7TH INTERNATIONAL WORKSHOP ON
DEEP INELASTIC SCATTERING AND QCD
APRIL 19 - 23, 1999

P - 4

Results from the H1 Experiment

T. Carli

From Brussels to Berlin: Latest Results from the H1 Collaboration

Tancredi Carli

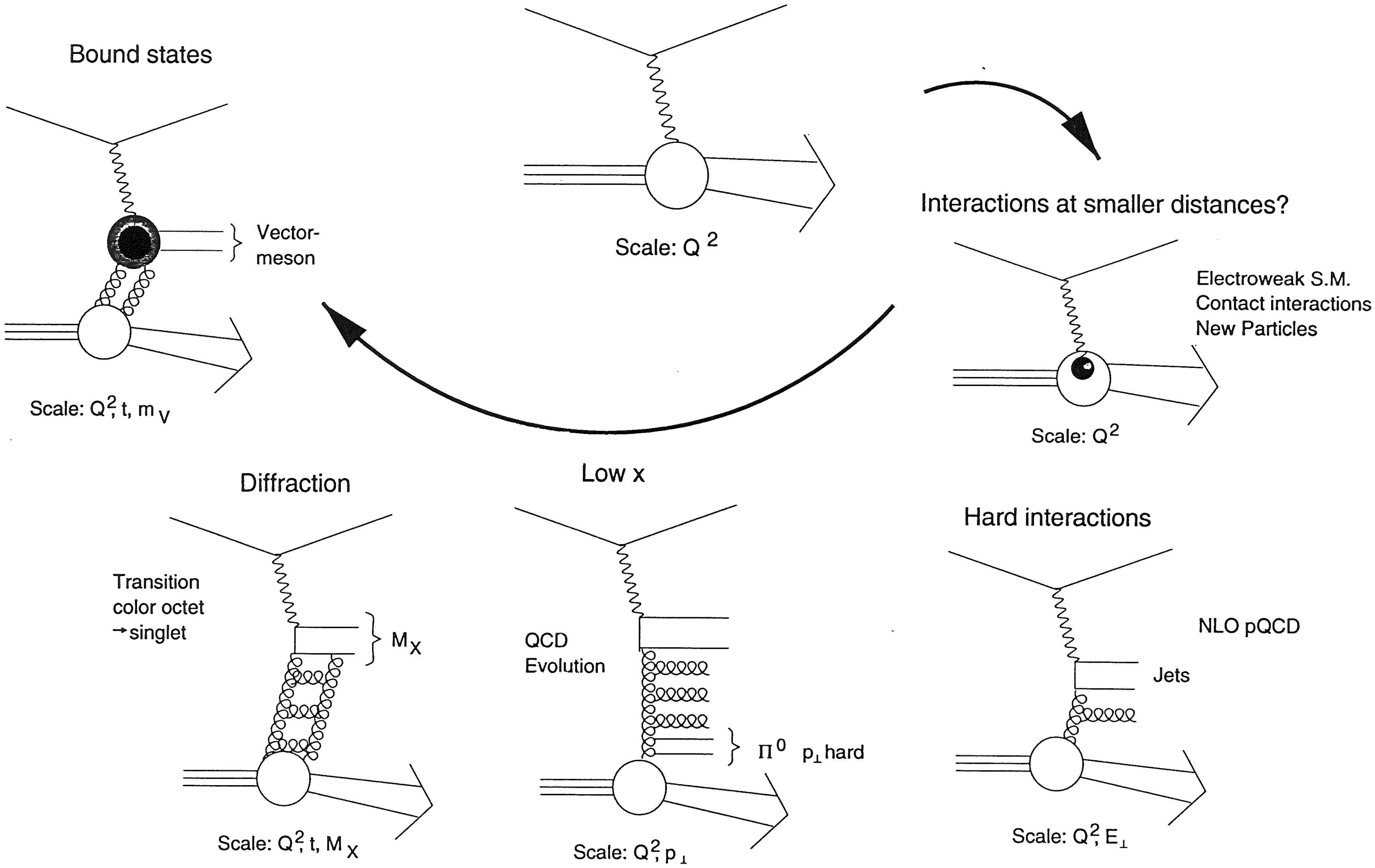
Max-Planck Institut für Physik, Munich.

April 1999

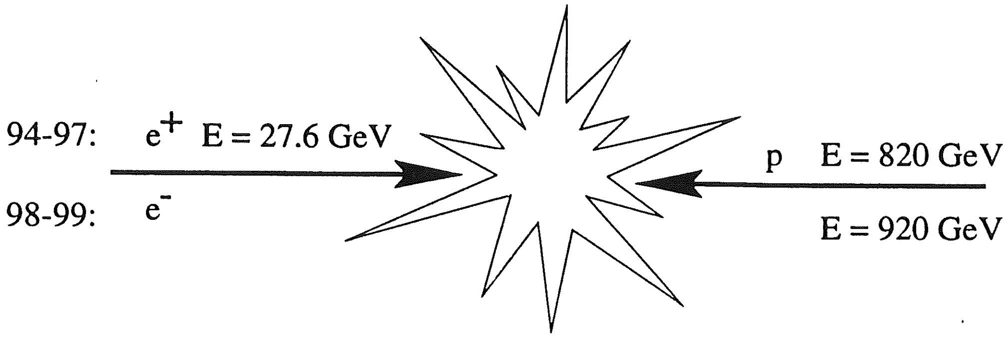
http://dice2.desy.de/ h01rtc/talks/dis99.ps.gz

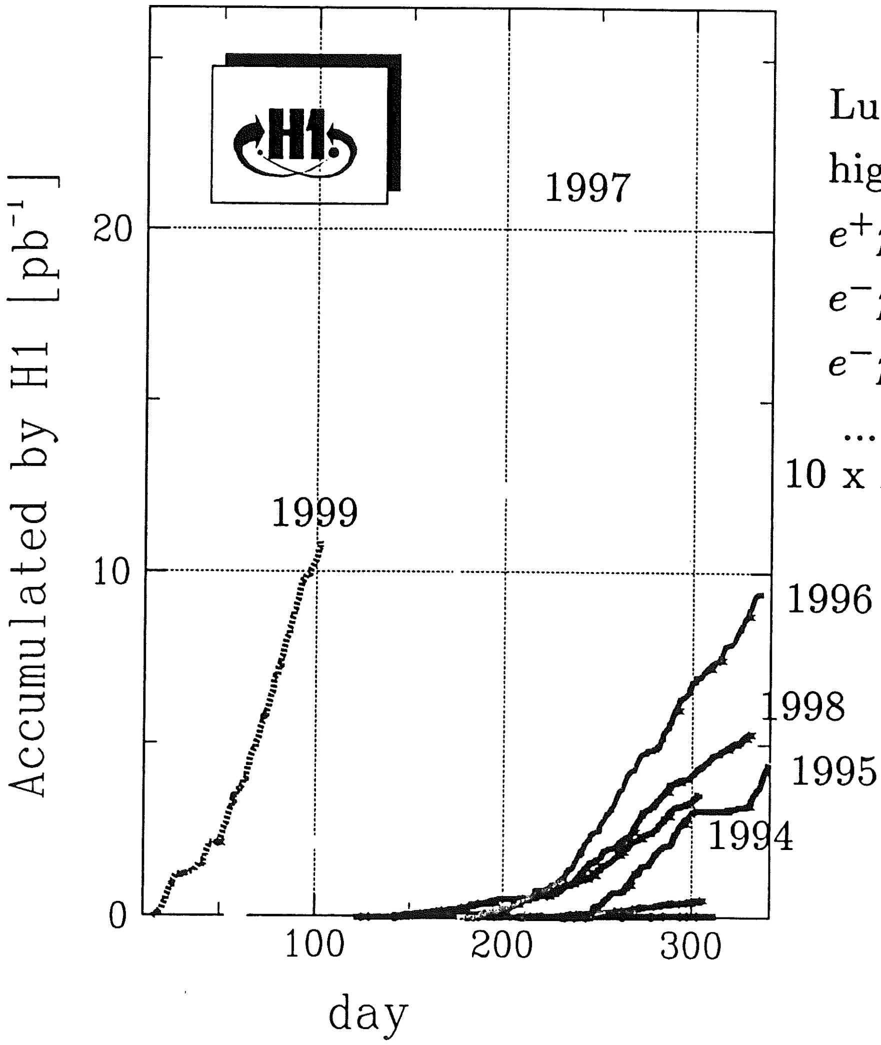
H1 Collaboration

Exploring Hadron Structure with HERA



HERA Performance





Luminosity for
high Q^2 analysis:
e^+p (94 – 97) $\mathcal{L} = 37$ pb^{-1}
e^-p (1998) $\mathcal{L} = 3.4$ pb^{-1}
e^-p (1999) $\mathcal{L} = 1.9$ pb^{-1}
... analysed so far !
10 x more electrons than befor

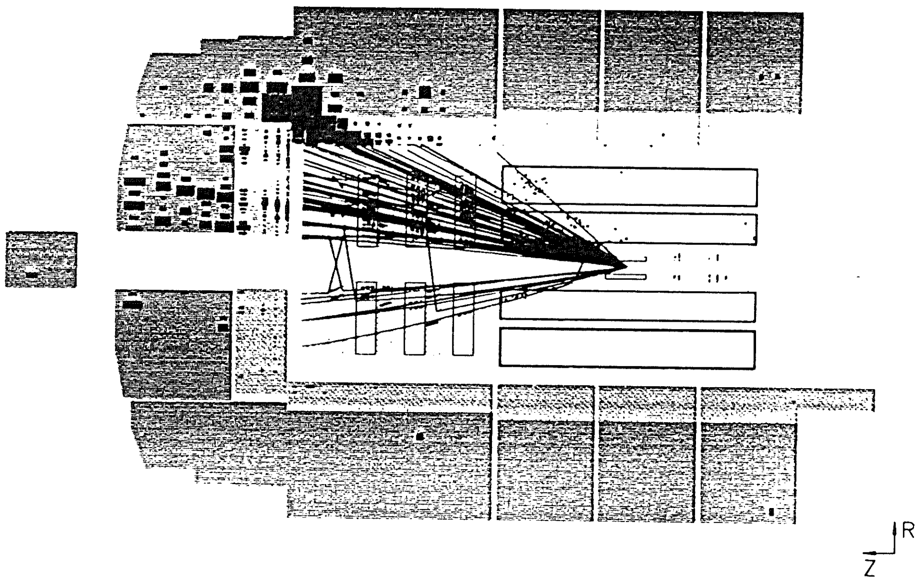
1999 HERA delivers ≈ 1 pb^{-1} per week !
Hope for $\mathcal{L} \approx 20$ pb^{-1} until May

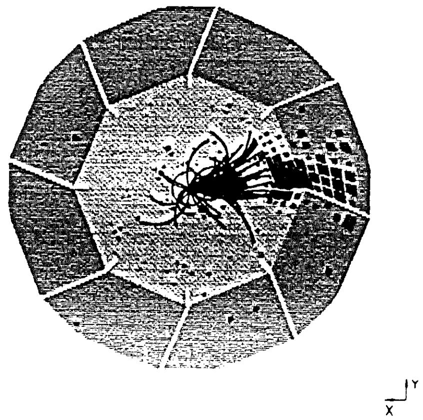
Charged Current Event

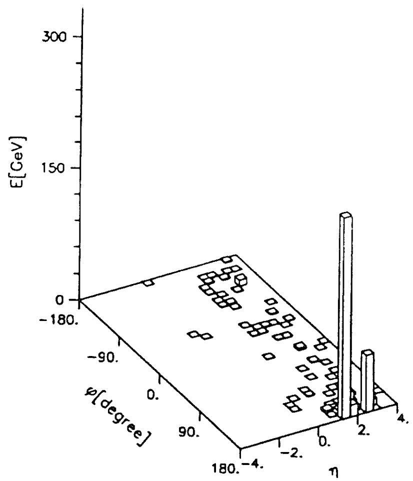
Run 238837 Event 8595 Class: 4 5 6 7 11 19 25 26 28 run date 290399

Pt=139 Q2=41067 x=0.77 y=0.53

from electron running !







T. Carli, MPI

Measurement Proton Structure Function

inclusive electron measurement needs precision

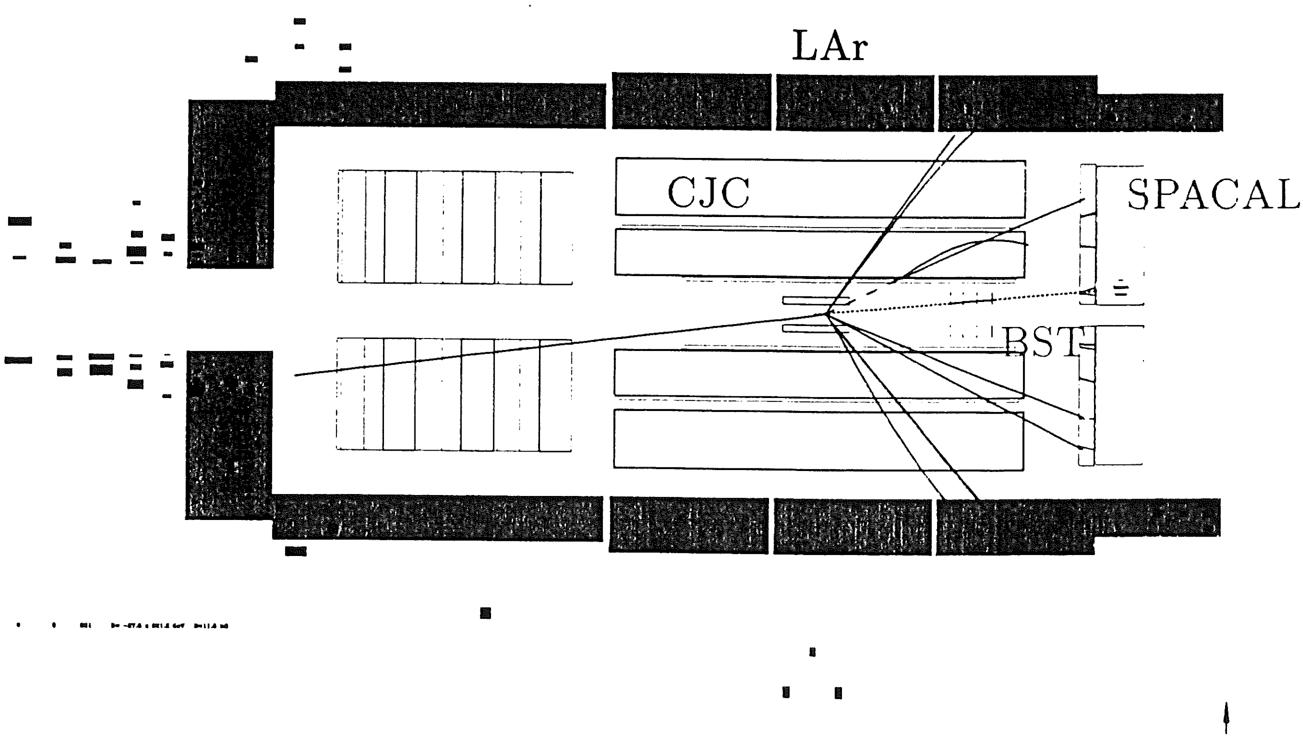
1. good statistics   2. good detector

$150 \lesssim Q^2 \lesssim 30000\ \text{GeV}^2$	$\int \mathcal{L}dt = 37\ \text{pb}^{-1}$	1994-1997
$12 \lesssim Q^2 \lesssim 120\ \text{GeV}^2$	$\int \mathcal{L}dt = 15\ \text{pb}^{-1}$	1997
$2 \lesssim Q^2 \lesssim 8.5\ \text{GeV}^2$	$\int \mathcal{L}dt = 2\ \text{pb}^{-1}$	dedicated run 1997
$2 \lesssim Q^2 \lesssim 5\ \text{GeV}^2$	$\int \mathcal{L}dt = 4.8\ \text{pb}^{-1}$	rad. analysis 1996

For $Q^2 < 120\ \text{GeV}^2$: $2 \cdot 10^6$ events !

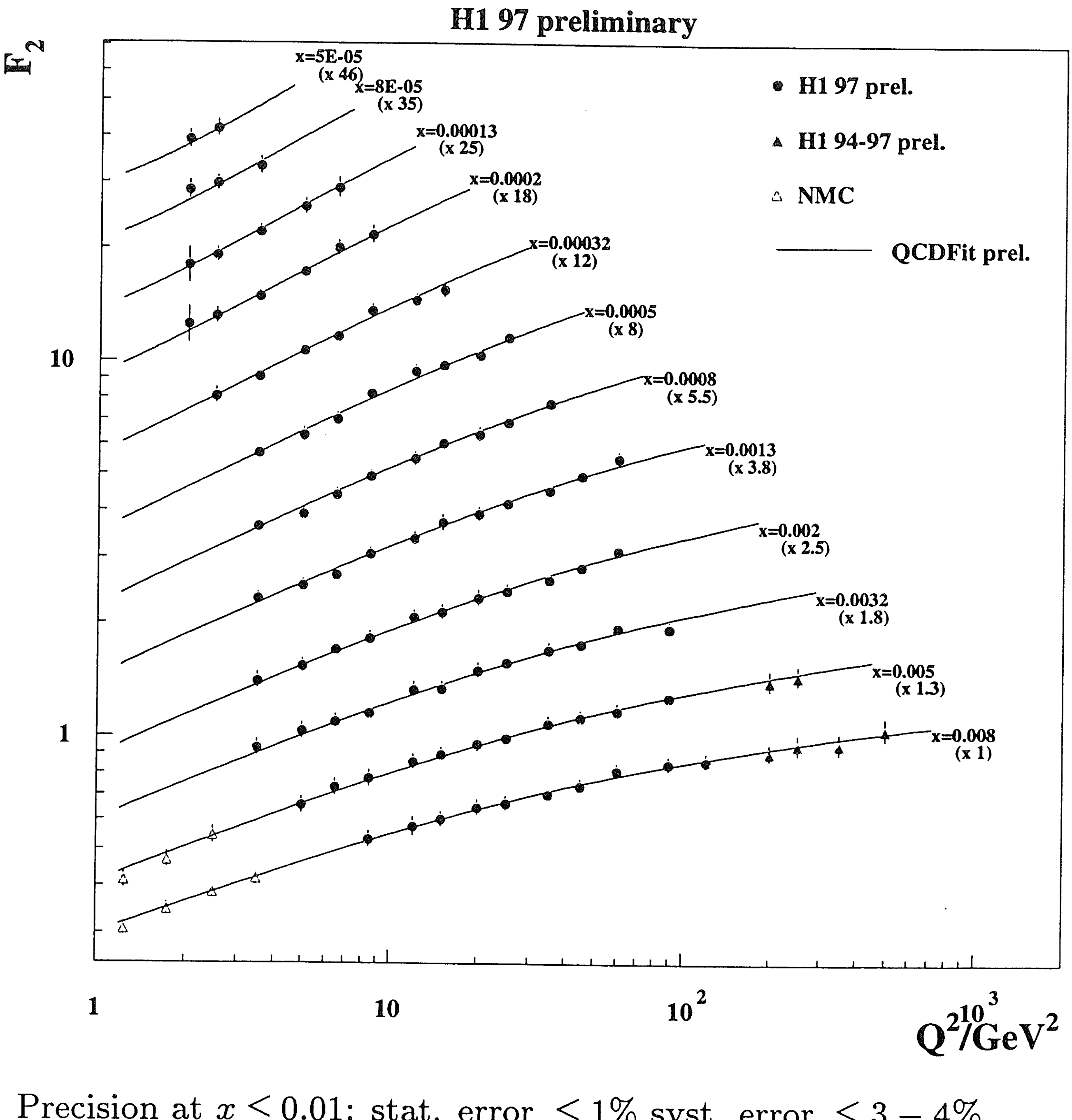
New device since 1997: 4 plane silicon strip detector (BST)

e.g. high y event:



low E_{el}, electron track in BST only, had. final state backwards

Proton Structure Function - 1997 Measurement



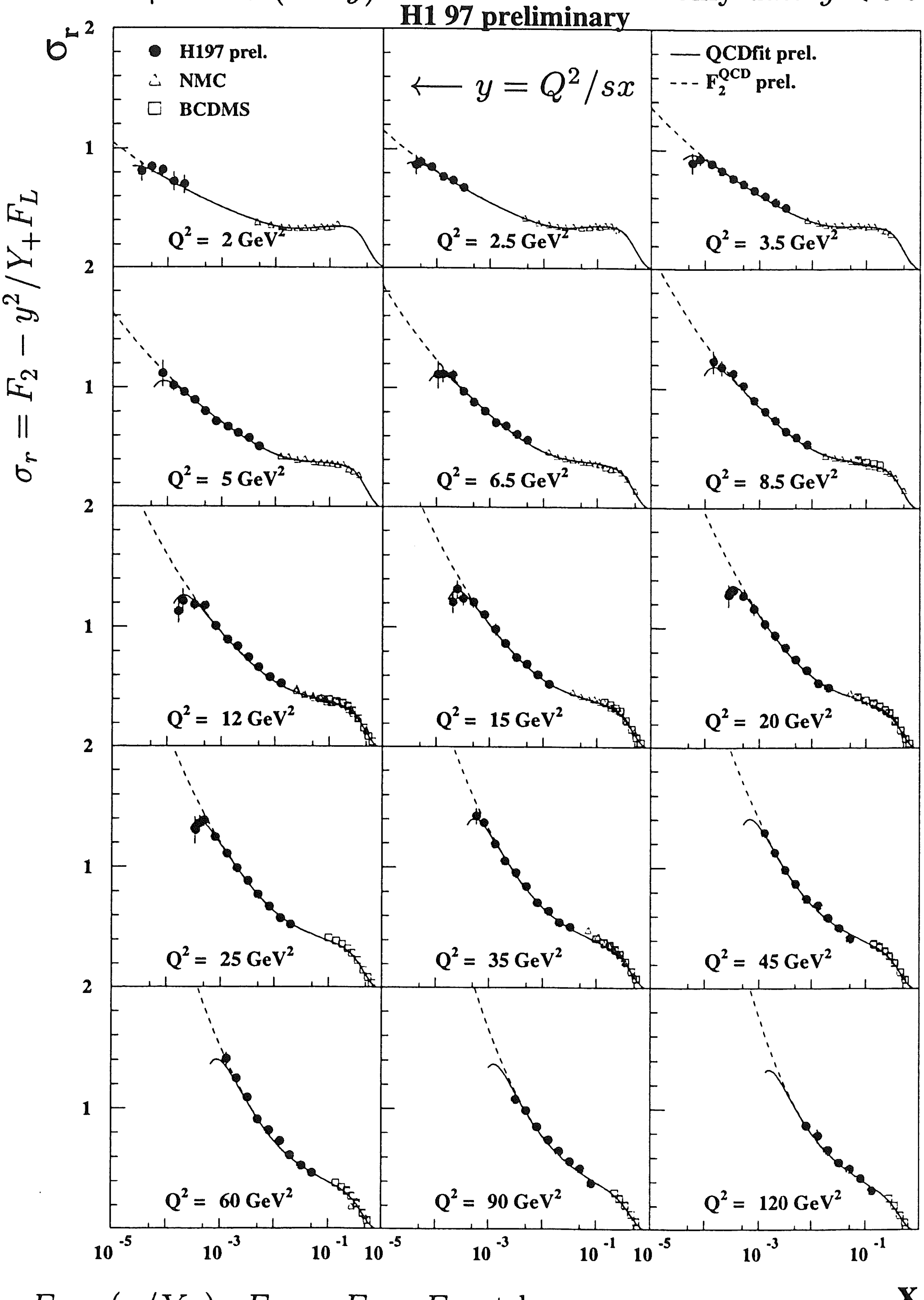
Precision at $x \lesssim 0.01$: stat. error $\lesssim 1\%$ syst. error $\lesssim 3-4\%$

...approaching fixed target experiments !

