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Recent developments for an active UF_6 gas target for photon-induced fission experiments

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Abstract. Recent developments for an active uranium-hexafluoride-loaded gas target as well as results on the detector gas properties are presented. The gas of choice is a mixture of argon with small amounts of UF_6. This contribution presents the experimental setup and focusses on the electron drift velocity with increasing UF_6 content. A time-dependent decrease in electron drift velocity is observed in our setup.

1. Introduction

Although nuclear power is used technically since several decades now, a detailed microscopic theoretical understanding of the underlying fission process has not been achieved so far [1]. Further experimental precision data may help gaining insight into the details of the process. Examples for possibly interesting aspects comprise fissioning shape isomers or an accurate determination of mass and total kinetic energy (TKE) distributions – often parameterized in the fission-mode concept developed by Brosa *et al.* [2]. The detection of angular distributions associated with the fission modes contain information about the intermediate compound states of the fissioning nucleus as well as the structure of the fission barrier. The availability of such data could spark theoretical studies on the microscopic description of fission dynamics.

Recent experiments at the superconducting Darmstadt electron linear accelerator S-DALINAC [3] on photofission of ^{234,238}U and ^{232}Th [4, 5] have studied these quantities in some detail for energies around the fission barrier. A twin Frisch-grid ionization chamber with a solid target located at the common cathode [6] was used in these studies. Angular distributions of the fission fragments were obtained from the measurement of the electron drift times [7]. As the present method requires a "transparent" spectroscopic target, an improved statistical accuracy or searching for small effects can only be obtained through an increase in beam current and data-taking time. Alternatively, an active gas target "if feasible" could allow one to improve the sensitivity.

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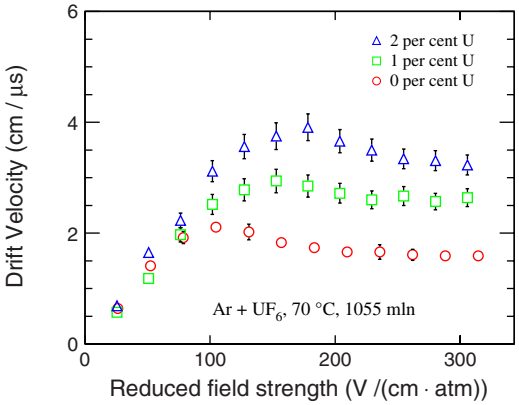

Figure 1. Measured electron drift velocities as a function of reduced field strength in Ar (1055 mln) atmosphere with different admixtures of UF_6, at 70 °C.

Examples for possible experiments that require much increased accuracy comprise the investigation of fission fragments well below the fission barrier and through fission isomers as well as the search for parity non-conservation (PNC) in photofission. The latter could become accessible at the S-DALINAC using the newly installed source of spin-polarized electrons [8].

As a first step towards an active UF_6 target, the properties of the counting gas are investigated. We use argon in an ion chamber and study the influence of small amounts of UF_6 gas at temperatures above 56 °C on signal quality and electron drift velocity.

2. Setup and electron drift velocity measurement

The Frisch-grid ionization chamber set up for test purposes features a distance $D = 4.2$ cm between cathode and grid, and a distance of 1 cm between grid and anode. As UF_6 is highly hygroscopic and can form hydrofluoric acid, all appliances have to be baked out in order to reduce the water content, and they must be corrosion resistant. The same is true for elastomer materials, where only those with a fluorine content do resist hydrofluoric acid. Hence, due to these safety reasons, all conducting parts inside the chamber are made out of stainless steel (AISI 316L), and all insulators are made out of polytetrafluorethylen (PTFE).

The system was first tested for functionality with pure argon gas. The ionization chamber was then filled with small amounts of UF_6. Results on signal quality and drift velocity for different uranium contents were derived [9]. The electron drift velocity measured with one and two mass percent uranium content as a function of reduced field strength is shown in Figure 1. Corresponding values for pure argon are included as reference. All three measurements exhibit similar behavior at small field strengths. At higher field strength the maximum drift velocity increases with uranium concentration, eventually leading to saturation.

