Development of compact MWPC detectors for TRINAT experiment (MWPC demonstrator)

J. Klimo, D. Melconian, G. Chubaryan, V. Iacob, D. McClain, M. Nasser,
B. Diaz, and B.M. Vargas-Calderon

As the analysis to measure the Fierz interference parameter from the last TRINAT (Neutral Atom Trap for β Decay) wraps up, we are preparing for the next correlation measurement of polarized ^{37}K at TRIUMF. One of our limiting systematics is the performance of our current β detectors, which are made up of 300 um-thick double-sided Si-strip (DSSSD) ΔE-detector backed by a BC408 plastic scintillator E-detector. We are upgrading these telescopes to reduce the large (~100 keV) energy loss in the DSSSD and the (back-) scattering by replacing the DSSSD with a multiwire proportional counter (MWPC), see Fig 1. We will also replace the magnetic-field-sensitive PMT readout of the scintillator with Si photomultipliers (SiPMs). In order to avoid completely changing our overall system, we will use the same detection chamber and in particular the existing re-entrant flanges for the β telescopes. This set the limits for the new telescope dimensions. In the present work, we describe development of two compact, small area, position sensitive MWPC detectors for the detection of β particles in spin-polarized β^+ decay experiment. The detectors will help to reconstruct momentum vector of β particles on event-by-event basis, with higher precision than DSSSD detectors.

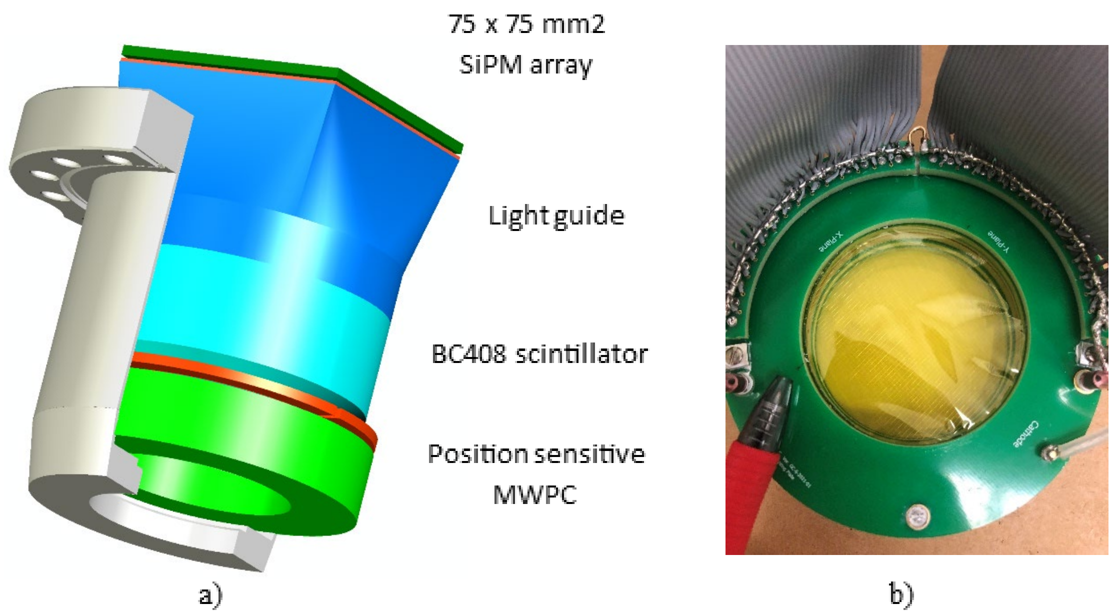

Fig. 1. a) New design. for TRINAT's β telescope b) The design of MWPC detector.

MWPC detector design

All wire frames are made from PCB material, where gold plated tungsten wires of 16 um in diameter are stretched and soldered on PCB frame of three electrodes. The thickness of each PCB frame is 3 mm and two electrodes are always span by a spacer of the same thickness, thus resulting in 6 mm distance in between electrodes. One can find in a comparable design in [1]. The spacing in between wires is 3.75 mm and 1.0 mm, for anode and cathodes, respectively. The central electrode, the anode, is supposed to be biased to high voltage of 2.5-3.0 kV relative to the cathodes floated at 0 V.

Signal readout and XY – position reconstruction

Anode signal serves as trigger (start) signal for cathode (stop) signals, two signals for one cathode, and this trigger can be used as a master trigger in TRINAT DAQ system. All signals from anode wires are sum up to one signal, typically with higher amplitude than signal from single cathode wire. For processing of anode signal a standard ORTEC 9306 fast pre-amplifier can be utilized after decoupling stage of the detector, managing by high voltage decoupling box. The fast pre-amplifier is then followed by TRINAT digital electronics.

Besides the resistive charge division method, the delay-line (DL) technique represents another centroid finding method. DL technique is a simple and relative accurate technique for MWPC. The position of a particle traversing the MWPC sensitive volume is reconstructed from X_1 and X_2 signals readout for the top (X-plane), and from Y_1 and Y_2 signals from the bottom (Y-plane) cathode, only two signals per cathode. Coincidence of two signals from DL board also helps to suppress spurious events and electronical noise. In the order to reach high position resolution a custom-made DL boards have been made, one for every cathode, and are currently in testing phase. Every DL board gathers a passive DL chip of inductors and multi-layer capacitors (series SP10), taking care of stable transmission of signal and reliable performance. Two cathode wires are electronically always bunched together and the delay time between two consecutive pairs of wires is 2 ns, corresponding to 2 mm spacing. After a delay stage, a signal from cathode wire is then gained by a custom-made fast pre-amplifier. A characteristic for this pre-amplifier is its high dynamic range with gain ranging as 10 up to 10^2. Such high gain is demanded as the most of β particles deposit only small fraction of its total energy in sensitive volume of MWPC, typically not more than ~ 5 keV. This must be compromised with electronic noise to be able to read cathode signal with amplitude of about ~10 µV/wire. Then DL signals from a cathode are feed to Constant Fraction Discriminator (CFD) resulting two fast discriminator signals with sub-ns rise time. The delay time is then measured using time-to-digital converter (TDC) as $(T_{x1} - T_{x2})$ and the sum of DL total time is always constant for one DL board, determined by the sum of all delay stages, i.e.

