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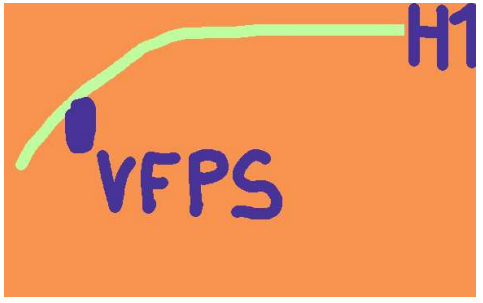
On behalf of the H1 Collaboration



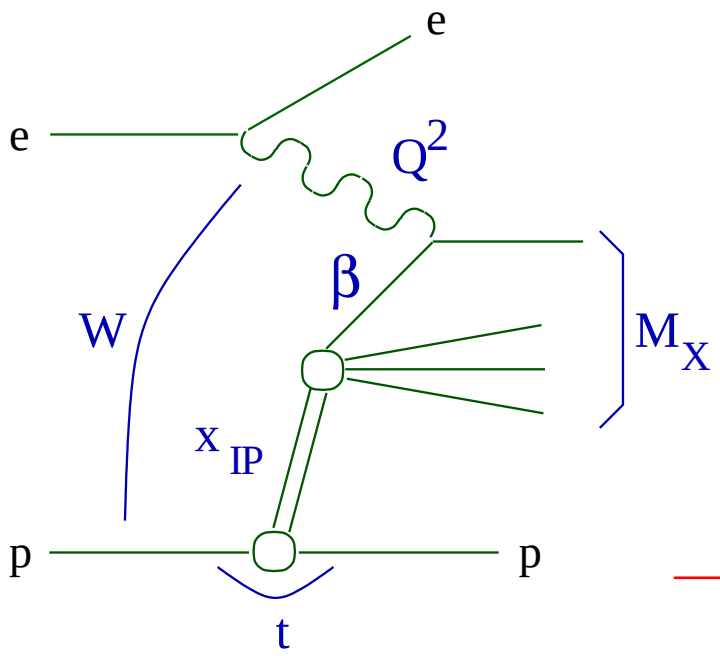

# Status of the H1 Very Forward Proton Spectrometer

XIIth International Workshop on Deep Inelastic Scattering

Strbske Pleso, Slovakia, April 14rd - 18th, 2004

# 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

$\beta$ : fraction of exchange momemtum of struck $q$

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

$t$ : 4-momemtum transfer squared

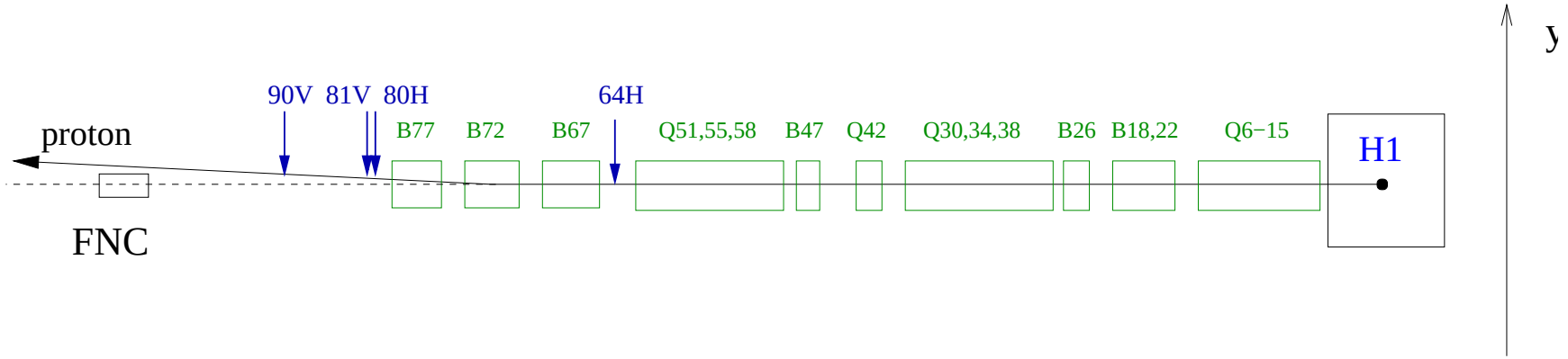
$\longrightarrow$ Probe QCD structure of colour singlet

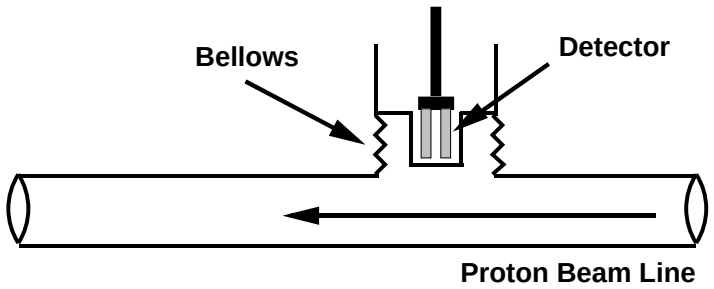
HERA I: Measurments of $F_2^D$, jets, charm, Vector Mesons, DVCS,...

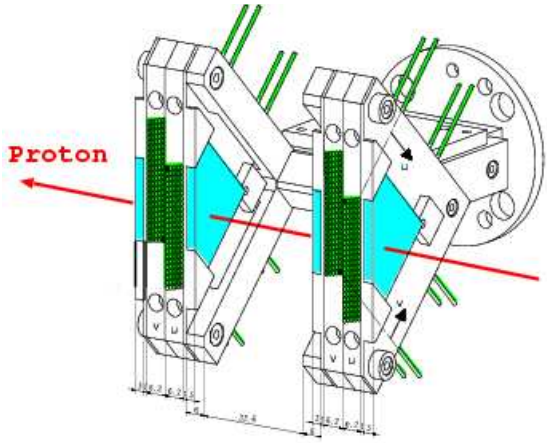
BUT Statistically (exclusive channels) or
Systematically (proton dissociation) limited

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

# HERA I: Forward Proton Spectrometer




- Scintillating fibre detector
- Free of proton dissociation bkgd
- proton 4-momentum measurement $\longrightarrow$ $t$
- Small acceptance

