Experiment E964 – TACTIC
TRIUMF Annular Chamber for Tracking and Identification of Charged Particles

(G. Ruprecht for the TACTIC collaboration)*

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 feasable 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.

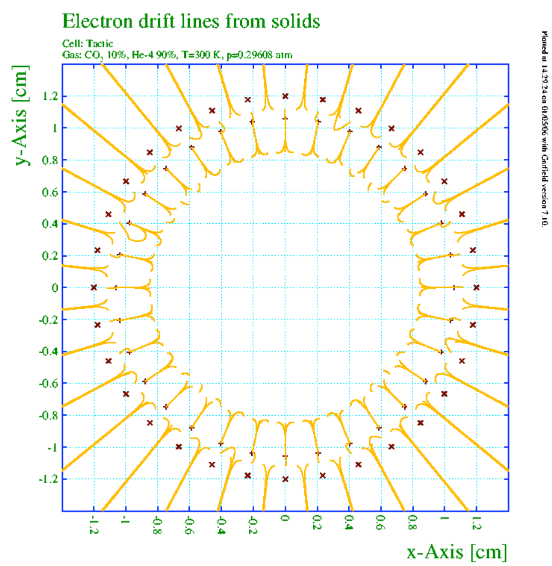

Fig. 1. A Garfield simulation of the TACTIC cathode. The black crosses represent the concentric arrangement of wires, there are 32 in each ring. The inner wires are held at a potential of -1800 V, the outer wires at -2000 V.

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 $r > 1.2$ 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 coefficents in Fig. 2.

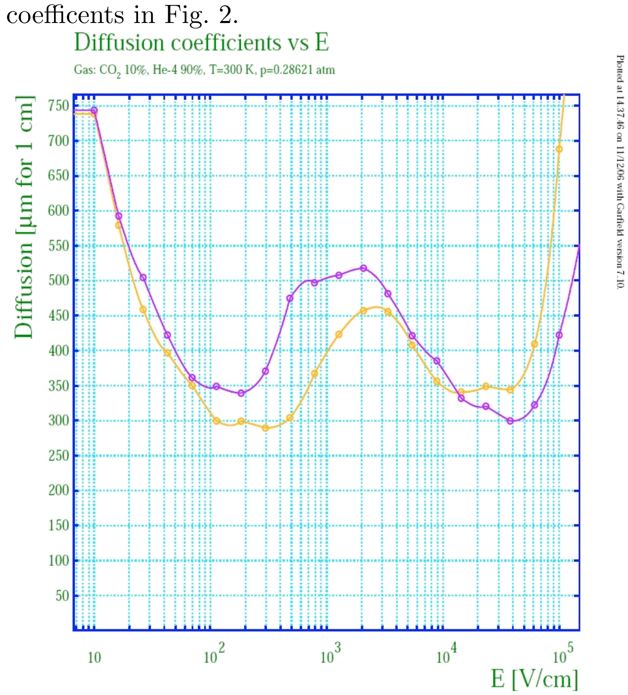

Fig. 2. Longitudinal (yellow) and lateral (purple) diffusion coefficients for a 90% He, 10% CO_2 gasmixture at 290 mb and 300K.

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 unacceptabe 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

[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 evaulation of all experimental data. However, SRIM 2003 which is generally accepted as the reference for stopping powers is based on a complete new evaulation of experimental data and there are a some considerable changes in them. Unfortunately, undocumented slight changes have been made in the fit formulas and the new coefficients can not 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 excactly 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)*

