Activities at the Laser-Electron Photon Facilities in 2016
— Startup of the commissioning for the LEPS2 solenoid spectrometer —

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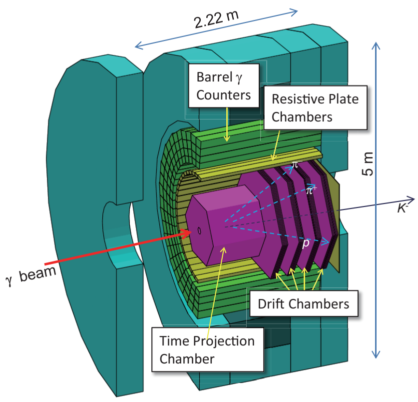
RCNP has operated two high-energy photon beamlines, BL33LEP (LEPS) and BL31LEP (LEPS2), at SPring-8. In both beamlines, linearly polarized photon beams up to 2.9 GeV produced by laser-induced backward Compton scattering from 8-GeV electrons have been used to study the quark-nuclear physics via the photoproduction of hadrons. The LEPS experiments have been carried out mainly using the forward charged-particle spectrometer since 2000, while in the LEPS2 facility, large acceptance detectors have been prepared to measure precisely both the photoproduction process and decay process simultaneously. In 2016, the LEPS2 project has reached a new stage. Since 2013, the experiment using a high-resolution and large acceptance calorimeter (BGOegg) in conjunction with a high time-resolution TOF system has been performed at LEPS2 to search for the η'-mesicnuclei, etc. [1] After the summer in 2016, we have switched the main detector system from BGOegg to a 1-T solenoid spectrometer, and have started installation of parts of detectors into the solenoid magnet and developed a new DAQ system. Although the detector system has not been the full setup yet, the first commissioning run with beam has been done in December. Here we report the status of the LEPS2 solenoid spectrometer.

LEPS2 Solenoid Spectrometer

One of the main physics objectives in the LEPS2 project is the confirmation of the pentaquark Θ^+ with higher statistics and different detection modes from the LEPS experiment. At LEPS, the Θ^+ was searched through the $\gamma d \to K^+K^-pn$ reaction by only detecting both K^+ and K^- at forward angles. Here, the ϕ meson contribution was rejected in the invariant mass of K^+K^-, and by assuming the minimum momentum spectator approximation, the quasifree reaction from neutron was selected with a good correction for the Fermi motion. [2] We have recently improved the analysis to reject the quasifree process from proton by using the energy loss information in the trigger scintillation counter. [3] The new data with high rejection efficiency of proton is now being analyzed. At LEPS2, we intend to measure the angular distribution of the differential cross section by detecting $\Theta^+ \to K^0_S p \to \pi^+\pi^- p$ decay mode with a large solid angle detector. Since Θ^+ is identified in the invariant mass, this is free from the Fermi motion correction and also from the ϕ background.

Another physics topic is the study of hyperon resonances, especially, $\Lambda(1405)$. It is well known the mass of $\Lambda(1405)$ is too light if it is a SU(3) three-quark state. Some of the theoretical models describe $\Lambda(1405)$ as a mixture of two meson-baryon states, $\pi\Sigma$ and $\overline{K}N$.[4] The latter has higher mass and a narrow width, whose pole position is important to determine the strength of the $\overline{K}N$ interaction. This is strongly related to the existence of the $\overline{K}$-nucleus (like the K^-pp bound state) which is one of the recent hot subjects in hadron physics.



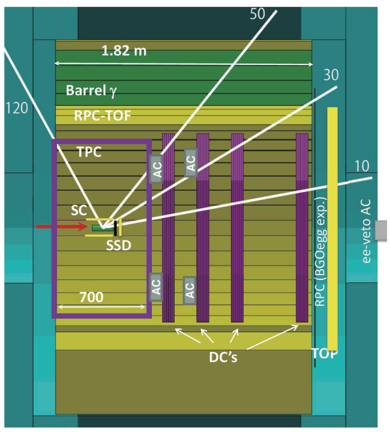


Figure 1: (Left) Schematic drawing of the LEPS2 solenoid spectrometer. (Right) Cross sectional view of the detector system inside of the solenoid magnet.

We will measure such a state by controlling the parity of exchanged particles with use of the linearly polarized beam and detecting vector K^* meson. By selecting unnatural-parity (K^-) exchange, we can study the lineshape of the $\Lambda(1405)$ in comparison with those measured by $K^+\Lambda(1405)$ photoproduction [5]. For this measurement, we need to detect all decay products from K^* and $\Lambda(1405)$.

A schematic view of the LEPS2 solenoid spectrometer is illustrated in Fig. 1. All detectors are installed in a large solenoid magnet, which had been used for the kaon rare-decay experiment at BNL/E949 and was transported from BNL to SPring-8 in 2011. Its inner bore size is 2.22-m long and 2.96-m in diameter. The detector system of the LEPS2 solenoid spectrometer consists of drift chambers (DC), a time projection chamber (TPC), forward and side start counters (SC), resistive plate chambers (RPC), barrel electromagnetic calorimeters (Barrel γ), and aerogel Čerenkov counters (AC). Charged particles are momentum-analyzed by the magnetic field of $\sim$0.9 T, and their trajectories are reconstructed by the position information of DCs and TPC. A photograph of the TPC and three DCs on the rails, just before being installed inside of the magnet, is shown in Fig. 2.

