MANCHESTER 1824

The University of Manchester

VELO as seen by the alignment

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05/12/2022

Outline

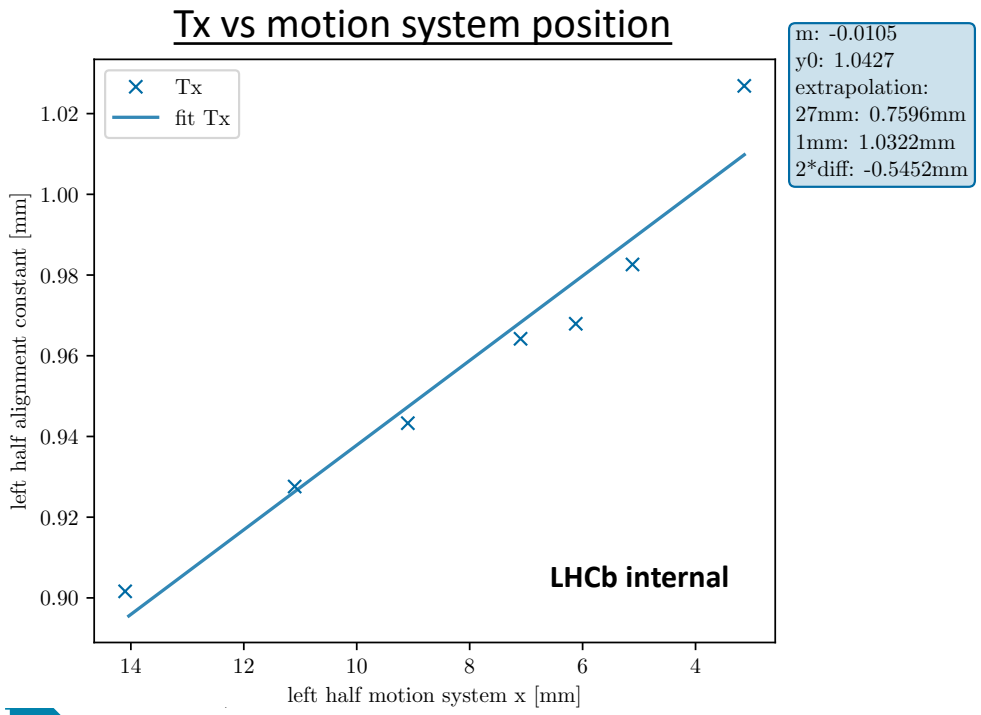
- C side misalignment depends on the VELO opening distance
- Drift of C side at the same opening position
- Reproducibility of the drift
- Reproducibility of initial misalignment
- Is the RF foil drifting?
- Conclusion

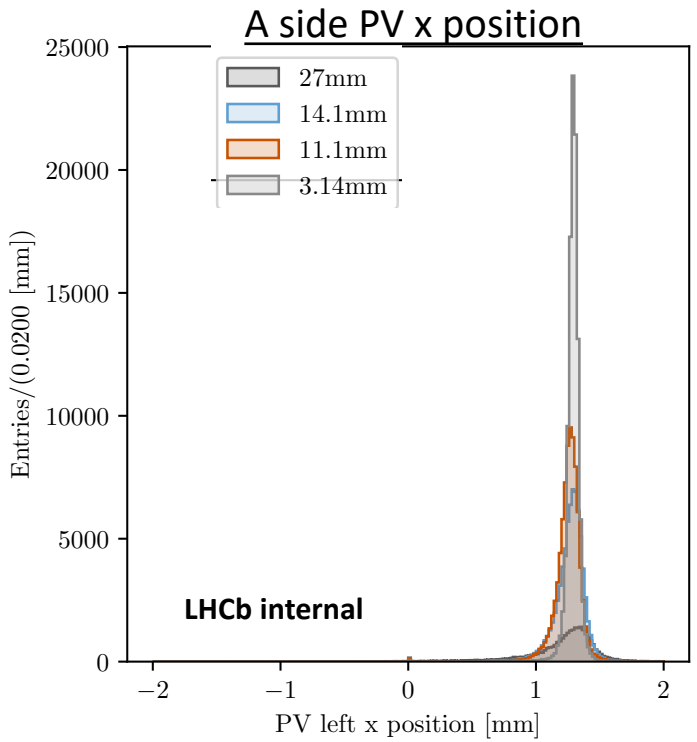
C side misalignment depends on the VELO opening distance

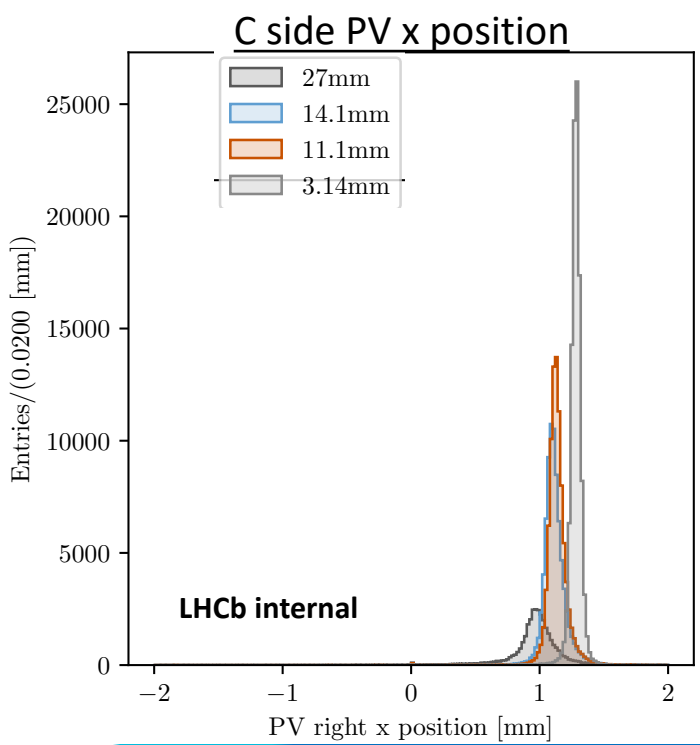
Half misalignment vs opening position

- The misalignment of the half is changing at the different opening position
- Looking at the PV reconstructed with each half separately. If the beam is really moving, this should be observed coherently by the 2 halves
  - PV reconstructed in the A side remains at the ~same position
  - PV reconstructed in the C side changes as function of the opening.

=> misalignment variation is due the right (C) side



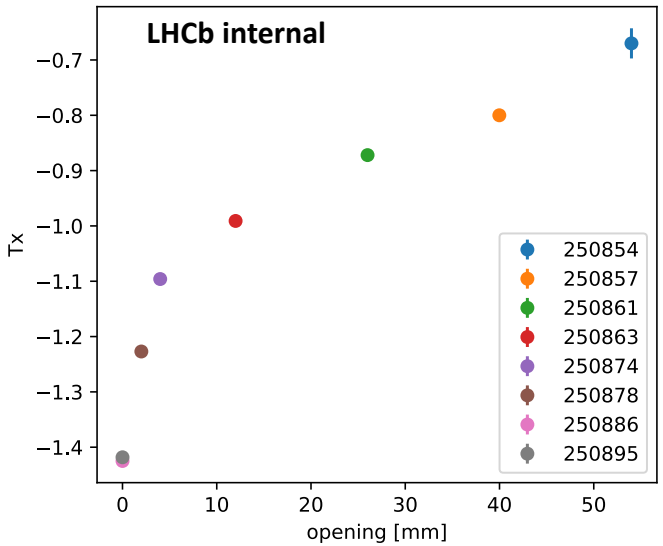




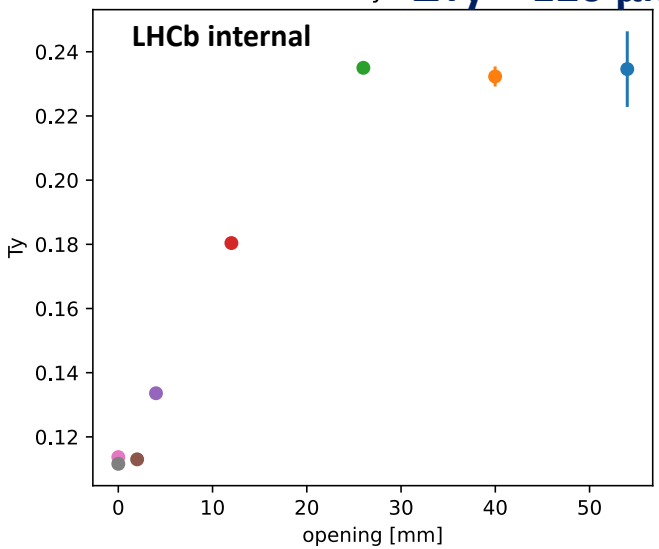
Half alignment constants vs opening

Wouter Hulsbergen

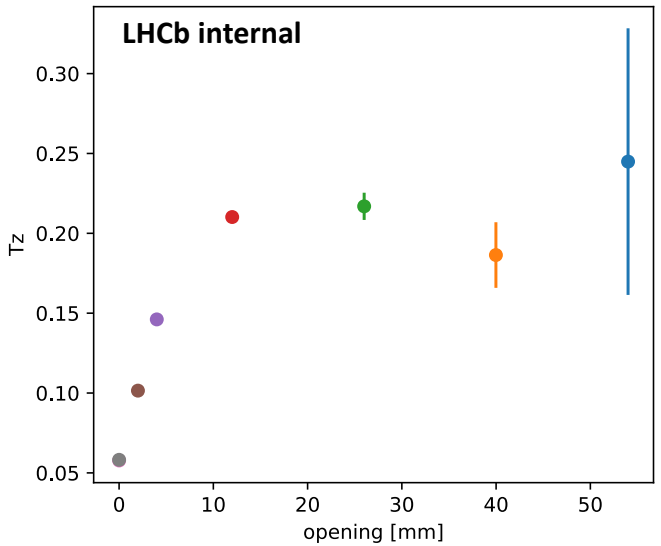
Tx **ΔTx ≈ 700 µm**



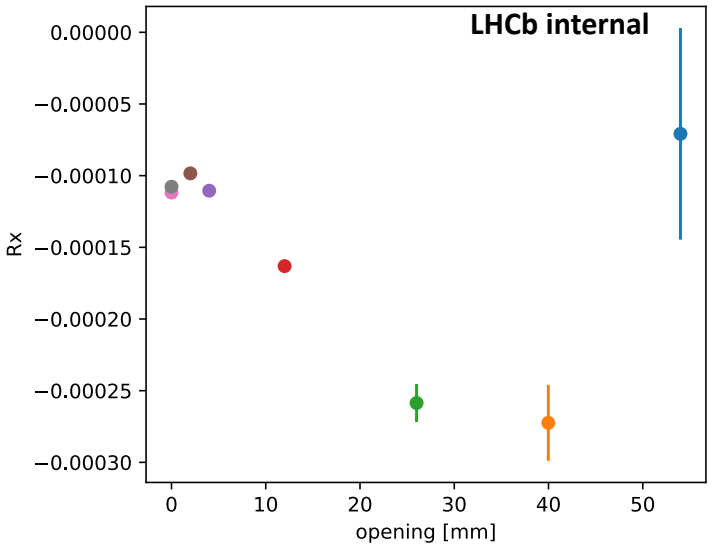
Ty **ΔTy ≈ 120 µm**



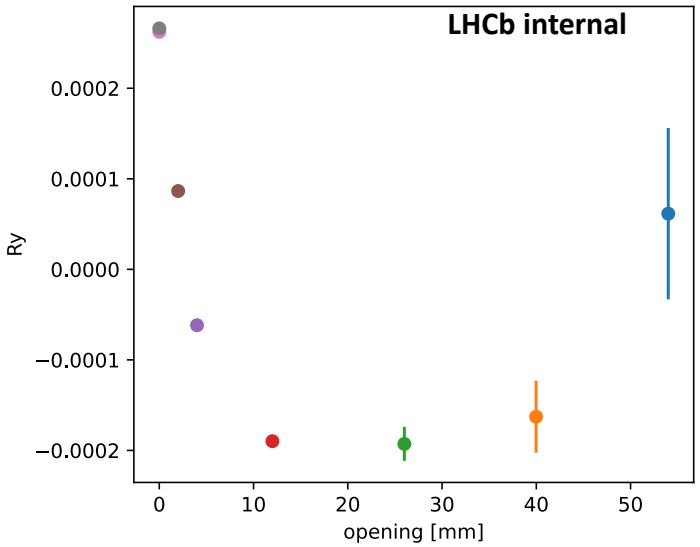
Tz **ΔTz ≈ 150 µm**



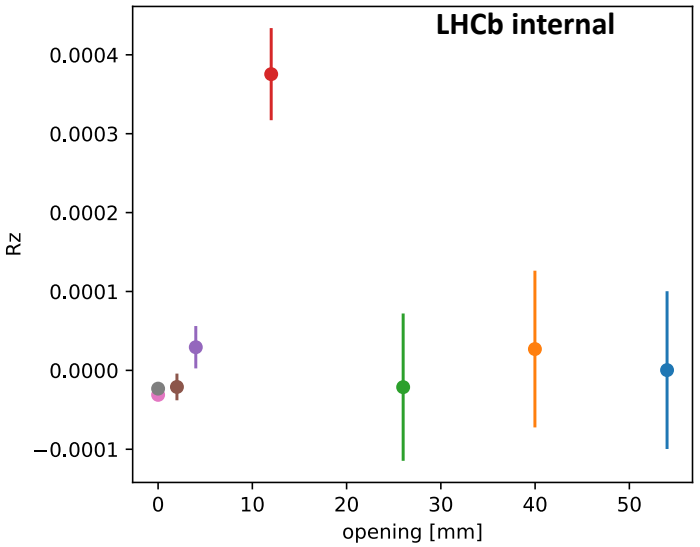
Rx **ΔRx ≈ 200 µrad**



Ry **ΔRy ≈ 450 µad**



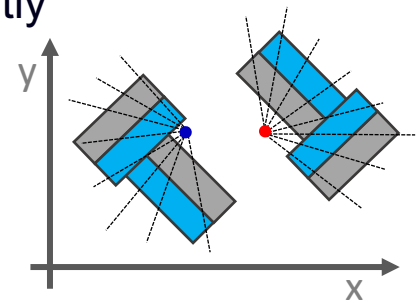
Rz **ΔRz < 50 µrad**



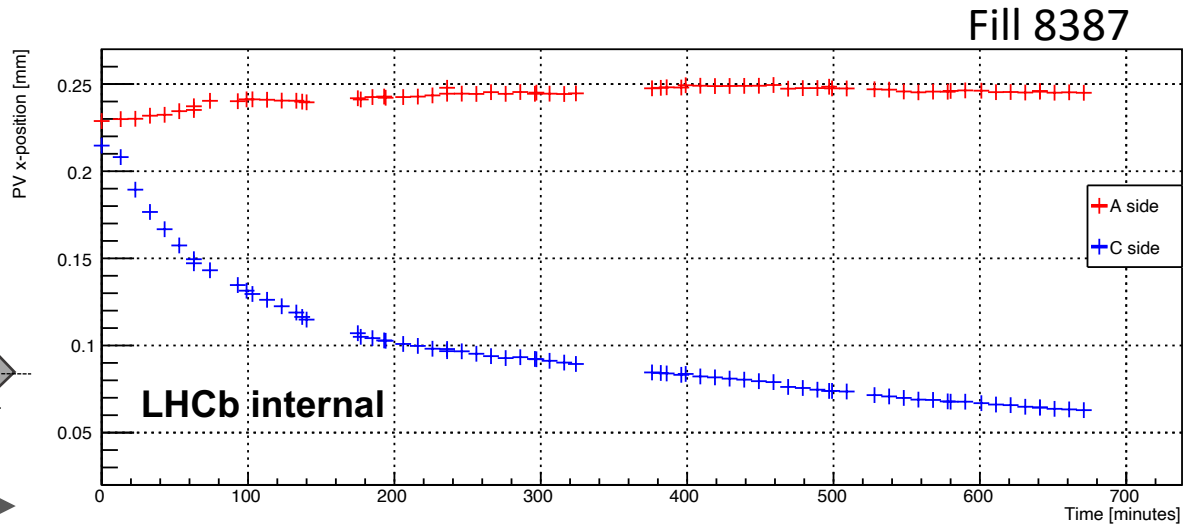
Drift of C side at the same opening (motion system) position

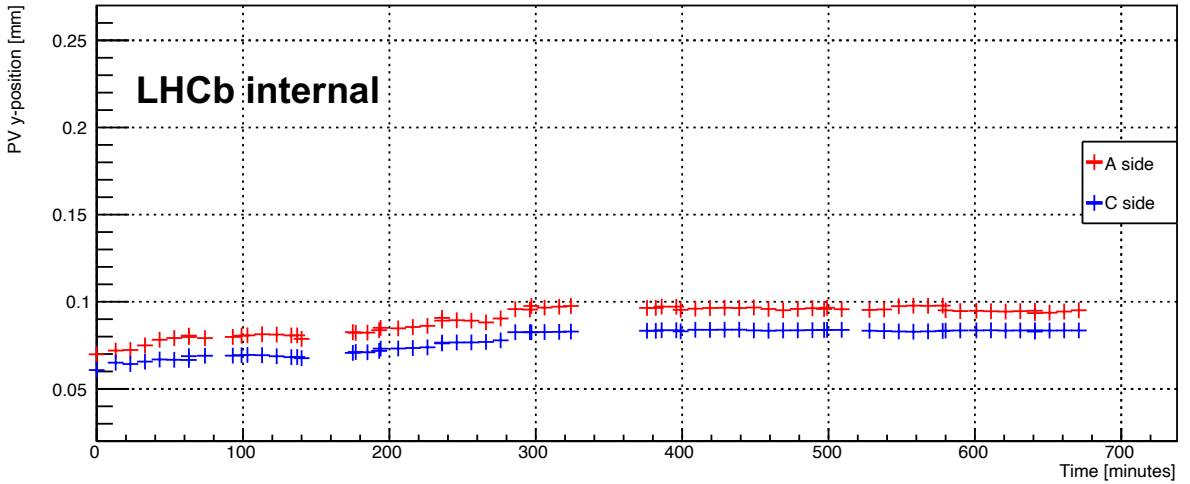
Drift of VELO C side

- Two VELO halves could act as separated detector
- PV position reconstructed independently by each half should be at the same position
  - Difference of PV position is a relative misalignment between the two halves



