BESS Polar-II Experiment

- The 2007-2008 Scientific Flight in Antarctica -

Masaya Hasegawa

for BESS collaboration

High Energy Accelerator Research Organization (KEK)

KEK Seminar

May 13th, 2008

The BESS Collaboration

As of May, 2008

KEK

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Principle Investigators

Project Manager

Outline

- Introduction
  - BESS
- BESS-Polar Experiment
  - BESS Polar-I Campaign
  - BESS Polar-II
    - Overview
    - Spectrometer
    - Antarctica campaign
- Summary and prospects

Introduction of BESS

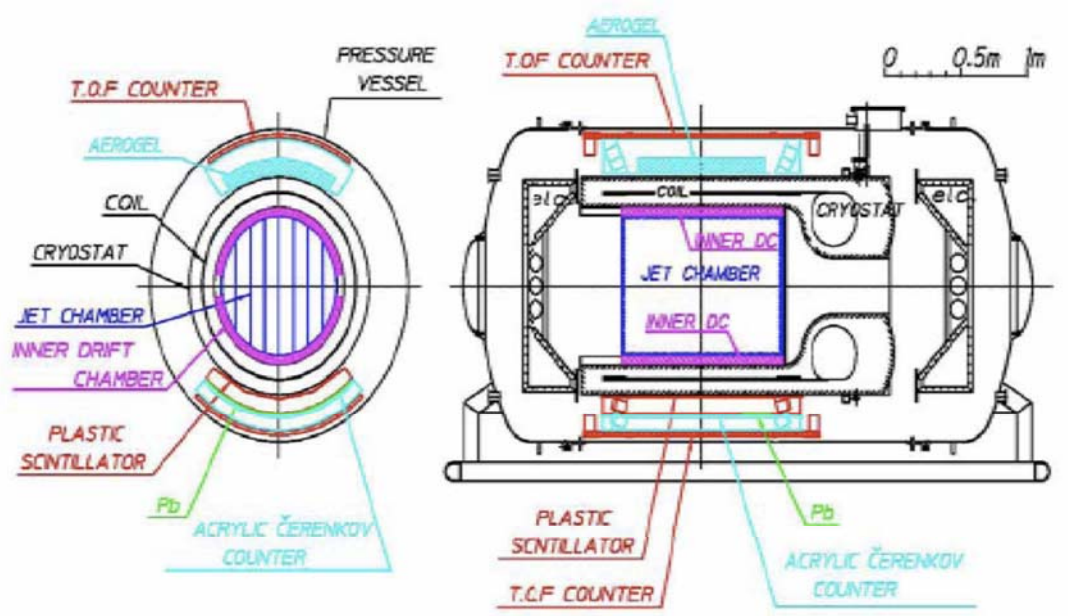
BESS Experiment

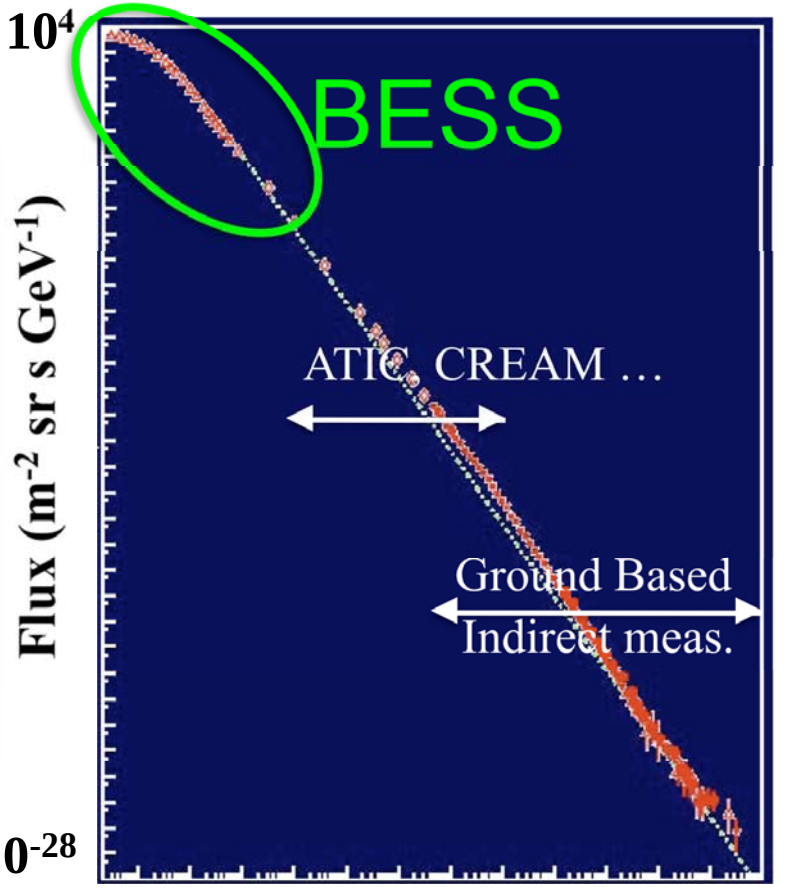
Balloon-borne
Experiment with a
Superconducting
Spectrometer

Measurement of various
cosmic-rays near the space.

- Search for antiparticle/antimatter
  - Anti-protons : Novel primary sources?
  - Anti-helium : Asymmetry of matter/antimatter
- Precise measurements of various cosmic ray primaries
  - Fundamental data for studies (propagation, atmospheric ν)

BESS Experiment – cont'd -

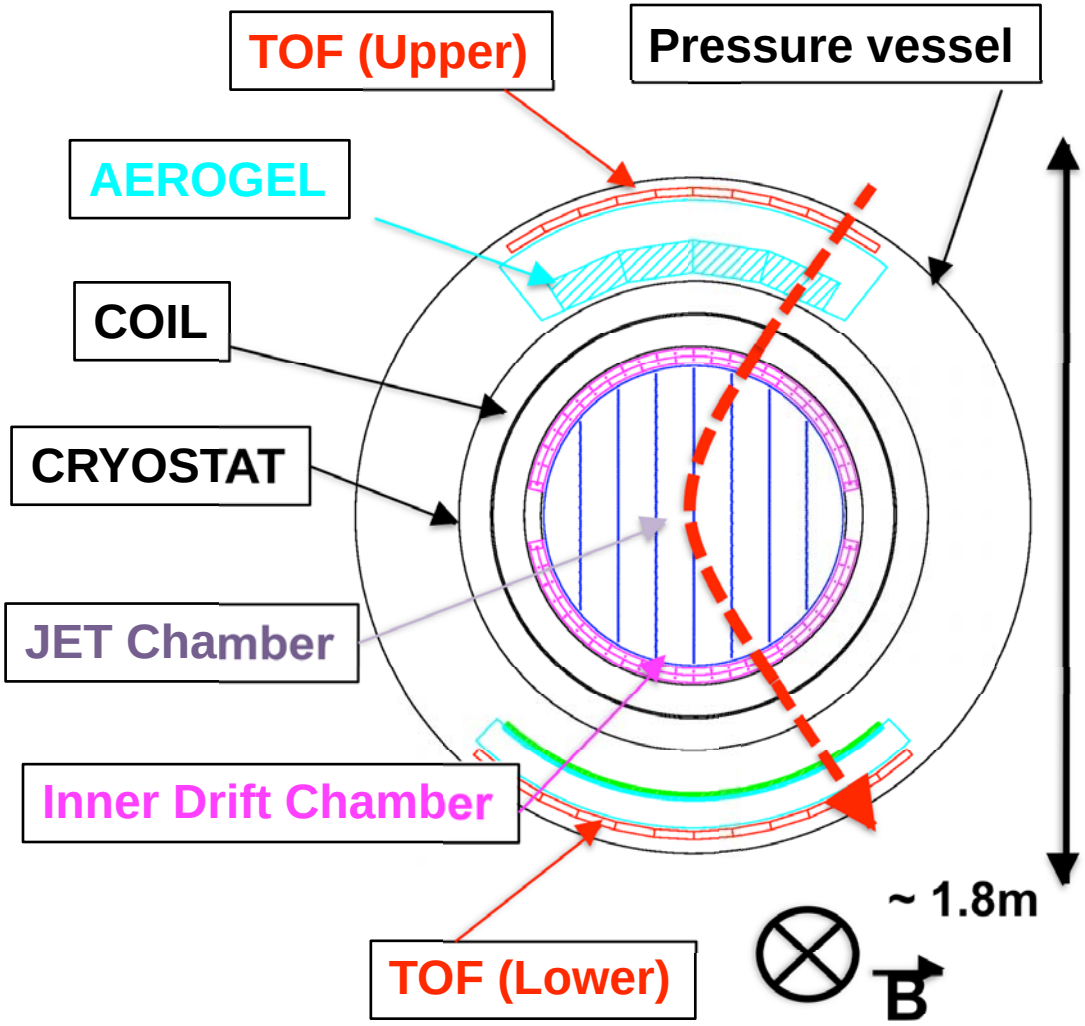




- BESS covers low energy region.
- Special futures as a balloon-borne experiment
  - Large acceptance (0.3m^2sr, ~100 times than previous experiments)
  - Good energy resolution (MDR ~ 200GeV)
  - Clear (redundant) PID → Next page

Measurement Scheme

BESS2000 Spectrometer

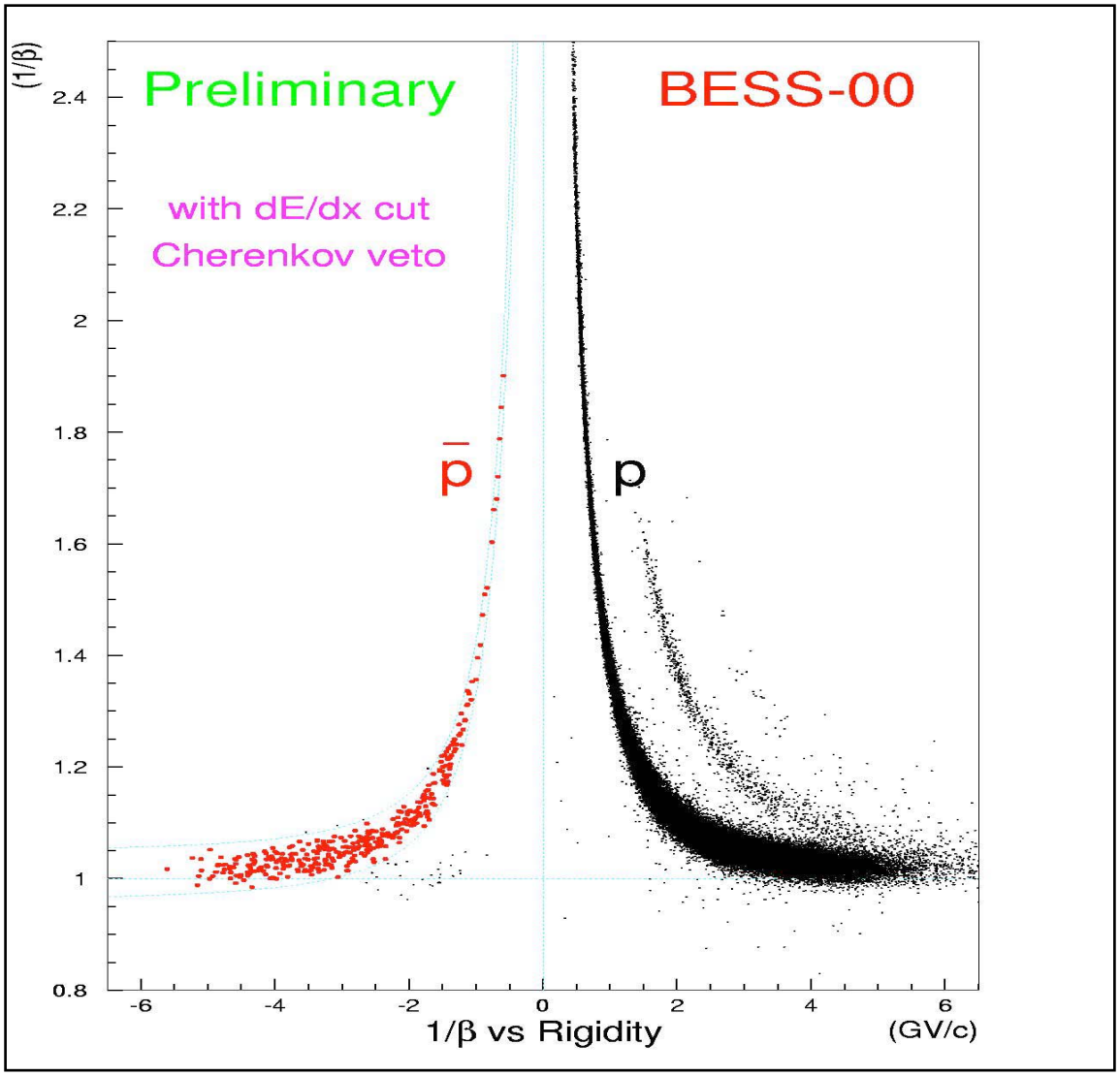


- SC Solenoid Magnet
  → Uniform B field ~ 1Tesla
- Central tracker (JET/IDC)
  → Momentum & Charge sign
- Time-of-flight hodoscope (TOF)
  → Velocity & Charge
- Aerogel Cherencov Counter
  → e/μ rejection

$$m = ZeR\sqrt{1/\beta^2 - 1}$$

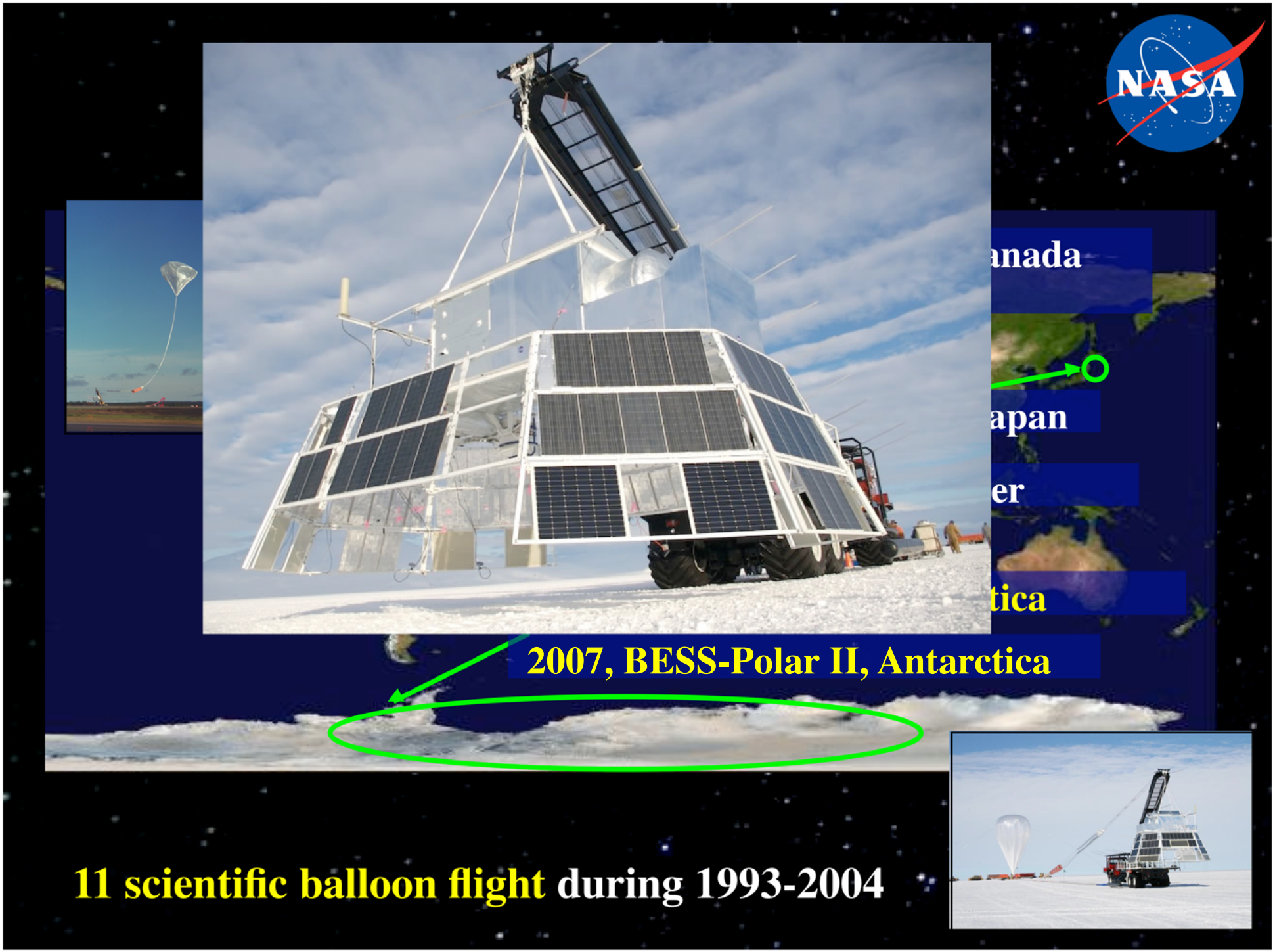
(R : Rigidity Pc/Ze)

Measurement Scheme



- SC Solenoid Magnet
  → Uniform B field ~ 1Tesla
- Central tracker (JET/IDC)
  → Momentum & Charge sign
- Time-of-flight hodoscope (TOF)
  → Velocity & Charge
- Aerogel Cherencov Counter
  → e/μ rejection

Particles are identified by mass and charge.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2007, BESS-Polar II, Antarctica
11 scientific balloon flight during 1993-2004

BESS Polar Experiment

Cosmic-ray Antiprotons

Last solar minimum period (BESS95+97)

- Flatter flux below 1GeV

than secondary production model.

$$(p + p \rightarrow p + p + p + \overline{p})$$

- If it's true, it strongly

indicates primary source.

But…,

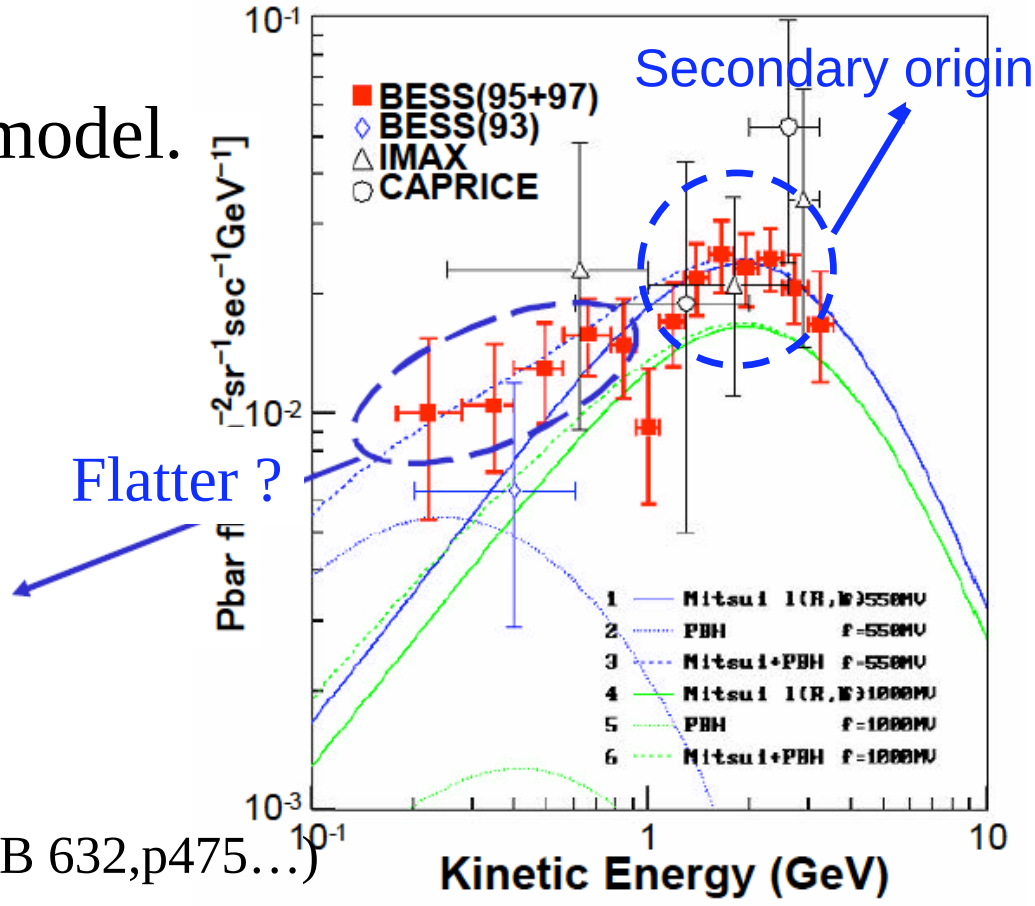
– Statistics ?

– Model ?

(checked in subsequent flights, PLB 632,p475…)

– Systematics ?

