Disc DIRC Endcap Detector for PANDA@FAIR

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Abstract

A new concept for an Endcap DIRC of the PANDA experiment is proposed, incorporating both a time-of-propagation (ToP) technique and a chromatic correction based on dichroic mirrors which split the spectral range of the Cherenkov photons. This combination allows both to avoid the decrease of resolution usually connected with dispersion and to lengthen the travel path of light inside the radiator. Leading to larger time differences in the time-of-propagation measurement it makes it less challenging to discriminate different particle species at large momenta.

Key words: PANDA, PID, Cherenkov, DIRC

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, the 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 seems to be 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 (impact point of a Cherenkov photon on the photo detection plane or a combination of one (or two) position coordinate(s) 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. The concept which uses two position coordinates has a polygon radiator disc with 16 edges. A pixelised readout together with LiF bars for dispersion correction is used. It is described in detail in (5). In this paper, a ToP DIRC detector is presented, which uses dichroic mirrors to minimize dispersion effects.

Both concepts for the PANDA Disc-DIRC use a fused silica radiator. The radiation hardness of this material has been studied (8) 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 cover polar angles from 5° to 22° in horizontal direction and 10° to 22° in vertical direction(see Fig.2). A position 2.2 m away from the IP has been

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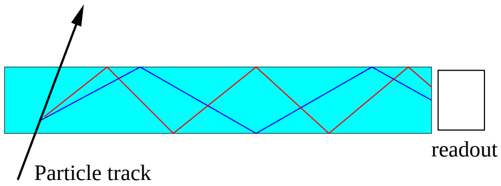

Fig. 1. Light propagation inside a DIRC radiator for two different Cherenkov angles. The time of propagation of a photon depends on its Cherenkov angle

studied too and showed within error bars equal performance. However, if the detector is placed closer to the IP less material is needed and the cost is reduced too.

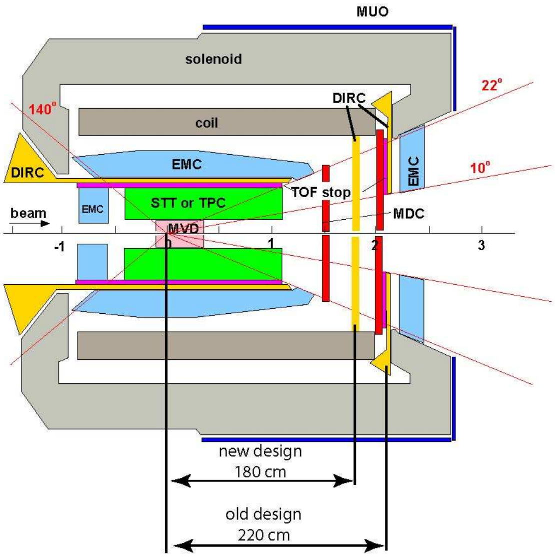

Fig. 2. Setup of the PANDA detector with two possible positions for the endcap Cherenkov detector

To study the design of the TOP-DIRC a simulation software package has been developed (6). This simulation provides a true three dimensional propagation of the photons. Smearing 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 make optimal use of the space given by the magnet joke (see Fig. 2) this disc has to be octagonal shaped (see Fig. 3).

Each side of this disc will be equipped with 120 photon sensors, overall 960 channels, giving an angle resolution in ϕ 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. 4 and Fig. 5) the combined resolution in ϕ and time corresponds to approximately 400,000 pixels in the two-dimensional *position-versus-time* plane.

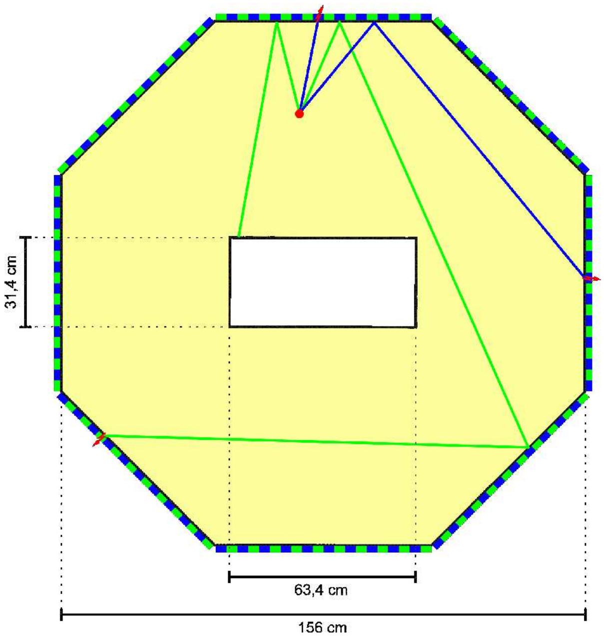

Fig. 3. Octagonal radiator disc with tracks of photons of different wavelengths

Several Microchannelplate-PMTs (MCP) have been studied (7) and a timing resolution of $\sigma = 30$ ps have 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.