We have to precisely pin down F_2 to get handle on QCD evolution and constrain non-pert pdf

Proton Structure Function - 1997 Measurement

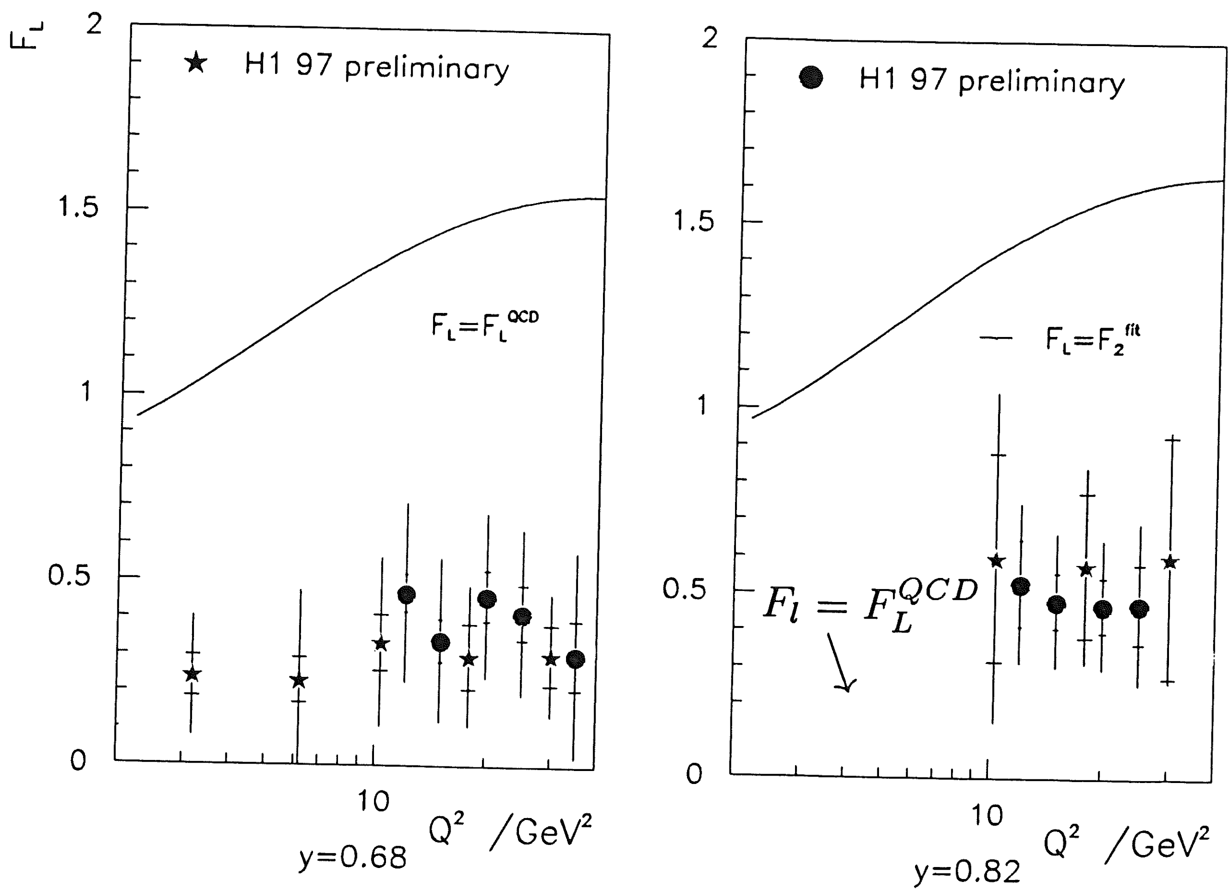
$Y_+ = 1 + (1-y)^2$ Fits includes only data $y < 0.35$



$F_2 - (y/Y_+) \cdot F_L \rightarrow F_2 - F_L$ at large y

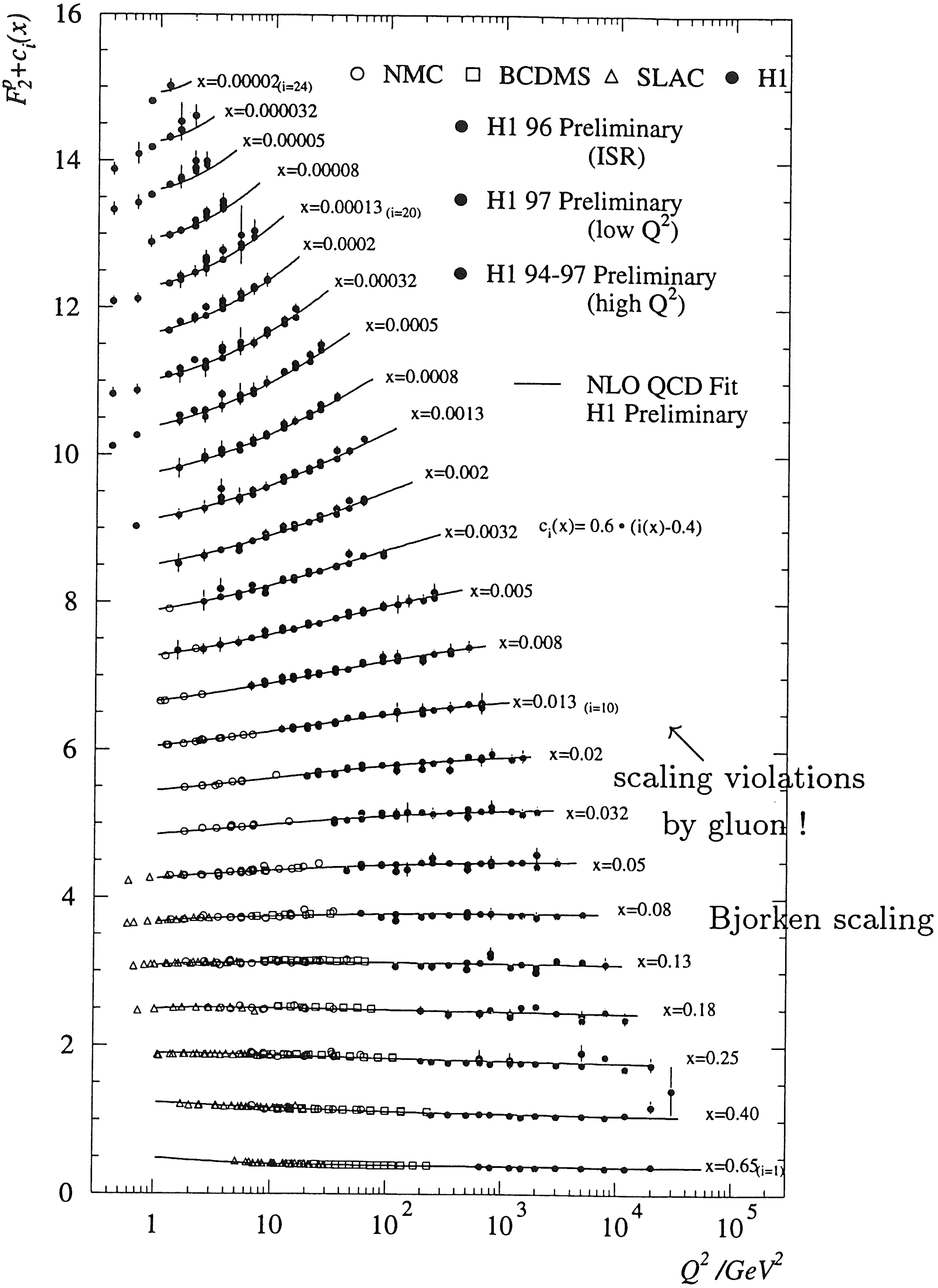
Determination of F_L

Access to F_L using assumption on F_2
by extrapolation of DGLAP-fit
from low y using high-y cross sections
Experimental challenge: $E_{el} \approx$ few GeV
requires goods control of background

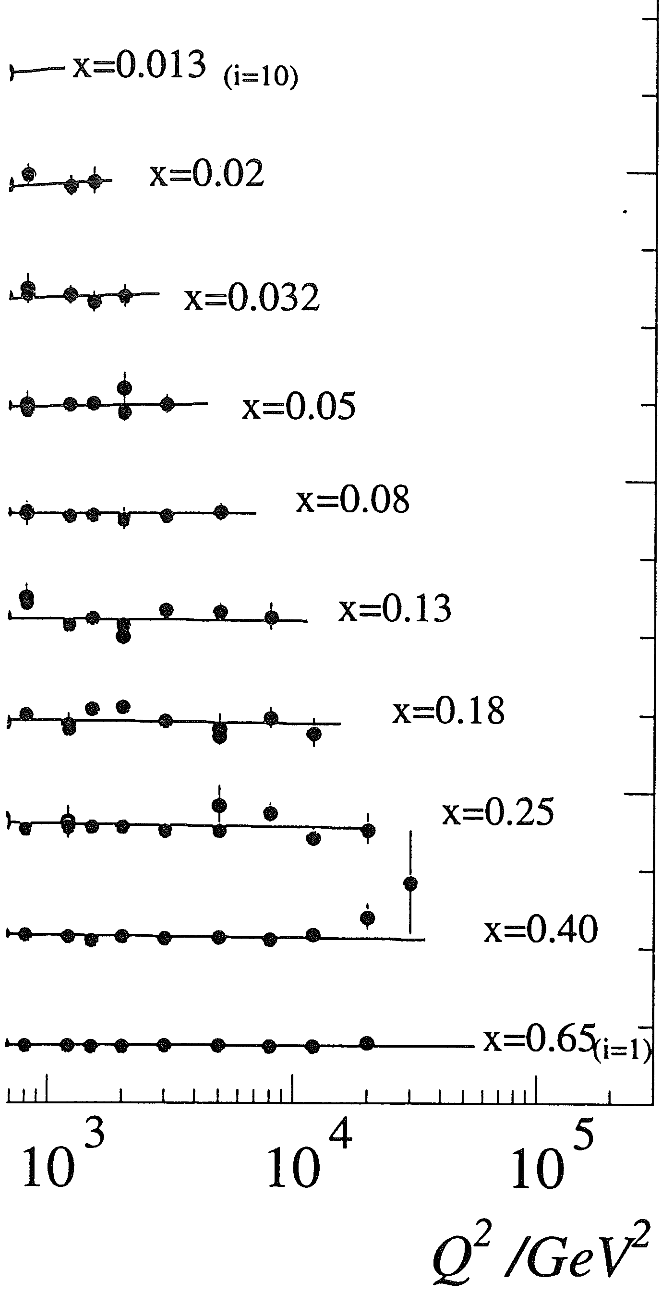


extractedF_L consistent with QCD
at highest y systematically higher
Data indicated by star obtained by new method
$\longrightarrow$ see talk by V. Arkadov

Proton Structure Function Summary



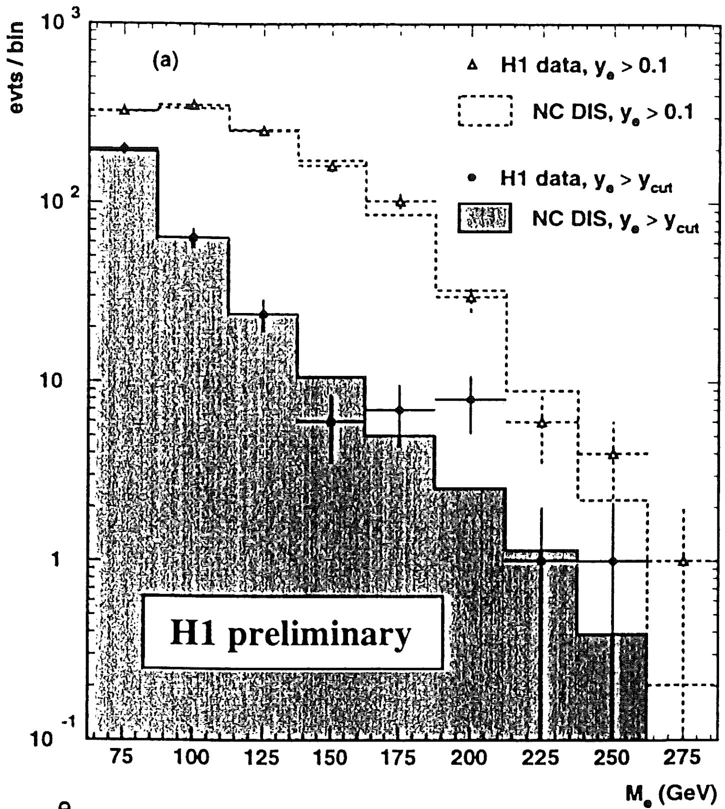
Pdf extraction still rely on fixed target systematic
NLO DGLAP (almost) works well for all Q^2 GeV^2

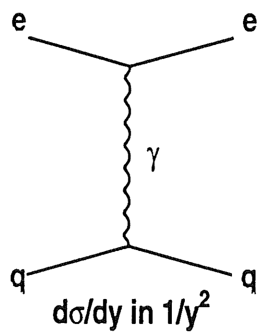


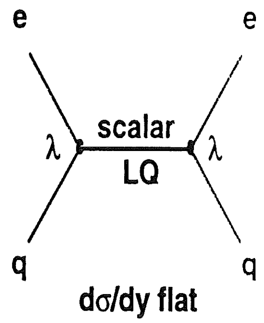
New Interaction at Small Distances ?

locally cross section extends
to 2σ $x \sim 0.45$ $M = 200$ GeV
$>$ 200 papers since 1996

Dedicated search analysis:
Shoulder developing, significant ?







$\Rightarrow$ optimize $y > y_{cut}(M)$
($y_{cut} \downarrow$ when $M_e \uparrow$)
given DIS expectation

Intensive search for other signatures
Limits on new particles $\rightarrow$ see talk by H.C. Schultz-Coulon

Neutral Current Cross Sections

$$\frac{d^2\sigma^{e^\pm p}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left[Y_+\tilde{F}_2(x,Q^2) - y^2 F_L(x,Q^2) \mp Y_- xF_3(x,Q^2)\right]$$

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

$$\tilde{F}_2(x,Q^2) = F_2^{em} + \frac{Q^2}{Q^2+M_Z^2}F_2^{\gamma Z} + \left(\frac{Q^2}{Q^2+M_Z^2}\right)^2 F_2^Z$$

$$F_3 = \frac{Q^2}{Q^2+M_Z^2}F_3^{\gamma Z} + \left(\frac{Q^2}{Q^2+M_Z^2}\right)^2 F_3^Z$$

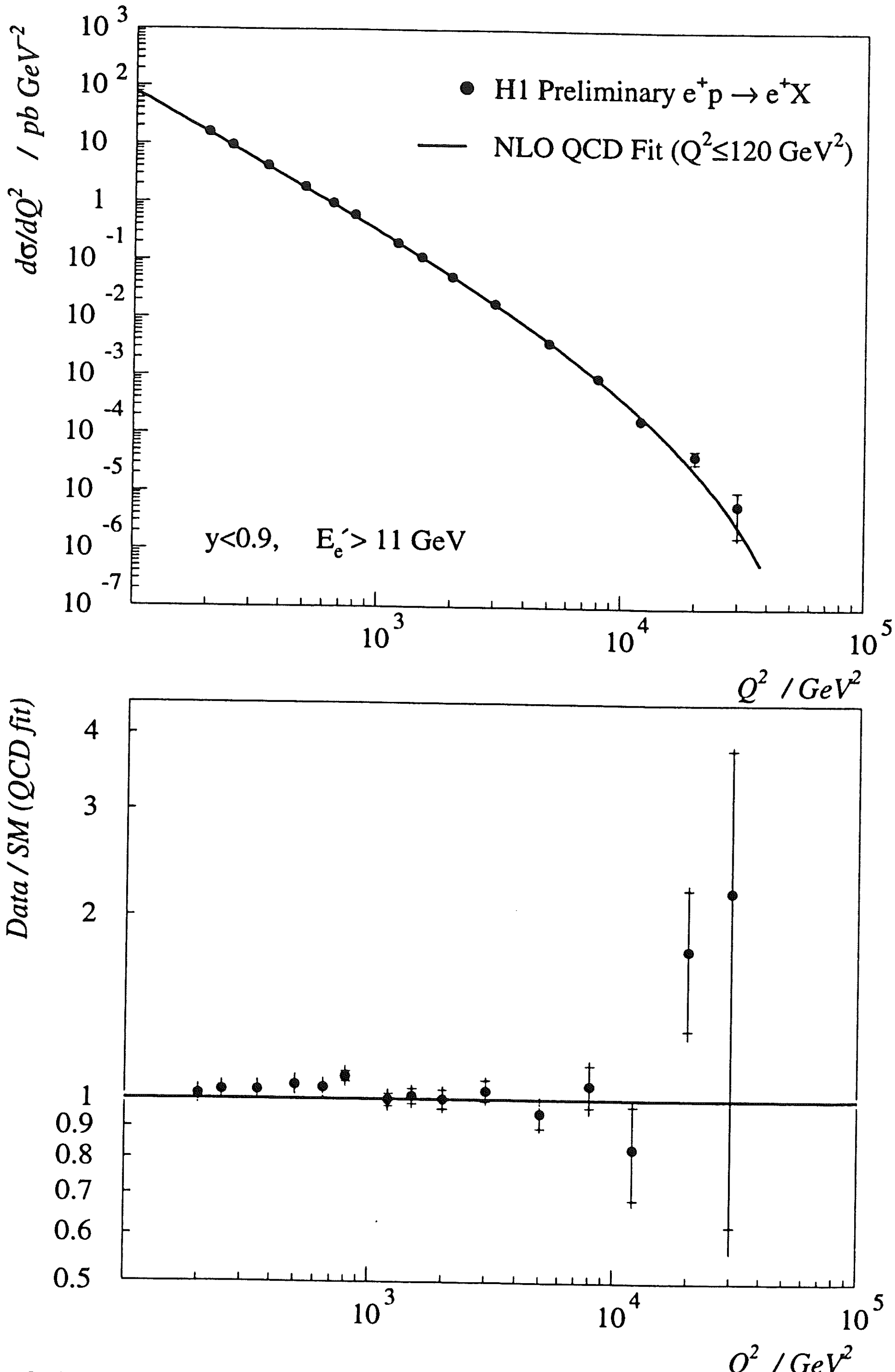
$\delta_z - \delta_3 < 1\%$ for $Q^2 < 1500$ GeV^2

$\approx 10\%$ at $Q^2 = 5000$ GeV^2 and $x = 0.08$

δ_L negligible at $y < 0.5$

$\approx 5\%$ at $y = 0.9$

Single differential NC cross section $\frac{d\sigma^{e^+p}}{dQ^2}$



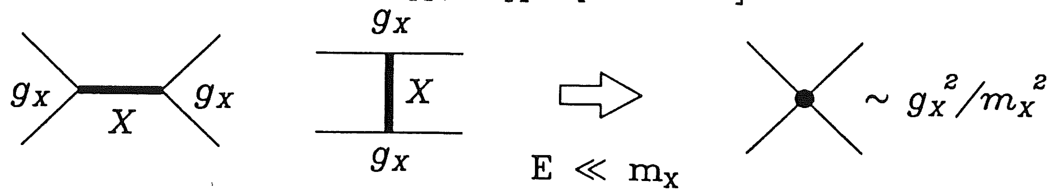
$\frac{d\sigma^{e^+p}}{dQ^2}$ falls over 7 orders of magnitude

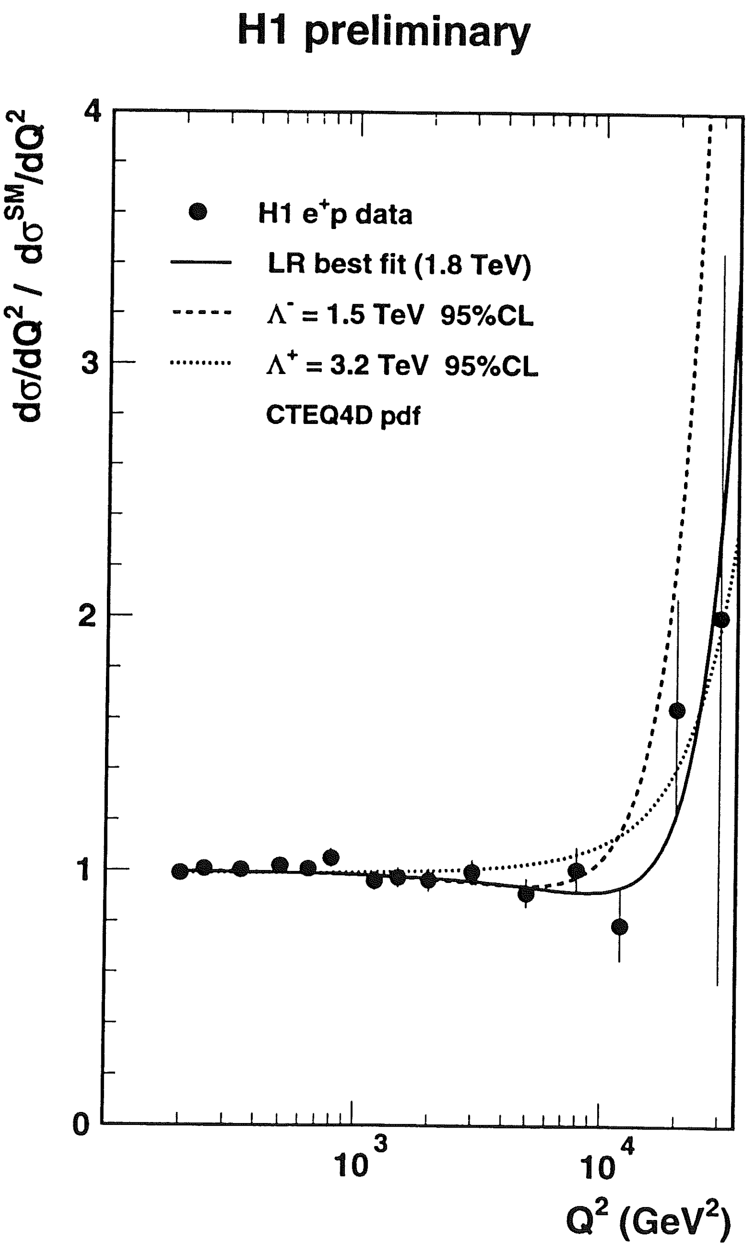
NLO QCD fit works, but better precision needed to constrain PDFs
...slight excess for $Q^2 > 15000$ GeV^2 remains

Benchmark for Standard Model

Contact Interactions

New phenomena above kinematic limit ?
At $M_X \gg \sqrt{s}$ propagators contract to pointlike Four Fermion CI with effective coupling g_X^2/M_X^2 $[mass^{-2}]$





e.g. $\mathcal{L}_{CI} = \sum_{q=u,\,d} \eta_{LR}^q\,(\bar{e}_L\gamma_\mu e_L)(\bar{q}_R\gamma^\mu q_R)$