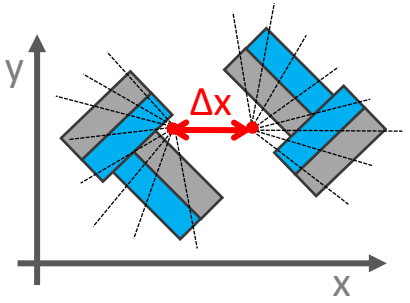
- Some drift of PV is expected due to LHC beam movement (e.g. luminosity levelling)
- PVx position versus time shows a large and unexpected drift of the C-side
- Effect is (almost) reproducible for several fills with the VELO fully close and opened by 1 mm (e.g. during VdM scans)



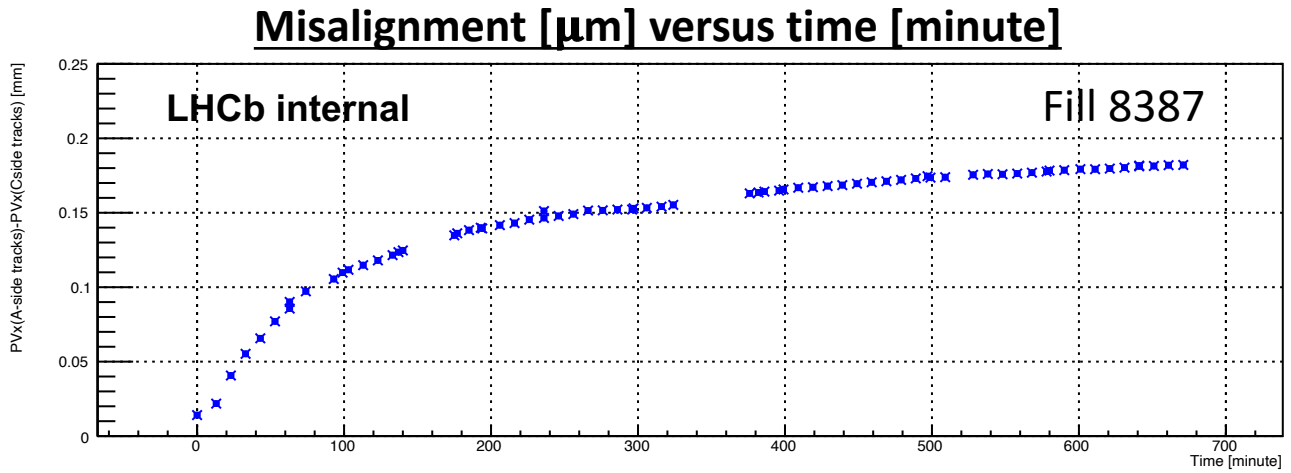


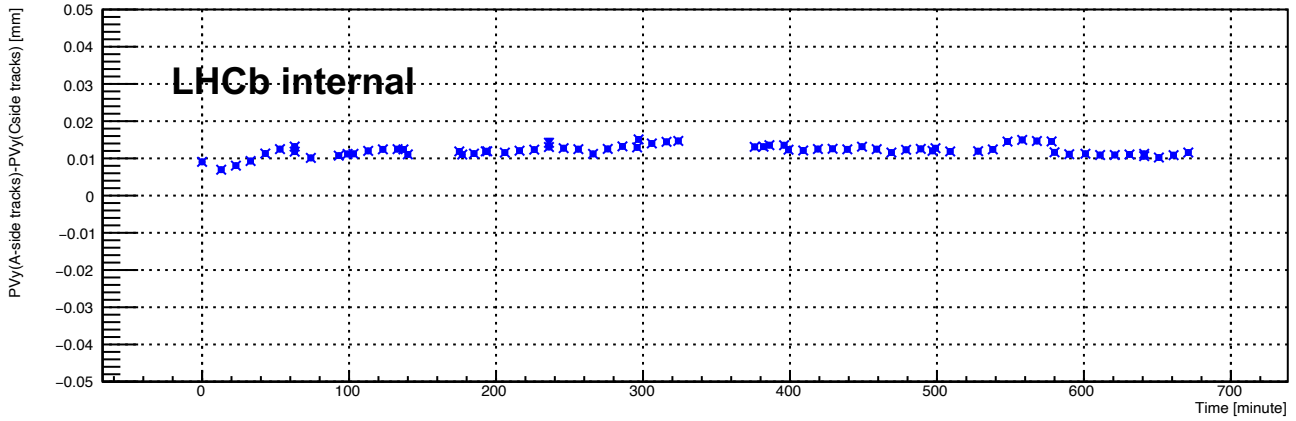
Evaluation of the drift by monitoring plots

- Assuming A side PV describes the LHC beam movement => misalignment due to C -side
- Time dependence of the misalignment evaluated by the distance of the PV reconstructed with only A tracks and PV reconstructed with only C tracks.



- Observed drift:
  - **~100 µm during the first 100 minutes**
  - **~5 µm/hour after 3 hours**
- Time dependence is well reproducible overall several fills (but **not all**, see later)

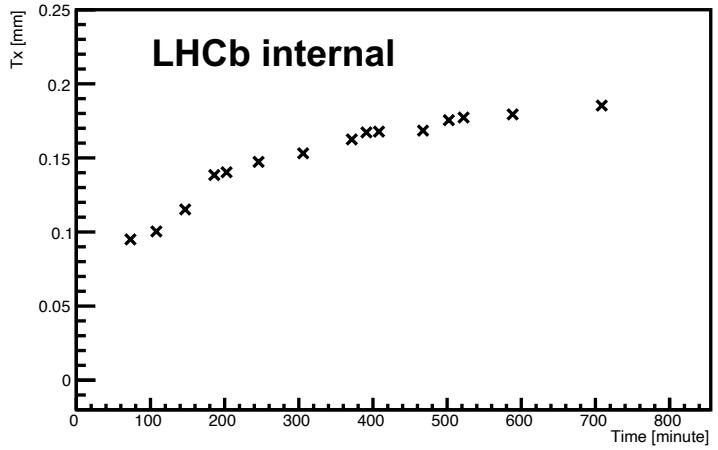


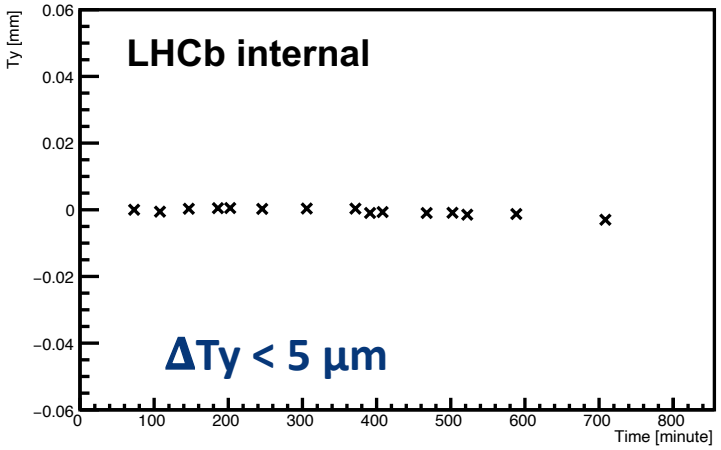


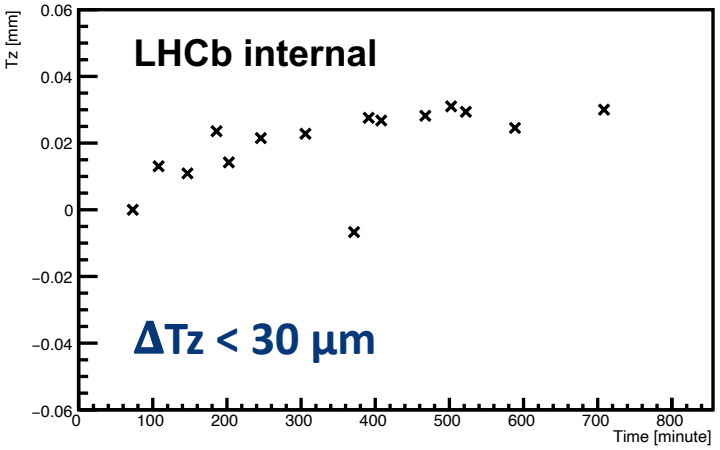
Study the half misalignment = C drift by the spatial alignment

Fill 8387

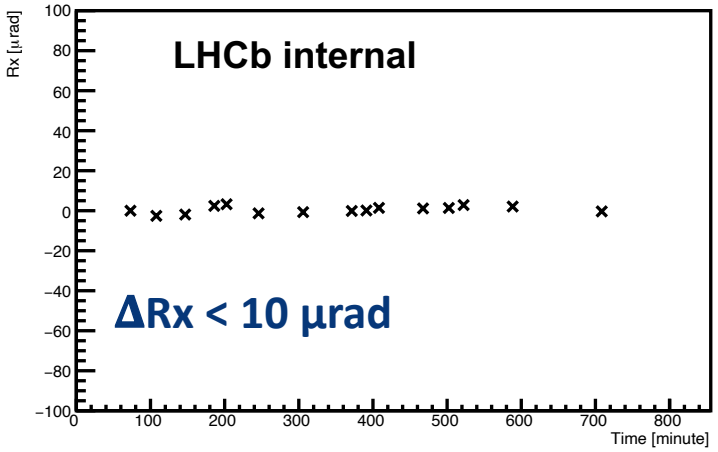
translations

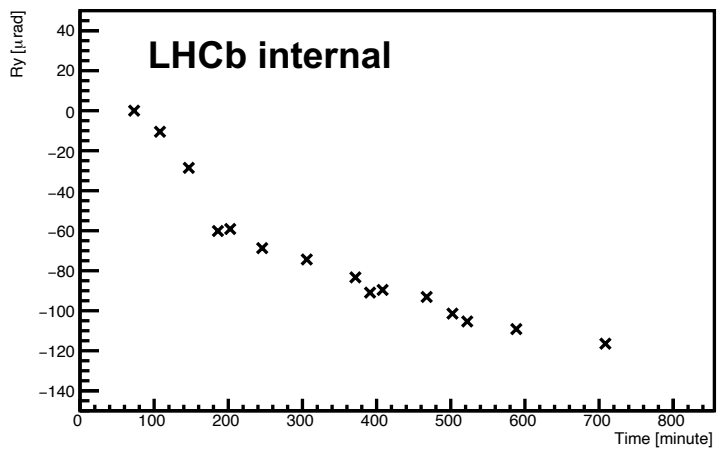


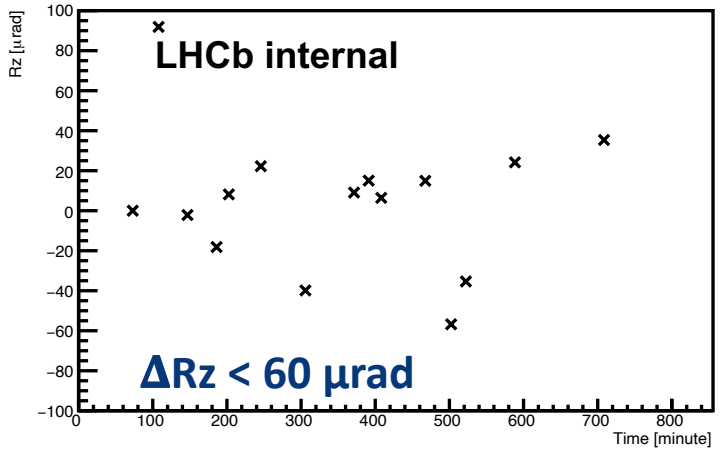




rotations



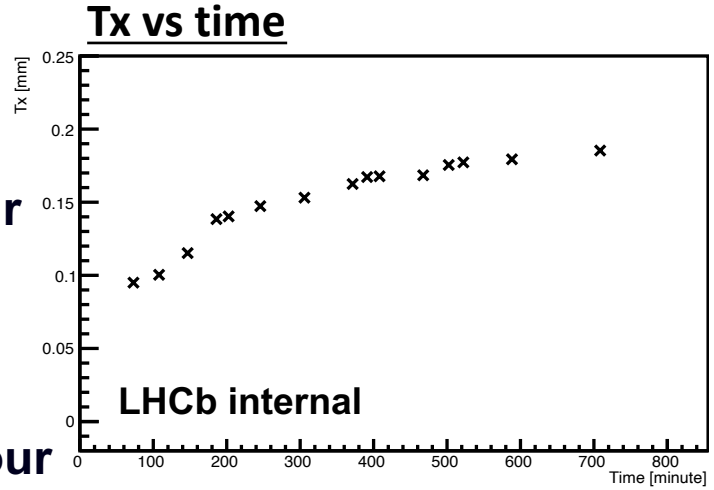


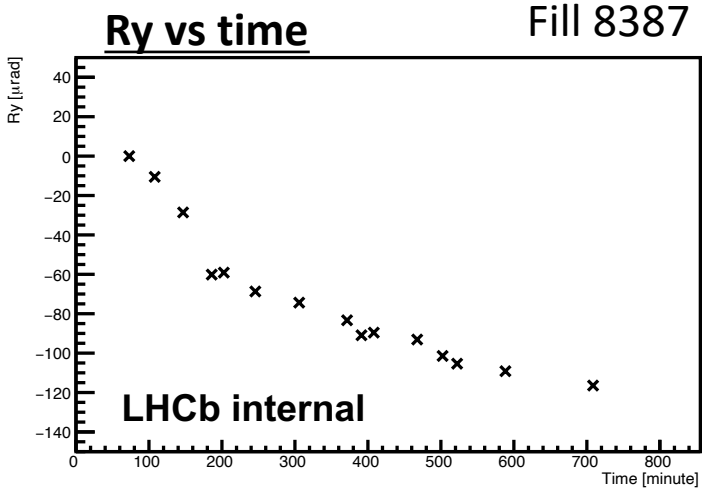


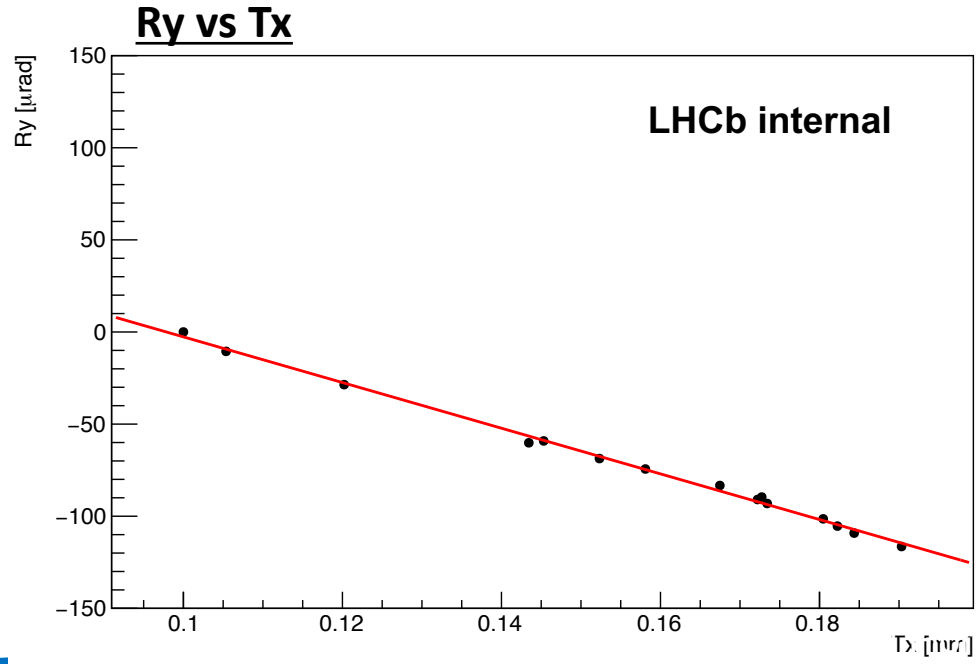
Study the half misalignment = C drift by the spatial alignment

- Main movements
  - Translation along x:
    - variation of **~80 µm in the 1st hour**
    - then **~100 µm over 10 hours**
  - Rotation around y (pivot point origin of LHCb reference system):
    - variation of **100 µrad in the 1st hour**
    - then **~120 µrad over 10 hours**
  - Linear correlation => compatible with single **rotation around y with a pivot point at about z≈ + 800 mm**

