

# Outer Tracker:

What have we learned from TED data and cosmics?

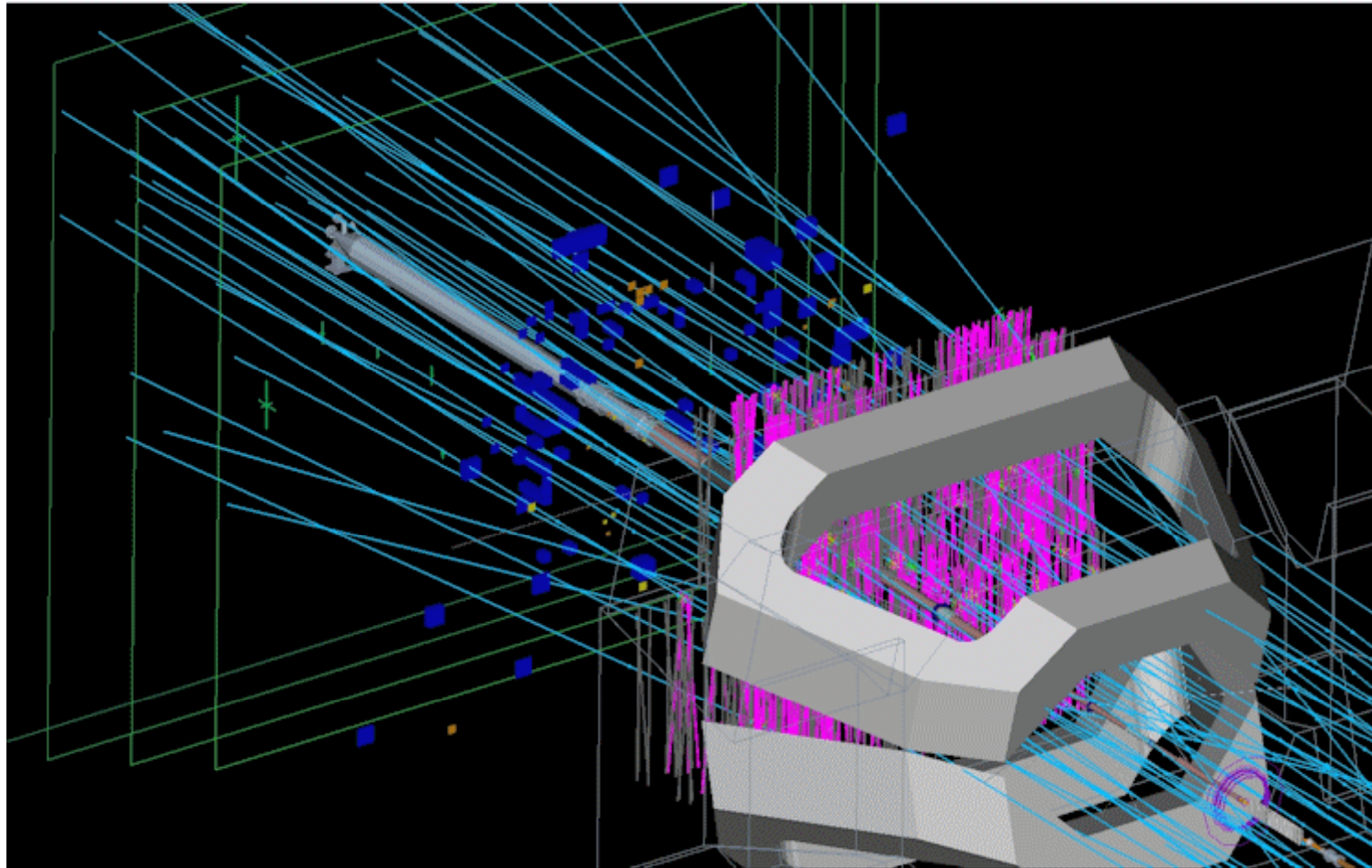
## Disclaimer:

All the work I am presenting was done by other people!

*Ulrich Uwer  
Physikalisches Institut Heidelberg  
Tracking Workshop, Heidelberg,  
Feb-16-2009*

# TED Events

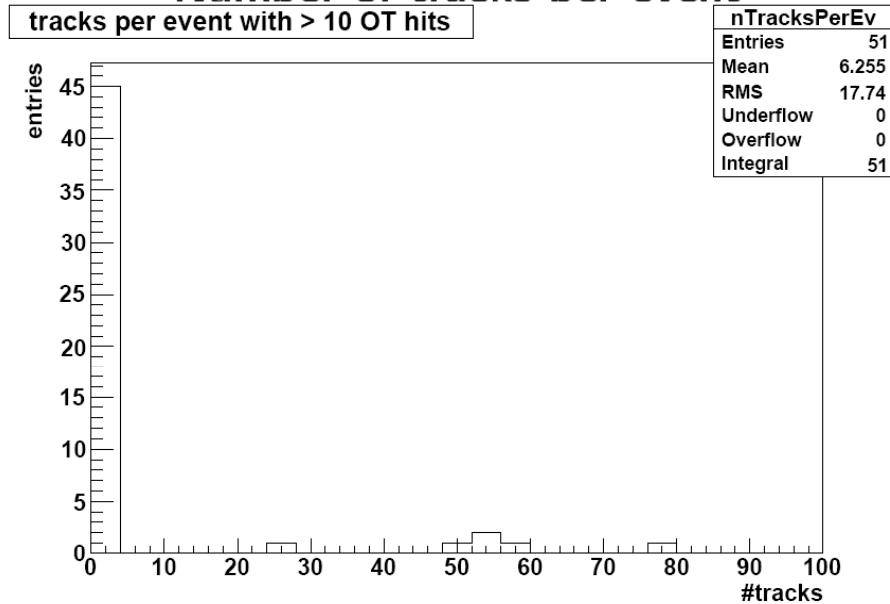
10.9.2008 11:32:26 0ns



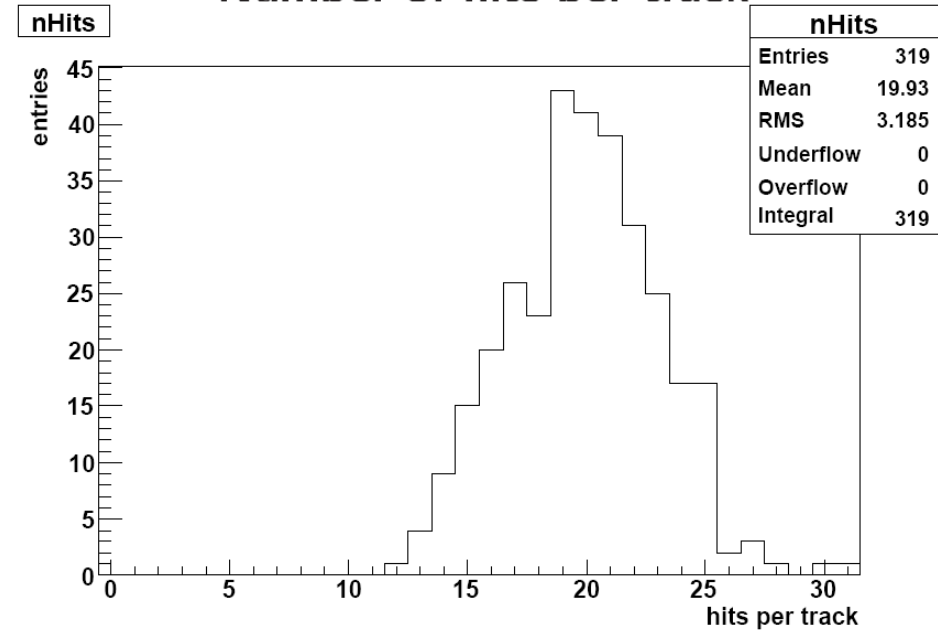
# TED events

Manuel Schiller

## Number of tracks per event



## Number of hits per track

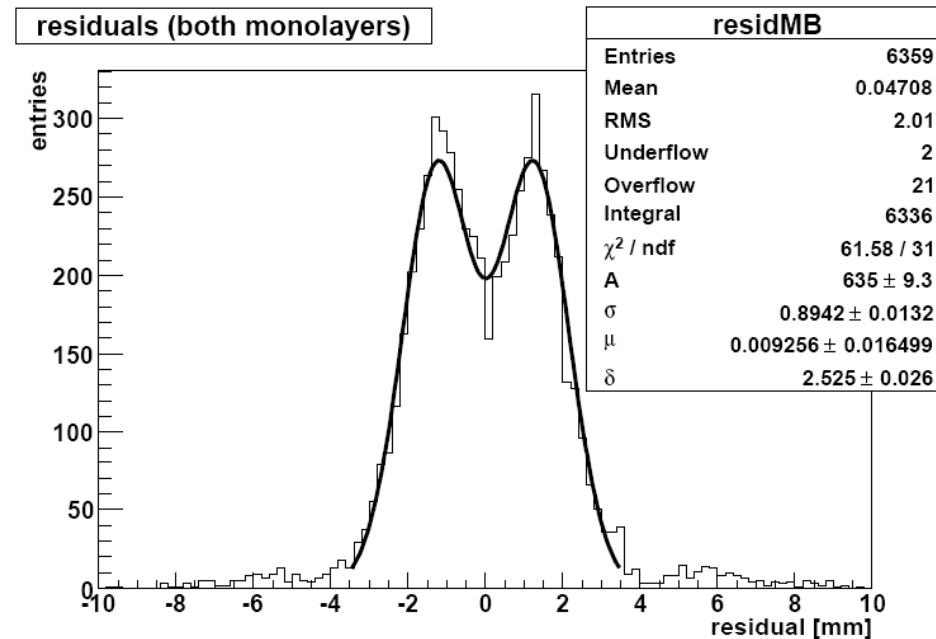


- about 20 hits per track on average
  - just like in simulation

# Track residuals – No drift times

Manuel Schiller

## Residuals



- expected RMS of one such peak:  $\frac{5.25\text{mm}}{2\sqrt{12}} = 0.76\text{mm}$
- \* misalignments make it wider
- e.g. naively:  $\sqrt{0.76^2 + 0.5^2} \text{mm} = 0.90 \text{mm}$

