H1
Status and Perspectives

DESY, 16 May 2002

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DESY

- recent results
- outlook to HERA II

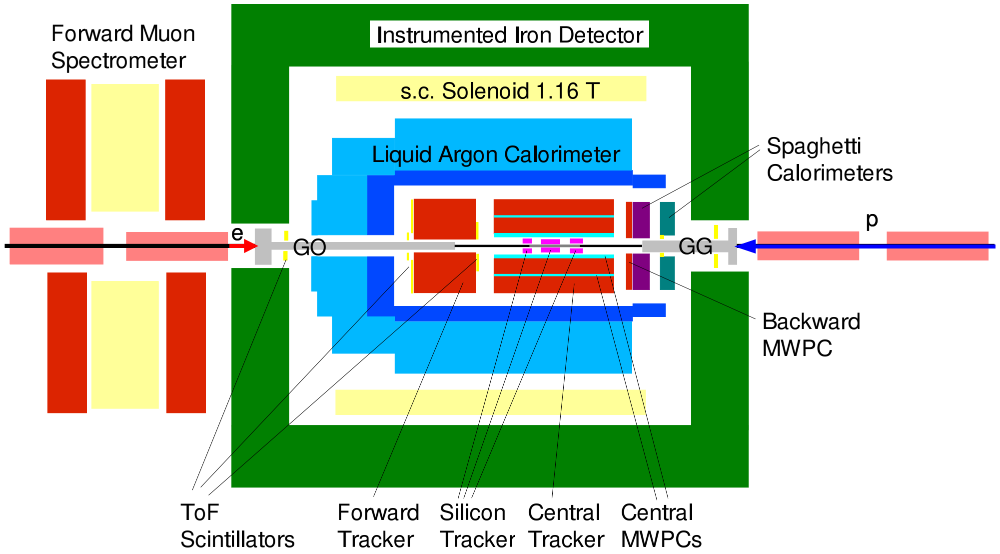
  here: low-x, diffraction, searches

  next talk: structure functions, EW
- status of H1

HERA II

The HERA upgrade

- Strong focussing at interaction point
  increase to L=1000 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: $Q^2 \gtrsim 8$ 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

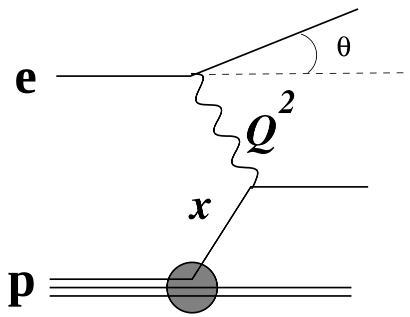
small Q^2: large distance QCD

- non-perturbative, confinement

large CMS energy:

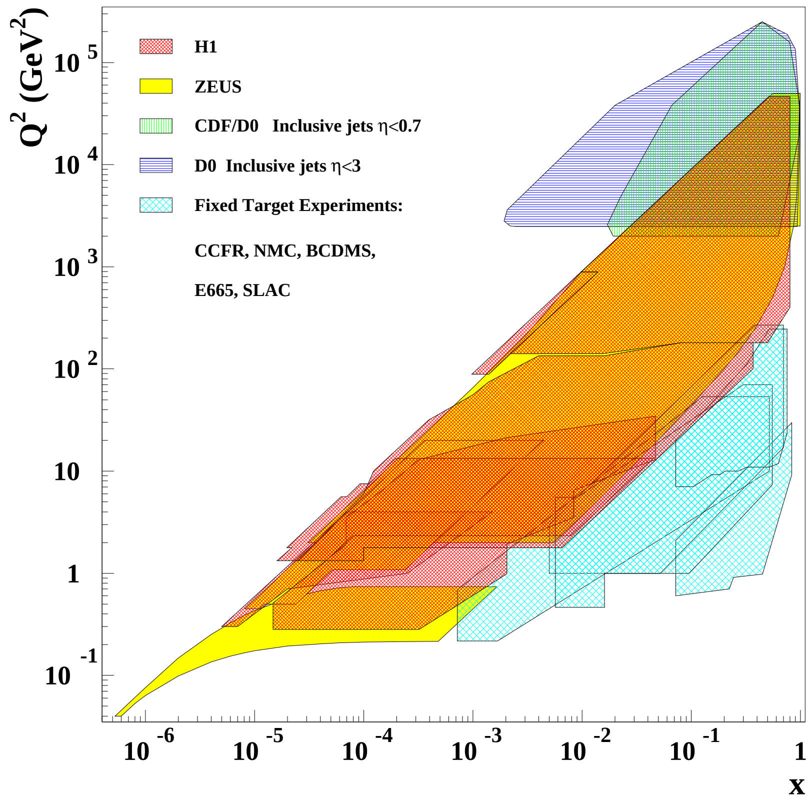
- (beyond) the EW standard model (largest E_{CMS} with lepton in initial state)

$\longrightarrow$ reason why H1 / ZEUS are leading QCD experiments



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

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



Latest H1 results

Inclusive	Diffraction	QCD final state	Searches
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

$ep \longrightarrow eX$ 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:

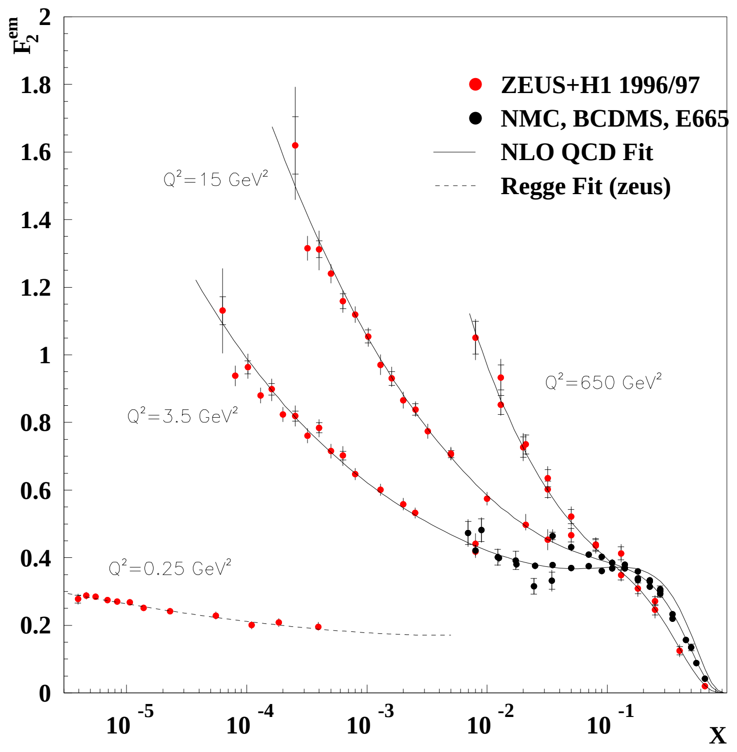
$$F_2\left(x, Q^2\right) \sim x \sum e_q^2 (q + \bar{q}$$

