The Laser Alignment System in Track-based Alignment

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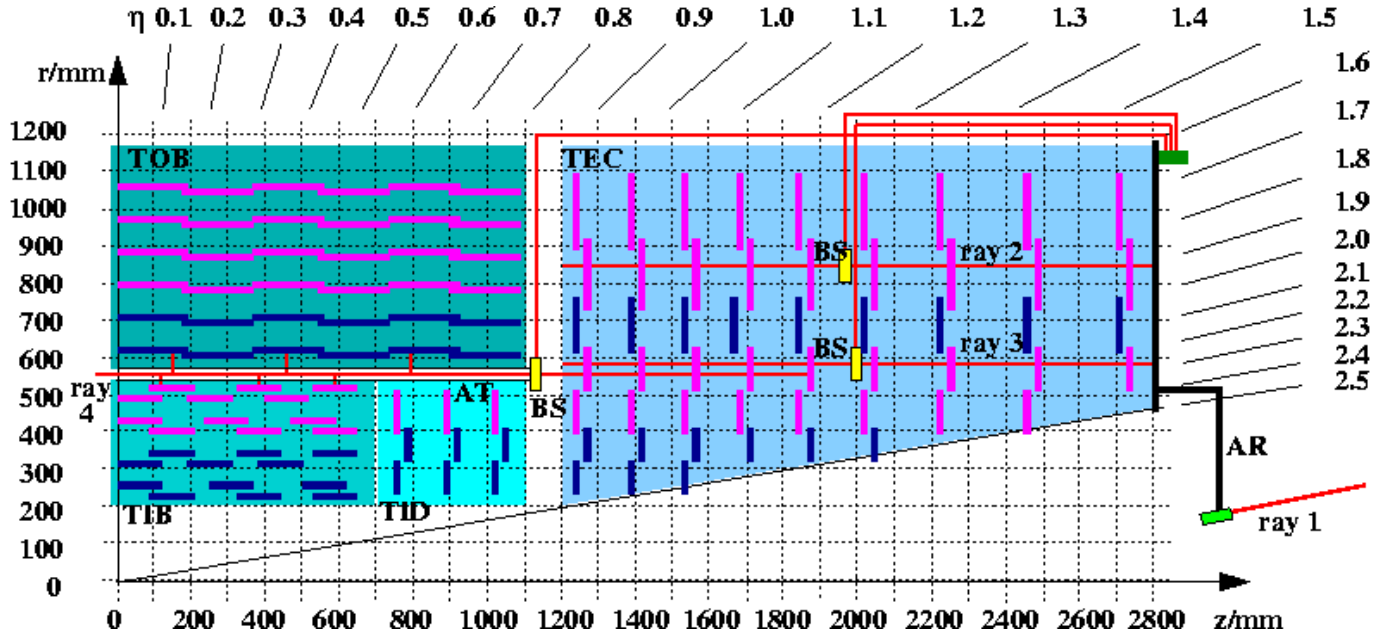
Outline

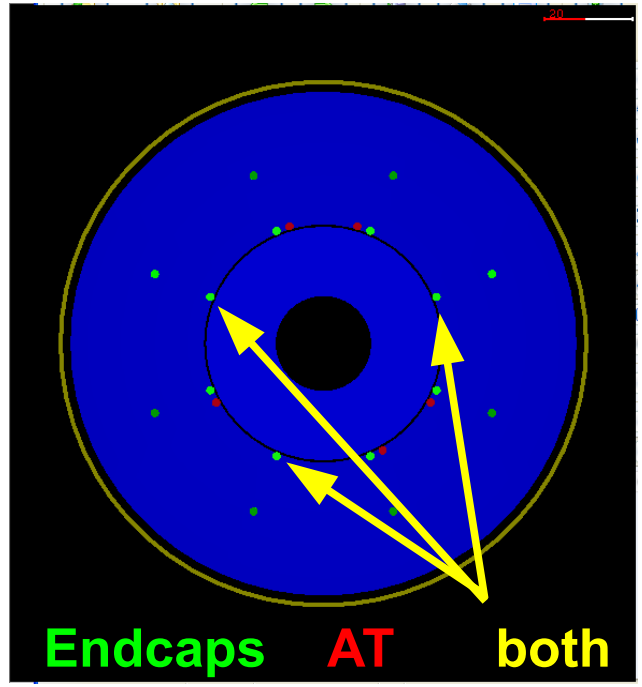
1. The Laser Alignment System (LAS)
2. Parametrization of LAS Beams
3. An Idealized Alignment: Proof of Principle
4. CRAFT Data: Hits and Residuals
5. Conclusion & Outlook