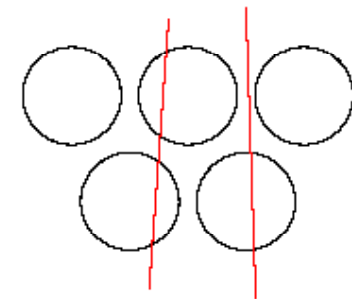
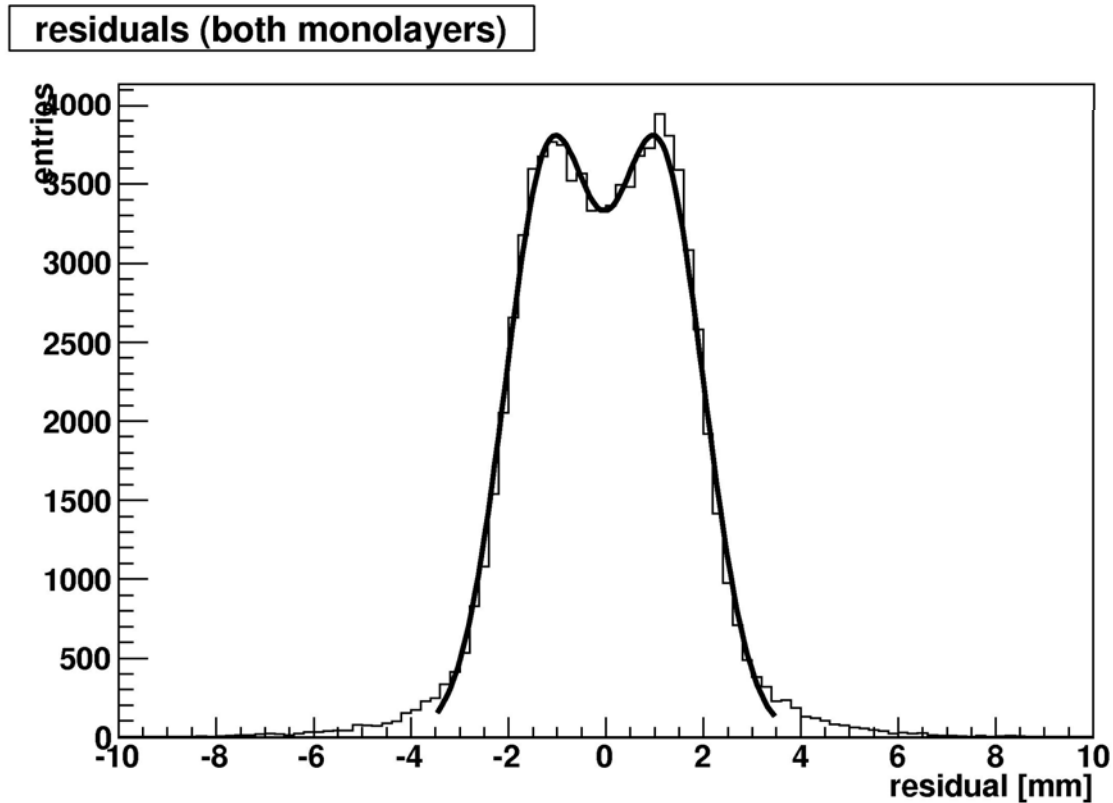
A lot of discussions about the double peak structure:

Manuel: geometrical effect

Marcel: problems with the geometry

# Residuals in Monte Carlo

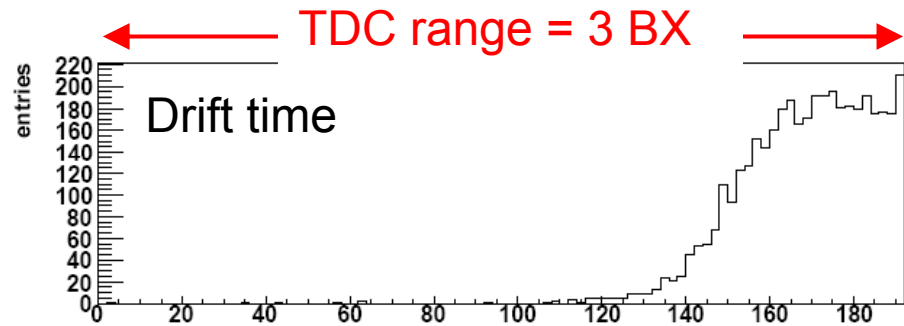
*Manuel Schiller*



Double peak structure also seen in MC ... it was confirmed that this is a pure geometrical effect which appears when residuals are calculated in case no drift times are used.

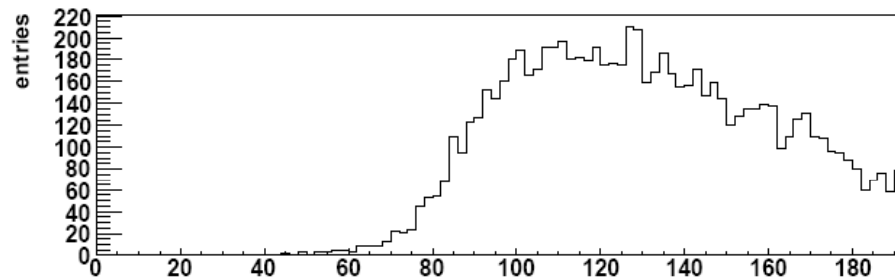
A bottle of whisky (?) for Jan Amoraal

# First absolute time alignment check

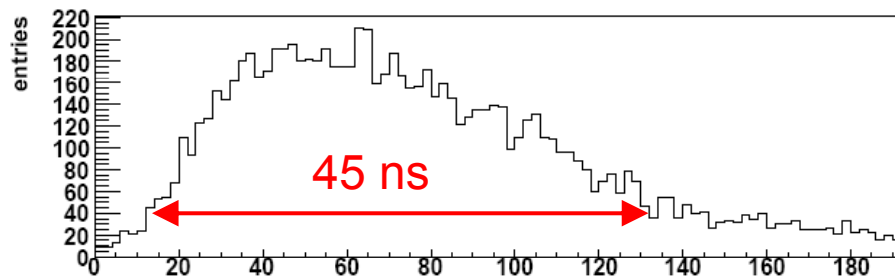


Trigger

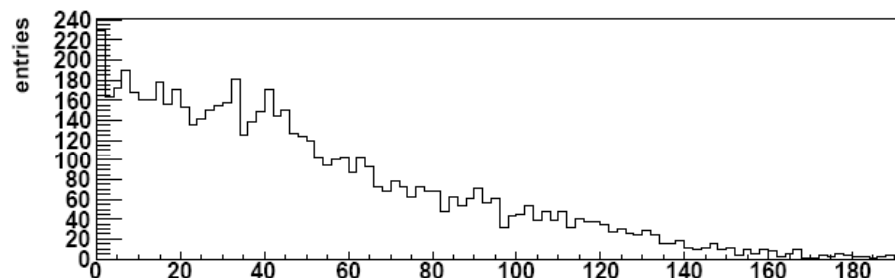
$BX = n - 2$



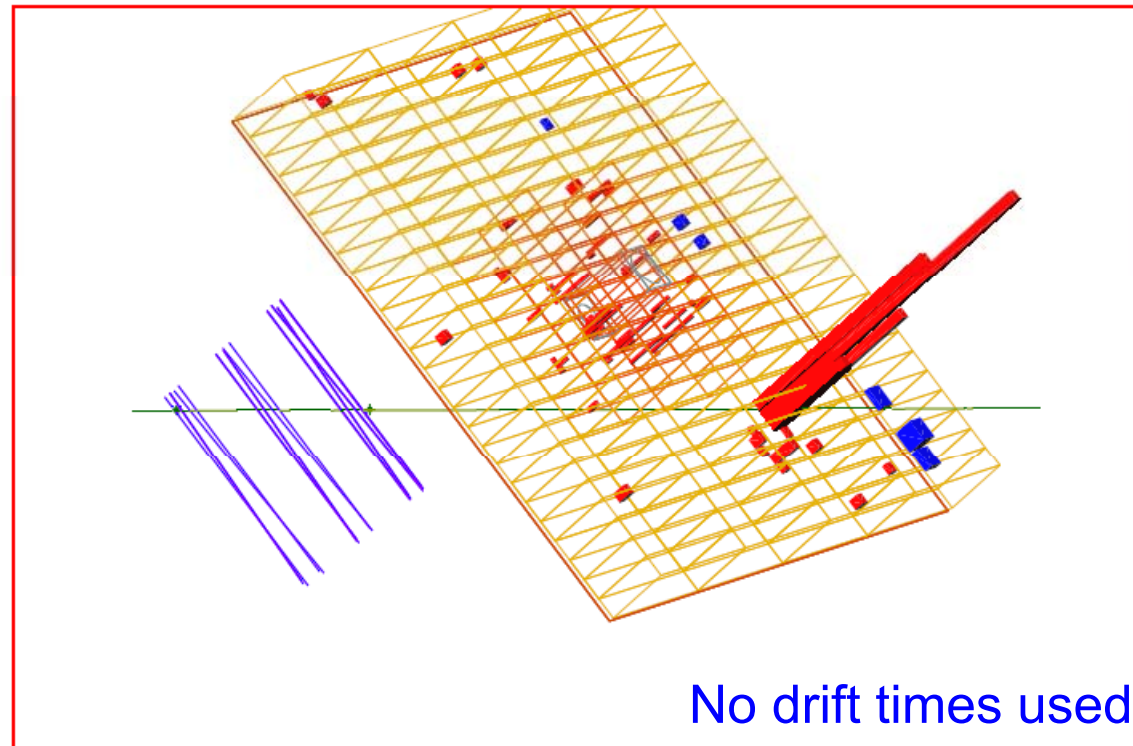
$BX = n - 1$



$BX = n$



$BX = n + 1$



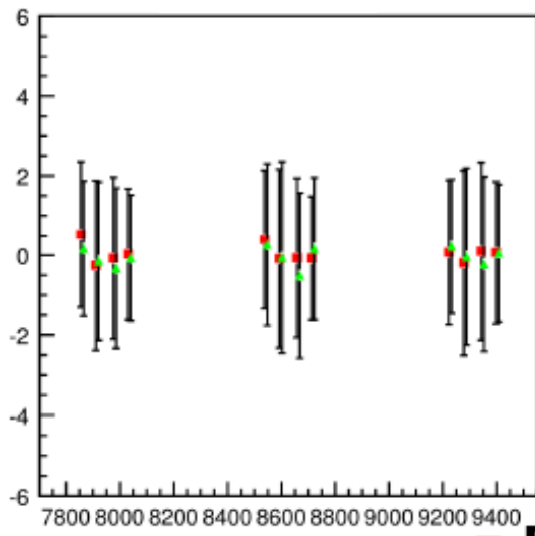
## Reconstruction of Cosmics:

- Standard tracking algorithm: PatSeeding
- Changes: wider search windows, relax pointing constraints

