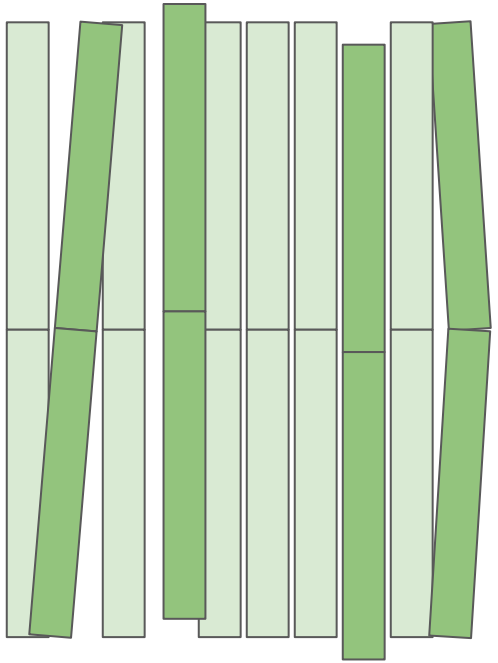
SciFi alignment



Miguel Ruiz Díaz, for the SciFi alignment team

111th LHCb week, SciFi general meeting

19 February, 2024

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Outline

- **Status of SciFi alignment in 2023**
- Global SciFi + VELO alignment
- Mat contraction calibration
- SciFi alignment accuracy study
- Plans for 2024 data-taking

New tag to fix the curvature bias in 2023

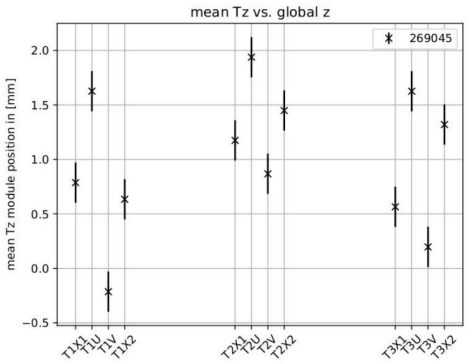
We have released a new alignment tag fixing the curvature bias on 2023 data. We ran the alignment in two steps **starting from design positions**

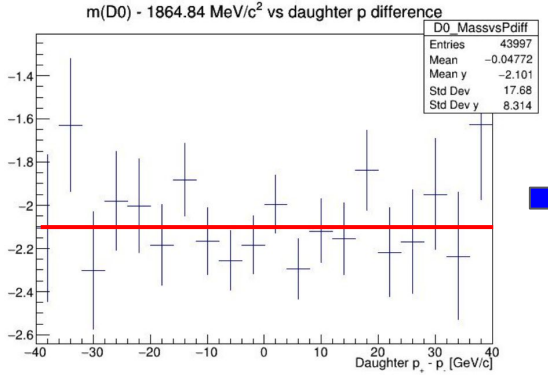
Run the alignment on **TxRz for LongModules**. The back layer (T3X2) was fixed and shifted “by hand” to correct the curvature bias

Update constants from previous step

Align **LongModules on TxRzTz** including a D^0 mass constraint to correct for residual effects

- We employed **Commissioning23 data filtered with the line ‘Hlt2Charm_DstToD0Pip_ToKmPiP’** to increase the purity of D^0 candidates and selections in the alignment jobs were tightened to reduce the background level
- The constants of the CFrames were fixed to the surveyed positions measured in February 2023 (see slides from Maria)



