BRAND - Low energy proton detector

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Introduction

The standard model (SM) has attempted to establish the understanding of fundamental particle physics and its interactions, but the physics of baryon asymmetry, neutrino mass hierarchy, the origin of parity violation, dark matter remain unexplained. Nuclear and neutron beta decay correlation coefficients are linearly sensitive to exotic couplings, which are not included in SM. The free polarized neutron can be used as a tool to search for physics beyond the Standard Model (BSM).

Within SM, electrons emitted in beta decay have longitudinal polarization, which indicates parity-violating the nature of weak interaction. The departure of the polarization vector from strict collinearity with electron momentum can be caused by electromagnetic effects, recoil order corrections, or genuine scalar and tensor interactions, which are absent in SM. Thus, provided that the electromagnetic and recoil order corrections are under control, the transverse electron polarization is an ideal observable for searches of BSM effects.

The BRAND [1] is unique experimental initiative attempting to measure 11 correlation coefficients (a, A, B, D, H, L, N, R, S, U, V) simultaneously in differential decay rate ω [2], of which (H, L, N, R, S, U, V) depend on transverse electron polarization. The correlation coefficients H, L, S, U, V were never measured before.

$$\begin{aligned}\omega(E_e,\Omega_e,\Omega_{\bar\nu}) \propto\ & 1 + a\frac{\mathbf{P_e}\cdot\mathbf{P}_{\bar\nu}}{E_eE_{\bar\nu}} + b\frac{m_e}{E_e} \\ & + \frac{\langle\mathbf{J}\rangle}{J}\cdot\left[A\frac{\mathbf{P_e}}{E_e} + B\frac{\mathbf{P}_{\bar\nu}}{E_{\bar\nu}} + D\frac{\mathbf{P_e}\times\mathbf{P}_{\bar\nu}}{E_eE_{\bar\nu}}\right] + \\ \sigma_\perp\cdot & \left[H\frac{\mathbf{P}_{\bar\nu}}{E_{\bar\nu}} + L\frac{\mathbf{P_e}\times\mathbf{P}_{\bar\nu}}{E_eE_{\bar\nu}} + N\frac{\langle\mathbf{J}\rangle}{J} + R\frac{\langle\mathbf{J}\rangle\times P_e}{JE_e}\right] + \\ \sigma_\perp\cdot & \left[S\frac{\langle\mathbf{J}\rangle}{J}\frac{\mathbf{P_e}\cdot\mathbf{P}_{\bar\nu}}{E_eE_{\bar\nu}} + U\mathbf{P}_{\bar\nu}\frac{\langle\mathbf{J}\rangle\cdot\mathbf{P_e}}{JE_eE_{\bar\nu}} + V\frac{\mathbf{P}_{\bar\nu}\times\langle\mathbf{J}\rangle}{JE_{\bar\nu}}\right]\end{aligned} \quad (1)$$

This contribution focuses on the BRAND detector systems with emphasis on recoil proton detectors.

Experimental Setup of BRAND

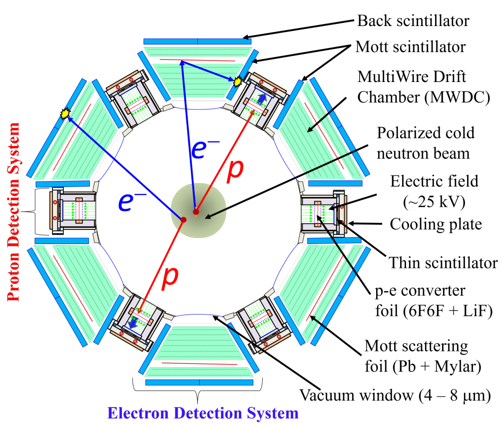

FIG. 1: Cross section of the BRAND apparatus [1].

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The BRAND apparatus consists of a decay chamber surrounded by electron polarimeters and recoil proton detectors. The schematic of BRAND is shown in fig. 1. Decay electrons were tracked in a MultiWire Drift Chamber (MWDC) [3], back-scatter from a thin Mott target or pass without any back-scattering from Mott target deposit their energy in a plastic scintillator detector. The proton detection system [4] consists of accelerating potential (25 - 30 kV), p-e conversion crystal (LiF,∼10 nm) evaporated on 6F6F polymer, and a thin scintillator-based electron detector with SiPM readout array arranged in triangular geometry. The schematics of the proton detector and arrangement of SiPMs are shown in fig. 2.

Proton Detector

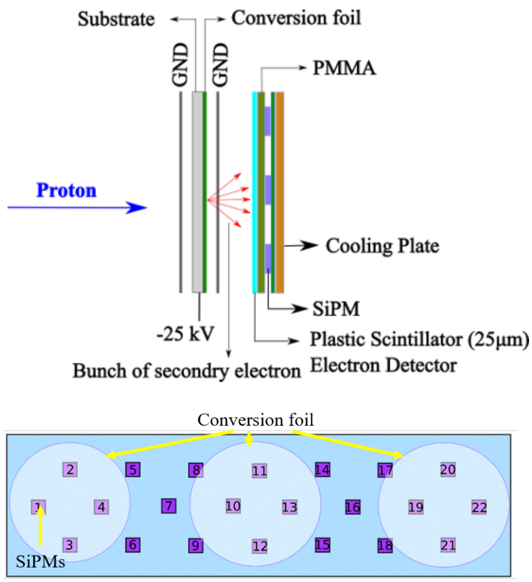

FIG. 2: Upper panel: schematics of Proton Detector. Lower panel:arrangement of SiPM array.

The essential feature of proton detectors in BRAND setup are: (i) particle identification capability: it should be able to discriminate decay electrons from bunches of secondary electrons produced in the conversion foil, (ii) position sensitivity: it should be able to reconstruct hit position with a precision of about 10 mm, (iii) good timing: it should be fast (of the order of ns) enough as it will measure the time of flight.

The characterization of proton detector prototypes involves the stability of a high voltage system, gain calibration, and stability of lower temperatures to reduce the dark current of SiPMs. The gain calibration was done using ^{241}Am radioactive alpha source.

The SiPM signals were acquired using CAEN V1190 multihit TDC. Time of Flight with respect to the detection of the decay electron was acquired together with the signal pulse height after conversion to the time. In each event, a cluster of nearest SiPM that fired was identified, and the hit position is deduced using the centroid method. During Sept-Oct 2021, a pilot run of the test setup was conducted on the PF1B cold neutron beam line at the Laue-Langevin Institute, Grenoble, France. The fig. 3 represents a typical reconstruction of hit position.

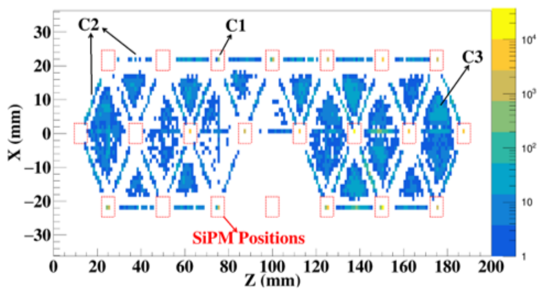

FIG. 3: Reconstructed hit position.

The results of the proton detector data will be presented.

References

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