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Recent results on a simple scheme for 2D localization of particles in a wire chamber

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Abstract

A simple scheme for 2D localization of ionizing particles in a multiwire proportional chamber has been proposed, in which a multilayer printed circuit board replaces the usual X and Y cathode wire planes involved in the position encoding. Results are shown that illustrate performance improvements: differential non-linearity $<10\%$, integral non-linearity $<0.1\%$ and spatial resolution <1 mm in both directions. Also presented are two image acquisition interfaces for PCs. One of these makes use of the PC's Pentium processor to histogram data in the computer memory, reaching counting rates up to 3×10^5 events per second. In the other one, a logic machine is used instead of a dedicated processor, allowing histogramming rates up to 10^6 events per second into an on-board 1 Mword memory.

1. Introduction

Particle detectors using a gas as absorbing medium and wires as charge collection electrodes are widely used in several applications, from simple counters up to large area 2D position sensitive detectors. Important developments in this field do not seem to be close to exhaustion. One of these recently established the use of the gas electron multiplier structure [1], which opens new trends to the use of gaseous detectors by improving their operating conditions. New applications extending the use of multiwire proportional counters beyond the physical research domain are also being considered [2]. In the present work, we report recent results of a simplified scheme for 2D localization in a multiwire proportional chamber, in which only one wire electrode is used to collect the avalanche electric charge. The position readout is done by sampling the charge induced by avalanches on conducting pads distributed over a cathode plane (X&Y cathode), manufactured as a multilayer printed circuit board [3]. The delay-line method [4] is used to encode position coordinates. A description of the data acquisition interfaces developed for real-time storage and display of images generated by the detectors is also presented.

2. Results

The first published results [3], intended to demonstrate the applicability of the X&Y cathode, were obtained with a detector in which the wire pitch of the anode was 2 mm. This implied a poor spatial resolution, particularly in the regions between adjacent anode wires. The differential

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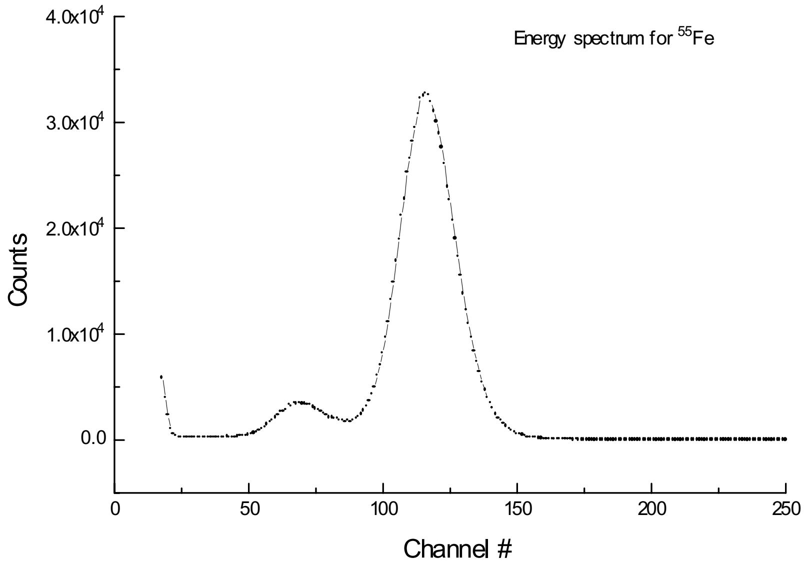

Fig. 1. Energy spectrum obtained by the illumination of an 11 mm diameter circular region in the center of the detector by an ^{55}Fe X-ray source.

non-linearity was also rather poor, since the detection efficiency was strongly modulated by the anode wire pitch and the $X\&Y$ cathode was not geometrically optimized for the avalanche charge sampling. By changing the design of the $X\&Y$ cathode and the wire plane (1 mm pitch, 10 μm diameter), we have been able to improve these features. The results here reported refer to detectors with $8 \times 8\,\text{cm}^2$ active window. The operating gas is argon + 25% ethane, 0.1 atm above normal pressure.

