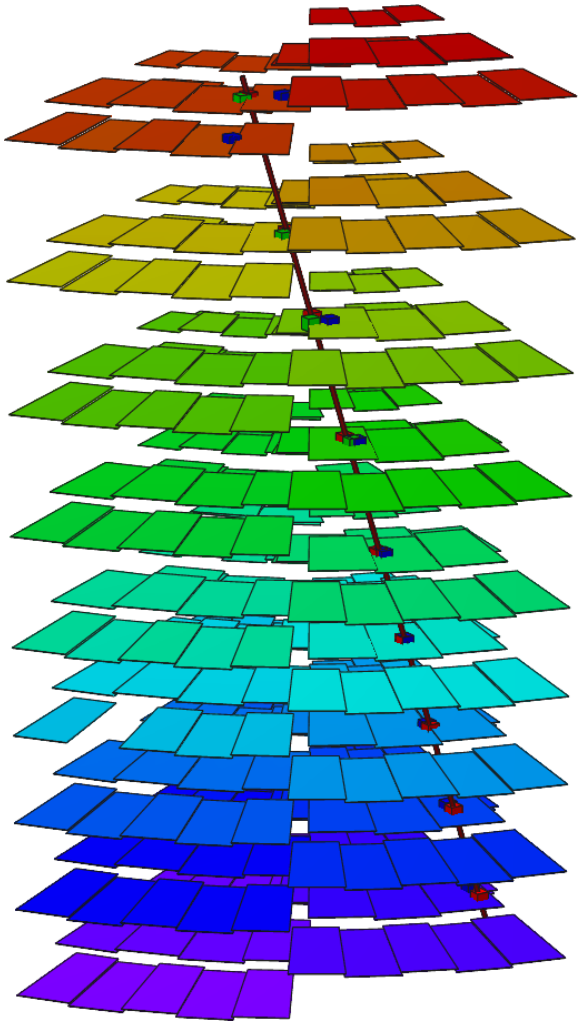
Tracker Endcap alignment

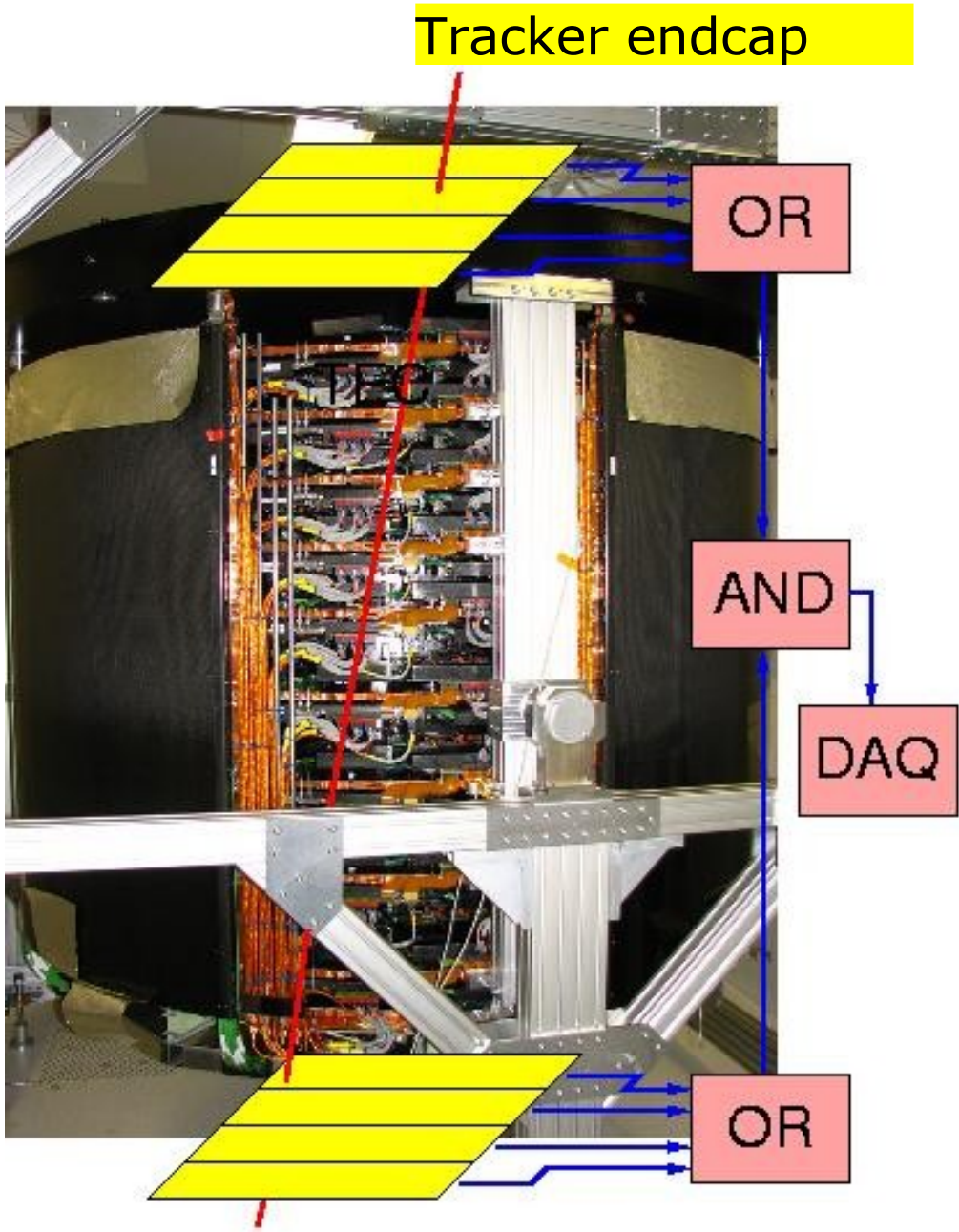


Martin Weber
RWTH Aachen

DCMS Live Meeting
Karlsruhe
October 4th - 6th

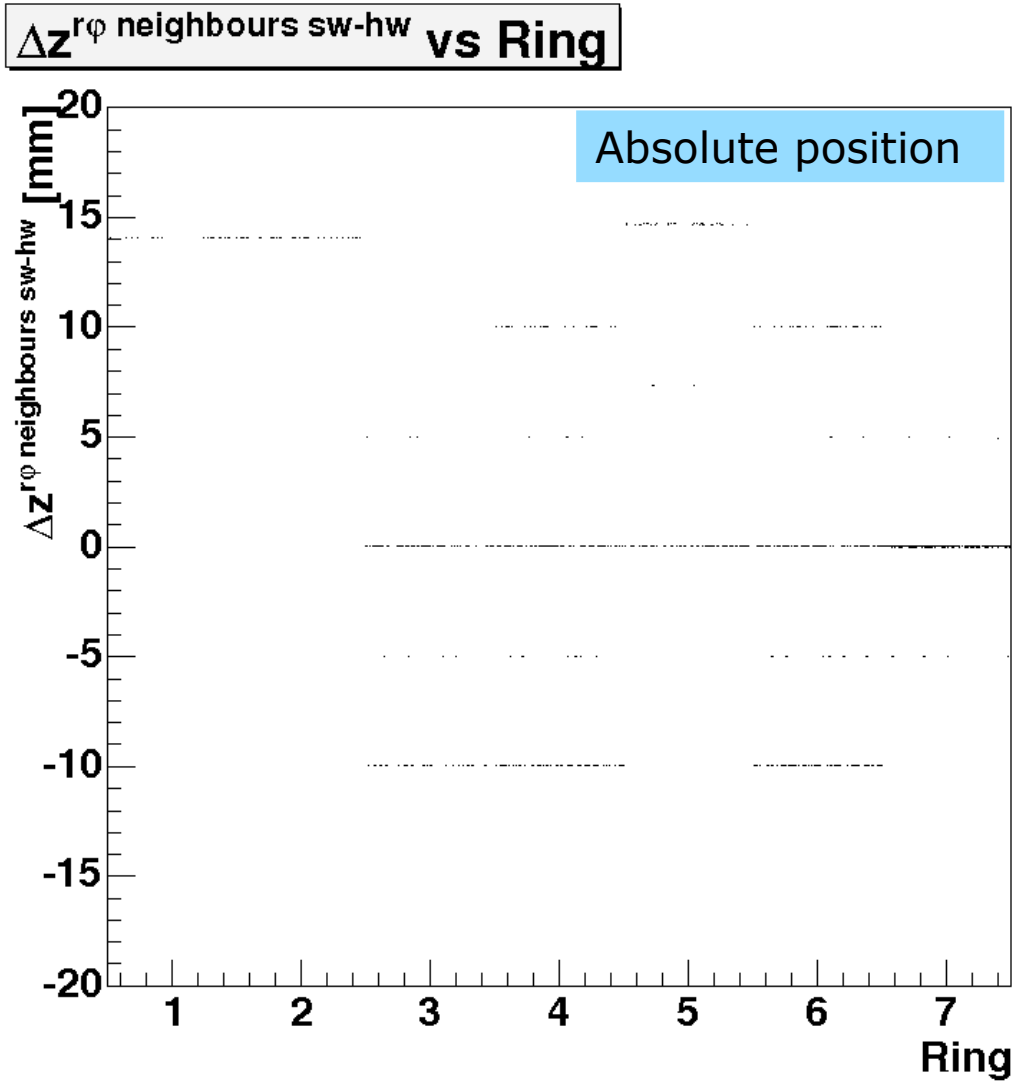
TEC Integration and Alignment

- TEC-Integration in Aachen
  - All petals integrated
  - Six from eight sectors tested
  - Katja Klein, Lutz Feld, Richard Brauer, ..
- Cosmic muon trigger
  - 10 cm lead shielding
  - Took ≥ 1000 tracks for each sector
- Track reconstruction working
  - Much progress on TEC+ geometry, module layout, ...
