Status of Alignment, Calibration and Performance

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on behalf of RTA-WP4

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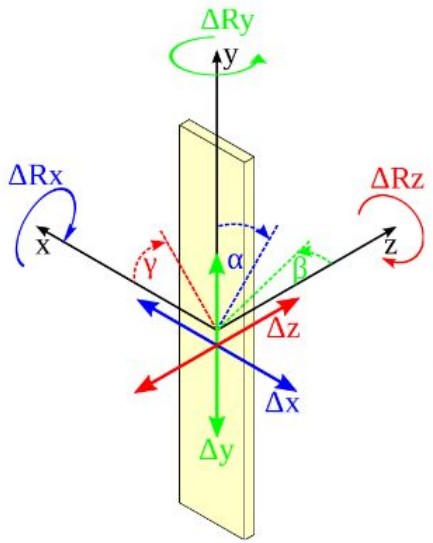
Introduction

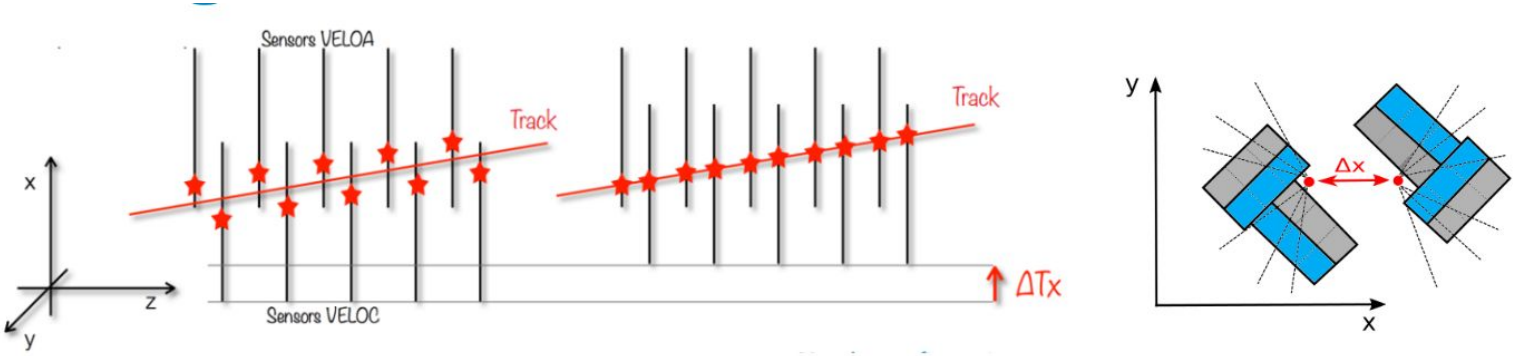
- Real-time alignment and calibration needed to profit for best physics performance in HLT reconstruction
- Many achievements in 2023, including:
  - VELO and SciFi alignment were automatically run at the beginning of each fill
  - For the VELO, the automatic update of the constants was also enabled
- See also last update by Florian
- This presentation: selection of ongoing studies to improve our understanding of 2023 data

Tracker alignment

- From the subdetectors: hits coordinates in local system
  - ➢ need knowledge about spatial position of detectors elements to get global coordinates and reconstruct tracks → alignment
- Start from a survey of physical detector, then improve precision on alignment constants using tracks

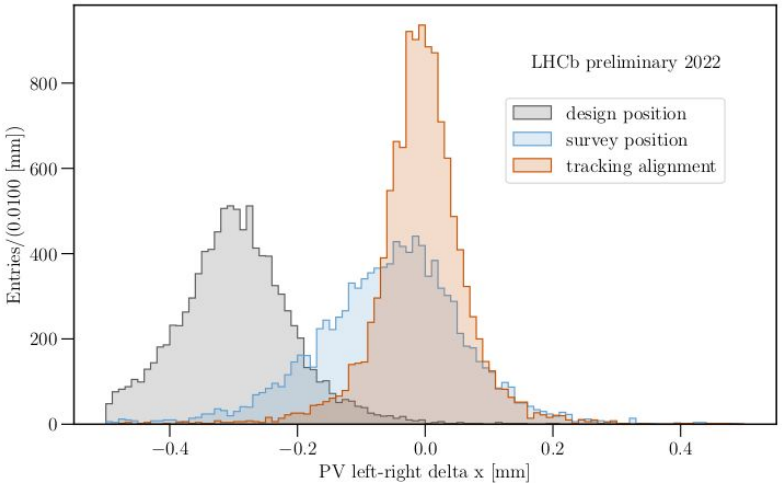


VELO alignment: strategy in 2023



LHCb-FIGURE-2022-016

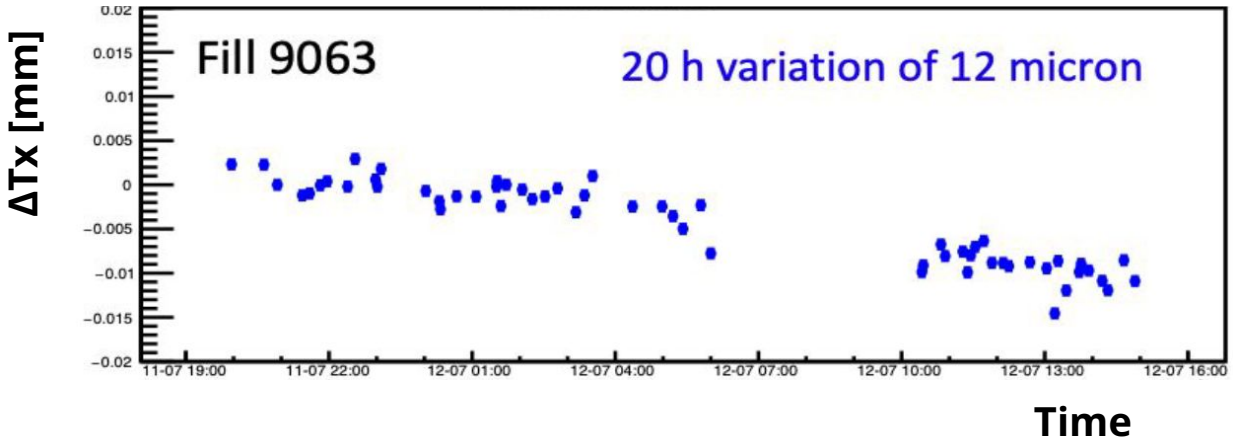
- Alignment of VELO halves run at the beginning of each fill
- Quality evaluated looking at PV position reconstructed using the left and the right side independently
- Now performing stability checks



VELO alignment: time dependence in 2023

- In 2023, VELO position fixed at 49 mm
- Observed time variation of half alignment
  - Correlated with temperature variation in the RF foil

