ALERT: A Low Energy Recoil Detector

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Abstract

We present here a preliminary study of a tracker that could be used to reconstruct recoil nuclei fragments at CLAS. The main characteristics of this tracker are its ability to reconstruct protons with a minimum momentum of about 70 MeV/c and to identify all particles with a mass between the proton and the alpha. The detectors have also been selected in order to be included in the trigger to ensure a fast event selection. This paper focused on the state of our research on the project as well as on the expected performances obtained from simulations.

Keywords: Tracker, Drift chamber, stereo-angle, hadronic physics

1 Introduction

The ALERT tracker is intended to be used at Jefferson Laboratory (JLab) is located in Virginia (USA). It is an electron accelerator facility, with a beam of energy up to 12 GeV now accessible after the recent three years long upgrade. The beam will be distributed to four halls and in particular in Hall B where the CLAS12 experiment will start taking data at the end of 2016. With the predecessor of CLAS12, CLAS [1], a whole new physics program has emerged based on the use of detectors dedicated to low energy nuclear recoils (kinetic energy of few MeV). The recoils are produced during high energy reactions such as deep inelastic scattering (DIS) eA $\rightarrow$ eX or deep virtual Compton Scattering (DVCS) eA $\rightarrow$ eA. In particular, radial time projection chambers (rTPC) were successfully used in CLAS to measure the structure function of the free neutron by tagging slow protons out of deuterium targets [2] and to measure coherent DVCS off helium nuclei [3]. An international group of scientists from the CLAS collaboration has formed around the project of creating a new nuclear recoil detector for the upgraded CLAS12. We seek to develop a new detector offering better timing and spatial resolution as well as better particle identification than the previous rTPCs [4].

2 Detector setup

The construction of a low energy recoil detector for CLAS12 is challenging in many aspects. Indeed such detector will have to run in a high rate region (several MHz of protons in particular) in a very strong magnetic field (5T) due to the magnetic shield of the CLAS12 spectrometer. At the same time it needs to provide fast and precise response (< 2 μs) in order to be used by the trigger, in coincidence with the normal CLAS12 trigger. Finally, in order to detect the recoil before they are absorbed in any materials the chamber needs to be right around the target. We envision a 30 cm long detector with a radius of 10 cm surrounding a 30 cm long gaseous target at 3 bars, the layout can be seen figure 1.

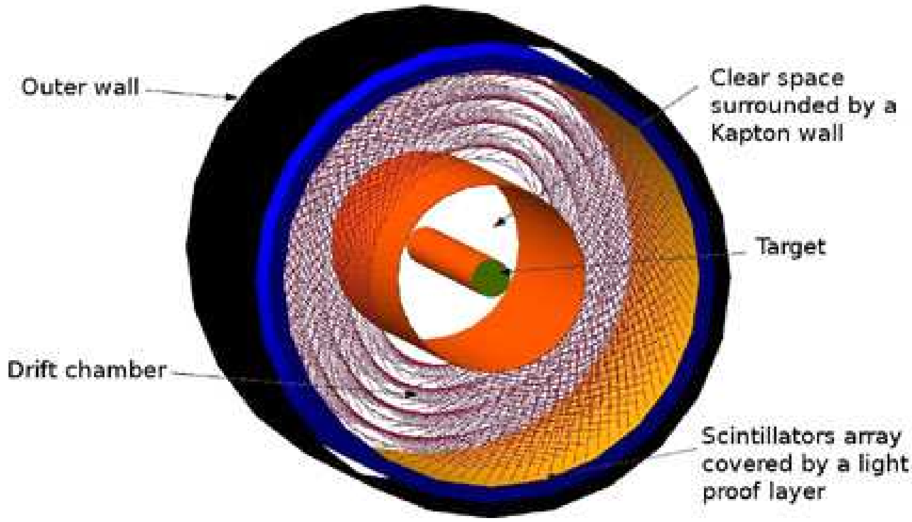

Figure 1: Schematic layout of the detector, viewed from the beam direction.

