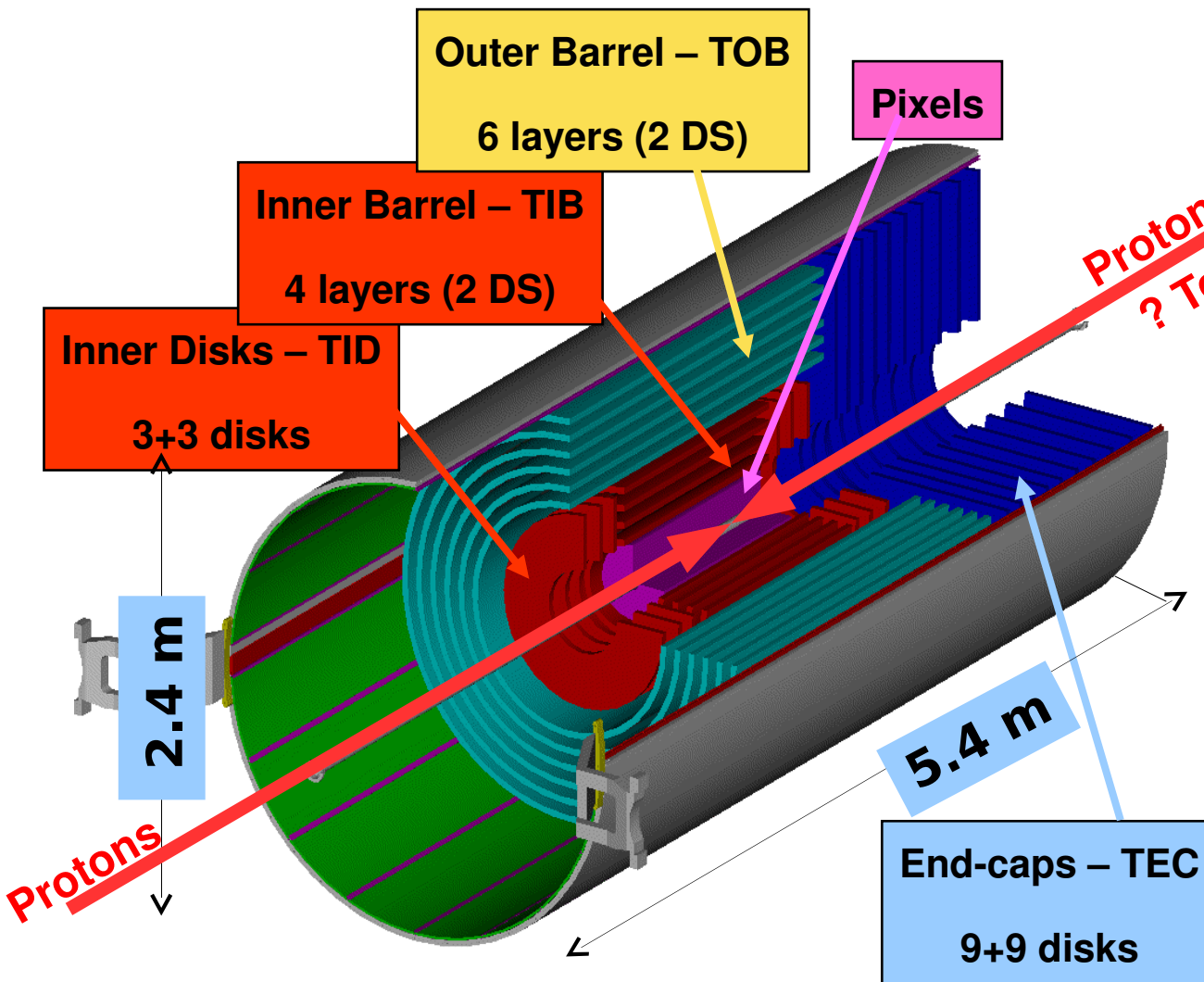# Alignment Position Errors Status

M. Musich
CMS Torino Group / Tracker Alignment Group

– Torino Group Internal meeting –

The CMS Silicon Tracker

Outer Barrel – TOB

6 layers (2 DS)

Pixels

Inner Barrel – TIB

4 layers (2 DS)

Inner Disks – TID

3+3 disks

Protons
? TeV

Protons

2.4 m

5.4 m

End-caps – TEC

9+9 disks

Tracker Layout

- Volume 24 m³ / covered area 200 m²

- Running temperature: -10° C

- **STRIP:**

  - *15148 modules* (pitch 80 – 205 μm)

  - single point resolution of 20 – 60 μm

  - 2D measurements from DS modules, mounted back to back (tilt 100mrad)

- **PIXEL**:

  - *1440 modules* (pitch 100(r) x150(z) μm²)

  - resolutions: 9 (r) 20 (z) μm

Why Alignment?

- The CMS tracker is build in *order to optimize the particle momenta resolution*.
- It depends on two factors:

C_1 depends on the geometry of the detector

$$\frac{\delta p}{p} = C_1\, p \oplus C_2$$

C_2 depends on multiple coulomb scattering (MCS)

$$C_1 = \frac{\sigma_{pos}}{\sqrt{N} \cdot B \cdot L^2}$$
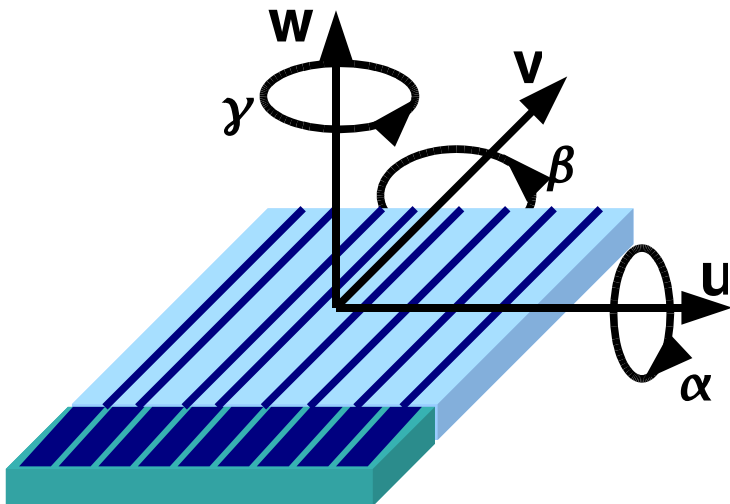
- B = magnetic field intensity
- N = number of track hits
- L = track length
- σ_{pos} = resolution on measured point

~10 μm (Si)

$$\sigma_{pos} = \sqrt{\sigma_{intr}^2 + \sigma_{sist}^2}$$

MISALIGNMENT

- The challenge is to determine at **O(10μm)** corrections for the **6 d.o.f** (3 rotations + 3 translations) of each of the > 19k modules in CMS Silicon Tracker!

$$19\mathrm{k}\ modules \times 6\ n.d.of. \simeq 100\mathrm{k}\ unknowns\ !$$

Alignment formalism

- In the CMS Tracker alignment formalism the hit position in local coordinates of the module is **q = (u,v,w)** and **r =(x,y,z)** w.r.t the global reference frame of CMS.

- The two sets of coordinates are related via a roto-translation:

$$\begin{cases} \boldsymbol{r}=(x,y,z) \Rightarrow \textbf{\textit{global}} \text{ coordinates} \\ \boldsymbol{q}=(u,v,w) \Rightarrow \textbf{\textit{local}} \text{ coordinates} \end{cases} \qquad \boldsymbol{r}=R^T \boldsymbol{q}+\boldsymbol{r_0}$$

- The alignment procedure determines corrections to the original transformation via an additional rototranslation:

$$\boldsymbol{r}=R^T \Delta R(\boldsymbol{q}+\Delta \boldsymbol{q})+\boldsymbol{r_0}$$

- The alignment parameters are **Δq = (Δu,Δv,Δw)** which parametrize translations, while the angles **α,β** and **γ** appearing in ΔR parametrize the rotation

local coordinates on sensor

impact point
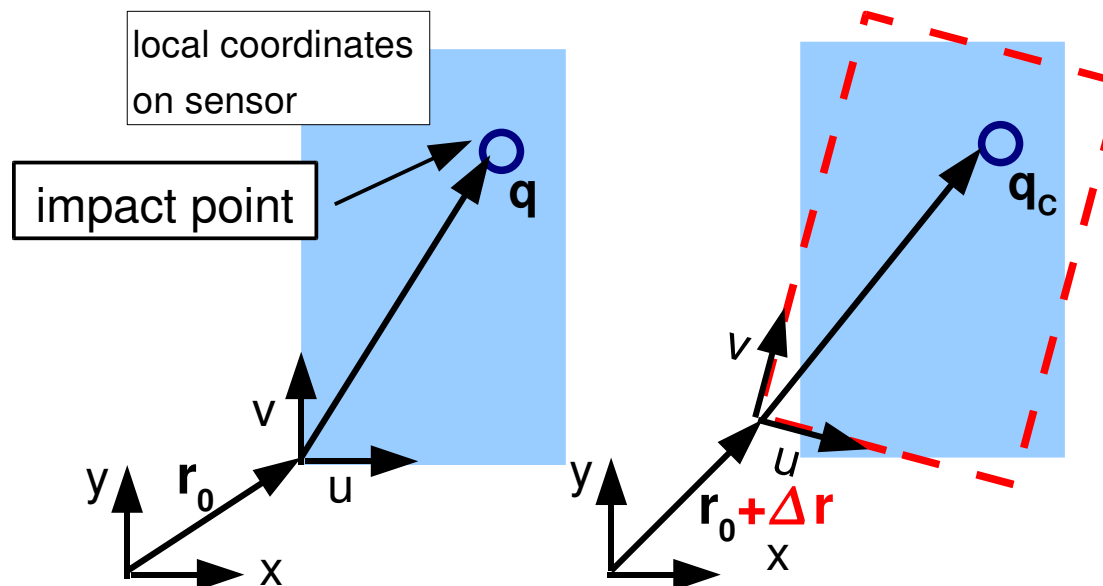
Final goal of alignment:

- Determine for each of the O(20k) detunits the 6 parameters **(Δu,Δv,Δw,α,β,γ)** 3 translations and 3 rotations w.r.t the nominal geometry

- Determine for each of the modules the statistical error associated to the aligned postion **(APE)**

Track Based Alignment

- Several methods are deployed (optical survey/LAS/track based aligment) ultimate precision O(10 μm) reached via track based aligment

- Definition of track χ^2:
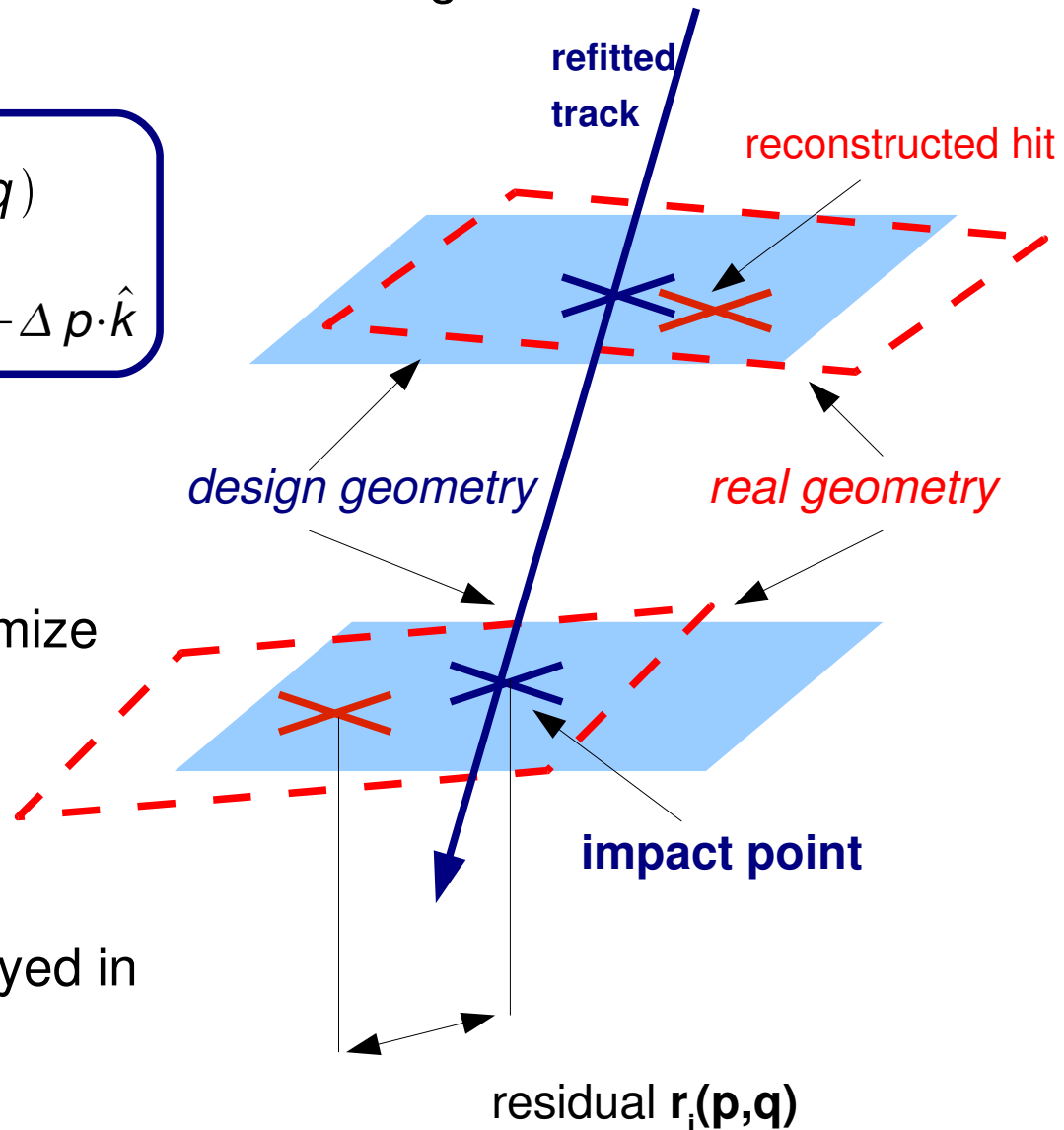
$$\chi^2 = \sum_{i=1}^{n_{hits}} r_i^T(p,q) V_k^{-1} r(p,q)$$

$$r_i(p,q) = u^{hit} - u^{fit}(p,q) = u^{hit} - \Delta p \cdot \hat{k}$$

V = covariance matrix
p = alignment parameters
q = track parameters

- Aligment algorithms attempts to minimize this χ^2 function and therefore track residuals

- A complex system of equations to be solved (O(100k unknowns))

- Fast and robust algorithms are deployed in CMS framework

refitted track

reconstructed hit

design geometry   *real geometry*

impact point

residual r_i(p,q)

Alignment Position Errors

- *The alignment position error (APE)* **characterizes the measurement uncertainty** *of each detector due to misalignment effects.*

- The APE is combined with the spacial (intrinsic) resolution of the device giving the total error of hit positioning on the silicon modules:

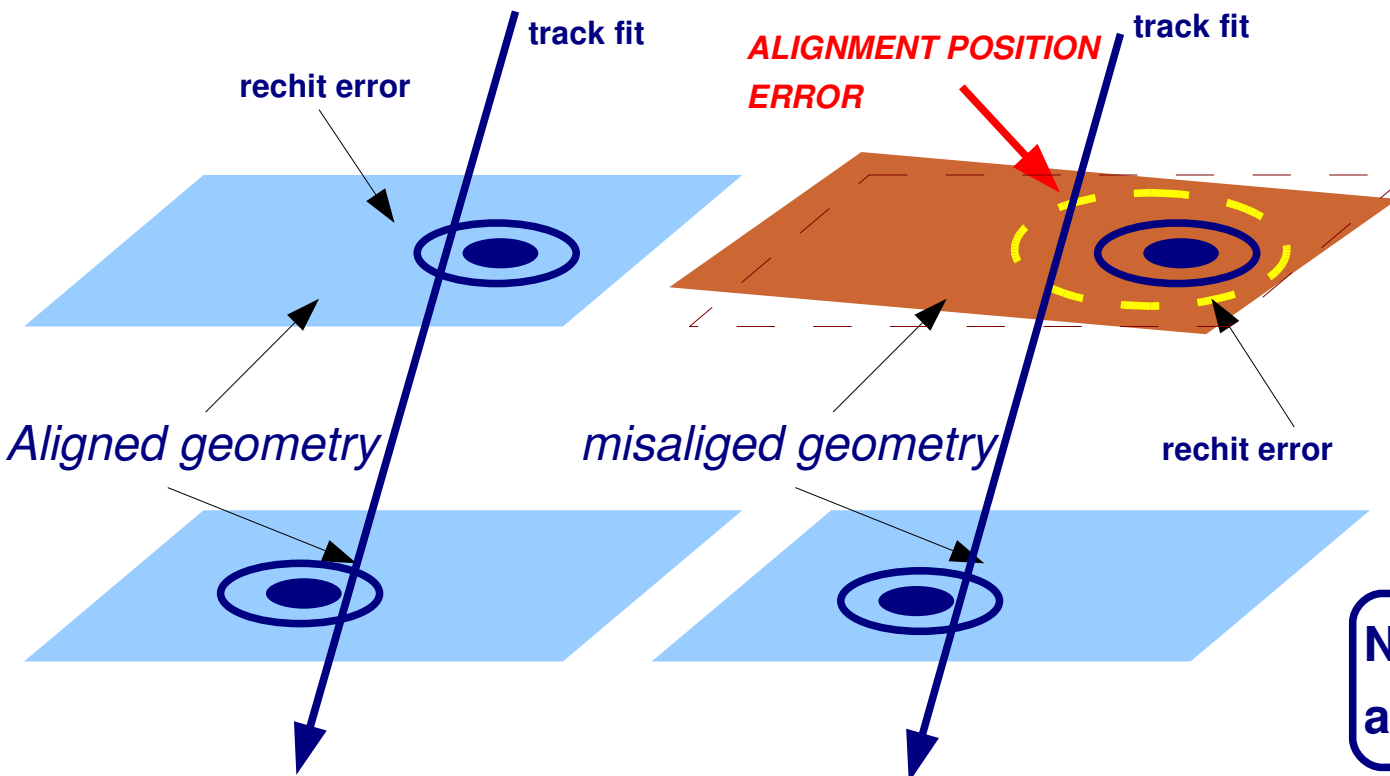$$\sigma^{HIT}_{TOT} = \sigma^{HIT}_{intr} \oplus \boldsymbol{APE}(DET)$$

- The APE affects the search window of pattern recognition in track finding

APE have direct impact on:

- **performance / efficiency** of track reconstruction
- **track quality (χ^2)**
- **fake rate**
- **momentum resolution**

track fit

rechit error

ALIGNMENT POSITION ERROR

track fit

Aligned geometry

misaliged geometry

rechit error
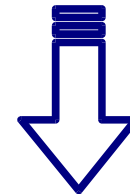
Need good estimation of APE according to alignment status

Track residuals

- To check alignment quality and determine remaining misalignment look to track residuals at Subdet level and layer level.

