Upgrade of TRINAT's β telescopes

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As the analysis to measure the Fierz interference parameter from the last TRINAT 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 a 40 mm × 40 mm × 300 μm double-sided Si-strip (DSSD) ΔE detector backed by a BC408 plastic scintillator E detector (see the left schematic of Fig. 1). We are upgrading these telescopes to reduce the large (~100 keV) energy loss in the DSSD and the (back-) scattering it induces by replacing the ΔE with a multiwire proportional counter (MWPC). 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 constrains the dimensions of the new telescope.

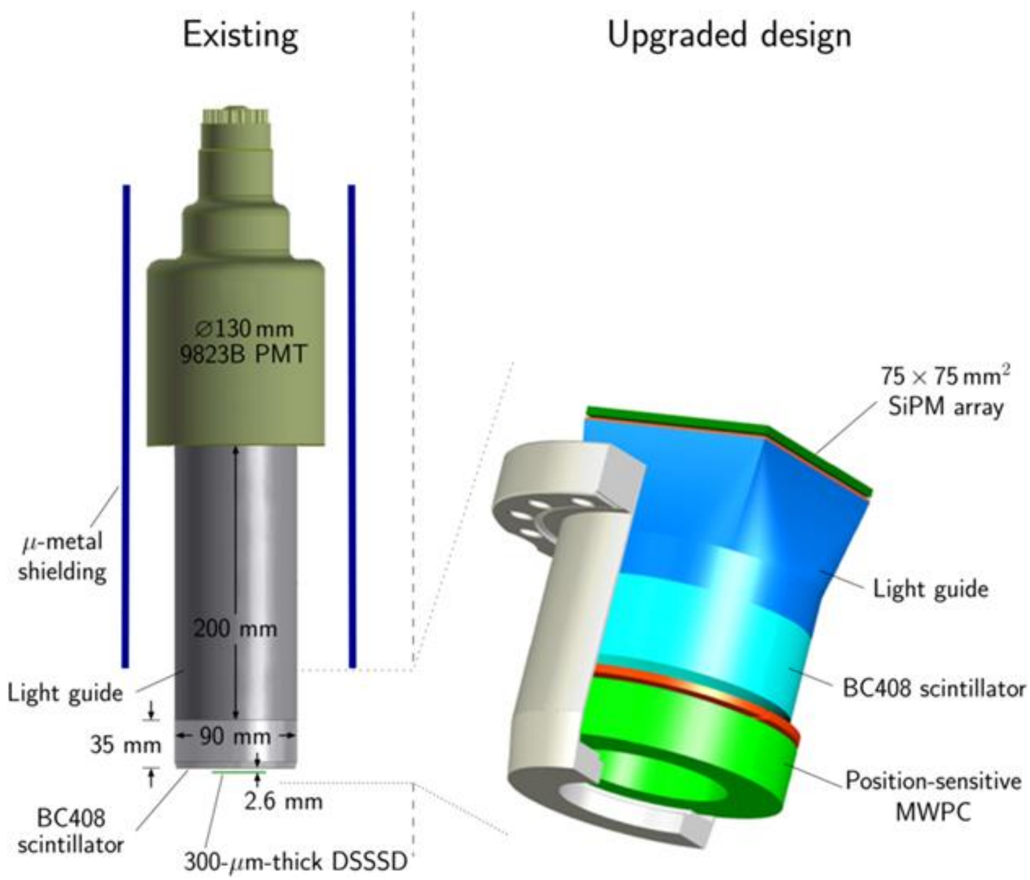

Fig. 1. Old (left) and new (right) design for TRINAT's β telescopes. The new design will be more compact, have much smaller energy loss and large-angle scattering in the ΔE, and be much less sensitive to the varying magnetic field used by TRINAT for trapping and polarizing neutral atoms.

The multiwire proportional chamber

The choice of the gas detector was defined by the main requirement to minimize the energy loss and angular scattering of the detected β particles, and to make it position sensitive. The MWPC consists of two mutually perpendicular wire planes with a wire-winding pitch of 1 mm. The wires of gold-plated beryllium-bronze with a diameter of 16 microns are connected in pairs, with better than 2 mm resolution obtainable based on the centre-of-gravity of ionization. The cathode is made of a thin (< 1 μm thick) double-sided aluminized-mylar foil situated in the middle between the wire planes. Such a design of the electrodes allows forming a uniform electric field throughout the entire volume of the detector. A fast-timing signal also will be taken from the central cathode.

The MWPC will be filled with P10 gas (a mixture of 90% argon and 10% methane) at a pressure slightly above atmospheric by a few Torr. The detector will be operated with a constant gas flow which simplifies the entire design of the gas system. The MWPCs windows are made of 5 μm-thick Kapton films. This choice of the film material and the thickness was made to avoid the use of a supporting grid. The active area of this cylindrical detector has a diameter of 58 mm, and the whole assembly has an outer diameter of 95 mm, which fits in the existing re-entrant flanges. Due to the severe lack of space for the wiring, electrical, and gas fittings, sophisticated multilayer PCBs have been designed.

The scintillation detector

After passing through the MWPCs, the bulk of the energy of the β particles will be detected using a BC408 plastic scintillator as before. The new ΔE requires us to replace the scintillators so we decided to also change the light readout from a PMT to SiPMs; this makes the overall length of the telescope much more compact, and removes the PMT's sensitivity to varying magnetic fields. The scintillator thickness is 40 mm, slightly longer than the previous 35 mm which was optimized for ^{37,38m}K which have 5 MeV Q-values; the extra 5 mm will contain βs with energies up to 8 MeV, extending the cases that can be studied at TRINAT. The diameter of the scintillator should be as large as possible for the given volume to maximize the solid angle and minimize the likelihood of a β escaping out the side before being stopped. In our case, to leave room for the MWPC's wiring and gas-flow plumbing, the scintillator's diameter can be 88 mm. A short light-guide will bring the light out of the re-entrant flange to an array of SiPMs, flaring out slightly and changing from cylindrical to square to match the 75×75 mm^2 area of the array (3×3 set of Hammamatsu S14161 series, each 25×25 mm^2).

We have completed our design and are in the process of constructing the telescopes. We expect to test and characterize them this Fall at the Cyclotron Institute and then install them in the TRINAT lab at TRIUMF early in 2022.

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