ATLAS inner detector alignment

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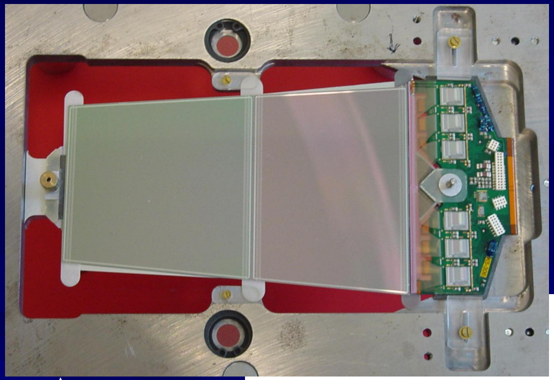
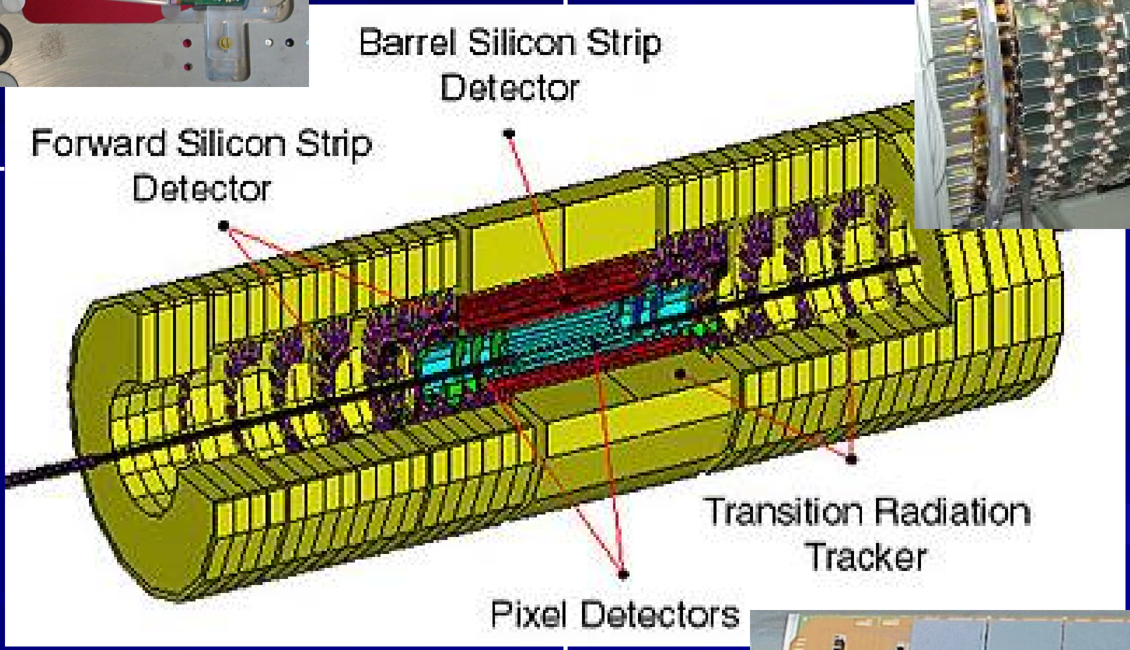
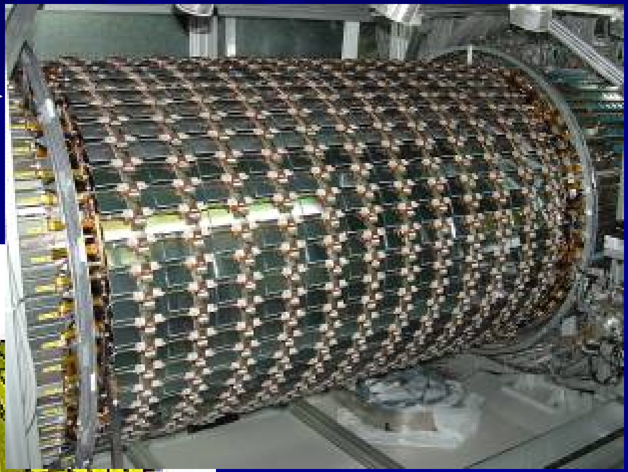
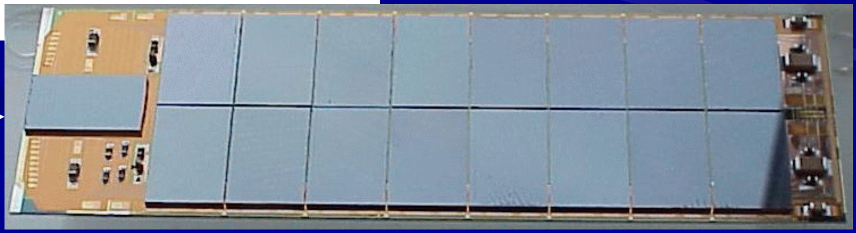
Inner detector

