Endcap Disc DIRC for PANDA at FAIR

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Abstract

The Endcap Disc DIRC (EDD) has been developed to provide an excellent particle identification in the future PANDA experiment by separating pions and kaons up to a momentum of 4 GeV/c with a separation power of 3 s.d.. The detector is placed in the forward endcap of the PANDA target spectrometer. It consists of a fused silica plate and focusing elements placed at the outer rim, which focus the Cherenkov light on the photo cathodes of the attached MCP-PMTs. A compact and fast readout of the signals is realized with special ASICs. The performance has been studied and validated with different prototype setups in various testbeam facilities.

Keywords: Particle Identification, Cherenkov Detector, DIRC

1 Detector Design

The future Disc DIRC detector for the PANDA [1] experiment has a compact and modular design, that consists of four independent quadrants of fused silica Cherenkov radiators 20 mm thick and a surface roughness of less than 1 nm. It is designed to separate pions and kaons in the momentum range of 1–4 GeV/c with a separation power of 3 s.d. covering polar angles between 5° and 22°.

The detector is shown in Figure 1. The created Cherenkov light inside the radiator disk is internally reflected to the outer rim of each quadrant, where 96 focusing elements (FELs) are attached. Every FEL is bonded to a bar connected to the radiator disk and has a cylindrical mirror coating on the backside. The Cherenkov photons captured in the bars are focused on a focal plane formed by the photo cathode of the MCP-PMT. Each MCP-PMT contains a segmented anode with 3×100 pixels for acquiring the Cherenkov photon hit pattern of the

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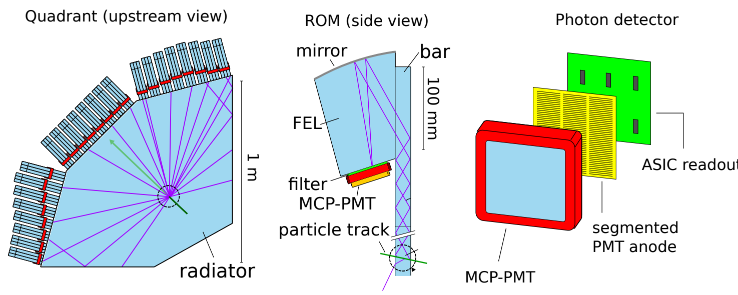

Figure 1: Concept of the Disc DIRC for PANDA showing one quadrant with radiator and FELs (left), the functionallity of the focussing elements (center), and a sketch of the attached MCP-PMTs plus readout (right).

traversing particle. From the measured hit pattern the mean Cherenkov angle and the likelihood values for different particle hypotheses are reconstructed.

A long-pass color filter in front of the MCP-PMT entry window, that filters out photons below a specific wavelength, increases the detector resolution, which largely depends on the chromatic error inside the fused silica radiator and the number of measured photon hits. For the signal readout TOFPET ASICs [2] with a time resolution of 25 ps are used.

2 Performance Analysis

The detector performance has been simulated in the PandaRoot framework [3] including all wavelength dependent parameters. The important parameters are the transmission values for fused silica, the reflectivity of the mirrors and the MCP-PMT detection efficiency with an assumed collection efficiency of 65%.

Two candidate photo cathodes with a maximum quantum efficiency of 30% have been studied with Monte-Carlo simulations: a blue photo cathode with a maximum between 250 nm and 400 nm and a green photo cathode with an enhanced sensitivity between 400 nm and 500 nm, that slopes up between 330 nm and 370 nm. One result of the simulation is, that the best resolution is obtained for a value around 360 nm for the long-pass filter cut-off wavelength.

For this filter value the separation power for pions and kaons has been calculated for all azimuth angle ϕ and polar angle θ combinations as shown in Figure 2 left tile. The average value is calculated to a value of 4.4 s.d.. A one-dimensional projection is presented in Figure 2 right tile, showing the separation power as a function of the polar angle θ for several particle momenta and two choices for the photo cathode of the MCP-PMTs. For very large angles above $\theta = 21°$ the separation power drops slightly below 3 s.d. at the highest momentum due to larger geometrical errors affecting the reconstruction algorithm.