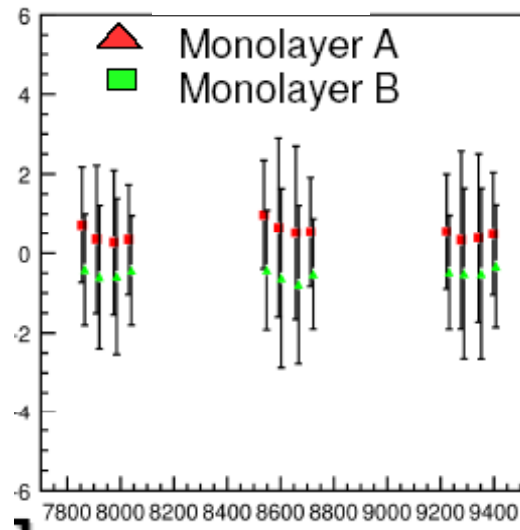
# Bugs in decoding and hit preparation

Jan Amoraal

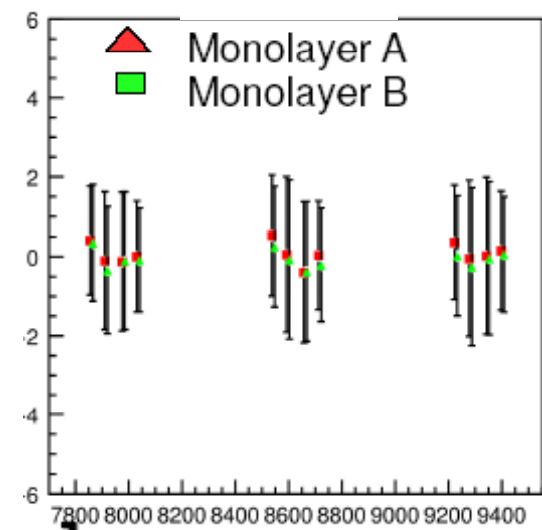
## Stereo layer residuals (mm)



1. Wrong decoding,  
wrong staggering



2. correct decoding,  
wrong staggering



3. correct decoding,  
correct staggering

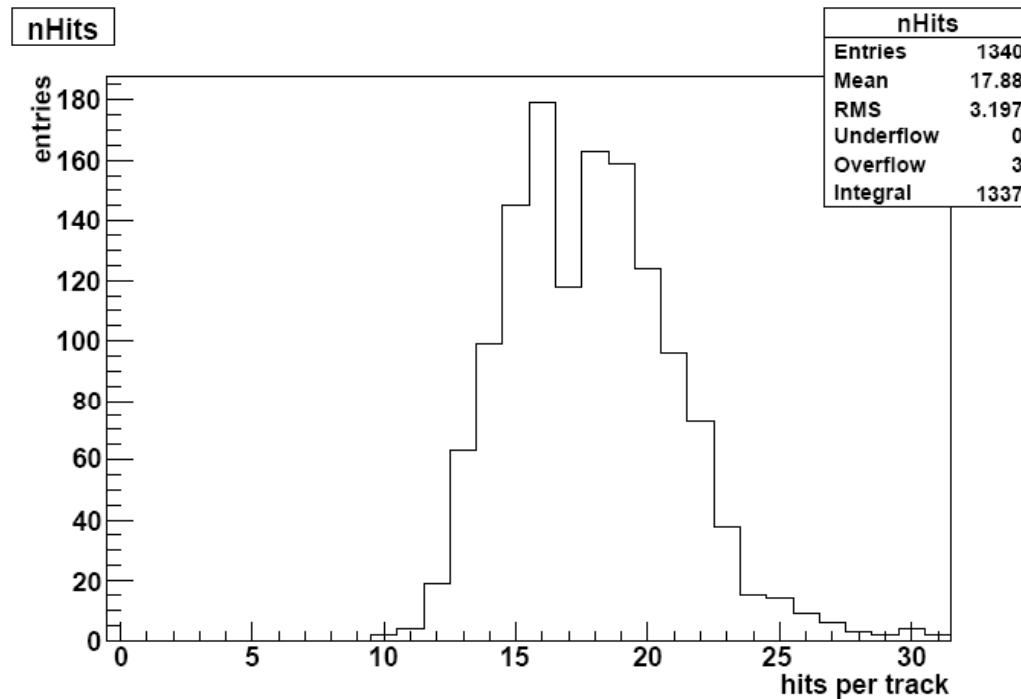


# More bugs found in geometry

*Jan Amoraal*

- Relative position of X and U layer on C frame was wrong:  
~2mm effect in y  
  
⇒ large effects in  $T_y$  seen when matching to muon chambers  
(corresponding to cm !)
- z-coordinates were the ones for the detector frames  
(~ 60 microns in z)
- C-frames (and not stations) are tilted in LHCb frame: two rails per station !
- y-coordinate of S2/S3 modules wrong (up to 14 mm (!))
- module length should be equal to wire length (~40 micron off)

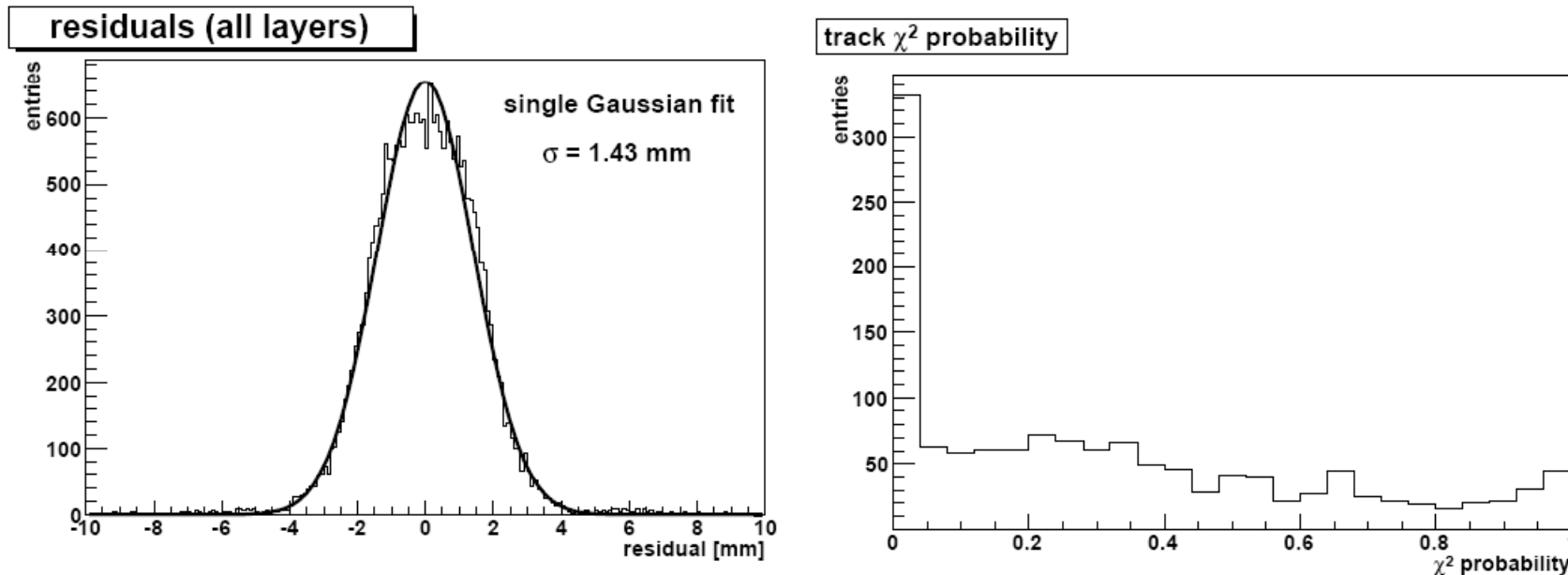
## Number of Hits on a Track



- on average, roughly 18 hits per track
- not too far from what we expect from Monte Carlo

# Track quality

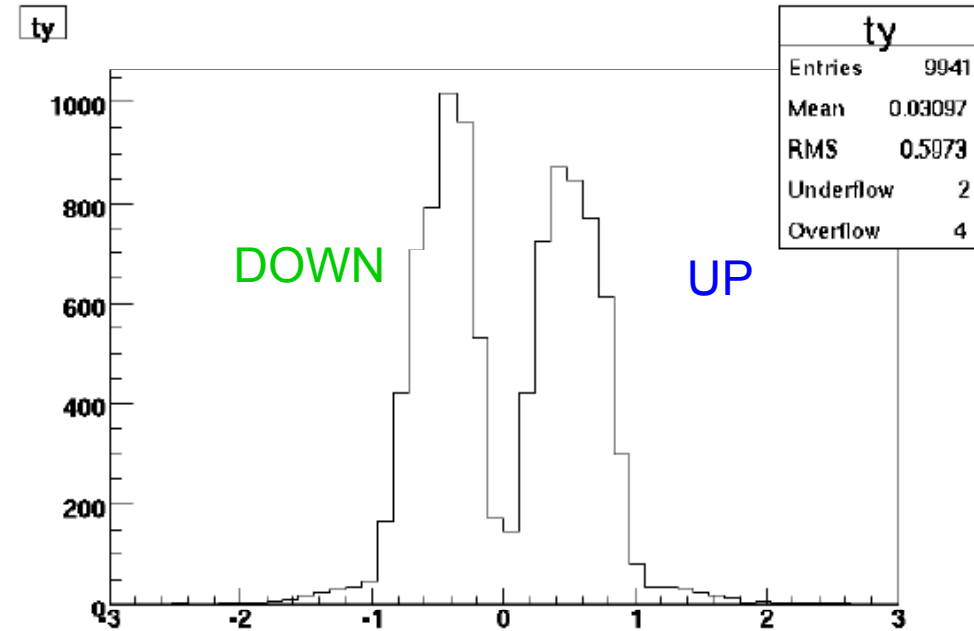
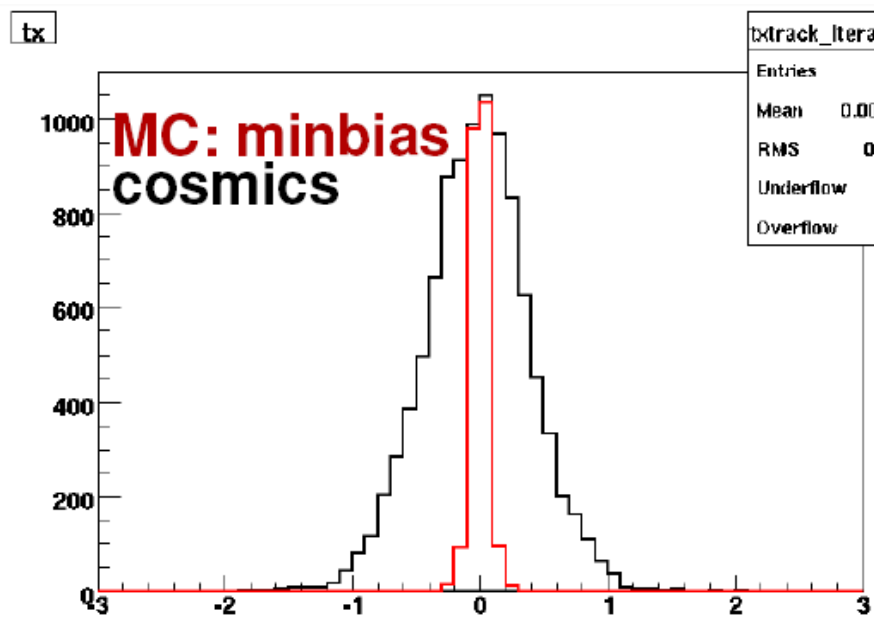
Manuel Schiller



