Working group
OUTREACH of APPLICATION FOR SOCIETY
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Unraveling Cosmic Mysteries: The collaboration between International Space Station and CERN

What is the International Space Station?

The International Space Station (ISS) is a large spacecraft in orbit around Earth. Think of the ISS as a regular laboratory, but with one tiny difference, it orbits over 250 miles above Earth's surface. There, astronauts embark on scientific missions and analyze social dynamics in space.

The 3000 experiments on the ISS have been conducted with the most important mission: enhance life on Earth and prepare us for future stages of space exploration, with the goal of reaching Mars. So, why do we find particle physics experiments within the ISS?

Fig. 1) The starboard truss of the International Space Station. Credit: NASA

CERN: Pioneering Particle Physics on Earth

Meanwhile, nestled near Geneva in Switzerland, CERN, the world's largest particle physics laboratory, operates at the forefront of scientific inquiry. Renowned for its monumental discoveries and the birthplace of the World Wide Web, CERN's Large Hadron Collider (LHC) delves into the fundamental fabric of the universe by probing subatomic particles and unveiling their enigmatic behaviors.

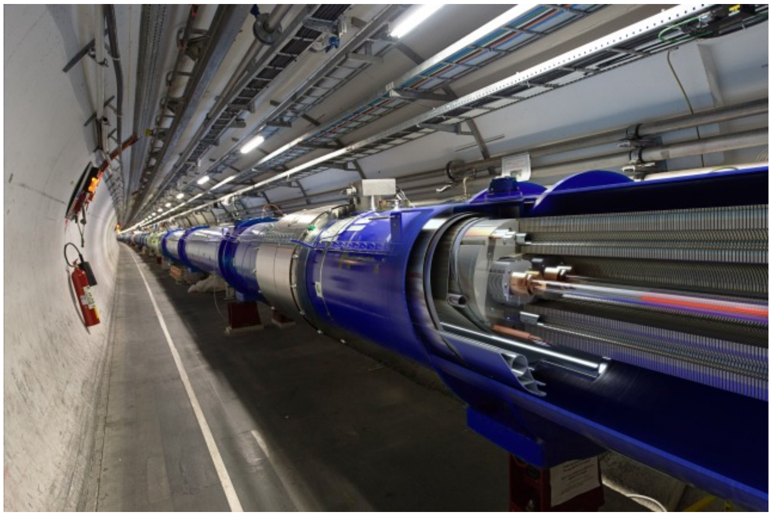

Fig. 2) 3D cut of the LHC dipole Image Credit: CERN

The Cosmic Link:

The ISS and CERN have joined forces in unprecedented and cutting-edge experiments to reveal the mysteries of the universe. Of course, with the ISS serving as an off-planet laboratory, the projects resulting from this collaboration go beyond the boundaries of traditional scientific fields.

The Alpha Magnetic Spectrometer (AMS), for example, is the most intricate physics experiment ever sent into space. It was first proposed in 1994 by Samuel Ting, a Nobel Prize-winning physicist and Professor of Physics at MIT, to study the composition and origin of cosmic rays and to search for dark matter.

During its construction phase, the AMS experiment encountered a significant obstacle due to the Space Shuttle Columbia tragedy in 2003. Subsequently, the decision was made to terminate the Space Shuttle program, and AMS was removed from scheduled missions. Despite a decade of effort and $1.5 billion invested, the project was left without a means of reaching the space station.

The project was revived as a collaboration between CERN and NASA, and on its final flight on 16 May 2011, the Space Shuttle Endeavour delivered AMS-02 to the ISS as part of the space shuttle mission STS-134, along with its critical supplies, including two communications antennas and ancillaries. AMS is the first and only high-energy physics experiment mounted on the ISS.

It was installed on one of the arms of the ISS in May 2011. For this to happen the science and technology working group (that involved Europe, US, China and Taiwan) had to consider the complications that face any space exploration project, like that the equipment had to be able to withstand the acceleration given when the space shuttle is launched.

They also had to ponder the astrophysical uncertainties of maintaining the health and status of all subsystems and the temperatures of the individual components of the experiment, along with the measurements and data produced by the instrument, which may be affected by complications such as the load-dependent solar modulation.

Even when all these issues were taken into account and AMS was collecting data on cosmic rays and other particles, over time some of its systems began to fail over time, and so, in November 2019, special tools and equipment were sent to the space station to complete the repairs, described by NASA as the most challenging since the repairs to the Hubble Space Telescope. Repair works were carried out by astronaut Andrew R. "Drew" Morgan, who needed a total of four spacewalks to complete them.

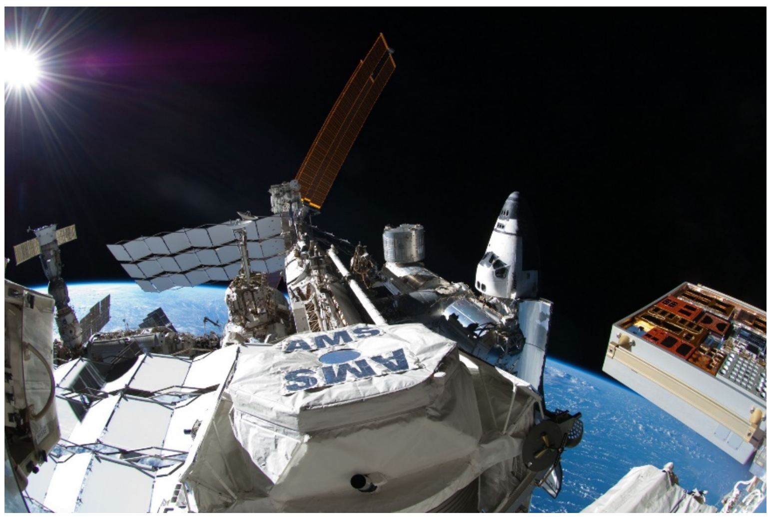

Fig. 3) AMS detector installed on the International Space Station's integrated truss structure. Image Credit: NASA

Now, after more than a decade in space, the AMS detector on the ISS is due for another upgrade in 2026, which involves adding a new layer of detectors that are much more sensitive to incoming particles, and the addition of three new cooling surfaces to maintain its optimal operating temperature.

