Report P2IO 2014

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Contents

1 Project goals **1**

2 Work achieved **2**
2.1 Introduction to the Time Projection Chamber 2
2.2 Hardware 2
2.3 Software framework 2
2.4 Simulation 3
2.5 Publications 3

3 Relevance within P2IO **4**

1 Project goals

HARPO is a detector development project aimed at improving gamma ray detection and polarimetry with the use of a Time Projection Chamber (TPC). The TPC is a gas detector well known in particle physics, and its performance have been improved in the past decade by the use of Micro-Pattern Gas Detectors (MPGDs) such as Gas Electron Multipliers (GEM) and MicroMEsh GAS detectors (Micromegas). A TPC prototype using both GEM and Micromegas has been developed and built at LLR to test the detector performance in cosmic rays and in a polarised photon beam.

The goal of the post-doc position is both to participate in the development and running of the TPC prototype and to develop software tools for the analysis of the data and the simulation of the full detector. A detailed simulation will be validated with beam data, and extended to study the capabilities of a full size detector in space.

2 Work achieved

2.1 Introduction to the Time Projection Chamber

The TPC is a gaseous tracker for charged particles. The charges particle ionise gas along their trajectory. An electric field is applied within the gas volume that drift the ionisation electrons to a readout plane. The readout plane is equipped with electron amplifiers (MPGDs in our case) and a segmented readout electronics which will measure the position of the electrons, giving a 2-dimensional projection of the track. The timing information, combined with the knowledge of the electron drift velocity in the electric field, gives the third coordinate. The challenges of such a detector are mostly related to the gas quality, which will affect the electron drift and the amplification in the MPGDs.

2.2 Hardware

The hardware work covered a large spectrum of tasks, providing support for the mechanics and electronics developments.

One of the main works was the characterisation of the new electron amplification system using both Micromegas and GEM. A number of measurements were done in a small controlled environment, using radioactive sources (^{55}Fe) at CEA. This allowed the understand the gain variations with the different electric fields involved in the system. These results were presented at an RD51 collaboration meeting in February 2014.

These measurements were compared and extended with measurement in the full TPC, using cosmic rays. The use of the full TPC allowed higher gas pressure, which is the expected environment for the final detector. The results of both experiment showed good agreement, in spite of very different methods.

Some more work was done on the triggering system for the TPC prototype. Most of it consisted in validating the optimal working conditions of the newly introduced PMm2 readout card. Another part was to extract the signal directly from the amplification plane (before any electronics treatment) and use it to create a better trigger for the photon beam environment.

2.3 Software framework

A software framework had already been developed to read and analyse the data from the different detector systems. I had to extend it to include more detector subsystems, and also to interface it with a simulation. I participated in the development of data reconstruction algorithms developed by Shaobo Wang. We had in particular to improve the computing efficiency and memory usage to be able to analyse large data sets.

2.4 Simulation

The simulation software has two parts:

- simulation of the interaction of the incoming high energy particles (electrons or muons) with the detector using the Geant4 framework. In particular, a detailed description of the ionisation of the gas is necessary.

- specific simulation of the different processes taking place in the detector that get from the ionisation electrons to the digital readout signal.

For now, the Geant4 simulation is restricted to the gas volume in the detector (which is the main active volume). The first challenge was to configure Geant4 to describe the interaction with a level of detail adapted to our setup. On one hand, multiple scattering of low energy electrons in the gas need to be described down to sizes smaller than the resolution of our readout (under 1mm). On the other hand, ionisation has to be described at the same scale to properly account for fluctuations and correlation. This was done using the PhotoAbsorption Ionisation (PAI) model in Geant4.

The other challenge is to interface the Geant4 simulation with the rest on the code, which uses the ROOT framework. For now, this is done in a cumbersome way, which allows to generate specific simulations with an ad hoc configuration, but is too heavy and not reliable enough to complete extended productions.

The rest of the simulation (from the ionisation electrons to the readout data) is done with original code in ROOT which I first developed for studies of the LCTPC (TPC for the International Linear Collider) and adapted for the HARPO configuration. The description used gave good agreement with LCTPC data, and seems to perform correctly for HARPO.

2.5 Publications

The results from the MPGD characterisation experiments with radioactive sources and cosmic rays were presented in several international conferences:

- at TIPP2014 in Amsterdam by P. Gros. The proceedings will be published in Proceedings of Science in the end of 2014.

- at SPIE, Space Telescopes and Instrumentation 2014: Ultraviolet to Gamma Ray in Montréal by D. Bernard. The proceedings are published in SPIE.

- in a poster at NDIP2014 in Tours.

3 Relevance within P2IO

The HARPO project offers to use detector experience from particle physics and adapt it to bring new observational possibilities to the field of high energy astrophysics. It involves member coming from both communities for technical aspects on one hand and scientific application on the other.

The HARPO project relies on a collaboration between LLR and CEA-Saclay. The Micromegas technology originally used was heavily developed in CEA, and they provide a lot of expertise on its usage. On the other hand, GEMs were added in the detector, which I know well for working with them in my previous experience in Lund University (Sweden) and Saga University (Japan). CEA also provided readout electronics, which was integrated into the detector at LLR, bringing valuable experience.