

LOW-PRESSURE MWPC SYSTEM FOR THE DETECTION OF ALPHA-PARTICLES AND FISSION FRAGMENTS

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Received 15 June, 2010

Abstract A low-pressure, position-sensitive, multi-wire proportional chamber (LPMWPC) system with an active area $12 \times 12 \text{ cm}^2$ for the detection of heavy nuclear fragments, has been developed for use in tagged photon beam experiments. The LPMWPC system can be operated in single as well as double step operational modes. In the case of double step operational mode with a high gas amplification factor, signals from α -particles reside well above the electronic noise. Typical energy loss spectra of alpha particles and fission fragments (FF) obtained from a ^{252}Cf source are shown and discussed. The pulse height distributions of α -particles have a Landau distribution shape, while the pulse height distribution of FFs differs from Gaussian shape. It has long tails at both low- and high- energy sides. The average pulse height ratio of alpha particles and FF's is close to the theoretical value and amounts to about 1/80.

Keywords: low-pressure MWPC, ionization energy loss, fission fragment, alpha particle

1. Introduction

A fission-fragment detection system, FFD, was designed and built in order to measure the absolute photofission cross sections for the actinides ^{238}U and ^{237}Np at MAX-lab tagged photon beam within statistical and systematic error less than 3% [1]. The FFD should have capability operate with tagged photon beam and separate unambiguously binary photofission events from background reactions, e.g. from fragmentation reactions. Our FFD is based on low-pressure multi-wire proportional chamber (LPMWPC) techniques, the properties of which are suited for these goals. The history of LPMWPC techniques and its applications are enlightened in [2] (and references therein). The FFD is displayed schematically in Fig. 1. It consists of four windowless LPMWPC units, which form two symmetric arms placed above and below the central beam. The chambers have an active area of $12 \times 12 \text{ cm}^2$. The inner chambers have a separation distance of 3 cm from the anode plane to the central beam. The outer chambers are located 8 cm away from the central beam. The solid state detectors will be mounted just behind outer chambers and will provide only pulse height information for evaluation of the energy of fission fragments. Each arm provides about 2.5 sr of solid angle coverage and measures the time-of-flight (TOF) as well as the fragment trajectory and energy. The target is located at the center of the two arms. When a photofission event occurs, two fission fragments are emitted in opposite directions, go through the FFD and are registered. The assembly of the windowless LPMWPC system and experimental target is placed in

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a cylindrical vacuum chamber. There are two windows for the incoming beam and outgoing particles.

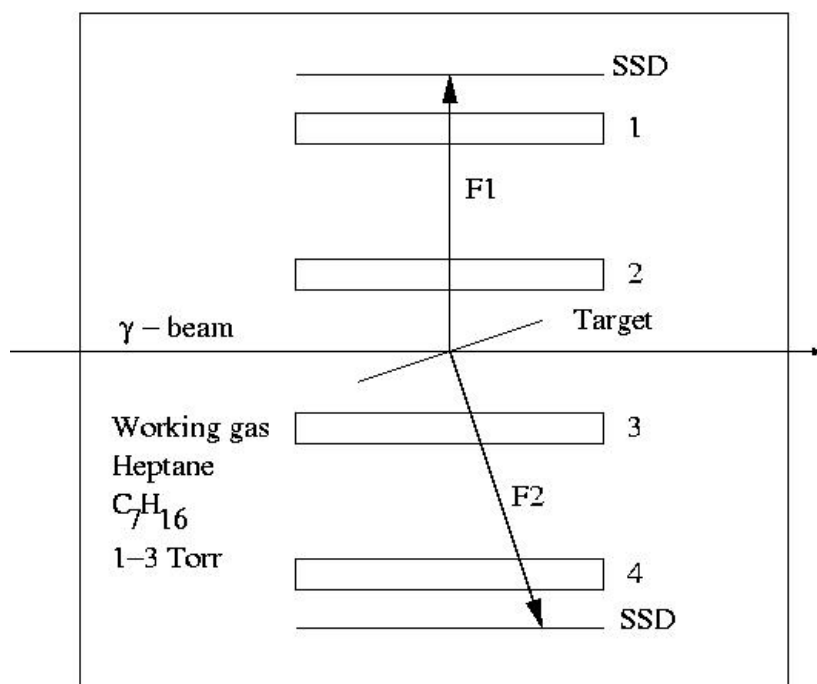


Fig. 1. A schematic sketch of the fission fragment detector.

