

H1

Status and Perspectives

DESY, 16 May 2002

Peter Schleper

DESY

- recent results
 - outlook to HERA II
 - here: low- x , diffraction, searches
- next talk: structure functions, EW
- status of H1



The HERA upgrade

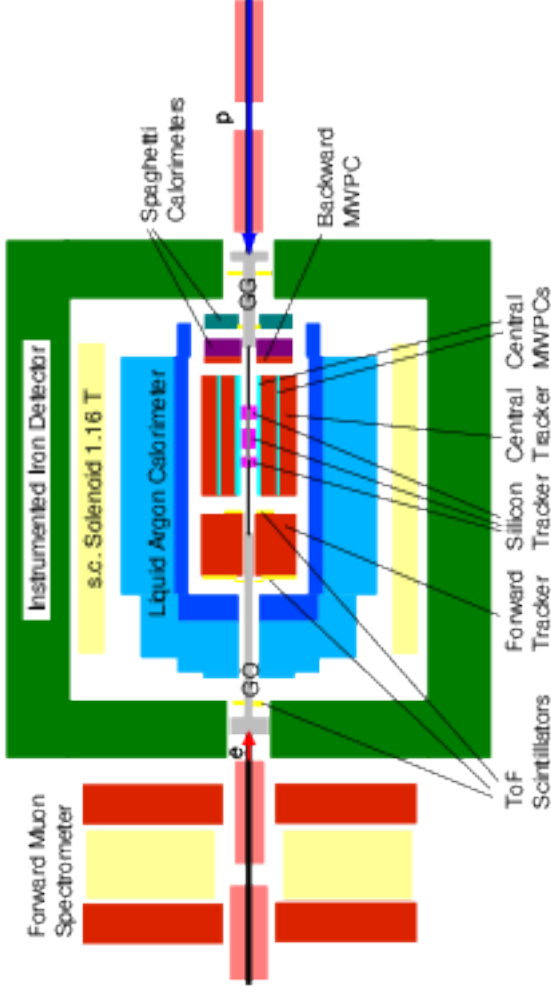
- Strong focussing at interaction point
increase to $L=1000 \text{ pb}^{-1}$
- both e^+ and e^- with L, R polarisation

The Challenges

- Magnets inside main detector: back-scattering
- Synchrotron radiation

The H1 detector upgrades

- Trigger !
- New luminosity system
- New forward tracking
- Extended silicon tracking
- New very forward proton spectrometer VFPS
- Smaller acceptance at low angles: $Q^2 \gtrsim 8 \text{ GeV}^2$



Virtues of ep scattering at HERA

large Q^2 lever arm: precision QCD

- α_s , quark and gluon densities

small - x : high parton densities

- novel quantum system

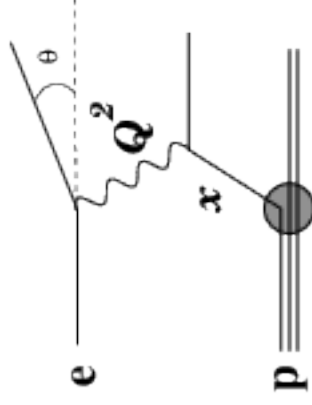
small Q^2 : large distance QCD

- non-perturbative, confinement

large CMS energy:

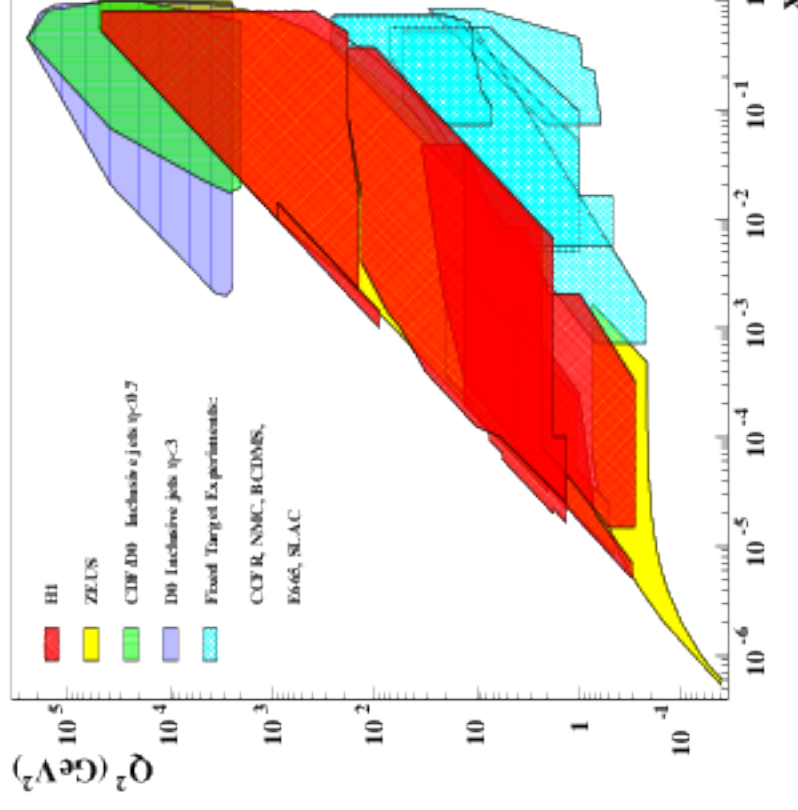
- (beyond) the EW standard model
(largest E_{CMS} with lepton in initial state)

→ **reason why H1 / ZEUS are leading QCD experiments**



$$Q^2 = \gamma/Z/W \text{-virtuality}$$

$$x = E_{\text{parton}} / E_p$$



Latest H1 results

<u>Inclusive</u>	<u>Diffraction</u>	<u>QCD final state</u>	<u>Searches</u>
F_2 shifted vertex	Diff. $\Psi(2S)$	Instanton	Contact Inter.
	Diff. ρ high Q^2	$D^* - \mu$ correlation	Leptoquarks
	Diff. QCD fit	D production	Excited electrons
	Diff. dissoc.	Inelastic J/Ψ	FCNC top
		forward π^0	multi-electron
			multi-muon

Proton Structure

$ep \rightarrow eX$ at small Q^2 :

$$\frac{d^2\sigma}{dx dQ^2} \sim \frac{2\pi\alpha^2}{xQ^4} F_2$$

momentum distribution of quarks:

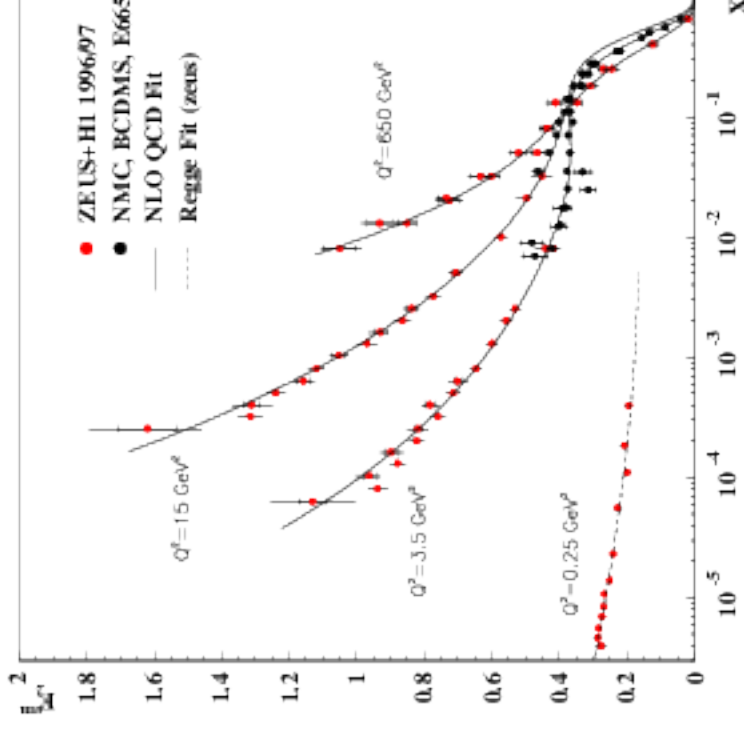
$$F_2(x, Q^2) \sim x \sum e_q^2 (q + \bar{q})$$