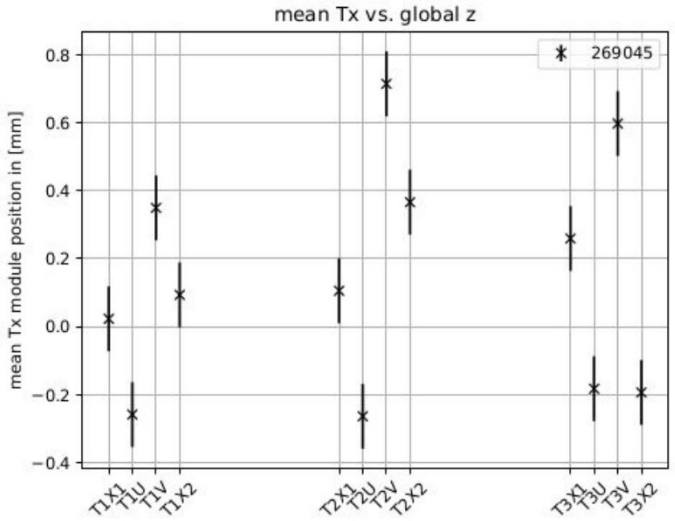


- Mass shift of ~2.1 MeV wrt PDG value can be partially explained due to a global translation in z of ~1mm away from the magnet.
- It can be reduced to ~0.5 MeV running the alignment on Tz only, but an unrealistic ~3mm global shift in z is introduced

Unofficial tag to test the SciFi alignment and tracking efficiencies, not to be used for analysis or processing

On going work

- Alignment constants for **mats have been also reset to default** values
  - Worse mass resolution than in the SciFi v9 alignment version
  - We plan to perform the mat alignment once all other issues have been fixed
- Constants evaluated on runs with **warm SciFi**
  - Worse resolution expected for cold runs
  - This should be fixed with the mat contraction calibration constants (more on this later)
- We still need to include Rx at the level of HalfModules to **describe the "banana shape effect"**
- Need to understand and fix the **zig-zag patterns observed in Tx** between layers
- Tag has been tested by the tracking efficiency group, see slides from Rowina



Outline

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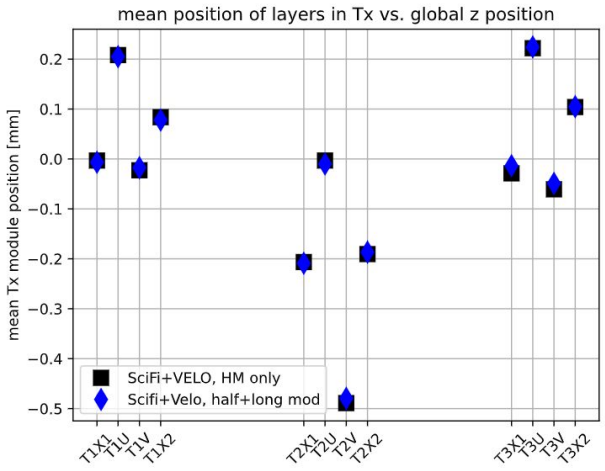
Aligning SciFi and VELO together (1)



Black: HalfModules aligned without LongModules

Blue: LongModules + HalfModules in two separate steps

- Relative shift between U and V layers can be explained by a ~2mm shift in y caused by a **global rotation of the VELO**
- Try to address it by including both detectors in one single alignment job employing **long tracks**

VELO configuration

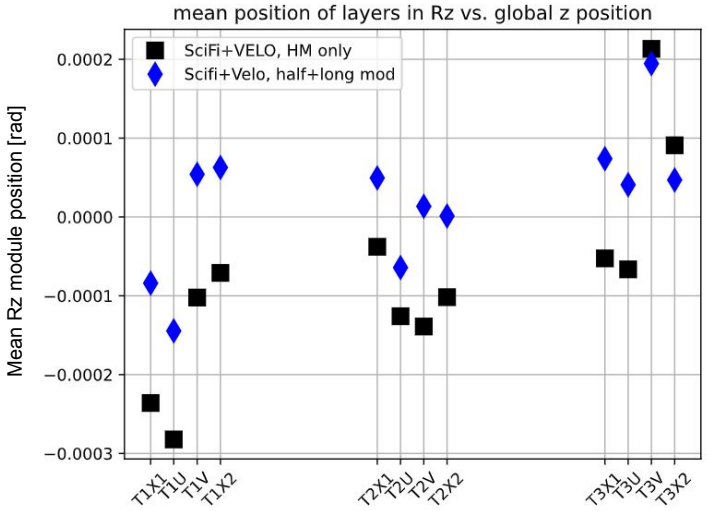
- VELO halves: TxTyTz
- VELO global: RxRz
- Employing VELO survey constraints for 2023

