Search for novel origins of cosmic-ray antiprotons and antimatter with BESS-Polar flight over Antarctica.

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The primary aims of the BESS-Polar program are precise measurements of the low-energy antiproton spectrum and search for cosmologically significant antimatter, which would provide new clues to understand the early Universe. The second flight (BESS-Polar II) over Antarctica was successfully carried out in December 2007 - January 2008. We performed 24.5 days scientific observation just at the solar minimum. The payload worked well during the flight and 4.7 billion cosmic-ray events were collected, which corresponds to 10 times statistics of the BESS data taken in the previous solar minimum period (1995 and 1997). Based on the BESS-Polar II data, we will present recent preliminary results of cosmic-ray antiproton measurements and sensitive search for antimatter.

INTRODUCTION

The objectives of the BESS-Polar experiment are definitive measurements of various low-energy cosmic-ray phenomena with high statistics; particularly providing a firm answer on possible primary component of cosmic-ray antiprotons, (Fig. 1) searching for antinuclei down to an unprecedented level, and studying the origin and propagation of other galactic cosmic-ray species.

After its first successful flight in 2004 (BESS-Polar I), the second flight of BESS-Polar (BESS-Polar II) has been prepared to be carried out at the solar minimum with an improved instrument and capability for an extended long-duration flight. successfully carried out the second Antarctic flight at the present solar minimum as shown in Fig.2.

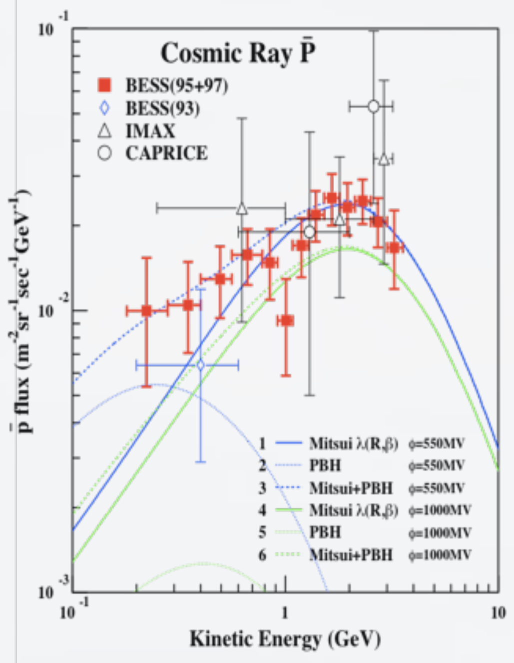

Fig. 1: Antiproton flux measured in the last solar minimum period (1995+1997).

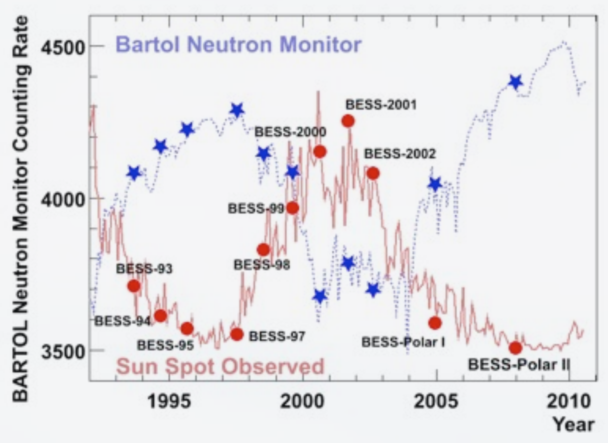

Fig. 2: Sunspot number and neutron monitor varying with solar modulation at the time of BESS and BESS-Polar Flight.

BESS-POLAR II

Instrument

Figure 3 shows the general layout of the BESS-Polar II spectrometer. The following main features were inherited from the BESS Spectrometer.

- Large geometrical acceptance: 0.3m^2 sr
- Ultrathin spectrometer: 4.5 g/cm^2/wall
- Good rigidity measurement: MDR~270 GV
- Redundant particle identification: β , dE /dx

