LAWRENCE LIVERMORE NATIONAL LABORATORY

LLNL-TR-462118

Compact fission counter for DANCE

C. Y. Wu, A. Chyzh, E. Kwan, R. Henderson, J. Gostic, D. Carter, T. Bredeweg, A. Couture, M. Jandel, J. Ullmann

November 12, 2010

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

LLNL-TR-pending

Compact fission counter for DANCE

C.Y. Wu, A. Chyzh, E. Kwan, R. Henderson, J. Gostic, and D. Carter
Lawrence Livermore National Laboratory, Livermore, CA 94551
T. Bredeweg, A. Couture, M. Jandel, and J. Ullmann
Los Alamos National Laboratory, Los Alamos, NM 87545

I. Introduction

The Detector for Advanced Neutron Capture Experiments (DANCE) [1] consists of 160 BF_2 crystals with equal solid-angle coverage. DANCE is a 4π γ-ray calorimeter and designed to study the neutron-capture reactions on small quantities of radioactive and rare stable nuclei. These reactions are important for the radiochemistry applications and modeling the element production in stars. The recognition of capture event is made by the summed γ-ray energy which is equivalent of the reaction Q-value and unique for a given capture reaction. For a selective group of actinides, where the neutron-induced fission reaction competes favorably with the neutron capture reaction, additional signature is needed to distinguish between fission and capture γ rays for the DANCE measurement. This can be accomplished by introducing a detector system to tag fission fragments and thus establish a unique signature for the fission event. Once this system is implemented, one has the opportunity to study not only the capture but also fission reactions.

A parallel-plate avalanche counter (PPAC) has many advantages for the detection of heavy charged particles such as fission fragments. These include fast timing, resistance to radiation damage, and tolerance of high counting rate. A PPAC also can be tuned to be insensitive to α particles, which is important for experiments with α-emitting actinides. Therefore, a PPAC is an ideal detector for experiments requiring a fast and clean trigger for fission. A PPAC with an ingenious design was fabricated in 2006 [2] by integrating amplifiers into the target assembly. However, this counter was proved to be unsuitable for this application because of issues related to the stability of amplifiers and the ability to separate fission fragments from α's. Therefore, a new design is needed.

A LLNL proposal to develop a new PPAC for DANCE was funded by NA22 in FY09. The design goal is to minimize the mass for the proposed counter and still be able to maintain a stable operation under extreme radioactivity and the ability to separate fission fragments from α's. In the following sections, the description is given for the design and performance of this new compact PPAC, for studying the neutron-induced reactions on actinides using DANCE at LANL.

II. Parallel-plate avalanche counter

The design work is difficult because of the limited space to accommodate the proposed counter assembly and was carried out initially by Mechtronic Solutions, Inc.. Later, an extensive redesign work was made at LLNL mainly to correct issues related to the vacuum seal and both the electric and gas feedthroughs. The fabrication work was carried out entirely at LLNL.

The newly designed PPAC has three mechanical parts, shown in Fig 1. They are the front cover with the attached target assembly, the aluminum container to host the target assembly, and the back cover with both the electric and gas feedthroughs. The front and back windows for the beam entrance and exit are made of the 25.4 μm thick Kapton foils. The target assembly consists of two anodes and one cathode. The latter also serves as a host for the target. All are housed by the polyimide rings. Fig 2 shows the cathode/target polyimide ring, where the 3 μm thick Ti foil is sandwiched between two double-side aluminized mylar, each having a thickness of 1.4 μm. The mylar is glued to the copper ring with a thickness of 0.25 mm. A delrin retaining ring of 0.66 mm thickness is used to keep the assembly in place. The target material is double-side electroplated using the plating cell, shown in Fig. 3. The anode signal is transmitted through a custom-designed flexible cable, which can be seen in an overall view of various counter parts in Fig. 4.

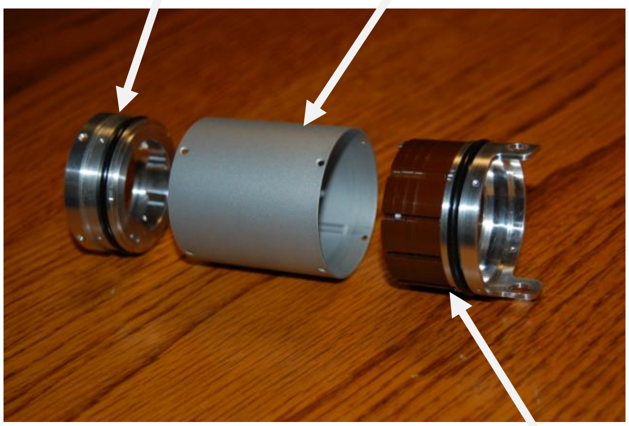

Fig 1. Pre-assembling detector arrangement

Fig 2. The cathode/target polyimide ring. The copper ring holding the mylar, can be seen beneath the derlin retaining ring.

