# TRT Alignment

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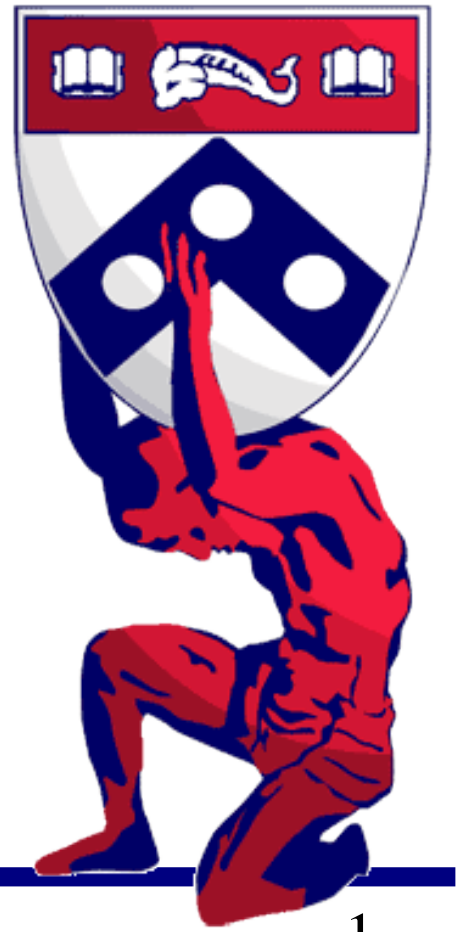


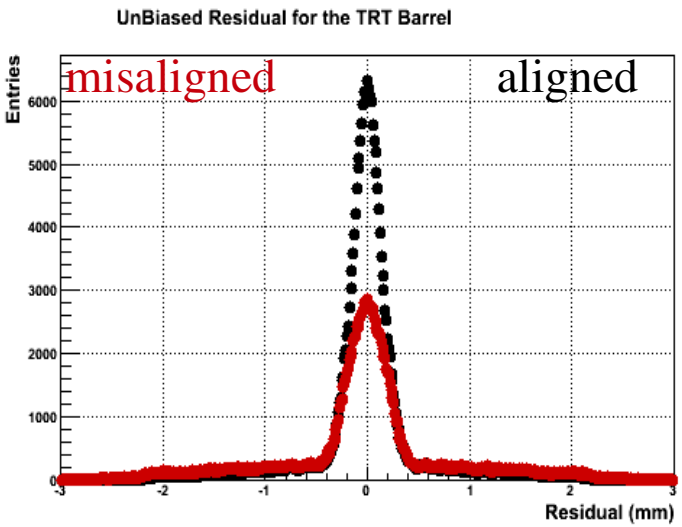
**Outline:**

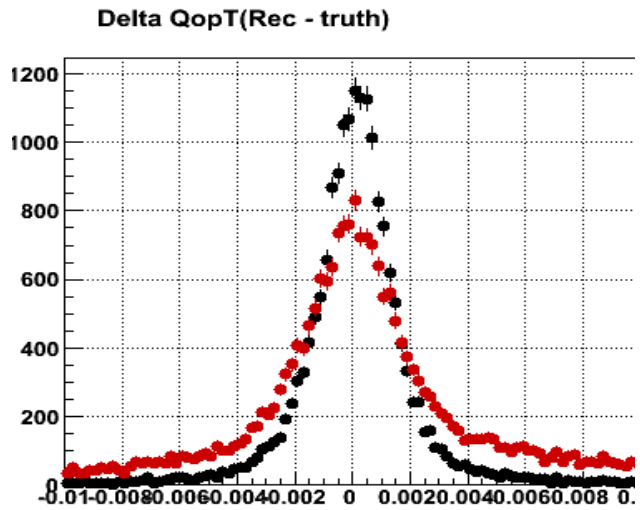
- What we're trying to do.
- How we're doing it.
- Results.
- Plans for the future.

