The NIFFTE TPC Gas Handling System

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1. Motivation

The Neutron Induced Fission Fragment Tracking Experiment (NIFFTE) uses a time projection chamber (TPC) to determine the fission cross section of actinides. Although the cross section has been previously measured using various methods, the uncertainty can be reduced to sub 1% using a TPC. See Figure 1. Higher accuracy of cross section measurements will improve efficiency of nuclear reactor operations and will lead to better understanding of the fission process.

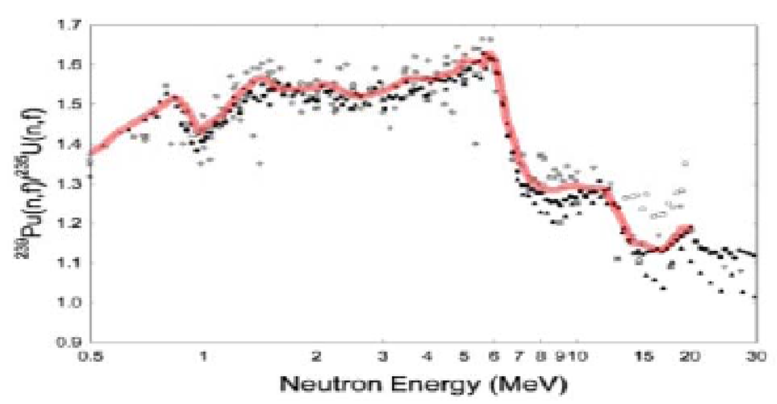

Fig. 1: The plot shows a comparison of the cross section of Pu-239 with U-235 as a function of neutron energies as it is presently known. The red line shows an estimate of the ±1% uncertainty improvement that NIFFTE can offer.

2. Fission Cross Sections

A cross section is a property of the target and projectile during a collision. The fission cross section extends this idea to nuclear fission to determine the probability of whether a fission event will occur. Fission cross sections vary with the energy of the incoming particle and is given by the equation:

$$C = N\sigma\phi$$

Located at the LANSCE-WNR fast neutron beam at 90L, incident neutrons are directed at actinide targets. The neutron flux is given by ϕ, σ is the cross section, N is the number of target nuclei, and C is the number of fission counts. Cross sections are usually measured in a ratio with a U-235 cross section. Thus, higher precision in the measurement of U-235 will affect all cross section data.

2. The NIFFTE TPC

A TPC houses a target and gas. The TPC can been seen in Figure 2. When an incident neutron collides with a target plate, it may induce fission. Gas particles are ionized as they move through the chamber. The resulting electrons will drift towards detecting pad planes through an electric field. By reconstructing the trail, the particle identity, velocity, and trajectory are measured. See Figure 5 for an example of particle tracking using ionization.

The TPC will significantly reduce systematic errors associated with fission cross section measurements through use of a sophisticated detection system. This will ensure that each fission fragment will be identified, delivering fission cross sections with unprecedented precision.

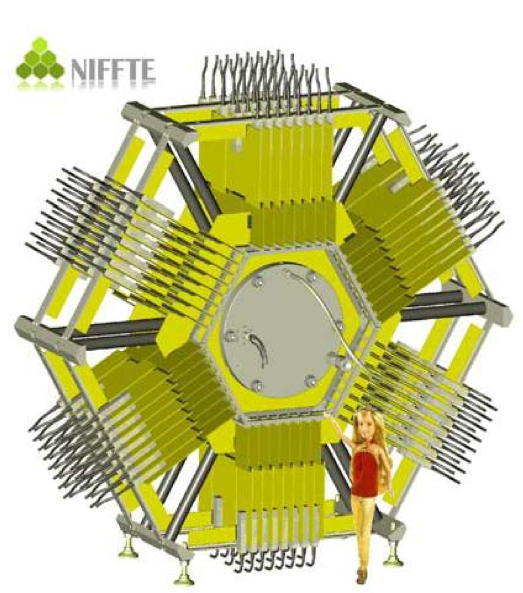

Fig. 2: A computer generated image of the NIFFTE TPC. The central chamber houses the gas and targets. It is surrounded by detector components. A doll is shown for scale.

