

Full Scale Tracker Alignment with Millepede II and CMSSW

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Outline

- Data Sets
 - Cosmics production
- Scenario and Pedestal Settings
- Pixel Endcap Hit Statistics
- Alignment Result
- Comparison with ORCA Study
- Summary and Outlook

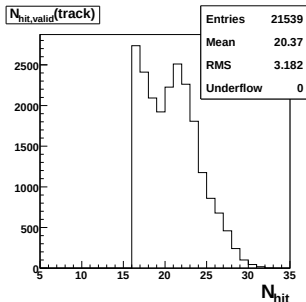
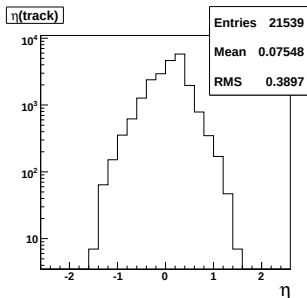
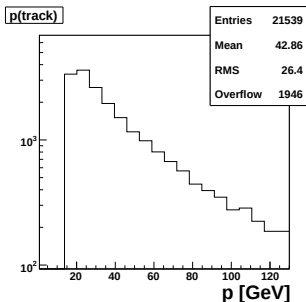
$Z \rightarrow \mu\mu$

- Rainer's AlCaReco
(from Spring07
CMSSW_1_3_1 production)
- 774 981 events
- Use single μ tracks
- Additional cuts:
 - $p_t(\mu) > 15 \text{ GeV}$
 - $N(\text{hit}) \geq 10$
 - $\chi^2 < 9999.$
 - no invalid hits

Cosmics

- Spring07 production (CMSSW_1_3_4)
- Re-reconstructed with later tags
 - CTF and CosmicTF
 - 827 863 events (i.e. 86%) survive
(memory problem in CTF)
 - details in TWiki: TkAlignmentMC#Spring07
 - about 60% without CTF track
- Use CTF tracks
- Additional cuts:
 - $p_t(\mu) > 15 \text{ GeV}$
 - $|\eta| < 2.4$
 - $N(\text{hit}) \geq 16$
 - $\chi^2 < 999.$
 - only highest p_t track
 - no invalid hits

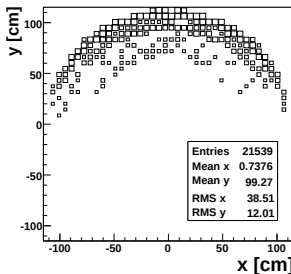
The Cosmic Tracks (no Misalignment)



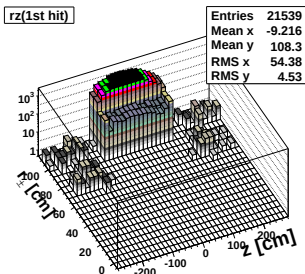
- η cut
superfluous
- 21 500 high
momentum
tracks with
sufficient
 $N(hit)$
- slightly less
than Markus'
high p_t
production

The Cosmic Tracks (no Misalignment) II

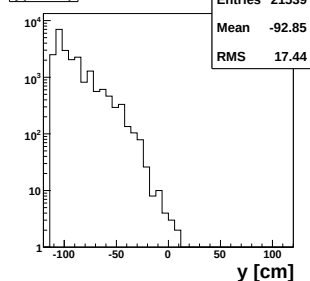
xy(1st hit)



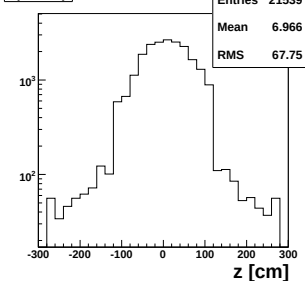
rz(1st hit)



y(last hit)



