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Author(s): Meierbachtol, Krista C.
Tovesson, Fredrik K.
Arnold, Charles
Shields, Dan

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Characterization of the ionization chamber for the SPIDER detector

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Krista Meierbachtol[1], Fredrik Tovesson[1], Charles Arnold[1], Dan Shields[2]
[1] *Los Alamos National Laboratory, NM, 87545, USA*
[2] *Colorado School of Mines, Boulder, CO, USA*

Abstract

We request 3 days of ATLAS beams for testing the ionization chamber component of the SPIDER detector, a spectrometer for measuring the mass yields of neutron-induced fission fragments. The ionization chamber will be a stand alone detector to be coupled to the end of the beam pipe at zero degrees. These tests are a mass and energy specific characterization of the ionization chamber operating conditions specific to SPIDER, including entrance window material options. Once tested, the results will be applied to the energy calibration process of SPIDER, a crucial step to achieving high mass resolution.

1 Scientific Justification

The SPIDER (SPectrometer for Ion DEtermination in fission Research) detector is currently being developed at Los Alamos National Laboratory to measure high resolution mass distributions of neutron-induced fission fragments as a function of fragment mass, charge, total kinetic energy, and incoming neutron energy. These mass distributions are important for both applications such as spent fuel source terms and the basic understanding of the fission process. Theoretical modeling of the fission process, an active component of the SPIDER project, requires high resolution mass distributions to compare to predictive outputs of the fission model as well as data points that correlate fission fragment parameters of mass, charge, and total kinetic energy.

Several detector systems are combined to determine the mass of a fragment using the method of '2E,2v' or two energy, two velocity method. Figure 1 is a schematic of the recently constructed 'arm pair' prototype for measuring both the energy and velocity of the two fission fragments.

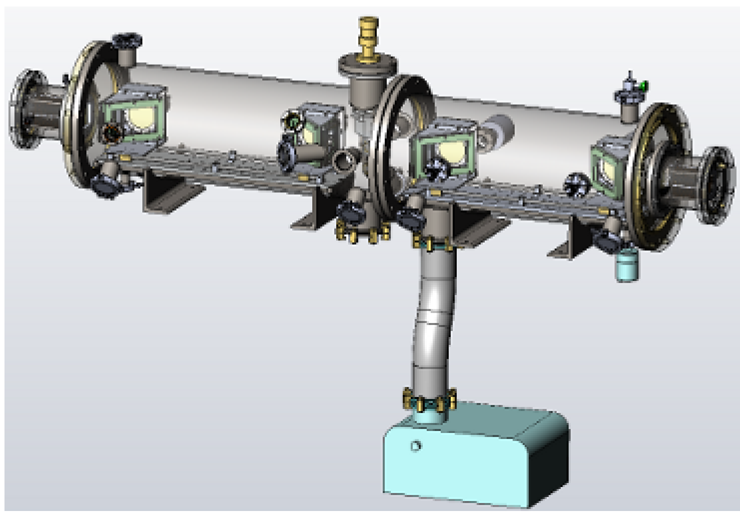

Figure 1: Schematic of the recently built prototype SPIDER arm pair.

Two timing micro-channel plates (MCPs) with position sensitivity are placed approximately 70 cm apart to measure the time-of-flight of the fragment. Immediately following the second timing detector is a gas-filled ionization chamber. The high vacuum portion required for the timing detectors is separated from the gas-filled ionization chamber by a thin window. The goal mass resolution of one atomic mass unit requires high resolutions in the individual measurements of time-of-flight, path length, and energy. In particular, the energy resolution must be on the order of 0.5 %.