Laser Alignment System

40 fixed infrared laser beams, 16 per Endcap, 8 Alignment Tubes

- directed perpendicularly onto 434 Si-Strip-modules via Beam Splitters (BS)
- position measurements (in local x) with accuracy < 100 µm





- Laser beams are measured by Si-Strip sensors
- Endcap modules are semi-transparent to the lasers
- 8 Alignment Tube (AT) beams are directed onto barrel modules via semi-transparent mirrors

LAS & Track-based Alignment

Track-based Alignment

- desirable to combine many different tracks
  → reduction of χ^2-invariant deformations

Laser Alignment System

- unique beam shape not found in collision tracks
- monitor relative movements of endcap disks
- positions of endcaps, inner, and outer barrel wrt each other
- currently only stand-alone alignment with LAS data

Interface

- treat LAS beams like „tracks“
- use LAS hits to fit each beam separately
- different beam models for endcaps, Alignment Tube beams
- calculate track residuals
- write objects to be used by alignment algorithms (HIP, MillePede)

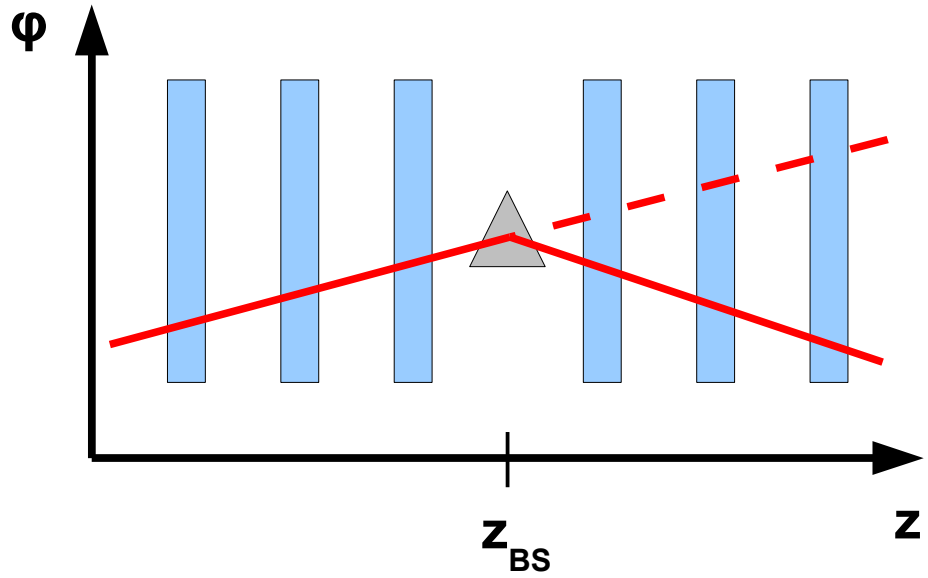
Beam Model

Tracker Endcaps

Laser beams assumed to be straight

$$\varphi_{hit} = a \cdot z_{module} + b$$

sensitive coordinate of Strip Tracker modules is global φ
→ no measurement in global r and z



Beam splitter kinks cause offset of beam on module

$$\Delta\varphi_{BS} = 2 \tan(\alpha/2) \cdot (z_{module} - z_{BS})/r_{beam}$$

- applied to modules on one side of beam splitter, e.g.