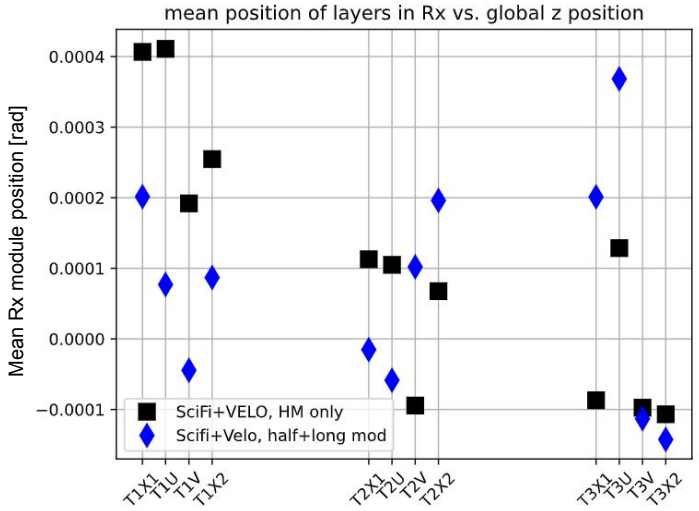
SciFi configuration

- LongModules: TxRxRz
- HalfModules: TxRxRz
- Back frame (T3X2) fixed to improve convergence
- Starting from the new SciFi alignment tag

- **SciFi alignment run in two steps:** first LongModules and then HalfModules starting from the obtained constants
- No significant improvements on the Tx pattern so far

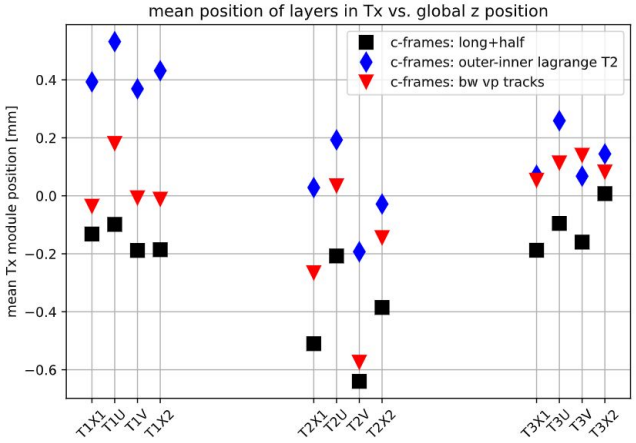
Aligning SciFi and VELO together (2)

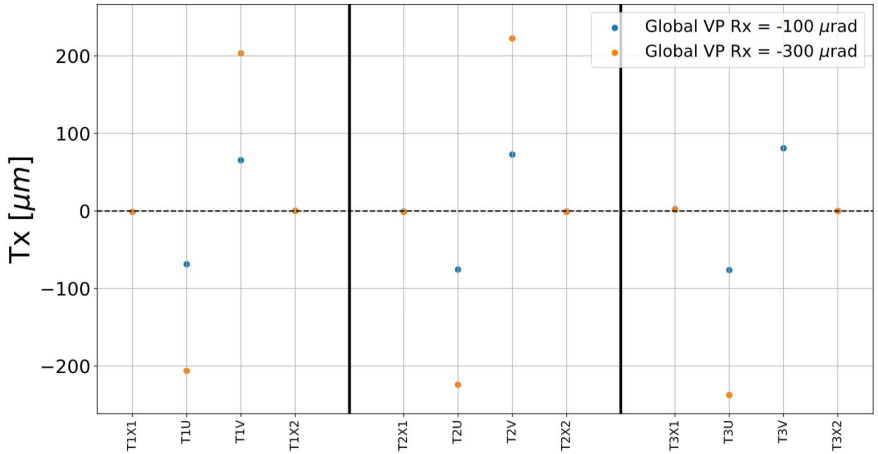




- Alignment on Rx and Rz improves when HalfModules are aligned after LongModules
- Aligning both at the same time not viable in 2023 due to the asymmetric acceptance but possible in 2024