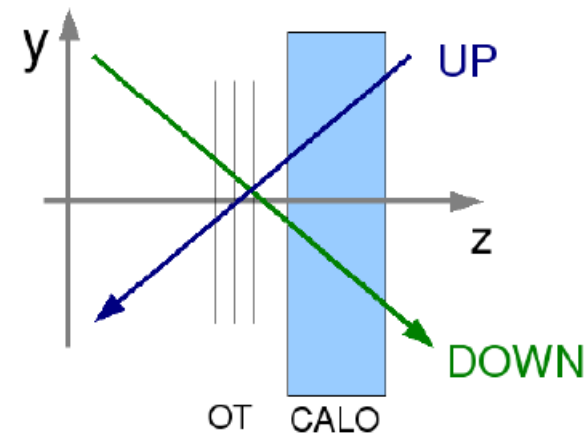
- residuals look reasonable for unaligned OT without drift times
  - expect  $5 \text{ mm} / \sqrt{(12)} = 1.44 \text{ mm}$   
→ very good agreement with expectation
- $\chi^2$  probability looks similar to Monte Carlo

# Cosmic specifics

Marc Deissenroth

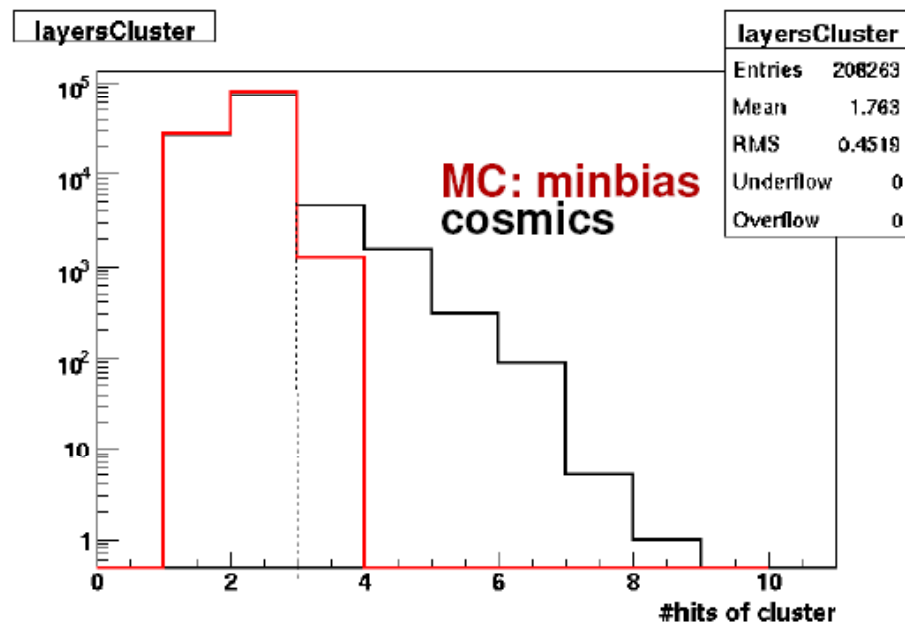


Large Tx slopes: several hits/monolayer  
Large Ty slopes: large ionization → Xtalk

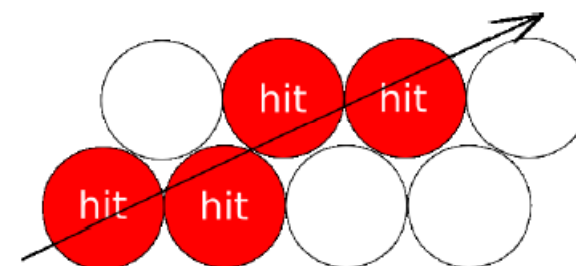
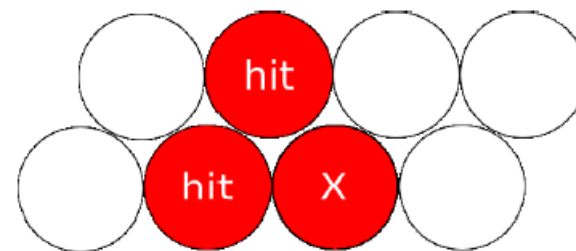


# Hit Clusters

Marc Deissenroth

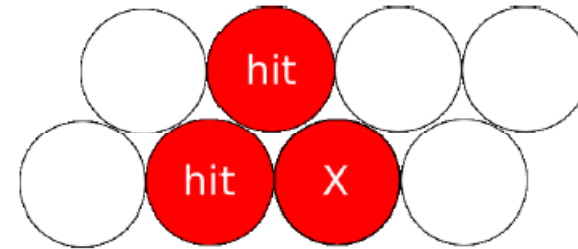
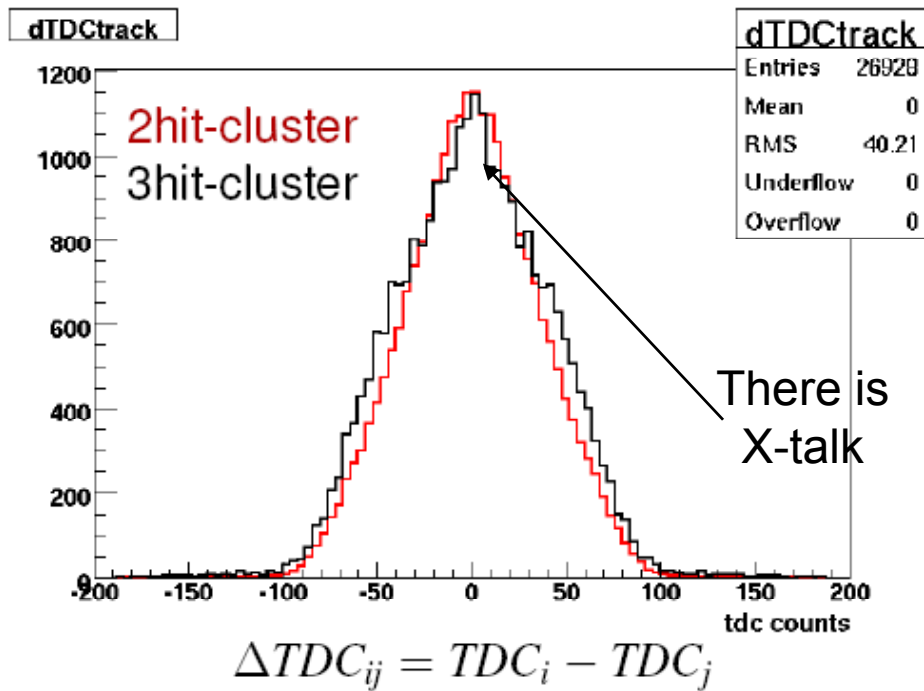


≈ 5% of clusters are big clusters  
( → that are ca. 10% of used strawIDs)



# Cross Talk

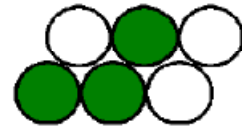
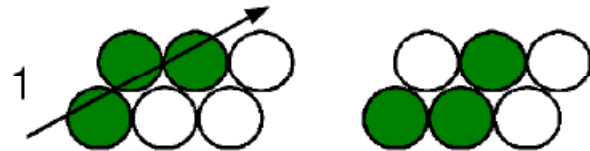
Marc Deissenroth



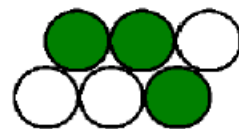
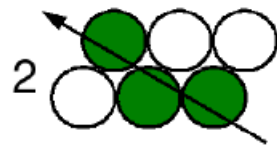
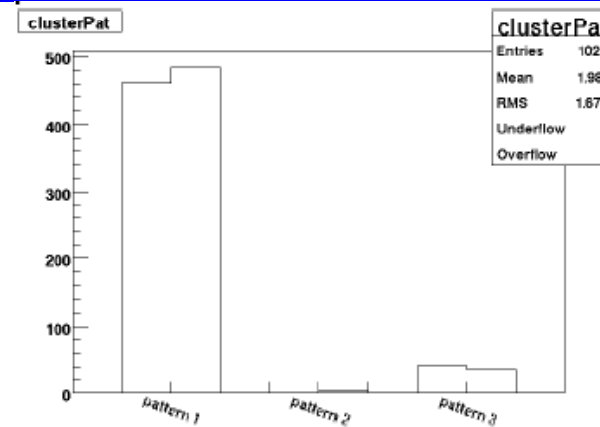
Cross talk hit should have the same measured time as one of its neighbor

# Geometrical effect ?

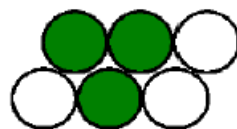
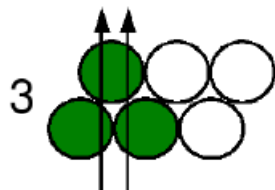
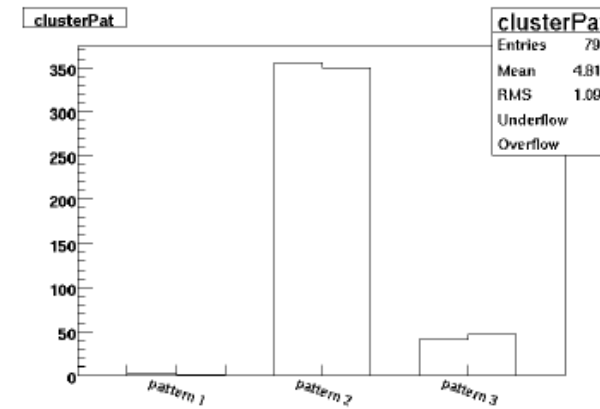
Marc Deissenroth