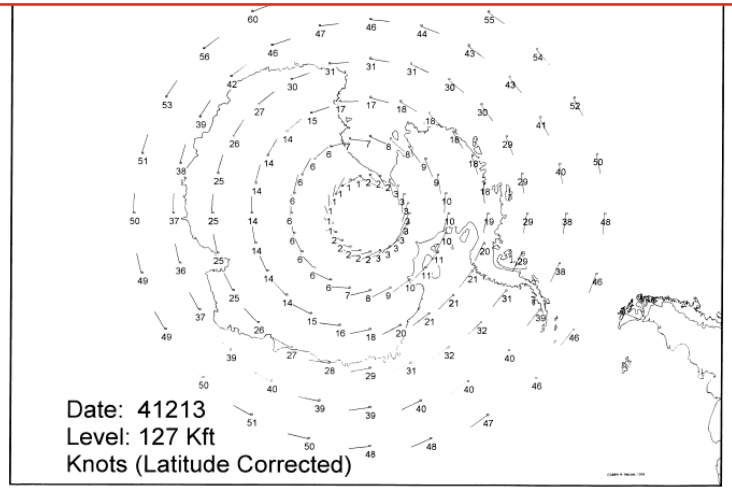
(verified with beam test, NIM A489,p179)

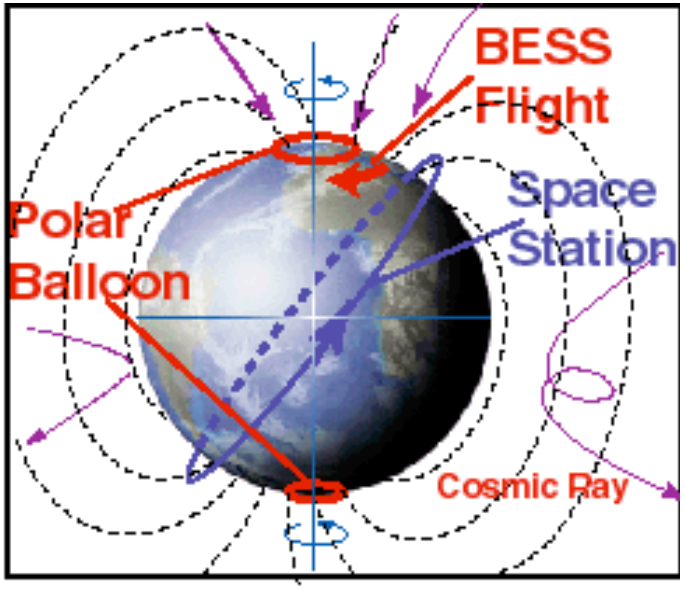


More Statistics necessary → Polar long duration flight

Polar Long Duration Flight

Circumnavigating wind over Antarctica





Advantages

- Longer observation period (~1day → > ~10 days)

  → Higher statistics

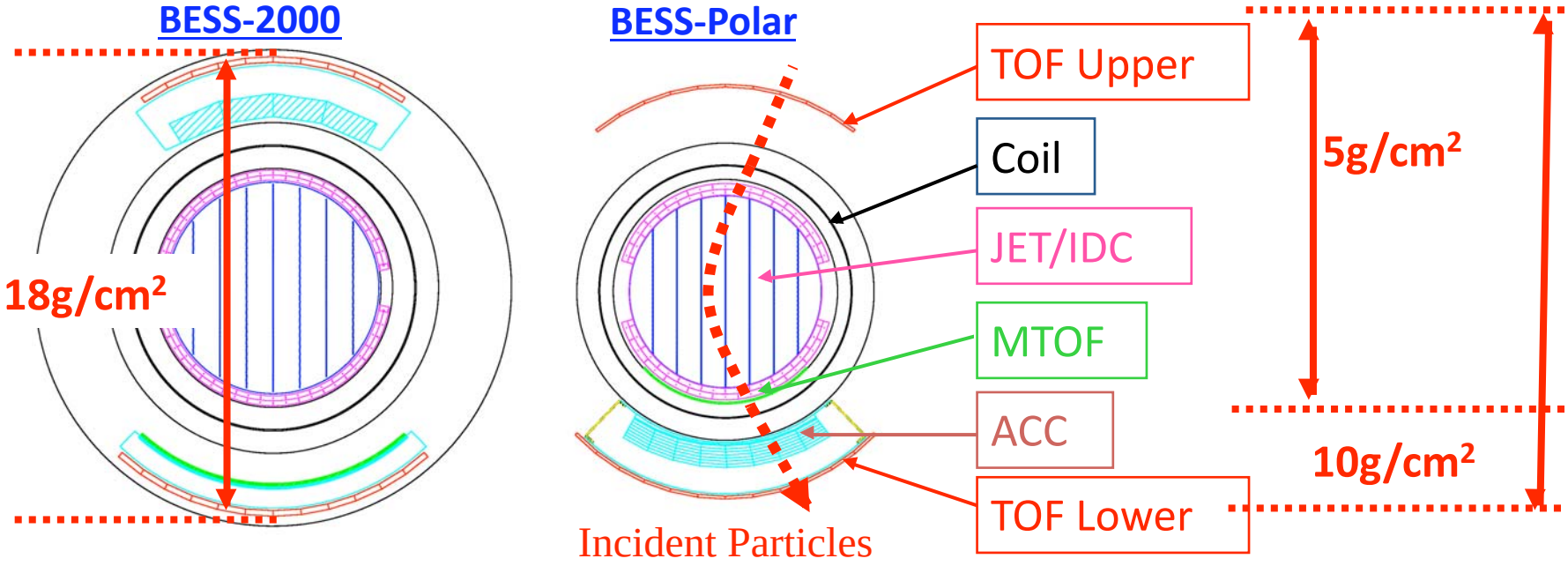
- Low energy cut-off (~0.5GV/c → ~0.2GV/c)

  → (Efficiently) detect low-E antiproton

Disadvantages (not scientific)

- Not easy access, severe weather …, but good memories (talk later)

BESS-Polar Spectrometer



Features

- Minimize materials in spectrometer
- New detector (Middle TOF)

→ Energy range extended down to 0.1GeV.

- Longer life for cryogen, LHe
- Solar power system

→ Long duration flight.

BESS Polar-I Flight (2004)

- 8.5 days flight
- Stable altitude (37~39km)
- Detector worked well except
  - ✓ PMT HV over-current (18/44)
    - Acceptance was reduced to be 2/3.
  - ✓ ACC rejection is not sufficient
- 900M events (2TB)
- 1520 antiprotons were detected.
  (4 times as many as BESS 97)

Flight trajectory

Established the techniques
for long duration flight

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Spectrum (be
is consistent
the secondar

Important ba
to be compar
Polar-II (sola

Measurement of cosmic-ray low-energy antiproton spectrum with the first BESS-Polar Antarctic flight

K. Abe [a,1], H. Fuke [b], S. Haino [c,2,*], T. Hams [d,3], A. Itazaki [a], K. C. Kim [c], T. Kumazawa [c], M. H. Lee [c], Y. Makida [c], S. Matsuda [c], K. Matsumoto [c], J. W. Mitchell [d], A. A. Moiseev [d], Z. Myers [c,4], J. Nishimura [f], M. Nozaki [c], R. Orito [a,5], J. F. Ormes [g], M. Sasaki [d], E. S. Seo [e], Y. Shikaze [a,6], R. E. Streitmatter [d], J. Suzuki [c], Y. Takasugi [a], K. Takeuchi [a], K. Tanaka [c], T. Yamagami [b], A. Yamamoto [c], T. Yoshida [b], K. Yoshimura [c]

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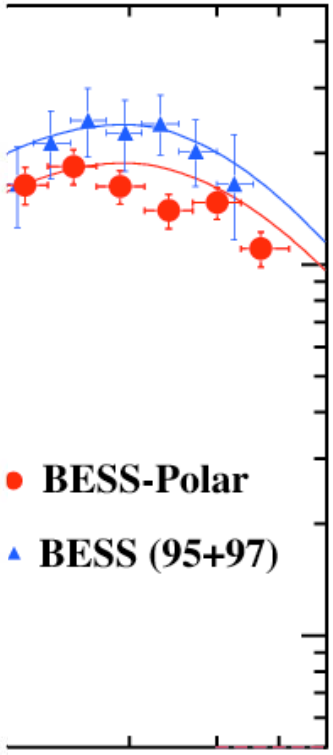
Abstract

The BESS-Polar spectrometer had its first successful balloon flight over Antarctica in December 2004. During the 8.5-day long-duration flight, almost 0.9 billion events were recorded and 1,520 antiprotons were detected in the energy range 0.1–4.2 GeV. In this paper, we report the antiproton spectrum obtained, discuss the origin of cosmic-ray antiprotons, and use antiprotons to probe the effect of charge sign dependent drift in the solar modulation.

Key words: cosmic-ray antiproton, solar modulation, superconducting spectrometer
PACS: 95.85.Ry, 96.40.Kk, 98.70.Sa

Preprint submitted to Elsevier *12 May 2008*



(GeV)

:0805.1754

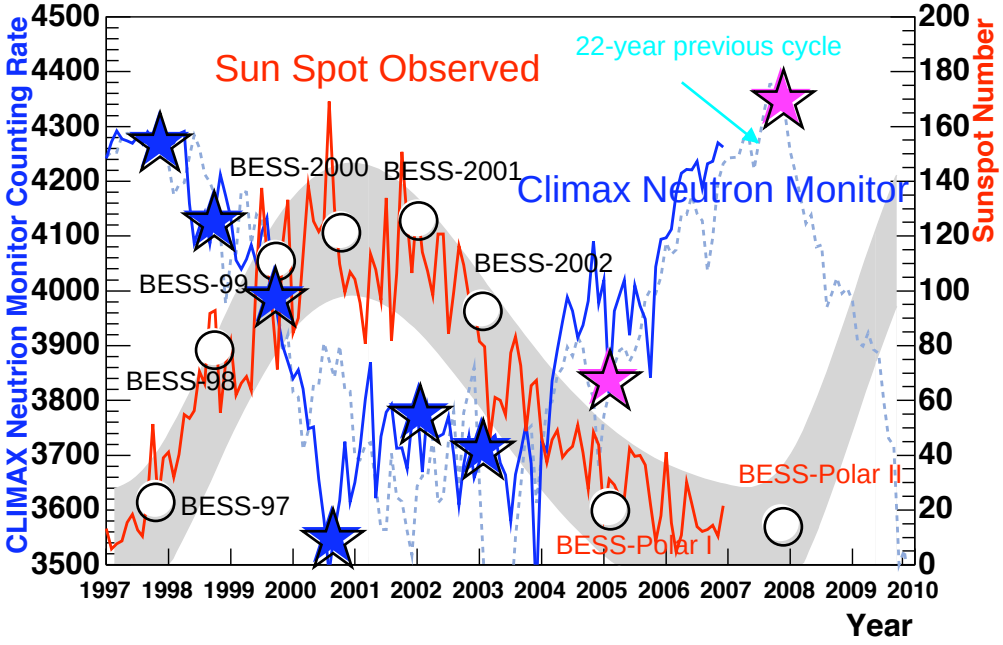
BESS Polar-II Experiment

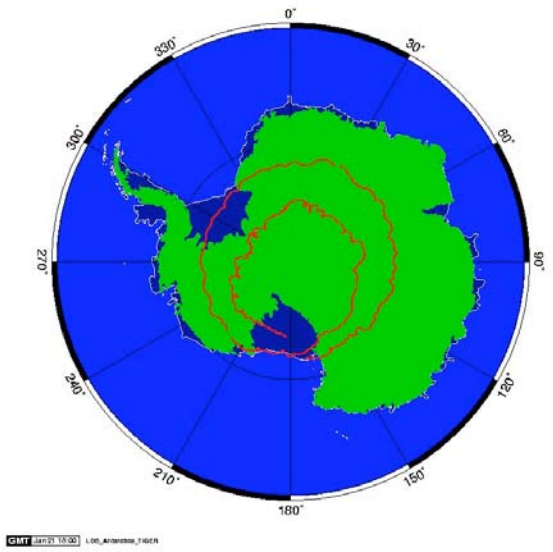
- Overview and (expected) physics outputs
- Polar-II Spectrometer
- Preparation
- Antarctic campaign
  - Onsite preparation (+ Antarctic life)
  - Flight
- Detector Performance

BESS Polar-II

Unprecedented sensitive search for ‘primary antiproton’

- Solar minimum in 2007 - 2008
- Two circle around the pole (flight of > 20 days)
  → 20 x BESS97 (4~5 x Polar-I) statistics





BESS Polar-II

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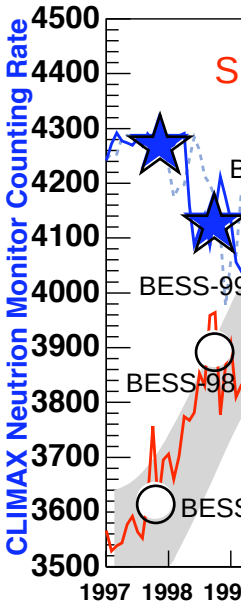
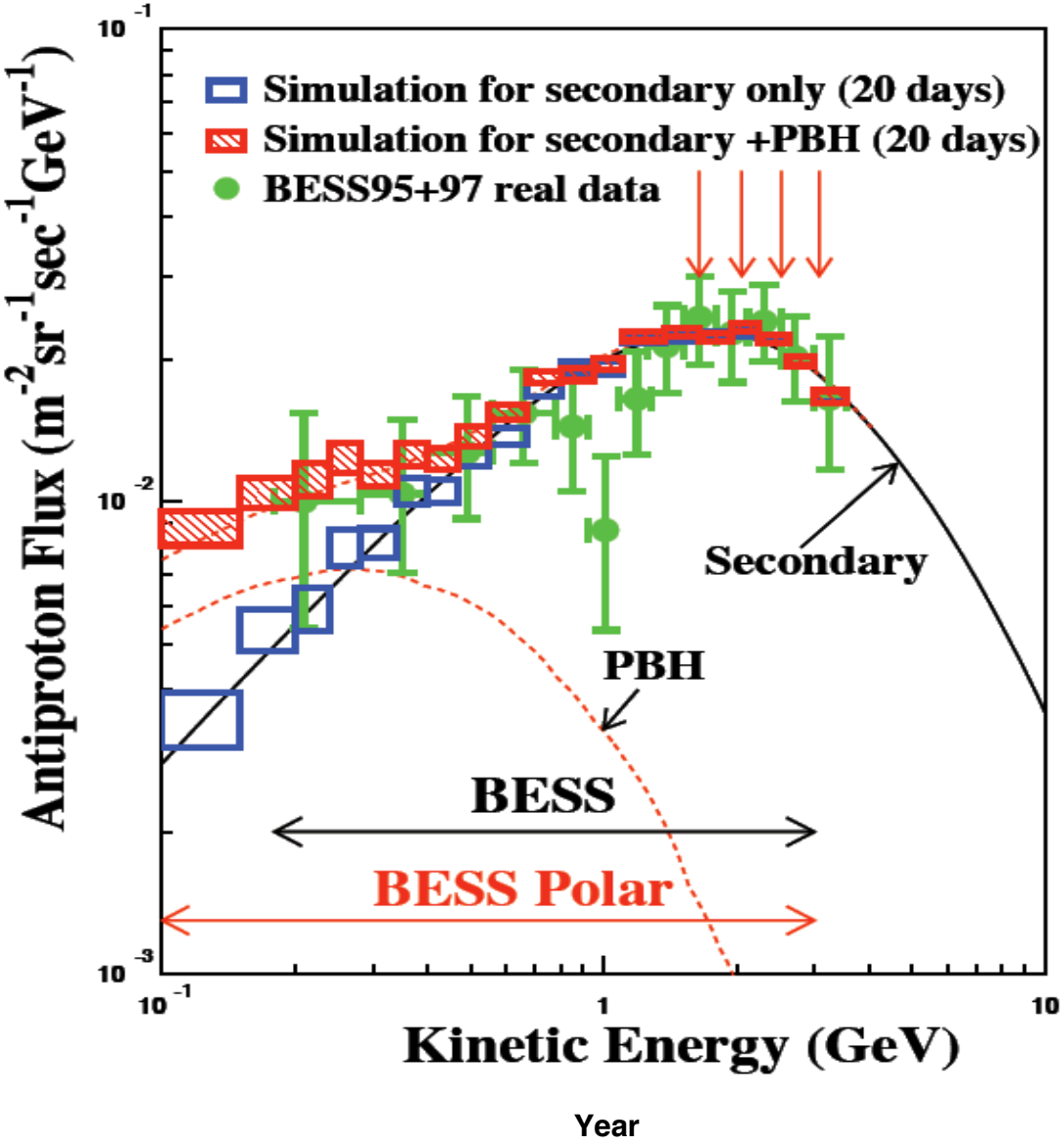
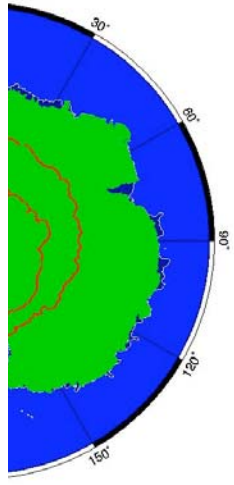
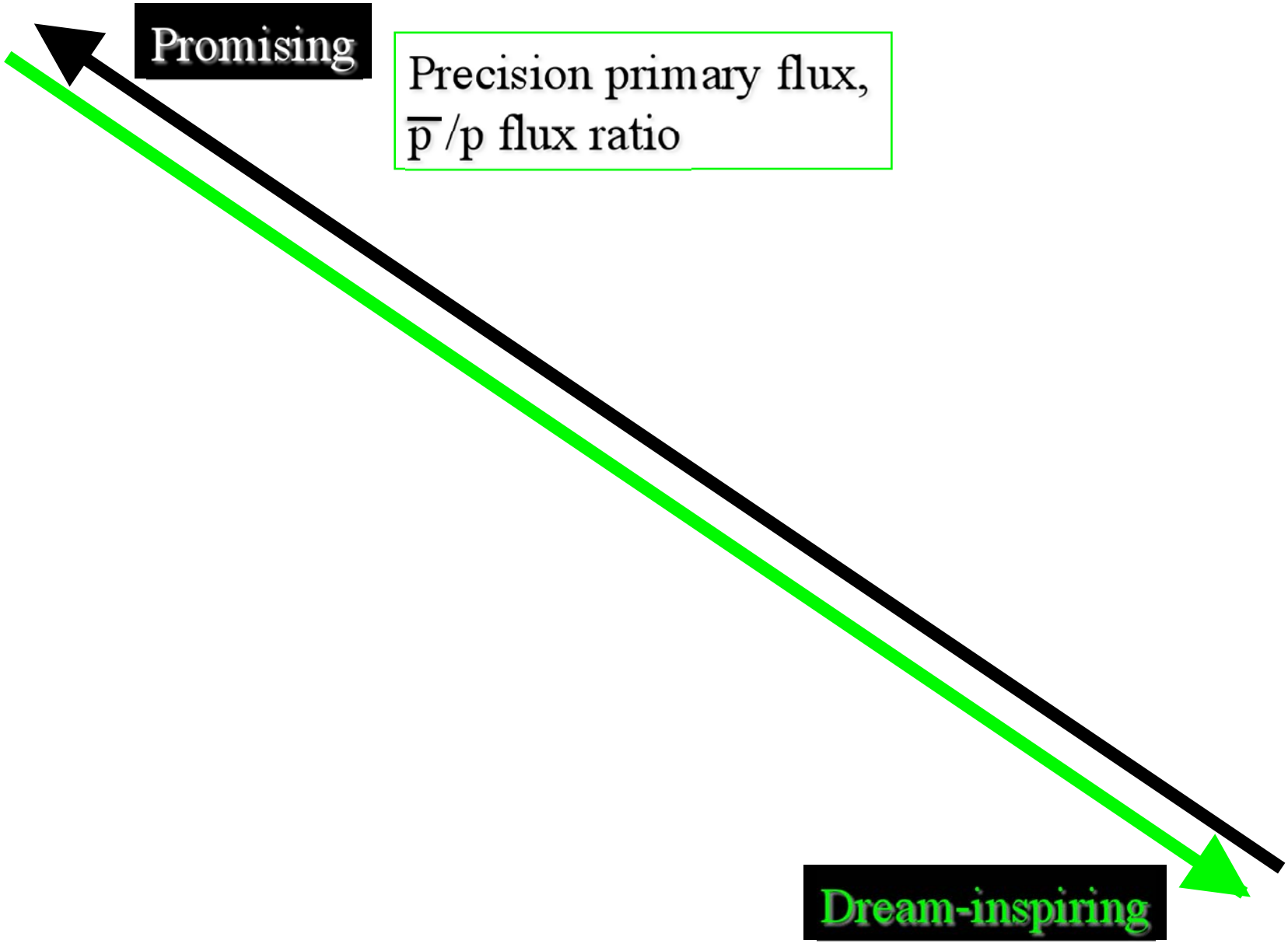