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

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

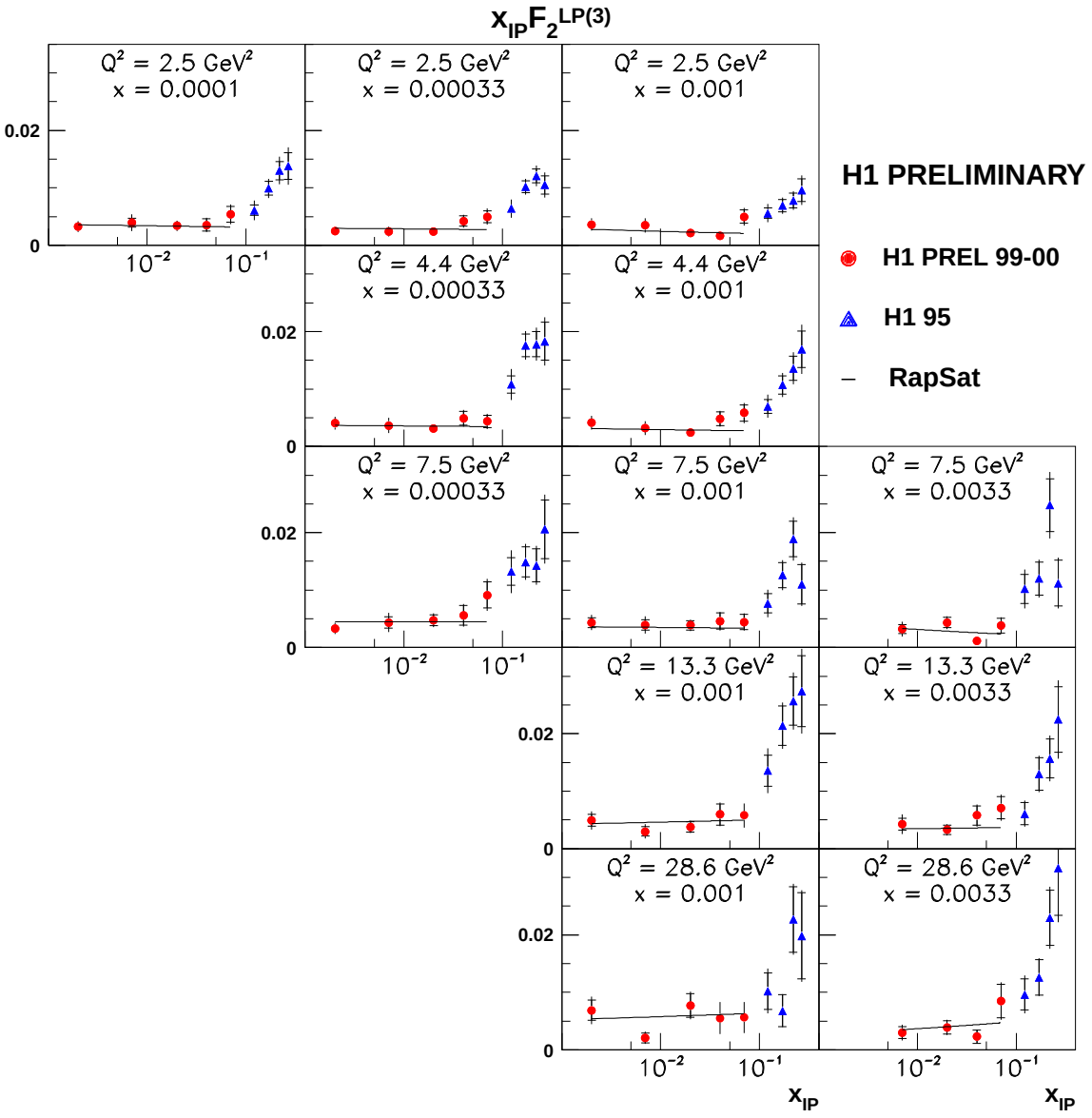
## Horizonal FPS Stations:

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

## Vertical FPS Stations:

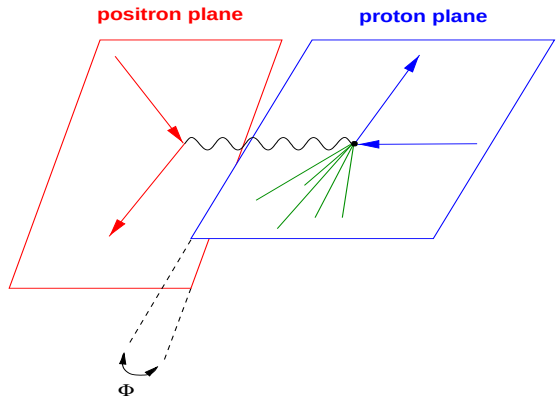
- Large acceptance at low $|t|$ and high $x_{I\!P}$
- 1995 data : 1.4 pb$^{-1}$

## BUT statistically limited



# HERA I Results: $\phi$ Measurement

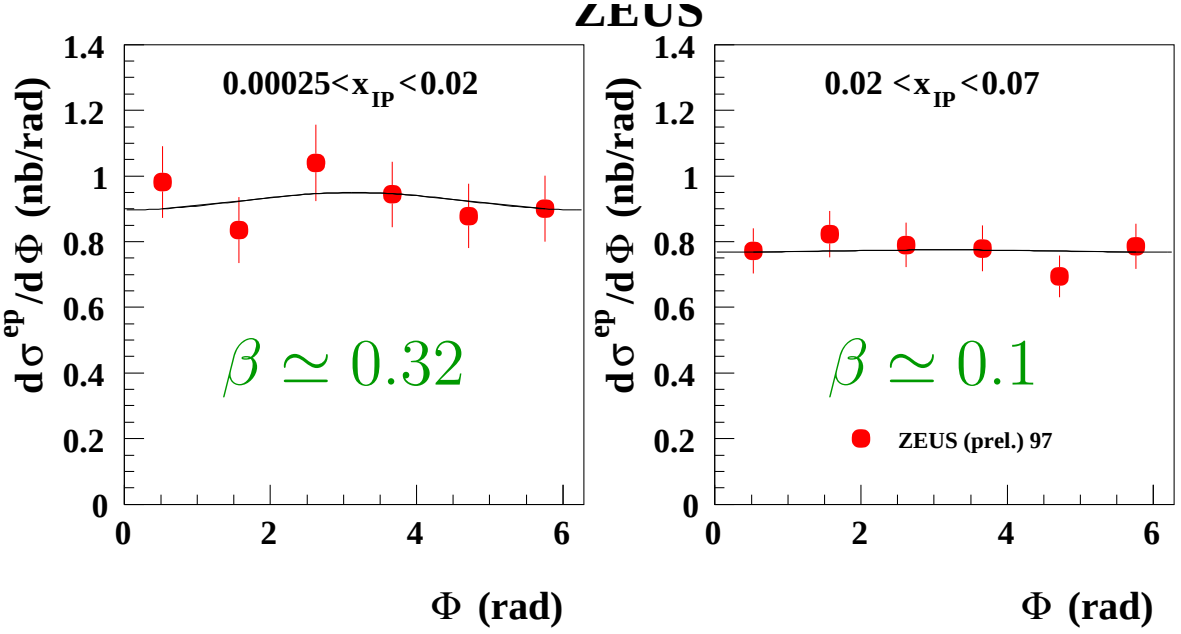
$\frac{\mathrm{d}\sigma^D}{\mathrm{d}\phi}$ sensitive to $\sigma_L^D$ through interference term :




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

Fit asymmetries :

