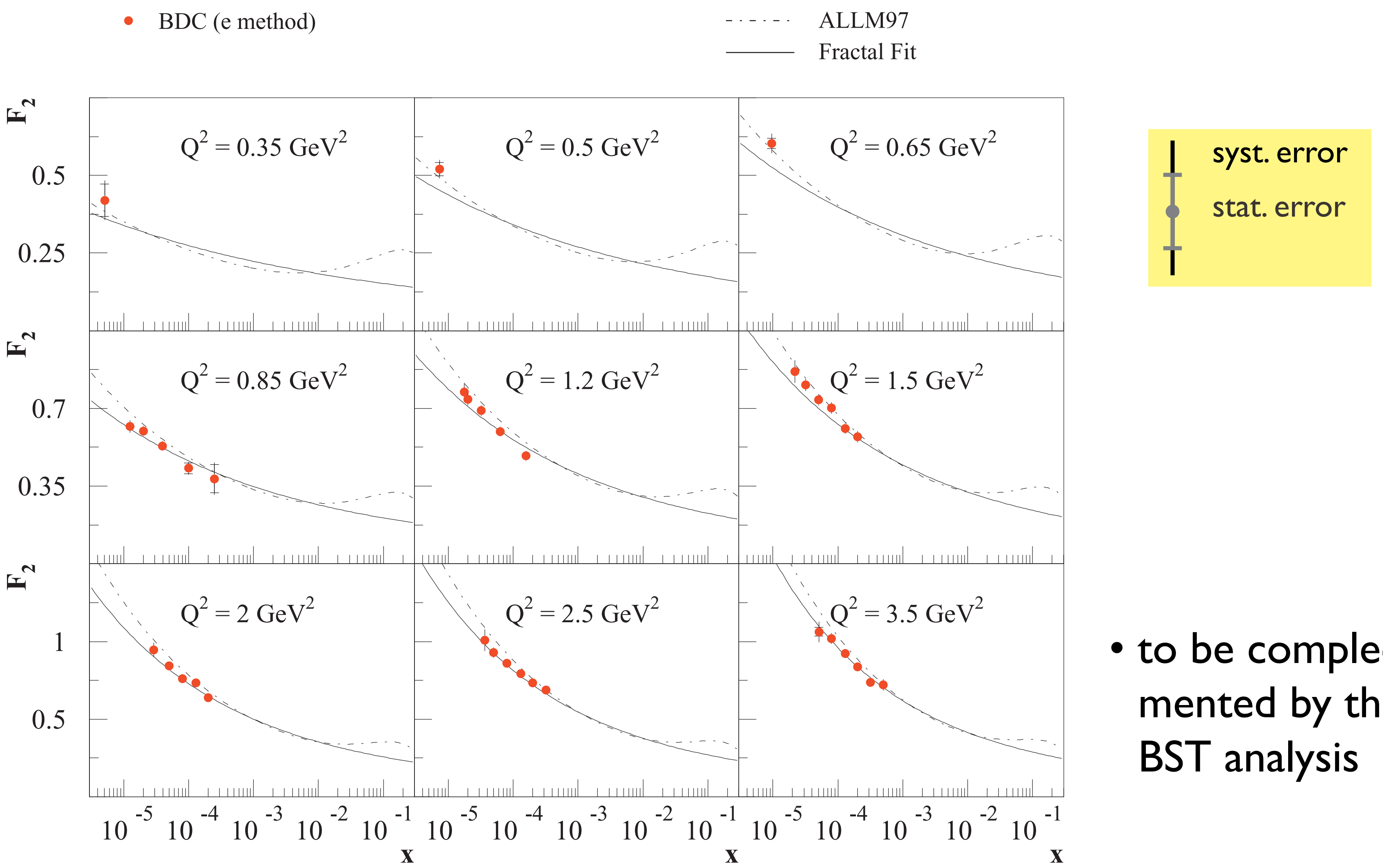
Influence on the F_2 Measurement

Q^2 [GeV]	x	σ_{tot}	σ_{stat}	σ_{uncor}	σ_{cor}
1.50	$2.2 \cdot 10^{-5}$	5.86	2.09	2.34	4.95
1.50	$3.2 \cdot 10^{-5}$	3.46	1.61	2.22	2.11
1.50	$5.0 \cdot 10^{-5}$	3.45	1.53	2.20	2.18
1.50	$8.0 \cdot 10^{-5}$	3.72	1.65	2.22	2.49
1.50	$1.3 \cdot 10^{-4}$	3.97	1.88	2.25	2.67
1.50	$2.0 \cdot 10^{-4}$	4.55	2.26	2.30	3.21
2.00	$2.9 \cdot 10^{-5}$	4.97	1.83	2.26	4.03
2.00	$5.0 \cdot 10^{-5}$	3.17	1.62	2.20	1.61
2.00	$8.0 \cdot 10^{-5}$	3.35	1.58	2.19	1.98
2.00	$1.3 \cdot 10^{-4}$	3.57	1.58	2.20	2.32
2.00	$2.0 \cdot 10^{-4}$	3.60	1.76	2.21	2.22

σ_{cor} contains the uncorrelated and normalisation errors!

- benefit from the increased statistics
- systematic errror reduced by a factor of two
- measurement precision is limited by systematic error

Result for the BDC Analysis



- to be comple-mented by the BST analysis

Measurement of F_2 in the transition region

Status:

- full analysis chain to extract F_2 available
- relevant systematic uncertainties identfied and quantified
- resulting error on F_2 calculated

Outlook:

- comparison with the 2nd analysis group
- combination of BDC and BST analysis
- combination of the results with other low Q^2 data [MB99]
- publication