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Low-mass fission detector for the fission neutron spectrum measurement

C. Y. Wu, R. Henderson, J. Gostic, R. C. Haight, H. Y. Lee

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LLNL-TR-pending

Low-mass fission detector for the fission neutron spectrum measurement

C.Y. Wu, R. Henderson, and J. Gostic
Lawrence Livermore National Laboratory, Livermore, CA 94551
R.C. Haight and H.Y. Lee
Los Alamos National Laboratory, Los Alamos, NM 87545

I. Introduction

For the fission neutron spectrum measurement, the neutron energy is determined ina time-of-flight experiment by the time difference between the fission event and detection of the neutron. Therefore, the neutron energy resolution is directly determined by the time resolution of both neutron and fission detectors. For the fission detection, the detector needs not only a good timing response but also the tolerance of radiation damage and high α-decay rate. 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. In the following sections, the description will be given for the design and performance of a new low-mass PPAC for the fission-neutron spectrum measurements at LANL.

II. Parallel-plate avalanche counter

The newly designed PPAC encloses ~ 100 mg of target material distributed over 10 thin titanium foils. The target material is electroplated over an area of 4 cm diameter with the surface density about 400 $\mu g/cm^2$ on both sides of each titanium foil. The electroplating cell used in the target fabrication is shown in Fig 1. These loaded titanium foils of ~ 3 μm are then covered by the 1.4 μm double-side aluminized mylar, forming the cathodes. Two anodes made of the 1.4 μm double-side aluminized mylar are located at either side of cathode with a 3 mm gap. A Pt foil, 5 µm thick, is added to the anode to stop the fission fragments from going to the adjunct target assembly and to minimize the electric interference. All thin foils are held by G-10 rings of 0.79 mm thick except for the target material loaded Ti foil. Fig 2 shows one of 10 target assemblies for the PPAC. Then the complete target assembly is housed by a cylindrical tube with open ends for the neutron beam entrance and exit. The open ends are sealed with 25.4 μm Kapton foil. The cylindrical tube is made of aluminum with a wall thickness of 1.57 mm. Specially designed gas feedthroughs, made of aluminum, are glued to this tube to minimize the counter mass. The overview of this PPAC design is shown in Fig 3.

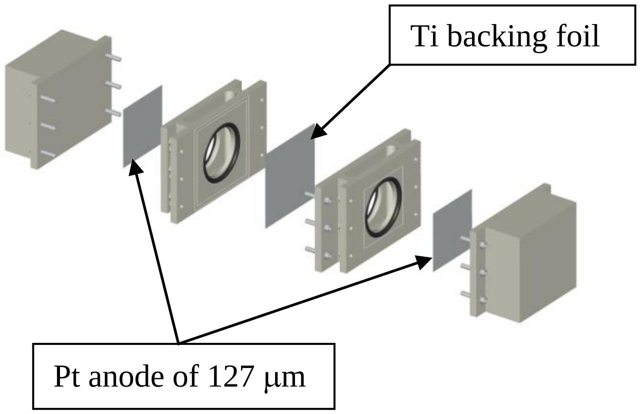


Fig 1. The exploded view of the electroplating cell made of teflon.

