technische universität
dortmund

Arbeit zur Erlangung des akademischen Grades
Master of Science

Alignment studies for the LHCb SciFi Detector

Nils Breer
geboren in Unna

2022

Lehrstuhl für Experimentelle Physik IV
Fakultät Physik
Technische Universität Dortmund

Erstgutachter:	Prof. Dr. Albrecht
Zweitgutachter:	Prof. Dr. Weingarten
Abgabedatum:	May 4th 2022

Abstract

Kurzfassung

Hier steht das selbe wie im Abstract nur auf deutsch.

Inhaltsverzeichnis

1 Introduction

2 The Large Hadron Collider[2]

The Large Hadron Collider (LHC) is the most powerfull particle-accelerator on planet earth. With a circumference of $26,7$km it is also the longest ring accelerator and it lies between 45m and 170m below the surface near Geneva in Swizerland. 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 $\sqrt{s} = 13\,\mathrm{TeV}$ in proton-proton collisions during Run 2. After the upgrade the LHC will collide particles with the centre of mass energy $\sqrt{s} = 13\,\mathrm{TeV}$. An image of the accelerators and the experiments is shown in fig. 2.1[1].

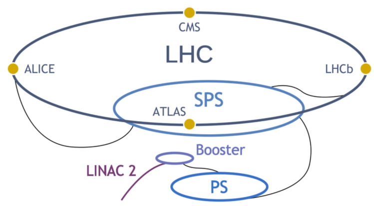


Abbildung 2.1: an overview of the LHC facilities.

By ionizing hydrogen gas, protonsare created and accelerated to $50\,\mathrm{MeV}$ by the linear accelerator (LINAC 2). Afterwards the beam is injected into the Proton Syncrotron and the Super Proton Synchrotron to a maximum of $450\,\mathrm{GeV}$ before the beam is brought into the LHC. The beam containts several bunches with around $1{,}15 \cdot 10^{11}$ and a bunch spacing of $25\,\mathrm{ns}$, which is a collision rate of $40\,\mathrm{MHz}$. 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 build for. The other two Experiments located at the LHC are ALICE and LHCb. The ALICE experiment main 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 on the following chapters.

2.1 The LHCb Experiment[4]

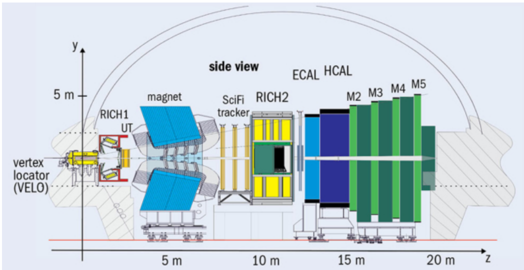


Abbildung 2.2: a sideview of the LHCb experiment.

The LHCb experiment is a forward spectrometer covering $2 < \eta < 5$ in the pseudo-rapidity 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 direction[1]. 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 Scinitllator Pad Detector (SPD) and a Preshower (PS) are mounted followed by the electromagnetic calorimeter and the hadronic calorimeter. In the very back, several muon chambers are mounted for every track that is yet to be determined.

2.2 the Scintillating Fibre Tracker[3]

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 SciFi Tracker consists of three (T-)stations T1, T2 and T3 with each

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

having four Layers $(X1, U, V, X2)$. The orientation of these planes with respect to the vertical axis are $(0°, 5°, -5°, 0°)$. 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].

3 Alignment

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!

3.1 what is alignment used for?

short answers:

for these 3 bullet points i need a subsection explaining it!

3.2 when does alignment happen?

at which point during a run will alignment come into play?

3.3 Alignment Methods

3.3.1 using tracks fitted with kalman

talk pdf. quelle herausfinden!

3.3.2 'global' alignment with collision data

wouter pdf. quelle herausfinden!

3.4 Alignment goals

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

all of the above is just theory. Now, the story i want to tell starts.

4 Alignment Studies

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.

4.1 all plots

4.1.1 june plots

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?

maybe show this plot 4.3

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 seperation 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.