3. The Gas Handling System

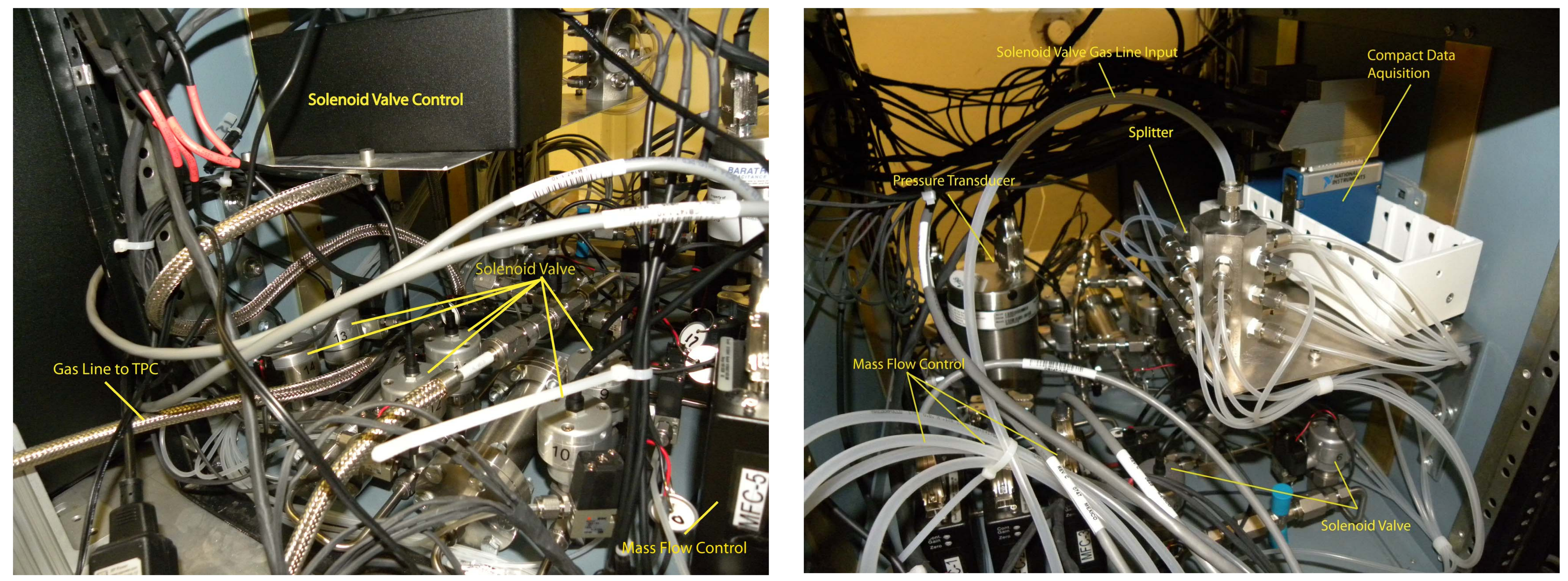

Fig. 3: The gas handling system hardware is shown from the left and right sides respectively. Major components are labeled. Gas lines to the TPC are not shown.

A gas handling system is essential for a TPC apparatus since its tracking method is based on gas ionization. The GHS is responsible for controlling the flow of gas and pressure within the TPC. The NIFFTE TPC is capable of measuring cross sections for gaseous targets and use them for normalization. The cross-section of elastic Hydrogen scattering will be measured for calibration purposes since the H(n,n)H cross-section is known to a high degree of certainty.

The system will initially use P10 (90% Ar, 10% CH_4) for the drift gas until Hydrogen testing on solid targets is performed. In the future, gaseous Rb-83 will also be flowed through the system intermittently with the counting gasses for calibration. One of the innovations of this GHS is its ability to flow multiple gas sources through the system. Additionally, the TPC can be calibrated regularly during data runs.

