The DIRC projects of the PANDA experiment at FAIR

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Abstract

For the charged particle identification of the PANDA experiment at FAIR, one foresees three imaging Cherenkov detectors. An aerogel detector of standard design will cover the forward spectrometer acceptance. Two DIRC detectors will be located in the target spectrometer part of PANDA, a barrel shape DIRC with bar radiators and a disc DIRC in the endcap section, one option of the readout being time-of-propagation, one option being focussing lightguide dispersion-correcting one-dimensional disc DIRC.

Key words: Particle identification, Cherenkov counter, ring imaging
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The PANDA [1] experiment at the future FAIR laboratory is a fixed target experiment using cooled antiprotons from the High Energy Storage Ring (HESR) in the energy range of 1-15 GeV/c at interaction rates of up to $2{\cdot}10^7$ 1/s to perform high precision experiments in the charmed quark energy range. The target spectrometer section with a superconducting solenoid and subdetectors housed

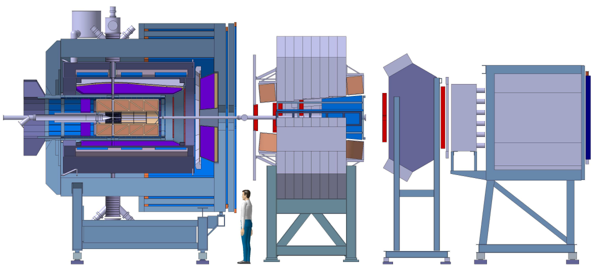

Fig. 1. PANDA spectrometer side view, target spectrometer left, further downstream the dipole in the middle with several forward spectrometer sections to the right.

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[1] Antiprotons at Darmstadt

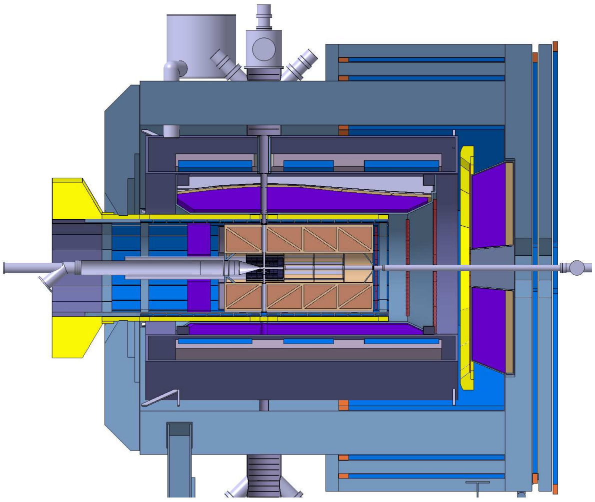

Fig. 2. PANDA target spectrometer. The Barrel and the Endcap DIRC detector positions are shown in yellow/bright colour.

inside a return yoke covers most of the acceptance. The forward acceptance of ϑ=10° horizontal and 5° vertical is covered with a dipole providing additional bending power and the subdetectors of forward spectrometer section.

Three imaging Cherenkov detectors are foreseen for the charged particle identification of the PANDA experiment. For PID their information will be combined i.e. with tracking and calorimetry detectors. The RICH detector in the forward spectrometer part will be of a standard aerogel radiator and curved mirror design similar to the HERMES RICH[3].

1. DIRC

There is little space for PID detectors

Inside the almost hermetically sealed PANDA target spectrometer space is at a premium. The possibility of using thin radiators and placing the readout elements outside the acceptance and potentially outside the magnet return yoke favours DIRC (Detector of Internally Reflected Cherenkov light) designs to use as Cherenkov imaging detectors for particle identification

With the momentum ranges anticipated for the physics reactions in PANDA, each of the DIRC designs suggested for PANDA has to improve over currently implemented DIRC design, and hence needs to address the effects of chromatic dispersion of the Cherenkov light. For the time-of-propagation design a narrow wavelength band limits the group velocity time spread. For the optical imaging design a prism element can largely correct the dispersion angle spread.

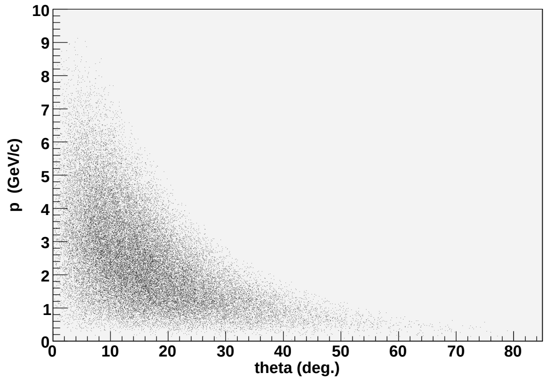

Fig. 3. acceptance plot for 15GeV/c $p\bar{p} \rightarrow \psi_h \eta$

The detectors are being located in a high radiation area, with irradion tests[6] indicate that different to several glasses the amorphous fused silica is radiation-hard. The photon detectors have to stand a high magnetic field of B≈1T.[7] and high photon rates.