$$dF_2/d\ln Q^2|_x \sim \alpha_s \times g(x, Q^2)$$

small $x \rightarrow$ high quark density

strong rise of quark density

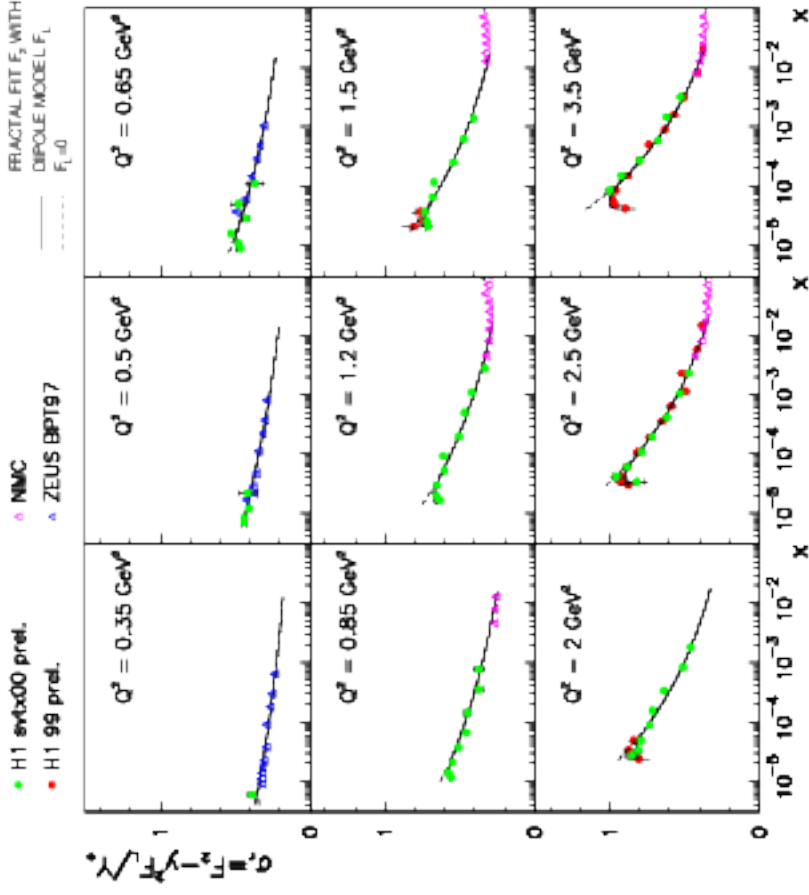
\rightarrow high gluon density



**Gap around $Q^2 \approx 1 \text{ GeV}^2$
run with shifted vertex at $z \approx 70 \text{ cm}$**

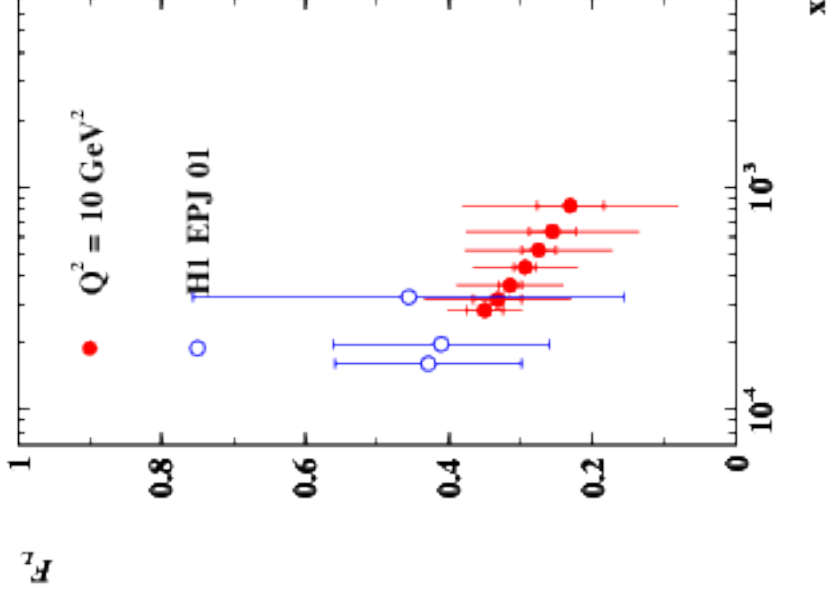
Longitudinal Structure Function F_L : gluon at small x

Shifted vertex data



F_L from reduced beam energy

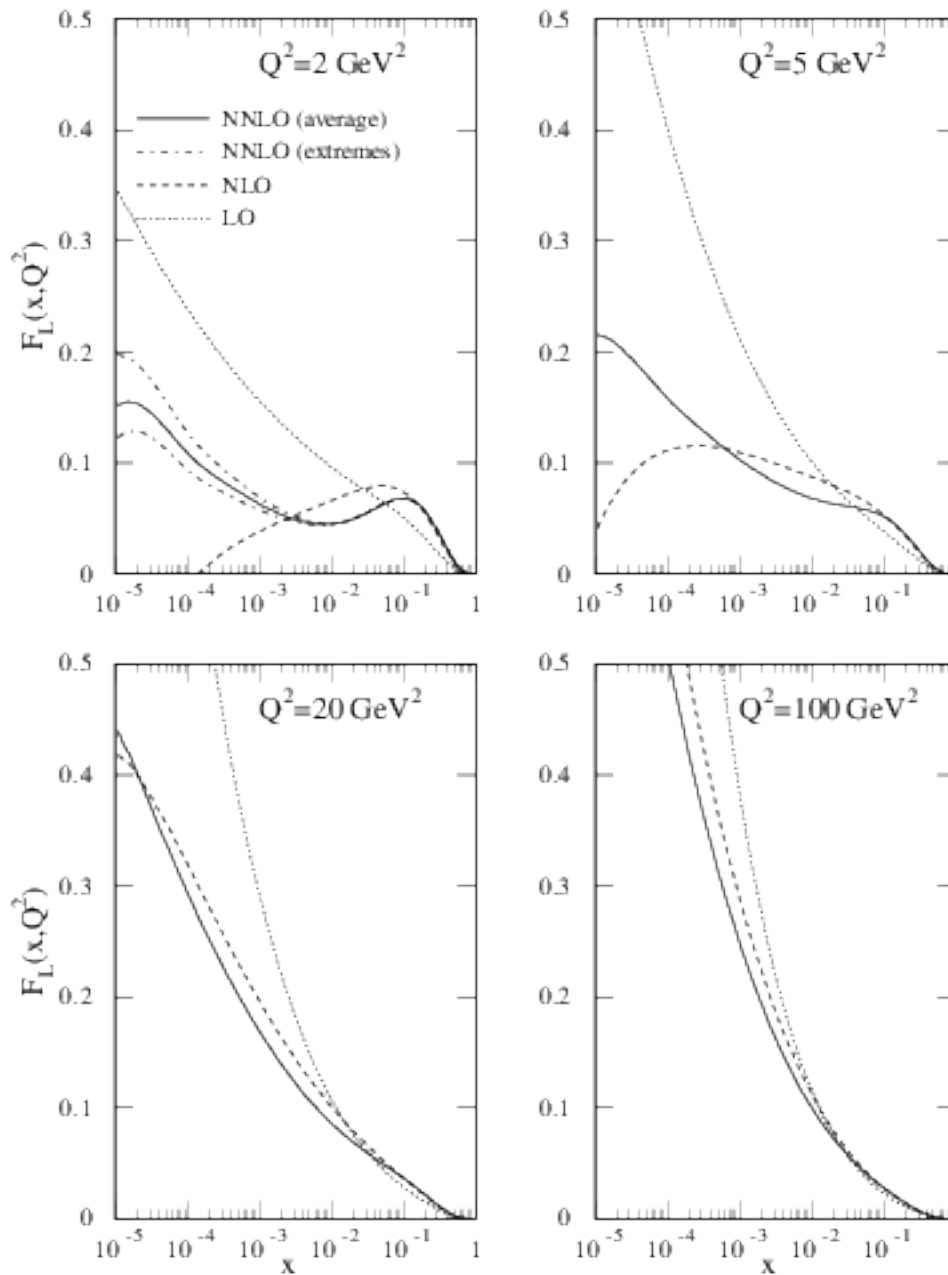
- e.g. $E_P = 300, 350, 465$ GeV



$$F_L \sim \sigma_r - F_{2,\text{extrapol.}}$$

- depends on extrapolation to high y
- limited in precision

F_L comparison to MRST pdf

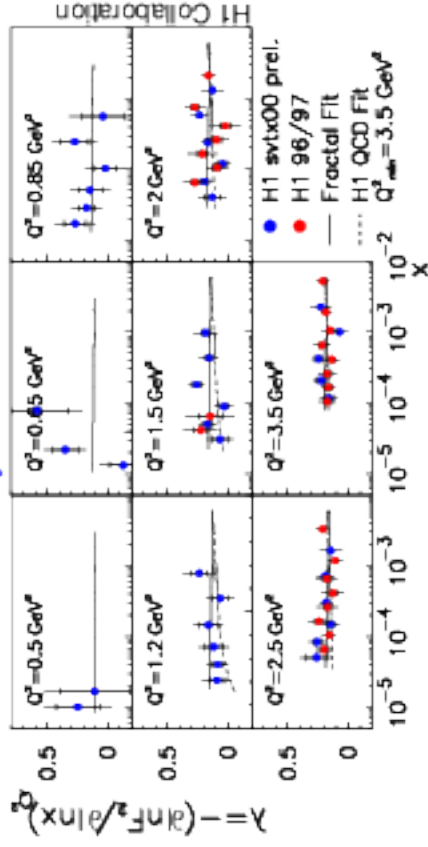


**Large differences between LO – NLO – NNLO(approx)
needs precision F_L data**

Low- x behaviour of F_2

local derivative of F_2 :

$$\lambda = - \left(\frac{d \ln F_2}{d \ln x} \right) Q^2$$

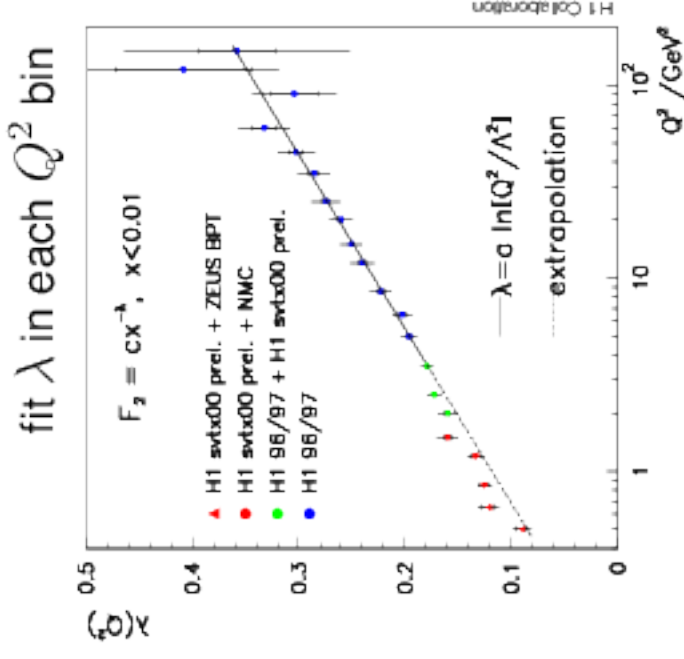


- fixed Q^2 :