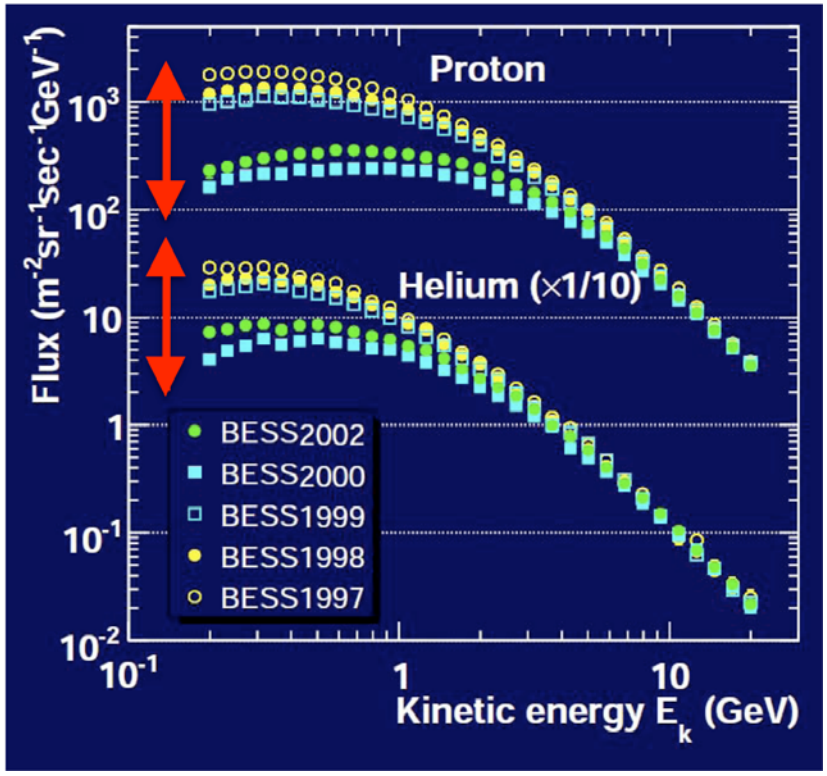


Physics potential of polar-II

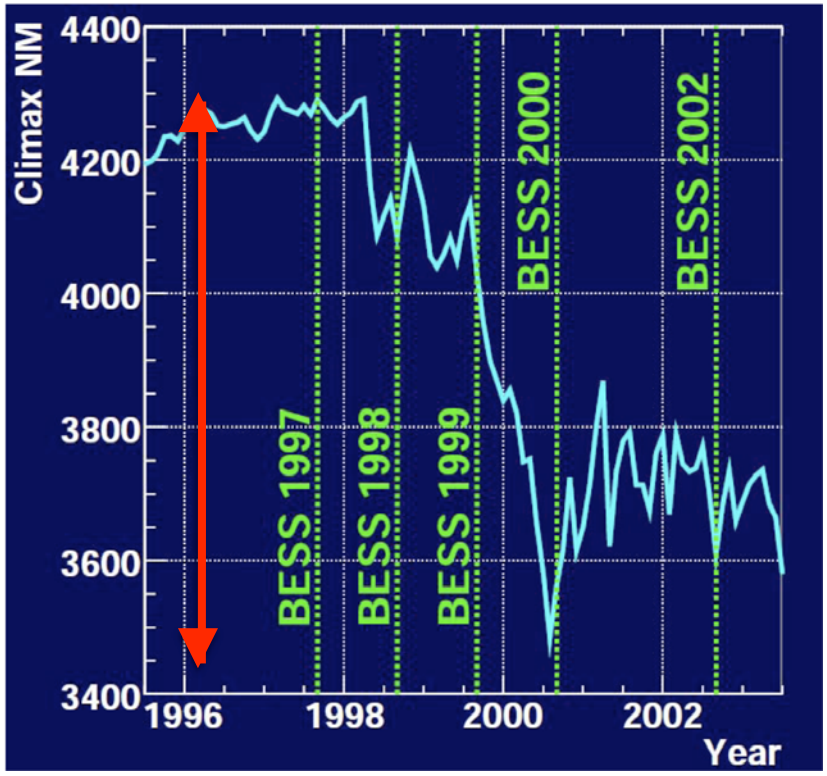


Correlation of cosmic-ray flux with solar modulation

Time variation of primary CR flux



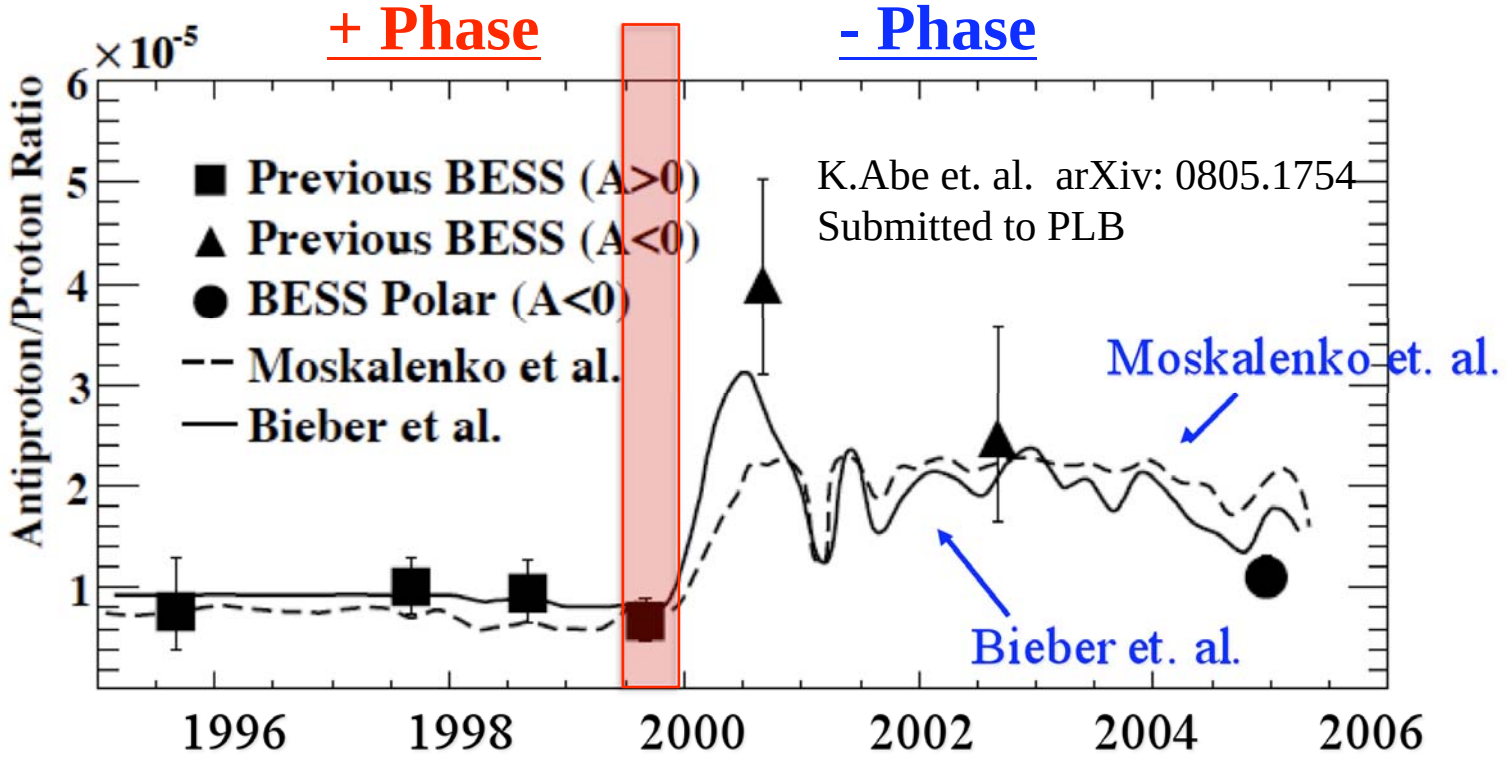
Solar activity (Neutron Monitor)



BESS has observed primary flux for more 1 solar cycle.

Fundamental data for solar modulation study.

Solar Modulation Effect on p-bar/p

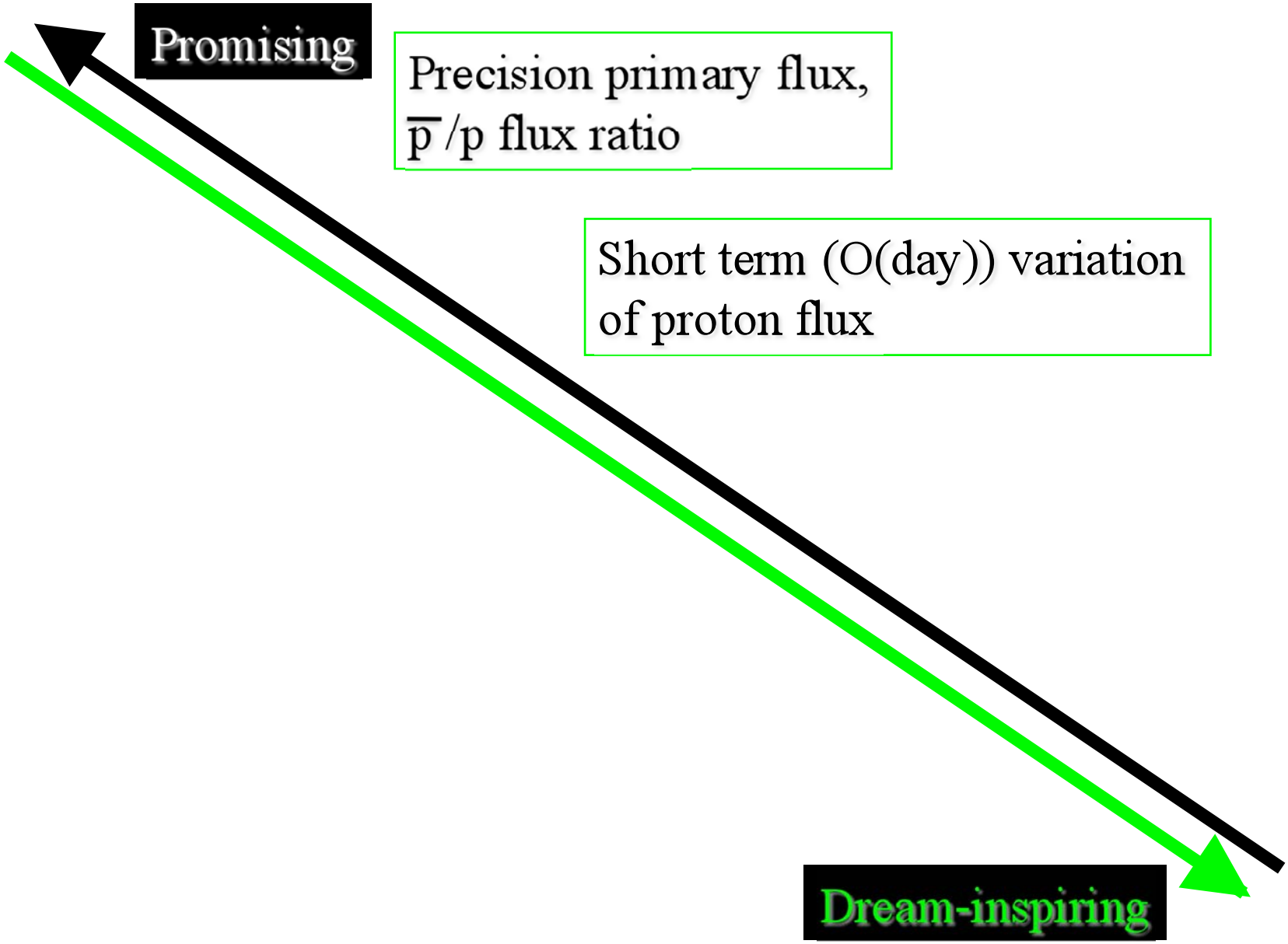


Bieber et al. PRL, 88, 4, 8 (1999) 674
Moskalenko et al., APJ, 565 (2002) 280.

BESS clearly observed charge dependent modulation.

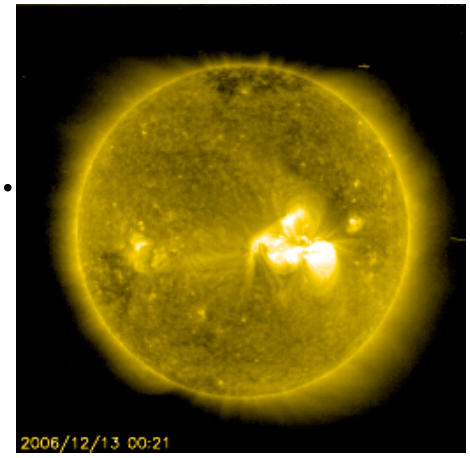
→ Continuous observation is useful for further study.

Physics potential of polar-II



Short-term flux variation

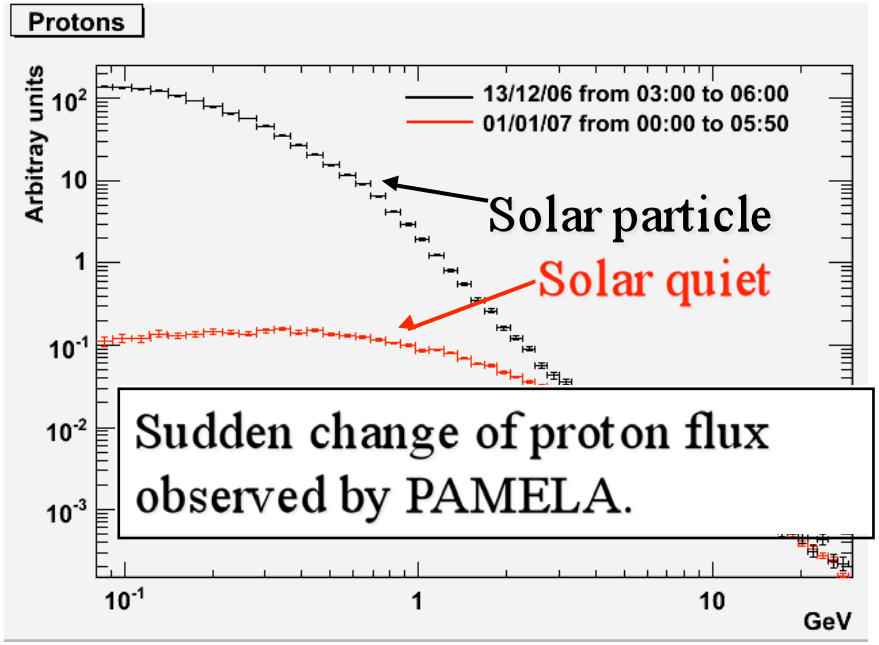
- BESS Polar-II covers ~ 1 solar rotation cycle.



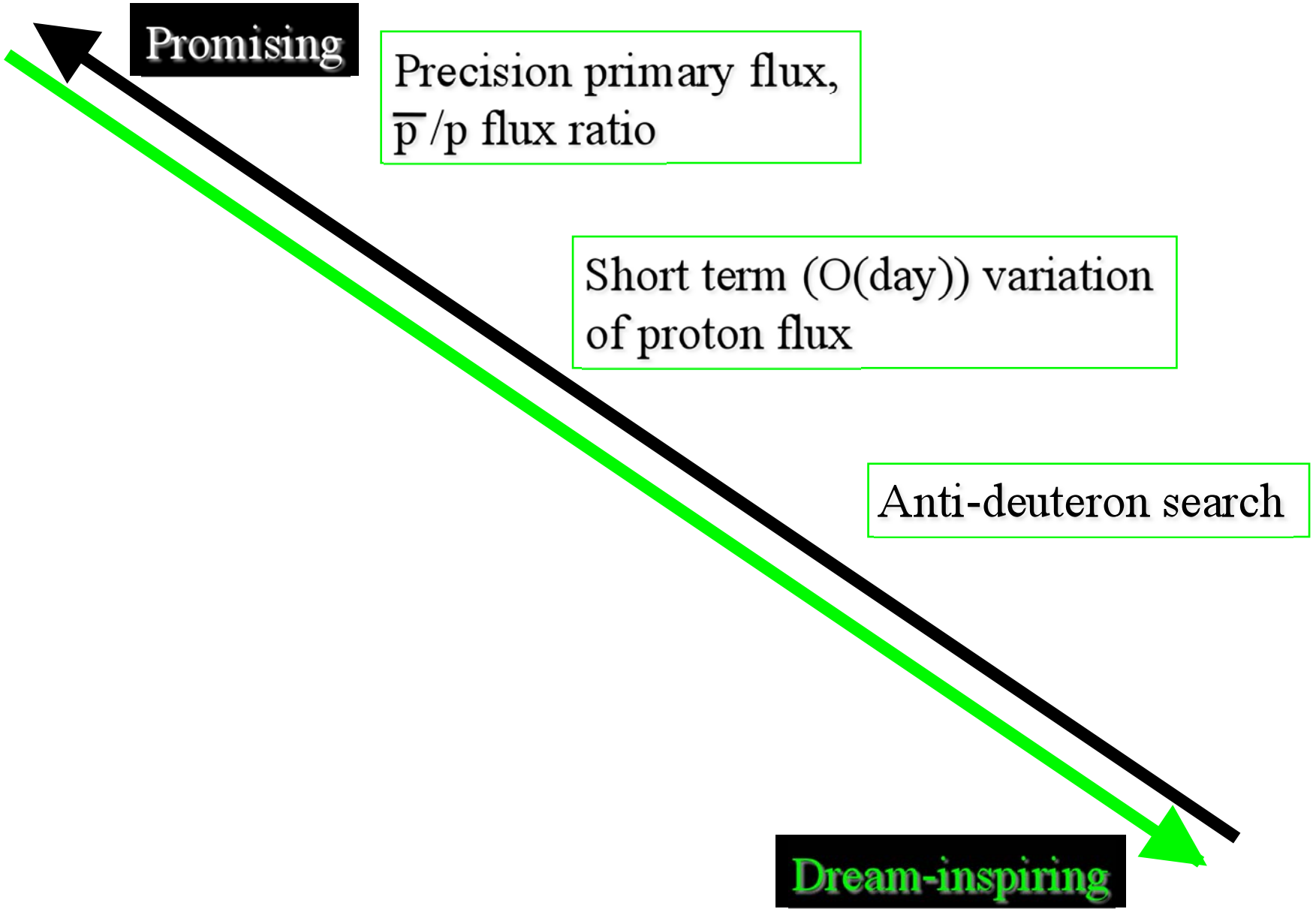
- Polar-II can observe the short-term flux variation synchronized with
  1. Solar daily rotation
  2. CME (coronal mass ejection)
  3. Forbush decrease

if it happens

Address some aspects of solar cosmic-ray physics together with other observations.



Physics potential of polar-II



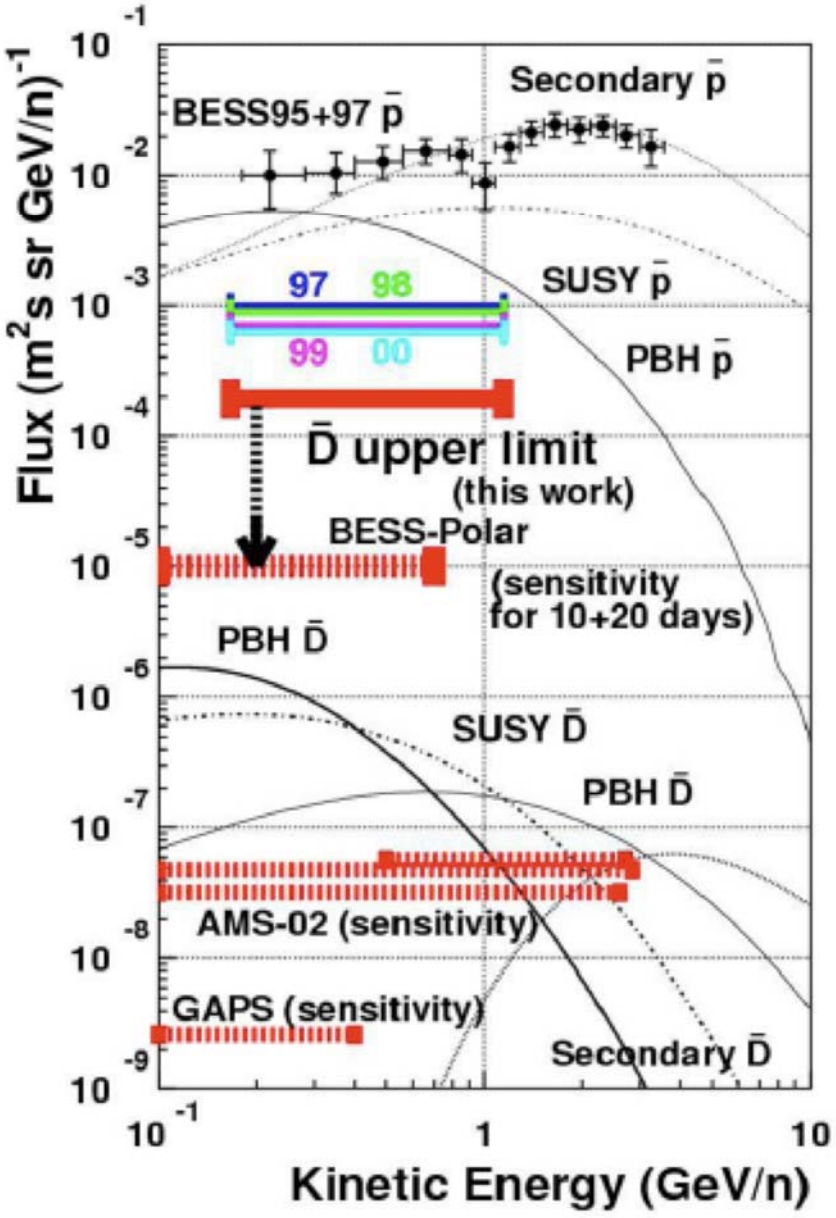
Cosmic-ray Anti-deuteron search

- Anti-deuteron is produced through the same process as $\bar{p}$

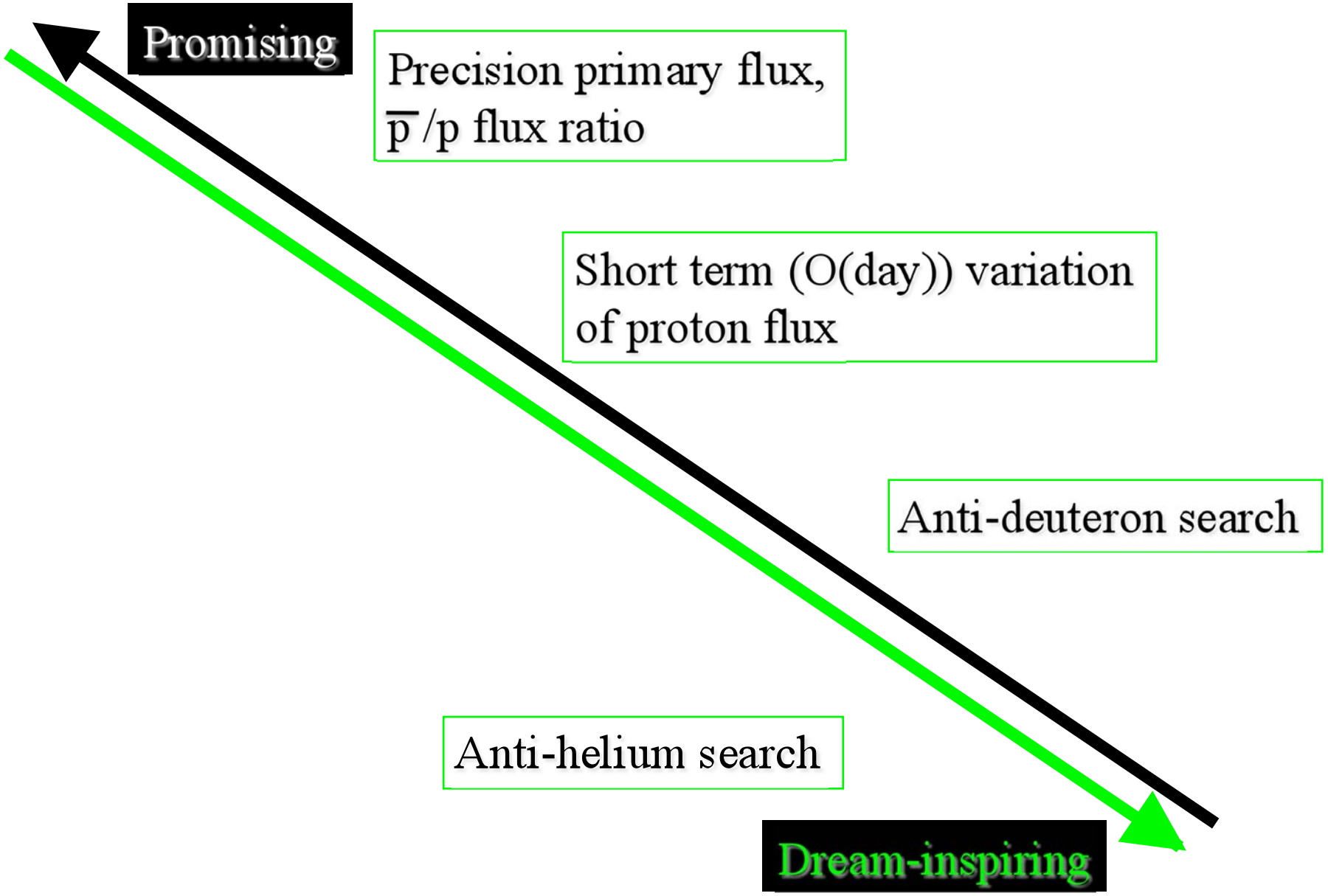
- Below ~1GeV/n
  Secondary : suppressed

→ Unique window
for primary origin
(Even single event
give a great impact on physics)

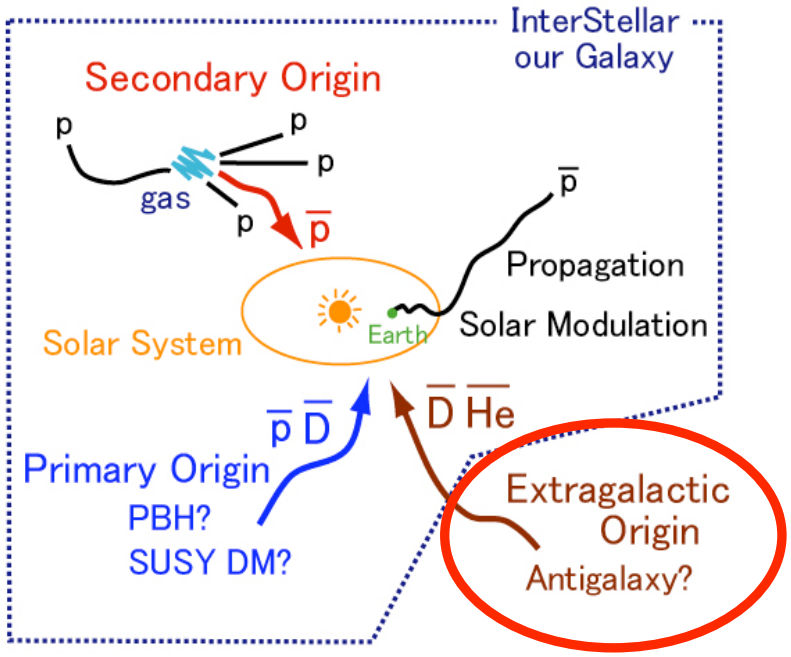
- Polar-II will push down the limit to ~ 10^{-5} level.