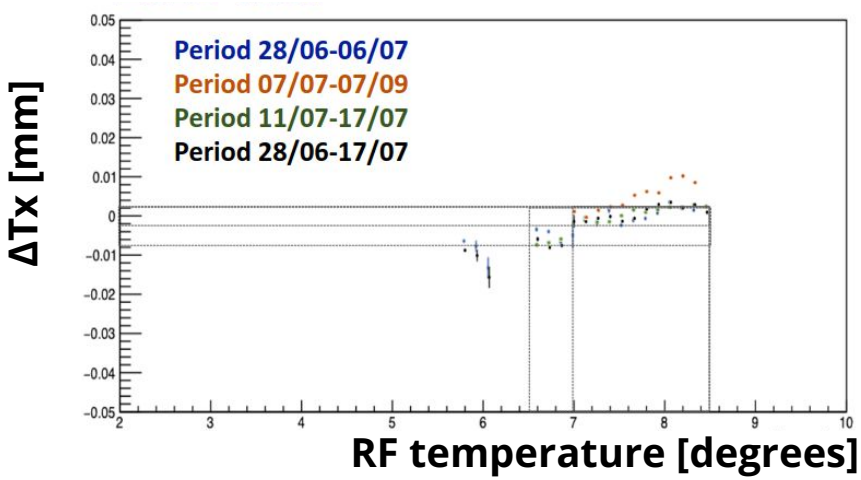
from Silvia's slides



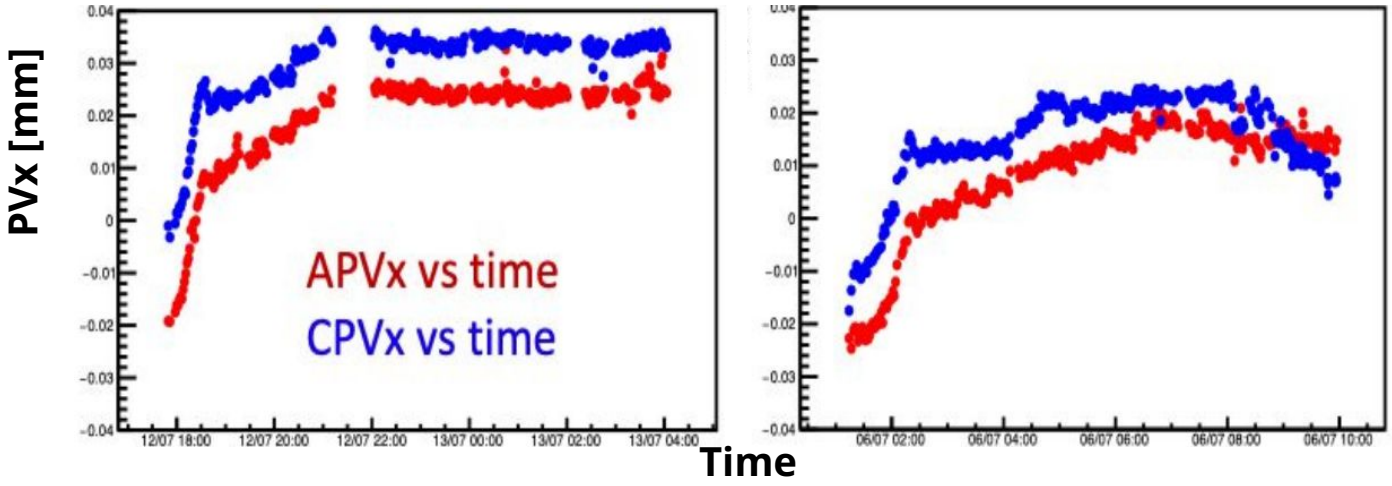
VELO alignment: time dependence in 2023

- ΔTx ~ 5 - 10 μm over Δtemperature ~1.5-2 degrees

from Silvia's slides



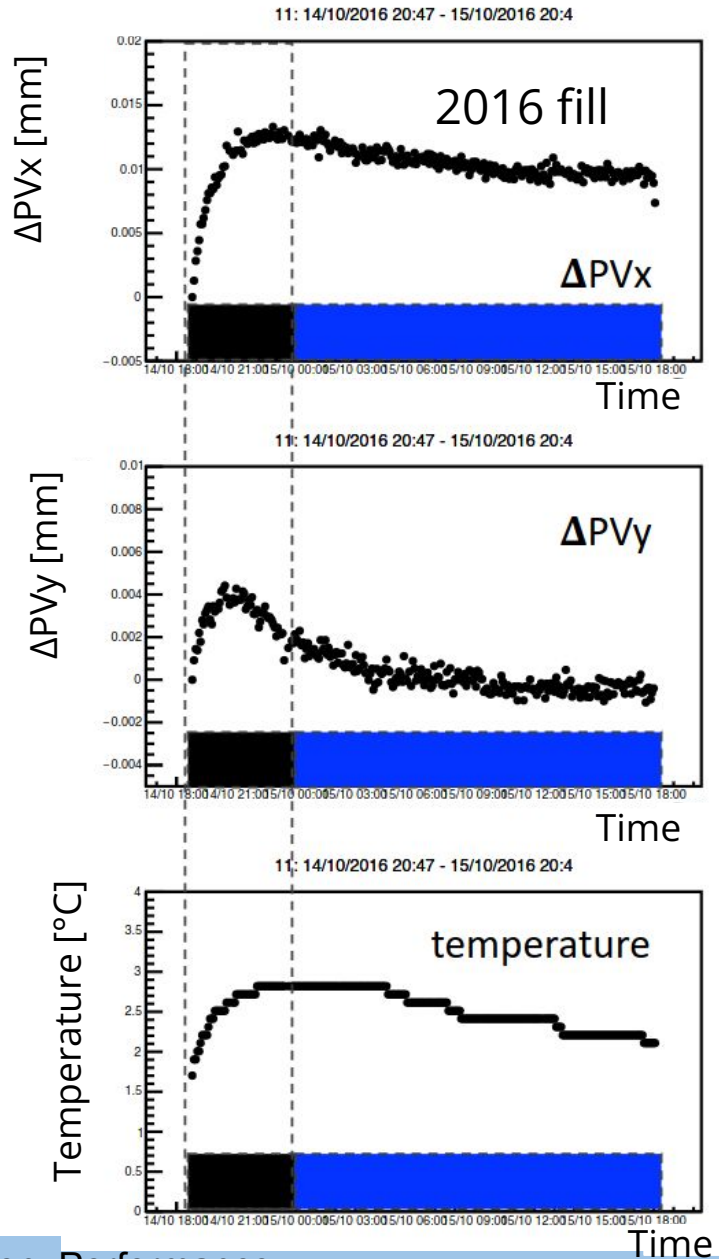
- Observed also different time-dependent behaviour when comparing A- and C-side



