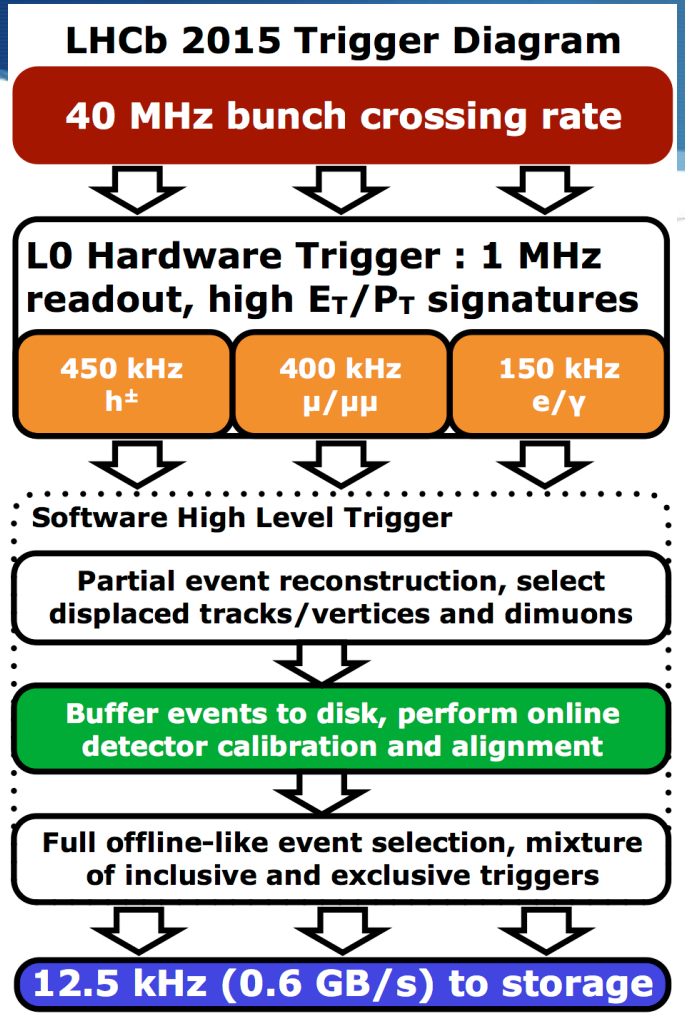
Real-time alignment and calibration: the tracking systems

Silvia Borghi

On behalf of the alignment group

Run 2 strategy



- Buffer all events to disk before running 2nd software level trigger (HLT2)
- **Perform calibration of PID detectors and alignment of the full tracking system in real-time**

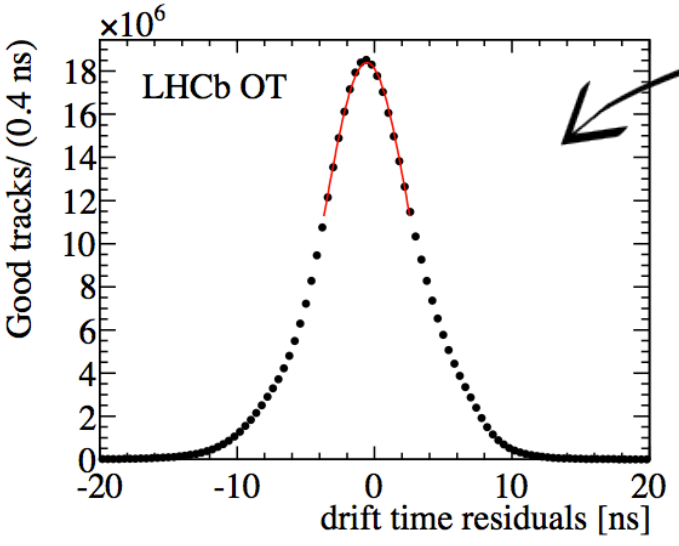
  ➔ same constants in the trigger and offline reconstruction
- Last trigger level runs the same offline reconstruction
- This results to have in the trigger the full reconstruction with the best performance

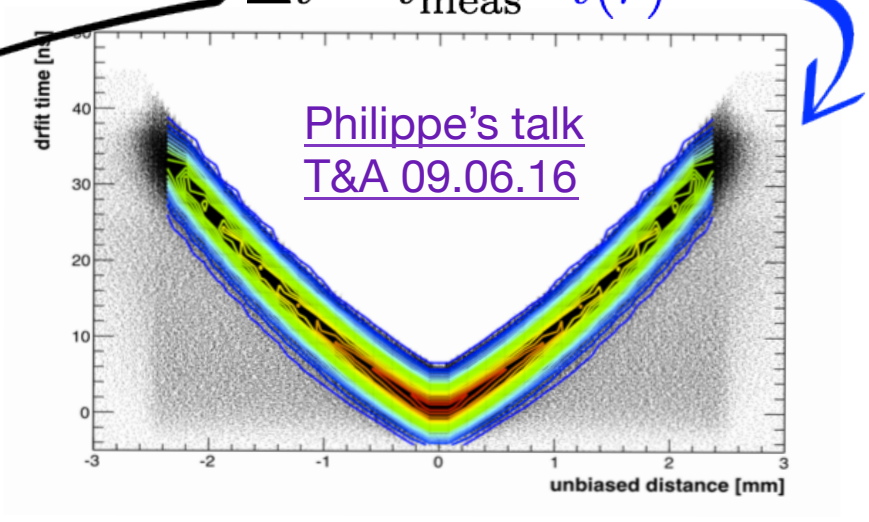
➥ Allowing to profit of the best detector performance and of all PID information in the trigger selection

OT time (t0) calibration

- Measured drift time is different from time estimated from the distance of the track to the wire due to the readout electronics
  - The dominant effect is a global offset due to the difference between the collision time and the LHCb clock, which is time dependent
  - The time offsets per module are stable in time, besides hardware interventions
    - ➡ Real-time global t0 offset calibration + per module (OTIS) offsets calibrated offline
  - The calibrations exploits drift time residuals

$$\Delta t = t_{\text{meas}} - t(r)$$





- Studies of TR relation and resolution in Run 2: TR relation no significantly different, Average time resolution reduced from 3 ns to 2.40 ns (Monolayer alignment + new t0 calib.)

