Study of Neutral Current Deep Inelastic ep Scattering at High x and Q^2 with the ZEUS Detector at HERA

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CERN Seminar, 4 March 1997

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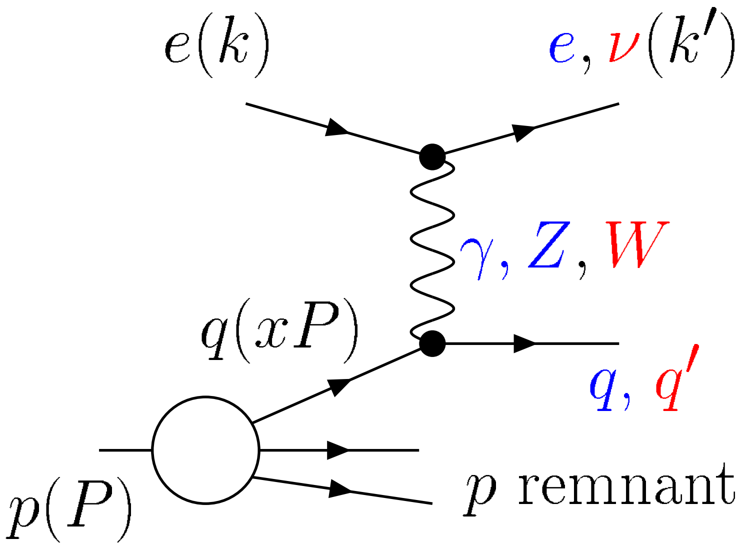
ZEUS 1994–1996 integrated luminosity = $20.1\,\mathrm{pb}^{-1}$
$\rightarrow$ sensitive to $\sigma \sim 50$ fb
$\sqrt{s} = 300$ GeV, $x = 0.5 \rightarrow M = \sqrt{sx} = 212$ GeV
$Q^2 = 10000\,\mathrm{GeV}^2 \rightarrow$ spatial resolution $= 2 \cdot 10^{-16}$ cm

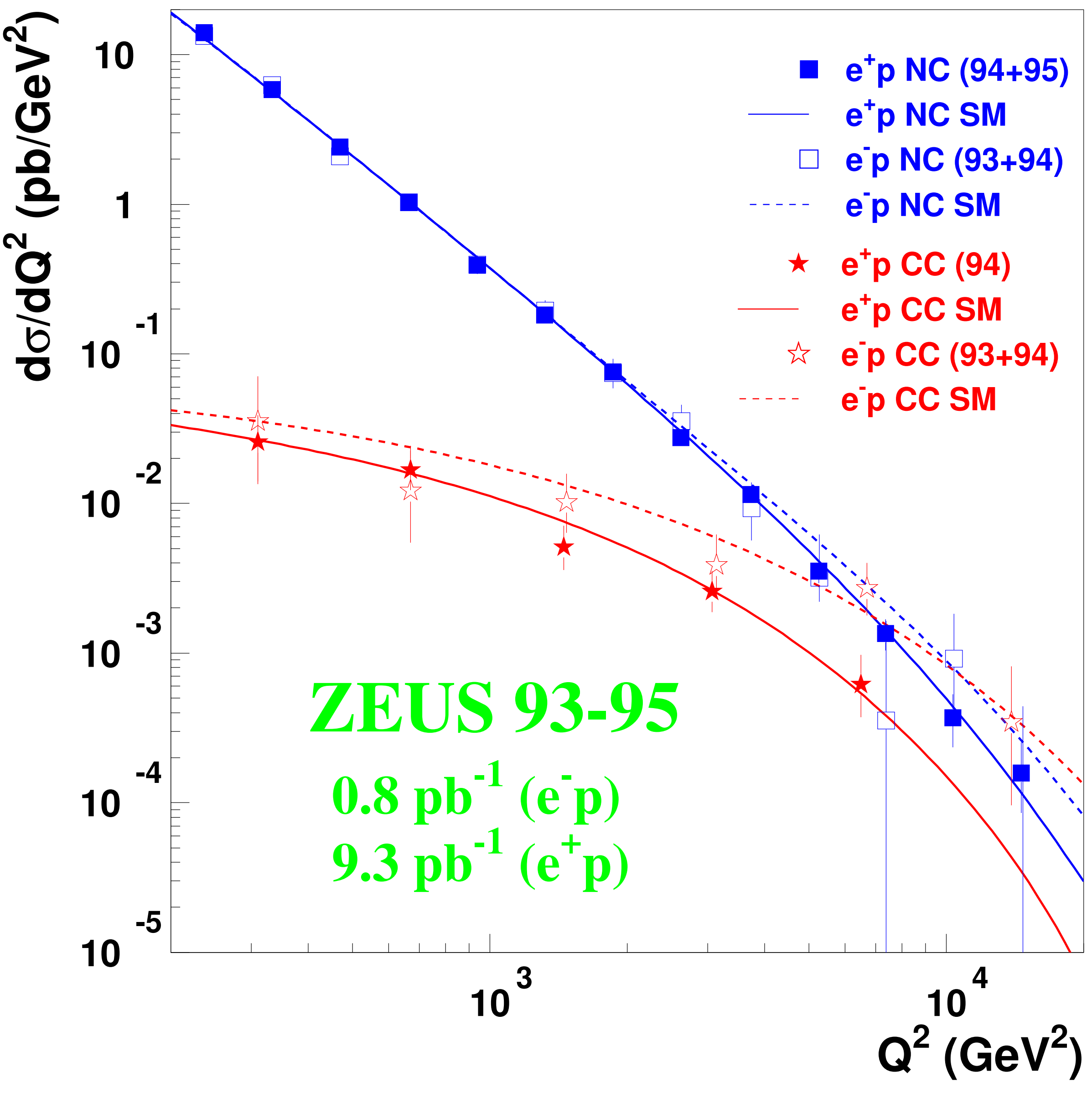
Deep Inelastic ep Scattering



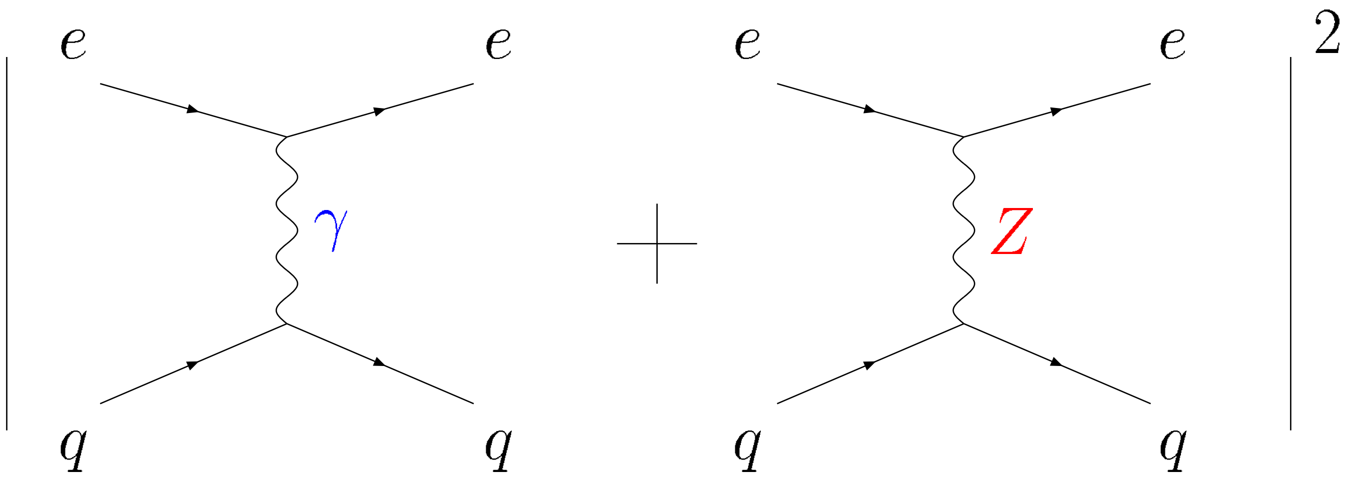
$$Q^2 = -(k - k')^2$$

$$x = \frac{Q^2}{2P \cdot (k - k')}$$

$$y = \frac{P \cdot (k - k')}{P \cdot k}$$



Standard Model Reaction: t-channel γ or Z Exchange



$$\frac{d^2\sigma}{dx\ dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\{Y_+\,\mathcal{F}_2(x,Q^2) - Y_-\,x\mathcal{F}_3(x,Q^2)\}$$

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

The structure functions $\mathcal{F}$ are given by

$$\begin{pmatrix} \mathcal{F}_2(x,Q^2) \\ x\mathcal{F}_3(x,Q^2) \end{pmatrix} = x \sum_{q=\text{quarks}} \begin{pmatrix} C_2^q(Q^2)\,[q(x,Q^2)+\overline{q}(x,Q^2)] \\ C_3^q(Q^2)\,[q(x,Q^2)-\overline{q}(x,Q^2)] \end{pmatrix}$$

with coefficient functions

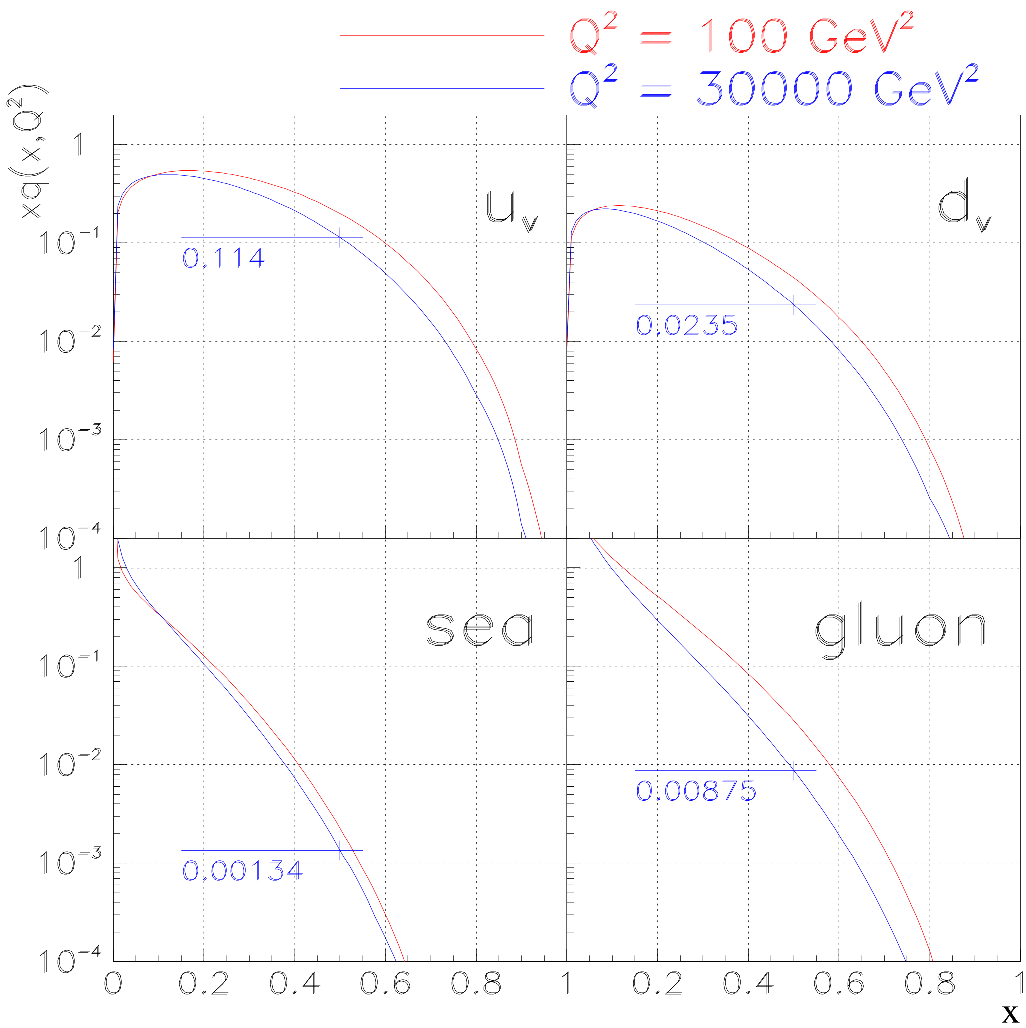
$$\begin{pmatrix} C_2^q(Q^2) \\ C_3^q(Q^2) \end{pmatrix} = \begin{pmatrix} e_q^2 & -2e_q v_q v_e \chi_Z + (v_q^2+a_q^2)(v_e^2+a_e^2){\chi_Z}^2 \\ & -2e_q a_q a_e \chi_Z + (2v_q a_q)(2v_e a_e){\chi_Z}^2 \end{pmatrix}$$

$$\chi_Z = \frac{1}{4\sin^2\theta_w \cos^2\theta_w}\frac{Q^2}{Q^2+M_Z^2}$$

Experimental Input to Cross Section Prediction

The NC DIS cross section depends on:

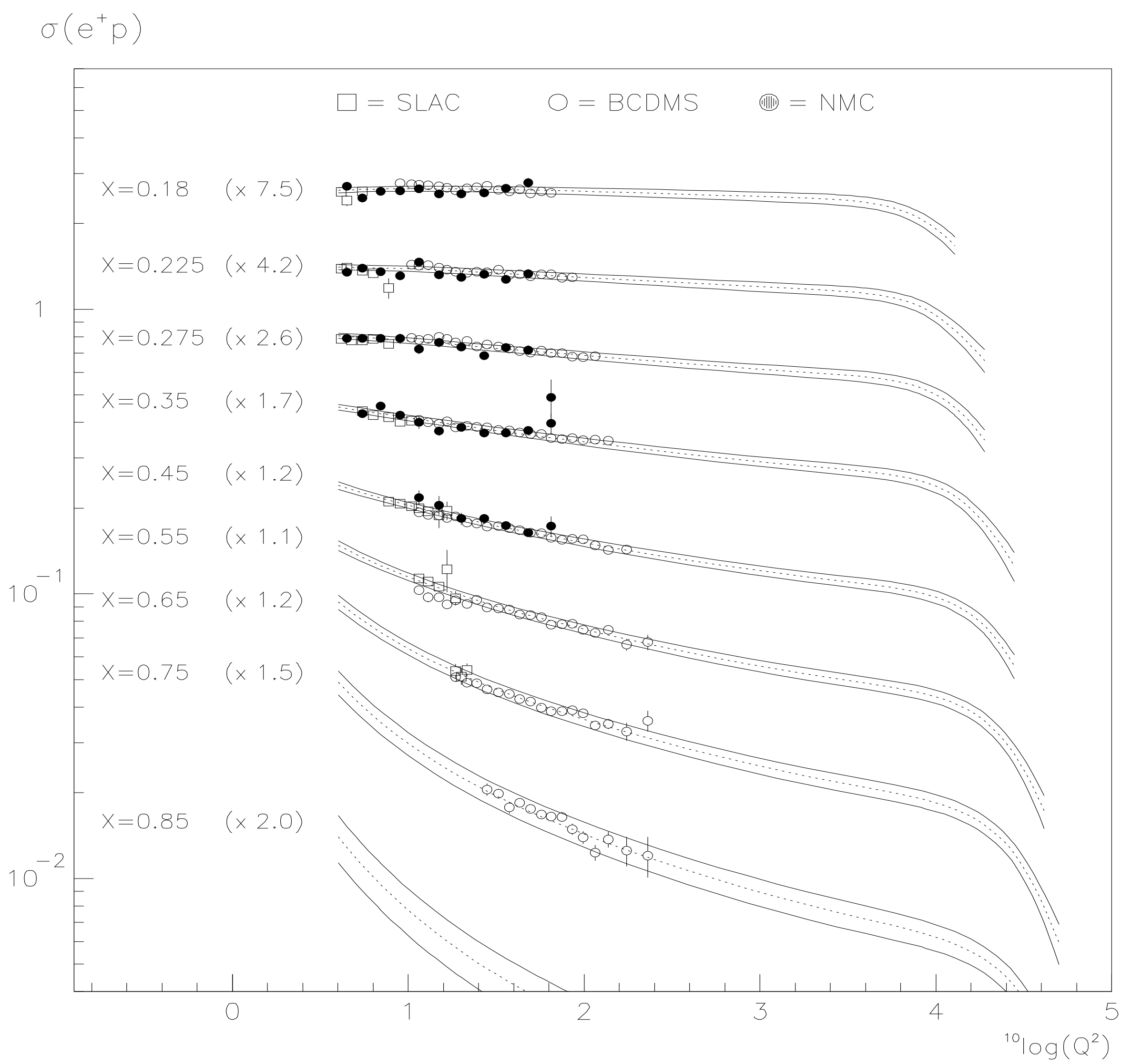
- well measured Electroweak parameters α, θ_w, M_Z
  $\longrightarrow$ uncertainties at the 0.25 % level.
- the quark structure in the proton, $q(x, Q^2)$, $\overline{q}(x, Q^2)$.



At high x, Q^2:
$\longrightarrow$ Quark densities are determined from a NLO DGLAP evolution of parton densities at higher x and lower Q^2.
$\longrightarrow$ The u quark dominates the cross section since $q \gg \overline{q}$ and $u > d$ and $|e_u| = 2|e_d|$.

ZEUS DGLAP Fit to SLAC, BCDMS, and NMC Data

$$\sigma(e^+p) \equiv \frac{xQ^4}{2\pi\alpha^2 Y_+}\frac{d^2\sigma_{NC}^{e^+p}}{dx dQ^2} = F_2 - \frac{y^2}{Y_+}F_L - \frac{Y_-}{Y_+}xF_3$$



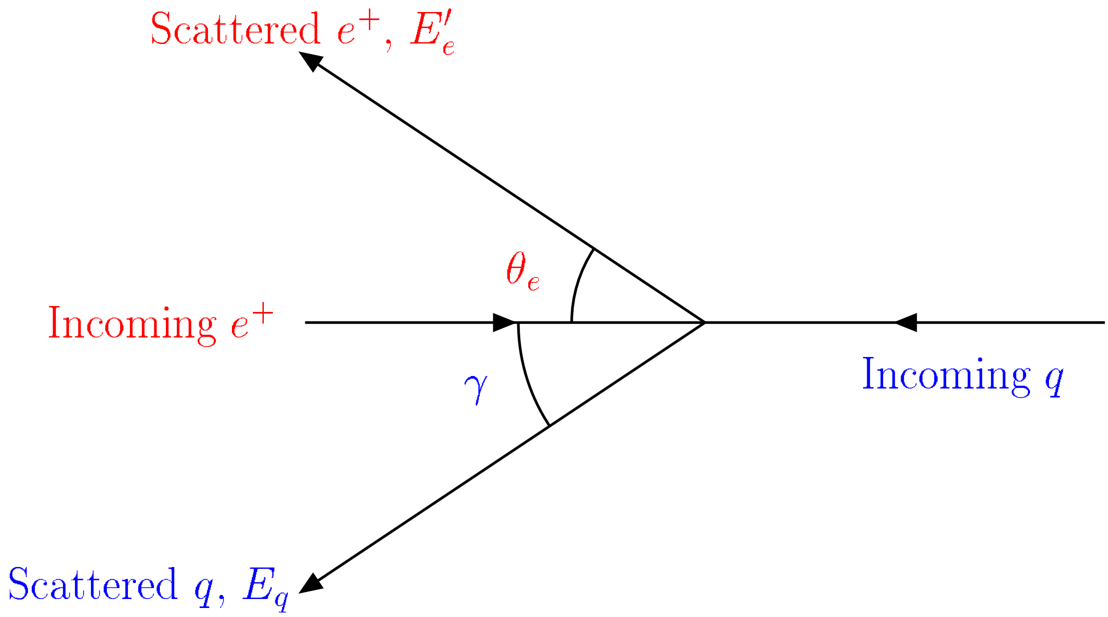
Error Bands include:

⟶ SLAC, BCDMS, NMC statistical and systematic errors

⟶ the effect of varying α_s between 0.112 and 0.122

NC DIS cross section predictions at high x, Q^2
accurate to $\approx 6.5\,\%$

Kinematic Reconstruction



ZEUS uses the Double Angle Method :

$$x_{\text{DA}} = \frac{E_e}{E_p} \frac{\sin\gamma}{(1-\cos\gamma)} \frac{\sin\theta}{(1-\cos\theta)}$$

$$y_{\text{DA}} = \frac{\sin\theta_e(1-\cos\gamma)}{\sin\gamma+\sin\theta_e-\sin(\gamma+\theta_e)}$$

$$Q^2_{\text{DA}} = s\; x_{\text{DA}}\; y_{\text{DA}}$$

insensitive to energy scale

The Electron Method is used as a cross–check:

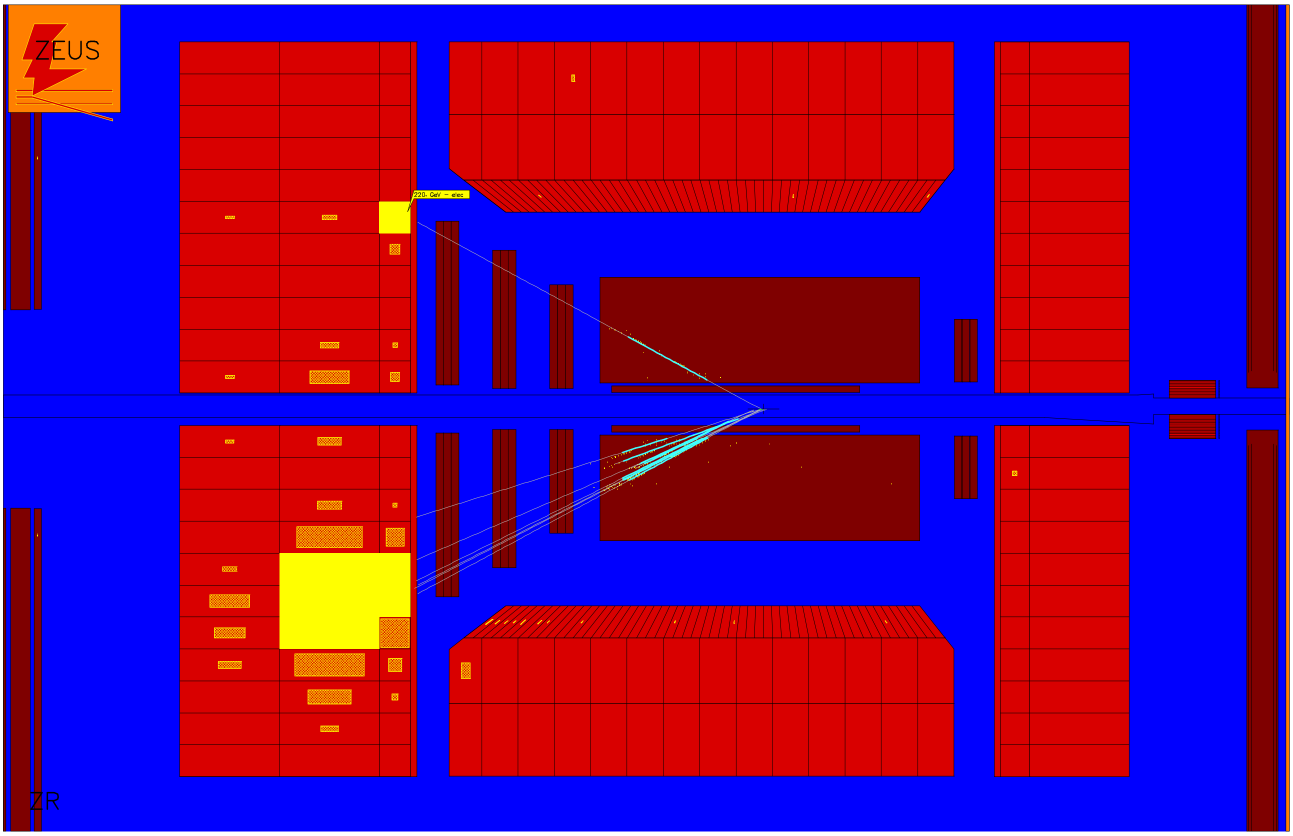
$$x_e = \frac{E_e}{E_p} \frac{E'_e(1+\cos\theta_e)}{2E_e - E'_e(1-\cos\theta_e)}$$

