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On behalf of H1 and ZEUS Collaborations

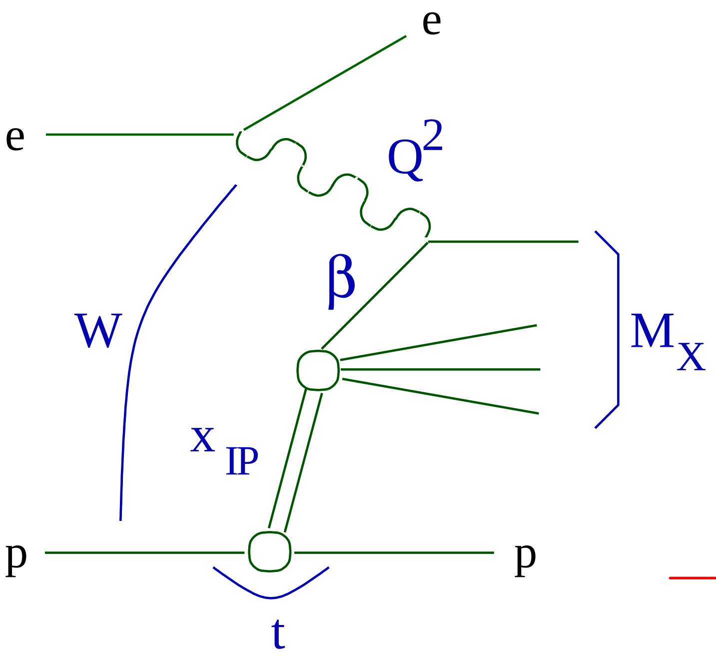
Leading proton detectors at HERA
Past experience and future plans

Xth Blois Workshop on Elastic and Diffractive Scattering

Helsinki, Finland, June 23rd - 28th, 2003

Diffraction at HERA

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



Q^2 , x (or W) , M_X (or M_{VM})

$x_{I\!P}$: momemtum fraction of colour singlet exchange

β : fraction of exchange momemtum of struck q

$$x = x_{I\!P}\,\beta$$

t : 4-momemtum transfer squared

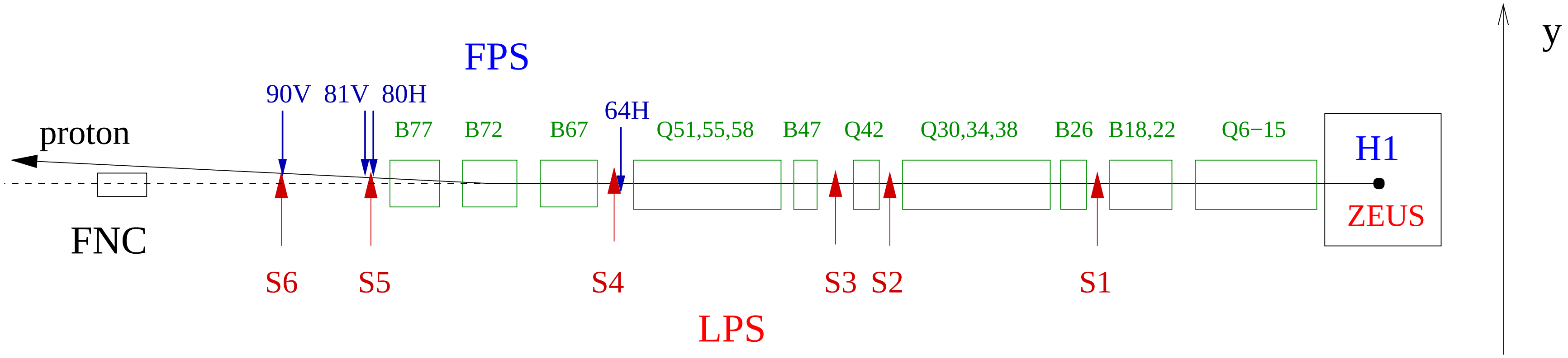
$\longrightarrow$ Probe QCD structure of colour singlet

HERA I: Measurments of F_2^D, jets, charm, Vector Mesons, DVCS,...

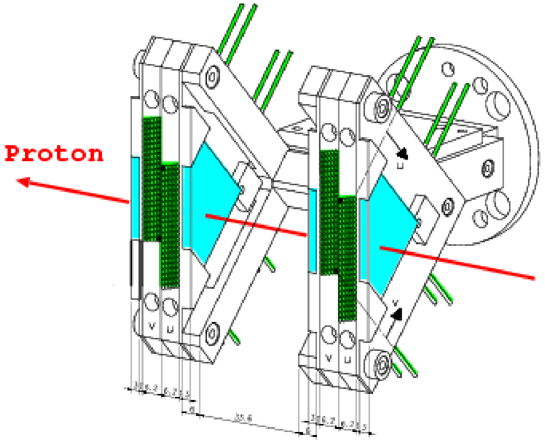
BUT Statistically (exclusive channels) and/or
Systematically (proton dissociation) limited

HERA II:
- High luminosity regime, e polarisation
- New forward proton spectrometer in H1
  $+$ t-dependences

