Radiation-Hard Fast Scintillation Counter for Heavy-Ion Beam Diagnostics

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Summary

The prototype detector has been developed for beam diagnostics at high-energy beam lines of the SIS18 synchrotron at the GSI Helmholtz Center for Heavy Ion Research GmbH. The new detector consists of multiple ZnO(In) scintillating ceramics tiles stacked on the front and back sides of a borosilicate light guide. The performance of the detector was tested in comparison to a standard plastic scintillation detector with 300 MeV/u Ar, Au, Pb, and U ions. The prototype exhibits 100% counting efficiency and radiation hardness of a few orders of magnitude higher than the standard plastic scintillation counter. Therefore, it provides an improved beam diagnostics tool for relativistic heavy-ion beam measurements.

Heavy-ion beam intensity measurements at GSI

GSI high-energy beam transport lines provide a huge variety of ion species from proton to uranium at energies above 150 MeV/u for numerous physics experiments. The intensity of slowly extracted heavy ion beam from the SIS18 synchrotron is routinely measured using Particle Detector Combinations (PDC). The damage occurs for detector materials inserted into heavy ion beams. Therefore, radiation-hard materials are in demand.

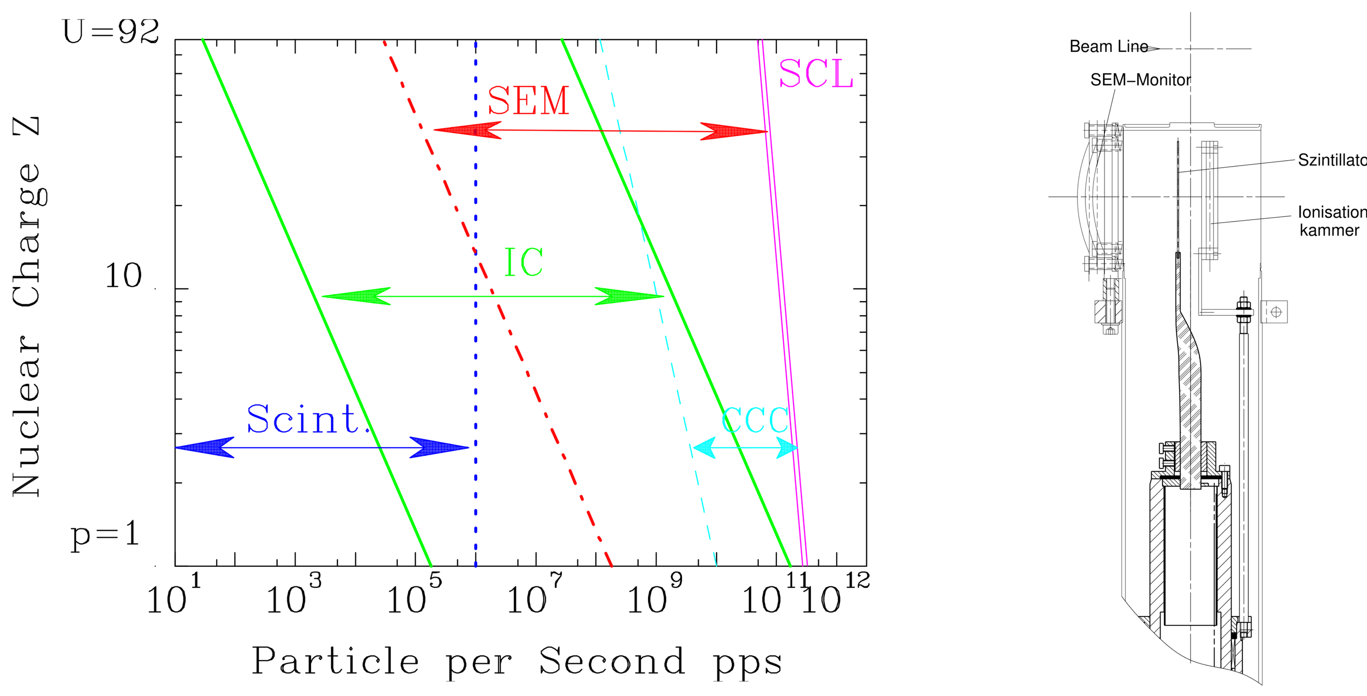

Fig. 1: Typical counting rates at which different detectors are used at the GSI facility (left). Picture of the PDC assembly used for beam intensity measurements at GSI (right) [1,2].

