Search for a Deviation from the Standard Model in $ep \to eX$ Scattering at High x and Q^2 using the ZEUS Detector at HERA

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ZEUS 1994-1996 Integrated Luminosity = 20.1pb^{-1}

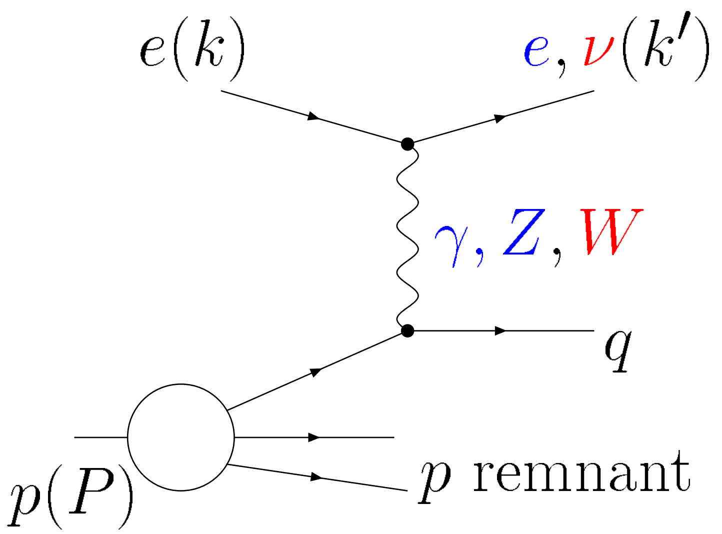
$\to$ sensitive to $\sigma \sim 50$ fb

$x = 0.5, \sqrt{s} = 300$ GeV $\to M = \sqrt{sx} = 212$ GeV

$Q^2 = 10000\text{GeV}^2 \to$ spatial resolution $= 2 \times 10^{-16}$cm

- Standard Model Deep Inelastic ep Scattering
- Neutral Current DIS Kinematics and Reconstruction
- Data Selection
- Final Data Sample
- Backgrounds
- Theoretical and Experimental Systematic Errors
- Significance Analysis
  1. Search for an excess in the x spectrum
  2. Search for an excess in the Q^2 spectrum
  3. Likelihood of the (x, y) distribution
- Conclusions

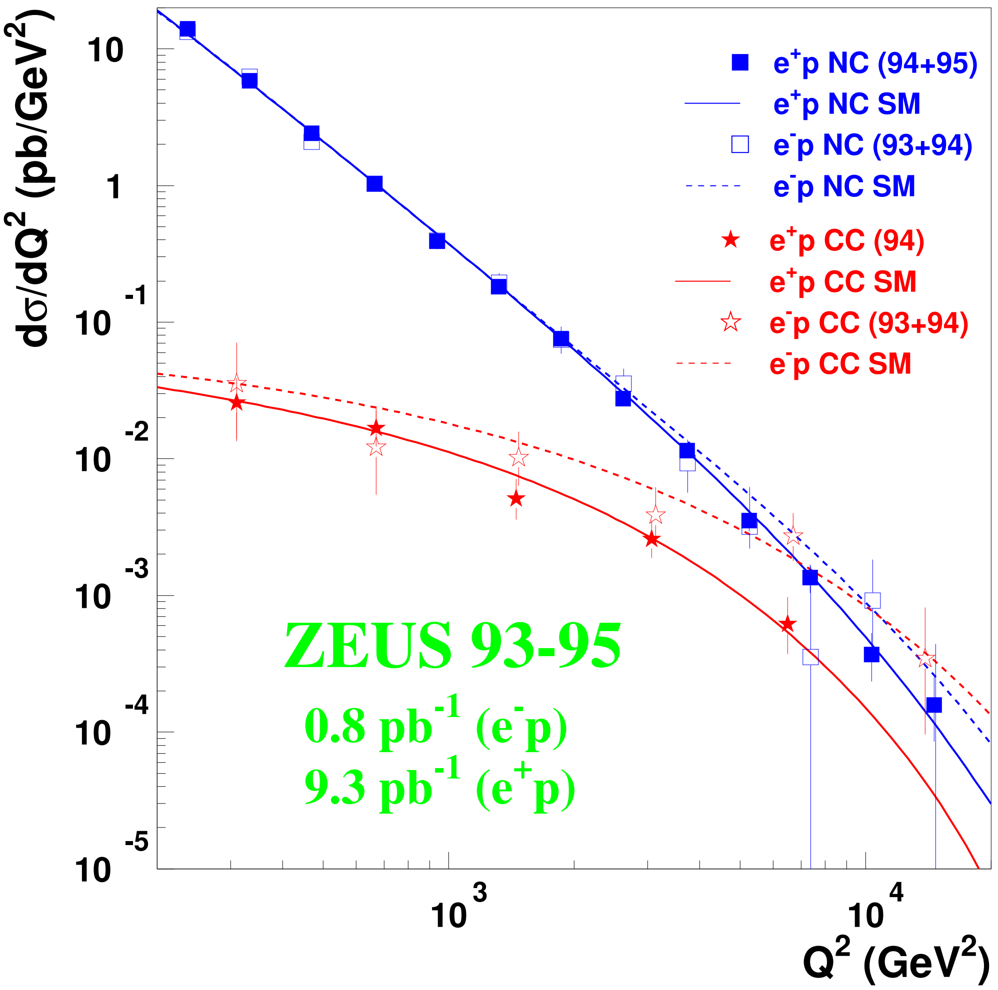
Deep Inelastic ep Scattering



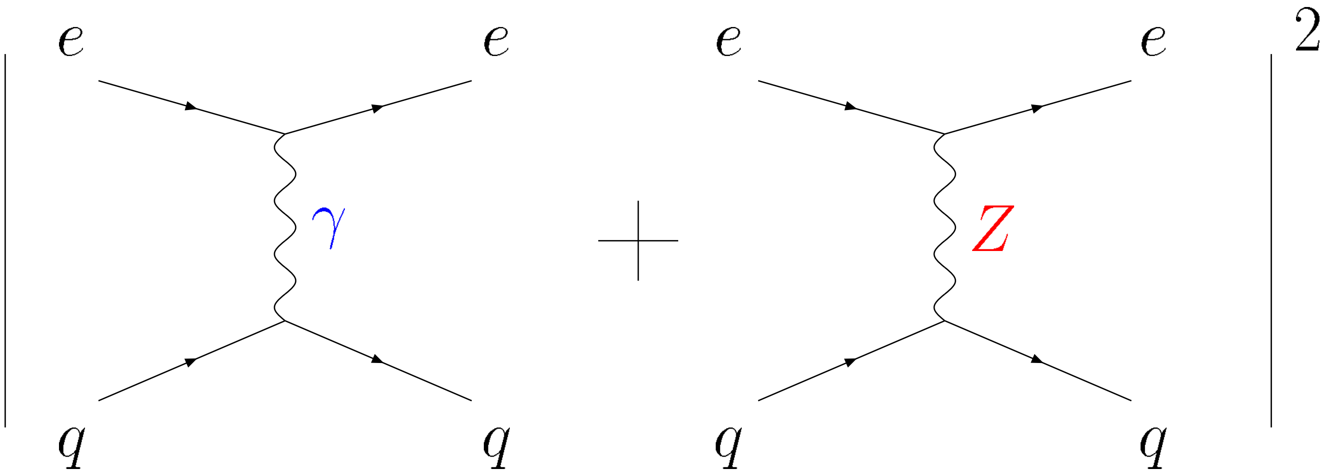
$$Q^2 = -(k-k')^2$$

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

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



Standard Model reaction: t-channel γ or Z exchange.



The cross section is

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

where

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

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

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

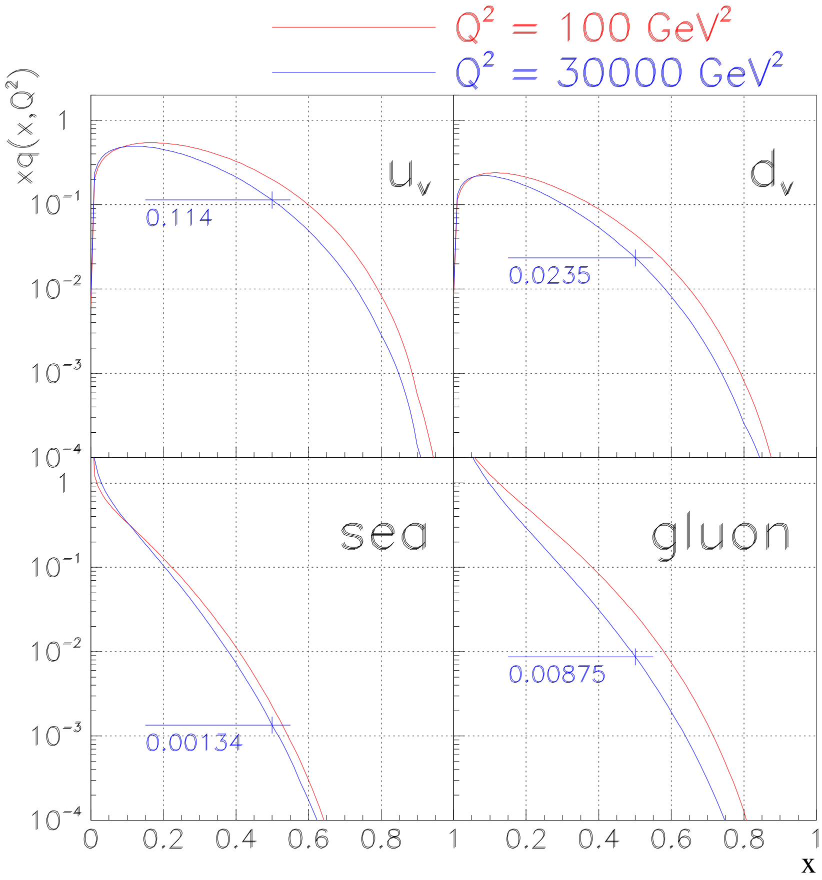
and

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

Standard Model – continued

The NC DIS cross section depends on:

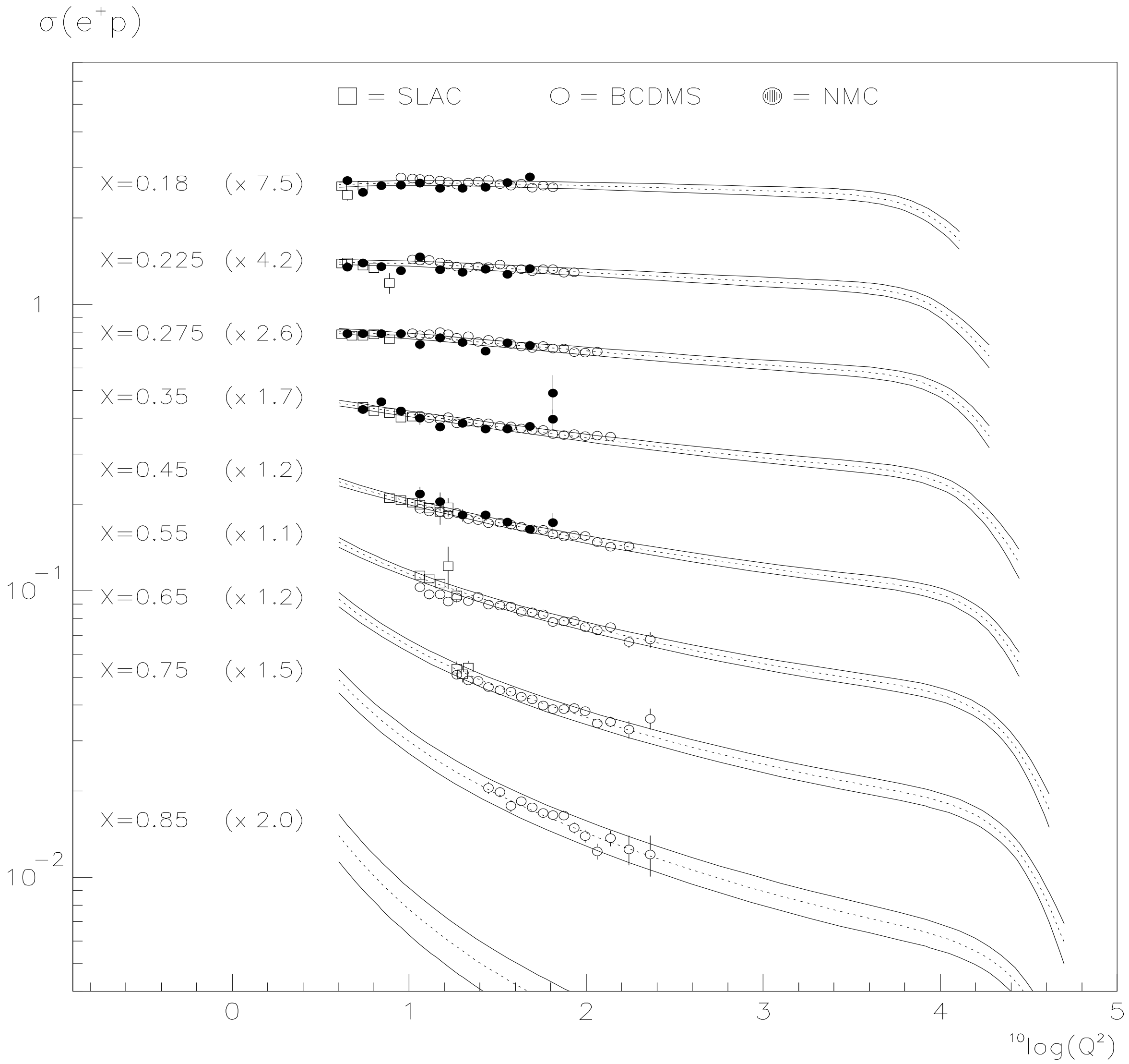
- well measured Electroweak parameters α, θ_w, M_Z . These give uncertainties at 0.25 % level.
- the quark structure in the proton, $q(x, Q^2)$, $\overline{q}(x, Q^2)$.



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

ZEUS fit to SLAC, BCDMS, and NMC data

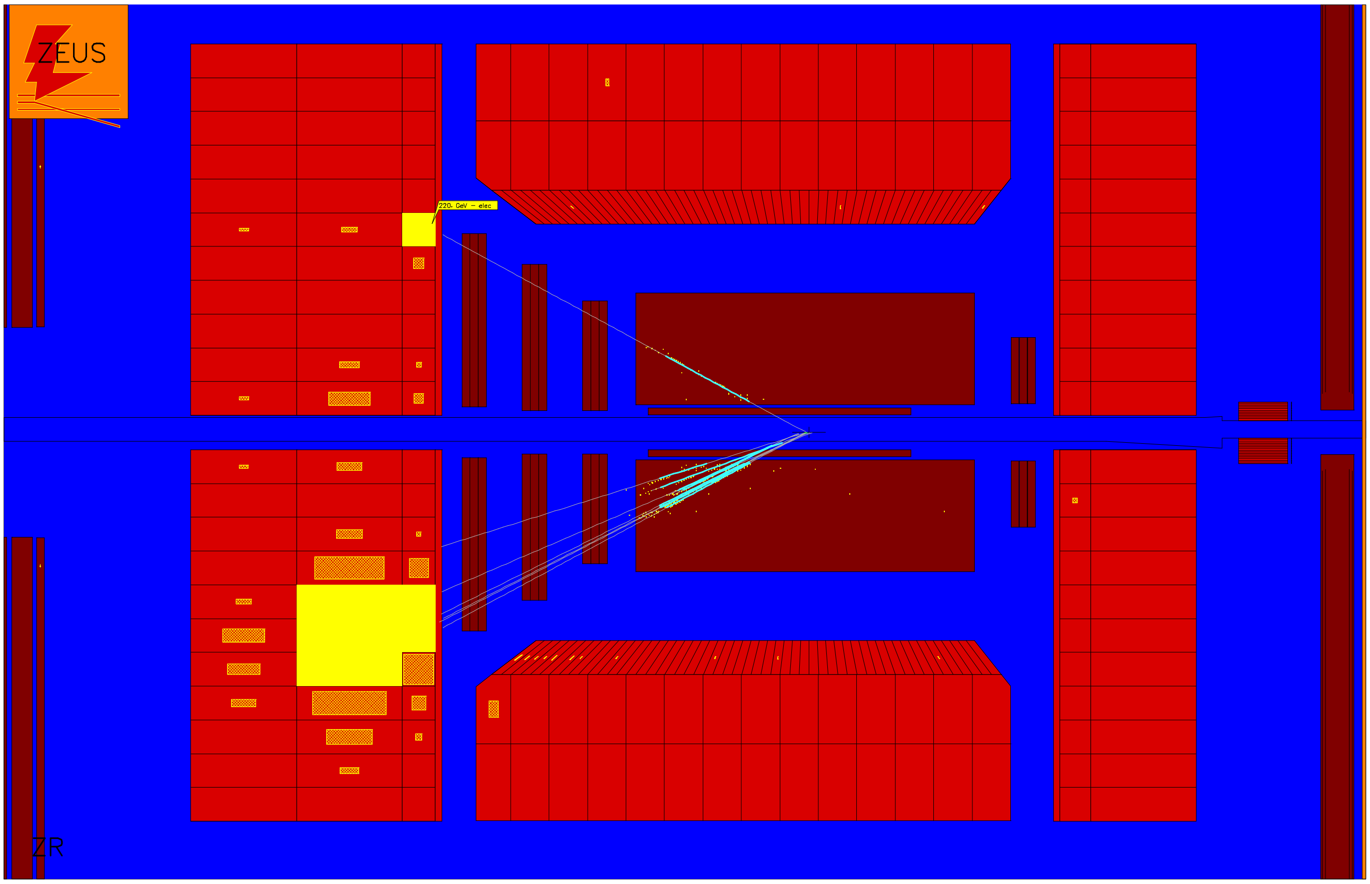
$$\sigma^{\pm} \equiv \frac{xQ^4}{2\pi\alpha^2 Y_+} \frac{d^2\sigma^{\pm}_{NC}}{dx dQ^2} = F_2 - \frac{y^2}{Y_+} F_L \mp \frac{Y_-}{Y_+} x F_3$$



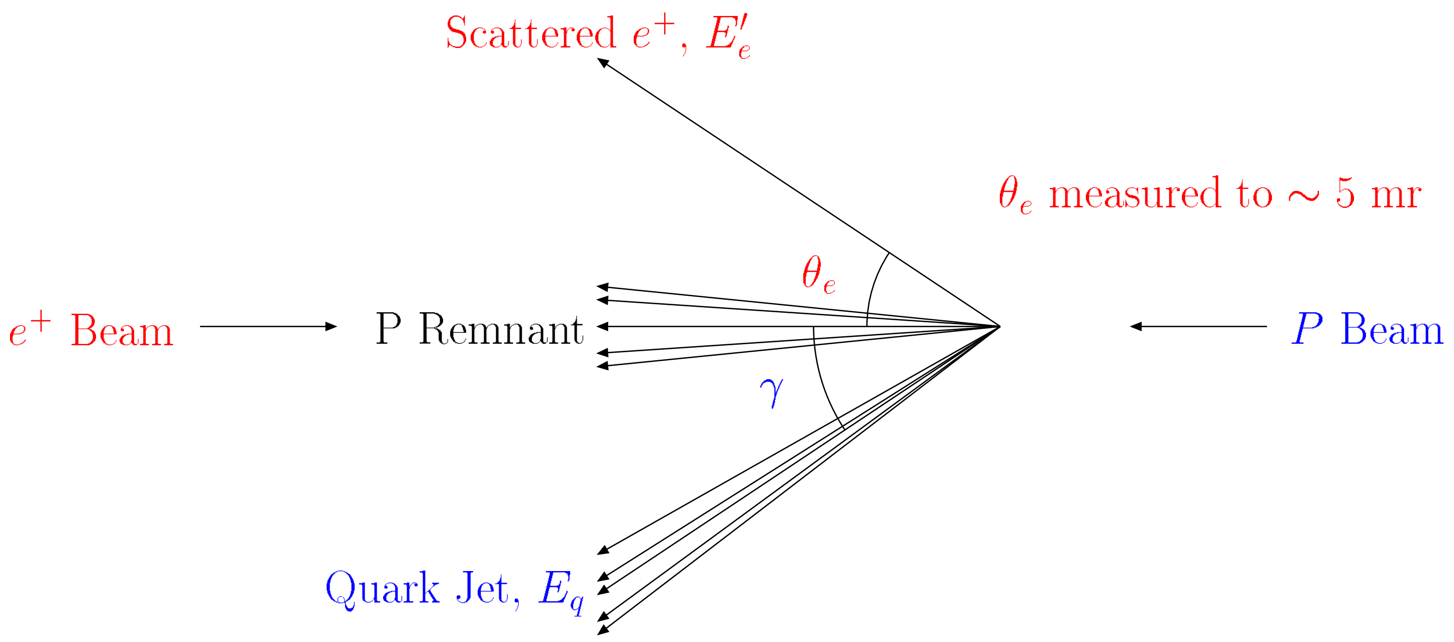
Error Bands include SLAC, BCDMS, NMC statistical and systematic uncertainties and also the effect of varying α_s between 0.112 and 0.122 $\Rightarrow$ NC DIS cross section predictions at high–x, Q^2 are known to ≈ 6.5 %.

