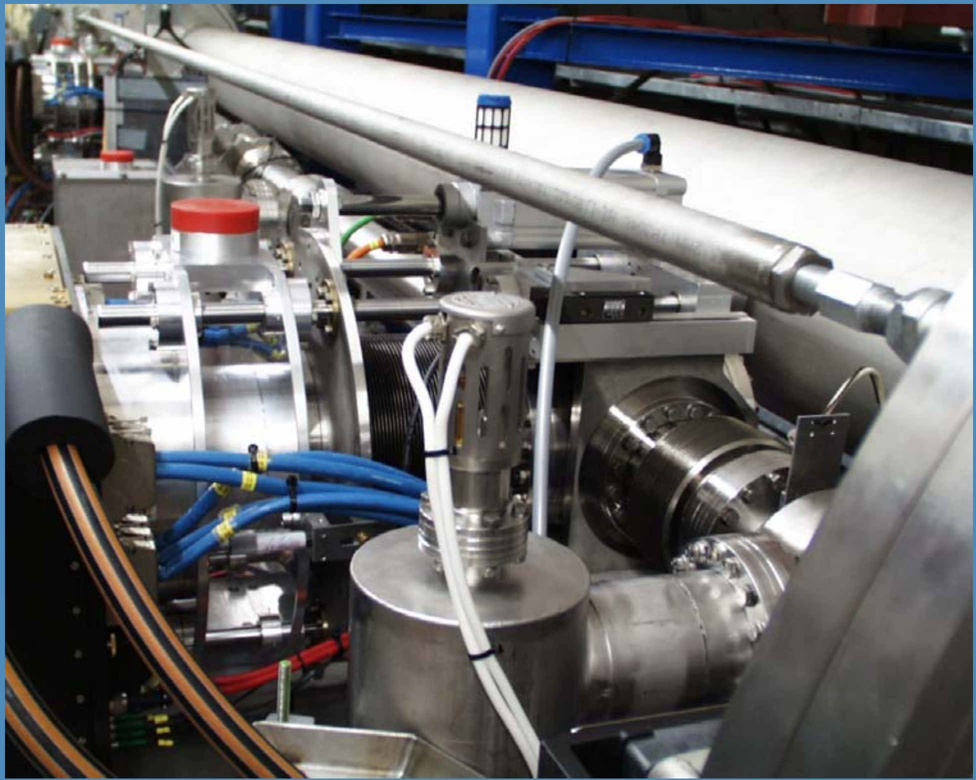
Alignment of the VFPS.



Through *elastic ρ production at the central detector* and through the kinematic peak method.

