

## The Endcap Disc DIRC for PANDA at FAIR

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ON BEHALF OF THE PANDA COLLABORATION

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### 1. – The Endcap Disc DIRC in PANDA

The PANDA experiment is designed as a fixed target experiment for  $\bar{p}p$  collisions up to an antiproton beam momentum of 15 GeV/c and a maximum interaction rate of 20 MHz in the HESR that is a part of the future FAIR facility in Darmstadt. The goal of PANDA is to cover a large variety of physics studies in the strange and charm sectors [1]. PANDA needs an excellent Particle Identification (PID) which will be achieved with two Cherenkov detectors in the target spectrometer: the Endcap Disc DIRC (EDD) and the Barrel DIRC. Additionally, a third Cherenkov detector for very small polar angles will be placed in the forward spectrometer.

The EDD for PANDA is a new type of Cherenkov detector that is based on photon propagation via internal reflection in a radiator plate [2]. The detector consists of 4 independent quadrants made of fused silica with highly polished surfaces in order to preserve the photon angles while propagating through the radiator and to guarantee a minimum amount of photon losses.

As shown in Figure 1, the detector is placed at the forward endcap of the PANDA target spectrometer and is supposed to separate charged pions and kaons up to a momentum of 4 GeV/c in the polar angle range between  $5^\circ$  and  $22^\circ$  with a separation power of more than 3 s.d. Larger polar angles between  $22^\circ$  and  $140^\circ$  will be covered by the Barrel DIRC [3]. Both detectors together cover almost the full phase space of the created kaons.

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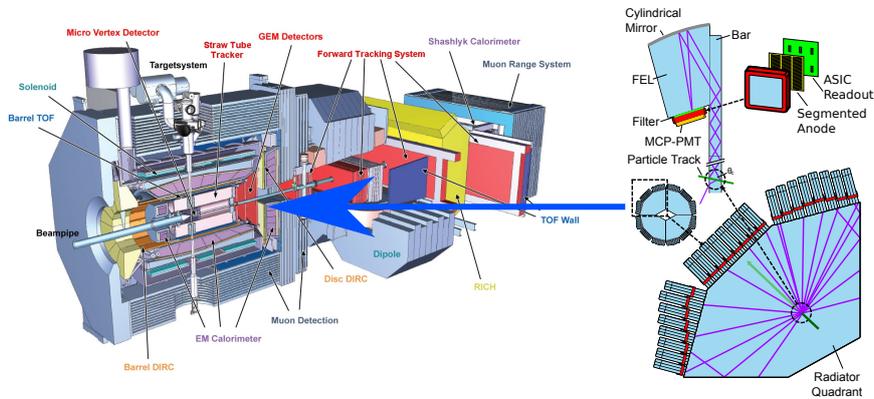


Fig. 1. – The PANDA experiment (left) and a sketch of different components of the Endcap Disc DIRC in PANDA (right).

After Cherenkov light is produced along the particle track, each photon propagates to the outer rim. There it enters one of the 72 Focusing Elements (FELs) that are glued to each radiator quadrant and contain a cylindrical mirror to focus the incoming photons (Figure 1). Three consecutive FELs are combined to one Readout Module (ROM) with an attached Micro Channel Plate Photo Multiplier Tube (MCP-PMT). Optical filters are used to minimize a deterioration of the resolution as a result of chromatic errors.

The anode of the MCP-PMT is segmented into small pixels to receive the exact information about the photon position. The pixel number, a time stamp, and the Time over Threshold (ToT) value will be acquired by the TOFPET ASIC that has been designed by the company PETsys Electronics S.A. The intrinsic time resolution of the readout is 50 ps and therefore suitable for the acquisition of fast MCP-PMT signals [4].

The focal plane of the cylindrical mirror is identical to the photo cathode surface of the MCP-PMT in order to image the projection of the Cherenkov cone. The cylindrical shape of the mirror ensures a linear dependency between the pixel number and photon angle that is used for either the direct computation of the Cherenkov angle  $\theta_C$  or the calculation of a theoretical hitpattern in combination with a reconstruction algorithm. This algorithm is based on likelihood values by taking the tracking information of the charged particle into account [5].

## 2. – Performance Studies of the EDD

The left side of Figure 2 illustrates the simulated detector resolution for  $\pi^+$  and  $K^+$  with a momentum of 4 GeV/c as a function of the particle position on one radiator quadrant. The simulations have been performed with the full detector geometry implemented in the PandaRoot framework [6]. It turns out that the desired resolution of 1.4 mrad can be achieved almost everywhere on the radiator surface with the proposed design.

On the right side of Figure 2 the analysis results from a testbeam campaign in 2016 at DESY are presented. Several scans regarding the angle of incidence and horizontal resp. vertical scans have been performed [7].