ZEUS Detector

$$\frac{\sigma_E}{E} = \begin{cases} 18\%/\sqrt{E} & \text{electromagnetic} \\ 35\%/\sqrt{E} & \text{hadronic} \end{cases}$$



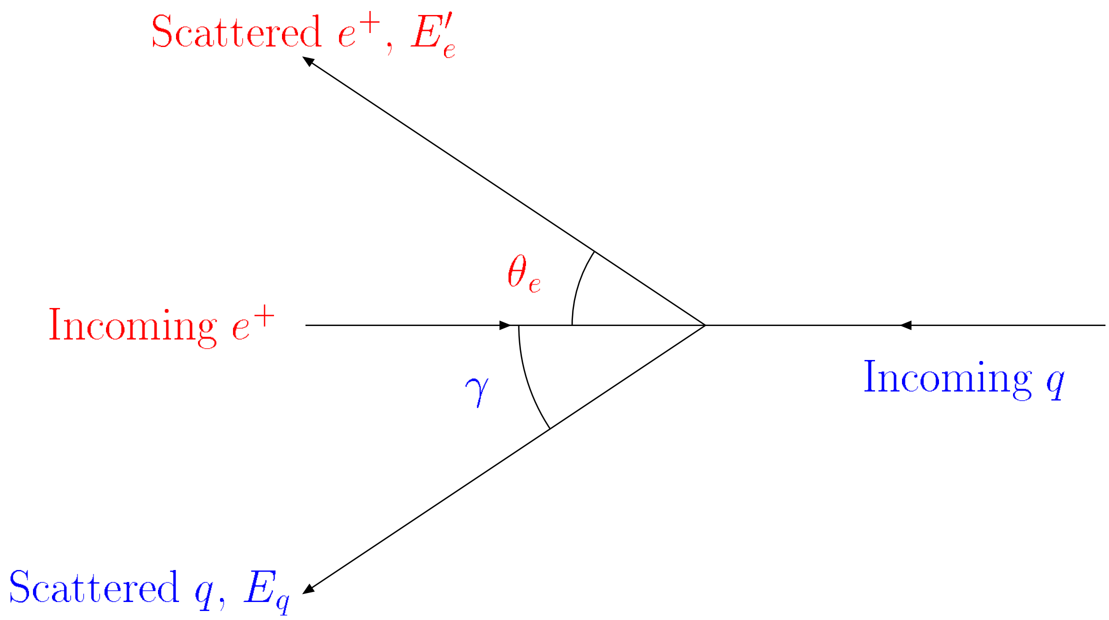
NC DIS Kinematics and Event Variables



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

$$
\begin{aligned}
p_t &= \sqrt{\left(\sum_i p^i_X\right)^2 + \left(\sum_i p^i_Y\right)^2}\ , \\
E - p_Z &= \sum_i \left(E^i - p^i_Z\right)\ , \\
E_t &= \sum_i \sqrt{(p^i_X)^2 + (p^i_Y)^2}\ , \\
(p_t)_{\text{had}} &= \sqrt{\left(\sum_i{}' p^i_X\right)^2 + \left(\sum_i{}' p^i_Y\right)^2}\ , \\
(E - p_Z)_{\text{had}} &= \sum_i{}' \left(E^i - p^i_Z\right)\ , \\
\cos\gamma &= \frac{(p_t)^2_{\text{had}} - (E - p_Z)^2_{\text{had}}}{(p_t)^2_{\text{had}} + (E - p_Z)^2_{\text{had}}} \qquad \text{and} \qquad E_q = \frac{(p_t)_{\text{had}}}{\sin\gamma}\ .
\end{aligned}
$$

Kinematic Reconstruction



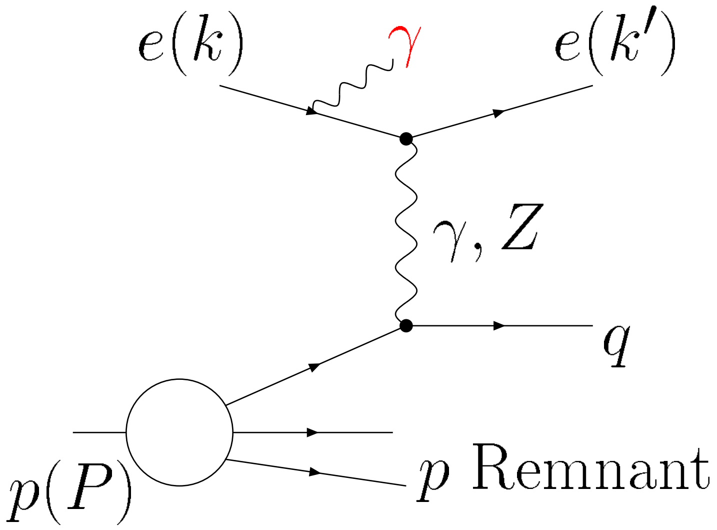
We use the Double Angle Method which is insensitve to the energy scale.

$$
\begin{aligned}
x_{\mathrm{DA}} &= \frac{E_e}{E_p}\,\frac{\sin\gamma}{(1-\cos\gamma)}\,\frac{\sin\theta_e}{(1-\cos\theta_e)}\ , \\
y_{\mathrm{DA}} &= \frac{\sin\theta_e(1-\cos\gamma)}{\sin\gamma+\sin\theta_e-\sin(\gamma+\theta_e)}\ , \\
Q^2_{\mathrm{DA}} &= s\ x_{\mathrm{DA}}\ y_{\mathrm{DA}}\ ,
\end{aligned}
$$

The Electron Method is used as a cross-check

$$
\begin{aligned}
x_e &= \frac{E_e}{E_p}\,\frac{E'_e(1+\cos\theta_e)}{2E_e-E'_e(1-\cos\theta_e)}\ , \\
y_e &= 1-\frac{E'_e}{2E_e}(1-\cos\theta_e)\ , \\
Q^2_e &= s\ x_e\ y_e\ .
\end{aligned}
$$

Effect of Initial State Radiation on Kinematic Reconstruction



Events with initial–state photons with energy $E_\gamma > 7.5$ GeV are rejected by the cuts.

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

Then,

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

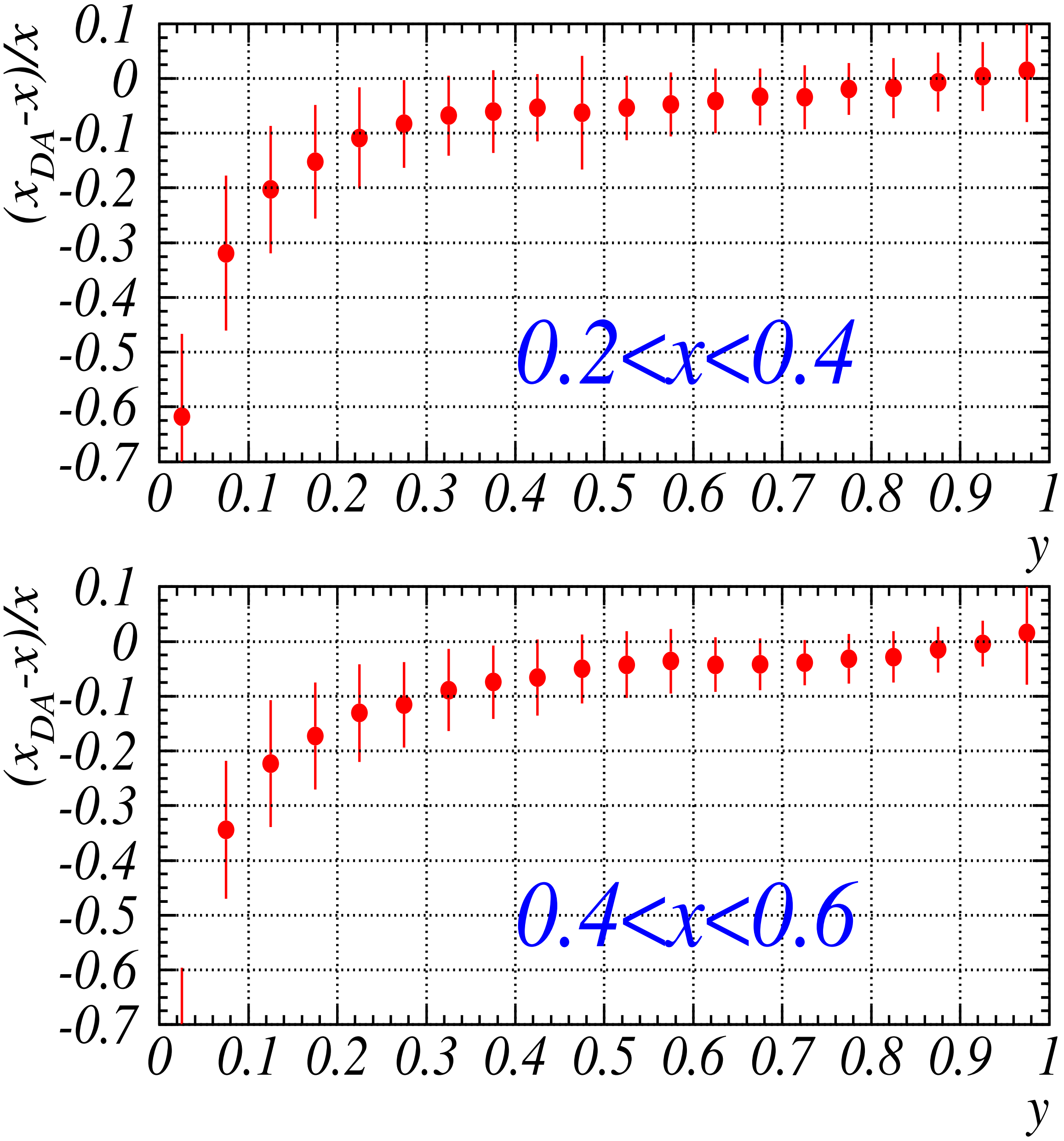
$$x_{\mathrm{DA}} = x \frac{1}{1-f_\gamma} \quad Q_{\mathrm{DA}}^2 = Q^2 \frac{1}{\left(1-f_\gamma\right)^2}$$

Shifts in x for true variables (e.g. $\delta x_e = x_e - x$) for events which pass all cuts and have $0.4 < x < 0.6$ and $y > 0.25$:

$$\delta x_e = -2.5\% \quad \delta Q_e^2 = +1.8\%$$

$$\delta x_{\mathrm{DA}} = +1.7\% \quad \delta Q_{\mathrm{DA}}^2 = +2.5\%$$

Shifts and Resolution of measured x_{DA} vs true y



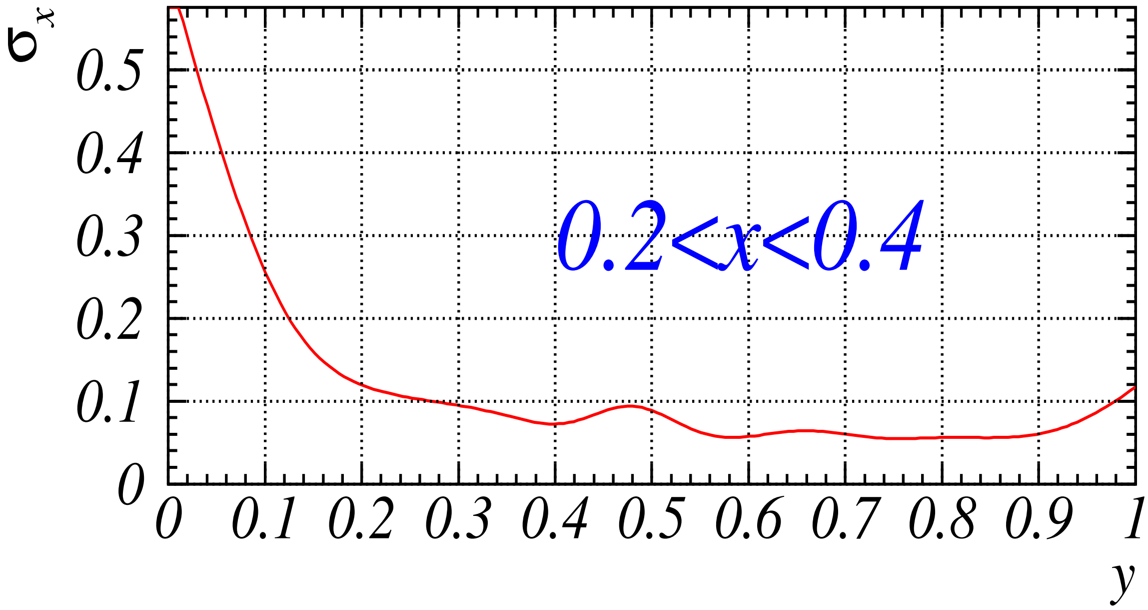
Low $y \rightarrow$ small γ

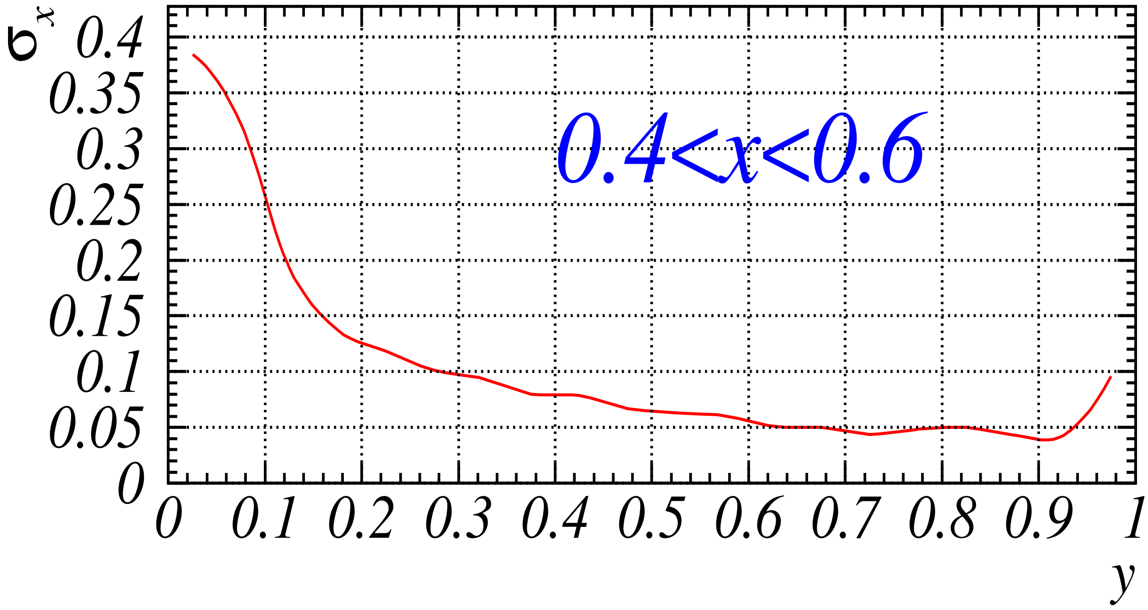
$\rightarrow$ At small γ, $\gamma_{meas} > \gamma_{true}$ on average.

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

$\rightarrow$ We correct γ event by event.

Resolution of the corrected x_{DA} *vs.* the true y.





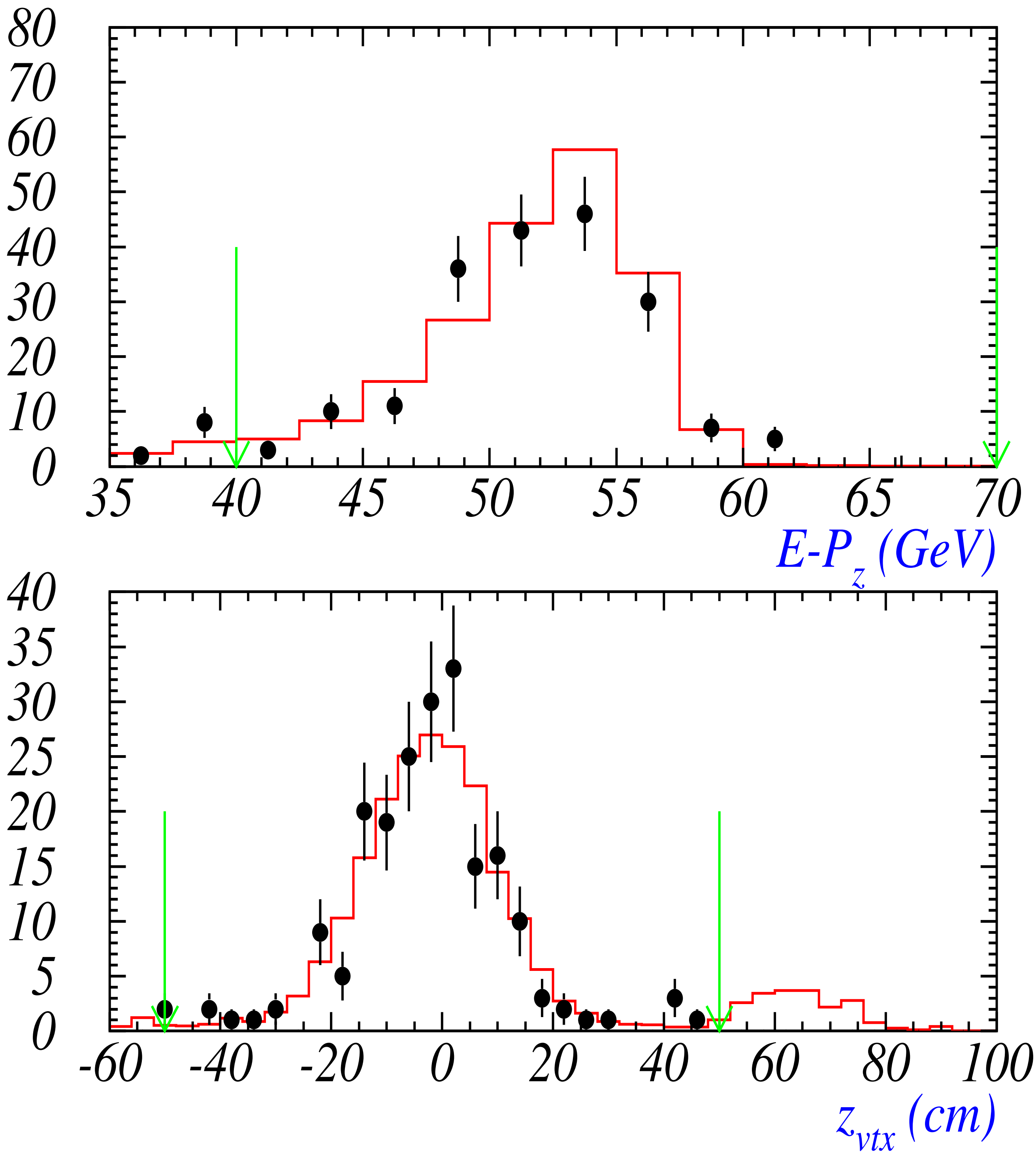
$$\sigma_x = \text{RMS of } \frac{x_{\mathrm{DA}} - x}{x}$$

Selection cuts and efficiencies

Efficiencies evaluated using NC MC events with $Q^2_{true} > 5000$ GeV.

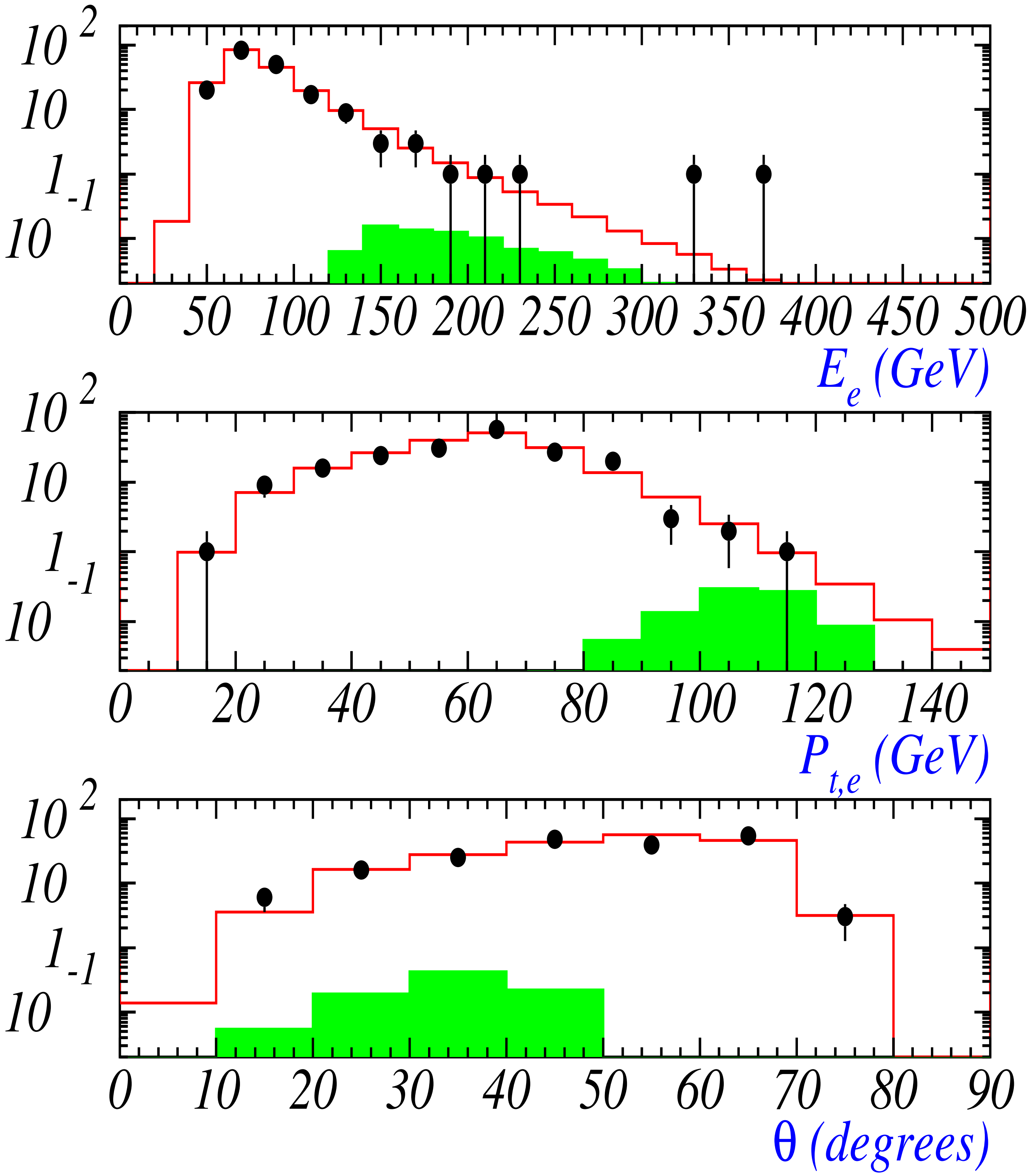
Selection	Efficiency
Vertex found	100.0%
$\lvert Z_{\rm vtx}\rvert < 50\,\rm cm$	94.9%
40 GeV $< E - p_Z <$ 70 GeV (lower cut rejects Photoproduction or hard ISR)	92.0%
Positron identification in CAL with $E'_e > 20\,\rm GeV$	89.4%
Positron isolation $E^{R=0.8}_{cone} < 5\,\rm GeV$	87.2%
If $\theta_e > 17.2°$: track-cluster match (DCA $<$ 10 cm)	85.7%
If $\theta_e < 17.2°$ require $p_{t,e} > 30\,\rm GeV$	83.9%
If $\theta_e < 17.2°$ require $E - p_Z >$ 44 GeV (tighter Photoproduction rejection)	83.8%
Reject events with 2 e.m. clusters with $E_{clu} > 8$ GeV, $E^{R=0.8}_{cone} < 2$ GeV (Compton rejection)	83.4%
$Q^2_{\rm DA} > 5000\,\rm GeV^2$	81.5%

Data/MC comparison for $E - P_z$ and vertex z-position.