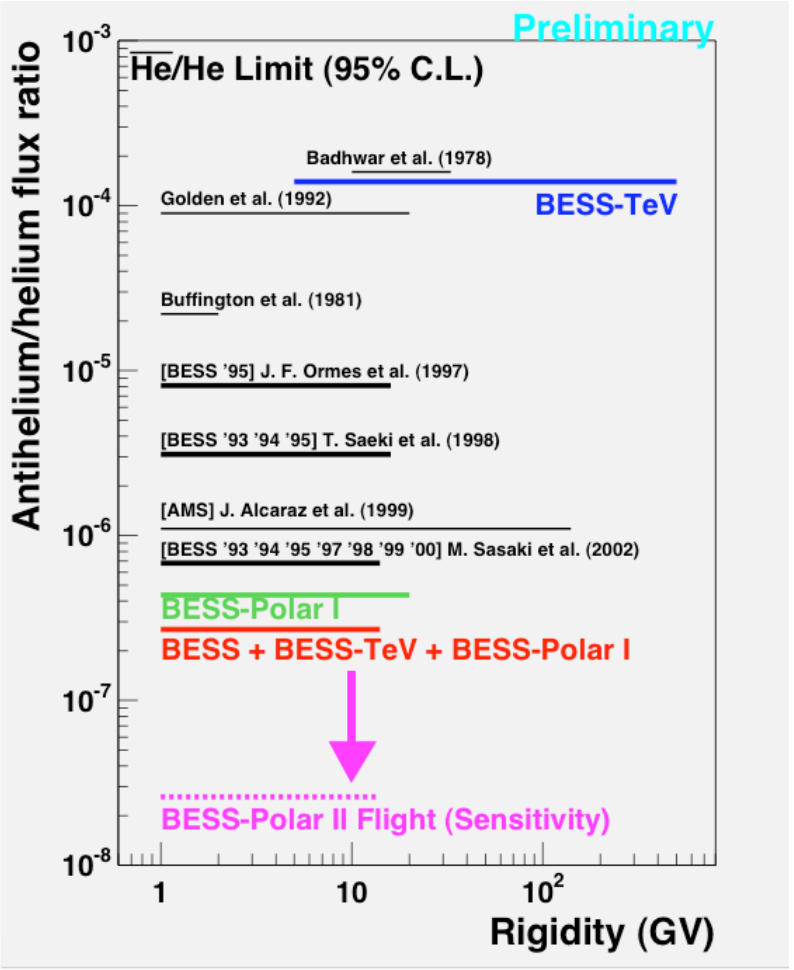


Physics potential of polar-II



Anti-helium search





Extragalactic origin ?

$$\overline{He}/He < 2.7 \times 10^{-7} (95\%CL)$$

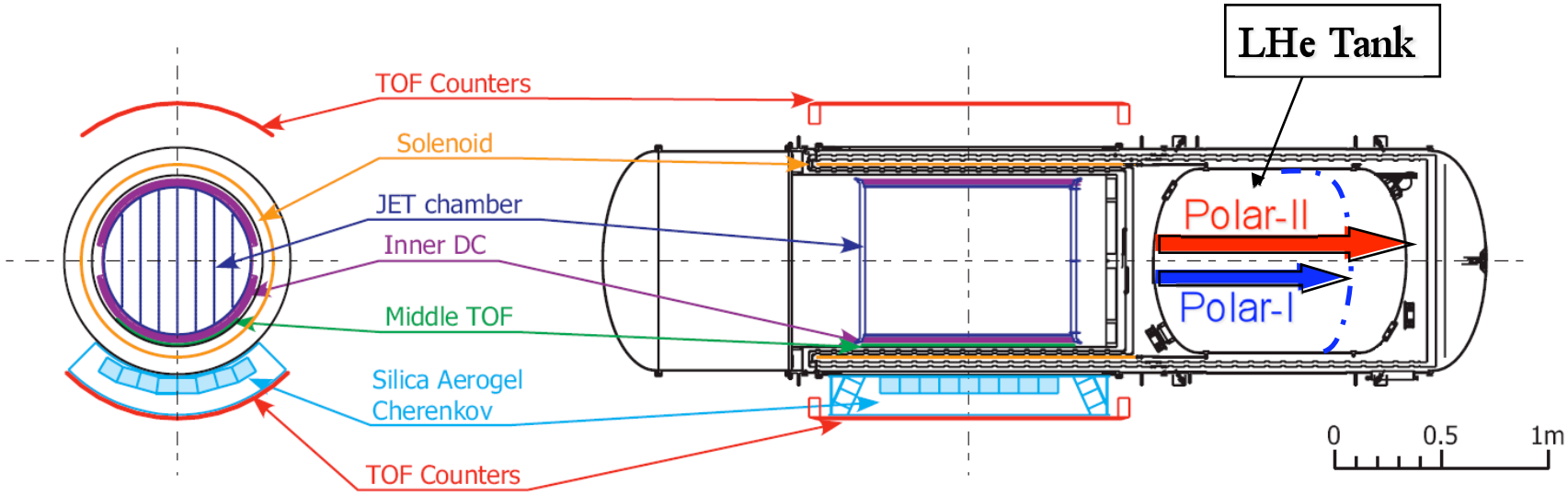
Most direct evidence that
our neighbor space is made of matter.

Even single event strongly indicates the existence of anti-domain.
(+ Novel prize …)

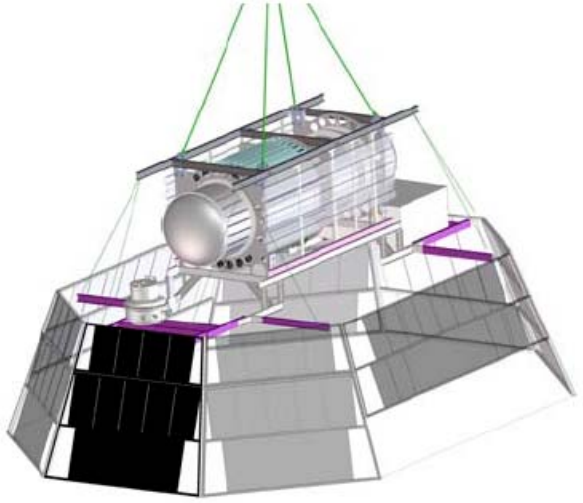
BESS Polar-II Experiment

- Overview and (expected) physics outputs
- Polar-II Spectrometer
- Preparation
- Antarctic campaign
  - Onsite preparation (+ Antarctic life)
  - Flight
- Detector Performance

BESS Polar-II Spectrometer



- Configuration is same as Polar-I.
- Almost all components (except for JET/IDC) were re-developed and re-fabricated
  - for longer flight (8.5 days to >20days)
  - improvement based on Polar-I status.



Detector improvement

- Longer life (8.5 days => >20days)
  - Longer life of Liquid He
    - ✓ Larger tank, 3rd radiation shield
- Improvement
  - TOF PMT HV over-current
  - ACC Particle ID
  - MTOF will be both-side readout
  - JET Noise reduction

    * Performance will be presented later.
- Maintain weight balance
  - Compactify Solar panel

Detector improvement

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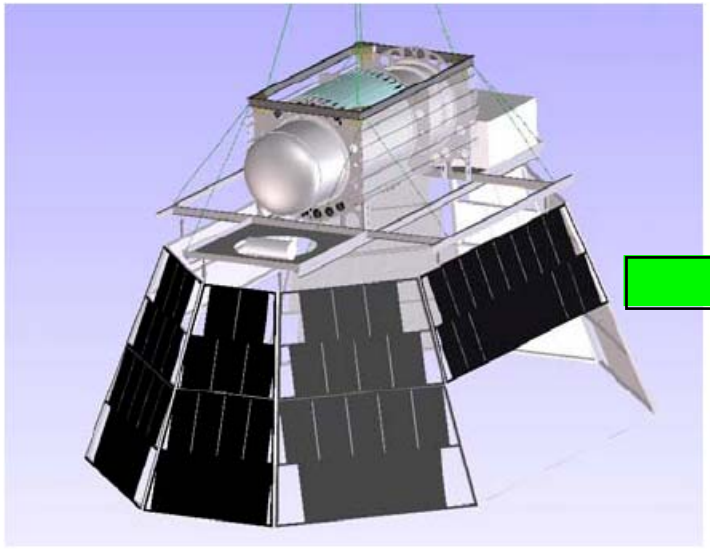
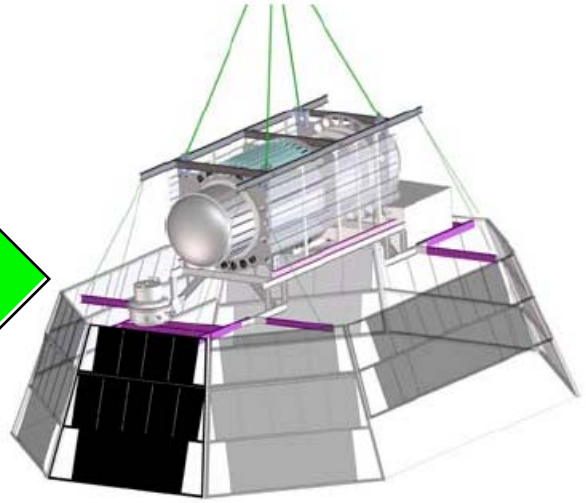
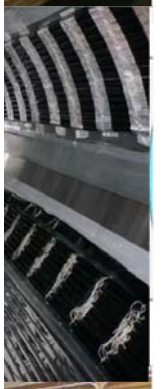
Polar-I



Polar-II





- Maintain weight balance
  - Compactify Solar panel

Improvement toward Polar-II

Subject	BESS-Polar-I	BESS-Polar-II
Magnet Cryogen Life	~ 11 days	> ~22 days
TOF-PMT housing	Resin potting (HV over-current)	Pressurized housing
JET gas life	~10 days	> ~ 20 days
ACC Particle ID	Rejection ~ 630	Rejection >> 1000
Solar-power gen.	4 stage 900 W	3 stage 675 W
HDD	2 of 3.6TB	16TB
Effective Acceptance	0.17 m^2sr (0.13 m^2sr in analysis)	0.27 m^2sr
Observation time	8.5 days	> 20 days
Statistics	4 x BESS97	20 x BESS97

BESS Polar-II Experiment

- Overview and (expected) physics outputs
- Polar-II Spectrometer
- Preparation
- Antarctic campaign
  - Onsite preparation (+ Antarctic life)
  - Flight
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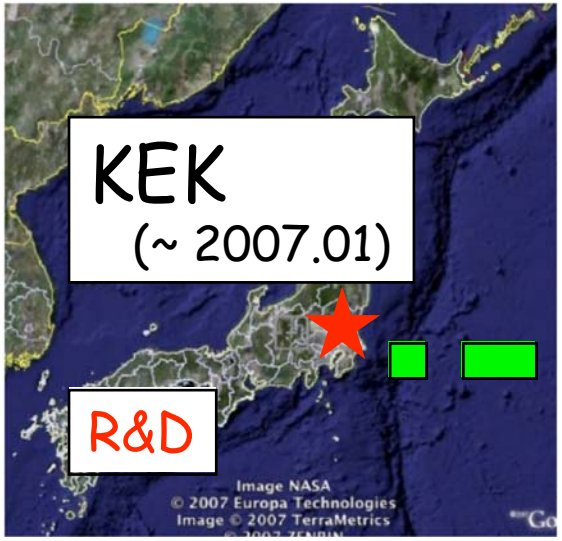
BESS Polar-II History

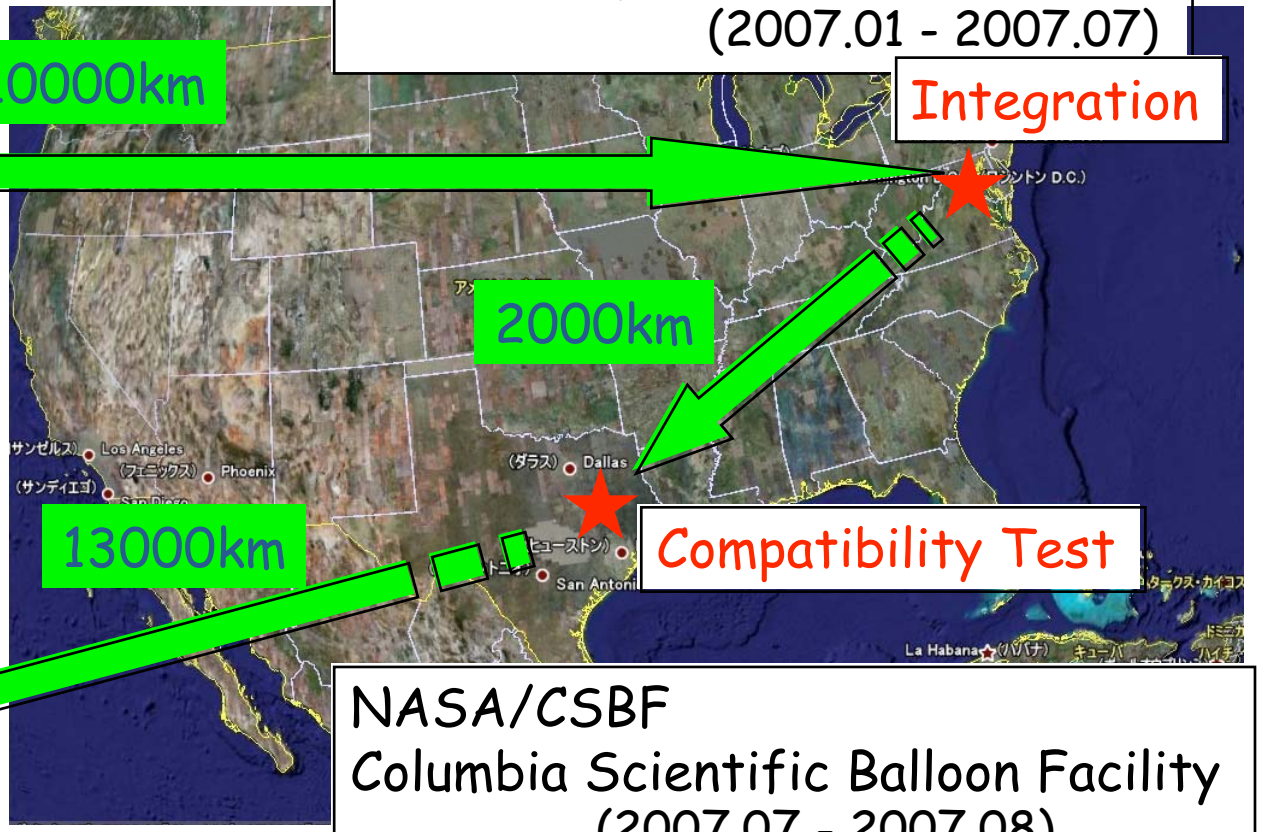
Start preparation in Jan. 2005



NASA/GSFC
Goddard Space Flight Center
(2007.01 - 2007.07)

10000km

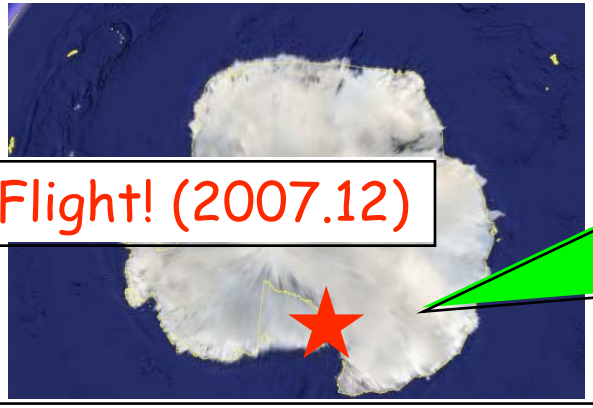
Integration



2000km

13000km

Compatibility Test

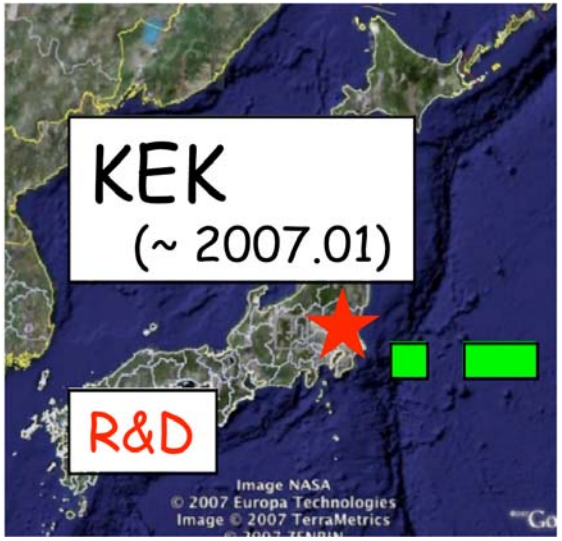


Flight! (2007.12)

Antarctica/Williams field

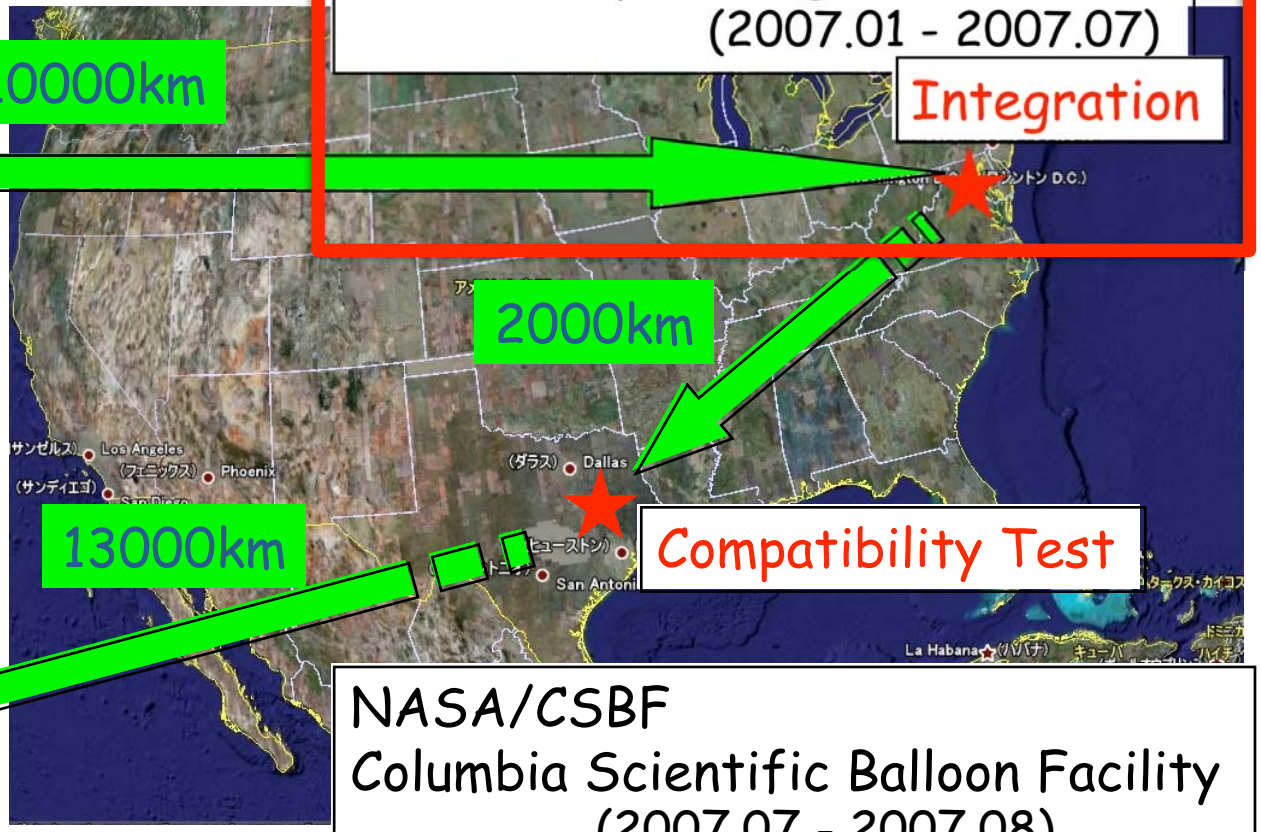
NASA/CSBF
Columbia Scientific Balloon Facility
(2007.07 - 2007.08)

BESS Polar-II History



10000km

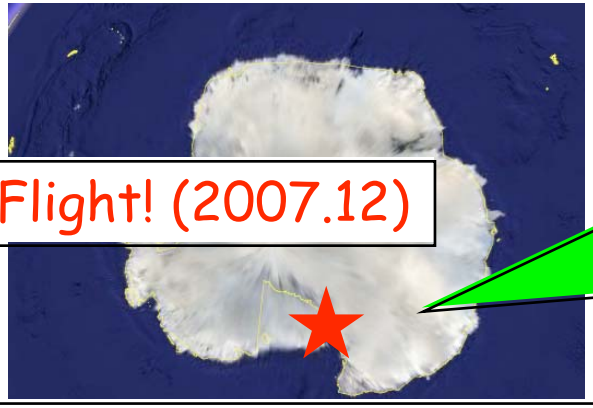
NASA/GSFC
Goddard Space Flight Center
(2007.01 - 2007.07)
Integration