Phillippe A., Lucia G.

Real-time OT global t0

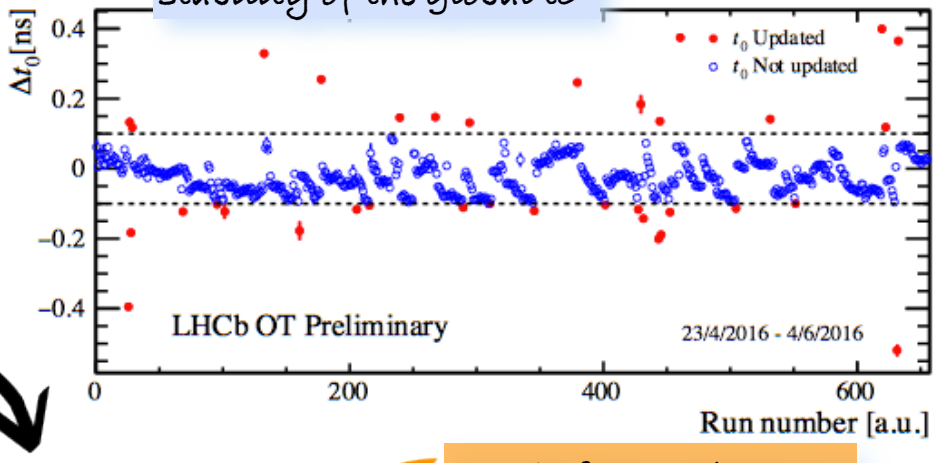
[2016 alignment&calib plots PPTS 06.06.16]

- Calibration fully automatic since beginning of 2015
- Studies of the variation of the t0 nicely consistent with variation of LHC clock wrt. beam (further studies on going)

Operational improvements:

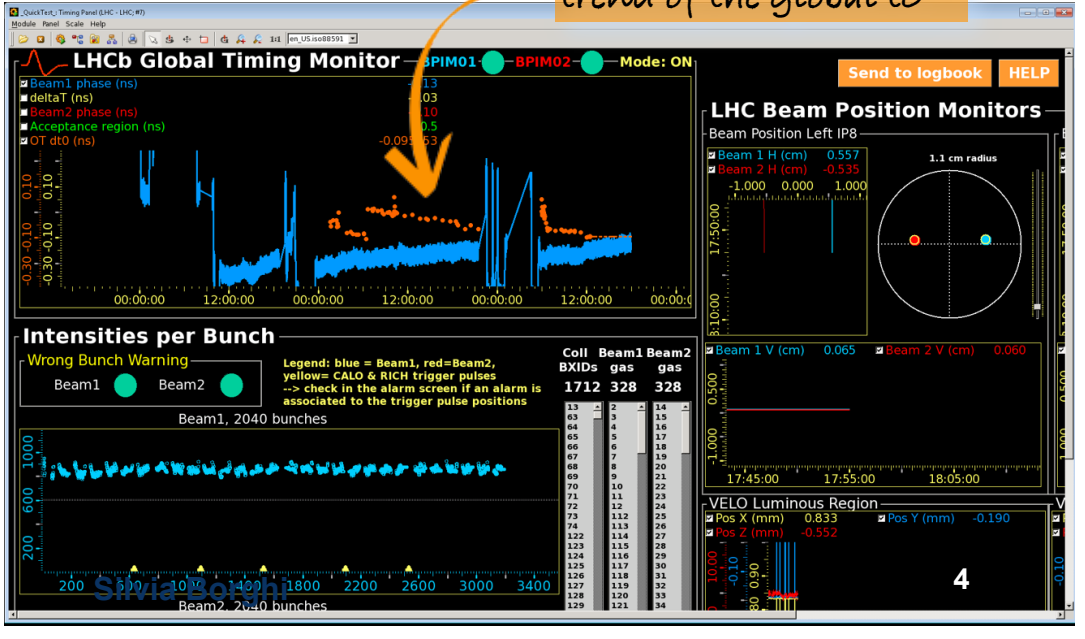
- t0 data points on the LHCb Global timing monitor in Control Room useful to spot a problem with the clock
- Alarm for a too large t0 variation, useful to spot a problem with the clock (these are triggered by an independent system wrt other alarms)
- Alarm when the task is not running (useful to spot problems with the machine used also by the RICH refractive index calibration)
- Still in the process of improving online monitoring

