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A Specialized System to Measure the Performance of TOF Detectors and its Application to a New, Compact Magnetic TOF Detector

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Overview

ETP's *standard* detector test system has been modified to provide more detailed performance characteristics of TOF detectors. Essentially this was accomplished by incorporating a very small linear TOF system as a part of ETP's *standard* detector test system. It will be most straightforward to first look at the structure of the standard system and then look at the details of the incorporated linear TOF system.

The newly configured system has been used to measure the maximum linear pulse capability of a new compact magnetic TOF detector and has shown its output pulse to be linear with levels up to ~400 mV (into 50Ω) . Other characteristics of the new detector are also detailed.

Test system details

The *standard* test system utilizes a conventional electron impact ion source to generate ions, usually from air injected via a capillary tube. (See figure 1) These ions are then directed through a lens (focusing optics) so that they are focused to a small "spot" of ions ~2 mm in diameter in the region of the detector (right hand side of figure 1.) After leaving the focusing optics the ions pass through a set of X-Y deflection plates so they can be accurately steered to any desired position. In figure 1 the ion beam is shown to be directed at a detector and also at a faraday cup. This demonstrates the basic method used to measure gain of all its detectors. Alternately directing the ion beam from detector to faraday cup enables a direct measure of absolute gain as the detector output current divided by the ion input current (as measured by the faraday cup).

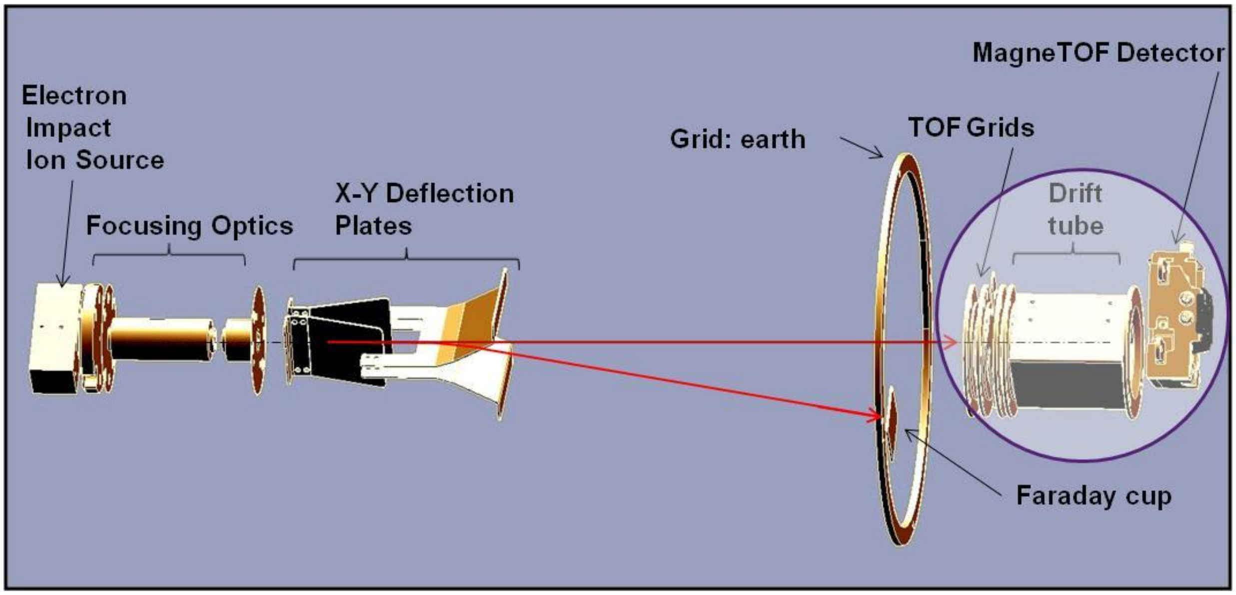

Figure 1. Ion optics of the ETP detector test system. The new components added for the work described in this paper are highlighted in the circle on the right side of the diagram.