$F_2 \sim x^{-\lambda(Q^2)}$ with $\lambda \approx \text{const}$

- no sign of deviation from $x^{-\lambda(Q^2)}$ at small x

- no saturation visible in F_2

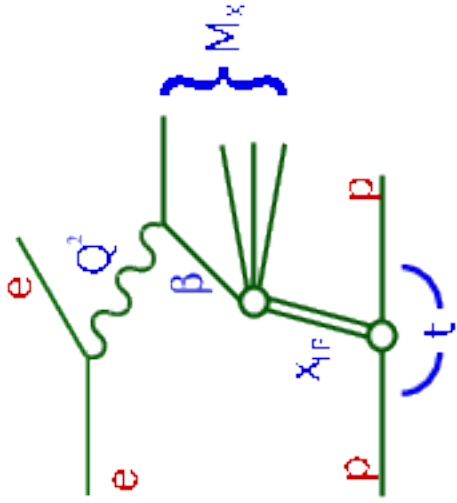


fit λ in each Q^2 bin

$$F_2 = c x^{-\lambda}, \quad x < 0.01$$

- for $Q^2 \lesssim 3 \text{ GeV}^2$: deviation from log
- expect $F_2 \sim x^{-0.08}$ for soft hadronic interactions: compatible for $Q^2 < 1 \text{ GeV}^2$

Hard Diffraction



Hard scattering factorization

$$\sigma \sim \sum_i f_{i/p}(x_{\mathbb{P}}, t, x, Q^2) \times \hat{\sigma}_i(x, Q^2)$$

with DGLAP evol. $f_{i/p}(x_{\mathbb{P}}, t, x, Q^2)$ at fixed $x_{\mathbb{P}}, t$.

- Proof for diffractive DIS
- Partonic picture of diffraction

$|t|$ - dependence

- t : fourier transform of impact parameter
- q, g structure dependence of t
- new forward proton spectrometer VFPS

colour singlet exchange of more than one parton (2 gluons or more)

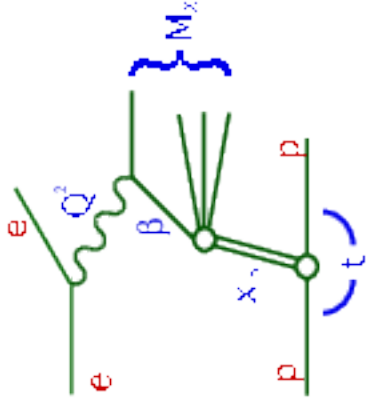
→ Correlations

GPD's: Generalized Parton

Distributions

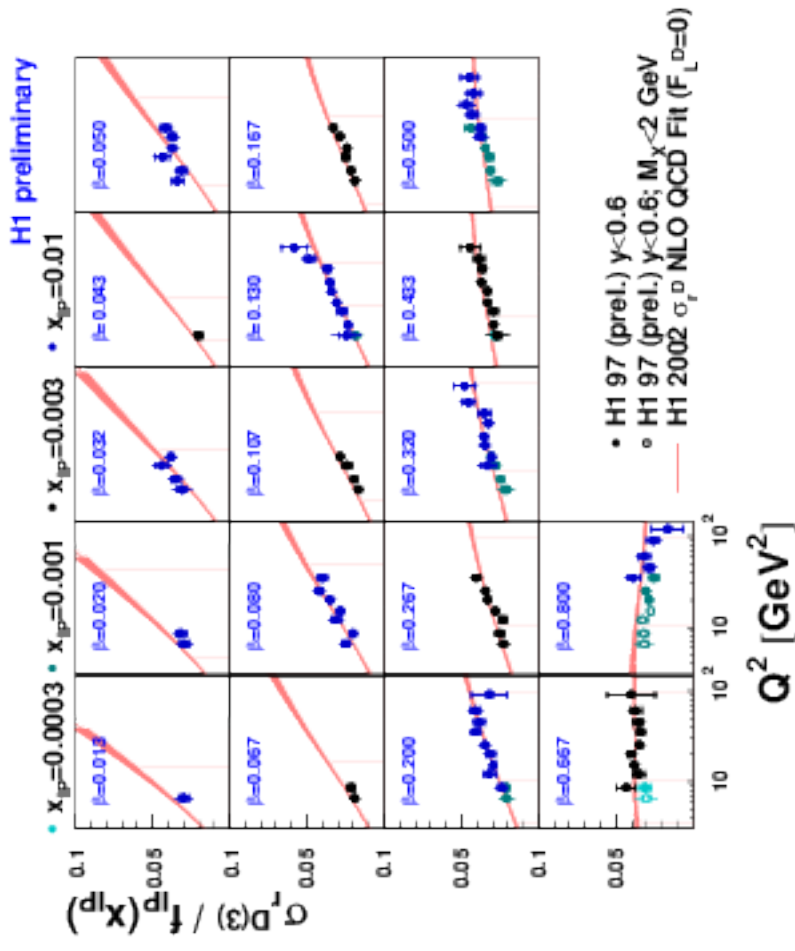
- $f_{i/p}(x_1, x_2, Q^2)$
- DVCS $\gamma^* p \rightarrow \gamma p$
- vector mesons $\gamma^* p \rightarrow V p$

Diffractive Structure Functions

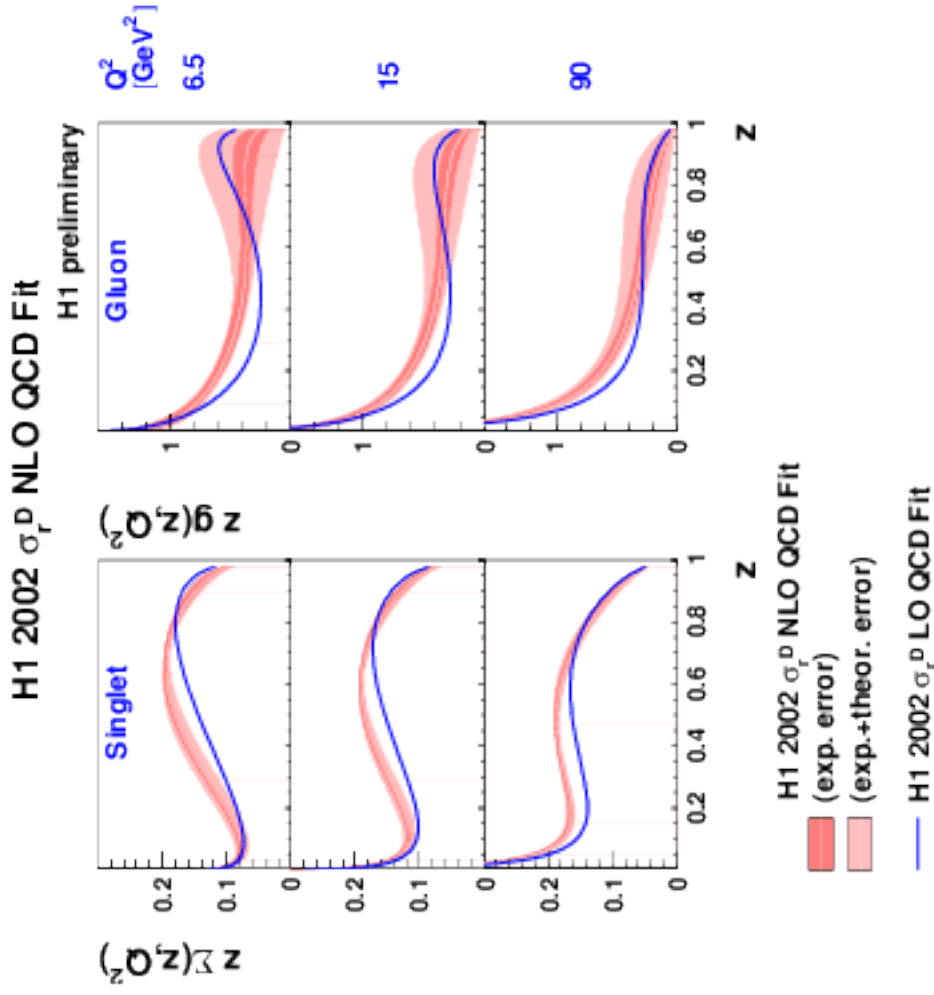


New NLO QCD fit to new $F_2^{D(3)}$

- first time with error calculation (same technique for F_2^D as for F_2)
- strong scaling violations: gluon dominates
- x_F dependence taken from data (divided out)