The time and position resolutions of a similar FF detector, operating in the single step mode, have been studied before and results are documented in [2]. Typical values of the time and position resolutions (FWHM) are about or less than 300 ps and 1 mm consequently for fission fragments. However, the energy loss spectrum of α -particles and fission fragments in the LPMWPCs, which are very useful and needed for a correct threshold adjustment of the timing discriminators in photofission experiments to minimize the systematic error, has not been investigated in detail previously. The theoretically expected ratio of ionization energy loss, dE/dx , of α -particles and fission fragments is about 1/88. The existing experimental data, which was obtained mainly by using parallel plate avalanche chambers (PPACs), lay in the range from 1/5 to 1/35 [3-9]. Such a big differences between measured and theoretically expected values was explained by space charge effects, which decreases the pulse heights produced by the strongly ionizing fission fragments.

We present here an energy loss, dE/dx , spectrum of α -particles and fission fragments from a ^{252}Cf source, measured by the MAX-lab prototype FF detector in the single step and double step operating modes. The architecture of LPMWPC and schematic of the test experiment are presented in Section 2. The signal processing and results of the investigations of the energy loss, dE/dx , spectrum of α -particles and fission fragments from a ^{252}Cf source, measured in the single and double step operating modes of LPMWPC, are discussed in Section 3.

2. Architecture and operational modes of the LPMWPC system

The structure of the MAX-lab LPMWPC is similar to the FF detector which has been developed earlier for hypernuclear studies [2], therefore only a short description is presented here. In Fig. 2 the structure of the LPMWPC unit is illustrated schematically. It consists of five electrodes made of wire planes. The electrodes are made of G10 (epoxy) with a thickness of 3 mm, which is also the plane spacing. The central electrode is a wire-anode plane from which the time signal is extracted. All anode wires are grouped together with a special passive mean timing scheme (see [2] for details]. The anode is placed between two cathode wire planes which have their wires oriented at an angle of 90 degrees with respect to each other. The active area of the chamber is $12 \times 12 \text{ cm}^2$.

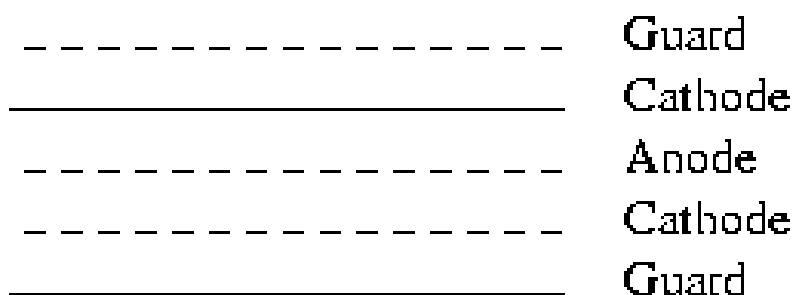


Fig. 2. Schematic diagram of the structure of LPMWPC.

The positive signals induced on the cathodes are used for (x,y) position readout, one coordinate from each cathode plane. Both the anode and cathode planes have wire spacing of 1 mm. The anode plane uses 20 micrometer diameter gold-plated tungsten wire, while the cathode planes use 40 micrometer diameter copper-beryllium wires. For position resolution, groups of three cathode wires are connected to delay lines taps (2 ns/tap, 1507-20B, from Data Delay Devices, Inc.). The two outer wire planes function as either guard planes against electrons from ionization taking place outside of the chamber region, or additional electrodes to form the double-step gas amplification. Due to the large active area, a passive mean timing was made in grouping the anode wires to minimize position dependence of the time resolution [2].

A test experimental setup was designed and built in order to investigate operational modes of the LPMWPC unit and measure the energy loss (dE/dx) spectrum of α -particles and fission fragments from a ^{252}Cf source. The LPMWPC unit is mounted on the mounting frame. The side view of this unit is shown in Fig. 3. Fast amplifiers are mounted on the chamber mounting frame, and have a maximum input cable length from amplifiers to MWPC planes of about 10 cm, to optimize the signal to noise ratio and fast response. Cables from the amplifiers and for low and high voltage supplies are connected to vacuum connectors mounted on the same frame to provide easy access to electrical connections outside the vacuum chamber. This unit is mounted in a cylindrical vacuum chamber. The vacuum chamber is connected to a vacuum pumping system and can be

evacuated to a pressure of 10^{-3} Torr. It is equipped with stainless-steel valves for gas handling and two barometers for pressure measurements. The chamber volume is connected to a reservoir of liquid heptane, with a reducing valve, and filled with about 3 Torr of gas vapor, the density of which is equal to ~ 4.2 microgram/(cm³ Torr). The ²⁵²Cf source is mounted in a source holder with a collimator at a distance 11 cm from the LPMWPC central plane and provides alpha and FF for calibration and testing procedures. Due to collimation only alpha particles and FF with angles less than 15 degrees, relative to the axis perpendicular to the anode plane, are detected.