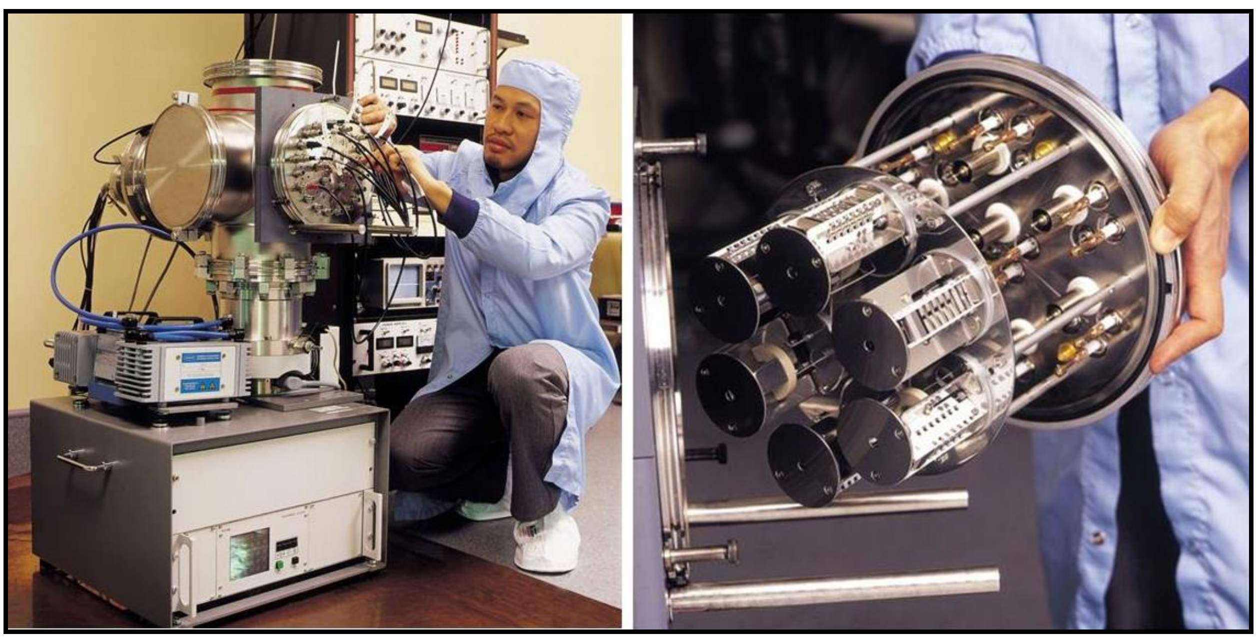

Figure 2. Photo of the ETP detector test system. The ion source is at the back of the system (as shown) and detectors are mounted on the flange being wired in the left hand photo. The associated electronics can be seen in the background. These electronics are controlled by a computer utilizing Labview software. The right hand photo shows the other side of this flange where six detectors have been mounted for testing. A steerable ion beam enables the testing of up to 10 detectors in one pump-down. ETP currently operates three nearly identical test systems which all have interchangeable components.

