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J- PET detection modules based on plastic scintillators for performing studies with positron and positronium beams at the Anti-Matter Laboratory

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The J- PET detector, which consists of inexpensive plastic scintillators, has demonstrated its potential in the studies of fundamental symmetries [1,2] and in applications to medical physics [3,4]. In recent years, a prototype with 192 plastic scintillators arranged in 3 layers has been optimized to register the multiple annihilation photons emitted in the decays of positronium atoms (Ps) [5]. This allows performing precision tests of the discrete symmetries (C, P, T) in the decays of ortho-positronium atoms (o-Ps: triplet state of Ps) by measuring the expectation value of the odd symmetry operators consisting of the momentum vector of photons and the spin of o-Ps [2,6]. Moreover, the geometric acceptance of J- PET allows the measurement of the polarization direction of the photon based on Compton scatterings and thus, for the first time, the study of a new set of operators including the polarization of photons. Since it can measure the lifetime of o-Ps atoms, it also enables positronium imaging, which has direct applications in the medical field [3,7].
Recently, a new prototype was put into operation based on a modular design consisting of 24 individual units [8]. Each module consists of 13 plastic scintillators and can be used as a stand-alone, compact and portable detection unit. Data acquisition is performed in triggerless mode and is based on real-time data processing using the Field Programmable Gate Array (FPGA), which can process 48 data streams, each at a rate of 5Gbps [9].
At the University of Trento, a facility for the production of a bunched positron beam and positronium into vacuum has been commissioned at the Anti-Matter Laboratory (AML). With the know-how to produce transmission targets [10] (which convert positrons into positronium atoms in the forward direction) and to manipulate positronium atoms into a metastable state with increased lifetime [11], the production of Ps beam is envisaged. It is planned to move the portable modules of the J- PET detector to the AML facility to perform studies with positrons and metastable positronium atoms in defined quantum states.

The presentation will cover the main features of the J- PET detector, the modular prototype, and preliminary plans to perform studies with positron and positronium beams.

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