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Reconstruction methods — $\overline{\text{P}}$ANDA Focussing-Lightguide Disc DIRC

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ABSTRACT: The Focussing-Lightguide Disc DIRC will provide crucial Particle Identification (PID) information for the $\overline{\text{P}}$ANDA experiment at FAIR, GSI. This detector presents a challenging environment for reconstruction due to the complexity of the expected hit patterns and the operating conditions of the $\overline{\text{P}}$ANDA experiment. A discussion of possible methods to reconstruct PID from this detector is given here. Reconstruction software is currently under development.

KEYWORDS: Particle identification methods; Cherenkov detectors; Pattern recognition, cluster finding, calibration and fitting methods; Analysis and statistical methods

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1 Introduction

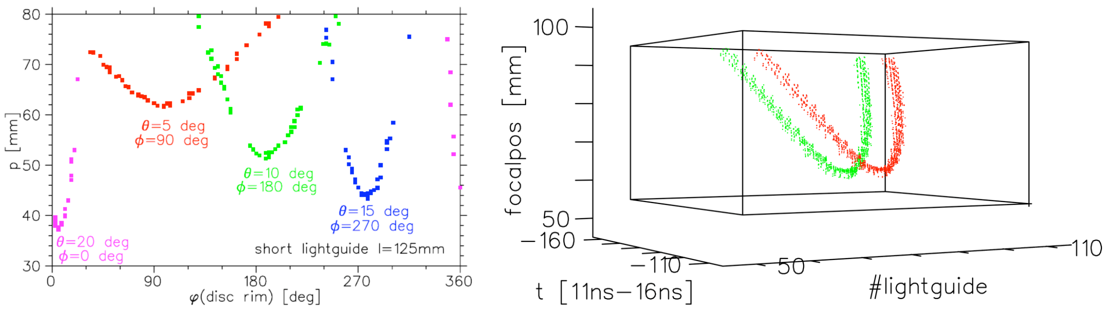
The $\overline{\text{P}}$ANDA experiment [1] at the proposed FAIR facility, Darmstadt, Germany, will employ detectors based on the DIRC (Detection of Internally Reflected Čerenkov light) principle for Particle Identification (PID) [2]. The end-cap Disc DIRC detector covers the forward angle range $\theta < 22^\circ$, with the exception of an aperture of 5° vertically and 10° horizontally.

Two competing designs are currently under investigation for the end-cap DIRC detector [3, 4]: the Time-of-Propagation (TOP) Disc DIRC [5] and the Focussing-Lightguide Disc DIRC (FLDD) [6]. Both utilise a disc radiator geometry and differ in the methods used to reconstruct the Čerenkov angle. These proceedings will focus on investigations into reconstruction methods for the FLDD design. Details on this design can be found in [7]. The FLDD will reconstruct the Čerenkov angle from two detector parameters using a pattern recognition technique, which in turn will be used in PID.

2 PID in the focussing-lightguide disc DIRC

The FLDD will reconstruct the Čerenkov angle from measurements of two parameters: the position of the hit around the rim of the disc, ϕ_{rim}, and the position of the hit on the photon detection plane, p. Figure 1(a) shows a typical simulated event, illustrating the hit patterns obtained for various combinations of incident particle polar and azimuthal angles, θ and ϕ. Readout time information will be available for each hit in the FLDD design, allowing separation of overlapping hit patterns. This will reduce multiplicities and background and is illustrated in figure 1(b).

PID in Čerenkov detectors is carried out by calculating the probability of the particle belonging to a particular species from the reconstructed Čerenkov angle. By calculating the particle velocity, directly related to the Čerenkov angle, and including momentum measurements provided by reconstruction from external detector systems the particle species can be identified.



(a) Overlapping patterns

(b) Time separated patterns

Figure 1. (a): Simulated hit patterns for the Focussing-Lightguide Disc DIRC for various combinations of incident particle polar and azimuthal angles, θ and ϕ. (b): Separation of overlapping hit patterns using readout time information. This will reduce multiplicities and background in the reconstruction.

3 Possible reconstruction methods

Reconstruction methods for the Čerenkov angle can be categorised as either "track independent" or "track dependent". In this section the benefits and drawbacks of these methods are discussed, in particular with regards to their suitability for implementation for the FLDD.