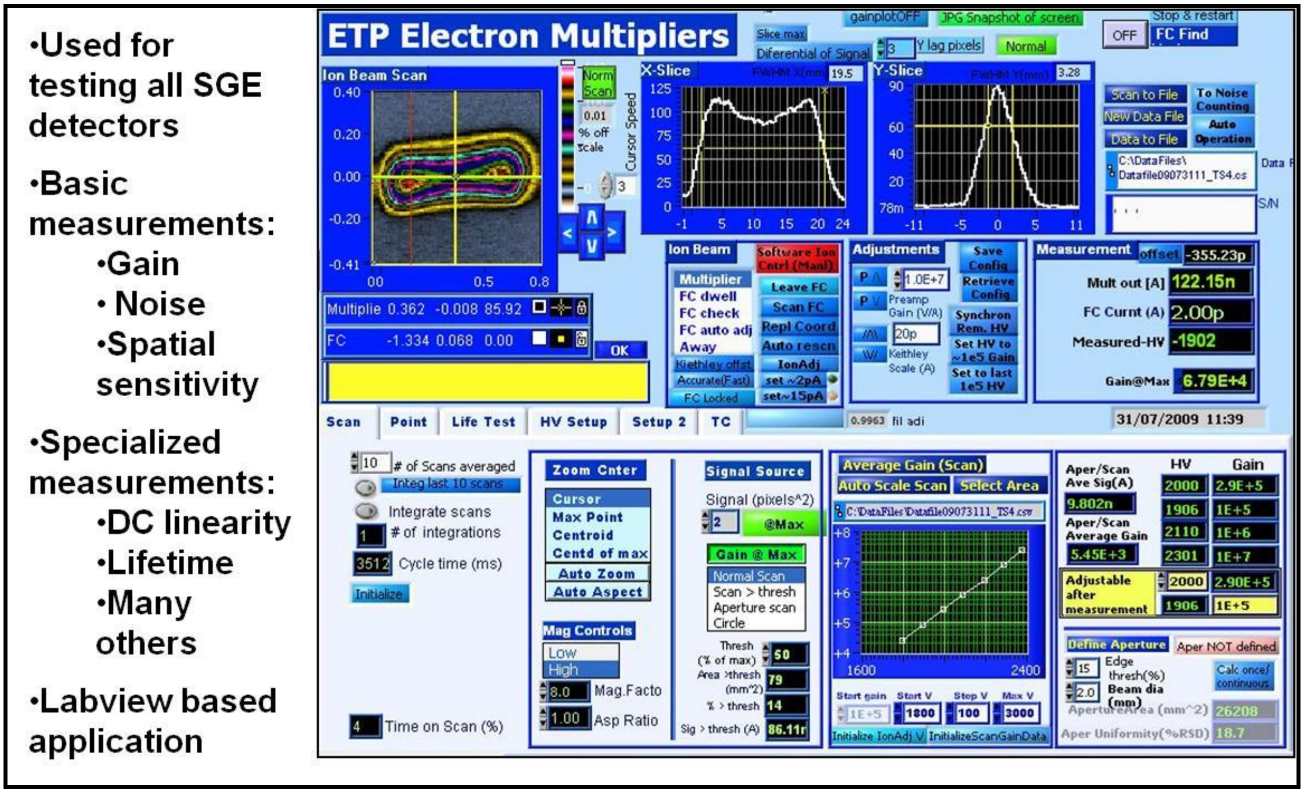

Figure 3. This is a screen print from computer used to control the detector test system. The upper left display is a contour map of the detector's spatial sensitivity, developed by X-Y raster scanning the 2mm ion beam across the detector's input aperture. The adjacent graphs are slices taken through this contour map. Another obvious feature is the gain vs. voltage curve in the lower right portion of the screen.

The ETP detector test system is very flexible and is used for both production and R&D testing. Production tests generally measure spatial sensitivity, gain and noise along with specialized tests for some detectors such as pulse shape and width for TOF detectors. As well as the standard tests R&D utilize a large number of specialized tests such as linearity and lifetime measurements. This system has been in use for >10 years and during that time a new function has been added to the system approximately once every second month.

Linear TOF arrangement

To enable more realistic test conditions for TOF detectors in this test system a simple linear TOF section was added just in front of the detector (in highlighted circle in right side of figure 1). The details of this TOF system are shown in figures 4 and 5. To get a feel for how it fits into the overall picture the grid G1 in figure 4 corresponds to the grid on the right side of figure 1 labeled “Grid: earth”.

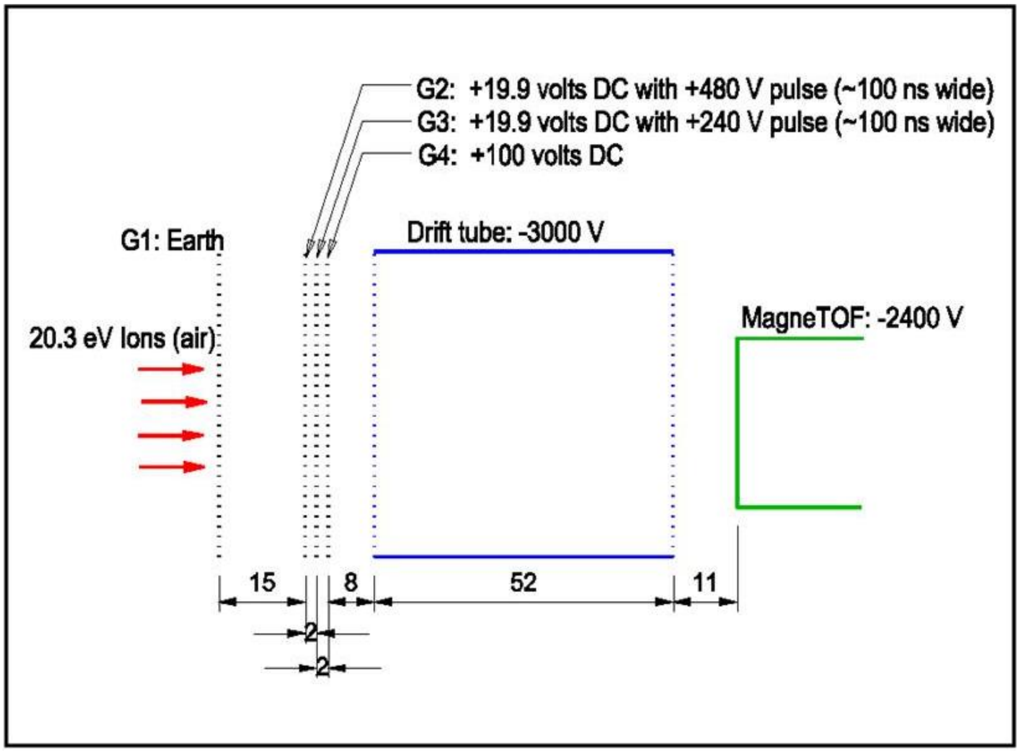

Figure 4 Linear TOF mechanical arrangement.