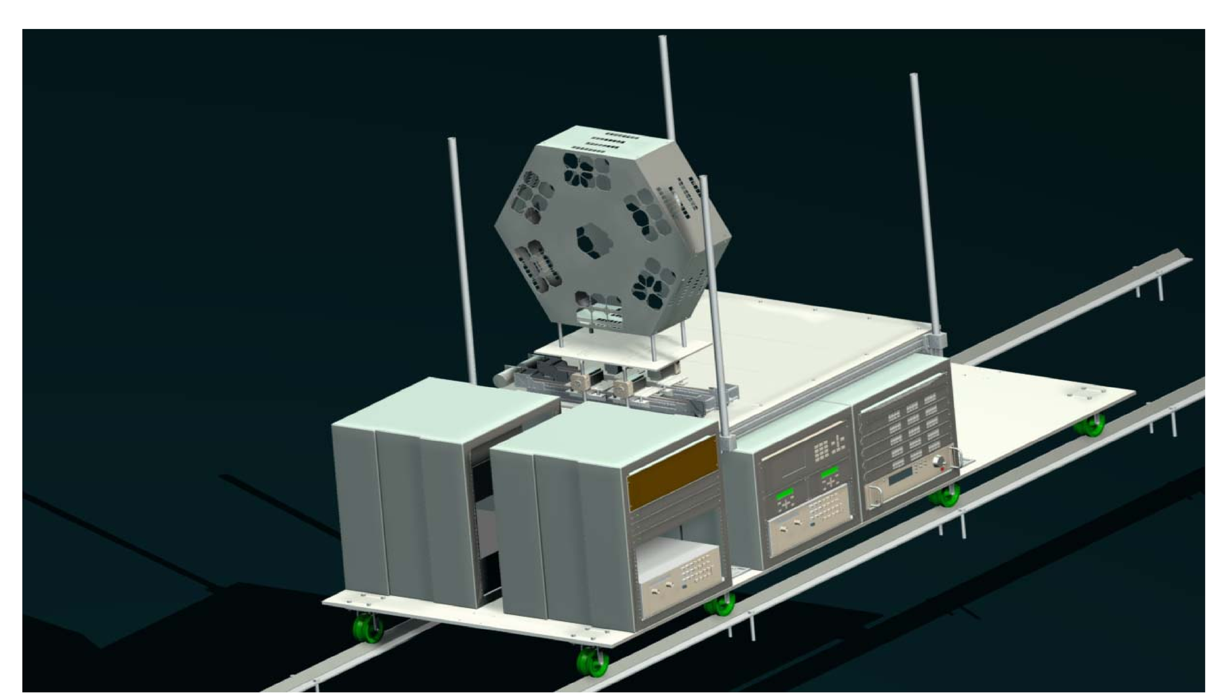

Fig. 4: A computer rendering of the TPC mounted on the adjustable table with slow controls and the gas handling system.

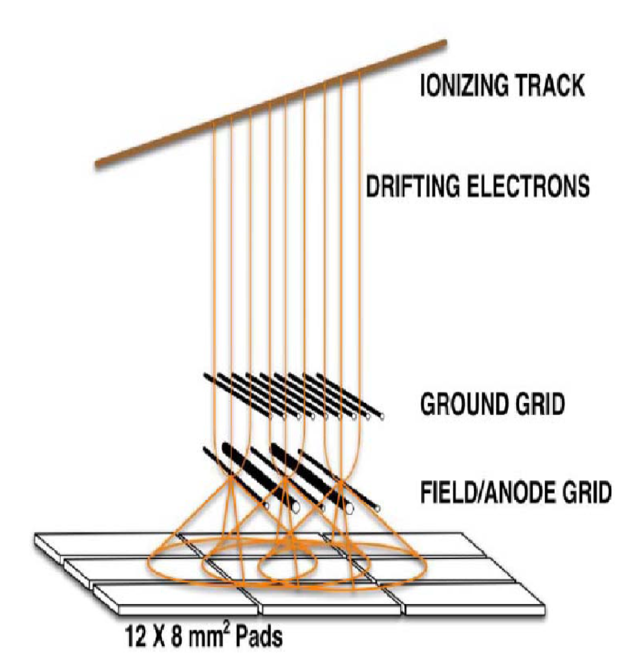

Fig. 5: A fission fragment travels along a path. It ionizes electrons which move through the electric field and strike the pad plane . By tracing these pulses, the fragment's path in the xy-plane can be reconstructed. By knowing electron drift velocity in the gas medium and measuring time, the z-component of the fragment can be determined.