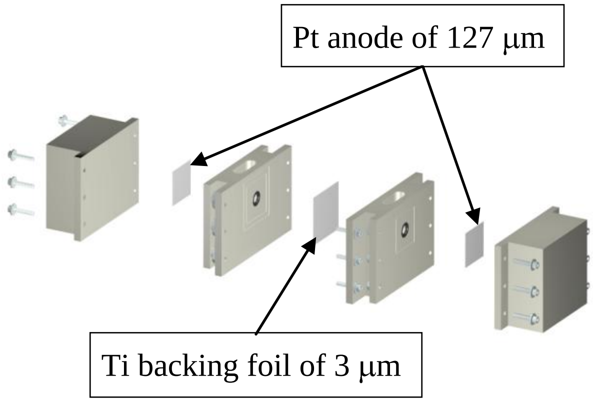

Fig3. The exploded view of the electroplating cell, made of Teflon.

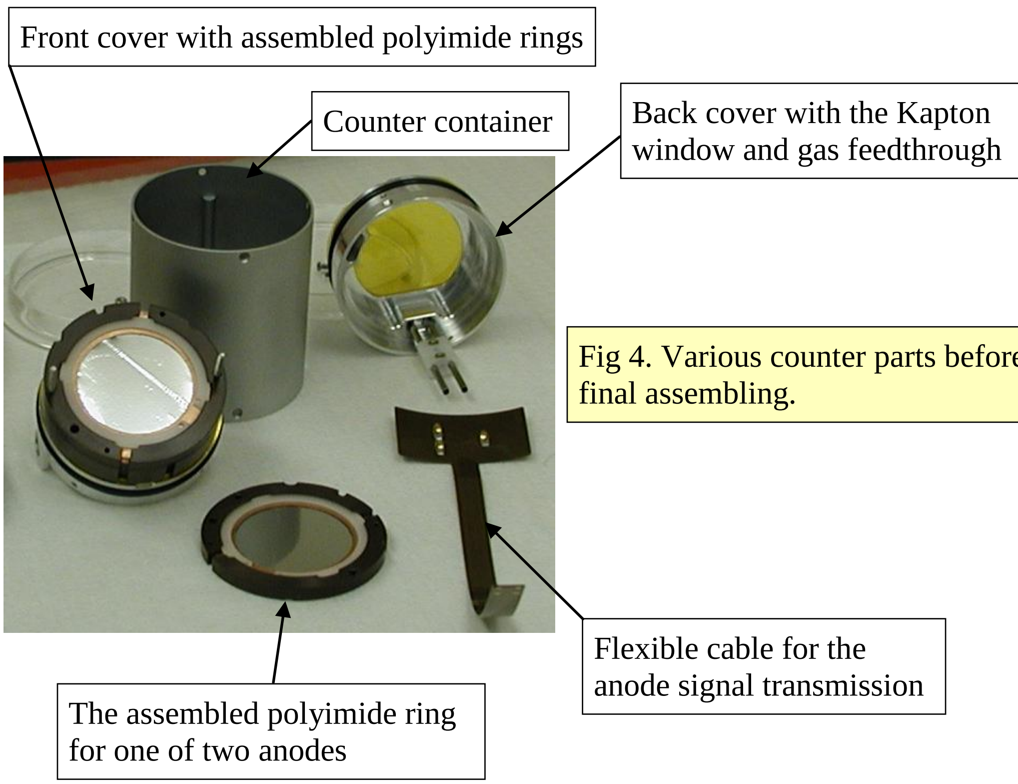

Fig 4. Various counter parts before the final assembling.

III. Operation and performance

For a stable operation of the PPAC, it requires continuous gas flow into the counter while maintaining a constant gas pressure. This can be achieved by using a specialized gas handling system to regulate the gas flow via a feedback loop on the measurement of gas pressure. The description of a similar gas handling system and its operation is detailed in Appendix A of the technical report (LLNL-TR-461044).

The PPAC is operated at ~ 4 torr of isobutane with a gas flow up to 50 sccm. The anode signal, biased at ~ +400 V, is processed by a fast amplifier with a gain of about 300 and a bandwidth of 500 MHz, located outside the DANCE array. The output of amplifier is directly fed into the same Acqiris digitizers, used for DANCE. The timing and pulse height of the anode signal are derived from the recorded waveform.

