The R^3B Experiment*

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The experiment Reactions with Relativistic Radioactive Beams (R^3B) at the high-energy branch of the FAIR facility will allow for kinematically complete nuclear reaction studies with short-lived radioactive ion beams in inverse kinematics, utilizing a wide beam energy range from about 100–1000 MeV/u covering the full mass range up to uranium. Experimental programs will address fundamental questions in nuclear structure and reaction physics, as well as nuclear astrophysics.

The planned physics program requires a high resolution and high efficiency for all detection systems. This is reflected in the proposed experimental setup, which has been or will be designed and constructed by the R^3B collaboration based on many years of experience with the ALADIN/LAND setup at GSI.

Each part of the former LAND setup has its improved counter part in the proposed R^3B setup, adapted to reach much higher resolutions, to deal with the high-rigidity beams available at FAIR, and to deal with the large variety of reaction types to be studied. Several milestones toward the realization of the R^3B experiment have been reached this year: the technical design reports (TDR) for two core components of the R^3B setup, the NeuLAND high-resolution neutron time-of-flight spectrometer and the CALIFA Barrel detector, which serves as a γ-ray spectrometer, calorimeter and, together with the Si-tracker, as a target-recoil detector, have been accepted by FAIR following the recommendation by the expert committee experiments (ECE).

The NeuLAND detector is a next-generation neutron time-of-flight spectrometer featuring high detection efficiency, high resolution and an excellent multi-neutron hit resolving power. This is achieved by a high granularity—the detector consists of 3000 sub-modules with dimension of $5 \times 5 \times 250$ cm^3—and a fully active detector volume with good calorimetric properties. At the high-acceptance position 15.5 m downstream from the target the detector face covers the full acceptance of the R^3B-GLAD magnet of ± 80 mrad, corresponding to 100% acceptance for neutrons with a decay energy of up to 5 MeV for $E_{\mathrm{beam}} = 600$ MeV/u. The position and time resolutions of 1.5 cm and 150 ps, respectively, result in a decay energy resolution of 60 keV for a neutron with a decay energy of 1 MeV. At the furthest distance in the high-energy cave of FAIR the NeuLAND detector is 35 m downstream of the target. In this case the geometric acceptance is reduced to 35 mrad, but the decay energy resolution is less than 20 keV at 100 keV decay energy. Another major step forward is the improved multi-neutron hit recognition capability. For instance, a 4 neutron hit can be identified as such with an efficiency of 60% and the decay energy resolution is still 42 keV for a decay energy of 100 keV.

In order to benchmark the NeuLAND design under experimental conditions the experiment S406 was carried out. A dedicated setup was constructed consisting 150 NeuLAND modules (bars) mounted in an array of 15 layers. This array was the irradiated with nearly mono-energetic neutrons stemming from quasi-free breakup of deuterons with energies ranging from 200 to 1500 MeV/u. The data are currently under analysis.

The CALIFA calorimeter will surround the R^3B target position. The detector is sub-divided into a forward endcap and barrel section covering laboratory angles up to 43° and 43–140°, respectively. Very high demands are placed on this detector by the planned physics program. It should not only detect γ-rays with energies from 100 keV up to several tens of MeV energy, but also highly energetic light charged particles, mainly protons, with energies reaching hundreds of MeV. The barrel section of the detector will consist of almost 2000 individual detector CsI crystals, which will be read out by avalanche photo diodes. This results, for instance, in an energy resolution of 5.5% and a full-energy peak efficiency of over 50% is achieved for 2 MeV photons emitted into the direction of the barrel section of CALIFA from a 700 MeV/u projectile.

The construction of another core component of the R^3B-setup, the superconducting large-acceptance large-gap dipole magnet R^3B-GLAD, is underway with an expected delivery at GSI in the fall of 2013.

Furthermore, the design and construction of the R^3B Si-tracker, which is already fully funded, is progressing well. Together with the CALIFA detector it will comprise the R^3B target recoil detector to accurately determine the momentum vectors of light charged particles after e.g. a (p,2p) reaction.

In addition a new thin and high-resolution fiber detector was commissioned with heavy ions and various new hard- and software components for the coupling of several DAQ systems were tested and evaluated.

First commissioning and physics experiments at GSI with R^3B-GLAD and 20%-versions of NeuLAND and the CALIFA Barrel will be carried out in 2014. Until 2016 the setup will be largely completed at GSI, used for commissioning and physics runs and moved to the new high-energy cave at FAIR in 2017/18.

* Support by HIC for FAIR, BMBF (06DA70471), and through GSI-TU Darmstadt Cooperation is thankfully acknowledged.