VELO alignment: checks on Run 2 data

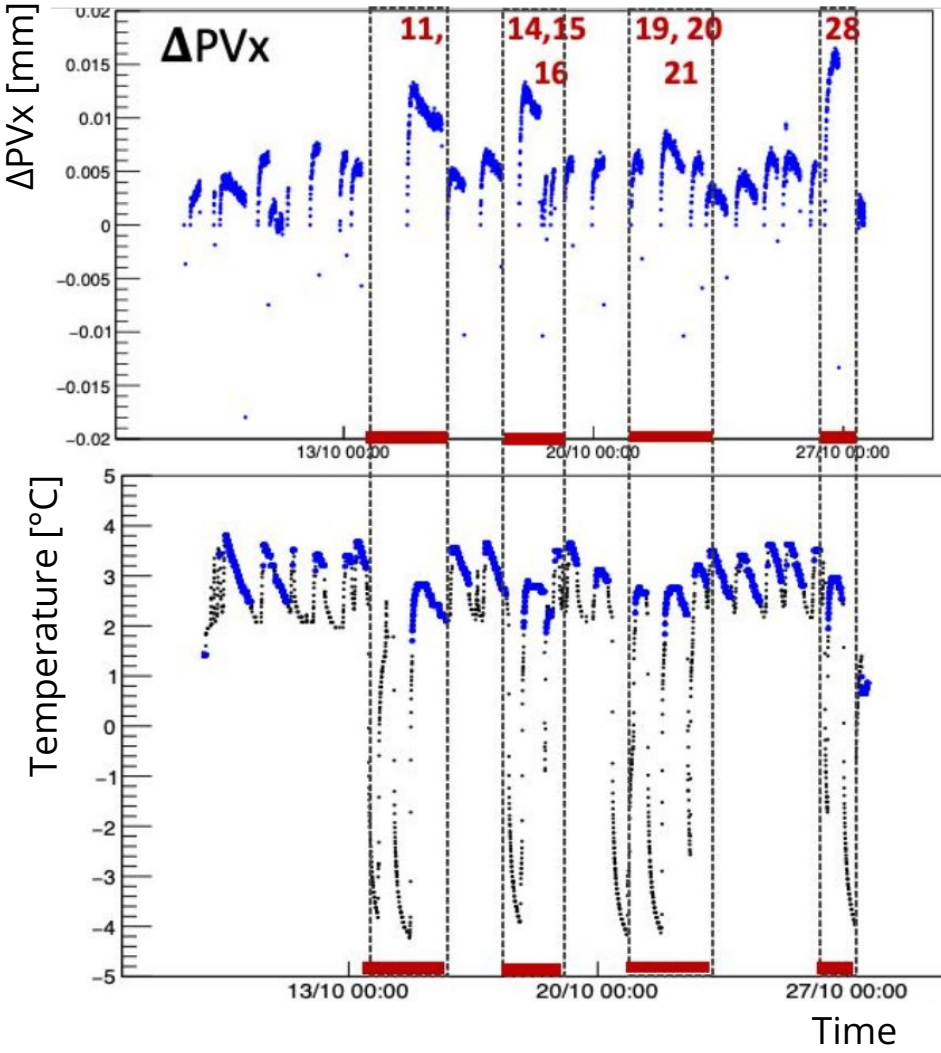
from Silvia's slides

- Was a similar effect observed also in Run 2?
- Time variation of the half alignment correlated to the temperature
- Systematically, a different temperature before the start of the fill results in a different time dependence of the half misalignment



VELO alignment: checks on Run 2 data

- This effect explains what observed in Run 2 analyses
  - E.g. delta ms, phi_s, B → D*μν CPV
- This effect explains the difference with the 2018 Z alignment
  - Real-time alignment runs at the beginning of each fill, Z alignment uses all the data collected in a year

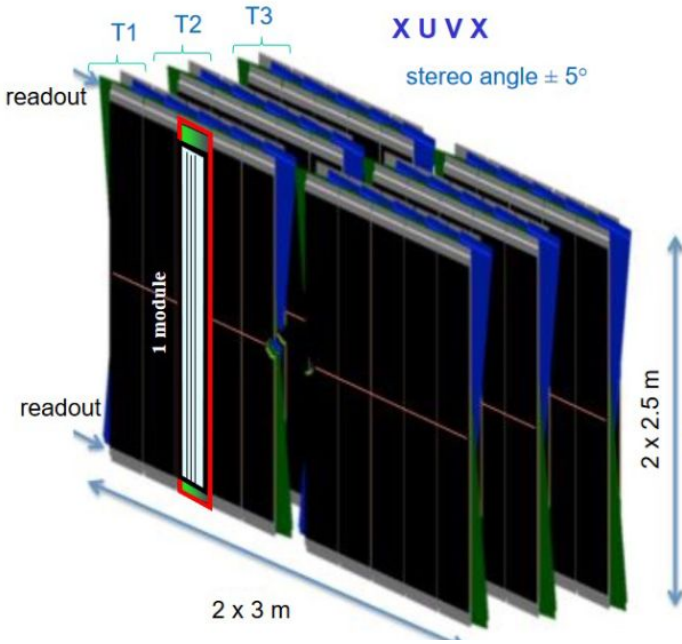


VELO alignment: status of 2023 studies

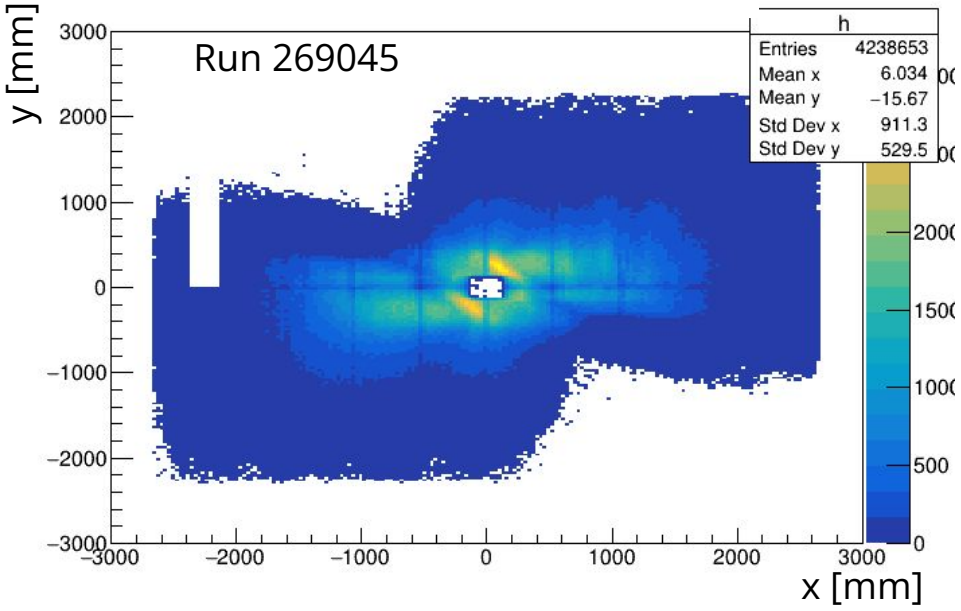
- A variation of the half alignment has impact on time-dependent measurements
- To be decided how we want to correct for it in 2024
  - ➢ Run the alignment more often during the fill, e.g. triggered by the monitoring plots
- Useful to understand the operation condition correlated to the temperature variation (i.e. to misalignment) → minimize the effect

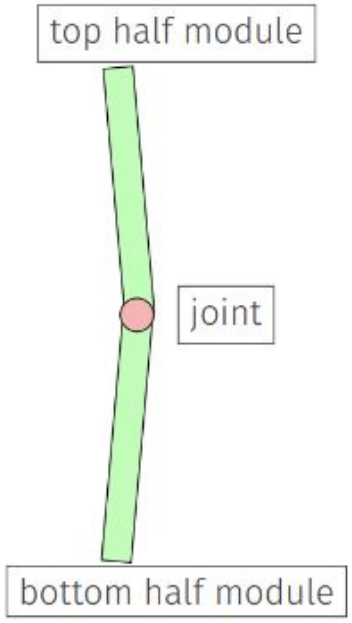
SciFi alignment: strategy in 2023

- Align Half Modules for TxRz
- VELO open: asymmetric acceptance for long tracks
- Several versions deployed to fix issues observed during data-taking



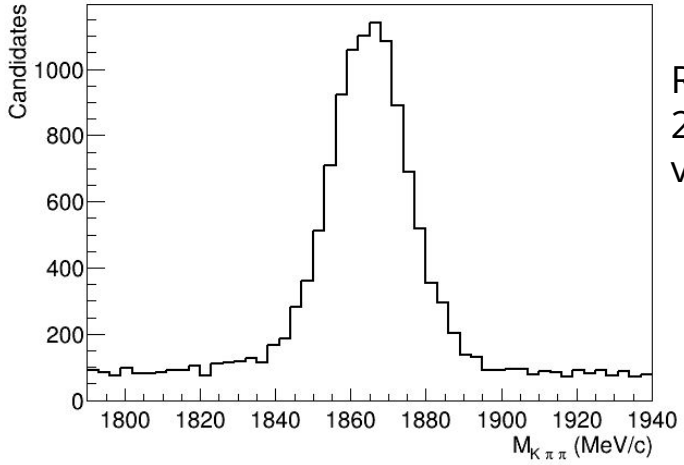
Distribution of hits on track for layer T2X2