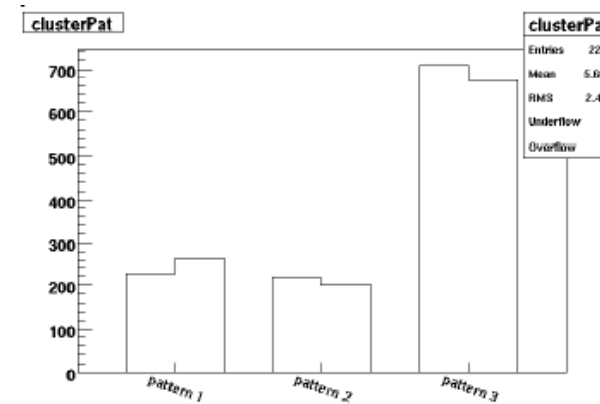
$tx < -0.5$



$tx > +0.5$



$-0.5 < tx < 0.5$



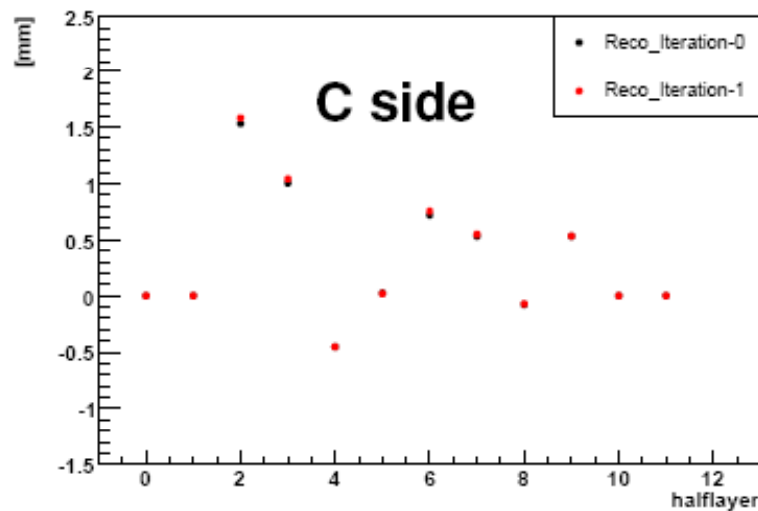
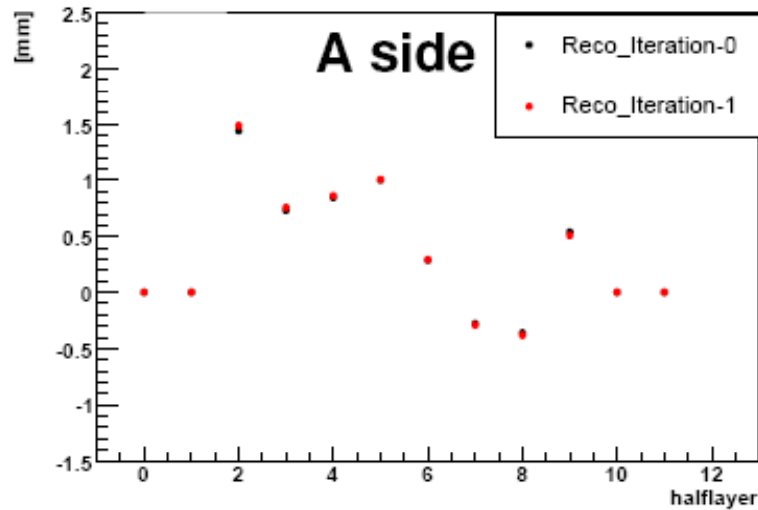
- Cosmics are a challenge due to large slopes
- Most of hits seem to be real hits, but there is contribution from Xtalk
- Large clusters (>2 hits) related to tracks with large slopes
- Iterations are necessary if large clusters are used in alignment, also explains why relative large fraction of hits in each iteration is different.



# Alignment

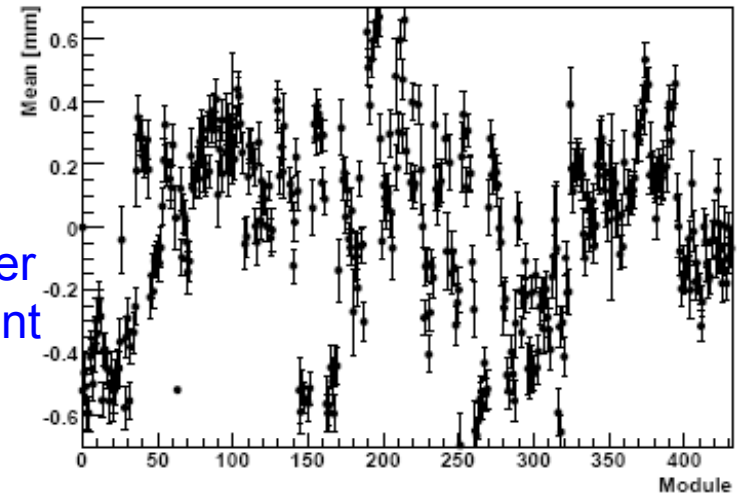
Jan Amoraal, Marc Deissenroth

Half-layer alignment:

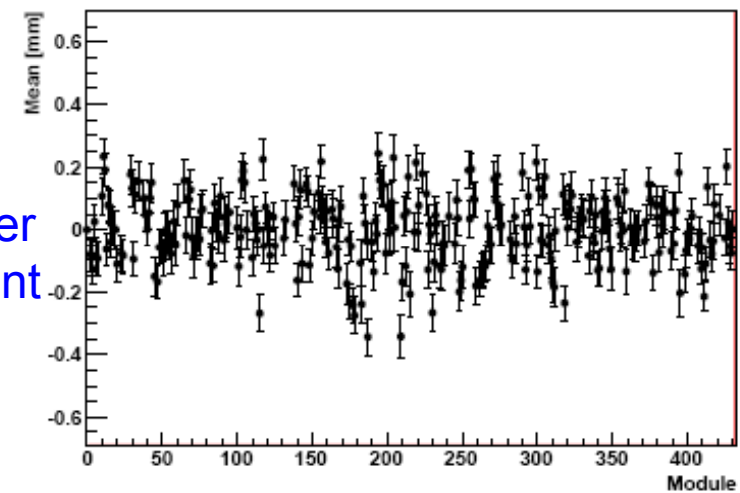


Track residuals per module:

w/o  
half-layer  
alignment



with  
half-layer  
alignment



# Module Alignment

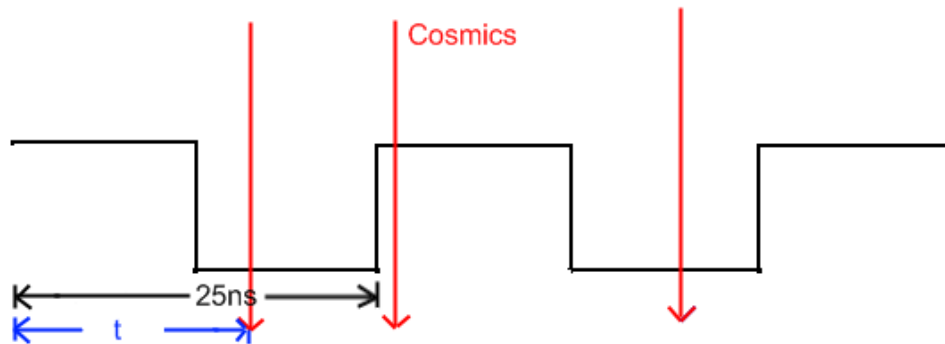
*Jan Amoraal, Marc Deissenroth*

# Cosmic – Event T0

Alexandr Kozlinskiy, Roel Aaij  
Timethy Bartsch

Average drift time:

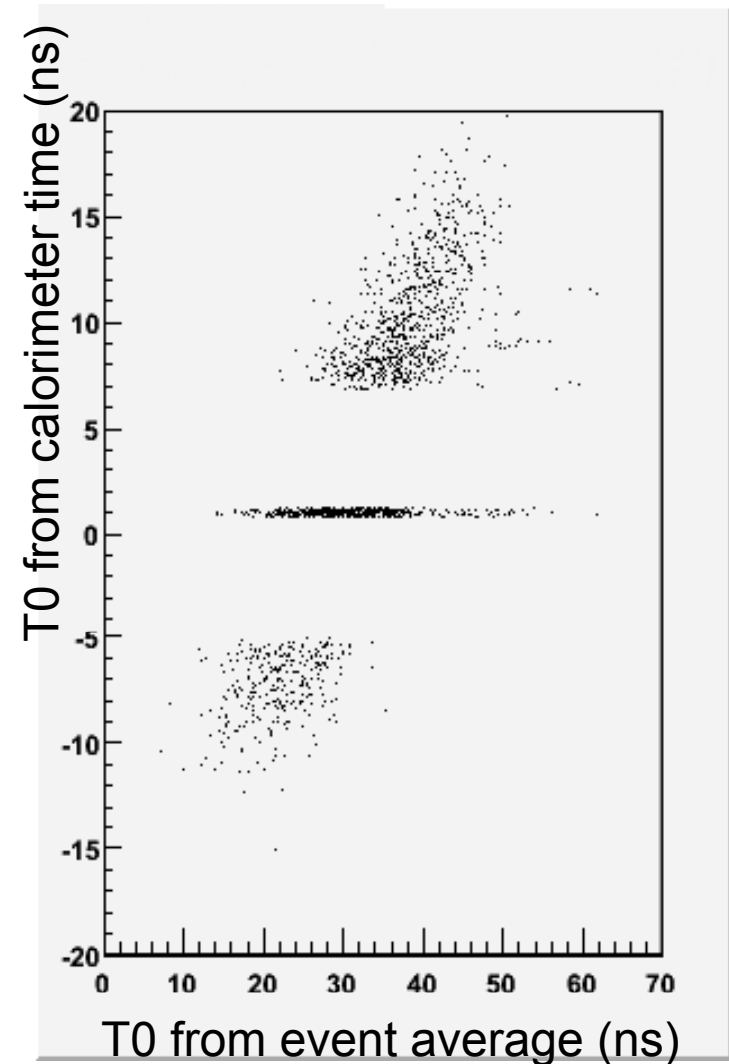
Method proposed by **Wouter** in Oct 2008



Estimate  $t_{\text{cosmics}}$  from average  $t_{\text{drift}}$

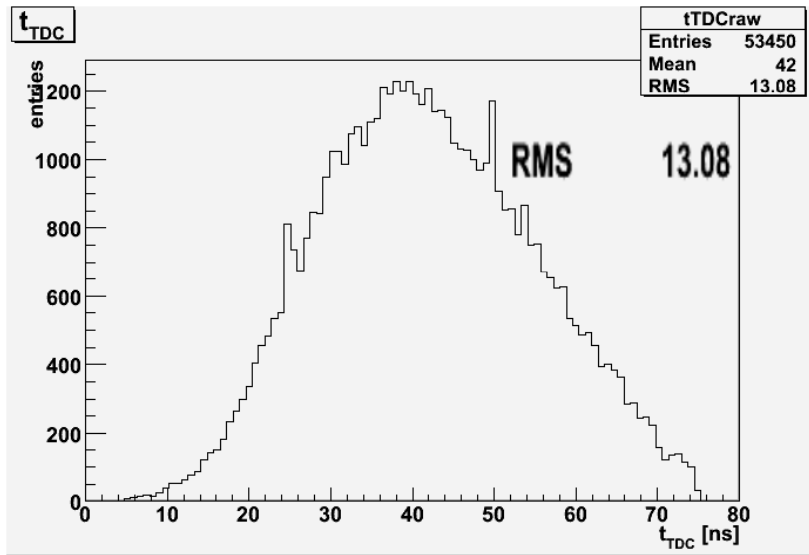
$$\langle t_{\text{dc}} + t_{\text{tof}} - t_{\text{prop}} - t_{\text{drift}} - t_0 \rangle = t_{\text{cosmic}}$$