TIB track residuals
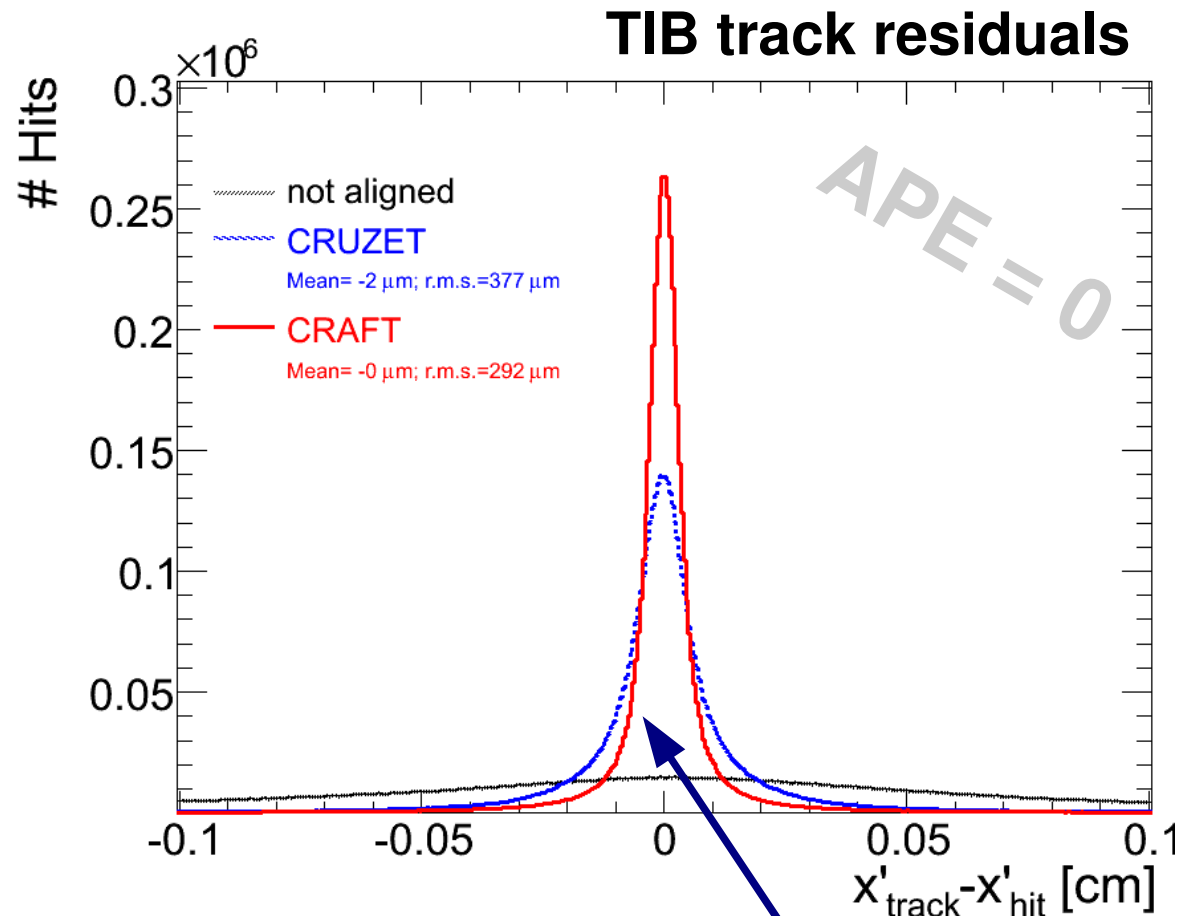
- Several effects folded in the residuals distributions:
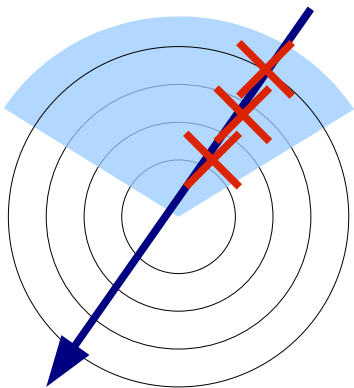
  - **hit resolution:**
    - cluster width
    - strip pitch
  - **tracking extrapolation**
  - **multiple scattering** in silicon:

$$\delta x \simeq l \cdot \delta \theta = l \cdot \frac{1}{p} \sqrt{\frac{t}{X_0}}$$

  - **alignment precision**

$$RMS(\Delta X) = \sigma_{hit} \oplus \sigma_{track} \oplus \delta X_{MS} \oplus \boldsymbol{\sigma_{misalign}}$$

Trends of Residuals

- In order to have a sound **_estimate of remaining misaligment_** take a well aligned region (upper quarter of Tracker) select tracks hit pattern to satisfy test-beam like geometry and plot residuals as a function of track momenta

> Residuals in the different subdets **saturate** at some threshold value ($p>20GeV$), for which the MCS starts to be dominated by the strip (pixel) pitch and misaligment effects
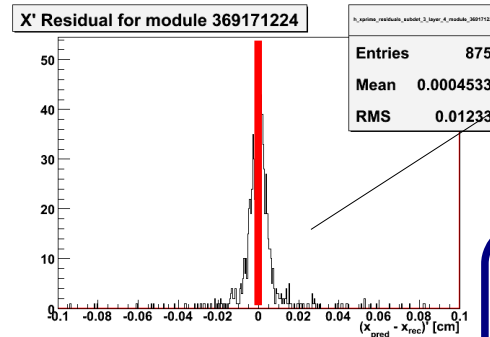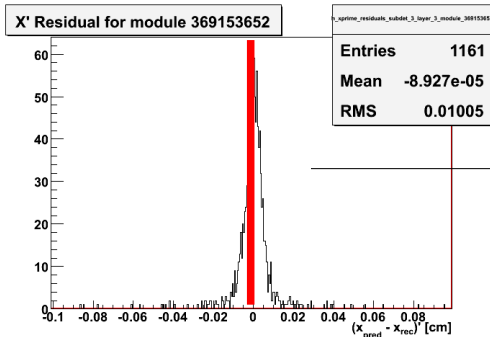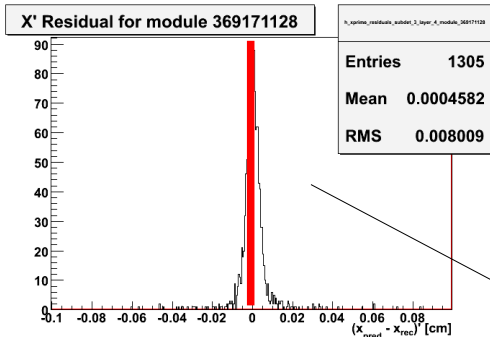
Subdets Residuals vs momentum
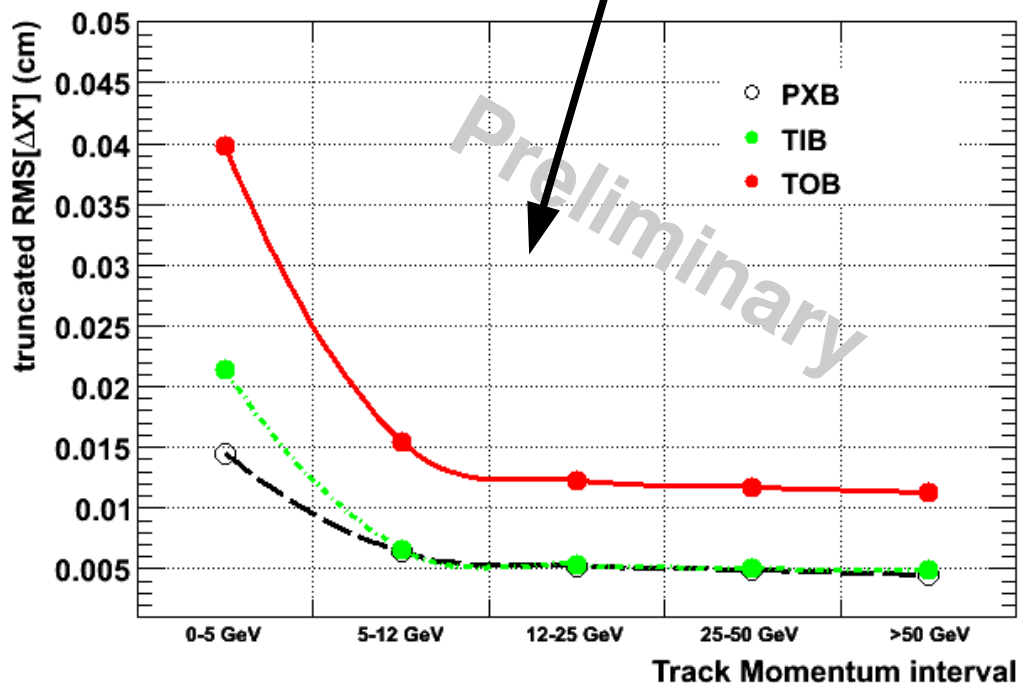
Residuals Barrel Layers
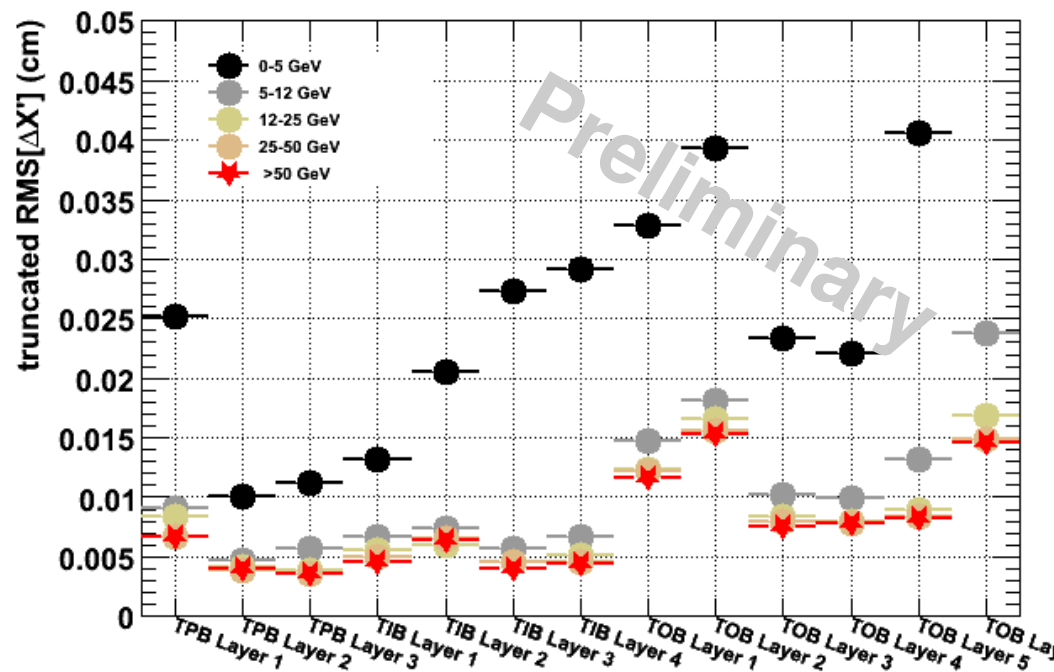
Distribution of Median of Residuals (DMR)

- To check residual misalignment:

- **DMR** (distribution of median of residuals) is a better way to disentangle alignment effects

  - *It has been demostrated using misaligned MC simulation that width of the distribution of median of residual is the best estimator of the input misalingment*

  - for each module take the residual. **If entries > 30 hits** take median and fill the DMR

- multiple scattering averages out when considering DMR.

- Able to spot uncoeherent misalignment of modules respect the others. NOT displacements that leave track χ^2 invariant (weak modes)

- **MR of TPB modules (x_{local} coord)**

  not aligned
  CRUZET
  CRAFT

- •The **RMS of DMR** is taken as width of the remaining statistical misalignment after the alignment procedure

Motivation for module dependent APE

- **Old APEs** were **much larger** than latest (shown at CRAFT Torino Workshop) **RMS of Distribution of Median of Residuals (= DMR)**

- need to define a new set of APEs which reflects better the current status of Tracker alignment

- They need to be module-dependent since there are regions aligned better than others.

- **New code for writing APE object starting from local module dependent input values** (G. Flucke + I. Reid)

Subdet	APE (µm)	RMS OF DMR	
		Mean (µm)	Median (µm)
TPB	200	41	14
TPE	1000	90	37
TIB	100	18	10
TID	300	46	23
TOB	100	21	9
TEC	300	49	28

- Every study in the following has been performed using the *CRAFT first reprocessing datasample*, and using the *CRAFT – signoff alignment object* (`Tracker_Geometry_v3_offline`)

- It is the first attempt to determine module level APE for CRAFT alignment

Strategy

- Tuning of remaining misalignment (`Tracker_Geometry_v3_offline` as reference for DATA)

 - selecting tracks / hits where MS and extrapolation are small (**p> 20GeV**)

Hit Map XY

We are left with a supposedly well aligned region
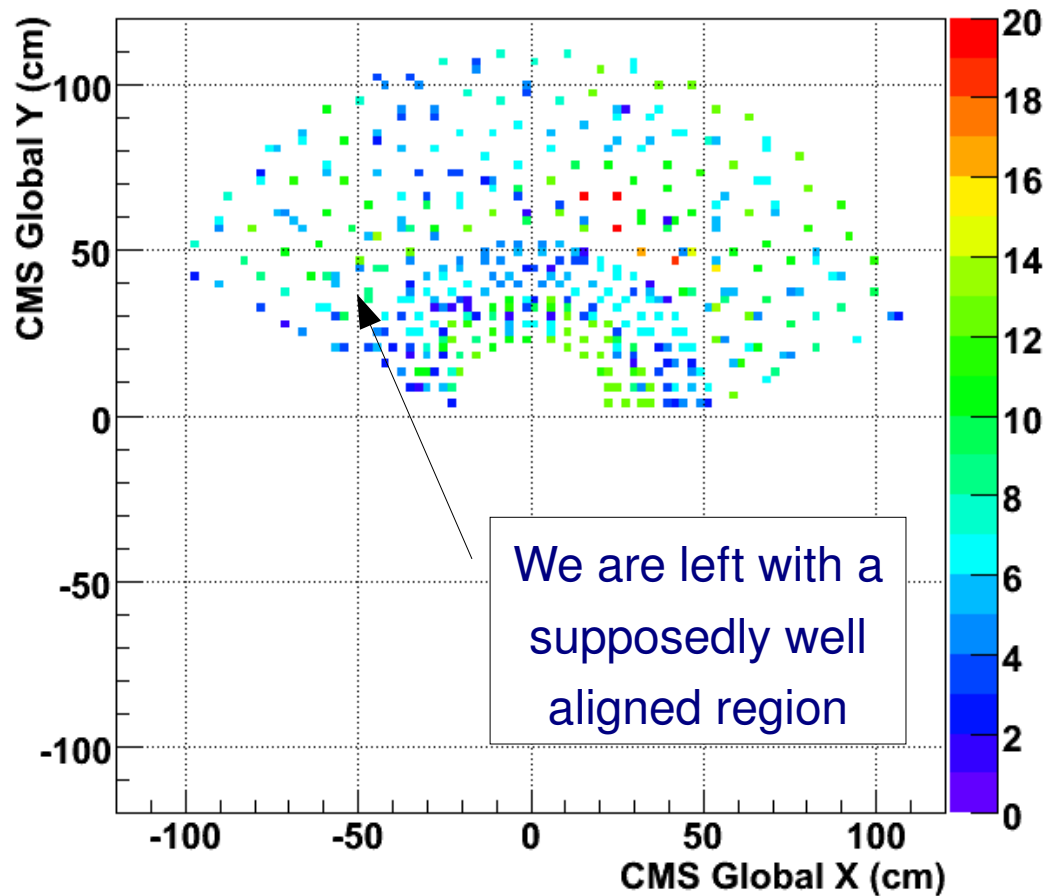
- Track/Hits quality cuts applied

  - **Standard Validation cuts**

    - $N_{hits} > 10$
    - $N_{hits\ -2D} > 2$
    - $S/N_{cluster} > 18$

  - **Fiducial (pixel-like) volume cuts**

    - $(x^2_{DCA} + y^2_{DCA})^{1/2} < 11$ cm
    - $|z_{DCA}| < 60$ cm

  - **Hit pattern selection**

    - **14 split hits (10 SS + 4 DS)**
    - **Test-Beam like topology:**
      - **TOB L6**
        - **TOB L5**
          - **...**

Tuning of Δu,(Δv),Δγ

- **Look at DMRs and residuals in Barrel Layers and compare Craft data with cosmic MC @ 3.8 T**
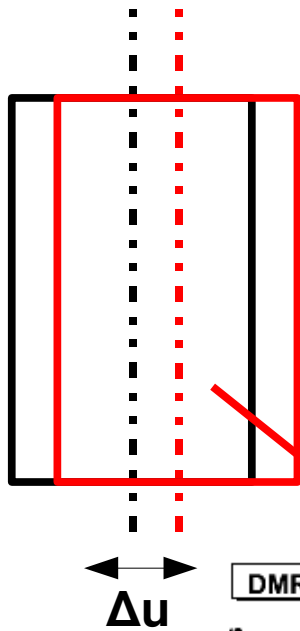
- Δu (Δv) affecting the DMR
- so tune layer by layer Δu comparing **misaligned MC** and **data**