Fill 8387

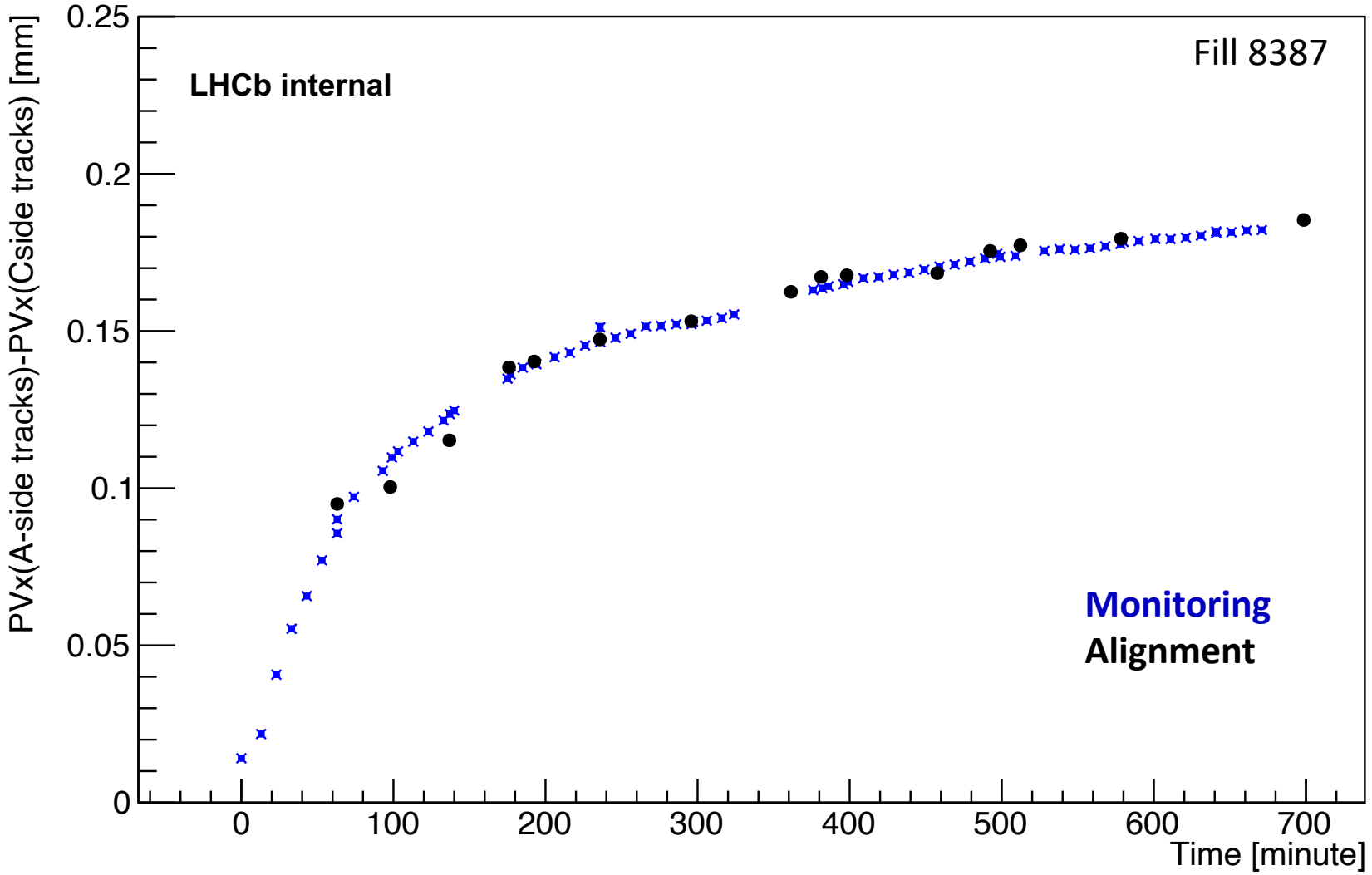






Variation each 10 minutes		ΔTime from time(0)
ΔTx = 20 µm	ΔRy = 50 µrad	0-30 min
ΔTx = 10 µm	ΔRy = 30 µrad	30-60 min
ΔTx = 5 µm	ΔRy = 10 µrad	1h-2h
ΔTx = 2 µm	ΔRy = 2 µrad	2h-4h
ΔTx = 1 µm	ΔRy = 1 µrad	4h-10h

Good agreement between monitoring and spatial alignment



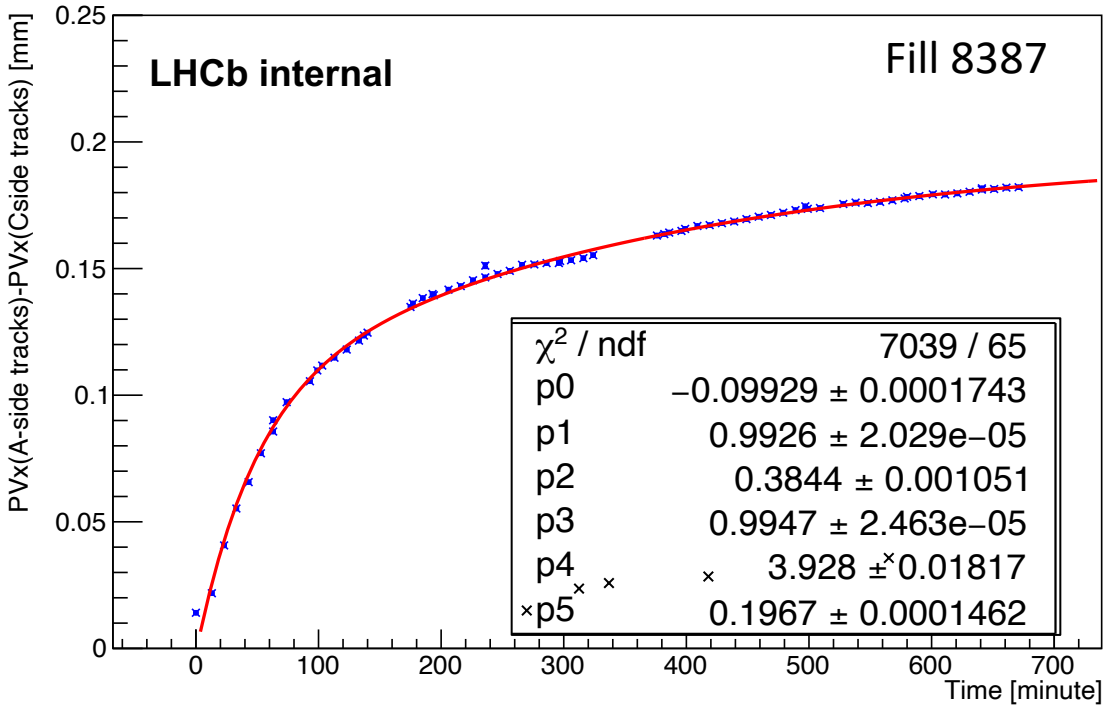
Parametrization: Tx vs time on monitoring and Ry vs Tx from alignment

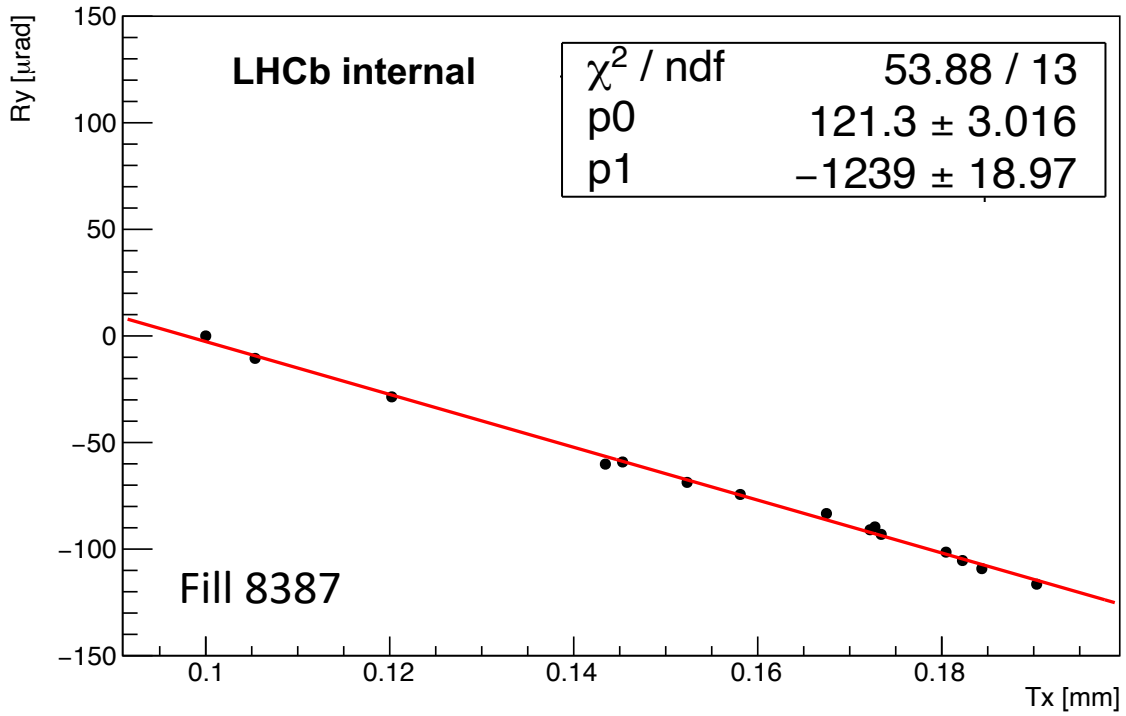
Fit by double exponential

$$Tx[mm] = p_0 * (p_1^{p2*time} + p_3^{p4*time}) + p_5$$

Fit by a line

$$Ry[\mu rad] = p_0 + p_1 * Tx[mm]$$





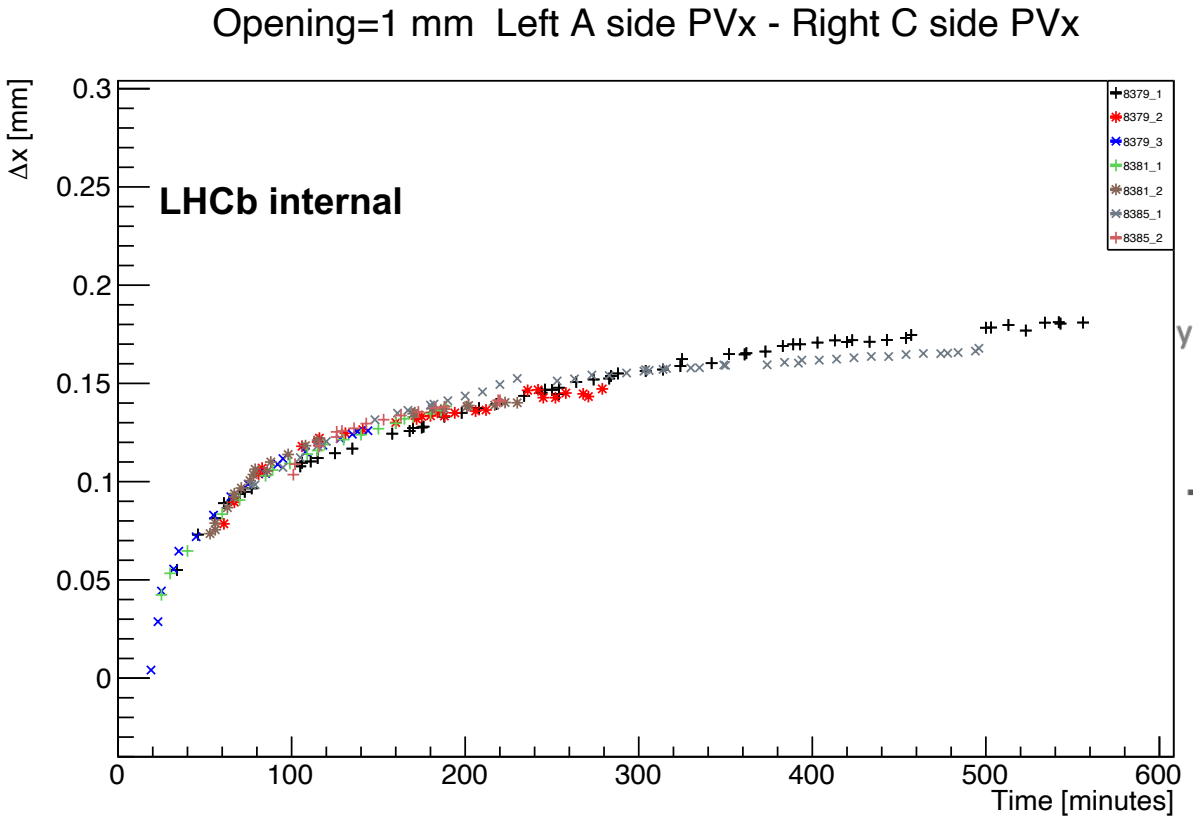
X translation fitted by double exponential

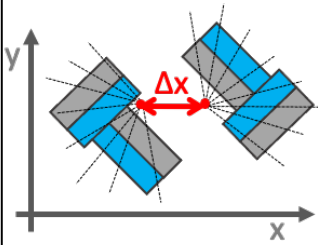
Linear dependency of Ry vs Tx

Reproducibility of the drift after several closings

Reproducibility:
adjusting the initial time of the drift by hand

- Study the time dependence after different closing procedure
- VELO close at an opening distance of 1 mm
- Comparing the behaviour adjusting “by hand” the start of the drift
- Similar results for VELO fully close



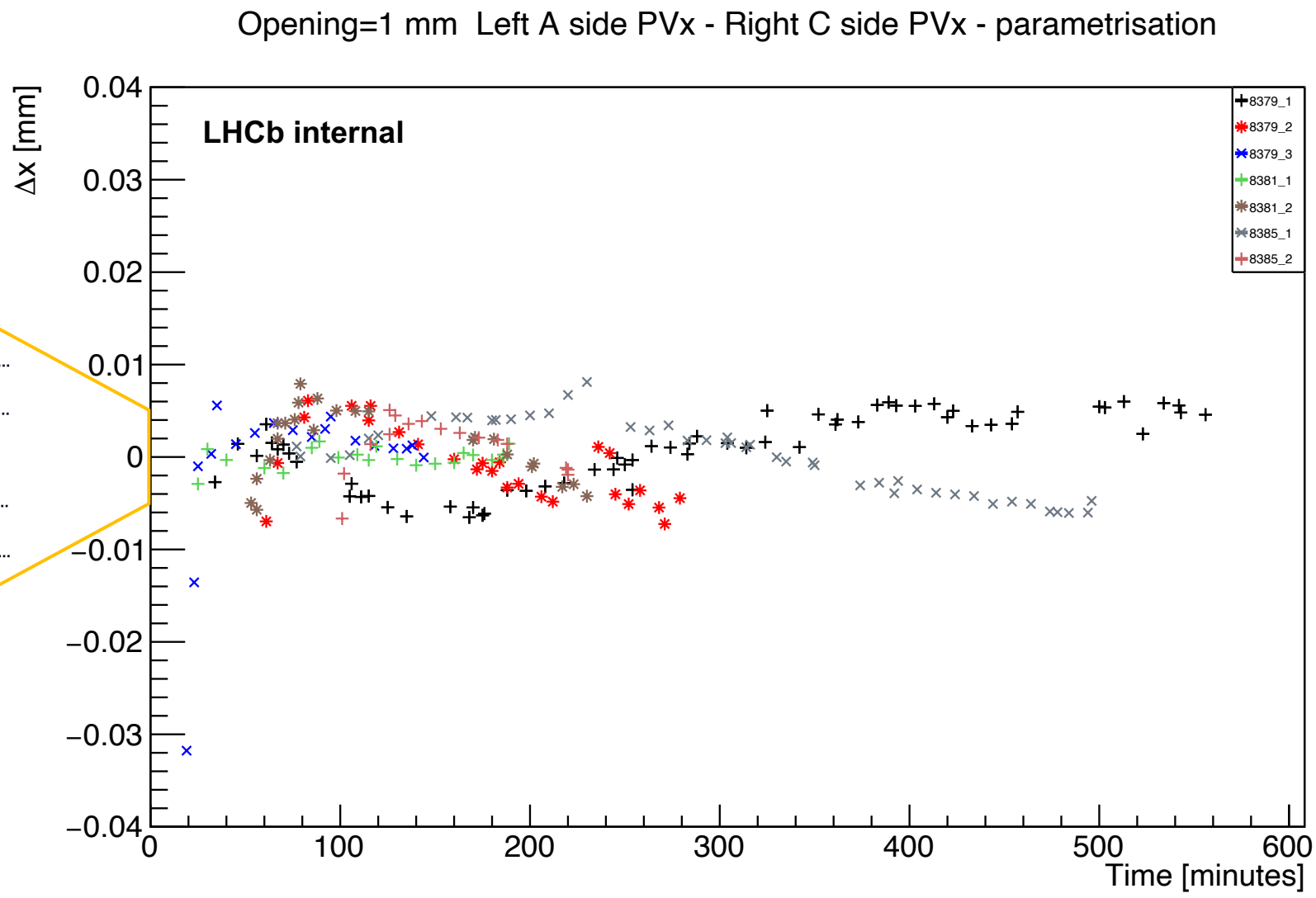


The time-dependence is well reproduced among fills at “macroscopic level”

How well parametrized?
adjusting the initial time of the drift by hand

- Comparing the misalignment with parametrization evaluated on fill 8387, with VELO fully close

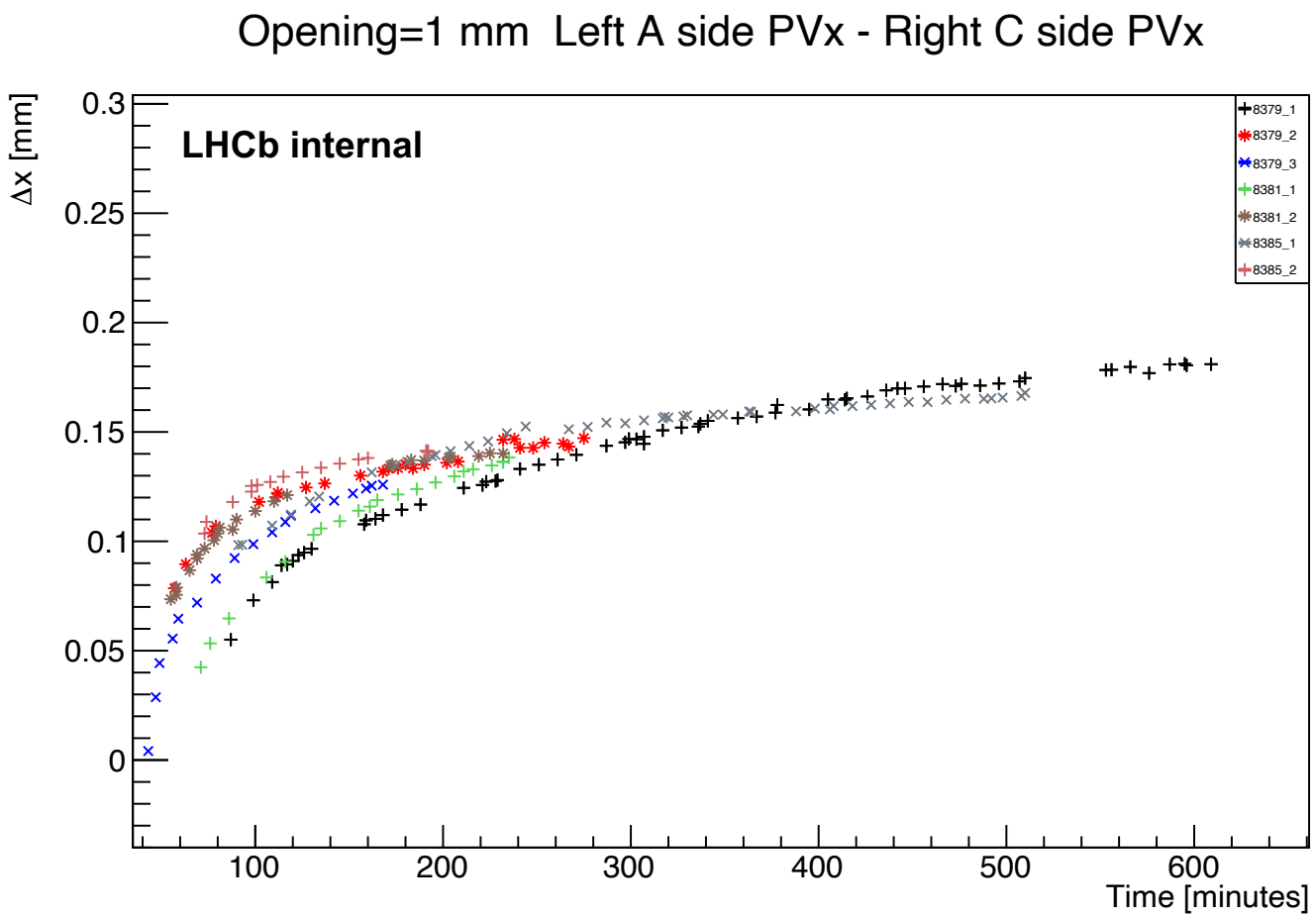
The time-dependence is described by the parametrization within ± 5 µm

