VELO alignment

VELO parallel session
109th LHCb Week

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on behalf of the VELO alignment team

25.09.2023

Overview

Goals of past months (as of April VELO group meeting):

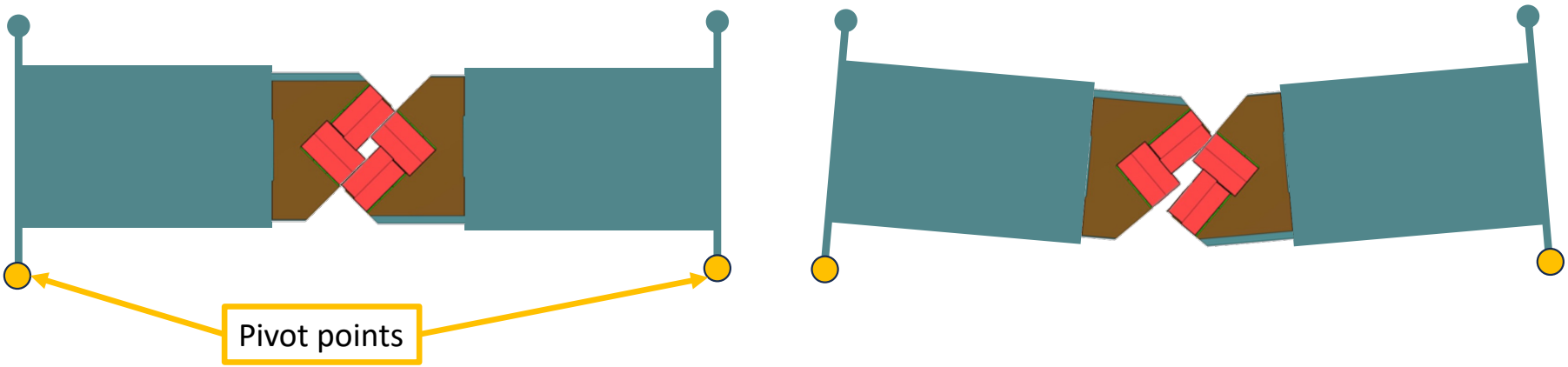
- understand current half misalignment after vacuum incident
- check if module alignment changed
- validate sensor alignment
- full commissioning of online alignment $\rightarrow$ main priority for this year

Additional studies:

- global VELO position
- motion system precision
- stability of half alignment

2023 half alignment

At start of this year, half alignment impacted by vacuum incident

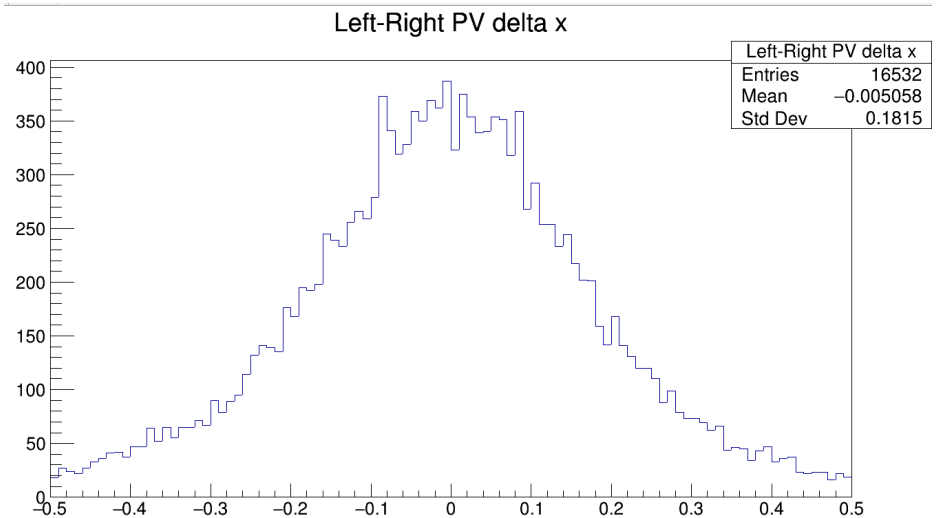


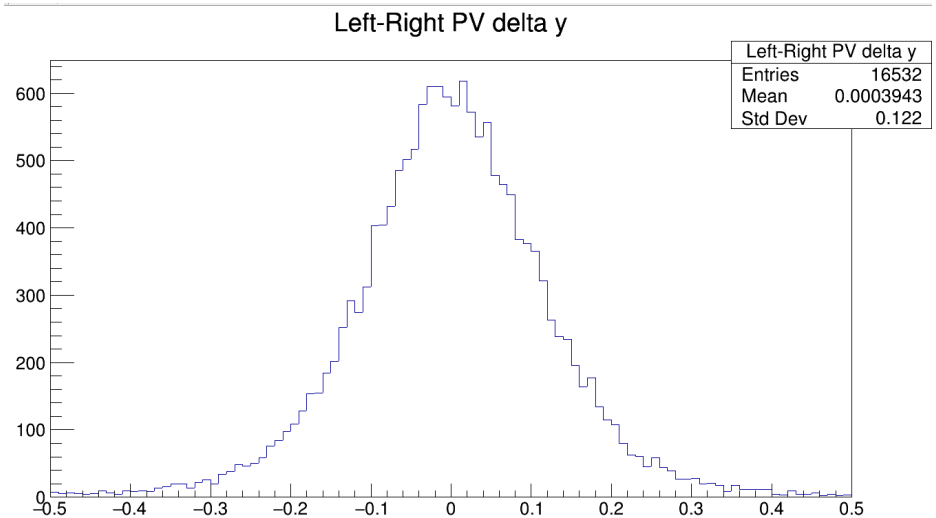
- rotation R_z leading to shifts in x and y
  - half alignment somewhat sensitive and shows $R_z \approx 3\,\text{mrad}$
- half alignment sensitive to x shift
- global movement in y
  - can not be corrected for by half alignment

2023 half alignment

Large half misalignment seen at start of 2023 data-taking

- half constants from last year VELO open
- $\Delta x(PV_{left} - PV_{right}) \approx 2\,\text{mm}$
- $\Delta y(PV_{left} - PV_{right}) \approx -0.17\,\text{mm}$





run 261204 after half alignment converged

- half alignment can recover misalignment in x and y
- global shift in y required dedicated study

VELO global position

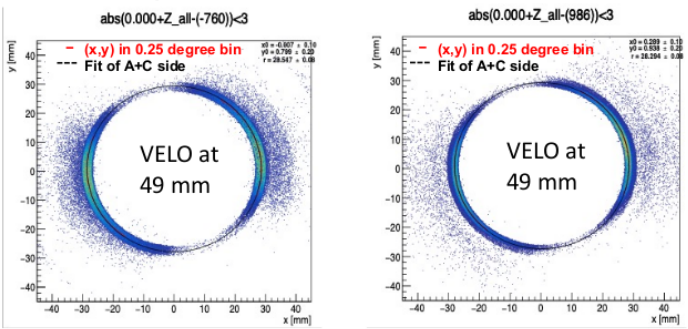
Determine VELO global position using material interactions and survey measurements [slides]

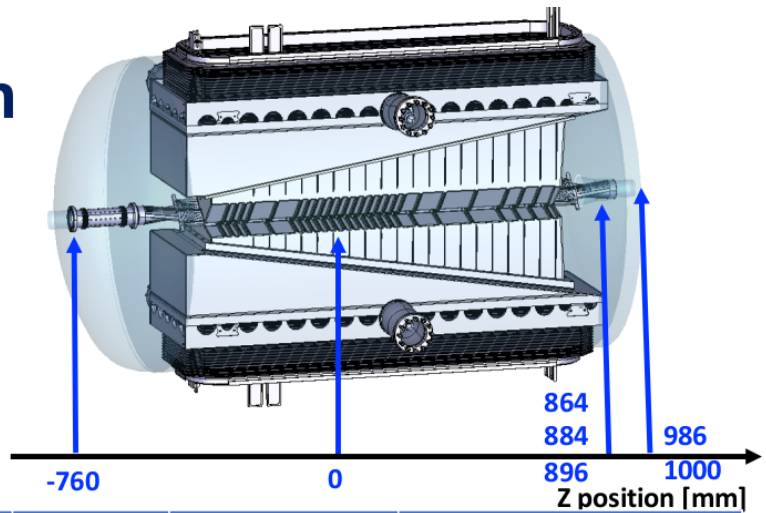
- global x and y using beam pipe

VELO x and y global position

- Determination of x and y position by fitting circular section reconstructed by tomography data at different z: expected to be centred at (0,0)

  Example: slice of downstream beam pipe





		VELO at 49 mm		Δ (VELO open; at 49 mm)		
	Z sel. [mm]	x pos. [mm]	Y pos. [mm]	Δx [µm]	Δy [µm]	Δr [µm]
Upstream beam pipe	**-760**	**0.01**	**0.800**	50	50	-200
Conical connection between RF foil box and tank	864	0.35	1.05	100	80	+300
	884	0.35	1.01	110	50	+300
	896	0.35	1.00	110	50	+300
Downstream beam pipe	**986**	**0.29**	**0.94**	90	-10	+200
	1000	0.22	0.86	90	-10	+300

- ➔ **All results are consistent with a y-shift**
- ➔ **VELO would be lower by this shift.**
- ➔ **Difference upstream/downstream could be du to some global rotation**
- ➔ **Global y-position determined by average of z-position at -760 mm and 986 mm at 49 mm:**

Y shift = 870 µm

VELO global position

Determine VELO global position using material interactions and survey measurements [slides]