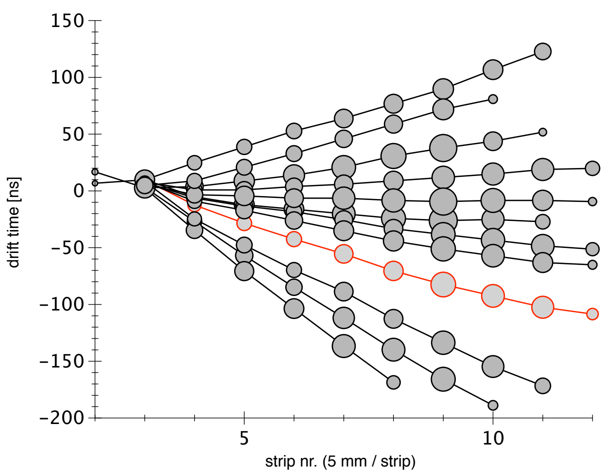

Fig. 3. Drift time vs. strip number for some selected events. The 3.1-MeV α source is placed in the middle of a planar drift chamber above strip nr. 3. Since the drift time is assumed to be proportional to the distance to the GEM we obtain a projected picture of the ion trajectory. There is no trigger 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" devoloped 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.

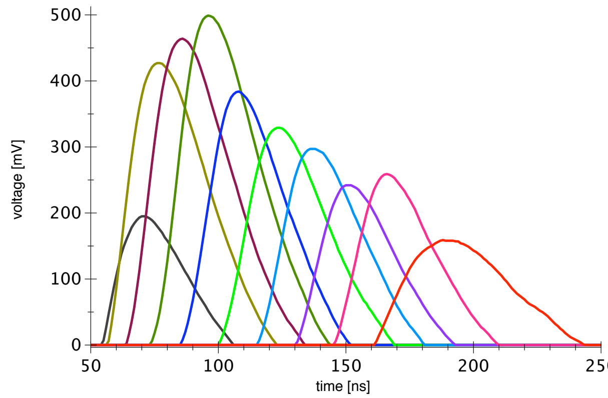

Fig. 4. Signals from the event highlighted in the previous figure. The Bragg peak can clearly be seen.

Fig. 3 shows some ion trajectories in the mock chamber filled with 90% He / 10% CO_2 gas mixture at atmospheric pressure. The trajectories can be visualized online with a new analyzer implemented in collboration with Jonty Pearson. The analyzer can remotely connect with the MIDAS DAQ system and visualize the events with a high frame rate. Additional (slowly changing) histograms are provided on a Roody port. The rate was limited by the still missing interrupt feature of the VF48 module. This will be provided with the next firmware update.

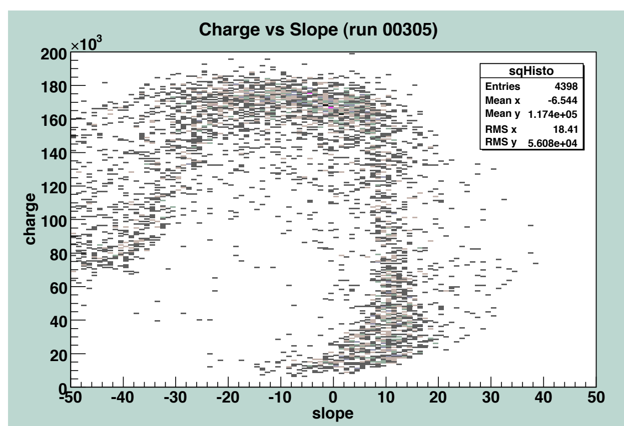

Fig. 5. Integrated charge (arb. units) vs. slope. The slope is the mean time difference (in ns) per strip of an ion track. Positive slope means that the ion moves towards the cathode.

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, forther 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 Labortory, 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.

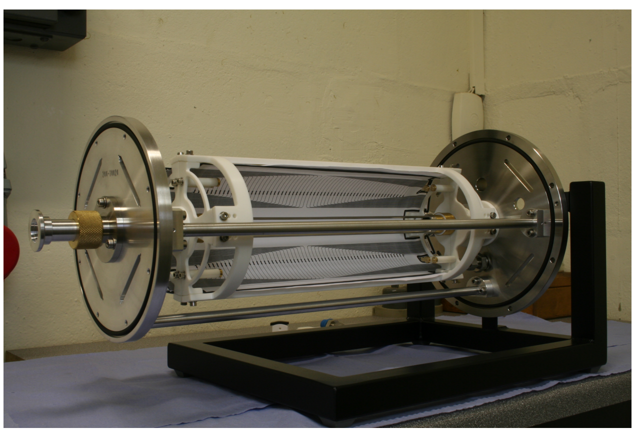

Fig. 6. The TACTIC prototype in York - total view.