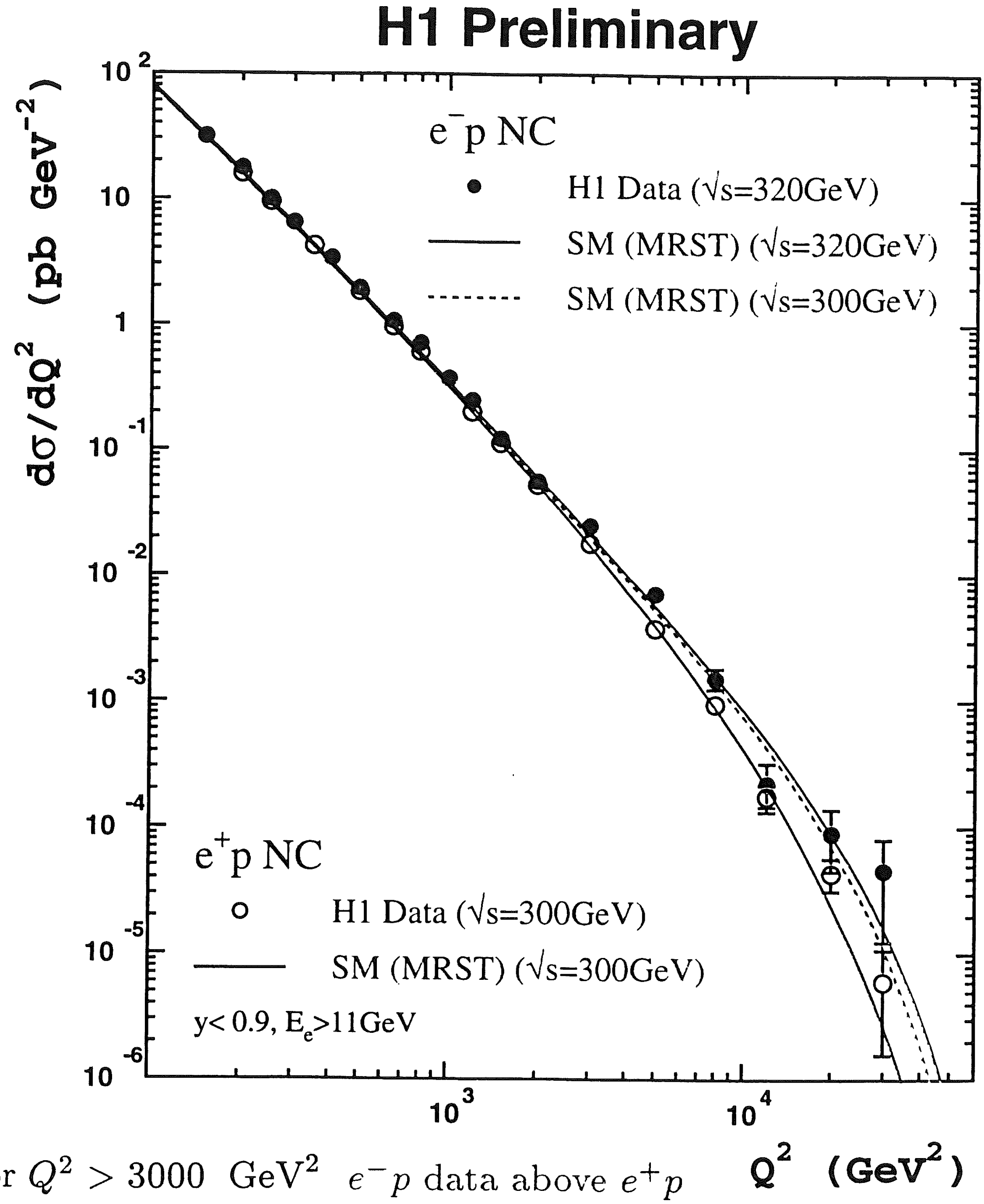
$\eta_{LR} \equiv \pm g^2/\Lambda_{ij}^2$
Scale parameter $\Lambda_{LR}^{\pm} \equiv M_x$

Sensitivity to
positive and negative
interference effects

→ see talk by J. Scheins

Single differential NC cross section $\frac{d\sigma^{e^{\pm}p}}{dQ^2}$

1998/1999 Data ! $\int \mathcal{L} \approx 5 \text{ pb}^{-1}$ analysed so far !



for $Q^2 > 3000$ GeV^2 e^-p data above e^+p

Evidence for positive γZ^0 interference in the e^-p case

Better agreement for e^-p at very large Q^2

Need more e^-p and e^+p data !

→ talk by B. Reisert

Charged Current Cross Sections

$$\frac{d^2\sigma_{CC}^{e^\pm p}}{dxdQ^2} = \frac{G_F^2}{2\pi x}\left(\frac{M_W^2}{Q^2+M_W^2}\right)^2 \cdot \Phi^\pm(x,Q^2)$$

Leading order:

$$\Phi^+(x,Q^2) = (\bar{u}+\bar{c}) + (1-y)^2 \cdot (d+s+b)$$

$$\Phi^-(x,Q^2) = (u+c) + (1-y)^2 \cdot (\bar{d}+\bar{s}+\bar{b})$$

1. Sensitivity to propagator mass propagator:

   $M_{prop} = 81.2 \pm 3.3(stat.) \pm 4.3(syst)$ GeV

   from shape of $d\sigma/dQ^2$ (1994-1997 preliminary)
   Note: W is spacelike at HERA !
   compatible to $M_W = 80.41 \pm 0.1$ GeV (PDG 98)

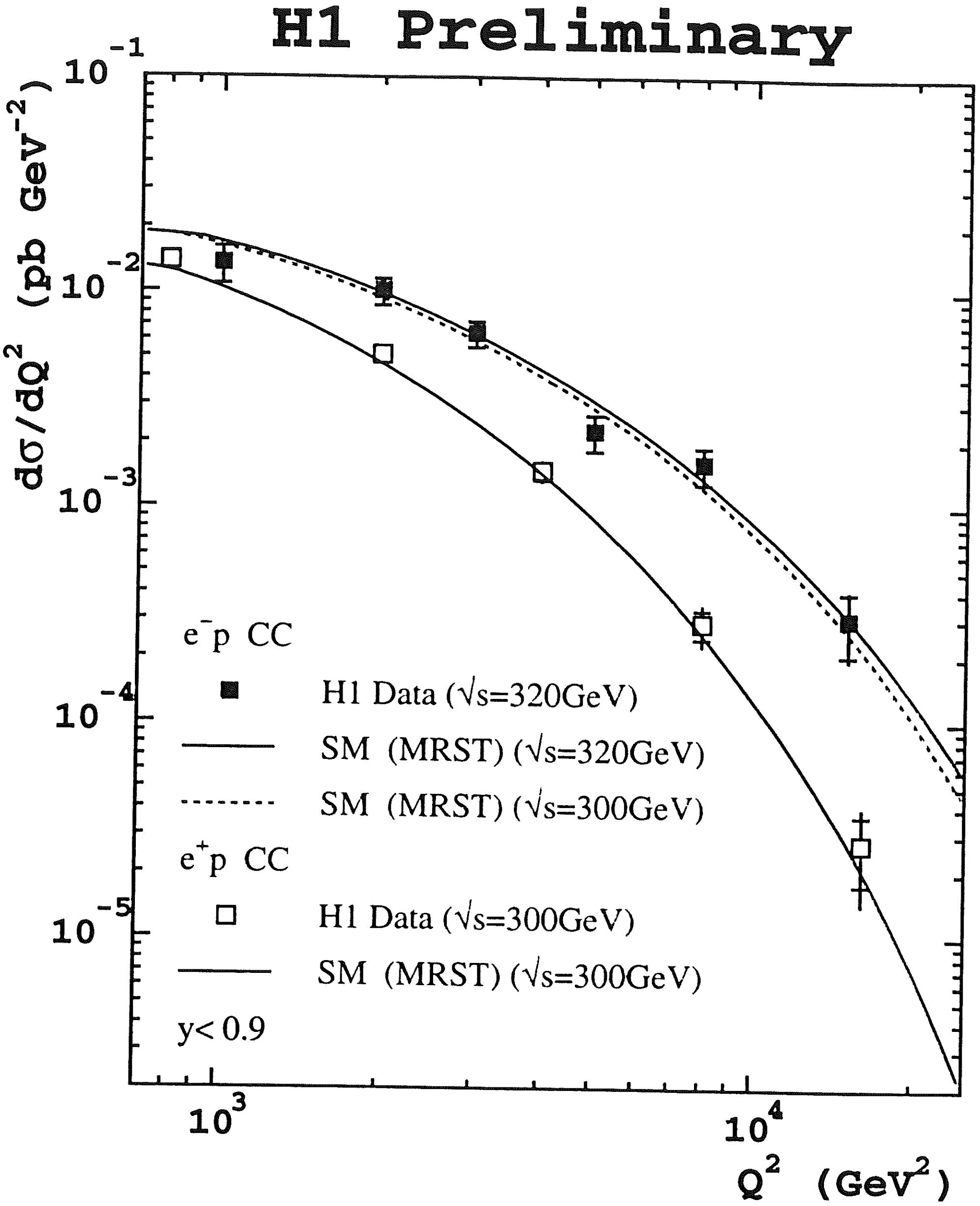
2. Probe valence u, d quarks at large x and Q^2:

   at $x = 0.3$: $u \approx 1.5 - 3$ times larger than d valence

   from 1994-1997 $\frac{d^2\sigma_{NC}^{e^+p}}{dx}$ and $\frac{d^2\sigma_{CC}^{e^+p}}{dx}$ (preliminary)
   $\rightarrow$ future determination of u/d ratio possible

Single differential CC cross section $\frac{d\sigma^{e^\pm p}}{dQ^2}$

1998/1999 Data !

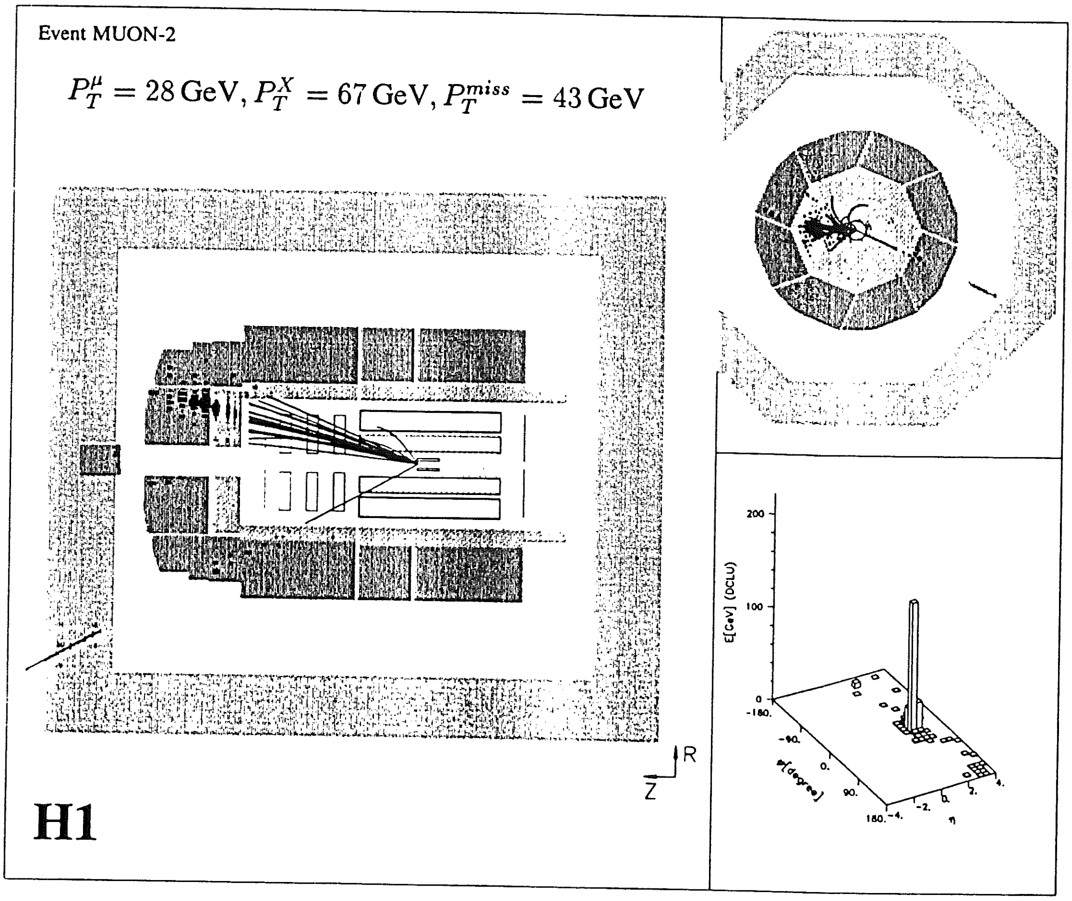


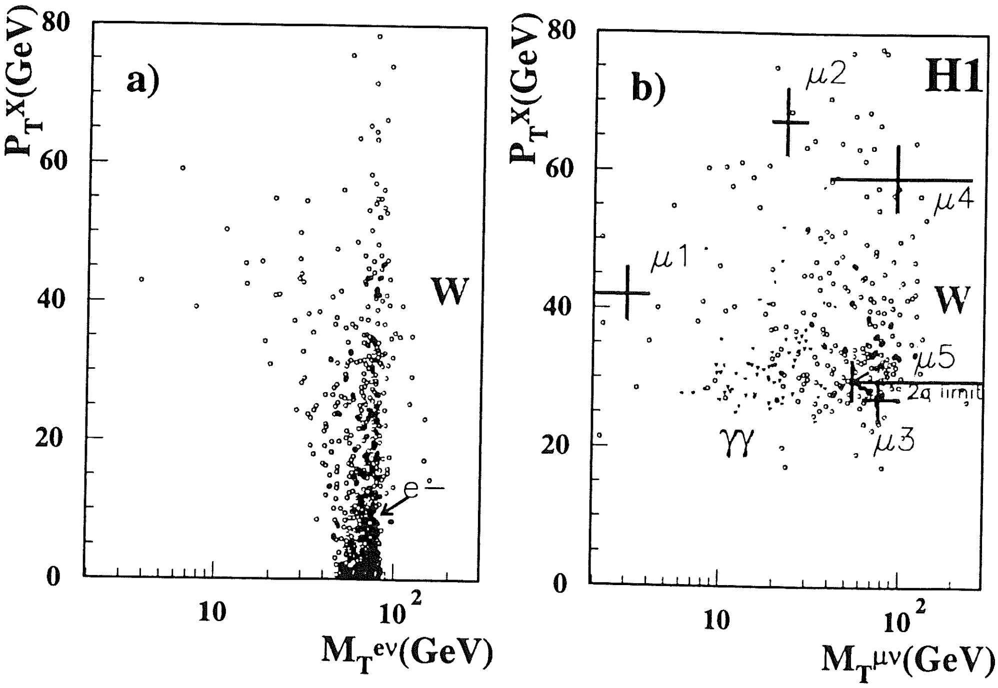
e^-p data order of magnitude above e^+p
due to: $e^-p \sim (u+c)$ while $e^+p \sim (1-y)^2\ (d+s)\ (u<d)$
sensitivity to different quark flavours by e^+/e^- and NN/CC !
This physics is just starting at HERA

...we hope for surprise !

Reminder: Observation of Events with Isolated Leptons at High E_T

$$e^+p \to \mu^+ X$$





W-MC 500 x mor $\mathcal{L}$ than data

P_T^X hadronic recoil, $M_T^{\mu\nu}$ trans. mass

Search for events with high P_T leptons and P_T^{miss}

H1 Collaboration

<u>Selection:</u> $P_T^{calo} > 25$ GeV

$P_T^{track} > 10$ GeV

isolated track:

distance to closest track $D_{track} > 0.5$

distance to closest jet $D_{jet} > 1.0$

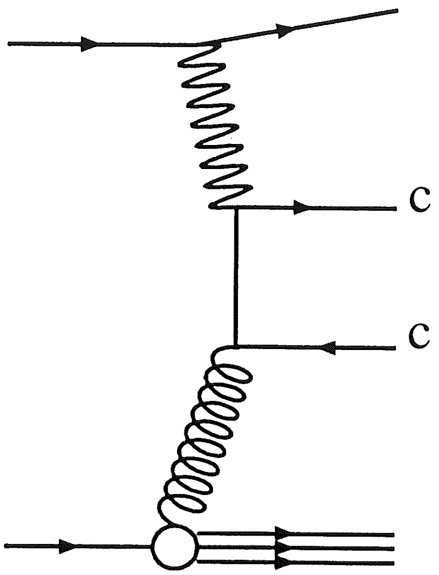
data	$e^+ p$ at $\sqrt{s}$=300 GeV 36.5 pb^{-1} 1994-97 published	$e^- p$ at $\sqrt{s}$=320 GeV 5.1 pb^{-1} 1998-99 PRELIMINARY
e chan.	N_{data} = 1 N_{SM} = 2.4±0.5 (1.7 ±0.5 from W)	N_{data} = 0 N_{SM} = 0.37±0.07 (0.23±0.07 from W)
μ chan.	N_{data} = 5 N_{SM} = 0.8±0.2 (0.5±0.1 from W)	N_{data} = 0 N_{SM} = 0.14±0.04 (0.09±0.02 from W)

so far no event seen in e^- data

How does QCD effects alter W background prediction ?

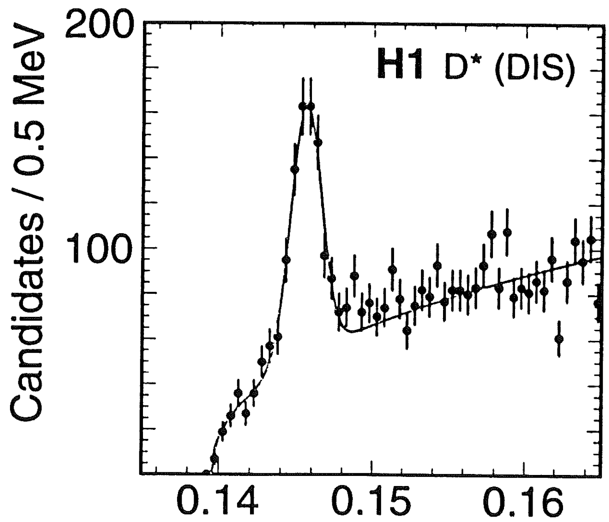
Charm Tagging - (Direct) Access to Gluon

Dominating LO Diagram:
Boson Gluon Fusion



$x_g = \frac{M^2+Q^2}{ys}$
$M^2 = \frac{Pt_c^2+m_c^2}{z(1-z)}$
$z = \frac{(E-P_z)_c}{2E_\gamma}$

Analyses based on $\int \mathcal{L} \approx 10\ \text{pb}^{-1}$
1) DIS: $2 < Q^2 < 100\ \text{GeV}^2$
2) γp: $Q^2 < 0.01\ \ \text{GeV}^2$
$|\eta(D^*)| < 1.5\ Pt_{D^*} > 1.5$



D^* tagging via:
$D^* \to D^0 \pi^+_{slow} \to (K^-\pi^+)\pi^+_{slow}$
$\Delta M = M(K\pi\pi) - M(K\pi)$

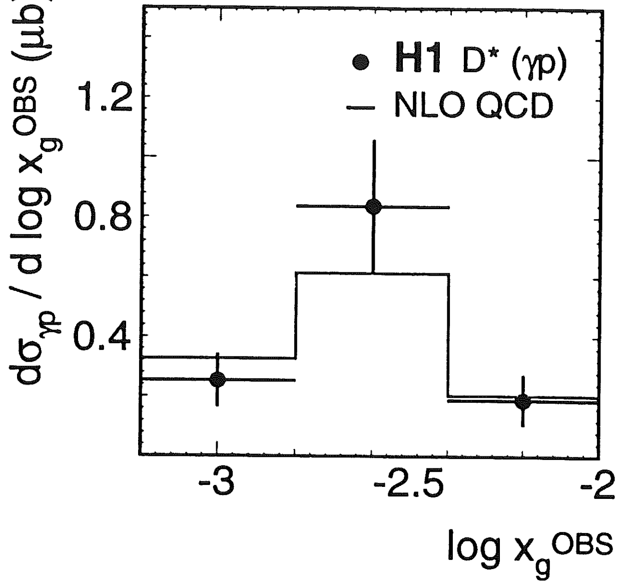
Approximations:
$Pt_c = 1.2\ Pt_{D^*}$
$(E-P_z)_c = (E-P_z)_{D^*}$

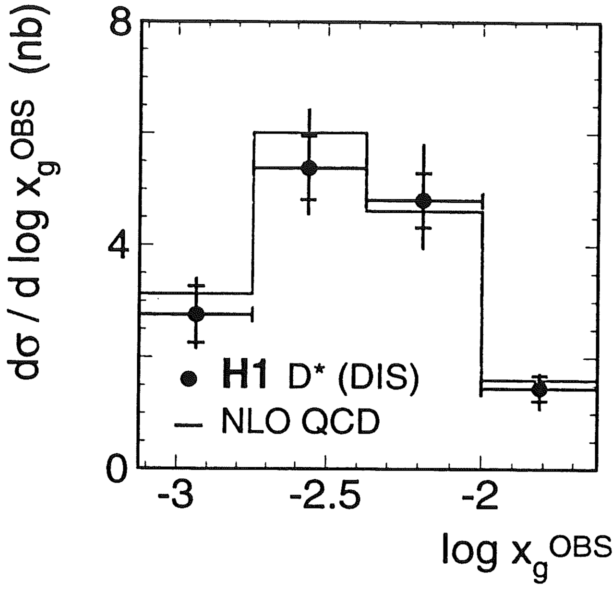
Comparison to NLO calculation by:

Frixione et al. (γp) Harris and Smith (DIS)

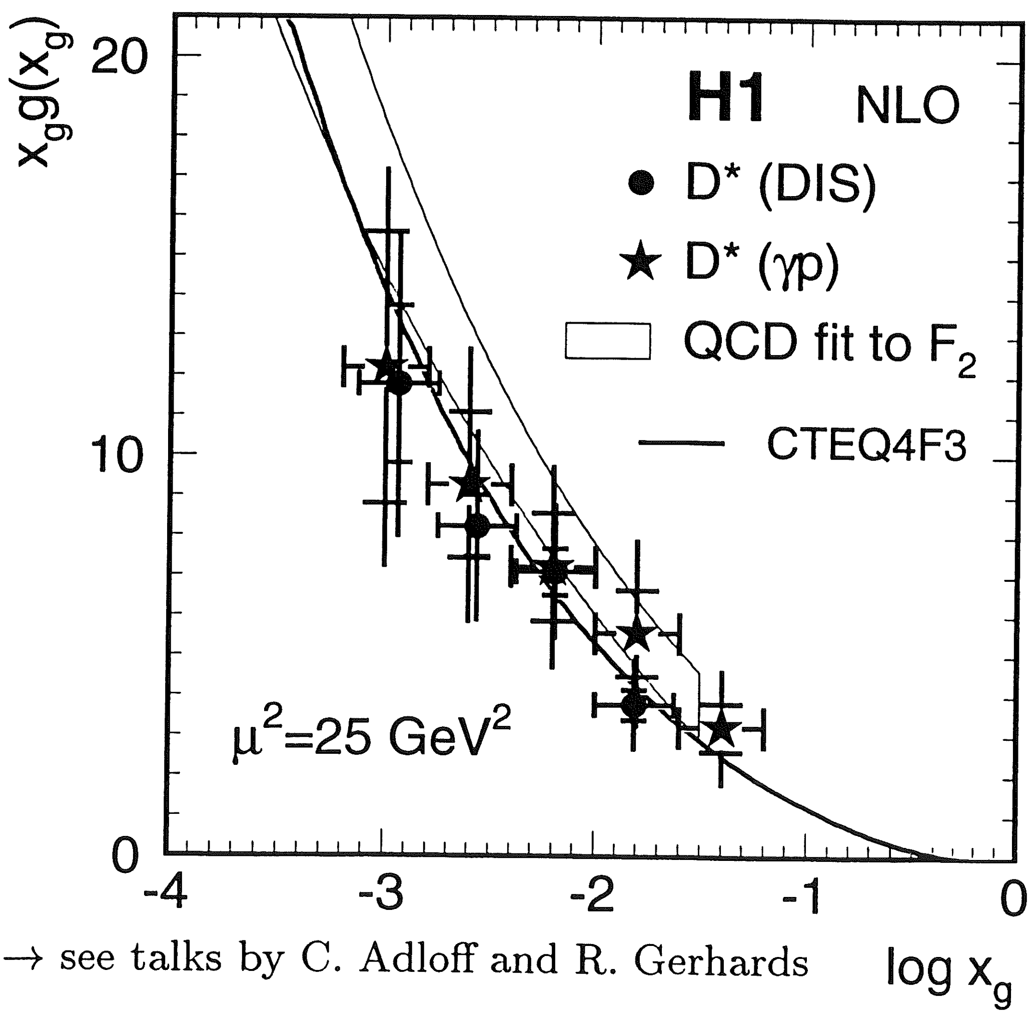
$m_c = 1.5$ GeV, band: $m_c = 1.3 - 1.7$ GeV