2.1 Drift chamber

The drift chamber is composed of 8 layers of sense wires. The later are each surrounded by field wires to create the electric field. The geometry of the basic cell, composed of one sense wire and a certain number of field wires, needs to be determined. The cell must ensure a good uniformity of the electric field around the sense wire but the total number of wires should be as low as possible to reduce multiple scattering, the total tension on the forward end plate and the number of particles stopped by the wires. The quantity of material in the detector can also be limited by using lighter wires, such as aluminium wires or any other light conductive material.

As mentionned earlier, the thickness of the forward end plate is critical as the scattered electrons will go through it. In order to keep it thin, the wires will be readout only on one side of the chamber. The position along the beam axis is thus determined by the stero-angle given to the wires. This angle will probably be between 10° and 15°. Its value will be tuned by simulations.

The last key parameter of the drift chamber is the space between the wires. Indeed, it influences the speed and the precision of the detector.

To optimize the parameters, tests on a prototype will be carried out. It will be an 8 layer drift chamber. Each layer will have either a different cell geometry or different spacing between wires (from 1.5 mm to 3 mm). We will also test different gas mixtures to study its influence on the efficiency and the speed of the detector.

2.2 Scintillators

The scintillators are used to measure the time of flight for particle identification. The main aspects considered to determine their size and material are the following ones:

- Simulations have shown that a resolution of 200 ps or less may be necessary to perform separation at an acceptable level (see next section)

- They should have a granularity that will allow a matching with the drift chamber without ambiguity
- Precise light detection in a 5 T magnetic field when coupled to a silicon based photo-detectors
- Number of channels and cost

The preliminary design for the scintillators is based on a multi-layer array of which the granularity still remains to be determined. The layer closest to the beam would be thinner to detect alpha and low momentum particles and give a good time resolution. The second layer would stop the particles to determine their energy. The use of several thin layers of scintillators will also help to differentiate the different nuclear species which are penetrating the scintillators differently. In particular time of flight has difficulties differentiating nuclei that have same mass/charge ratio.

2.3 Electronics

The main requirements for the electronics is to have a 10 ns time resolution or better while keeping an energy resolution that allows particle identification through energy deposition in the detector. In this project, we will perform tests on electronics initially developed for other detectors and eventually propose modifications. First, we will investigate the possibility to use stand-alone preamplifiers. Based on the gain in the drift chamber and the number of primary ionizations, it should be possible to use a design similar to the one developed for the Heavy Photon Search [5] experiment installed in the Hall B. The main challenge is to adapt the board and elements to the higher voltages (up to 2 kV for the drift chamber). The time resolution has already been shown to be around 2 ns [5], so well below our 10 ns requirement. However, more studies will be needed to evaluate how the gains of the chamber and the preamplifier can be tuned to ensure a signal over noise ratio that allows to discriminate electrons from protons and light nuclei between each other (p, 2H, 3H, 3He and 4He). Second, we will study the possible use of DREAM electronics [6] which was developed for the Micromegas detectors of CLAS12. A charge simulator of drift chamber wire signal will be built and used with existing electronics in order to optimize its parameters for our application: sampling frequency, peaking time and gain. Like the previous solution, it has the advantage to be already compatible with the CLAS12 data acquisition system.

3 Expected performances

3.1 Implementation

A simulation of ALERT has been developed using Geant4 [7]. In order to include multiple scattering and energy loss effects, all the different layers and elements, in particular the wires, have been included. A Kalman filter is under development but for now the fitting algorithm is using a global helix fit. The point coordinates sent to the fit are given by using the particle path returned by Geant4 and smearing its position each time it crosses a signal wire layer by the resolutions expected. The resolutions are given by the product of the time resolution (10 ns) by the drift speed ($\approx 2 \cdot 10^4$ m$\cdot$s^{-1}) expected in the ^{4}He (90%)- iC_4H_{10} mixture in a plan perpendicular to the wire. The resolution along the wire also takes into account the stereo-angle.

3.2 Acceptance and resolutions

Figures 2 and 3 show from top left to bottom right, the angular resolutions, the z resolution, where z is the coordinate along the beam axis, and the transverse momentum resolution at the vertex for protons and for alphas. To understand the acceptance, it is important to notice that a particle is considered detected when it reaches the scintillators.