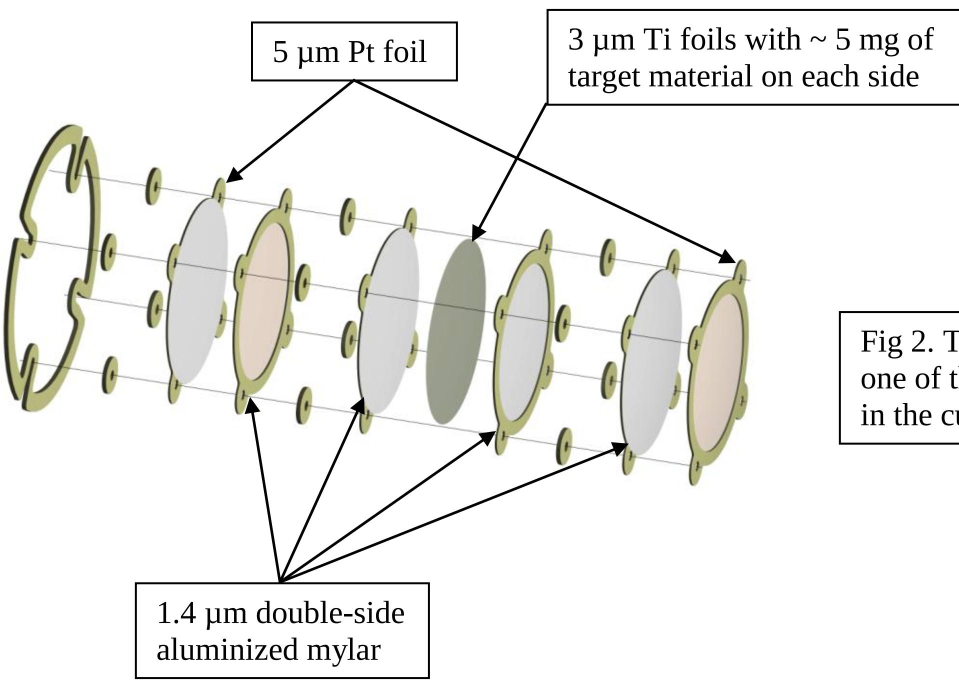


Fig 2. The exploded view of one of the target assemblies in the current PPAC.

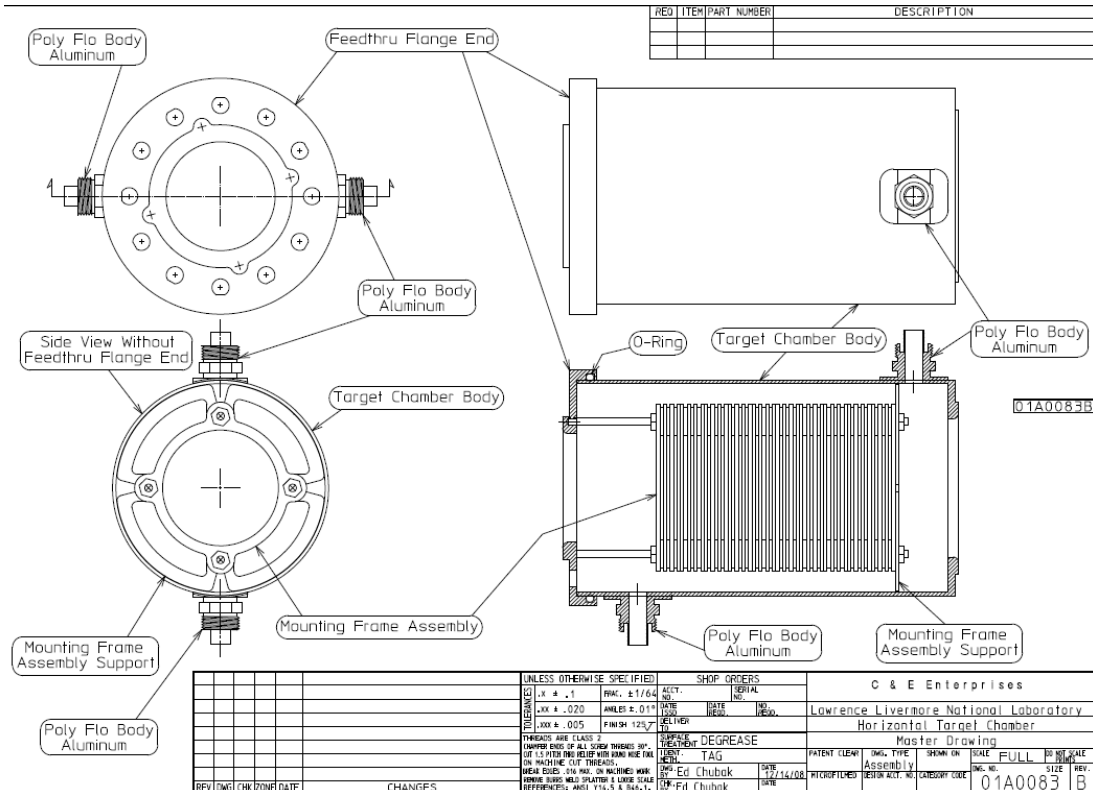


Fig 3. The overview of the housing for 10 target assemblies. The gas feedthroughs have a 90^{o} bend in the most recent design of this PPAC.

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 this gas handling system and its operation is detailed in Appendix A.

The PPAC is operated at ~ 4 torr of isobutane with a gas flow up to 50 sccm. The anode signals, biased at ~ +400 V, will be processed by fast amplifiers with a gain of about 300 and a bandwidth of 500 MHz. For experiment fielded in 2010, a modified version of this fast amplifier is used for recording the pulse height through FERA and the timing through CFD and TDC.