stability of the global to



Thanks Clara, Federico

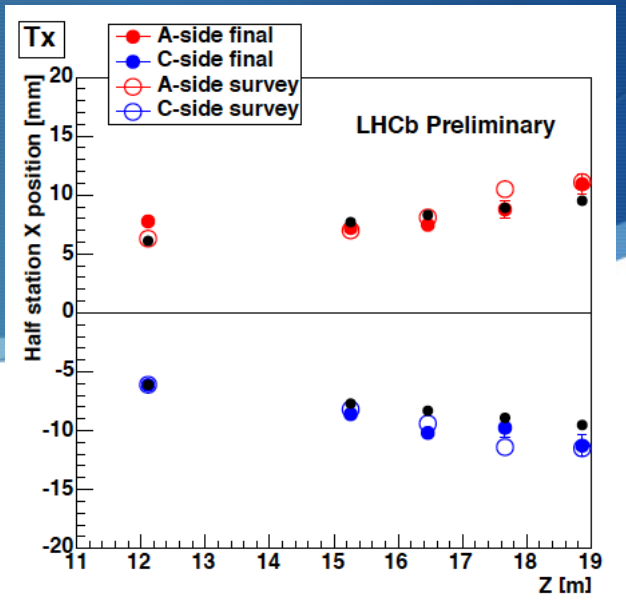
trend of the global to

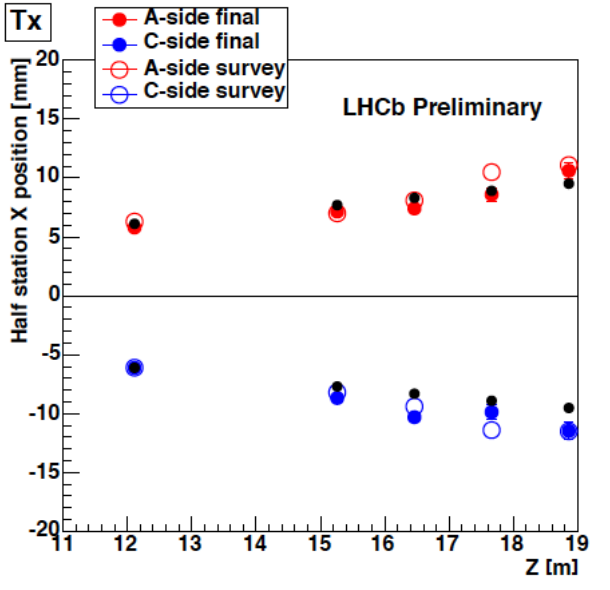


Muon alignment

- Sample: 500k selected muon tracks
- It relies on the tracker alignment
- Needs to have good A/C asymmetry to not create L0 asymmetry
- First 2016 alignment
  - it shows a M1 Tx misalignment of about 2 mm
  - ➡ Mechanical movement
  - New position: good M1A projective
- Run automatically for each fill (or few fills)

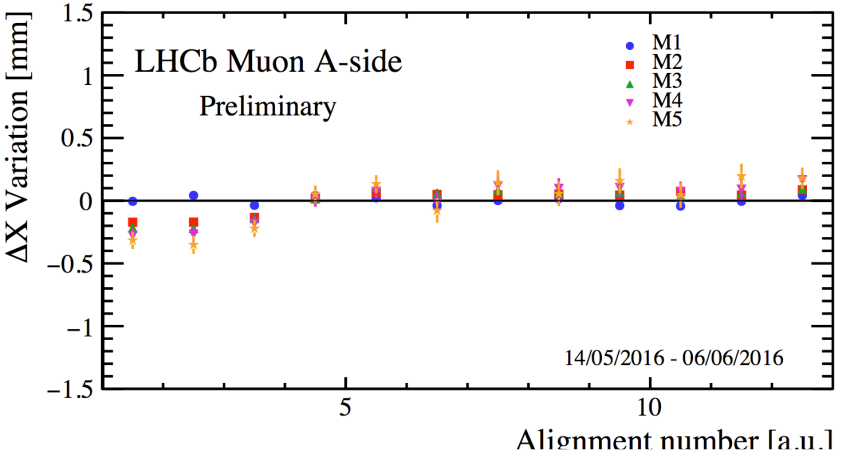
[Stefania, T&A, 6/05/2016, PPTS, 6/06/2016]