BR$(c \to D^*)$=27%, $\epsilon_c = 0.036$





Unfolded Gluon Density:



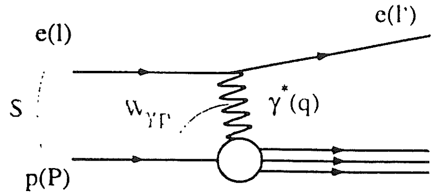
Good agreement with NLO F_2^{incl} Fit

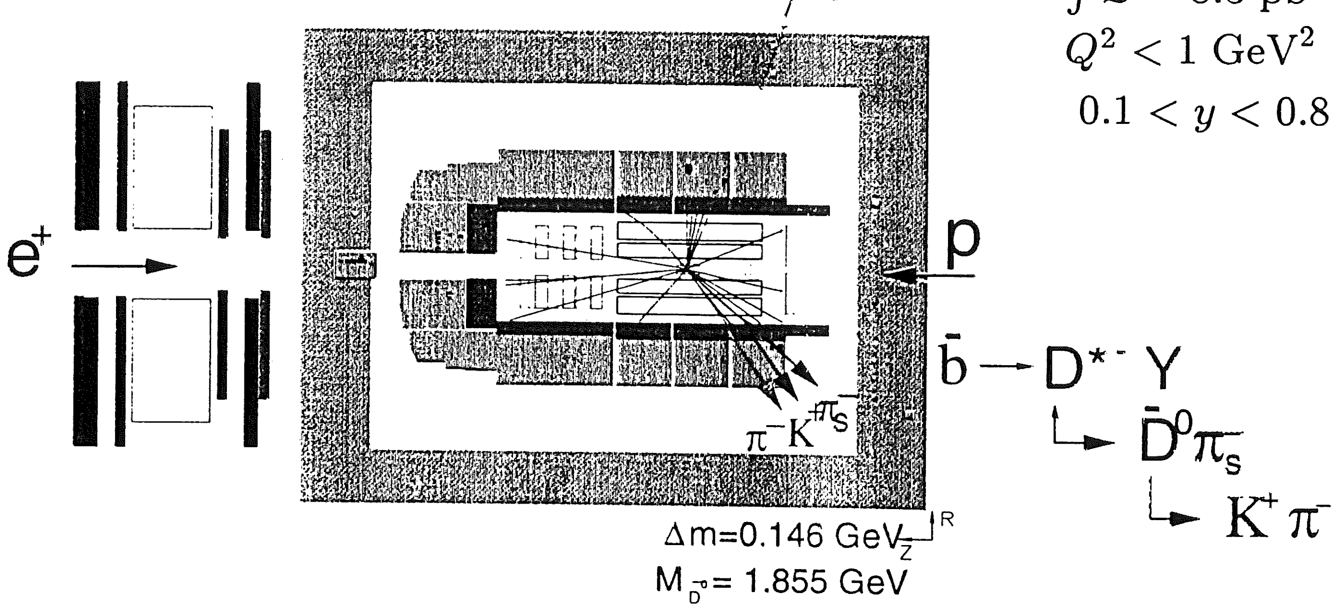
errors still large !

→ see talks by C. Adloff and R. Gerhards

Reminder: Open b Production

Tag b by muon with high relative P_T muon/thrust axis of jet





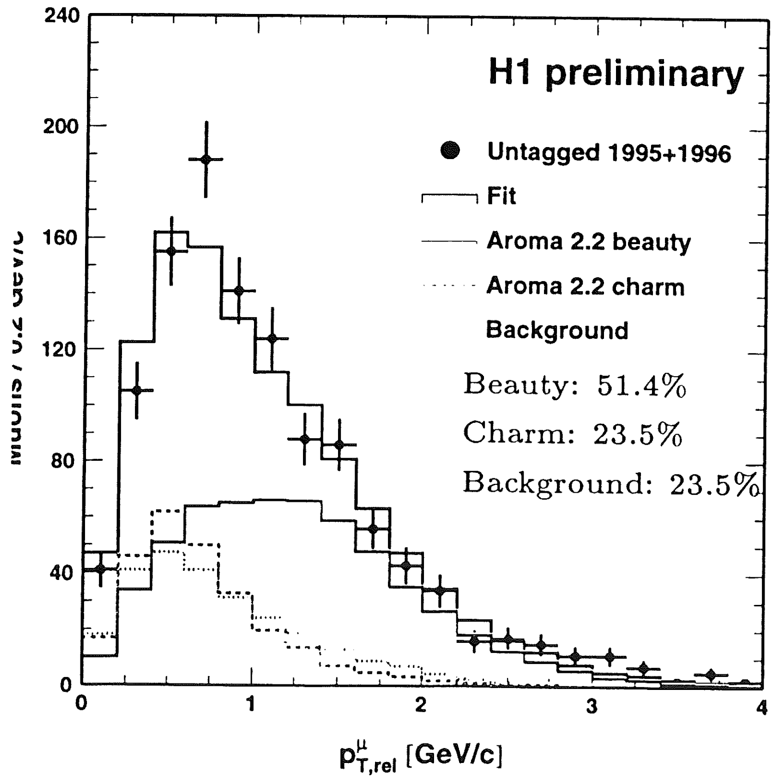
1996 data

$\int \mathcal{L} = 8.3\ \text{pb}^{-1}$

$Q^2 < 1\ \text{GeV}^2$

$0.1 < y < 0.8$

b/c deduced on statistical basis:



Jet: $|\eta| < 2.5$, $E_T > 6$ GeV

Muon: $p^{\mu}_{T,lab} > 2$ GeV

$35^o < \theta_\mu < 130^o$

$\sigma^{vis}_{b\bar{b}} = 0.93 \pm 0.08^{+0.21}_{-0.12}$ pb (prel.

$\sigma^{vis}_{b\bar{b}} = 0.19$ pb (LO)

$\sigma^{tot}_{b\bar{b}} = 3.80$ nb (LO)

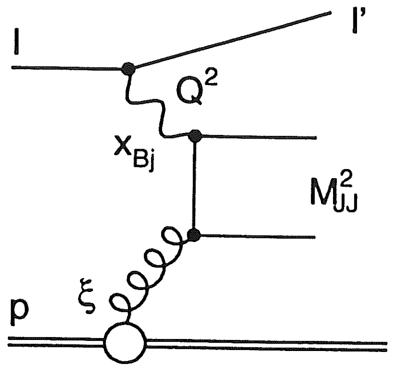
$\sigma^{tot}_{b\bar{b}} = 5 - 10$ nb (NLO)

Why charm ok,

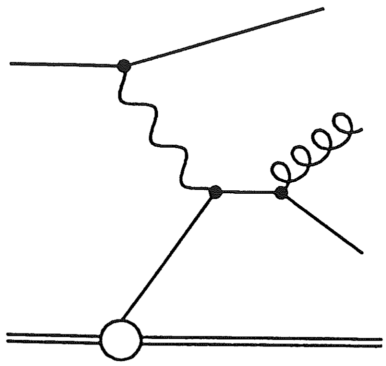
but b much too high ??

→ see talk by P. Newman

Jet production in DIS



photon-gluon fusion



QCD-Compton

⇒ direct sensitivity to α_s and the $g(x, Q^2)$, $q(x, Q^2)$ in proton

⇒ test perturbative QCD in presence of two hard scales Q^2, E_T^2

Well defined measurement and theory (NLO pQCD)

H1 reported first fundamental understanding of jet production at DIS 98:

Dijet Cross sections: $10 < Q^2 < 5000$ GeV^2 and $0.2 < y < 0.6$

$-1 < \eta_{\text{jet,lab}} < 2.5$, $E_{T,1} + E_{T,2} > 17$ GeV, $E_{T,\text{Breit}} > 5$ GeV

using incl. K_T algorithm in Breit frame

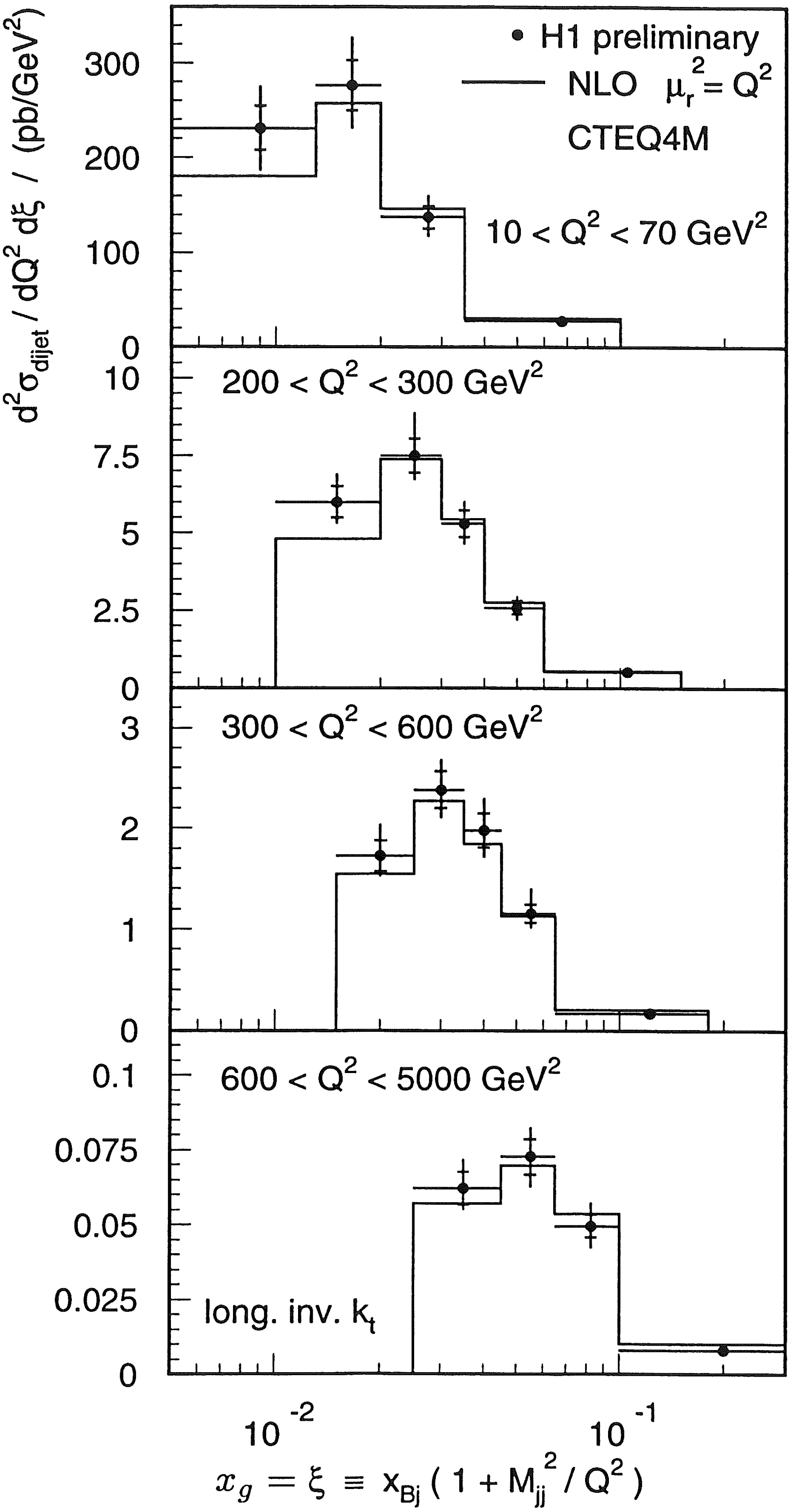
→ see talks by:

M. Wobisch: single jets, dijets and gluon density

N. Tobien: differential jet rates

P.O. Meyer: internal jet structure

Fractional parton momentum from Dijets



Parton momentum

$x_g = x_{\mathrm{Bj}} (1 + M_{\mathrm{jj}}^2/Q^2)$

$5 \cdot 10^{-3} < x_g < 0.3$

had. corrections:

$\approx 10 - 15\%$

good overall description by NLO pQCD

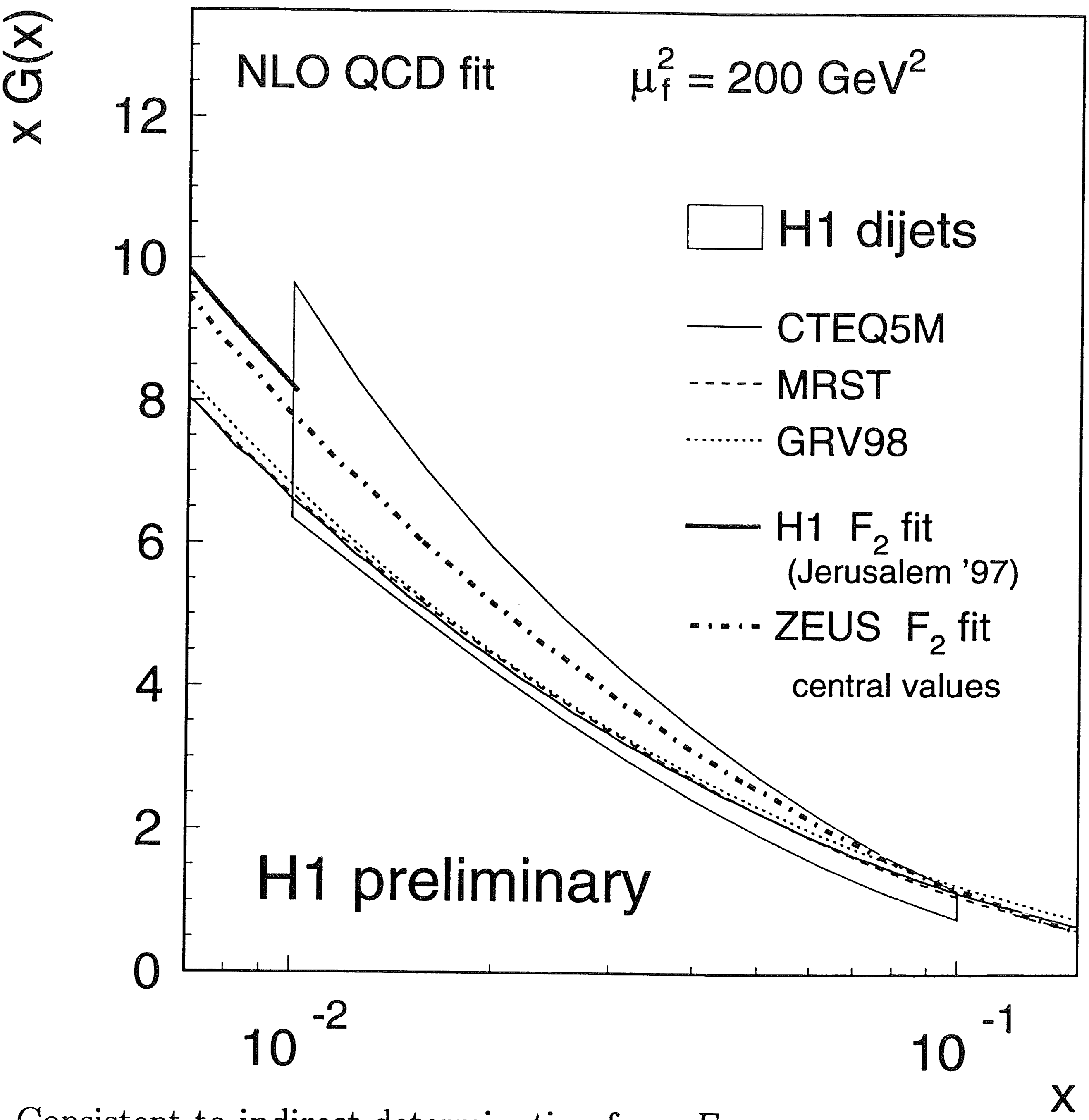
data higher at smallest ξ

$\Rightarrow$ higher parton densities

$\Rightarrow$ Fit dijet combined with F_2 at $\mu_f^2 = 200$ GeV^2

(Direct) Gluon Density from Dijets

determined for $\alpha_s(M_Z) = 0.119 \pm 0.005$

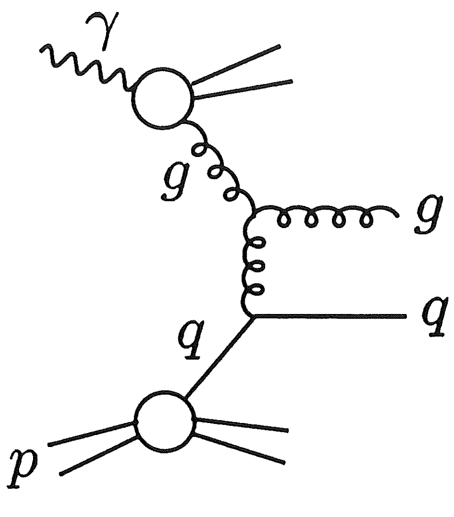


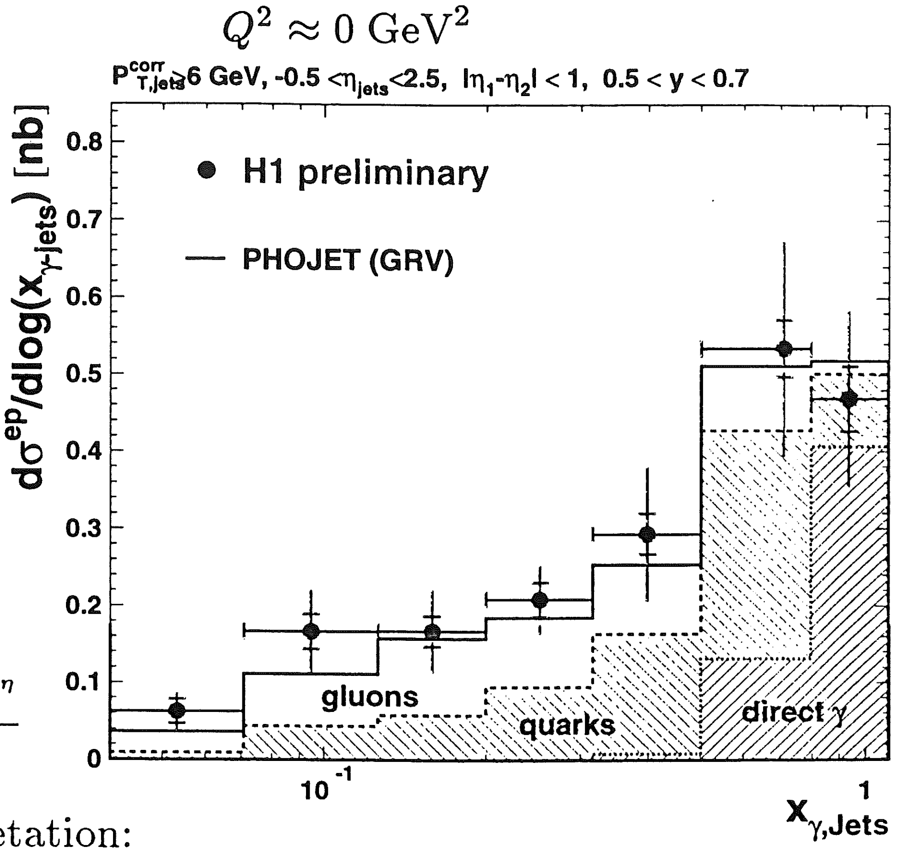
Consistent to indirect determination from F_2

Constrains gluon at large $x \rightarrow$ LHC !

Note: HERA gluon comes out higher than from global fits !