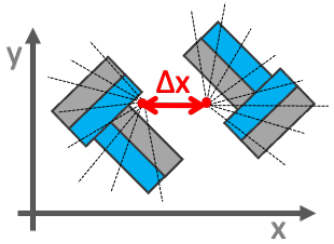


Reproducibility:
adjusting the initial time to the time when the VELO was closed

- Hypothesis: drift starts when the VELO is closed at 1 mm

Drift doesn't start at the same moment.
Difference of tens of minutes

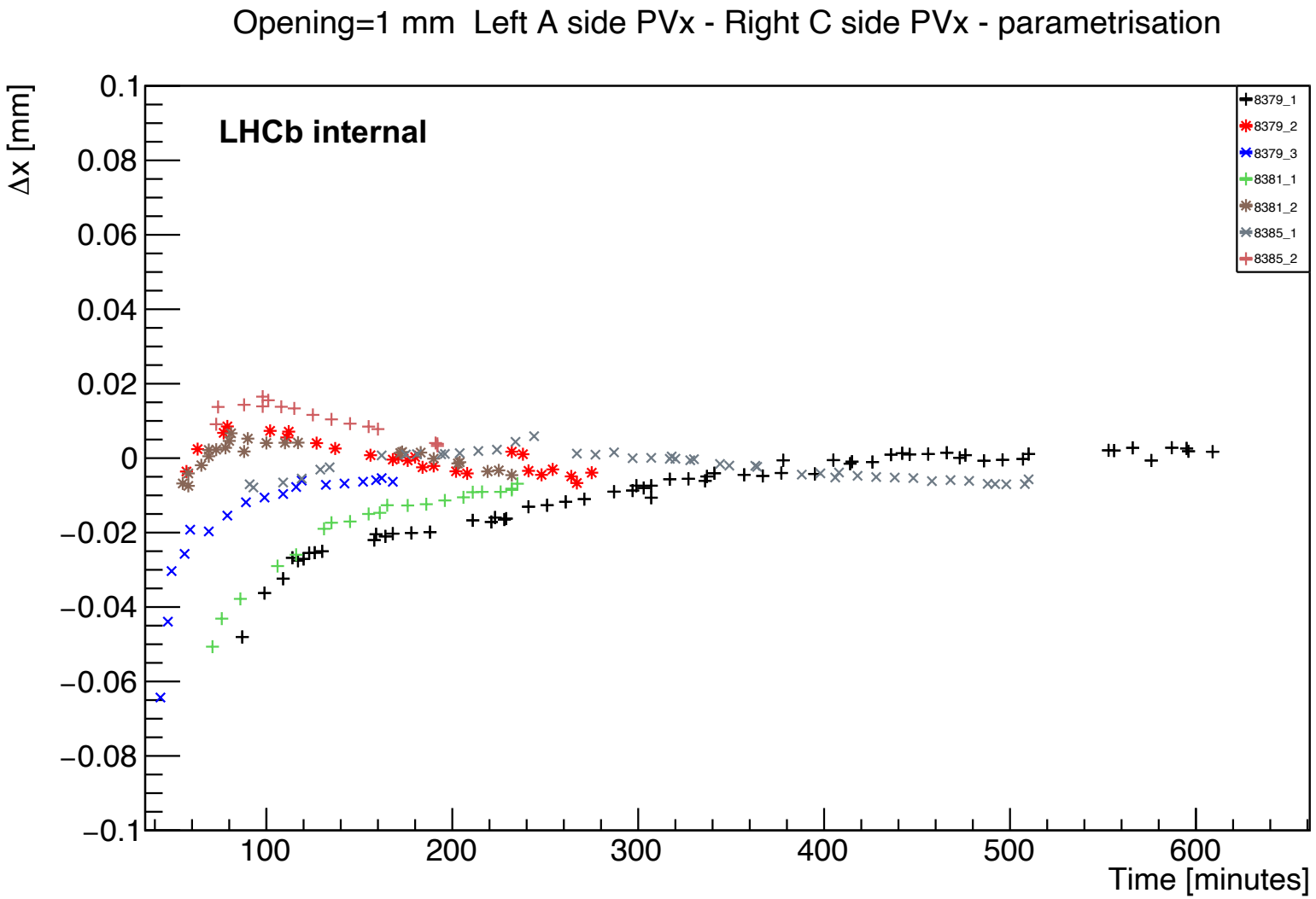




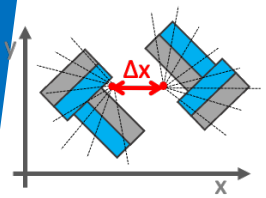
How well parametrized?
adjusting the initial time to the time when the VELO was closed

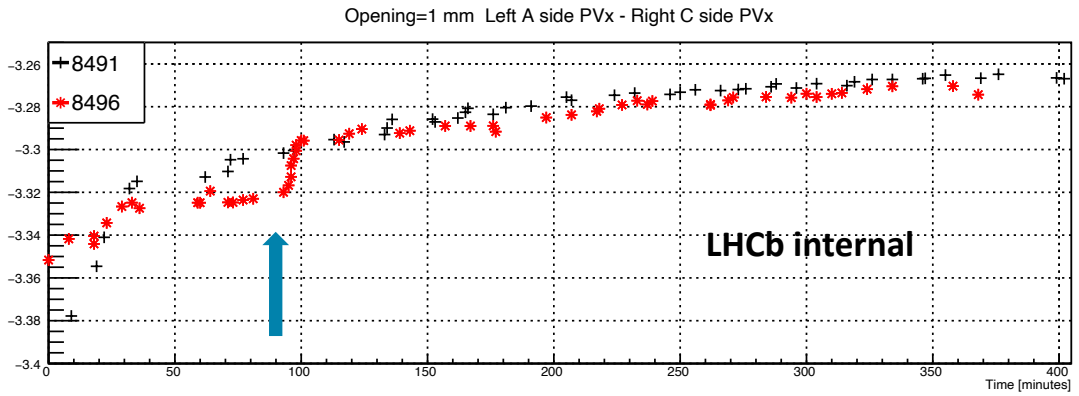
- Hypothesis: drift starts when the VELO is closed at 1 mm
- Comparing the misalignment with parametrization evaluated on fill 8387, with VELO fully close

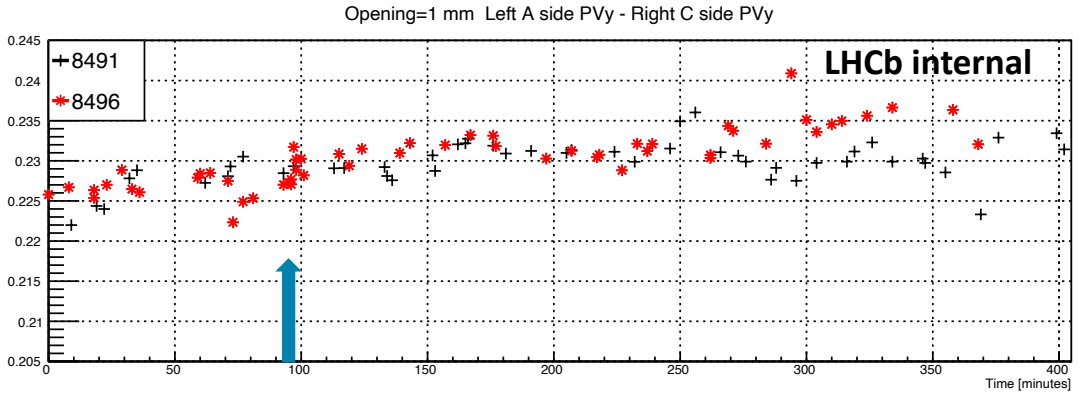
Difference up to 70 µm
Parametrization cannot describe well the drift, without knowing when the drift starting time



BUT… in last fill behaviour was different

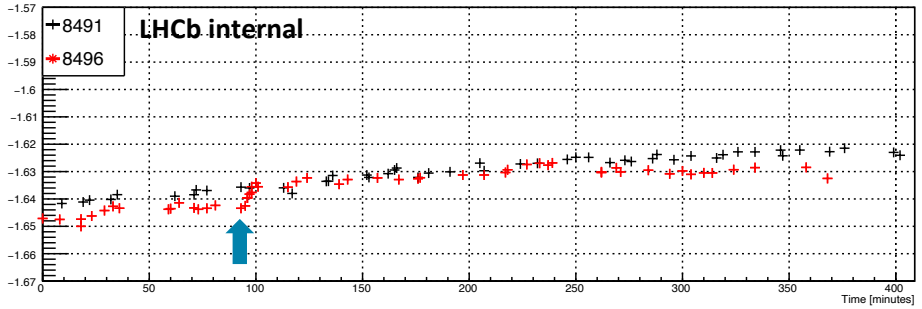




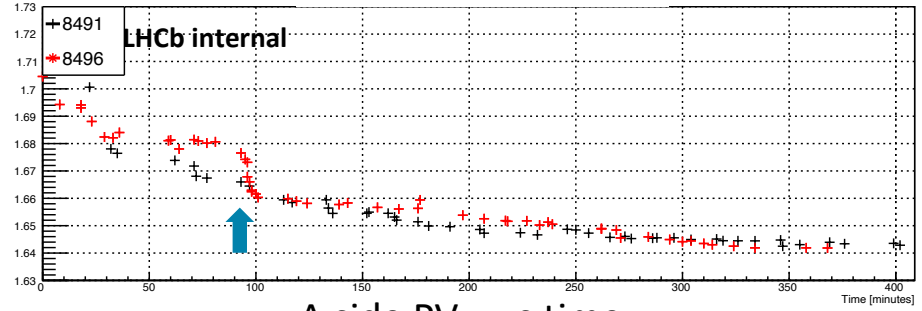


Initial behaviour different
A suddenly step after a while, it seems that this movement has an impact also on the A side

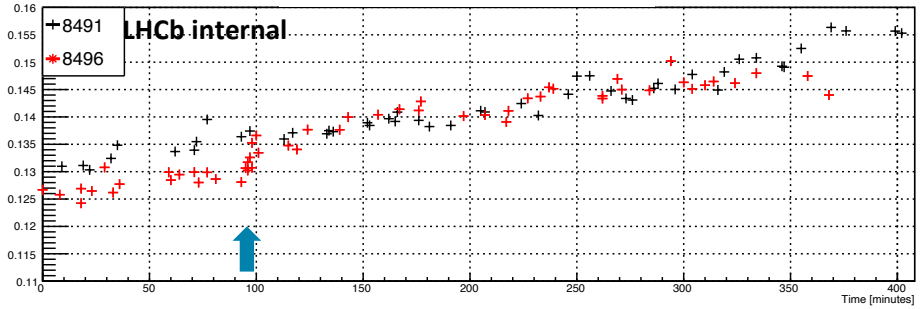
A side PV x vs time



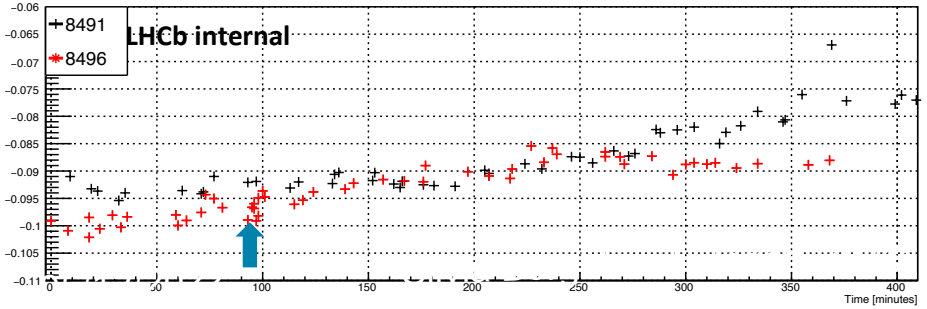
C side PV x vs time



A side PV y vs time



C side PV y vs time



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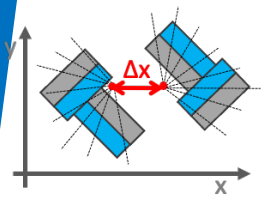
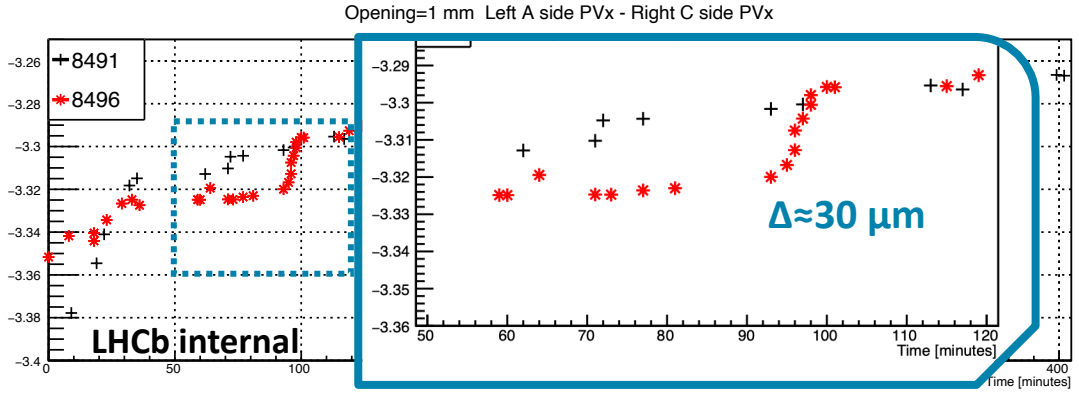
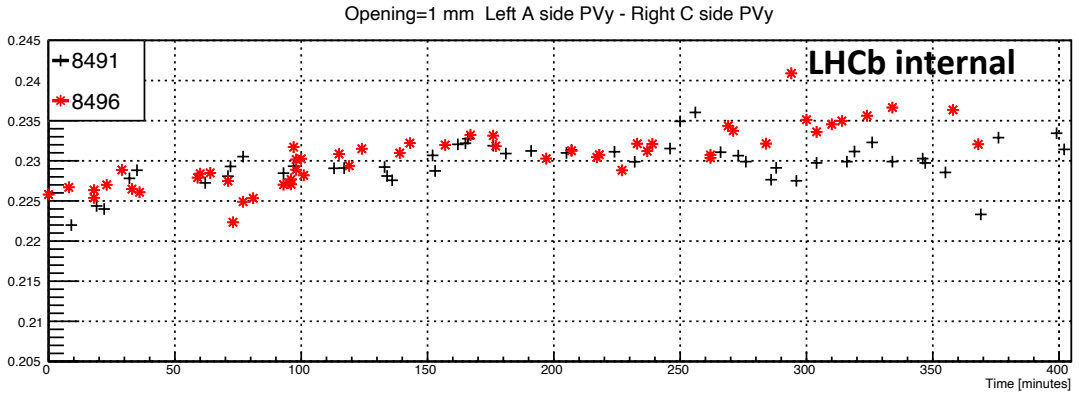


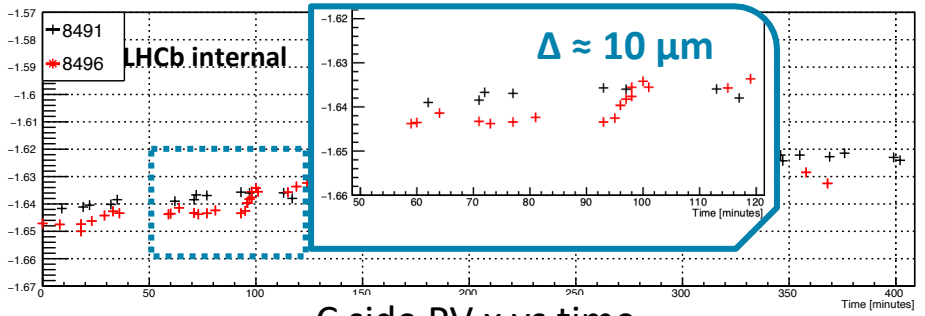




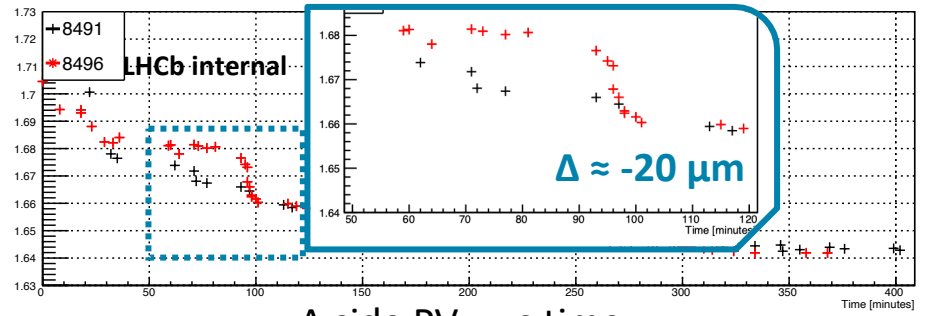
In less than 10 minutes

- x movement of -20 µm of C side
- x movement of +10 µm of A side
- y movement of 5-7 µm of A and C side

