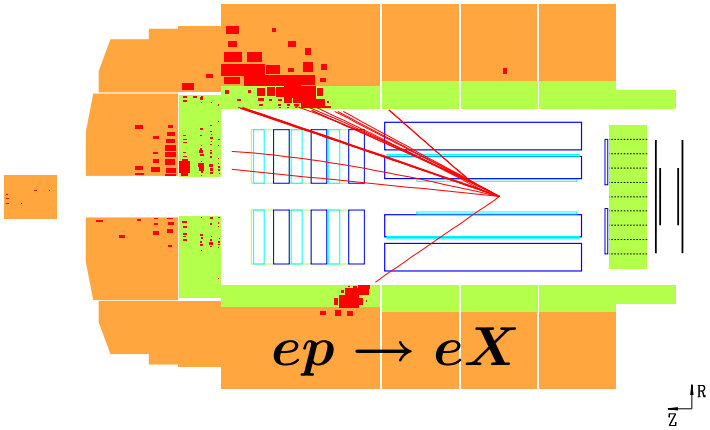
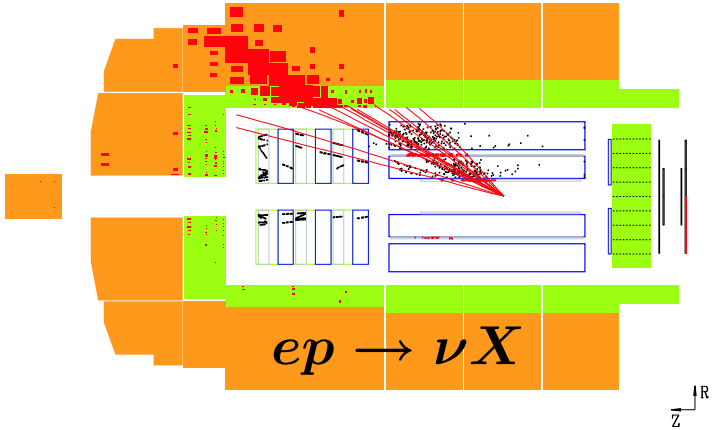
H1 Status and Prospects, May 2004

Paul Newman Birmingham University

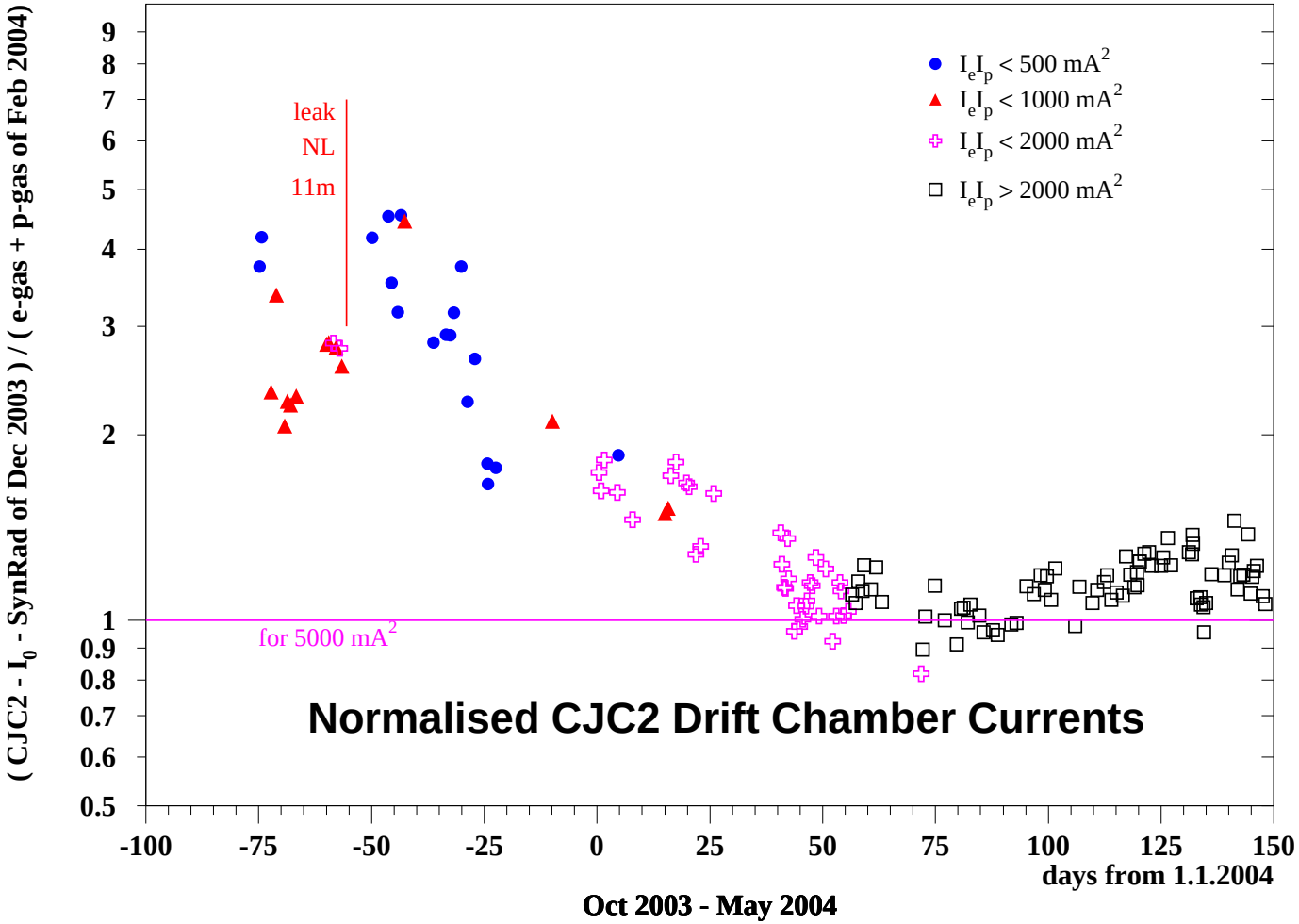




- ***Data Taking***
- ***Recent Physics Results***
- ***Physics Status and Aims***

57th Meeting of the DESY PRC, 27 May 2004

HERA-II Data Taking: Backgrounds



Steady improvement after last vacuum leak (November 2003) . . . pumping takes time

H1 able to run with recent high currents ($\sim$ design) . . . acceptable limits for trackers adjusted

Still suffer from ‘spikes’ in backgrounds

Background conditions remain “harsh” and cause radiation damage . . . FST now inoperational

HERA-II Data Taking: Luminosity

Big improvement on 2003!

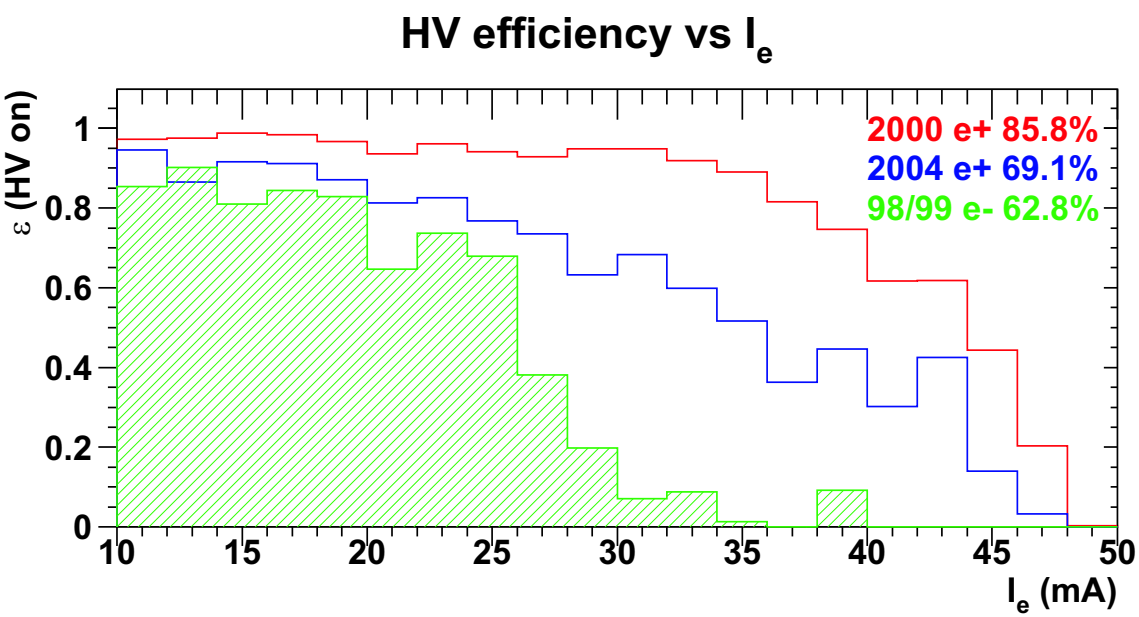
$> 15\ \mathrm{pb}^{-1}$ taken with each lepton polarisation state

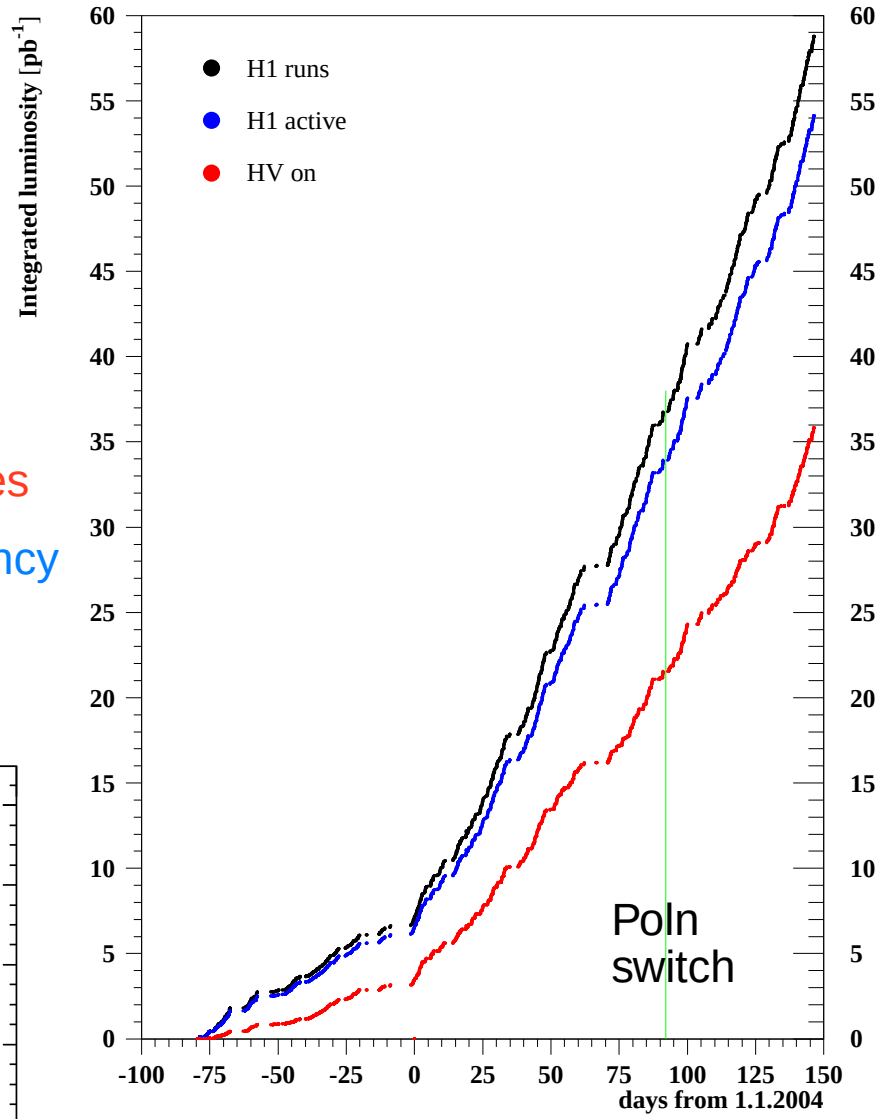
Polarisation typically $30 - 40\%$

Small data acquisition deadtimes (H1 active)

Significant HV inefficiencies due to backgrounds / spikes

Only recently reached 2000 level of 85% HV-on efficiency





Recent H1 Papers

8 papers released since October 2003 PRC . . .

