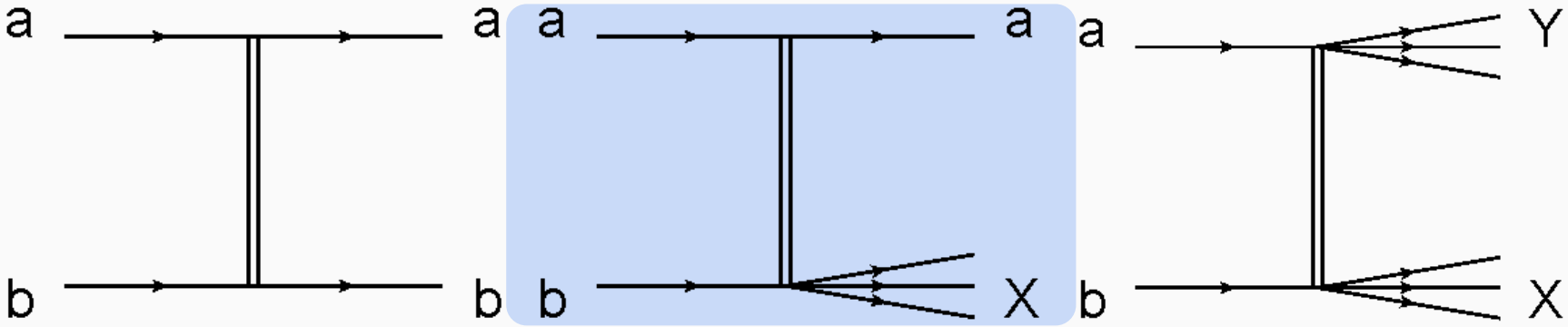
Hot-spot method for alignment of forward proton detectors at the LHC

Paweł Buglewicz

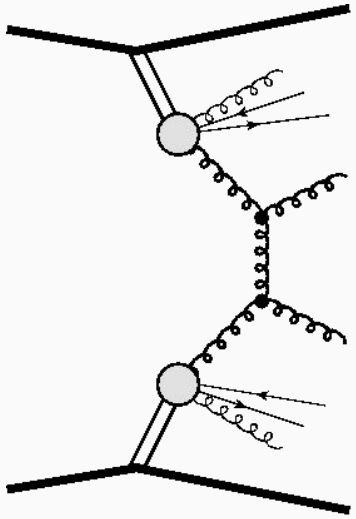
Cracow University of Technology

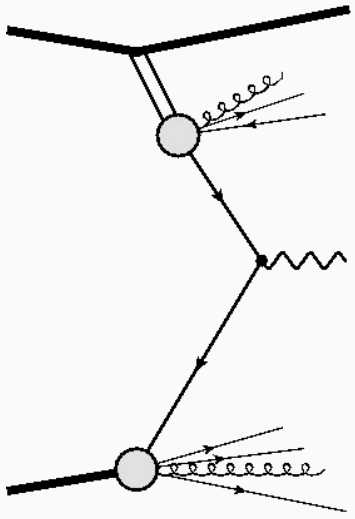
Epiphany 7-9.01.2016

Diffractive Processes



- pp interaction,
- color singlet (Pomeron) exchange,
- hard & soft diffractive processes
- diffractive signatures:
  - large rapidity gap
  - **intact forward proton**