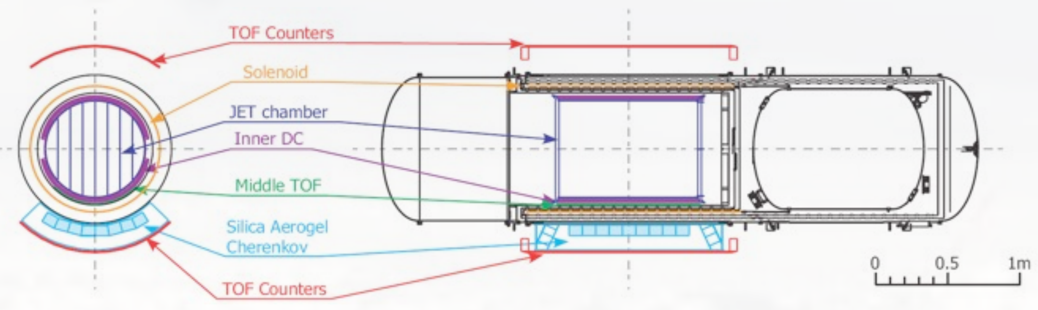

Fig. 3: BESS-Polar II spectrometer

- Long duration capability: 20 days

BESS-Polar II Flight

BESS-Polar II payload was successfully launched from the Williams Field on December 23, 2007. Figure 4 and 5 show, respectively, the trajectory and pressure and altitude profile of the BESS-Polar II flight. The payload flew with one and 3/4 circumnavigation over Antarctica in 29.5 days. Science observation was successfully performed during 24.5 day science observation. Flight parameters are summarized together with BESS-Polar I (2004) in Table 1.

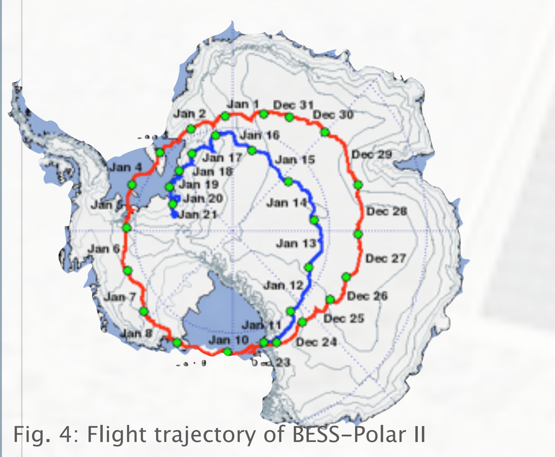

Fig. 4: Flight trajectory of BESS-Polar II

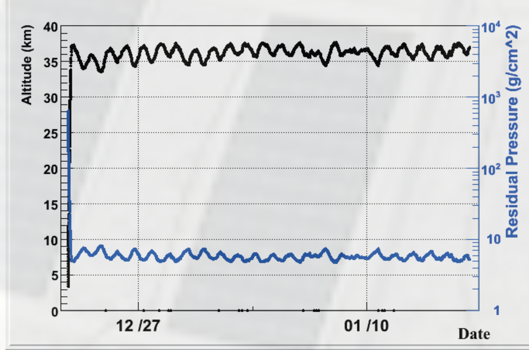

Fig. 5: Altitude and Residual atmospheric pressure.

Table. 1: Summary of BESS-Polar I and BESS-Polar II

	BESS-Polar I	BESS-Polar II
Total Float Time	8.5 days	29.5 days
Observation TIme	8.5 days	24.5 days
Recorded Event	900 M	4700 M
Recorded Data Size	2.1 TB	13.5 TB
Trigger Rate	1.4 kHz	2.4 ~ 2.6 kHz
Live Time Fraction	0.8	0.77
Altitude	37 ~ 39 km	34 ~ 38 km
Air Pressure	4 ~ 5 g/cm2	4.5 ~ 8 g/cm2

MEASUREMENT OF ANTIPROTON

Single Track of Good Track Quality

At first, we select events with only one good single track without any interaction as shown in the Fig.6. And then we apply TQ (track quality) cut, which requires number of hits in the tracker, goodness of fitting, consistency between the tracker and other detectors, and so on. This assures the quality of track and hence all detector performance.