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

small $x \longrightarrow$ high quark density

strong rise of quark density

$\longrightarrow$ high gluondensity

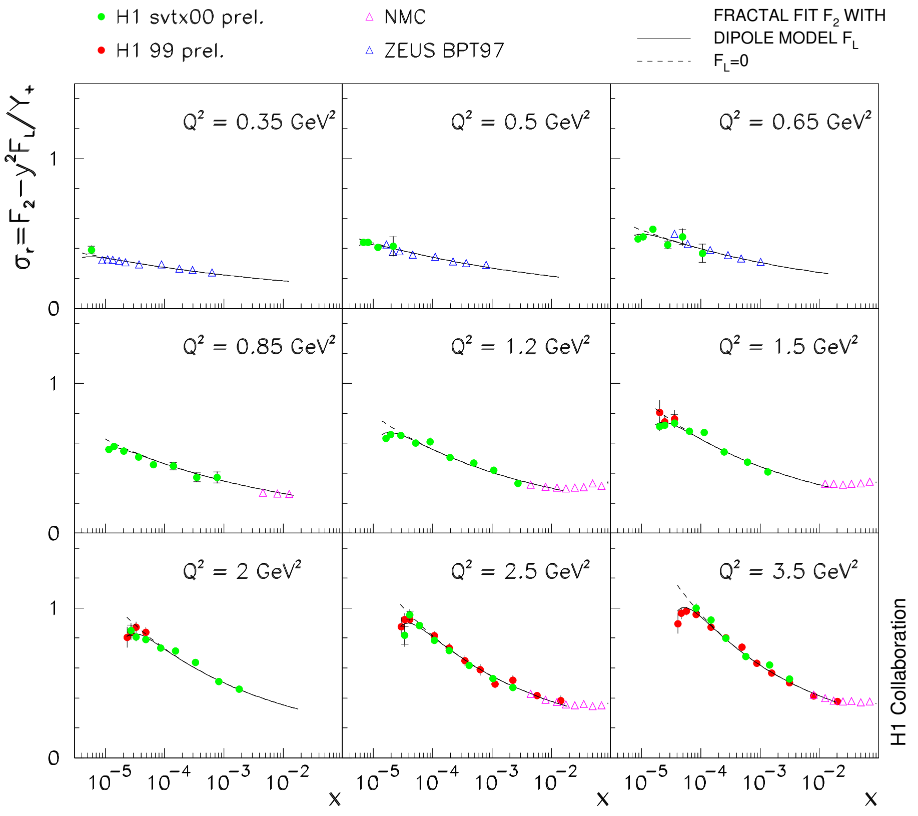


Gap around $Q^2 \approx 1$ GeV^2

run with shifted vertex at $z \approx 70cm$

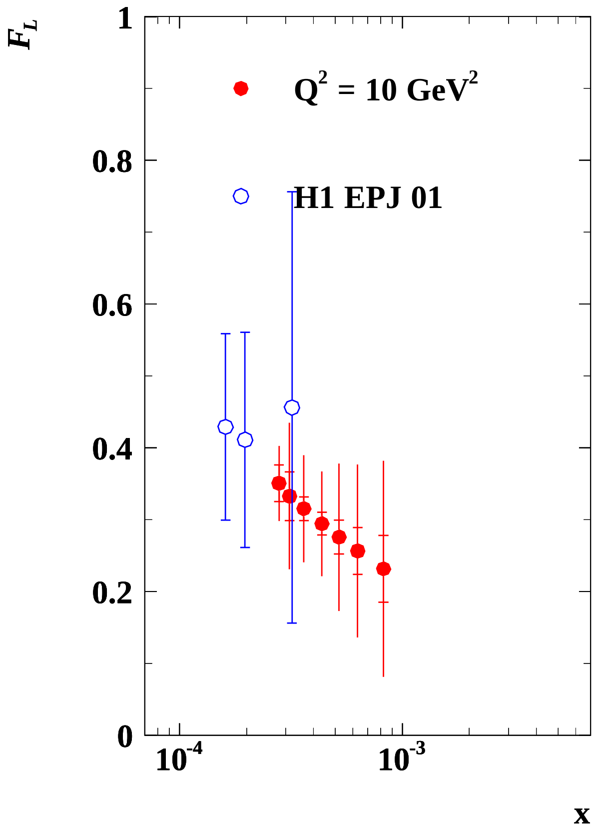
Longitudinal Structure Function F_L: gluon at small x

Shifted vertex data



$\mathbf{F_L}$ from reduced beam energy

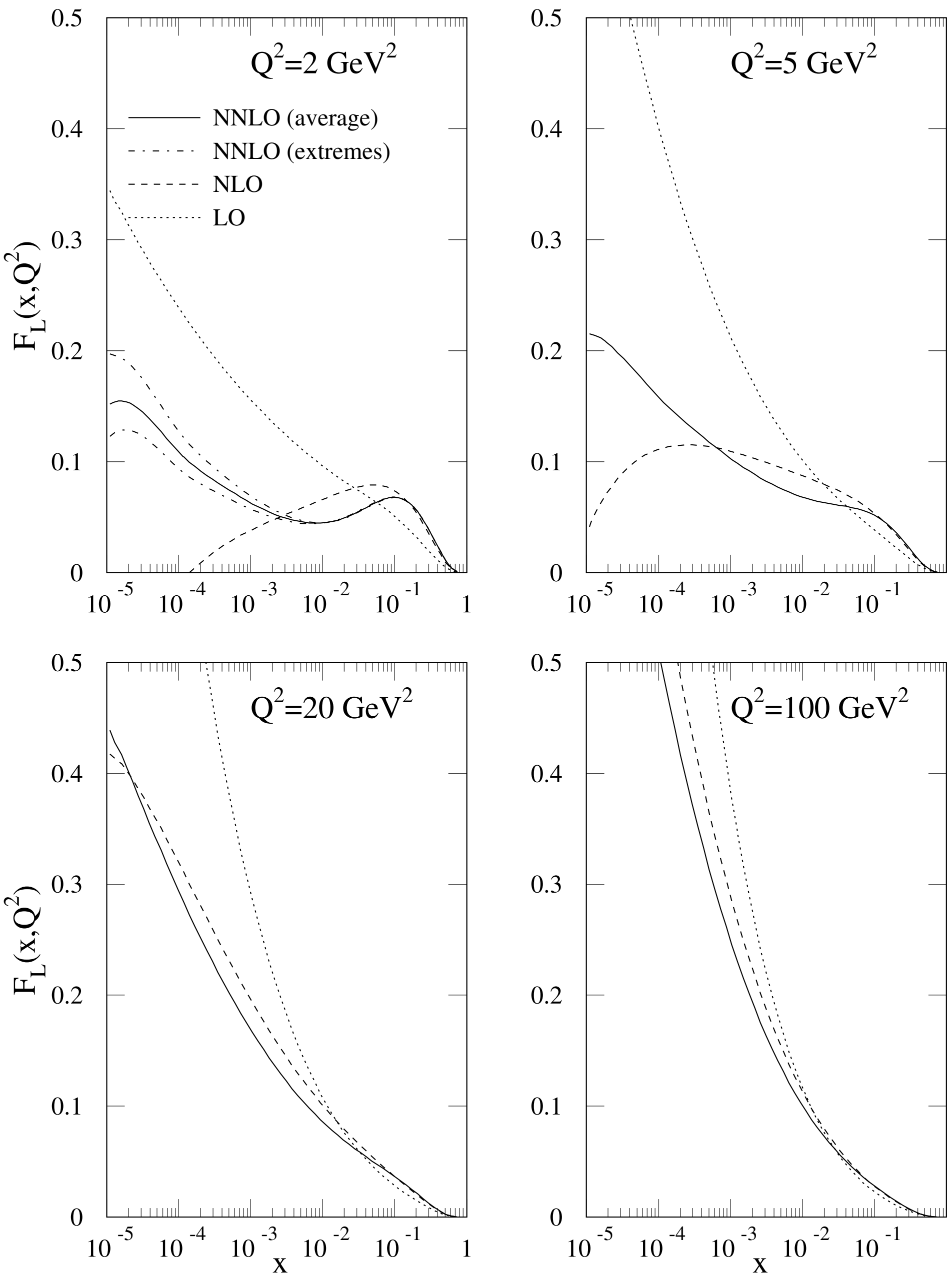
- e.g. E_P=300,350,465 GeV



$$\mathbf{F_L} \sim \sigma_\mathbf{r} - \mathbf{F}_{\mathbf{2},\mathrm{extrapol.}}$$

- depends on extrapolation to high y
- limited in precision

F_L comparison to MRST pdf



Large differences between LO – NLO – NNLO(approx)

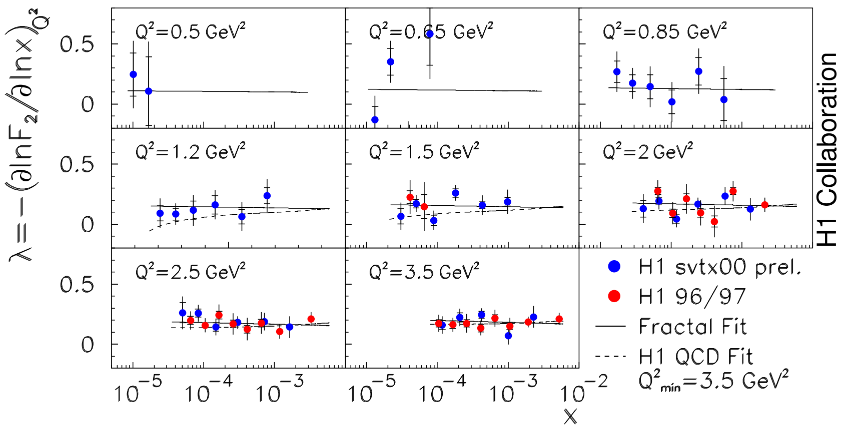
needs precision F_L data

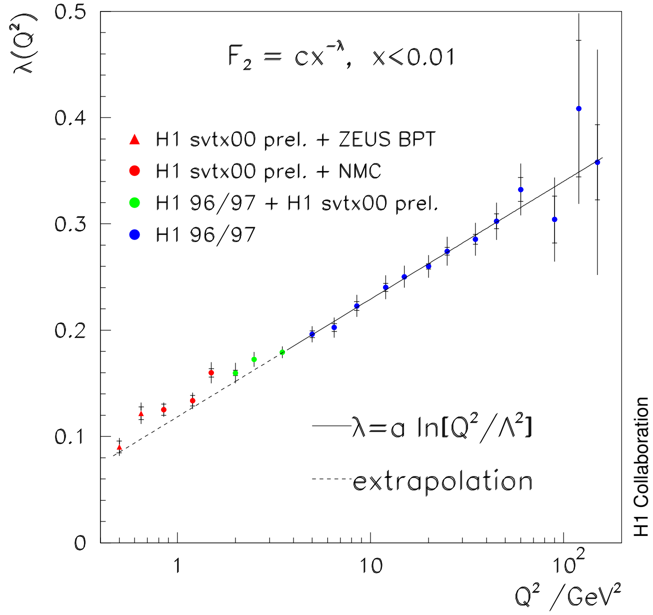
Low-x behaviour of $\mathbf{F_2}$

fit λ in each Q^2 bin

local derivative of F_2:

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



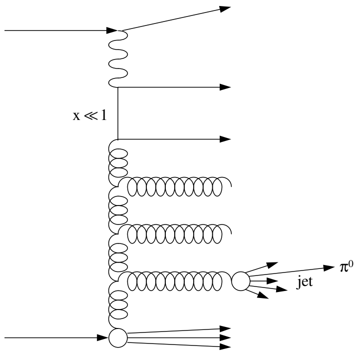


- fixed Q^2 :
  $F_2 \sim x^{-\lambda(Q^2)}$ with $\lambda \approx$ const
- no sign of deviation from $\mathbf{x}^{-\lambda(\mathbf{Q^2})}$ at small x
- no saturation visible in F_2

for $Q^2 \lesssim 3$ GeV^2: deviation from log

expect $F_2 \sim x^{-0.08}$ for soft hadronic interactions: compatible for $Q^2 < 1$ GeV^2