4.1.2 july plots

test 3:

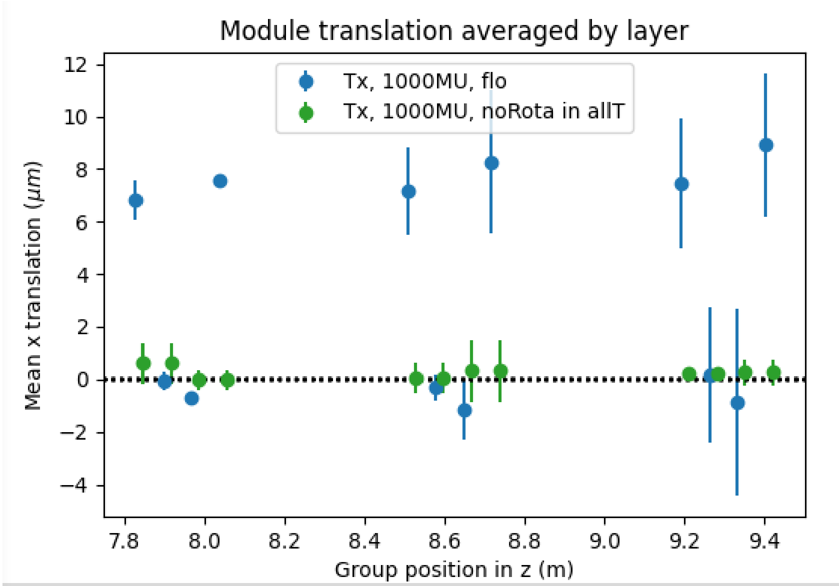


Abbildung 4.1: comparison of different configurations without rotational constraints in every station, magnet up and 1000 events. plotted is translation in x versus global z.

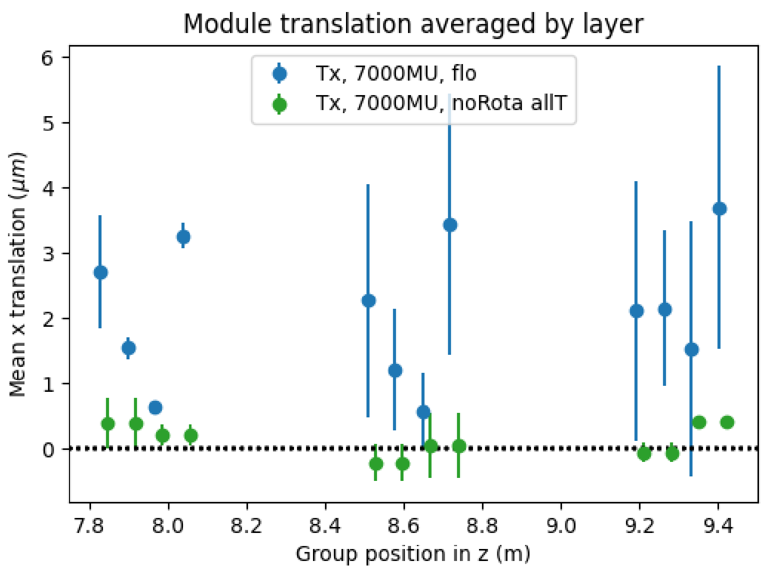


Abbildung 4.2: comparison of different configurations without rotational constraints in all stations, magnet up and 7000 events. plotted is x translation versus global z.

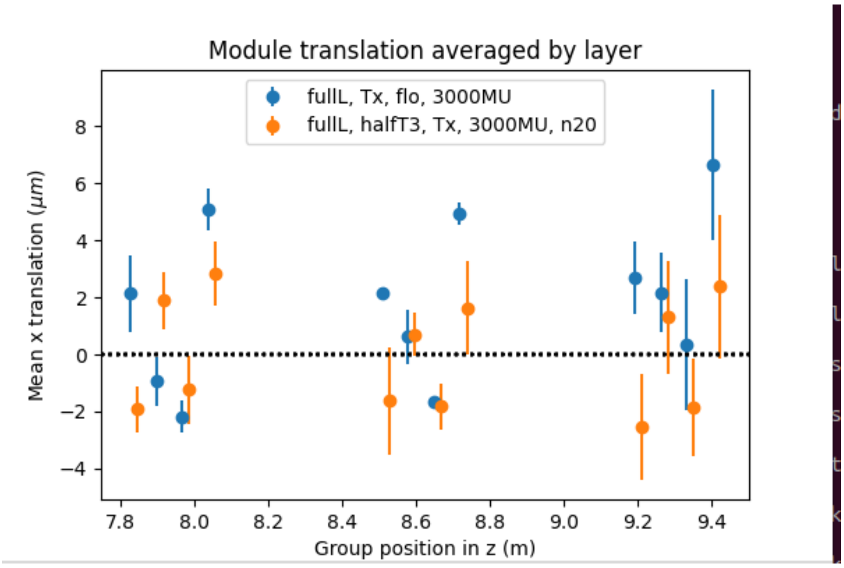


Abbildung 4.3: analysed 20 iterations for x translation behavior (look up exact constraints and dofs)

