Measurement of Inclusive Diffractive Deep Inelastic Scattering Using VFPS at H1

Tomáš Hreus
Université Libre de Bruxelles

On behalf of the H1 Collaboration

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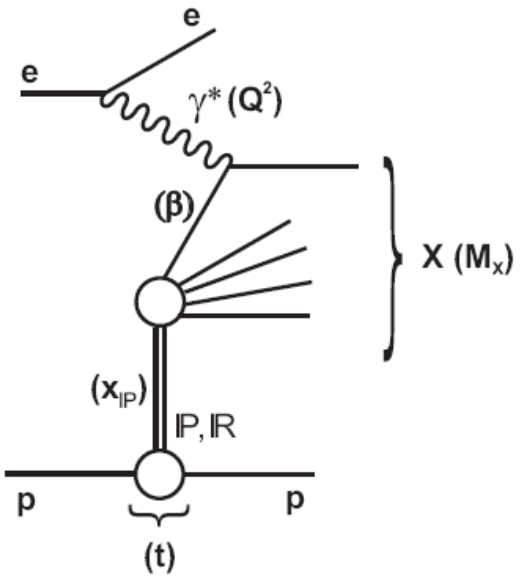
Diffraction at HERA

At HERA, 10% of low-*x* DIS events are diffractive



additional kinematics defined wrt DIS:

x_{IP}: momentum fraction of colour singlet exchange

β: momentum fraction of struck quark

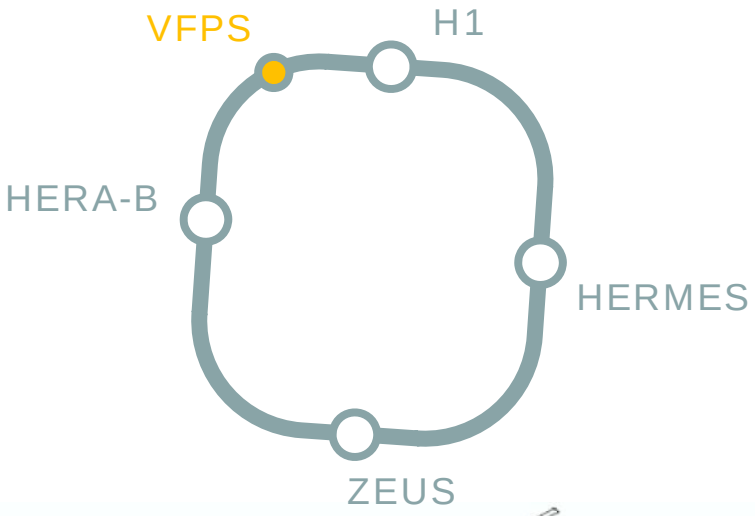
t: 4-momentum transfer squared

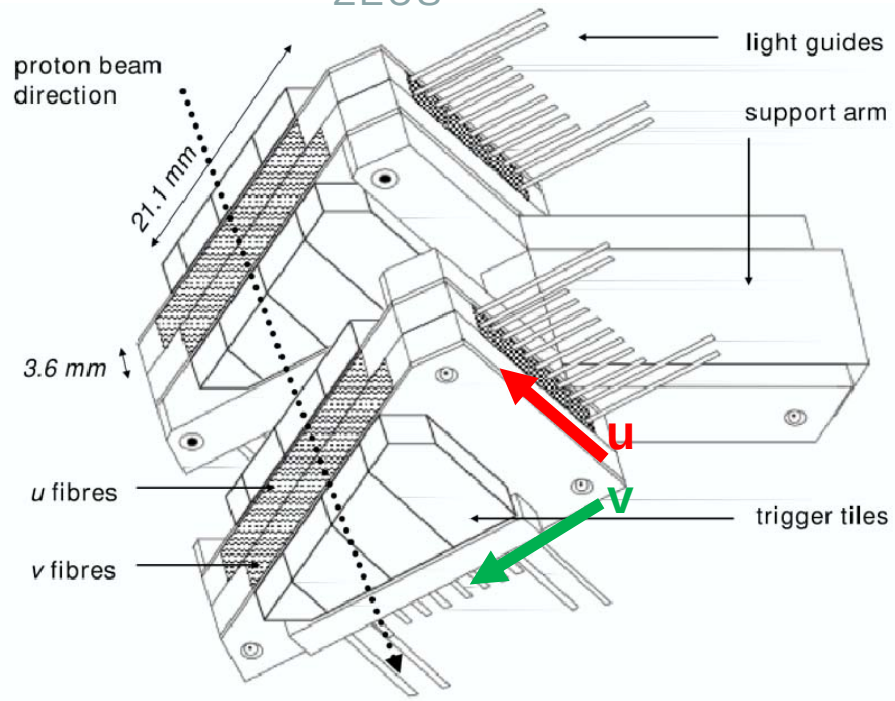
Probe QCD structure of colour singlet

HERA1: measurements of F2D limited: statistically (using proton spectrometer) or systematically (LRG method: proton dissociation background)

HERA2: luminosity upgrade, **new Very Forward Proton Spectrometer** with high acceptance and low background

A Very Forward Proton Spectrometer in H1





- VFPS location is optimised for acceptance: 220m from IP, using bending of HERA beam

- proton beam is approached horizontally

- VFPS in cold section: bypass needed to re-route the cold beam line segments
  - 10m drift section replaced by a new warm beam pipe