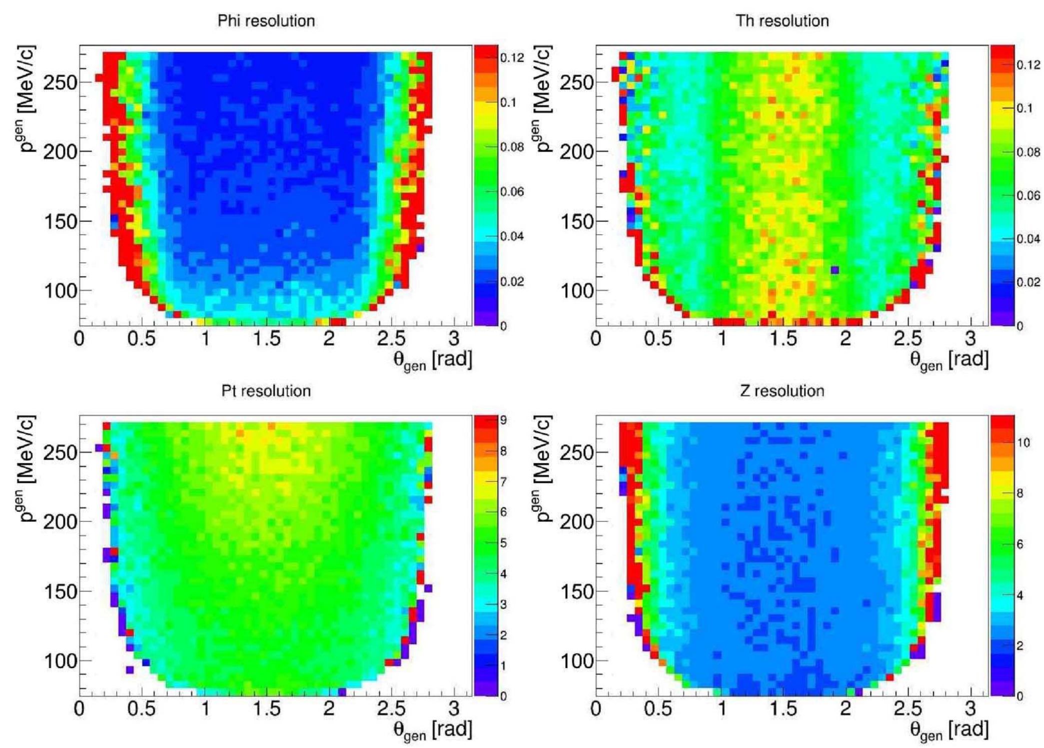

Figure 2: Expected time of arrival as a function of the radius of the trajectory for protons.

As expected the acceptance is larger near $\pi/2$ as the particle goes through less material when emitted at this angle. Also the resolutions for alphas are generally better than for protons due to the fact that the curvature is larger making the fit easier. A fast Monte Carlo using the acceptances and energy resolutions has been made available for collaborators. Conclusions concerning the match between our design and their needs will then be made.

3.3 Particle identification

One of the key point of this detector is its ability to differenciate different species. The differentiation relies upon the time of arrival in the scintillators, the initial time being given by another particle reconstructed by the rest of CLAS12, and the reconstructed radius in the drift chamber (fig. 4).

