KERNFYSISCH VERSNELLER INSTITUUT

Proposal form

For KVI use

Exp. No.:
PAC:

Date: 27/10/2006

Title of experiment: Radiation hardness test of radiator materials for the PANDA DIRC detector .

Collaborators :

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Beam request; Number of 8-hour shifts: 1 shifts

Target	Beam and Charge state	Energy(MeV)	Intensity(pnA)
–	$^{1}H^{1+}$	150	20

Beam line: Irradiation beam line

Required equipment:beam diagnostics and dosimetry

Preferred period:

Periods can not run: not before 03/2007

Special Requirements: can run parasitically, but need frequent access

Special Safety Procedures: none

Special Laboratory Support Requirements: none

EU support requested: yes/no

Short Summary of the experiment

The experiment aims at testing the radiation hardness of several radiator materials considered for the PANDA Endcap DIRC detectors. This detector located at the downstream end of the PANDA central spectrometer is vital for particle identification for polar angles of $5^\circ < \theta < 22^\circ$. The detection principle relies on detecting internally reflected Cherenkov light. The detector will be operated downstream of a fixed target experiment operating at high interaction rates of about $10^7/s$ or more with an expected mean multiplicity of 4-6. Within the detector acceptance, this corresponds to an expected dose of 100 krad over the expected lifetime of the experiment. It is proposed to measure 4 different materials (Corning 7980, Lithosil, Suprasil 1, Plexiglass) and 3 different glues at 1/2 the expected dose. the expected dose, 10 times the expected dose and 100 times the expected dose to evaluate possible degradation of performance due to radiation damage. The evaluation will be performed using optical methods at the University of Glasgow. The dose will be monitored by dosimeters and the beam diagnostics in place.

Justification of the Experiment

The PANDA Experiment

The PANDA collaboration proposes to build a state-of-the-art universal detector system to study reactions of anti-protons impinging on a proton or nuclear target internal to the high energy storage ring HESR at the planned FAIR facility at GSI, Darmstadt, Germany. The detector aims at taking advantage of the extraordinary physics potential offered by a high intensity phase space cooled anti-proton beam colliding with a flexible arrangement of targets.

The physics aims of the PANDA collaboration are manifold, reaching from high precision Charmonium spectroscopy, discovery of hitherto unknown particles states (glueballs, hybrids to name but two), rare processes like Drell-Yan Production and hard exclusive reactions providing new insights into the structure of the nucleon itself or the study of CP violation to a rich program in hyper-nuclear physics. The physics program the PANDA collaboration aims at providing unique new insights into one of the four fundamental focusses, the strong interaction. It will allow to study Quantum Chromodynamics – the quantum field theory describing the strong interaction – both with unprecedented precision and novel tools. The combined performance of the detector system and the accelerator providing the anti-proton beam together with the high interaction rate will allow precision studies even of rare reactions or decay channels. Clearly, the design requirements on a detector system fulfilling these physics aims is demanding. It will require a combination of large angular and momentum coverage with excellent particle tracking and identification capabilities while withstanding the data rate and radiation load expected. Exploiting the latest developments in detector technology is mandatory.

The case for a Cherenkov Detector for Particle Identification

The expected final states in anti-proton annihilation reactions are usually comprised of many hadrons of different species. In addition, rare reaction occur leading to scarcely populated final states where the few particles produced obtain comparatively large momenta. To fulfill the physics aims of the PANDA collaboration, the detector system thus has to be able to identify particle species over a large momentum range.

Clearly, this goal will only be fulfilled by a successful interplay between the various detector components providing a response depending on the particle species. The main component of this system of particle identification detectors will be three Cherenkov counters aiming at discriminating between pions, Kaons and protons, the most prevalent charged particle species within a certain flight path from the interaction point. In certain momentum ranges, these detectors might provide a lepton/hadron discrimination as well. The emphasis of the Cherenkov counters, nevertheless, will be on pion/Kaon separation as these particles are the hardest to distinguish by other means in the momentum range where the Cherenkov counters will be optimised to work. The separation of protons from Kaons and pions is then implicitly guaranteed. The pion/Kaon separation power as a function of the parameters of the particles trajectory will thus be the main design criterion.

The lay-out of the PANDA detector necessitates a compact design for all detector components located between the beam pipe and the electromagnetic calorimeter both in the barrel as well as in the endcap regions. This in term calls for a very slim detector design which can only be achieved by using thin radiators. In order to achieve a reasonable photon yield fused silica has to be chosen as radiator material. The design will follow and improve the idea of a so called DIRC Cherenkov counter successfully running at the BaBar Experiment at SLAC. While this is easier in the barrel region where optimisation of a proven detector concept is a working fallback solution, it requires a completely new design in the endcap region on which this proposal focusses. The concept of a so called endcap disc DIRC was proposed for the upgrade of the Belle detector at KEK, Japan, but was not realized so far.