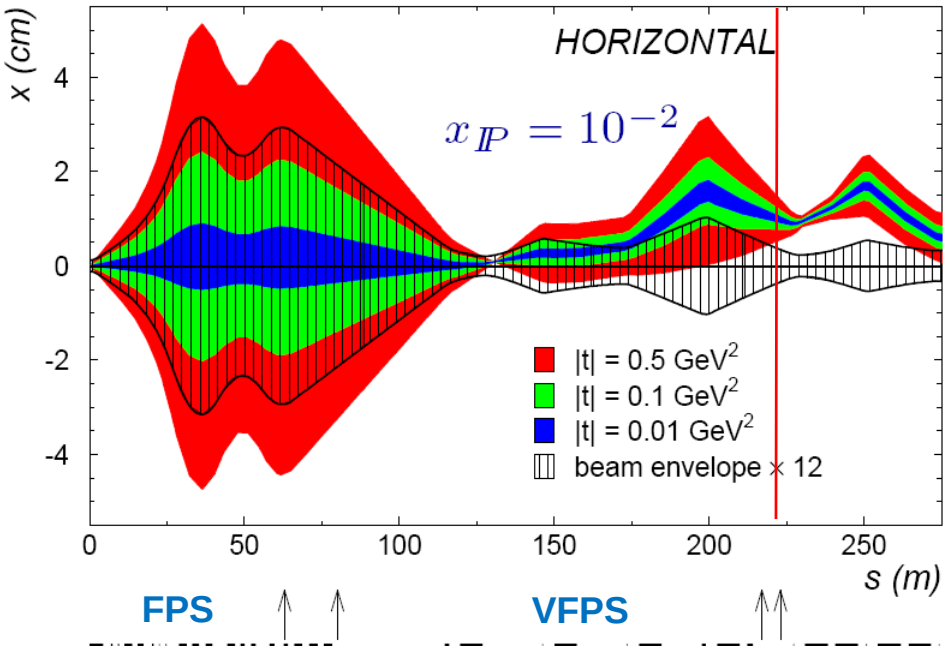
Detectors:

- 2 retractable “Roman Pot” stations (218m, 222m) equipped with 2 scintillating fibre detectors each

- 1 fibre detector measures both ***u*** and ***v*** track coordinates

- 4 Trigger Tiles / plane, 4 planes per RP (deliver a Level1 trigger signal)

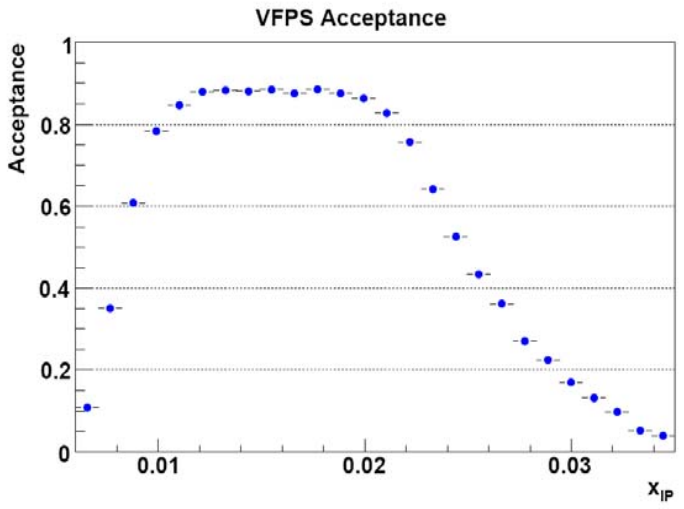
VFPS: Acceptance

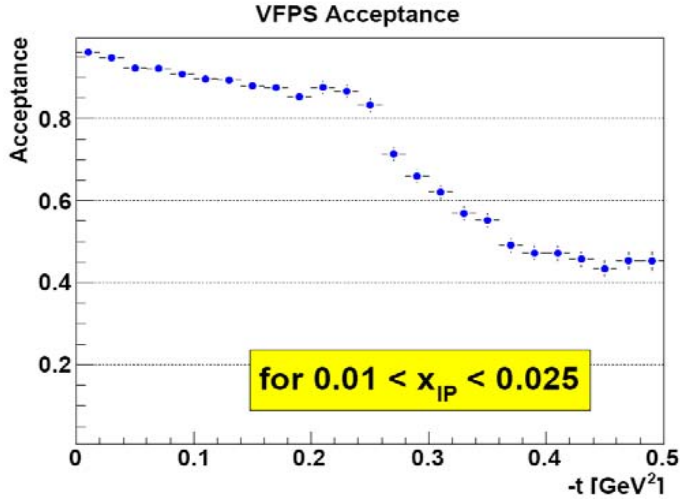


- acceptance is highest between

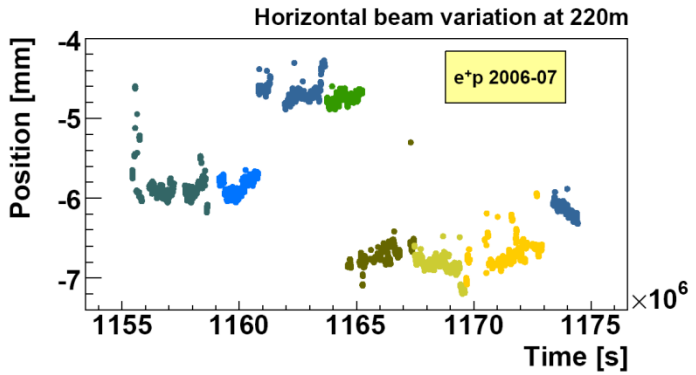
  $0.006 < x_{IP} < 0.025$ and $|t| < 0.25$ GeV^2 (down to lowest |t|)