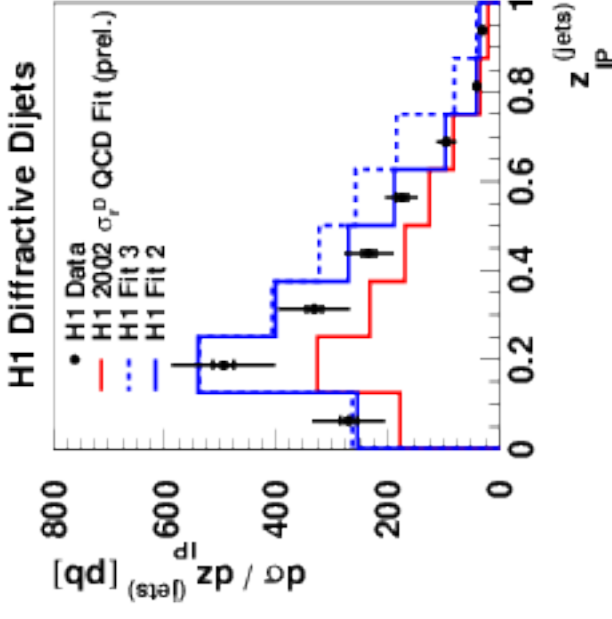
Diffractive parton Densities



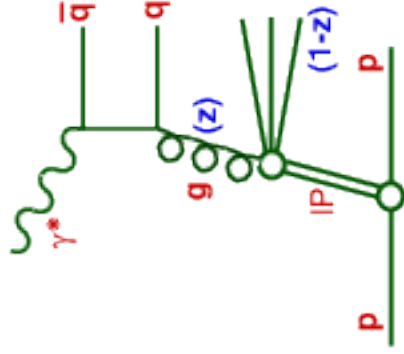
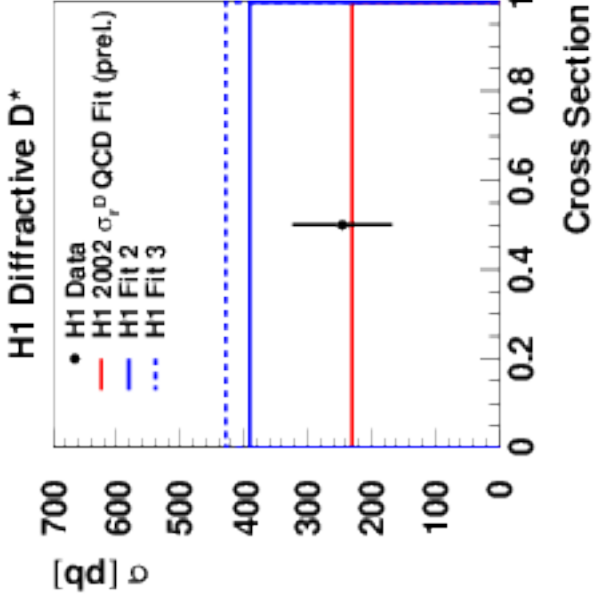
- NLO QCD interpretation of diffraction
- quark pdf's well constrained
- gluon with larger uncertainties at large β
- gluon dominates
- "hard" component of gluon (c.f. proton)
- LO not very different from NLO
- errors on LO similar to NLO

LO Predictions for Diffractive Jets and Charm

2-Jet production



Charm production

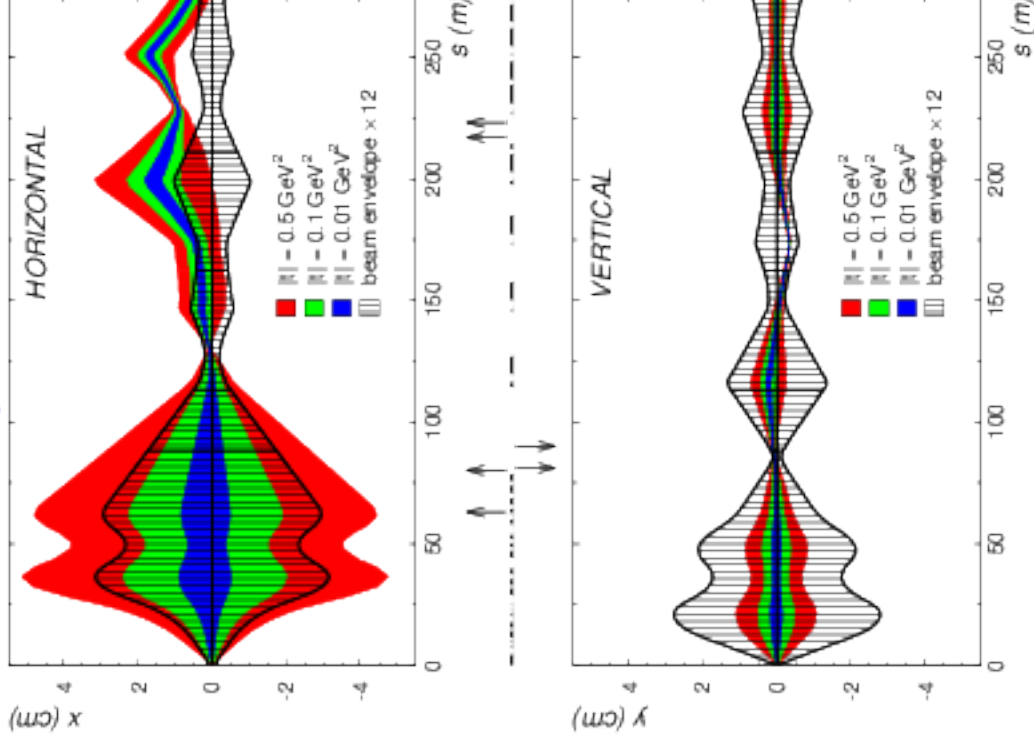


LO: good agreement with charm and jets
if true also at NLO: major success of QCD in
hard diffraction

HERA II: NLO QCD, $|t|$, GPD's (VFPS)

Very Forward Proton Spectrometer (VFPS)

Proton beam optics



New detector at $z = 200m$

- full acceptance at $0.005 < x_P < 0.02$, $|t| < 0.25 \text{ GeV}^2$
- trigger for all diffractive processes
- $|t|$, ϕ measurement
- no contribution from p-dissociation

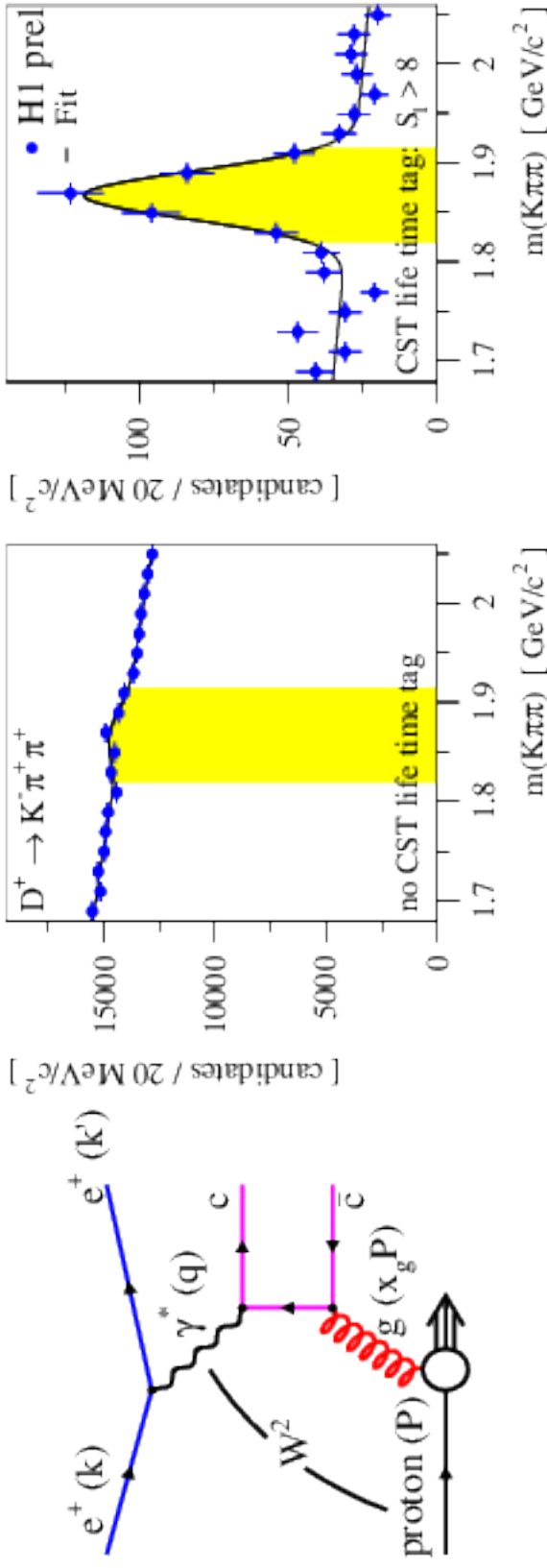
→ **High statistics test of QCD**

interpretation of diffraction:

$F_2^{D(4)}$, jets, charm, DVCS

Charm Production in DIS

secondary vertex with central silicon tracker: first D^+ measurement



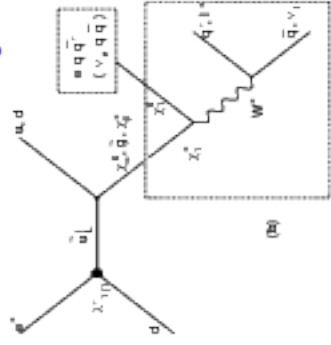
Fragmentation parameters, e.g.:

$$\begin{aligned}
 P_V &= \frac{VM}{PS + VM} = \frac{f(c \rightarrow D^{*+})}{f(c \rightarrow D^+) + f(c \rightarrow D^{*+})} BR(D^{*+} \rightarrow D^0 \pi^+) \\
 &= 0.693 \pm 0.045 \text{ (stat)} \pm 0.004 \text{ (syst)} \pm 0.009 \text{ (theory)} \\
 &(\approx 0.601 \pm 0.032 \quad \text{world average})
 \end{aligned}$$

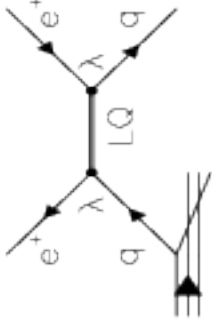
Support of universality of charm fragmentation

Searches: examples...