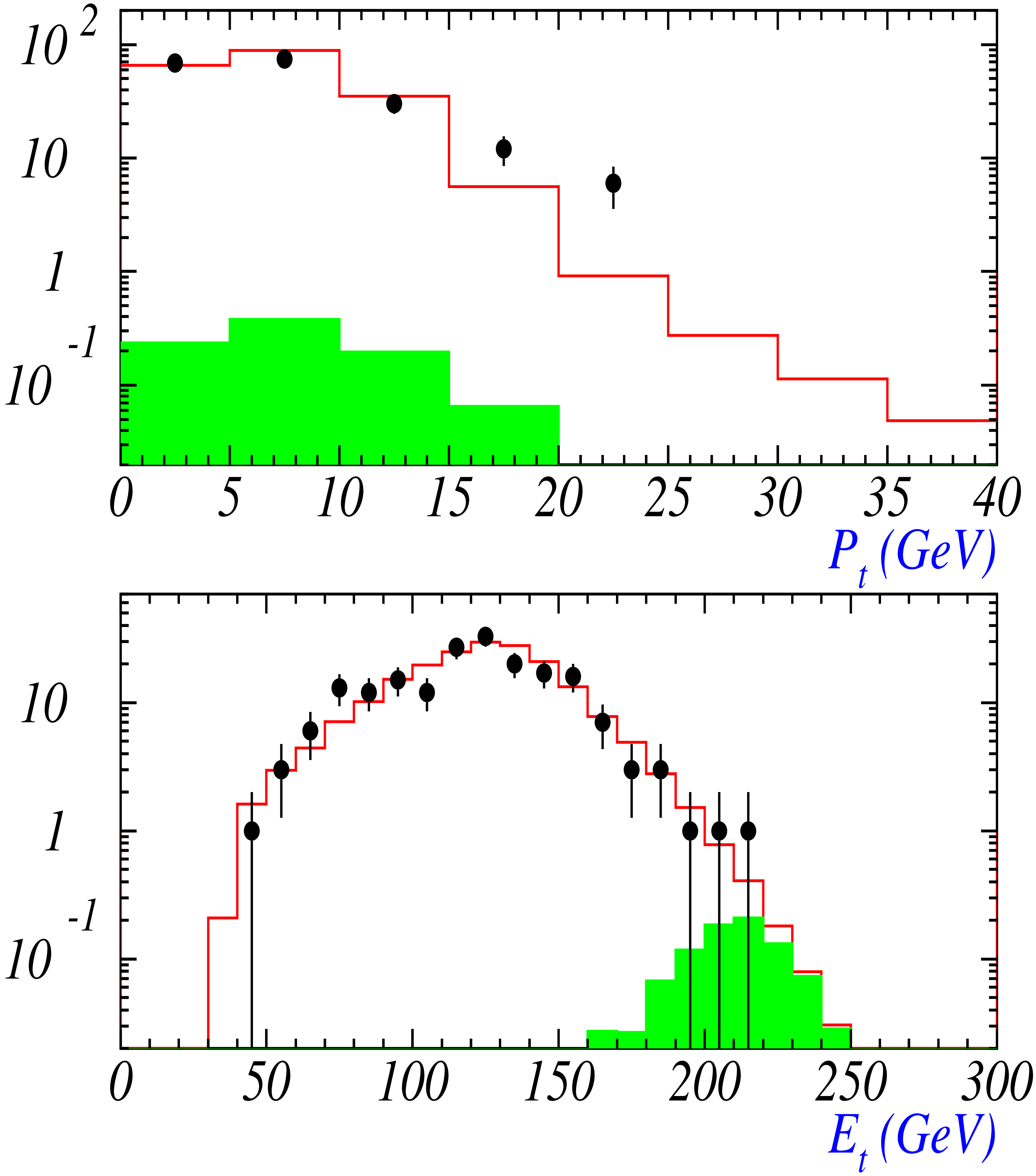


Data is plotted only for $|z_{vtx}| < 50$ cm.

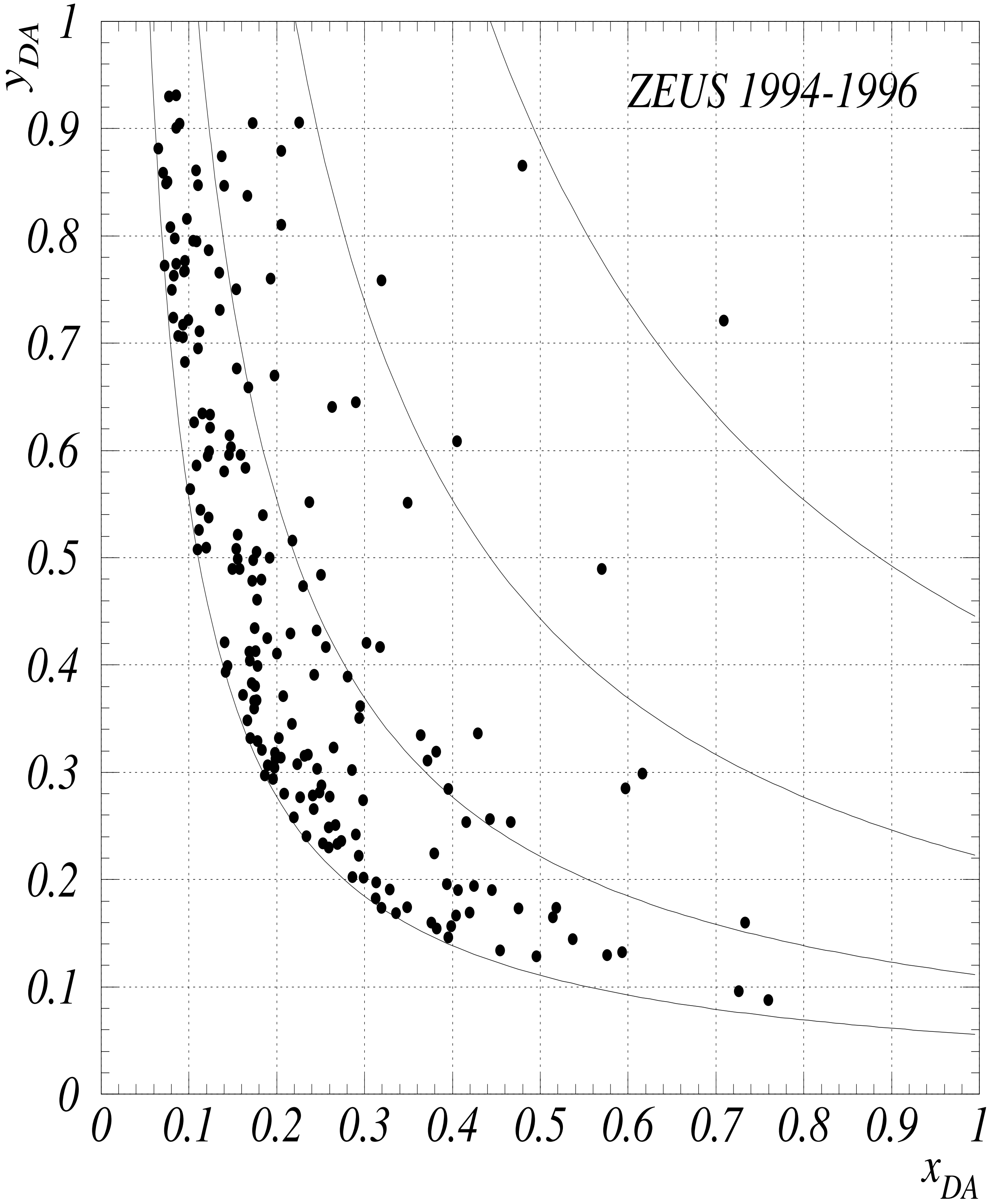
Data/MC comparison for final state positron. Green indicates $x_{\mathrm{DA}} > 0.55$ and $y_{\mathrm{DA}} > 0.25$.



Data/MC comparison for net transverse momentum and energy. Green indicates $x_{\mathrm{DA}} > 0.55$ and $y_{\mathrm{DA}} > 0.25$.



Final sample of 191 events. Curves indicate $Q^2_{\rm DA} = 5000$, 10000, 20000, 40000 GeV^2.