Low-x Parton Dynamics: forward π^0 production

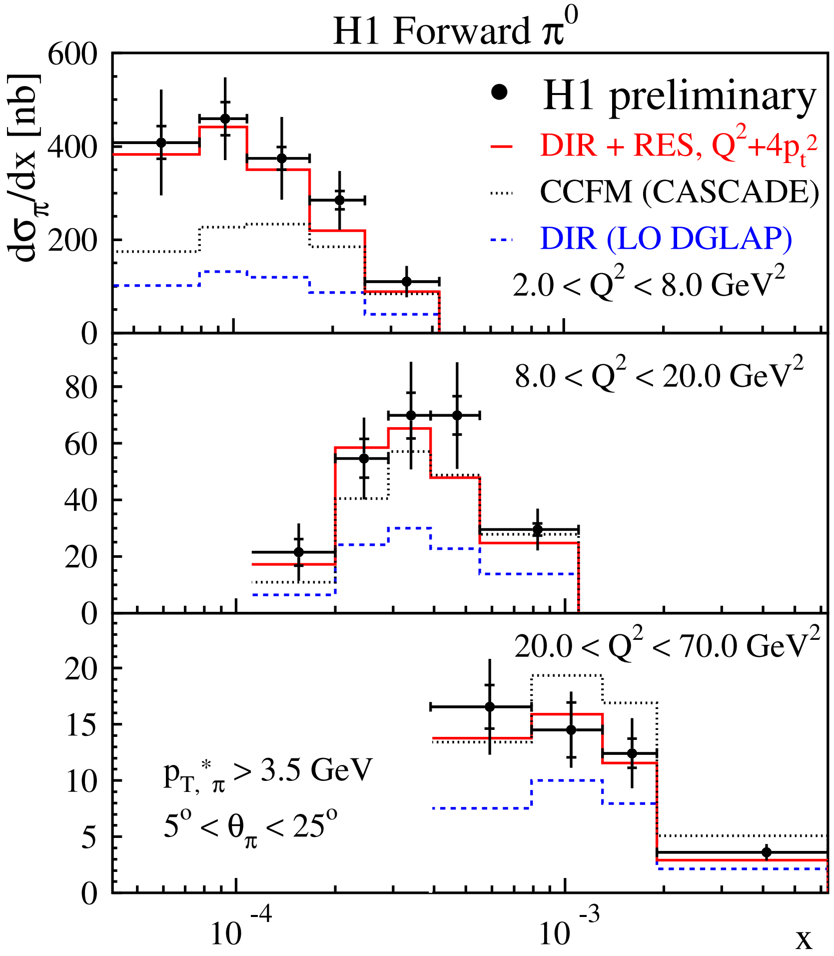


2 scales:

Q^2, $k_{T,j}^2$

no k_T order

- test case for DGLAP–BFKL–CCFM–$\gamma^*_{\text{resolved}}$
- unintegrated parton distributions



DGLAP fails,

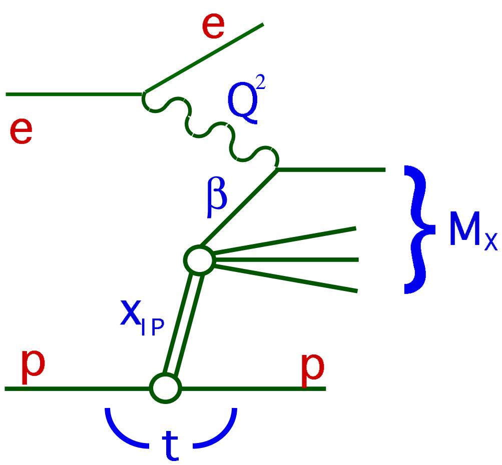
resolved virtual γ^* structure o.k.

CCFM (CASCADE) too low

(missing quarks)

or NNLO calculations of jets ?

Hard Diffraction



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

$\longrightarrow$ Correlations

GPD's: Generalized Parton Distributions

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

Hard scattering factorization

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

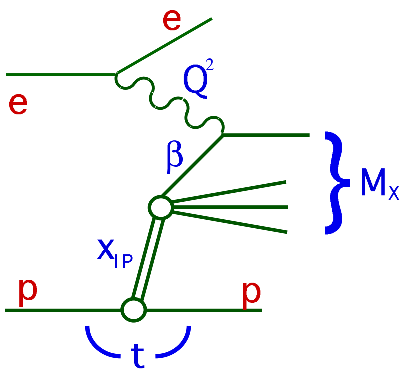
with DGLAP evol. $f_{i/p}(x_{I\!P}, t, x, Q^2)$ at fixed $x_{I\!P}, t$.

- Proof for diffractive DIS
- Partonic picture of diffraction

$|t|$ - dependence

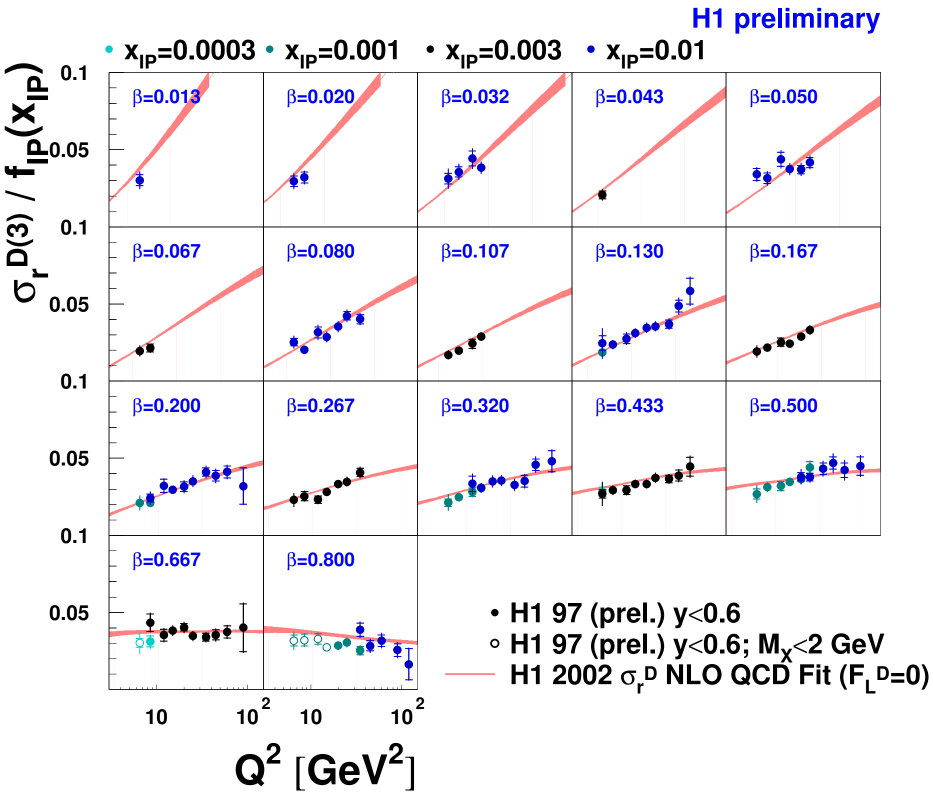
- t: fourier transform of impact parameter
- q, g structure dependence of t
- new forward proton spectrometer VFPS

Diffractive Structure Functions

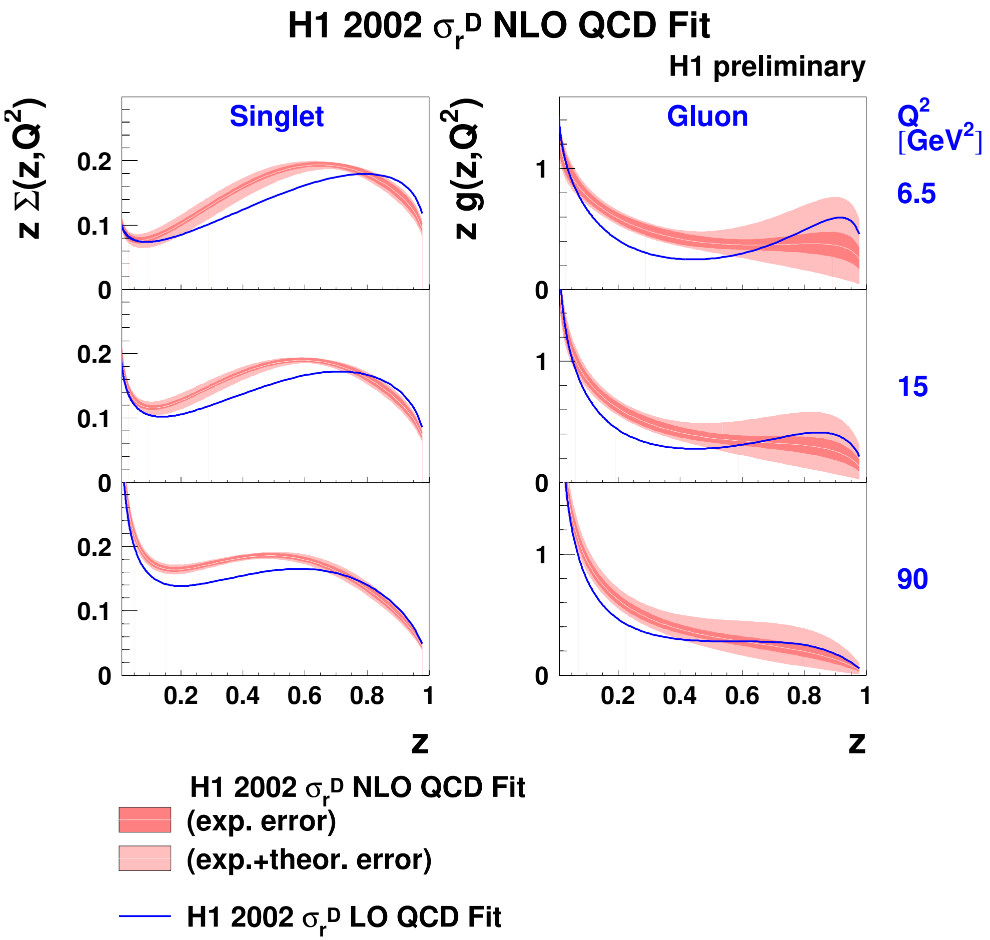


New NLO QCD fit to new $\mathbf{F_2^{D(3)}}$

- first time with error calculation (same technique for F_2^D as for F_2)
- strong scaling violations: gluon dominates
- $x_{I\!P}$ dependence taken from data (devided out)



