VELO alignment with TED data and VELO monitoring

Silvia Borghi

University of Glasgow

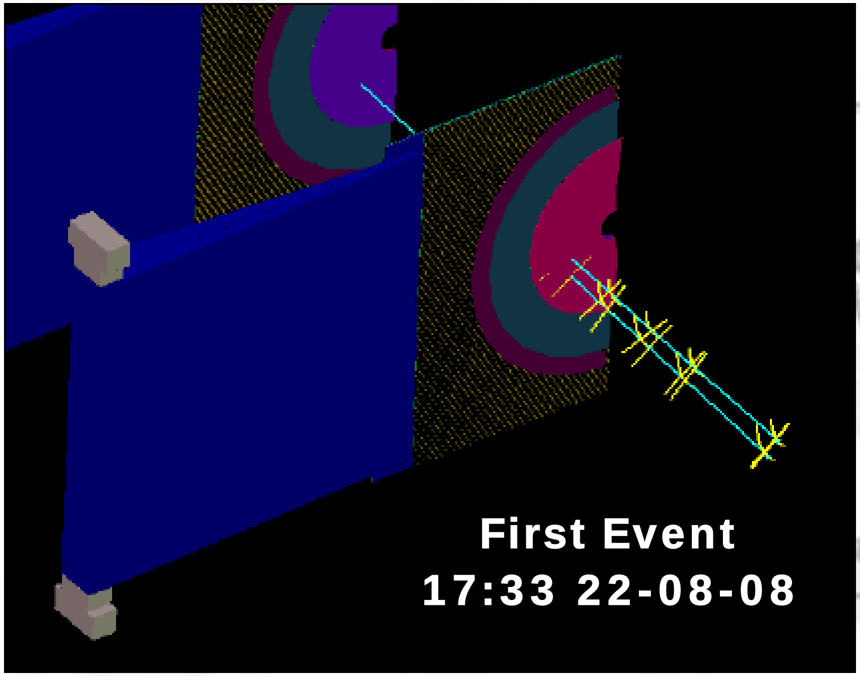
For the VELO group

Outline

- **TED data results**
  - Timing
  - Reprocessed data
  - Module Alignment
  - Resolution
- **Beam position monitoring**
- **Resolver Position**
- **VELO Monitoring**

Results on TED data

- No cosmics for VELO!
- First TED data extremely valuable:
  - Timing study
  - Reprocessed data results
  - First module alignment
- Data taken on August and September
- About 410 events with about 1400 tracks



Friday 22nd August 2008
- Powered HV channels of 10 modules:
  - 5 modules on A side
  - 5 modules on C side
- 2 Runs with about 80 tracks

Sunday 24th August 2008
- Powered all HV channels
- TELL1 on for 76 sensors
- 5 Runs with about 700 tracks
- Mixture of ZS and NZS+ZS data

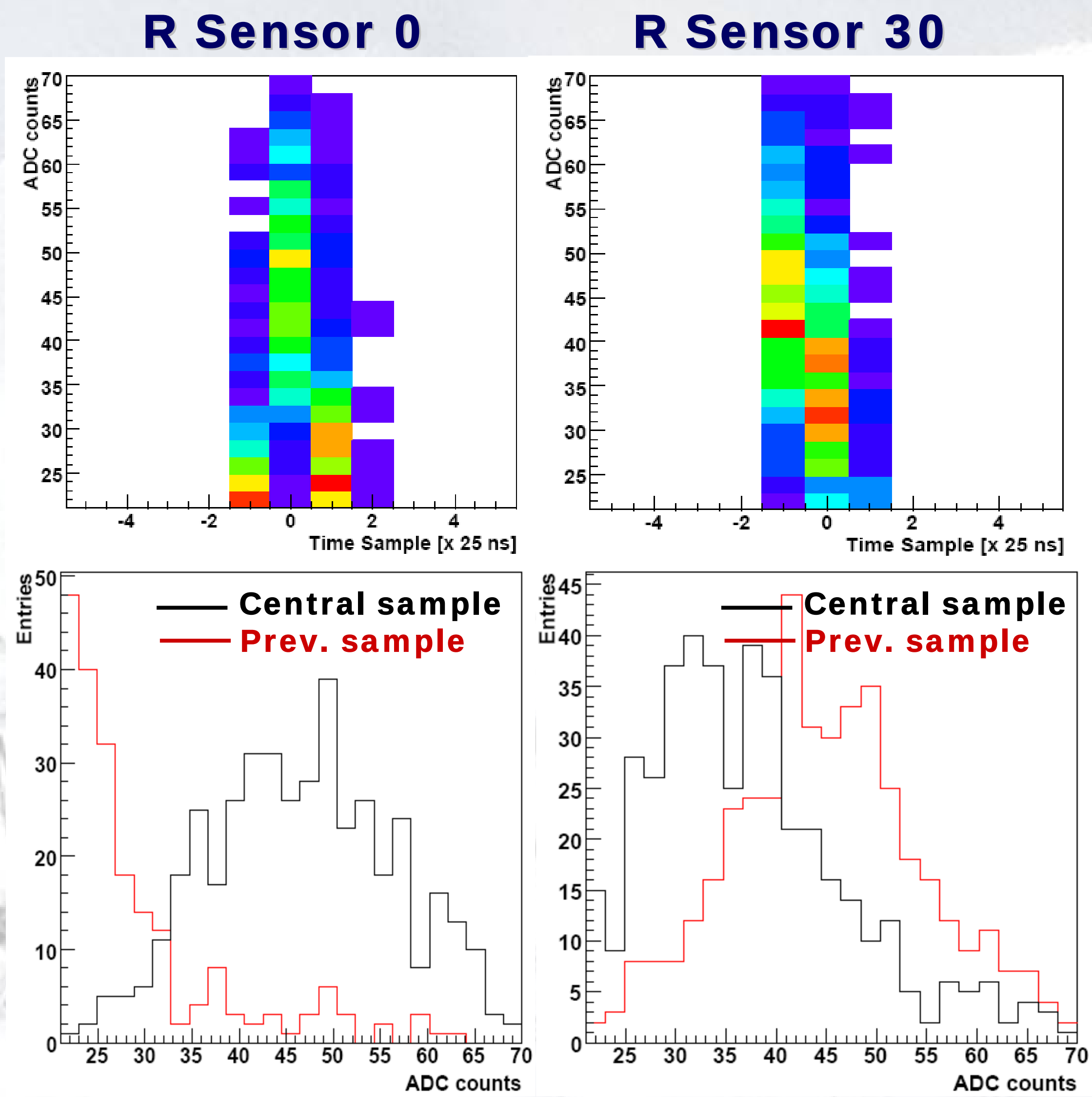
5th and 6th September 2008
- Powered all HV channels
- TELL1 on for 76 sensors
- 16 Runs with about 700 tracks

Timing for individual sensors

- 15 consecutive triggers
- ADC counts collected in a cluster versus the time sample

Different Timing for the sensors
⇒ inefficiency at reconstruction

Automated timing scan procedure developed and being tested.



Data Taking configuration

- All TELL1 parameters were not tuned
- We observed the following effects:
  - Noisy strips
  - Inefficiency in some sensors
  - Timing not optimized for all the sensors

- Few runs with about 30 events with ~70 tracks taken also in non-zero suppressed mode

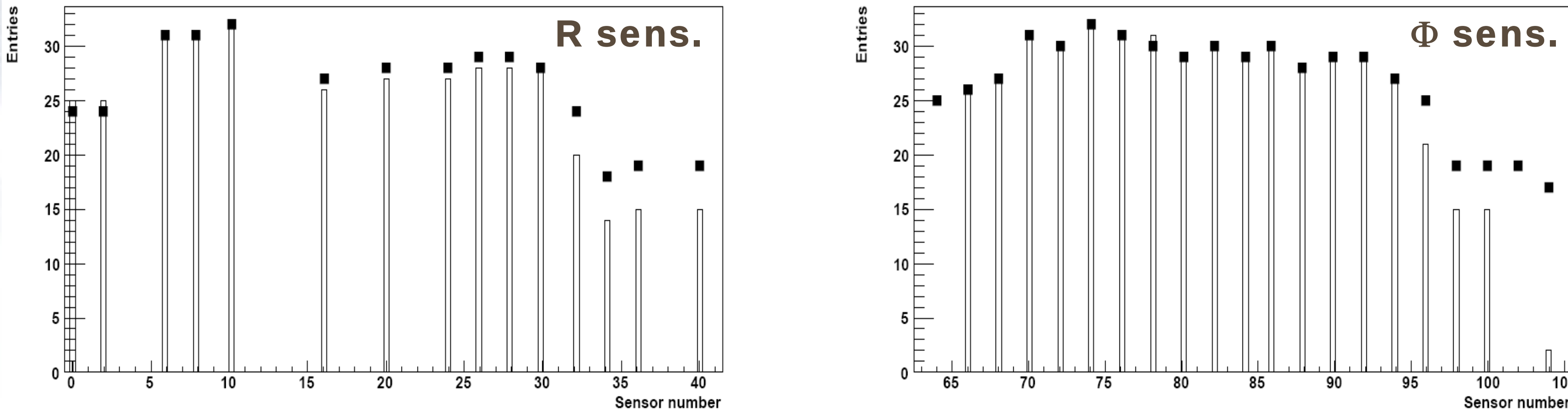
→ they can be reprocessed with a different configuration:
  - Introduced Beetle header correction
  - Subtracted fixed pedestal bank after a proper training on noise data
  - Evaluation of seeding thresholds for each individual strip

Data taking period	August/September
Number of Tracks	About 700
TELL1 configuration	
Pedestal correction	Const for all channels
Cable Cross talk filter	Off
Beetle header Cross talk correction	Off
Mean Common mode	Off
Reordering	On
Linear Common mode correction	On
BEETLE parameters	
$V_{feedback\ shaper}$	1000/500
Clusterization	
Seeding threshold (high threshold)	Const for all channels
Inclusion threshold (low threshold)	Const for all channels
Spillover threshold (sum threshold)	Const for all channels
Maximum number of cl. per sens.	1020 per sensor

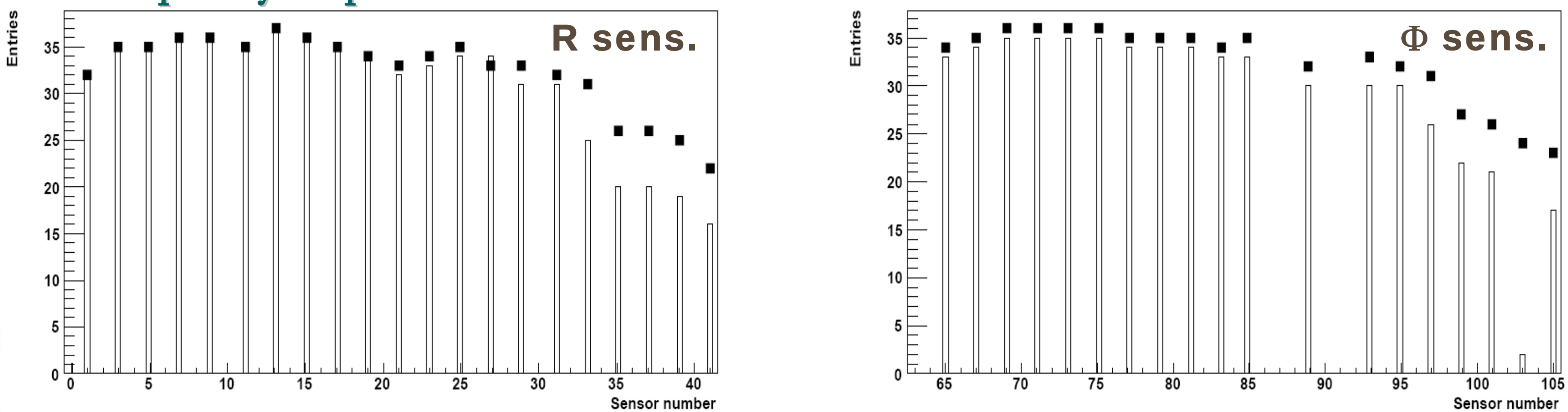
Reprocessed data with new TELL1 configuration