- Started Alignment studies
  - Kalman Filter algorithm implemented, still in development phase...
  - Work in progress...



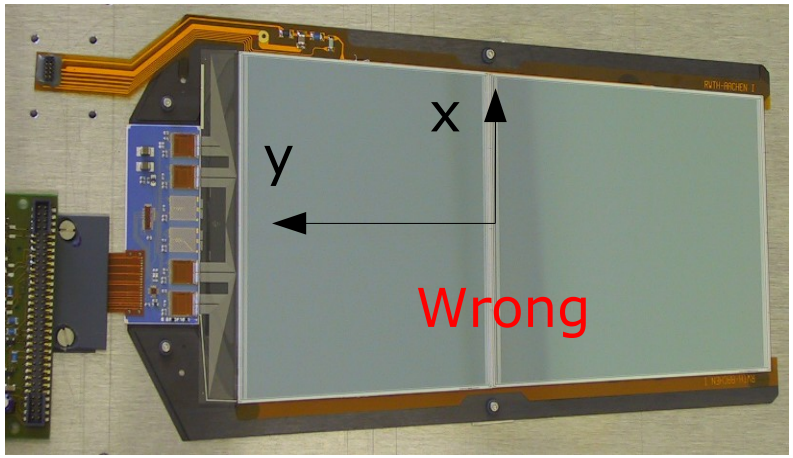
Ideal geometry

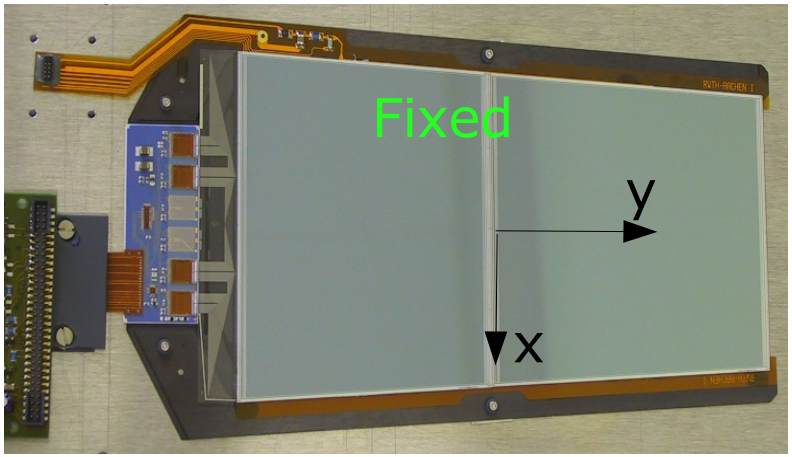
- In order to reconstruct tracks, the ideal geometry had to be refurbished
- CMSSW geometry before 0_7_0 was wrong
- Picture shows e.g. Difference in z position (along beam) in cm
- Differences up to 1.5 cm corrected
- Correction was a collaborative effort of M. Wlochal, M. Weber, R. Ranieri, S. Banerjee
- Huge amount of work
  - ~ 2 month