HERA I Proton Spectrometer

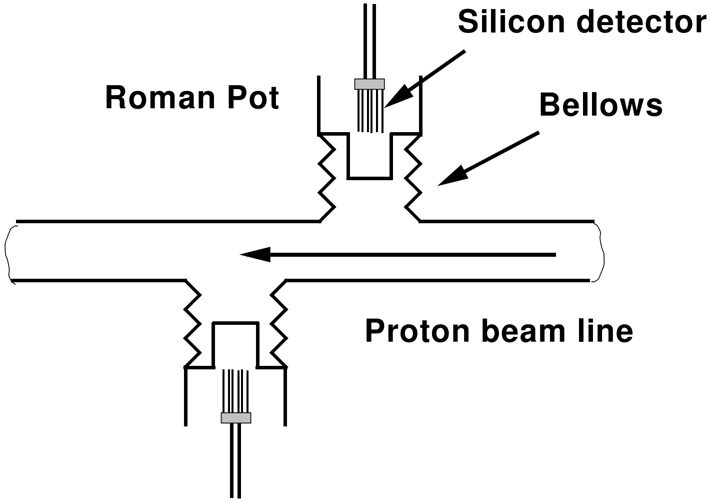


Forward Proton Spectrometer



Scintillating fibre detector

Leading Proton Spectrometer

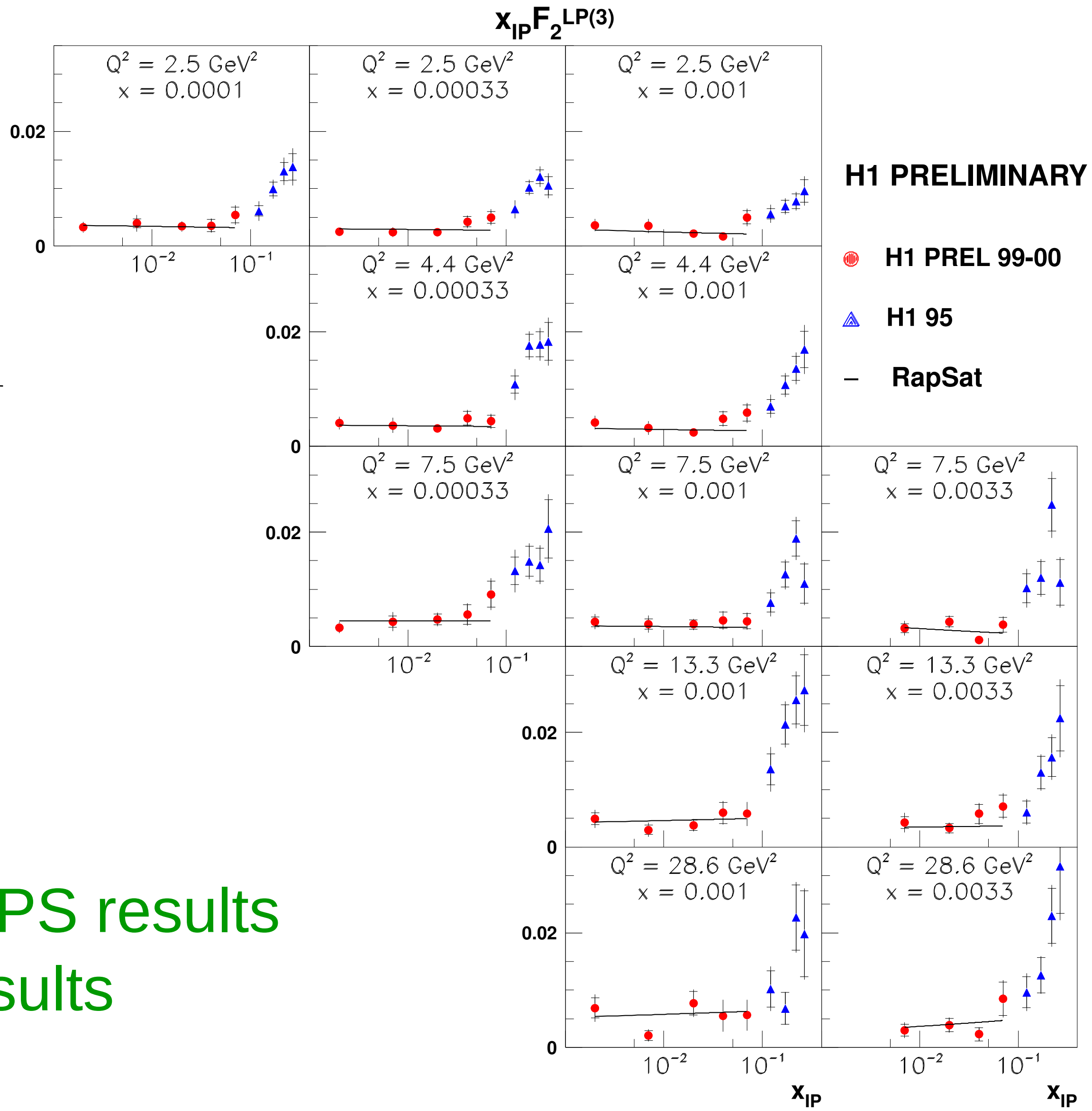


Silicon Micro-Strip Detector

- Free of dissociation bkgd
- p 4-momemtum measurment $\longrightarrow$ t
- Low statistic (acceptance)

HERA I Results: $F_2^{D(3)}$

$$\frac{d^4\sigma_{ep\to eXp}}{dQ^2 dx_{I\!P} dt d\beta} = \frac{4\pi\alpha_{em}^2}{\beta Q^4}\left(1-y+\frac{y^2}{2}\right) F_2^{D(4)}(Q^2, x_{I\!P}, t, \beta)$$



Horizonal FPS Stations:

- Few % acceptance at high $|t|$ and low $x_{I\!P}$
- 99/00 data : 28.8 pb^{-1}

Vertical FPS Stations:

- Large acceptance at low $|t|$ and high $x_{I\!P}$
- 1995 data : 1.4 pb^{-1}

Compatible with ZEUS LPS results and with Rapidity gap results

BUT statistically limited

HERA I Results: t Measurement

$$|t| < 0.4 \text{ GeV}^2$$

($|t| > 0.08 \text{ GeV}^2$ for FPS)

$$\frac{d\sigma}{dt} \propto e^{-b|t|}$$

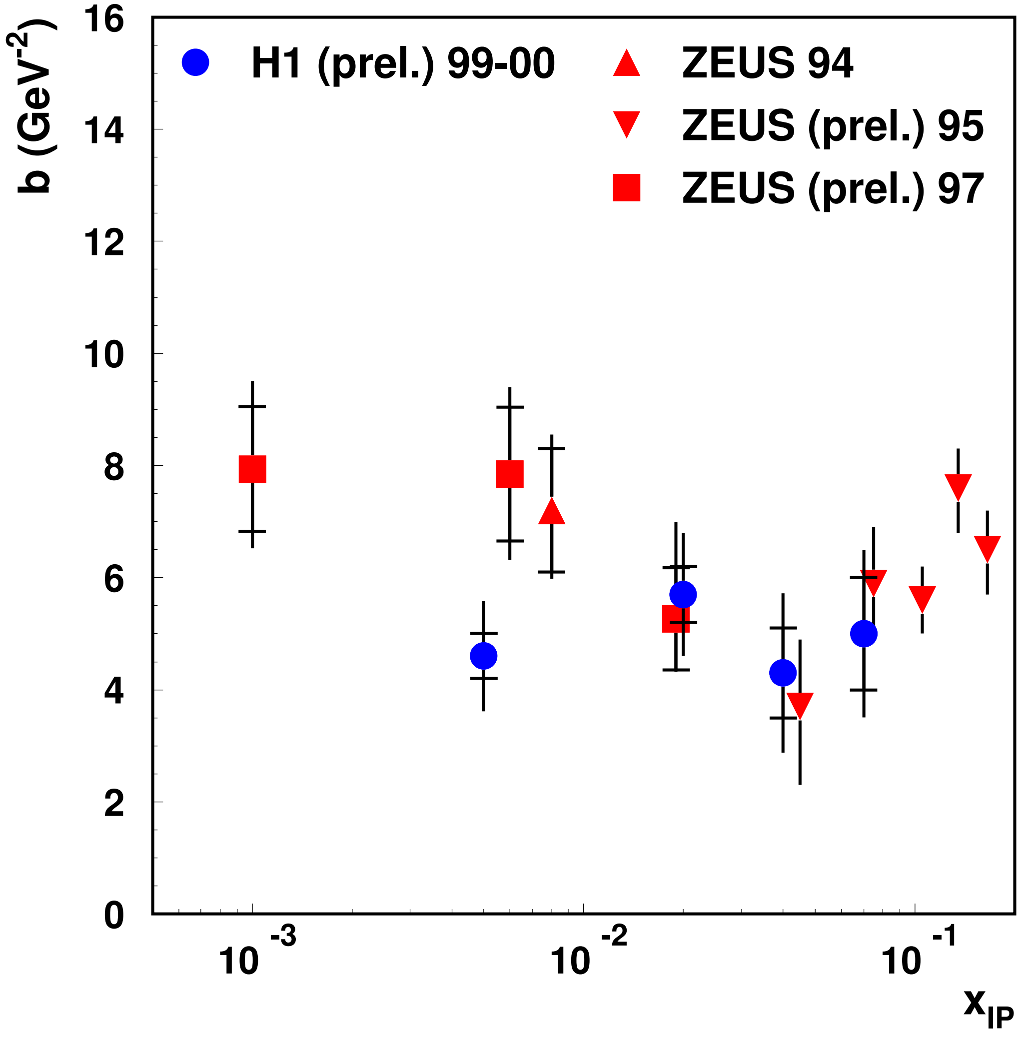
Regge phenomelogy :