Dijet Cross Section - The Gluon in the Photon



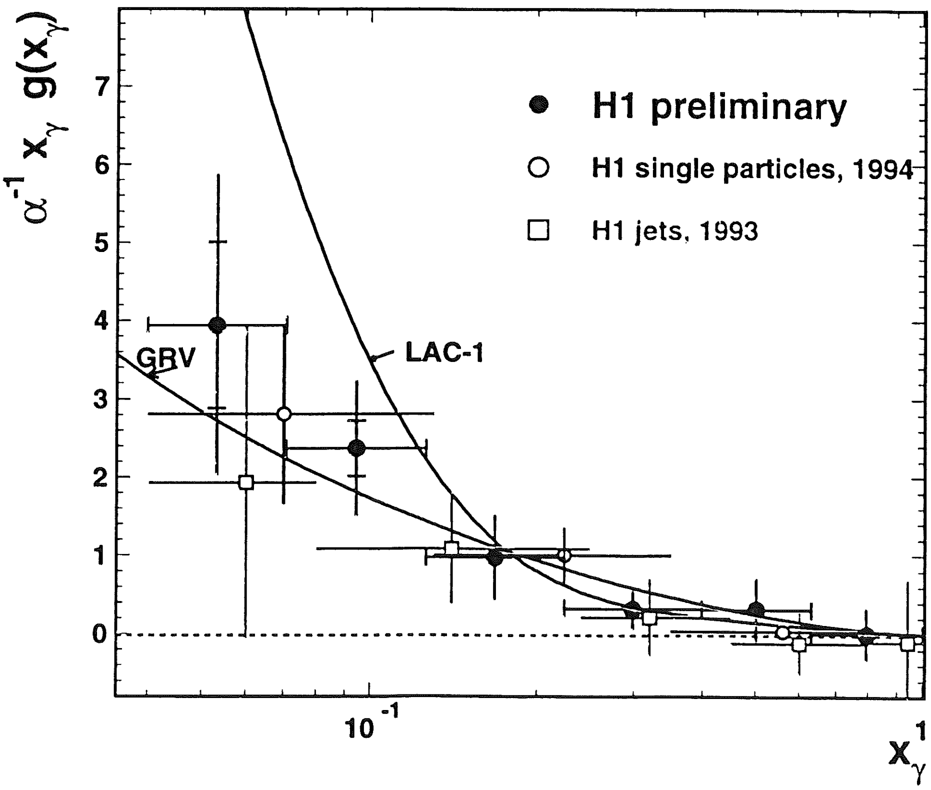


Experimental difficulty:

access low $x_\gamma = \frac{\sum_{1,2} P_T e^{-\eta}}{2E_\gamma}$

Leading Order Interpretation:

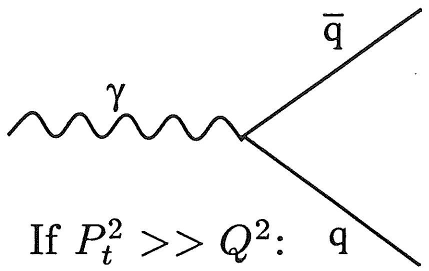
$\frac{d\sigma}{dx_\gamma} = f^{\gamma/e} \cdot f^{\gamma}_{\text{eff}} \cdot f^{p}_{\text{eff}} \cdot |ME_{\text{eff}}|^2$ where $f^{\gamma}_{\text{eff}} = q + \bar{q} + \frac{9}{4} g$



Large gluon contributio[n]
at low x_γ
rise of $g(x, Q^2)$ seen !
Jets agree with
single charged particles

→ see talk by J. Cvac

$\frac{d^3\sigma}{dQ^2 dP_T^2 dx_\gamma}$ - Parton Density of Virtual Photon



Photon real: $f(x) \cdot \log \frac{P_t^2}{\Lambda^2}$

Photon virtual: $f(x) \cdot \log \frac{P_t^2}{Q^2}$

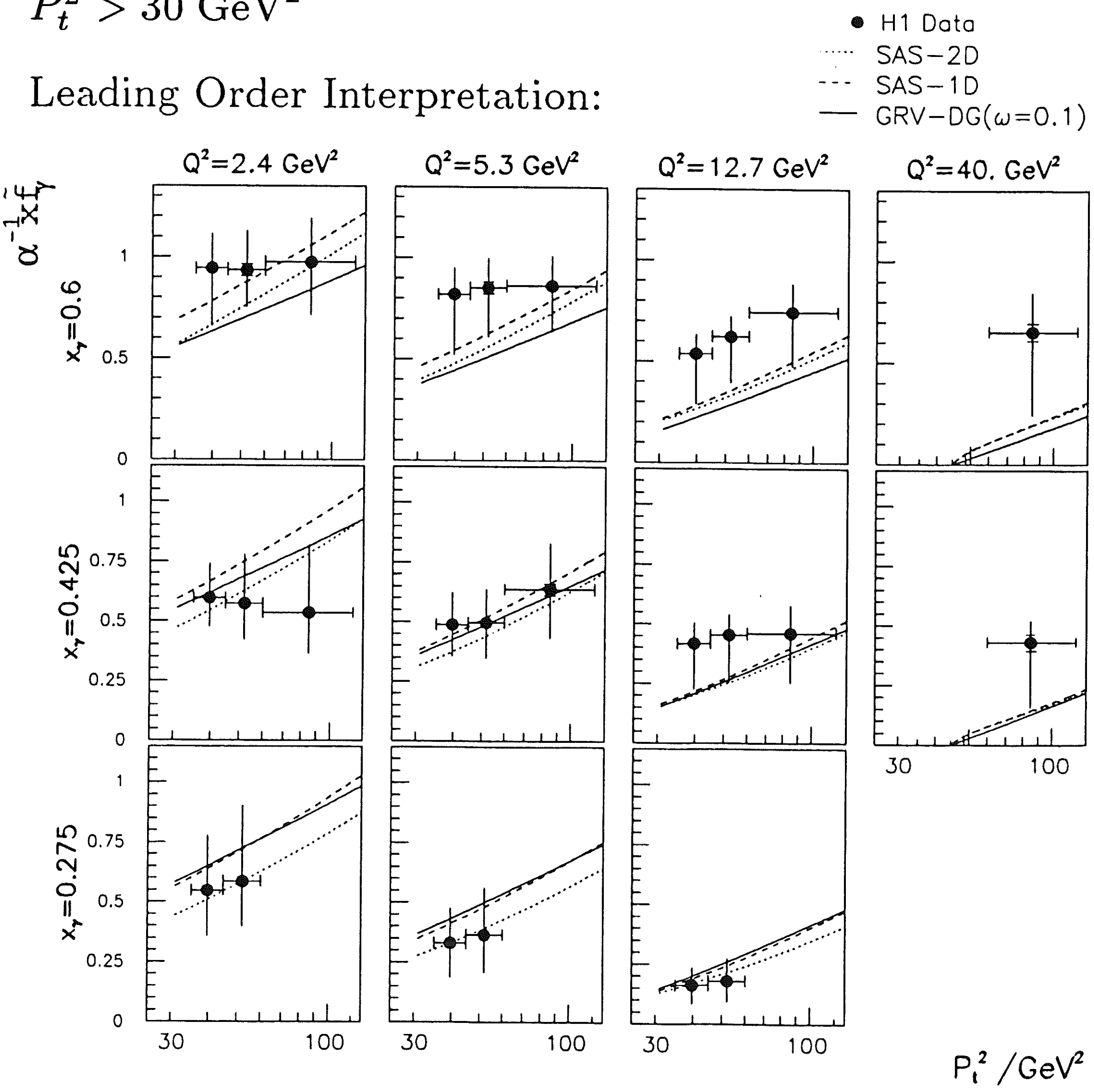
If $P_t^2 >> Q^2$:
jet P_t^2 resolves photon
$Q^2 \sim$ size of the target

Prediction:
$PDF \propto \log P_t^2$ and PDF falls with Q^2

Measurement: $\frac{d^3\sigma}{dQ^2 dP_t^2 dx_\gamma}$

$1.6 < Q^2 < 80$ GeV^2 and $0.1 < y < 0.7$
$P_t^2 > 30$ GeV^2

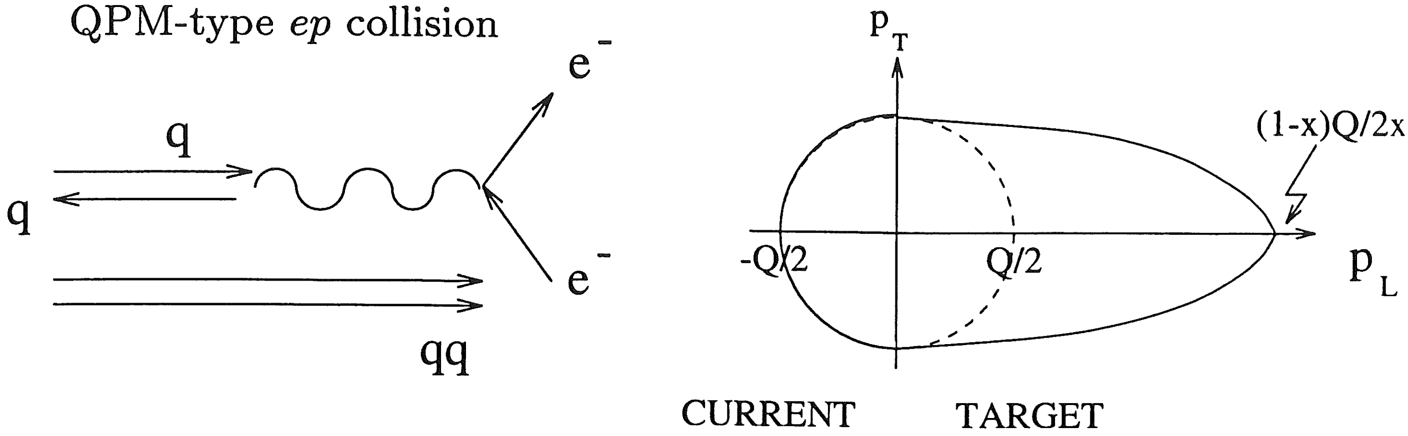
Leading Order Interpretation:



Consistent with normalisation and the expected logarithmic rise over large domain of photon virtualities

Event Shapes in Current Region of Breit Frame

Breit System at HERA (brick wall frame):
QPM-type *ep* collision

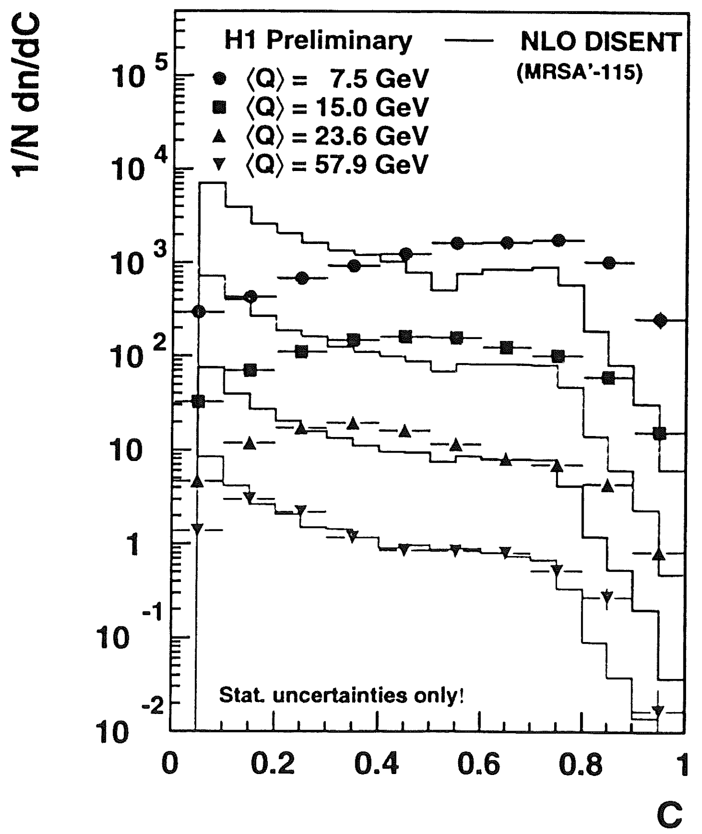


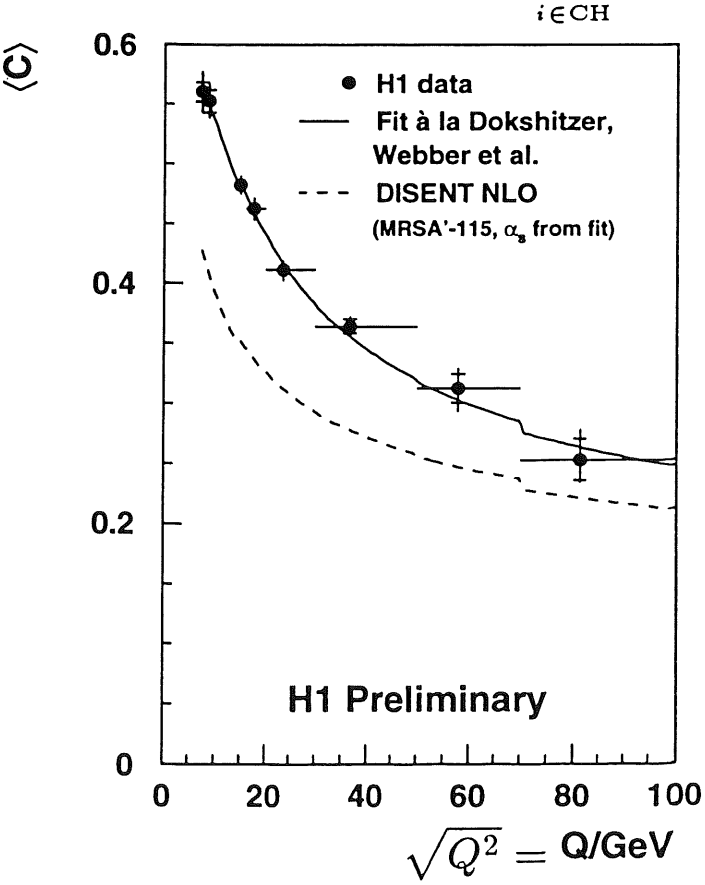
Event shapes F:

Thrust, jet broadening, jet mass

New: C-parameter, y_2 using JADE and k_T algorithm

$$C := 3(\lambda_1\lambda_2 + \lambda_2\lambda_3 + \lambda_3\lambda_1) \text{ eigen values of } \Theta^{\star}_{jk} := \frac{\sum_{i\in CH} \frac{p^{\star}_{j_i} p^{\star}_{k_i}}{|\vec{p}^{\star}_i|}}{\sum_{i\in CH} |\vec{p}^{\star}_i|}$$





Power Corrections

à la Dokshitzer, Webber et al.

$$\langle F \rangle = \langle F \rangle^{\text{pert}} + \langle F \rangle^{\text{pow}}$$

$$\langle F \rangle^{\text{pert}} = c_{1,F}(x)\, \alpha_s(Q) + c_{2,F}(x) \alpha_s^2(Q)$$

New for DIS 99:
improved treatment of x-dependence of $c_F(x)$

$$\langle F \rangle^{\text{pow}} = a_F \frac{32}{3\pi^2} \left[\overline{\alpha}_0(\mu_I) - \alpha_s(Q) - f(\tfrac{Q}{\mu_i})\, \alpha_s^2(Q) \right]$$

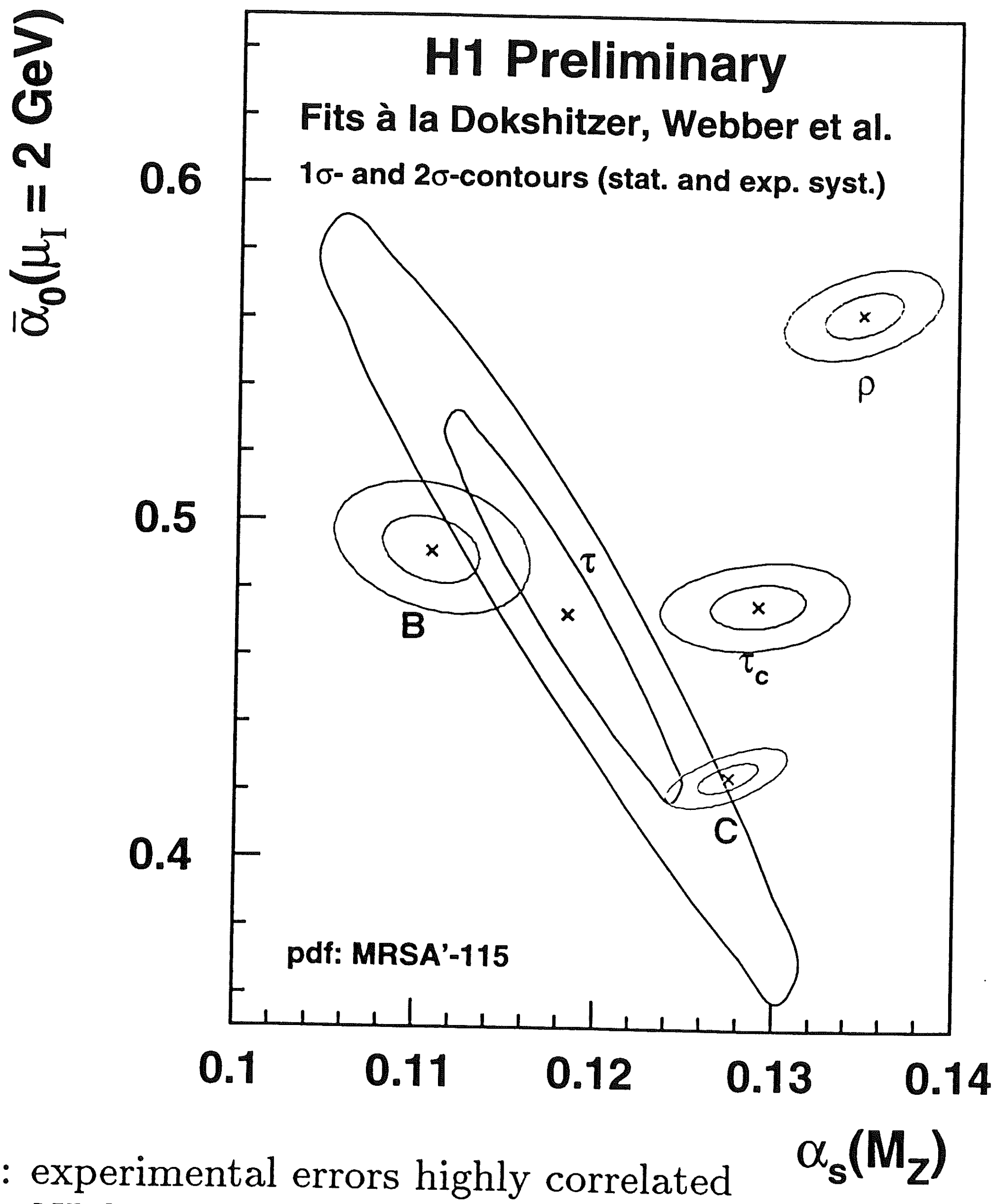
- a_F: calculable F dependent constants
- μ_I: infrared matching scale
- $\overline{\alpha}_0(\mu_I)$: universal (?) non-pert. parameter to fit
- New (12/98) analytical form for B included $\rightarrow$ better results

Do we need also x-dependent a_F ?
Promising way to get (analytical) understanding of hadronisation for specific variables ?

$\rightarrow$ see talk by K. Rabbertz

Power Correction Fit Result

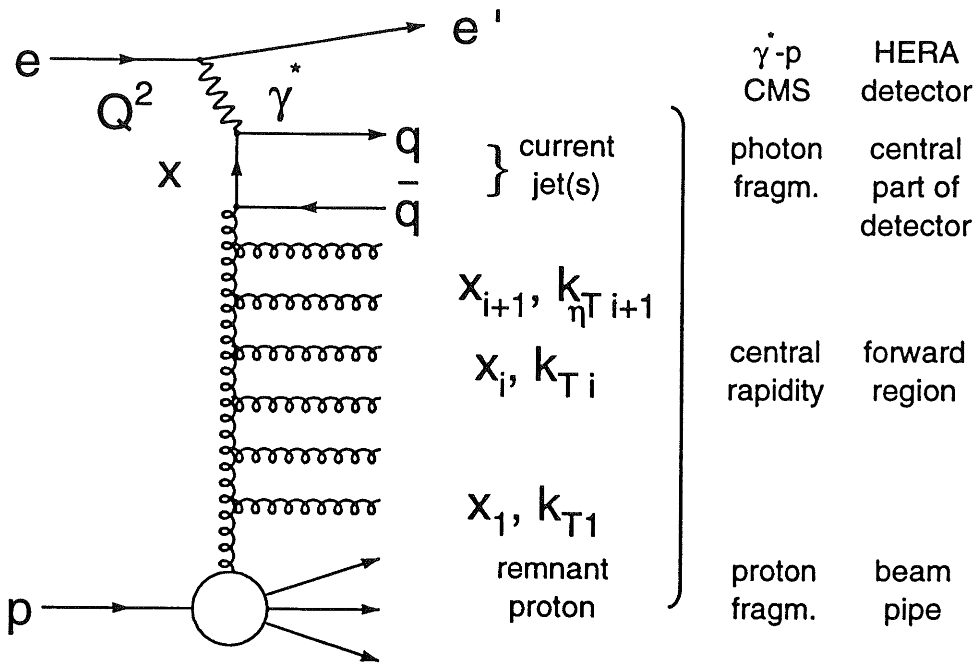
Consistency check:



Note: experimental errors highly correlated
NLO scale dependence not included

Success: $\overline{\alpha}_0(\mu_I)$, α_s come out about right,
but not fully satisfactory (large α_s spread)
Need more precise data and better theory !
Do we need $x-$ dependent coefficients or higher orders ?

QCD parton dynamics at low x

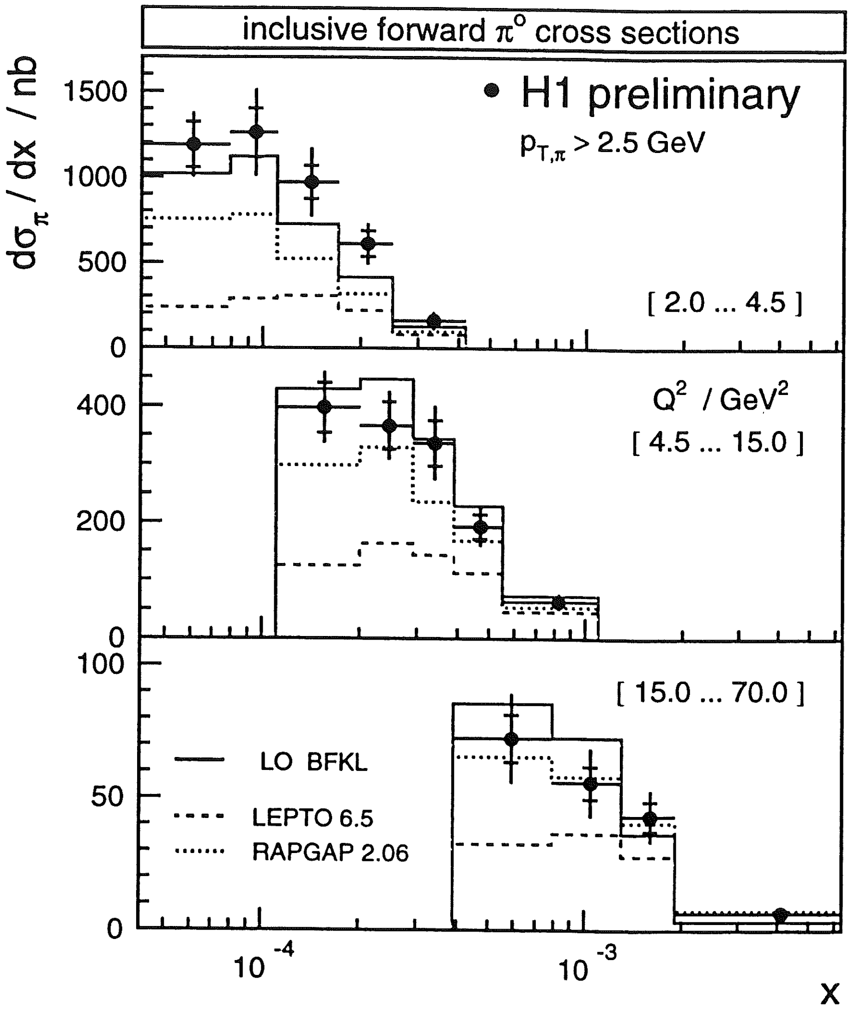


Are they are hard partons in the central rapitiy region of the proton
High P_T → suppress DGLAP, forward → long ladder

Experimental access by hard identified particles or jets
Exploring particle/density in forward detector
High energy π^0 → no mass peak → need finely segmented H1 calo !