- DESY-03-159 (11/03): Muon Pair Production in ep Collisions
- DESY-03-206 (01/04): Measurement of Dijet Production at Low Q^2
- DESY-04-025 (03/04): Search for Squark Production in R-Parity Violating Supersymmetry
- DESY-04-032 (03/04): Measurement of Anti-Deuteron Production
- DESY-04-038 (03/04): Evidence for a Narrow Anti-Charmed Baryon State
- DESY-04-051 (04/04): Forward π^0 Production and Associated Transverse Energy Flow
- DESY-04-083 (05/04): Measurement of F_2 at low Q^2 in QED Compton Scattering
- DESY-04-084 (05/04): Search for bosonic stop decays in R-parity violating supersymmetry

Recent and Forthcoming Conferences

At **DIS04** there were 30 talks by H1 members

summarising work in last year, including newly released data on . . .

- Polarised $\sigma(CC)$ from HERA-II
- High p_T Particle Production at HERA-II
- F_2 at low Q^2, high x from ISR events
- τ production
- Forward Jet Production
- $b \to \mu X$ in low Q^2 DIS
- F_2^b and F_2^c at Large Q^2

(Almost) all on completely original and new topics!

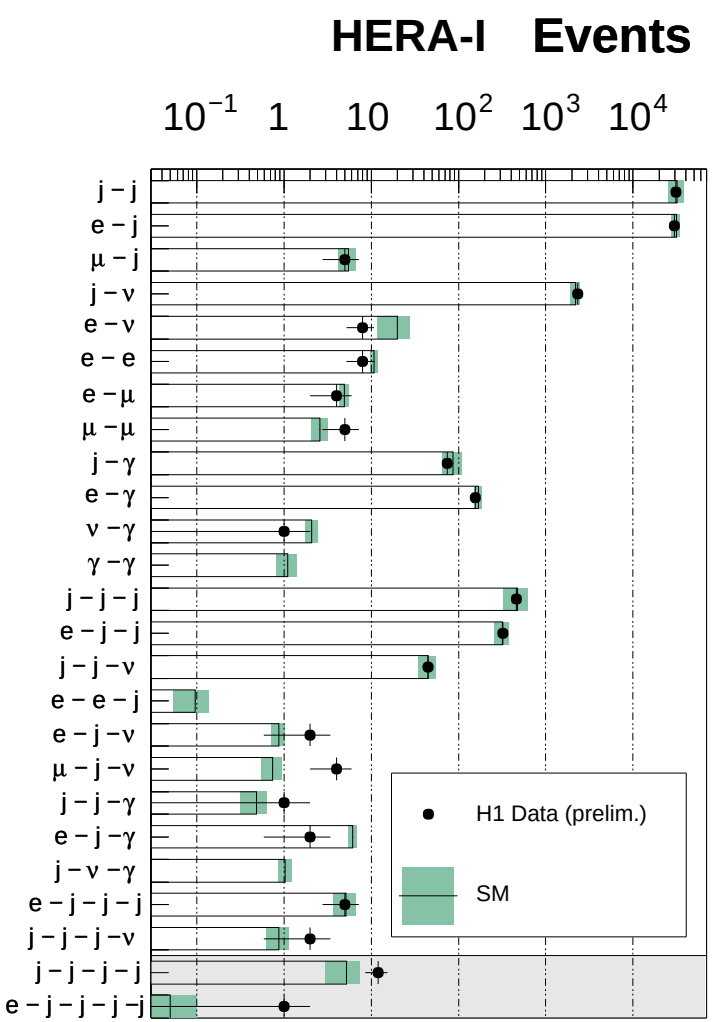
Preparations for **ICHEP04** summer conference are well underway

54 abstracts submittted, summarising work of past two years

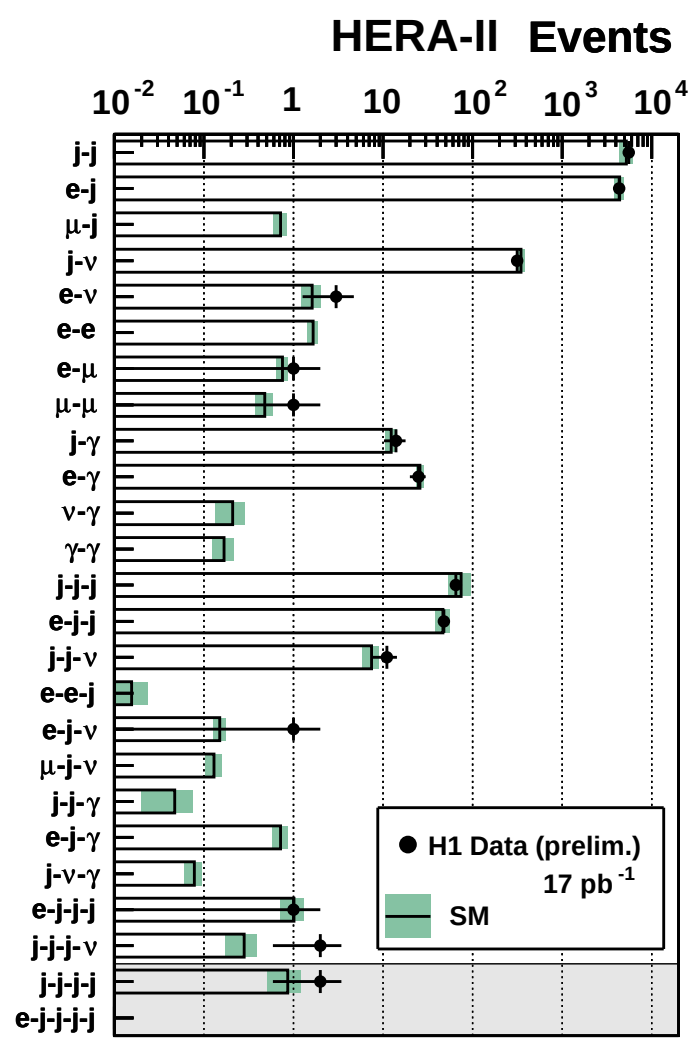
Systematic Searches For Anomalies in High p_T Data

Investigation of all final states with isolated j, e, μ, γ, ν $\quad (p_T > 20\ \mathrm{GeV}, 10^\circ < \theta < 140^\circ)$

Overall highly impressive agreement with Standard Model predictions . . . but $\mu j \nu$, $e j \nu$?



H1 General Search



H1 General Search (Hera-II)

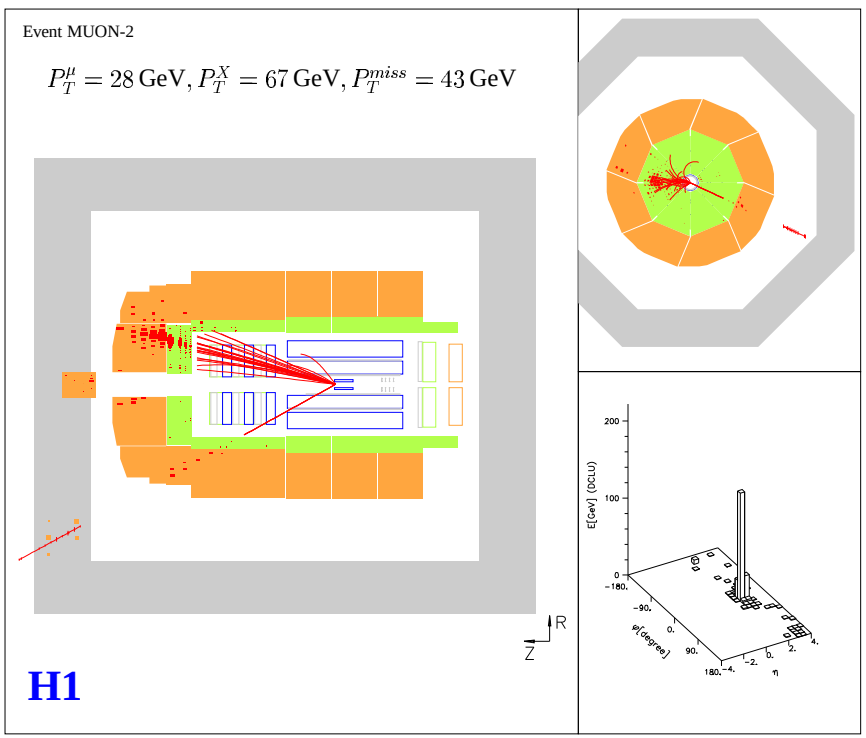
Dedicated Studies of Isolated Leptons with Missing p_T

Study events with isolated high p_T μ, e or τ, missing p_T and large hadronic p_T^X in e^+p data

Events observed and expected in Standard Model . . .

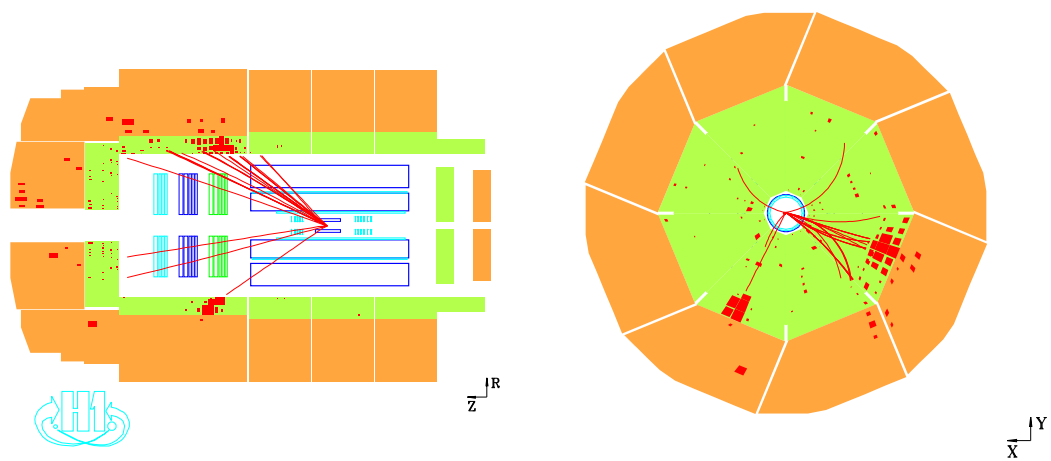
	HERA-I ($110\ \mathrm{pb}^{-1}$)			HERA-II ($17\ \mathrm{pb}^{-1}$)	
	μ	e	τ (prel)	μ (prel)	e (prel)
$p_T^X > 25\ \mathrm{GeV}$	6 / 1.44	4 / 1.48	0 / 0.53	0 / 0.29	2 / 0.34

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



HERA-II $e^+p \to e\,\not{p}_T X$

$p_T^e = 37\ \mathrm{GeV},\ p_T^{miss} = 44\ \mathrm{GeV},\ p_T^X = 29\ \mathrm{GeV}$



Possible Interpretations?

