GSI short reports 2020-7, 10.15120/GSI-2020-00953

Progress Report on Developments for the HADES and R3B Fair Phase-0 Experiments*

L. Fabbietti†[1], J. Friese[1], R. Gernhäuser[1], for the TMLFRG1316 project
[1] Physik Department, Technische Universität München, Garching, Germany

Abstract

The present GSI F&E cooperation project TMLFRG1316 with the Physics Department der Technischen Universität München (TUM) includes 3 research and development projects within the framework of the FAIR pillars HADES/CBM and NUSTAR. All projects are intimately connected to upcoming FAIR Phase-0 experiment campaigns. These projects have supported the existing hardware and software developments at the TUM Physics department connected with the HADES and R3B experiments and strengthened the synergies between TUM and GSI-FAIR.

THE NEW RICH PHOTON DETECTOR IN HADES FAIR PHASE-0 CAMPAIGNS & PREPARATIONS FOR FAIR PHASE-1

The ring imaging Cherenkov detectors (RICH) of the HADES and CBM experiments are crucial devices for the identification of high momentum electrons and positrons needed for e+e- - pair spectroscopy of meson and baryonic resonance decays in fire balls of dense and ground state nuclear matter. The related physics programs of both experiments are complementary with HADES focusing on projectile energies in the range 1 - 4 AGeV and CBM probing higher collision energies up to 15 AGeV. Both experiments require an optimum signal to background ratio for e+/e- identification at high interaction trigger rates (R > 50 kHz) and pose respective challenges for the detection of single Cherenkov photons.

In close collaboration with the CBM RICH group and the GSI EE department we have replaced the MWPC photon detector of the HADES RICH with a system of 64 channel **MAPMTs** (multi anode photo multiplier tubes) for Cherenkov light detection and new DiRICH front end electronics for fast signal readout. This is the demonstrator system for the CBM RICH, also. Within the Phase-0 campaign of FAIR a substantial fraction of the available beam time in 2019 was granted to the S477 experiment of HADES. The collision system Ag + Ag (E = 1.58 AGeV) has been measured with the upgraded HADES spectrometer at typically 15-20 kHz trigger rates. The efficient and extremely stable operating detector system resulted in the recording of altogether 1.5 x 10^{10} semi-central collisions. The RICH has been operated with a modified gas radiator (C_4H_{10} instead of C_4F_{10}) and detected an average number of 15 hits per e+/e- induced Cherenkov ring pattern with the ring centers distributed homogeneously all across the azimuthal acceptance of the sensitive detector area. The excellent timing of the detector allowed for a significant noise and background reduction resulting in a single e+/e- -identification efficiency of >90%. These (still preliminary) analysis results have been obtained in close collaboration with our colleagues from BU Wuppertal and JLU Giessen and have been submitted to the proceedings of the DIRC 2019 workshop [1].

Future campaigns at significantly higher projectile energies (FAIR Phase 1) require admixtures to the radiator gas (C_4H_{10} + N_2, CH_4, etc.) to keep the RICH detector hadron blind. At incident energies already around 3-4 AGeV, ω-mesons thermalized in the fireball will decay dominantly into charged pions with lab momenta p > 2.3 GeV/c, well above the C_4H_{10} Cherenkov threshold. Their Cherenkov radiation will obscure the rare signal from di-electron decays. In the present RICH gas system the necessary modifications seem to be straight forward.

PION – INDUCED REACTIONS WITH HADES

Secondary pion beams were successfully employed in two experimental campaigns with the HADES spectrometer. A tracking device located along the pion chicane and composed of two silicon detectors and one monocrystalline diamond device were developed within the HADES collaboration and allowed for the momentum reconstruction of each beam particle with a precision of 2 per mil. Our group at the TUM was strongly involved in this project heading the publication of the achieved results [2].

