Introduction

The basic functionality of TACTIC is described in previous annual reports. In short, TACTIC is a Time Projection Chamber for ion tracking. The cylindrical design makes it possible to separate the target from the detection region and hence apply higher beam currents. Since TACTIC also covers a large solid angle, very low cross sections can be measured. The cylindrical design is only feasible using a gas electron multiplier (GEM) foil which has now been thoroughly tested in a planar mock chamber.

Garfield (Paul Mumby-Croft)

Garfield is a simulation package which allows us to simulate the drifting of electrons through TACTIC in 2 and 3 dimensions. Garfield also calculates key drift parameters of the detector gas, such as the electron drift velocity; longitudinal and lateral diffusion; Townsend coefficients and attachment coefficients. This allows us to calculate drift times, position resolution and ultimately simulate the signals we can expect to measure with TACTIC.

Electron drift lines from solids

Thus far Garfield has been used as an aid to design the concentric cathode cage for TACTIC. The cathode cage is designed to trap ionisation electrons created by the beam as it is attenuated in the chamber. The separation, thickness and potential of the wires has been adjusted to trap the maximum number of electrons (see Fig. 1). Almost all electrons created inside the radius of the inner cathode drift onto that electrode. Only electrons created between the two sets of wires manage to escape into the drift region at \( r > 1.2 \text{ cm} \).

Electron diffusion in the detection and induction regions of TACTIC is an important factor in both energy and position resolution. Garfield has been used to estimate the diffusion in both regions. Diffusion increases with the square root of distance travelled by the electrons, so the diffusion in the drift region dominates over the contribution from the induction region. Garfield calculations show that the longitudinal electron diffusion corresponds to a difference in drift velocities of about 2\% of the total drift time. The lateral diffusion over the drift region corresponds to about 1 mm. These values can be calculated from the diffusion coefficients in Fig. 2.

Geant4 (Götz Ruprecht)

Two main problems make Geant4 difficult to use for ion physics. Firstly, there exists no process for single Coulomb scattering \(^1\), and secondly, there are unacceptable deviations of the stopping powers and ranges of ions as compared to the values given by SRIM 2003. The first problem was solved by implementing our own Coulomb scattering process that has been described in

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\(^1\)Geant version 4.8.2 which was released in Feb. 2007 has now a process called G4CoulombScattering. We still have to check whether it matches our needs.
the Annual Report 2005. The second problem and its solution is described in the following.

Geant offers several models for low-energy stopping powers. They are all based on tables of coefficients for protons in different materials but with slightly different formulas and coefficients; stopping powers for heavier ions are scaled from the proton stopping powers using the effective charge model. As it turned out, even the latest models are quite out-of-date. Although there are small deviations between them, they all are based on Ziegler’s SRIM/TRIM coefficients from 1985 that in turn are based on an evaluation of all experimental data. However, SRIM 2003 which is generally accepted as the reference for stopping powers is based on a complete new evaluation of experimental data and there are some considerable changes in them. Unfortunately, undocumented slight changes have been made in the fit formulas and the new coefficients cannot be used to just replace the old ones in Geant4.

To overcome this dilemma, we extracted the stopping-power curves from SRIM 2003 and fitted an extended formula to these data. As a result, the new modified energy loss process exactly matches the SRIM 2003 data. An evaluation of this energy loss process also in combination with elastic scattering for all ions in all materials is still ongoing.

Test chamber measurements (Götz Ruprecht)

![Drift time vs. strip number for some selected events.](image)

![Charge vs Slope (run 00305)](image)

Fig. 3. Drift time vs. strip number for some selected events. The 3.1-MeV α source is placed in the middle of a planar drift chamber above strip nr. 3. Since the drift time is assumed to be proportional to the distance to the GEM we obtain a projected picture of the ion trajectory. There is no trigger for the emission of the α’s, so the trajectories have been normalized to t = 0 at strip nr. 3. The size of the blobs represents the height of the signal, assumed to be proportional to the energy loss per strip.

Prototypes of the flash ADC VME modules “VF48” developed at the University of Montreal have been finally delivered and we can present here some first results of particle tracking in the planar mock chamber. We employed a TRIUMF-made 32-channel amplifier board provided by Leonid Kurchaninov as used for the LiXe project for the amplification of the GEM signals.

![Signals from the event highlighted in the previous figure.](image)

![Integrated charge (arb. units) vs. slope. The slope is the mean time difference (in ns) per strip of an ion track. Positive slope means that the ion moves towards the cathode.](image)

Fig. 5. Integrated charge (arb. units) vs. slope. The slope is the mean time difference (in ns) per strip of an ion track. Positive slope means that the ion moves towards the cathode.

The largest problem is the selection of “good” events. The range of the 3.1-MeV α particles from the source in this gas mixture is about 5 cm but the height of the drift frame is only 2 cm. Therefore many ions hit the wall and produce incomplete signals. This can be clearly seen from Fig. 5 where the total energy is drawn...
versus the slope of the trajectory. If the ions hit the wall no further drift electrons are produced and the collected charge is incomplete, leading to a wide energy spread (the source is not quite centered, hence the asymmetry). Therefore, only a small region around slope = 0 can be used for an energy measurement. The gas is also slightly contaminated so that some drift electrons are absorbed when moving towards the GEM, further reducing the resolution. For the next series of tests we will have an improved test chamber with a better sealing, a larger volume and a higher number of sensitive strips.

Construction (Simon P. Fox)

The initial concept drawings for the TACTIC detector were made at TRIUMF. These drawings formed the basis for the technical designs provided by the Design Workshop at the CCLRC Daresbury Laboratory, U.K. Over several meetings between the University of York and the Daresbury Design Group, the designs were finalised. In May 2006 Pierre Amaudruz who had drawn up the initial concept of TACTIC met with the York and Daresbury groups to confirm the finalised design and the Daresbury group provided the University of York with a set of working technical drawings.

In Summer 2006 construction of the TACTIC chamber commenced in the Mechanical and Electronic Workshops at the Department of Physics, University of York, UK. Figure 6 shows the interior of the detector support structure together with the end flanges. The beam pipe which will conjoin with the support structure being built at TRIUMF is clearly visible. The construction of the support structure for the GEM and anode (the white plastic cylindrical assembly visible in Figures 6 and 7) was particularly challenging but has now been completed.

Schedule

A beam request (Experiment E964, Beam Request ID 581) has been submitted for $^{11}\text{B}$ beam for early summer 2007 and if there is sufficient time for $^{10}\text{B}$ and $^7\text{Li}$ also. Elastically scattered $^{11}\text{B}$ will provide a full test of TACTIC in preparation for the running of Experiment E964 ($^8\text{Li}(\alpha,n)^{11}\text{B}$) by actually detecting the recoil ion at similar energies to that expected in the final experiment.

The full schedule of tests to be undergone in the stable beam run is to be finalised but will include:
1. confirmation of the optimum gas mixture to be used (previously studied using a planar test chamber at TRIUMF - see Annual Report 2005, E964)

2. test of the capabilities of the VF48 DAQ system (data will also be collected with a conventional DAQ for offline comparison).

3. study of the particle identification capabilities of the detector by studying the differences between the signals detected from scattered $^{11}\text{B}$, $^{10}\text{B}$ and $^7\text{Li}$.

It is expected that the analysis of these test data will confirm the readiness of TACTIC for taking $^8\text{Li}$ beam for E964 in late 2007.

References


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