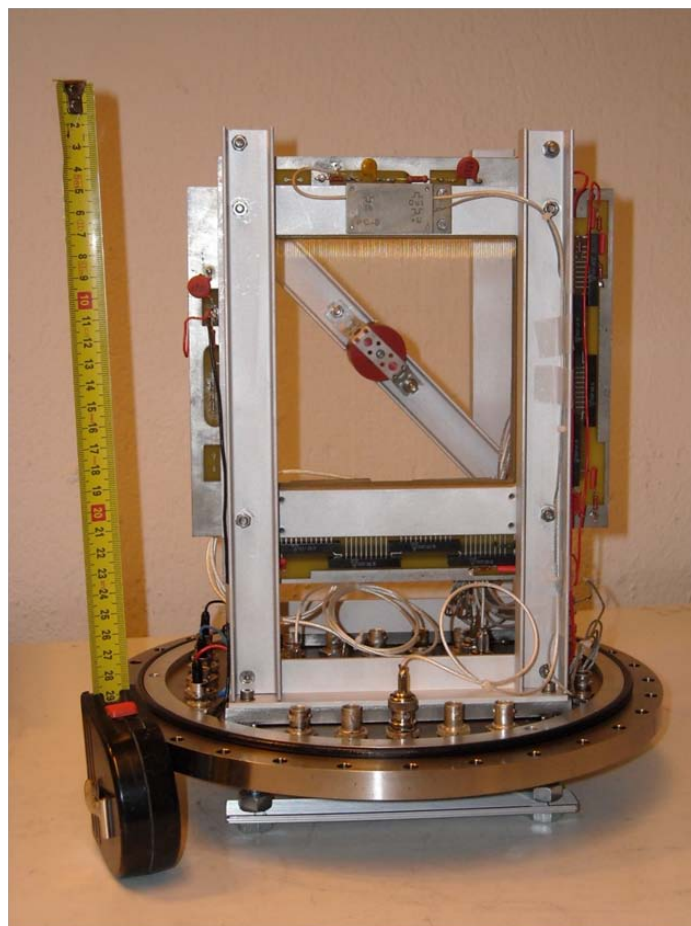


Fig. 3. Side view of the LPMWPC unit with the Cf-252 source mounted behind the unit.

The LPMWPC system can be operated in the so-called single-step and double-step operational modes [2, 10]. In the case of the single step operational mode the typical potentials applied to the anode, cathode and guard planes are about +400, -100 and 0 V respectively and the resulting signals from the FF have about 200-300 mV amplitudes, while signals from α -particles are less than the amplitudes of electronic noise of the preamplifier which is about or less than 5 mV. The typical one step mode signal generated by FF and detected with a digital scope is shown in Fig. 4. The oscillations in the tail of signal are due to the applied passive mean timing scheme.

In the case of the two step operational mode the typical potentials applied to the anode, cathode and guard planes are about +300 V, 0 V and -300 V respectively and the resulting signals

from the FF are about 1.0 -1.5 V, while signals from α -particles are in the range 12-20 mV, well above the electronic noise of the detector. The typical signals from FF and α -particles are shown in Fig. 5 and Fig. 6, respectively.