*Wouter already performed a full calibration cycle in October!*

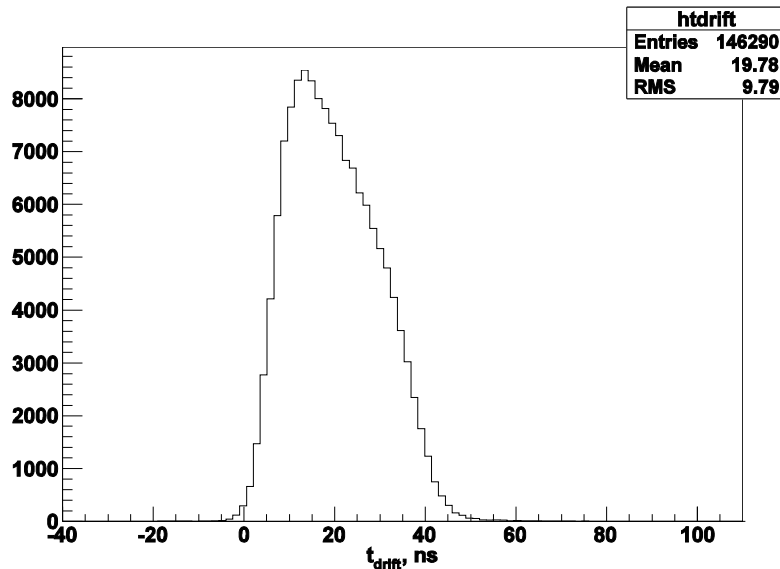
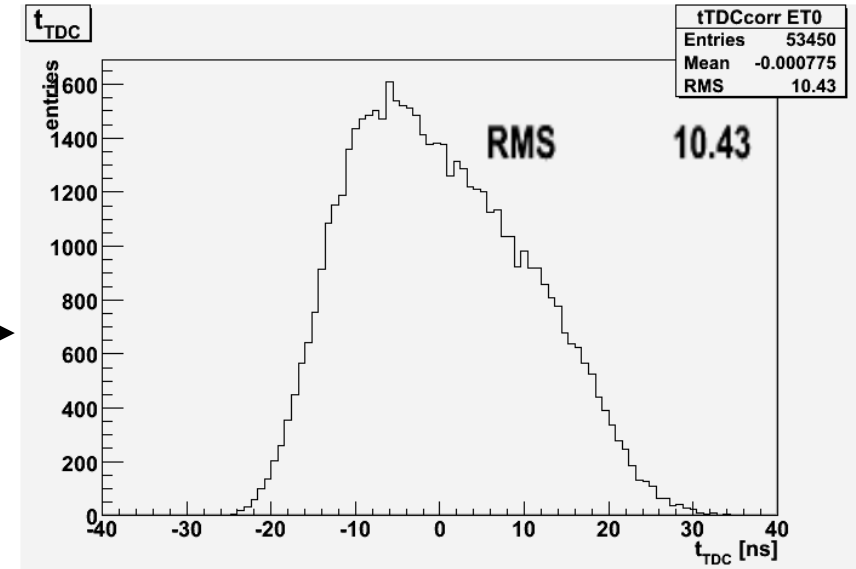


# Drift time spectrum

Timethy Bartesch



+ ETO



Alexandr Kozlinskiy, Roel Aaij

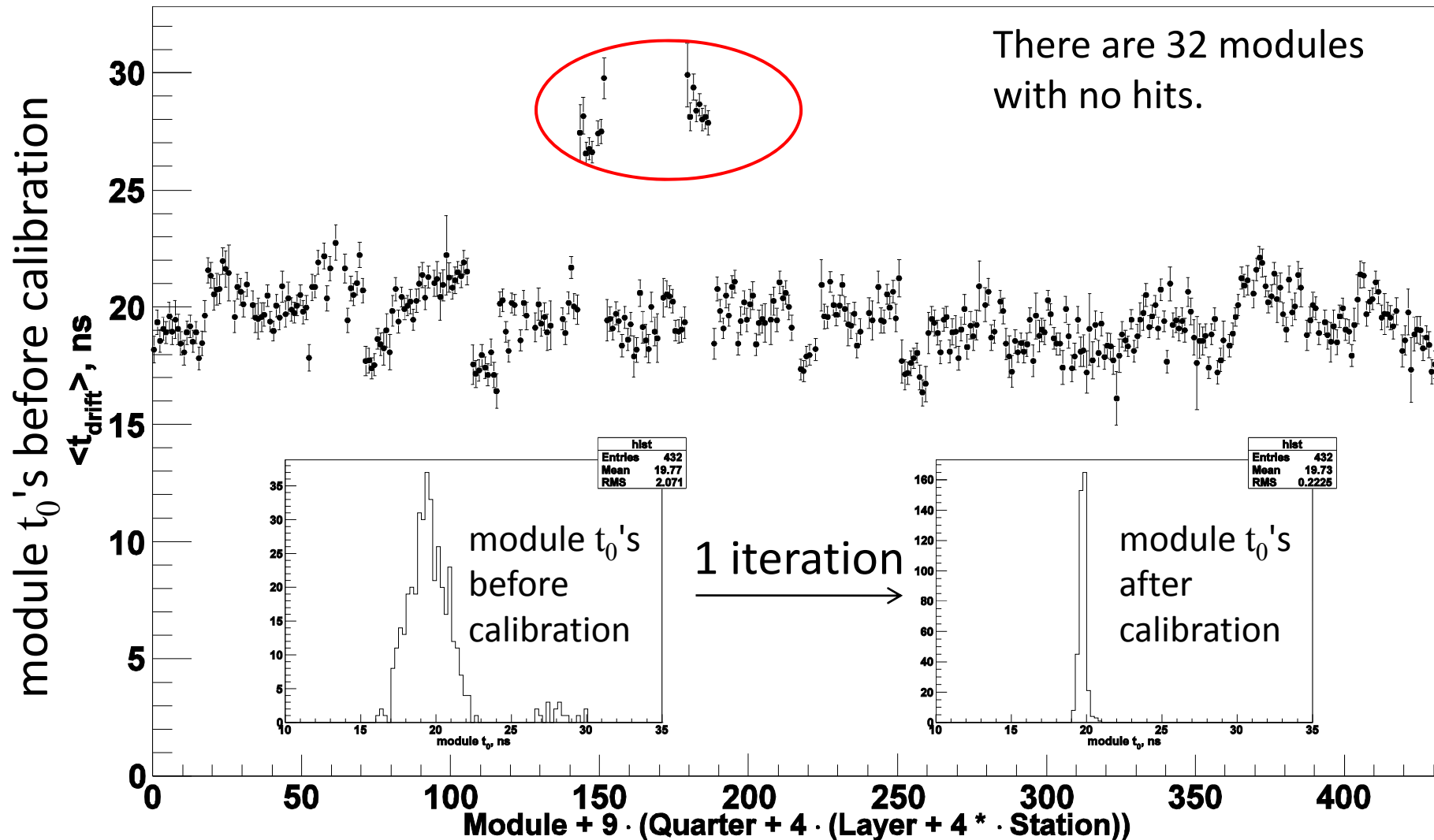
Drift time including all corrections:

- Event T0
- Signal propagation
- T of flight

# Module t<sub>0</sub> calibration

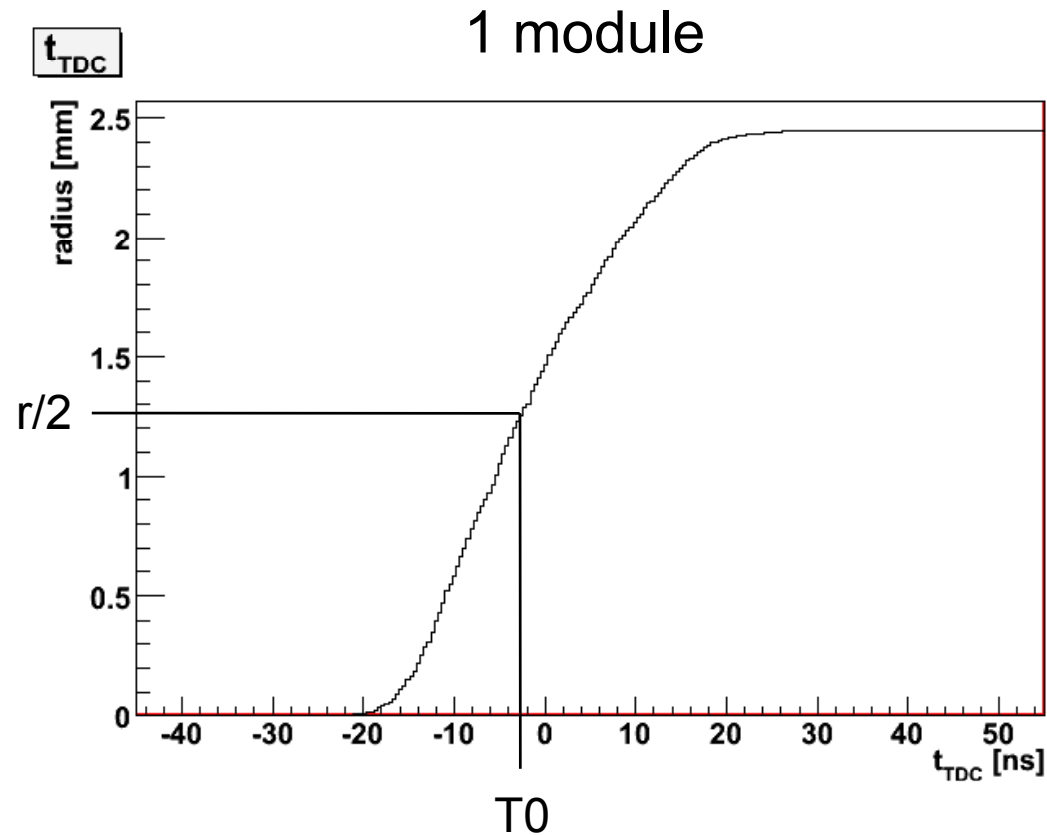
Alexandr Kozlinskiy, Roel Aaij

Use same approach to calibrate module t<sub>0</sub>'s ( $\sigma = 1$  ns):  
average drift times for each module



