
BESS-Polar Experiment

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Abstract

The BESS-Polar experiment was proposed for further studies of the low-energy antiprotons and extensive searches for antinuclei in the cosmic radiation. To extend detectable energy range of the antiprotons down to 100 MeV at the top of the atmosphere, and to satisfy the requirements of long duration balloon flights, new payload components have been developed with features of an ultra-thin superconducting solenoidal magnet and a dedicated solar battery system for the front-end and the data acquisition electronics. A technical flight is scheduled in September 2003, and the first scientific balloon flight will be conducted in 2004.

1. Introduction

BESS (Balloon-borne Experiment with a Superconducting Spectrometer) has been carried out since 1993 to investigate elementary particle phenomena in the early Universe. Results of the previous BESS flights [4] show that cosmic-ray antiprotons are predominantly produced by collisions of high-energy primary cosmic-rays with interstellar matter. But possible existence of some novel processes of the antiproton production in the Universe, such as evaporation of primordial black holes [6,9] or annihilation of supersymmetric dark matter [8], cannot be ruled out because the spectrum below 1 GeV seems to be softer than the prediction of the secondary production models.

A direct search for cosmic antimatter has also been continued by BESS, to

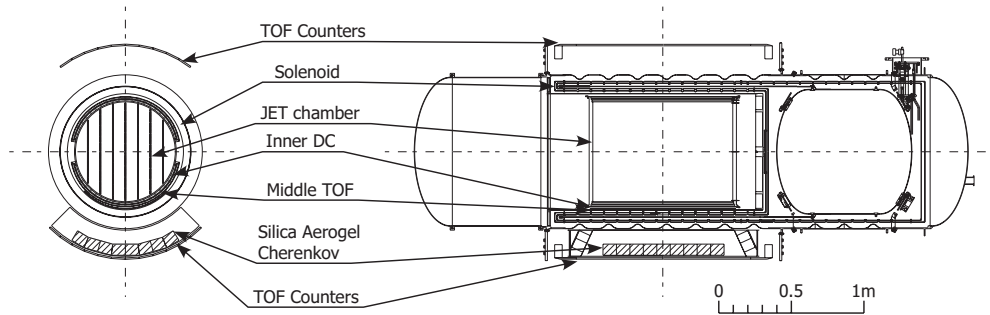


Fig. 1. Cross-sectional views of the BESS-Polar spectrometer

investigate matter/antimatter asymmetry in the Universe. Our previous searches have placed the most stringent upper limit on the ratio of antihelium to the helium nuclei of 6.8×10^{-7} (95% C.L.) in the rigidity range between 1 and 14 GV from null the result [7].

Based on these results from the BESS experiments, we are preparing a new long-duration balloon-borne experiment to carry out further studies of low energy antiprotons [11]. This “BESS-Polar” experiment aims to probe the early Universe by searching intensively for antiprotons of cosmic origin. A search for antimatter in the cosmic radiation will also be performed with higher sensitivity.

2. Development of the BESS-Polar detector

The design concept of the BESS-Polar spectrometer (Fig. 1) is basically the same as that of the current BESS spectrometer [3]. A tracking system sitting in a thin superconducting solenoid measures the curvature of the trajectory of the incident particles. Time-of-flight plastic scintillation paddles will be mounted at the top and the bottom of the spectrometer, in order to measure the velocity and the energy deposit of the incident particles. A silica-aerogel Čerenkov counter will also be utilized as a redundant particle identifier.

We have to reduce the weight of the payload to meet the requirements of long duration flights over Antarctica, and must also reduce material thickness in the payload, in order to measure antiprotons at the lowest possible energy. To reduce weight and material thickness there will be no pressure vessel outside the detector. The Čerenkov counter will be installed beneath the magnet to reduce the thickness of materials in the upper half of the spectrometer, since the counter is used to identify antiprotons in the high energy region. To maintain high trigger efficiencies even for very low energy particles which cannot penetrate the lower half of the solenoid, an additional scintillation counter system (Middle TOF) is placed inside the magnet bore.