Radiation hardness of zinc oxide scintillator

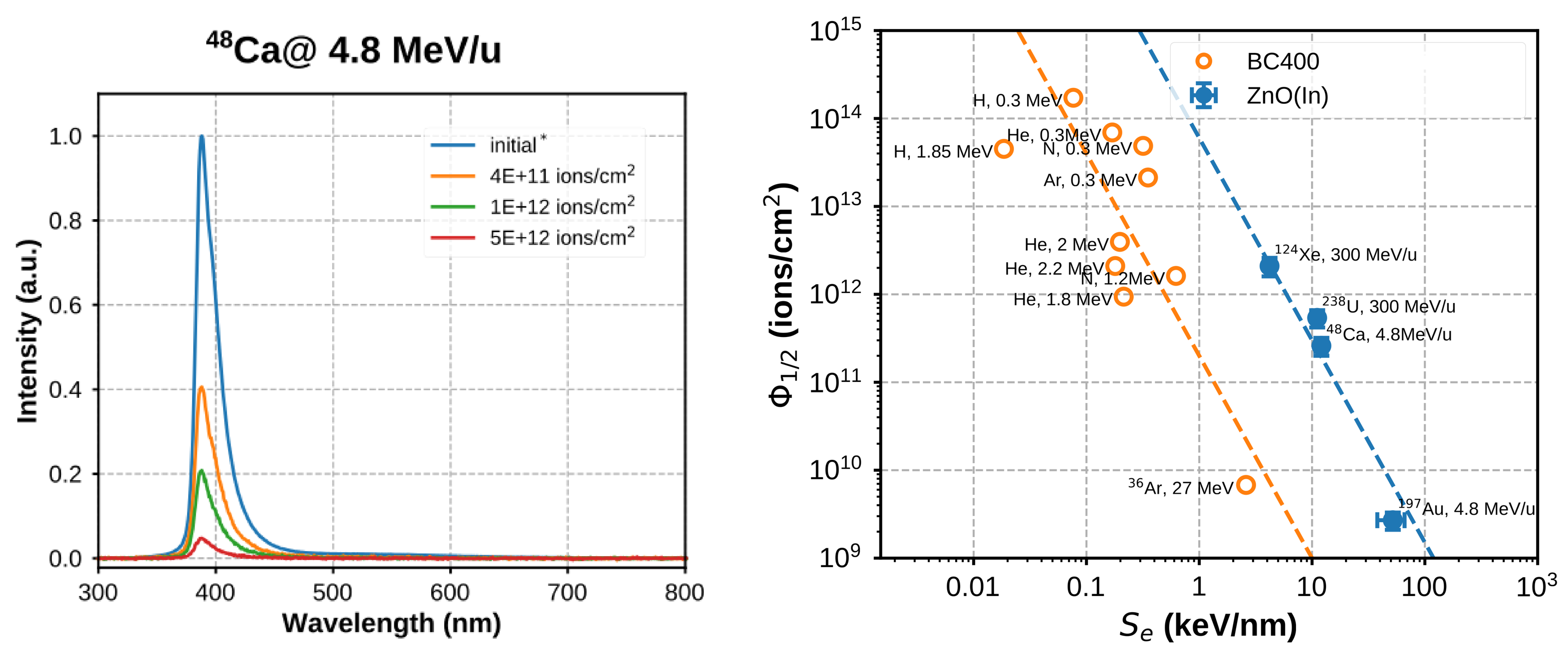

Fig. 2: Scintillation light spectrum of ZnO(In) ceramics at various fluences (left). Critical fluence of ZnO(In) and BC400 scintillator as defined by the Birks–Black model (right)[3–6].

