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Direct detection of antiproton annihilations with the Timepix3 using GRACE a facility for extraction of very low energy antiprotons at the CERN AD

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One of the key aspects in antimatter research is the detection and tagging of antiprotons and antihydrogen, which is usually achieved via tracking of the annihilation products while the annihilation occurs somewhere else, e.g. on the walls of the traps. We hereby report on a novel approach of a so-called direct detection of antiprotons, in which they annihilate within the detector volume and which has the potential of sensibly improving the resolution on the position determination.

The R&D effort was made within the AEgIS experiment at CERN that aims to study antimatter gravity, i.e. to directly measure the free fall of antihydrogen with a precision of the order of few percent. The design of the experiment requires detection of antihydrogen annihilations with a resolution on the position of the order of 10 um. The development of a position sensitive detector that would measure the vertical shift of the antihydrogen atoms influenced by the Earth\u2019s gravity included evaluation of different detector technologies for direct antiproton annihilation.

The first tests and measurements were performed in 2012, using monolithic active pixel and 3D sensors within the main AEgIS apparatus. The promising results lead to the development and construction of a dedicated facility for detector studies, GRACE, which is operational since 2015. This beam line makes use of the secondary branch of the existing antiproton beam line at the Antiproton Decelerator, which it shares with the AEgIS experiment . GRACE exploits simple beam optics and an electrostatic deflector to provide antiprotons with very low energy (1-8 keV).

Over the last two years GRACE has been employed to study the performance of the Timepix3 as a direct annihilation detector. The Timepix3 is an ASIC developed within the Medipix3 collaboration at CERN, characterized by an extremely high spatial resolution and accurate TOA (time-of-arrival) and TOT (time-over-threshold) information. For our application, the Timepix3 chip was coupled to a particularly thick (675 um) silicon sensor, allowing a much-improved tracking length. These characteristics make it ideal to tag the typical signature of antiproton annihilation, where several charged products depart from the annihilation point, with typical energies of hundreds of MeV, creating a signature star-shaped event. Some of the results on the performance of GRACE as well as a detailed study of the Timepix3 capabilities as an annihilation detector will be presented.

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