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$^{252}_{98}$Cf Source User's Manual

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Contents

1 Introduction

Neutron detector calibration requires a neutron source with a known energy distribution. ^{252}Cf undergoes spontaneous fission and emits neutrons with a known energy distribution [CSEWG]. If the ^{252}Cf sample is contained inside an ionization chamber, the chamber generates electric pulses when a radioactive decay occurs.

The chamber described in this manual is used at Triangle Universities Nuclear Laboratory (TUNL) [1] and Duke Free Electron Laser Laboratory (DFELL) [2] which are located at Duke University in Durham, North Carolina, USA. This report documents how to use the source in the DFELL gamma vault. It details steps that must be taken before and during a research trip to Duke and contains a section for notes from previous trips.

2 General Information

^{252}Cf undergoes radioactive decay through two processes. The most common process is alpha decay, which has a branching ratio of 96.91%. ^{252}Cf also undergoes spontaneous fission which has a branching ratio of 3.09%. Spontaneous fission releases an average number of 3.77 neutrons per event. ^{252}Cf has a half live of 2.65 years [CSEWG].

The ^{252}Cf fission chamber has a thickness of 3.6 mm and an outer diameter of 40 mm. The source sits inside the innermost part of the chamber, which has a diameter of 20 mm. The back side of the chamber has two gas lines for methane; one line is for fresh methane and the other is for exhaust. There is also a single electrical connection. This connection has two functions. It supplies power to the chamber and at the same time transmits signals from the chamber to the electronics. A side profile of the source be viewed in figure 1 with the lines wrapped in tape.

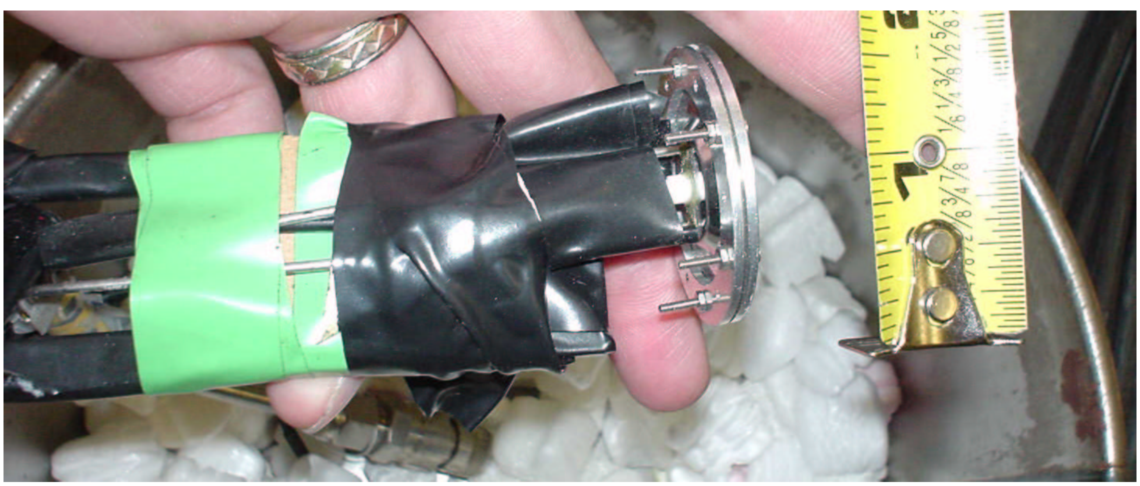

Figure 1: ^{252}Cf chamber with methane and electrical lines.

The ionization chamber contains two plates with different charges. These plates create an electric field across the Californium. Since molecules are neutrally charged, their interaction with the electric

[1] www.tunl.duke.edu

[2] www.fel.duke.edu

field does not create a signal. When a radioactive decay occurs, a charged particle travels through methane inside the chamber. The charged particle ionises gas molecules. This causes a cascade effect and an electric current. The signal generated is measurable and can be used to determine when a radioactive decay has occurred. For more information about fission chambers, see [Leo].

3 Preparation

The ^{252}Cf source ionization chamber uses a 300V Eveready No. 493 NEDA 722 battery. It does not use an AC/DC power supply because of the line noise associated with such supplies. A non-dead battery must be located before the source is to be used. This battery is rare and a replacement would likely have to be special ordered. Thus, a good battery should be located days before the source is to be used.

A methane source must be found before using the ionization chamber. Since the methane will be in a gas cylinder, a full cylinder and regulator are required.