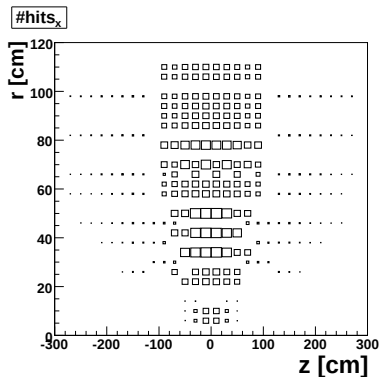
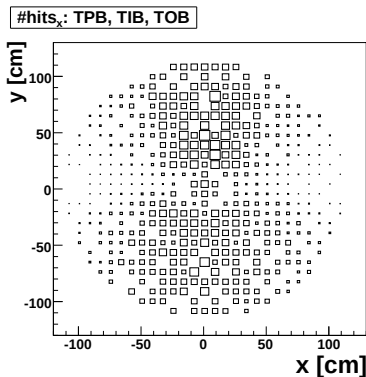
z(last hit)



First and Last Hits

- Tracks start/end in upper/lower hemisphere.
- Only few start/end in TEC.

The Cosmic Tracks: Hit Maps

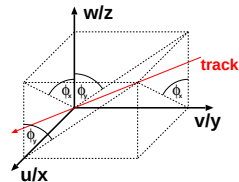
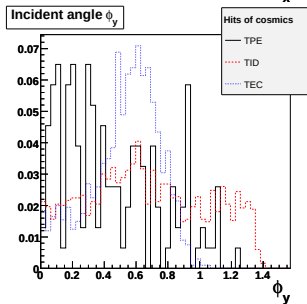
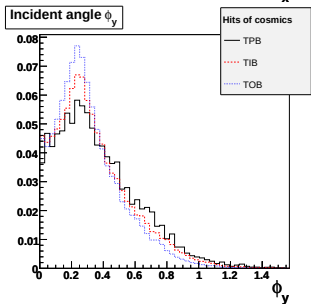
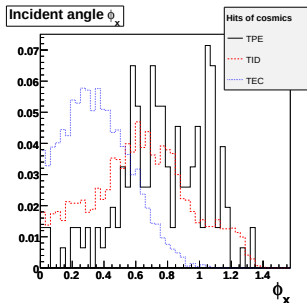
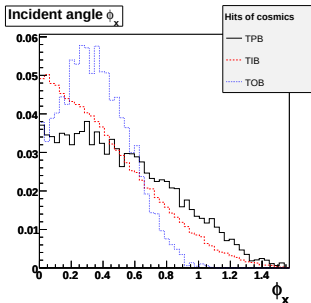


- Hits per Det on Det position.
- Barrel hit mainly around $\phi \approx \pi/2$.
- Endcaps rarely hit.
- **Note:** Spring07 production too optimistic about pixel hits (CSA07 fine): significant fraction out of time (no “peak” mode)

Total Hit Statistics

TPB	11 410
TPE	154
TIB	148 884
TID	4 136
TOB	267 515
TEC	6 616

Cosmics: Incident Angles



Definition

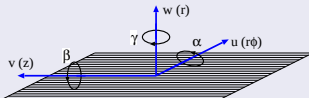
$\angle(\text{sensor}, \text{normal})$
projected on

- **xz-plane:** ϕ_x
- **yz-plane:** ϕ_y

- Various angles
- Probing wide range of σ parametrisation

- Misalignment: TrackerORCASHortTermScenario.
- Cosmics refit **with** hit refit (clusters available, only 5% more CPU time).
- AlignmentParameters:

1D Dets	u, w, γ
2D Dets	u, v, w, γ
HalfBarrels, Endcaps	u, v, w, γ



γ of PixelHalfBarrels around global z-axis as in ORCA (symmetry!)

