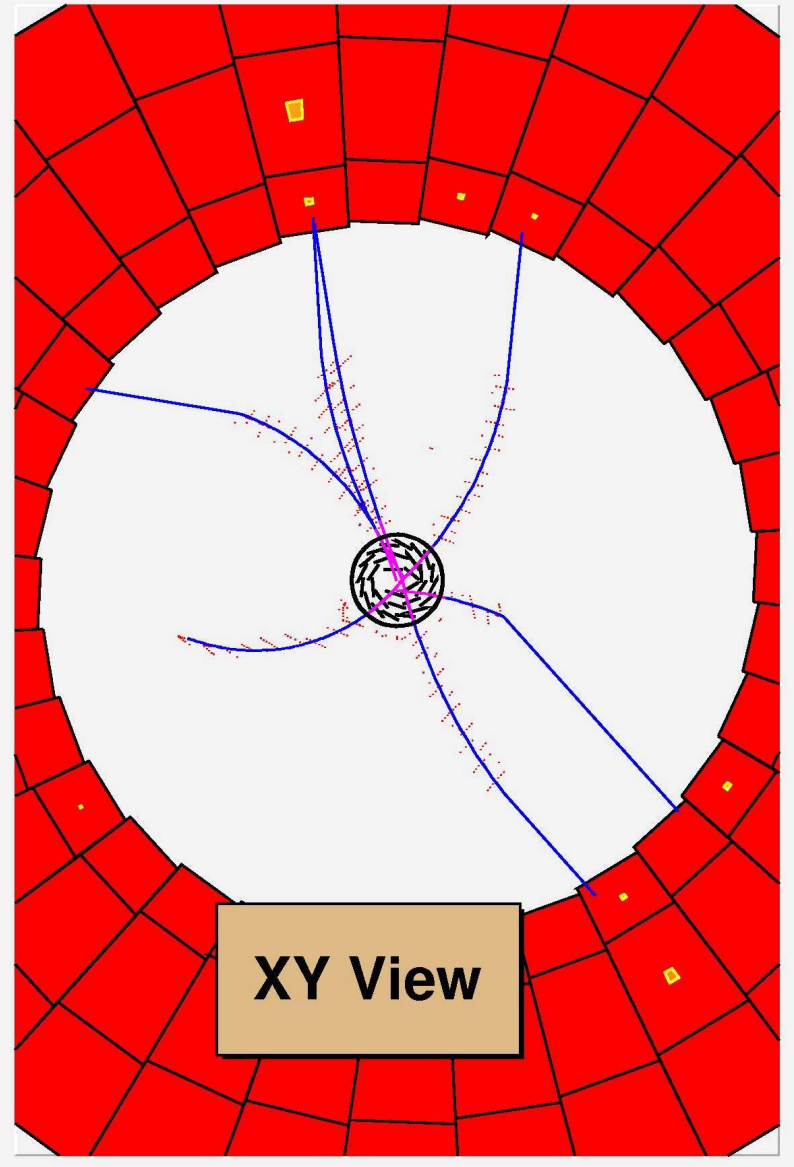
ZEUS status, results and outlook

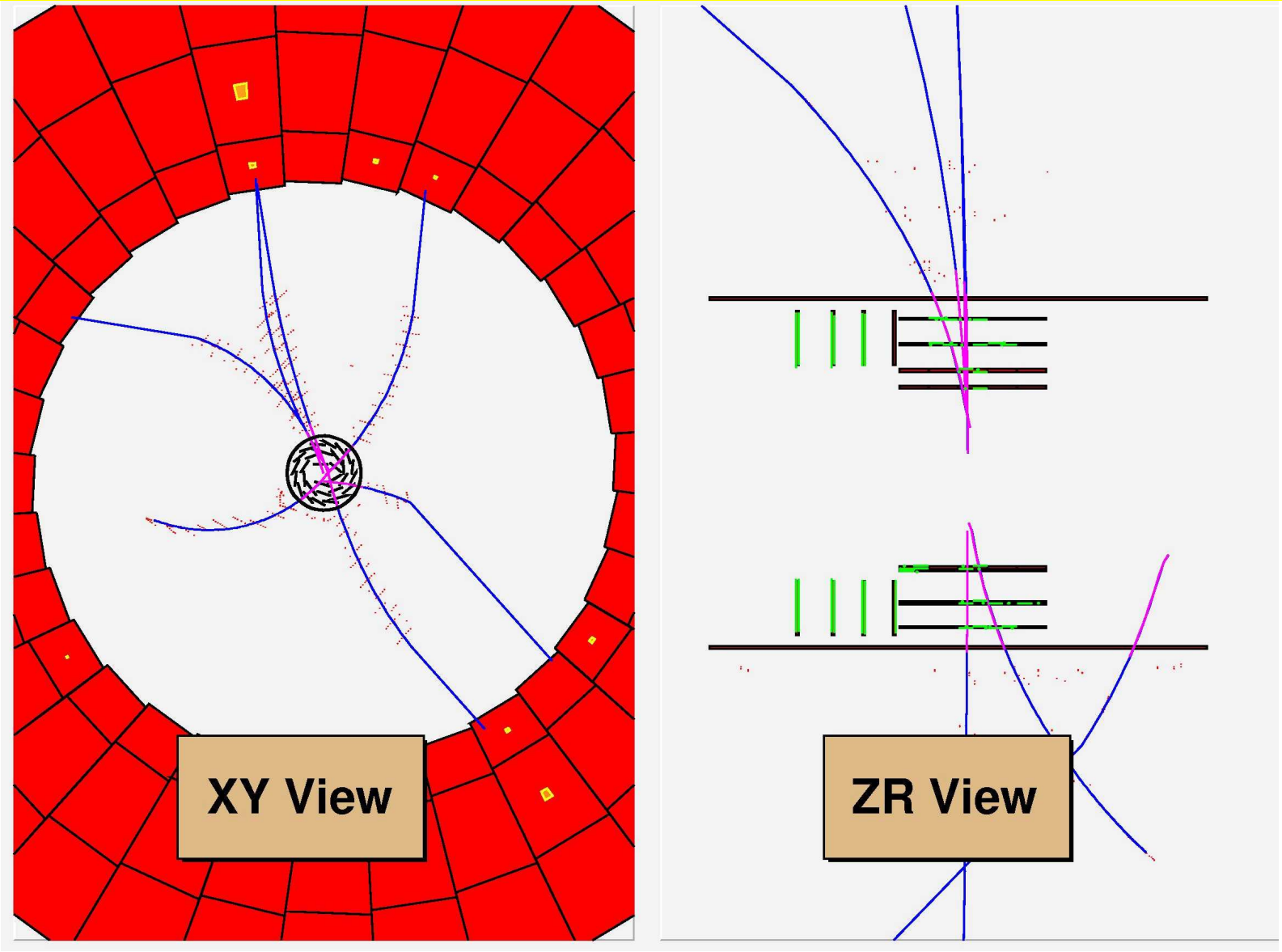
DESY PRC, 16May02

K. Long, Imperial College London

- Detector status
- Physics from HERA I
  - ➤ Searches
  - ➤ Multi-jet production
  - ➤ Heavy quarks
  - ➤ Diffraction
- HERA II physics