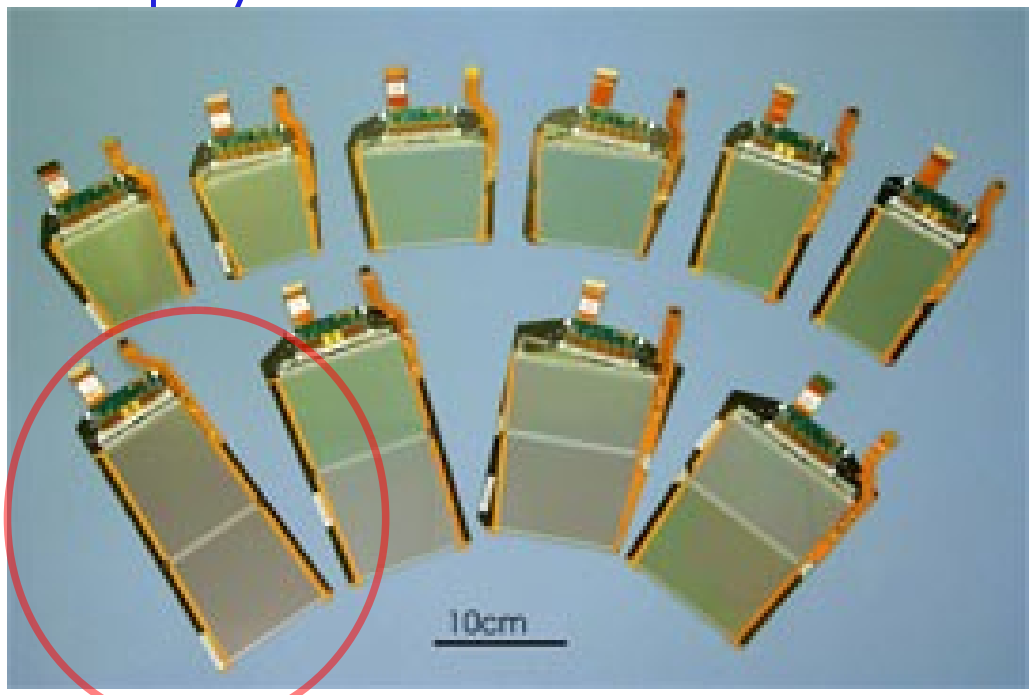


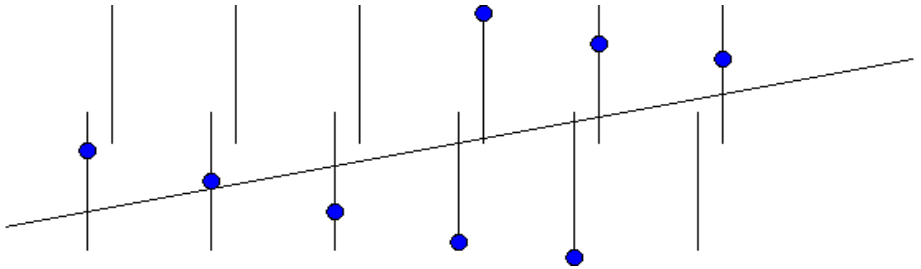
Where are my tracks?

- CMSSW assumed hybrid always on smaller side of module
- Only true for ring 7
- Leads to swap of local x and y axis
- Zig-zag pattern observed in event display