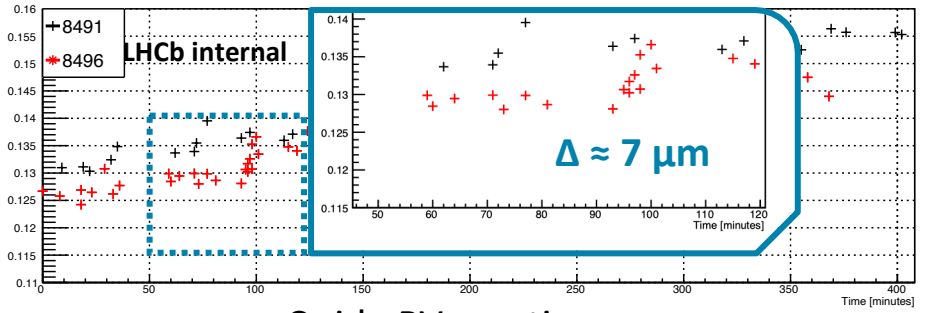
A side PV x vs time



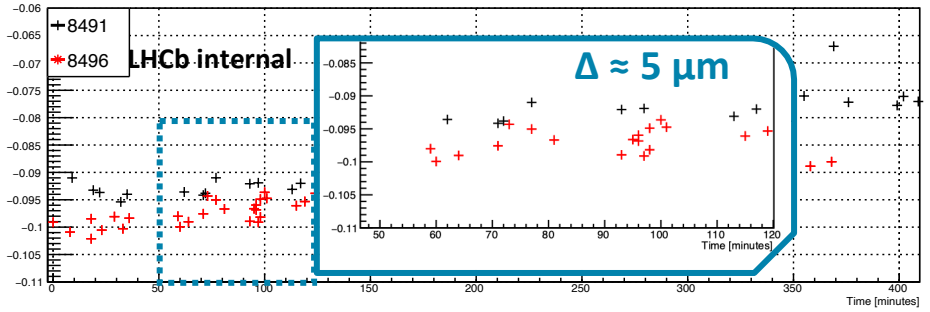
C side PV x vs time



A side PV y vs time



C side PV y vs time



Closing steps were different

Fill 8491 27th November 2022

Steps (half gap) 20, 10, 5, 2, 1, 0.5

Time (XA, XC, Y)

27-Nov 00:09:30 - (21.073,-18.927,0.501)

2.5 minutes

27-Nov 00:12:00 - (11.098,-8.902,0.491)

1 minutes

27-Nov 00:13:13 - (6.095,-3.905,0.446)

1 minutes

27-Nov 00:14:01 - (3.116,-0.884,0.449)

9 minutes

27-Nov 00:25:15 - (2.142,0.142,0.463)

3.5 minutes

27-Nov 00:28:42 - (1.680,0.680,0.465)

Fill 8496 27th November 2022

Steps (half gap) 20, 10, 5, 2, 1, 0.5

Time (XA, XC, Y)

27-Nov 23:16:48 - (21.071,-18.929,0.515)

2 minutes

27-Nov 23:18:27 - (11.087,-8.913,0.488)

1 minutes

27-Nov 23:19:41 - (6.090,-3.910,0.469)

1 minutes

27-Nov 23:20:44 - (3.107,-0.893,0.458)

1 minutes

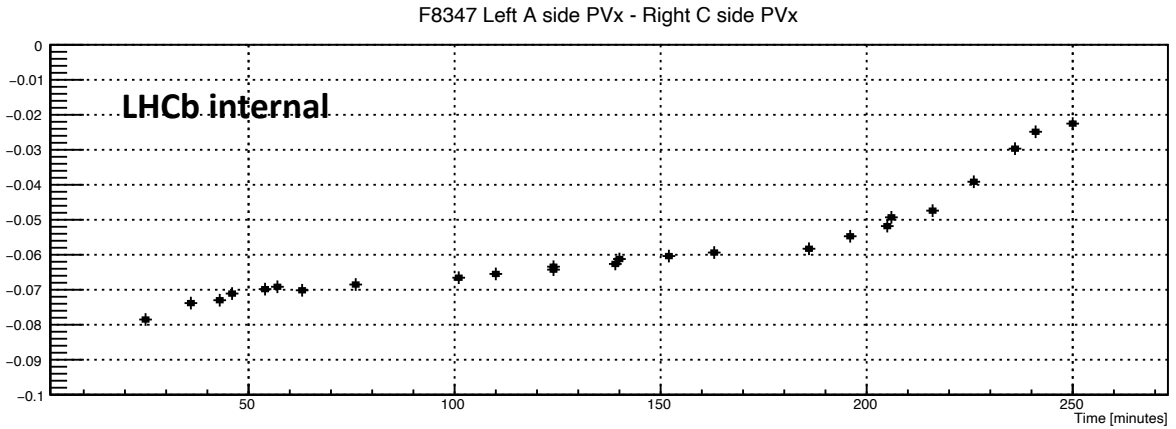
27-Nov 23:21:31 - (2.150,0.150,0.469)

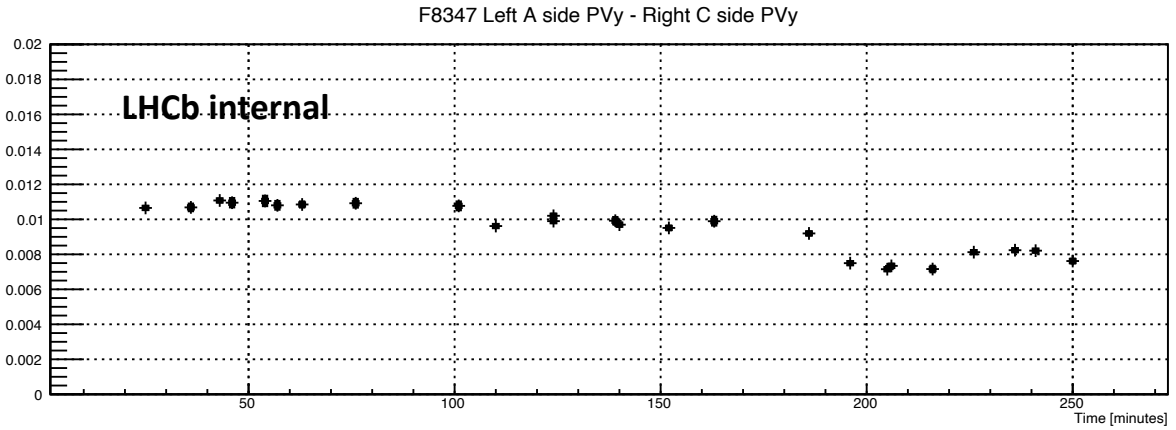
3 minutes

27-Nov 23:24:44 - (1.682,0.682,0.471)

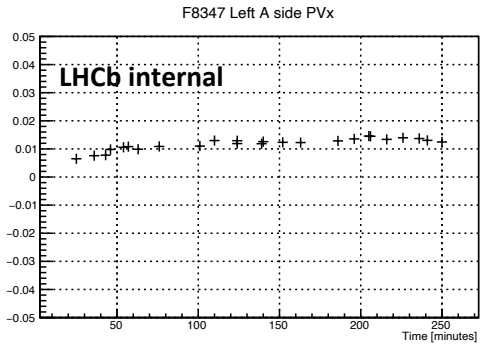
BUT… in one of first fill with VELO close behaviour was different

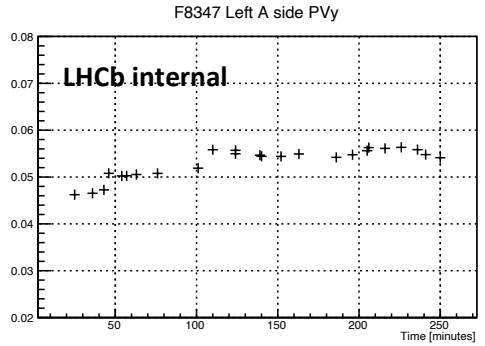
Fill 8347

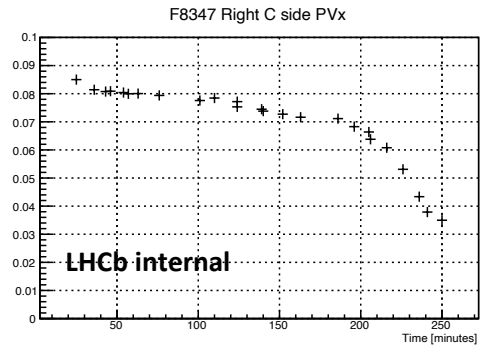


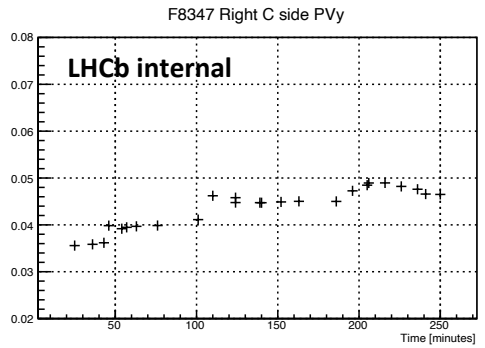


Initial behaviour different much flatter for about 200 minutes. Then it seems that usual drift starts









Closing steps quite similar

Fill 8387 12th November 2022

Steps (half gap) 20, 10, 5, 2, 1, 0.5, 0

Time (XA, XC)

18:55:13 (21.124,-18.876)

3 minutes

18:58:09 (11.146, -8.854)

2.5 minutes

19:00:39 (6.125, -3.875)

2 minutes

19:02:46 (3.132, -0.868)

3.1 minutes

19:06:01 (2.156, 0.156)

14 minutes

19:21:00 (1.683, 0.683)

4.5 minutes

19:25:43 (1.227, 1.227)

Fill 8347 5th November 2022

Steps (half gap) 20, 10, 5, 2, 1, 0.5, 0

Time (XA, XC)

11:38:56 (21.07, -18.93)

2 minutes

11:41:07 (11.09, -8.91)

2 minutes

11:43:08 (6.10, -3.90)

3 minutes

11:45:09 (3.12, -0.88)

3 minutes

11:48:42 (2.18,0.18)

11.5 minutes

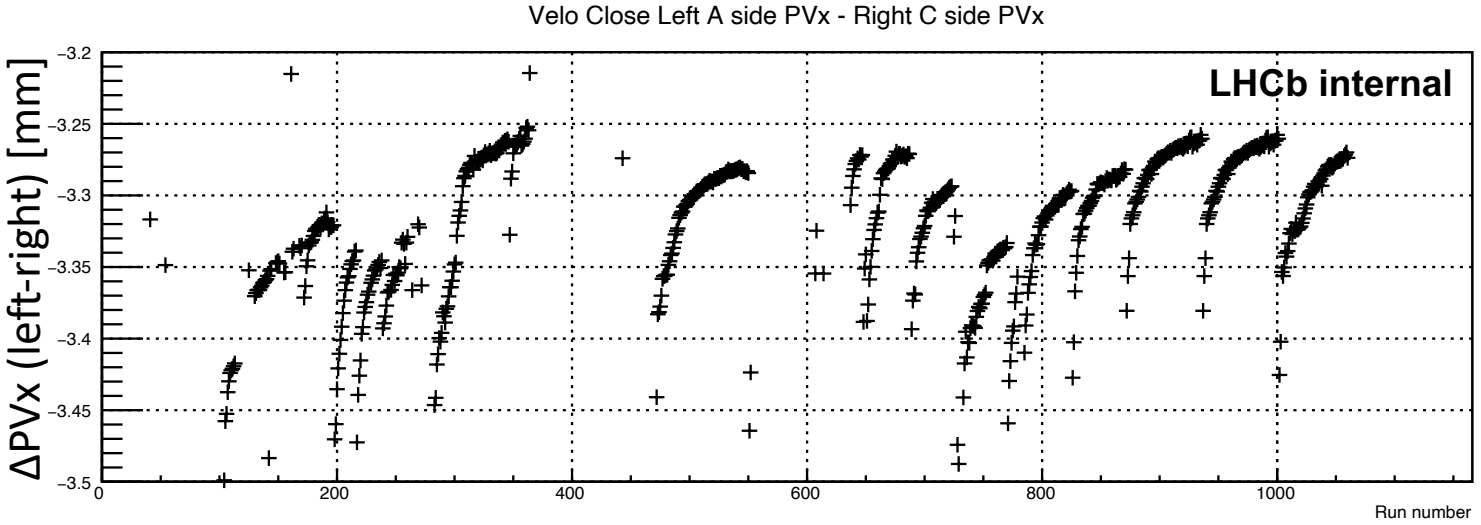
12:01:08 (1.75,0.75)

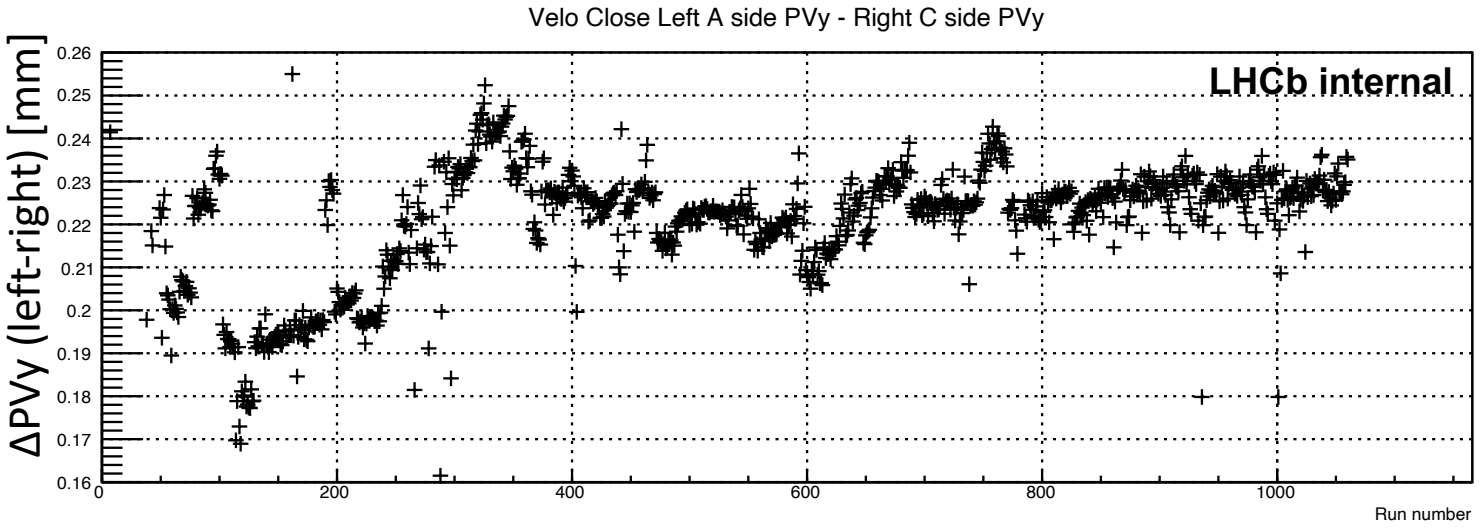
2 minutes

12:03:41 (1.31,1.31)

Reproducibility of initial misalignment just after closing

Initial alignment variation per fill
plotting ost of the fills with the VELO close





Initial Tx misalignment can vary by 100 µm or even 200 µm among fills

Initial Ty misalignment usually varies by 10 µm or 20 µm among fills

Warning
Run number is not proportional to the time

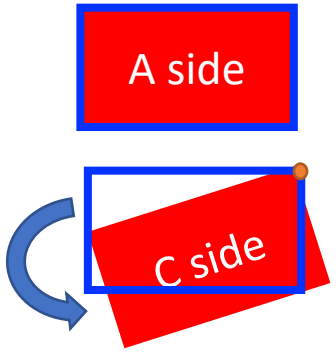
Description of the drift

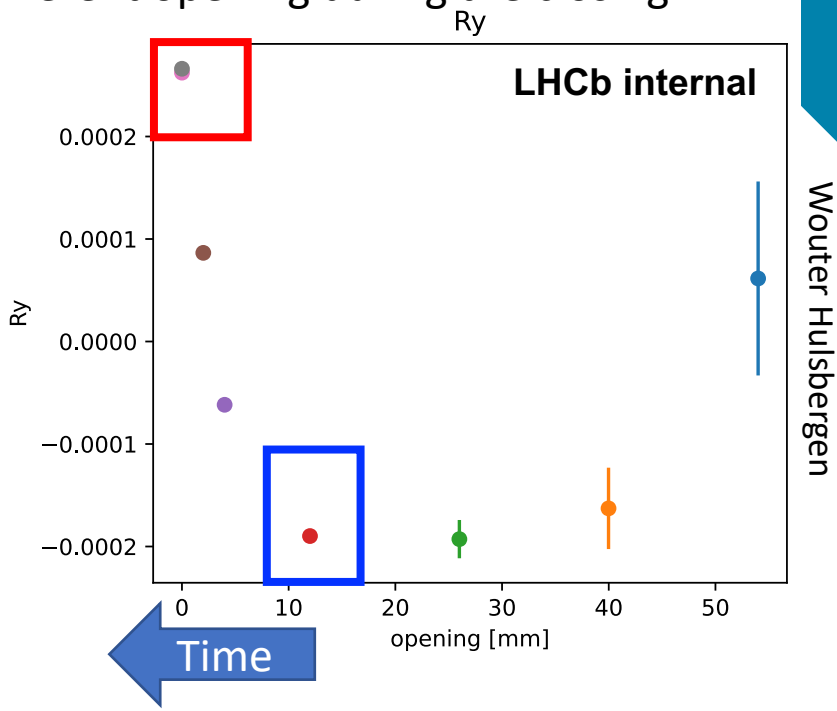
Direction of the movement

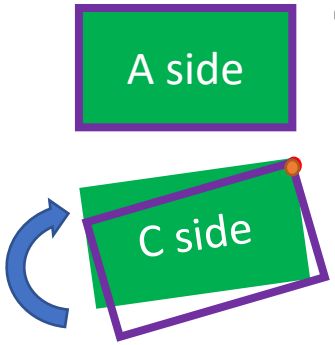
- The C side is rotated around y when is closing. The C side backward region remains behind (vs negative x) from an opening of about 12 mm:
  - Ry about 450 μrad with pivot at z≈850 mm
  - Pivot point = LHCb reference system origin: Ry about 450 μrad and Tx about 430 μm
- The C side drift when the VELO is at the same motion system position. The C side backward region is approaching the A side (vs positive x). In ~10 hours
  - **Ry about 220 μrad pivot at z≈800 mm**
  - Pivot point at the LHCb reference system origin: Ry about 220 μrad and Tx about 180 μm