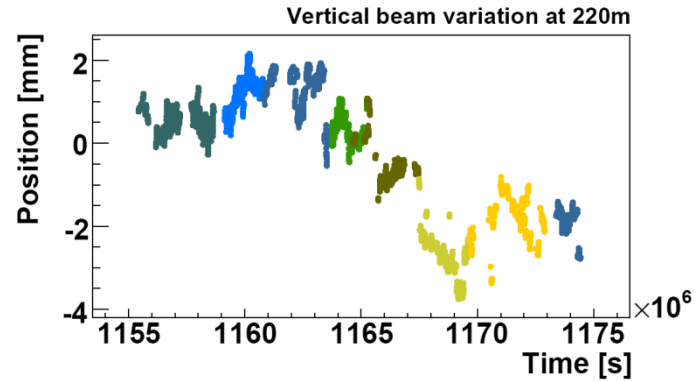
and depends on **VFPS position** during run (affects low x_{IP})

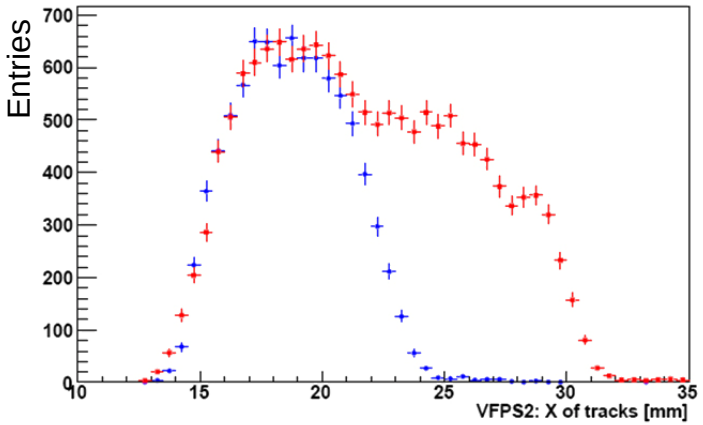




VFPS Detector: Calibration





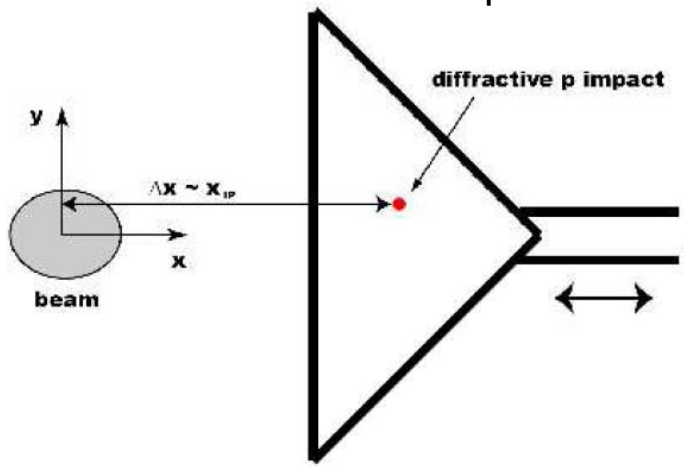


(bump: ● 1mm ● 6mm)

To increase acceptance, a HERA-operated local beam bumps were applied during 2006/07

- beam position is measured by monitors (by current induction) and corrected on event-by-event basis

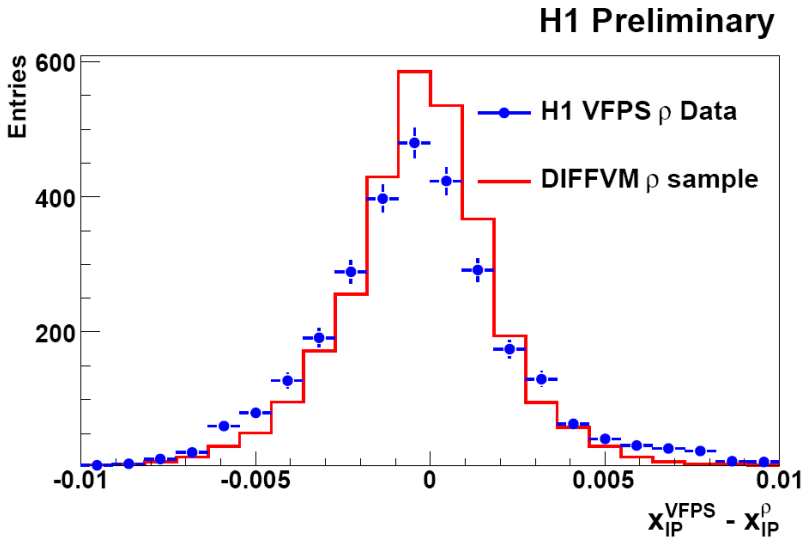
- x_{IP} is reconstructed assuming linear (and t=0) approximation after a calibration procedure