- Hierarchy constraints (automatically detected).
- Coordinate system:
 - prohibit overall movement of PixelHalfBarrels (via constraints)
 - (automatically) correct misalignment to fulfil this
(for MC truth comparison, moving $x, y \approx 7 \mu\text{m}$, $z \approx 0.6 \mu\text{m}$, $\gamma \approx 2 \mu\text{rad}$)
- A priori knowledge: “presigas”
 - σ^{pre} of HalfBarrel/EndCap parameters as misalignment width (ignore Gaus vs flat), factor $\frac{1}{10}$ for Dets, $\sigma_{\gamma}^{pre} = 10 \mu\text{rad}$
 - Blobel: damping of weakly defined d.o.f. similar to regularisation in unfolding

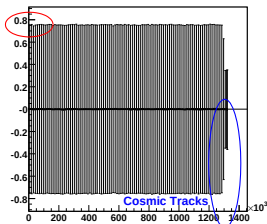
Settings

- Dets with < 50 hits $\Rightarrow$ not aligned, parameters kept at 0.
- Outlier downweighting:
 - 4 “local” iterations (3 Huber, 1 Cauchy)
 - downweight fraction cut 0.2
- matrix solution: sparesGMRES
 - preconditioning: band width 6
 - 5 “global” iterations

Requirements

- 3.0% matrix occupancy: about 400 MB
- 2176 s CPU time (3 GHz 32bit SLC3)
- 190 s for further loops over data (χ^2 -minimum not yet reached)

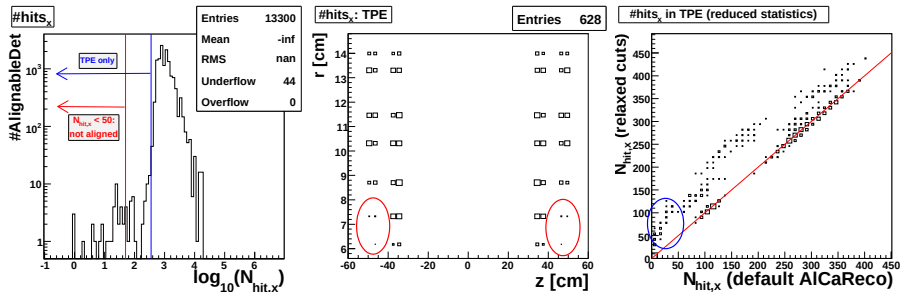
location and dispersion vs record nr (version 5)



Finding

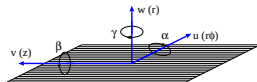
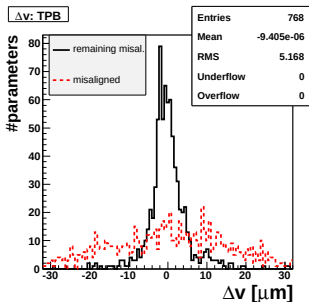
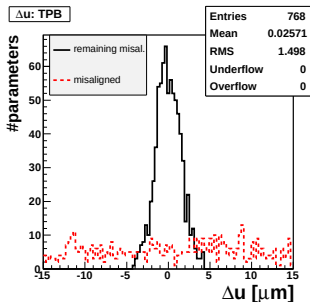
- normalised residuals smaller than 1
- probably due to neglecting correlations from multiple scattering
- more pronounced for cosmic tracks
 - checked: difference not due to hit refit
 - longer tracks $\Rightarrow$ more multiple scattering?
 - or just version incompatibilities?

Statistics Problem in Pixel Endcap

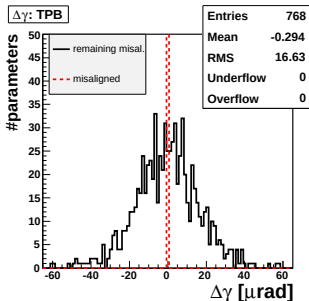
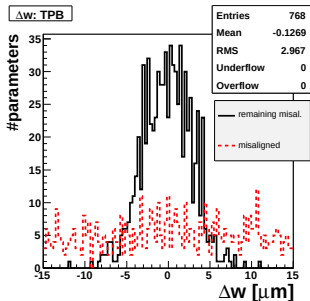


- About 80 Dets in TPE with $N(hit) < 50$, 44 even with $N(hit) = 0$.
- Smallest r and mainly larger $|z|$ affected.
- Can be partly cured by relaxing AICaReco cuts:
 - remove $|\eta| < 2.4$
 - relax $N(hit) \geq 8$ to $N(hit) \geq 5$
 - should be more sophisticated, e.g. $N(hit_{valid}) \geq N(\eta)$
- In the following stay with AICaReco cuts (otherwise limited statistics or Castor problems).