The setup was improved to allow higher uranium concentrations to be used. However, first tests after reassembling showed uranium remnants in the spectrum. In addition, the new installed grid shows significantly higher grid ineffiency (GI). The GI $\sigma = 0.19$ was determined and corrected for using the method of applying the Shockley-Ramo theorem on the GI of Frisch grid ionization chambers [10].

In the next series of experiments, the chamber was loaded also with much higher concentrations of UF_6 in the detector gas. The measurement for the electron drift velocity with 21 mass per cent uranium in the gas mixture is shown in Figure 2 (red dotted data points). Corresponding values for pure argon are shown for comparision in green. Due to an improved electrical insulation, higher electrical field

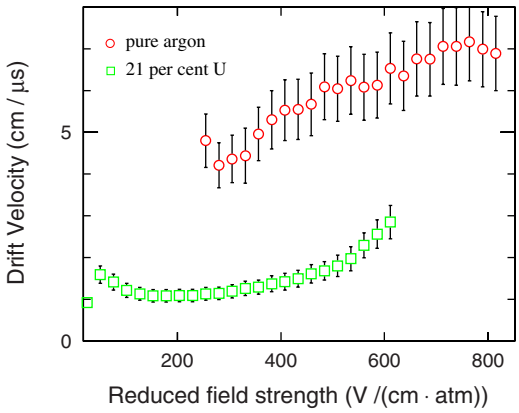

Figure 2. Measured electron drift velocities as a function of reduced field strength for pure argon and 21 mass per cent uranium with the new chamber design.

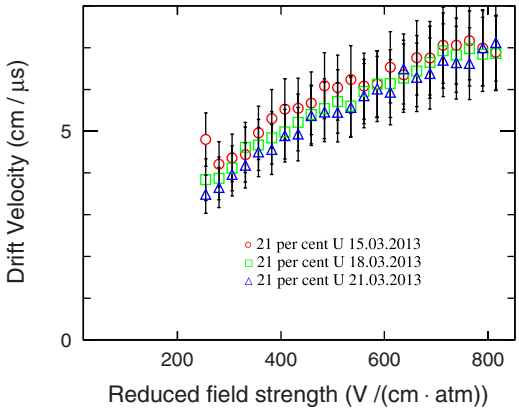

Figure 3. Electron drift velocities measured over a one week period with 21 mass per cent uranium in the chamber.

strengths could be applied to the chamber. As a consequence one can see a second peak in the electron drift velocity for higher field strengths in the pure argon data. For the uranium data one can only see a slightly increasing trend towards higher field strengths as the peak is already shifted towards even higher field strengths, which are not available with present electronics.

When new UF_6 is filled into the detector, the signal quality quickly deteriorates. Especially for concentrations around 20 mass per cent, this effect proved to be significant. However, a recovery of the signals is observed after typical time spans of several hours to a few days. The electron drift velocities at a fixed uranium content of 21 mass per cent were studied over a longer period. During this time the chamber was kept at a temperature of $T = 90\,^{\circ}C$ with all valves closed. The results for a one week measurement are shown in Figure 3. Despite of the quite large errorbars one can see a trend that the electron drift velocity decreases slightly with time. A possible explanation to this phenomena could be the adhesion of the UF_6 molecules on the PTFE shieldings or the disintegration of the gaseous UF_6 to solid UF_5 or UF_4 respectively. Should this surmise prove true, the exact determination of the gas in the sensitive volume of an active target will be a particular challenge for future experiments.

3. Conclusions and outlook

A technically very challenging setup for testing the feasibility of a UF_6-loaded active gas target was investigated. Data have been collected for gases from pure argon to a mixture containing 21 mass per cent of uranium in the gas. One observes signal deterioration and subsequent restoration, and the effect of the concentration on the electron drift velocity was studied. Further investigations with even higher electrical field strengths to detect a plateau region in electron drift velocity for moderate uranium mass contents were limited due to technical reasons with the present setup. A trend for long term instability of the UF_6 molecules inside the closed system was found and is currently under a detailed investigation. Possible reasons are the adhesion of UF_6 at the PTFE isolating materials or the disintegration of the UF_6 molecules. The latter possibillity would limit the use of UF_6 as a stationary admixture. During long run experiments this could be overcome, e.g., by a constant flow of gaseous UF_6 into the ionization chamber.

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