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Heritage and challenges for next generation charged cosmic-ray space missions

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The current generation of Charged Cosmic Ray (CCR) experiments in operation in space (e.g. AMS-02, DAMPE, CALET) is providing novel information and is measuring unexpected features that are challenging the phenomenological community to revisit the paradigms behind the established theories of cosmic-ray origin, acceleration and propagation, and to formulate comprehensive models able to consistently explain all the observed structures. This achievement has been made possible thanks to the observation of features in cosmic-ray spectra unveiled by the high granularity (in energy and in time), high resolution and high statistics measurement of all the CCR components, in a wide range of energies ($O(\text{GeV})$ - $O(100 \text{ TeV})$). Leveraging on the experience and on the heritage of the current detector generation, several new ideas to further improve, and possibly lead to a breakthrough, the field are being studied, developed, and being applied. The first two experiments benefiting of these novel ideas are the AMS-02 experiment with its “Layer0 Upgrade” (2026) and the HERD experiment to be installed on the Chinese Space Station (2026 - 2027). The same concepts, in addition to other technological steps forward, are also being applied to the design of a new generation of revolutionary CCR experiments (e.g. ALADInO and AMS-100).

The lessons learned from the operations of the current generation of CCR detectors and the perspectives for future CCR space missions will be reviewed and discussed.

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