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




$\longrightarrow$ Asymmetries small

BUT high $\beta$ not covered

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

# 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 $t$

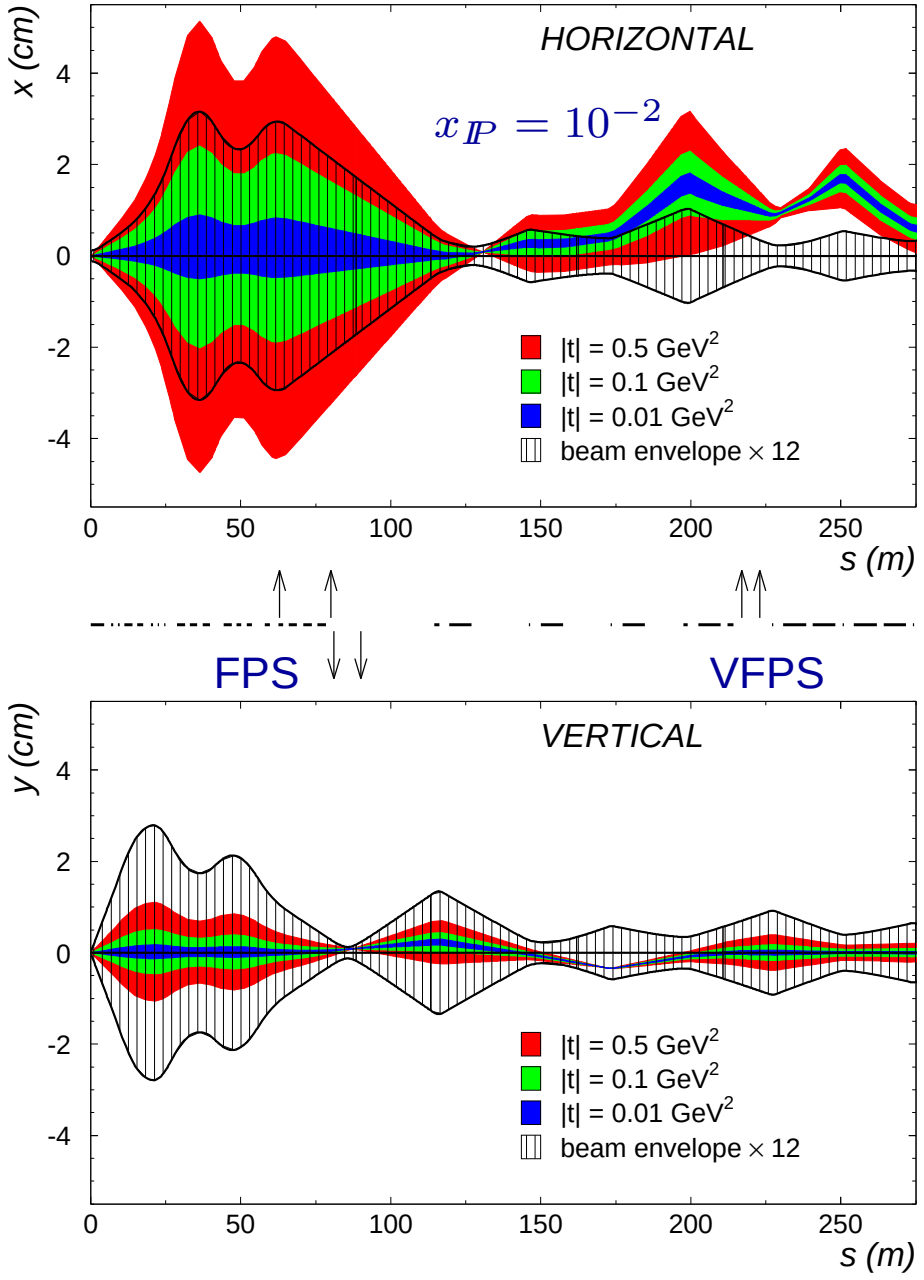
$\Rightarrow$ Precision studies of $ep \to epX$