Two fission detectors were fabricated for ^{235}U so far. One was made in 2009 with a total mass of ~ 17 mg and the other was made in 2010 with a total mass of ~113 mg. Both performed well during the experiment together with the Chi-Nu array for the neutron detection. Fig 4 shows the fission detector together with the Chi-Nu array. The complete 10-target assembly is shown in Fig 5. The time spectrum of PPAC vs T0 of the beam pulse is shown in Fig 6 and a time resolution ~ 1 ns is achieved, which is sufficient for the current work on the fission neutron spectrum measurement.

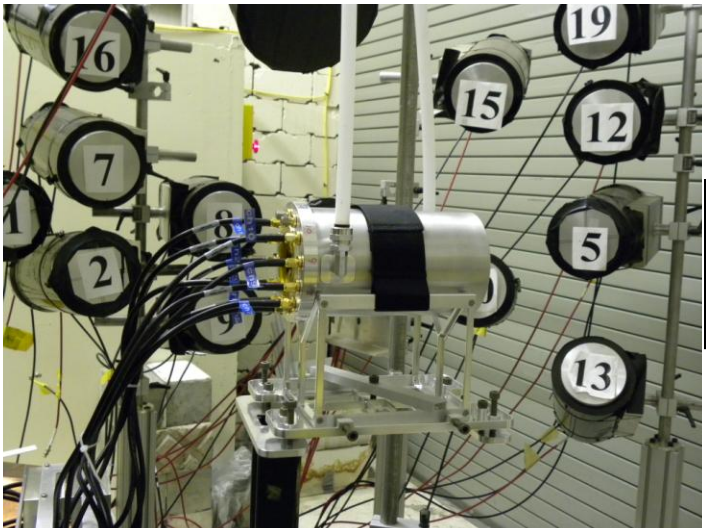


Fig 4. The PPAC was supported by an adjustable platform for the alignment. The Chi-Nu array is shown in the background.

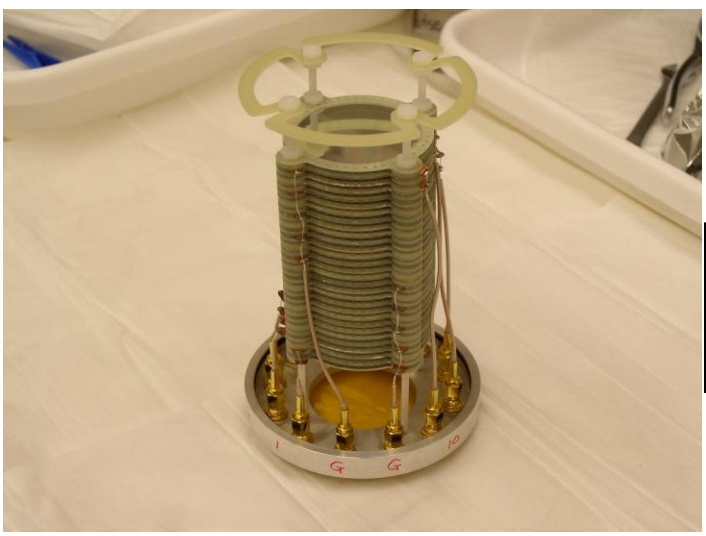


Fig 5. The complete target assembly for ^{235}U. The signal cable connection is visible for 10 target assemblies.

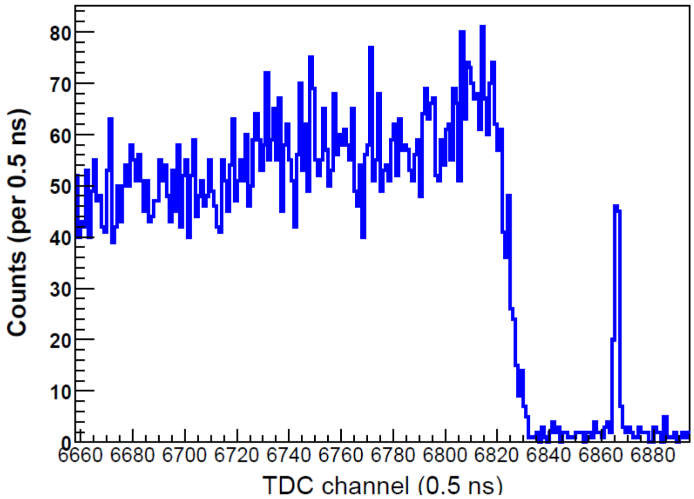


Fig 6. The time spectrum of PPAC vs the beam pulse. The sharp peak near channel 6870 is the photon-induced fission.