3.1 Track independent methods

Reconstruction techniques which do not rely on track reconstruction information from external detector systems are known as track independent. Track parameters such as momenta, angles and vertex positions are not used in the reconstruction of the Čerenkov angle, instead relying on complex reconstruction algorithms to reconstruct from raw data from the detector alone. Examples of track independent methods include Spatial Hough Transforms, Elastic Net algorithms and Statistical Searches, described further in e.g. [8].

These methods have the advantage that the reconstruction can be carried out online, as no external information is needed and raw data can be processed immediately. In turn, this can be used to reduce data volume by rejecting unwanted events or tracks online and mapping onto parameter space. This is considered to be advantageous for an experiment such as $\overline{\text{P}}$ANDA where the primary interaction rates are expected to be as high as 20 MHz [9] and no event level trigger is available due to the similarity between the obtained hitpatterns from proton-antiproton collisions and noise in the spectrometer.

However, track independent methods have many disadvantages. A very complex method must be employed on a short timescale, with an excellent knowledge needed of the expected pattern shape and the detector performance. For the FLDD the expected pattern shape may not be easily parameterised as a simple parabola or low order polynomial function, thus making track independent methods difficult to implement.

For online processing there are further complications in the case of the FLDD. A complex readout would be required with very fast timing and comparatively high onboard processing capacity. There is limited space available for onboard electronics in the design specifications of the Target

Spectrometer [10], where the FLDD will be installed, thus making this approach unfavourable. Finally, separation of overlapping patterns would be difficult in an online track independent method, leading to a high likelihood of false PID results.

3.2 Track dependent methods

In contrast to track independent methods discussed in the previous section, track dependent methods use external tracking information in the reconstruction. This has many advantages over the track independent approach. Track parameters can be used to limit the pattern search area and thus help reject noise hits. The parameterisation of the pattern is less important for this method and the algorithms employed are generally faster. Examples of track dependent methods include (In)Direct Ray Tracing, Yield Determination, Pattern Comparison Angular Hough Transforms, described further in e.g. [8].

Generally for this method a comparison is made between the measured Čerenkov angle and possible Čerenkov angles for each possible particle type calculated from the externally reconstructed track parameters. These possible angles are generated from either Monte Carlo simulations of the experiment or from test beam reconstruction. The most probable result identifies the particle type of the track.

An obvious disadvantage of this approach is that it must be carried out offline to first allow the reconstruction of the tracking detector information. As the final decision of online or offline reconstruction has still to be made, offline reconstruction is the preferred approach for the FLDD reconstruction.

4 Preferred reconstruction method — Maximum likelihood

The method currently in development for PID in the FLDD is based on the principle of maximum likelihood fitting. This method was employed by the BABAR collaboration in the reconstruction of the BABAR DIRC detector [11]. The Čerenkov angle is reconstructed for each detected photon, with a maximum likelihood fit based on known detector performance parameters employed to calculate the most probable PID result.

Two algorithms were developed for the BABAR DIRC. A local track-based algorithm, with each track fitted individually, was used for alignment of the detector. A global, event-based algorithm fitted each track within an event simultaneously, giving the highest performance and allowing noise and alignment information to be taken into account. A similar approach is proposed for the FLDD, allowing for alignment information to be used for the best performance in PID.

Furthermore, the maximum likelihood approach is comparatively simple to implement in the $\overline{\text{P}}$ANDA software framework, known as PANDARoot [12]. PANDARoot includes the CERN software packages ROOT [13] and MINUIT [14], the latter a minimisation package important in the maximum likelihood method. Investigations are ongoing into the applicability of this approach to the FLDD design.

5 Conclusion and outlook

The FLDD will form an integral part of the $\overline{\mathrm{P}}$ANDA PID system. Reconstruction software is currently in development based on a track dependent maximum likelihood algorithm, having been proposed as the most suitable based on the specifications of the detector and past employment in detectors based on the DIRC principle. A simulation of the detector has been included in the PANDARoot software framework and reconstruction algorithms are currently under development in this framework, using the latest geometric description of the detector. Preliminary studies suggest that the detector reconstruction will operate within the desired performance criteria.

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