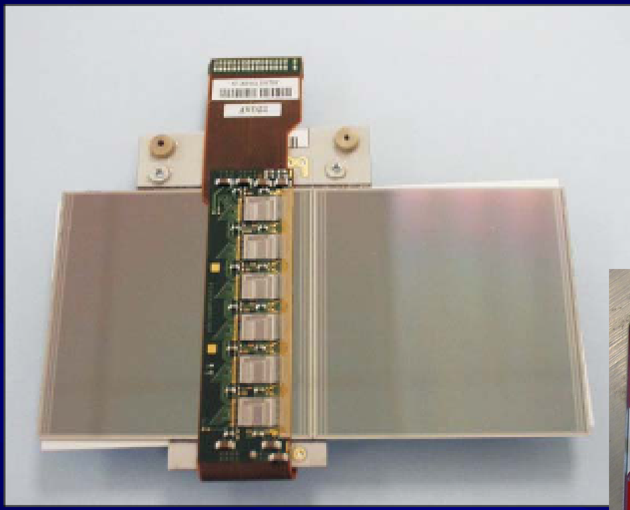






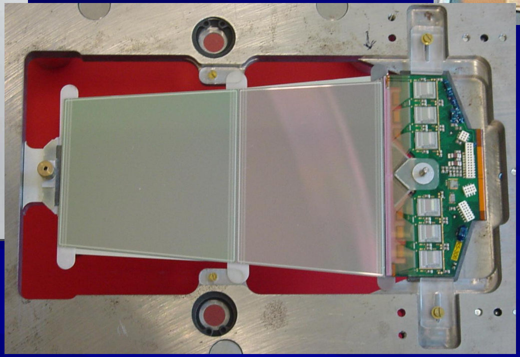


Module geometry



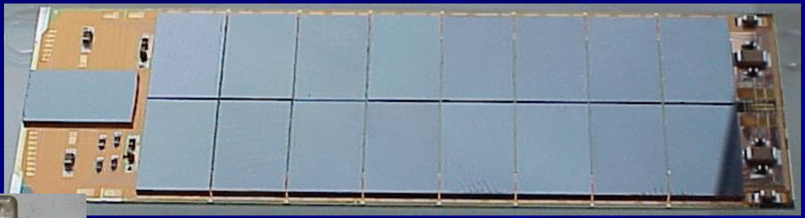
SCT barrel

- 2112 double-layer modules
- 768 strips, parallel to beam
- 80 µm pitch



SCT endcap

- 1976 double-layer modules
- 768 strips
- 60-120 µm pitch



pixel

- 1744 modules
- 60.8x16.4 mm divided in 16 chips
- 46080 pixels, each 50x400 µm

Physics motivation for alignment

Alignment needs to be accurate to

- Ø 7 µm (pixels) & 12 µm (SCT)
  to not degrade the track parameters by more than 20%
- Ø <10 µm for good high-p_T b-tagging
- Ø ~1 µm to measure W-mass more precisely than CDF
  (ambitious!)