$$\varphi_{hit} = a \cdot z_{module} + b + \Delta\varphi_{BS} \quad \text{if} \quad z_{module} > z_{BS}$$

Beam Model

Alignment Tubes

- endcap beam segments treated as shown last slide

Barrel beam model

- radial distance of modules to beams

$$\Delta\varphi = - a \cdot r_{offset}$$

- rotation of Alignment Tubes

$$\Delta\varphi_1 = \pm r_{offset}/r_{module} \cdot \tan(\varphi_{AT})$$

- tilt of Alignment Tubes

$$\Delta\varphi_2 = - r_{offset}/r_{module} \cdot \tan(2\theta_{AT})$$

- no corrections for individual mirrors (yet?)

$$\varphi_{hit} = a \cdot (z_{module} - r_{offset}) + b + \Delta\varphi_1 + \Delta\varphi_2 \qquad \text{if barrel module}$$

Idealized Alignment

Beam model

- endcaps only, no beam splitters

$$\varphi_{hit} = a \cdot z_{module} + b$$

Data (toy Monte Carlo)

- one set of „LAS beams“, all hits at center of module (x = 0.0)

Misalignment

- endcap disks shifted in global x, y, φ by 100 µm (gaussian distributed)

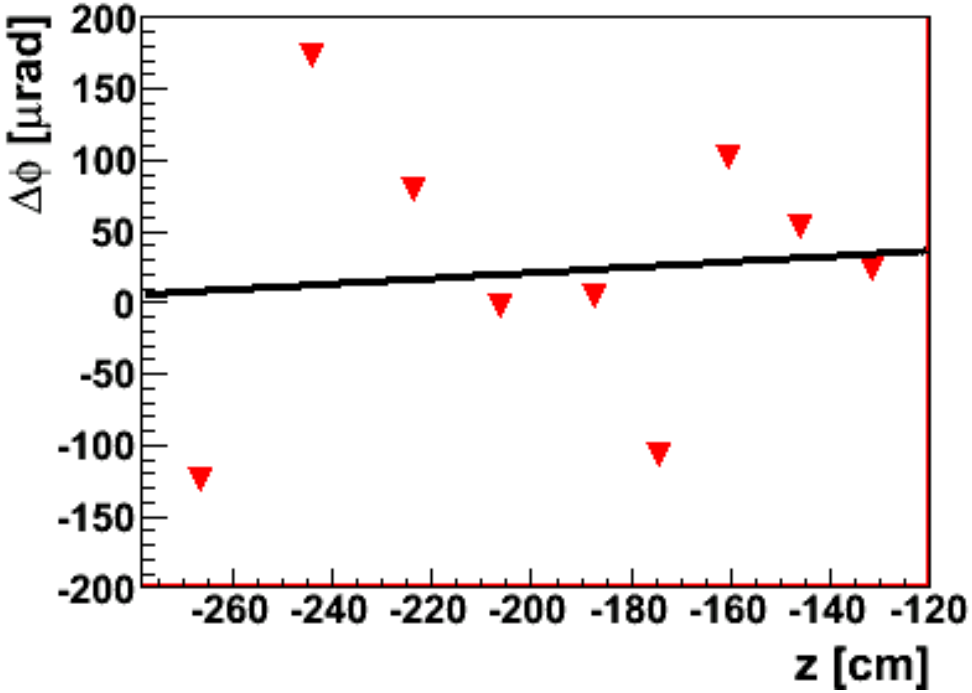
Alignment

- created interface to Millepede
- 6 constraints of global movements of endcaps
  (rotation, twist, shifts in x, y, tilts in x, y)
- aligned in global x, y, φ