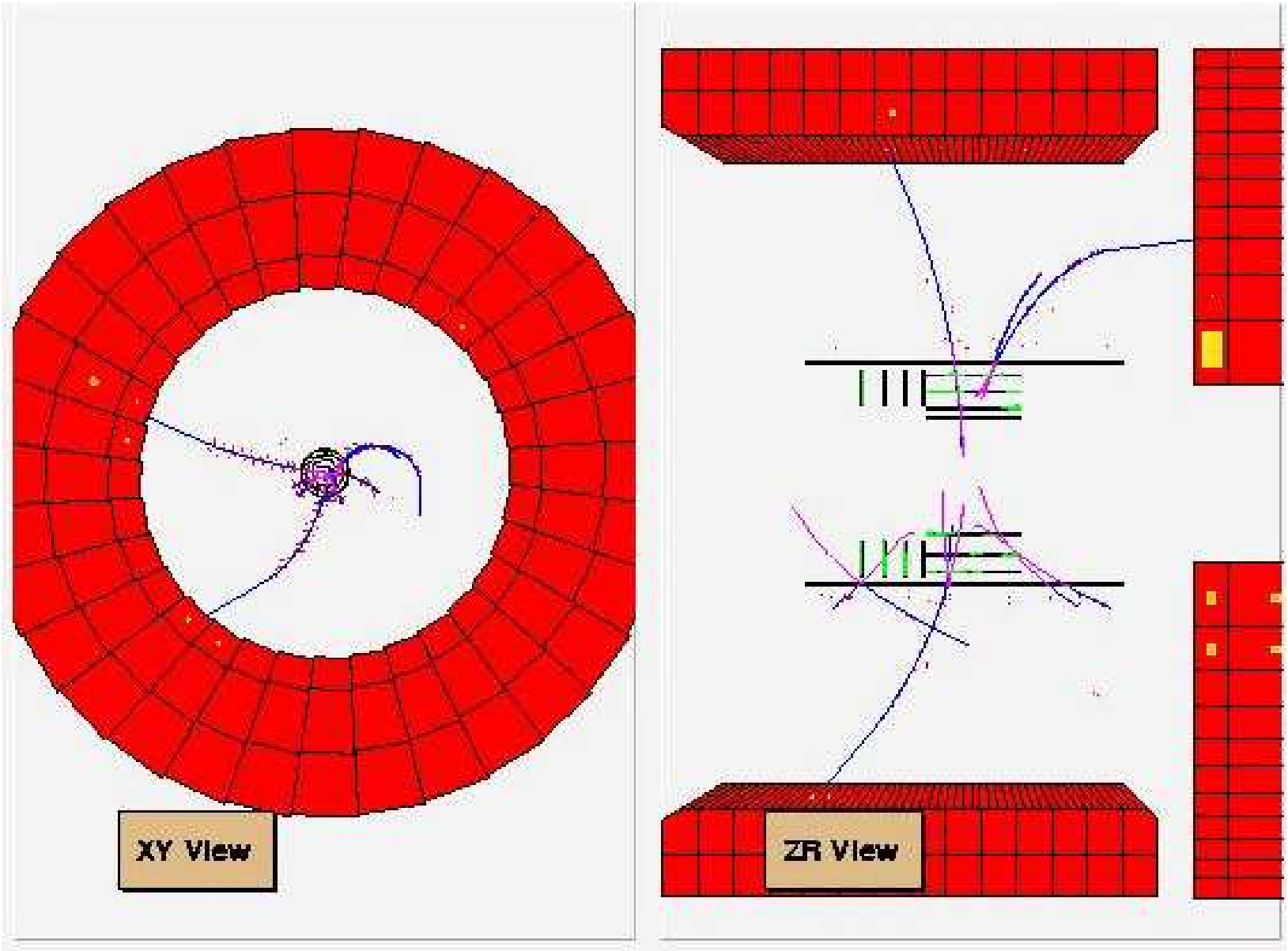


ZEUS detector status



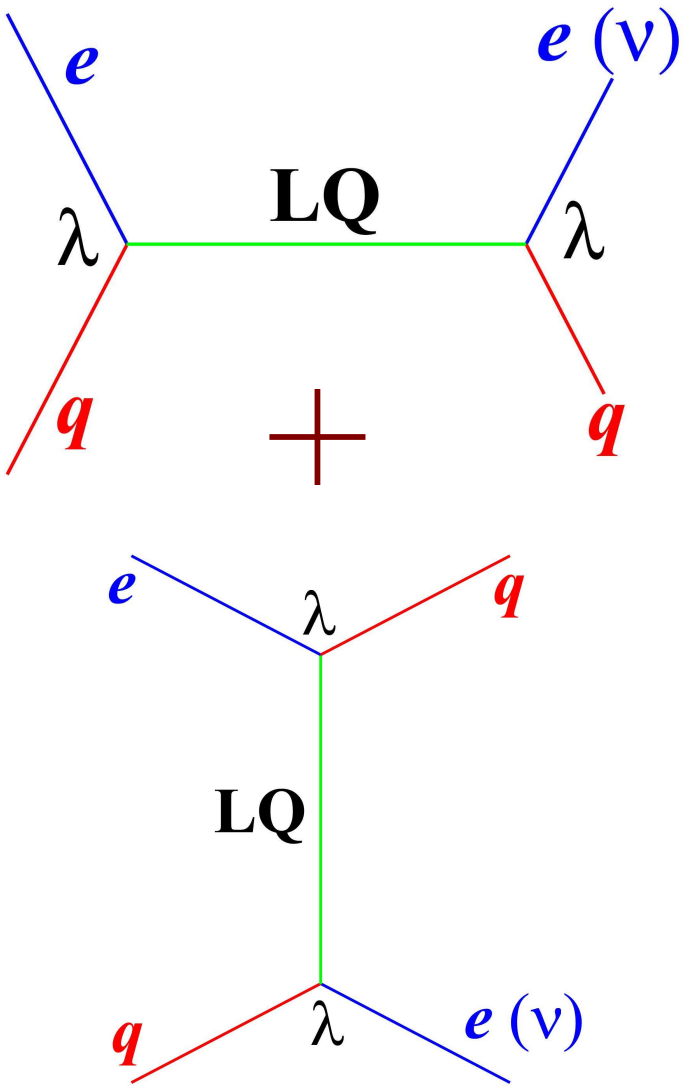
MVD/STT/LUMI fully integrated

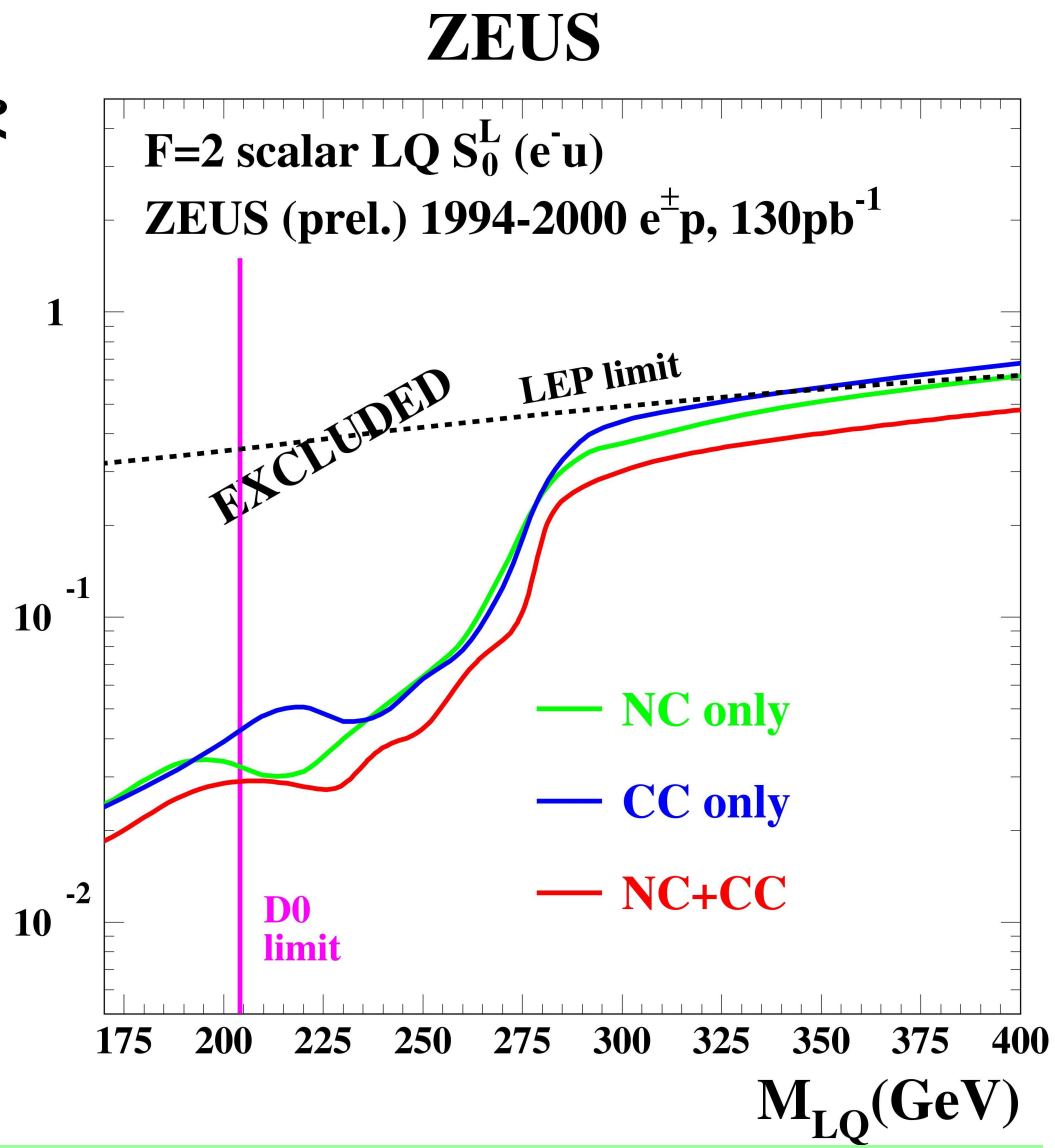
ZEUS detector status



‘Pre-upgrade’ components re-commissioned

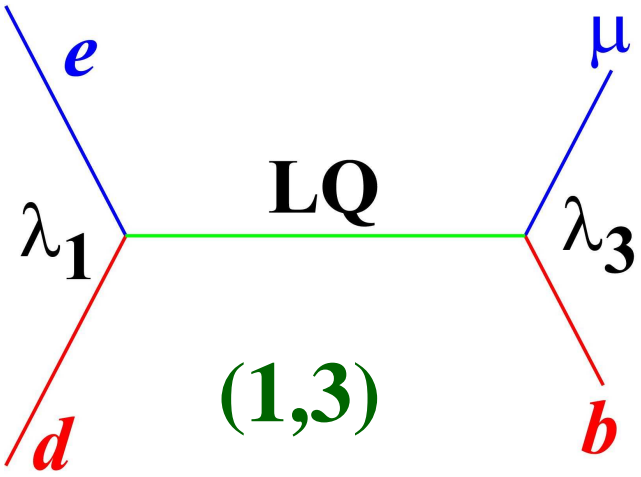
Leptoquark search



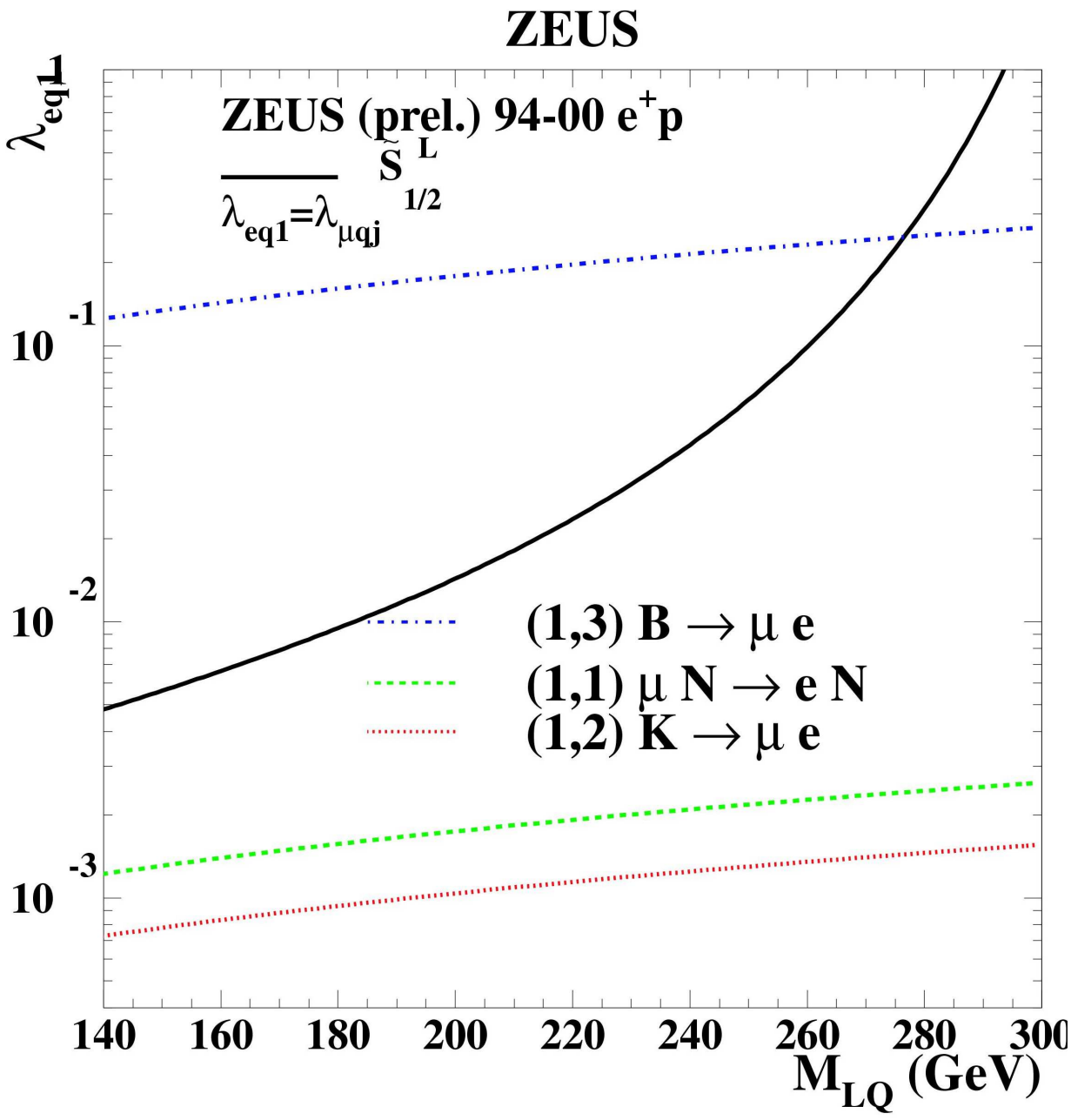


$$F = 3B + L \quad e^- p \to \mathrm{LQ}(F=2) \quad e^+ p \to \mathrm{LQ}(F=0)$$

Lepton-flavour violation



Best limits for LQ with coupling to third generation quarks

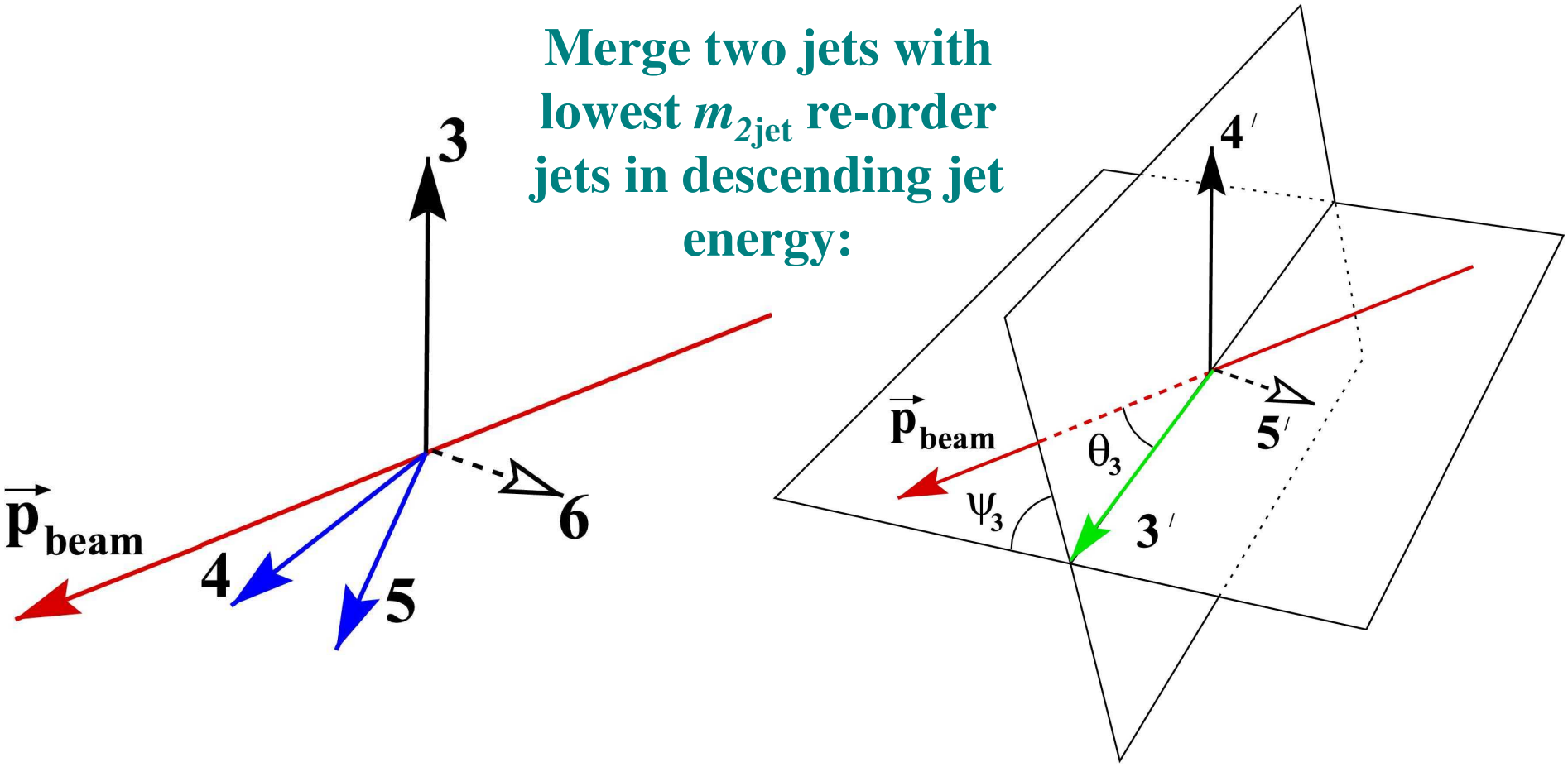


Multi-jet photoproduction

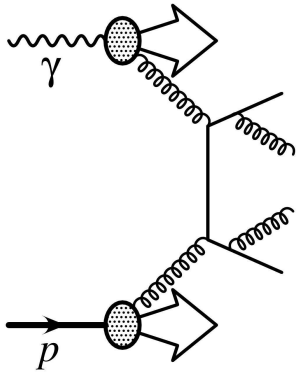
4-jet production $\gamma + p \rightarrow j_3 + j_4 + j_5 + j_6$

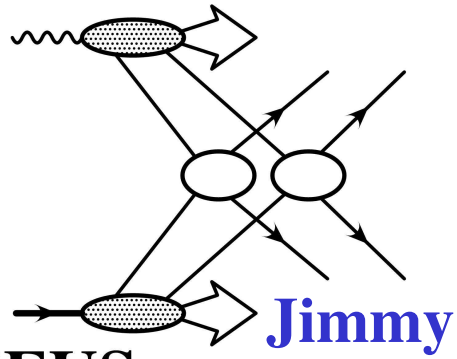
- Intrinsically sensitive to QCD at $O(\alpha_S^3)$ and Multi-parton interactions
- Study angular distribution - sensitive to dynamics

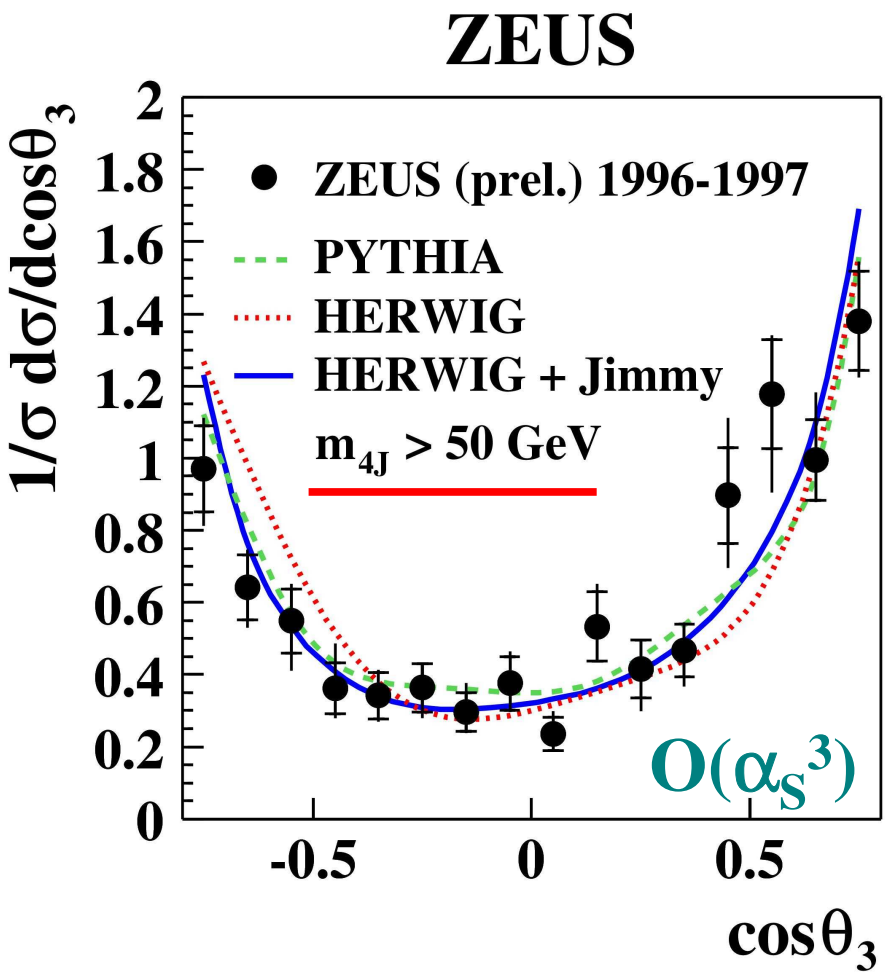
Merge two jets with lowest m_{2jet} re-order jets in descending jet energy:

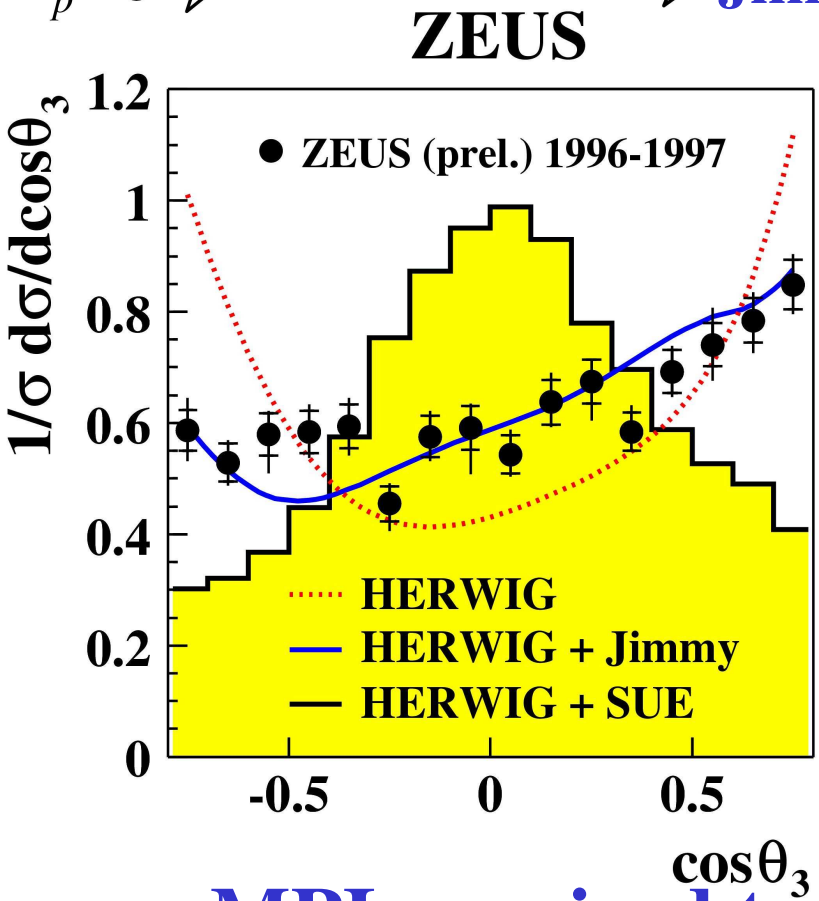


Multi-jet photoprod





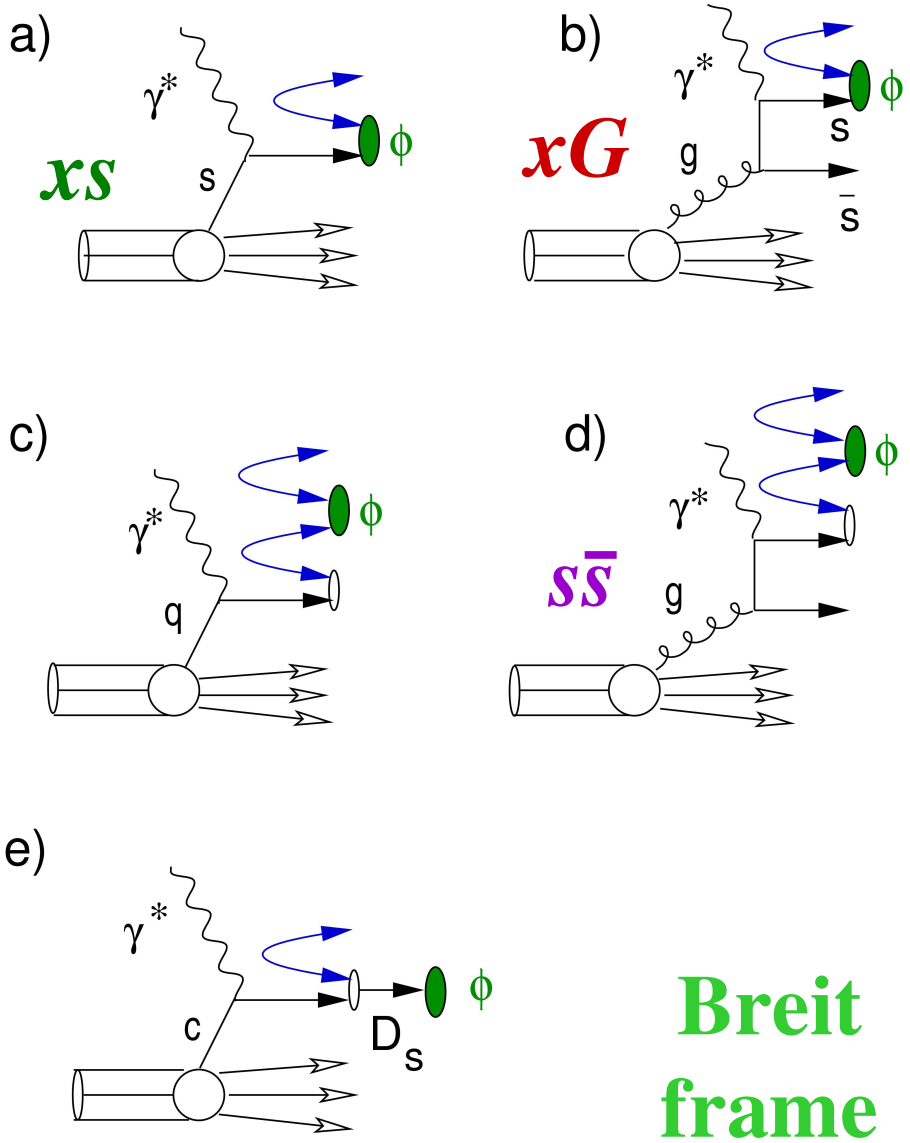




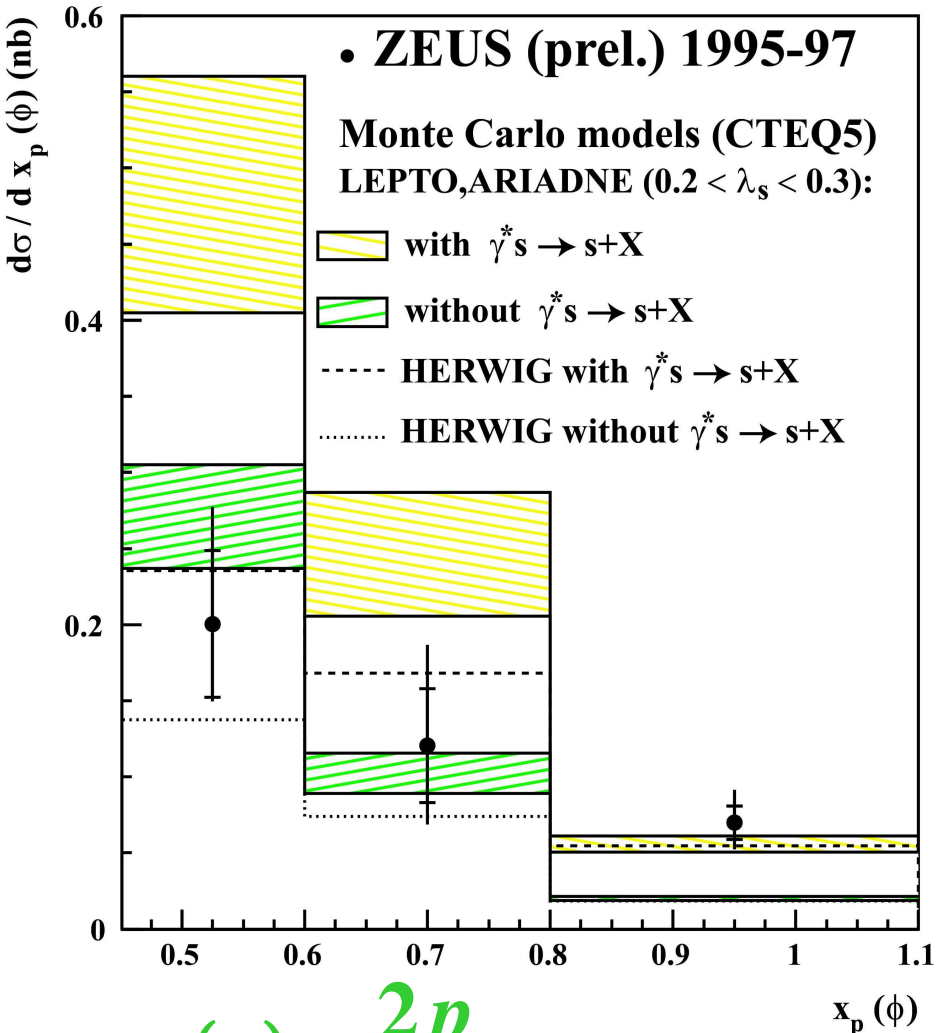
- Large m_{4jet} leading-log shower MC OK
- MPI required to describe data

$\phi(1020)$ production in DIS

Sensitive to: xs, xG and $s\bar{s}$ production in fragmentation



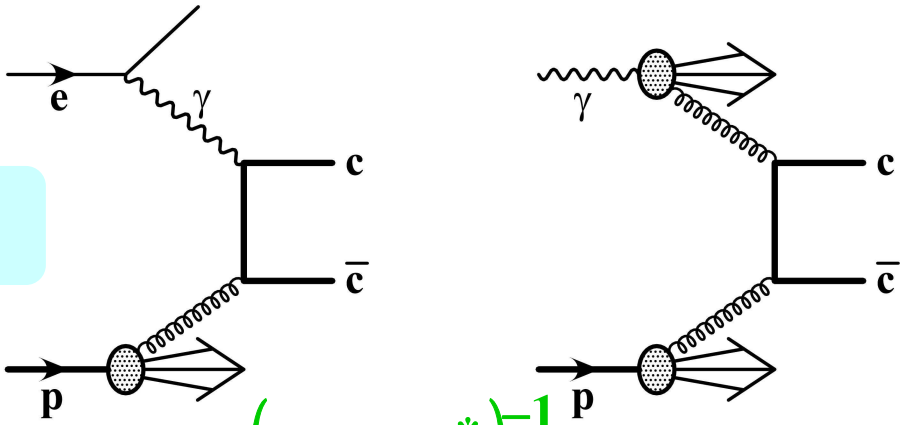
Breit frame



$$x_p(\phi) = \frac{2p}{Q}$$

D^*-di-jet angular distributions

- Dominant exchange mechanism in resolved γ-prod?
- Charm PDF in photon?



