BESS-Polar Flight Report

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For the BESS Collaboration
BESS Collaboration

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- Kobe University

- University of Maryland
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  H. Fuke, and T. Yamagami
**BESS Experiments**

Balloon-borne Experiment with a Superconducting Spectrometer

A high resolution magnetic spectrometer
9 successful flights from 1993 to 2002

Search for rare components of cosmic-rays

- **Antiprotons**
  - Mainly secondary origin
  - Possible primary sources?

- **Antihelium**
  - None observed in cosmic rays
  - Asymmetry of matter/antimatter

Precise measurements of various cosmic ray primaries

- p, He, Be isotopes.....

Probe to the early Universe
Measurement Scheme

BESS2000 spectrometer

Superconducting solenoidal magnet
- Uniform magnetic field
Central Tracker (JET/IDC)
- Track deflection
Time-of-Flight hodoscopes
- Velocity & Charge
Silica-aerogel Cherenkov detector
- Background rejection

Particle identification by mass and charge

\[ m = \frac{R Z e}{\gamma \beta c} \]
Cosmic-ray Antiprotons

BESS 9 annual Flights

- Detection energy range of 0.18 – 4.2 GeV

- Characteristic peak around at 2GeV (Mass identification method)
  - Most antiprotons are secondary products

The latest solar minimum,

- Flatter flux below 1GeV?
Cosmic-ray Antiprotons

- Simulated significance of 20 days data
- Detection Limit of previous BESS
- Assumed Spectrum
- If possible ‘primary’ source exists ...
  - Evaporation of primordial black holes
  - Decay of super symmetric particles
- More sensitive measurement of low energy antiprotons can be an ideal probe.
**Polar Long Duration Flight**

Long duration balloon flight over Antarctica (BESS- Polar).

**Advantages**
- Longer observation period  □  **Higher statistics**
- Higher Latitude  □  **Lower geomagnetic cut-off**

BESS - Polar provides

Sensitive search for ‘primary’ sources and other antimatters at low energy region.

More precise study of secondary antiprotons  
( **Solar modulation, propagation** … )

Complementary data with Space-based experiments
Reduce the material thickness in spectrometer (Minimum material for the trigger is 5g/cm²).

Development of a new detector for the lowest energy particles.

For the long duration flight (10 – 20 days)

Longer life for liquid He

Lower power consumption, lighter weight.

Solar battery system as the electrical power supply.
Newly developed ultra-thin superconducting solenoidal magnet

Produce a uniform magnetic field of 0.8 T in the tracking region.

Using high-strength aluminum stabilized superconductor.

Inner cryostat wall material is reduced to $2.5\text{g/cm}^2$ (half of previous BESS).

Inner cryostat wall can be used as a pressure vessel for JET/IDC.
Particle Detectors (JET/IDC)

JET/IDC central tracker

Consists of a jet-type drift chamber (JET) and two inner drift chambers (IDCs).

To prevent inside gas from degrading
  - Gas flowing system

Operated by pure CO$_2$ gas
  (CO$_2$/Ar mixture gas in previous BESS)
  - Development of new amplifiers

Integrated to BESS2002 spectrometer, and performances were verified.

<table>
<thead>
<tr>
<th></th>
<th>Spatial Resolution</th>
<th>Sampling points</th>
<th>Number of Channels</th>
</tr>
</thead>
<tbody>
<tr>
<td>JET</td>
<td>$139\mu$m / 1.0 cm</td>
<td>48</td>
<td>320</td>
</tr>
<tr>
<td>IDC</td>
<td>$127\mu$m / 500 $\mu$m</td>
<td>4</td>
<td>204</td>
</tr>
</tbody>
</table>

- Performance in BESS2002-Flight
Particle Detectors (TOF)

Time-of-flight counter hodoscope

Measurement of velocity and energy loss.

Time resolution of 85 ps (Beamtest @KEK).

Thickness is reduced to a half of that used in previous BESS (20 mm → 10 mm).

Counter and PMTs are placed in the magnet field and also in the vacuum.
**Particle Detectors (ACC)**

**Silica Aerogel Cherenkov Counter**

Threshold type detector for the rejection of background light particles ($\pi^+/e^-$).

Refractive index $n = 1.02$.

$N_{pe} \sim 9$

Placed at the lower half of the spectrometer.

