

BL31LEP Laser-Electron Photon II

1. Introduction

BL31LEP, also known as LEPS2, provides a backward Compton scattering γ -ray beam for hadron physics. The maximum energy of the γ -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.

2. Progress of BGOegg Phase-II Experiment

The aim of the BGOegg experiment is to investigate whether hadron masses arise from the spontaneous breaking of chiral symmetry, by precisely measuring possible mass modifications of mesons in the high-density environment of nuclear matter. Specifically, the experiment focuses on the photoproduction of η' , ω , ϕ , and $f_1(1285)$ mesons and on obtaining their mass spectra to examine potential in-medium mass shifts.

In the BGOegg Phase-II experiment, a forward PWO calorimeter (Forward Gamma) was installed to enhance the detection acceptance for photons emitted from meson decays. Plastic scintillators for charge detection were also installed immediately before the Forward Gamma detector. These detectors covered up to 16 degrees, thereby significantly reducing backgrounds originating from multimeson photoproduction processes and improving the precision of in-medium decay signals. In FY2024, dedicated data-taking for the Phase-II

experiment was carried out. With the upgrade of the laser system, a maximum beam intensity of 5 Mcps was achieved. In parallel, the data acquisition system was upgraded to enable stable operation at a trigger rate of 1.5 kHz. As a result, approximately 80% of the target statistics were accumulated, providing a sufficient dataset for subsequent detailed analyses.

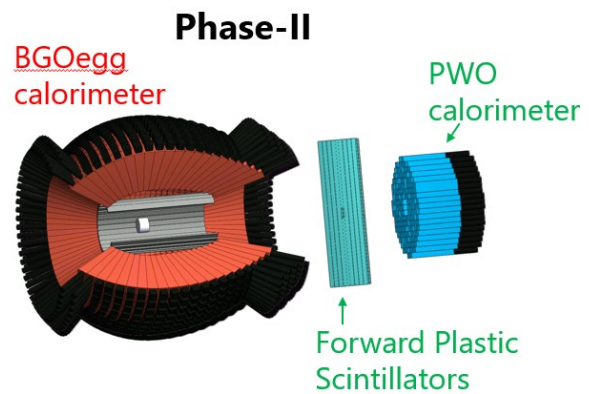


Fig. 1. Setup of BGOegg Phase-II experiment.

3. Status of the Solenoid 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 (Fig. 2).

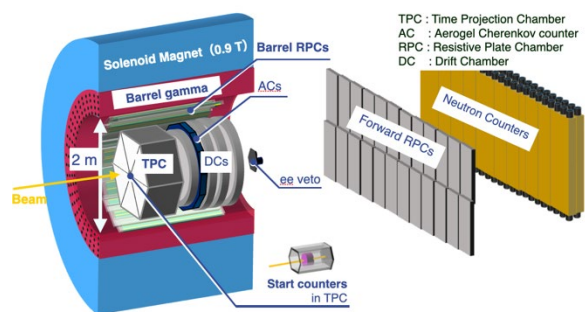


Fig. 2. Setup of solenoid experiment.

3.1 Run 2024A

Identifying kaons in the forward region is important to our study. The Forward Resistive Plate Chamber (FRPC) for particle time-of-flight measurements was not working properly owing to aging and a circuit failure. Therefore, a new plastic scintillator system was installed in the forward region.

During the 2024A beam time, data were collected to evaluate the particle identification performance of the forward detector system. The scintillators employed for the new TOF system were recycled from the BL33LEP beamline. These characteristics were found to be insufficient for reliable kaon identification. As a result, we are currently replacing the critical region with new scintillators that meet the required performance.

3.2 Run 2024B

A new 266 nm pulsed laser was introduced for photon beam generation, enabling one month of data acquisition. Compared with the previously used 355 nm laser, the 266 nm system increases the maximum photon energy from 2.4 to 2.9 GeV, thereby allowing access to reactions involving heavier particles.

Although the photon beam intensity was lower than that obtained with the 355 nm laser and operational issues such as a rise in chiller temperature limited stable operation, one month of data was successfully collected. We are currently using these data to investigate the feasibility of future hadronic photoproduction experiments.