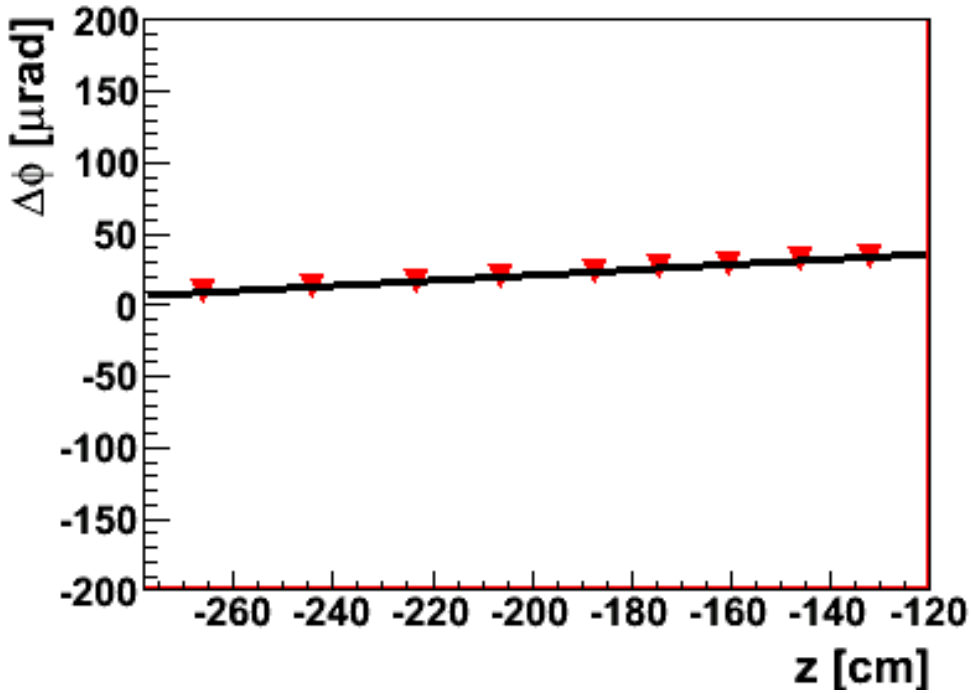
Idealized Alignment

TECminus Disk Alignment

Misaligned



Aligned



- φ-position of disks wrt ideal geometry
- linear fit to data points: slope (global twist) and offset (rotation) unchanged
  → LAS insensitive to those global shifts
  → **expected alignment of disks**

Residuals From CRAFT

LAS data taking at CRAFT

- 2000 shots per beam for good signal-to-noise ratio
- beam position on module determined from distribution of shots

- overlapping beams of ATs/TEC rings 4 not disentangled, thus ignored
- several other bad modules ignored

- no sensible error estimation yet, assume 30 μm uniformly

Fit performed

- Beam splitter angles fitted along with hit positions
- Alignment Tubes: no correction for rotation, tilt
- residuals calculated in global φ-coordinate

