TACTIC - Ion tracking in nuclear physics

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Abstract. Ion tracking is still an unusual detection method in nuclear physics. TACTIC (TRIUMF annular chamber for tracking and identification of charged particles) is suitable for tracking low-energy ejectiles. The cylindrical design allows for an electrical separation of target and drift region without hindering the ejectiles to enter the drift region. The first experiment with radioactive beam – the reaction \(^{8}\text{Li}(\alpha,n)^{11}\text{B}\) which is important for the \(\alpha\)-process in neutrino-driven supernova winds – took place in June '09. Since no off-the-shelf analysis tools and methods are available for this kind of tracking, TRIUMF’s TACTIC group developed graphical tool for analysing data that can also be used for other modern nuclear physics detectors.

1. Introduction

Time projection chambers (TPC) are well known and widely used tools in particle physics [1, 2], but not very common in nuclear physics [3, 4]. TACTIC is an active target TPC [5, 6], designed for charged particle reactions preferably on helium like \(^{8}\text{Li}(\alpha,n)^{11}\text{B}\), an astrophysically interesting reaction [8].

TACTIC is a cylindrical chamber with a blind centre region (details of the geometry in [5]), so only particles from reactions or scattered beam particles are detected, increasing the signal to background ratio, but sacrificing part of the ion tracks. Because all planned experiments are symmetric around the beam axis, TACTIC was built with a poor resolution in \(\phi\) (8 anode sectors) in favour of better resolution in \(z\) (60 anode pads per sector). The \(r\)-coordinate can be derived from electron drift times.

2. Data acquisition

The signals from the 480 anode pads are preamplified and then digitized in 1 flash-ADC-modules (type VF48 [7]). These sample the signals with a frequency of 40 MHz and provide triggers, maximum position, pulse height and –optionally– full signals for all channels, eliminating the need for a separate timing- and energy-branch. The modules are read out by a VME computer which transmits the data via private ethernet to a PC running a MIDAS-server [9] (see figure [1]). Analyzers can run on this PC or any other computer on the network, usually most analyzing is done remotely on a computer running MacOS X ("iTactic" in the figure). Multiple analyzers can connect at the same time.
3. The FlowAnalyzer

A new analysis software is being developed to process the TACTIC data [10]. It is comprised of a manager and a multitude of plugins or modules. This clean object-oriented concept allows to connect and disconnect plugins in runtime, thereby making recompilation unnecessary for changes in the analysis. This makes a simple graphical user interface possible, organizing data flow visually and intuitively (see figure 2). It also facilitates the collaboration of several developers. Additionally exchanging the input plugin allows to send real (online and offline) and simulated data through exactly the same analyzer, facilitating checks and debugging.

![FlowAnalyzer Diagram]

Figure 1. DAQ-setup: Everything before the analyzer is modular.

![FlowComposer Diagram]

Figure 2. FlowComposer: In this program, an analyzer can be assembled from existing modules at runtime even without programming skills.

All modules can be loaded dynamically into the running application. Each module is free to use a custom system for visualization like histogramming or tracking. However, 2 quasi-standardized interfaces are supported, AIDA [11] for histogramming, and OpenInventor for 3D visualization (see figure 3). The concrete implementations are not fixed and can be dynamically changed. OpenScientist [12] provides both interfaces and has therefore been chosen as the default option. Another AIDA implementation for CERN’s ”ROOT” is in
Figure 3. A FlowAnalyzer consists of one manager controlling several plugins. These can interface to the outside world by text output or interfaces like AIDA and OpenInventor.

preparation.

Therefore, the central program, here "FlowComposer" for Mac OS X, is just a hub for loading all the plugins for the analyzer and for the histogramming/3D visualization and can easily be implemented on other systems. We also have a version for Linux using the Qt GUI system.

4. Radioactive beam in TACTIC
The first radioactive beam run with TACTIC took place in June 2009 at TRIUMF. It was also the first run using a BGO array from DRAGON (10 of DRAGON’s 30 BGOs)\textsuperscript{13} in connection with TACTIC.

There were two main concerns about the $^{8}$Li beam prior to this run: the 2$\alpha$-decay inside TACTIC and the background bremsstrahlung from decay betas in the BGO array.

2$\alpha$-decay: We do see tracks from the double-$\alpha$ decay of $^{8}$Be in TACTIC, but we can easily distinguish them from other tracks (see figure\textsuperscript{1}) by which sectors are involved and by the difference in specific energy loss and they are not so numerous as to drown our DAQ. Further analysis might even allow us to reconstruct a complete decay event (i.e. the track of a scattered $^{8}$Li up to the stopping point (or point of in-flight decay), decay gammas and the track of both alphas.) Although not being the point of the experiment this would be a good test of the system.

bremsstrahlung: The high energy betas from the decay of $^{8}$Li to $^{8}$Be can produce bremsstrahlung up into the energy range of the reaction gammas. Of course the actual spectrum depends on the stopping material, which makes this problem very difficult to estimate. As a precaution the beam dump was shielded with lead bricks. A quick preanalysis shows a clear coincidence between tracks in TACTIC and BGO events, indicating a ratio of real to accidental coincidences of the order of $10^{3}$. Since TACTIC is self-triggering, the time between a trigger and the actual physical event depends on the electron drift time, i.e. the $r$-coordinate of the ionization event. It is therefore very difficult to set up a hardware coincidence, so coincidences have to be determined in analysis.
Figure 4. Tracks inside TACTIC: color: 2-α-decay of $^8$Be (some channels in the orange sector didn’t work in this run), grayscale: scattered $^8$Li

A different problem turned up, however. The energy resolution per point seems to be non-linear and sector dependent. We are currently examining if this is a problem with the GEMs. Unfortunately there is very little literature on the characteristics of GEMs in conditions as ours (He/CO$_2$ gas and highly ionizing radiation).

5. Conclusions
There are no major problems with running TACTIC with a $^8$Li beam and the coincidence setup with the BGO array works. The next beamtime can focus on the more interesting lower beam energies. Improvement is needed to check and handle the non-linearity of the GEM gain which probably requires a laser calibration system and a detailed simulation of the electron cascade through the GEM, including charge recombination.

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