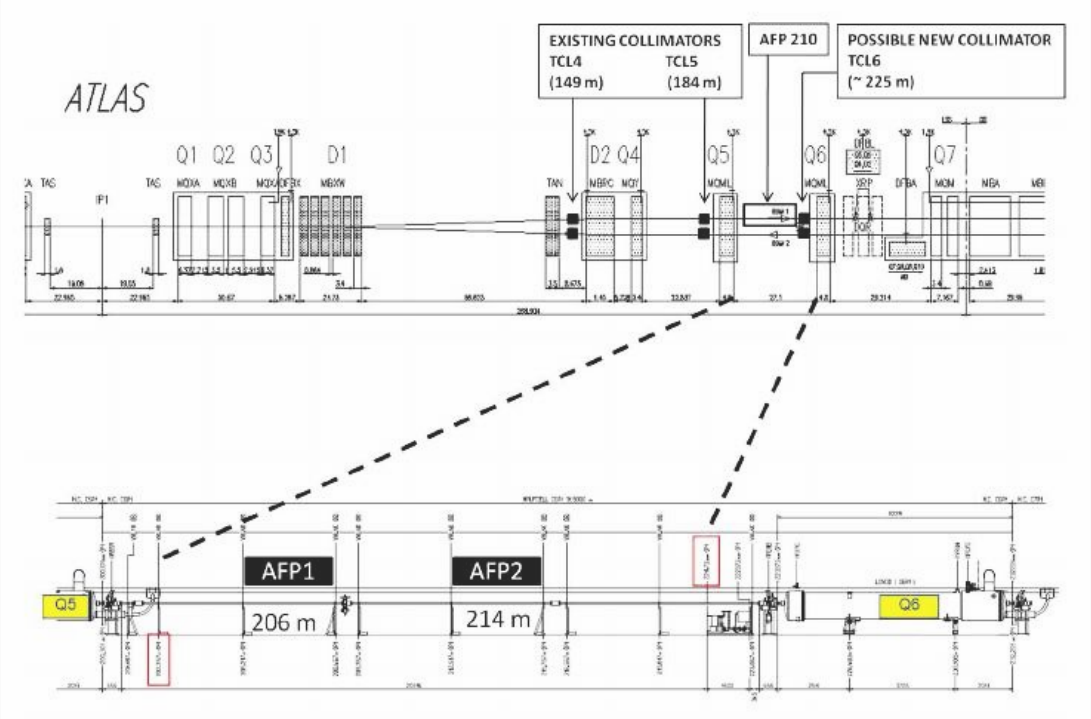




Example: ATLAS Forward Proton (AFP) detectors

Measurement of protons scattered at very small angle that escape the acceptance of central detectors:

- ~200 m from IP
- Few mm from the beam
- 4 stations: 2+2 (0+2 in first phase)
- Tracker - 4 layers of silicon pixel detector
- Tracker resolution (x,y):
  - 10μm x 30μm
- ToF detectors in outer stations



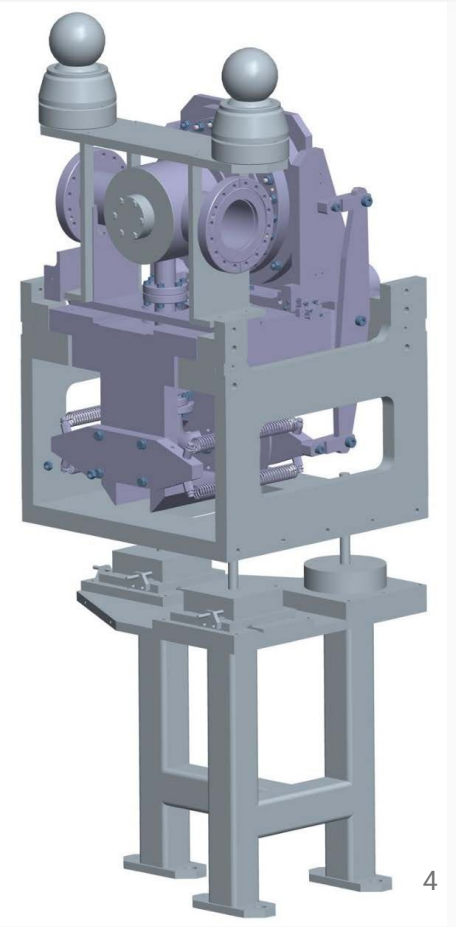
Motivation

Detectors are placed in roman pots - measurement inside the LHC beam pipe.

Moved in and out for every run → position of detectors changes very often.

Precise information about the position needed for data analysis.

A need for dedicated alignment methods.



