Latest Results from BESS and Related Topics

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for the BESS Collaboration

(KEK / NASA-GSFC / Tokyo / Kobe / Maryland / ISAS)

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BESS Collaboration

(as of July 2003)

•KEK

T.Kumazawa, Y.Makida, K.Matsumoto, J.Suzuki, K.Tanaka, A.Yamamoto, T.Yoshida, K.Yoshimura

•NASA/Goddard Space Flight Center

T.Hams, J.W.Mitchell, A.A.Moiseev, J.F.Ormes, M.Sasaki, R.E.Streitmatter

•The Univ. of Tokyo

H.Fuke, S.Haino, K.Izumi, S.Matsuda, N.Matsui, H.Matsumoto, J.Nishimura, T.Sanuki, Y.Yamamoto

•Kobe Univ.

K.Abe, A.Itasaki, M.Nozaki, Y.Shikaze, Y.Takasugi, K.Takeuchi, K.Tanizaki, K.Yamato

•Univ. of Maryland

M.H.Lee, Z.D.Myers, E.S.Seo

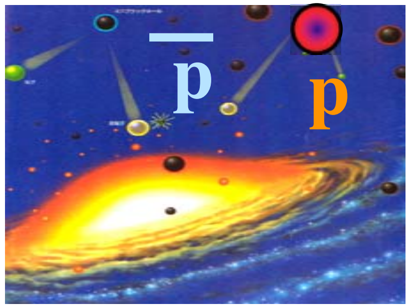
•ISAS

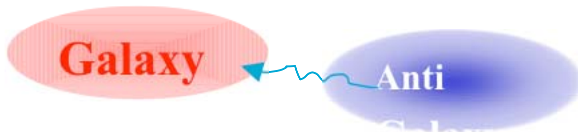
T.Yamagami

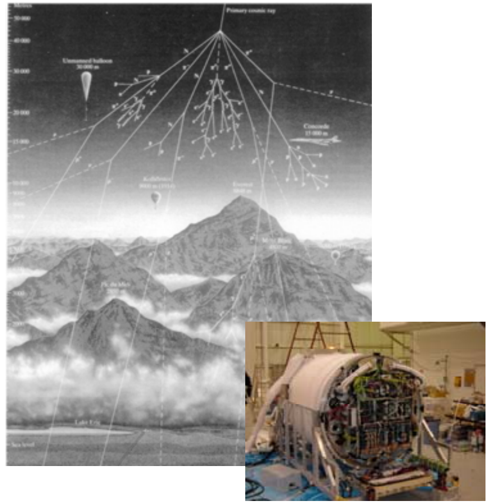
BESS

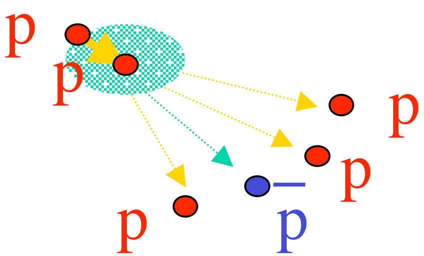
Balloon-borne Experiment with a Superconducting Spectrometer

- **Antiparticle/Antimatter**
  - **$\bar{p}$, $\bar{D}$** Novel cosmic origins
    - Evaporation of Primordial Black Holes
    - Annihilation of super-symmetric particles
  - **$\overline{He}$** Baryon Asymmetry in Universe
- **Fundamental Cosmic-ray Data**
  - **Precise spectra**,
    - Propagation, solar modulation, charge-sign dependence, atmospheric secondaries









$$p + A \rightarrow \pi + \pi + \cdots$$
$$\pi \rightarrow \mu + \nu_\mu$$
$$\mu \rightarrow e + \nu_e + \nu_\mu$$

Reports submitted to ICRC-03

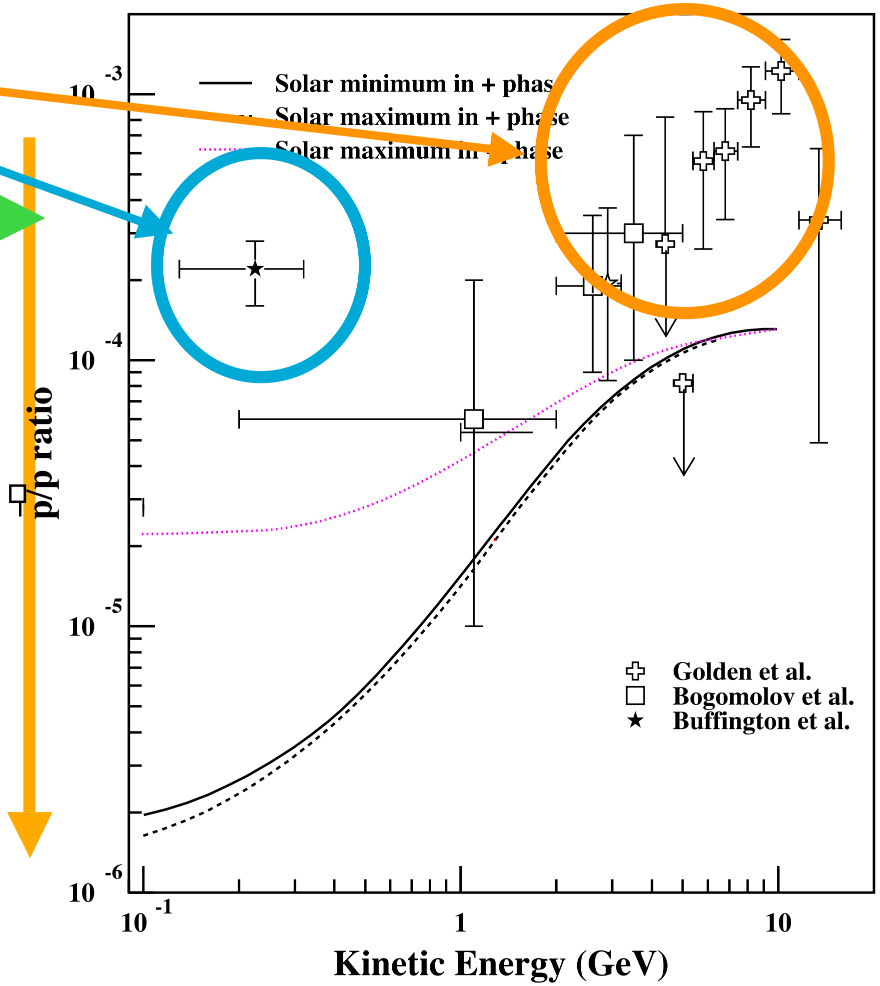
Search for cosmic-ray D-bar with the BESS,	**(OG1.1; H. Fuke),**
p and He spectra meas. with BESS-TeV,	**(OG1.1.14, S. Haino)**
Solar modulation effect on **p** spectra meas. by BESS	**(SH3.4.2; Y. Shikaze)**
3He and **4He** spectra from BESS 9 8 ,	**(OG1.1.10, Z. Myers)**
Detecting **3H** with the BESS Spectrometer,	(OG1.1; Z. Myers)
e spectrum to high energies with the BESS-1999,	(OG1.1.12, T. Hams)
Observation of atmospheric "p-bar" with BESS,	**(OG1.1; K. Yamato)**
p, p-bar and μ spectra at mountain altitude"	**(HE 2.1; T. Sanuki)**
Absolute flux of atmospheric μ with BESS",	(HE2.1.8; Y. Yamamoto)
Calculation of μ **fluxes at the small atmos. Depths**	**(HE2.4.6; K. Abe)**
Geomagnetic cutoff effect on μ spectra at ground	(HE2.1.7; (K. Tanizaki)
BESS-Polar experiment,	**(OG1.5.3, T. Yoshida)**

BESS Highlight

- BESS Progress
- Latest Results from BESS
  - Antiparticle search
  - High E. Protons at > 100 GeV
  - Atmospheric muons and antiprotons
  - Low E. particles and solar modulation
- BESS-Polar Plan

Search for Cosmic-ray Antiparticles

1979: First observation (Golden et al)
1981: Anomalous excess (Buffinton et al)
1985: ASTROMAG proposed
1987: LEAP
1988: Astromag frozen
1992: MASS
1993: BESS First Flight
1994: CAPRICE, HEAT
1996: Solar minimum
1997: ISOMAX
1998: CARPRICE, AMS-I
2000/2 Heat-pbar
PAMELA (Polar-orbit)
AMS (Space Station)
2007: Solar minimum

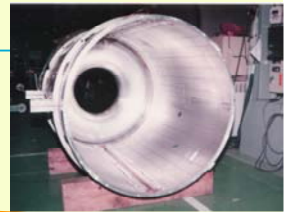


Search for Cosmic-ray Antiparticles

World-wide

1979:	First observation (Golden et al)
1981:	Anomalous excess (Buffinton et al)
1985:	ASTROMAG proposed
1987:	LEAP
1988:	Astromag frozen
1992:	MASS
1993:	BESS First Flight
1994:	CAPRICE, HEAT
1996:	Solar minimum
1997:	ISOMAX
1998:	CARPRICE, AMS-I
2000/2	Heat-pbar
	PAMELA (Polar-orbit)
	AMS (Space Station)
2007:	Solar minimum

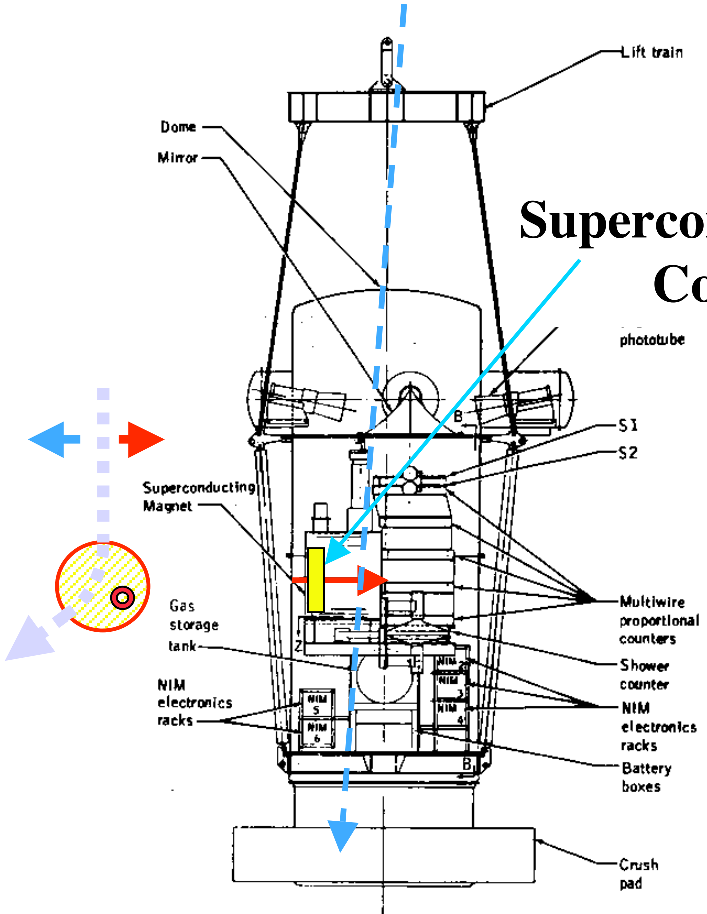
BESS



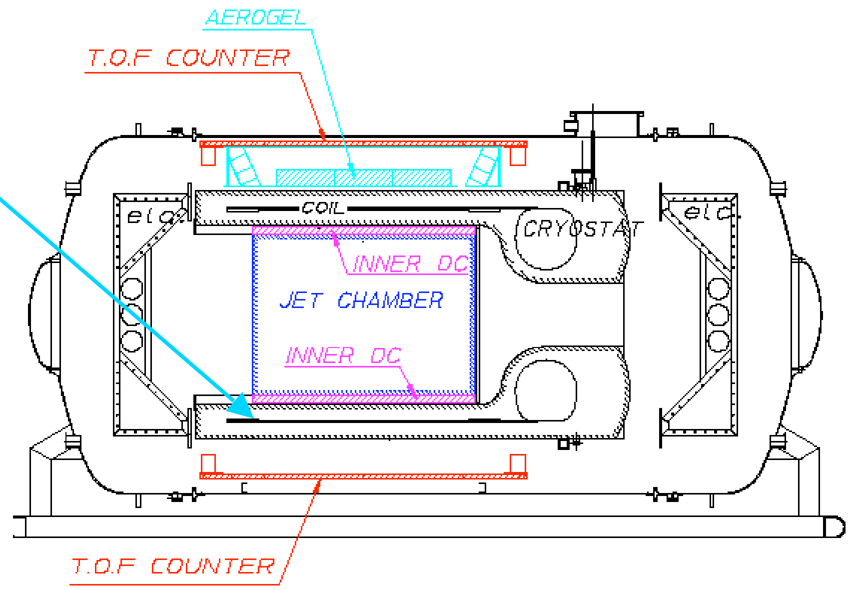
1985	Thin Solenoid conf. proposed
1987:	Collaboration formed
1993/4:	First Mass-identified Detect.
1995~7:	Distinctive peak at 2 GeV
1998:	Spectrum at < 4.2 GeV
	Proton spectrum up to 120 GeV
2000:	Charge dependence, p-bar/p
2001:	Atmospheric p and p-bar, mu
2002:	BESS-TeV
2004:	BESS-Polar (Plan)
2006/7	BESS-Polar (Plan)

BESS Thin Solenoid Spectrometer with Large Acceptance

Supercond. Coil



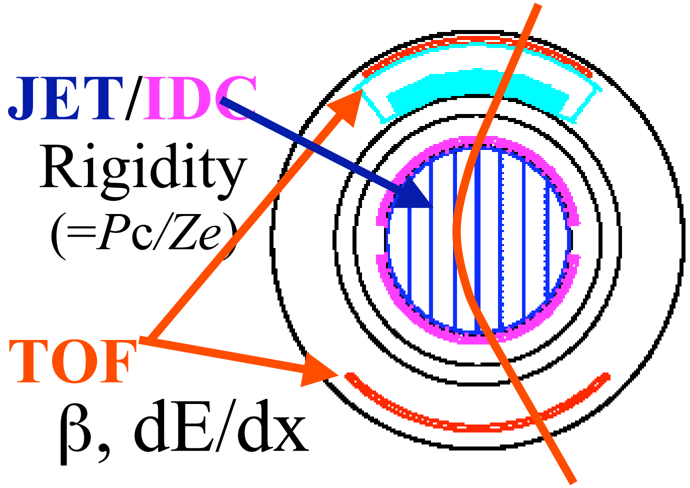
LEAP/CAPRICE



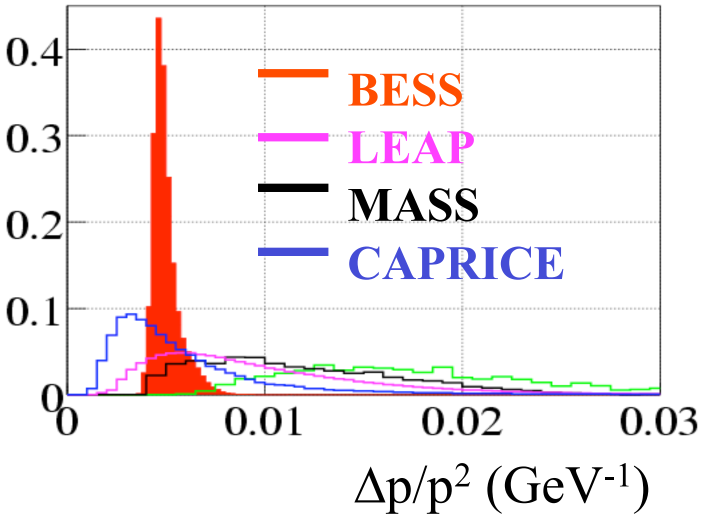
BESS

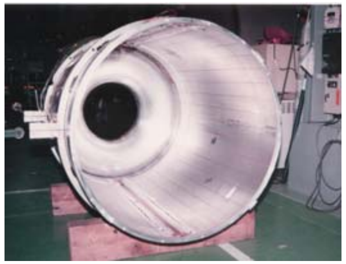
Thin Solenoid Spectrometer

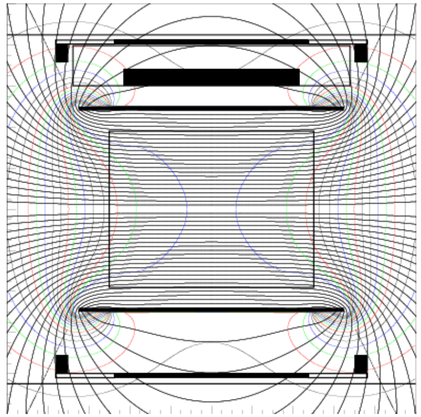
- Large Acceptance
  - High Statistics
- Uniform magnetic field
  - High, uniform resolution
  - MDR=200 GV
- Definitive mass ID



$$m^2 = R^2 e^2 Z^2 \left(\beta^{-2} - 1\right)$$

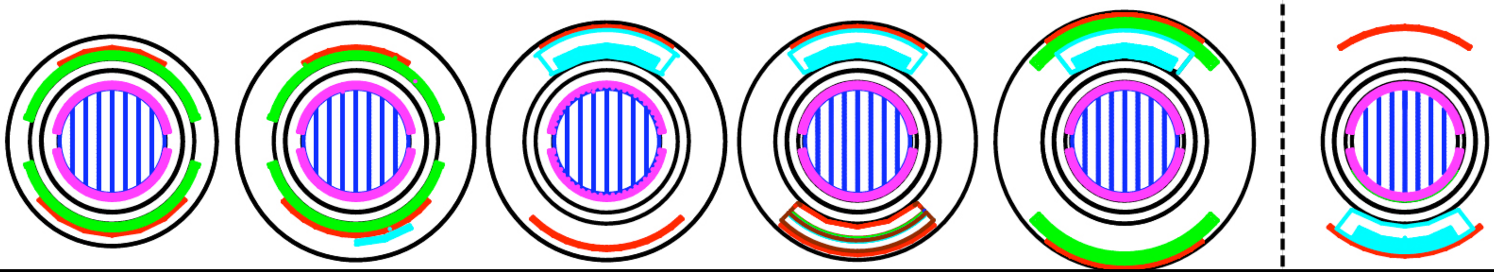






BESS Spectrometer Progress

⇒Future



BESS-93,94	BESS-95	BESS-97,98	BESS-99,00	BESS01,02 BESS-TeV	BESS-Polar
	Larger Vessel			Larger Vessel	No Vessel
σ_{TOF} =300 ps	σ_{TOF} =110 ps	σ_{TOF} =70 ps Aerogel C 97 n=1.03 $\bar{p}$ 0.2-3.5 GeV 98 n=1.02	Shower Counter $2X_0$ Lead e/μ sep.	New ODC's New JET/IDC's p/He up to 1 TeV	New Mag (ultra thin)
$\bar{p}$ 0.2-0.6 GeV	$\bar{p}$ 0.2-1.4 GeV	$\bar{p}$ 0.2-4.2 GeV	$\bar{p}$ 0.2-4.2 GeV	$\bar{p}$ 0.2-4.2 GeV	$\bar{p}$ 0.1-4.2 GeV

- **BESS improved in every 9 flights successful, with**
- **Maximizing advantages in Balloon Experiments, and**

