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Upgrade and commissioning of the Lund-York-Cologne CAlorimeter*

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Introduction

The Lund-York-Cologne CAlorimeter (LYCCA) is a charged-particle detector for the FAIR/NUSTAR collaboration, to discriminate heavy ions produced in nuclear reactions of relativistic radioactive-ion beams (RIB). The charge number Z and mass number A of the reaction products can be determined measuring their Time-of-Flight (ToF), energy loss and total energy. Employing the position sensitivity of LYCCA the flight paths of the reaction products can be tracked event-by-event, enabling the HIgh-resolution in-beam γ-ray SPECtropscopy (HISPEC) far from the line of stability (concept and design of LYCCA see Ref. [1]).

Upgrade of Electronics

The precursor LYCCA-0 using 12 ΔE-E telescopes and analog electronics was employed in the PreSPEC campaign from 2009 to 2014. A high resolution of Z and A was proven for proton number around 33 and mass region around 100 [2,3,4]. Afterwords the major upgrade from analog to digital electronics for LYCCA was carried out by the STFC Daresbury Laboratory. Using high-integrated Front-End Electronics (FEE) with Application-specific Integrated Circuits (ASICs), the electronic arrangement and data-acquisition process were significantly simplified. As

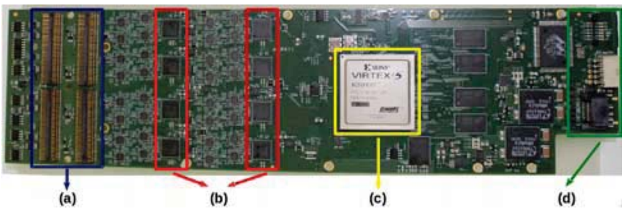

Figure 1: The view of a FEE-card. (a) four 16-channel ASICs; (b) eight 14-bit ADCs; (c) Virtex-5 PowerPC; (d) Connections: HDMI (Clock), Power and Gbit-Ethernet.

shown in Fig. 1, each FEE card contains four 16-channel ASICs, which amplify the signals from all 64 channels of one Double-Sided Silicon Strip Detector (DSSSD). The ASIC is optimized for high dynamic range with excellent linearity and noise performance. Each ASIC covers three energy ranges: (i) high gain up to 20 MeV, (ii) medium gain up to 1 GeV, and (iii) low gain up to 20 GeV. The pre-amplified signals are digitalised in ADCs, processed in the Virtex-5 PowerPC and then stored in a LYCCA-Server. A master-slave control delivers a synchronous time stamp via HDMI-cables on all FEE cards in use. The Multi-Instance Data-Acquisition System (MIDAS) ensures the hardware configuration, experiment control, data merging and data storage.

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Commissioning at IKP Cologne

Since 2016 the LYCCA setup is located at the Cologne tandem accelerator. A new three-stage beam tube was built for LYCCA, which allows for three different distances between target position and the DSSSD-wall (cf. Fig. 2). Thus, the corresponding opening-angles range from 1.5 to 16 degree. Currently 25 FEE modules and 14 ΔE-E telescopes are installed on LYCCA. In order to check the specifications and energy resolutions of the DSSSDs with the new digital FEE modules, measurements were performed with a triple-alpha source. Employing the Multi-Instance-Data-Acquisition System (MIDAS) experiment data were stored, sorted event by event and analyzed using the data-analysis framework ROOT. The results show that more than 99% DSSSD-channels were working successfully. A consistent energy resolution of around 1.1% at 5.8 MeV was obtained for all 14 DSSSDs in use. At the IKP several in-beam experiments were also curried out to test the performance of the LYCCA system. In collaboration with the University of York, a 2 mm thick plastic scintillator for later ToF-measurement was tested on the LYCCA setup in March 2016. A ^{12}C beam with an en-

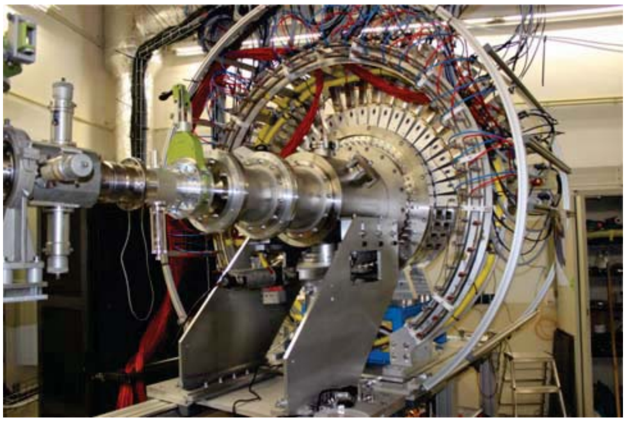

Figure 2: The current LYCCA-construction in the IKP Cologne. With the 25 installed FEE-modules all DSSSDs can be operated.