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 $x_{I\!P} \sim 10^{-2}$

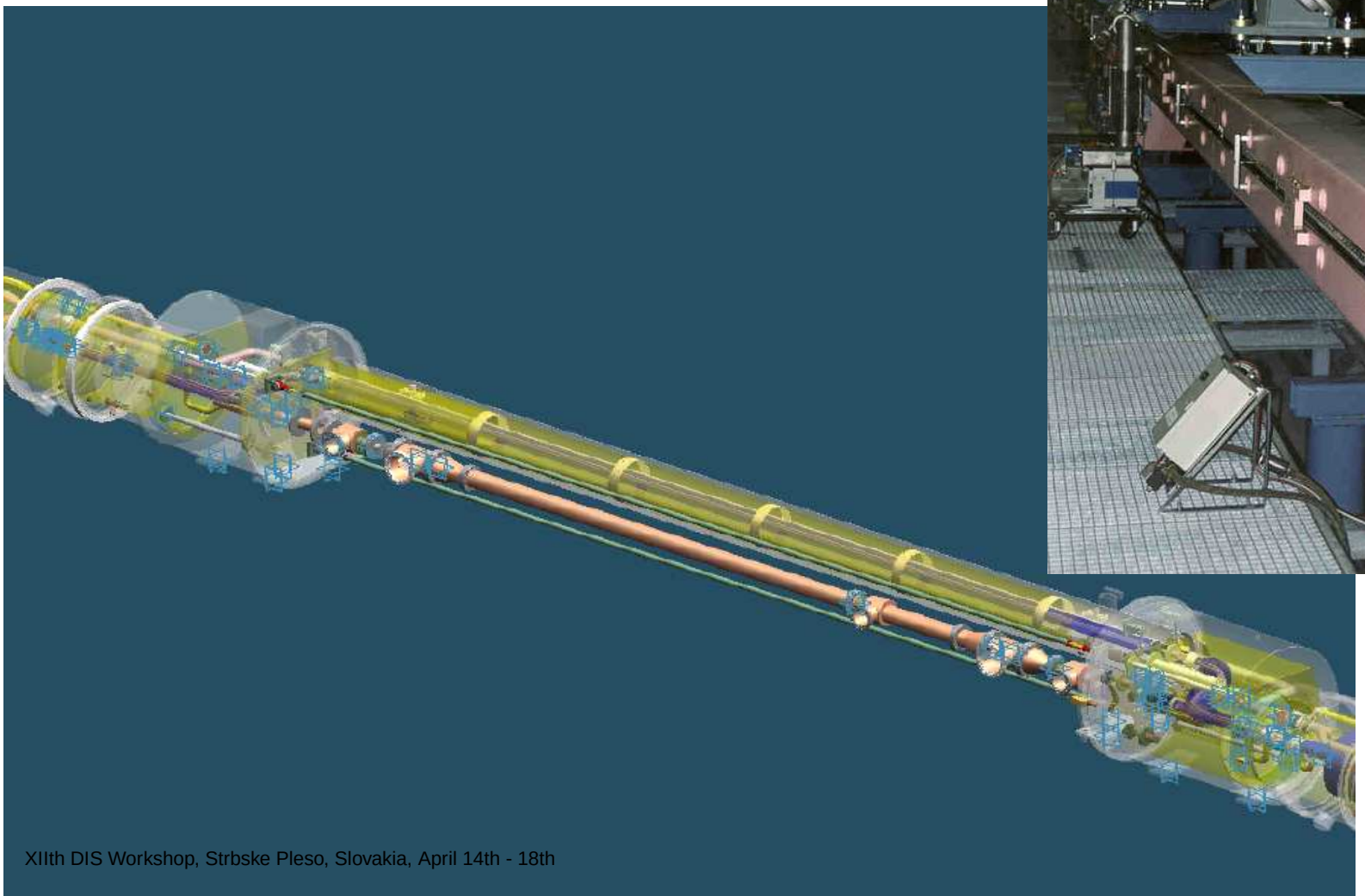
BUT Cold Magnet Section



# Cold Beam Line Bypass

Horizontal Bypass for helium and superconducting lines

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

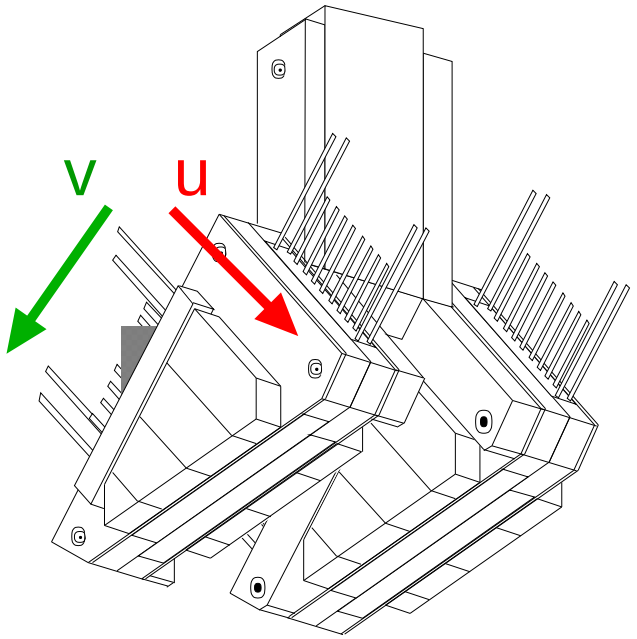


# VFPS Detectors

## Detectors :

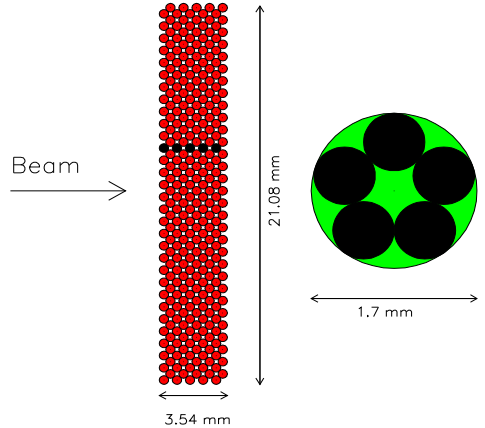
- Same design as Vertical FPS
- 2 detectors: 218 m and 222 m
- 4 Trigger Tiles / plane, 4 planes
- Fibers for spatial reconstruction

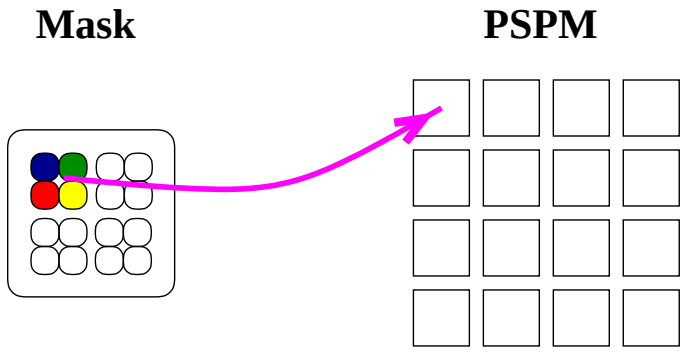
  $\longrightarrow$ Resolution = 100 $\mu$




## Optical Connection :

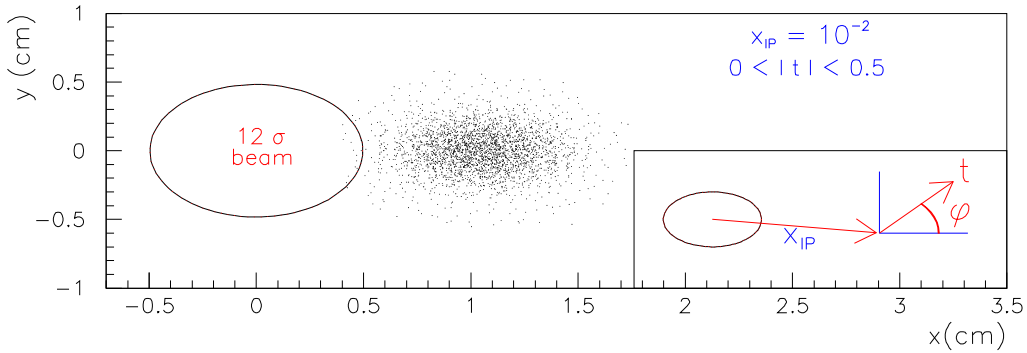
- Tiles : PM , Fibres : PSPM
- 5 fibers layers (= 1 plane) $\longrightarrow$ 1 light guide
- 4 light guides $\longrightarrow$ 1 PSPM pixel (multiplexing)

