COSMIC-RAY PHYSICS WITH THE AMS EXPERIMENT ON THE INTERNATIONAL SPACE STATION (jara0052)

AMS is a detector designed for precision spectroscopy of cosmic rays that was installed on the International Space Station in May 2011 (Fig. 1). With dimensions of 5x4x3 m³ and a weight of 7.5 tons, AMS is the largest cosmic-ray spectrometer ever built. Its construction began in 1995, and a successful prototype flight aboard the Space Shuttle Discovery proved the feasibility of the detector concept in 1998. Led by Nobel laureate Professor Samuel Ting from MIT, AMS has been constructed and is now operated by an international collaboration of more than 200 scientists and engineers, from Europe, America and Asia. The overall construction costs, including the flight of AMS to the Space Station aboard Space Shuttle Endeavour, have amounted to 1.5 billion US dollars. In Germany, RWTH Aachen has been strongly involved in the AMS project since its inception. One of the main components of AMS, the transition radiation detector (TRD), has been designed and constructed by the
I. Physikalisches Institut B under the direction of Professor Stefan Schael. Today, the Aachen group, comprising 20 scientists and students, plays a major role in the analysis of the data gathered by AMS and in the operation and calibration of the instrument.

Since their discovery in 1912, cosmic rays have held many surprises in stock for us, from the discovery of new elementary particles to the most violent processes taking place in the Universe and accelerating cosmic rays to enormous energies. As a multi-purpose instrument for the precision spectroscopy of cosmic rays, AMS was conceived to answer fundamental questions about our Universe: What is the nature of Dark Matter? What happened to the antimatter that must have been produced in the Big Bang? Where are cosmic rays accelerated and how do they propagate through the Milky Way? Answers to these questions will have a profound impact on our understanding about the inner workings of our Universe and help advance fundamental science. In particular, the search for dark matter complements the endeavour to search for new elementary particles at the Large Hadron Collider (LHC) at CERN, Geneva.

AMS so far has recorded more than 125 billion individual particle crossings (so called “events”). The raw data volume collected is on the order of 40 TB per year. AMS employs three different sub-detectors for particle identification (the TRD, an electromagnetic calorimeter and a ring-imaging Cherenkov counter) and two sub-detectors for energy or momentum measurements (a silicon tracker and a time-of-flight system). Before any physics analysis of the data can be performed, the information from all these subdetectors has to be pieced together and complicated reconstruction algorithms have to be run for each of them. The resulting high-level data serves as the input for physics analyses and occupies a volume of 160 TB per year of AMS flight on disk. Several processing runs of AMS data have already been conducted successfully on the JUROPA and JUAMS clusters at JSC as the result of the cooperation within JARA.

So far, fourteen publications from the AMS collaboration have appeared in the renowned Physical Review Letters. The findings have received considerable attention among astrophysicists and triggered an enormous amount of theoretical work.

In 2018, the Aachen group has led the publication on the discovery of complex time structure in the fluxes of cosmic-ray positrons and electrons in Physical Review Letters. The paper was chosen as an “Editor’s Suggestion” for its outstanding quality and relevance. The data cover the time range from May 2011 to May 2017 and the energy range from 1 to 50 GeV. Results for five characteristic energy bins are shown in Fig. 2. They show a rich time structure of the fluxes. The ratio of the positron flux to the electron flux, shown in Fig. 3, reveals a long-term trend, namely a smooth transition from one constant value to another, roughly one year after the polarity reversal of the heliospheric magnetic field that took place in the year 2013. This behaviour is caused by charge-sign dependent solar modulation effects.
Figure 2: Fluxes of cosmic-ray positrons (red, left axis) and electrons (blue, right axis) as functions of time, for five selected energy ranges. Prominent and distinct time structures visible in both the positron spectrum and the electron spectrum and at different energies are marked by dashed vertical lines.
Figure 3: The ratio of the positron flux to the electron flux as a function of time. The data are parameterized by smooth red curves. The polarity of the heliospheric magnetic field changed from negative ($A < 0$) to positive ($A > 0$) during the year 2013. The period without well-defined polarity is marked by the shaded area. The observed behaviour is caused by charge-sign dependent solar modulation effects.
Ten selected honors, prizes, awards, offers of professorship during reporting period (JARA-HPC member and her / his institute)

Selected conference participations (e.g. invited keynote lectures)


S. Schael, “AMS Positron and Electron Results I”, AMS Days, La Palma, Spain, 9 - 12 April 2018.

S. Schael, “The next generation AMS experiment”, AMS Days, La Palma, Spain, 9 - 12 April 2018.

H. Gast, “Observation of complex time structures in the cosmic-ray electron and positron fluxes”, AMS Days, La Palma, Spain, 9 - 12 April 2018.


H. Gast, “Latest results from the AMS Experiment on the International Space Station”, 23 May 2018, ECAP, Erlangen


Five selected national and international cooperations

Prof. Dr. Samuel C. C. Ting, Massachusetts Institute of Technology, United States of America

Prof. Dr. Bruna Bertucci, INFN and University of Perugia, Italy

Prof. Dr. Bernd Heber, Christian-Albrechts-Universität zu Kiel, Germany

Dr. Iris Gebauer, Karlsruhe Institute of Technology, Germany
Visiting scientists at your institute

Publications related to the project


M. Aguilar et al., Observation of Fine Time Structures in the Cosmic Proton and Helium Fluxes with the Alpha Magnetic Spectrometer on the International Space Station, Physical Review Letters 121 (2018) 051101