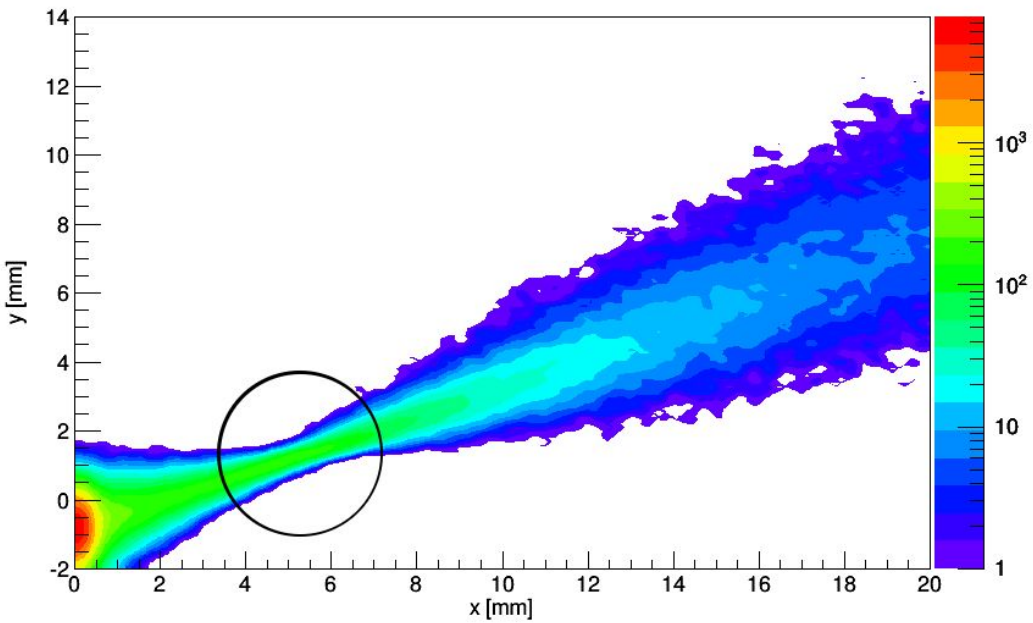
Proton transport & hit pattern

Particles are transported through LHC lattice.

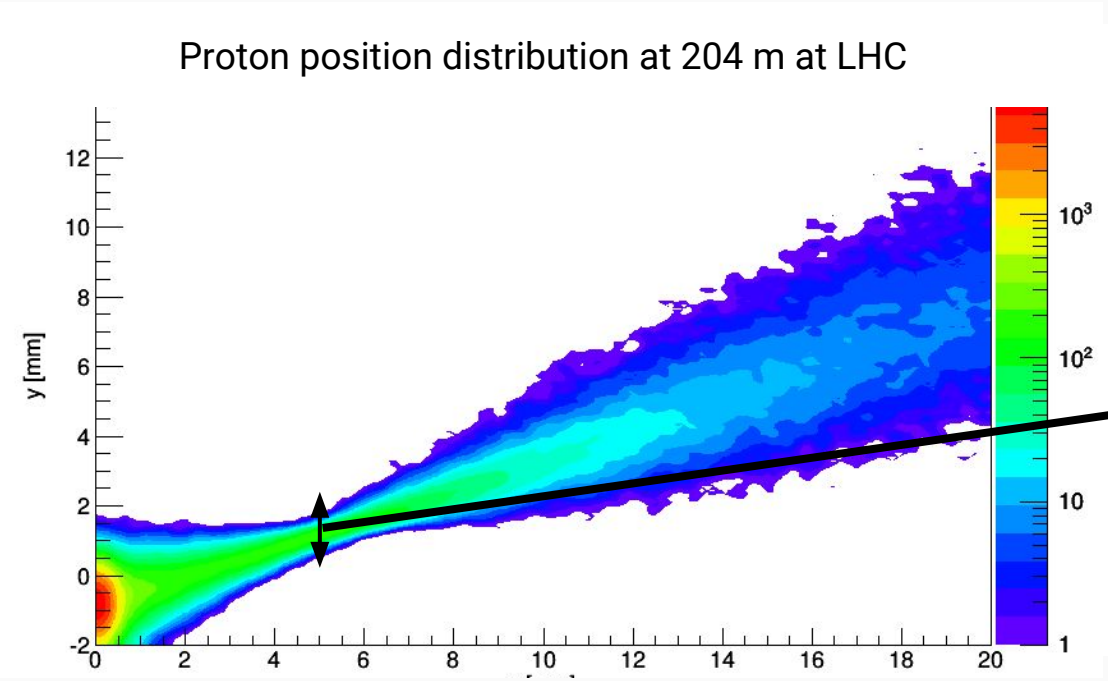
Characteristic pattern due to properties of LHC optics.