$$y_e = 1 - \frac{E'_e}{2E_e}(1-\cos\theta_e)$$

$$Q^2_e = s\; x_e\; y_e$$

does not use hadronic final state

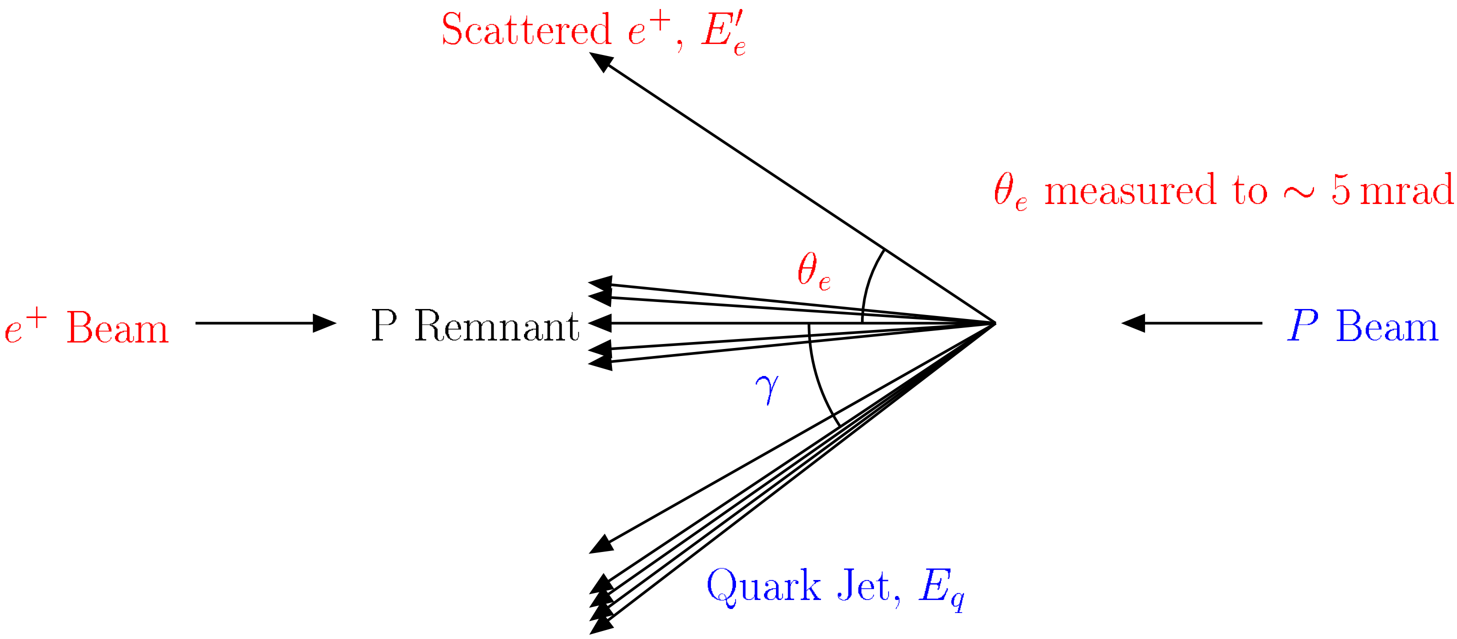
The ZEUS Detector



- **Calorimeter (CAL):**
  - Energy resolution: $\frac{\sigma(E)}{E} = \begin{cases} 18\%/\sqrt{E} & \text{em.} \\ 35\%/\sqrt{E} & \text{hadronic} \end{cases}$
  - Energy scale uncertainty: $\pm 3\%$

- **Central tracking detector (CTD):**
  - Angular acceptance: $15^\circ < \theta < 164^\circ$
  - Resolution: $\frac{\sigma(p_t^{\text{track}})}{p_t^{\text{track}}} = [0.005\, p_t^{\text{track}}\,(\text{GeV})] \oplus 0.016$
    (for full length tracks)

Reconstruction of Event Variables



$(E^i, p^i_X, p^i_Y, p^i_Z)$ = measured 4-momentum in calorimeter cell i.

$$p_t = \sqrt{\left(\sum_i p^i_X\right)^2 + \left(\sum_i p^i_Y\right)^2}$$

$$E - p_Z = \sum_i \left(E^i - p^i_Z\right)$$

$$E_t = \sum_i \sqrt{(p^i_X)^2 + (p^i_Y)^2}$$

$\sum_i$ = sum over all cells

$$(p_t)_{\rm had} = \sqrt{\left(\sum_i{}' p^i_X\right)^2 + \left(\sum_i{}' p^i_Y\right)^2}$$

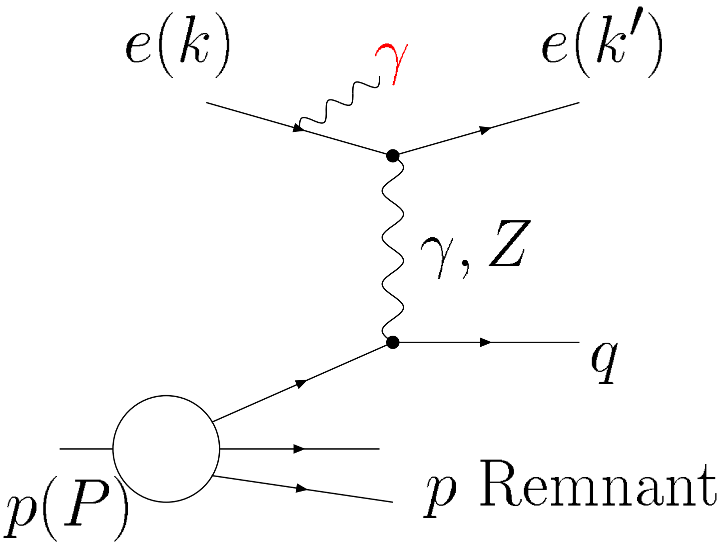
$$(E - p_Z)_{\rm had} = \sum_i{}' \left(E^i - p^i_Z\right)$$

$$\cos\gamma_{\rm raw} = \frac{(p_t)^2_{\rm had} - (E - p_Z)^2_{\rm had}}{(p_t)^2_{\rm had} + (E - p_Z)^2_{\rm had}}$$

$$E_q = \frac{(p_t)_{\rm had}}{\sin\gamma}$$

$\sum_i{}'$ = sum over all cells excluding e^+

Initial State Radiation and Kinematic Reconstruction



Initial State Radiation (ISR):

- mostly collinear with e beam
- can escape detection
- effectively reduces E_e
- events with ISR photons with $E_\gamma \gtrsim 7.5\,\mathrm{GeV}$ rejected by cuts

$$f_\gamma = \frac{E_\gamma}{E_e} = \text{fractional energy carried by } \gamma$$

$$x_{\mathrm{DA}} = x\,\frac{1}{1-f_\gamma} \qquad Q^2_{\mathrm{DA}} = Q^2\,\frac{1}{(1-f_\gamma)^2}$$

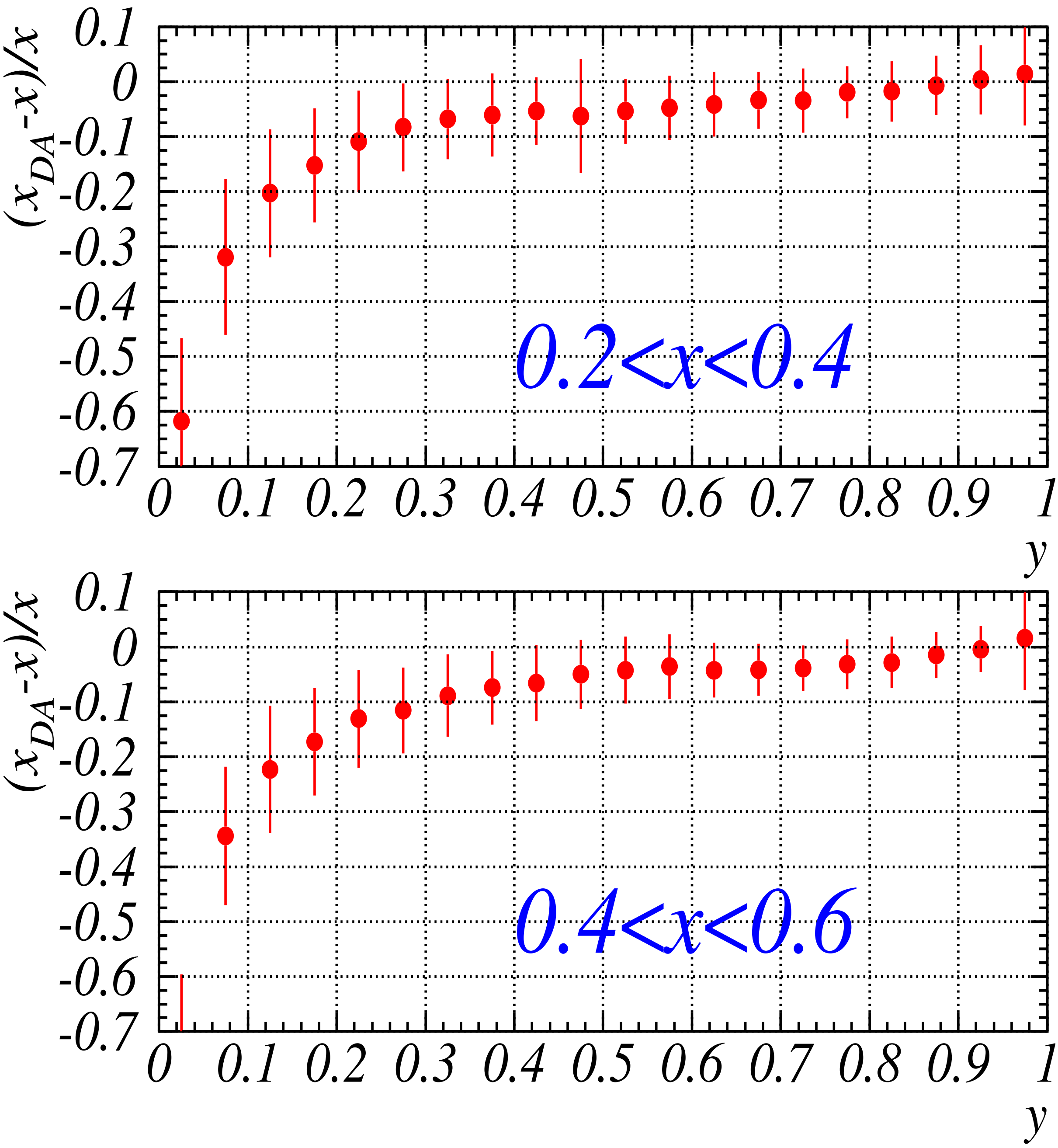
$$x_e = x\,\frac{(1-f_\gamma/y_e)}{(1-f_\gamma)} \qquad Q^2_e = Q^2\,\frac{1}{(1-f\gamma)}$$

Average shifts of true kinematic variables due to ISR
for events passing all cuts and having $0.4 < x < 0.6$, $y > 0.25$

$$\langle \delta x_{\mathrm{DA}} \rangle = \left\langle \frac{x_{\mathrm{DA}} - x}{x} \right\rangle = +1.7\% \qquad \langle \delta Q^2_{\mathrm{DA}} \rangle = \left\langle \frac{Q^2_{\mathrm{DA}} - Q^2}{Q^2} \right\rangle = +2.5\%$$

$$\langle \delta x_e \rangle = \left\langle \frac{x_e - x}{x} \right\rangle = -2.5\% \qquad \langle \delta Q^2_e \rangle = \left\langle \frac{Q^2_e - Q^2}{Q^2} \right\rangle = +1.8\%$$

