**Experiment E964 – TACTIC**
**TRIUMF Annular Chamber for Tracking and Identification of Charged Particles**
*(G. Ruprecht for the TACTIC collaboration*)*

TACTIC is a cylindrical time projection chamber for the detection of low-energy ejectiles from nuclear reactions. It allows the three-dimensional reconstruction of ion tracks by means of a two-dimensional anode array combined with a time-of-flight measurement of the drift electrons. Although it will be used as a facility for many experiments, its design parameters are mainly dictated to resolve the $^4$He($^8$Li,$^{11}$B)n reaction at astrophysical energies. For more details see the E964 writeup in the 2004 Annual Report, or visit the TACTIC website http://tactic.triumf.ca.

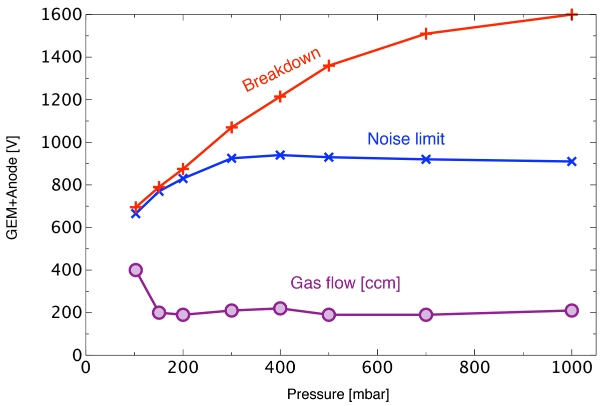


Fig. 1. GEM voltage operating range for different pressure ranges.

The cylindrical design is possible by utilizing gas electron multiplier (GEM) foils as a first stage of amplification. For information on GEMs see Sauli and Sharma [Ann. Rev. Nucl. Part. Sc. **49** (1999) 341] and Sharma and Pauli [Nucl. Inst. Meth. **A 350** (1994) 470]. The planar test chamber we used last year [E964 2004 Annual Report] has been improved to allow for sub-atmospheric pressures down to 100 mbar. With a 5486-keV $\alpha$ source and a 90% He / 10% $CO_2$ gas mixture the gain of the GEM has been determined. At 100 mbar the signals are still on an acceptable level, though the range of operating voltage between noise and break-down is much smaller (see Fig.1).

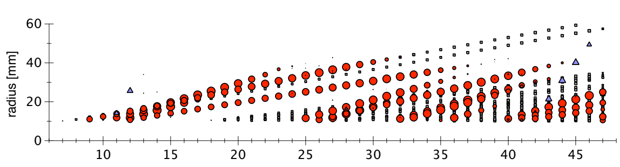


Fig. 2. Simulated ion tracks for the $^8$Li+$^4$He reaction as seen by the 48 anode pads which can detect only electrons from the drift region (r = 10-60 mm). Circles = $^{11}$B, squares = $^8$Li, triangles = $^4$He. The size of the symbols reflects the energy collected per anode strip.

A sizeable effort has gone into creating a GEANT4 simulation for TACTIC in which all ion relevant processes can be simulated. The largest effort went into writing a coulomb elastic scattering code to replace the GEANT4 built-in multiple scattering process (MSC). The MSC code assumes a light projectile moving in a dense medium where the nuclear scattering centres are heavy and fixed in position. Each step in the MSC process assumes a number of single scatterings and statistical methods are employed. Clearly this code will not work for the TACTIC environment where the projectile is a heavy ion with a mass comparable to the scattering centres which are nuclei in a tenuous gas. A single scattering process code was written based on a screened Thomas-Fermi potential model [Nucl. Instrum. Methods **130** (1975) 265] and, unlike the GEANT4 MSC process, can even produce recoils, so the full cascade of ions could be simulated. This code has the advantage that it can also be used to generate the correct large angle distribution of $^8$Li+$\alpha$ scattering events where the $^8$Li and $\alpha$ ions enter the drift region and become a background for the $^4$He($^8$Li,$^{11}$B)n events. The simulations show that most of the $^4$He recoils do not reach the drift region and that the number of $^8$Li ions will be tolerable. Figure 2 depicts the situation.