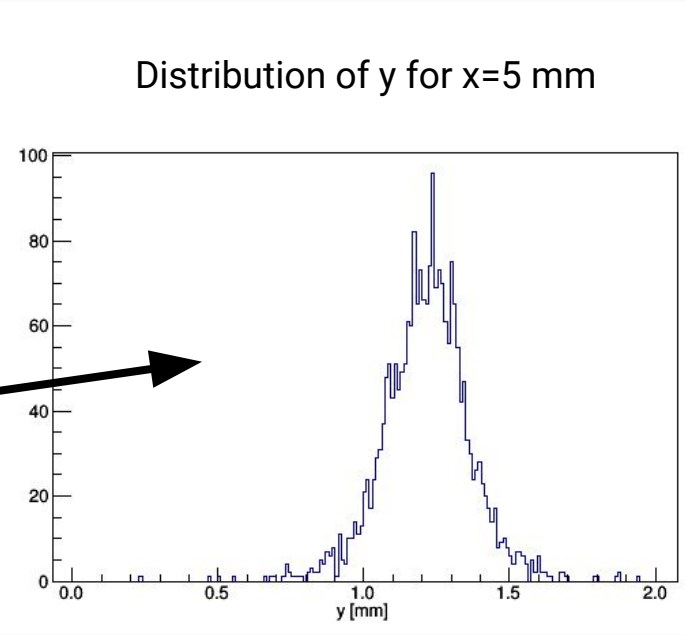
Hot-spot alignment method: positioning the detector w.r.t. the narrow region.

Proton position distribution at 204m in LHC



Width measurement





- Width in y measured in bins of x
- Methods of width measurement
  - Gaussian width
  - Standard deviation

Position of the narrow region

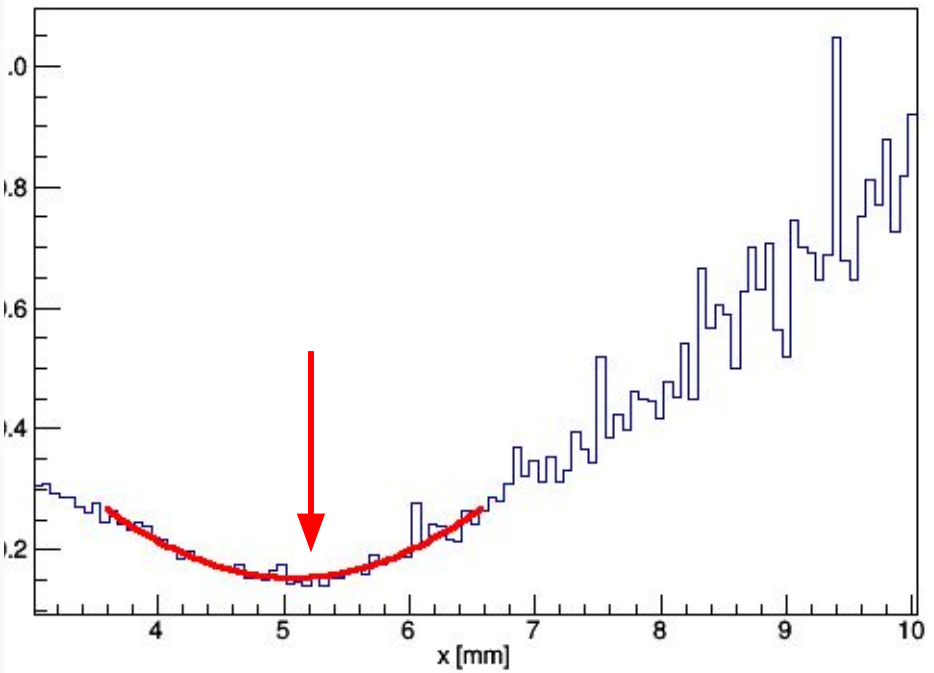
For each x bin a width value (w) is found.

A clear minimum is observed in w(x).

A 2nd rank polynomial is fitted to w(x).

Minimum of the polynomial gives the hot-spot position.

