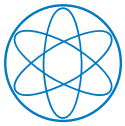
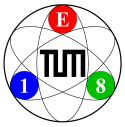


Institute for Hadronic Structure and Fundamental Symmetries
School of Natural Sciences
Technical University of Munich

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:
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Abstract

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

Zusammenfassung

German Abstract

Contents

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 innnerworkings of our world, the standart model of particle physics shows us, that the matter we see around us is mostly made up of up and down qurks, 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 quraks is not a fundamental particle, and thus has a charge radius.
The Amber experiment at CERN aims to reselove a discrepency 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 puzzel.

CHAPTER 2

Theoretical concepts

2.1. Measurment of the charge radius 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. The internal distrubiton of the charge defines the charge radius of the proton.

2.1.1. 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 five standard deviations as shown in figure 2.1, this has given rise to the so called proton radius puzzle [BAd19].

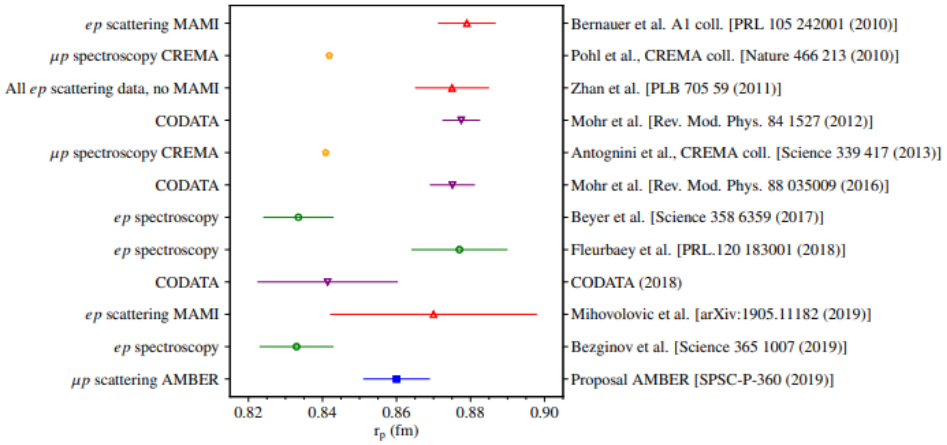

Figure 2.1.: Previous measurements of the proton radius from electron scattering experiments and the Lamb shift in muonic and ordinary hydrogen [BAd19]

2.1.2. Measurment of the proton radis with elastic scattering of muons on protons

The Amber experiment at CERN aims to reslove the proton radius puzzle, by measuring the elastic scattering of muons on protons.
The first order cross section for the elastic scattering of muons on a proton target is [Ada19] INSERT: maybe here more explantation

$$\frac{d\sigma}{dQ^2} = \frac{\pi\alpha^2}{Q^4 m_p^2 p_\mu^2}\left[\left(G_E^2 + \tau G_M^2\right)\frac{4E_\mu^2 m_p^2 - Q^2(s-m_\mu^2)}{1+\tau} - G_M^2\frac{2m_\mu^2 Q^2 - Q^4}{2}\right] \tag{2.1}$$

with $Q^2 = -q^2$, $\tau = Q^2/4m_p^2$, $s = (p_\mu + p_p)^2$, p_μ the momentum of the muon, p_p the momentum of the proton, m_p the mass of the proton, m_μ the mass of the muon, E_μ the energy of the muon, G_E the electric form factor of the proton, G_M the magnetic form factor of the proton and α the fine structure constant. INSERT: maybe here more explantation Through determening the form factors G_E and G_M, the charge radius of the Proton can be claculated with the following equation [Ada19]

$$r_p^2 = -6\frac{dG_E}{dQ^2}\bigg|_{Q^2=0} \tag{2.2}$$

2.2. General setup at AMBER

To determine the magentic and electric form factors of the proton and thus the charge radius of the Proton, the experimental cross section of the elastic scattering of muons on protons has to be measured. The general setup of the Amber experiment is shown