Prototype detector design

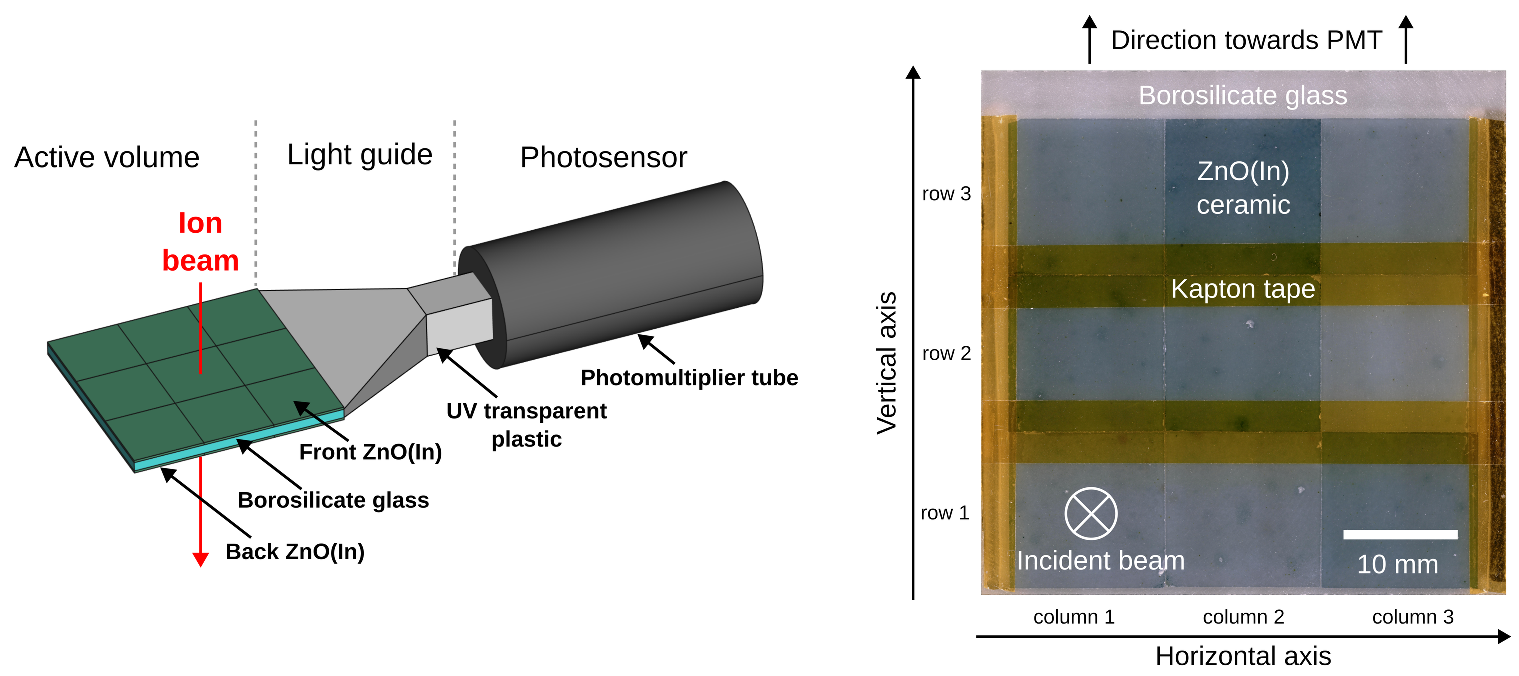

Fig. 3: The prototype detector, consisting of an active volume, light guide, and photosensor (left). Photo of the active area of 45 mm × 45 mm (right). ZnO(In) scintillating tiles are stacked in 3×3 arrays in the front and back side of the BK7G18 glass.

