A position sensitive cathode strip detector with single-strip readout for the Munich Q3D magnetic spectrograph

H.-F. Wirth *, H. Angerer, T. von Egidy

Physik-Department, Technische Universität München, D-85748 Garching, Germany

R. Hertenberger, G. Graw

Department für Physik, Ludwig-Maximilians-Universität München, D-85748 Garching, Germany

Abstract

The detector presented is a multiwire proportional chamber (MWPC) to be placed in the Munich Q3D magnetic spectrograph for high precision nuclear spectroscopy. It allows position determination and particle identification of incident light ions. The horizontal position information is achieved via single strip readout of an induced charge distributions on the cathodes of the MWPC. The particle identification is done via energy loss signals of two wire planes and a scintillator signal. A vertical position control is possible through the separate readout of two parallel wires one obove the other.

Key words:
PACS:

1. Introduction

The Q3D magnetic spectrograph [1] at the tandem Van de Graaff accelerator of the Maier-Leibnitz-Labor (MLL) of Ludwig-Maximilians-Universität and Technische Universität München has an energy resolution of $\delta E/E = 2\times10^{-4}$ making it an excellent tool for high precision nuclear particle spectroscopy. However, advanced focal plane detectors are needed to make the optimum benefit out of it. A variety of detectors was developed in the last decades [2–8] with the goal to build a detector that covers most of the 1.8 m long curved focal plane with sufficient position resolution of FWHM < 0.5 mm and no periodic effects in the position determination, good particle identification, and the capability to withstand the high background situation.

In Ref. [8] a detector was decribed which fulfilled all criteria except the fact that it had an useable active length of only 35 cm. Its detector concept was used for our new detector whose active length is increased to nearly 90 cm. It still makes use of only half the length of the focal plane of the Q3D; the correlated advantages will be described later. The basic idea of the sophisticated detector electronics and important advancements of the mechanical design will be described in this paper.

2. Detector

The detector consists of two proportional detectors followed by a scintillator. The second proportional detector provides the position information.

The working principle of the position readout is following the idea of Lindner et al. [5] and is illustrated in Fig. 1. It uses the feature of the spectrograph where the particles cross the focal plane with an angle between 40-50 degrees. Particles which enter the gas-filled detector generate free electrons through ionisation. This leads to an extended avalanche around the anode wire which generates a signal which is proportional to the specific energy loss of the particle. At the same time the avalanche induces a Gaussian shaped charge distribution on several neighboring strips of the cathode strip foil (see Fig. 1). This charge has positive sign and its center is basically equivalent to the position where the particle crossed the anode wire.

The cathode plane distance is 8 mm and the repetition length of the cathode strip foil is 3.5 mm. The vertical wire distance is 6 mm. This makes the detector very similar to the detector descibed in Ref. [8]. New is the 2.5-fold active

* Corresponding author.
Email address: wirth@tum.de (H.-F. Wirth).

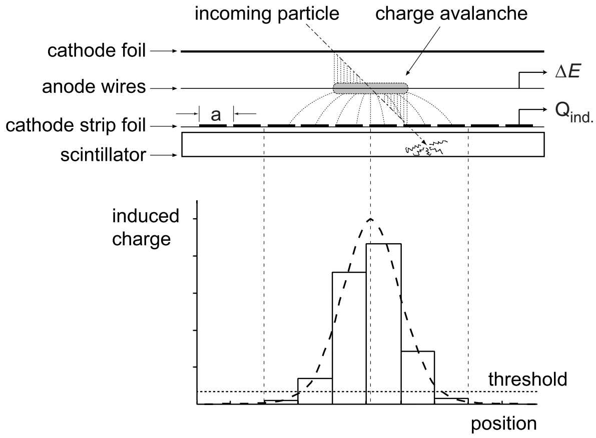

Fig. 1. Working principle of the detector. Top: Shown is the top view of the position sensitive MWPC followed by the scintillator. The electrons generated along the particle track drift to the anode wire and generate a wide charge cloud which induces positive charge on the cathode strip foil (repetition length 'a' = 3.5 mm). Bottom: The histogram shows the digitized amount of the induced charge on each single strip. The histogram can be described by a Gaussian distribution (dashed line).