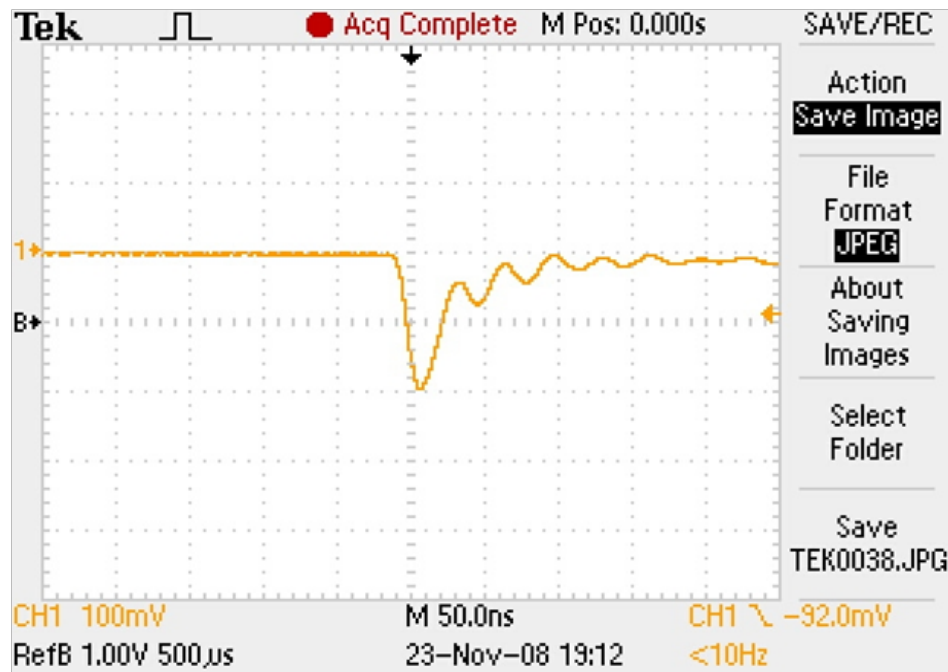


Fig. 4. Typical FF signal. One-step operational mode.

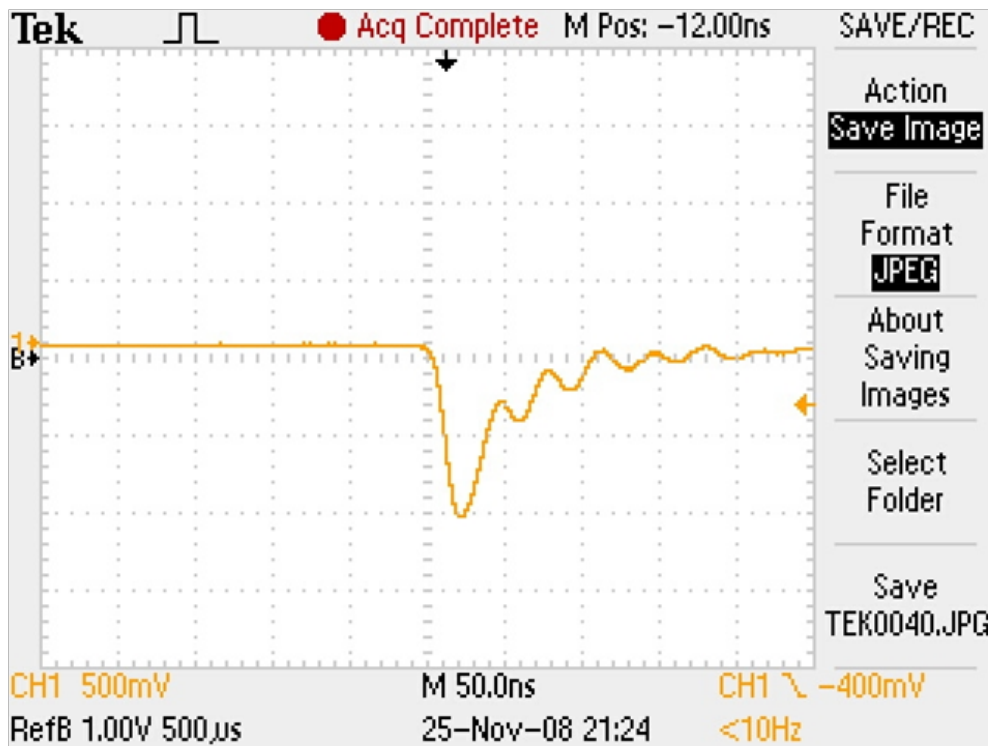


Fig. 5. Typical signal generated by FF. Two step operational mode.