Expect shrinkage with W

$$b = b_0 + 2\alpha'_{I\!P} \log 1/x_{I\!P}$$

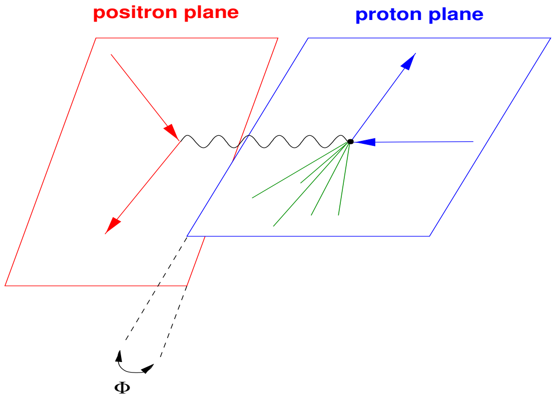
$\longrightarrow$ Inconclusive so far

$\longrightarrow$ Need more data



$$W^2 \sim M_X^2 / x_{I\!P}$$

HERA I Results: ϕ Measurement



$\frac{d\sigma^D}{d\phi}$ sensitive to σ_L^D through interference term :

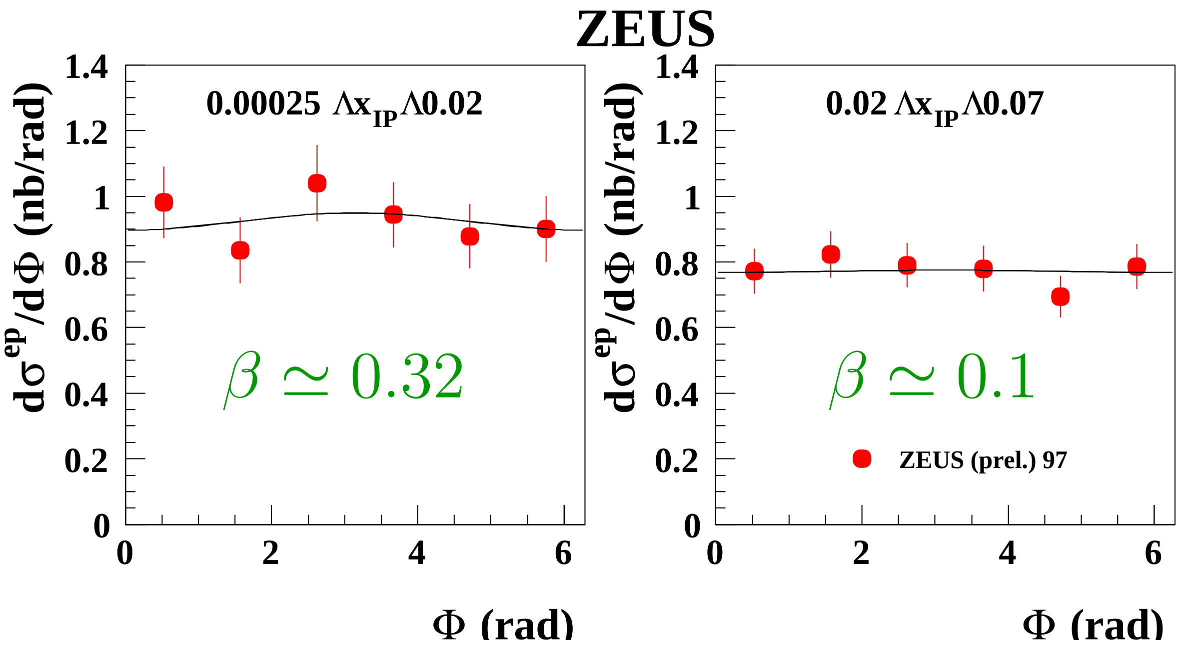
$$\frac{d\sigma^D}{d\phi} \propto \sigma_T + \sigma_L - 2\sqrt{\epsilon(1+\epsilon)}\sigma_{LT}\cos\phi - \sigma_{TT}\cos 2\phi$$

Fit assymetries :

$$\frac{d\sigma^D}{d\phi} \propto 1 + A_{LT}\cos\phi$$

$\longrightarrow$ Assymetries small

BUT high β not covered



$$A_{LT} = -0.029 \pm 0.066^{+0.026}_{-0.047} \qquad = -0.005 \pm 0.052^{+0.048}_{-0.047}$$

The H1 Very Forward Proton Spectrometer

Tag and measure the scattered proton at HERA II with large acceptance at low $x_{I\!P}$ and down to lowest t

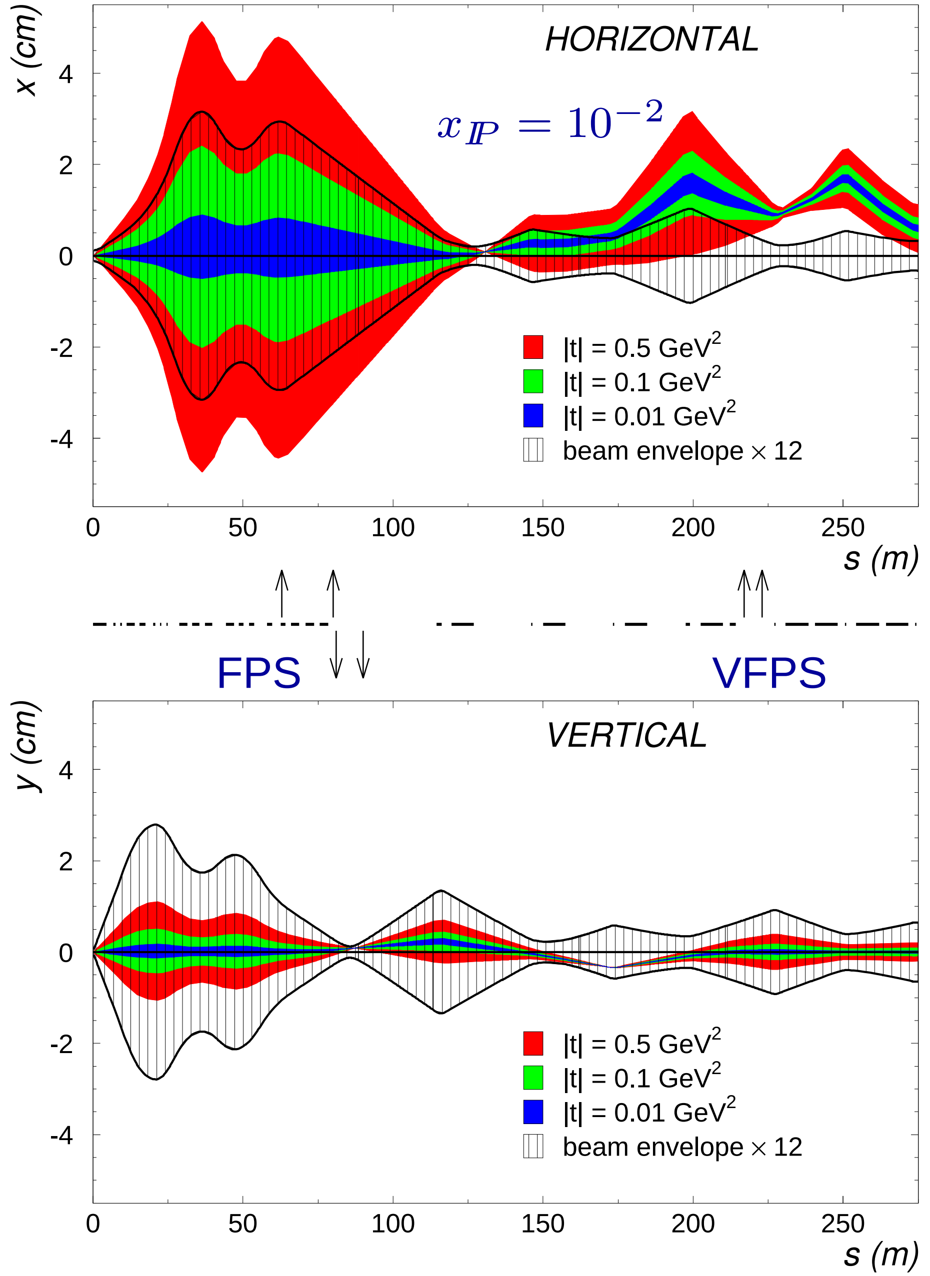
$\Rightarrow$ Precision studies of $ep \rightarrow epX$