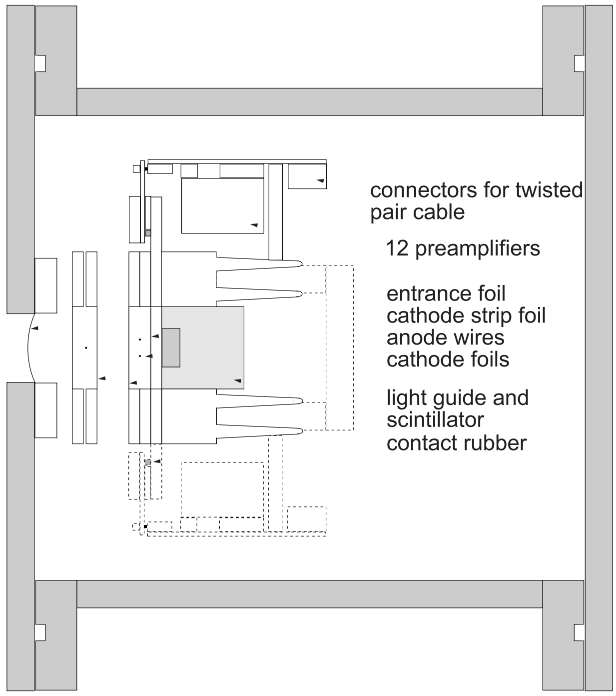

Fig. 2. Schematic vertical cut through the detector. Particles enter from the left. Printed circuit boards carrying 12 preamplifiers each are mounted alternately on top and on bottom of the cathode foil (cf. Fig. 3).

length of 890 mm with 255 read-out strips instead of 114 (partly covered by a too small entrance window) and the complete mechanical setup. Hence, several aspects could be optimized. The outer dimensions of the detector housing are 1600 × 190 × 250 mm^3 (L × W × H). All connections are guided in a flexible metal hose with 50 mm inner diameter and flanges through the wall of the spectrograph. To withstand the pressure difference between the gas-filled (500 mbar isobutane) inner of the detector and the vacuum of the detector chamber of the spectrograph the entrance window is made of 25 μm Kapton foil. A schematic cut is shown in Fig. 2. The particle enters the detector from the left. It penetrates the entrance foil, the first proportorional detector, the second proportioal detector with cathode strip readout, and is stopped in the scintillator. The combination of two ΔE signals with the E_{rest} signal from the scintillator allows for excellent particle identification and a three-fold coincidence for triggering.

A separate readout of the signals of the upper and the lower anode wire in front of the cathode strip foil allows besides for ΔE information for a control of the correct height of the detector. The additional energy loss signal of the single wire proportional detector allows to run the detector coincidence trigger without the need of the scintillator signal and turned out to be especially useful for the detection of α- and ^{3}He-particle signals.

Three mechanical imrovements out of many compared to the prototype shall be mentioned here:

i) The cathode strip foil pattern was produced via photolithography like in printed circuit board (PCB) production. The etching of the aluminum evaporated on the 10 μm Kapton foil was done with a mixture of hydroflouric and hydrochloric acid.

ii) The cathode strips are connected to the preamplifiers via an electrically conductive rubber as used in liquid cristal displays. It has a quadratic cross section of 2 × 2 mm^2 and consists of alternately electrically conductive and isolating layers of about 0.1 mm thickness which makes it conductive perpendicular to its length. This rubber is pressed between the cathode strips and a gold plated PCB with the same structure. The contact resistance of approx. 2 kOhm plays no role because of the capacitive coupling of the preamplifiers with much higher entrance resistance.

iii) The scintillator (NE 104) of 7 × 14 mm^2 cross section is embedded in a plexiglass light guide of the size 30 × 30 × 1030 mm^3. This was done by glueing a strip of the scintillator material on a long plexiglass rod, then milling it to a width of 14 mm. After glueing two more plexiglass rods on both milled sides the whole assembly was milled to its final size. All milling was done with a diamond tool without any further polishing. This resulted in a bubble-free connection and a very good light collection. The scintillator depth of 7 mm is the minimum thickness to stop 30 MeV protons under an angle of 45 degrees, and 14 mm is the minimum height to detect all incoming reaction products. The 30 × 30 mm^2 cross section of the light giude was chosen to couple to 1.5 inch diameter photomultplier tubes (Philips XP2201B) on both ends.