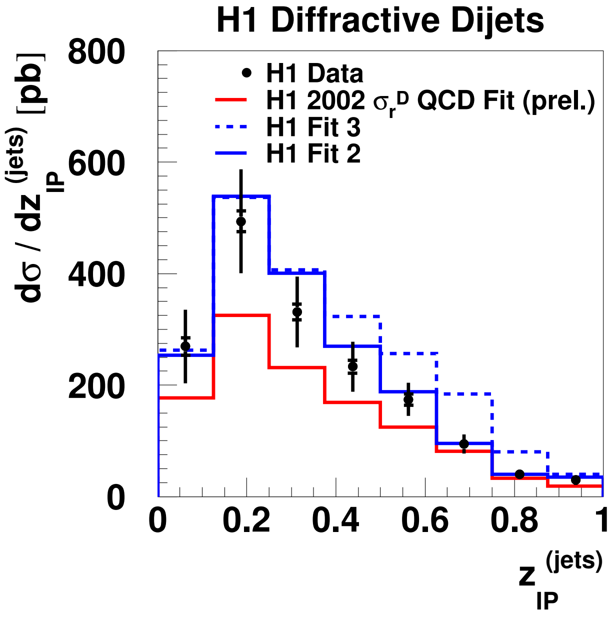
Diffractive parton Densities



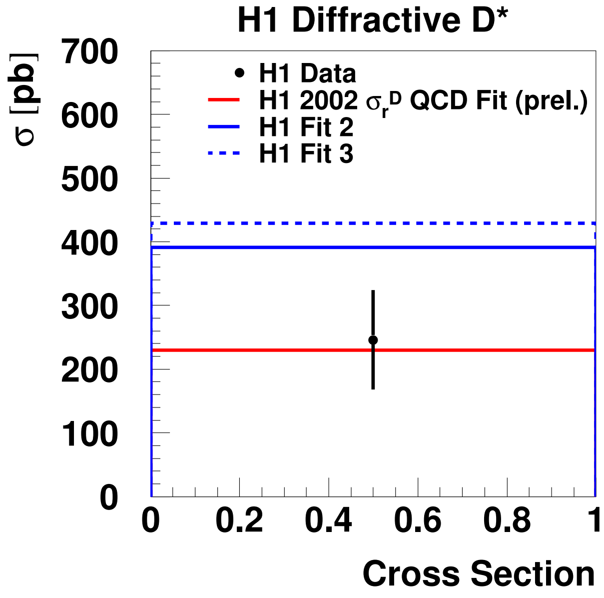
- NLO QCD interpretation of diffraction
- quark pdf's well constrained
- gluon with larger uncertaintis at large β
- gluon dominates
- "hard" component of gluon (c.f. proton)
- LO not very different from NLO
- errors on LO similar to NLO

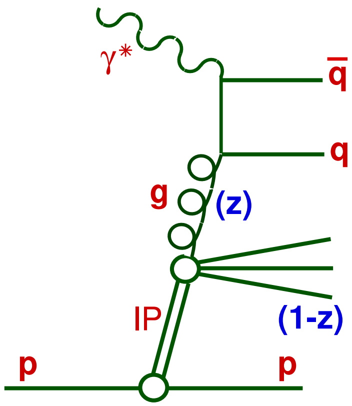
LO Predictions for Diffractive Jets and Charm

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)

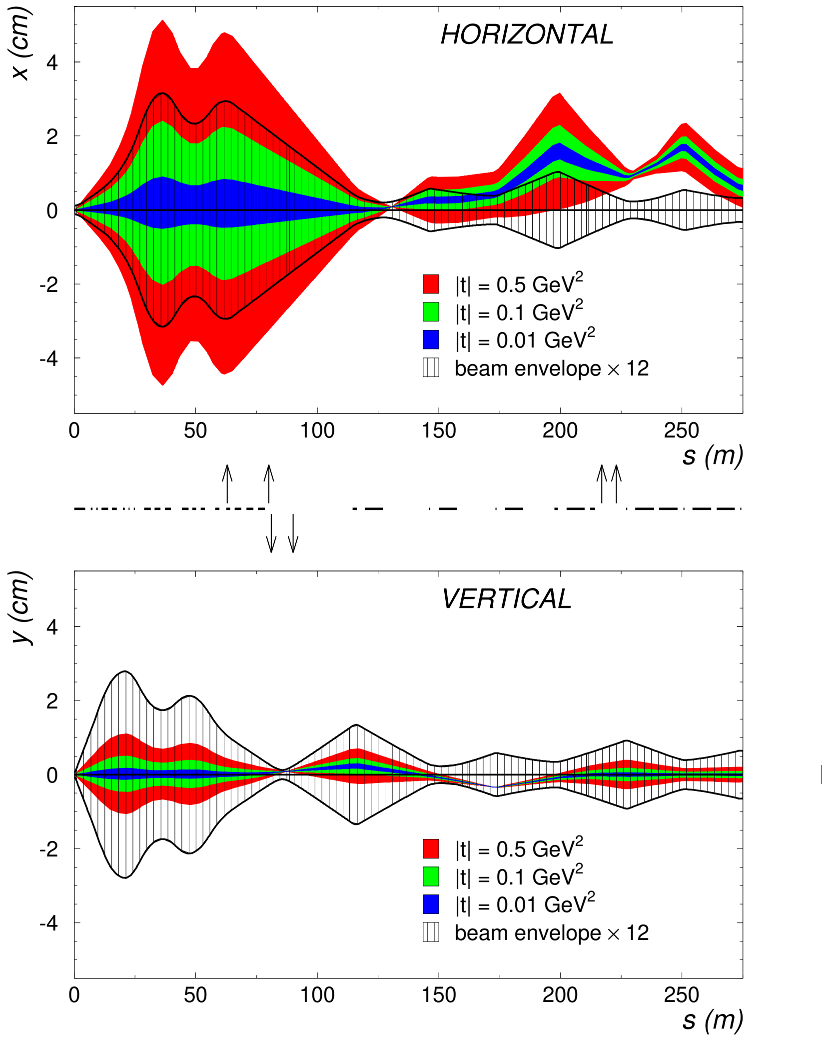
Very Forward Proton Spectrometer (VFPS)

New detector at $z = 200m$

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

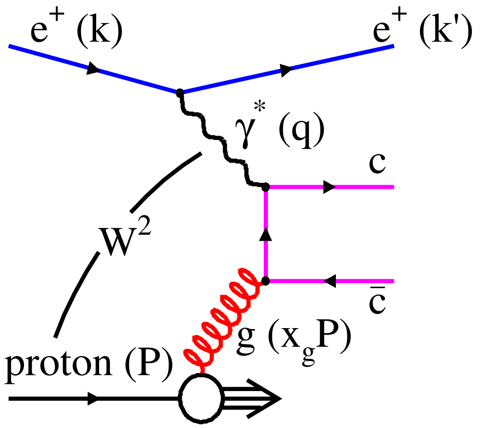
$\longrightarrow$ High statistics test of QCD interpretation of diffraction: $F_2^{D(4)}$, jets, charm, DVCS

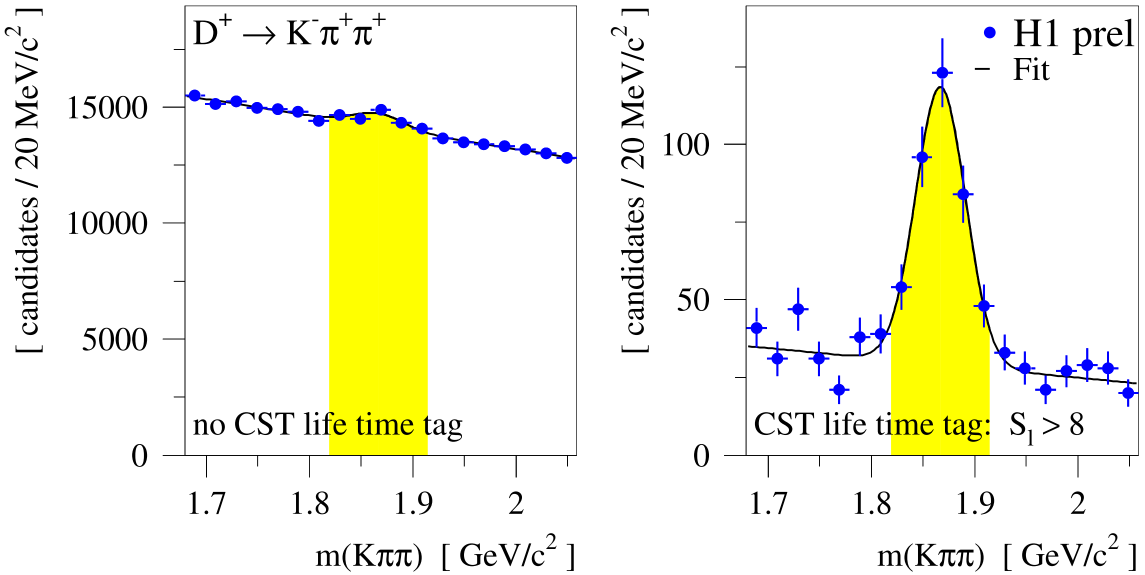
Proton beam optics



Charm Production in DIS

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





Fragmentation parameters, e.g.:

$$P_V \quad = \frac{VM}{PS+VM} = \frac{f(c \to D^{*+})}{f(c \to D^+) + f(c \to D^{*+})\, BR(D^{*+} \to D^0\pi^+)}$$

$$= 0.693 \; \pm 0.045 \; (stat) \; \pm 0.004 \; (syst) \pm 0.009 \; (theory)$$

$(= 0.601 \; \pm 0.032$ world average)