Two fission counters with this design were fabricated in 2010. One is for the ^{239}Pu sample with a total mass of 937 μg and the other is for the ^{241}Pu sample with a total mass of 147 μg. Both performed well during the experiment together with the DANCE array. Fig. 5 shows the pulse height spectrum from the fission counter for the ^{239}Pu experiment. The same spectrum for the ^{241}Pu experiment is shown in Fig 6. Fission fragments were separated reasonably well from α's using this newly designed PPAC despite the extreme radioactivity presented. The detection efficiency for fission fragments reached ~ 70 – 75% by the comparison of events with and without the PPAC tagging in addition to the requirement on the measured total γ-ray energy and multiplicity by DANCE, where only fission events exist.

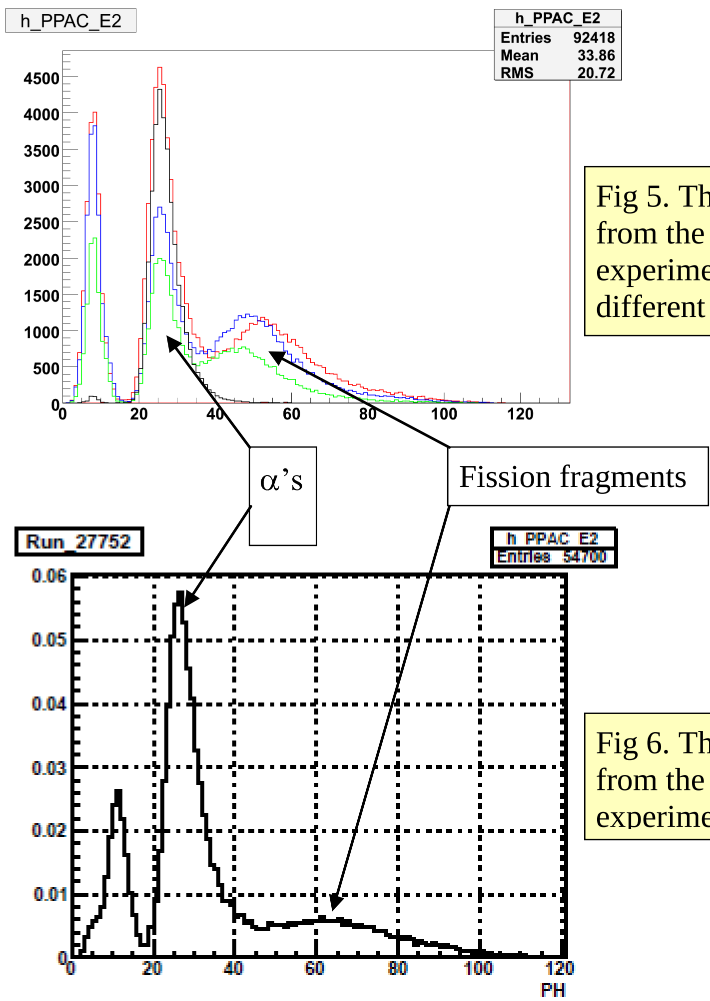

Fig 5. The pulse height spectrum derived from the recorded waveforms for the ^{239}Pu experiment. Different colors represent different runs.

Fig 6. The pulse height spectrum derived from the recorded waveforms for the ^{241}Pu experiment.

IV. Future plan

The success of this newly designed PPAC for detecting the fission fragments in experiments fielded in 2010 is very encouraging. We are going to fabricate a counter for ^{238}Pu with a total mass of ~ 300 μg in 2011 to study the neutron-induced reactions on capture and fission using DANCE. A counter for ^{252}Cf will also be assembled soon for the efficiency calibration and studying the prompt γ-ray energy and multiplicity distribution in spontaneous fission. Additional works are planned to improve 1) the design of the flexible cable for the anode signal transmission and 2) the accessibility of the gas feedthrough to the PPAC cavity. This is a needed step to continue to improve the reliability and accessibility of the fission counter for DANCE.

[1] M. Heil, R. Reifarth, M.M. Fowler, R.C. Haight, F. Kappeler, R.S. Rundberg, E.H. Seabury, J.L. Ullmann, J.B. Wilhelmy, and K. Wisshak, Nucl. Instrum. Methods Phys. Res. A 456, 229 (2001).
[2] T.A. Bredeweg, M.M. Fowler, J.A. Becker, E.M. Bond, M.B. Chadwick, R.R.C. Clement, E.-I. Esch, T. Ethvignot, T. Granier, M. Jandel, R.A. Macri, J.M. O'Donnell, R. Reifarth, R.S. Rundberg, J.L. Ullmann, D.J. Vieira, J.B. Wilhelmy, J.M. Wouters, and C.Y. Wu, Nucl. Instrum. Methods Phys. Res. B 261, 986 (2007).

Acknowledgement

This work performed under the auspices of the US Department of Energy by Lawrence Livermore National Security, LLC under contract DE-AC52-07NA27344 and by Los Alamos National Security LLC under contract DE-AC52-06NA25396.