An endcap disc DIRC relies on a prefect reflection of a significant part of the Cherenkov cone one two surfaces of the disc. The light will then be transported towards the rim of the disc while the emission angle is conserved. Suitable optics at the detectors rim focus the light on a two dimensional read-out plane allowing the reconstruction of the emission angle. Precise time information will help to disentangle infor- mation from different interactions and corrections for dispersive effects. Good timing resolution of the de- tection system is thus an asset. Preliminary estimates on the detector performance even without relying on the time information show that a pion/Kaon separation of more than 3 standard deviations can be achieved over the complete desired phase space range.

Choice of Radiator Material

The proposed experiment has to take up as little space as possible while on the other hand providing a proper refractive index matching the particle species and momentum range as well as producing enough photons to be detected and exploited to extract a suitable signal. This in turn calls for a solid material, transparent in the visible and near UV having a large attenuation length, no absorption bands within the desired wavelength range and proper mechanical and optical properties. In addition, the material should be radiation hard and cost effective.

Test of Radiator Material

Taking the requirements on radiator material together fused silica are the material of choice. Several in- dustrial suppliers are available offering various qualities which fulfill and very often exceed the needs of the experiment considered here. In collaboration with optical finishing companies various radiator materials will be evaluated. These tests will focus on their optical properties like refraction index, dispersive behavior, impurities, surface finish etc. In addition, a series of tests aiming to establish the radiation hardness have to be carried out at different laboratories providing electron, proton and neutron beams. KVI is the ideal laboratory for testing radiation damage due to protons. These tests should also reveal any activation and color centers created as a result of the irradiation. The transmission spectrometer will allow the classification of fused silica materials supplied by different manufacturers. Spectrometers of this type allow to study the transmission, absorption and surface properties as a function of the wavelength of the incident light very precisely. The geometrical dimensions of the chosen apparatus allow to test small size sample easily. Larger samples can be examined using special light feeds. As the area which can be irradiated at the proposed irradiation tests is limited small scale samples can be used. The spectrometer will be used to measure the aforementioned optical properties prior and after irradiation to study any changes in the optical properties of the candidate materials. The sensitivity of this method has been demonstrated by irradiating neutron samples with an AmBe source.

Irradiation hardness test at KVI

The accumulated dose the radiator material will receive ist estimated to be app. 100 krad. This assumption is based on the anticipated interaction rate of 10^7/s with a mean particle multiplicity of 5. Given an effective life time of the experiment of 5 years, in total 10^{16} particles are expected to impinge on the detector. Most of these particles will have momenta in the GeV-regime. Their estimated energy deposition within the detector is 24 MeV/particle, corresponding to the energy loss of Minimum Ionising Particles (MIP) times a factor of 3 taking the relativistic rise into account. Due to geometric reasons, only the central part of the detector will be exposed. Therefore, an effective disc with a radius of 500 mm and a thickness of 20 mm is assumed to evaluate the accumulated dose. An irradiation profile for the fused silica samples ($50\times50\times15$ mm^3) is suggested taking inaccuracies of the estimated dose into account. Each quadrant of a fused silica sample should be irradiated with 0.5, 1, 10 and 100 times the estimated dose, respectively. The size of each quadrant, see Fig. 1, allows to distinguish and measure the radiation damage induced by the corresponding dose, assuming a beam spot size of 30 mm^2. The necessary fluence to accomplish the upper irradiation limit corresponds to $7{\cdot}10^{13}$ cm^{-2} at a beam energy of 60 MeV. The irradiation line at the KVI would be ideally suited, being equipped with ionisation chambers to measure precisely the accumulated dose. The maximum flux of this beam line is 2–$3{\cdot}10^{10}$ s^{-1} allowing to irradiate the fused silica samples within several minutes with the maximum anticipated dose. This would also allow to increase the beam energy to 150 MeV which prolongates the irradiation period by a factor of two, but yields a much more precise determination of the accumulated dose.

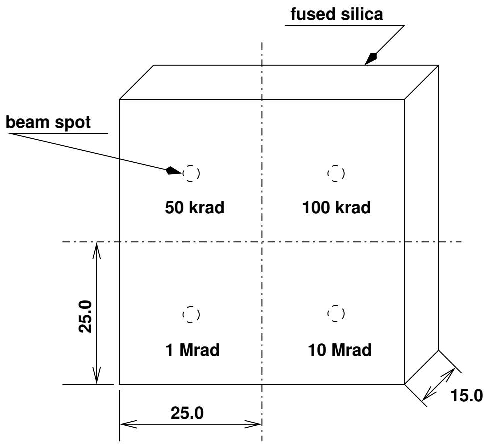

Figure 1: Schematic drawing of fused silica sample with irradiation spots.

In addition to the fused silica samples, a range of optical couplants need to be tested regarding their radiation hardness, since the final endcap disc DIRC will consist of several fused silica pieces. Therefore, several types of optical glue should be exposed to the same irradiation profile as the fused silica samples.