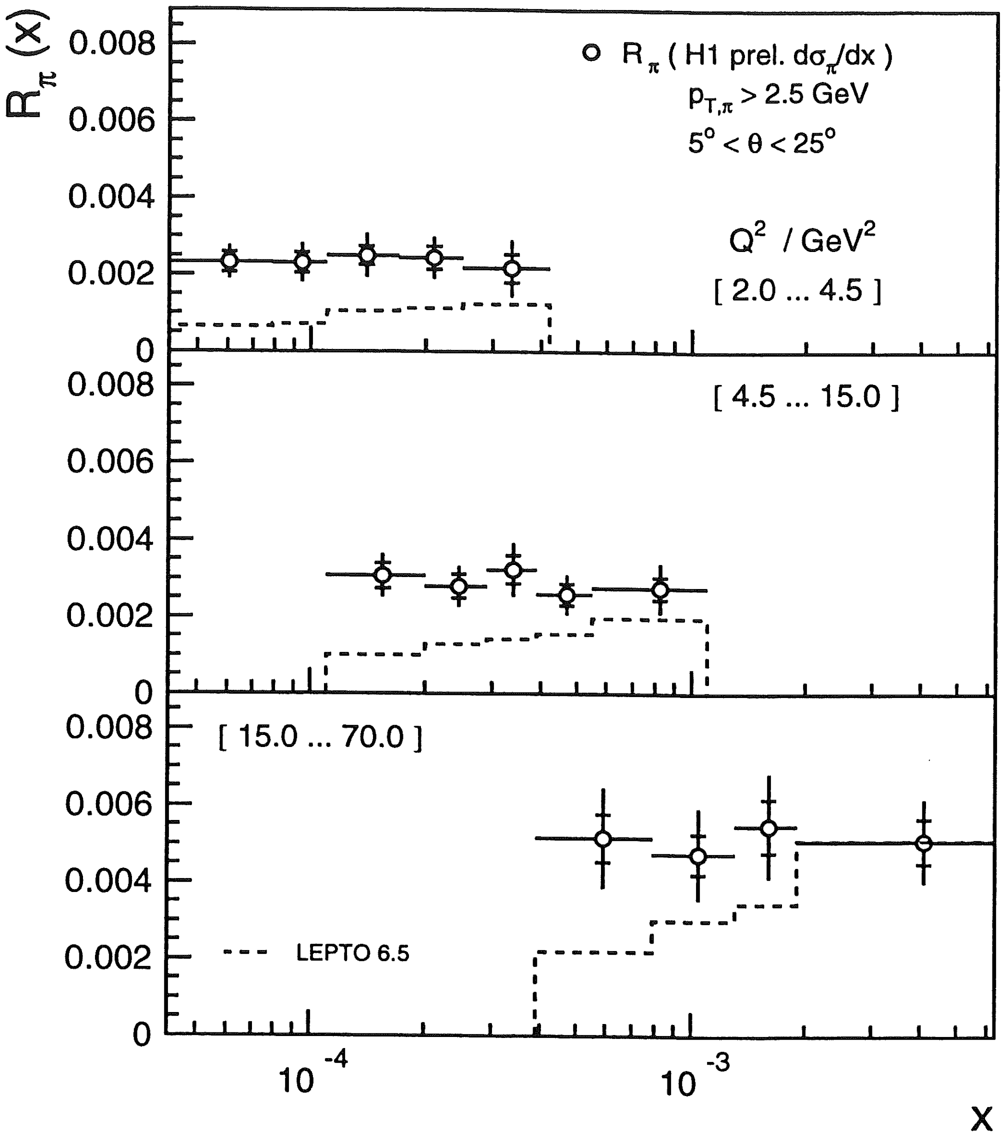
→ see talk by T. Wengler

Forward-π^0 Cross Section



- modified LO BFKL – Kwiecinski, Martin, Outhwaite
- LEPTO: ME $\mathcal{O}(\alpha_s)$ + PS (leading $\log Q^2$)
- RAPGAP: ME $\mathcal{O}(\alpha_s)$ + PS (leading $\log Q^2$) + PS from photon side ("resolved" photon)

Ratio Forward-π^0 to Inclusive Cross Section



Strong rise of F_2 towards low x (described by NLO DGLAP)

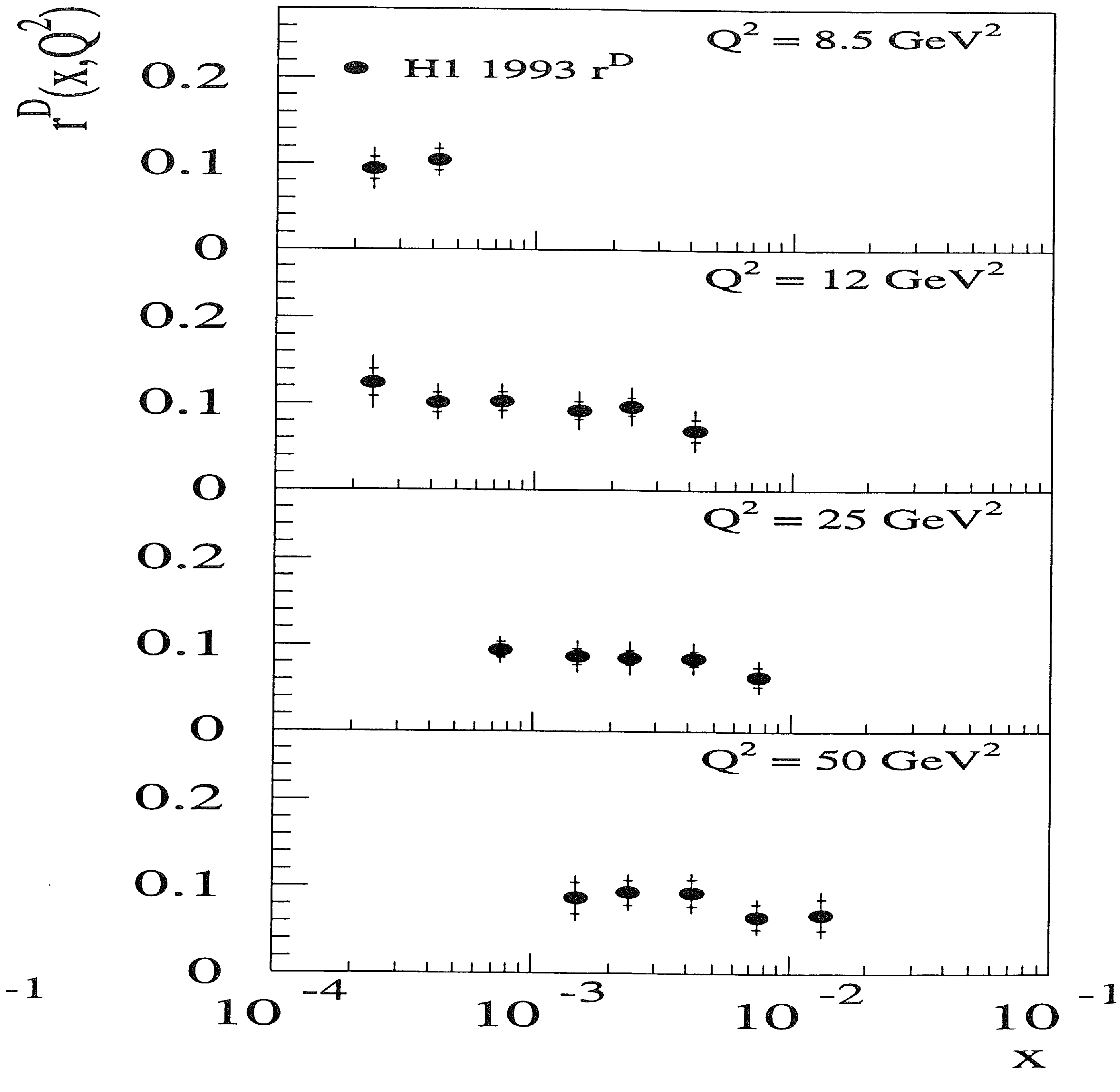
Forward particle/jet rises as F_2 towards low x for $2.5 < Q^2 < 70$ GeV^2

LO-DGLAP as implemented in parton shower too restrictive

Models allowing for larger phase space in agreement with data

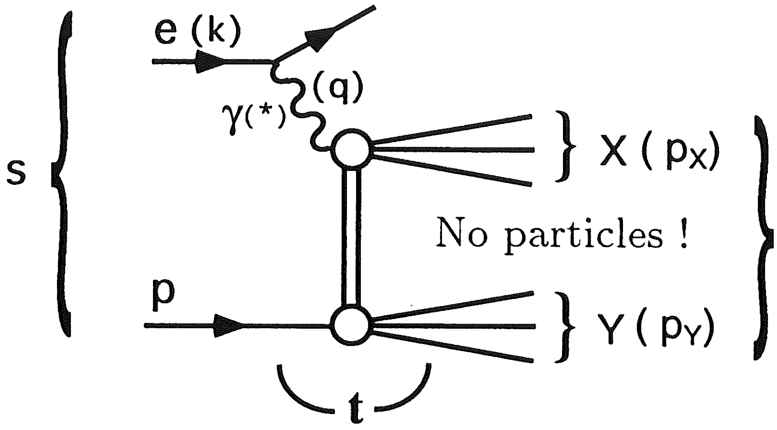
Remember ? $\frac{\text{Diffractive}}{\text{inclusive}} \approx$ const

Ratio Diffractive to Inclusive Cross Section



Same evolution for incl. ≈ hard particle ≈ no particle ??

Diffractive DIS, $\gamma^\star p \to XY$



$$x_{I\!P} = \frac{q.(p-p')}{q.p} \simeq \frac{Q^2+M_X^2}{Q^2+W^2}$$

$$\beta = \frac{Q^2}{q.(p-p')} \simeq \frac{Q^2}{Q^2+M_X^2}$$

$I\!P$ colourless exchange

$x_{I\!P}$: Fraction of proton momentum transferred to $I\!P$

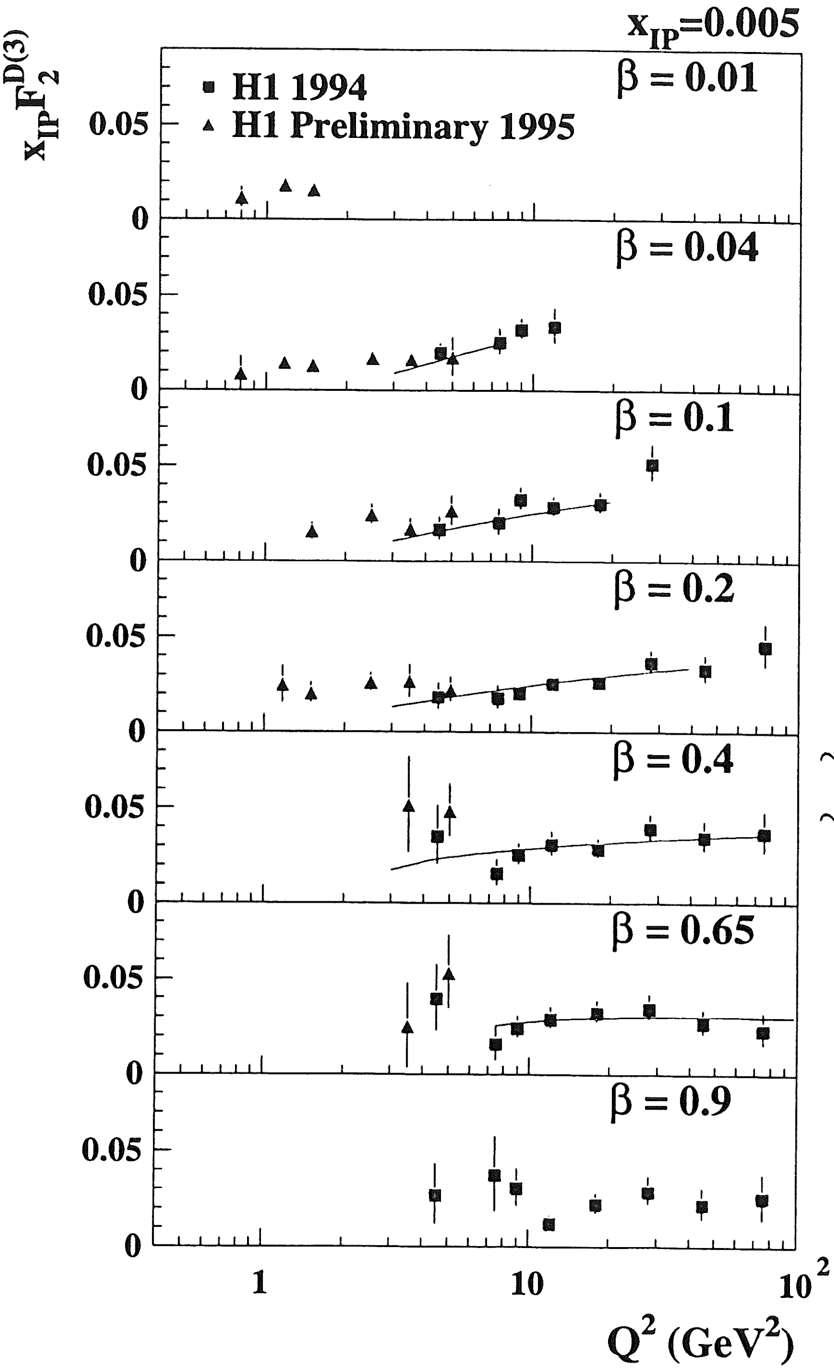
β: Frac. of $I\!P$ momentum carried by quark coupling to $\gamma^\star$.

Semi-inclusive cross section measurements are presented as a 'diffractive' structure function $F_2^{D(3)}(\beta, Q^2, x_{I\!P})$, defined as

$$\frac{d\sigma^{ep\to eXY}}{d\beta\ dQ^2\ dx_{I\!P}} = \frac{4\pi\alpha^2}{\beta Q^4}\ (1-y+\frac{y^2}{2})\ F_2^{D(3)}(\beta, Q^2, x_{I\!P})$$

1. Parton densities can be extracted
2. They can be used to predict hadronic final state

Scaling Violations of $F_2^{D(3)}$



Rising scaling violations up to large β

Highly suggestive of a gluon dominated mechanism

From fits:

$\sim$ 90% gluon at $Q^2 = 4.5$ GeV

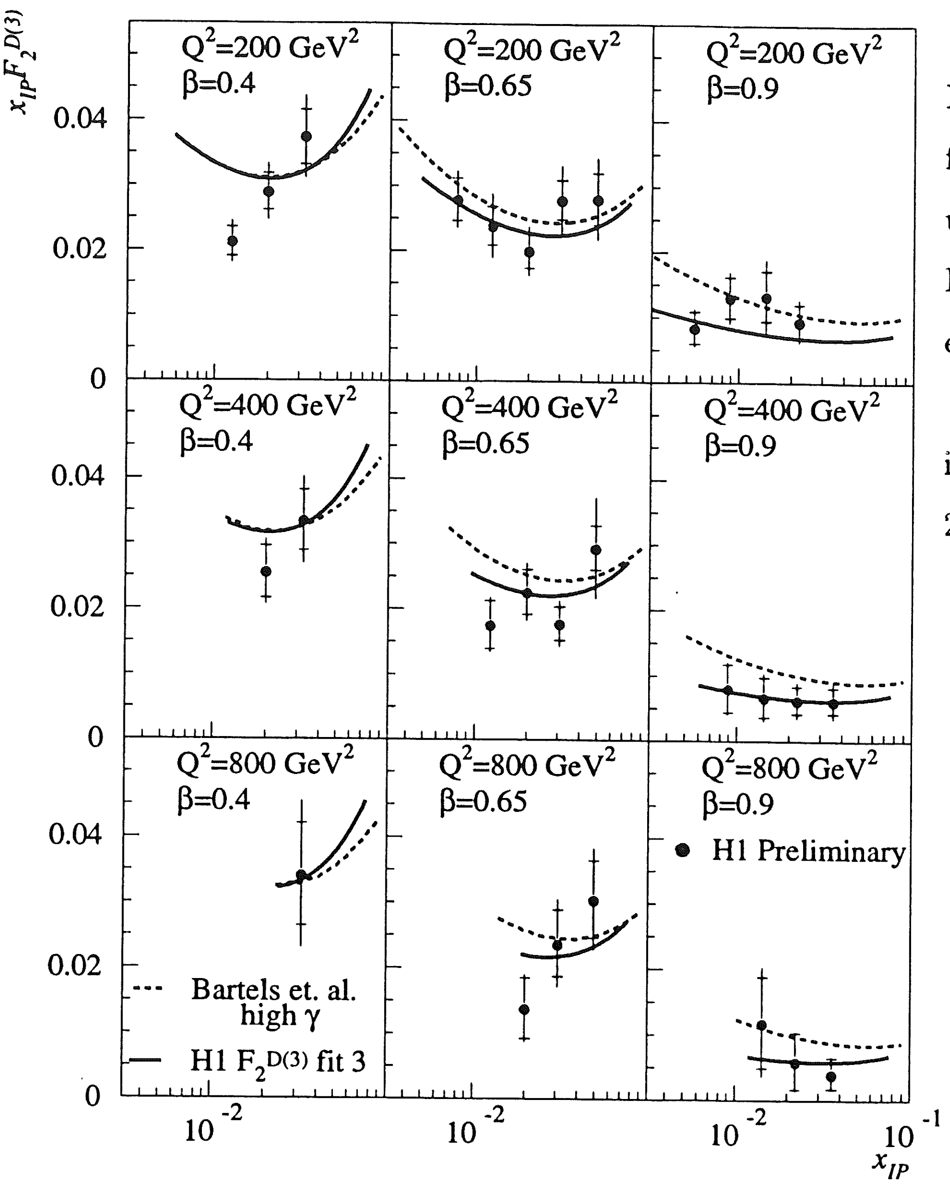
$\sim$ 80% gluon at $Q^2 = 75$ GeV

Changes scaling behaviour at low Q^2?

Do we understand diffractive physics over the whole kinematic domain ?

$\rightarrow$ see talk by C. Royon

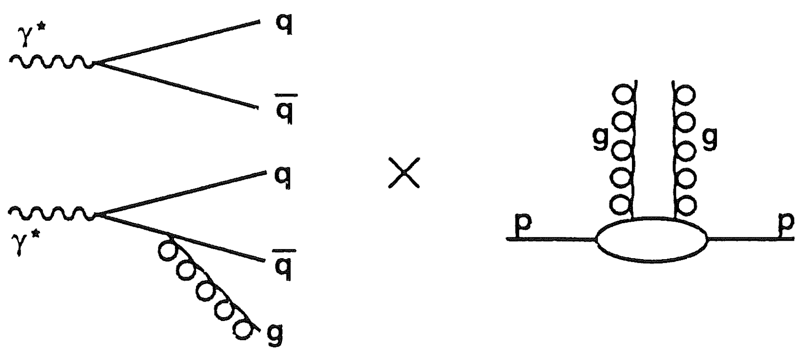
New $F_2^{D(3)}$ Data at large Q^2



Extrapolations of DGLA
fits describe the data
up to $Q^2 = 800$ GeV^2
Important test of evolut
errors still large

is also ok
2-gluon exchange model

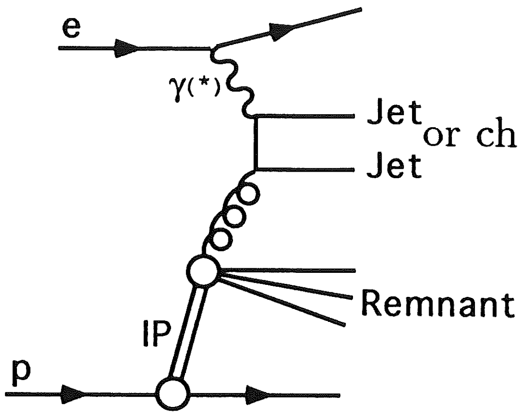
$q\bar{q}$ / $q\bar{q}g$ production via the exchange of 2 gluons / BFKL ladder from the proton.



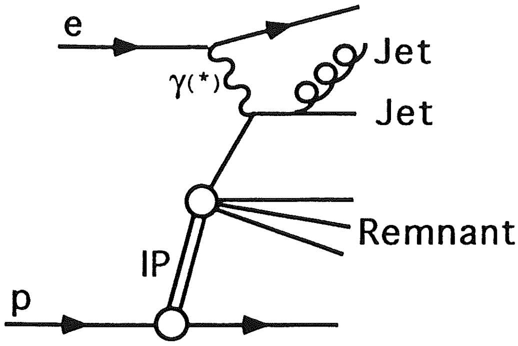
Diffractive Hadronic Final State

Direct sensitivity to gluons in diffractive dijet and charm production through $\mathcal{O}(\alpha_S)$ processes:

BGF



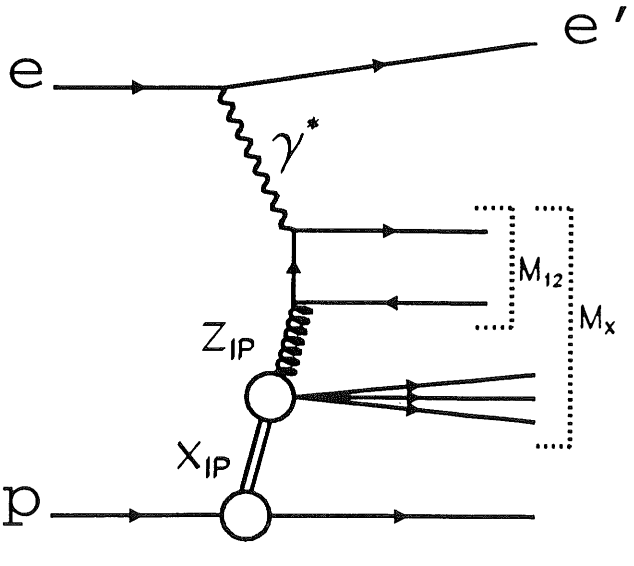
QCDC



DGLAP: quark or gluon dominated 'resolved' pomeron ?

2-gluon model: decomposition of $q\bar{q}$ $q\bar{q}g$ final states ?