▯ No TELL1 tuning
■ With TELL1 tuning

Multiplicity of points associated to a track in A side



Multiplicity of points associated to a track in in C side



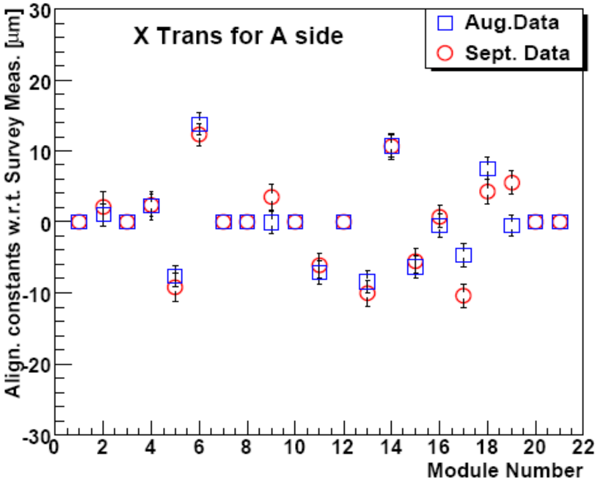
Alignment results for TED data

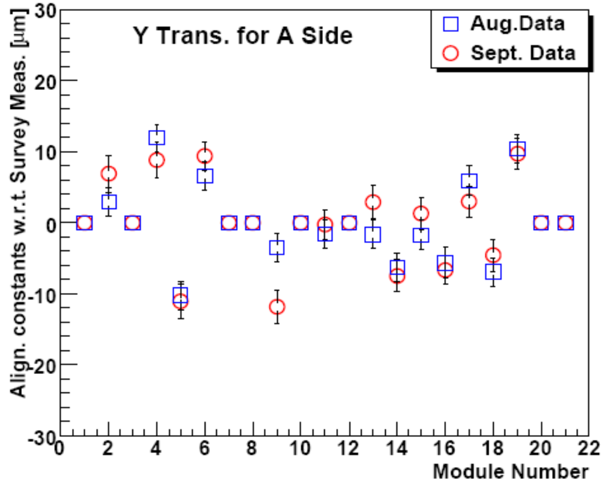
- **Alignment results using TED data:**
  - Metrology for Sensors and Modules as input
  - Module alignment for X, Y translation and Z rotation
  - No sensor alignment
  - Turn off the 3 modules with a very low statistics

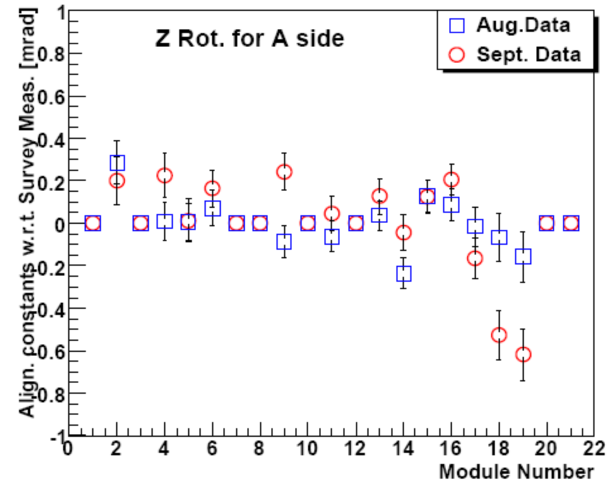
- **Comparison of alignment constants evaluated by different methods using Aug. and Sept. data samples:**
  - Millepede considering X & Y trans and Z rot,
  - Millepede considering X & Y trans.,
  - Kalman considering X & Y trans.

Comparison Sept.-Aug. Alignment constants by Millepede (difference w.r.t Metrology)

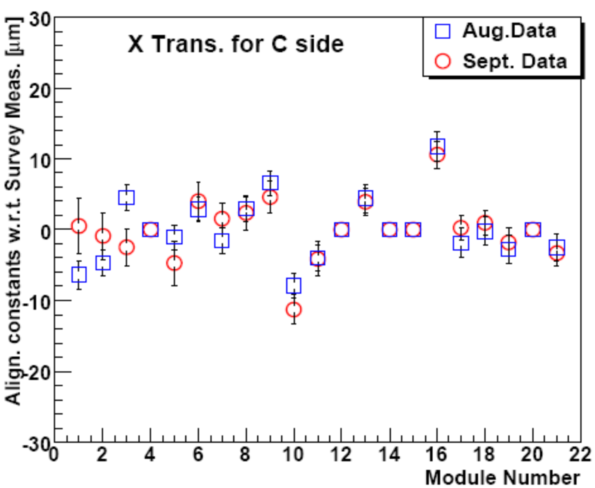
A side

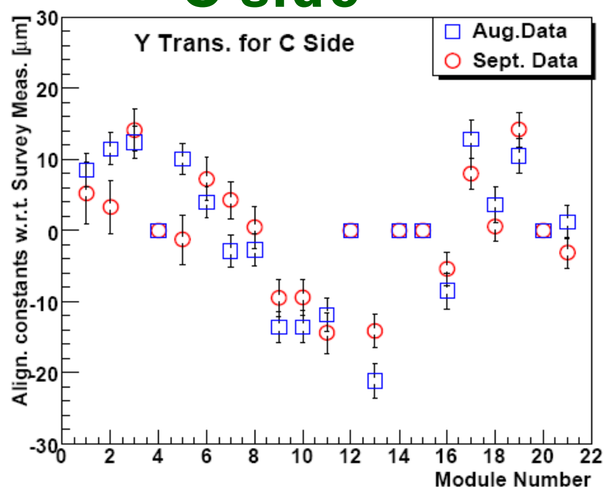


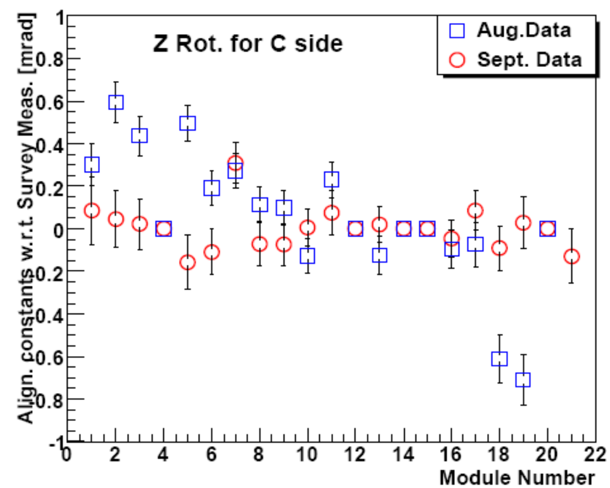




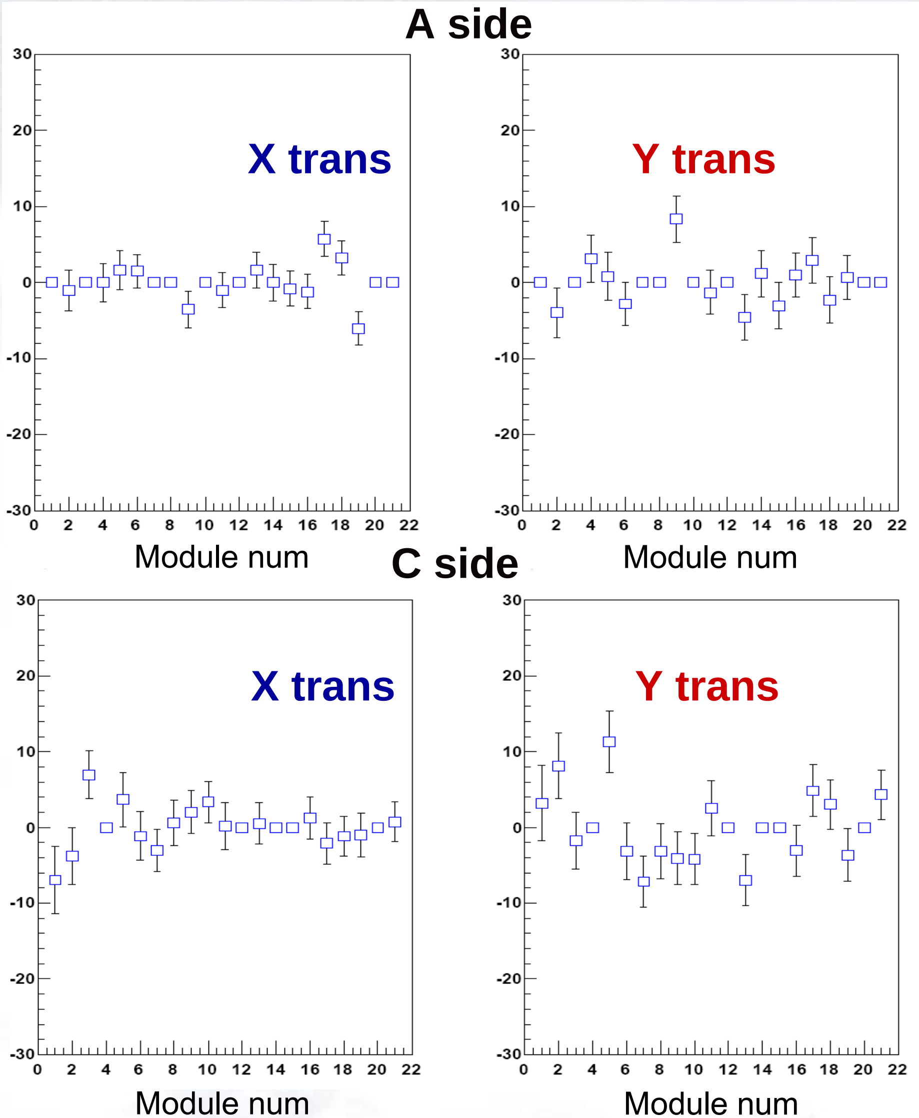
C side



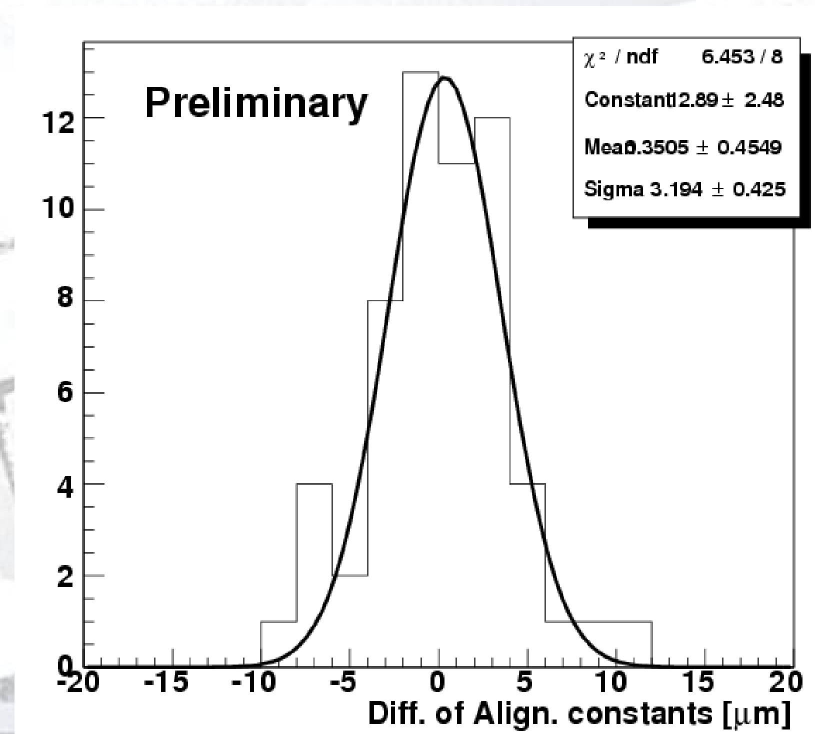




Comparison Sept.-Aug. Alignment constants by Millepede (difference w.r.t Metrology)



Difference of alignment constants obtained using August and September data sample for X and Y translations