$$T_{sum} = T_{x1} + T_{x2} = 29 \text{ wire pairs} \times 2 \text{ ns} = 58\text{ns},$$

and the centroid in X and Y direction is reconstructed as [2],

$$X = K_x . \frac{(T_{x1} - T_{x2})}{2} + X_{\text{off}},$$

where X_{off} (mm) is the offset correction, K_x (mm/ns) is the position coefficient.

Gas system

A high purity quenching mixture of Ar+Co2 (90%-10%) is considered as an optimal detection medium for both MWPC detectors. The pressure stability of MWPC is critical for the whole operation and thus the gas pressure and flow must be under control. For this purpose, we use a manual gas system consists of 2 stage pressure regulators with a needle valve. The outlet of MWPC can be monitored by pressure and flow meter at the outlet stage. A critical situation, like high overpressure scenario of the MWPC is prevented by 1 mm inlet port of much smaller diameter than diameter of injection line, and by the fact that the detector is leak tight up to ~ 6 mbar.

Efficiency test with ^{90}Sr

The β counting curve was measured for both detectors (Fig 2) to select an appropriate operating voltage to stabilize variation in counting rate, caused by high voltage instability leading to gain variation, and considering an acceptable background condition. The counting rate was recorded under constant

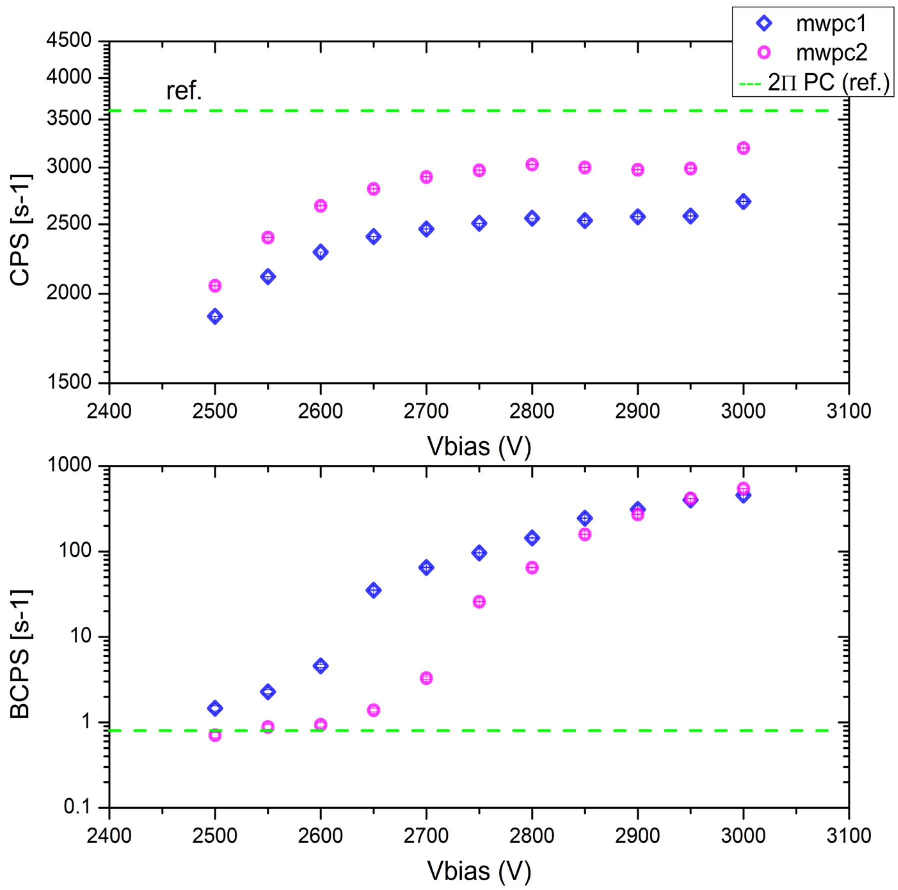

Fig. 2. The counting curve measurement for both MWPC detectors and compared with a reference measurement by 4π detector used in 2π configuration. CPS represents background subtracted count rate of the β source ^{90}Sr. BCPS is for background measurement.

source conditions as the detector voltage is varied. An operating point is then selected, normally, corresponding to a flat region or "plateau" on the resulting rate versus voltage curve. The efficiency test for MWPC is compared with 4π single wire proportional detector measurement [3], which is well characterized with detection efficiency exceeding 99%. That detector is also characteristic by very low background. The geometry of 4π detector is slightly different but provide a good reference point to ongoing simulations. The difference in efficiency curve in between two detectors can be canceled by the next optimization of the detectors so they will match each other, and approach 100% limit. Efficiency for cathodes is usually not as high as for anode.

[1] Ran Hong, Ph.D. Thesis, University of Washington, 2016.
[2] H. Kumagai *et al.*, Nucl. Instrum. Methods Phys. Res. **B317**, 717 (2013).
[3] V.E. Iacob *et al.*, Phys. Rev. **C 77**, 045501 (2008).