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Feasibility studies of the EXL setup for FAIR using the GSI storage ring ESR

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Abstract. The investigation of light-ion induced direct reactions in inverse kinematics, using stored and cooled radioactive beams, interacting with internal H, He, etc. gas-jet targets, bears a large potential for nuclear structure and astrophysics studies on exotic nuclei. An extended research project EXL has been accepted for the future facility FAIR in Darmstadt, Germany. In order to explore the experimental conditions for measurements planned at FAIR, a first test experiment for proving the feasibility of the EXL concept was performed.

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1 Introduction

The experimental conditions at the future facility FAIR [1,2] will provide unique opportunities for nuclear structure studies on nuclei far off stability, and will allow exploration of new regions in the chart of nuclides of high interest for nuclear structure and astrophysics. The use of stored beams and internal targets at the future storage ring NESR provides in many cases a gain in luminosity from accumulation and recirculation of the radioactive beams. This technique applied in inverse kinematics enables high resolution measurements down to very low momentum transfer.

The objective of the EXL-project (EXotic nuclei studied in Light-ion induced reactions at the NESR storage ring), which is part of the NUSTAR (NUclear STructure, Astrophysics and Reactions) [3] program at FAIR, is to capitalize on light-ion induced direct reactions in inverse kinematics using novel storage ring techniques, and a universal detection system providing high resolution and large solid angle coverage in kinematically complete measurements.

The key nuclear structure physics issues to be studied by the EXL setup are described in [4] and [5]. For many light-ion induced direct reactions the relevant nuclear structure information is located in the region of moderate to very small momentum transfer and the need for cooled stored beams interacting with a thin internal gas-jet target is obvious.

Within EXL a complex detection setup was designed with the aim to provide a highly efficient, high-resolution universal system, applicable to a wide class of reactions. The apparatus foreseen being installed at the internal target of the NESR storage cooler ring includes a Si-detector array for recoiling target-like reaction products, completed by gamma-ray and slow-neutron detectors, as well as forward detectors for fast ejectiles and an in-ring spectrometer for the detection of beam-like reaction products. A first test experiment for proving the feasibility of the EXL setup was performed at the Experimental Storage Ring ESR in GSI, Darmstadt.

2 Experiment and Results

The test experiment was performed using a beam of ^{136}Xe at energy 350 MeV/u interacting with an internal hydrogen gas-jet target. Detectors representing all the major detector systems of EXL were installed at the ESR (Fig. 1). An UHV capable single-sided Si strip detector was mounted in the vacuum chamber close to the internal gas-jet target to detect the recoiled protons. Two walls of organic scintillators with iron converters have been installed at distances of 2.5 and 4 meters from the target. They were used to detect the fast ejectiles (i.e. neutrons and light charged particles). A scintillator and a position sensitive

[a] http://ns.ph.liv.ac.uk/∼mc/EXL/collaboration/EXL-collaboration.html

p-i-n silicon diode with a thickness of 300 μm were installed in a moveable vacuum pocket driven in and out of the beam tube after the first dipole magnet of ESR. They have been used

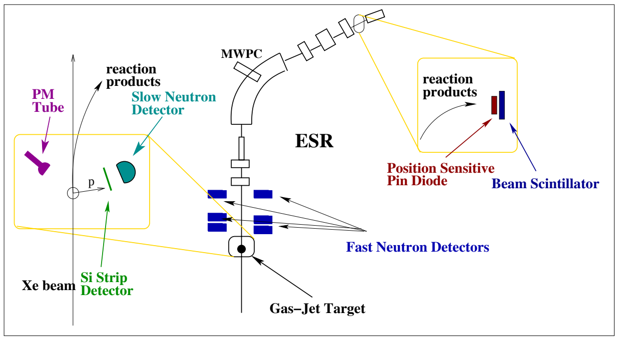

Fig. 1. Experimental setup for the current experiment (for details see text).

for identification and fast timing of the beam-like heavy ions. A multi-wire proportional chamber (MWPC) was used as a luminosity monitor, detecting ^{136}Xe ions deflected out of central orbit due to atomic charge-exchange. The luminosity has been also measured by a photomultiplier installed near the target, detecting UV light produced by the interaction of the heavy ions with the hydrogen atoms. The Si strip detector served as a third luminosity monitor using the fact that the small angle proton (i.e. Coulomb) elastic scattering cross section is well known. The setup was completed with a scintillator for detecting slow neutrons from (p,n) reactions.

During the experiment the beam was scanned over the target. The target profiles obtained with different detectors are consistent with each other (Fig. 2). The obtained profile reflects the overlap between the target and the beam. The size of the jet target was determined to be 7.0±0.2 mm (FWHM). The absolute luminosity has been deduced with the help of a current transformer and reached $(6 \pm 2) \times 10^{27}$ cm^{-2}s^{-1}.

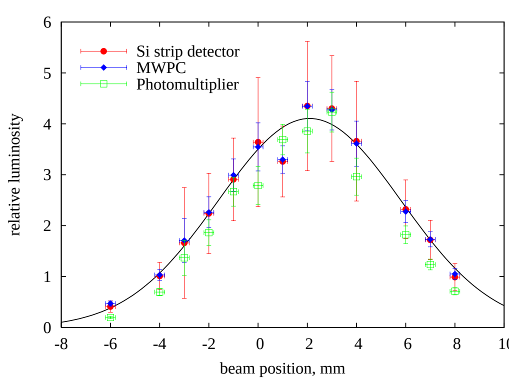

Fig. 2. Target profile of the gas jet as observed from measurements with 3 different luminosity monitors by scanning the beam over the target.

The recoiled protons from the elastic scattering are identified using their energy loss and position in the Si strip detector. The obtained preliminary cross section is in good agreement with the theoretical one, calculated with the use of the Glauber theory [6] (Fig. 3). This demonstrates the possibility to measure

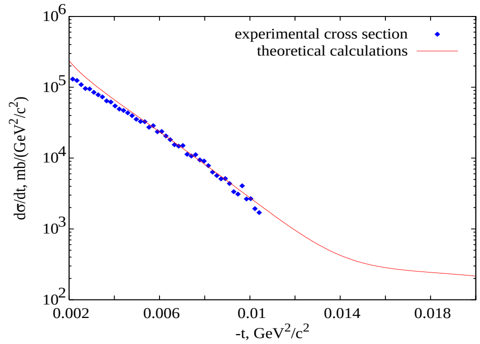

Fig. 3. p^{136}Xe elastic scattering differential cross section versus the four momentum transfer squared.

elastic scattering and to deduce nuclear matter distributions of exotic nuclei using the EXL setup.

Other reaction channels, like (p,n), (p,pn), (p,2p) could be identified using correlations between the detectors for fast ejectiles or the detector for slow neutrons and the detectors for beam-like heavy ions.

3 Conclusions

A first test experiment with prototype detectors for the EXL setup was performed. An absolute luminosity of the order of 10^{27} cm^{-2}s^{-1} was reached with the internal hydrogen target. Different methods for luminosity monitoring, applicable for EXL, were tested. Coincidences between the different detector systems were observed and the separation of several reaction channels was possible. This confirms the feasibility of the EXL setup, which is a very important milestone towards scattering experiments with exotic nuclei at the NESR. In the future further experiments with stable and unstable beams and extended setup are foreseen.

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