HERA II beam optic simulation :

$\Rightarrow$ Best location is 220 m in the horizontal plane (Use HERA bend)

$\Rightarrow$ Down to $t = 0\ \mathrm{GeV}^2$ for $x_{I\!P} \sim 10^{-2}$

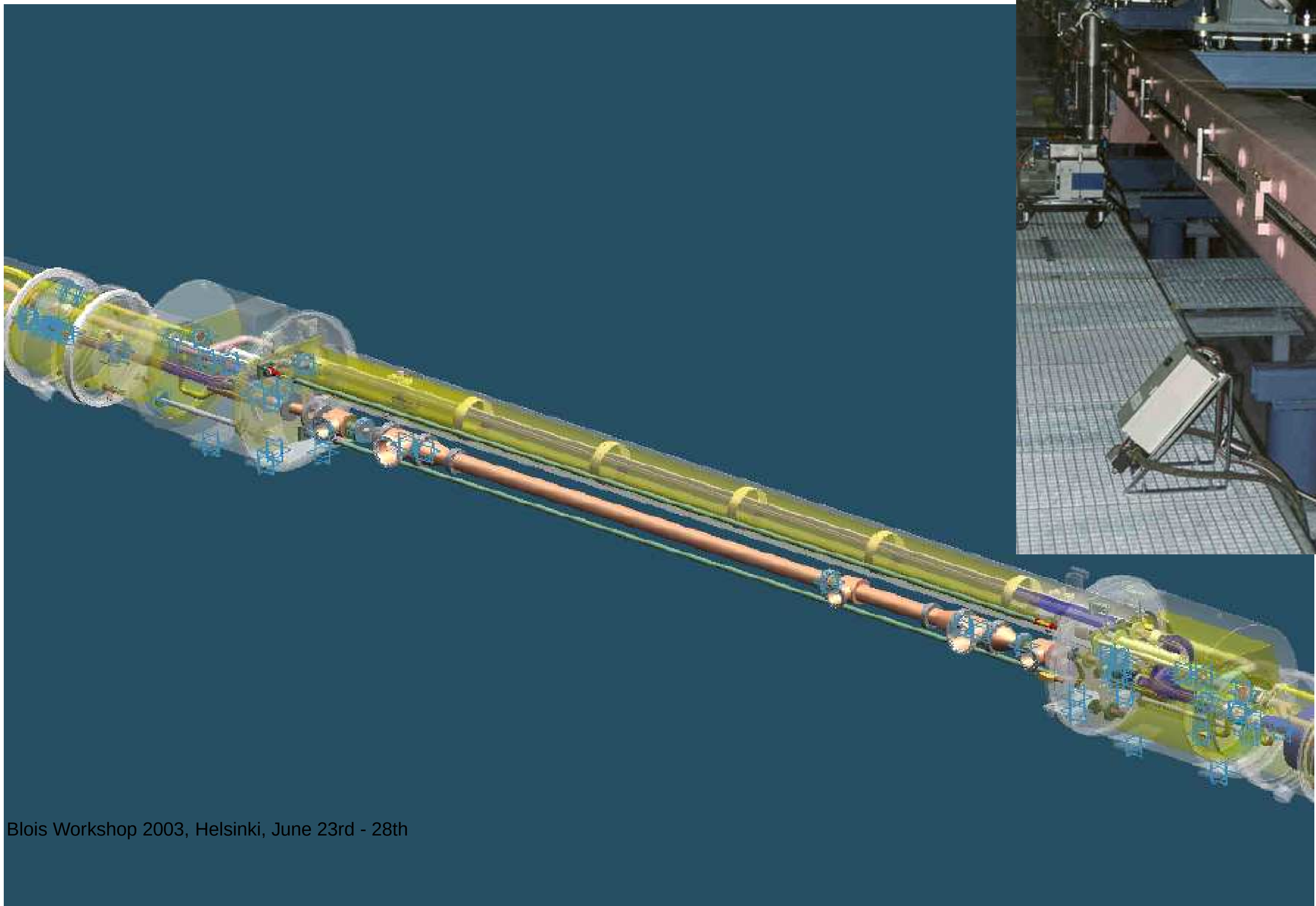
BUT Cold Magnet Section



Cold Beam Line Bypass

Horizontal Bypass for helium and superconducting lines

$\Rightarrow$ Access to proton beam tube for 10 m

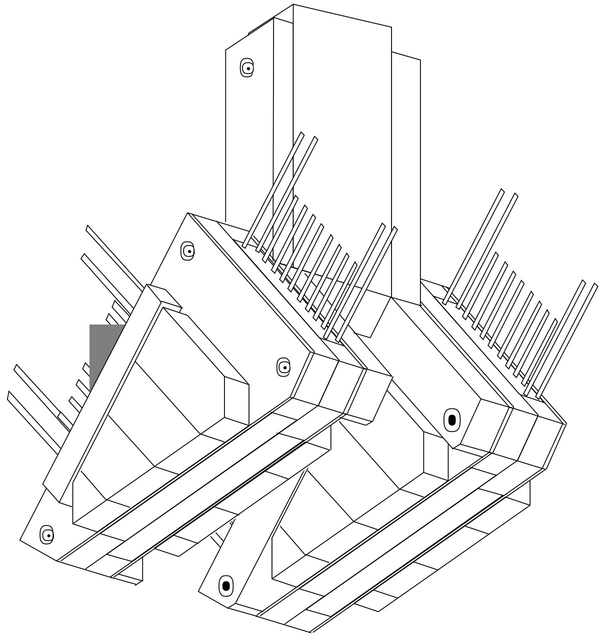


VFPS Detectors

Detectors :