Master thesis at the University of Antwerp
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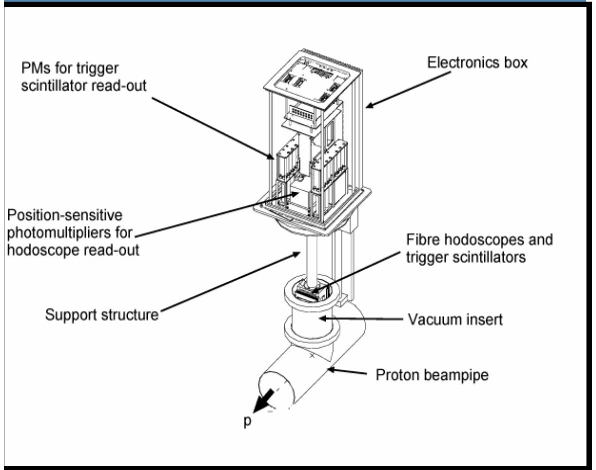
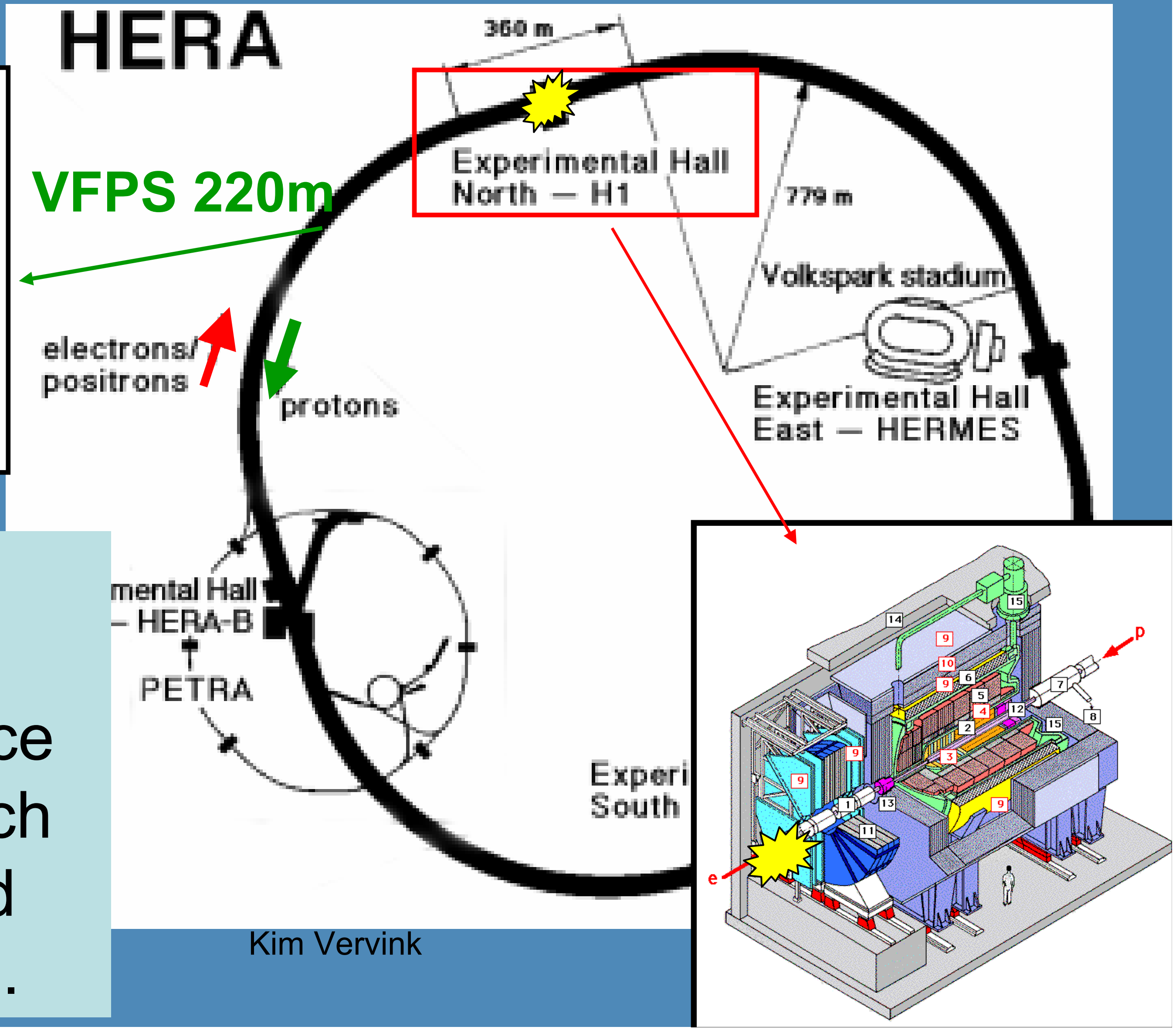
Contents

- Introduction
- VFPS detector
- Two main alignment principles used for the VFPS:
- Elastic production of ρ mesons in the central detector
- Kinematic peak method
- Conclusions

Outline: HERA with H1 and VFPS.



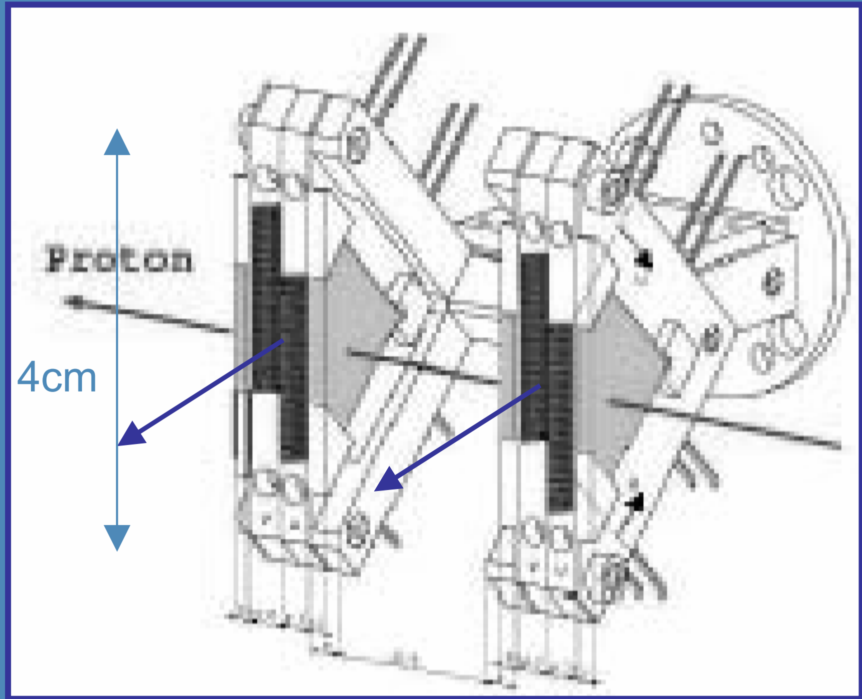


VFPS:

Roman Pot movable device i.o. to approach the diffracted proton beam.