2 Motivation

High resolution energy measurements of heavy ions can be achieved with gas-filled ionization chambers such as the one contained in the SPIDER detector. In order to obtain high resolution measurements several components of the ionization chamber must be well understood including the energy loss and straggling of the particles through the entrance window material and response of the detector as a function of incoming particle energy, mass, and charge. Energy loss and straggling through the entrance window of a gas-filled detector has long been a source of uncertainty in the resulting energy measurement. While simulations such as TRIM[1] can be used to estimate these changes in energy, a measurement is crucial to reconstructing the energy measurement accurately. The traditional entrance window material of Mylar is known to vary in thickness across a window dimension and from one piece of material to the next and therefore one estimate of energy loss through the material is inaccurate[2]. An energy loss measurement through the specific window material used during operation is therefore important. The second window material to be tested, silicon nitride, is thought to be more uniform in thickness and measured to have much smaller energy loss values[3] with low mass particles. It is important however to confirm these characteristics with particles with masses more similar to fission fragment masses. This can be accomplished with stable beams at ATLAS.

The response of the an ionization chamber to incoming particle energy, mass, and charge has been studied for many different detector operating conditions including drift distance, gas pressure, applied voltages, and gas composition. Since all of these parameters work together to make a successful energy measurement of the particle(s) of interest it is very valuable to understand the specific response of a particular detector under specific operating conditions, especially when a high resolution energy measurement is the goal. Using stable beams with four different masses, a small, known energy distribution (around fission fragment energies of approximately 1 MeV/nucleon), and charge will give a response curve for the ionization chamber that will be used to measure the energies of fission fragments in future experiments with the SPIDER detector. Finally, it is known that ionization chambers exhibit 'pulse height defect', a reduction in expected signal height for heavy ions. This characteristic is gas type dependent as well as particle energy and mass depedent [4]. Several different empirical descriptions have been suggested to account for this reduction in signal height suggesting a detector specific measurement using known incoming masses and energies will be important to describe our specifc pulse height defect.

3 Feasibility

The stable beams available at ATLAS are excellently suited to properly characterize the ionization chamber of SPIDER. Three days of beam time are requested in order to ensure sufficient time to probe 4 mass species with 4 stable beams, ^{80}Se, ^{102}Ru, ^{120}Sn, and ^{130}Te, and 3 different beam energies for each species of 800 keV/u, 1 MeV/u, and 1.2 MeV/u, with one day of beam time for each energy. In order to minimize tuning time of the accelerator the 4 stable beams requested were chosen based on similar mass-to-charge ratios. Based on expected charge states, only one main beam tune should be necessary to deliver these beams at a particlular energy. The 3 different beam energies requested are . Therefore, each day will consist of an 8 hour tuning time, and 4 hours of data taking for each mass, totaling 24 hours of beam time for each energy. Four hours of beam time for each mass and energy setting will provide enough statistics for the detector calibration.

The minimal size of the detector lends itself to being set up on several different beam lines. The detector would be installed at zero degrees and be coupled to the beam pipe with a simple vacuum chamber with the proper sizes on each end.

4 Experiment Details

4.1 Technical Info

A cylinder shaped gas ionization chamber will be the sole detector, placed at zero degrees to the beam. The approximate dimensions are 6 inches in diameter and 14 inches in length. Two entrance window materials will be tested, a stretched mylar window supported by an aluminum mesh and a silicon nitride membrane array on the order of hundreds of nanometers. The detector will be filled with isobutane gas to no more than 100 Torr. The suporting gas system contains valves, flow meters, and gauges which are monitored in real time and integrated into the data acquisition system.

4.2 Safety Info

Since isobutane is a flammable gas, all components of the gas system have been built to minimize this risk. All the gas lines are either stainless steel or copper and flow meters are calibrated to this gas type in order to have an accurate measure of the flow rate. When in operation, a flammable gas monitor can be installed in the experimental area as necessary. The inlet and outlet gas lines on the detector volume contain in-line HEPA filters to prevent any possible contamination created inside the detector from outside of the detector volume.

5 Current status of SPIDER

The SPIDER detector prototype, including the ionization chamber has been set up at the Lujan Center at LANSCE (Los Alamos Neutron Science Center) at Los Alamos National Laboratory since early October, 2013. During this time, data as been collected to measure the mass distribution of fragments from thermal neutron induced fission of ^{235}U. The energy measurement from the ionization chamber portion of SPIDER is crucial to this measurement.

6 References

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