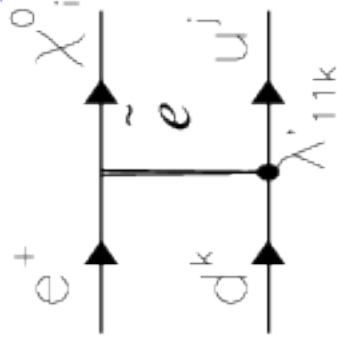
Squarks in R_p SUSY: $e^+ d \rightarrow \tilde{t}$



Leptoquarks: $eq \rightarrow eq, \nu q$

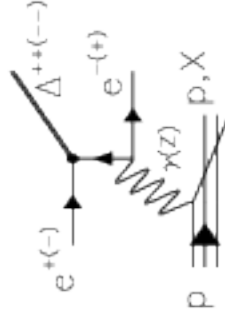


Selectrons in R_p SUSY: $e^+ d \rightarrow u \chi^0$



Doubly Charged Higgs:

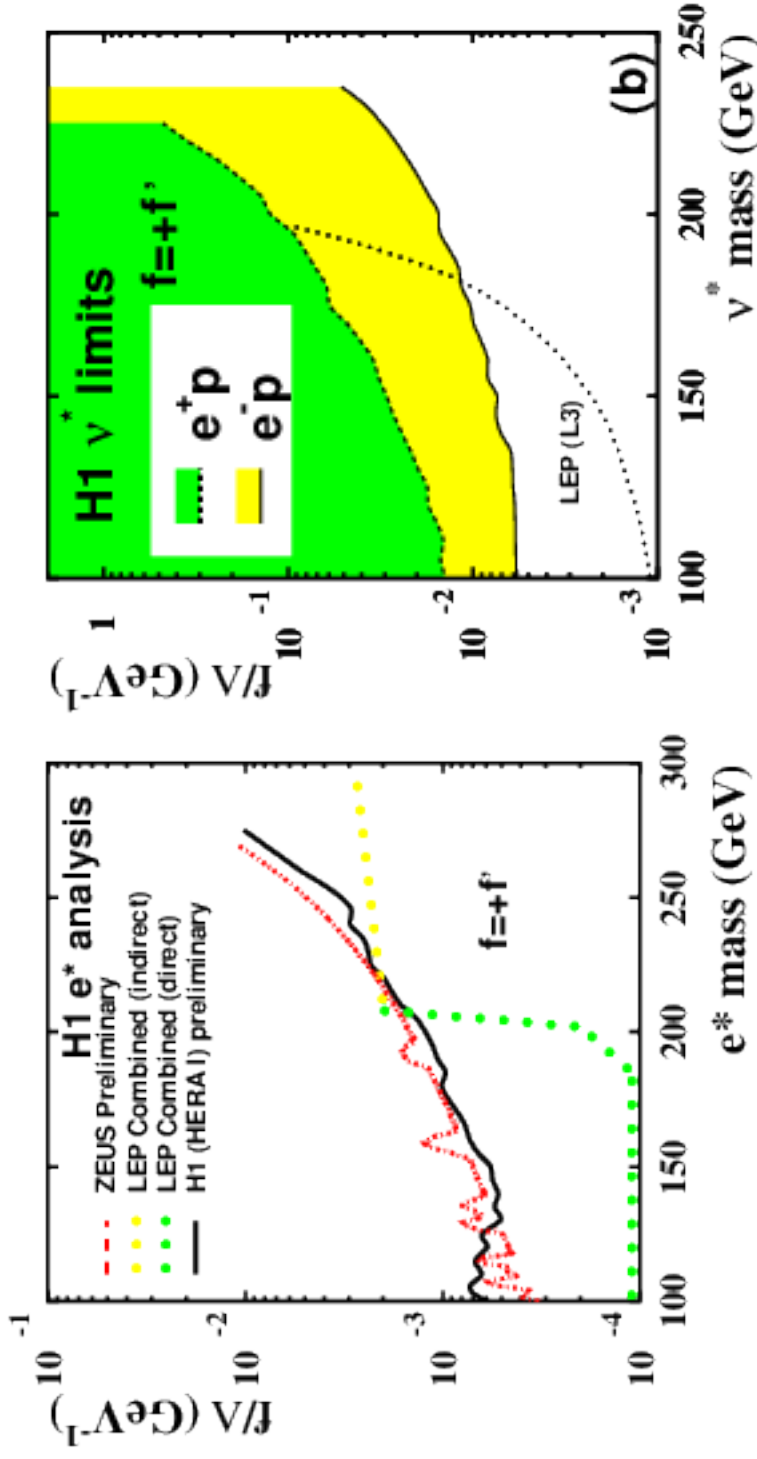
$e^+ \gamma \rightarrow e^- H^{++} \rightarrow e^- e^+ e^+$



Open windows for discoveries ?

Searches

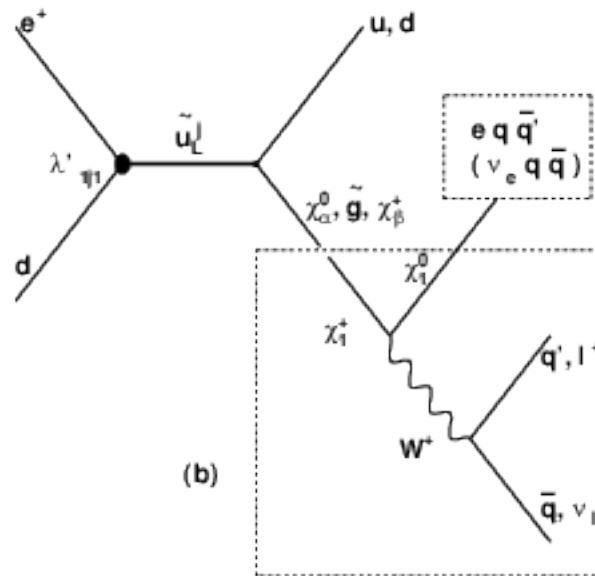
Excited Leptons



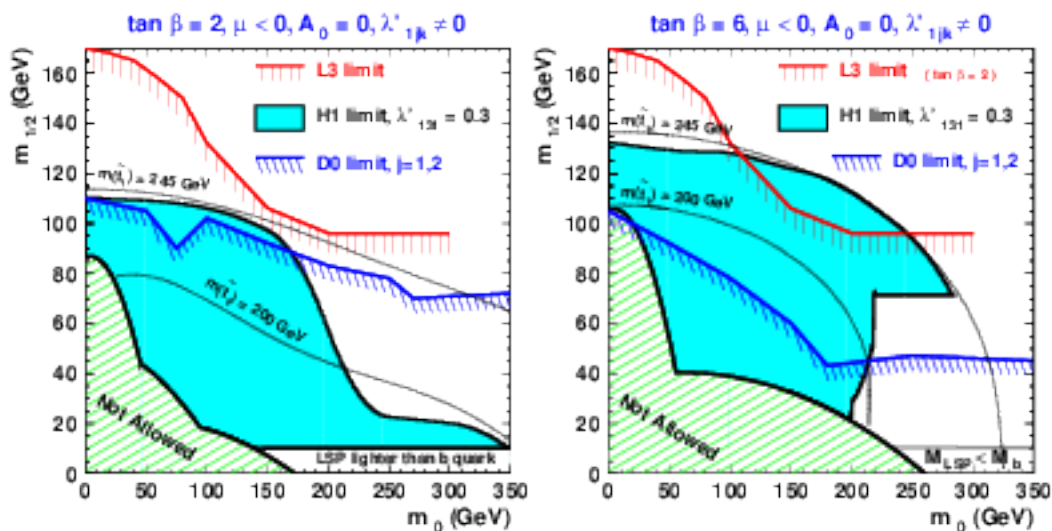
- still far from kinematic limit !
 → needs luminosity

Beyond the Standard Model: Supersymmetrie

single production of squarks in R -parity violating models



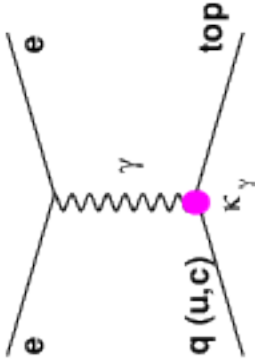
Minimal Supergravity + R_p Violation



- nothing found yet up to $M_{\tilde{q}} = 245$ GeV
- will reach sensitivity of $M_{\tilde{q}} \approx 300$ GeV