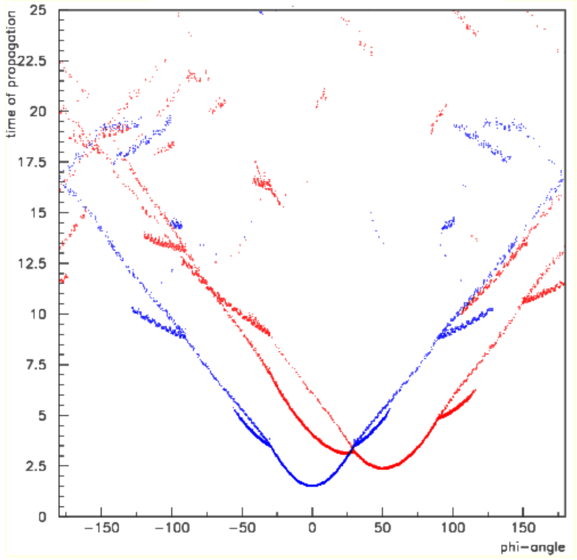

Fig. 4. ϕ-TOP hit pattern of an event with 4 GeV/c particles passing the disc under two different angles and positions (500 particles for each).

When the detection time of each photon is plotted against the ϕ-position of the photon-sensor a characteristic hit pattern is obtained. Fig. 4 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 visible. Fig. 5 shows the hit pattern of a pion and a kaon that hit the detector at the same time and position.

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. This way a fast start detector in PANDA is avoided. This 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 and after linear fitting four slopes are obtained (see Fig. 6).

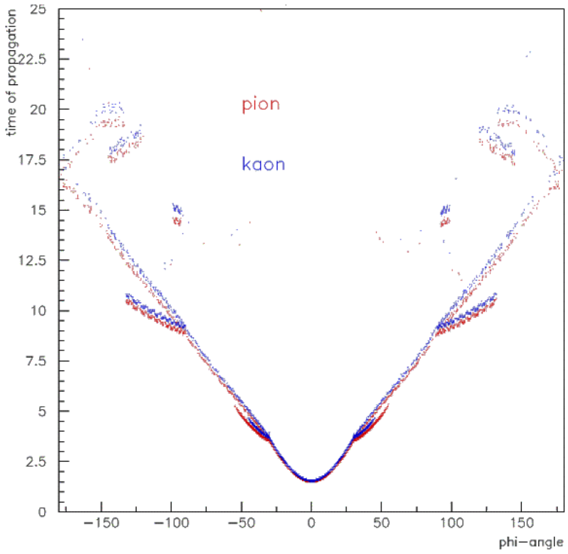

Fig. 5. ϕ-TOP pattern of pions and kaons passing the disc at an angle of 15° 50 cm away from center at the same time

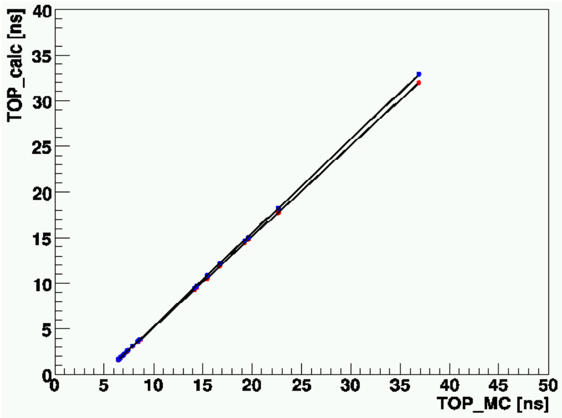

Fig. 6. Slope fitting method for pion and kaon. Without knowing a start time, the relative time of propagation alone is sufficient to discriminate pions and kaons.

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 aset of 500 pions and 500 kaons in Fig. 7.

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

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

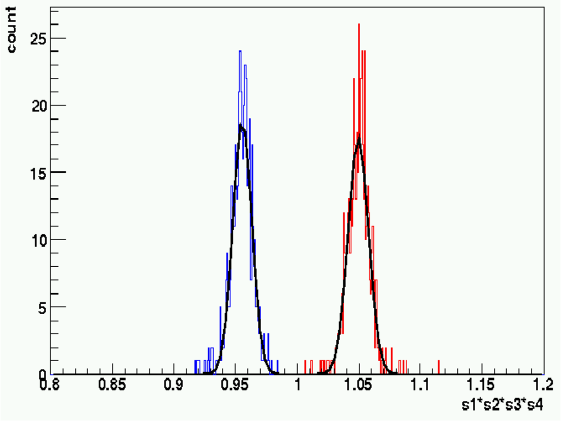

Fig. 7. Separation of pion and kaon at 2 GeV/c momentum (500 particles each)

As a result a separation between pions and kaons with 4 σ 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.*
[8] M. Hoek et al., *these proceedings.*
[6] R. Schmidt, *Diploma Thesis*, Giessen 2006.
[7] A. Lehmann et al., *these proceedings.*