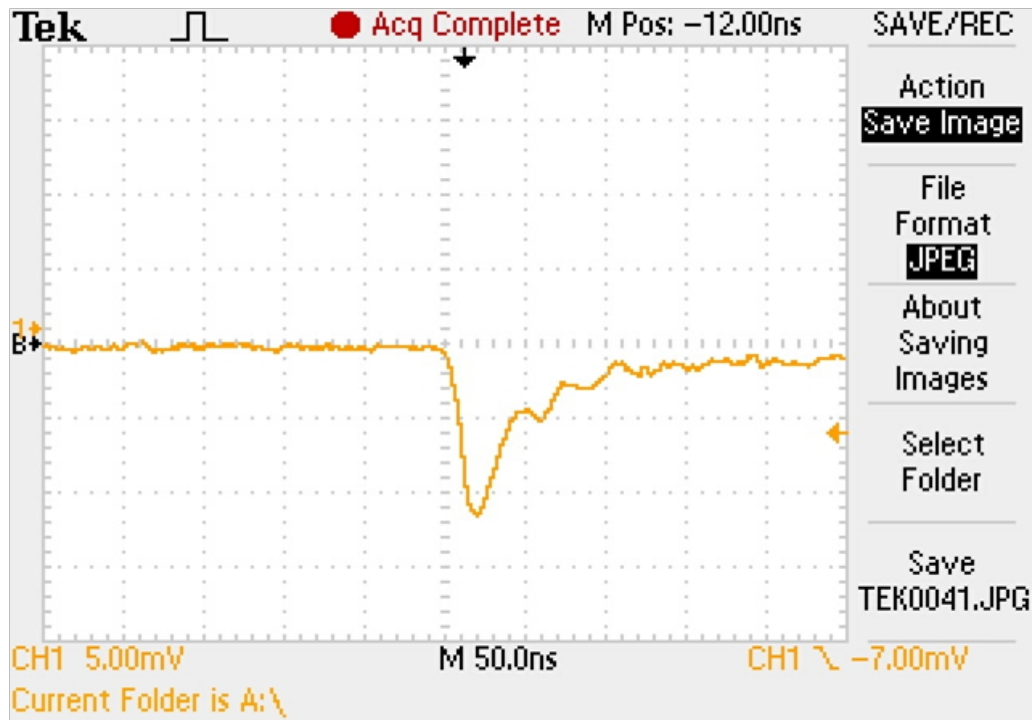


Fig. 6. Typical signal generated by an alpha particle. Two step operational mode.

3. dE/dx spectra of α -particles and FFs from a ^{252}Cf source

The time and position resolutions of a similar LPMWPC system, operating in the single step mode, have been studied before [2]. We present here an energy loss, dE/dx , spectrum of α -particles and fission fragments from a ^{252}Cf source, measured by the LPMWPC unit operated in the single and double step modes. Signals from the anode (T1) plane have been used for energy loss spectrum studies, while the cathode signals (X1R and Y1R) have been used for positioning. Fig. 7 ^{a), b)} shows the signals readout and data acquisition schemes.

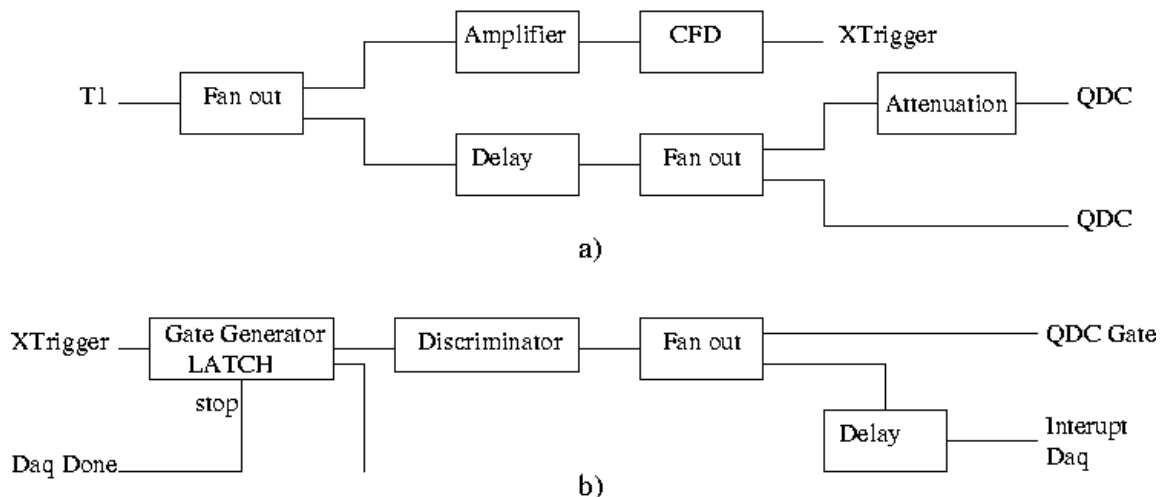


Fig. 7. Electronic scheme of the test experiment (a) and schematic of the data acquisition (b).

The T1 analog signal from the anode is fanned out; one is linearly amplified and fed to a constant fraction discriminator (CFD) and constitutes the trigger (XTrigger). The other signal is delayed and fanned out again. Here, one signal goes directly to the amplitude-to-digital converter (ADC) and the other copy is attenuated before being fed to the ADC.

The XTrigger starts a latch which is eventually stopped by the data acquisition (DAQ) when it has finished reading, filling the histogram and saving the data. The latch is fed to a discriminator whose output width is adjusted so that the ADC integrates the full pulse. The output from the discriminator is also used to set the DAQ interrupt flag. The DAQ interrupt flag is delayed to accommodate the conversion time of the ADCs.