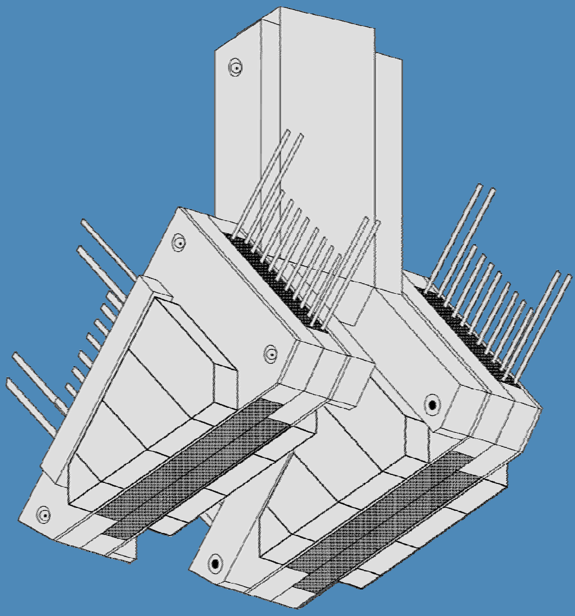
The Very Forward Proton Spectometer

- 220 m after the interaction point of H1(in the **arch of HERA)**
- Measures **diffractively scattered proton** (use HERA bend)
- Mechanical gear provides 2 movable **horizontal** Roman Pot stations to approach the scattered proton beam.
- Roman Pots **retracted** during injection and beam dumb
- Moved in **as close as** possible to the proton beam during stable beam conditions



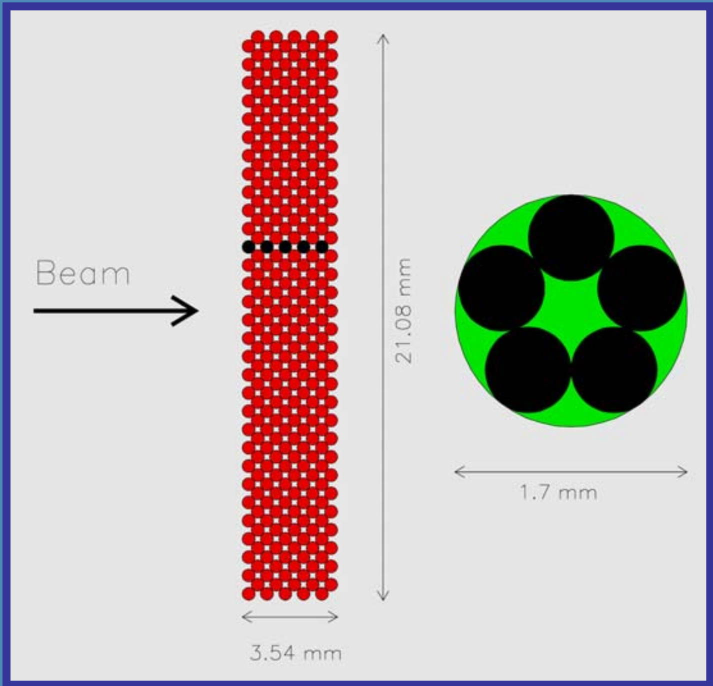
Status of the VFPS:
- Installation 2003
- Tests 2004
- Due to problems in the readout fibres: no real data available (everything presented here is based on simulations)

Detector Design



VFPS is a **Tracking Detector**:
Each Roman Pot station has 2 planes of scintillating fibers perpendicular to the beam line
One in the u-orientation one in the v-orientation
=> **4 coordinates** of impact points measured

1 plane = 5 **layers** of 120 scintillating **fibres**
➔ Resolution 100 micron



Signals become amplified by **Photo Multiplicators.**

Goal: reconstruct diffractive kinematics:
xpom (=1-Ep'/Ep); θx, θy

Kim Vervink

Trajectory simulation.