BESS Highlight

- BESS Progress
- Latest Results from BESS
  - **Antiparticle search**
  - High E. Protons at > 100 GeV
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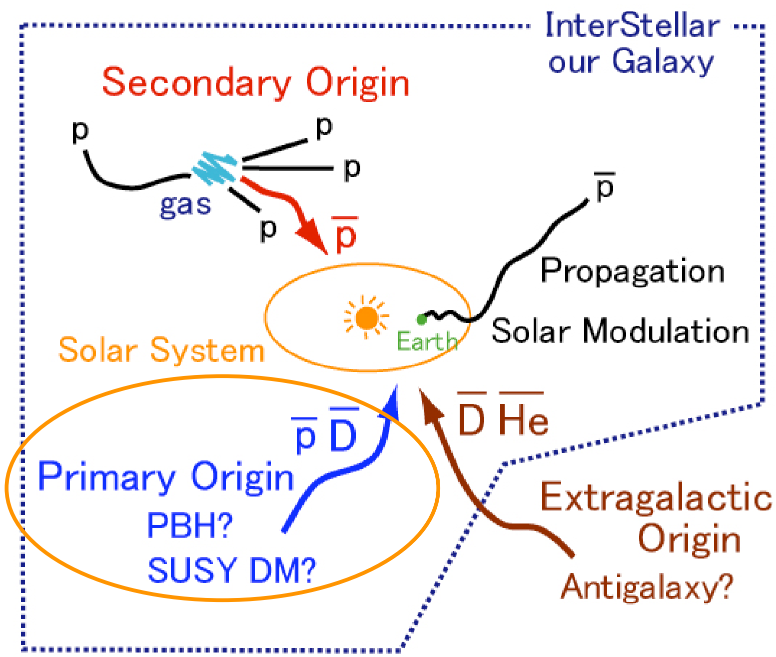
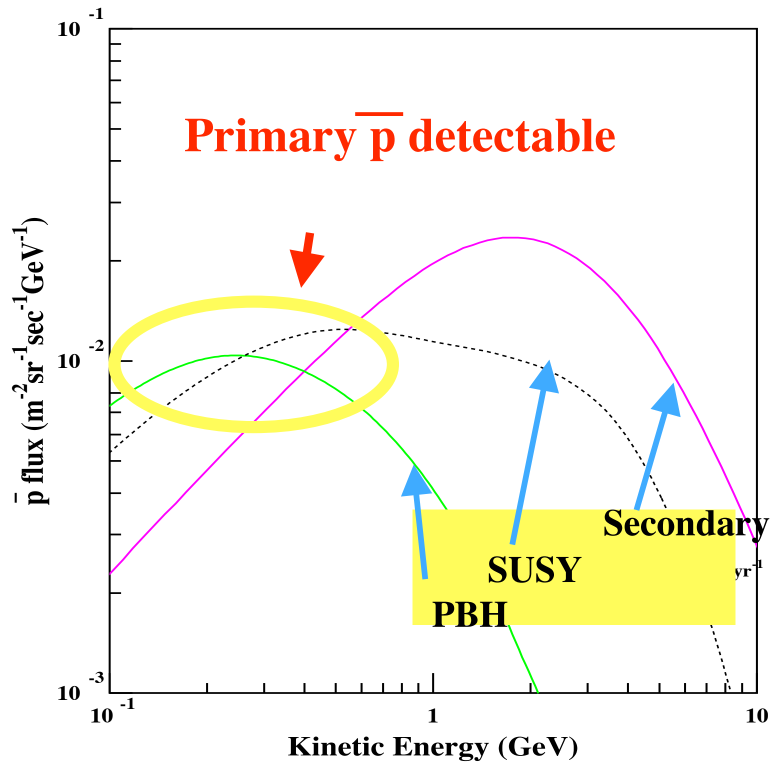
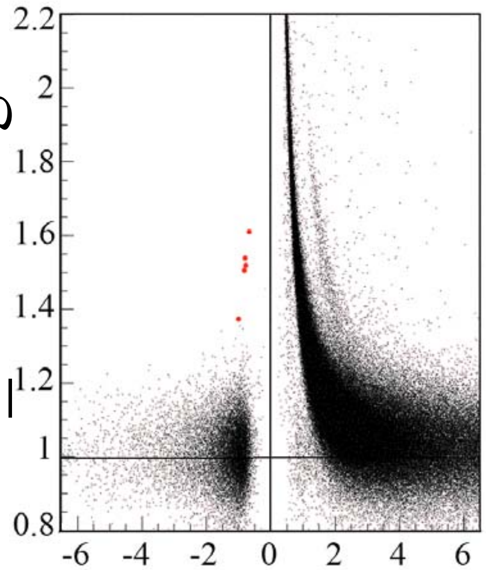
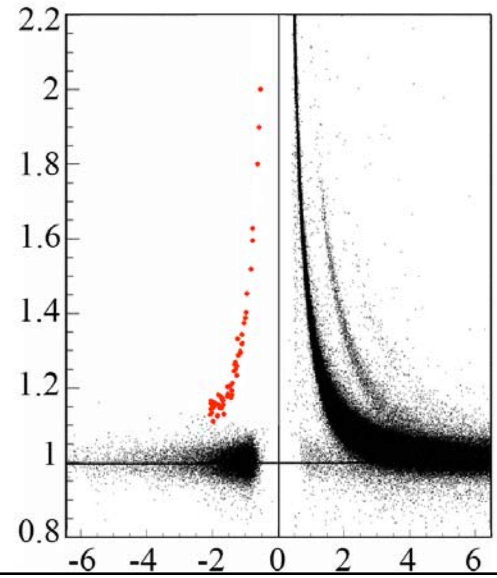
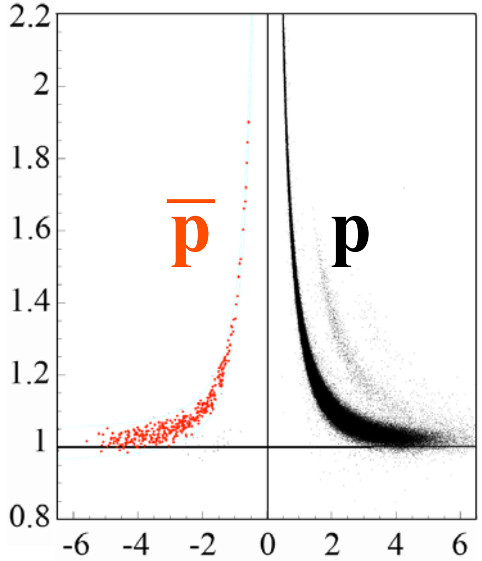
Search for Antiprotons of Novel Primary Origins



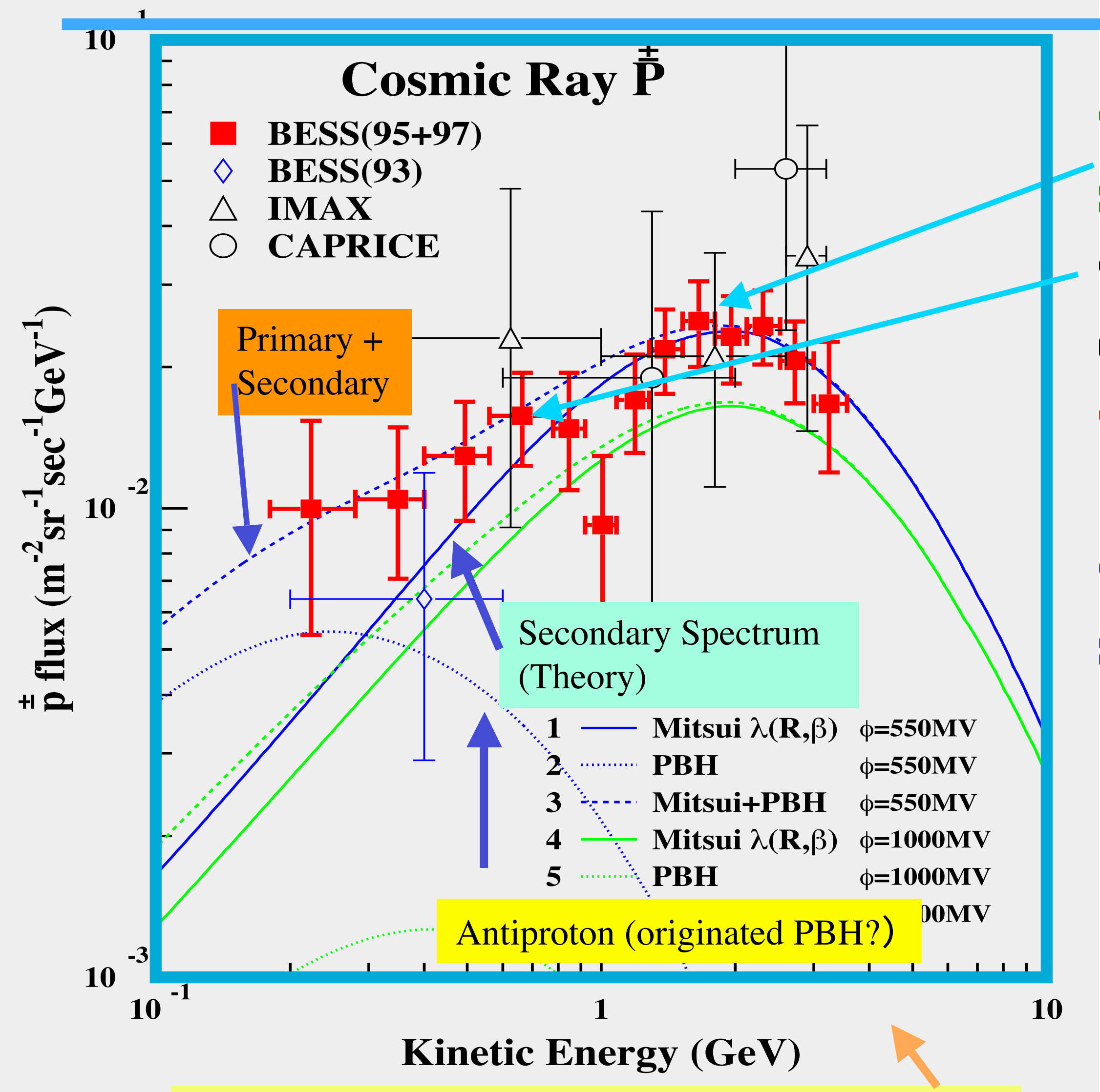


- Primary origins relatively enhanced at < 1 GeV,
- Low energy antiprotons are ideal probe.

Progress of Spectrometer and $\bar{p}$ measurement

	1993 + 94	1995	1997 ~
-1 vs. Rigidity			
_TOF	300 ps	100 ps	**70** ps
N_{obs}	8	~ 40	~ **500** /year
$E_{\bar{p}}$	0.2 ~ 0.6 GeV	0.2 ~ 1.4 GeV	0.2 ~ 4 GeV
	First mass-ID	**New-TOF**	**Cherenkov Veto**

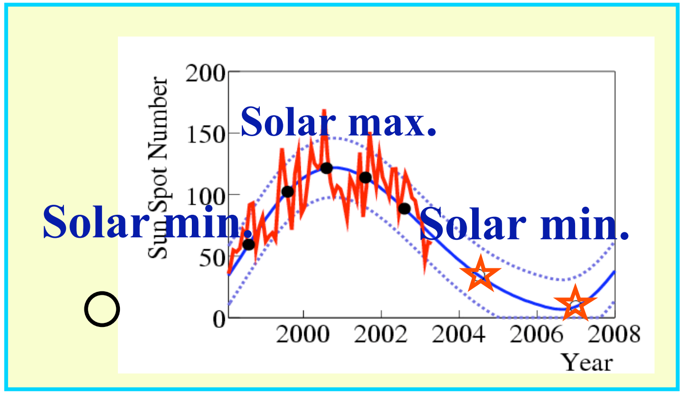
Low Energy Antiproton Spectrum



(S. Orito et al. PRL, Vol. 84, No, 6, 2000)

- Characteristic peak for secondary antiproton
- Flatter spectrum in low energy?
- Primary Origin?

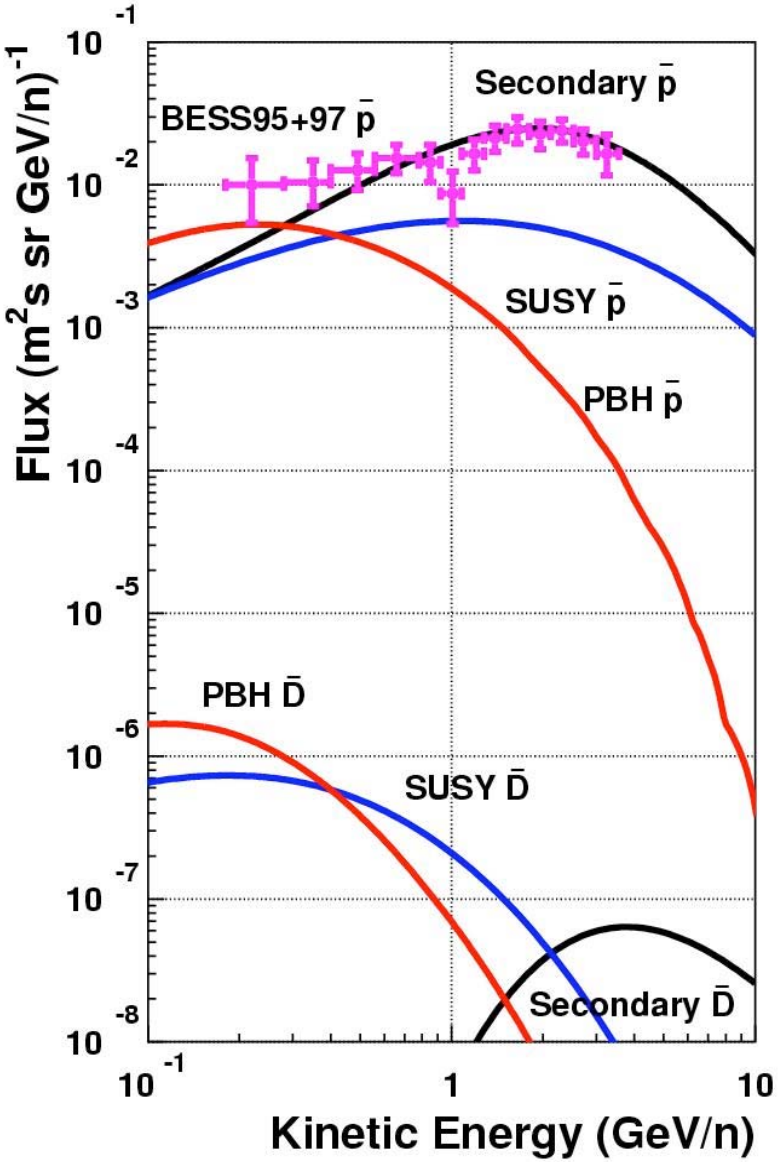
- High statistics in next solar mini. anticipated!



Search for Anti-deuteron

- **In contrast to $\bar{p}$,**
- **Secondary $\bar{D}$ should be negligible in L.E. region**

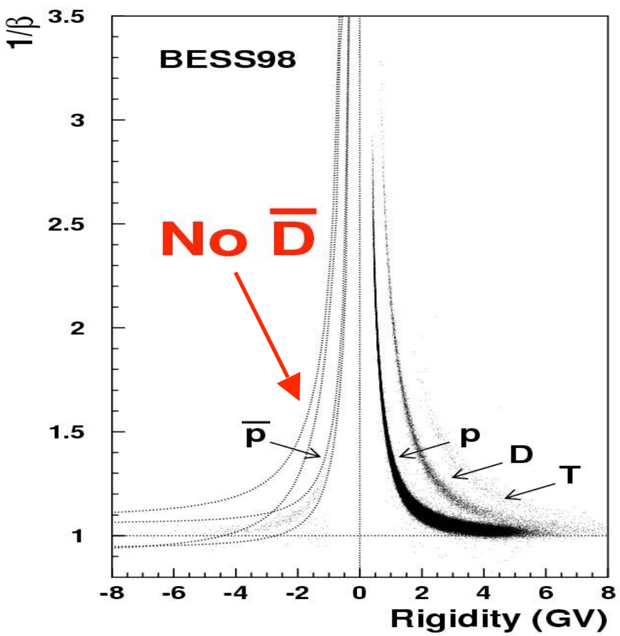
- **If $\bar{D}$ observed:**
  - **Primary Origin !!**

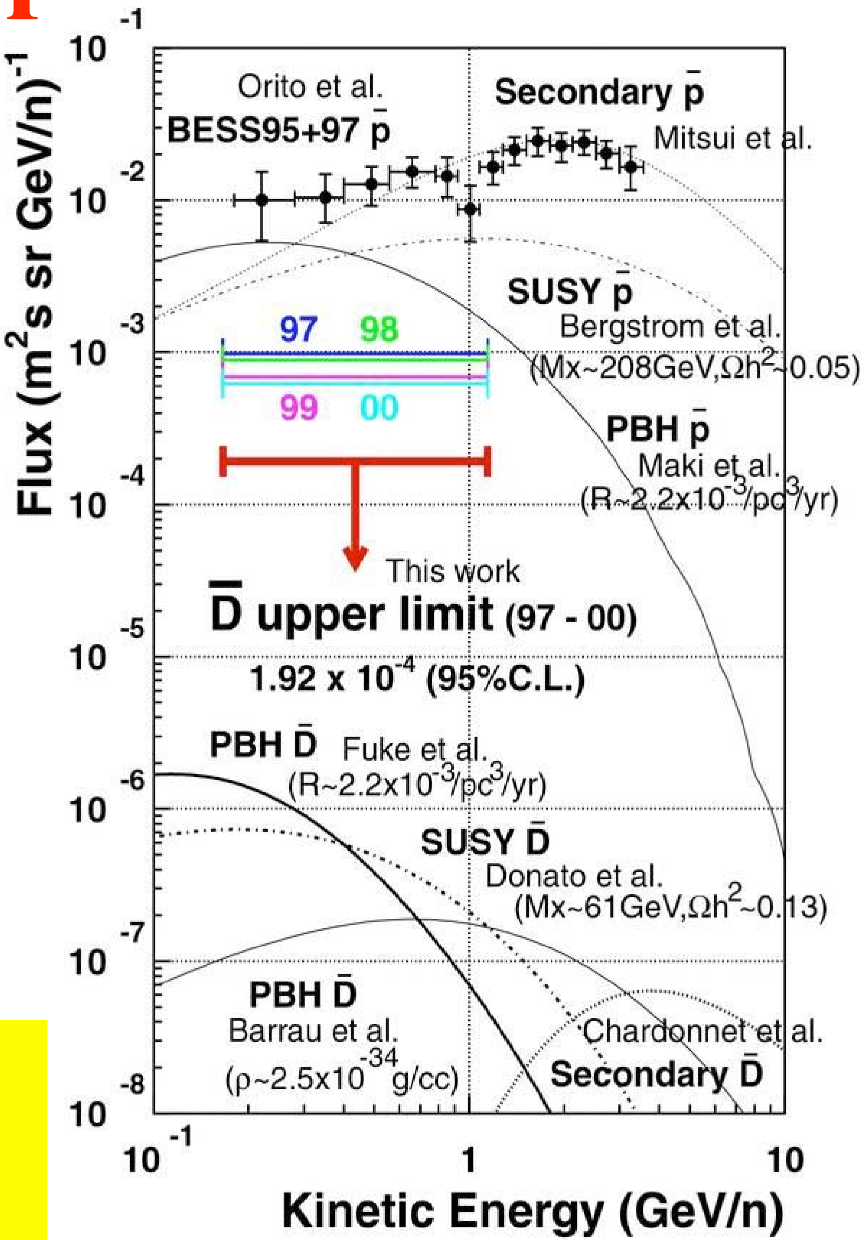


Antideuteron Upper Limit

(Fuke et al., OG1,1,-P)