The chamber may be needed by other groups at TUNL or DFELL so it should be requested in advance. It is stored in a vault at TUNL and a TUNL member is required to initially access it.

4 Physical Setup

The ^{252}Cf source is enclosed in a small disk with delicate pipes coming off the back. It must be supported to avoid stressing the pipes. A chemistry stand with two arm-clamps can be used to hold the methane lines and the source in mid-air. The source must be held off the ground to reduce the number of neutrons scattered from the cement. The detector should also be raised from the cement to reduce the number of neutrons scattered into it from the floor. Figure 2 shows a typical setup.

5 Methane Setup

The ^{252}Cf source ionization chamber must be filled with methane for proper operation of the device. The methane will most likely come in a gas cylinder with a regulator.

A bubbler will be used to control the flow of methane from the cylinder to the ionization chamber. The bubbler comprises of a filter flask with one tube submerged in mineral oil. Mineral oil is used for medical purposes and can be purchased at any pharmacy. The submerged tube is the input from the regulator and the side tube is the output to the chamber. By adjusting the line pressure with the regulator, one can cause the tube to make bubbles in the mineral oil. A bubble rate of one per second is sufficient to supply methane to the ionization chamber. Figure 3 shows the in and out methane lines and a bubble in the mineral oil.

After the bubbler, the gas flows through the lines into the chamber. From the chamber, the gas flows through an exhaust line and must be connected to an exhaust vent.

After turning on the gas, the system must be allowed to purge for one hour before the ionization chamber electronics can be connected to power.

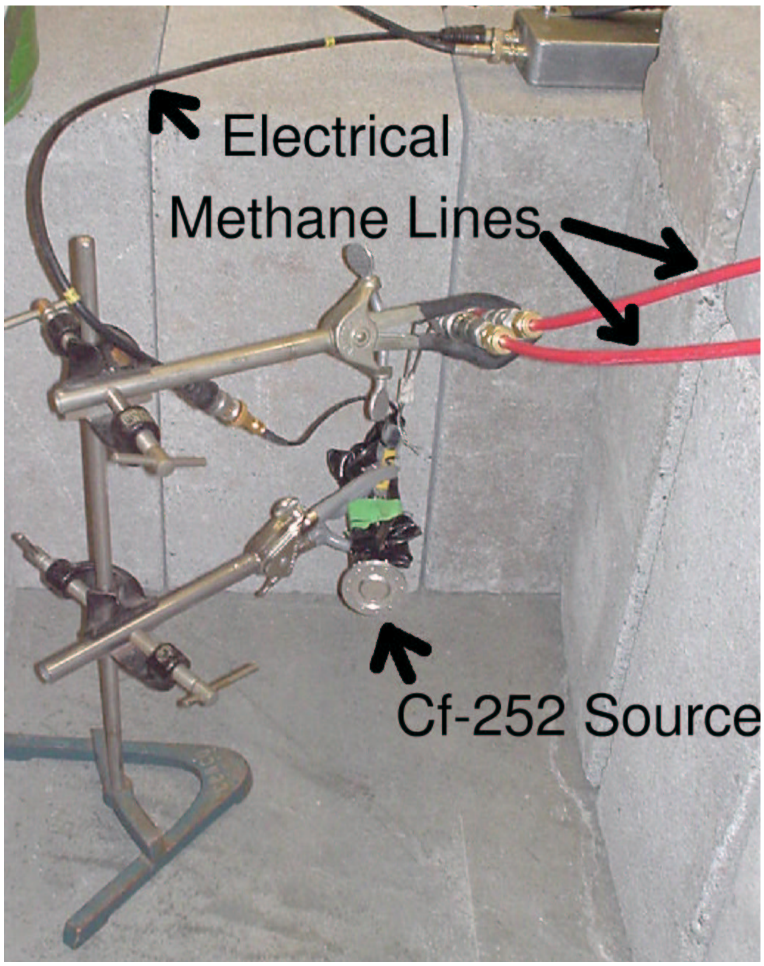

Figure 2: Source Setup.