Support of universality of charm fragmentation

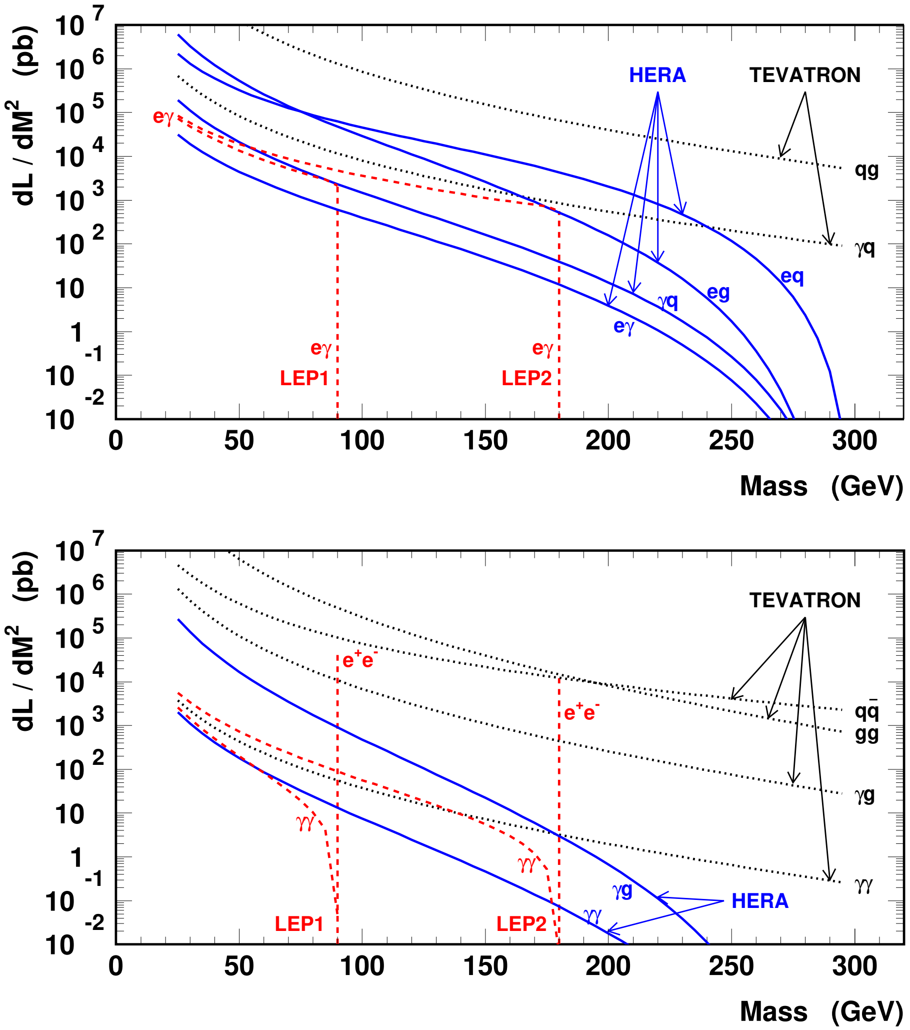
Beyond the Standard Model

Parton luminosities:

$$\sigma_c \approx \hat{\sigma}_{ab\rightarrow c}\; dL/d\hat{s}$$

$$\frac{dL}{d\hat{s}} = \frac{1}{s}\int_{\frac{\hat{s}}{s}}^{1} \frac{dx_a}{x_a}\, f_{A(x_A,\hat{s})}\, f_{B(\frac{\hat{s}}{sx_A},\hat{s})}$$

c.f. background, acceptance...



HERA:

best for eq and $e\gamma$ interactions:

Lepton number (violation),

e^*, ν^*, leptoquarks, $\not{R}_p$ SUSY,

eq contact interactions

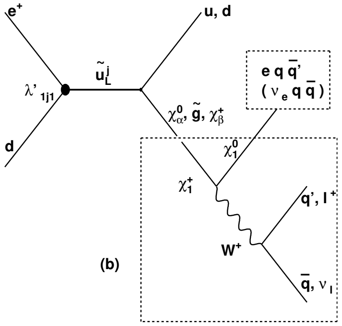
Sharp drop of parton luminosities at high x (high mass)

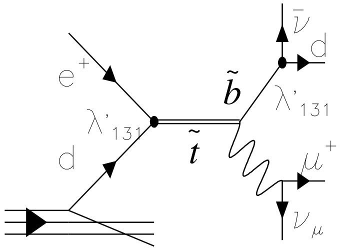
$\longrightarrow$ **highest possible beam energies**

$\longrightarrow$ **highest possible luminosity**

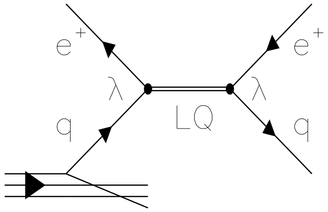
Searches: examples...

Squarks in $\not{R}_p$ SUSY: $e^+ d \rightarrow \tilde{t}$

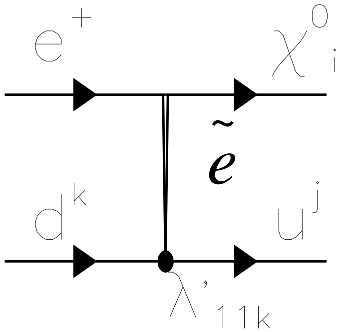




Leptoquarks: $eq \rightarrow eq,\ \nu q$

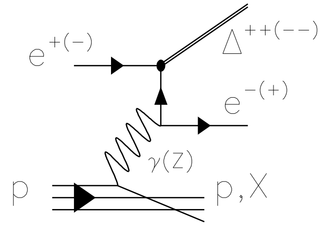


Selectrons in $\not{R}_p$ SUSY: $e^+ d \rightarrow u \chi^0$



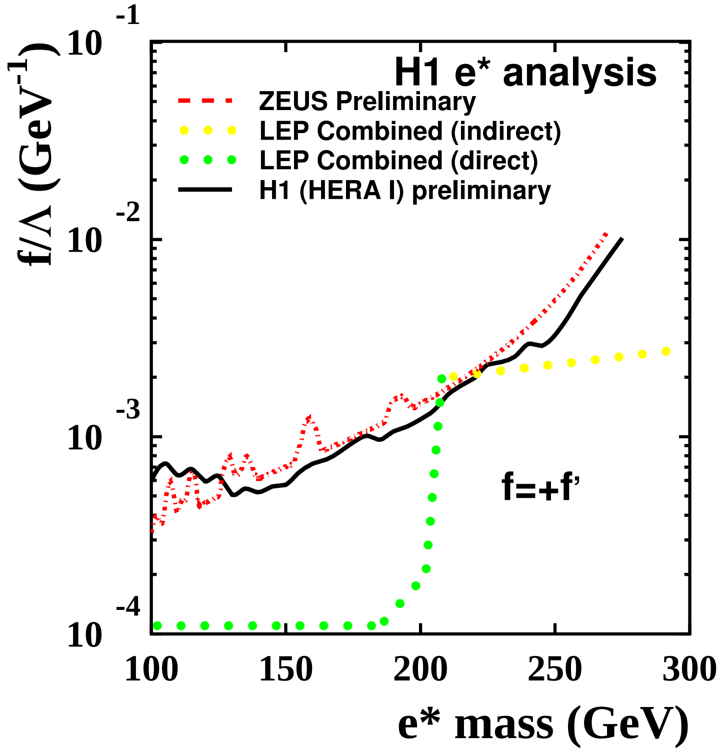
Doubly Charged Higgs:

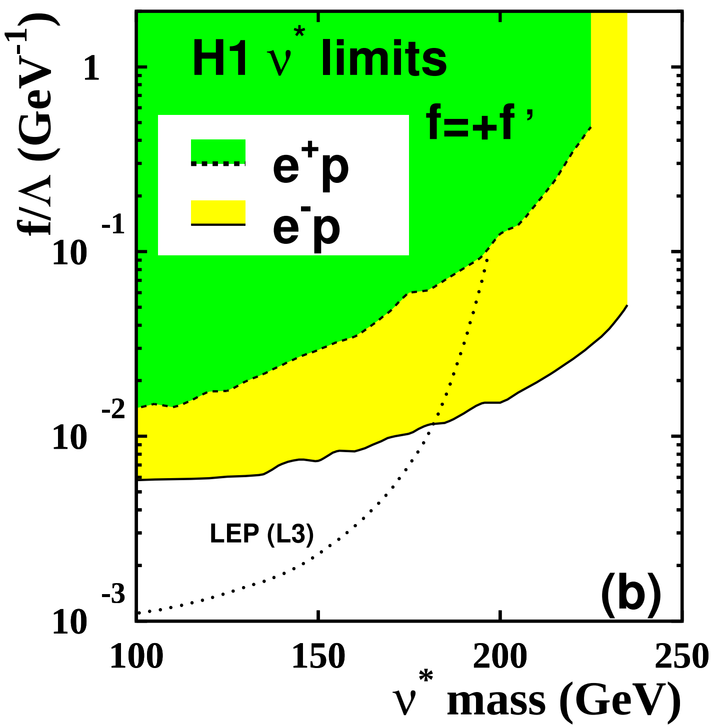
$e^+ \gamma \rightarrow e^- H^{++} \rightarrow e^- e^+ e^+$



Open windows for discoveries ?