2. Barrel DIRC

The DIRC in the barrel section covers the angular range from θ=23° to 135°. The design is initially based on a scaled version the BaBar DIRC[4]. Combining the time of arrival of the photons with their spatial image determines not only the particles velocity, but also the wavelength of the photons. Therefore dispersion correction at the lower and upper detection threshold is possible. See the separate paper[1] in these proceedings for details of this design.

3. Endcap DIRC

For PID covering the Endcap of the target spectrometer part there are two DIRC design options which differ in the readout technology but both use an amorphous fused silica radiator disc. The encdap detector covers forward angles up to $\vartheta = 23°$ excludingan inner rectangular acceptance with $\vartheta_x = 10°$ horizontal and $\vartheta_y = 5°$ vertical half-angles.

In these one-dimensional DIRC a photon is transported to the edge of a circular disc while preserving the angle information. This requires locally (in the order of millimetres) a surface roughness not exceeding several nanometres RMS.

The lower velocity threshold common to both designs depends on the onset of total internal reflecion for a part of the photons emitted in the Cherenkov cone.

3.1. *Time-of-Propagation disc DIRC*

In the Multi-Chromatic Time-of-Propagation design (see separate paper[2] for more detail) small detectors measure the arrival time of photons on the disc rim with the single photon resolution of σ_t=30–50 ps.

For any given wavelength the disc edge is effectively covered alternatingly with mirrors and detectors. This gives different light path lenghts and allows to extract the timing of the initial charged particle. The stored antiproton beam in the HESR has no suitable time structure to be used as an external time start.

As some of light is reflected several times before hitting a detector, the longer path lengths allow a better relative time resolution.

The use of dicroic mirrors as colour filters allows the use of multiple wavelength bands within the same radiator (the current design suggesting two bands) resulting in higher photon statistics. The narrow wavelength bands minimise the dispersion effects, and the photocathode material could be optimised for each wavelength band individually.

3.2. *Focussing lightguide disc DIRC*

The focussing lightguide dispersion-correcting one-dimensional disc DIRC is to be placed in the endcap of the PANDA target spectrometer and the implications of the environment and boundary conditions of the whole experiment.

In this one-dimensional DIRC a photon is transported to the edge of a circular disc and after entering into one of about hundred optical elements on the rim the two-fold angle ambiguity is lifted, the chromatic dispersion corrected and the photon focussed onto a readout plane. While the optical element entered determines the ϕ coordinate, the focussing lightguide part provides a one-dimensional spatial coordinate yielding the θ coordinate.

The low-dispersion lithium fluoride material is UV transparent and the radiation-produced colour centres are confined to sufficiently small wavelength ranges so this material can be used for correcting the Cherenkov radiation dispersion. The two boundary

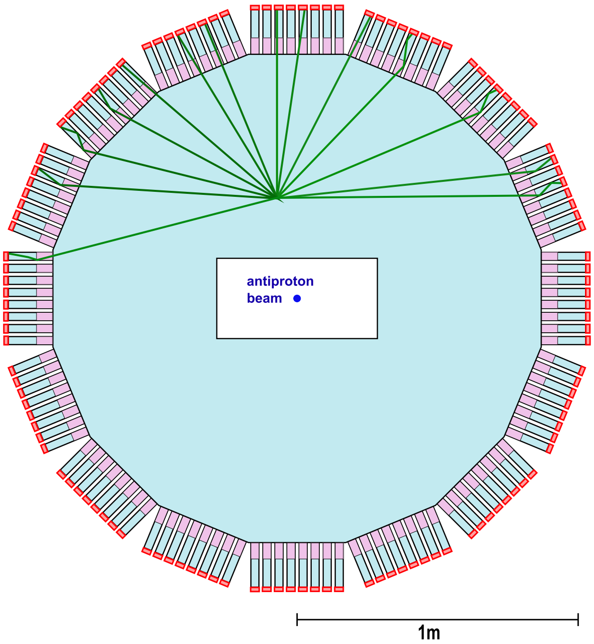

Fig. 4. Polygon disc with optical readout components attached to the rim.

