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A two-layer Timepix3 stack for improved charged particle tracking and radiation field decomposition

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Precise measurement of radiation levels and radiation field characteristics is a major concern in fundamental physics and life-science applications. In the present contribution, we describe a novel instrument which was in particular designed for application in harsh radiation environments, as found for example in ATLAS or, within the MOEDAL experiment, at a distance of ˜1 m from the interaction point (IP8) at LHCb. The device consists of two Timepix3 [1] assemblies with 500 μm thick silicon sensors in a face-to-face geometry. These detectors are interleaved with a set of neutron converters: 6Li for thermal neutrons, polyethylene (PE) for fast neutrons above 1 MeV, and PE with an additional aluminium recoil proton filter for neutrons above ˜4 MeV. The two-layer design combined with 3D track reconstruction capability in single layers, enabled by the nanosecond-scale time measurement of Timepix3, provides precise particle trajectory reconstruction [2]. Application of the coincidence and anticoincidence technique together with pattern recognition allows improved separation of charged and neutral particles, their discrimination against γ-rays and assessment of the overall directionality of the fast neutron field.
The instrument's charged particle tracking and separation capabilities were studied at the Danish Center for Particle Therapy (DCPT), the proton synchrotron (PS), and super proton synchrotron (SPS) with protons (50-240 MeV), pions (1-10 GeV/c and 180 GeV/c), heavy fragments and lead (330 GeV/c). After developing temporal and spatial coincidence assignment methodology (see Figure 1), we determine the relative amount of coincident detections as a function of the impact angle, present the device's impact angle resolving power (both in coincidence and anticoicidence channels) and illustrate its use as a stopping power spectrometer. The detector response to fast neutrons was determined at the Los Alamos Neutron Science Center (En up to 600 MeV), where measured tracks were assigned to their corresponding neutron energy by application of the time of flight technique [3]. We present the achieved neutron detection efficiency as a function of neutron kinetic energy and demonstrate how the ratio of events found below the different converters can be used to assess the hardness of the neutron spectrum, at least up to ˜20 MeV neutron kinetic energy (Figure 2). To illustrate the applicability of the methodology in mixed fields, we will outline data analysis in the MoEDAL experiment, where we perform precise tracking of relativistic particles coming from IP8 and determine neutron fluxes, and at DCPT, where we determine the composition of the stray radiation around a PMMA phantom during irradiation with protons.

[1] T. Poikela et al 2015 JINST 10 C01057
[2] B. Bergmann et al. Eur. Phys. J. C 77, 421 (2017).
[3] B. Bergmann et al 2014 JINST 9 C05048

Primary authors: BERGMANN, Benedikt Ludwig (Czech Technical University in Prague (CZ)); MRÁZ, František (Charles University); Dr SITARZ, Mateusz (Danish Centre for Particle Therapy,); Dr BROULIM, Pavel (University of West Bohemia (CZ)); BURIAN, Petr (Czech Technical University in Prague (CZ)); Mr MANEK, Petr (Czech Technical University); Dr SMOLYANSKIY, Petr (IEAP CTU in Prague); POSPISIL, Stanislav (Institute of Experimental and Applied Physics, Czech Technical University in Prague); Mr CELKO, Tomas (Institute of Experimental and Applied Physics, CTU in Prague); Dr SØNDERGAARD, Christian (Danish Centre for Particle Therapy,)

Presenters: BERGMANN, Benedikt Ludwig (Czech Technical University in Prague (CZ)); Dr SMOLYANSKIY, Petr (IEAP CTU in Prague)

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