# Disc DIRC Endcap Detector for PANDA@FAIR


Peter Schönmeier, [a,*] Derek Branford, [b] Michael Düren, [a] Markus Ehrenfried, [a] Wolfgang Eyrich, [e] Klaus Föhl, [b] Matthias Hoek, [c] Ralf Kaiser, [c] Albert Lehmann, [e] Shaojun Lu, [a] Oliver Merle, [a] Björn Seitz, [c] Georg Schepers, [d] Roland Schmidt, [a] Carsten Schwarz [d]

[a] *II. Physikalisches Institut, Universität Giessen,Giessen, Germany*
[b] *School of Physics, University of Edinburgh, Edinburgh, UK*
[c] *Department of Physics and Astronomy, University of Glasgow, Glasgow, UK*
[d] *Gesellschaft für Schwerionenforschung, Darmstadt, Germany*
[e] *Physikalisches Institut IV, Universität Erlangen-Nürnberg, Erlangen, Germany*



**Abstract**

In the PANDA experiment at FAIR, a Disc DIRC detector is forseen to realize particle identification in the Endcap region of the detector. Two different designs are proposed. One is based on a two-dimensional readout of space coordinates, the other one is based on one space coordinate and the readout of the Time-of-Propagation (ToP). The ToP-DIRC design uses dichroic mirrors to split the spectral range of the Cherenkov photons into two ranges. This allows to reduce dispersion effects and increases the travel path of the photons inside the radiator. A larger ToP helps in discriminating different particle species at large momenta.



*Key words:* PANDA, PID, Cherenkov, DIRC, ToP


An efficient and capable PID system is crucial for the physics objectives pursued by the PANDA experiment at FAIR (1). In the endcap region a clear separation of pions and kaons up to momenta of 4 GeV/c is required. Although the high momentum region is easily accessible with e.g. Aerogel RICH detectors, a low momentum cutoff would be unacceptable. Furthermore very limited space and acceptable material budget impose additional limitations. Considering this, a very compact PID detector, based on the DIRC (Detection of Internally Reflected Cherenkov light) (2; 3) principle is a very attractive solution.

The reconstruction of the Cherenkov angle requires the detection of at least two different coordinates this can either be two position coordinates

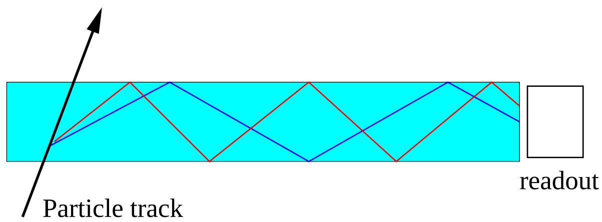


Fig. 1. Light propagation inside a DIRC radiator for two different Cherenkov angles. The time of propagation of a photon depends on its Cherenkov angle

(impact point of a Cherenkov photon on the photo detection plane) or a combination of one position coordinate and the time of propagation (ToP) of the Cherenkov light (4), as the arrival time of Cherenkov photons is directly connected to the Cherenkov angle (see Fig. 1). For the PANDA endcap DIRC both concepts are studied (5). The Focussing Disc


* corresponding author

DIRC design is under development, to provide two space coordinates for reconstructing the Cherenkov angle. The conceptual design is shown in (Fig. 2). The perimeter is equipped with 128 LiF plates for dispersion correction and focussing light guides. Cherenkov light is focussed onto a $5 \times 5$ cm$^2$ detection plane. The light guide system serves for two purposes. Light is coupled out from the radiator disc into a LiF plate. As the refractive index and dispersion curve of LiF is distinctly different from fused silica employed in the radiator, adverse effects from dispersion inside the radiator are mitigated image. Secondly, one side of the light guide has an aspheric shape focussing the light onto a detection plane, where it can be detected by photon detection devices. The current design foresees a single photon readout by multi-pixel photon detection counters. Therefore one of the two coordinates is provided by the lightguide hit along the rim of the disc, the second is given by the position of the photon detector.