Shifts and Resolution of Uncorrected x_{DA}



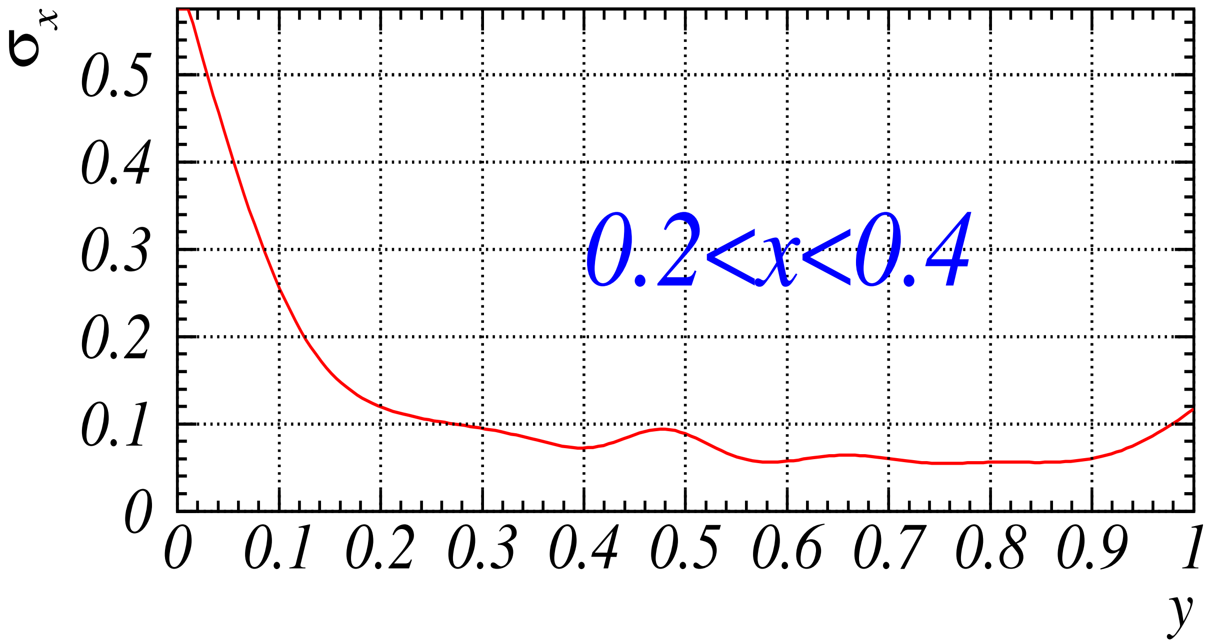
Problem at low $y \leftrightarrow$ small γ :

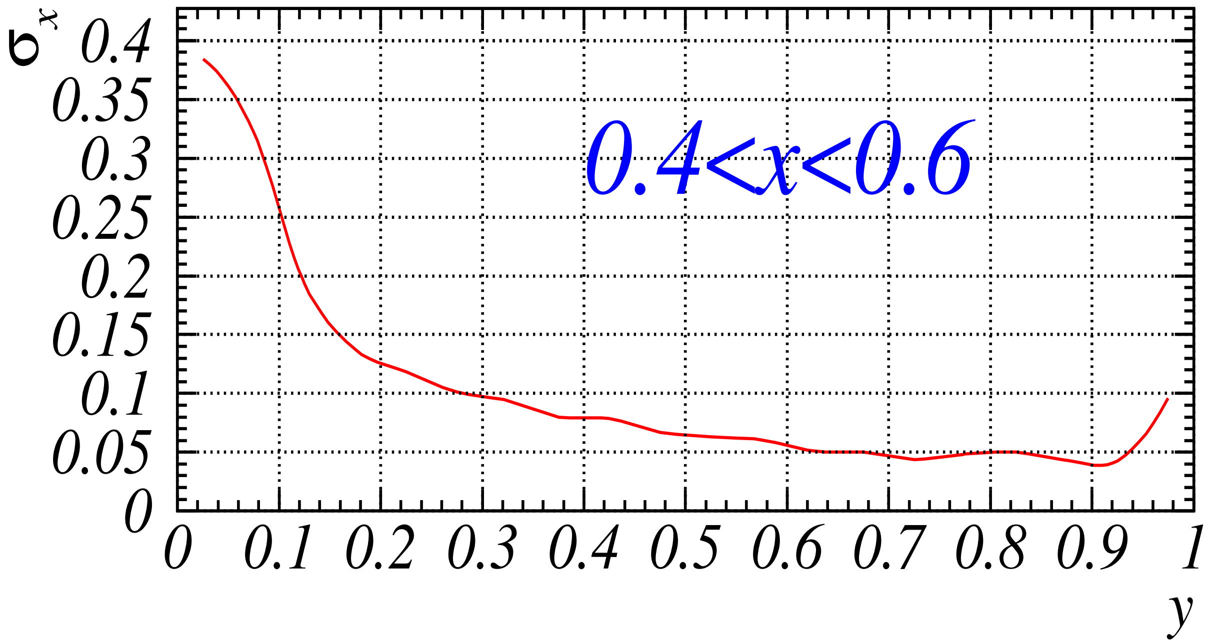
$\rightarrow$ At small γ, $\gamma_{\mathrm{raw}} > \gamma_{\mathrm{true}}$ on average.

$\rightarrow$ the uncorrected x_{DA} yields a biased x measurement.

We correct γ event by event.

Resolution of the Corrected x_{DA}





$$\sigma_x = \text{RMS of } \frac{x_{\mathrm{DA}} - x}{x}$$

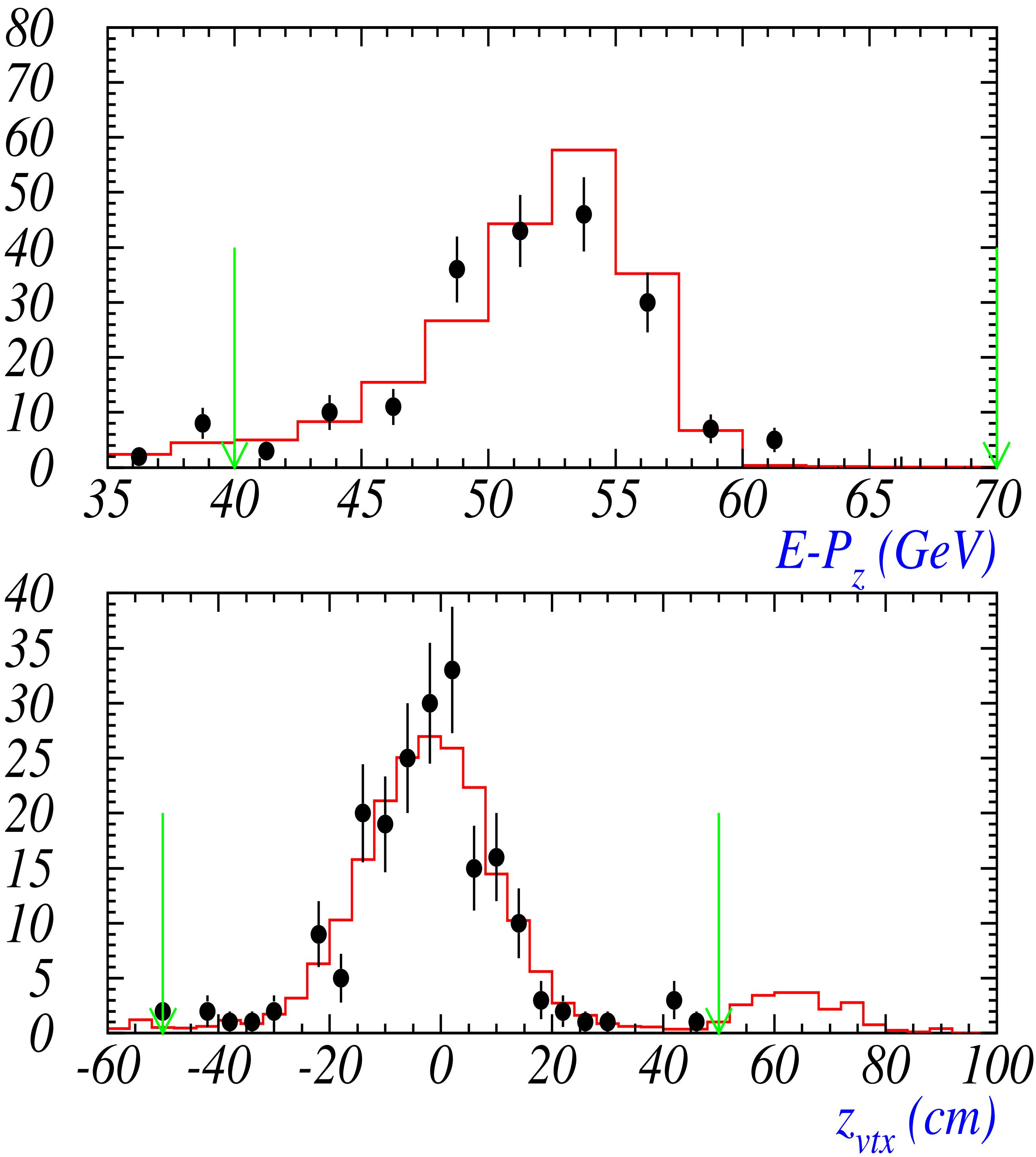
Effects of ISR are included.

Data Selection

Efficiencies are evaluated using NC MC events with $Q^2_{\mathrm{true}} > 5000\,\mathrm{GeV}$

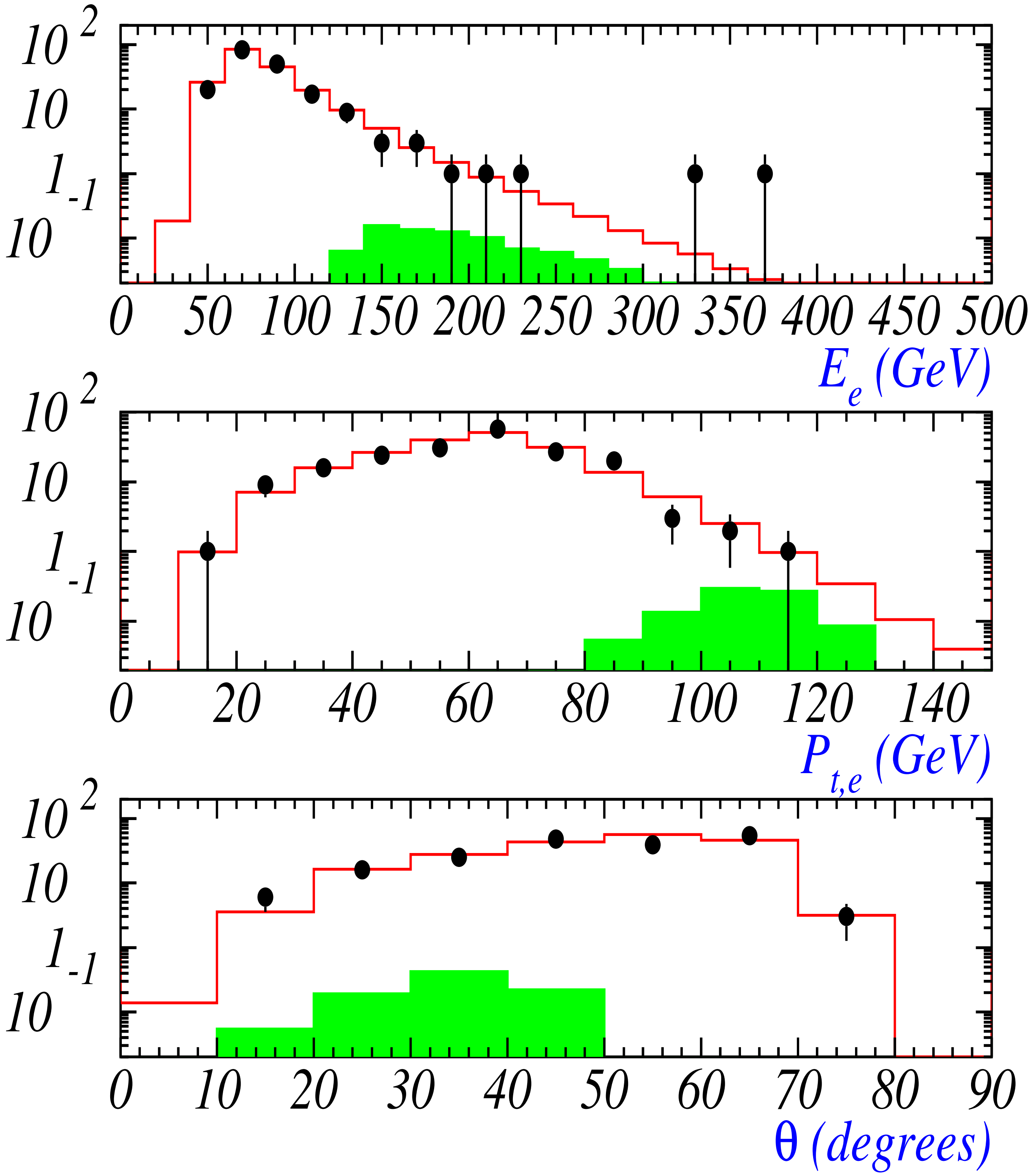
Selection	Efficiency
Vertex found	100.0 %
$\lvert Z_{\mathrm{vtx}}\rvert < 50\,\mathrm{cm}$	94.9 %
$40\,\mathrm{GeV} < E - p_Z < 70\,\mathrm{GeV}$ (lower cut rejects photoproduction or hard ISR)	92.0 %
Positron with $E'_e > 20\,\mathrm{GeV}$ identified in CAL	89.4 %
Positron isolation $E^{R=0.8}_{\mathrm{cone}} < 5\,\mathrm{GeV}$	87.2 %
If $\theta_e > 17.2^\circ$:	
track–cluster match (DCA $< 10\,\mathrm{cm}$)	85.7 %
If $\theta_e < 17.2^\circ$:	
$p_{t,e} > 30\,\mathrm{GeV}$	83.9 %
$E - p_Z > 44\,\mathrm{GeV}$ (tighter Photoproduction rejection)	83.8 %
Reject events with 2 isolated e.m. clusters (Compton rejection)	83.4 %
$Q^2_{\mathrm{DA}} > 5000\,\mathrm{GeV}^2$	81.5 %