Searches: exotic events

Flavour changing neutral current



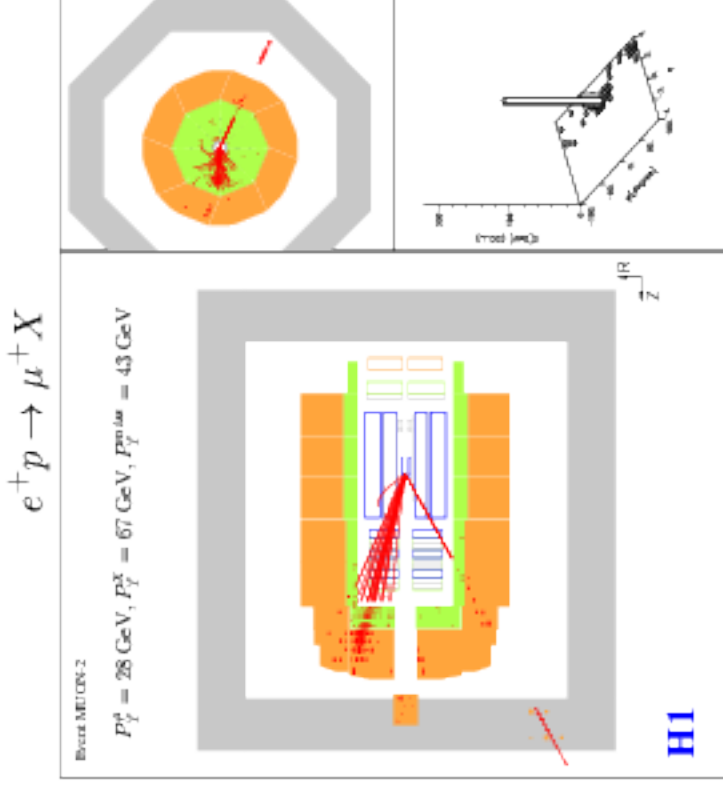
Leptonic decay

- $e, \mu + P_{T,miss} + \text{jet}$

dedicated top analysis:

- 5 events seen
- 1.7 ± 0.3 expected

Hadronic channel ?



$$M_{\mu\nu X} = 181 \pm 10 \text{ GeV}$$

Searches: Single top production

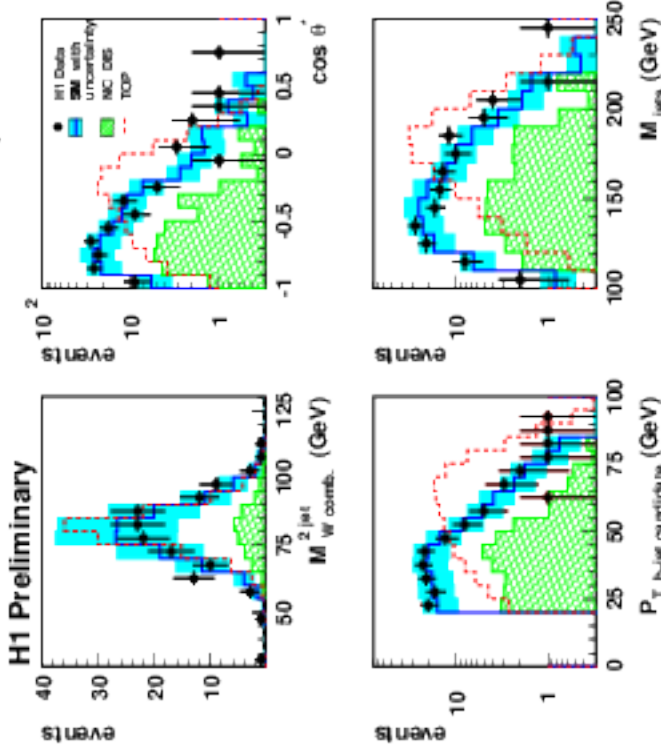
after cuts on M_{W}^{2jet} , M_{jets} , $\cos\theta^*$:

14 events seen, 19.6 ± 7.8 expected

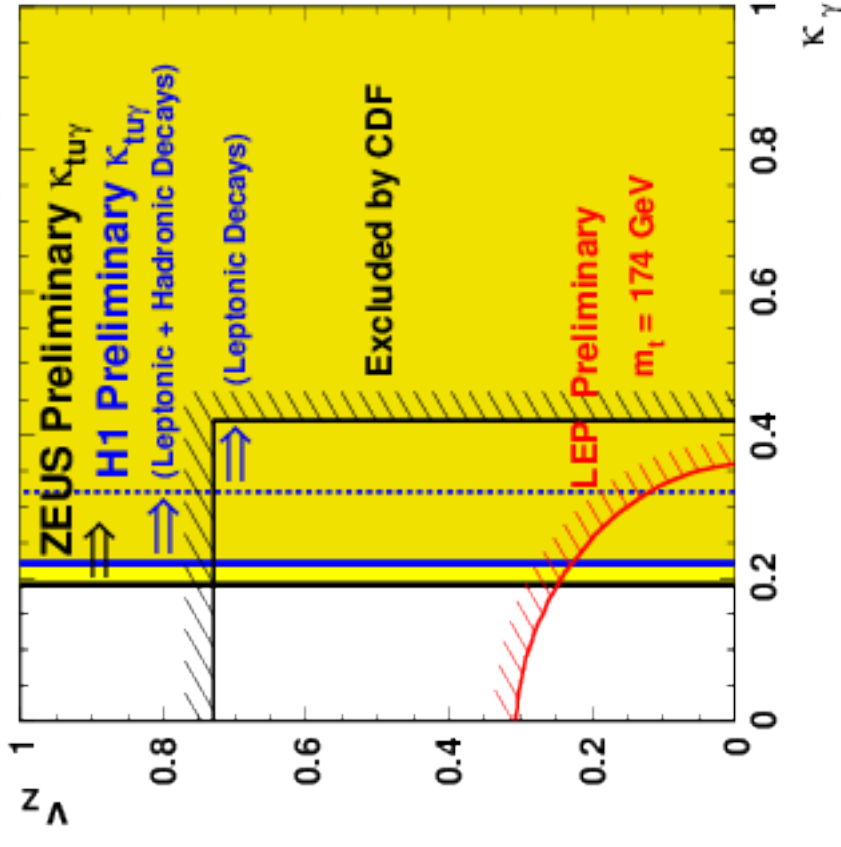
Hadronic channel:

3 jets with $P_T > 40, 25, 20$ GeV

Search for hadronic top decays - high E_T sample



Limit on anomalous top couplings



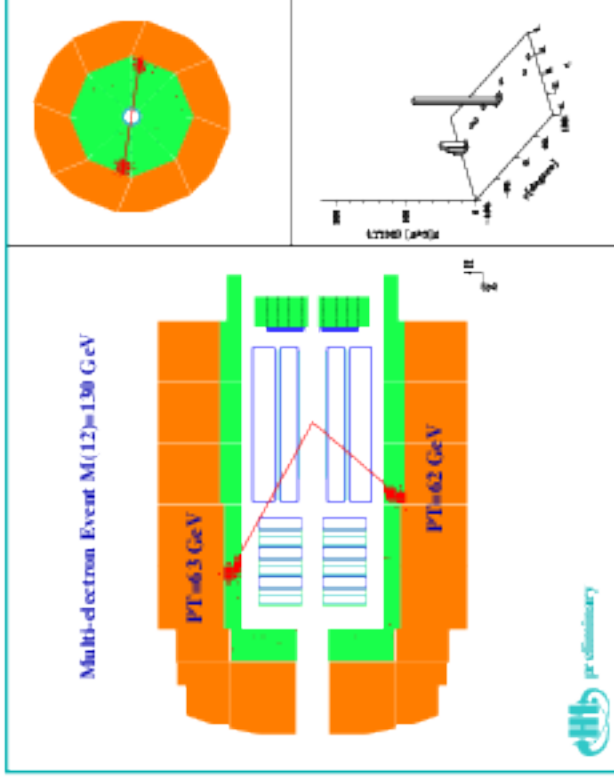
Hadronic channel does not rule out top interpretation of lepton events yet.

