Development of RICH detector for Secondary Beam Particles at J-PARC High-momentum Beamline

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The high-momentum beamline (high-p beamline) has been newly constructed at the J-PARC Hadron Facility on May 2020. It delivers primary protons up to 30 GeV, in addition, will be also utilized as a secondary beamline in near future. It enables us to extend hadron spectroscopy into heavy systems, like Ξ, Ω and/or charm baryons. It should be noted that the maximum beam momentum of existing beamlines is 2 GeV/c, smaller by an order of magnitude compared with that at the high-p line. The secondary beam particles like pions and kaons are, unfortunately, not separated in the present high-p design. Therefore, it is a key to implement particle identification detector for beam particles in the momentum range of 5 to 20 GeV/c for future studies.

We are developing a RICH-type detector for the beam particle identification. Since the intensity of pions is higher than that of kaons by three orders of magnitude, beam kaons should be actively identified instead of pion veto technique. A prototype detector of the RICH has been designed with the silica aerogel whose refractive index is 1.02, developed at Chiba university. Cherenkov photons are once reflected at a spherical mirror and collected into MPPC arrays, as shown in Fig. 2 (left). The expected number of photons is 9.3 p.e. with the 8 cm

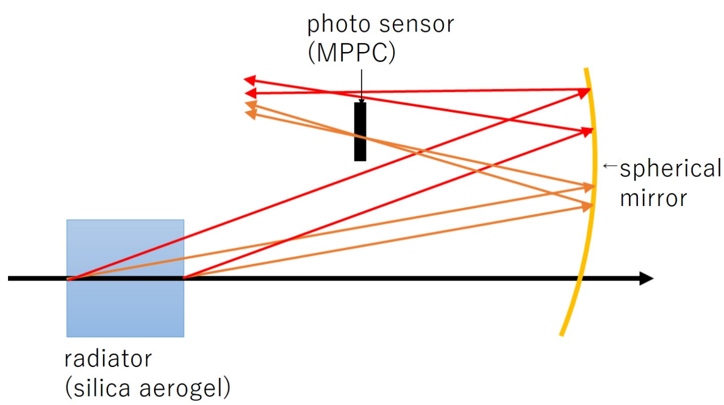

Figure 1: conceptual design of RICH detector

aerogel radiator. The separation power is characterized by an angle resolution of Cherenkov ring, depends on a position resolution of MPPC, the radiator length and a spherical aberration. The performance of prototype detector was examined at the LEPS beamline using electrons produced in γA conversions with a lead photon converter. The number of MPPC arrays of the prototype detector is half compared with that of the real device. The observed number of photons, N, depending on the the radiator length is shown in Fig. 2 (middle) [1]. The numbers are well reproduced with the function;

$$N = 2\pi\alpha * acceptance * \sin^2\theta_c * \int \frac{R(\lambda)Q(\lambda)}{\lambda^2} d\lambda \int_0^L e^{-(L-x)/d} dx$$

where λ is wave length, $R(\lambda)$ is a reflectance of the mirror, $Q(\lambda)$ is a quantum efficiency of MPPC, L is the length of the radiator, d is the transmission length of the aerogel and θ_c is the Cherenkov angle. The transmission length is evaluated to be 4.8 cm from the fit. The number of photon of the real device is estimated to be 10 p.e. The measured angle resolution is shown in Fig. 2 (right). Based on the result, the expected Cherenkov angle resolution is obtained to be 1.5 mrad for 8.5 GeV/c beam kaons. It enable us to identify kaons with 50% efficiency under the 3% contamination of π in the beam momentum range of 5 to 8.5 GeV/c. The final specification of the RICH detector has possibly determined due to theses basic performance. Before the construction, we plan to study the high rate capability of read-out modules and establish a selection scheme of the Cherenkov ring corresponds to beam kaons.

The authors are deeply grateful to staff members of LEPS. We would also like to express our gratitude to H. Noumi and A. Sakaguchi for the support and encouragement.

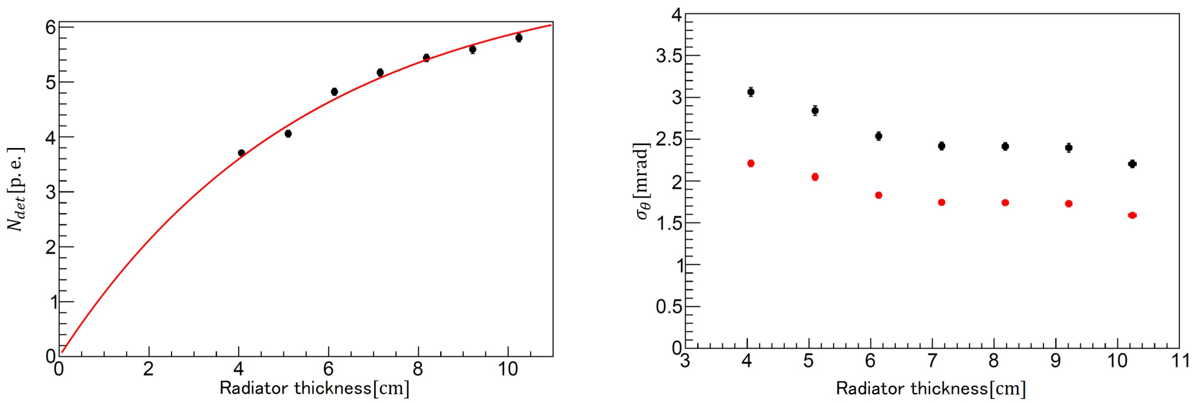

Figure 2: (left) Measured photon numbers (vertical axis) for corresponding depth of radiator (horizontal axis). The red line shows the fit result with the function parameterized with the transmission length (see text). (right) Measured Cherenkov angle resolution (black points). The estimated angle resolution for the real device is plotted with red points.

References

[1] S. Kajikawa, Master thesis, Tohoku University (2020)