3. Readout electronics

The working principle of the readout electronics is descibed in detail in Refs. [8,9]. The application specific integrated circuit (ASIC) described in Ref.[8] was already designed to read a 255 Bit long word, i.e., to be used for the

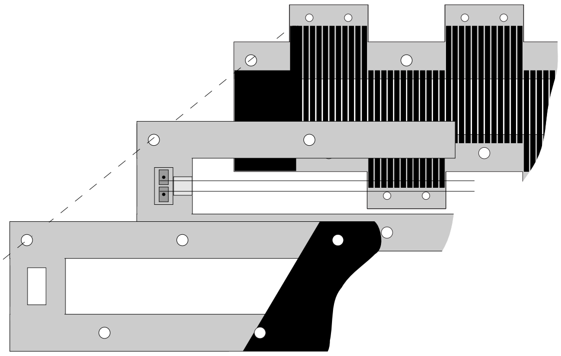

Fig. 3. Cathode strip-, wire-, and cathode plane boards. The cathode strip foil has 23 groups of 12 strips which are vertically shifted for mounting. 255 of the strips measuring 63 $\times$ 3 mm^2 are connected to preamplifiers, the others are grounded. The etched gap between the strips is 0.5 mm wide. The opening of the 4 mm thick epoxy frames measures 967 $\times$ 30 mm^2.

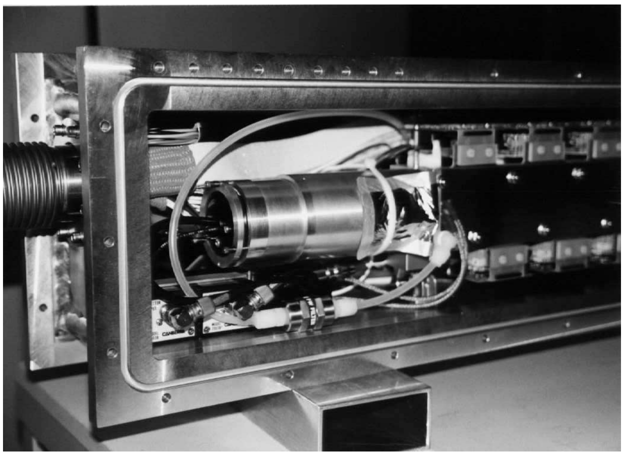

Fig. 4. Photography of the high energy side of the detector. The single wire plane is not yet installed. Amongst others, one sees the cylindrical holder for one of the photomultipliers, and the wire peamplifiers (CANBERRA 2003) below it. The inner dimensions of the aluminum detector housing are 1520 $\times$ 170 $\times$ 170 mm^3.

readout of 255 cathode strips. Consequently, the electronics was extended to 255 strips for the new detector descibed here and the principle stayed the same as in the prototype: If one of the strips has detected a signal above the threshold a digital signal is sent to the ASIC which then scans the strips for an event with multiplicity 3-7, i.e., 3-7 neighboring strips must have seen unduced charges above the threshold. This threshold is hardware adjustable (typically 50 ADC channels of 10 Bit). The charge collection time (ASIC gate) the ASIC waits before it starts to scan the strips is also hardware adjustable and typically 1 μs long.

The multiplicity of 3-7 is typical for particles entering the detector under 40-50 degrees, the entrance angle of the reaction products. If the ASIC has found a good event the charges are digitized in 8 ADCs and delivered to an output buffer.

The charge amplitude on the strips for the reaction products of interest can be adjusted via the wire voltage (1200-

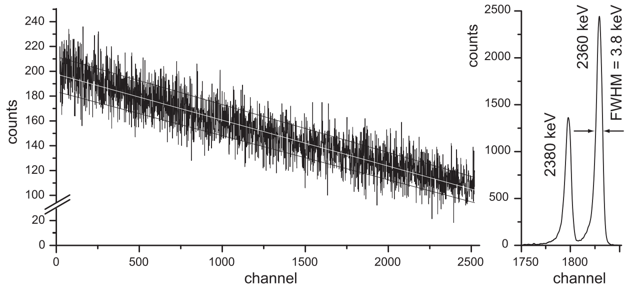

Fig. 5. Spectra measured with the detector. The left one is a so called white spectrum of elastically scattered deuterons. The white line is a linear fit, the two black lines are each $1\,\sigma$ away. χ^2 of the fit is 1.2. The number of channels is 10 times the number of strips, this means one strip is related to 10 channels. The right one is a part of the proton spectrum of the reaction $^{128}\mathrm{Te}(\vec{\mathrm{d}},\mathrm{p})^{129}\mathrm{Te}$ at 22°, E_{d}=18 MeV, pol.=−1. The FWHM is 3.8 keV.