W radiation is dominant SM process . . .

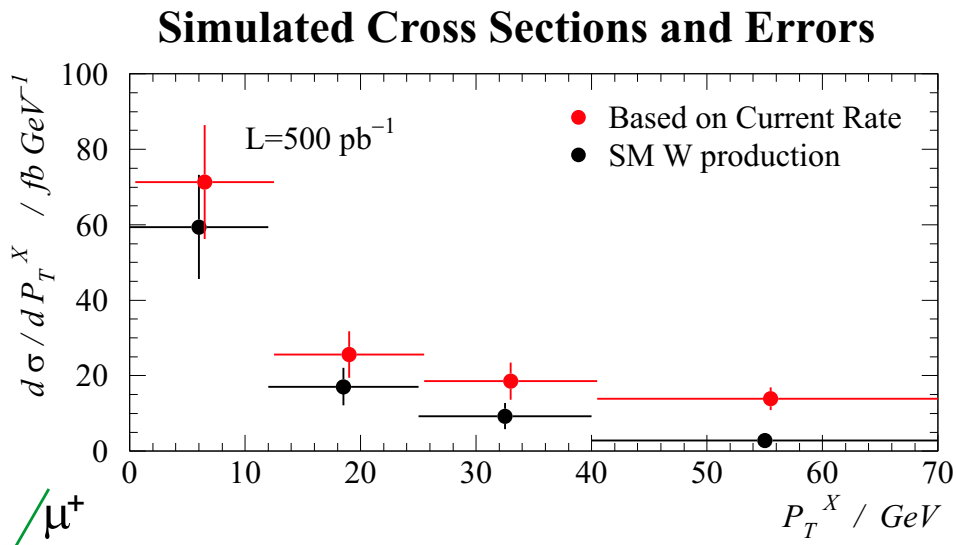
Excess in HERA-I $e + \mu$ is $\sim 10^{-3}$ fluctuation

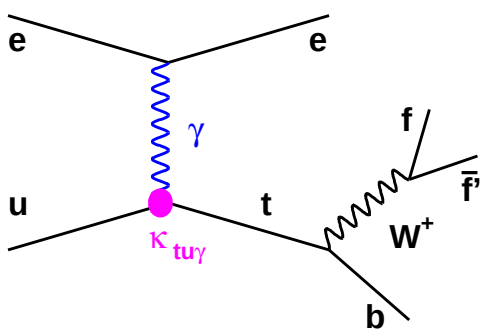
Beyond the Standard Model . . .

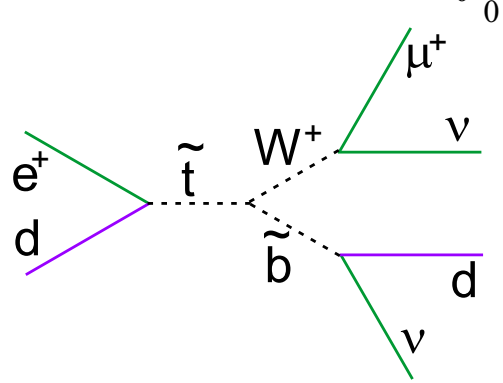
Anomalous single top production?

$\not{R}_p$ $\tilde{t}$ production with $\tilde{t} \to \tilde{b}W$?

. . . dedicated searches published





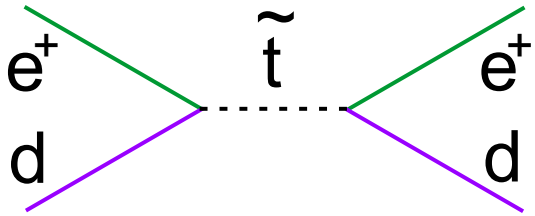


This anomaly can only be clarified with large increases in e^+p luminosity

If current event rate persists, 5σ "discovery" possible with $500\ \mathrm{pb}^{-1}$

See also anomalously high H1 yields of multi-electron events in e^+p scattering

$\not{R}_p$ SUSY at HERA-I



Search programme with HERA-I data nearing completion

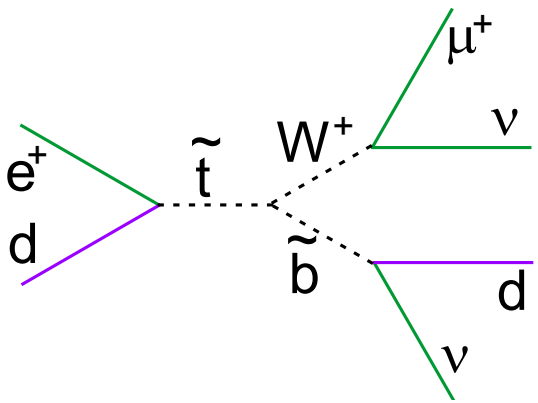
e.g. Recent searches for $\not{R}_p$ SUSY $\tilde{q}$ production

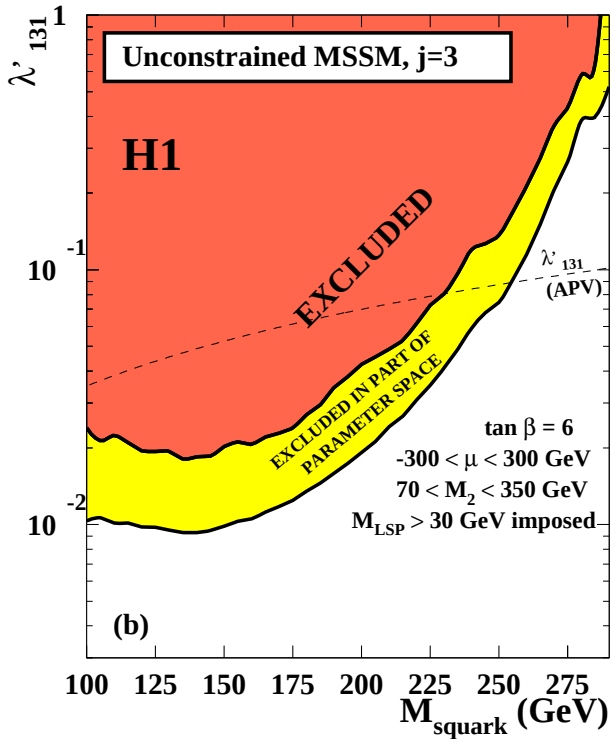
Search for e.g $e^+ d \to \tilde{t}$ via λ'_{131}, $\quad e^- u \to \tilde{b}$ via λ'_{113}

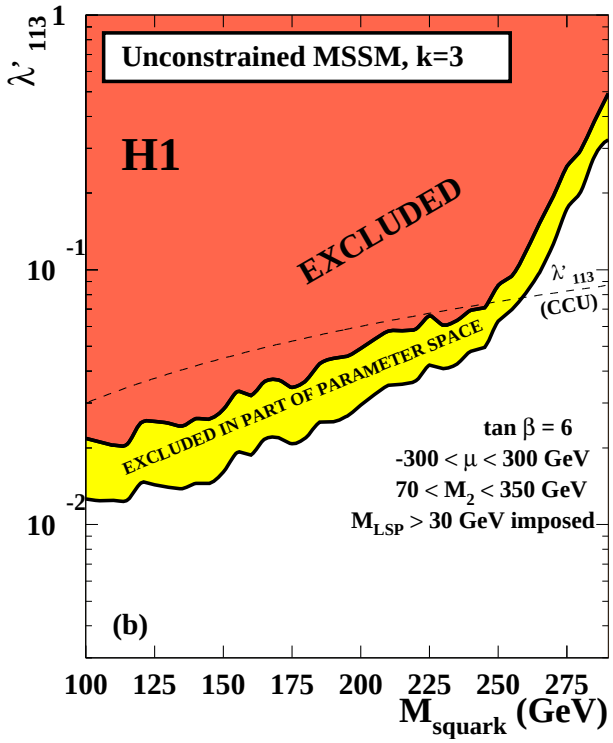
Consider R_p and $\not{R}_p$ decays covering most of BR for all $m(\tilde{q})$

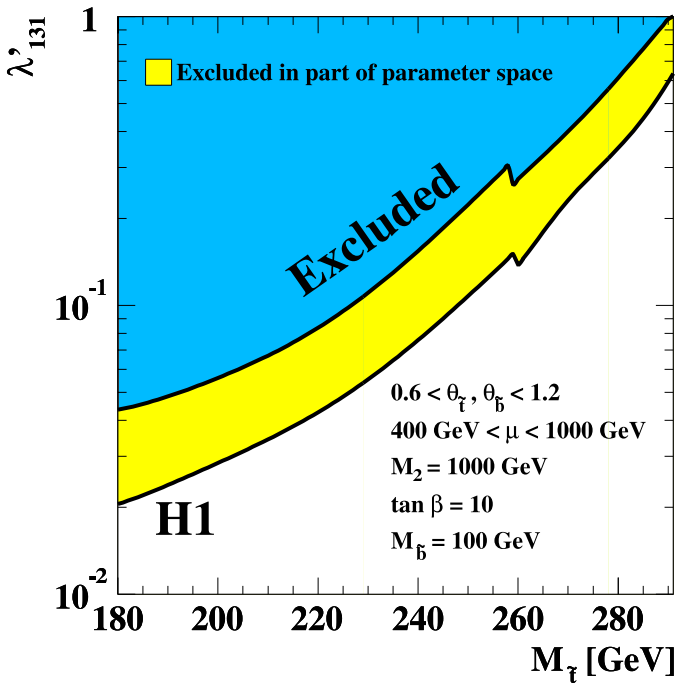
Also consider for first time $\tilde{t} \to \tilde{b}W$