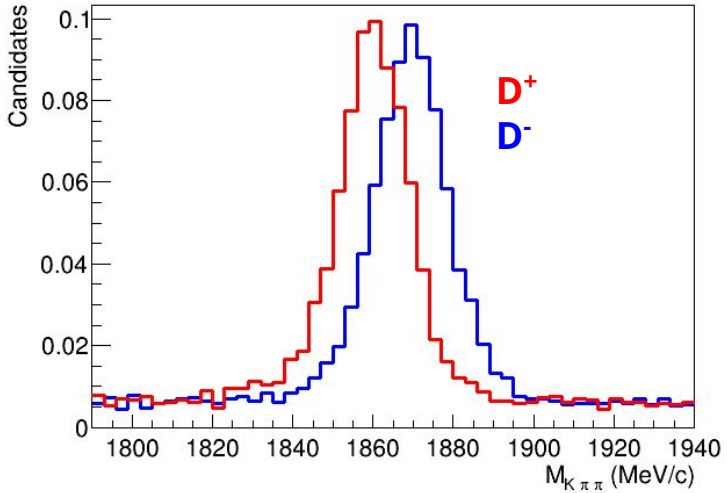


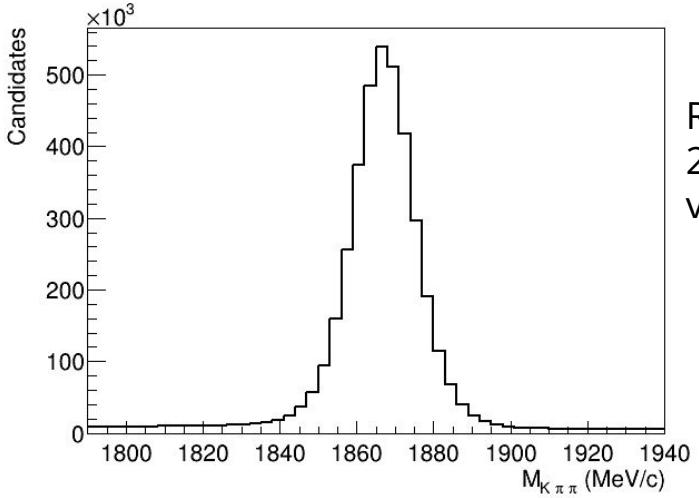
SciFi alignment: mass shift in 2023

- Many thanks to Gregory Ciezarek for the plots!

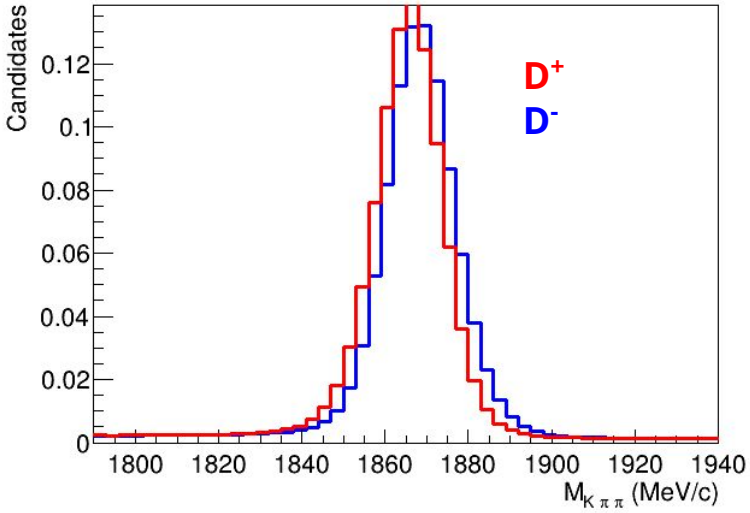


Runs
263810–263839
v3 alignment





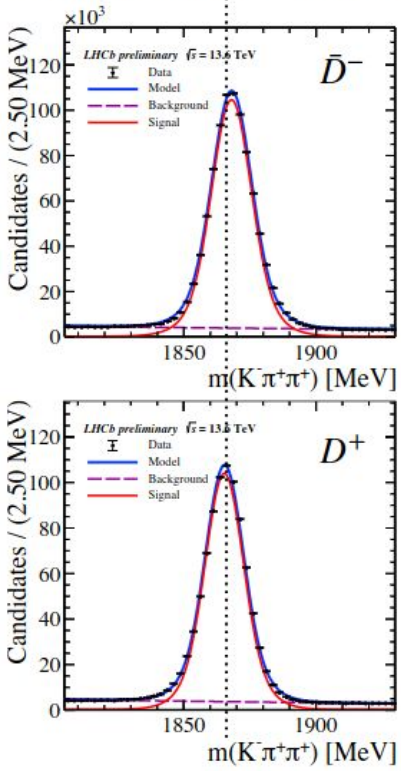
Runs
269370–269542
v6 alignment



SciFi alignment: mass shift in 2023

- We expected a further improvement with the latest version of SciFi alignment (v9), but this is not the case
  - See, as an example, Peilian's slides

- Mass fit to D^+ and D^- for commissioning 23 data



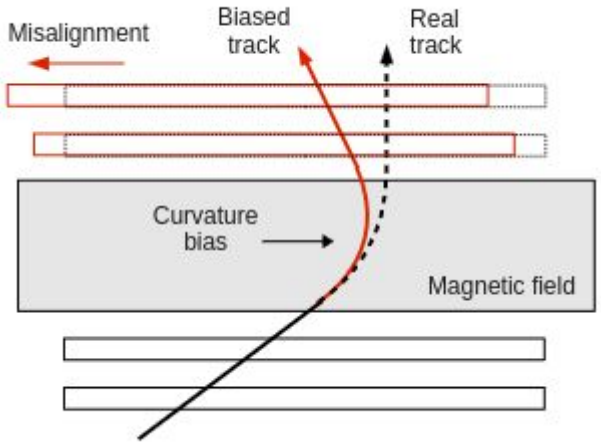
Data	D-	D+
Mass (MeV)	1868.28 +/- 0.01	1865.66 +/- 0.01
width (MeV)	8.22 +/- 0.12	8.56 +/- 0.15

- Significant shift between D^+ and $\bar{D}^-$ ~ 2.6 MeV
- mean mass in both D^+ and D^- shift w.r.t PDG mass:
  $M^{\mathrm{PDG}} = 1869.66 \pm 0.05$ MeV

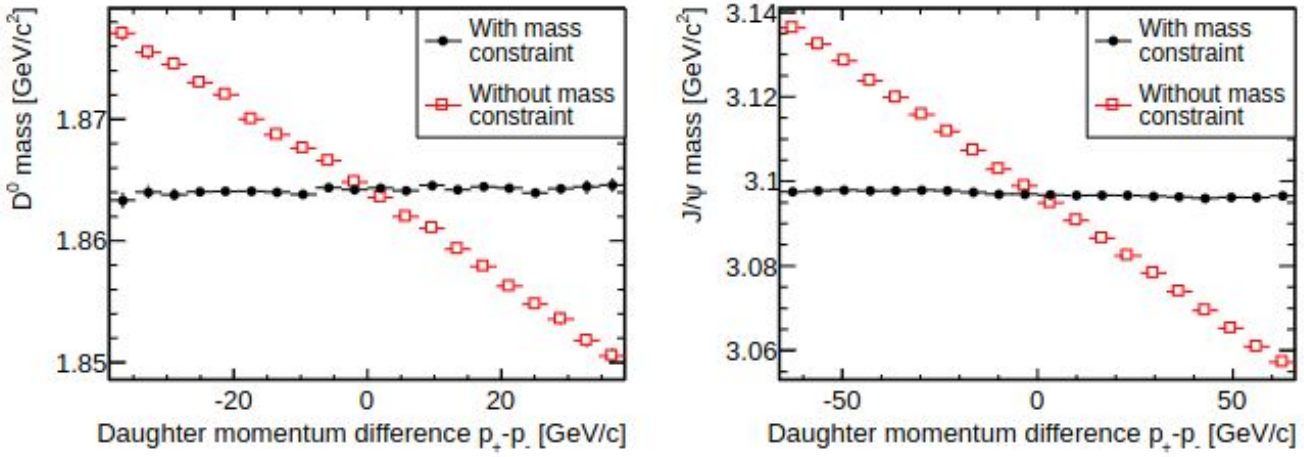
*Double Gaussian for both MC and data

SciFi alignment: understanding of the mass shift

- Track-based alignment: χ^2 minimization
- → weak modes: alignment degrees of freedom to which the total track χ^2 is mostly or completely insensitive
- Curvature bias: can be fixed adding a mass constraint