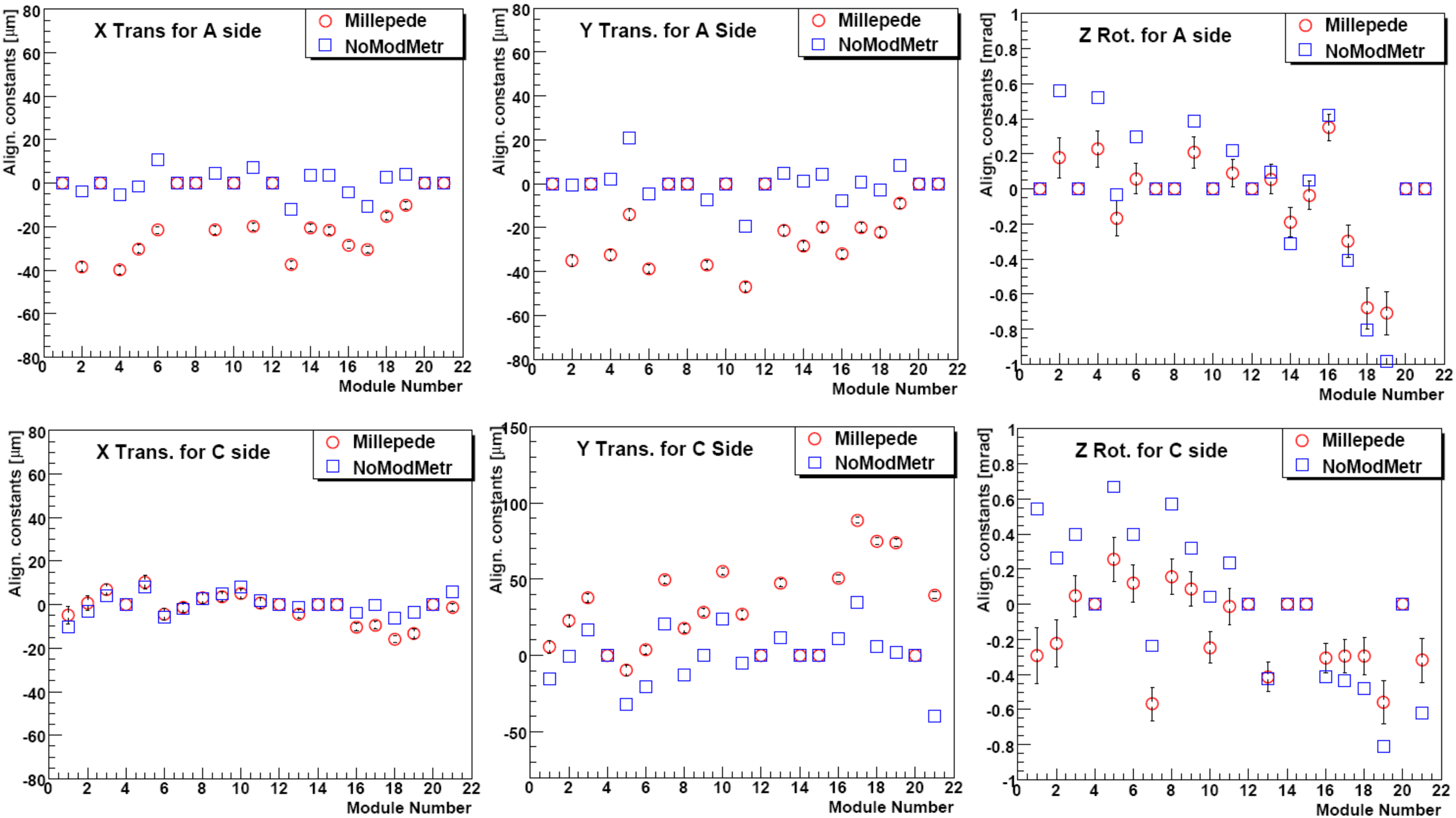


VELO Alignment

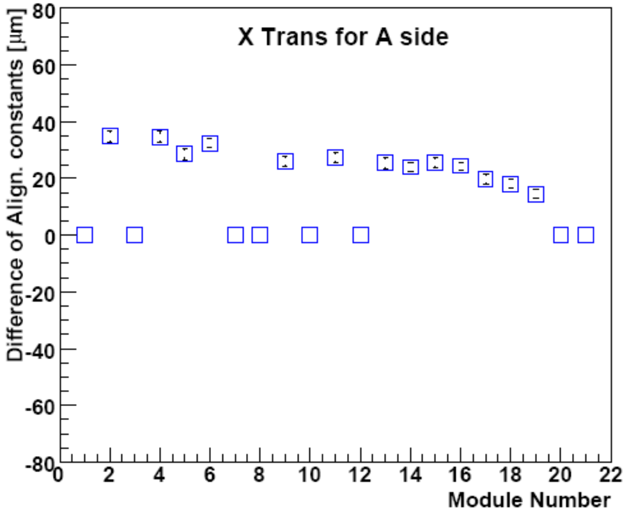
- Evaluation of Alignment constants by a method based on Millepede using as input
  1. NoModMetr
     - No Metrology for the modules
     - Metrology for the sensors
  2. Millepede
     - Metrology for the modules
     - Metrology for the sensors

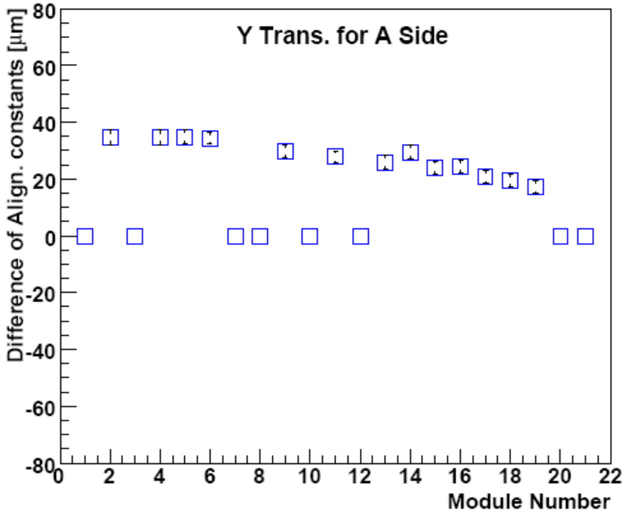
- Alignment for X and Y translation and Z rotation
- Data Sample: September TED data

