Vol. 51 (2020) *Acta Physica Polonica B* No 1

HYPERON STUDIES AND DEVELOPMENT OF FORWARD TRACKER FOR HADES DETECTOR*

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(Received November 18, 2019)

The HADES detector is a versatile detector specialized in dilepton and strangeness measurements at GSI/FAIR. It has been recently upgraded with an Electromagnetic Calorimeter (ECAL) and a new RICH photon detector. In the year 2020, an additional Forward Tracker (FT) will be installed. It will extend the acceptance of HADES at forward angles (0.5° to 7°) essential for many reaction channels. The Straw Trackers are currently assembled by the Kraków and FZ Juelich teams, based on developments for the PANDA Forward Tracker. The increase of acceptance will play a significant role in studies of $N(\pi)+N$ and $p+A$ reactions, where this detector is essential for exclusive channels and PWA analysis of hyperon production and decays such as, for example, $\Lambda \to p\pi^-$, $\Lambda(\Sigma) \to \Lambda e^+e^-$ and $\Xi^- \to \Lambda\pi^-$ (hyperon transition form factors). The feasibility studies of hyperon reconstruction together with performance of the tracking detectors in HADES framework are shown in this contribution.

DOI:10.5506/APhysPolB.51.239

1. Introduction

Hyperons are bound systems consisting of quarks in which one of them is strange (with the gluons as the field quanta of the strong interaction between the quarks). To have deep understanding of all such hadronic structures and its transitional properties, the first step is always to measure their form factors. When electrons are scattered on hadrons, the internal electric structure becomes visible, if the momentum transfer is large enough and, as electrons, also have an additional property of spin-1/2, therefore, the magnetic structure can also be observed. The differential cross section for elastic scattering is given by the Rosenbluth formula:

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* Presented at the 3rd Jagiellonian Symposium on Fundamental and Applied Subatomic Physics, Kraków, Poland, June 23–28, 2019.

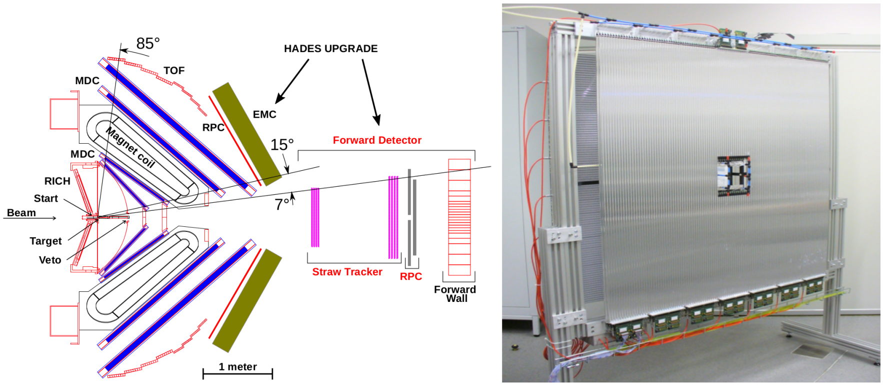
$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}=\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}_{\mathrm{mott}}\left[\frac{G_{\mathrm{E}}^{2}\left(Q^{2}\right)+G_{\mathrm{M}}^{2}\left(Q^{2}\right)}{1+\tau}+2\tau G_{\mathrm{M}}^{2}\left(Q^{2}\right)\left(\tan\frac{\Theta}{2}\right)^{2}\right]. \qquad (1)$$

The non-relativistic form factors $G_{\mathrm{E}}^2(Q^2)$ (electric form factor) is a Fourier transformation of the spatial distribution of charge and $G_{\mathrm{M}}^2(Q^2)$ (magnetic form factor) of magnetic moment. These form factors are determined when the elastic scattering cross section for a fixed q^2 (4-momentum transfer) as a function of the scattering angle is measured. This is repeated for different values of q^2. The resulting data is analyzed in terms of the Rosenbluth formula yielding $G_{\mathrm{E}}^2(Q^2)$ and $G_{\mathrm{M}}^2(Q^2)$. The q^2 dependence of the measured form factors leads then to the spatial distribution of charge and magnetic moment. In this way, the electromagnetic structure of hadrons can be studied by taking hadronic transition which is parametrized by using electromagnetic form factors and is expected to be an analytic function of the four momentum transfer squared q^2. In space-like domain, where $q^2 < 0$, it is studied by scattering experiment which is done by CLAS MAMI at Jefferson Lab and in time-like domain, where $q^2 > 0$, it is studied by annihilation experiment which is done by HADES at GSI [1].

2. HADES spectrometer

HADES [2] is a magnetic spectrometer detector operating at SIS18 synchrotron in GSI Helmholtz Institute for Heavy Ion Research in Darmstadt (Germany). It is a universal experimental apparatus designed for the study of hadronic matter using rare penetration probe such as dielectrons or strange particles in the 1–3.5 AGeV incident energy. The mesurements of dielectron production in the elementary collision give access to the Dalitz decay of baryonic resonances providing information on electromagnetic structure of baryon which is corelated to the results of electron scattering reaction. The experiment with pion beam at GSI allows us to directly study such baryonic resonances via the Dalitz decay [3].