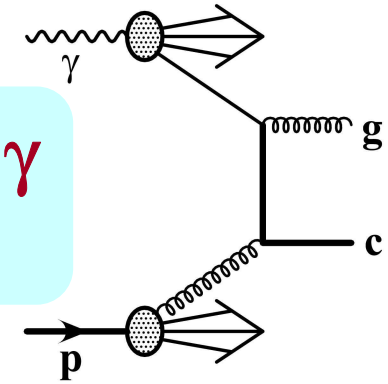
symmetric

$(1-\cos\theta^*)^{-1}$

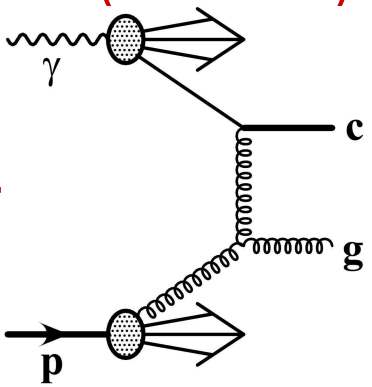
$\cos\theta^*$

$(1-\cos\theta^*)^{-2}$

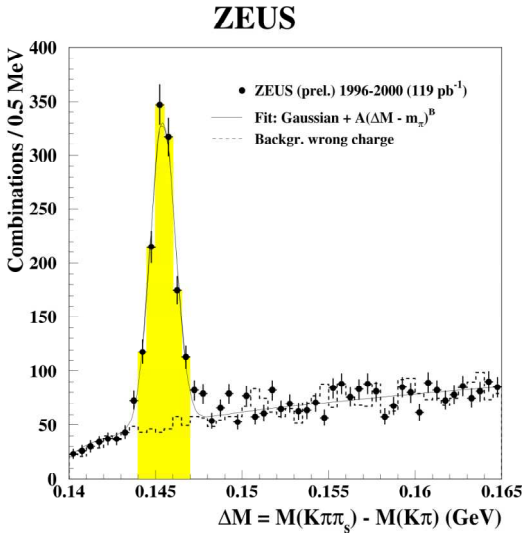
peaked in γ direction



+



D^* sample …

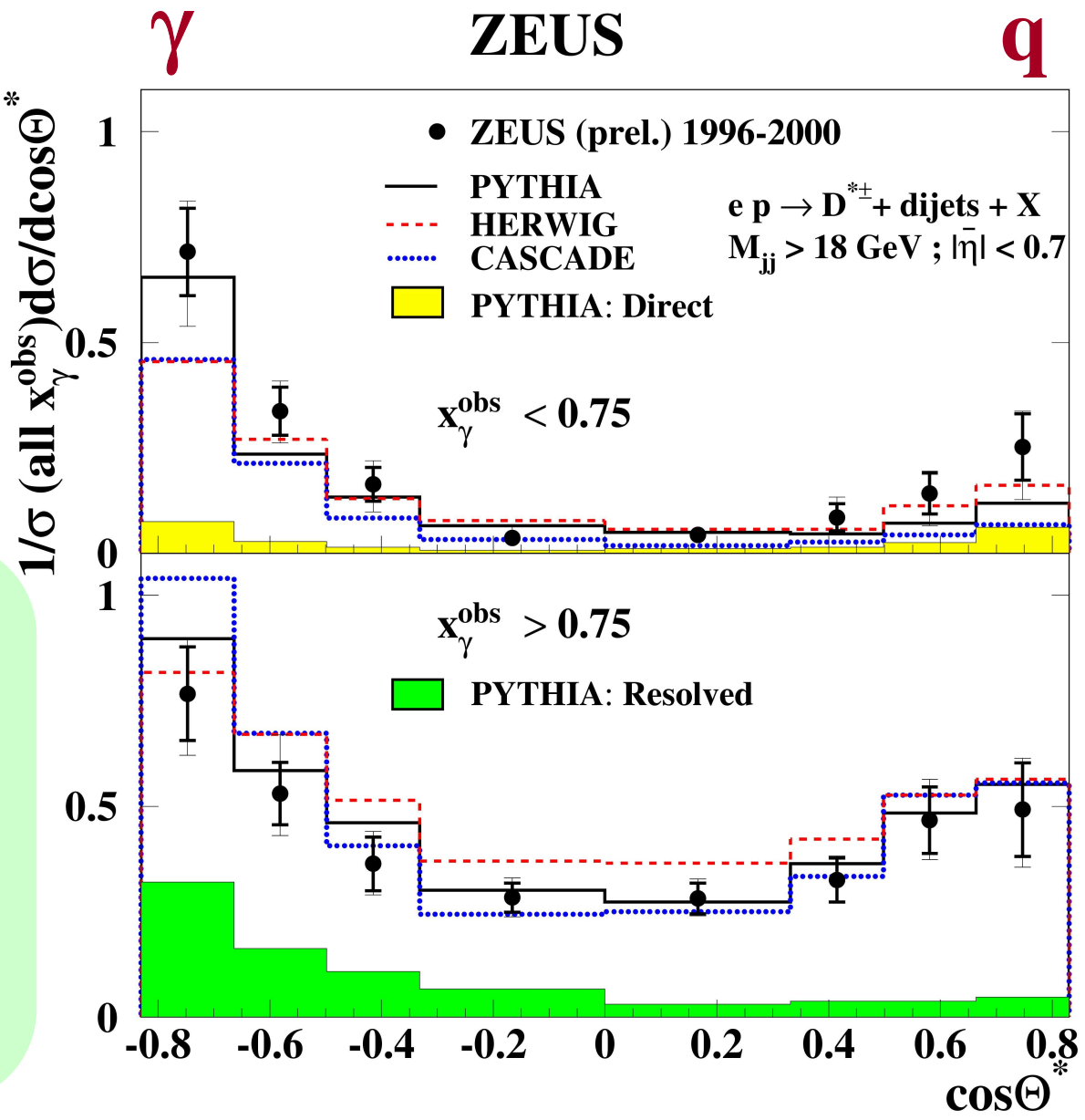


… plus two jets

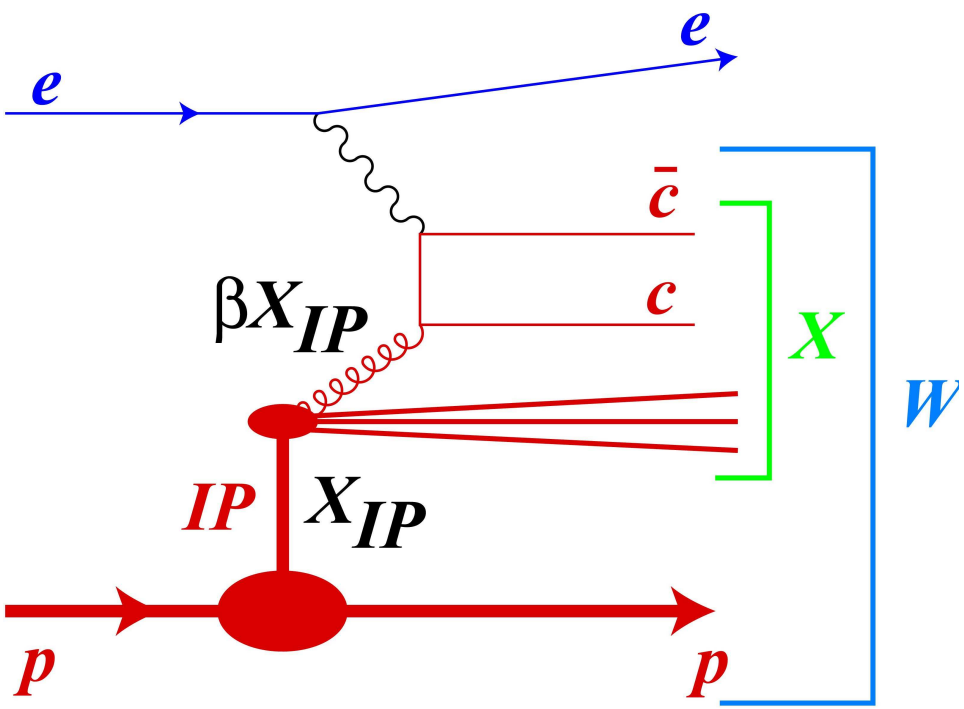
D^*-di-jet angular distributions

F-B asymmetry indicates charm in photon

Relatively rapid rise to low cos θ* in resolved distribution evidence for gluon exchange



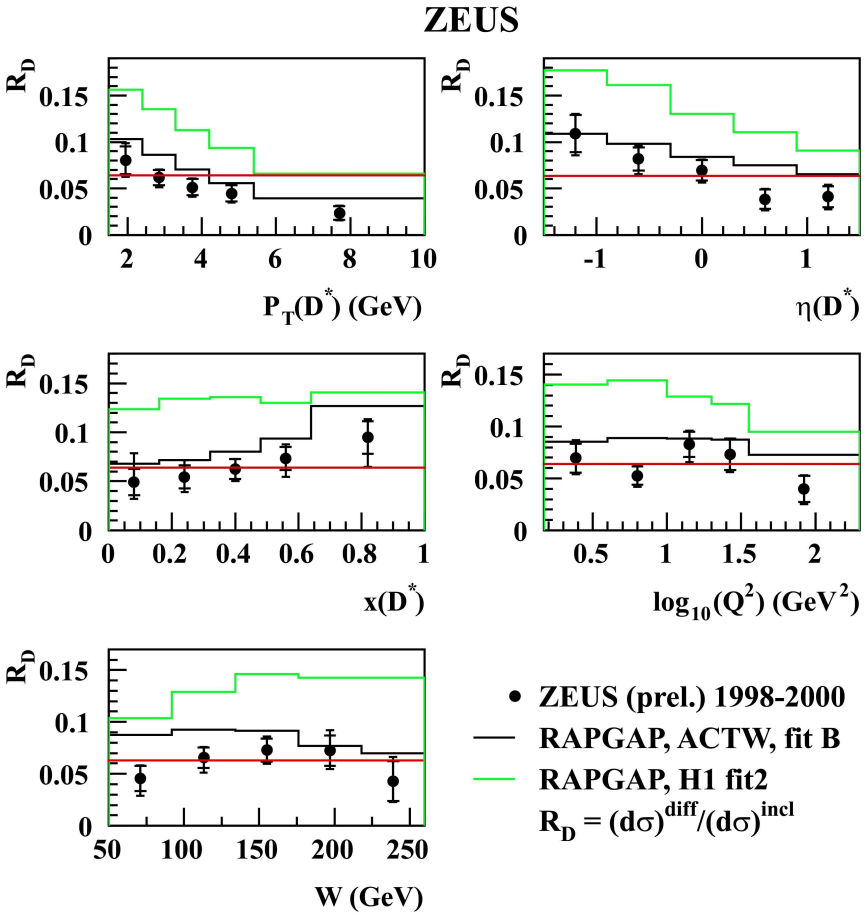
Diffractive D* production in DIS



- Charm to tag gluon in *IP*
- D* tag
- FPC tag (and $\eta_{max} < 3$)

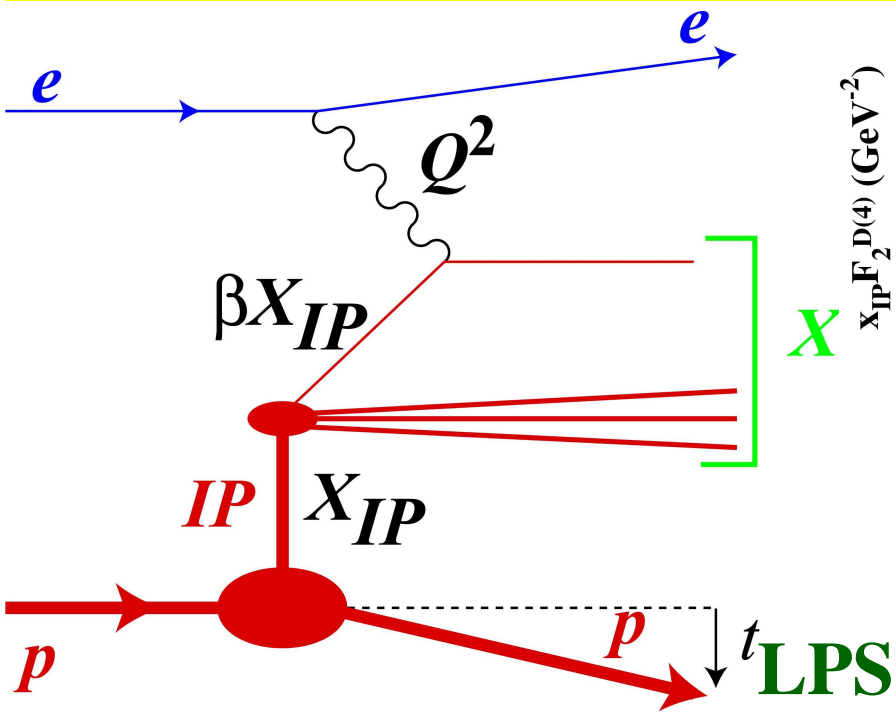
$E_{FPC} < 1.5$ GeV

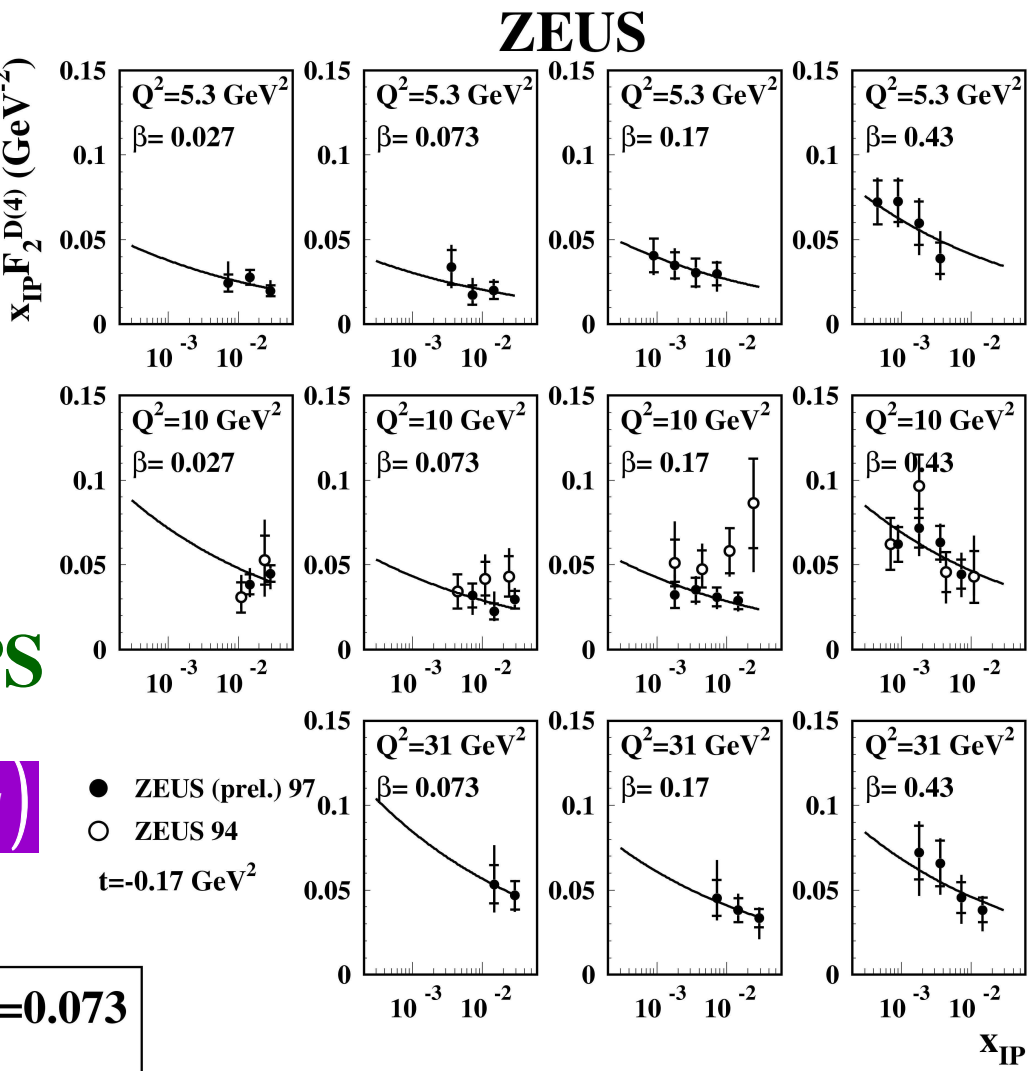
Diff./total ratio



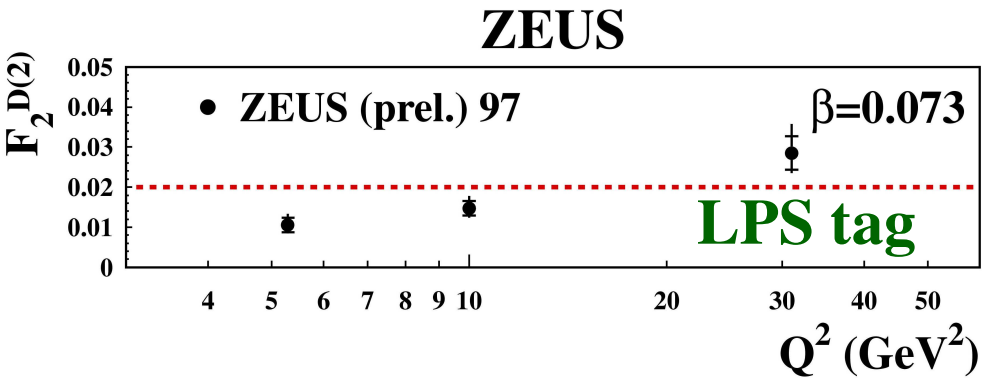
- No significant *W* dependence
- Sensitive to *IP* PDF params

Inclusive diffraction in DIS



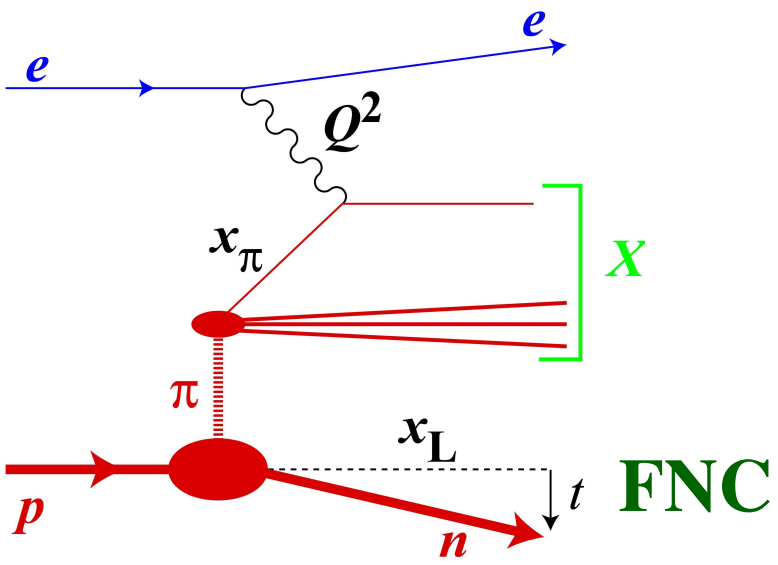


$$F_2^{D(4)} = f_{IP}(x_{IP}, t) F_2^{D(2)}(\beta, Q^2)$$



$$\frac{d^4\sigma}{d\beta Q^2 dx_{IP} dt} = \frac{2\pi\alpha^2}{\beta Q^4} Y_+ F_2^{D(4)}$$

