

SciFi alignment

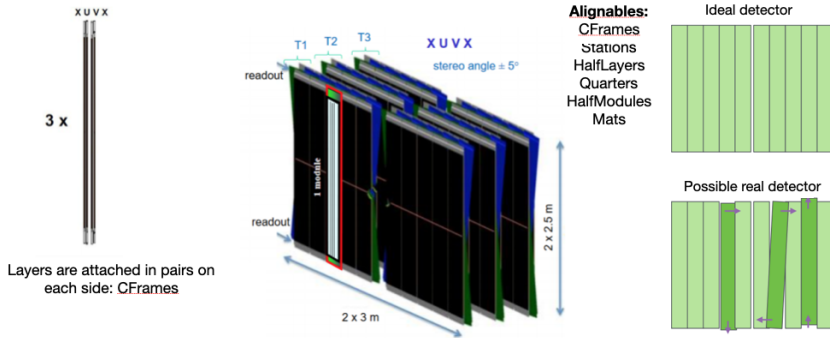
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for the SciFi alignment team

LHCb week
04.12.2023

- ① SciFi alignment in 2023
- ② Joint constraints
- ③ Curvature bias
- ④ Global alignment
- ⑤ Mat contraction calibration
- ⑥ Summary

1 SciFi alignment in 2023

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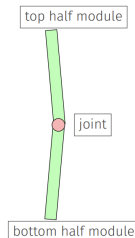
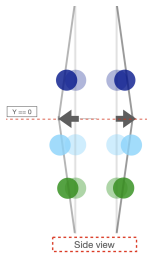
- ▶ In 2023 aligning for HalfModules (+ joint constraints) $T_x R_z$, starting from 2022 condition and 2022 mat constants
- ▶ Long tracks used for alignment
- ▶ Asymmetric acceptance due to VELO open
- ▶ Curvature bias present
- ▶ No mat contraction calibration

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2 Joint constraints

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- ▶ SciFi modules are bending at the center ($y = 0.0$), inwards or outwards along the beam direction
- ▶ Half modules + joints reproduce the real shape



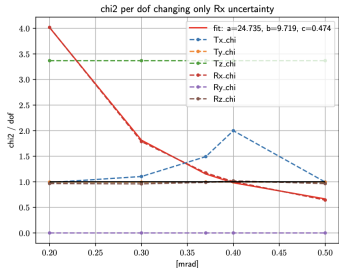
- ▶ Joints = survey constraint at the joint position
- ▶ Constraining two alignable elements: $\chi^2 = (p_A - p_B)^T V^{-1} (p_A - p_B)$
- ▶ No survey available for all degrees of freedom \rightarrow tuning of survey constraint uncertainties needed to control their χ^2

2 Joint constraints

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- ▶ Look at the χ^2 contribution of all translations and rotations of joints
- ▶ Alignment scans for a range of uncertainties until $\chi^2/\text{dof} = 1$

Example: Tuning of Rx uncertainty



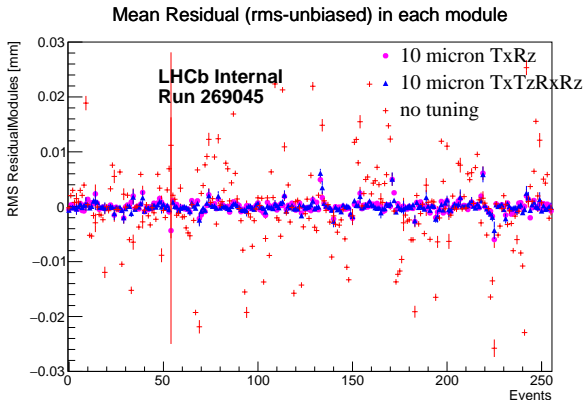
Parameter	uncertainty
Tx	10 μm
Ty	10 μm
Tz	2 μm
Rx	0.4 mrad
Ry	0.2 μrad
Rz	0.2 mrad

▶ Rec I418

Obtained Rx uncertainty = 0.4 mrad
Stability checks of the modules shape from
hardware \rightarrow 0.35 mrad

2 Joint constraints

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- Improvements seen in residuals and tracking
- We will continue using the tuned uncertainties for the next data taking period

3 Outline

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3 Curvature bias: D^\pm mass

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A particle reconstructed by 2 oppositely charged tracks :

$$m^2 = m_+^2 + m_-^2 + 2p_+p_-(1 - \cos\theta)$$

- If momentum has a small bias:

$$m = m + (p_+\delta p_- + p_-\delta p_+)(1 - \cos\theta)$$

Case 1 : There is bias in T_x , δp_+ and δp_- have opposite variation

$$\delta m = (1 - \cos\theta)(p_- - p_+)\delta p \sim C\delta r(p_- - p_+)$$

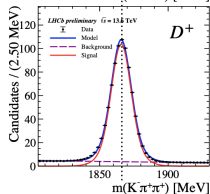
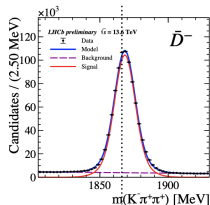
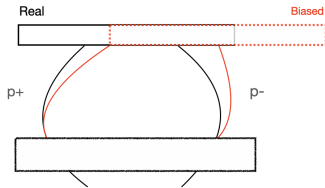
Note: mass shift over $(p_- - p_+)$