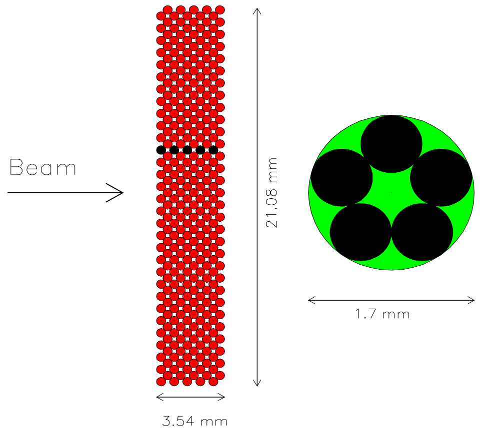
- Same design as Vertical FPS
- 2 detectors: 218 m and 222 m
- 4 Trigger Tiles / plane, 4 planes
- Fibers for spatial reconstruction

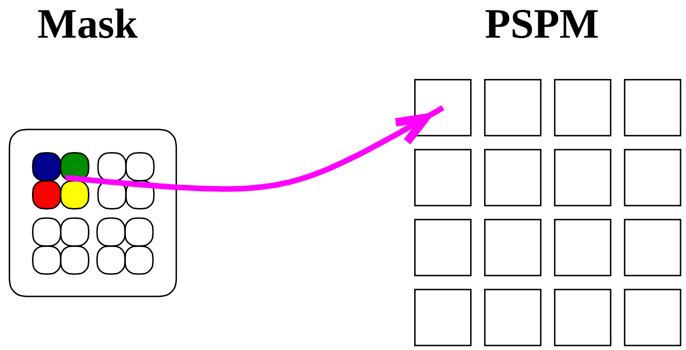
  $\longrightarrow$ Resolution = 100 μ



Optical Connection :

- Tiles : PM , Fibers : PSPM
- 5 fibers layers (= 1 plane) $\longrightarrow$ 1 light guide
- 4 light guides $\longrightarrow$ 1 PSPM pixel (multiplexing)