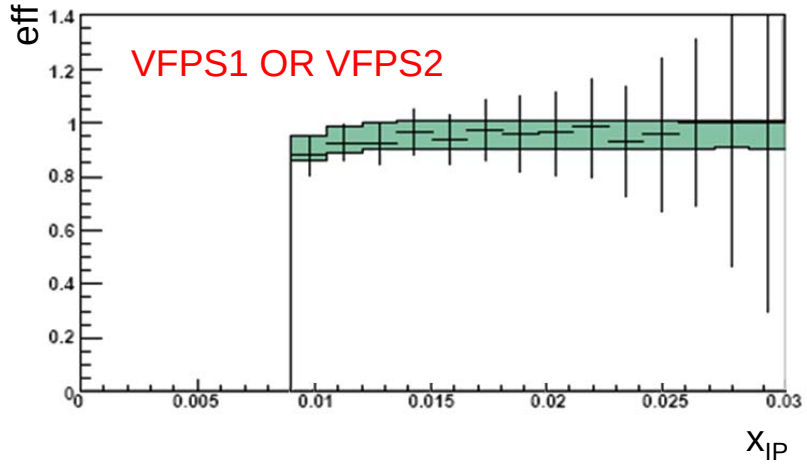


x_{IP} = ***A*** * VFPS_track_x + **B**

- distance in x-coor between the beam center and VFPS impact gives the x_{IP} value (more complete calibration allowing reconstr. of p_x and p_y to follow)

Calibration & Track Efficiency: ρ x-check





- cross-check of the calibration with ρ events

$$e+p \rightarrow e + \rho + p$$

$$\downarrow$$

$$\pi+\pi-$$

- comparing x_{IP}^{ρ} reconstructed from ρ decay tracks to x_{IP}^{VFPS} reconstructed using VFPS

- check independent of MC, shows that x_{IP} is correctly reconstructed from VFPS

absolute calibration 5%
resolution 12%

- simulation of VFPS track reconstruction efficiencies cross-checked using ρ in DIS data sample

track efficiency 96% +/- 4%

Motivation & Event Selection

$$\frac{d^3\sigma^{ep\to eXp}}{dQ^2 d\beta dx_{IP}} = \frac{4\pi\alpha^2}{\beta Q^4} \cdot \left(1 - y + \frac{y^2}{2}\right) \cdot \sigma_r^{D(3)}(Q^2, \beta, x_{IP})$$

- free of proton dissociation (VFPS is at 220m)
- high acceptance in $0.006 < x_{IP} < 0.025$ and $|t| < 0.25$ GeV^2
  - low normalisation uncertainty (5%)
- improved resolution in x_{IP} and β (both reconstructed from VFPS)

Using H1 data collected in 2006 and 2007 (e^+p reactions, $s^{1/2}$ = 319 GeV), integrated luminosity when VFPS was in operation (close to beam): **87.4 pb^{-1}**

Kinematic reconstruction:

$$\begin{aligned} y &= y_{el}^2 + y_{da}(1 - y_{da}) \\ Q^2 &= 4E^2(1-y)/\tan^2(\theta_{e'}/2) \\ x_{IP} &= A \cdot \text{VFPS-track-X} + B \\ \beta &= x/x_{IP} \end{aligned}$$

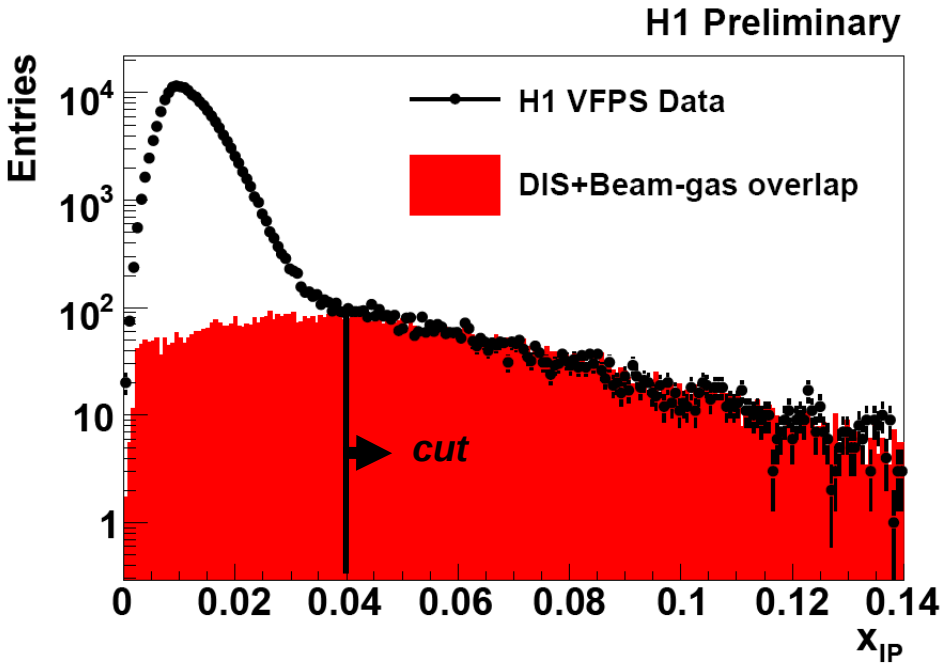
Basic event selection:

scattered electron energy	> 10 GeV
reconstructed vertex	needed
VFPS trigger	either of VFPS stations
VFPS tracks	either of VFPS stations
y (inelasticity)	> 0.02

Kinematic range:

$$\begin{aligned} 4.5 &< Q^2 < 100\ \text{GeV}^2 \\ 0.008 &< \beta < 1 \\ 0.009 &< x_{IP} < 0.026 \end{aligned}$$