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 detectors 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.

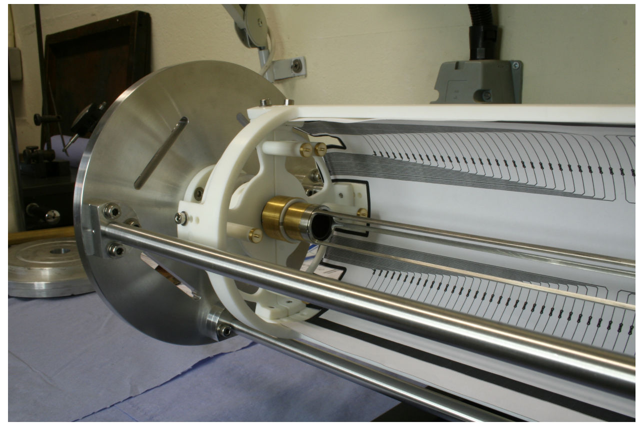

Fig. 7. The TACTIC prototype in York - beam inlet.

The design of the cathode was arrived at following GARFIELD simulations of possible arrangements of wires that might contain the ionisation in the gas caused by the beam passing through it. Final construction of this unique cathode structure is underway.

Other aspects of the construction are being undertaken at TRIUMF. A gas handling system capable of accurately regulating the pressure of the gas flowing through the detector is currently being built. The support structure which will mount the TACTIC detector onto the beamline at ISAC is also being designed and built by the TRIUMF group.

Test assembly of the TACTIC detector is about to commence at the University of York. Once this has established a working procedure for constuction of the detector the full detector (including the GEM) will be built in a clean room environment. Benchtop tests will establish the vacuum integrity of the detector and, using suitable radioactive sources, physical signals will be extracted from the detector. These tests will be undertaken with the participation of some members of the TACTIC collaboration from TRIUMF. It is envisaged all tests at York will be completed by the end of April 2007 and the detector will then be transported to TRIUMF in preparation for in-beam tests in Summer 2007

Schedule

A beam request (Experiment E964, Beam Request ID 581) has been submitted for ^{11}B beam for early summer 2007 and if there is sufficient time for ^{10}B and ^{7}Li also. Elastically scattered ^{11}B will provide a full test of TACTIC in preparation for the running of Experiment E964 (^{8}Li(α,n)^{11}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}B, ^{10}B and ^{7}Li.

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

References

1. *G. Ruprecht, P. Amaudruz, P. Mumby-Croft, L. Buchmann, S. Fox, B. Fulton, A. M. Laird, R. Openshaw, M. M. Pavan, J. Pearson and P. Walden*
"The TRIUMF Annular Chamber of Tracking and Identification of Charged Particles (TACTIC)", Proc. Sci. PoS(NIC-IX)170.

2. *G. Ruprecht, D. Gigliotti, P. Amaudruz, L. Buchmann, S. P. Fox, B. R. Fulton, T. Kirchner, A. M. Laird, P. D. Mumby-Croft, R. Openshaw, M. M. Pavan, J. Pearson, G. Sheffer and P. Walden*
"Status of the TRIUMF annular chamber for the tracking and identification of charged particles (TACTIC)", Europ. Phys. J. A **27**(2006)315c.

* P. Amaudruz[1], L. Buchmann[1], S. Fox[2], B. Fulton[2], D. Gigliotti[1], T. Kirchner[1], A. M. Laird[2], P. Mumby-Croft [1], R. Openshaw [1], M. Pavan[1], J. Pearson[1], G. Ruprecht[1], P. Walden[1] ([1] *TRIUMF*, [2] *University of York, U.K.*)