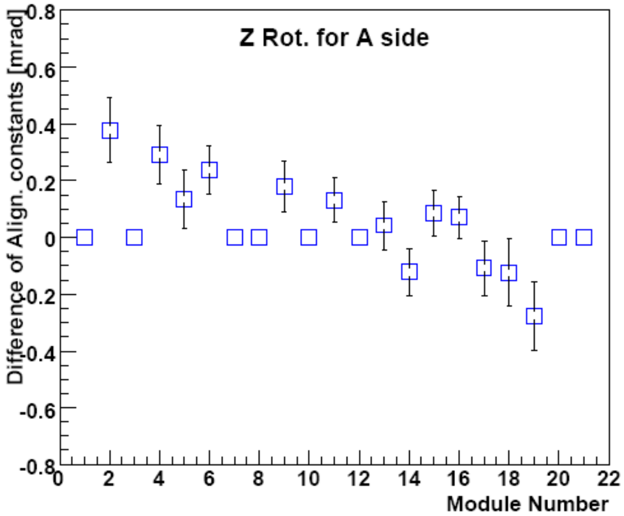
Comparison of Alignment constants

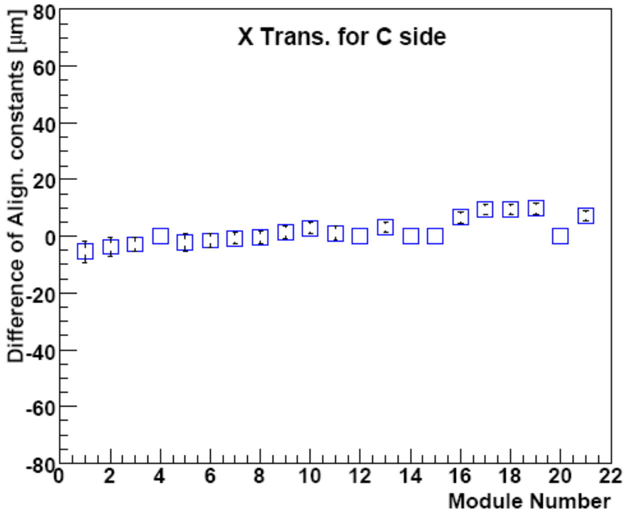


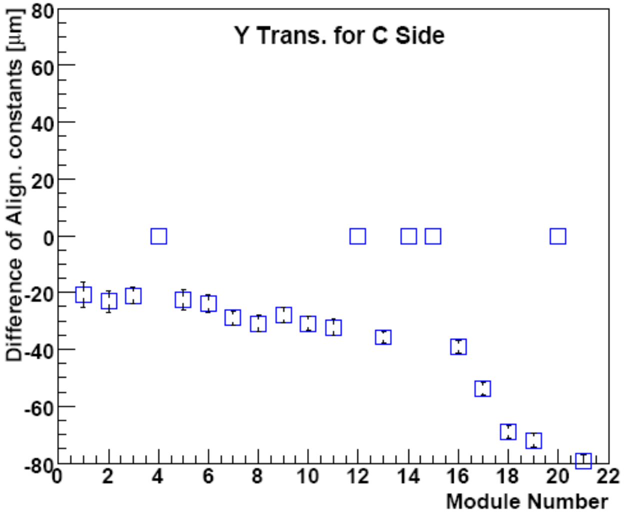
Difference of Alignment constants

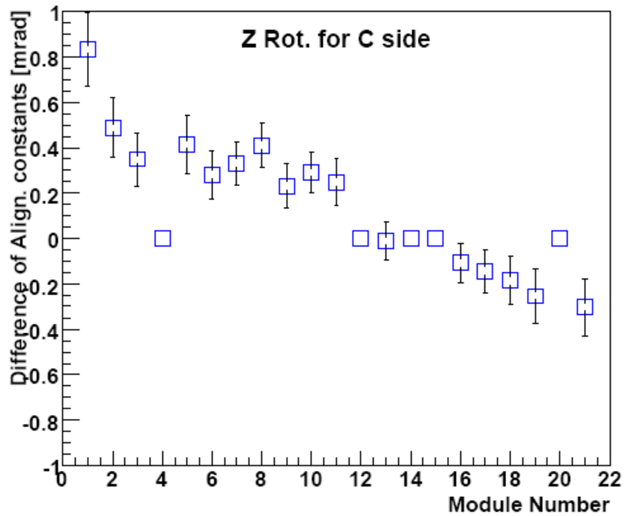






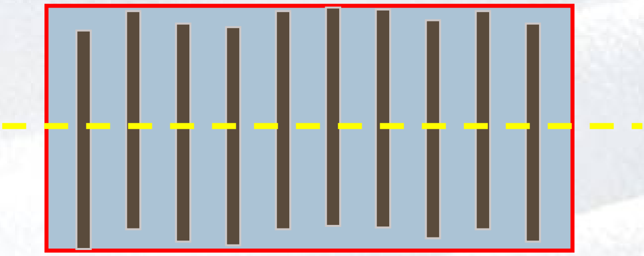




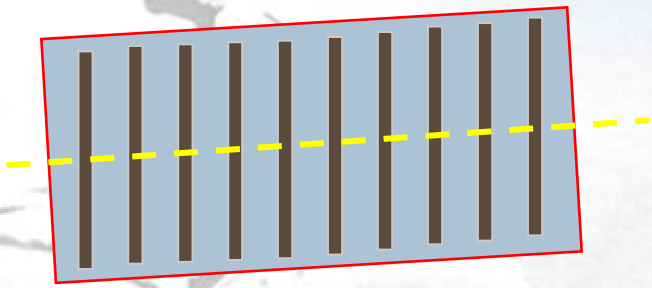


Global shift or rotation

- Module alignment fixes the average position of the modules

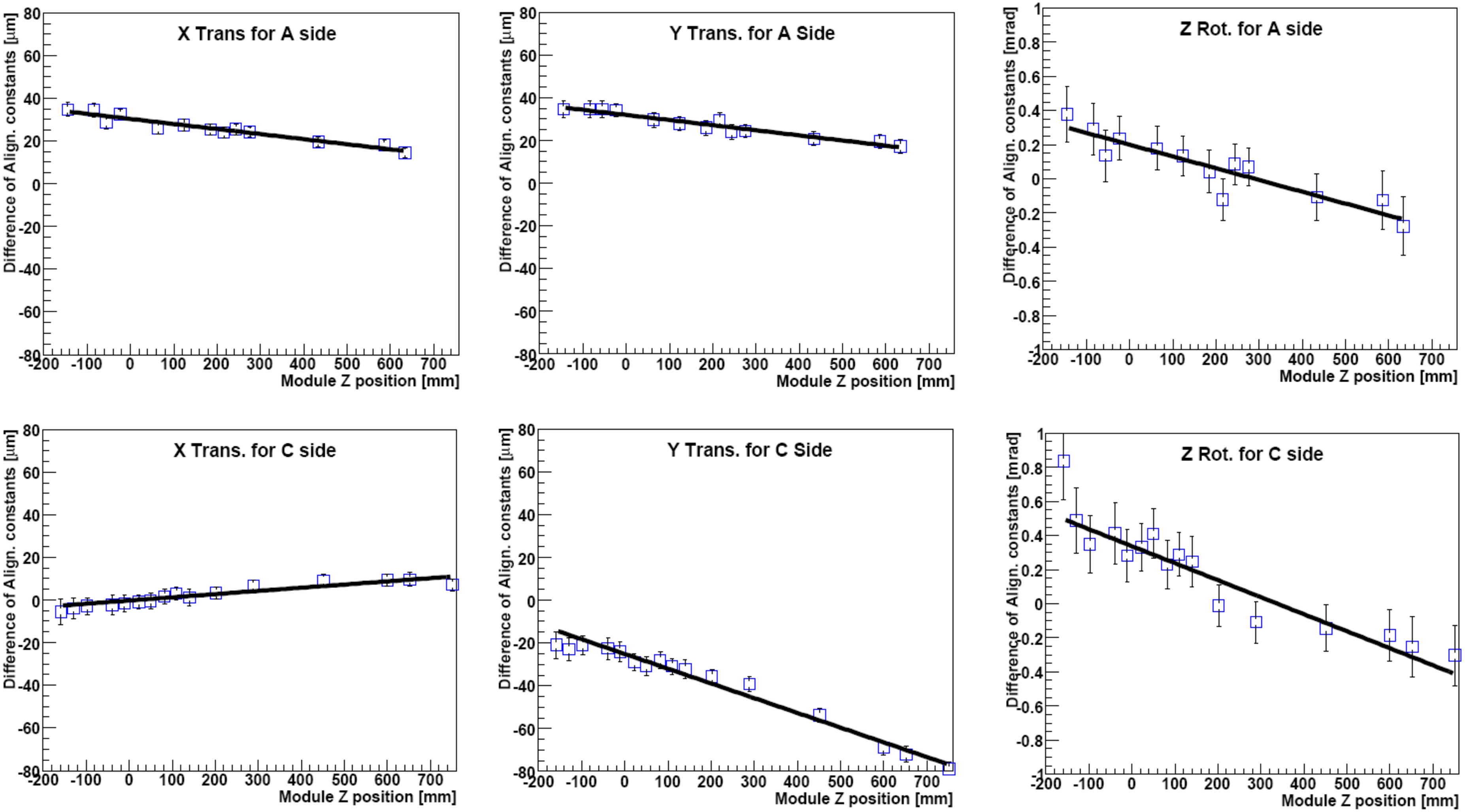


- Module alignment cannot determine a systematic shift that can be justified as a global shift or a global rotation

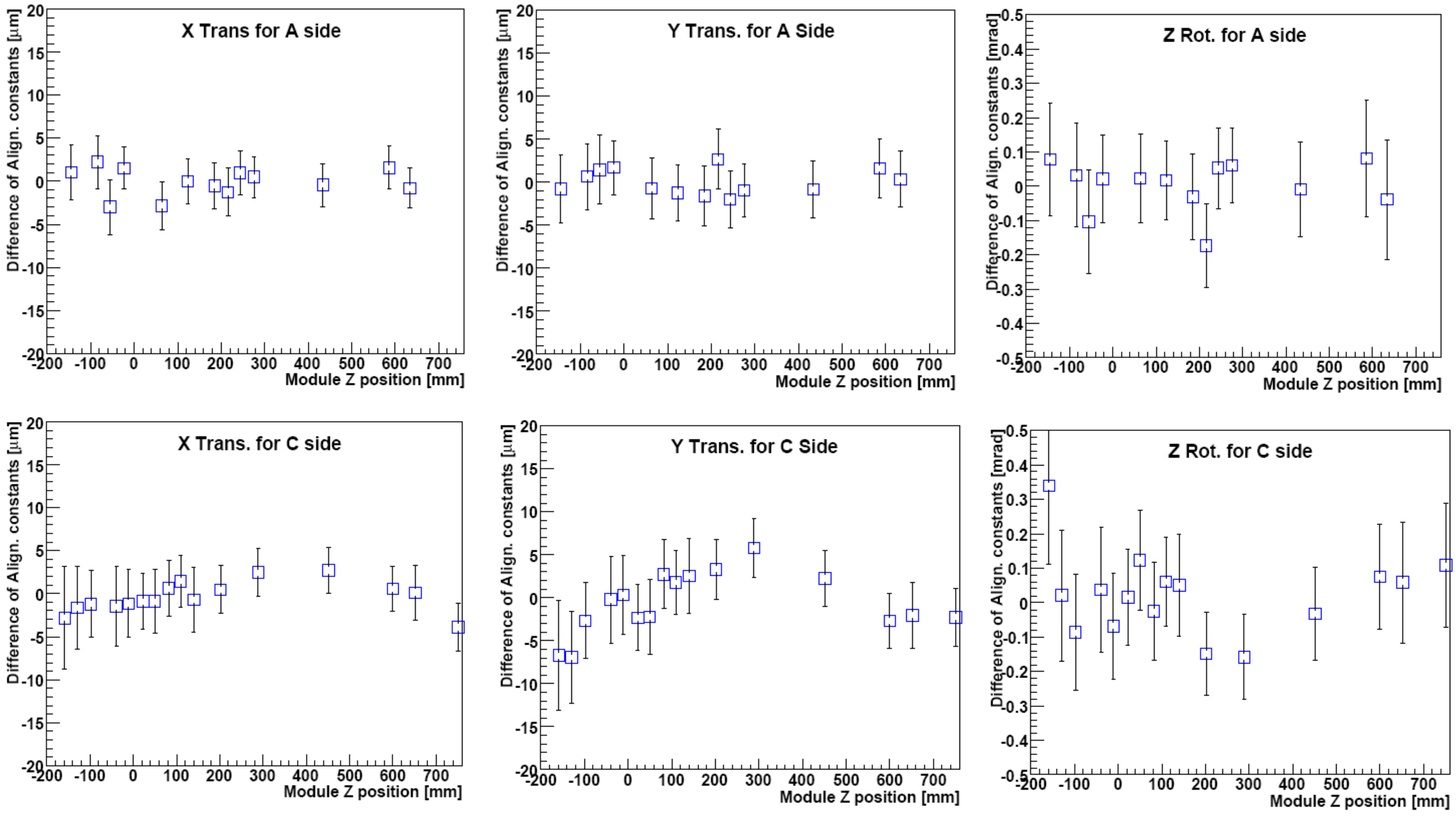


- One should evaluate the difference after the subtraction of the global shift or global rotation

Extract the global component



Difference of alignment constants excluding the global component

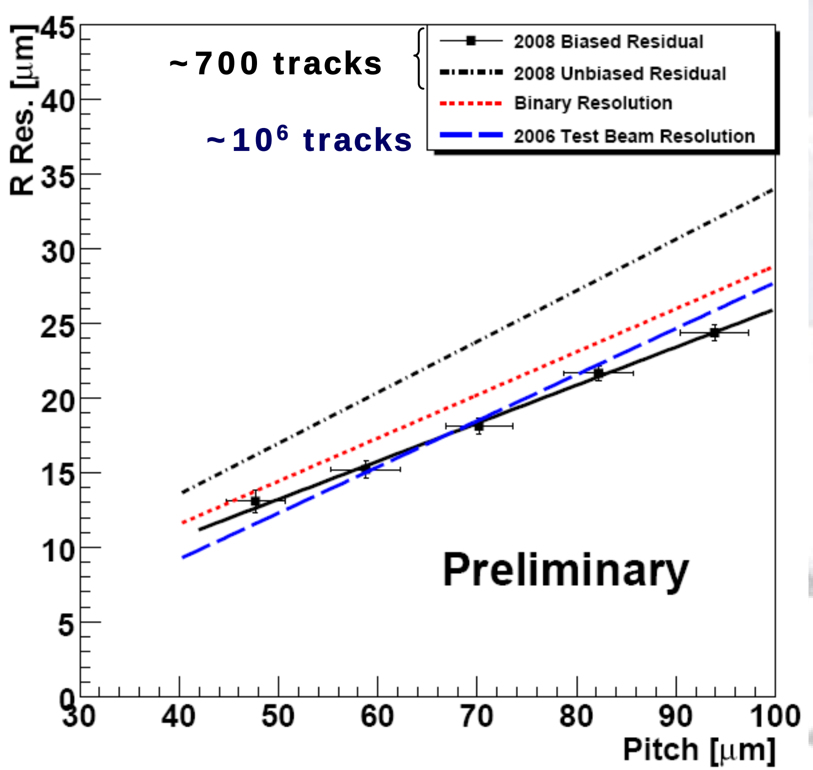


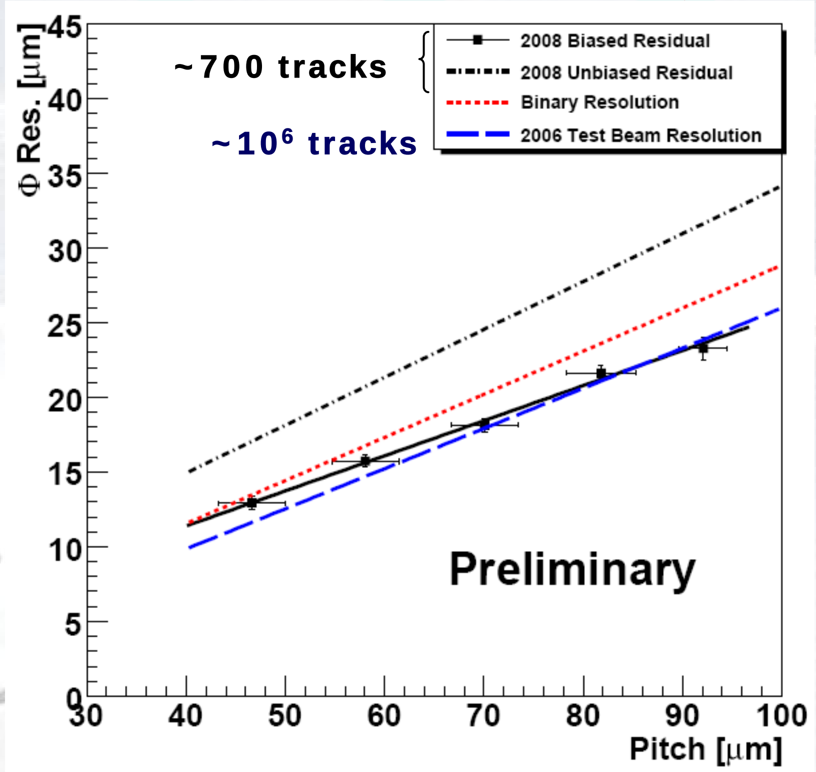
Conclusion on VELO alignment with TED data

- Alignment constants evaluated by different methods using Aug. and Sept. data samples
  - Millepede considering X & Y trans and Z rot,
  - Millepede considering X & Y trans.,
  - Kalman considering X & Y trans.
- Evaluation of alignment constants with and without Metrology measurement for modules as input.
- The detector displacement from metrology is less than 10 μm
- The differences on the translation constants between the two data samples (August and September) are of the order of few microns, up to 10 μm in few cases for both methods (and about 200 μrad for Z rot, if applied).
- Module alignment precision is 5 μm for X and Y translation and 200 μrad for Z rotation
- Results presented in previous alignment meetings:
  - 12 November 2008
    http://indico.cern.ch/getFile.py/access?contribId=6&resId=0&materialId=slides&confId=43986
  - 12 December 2008
    http://indico.cern.ch/getFile.py/access?contribId=100&sessionId=12&resId=0&materialId=slides&confId=44134e