$\overline{D}$ searched in BESS-97, 98, 99, 00





$\overline{D}$ upper limit, for the first time,

1.92×10^{-4} $(m^2 s.sr.GeV/n)^{-1}$

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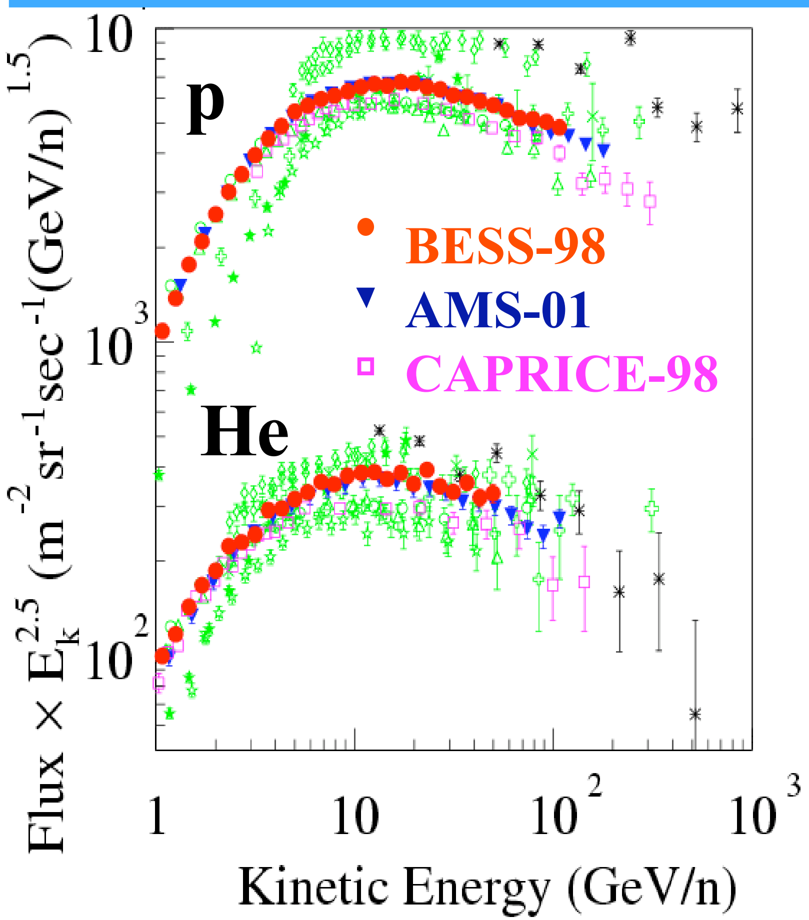
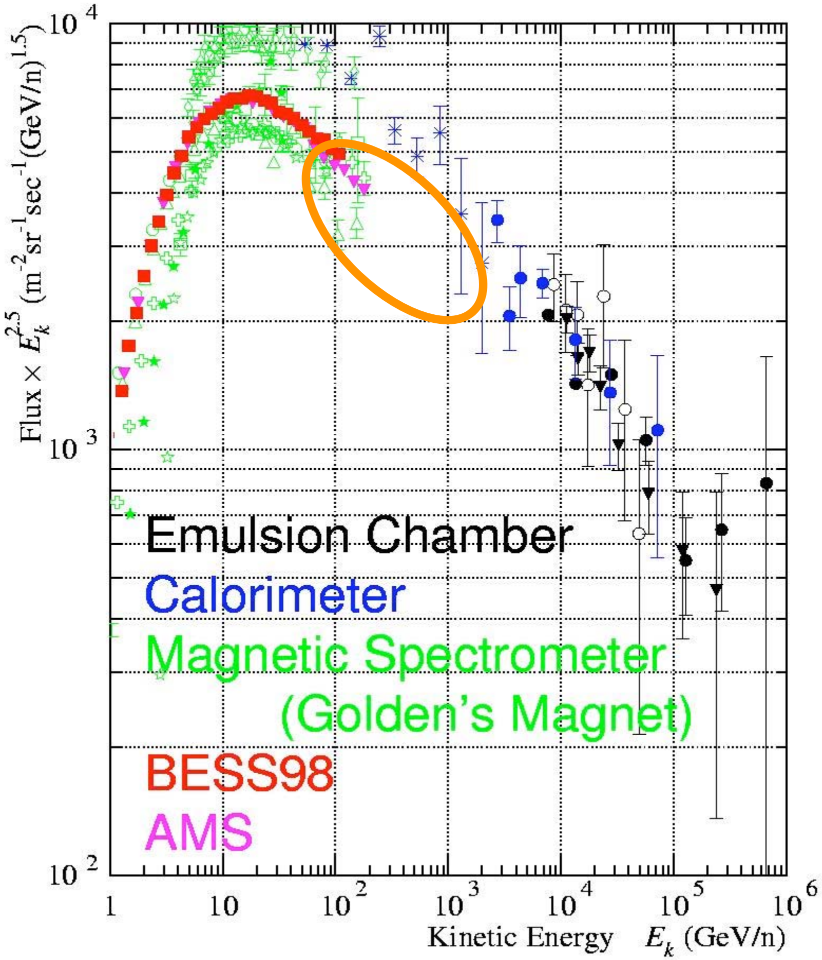
P and He Spectra from BESS-98





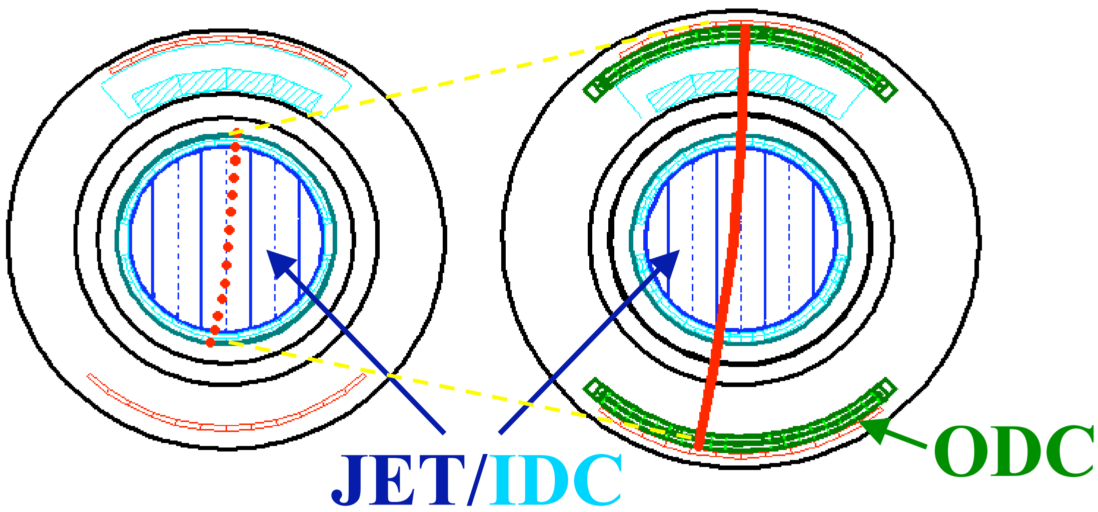
- To be extended up to: > 500GeV
- Spectrometer Upgraded: MDR ~ 1.5 TeV

Improvement in BESS-TeV

Tracking upgraded:

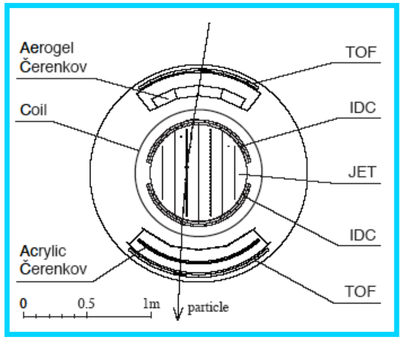
JET/IDC
Outer Drift Chambers
Istalled to improve
Momentum resolution

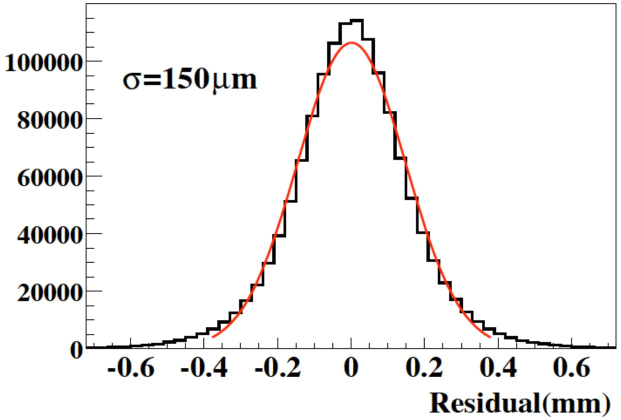
- **Sampling: ~ x 2**
- **Track-length: ~ x 2**



	BESS-98	BESS-TeV
JET/IDC; **N**-track(δx)	24 (200 μm)	52 (150 μm)
JET/IDC/ODC; **L**-track	0.8 m	1.6 m
MDR	**200 GV**	**1400 GV**

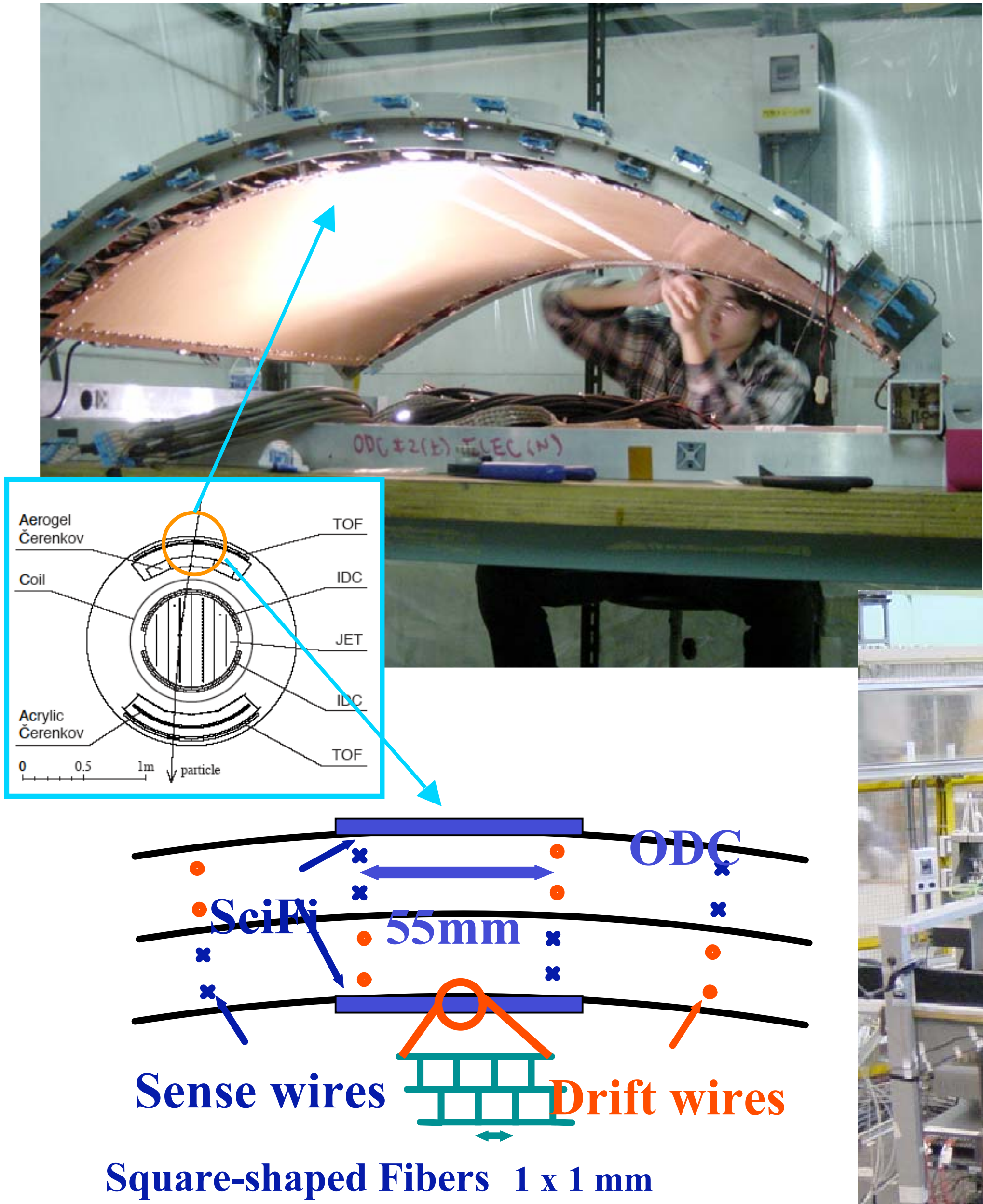
JET/IDC Development for
BESS-TeV (-Polar)

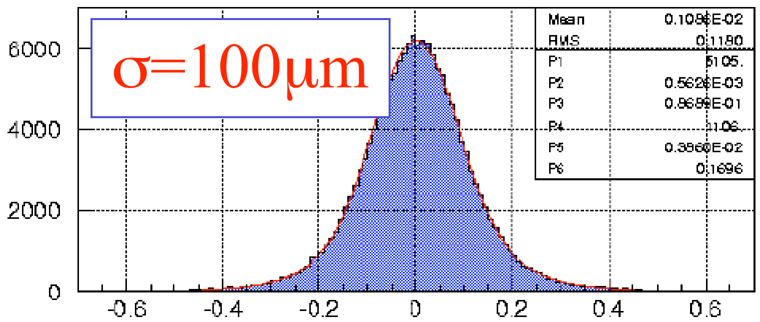


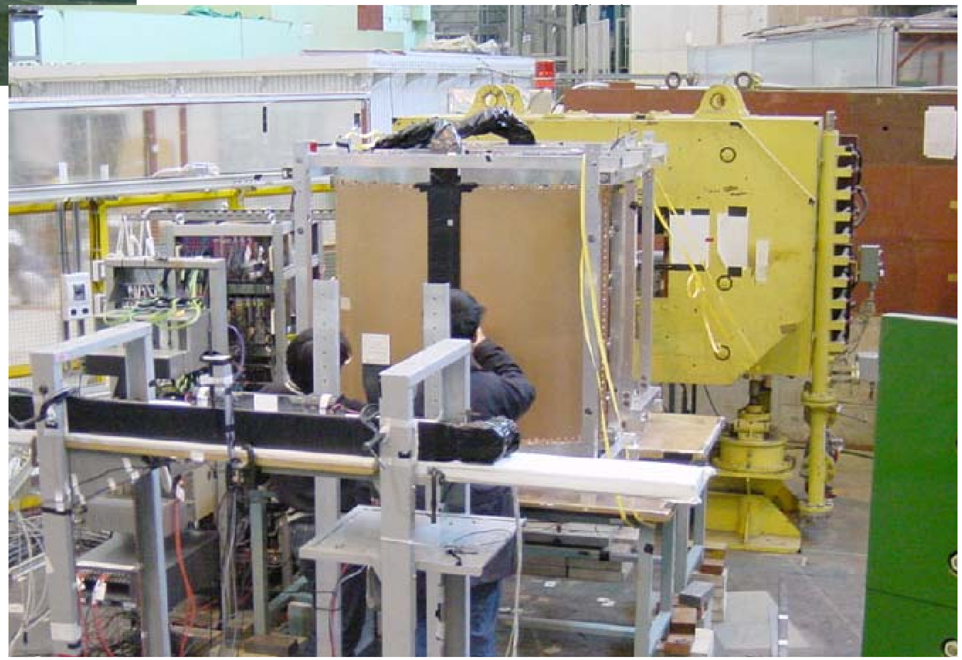


Spatial resolution

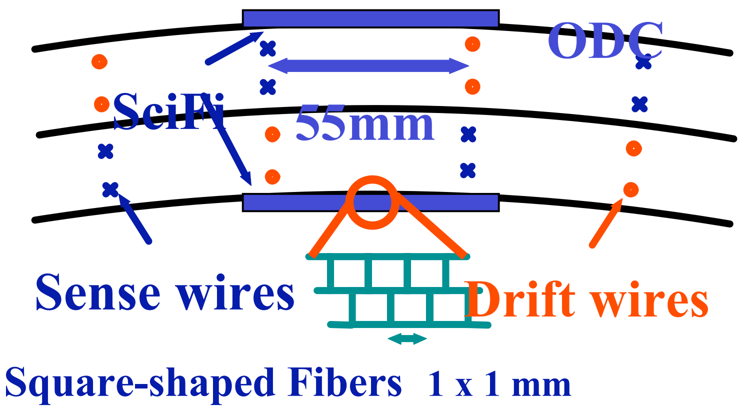
ODC
and Beam Test

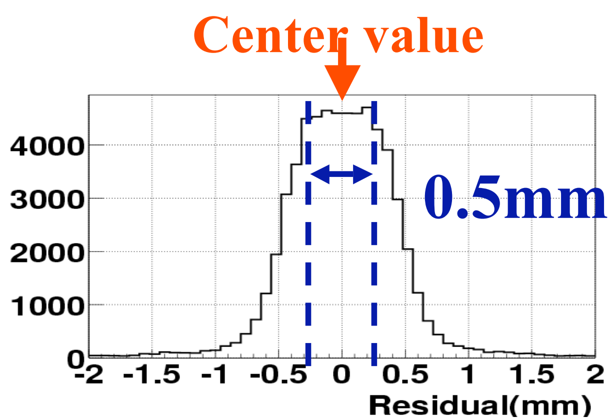


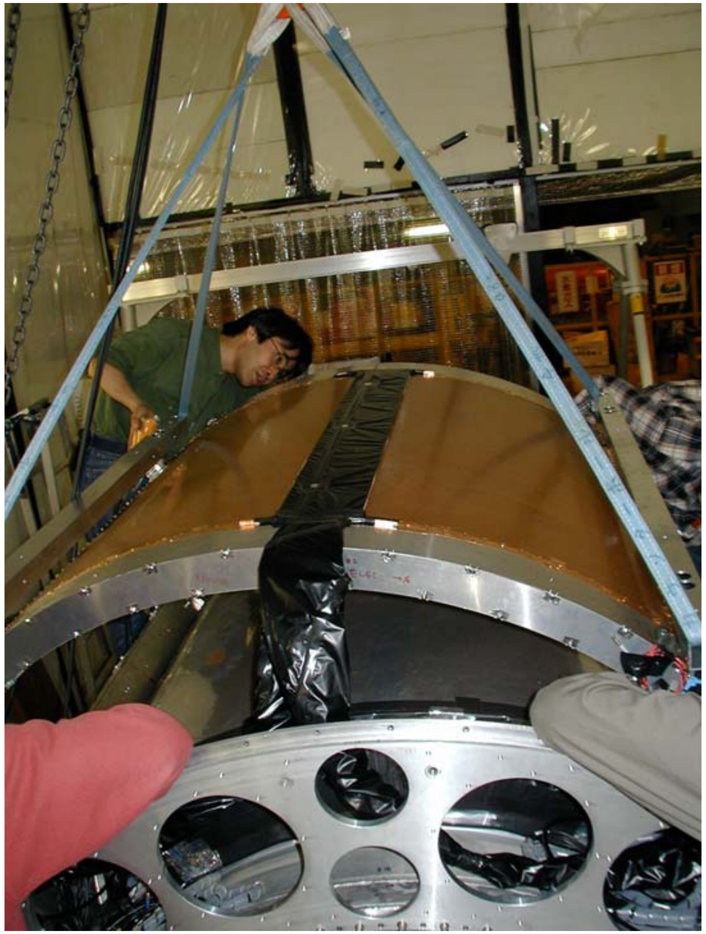




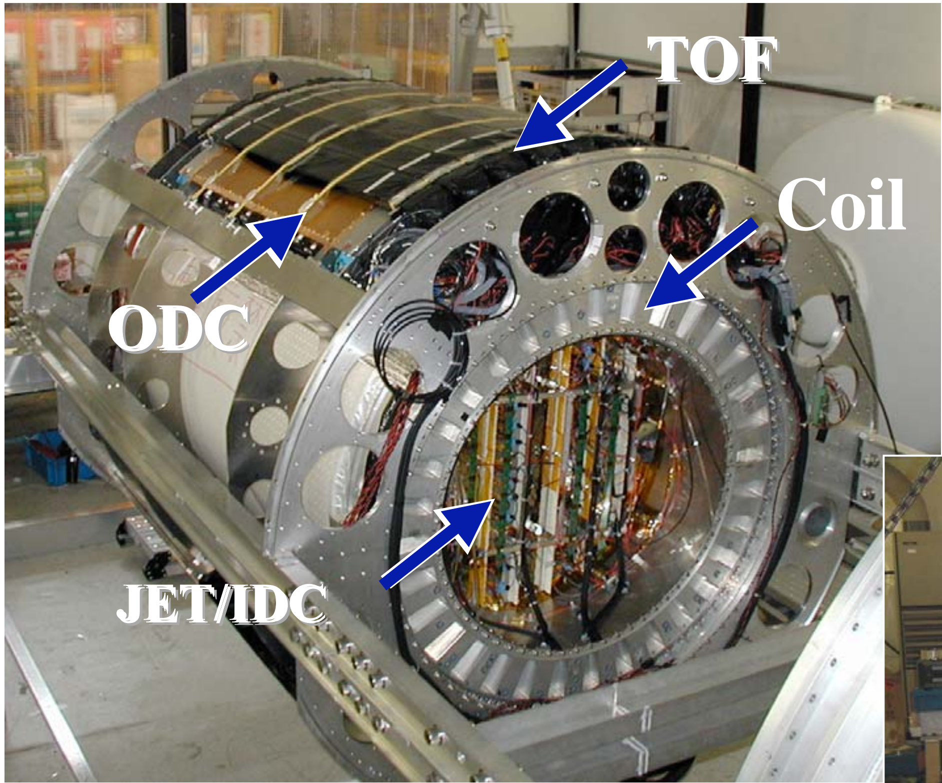
Scintillation-Fiber Counters for absolute calibration