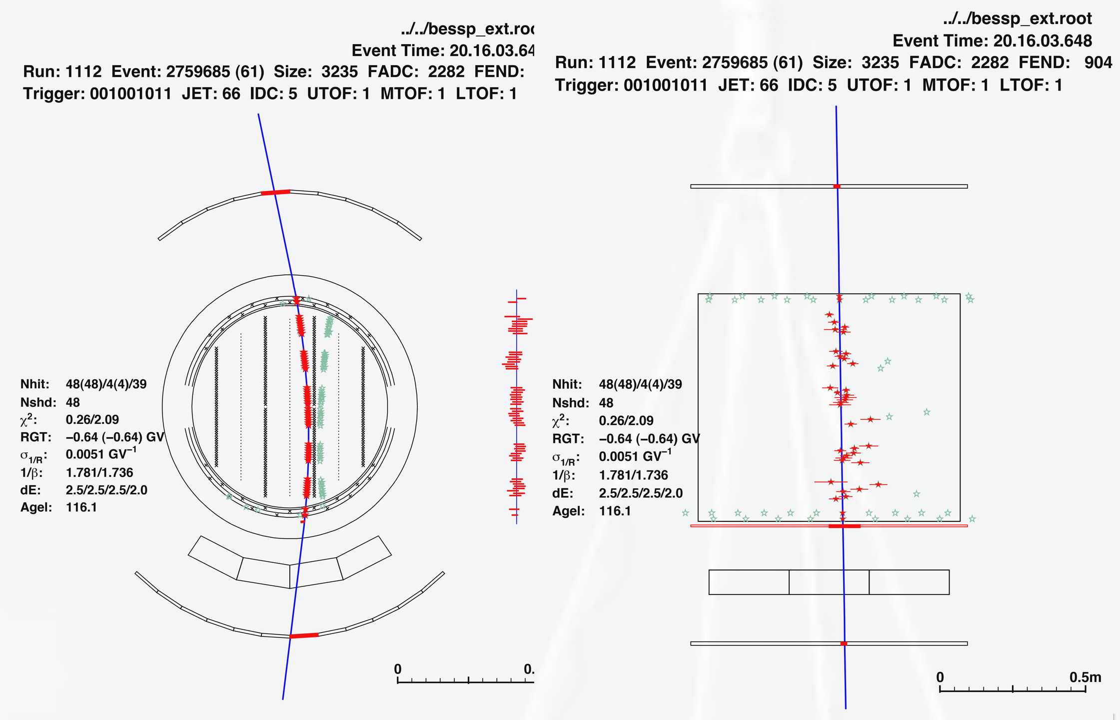

Fig. 6: Event display of a selected event by single track selection and TQ cut. A track and hits in r-phi plane (left) and in y-z plane (right) are shown.

Particle Identification

Antiproton candidates are extracted according to particle identification information. Figure 4 shows 1/β vs. rigidity for events which survive all selection with dE/dx of TOF, MTOF, and JET and Aerogel veto. In the figure, band structure is clearly seen, each of which is correspond to mass of the particle species, e.g. proton, deuteron, triton and so on. We can identify more than 8000 antiprotons within the band just at the opposite position as proton. In the very low energy region where most of proton would stop before reaching low TOF due to energy loss. By using MTOF, which located between JET and Magnet, we could identifanalysis is in now progress.

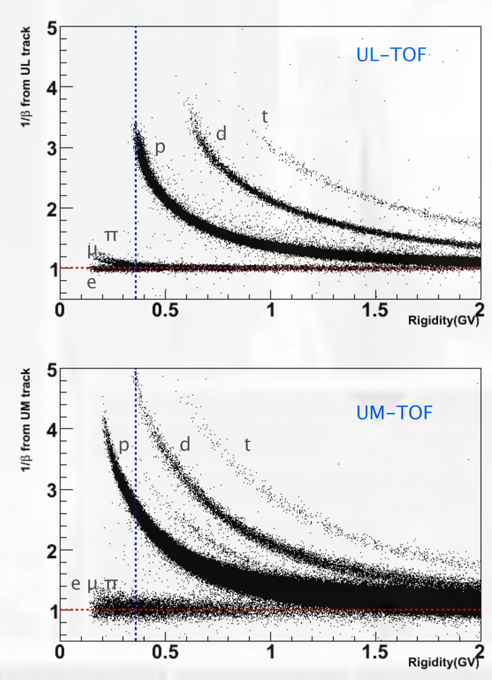

Fig. 7: 1/β vs rigidity for unbiased sample with UL-TOF (top) and with UTOF and MTOF(bottom).

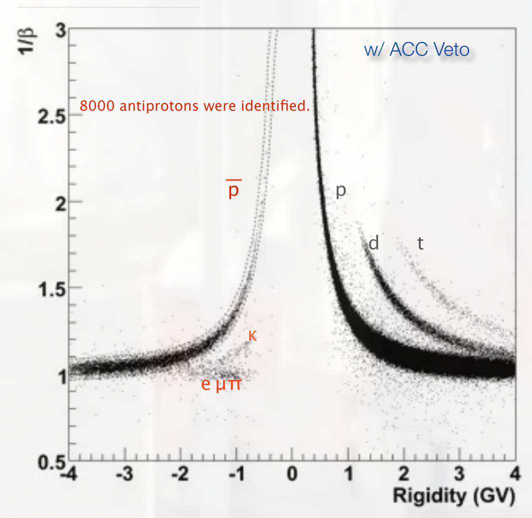

Fig. 8: 1/β vs rigidity for the event sample with ACC Veto.