➔ **Note in preparation**

Residual on September sample

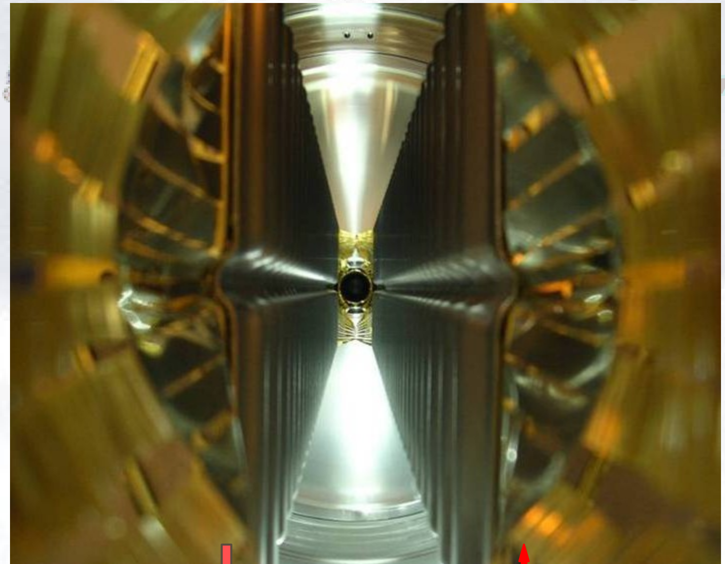




- **The unbiased residual overestimated the resolution due to the extrapolation error**
- **The biased residual underestimated the resolution**
- **TELL1 parameters configuration and the timing not optimized for all the sensors: the percentage of 1 strip cluster is about 85%**
  - ➔ **the expected resolution is the binary one.**
- **Improvement expected when the TELL1 tuned parameters are applied and the proper timing calibration is determined**

Beam position monitoring in the closing procedure

VELO closing implementation - Malcolm John



HLT farm
- 3D vertex reconstruction
- Two lines: VeloASideDecision, VeloCSide Decision
- Uses only standard PR + vertexing packages

Triggered RawEvent

Online Monitoring
- Fill Histograms
- Calculate and suggest next VELO position
- Generate parsing XML
- Calculate validation data (e.g. VELO residuals)

motion PLC

human validation

PVSS data-points

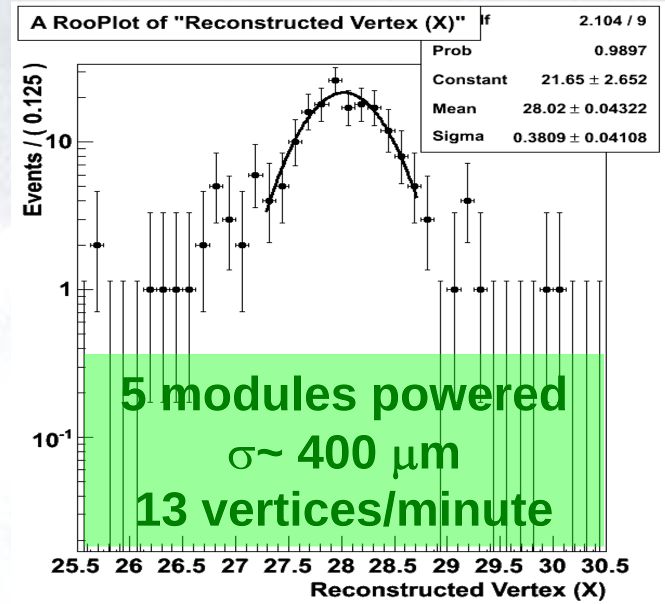
CondDB

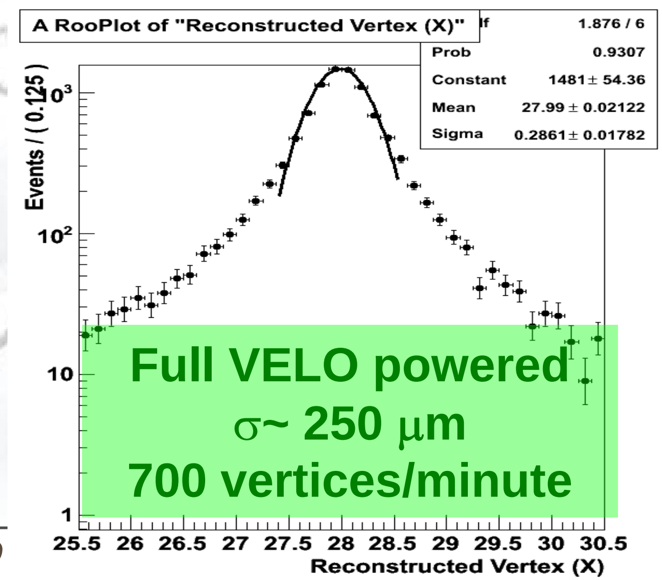
PVSS Closing Manager

Closing: Performance

- The triggered object (the vertex) is stored in the RawEvent via the HltVertexReport class
  - This object is decoded in the online monitoring and histogrammed
- Histogram available via DIM
- Key information (mean, RMS etc...) published regularly to DIM.
  - Observe 2s refresh rate in PVSS
- At nominal luminosity, the time to reconstruct the luminous region and take a decision is negligibly small compared to the motion.
- At $L=10^{28}$ cm^2s^{-1} and $\sqrt{s}$=900GeV, get 70Hz of useful vertices in the open position.

VELO fully open; $L=10^{28}cm^2s^{-1}$





PVSS closing manager

Real-time vertex monitoring

Resolver measurement

LHC beam position information at IP8

Silicon bias current

BCM relative flux

Performs consistency checks between motion and measurements as well as monitoring the key hardware.

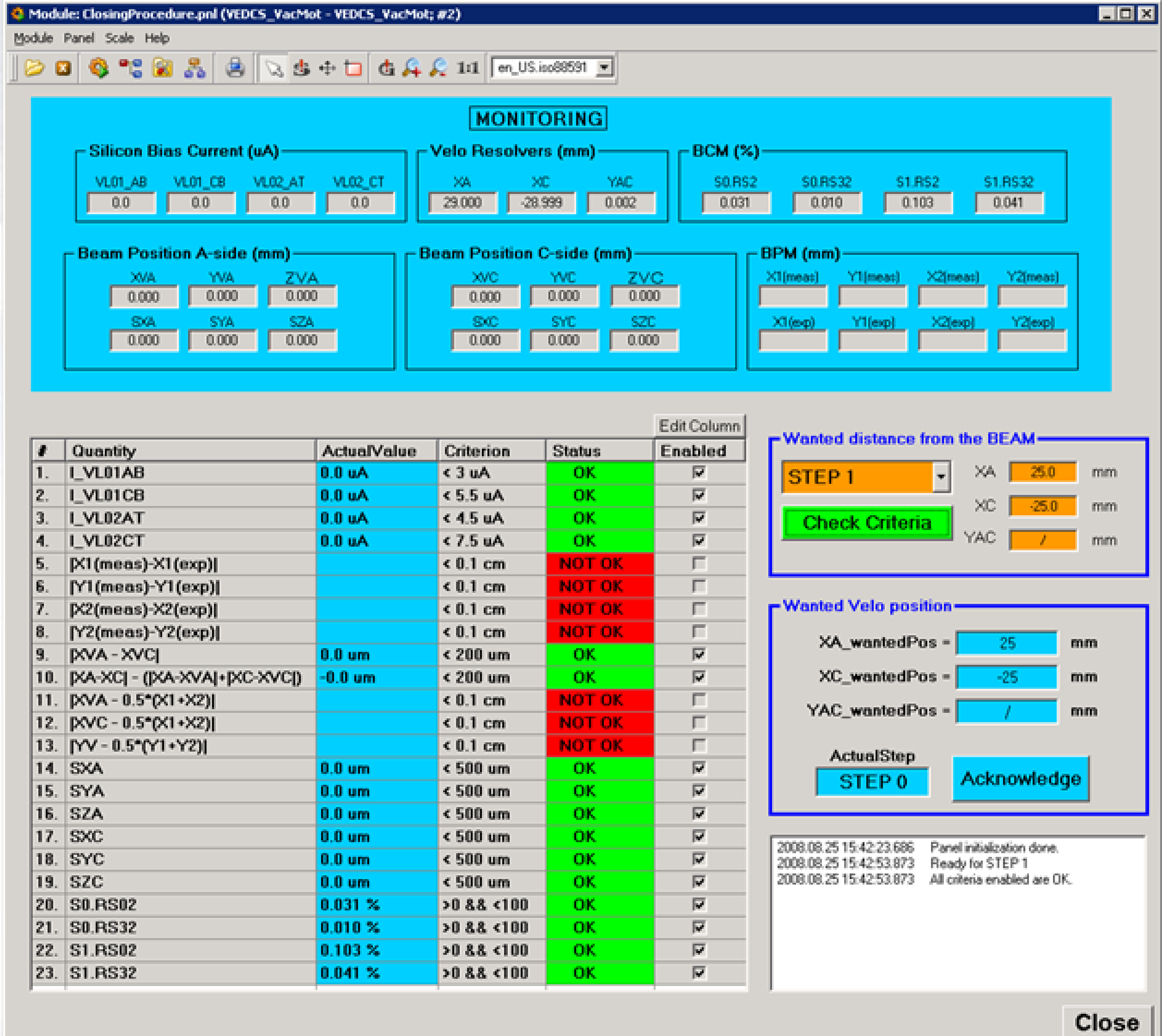
Its output can be:

***a*. Retract and park!**
***b*. Request human!**
***c*. Move to new position!**

PVSS expert panel

SCREEN-SHOT (Stefano de Capua)