Further checks





- New tests including **CFrames and backwards VELO tracks** on top of long tracks show some promising results
  - CFrames are aligned on the first step with the LongModules starting from the surveyed positions and including the survey constraints
  - Alternating pattern still present in T2 but the overall shifts are smaller

- We simulated a **configuration introducing a global rotation of the VELO around the x axis** and we are able to reproduce the alternating pattern between layers employing realistic **2023 minimum bias MC samples**
  - We need a rotation of about 300 μrad to get the same order of magnitude -> Probably too large
  - A combination of a smaller rotation + some mislignments on either the SciFi or the VELO might also reproduce the size (to be tested)
  - WIP: repeat the study pre-filtering the minimum bias samples to have a larger purity of D^0 candidates

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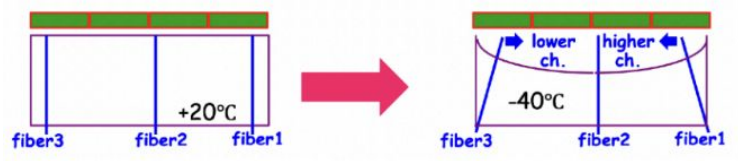
Mat contraction calibration algorithm

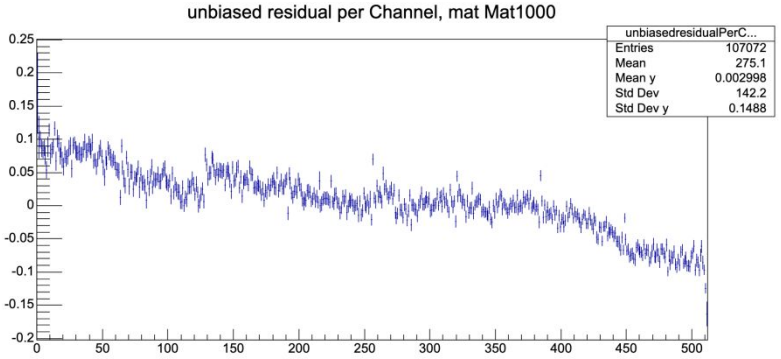
- Fiber mats are bent due to the cooling of the SiPMs -> **x mapping of hits to SiPMs channels is modified**
- **Degradation of the track residuals and momentum resolution**
- Apply calibration conditions to the SiPM channels to correct the channel-to-hit mapping
- Calibration constants obtained from track residuals per channel:

c = - residual

- We have **one independent set of calibration values per mat** -> Stored in a yaml file and **applied when determining the hit positions** in PrStoreSciFiHits
- Histograms of residual per channel have been added in online monitoring (one mat per layer) together with yaml files to update when necessary
- **WIP**: investigate possible parameterisations to smooth the values of the constants