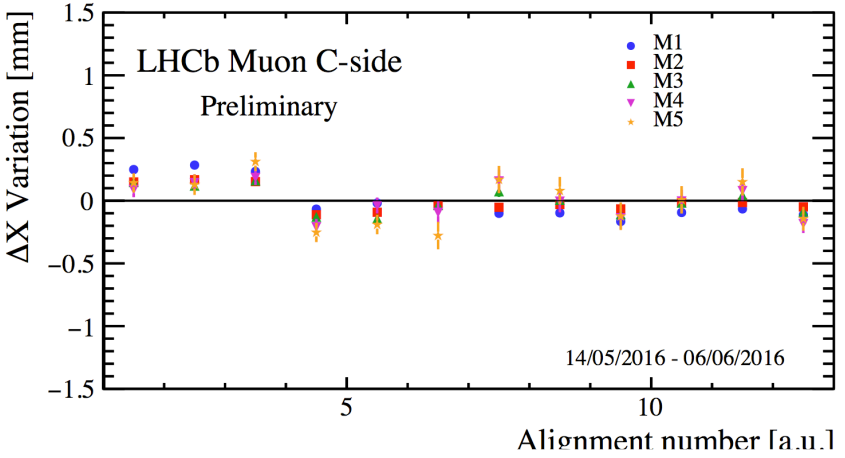


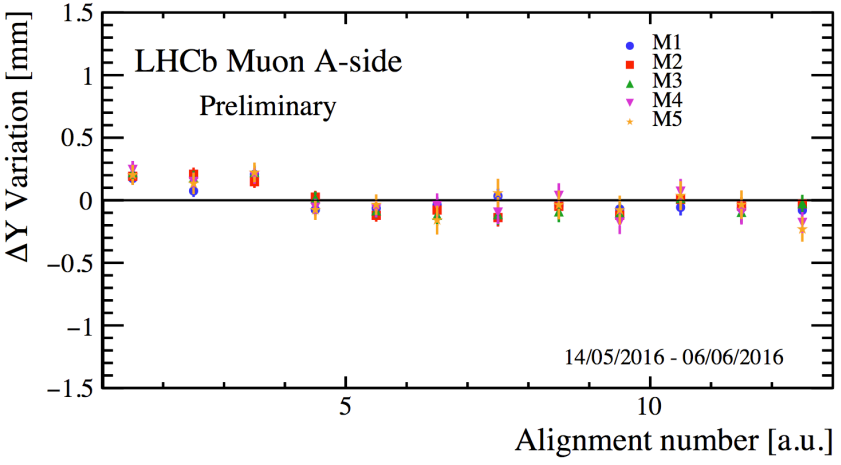


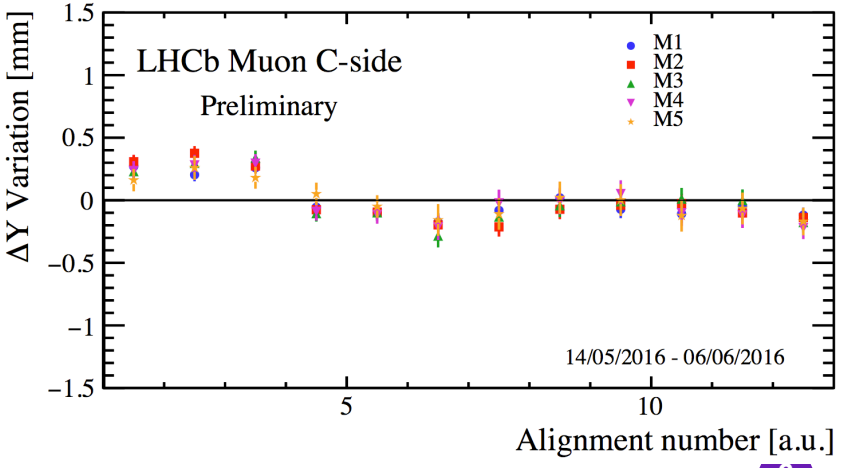
Muon alignment

- Stable condition: variation well below the required precision
- Time to collect data in the latest fills: ~ 3 hours
- It takes ~ 7 minutes to run





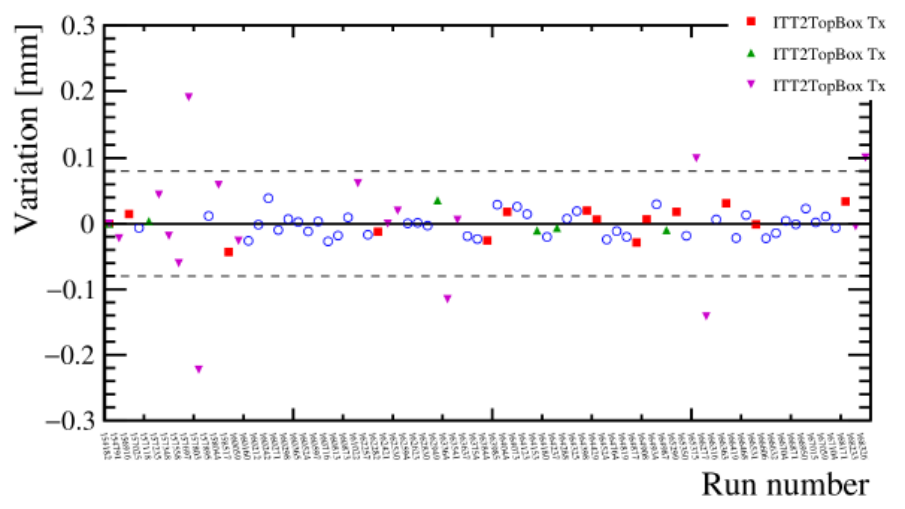


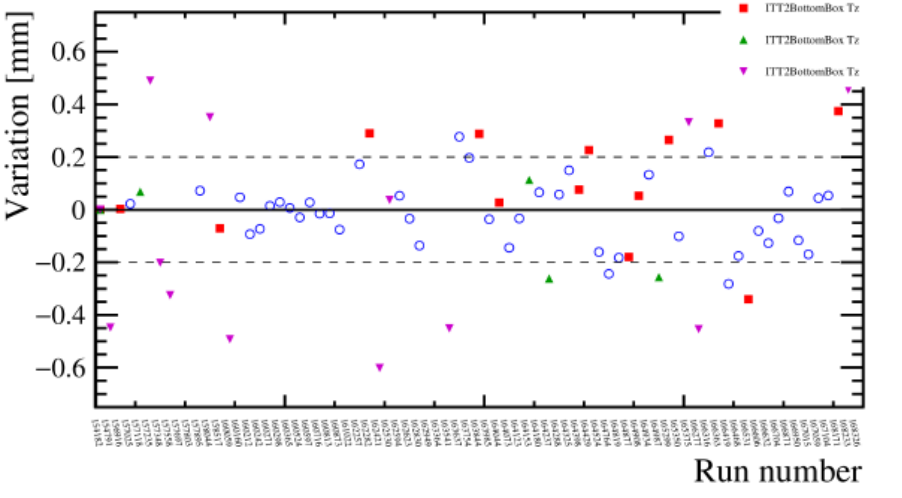


Francesca D., Lucia G.,
Maurizio M., Wouter H.

Tracker alignment

- Several studies during the WS
- Systematic study of the stability of the tracker alignment
  - Optimization of the thresholds [Francesca's talk at T&A 19.04.16]
- As observed for the alignment with Z [Wouter, 15.12.15], internal tracker alignment improves quality
  - OT modules split, split TT modules, IT layers and ladders
  - Internal alignment stable, need to perform only 1 per year





Francesca D., Lucia G., Maurizio M., Wouter H.