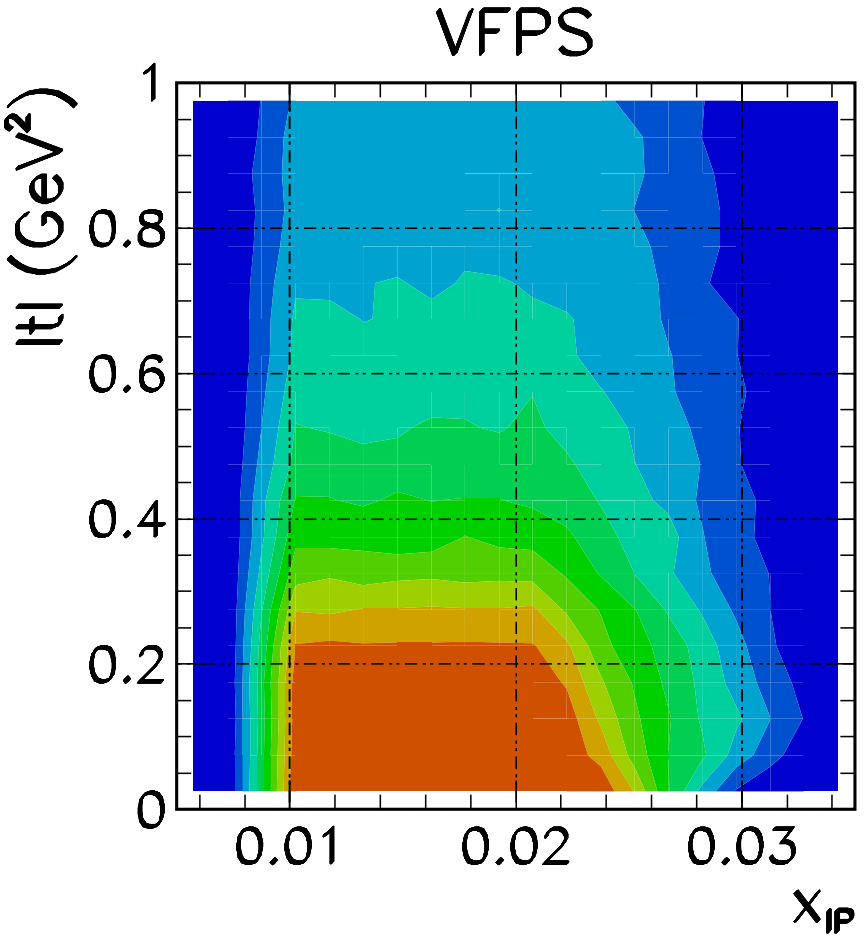


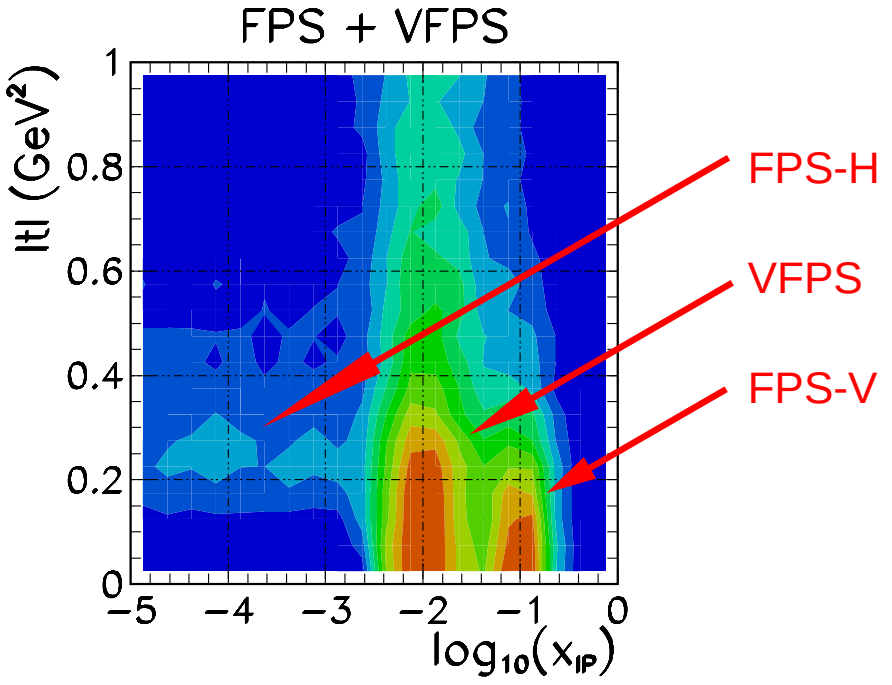
# VFPS Acceptance

Acceptance defined by beam optics and envelope (12 $\sigma$ detector approach limit)



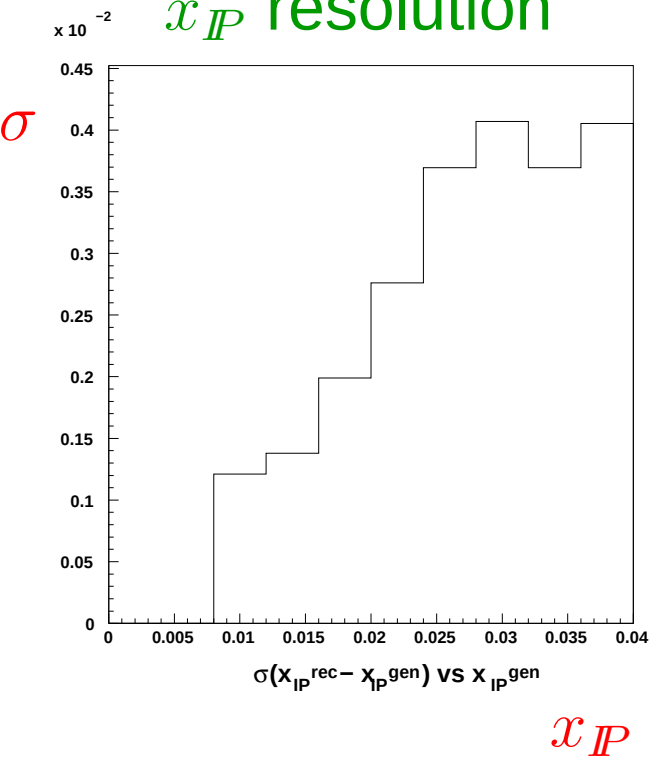

Complementary to FPS (High $x_{I\!P}$)



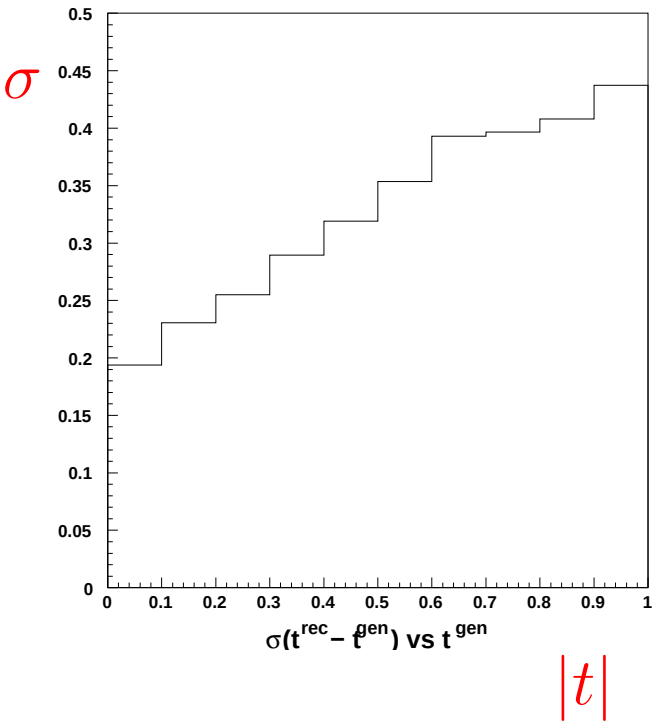

$\Longrightarrow \sim 100\%$ acceptance for $|t| \lesssim 0.2\ \mathrm{GeV}^2$ and $0.01 \lesssim x_{I\!P} \lesssim 0.02$

