Recoil detector system for the R3B setup

O.A. Kiselev, T. Aumann, W. Catford, M. Chartier, P. Egelhof, H. Emling, M. Freer, J.V. Kratz, M. Labiche,R. Lemmon, T. Nilsson, G. Nyman, G. Schrieder, H. Simon, A. Shrivastava, M Stanoiu, K. Sümmerer for the R3B Collaboration

A new universal setup with high efficiency, acceptance, and resolution for kinematically complete measurements of reactions with high-energy radioactive beams is planned to be installed at the focal plane of the high-energy branch of the Super-FRS at FAIR. The experimental configuration is based on a concept similar to the existing LAND setup introducing substantial improvement with respect to resolution and an extended detection scheme including a detector system for light (target-like) recoil particles in coincidence with the heavy fragments, neutrons and protons. The experimental setup is aiming at utilizing a wide variety of scattering experiments. Among them are light-ion (in)elastic and quasi-free scattering in inverse kinematics. The combination of the detection of fragments in forward direction with the target-recoil detection allows for the first time a kinematical complete measurement of, e.g., quasi-free nucleon knockout reactions.

The recoil particle detector provides precise tracking, vertex determination, energy and multiplicity measurement with high efficiency and acceptance. A general overview of the light ion detector has been given in the R3B Letter of Intent [1] and the Technical Proposal [2]. A thick liquid hydrogen target ($\sim$200 mg/cm^2 or $\sim$3 cm) will be used to reach the required luminosity for the radioactive beams. The use of an extended target requires the determination of the interaction vertex with a precision of 1-2 mm. This corresponds to an effective target thickness below 20 mg/cm^2 thus making possible a precise correction for the energy loss of the fragments in the target.

The barrel-like tracking system consists of two layers of position sensitive detectors placed into a vacuum chamber in order to minimize multiple scattering. The whole tracking system will be placed inside the gamma-ray calorimeter. The calorimeter will cover approximately 75% of the total solid angle with an opening in the backward hemisphere. This space free of the detectors will be used by the infrastructure of the liquid hydrogen target and the electronics of the tracker detectors. Study of knockout reactions and quasi-free scattering in inverse kinematics requires detection of recoils with energies in the range of 50 - 300 MeV, which corresponds to an angular range of 20° to 70° for an incident energy of 700 MeV/u. Extensive simulations using the GEANT4 package have been done in order to optimize the system performance. The first preliminary results show that the first layer of the barrel should be as thin as possible to reduce multiple scattering of the recoils, while the second layer can be 300 - 400 μm thick. The noise of the readout electronics and the small energy deposition of the fast particles, especially protons, limit the minimum thickness of the Si detectors; a reasonable thickness of the first layer is $\sim$100 μm. A strip pitch size on both sides of 100 μm is needed to obtain the required angular resolution of a few mrad.

Silicon microstrip detector have been developed in collaboration with the University of Geneva, Switzerland. The compact modules consist of double sided sensors mounted together with the readout electronics. The modules will serve as the prototypes of the recoil proton detectors for the R3B setup and will be used at the same time for experiments with the existing LAND reaction setup at Cave C. They will be installed into the target section for precise coordinate and ΔE measurements; the total energy of the recoils will be measured with the surrounding NaI Crystal ball. The suggested prototypes will be able to detect many particles at the same time due to their granularity and individual-strip readout. Each sensor has a size of 72$\times$41 mm^2, a thickness of 300 μm and a 110 μm readout pitch.

The detector prototypes have been tested with a β-source and cosmic rays. A good signal-to-noise ratio was observed even for very low energy deposit. Several detectors have been installed in a vacuum chamber and were tested using a ^{12}C beam at 350 MeV/u in November 2005 at the FRS. The beam has been fragmented in a thick target to check the Z separation of the detectors. An example of the measurements with a secondary ^{8}B beam is shown in a Fig.1 (the energy spread of the beam is not corrected for). The preliminary results show very good beam profiles, a small noise level and a good energy loss measurement. The detectors will be used to detect recoiling protons in scattering experiments with the LAND setup in 2006 and 2007. This work is partially supported through EURONS (EC contract Nr. 506065), BMBF contract 06MZ174 and HGF Virtual Institute VH-VI-061 (VISTARS).

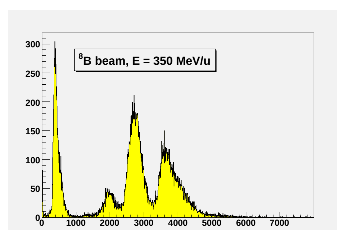

Figure 1: Z separation of Si microstrip detectors obtaned with a secondary ^{8}B beam, X-axis represents an energy loss in Si detector in arbitrary units.

References

[1] http://www-land.gsi.de/r3b/docu/R3B-LoI.pdf

[2] http://www-land.gsi.de/r3b/docu/R3B-TP-Dec05.pdf