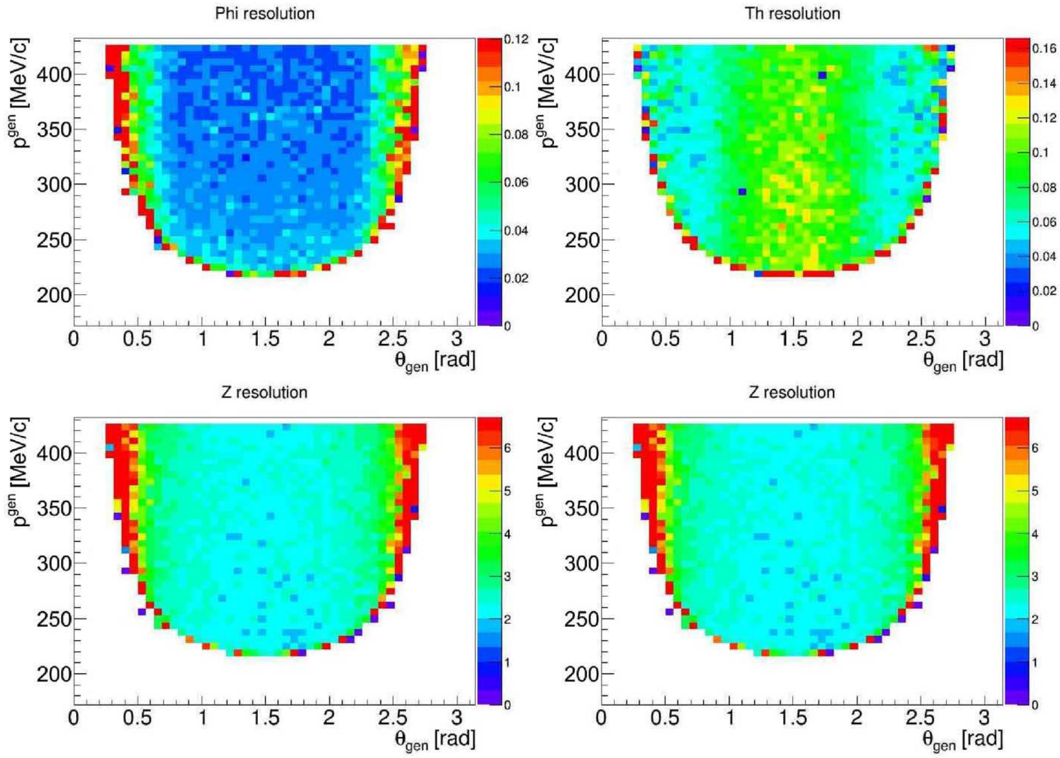

Figure 3: Expected time of arrival as a function of the radius of the trajectory for alpha particles.

As one can see, this method allows to separate clearly almost all kind of species we are interested in. To discriminate ^{2}H from α a more traditional method based on the energy deposited in the drift chamber and/or the scintillators will be used.

4 Conclusions

The preliminary design shows that the speed, precision as well as separation power of a drift chamber coupled with an array of scintillators fullfills the needs of the second generation of experiments measuring recoil nuclei fragments. Two prototypes will be build in the next years. These prototypes will permit to finalize the design of the detector. In the mean time, collaborators will use the available fast Monte Carlo to check if it meets their needs. Finally, depending on the results of the two previous steps, the ALERT collaboration will submit a proposal to conduct experiment at CLAS12 using the detector described here.

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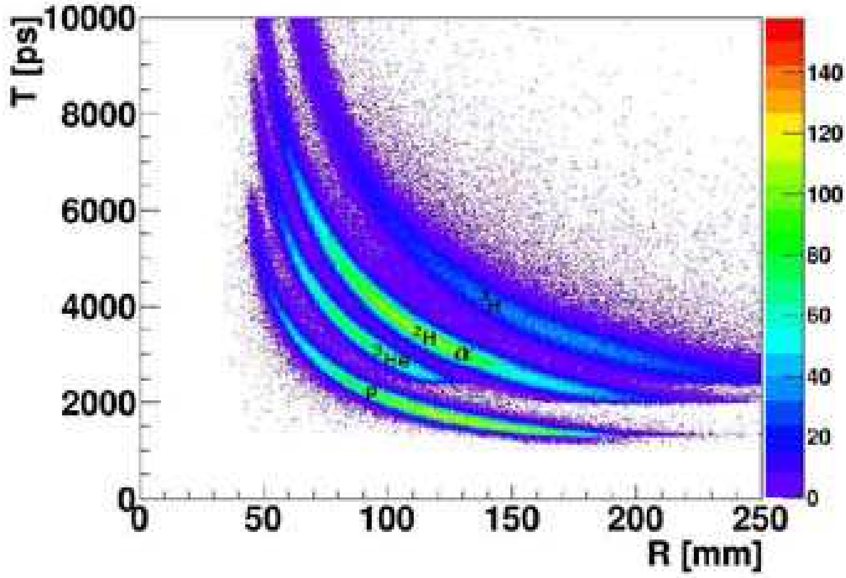

Figure 4: Expected time of arrival as a function of the radius of the trajectory for different particles.

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