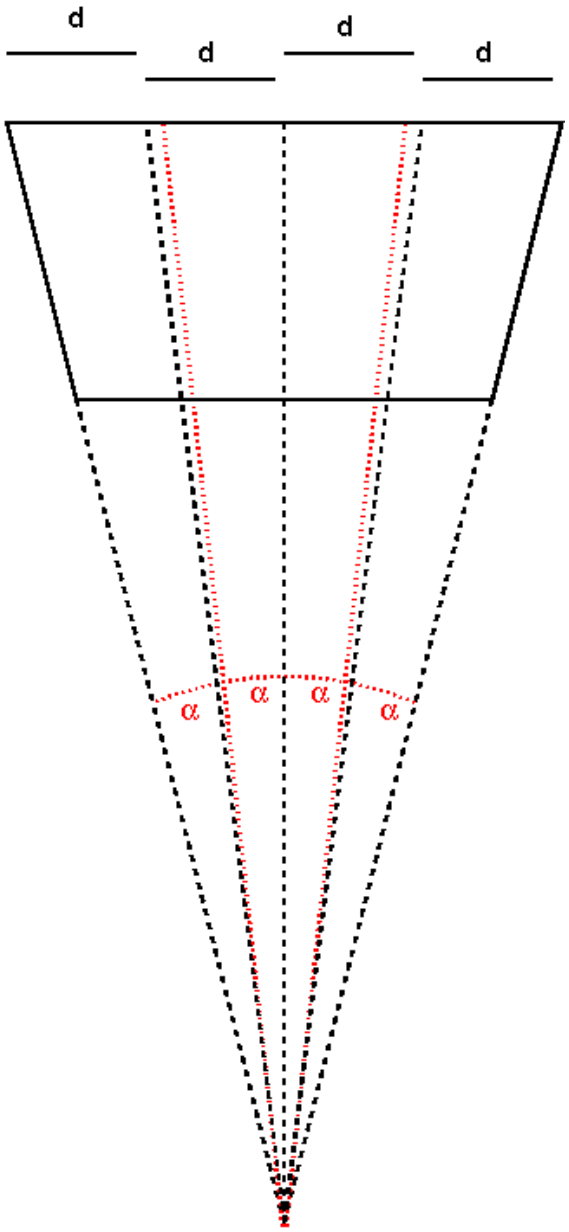
Software assumptions

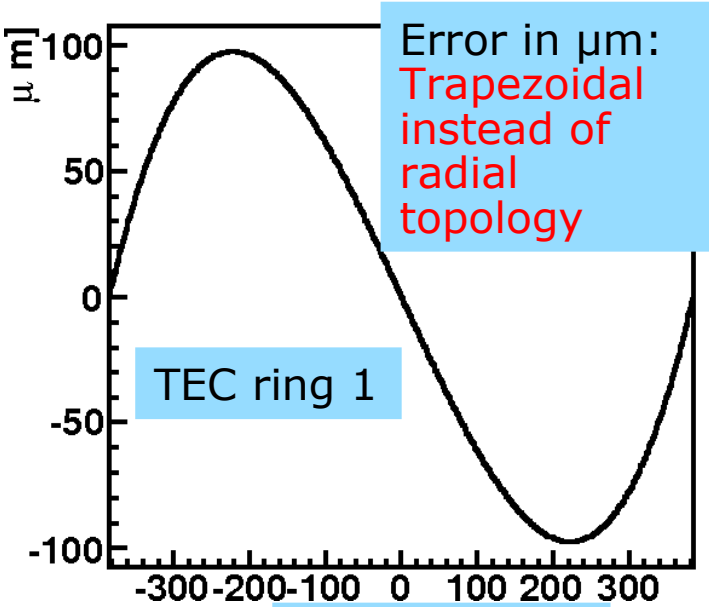
- CMSSW software was not capable to handle this "inverted y axis"
- Changes to the Geometry and the software module builder lead to zero reconstructed tracks in TEC
- Inverted y axis had to be implemented in the module topology
- Changes to the "TrapezoidalStripTopology" were implemented to CMSSW
- But: Trapezoid assumption turned out to be wrong, radial instead

```
  localP = localPitch(localPosition(mp));
  sp2 = merr.uu() * localP*localP;
  sl2 = merr.vv() * localL*localL;
  spl = merr.uv() * localP*localL;
  return LocalError(lc2*sp2+ls2*sl2-2*lslc*spl,
                    lslc*(sp2-sl2)+(lc2-ls2)*spl,
                    ls2*sp2+lc2*sl2+2*lslc*spl);
}

float
TrapezoidalStripTopology::strip(const LocalPoint& lp) const {
  float aStrip =

    ((lp.x()*theDistToBeam/(theYAxOr*lp.y()+theDistToBeam))-theOf
  aStrip = (aStrip >= 0. ? aStrip : 0.);
  aStrip = (aStrip <= theNumberOfStrips ? aStrip : theNumberOfStr
  return aStrip;
}

MeasurementPoint
TrapezoidalStripTopology::measurementPosition(const LocalPoint& lp
  return
    MeasurementPoint(((lp.x()*theDistToBeam/(theYAxOr*lp.y()+theD
                      lp.y()/theDetHeight);
}

MeasurementError
TrapezoidalStripTopology::measurementError(const LocalPoint& lp,
                                           const LocalError& lerr
  float lt,lc2,ls2,lslc;
  float localL,localP;
  float sl2,sp2,spl;
  lt = -lp.x()/(theYAxOr*lp.y()+theDistToBeam);
  lc2 = 1./(1.+lt*lt);
  lslc = lt*lc2;
```

What the heck is a topology?

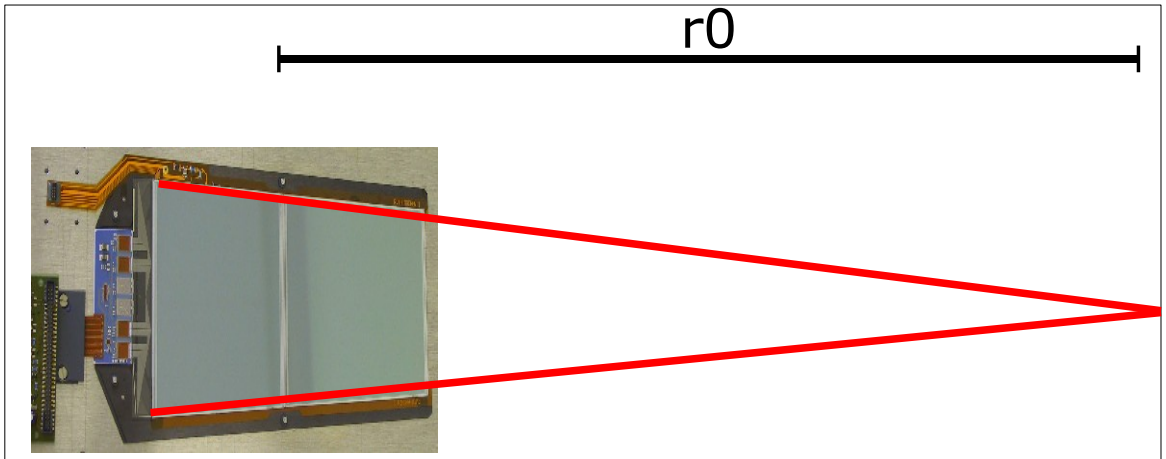
- Module topology
  - Converts local coordinates to global coordinates
  - Converts strip number (measuring phi) in x and y
- CMSSW: Trapezoid
  - Means constant pitch "d" along module y axis
- But: Sensor is radial
  - Means constant angle α between strips
  - CMS Note 2003/022
- Sensitive coordinate wrong up to 100 µm!
- Has been corrected
  - Not yet committed