The overall detector resolution of 2.5 mrad has been obtained with a combination of events from the vertical position scan in order to simulate the existence of 30 independent

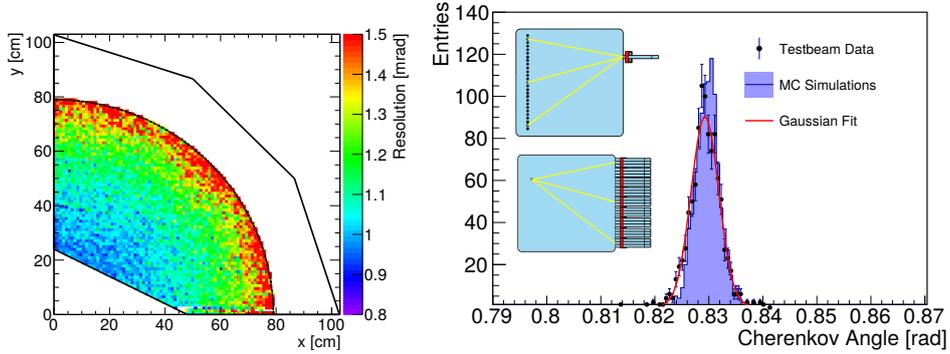


Fig. 2. – The simulated detector resolution for one quadrant of the final detector (left) and the measured resolution from the DESY testbeam campaign 2016 by using event combination with an inset sketch of the measurement setup (right).

FELs while only one physical FEL has been taken into account. The matching of the two histograms show that the measured data fits very well to the predicted resolution that are taken from dedicated Monte-Carlo simulations.

The reason for not being able to obtain a resolution of better than 2 mrad can be explained by the absence of optical filters in the DESY setup and the larger background due to the use of an electron beam with a momentum of 3 GeV/c. The effect of an increased angular straggling and energy loss of the electron beam together with larger beam size uncertainties set an upper limit for the maximum achievable detector performance.

### 3. – Estimated Radiation Damage

The simulations for obtaining the estimated radiation dose in the PANDA experiment have been performed with the Dual Parton Model (DPM) generator that is implemented in the PandaRoot framework including all PANDA subdetectors. This particle generation algorithm has been originally designed with the intention to study background rates of charged particles and resulting detector occupancies. For the particle generation process based on the anti-proton beam momentum, a large-N expansion of non-perturbative Quantum Chromodynamics (QCD) and the Reggeon field theory is used to compute the kinematics of the created hadrons [8].

The optical filter between the ROM and the MCP-PMT can be seen as the critical component regarding radiation damage in the EDD. The left side of Figure 3 shows the simulated radiation dose for one filter in the final detector setup after a PANDA lifetime of 10 years with a duty cycle of 50%. The results indicate an overall radiation dose of 3.16 Gy for each filter volume.

The right side of Figure 3 represents the measured transmission of a longpass color filter FGL400S from the company Thorlabs with cut-on wavelength of 400 nm as a sample measurement [9]. The transmission loss for radiation damages of around 3 Gy could be estimated to 1.5% at 500 nm and 3.5% at 400 nm. The measured points follow roughly an exponential decrease. In case of a 10 times larger radiation dose, the transmission loss has been determined as values between 3.5% and 4.5% depending on the wavelength of the transmitted light.

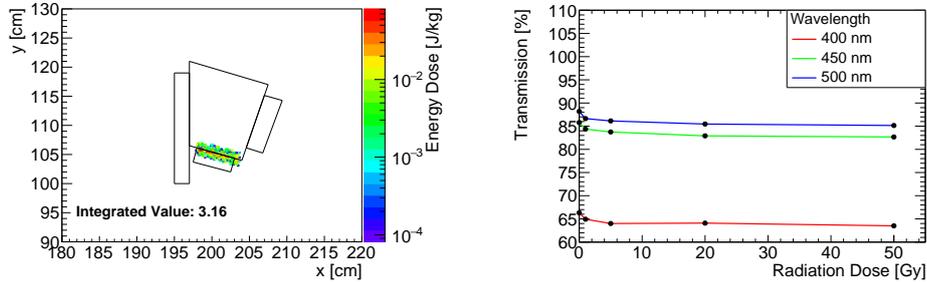


Fig. 3. – The simulated radiation dose for one optical filter (left) in the final setup and the measured transmission behavior as a function of the radiation dose for a sample filter (right).

#### 4. – Conclusion & Outlook

The simulation results and analysis of testbeam data have been used to validate the actual design of the EDD and show that a separation power of 3 s.d. can be achieved for the separation of pions and kaons over the full polar angle range. A new testbeam campaign with an updated setup and a new TOFPET-ASIC version has been completed in August 2018 and the results are currently being analyzed. The goal is to show a clear separation between two particle species in order to proof the working principle of the EDD prototype regarding photon yield and spatiotemporal resolution with the actual design parameters.

The radiation dose measurements and simulation results show that color filters are safe regarding radiation damages for the final setup of the EDD. The acquired data for other filter types from various companies indicate similar transmission losses of less than 4.5% for an energy deposition up to 30 Gy. According to the latest predictions, this high radiation dose will not be attained during the whole lifetime of PANDA. As a result, it is possible to say that the expected transmission loss is not going to affect the performance of the EDD significantly.

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