Geometry

- recent CRAFT MillePede Alignment

Residuals From CRAFT

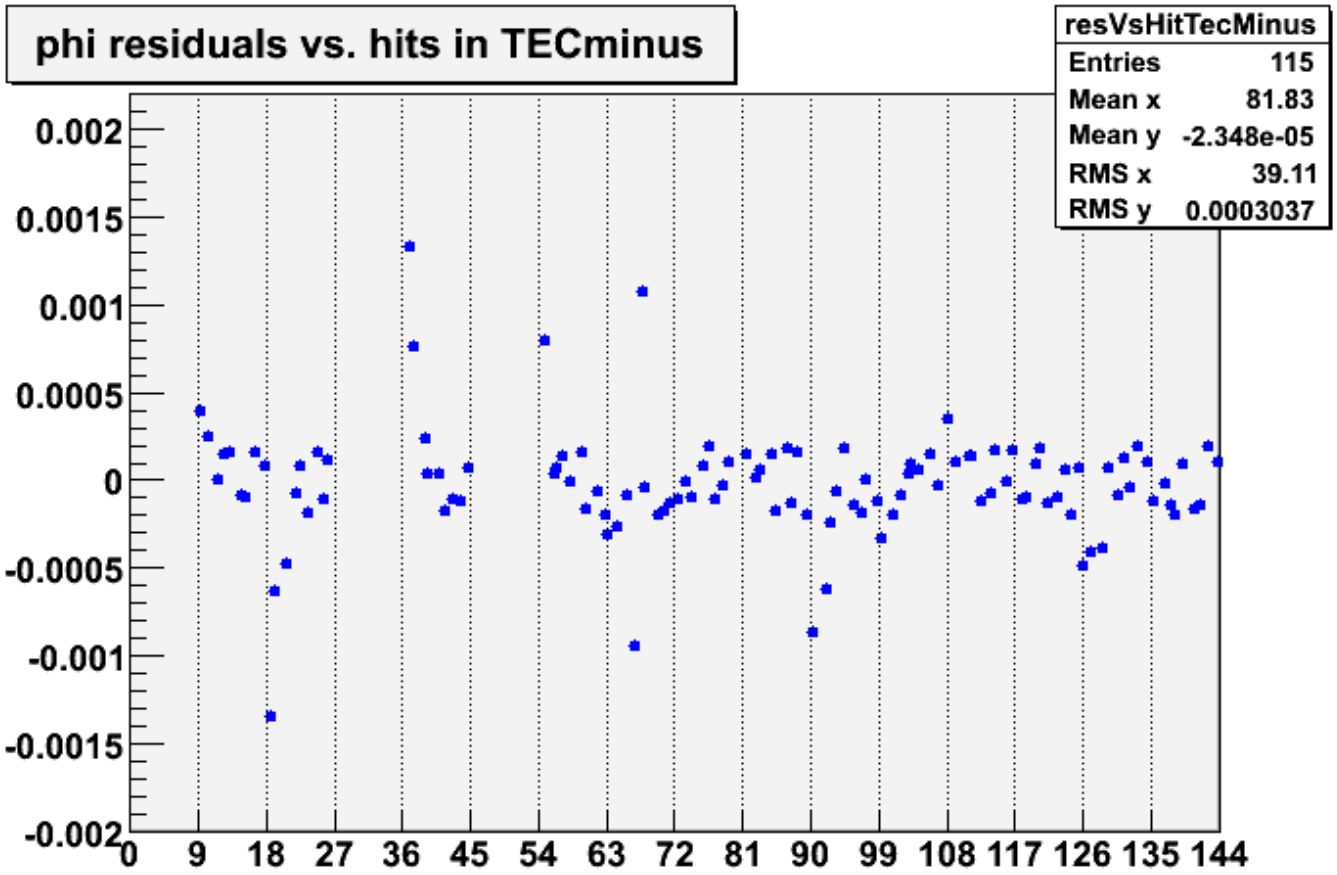
TECminus

residuals in φ

- scale: radians
- for each hit
- sorted by beam

RMS = 304 µrad

some outliers present



divided in x for all 16 beams
beams 1, 4, 6 ignored due to overlap with AT beams