Δu
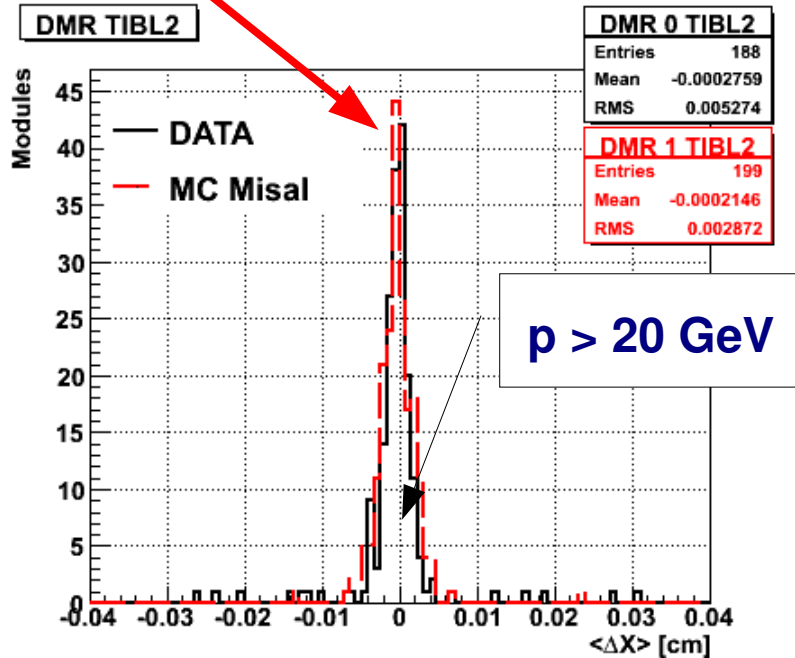
- Δγ not affecting DMRs but spread in the residuals
- so tune **MC** in order to reproduce the trend of Barrel layer residuals of **data**

Δγ

DMR TIBL2

DMR 0 TIBL2	
Entries	188
Mean	-0.0002759
RMS	0.005274

DMR 1 TIBL2	
Entries	199
Mean	-0.0002146
RMS	0.002872

DATA
MC Misal

p > 20 GeV

Residuals Barrel Layers

p > 20 GeV
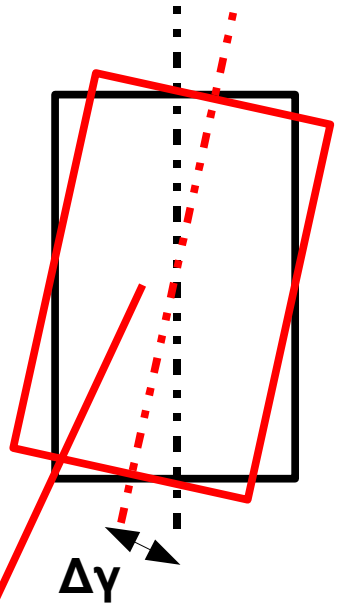
DATA
MC Mis uncorrectd
MC Mis
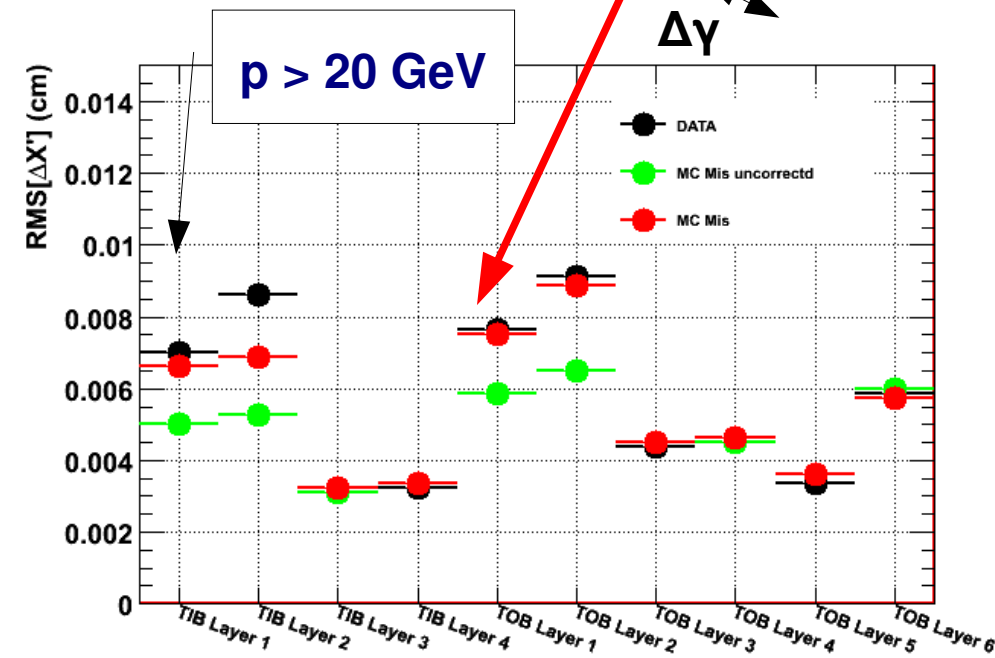
Estimation of new APE

- In **TIB/TOB**

  - Misalignment parameters Δu, (Δv for DS), Δγ obtained as described before are used to define a NEW layer dependent APE (**APE**$_{NEW}$) in the local x coordinate

$$APE_{NEW} = \sqrt{\sigma_{uu}} = \underbrace{\Delta u}_{\substack{u\ correction \\ from\ MC\ tuning \\ of\ DMR}} \oplus \overbrace{\frac{L_{mod}}{4}}^{\substack{average \\ lever\ arm}} \underbrace{\Delta \gamma}_{\substack{\gamma\ from \\ MC\ tuning \\ of\ residuals}} \oplus \overbrace{(C\,\delta\,v)}^{\substack{ad\ hoc\ correction \\ for\ DS}}$$
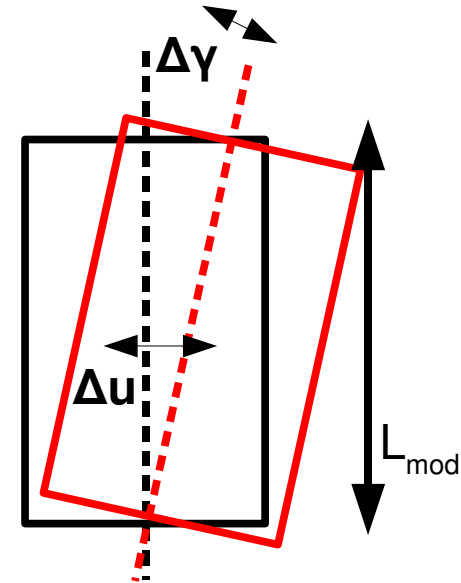
- In **TPB/TPE/TID/TEC** (Endcap and Pixels)

  - since a detailed analysis of layer dependent matching with misaligned MC was not performed → Take the **DMR**

$$APE_{NEW} = \sqrt{\sigma_{uu}} = Median(Residual_{x'})$$

Subdet	Median (μm)
TPB	14
TPE	37
TID	23
TEC	28

Scaling Law

- We know that the quality of Alignment is φ-dependent, so introduce a scaling law, which increases the APE in modules having fewer hits in the alignment procedure:

RMS of DMR vs φ ((null) - Layer1 - Dete... TOB L1

CRAFT

- **Structure in DMR(φ) clearly visible**
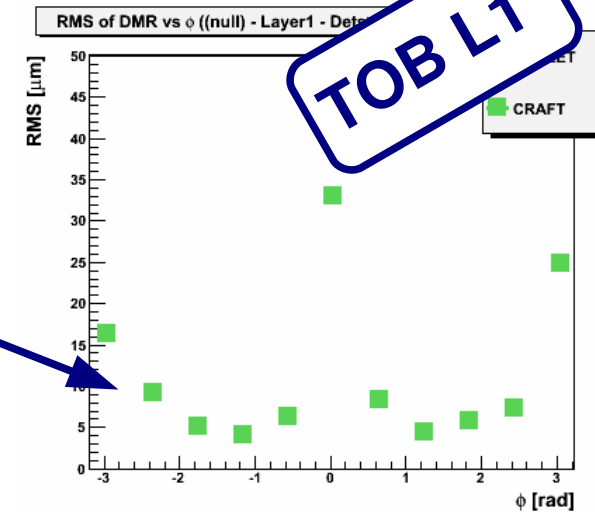
- so said N, the number of hits/module

$$
\begin{cases}
\left|\langle residual_x \rangle\right| > 3\, APE_{old} & APE = \left|\langle residual_x \rangle\right| \\
N < N_{min} & APE = APE_{old} \\
N > N_{max} & APE = k\, APE_{new} \\
\\
N_{min} < N < N_{max} & APE = k\, APE_{new} \cdot \sqrt{\left(\dfrac{N_{max}}{N}\right)}
\end{cases}
$$

Subdet	Old APE (μm)
TPB	200
TPE	1000
TIB	100
TID	300
TOB	100
TEC	300

- **k, N$_{MAX}$,N$_{MIN}$ parameters to be tuned!**

- This procedure should avoid introducing errors too small to bad aligned modules (which have very large median of residuals / too few hits)

Current status

I. Reid + G. Flucke

- Using the numbers as shown in the previous slides we define the following parameters:

	K*APE0 (µm)	Nmax	Nmin
TPB	*19*	400	25
TIB L1/L2	*20/16*	4000	100
TIB L3/L4	*19*	4000	100
TOB L1/L2	*38/23*	8000	200
TOB L3/L4	*16*	8000	200
TOB L5/L6	*15*	8000	200
TPE	*55*	100	25
TID	*35*	1500	500
TEC	*31*	1600	30
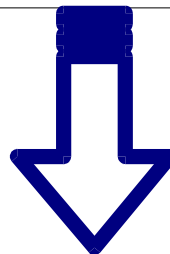
to rescale

- **Local coordinate** input given to generate module dependent APE
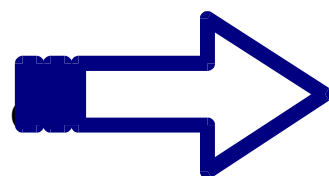
- First module dependent APE object successfully produced.

- set $\sigma_{uu} = \sigma_{vv} = \sigma_{ww}$

- "spherical" local APE → "spherical" global APE

$$V_{uvw} = \begin{pmatrix} \sigma_{uu} & 0 & 0 \\ 0 & \sigma_{vv} & 0 \\ 0 & 0 & \sigma_{ww} \end{pmatrix} = \begin{pmatrix} \sigma_0 & 0 & 0 \\ 0 & \sigma_0 & 0 \\ 0 & 0 & \sigma_0 \end{pmatrix}$$

```
369120493   0.00475   0.00475   0.00475
369120494   0.00628   0.00628   0.00628
369120501   0.00418   0.00418   0.00418
369120502   0.00723   0.00723   0.00723
```

moduleId σ_{uu} σ_{vv} σ_{ww}

Error "spectrum"

- Define the error in the rφ plane as the squared sum of the global X and Y errors

$$error = \sqrt{(\sigma_{xx} + \sigma_{yy})} = \sqrt{(dxx + dyy)}$$

- Plot it for **"default" APE (TkGeomErr_Offline_v3)** and new **module-dependent APE;**

OLD APE

Sqrt(dxx+dyy) of Old APE object

APEs	
Entries	19876
Mean	0.02899
RMS	0.01795

discrete spectrum (values uniform over the subdet)

NEW APE

Sqrt(dxx+dyy) of New APE object

APEs	
Entries	19876
Mean	0.008975
RMS	0.01531

discrete spectrum due to modules left with default APE
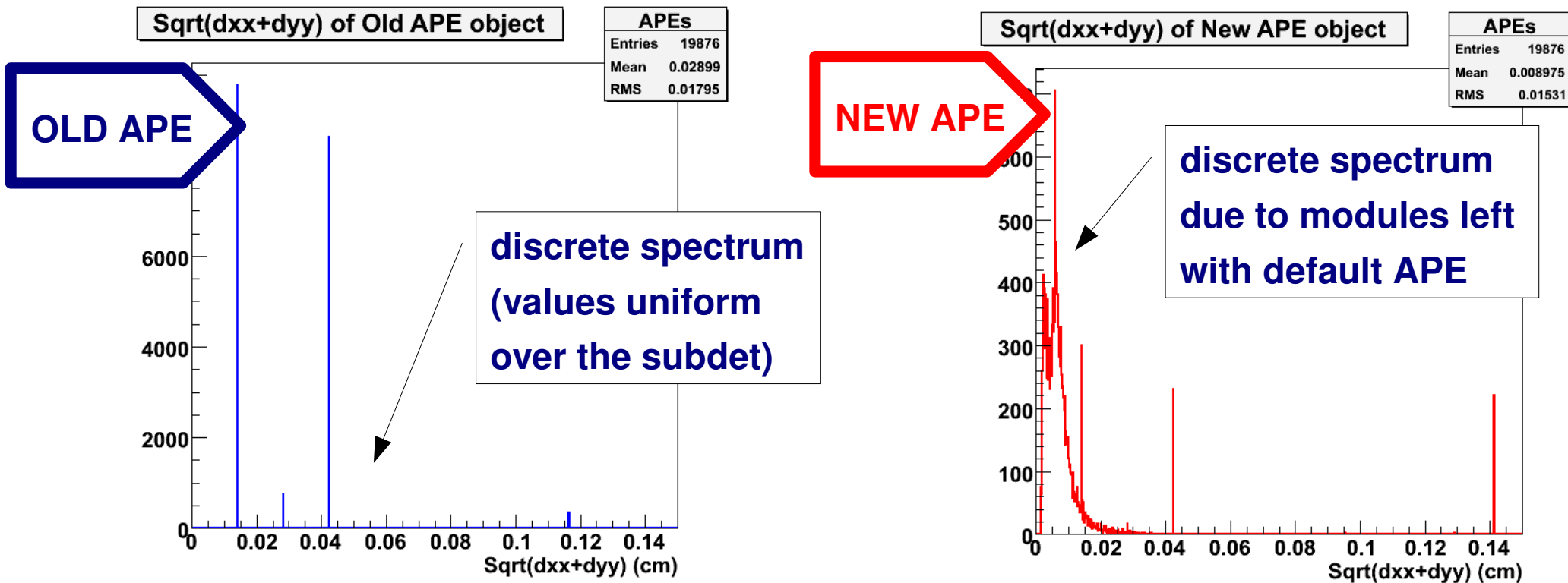
Error "spectra" for Subdets

modules left to the old APE

In the plots APE=sqrt(σ_{uu})

Double peak due to stereo/rϕ separately
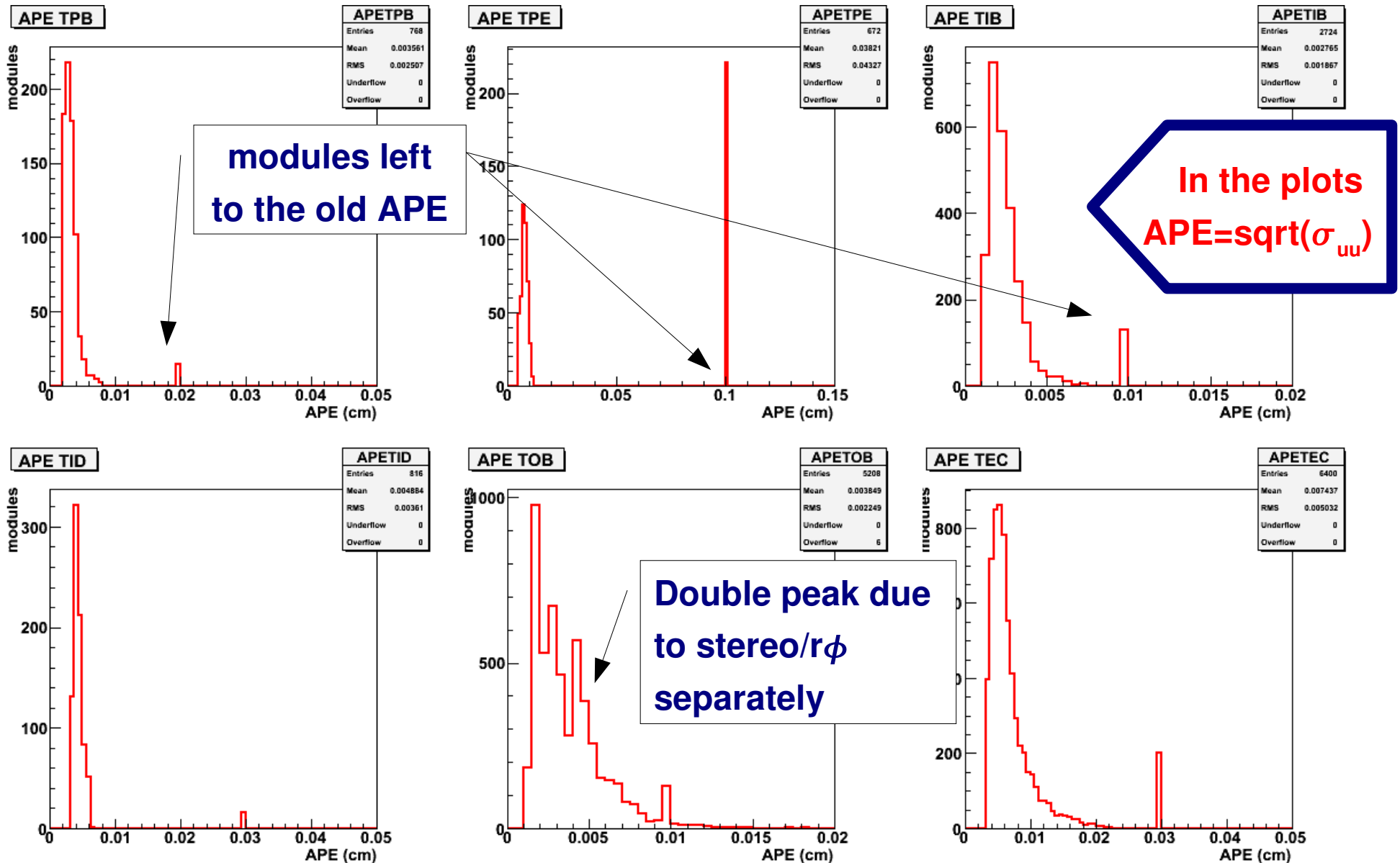
2D map of APE - TIB
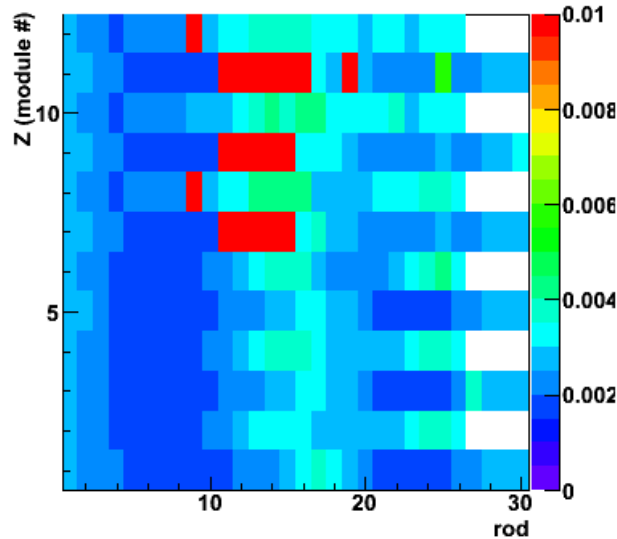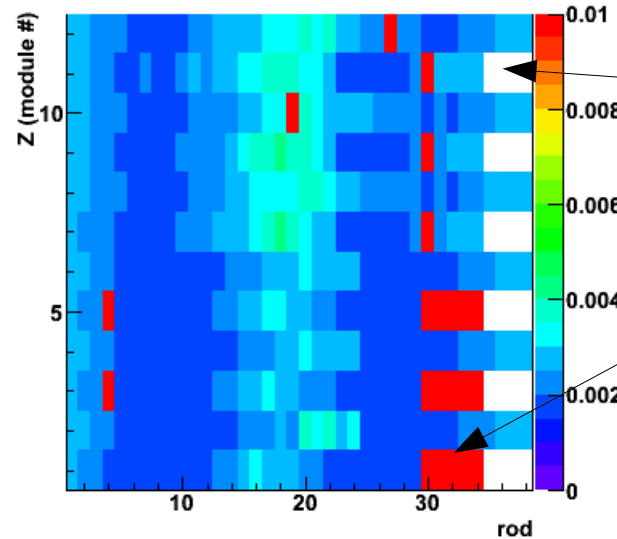
white spots are due to binning issues (internal/external strings)