Determination of Antiproton/Proton

Based on identified antiproton and proton samples, we obtain antiproton/proton ratio. We only used last 1/4 data for this preliminary analysis, conservatively, since performance of tracking detector as well as trigger condition are stable in this time window. Figure 9 shows preliminary antiproton/proton flux ratio using 1/4 statistics of BESS-Polar II, except for lowest energy region where data analysis with MTOF is now in progress. Data are compared with previous BESS data and PAMELA data reported recently.

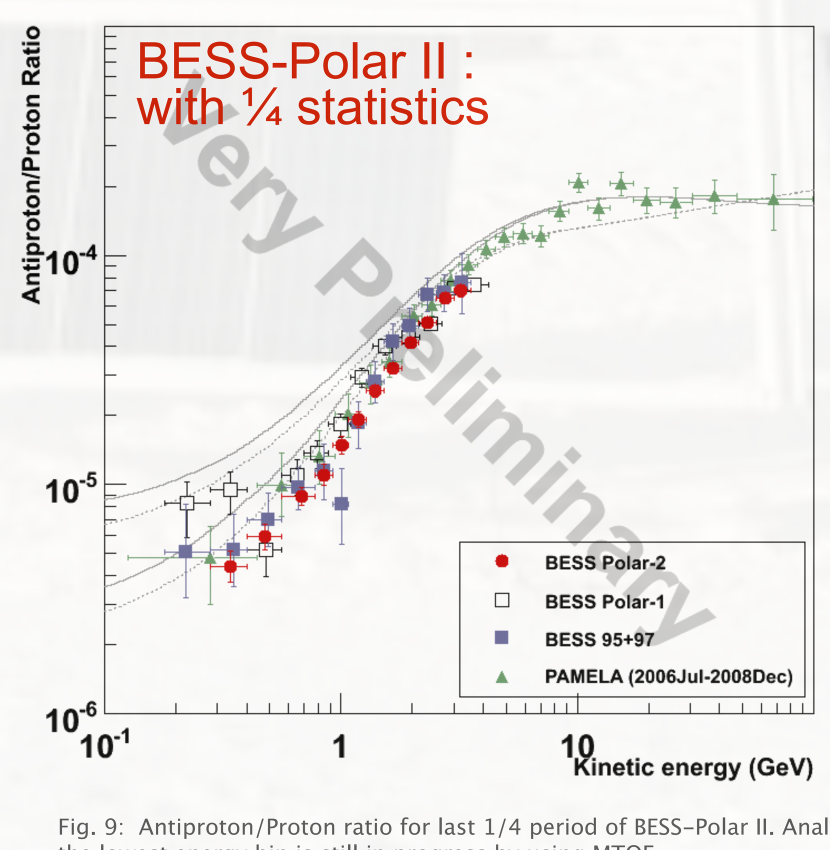

Fig. 9: Antiproton/Proton ratio for last 1/4 period of BESS-Polar II. Analysi in the lowest energy bin is still in progress by using MTOF.

SEARCH FOR ANTIHELIUM

Identification of helium(antihelium)

After single track selection, TQ cut, dE/dx cut and 1/β cuts are applied to select charge z=2 events. Figure 10 and 11 show selection bands for dE/dx of UTOF and 1/β of UL-TOF, respectively. Helium and possible antihelium samples are clearly identified compared with other particle species with charge z=1.

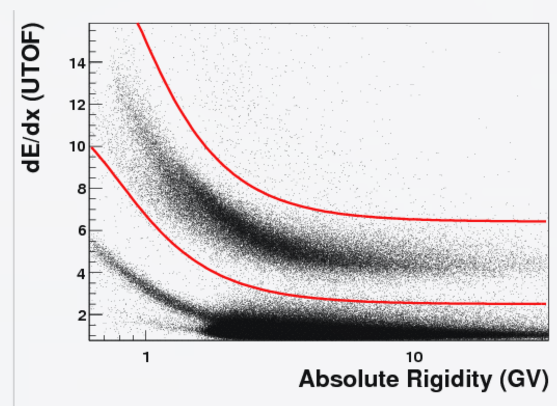

Fig. 10: Selection of charge z=2 by using dE/dx of UTOF.