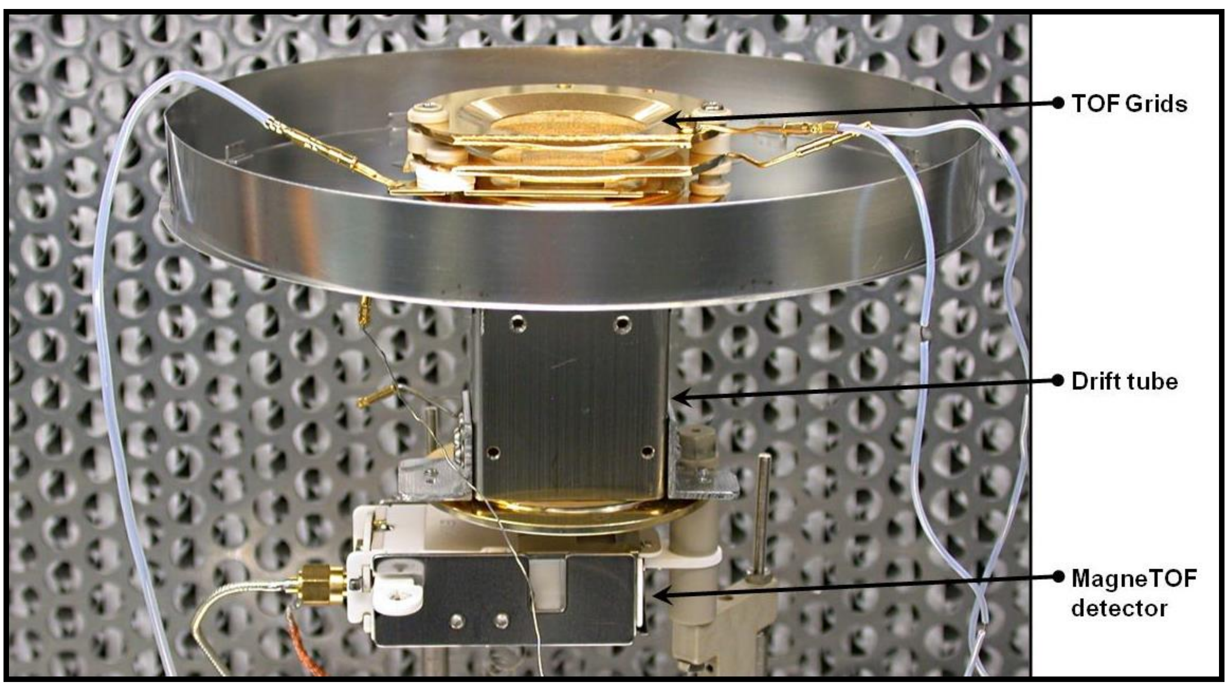

Figure 5 Photo of linear TOF portion of test system. The pan shaped arrangement near the top is a shield to minimize stray ions.

Axial ion injection leads to a significant compromise in resolution due to the unavoidable initial axial velocity of ions in this arrangement. However, this compromise enables collection of spatial information along with TOF information which provides a powerful tool for developing TOF detectors. To minimize

this compromise ions are decelerated to ~0.4 eV as they approach G2 and maintain this energy in the field free region between G2 and G3. Most ions will reside between G2 and G3 until arrival of the pusher pulse. A +480 volt pusher pulse applied to G2 then drives the ions through the drift tube to the detector.

The arrangement was designed to satisfy 2nd order space focusing criteria and achieves a resolution of a bit less than 100. Because of the very short (52 mm) drift tube typical pulse widths are ~3 ns wide which corresponds well with typical high resolution TOF mass spec peaks. Figure 6 shows a typical air spectrum generated with this system.