NOT the final, top panel for shifters

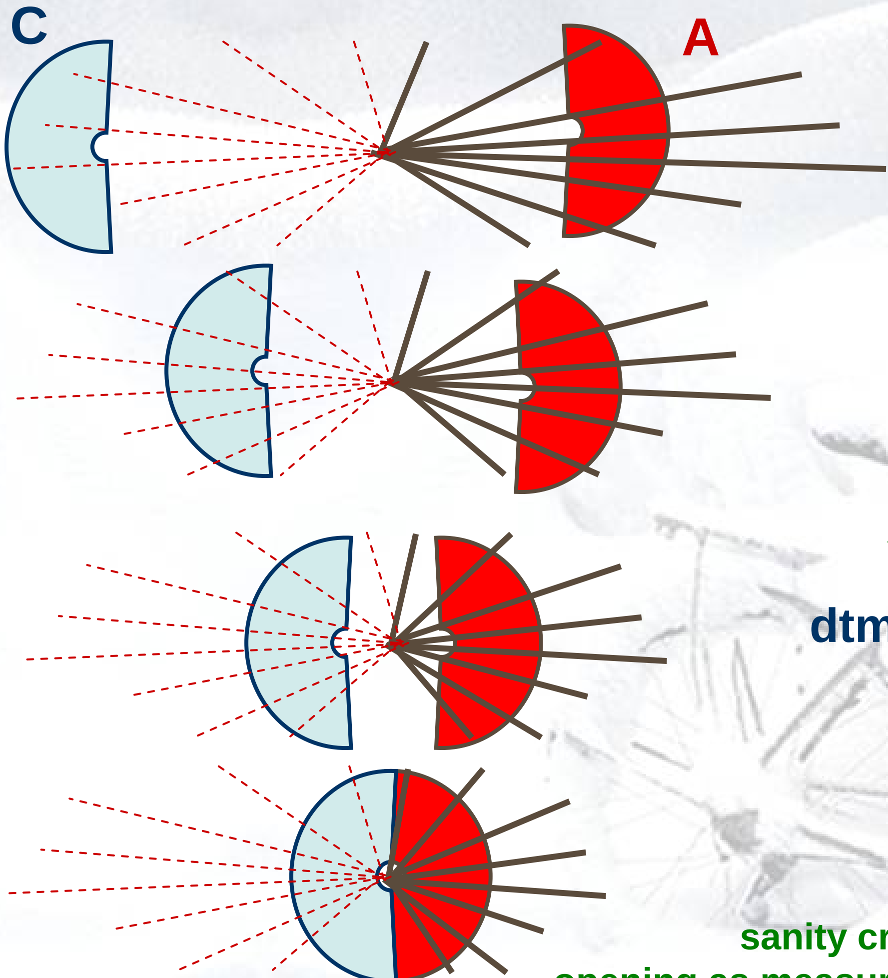


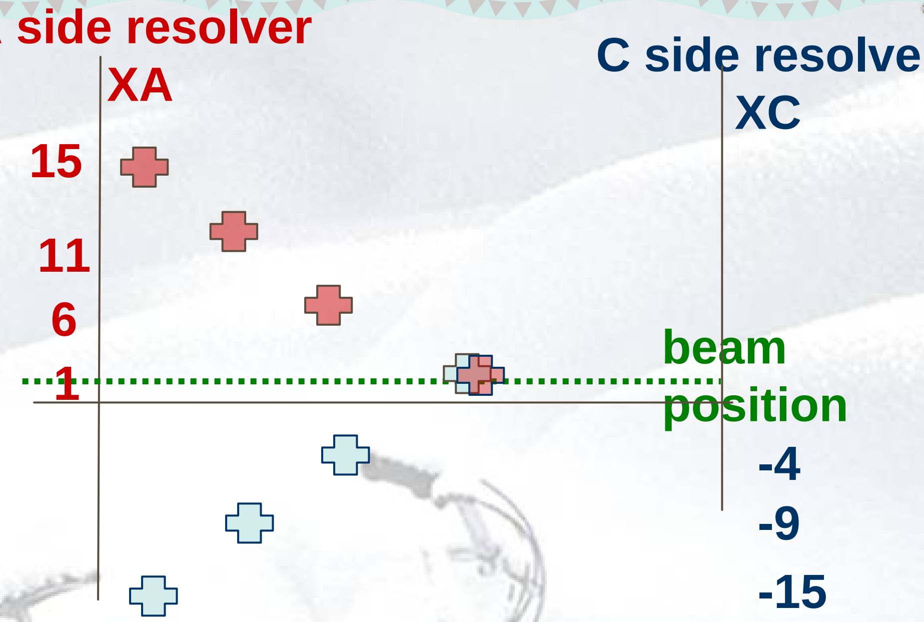
#	Quantity	ActualValue	Criterion	Status	Enabled
1.	I_VL01AB	0.0 uA	< 3 uA	OK	☑
2.	I_VL01CB	0.0 uA	< 5.5 uA	OK	☑
3.	I_VL02AT	0.0 uA	< 4.5 uA	OK	☑
4.	I_VL02CT	0.0 uA	< 7.5 uA	OK	☑
5.	|X1(meas)-X1(exp)|		< 0.1 cm	NOT OK	☐
6.	|Y1(meas)-Y1(exp)|		< 0.1 cm	NOT OK	☐
7.	|X2(meas)-X2(exp)|		< 0.1 cm	NOT OK	☐
8.	|Y2(meas)-Y2(exp)|		< 0.1 cm	NOT OK	☐
9.	|XVA - XVC|	0.0 um	< 200 um	OK	☑
10.	|XA-XC| - (|XA-XVA|+|XC-XVC|)	-0.0 um	< 200 um	OK	☑
11.	|XVA - 0.5*(X1+X2)|		< 0.1 cm	NOT OK	☐
12.	|XVC - 0.5*(X1+X2)|		< 0.1 cm	NOT OK	☐
13.	|YV - 0.5*(Y1+Y2)|		< 0.1 cm	NOT OK	☐
14.	SXA	0.0 um	< 500 um	OK	☑
15.	SYA	0.0 um	< 500 um	OK	☑
16.	SZA	0.0 um	< 500 um	OK	☑
17.	SXC	0.0 um	< 500 um	OK	☑
18.	SYC	0.0 um	< 500 um	OK	☑
19.	SZC	0.0 um	< 500 um	OK	☑
20.	S0.RS02	0.031 %	>0 && <100	OK	☑
21.	S0.RS32	0.010 %	>0 && <100	OK	☑
22.	S1.RS02	0.103 %	>0 && <100	OK	☑
23.	S1.RS32	0.041 %	>0 && <100	OK	☑

Data from vertices vs data from resolver

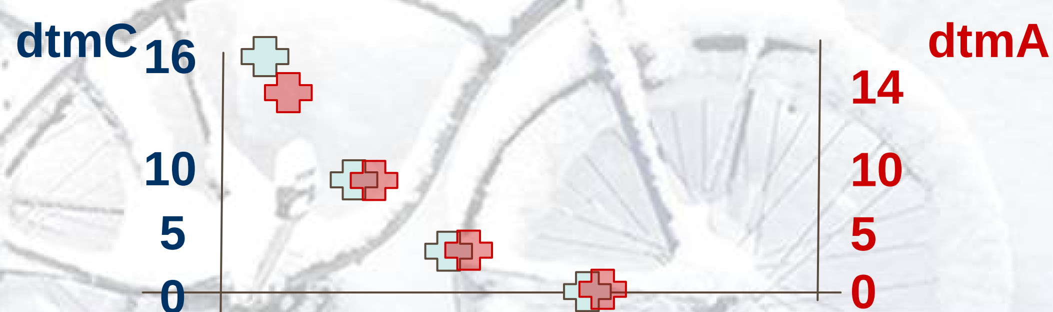
Real Position of the Velo

Example: beam is at x=1 mm





Software calculated distance to nominal



sanity cross check: XA-XC must equal dtmA+dtmC

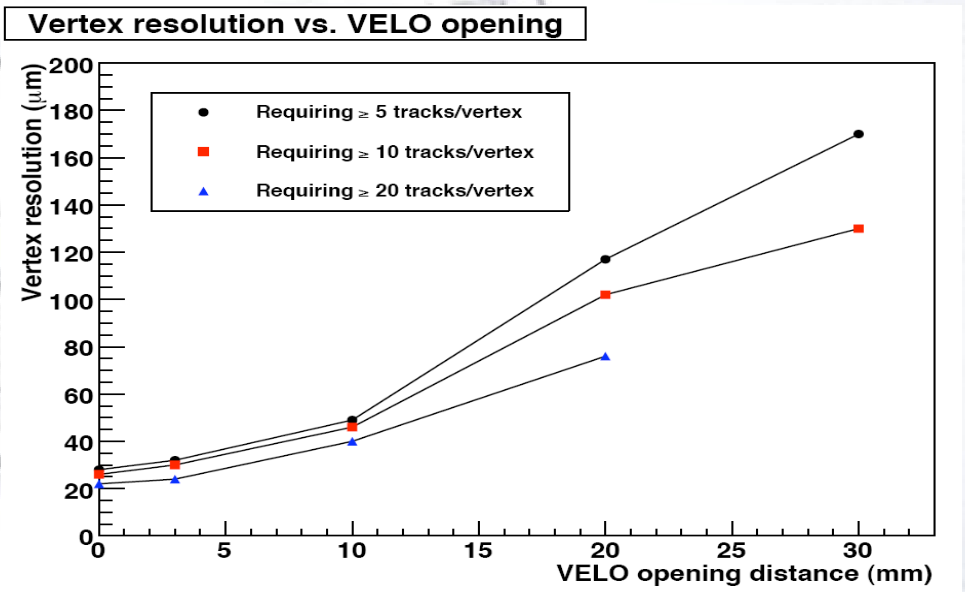
opening as measured with resolvers = opening as measured with software

Control plots used during closing

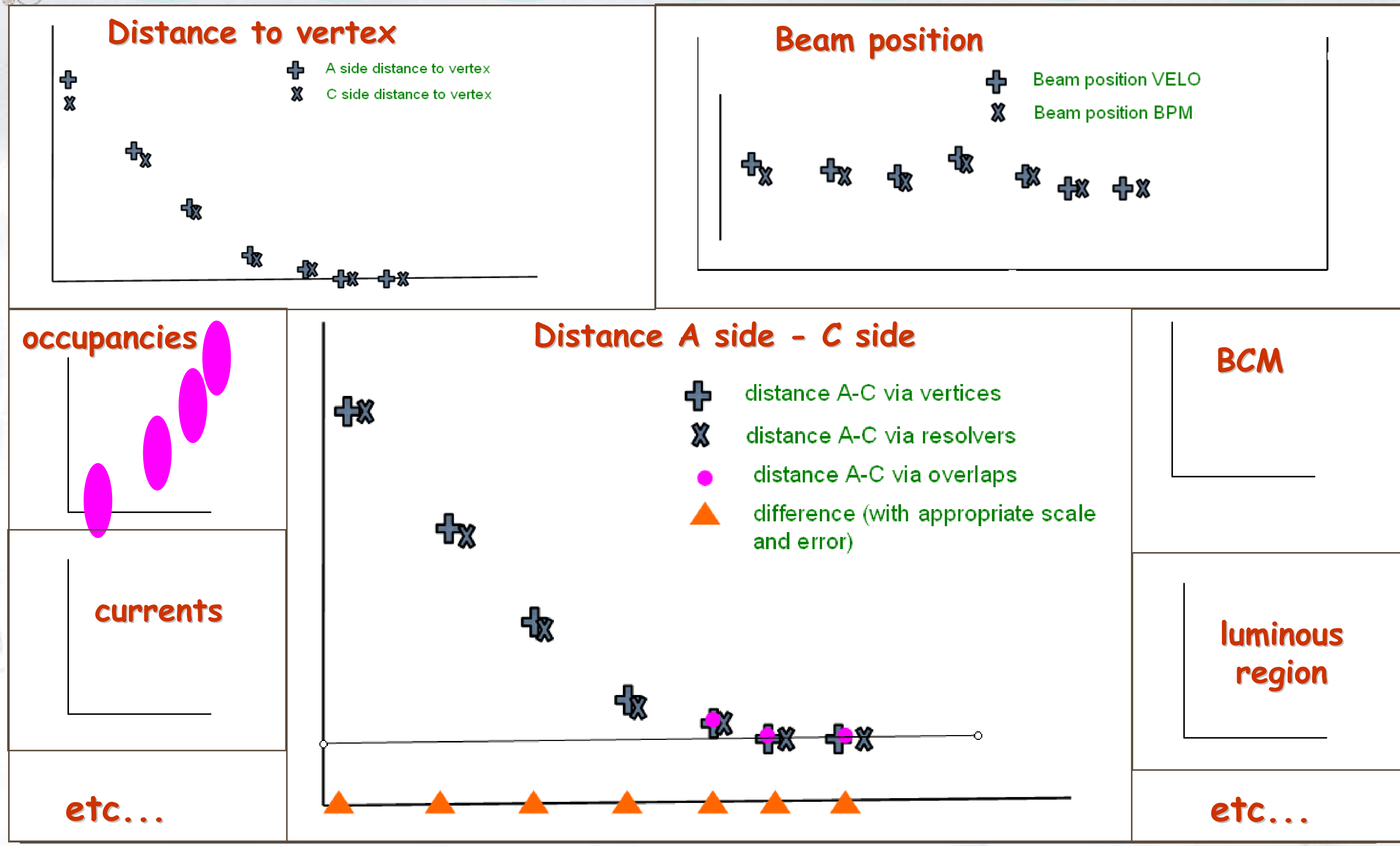
- Resolver measured opening vs software measured opening
- Change in position and total opening as
  - asked to motion control system
  - measured by resolvers
  - measured w.r.t. beam
- Reconstructed position of beam in LHCb coordinates
  - needs software and resolver information
  - Here we are looking for stability and correspondence with BPMs

in x and y independently

- When we are close
  - reconstructed opening distance from vertices vs reconstructed opening distance from overlaps
- The required tolerance will change as we approach



Principal control plots (examples):



Status and Plan

- Demonstrate using decoding HltVertexReports in the online monitoring (January)
- Demonstrate complete chain from HLT input to motion control with FEST data (February)
- Critically review / improve monitoring plots, PVSS interface and human interface (March)
- System check-out (April 1st)

- Extensions: More algorithms.... overlap, cross-checks.