Excited Leptons



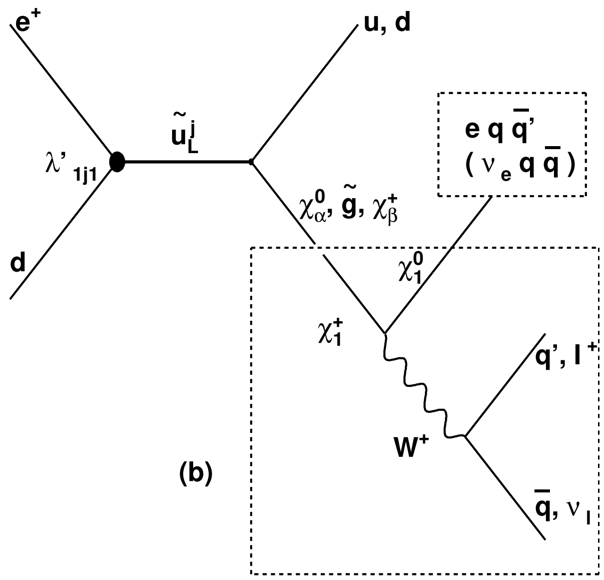


- still far from kinematic limit !

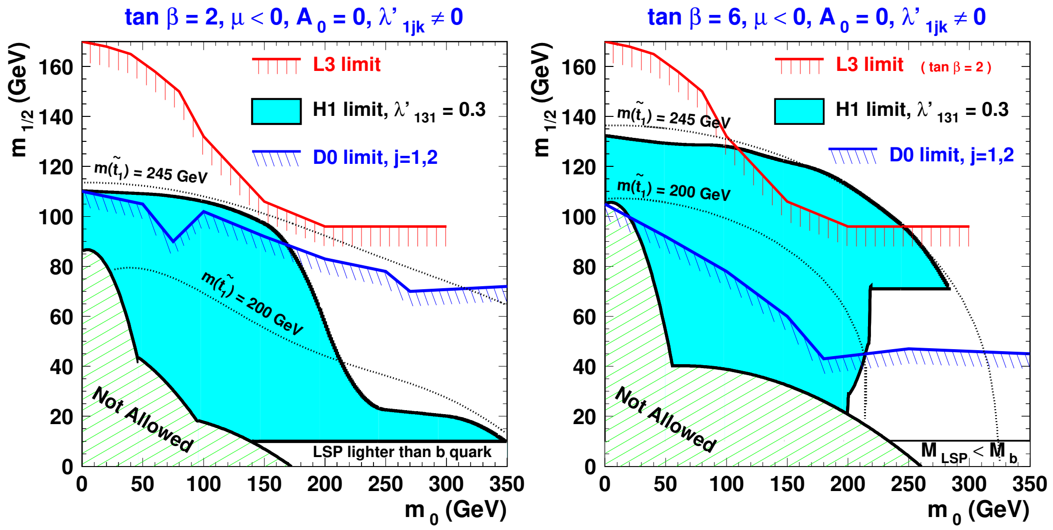
  $\longrightarrow$ needs luminosity

Beyond the Standard Model: Supersymmetrie

single production of squarks in R-parity violating models



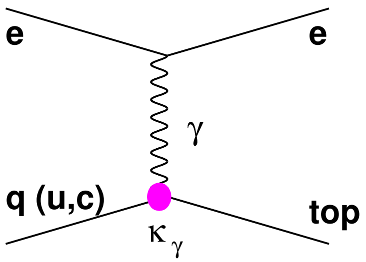
Minimal Supergravity + R_p Violation



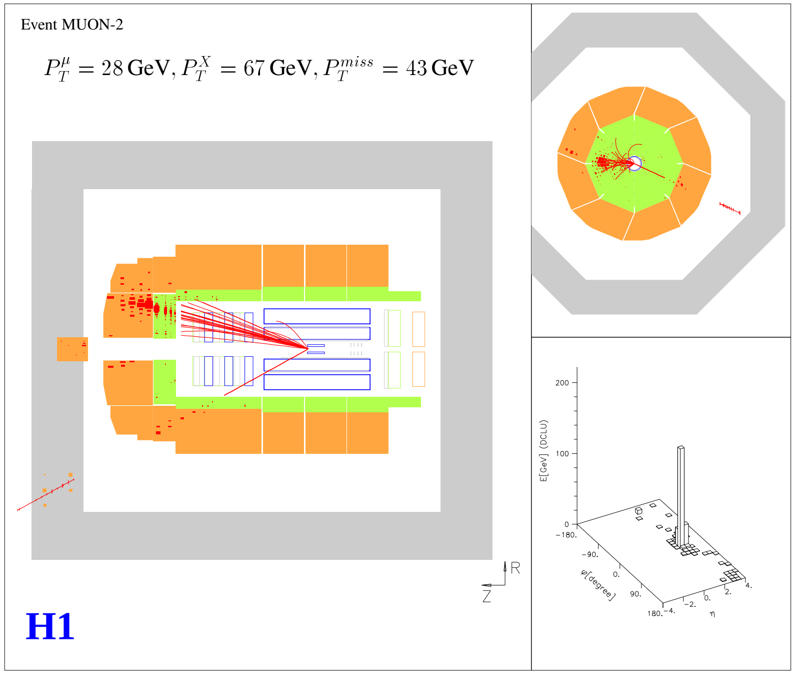
- nothing found yet up to $M_{\tilde{q}}$ =245 GeV
- will reach sensitivity of $M_{\tilde{q}} \approx$ 300 GeV

Searches: exotic events

Flavour changing neutral current



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



Leptonic decay

- e, μ +$P_{T,miss}$ + jet

dedicated top analysis:

- 5 events seen
- 1.7± 0.3 expected

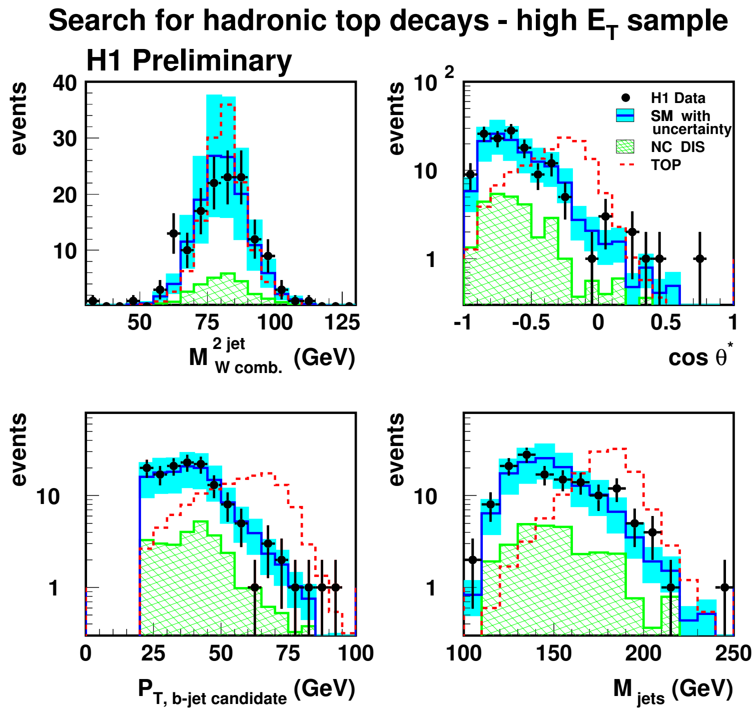
$$M_{\mu\nu X} = 181 \pm 10 \text{ GeV}$$

Hadronic channel ?

Searches: Single top production

Hadronic channel:

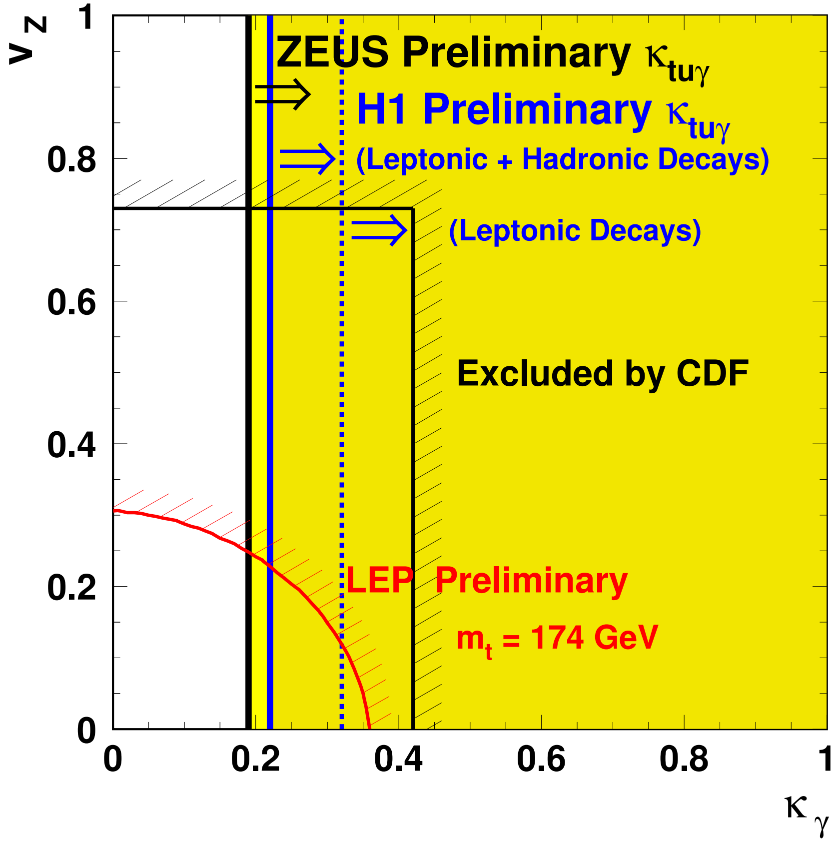
3 jets with $P_T > 40, 25, 20$ GeV



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

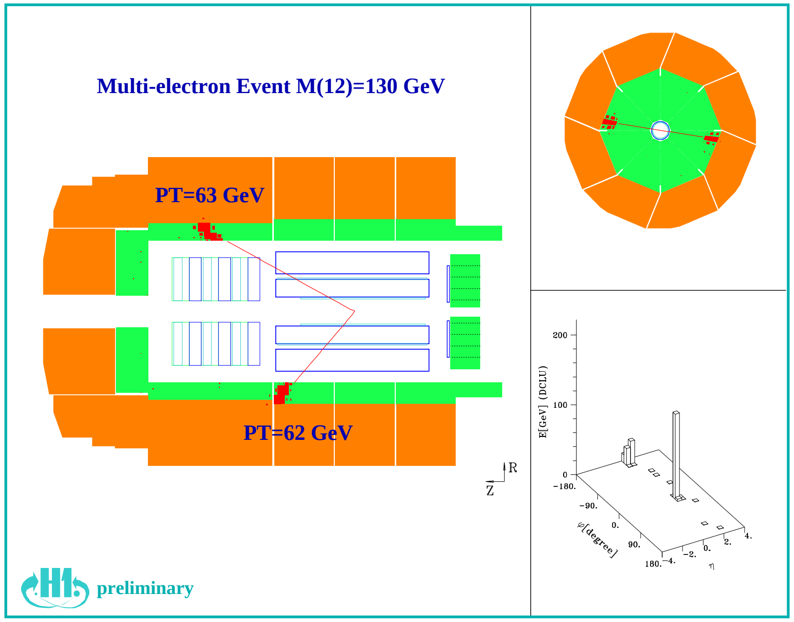
14 events seen, 19.6 $\pm$ 7.8 expected

Limit on anomalous top couplings



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

Electron Pair Production

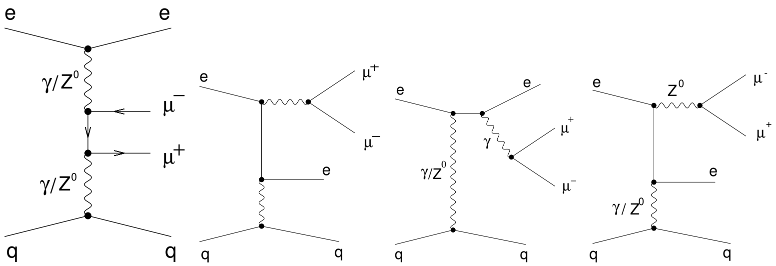


Selection:

- 2 electrons with
  $E_{1,2} > 10GeV\ (5GeV)$
  with $20^0 < \theta < 150^0$
- 3rd electron with $E_3 > 10GeV$
  with $5^0 < \theta < 175^0$

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

Expectation from GRAPE (GRACE):

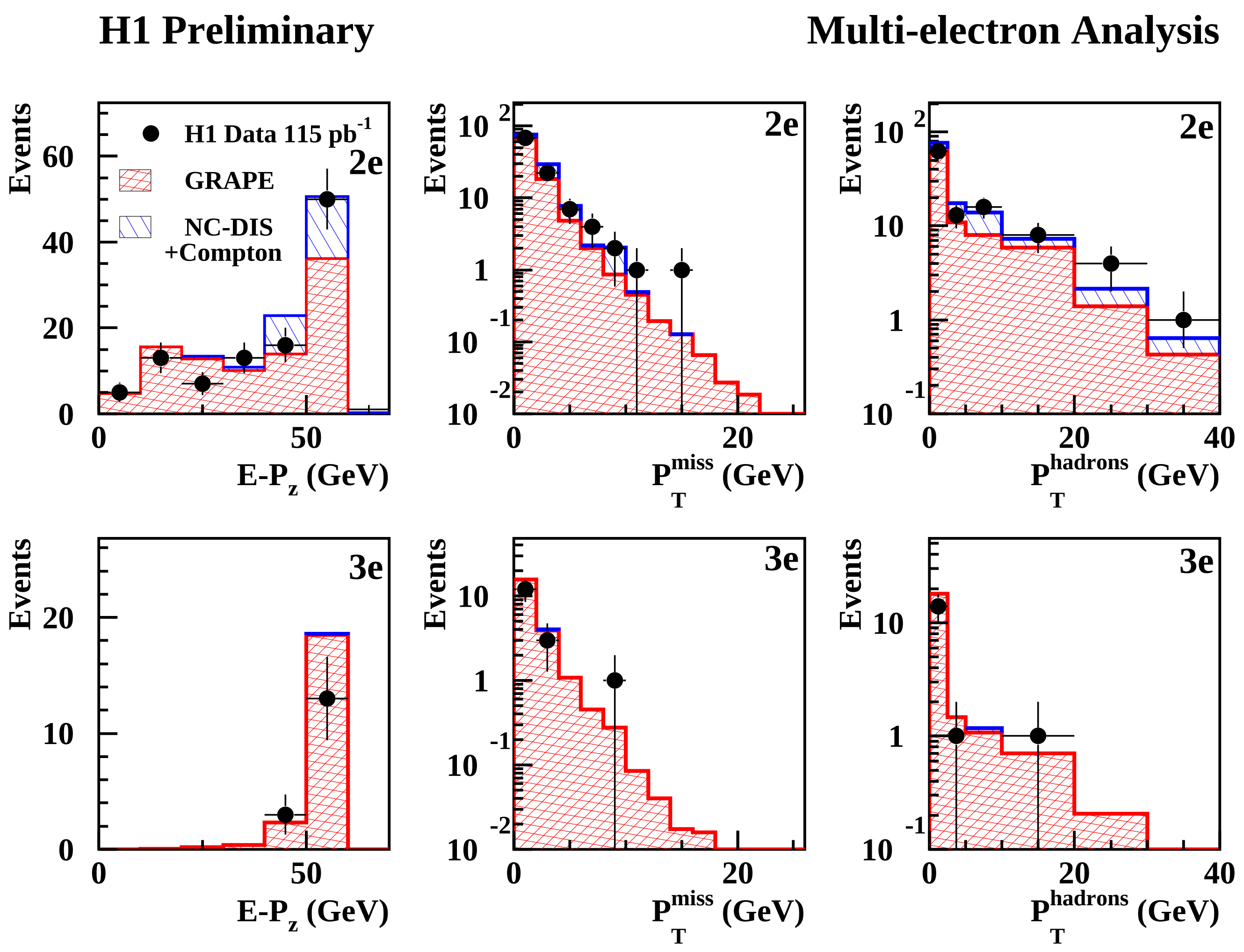


$$e^+q \longrightarrow e^+e^-e^+q$$

4-fermion final state

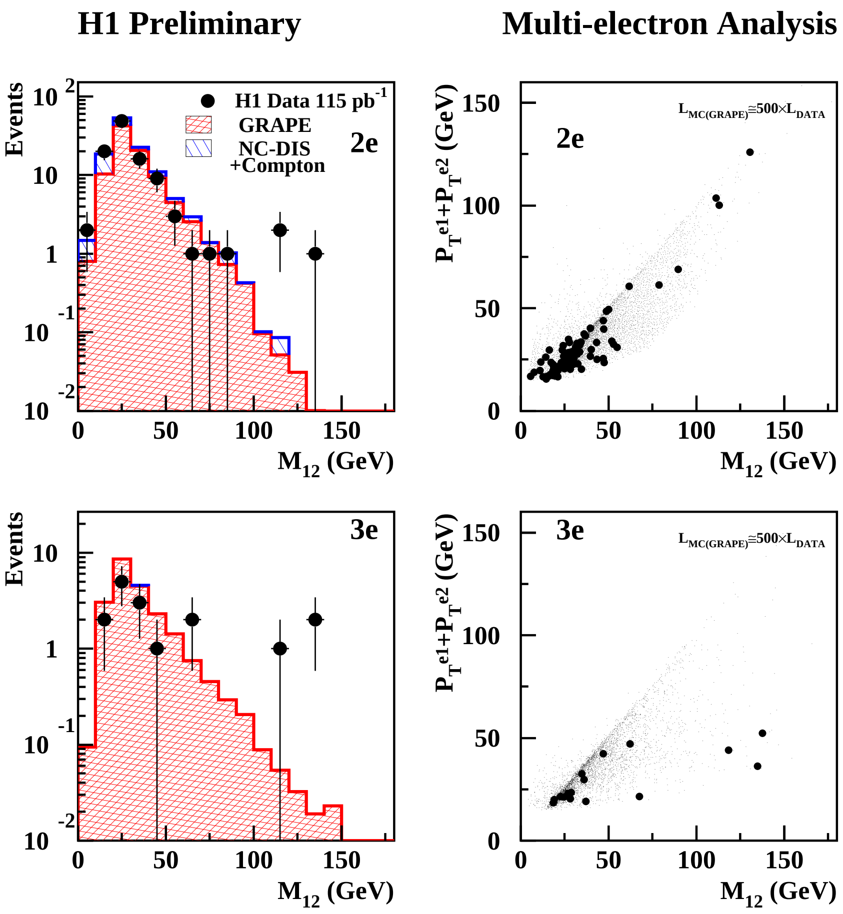
- complete set of EW diagrams
- for electrons: interference
- elastic + inelastic

