

Institute for Hadronic Structure and Fundamental Symmetries
School of Natural Sciences
Technical University of Munich

Development of FPGA frontend electronics of the scintillating fiber hodoscope of AMBER at CERN

Tim Maehrholz

Bachelor's Thesis

Supervisor:

Prof. Dr.

Chair of

Second Examiner:

PD Dr.

January 2025

Abstract

Here will be my abstract for thesis Thesis template from the ZNN, updated for Biblatex and Biber.

Zusammenfassung

German Abstract

1. Introduction	1
2. Theoretical concepts	3
2.1. Measurment of the charge radius of the proton	3
2.1.1. The sturucture of the proton	3
2.1.2. Previous measurements of the proton radius	3
2.1.3. Elastic scattering of muons on protons	4
2.2. FPGA stuff	5
3. Experimental Procedures	7
4. Results	9
5. Discussion	11
6. Conclusion and Outlook	13
6.1. Conclusion	13
6.2. Outlook	13
Appendix A. Code	15

CHAPTER 1

Introduction

”Nature will reveal its secrets, but only if we ask the right questions.” [**Werner Heisenberg**]

Progress in particle physics has always been driven by the desire to understand the fundamental building blocks of our universe.

Our best theory for the innerworkings of our world, the standard model of particle physics shows us, that the matter we see around us is mostly made up of up and down quarks, who together form protons and neutrons. These particles are the nuclei of the atoms that make up the world around us. The Proton unlike the electron or the quarks is not a fundamental particle, and thus has a charge radius.

The Amber experiment at CERN aims to resolve a discrepancy between the radius of the proton as measured by the Lamb shift in muonic and ordinary hydrogen and the electron scattering experiments, the so called proton radius puzzle.

CHAPTER 2

Theoretical concepts

2.1. Measurment of the charge radius of the proton

2.1.1. The sturucture of the proton

The proton is a baryon, a composite particle made of up two up quarks and one down quark. From this follows that the proton is not a point particle, but has an internal sturucture. This internal sturucture is described by the sturucture functions of the proton. The charge radius of the proton is a measure of the spatial distribution of the charge of the proton.

2.1.2. Previous measurements of the proton radius

The charge radius of the proton has been massured several times before with different methods. The two premier methods are electron proton scattering experiments and the Lamb shift in muonic and ordinary hydrogen. The results of these measurements differ by several standard deviations as shown in figure 2.1, this has given rise to the so called proton radius puzzle.