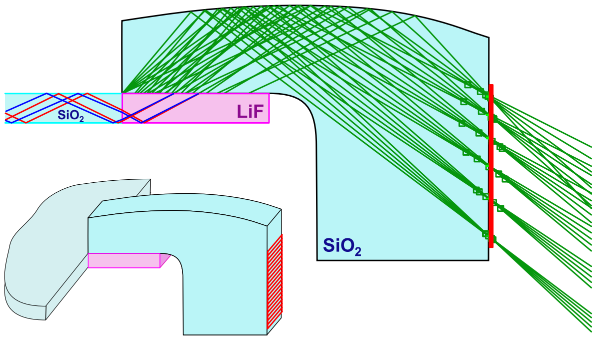

Fig. 5. lightguide side view with rays. Reflections at the parallel top and bottom surfaces keep the light inside but do not affect the focussing properties.

surfaces, with the radiator disc and the subsequent lightguide, make the chromatic dispersion correction angle-independent in first order.

As with the radiator, the light impinging on the inside of the lightguide's curved surface undergoes total internal reflection, hence no mirror coating is needed. The mirror makes the focussing also independent of the wavelength.

As the light stays within the dense optical material of the lightguide most of the phase space of the incoming light from the disc can be mapped onto the focal plane with one-dimensional readout. The focussing surface with cylindrical shape of varying curvature has been optimised to give an overall min-

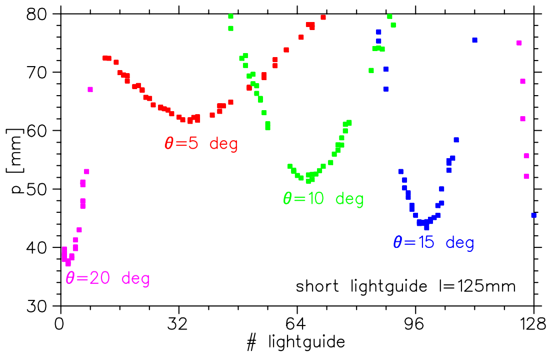

Fig. 6. Simulated photon hit pattern for four particles emitted at different angles θ and ϕ from the target vertex.

imum for the focus spots of the different angles on the focal plane, individual standard deviations being well below 1mm for the instrumented area..

Simulations: ingredients: 3d simulation, angular straggling, Sellmeier parametrisation of refractive indices wavelength dependence, analysis based on photon hit patterns, seeded with smeared Monte Carlo truth vertex equivalent to tracking information, resolution derived from event sample analysis distributions.

ideal geometry ideal light transmission, bulk, full reflectivity (no Fresnel formula yet, photons unpolarised, hard cutoff for non-total internal reflection, no background photons

Within the given geometrical boundary conditions of placing the Endcap DIRC inside the target spectrometere return yoke the simulations show the angle-dependent pion-kaon 4σ separation power reaching up to 6 GeV/c within the range 5-23 degrees.

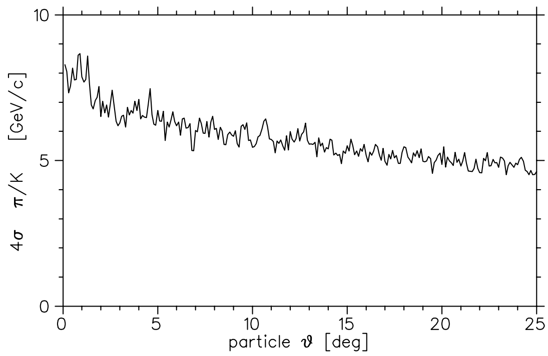

Fig. 7. Pion-kaon separation power for a design based on 15mm disc thickness, 96 lightguides with 32 pixels each and 0.4eV (ϵ_{QE}=0.2 for λ=300-600nm. The simulation results extend beyond the actual angular coverage.

4. Conclusions

For several DIRC designs suggested for PANDA performance adequate.

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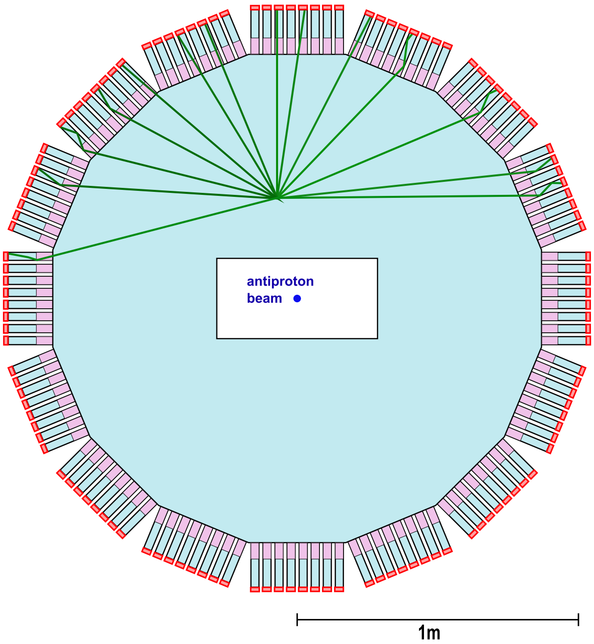

Fig. 8. disc 16 polygon.