1500 V) and controlled by the maximum ADC values which should not exceed 1024 (10 Bit). The readout of the digital position information consisting of start strip number, multiplicity, and the charge values on the 3-7 strips, is triggered by a detector coincidence between the wire planes and the scintillator signal. The ASIC signal is not included. As a consequence, no position information is read (values 0) if the ASIC is busy working on events with wrong multiplicity ($< 3, > 7$) or multiple events with correct multiplicity, which deliver no output but need a so-called fast reset. This is, e.g., the case at increased background rates of gammas and neutrons. The 0-values in the position spectra are monitoring this detector correlated deadtime which can be easily corrected for in the analysis and which is normally well below 10 %.

4. Measured spectra

The detector has already proven its capabilities in many transfer experiments. It turned out that the disadvantage of the useage of only half of the length of the Q3D focal plane is mostly compensated by two aspects: First, the beam current at the target often can be so high that measuring two or more overlapping spectra does not take too much time and, second, the energy calibration is very well decribed by a second order polynomial which is not the case any more for longer detectors like the one of Ref. [7]. This makes the energy calibration of the position spectra more easy and accurate. An important feature of the detector is that it produces no systematic errors in the position determination which would be reflected in a remaining strip structure in the spectra. This was verified by a Fourier analysis of a so-called white spectrum of elastically scattered deuterons and is shown in Fig. 7. The center of gravity method which is used for the online position determination is known to produce systematic effects [8]. This is visible in Fig. 6 where the strip structure clearly dominates the spectrum (cf. also Fig. 4 of Ref. [8]). Using the Gaussian fit method this structure disappears. This is proven by a Fourier analysis of the spectra shown in Fig. 7.

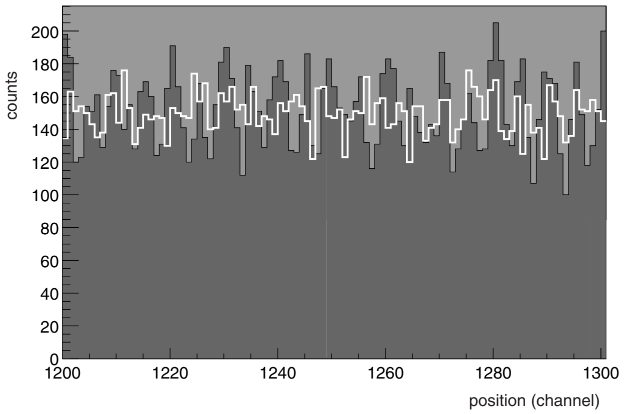

Fig. 6. Section of a white position spectrum generated with the center of gravity method (dark) and the Gaussian fit method (white line). The periodic structure is not visible any more with the Gaussian fit method. For generating the position spectrum the events are sorted into spectra where the width of one strip (3.5 mm) corresponds to 10 channels.

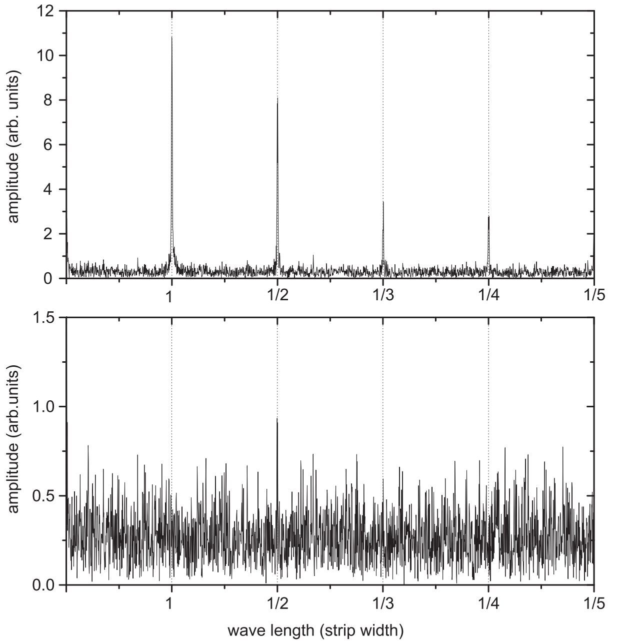

Fig. 7. Fourier analysis of the white position spectrum. Top: analysis of the online spectrum obtrained with the center of gravity method. Bottom: Analysis of the white spectrum shown in Fig. 5 obtained with the Gaussian fit method. Here, no periodicity os observed.