Residuals From CRAFT

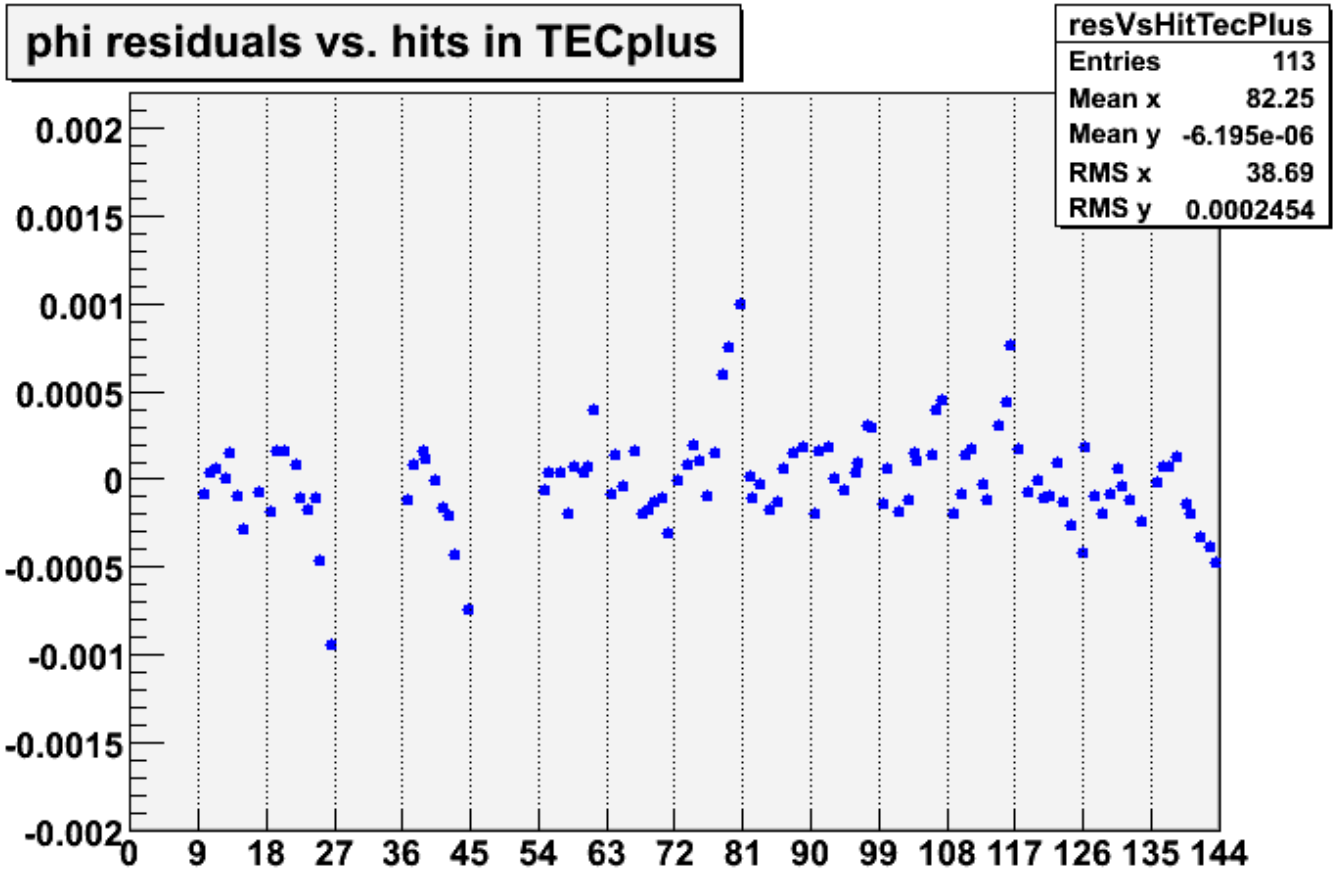
TECplus

residuals in φ

- scale: radians
- for each hit
- sorted by beam

RMS = 245 µrad

still some kinks visible



divided in x for all 16 beams
beams 1, 4, 6 ignored due to overlap with AT beams

Residuals From CRAFT