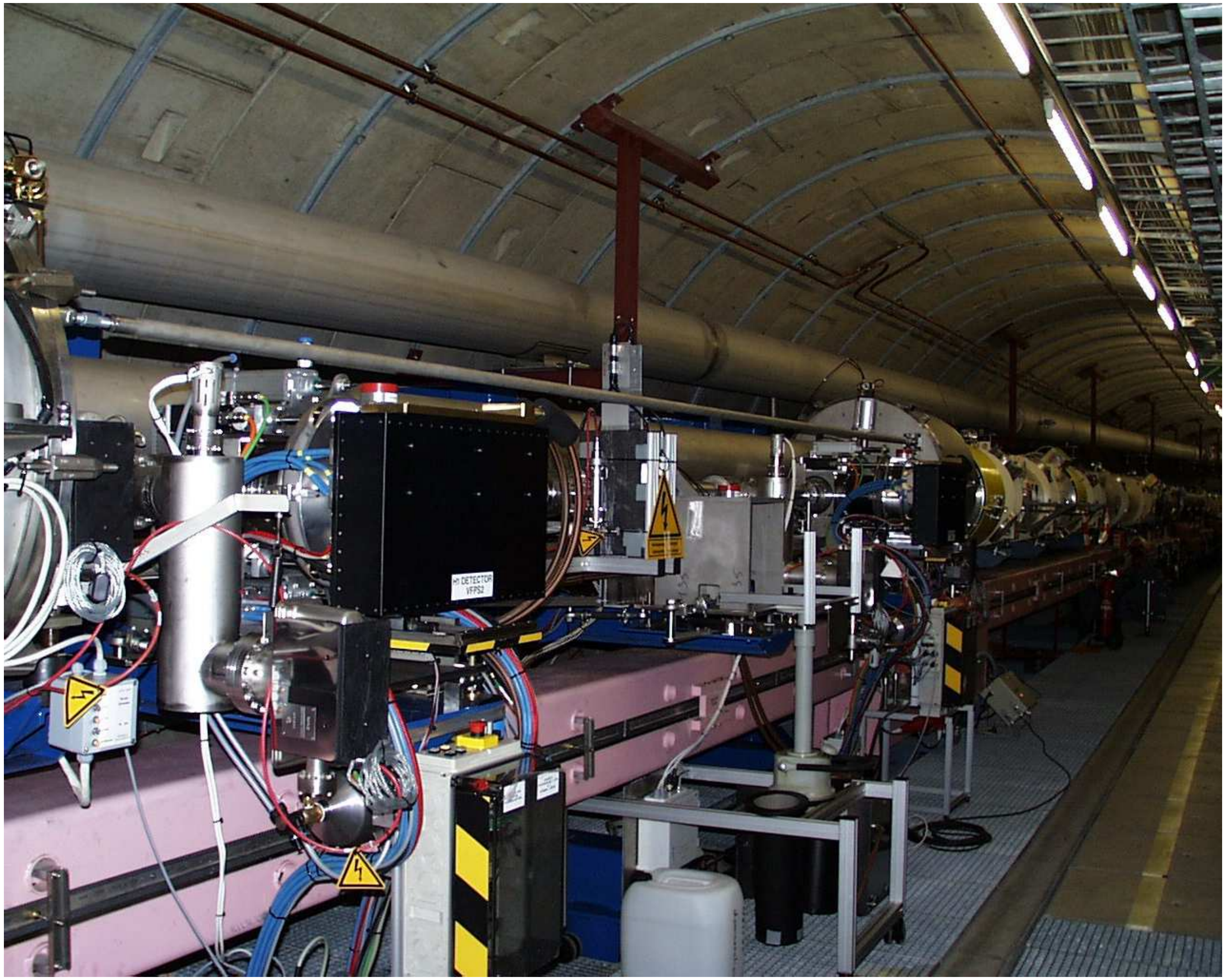




VFPS Installation

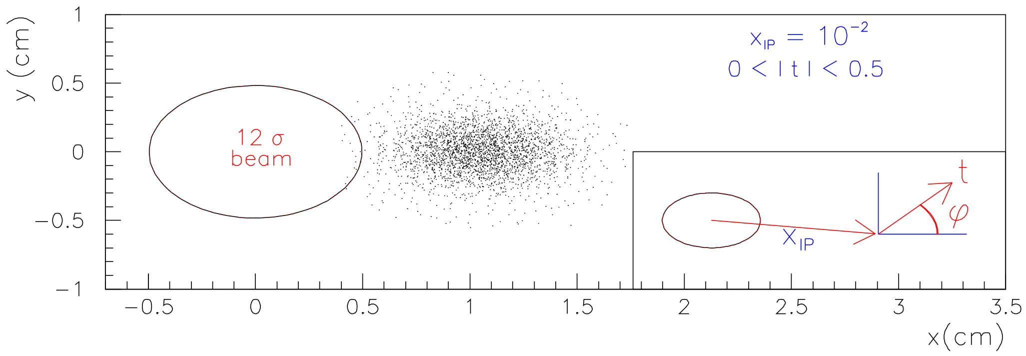
Done during the present HERA shutdown

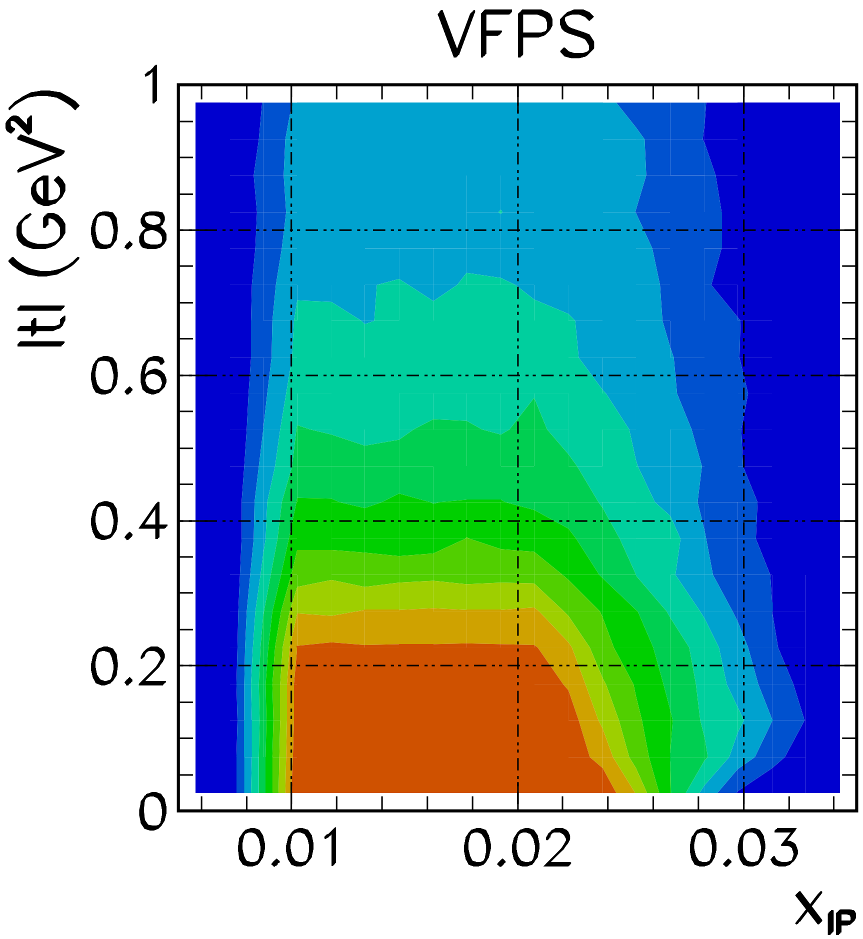
$\longrightarrow$ Will be ready for data taking at HERA startup (september)



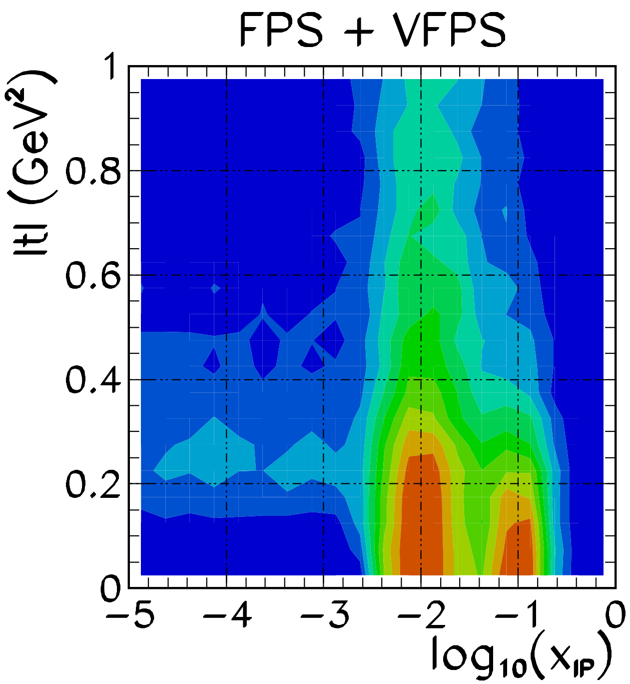
VFPS Acceptance

Acceptance defined by beam optics and enveloppe (12 σ detector approach limit)





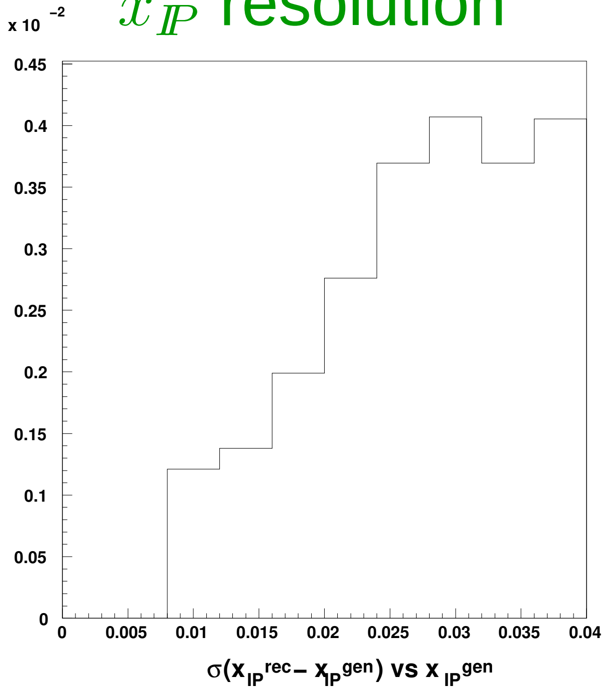
Complementory to FPS (High $x_{I\!P}$)



$\Longrightarrow \sim 100\%$ acceptance for $|t| \lesssim 0.2\ \mathrm{GeV}^2$ and $0.01 \lesssim x_{I\!P} \lesssim 0.02$