IV. Future plan

The success of this newly designed PPAC for the detection of fission fragment in experiments fielded in 2009 and 2010 is very encouraged. We are going to fabricate a counter for ^{239}Pu with a total mass of ~ 100 mg in 2011 for the fission neutron spectrum measurement. A counter for ^{252}Cf will also be assembled soon for the neutron detector efficiency calibration. Two tasks will be initiated to improve the electronics. One is to improve the signal cable by having the ground connection (cathode) next to the anode connection. The other is to modify the amplifier with the rise time compatible to the digitizer of 400 Megasamples/sec rate. The integration of this PPAC together with the Chi-Nu array into the digital data acquisition system is the next grand challenge.

Appendix A: Gas handling system

As stated earlier, the purpose of this specialized gas handling system is to provide an environment for optimum PPAC operation, which is achieved by regulating continuously the gas flow to stabilize the gas pressure through the MKS PR4000 gas flow controller. In addition, a customized LabView program is used to monitor the gas pressure and flow of PR4000 through the NI cFP-2120 real-time controller. In case of emergency such as a power failure or gas operation conditions beyond the preset boundary, this computer program will isolate the detector system by switching off the current supply to the solenoids, which are normally closed and installed in both gas inlet and outlet. It also will cut off the power to the bias supply to the detector at the same time. This LabView program was developed at LLNL and employed successfully for the fission trigger detector at DANCE since 2006. It was overhauled to improve the portability and the response time in 2009.

I. Operation

Since the detector assembly of this PPAC is not isolated from the vacuum chamber, both evacuating the vacuum chamber and regulating the gas flow are operated via the gas handling system. The front panel of this gas handling system is given in Appendix B, showing the gate valves, the gas flow, the pressure reading gauge, and the control instrument. Operating procedures of this PPAC via the front panel of the gas handling system are described below. It is important to make sure the gas pressure regulator on the isobutane bottle is installed properly before the operation, which includes the pressure relief valve, the vent valve, and the gas flow restriction valve. The pump installed at the gas handling system should have the capability of pressure monitoring and dust filtration in addition to an isolation valve.

II. Pumping down

As mentioned above, evacuating the vacuum chamber and regulating the gas flow are operated via the gas handling system. Therefore, before pumping down, connections between the gas handling system, the detector body, the gas regulator on the isobutane bottle and the pump, should be tested under air pressure and without any power source. All valves should be open except for the valve on the isobutane bottle. Note that all the terms with green underlined, cited below, are valves located at gas handling system. Once this is done, the system is ready to pump down by following the procedures below:

1. Close all the valves except for V6, V8, Detector Bypass, MFC Bypass, Isobutane Gas Inlet, and the valve open to the gas pressure regulator. This allows to pump down the whole system without any restriction.
2. Start the (external) pump installed at the gas handling.
3. Open solenoids (located at both inlet and outlet of the gas handling system) via the LabView program on the monitor computer to allow the access to the pump.

4. Begin the pumping down by opening fully the isolation valve on the pump then opening V9 slowly to make sure the fore-pump pressure not exceed ~0.5 torrs at any given time until fully opened.
5. Turn the power on for PR4000 when the pressure on Gas Return Pressure reaches ~0.15 torrs. The pressure reading on PR4000, which is the gas inlet pressure, should be close to 0.15 torrs.

III. Gas input to the counter

Once the vacuum reaches ~ 0.15 torrs, it is ready for the gas input to the counter. Since the detector assembly is not isolated from the vacuum chamber, there is no risk of breaking any component in this PPAC by following procedures below:

1. Close Detector Bypass, MFC Bypass, and Isobutane Gas Inlet to force the gas flow through the Mass Flow Controller into to PPAC.
2. Close V9 all the way then open a 1/4 turn to restrict the gas flow into PPAC.
3. Open the gas flow restriction valve on the isobutane bottle to begin the gas flow.
4. Turn on the control of PR4000 (the unit is preset to 4.2 torrs initially). One can check the preset values on PR4000 if necessary.
5. Open Isobutane Gas Inlet slowly and adjust the speed of opening by watching the gas-flow reading of PR4000 until fully opened.
6. Adjust V9 gently to reach the desired gas flow (10 – 50 sccm), read from PR4000