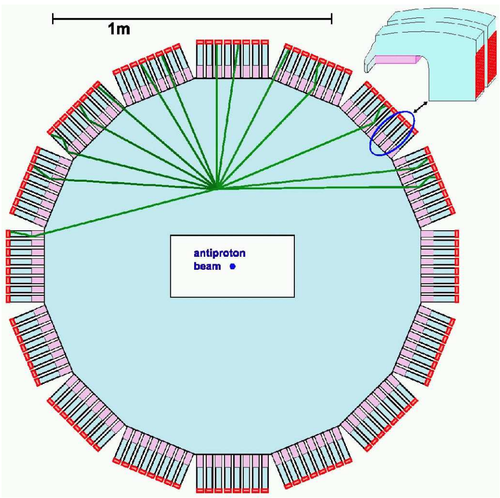


Fig. 2. Focussing ligthguide Disc DIRC

Both concepts for the PANDA Disc-DIRC use a fused silica radiator. The radiation hardness of this material has been studied (6) and meets the requirements for PANDA's endcap DIRC detector. For the ToP DIRC a 2 cm thick radiator disc will be used, which will be placed 1.8 m downstream from the IP and covers polar angles from 5° to 22° in horizontal direction and 10° to 22° in vertical direction(see Fig.3). A position 2.2 m away from the IP has been studied too and showed equal performance within uncertainty. If the detector is placed closer to the IP less material is needed and the cost is reduced too.

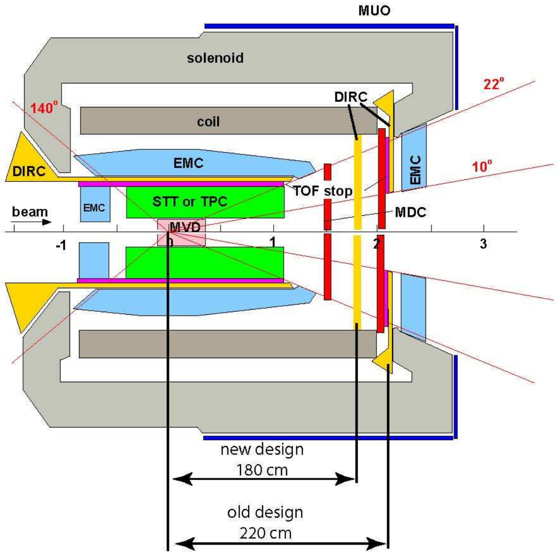


Fig. 3. Setup of the PANDA detector with two possible positions for the endcap Cherenkov detector

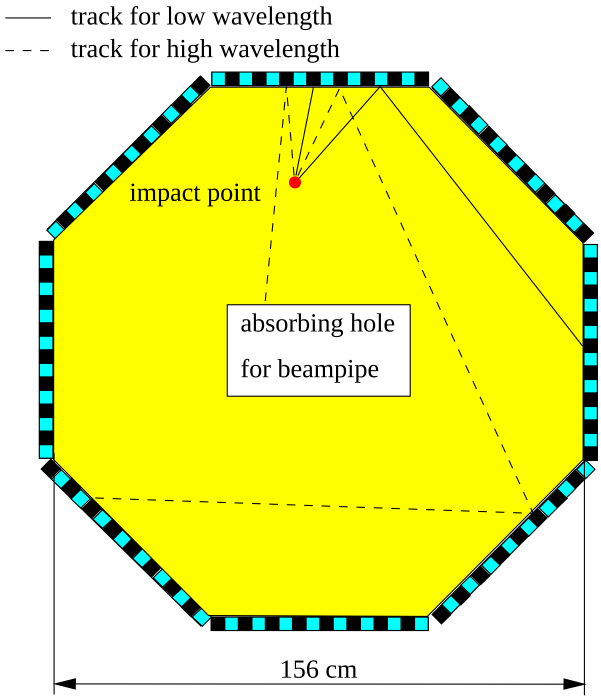


Fig. 4. Octagonal radiator disc with tracks of photons of different wavelengths. Dichroic mirrors in front of the photon detectors allow to separate two wavelength ranges and to reduce dispersion effects.

A simulation package to study the design of the TOP-DIRC has been developed (7). This simulation provides a true three dimensional propagation of the photons. Resolution of time, position of the hit point and group velocity are taken into account.