- global z using downstream material

VELO z global position

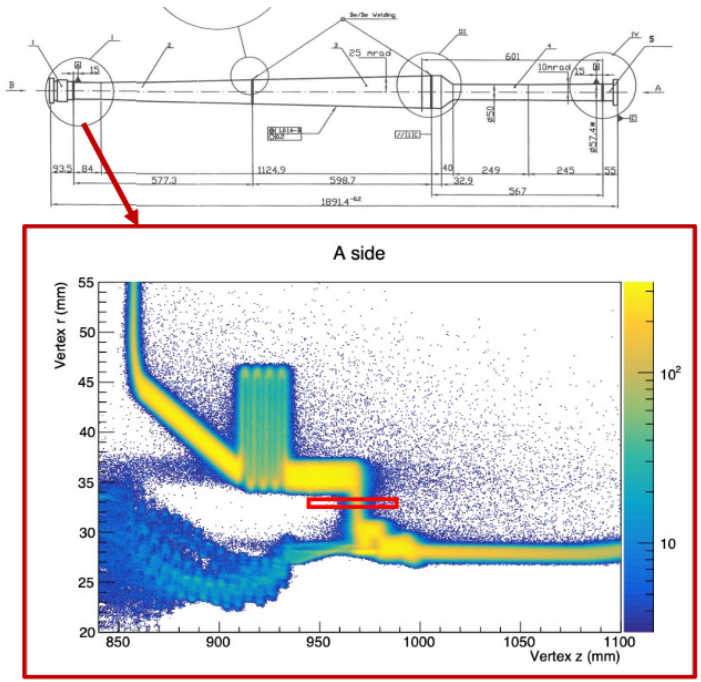
- Same method used in Run 1 LHCb-INT-2014-013
- Reconstruct the z position of the downstream end of the beam pipe by material interaction. Select the radial region 32-33 mm. Fit the Z position distribution.
- Compare the z position to the 2023 survey measurements taken with beam pipe under vacuum. Survey precision 300 µm.

Results

Z position (VELO fully open): 968.6 mm
Z position (VELO at 49mm): 968.8 mm
Z survey (2023): 967.4 ± 0.3 mm
➔Global VELO Misalignment 1.3 mm

➔ **The corrected VELO z position is 1.3 mm in upstream direction**

Thanks to Gloria Corti Pascal Sainvitu et al. for the information



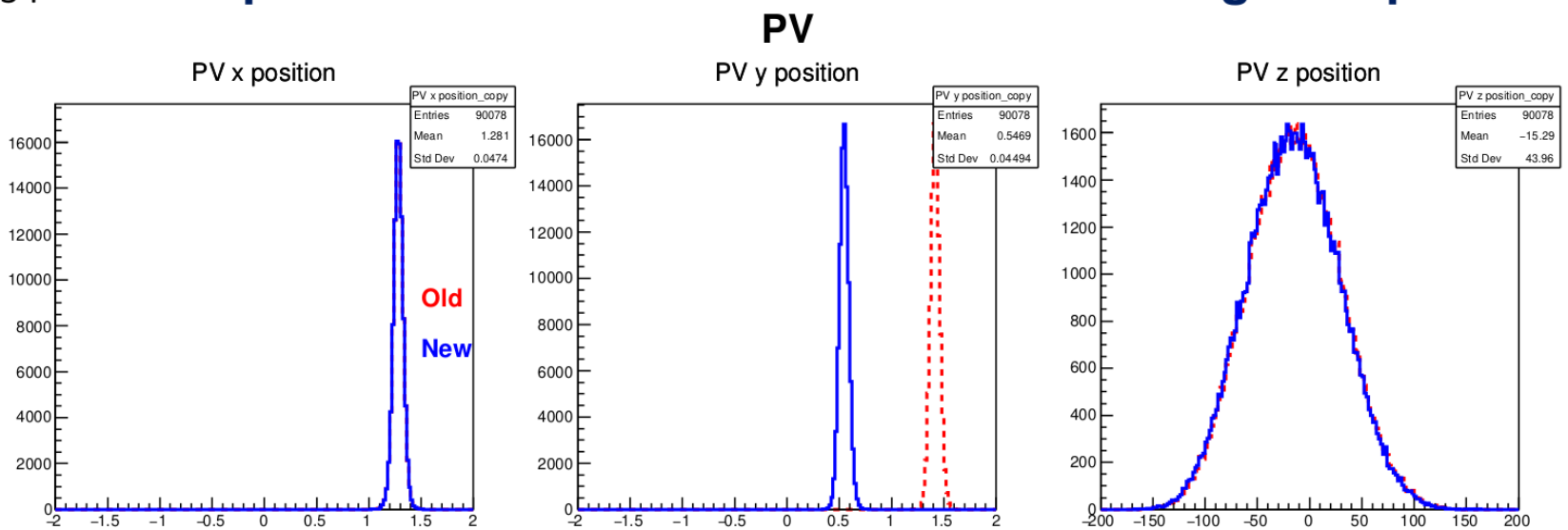
VELO global position

Added global shift of VELO and study effect

- $\Delta y = -0.87\,\text{mm}$
- $\Delta z = -1.30\,\text{mm}$

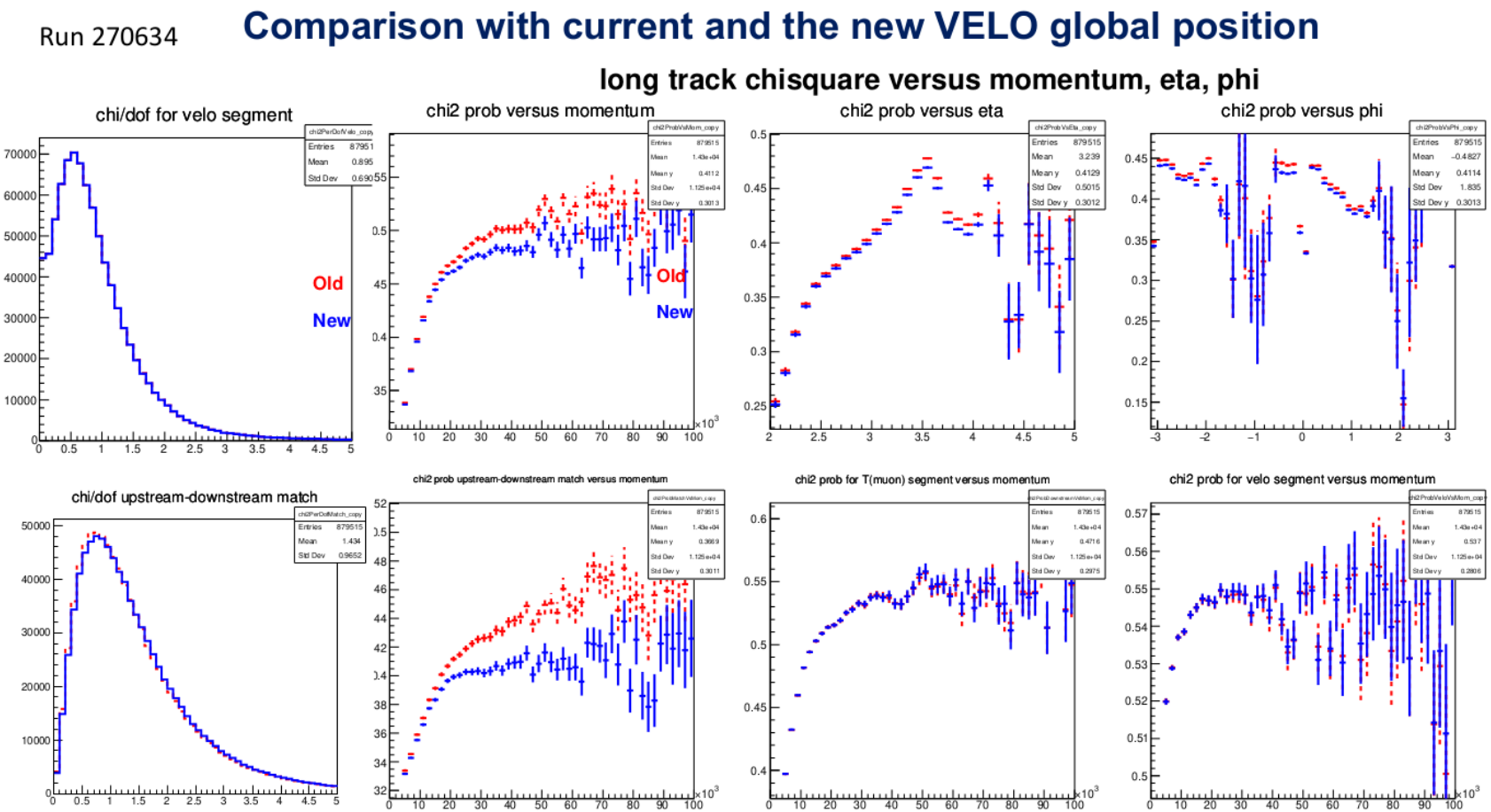
Run 270634

Comparison with current and the new VELO global position



VELO global position

Added global shift of VELO and study effect



Knock-on effect on long tracks and SciFi and Muon alignment

VELO global position

For the global VELO position it would be useful to have survey measurements also in the upstream region outside the tank. To be discussed with CERN survey team to find a good point measurable by them and by the material interaction.
Should discuss if this is feasible to fit in during the YETS work

Beamspot position

Contacted by CERN survey team via Heinrich

- they requested x and y position of beam spot per year
- asked if we have any request to change beam spot position
  - should be discussed more broadly