Case 2 : There is bias in T_z , δp_+ and δp_- have same variation

$$\delta m = (1 - \cos\theta)(p_- + p_+)\delta p \sim C\delta z t_x(p_- + p_+)$$

Note: mass shift to PDG value

- ▶ Residual misalignment in T_x in one of the stations/layers in the SciFi
- ▶ T_z positions used from 2022: residual in z
- ▶ Interplay with rotations of joints of modules
- ▶ Mass constraint not working



3 Curvature bias: alignment configurations

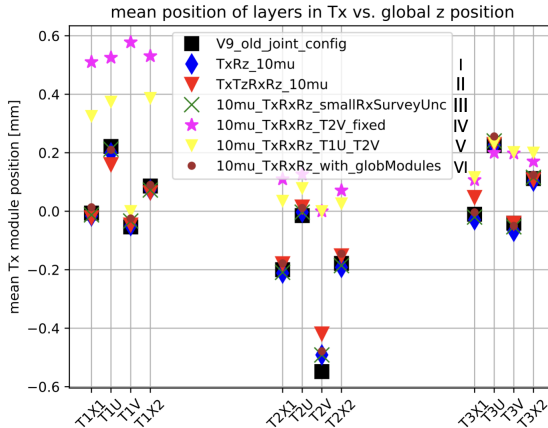
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- Several configurations checked starting from latest alignment version in 2023 (v9)

Configuration	I	II	III	IV	V	VI
Modules	TxRz	TxTzRxRz	TxRxRz	TxRxRz	TxRxRz	TxTzRxRz
Average constraint						
All modules	✗	✗	✗	✗	✗	✓
T2V+T1U	✗	✗	✗	✗	✓	✗
T2V layer av. pos.	✗	✗	✗	✓	✗	✗
Small Rx survey uncert.	✗	✗	✓	✓	✓	✓
Back layer in stat. 3	TxRz	TxTzRxRz	TxRxRz	TxRxRz	TxRxRz	TxTzRxRz
Modules joints	all dofs	all dofs	all dofs	all dofs	all dofs	all dofs
Survey	not used	not used	not used	not used	not used	not used

3 Curvature bias: Tx movements

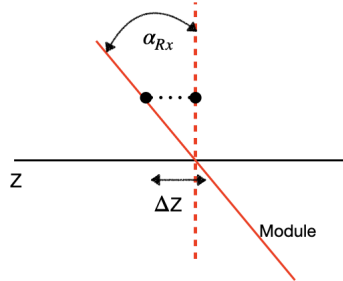
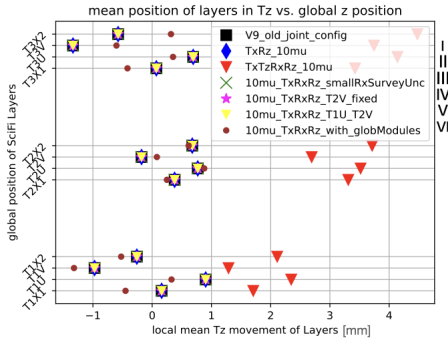
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- ▶ All layers in T2 have a shift in x compared with the other stations
- ▶ Configuration IV and V constrain layers in T1 and T2 that partly solve the discrepancy

3 Curvature bias: Tz movements

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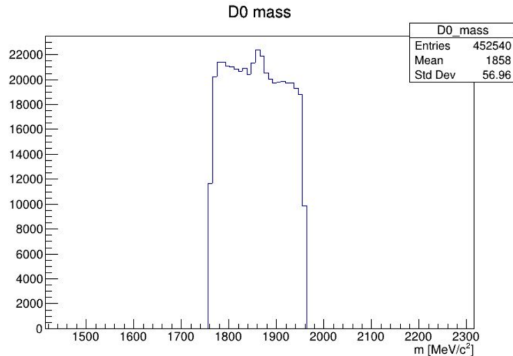


- ▶ Conf. II introduces large shifts: max 4 mm in z, all because Rx compensation
- ▶ To be able to disentangle between the both we put small survey uncertainty in Rx and then align for TxTzRxRz (VI)
- ▶ Not planning to include Rx and Tz in further data-taking

3 Curvature bias: Mass constraint

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- ▶ SciFi alignment events are collected using:
RB 3 Tracker alignment
'Hlt1(D2KPi|DiMuonHighMass|DisplacedDiMuon)Alignment'
- ▶ $D^0 \rightarrow K\pi$ candidates used in alignment, need high purity