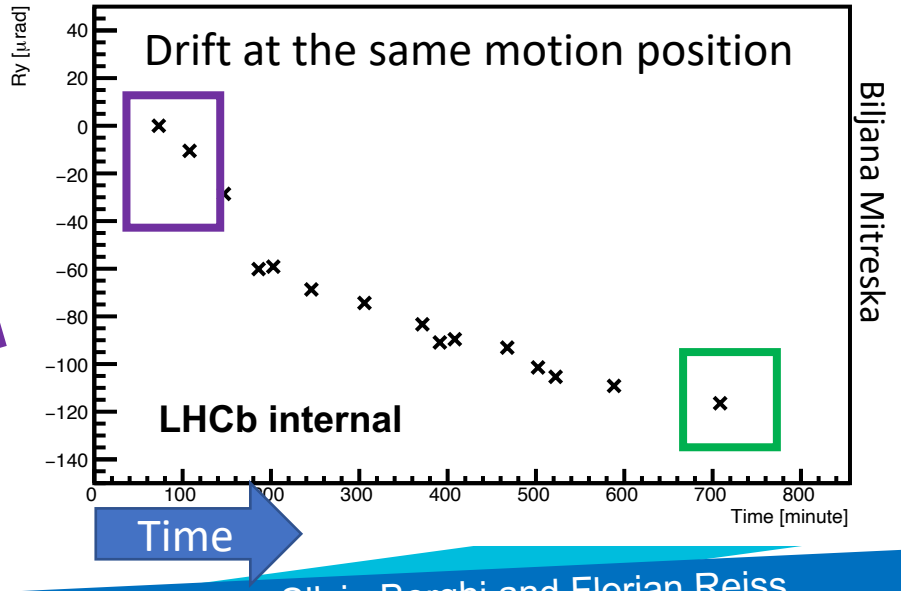
The 2 movements are in opposite direction. They can be described by the same rotation around y axis at a pivot point at the end of the VELO (at z around 800 mm)

At different opening during the closing



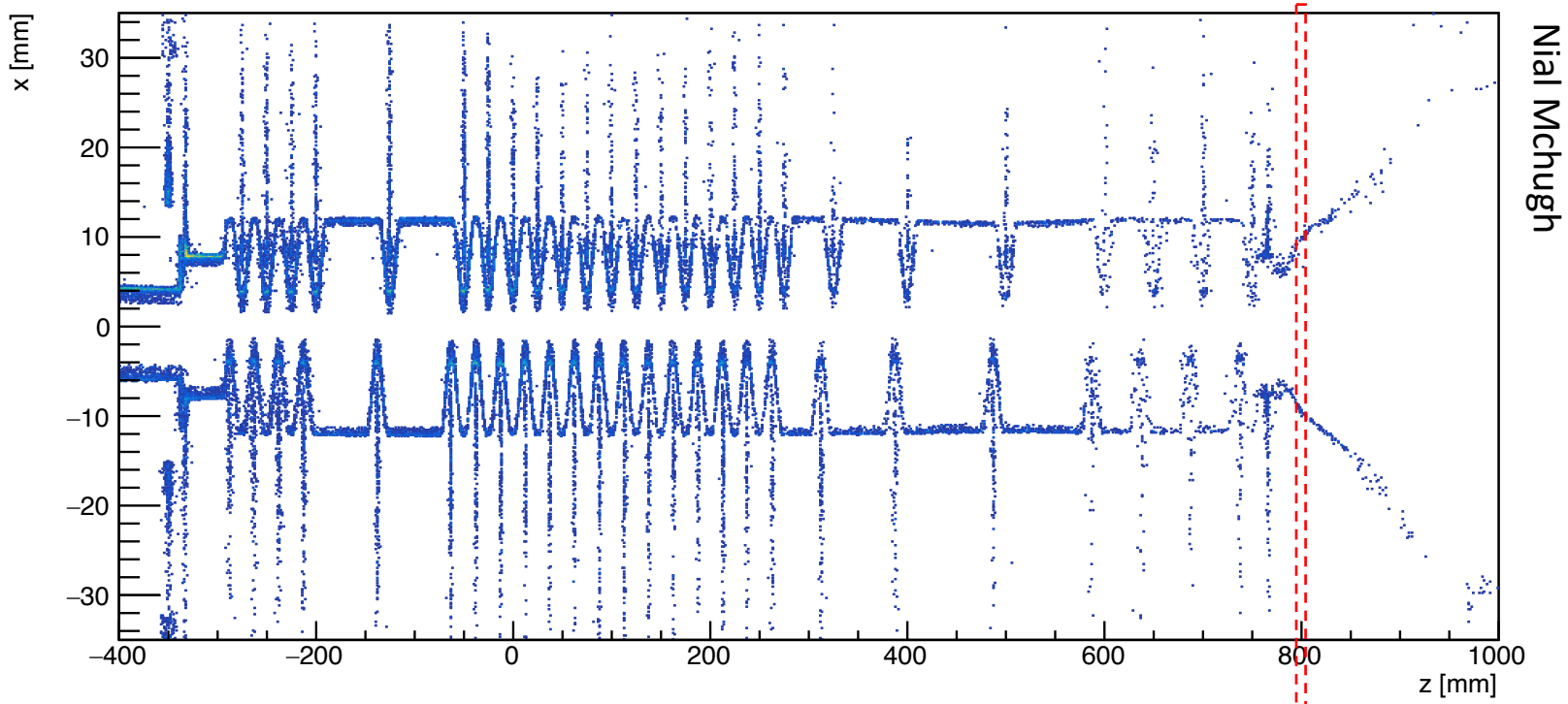




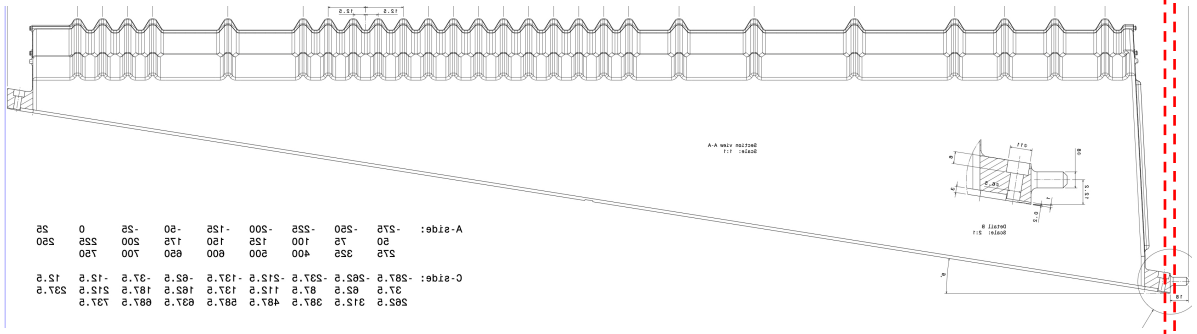


Where is the pivot point?

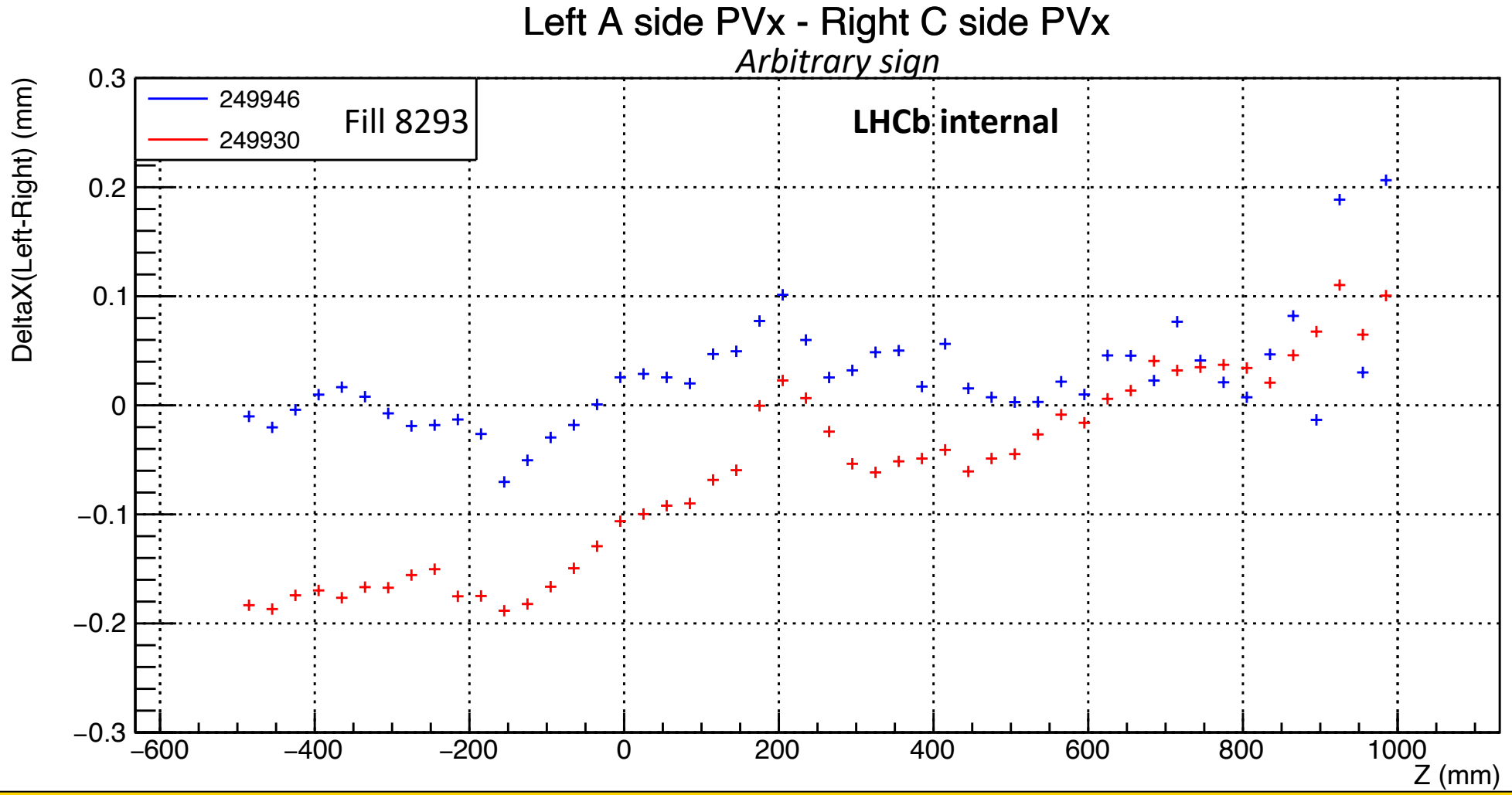
Top View



RF box



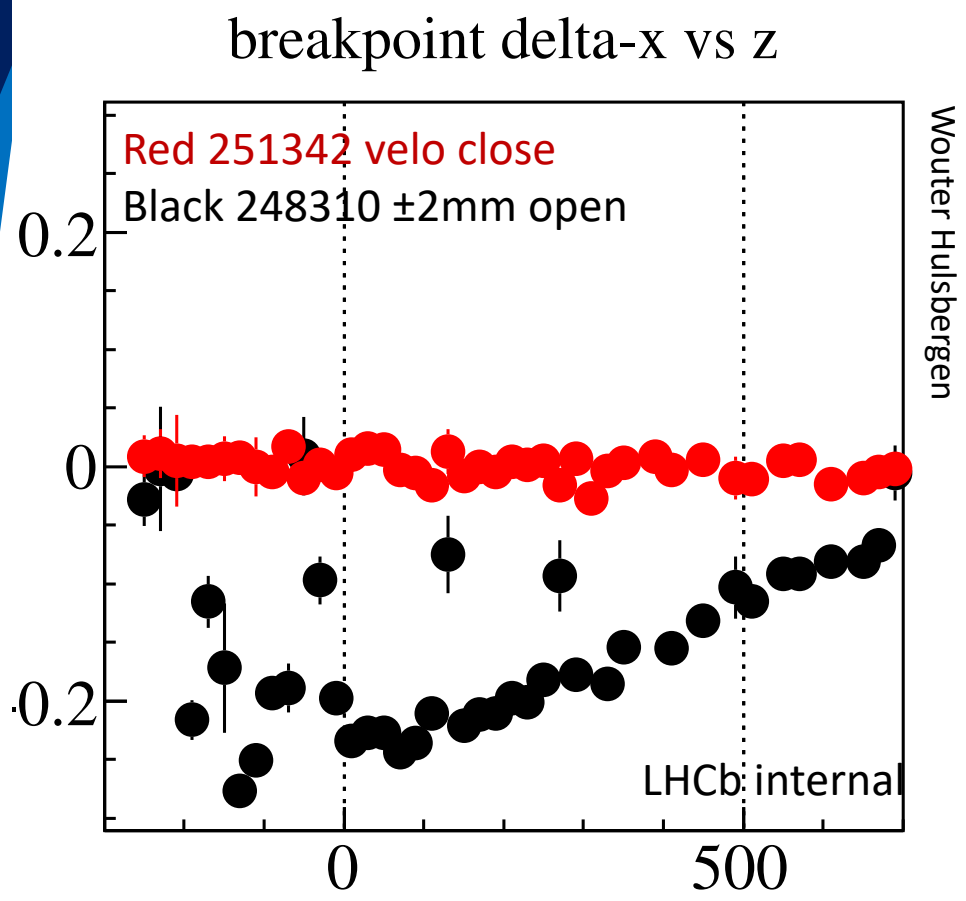
X Misalignment with beam-p collisions vs z



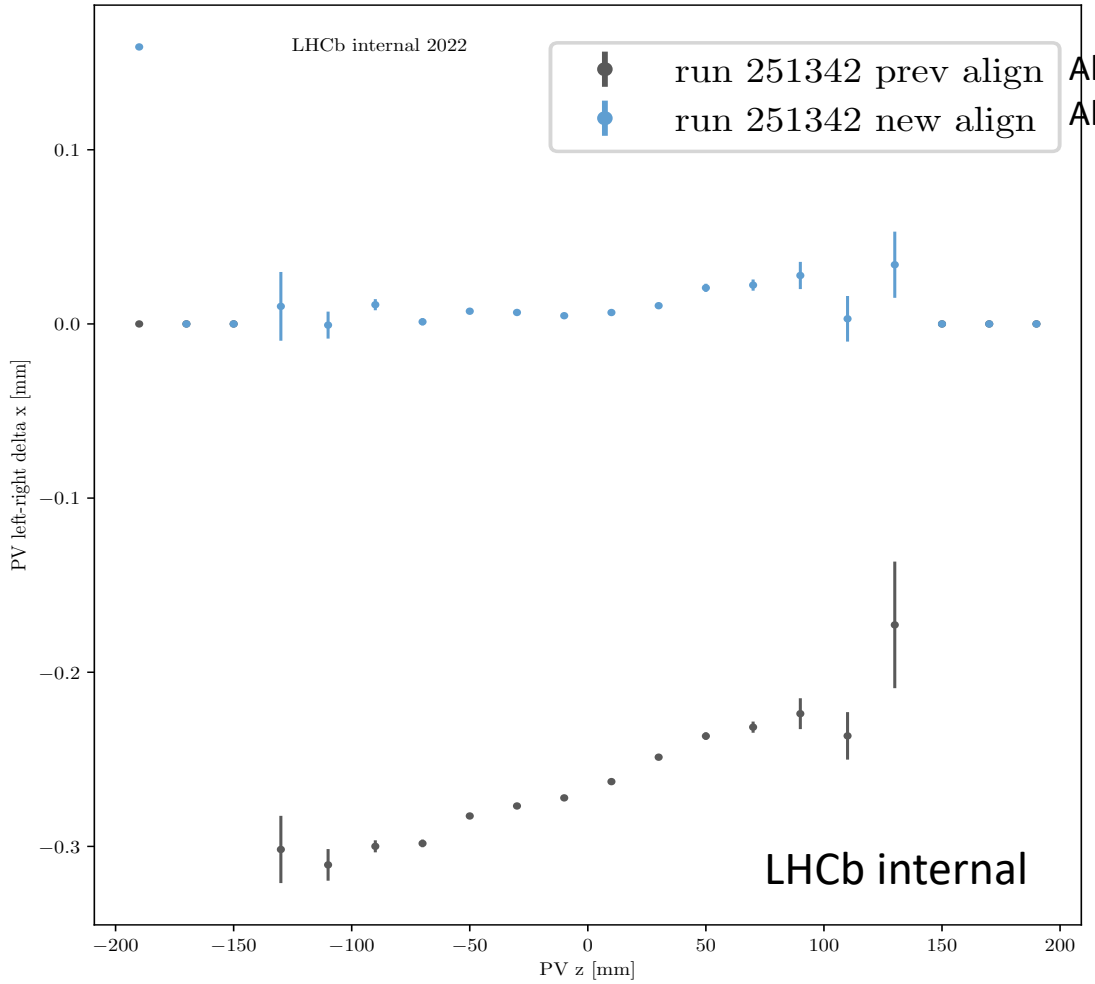
Delta in the backward region ~180 μm, almost zero in the forward region

Tx misalignment 4 mm opening vs close position

Overlap tracks vs z



PV left-right vs z postion



A rotation around Y of C side is observed
Nb: the global shift difference between the 2 plots is due to different starting alignment

Is the RF foil drifting?