Limits: e.g. $m(\tilde{t}) > 275$ GeV for λ'_{131} of em strength









Search Prospects at HERA-II

HERA has unique discovery potential for some time to come in several areas

e^+ or e^-

Anomalous $tu\gamma$

q radius / form factor

Contact Interactions

Double charged Higgs

Large Extra Dimensions

e^*

q^*

e^+

$F = 0$ LQ / LFV

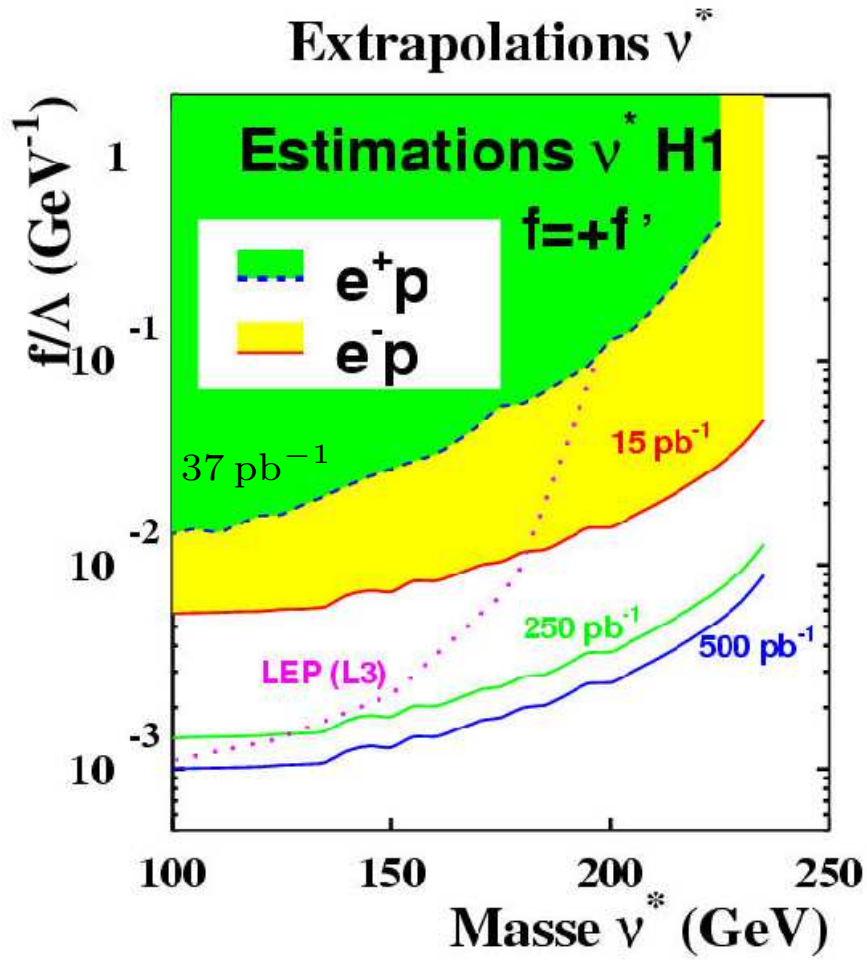
$\tilde{t}$ (& $\tilde{c}, \tilde{u}$)

e^-

$F = 2$ LQ / LFV

$\tilde{b}$ (& $\tilde{s}, \tilde{d}$)

ν^*

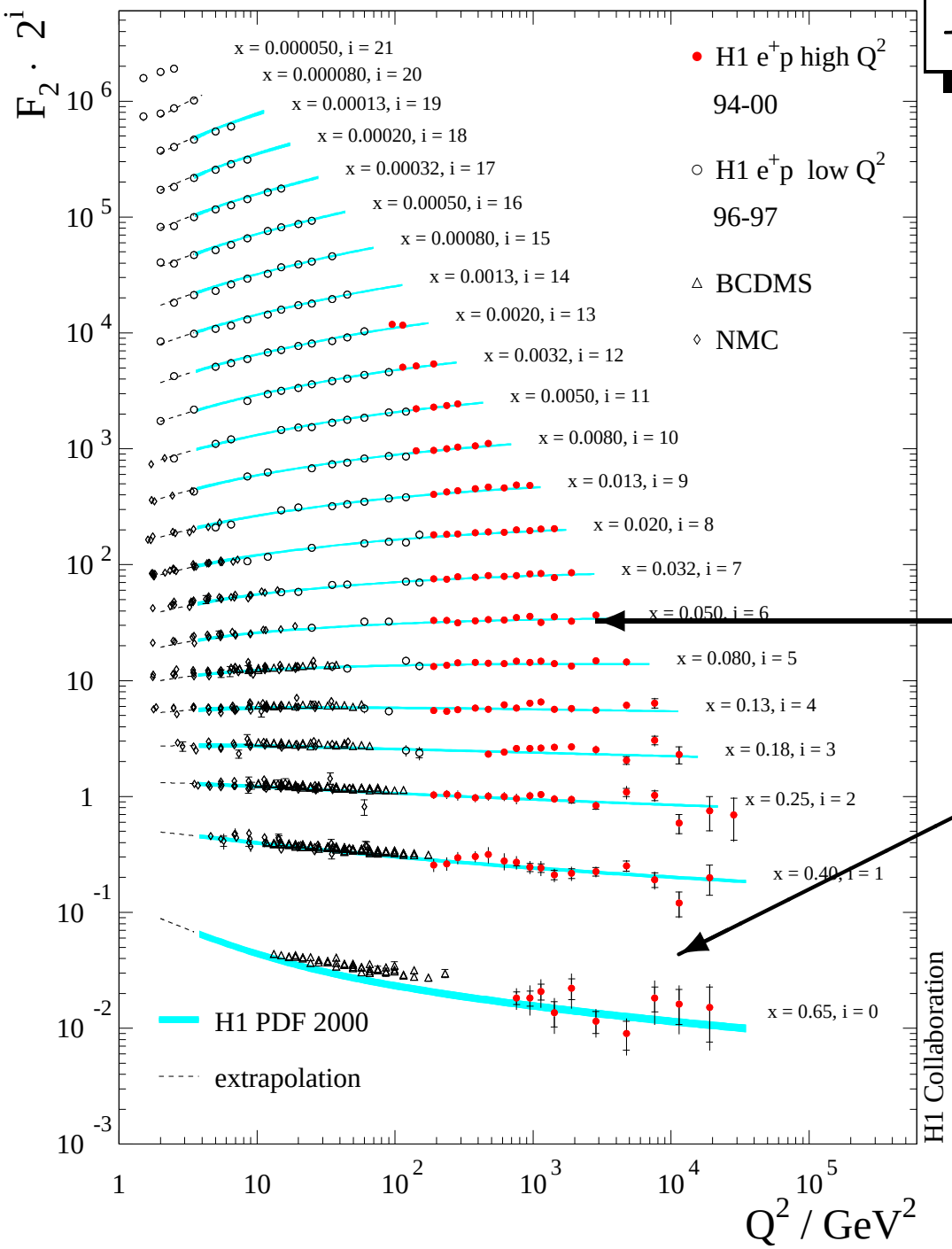


Improvements on current sensitivity require large increases in $\mathcal{L}$

. . . top priority to optimise overall search programme

e^+p and e^-p complementary in some areas, both interesting

$F_2^{\mathrm{em}}(x, Q^2)$ and u at high x



$$\tilde{\sigma}^{\pm}_{\mathrm{NC}} = F_2 \mp \frac{Y_-}{Y_+} xF_3 - \frac{y^2}{Y_+} F_L$$

$$F_2^{\mathrm{em}}(x, Q^2) = x \sum_q e_q^2 (q + \bar{q})$$

. . . dominates in most of phase space

Measured over huge kinematic range

well matched to LHC predictions via DGLAP

2-3% precision in bulk of phase space

Highest x region requires much more luminosity (e^+ or e^-) and / or reduced $E_p \longrightarrow$ high x, moderate Q^2

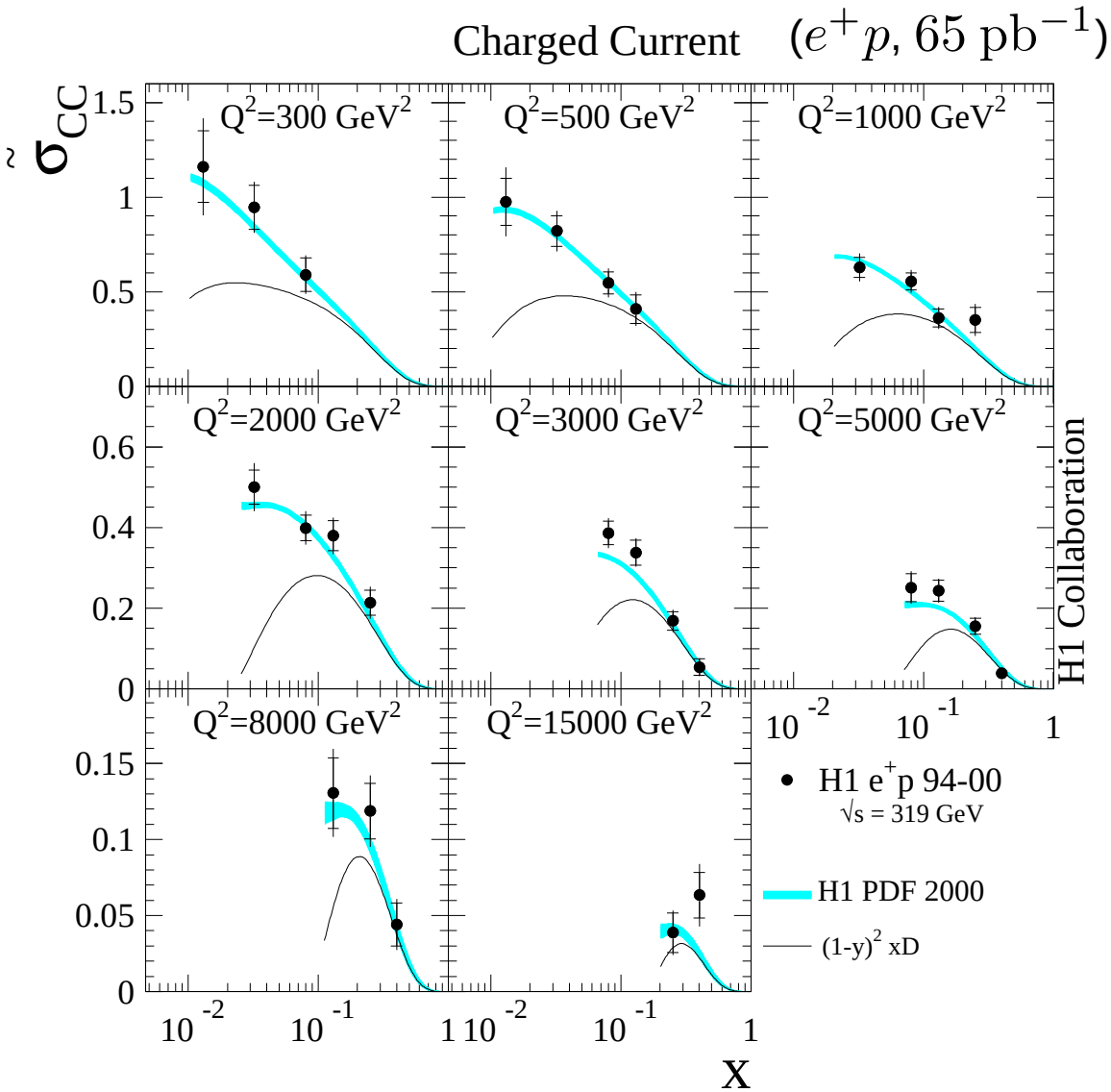
Beautifully described by QCD fits

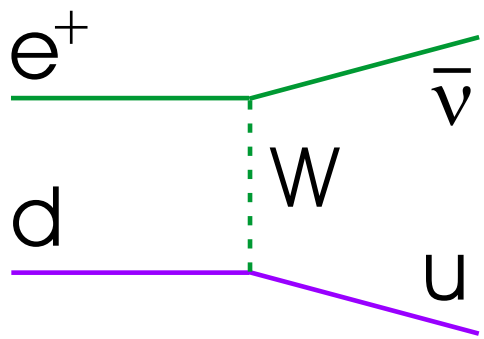
$\longrightarrow$ strongest constraint on u, $\bar{u}$

