

Arbeit zur Erlangung des akademischen Grades
Master of Science

Alignment studies for the LHCb SciFi Detector

Nils Breer
geboren in Unna

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Lehrstuhl für Experimentelle Physik IV
Fakultät Physik
Technische Universität Dortmund

Erstgutachter:	Prof. Dr. Albrecht
Zweitgutachter:	Prof. Dr. Weingarten
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Abstract

Kurzfassung

Hier steht das selbe wie im Abstract nur auf deutsch.

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1 Introduction

2 Particles and The Large Hadron Collider

2.1 The Standard Model

2.2 particle decays and hadrons

2.3 The LHC and LHCb

2.3.1 The LHC

The Large Hadron Collider (LHC)[2] is the most powerful particle-accelerator on planet earth. With a circumference of 26,7km it is also the longest ring accelerator and it lies between 45m and 170m below the surface near Geneva in Switzerland. The tunnel was constructed for the LEP experiment between 1984 and 1989 and is operated by the European Organization for Nuclear Research (CERN). The LHC can produce centre of mass energies of $\sqrt{s} = 13 \text{ TeV}$ in proton-proton collisions during Run 2. After the upgrade the LHC will collide particles with the centre of mass energy $\sqrt{s} = 13 \text{ TeV}$. An image of the accelerators and the experiments is shown in fig. 2.1[1].

By ionizing hydrogen gas, protons are created and accelerated to 50 MeV by the linear accelerator (LINAC 2). Afterwards the beam is injected into the Proton Synchrotron and the Super Proton Synchrotron to a maximum of 450 GeV before the beam is brought into the LHC. The beam contains several bunches with around $1,15 \cdot 10^{11}$ and a bunch spacing of 25 ns, which is a collision rate of 40 MHz. The LHC houses four major experiments. ATLAS and CMS are classified as general purpose detectors with a detection range of close to 4π . The interaction in these detectors is located in the very center so that tracks going in every direction can possibly be found. Searches for the Higgs Boson is just one of many physics aspects these detectors are built for. The other two experiments located at the LHC are ALICE and LHCb. The ALICE experiment mainly studies the quark gluon plasma during the runs with lead ion collisions instead of protons. In this thesis the Scintillating Fibre Tracker (SciFi Tracker) located at the LHCb will be focused at and discussed in the following chapters.

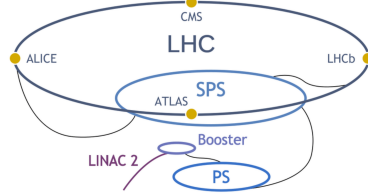


Abbildung 2.1: an overview of the LHC facilities.

2.3.2 The LHCb

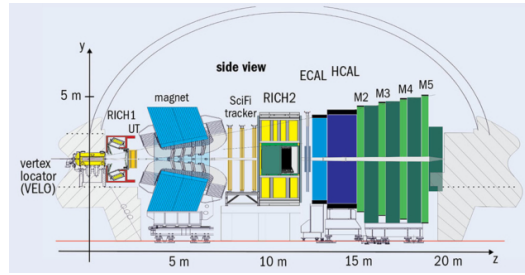


Abbildung 2.2: a sideview of the LHCb experiment.

The LHCb experiment[4] is a forward spectrometer covering $2 < \eta < 5$ in the pseudorapidity range. This experiments main physics goal is beauty quark physics and for high energies, b - and \bar{b} -hadrons are heavily produced in a tight forward direction¹. A sideview of the LHCb is shown in figure 2.2. The LHCb consists of several smaller detector components namely the Vertex Locator (VELO) right on the intercation point, two Ring Imaging Cherenkov counter (RICH 1 and RICH 2), in front of the spectrometers lies the Trigger Tracker and behind them the SciFi Tracker which is the important part of this thesis. Further back a Scintillator Pad Detector (SPD) and a Preshower (PS) are mounted followed by the electromagnetic calorimeter (ECAL) and the hadronic calorimeter (HCAL). In the very back, several muon chambers are mounted for every track that is yet to be determined.