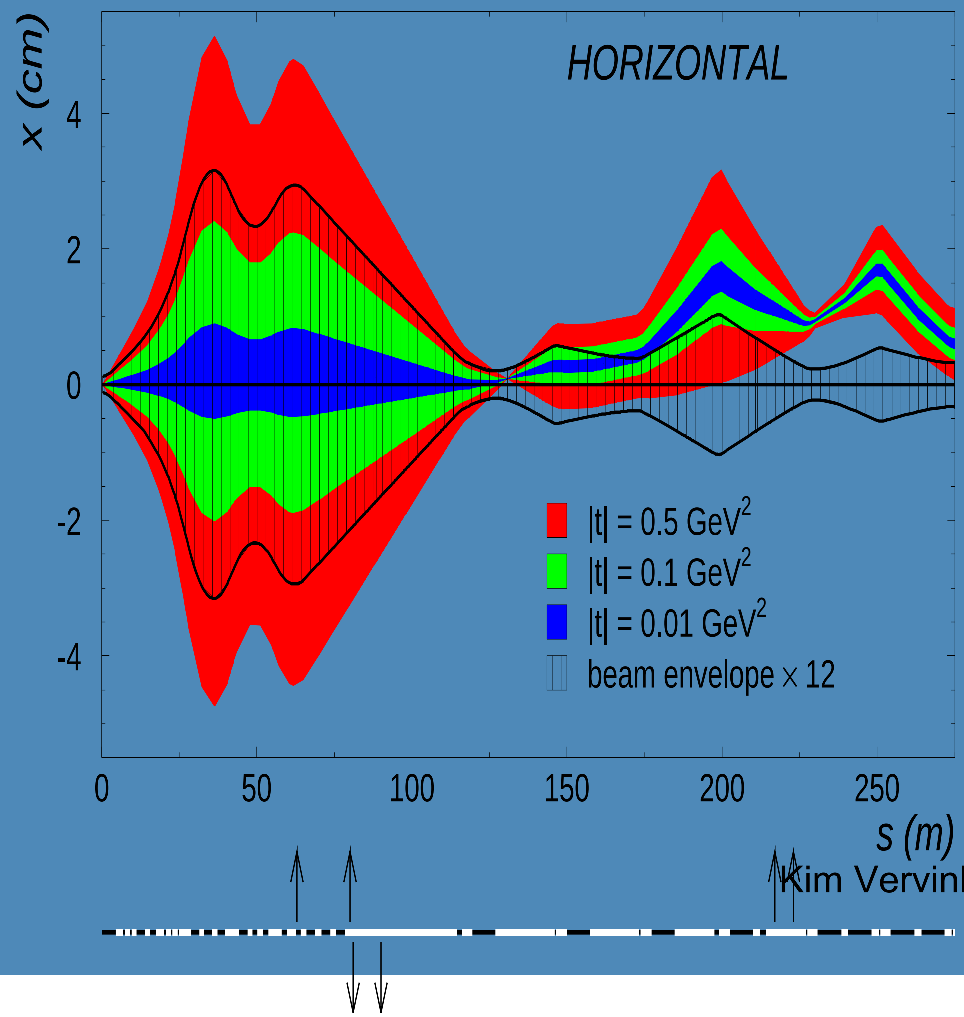
Position, slope and proton energy at the VFPS detector

Beam postition, divergence and proton energy at H1 detector.

$$\begin{pmatrix} x(s) \\ x'(s) \\ \xi \end{pmatrix} = \begin{pmatrix} T_x^{11}(s_0,s) & T_x^{12}(s_0,s) & D_x(s_0,s) \\ T_x^{21}(s_0,s) & T_x^{22}(s_0,s) & D'_x(s_0,s) \\ 0 & 0 & 1 \end{pmatrix} \cdot \left[\begin{pmatrix} x_0 \\ x'_0 \\ \xi_0 \end{pmatrix} + \begin{pmatrix} 0 \\ \theta_x \\ x_{I\!P} \end{pmatrix} \right]$$

Beam optics Transport matrix

Diffractive variables



- Contains non-linear effects
- Sextupole magnets.

The spectroscopic effect makes that scattered protons follow a trajectory closer to the inside of the circle. It will leave the nominal beam and therefor be available for acces for the VFPS.

Calibration: I

- Changes in **beam position** during one lumi-run
  - ➔Relative position
  - ➔Measured by Beam Position Monitors
- Changes in position of **Roman Pots** (aproaching the beam) very well known.
- Positioning of VFPS **detectors w.r.t. nominal proton beam**
  - ➔ Absolute position
  - ➔ Time-dependent calibration / run

Calibration: II

→Minimization procedure between a **measured** variable (dependent of position) and **"true" values**:

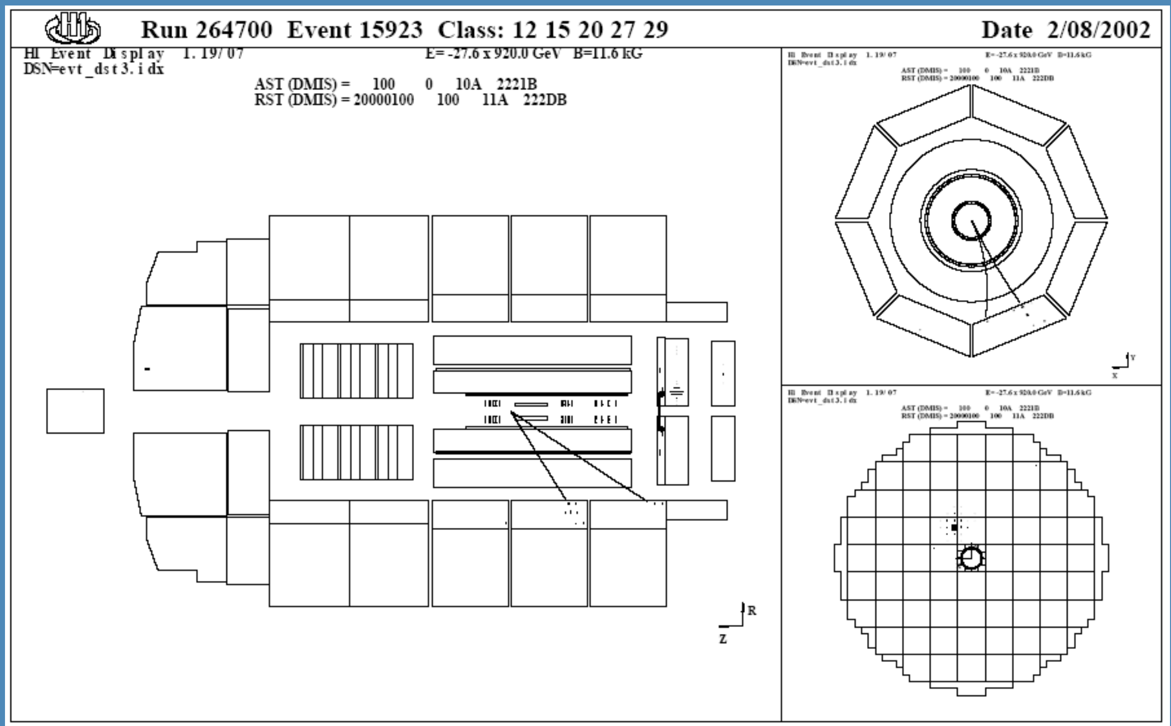
$$\chi^2 = \sum_{events} \left(\sum_{variables} \frac{(x_i^{\exp} - x_i^{true})^2}{\sigma_{x_i}^2} \right)$$