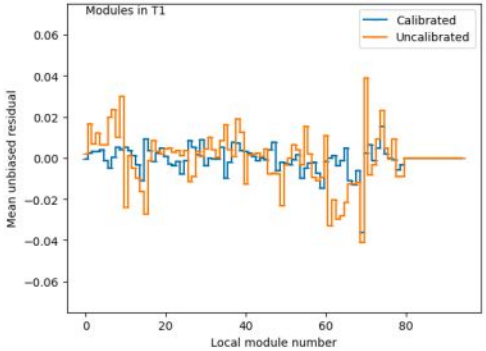


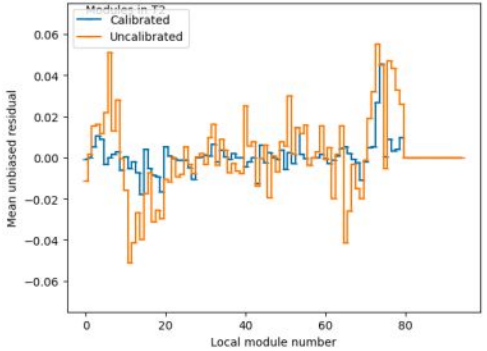
Taken from: slides

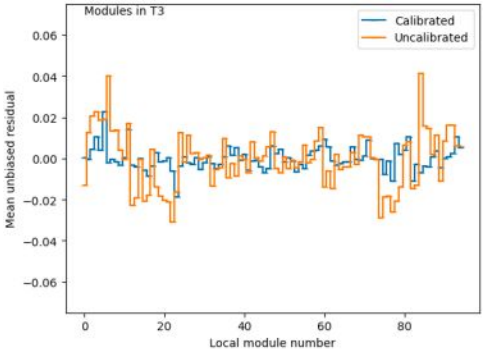


Closure test (1)

Effect of the calibration constants on the same sample they were derived from

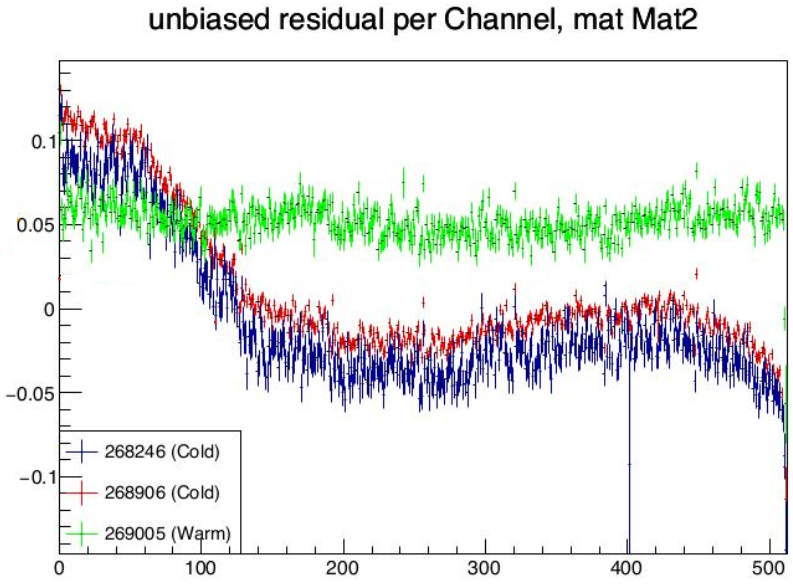






In average, residuals get close to 0 for all modules

Closure test (2)



- Check that the shape of residuals, and thus calibration constants, are consistent for different **runs**
- As expected, residuals are constant across channels for **warm runs**

Outline

- Status of SciFi alignment in 2023
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- **SciFi alignment accuracy study**
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SciFi alignment accuracy study

Goal: determine the precision of the alignment algorithm to different degrees of freedom for several alignment configurations:

- Decide what is the **best strategy** both for the first alignment at the start of data-taking and for the online alignment
- Determine the **thresholds for the automatic update** of the alignment constants

We are using a $D^{*+} \rightarrow \pi D^0 (\rightarrow K^- \pi^+)$ MC sample simulated under the expected 2024 conditions and prefiltered with a custom HLT2 line that matches the selections from the dedicated HLT1 that will be used during 2024 data-taking

- Main results will be cross-checked with a minimum bias sample, more aligned with the conditions during data-taking

We run the alignment jobs starting from different misaligned configurations -> The width of the distribution of the alignment constants per module after convergence gives us an estimate of the alignment precision

Simulation of random misalignments

- Generated following **2D normal distributions** for every pair of half-modules taking into account the correlation between the constants due to the joint constraints
- Size chosen to match the expected **conditions at the beginning of data-taking** before the first alignment
- One independent yaml file with random misalignments is generated for each alignment job

