



BESS-Polar II experiment

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Abstract: BESS-Polar II (the 2nd phase of the BESS-Polar spectrometer) has been prepared for the next Antarctic campaign scheduled in December 2007. The aims of the experiment are precise measurements of the low-energy antiproton spectrum and search for cosmologically significant antimatter at this solar minimum period, with 5 times higher sensitivity than the previous measurements in BESS-Polar I. Most of the detector components have been redesigned and upgraded to improve their performance and to increase the data taking period and capacity.

Introduction

After various studies on cosmic-ray antiprotons (\bar{p}) over many years, the origin of \bar{p} has been gradually uncovered. By now, most of the observed cosmic-ray \bar{p} are well understood as secondary products of collisions between primary cosmic-rays and the interstellar medium. However, there still exists room for additional \bar{p} components, which might exhibit their presence as excesses over the secondary spectrum. To investigate their origin further, both statistics and data quality (i.e. detectable energy range and systematics) should be greatly improved over the previous results. This is the motive for building the next generation experiments, which can be carried out only by long-duration balloon

payloads and space missions on satellites or the international space station. BESS-Polar, flown over Antarctica in a long-duration balloon flight [1, 2], is one such experiment. The first flight of BESS-Polar was successfully carried out in 2004 and proved that long duration observation was feasible by BESS (see two talks in this conference [3, 4]). PAMELA, a satellite mission, was launched June 2006 and has been taking data successfully. BESS-Polar II, the second flight of BESS-Polar, is now prepared to be carried out in December 2007, with an improved instrument and capability for an extended long-duration flight. This will be the last chance to observe the low-energy spectra at this solar minimum. We expect a 20 day flight to gather cosmic-ray events with 5 times more statistics than

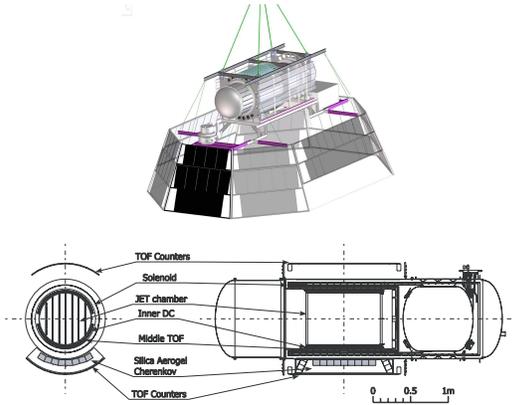


Figure 1: BESS-Polar II instrument (a) perspective and (b) cross sectional view

BESS-Polar I. Thanks to its large acceptance and a long steady-state observation at this solar minimum, BESS-Polar II will investigate the possible origin of primary \bar{p} with unprecedented precision, especially in the low-energy range below 1 GeV. Here, we present the instrument description and status update as well as the expected physics results from BESS-Polar II.

BESS-Polar II Instrument

Figure 1 shows the general layout of the BESS-Polar II spectrometer. Based on feedback from analysis of the BESS-Polar I data, various improvements were done and many of the detectors and systems were redesigned and refabricated both to improve performance and flight duration. The detailed description of the instrument was reported elsewhere [5]. Here major improvements and modifications from BESS-Polar I are highlighted and discussed.

Magnet

A new superconducting magnet was constructed for the BESS-Polar II flight while keeping basic features such as ultra thin material (2 g/cm^2 per wall) [6]. The main improvement is its longer cryogen life, up to more than 22 days, compared with 11 days for the previous magnet. The longer life is achieved by installing a larger He reservoir tank with a 520 l capacity (400 l previously) and



Figure 2: Layout of MTOF with both-end readout using fiber-bundled light guide

an additional layer of radiation shield to improve the dewar's thermal insulation.

Central Tracker (JET)

In the previous flight, the axial-position resolution of the jet-type central tracker (JET) was not as good as expected, mainly due to noise induced by the DC-DC converters. We added a thin layer of aluminum foil to eliminate noise and employ a new data-compressing algorithm to improve the axial position resolution.

Middle Time of Flight (MTOF)

A middle time of flight hodoscope (MTOF), located between the JET and the magnet wall, was used to detect very low energy \bar{p} that cannot penetrate all the detectors. Its performance was very limited due to a single-ended scintillator readout, though. Readout of both ends of the scintillators has now been realized for the new MTOF system by employing clear fiber-bundled light guides as shown in Fig. 2. The new system enables axial position measurements by using timing and amplitude differences of both ends of the scintillators, in addition to improving performance and efficiency.