Several configurations have been studied, e.g. a disc with more than 100 edges, hexagonal and octagonal shaped discs. Simulation runs show for discs with a lower number of edges a better resolution than discs with a larger amount of edges. To match the pace constraints given by the magnet joke the shape of the disc is preferencially octagonal (see Fig. 4).

Each side of this disc will be equipped with 120 photon sensors, overall 960 channels, giving an angular resolution in $\phi$ of 0.375°. These sensors must be sensitive to single photons in a wavelength band between 400 and 700 nm with a timing resolution of about $\sigma = 30$ ps. Assuming a TDC with 25 ps LSB (least significant bit) resolution and a time difference of appr. 15 ns between first and last detected photon (see Fig. 5 and Fig. 6) the combined resolution in $\phi$ and time corresponds to approximately 400,000 pixels in the two-dimensional *position-versus-time* plane.

Several Microchannelplate-PMTs (MCP) have been studied (8) and a timing resolution of $\sigma = 30$ ps has been reached. The sensors will be located behind wavelength separating dichroic mirrors. These mirrors reflect photons with a certain wavelength range and let photons outside this range pass. For the TOP-DIRC two types of these mirrors will be used. One type will reflect all photons with wavelengths less than 500 nm, the other will reflect all photons with wavelengths larger than that. Mirrors of these two types are placed in an alternating sequence between radiator and sensors so that for all detected photons it is known to which wavelength band they belong to. This way, dispersion effects are reduced and furthermore the path lengths of 50% of the photons are increased, which helps to discriminate photons with similar but unequal time of propagation.
For every particle passing the disc approximately 420 photons are emitted. Of these appr. 250 are reflected under the condition of total reflection. With the constrain of maximum 3 reflections at the rim of the disc 210 photons will hit the detector surface. Assuming a quantum efficiency of 0.3, 70 photons are available for reconstruction.

When the detection time of each photon is plotted versus the $\phi$-position of the photon-sensor a characteristic hit pattern is obtained. Fig. 5 shows this pattern for particles hitting the detector at two different positions at the same time. A separation of the two hit-patterns is clearly observable. Fig. 6 shows the hit pattern of a pion and a kaon that hit the detector at the same time and position.

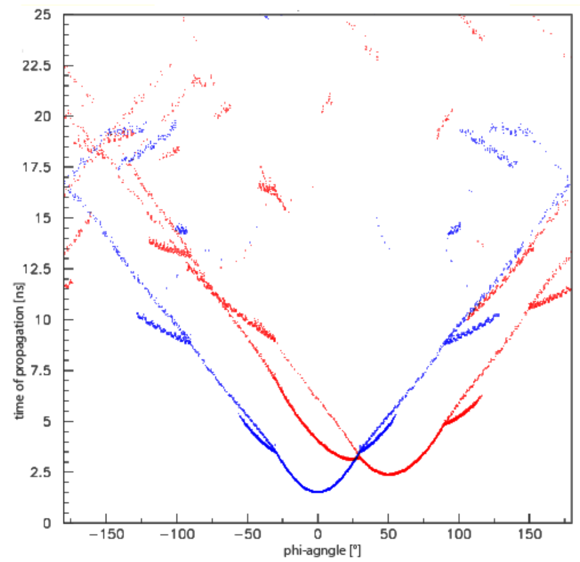


Fig. 5. $\phi$-TOP hit pattern of an event with 4 GeV/c particles passing the disc under two different angles and positions (500 particles for each).

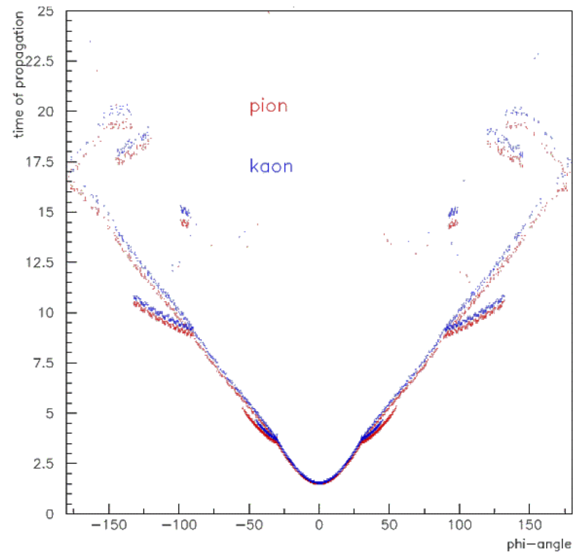


Fig. 6. $\phi$-TOP pattern of pions and kaons passing the disc at an angle of 15° 50 cm away from center at the same time