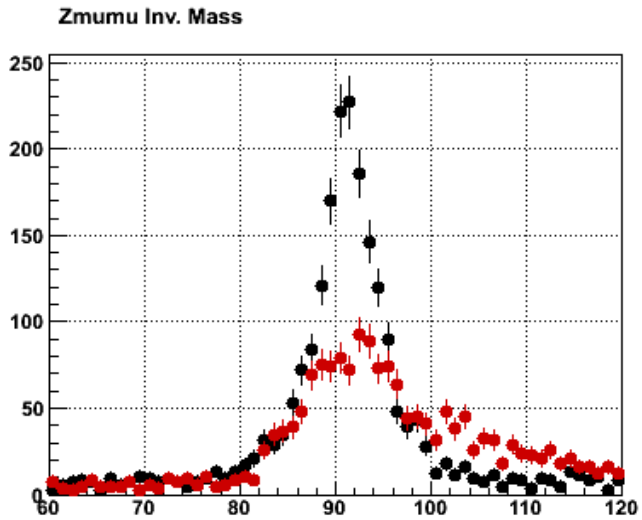
# Why is alignment a problem?

Detector positions used in offline reconstruction do not correspond to the actual relative positions of the installed detector.

Spatial Misalignments → effect track parameters → compromise end physics results




**Alignment Objective** - measure relative position of insitu detectors well enough to:

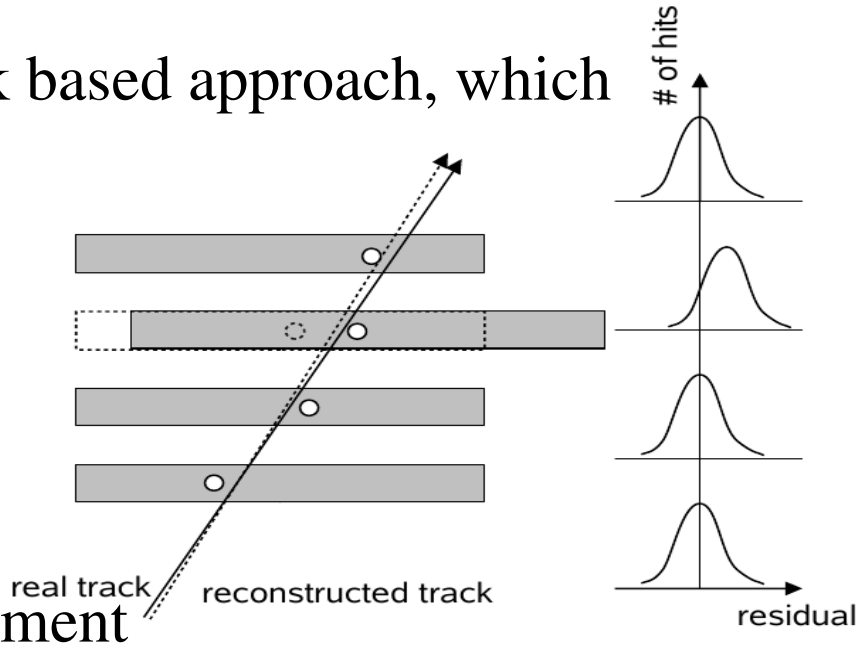
- allow for efficient track reconstruction
- minimize degradation to track parameter resolution to < 20% (goal from TDR)

# How we address the Problem.

- Alignment of TRT is done with a track based approach, which depends on optimizing hit residuals

$$\chi^2 = \sum_{\text{tracks j}} \left( r^T V^{-1} r \right)_j$$

r – residual
V – measurement error




- Taking derivatives of the chi2 wrt the degrees of freedom used to align detector allows one to infer true alignment

- A linearizion approximation (moral equivalent of $f(x) \approx f(x_0) + f'(x_o)(x - x_0)$ ) turns the minimization problem into one of inverting an NxN matrix

N = # of alignment parameters

While providing a feasible and accurate solution to alignment problem, track based approach introduces its own complications. (convergence, consistency, weak modes)

# Where are we?

Successfully participated in large scale tests of software & calibration procedure

**CSC Challenge**

Performance of ID Alignment was tested on dedicated commissioning events generated with realistic detector misalignments. Alignment groups provided constants for other studies

**FDR Exercises**

A series of project wide tests of software and computing infrastructure required for collisions data taking. Full Alignment chain from byte stream data to constants for bulk reconstruction