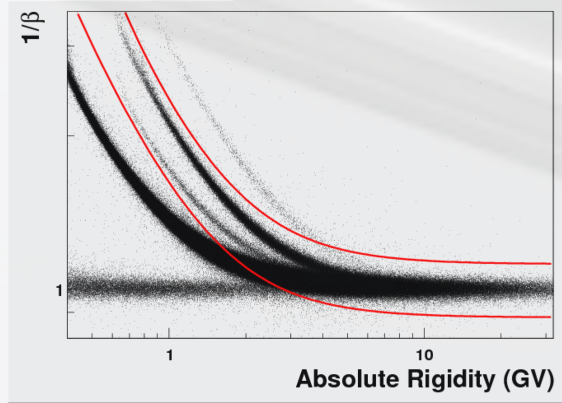

Fig. 11: Selection of Helium(antihelium) by using 1/β

Antihelium Selection with Rigidity

Separation of helium and antihelium is performed by using curvature of the track. Figure 12 shows inverse rigidity distribution for the event samples which are idendified as helium and antihelium identification. We can see spill over from positive rigidity side to negative due to finite resolution in rigidity measurement. No antihelium candidate was not found in the rigidity -14 GV < R < -1 GV among 4x10^7 helium samples.

Upper limit on Antihelium/Helium

Based on the number of the helium event, we place upper limit on antihelium/helium ratio in the rigidity range of -14 GV < R < -1 GV.

- BESS-Polar II data only.
  $\overline{He}/He < 9.4 \times 10^{-8}$ (95% C.L.)
- Combined all BESS data
  $\overline{He}/He < 6.9 \times 10^{-8}$ (95% C.L.)

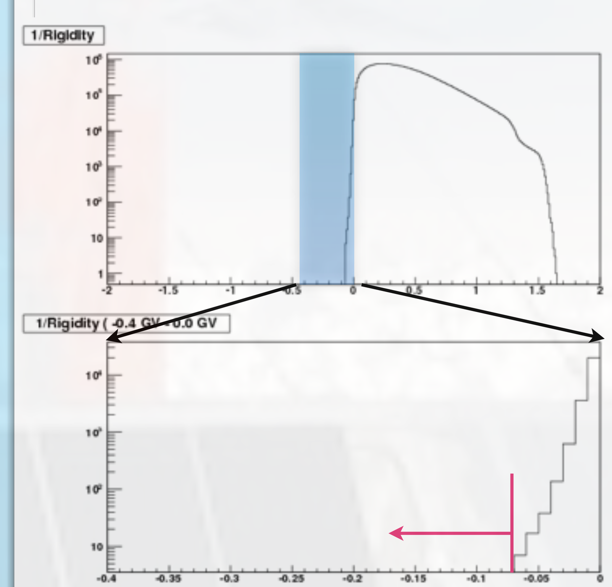

Fig. 12: 1/Rigidity distribution for all identified helium samples.

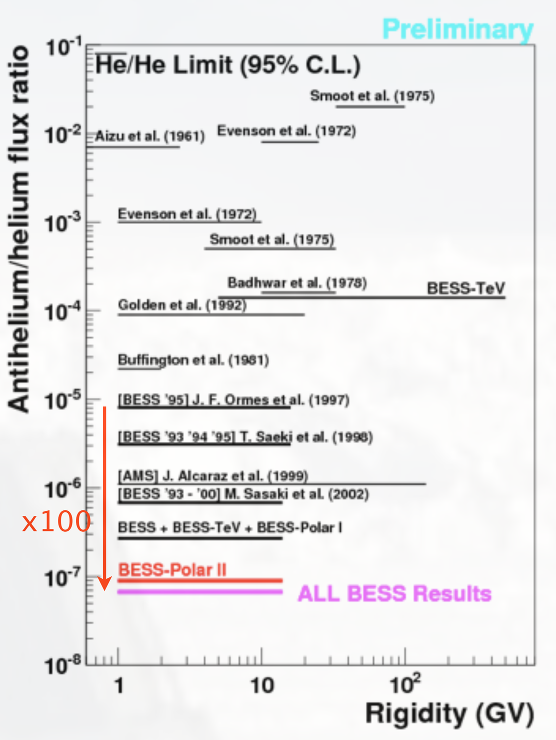

Fig. 13: New preliminary upper limit on antihelium/helium ratio.

SUMMARY

BESS-Polar II successfully gathered cosmic-ray data in the solar minimum period with 10 times statistics of the previous solar minimum ('95 + '97).

Antiproton/proton ratio except lowest energy region was very preliminary obtained, based on 1/4 statistic of BESS-Polar II data. Analysis with full statistics and low energy region is now in progress.

We searched for antihelium in all of BESS-Polar II data. No antihelium candidate was observed and we set a stringent upper limit on antihelium/helium ratio.

ACKNOWLEGEMENT

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