Kinematics:



$$x_{\mathbb{P}} = \frac{Q^2+M_X^2}{Q^2+W^2}$$

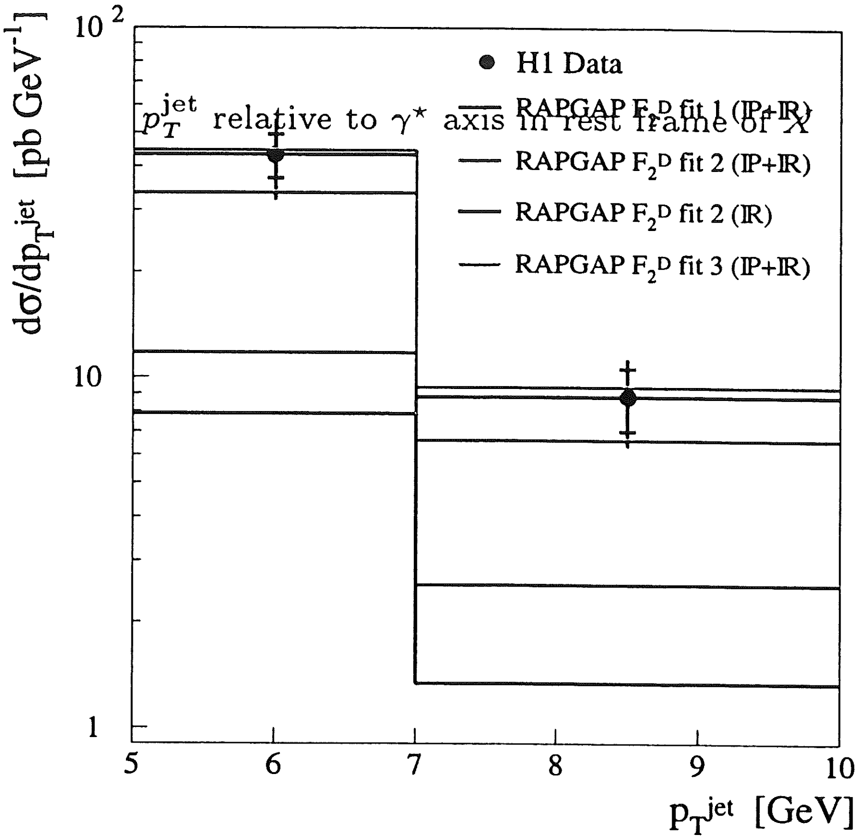
$$z_{\mathbb{P}} = \frac{Q^2+M_{12}^2}{Q^2+M_X^2}$$

$z_{\mathbb{P}}$ measures momentum fraction of the struck partor

if $z_{\mathbb{P}}$ small, $M_{12}^2 < M_X^2$

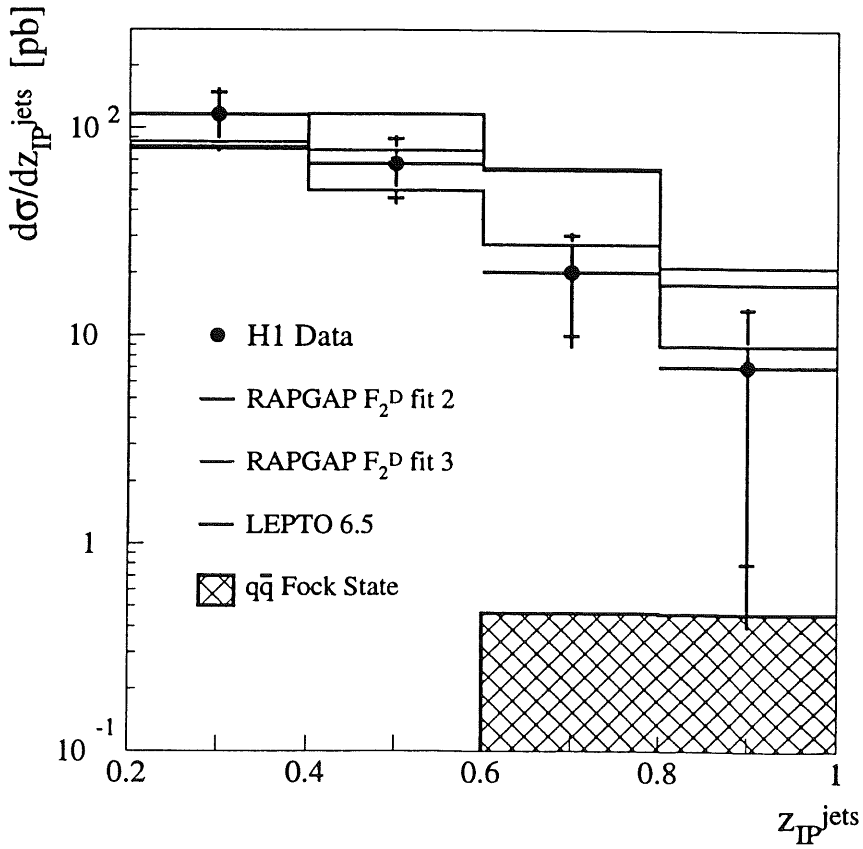
not entire energy from colourless exchange is tagge

Diffractive Dijet Production



Jets reasonably described by gluon dominated IP

Quark dominated IP low by a factor ~ 5



RAPGAP ('resolved' IP) ok

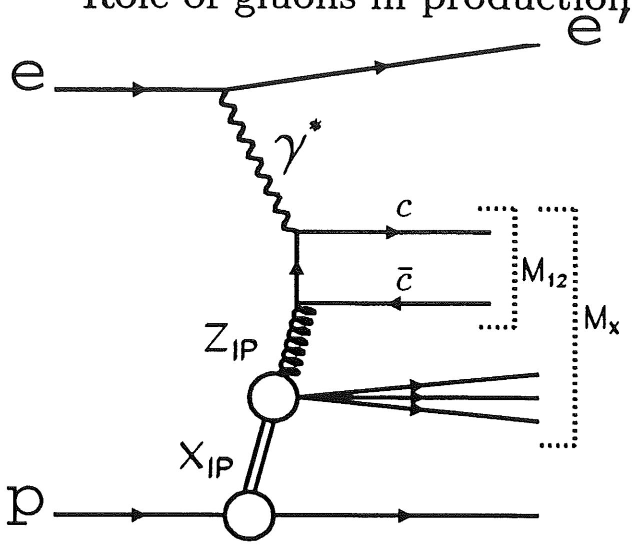
2-gluon too low even at z_{IP} =

→ see talk by F. Schilling

What about charm ?

Diffractive Charm Production

Rôle of gluons in production mechanism of diffraction ?



Phase space:

$2 < Q^2 < 100$ GeV^2 $0.05 < y < 0.7$

$p_T(D^*) > 2$ GeV$|\eta(D^*)| < 1.5$

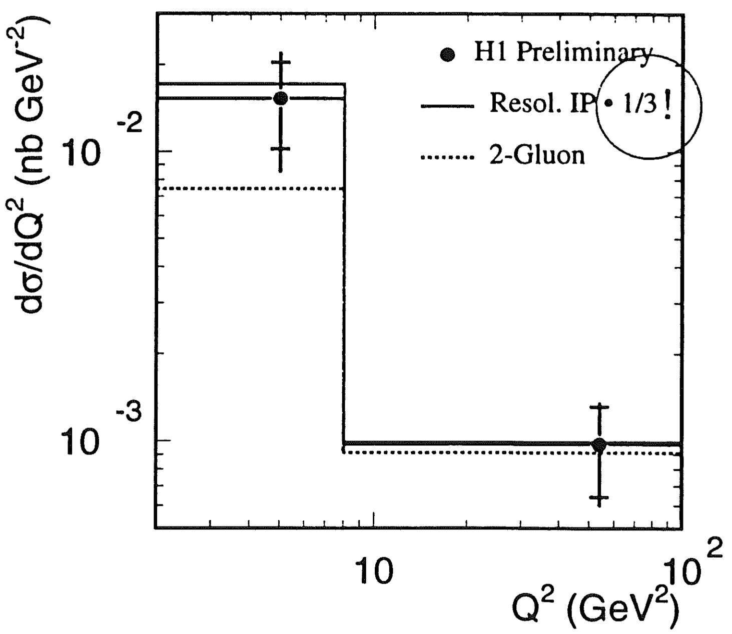
$x_{\mathbb{P}} < 0.04$ $M_Y < 1.6$ GeV

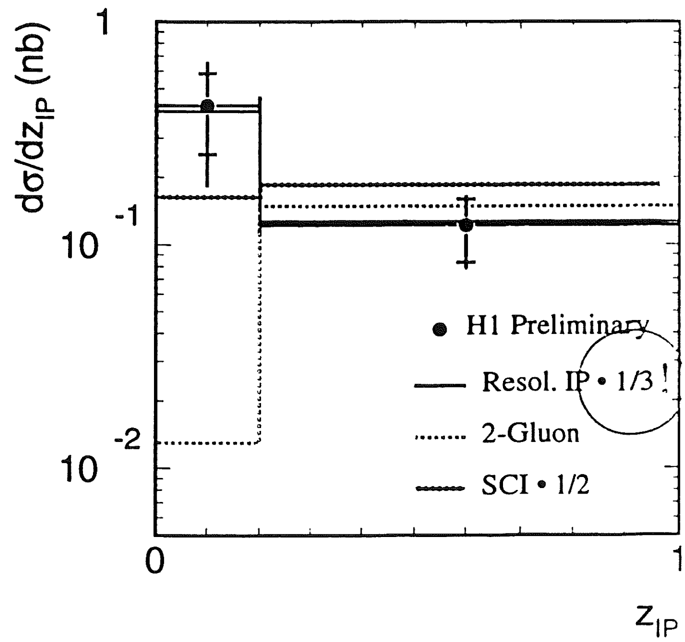
1995-1997 data

$\int \mathcal{L}dt = 21$ pb^{-1}

only ~ 45 events

$$\sigma_{vis}(ep \to (D^*X)Y) = 154 \pm 40(stat) \pm 35(syst) \text{ pb}$$



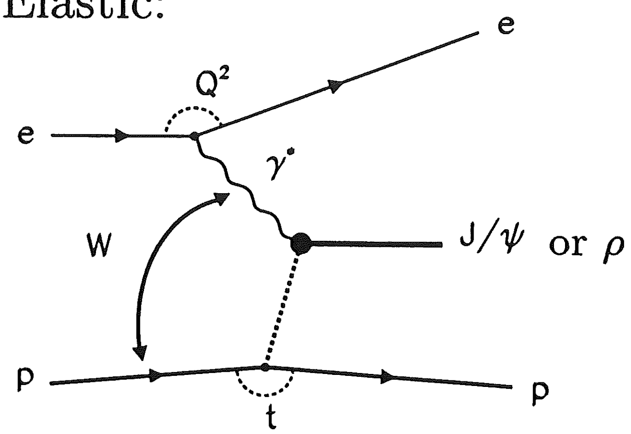


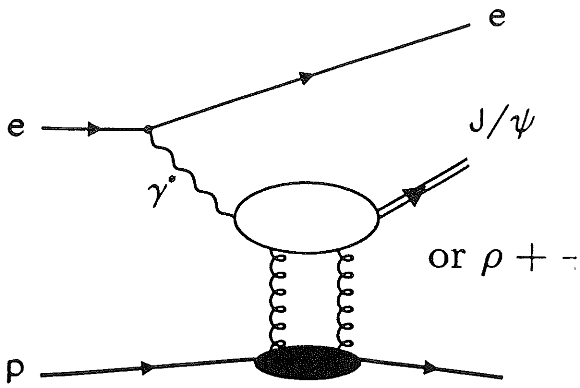
PDFs from $F_2^{D(3)}$ $\to$ RAPGAP $\to$ diffractive D^* failure ! (Factor 3)
2-gluon model, if averaged over $z_{\mathbb{P}}$, much better !
Signal more pronounced at low $z_{\mathbb{P}}$:
not entire colourless exchange couples to $c\bar{c}$ system
Need to bring more data to clarify the picture...
What is wrong ?

$\to$ see talk by S. Hengstmann

Vector Meson Production

Elastic:





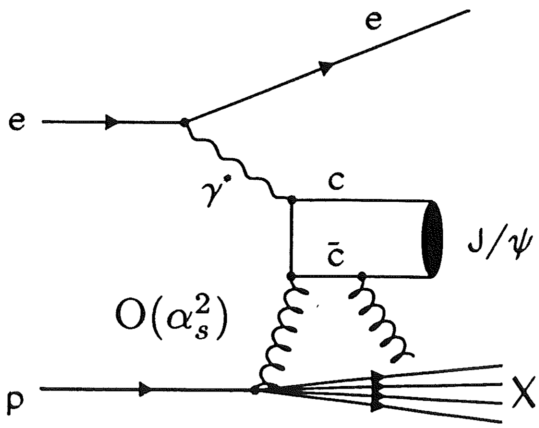
Soft: $\sigma_{\gamma^* p \to Vp} \sim W_{\gamma p}^{\delta}$
δ as in soft collisions

Hard: stronger rise with W expected à la QCD:
$\sigma_{\gamma^* p \to Vp} \sim (\alpha_s \, x \, g(x, Q^2))^2$

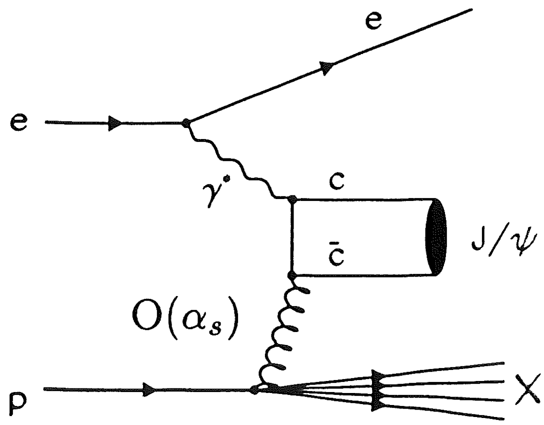
Three Scales: Q^2, M_V, t

Inelastic: $X \neq$ proton

Colour singlet

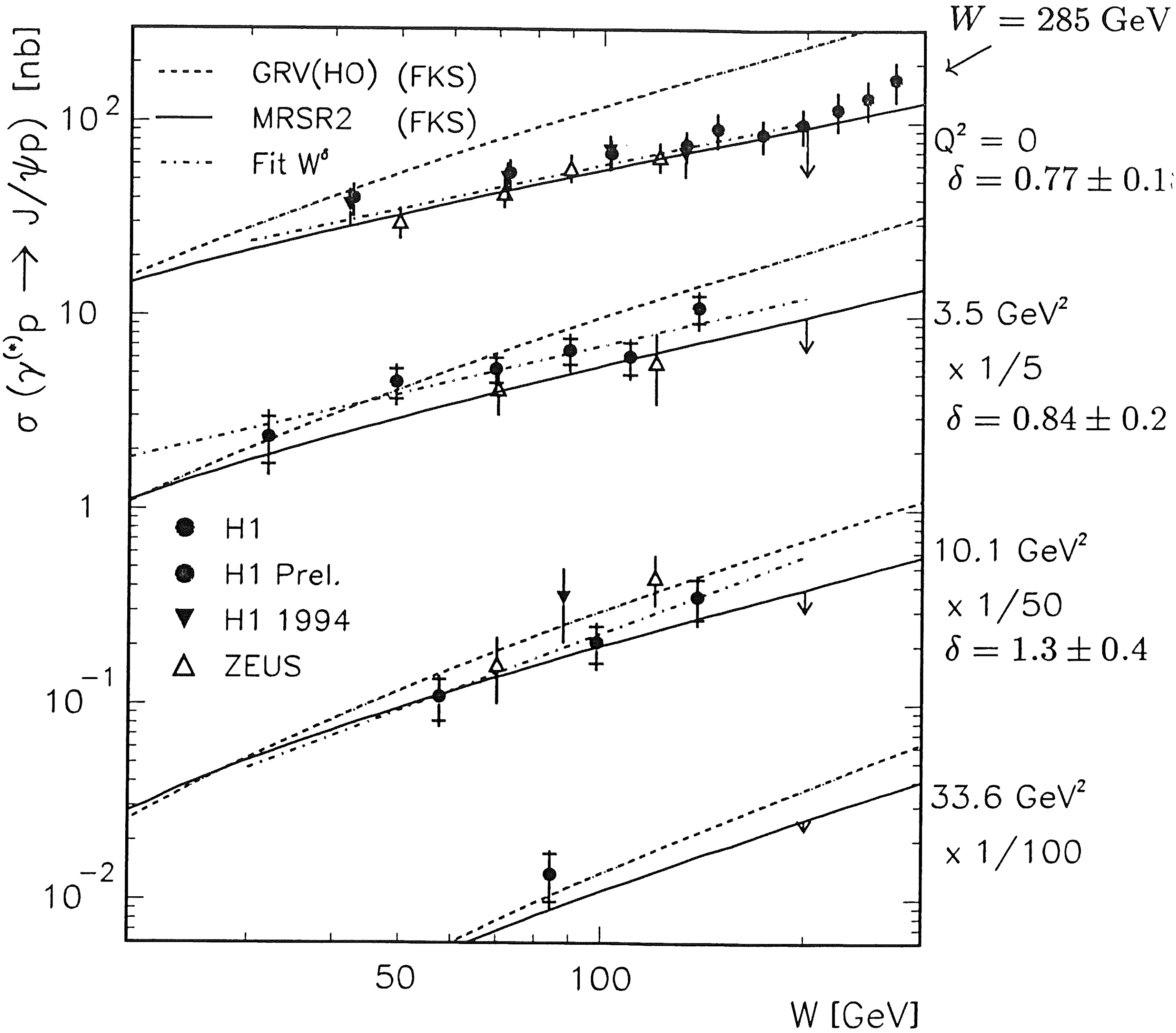


Colour Octet



Colour octet ME fitted to TEVATRON data (J/ψ at large P_t)
$\rightarrow$ crucial test at HERA

Elastic J/ψ Production



Fast increase with W^{δ}, fast decrease in Q^2

Q^2 dependence $\sim 1/(Q^2 + M^2_{J/\psi})^n$ with $n = 2.38 \pm 0.11$

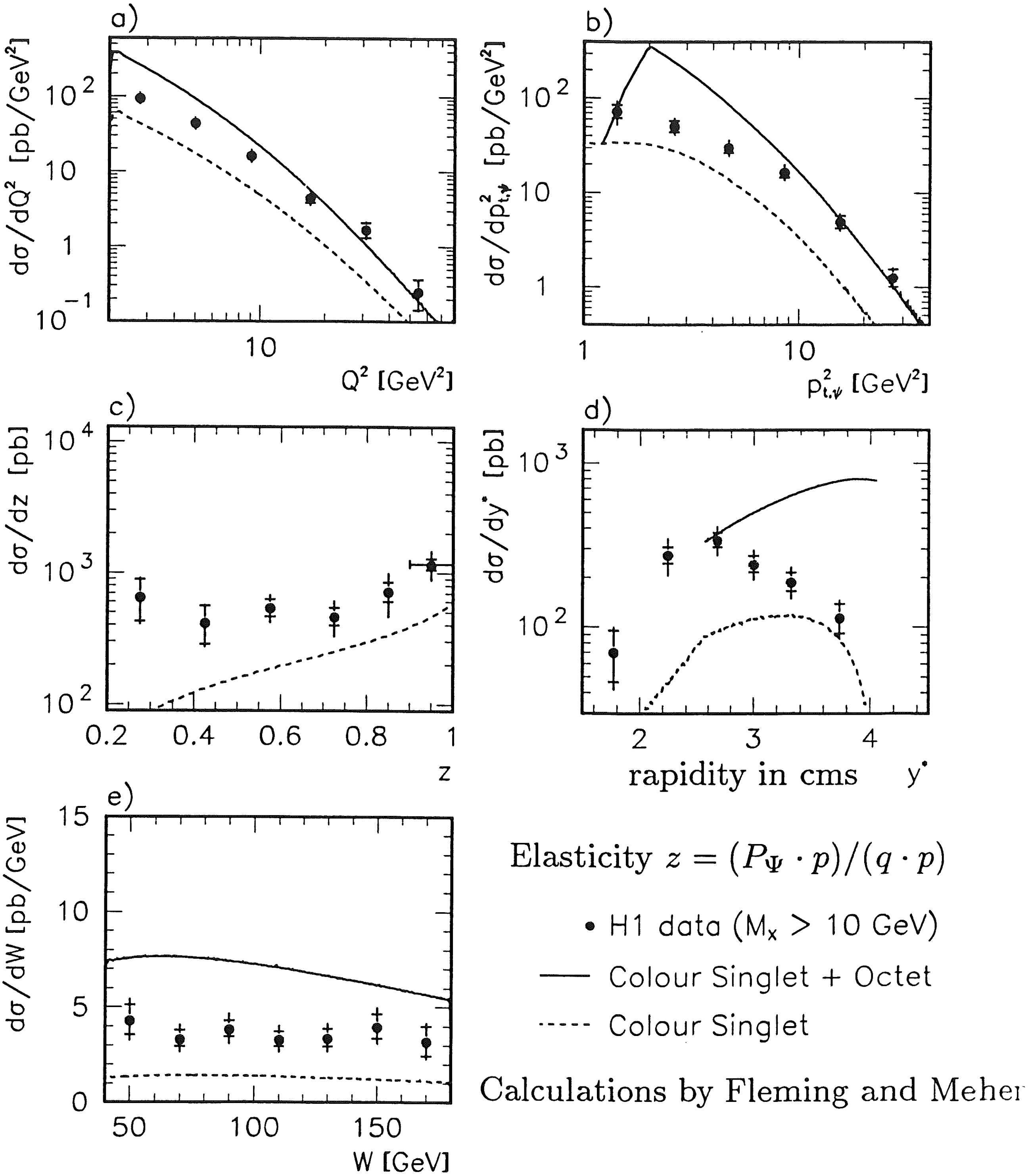
Sensitivity to $|g(x, Q^2)|^2$ and charm mass decreasing with Q^2

arrow indicating m_c=1.4-1.5

Succes of QCD, but what approximations behind ??

→ see talk by S. Mohrdieck

Inelastic J/ψ Production

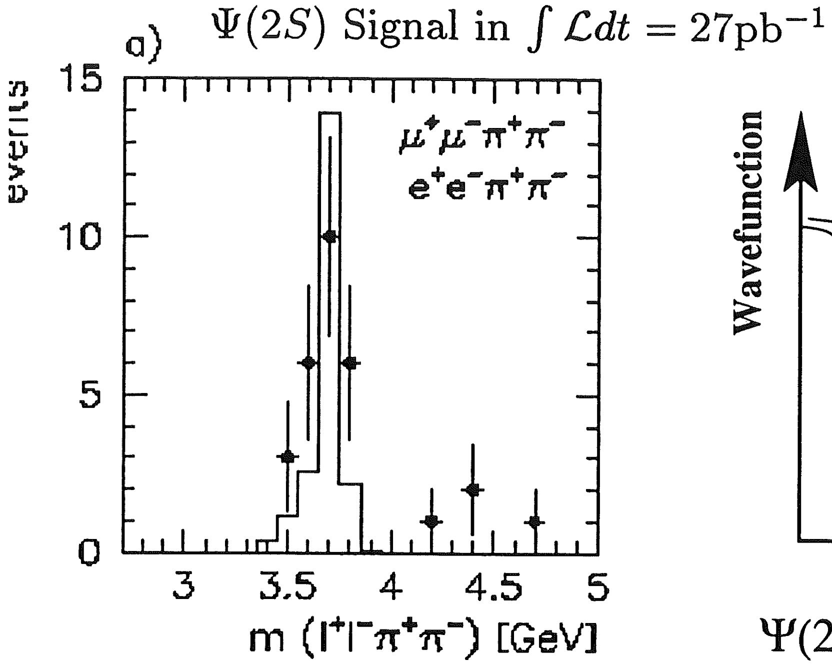


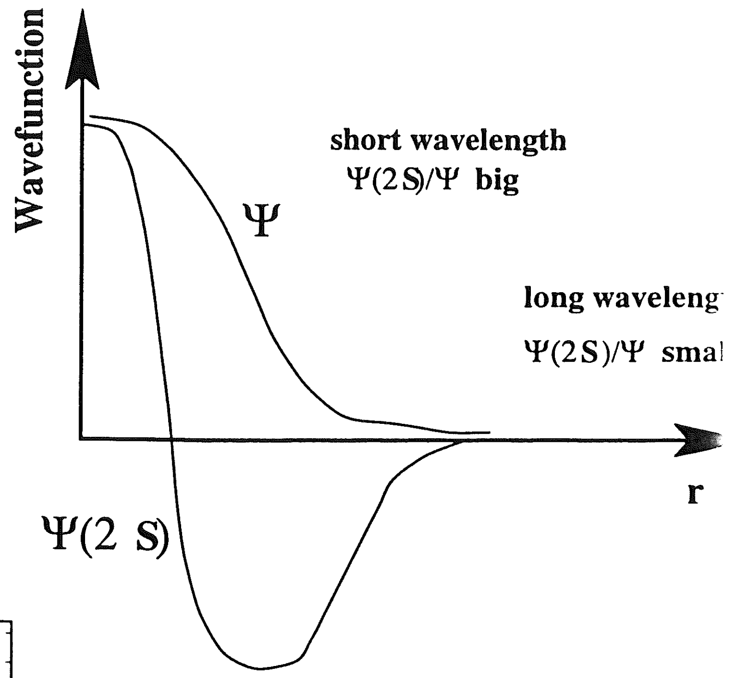
Singlet too low, sum of singlet and octet too large by factor of 2-3

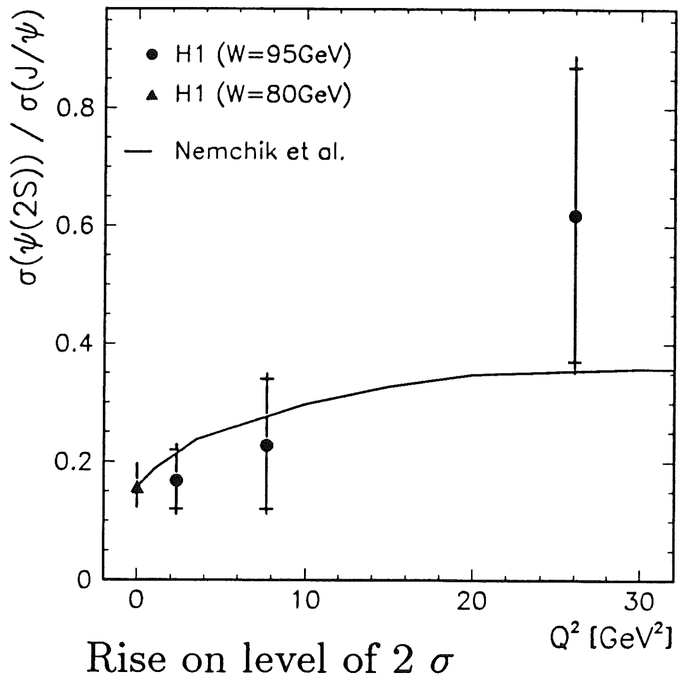
$\rightarrow$ overall adjustment of transition ME ? include higher orders ?