Electron Pair Production

Selection:

- 2 electrons with $E_{1,2} > 10\text{GeV}$ (5GeV) with $20^\circ < \theta < 150^\circ$
- 3rd electron with $E_3 > 10\text{GeV}$ with $5^\circ < \theta < 175^\circ$

observe events with $M_{ee} > 100\text{ GeV}$

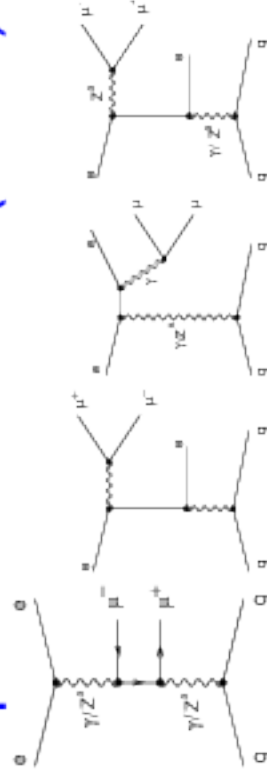


$$e^+q \rightarrow e^+e^-e^+q$$

4-fermion final state

- complete set of EW diagrams
- for electrons: interference
- elastic + inelastic

Expectation from GRAPE (GRACE):

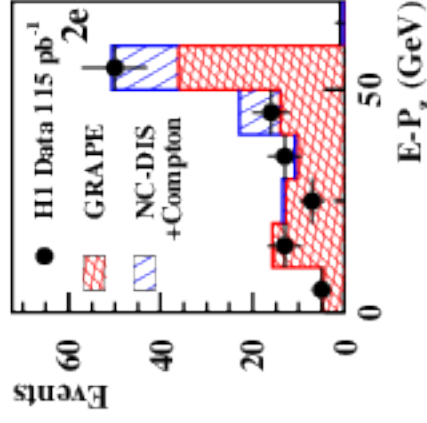


H1 – status and perspectives

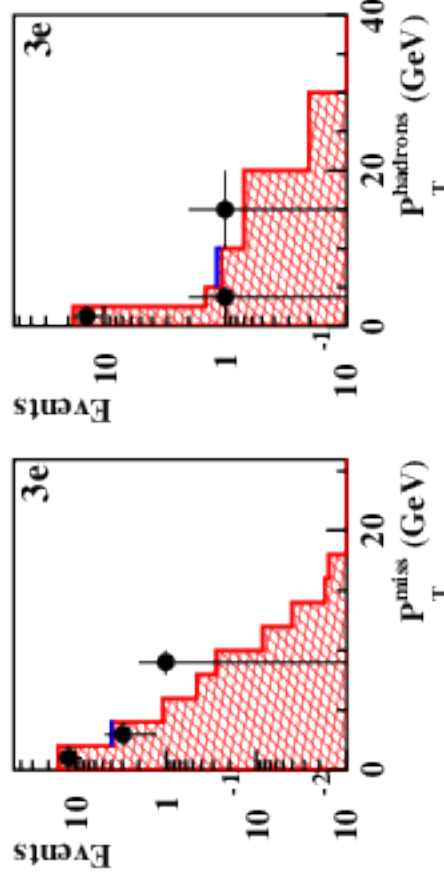
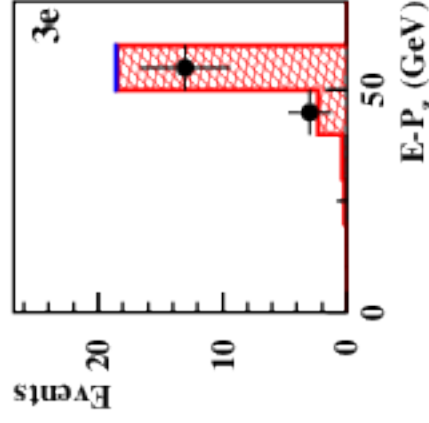
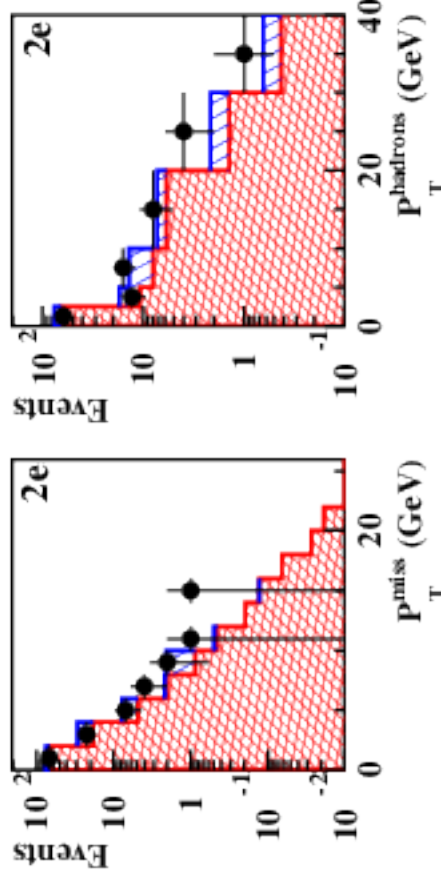
Peter Schleper, DESY

Electron Pair Production

H1 Preliminary



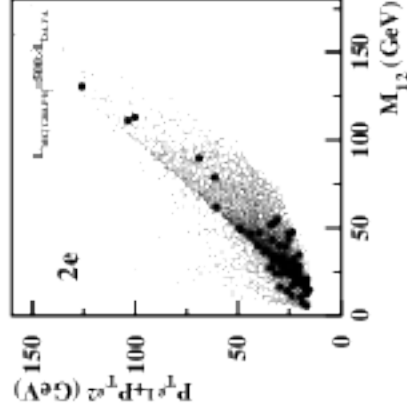
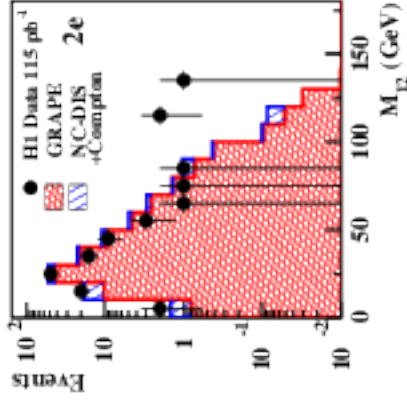
Multi-electron Analysis



→ **Good overall agreement**

Electron Pair Production

H1 Preliminary



Multi-electron Analysis

$M_{12} > 100 \text{ GeV}$ **H1 prel.**

	DATA	SM
2e	3	0.25 ± 0.05
3e	3	0.23 ± 0.04

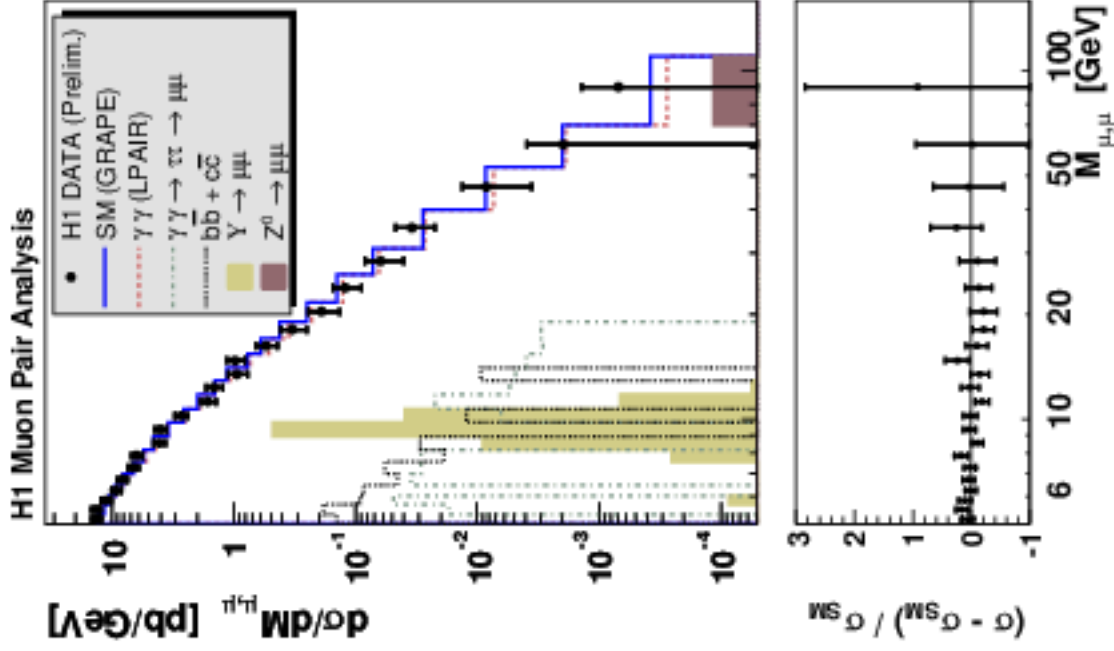
Excess at high $M_{ee} > 100 \text{ GeV}$

Note: different topology of

2e and 3e events

→ **needs confirmation with independent data**

Muon Pair Production



Selection:

2 muons with $20^\circ < \theta < 160^\circ$

- Good overall agreement with expect.
- Comparison with multi-e sample:
 - **no excess at high masses**
but only central θ region, lower efficiency and luminosity
→ **not conclusive**

Overview HERA II Running Conditions

Topic	Preferred beam	Luminosity (pb ⁻¹)
Structure functions	$\sigma_{\text{NC}}, F_2, xG, \alpha_S$	500 - 1000
	$x F_3$	500 - 1000
	G_2	500/beam
	$F_2^{\text{cc}}, F_2^{\text{bb}}$	1000
	ss from CC	1000
	d/u from CC	1000
	F_L and high- x partons	$e^\pm 300 < E_p < 920$ 100 ($L \propto 1/E^3 \dots 1/E^2$)
Electroweak	CC versus polarisation	250/beam
	NC versus polarisation	250/beam
	G_F vs m_t (and M_W, M_H)	1000
	M_{W_R}	1000
	Jets, c, b, α_S	1000
Searches	High- P_T leptons	1000
	R_P -violating SUSY, stop	1000
	LQ, CI	1000
	R_q , LED	1000
	Single top	1000
	$e^* \nu^*$	1000
	e^-_L	1000