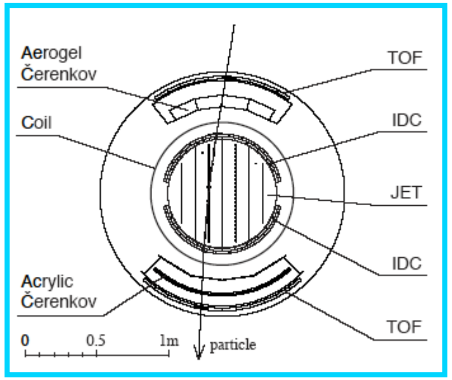


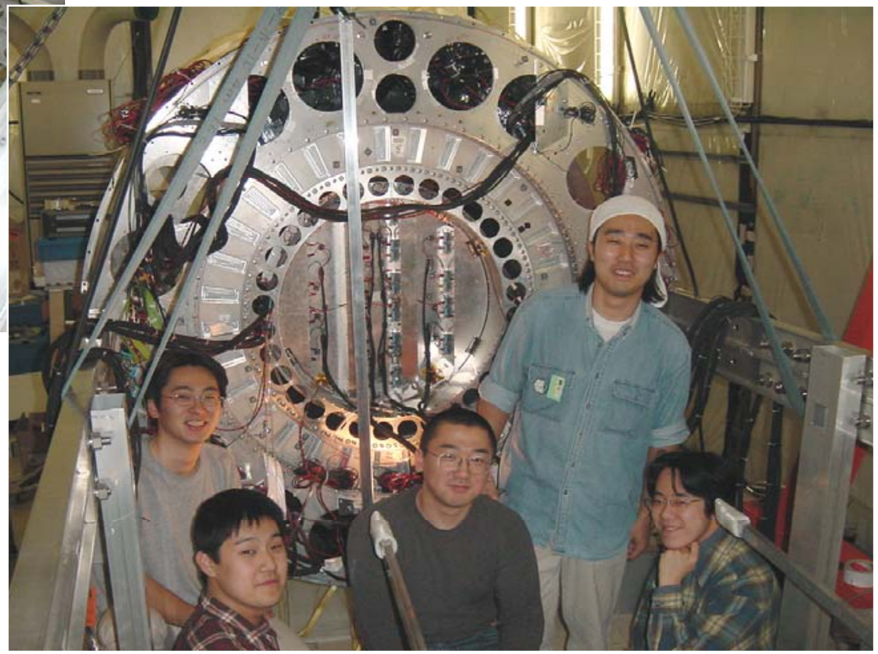




BESS-TeV Assembled

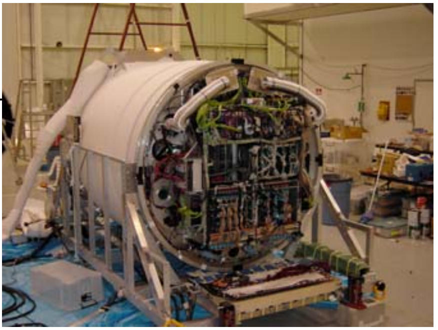






History of BESS-TeV (01 and 02)

1999 Construction started



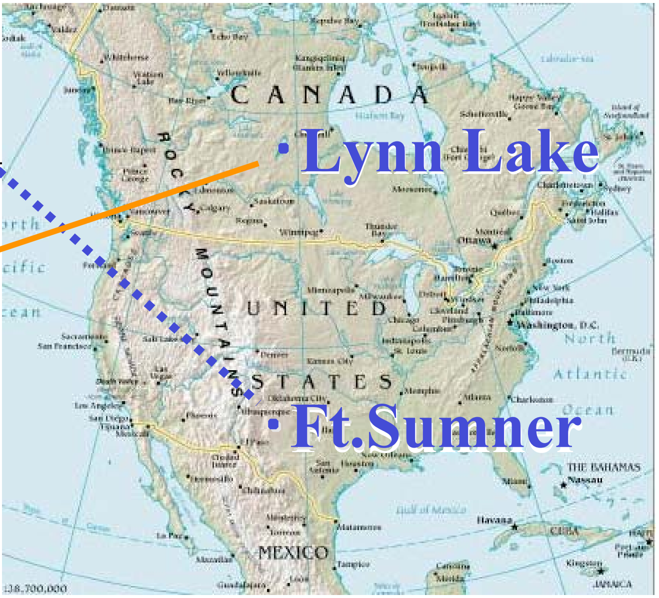
2001 **Flight at Ft.Sumner**

New ODC installed

Balloon not staying at float,

Slow descending

μ/p/He at small atm. depth



2002 Flight at Lynn Lake

New JET/IDC installed,

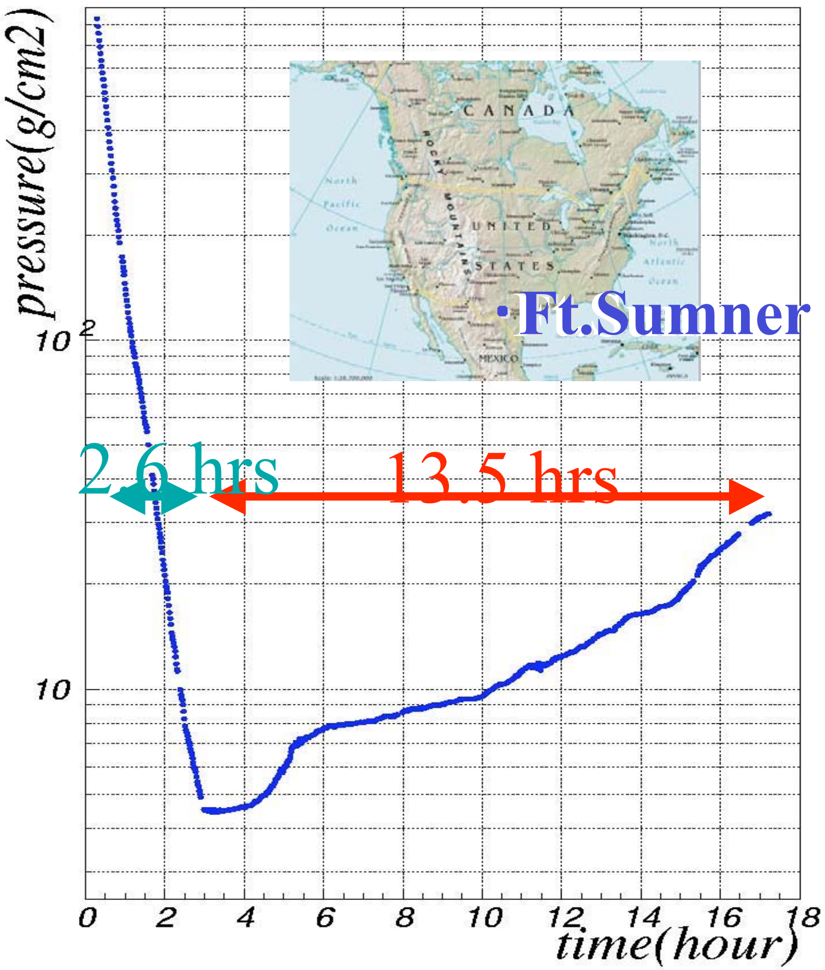
Flight successful, but shorter

p/He,

low energy $\bar{p}$

BESS-01

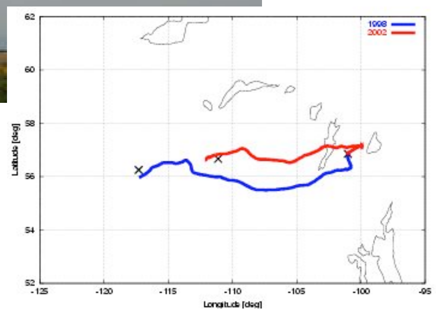
Balloon slowly descended

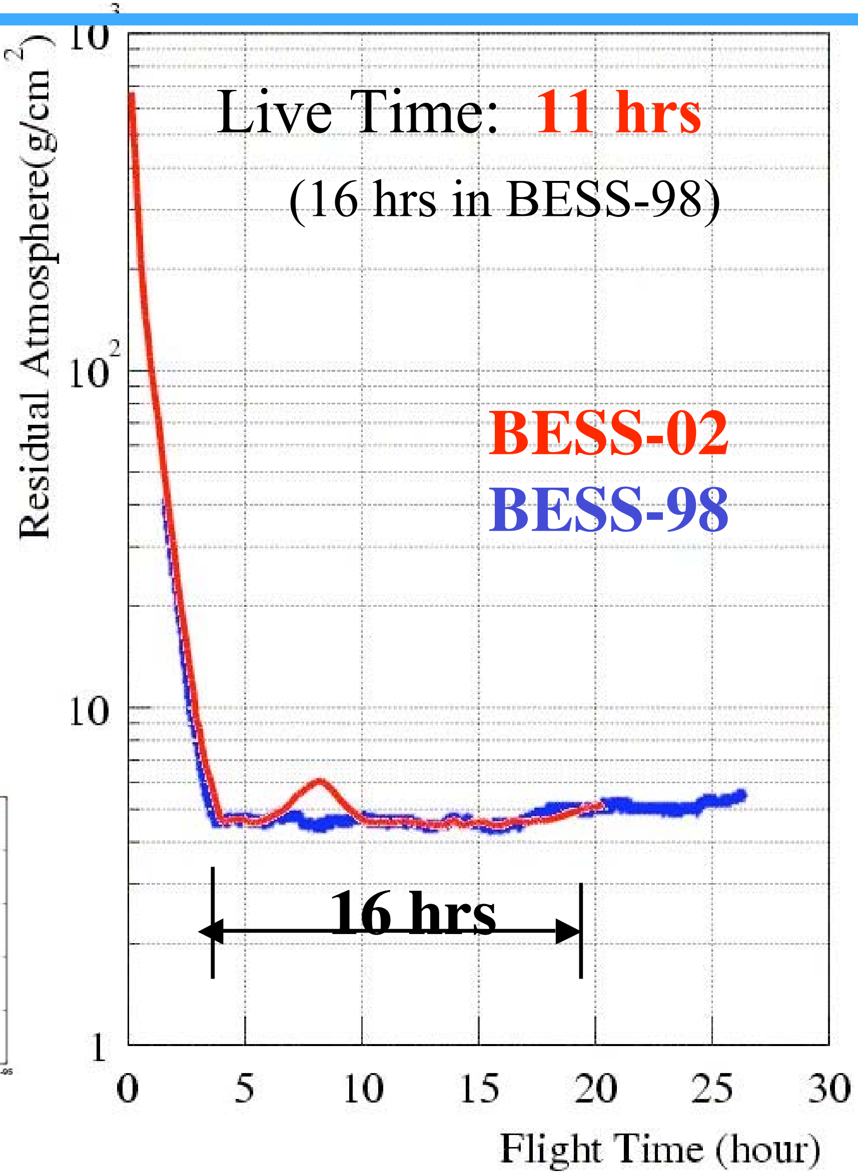


- Floating not enough for high energy proton/helium observation, however,
- A unique chance to observe atmospheric muons and antiproton
- (to be discussed later)

BESS-02 Flight

Successful

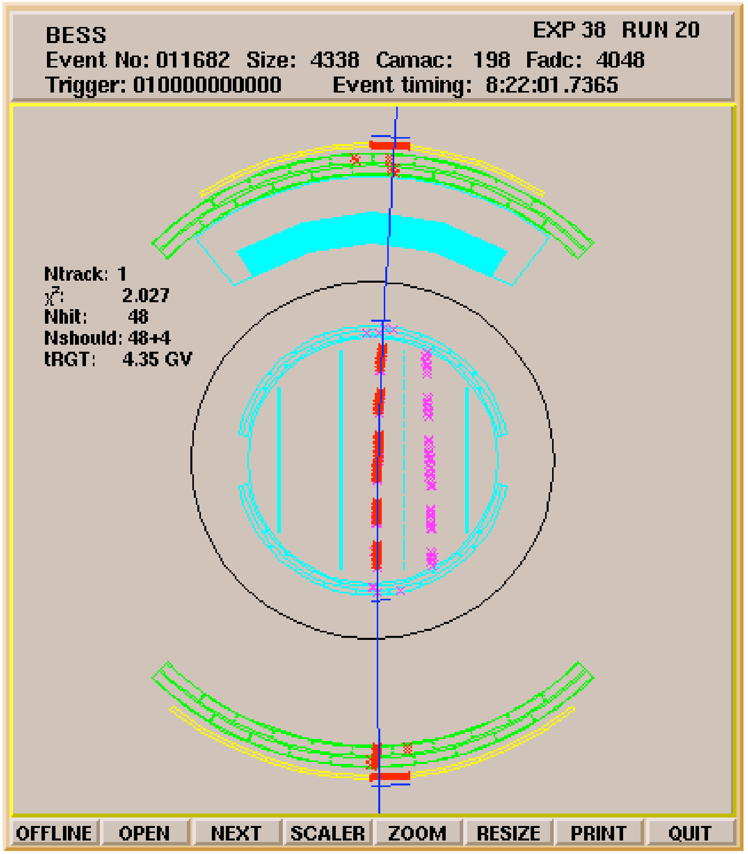




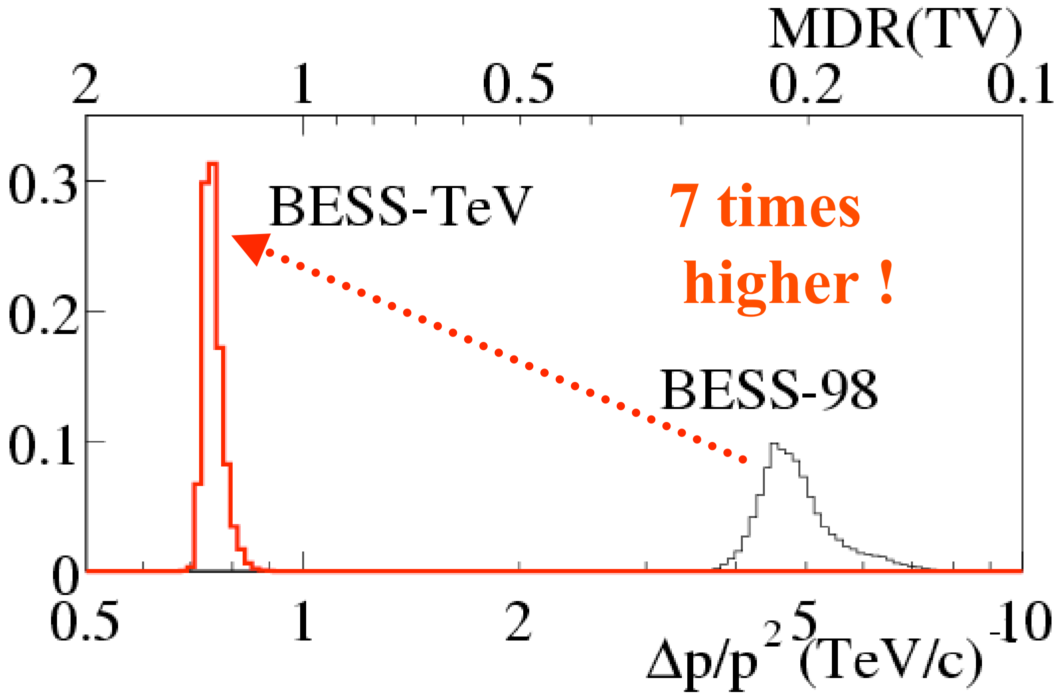
BESS-TeV (-02)

- **Flight successful, but short because of earlier termination,**
- **Observation with a live time of 11 hrs,**
- **Data corresponding to ~1/4 compared with the original plan for BESS-TeV (two flight in 01 and 02),**
- **Analysis progressing with maximizing data reduction efficiency, and**
- **The preliminary result, obtained with ~70 % data, is given as follows:**

MDR achieved in BESS-TeV (-02)



Event Display in Flight



- **Momentum resolution achieved**

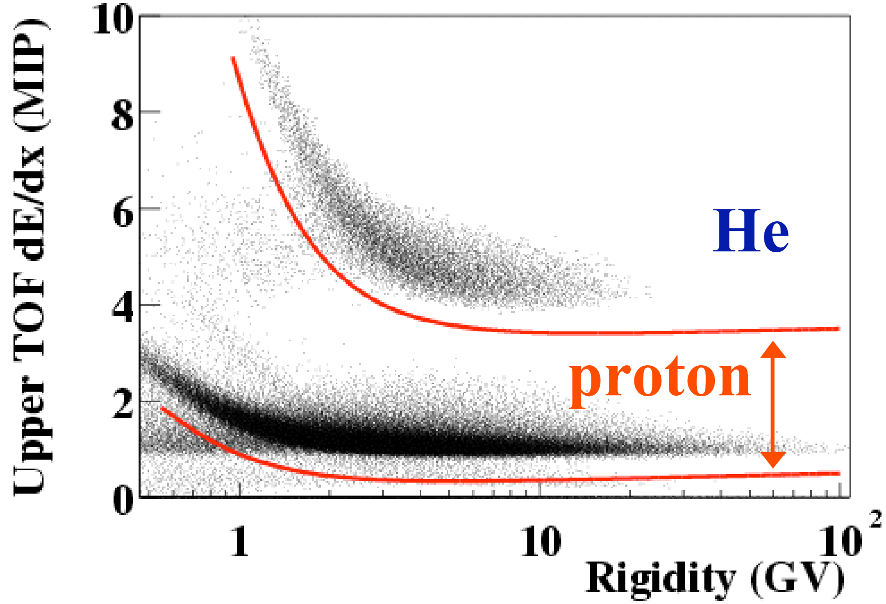
  $\Delta p/p^2$ = **0.7** $(TeV/c)^{-1}$

  MDR = **1.4 TV**

Particle identification

Charge determination

dE/dx at Upper/Lower TOF counters

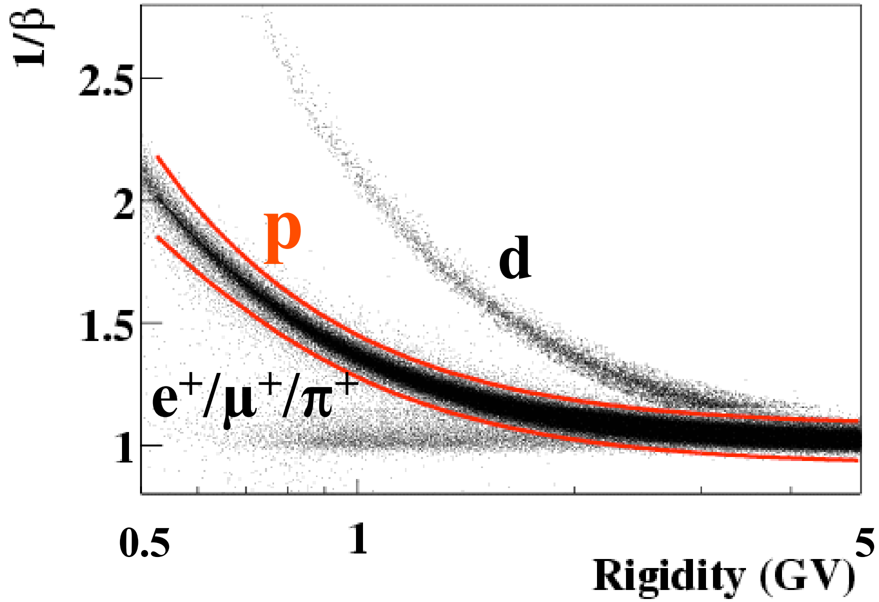


Mass reconstruction

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

d contamination < 2%

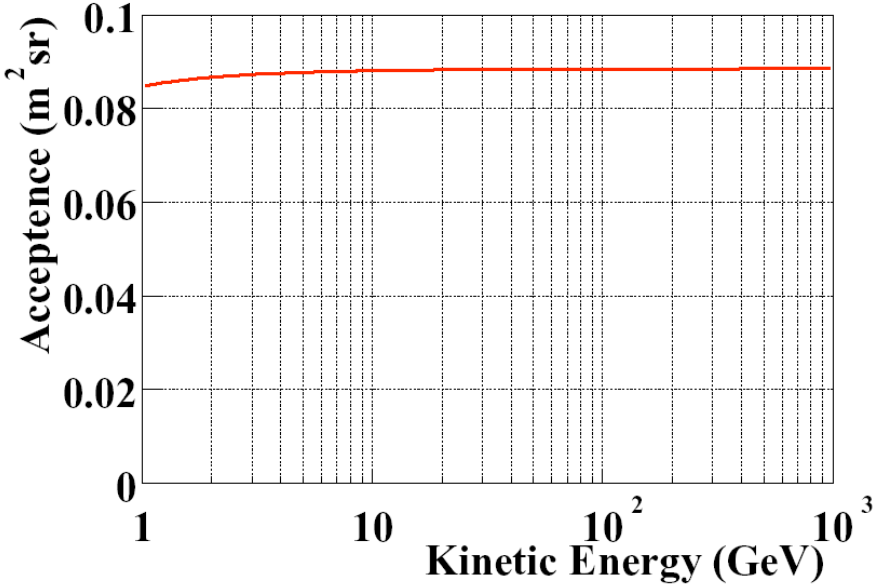
(R > 3GV)