arXiv:1207.4756



SciFi alignment: understanding of the mass shift

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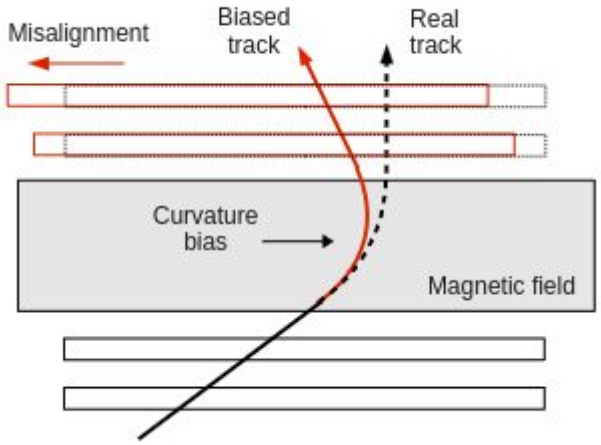
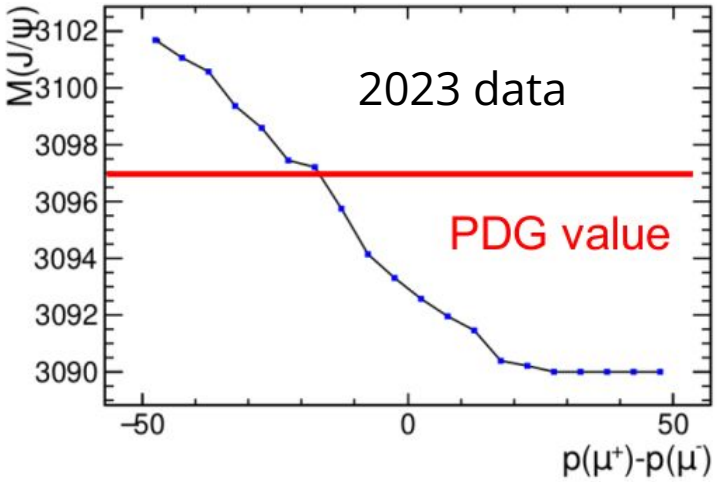
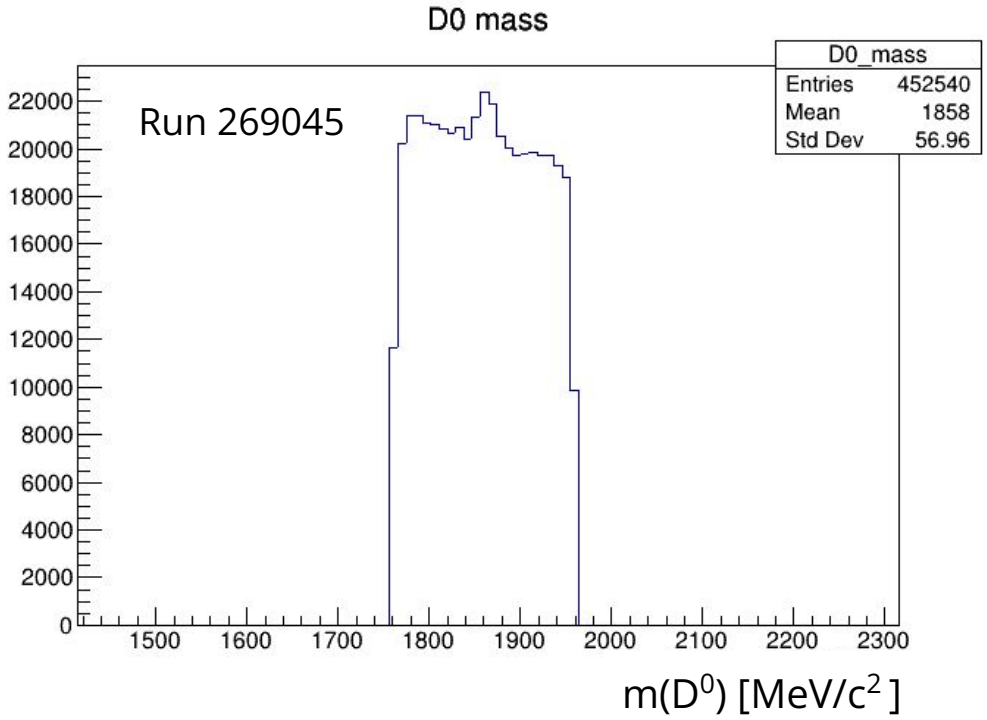




Many thanks to Zehua Xu for the plot!

SciFi alignment: understanding of the mass shift

- Mass constraint applied during 2023, but our D^0 candidates were mainly background

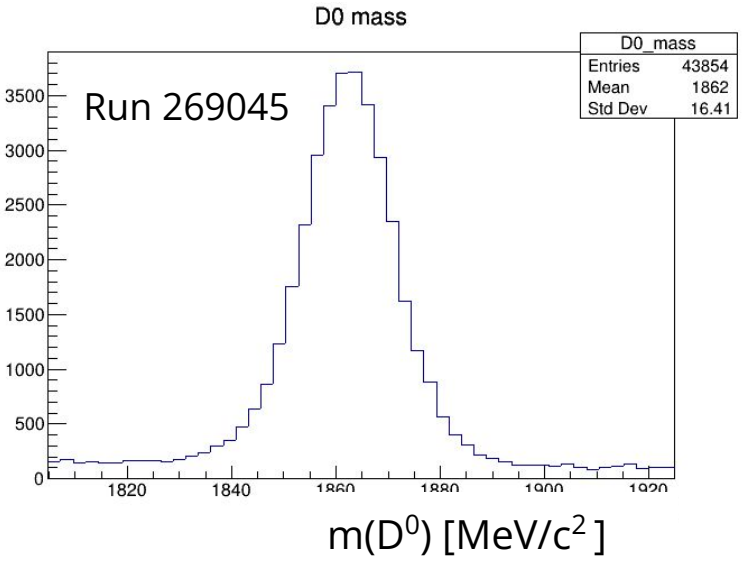


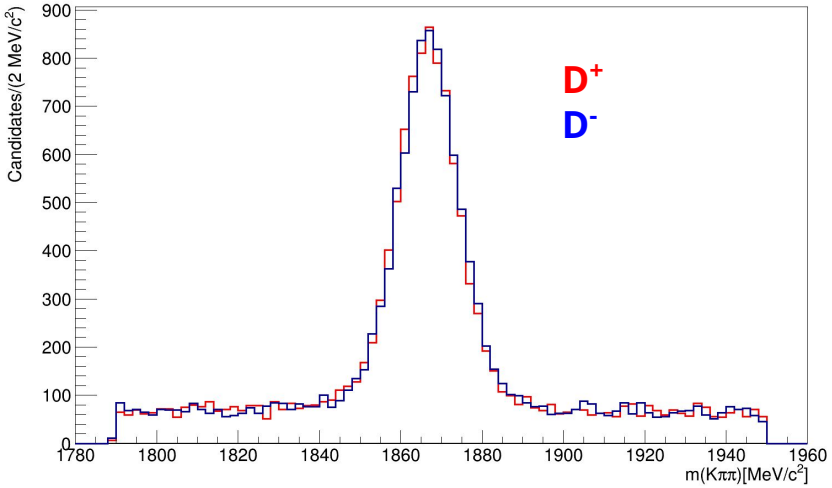
SciFi alignment: understanding of the mass shift