Alignment Tubes

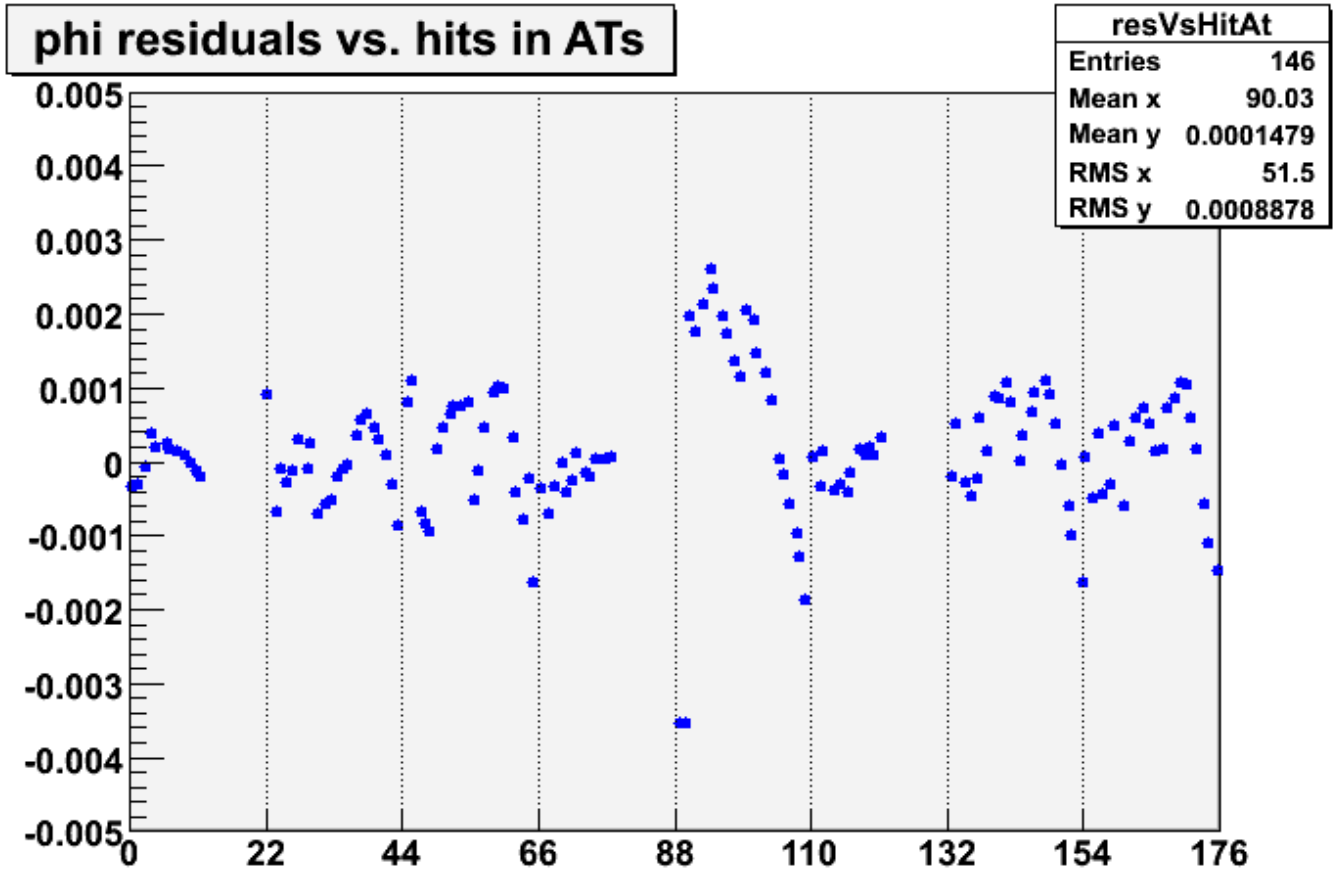
residuals in φ

- scale: radians
- for each hit
- sorted by beam

RMS = 888 µrad

Beam 5 strange
→ to be understood

some kinks left



- divided in x for 8 beams
- beams 1, 4, 6 without TEC hits due to overlap with AT beams

