GAPS Trieste – PhD Projects 2022

Cosmic rays (CRs) are a sample of solar, galactic, and extragalactic matter that include all known nuclei, electrons and antiparticles. Their origin, acceleration mechanisms, and subsequent propagation have intrigued scientists since their discovery. What are the sources of CRs? How do they propagate toward Earth? What is the nature of dark matter (DM) and does it contribute to CRs?
CRs, up to about 10^15 eV, are considered to be of galactic origin, and diffusive shock acceleration at supernova remnants emerges as an ideal mechanism to supply their accelerations. Once accelerated, CRs diffuse under the influence of the local magnetic field undergoing energy losses and hadronic interactions with the interstellar matter.
Antiparticles are a secondary component of CRs, being produced in the interaction between primary CRs and interstellar matter. Particularly intriguing is the possibility to extract from the abundances of antiparticles in CR information about novel sources of either astrophysical or particle physics origin. Indeed, for many years, it has been known that antimatter can shed light on the nature of DM.

Many beyond the Standard Model theories, such as supersymmetry and extra dimensions, provide excellent weakly interacting massive particle (WIMP) candidates for DM. Such particles could self-annihilate or decay producing a signal of ordinary matter in CRs. So far, it has been impossible to identify conclusively a DM signature in CRs due to uncertain astrophysical backgrounds.

The General Antiparticle Spectrometer (GAPS) is an Antarctic balloon-borne detector designed to study the low energy (< 0.25 GeV/n) antinuclei (antiproton, antideuteron and antihelium) cosmic ray component as a distinctive signal from dark matter annihilation or decay in the Galactic halo. GAPS is an American-led experiment resulting from the collaboration between Institutes and Universities in Italy, Japan and the USA with the fundamental support of NASA. In Italy, the experiment is supported by INFN and ASI.
The primary scientific goals of the experiment are low-energy antideuterons since at these energies the expected intensity from secondary/tertiary interactions should be several orders of magnitude lower with respect to those predicted by beyond the standard model theories. GAPS will also conduct a low-energy antihelium search and will provide the highest-statistics spectral measurement of antiproton at these energies. The first flight is expected in late 2023.
The detector consists of a tracker, made up of ten planes of lithium-drifted silicon Si(Li) detectors, surrounded by a plastic scintillator time-of-flight system.

GAPS uses a novel particle-identification method based on exotic atom capture and decay with the emission of pions, protons and atomic X-rays from a common annihilation vertex. The resulting "nuclear star" topology provides sufficient rejection power to suppress any non- antiparticle cosmic ray background.

Trieste GAPS group leads the Italian groups in the experiment and it is involved in the design of the tracker read-out electronics and, with other institutes, is developing and testing on simulated events the reconstruction and identification algorithms. The GAPS simulation software is based on GEANT4, C++ and ROOT and fully reproduces the detector geometry. Various techniques like Kalman filter, Hough-3D transform, Least

Squares minimization, machine-learning approaches are studied to precisely reconstruct the topology of the "nuclear star" and identify the particles.
We propose as possible thesis topics:

- study and optimization of the reconstruction algorithm code and its performances with simulated data

- study of the antinuclei and CR identification capabilities

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