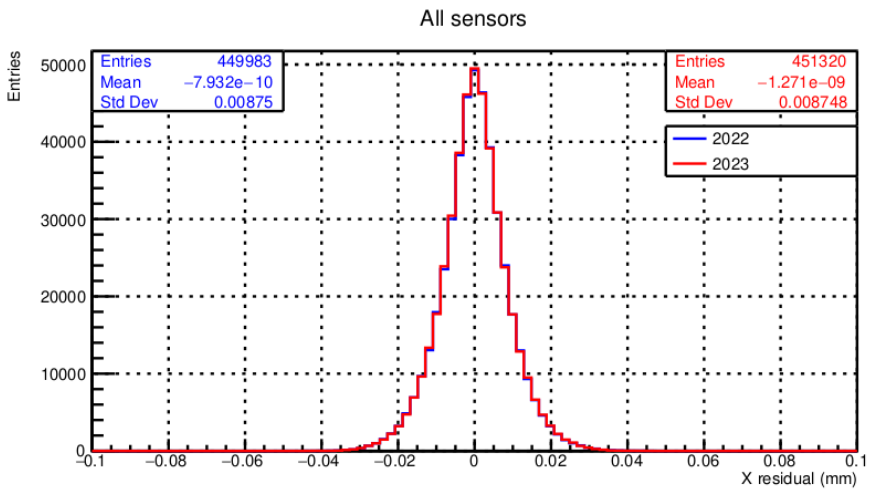
Summary: Average position and width

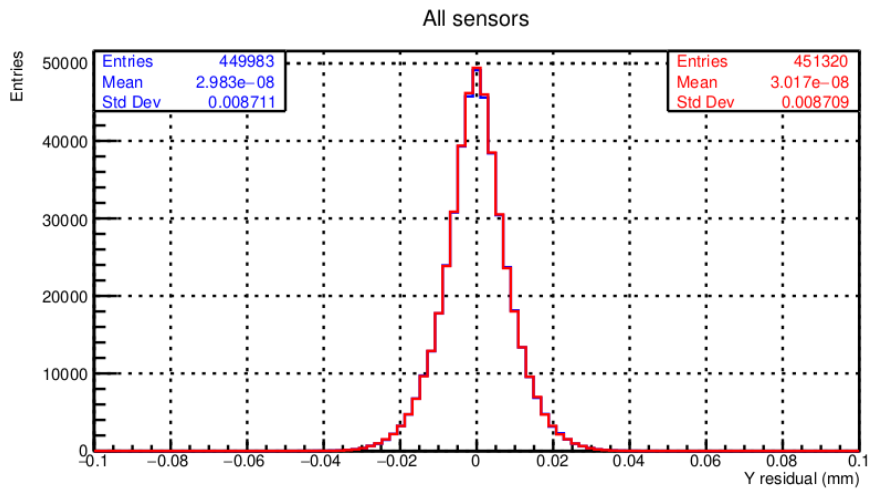
	PV x pos (mm)	PV x width (mm)	PV y pos (mm)	PV y width (mm)	PV z pos (mm)	PV z width (mm)
2011 both polarity	0.456	0.04	0.01	0.04	1.00	48.9
2012 both polarity	0.626	0.04	0.10	0.04	22.5	51.8
2015 down polarity	0.79	0.03	0.09	0.03	8.64	39.3
2015 up polarity	0.78	0.03	0.13	0.03	3.0	49.6
2016 down polarity	0.84	0.03	-0.18	0.03	-3.1	37.5
2016 up polarity	0.84	0.03	-0.18	0.03	-2.6	44.6
2017 down polarity	0.81	0.03	-0.10	0.03	1.36	36.8
2017 up polarity	0.82	0.03	-0.10	0.03	3.93	44.1
2018 down polarity	0.85	0.03	0.11	0.03	1.48	36.9
2018 up polarity	0.85	0.03	0.13	0.03	1.70	45.1
2022 down polarity	1.092	0.055	0.474	0.053	0.65	38.0
2022 up polarity	1.092	0.055	0.474	0.053	0.65	52.0

Collision region information will be summarised in an internal note

2023 module alignment

Run module alignment on 2023 data and compare with 2022 alignment





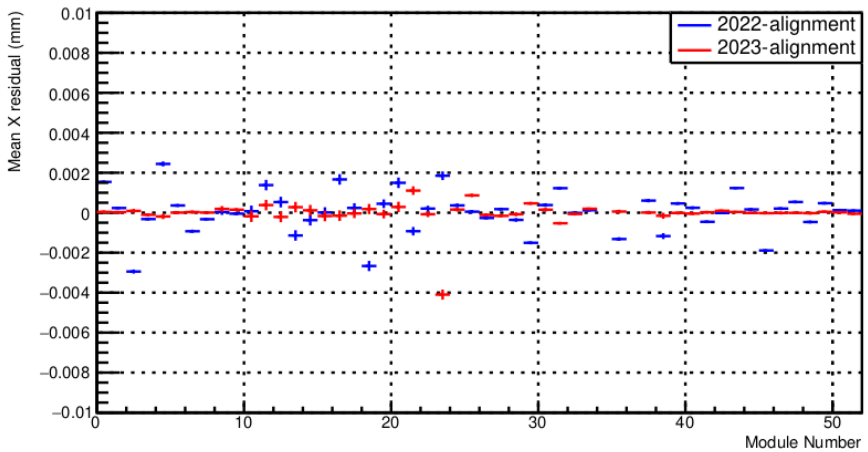
run 263123 (2023-05-11)

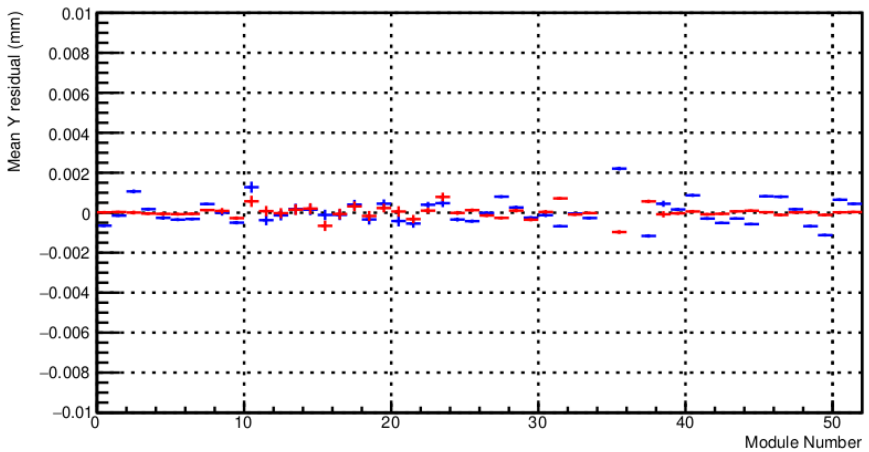
- no major differences seen

Caveat: 2023 conditions not necessarily ideal for module alignment (typically short VELO tracks). Use samples with SMOG?

2023 module alignment

Run module alignment on 2023 data and compare with 2022 alignment





run 263123 (2023-05-11)

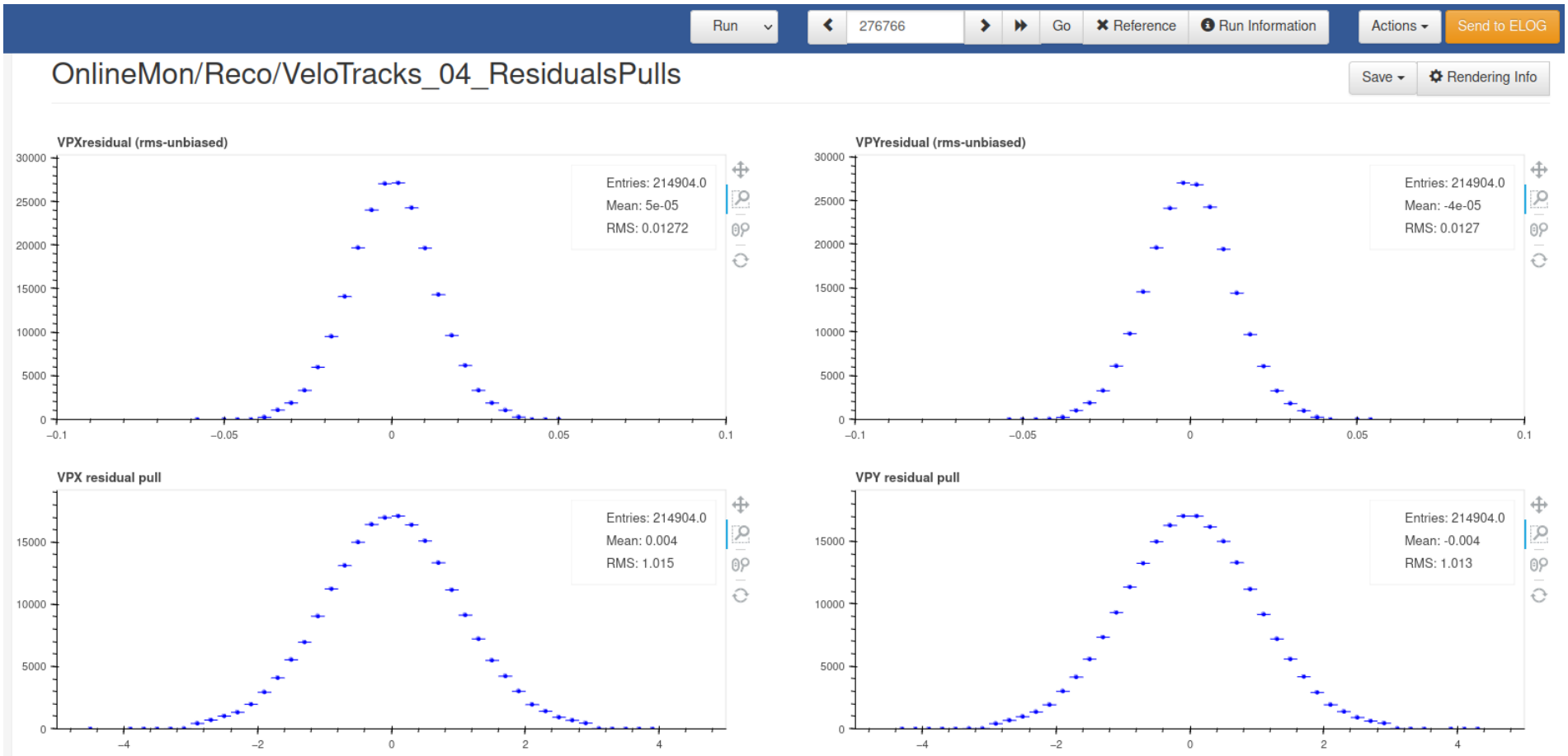
- remaining bias $< 2\,\mu m$ for most modules
- expected precision of module alignment $T_x,\ T_y \approx 1\,\mu m$