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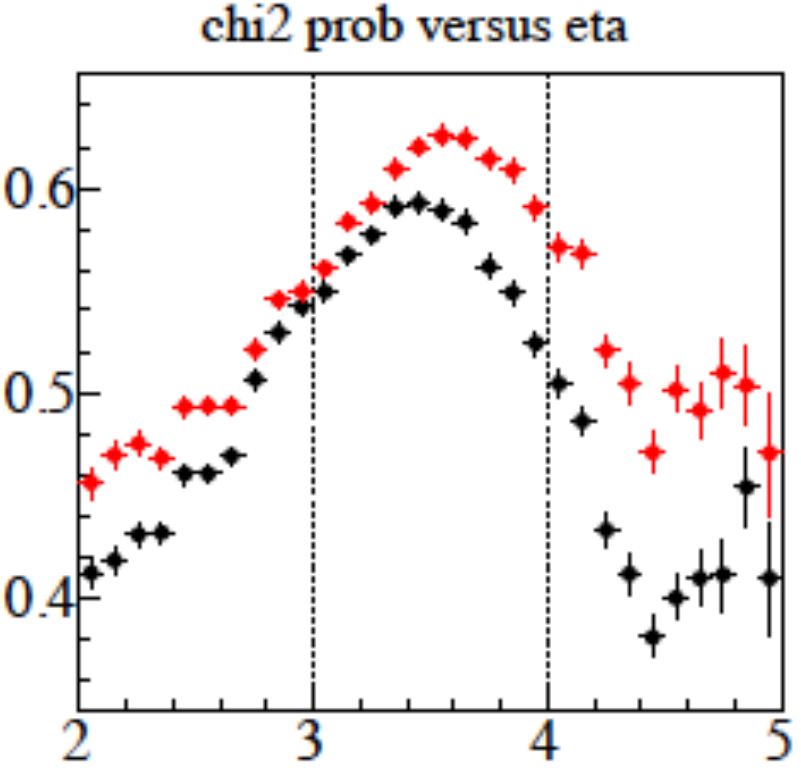
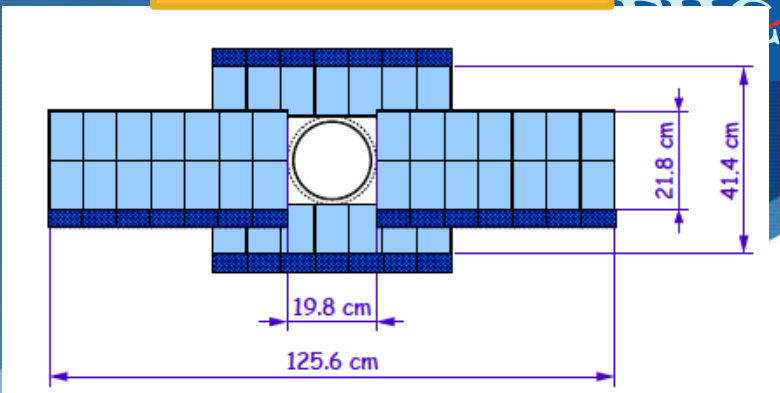


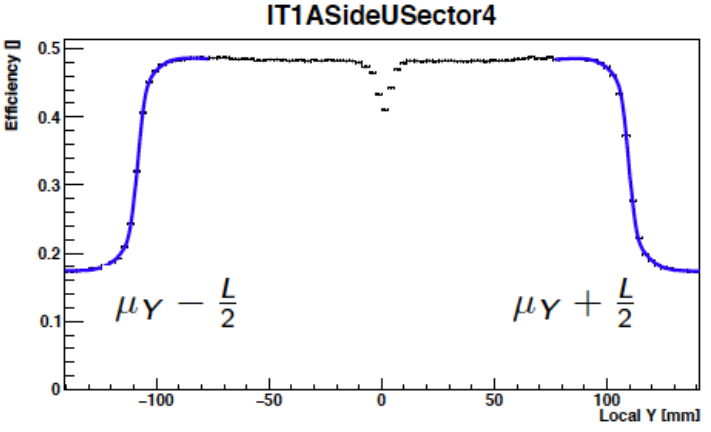
Zhirui X., Pavol S.

Tracker y alignment



- Due to detector geometry, track based alignment not sensitive to Ty
- Ty alignment determined by a ad-hoc method that determines the edges of the detector elements (e.g. sensors)
- Evaluated on Magnet off data collected at the begin of each year.
- Significant variation observed only for IT

[Zhirui, T&A, 17 May 2016]