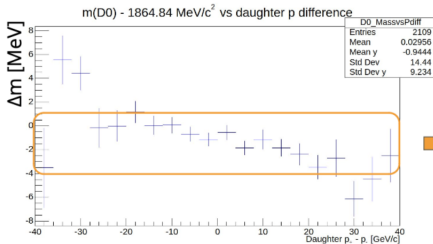
- ▶ Loose selections in the online alignment configuration → too much background
- ▶ Not possible to make use of the mass constraint fully

3 Curvature bias: starting from default

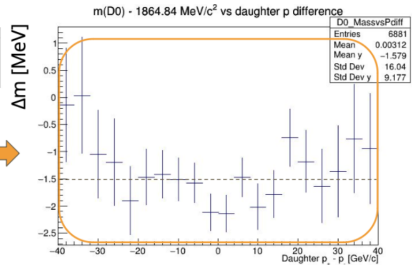
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- ▶ Full modules in TxRz, start from design position
- ▶ Using CFrames survey + mats in design position
- ▶ Removed mass constraint
- ▶ Evaluate residual shift in x and apply correction by hand

With Tx bias present



Corrected for Tx bias

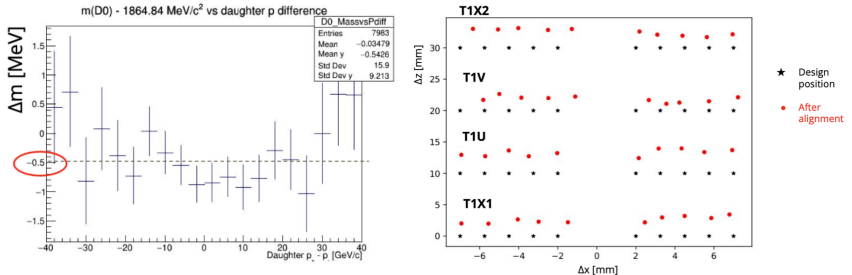


- ▶ D^0 mass vs momentum stable after shifting the layers in x
- ▶ Bias wrt PDG value at 1.5 MeV

3 Curvature bias: adding T_z

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- Full modules in $T_x R_z T_z$, using previous conditions (slide 11)



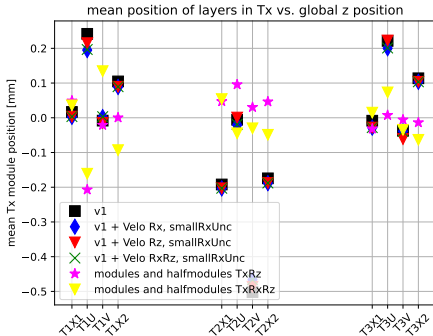
- Adding T_z fixed the PDG bias but large movement in z
- Effect in z expected from BCAM: Survey taken with magnet OFF
- Effect in z expected from BCAM: CFrames move towards the magnet when magnet ON
- Survey to be corrected for this effect
- There can also be residual effect from magnetic field description

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4 Global alignment: VELO + SciFi

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- ▶ Can help to further constrain the movement in x of the SciFi layers
- ▶ Aligning the VELO halves together with the SciFi modules



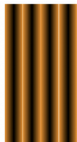
- ▶ Aligning modules (TxRz) + half modules (Rx) results with smaller difference in Tx between layers
- ▶ WIP: adding CFrames to understand movements in z

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5 Mat contraction calibration

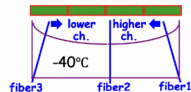
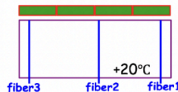
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- Cooling bends the fibre mats → modified x mapping of hits

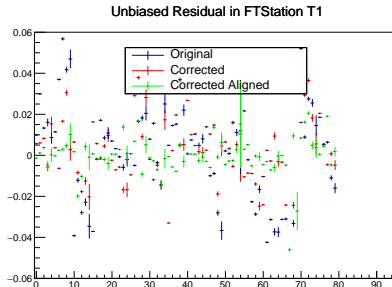


Overview of module

- Parts of mats where SiPM mapping will probably not change with temperature
- Parts of mats most affected by temperature mapping at ends



- Calibration procedure setup by Izaak Sanderswood
- Correction and null test done via residuals per module



- WIP: automatize the procedure to be propagated when running online

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- ▶ Curvature bias present: comes from poor mass constraint in the alignment or changes in magnetic field description
- ▶ Adding T_z to further fix for the PDG bias gives unphysical movements

Next steps:

- ▶ VELO + SciFi alignment to further constrain(understand) the SciFi movements
- ▶ SciFi alignment with tighter selection for D^0 mass constraints
- ▶ Accuracy study and sensitivity to weak modes: evaluation with realistic 2023 simulation and expected 2023
- ▶ Automatic procedure for mat contraction calibration

Thank you!