red spots are modules left with default APE
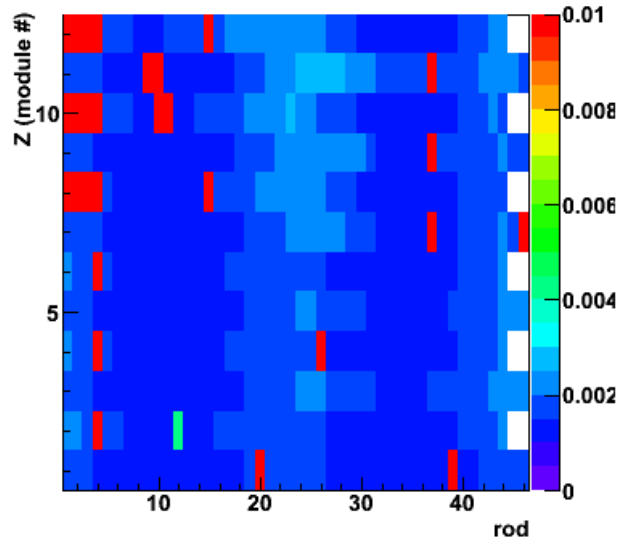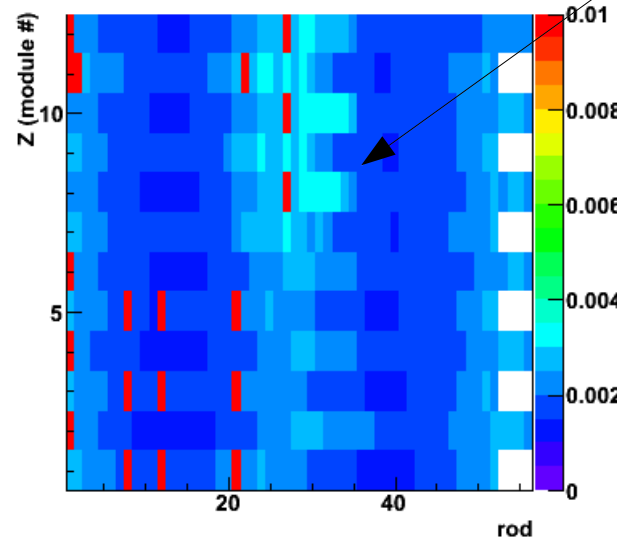
values in-between are due to the modulation as a function on the number of entries (structure Top-Bottom visible)

2D Map of APE - TOB
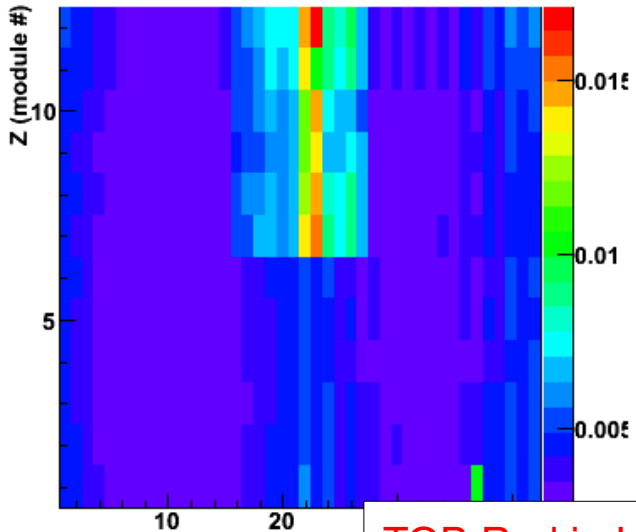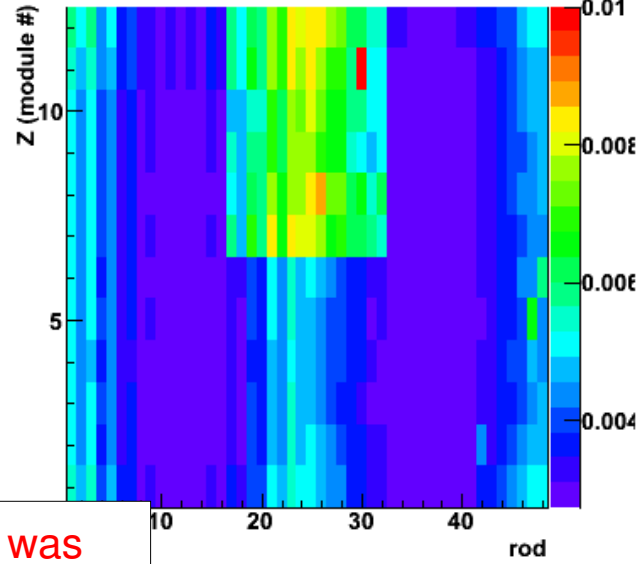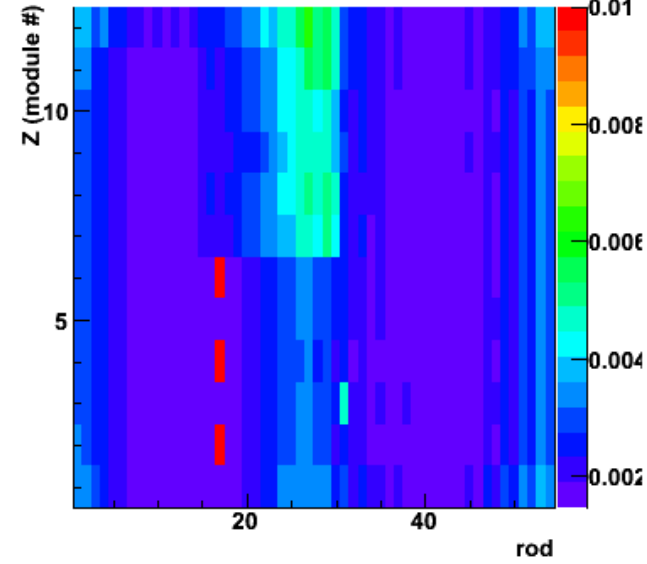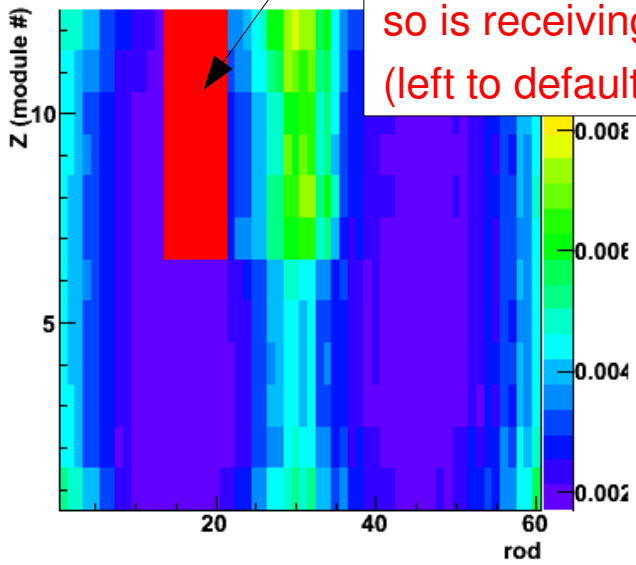
TOB Rod in L4 was out of the DAQ and so is receiving no hits (left to default APE)
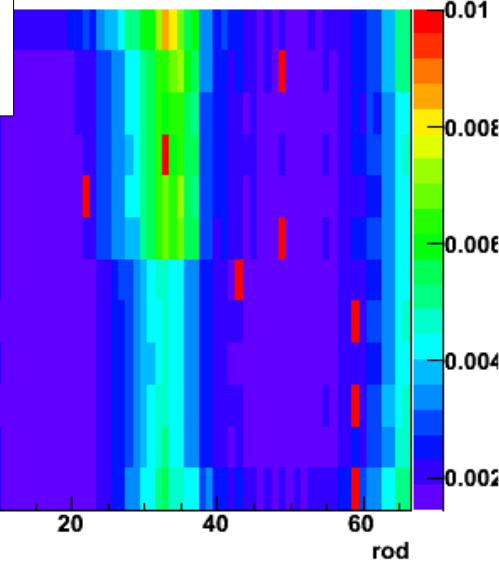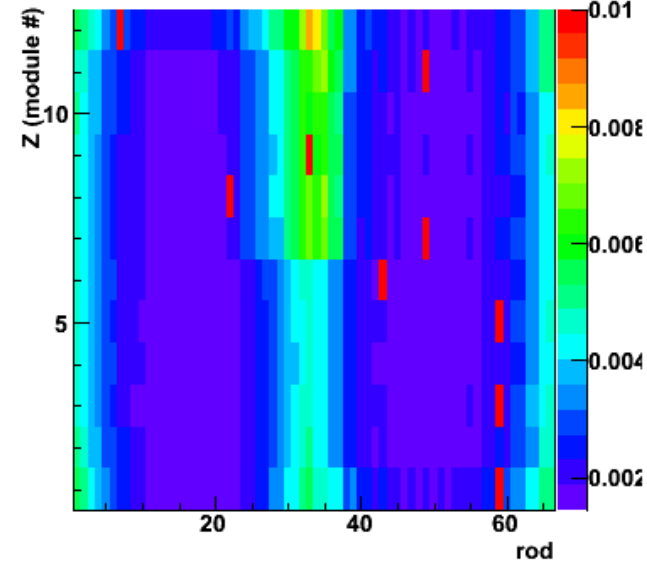
Validation

J. Hauk

Residual for TOBBarrel 3 in Strip

h_NormXprime_TOBBarrel_3	
Entries	2998853
Mean	0.0002552
RMS	1.184
χ^2 / ndf	3254 / 37
Constant	1.17e+05 ± 94
Mean	-0.00556 ± 0.00065
Sigma	0.9623 ± 0.0006
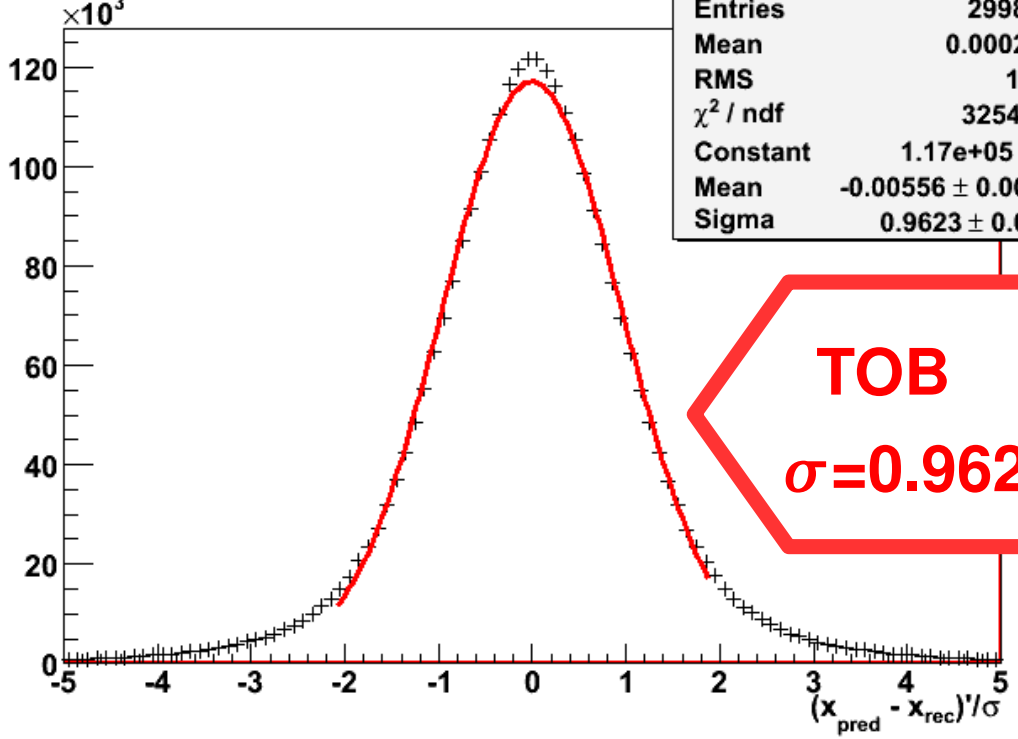
First rough validation, using normalized track residuals:

$$r_i = \frac{u_i^{hit} - u_i^{fit}}{\sigma_i}$$

$$\sigma_i = \sigma_i(APE, hit)$$

TOB

σ=0.962

- ***If the errors were correctly estimated the RMS should be 1***

TIBBarrel 0 in Strip

h_NormXprime_TIBBarrel_0	
Entries	745699
Mean	-0.007308
RMS	1.311
χ^2 / ndf	1206 / 37
Constant	2.747e+04 ± 46
Mean	-0.006425 ± 0.001359
Sigma	0.9679 ± 0.0014

TIB

σ=0.968
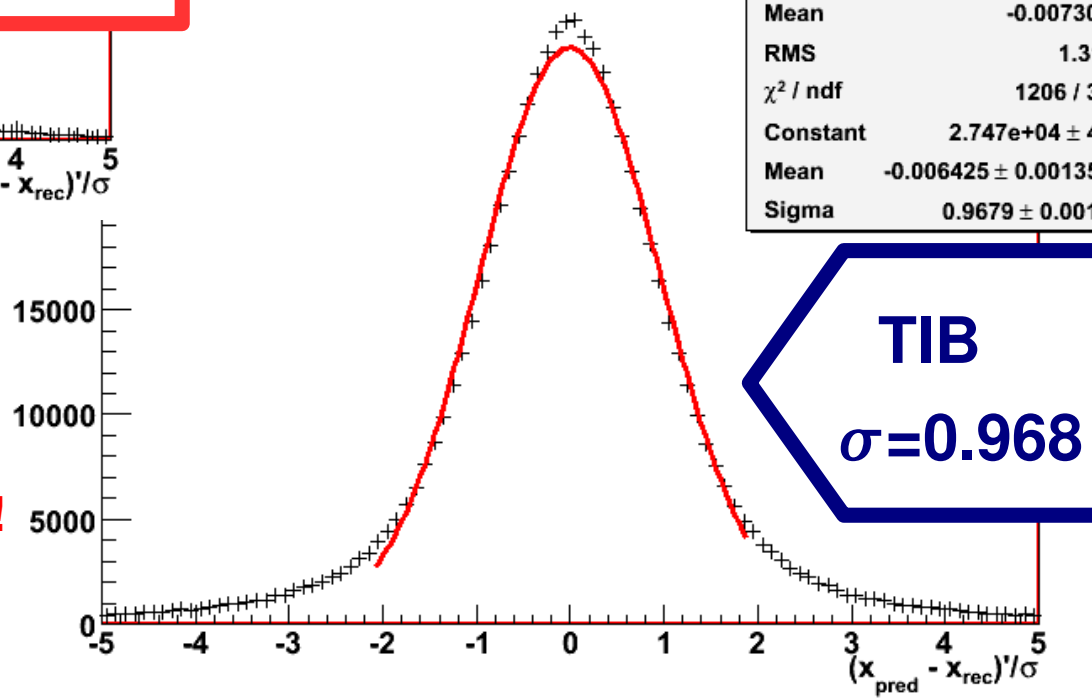
- Take the width of a gaussian fit (~1 in the subdets) and use it to adjust calibration