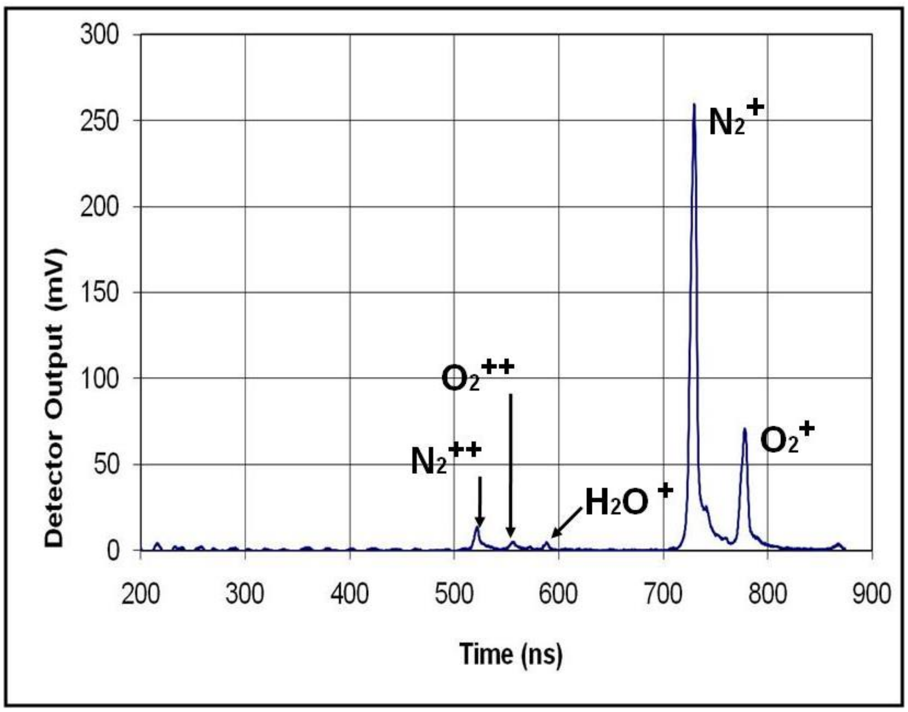

Figure 6. Spectrum of air from linear TOF system. Data collected with Agilent Acqiris U1084A 4 Gs/s Digitizer/Averager

Pulse linearity measurements

Measuring the abundance ratio of the singly to doubly charged N_2 ions while increasing the ion flux provides a convenient method of measuring the maximum linear pulse capability for a TOF detector. As the signal level of the singly charged N_2 peak is increased it will eventually distort. Because the doubly charged N_2 peak occurs at ~20X lower intensity, it will remain unaffected and provide a reliable monitor of the relative ion input flux. Thus the change in the ratio of these abundances will be an accurate measure of the linear limit for high level pulses.

Dynamic range or *pulse dynamic range* is the common term used to describe a detector's linearity. This refers to the ratio of largest linear pulse to smallest measurable pulse in a single shot spectrum. Because the level of the smallest measurable pulse is determined by the details of a specific TOF system, the most meaningful measurement for a detector will be the level of the maximum linear pulse delivered by the detector. For convenience this is generally expressed as millivolts (mV) into a 50Ω load (the usual preamp or digitizer impedance).

Figure 7 shows the results from this linearity measurement when performed on detector model DM430: a new compact magnetic TOF detector. From the data it is clear that the detector operates very linearly with output pulses up to ~400 mV (into 50Ω) after which it over-responds. This is a typical characteristic of ion detectors and indicates that the voltage distribution along the dynode surface is distorted during high level pulses.

The singly charged O_2 linearity data is also plotted. Because the singly charged O_2 peak occurs ~50 ns after the singly charged N_2 peak it provides a good indication of the detector's performance almost immediately after experiencing a large peak. The data shows no apparent O_2 distortion until the N_2 peak becomes non-linear.

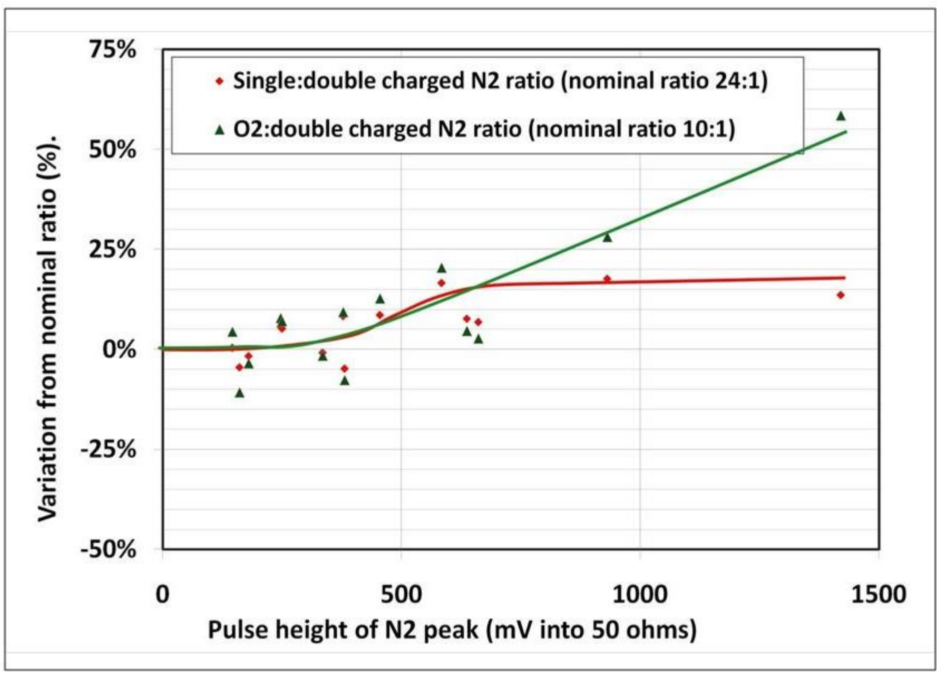

Figure 7. Abundance Ratio vs. Pulse Height: A measure of Pulse Linearity for the new DM430 compact magnetic TOF detector.