¹They are also produced in a tight backward direction but the experiment is only build for the forward cone.

In this section, a general overview about the requirements for the SciFi Tracker as well as the layout will be described based on the presentation in the *technical design report*[3] of the upgrade.

The upstream and downstream trackers provide a good precision estimate of the momentum of charged particles so that mass resolution of decayed particles can be precisely measured. For particle identification the reconstructed trajectories of charged particles are used as input for the RICH detectors. The limiting factor for the momentum resolution is multiple scattering for tracks with a momentum lower than 80 GeV/. For tracks with a higher momentum the detector resolution is the limiting factor.

The SciFi Tracker replaced the inner Tracker (IT) and the outer Tracker (OT) and is located in the same place as the downstream trackers that were previously installed.

The instantaneous luminosity after the upgrade is expected to be $1 \text{ 1}/(\text{cm}^2 \text{ s})$ bis $2 \cdot 10^{33} \text{ 1}/(\text{cm}^2 \text{ s})$. The bunch spacing will be 25 ns and the number of proton-proton interactions per bunch crossing will be $\nu = 3.8$ during the ramp-up phase of the LHC and $\nu = 7.6$ "during the active phase." (how can i write this differently?)

2.3.3 Layout of the Detector

The SciFi Tracker consists of three (T-)stations T1, T2 and T3 with each having four Layers ($X1, U, V, X2$). The orientation of these planes with respect to the vertical axis are $(0^\circ, 5^\circ, -5^\circ, 0^\circ)$. The tilted layers are called stereo layers and serve the purpose of 3D hit localization. Each layer consists of 8 fibremats A right-handed coordinate system is used with positive z pointing away from the interaction point following the beam direction. positive y points upwards, towards the surface and positive x and negative x are defined as A-Side and C-Side[3].

2.4 The LHC data cycle

(not sure if that's a good name, but like, an explanation of how electrical information is turned into hits and then tracks, and also when alignment runs in the system of data taking)

3 The Theory of Alignment

3.1 kalman filters and track reconstruction

talk pdf. quelle herausfinden!

3.2 alignment using derivatives

wouter pdf. quelle herausfinden!

martinelli pdf! use some of that information -> alignment is a minimizing problem (chi2) thats why i looked at chi2 plots

-> global translation and sheering motion don't change chi2 values because residuals are unchanged.

-> weak modes: presence of weak modes affect the convergence (poor, takes many iterations), bias in track parameters.

-> most visible weak modes is the "curvature bias" (sophie has mentioned it sometime. must be on one of my sheets) also look at twiki!

goals: source for now: DPG2021 pdf exact source will be included!

4 Main part

taking notes for now so i know what plots to use

1. started with null tests.
2. which constraint does what?
3. which degree of freedom moves what part of the scifi?
- 4.

need to be sorted to according part of the story.

compare 1000 to 7000 events for Tx flo versus my constraints. what exactly were flo's changes?