- **It does not take into account tails yet!**

Cosmic Track Splitting Validation

- Take a tracker track:

  - split it along its **PCA** (*P*oint of *C*losest *A*pproach)

  - refit separately the two hits collections coming from the the two cosmic halves

  - compare the track parameters of the the two legs updated at the PCA:

  $$X = (d_{xy}, d_z, p_T, \theta_{tk}, \phi_{tk})$$

  - define residuals r_X as thedifference of the parameters from above and below

  $$r_X = \Delta_X = X(PCA)_{TOP} - X(PCA)_{BOT}$$

  - if alignment is good the two parameter sets should coincide and *small residuals are expected*

- Correct estimation of errors is reflected in the normalized residuals or pulls

$$\frac{r}{\sigma_r} = \frac{\Delta X}{\sigma_{\Delta X}} = \frac{X_{top} - X_{bot}}{\sqrt{\sigma_{Xtop}^2 + \sigma_{Xbot}^2}}$$

original Tk Track

refitted upper leg

refitted lower leg

RMS of normalized residuals should be 1
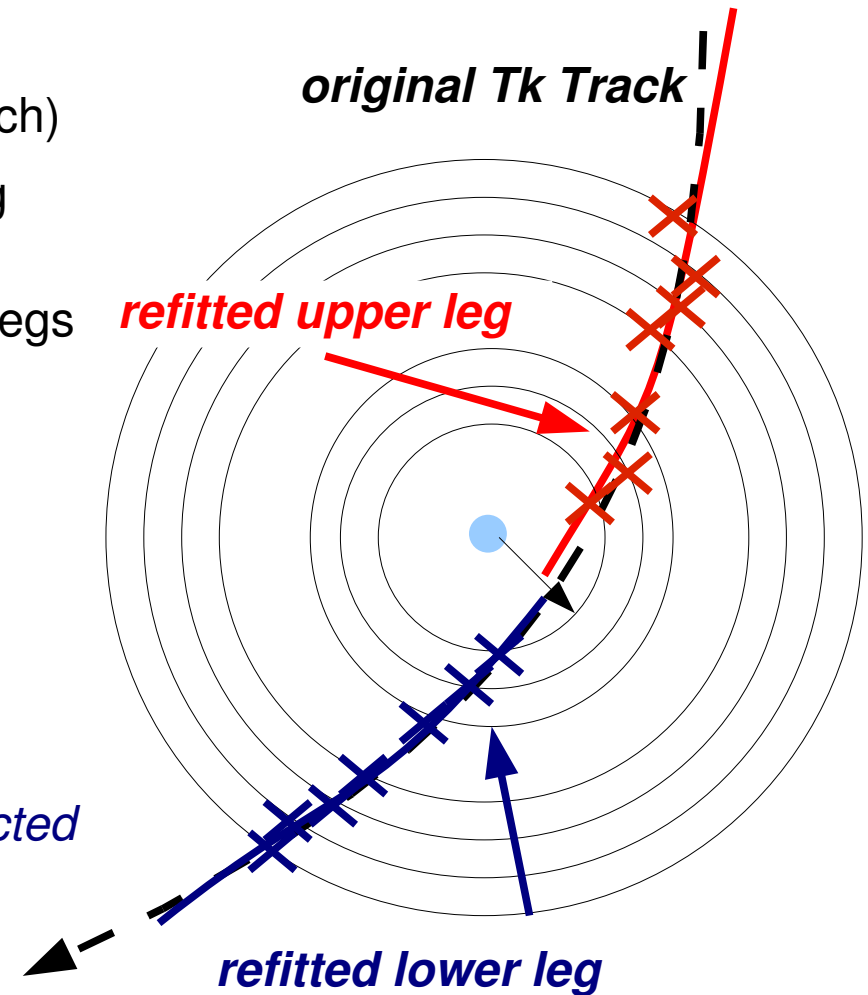
Cosmic Track Splitting Validation*

N. Tran
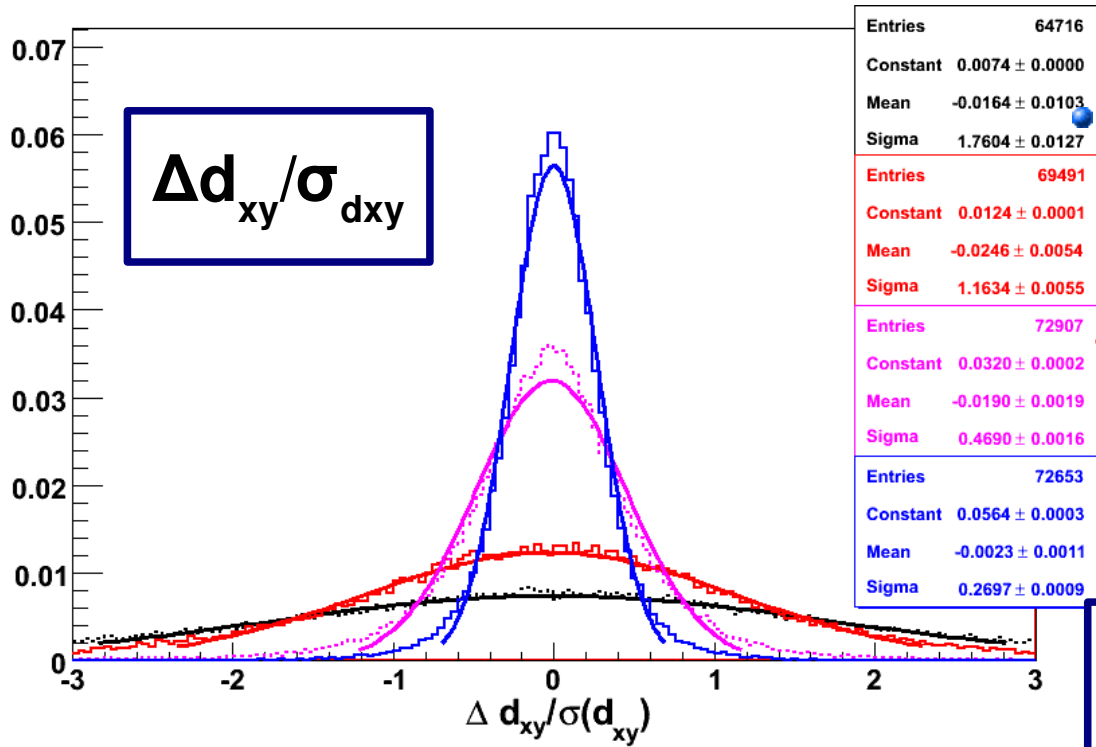
Pull of impact parameters d_{xy} and d_z

Entries		64716
Constant	0.0074 ±	0.0000
Mean	-0.0164 ±	0.0103
Sigma	1.7604 ±	0.0127
Entries		69491
Constant	0.0124 ±	0.0001
Mean	-0.0246 ±	0.0054
Sigma	1.1634 ±	0.0055
Entries		72907
Constant	0.0320 ±	0.0002
Mean	-0.0190 ±	0.0019
Sigma	0.4690 ±	0.0016
Entries		72653
Constant	0.0564 ±	0.0003
Mean	-0.0023 ±	0.0011
Sigma	0.2697 ±	0.0009

$\Delta d_{xy}/\sigma_{dxy}$

NEW APE
mean: -0.02
RMS: 1.16

$\Delta d_z/\sigma_{dz}$

Entries		64716
Constant	0.0098 ±	0.0001
Mean	-0.0556 ±	0.0080
Sigma	1.5415 ±	0.0089
Entries		69491
Constant	0.0147 ±	0.0001
Mean	-0.0310 ±	0.0047
Sigma	1.0466 ±	0.0047
Entries		72907
Constant	0.0432 ±	0.0002
Mean	-0.0064 ±	0.0014
Sigma	0.3577 ±	0.0013
Entries		72653
Constant	0.0726 ±	0.0004
Mean	0.0011 ±	0.0008
Sigma	0.2105 ±	0.0008

- Four APE objects considered:

NEW APE
mean: -0.03
RMS: 1.05

- ···· CRAFT 0 APE
- —— CRAFT **New** APE
- ···· CRAFT Default APE
- —— CRAFT Inflated APE **(default * 100)**

*see: http://www.pha.jhu.edu/~ntran/cms/splitTracks/alignment/plots_forMarco_forAPE/

Normalized Residuals (p_T / κ)

$\Delta p_T / \sigma_{pT}$

Entries		64716
Constant	0.0127	$\pm$ 0.0001
Mean	0.1855	$\pm$ 0.00??
Sigma	1.1636	$\pm$ 0.0056
Entries		69491
Constant	0.0152	$\pm$ 0.0001
Mean	0.1518	$\pm$ 0.0045
Sigma	0.9979	$\pm$ 0.0043
Entries		72907
Constant	0.0240	$\pm$ 0.0001
Mean	0.0783	$\pm$ 0.0026
Sigma	0.6257	$\pm$ 0.0025
Entries		72653
Constant	0.0427	$\pm$ 0.0002
Mean	0.0423	$\pm$ 0.0014
Sigma	0.3458	$\pm$ 0.0014
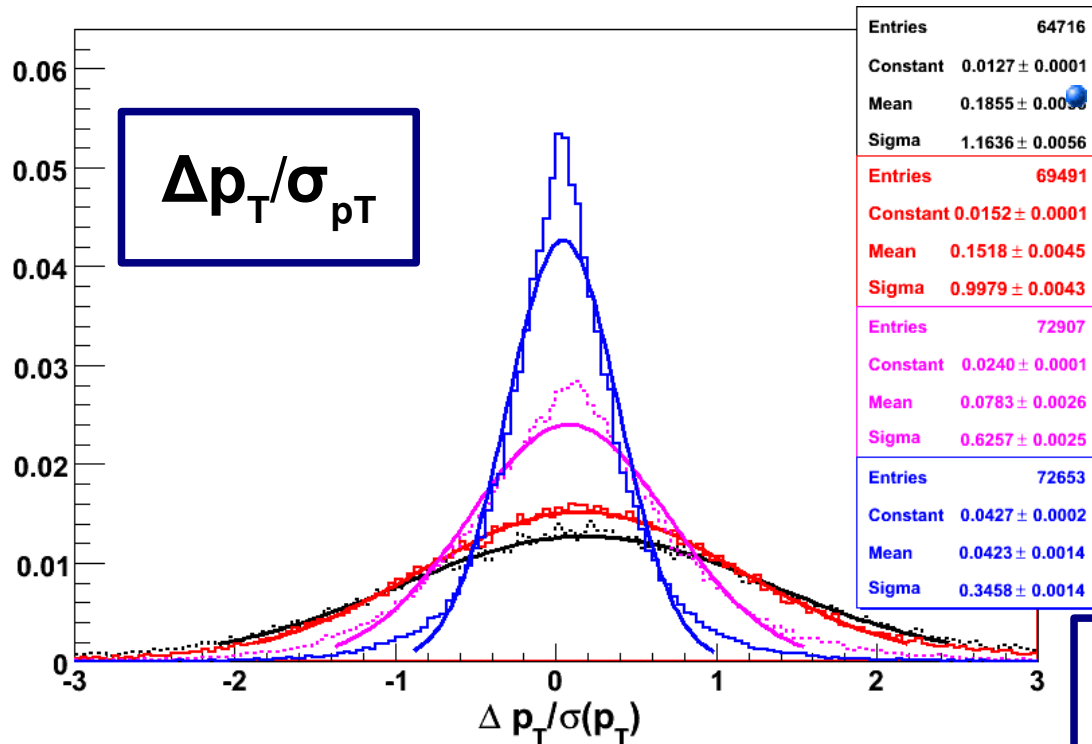
Pull for momentum/curvature p_T / $1/p_T$

NEW APE mean: 0.15 RMS: 0.99
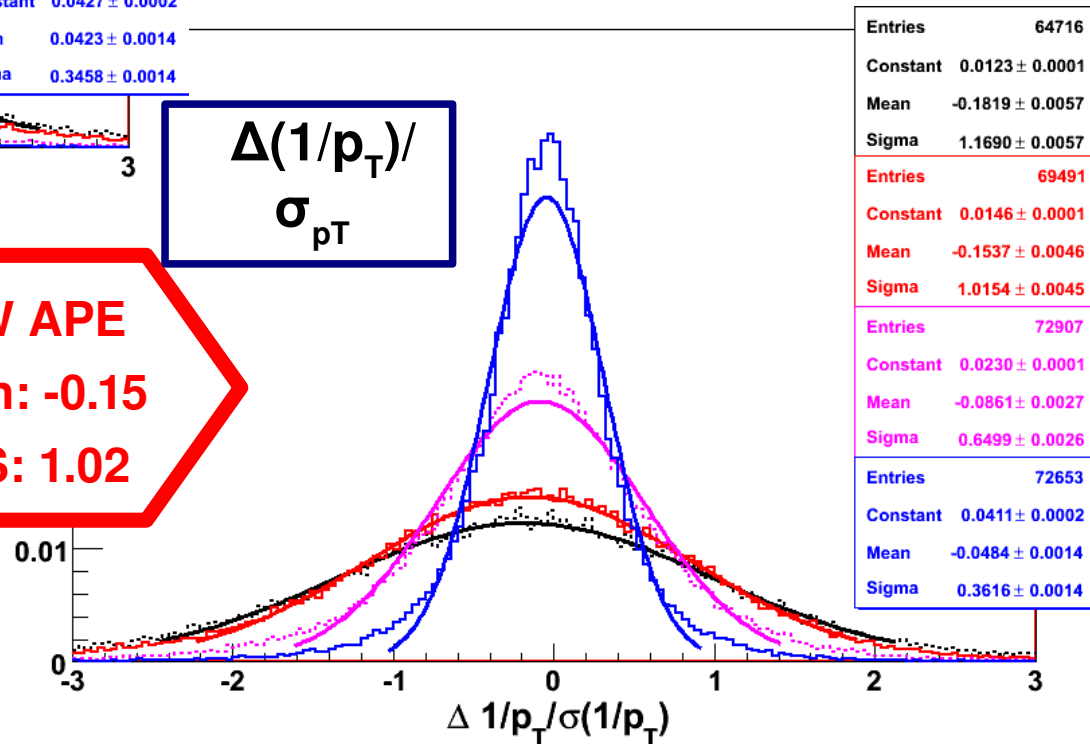
Pulls in general show a slight underestimation of the errors

NEW APE mean: -0.15 RMS: 1.02

$\Delta(1/p_T)/\sigma_{pT}$

Entries		64716
Constant	0.0123	$\pm$ 0.0001
Mean	-0.1819	$\pm$ 0.0057
Sigma	1.1690	$\pm$ 0.0057
Entries		69491
Constant	0.0146	$\pm$ 0.0001
Mean	-0.1537	$\pm$ 0.0046
Sigma	1.0154	$\pm$ 0.0045
Entries		72907
Constant	0.0230	$\pm$ 0.0001
Mean	-0.0861	$\pm$ 0.0027
Sigma	0.6499	$\pm$ 0.0026
Entries		72653
Constant	0.0411	$\pm$ 0.0002
Mean	-0.0484	$\pm$ 0.0014
Sigma	0.3616	$\pm$ 0.0014

Absolute Residuals

Δd_{xy}

Entries	64716
Constant	0.0433 ± 0.0002
Mean	-0.0001 ± 0.0000
Sigma	0.0045 ± 0.0000
Entries	69491
Constant	0.0473 ± 0.0003
Mean	-0.0001 ± 0.0000
Sigma	0.0041 ± 0.0000
Entries	72907
Constant	0.0401 ± 0.0002
Mean	-0.0002 ± 0.0000
Sigma	0.0048 ± 0.0000
Entries	72653
Constant	0.0105 ± 0.0001
Mean	-0.0001 ± 0.0001
Sigma	0.0177 ± 0.0001

Four APE objects considered:

- ···· CRAFT 0 APE
- —— CRAFT **New** APE
- ···· CRAFT Default APE
- —— CRAFT Inflated APE

Δd_z

Entries	64716
Constant	0.0272 ± 0.0002
Mean	-0.0002 ± 0.0000
Sigma	0.0069 ± 0.0000
Entries	69491
Constant	0.0280 ± 0.0002
Mean	-0.0002 ± 0.0000
Sigma	0.0067 ± 0.0000
Entries	72907
Constant	0.0260 ± 0.0001
Mean	-0.0002 ± 0.0000
Sigma	0.0072 ± 0.0000
Entries	72653
Constant	0.0027 ± 0.0000
Mean	0.0015 ± 0.0009
Sigma	0.0568 ± 0.0024

- Absolute residuals show:
  - little dependence on APEs
  - the **new APE** object has the best performance
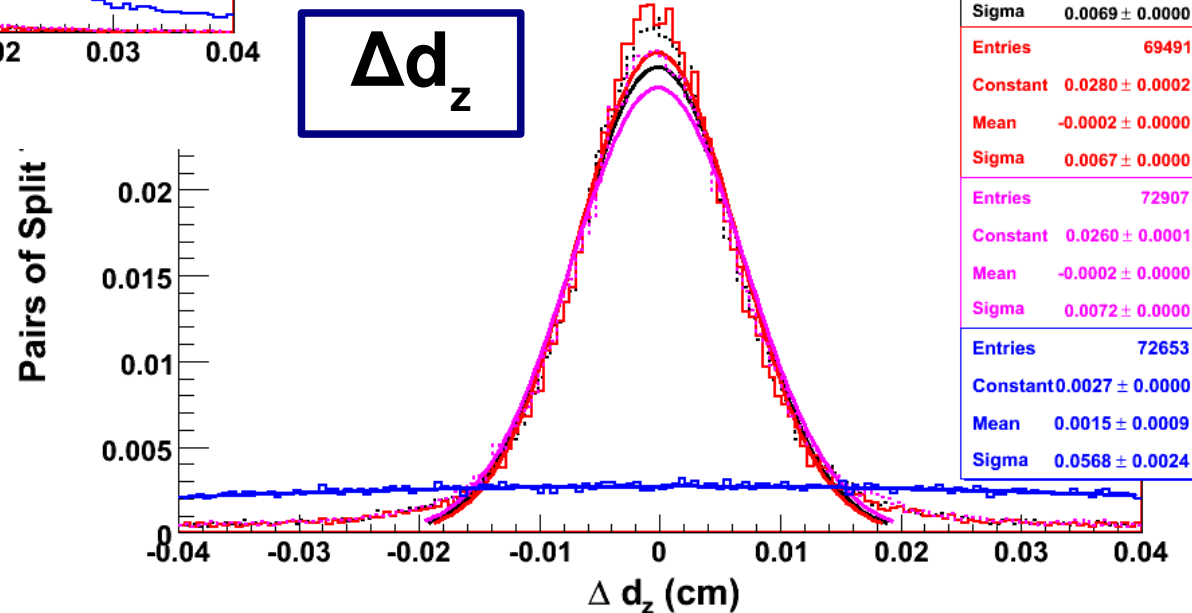
APE in tracking efficiency