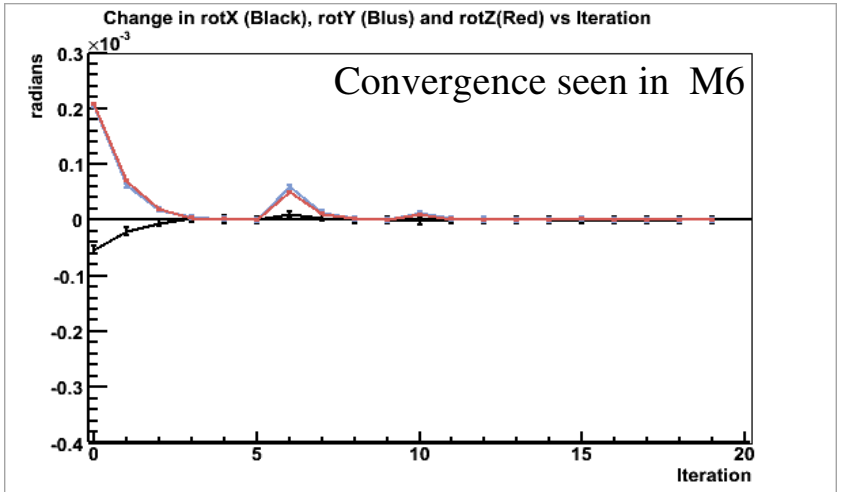
**Two fold success for the Inner Detector Alignment groups**

- Validated overall alignment scheme in realistic setting (both in terms of accuracy and time scale)
- Exposed potential problems, identified areas in need of more attention

(Db management, weak modes, Si-TRT coordination)

Recent improvements overall internal alignment

- TRT-specific vulnerability to systematic misalignments significantly reduced
- more mature outlier logic ("tube hits")
- more realistic hits errors (function of drift radius)
- improvement chi2 minimization technique



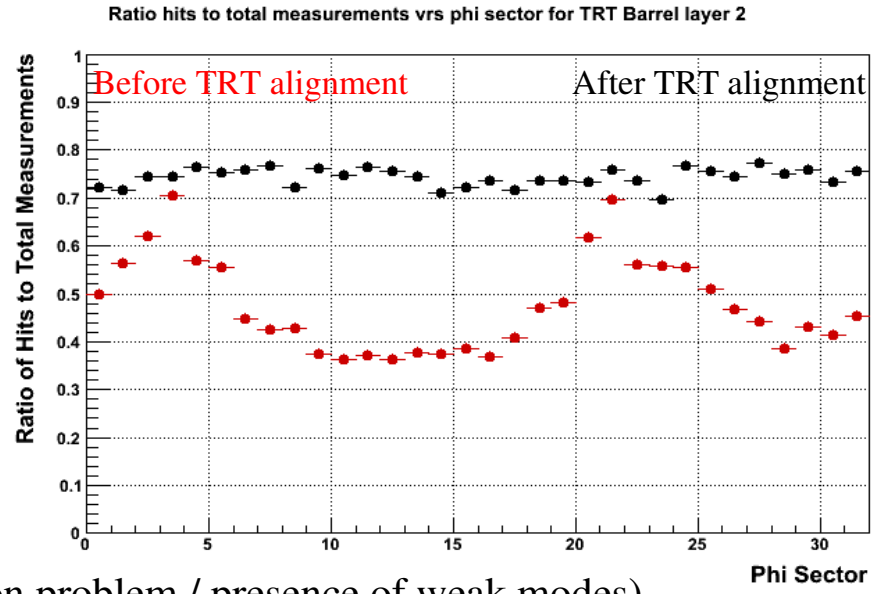
# Alignment Monitoring

Rich monitoring framework designed specifically for the Inner Detector Alignment

## Goals

- diagnose alignment quality, access need for realignment, sign-off on alignment constants
- provides a setting to study systematic misalignments and alternative alignment strategies
- provide direct feedback/input to alignment groups

Example from CSC Challenge




## Strategy

Monitor physical observables sensitive to misalignments

(residuals/ hit efficiencies/ resonance widths)

## Status

Over the past year monitoring infrastructure has come into place and is ready for first data

Participated in CSC, FDR exercises (spotted calibration problem / presence of weak modes)