References

[1] M. Löffler, et al., Nucl. Instrum. Methods 111 (1973) 1.
[2] P. Glässel, Nucl. Instrum. Methods 140 (1977) 61.
[3] A. Chalupka, et al., Nucl. Instrum. Methods 217 (1983) 113.
[4] R. Hertenberger, et al., Nucl. Instrum. Methods A 258 (1987) 201.
[5] H. Lindner, et al., Nucl. Instrum. Methods A 273 (1988) 444.
[6] H. Wessner, et al., Nucl. Instrum. Methods A 286 (1990) 175.
[7] E. Zanotti, et al., Nucl. Instrum. Methods A 310 (1991) 706.
[8] J. Ott, et al., Nucl. Instrum. Methods A 367 (1995) 280.
[9] H.-F. Wirth, PhD thesis, TUM 2001.
[10] H.-F. Wirth, Jahresbericht BL, 2000, p. 71.

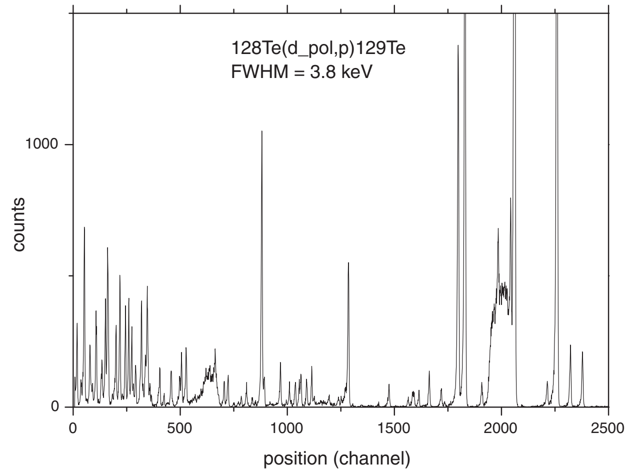

Fig. 8. Complete position spectrum of the reaction ^{128}Te($\vec{\mathrm{d}}$,p)^{129}Te at 22°, E_d=18 MeV, pol.=−1. The FWHM is 3.8 keV.

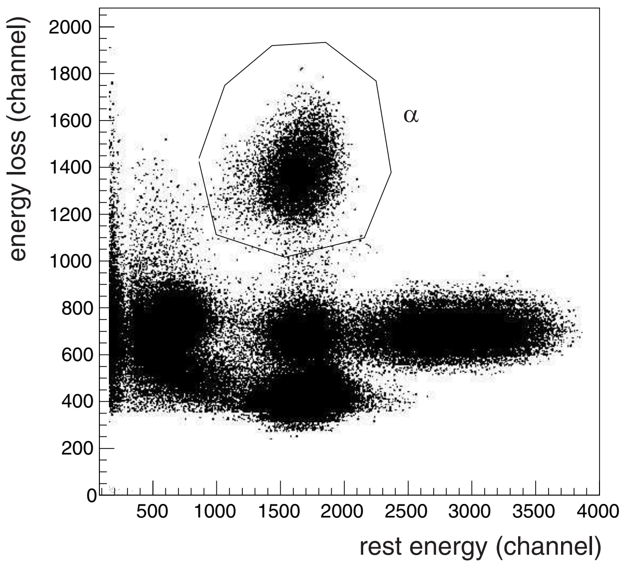

Fig. 9. Banana for alphas set in the $\Delta E/E_\mathrm{rest}$ plot of the reaction ^{204}Hg($\vec{d},\alpha$)^{202}Au, E_d = 18 MeV, pol. = -1, at a lab. angle of 10°. The data acquisition was triggered with a coincidence of the two wire planes only.