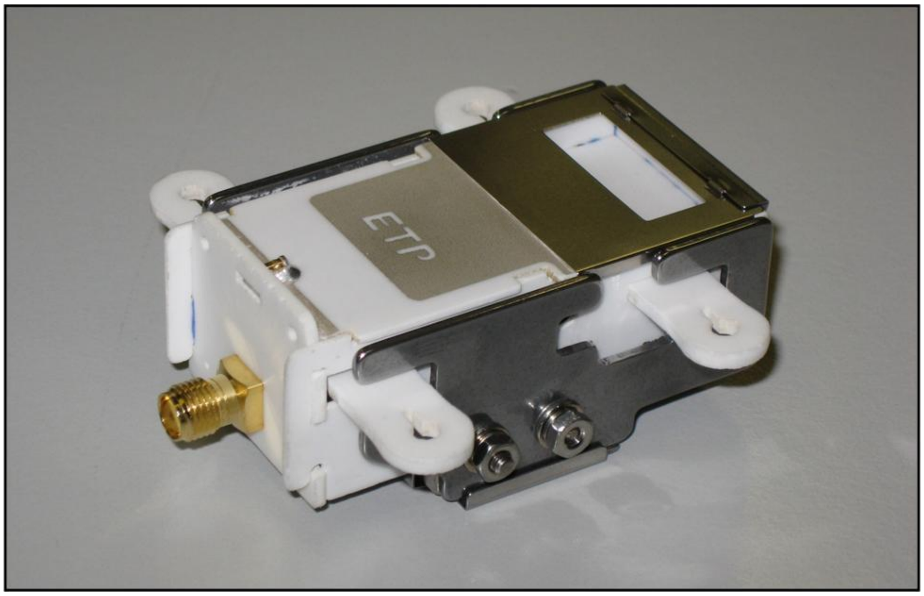

Figure 8. Photo of the new DM430 compact magnetic TOF detector. The SMA signal connector gives an indication of size.

The new DM430 compact magnetic TOF detector

The DM430 is a magnetic TOF detector which has all the superior features of the very successful MagneTOF detector but in a much smaller size. Because of the smaller size the pulse width and jitter are increased in the DM430. The DM430 features are:

- Multiple ion pulse width: <1.4 ns
- Linear response:
  ◊ during & after a burst of 300,000 ions
  ◊ >400mV output pulse (into 50 Ω)
  ◊ 10 µA sustained output current
  ◊ for spatially concentrated ion beams
- Exceptional operating life
- Impact surface flatness: ±10 µm
- Full performance just after pump-down
- No special storage requirements
- Robust mechanical construction
- Low noise
- High pressure operation
- Jitter =~300 ps

The DM430 retains all of the original MagneTOF features except for pulse width and jitter. (The typical DM167 pulse width = ~400 ps.) Detector jitter is defined as the variation of transit time as a function of ion input position. The DM167's jitter is on the order of 10's of picoseconds. An analysis of the DM430 indicates

~300 ps of jitter is expected. This is due to electron transit time variations and therefore, independent of ion mass and energy.

DM430 electron optics

The electron optics of the DM430 TOF detector is similar in concept to ETP's other magnetic TOF detectors (see figure 9.) Input ions generate secondary electrons as a result of striking the ion input surface. These secondary electrons are electro statically attracted up (in the diagram) but deflected to the right by a magnetic field which is oriented into the page. By increasing the magnetic field strength from left to right in the diagram, the electron "hop distance" is decreased, enabling a large number of multiplication stages in a short distance.