In order to minimize material thickness along the trajectory of the incident particle, an ultra-thin superconducting solenoidal magnet has been developed.

The key technology necessary to realize such a superconducting solenoid is the development of high strength superconductor [10]. Adopting a high strength aluminum stabilizer, the solenoid's material including a cryostat was reduced down to a half of the superconducting solenoid of the current BESS spectrometer [12]. The superconducting magnet has successfully tested up to 0.84 Tesla with a flight-model cryostat. The magnetic field was stable against an acceleration load over 4 G. The magnet will be available after several modifications of the cryostat to improve mechanical strength and life-time of cryogen.

To supply electric power continuously up to 20 days to the electronics onboard, a new power supply system using solar cells should be developed. An omni-directional solar-cell array structure has been designed to realize maximum reliability of power production, and tested by a technical flight performed at Sanriku Balloon Center, ISAS in Japan. In the flight, mechanical strength of the array structure was proofed and the partially-mounted solar-cells were worked as designed. The flight model of the solar-cell power system is now in production.

The tracking system consisting of drift chambers worked successfully in the BESS scientific flight in 2002 [5]. TOF counters are under production and new front-end electronics based on the ACE electronics are also being developed. The design of the data acquisition system is basically the same as those of the BESS detector, and the flight models are presently under development.

3. Schedule

As described above, detector components of the BESS-Polar spectrometer are presently under development. Core components, such as the superconducting spectrometer, a part of the solar battery system, and the communication system will be examined by a technical flight at Fort Sumner, New Mexico, in September 2003. General integration of the spectrometer will be carried out after the technical flight. The first scientific flight is planned to be conducted either at either Fairbanks (Alaska), Karlsbörg (Sweden) or Antarctica in 2004. Then, during the period of the coming solar minimum, we are eager to conduct a second scientific long duration flight over Antarctica in the 2006/2007 Antarctic summer in order to optimize the search for the existence of antiprotons of cosmic origin.

4. Summary and future prospects

For extensive searches for antiprotons and antinuclei of cosmic origin, the BESS-Polar experiment has been proposed. A new ultra-thin superconducting spectrometer is being developed. A technical flight of the core components of the BESS-Polar spectrometer is scheduled in September 2003, and the first and the second scientific flights by long duration ballooning are planned to take place in 2004 and in the 2006/2007 Antarctic summer, respectively.

For now two other space-based experiments, AMS [2] and PAMELA [1], are developed to investigate similar objectives. The observation by a long duration balloon is much shorter compared to the space-based experiment. However, the long-duration balloon flight can stay at high geomagnetic latitude. Thus BESS-Polar is still ideal for the search for low-energy antiprotons of cosmic origin (Fig. 2). PAMELA will cover the overall energy range, and the energy range of BESS-Polar and AMS will overlap. BESS-Polar will provide a very precise measurement of the spectrum of the cosmic-ray antiprotons together with other two independent and complementary experiments.

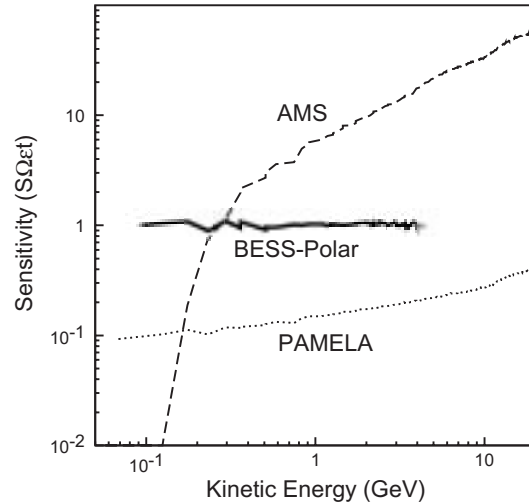


Fig. 2. Relative sensitivities for low energy antiprotons of three experiments as a function of kinetic energy

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