4. Hardware

In order to provide optimum control over various properties of the gas (e.g. flow rate, pressure, type of gas, etc.) the GHS uses several different forms of hardware. Mass flow controllers are used to regulate the amount of gas entering and exiting the system, thereby controlling the flow rate within the TPC. Solenoid valves control which gases flow and the pipes through which they travel. Pressure transducers measure the gauge pressure inside the system, and are also responsible for the relay that prevents overpressure in the GHS and TPC. See Figure 3 for a photograph of the assembled hardware for the system. A rendering of the experiment setup is shown in Figure 4.

5. Software

In order to control the GHS while the TPC is collecting data, a LabVIEW program has been developed. See Figure 7. This program uses RS-232 cables to enable the adjustment of the mass flow controllers, as well as the monitoring of pressure within the system. In addition, each individual solenoid valve can be opened or closed by using two modules connected to the compact data acquisition system (cDAQ).

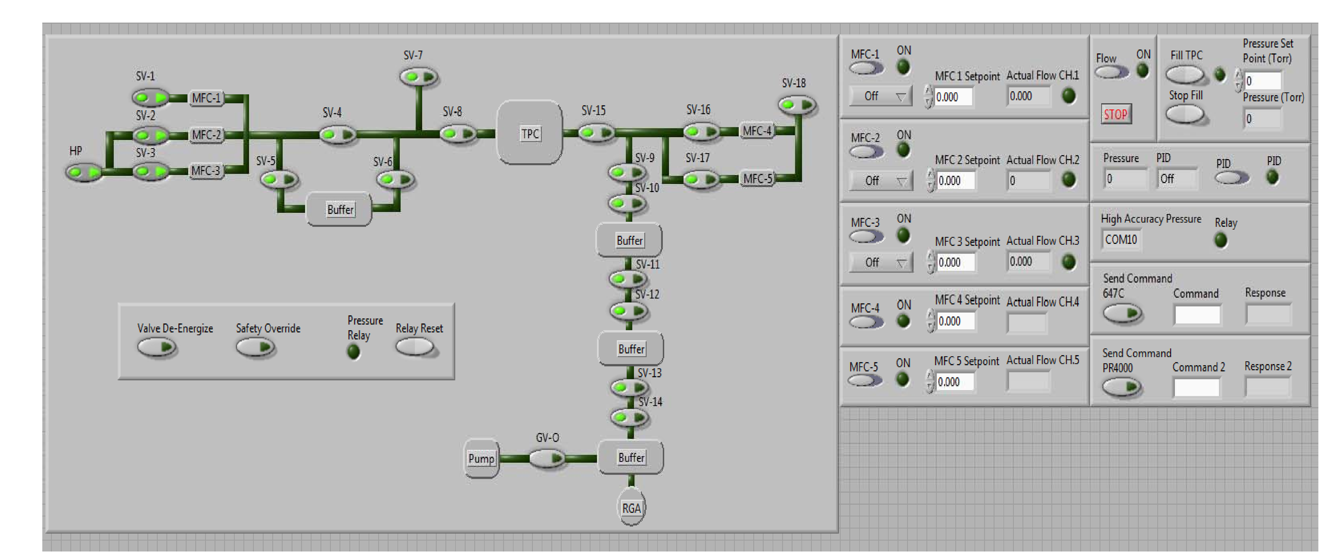

Fig. 7: The front panel of the LabVIEW program. This is used to control the gas handling system by opening solenoid valves and varying the amount of gas through the MFCs. The pressure in the system can also be monitored.

6. Experiment Status

The gas handling system is being installed at LANSCE as of July 2010. Prototype testing began in December 2009. Beam tests will begin on the NIFFTE TPC prototype in August-September 2010.

6. Acknowledgements

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