BL31LEP
Laser-Electron Photon II

1. Introduction

BL31LEP, also known as LEPS2, provides a backward Compton scattering gamma rays beam for hadron physics. The maximum energy of the gamma ray is approximately 2.4 GeV when we inject 355 nm UV laser photons into 8 GeV stored electrons. We deliver the beam to the LEPS2 building, which is located outside the storage ring. We study hadron physics by irradiating a nuclear target with the beam, and we have two independently operated large detectors BGOegg and a solenoid spectrometer in the LEPS2.

In FY2023, we installed an additional electromagnetic calorimeter to BGOegg and continued to collect physics data using the solenoid spectrometer.

2. Status of the BGOegg experiment

The BGOegg experiment aims to further advance research into the properties of hadrons.

Quarks and gluons moving freely in the early universe formed hadrons, being confined within them as temperature decreases and the interaction acting on quarks and gluons became stronger. The hadron formation led to the generation of a large amount of the matter mass and was the first step in the evolution of the matter. A photon beam of energy around 1 GeV has an important function in hadron physics, which is a research field in which we study the structure of hadrons in detail. Well-established baryons might have the configuration of more than three (two) valence quarks as fraction such as five (four) quarks. In this regard, we study exotic hadrons such as pentaquark baryons (tetraquark mesons). The $f_0(980)$ meson is one such tetraquark candidate. We report differential cross sections and photon beam asymmetries were measured for the reaction $\gamma p \to f_0(980)\, p \to \pi^0\pi^0 p$ for the first time [1] (Fig. 1). The results indicate the t-channel exchange of vector mesons as a mechanism of $f_0(980)$ photoproduction at $E\gamma$~2.1GeV, putting constraints on the nature of $f_0(980)$.

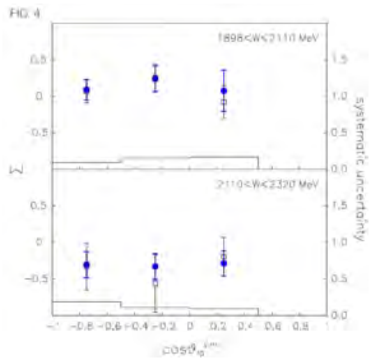

Fig. 1. Photon beam asymmetries Σ of the reaction $\gamma p \to f_0(980)\, p$.

Dynamical hadron mass generation is another subject to be studied in hadron physics, where chiral symmetry plays a key role. From this point of view, we are interested in the medium modification of hadrons in a nucleus. Due to the $U_A(1)$ anomaly effect, the mass of the η' meson is expected to change significantly owing to the nuclear medium effect in the nucleus.

BGOegg is a large solid angle electromagnetic calorimeter consisting of 1,320 $Bi_4Ge_3O_{12}$ crystals stacked in an egg shape. This calorimeter covers a polar angle range of 24 to 144 degrees and mainly detects gamma rays from neutral mesons for the study of the photoproduction mechanism of hadrons. BGOegg can measure the energy of 1 GeV gamma rays with a resolution of 1%. This is the world's highest resolution in this energy range. The first phase of BGOegg experiments was carried out in 2015 and included measurements of the differential cross sections and polarization observables of neutral mesons, a search for bound nuclei with η' mesons, and precise measurements of the mass distribution of η' mesons in nuclei. The analysis of η'-mesic nuclei is ongoing [2].

In FY2023, we are preparing for the second phase of experiments, aiming to elucidate the hadron production mechanism with higher statistics and precision. In this second phase of experiments, we plan to install a new calorimeter (Forward Gamma, FG) to fill the blind area ahead and use various targets. Figure 2 shows the actual setup of BGOegg and FG in BL31LEP. We are also increasing the intensity of the photon beam and improving the data collection system. After adjusting the detectors, introducing a new laser system, and reinforcing the γ beam stopper (summer 2023), the main experiment with a copper target has begun at the end of FY2023.

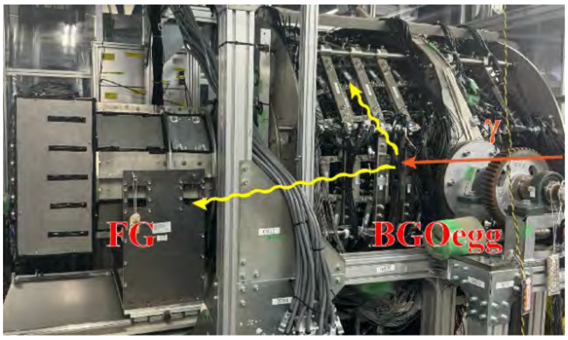

Fig. 2. Setup of BGOegg experiment.

3. Status of the solenoid spectrometer experiment

We aim to study exotic hadrons such as a pentaquark candidate composed of five quarks, meson–baryon molecule candidates, and deeply bound anti-kaonic nuclei in the solenoid spectrometer experiment.

In FY2023, we obtained data on hadron photoproduction from liquid hydrogen and liquid deuterium targets using the solenoid spectrometer. We successfully collected data using a newly installed time-of-flight detector and observed trajectories of charged particles with the TPC and the DCs. The momenta of particles were measured from the trajectories in the TPC, and the kinds of particles were identified using the time-of-flight detectors (RPC) [3] and dE/dx information obtained with the TPC (Fig. 3). We continue to collect data for the study of exotic hadrons, including the search for $\bar{K}$pp bound states.

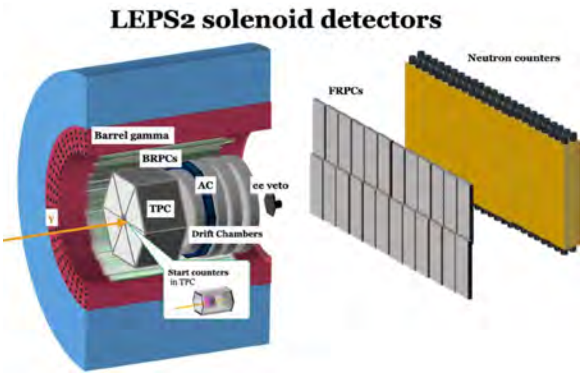

Fig. 3. Schematic view of LEPS2 solenoid spectrometer.

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[2] Muramatsu, N. et al. (2024). *EPJ Web Conf.* **291**, 01009.

[3] Tomida, N. et al. (2023). *Nucl. Instrum. Methods*

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