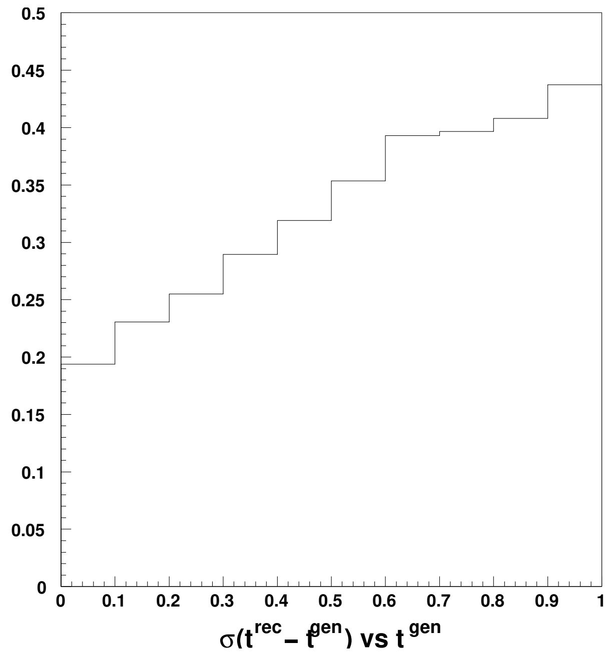
VFPS Resolution

$x_{I\!P}$ resolution



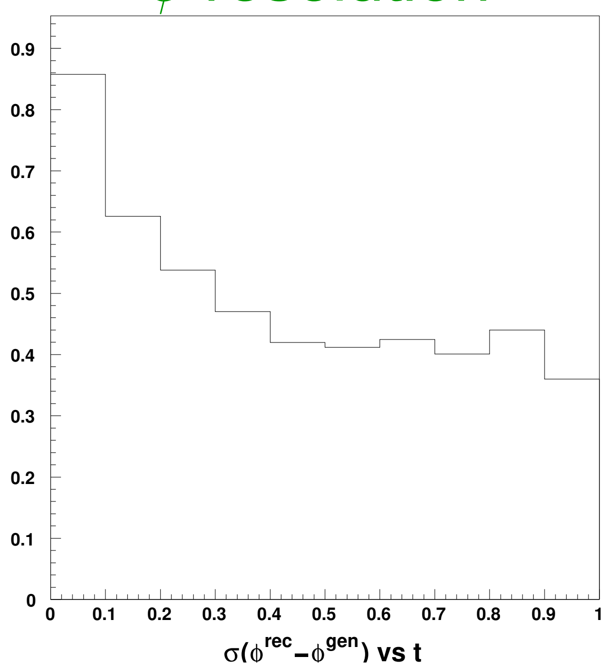
$x_{I\!P}$

t resolution



$|t|$

ϕ resolution

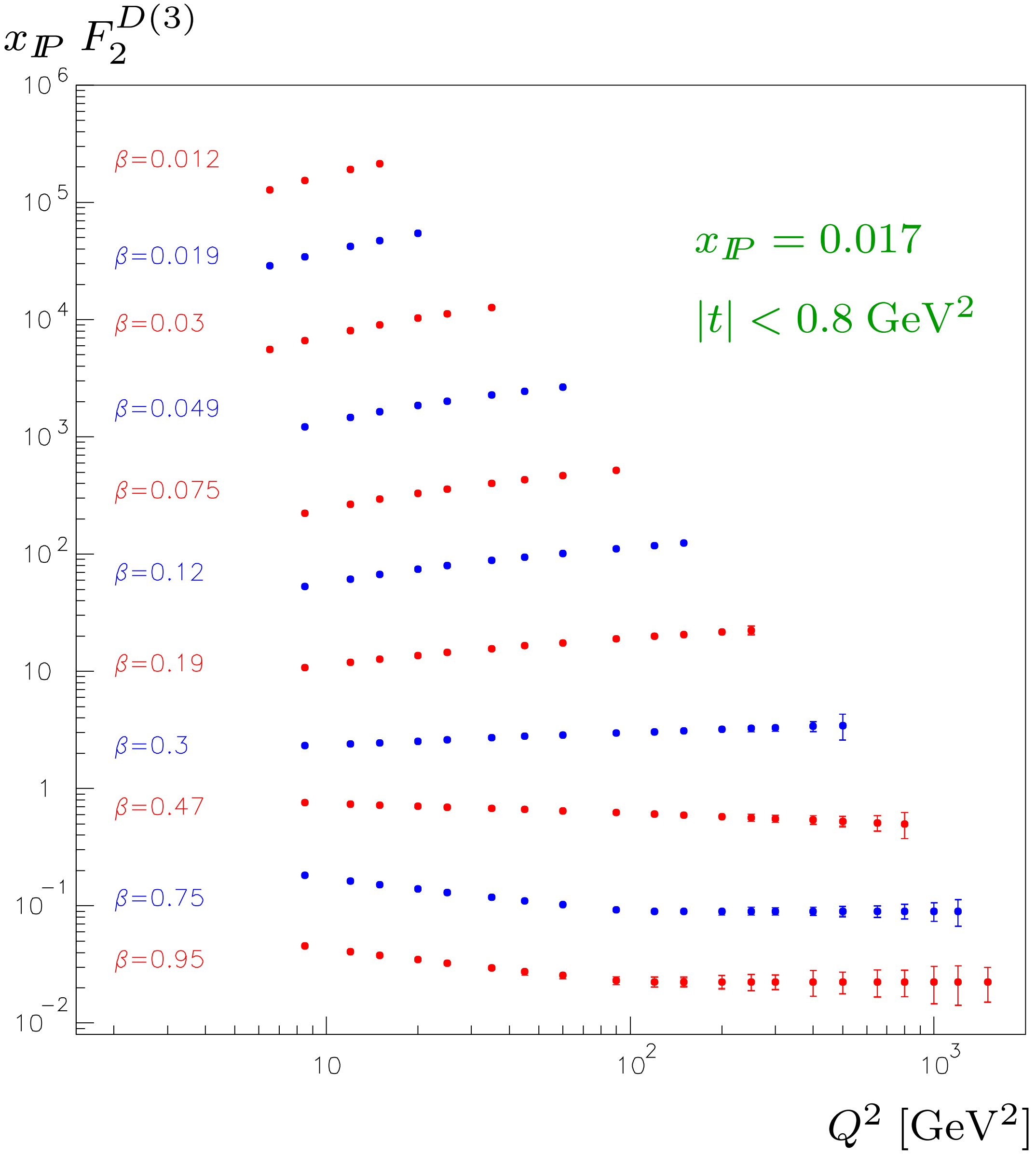


$|t|$

- Resolution dominated by beam characteristics
- $x_{I\!P}$ resolution competive with central H1 $x_{I\!P}$ reconstruction
- $\sim$ 4 bins in $|t|$
- $\sim$ 15 bins in ϕ for $|t| > 0.2\ \mathrm{GeV}^2$

Expected Results: Inclusive Diffraction

Predicted $F_2^{D(3)}$ for 350 pb^{-1} (50% VFPS operation efficiency over 3 years)



10^6 Events for $Q^2 > 5\ \mathrm{GeV}^2$

$\longrightarrow$ Study t dependence

$\longrightarrow F_2^{D(4)}(Q^2, \beta, x_{I\!P}, t)$

Uncorrelated systematics errors can reach 2-3 % (similar to F_2 precision)

$\longrightarrow$ Extract diffractive pdf's at fixed $x_{I\!P}$ and t and predict final states at same $x_{I\!P}$ and t to test factorization theorem

Expected Results: F_L^D Measurments

$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{2(1-y+y^2/2)} F_L^{D(4)} \qquad y = Q^2/s_{ep}\, x$$

ϕ Assymetry

pQCD calculable higher twist F_L^D expected dominant at high β

$\longrightarrow$ Measure ϕ assymetries as function of β (and Q^2)

VFPS : 15 bins in ϕ with 10000 events each for $|t| > 0.2\ \mathrm{GeV}^2$

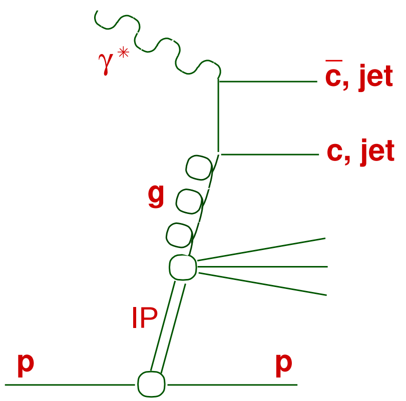
Leading Twist F_L^D

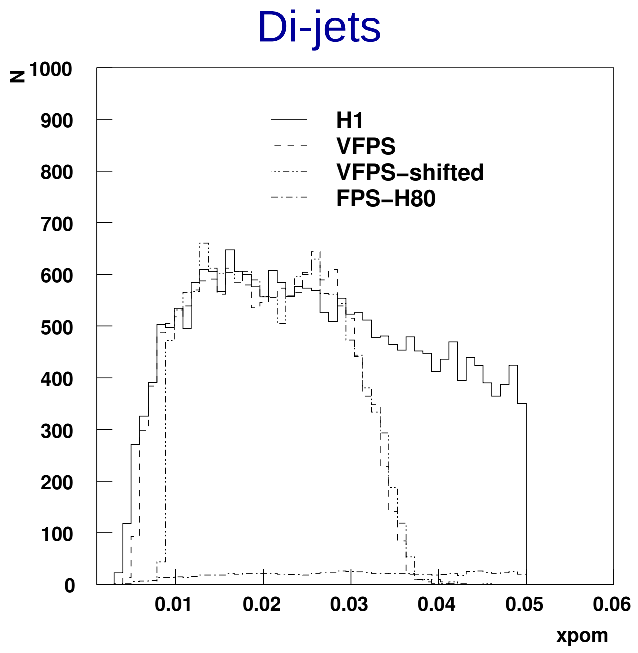
Indirect extraction at low β from NLO QCD fits (gluons !) to $\sigma_r^{D(4)}$