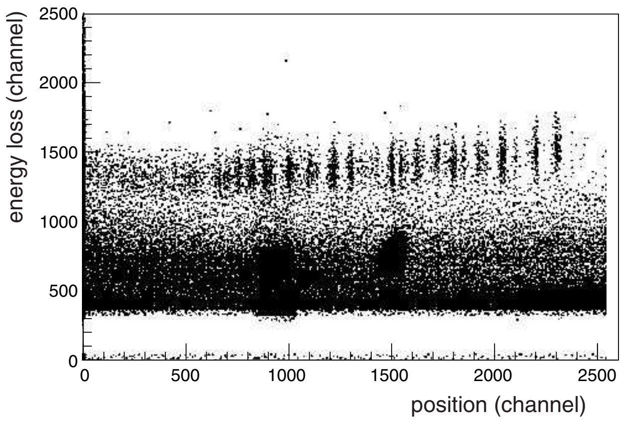

Fig. 10. ΔE/position plot of the reaction ^{204}Hg($\vec{d},\alpha$)^{202}Au, E_d = 18 MeV, pol. = -1, at a lab. angle of 10°.

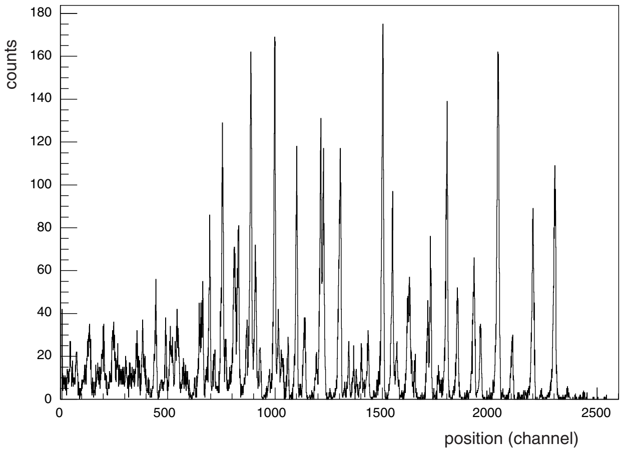

Fig. 11. Position spectrum of the reaction $^{204}\mathrm{Hg}(\vec{d},\alpha)^{202}\mathrm{Au}$, $E_d = 18$ MeV, pol. = -1, at a lab. angle of 10°.

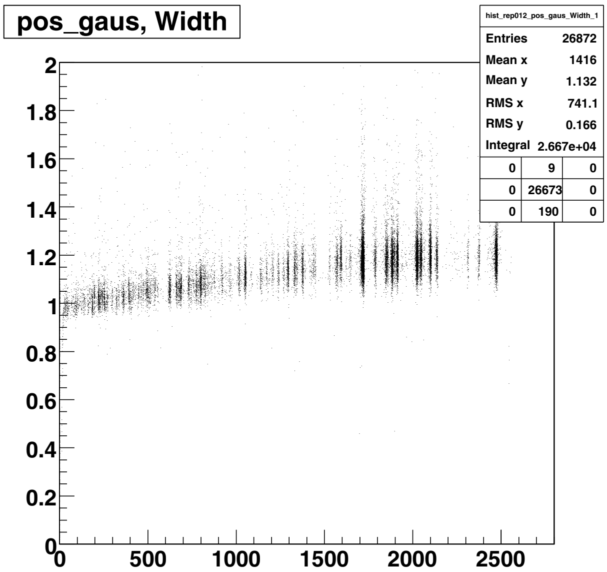

Fig. 12. Normalized width of the Gaussian distribution for each event over the position. The peaks have to be vertical lines.

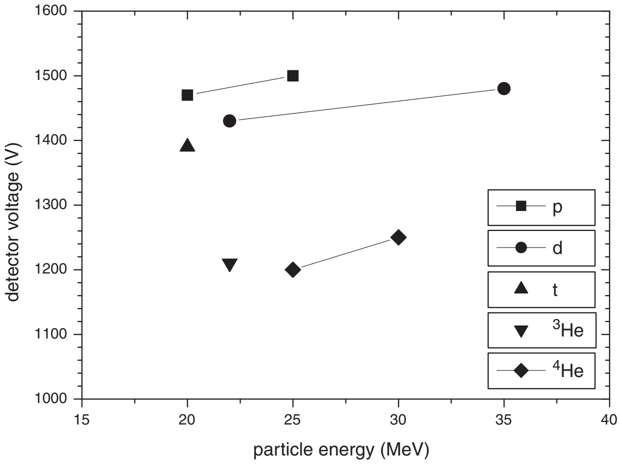

Fig. 13. Detector anode wire voltages nedded for different particles/energies.