Beamgas+DIS Background Estimate



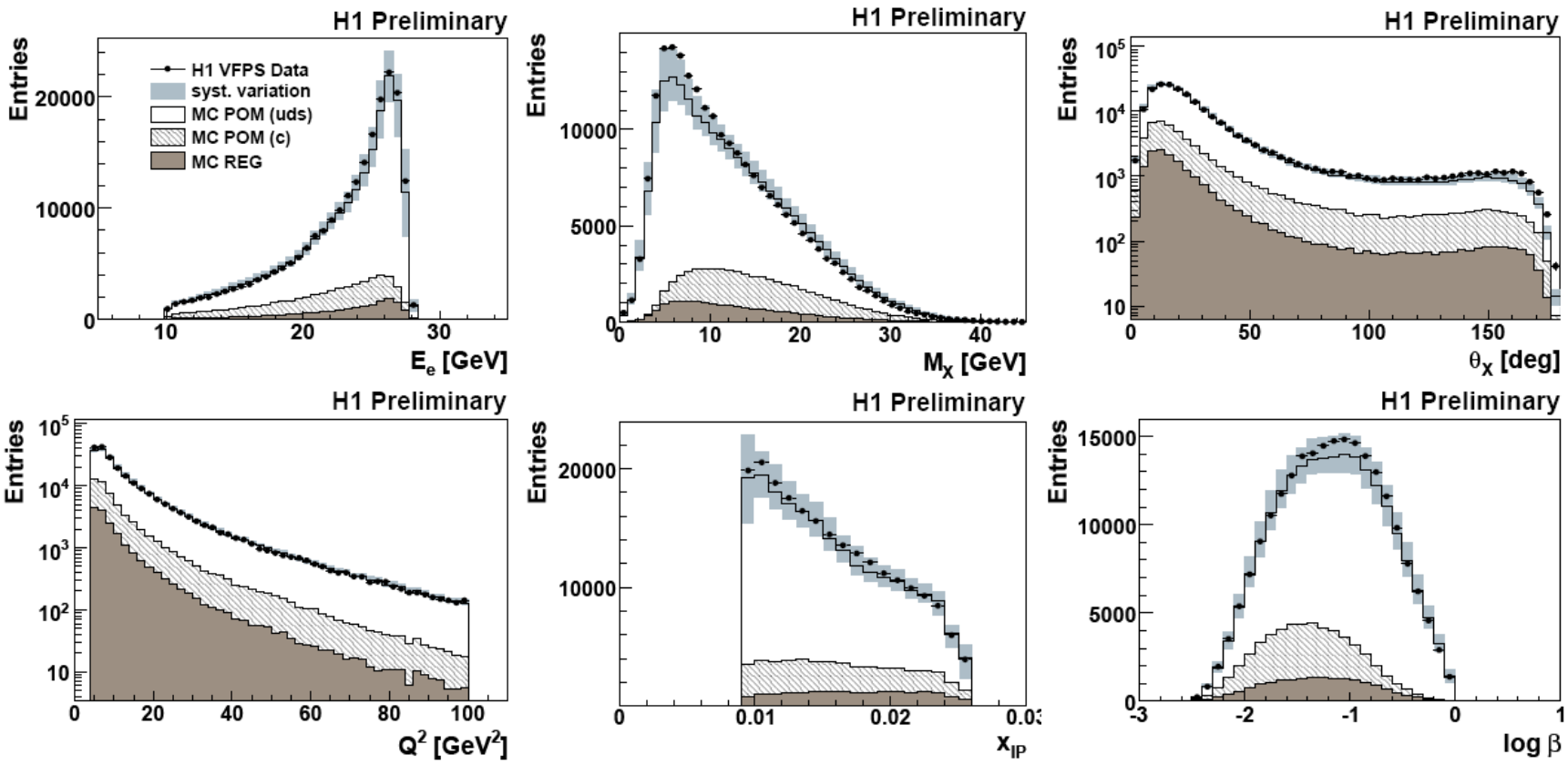
- Want to estimate the contamination from the beam-gas events in VFPS with an overlap of the DIS event in the main H1.

$$\begin{cases} ep \rightarrow eX \\ pA \rightarrow p(A') \end{cases}$$

- background estimated from data (using independent trigger) to be **2%** for x_{IP} (main H1) < 0.04 (analysis cut)

- low background: proton beam bending supresses the beam-gas protons accumulated in the straight section around interaction point

Control Plots



- MC: RAPGAP31 with H1 2006 DPDF Fit B (scaled to M_p)
- good agreement between Data and MC within total systematics

Dominant Systematics & Cross Section

Dominant Detector Systematics

source	shift	error (max)
VFPS track eff	4% (norm.)	4%
VFPS trig eff	1% (norm.)	1%
x_{IP} calibration (B)	5%	5%
x_{IP} calibration (A)	5%	8%
VFPS x-position calibration	400 microns	2%

