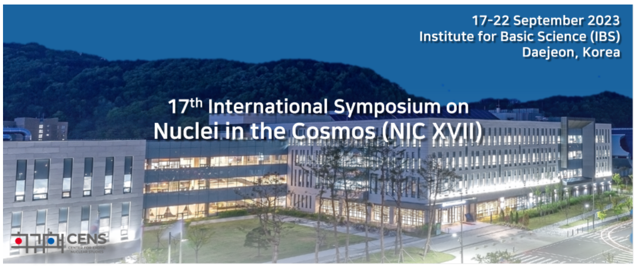

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A novel approach to nuclear and astrophysical studies using a laboratory plasma: the PANDORA project

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Theoretical predictions and past experiments on highly ionized atoms have shown that the β-decay lifetime can be modified even by several order of magnitudes relative to the value observed in neutral atoms due to the opening of a new decay channel called bound-state β-decay [1,2]. The effect of this variation is particularly relevant for those nuclei placed at the branching point of the s-process. A change in their lifetime would lead to a modification of the nucleosynthesis yield of elements produced accordingly to the competing beta-decay and neutron capture rates.
The PANDORA (Plasmas for Astrophysics Nuclear Decays Observation and Radiation for Archaeometry) project aims to measure, for the first time, possible variations of in-plasma β-decay lifetimes in selected isotopes of astrophysical interest as a function of the thermodynamical conditions of the in-laboratory controlled plasma environment.
The new experimental approach consists of creating and confining a plasma whose main features can mimic specific stellar-like conditions and mapping the evolution of the nuclear lifetime as a function of plasma density and temperature which affect the ions'charge state distribution [3]. To achieve this goal a dedicated plasma trap, based on a superconducting magnetic system where the radionuclides can be maintained in dynamical equilibrium for weeks, has been designed and is under construction at INFN –Laboratori Nazionali del Sud (Catania, Italy). The β-decay events will be tagged by detecting the γ-ray emitted by the daughter nuclei populated in the decay process using an array of 14 HPGe detectors placed around the trap. Plasma parameters will be monitored online and measured through an innovative non-invasive multi-diagnostic system which will work synergically with the γ-ray detection system and will allow to correlate plasma thermodynamic properties with the in-plasma β-decay lifetime [3].
Three physics cases were selected for the first PANDORA experimental campaign: 134Cs, 94Nb, and 176Lu. The sensitivity of the PANDORA setup to the expected variations of the nuclear lifetimes of the selected isotopes was evaluated through GEANT4 simulations. Results indicate that the designed setup is able to map the evolution of the nuclear lifetime variation as a function of the plasma parameters, with at least a 3σ level of significance, within a range of experimental run duration varying from a few days to about 3 months, depending on the initial value of the lifetime and the amount of relative variation observed.
The PANDORA plasma trap can be also employed for measuring opacity and optical properties of under-dense and low-temperature plasma relevant for kilonovae study. Preliminary results of the tests performed at the LNS using the compact Flexible Plasma Trap (FPT) will be presented [4].

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