Study of a PANDA Barrel DIRC design based on radiator plates*

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A Cherenkov detector based on the DIRC (**D**etection of **I**nternally **R**eflected **C**herenkov light) principle [1] will be used in the target spectrometer of the PANDA experiment to distinguish between charged pions and kaons for momenta between 0.5 and 3.5 GeV/c. It is centered around the target point, in the shape of a barrel to cover polar track angles between 22 and 140°. The design of the PANDA Barrel DIRC is based on the BABAR DIRC [2] (the first successful DIRC counter) with some important improvements, such as fast photon timing, focusing optics, and a compact expansion volume [3].

In the PANDA Barrel DIRC baseline design the barrel of 47.6 cm radius comprises 16 sections with 5 fused silica radiator bars (1.7 cm×3.2 cm×240 cm) each. Cherenkov photons, produced along the charged particle track in the bar, are guided inside the radiator via total internal reflection. A mirror is attached to the forward end of the bar to reflect photons towards the read out end, where they are focused with a lens and projected onto a flat photo detector plane behind the 30 cm-deep oil-filled expansion volume. An array of Micro-Channel Plate Photomultiplier Tubes (MCP-PMTs) is used to detect the photons and measure their arrival time with a precision of about 100 ps.

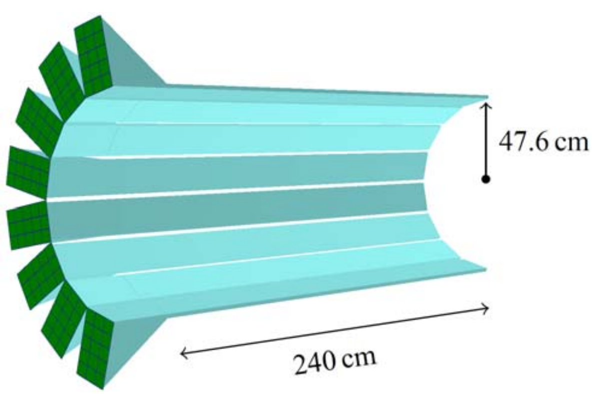

Figure 1: Geant simulation of one half of a barrel DIRC using radiator plates.

In order to meet the PANDA resolution requirement and reduce the detector cost, the influence of different parameters and geometry options on the detector performance are being studied in simulations. The use of one wide plate per bar box significantly reduces the total detector production cost in comparison to the baseline design with narrow bars, as there are fewer pieces to be polished. In addition, a compact fused silica prism can be used as a photon camera in front of each bar box instead of the single volume filled with mineral oil. This option reduces the number of pixels and provides better optical properties, which improves the photon yield. Figure 1 shows a simulation of a DIRC where both options are applied. Figure 2 illustrates the propagation paths of Cherenkov photons inside the plate and prism.

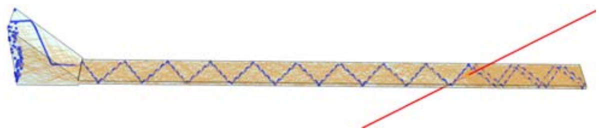

Figure 2: A single DIRC module, comprising a radiator plate, forward mirror, prism, and MCP-PMT array. The kaon track is shown in red, Cherenkov photon trajectories in orange. For clarity, the path of a single photon is highlighted in blue.

In 2013, two reconstruction approaches were developed for these design options and tested with Geant [4] simulations. The first approach, reconstructing the Cherenkov angle with lookup tables and geometrical photon path reconstruction, fails to meet the PANDA requirements due to excessive combinatorial backgrounds created by chromatic dispersion.

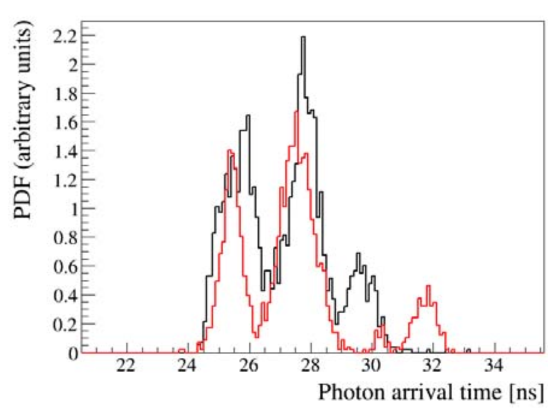

Figure 3: Propability density functions of pion (red) and kaon (black) hypotheses for a selected pixel.

A second approach uses the photon arrival time for each track momentum and direction, pixel by pixel, to produce

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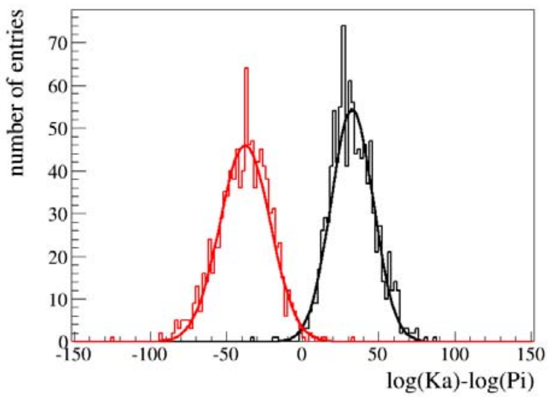

Figure 4: Log-likelihood difference for pion and kaon hypotheses for a sample of pions (red) and kaons (black) at 3.5 GeV/c track momentum and 22° polar track angle.

probability density functions (PDF, see fig. 3), so that for each particle track time-based likelihoods can be assigned to the particle hypotheses. This approach shows promising results with realistic DIRC geometries and PDFs created from simulation, and seems to meet the resolution requirements for PANDA, even without the aid of focusing elements. A critical region in the final state kaon phase space for the barrel DIRC is at 3.5 GeV/c track momentum and 22° polar track angle, as most of the kaons are expected in forward direction at high momenta, and a pion/kaon separation is challenging due to the small Cherenkov angle difference at higher momenta. The separation power, which is defined by the difference of the kaon and pion likelihood-ratio distribution divided by the average standard deviation, is a figure of merit for the PID performance. Figure 4 shows a separation power of 4.7 standard deviations at 3.5 GeV/c track momentum and 22° polar track angle, which is better than the 3 standard deviations set as goal of the PANDA PID. Simulation studies of the performance of the wide plate in combination with a cylindrical lens are ongoing.

The reconstruction approach is currently being applied to experimental data taken with a DIRC prototype at CERN in 2012. Additional data will be taken with an improved prototype setup at GSI in summer 2014.

References

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