Result: Misalignment Parameters in Pixel Barrel



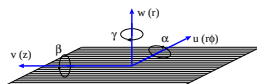
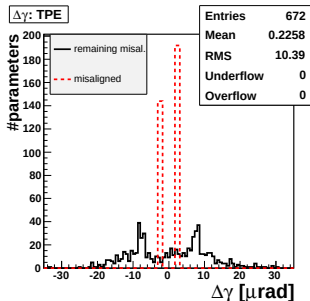
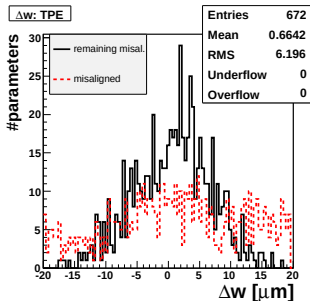
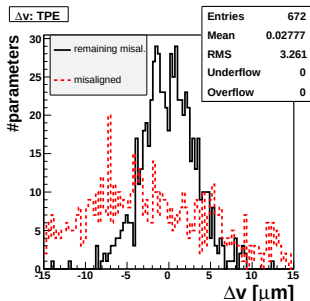
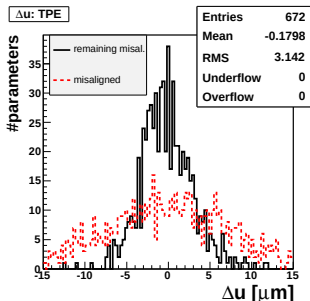
- Mean at 0 by constraint.
- $\text{RMS}(u, v, w)$ a few μm !



Worry about γ ?

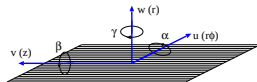
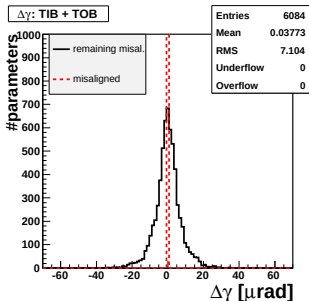
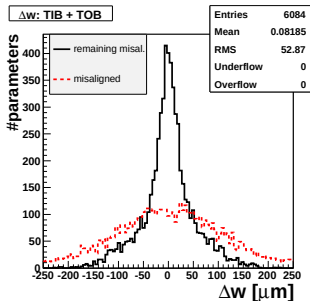
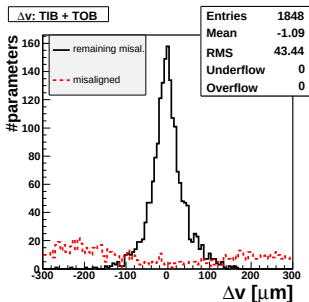
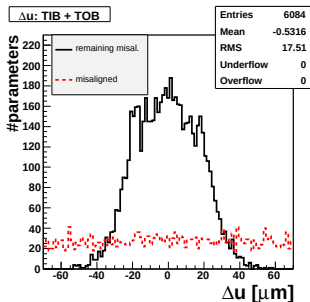
- hardly documented by Markus
- the only shown plot much better for **all** sub-detectors