2000km

Compatibility Test

13000km

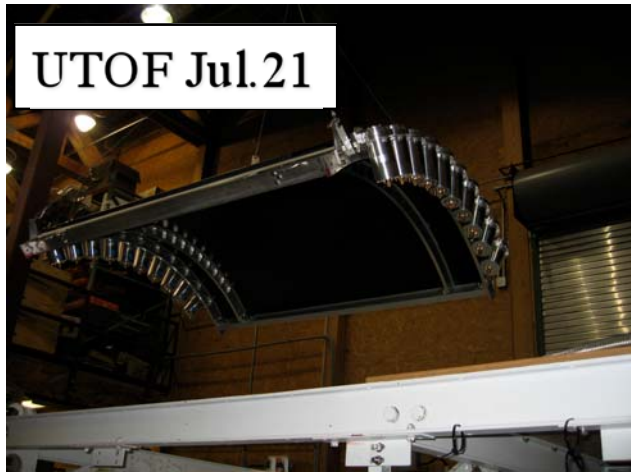


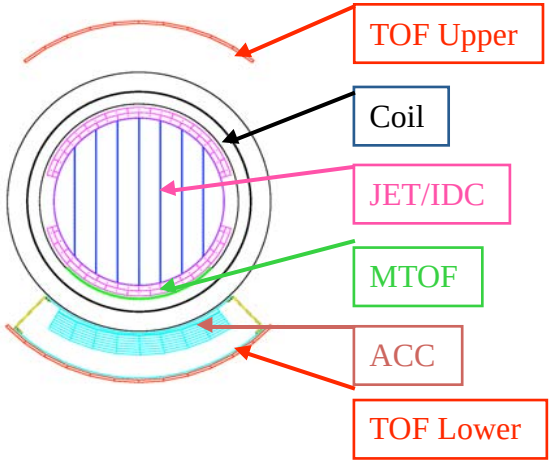
Flight! (2007.12)

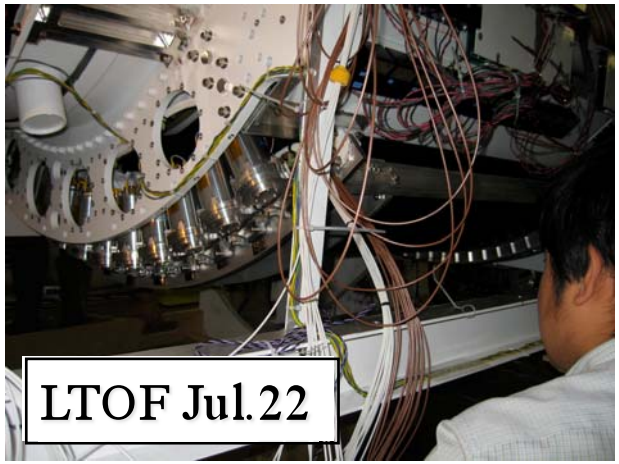
Antarctica/Williams field

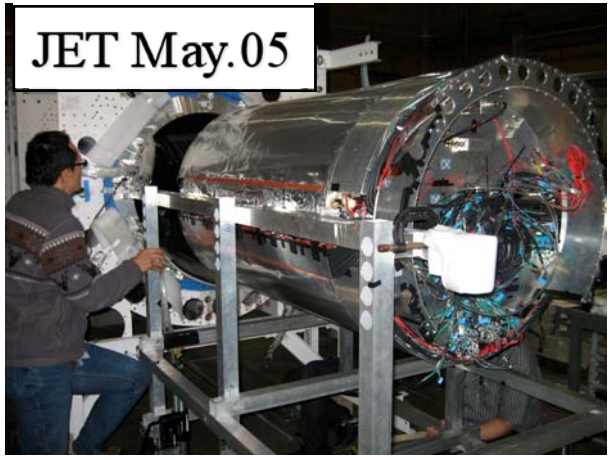
NASA/CSBF
Columbia Scientific Balloon Facility
(2007.07 - 2007.08)

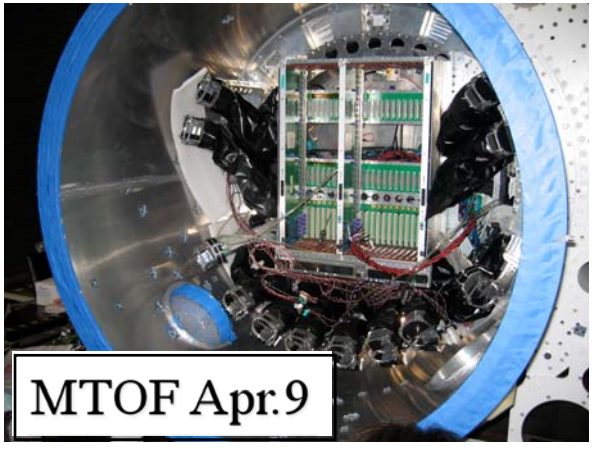
Preparation @ NASA/GSFC

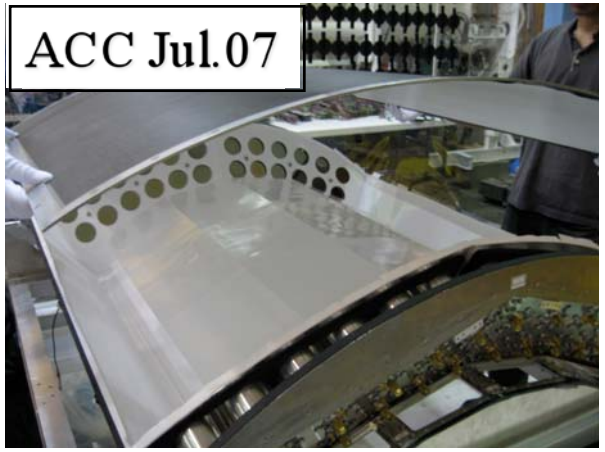




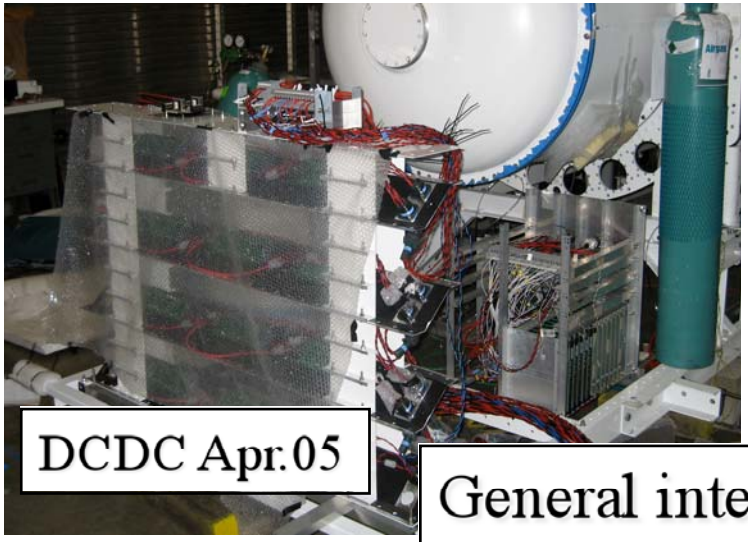


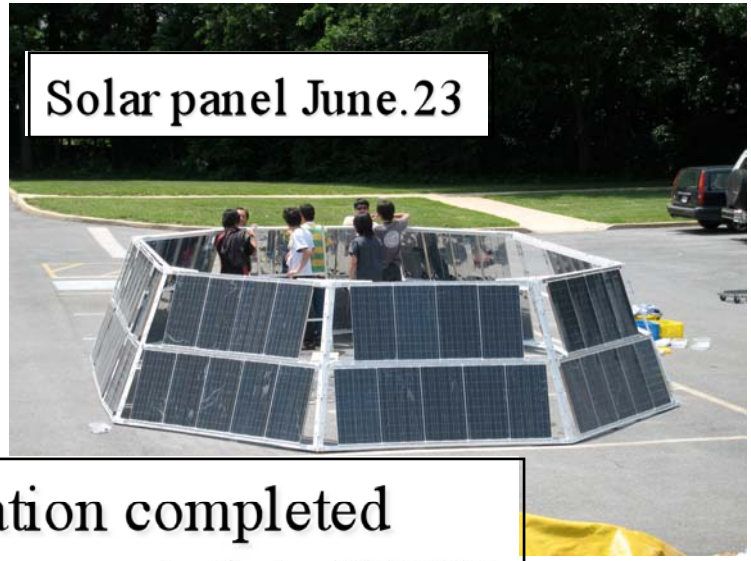




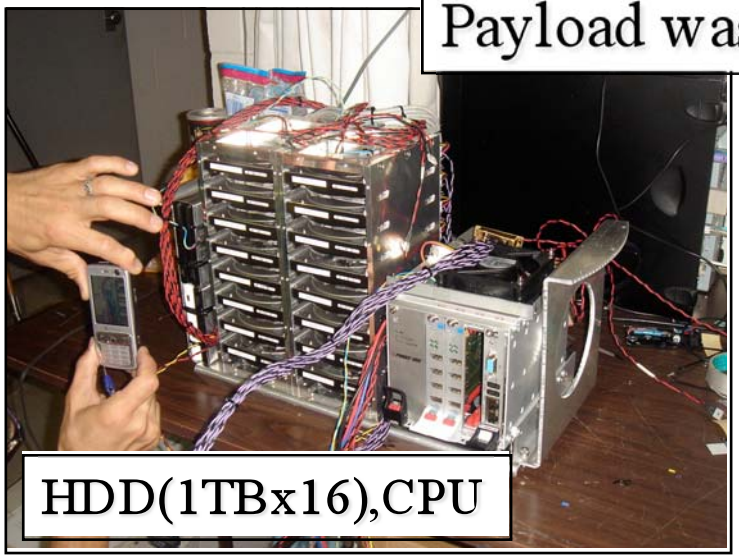


Preparation @ NASA/CSBF


DCDC Apr.05

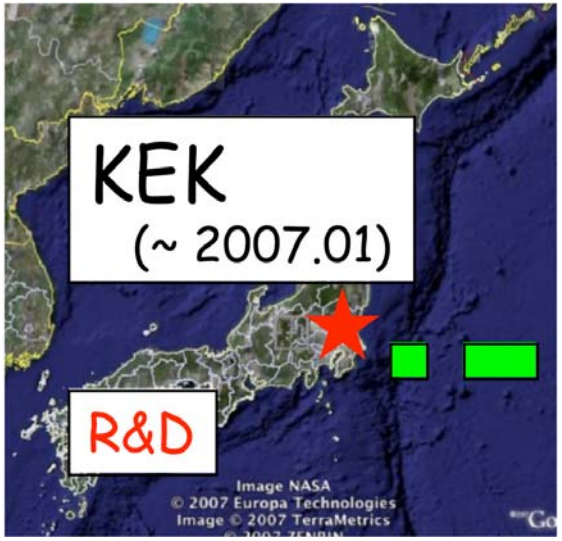

Solar panel June.23

General integration completed
Payload was transported to CSBF


HDD(1TBx16),CPU


Elec.,Data vessel Jul.22

BESS Polar-II History



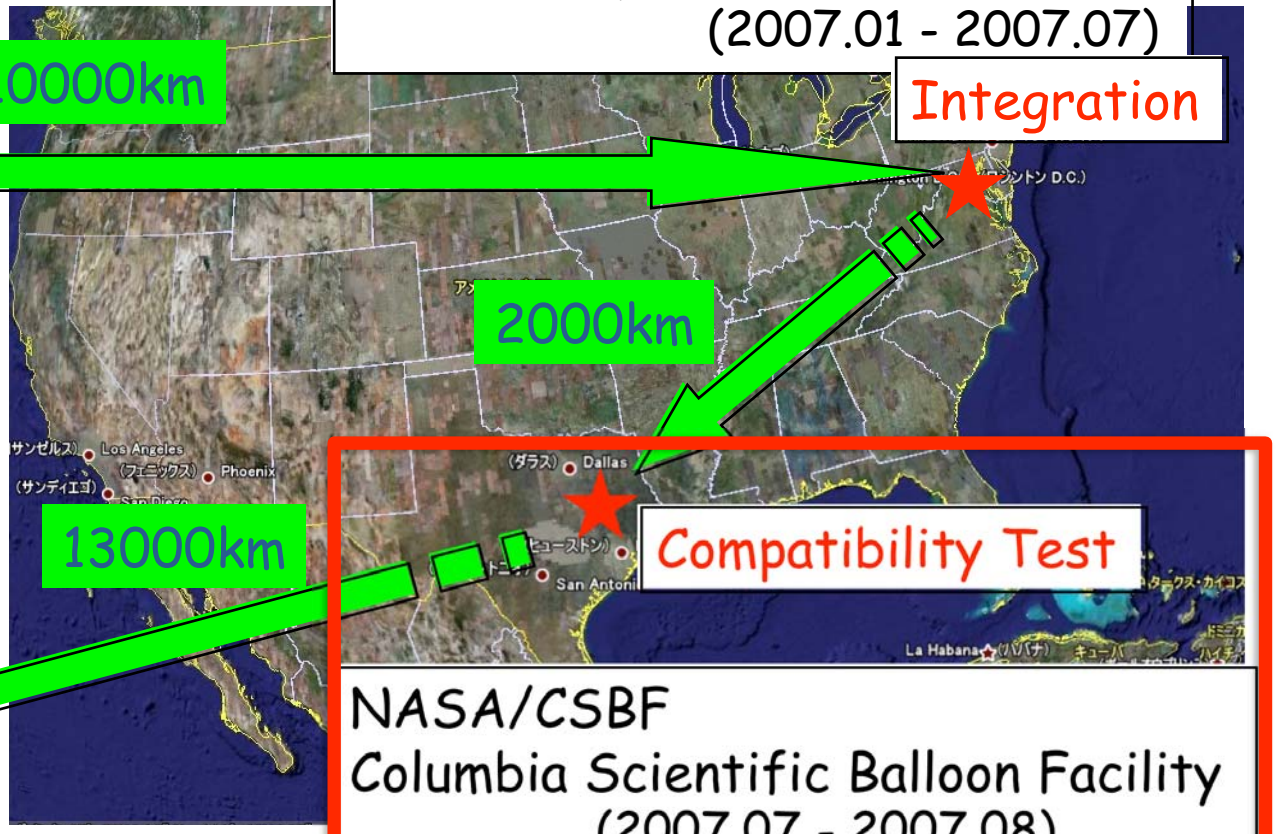
NASA/GSFC
Goddard Space Flight Center
(2007.01 - 2007.07)

Integration

10000km

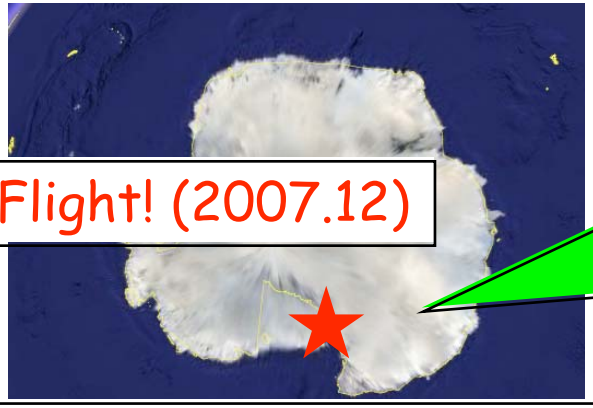
2000km

13000km



Compatibility Test

NASA/CSBF
Columbia Scientific Balloon Facility
(2007.07 - 2007.08)

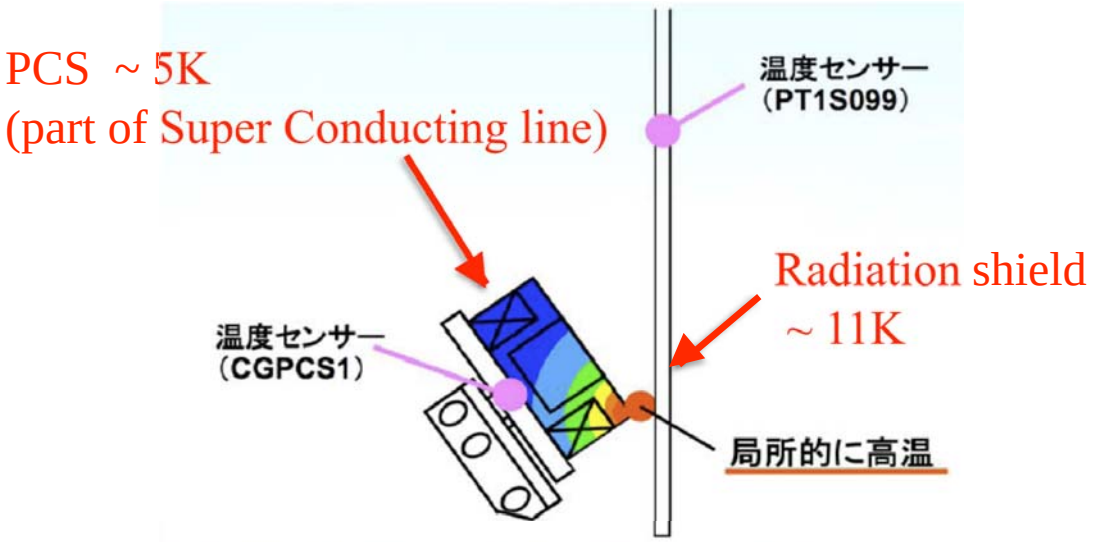


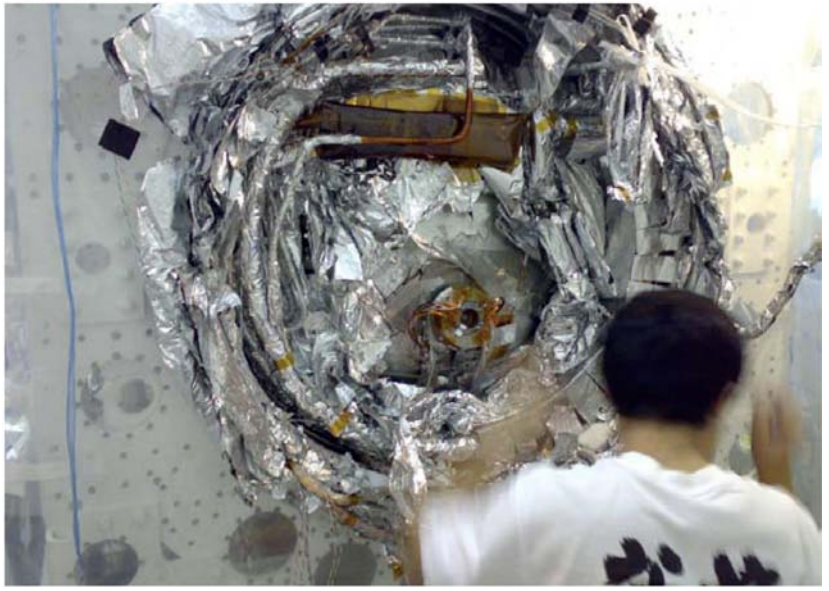
Flight! (2007.12)

Antarctica/Williams field

Texas Crisis !

- The magnet cryostat (thermal insulation) was suffered during transportation.
- Experts (Toshiba Co.) & tools was arrived four days later !
- The thermal-short of radiation shield to the PCS (persistent current switch) was successfully repaired on site !





Schedule delay was only 1 week !

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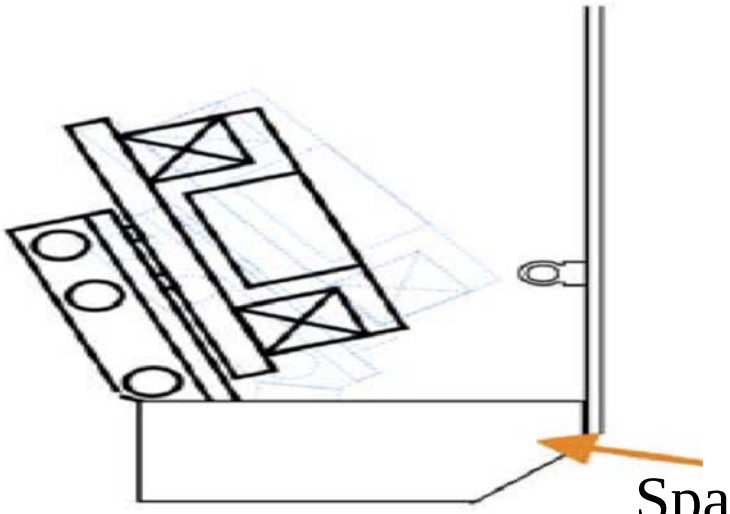
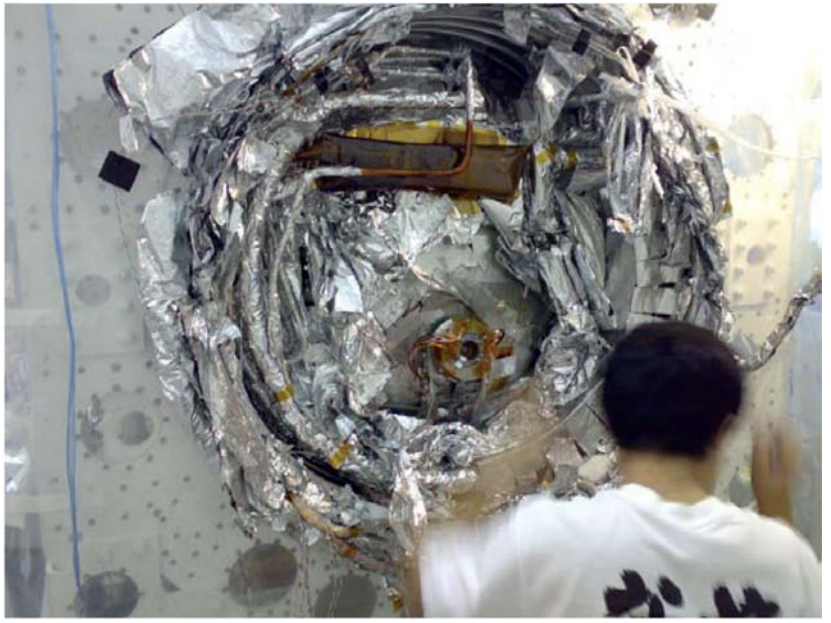




Schedule delay was only 1 week !

Compatibility Test @ NASA/CSBF

2007 Aug

Final Compatibility test with
Columbia Scientific Balloon Facility
Was achieved at Palestine, TX, USA

Establishment of

- Mechanical compatibility
- Communication in the B-Field

BESS Polar-II Experiment

- Overview and (expected) physics outputs
- Polar-II Spectrometer
- Preparation
- Antarctic campaign
  - Onsite preparation (+ Antarctic life)
  - Flight
- Detector Performance

BESS Polar-II Crew

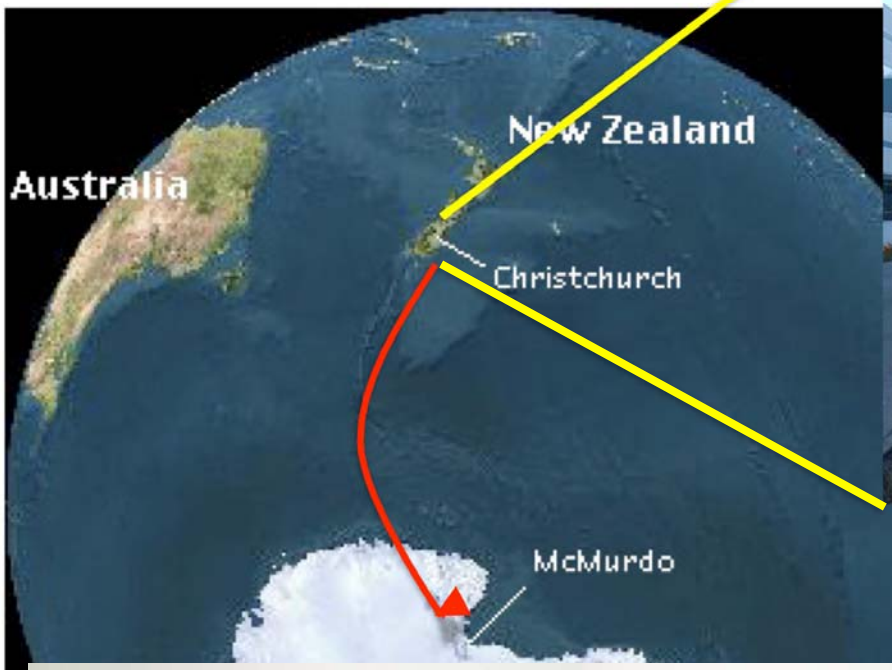
- 南極現地部隊:15名

November 11, 2007@Antarctica

November 27, 2007@Antarctica
Compatibility test

Military flight to Antarctica

Military flight to Antarctica



Antarctic Center

Everyone can enjoy
- shopping
- attraction
- see penguin

Extremely Cold Weather (ECW) clothing (~>10kg in total)

Military flight to Antarctica

NZ – McMurdo station

- 2,3 flights / day
- 5~8 hours

Flesh food and much cokes are transported every day !
(Also Amazon is available !)