Data/MC Comparison for $E - P_z$ and Vertex Z–Position.



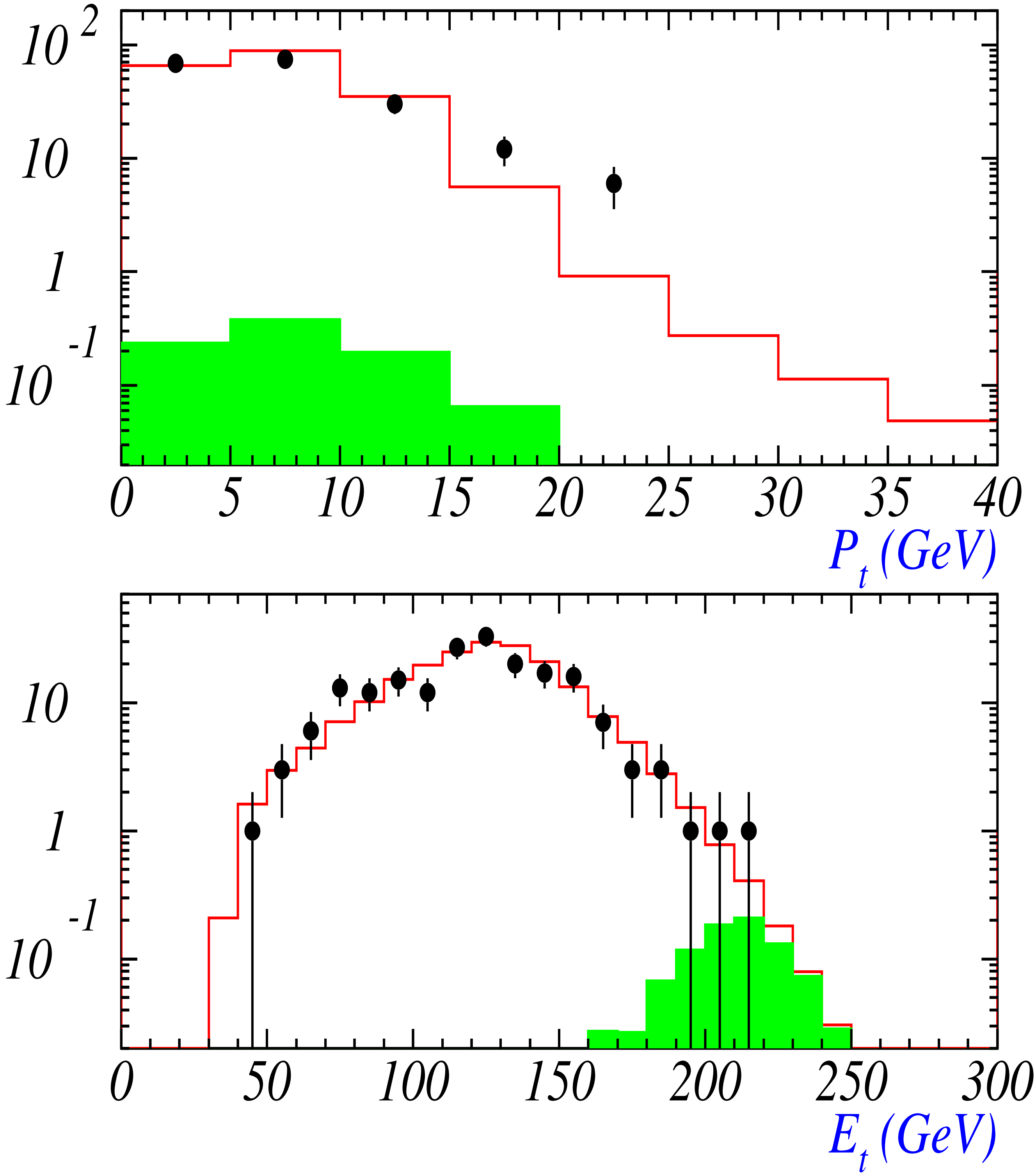
Data is plotted only for $|z_{vtx}| < 50\,\text{cm}$.

Data/MC Comparison for Final–State Positron



Green indicates MC distributions for $x_{\rm DA} > 0.55$ and $y_{\rm DA} > 0.25$.

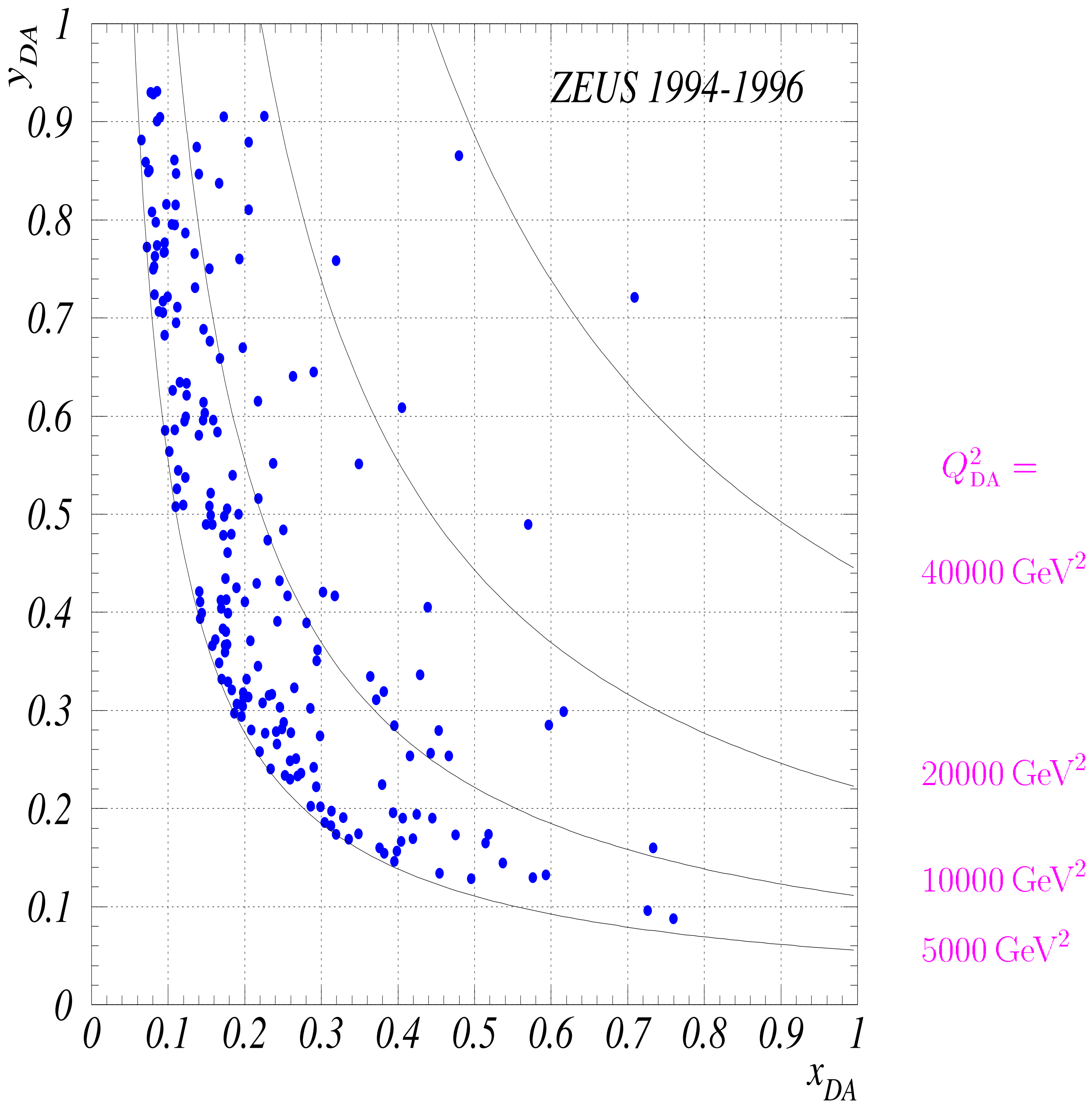
Data/MC Comparison for p_t and Energy



Green indicates MC distributions for $x_{\mathrm{DA}} > 0.55$ and $y_{\mathrm{DA}} > 0.25$.