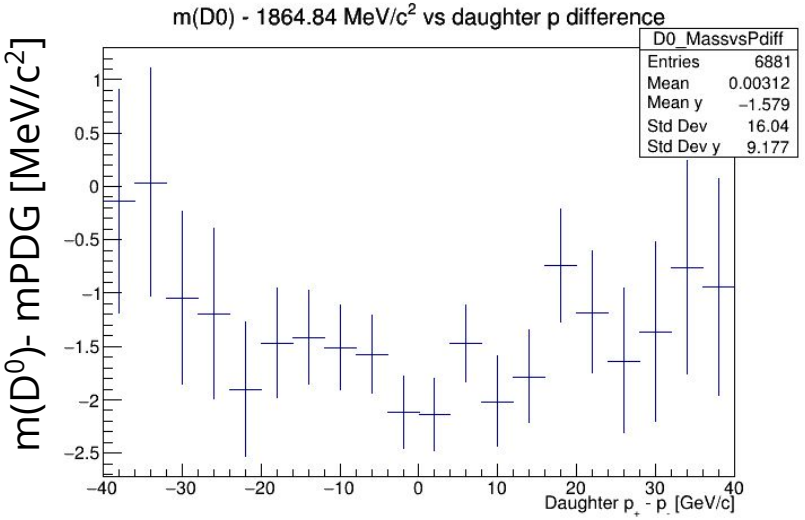
- Cleaning up our D^0 we obtain much better results!
- Still investigating shift w.r.t PDG value

  (residual misalignment in z)

D^0 candidates used to constraint weak modes

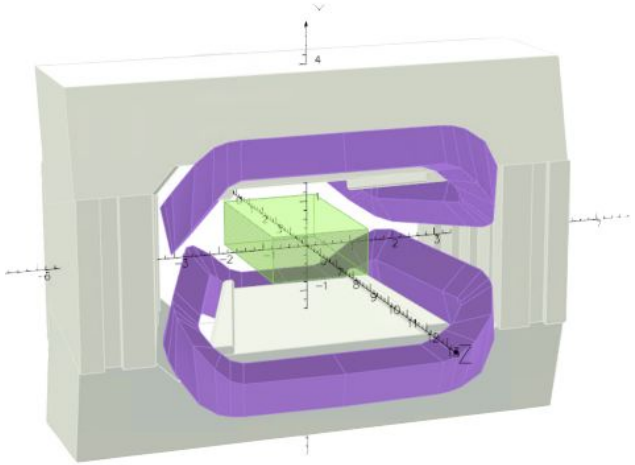






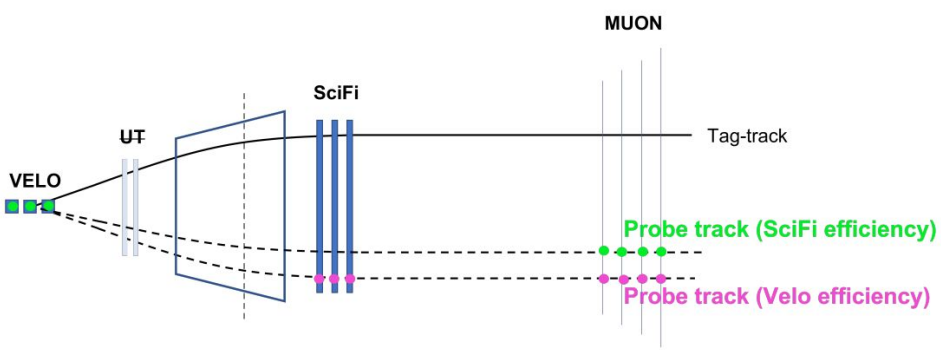
Magnetic field map

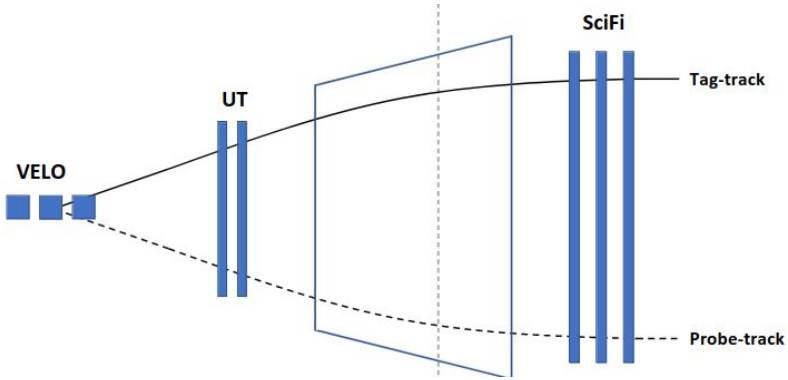
- A bias of the momentum estimate could also be caused by a bias in the magnetic field map
- Work ongoing to improve our knowledge of the magnetic field
  - Add missing material in simulation and test new map on Run 2 data
  - More details in Marie's and Aravindhan's slides



Tracking efficiencies

- Extract tracking efficiency on data (e.g., using tag-and-probe method) and on MC
- If detector and tracking performance are well understood → data/MC agreement expected at the ~ percent level
- Various methods being used, see Rowina's slides and Guillaume's slides



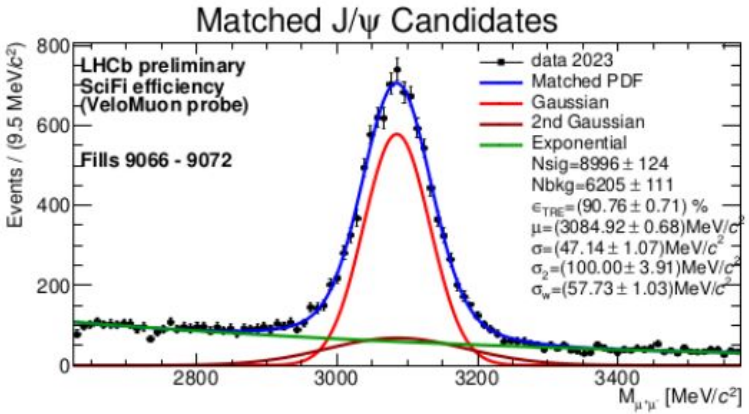


Tracking efficiencies

see Rowina's slides

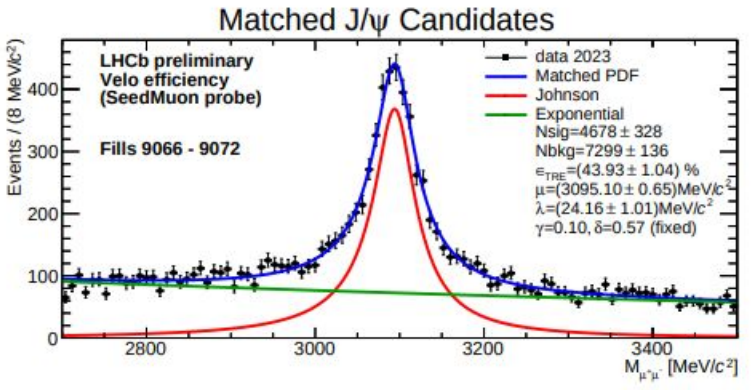
- While our understanding has improved w.r.t. 2022, there are still discrepancies
  - ➢ Need to understand in detail the origin of the differences
  - ➢ Few things not perfect in data-taking as in MC

SciFi tracking efficiency



Data: (90.76 +- 0.71)%
MC: (96.98 +- 0.04)%

VELO tracking efficiency

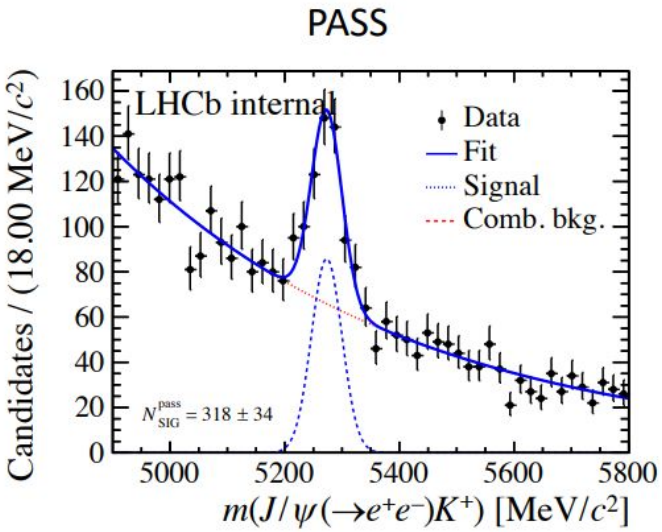


Data: (43.91±1.04)%
MC: (46.54±0.08)%

Tracking efficiencies

see Guillaume's slides

- Not only muons: looking also at electrons with $B^+ \rightarrow J/Psi(\rightarrow e^+e^-)K^+$