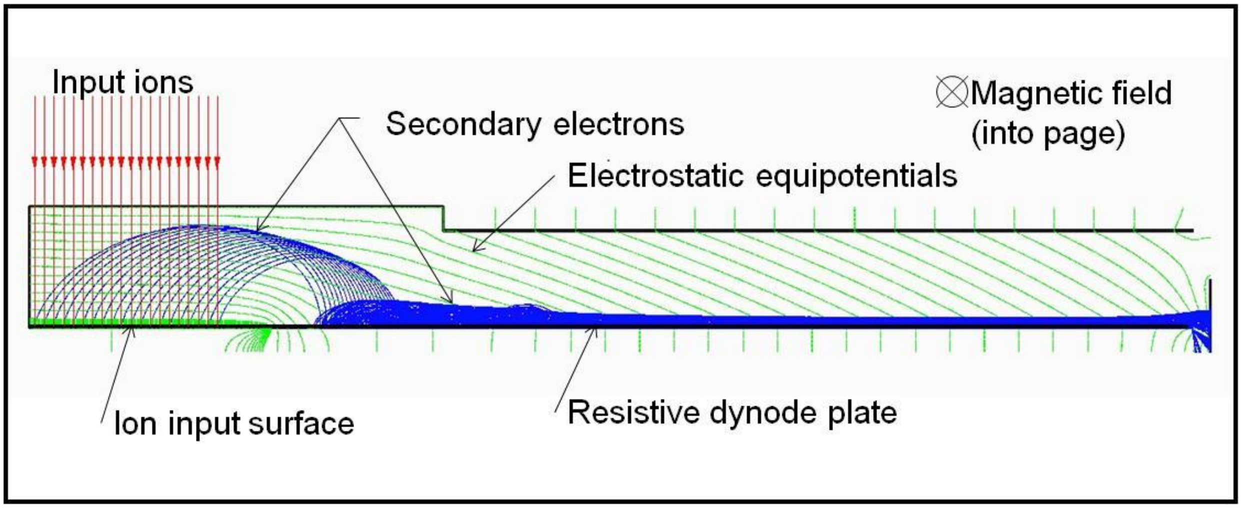

Figure 9. Electron optics diagram of the new DM430 compact magnetic TOF detector.

DM430 performance characteristics

The typical pulse shape for a DM430 as shown in figure 10 exhibits ~1.1 ns pulse width. Multiple ion pulse widths will be <1.4 ns.

The spatial sensitivity in figure 11 shows ~20% dip in the center of its aperture. This is likely a result of the larger angle of incidence of electrons emitted from the edges of the aperture resulting in larger secondary electron yield.

Mechanical details are shown in figure 12.

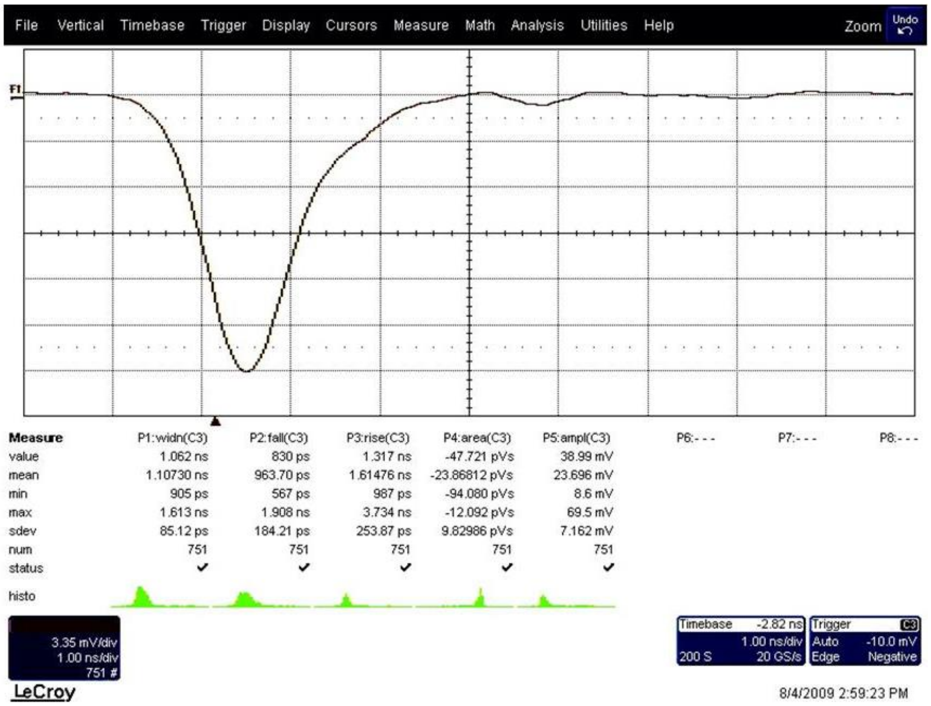

Figure 10. The single ion pulse shapes from the DM430 magnetic TOF detector is typically 1.1 to1.2 ns wide. The small peak ~3.5 ns after the pulse is a reflection from the chamber wall.