One of the consequences of changing the detector design was the improvement in energy resolution. As seen in Fig. 1, the Argon escape peak in the energy spectrum for an ^{55}Fe X-ray source is presently well observable. This figure corresponds to pulse height analysis of the anode signal, when a circular region of 11 mm diameter at the detector center is illuminated. The energy resolution for this spectrum is $\delta E/E = 23.4\%$.

In order to evaluate the differential non-linearity of the detectors, we have exposed them to isotropic illumination by an ^{55}Fe X-ray source placed about 30 cm away from the window. Fig. 2 shows the distribution of event counts over the window surface obtained in one of the measurements. In Fig. 3 are shown slices of the complete data set, in which it may be noticed that the detector response is homogenous in both X- and Y-directions, except at the sides of the window, where edge effects are present. A typical data set has been taken, where the average number of counts per channel was around 10^4. As shown in Fig. 4, the variations around the mean number of counts are within 10%. The standard deviation for this data set is 405 counts, indicating differential non-linearity around 4%.

Integral non-linearity measurements were carried out with a steel mask where a series of fifteen 300 μm slits at 5 mm pitch are provided. The mask is placed upon the detector window, oriented vertically or horizontally, according to the direction in which the non-linearity is evaluated. The detector is then irradiated with the ^{55}Fe X-ray source and images are acquired. Quantitative evaluation is done from any linear spectrum corresponding to a strip of the 2D set of data. Fig. 5 shows the results of this procedure applied to the X-direction. The top and right axes refer to a linear spectrum showing Gaussian shape peaks

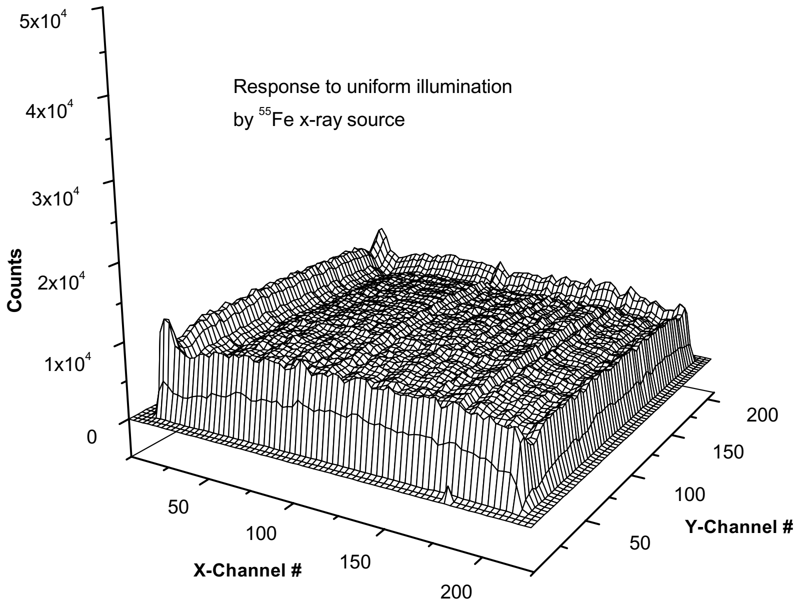

Fig. 2. Detector response to uniform illuminiation by an ^{55}Fe X-ray source. Pre-set total number of counts: 3×10^8.

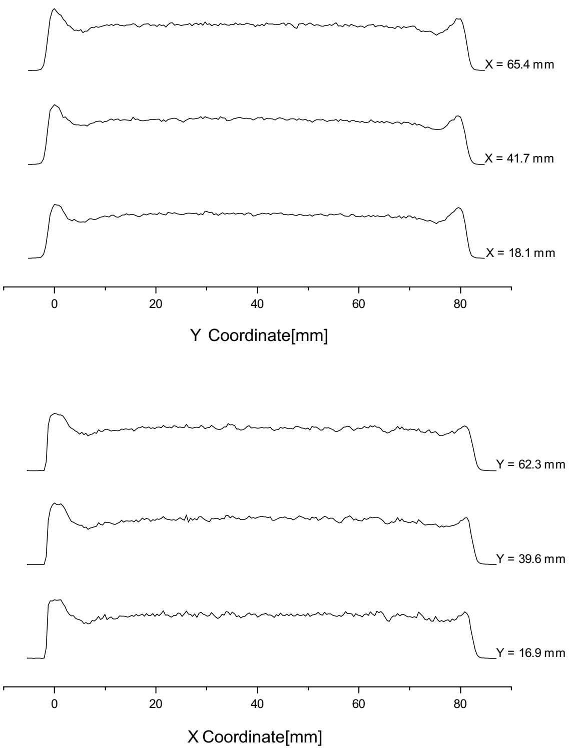

Fig. 3. Slices, from Fig. 3, illustrating the uniformity of response along the X- and Y-directions.