# Integration Method

Timethy Bartsch



• integrated drift time spectrum



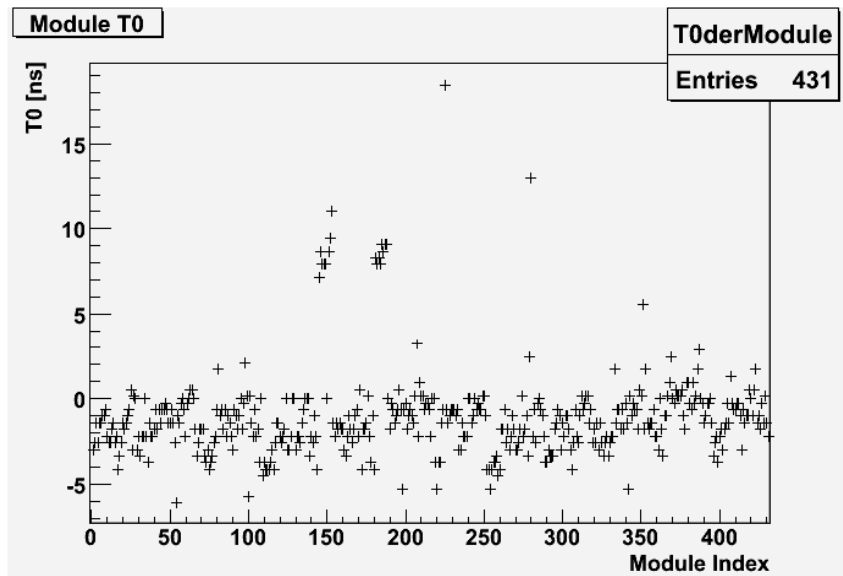
• module T0

- r-t relation
  - look up table
  - drift time fit

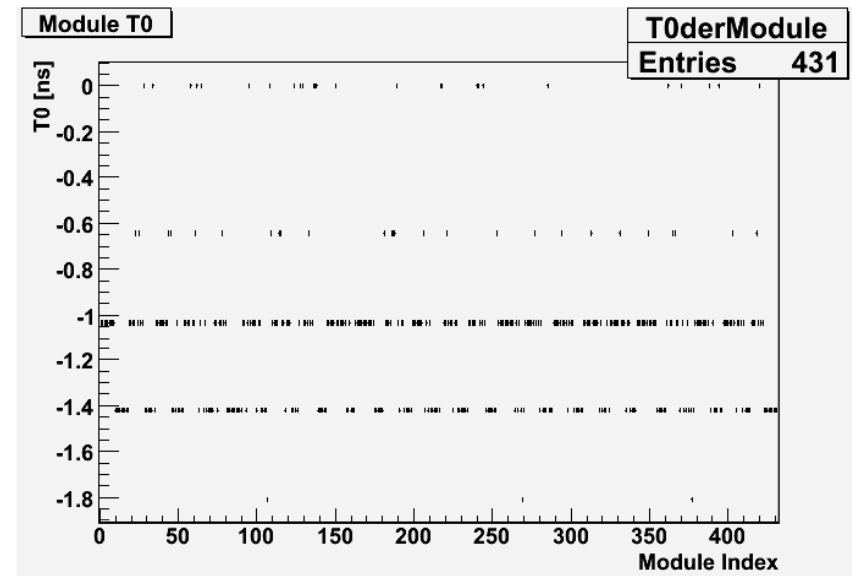
# Module T0 (II)

Timethy Bartesch

module T0 differences



corrected module T0 5 iterations



index = Nmodules\*NQuadrants\*NLayers\*station  
+ Nmodules\*NQuadrants\*layer  
+ NModules\*quadrant + module

- modules with T0 = 0 have no hits
- C-Side mainly at -1ns
- A-Side mainly at -1.4ns

# Towards full calibration

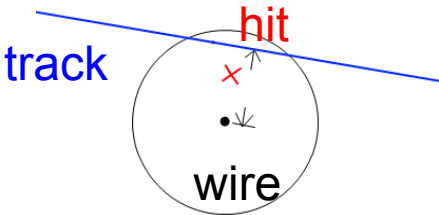
*Timethy Bartesch*

- drift time fit
  - r-t relation from integrated drift time
  - solve ambiguities using the pattern recognition approach
  - set error for radius for each hit to 0.5mm
  
- alignment
  - use alignment constants by Marc Deissenroth
  - half layer alignment + module in x alignment



# Drift time space relation

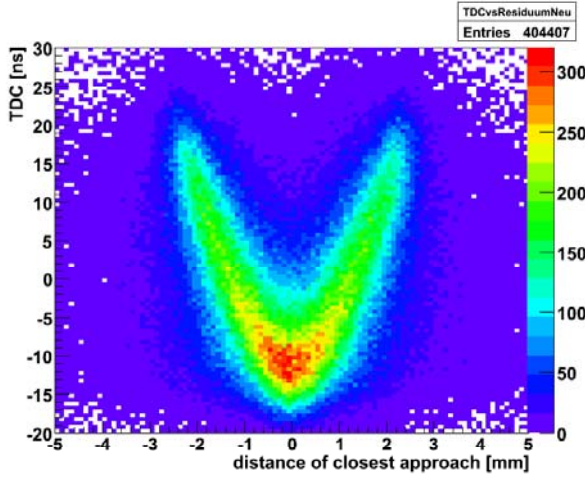
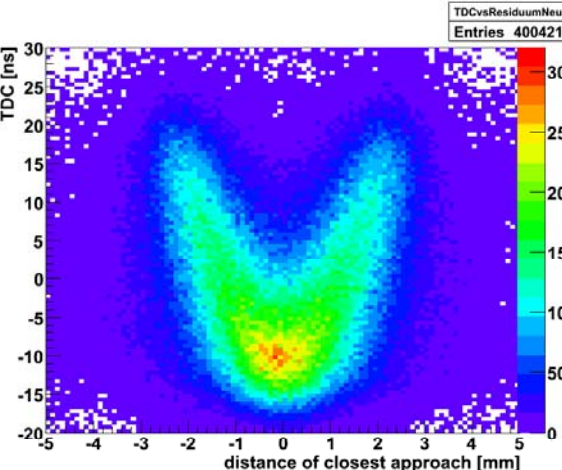
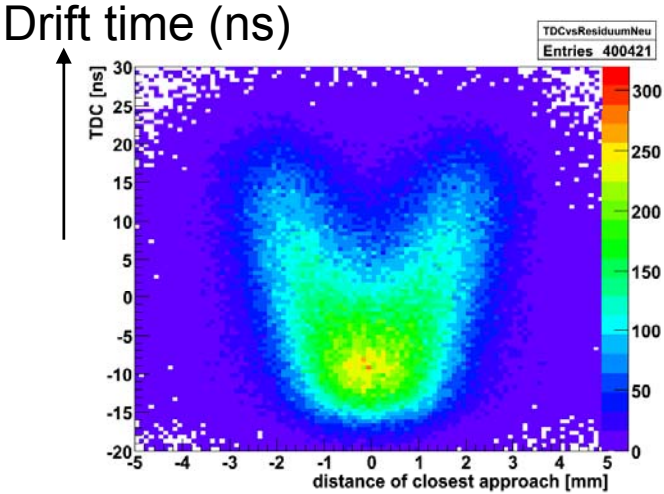
Timethy Bartesch



no drift time in fit  
no alignment

drift time in fit  
no alignment

drift time in fit  
+ alignment



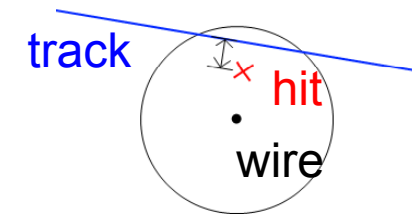
Distance to wire (from fit)

comparison no alignment / alignment module based

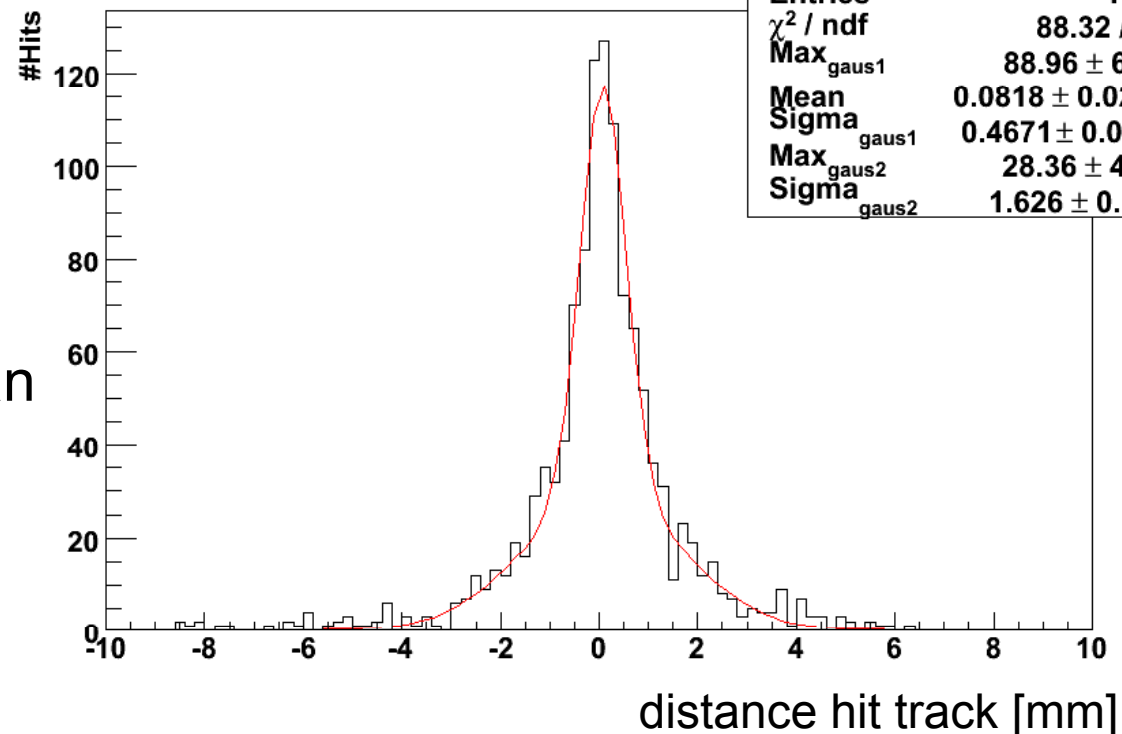
# Residuals after Alignment

Timethy Bartsch

- double gauss fit for each module to unbiased residual distribution
- use only modules with
  - hits > 300
  - reduced  $\chi^2 < 3$



