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Fast neutron micro-imaging by 2025?

X-ray microtomography (i.e. tomography at the micrometer scale) is made possible nowadays by the availability of imaging detectors with adequate spatial resolution and suitable high brillance X-ray sources. Achieving the same spatial resolution in cold/thermal neutron tomography is more challenging but constant developments in the field suggest that micrometer-scale neutron imaging will soon be possible by careful optimization of existing technologies.

What about micro-imaging with fast neutrons? Is high resolution fast neutron imaging a realistic proposition for a dedicated detector development effort in the next decade? Here we propose a novel detection scheme where micropattern gaseous detectors are used for particle tracking to push fast neutron detection into the micrometer scale.

At the heart of any neutron detector is a suitable interaction mechanism that can be used to convert neutrons into a detectable particle - usually a charged particle. The range of the resulting charge particle in the detector is usually assumed to be the fundamental limit setting the order of magnitude of achievable spatial resolutions. By recording the full track of the charged particle the neutron interaction point can be inferred with an accuracy that is typically a small fraction of the charged particle range. Micro-Pattern Gaseous Detectors (MPGDs) are often used for charge particle tracking, as exemplified at the LHC experiments. In recent years, these devices found applications beyond high energy physics mainly due to their imaging capabilities. MPGDs (i.e. GEMs, Micromegas and their derivatives) coupled to suitable converter cathodes have proven in the recent years to be able to efficiently detect neutrons (with different energies) at high rates (> MHz/cm2), with a sub-mm space resolution and with a gamma background rejection <10-6. The technique used for fast neutron detection is the measurement of the recoil proton coming from an elastic scattering on a hydrogenated material composing the cathode (e.g. polyethylene).

A detailed measurement of the proton track using a Time Projection Chamber (TPC) based on MPGDs would give the possibility to significantly improve both the spatial and time resolution compared to the detectors developed so far, since the contribution of the track length could be reduced substantially. A high resolution fast neutron TPC-MPGD can be realized by coupling a single GEM (or Micromegas) with a plastic converter cathode to a high definition read-out chip like the Timepix2 that allows to reach space resolutions better that 100 µm and time resolutions around few ns. This approach can lead to high rate and high resolution imaging detectors for fast neutrons and is open to make immediate use of the foreseeable advances in read out resolutions in the next decade. Possible applications include fast neutron imaging, accurate monitoring of fast neutron beamlines and neutron measurements in magnetic or inertial fusion experiments.

Summary

Is high resolution fast neutron imaging a realistic proposition for a dedicated detector development effort in the next decade? Here we propose a novel detection scheme where micropattern gaseous detectors are used for particle tracking to push fast neutron detection into the micrometer scale.

By recording the full track of the charged particle the neutron interaction point can be inferred with an accuracy that is typically a small fraction of the charged particle range. Micro-Pattern Gaseous Detectors (i.e. GEMs, Micromegas and their derivatives) coupled to suitable converter cathodes have proven in the recent years to be able to efficiently detect neutrons at high rates (> MHz/cm2). The technique used for fast neutron detection is the measurement of the recoil proton coming from an elastic scattering on a hydrogenated material composing the cathode (e.g. polyethylene).

A detailed measurement of the proton track using a Time Projection Chamber (TPC) based on MPGDs coupled to a high definition read-out chip like the Timepix2 allows for space resolutions better that 100 µm and time resolutions around few ns. This approach is open to make immediate use of the foreseeable advances in read out resolutions in the next decade.

Author: Dr CROCI, Gabriele (Università & INFN, Milano-Bicocca (IT))

Co-authors: MURARO, Andrea (CNR & Università Milano-Bicocca (IT)); Dr PERELLI CIPPO, Enrico (CNR & Università Milano-Bicocca (IT)); Dr MURTAS, Fabrizio (Istituto Nazionale Fisica Nucleare (IT)); Prof. GORINI, Giuseppe (Università & CNR, Milano-Bicocca (IT)); Dr KANAKI, Kalliopi (European Spallation Source, (SE)); Dr TARDOCCHI, Marco (CNR and Università Milano-Bicocca (IT)); Prof. HALL-WILTON, Richard (European Spallation Source (SE))

Presenter: Dr CROCI, Gabriele (Università & INFN, Milano-Bicocca (IT))