Corrections to module layout

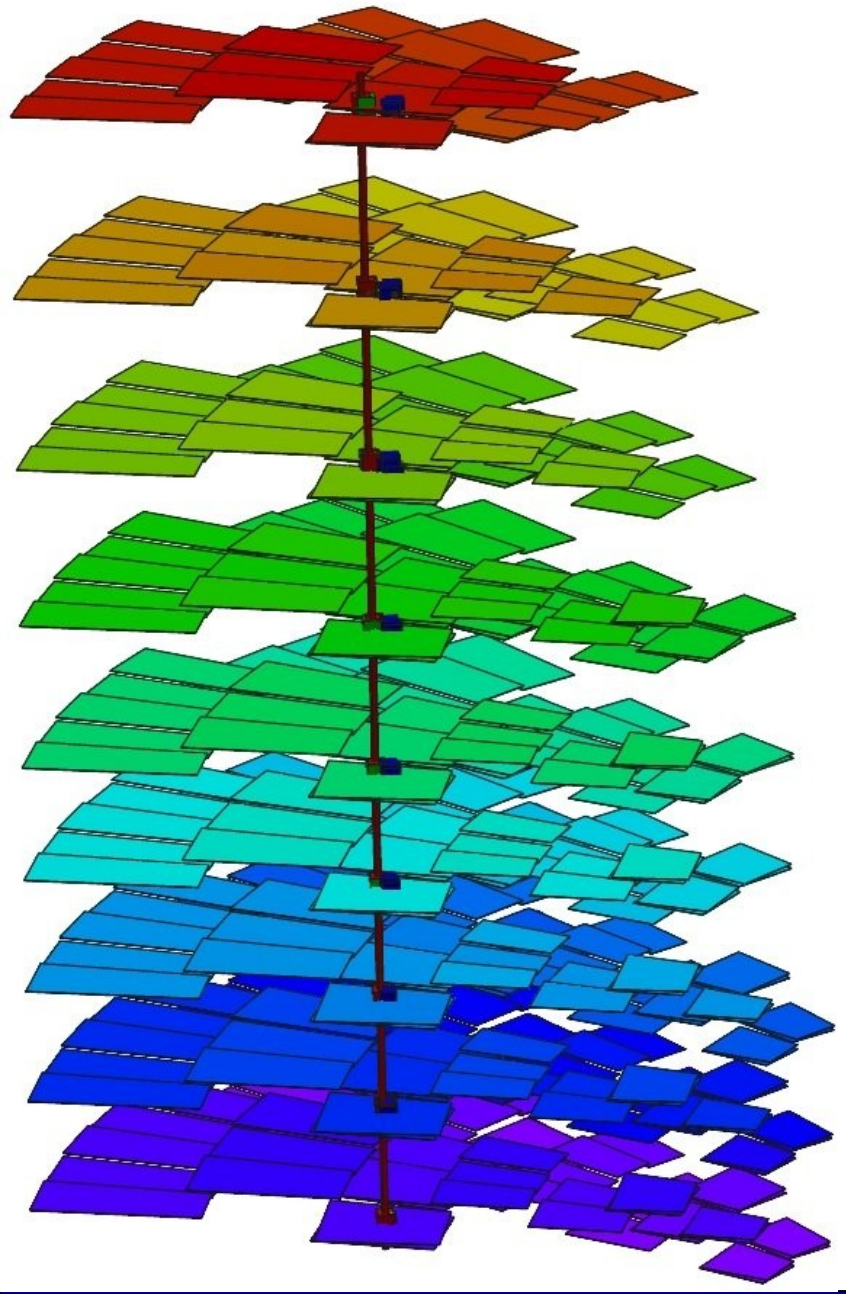
- Wrong values in CMSSW for sensor layout used
  - Mean pitch (average along local y)
  - Distance r0 from active center to crossing point of strips
  - Active area width and length
- Corrections sum up to total of 5-200 µm for a module
- After fixing this, nice tracks are being reconstructed
- Many more cross-checks were performed
- Very time-consuming!



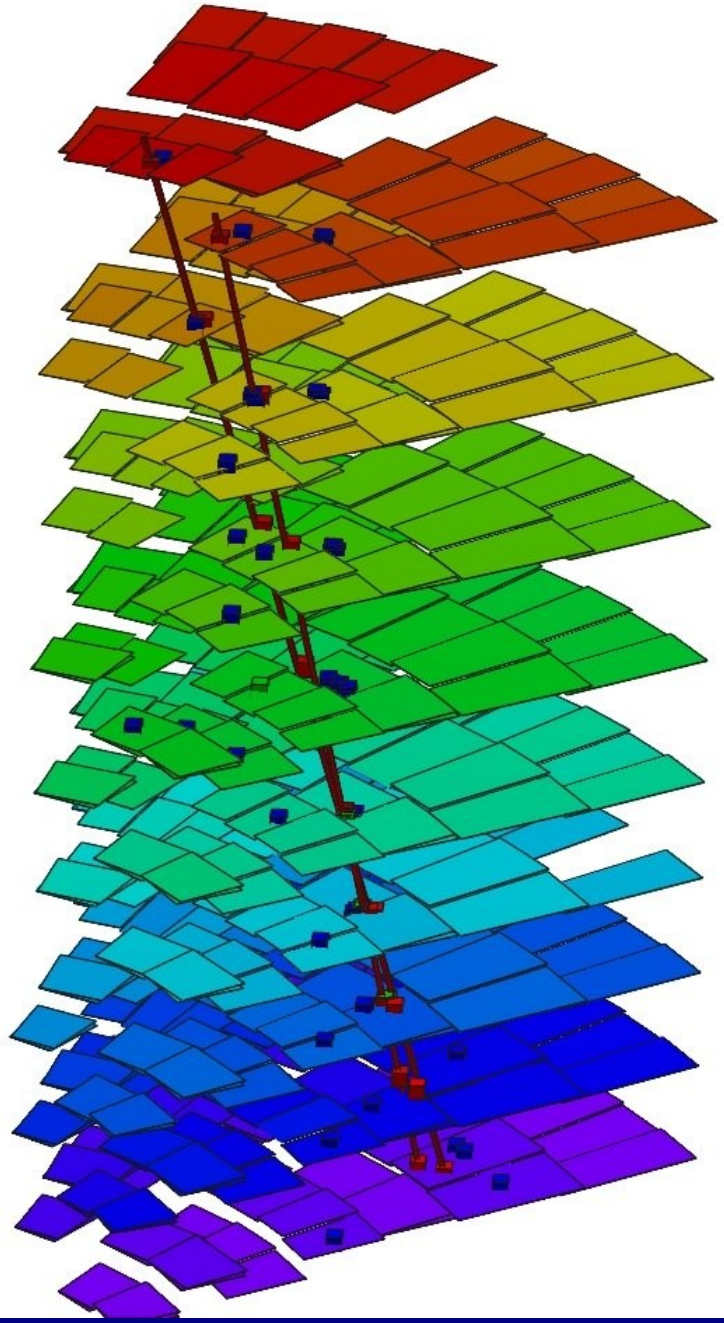
TEC module	reco r0 / µm	true r0 / µm	reco pitch / µm	true pitch / µm
Ring 1	268296	277680	96.10	96.78
Ring 2	357861	367080	128.00	127.93
Ring 3	438146	447430	140.82	140.79
Ring 4	551201	561680	126.27	126.17