# VFPS Resolution

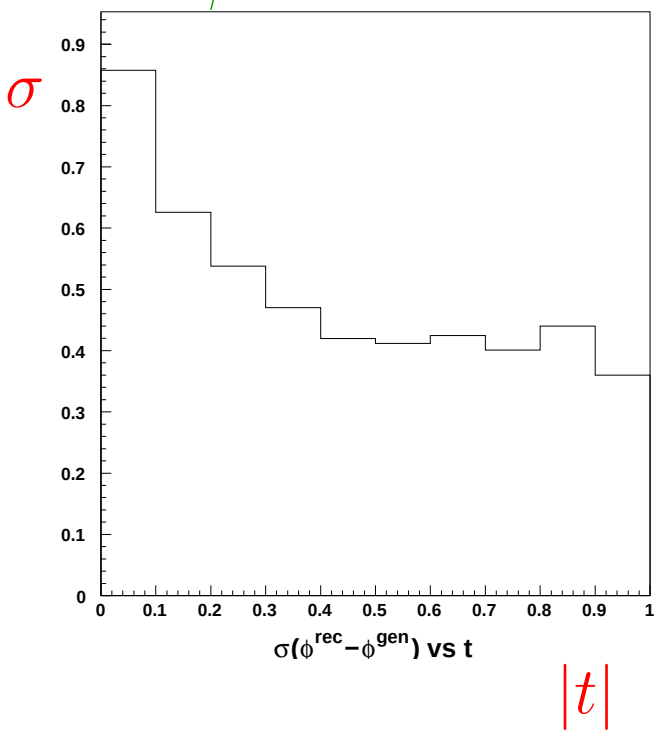
$x_{I\!P}$ resolution




$t$ resolution




$\phi$ resolution

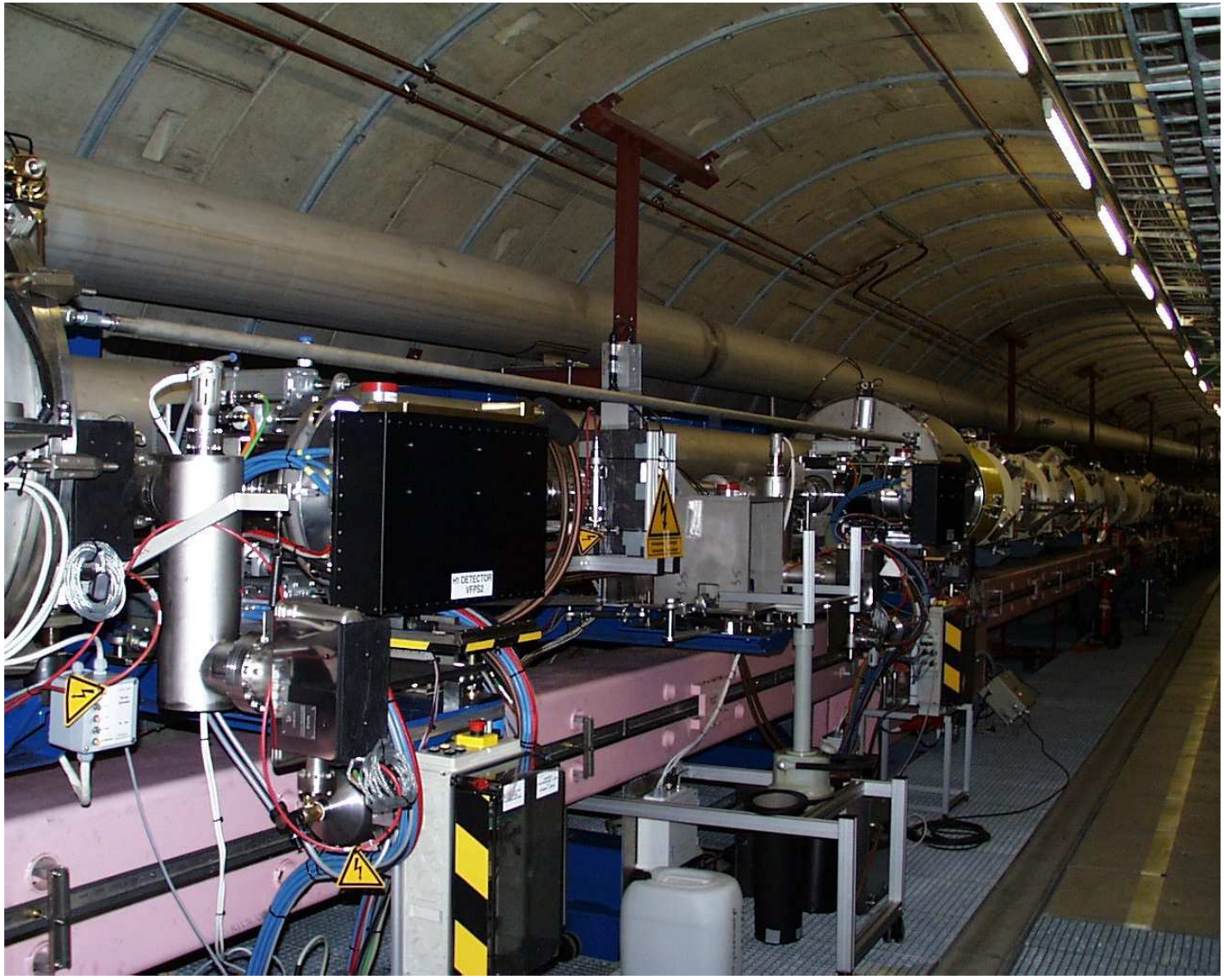



- Resolution dominated by beam characteristics
- $x_{I\!P}$ resolution competive with central H1 $x_{I\!P}$ reconstruction
- $\sim$ 4 bins in $|t|$ for $|t| < 0.4\ \mathrm{GeV}^2$
- $\sim$ 15 bins in $\phi$ for $|t| > 0.2\ \mathrm{GeV}^2$

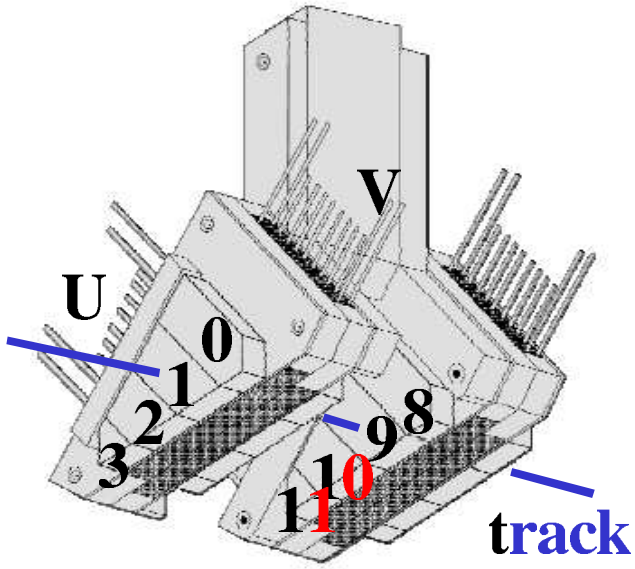
# VFPS Installation

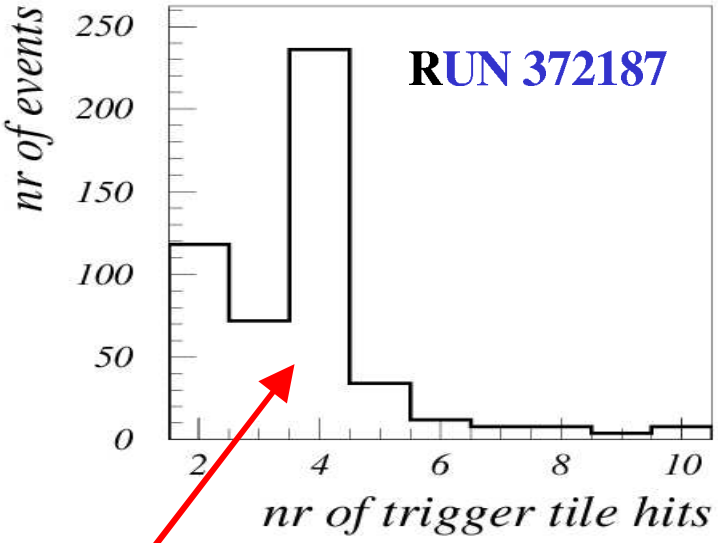
Done during the summer 2003 HERA shutdown