Normalization for abs. flux

Geometrical acceptance

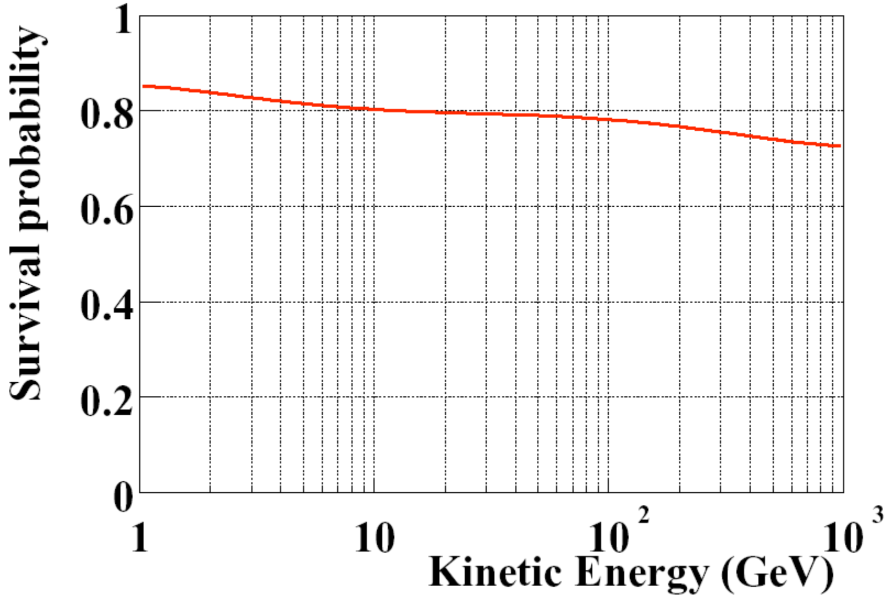
Simple cylindrical shape and **uniform** B field



Small corrections

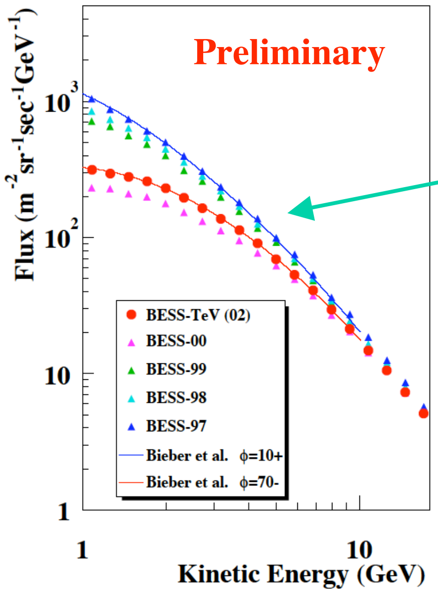
Survival prob. against interaction loss **~80%**

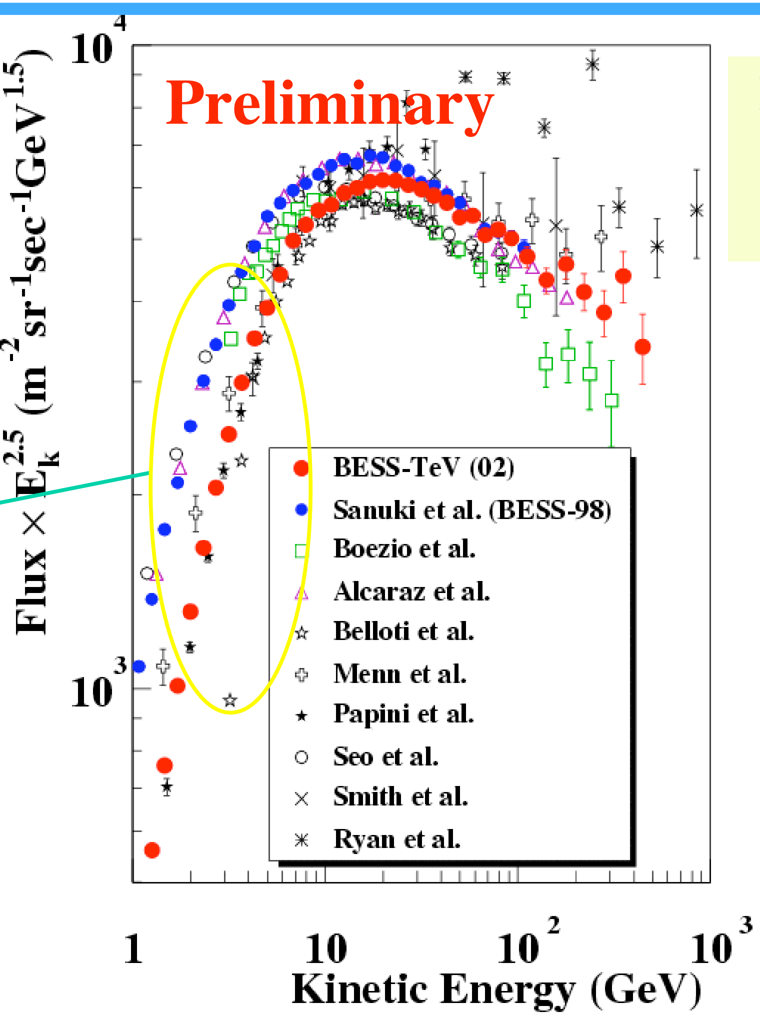
Few event quality cuts required



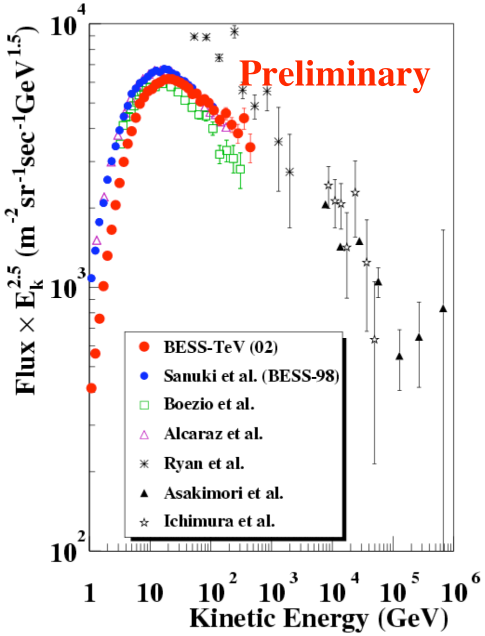
Proton Spectrum Extended to 500 GeV

(S. Haino et al.; OG1.1.14)





BESS-TeV Preliminary Result, Systematic Error not included



- **BESS-TeV result consistent with BESS-98, and AMS-I, at ~ 100 GeV,**
- **Lower energy fluxes may be explained with "Solar Modulation"**

Further analysis in progress

- **Estimation of systematic errors**
  efficiencies/corrections
  Drift chamber **calibration/alignment**

- **Improvement of statistics**
  by now, **half of the ODC** drift area used for
  E>100GeV where the best performance achieved.

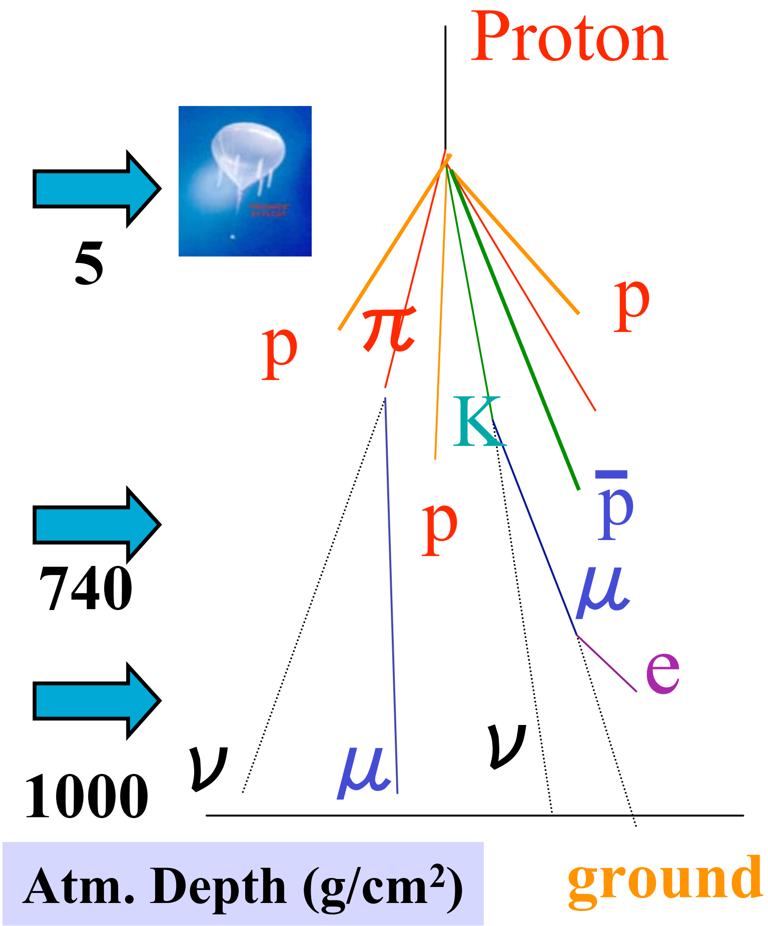
- **He spectrum**

BESS Highlight

- BESS Progress
- Latest Results from BESS
  - Antiparticle search
  - High E. Protons at > 100 GeV
  - **Atmospheric muons and antiprotons**
  - Low E. particles and solar modulation
- BESS-Polar Plan

BESS Providing Fundamental Data

at Various Atmospheric Depths

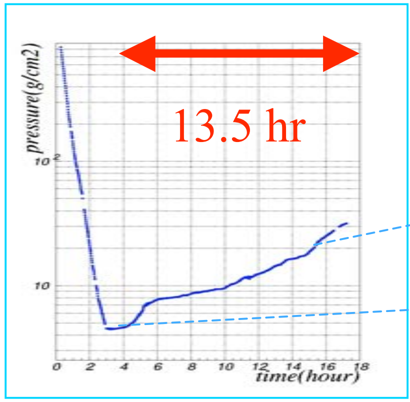


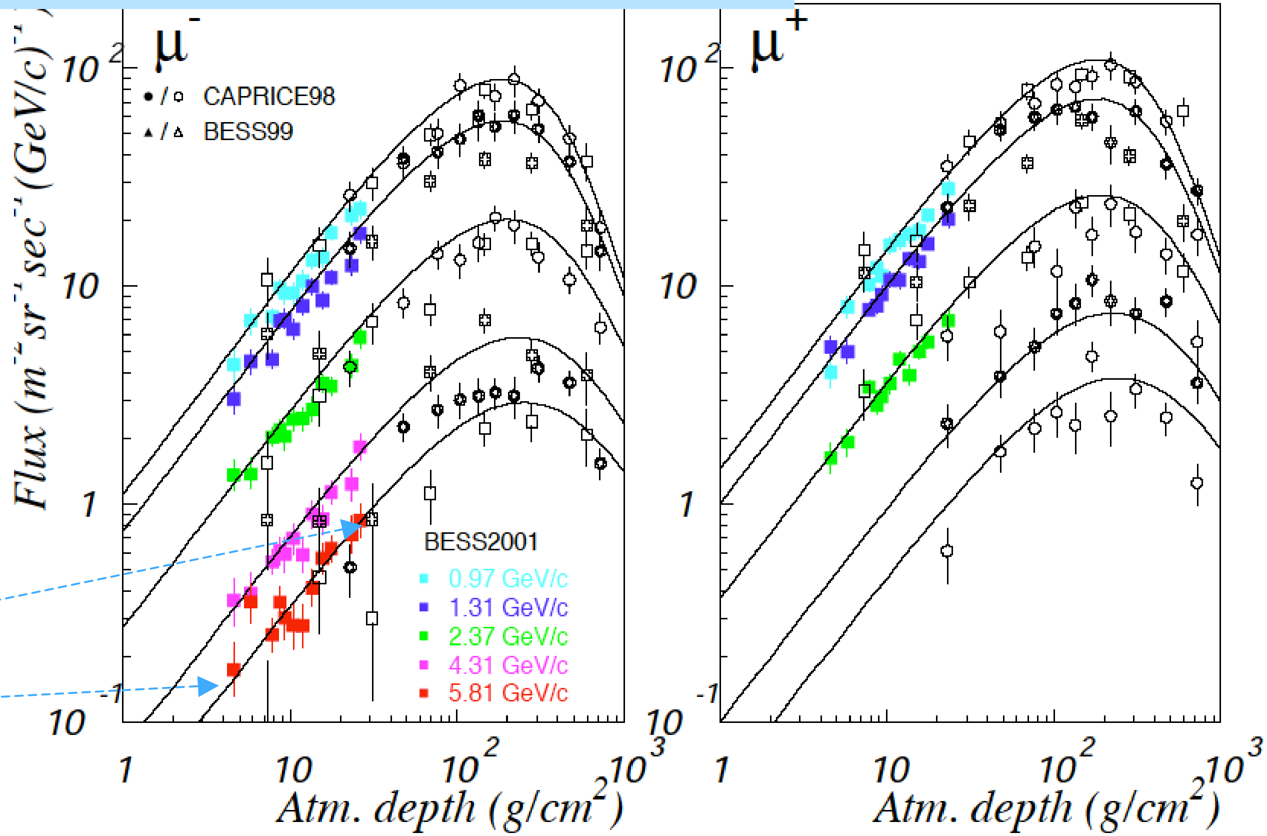
	Depth	Exposure
Float. (93~02)	5 g/cm^2	~1 d/yr
Descend. (01)	5~30	~10 hr
Mountain (99)	740	~ 3 days
Ground (95~02)	1000	~ 3 days
Ascend. (99~02)	5~1000	~3 hr/yr

Atmospheric Muons at 5~26 g/cm^2

K. Abe et al.; HE2.4.6

Sensitive to hadronic interaction model

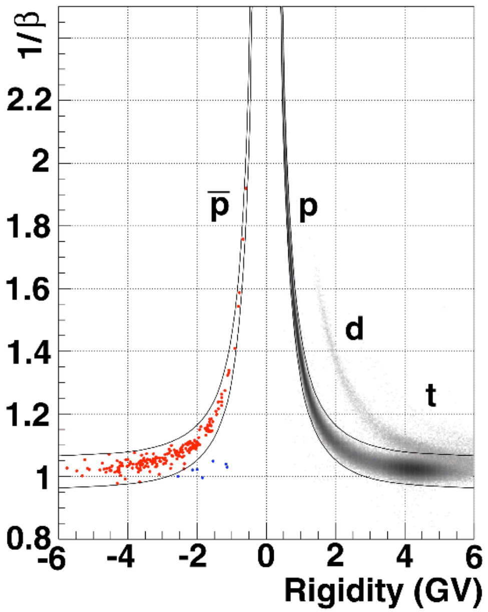


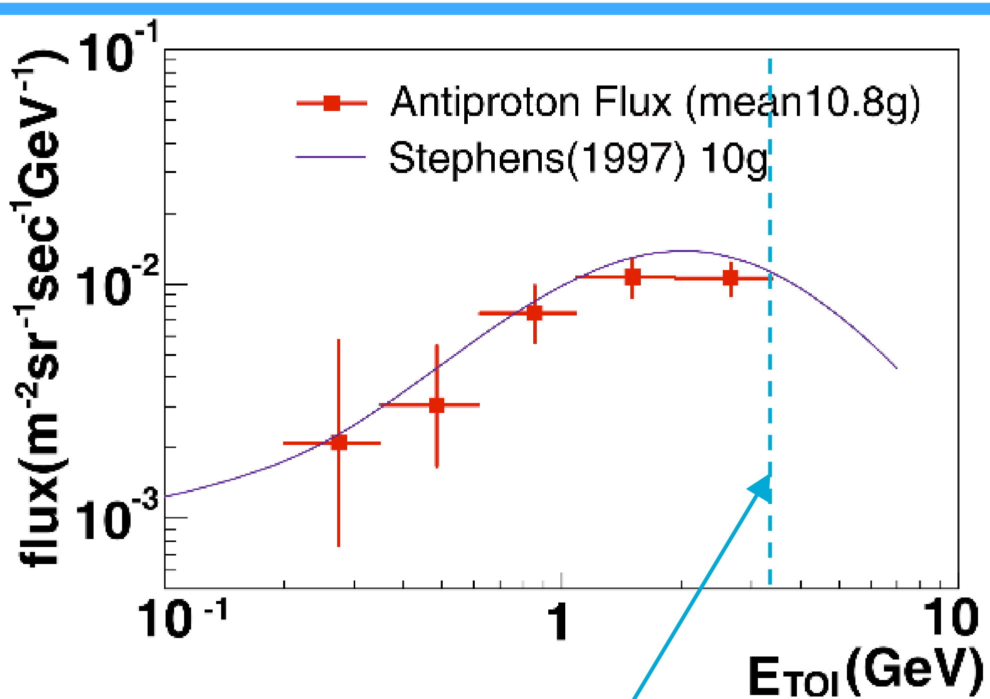


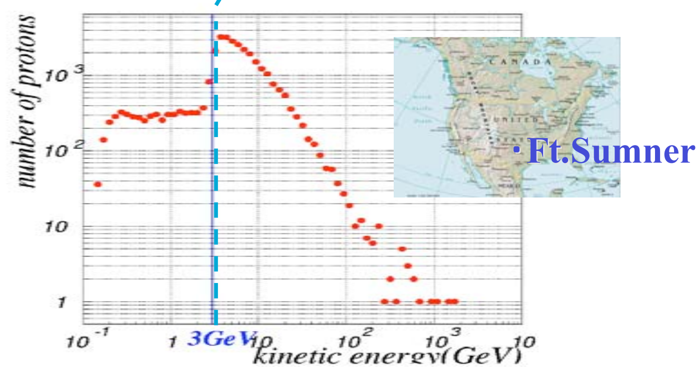
Reflect the first interaction of primary cosmic-rays in small atm. Depth,
BESS results most favored with calculations using DPMJET-III

Antiproton Detected at 4 - 26 g/cm^2

(Yamato et al., OG1.1,P)