Final Data Sample

The final sample consists of 191 events



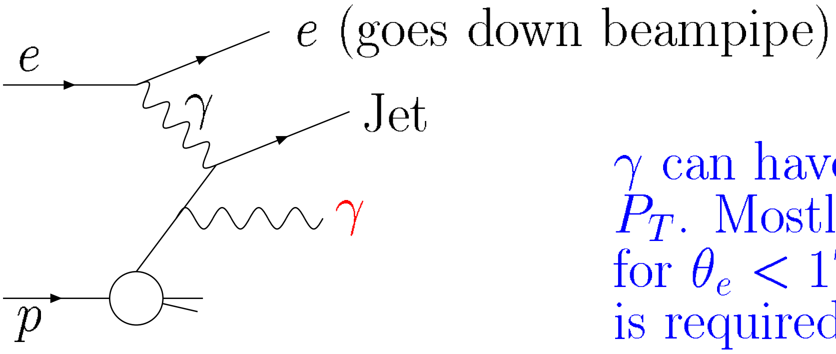
y_{DA} range	x_{DA} range 0.05 — 0.15	0.15 — 0.25	0.25 — 0.35	0.35 — 0.45	0.45 — 0.55	0.55 — 0.65	0.65 — 0.75	0.75 — 0.85	0.85 — 0.95	0.95 — 1.00
0.95 — 1.00	0.15	0.015	0.033	0.013	0.0055	0.0015	0.0012			
0.85 — 0.95	8.8 9	1.2 3	0.32	0.10	0.028 1	0.01	0.0034			
0.75 — 0.85	12 16	2.5 4	0.50 1	0.15	0.050	0.011	0.0039			
0.65 — 0.75	13 10	3.7 3	0.86	0.26	0.082	0.022	0.0054 1	0.0020		
0.55 — 0.65	15 12	6.1 3	1.65 3	0.46 1	0.15	0.046	0.0090	0.0024		
0.45 — 0.55	12 6	11 13	2.5 1	0.85	0.28	0.084 1	0.0208	0.0032		
0.35 — 0.45	4.6 3	18 17	5.5 6	1.75	0.52	0.16	0.0403	0.0093		
0.25 — 0.35		18 23	11 6	3.74 7	1.19 1	0.34 2	0.1104	0.0175	0.0066	
0.15 — 0.25		2.2 1	14 15	9.6 10	3.32 3	1.2	0.2784 1	0.0717	0.0077	
0.05 — 0.15				1.3 1	2.14 3	1.6 2	0.9052 1	0.3022 1	0.1216	

ZEUS 1994–1996 Selected Events

Event Date	11-Oct-94	03-Nov-95	12-Sep-96	12-Oct-96	21-Nov-96
E_t [GeV]	123.	217.	193.	204.	187.
p_t [GeV]	8.9	8.2	2.9	2.2	10.2
$E - p_Z$ [GeV]	47.8	53.2	49.7	50.2	49.1
E_q [GeV]	67.4	235.	270.	151.	276.
$\gamma_{\rm raw}$ [degrees]	69.0	28.1	19.9	40.7	19.7
E'_e [GeV]	324.	220.	149.	366.	134.
θ_e [degrees]	11.9	27.8	39.3	15.4	41.1
$[x_{\rm DA}]_{\rm raw}$	0.468	0.541	0.535	0.668	0.515
$[y_{\rm DA}]_{\rm raw}$	0.868	0.503	0.330	0.733	0.316
$(Q^2_{\rm DA})_{\rm raw}$ [10^4 GeV^2]	3.67	2.45	1.59	4.42	1.47
γ [degrees]	67.6	26.7	17.3	38.6	17.0
$x_{\rm DA}$	0.480	0.570	0.617	0.709	0.597
$\delta x_{\rm DA}$	0.035	0.029	0.054	0.034	0.053
$y_{\rm DA}$	0.865	0.490	0.299	0.721	0.285
$\delta y_{\rm DA}$	0.008	0.010	0.017	0.008	0.017
$Q^2_{\rm DA}$ [10^4GeV^2]	3.75	2.52	1.66	4.61	1.54
$\delta[Q^2_{\rm DA}]$ [10^4GeV^2]	0.26	0.07	0.05	0.16	0.04
x_e	0.525	0.536	0.562	0.605	0.443
δx_e	0.048	0.048	0.102	0.060	0.063
y_e	0.854	0.505	0.319	0.752	0.350
δy_e	0.018	0.024	0.039	0.021	0.032
Q^2_e [10^4GeV^2]	4.05	2.44	1.62	4.10	1.40
$\delta[Q^2_e]$ [10^4GeV^2]	0.31	0.11	0.09	0.30	0.07

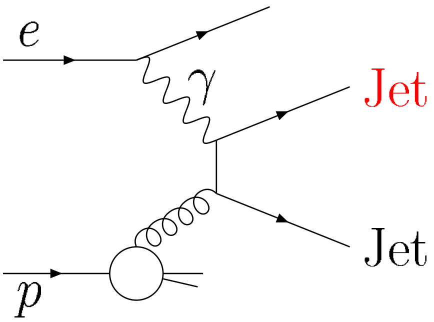
Backgrounds

Prompt Photon Production:

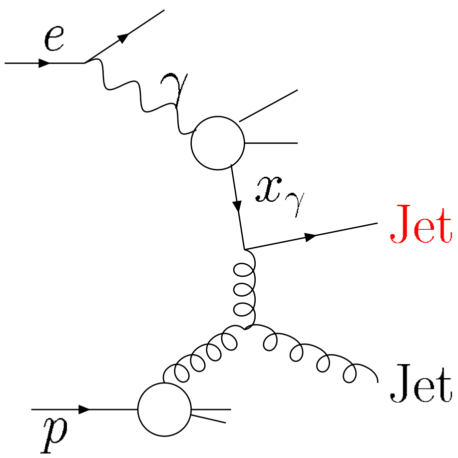


γ can have large energy, and P_T. Mostly a background for $\theta_e < 17.2°$ where no track is required.

Photoproduction of Dijets:



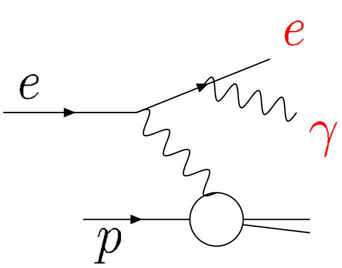
Direct Photoproduction



Resolved Photoproduction

Background when jet satisfies electron requirements

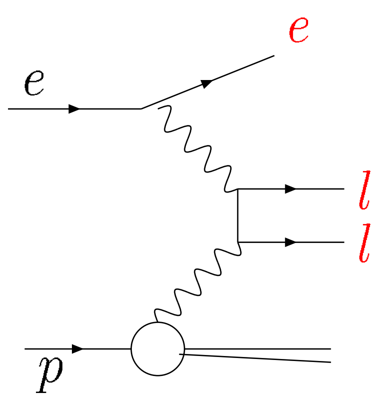
QED Compton:



e, γ can be produced with large transverse momentum

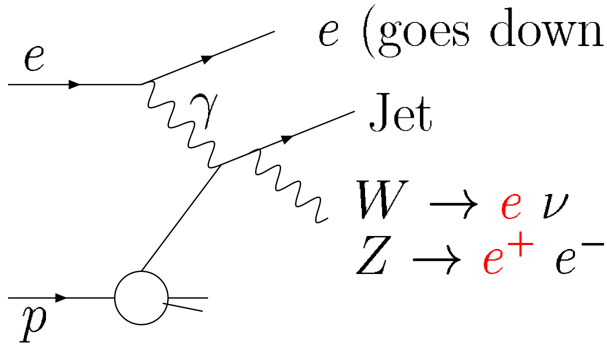
Backgrounds — continued

Dilepton Photoproduction:



l can have large P_T.
Background if e or l misidentified

Weak Boson Production:



Can produce e with large transverse momentum

Expected cross sections for backgrounds
(< indicates 90% confidence level upper limit)

Background Process	Cross–section [fb] $x > 0.45$	$x > 0.55$
$\gamma p \to \gamma X$	0.28	0.28
$\gamma p \to$ dijets	< 1.8	< 1.8
$ep \to e\gamma X$	< 0.2	< 0.2
$\gamma\gamma \to \ell\ell$	< 0.1	< 0.1
$W \to e\nu$	< 0.5	< 0.5
Accepted NC DIS	165	46

Systematic errors in SM predictions

Luminosity uncertainty	2.3%
Electroweak parameters	0.25%
Radiative corrections	2%

Evaluated with HERACLES and HECTOR
ISR E_γ spectrum in LUMI monitor agrees well with MC.

Detector simulation	4.4%
	$\sim 2\%$ for $y_{\rm DA} > 0.2$
	$4 - 7\%$ for $y_{\rm DA} > 0.5$

Effects included:

- variation of $\pm 3\%$ in the FCAL, BCAL energy scales
- smearing of the electron scattering angle (5 mrad)
- variation in the electron finding efficiency
  - variation of HAC fraction of electron candidate
  - variation of lateral energy profiles of the electron
  - variation of non–electron energy in the cone
  - variation of track–cluster matching angles
  - variation of track momentum resolution

Systematic errors in SM predictions — continued

Structure Functions	6.5%

Uncertainties from structure function fit:

Fixed–target experimental uncertainties	$\pm 6.2\%$
$0.112 < \alpha_s < 0.122$	$\pm 1.9\%$

Cross checks on SF uncertainties include:

$10\% <$ strange fraction $< 30\%$	small
Uncertainties in charm evolution	$< 0.5\%$
GRV94, MRSA, CTEQ3 comparison	$\pm 2.0\%$
GRV94 NLO versus LO	$+1.0\%$
High–x gluon (CDF inspired, CTEQ4 HJ)	$+1.9\%$

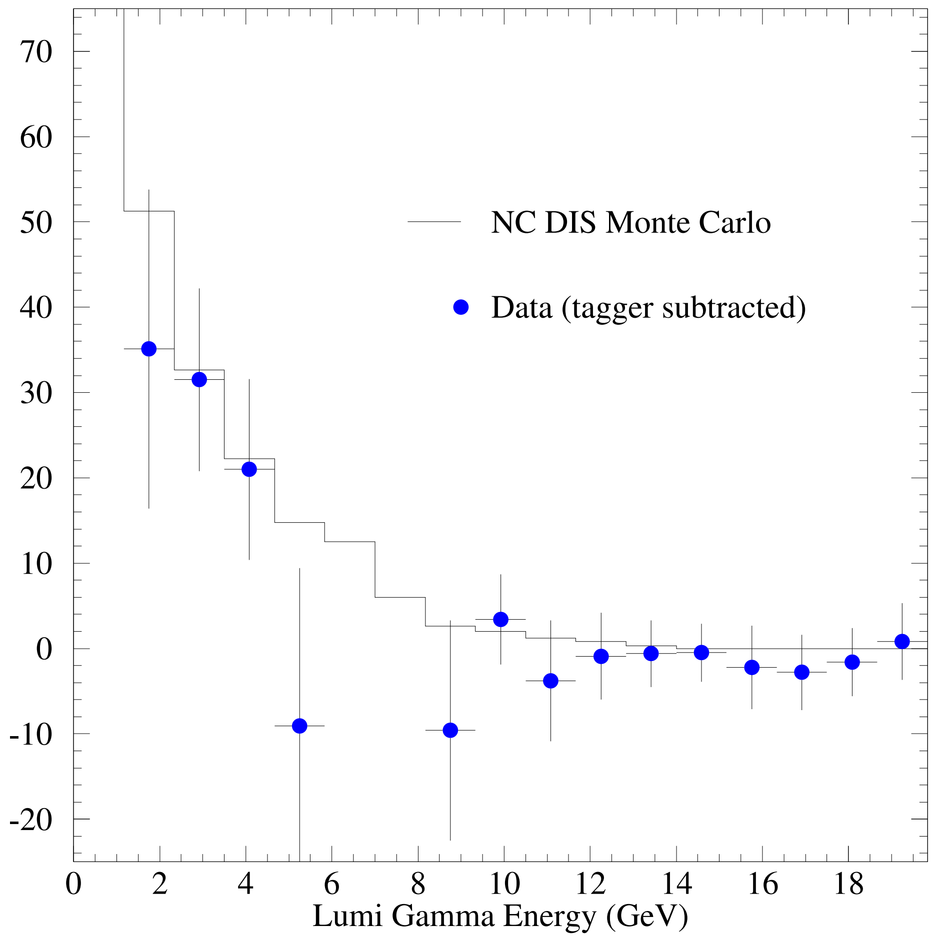
Summary of systematic errors in SM predictions

for $x > 0.55$ and $y > 0.25$

Luminosity measurement	2.3%
Electroweak parameters	0.25%
Radiative corrections	2%
Detector simulation	4.4%
Structure Functions	6.5%
Total	8.4%