2022 module alignment looks stable and good enough for this year as well

Alignment quality

Overall VELO track quality looks good

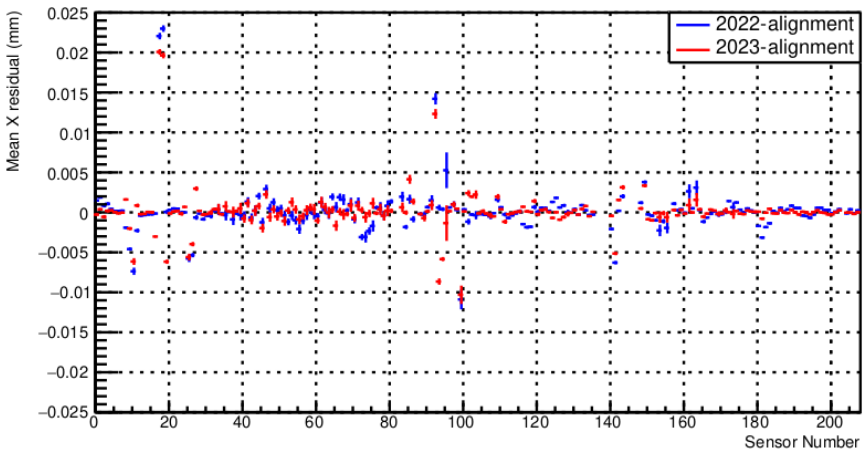
- integrating over all VELO tracks and modules

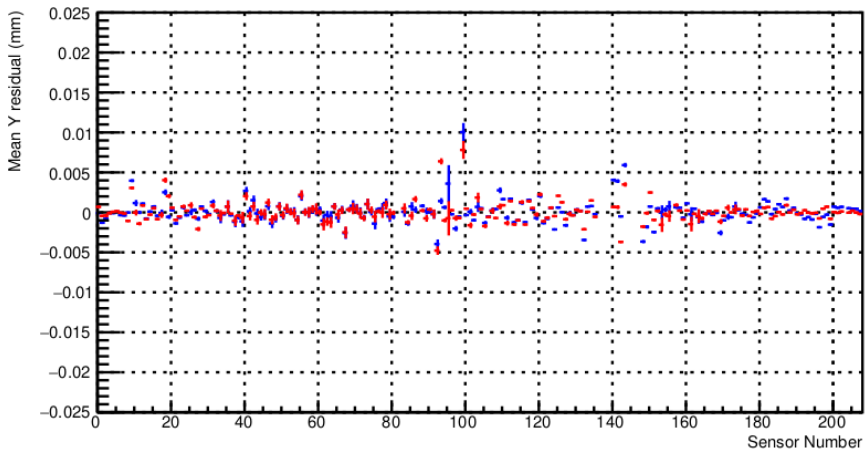


- width of residual pull close to one
  - uncertainty associated to clusters seems sensible

2023 sensor alignment

Look at quality of sensor alignment obtained in 2022 (not re-done for 2023 yet)





run 263123 (2023-05-11)

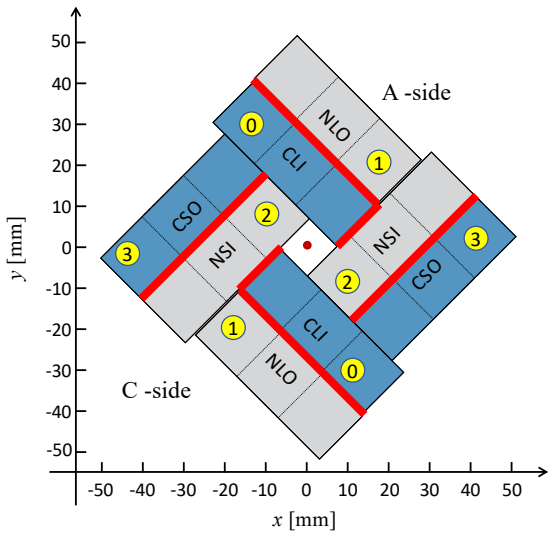
- remaining bias $< 2 - 3\,\mu$m for most sensors
- some sensors could not be aligned with 2022 data
  - show misalignment up to 20 μm
  - can be improved

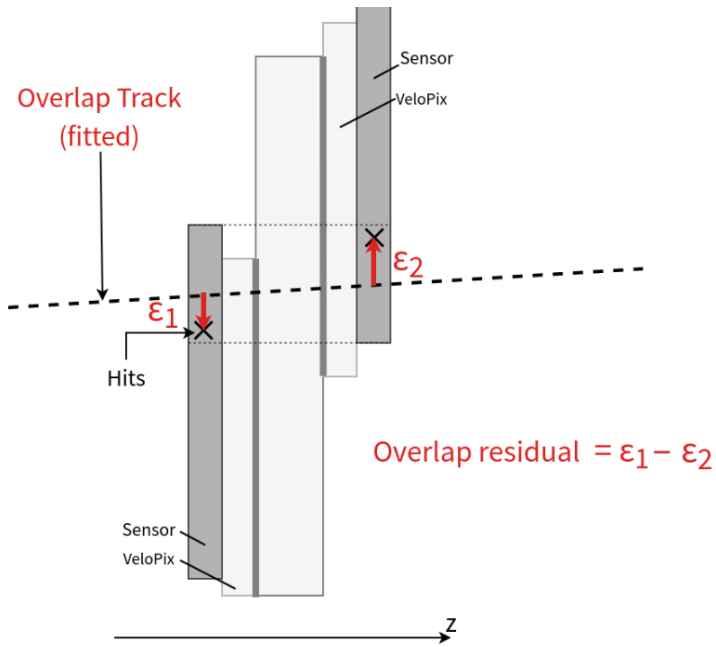
Need to re-run sensor alignment with data from this year

Sensor overlap study

Ongoing study of sensor overlap residuals [slides]

- uses overlapping region between sensors
- check of relative sensor misalignment

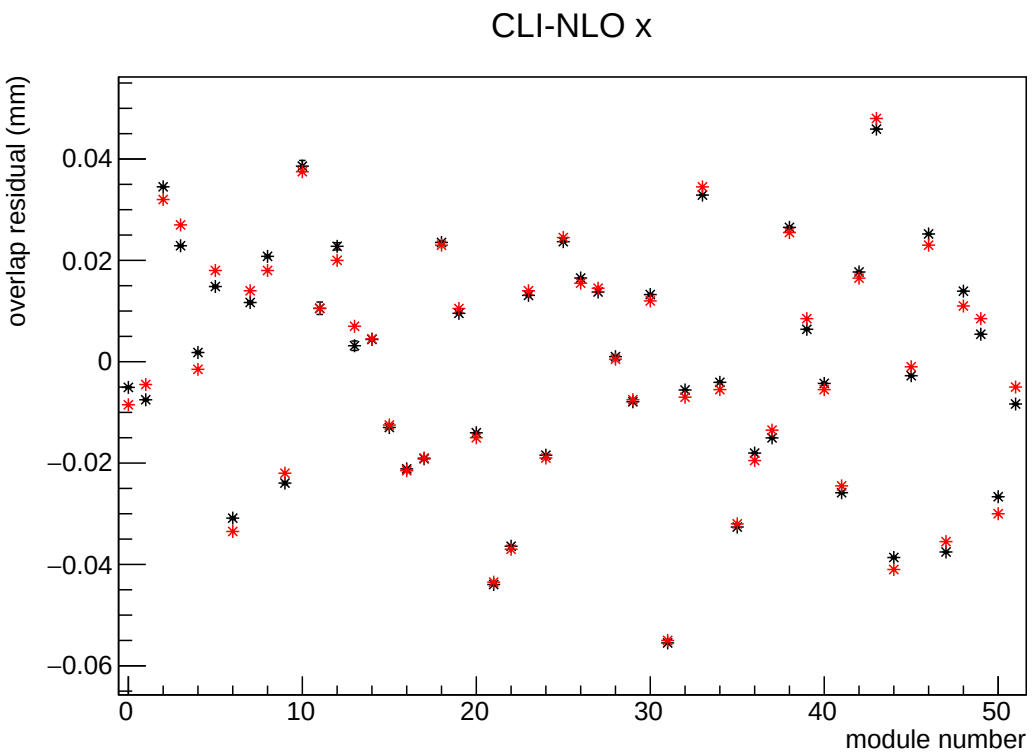




Judge quality of sensor alignment by looking at mean of overlap residual distribution