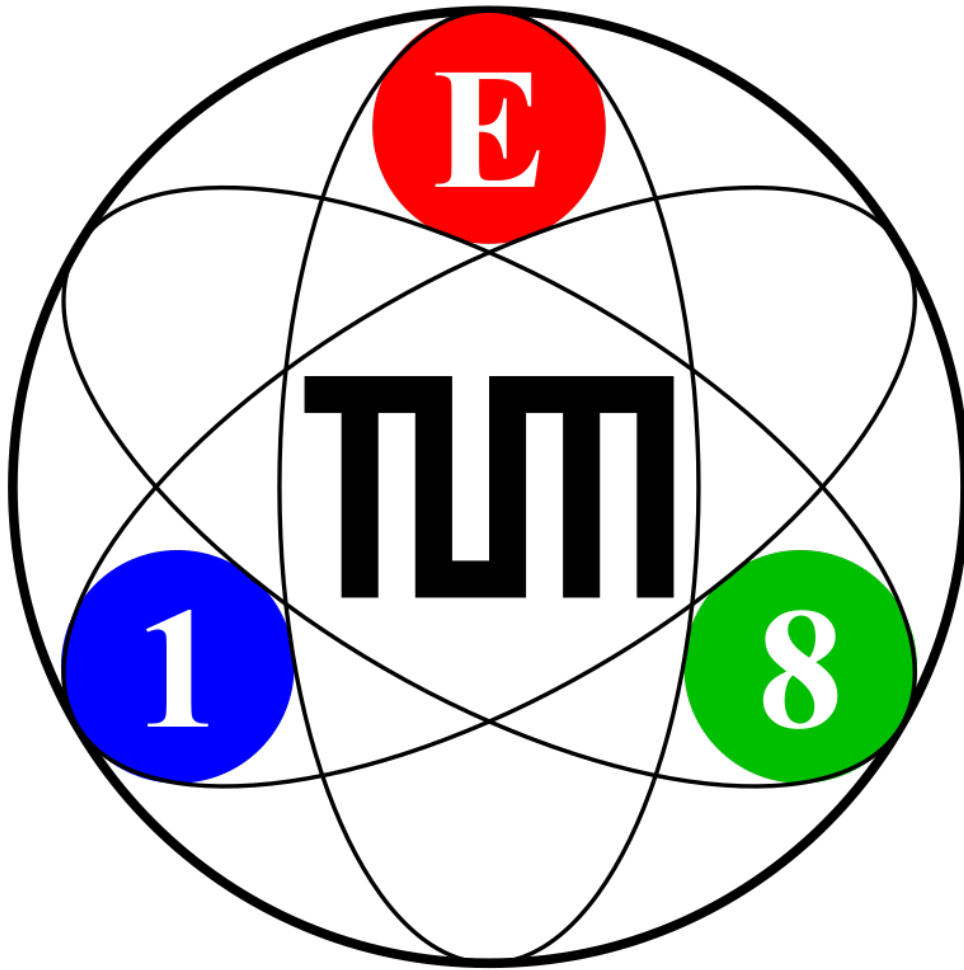


Figure 2.1.: Previous measurements of the proton radius

2.1.3. Elastic scattering of muons on protons

The Amber experiment at CERN aims to resolve the proton radius puzzle, by measuring the elastic scattering of muons on protons as shown in figure 2.2.

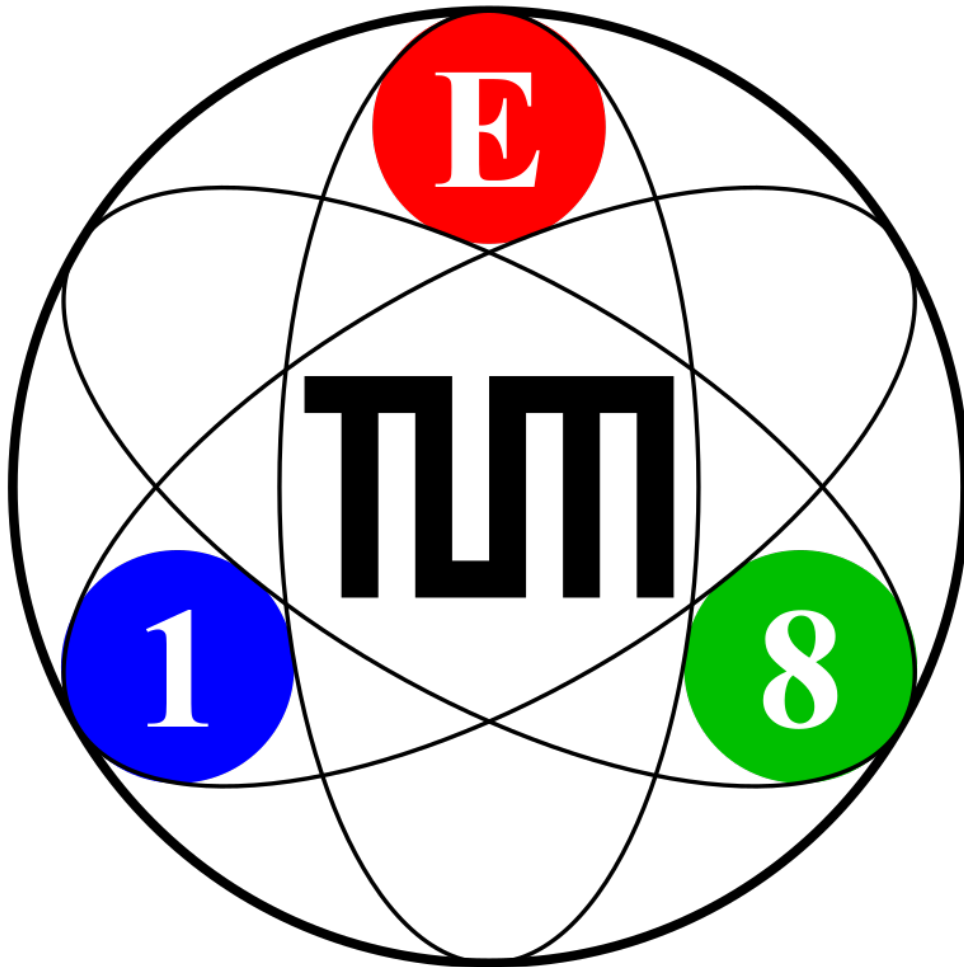


Figure 2.2.: Elastic scattering of muons with incoming momentum p and outgoing momentum q on protons

2.2. FPGA stuff

here i will write about FPGAs and how they work and why they are used in the Amber experiment. advantage of FPGAs is that they can be programmed to do a specific task, and that they are faster than CPUs for some tasks.

CHAPTER 3

Experimental Procedures

CHAPTER 4

Results

CHAPTER 5

Discussion

Discussion

CHAPTER 6

Conclusion and Outlook

6.1. Conclusion

Conclusion

6.2. Outlook

Outlook

APPENDIX A

Code

```
1 this is code
```

Acknowledgement

I want to thank:

Tutor .

Professor .

Eidesstattliche Erklärung

Ich versichere hiermit an Eides statt, dass ich die von mir eingereichte Arbeit bzw. die von mir namentlich gekennzeichneten Teile selbständig verfasst und ausschließlich die angegebenen Hilfsmittel benutzt habe. Die Arbeit wurde bisher in gleicher oder ähnlicher Form in keiner anderen Prüfungsbehörde vorgelegt und auch noch nicht veröffentlicht.

Ort, Datum

Unterschrift