Constrains gluon and α_s

via $\frac{\partial F_2}{\partial \ln Q^2} \sim \alpha_s x g(x)$ (LO QCD)

e^+p Charged Current Cross Section and d at "high" x

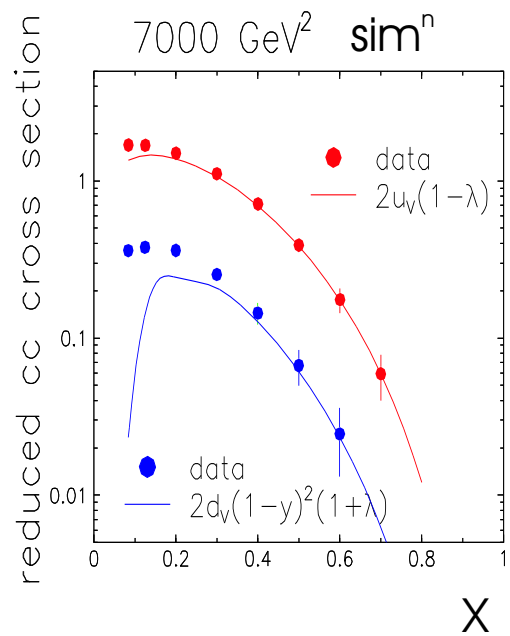




$$\tilde{\sigma}^+_{CC} \sim x(\bar{u}+\bar{c}) \; + \; (1-y)^2\, x(d+s)$$

Promising for d density at $x \sim 0.3$

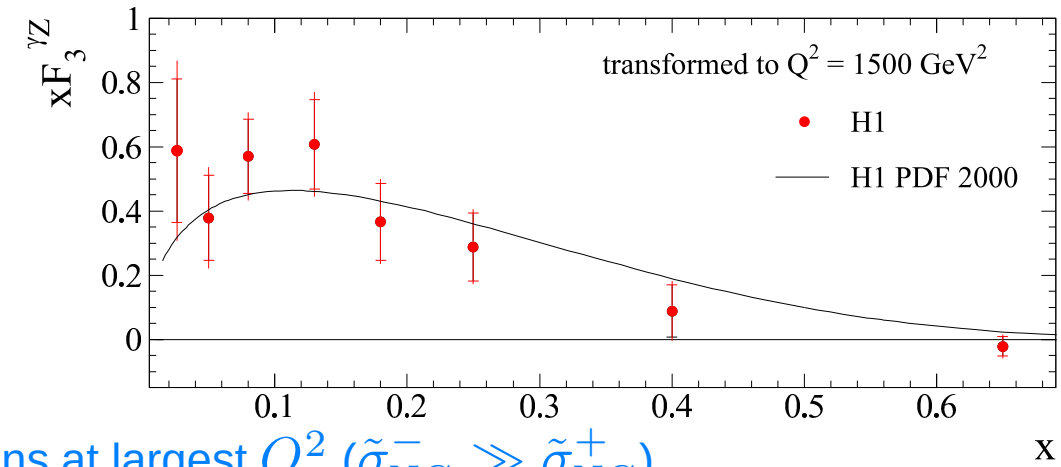
Higher x Suppressed by $(1-y)^2$ factor



250 pb^{-1}

$e^{\pm}$

$xF_3(x, Q^2)$ and u_v, d_v



$$xF_3 = \frac{1}{2y(1-y)}\left(\tilde{\sigma}^-_{\rm NC} - \tilde{\sigma}^+_{\rm NC}\right)$$

$$\sim 2u_v + d_v$$

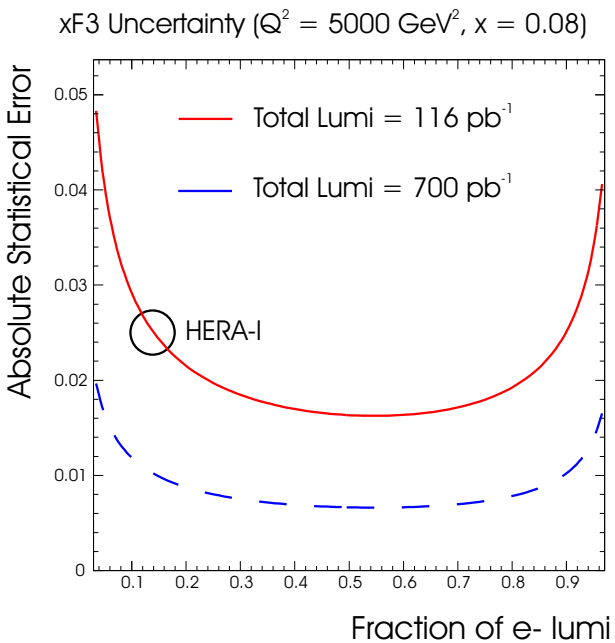
Assumption-free access to valence distributions at largest Q^2 ($\tilde{\sigma}^-_{\rm NC} \gg \tilde{\sigma}^+_{\rm NC}$)

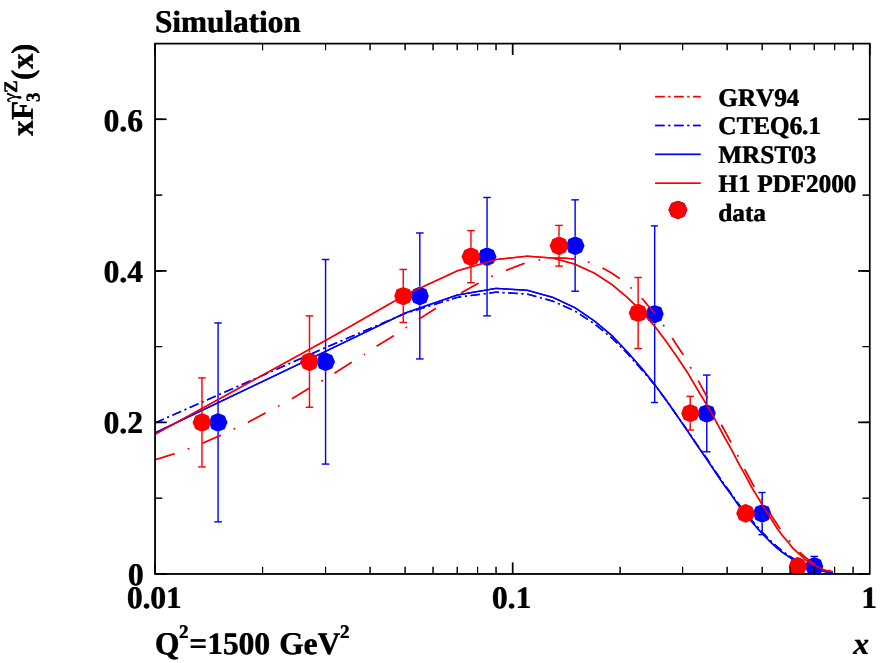
y factors suppress highest x, kinematics suppress lowest x, potentially competitive for $x \sim 0.1$

First "exploratory" HERA-I extractions agree well with predictions

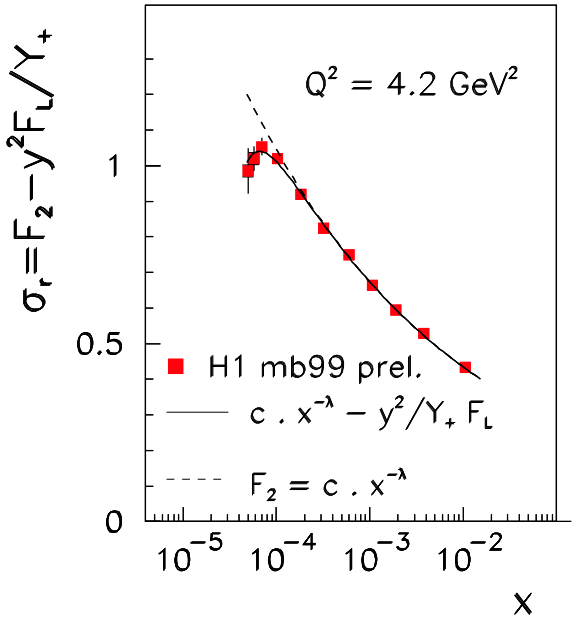
Errors rather insensitive to exact e^+/e^- sharing within reasonable limits

Total e^+ and e^- luminosity most important for significant progress





F_L and the Gluon at Low x



Gluon only indirectly determined in DGLAP fits

Important to test with jets, charm, $F_L \ldots \sim \alpha_s x g(x)$ (LO QCD)

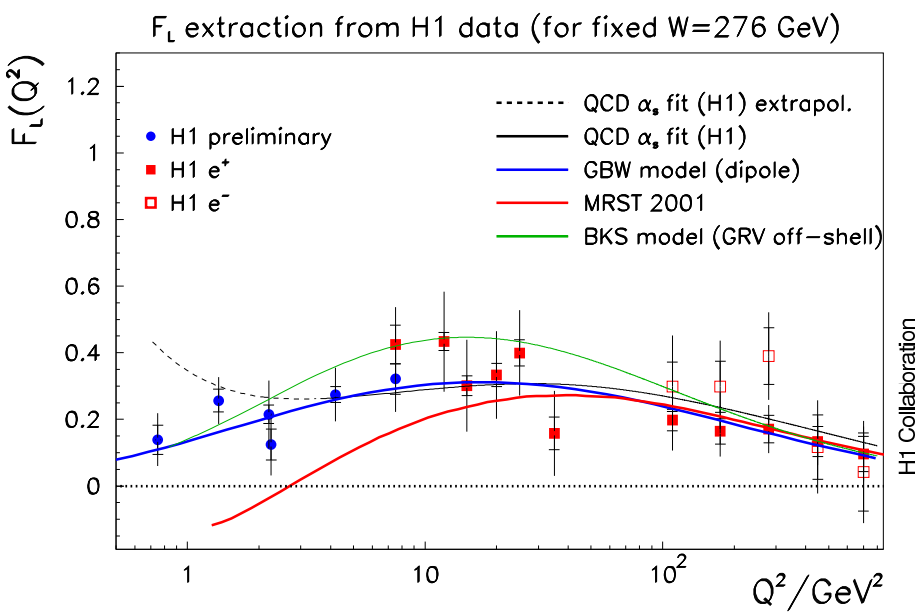
$$\tilde{\sigma} = F_2 - (y^2/Y_+)\, F_L$$