Alignment configurations

- Detector elements: **LongModules and Halfmodules**
- The same D^0 **mass constraints** as for data-taking
- Testing configurations with and without fixing the back frame (T3X2)
- Different combinations of dof including Tx, Tz, Rx, and Rz

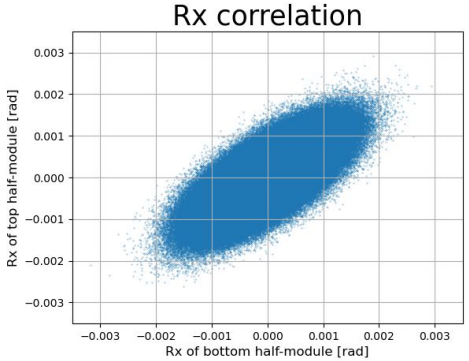
Generation of random misalignments: overview

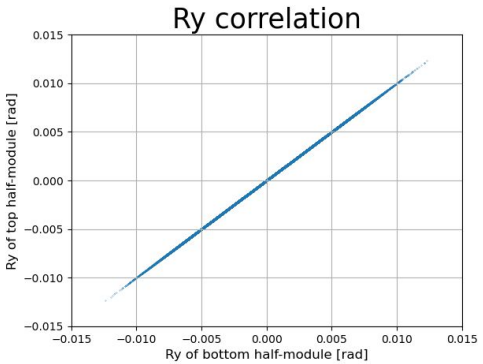
Constant	T_x [μm]	T_y [μm]	T_z [μm]	R_x [mrad]	R_y [mrad]	R_z [mrad]
σ	200	200	700	0.58	2.63	0.16
σ_{joint}	1	1	1	0.4	0.001	0.001
ρ	0.999987	0.999987	0.999999	0.721	0.999999	0.99998

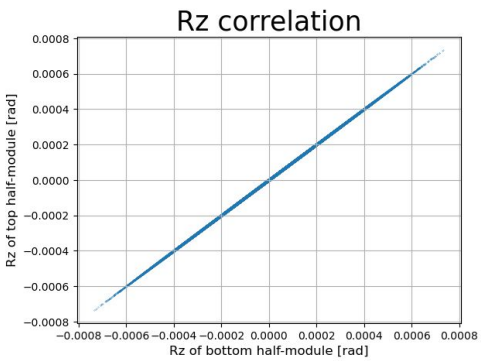
- **Joint uncertainties** are based on expected physical constraints on the relative motion of the module halves
  - Tighter than the joint constraints employed in alignment jobs. See last report
  - Size of $\sigma_{\mathrm{joint}}(\mathrm{R}_x)$ from hardware stability checks on the modules shape
- **Correlation coefficient** matches the desired value for the joint uncertainties

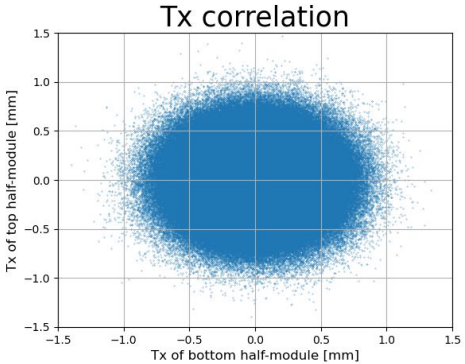
$$\rho = \sqrt{1 - \frac{\sigma_{joint}^2}{\sigma^2}}$$