Setup for the in-beam tests

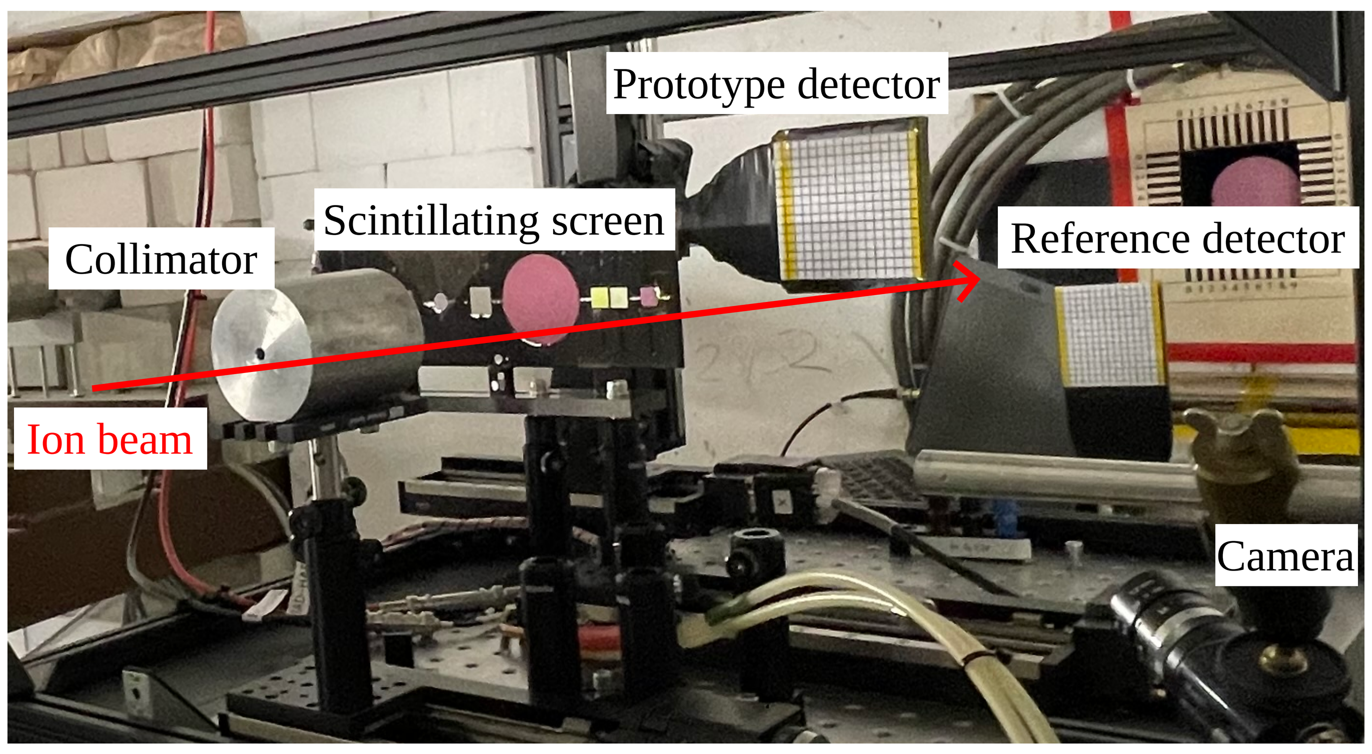

Fig. 4: Photo of the experimental setup for the in-beam tests of the prototype at SIS18.