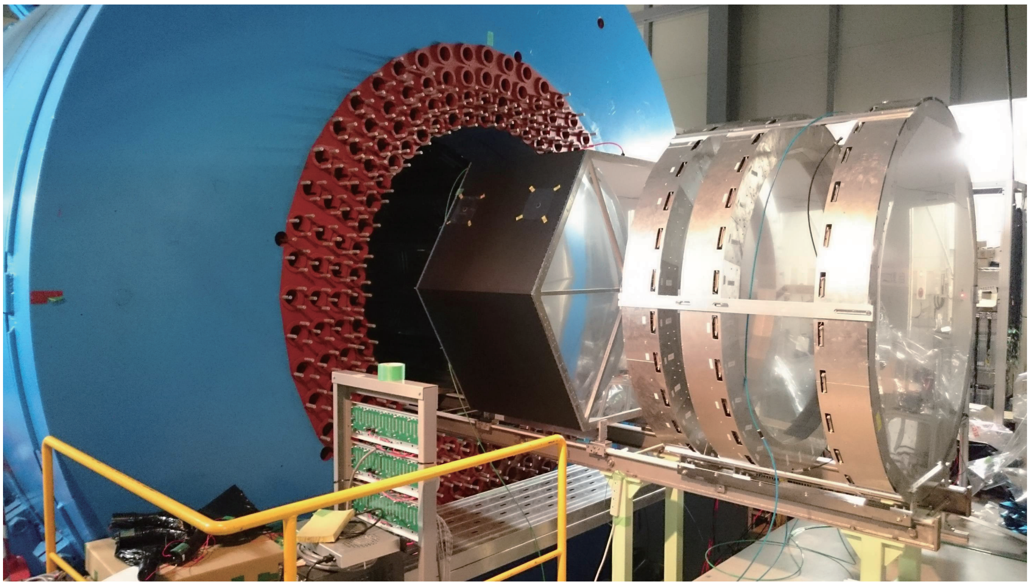


Figure 2: Photograph of the Time Projection Chamber (TPC) and three Drift Chambers (DCs) just before being installed into the solenoid magnet.

The design value of the momentum resolution is 1 % for 1 GeV kaons in the range of polar angle $\theta > 10°$. The energy and direction of photons are measured with Barrel γ, which is a segmented sampling calorimeter stacking leads and plastic scintillators alternately. The velocity of each charged particle is measured by a time of flight (TOF) from the target to RPC and is used for the particle identification. In order to distinguish K from π at high momentum region (> 1 GeV/c), ACs will be employed and placed between DCs. Another small AC is placed on the beam axis just downstream of the solenoid magnet to reject e^+ and e^- in the trigger level. The trigger signals are produced by the forward SC or side SC surrounding the target. A schematic drawing of SCs is shown in Fig. 3. Since they are placed in the strong magnetic field, MPPCs (multi-pixel photon counter) are used for the readout of the scintillation light. A time-resolution of about 300 ps has been obtained in the test experiment of SCs. The trigger rate of hadron production is estimated to be about 5 kcps. We have developed some new high-rate readout electronic modules, such as FADC board for TPC and TDC for DC. [6] We have also been developing a new data acquisition (DAQ) system based on the DAQ-Middleware, which is a software framework for network-distributed DAQ system. [7]

After installing SCs, three DCs, and TPC, we have performed a commissioning run in the middle of December, 2016. Although, unfortunately, the signals of TPC could not be read in the run with a photon beam due to a spark problem in some capacitors used in it, much progress in the development of DAQ system has been made during the commissioning run. An online histogram for the DC hit pattern obtained by using new TDC modules is shown in Fig. 4. We will continue the commissioning experiments for the LEPS2 solenoid spectrometer in 2017 to confirm the detector performance.

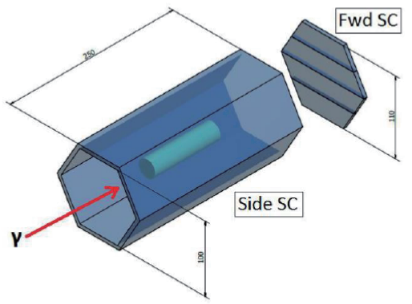


Figure 3: Drawing of the forward and side start counters (SC). On both sides of each scintillator, MPPCs are sticked for the signal readout. These are installed in the inner bore region of TPC.

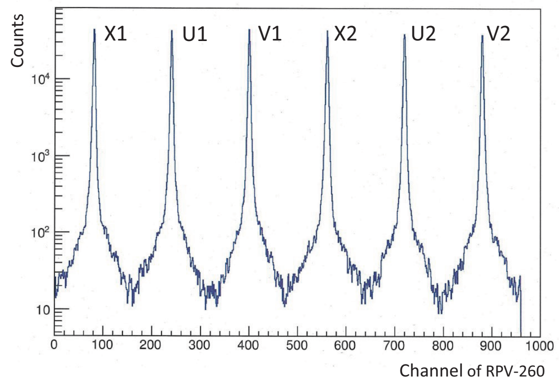


Figure 4: Online histgram of the Drift Chamber (DC) hit pattren obtained during the first commissioning run. Newly developed modules (RPV-260) have been used as TDCs for DCs.

References

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[6] FPGA Universal Board RPV-260 by REPIC. (https://www.repic.co.jp/product/module/vme/rpv-260.html?route=p)

[7] DAQ-Middleware Home Page. (http://daqmw.kek.jp/)