in figure 2.2. INSERT: MAYBE FLUX;ENERGY The incoming muon beam is scattered

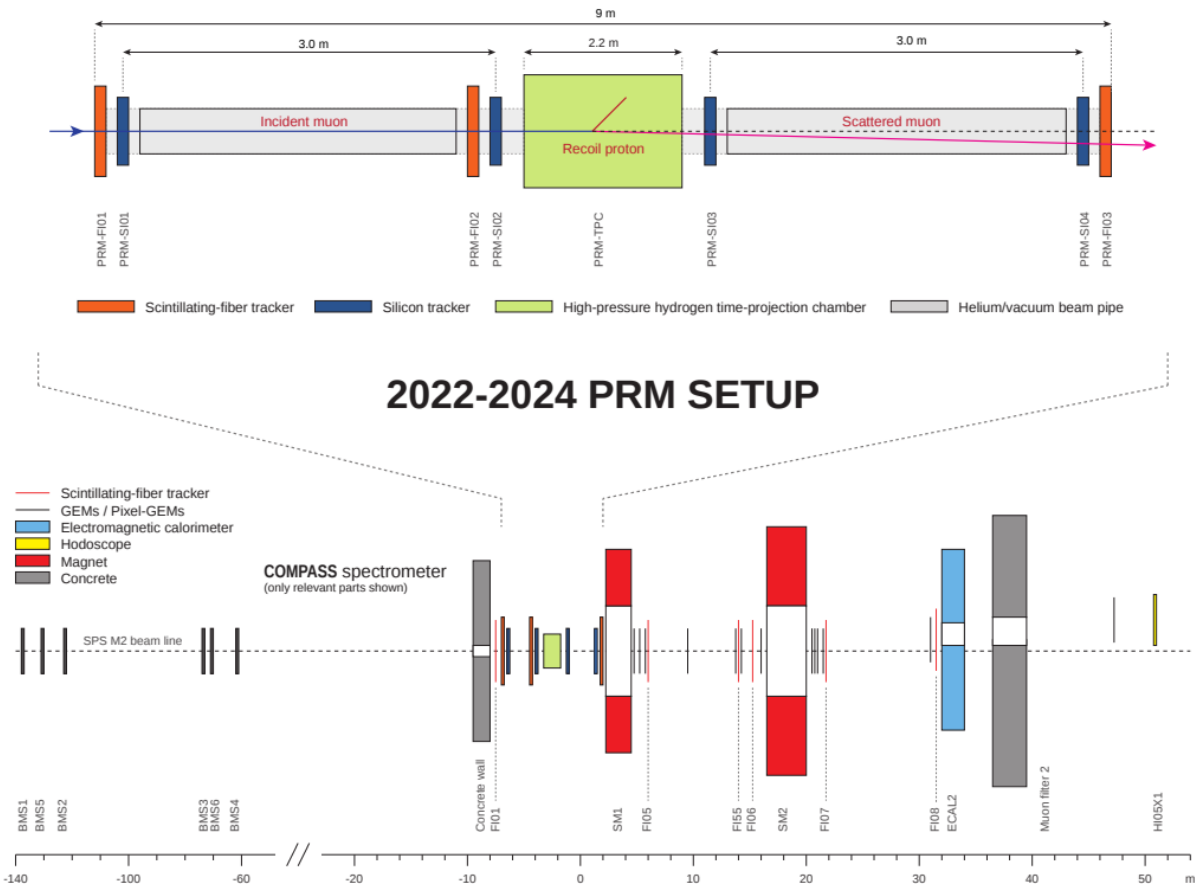

Figure 2.2.: General setup of the Amber experiment with new detectors for PR-Measurments,INSERT:BETTER DISCRIPTION [BAd19]

on a pressurized hydrogen gas target, located in the Time Projection Chamber (TPC), which also acts as the detector for the recoil path of the proton. The reconstruction of the path of the muon is achieved through the usage of two detector types.

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

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this is code
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Bibliography

[Ada19] B. Adams, C. A. Aidala, R. Akhunzyanov, and et al. *Letter of Intent: A New QCD facility at the M2 beam line of the CERN SPS (COMPASS++/AMBER).* 2019. arXiv: 1808.00848 [hep-ex]. URL: https://arxiv.org/abs/1808.00848 (cit. on p. 4).

[BAd19] e. a. B.Adams C. A. Aidala. *COMPASS++/AMBER: Proposal for Measurements at the M2 beam line of the CERN SPS Phase-1: 2022-2024.* Tech. rep. Geneva: CERN, 2019. URL: https://cds.cern.ch/record/2676885 (cit. on pp. 3–5).

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Professor .

Eidesstattliche Erklärung

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