Parameters of minimization: the position offsets. Get as **fast as possible** a minimum in χ^2 by having lots of **statistics** or a low **sigma** value.

Calibration VFPS through elastic production of ρ mesons in H1

- Principle: look at a **clean and precise** measurable proces in central detector:

$e+p \rightarrow e'+p'+\rho$ $\qquad\qquad$ $\rho \rightarrow \pi^+\pi^-$



Selection:
- Quality of data
- 1 electron SpaCal
- Two tracks of opposite charge
- Minimise background

Suppress background:

Background introduced by **simular** looking processes. Selection on **tracks** has no effect.

$\rho \rightarrow \pi^{+} \pi^{-}$
$\omega \rightarrow \pi^{-} \pi^{+} \pi^{o}$
$\phi \rightarrow K^{-} K^{+}$

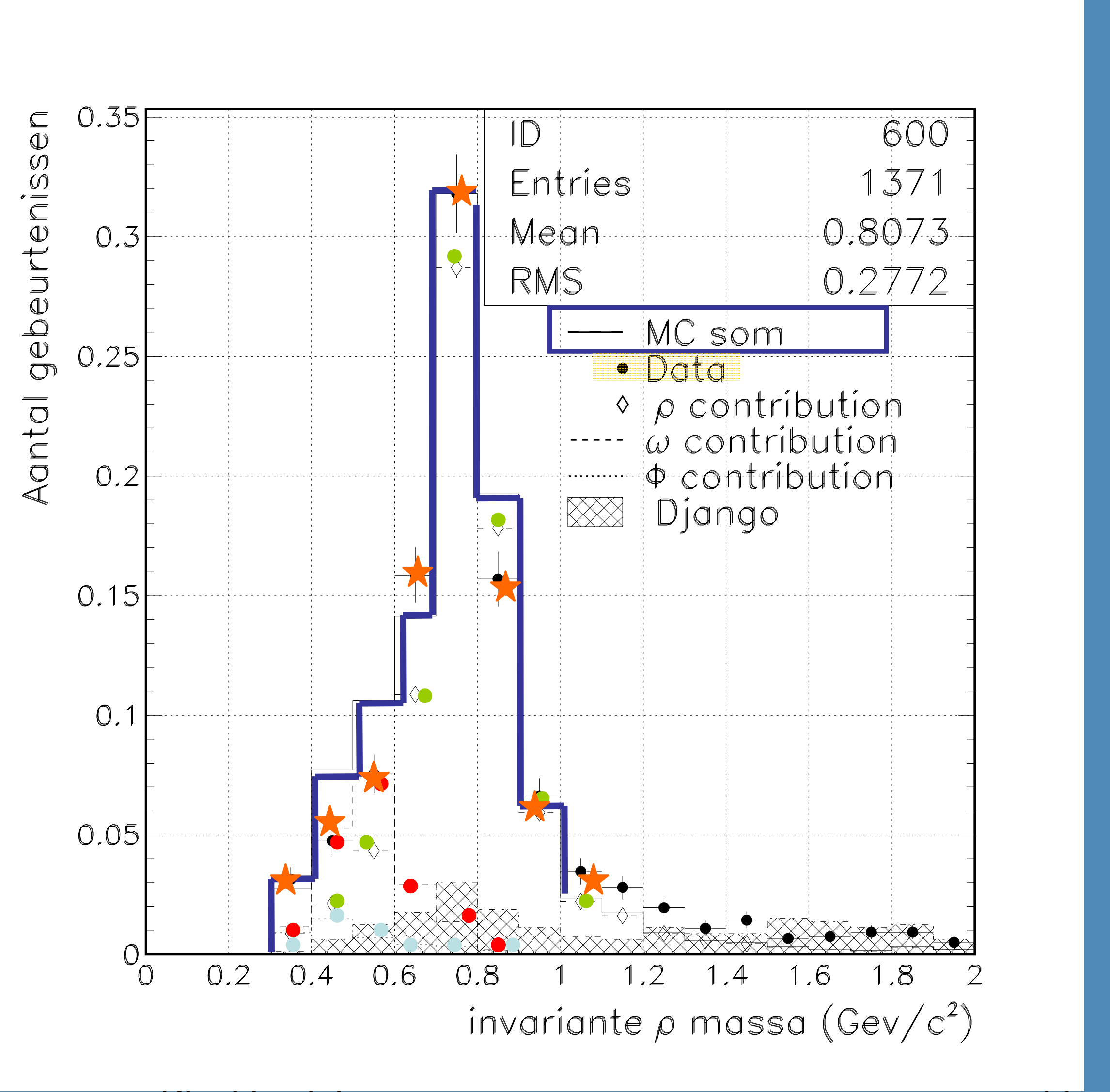
Selection on **energy** → cluster without track