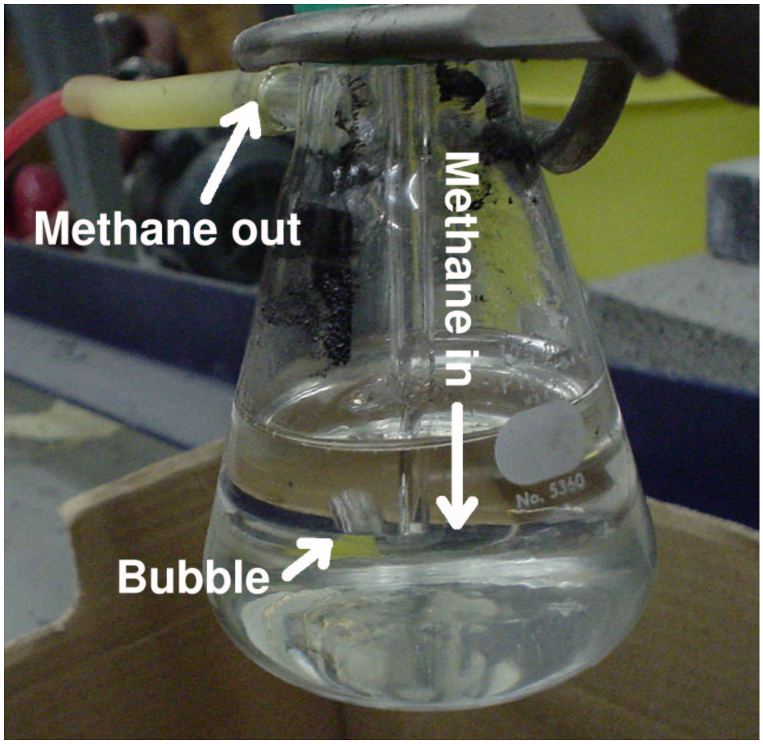

Figure 3: Bubbler Setup.

6 Electronics Setup

6.1 Ionization Chamber Power

The ionization chamber is powered by a 300V Eveready number 493 battery. The battery is contained inside an aluminum box. It is connected to a switch and a fine adjustment system using banana cable connectors. The connector on the outside of the battery box is BNC type with the center pin biased negatively. The battery box connects to a power-distribution box. The power-distribution box has an SHV type connector so a BNC to SHV adapter is required. An electronics diagram is shown in figure 4.

The power-distribution box has three ports. One port is the SHV power connector. A second port is used to connect the ionization chamber (both power and signal travel down the same line). A third port is a signal-out port that goes to a pre-amplifier. Figure 5 shows the power-distribution box and pre-amp.

When not in use, the battery must be disconnected to prevent drainage.

6.2 Ionization Chamber Signal

The pre-amplifier generates a usable analog signal. However, this signal is not properly conditioned for a discriminator. Due to the small amplitude of the signal, its rough shape and multiple peaks, the signal should be shaped and amplified before being sent to the discriminator. A timing-filtering amplifier (TFA) should be used to condition the signal. After the TFA, the signal can be sent to a discriminator and converted into a NIM logic pulse.

The chamber responds differently to spontaneous fission decays versus alpha decays. Alpha decays