Model Systematics

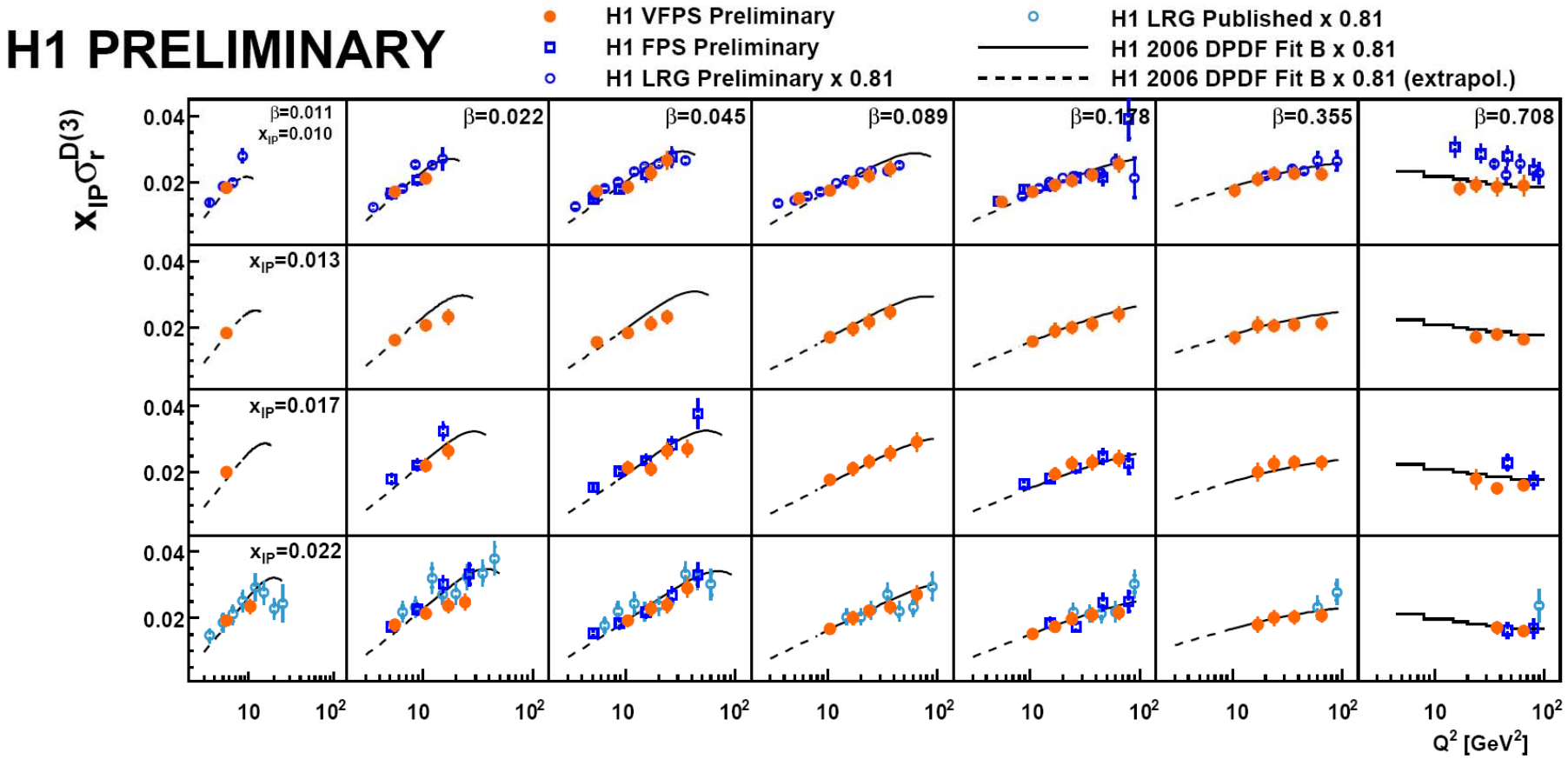
source	reweight	error (max)
x_{IP}	1/xp ^ +-0.1	1%
β	1/β ^ +-0.05	3%
t	e ^ +-t	1%

total systematic error: 8% - 14 %

$$\sigma_{r,i}^{D(3)}(Q^2,\beta,x_{IP}) = \frac{N_i^{data}\cdot(1-B)}{N_{RAD,i}^{MC}}\cdot\sigma_{r,i}^{D(3),BORN}(Q^2,\beta,x_{IP})$$

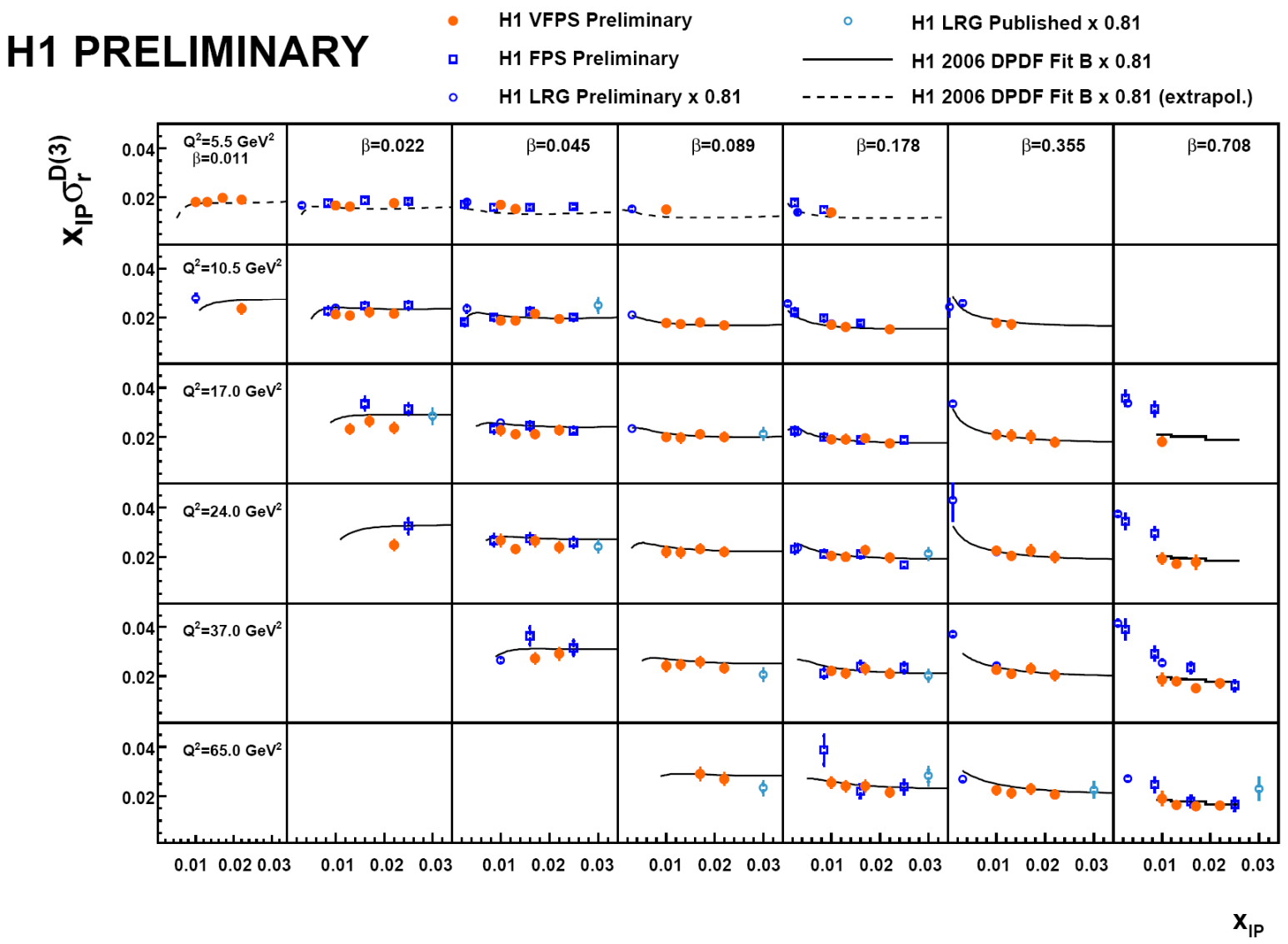
- B = 2%, a global subtraction of beam-gas events
- theoretical prediction averaged over the bin volume
  - important effect at large β, where DPDFs have complicated shape