Selection on **reconstructed mass** → use difference of mass of mother particles.

Control: invariant ρ mass

Compare distribution of data + cuts with simulation of the different (ρ and BG) contributions

➔Selected data need to look **simular** to ρ contribution
=> ok



Resolutions on ρ (~p):
$p_x^\rho = p_y^\rho$ = 300 MeV;
p_z^ρ =900 MeV; $E^\rho = 1$ GeV

Use this information for calibration.

- **Compare** kinematic variables from p' (H1) with the ones measured by VFPS
- Properties: low statistics ☹, high precision ☺

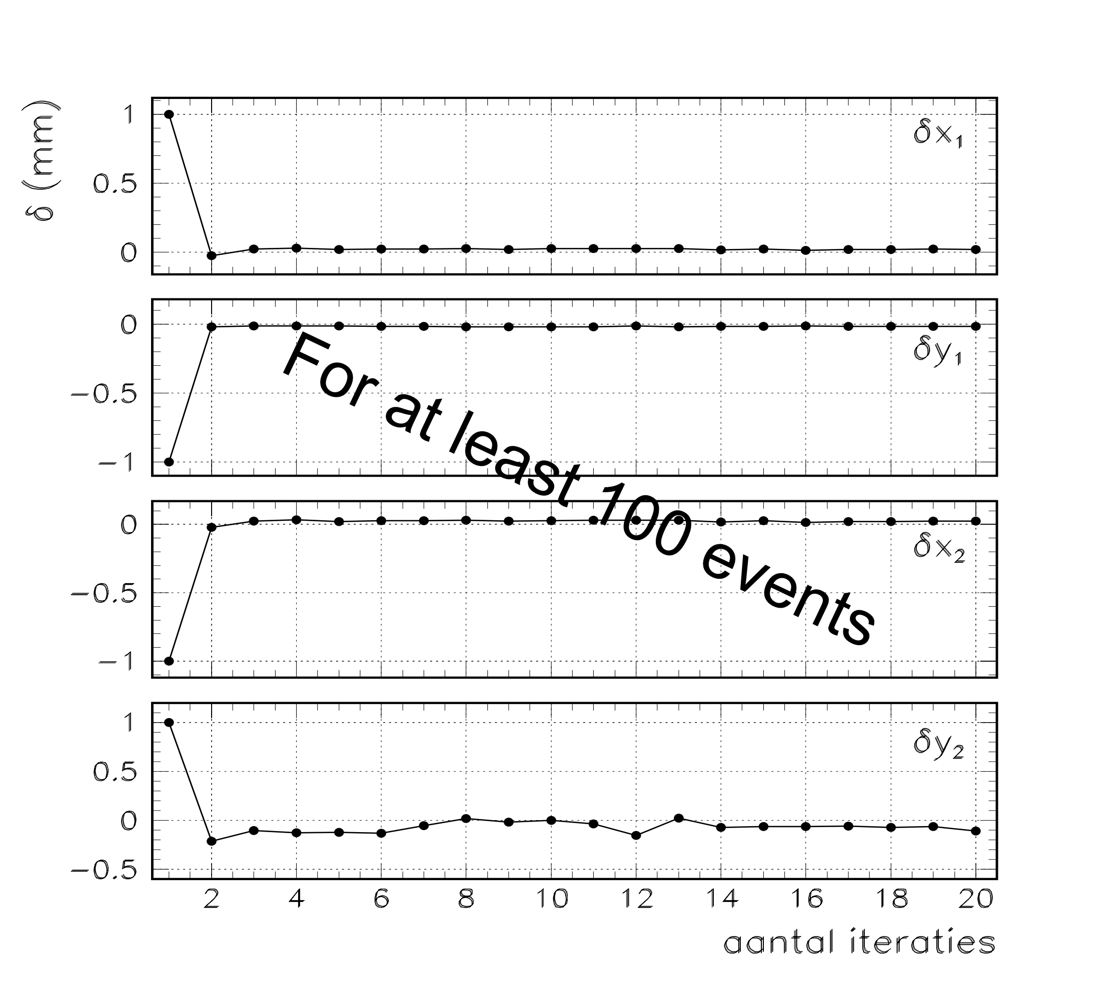
→ Cross check method

$$\chi^2 = \sum_{events} \frac{(\vartheta_x^{\rho} - \vartheta_x^{VFPS})^2}{\sigma_{\vartheta_x}^2} + \frac{(\vartheta_y^{\rho} - \vartheta_y^{VFPS})^2}{\sigma_{\vartheta_y}^2} + \frac{(xpom^{\rho} - xpom^{VFPS})^2}{\sigma_{xpom}^2}$$