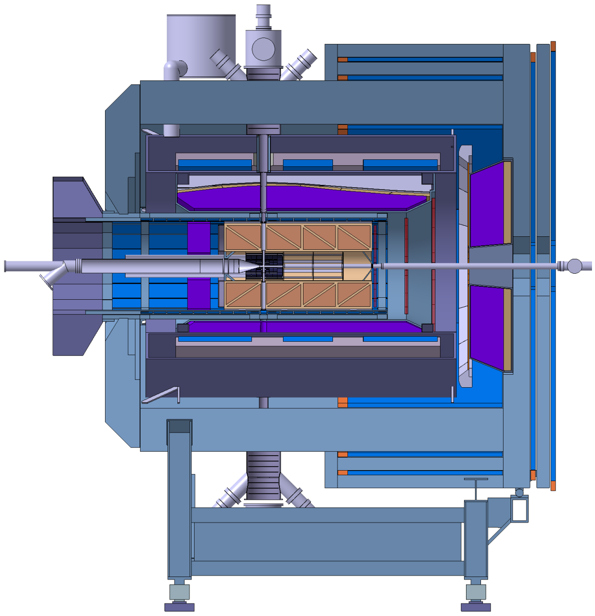

Fig. 11. PANDA target spectrometer

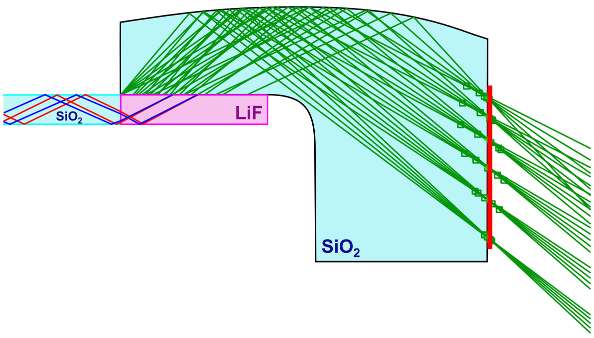

Fig. 9. lightguide side view with rays.

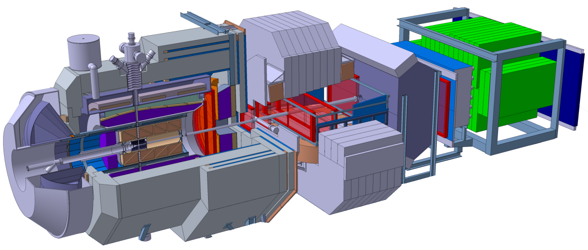

Fig. 12. PANDA spectrometer3d

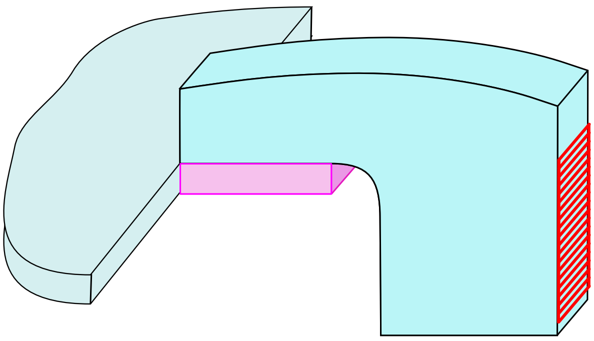

Fig. 10. Lightguide 3d visualisation.

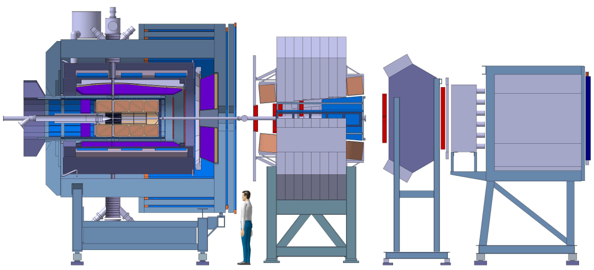

Fig. 13. PANDA spectrometer2d