Reduced Cross Section

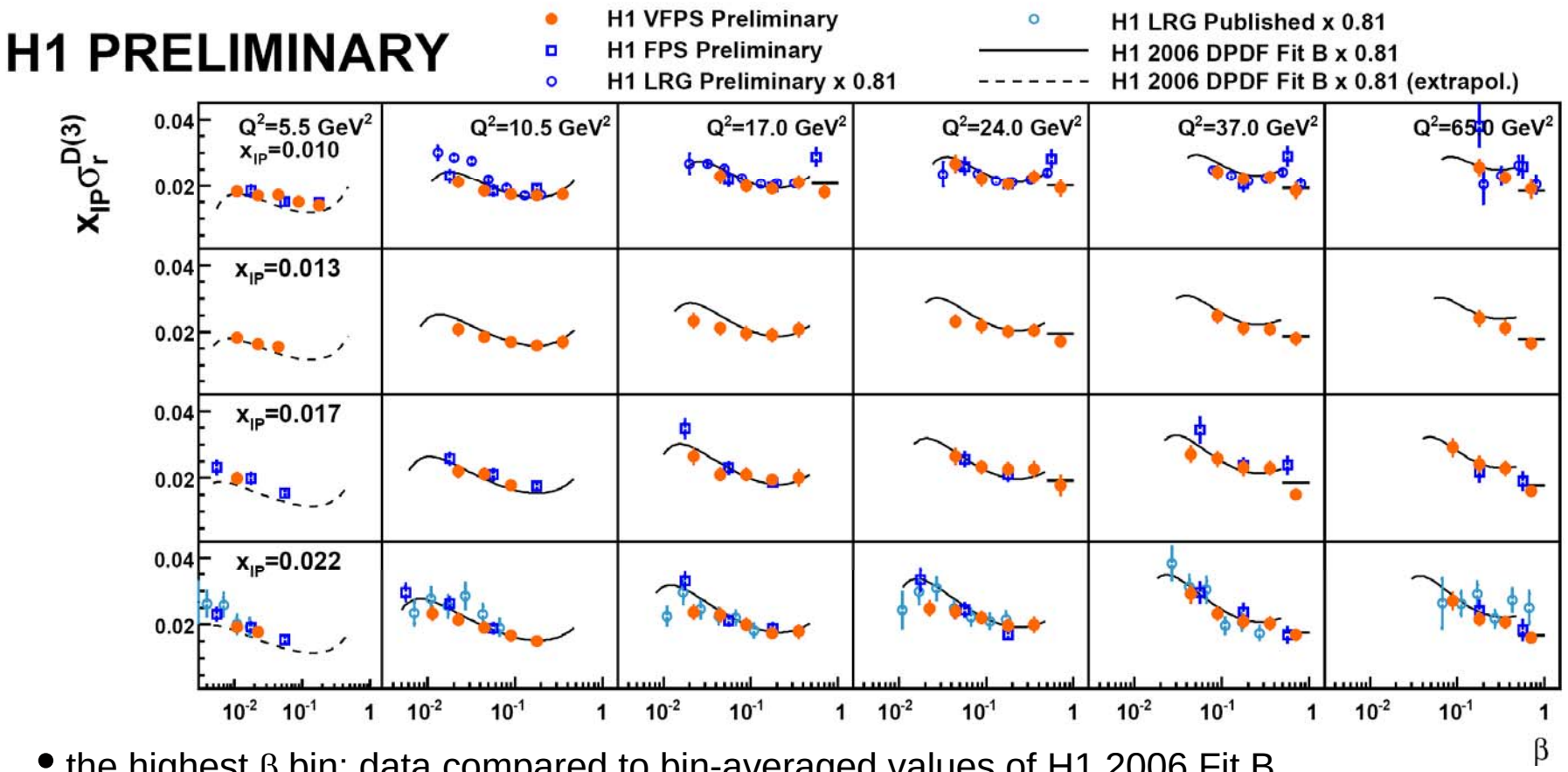


- scaling violations
- higher precision in x_{IP} – thinner binning
- improved normalisation uncertainty (5%)
- very good agreement with H1 2006 Fit B, scaled to proton mass (from M_Y < 1.6 GeV)
  - highest β bin: comparison to bin-averaged values