2022 passthrough data

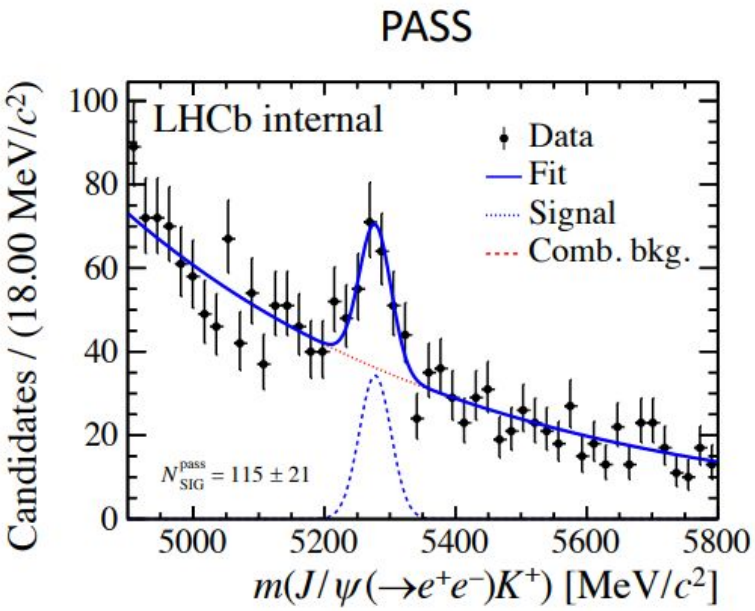
ε data = (77.6 +- 3.5)%

ε MC = (87.2 +- 0.1)%

2023 TURCAL data

ε data = (85.0 +- 7.4)%

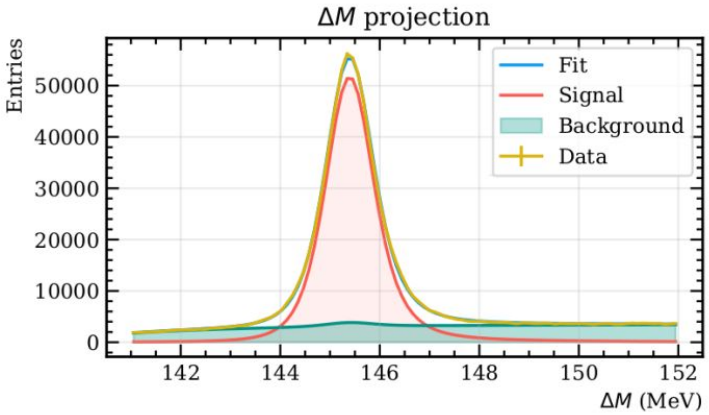
(2023 MC will be soon analysed)

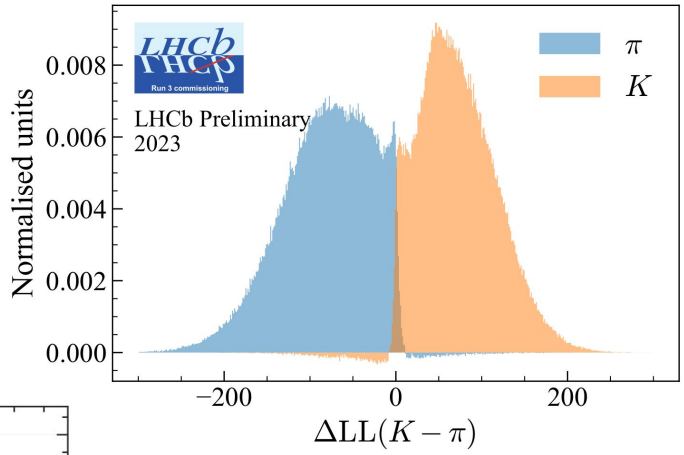


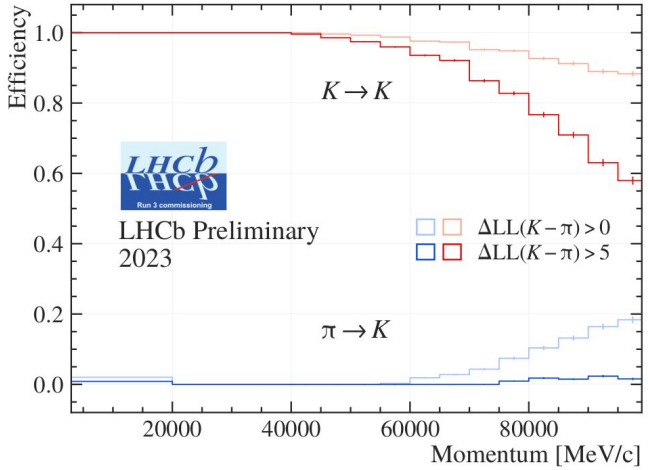
PID lines

- Currently studying PID performance on 2023 data

$D^{*+} \to D^0(\to K^-\pi^+)\pi^+$







LHCb-FIGURE-2023-023

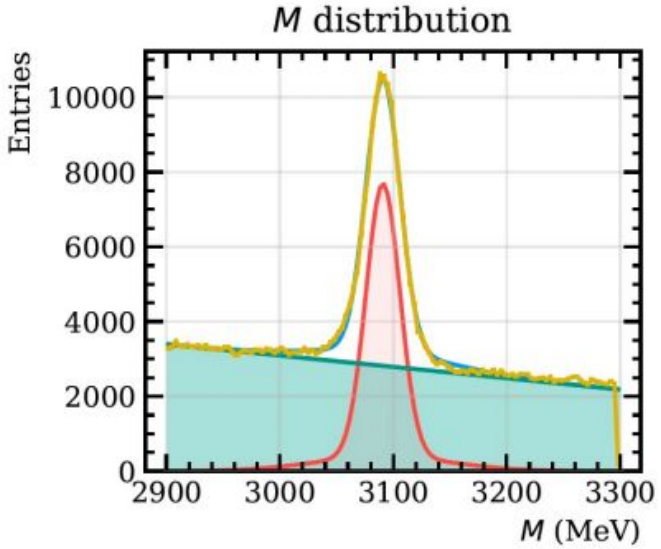
- Ongoing work to retune trigger lines for PID calibration (and in general all the Turcal lines) to fit in the throughput budget (see dedicated meeting)