$\longrightarrow$ First tests and commissioning started in january 2004



# VFPS Tests Data

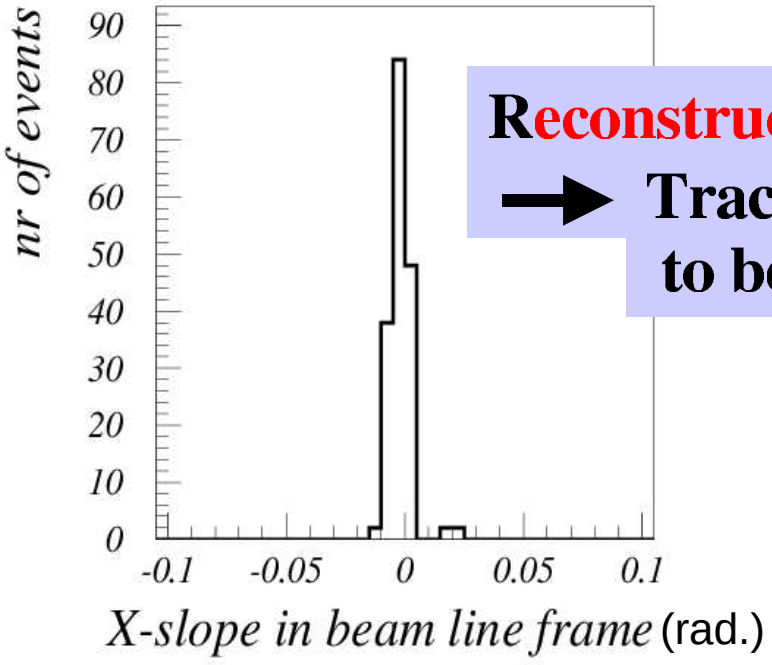


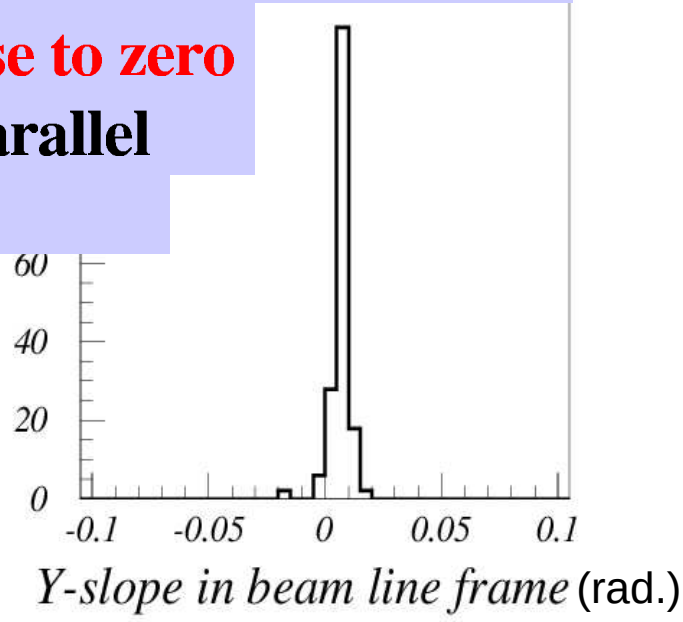




**Coincidence of 4 triggered planes**

**Reconstructed slope is close to zero**

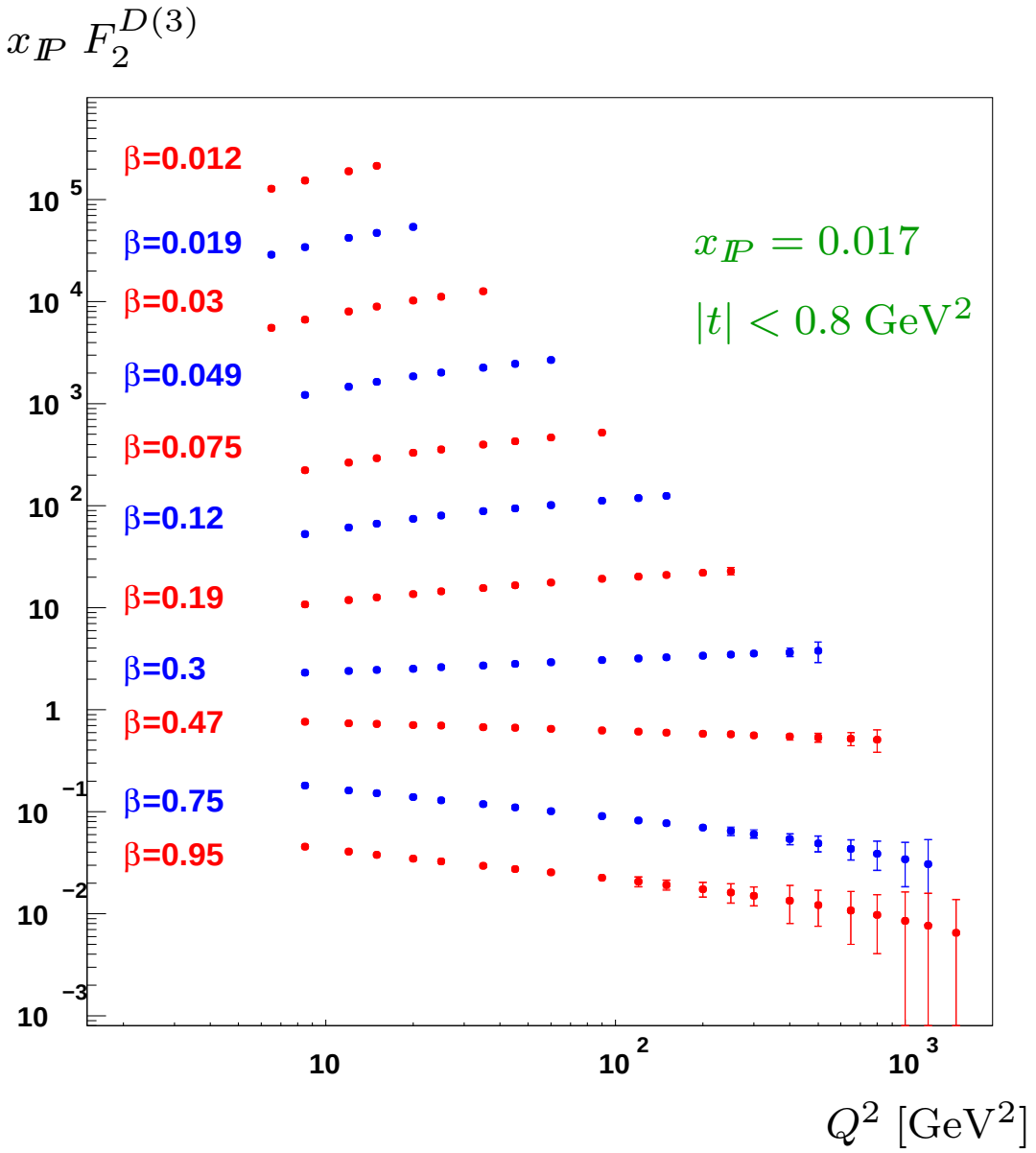
→ **Tracks are nearly parallel to beam line**



# Expected Results: Inclusive Diffraction

Predicted $F_2^{D(3)}$ for 350 pb$^{-1}$ (50% VFPS operation effi ciency 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 systematic 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

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

## $\phi$ Asymmetry

pQCD calculable higher twist $F_L^D$ expected dominant at high $\beta$

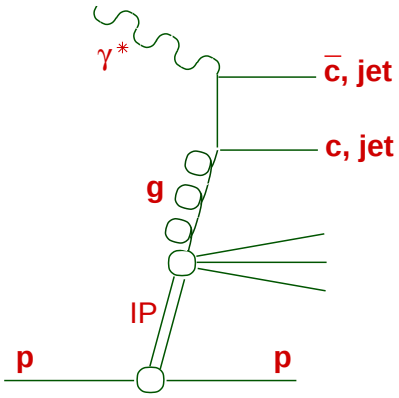
$\longrightarrow$ Measure $\phi$ asymmetries as function of $\beta$ (and $Q^2$)