Residuals From CRAFT

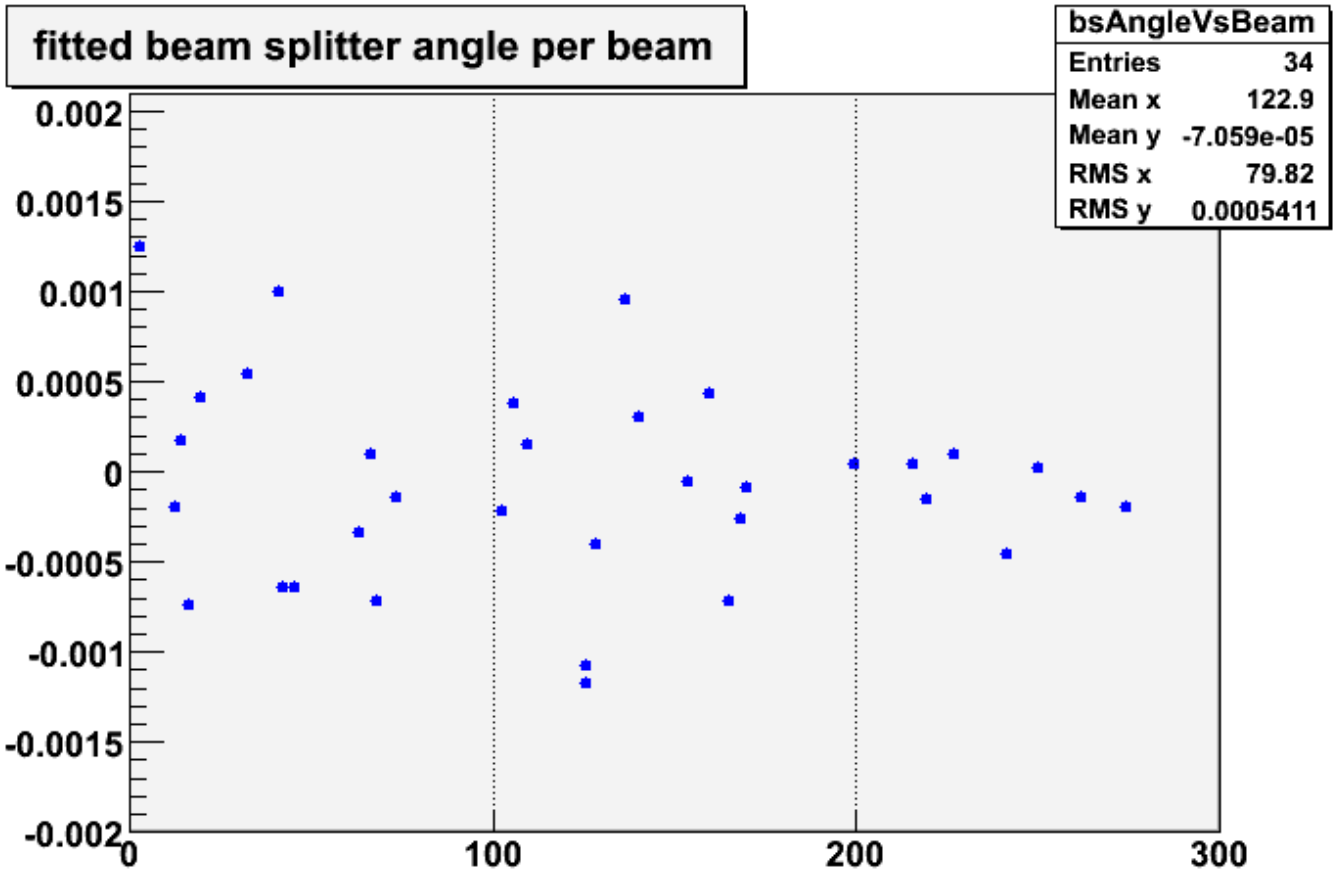
fitted
beam splitter angle

- scale: radians
- for each beam

RMS = 541 µrad

expected values of
up to 2 mrad

values for ATs quite small
(ignore beams 1, 4, 6)



divided in x for TECplus, TECminus, AT
6 TEC beams ignored due to overlap with AT beams

Conclusion & Outlook

Alignment of endcap disks with LAS-like data possible in idealized conditions

LAS CRAFT data used to calculate track residuals for all beams

- corrections for Beam Splitters, Alignment Tube displacements possible
- calculates track parameters

To do

- investigate CRAFT data to understand strange effects

- make output (residuals, track parameters, derivatives) readable to alignment algorithms (HIP, MillePede)

- combine LAS data with other tracks in track-based alignment

Backup

Alignment Tubes