- Not yet committed to CMSSW

Reconstructed tracks from sector 2

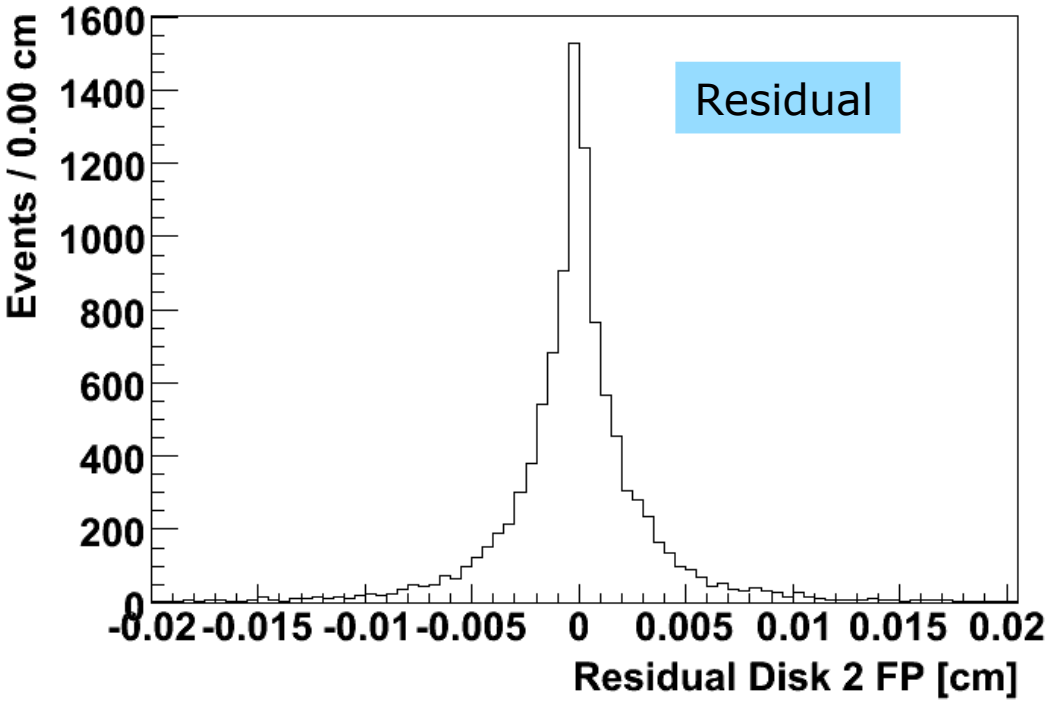


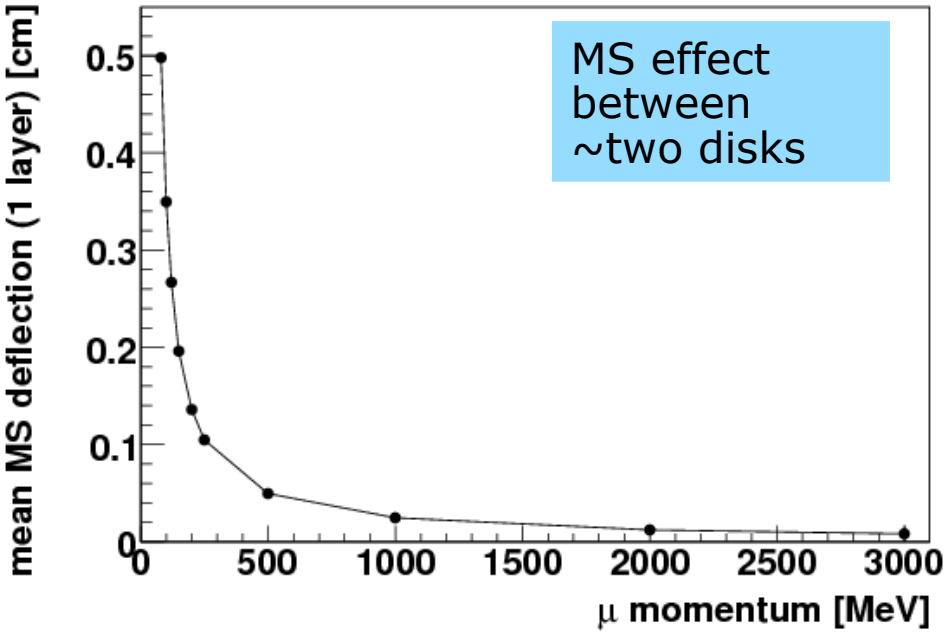
- Examples for tracks
- Blue: Cluster (1-dim)
- Green: RecHit position
- Red: Track and impact points

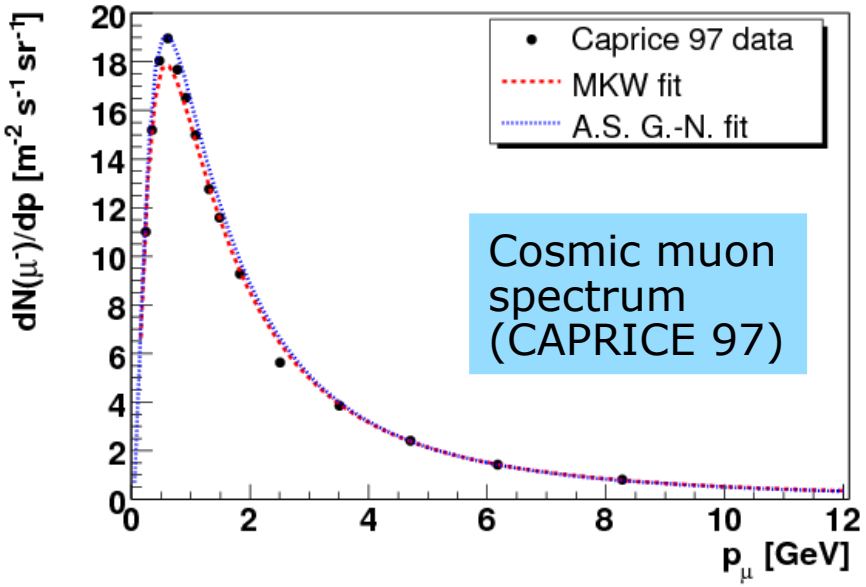


Track residuals

- Look at track residuals
- Non gaussian tails
- Strong multiple scattering
- 10 cm lead shield → Low energy cutoff (~120 Mev)

