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Cosmic rays: direct measurements

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In this talk I will review the field of cosmic ray measurements by direct observations.

A wealth of new results obtained by balloon-borne and space-based experiments have enriched the field, covering several observation targets from nuclei and isotopes, to electrons and positrons, to antiprotons, measured over six decades in energy from few MeV up to some TeV.

The measurements from the AMS-02 and PAMELA spectrometers are characterized by a precision never reached before in CR history; they allowed to discover features in the CR energy spectra that compel a revision of the simple idea that CR fluxes are described by smooth single power-laws in energy, and prompted an intense theoretical activity to interpret the results.

Among the most interesting outcomes of the last years, the first measurement of the CR spectra outside the heliosphere (Voyager 1), the high-statistics measurement of the abundances of nuclei heavier than iron (SuperTIGER), and the first detection of a primary CR clock (ACE-CRIS) are certainly worth considering.

Moreover, very recent calorimetric missions (CALET, DAMPE) are collecting unprecedented statistics of CRs even at higher energies, in the multi-TeV range and finally approaching the knee. The first results on the electron spectrum are already stimulating interesting discussions.

All these advances indicate that we have entered a new era of precision measurements of CRs, which can contribute to shed light on several fundamental questions in CR physics, still open a century after their discovery, like the mechanism of acceleration of galactic cosmic rays (GCRs), the nature and composition of their sources, the CR propagation in the interstellar medium (ISM).

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