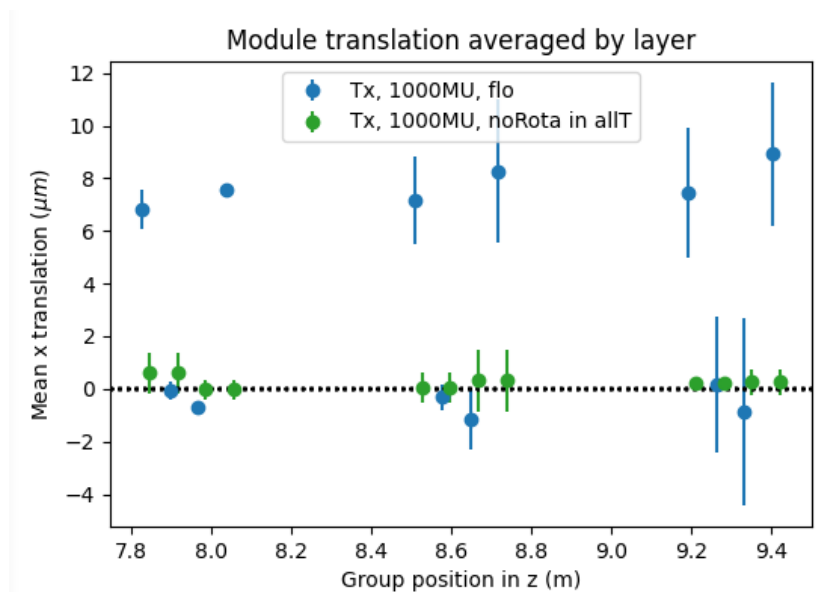


Abbildung 4.1: comparison of different configurations without rotational constraints in every station, magnet up and 1000 events. plotted is translation in x versus global z.

maybe show this plot 4.3

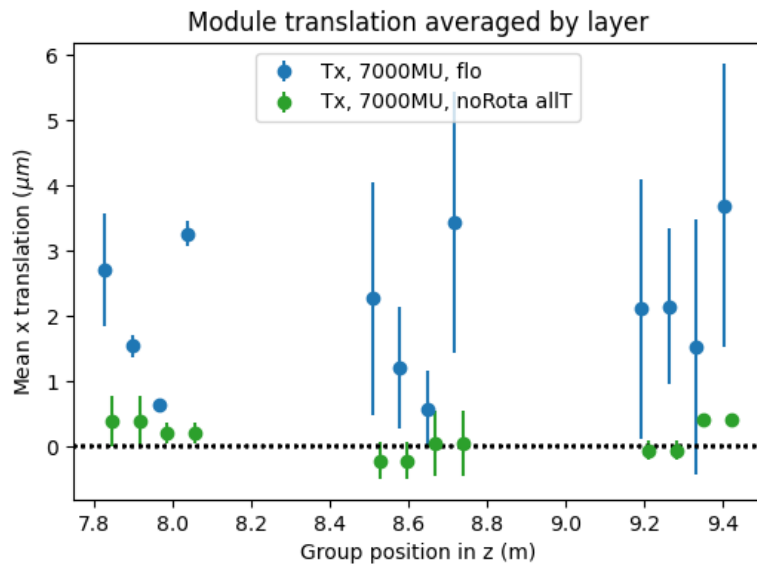


Abbildung 4.2: comparison of different configurations without rotational constraints in all stations, magnet up and 7000 events. plotted is x translation versus global z.

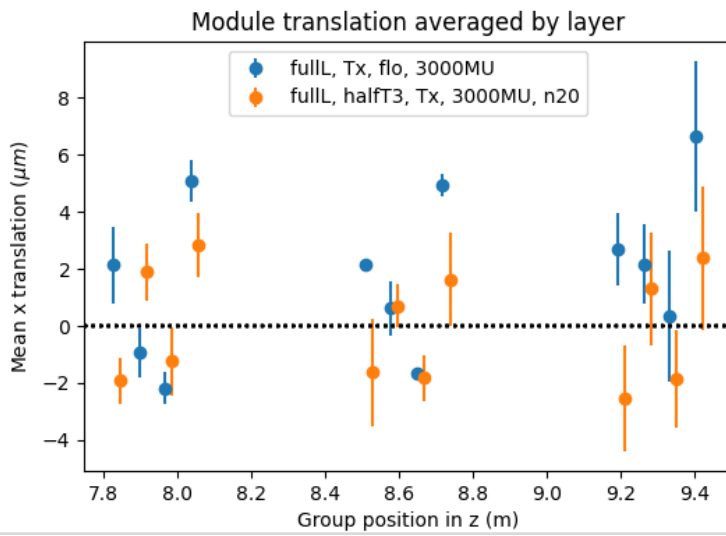


Abbildung 4.3: analysed 20 iterations for x translation behavior (look up exact constraints and dofs)