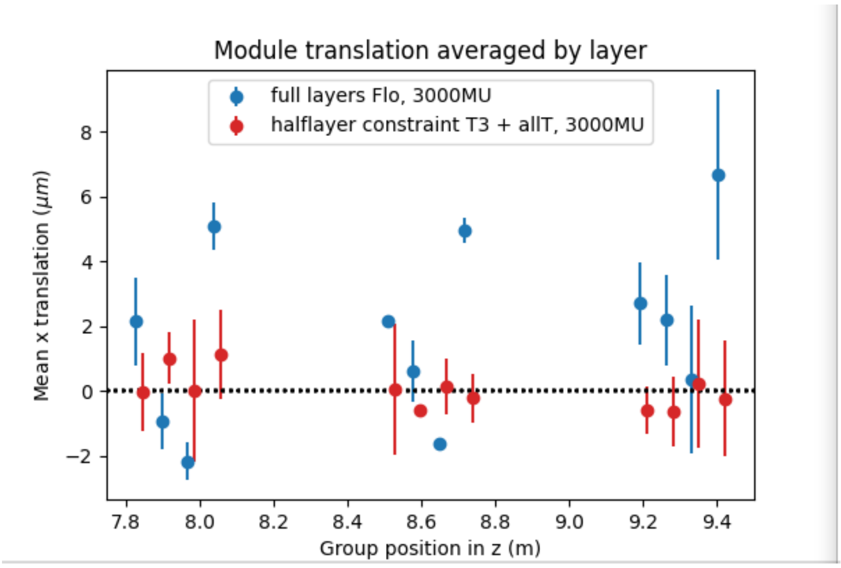


Abbildung 4.4: halflayer constraints and full layer constraint, very strict (look up exact constraints and dofs)

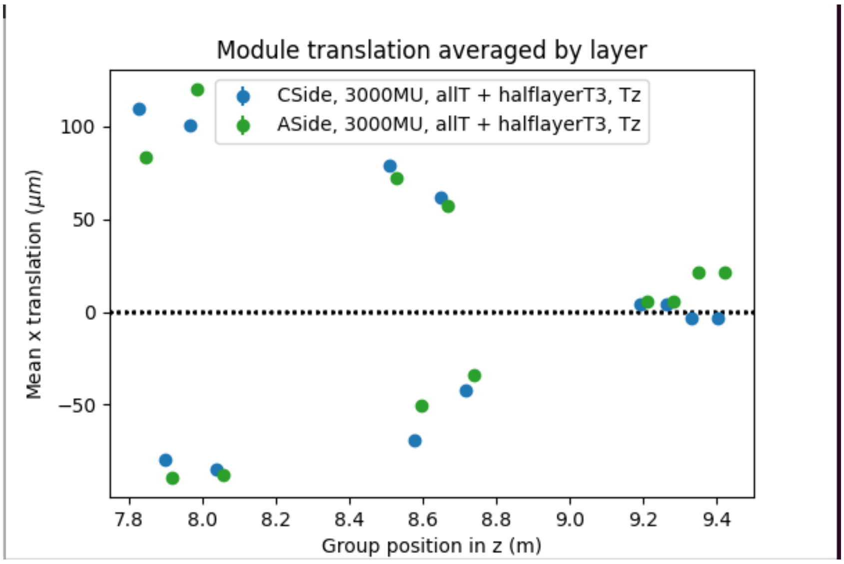


Abbildung 4.5: compare C-Side to A-Side for Translation in z direction. (look up exact constraints and dofs)