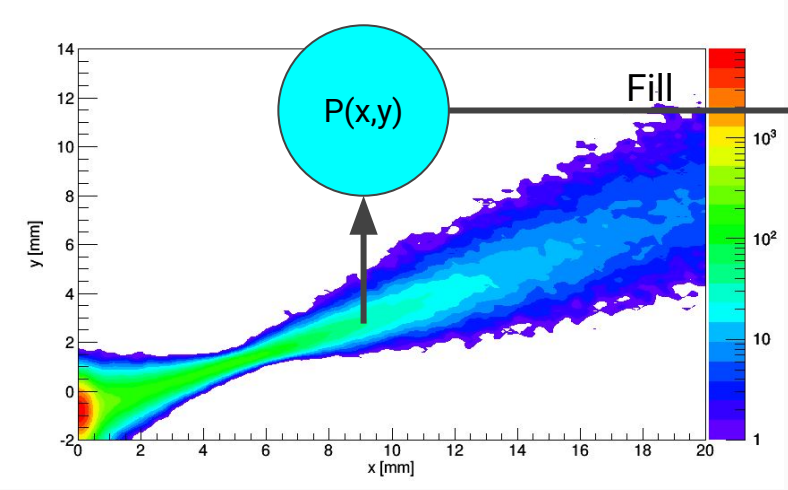
RMS as a function of distance.



Statistical uncertainty of the method

Statistical Uncertainty:
Bootstrap is a statistic method of evaluating statistical uncertainties. From a given sample a new statistically independent sample is created.

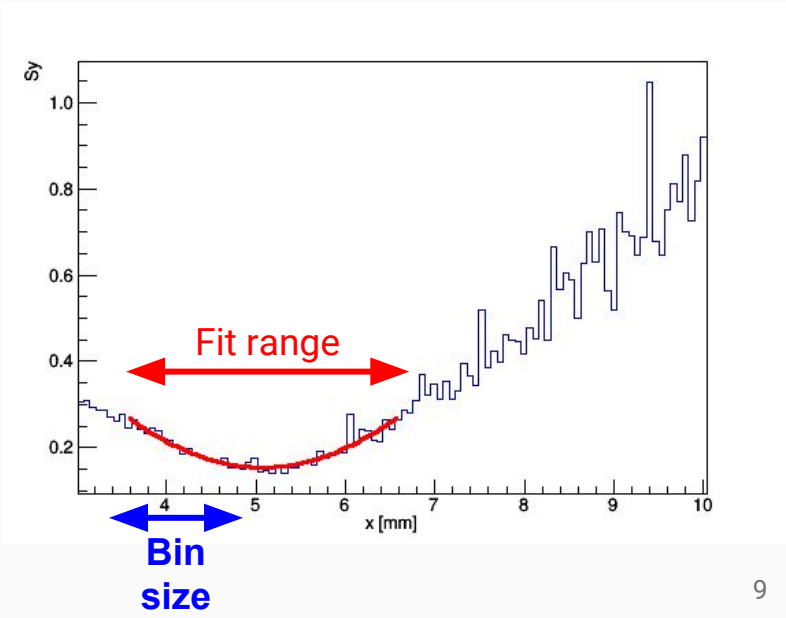
(New histogram is filled with new values drawn from Poisson distribution with mean from the original histogram).



Systematic uncertainties

Systematic uncertainties:
(for 600K events registered by detectors 3 mm from the beam, which corresponds to integrated luminosity of 200 μb^{-1})

- Method for width measurement:
  - **Difference between RMS and Gaus: 240 μm**
- Details of the algorithm
  - Bin size: RMS: 40 μm, Gauss: 20 μm:
  - Polynomial fit range: RMS 70 μm, Gaus 30 μm
- Physics/background
  - SD vs SD+DD: **RMS - 65 μm**, Gaus: 4 μm



Summary

- Physics motivation - diffractive processes with intact forward protons
- Measurement with dedicated detectors, e.g. AFP
- Roman pot mechanism → detectors change position every run
- Need for dedicated alignment methods

- Hot-spot method - positioning w.r.t. narrow region in hit pattern
- Measurement of y-width in bins of x: std. dev. / Gauss
- Position of the minimum obtained from a quadratic fit
- Studies of uncertainty sources: statistical and systematic

Thank You for Your attention!