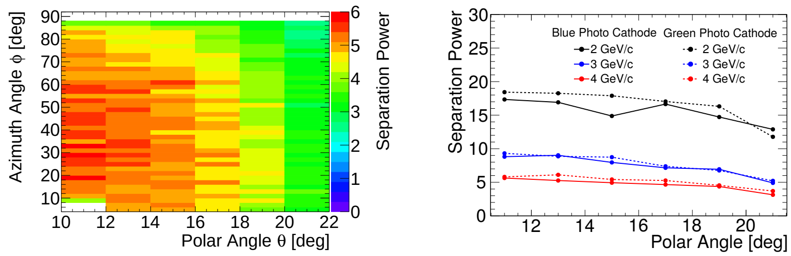

Figure 2: Separation power of the final detector as a function of θ and ϕ instrumented with the blue photo cathode (left) and as a function of the polar angle θ (ϕ averaged) for several momenta (right) and both photo cathodes.

3 Testbeam Results

The first particle identification with a Disc DIRC prototype was achieved in 2012 at the T9 testbeam at CERN [4]. In 2015 an upgraded prototype consisting of a 500 mm square radiator plate with fused silica components and a TRB3 readout was tested in the same beam line. The measured single photon resolution compared well with the Monte-Carlo data [5]. For the following testbeam in 2016 at DESY with a 3 GeV/c electron beam the prototype design is comparable to the one of the final detector regarding optical precision and TOFPET based readout electronics.

Figure 3 left side shows the comparison of the single photon resolution between the testbeam and Monte-Carlo data for a performed angle scan. The distance from the particle punch-through point to the FEL was 450 mm. The resolution changes as a function of the polar angle due to an increasing number of reflections inside the FELs. On the right side of Figure 3 the comparison of the photon yield is presented. The simulation output incorporates the results of an independent charge sharing analysis, which studied the number of hits from

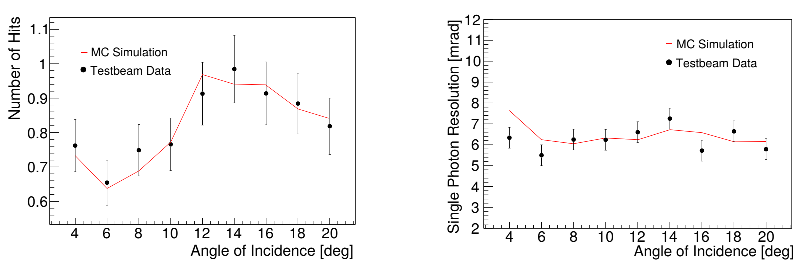

Figure 3: Comparison between the simulated and measured photon yield (left) and single photon resolution (right) as a function of the polar angle.

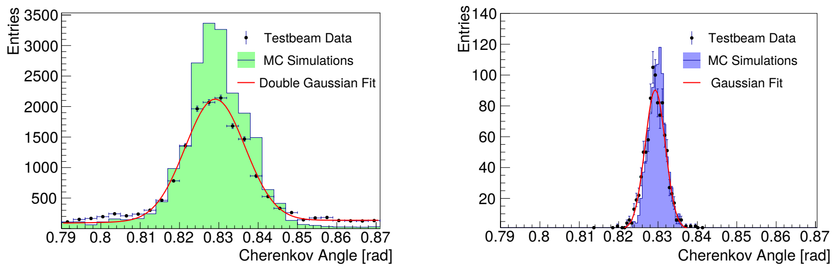

Figure 4: Single photon resolution (left) and the average Cherenkov angle (right) from the event combination of 30 equidistant positions on the radiator disk.

the detected charge cloud of a single photo electron in the MCP-PMT.

A position scan perpendicular to the FELs was performed and used for an event mixing study simulating a 30 FEL readout with 30 equidistant positions. The large background of the testbeam data could be handled by applying a reconstructed coarse time cut and a truncated mean method to derive a mean Cherenkov angle value for each mixed event.

Figure 4 compares the result of the single photon resolution with the distribution of the truncated means of the mixed events. The resolution of the mean value scales approx. with the factor $1/\sqrt{N}$ as expected. The obtained resolution of $\sigma = 2.5\,\text{mrad}$ is within a factor of less than 2 away from the anticipated performance of the fully equipped final Disc DIRC with a resolution of $\sigma = 1.8\,\text{mrad}$ for the same momentum. The reason for the still existing discrepancy can be found in the absence of a chromatic filter, less FELs and a larger effect of multiple scattering of the electrons inside the radiator disk. The resolution of the testbeam data agrees with the Monte-Carlo simulations. Also the photon yields of 18 (14) hits per event from the measured (Monte-Carlo) data agree within the precision of the simulation.

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