HADES consists of 6 superconducting toroidal coils in its central part which produces a toroidal magnetic field. The toroidal magnet together with two modules (6 planes each) of mini drift chambers (MDC) in front and two planes of MDC behind the magnet build a magnetic spectrometer for measuring momenta of charged particles. In front of the magnet, a RICH detector is placed for electron identification. This detector is crucial, because it is hadron blind and for higher level of trigger, it provides most essential information for data reduction to get clean signals for electrons. Behind the magnet, there is the TOF detector which is used for particle identification (angles $> 45^\circ$) as well as the first level triggering, which is based on the multiplicity trigger of charged particles (Fig. 1 (a)).

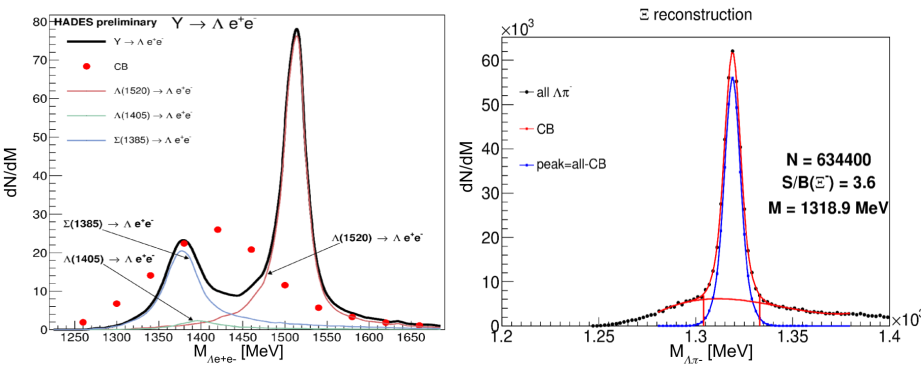


(a) (b)

Fig. 1. A cross section of the HADES detector (a) with the installed Forward Detector and Electromagnetic calorimeter upgrade. Two out of six segments are shown. Particles cross the detector from the target through the RICH, two planes of MDC modules, the toroidal magnet, again 2 planes of MDC, the TOF wall and both upgraded systems ECAL and FT (b).

Forward Tracker (FT) [4] (Fig. 1 (b)) is made up of straw tubes which are cylindrical mini drift chambers filled with the over pressurized gas mixture making straws self-supporting. In HADES, FT will be arranged in two stations STS1 and STS2. STS1 comprising 540 straws arranged in four layers with the tilt of 0°, 90°, 90° and 0° is built in FZ Juelich and STS2 comprising of 1024 straws also arranged in 4 layers with the tilt of 0°, 90°, 45° and −45° with an active region over 1 m^2 is built in the Jagiellonian University, Kraków.

The HADES Collaboration group in Kraków had already done the simulations for two types of benchmark channels for proton–proton collisions at 4.5 GeV kinetic beam energy using Geant3 package which includes HADES geometrical description. Events were generated for both signal and background channels using the PLUTO Monte Carlo package. $\Lambda(1520) \to \Lambda(1405) + X$ (Fig. 3 (a)) and Ξ^- production (Fig. 3 (b)) are two benchmark channels which were simulated and in which final state particles of interest are p and $\pi^{\pm}$ produced through a weak decay of parent Λ. As Λ is neutral, therefore, it is reconstructed by using charged decay channel $p + \pi^-$ (BR is 69%). The simulated phase space for Ξ^- signal channel shows that most pions will be registered in HADES (angle above 10°), while protons will be measured in forward detector (angles below 8°) [5]. Therefore, hyperons are reconstructed by treating all particles flying into FT as proton, dileptons are identified using RICH and pions can be identified using TOF and momentum reconstruction.



(a) (b)

Fig. 2. Two types of benchmark channels for proton–proton collisions at 4.5 GeV kinetic beam energy have been chosen to study with the new HADES detector, namely production of excited hyperons $\Lambda(1520)$, $\Sigma(1385)$ and $\Lambda(1405)$ (a) and production of Ξ^- (b).

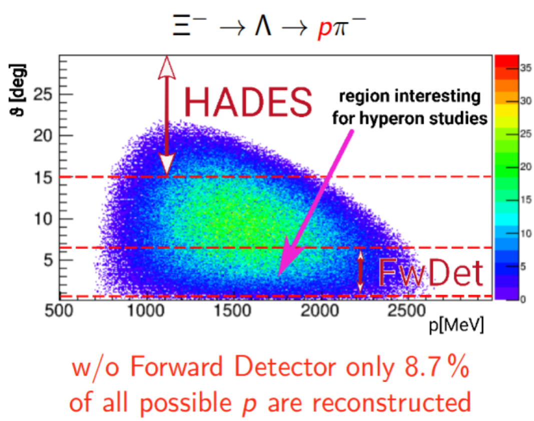


Fig. 3. Observed simulated p distribution in the forward angles of HADES at 4.5 GeV clearly shows the increase in detection capability.

3. Summary

The simulations of two benchmark channels are shown using newly developed FT in HADES. The blind region of HADES will be covered with the straw tube FT covering forward angles from 0.5°–7°, which will increase the acceptance for HADES. The estimated reconstruction efficiency for both the simulated channels is 0.5%.

This project is supported by the European Unions Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No. 665778, the National Science Centre, Poland (NCN) 2016/23/P/St2/04066 POLONEZ and by Ministry of Science and Higher Education 7150/E-338/M/2018.

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