Detector response to heavy-ion beams

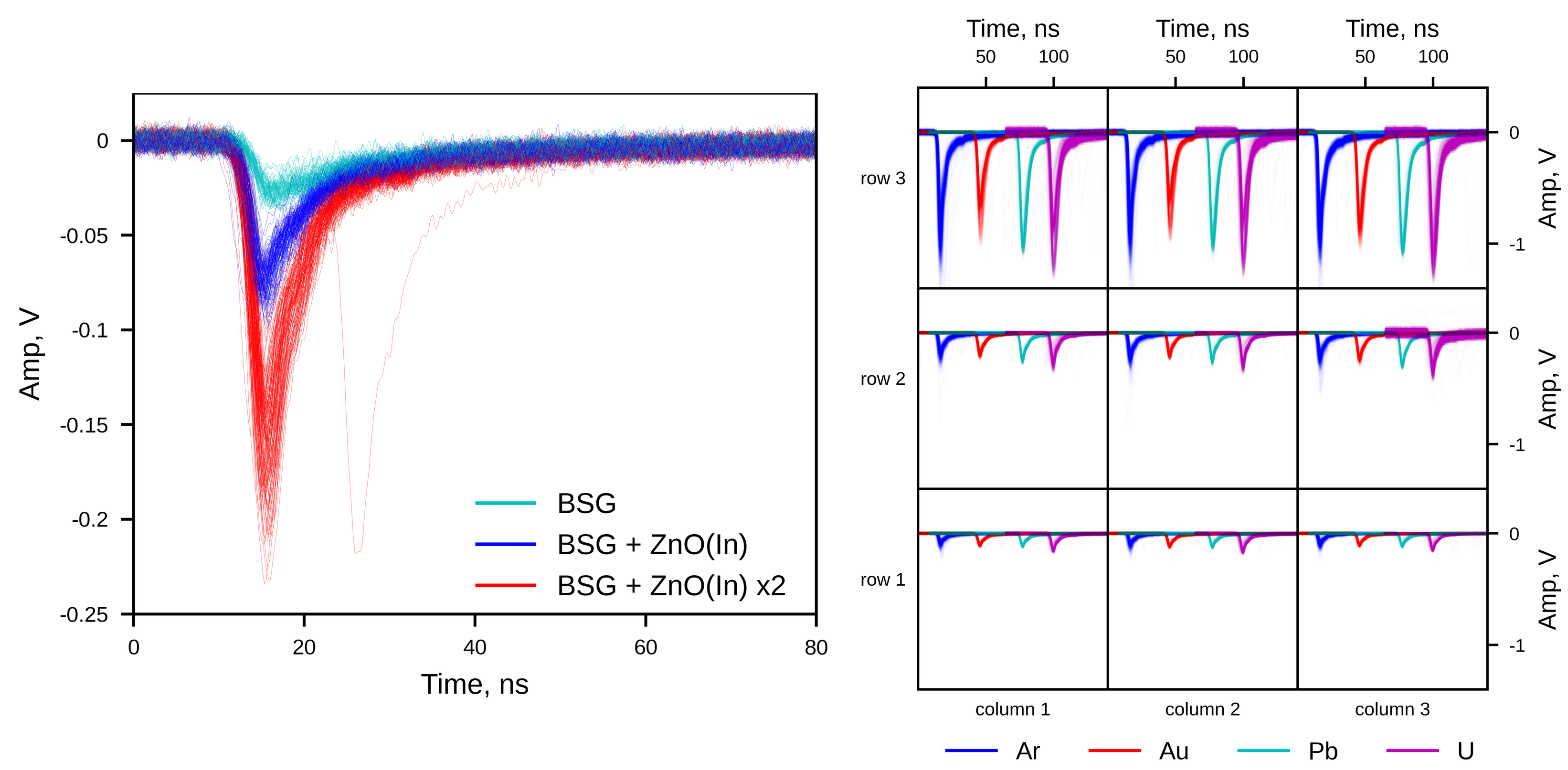

Fig. 5: Detector response when ion beam passes through different layers of the active volume (left). Detector response when ions hit different locations on the active area of the prototype (right).

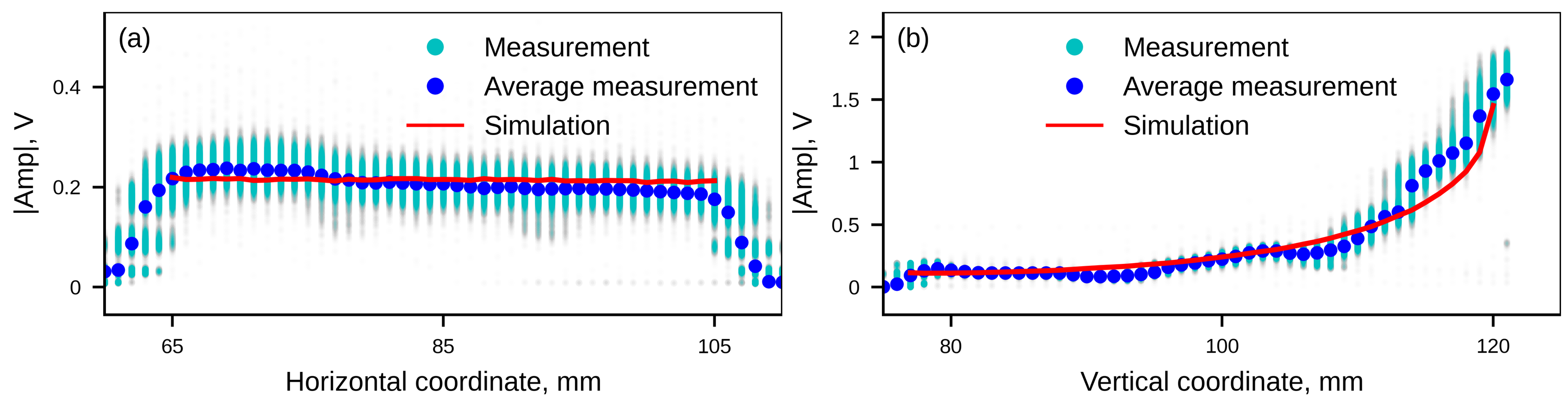

Fig. 6: Change of the amplitude of the signal along horizontal (a) and vertical (b) direction on the prototype active area (measurement vs. simulation)[7].

Conclusion and outlook

– The design and performance tests of a prototype radiation-hard fast scintillation detector were successfully conducted at GSI.
– We observed a spatial dependency of the amplitude of the prototype signal when the ion beam hits different positions on the active area, that is due to the change of scintillation light transmission efficiency through the BK7G18 light guide.
– Further investigations are required to eliminate the spatial dependency of the light transmission efficiency through the BK7G18 light guide.

Questions? Please contact:
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Literature: [1] P.Forck *et al.*, Proc. DIPAC97, 1997, pp. 165–167; [2] P.Forck, JUAS Lect. Notes, 2011; [3] E.Gorokhova *et al.*, J. Opt. Tech., 2015, pp. 837–842; [4] E.Gorokhova *et al.*, J. Opt. Tech., 2018, pp. 729–737; [5] P.Boutachkov *et al.*, Proc. IBIC22, 2022, pp. 515–518; [6] M.Saifulin *et al.*, J. Appl. Phys., 2022, 195901; [7] http://www.opengatecollaboration.org;

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