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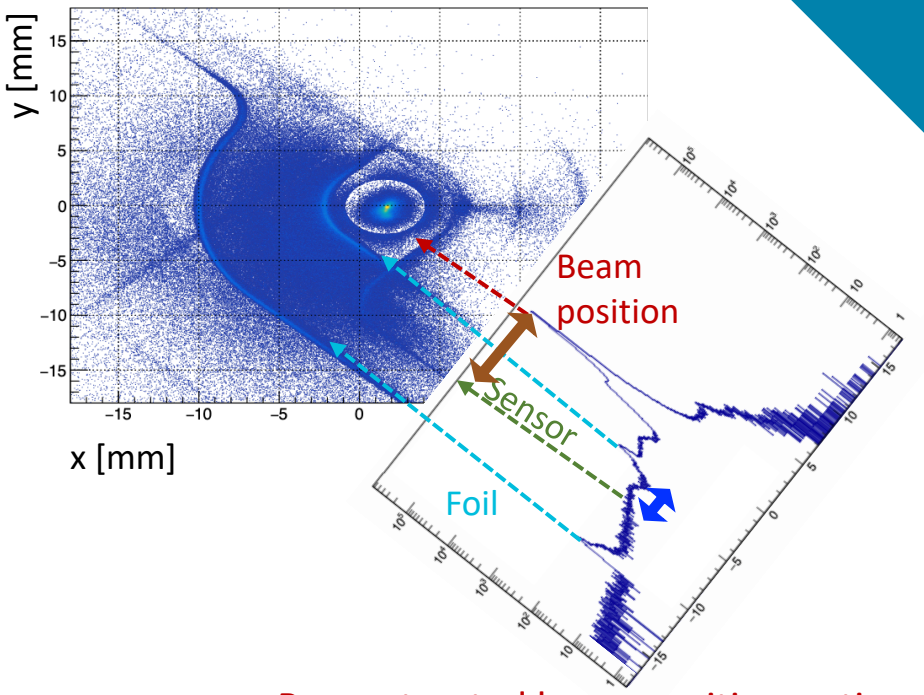
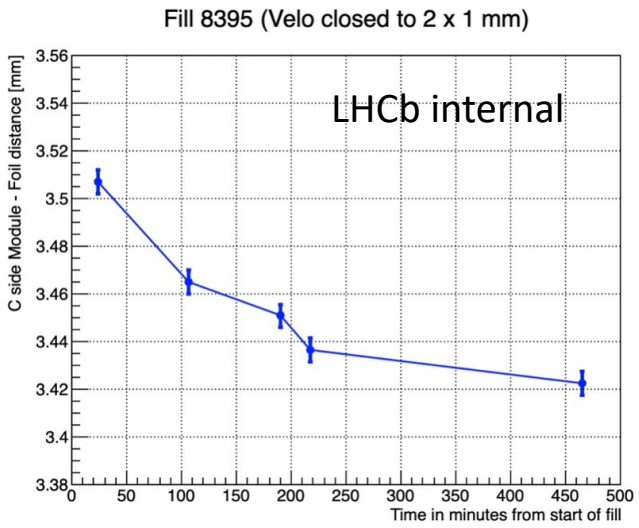
RF foil position vs time at the same motion system position

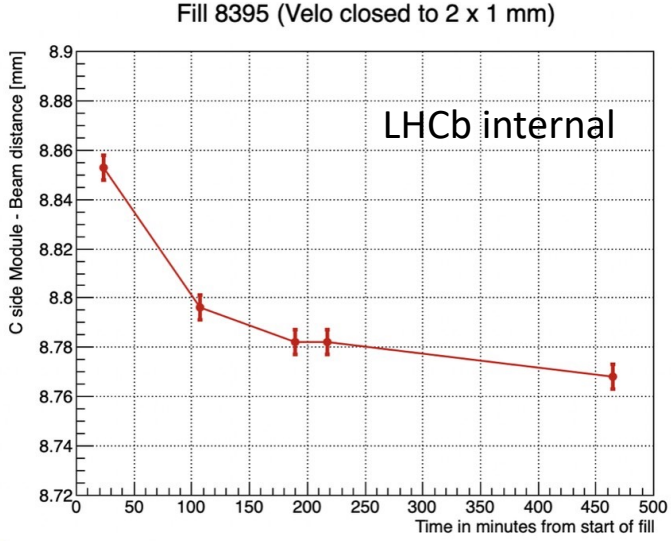
- Use only C side to reconstruct PV to determine beam position and to make material scan determining the RF foil position
- Evaluate distance
  - between modules and the foil
  - Between modules and the beam
- If the RF foil is moving with the C side, distance remains constant
- If RF foil stay at the same position (no drift) the RF foil position should consistently change as the beam position
- **Once the module is closed, the modules continue to approach the foil, at first steeply and then with a slower drift of 10-20 μm**



Reconstructed RF position vs time



Reconstructed beam position vs time



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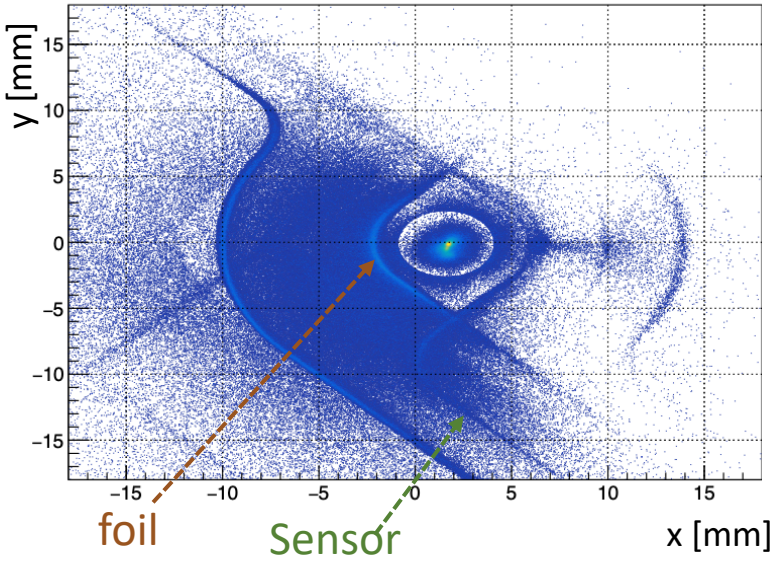
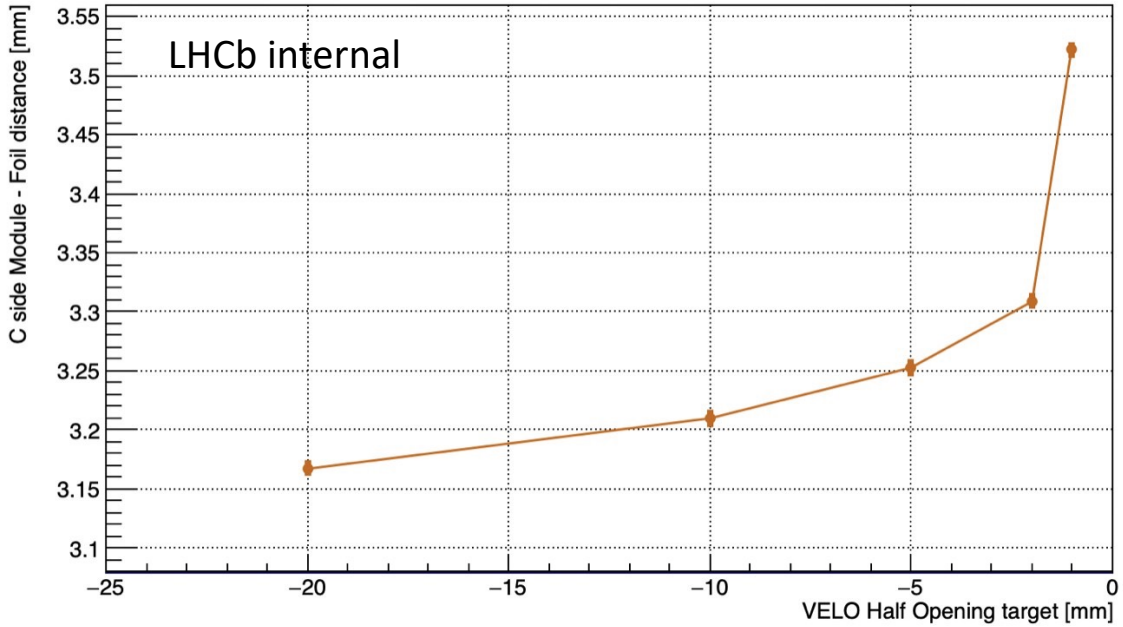
RF foil position vs VELO opening at the same motion system position

- Tracking the distance from the modules to the foil **during closing** indicates that the foil moves ahead of the module

- Combined with the previous measurements shows that **modules "catch up" after the VELO stopped moving**



Fill 8381 (Velo closed to 2 x 0.5 mm)



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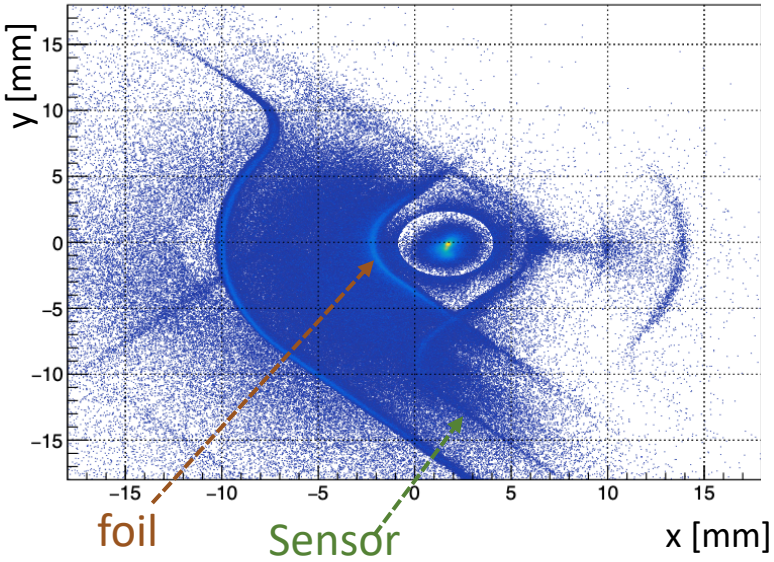
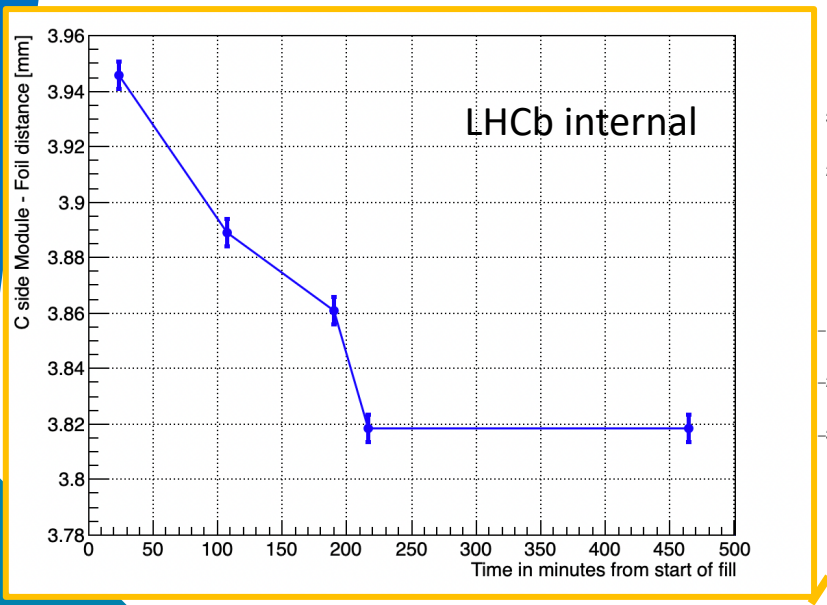
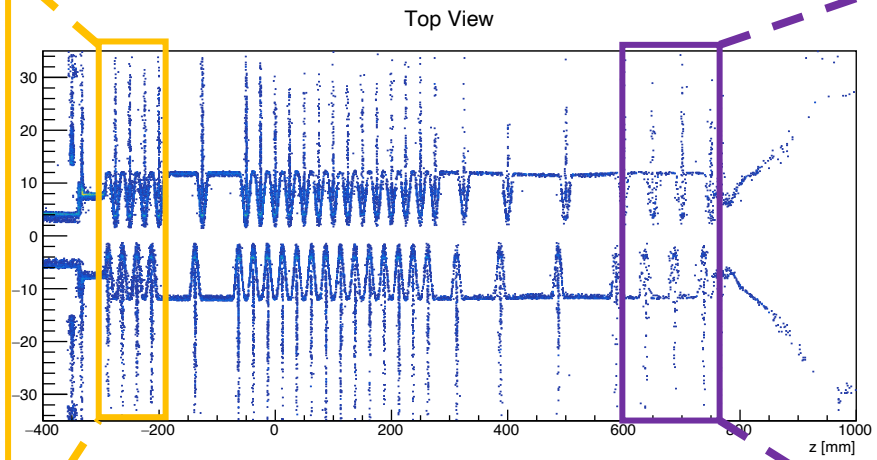
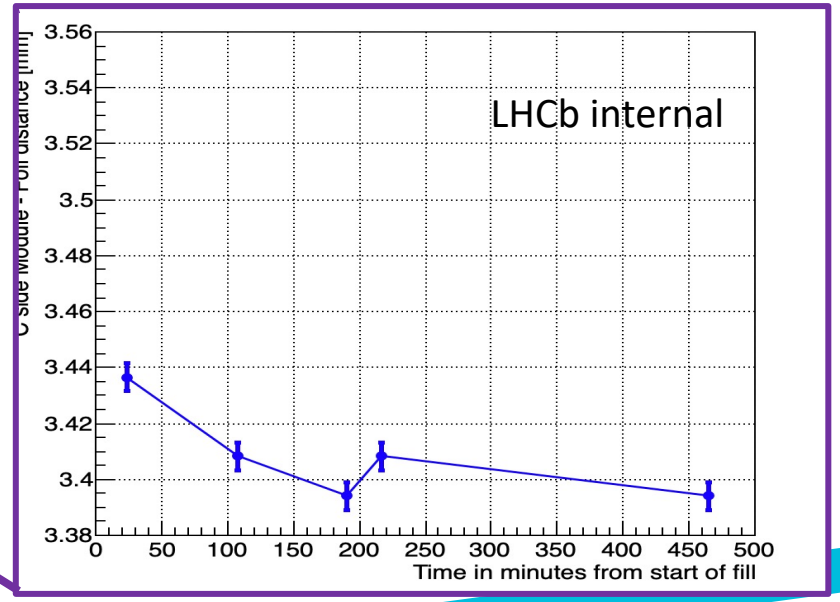
RF foil position vs time in upstream and downstream region

- In the upstream region variation of 120 μm
- In the downstream region variation of 40 μm
- Consistent with Ry rotation with pivot point at the end of the VELO in downstream region









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Conclusion

Some conclusions 1st part

- Monitoring, alignment and material scan give a consistent picture
- **During the closing** the C side starts to **rotate around the y axis** with a pivot point around 850 mm, consequently the backward (upstream) region remains behind (going vs negative x)
- **At the same opening position** (from opening distance of about 10 mm), the C side drifts along x **rotating around the y-axis** with a pivot point around 800 mm, consequently the backward (upstream) region catch up (going vs positive x).
  - Large drifts in particular during the first 1-2 hours
  - The drift can be described by a double exponential and has similar behaviour in several fills, but not all
  - The start of the drift is not well defined, it seems correlated how the VELO was closed: which steps and how long it stays at the same opening position
- **C side rotations around y axis** during the closing and during the drift are in **opposite direction**
- It happened that a quick 20 μm C side drift in few minutes correlated to a movement also of the A side of 10 μm
- Material scan study shows that the **C-side foil** is **not affected** as the C-side modules by the displacement during the closing and the drift at the same opening position
- Check ongoing to correlate the PV variation observed by A side with the variation of LHC beam

Some conclusions 2nd part

- Large C side drifts at the same motion system position: up to 10-20 μm during the first hour

  ⇒ This would imply correction each minute

Variation each 10 minutes		ΔTime from time(0)
ΔTx = 20 μm	ΔRy = 50 μrad	0-30 min
ΔTx = 10 μm	ΔRy = 30 μrad	30-60 min
ΔTx = 5 μm	ΔRy = 10 μrad	1h-2h
ΔTx = 2 μm	ΔRy = 2 μrad	2h-4h
ΔTx = 1 μm	ΔRy = 1 μrad	4h-10h

- The start of the drift is unpredictable

  ⇒ Making difficult to apply a time dependence correction

- Observed at least in one fill a global movement

  ⇒ Any movement of both side in the same direction cannot be corrected

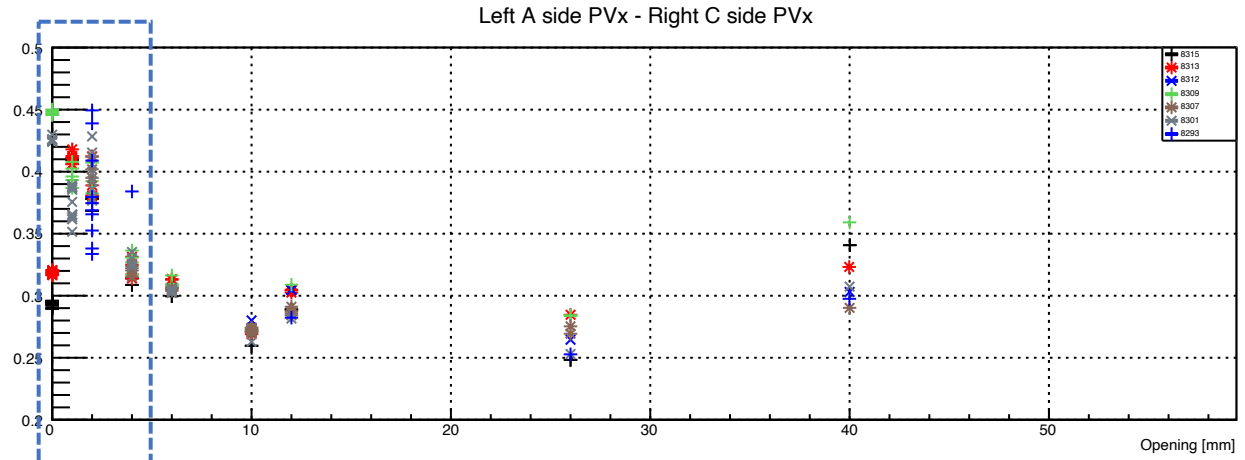
- Hard to determine the size of systematic associated to the drift and its correction