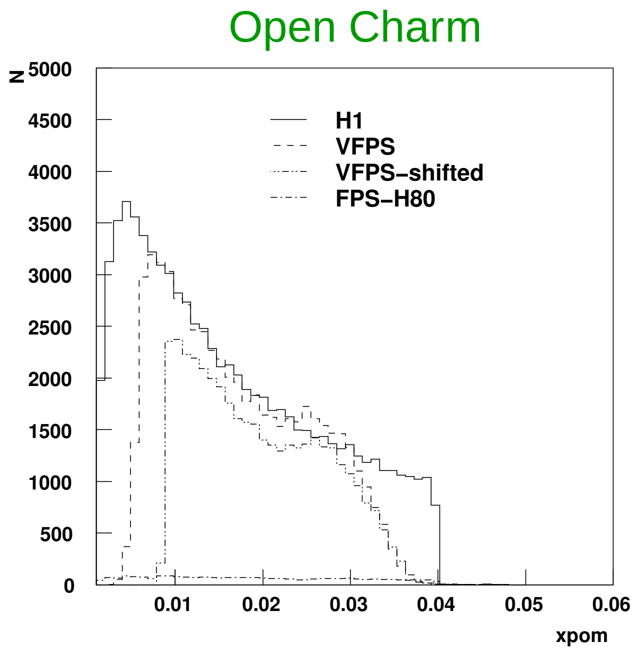
Reduced proton beam energy

40 % precision on σ_L^D/σ_T^D expected with 50 pb^{-1} data at $E_p = 500\ \mathrm{GeV}$

Expected Results: Final States







Di-jets electroproduction

- 96/97 analysis: 2500 events
- VFPS: expect 22900 events

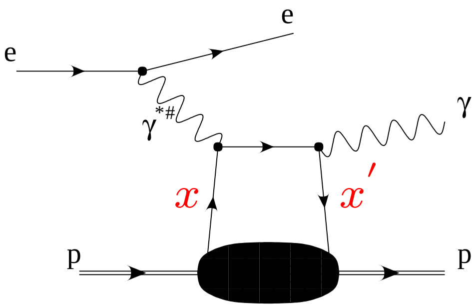
Open Charm (D^*)

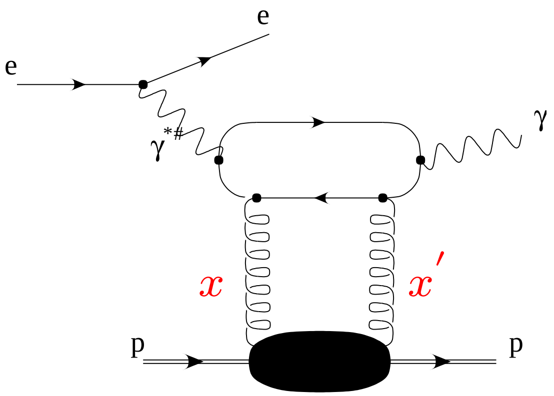
- 96/97 analysis: 46 ± 10 events
- VFPS: expect 380 events

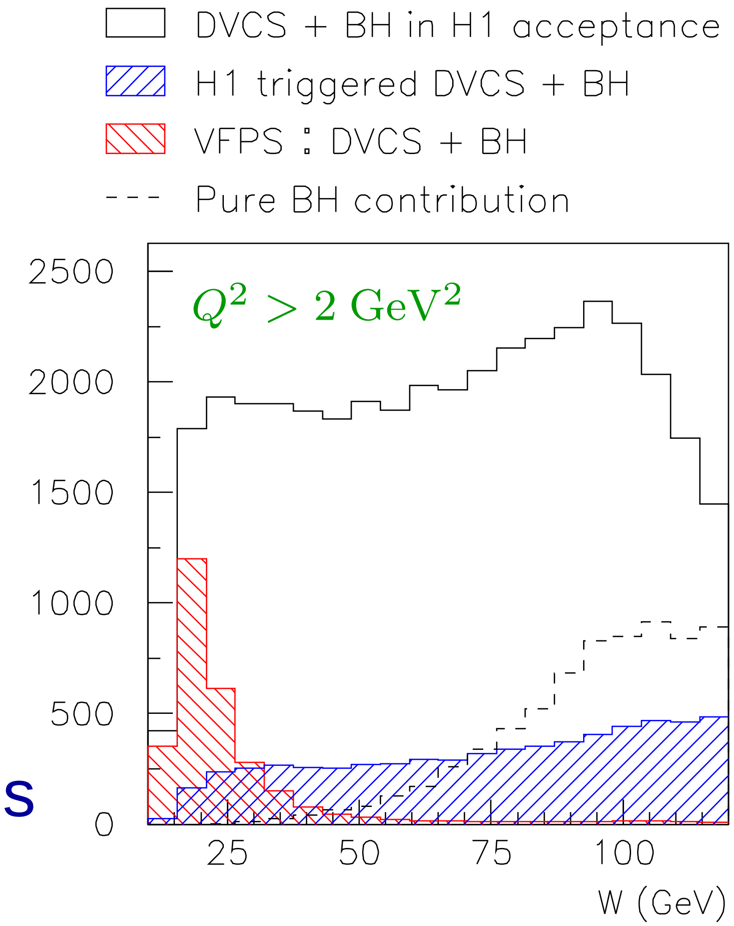
$\longrightarrow$ More differential studies (in particular for D^*)
$\longrightarrow$ Direct (vs) resolved photon contributions
$\longrightarrow$ Test of diffractive factorization theorem

Expected Results: Exclusive Channels

Deeply Virtual Compton Scattering







Sensitive to GPD (extension of pdf for $x \neq x'$) via interf. with Bethe Heitler

$\longrightarrow$ Measure charge ($\propto$ Re A_{DVCS}) and helicity ($\propto$ Im A_{DVCS}) assymetries

Vector Meson Production

$$e + p \longrightarrow e + p + VM \quad ; \quad VM = \rho, J/\psi, \ldots$$

Clean elastic channel selection BUT only low W accesible

CONCLUSION

HERA I :

ZEUS LPS and H1 FPS have allowed to study elastic diffraction:

$F_2^{D(4)}(Q^2, x_{I\!P}, \beta, t)$, ϕ Assymetries, t Dependence,

Elastic ρ Meson Production, ...

HERA II :

H1 has installed a new proton spectrometer (VFPS) with a large acceptance for low $x_{I\!P}$ and $0 < |t| < 0.5\ \mathrm{GeV}^2$

$\longrightarrow$ High precision studies of diffraction :

F_2^D , t Dependence, F_L^D and ϕ Assymetries

Final states (di-jets, open charm) + Test of factorization

DVCS (access to GPD) and Vector Meson