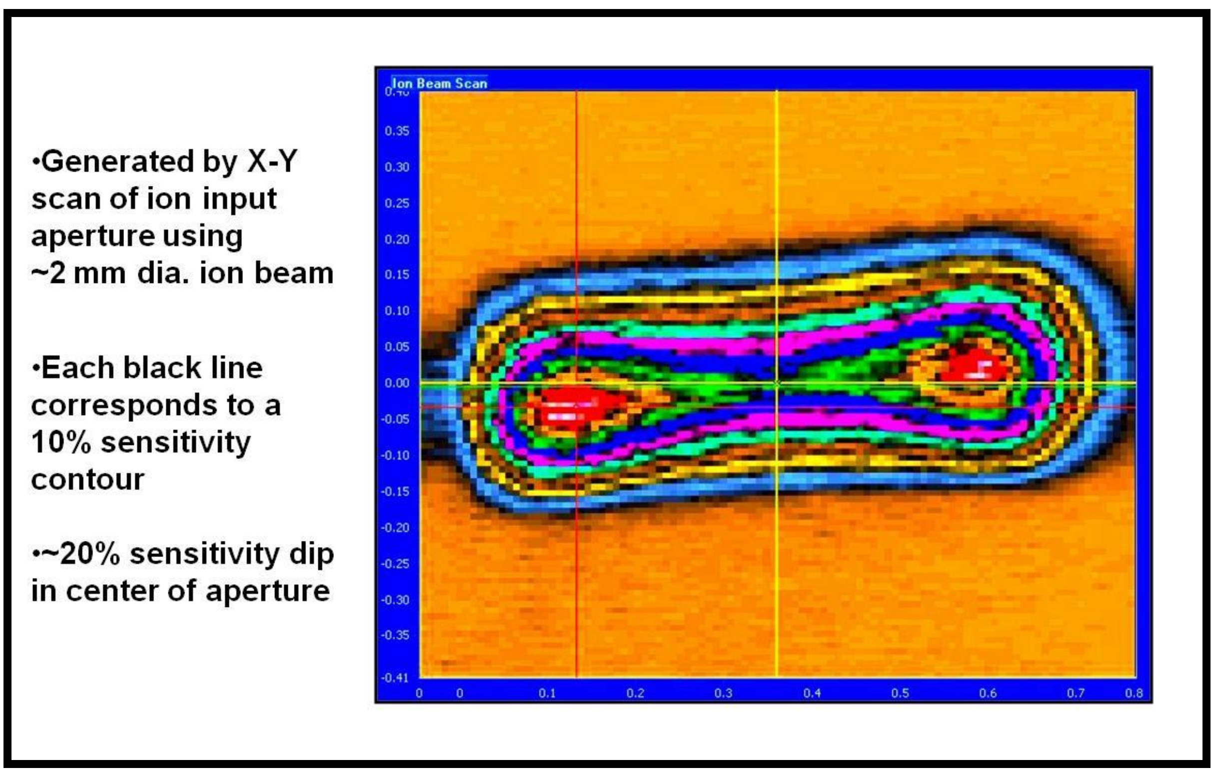

Figure 11. Spatial sensitivity of the DM 430 magnetic TOF detector.

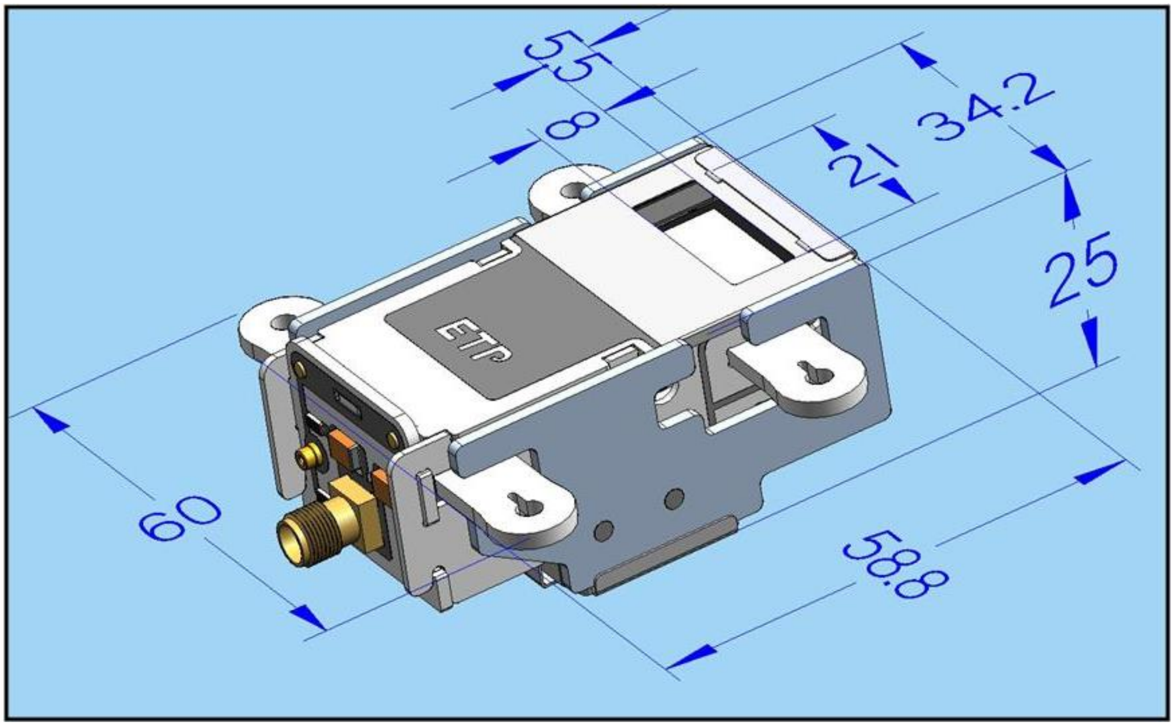

Figure 12. Mechanical details of the DM430 magnetic TOF detector. Dimensions in mm.