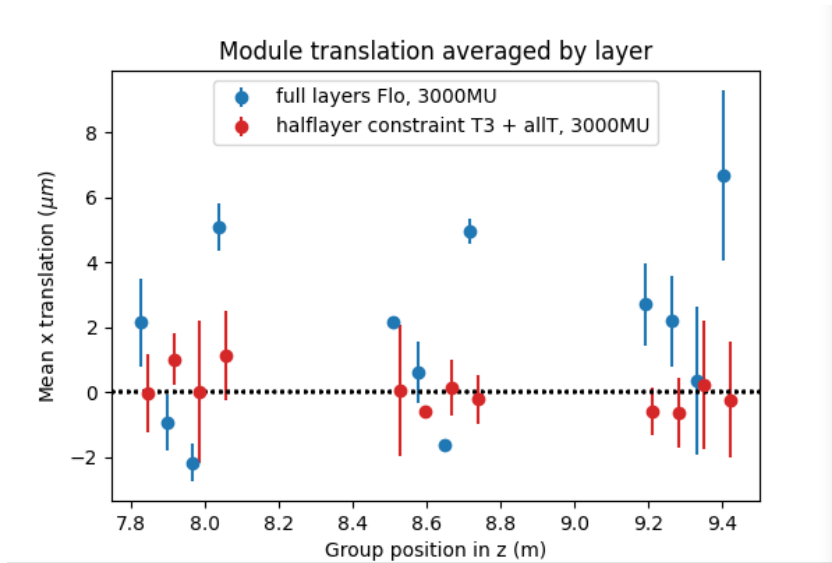


Abbildung 4.4: halflayer constraints and full layer constraint, very strict (look up exact constraints and dofs)

the figure in 4.4 shows that very strict Tx constraints make Tx look better but when comparing to Tz as we can see in figure 4.5 a clear layer separation is visible. because of the many constraints that are applied to T3, a compensation is happening in the other two stations.

Looking at figure 4.6, the last two layers in station 3 are separation from the first two. Especially the last station should be fixed around zero with the constraints added. The sum of all translations should be zero with each individual layer movement being small.

test 3:

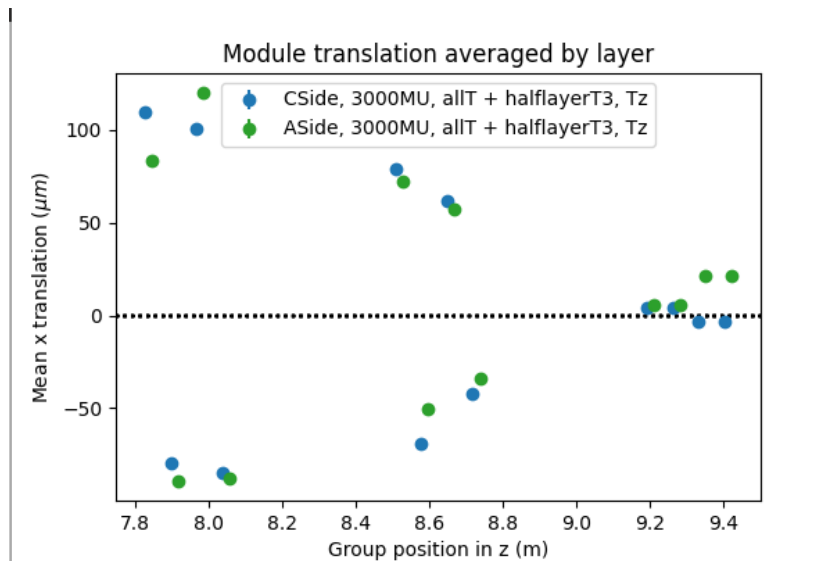


Abbildung 4.5: compare C-Side to A-Side for Translation in z direction. (look up exact constraints and dofs)