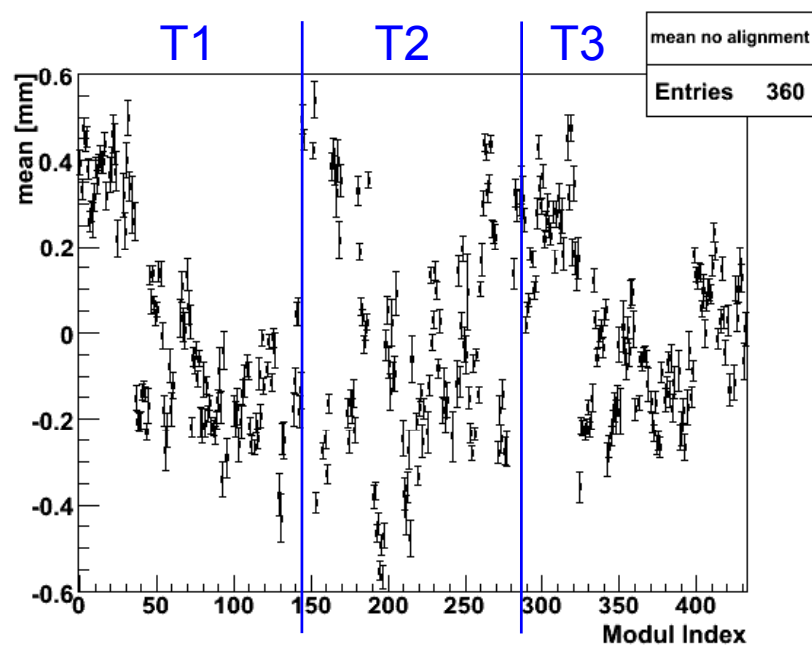
- next slides:
  - mean
  - sigma inner gaussian



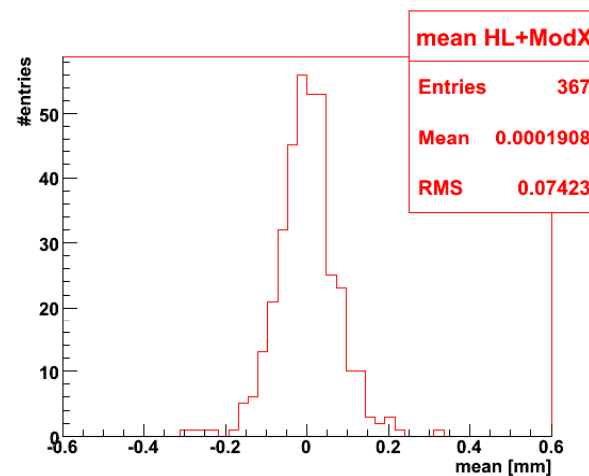
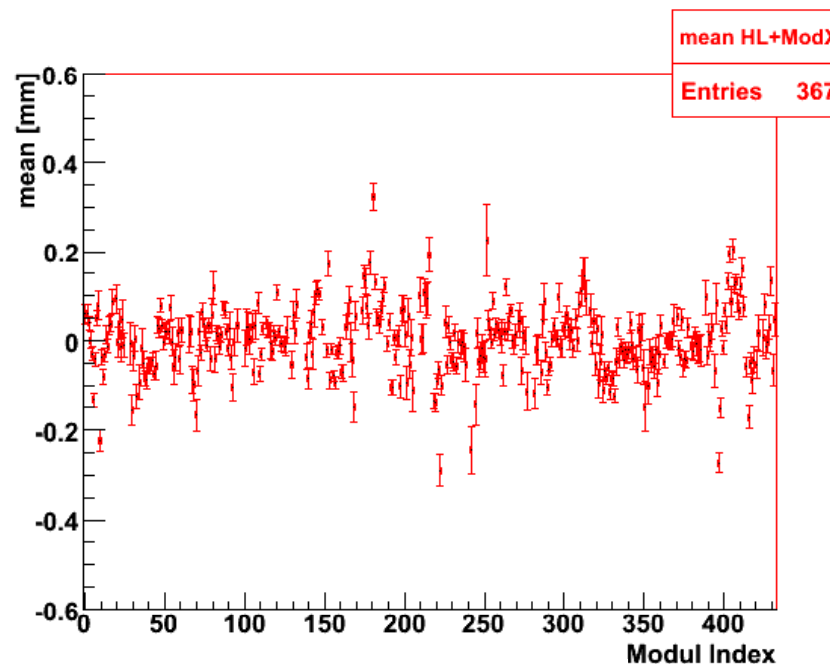
# Residuals per Module

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without alignment

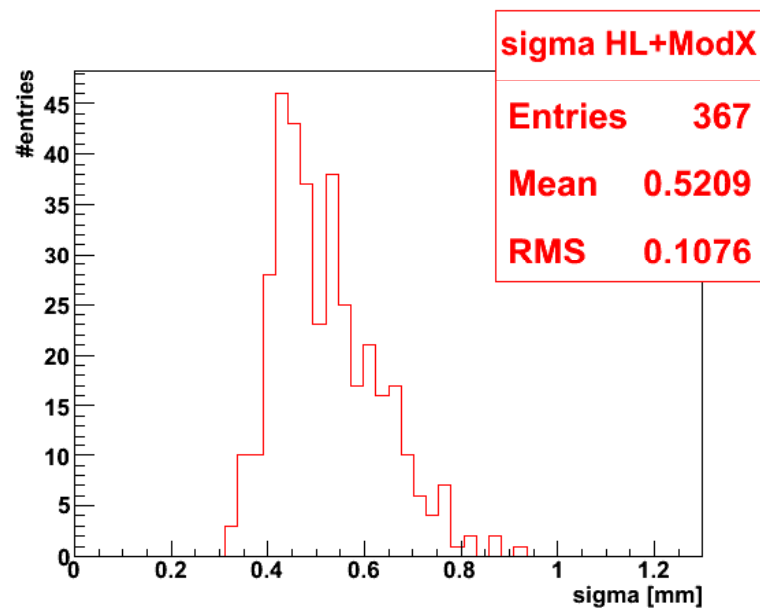
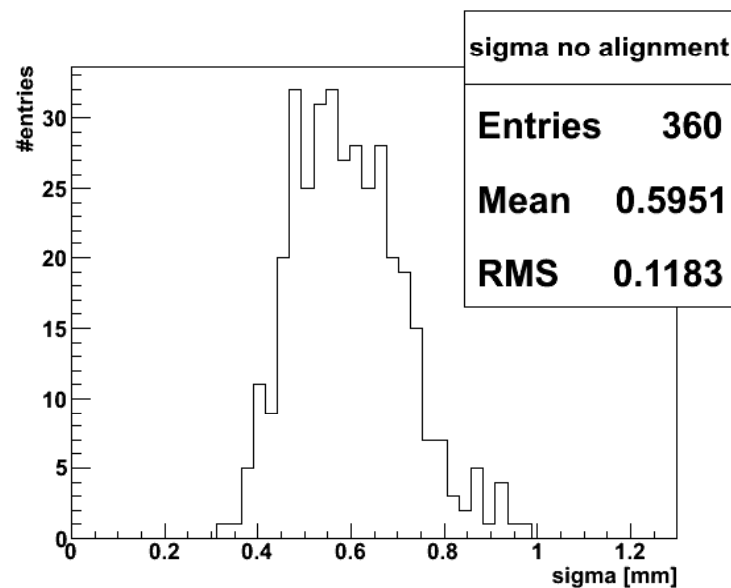
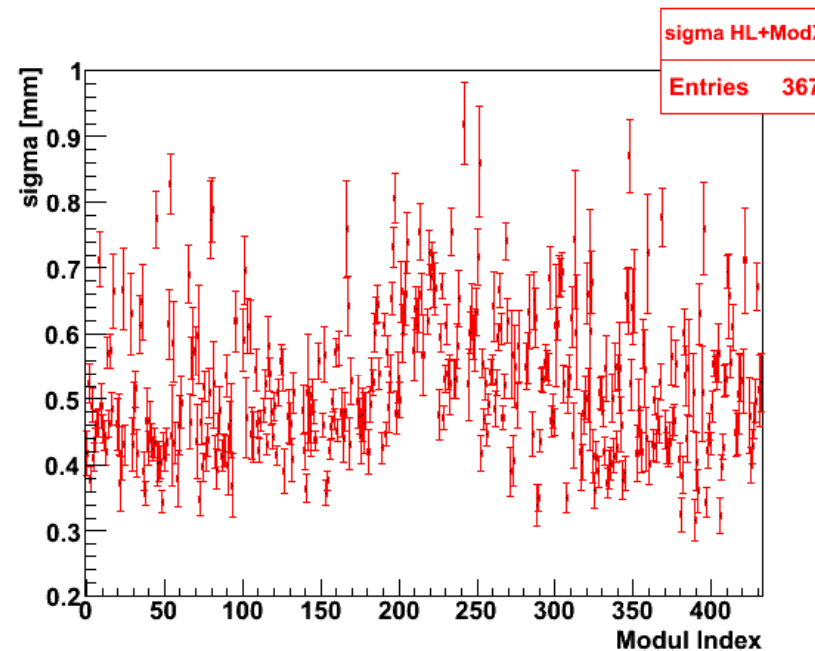
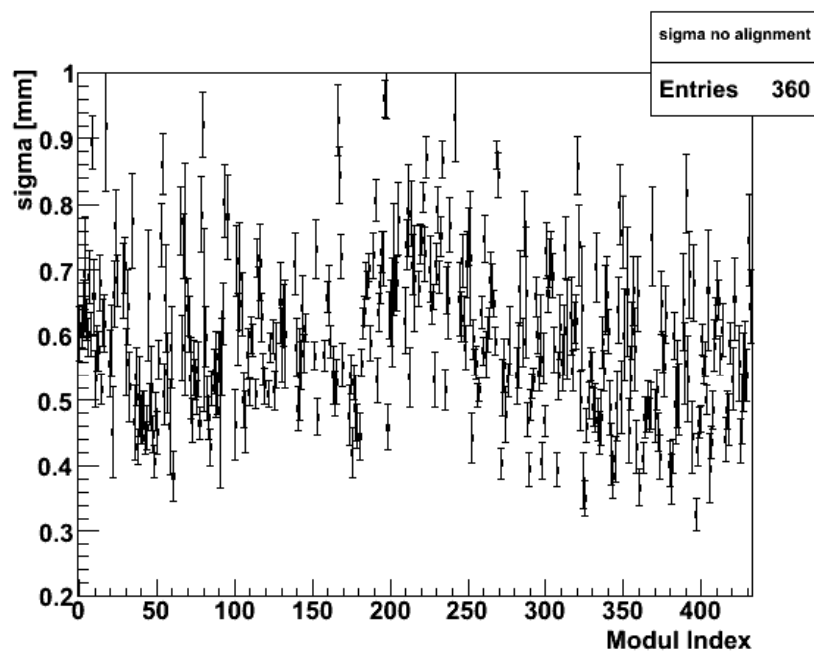


with alignment



# Residual Resolution

Timethy Bartesch



# Conclusion

Significant progress in many areas:

- Track reconstruction of cosmics and beam data
- Decoding and geometry
- T0 calibration
- Rt calibration and residual resolution
- Alignment

... we are still learning