Z. Guo

- APE have a **direct impact on tracking efficiency** since:

  - the search window of hits in pattern recognition is tuned on APE (hit is taken if it does not deteriorate the track χ^2 more than some value)

  - track extrapolation is sensible to APE $\Rightarrow$ in the refit procedure hits are"weighted" with the APE

- APE-related efficiency is a responsibily of Tracker Alignment Group

- **Idea: Re-reco ~ 3k tracks from CRAFT**

  - Number of tracks with at least a TXX (TIB/TEC/...) hit

CTF	PXB	PXE	TIB	TID	TOB	TEC
Zero	22	15	466	256	1456	724
New	**22**	**18**	**464**	**256**	**1450**	**720**
Default	**24**	**19**	**474**	**261**	**1453**	**736**

Cosmic TF	PXB	PXE	TIB	TID	TOB	TEC
Zero	25	20	469	262	1502	1070
New	**24**	**19**	**471**	**262**	**1514**	**1079**
Default	**25**	**23**	**482**	**264**	**1536**	**1100**

hit search window
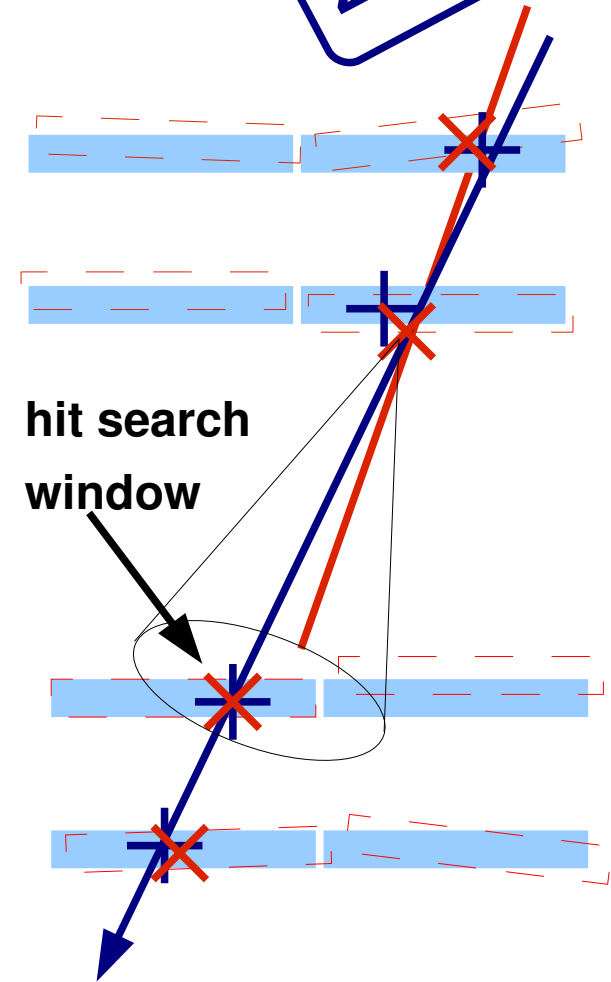
Within the **same tracking algo,** very little differences are observed among the different APE objects

Track χ² (Default Vs New APE)

- Definition of track χ²:

$$\chi^2 = \sum_i^{N_{hits}} \frac{r_i^2(p,q)}{\sigma_i^2} = \sum_i^{N_{hits}} \frac{\left(u^{hit}(p,q) - u^{fit}(p,q)\right)^2}{\sigma_i^2}$$

$$\sigma_i = \sigma_{i,track}(\textbf{APE}) \oplus \sigma_{i,hit} \oplus \sigma_{\textbf{APE}}$$
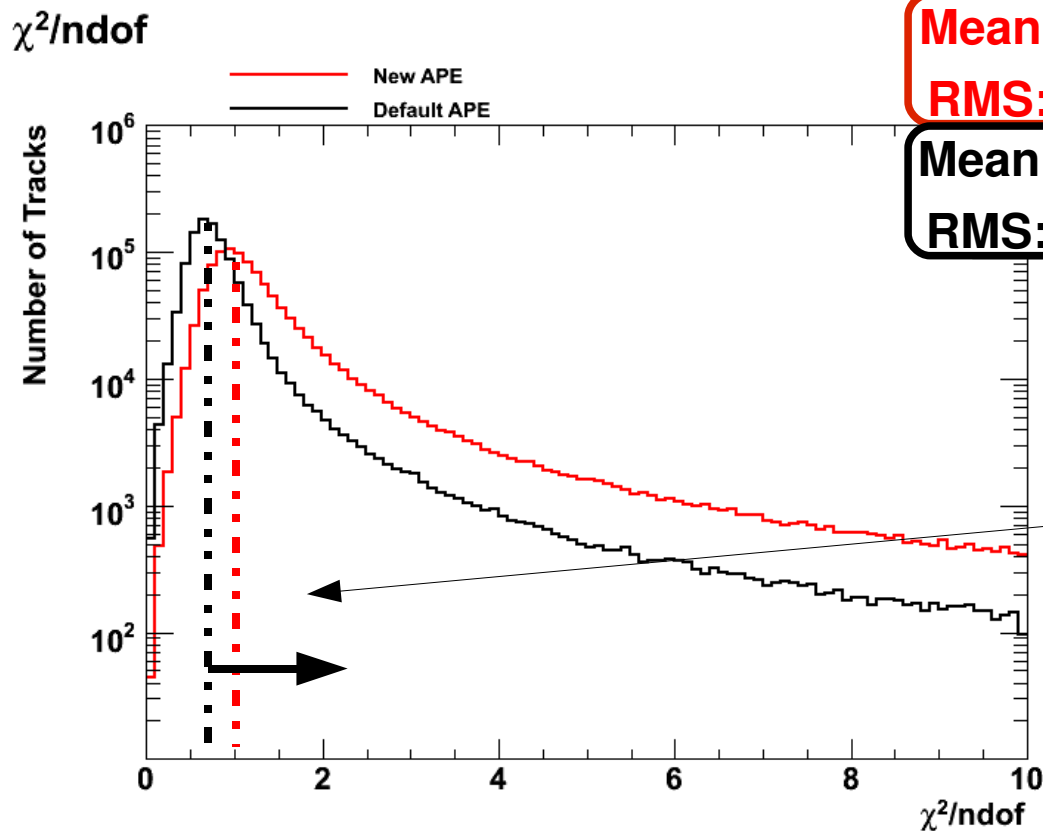
Mean: 1.57
RMS: 1.35

Mean: 0.94
RMS: 0.87

- The track χ² depends strongly on the **Aligment Position Error**

- Idea: refit tracks with new and old APE and check that the χ² shifts and indeed peaks at 1.

χ^2 **peak shitfting to 1.** Mean values is still to high due to the heavy tail. More sensible to fit the distribution and extract the curve parameters?

Probability of χ²
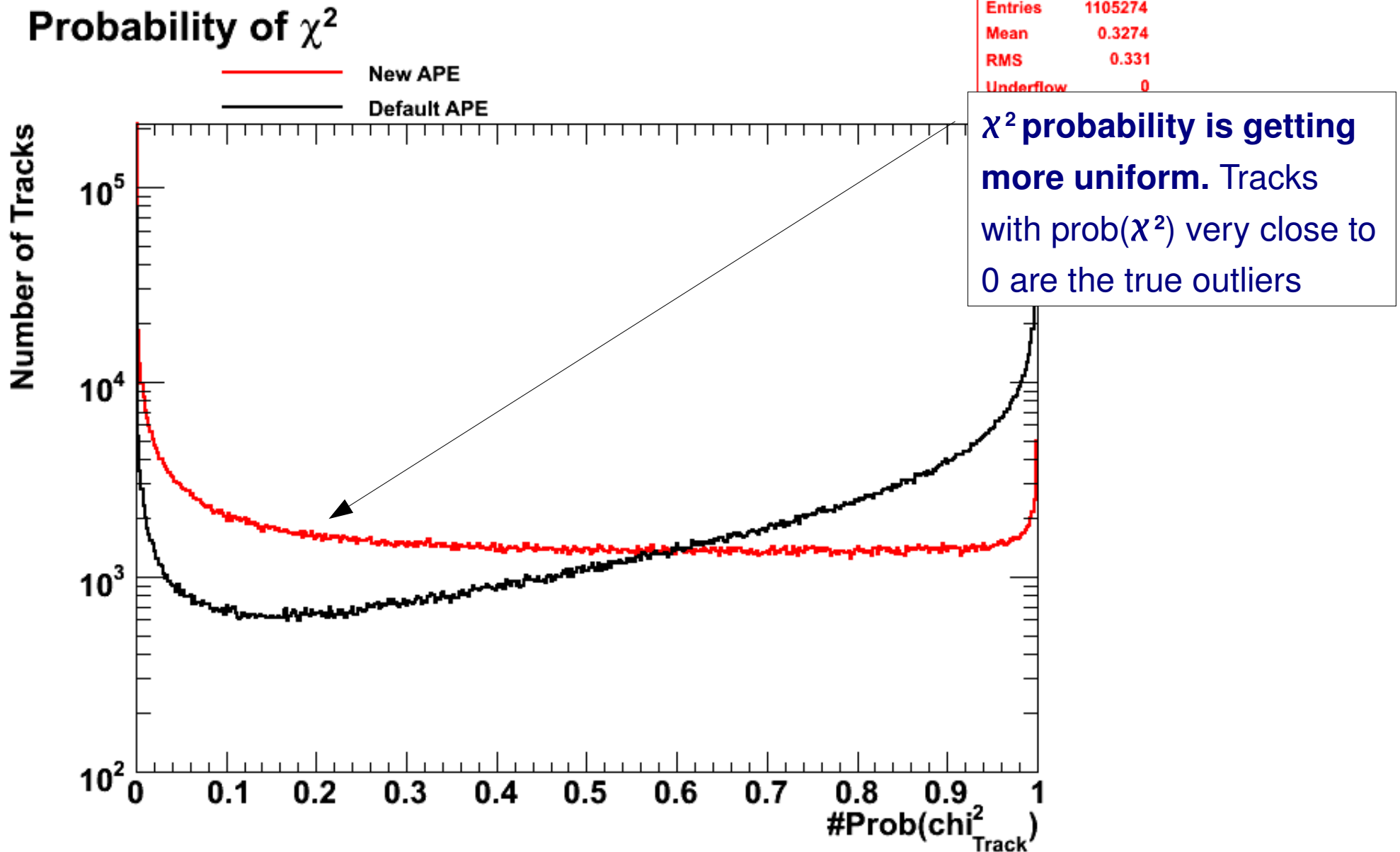
Further Validation of APE object

- Perform Standard Validation using **Tracker_Geometry_v3_offline** on ~ **1.5 M Tracks** (half of CRAFT Datasample)

- Extract at **module level** the witdh of the distribution containing 95.44% (i.e. ±2σ if dealing with perfect gaussians) of the **normalized residuals**
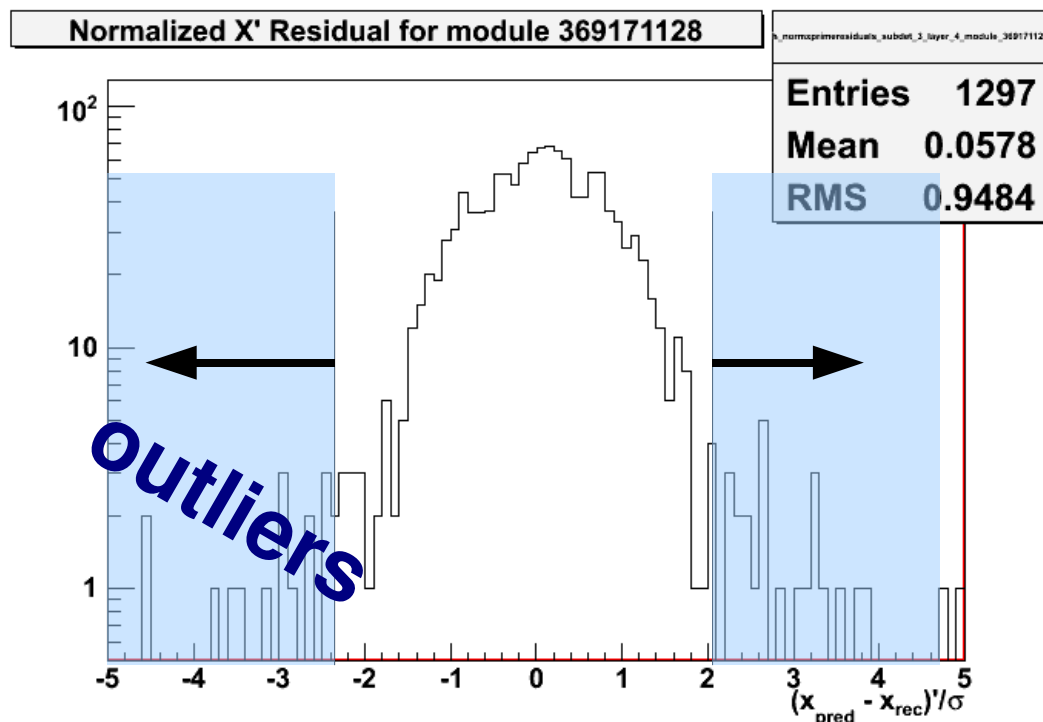
- Look at 1D distribution of Truncated RMS of normalized residuals at subdet and Layer level for Strip Barrel (Ideal world $\Rightarrow$ peak to 1, as narrow as possible)

- Look at the TH2 distribution of Truncated RMS at Layer level for **TPB/TIB/TOB** for each module (check for inhomogeneities)