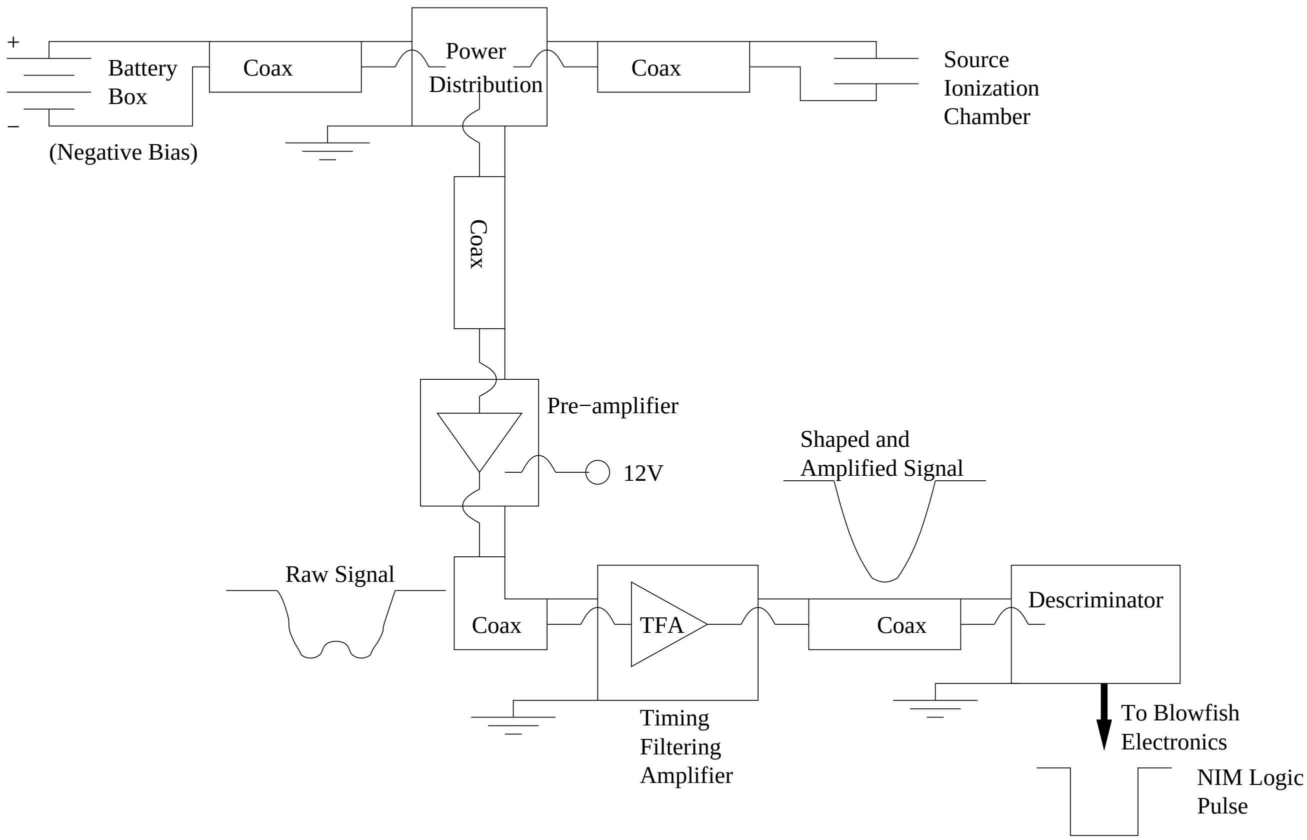

Figure 4: Diagram of the Ionization Chamber's Signal Conditioning Electronics.

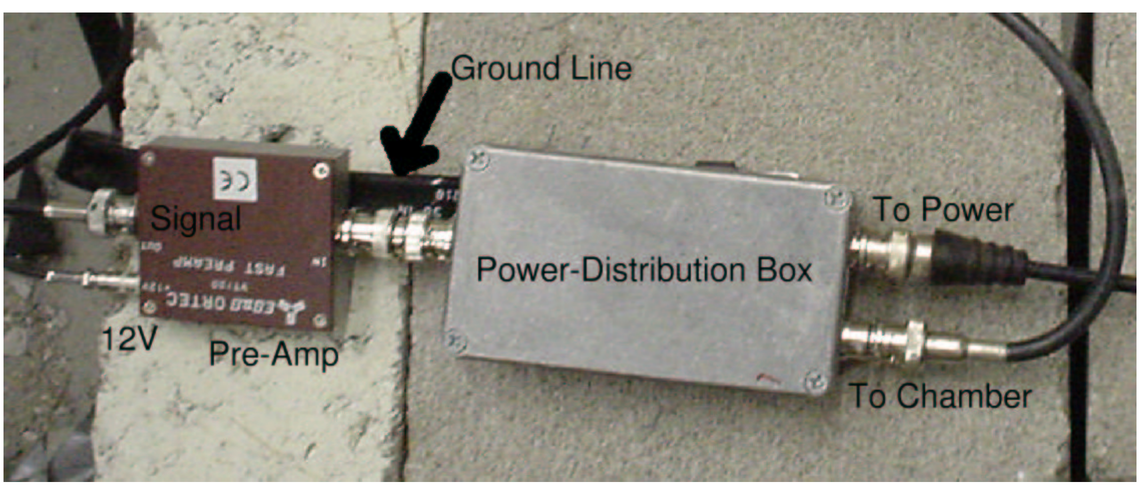

Figure 5: Power-Distribution Box.

generate a much smaller signal in the fission chamber than spontaneous fission decays [Böt]. In setting the discriminator threshold there is a plateau region clearly separating the alphas and the fissions. The discriminator threshold should be set in this region to filter out all the alpha decays but allow the spontaneous-fission decays. A measured ADC spectrum can be seen in figure 6. Notice that the alpha decays are filtered out by the discriminator and the hump is due entirely to fission decays. The sharp edge in figure 6 is normal for spontaneous-fission decays and not due to a discriminator threshold.