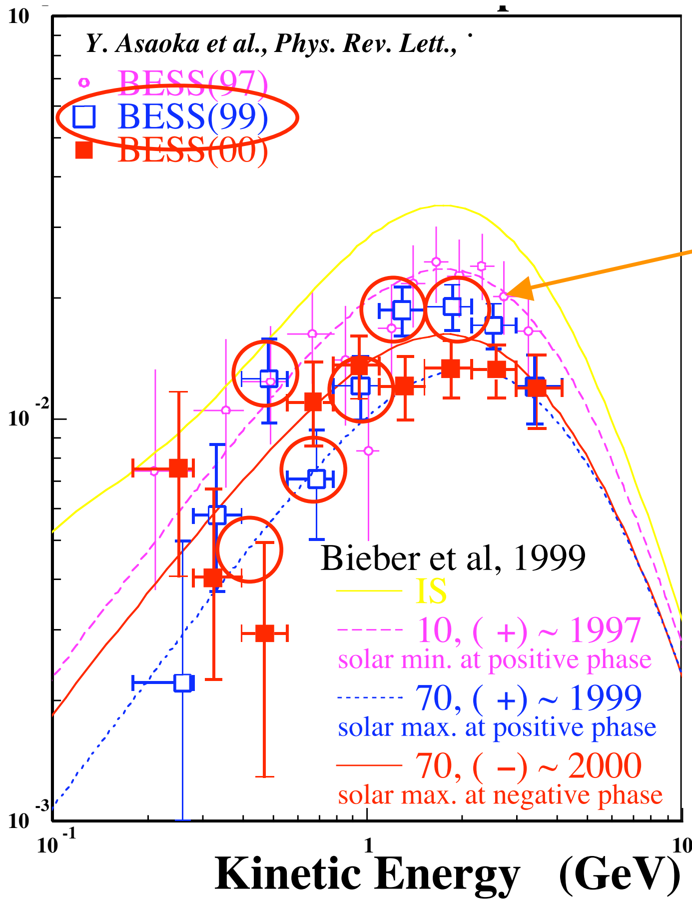


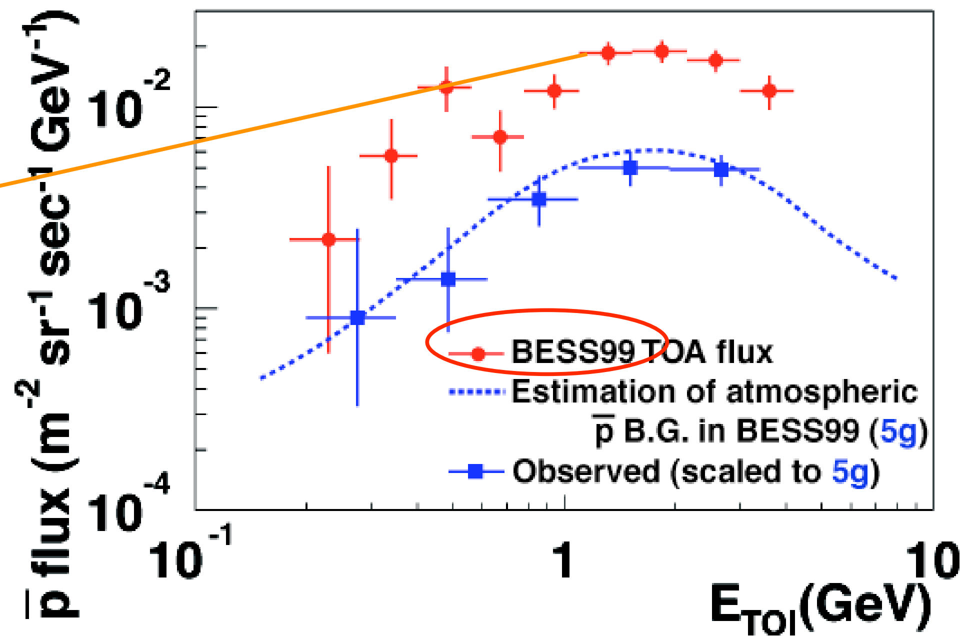


140 atmospheric $\overline{\text{p}}$ observed

at 4 - 26 g/cm2, below E_{cutoff}

Atmospheric Antiprotons
subtracted in BESS-99

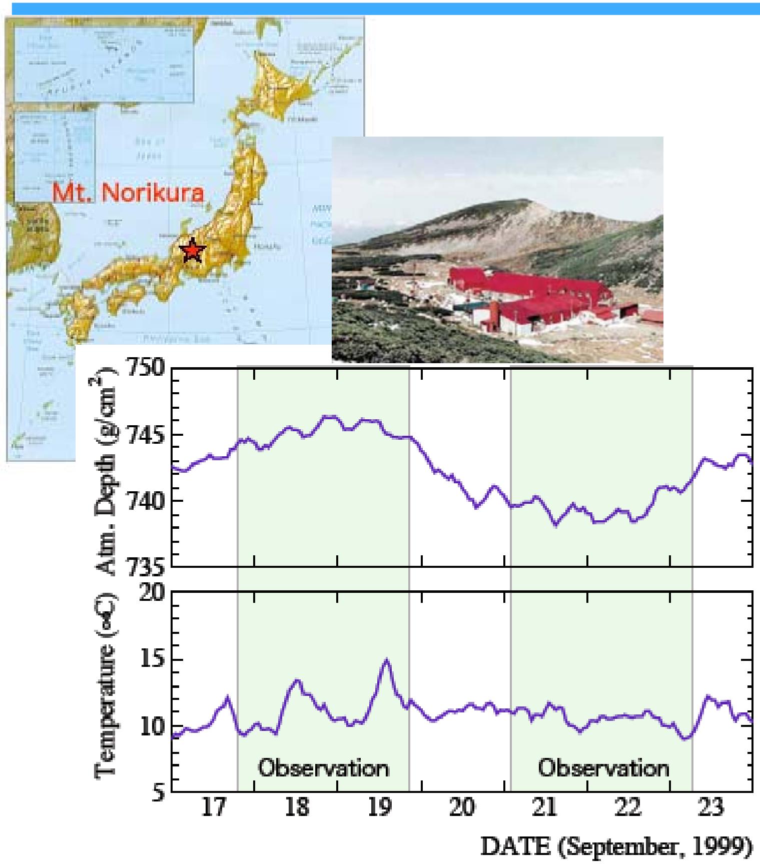


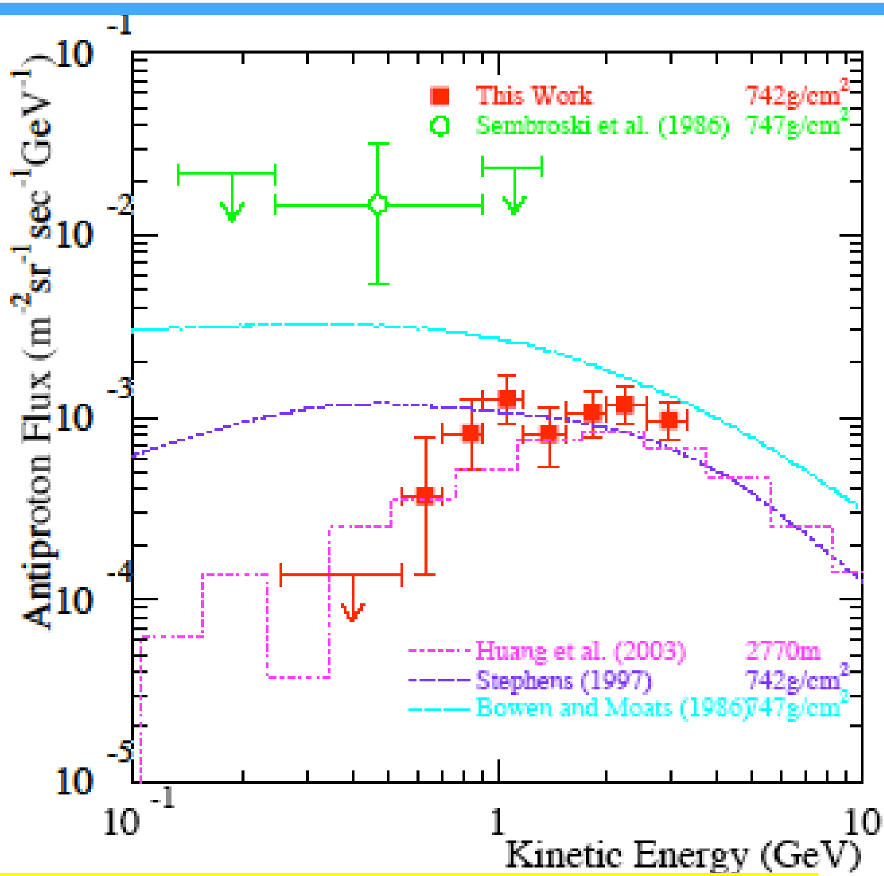


The correction for the atmospheric antiproton was appropriate.

Atmospheric $\bar{p}$ at Mt. Norikura,

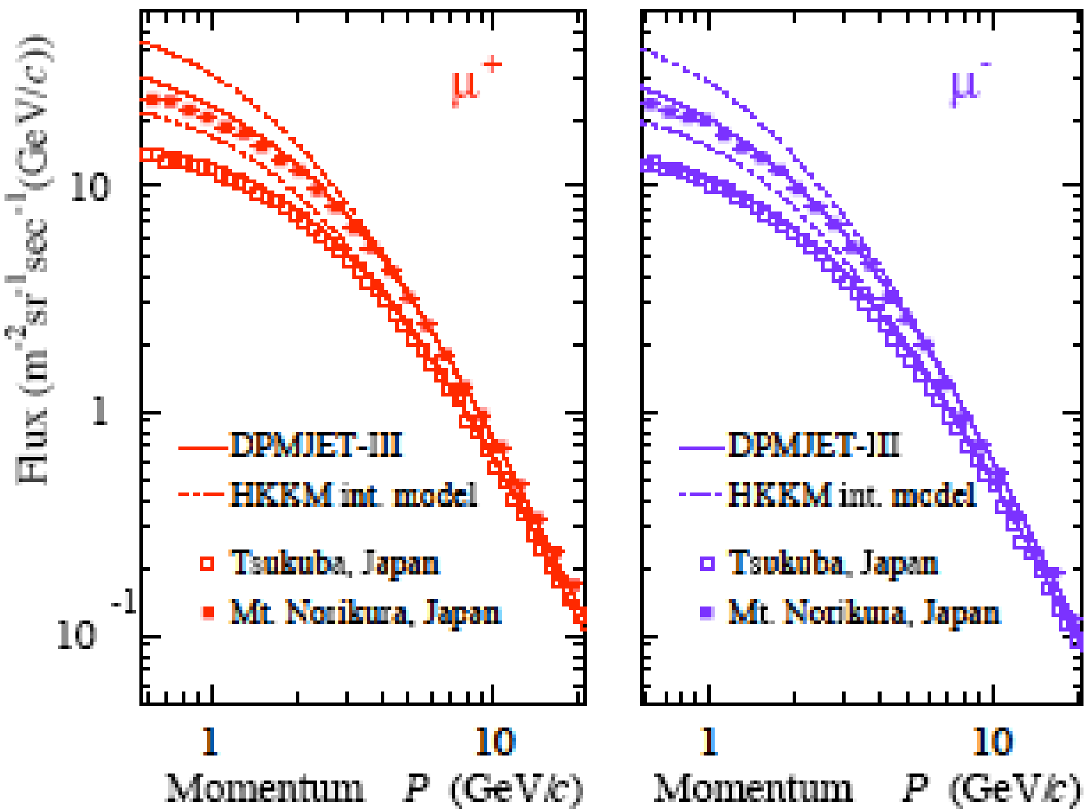
at 740 g/cm^2, in 1999 (Sanuki et al., HE 2.1.p)





- The observation most consistent with a theoretical calculation by Huang et al., at < 1 GeV.

Atmospheric Muons at Mt. Norikura, at 740 g/cm^2 (Sanuki et al., HE 2.1.p)



- BESS results consistent with theoretical calculations using such as the DPMJET-III hadronic interaction model.

BESS Highlight

- BESS Progress
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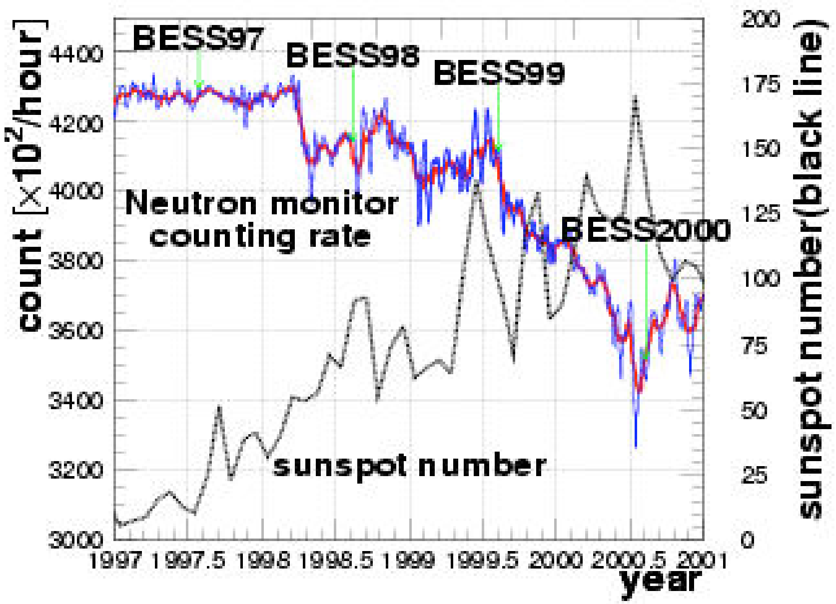
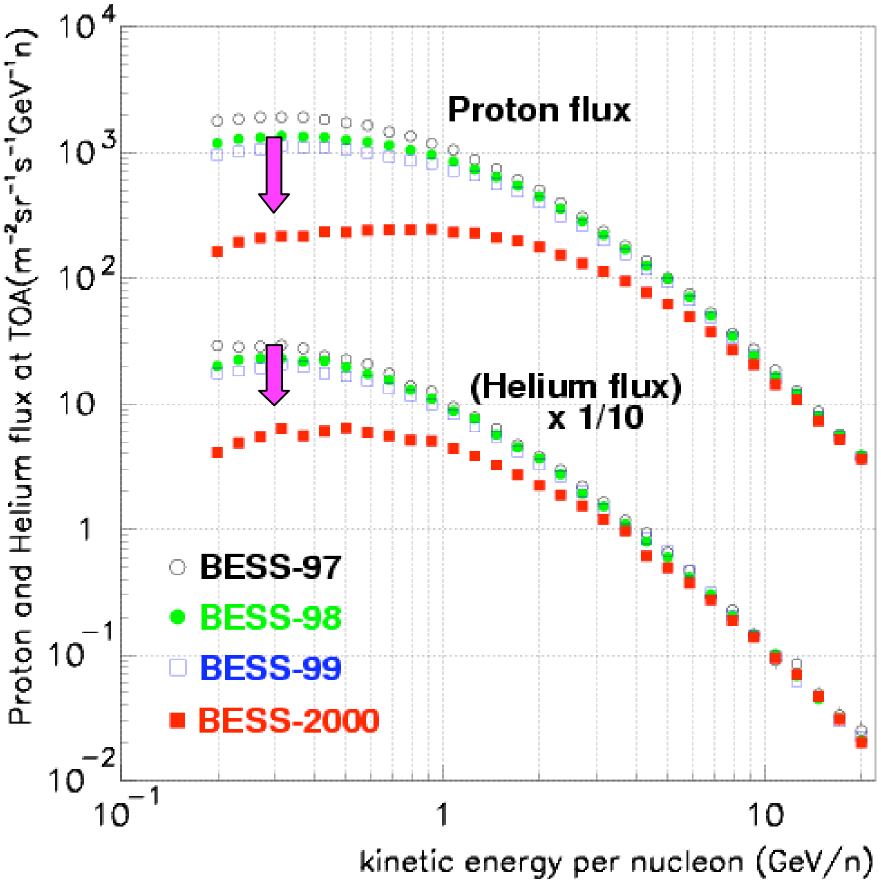
- BESS-Polar Plan

Proton and Helium Spectra

for a half solar cycle from 1997 to 2000

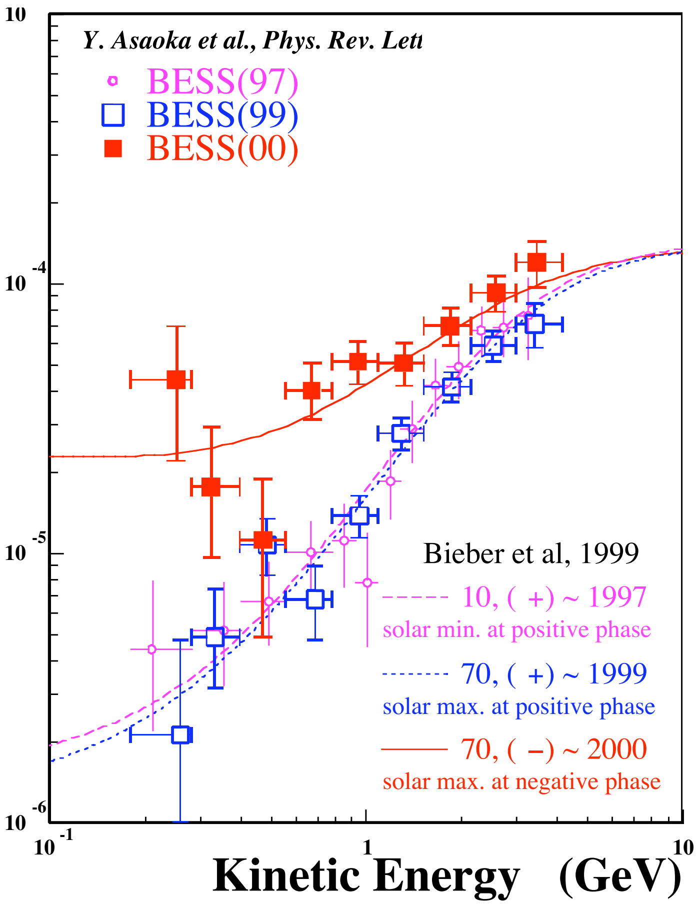
(Shikaze et al., SH3.4.2)

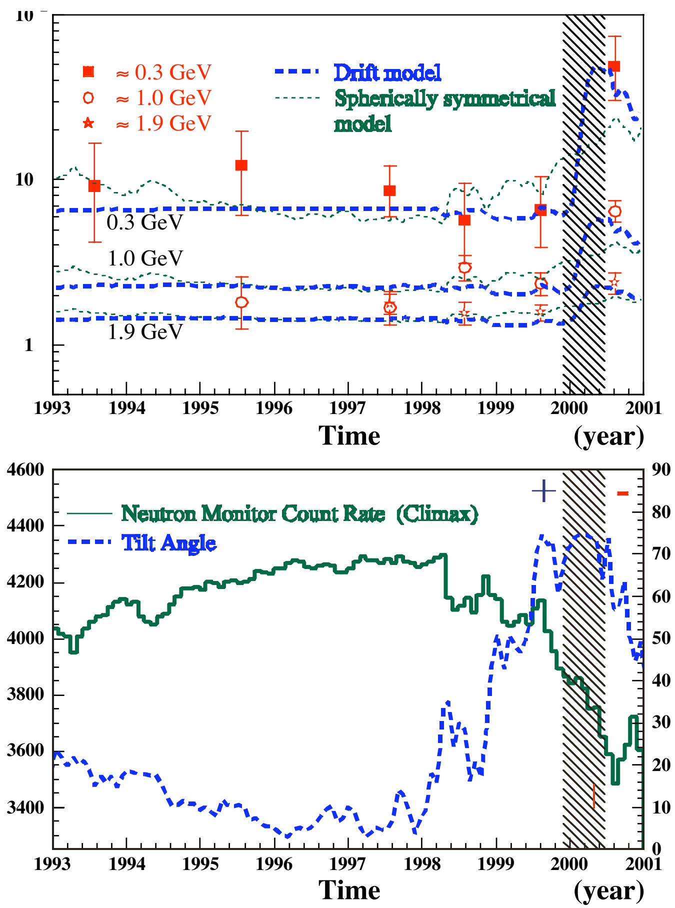




$\bar{p}/p$ Ratio and Solar modulation Effect

(Y. Asaoka et al., PRL 88, No. 5 (2002) 051101)

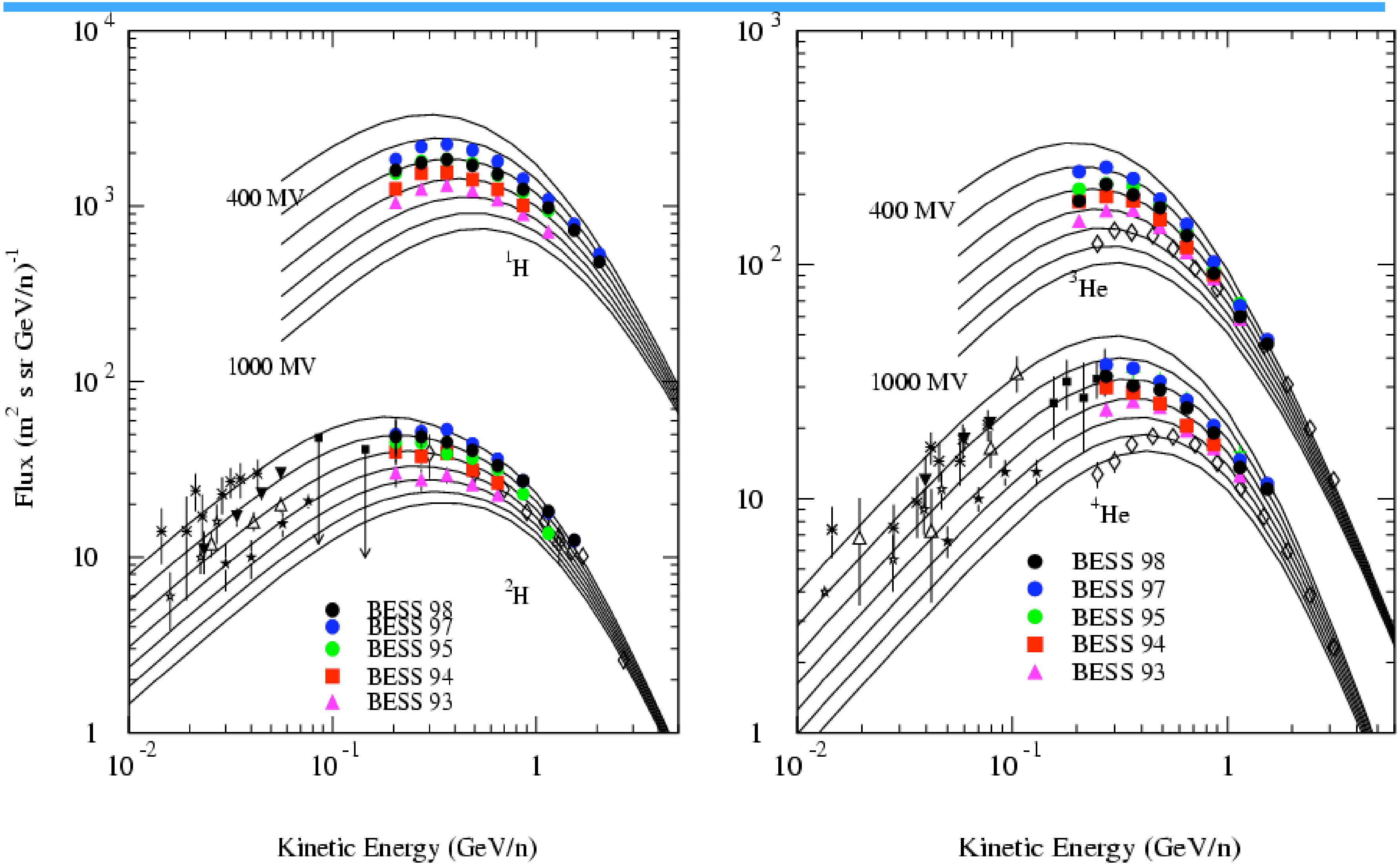




Energy Spectra P & He Isotopes

Wang, Seo, Sanuki et al., ApJ, 564, 244, 2002

Z. Myers et al., OG1.1.10, &Poster)



BESS Highlight

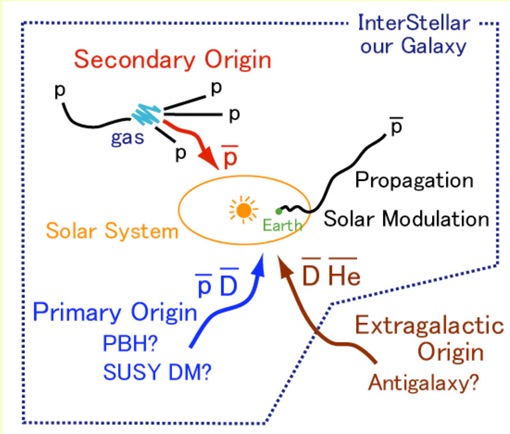
- BESS Progress
- Latest Results from BESS
  - Antideuteron search
  - High E. Protons at > 100 GeV
  - Atmospheric muons and antiprotons
  - Low E. particles and solar modulation
- BESS-Polar Plan
  - We are ready to realize Long Duration flight in Polar Region!,