An analysis program has been developed, that does not need an external information about the absolut time when the particle has crossed the radiator. Instead, only relative times of the TDC information of all photon detectors that have a hit are used. Therefore a fast start detector in PANDA is not needed for this device. The reconstruction program is based on the calculation of all possible light trajectories from a given sensor, taking the dichroic mirrors into account. For each light path four ToP values are calculated according to the two particle hypotheses (pion and kaon) and the two wavelength ranges of the dichroic mirrors (less and larger than 500 nm). For each of these four possibilities the calculated TOP is compared with the measured TOP. After linear fitting four slopes are obtained (see Fig. 7).

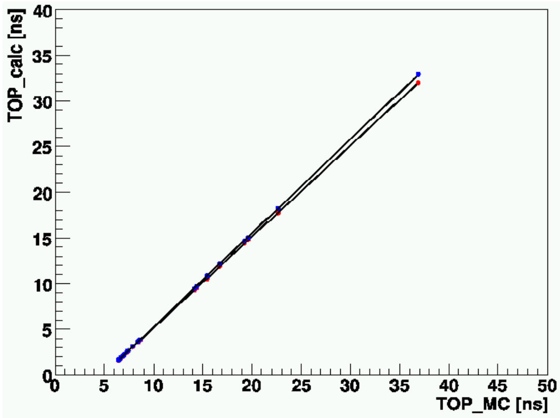


Fig. 7. Slope fitting method for pion and kaon. Without knowing a start time, the relative time of propagation alone is sufficient to discriminate pions and kaons.

These four slopes are multiplied and give a characteristic value $X$. For pions the value $X$ is less than 1, for kaons it is larger than 1. The distribution of $X$ is shown for a data set of 500 pions and 500 kaons in Fig. 8.

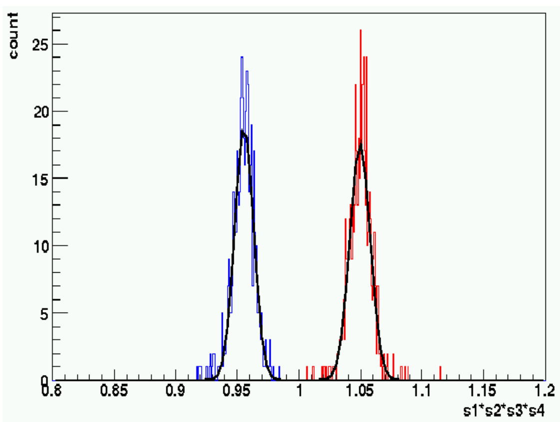


Fig. 8. Separation of pion and kaon at 2 GeV/c momentum (500 particles each)

After applying Gaussian fits to these distributions the separation in units of $\sigma$ between pions and kaons can be extracted using the definition

$$N_\sigma = \frac{|Mean_1 - Mean_2|}{(\sigma_1+\sigma_2)/2}.$$

As a result a separation between pions and kaons with 4 $\sigma$ up to about 4 GeV/c is obtained. Currently further improvements by changing the wavelength ranges of the dichroic mirrors or by splitting the wavelength into more than two intervals are investigated.

## References

[1] PANDA Collaboration, Technical Progress Report, *FAIR-ESAC/Pbar 2005*
[2] R. Aleksan et al., *Nucl. Inst. Meth. A397, 261 (1997)*
[3] B. Ratcliff, *Nucl. Inst. Meth. A502, 211 (2003)*
[4] Y. Enari et al., *Nucl. Inst. Meth. A494, 430 (2002)*
[5] K. Föhl et al., *these proceedings.*
[6] M. Hoek et al., *these proceedings.*
[7] R. Schmidt, *Diploma Thesis*, Giessen 2006.
[8] A. Lehmann et al., *these proceedings.*