Shape not reproduced $\rightarrow$ relative adjustment of individudal contributions

Evidence for $\Psi(2S)$ at HERA







Rise on level of 2 σ

QCD model Prediction: $\sigma_{\Psi(2S)}/\sigma_{\Psi} \approx 0.5$ for $Q^2 >> M_{\Psi}^2$

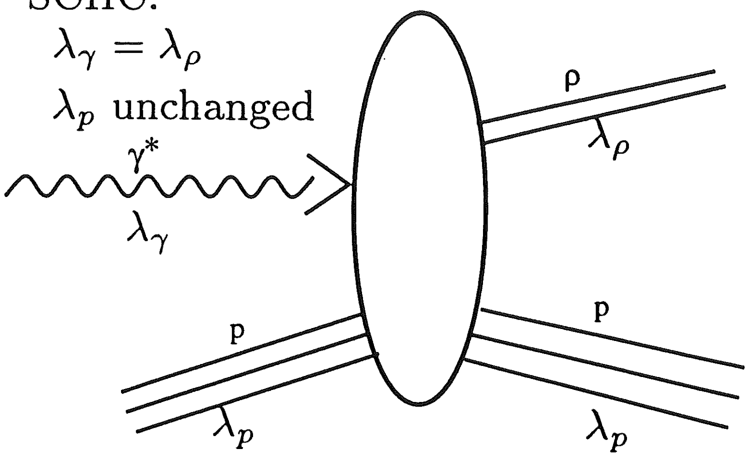
→ see talk by P. Merkel

ρ^0 Production - Spin Helicity Analysis

SCHC:

$\lambda_\gamma = \lambda_\rho$

λ_p unchanged



$W(\cos\theta, \phi, \Phi) = f(r^i_{\lambda_\rho,\lambda_\gamma})$

where Spin density-ME

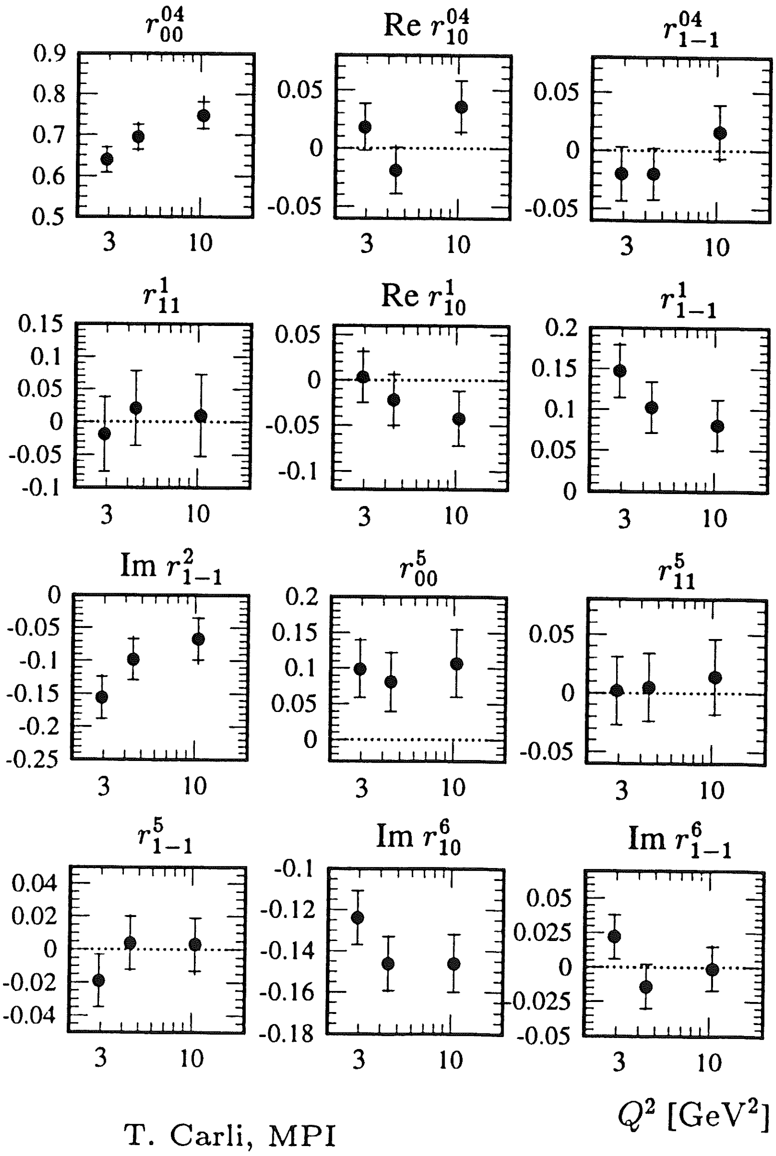
$r^i_{\lambda_\rho,\lambda_\gamma} = f(T_{\lambda_\rho,\lambda_\gamma})$

θ^*, ϕ^* of $\rho \to \pi^+\pi^-$

Φ lepton and ρ planes

Helicity amplitudes: T_{00}, T_{11} no flip T_{01}, T_{1-1} flip/double-flip

$\frac{|T_{01}|}{\sqrt{|T_{00}|^2+|T_{11}|^2}} \sim r^5_{00}\sqrt{\frac{1+R}{2R}} = 8 \pm 3$ %. (Ratio flip/non-flip)



$r^5_{00} \sim T_{00}T_{01} \neq 0$, indicating a significant probability for longitudinal γ^* $\to$ transverse ρ as predicted by Iwanow, Kirschne[r]

SCHC-violation sma[ll] but significant

Helicity amplitudes: $T_{\lambda_\rho,\lambda_\gamma}$

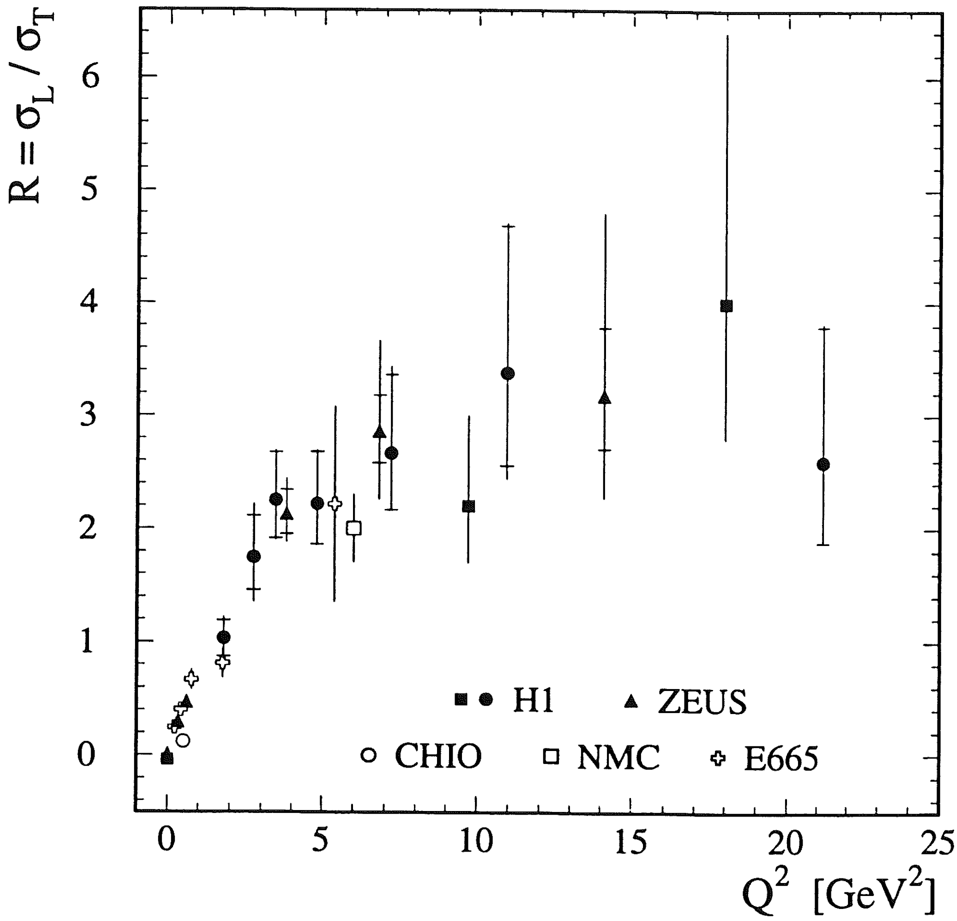
$|T_{00}| > |T_{11}| > |T_{01}| > |T_{1-1}|$

Long. Trans. r^5_{00}

→ see talk by B. Clerbaux

Ratio of Longitudinal to Transverse Photon Cross Sections

$$R = \frac{\sigma_L}{\sigma_T} = \frac{1}{\epsilon} \frac{r_{00}^{04}}{1 - r_{00}^{04}} \quad \text{with} \quad \epsilon = \frac{\Gamma_L}{\Gamma_T} = \frac{2(1-y)}{1+(1-y)^2}$$



Longitudinal γ^* cross section dominant at large Q^2

R scales like $\frac{Q^2}{M_V^2}$

for J/Ψ:

$R = 0.18^{+0.18}_{-0.14}$ for $Q^2 = 4$ GeV^2

$R = 0.94^{+0.79}_{-0.43}$ for $Q^2 = 16$ GeV^2

R significantly smaller for J/ψ at similar Q^2

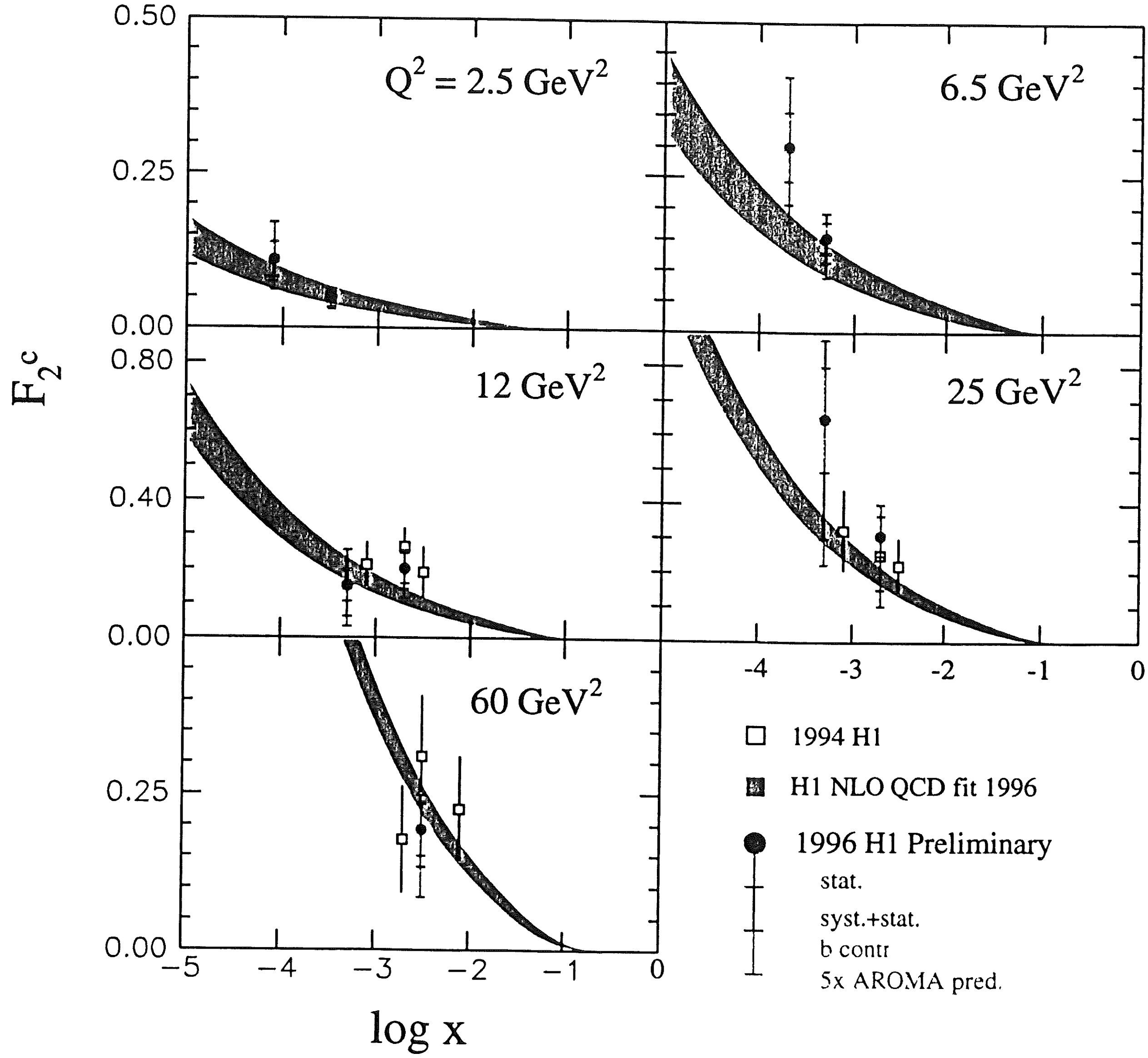
but similar at the same value of Q^2/M_V^2

Conclusions

1. H1 takes good data in 1999 ... a lot more to come !
2. First NC/CC cross section from electron runnning
   → 10 x more statistics than before
   → HERA starts to probe electroweak sector
3. QCD evolution describes F_2 for large domain
   needs more precision to pin down PDFs
   at $Q^2 \gtrsim 15000$ GeV^2 too many events
   new interaction on top of QCD ??
   → wait for end of 1999 !
4. Jets and charm give direct access to the gluon density (especially at large x), but need more statistics and better theory
5. Power correction: needs work on data and theory to get consistent picture
6. New measurement at low-x with hard scale: What is the right QCD evolution ?
7. What is the link between low-x and diffraction ?
8. Test of gluon dominated diffractive production mechanism by inclusive, jet and charm measurements
9. Is our QCD template of diffraction still ok ?
10. Precise data (cross section and helicity analysis) on vector meson (J/ψ and ρ), generally sucess of pQCD models for elastic, but inelastic ? How much is really QCD ?

Measurement of F_2^c

$$\frac{d^2\sigma_{c\bar{c}}}{dx dQ^2} = \frac{2\pi\alpha^2}{x\,Q^4}(1+(1-y)^2)\;F_2^c(x,Q^2)$$



Extraploation to full η, P_t range required, F_L^c neglible $< 2\%$

Precision $10-20\%$ (includes variation of m_c and fragmentation)

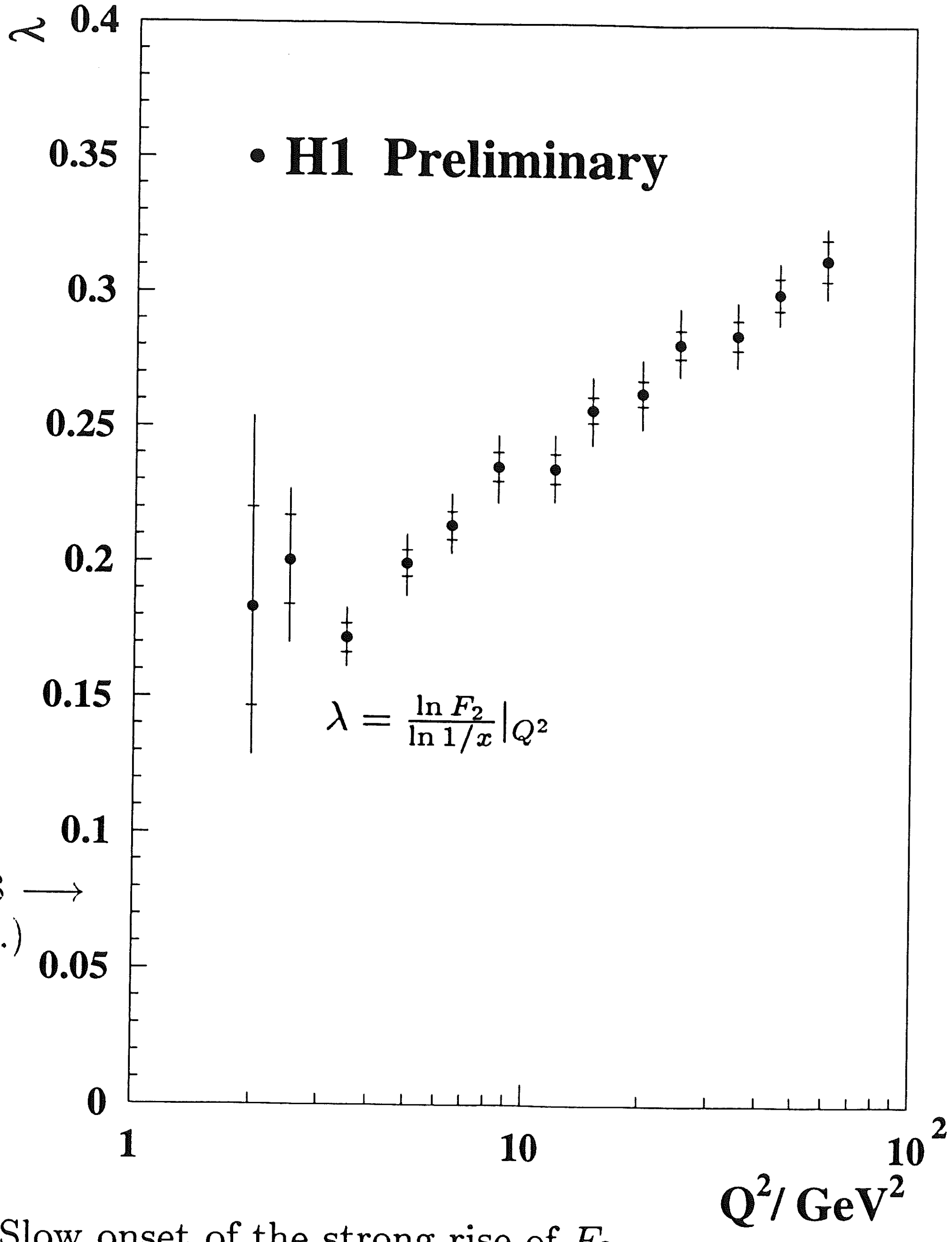
Steep rise towards small x

Good agreement of (direct) charm measurement
with (indirect) prediction from NLO QCD

Proton Structure Function - 1997 Measurement

λ describes rise of F_2 for fixed Q^2
assuming $F_2 \sim x^{-\lambda}$ for $x < 0.1$ and $y < 0.6$

$\lambda = 0.08 \longrightarrow$
(soft coll.)



Slow onset of the strong rise of F_2
Nice illustration of transition region soft to hard

$\rightarrow$ see talk by J. Zacek

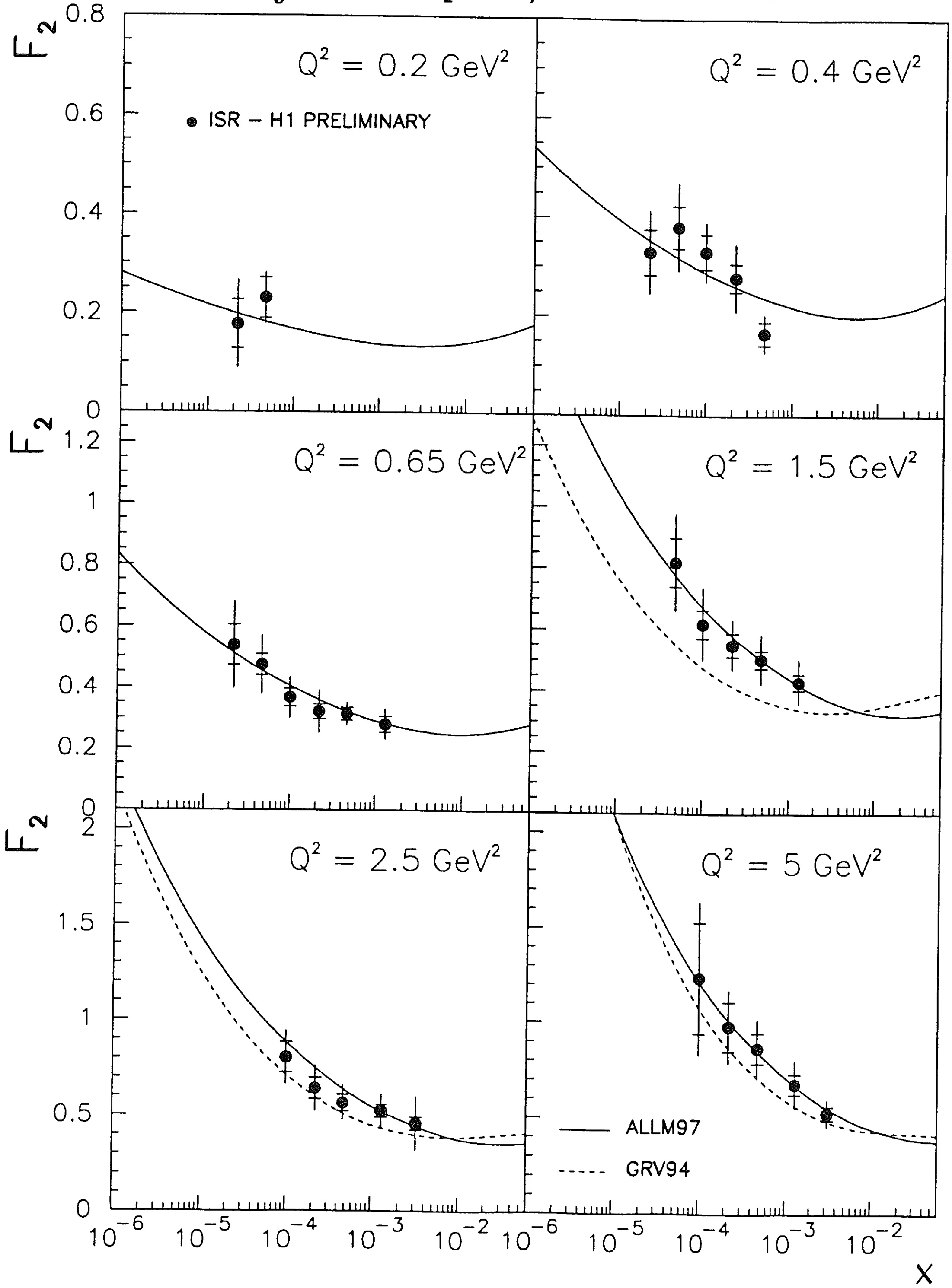
F_2 - From Radiative Events

Access to very low Q^2 using radiative events:

$Q^2 = 4E_0 E'_e \cos\frac{\theta}{2}^2$ where $E_0 = E_e - E_\gamma$

Measurement of $\sigma(ep \rightarrow e\gamma X)$ where γ is tagged

1996 data, $\int \mathcal{L}dt \approx 3\ \mathrm{pb}^{-1}$, ~ 8000 events



Syst. error $\sim 20\%$ agreement where overlap with F_2^{nrad}

Study tansition region $\gamma p \longleftrightarrow$ DIS, Aim for F_L extraction