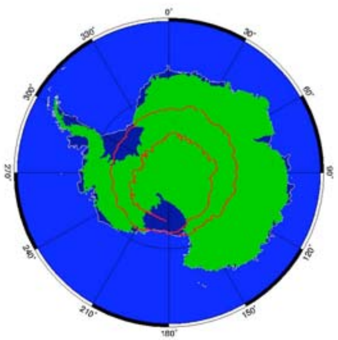
BESS Polar

Long Duration Flights in Antarctica

(T. Yoshida et al., O.G.1.5.3)

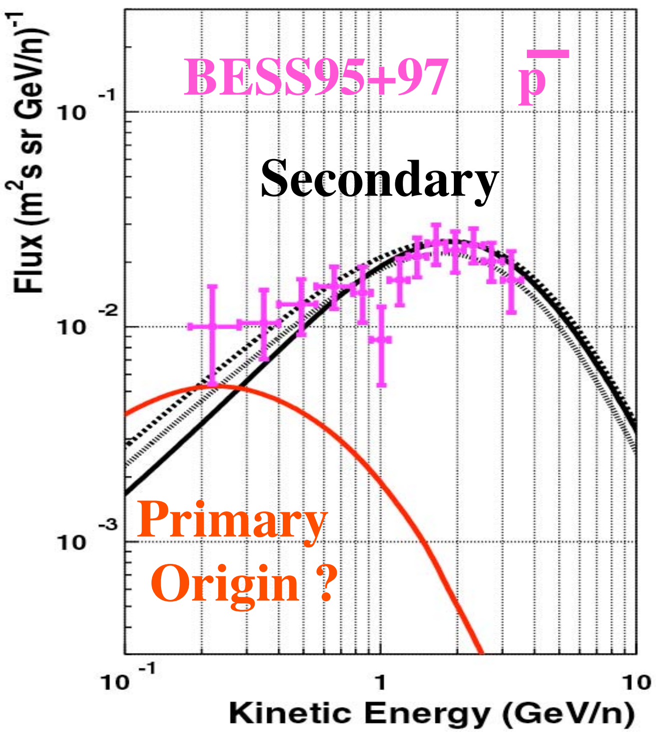
- **Low Energy Antiprotons to be observed;**
  - 10^3 at < 1 GeV, 10^4 at < 4 GeV
- **Antidueteron Search with the Sensitivity**
  - 1 x 10-5 $(m^2.s.sr.GeV/n)^{-1}$
- **Antihelium Search with the Sensitivity**
  - $\overline{He}$/He ratio: 3 x 10^{-8}
- **Further Precise Cosmic-ray Observations**

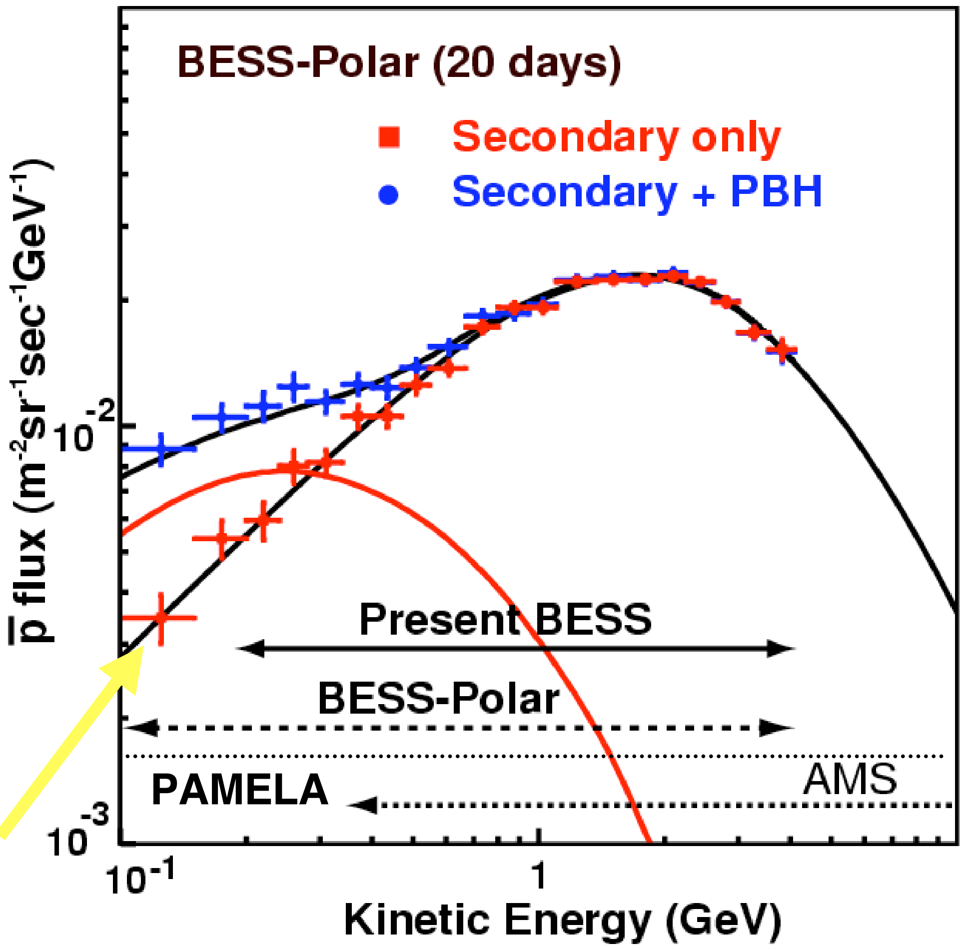




From NASA web page, TIGER Antarctica Ballon Campasign , 2001/2002

Precise measurements of Antiprotons with BESS-Polar





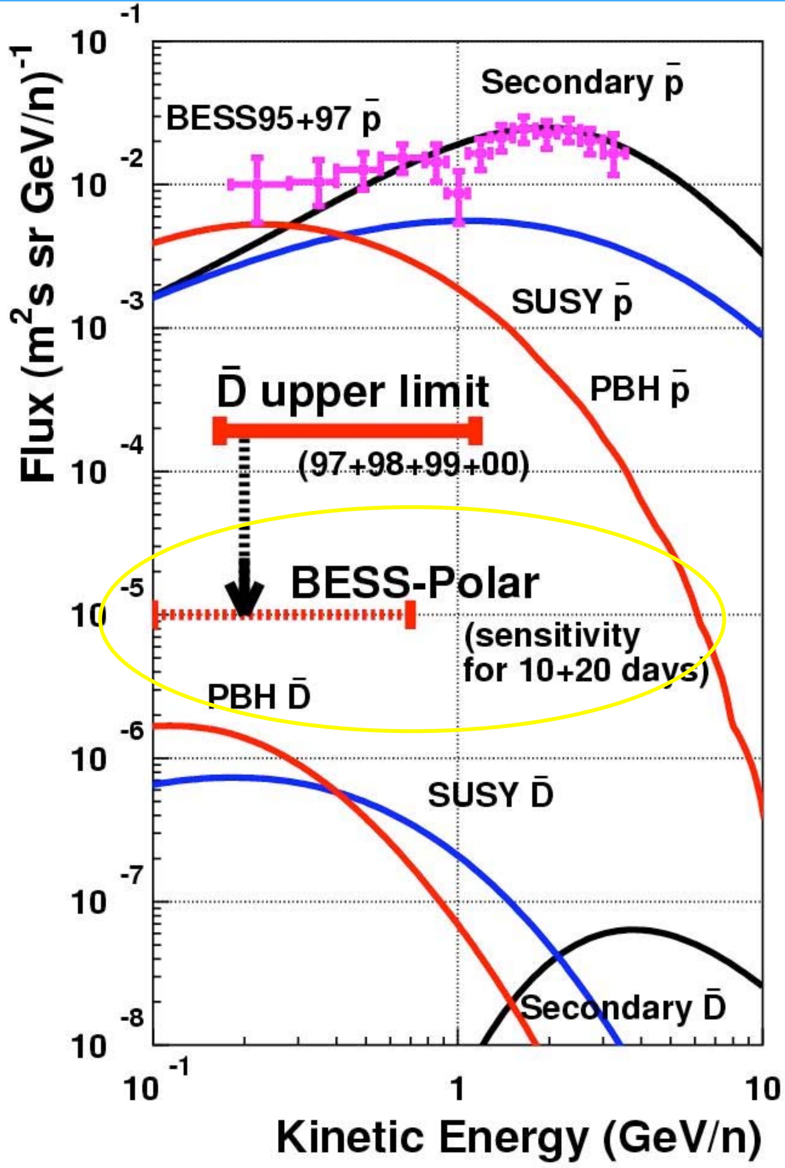
Spectrometer to be sensitive down to 0.1 GeV

Search for Antideuteron

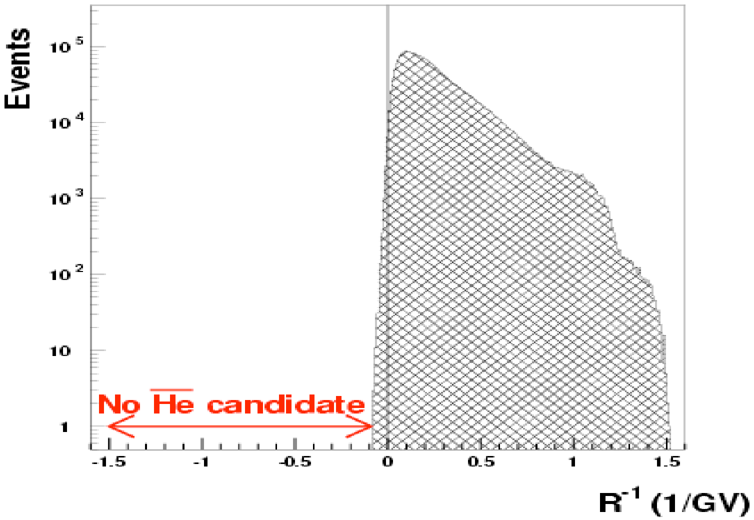
Sensitivity

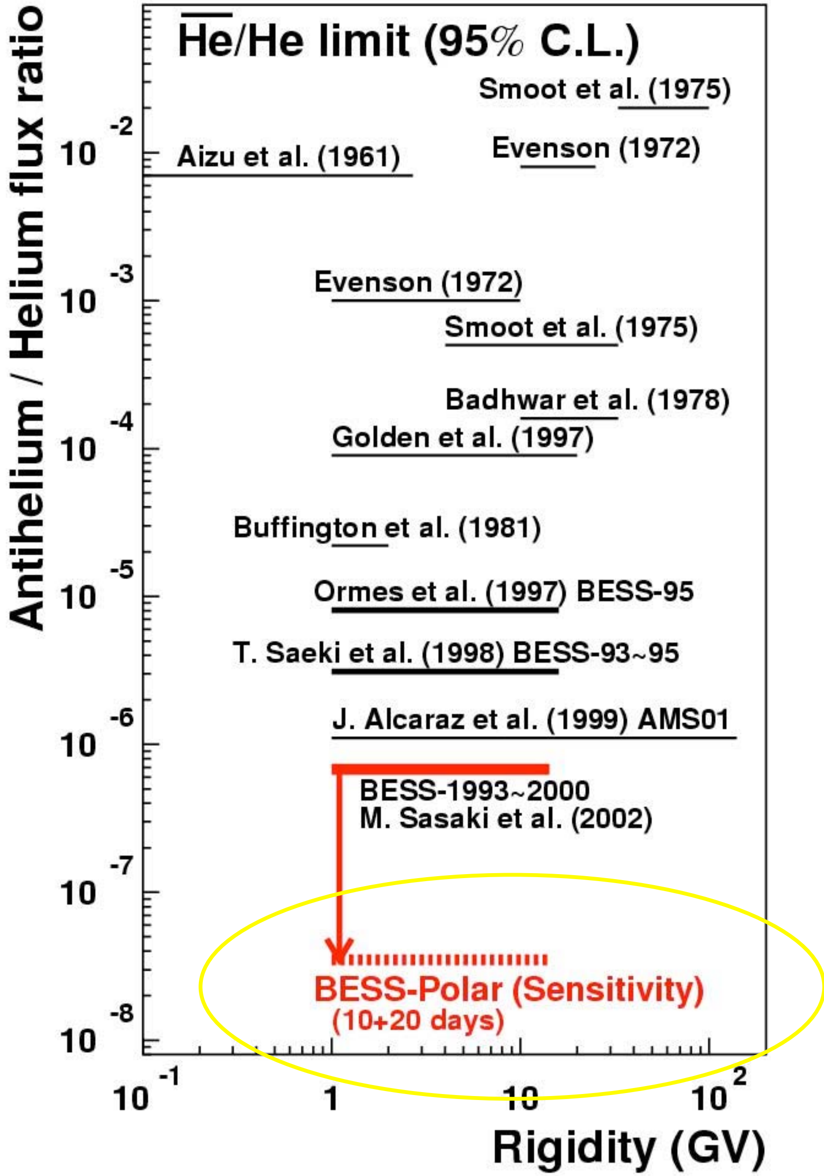
1×10^{-5} $(m^2 s.sr.GeV/n)^{-1}$

with assuming two flights for 10 + 20 days



Search for Antihelium





Progress in BESS93~00

Upper Limit:

$\overline{He}/He$: 7×10^{-7}

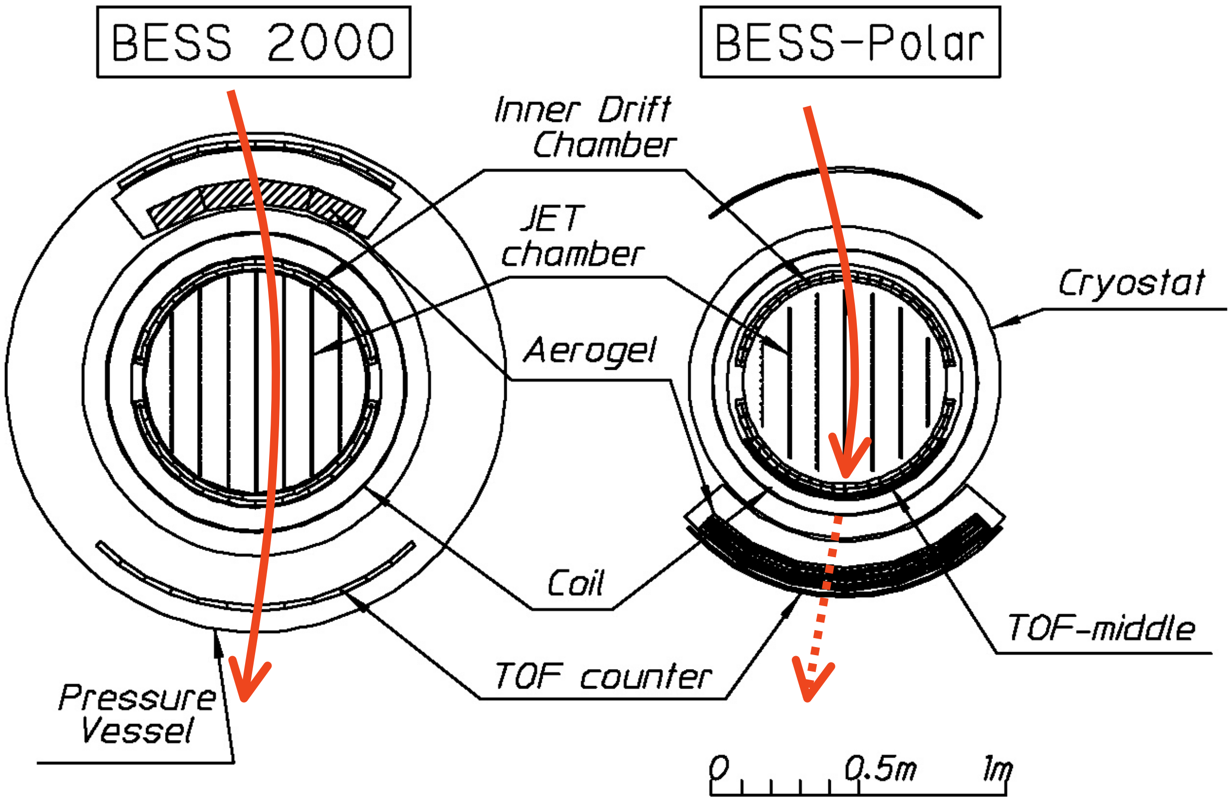
BESS-Polar:

Sensitivity:

$\overline{He}/He$: 3×10^{-8} (30 days)

New Spectrometer optimized
for Measurements in Low Energy

Spectrometer to be further transparent and compact

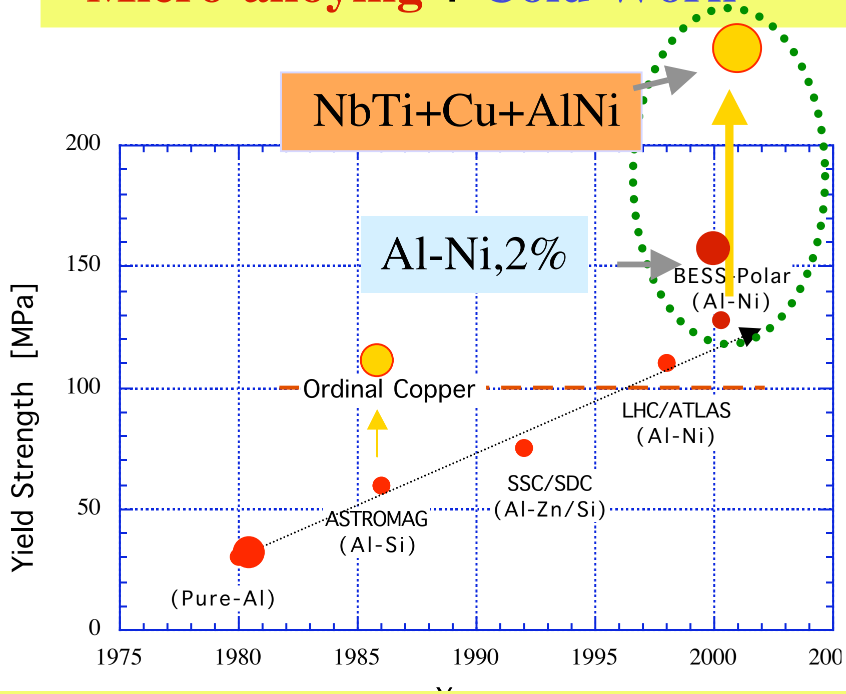


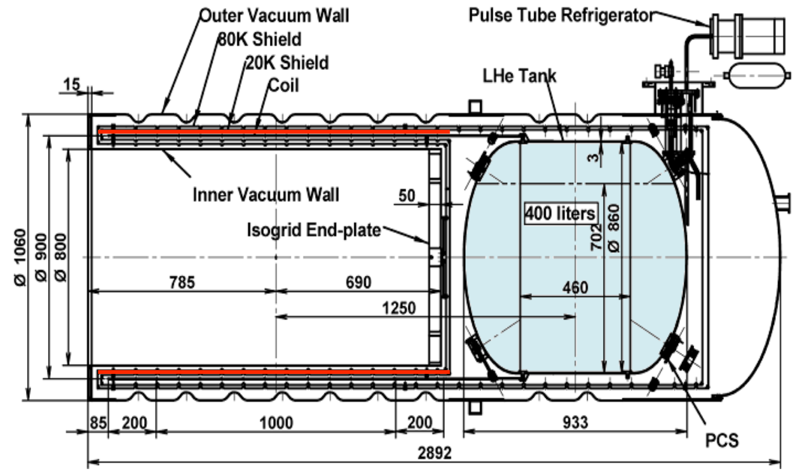
- No Pressure Vessel
- Ultra-thin Solenoid
- Middle TOF
- Aerogel at bottom