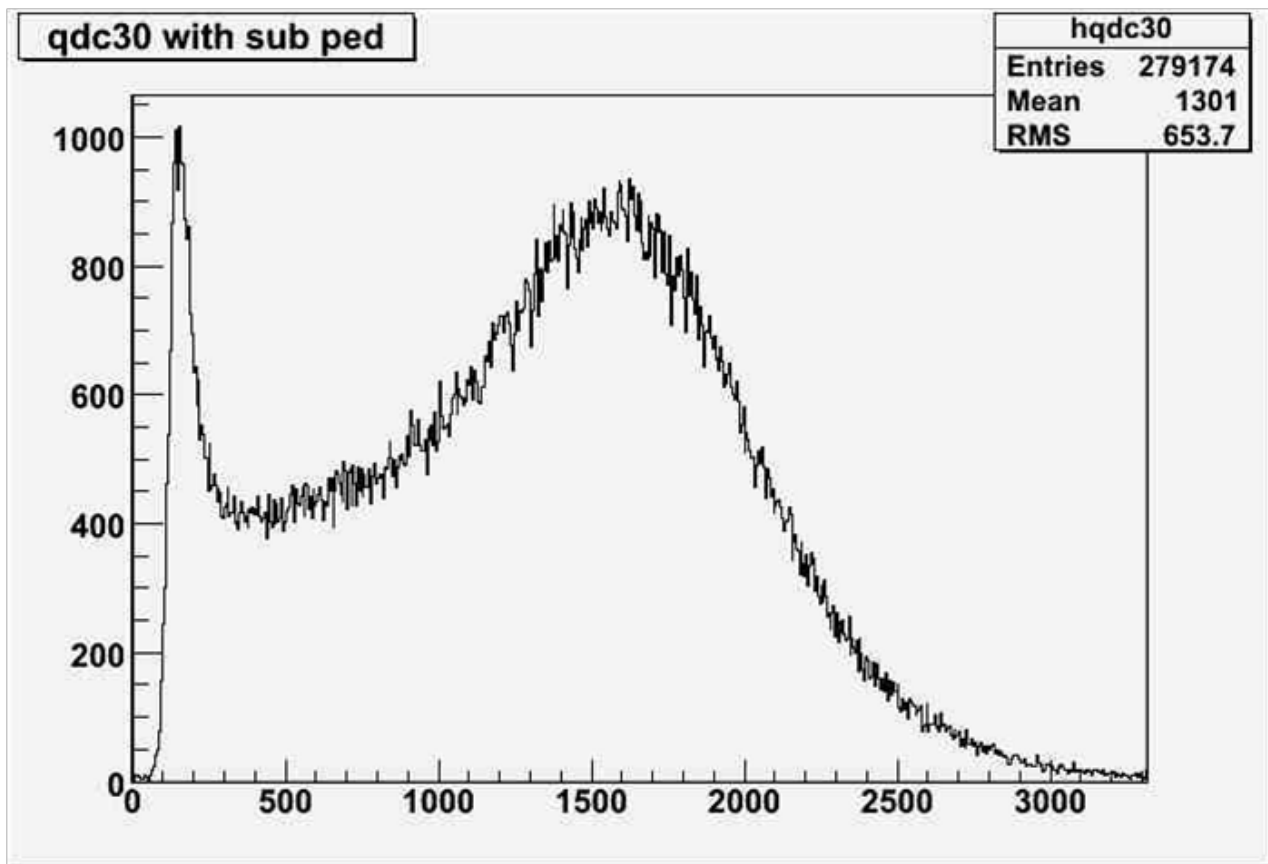


Fig. 8. Pulse height spectrum of FFs and α -particles from a ^{252}Cf source measured with a single step LPMWPC.

The measured energy loss spectrum for the single step operational mode of the LPMWPC is presented in Fig. 8. In this mode of operation we don't see signals from α -particles, which means that the amplitudes of the signals generated by α -particles is less than the discriminator threshold which is equal to 5 mV. The amplitude of the signals generated by FFs measured by a digital scope (Tektronix 2022B) is about 200 mV and consequently the pulse height ratio of FF's and α -particles is expected to be larger than 40. The rise time of signals in this case is about 7 ns. The obtained energy loss distribution is much wider than have been measured in previous experiments [3-9].