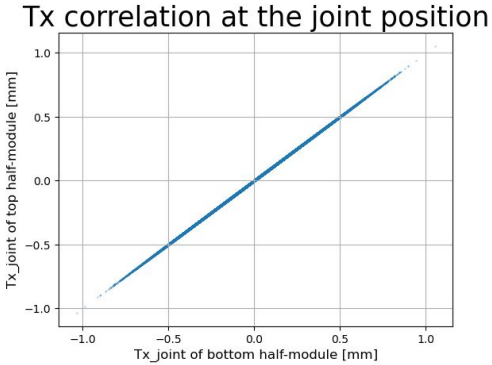
Generation of random misalignments

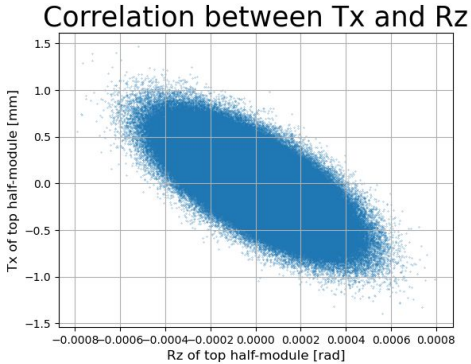






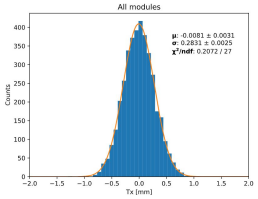
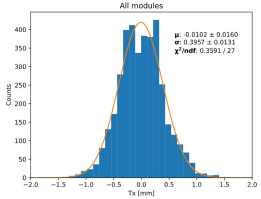
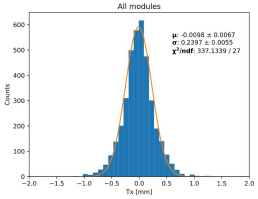
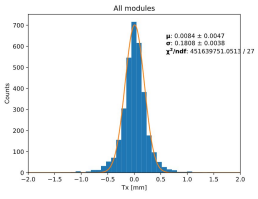
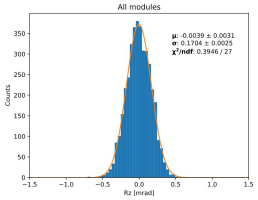
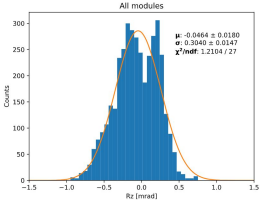
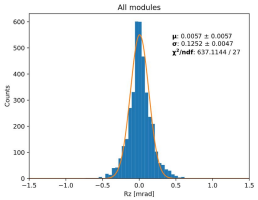
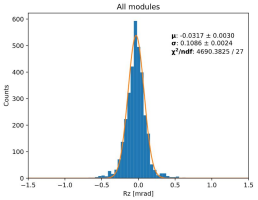
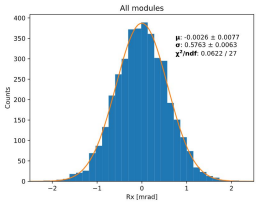
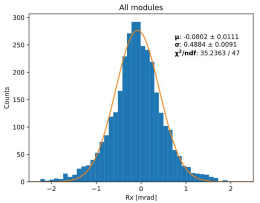






- Values of Ry and Rz are highly correlated, the correlation of Rx is smaller to model the “banana shape” bending
- Translations are generated at the joint position and then translated to the HalfModule centers taking into account the module rotations

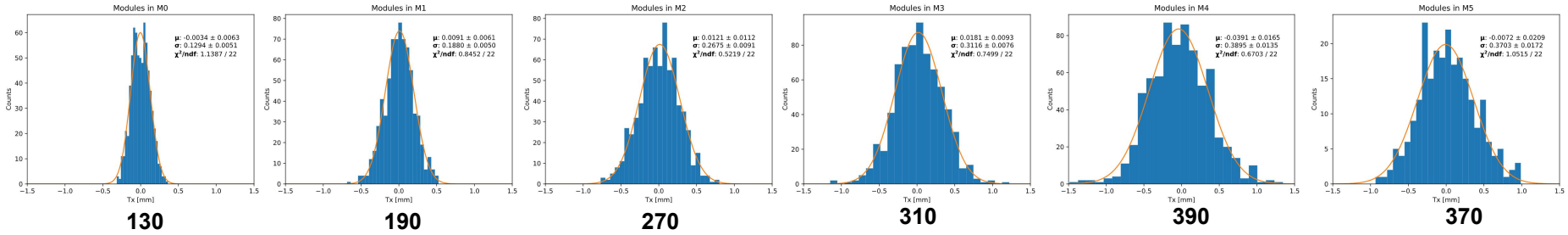
Preliminary results (1)