![Graph and diagram of ACC](image)
**Particle Detectors (Middle TOF)**

**Middle TOF counters**

Used as a lower TOF trigger system in the lowest energy region.

- **Keep sensitivity for the lower energy particles which cannot penetrate the lower half of the spectrometer.**

Consists of 64 plastic scintillator bars (cross section of 5 mm ~ 10 mm) and light guides of clear fibers.

Read out by multi-anode PMT (HAMAMATSU R6504MODX-M8ASSY)

Performance was obtained in a beamtest.

\[
N_{pe} \sim 48, \quad \tau_t (\text{psec}) \sim 160 \text{ (0.5 GeV/c proton)}
\]
Power consumption is reduced to 150W (About half of previous BESS)
Solar Battery System

Power supply system for the long duration flight

- 90 solar battery panels mounted on octagonal frame
  (No pointing system)

- Generation power of 900W

- Weight < 300kg

- Performance was verified in an engineering flight @ Sanriku, JAPAN
## Comparison with previous BESS

<table>
<thead>
<tr>
<th></th>
<th>BESS-2000</th>
<th>BESS-Polar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometrical Acceptance</td>
<td>0.3 m²sr</td>
<td>0.3 m²sr</td>
</tr>
<tr>
<td>Central magnetic field</td>
<td>1.0 T</td>
<td>0.8 T</td>
</tr>
<tr>
<td>Diameter of central tracker</td>
<td>0.83 m</td>
<td>0.76 m</td>
</tr>
<tr>
<td>Life for liquid He</td>
<td>5 days</td>
<td>10 days</td>
</tr>
<tr>
<td>Weight of payload</td>
<td>2400 kg</td>
<td>1900 kg</td>
</tr>
<tr>
<td>Power consumption</td>
<td>900 W</td>
<td>420 W</td>
</tr>
<tr>
<td>Power supply system</td>
<td>Li primary battery</td>
<td>Solar battery</td>
</tr>
<tr>
<td>Minimum material for trigger</td>
<td>18 g/cm²</td>
<td>5 g/cm²</td>
</tr>
<tr>
<td>Detectable energy range (for Antiprotons)</td>
<td>0.18 – 4.2 GeV</td>
<td>0.1 – 4.2 GeV</td>
</tr>
<tr>
<td>Maximum detectable rigidity</td>
<td>200 GV</td>
<td>240 GV</td>
</tr>
</tbody>
</table>
## Preparation for BESS-Polar

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>Feb</td>
<td>Preparation start</td>
</tr>
<tr>
<td>2002</td>
<td>Mar</td>
<td>Superconducting magnet complete</td>
</tr>
<tr>
<td></td>
<td>May</td>
<td>Engineering Flight of solar battery system (ISAS/JAXA)</td>
</tr>
<tr>
<td>2003</td>
<td>Jun</td>
<td>Detector beam test @ KEK</td>
</tr>
<tr>
<td></td>
<td>Oct</td>
<td>Technical flight @ Ft.Sumner</td>
</tr>
<tr>
<td></td>
<td>Oct</td>
<td>General integration start @ GSFC/NASA</td>
</tr>
<tr>
<td>2004</td>
<td>Aug</td>
<td>General integration complete</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compatibility test with NSBF</td>
</tr>
<tr>
<td></td>
<td>Oct</td>
<td>Preparation @ Antarctica start</td>
</tr>
</tbody>
</table>

2005/3/9 APPI2005
Integration in GSFC

2003 Oct - 2004 Aug

JET/IDC & MTOF

Upper TOF

Aerogel Cherenkov Counter

Integration complete!
Compatibility test with NSBF

2004 Aug

Final Compatibility test with National Scientific Balloon Facility was achieved at Palestine, TX, USA

Establishment of

- Mechanical compatibility
- Operations & communication in the Magnetic field
BESS-Polar Campaign 2004

Oct 27
Stuff arrived McMurdo station in Antarctica

Preparation start @ Williams Fields

Dec 3
Preparation complete
Compatibility test with NASA/NSBF

Flight ready

Dec 13
Launch!

21 Landing after 8.5 days flight

23 Recovery Work start

29 Recovery complete

2005
Jan 4
Complete BESS-Polar 2004 campaign
Final preparation for BESS-Polar 1st flight done in building called ‘Weatherport’.

