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A compact Cherenkov detector for measurement of the high energy anti deuteron flux in cosmic rays

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The measurement of the antideuteron flux in cosmic rays has been proposed as a probe towards the discovery of exotic sources, due to a smaller background from more ordinary process with respect to the antiproton flux in the low energy region of the spectrum. This comes from the higher mass of the antideuteron with respect to the antiproton, which leads to the suppression of its production from interaction between cosmic rays and the interstellar medium.

No antideuteron in cosmic rays has been detected yet and the best current limits on the flux comes in the energy region from 0.163 and 1.1 GeV/n comes from BESS-Polar II. Although the lowest energetic region of the spectrum is the most interesting one for exotic searches, measurement of antidueteron flux at higher energy is paramount to constrain the current models for ordinary production.
Here we present our design for a ring imaging Cherenkov detector that could provide PID between a proton and antideuteron hypothesis in a high momentum range.
The overall design of the detector is quite simple and consists of a rectangular plate of fused silica of dimension 500mm x 500mm x 18mm, which acts both as a Cherenkov radiator (with n_r around 1.5) for the incoming particle and as light guide via internal reflection for the photons emitted, in a similar fashion to the DIRC and TOP modules (from the BaBar and Belle II experiments respectively). The lateral faces of the crystal would be instrumented with an array of Silicon Photo Multiplier (SiPM) able to detect single photons and provide the 2D position information alongside with their timing with a resolution of the order of 100 ps. Suitable sensors are available from Hamamatsu photonics, for example the MPPC S1336 series, that would provide good quantum efficiency and satisfying position resolution.

A simulation using the GEANT4 tool was also developed to study the propagation of the photon inside the plate and to extimate the discrimination power between proton and antideuteron candidates. Some initial results we obtained with the simulation are presented in the additional material. We find that our setup offers good discrimination in the 5 GeV region. The simulations will be compared with a laboratory setup where a partially-instrumented prototype is explosed to cosmic muons.

The design we present is not limited to applications in astroparticle physics, but could also be implemented as a module for a segmented detector in the forward direction for collider experiments.

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