DRR – Subdet level
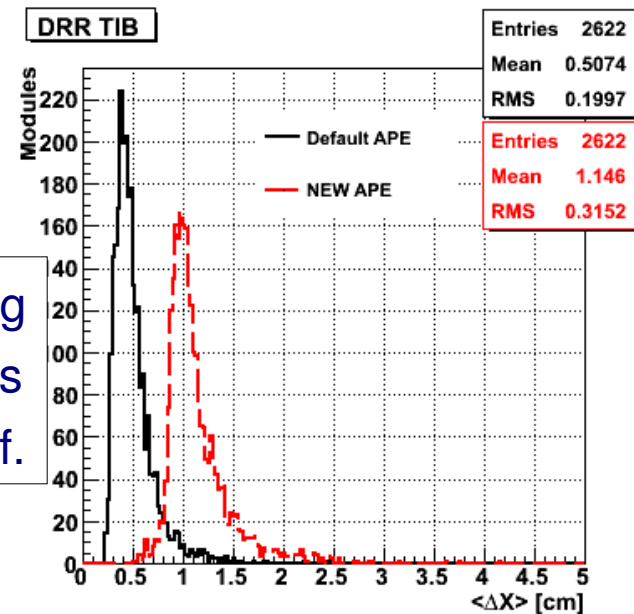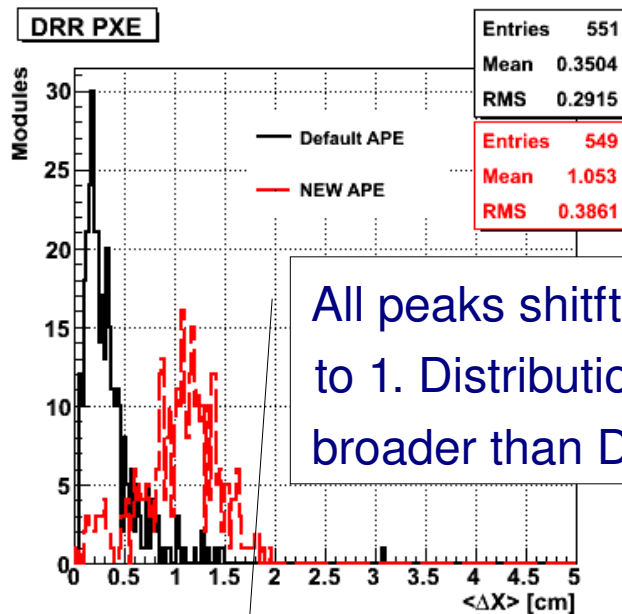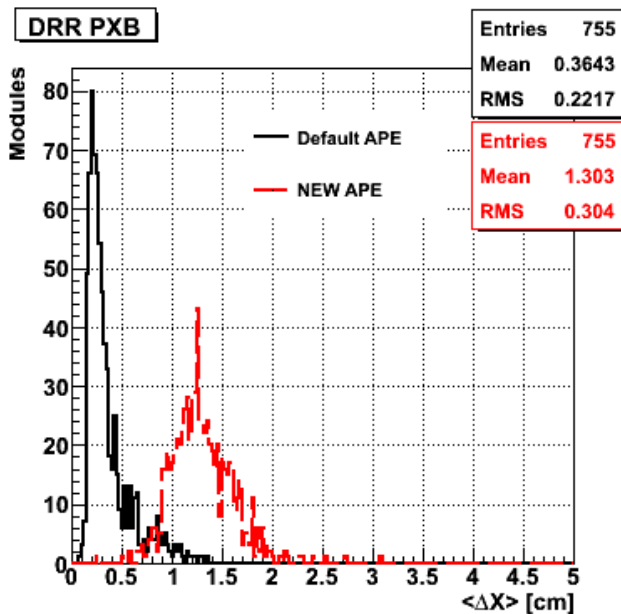
All peaks shitfting to 1. Distributions broader than Def.
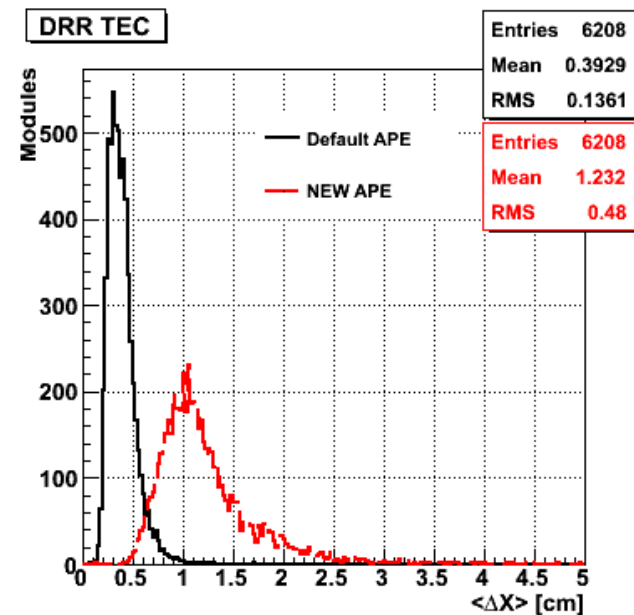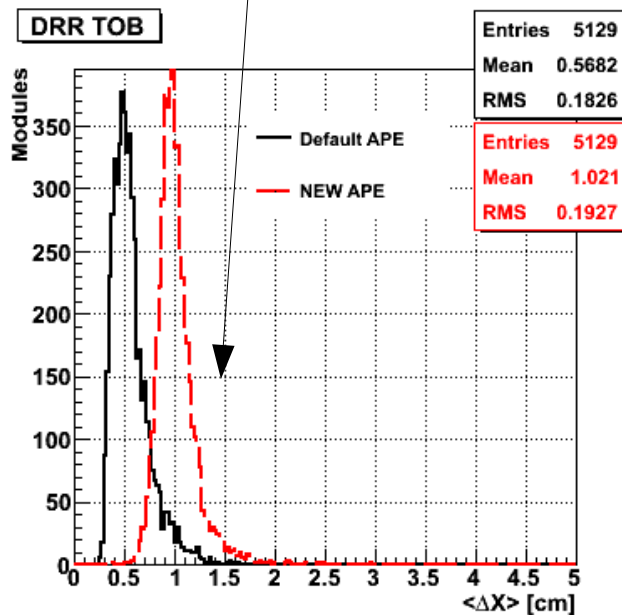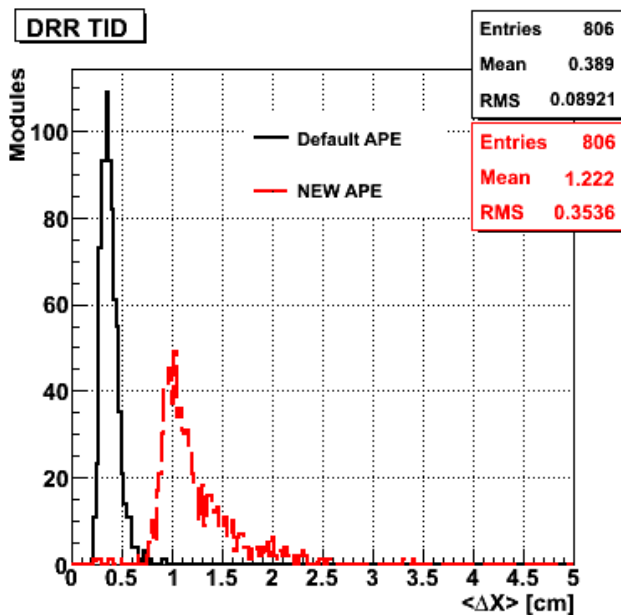
DRR – TIB (Layer Level)
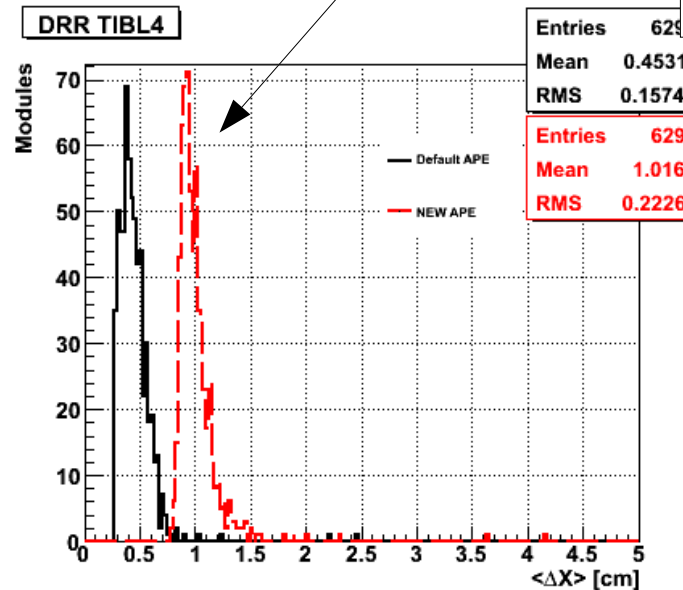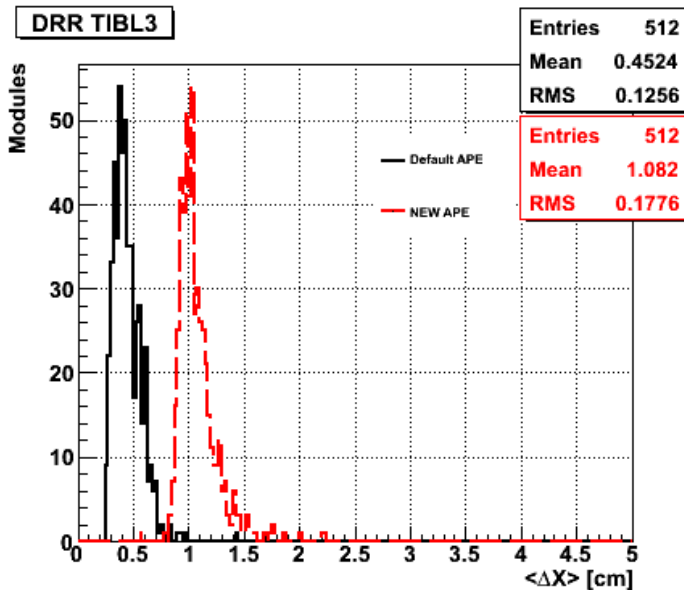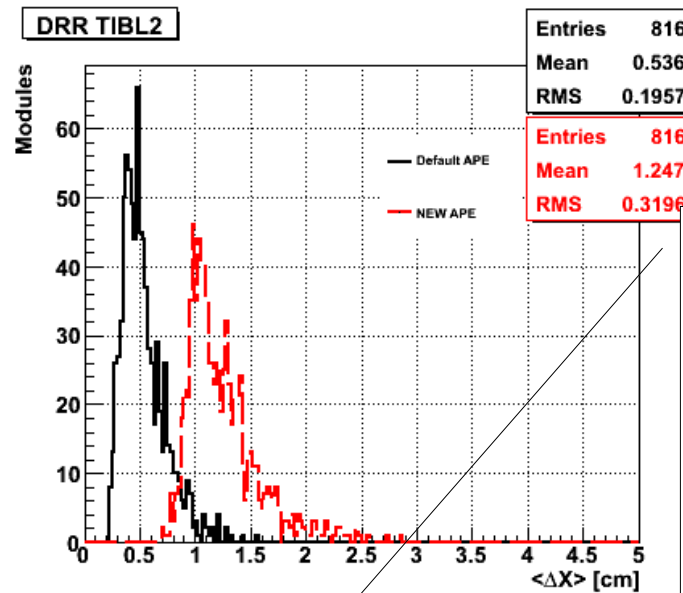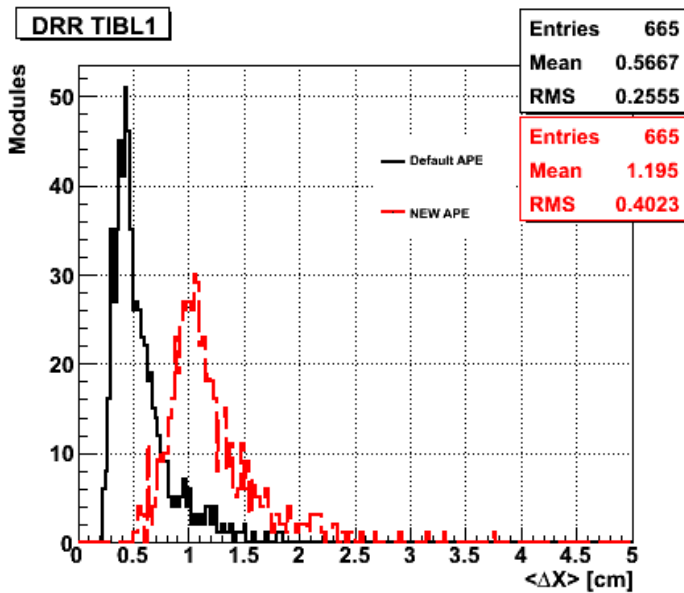
All peaks shiftting to 1. Distributions broader than Default. Distributions look crudely ok for SS Layers (L3/L4) while too broad in DS (L1/L2)

DRR – TOB (Layer Level)
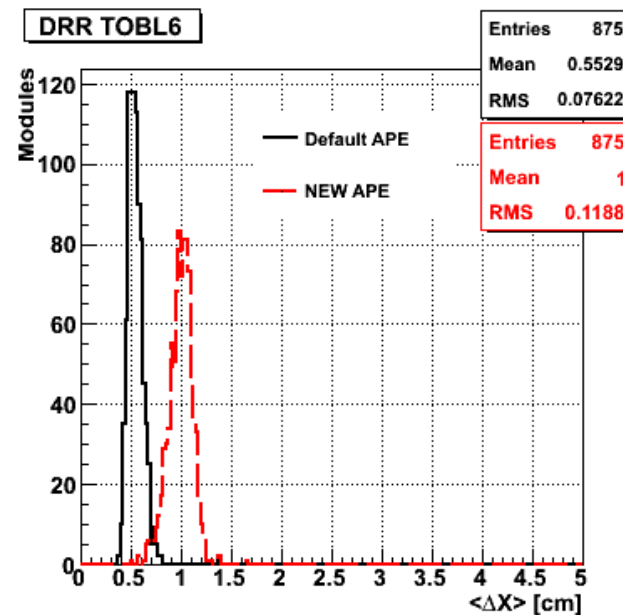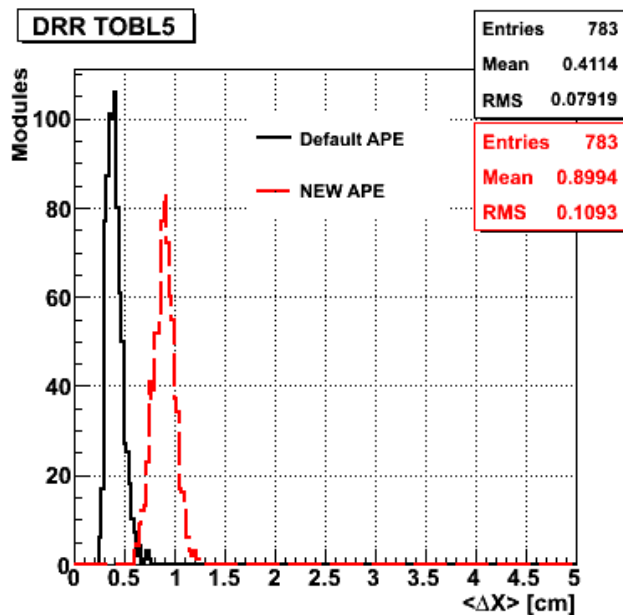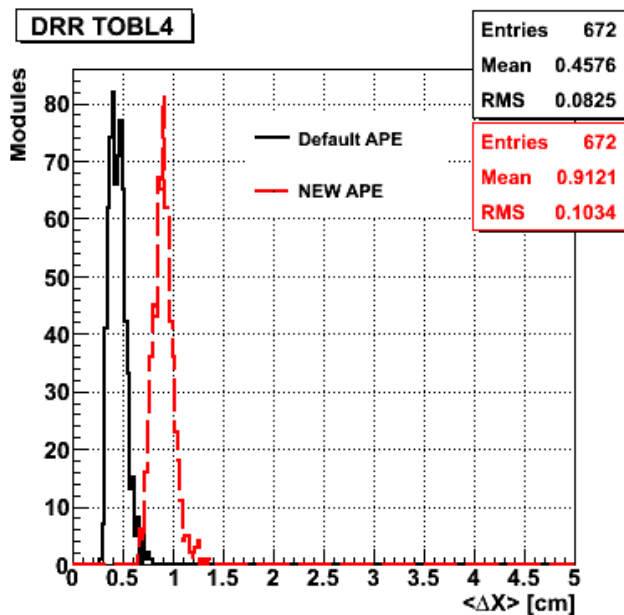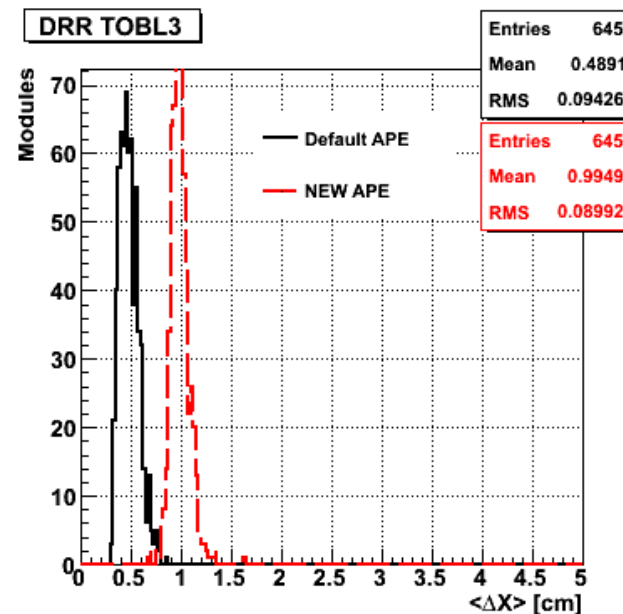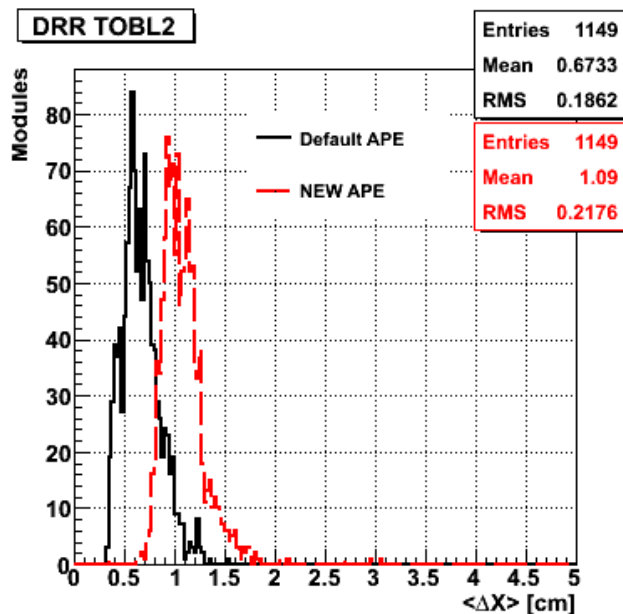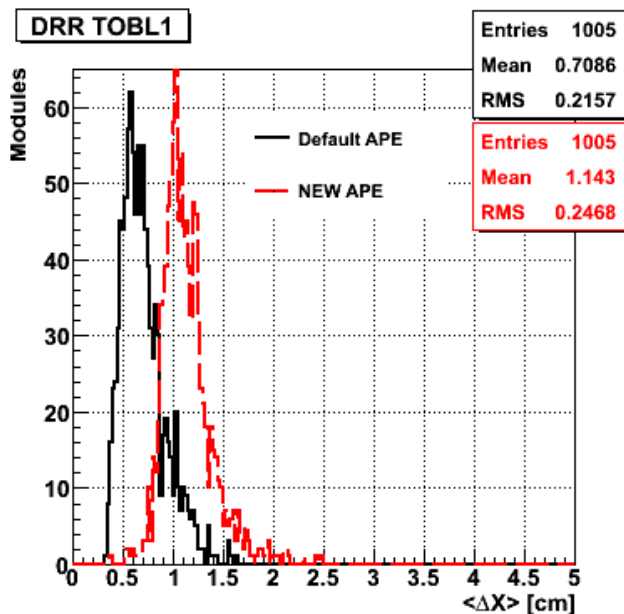
"Thermal Maps" of RMS - PXB
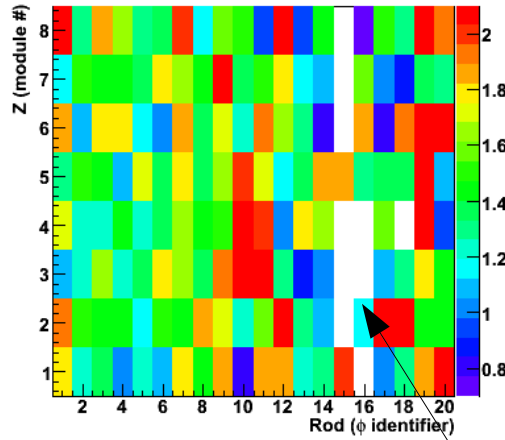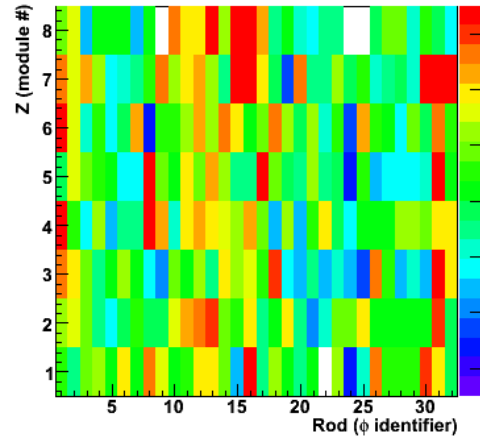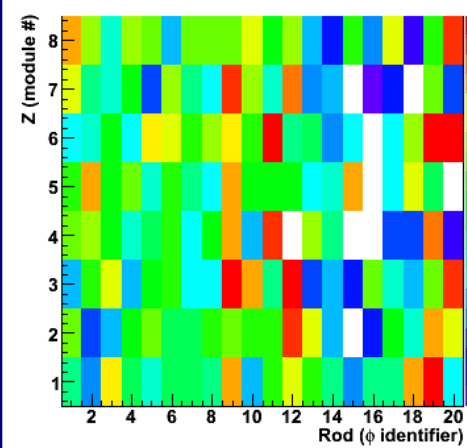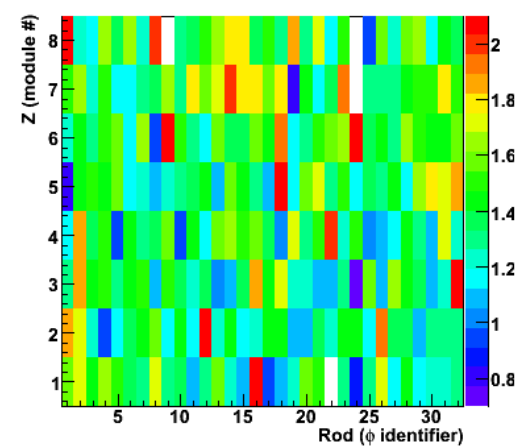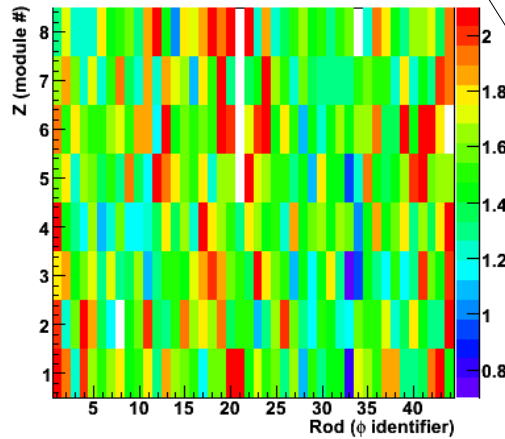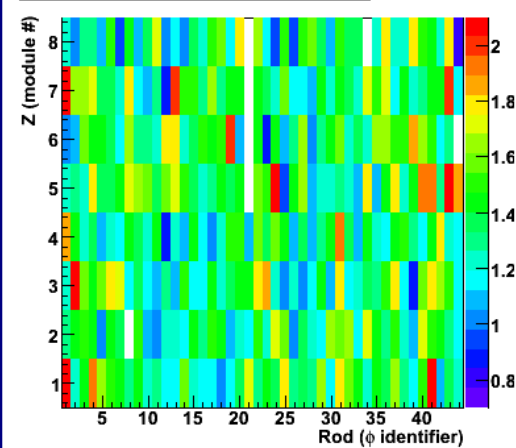
X - residuals