Result: Misalignment Parameters in Pixel Endcaps



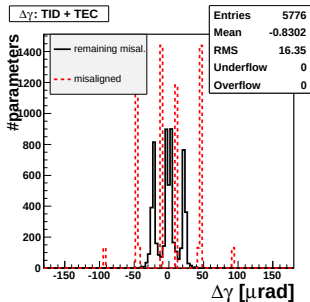
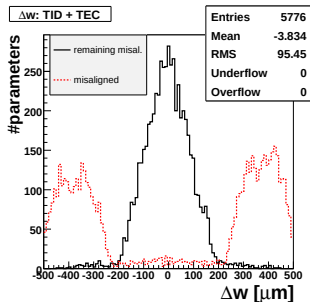
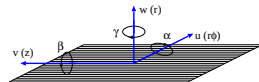
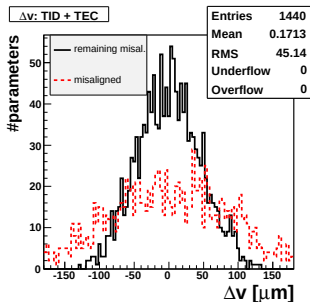
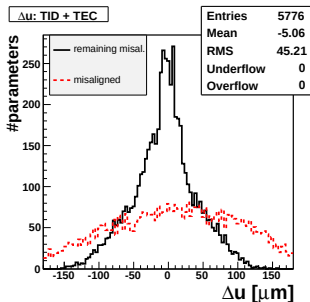
- $\text{RMS}(u, w)$ slightly worse than TPB.
- $\text{RMS}(v, \gamma)$ slightly better.
- Two peak start values for γ due to correction to misaligned TPB frame.

Result: Misalignment Parameters in Strip Barrel



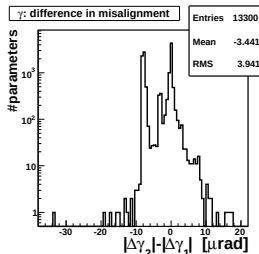
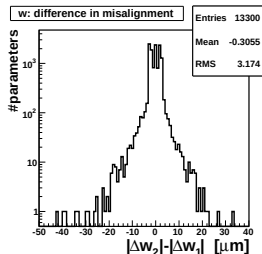
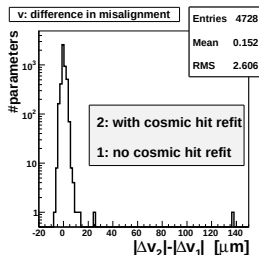
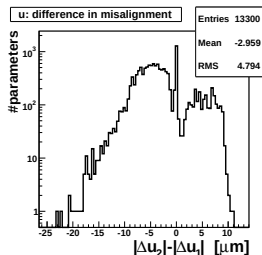
- $\text{RMS}(u/r\phi)$
= $17 \mu\text{m}$
- $\text{RMS}(v/z)$,
 $\text{RMS}(w/r)$
 $\approx 50 \mu\text{m}$
with tails
- $\text{RMS}(\gamma)$
= $7 \mu\text{rad}$:
better than in
pixel?

Result: Misalignment Parameters in Strip Endcaps

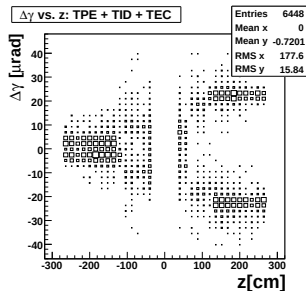
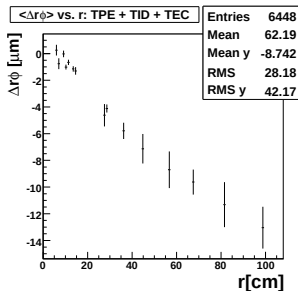
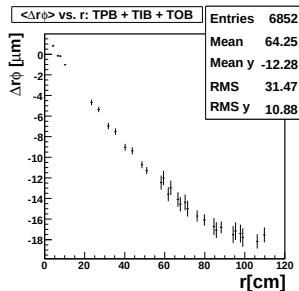


- comparable, but worse than barrel
- large tails for w (global z)
- spiky γ ($\Rightarrow$)

Influence of Hit Refit for Cosmics



- Cosmics hit modules under larger angles: possibly larger influence of hit refit
- Indeed small degradation seen if cosmics hit refit is skipped:
average of difference of absolute misalignment in u and γ increases by 3 μm and 3 μrad , respectively.
- Would need further studies.