Reduced Cross Section

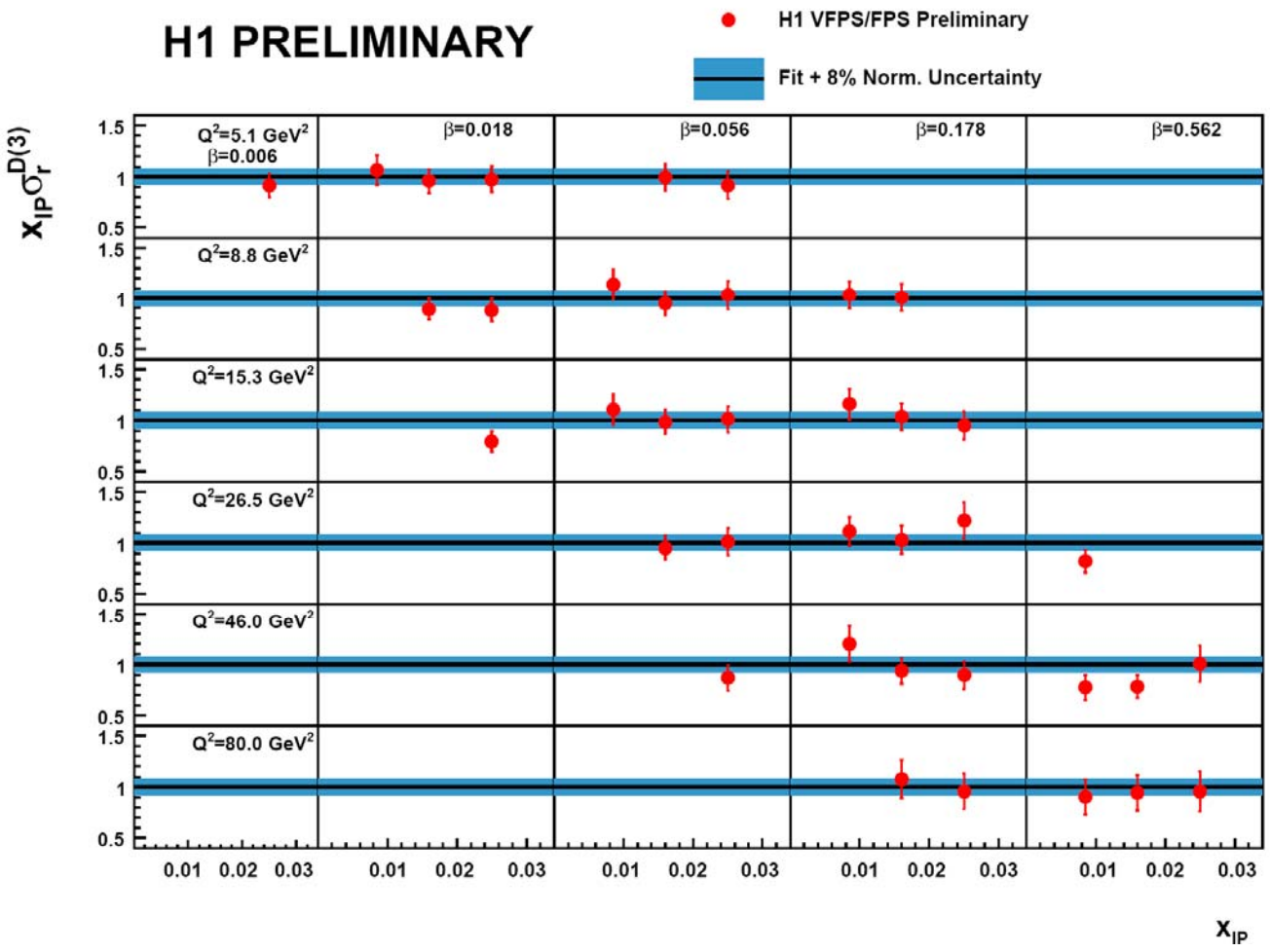


Reduced Cross Section



- the highest β bin: data compared to bin-averaged values of H1 2006 Fit B

Ratio VFPS / FPS (x_{IP})



- best is to compare measurements with tagged proton
  - no proton dissociation uncertainty
  - many systematic cancel

- analysis redone in FPS binning

ratio VFPS / FPS = 0.96 +/- 0.02 (stat) +/- 0.11 (syst) +/- 0.08 (norm)

- ratio stable in all points

conclusions

- VFPS took data during 2005-2007
- first measurement done with VFPS detector, based on 2006/07e+ data
- improvement of x_{IP} and β resolutions with respect to other methods
- VFPS normalisation uncertainty 5%
- up to now conservative systematics, possibility of improvement
- very low background contamination (2%)
- diffractive reduced cross-section measured, in agreement with
  - H1 2006 DPDF Fit B
  - H1 LRG measurements
  - H1 FPS measurement

BACKUP SLIDES

Reduced Cross Section