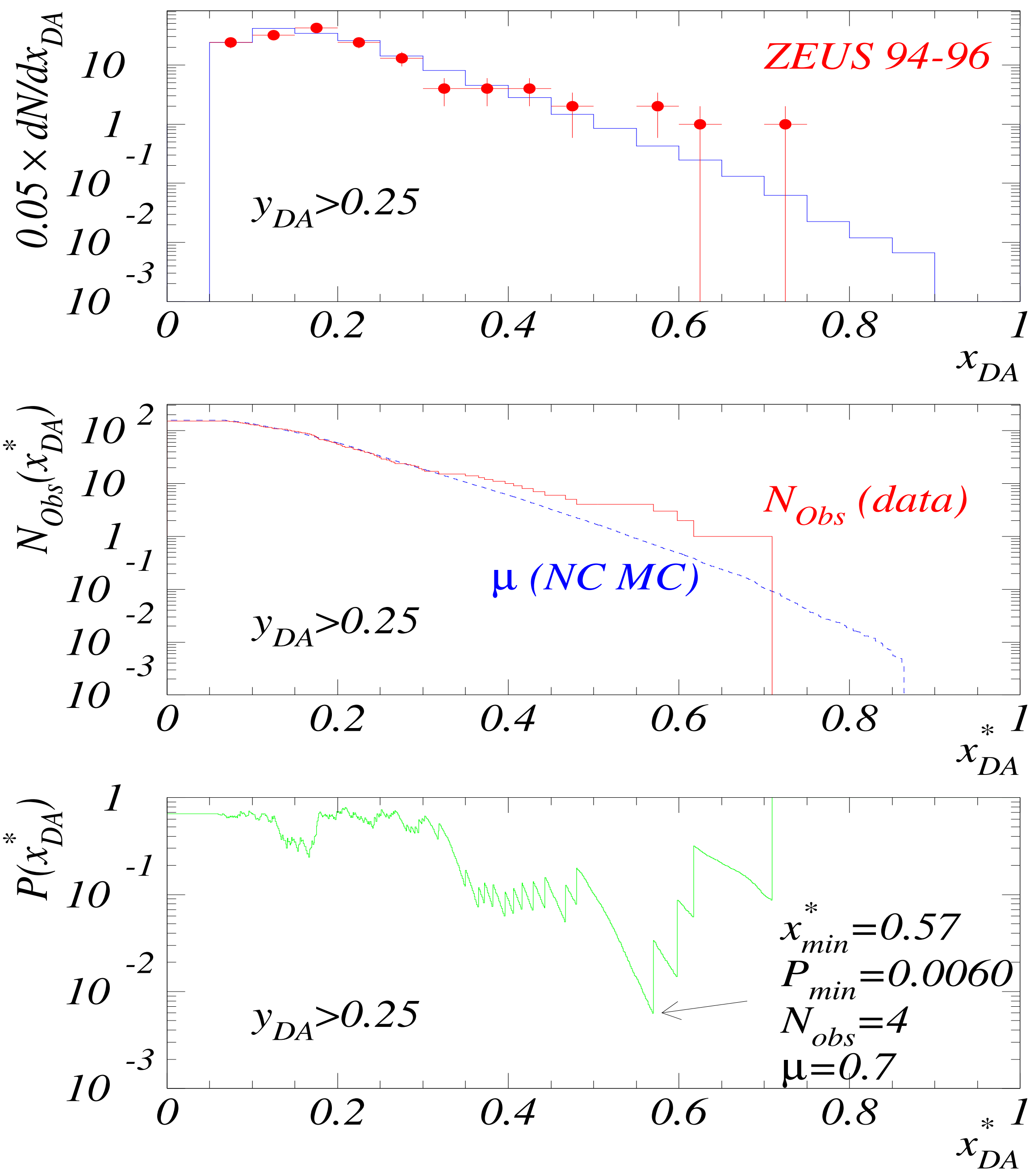
Comparison between data and MC of the ISR photon energy spectrum

- Data/MC comparison of E_γ spectrum in the luminosity monitor photon calorimeter (LUMI$-\gamma$).
- Select NC events with $Q^2_{\rm DA} > 400\,{\rm GeV}^2$ and $E_{{\rm LUMI}-\gamma} > 1.2\,{\rm GeV}$ (460 events out of 5630).
- Subtract rate of random bremsstrahlung conincidences using events in which the positron is tagged in the 44 m ($E_\gamma < 6\,{\rm GeV}$) or 35 m ($E_\gamma \approx 7 - 25\,{\rm GeV}$) calorimeters.
- The resulting E_γ spectrum agrees well with the MC prediction, with 88 ± 24 events measured and 105 expected in the range $1.2\,{\rm GeV} < E_{{\rm LUMI}-\gamma} < 4.8\,{\rm GeV}$.



Significance Analysis

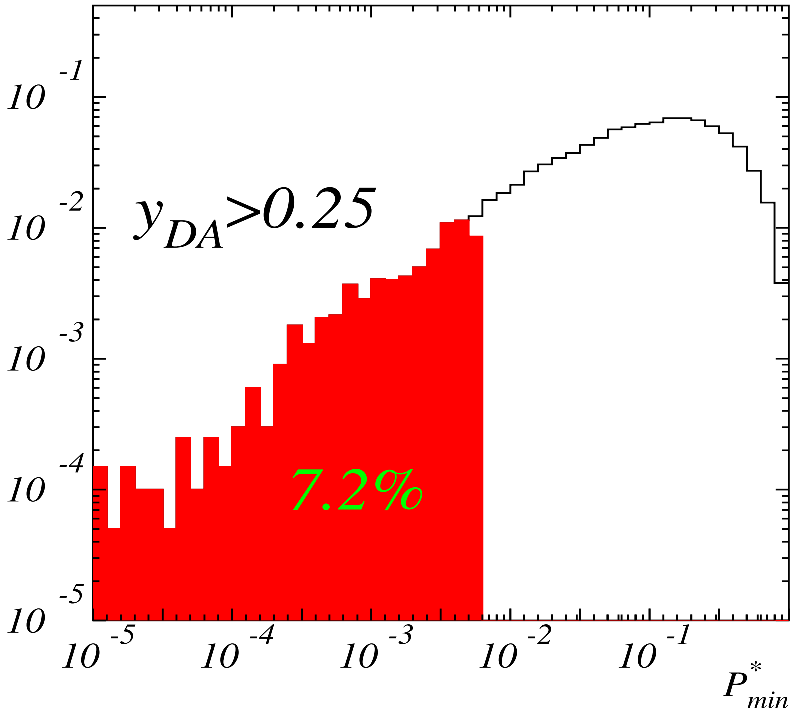
Excess in x



$$N_{\rm obs}(x^*_{\rm DA}) = \int_{x^*_{\rm DA}}^{1} dx_{\rm DA}\, dN/dx_{\rm DA}$$

$$\mathcal{P}(x^*_{\rm DA}) = \sum_{n=N_{obs}}^{\infty} e^{-\mu} \frac{\mu^n}{n!}$$

Excess in x — continued



Minimal Poisson probabilities of the x_{DA} distributions for different y_{DA} cuts

y_{DA} range	$\mathcal{P}_{min}(x^*_{\text{DA}})$ [%]	x^*_{DA}	N_{obs}	μ	P_{SM} [%]
$y_{\text{DA}} > 0.05$	1.61	0.708	4	0.95	16.0
$y_{\text{DA}} > 0.15$	2.57	0.708	2	0.25	23.0
$y_{\text{DA}} > 0.25$	0.60	0.569	4	0.71	7.2
$y_{\text{DA}} > 0.35$	3.38	0.708	1	0.034	26.6
$y_{\text{DA}} > 0.45$	1.32	0.569	2	0.17	12.7
$y_{\text{DA}} > 0.55$	0.96	0.708	1	0.010	9.5
$y_{\text{DA}} > 0.65$	0.50	0.708	1	0.005	5.0

$\mathcal{P}_{min}(x^*_{\text{DA}})$ = the minimal probability

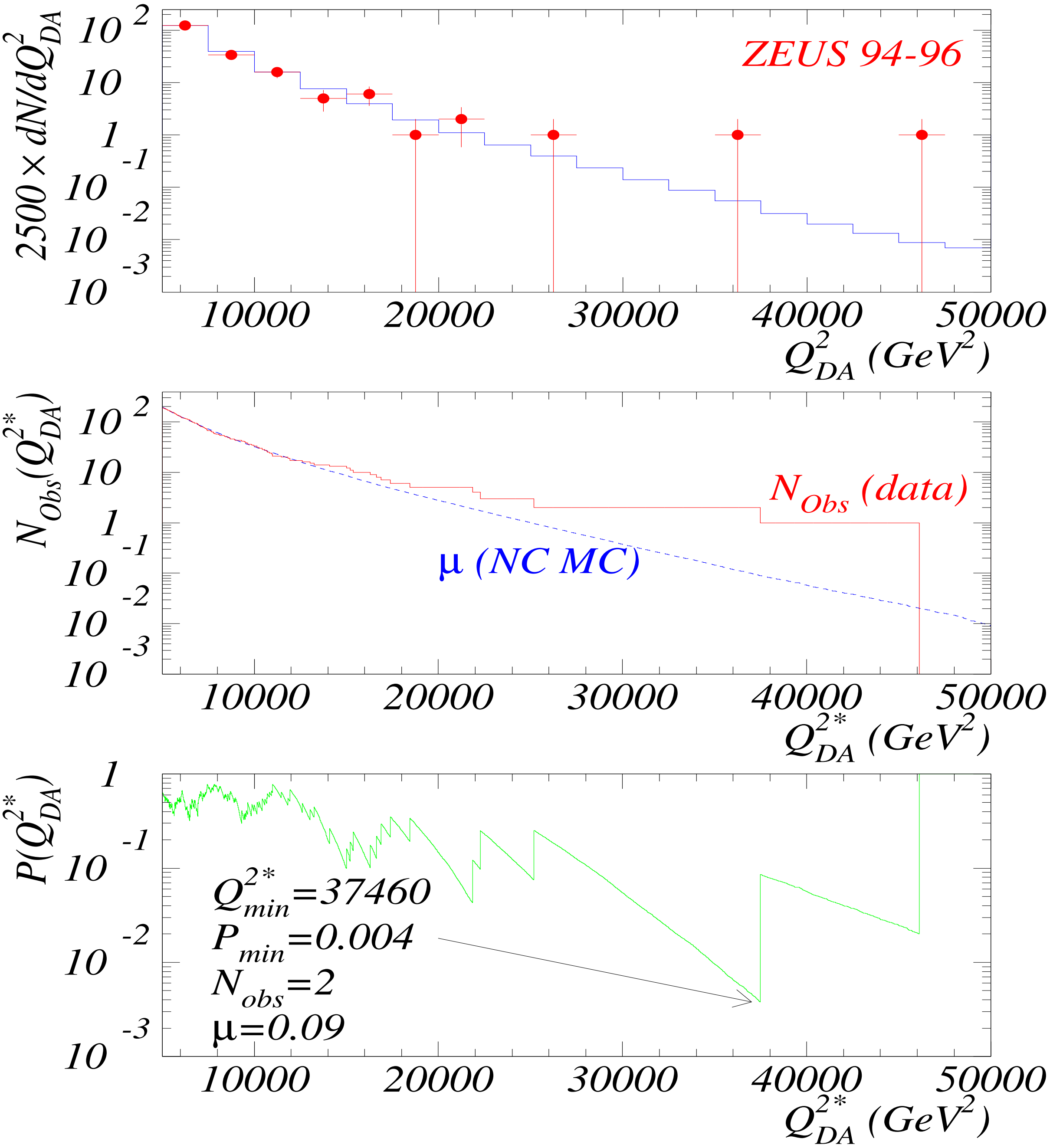
x^*_{DA} = the value of x_{DA} where it occurs

N_{obs} = number of events observed with $x_{\text{DA}} > x^*_{\text{DA}}$

μ = expected number of events with $x_{\text{DA}} > x^*_{\text{DA}}$

P_{SM} = prob. that a simulated experiment yields a lower $\mathcal{P}_{min}(x^*_{\text{DA}})$ than observed