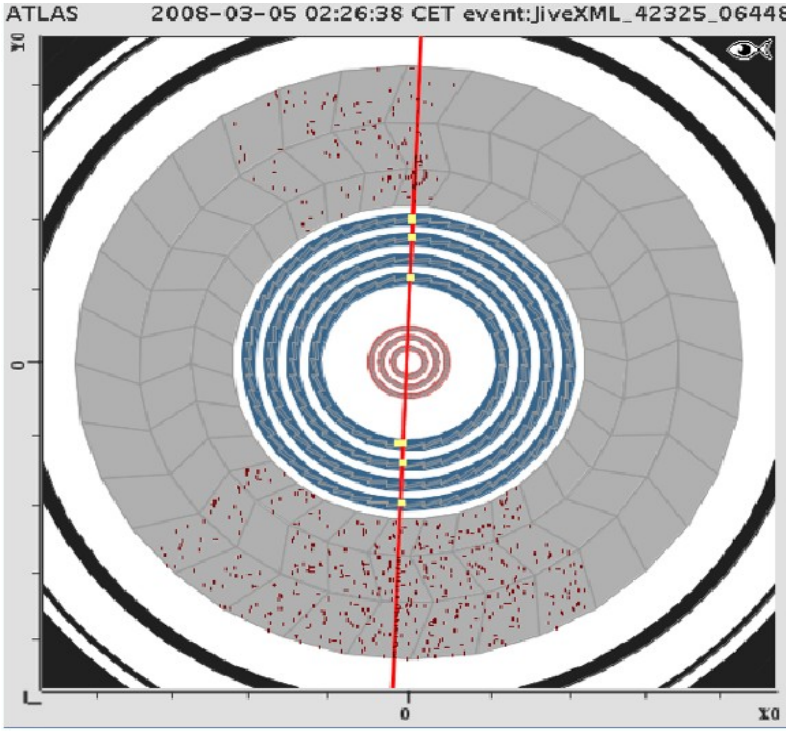
Used in recent cosmic runs, on going development to capitalize on commissioning period

# Cosmics from M6

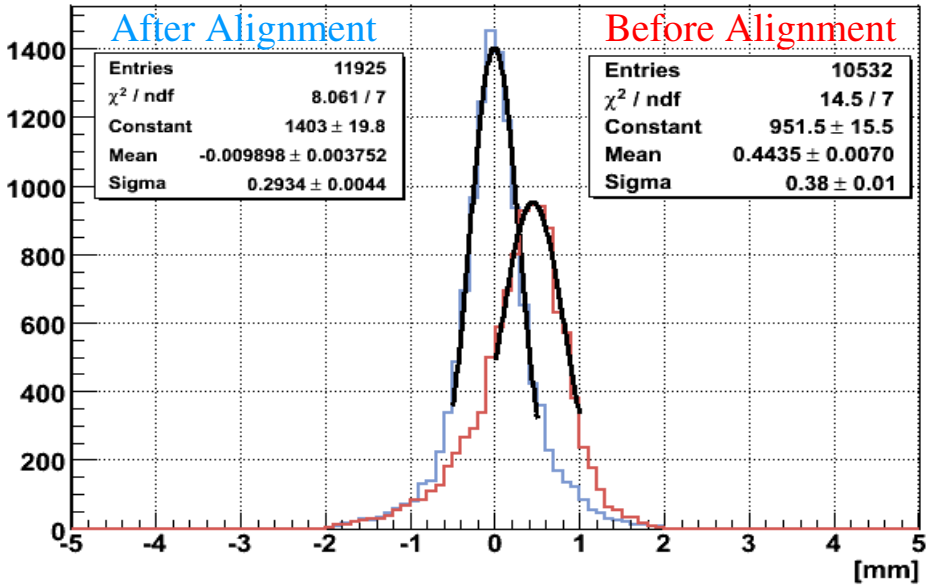
First combined cosmic run with SCT and TRT in the cavern. Over 12k events and 5000 tracks

First test of alignment / alignment validation algorithms on data after ID installation.

Provided test of new chi2 minimization strategy.