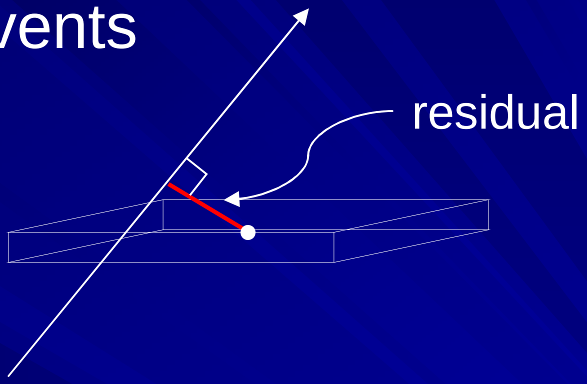
Alignment

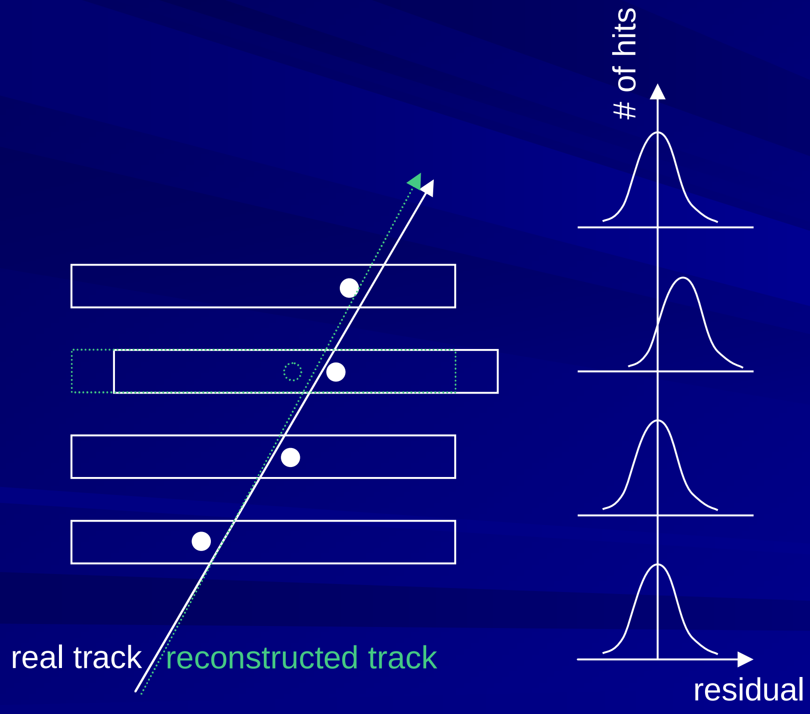
- Hardware alignment:
  - conventional survey:
    measures structures to 10-100 µm
  - interferometry (2 µm disc to disc)
- Software alignment:
  - use reconstructed particle tracks
    (beam or cosmic tracks)
  - perform minimization algorithm

Alignment using particle tracks

- use reconstructed tracks from many events
- use distribution of the residuals

to determine alignment parameters





different approaches:

- robust align
- robust χ^2
- global χ^2

robust χ² algorithm

r : residuals
σ : error of the residuals
a_i : alignment parameters

linearized χ²-minimization:

$$\chi^2 = \sum \left(\frac{r^2}{\sigma^2} \right)$$ (definition of χ²)

$$\frac{\partial \chi^2}{\partial a_i} = 0$$ (condition for minimum)

$$\chi^2 = \chi_0^2 + \sum_i \frac{\partial \chi^2}{\partial a_i}\bigg|_{\chi_0} \cdot a_i + \ldots$$ (linear Taylor expansion)

$$\rightarrow \quad \frac{\partial \chi^2}{\partial a_j} \overset{!}{=} 0 = \frac{\partial \chi_0^2}{\partial a_j} + \sum_i \frac{\partial^2 \chi^2}{\partial a_j \partial a_i} \Delta a_i = \frac{2}{\sigma^2} r \frac{\partial r}{\partial a_j} + \sum_i \frac{2}{\sigma^2} \frac{\partial r}{\partial a_j} \frac{\partial r}{\partial a_i} a_i$$