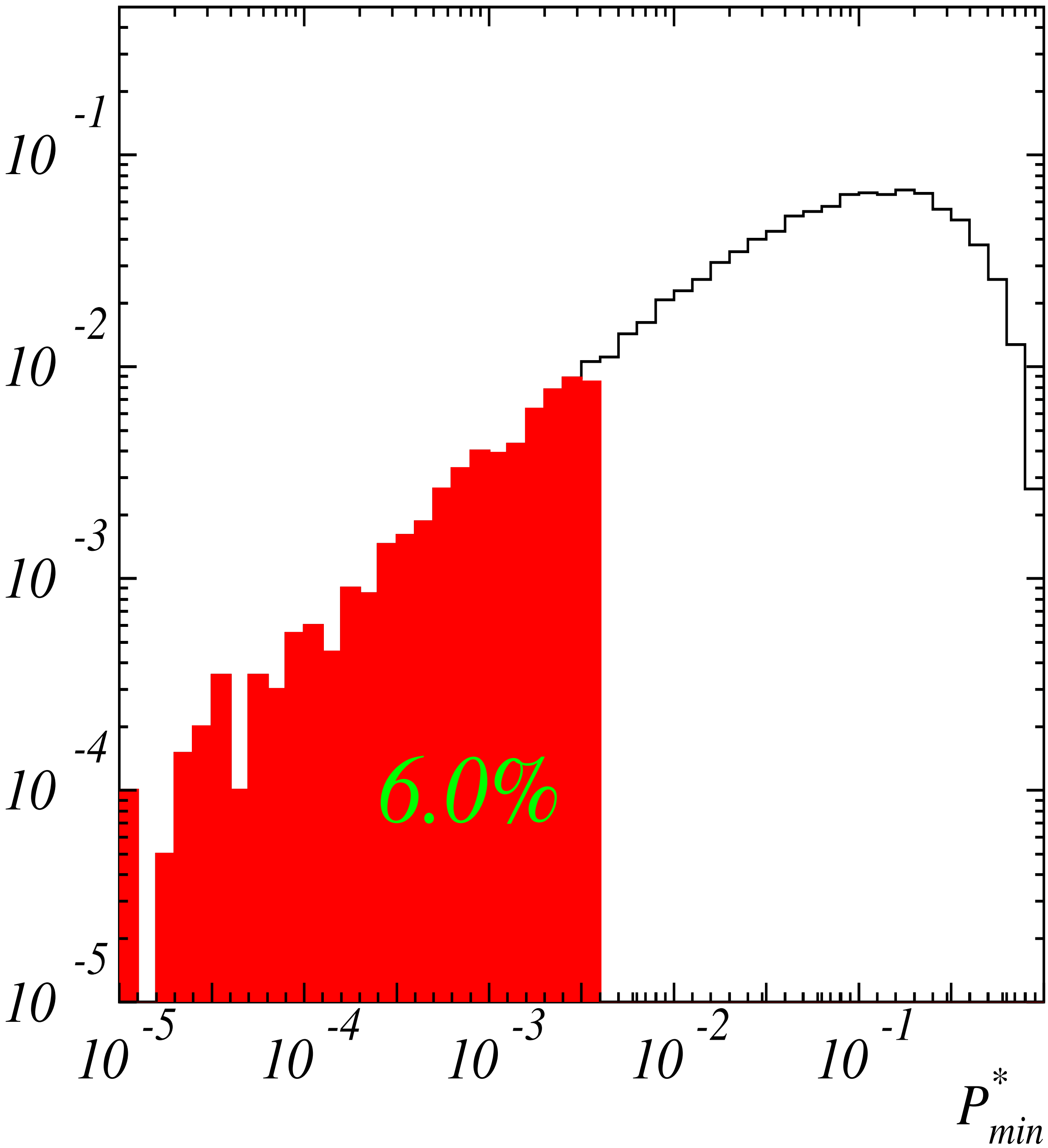
Excess in Q^2



$$N_{\rm obs}((Q^2_{\rm DA})^*) = \int_{(Q^2_{\rm DA})^*}^{1} dx_{\rm DA}\, dN/dx_{\rm DA}$$

$$\mathcal{P}((Q^2_{\rm DA})^*) = \sum_{n=N_{\rm obs}}^{\infty} e^{-\mu}\,\frac{\mu^n}{n!}$$

Excess in Q^2 – continued



The probability for a simulated experiment to obtain $\mathcal{P}_{min}((Q^2_{\mathrm{DA}})^*) < 0.004$ is 6.0%.

2–Dimensional Likelihood Test

- Divide x-y plane into 10×10 grid
- Assign Poisson probability to i^{th} bin

$$\mathcal{P}_i = e^{-\mu_i} \frac{\mu_i^{N_i}}{N_i!} \qquad \begin{array}{l} N_i = \text{Number observed} \\ \mu_i = \text{Number expected} \end{array}$$

- Form likelihood over a subset of bins $\mathcal{R}$

$$\mathcal{L}_{\mathcal{R}} = \Pi_{i \in \mathcal{R}} \, \mathcal{P}_i$$

- Evaluate the significance by performing many Monte Carlo experiments

$$\mathcal{L}_{\mathcal{R}} = \Pi_{i \in \mathcal{R}} \, \mathcal{P}_i^{(m)} \qquad \text{for } m^{\text{th}} \text{ experiment}$$

- Significance $\equiv$ Probability $(\mathcal{L}_{\mathcal{R}} \leq \mathcal{L}_{\mathcal{R}}{}^{\text{obs}})$

2–Dimensional Likelihood Test – continued

ZEUS 94-96

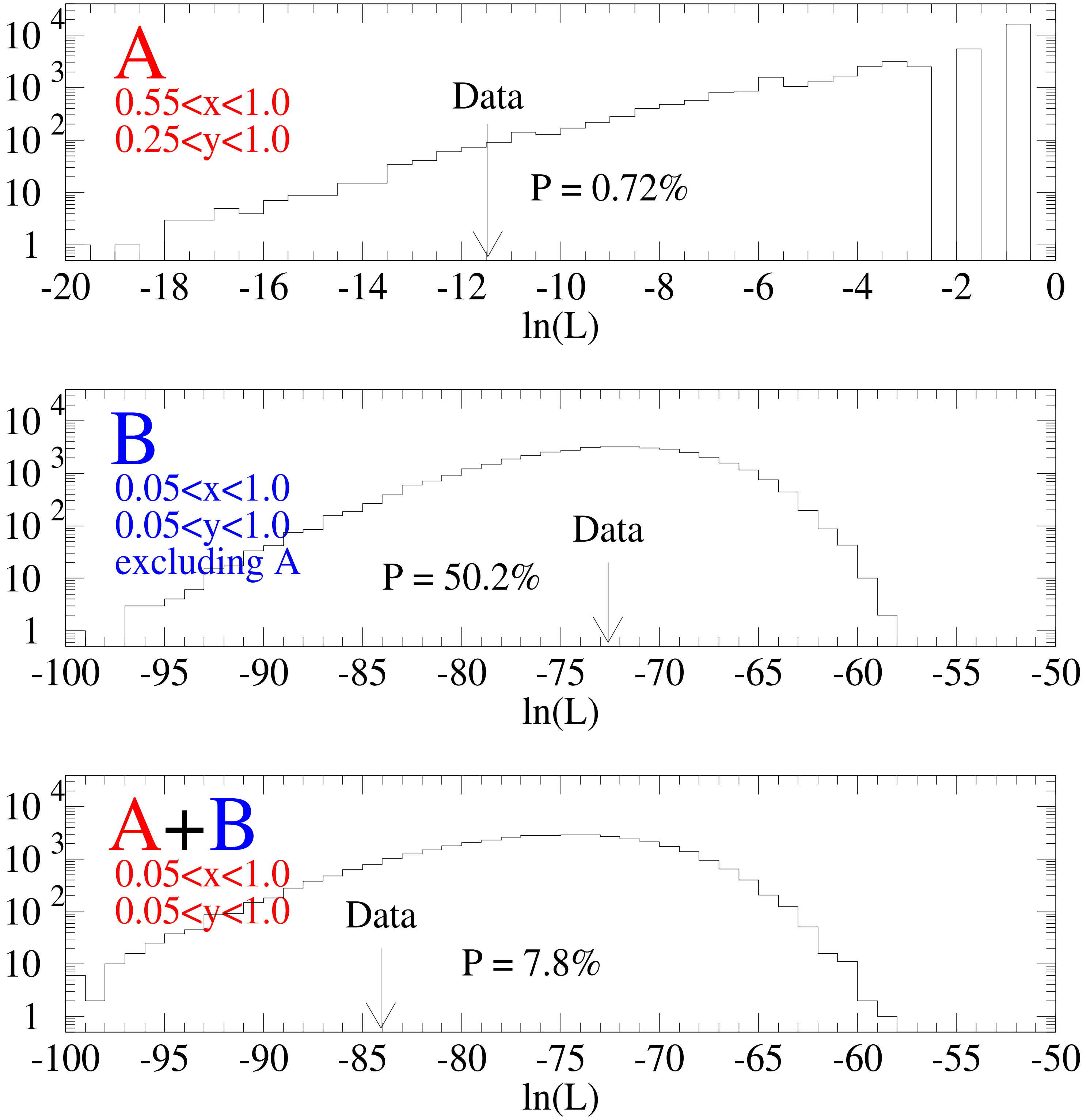
y_{DA} \ x_{DA}	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
1	0.15 / 0	0.015 / 0	0.033 / 0	0.013 / 0	0.0055 / 0	0.0015 / 0	0.0012 / 0	0 / 0	0 / 0	0 / 0
0.9	8.8 / 9	1.2 / 3	0.32 / 0	0.1 / 0	0.028 / 1	0.01 / 0	0.0034 / 0	0 / 0	0 / 0	0 / 0
0.8	12 / 16	2.5 / 4	0.5 / 1	0.15 / 0	0.05 / 0	0.011 / 0	0.0039 / 0	0 / 0	0 / 0	0 / 0
0.7	13 / 10	3.7 / 3	0.86 / 0	0.26 / 0	0.082 / 0	0.022 / 0	0.0054 / 1	0.002 / 0	0 / 0	0 / 0
0.6	15 / 12	6.1 / 3	1.6 / 3	0.46 / 1	0.15 / 0	0.046 / 0	0.009 / 0	0.0024 / 0	0 / 0	0 / 0
0.5	12 / 6	11 / 13	2.5 / 1	0.85 / 0	0.28 / 0	0.085 / 1	0.021 / 0	0.0032 / 0	0 / 0	0 / 0
0.4	4.6 / 3	18 / 17	5.5 / 6	1.7 / 0	0.52 / 0	0.16 / 0	0.04 / 0	0.0093 / 0	0 / 0	0 / 0
0.3	0 / 0	18 / 23	11 / 6	3.7 / 7	1.2 / 1	0.34 / 2	0.11 / 0	0.018 / 0	0.0066 / 0	0 / 0
0.2	0 / 0	2.2 / 1	14 / 15	9.6 / 10	3.3 / 3	1.2 / 0	0.28 / 1	0.072 / 0	0.0077 / 0	0 / 0
0.1	0 / 0	0 / 0	0 / 0	1.3 / 1	2.1 / 3	1.6 / 2	0.91 / 1	0.3 / 1	0.12 / 0	0 / 0

A

B

2–Dimensional Likelihood Test – continued

Likelihood Distributions



Conclusions

1. We have searched for deviations from Standard Model expectations in $eP \rightarrow eX$ scattering at high Q^2 and high x.
   - The Neutral Current DIS cross section predictions are known to an accuracy at the level of 6%.
   - The events are experimentally very clean. There are no significant backgrounds.

2. In a sample with integrated luminosity 20.1 pb^{-1}, we find:

   2 events with $Q^2 > 35\,000\,\text{GeV}^2$ where only 0.145 ± 0.013 are expected, corresponding to a Poisson probability of 0.96 %.

   4 events for ($x > 0.55$, $y > 0.25$) where only 0.91 ± 0.08 are expected, corresponding to a Poisson probability of 1.4 %.

   An analysis using a large ensemble of simulated Standard Model experiments indicates that statistical fluctuations at these levels would occur

   at *some* Q^2 for ($Q^2 > 5000$ GeV^2) in 6 % of all experiments;

   at *some* x for ($y > 0.25, Q^2 > 5000$ GeV^2) in 7.6 % of all experiments.

3. A likelihood analysis sensitive to the event distribution in (x, y) gives probabilities of

   0.72 % for the events in the region ($x > 0.55$, $y > 0.25$),

   50.2 % for the events in the region ($x > 0.05$, $y > 0.05$), excluding the region ($x > 0.55$, $y > 0.25$), indicating that the data are in good agreement with Standard Model expectations at lower x and Q^2.

4. The effect is particularly interesting because it occurs in an unexplored kinematic region.