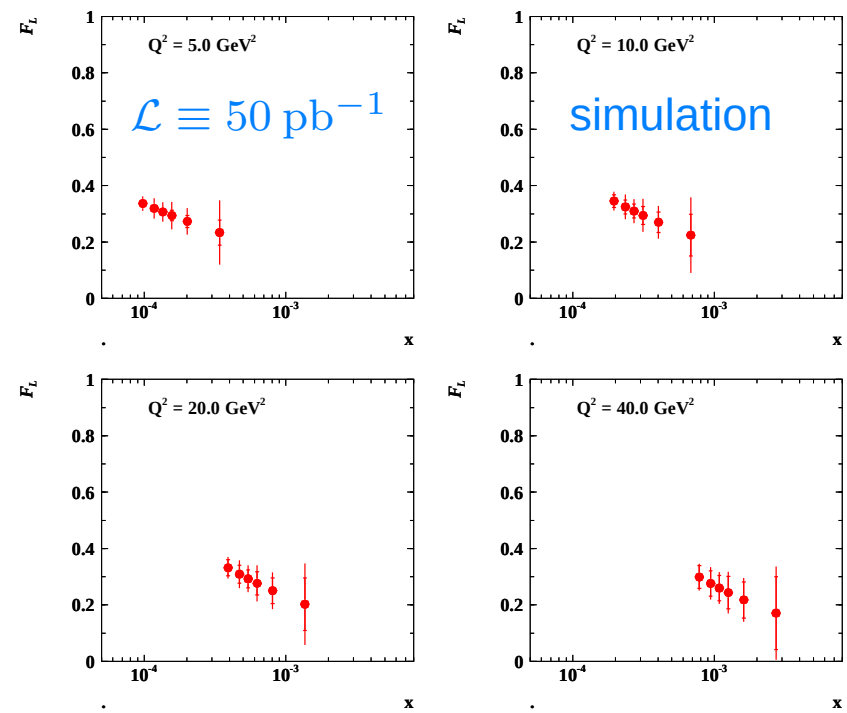
Sensitivity at highest $y \to 0.9 \quad (E'_e \to 3\ \mathrm{GeV})$

F_L determination spans 3 orders of magnitude in Q^2

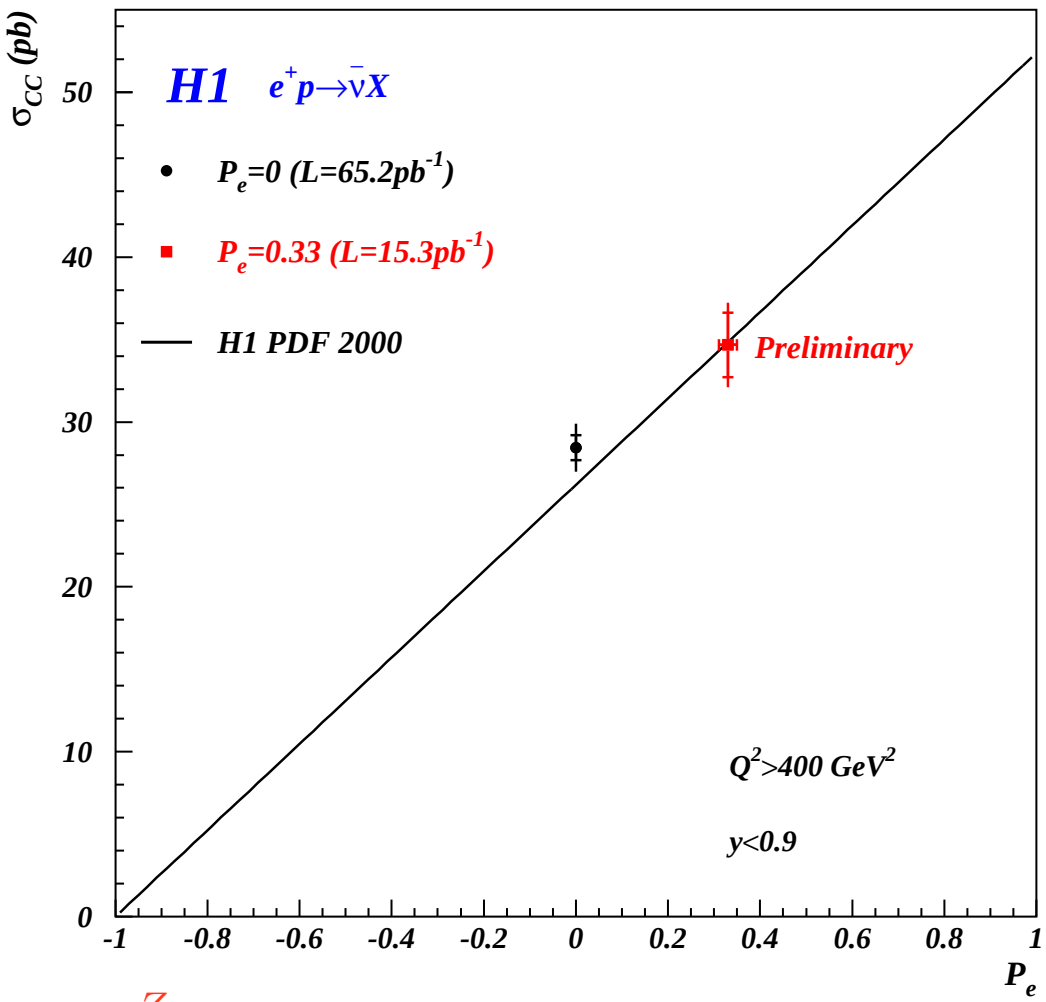
Distinguishes between DGLAP and other approaches at low Q^2

Better measurements from reduced E_p running $\longrightarrow$ relax F_2 assumptions and see x dependence





Polarisation and HERA-II



CC cross section has linear dependence on polarisation in Standard Model

First measurement of influence of lepton helicity on CC interactions in ep scattering

Polarisation $\sim 30\%$, Luminosity $\sim 15\ \mathrm{pb}^{-1}$

Effect established at $\sim 2.3\sigma$ level

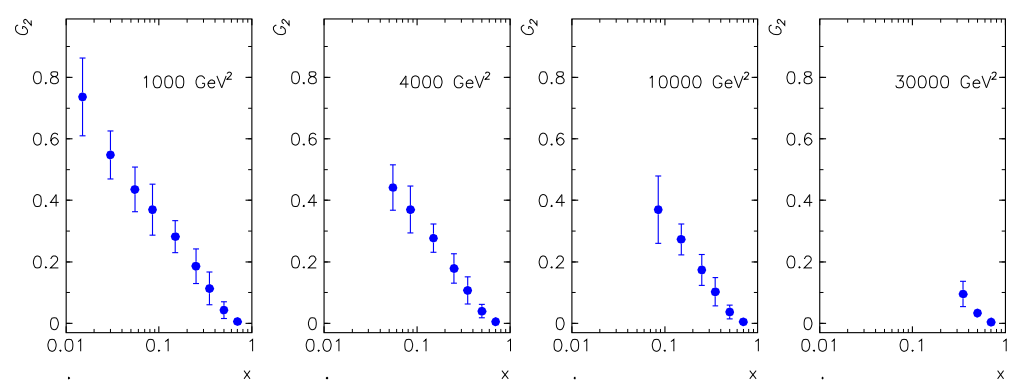
Similar luminosity collected with opposite helicity and $\sim 40\%$ polarisation

With larger luminosities, sensitivity to PDFs and electroweak couplings

eg $F_2^{\gamma Z}$ from NC polarisation asymmetry (e^+ or e^-, asymmetry $\propto P_e$)

$$F_2^{\gamma Z} \sim \frac{1+d/u}{4+d/u}$$

Simulation with $\mathcal{L} = 200\ \mathrm{pb}^{-1}$, $P_e = \pm 0.5$



Hadronic Final State Studies and QCD

Bulk of H1 physics programme concerned with understanding QCD through hadronic final state measurments (89/130 physics papers so far)

- Jet production and properties
- Open charm production
- Open beauty production
- Forward physics & QCD cascade dynamics
- Fragmentation
- Energy flow and particle spectra
- Diffractive cross sections / final states
- Tagged leading protons and neutrons
- Inclusive and exclusive vector mesons, DVCS
- Hadron spectroscopy . . .

Many of these measurements are statistically limited thus far

Theoretical progress $\longrightarrow$ most observables can be compared with NLO calculations

Improvements require highest possible $\mathcal{L}$, independently of beam charge or polarisation

Evidence for a Narrow Anti-charmed Baryon State

Following recent observation of θ^+ **pentaquark** in $K_s^0 p$ and $K^+ n$, search for charmed analogue

Use 'golden' charm decay channel $D^{*-} \to \bar{D}^0 \pi_s^- \to K^+ \pi^- \pi_s^-$ & c.c.

Combine with proton candidates from $\mathrm{d}E/\mathrm{d}x$ to form $M(D^* p)$

Clear signal with mass $3099 \pm 3\ (\mathrm{stat.})\ \pm 5\ (\mathrm{syst.})\ \mathrm{MeV}$ ... observed in γp and DIS

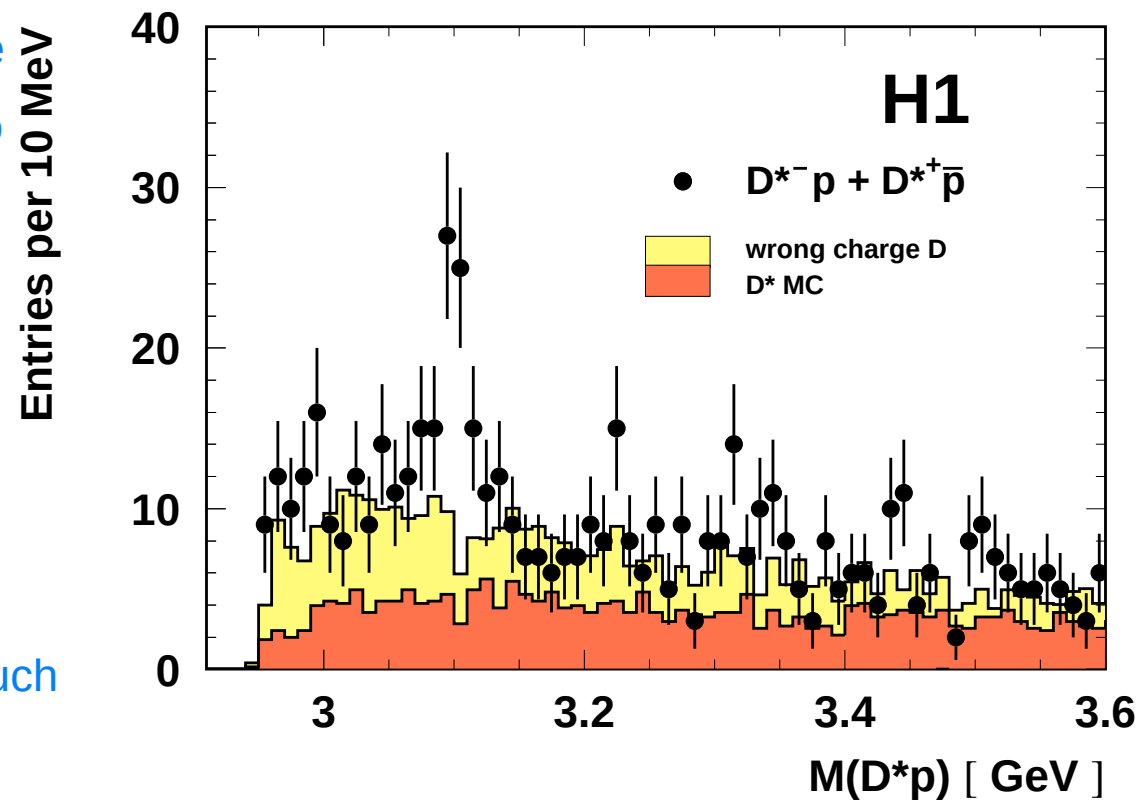
Background well modelled by wrong charge $K^\pm \pi^\pm$ combinations and D^* Monte Carlo