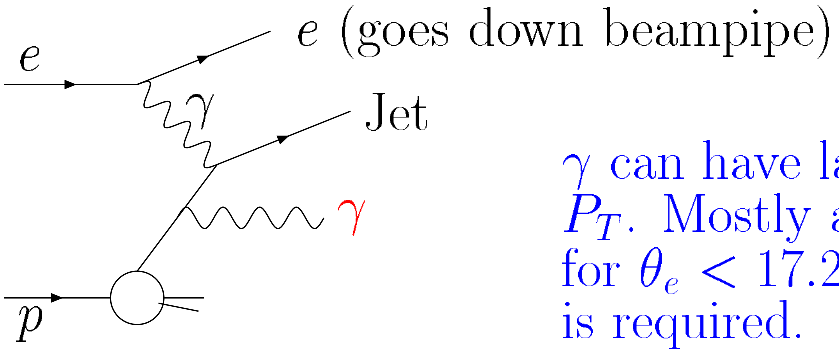
x_{min} x_{max}	0.05 0.15	0.15 0.25	0.25 0.35	0.35 0.45	0.45 0.55	0.55 0.65	0.65 0.75	0.75 0.85	0.85 0.95	0.95 1.00
$y_{max} = 1.00$ $y_{min} = 0.95$	0.15	0.015	0.033	0.013	0.0055	0.0015	0.0012			
$y_{max} = 0.95$ $y_{min} = 0.85$	8.8 9	1.2 3	0.32	0.10	0.028 1	0.01	0.0034			
$y_{max} = 0.85$ $y_{min} = 0.75$	12 16	2.5 4	0.50 1	0.15	0.050	0.011	0.0039			
$y_{max} = 0.75$ $y_{min} = 0.65$	13 10	3.7 3	0.86	0.26	0.082	0.022	0.0054 1	0.0020		
$y_{max} = 0.65$ $y_{min} = 0.55$	15 12	6.1 3	1.65 3	0.46 1	0.15	0.046	0.0090	0.0024		
$y_{max} = 0.55$ $y_{min} = 0.45$	12 6	11 13	2.5 1	0.85	0.28	0.084 1	0.0208	0.0032		
$y_{max} = 0.45$ $y_{min} = 0.35$	4.6 3	18 17	5.5 6	1.75	0.52	0.16	0.0403	0.0093		
$y_{max} = 0.35$ $y_{min} = 0.25$		18 23	11 6	3.74 7	1.19 1	0.34 2	0.1104	0.0175	0.0066	
$y_{max} = 0.25$ $y_{min} = 0.15$		2.2 1	14 15	9.6 10	3.32 3	1.2	0.2784 1	0.0717	0.0077	
$y_{max} = 0.15$ $y_{min} = 0.05$				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.
γ $[degrees]$	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
$[x_{\rm DA}]^{uncor}$	0.468	0.541	0.535	0.668	0.515
$[y_{\rm DA}]^{uncor}$	0.868	0.503	0.330	0.733	0.316
$[Q^2_{\rm DA}]^{uncor}$ $[10^4\ {\rm GeV}^2]$	3.67	2.45	1.59	4.42	1.47
γ^{cor} $[degrees]$	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
$[Q^2_{\rm DA}]$ $[10^4{\rm GeV}^2]$	3.75	2.52	1.66	4.61	1.54
$\delta[Q^2_{\rm DA}]$ $[10^4{\rm GeV}^2]$	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
$[Q^2_e]$ $[10^4{\rm GeV}^2]$	4.05	2.44	1.62	4.10	1.40
$\delta[Q^2_e]$ $[10^4{\rm GeV}^2]$	0.31	0.11	0.09	0.30	0.07

Backgrounds Studied

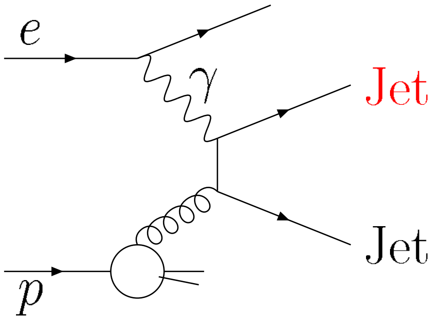
Prompt Photon Production:



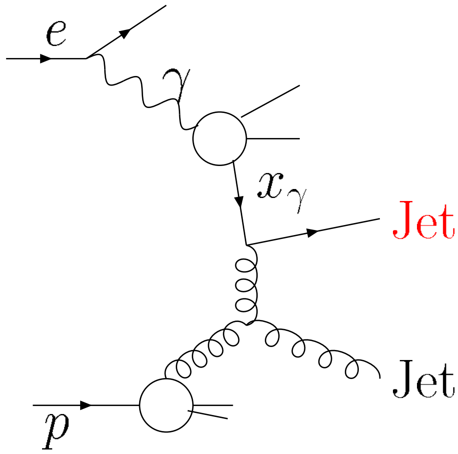
γ can have large energy, and P_T. Mostly a background for $\theta_e < 17.2°$ where no track is required.

Photoproduction of Dijets:

Background when jet satisfies electron requirements

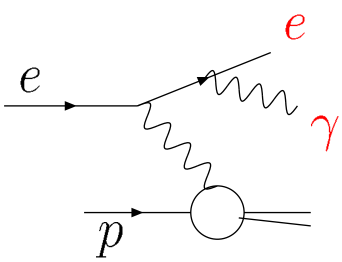


Direct Photoproduction



Resolved Photoproduction

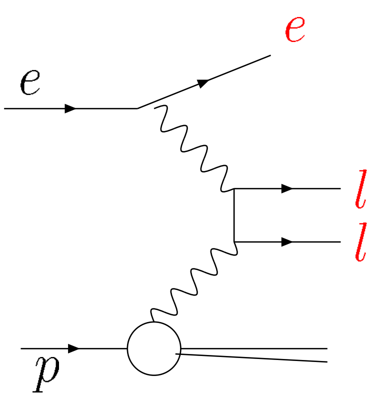
QED Compton:



e, γ can be produced with large P_T

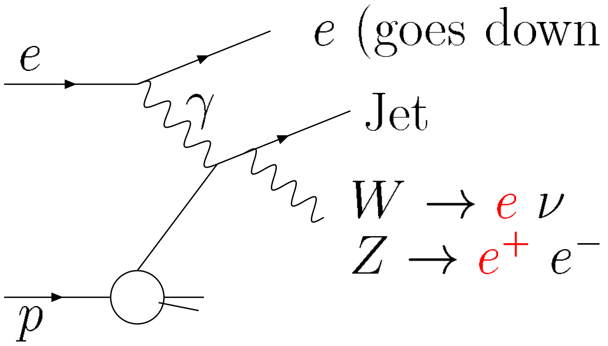
Backgrounds studied (cont.)

Dilepton Photoproduction:



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

Weak Boson Production:



Can produce large P_T e

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	1.5%
Electroweak parameters	0.25%
Radiative corrections	2%

Evaluated with HERACLES and HECTOR ; the ISR photon energy spectrum measured in the LUMI monitor agrees well with the MC simulation.

Detector simulation	6%

Uncertainty increases from about 2% for $y_{\mathrm{DA}} > 0.2$ to 4-7% for $y_{\mathrm{DA}} > 0.5$ and includes:

- variation of $\pm 3\%$ in the FCAL, BCAL energy scales
- smearing at 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 (cont.)

Structure Functions 6.5%

The uncertainties in the SF are studied using NLO QCD fits to fixed target F_2 measurements. The main contributions are:

Fixed-target experimental uncertainties	$\pm 6.2\%$
$0.112 < \alpha_s < 0.122$	$^{+1.9\%}_{-0.0\%}$

Cross checks on SF uncertainties include:

$10\% <$ strange fraction $< 30\%$	small
Uncertainties in charm evolution	$< 0.5\%$
GRV94, MRSA, CTEQ3 comparison	$\pm 2\%$
GRV94 NLO verses LO	$+1.0\%$
High-x gluon (CDF inspired, CTEQ4 HJ)	$+1.9\%$

Summary of systematic errors in SM predictions

Luminosity measurement	1.5%
Electroweak parameters	0.25%
Radiative corrections	2%
Detector simulation	6%
Structure Functions	6.5%
Total	9.2%

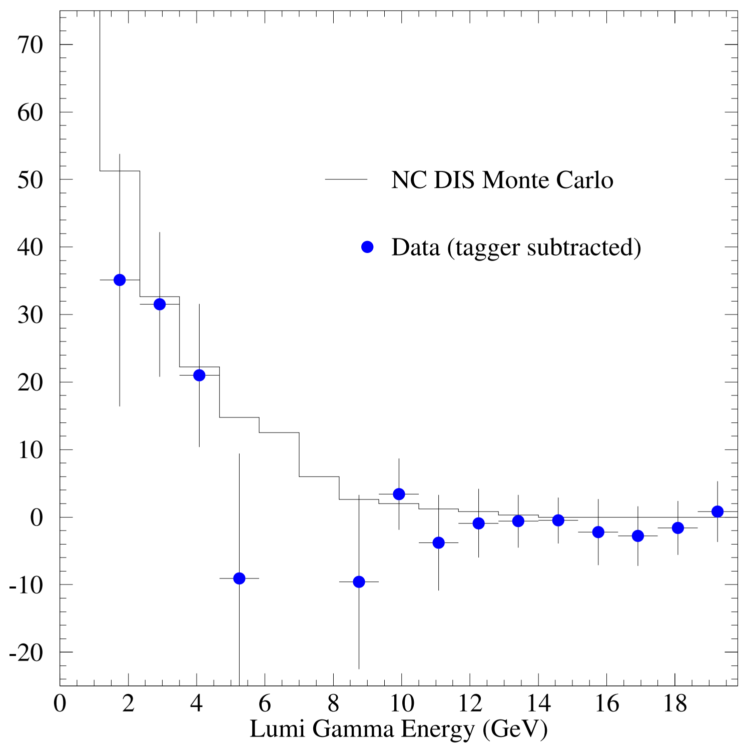
Comparison between data and MC of the ISR photon spectrum

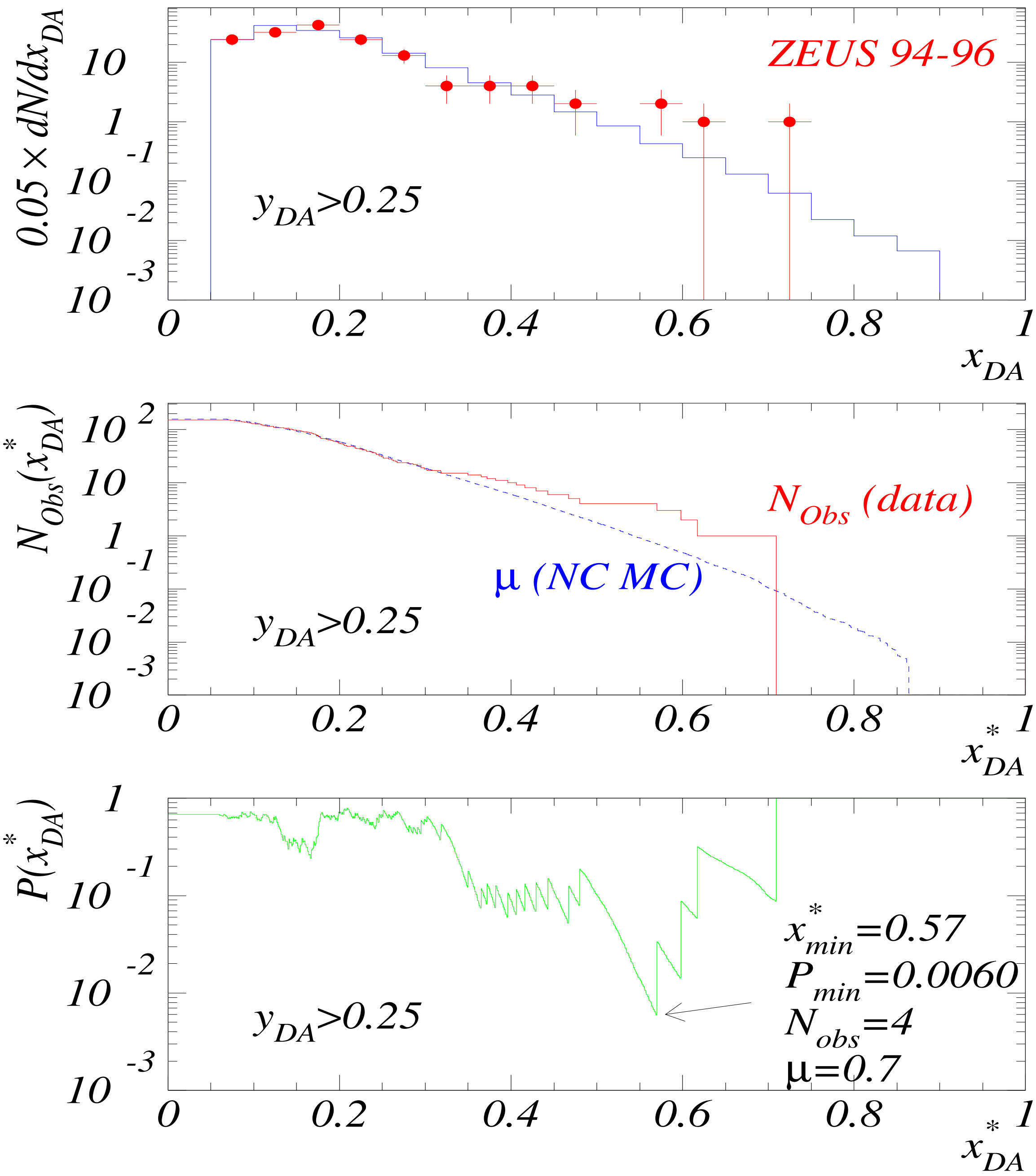
The comparison is performed measuring the photon spectrum as detected in the luminosity monitor photon calorimeter ($LUMI_\gamma$).