Alignment algorithm

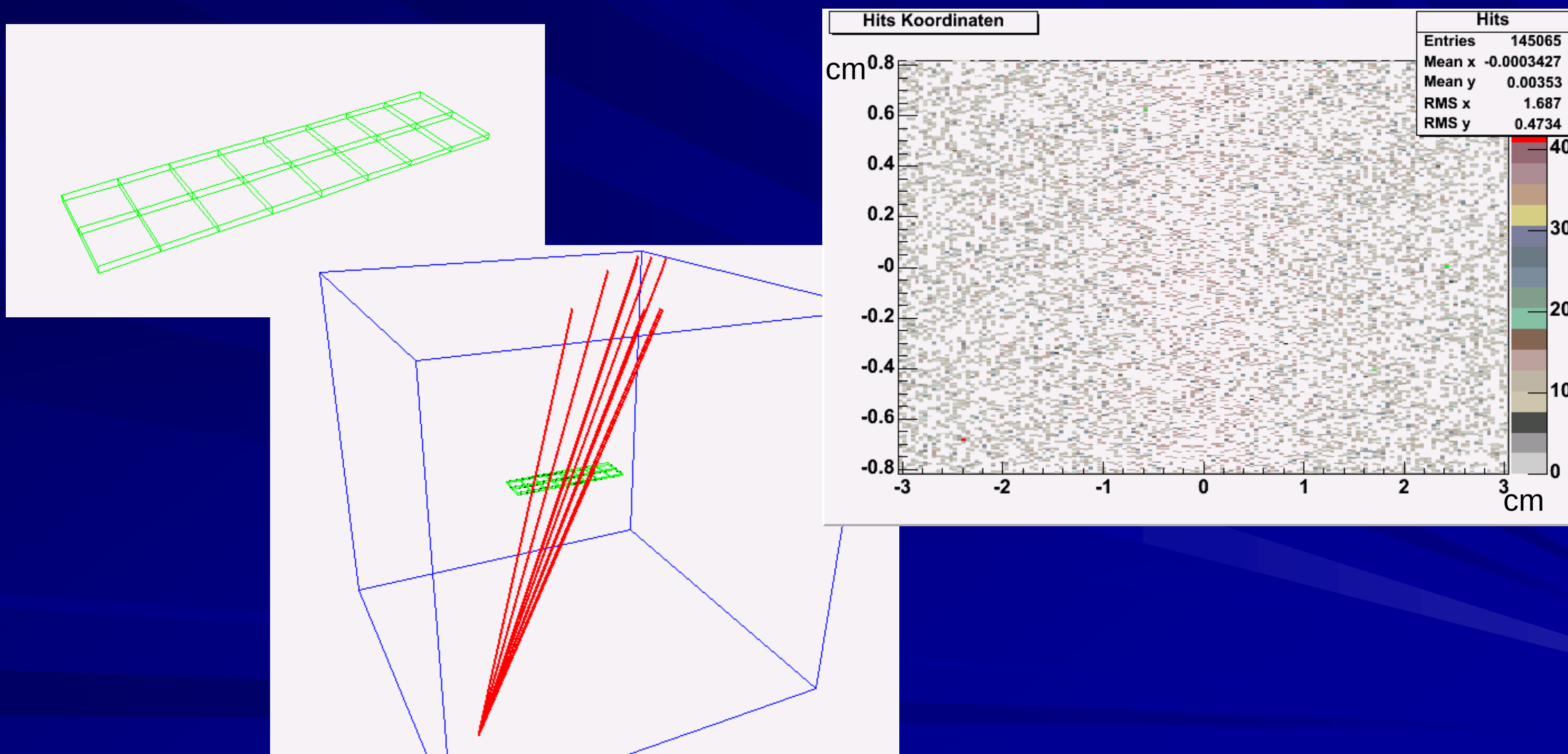
- solve these 6 linear equations for each module:

$$\vec{b} + \Lambda \vec{a} = 0$$

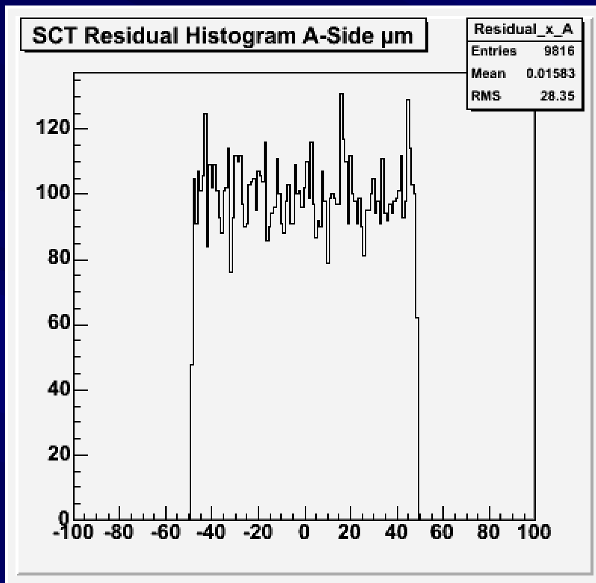
- redo track reconstruction and alignment procedure with newly found detector geometry $\rightarrow$ this way all the modules get „connected“ to each other
- iterate as long as necessary to produce well-aligned detector