51 ± 11 events $\quad (75\ \mathrm{pb}^{-1})$

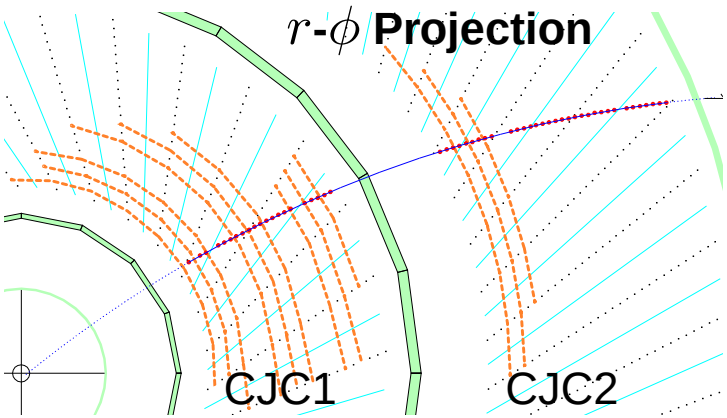
Compatible yields in $D^{*-} p$ and $D^{*+} \bar{p}$

As in strange case, width compatible with experimental resolution ($\sim 7\ \mathrm{MeV}$)

Minimal constituent quark composition of such a state is $uudd\bar{c}$ ... charmed pentaquark?



Fast Track Trigger Status



Required for continued triggering of interesting low p_T final states with track based signatures at high $\mathcal{L}$

L1: 2.3 µs	**L2**: 25 µs	**L3**: ≈100 µs
QT analysis, Track-Segment-Finding	Track-Segment-Linking, momenta, momentum sums	event reconstruction, jets, invariant masses, Δm…

Level 1

Hit finding with 95% efficiency

Track segment finding operational

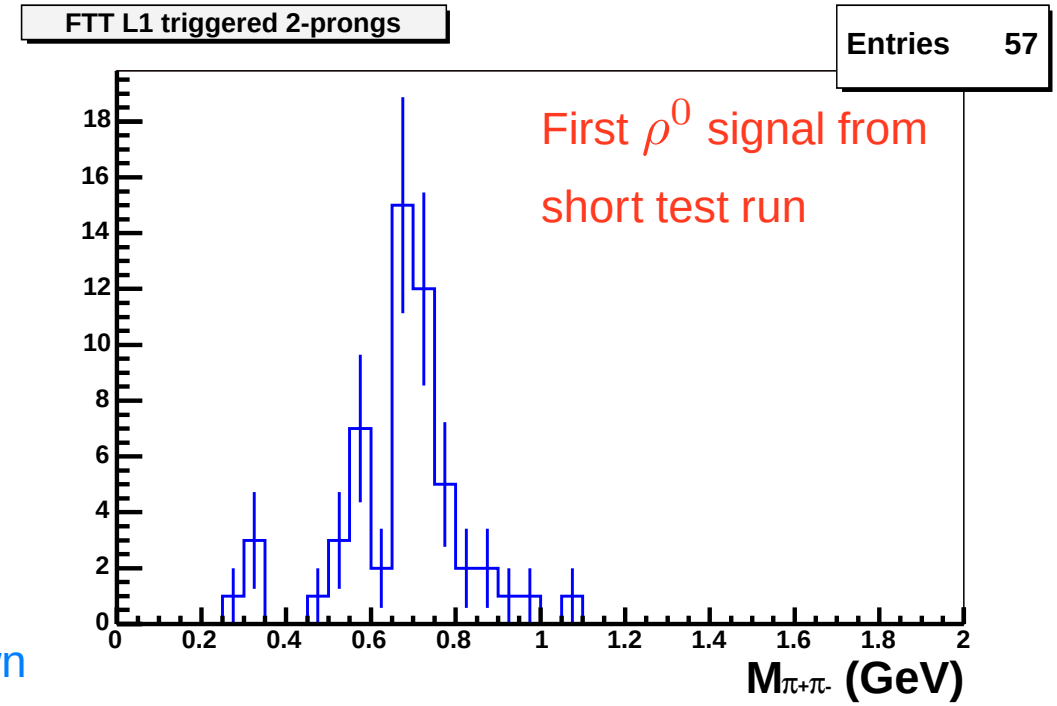
Coarse segment linking to form tracks

First L1 trigger implemented for exclusive vector mesons in events with no tagged electron

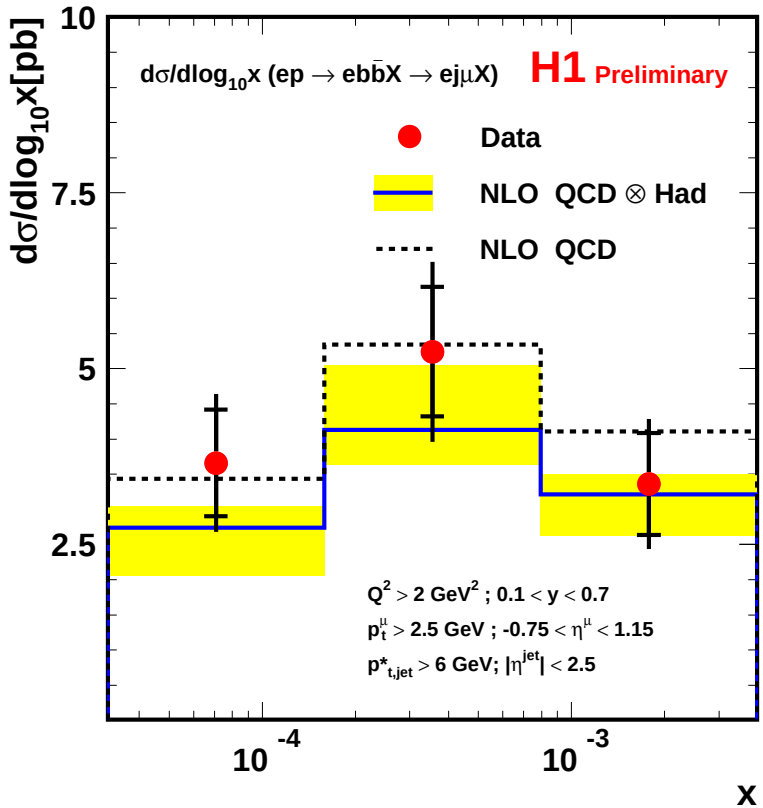
Level 2/3

Later stages of trigger being finalised

Aiming for full commissioning before shutdown



Recent Progress in Beauty Cross Sections



$\sigma(ep \to eb\bar{b}X \to e\mu jX)$ in DIS

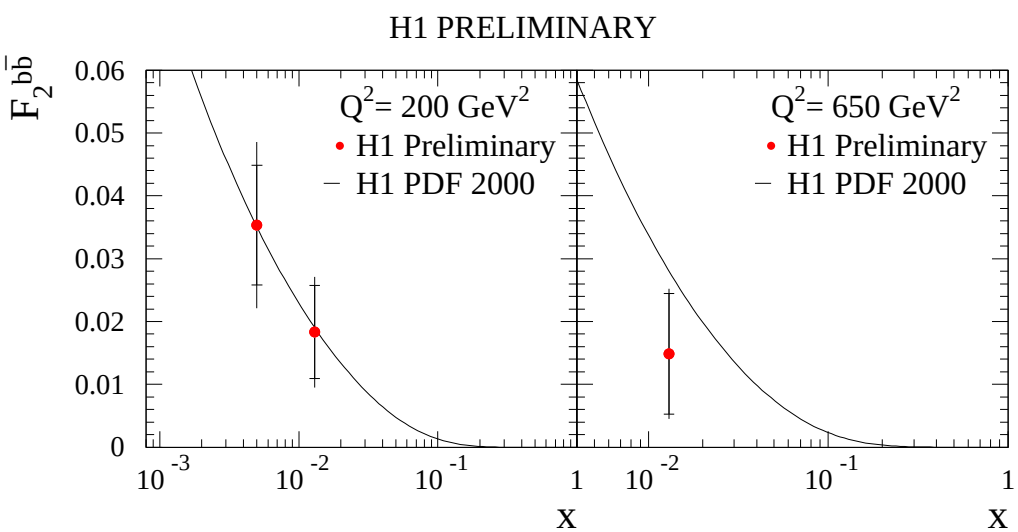
Use sample with muons associated with jets

Evaluate beauty contribution using @D fit to . . .