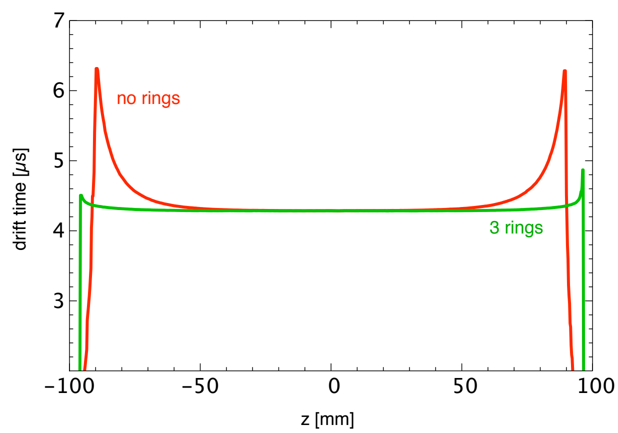


Fig. 3. Drift time of the electrons from the cathode (-500 V) to the anode (0 V) for a 90%Ar/10% $CO_2$ gas mixture at STP. Close to the end of the drift region (here at $z = \pm 100$ mm) the field is too inhomogenous so that only 50% of the drift region could be used. Three voltage supporting rings increase this region to 90%.

The drift field was modeled using FEMLAB. By numerical integration using the measurements of Peisert and Sauli [CERN 84-08, 1984, http://tactic.triumf.ca/cern] the total drift times for electrons released at the cathode at different z-postions were obtained. If nothing is done to fix the end cap fields, the cylindrical field becomes inhomogenous and the drift times of the electrons become a strong function of the logitudinal position in the chamber. FEMLAB showed that voltage supporting rings at both endcaps will correct this deficiency and make the drift times constant over most of the region (see Fig. 3). These results are discussed in a TACTIC resource document available on the web [Kirchner, http://tactic.triumf.ca/publications].

A precise numerical calculation of the motion of the electrons in the drift medium is in progress at the University of York, using the Garfield/Magboltz package from CERN. The results for the drift times and diffusion of the electrons will be included in the GEANT simulation.

The VF48 flash ADC board, a VME based flash ADC board being under development at the University of Montréal, has been designated as the main data quantizing device. Both pulse shape and timing of the anode signals will be digitized. Most of the development this year has gone into correcting a defective firmware problem. The designated MIDAS/ROOT-based data acquisition system, ROME [http://midas.triumf.ca], was found not to be fast enough to process the incoming data stream and inadequate for visual displays of ion tracks. A new ROME extension, ARGUS, is going to be tested. However, it will probably be necessary to write a special MIDAS/ROOT-based data aquisition system.

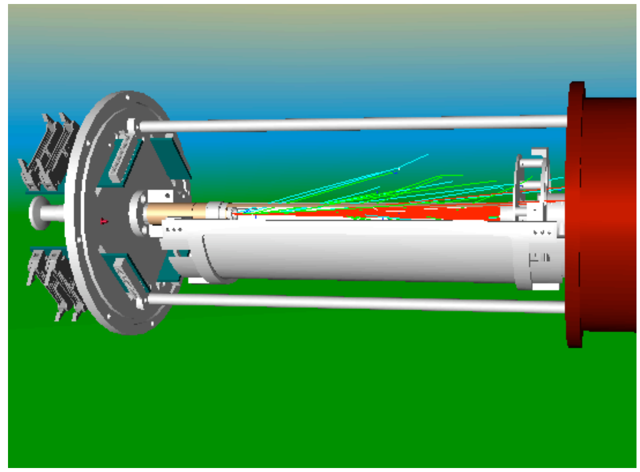

Fig. 4. Sketch of the entire TACTIC. The $^{8}$Li beam comes from the left and it expands as a solid envelope to the right due to scattering with the target gas in the target region. A few of the $^{8}$Li and $^{4}$He tracks make it into the drift region, however most of the tracks in the drift region are from $^{11}$B ions.

With the improved GEANT4 simulation and the detailed electric field calculation the final design could be fixed. The technical drawings are now being drawn up at Daresbury and the prototype chamber will be constructed at the University of York. The chamber is expected to be ready for first beam tests at the end of 2006. Fig. 4 shows a three-dimensional sketch of the final design combined with the ion trajectories as simulated with GEANT4. More details of the TACTIC chamber can be found in the European Journal of Physics online article (2006) [http://dx.doi.org/10.1140/epja/i2006-08-048-y].