3.3 Progress in Data Analysis

We continued the analysis of the physics data acquired since 2022. A major challenge has been the

distortion of the drift field in the Time Projection Chamber (TPC), caused by feedback ions from the readout region, particularly at high beam intensities. In earlier analyses, we assumed that the distortion was localized near the beam axis. The correction was determined by extrapolating tracks from the outer hits toward the inner region, where the additional electric field was parameterized as a polynomial function of the radial distance from the beamline.

However, as the analysis extended to various hadron photoproduction reactions, it became evident from missing mass spectra that the distortion affected positive and negative particles in opposite directions (Fig. 3). This clearly indicated that the previous correction scheme was incomplete.

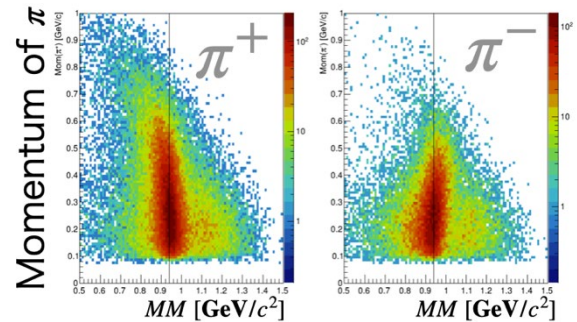


Fig. 3. Correlation between missing mass (MM) from $\gamma p \rightarrow \pi^+ \pi^- \pi^+ X$ and pion momentum using previous correction method. The black line indicates the neutron mass.

To address this, we adopted a more comprehensive approach inspired by correction methods used at other facilities^[1]. Specifically, we modeled the ion charge density in the TPC as decreasing with the square of the radius and solved the Laplace equation to calculate the global distortion of the electric field. Furthermore, we found that the distortion increases

with beam intensity, indicating that ion feedback depends on gas properties such as temperature and pressure.

For practical correction, we applied the millepede-2 (alignment software tool) to estimate scaling parameters for each run (approximately every 1.5 h). This improvement significantly enhanced the accuracy of hadron photoproduction analyses, eliminating distortions in the missing mass distributions (Figs. 4 and 5).

Currently, using the corrected data, we are conducting detailed studies of the reaction $\gamma d \rightarrow K^0 \Lambda p$, aiming to investigate the possible existence of the Kaonic nucleus bound state.

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References:

- [1] Rossegger, S. Schnizer, B. Riegler, W. (2011). *Nuclear Instruments and Methods in Physics Research Section A*. **632**, 52–58.

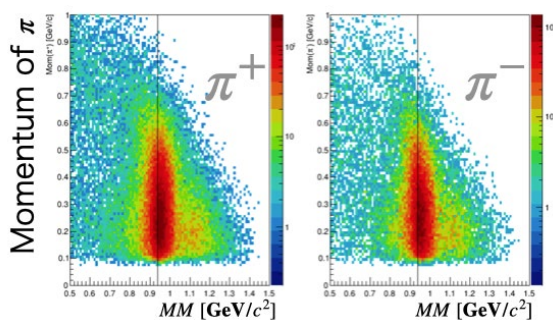


Fig. 4. Correlation between MM from $\gamma p \rightarrow \pi^+ \pi^- \pi^+ X$ and pion momentum using new correction method.

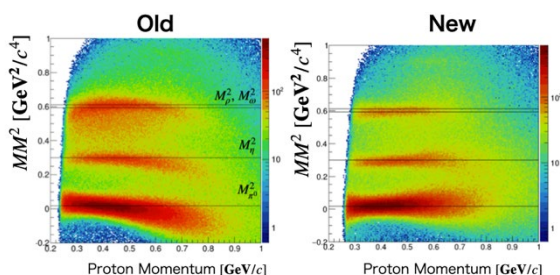


Fig. 5. Correlation between MM from $\gamma p \rightarrow pX$ and proton momentum.

The left panel shows the previous method and the right shows the new method.