Resolver position

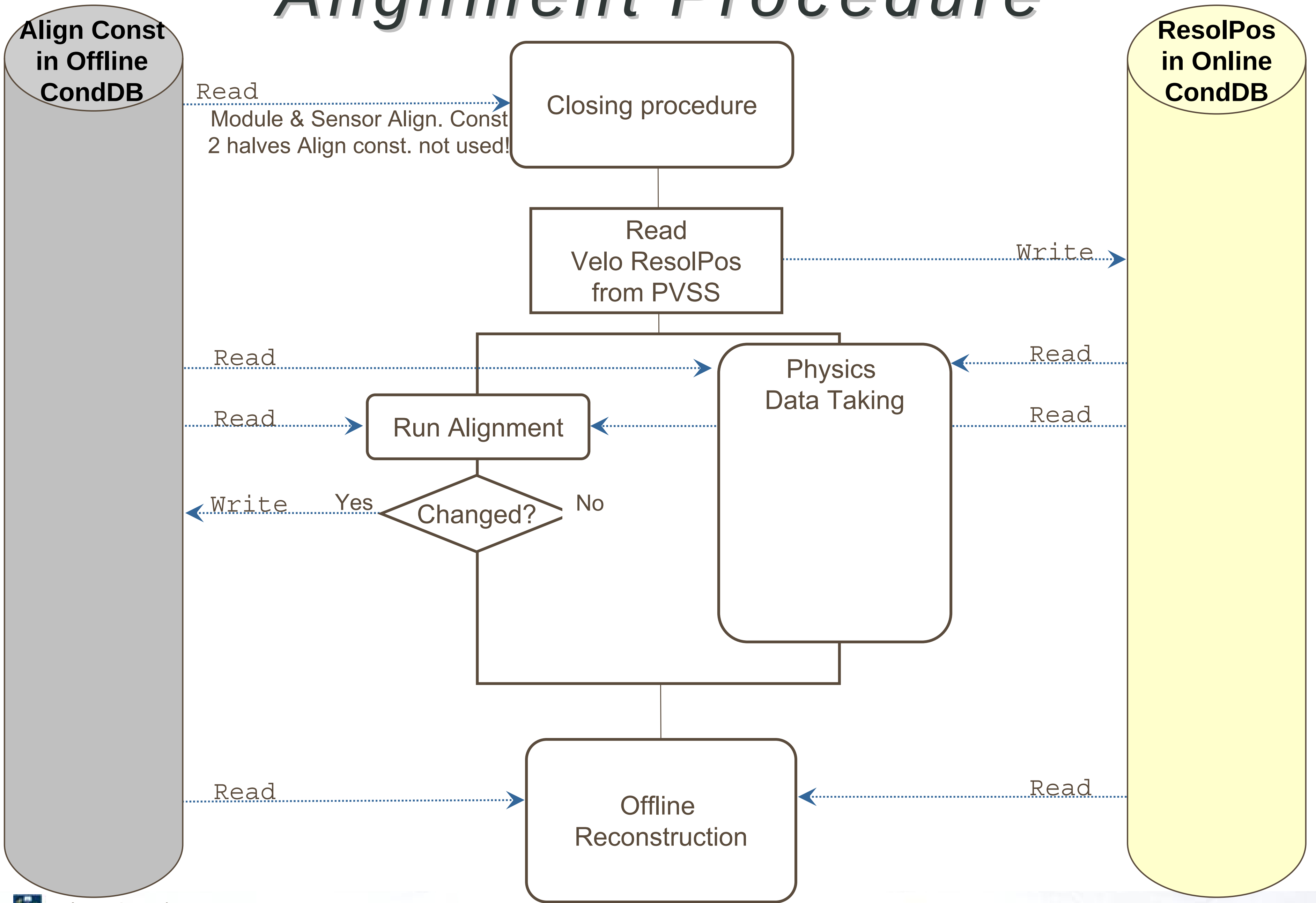
Motion System Summary

- Three pieces of information available (through PVSS):
  - Steppermotor (number of pulses sent)
  - Resolver measurement
  - Potentiometer reading (detector safety system - 0.1mm accuracy)
- Motion accuracy for resolver position:
  - Position accuracy about ~10 μm
  - Position reproducible (moving in the same direction) ~3 μm
- In x:
  - Steppermotor sends 2000 pulses for 50μm (1:40 gearing)
  - 1mm in 9 seconds; i.e. 4½ minutes to drive 30mm
  - Open position is at |x|=29mm
  - Each half can drive up to 5mm beyond nominal x = 0
- In y:
  - Steppermotor sends 2000 pulses for 250μm (1:16 gearing)
  - 1mm in 3 seconds
  - Motion in y is only possible for |x|<16mm
  - Range is –4.7<x<4.7 mm

Alignment information in Condition Database

- Alignment constants in 3 files:
  - Sensor, Module, Global
- Initial alignment from metrology measurements carried out at Liverpool and CERN.
  - Sensor, Module, Vacuum Tank
- Resolver position from the motion system for x and y position of each VELO half
  - It is automatically update into online CondDDB at beginning of run if it is changed from the previous one
  - It is used by the HLT
  - It is automatically update into a private CondDDB each time it changes
- VELO position used in the reconstruction in LHCb reference system is determined by a function that combines the Alignment constant and the resolver position (transparent for the user)

Alignment Procedure



VELO Monitoring

VELO Monitoring

- **Monitoring package**
  - **Package for "high-level" (= ZS) data [VeloRecMonitors]**
    - **Monitoring based on clusters [VeloClusterMonitor alg. in Velo/VeloRecMonitors]:**
      - Cluster ADC value, active chip links, number of strip in a cluster, cluster ADC value versus sampling, number of cluster per events, more…
      - Some of these distributions versus sensor number and/or sensor strip
    - **Monitoring based on tracks [VeloTrackMonitor alg. in Velo/VeloRecMonitors]:**
      - Number tracks, pseudo-rapidity, azimuthal angle, pseudo-efficiency, biased and unbiased residuals versus sensor number, vertex information, hits distribution in xy and xz, more…
  - **Package for NZS data [VeloDataMonitor]**
    - **Noise calculation, time alignment study, beetle pulse shape, …**

- **Scripts and macros are being developed to analyse data:**
  - **Time alignment study,**
  - **Noise calculation,**
  - **High voltage scan,**
  - **More…**

- **Wiki pages with documentation and HowTo's: https://lbtwiki.cern.ch/bin/view/VELO/VELODataQuality**

VELO alignment monitoring

Online monitoring:

- Residual distribution for each sensor
- Overview: Residuals versus sensor number
- Histogram of Mean and RMS of residual distribution for each sensor

Overview of the offline monitoring:

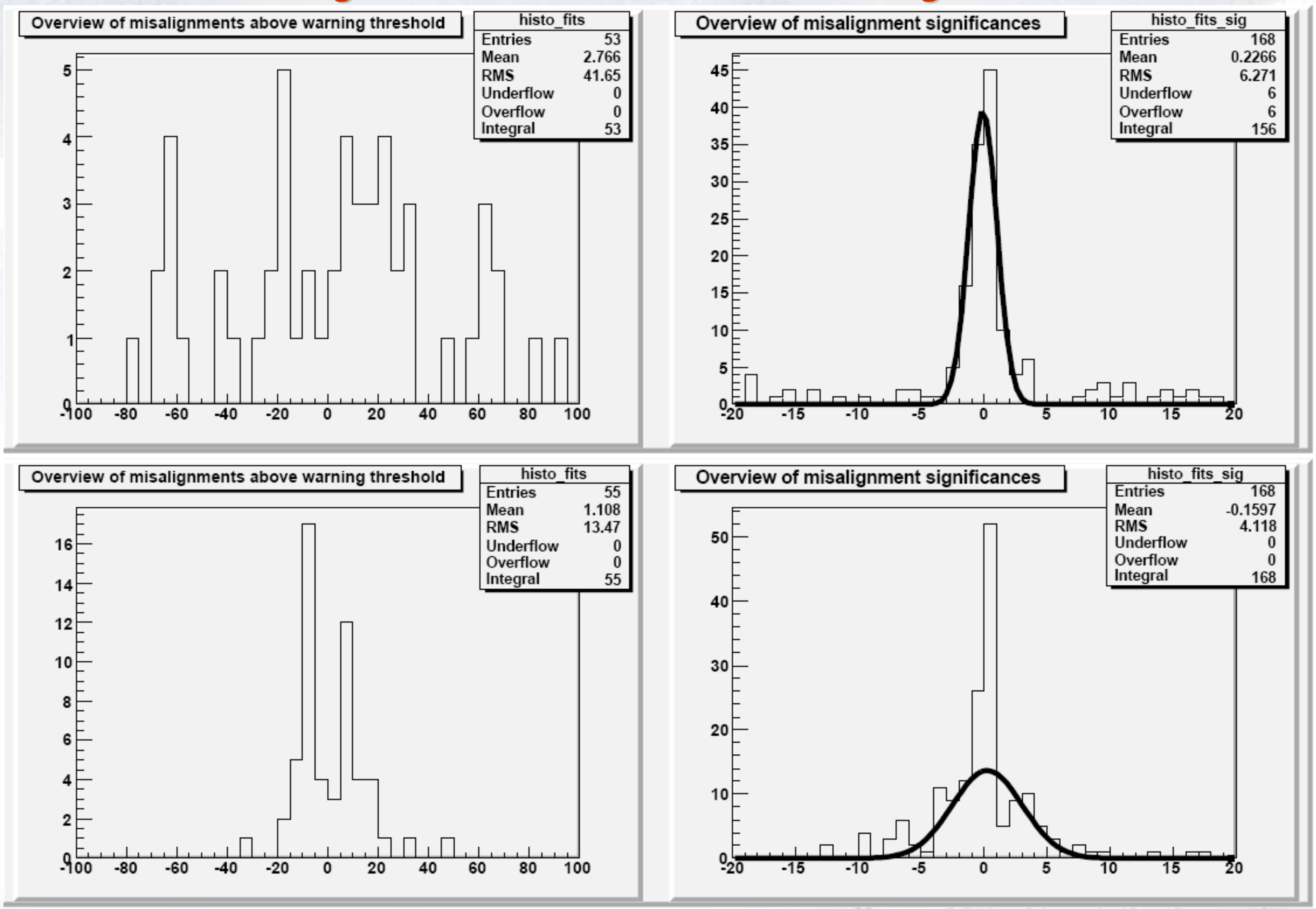
- Measure size of misalignment from residual vs Φ distribution
- Analyse the plots by fitting sinusoidal functions using python scripts
- Script has two levels: warnings and alarms
- Warnings are counted
- Alarms are counted and printed for each module that causes an alarm
- Thresholds depend on fit values (≈ misalignments) and their significances
- Produce overview plots of both