By 2030, the year that NASA scheduled for the deorbiting of ISS, AMS will have recorded plenty of cosmic ray events to explore the positron signature, which consists of analyzing the signals that positrons leave behind when they interact with the detectors inside AMS. By studying the characteristics of these signals, such as their energy levels, trajectories, and interactions with other particles, scientists can piece together a detailed picture of what's happening in space.

This project will always be a milestone in scientific and technological development worldwide, with great added value for society. While AMS focuses primarily on cosmic rays and dark matter, the technologies and methods developed for the experiment may lead to unexpected discoveries or applications. Such spin-off discoveries can have practical benefits for society, ranging from new materials and sensors to improved space exploration capabilities.

Therefore, AMS's contributions to advancing scientific knowledge, fostering technological innovation, inspiring future scientists, promoting international collaboration, and leading to spin-off discoveries highlight its broader relevance and benefits to society.

Just like AMS, there are other technological applications from the collaboration between CERN and NASA that brings benefit society. For example:

- RadMon. A flexible low-cost instruction for radiation monitoring in space to prevent radiation damage to electronics and satellites.

- Timepix. It consists of an array of tiny pixels, each capable of individually detecting and measuring the passage of charged particles, such as electrons or alpha particles. These detectors are highly sensitive and versatile, capable of recording the energy, position, and time of arrival of particles. A notable application of Timepix technology is its use in space missions and experiments aboard the ISS, where it helps to monitor radiation levels, cosmic rays, and space weather. It's also used in a variety of scientific research areas, including medical imaging, environmental monitoring, and materials analysis, due to its precision in particle detection and analysis. For more details on Timepix check the related IPPOG article on the Medipix/Timepix detectors and their applications.

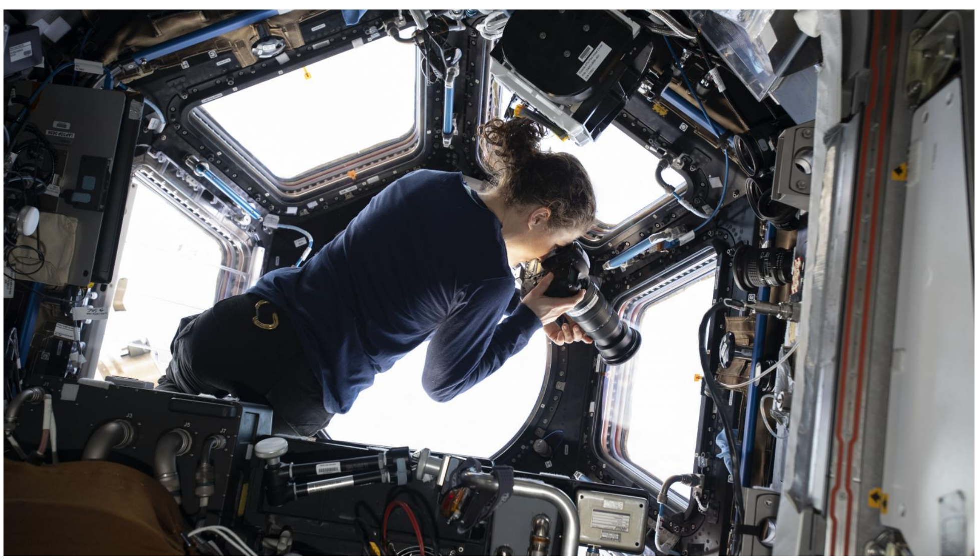

Fig. 4) Timepix detectors are used in numerous NASA projects, from the International Space Station to the Orion spacecraft. Image Credit: NASA

- **Optical fibers for large-scale spacecraft dosimetry.** Monitoring radiation exposure during long-duration missions is critical to ensure the safety of astronauts and the integrity of spacecraft components exposed to harsh space environments, such as cosmic rays and solar radiation. Optical fibers can be integrated into the spacecraft structure or strategically placed in different sections to detect and quantify radiation exposure.

Therefore, the impact of research and innovation from institutions such as the ISS and CERN is not limited to space exploration or particle physics. As an example the microgravity environment in the ISS allows creating materials that are not possible to develop on earth, exactly because of its gravity. Their discoveries often have far-reaching implications that permeate many sectors, inspiring educational initiatives, driving technological advancements and contributing to solutions to challenges on Earth.

Connection to IPPOG:

This article represents a bridge between the author's two passions and areas of expertise. The author, Verania Echaide is part of the National Polytechnic Institute of Mexico in the Physics Education department as PhD student. Since 2020, she has collaborated on IPPOG projects such as the ALICE MasterClass and did her masters thesis on a related subject. Currently, she is contributing to the IPPOG working group "Outreach of Application for Society." She has also been part of renowned educational projects such as the Space4Women project by the United Nations Office for Outer Space Affairs (UNOOSA), which strengthens the awareness, capacity, and skills of individuals and institutions to promote gender equality and women's empowerment in the space sector and its fundamental educational fields.

For more information about AMS and CERN-NASA collaboration projects, please visit:

- https://videos.cern.ch/record/2298487
- https://ams02.space/
- https://home.cern/news/news/knowledge-sharing/cern-and-nasa-join-forces-commit-research-future-open-and-accessible
- https://www.nasa.gov/alpha-magnetic-spectrometer/