Select NC events with $Q^2_{\mathrm{DA}} > 400\ GeV^2$ and $\mathrm{E}_{LUMI_\gamma} > 1.2\ GeV$ (460 events over 5630).

Estimate the rate of random bremsstrahlung conincidences using events in which the positron is tagged in the 44 m ($\mathrm{E}_\gamma < 6\ GeV$) or 35 m ($\mathrm{E}_\gamma \approx 7 - 25\ GeV$) calorimeters. The random background is subtracted out.

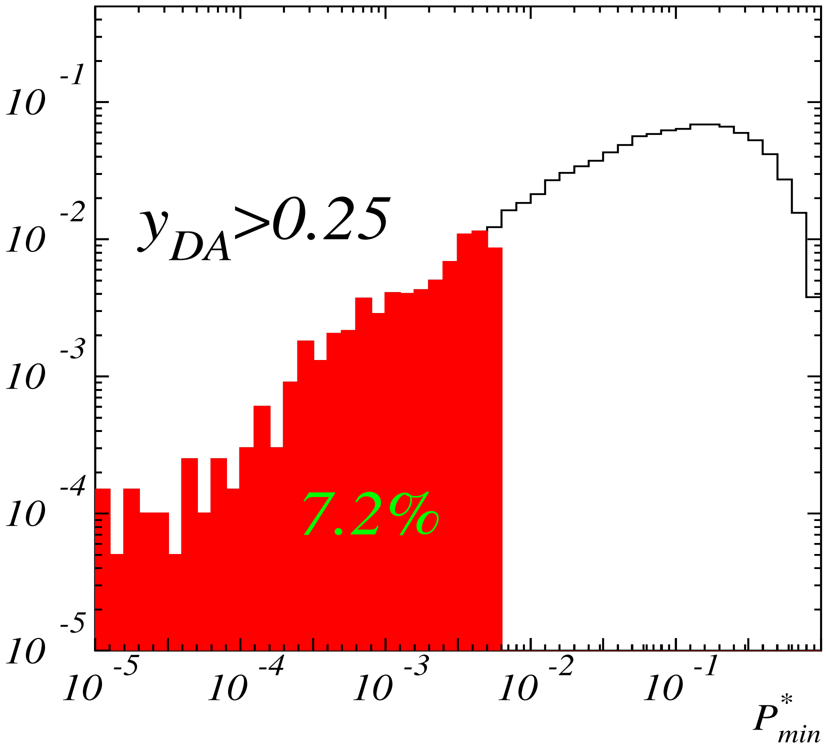
The background subtracted spectrum agrees well with the MC prediction, with 88$\pm$24 events measured and 105 expected in the range $1.2 < \mathrm{E}_\gamma < 4.8$ GeV.





$$N_{obs} = \int_{x^*_{\mathrm{DA}}}^{1} dx_{\mathrm{DA}} dN/dx_{\mathrm{DA}}$$

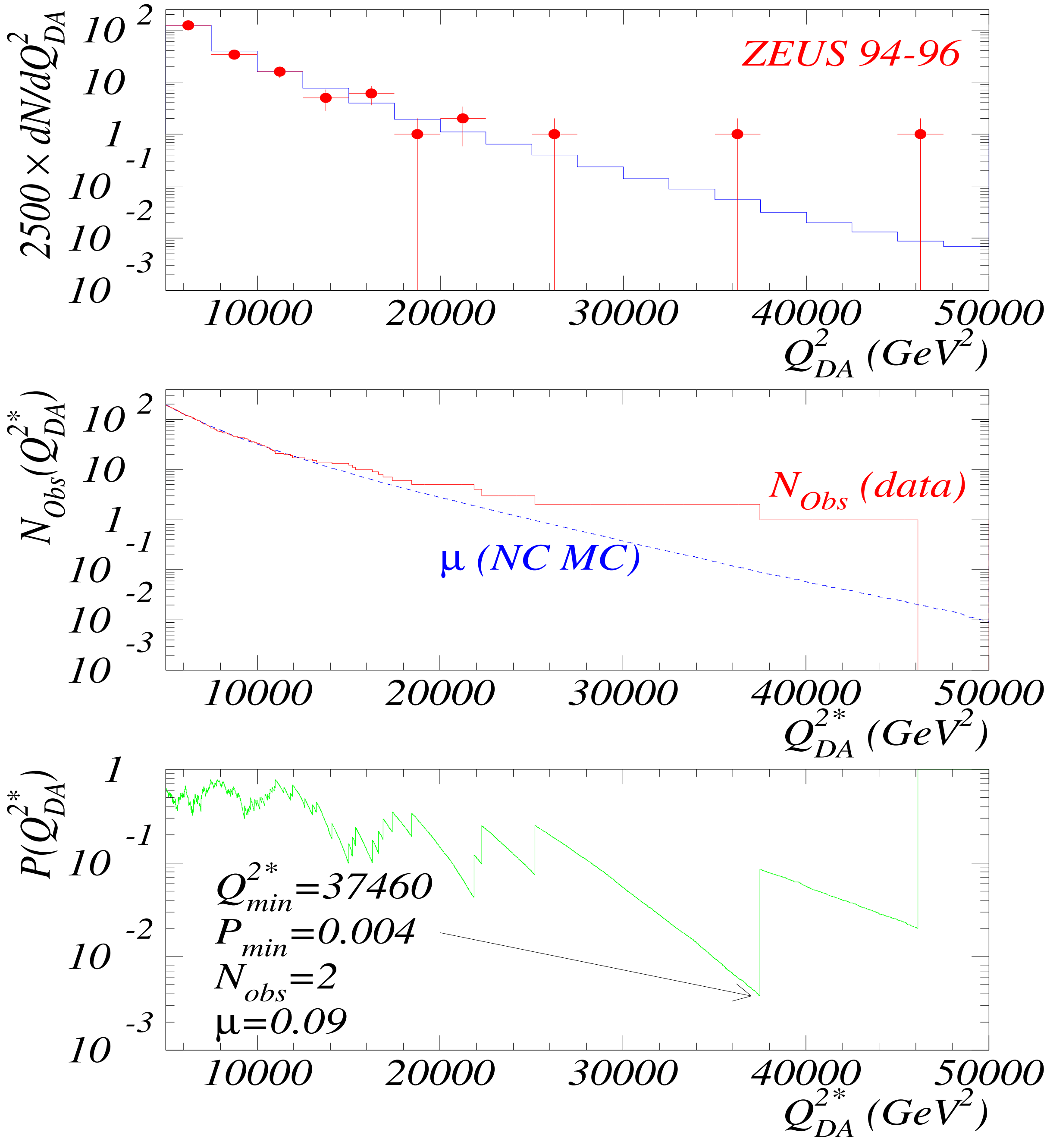
$$\mathcal{P}(x^*_{\mathrm{DA}}) = \sum_{n=N_{obs}}^{\infty} e^{-\mu}\frac{\mu^n}{n!}$$



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

y_{DA} range	$\mathcal{P}_{min}(x^*_{\mathrm{DA}})$ [%]	x^*_{DA}	N_{obs}	μ	P_{SM} [%]
$y_{\mathrm{DA}} > 0.05$	1.61	0.708	4	0.95	16.2
$y_{\mathrm{DA}} > 0.15$	2.57	0.708	2	0.25	23.0
$y_{\mathrm{DA}} > 0.25$	0.60	0.569	4	0.71	7.2
$y_{\mathrm{DA}} > 0.35$	3.38	0.708	1	0.034	26.6
$y_{\mathrm{DA}} > 0.45$	1.32	0.569	2	0.17	13.0
$y_{\mathrm{DA}} > 0.55$	0.96	0.708	1	0.010	9.5
$y_{\mathrm{DA}} > 0.65$	0.50	0.708	1	0.005	5.0

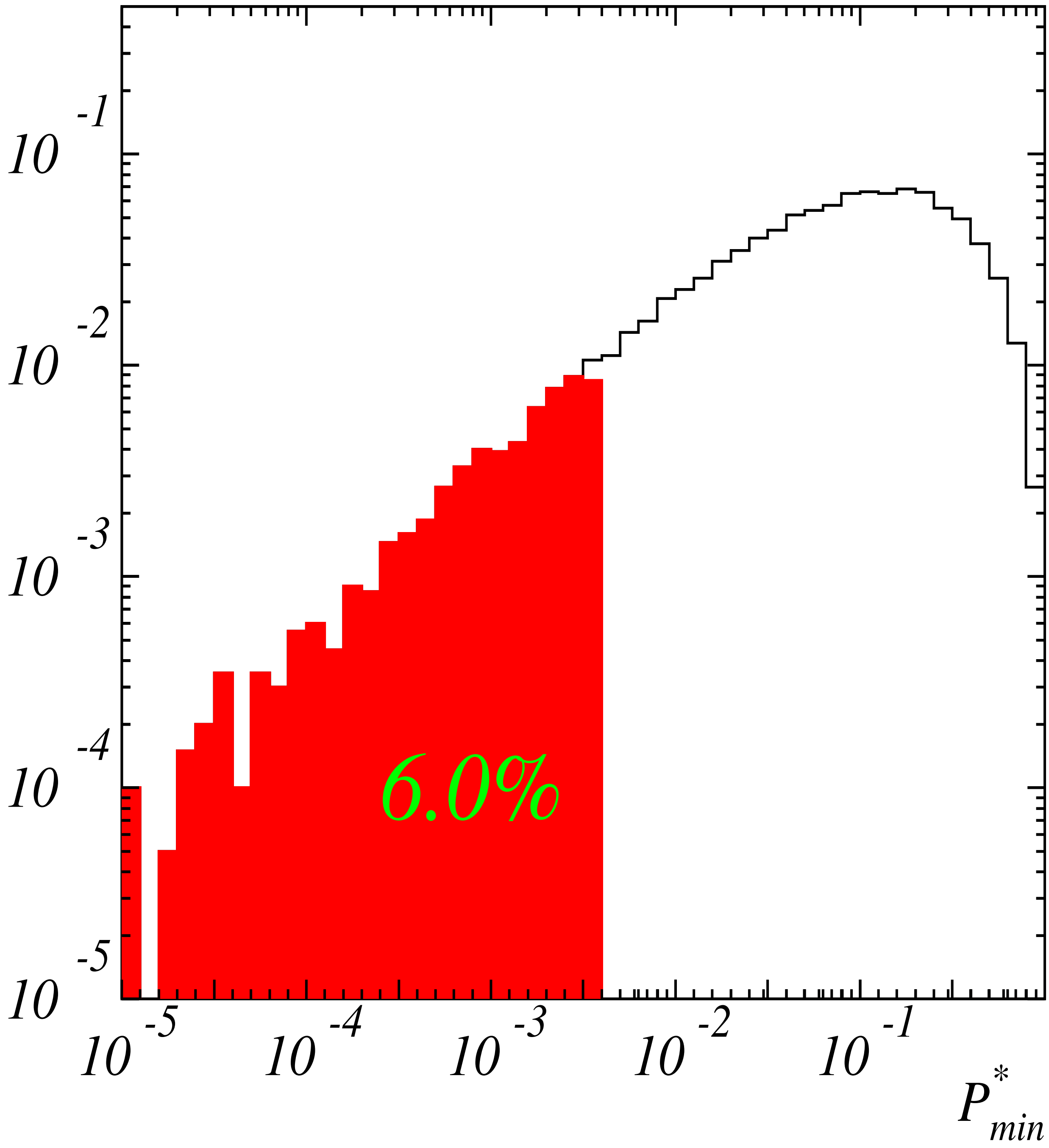
$\mathcal{P}_{min}(x^*_{\mathrm{DA}})$ = the minimal probability,
x^*_{DA} = the value of x_{DA} where it occurs,
N_{obs} = the number of events observed with $x_{\mathrm{DA}} > x^*_{\mathrm{DA}}$,
μ = the expected number of events with $x_{\mathrm{DA}} > x^*_{\mathrm{DA}}$,
P_{SM} the probability that a simulated experiment yields a lower value of $\mathcal{P}_{min}(x^*_{\mathrm{DA}})$ than the one observed.