The experimental campaign was mainly devoted to the measurement of baryonic resonances produced in π+p reactions and strange hadrons (such as K^+, K^-, K^0_S, Λ and ϕ) properties in π+C and π+W reactions. The TUM group supported by this F&E program completed successfully the analysis of K^+, K^-, K^0_S, Λ and ϕ production in π+C and π+W reactions at 1.7 GeV/c and a first publication of the results on charged kaons and ϕ was achieved in 2019 [3]. In this work, the antikaon absorption off two different nuclei could be quantified in a model independent way for the first time and also a model independent measurement of the ϕ absorption within the nucleus could be pinned down. The results favor an enhanced ϕN cross section with respect to previous hypotheses.

Based on the successful employment of the secondary pion beam at GSI with HADES and considering the exciting results that are currently finalized within the collaboration, the new experimental proposal for HADES includes

* Work supported by GSI F&E program, contract: TMLFRG1316
† Laura.Fabbietti@tum.de

a high statistics measurement with pion beams, now also implementing a new electromagnetic calorimeter and the upgraded RICH detector.

SETUP, TUNING AND OPERATION OF THE CALIFA CALORIMETER

The R3B-CALIFA calorimeter (CALorimeter for In-Flight gamma-ray and pArticle detection) is a key detector for the R3B experiment. CALIFA is dedicated to the detection, tracking and energy determination of light charged particles and gamma-rays emerging from the reactions induced by relativistic exotic ion-beams on the R3B target.

Already end of 2018 we started setting up the CALIFA Demonstrator for the first Phase-0 experiments of FAIR. With 448 crystals from the barrel, already here a substantial part of CALIFA was installed and operated in the open demonstrator configuration. The TUM group was not only participating in the mounting phase but especially was responsible for setting up and operating the dead time free DAQ system with 32 FEBEX cards. The detector has been brought to full operation in the S444 experiment lead by the TUM group and has been successfully used throughout the full spring campaign. The ongoing analysis of the ^{12}C(p.2p) and proton elastic scattering data have already proven the proposed resolution and particle separation of CALIFA as well as the advantages of the dead time free readout of CALIFA.

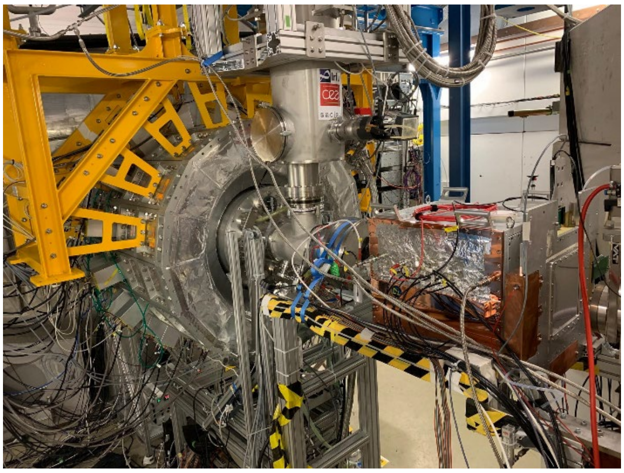

Figure 1: CALIFA setup in its final geometry prepared for the S444 experiment in spring 2020.

The second halve of 2019 was governed by the installation of the final CALIFA main frame with the Barrel and iPhos described in the TDR [4, 5] and the crystals in their final configuration in Cave-C (see figure 1). The TUM group has installed the full data acquisition system for CALIFA arranged in two large towers sliding together with the detector on a rail system with a capability to process 1024 crystals each. Using APD photon detectors especially the slow control for monitoring and adjusting gain parameters like high voltage, temperatures is essential for stable user operation and the later calibration. An automatic calibration routine for the 1216 detector elements currently installed, was intensively used and constantly improved. Now the CALIFA team is able to adjust the signal amplitudes by tuning the APD supply voltages for all channels within a few hours to fit to the dynamic range of all components in the signal chain. In addition we have developed a new network based slow control interface which allows for an EPICS based control of the large number of preamplifiers, power supplies, trigger modules and pulsers we operate in the setup. While the upcoming Phase-0 experiments this hardware will already be used. Together with the GSI and the IEM (Madrid) teams the corresponding software for the general R3B control system is developed.

In parallel we have operated several smaller CALIFA DAQ systems for quality assessment at the different crystal production and mounting sites of the R3B collaboration.

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