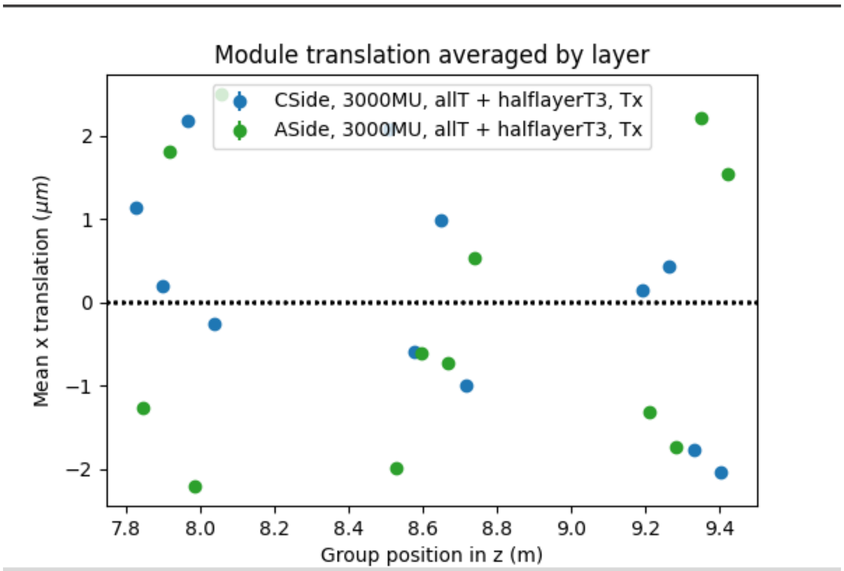
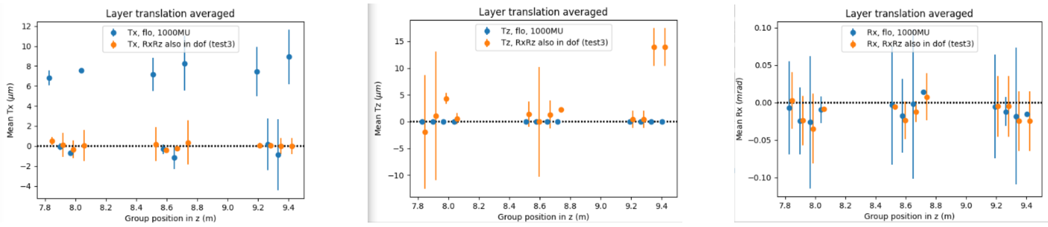


Abbildung 4.6: compare C-Side to A-Side for Translation in x direction. (look up exact constraints and dofs)



(a) Tx versus global z. (b) Tz versus global z. (c) Rx versus global z.

Abbildung 4.7: Testing a configuration versus florians changes.

4.1.3 august plots

5 Conclusion

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).

Danksagung

An dieser Stelle möchte ich mich bei all denen bedanken, die mir während meiner Bachelorarbeit zur Seite standen und mich immer unterstützt haben.

Zuerst möchte ich mich bei Herrn Professor Dr. Kevin Kröninger bedanken, durch welchen ich an seinem Lehrstuhl meine Bachelorarbeit schreiben konnte. Außerdem möchte ich mich bei der Abteilung der ATLAS Datenanalyse für die konstruktiven Anregungen bedanken.

Einen großen Dank spreche ich vor allem meinem Betreuer Dr. Johannes Erdmann aus, der mich mit voller Unterstützung und wertvollen Ratschlägen und Hilfestellungen durch meine Bachelorarbeit begleitet hat. Durch ihn habe ich viel gelernt und bei Fragen konnte er mir stehts weiterhelfen.

Ich möchte mich auch bei Herrn Professor Dr. Bernhard Spaan für die Zweitkorrekur meiner Arbeit bedanken.

Mein Dank gebürt außerdem Christopher Krause, Jan Lukas Späh, Michael Windau, Sebastian Lütge und Christian Beckmann für die fachliche Kompetenz bei Fragen aller Art.

Zuletzt möchte ich meiner Familie und Freunden dafür danken, dass sie mich während meines gesamten Studiums immer unterstützt und motiviert haben.

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.

Ort, Datum | Unterschrift

Belehrung

Wer vorsätzlich gegen eine die Täuschung über Prüfungsleistungen betreffende Regelung einer Hochschulprüfungsordnung verstößt, handelt ordnungswidrig. Die Ordnungswidrigkeit kann mit einer Geldbuße von bis zu 50 000,00 € geahndet werden. Zuständige Verwaltungsbehörde für die Verfolgung und Ahndung von Ordnungswidrigkeiten ist der Kanzler/die Kanzlerin der Technischen Universität Dortmund. Im Falle eines mehrfachen oder sonstigen schwerwiegenden Täuschungsversuches kann der Prüfling zudem exmatrikuliert werden (§ 63 Abs. 5 Hochschulgesetz –HG–).

Die Abgabe einer falschen Versicherung an Eides statt wird mit Freiheitsstrafe bis zu 3 Jahren oder mit Geldstrafe bestraft.

Die Technische Universität Dortmund wird ggf. elektronische Vergleichswerkzeuge (wie z. B. die Software „turnitin“) zur Überprüfung von Ordnungswidrigkeiten in Prüfungsverfahren nutzen.

Die oben stehende Belehrung habe ich zur Kenntnis genommen.

Ort, Datum | Unterschrift