Ice Run-way (Antarctica)

McMurdo Station

Transit point to South pole

~1000 people work in summer season

~ 100 buildings in the station

McMurdo Station

Transit point to South pole

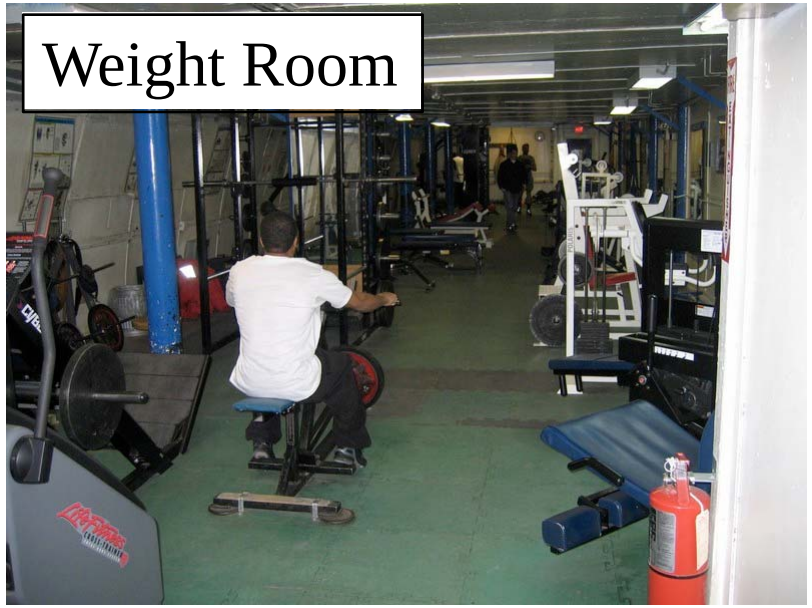
~1000 people work in summer season

~ 100 buildings in the station

Bank (ATM)
Barber shop
Hospital
Fire house
Church
Bowling alleys
Radio station
Post office
Store, Library
Rental video …

McMurdo Station

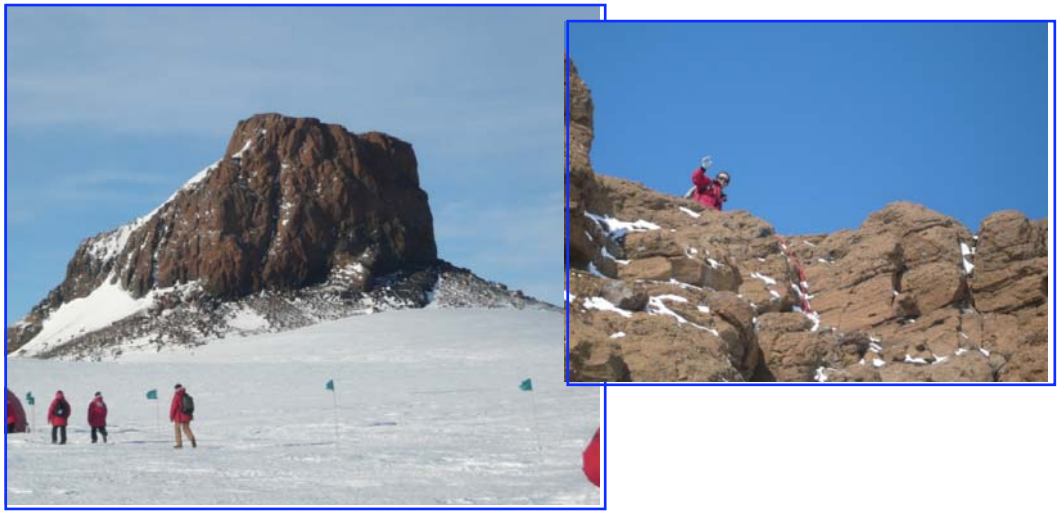
McMurdo Station (2)



McMurdo (recreation) Life

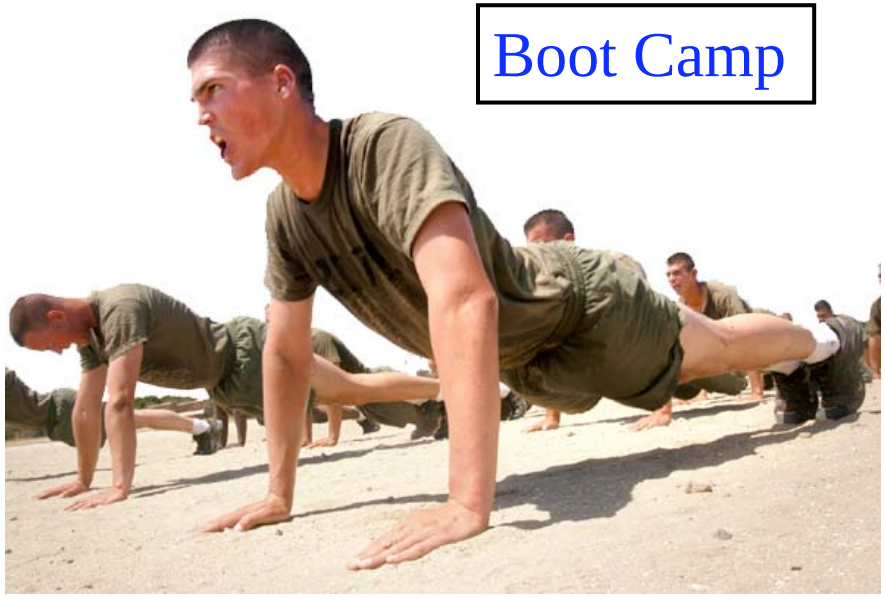
Message Board

Rock Criming



Scott's hut
(made ~100 years ago)

Boot Camp



Project manager's life

Tour

- Pressure ridge tour
- Hut point tour
- Cape Evans tour
- Pegasus tour
- Ice Breaker tour

Sports

- Dive to Antarctic sea
- Short (~5mile) & half marathon on the ice
- Ski

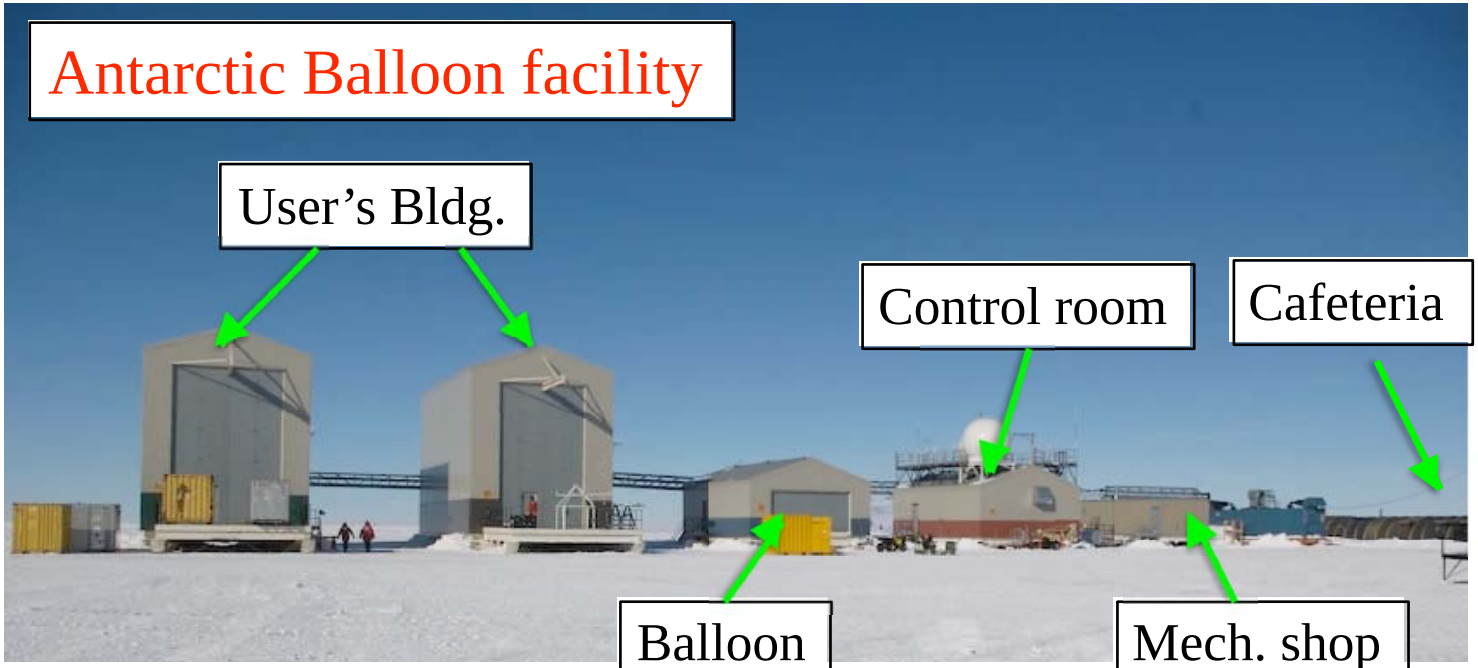
Hiking

- Observe hill
- Castle rock loop
- Hut point loop
- Ice runway

Onsite preparation

Williams Field

- Williams field
  - 10 miles from McM (30 minuits)
- Facilities were renewed in 2006
  - Towards 3 flights/year
- No toilet yet.



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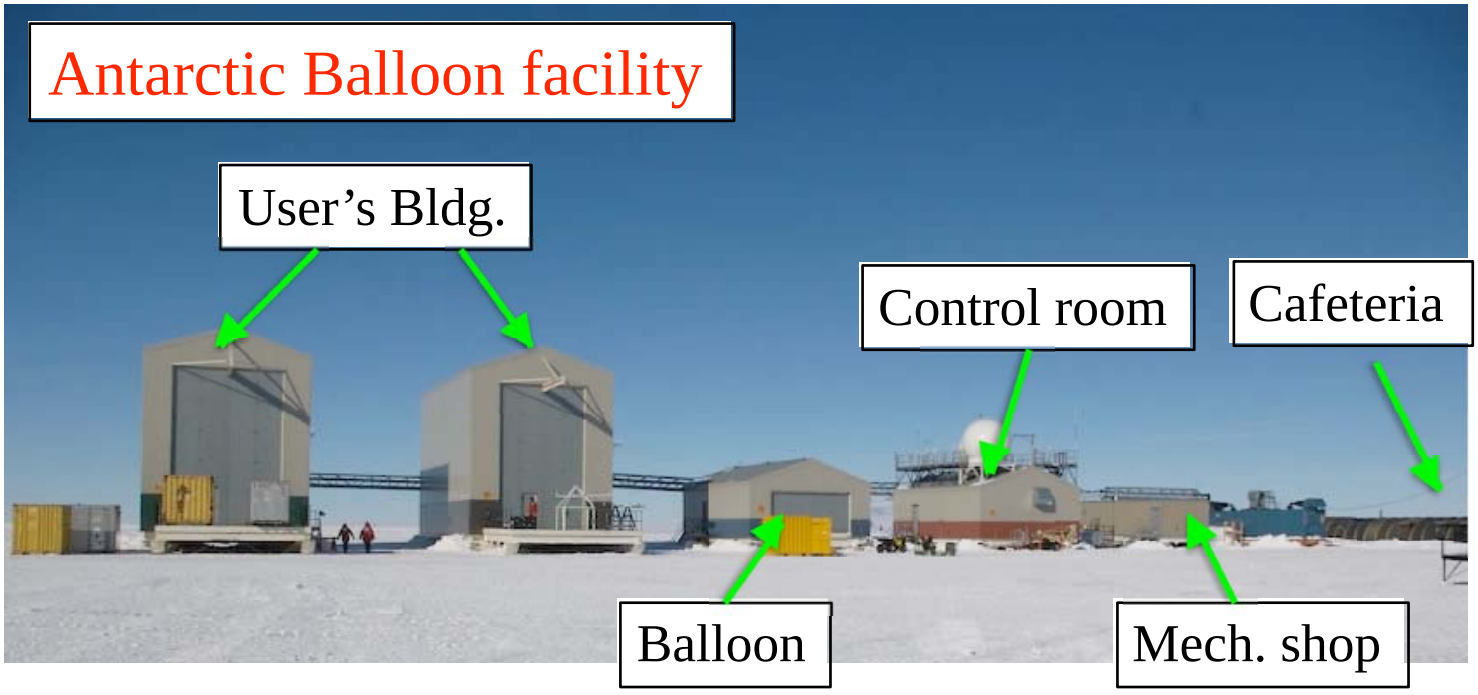

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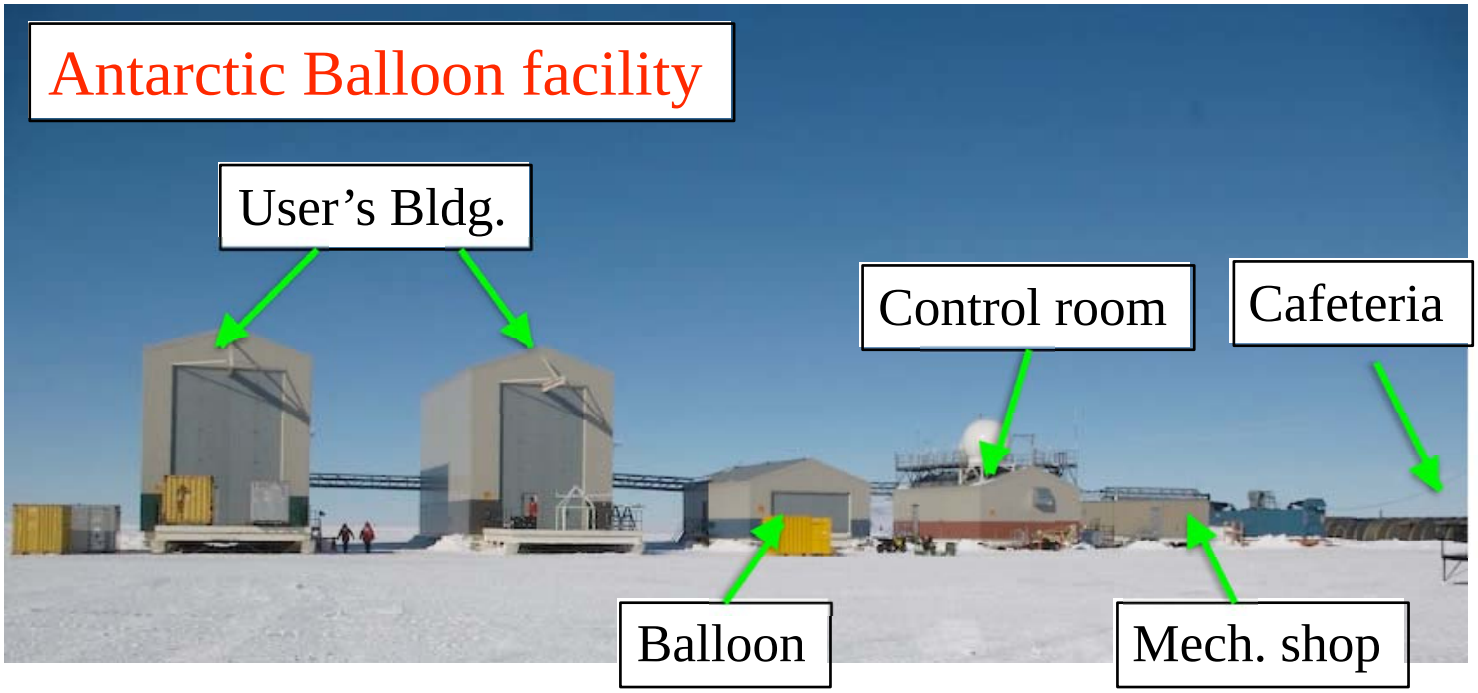


Preparation at Williams Field

- Final preparation for the flight done in the building
  (highest in the Antarctica)

- Detector integration and check
- Integration of Solar battery system
- Installation of SIP
- Thermal insulation

Flight Ready

Hang test prior to flight (11/27) was successfully done

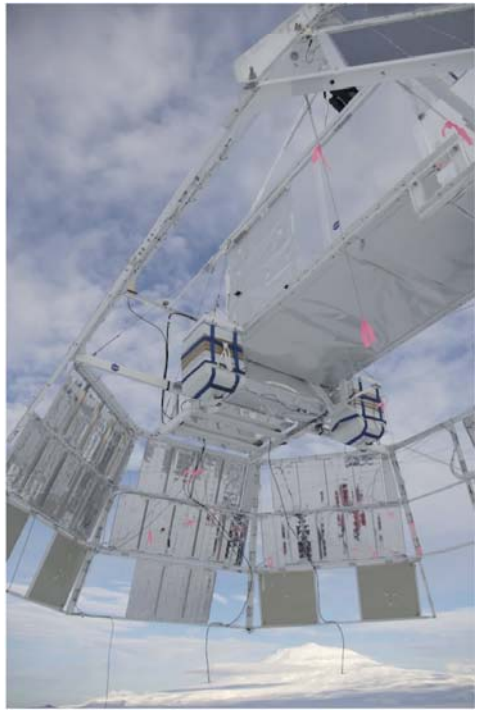
Full configuration of spectrometer, solar battery system, and Communication systems

→ Flight Ready

Flight day (Assembly)

Roll-out

Lift-up by launcher



Move to Runway

Transformation

Flight day (balloon)

Balloon inflation

Spool hold the balloon

Flight day (balloon)

Ready for flight

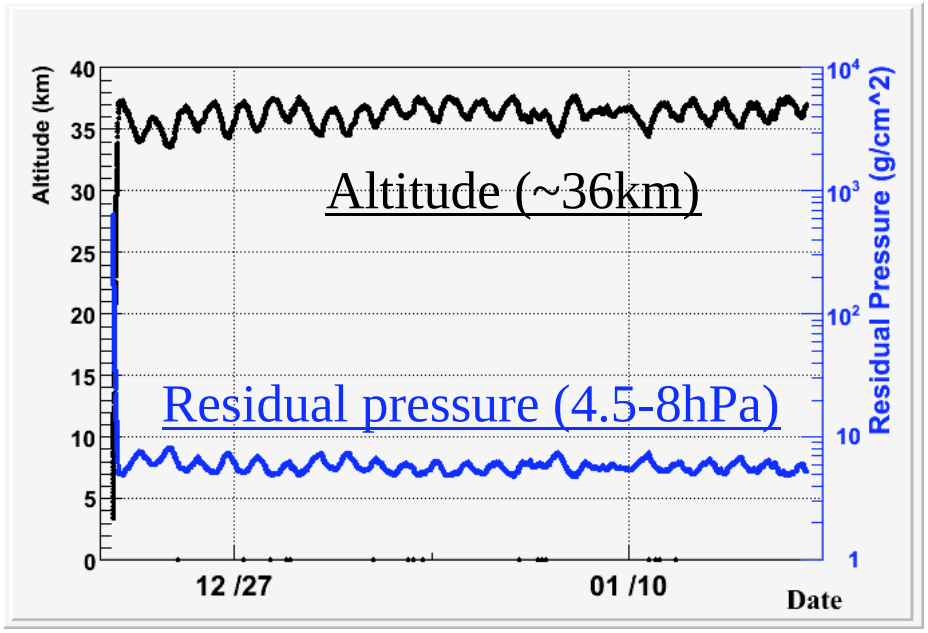
Launch

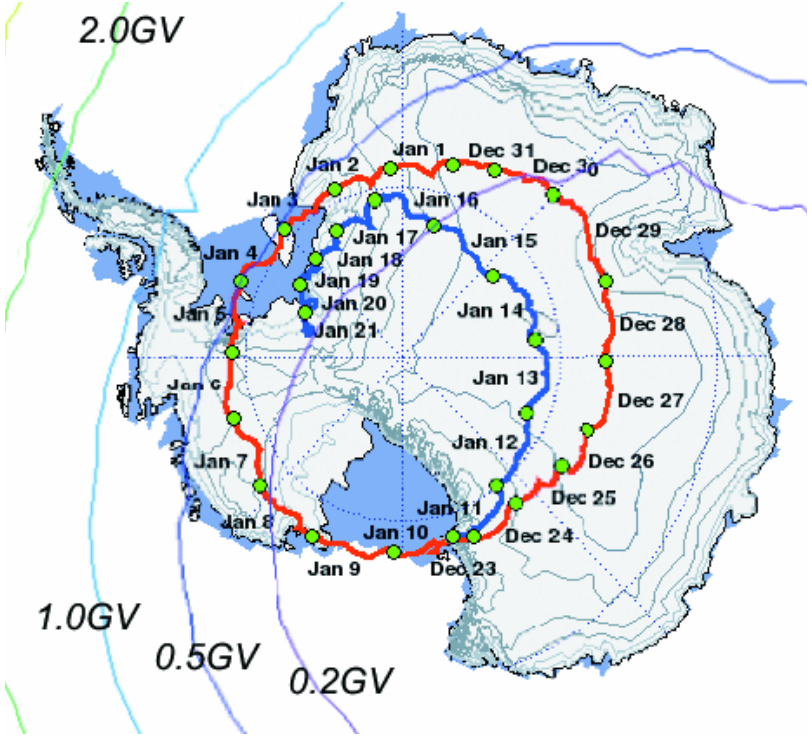
Launched from Williams Field, McMurdo, in Antarctica
(S77-51, E166-40), 06:27(McM), Dec. 23, 2007

Perfect launching !