Time of Flight hodoscope

In the last flight, some of the PMTs for the TOF showed high voltage leakage in the cold and vacuum environment due to imperfections in the potted seal. As a result, the high voltage of the PMTs had to be reduced or turned off, causing a 40% reduction of the instrument acceptance. To protect the PMTs from breakdown, a hermetic aluminum case has been developed. Figure 3 shows a newly designed TOF PMT with a hermetic aluminum shell. The thickness of scintillator was also



Figure 3: PMT enclosed with an aluminum hermetic case

changed from 10 mm to 12.7 mm as a compromise among material thickness, weight and performance.

Aerogel Cherenkov Counter (ACC)

The ACC was thoroughly redesigned and fabricated to increase rejection power against background for \bar{p} measurements, based on the results from the BESS-Polar I flight and the beam tests. We have optimized various parameters, e.g., height, PMT angle, and size of blocks, etc., using a Monte-Carlo simulation. We have also employed new, larger, aerogel blocks ($190 \times 280 \times 20 \text{ mm}^3$) with refractive index of 1.03. (Note that blocks with $100 \times 100 \times 10 \text{ mm}^3$ were only available for the previous counter).

DAQ System

The data acquisition system [7] has been upgraded to deal with the higher data rate and larger data volume in accordance with the higher event rate in a solar minimum period and with a longer flight. Flash ADC performance has been improved by changing the readout configuration and the data storage capacity has been increased to 16 TB by using larger hard disk drives (1 TB)

Solar Power

The basic concept of the solar power system is the same as in BESS-Polar I, using an omni-directional octagonal shape. The layout of the solar-cell array was optimized into a low-profile (3 stages instead 4 stages for the previous) while keeping a minimum generated power of 700 W.

Table 1 summarizes comparative specifications between BESS Polar I and BESS Polar II.

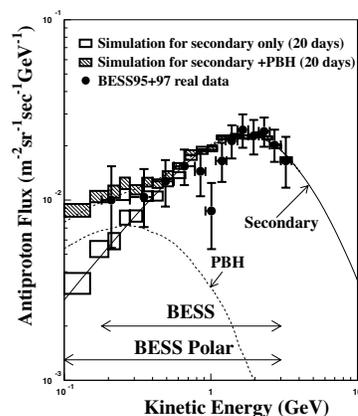


Figure 4: Simulated \bar{p} spectra expected for 20 days flight, together with BESS(95+97) real data. Hatched box and open box indicate simulated flux, respectively, for secondary + PBH and secondary only [8].

Expected Results

After integration of all detector components at NASA/GSFC and the pre-deployment compatibility test at Columbia Scientific Balloon Facility (CSBF), the payload is to be transported to Antarctica and launched in December 2007. If we take data during a 20 day flight, we can obtain 20 times higher statistics than the data taken during the last solar minimum period (BESS95+97). Figure 4 shows the \bar{p} spectra for a 20 day flight that would be expected from secondary \bar{p} production only and with the addition of a primary source from evaporation of primordial black holes [8]. At low energies, the two can be clearly distinguished. As for the antihelium search, we expect to place an upper limit on the antihelium/helium ratio down to the 1×10^{-7} level. In addition to antiparticles, BESS-Polar II can provide precise spectra of primary cosmic-ray species during a long-duration flight at the solar minimum period. These data, together with a precise \bar{p} spectrum, provide very important information not only for the study of solar modulation but also to investigate transient variations caused by sudden solar events, e.g., solar flare and coronal mass ejection (CME).

Table 1: BESS-Polar II specifications as compared with BESS-Polar I

	BESS-Polar I	BESS-Polar II
Magnet Cryogen Life	~ 11 days	> 22 days
Track detector (JET) gas quality	~10 days	> 20 days
TOF-PMT housing	Resin potting	Pressurized housing
ACC Particle ID	Rejection ~ 630	\gg 1000
Solar-power gen.	4 stage 900 W	3 stage 700 W
Effective Acceptance	0.1 m ² sr	0.3 m ² sr
Observation time	8.5 days	> 20 days
Statistics	4×BESS97	20×BESS97
Data storage (recorded)	3.6 TB (2.14 TB)	16 TB

Summary

After proof of the long duration science observation capability in the BESS-Polar I, feedback from the flight has allowed many improvements to be made for the BESS-Polar II instrument. This is the advantage of balloon payloads: the detectors can be upgraded and flown again after a short time period. In addition, special advantages of BESS-Polar II are its trajectory which is only in a high geomagnetic latitude and steady state conditions at the solar minimum period. BESS-Polar II will provide unique cosmic-ray data which will be crucial to understanding cosmic-ray physics.

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