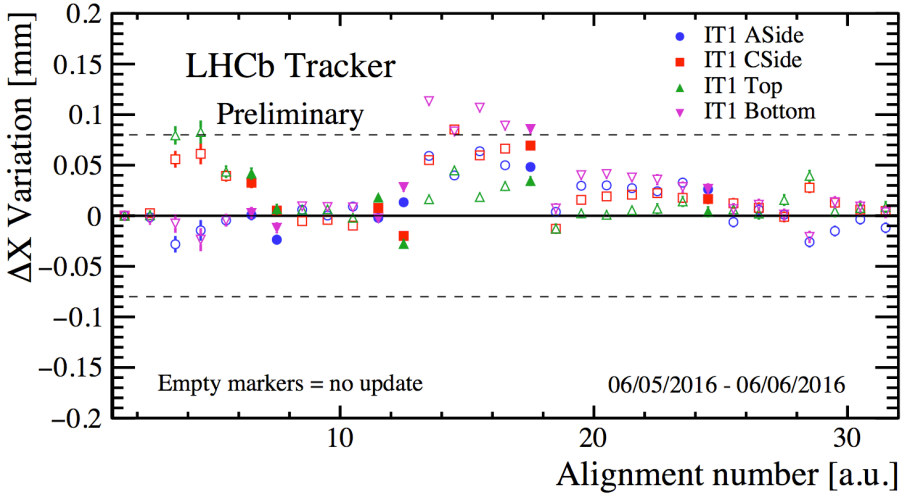


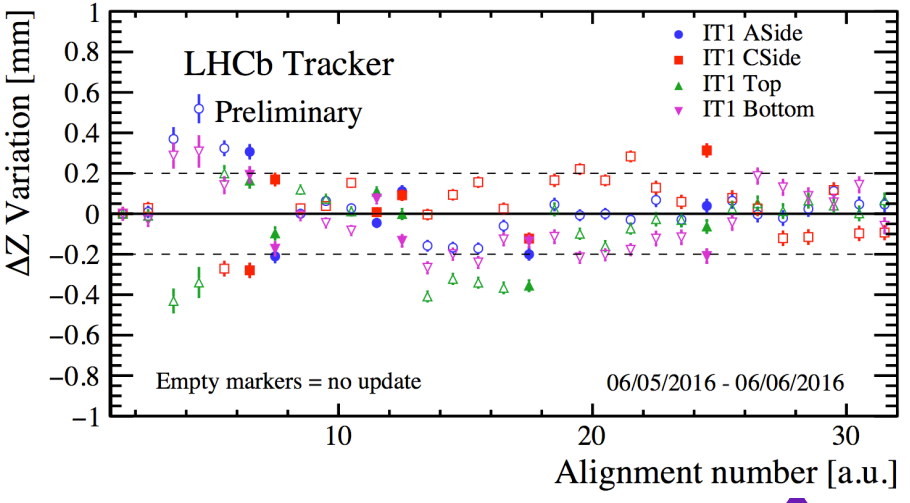
IT	Bottom [mm]	Top [mm]	ASide [mm]	CSide [mm]
IT1	0.03±0.07	0.90±0.05	0.26±0.02	-0.18±0.03
IT2	-0.09±0.08	1.12±0.08	-0.15±0.03	0.55±0.03
IT3	-0.16±0.10	1.63±0.09	-0.18±0.04	-0.30±0.03

Francesca D., Giulio D.,
Lucia G., Maurizio M.

Tracker alignment

- Stable condition: full automatic procedure both for running and updates
- Time to collect data in the latest fills: ~12 minutes
- It takes ~ 7 minutes to run
- Number of update of the alignment
  - Magnet Down: 8 times for 34 fills
  - Magnet Up: 2 times for 10 fills

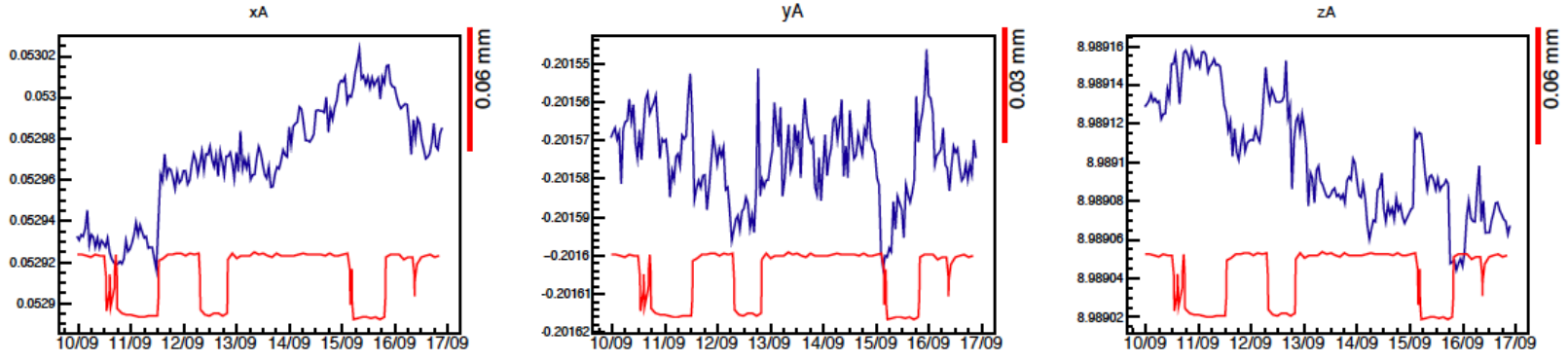




Alignment: hardware system

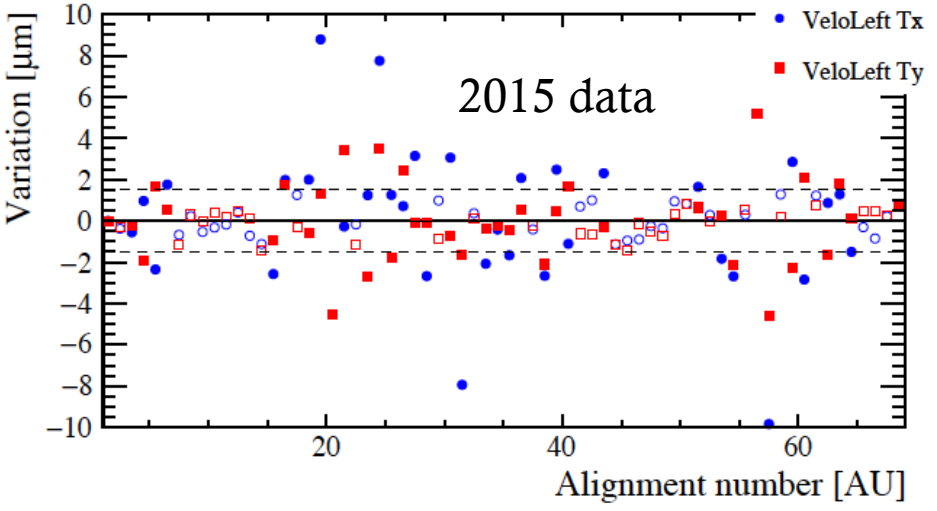
- RASNIK system for OT [more details in Niels summary]
- BCAM system for the IT studied on 2015 data [Pavol Štefko, T&A, 9/02/2016]:
  - Switch magnet polarity introduces substantial shifts T1:Δx~300μm, Δy~400μm, Δz~10 mm
  - Movements at the level of ~30 μm
  - Some trends not explained by the temperature
- Study ongoing to correlate the hardware measurements and track based alignment