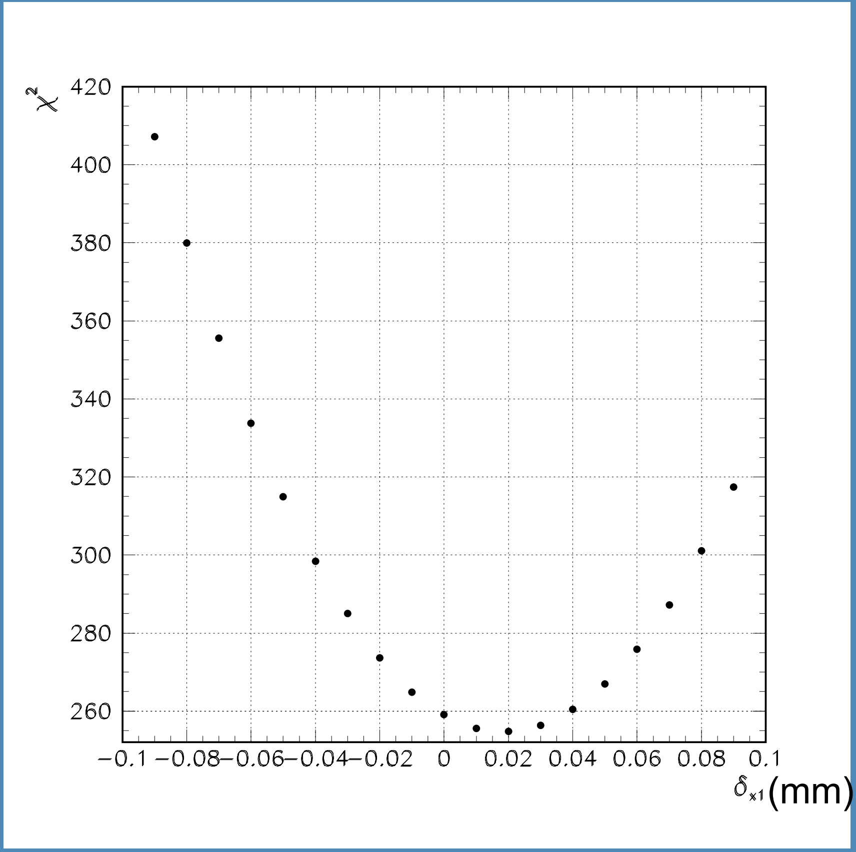
Results of the calibration.

Place VFPS on a **wrong offset** →does it find back the position with the correct alignment?

After a few **iterations** in the minimization procedure.



χ^2 minimum in function of offset.



Results (all in micron)

	gene	reco
$\delta x_1 \pm \sigma(\delta x_1)$	20 ± 27	120 ± 87
$\delta y_1 \pm \sigma(\delta y_1)$	-15 ± 13	-20 ± 63
$\delta x_2 \pm \sigma(\delta x_2)$	20 ± 26	150 ± 85
$\delta y_2 \pm \sigma(\delta y_2)$	-100 ± 68	400 ± 257

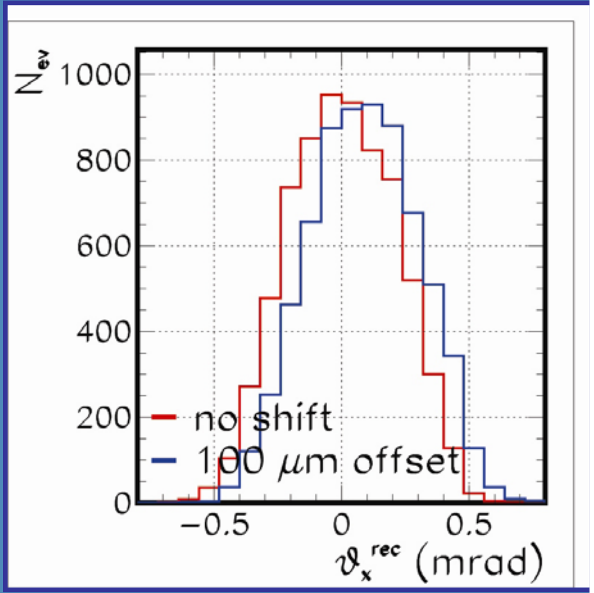
Resolution of glassfibers ≈ 100 micron

Calibration of the VFPS through kinematic peak method.