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

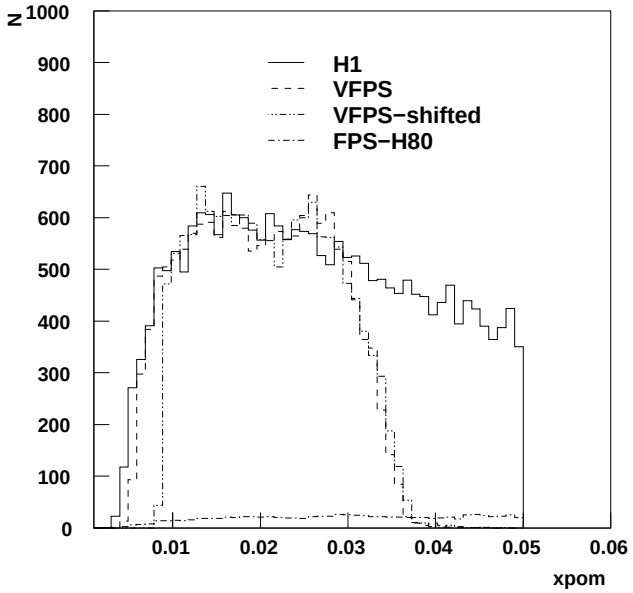
## Reduced proton beam energy

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

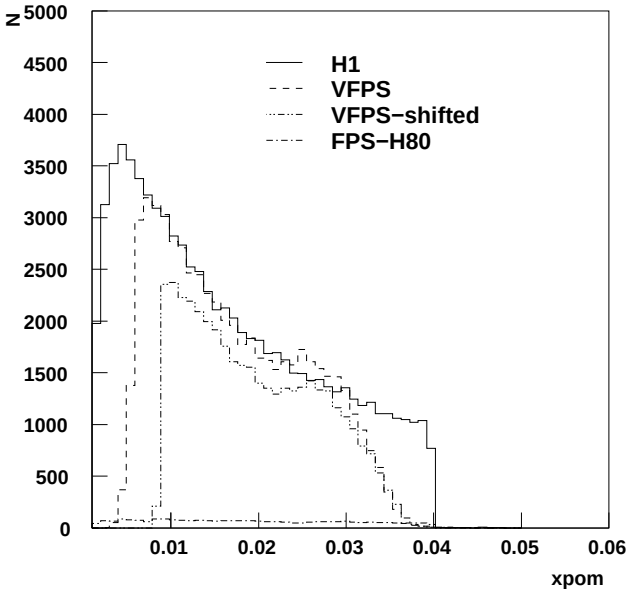
# Expected Results: Final States




Di-jets




Open Charm




## Di-jets electroproduction

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

## Open Charm ($D^*$)

- 96/97 analysis: $46 \pm 10$ events
- VFPS: expect 380 events

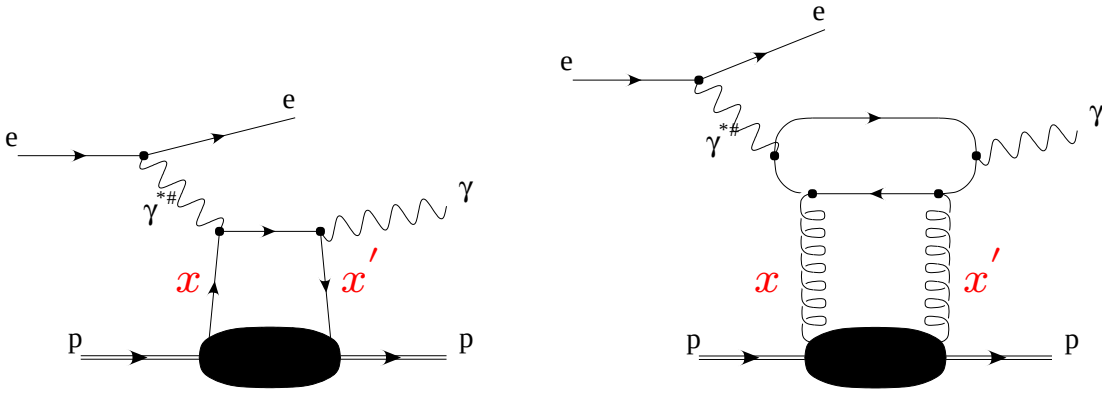
$\rightarrow$ More differential studies (in particular for $D^*$)

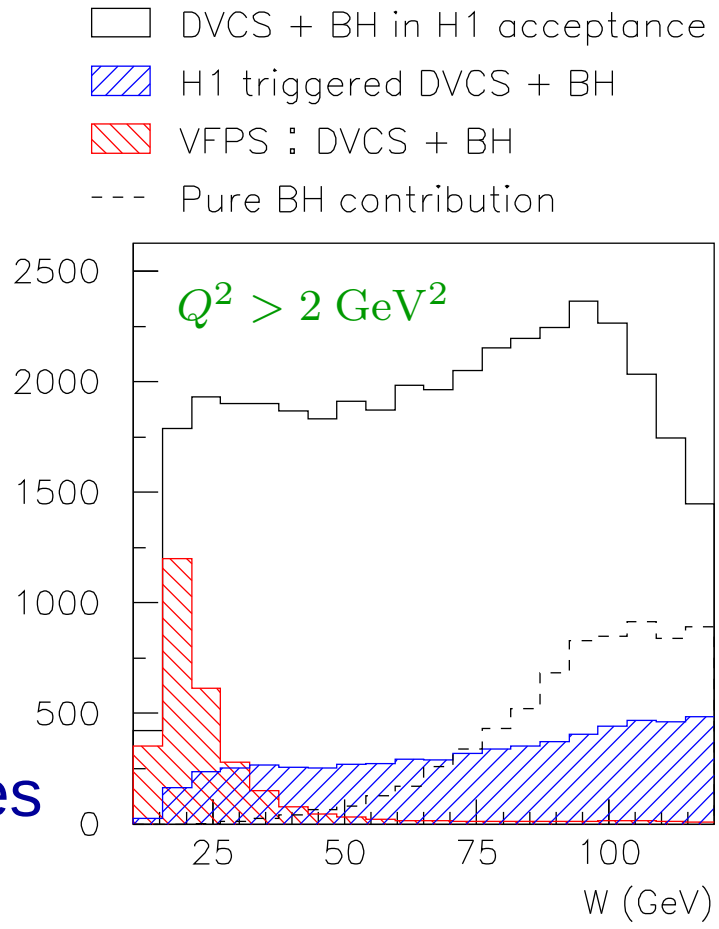
$\rightarrow$ Direct (vs) resolved photon contributions

$\rightarrow$ 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

$\rightarrow$ Measure charge ($\propto$ Re $A_{DVCS}$) and helicity ($\propto$ Im $A_{DVCS}$) asymmetries

## Vector Meson Production

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

Clean elastic channel selection BUT only low $W$ accessible

# CONCLUSION

- 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 $\phi$ Asymmetries

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

  DVCS (access to GPD) and Vector Meson

- First test data, including tracks, have been recorded and the detector commissioning is in progress

  $\longrightarrow$ Physics data have to be expected soon