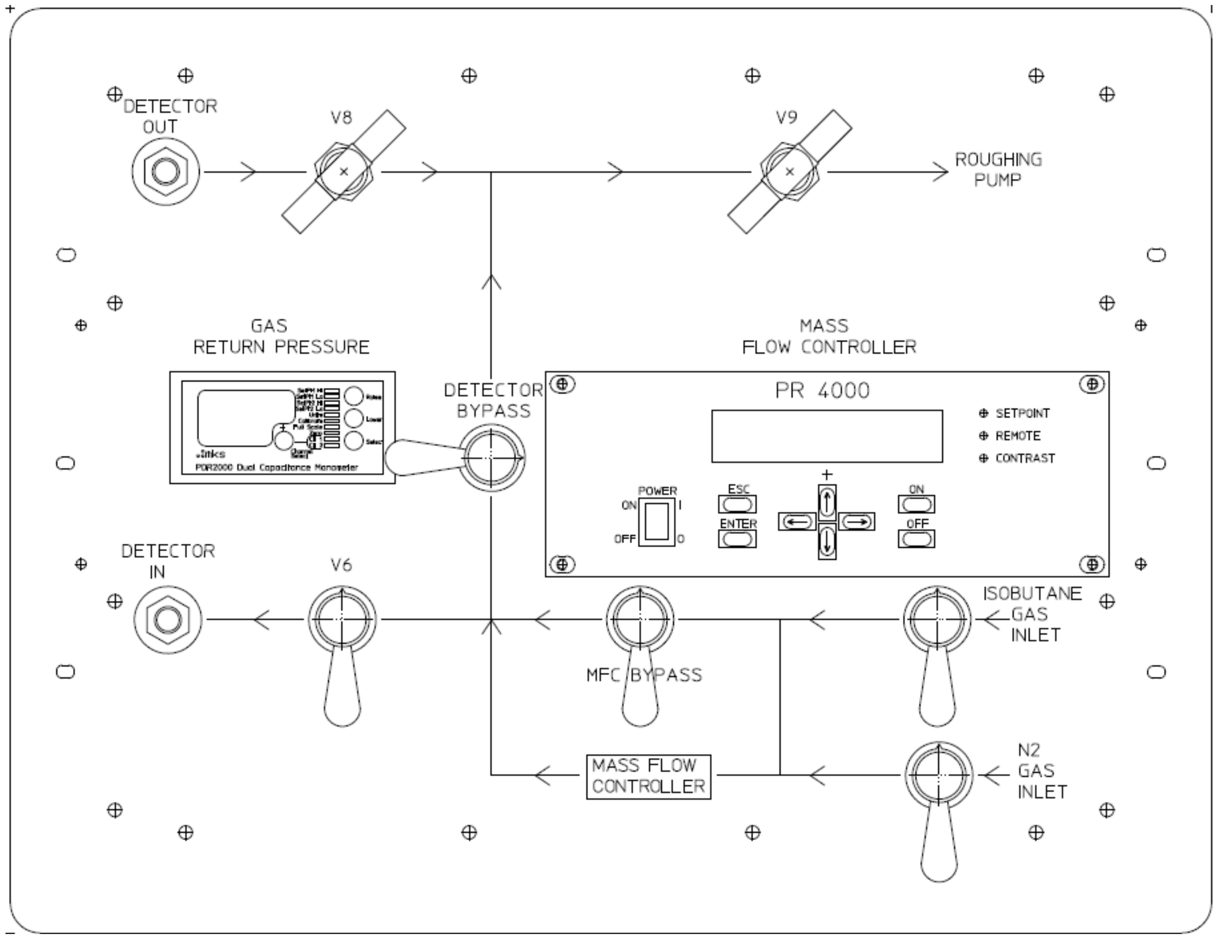
After the gas pressure and flow is stabilized, one then can bring up the bias (~ +400V) on anodes through the amplifier box and the counter is ready for beam.

IV. Letting up to air

It is necessary to dump the isobutane in the detector system before letting up to air. Procedures are described below:

1. Turn off the bias on the counter.
2. Turn off the control of PR4000 to stop the gas flow to the counter.
3. Close the isobutane bottle.
4. Open V9 gently until fully opened to pump out isobutane.
5. Open gently Detector Bypass and MFC Bypass to establish the flow path to the outlet for the remaining isobutane in between the gas regulator and the Mass Flow Controller.
6. Wait until the reading on Gas Return Pressure and PR4000 reaches ~0.15 torrs.
7. Close V9 fully and turn off the pump.
8. N_2 input to the counter can be made via either N_2 Gas Inlet or the vent valve installed on the gas regulator for the isobutane bottle.
9. Open slowly either Isobutane Gas Inlet or N2 Gas Inlet to the air pressure.
10. Turn the power off for PR4000.
11. Close the inlet when the counter is in air pressure.

Appendix B: The front panel of the gas handling system



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