Sensor overlap residuals

Studies with MC with input sensor misalignment



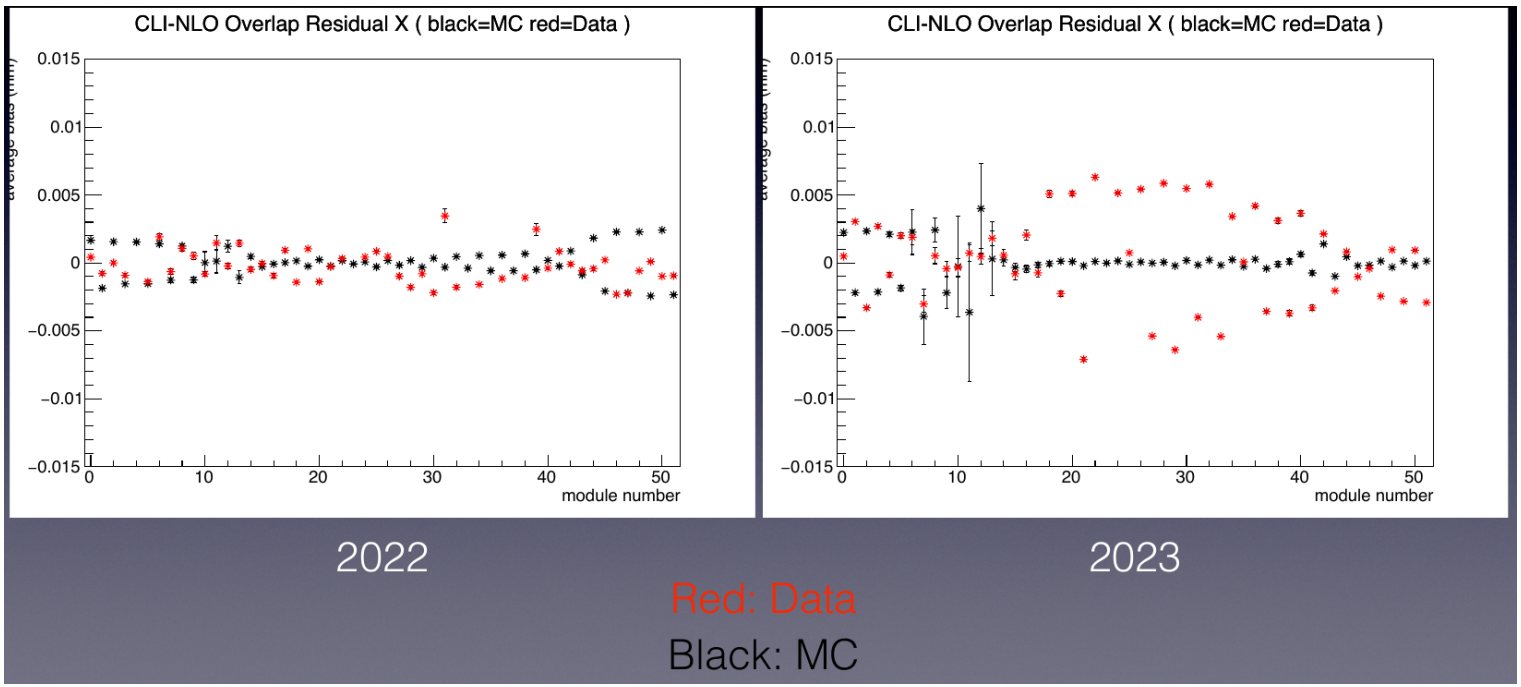
- black: mean of overlap residual
- red: input misalignment

Input misalignment clearly reflected by mean of overlap residual

Sensor overlap residuals

Compare overlap residuals on 2022 and 2023 data and MC

- 2023 data very different from MC?



Preliminary conclusions

- glue thickness causes angle-dependent effect
  - emphasised by 2023 angular distribution
- module R_x and R_y misalignments affect sensors overlaps

Comprehensive presentation will follow soon

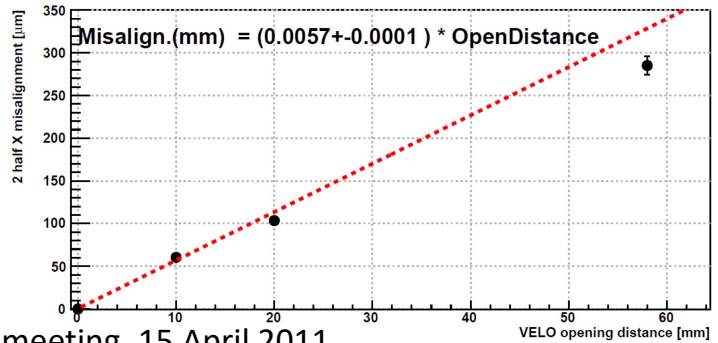
Motion system precision

Study half misalignment as function of motion system position

- allows to judge precision of motion

Tx misalignment vs VELO opening

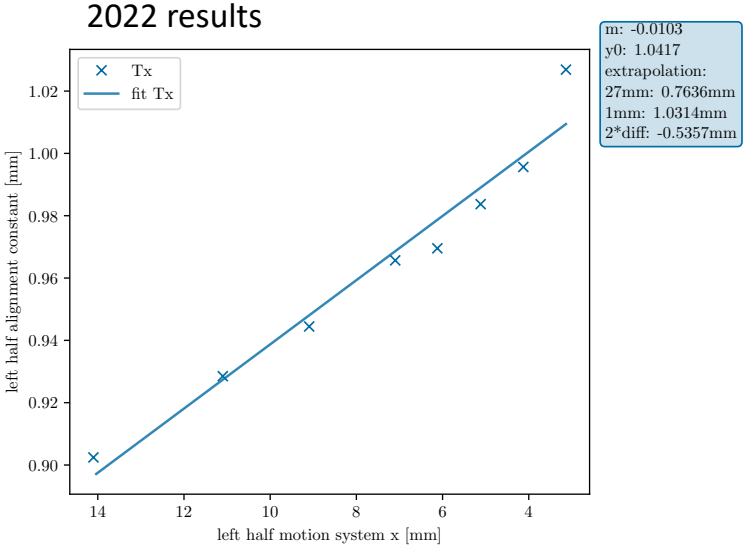
Run 1 results



Velo meeting, 15 April 2011

https://indico.cern.ch/event/121552/#4-alignment-when-velo-open

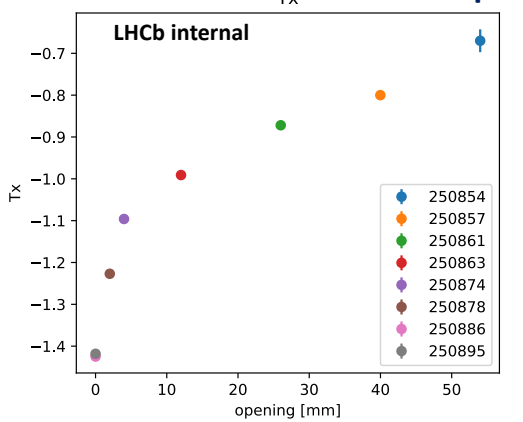
2022 results



Velo commissioning meeting, 13 October 2011

https://indico.cern.ch/event/1211250/#22-alignement-with-partially-c

2022 results



LHCb week, 5 December 2022

https://indico.cern.ch/event/1222355/#1-velo-as-seen-by-the-alignmen

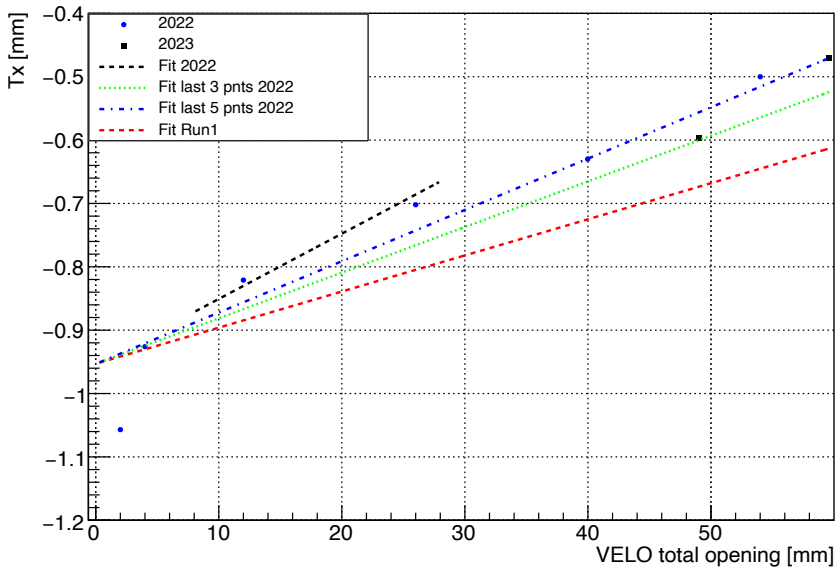
- half misalignment in x depends on opening

Motion system precision

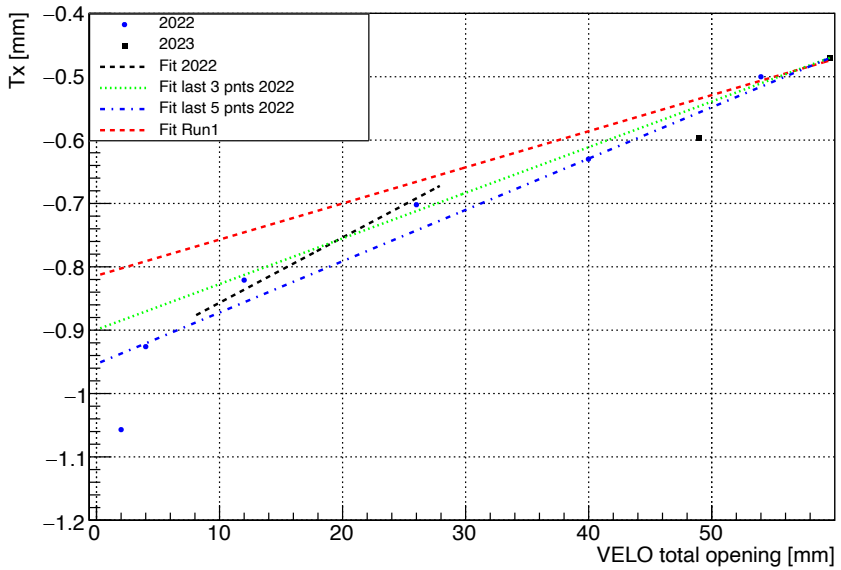
Tx misalignment vs VELO opening

Sample	slope
Fit 2022	1.03%
Fit last 3 pnts 2022	0.72%
Fit last 5 pnts 2022	0.81%
Fit Run1	0.57%