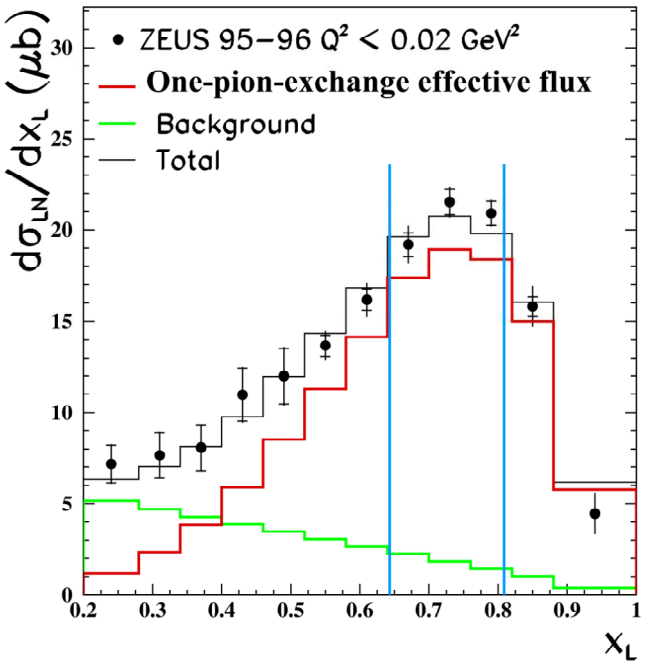
Forward-neutron production



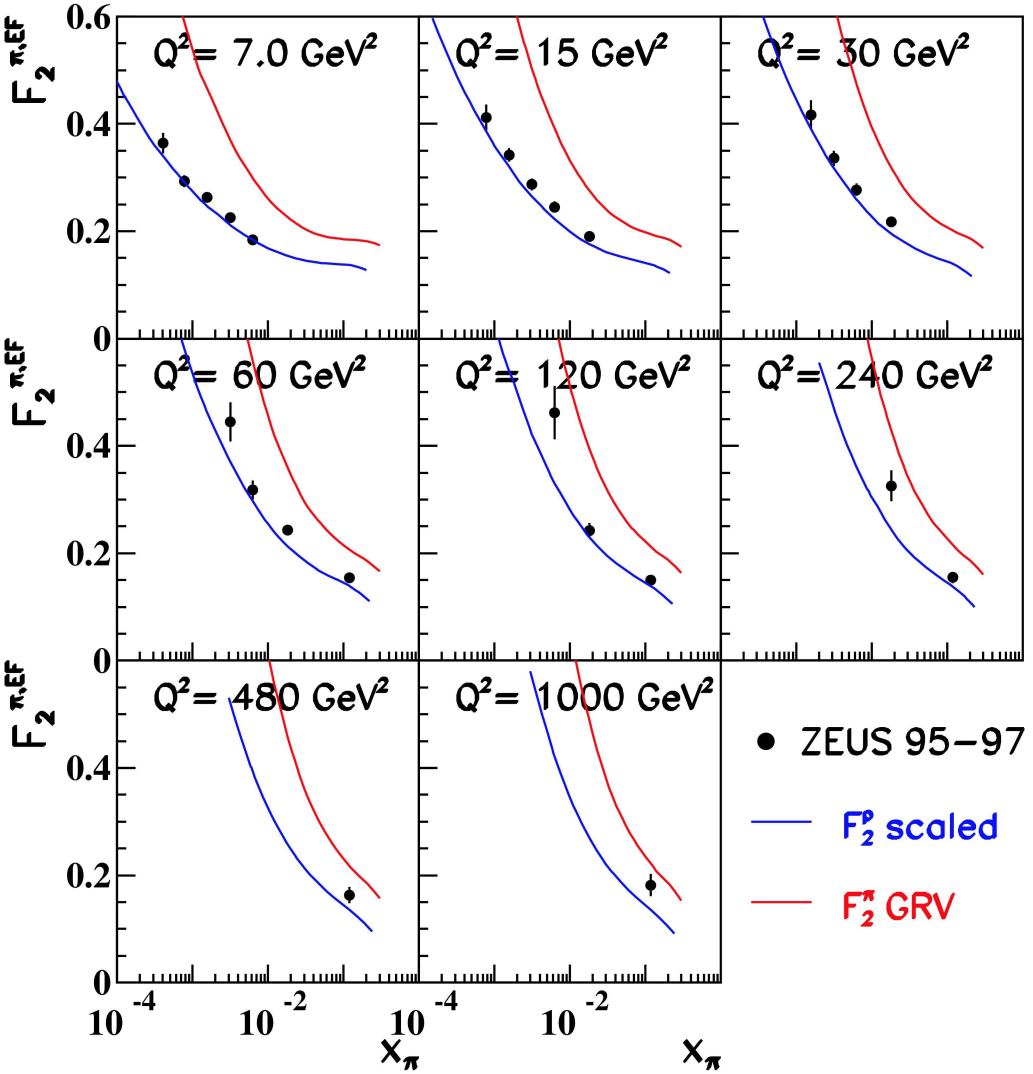
FNC

$$\frac{d^4\sigma(ep \to eXn)}{dxdQ^2dx_Ldp_T} \approx \frac{2\pi\alpha^2}{xQ^4} Y_+ F_2^{LN} \to F_2^{\pi}(x_\pi, Q^2)$$

ZEUS



ZEUS

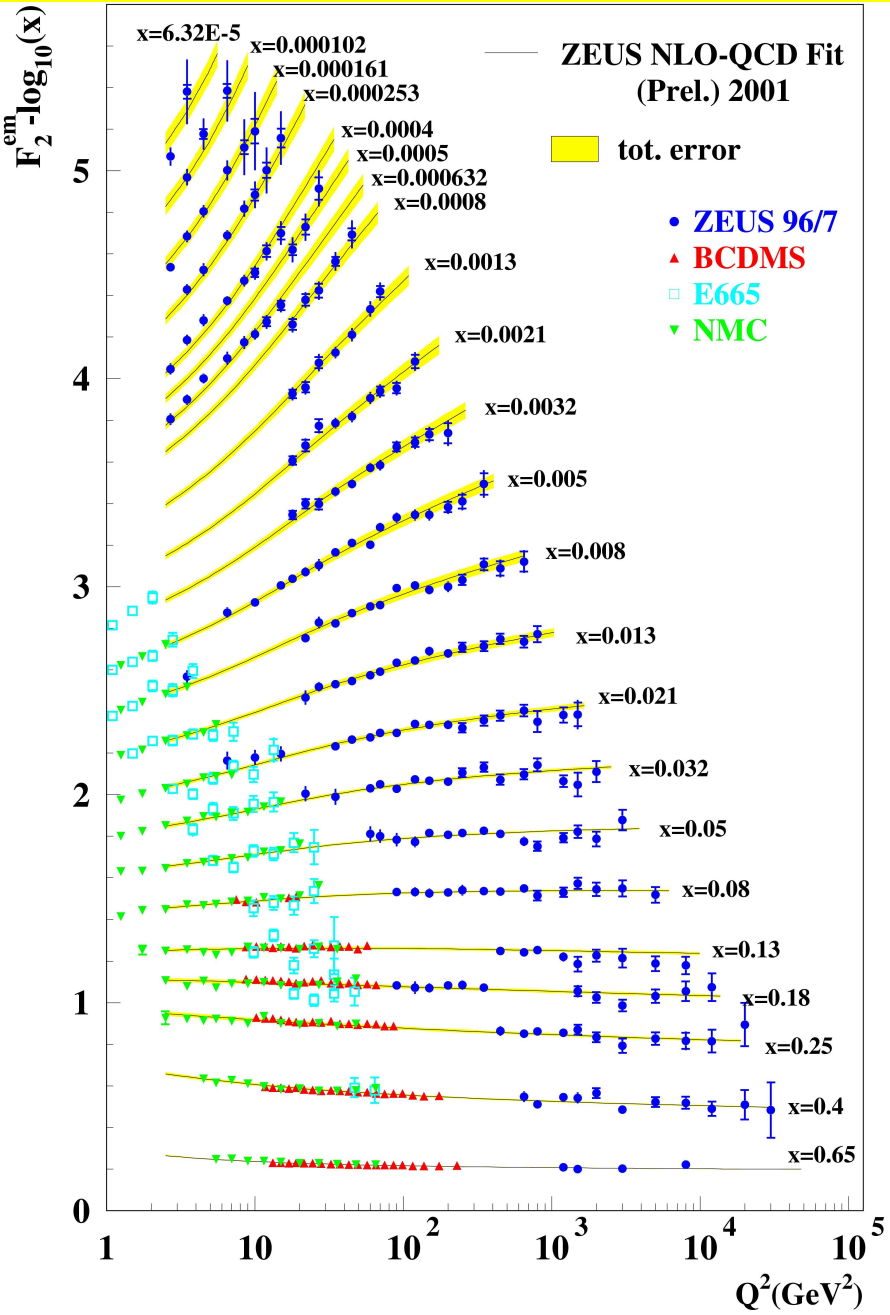


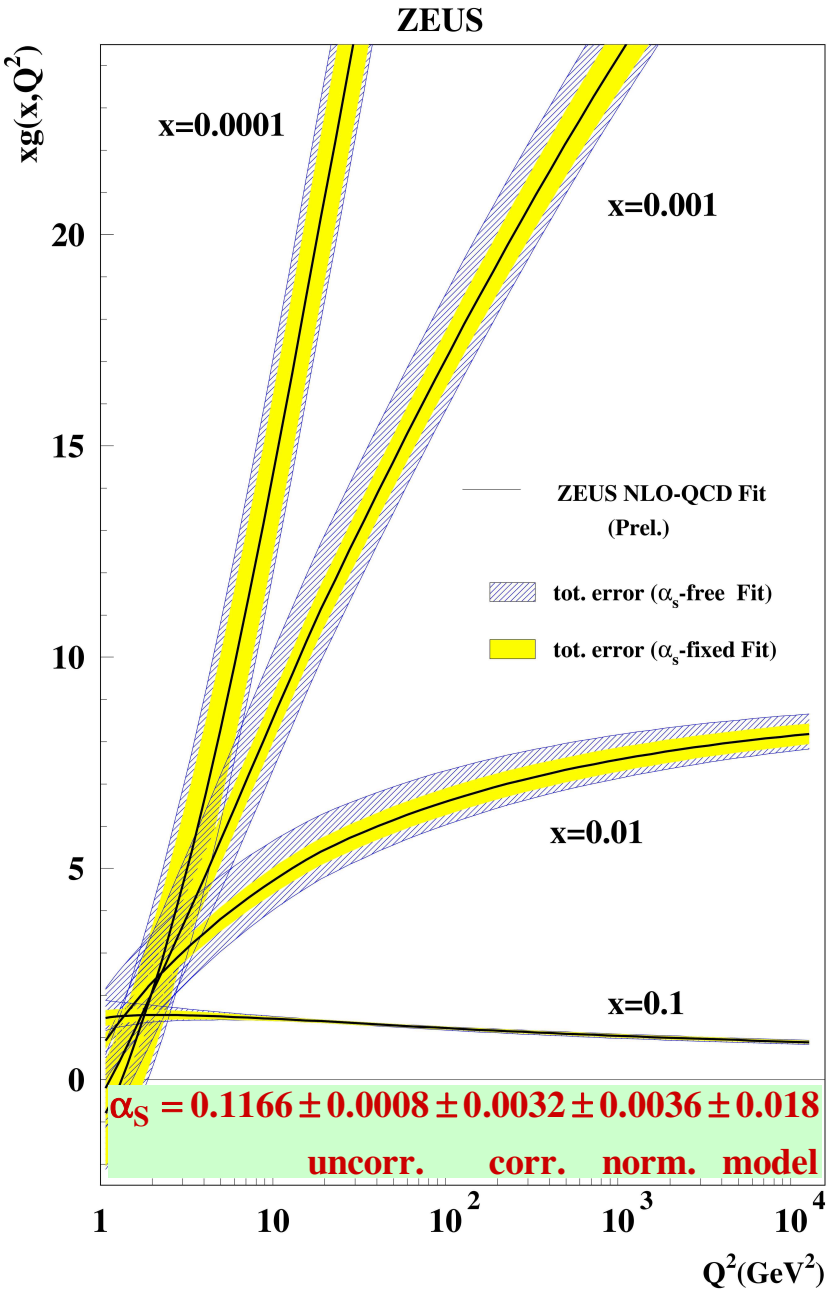
Physics at HERA II

Topic		Preferred beam	Luminosity (pb^{-1})
Structure functions	σ_{NC}, F_2, xG, α_S	e^-_L	500 - 1000
	xF_3	$e^\pm_{L,R}$	500 - 1000
	G_2	$e^-_{L,R}$	500/beam
	F_2^{cc}, F_2^{bb}	e^-_L	1000
	ss from CC	e^+_R	1000
	d/*u* from CC	e^+_R	1000
	F_L and high-*x* partons	$e^\pm$ $300 < E_p < 920$	100 ($L \propto 1/E^3 \ldots 1/E^2$)
Electroweak	CC versus polarisation	$e^\pm_{L,R}$	250/beam
	NC versus polarisation	$e^\pm_{L,R}$	250/beam
	G_F vs m_t (and M_W, M_H)	e^-_L	1000
	M_{W_R}	$e^-_{L,R}$	1000
QCD	Jets, *c*, *b*, α_S		1000
Searches	High-P_T leptons	e^+	1000
	R_P-violating SUSY, stop	e^+_R	1000
	LQ, CI	$e^\pm_{L,R}$	1000
	R_q, LED		1000
	Single top		1000
	e^*		1000
	ν^*	e^-_L	1000