corresponding to the slits in the mask. The left and bottom axes refer to a linear fit of the peak central channel, obtained from a Gaussian fit to each peak, to the true slit position. The maximum deviation from true position to measured channel is below 0.27 mm, which corresponds to about 0.3% of the window length. However, this maximum deviation only occurs for the first and last slits, where the divergence of the X-ray source contributes most to the parallax error. For the central peaks, the deviation is less than 0.1%. The same is valid for the Y-direction, as shown in Fig. 6.

From data in Figs. 5 and 6, we notice that the Full Width at Half Maximum (FWHM) for the central peaks is below 1 mm. This suggests that the spatial resolution is better than 1 mm. For a more accurate measurement of the spatial resolution, we have used two 90 μm slits, which were placed orthogonal to each other upon the detector window and illuminated with the X-ray source 30 cm away from it, so that the resolution could be measured in both directions. Images were then acquired, with 512×512 pixels resolution. From the slits profiles measured, and taking into account the slits width, distance

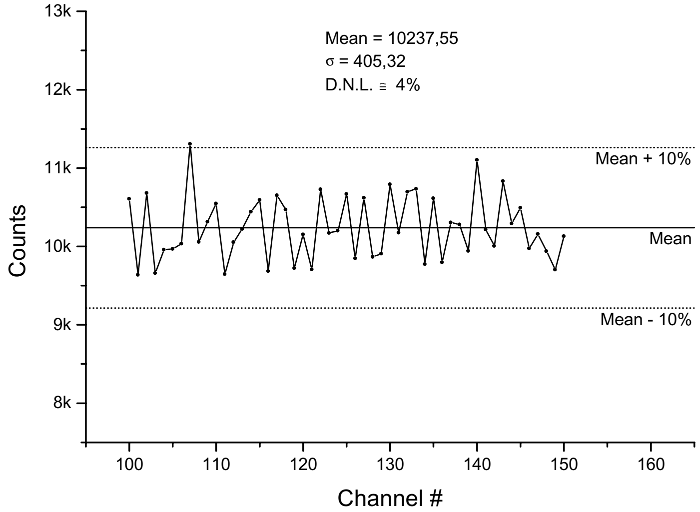

Fig. 4. Estimation of the differential non-linearity (DNL) for a typical data set.