- Detector check
- Integration of Solar battery system
- Installation of SIP
- Thermal insulation
Weather in Antarctica

Weather changes drastically in Antarctica

Preparation has been carried under critical weather conditioned at Antarctica.
Hang test prior to flight was successfully done

Full configuration of spectrometer, solar battery system, and communication systems.
Weather Condition

- 10 days after flight ready, 3rd flight chance came
  (1st and 2nd chance were postponed due to the bad weather)

Wind map of flight day

Date: 41213
Level: 127 Kft
Knots (Latitude Corrected)
Flight day (Assembly)

2005/3/9

APPI2005
Launch

Launched from Williams Field, McMurdo, in Antarctica, (S77-51, E-166-40), 5:56(UTC), Dec. 13, 2004
Data communication systems

1 RS-232C (19.2 kbps)
2 RS-232C (1200 bps)
28 Digital O.C. output
1 Timed-gate O.C. output
32 Analog input
16 Digital input

<table>
<thead>
<tr>
<th>Link</th>
<th>TDRSS</th>
<th>Iridium</th>
<th>LOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uplink</td>
<td>Scheduled</td>
<td>Backup</td>
<td>LOS</td>
</tr>
<tr>
<td>Downlink</td>
<td>6 kbps</td>
<td>255 bytes / 15 min.</td>
<td>83.33 kbps</td>
</tr>
</tbody>
</table>

Event data

ROCC (McMurdo)  POCC (Palestine)  White Sands (New Mexico)
Flight Trajectory

- Launch
- Landing
- Float
- Termination

Flight ~8.5 days
Landing

Impacted the ground at (S-83-06, W-155-35), at 22:56(UTC), Dec. 21
Recovery(1)

First quick access to the data vessel

Data vessel was **successfully recovered**.

Transported to the base camp @ siple dome.
Recovery(2)

Due to the capacity of the airplane,

  All detectors were disassembled.
  
  Magnet and frame were cut to several pieces.

After 1 week recovery work, all detectors and magnet were recovered successfully.

No serious damage to each components.

Detectors and magnet will come back to the U.S.A in this April.
Monitor during the flight

- During this flight, monitoring system worked well.
- Solar battery system continuously provided output voltage of 60-70V.
- Magnet generated stable magnetic filed throughout the flight.
Status of Detector (1)

JET/IDC

- JET/IDC worked well throughout polar-flight.
- Gas-Flow system could sustain stable flow.
- Gas condition inside was well kept. (Charge ratio of full-drift/near-wire was 0.8 after 8days)
Status of Detector (2)

TOF counter

- Some PMTs had to be turned off due to excessive leak current.

Signal read out mode changed from both-ends to single-end read out with keeping maximize the geometrical acceptance.

Aerogel Cherenkov Counter

- Worked well

- Number of photoelectrons were same as that of previous BESS.

Middle-TOF Counter

- MTOF continuously provided stable trigger.
## Flight Summary

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Floating Time</td>
<td>8 days and 13 hours</td>
</tr>
<tr>
<td>Flight Altitude</td>
<td>37-39 km</td>
</tr>
<tr>
<td></td>
<td>(5–4 g/cm²)</td>
</tr>
<tr>
<td>Flight Latitude</td>
<td>80-85 degrees</td>
</tr>
<tr>
<td>Average trigger rate</td>
<td>1.3 kHz</td>
</tr>
<tr>
<td>Average event size</td>
<td>2.3 kBytes</td>
</tr>
<tr>
<td>Number of events</td>
<td>900 Mevents</td>
</tr>
<tr>
<td>Total data size</td>
<td>2 Tbytes</td>
</tr>
</tbody>
</table>

Data is now under process & analysis

2005/3/9 APPI2005
Summary

- BESS-Polar experiment was prepared for polar long duration flight
  - Minimizing material
  - Lower power consumption
- BESS-Polar 2004 campaign was carried out from Oct28- in Antarctica
- Payload was launched on Dec 13 and terminated after 8.5 days flight.
- Due to an excessive current problem of TOF-counters, some of PMTs were turned off. The geometrical acceptance was kept maximize with changing the trigger mode with single-end read-out of TOF counters.
- By a 1 week recovery work, Data vessel, particle detectors, and magnet were recovered without serious damage.
- The 2004 BESS-Polar campaign was successful, and cosmic-ray events of 2 Tbytes (900 Mevents) were collected. Now analysis is underway.
- If we may obtain very interesting results from the first flight, we will propose the second flight to be realized within the coming solar minimum period.