HERA II: Inclusive DIS

Neutral current

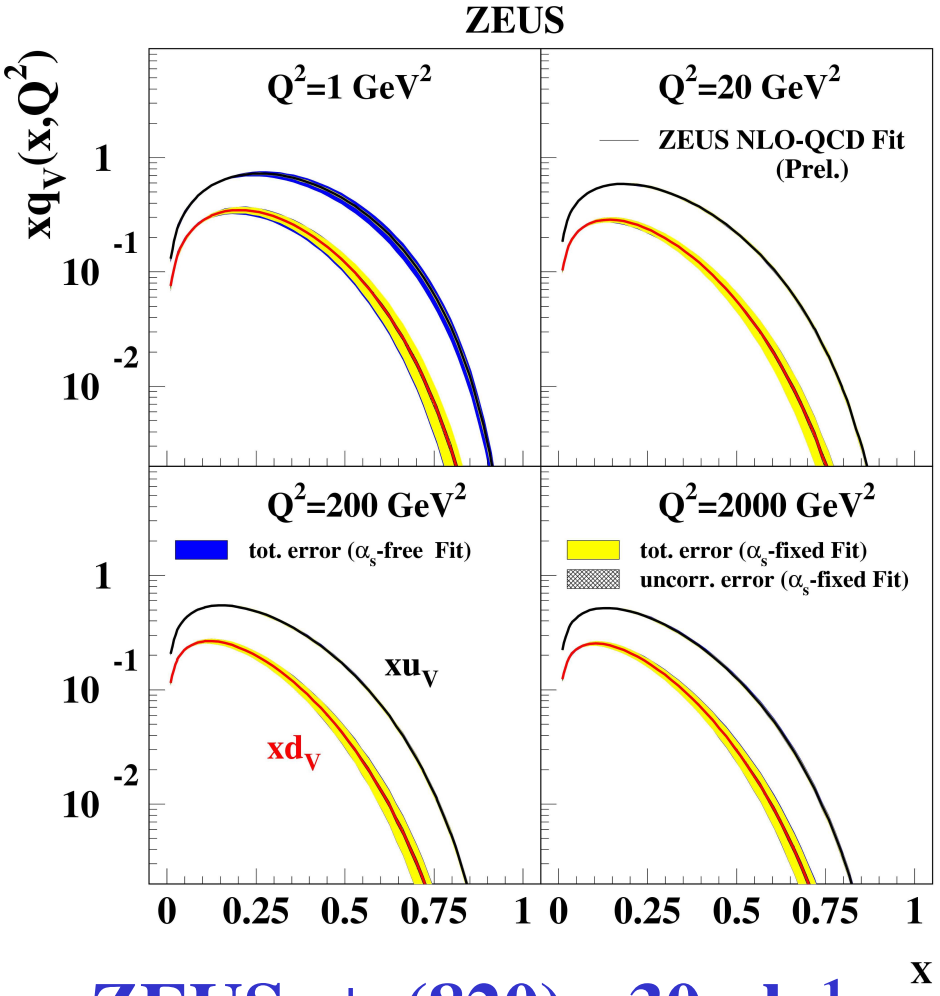


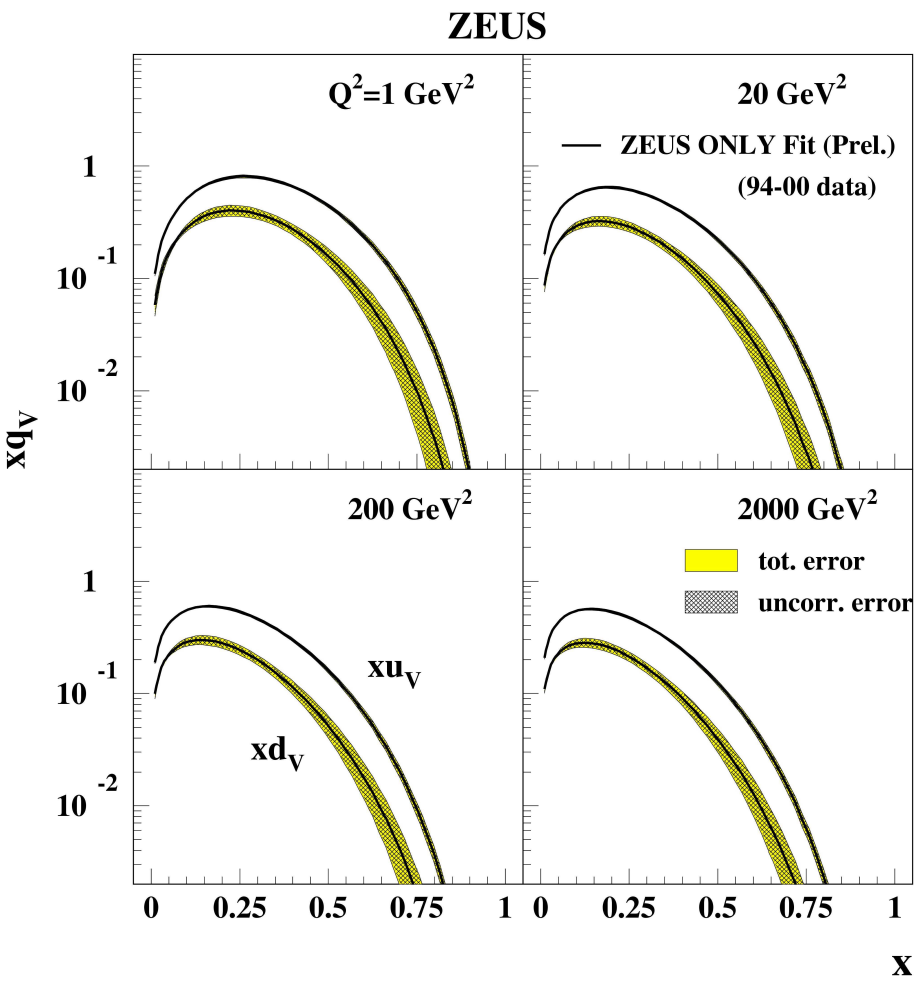


HERA II: Inclusive DIS

Neutral current

Status: *xu*, *xd*





- **ZEUS e^+p(820) - 30 pb^{-1} plus fixed target**
- **ZEUS $e^\pm p$ - 110 pb^{-1}**

HERA II: Inclusive DIS

Neutral current

		HERA I								
		e^+p (820)			e^-p (920)			e^+p (920)		
x	Q^2	Nevt	Stat. (%)	Sys. (%)	Nevt	Stat. (%)	Sys. (%)	Nevt	Stat. (%)	Sys. (%)
0.13	1200	460	5	1.5	264	10	2	1060	3	2
0.18	5000	81	11	5.2	65	13	3	172	8	3
0.25	12000	15	26	4.1	12	33	5	37	16	5
$\mathcal{L}$ (pb^{-1})		30			16			64		

		Luminosity required for stat. err. to equal sys. err.					
		920					
x	Q^2	e^- (-0.5)	e^- (+0.5)	e^-	e^+ (-0.5)	e^+ (+0.5)	e^+
0.13	1200	146	157	152	160	149	155
0.18	5000	249	303	274	457	373	411
0.25	12000	470	616	533	834	619	712

- e^-_L preferred for measurement of σ^{NC}
- At highest x, Q^2 stat. limited even with 1 fb^{-1}

HERA II: Inclusive DIS

Neutral current

$$\frac{d^2\sigma^{\pm(L,R)}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+F_2^0 \mp Y_-xF_3^0 + P\left(Y_+F_2^P \mp Y_-xF_3^P\right) - y^2F_L\right]$$

$$F_2 \propto \sum\left(q+\bar{q}\right)$$

- F_2^0 from *SUM*: $\sigma^-(L+R) + \sigma^+(L,R)$

  $\Rightarrow N_{Tot}$ criterion

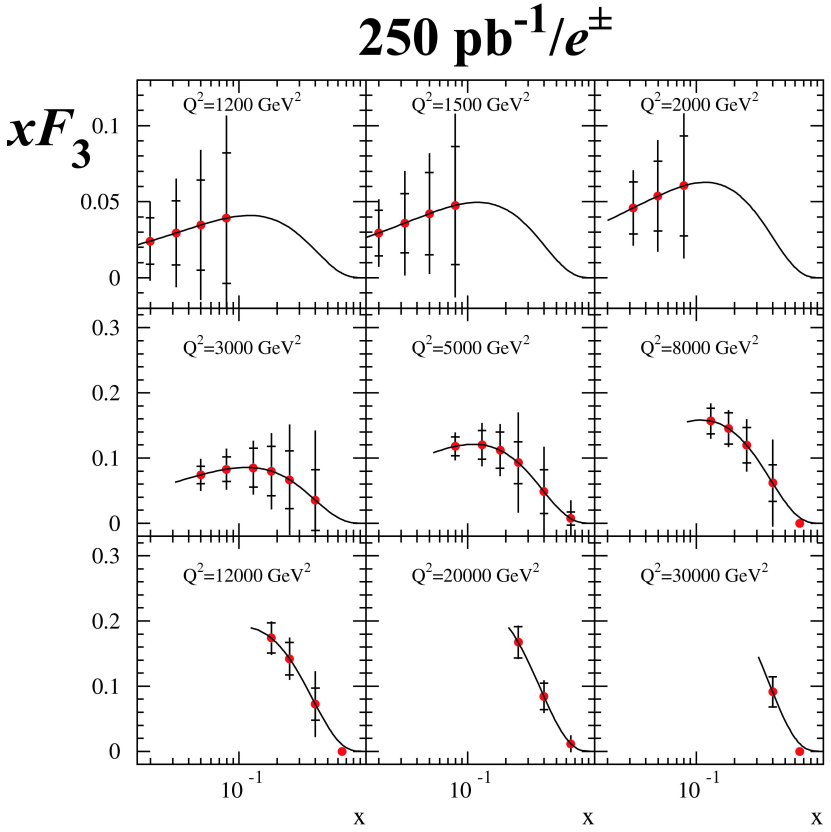
$$xF_3 \propto \sum\left(q-\bar{q}\right)$$

- xF_3^0 from *DIFFERENCE*

  $\sigma^-(L+R) - \sigma^+(L,R)$

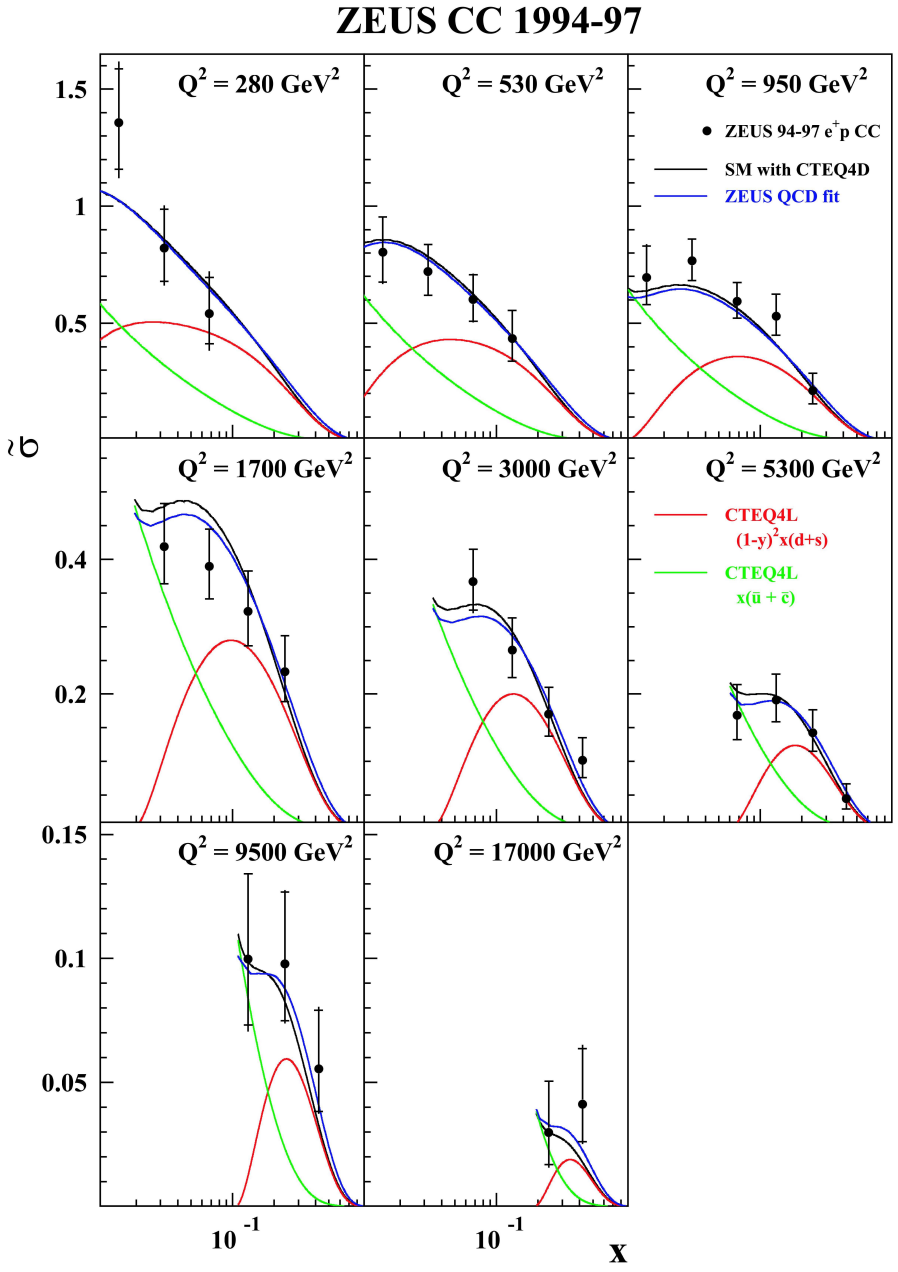
  $\Rightarrow N_{electron} \sim N_{positron}$

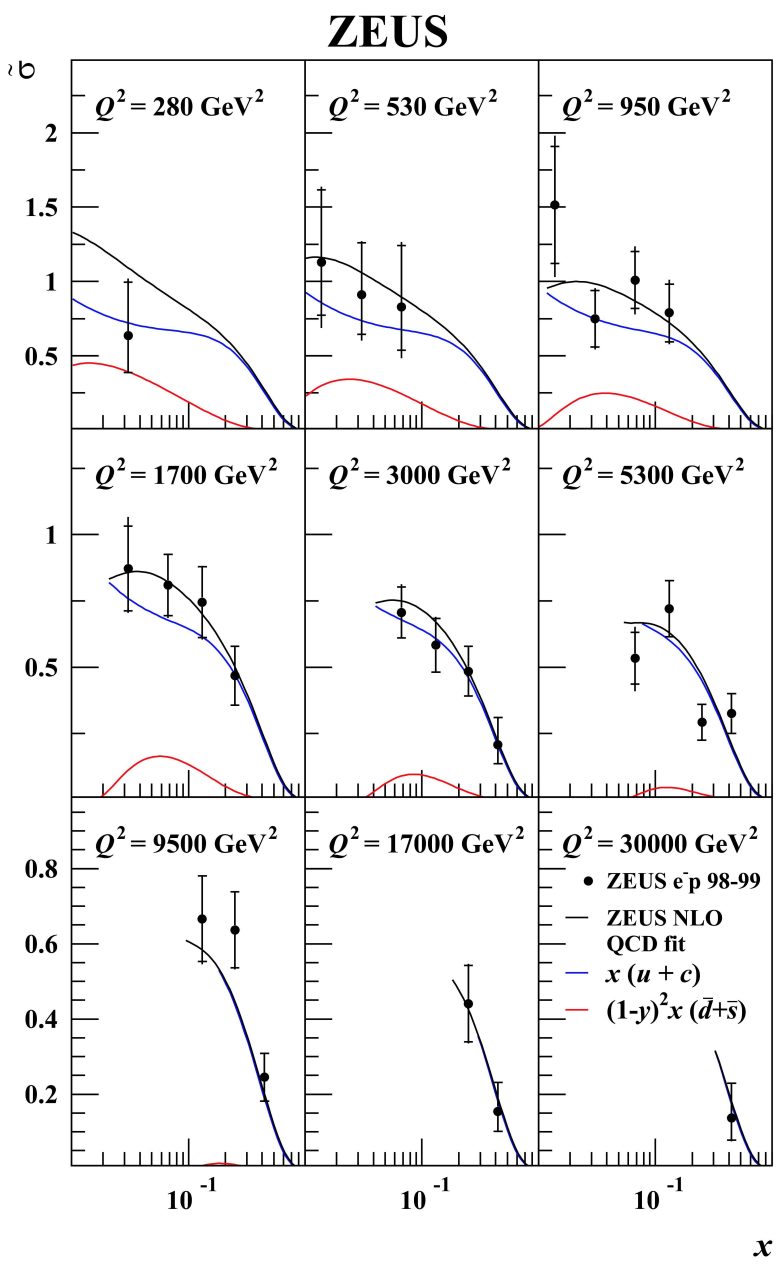
  $\Rightarrow \mathcal{L}_{positron} \sim 1.5\times(\mathcal{L}_{electron})$



HERA II: Inclusive DIS

Charged current





HERA II: Inclusive DIS

Charged current

		HERA I								
		e^+p (820)			e^-p (920)			e^+p (920)		
x	Q^2	Nevt	Stat. (%)	Sys. (%)	Nevt	Stat. (%)	Sys. (%)	Nevt	Stat. (%)	Sys. (%)
0.13	1700	40	16	2	31	18	4	80	11	4
0.24	5300	27	19	7	22	21	3	54	14	3
0.24	9500	18	24	7	39	16	6	36	17	6
$\mathcal{L}$ (pb^{-1})		30			16			64		

		Luminosity required for stat. err. to equal sys. err. (=3%)					
		920					
x	Q^2	e^- (-0.5)	e^- (+0.5)	e^-	e^+ (-0.5)	e^+ (+0.5)	e^+
0.13	1700	400	1196	599	2147	717	1075
0.24	5300	379	1138	568	3241	1081	1620
0.24	9500	412	1236	618	5455	1814	2727