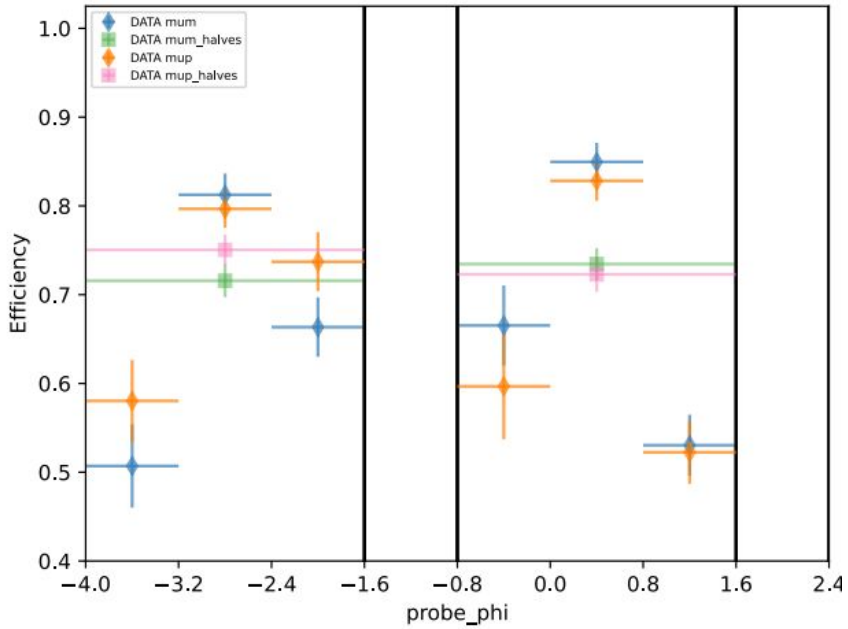
Muon ID efficiency and calibration

Dedicated session on the 16th of November

- Studying muon ID performance on 2023 data

Fit to J/Psi → $\mu^+\mu^-$ candidates from PID lines
Collision 2023 data, see Francesca's slides

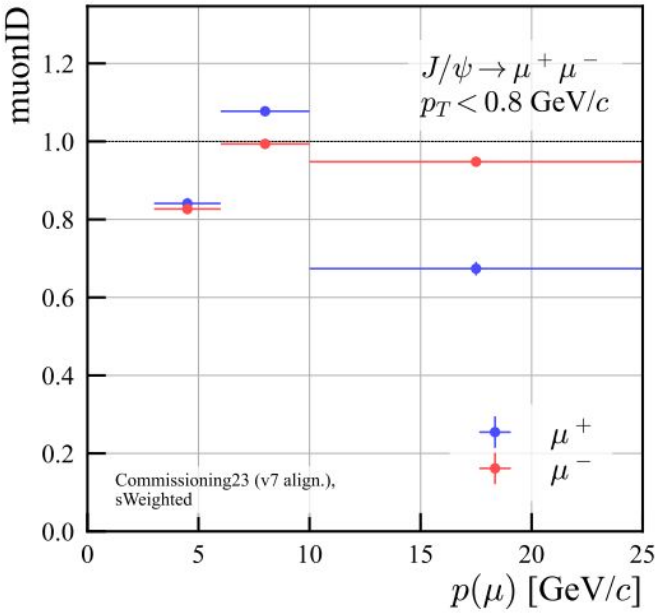


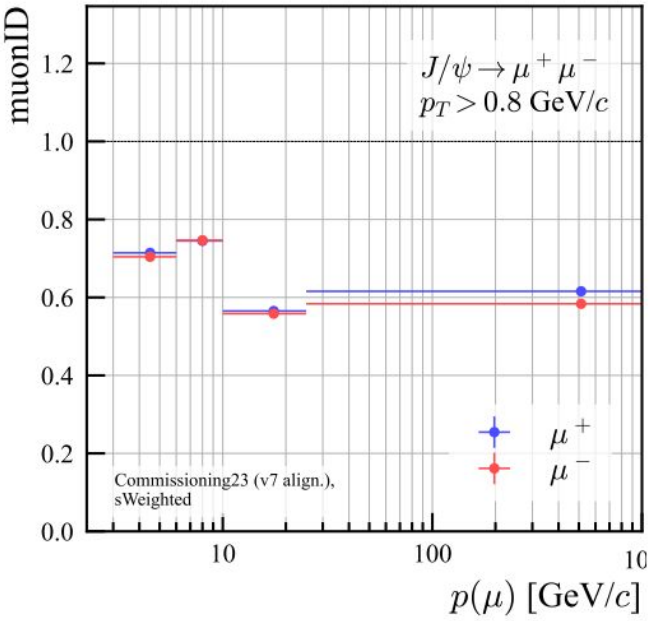


Muon ID efficiency with Z →$\mu^+\mu^-$ decays
see Luke's slides

Muon ID efficiency and calibration

Muon ID efficiency with detached J/Psi $\rightarrow \mu^+\mu^-$ decays, see Lea's slides





- Muon ID performance worse than Run 2
- Muon group identified and fixed an issue in the time-alignment procedure

Priorities for 2024 data-taking

- Test and consolidate the missing part (due to LHC incident) of the online alignment and calibration: RICH mirror alignment and π^0 calibration (they were determined offline)
- Assess the tracking and PID performance in bins of kinematics (too low statistics available in 2022-2023)
- Monitor the high-level performance in (almost) real-time (see Marianna's presentation)

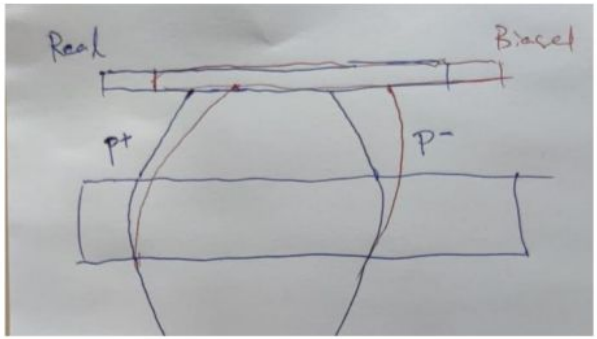
Conclusions

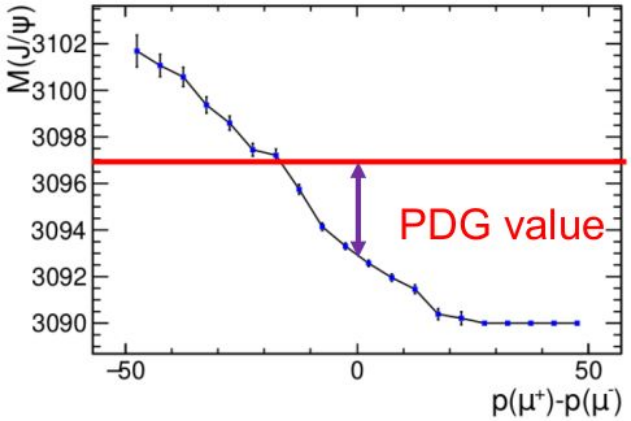
- Alignment and calibration making progress with 2023 data
  - Studying stability of VELO alignment constants
  - Source of mass shift in SciFi alignment identified and will be fixed for 2024
  - Tracking efficiencies are much improved w.r.t. 2022, and the remaining difference w.r.t. MC is under study
  - RICH PID efficiency reached the benchmark performance
  - Muon ID efficiency lower than MC, will be checked again in 2024 with the fixes put in place by the muon group
- Improvements in our understanding of 2023 features fundamental to be ready for 2024
- Thanks to everybody contributing to this effort!

Backup slides

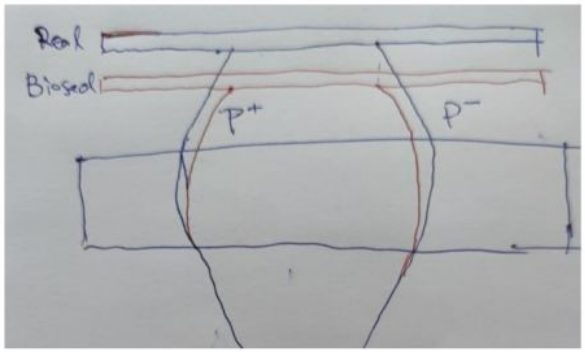
Sources of mass shift

- Curvature bias lead to mass shift; 2 types of bias observed in 2023 data
  1. Bias in T_x : $\delta m = (1 - cos\theta)(p_- - p_+)\delta p \sim C\delta r(p_- - p_+)$





  2. Bias in T_z : $\delta m = (1 - cos\theta)(p_- + p_+)\delta p \sim C\delta z\, t_x(p_- + p_+)$



Plot and drawings kindly provided by Zehua Xu!

Details in backup

Sources of mass shift

- Estimate the shift in T_x and T_z
- 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