Y - residuals

White spots are modules receiving too few hits to extract sensible RMS.

"Thermal Maps" of RMS - TIB
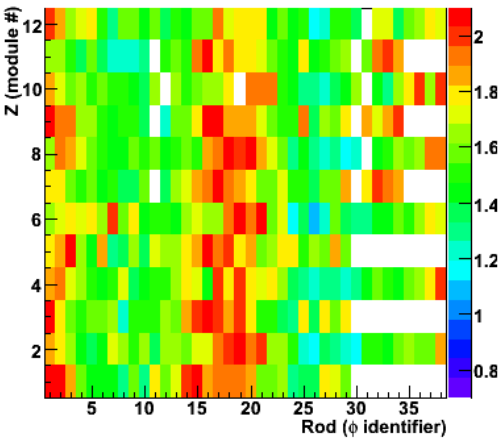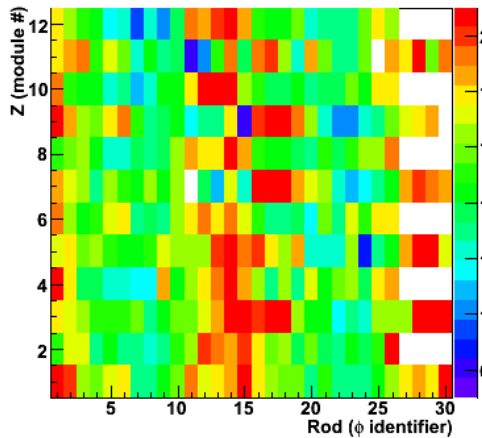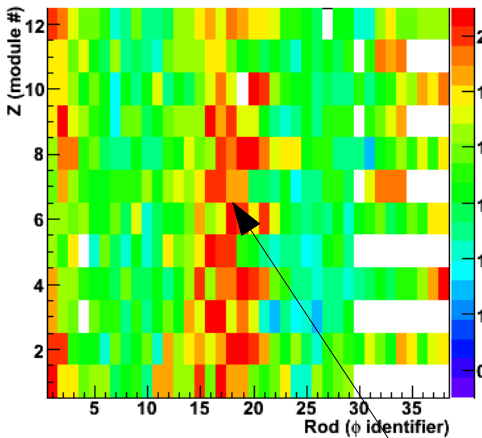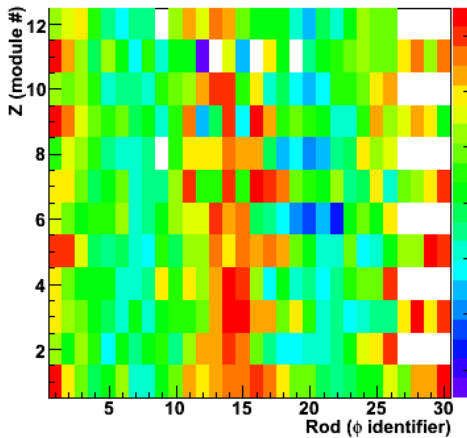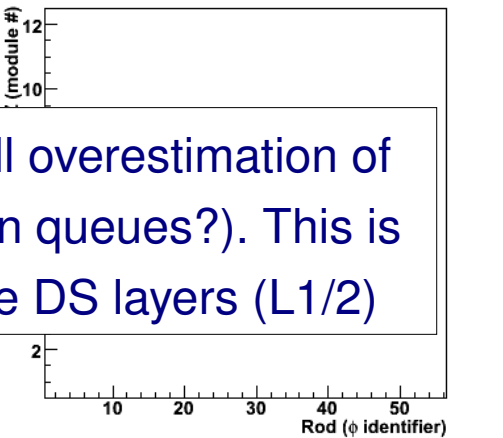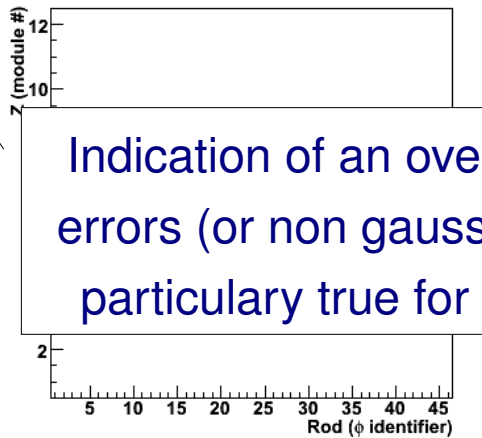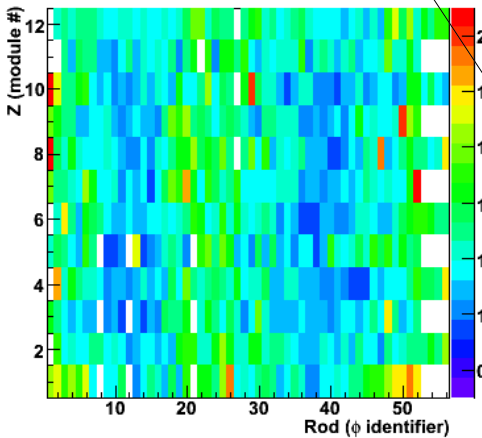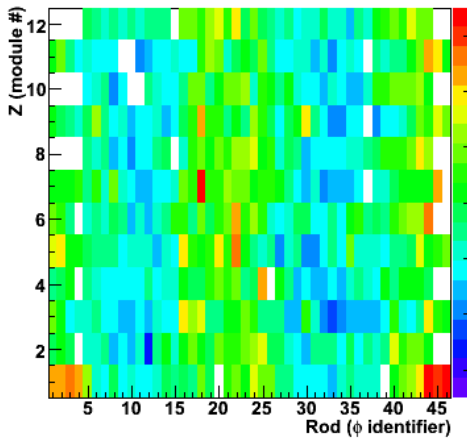
Indication of an overall overestimation of errors (or non gaussian queues?). This is particulary true for the DS layers (L1/2)

"Thermal Maps" of RMS - TOB (rφ)
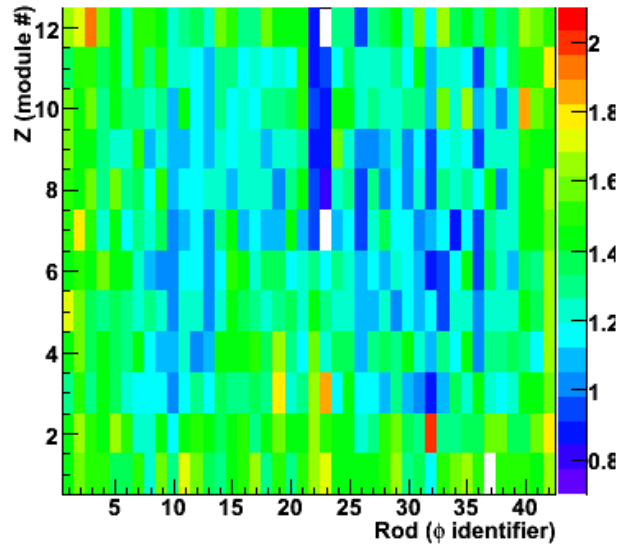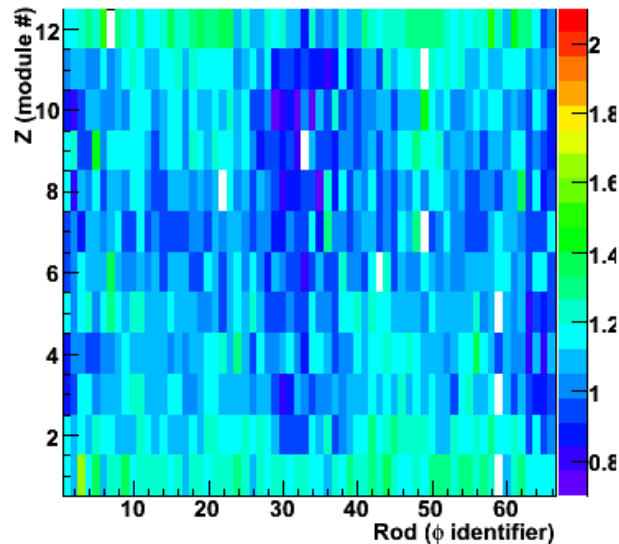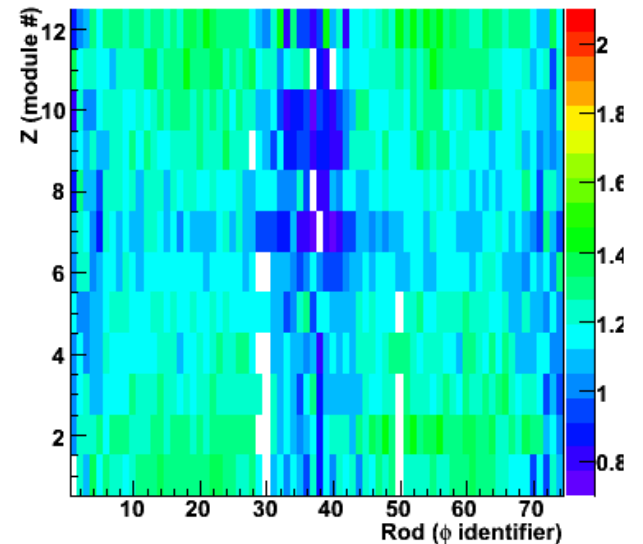
"Thermal Maps" - TOB (stereo)
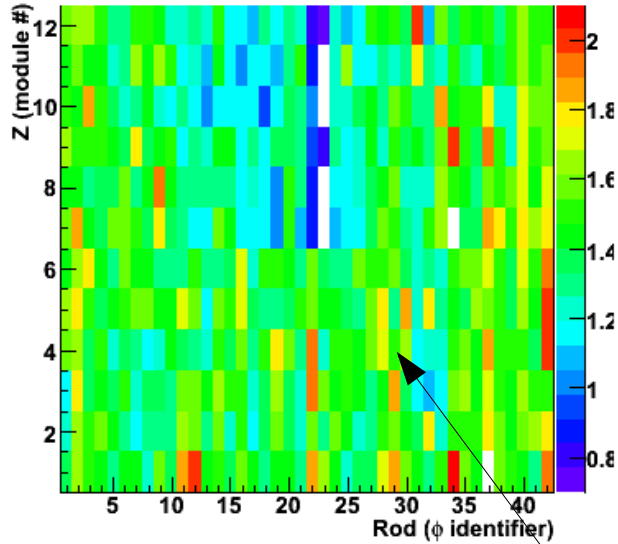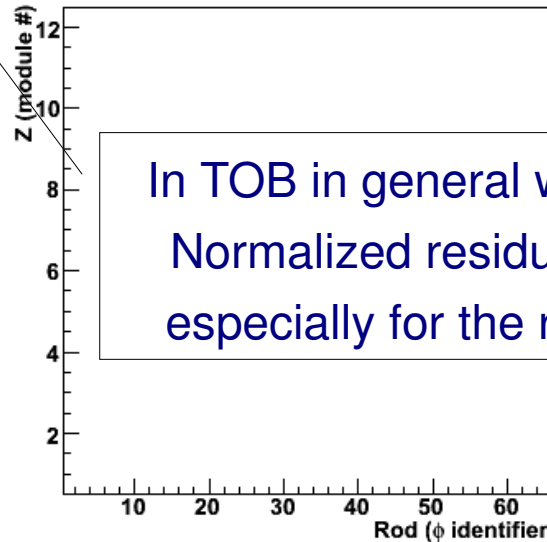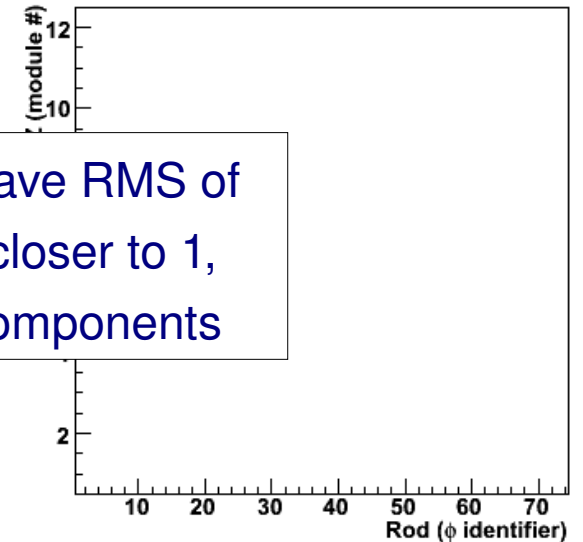
In TOB in general we have RMS of Normalized residuals closer to 1, especially for the $r\varphi$ components

Conclusions

- Motivation for module-dependent APE:

  - Old APEs (*TrackerGeometryErr_V3_offline*) were too large wrt to the RMS of DMRs.

  - Alignment is not uniform in the whole Tracker

- A first rough **module dependent APE object has been created** using newly developed code, using as an input "spherical" errors. It was produced mixing several ingredients:

  - MC tuning of remaining misalignment to match DMR and Residuals in a "well aligned" region in TOB/TIB

  - scale law with the number of hits on each DetUnit

- **Validation loop** looking at Normalized Residuals/ Cosmic Track Splitting / Tracking efficiencies completed

  - Newly determined APE entered the CMS Tracker conditions database

    - will eventually go in a new GlobalTag for new CRAFT analyses
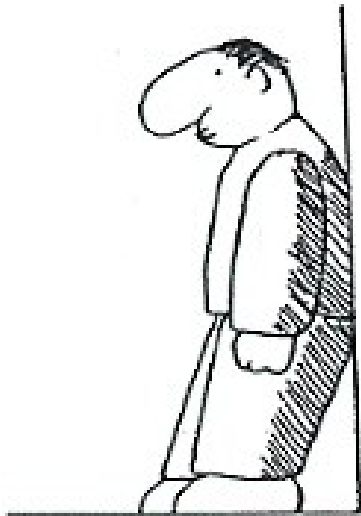
Back-up Slides

Tracking Efficiency

CTF	PXB	PXE	TIB	TID	TOB	TEC
Zero	62	18	3435	586	16079	7013
New	**66**	**27**	**3488**	**623**	**16173**	**7272**
Default	**68**	**35**	**3580**	**682**	**16352**	**7677**

Cosmic TF	PXB	PXE	TIB	TID	TOB	TEC
Zero	73	28	3567	650	15470	5784
New	**76**	**31**	**3616**	**650**	**15654**	**5924**
Default	**80**	**38**	**3662**	**672**	**15986**	**6212**

The number of hits associated to tracks re-recoed with new APE is larger than zero APE (= no hit loss)