Residual improvement of upper modules aligned in M6

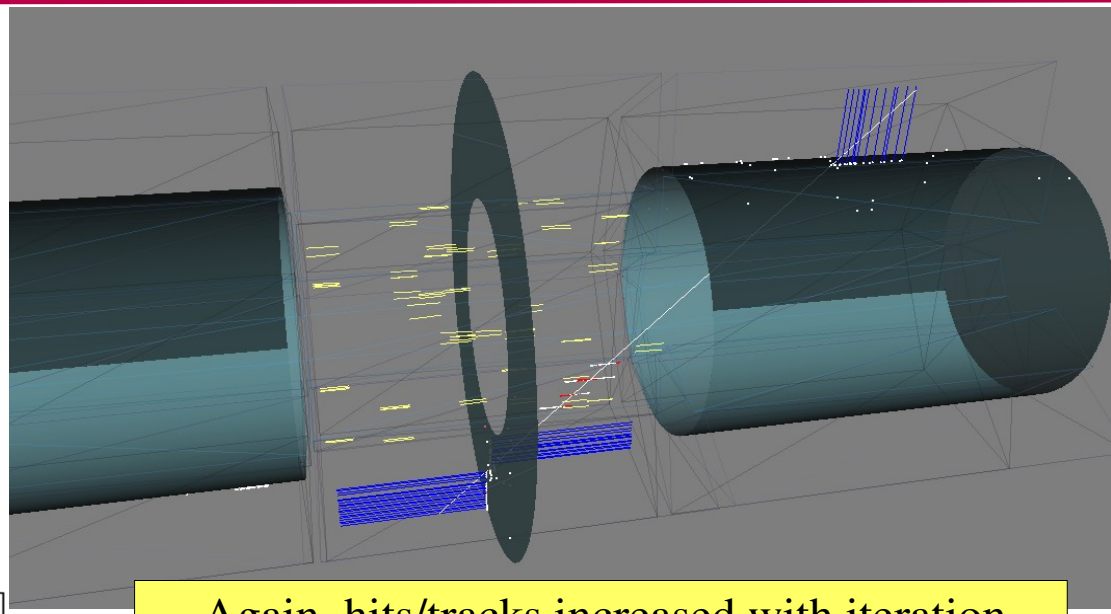


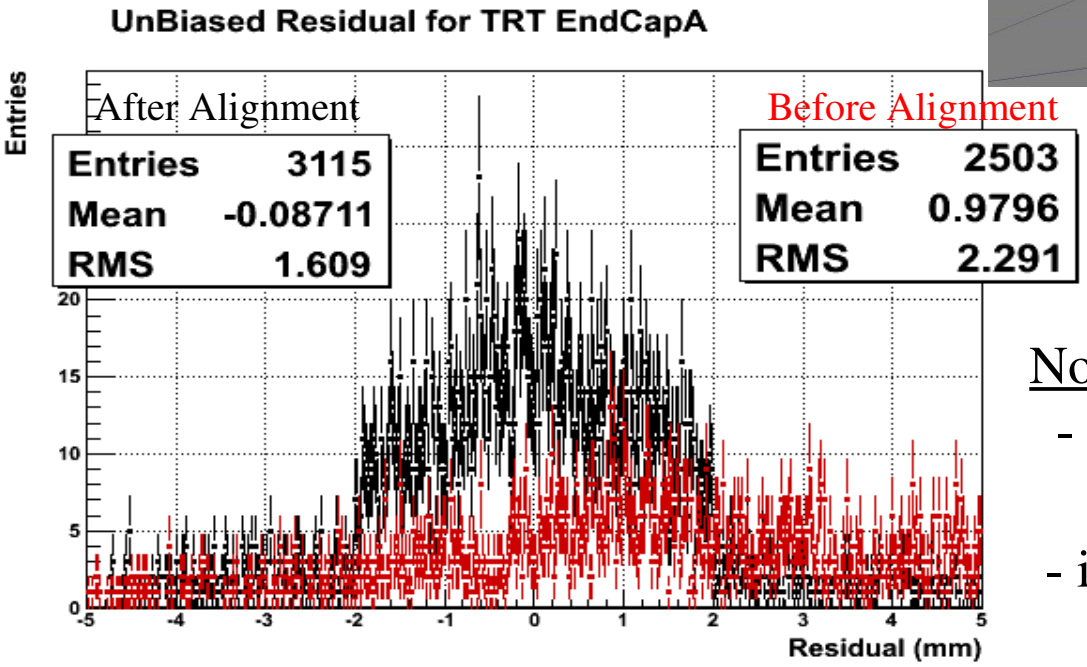

## Overall Success

- Resolution improvement 500 -> under 300 microns
- Saw appropriate convergence with increased number of hits/tracks with alignment iteration
- SCT/TRT relative alignment found was comparable to that reported by survey and seen with cosmics on the surface prior to Inner Detector installation

# Endcap Alignment in M6

-Upper ¼ of TRT endcapA readout in M6
-Originally few endcap A + SCT tracks found in M6 data
-Residuals implied large misalignment (some of which was expected)
-Alignment possible after pattern recognition road widened in TRT endcap.