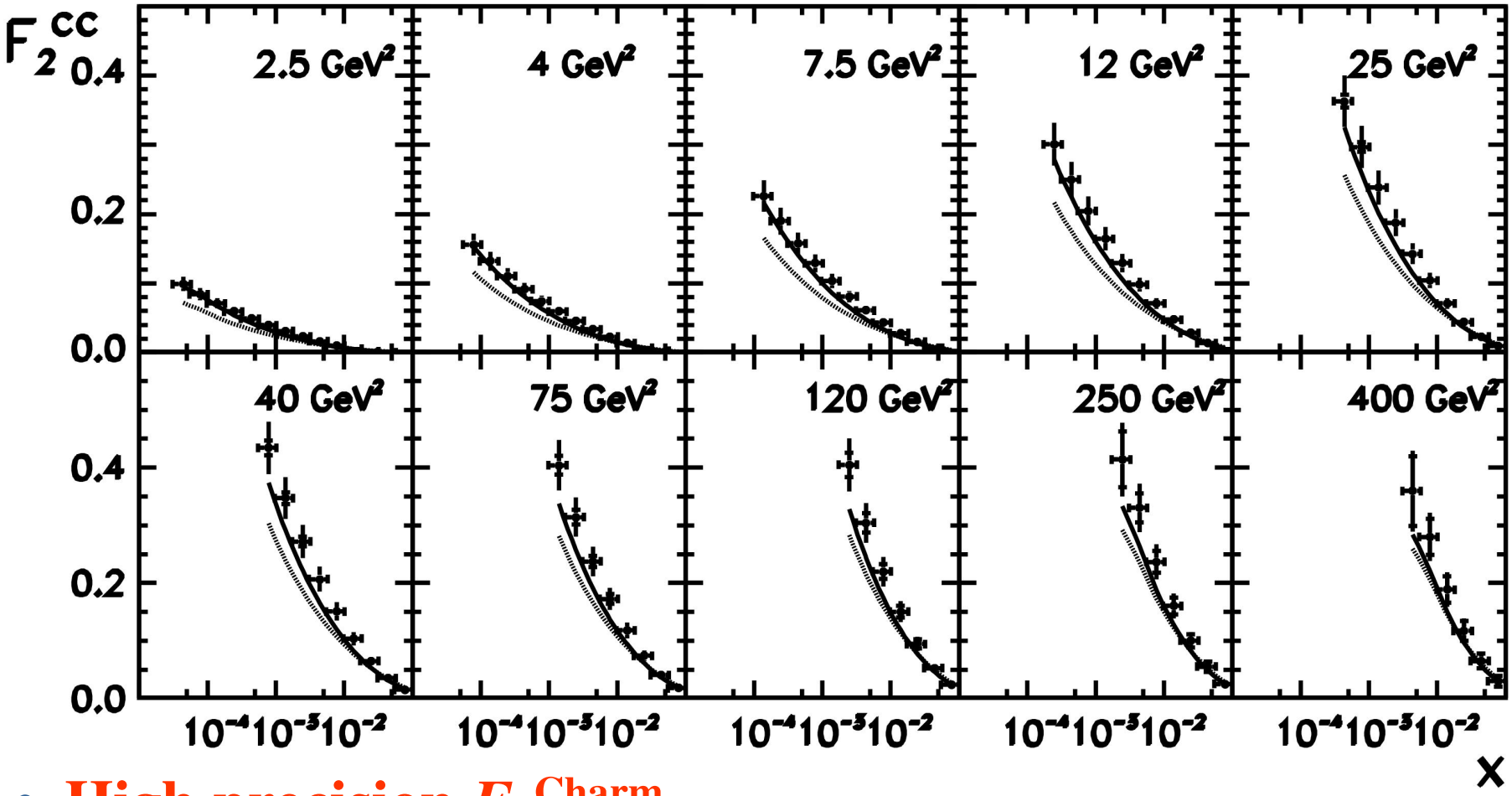
- e^+_R preferred for measurement of d/u
- At highest x, Q^2 stat. limited even with 1 fb^{-1}

HERA II: Heavy flavours in proton

Charm:

500 pb^{-1}

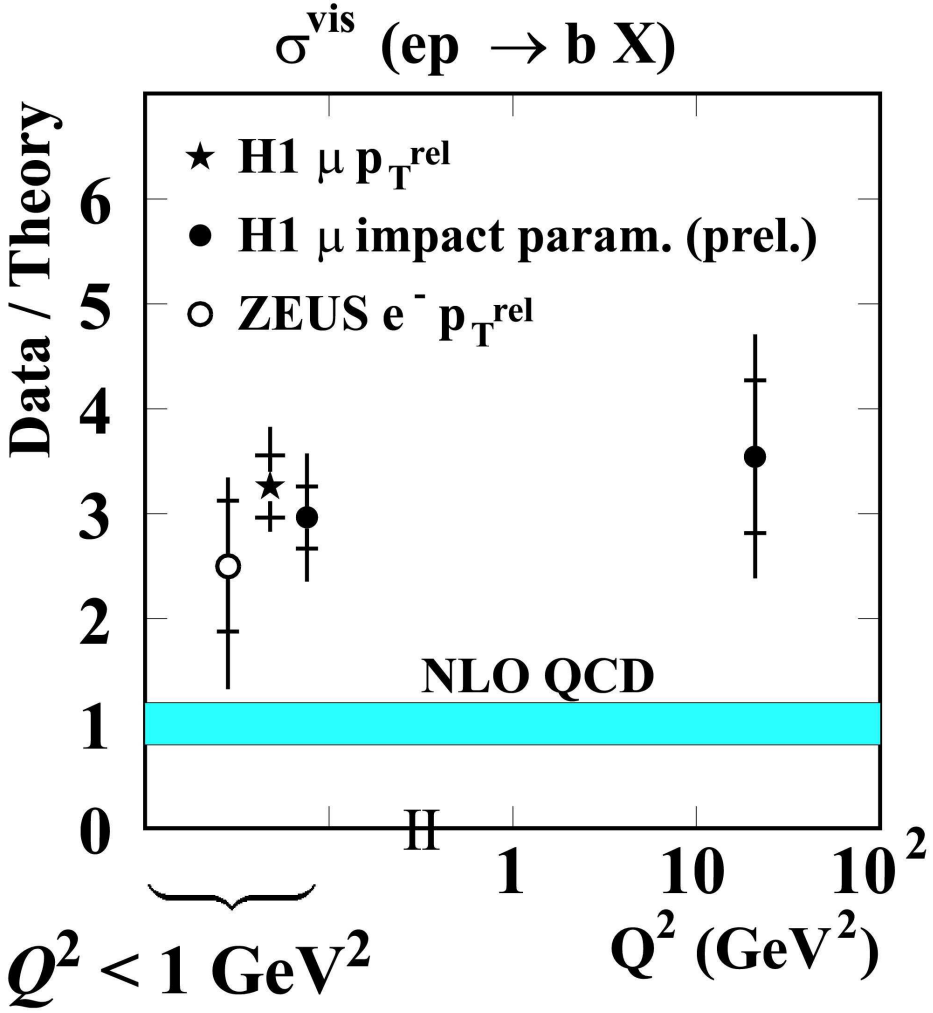
Silicon MVD tag



- High precision F_2^{Charm}
- N_{Tot} criterion - highest possible $\mathcal{L}$

HERA II: Heavy flavours in proton

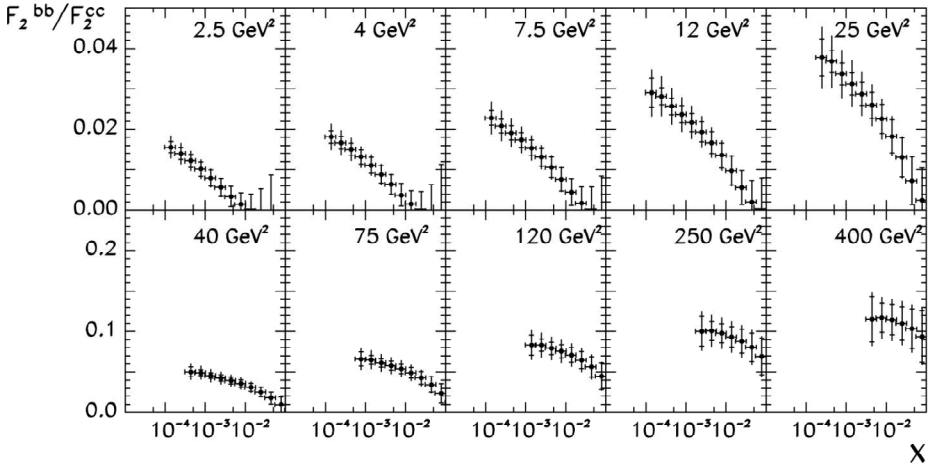
Beauty:



- First measurements

Silicon MVD tag

500 pb^{-1}

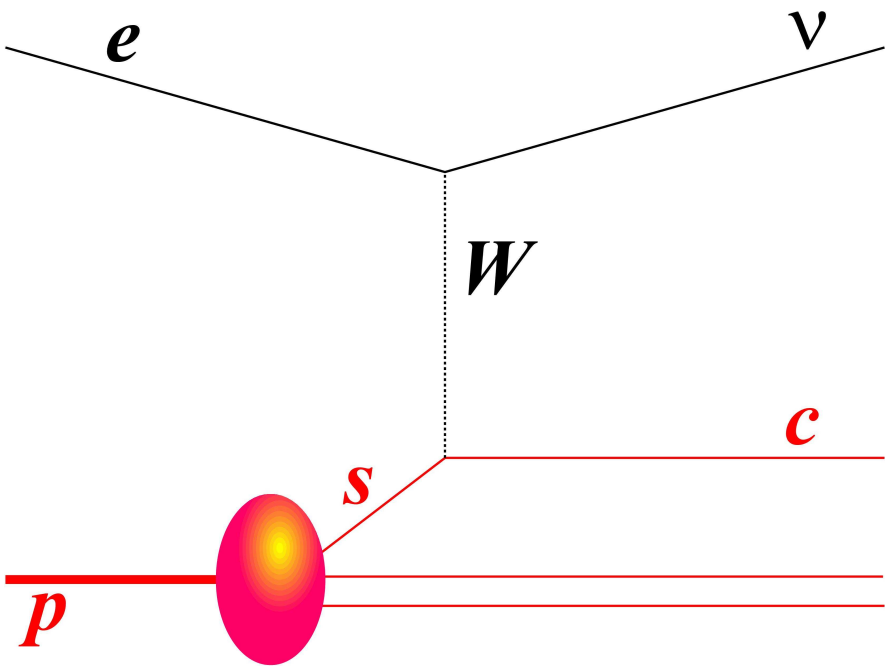


- Sensitivity to F_2^{Botton}
- N_{Tot} criterion - highest possible $\mathcal{L}$

HERA II: Heavy flavours in proton

Charm in Charged Current:

Silicon MVD tag



Tag charm in CC events using MVD:

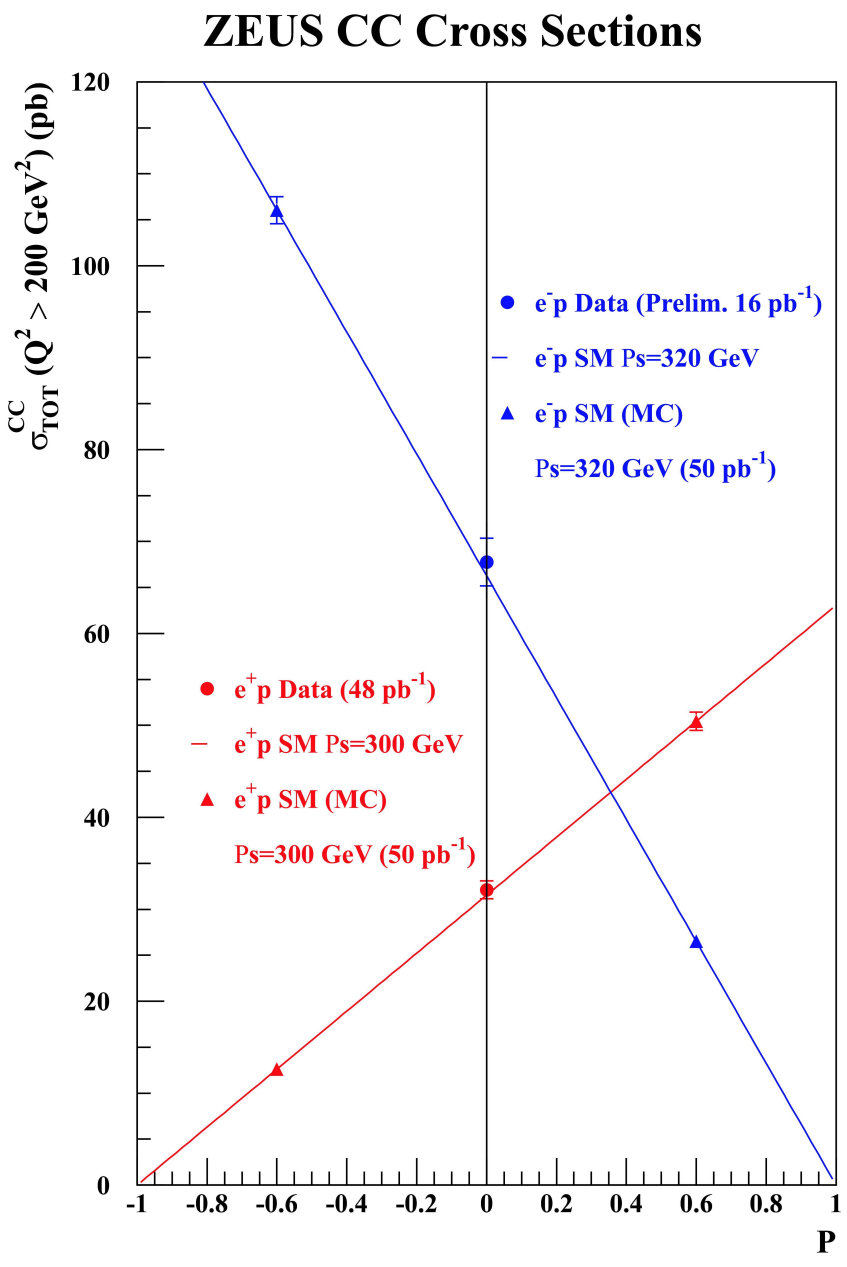
Strange contribution to F_2: with 500 pb^{-1} precision ~15 - 30%

$$\tilde{\sigma}^{e^+p} = x(\bar{u}+\bar{c})+(1-y)^2(d+s)$$

$$\tilde{\sigma}^{e^-p} = x(u+c)+(1-y)^2(\bar{d}+\bar{s})$$

- **Reduce 'background' from u, $\bar{u}$**
- **e^+p preferred $\Rightarrow e^+_R$**

HERA II: Right-handed charged current



$$\sigma^{e^+}_{\mathrm{Tot}}(820) = 32.10 \pm 0.97^{+0.78}_{-0.79}\ \mathrm{pb}$$