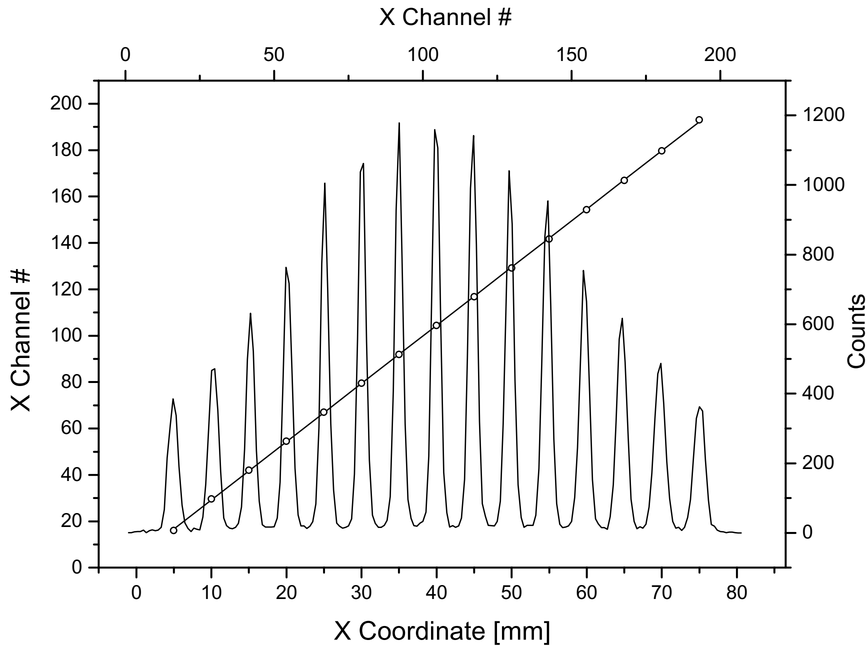

Fig. 5. Integral non-linearity measurements for the X-direction.

from detector to source and source surface dimensions, we could estimate the spatial resolution in both directions to be $\approx 700\,\mu m$ FWHM.

3. Data acquisition

Analog signals with heights corresponding to the X and Y position coordinates are generated by

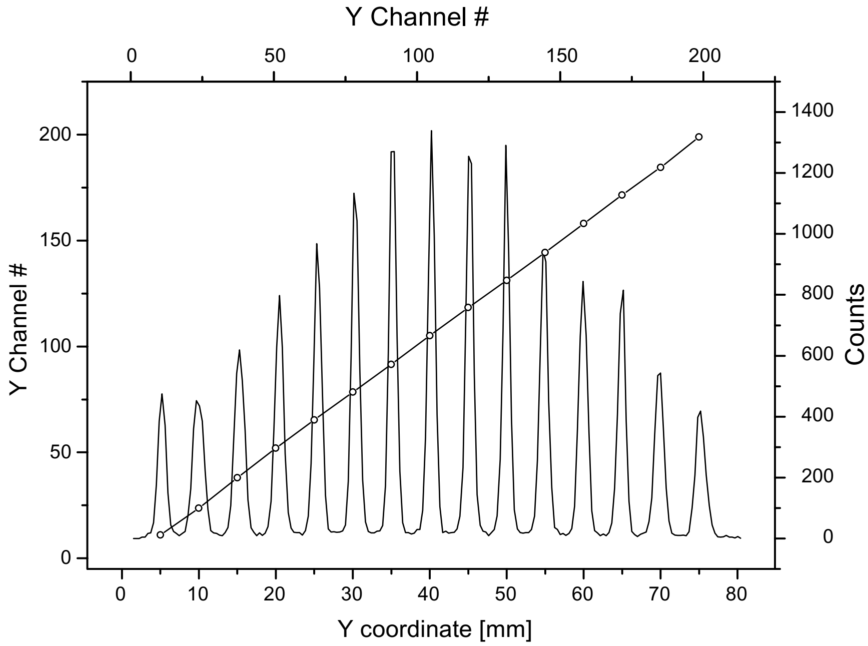

Fig. 6. Integral non-linearity measurements for the Y-direction.

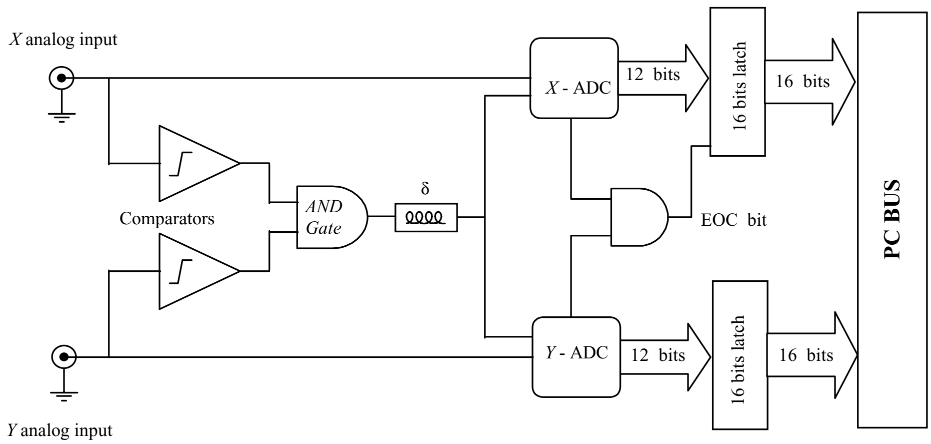

Fig. 7. Simplified circuit diagram from the data acquisition PC interface [5].