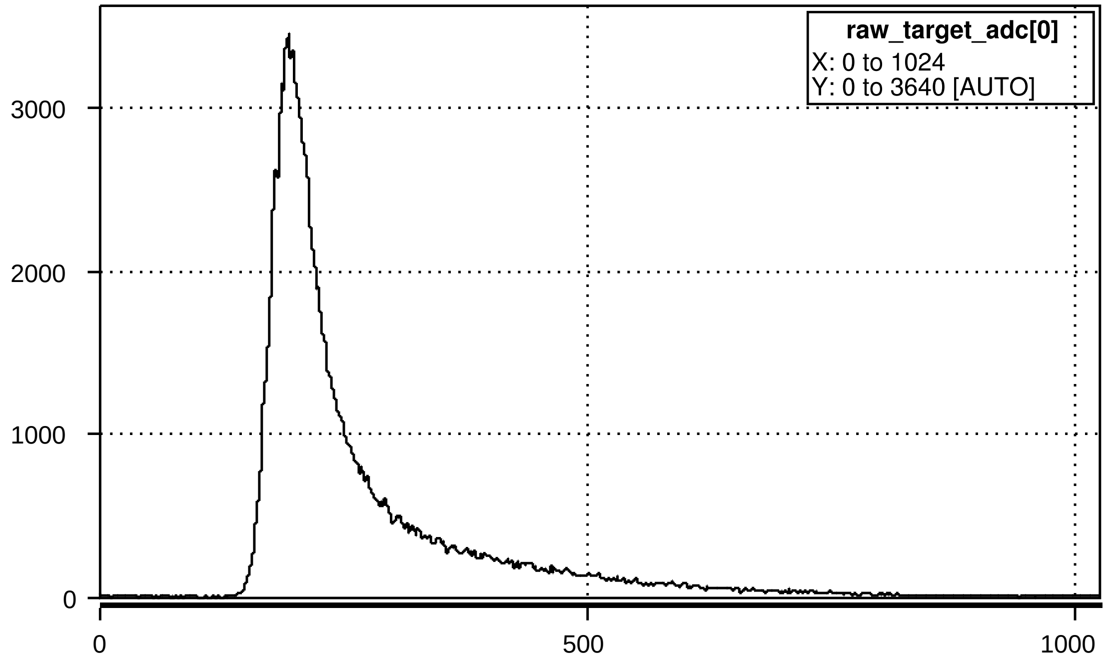

Figure 6: Fission Chamber ADC Spectrum With Arbitrary Units

7 Checklist

Before leaving for Duke University:

1. Request the source in advance from a TUNL member.
2. Ensure that there is a 300V Eveready No. 493 NEDA 722 battery available at Duke.
3. Ensure that a methane source will be available.

Before connecting the source to power:

1. Ensure the methane is flowing through the source.
2. Allow the methane to purge all air from the source for one hour.
3. Connect the electronics as shown in figure 4.

After connection the source to power:

1. When not using the source, disconnect the battery to prevent drainage.

8 Notes from Runs

8.1 August 2004

The timing-filtering amplifier (TFA) used for this run was an Ortec 454. The Coarse gain was set to 20 and the fine gain was set to the minimum. Differentiation was turned off and the integration time was set to 20ns. One should note that the input to the TFA is high impedance so a T-junction and 50Ω terminator were used to prevent reflections.

A CF 8000 constant fraction discriminator was used to convert the analog signals from the fission chamber and detector into NIM logic. The discriminator threshold was set to 50mV for both devices.

After the CF 8000, the signals were then sent into the labyrinth that is the blowfish electronics. The X-arm circuit was used to connect the chamber and the regular neutron circuit was used for the neutron detector.

A 300V battery and a bottle of mineral oil were purchased by the UofS and stored in the UofS/UVA cabinets.

References

[Böt] R. Böttger *et al.,* Nuclear Science and Engineering **106**, 377 (1990).

[CSEWG] Cross Section Evaluation Working Group, *Evaluated Nuclear Data File (ENDF) Database Version of February 09, 2004,* http://www.nndc.bnl.gov/endf/index.html (accessed 13 July 2004).

[Leo] W.R. Leo, *Techniques for Nuclear and Particle Physics Experiments.* Springer-Verlag, Berlin (1994).