- Bias $r\phi(r)$ ($r\phi \approx \pm u$ – but TIB, TPE!).
- Systematic rotational offset of TEC+:
 - seen as double peak: local coordinates with different z -sign
 - due to highly correlated (and weakly determined) high level parameters?

- Cosmics
 - Same size of cosmics set, but even harder p in ORCA.
 - used twice in ORCA, from both ends:
more determination power for $y < 0$ with otherwise large σ_{hit} due to multiple scattering (we neglect correlations...)
 - Ian Tomalin's hit uncertainty parametrisation used in ORCA, porting to CMSSW at least not in CMSSW_1_3_X
 - Pattern recognition in ORCA from SimHits:
 $\Rightarrow$ probably more tracks in endcaps?
- Known bug in SiStripRecHitConverter in CMSSW_1_3_X:
 - fixing for cosmics leads to inconsistencies
 - fixing by hit refitting on $Z \rightarrow \mu\mu$ AlCaReco would need clusters
- $Z \rightarrow \mu\mu$ with mass and vertex constraints not yet used, but available in later CMSSW versions.
- ORCA $Z \rightarrow \mu\mu$ dataset about twice as large (but not limiting).
- The unknown...?

Result Comparisons

		ORCA	CMSSW	CMSSW-6P
barrel $r\phi$ [μm]	mean	-12.1	-12.3	-8.8
	RMS	9.0	10.9	11.4
barrel (2D) z [μm]	mean	0.8	-3.8	-2.9
	RMS	23.8	34.7	34.4
barrel r [μm]	mean	0.1	-1.0	-1.0
	RMS	24.2	49.9	49.8
barrel γ [μrad]	mean		0.0	0.0
	RMS		8.7	12.5
endcaps $r\phi$ [μm]	mean	-13.3	-8.7	-5.5
	RMS	16.2	42.2	41.4
endcaps (2D) r [μm]	mean	1.8	-0.1	-0.1
	RMS	21.0	37.3	39.0
endcaps z [μm]	mean	-5.3	5.7	7.0
	RMS	47.8	90.3	94.8
endcaps γ [μrad]	mean		-0.7	-0.8
	RMS		15.8	12.8

CMSSW-6P: as CMSSW, but all 6 parameters of HalfBarrels/Endcaps

Spring07 cosmics production re-reconstructed

- about 20 000 long high momentum tracks
- very few hits in endcaps

⇒ First full scale tracker alignment in CMSSW!

- pixel aligned to few μm RMS, but “large” RMS for γ
- strip barrel better than endcaps
- hit refit for cosmics slightly improves result
- some distortions remain: $r\phi(r)$, γ in TEC+
(plus some smaller ones)
- some RMS significantly larger than in ORCA study
(but there are differences)
- low statistics problem in some pixel endcap regions
 - about 80 Dets not individually aligned
 - relaxed $Z \rightarrow \mu\mu$ AICaReco cuts can help (⇒ study?)

- Take care about γ (and other angles).
- Improved tracking in later CMSSW:
 - consistency between cosmics and standard tracks?
- Use of mass/vertex constraints via TwoBodyDecayTrajectory.
- Use of beam halo muons.
- Use of laser data as tracks: LaserReferenceTrajectory.
- Care about neglected correlations (long term project!):
 - special AlignmentParameters for wedge shaped Dets
 - KalmanReferenceTrajectory (avoiding multiple scattering correlations)
- AlignmentParameters with twist etc. for igher levels
- Study different misalignments: scenarios, seeds, . . .

Much higher priority on TIF and start-up analyses:

Be patient with improvements in full scale studies!