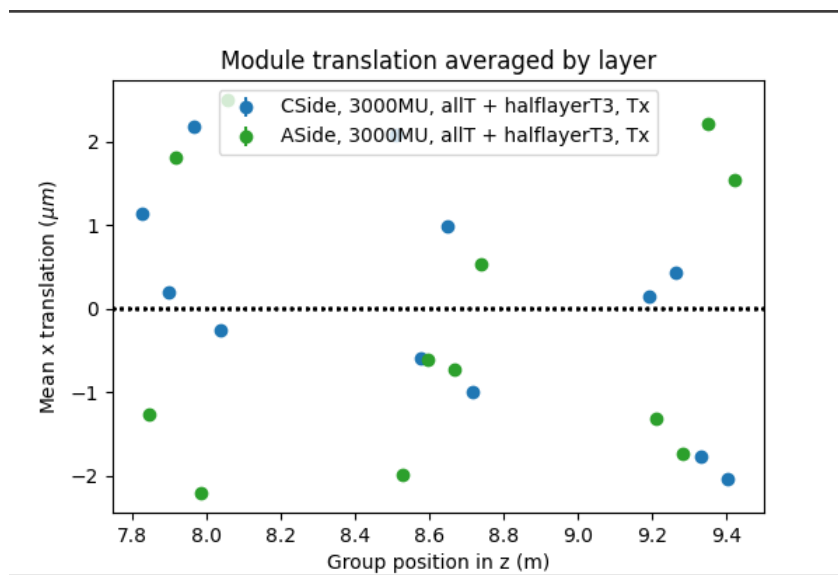


Abbildung 4.6: compare C-Side to A-Side for Translation in x direction. (look up exact constraints and dofs)

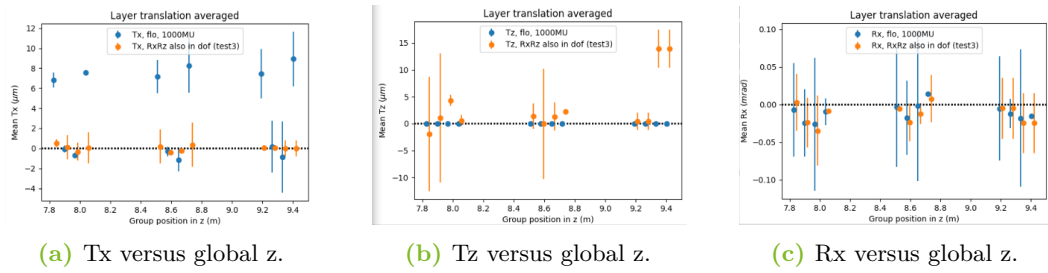


Abbildung 4.7: Testing a configuration versus florians changes.

5 Continuing Work

6 Future Work

7 Conclusion and Outlook

Literatur

- [1] *A diagram showing the complete structure of the LHC facility at CERN.* URL: https://www.researchgate.net/figure/A-diagram-showing-the-complete-structure-of-the-LHC-facility-at-CERN-There-are-the-4_fig8_348806406 (besucht am 09.03.2022).
- [2] *LHC Machine.* URL: https://cds.cern.ch/record/1129806/files/jinst8_08_s08001.pdf (besucht am 09.03.2022).
- [3] *LHCb Tracker Upgrade Technical Design Report.* URL: <https://cds.cern.ch/record/1647400/files/LHCB-TDR-015.pdf> (besucht am 09.03.2022).
- [4] *The LHCb Detector at the LHC.* URL: https://cds.cern.ch/record/1129809/files/jinst8_08_s08005.pdf (besucht am 09.03.2022).

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Eidesstattliche Versicherung

Ich versichere hiermit an Eides statt, dass ich die vorliegende Abschlussarbeit mit dem Titel „Alignment studies for the LHCb SciFi Detector“ selbstständig und ohne unzulässige fremde Hilfe erbracht habe. Ich habe keine anderen als die angegebenen Quellen und Hilfsmittel benutzt, sowie wörtliche und sinngemäße Zitate kenntlich gemacht. Die Arbeit hat in gleicher oder ähnlicher Form noch keiner Prüfungsbehörde vorgelegen.

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