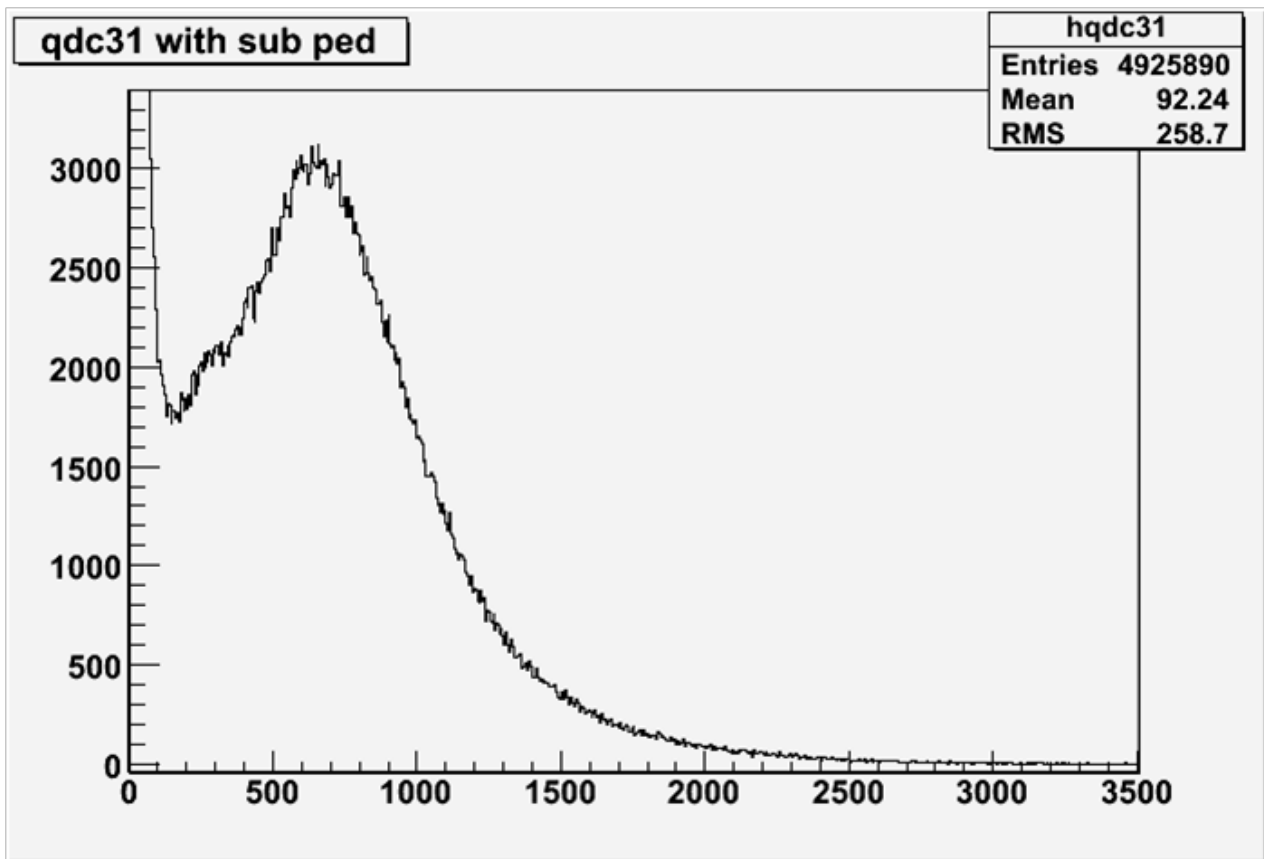


Fig. 9. Pulse height spectrum of FFs and α -particles from a ^{252}Cf source measured with a double step LPMWPC. Pulses are 10 times linearly attenuated.