Electron Pair Production



→ Good overall agreement

Electron Pair Production



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

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

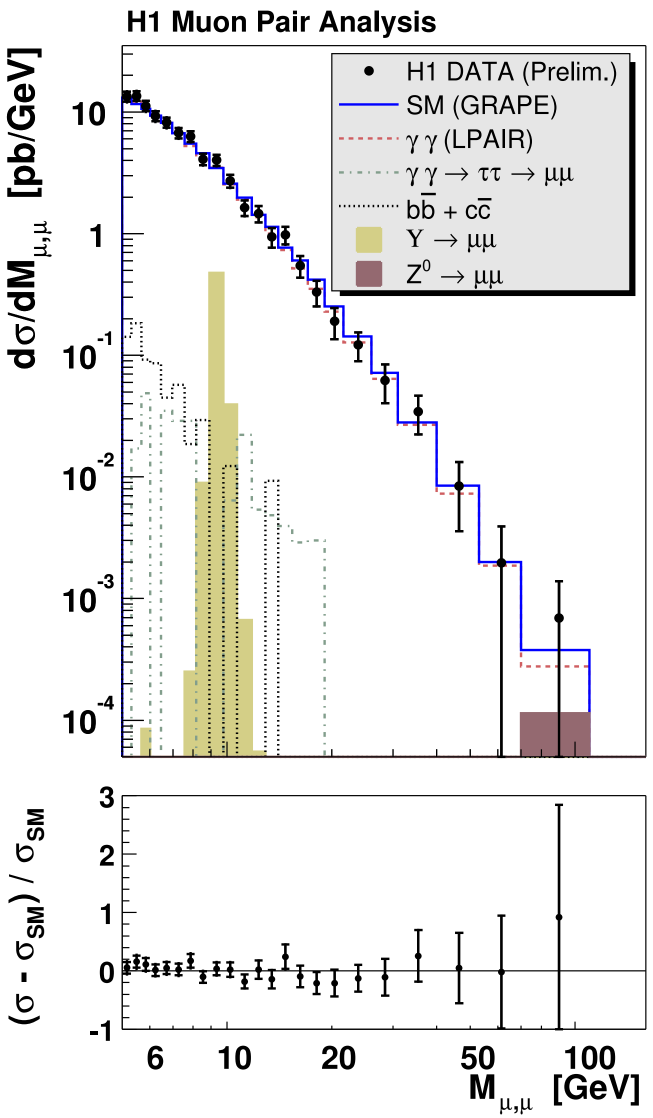
Excess at high $M_{ee} > 100$GeV

Note: different topology of

2e and 3e events

$\longrightarrow$ **needs confirmation with independent data**

Muon Pair Production



Selection:

2 muons with $20^0 < \theta < 160^0$

- Good overall agreement with expect.
- Comparison with multi-e sample:
  - **no excess at high masses**

    but only central θ region, lower efficiency and luminosity

    $\longrightarrow$ not conclusive

Overview HERA II Running Conditions

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 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**

H1 detector status

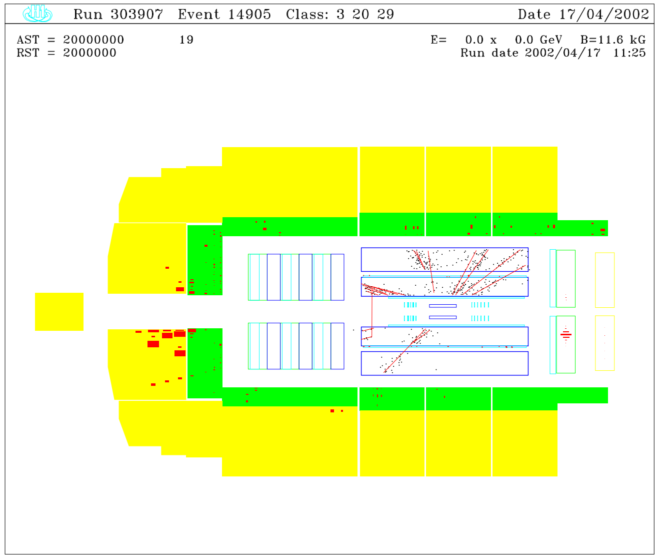
Detector Upgrades

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

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

  $(\pm 10\%)$

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



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:

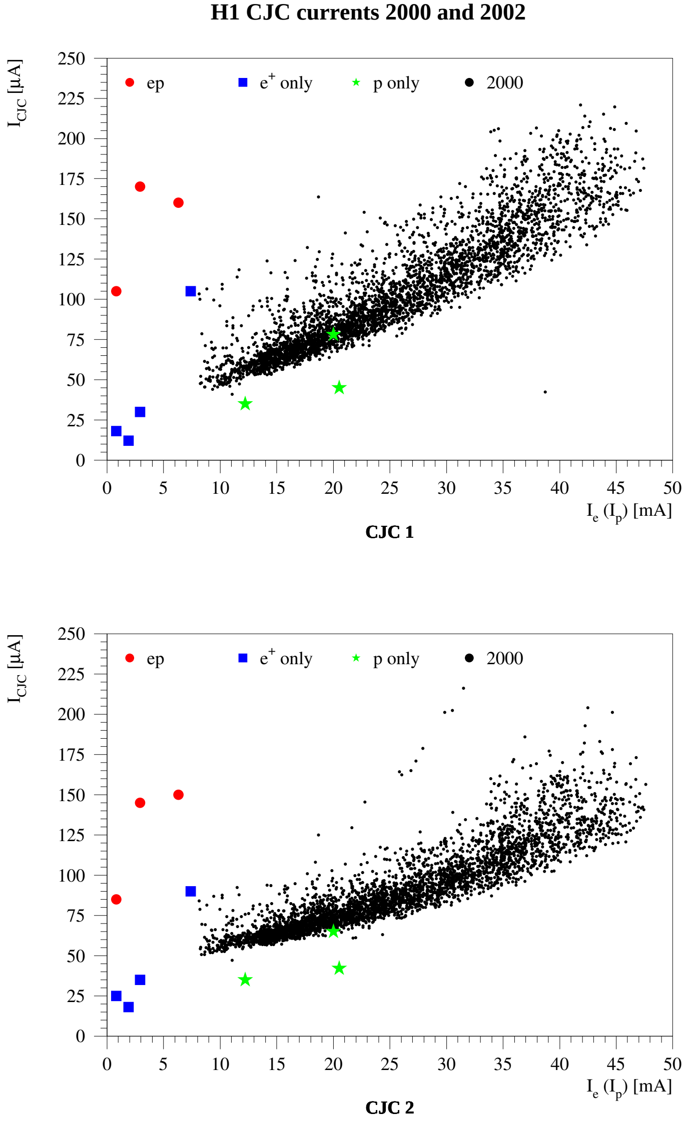
  very high e-induced bkg

  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

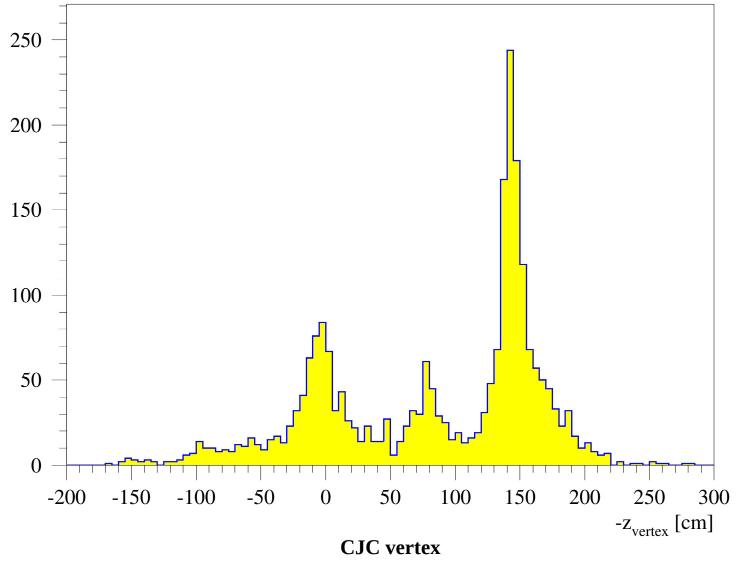


Background conditions

z-vertex from Jet Chamber tracks

$I_e = 3$ mA, $I_p = 35$ mA

ep run 303910 (17.4.2002)

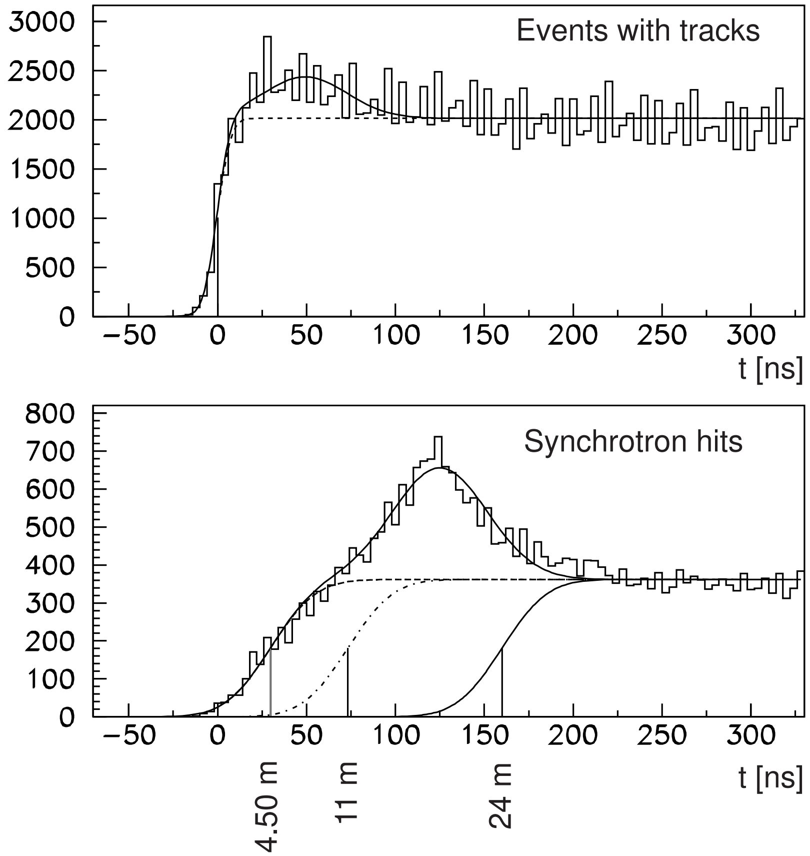


ep **vertex**

+ 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