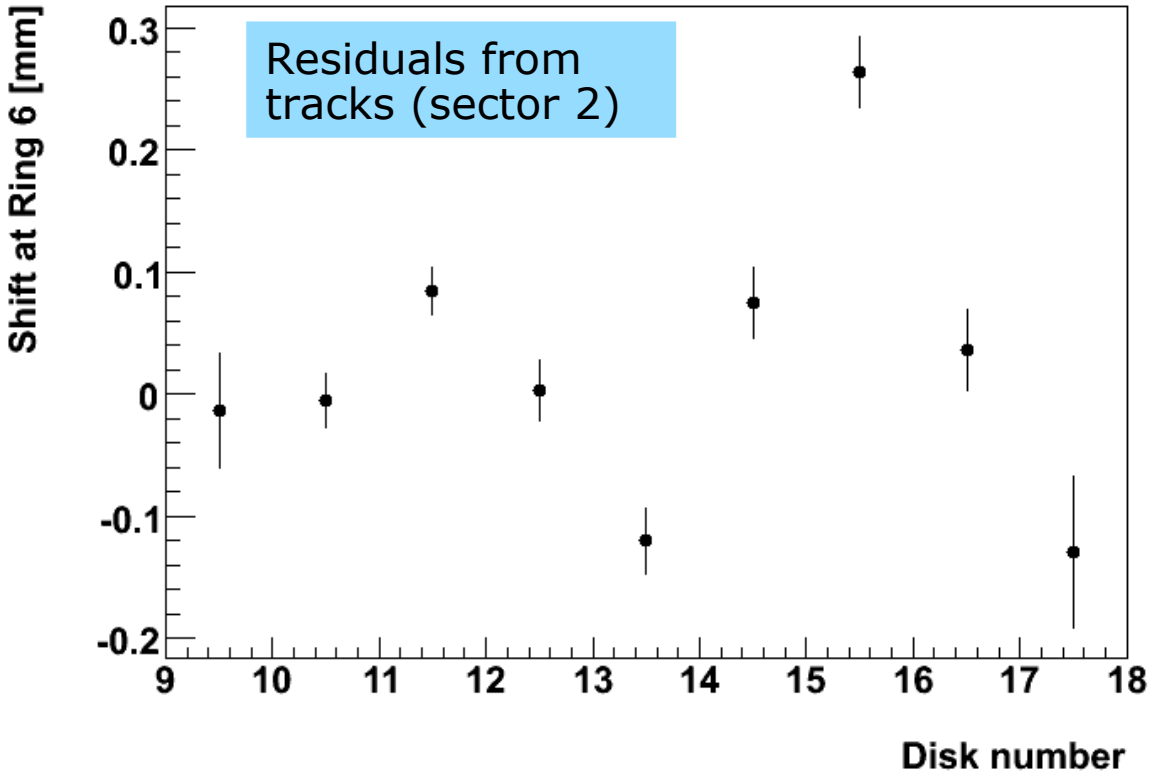


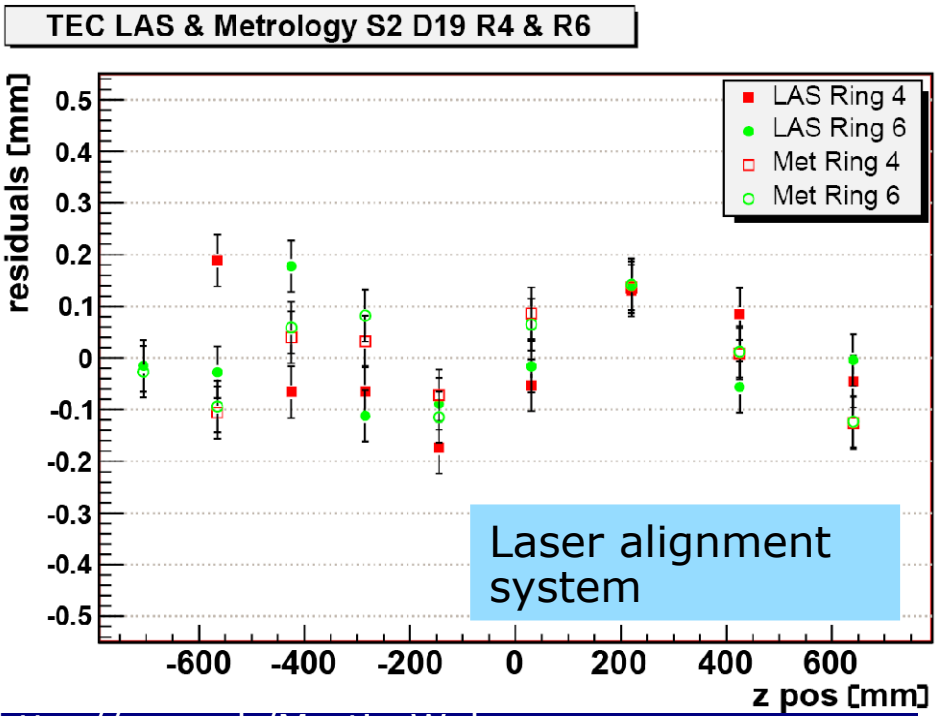




Fit to track residuals (biased)

- Estimate disk rotation from track residuals
- Compute residual in φ for Back-Petals, convert to ring 6 position
- Compare with results from Laser Alignment system