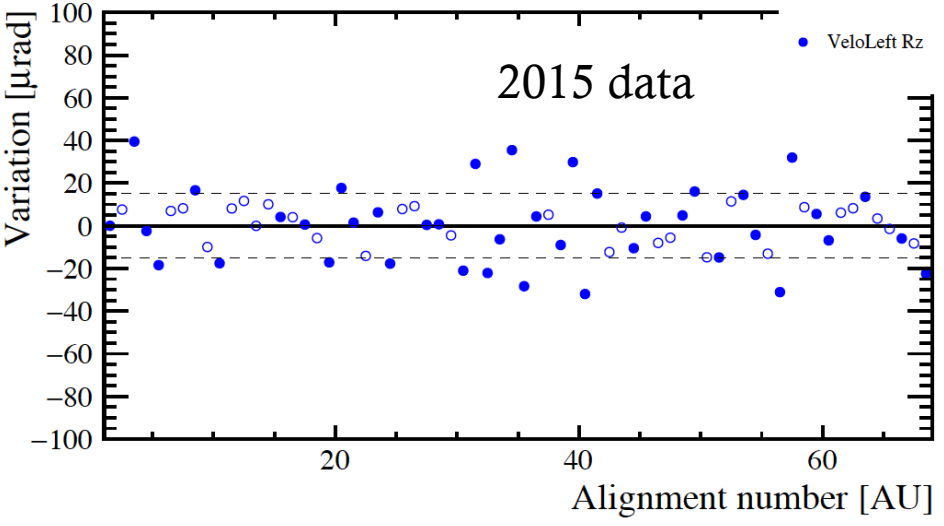
IT3



Velo alignment

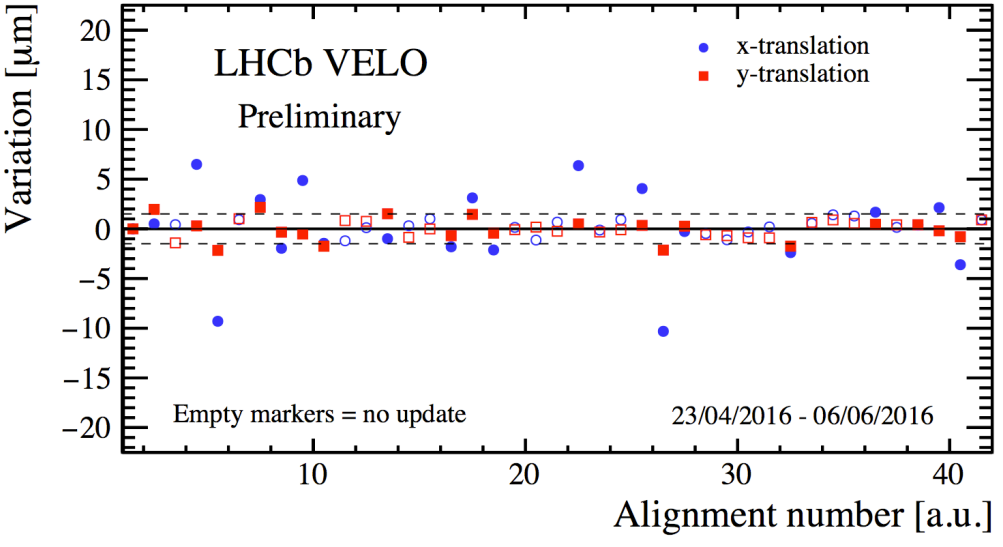
- Systematic study of the stability of the VELO alignment
  - Optimization of the thresholds [Giulio's talk at T&A 03.03.16 and 9.06.2016]
- Module alignment run manually and no significant variation was observed





VELO alignment

- Stable condition: full automatic procedure both for running and updates
- Time to collect data in the latest fills: ~ 5 minutes
- It takes ~ 2 minutes to run
- Number of update of the alignment 23 times over 52 fills



Alarms and Monitoring

- Many alarms implemented
  - Message to ask to the DM to check the alignment convergence plots
  - A new alarm in the panel + email to experts in case the alignment procedure fails
  - A new alarm in the panel + email to experts in case the alignment constant shifts are unreasonably large
  - Alarm when the OT task is not running (same machine used also by the RICH refractive index calibration)
- General alarm:
  - Online conditions are different for hlt and offline production
- Improvements of the monitoring:
  - Clean up for DQ and new pages for DM
- Still improvements in the monitoring ongoing

Conclusion

- Very successful run of the full automatic alignment procedure for the full LHCb tracking system!
- Move from experts to Alignment piquet system
- Plots for conference at: https://twiki.cern.ch/twiki/bin/view/LHCb/ConferencePlots
- Next steps:
  - Continue to monitor the stability and eventual weak modes
  - Further study to determine a chi^2 threshold to avoid iterations not needed
  - Work ongoing to correlate the hardware measurements and track based alignment results
  - Improvements of the monitoring