$$N_{obs} = \int_{Q^{2*}_{\mathrm{DA}}}^{s} dQ^2_{\mathrm{DA}} dN/dQ^2_{\mathrm{DA}}$$

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

The probability for a simulated experiment to obtain $\mathcal{P}_{min}(Q^{2*}_{\rm DA})$ less than 0.0038 is 6.0%.



2-Dimensional Likelihood Test

- Divide x-y plane into 10×10 grid

- Assign Poisson probability to i^{th} bin

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

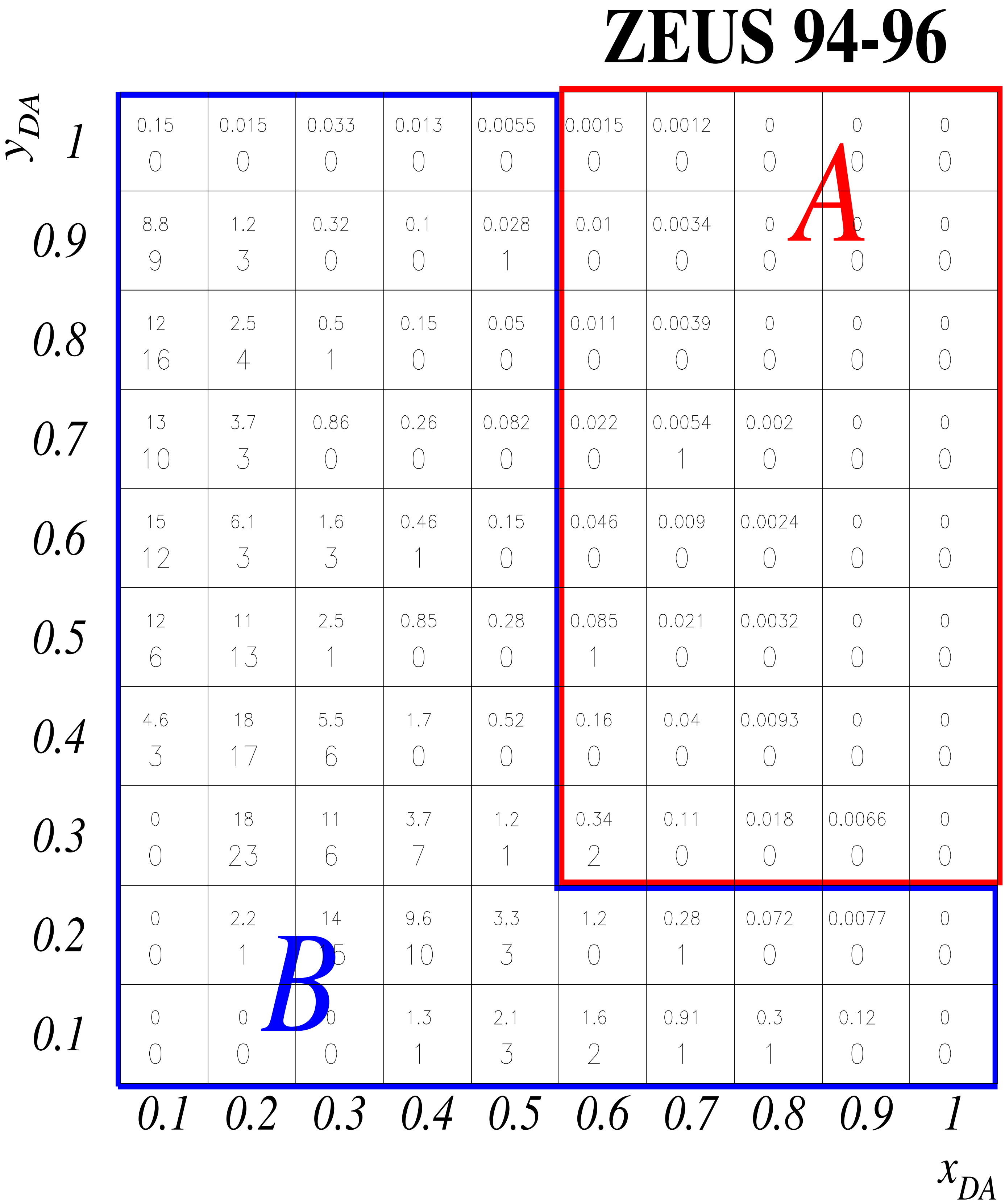
- Form likelihood over a subset of bins $\mathcal{R}$

$$\mathcal{L}^{(\mathcal{R})} \;=\; \Pi_{i \in \mathcal{R}}\, \mathcal{P}_i$$

- Evaluate the significance by performing many Monte Carlo experiments

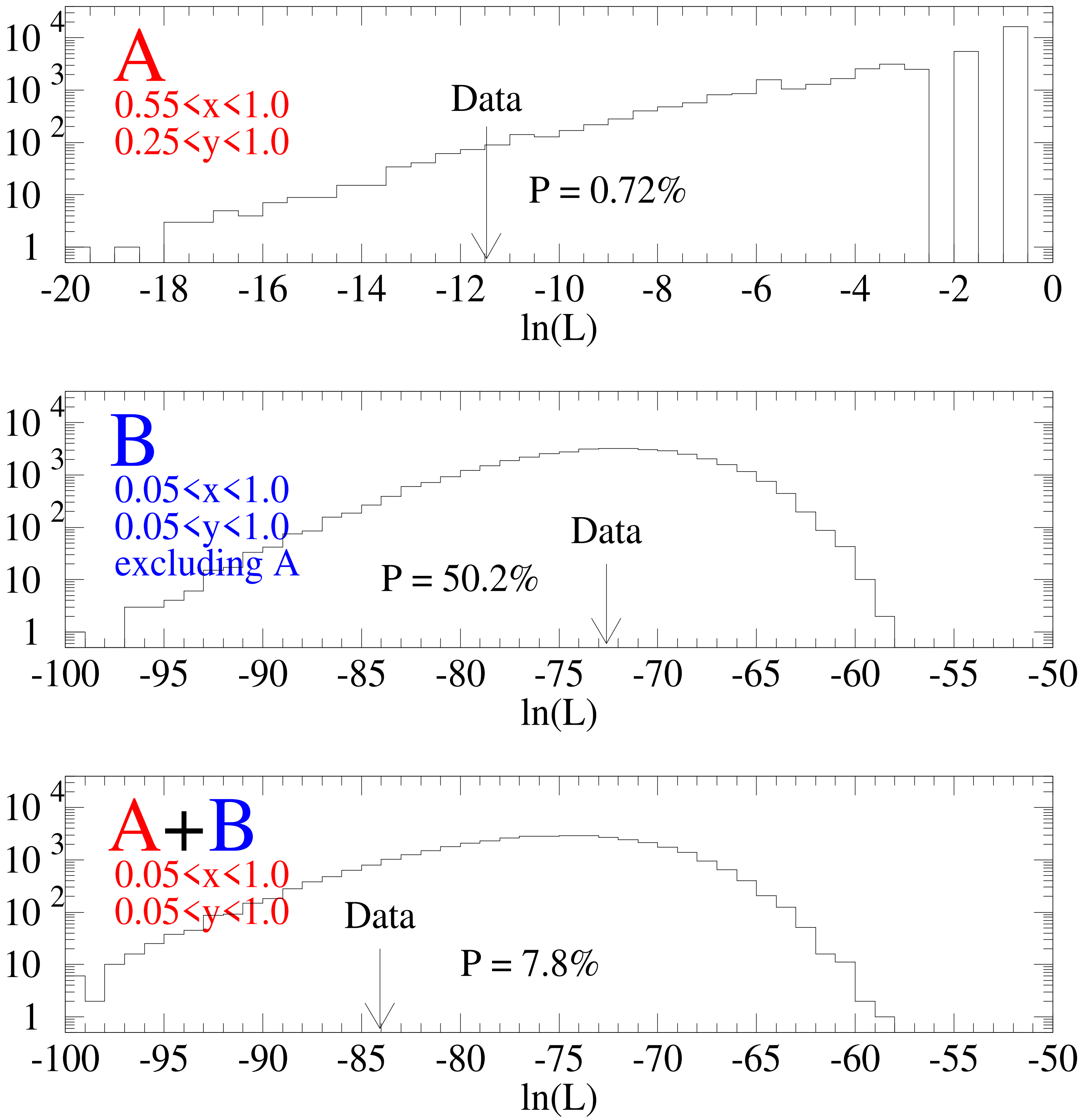
$$\mathcal{L}_m^{(\mathcal{R})} \;=\; \Pi_{i \in \mathcal{R}}\, \mathcal{P}_i^{(m)} \quad \text{for } m^{\text{th}} \text{ experiment}$$

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


ZEUS 94-96
A
B
y_{DA}
x_{DA}

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

Likelihood Distributions



Summary

1. We have searched for deviations from Standard Model expectations in $eP \to eX$ scattering at high Q^2 and high x.
   - The Neutral Current DIS cross section predictions are uncertain 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 $Q^2 > 35,000$ 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 maximum 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.