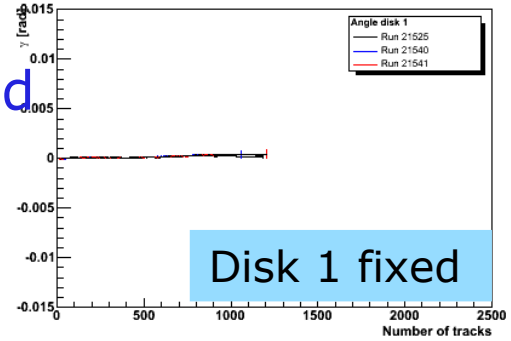


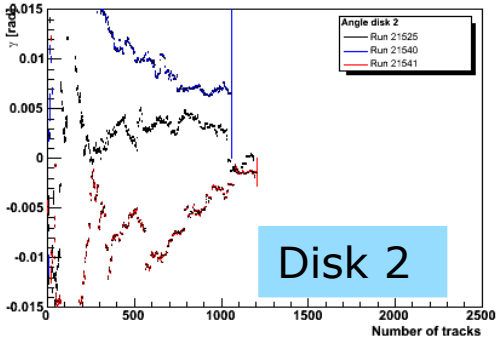


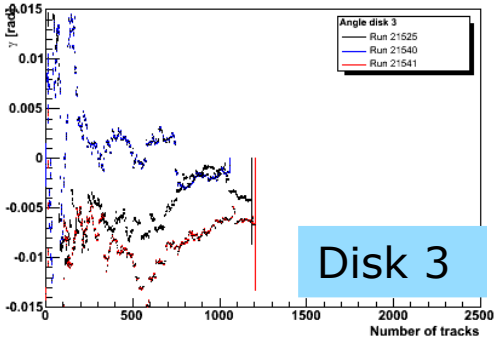
- LAS only using back petals
- Disk number is 9.5 to 17.5 for TEC back petals
- Good agreement observed

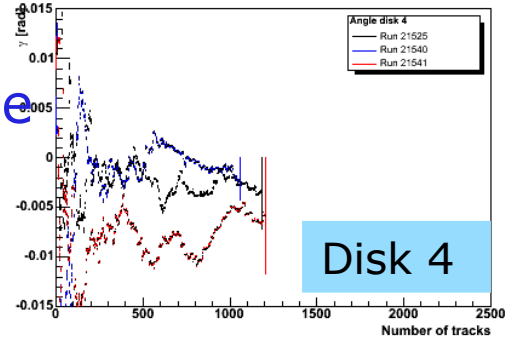
- Kalman Filter algorithm implemented
- Suffering from multiple scattering
- Convergence not optimal
- Not yet full tracks sample used
- Work in progress...

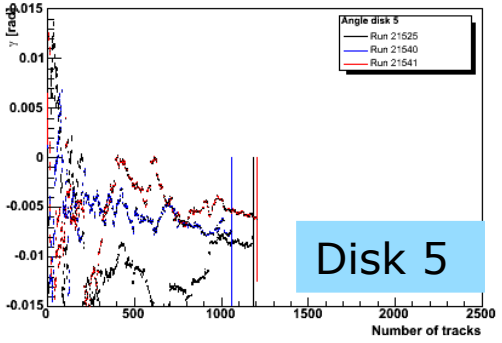
Evolution of alignment constants with tracks for three different runs

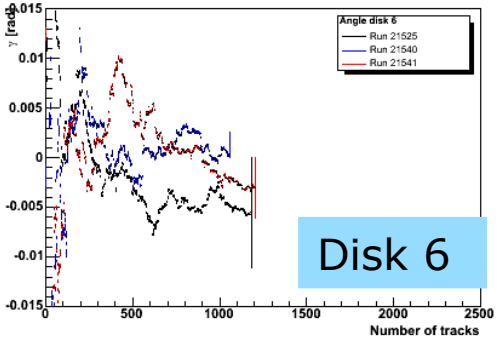


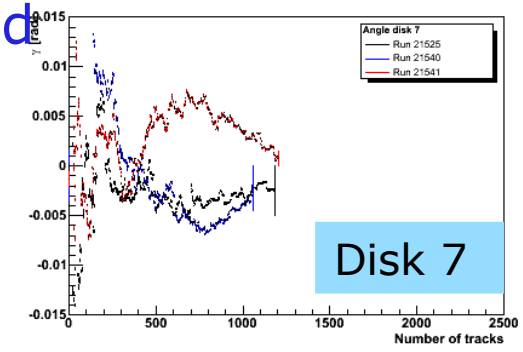


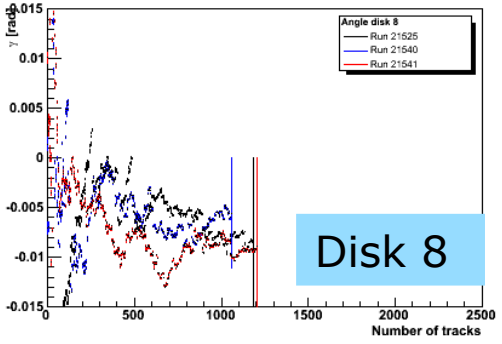


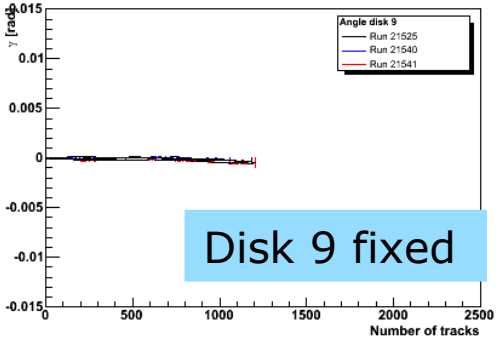












Conclusion

- Many corrections to CMSSW were necessary
  - TEC geometry
  - Module orientation, local y axis change
  - Module topology
  - Module parameters (pitch, distance to active area, ...)
- After corrections, residuals in good agreement with Laser Alignment
- Kalman Filter Alignment
  - Preliminary version working
  - Suffering from multiple scattering
  - Improvements foreseen
  - Comparison with Millepede planned (Hamburg contacted)