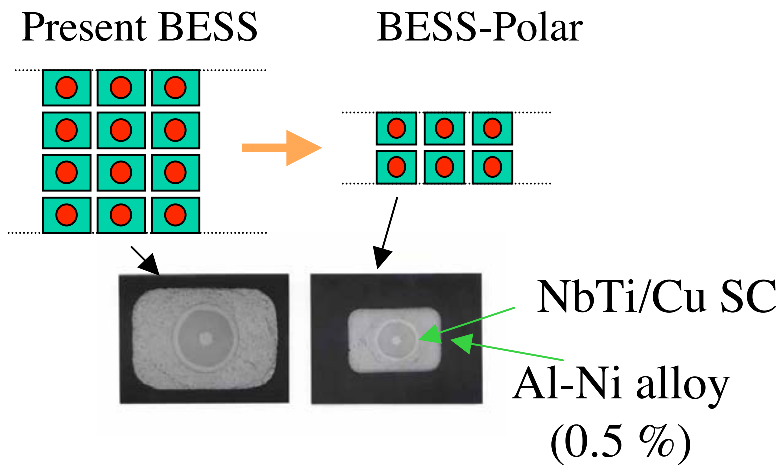
- Material in detector for Trigger
- **18 g/cm² -->> 5 g/cm²**

Superconducting Coil as a key technology

Technical breakthough in High strength Al-stabilized Superconductor by using;
Micro-alloying + Cold Work



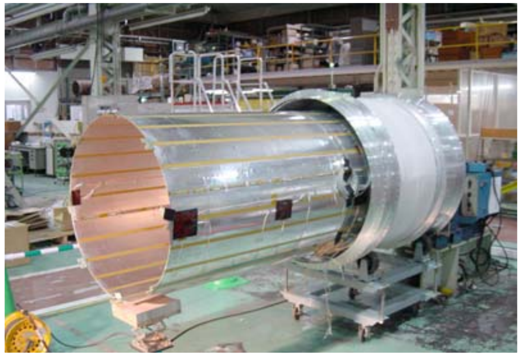


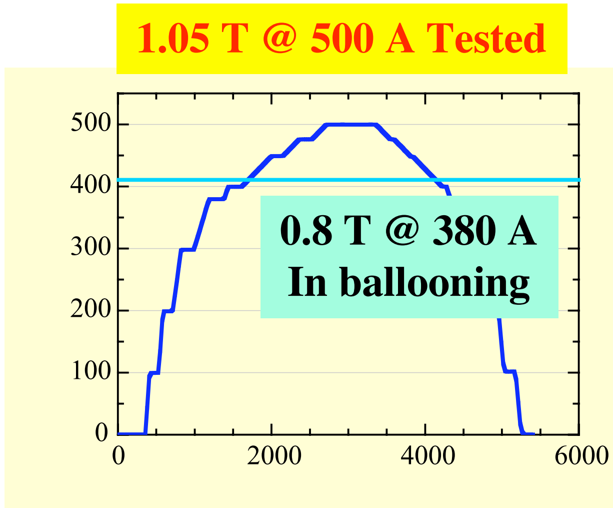


• **Ultra thin solenoid becomes available： 1 g/cm^2 / coil-wall**
-->> Contribute to low energy limit down to 0.1 GeV

BESS-Polar Thin Solenoid Coil

completed and tested up to 1.05 T

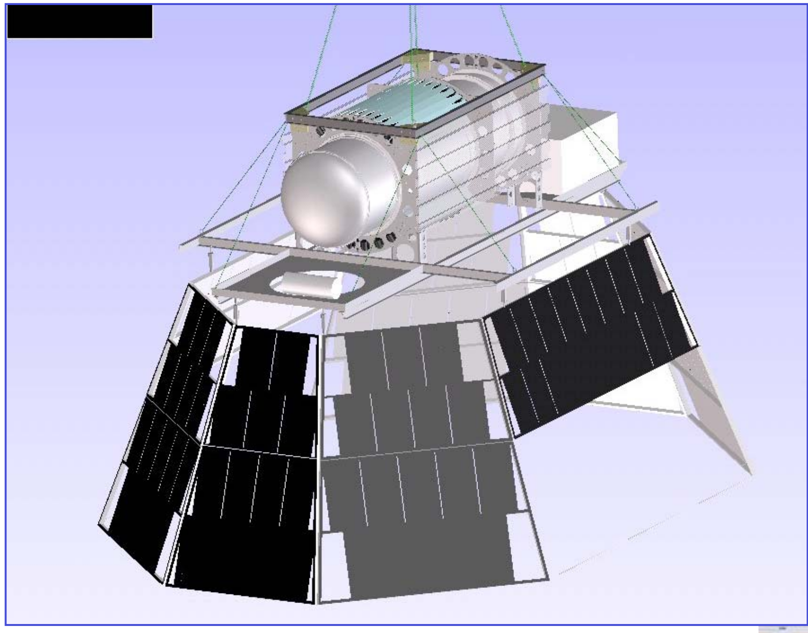




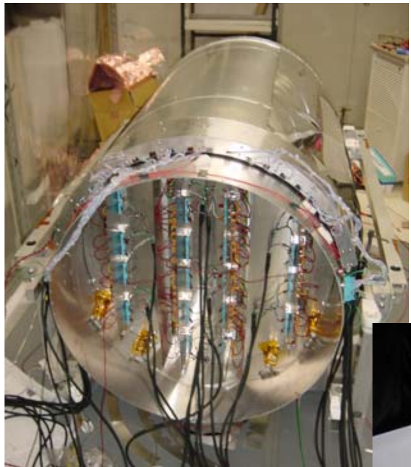
BESS-Polar Spectrometer

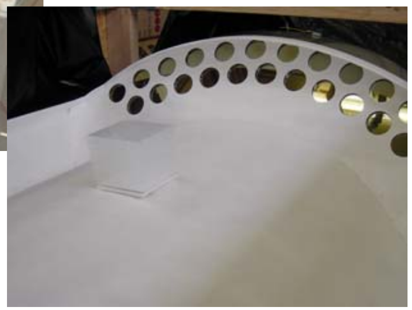
being prepared for a Technical Flight

to be carried out, Ft. Sumner, Sep. 2003



At Sanriku Tech. Flight, Japan, in 2002



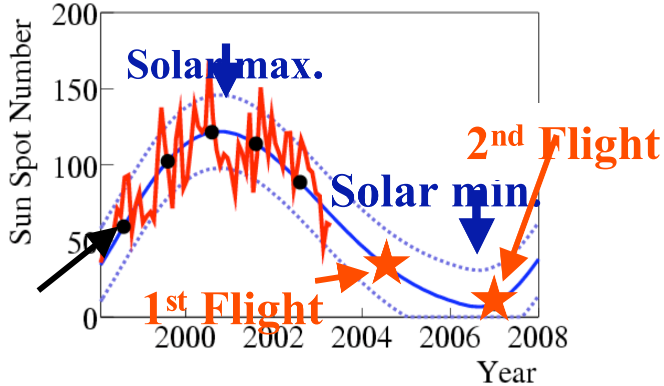


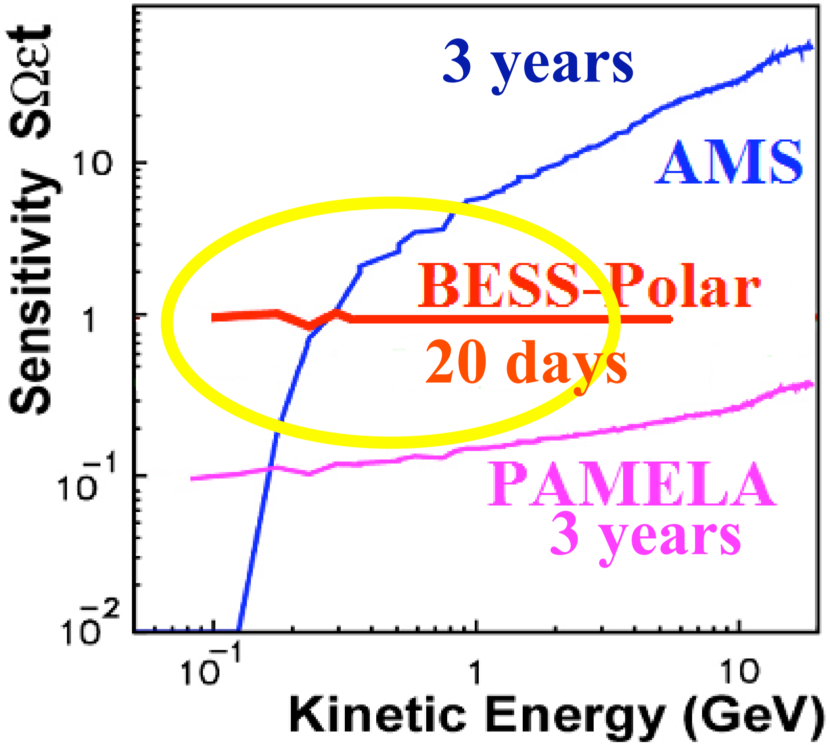
BESS-Polar Spectrometer

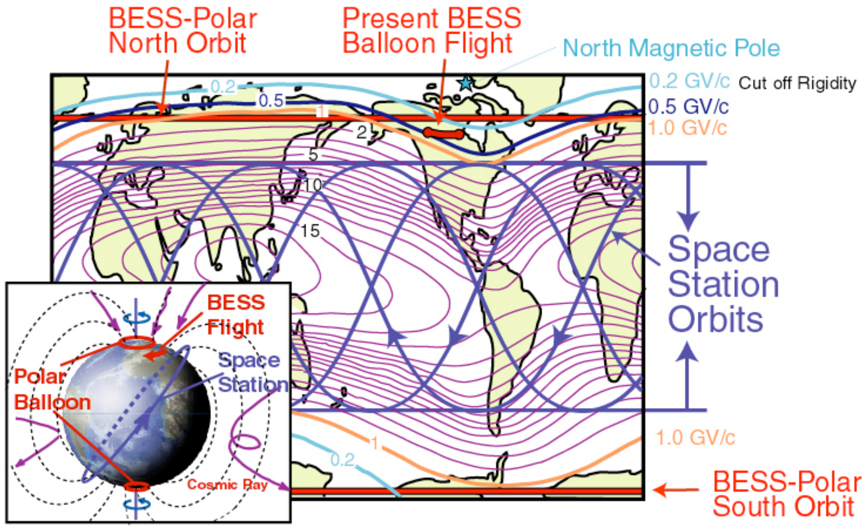
	Present	BESS-Polar.
Geom. Acceptance:	0.3	0.3 $m^2 \bullet sr$
Material for trigger:	18 g/cm^2	4.5 g/cm^2
Magnetic field	1.0 T	0.8 T
Weight	2.2	1.4 tons
Power	Battery	Solar-panel
Comsumption	1.2 kW	600 W
Cryogen life	5.5	20 days

BESS-Polar

- **Unique and ideal for low energy particles**
  Stay in **low magnetic cut-off** regions
  Complementary with PAMELA and AMS,
  And be maximized at Solar Minimum







Summary

- **First results in search for cosmic antiparticle:**
  - **$\bar{D}$ upper limit of 1.9 x 10^{-4} $(m^2.s.sr.GeV/n)^{-1}$, for the first time.**
  - **Atmospheric $\bar{p}$ flux at 5 - 26 g/cm^2, and at 740 g/cm^2.**
- **Fudamental data:**
  - **p spectrum extended up to 500 GeV, consistent with BESS-98, AMS-I.**
- **Atmospheric μ spectra**
  - **consistent with theoretical calculation using DPMJET-III hadronic interaction model (Honda et al.,)**
- **BESS-Polar**
  - **extend search for low energy $\bar{p}$, $\bar{D}$ and $\overline{He}$ of novel cosmic origins, as well as to provide fundamental data.**
  - **BESS-Polar spectrometer in progress :**
    - **Sensitive down to 0.1 GeV,**
  - **The first flight planned to be realized in 2004.**

Acknowledgements

We would thank:

NASA, ISAS, and KEK for their support and encouragements for BESS experiment as a US-Japan Cooperation Program carried out **since 1993**, funded by NASA grant for scientific balloon program (US) and MEXT grant-in-aid (Japan).

This talk given with our memory of BESS advisor/founders, the late **Prof. R. Golden** (NMSU), and **Prof. S. Orito** (Tokyo)

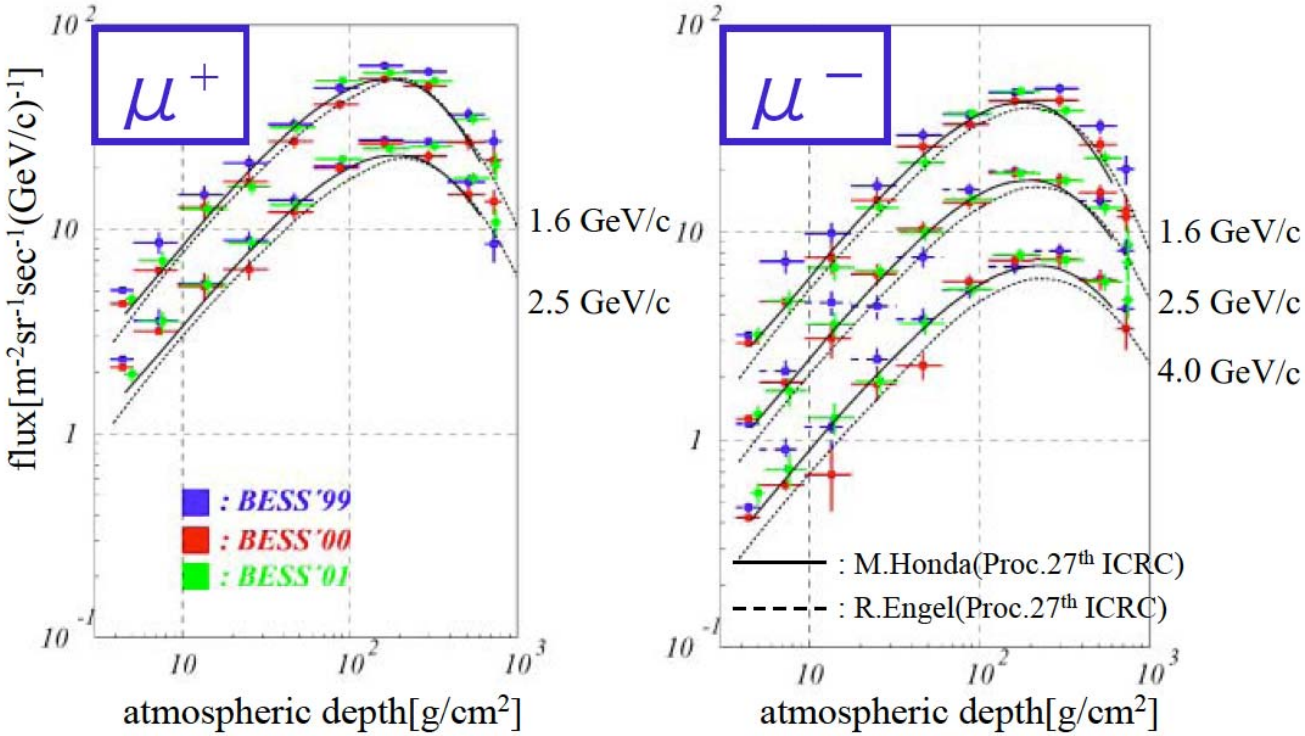
First Flight in Lynn Lake, 1993-7-27

Response to Questions
(added)

Absolute Fluxes of Atmospheric Muons

Atmospheric Depth Dependence

(Y. Yamamoto et al., HE2.1.8)



- Overall growth curve generally well produced by calculations

Muon Spectra and Flux Ratio

at Ground Level

(K. Tanizaki et al., HE2.1.7)

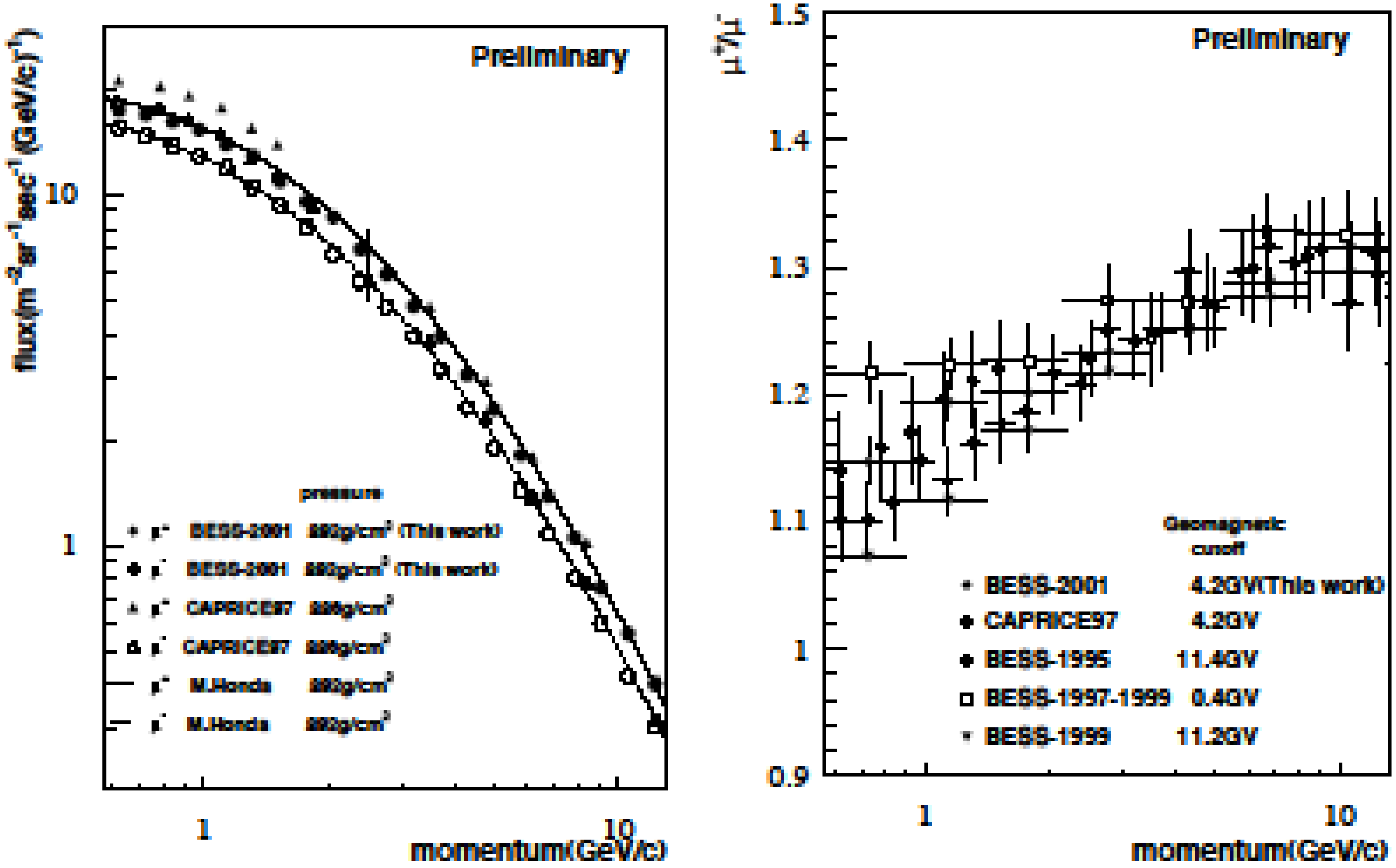


Fig. 1. (left):Result for momentum spectra of the positive and negative muons at Ft. Sumner. (right):μ^+/μ^- ratios at different geomagnetic locations, BESS-1999[11]