- Again, hits/tracks increased with iteration.
- Known endcap misalignment recovered(+)
- Alignment also implied large misalignment in x (rotz)

<u>No timing information used in endcap hits</u>

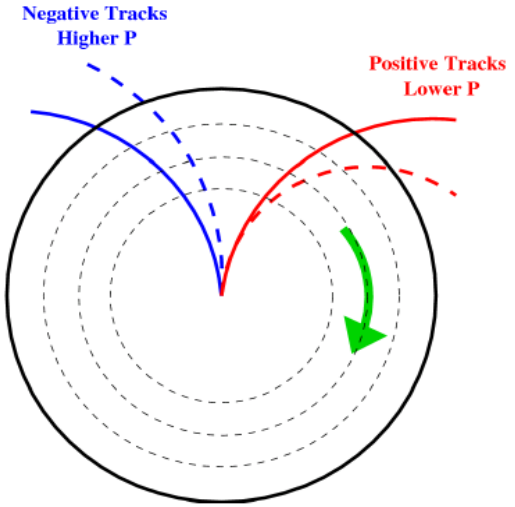
- hits have a position determined by straw center and error of straw-width/sqrt(12)
- ideal residual distribution is flat between -2 and 2 mm

# Weak Modes

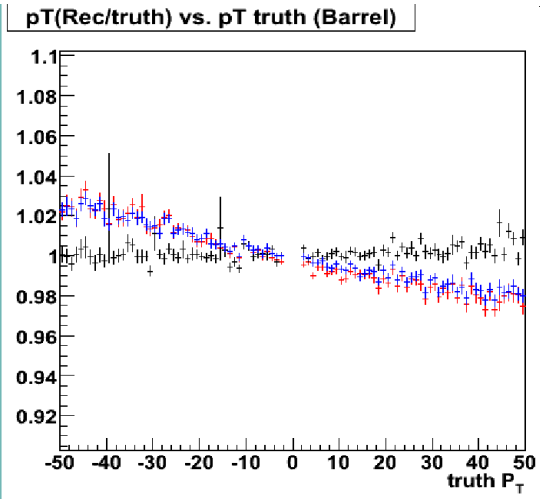
## Problem

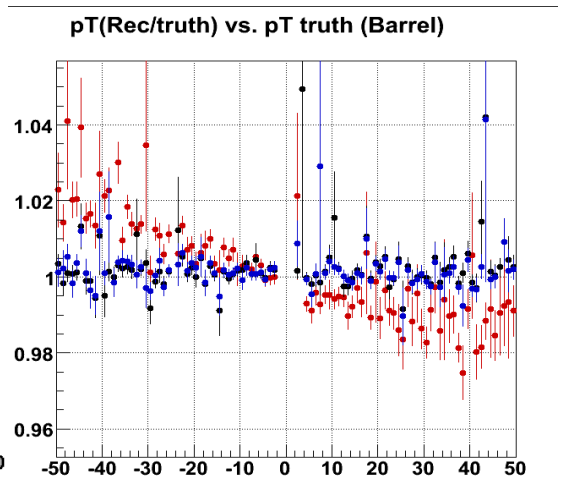
Systematic detector deformations (real or introduced by offline) which bias track parameters, and physics derived from them, while leaving hit residuals unchanged.

Track based alignment algorithms are, by construction, insensitive to these types of distortions




- Given recent improvements in TRT standalone tracking, alignment performance, we are in a position for the TRT to have a huge impact on Si alignment. (momentum constraint)




**Dedicated, on going study to address:**

- possible presence of these modes in the TRT
- their potential impact on physics
- strategies for eliminating them
  - event topology
    (cosmics, beam halo events, displaced verticies...)
  - expanded residuals / momentum constraints
    (modules internally isolated, resonances, E/p)

# Collaborators from other institutions

TRT Alignment
Andrea Bocci (Duke)

Inner Detector Tracking
Thijs Cornelissen (CERN)
Christian Schmitt (CERN)

Alignment Monitoring
Beate Heinemann, Juerg Beringer, Tobias Golling, Jed Biesiada (LBNL)
Ben Cooper, Kyle Stevenson (Queen Mary)
Sara Strandberg (UC Berkeley)
Weina Ji (Lund)

# Future.

**Recent and near future cosmic runs to internally align TRT Barrel**

- unique correlations is potential killer of weak modes
- provides starting point for alignment with beam data
- gain experience in running algorithms / monitoring, identify further weak links)

**Address the alignment calibration interplay**

- seen in FDR activities (large L1 misalignments huge impact timing calibration)
- goal solve before collisions (started in M6)

**TRT only tracks**

- use in eliminating Si weak modes
- factorize/parallelize the alignment procedure,
- adds robustness


**Endcaps**

- little MC experience
- cosmics of limited use

**Increase granularity of alignment**

- as of now alignment only goes down to the module/wheel level (straw level ultimate goal)
- evidence module distortions seen in early commissioning data