Normalized on y to the close position



Normalized on y to the open position



Motion system precision estimated from slope:

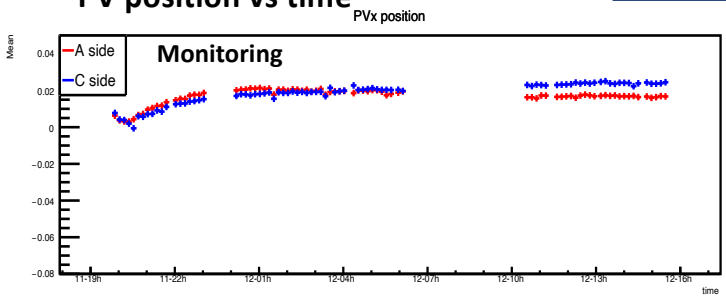
- Run 1: 0.57%
- Run 3: 0.72% – 1.03%

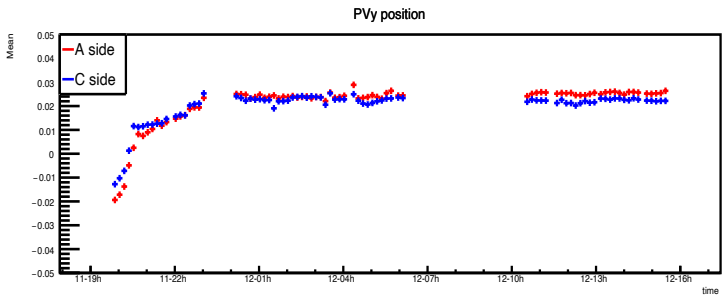
Half alignment stability

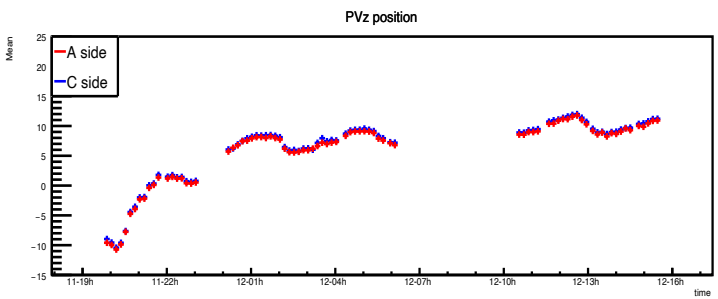
Something unexpected this year: VELO half alignment changes over a fill [slides]

Fill 9063

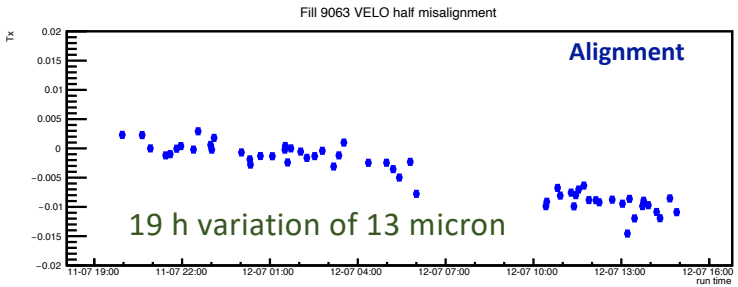
PV position vs time

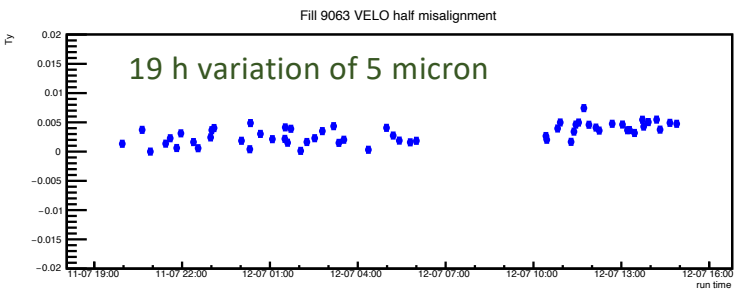


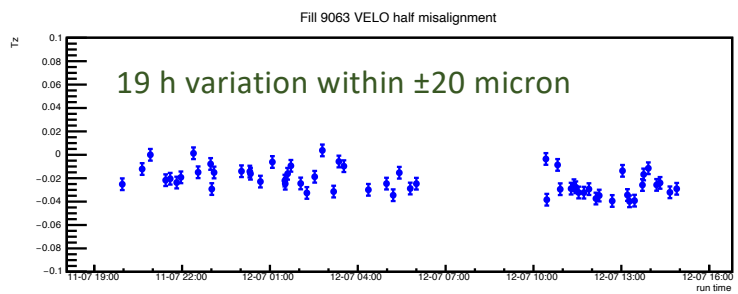




Alignment: total Half misalignment



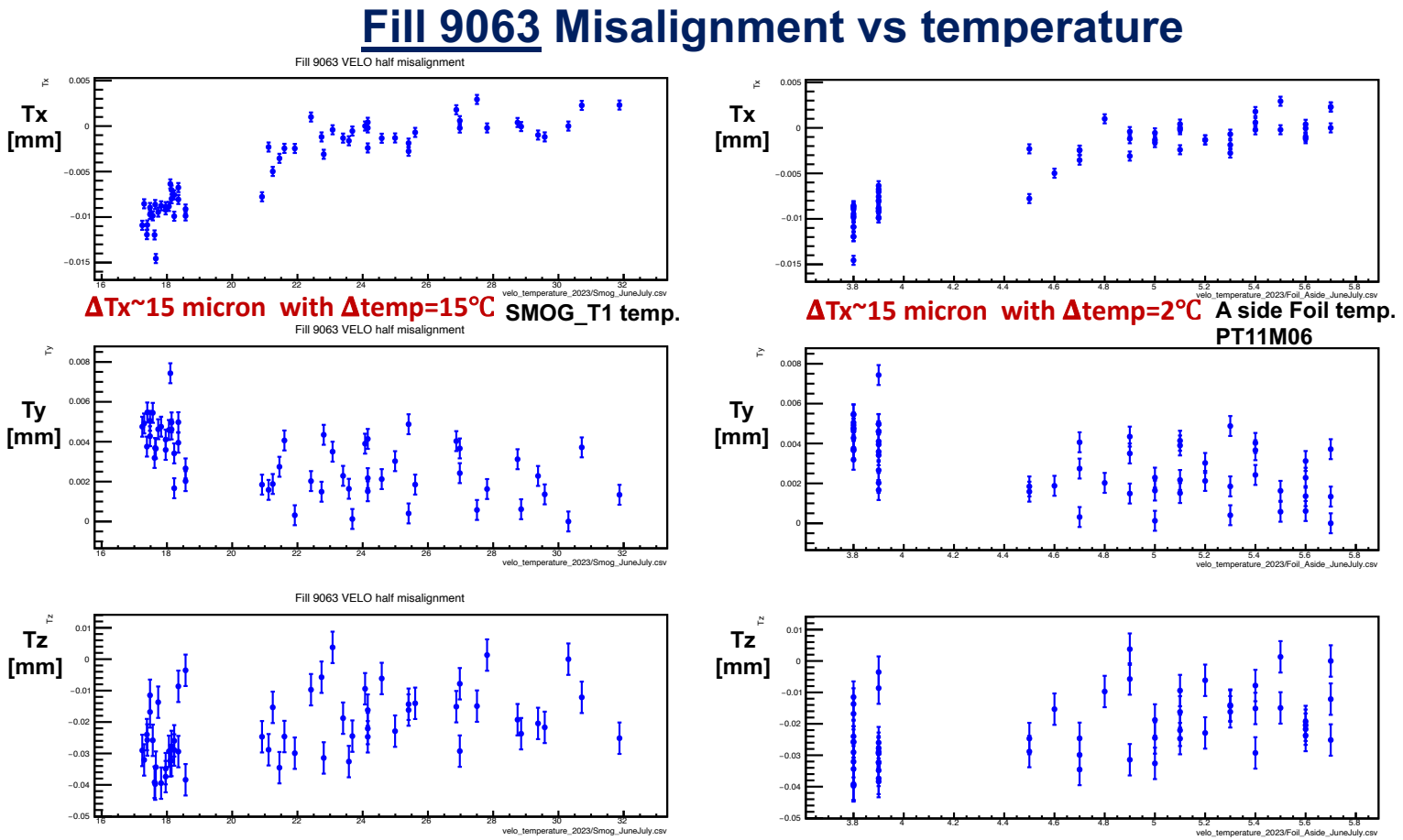




Temperature effect?