Simulation

- investigate algorithm on simple pixel geometry

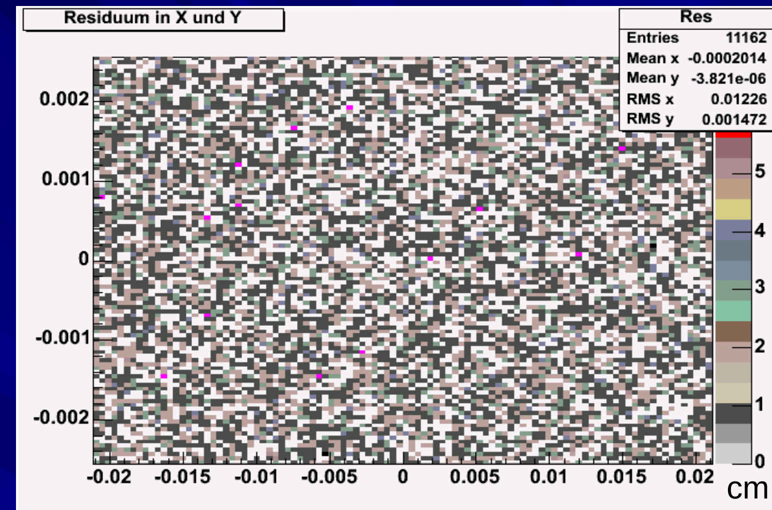


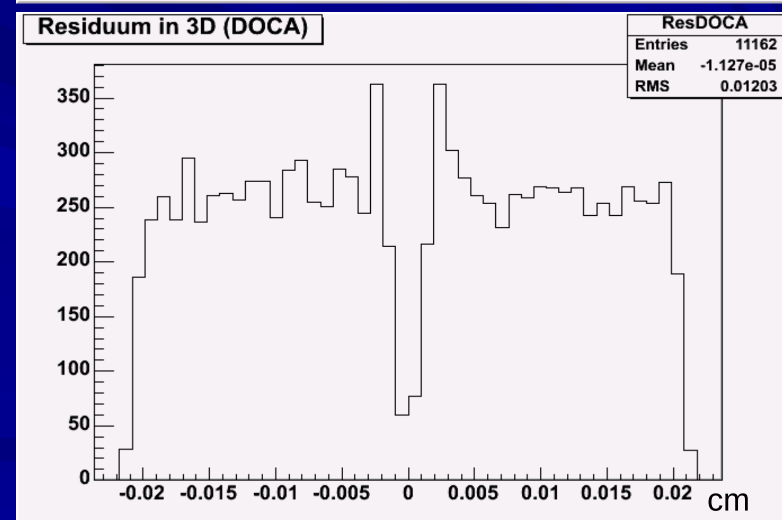
residual plots



← SCT

pixel →

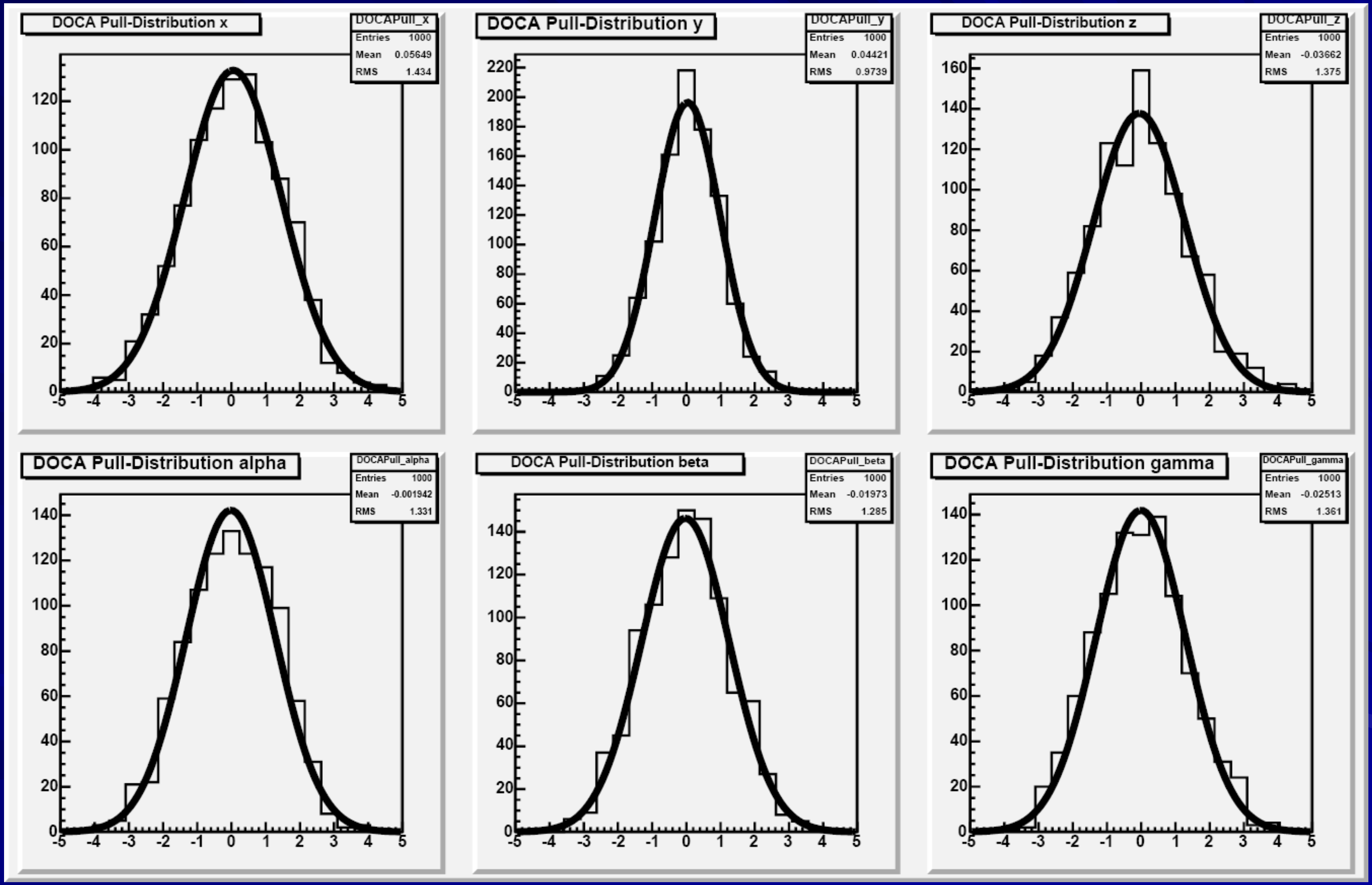




With the residuals and their derivatives, it is possible to determine alignment parameters

Pull distributions

$$Pull = \frac{A_{real} - A_{calc}}{\sigma}$$



Conclusion

- Inner detector alignment using robust χ^2 method seems possible up to a resolution of a few µm
- Iteration algorithm can be used for pixel & strip detector
- SCT is under implementation,
  pixel at first studies