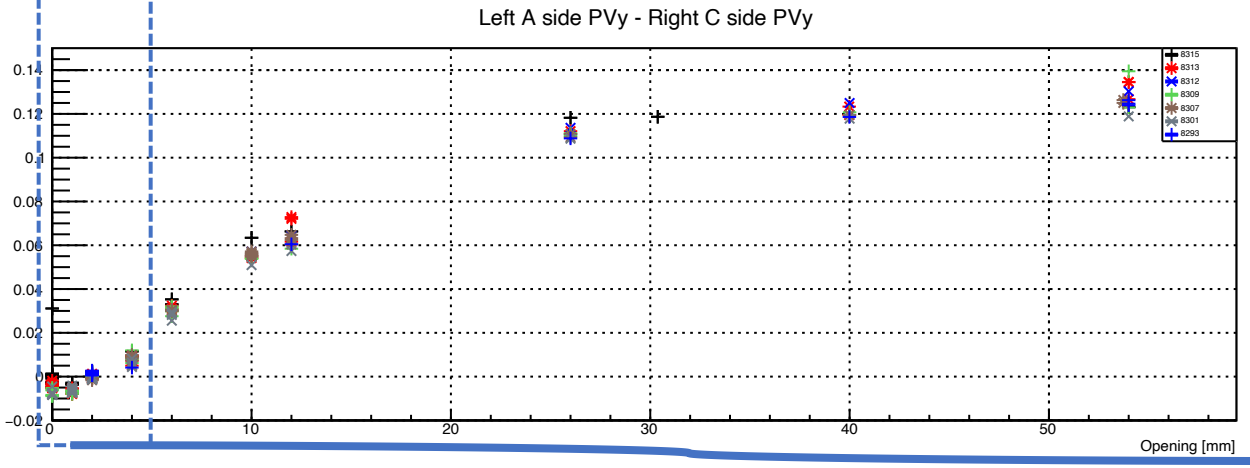
  ⇒ This could be a main systematic for many physics measurements

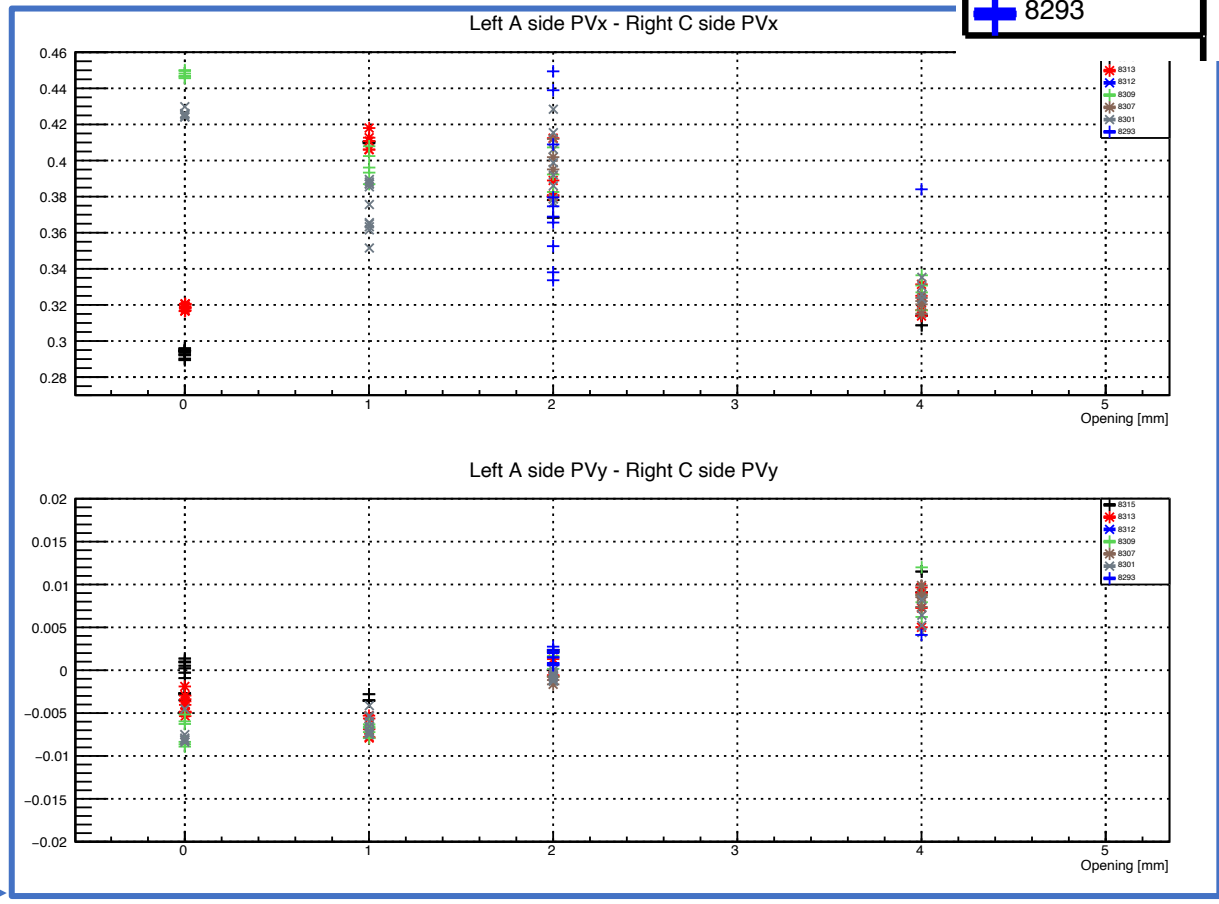
- Development for any eventual correction would require a lot of work by few experts: to be prioritized considering the other relevant tasks to be completed before restarting of the data taking
- RTA, Core Software, and Online teams are discussing the effort required to implement a scalable and maintainable approach for having per-minute alignment updates if this turns out to be necessary. Will present what is possible, with which effort, and which other work would have. to be delayed, at the postmortem run meeting

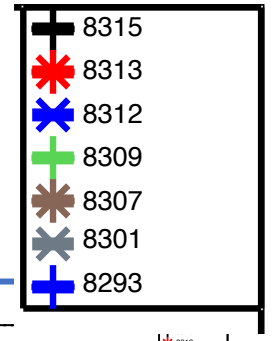
Backup

Half misalignment: distance of PV(left-right) versus opening distance









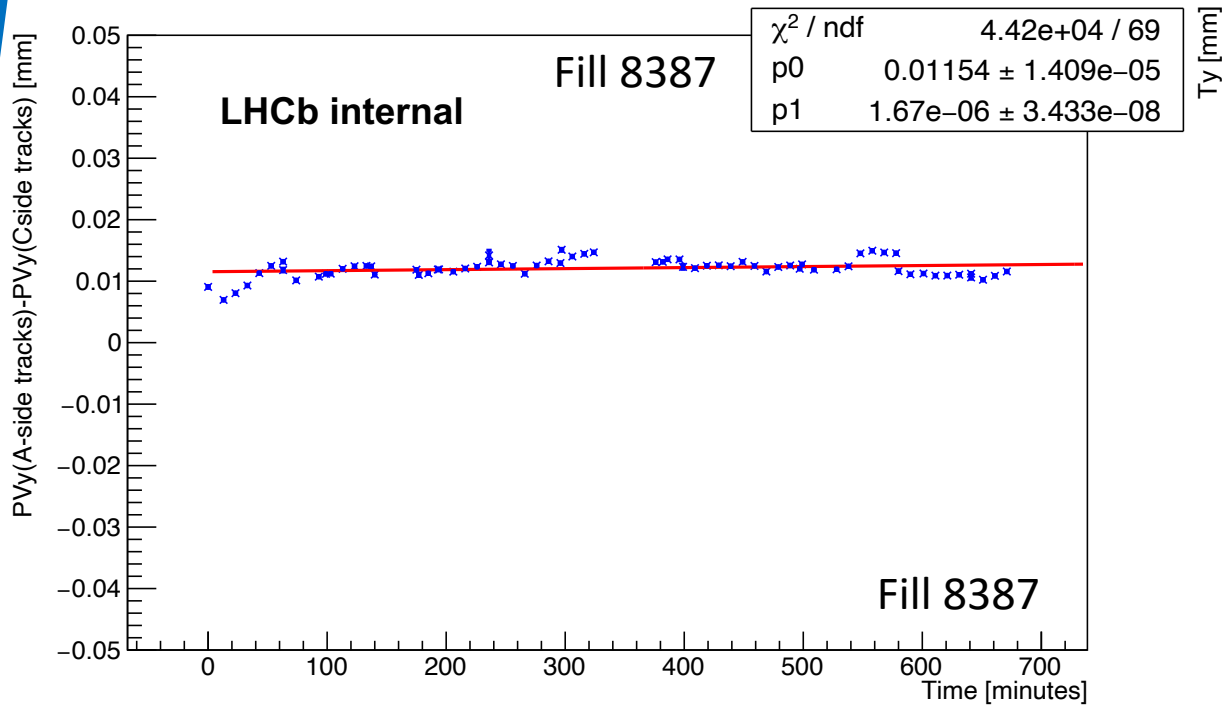
Zoom in

Variation between the fill could be up to 150 micron. It seems that fills with similar closing steps and timing have difference of 20 micron

Ty vs time on monitoring and on alignment

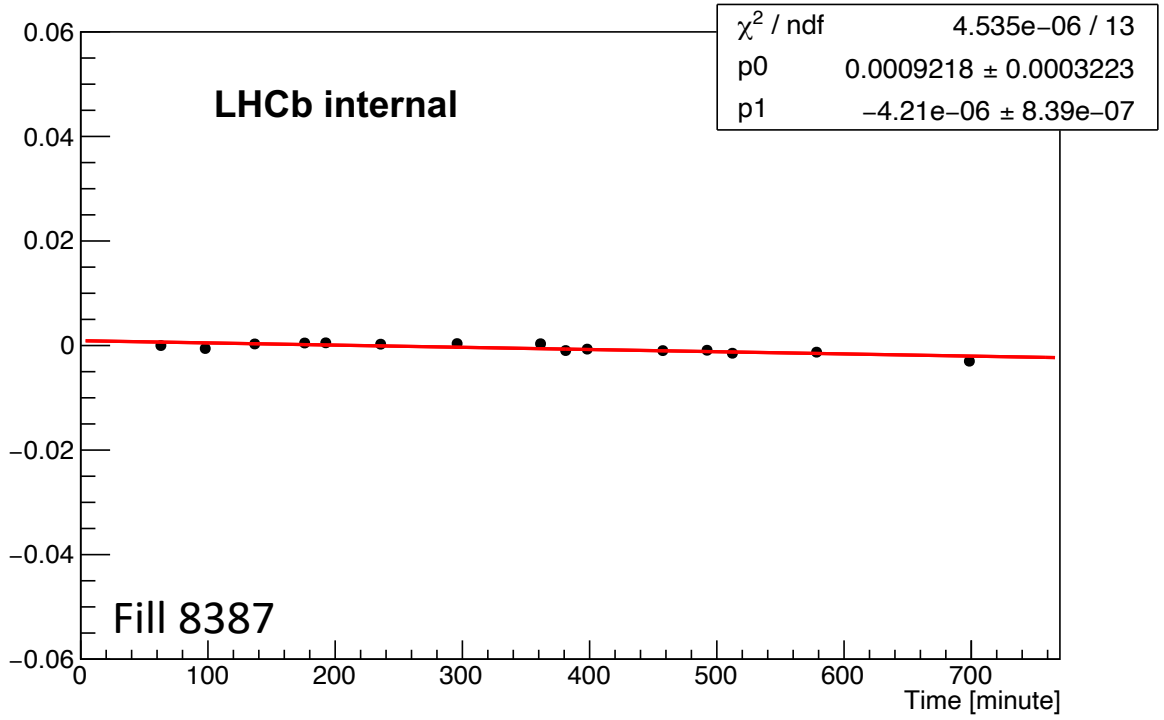
Fit by a line

$Ty[\mu m] = p_0 + p_1 * time[min]$



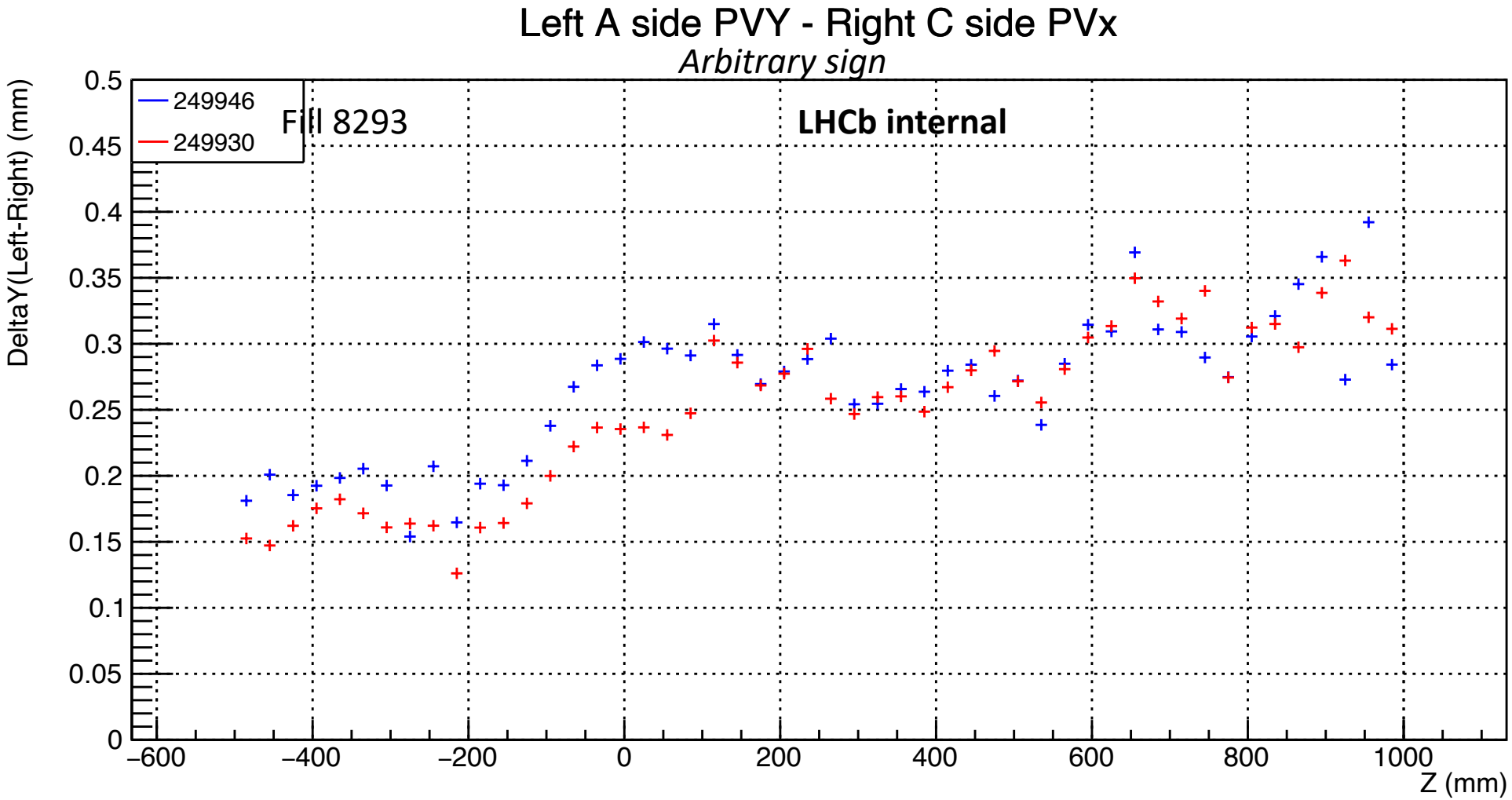
Fit by a line

$Ty[\mu m] = p_0 + p_1 * time[min]$



No significant trend

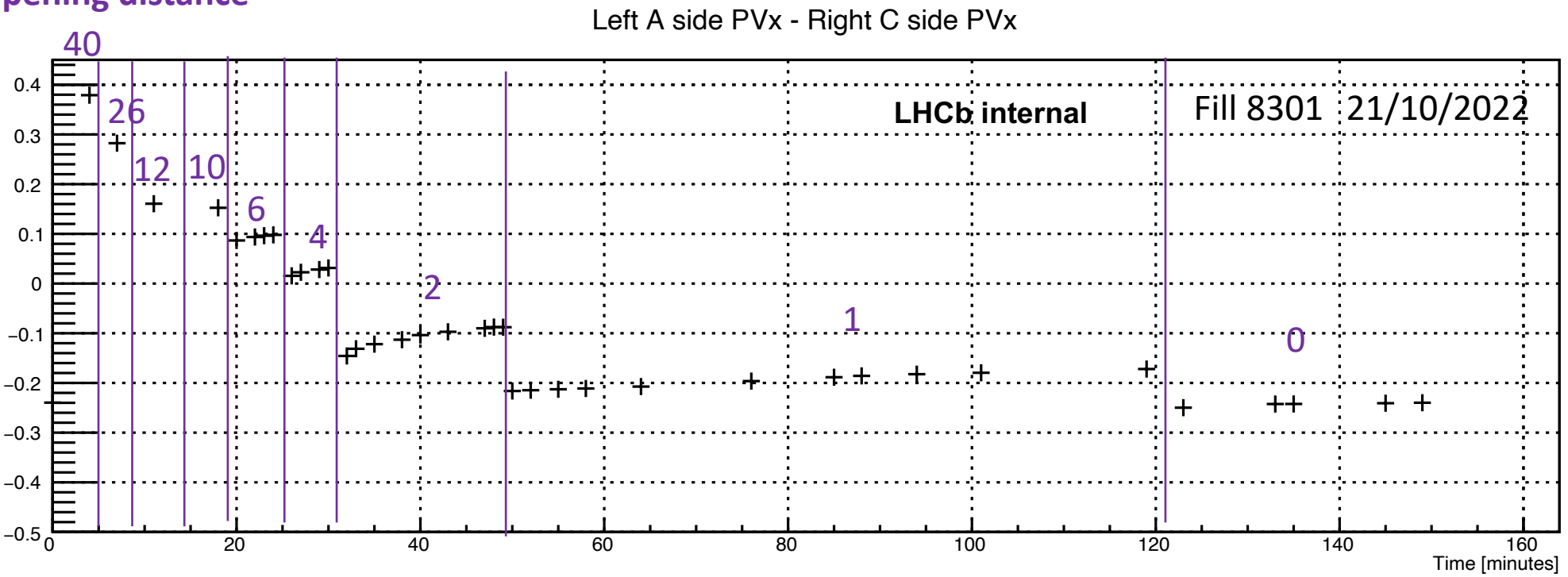
Y Misalignment with beam-p collisions vs z



Delta in the backward and central region 20-40 μm, almost zero in the forward region

Misalignment at different opening position

Opening distance



Direction of the movement

- The C side is rotating around y when is drifting at the same motion system position
  - **Ry about 220 μrad pivot at z≈800 mm**
  - Pivot point at the LHCb reference system origin: Ry about 220 μrad and Tx about 180 μm