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ergy of 60 MeV was scattered on the ^{197}Au target with a thickness of 0.2 mg/cm^2, and stopped in the ToF-detector. The generated light signals were detected with 32 photomultipliers (PMTs) mounted around the plastic scintillator. Together with the Lund University in May 2016, another beam time was scheduled to test the performance of the ΔE-E telescopes. A proton beam with an energy of 18 MeV was scattered on a thin gold foil and then detected in the DSSSDs and CsI-detectors. In November 2016 a further in-beam experiment of elastic scattering of heavy ions was conducted. In this measurement the medium-gain range (up to 1 GeV) of the FEE modules was tested successfully for the first time. A ^{12}C beam with a kinetic energy of 60 MeV was scattered on the ^{197}Au target with a thickness of 0.17 mg/cm^2. At a distance of 120 cm between the target and the DSSSDs, a continuous scattering-angle coverage of 1.5 to 9.5 degrees was obtained. The measured Full Width at Half Maximum (FWHM) of the DSSSDs are 350 keV to 400 keV at approximately 60 MeV. In order

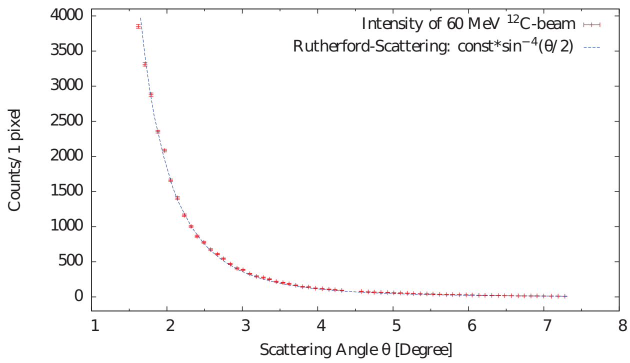

Figure 3: The measured intensity distribution of the elastically scattered ^{12}C-nuclei on ^{197}Au-target follows the expected distribution of the Rutherford scattering.

to investigate the exact angular distribution of the beam intensity after the elastic scattering, the measured data of the p- and n-side were correlated and, thus, the events in the DSSSDs were analyzed pixel by pixel. Figure 3 shows the intensity distribution of 64 contiguous pixels from two DSSSDs located vertically below the beam axis. The measured values, covering a range of 1.5 to 7.2 degree, reproduced the theoretically expected scattering-angle dependence of $\sin^{-4}(\theta/2)$ nicely.

Outlook

For further in-beam experiments at the Cologne tandem accelerator, a modified mechanical construction of the LYCCA chamber was realized by IKP's mechanical workshop. The new design consists of two octagon brackets and a back wall, which support up to 24 ΔE-E telescopes in operation (see Figure 4). The target ladder is located between the octagon brackets. This new construction increases the scattering-angle coverage from a maximum of 16 to a maximum of 120 degree, as well as the solid-angle coverage up to 60% of 4π significantly, which means that LYCCA can be used to further examine elastic and inelastic particle scattering. This configuration will be shortly installed and tested for the first time.

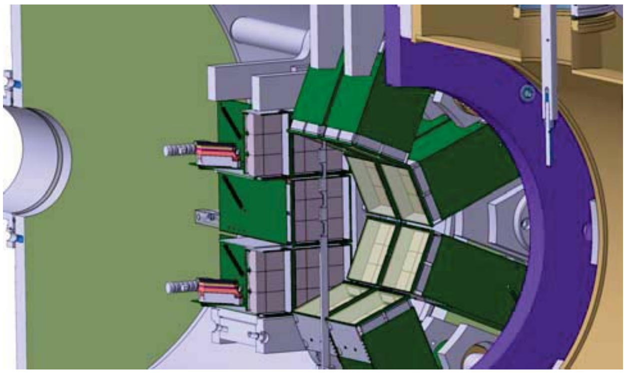

Figure 4: The new mechanical design of the LYCCA chamber. Each octagon bracket and the back wall support 8 ΔE-E telescopes.

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