Flight status

- Floating time 29.5 days (24.5days for data taking)
- Flight Altitude ~36km
- Cut-off rigidity ~0.2GeV/c (0.5GeV/c at most)

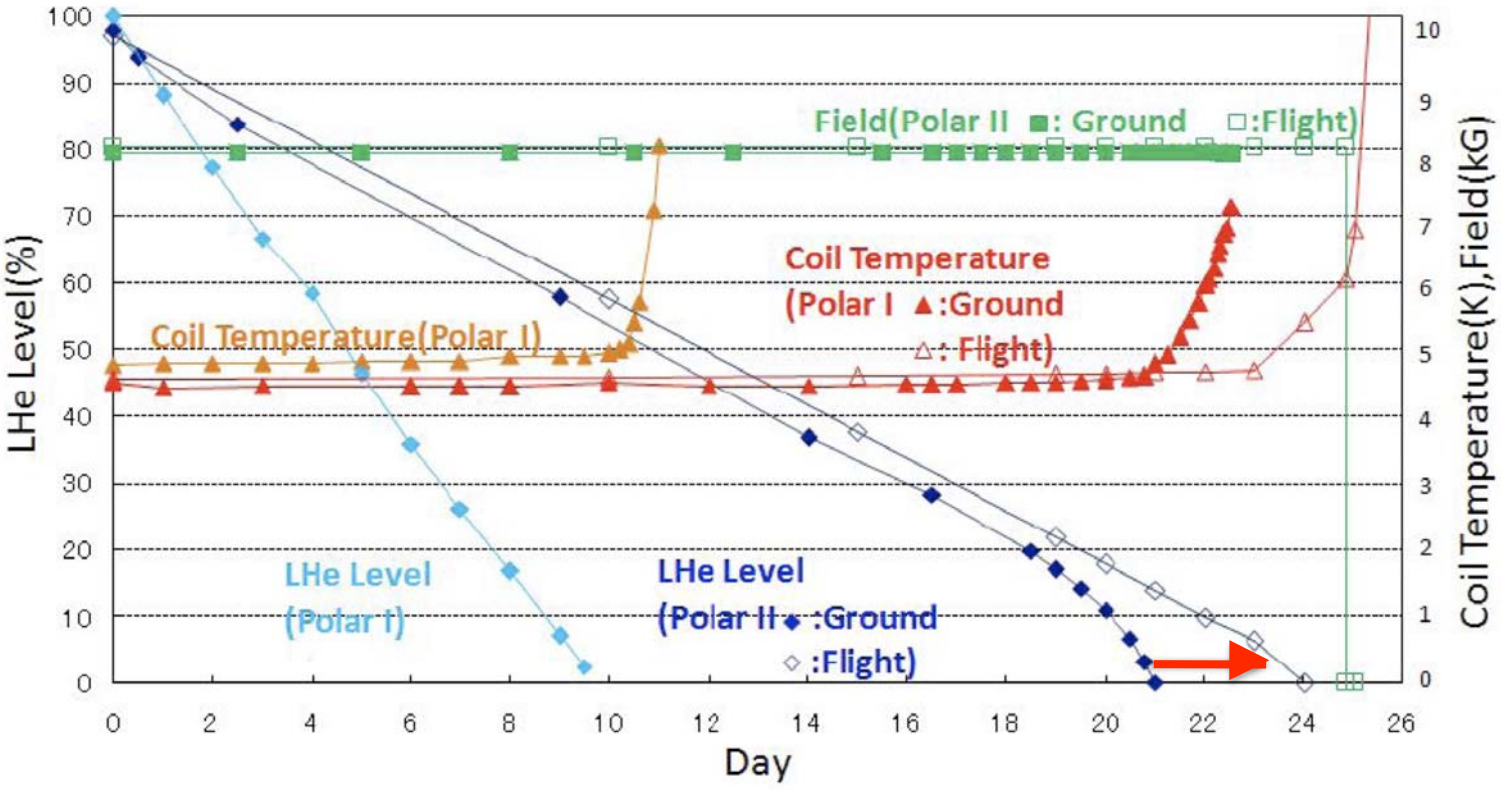




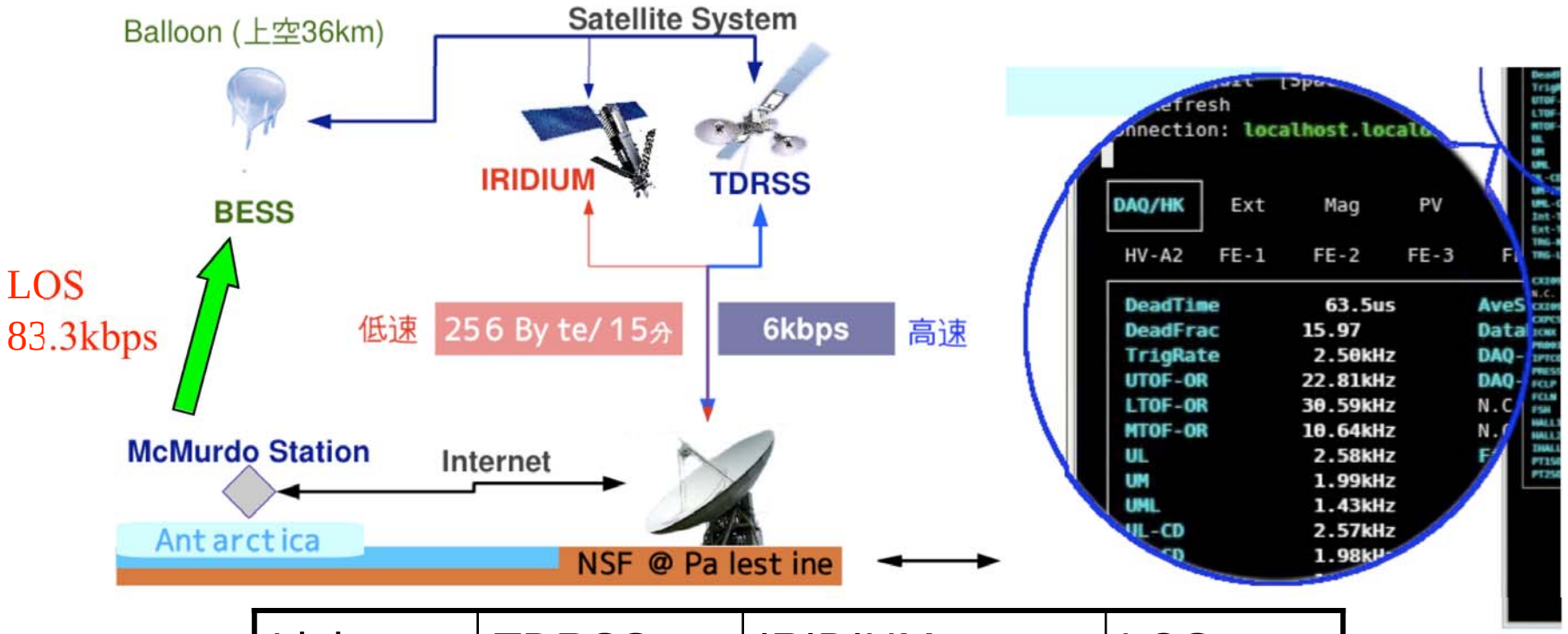
Flight status – cont'd -

- Duration time for science run is determined by
  - Magnet life 22.5 days in ground → ~25.5 days in flight
  - Disk storage ~ 25 days

24.5 days science run w/ B-field was achieved !



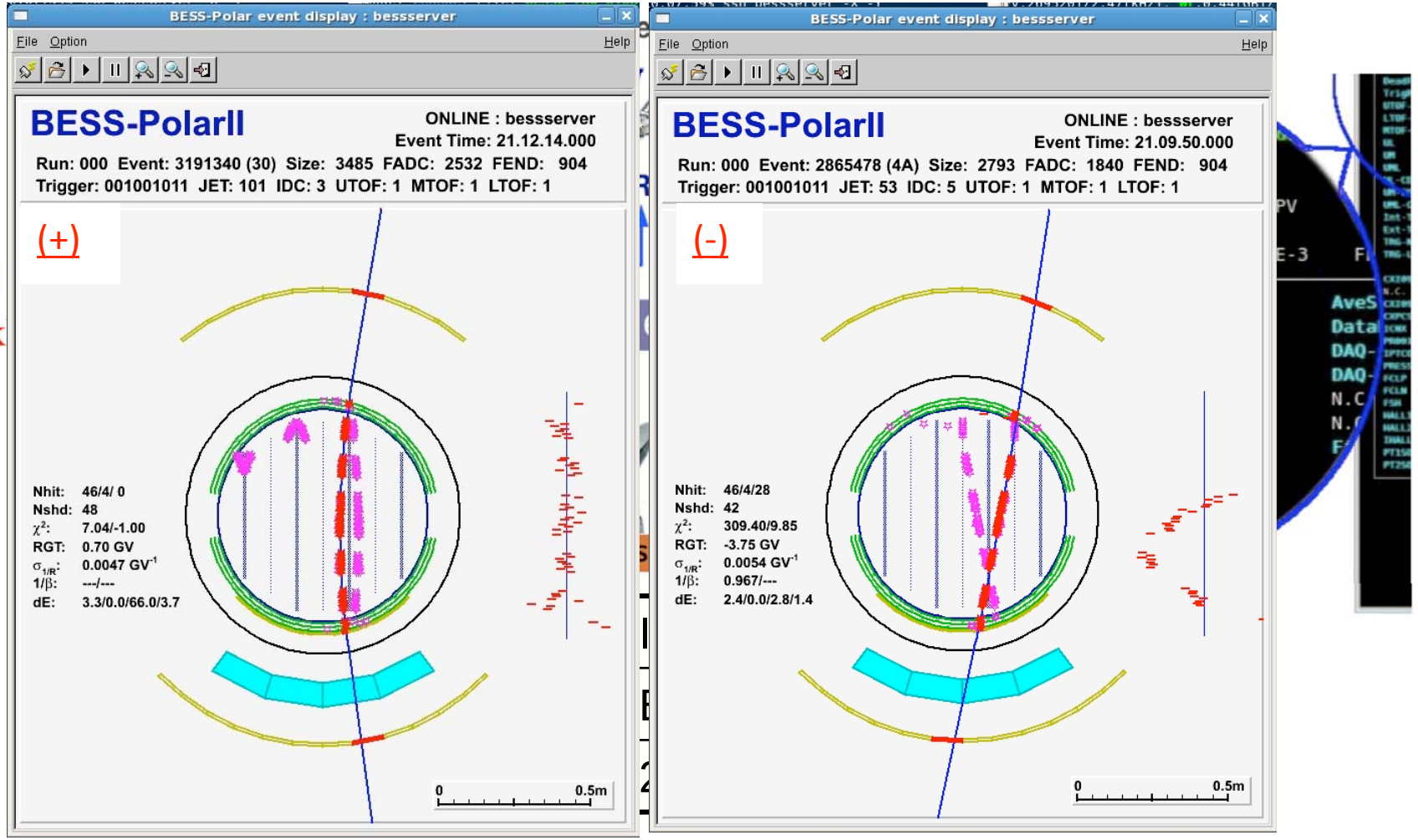
Control and Monitor



Link	TDRSS	IRIDIUM	LOS
Uplink	Scheduled	Backup	
Downlink	6kbps	256bytes/15min	83.3kbps

Payload was monitored and controlled through satellite system.

Control and Monitor



LOS
83.3k

Payload was monitored and controlled through satellite system.

→ Stable long-duration was realized.

Status of Detector

- Detector worked properly during the flight.

Good points

- TOF-PMT HV over current (18/44 → 0/44)
- No DAQ hung-up

Problems

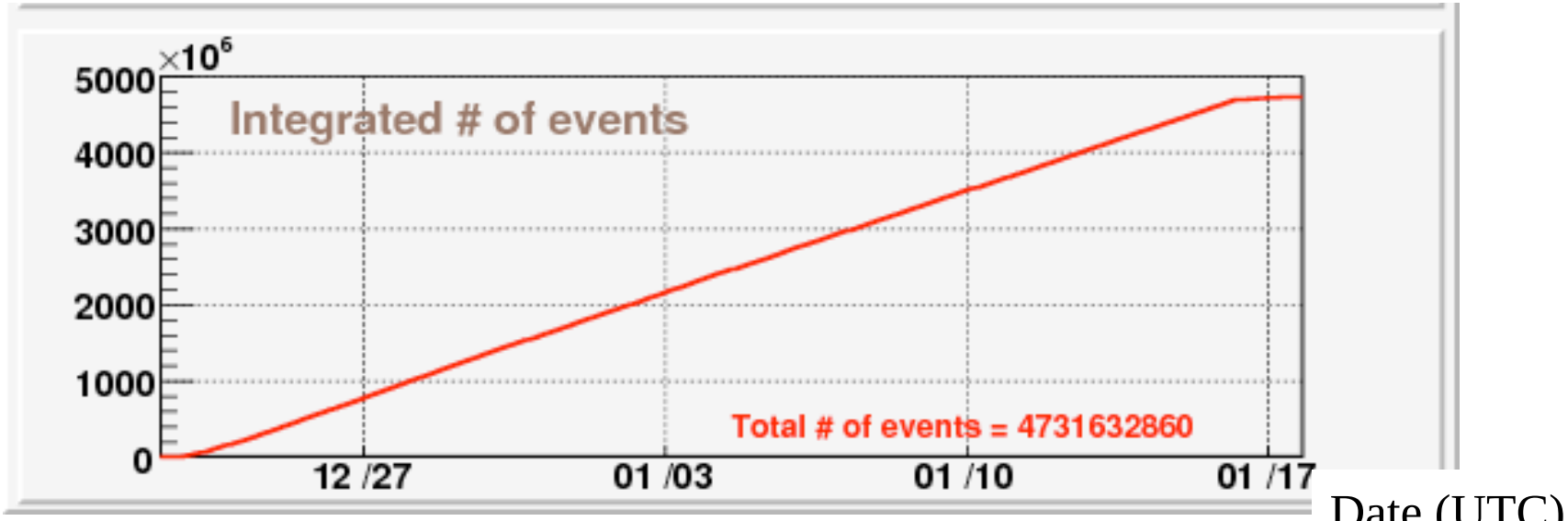
- HV monitor system of 2 TOF PMTs were broken.

  → HV-Off (No acceptance loss)
- HV controller of JET was suddenly unstable.

  → Operated with lower HV

  (keep the same performance)

Data Acquisition



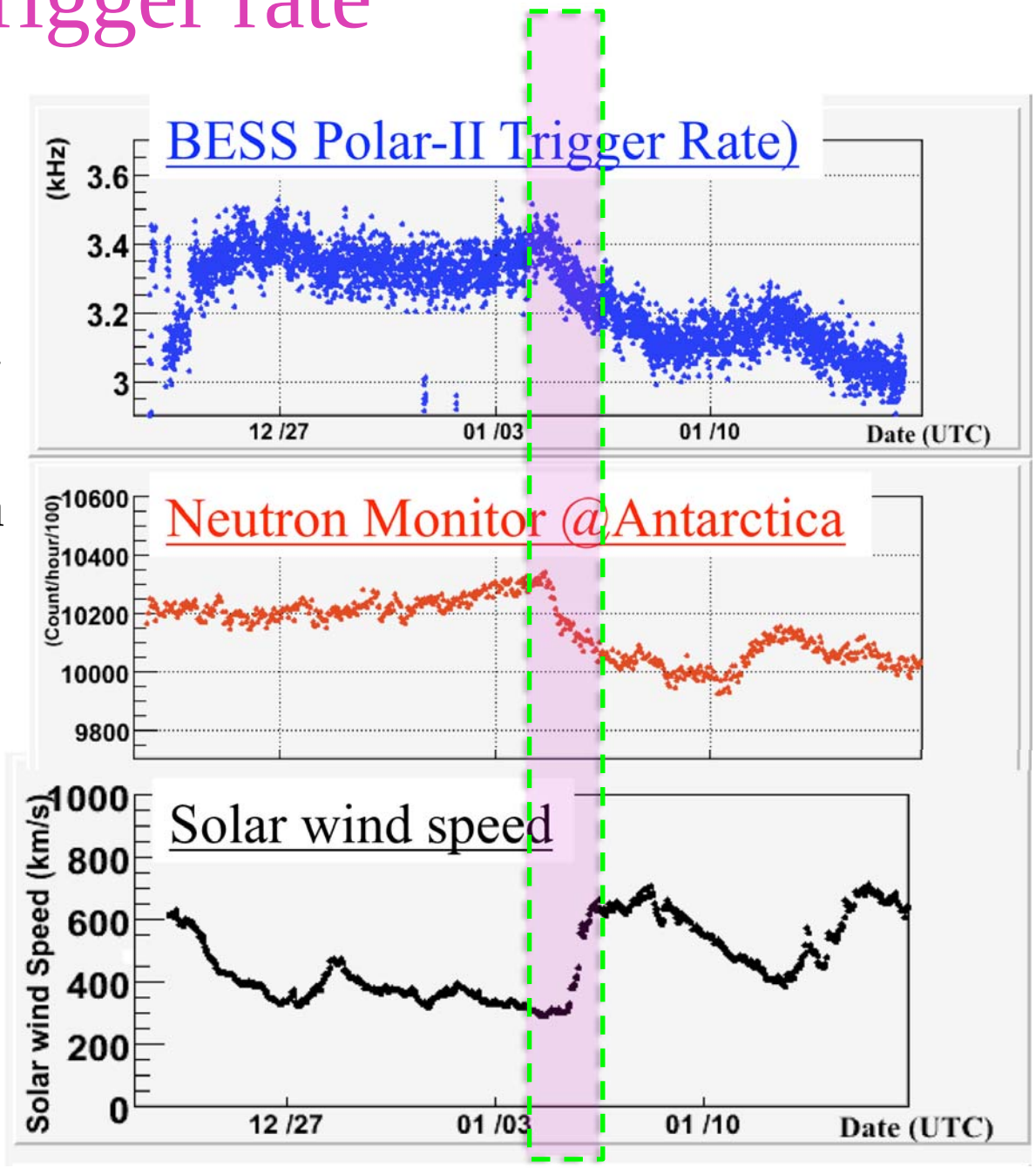
All triggered events (4700 M!) were recorded.

- Trigger rate ~3.4kHz
- Fraction of live time ~80% →700GB/day
- Event size ~3kB

All HDDs were used up in the sky.

Trigger rate

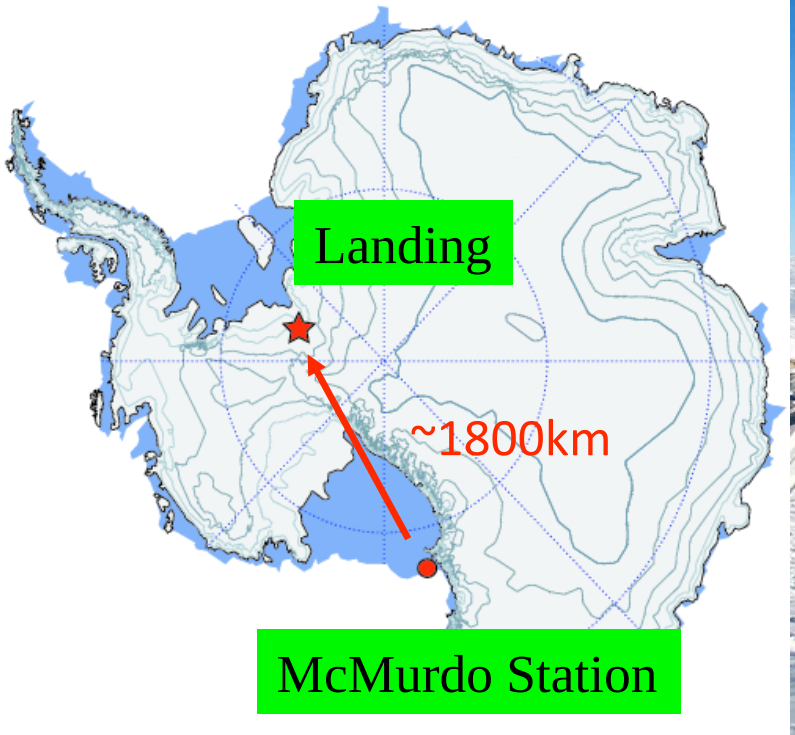
- Daily variation in CR flux was clearly observed.
- It is surely correlated with solar wind activity and neutron monitor.
- Daily variation of proton spectrum shape is useful for further study.

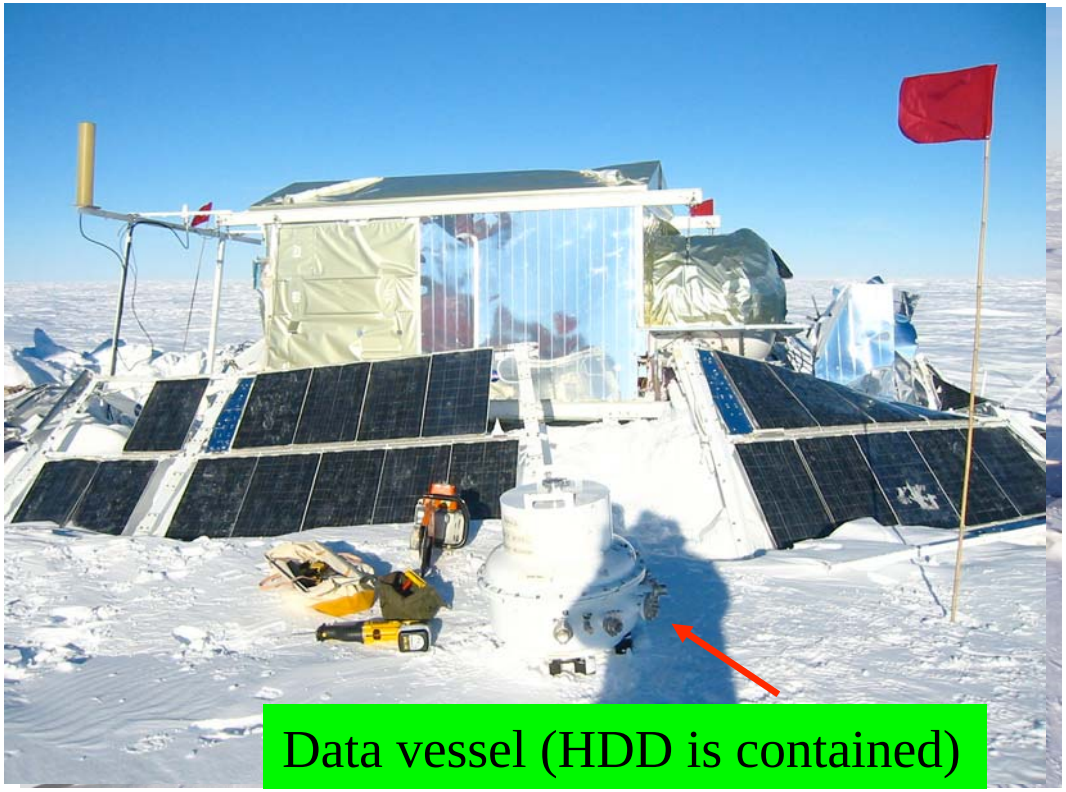


Flight Summary

項目	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	3.4 kHz
Live time Fraction	0.8	0.77
Altitude	37~39 km	34~38 km
Air Pressure	4~5 g/cm^2	4.5~8 g/cm^2

Landing & Recovery (1)

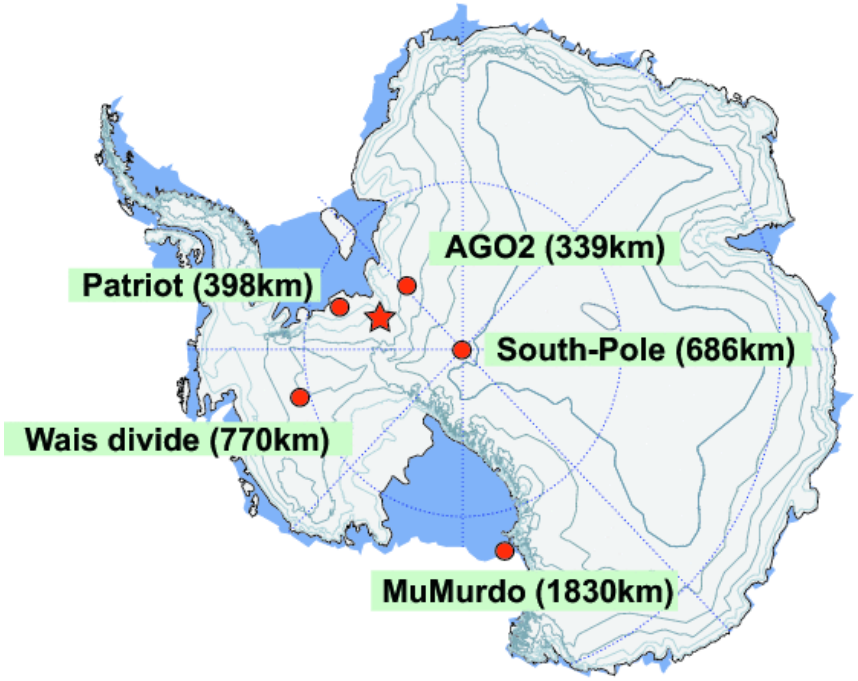




Impacted the ground at
(S83-51, W073-04), 09:02(UTC), Jan. 21, 2008

HDD was successfully recovered on Feb. 2
in -70 degree (wind chill).