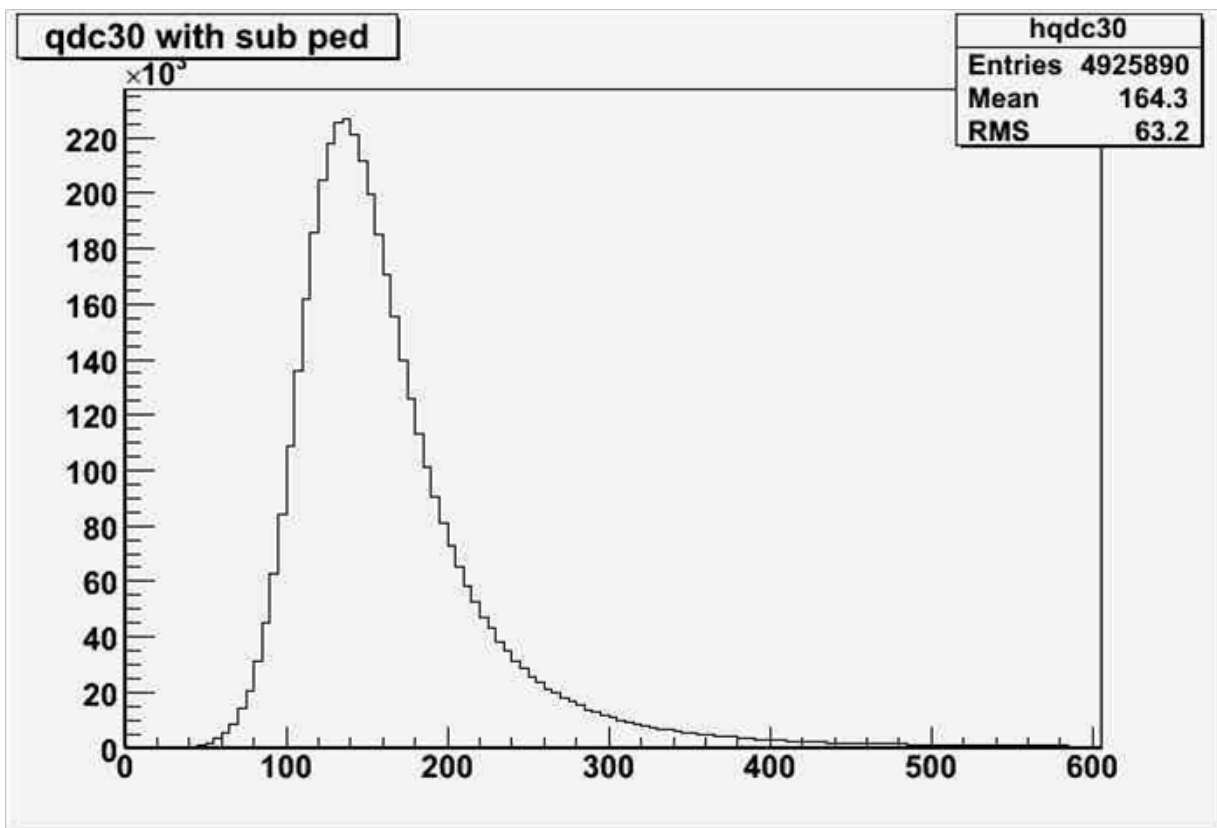


Fig. 10. Pulse height spectrum of α -particles from a ^{252}Cf source measured with a double step LPMWPC. Pulses are not attenuated.

The 10 times linearly attenuated pulse height spectrum of FFs and α -particles measured with a double step LPMWPC are shown in Fig. 9. The measured distribution has long tails at both low and high energy sides, which does not observed in the previous experiments [3-9]. The energy loss spectrum of α -particles is shown separately in Fig. 10 without attenuation. It has a typical Landau distribution shape with FWHM of about 60%. The observed yield ratio of FFs and α -particles from a ^{252}Cf source is close to the expected value 1/31. The average pulse height ratio of α -particles and FF's measured by digital scope is close to theoretical value and amounts to about 1/80. In previous measurements this ratio ranges from 1/5 to 1/35 [3-9].

4. Conclusions

In conclusion, we have described the construction and the performance of a position sensitive LPMWPC system with an active area $12 \times 12 \text{ cm}^2$ for the detection of fission fragments as well as α -particles. The energy loss spectra of α -particles and FFs from a ^{252}Cf source have been measured with a single and double step LPMWPC. In the double step mode of operation the pulses of α -particles reside well above the level of the electronic noise and can be processed by using the same electronics as the fission fragments. The pulse height distribution of the signals generated by α -particles, has a typical Landau distribution shape with $\sim 60\%$ FWHM, while the pulse height distribution of signals generated by FFs differs from Gaussian shape. It has long tails at both low and high energy sides. The average pulse height ratio of the signals generated by α -particles and FFs is about 1/80 and close to the theoretical value 1/88, i.e. the space charge effects play a minor role in this case and gas amplification is the same for the weakly ionizing alpha particles and strongly ionizing fission fragments.

These studies demonstrated that space charge effects play a minor role in double step operation mode of low-pressure MWPC. Such a linear response of the technique in a wide dynamic range from alpha particles to FFs is an important property for unambiguous separation of FFs and therefore precise measurements of photofission cross sections at MAXlab [1, 11]. Meanwhile the technique can be used for detection of low energy recoils such as ^3He and ^4He .

ACKNOWLEDGMENTS

A.M. would like to thank the members of the MAX-lab staff and Nuclear Group for their efforts and hospitality during his stay at MAX-lab and Dr. A. Sirunyan for useful discussions. This work is supported in part by Grant from the Swedish Foundation in Research and Higher Education, STINT.

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