Principle: VFPS measures |t| 0→0.25

$|t|=(p-p')^2 = -2p^2(1-\cos\theta)$

$$\frac{d\sigma}{dt} = \frac{1}{x_p} e^{-bt}$$



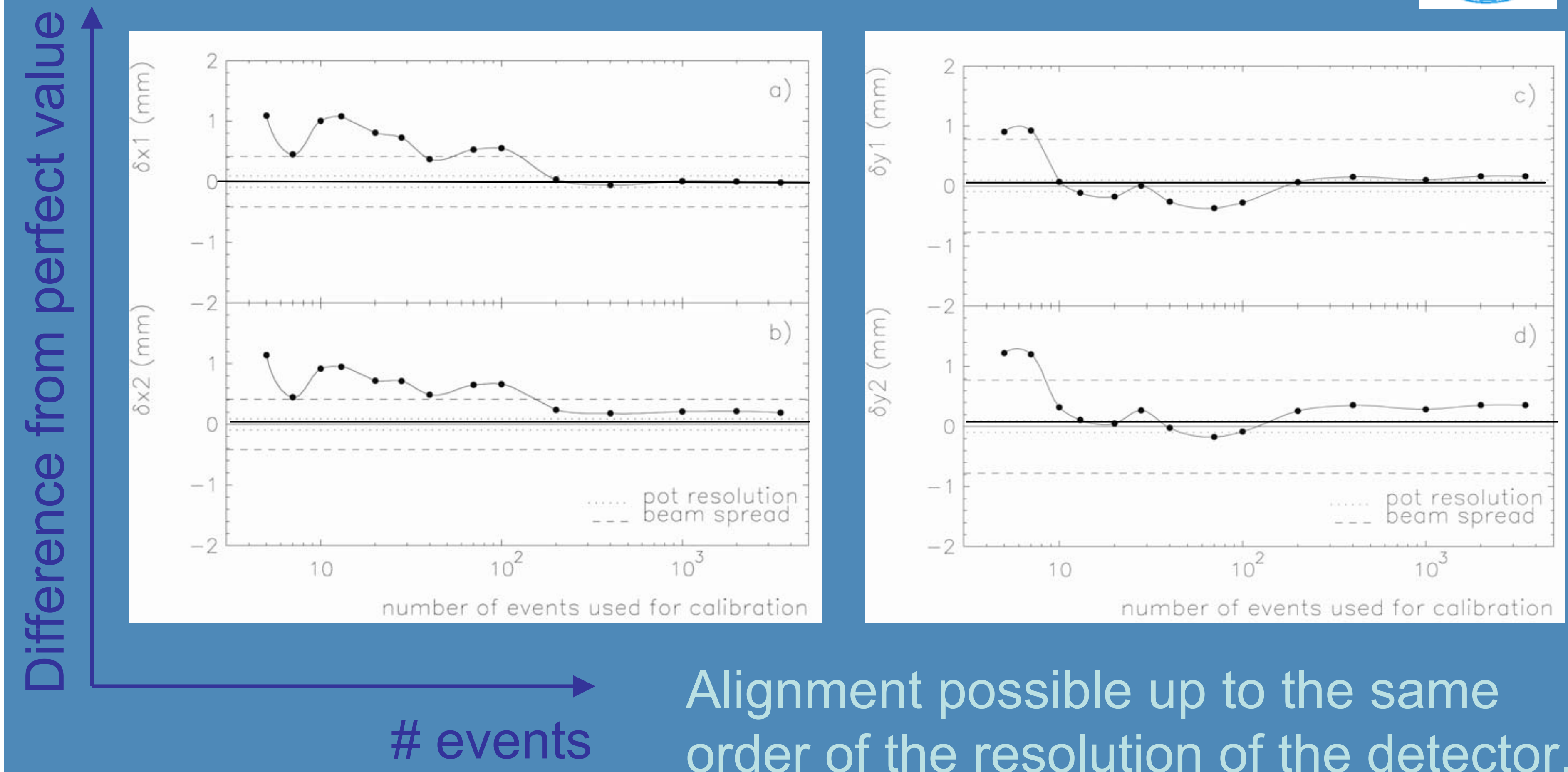
→θ: distributed around 0°

Misalignment => θ distribution won't peak anymore at 0°!

$$\chi^2 = \frac{\theta_x^2}{\sigma_{\theta_x}^2} + \frac{\theta_y^2}{\sigma_{\theta_y}^2} + \frac{\left(x_P - x_P^{H1}\right)^2}{\sigma_{(x_P - x_P^{H1})}^2}$$

Properties: high statistic ☺, large sigma ☹

Results…



Alignment possible up to the same order of the resolution of the detector.

Lots of events needed to compensate large sigma ➔ time consuming.

Conclusion

- **B**eam **P**osition **M**onitors not enough to calibrate!!
- **Kinematic peak** calibration method will be used to align VFPS within one lumi-run but the **elastic ρ** production method will be a useful **cross check**.
- Both methods have a **calibration resolution** less than 100 micron (= resolution of scintillating fibres)