Landing & Recovery (2)



Twin-otter (for transportation)

(Available within 400km from base camp)

- Near remote camps were closed.

  + severe weather condition

→ Recovery operation onsite was canceled, and is to be carried out in the next season (2008-2009)

BESS Polar-II Experiment

- Overview and (expected) physics outputs
- Polar-II Spectrometer
- Preparation
- Antarctic campaign
  - Onsite preparation (+ Antarctic life)
  - Flight
- Detector Performance

Plots and numbers are taken from
presentations at 63rd JPS Meeting

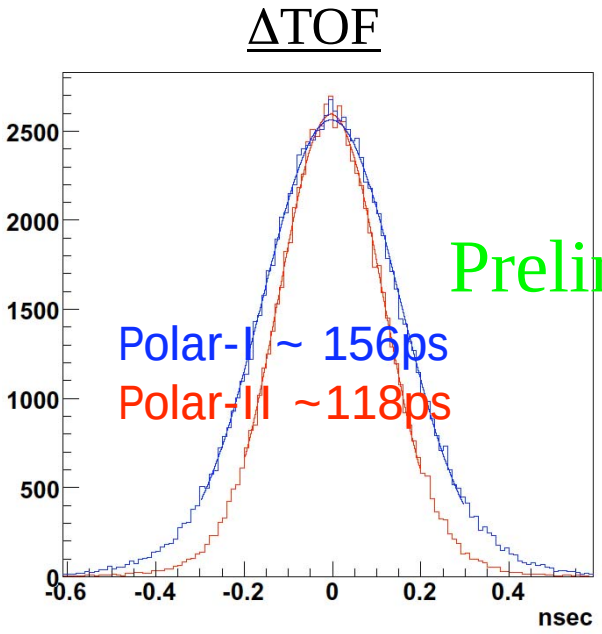
BESS Polar-II Experiment (2) –status of data analysis - R.Orito et. al.
Basic performance of BESS Polar-II Middle TOF counter - A.Horikosi et. al.
Basic performance of BESS Polar-II ACC - K.Sakai et. al.

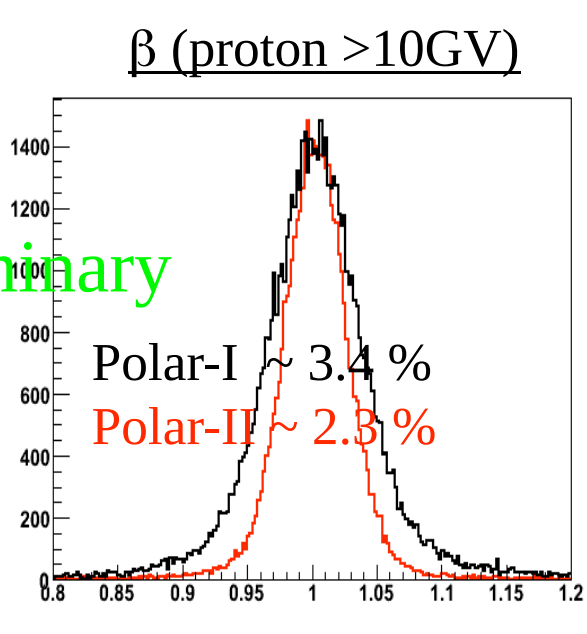
TOF (Upper & Lower)

TOF Status

	Both-side	Single-side	Dead	Acceptance
Polar- Ⅰ	8/22	10/22	4/22	66%
Polar- Ⅱ	20/22	2/22	0/22	100%

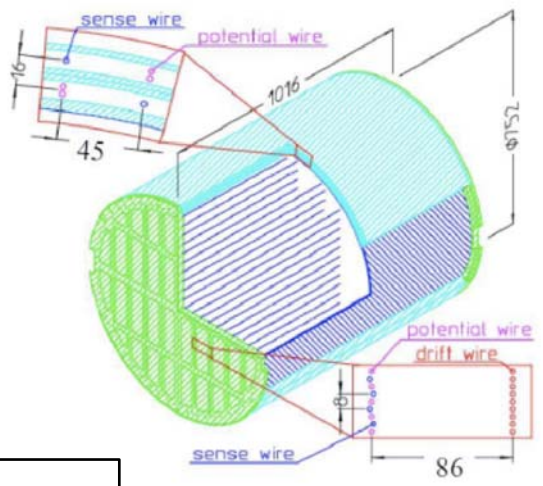
- No acceptance loss
- Time resolution
  - Polar-I : 156ps
  - Polar-II : 118ps
- β resolution
  - Polar-I : 3.4%
  - Polar-II : 2.3%





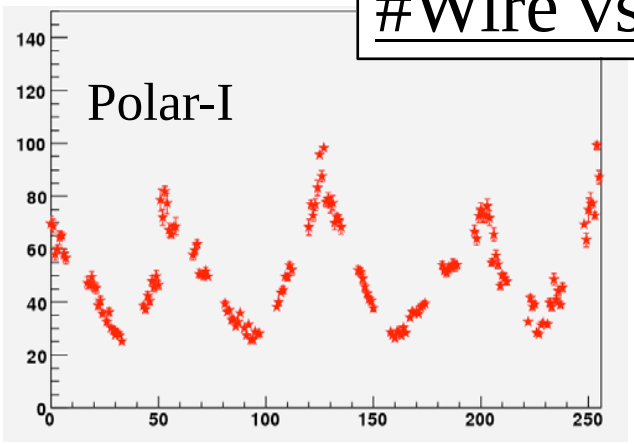
Note : worked in B-field (~0.1kG)

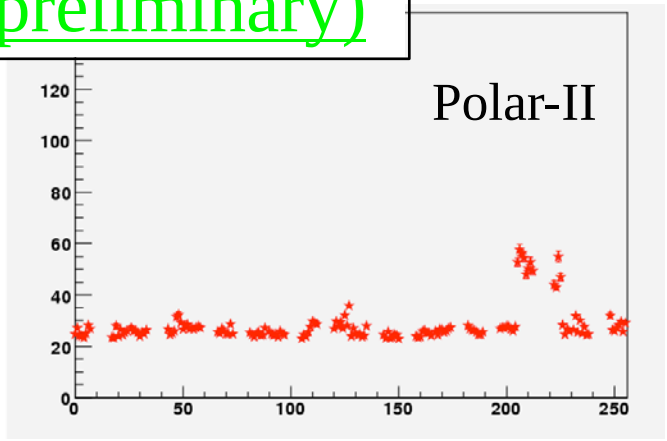
JET/IDC



- Position resolution was improved
  - ✓ r-ϕ resolution ~150μm → ~ 130μm
  - ✓ z resolution 25~80mm → ~ 25mm

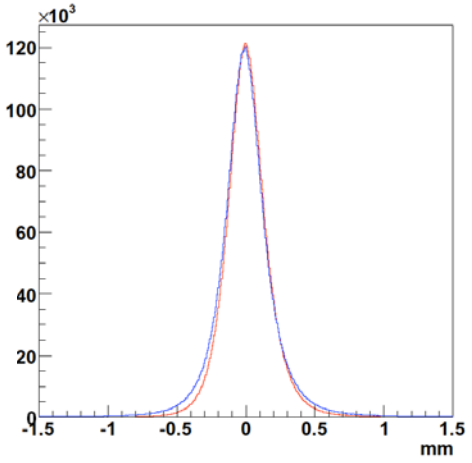
#Wire vs σ_z (preliminary)





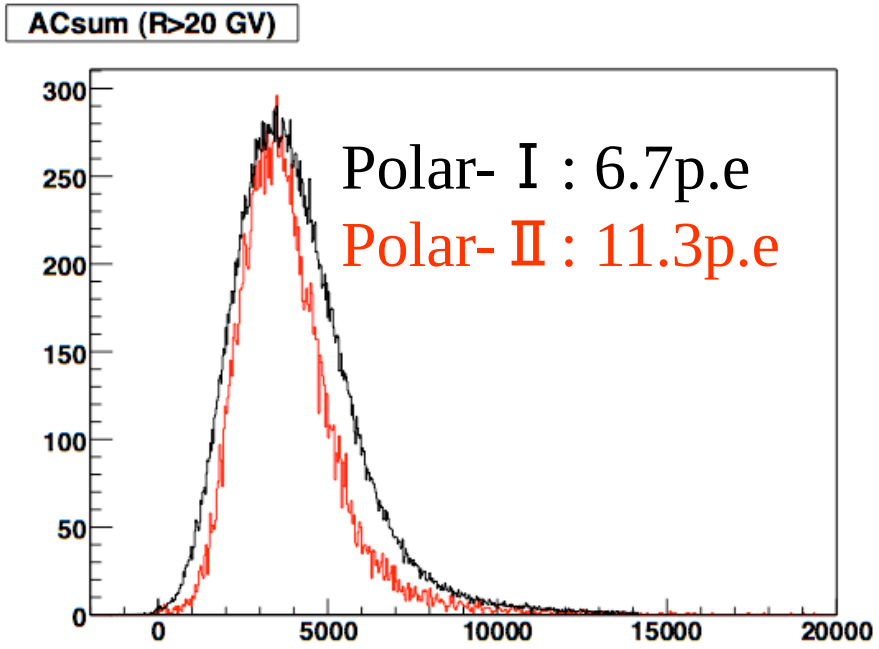
- Performance is almost same before/after HV changing.

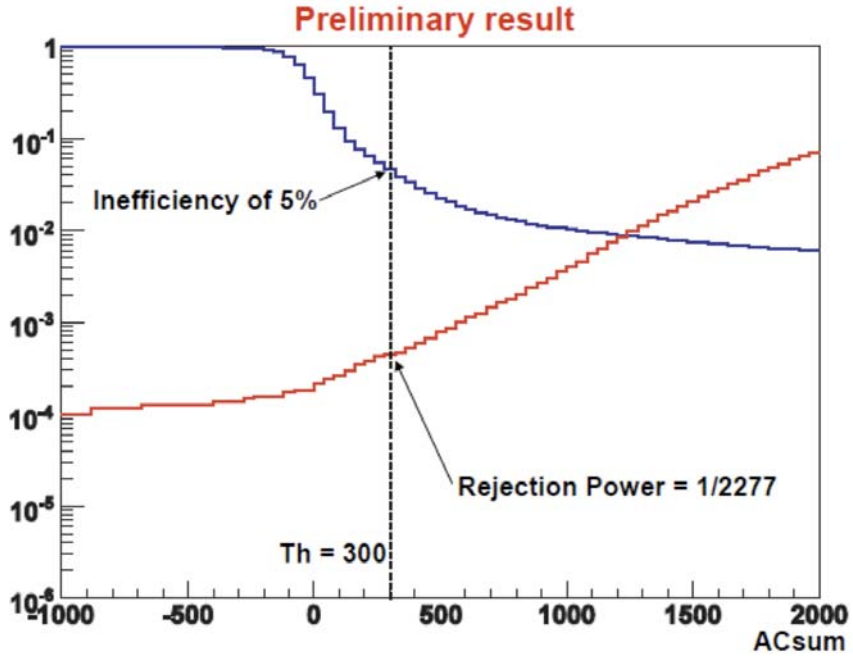
JET Resolution (r-ϕ)
HV (nominal) ~126um
HV (lower) ~130um



ACC

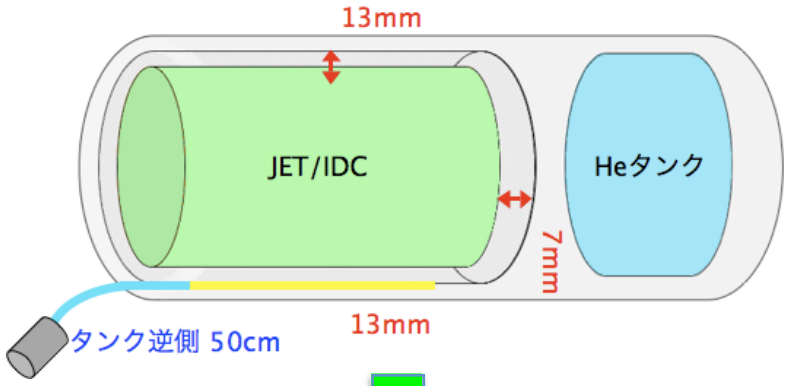
- Light yield (for relativistic proton)
  - 6.7 p.e. → 11.3 p.e. (expected = 11.9 p.e.)
- Background rejection power (600 → >2000)



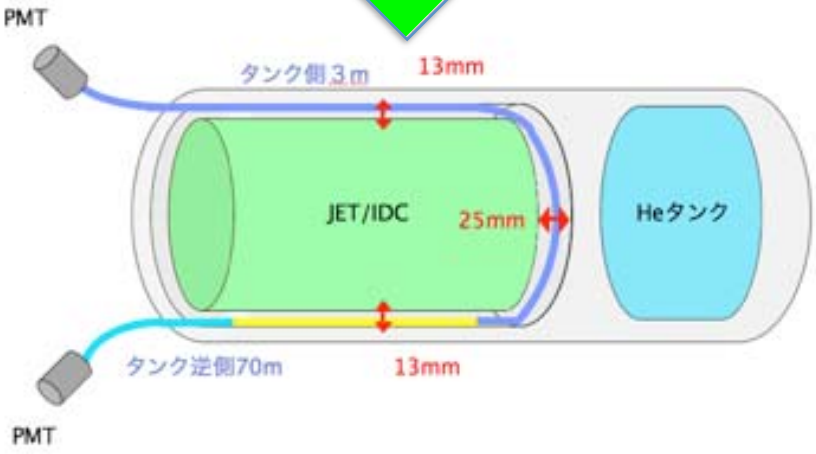


Middle TOF

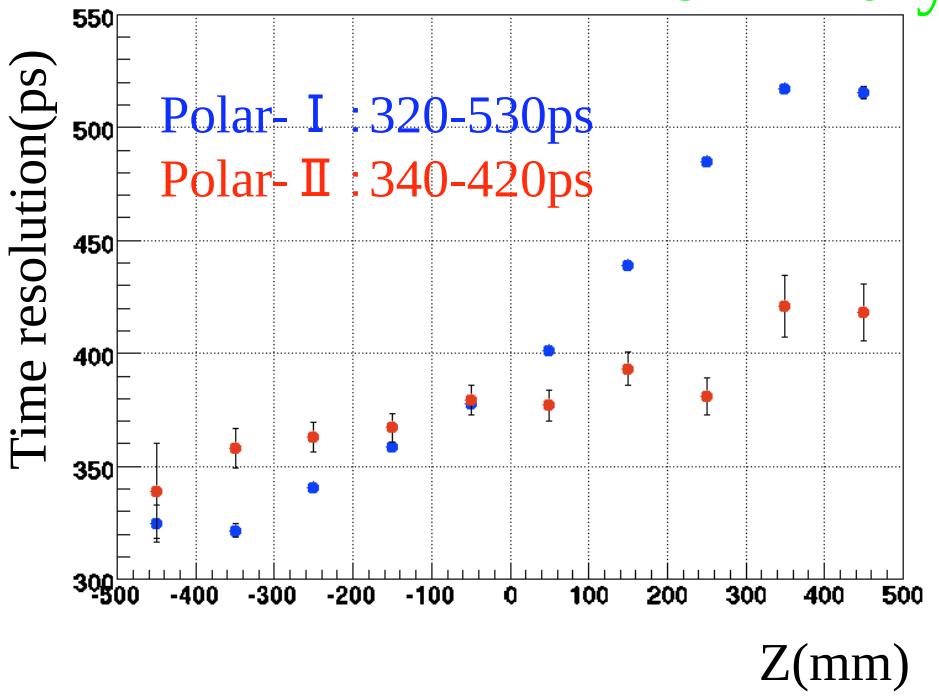
Polar-I



Polar-II



Preliminary



- Uniformity of timing resolution was improved.
- Axial position can be measured. (σ_z ~ 65mm)

Detector performance (summary)

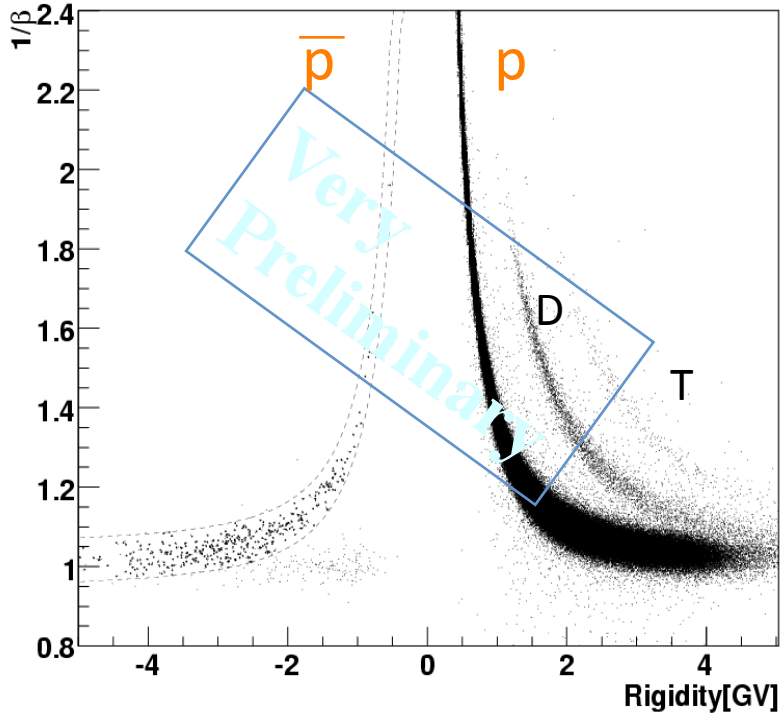
Preliminary

		BESS Polar-Ⅰ	BESS Polar-Ⅱ
JET	r-φ resolution (μm)	150	~130
	z resolution (mm)	25 – 80	25
ULTOF	Dead PMT or turn off	18/44	2/44
	Time resolution (ps)	~160	~120
MTOF	Time resolution (ps)	320-530	340-420
	z position resolution (mm)	N/A	68
ACC	Npe	6.7	11.3
	Background rejection power	~ 600	~ 2270 or more

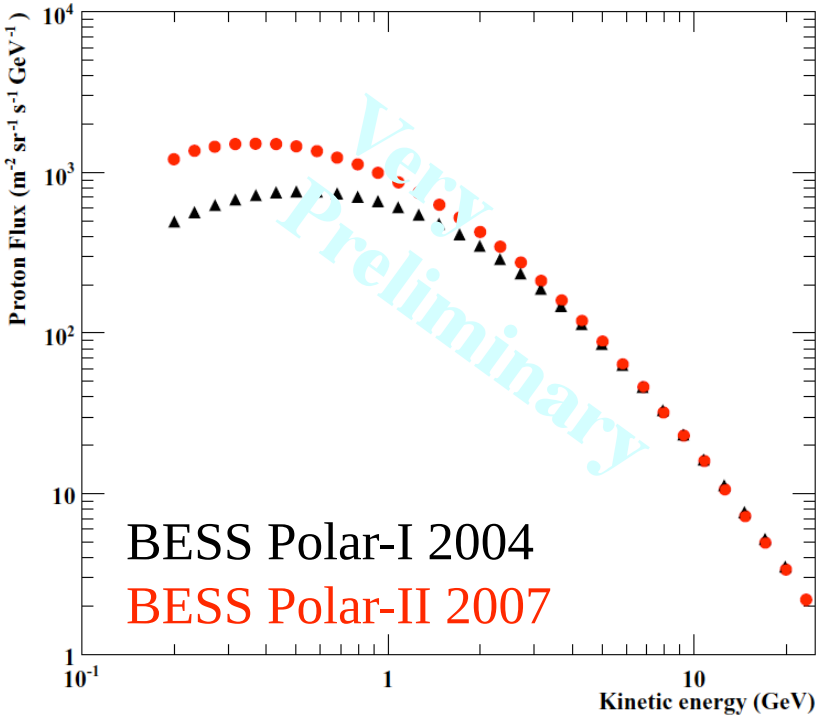
Almost everything was improved !

Data

1/β vs Rigidity (3rd days 10.4 hours)



Proton flux (3rd days 2.5 hours)



- Detector calibration and analysis is in progress.

  * More than 10000 Antiprotons is expected. (20 x BESS97)

Summary

- BESS is an unique experiment
  - balloon observations with continuous upgrades covering more 1 solar cycle (1993 – 2008)
- BESS Polar-I
  - establish the long duration flight
  - in progress to report/publish the result
- BESS Polar-II
  - successfully carried out just in the solar minimum
  - 10 ~ 20 x statistics of the previous solar minimum
  - Detector functioned well without critical problems
  - Analysis in progress.

Stay Tuned !

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