Huge thanks to the online and hlt piquets for all the support

Conclusion

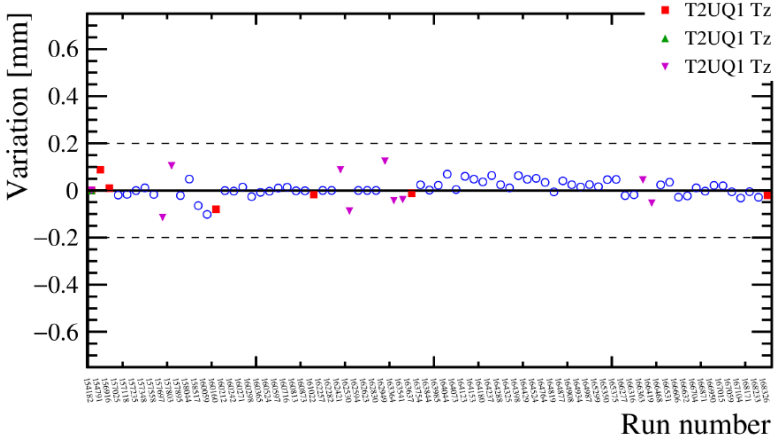
	VELO Alignment	Tracker Alignment	RICH mirror Alignment	Muon Alignment	OT t0 Calibration	RICH Calibration	CALO LED Calibration	CALO pi0 Calibration
run	**Automatic**	**Automatic**	**Automatic**	**Automatic**	**Automatic**	**Automatic**	**Automatic**	Manual
automatic update	**Automatic**	**Automatic**	no	no	**Automatic**	**Automatic**	**Automatic**	no
when the procedure run	each fill	each fill	each fill	each fill	each run	each run	each fill	~1 per month
type of events	min bias +beam gas	D0 sample	HLT1 selected sample	J/psi sample	min bias	HLT1 selected	min bias	min bias
num of events	50k	100k	3M	250k	run on SaveSets	run on SaveSets	O(1h) of LED data	~100M
std time to collect data	5 min	12 min	1.5 hours	3 hours	O(min)	~15 mins	Run only for fills >2.5h	3-4 days
average time to run	2 min	7 min	20 min (for both)	7 min	O(min)	O(min)	O(min)	5 hours

More information at https://twiki.cern.ch/twiki/bin/view/LHCbInternal/CalibAlignProcedures

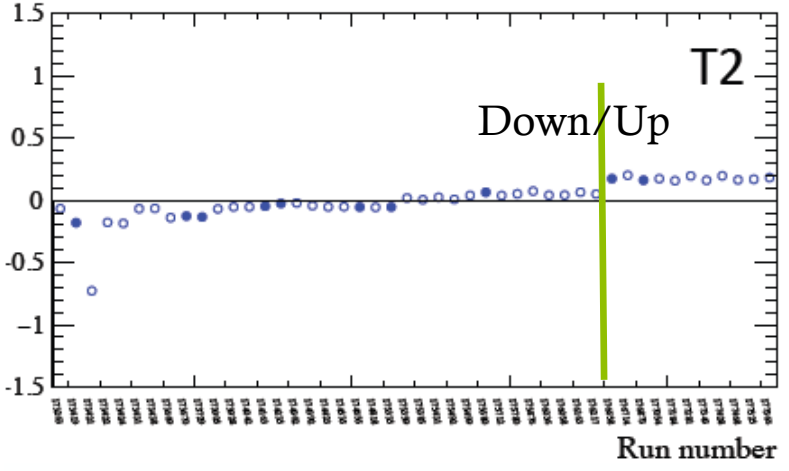
Backup

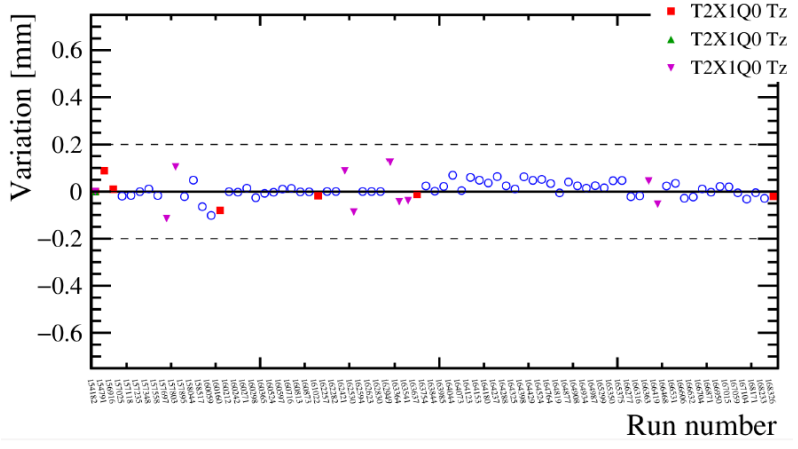
OT Tz trends

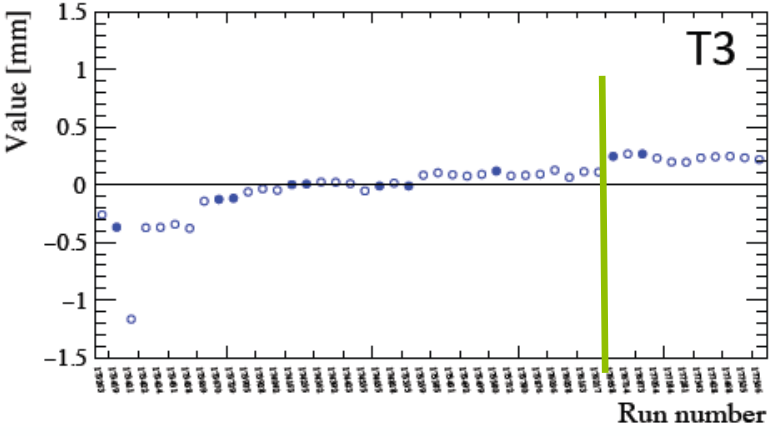
2015



2016







Convergence criteria

- total change in χ^2 / num alignables < 2
- largest change in χ^2 of a single mode $\lesssim 25$

modes: linear combinations of alignment parameters that diagonalize second derivative χ^2

Update criteria

dof	Min variation	Max variation
T_x T_y [μm]	1.5	10
T_z [μm]	5	10
R_x, R_y [μrad]	4	25
R_z [μrad]	30	100

- Usually 2-3 iterations before convergence is reached
- Update once every 2-3 fills

B. Jost, C. Gaspar, M.Frank

Procedure

- Requirements: to be fast, to be evaluated in real time, updated as soon as it is available
- Implemented in the new alignment online framework
  - Using the parallelization of the task on ~1700 nodes of hlt farm
  - Collect all the information in a single node for evaluation of the constants (matrix inversion or fitting histograms)
- Very flexible and improved to accomplish the different requirements of each task

Job configuration

parallelization on several nodes