Traces of a 'Gauss bug' in only 98 events

Misalignment | **Significance**

Without Metrology

With Metrology



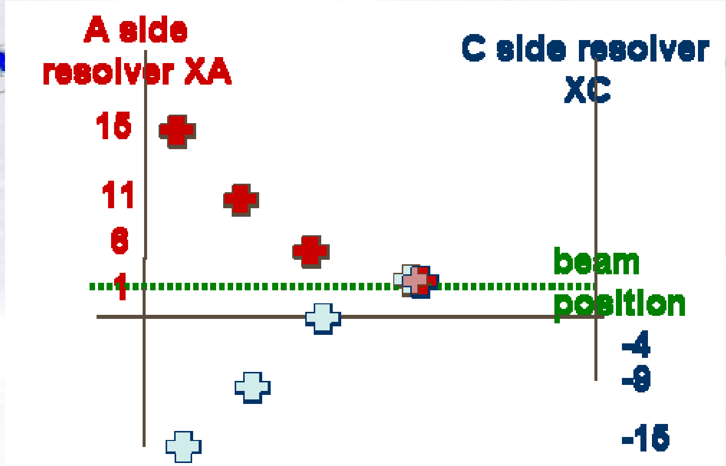
VELO alignment monitoring

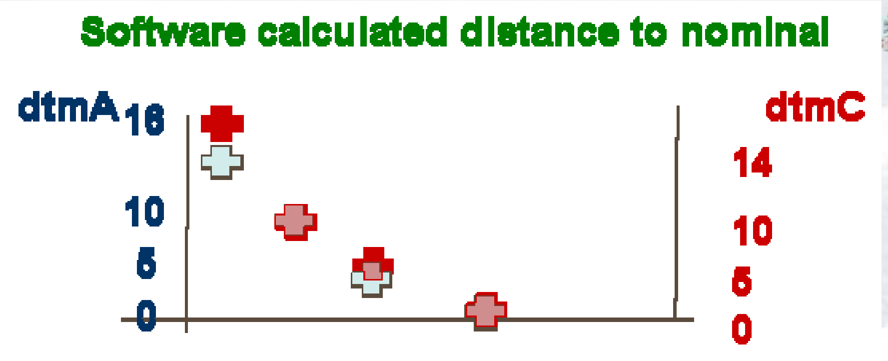
Monitoring of the VELO half alignment

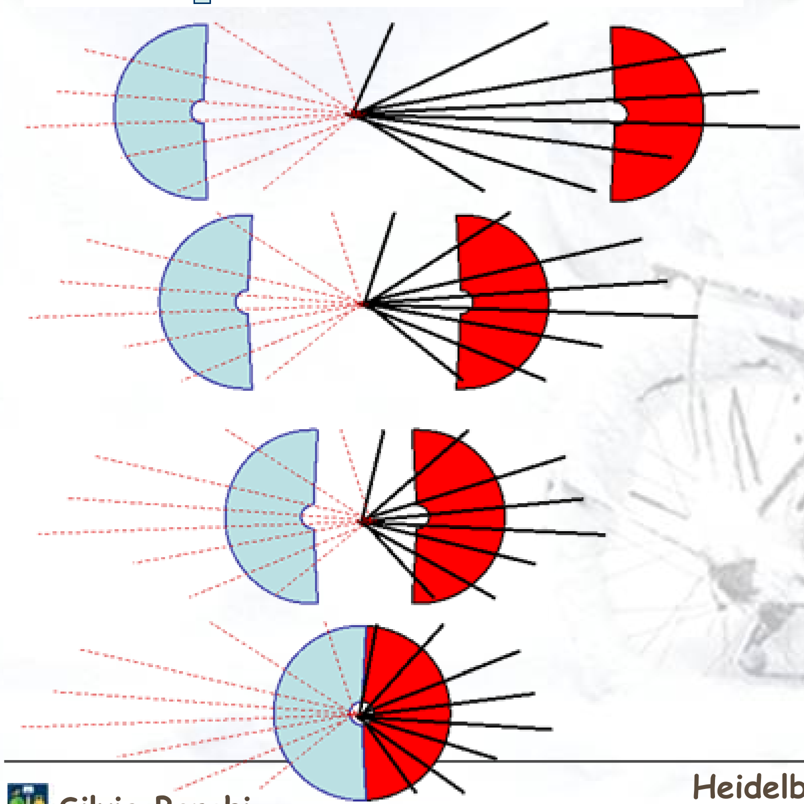
- Monitor VELO half alignment through primary vertices by Offline PV Tool
- Reconstruct PV position with tracks of only one half at a time
- Plot A and C side PV position
- Plot A-C side 2D difference in PV position
- To be implemented in parallel with changes to alignment code

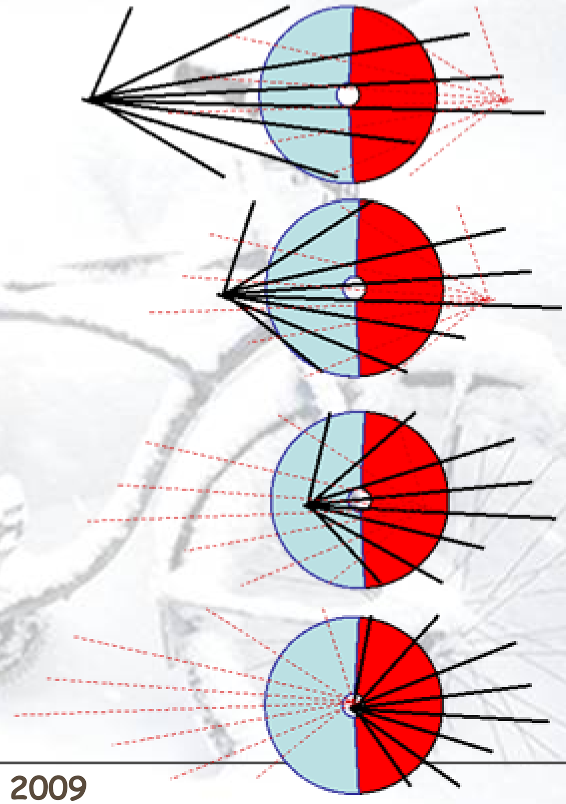
Backup

Closing procedure



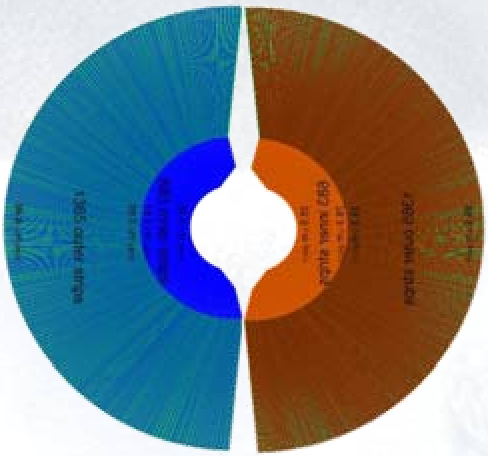


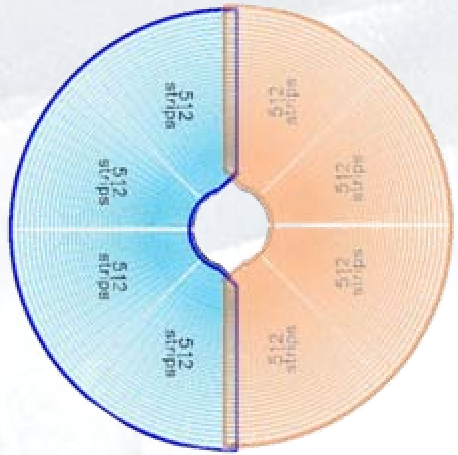


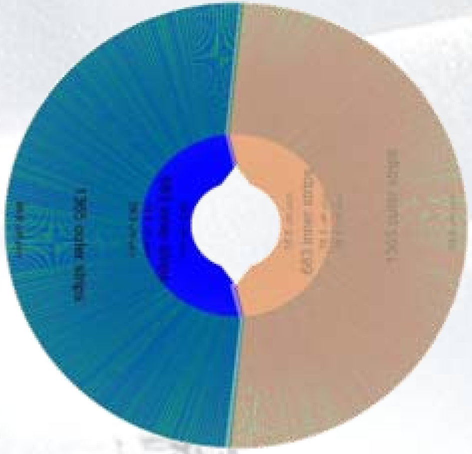


Some interesting closing moments I: Tracks linking A&C

1. Overlaps of sensitive regions:





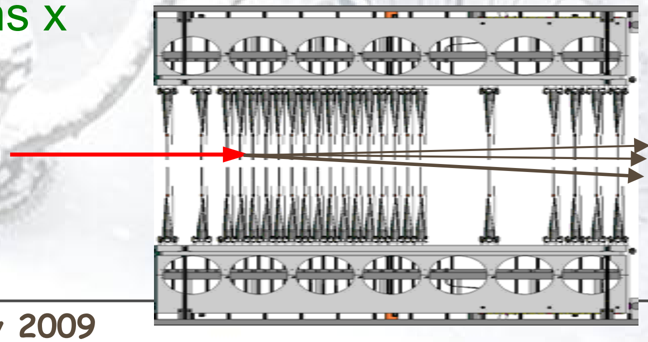


nominal-2.9mm	nominal-1.7mm	nominal-400 μm
ϕ sensors in every other station touch corners (Can we use this?)	R sensors start to give overlap: measure of y and in small regions x	Overlaps in all 4 sensor orientations and along ϕ strips.

2. Tracks passing from A side to C side

Powerful measure of separation

Useful at close distances

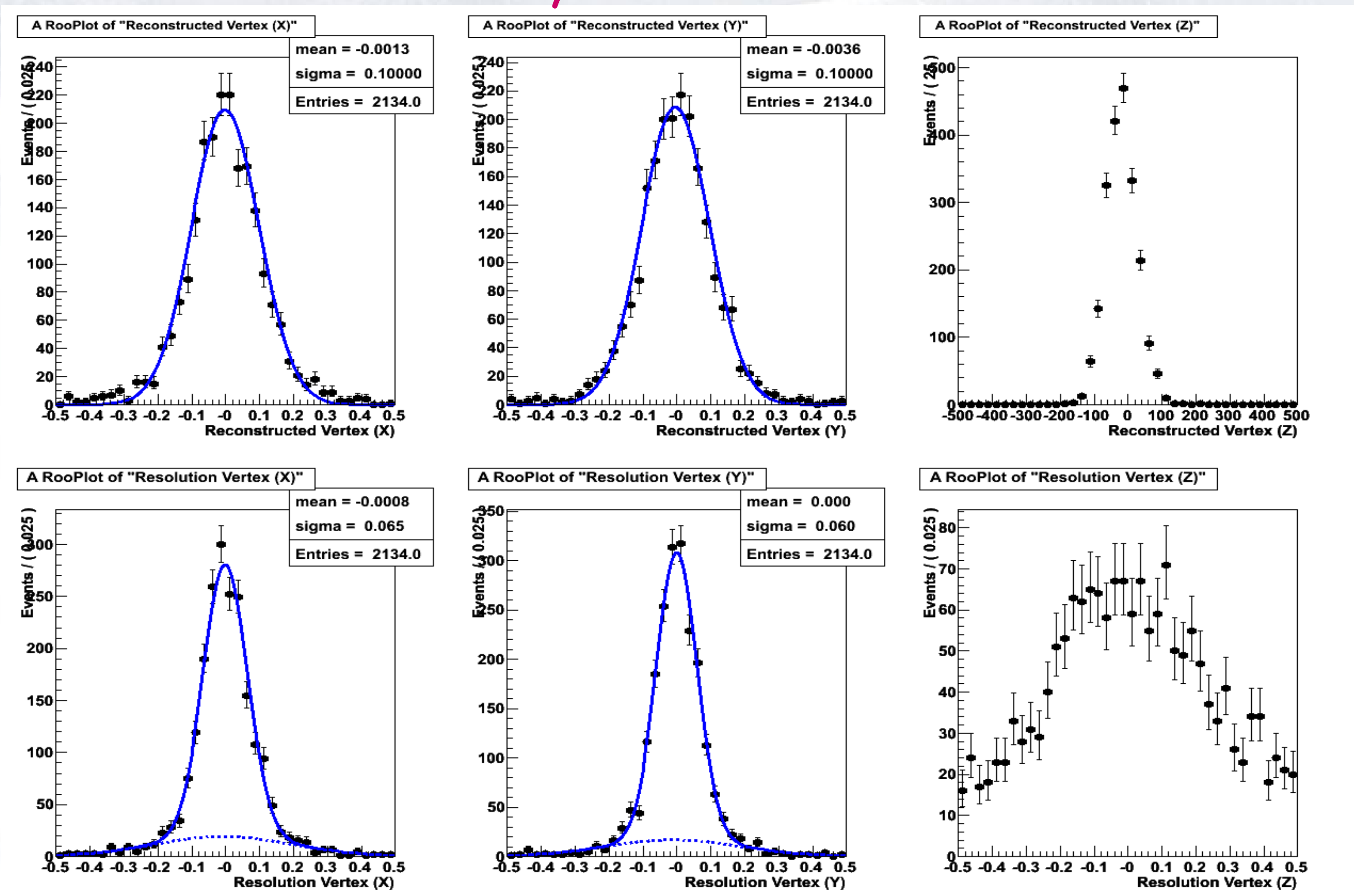


Vertex resolution

x σ_x=100 μm

y σ_y=100 μm

z



Using info of one VELO-half @ x=20 mm

20k min-bias
N(trks)>=10
χ^2(vtx)<=10

σ_{beam}=70 μm

Alignment Method

1. Sensor alignment
   - An iterative approach based on residuals
   - Do separate fits to residual distribution as function of phi and r (uncorrelated to first order)

     $\varepsilon = -\Delta_x \cos\phi_{track} + \Delta_y \sin\phi_{track}$ (R sensor)

     $\varepsilon = \Delta_x \sin\phi_{cluster} + \Delta_y \cos\phi_{cluster} + \Delta\gamma\, r_{track}$ (Φsensor)
   - Extract the misalignment constants:
     - x and y translation
     - rotation around z axis

2. Module alignment
   - Alignment via MILLEPEDE
   - Minimisation done with single matrix inversion
   - Extract the misalignment constants:
     - x, y, z translation
     - rotation around x, y, z axis

3. Velo half alignment
   - Alignment via MILLEPEDE
   - Minimisation done with single matrix inversion
   - Extract the misalignment constants:
     - x, y translation
     - rotation around x and y axis

For more details see notes LHCb-2005-101, LHCb-2007-067 and LHCb-2007-138