Half alignment stability

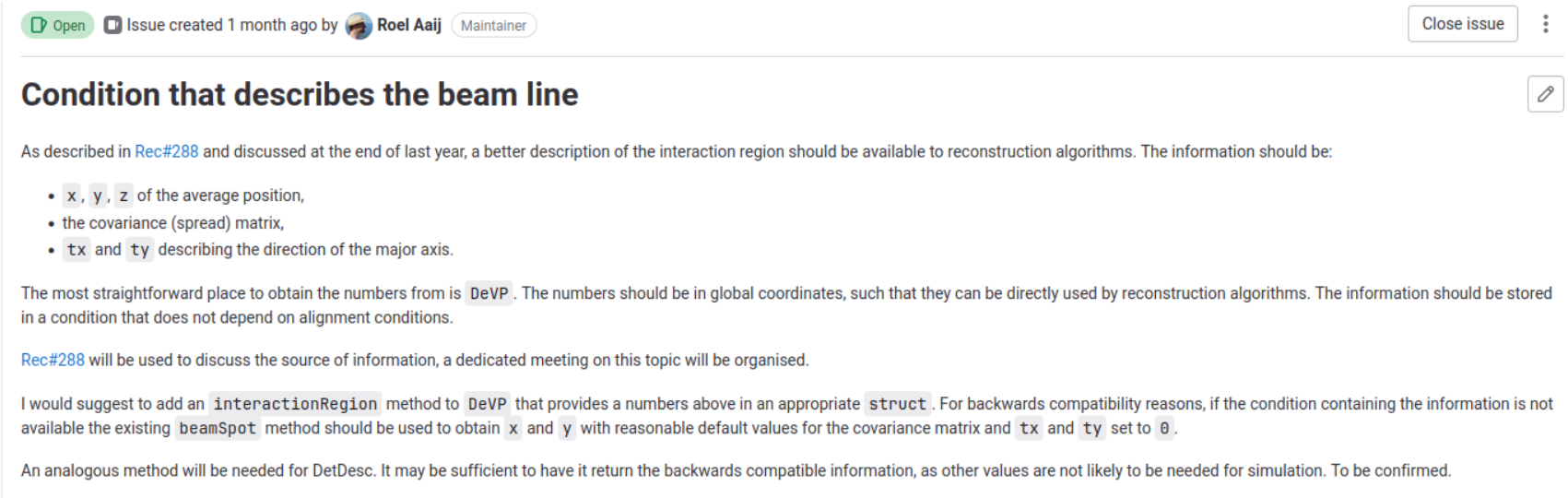
Misalignment correlated with temperature



To do:

- also study module alignment stability
- have a look again at Run 2

Beam line position



Open · Issue created 1 month ago by Roel Aaij · Maintainer · Close issue

Condition that describes the beam line

As described in Rec#288 and discussed at the end of last year, a better description of the interaction region should be available to reconstruction algorithms. The information should be:

- `x`, `y`, `z` of the average position,
- the covariance (spread) matrix,
- `tx` and `ty` describing the direction of the major axis.

The most straightforward place to obtain the numbers from is `DeVP`. The numbers should be in global coordinates, such that they can be directly used by reconstruction algorithms. The information should be stored in a condition that does not depend on alignment conditions.

Rec#288 will be used to discuss the source of information, a dedicated meeting on this topic will be organised.

I would suggest to add an `interactionRegion` method to `DeVP` that provides a numbers above in an appropriate `struct`. For backwards compatibility reasons, if the condition containing the information is not available the existing `beamSpot` method should be used to obtain `x` and `y` with reasonable default values for the covariance matrix and `tx` and `ty` set to `0`.

An analogous method will be needed for DetDesc. It may be sufficient to have it return the backwards compatible information, as other values are not likely to be needed for simulation. To be confirmed.

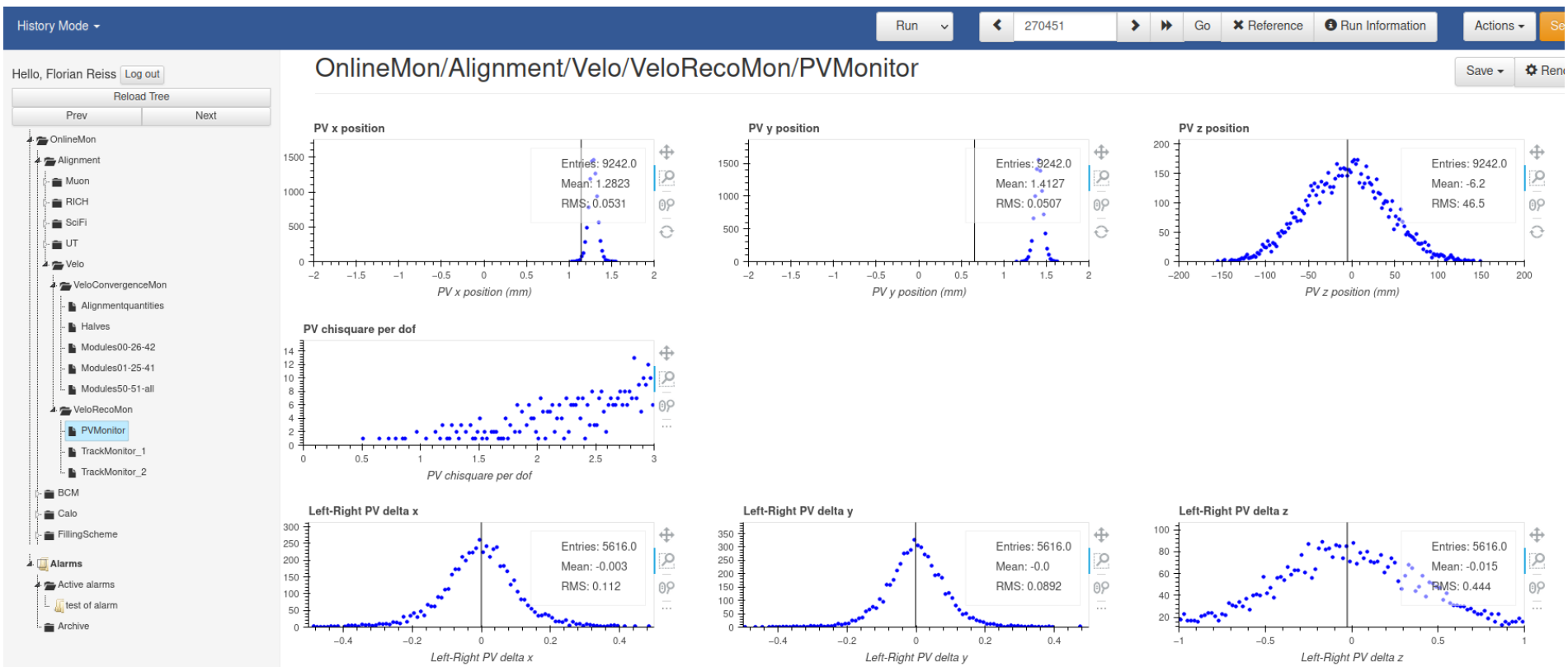
PV reconstruction sensitive to estimate of beam line position

- in the past, estimated from VELO motion system position + global shift
  - corrections/offset needed for optimal PV reconstructions
- now taken from dedicated beam line condition [Detector#47]
  - will be filled and updated automatically

Real-time alignment

Real-time alignment running with half alignment as prototype

- half alignment running at beginning of each fill
  - automatically from run 268249 [elog]
  - automatic update of half constants from run 269316 [elog]
- monitoring of real-time alignment running
  - e.g. looking at PV left-right



Real-time alignment

Current VELO alignment constants used online

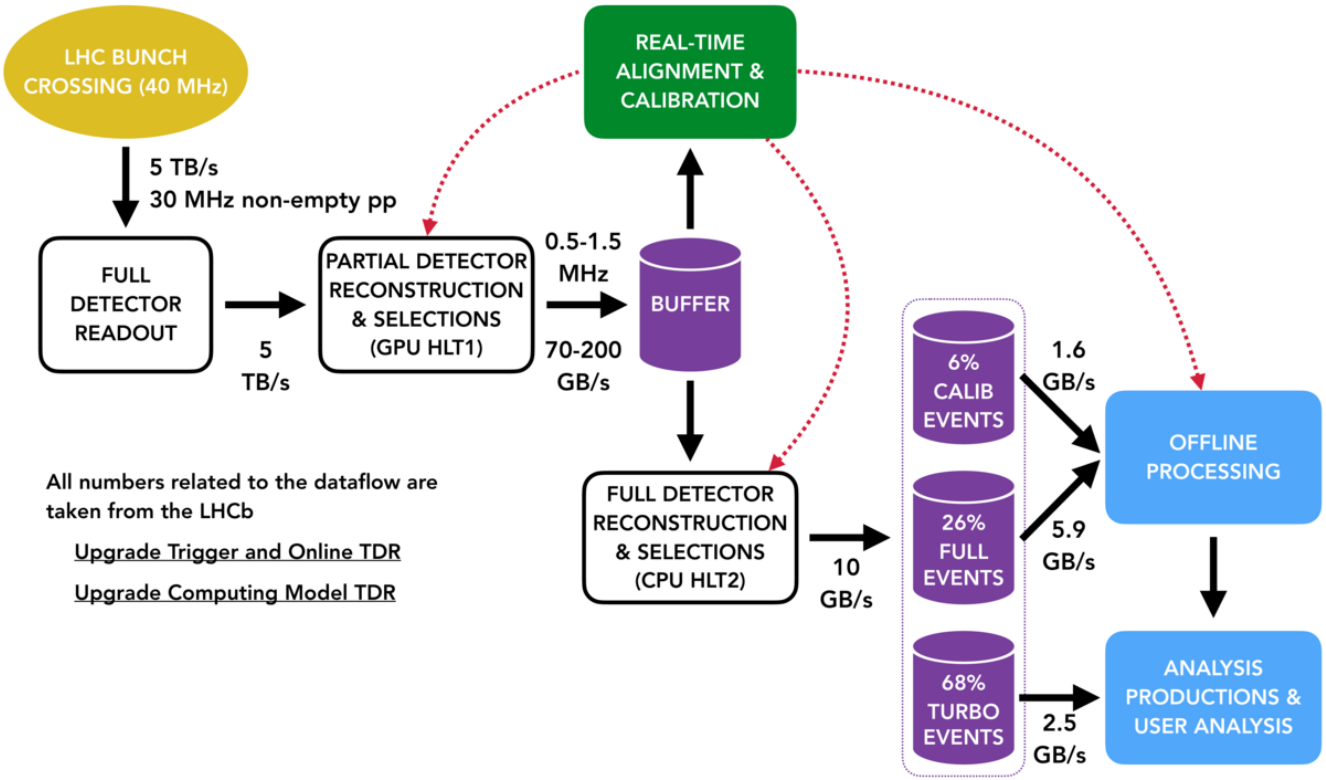
- global shift in y and z
  - picked up since run 274693
  - included in tag `Alignment2023_HLT2Processing_26_8_2023` for HLT2 processing
- half alignment updated per fill (if needed)
- module and sensor alignment from 2022