a time-to-amplitude converter [3]. These are input to a PC interface developed for image acquisition. The simplest version of the interface [5] comprises two analog-to-digital converters plus some analog and digital circuits. A coincidence signal is generated from the X and Y signals of each detected event, by use of comparators and an AND gate (See Fig. 7). The AND gate output is delayed, so that it triggers the ADCs conversion when the original X and Y input signals are stable, i.e., when they have reached their plateau amplitude. Signals are then digitized and histogrammed. In this version, the process of reading the ADCs and histogramming is controlled by the PC microprocessor. Data is histogrammed in the RAM memory. The possibility to use the PC

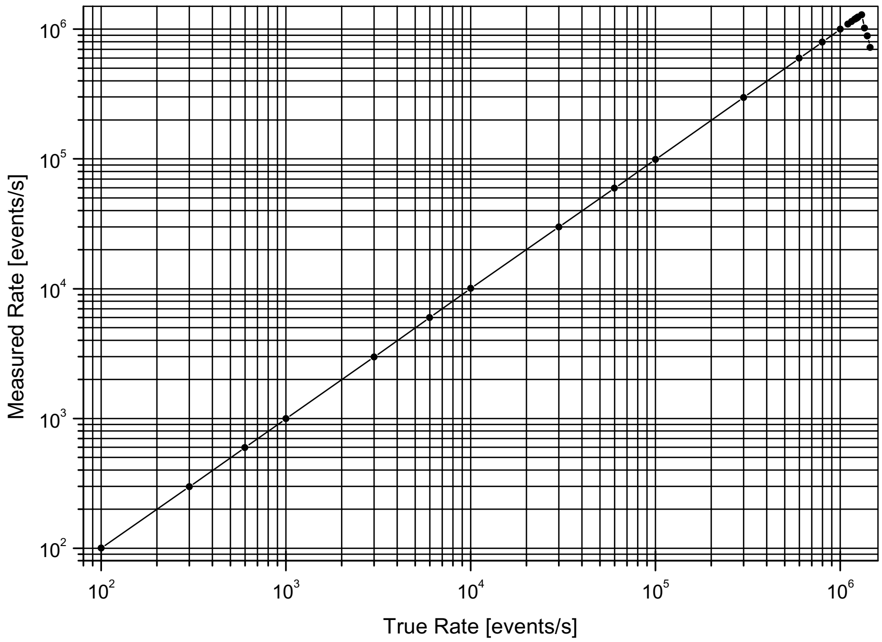

Fig. 8. Counting rate measurements with an image acquisition interface based on logic circuit controlled operation [6].

microprocessor in data acquisition is usually neglected due to speed considerations, since the processor has to handle other operations running in the PC. However, the speed of the microprocessors has increased by more than a factor of 10 in the last 10 years. We have been able to obtain counting rates up to 3×10^5 events per second in a PC running with Pentium 233 MHz processor [5].

For faster data acquisition, another PC interface is presently being tested [6]. In this case, the operations of reading the ADCs and incrementing the memory address corresponding to the data read are carried out by a logic circuit programmed in a Complex Programmable Logic Device – CPLD. The circuit timing is controlled by a 20 MHz clock. Once an event is detected, the clock is triggered and a series of 3 operations are performed by the logic circuit (read-increment-write). These operations take 4 clock pulses. Since no microprocessor is used and memory is provided on-board, the limit to counting rate is mainly determined by the used ADCs. With a 12-bit, 800 ns conversion time ADC, we have reached counting rates above 10^6 events per second. This result is shown in Fig. 8, where the true versus measured counting rate relation is plotted. The software code allows image acquisition in real time, with up to 1024×1024 pixels resolution.

4. Conclusion

The detection system presented here for 2D localization of ionizing particles includes two main features: a simple scheme for position encoding ($X\&Y$ cathode), and a simple technique to digitize and store data. Very low cost is possibly the major consequence of these features. Although several improvements can still be considered, the present performance is already adequate for many applications.

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