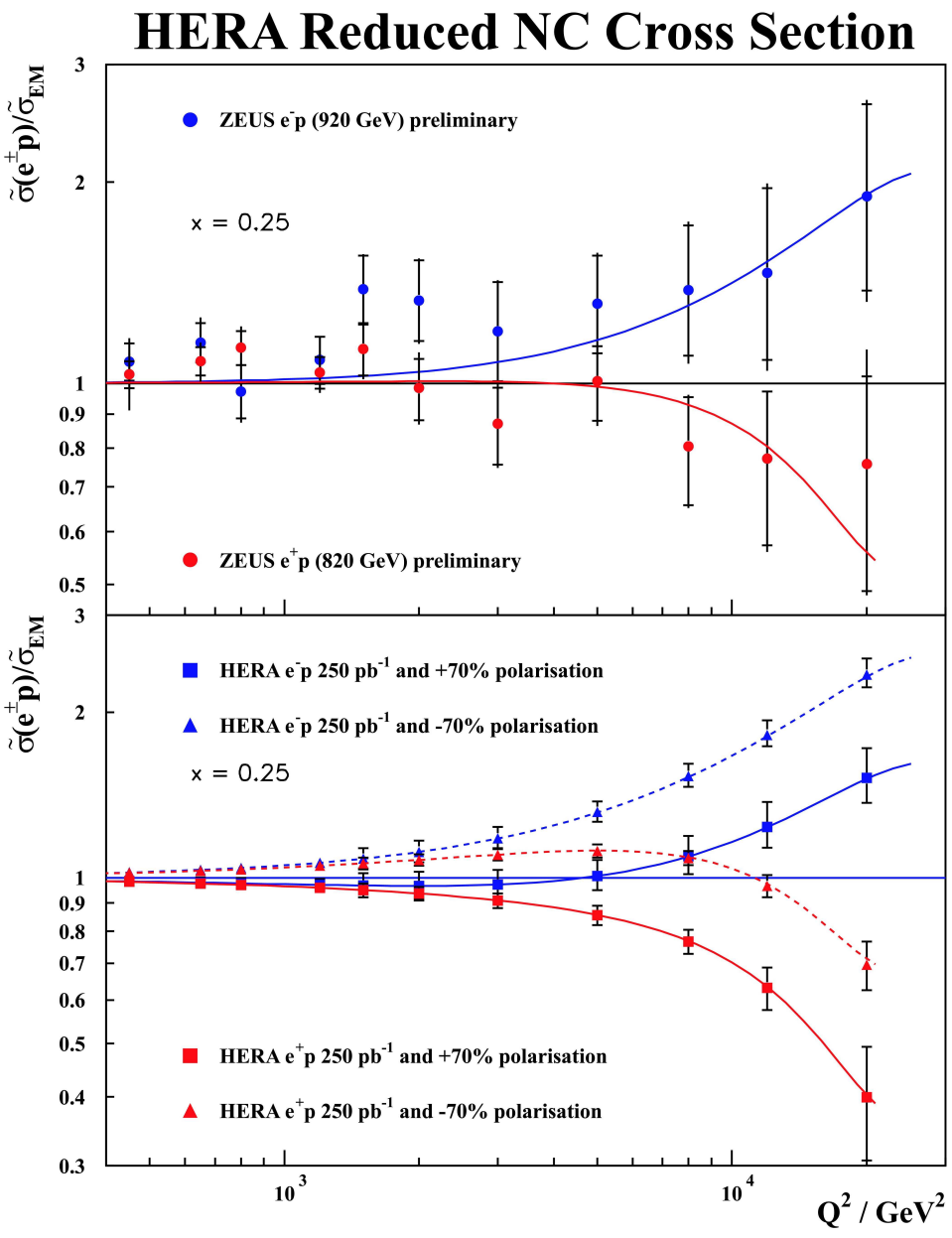
$$\sigma^{e^-}_{\mathrm{Tot}}(920) = 66.7 \pm 2.7^{+1.8}_{-1.1}\ \mathrm{pb}$$

$$\sigma^{e^+}_{P} = (1+P)\sigma^{e^+}_{\mathrm{SM}} + \sigma^{e^+}_{\mathrm{Exo}}$$

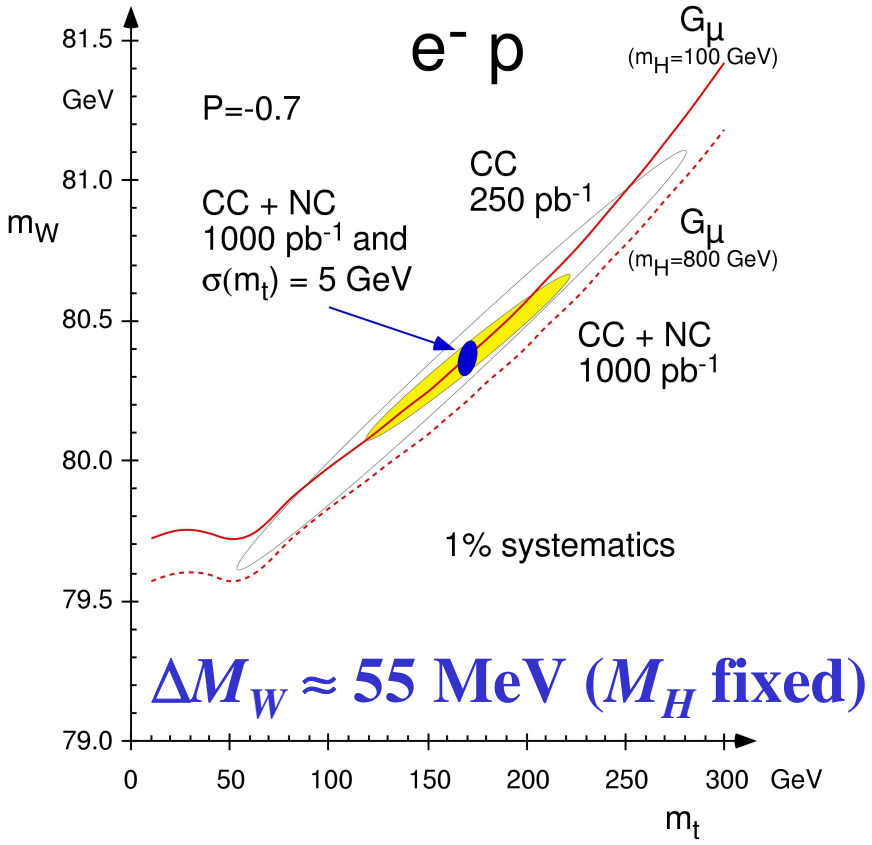
$$\sigma^{e^-}_{P} = (1-P)\sigma^{e^-}_{\mathrm{SM}} + \sigma^{e^-}_{\mathrm{Exo}}$$

- e^- steeper $\Rightarrow$ best sensitivity
- e^-_R preferred more signal, less SM bg
- Desirable to explore $e^{\pm}_{L,R}$

HERA II: Electroweak



G_μ *constraint* - can be used to test SM



$\Delta M_W \approx 55$ MeV (M_H fixed)

70% polarisation; 250 pb^{-1}:

$\Delta M_W \approx 80$ MeV

e^-_L preferred

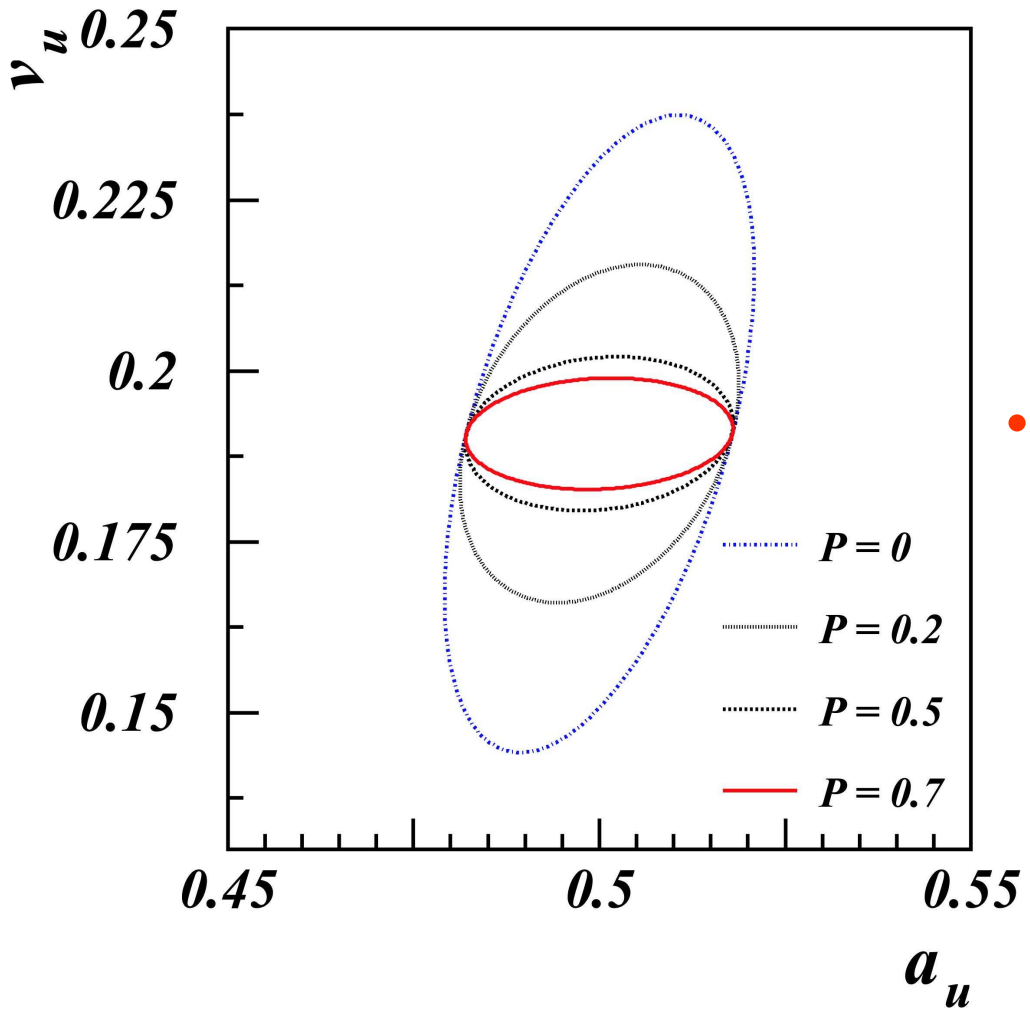
HERA II: Electroweak

Parity violation in SM $\Rightarrow g_L^{NC} \neq g_R^{NC}$

Determination of light quark couplings

$e^{\pm}_{L,R}$, $P = \pm 70\%$ and 250 pb^{-1} per beam →

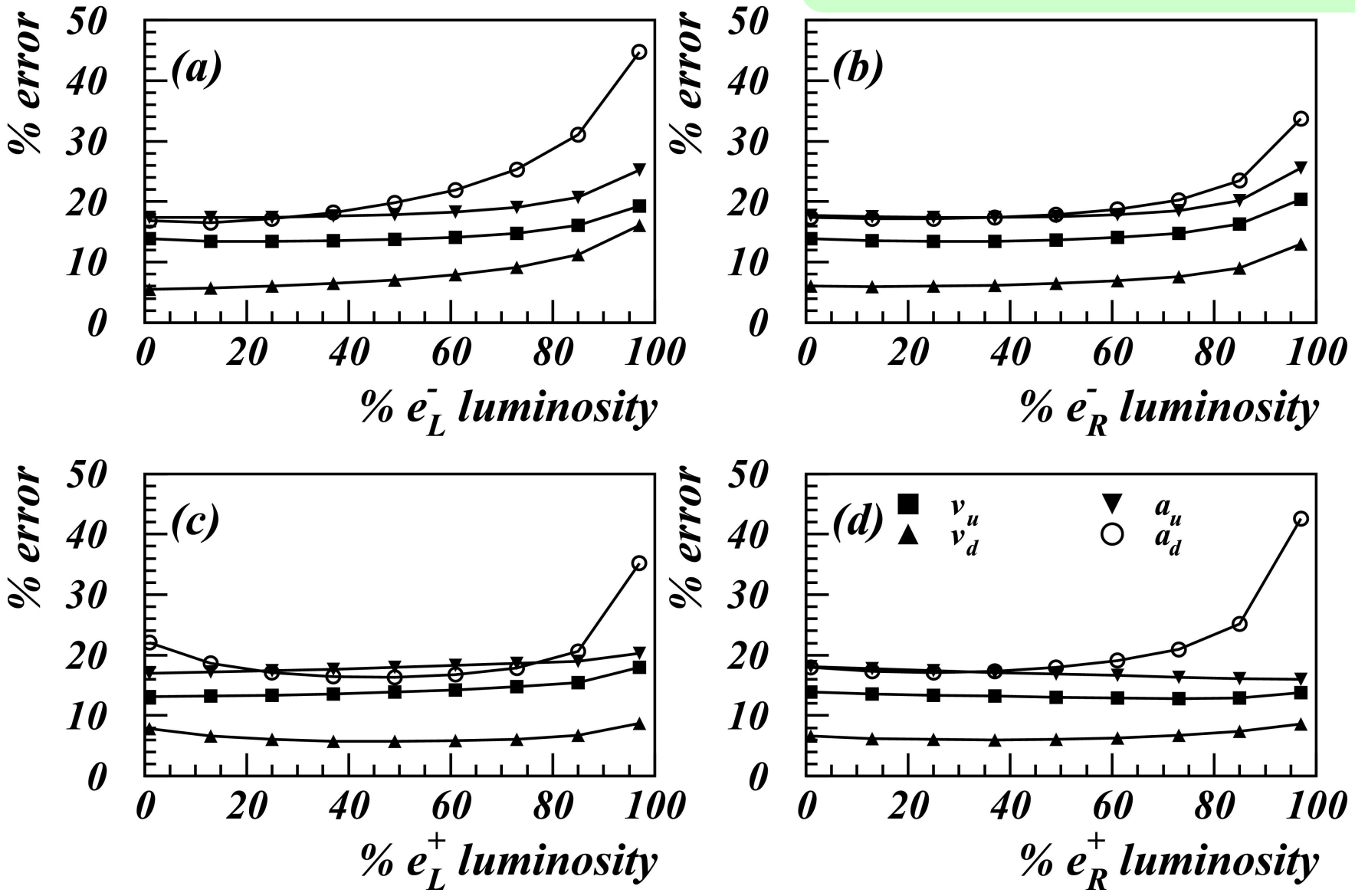
	v	a
u	13%	6%
d	17%	17%



- **Polarisation yields much improved sensitivity**

HERA II: Electroweak

Determination of light quark couplings



- **Equal sharing preferred**

Physics at HERA II: Summary

Assume: Always plan to run with highest possible P

Integrated luminosity $\mathcal{L}(e^{\pm}_{L,R}) = 1000\ \text{pb}^{-1}$

• NC cross sections (for PDFs)	$\mathcal{L}(e^{+}_{L,R}) \sim 1.5\ \mathcal{L}(e^{-}_{L,R})$
• CC cross sections (for d/u)	$\mathcal{L}(e^{+}_{R})$
• QCD	$\mathcal{L}(e^{-}_{L})$
• $M_{W(R)}$ from CC	$\mathcal{L}(e^{-}_{R}) > \mathcal{L}(\text{others})$
• NC electroweak	$\mathcal{L}(e^{\pm}_{L,R})$
• Searches	$\mathcal{L}(e^{\pm}_{L,R})$

HERA II objectives as seen by ZEUS and H1

- **Integrated luminosity $\mathcal{L}(e^{\pm}_{L,R}) = 1000\ \mathrm{pb}^{-1}$**
- **Data samples of approximately equal size**
- **Always plan to run with highest possible P**
- **Dedicated low-E_p runs for F_L and high-x PDFs**

Summary

- **ZEUS detector ready to take data**
- **Physics results from HERA I**
  - ➤ **Final publications (e.g. NC/CC cross sections, searches, …)**
  - ➤ **Important new results (diffraction, QCD, …)**
- **Looking forward to the diverse HERA II physics programme: High luminosity *ep* physics with polarised lepton beams**