HERA II objectives as seen by ZEUS and H1

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

H1 detector status

Detector Upgrades

- commissioning of all new detectors
- **H1 is ready for data taking**
- spec. luminosity measured:

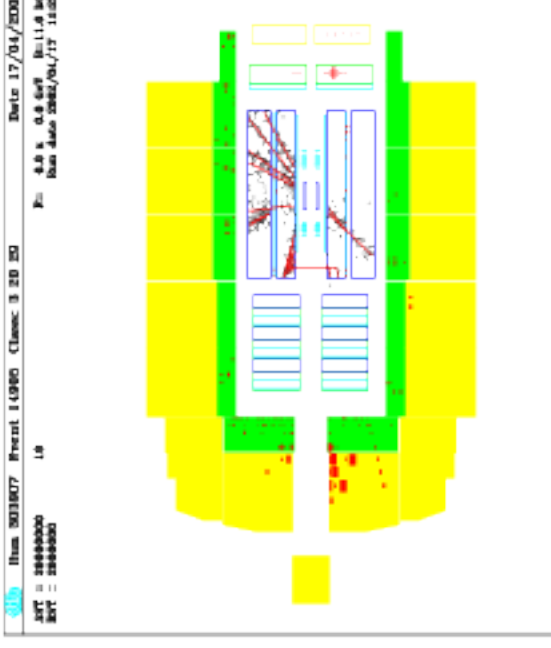
$$L_{spec} = 1.3 \cdot 10^{30} / \text{cm}^2 \cdot \text{s} \cdot \text{mA}^2$$

($\pm 10\%$)

$$\text{design:} = 1.8 \cdot 10^{30} / \text{cm}^2 \cdot \text{s} \cdot \text{mA}^2$$

To come:

- Fast Track Trigger, Jet trigger
 - VFPS: very forward proton spectrometer
- 10 weeks installation time in cold section of p-beam, earliest Jan. 2003.
- Repair of Central Inner Prop. Chamber CIP
- front end electronics problem, operate only 2-3 layers (of 5)
- 10 weeks installation time, earliest Jan. 2003



Background conditions

- very few luminosity runs taken
- bkg. monitored via Spacal, Silicon trackers, Jet Chamber

Jet Chamber Currents:

- proton beam: bkg o.k. (c.f. vacuum)
- e^+ running:

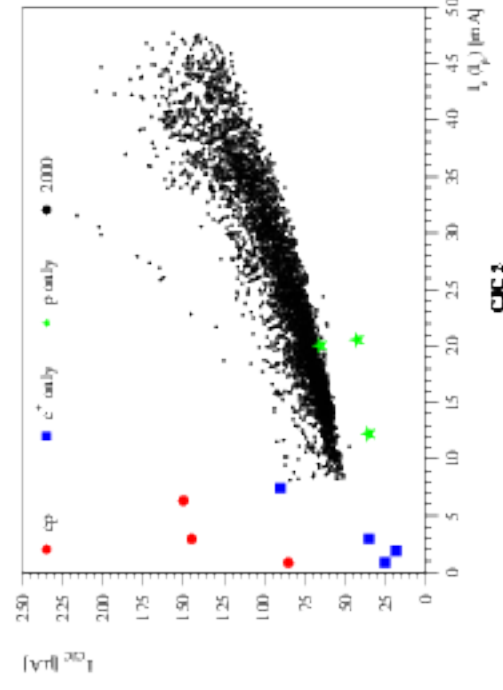
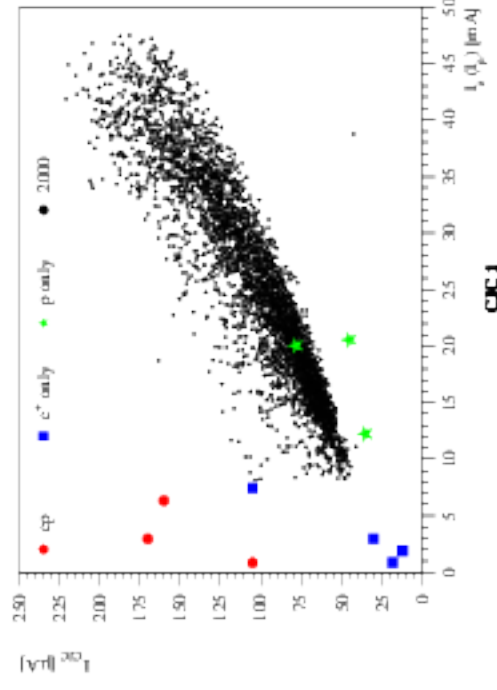
very high e^- -induced bkg

Note: single run with good bkg. conditions not yet reproducible ?

- similar bkg. in luminosity mode

Synchrotron radiation problem needs to be solved first

CJC vs beam currents
H1 CJC currents 2000 and 2002

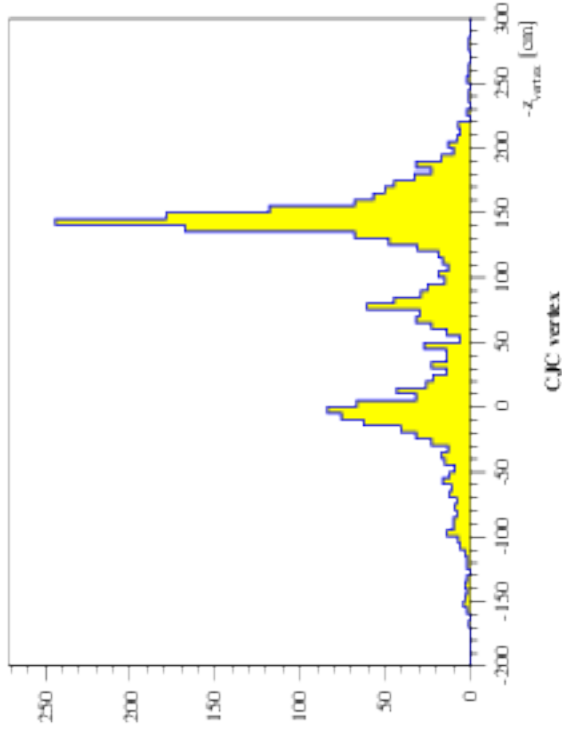


Background conditions

z-vertex from Jet Chamber tracks

$$I_e = 3 \text{ mA}, I_p = 35 \text{ mA}$$

ep run 303910 (17.4.2002)

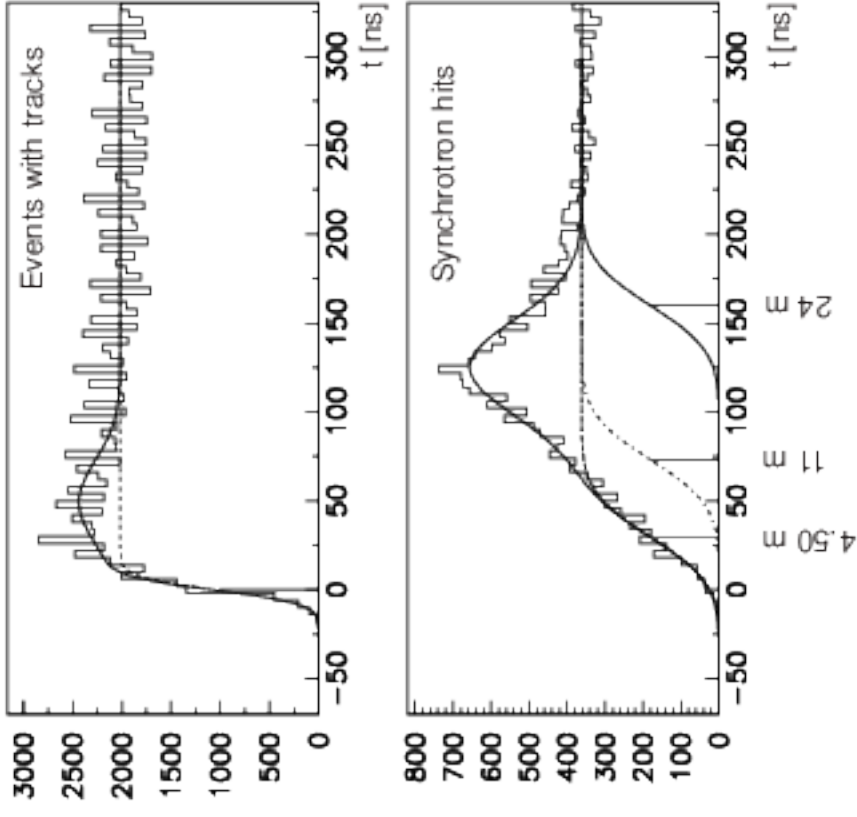


ep vertex

+ p-bkg from collimators

(cut by trigger)

Drifttime distribution for single bunch e+ run



synchrotron backscatter from

$z \approx 4.5m$?

Summary

low-x: new regime of QCD

- high parton densities – novel QCD dynamics
- the main theoretical activity so far
- QCD picture of Diffraction
- colour dipole – BFKL – CCFM

precision QCD: α_s , pdf's,

precision test of SM at 10^{-18} m

Searches

- **high P_T lepton (pair) events ?**
- SUSY with R_P violation
- contact interactions
- **+ ??**

H1 detector

- **high synchrotron radiation background**
- CIP repair, VFPS inst.: 10 weeks each earliest Jan 2003
- **H1 is ready for data taking**