. . . muon impact parameter (silicon detector)

. . . p_T^{rel} of muon relative to jet

Results consistent with NLO QCD



Inclusive F_2^b (and F_2^c) in high Q^2 DIS

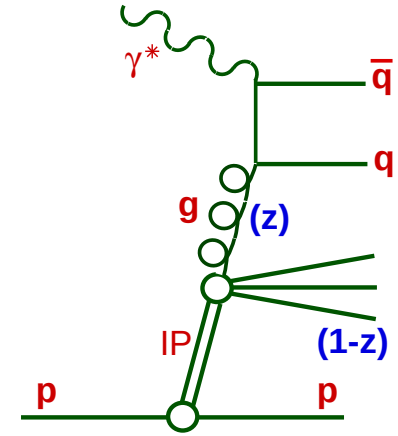
Inclusive secondary vertex sample from silicon

b, c contributions from fits to signed impact parameter distribution

For $Q^2 \gtrsim 100\ \mathrm{GeV}^2$, minimal extrapolation to inclusive b cross section

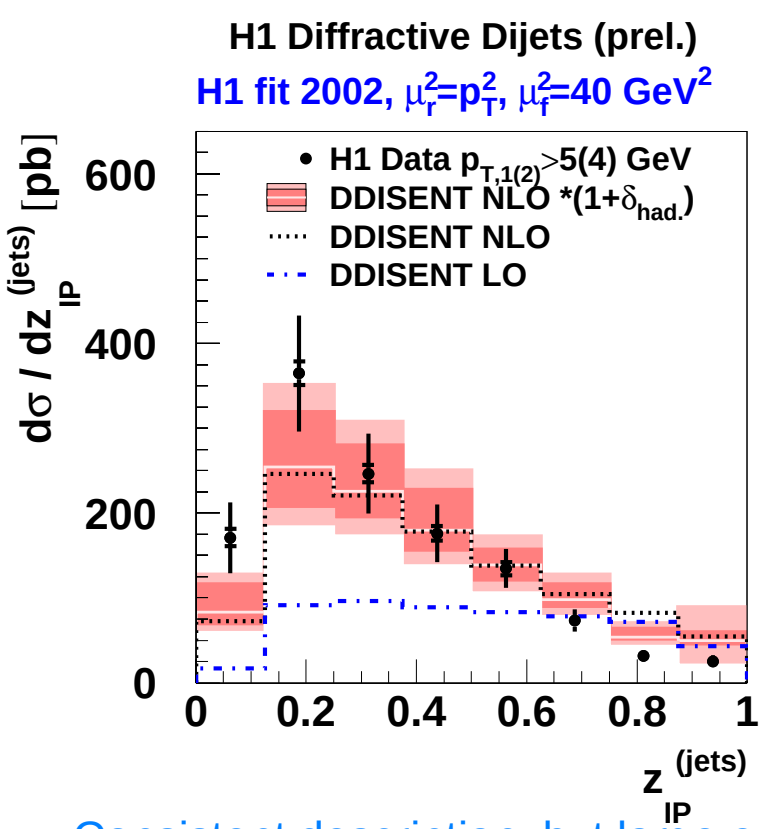
New technique!. . . First F_2^b measurement

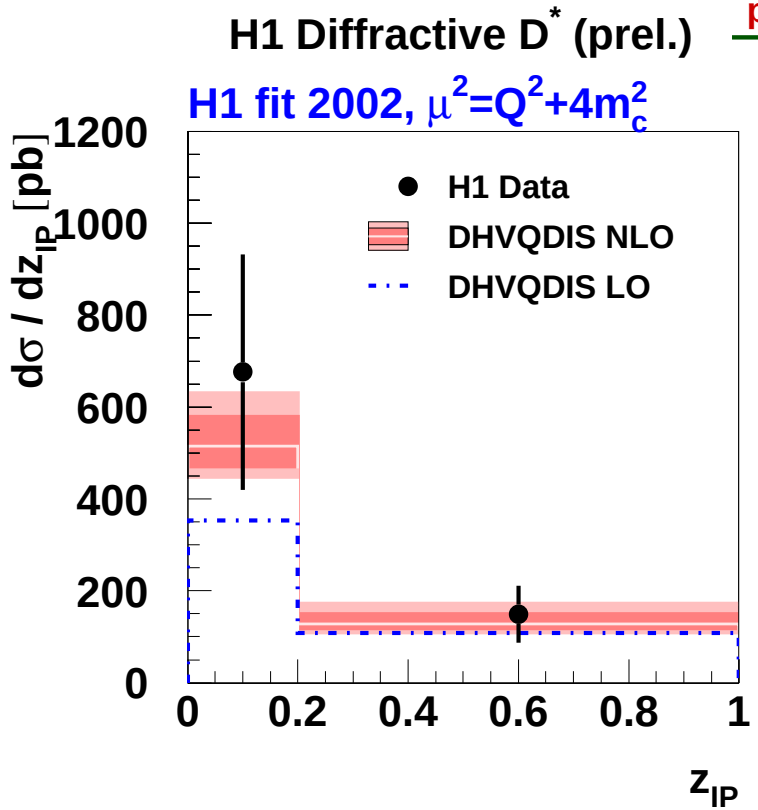
Diffractive final states and NLO QCD



Overlaps between different final state signatures give new sensitivities

e.g. test semi-inclusive QCD factorisation by predicting diffractive dijet and charm rates at NLO using diffractive parton densities from F_2^D



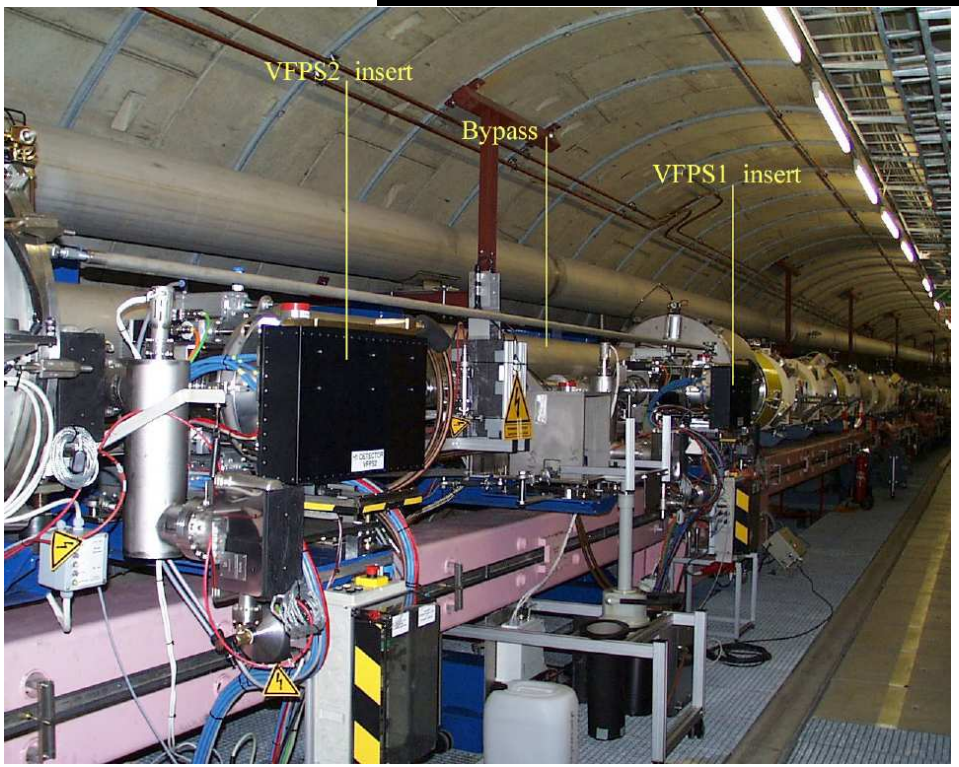


Consistent description, but large experimental and theoretical errors

Further progress needs high statistics data at fixed $x_{I\!P}$ and better systematics

Also improved theoretical errors . . . Relax “Regge” factorisation assumption, go to higher scales

Status of Very Forward Proton Spectrometer



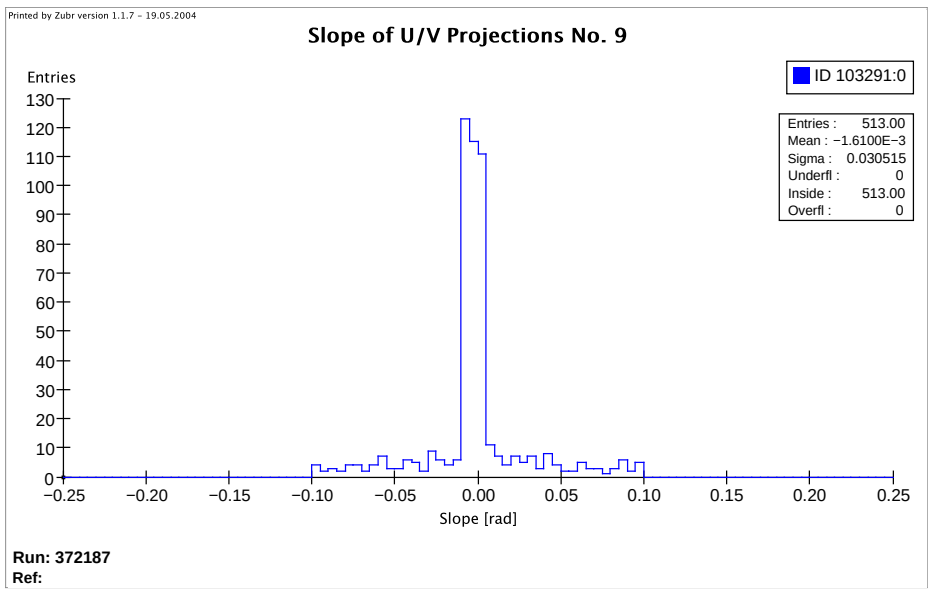
2 Roman pot stations near $z = 220\ \mathrm{m}$

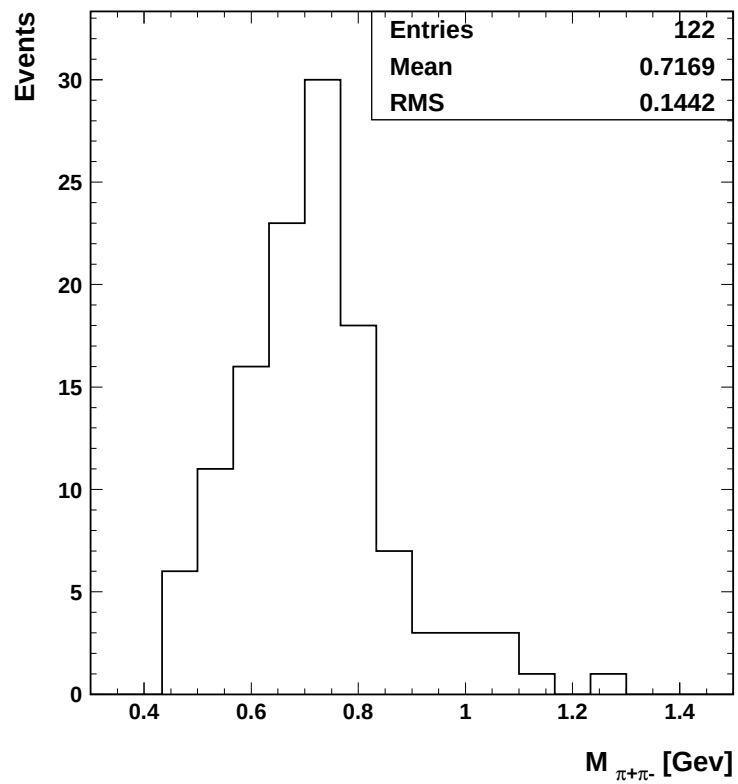
. . . Efficient triggering and measurement of leading protons in interesting region $|t| < 1\ \mathrm{GeV}^2, x_{I\!P} \sim 0.01$

Track reconstruction working . . . clear forward peak

First level 1 trigger implemented

Clear ρ peak (untagged γp) from short test run





Summary

- **Ongoing analysis of HERA-I data**

  . . . Many new measurements and techniques

- **Detector in good shape and taking high quality HERA-II data**

  . . . First physics results obtained with polarised leptons

- **Top future priority is highest possible luminosity as soon as possible**

  . . . New level of precision in broadest range of physics topics

  Can be realised with e^+ running, also necessary to clarify high p_T anomalies

  e^- data of interest for some searches and electroweak physics

  Reduced E_p running required for F_L, high x, moderate Q^2 and W dependences

- **H1 Collaboration remains firmly commited to full HERA-II programme**