Summary

- VELO module and sensor alignment of good quality
  - potential for further refinement with 2023 data
- alignment stability and temperature-dependence under study
- real-time VELO half alignment up and running
- should discuss survey for global position during YETS

Back-up

Real-time alignment

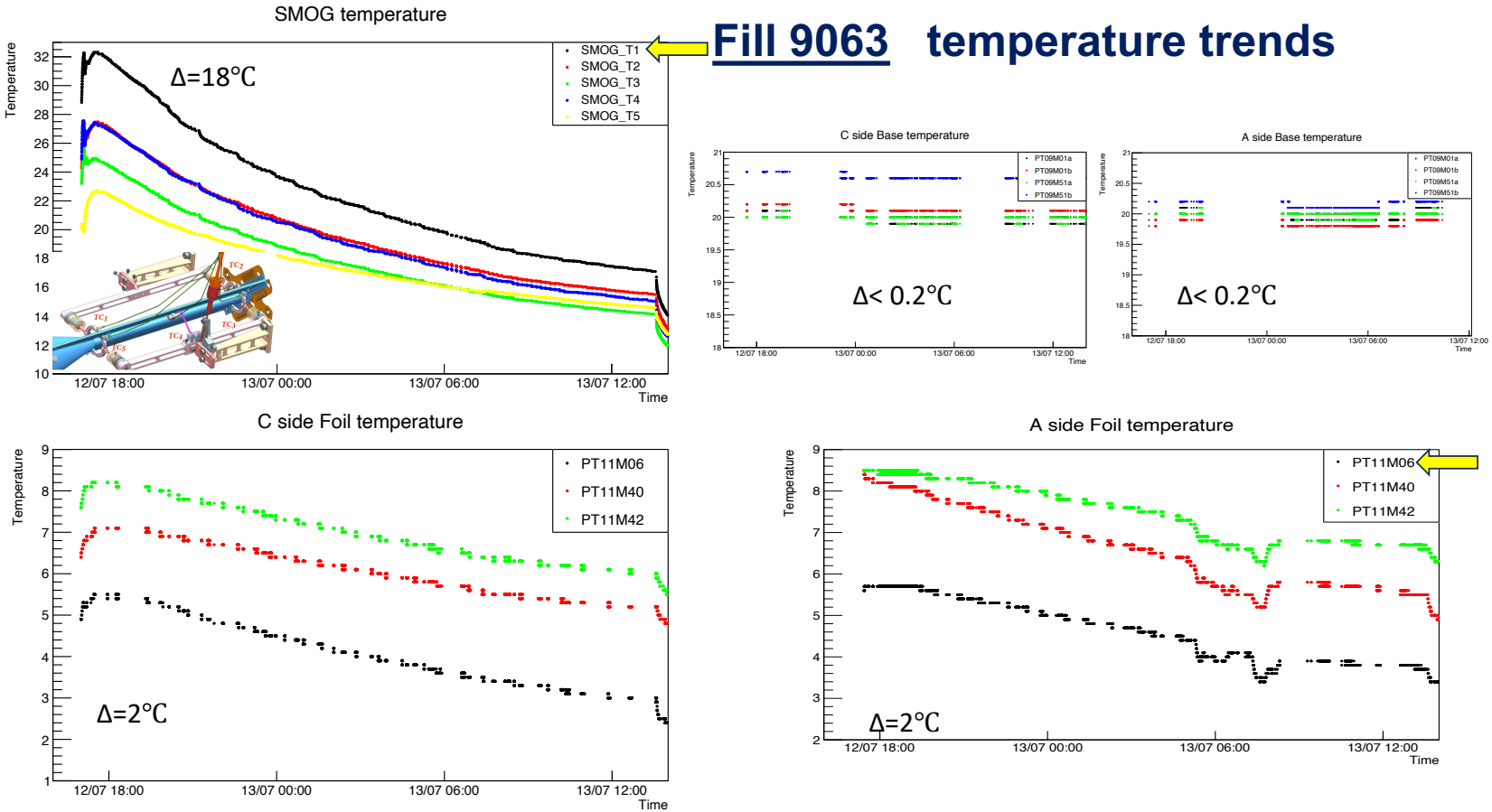


[LHCB-FIGURE-2020-016]

- alignment uses samples selected by HLT1 saved in the buffer
- alignment is executed at the start of each fill
- alignment&calibration used in the trigger $\rightarrow$ "real-time"

Half alignment stability

Misalignment correlated with temperature



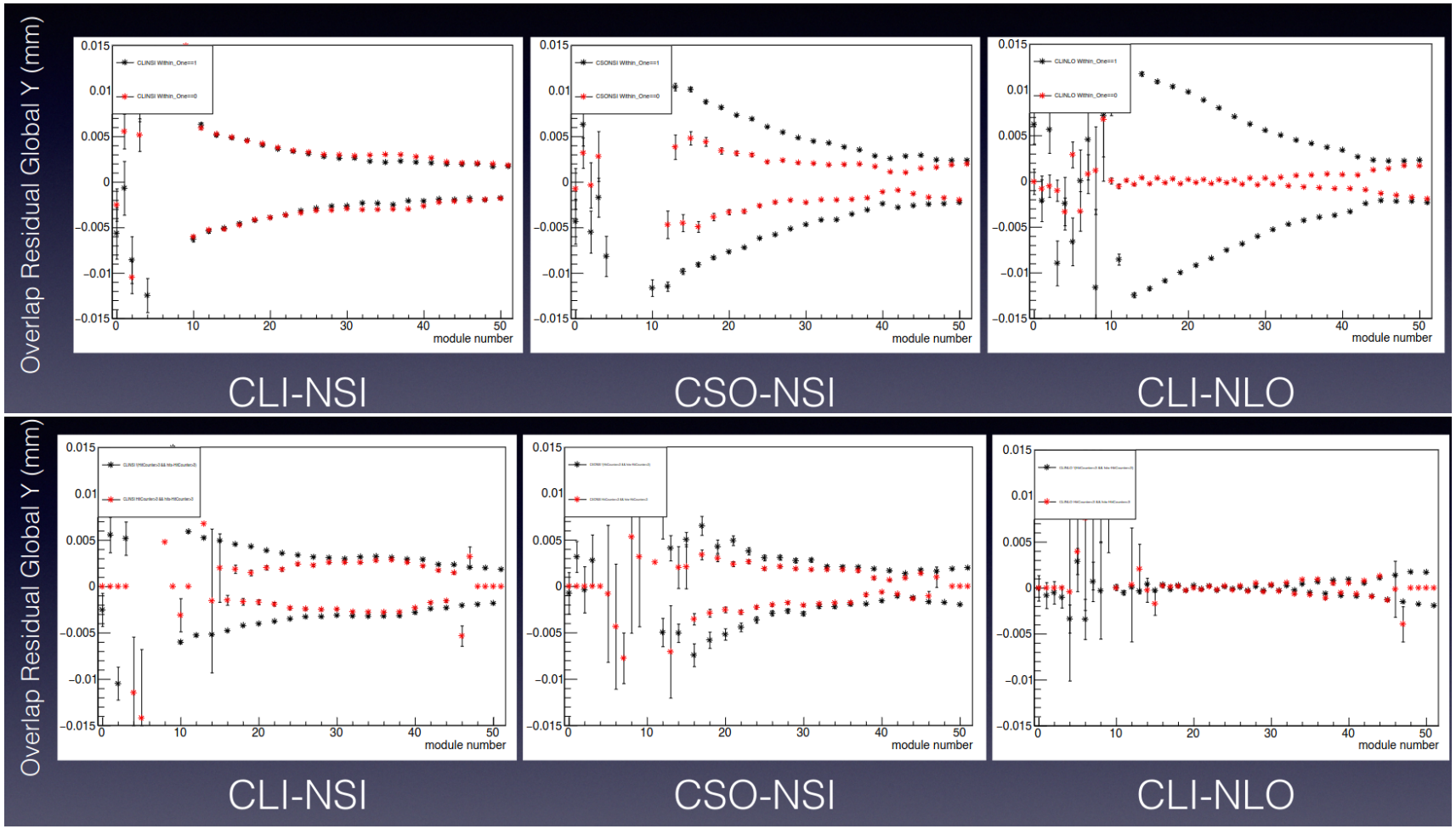
Name Convention: PT11M06 -> the station 06 is the nearest module to the temperature probe

To do:

- also study module alignment stability
- have a look again at Run 2

Sensor overlap residuals

Study of MC with perfectly aligned detector



- optimise selection and reduce inherent bias
  - avoid sensor edge effect
  - bias in first and last hits of track
- residual bias of around 2 µm