	Input misalignments	Modules TxRz	Modules TxRz with T3X2 fixed	Modules TxRzRx + HalfModules Rx
σ(Tx) [μm]				
	280	400	240	180
σ(Rz) [μrad]				
	170	300	130	110
σ(Rx) [μrad]				
	580			490

For each configuration we run 15 jobs on 100k events, misalignments are introduced on Tx, Tz, Rx, and Rz

Preliminary results (2)

Distribution of Tx values per module position [μm]



130 **190** **270** **310** **390** **370**

- Worse precision for external modules
- Same trend seen for all dof in every tested configuration

Some remarks

- Results seem to indicate that the **first alignment should be done in separate steps** and we might need to fix the last layer in the first step to constrain the momentum scale
- Still need to run jobs including **initial misalignments in Ty and Ry** -> We do not expect to see a big impact
- For the final result we will increase the number of toys 15 -> 50 and events per jobs 100k -> 1M in order to have better statistics
- **WIP:** agree on an alignment strategy and perform a full simulation, introducing misalignments in all dof and aligning different dof in separate steps to obtain the final result on the SciFi alignment thresholds during data-taking

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Requirements for SciFi alignment

The alignment of the SciFi will be updated at the beginning of 2024 data-taking since the detector conditions have changed from those in 2023. Before running the SciFi alignment we will need some inputs:

- The **VELO should be aligned first** -> We employ long tracks and apply requirements on PVs to select our D^0 candidates
- **SciFi time alignment** is crucial for us and should also be ready before running the spatial alignment
- If possible, having some runs with a warm SciFi will help us to validate the **mat contraction calibration** in 2024
  - Maybe we can test it on 2023 data once all other issues are fixed but the asymmetric acceptance due to the open VELO makes this particularly challenging
- Not having all links working from the beginning should not be a problem for us

Checklist

- Improve HLT1 selections to have a clean D0 sample as input to the SciFi alignment (Giulia)
  - A new ‘HLT1D2KPiAlignment’ line has been defined tightening the thresholds of the D0 selection. Created MR in Allen: Allen!1430
- Mat contraction calibration (Izaac, Biljana)
  - Basically finished, just waiting for the MRs to be merged: Rec!3693 Alignment!453
- Update Monitor plots in Monet (Biljana)
- Update the survey to correct for effects observed with the BCAM system (Dimitrios, Maria)
  - Report from Dimitrios today!
- Study alignment precision using MC with expected 2024 conditions to determine thresholds (Miguel)
  - Should be finished by the beginning of March
- Perform a global alignment of VELO and SciFi to understand patterns observed in 2023 (Nils)
- Converge on a baseline strategy to run the alignment at the start of 2024 data-taking (Biljana, Giulia, Miguel, Nils)
  - Need the results form the precision study
- Understand differences between alignment constants on 2022 and 2023 (Giulia, Miguel)
  - Need to re-run the alignment in 2022 from scratch, should be ready by the end of March
- SciFi y alignment (Biljana, Giulia, Miguel, Nils)
  - Not needed before the start of the data-taking, low priority

Backup slides

Curvature bias: reminder

- $D^{\pm}$ mass shift observed in 2023 due to residual global misalignments on Tx at the level of SciFi layers/stations
- There reconstructed momenta of positively and negatively charged particle tracks is shifted in opposite directions
- Global mass shifts with respect to the PDG value can also be explained due to residual misalignments on Tz
- The alignment algorithm selects a subset of tracks from $D^0 \to K\pi$ to apply a **mass constraint** and mitigate the curvature bias
- **Issues** during 2023 data-taking:
  - Events collected during 2023 were filtered with 'Hlt1(D2KPi|DiMuonHighMass|DisplacedDiMuon)Alignment' -> **Sample was not pure enough**
  - Selections in the alignment configuration were too loose -> **Too much background**
- The mass constraint was not effective

See last update by Biljana for more details