Report of the 2nd semester

Zsófia Jólesz (zsofia.jolesz@gmail.com)
PhD Program: Particle and Nuclear Physics
Supervisors: Gábor Bíró, Gábor Papp
Title of Thesis: Development of proton computed tomography applied in hadron therapy

Introduction

Hadron therapy is a very promising cancer treatment that utilises the radiation of ionizing particles. When such a particle enters a medium, it deposits its energy due to interactions, such as Coulomb scattering. The Water Equivalent Path Length (WEPL) of the beam in the respective medium can be defined by the Bragg curve. The WEPL expresses how much the material attenuates a beam of radiation in comparison to water.

The peak of the Bragg curve can be tuned finely with the energy of the beam. As a consequence of this, there is a great need for accurate dosage planning. The currently used and most widespread diagnostic method is X-ray CT; however, the conversion to the hadron beam results in significant uncertainty. The Bergen Proton CT Collaboration aims to address this issue via the development of a novel proton CT detector system, based on the ITS detector of the CERN ALICE Experiment.

The aim of my research is the development of an imaging method that has not yet been previously applied in medical imaging. This method is called the Richardson-Lucy algorithm that is based the Maximum Likelihood - Expectation Maximization approach [1,2]. The implementation of this algorithm employs the energy loss of protons and my ultimate goal is to adapt and refine it for clinical usability, contributing to the Bergen Proton CT Collaboration [3].

Description of research work carried out in the current semester

During this semester, I had the opportunity to spend seven weeks in Bergen, Norway, where I worked in collaboration with the Bergen Proton CT (pCT) Group. My primary task was to test a new batch of ALPIDE sensor chips, which had recently been soldered and shipped from Ukraine. These chips are intended for future use in the tracking detector system of the proton computed tomography scanner currently under development.

In addition to carrying out standard performance tests, I focused on improving the efficiency and user-friendliness of the chip testing scripts. Unfortunately, a significant proportion of the tested chips exhibited faulty behavior and failed to meet expected performance criteria. The root cause of these failures remains uncertain; potential explanations include damage during the production process or issues that may have occurred during transportation. To investigate further, the chips were examined under a microscope and with a thermal camera. These inspections did not reveal any visible cracks or other obvious defects.

During my stay, I was also given a tour of the Bergen Proton Therapy Center, which was at that time still under construction. The facility was scheduled to begin its first patient treatments in May, and it was exciting to see the infrastructure being put into place for advanced cancer therapy.

I had the opportunity to present my work at several conferences throughout the semester, as detailed below. Most notably, I presented my work at the National Scientific Students' Associations Conference (OTDK), where I was awarded first place in the "Biophysics and Environmental Physics" section.

In parallel, I began working on the further development of the image reconstruction framework. This involved reviewing relevant literature on three-dimensional reconstruction techniques and exploring methods to extend the current algorithms beyond the assumption of cylindrical symmetry. The aim is to allow the reconstruction of more complex phantom geometries, thereby improving the accuracy and versatility of the imaging system.

Publications

G. Bíró, Á. Sudár, Zs. Jólesz, G. Papp, G.G. Barnaföldi. *Proton Computed Tomography Based on Richardson-Lucy Algorithm*. ArXiv:2212.00126v2

B. Dudás, Zs. Jólesz, G. Bíró, G. Papp, G.G. Barnaföldi. *Reconstruction of proton relative stopping power with a granular calorimeter detector model*. International Journal of Modern Physics A, Special Issue: Zimányi School 2023.

Studies in current semester

When the semester started, I was still in Bergen, testing the ALPIDE chips. After I came home I took 3 courses in this semester:

- Advanced machine learning lab (FIZ/3/093)
- Experimental methods of nuclear physics (FIZ/2/022)
- Experimental methods in particle physics (FIZ/2/138)

I scored grade 5 from the first two, the last one is still under evaluation.

Conferences in current semester

- OTDK, 22-25.04.2025, Pécs (1st place)
- GPU Day, 22-23.05.2025, Budapest (Talk)

Upcoming:

- Fifth MODE Workshop on Differentiable Programming for Experiment Design, 08-13.06.2025, Crete (Poster + Talk)
- Hungarian-German WE-Heraeus Seminar – Particles and Plasmas in Strong Fields, 22-26.06.2025, Dresden & Görlitz (Poster)

Educational activities in current semester

Classical physics laboratory (fizlab2f19la)

Nuclear and particle physics, astrophysics (laboratory, ITS lab) (rplpartastf20lm)

References

[1] Leon B Lucy. An iterative technique for the rectification of observed distributions. Astronomical Journal, Vol. 79, p. 745 (1974), 79:745, 1974.
[2] William Hadley Richardson. Bayesian-based iterative method of image restoration. JoSA, 62(1):55–59, 1972.
[3] Johan Alme, Gergely Gábor Barnaföldi, Rene Barthel, Vyacheslav Borshchov, Tea Bodova, Anthony Van den Brink, Stephan Brons, Mamdouh Chaar, Viljar Eikeland, Grigory Feofilov, et al. A high-granularity digi-

tal tracking calorimeter optimized for proton CT. Frontiers in Physics, 8:568243, 2020.