ONLINE ICRC 2021
THE ASTROPARTICLE PHYSICS CONFERENCE
Berlin | Germany
37th International Cosmic Ray Conference
12–23 July 2021

Cosmic-ray beryllium isotope ratio measured by BESS-Polar II

T.Wada[1], K.Abe[2], H.Fuke[1], S.Haino[3], T.Hams[4], M. Hasegawa[3], K.C.Kim[5], M.H.Lee[5], Y.Makida[3], J.W.Mitchell[4], J.Nishimura[6], M.Nozaki[3], R.Orito[2], J.F.Ormes[7], K.Sakai[4], M.Sasaki[4], E.S.Seo[5], R.E.Streitmatter[4], N.Thankur[4], A.Yamamoto[3], T.Yoshida[1] and K.Yoshimura[8] **for the BESS Collaboration**

1. ISAS/JAXA
2. Kobe University
3. High Energy Accelerator Research Organization (KEK)
4. NASA-Goddard Space Flight Center (NASA-GSFC)
5. IPST, University of Maryland
6. The University of Tokyo
7. University of Denver
8. Okayama University

Introduction

The flux ratio of secondary to primary

- The flux ratio of secondary/primary is most commonly used to constrain propagation models
- Provides important information such as
  - the average amount of interstellar material
  - **the confinement time within the Galaxy**
- The ratio of stable particles **cannot strongly** constrain the confinement time

The cosmic-ray isotope ratio

- Measuring **the abundance of radioactive components** is the most direct method to estimate the confinement time
- The most attractive one is **beryllium** (^{7}Be, **^{9}Be** and **^{10}Be(unstable)**)
- **^{10}Be** has a decay time of **1.4×10^{6} year** comparable to the confinement time
- **^{10}Be/^{9}Be** ratio has not been reported, except for a few cases such as ISOMAX

The BESS Experiments

The Balloon-borne Experiment with a Superconducting Spectrometer

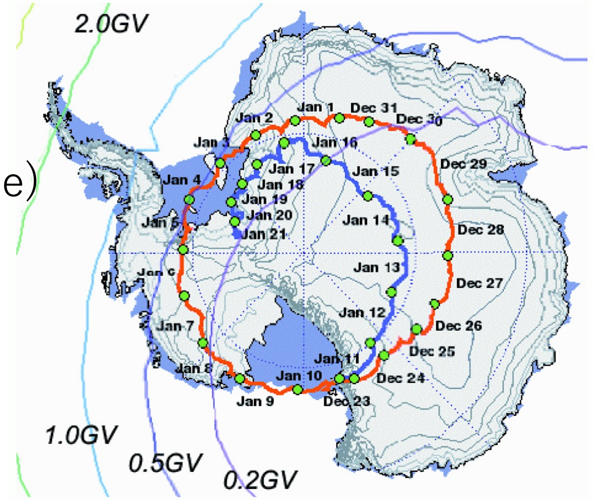
- International project to observe the low-energy cosmic rays (especially $\bar{\mathrm{p}}$)
- Since first flight in 1993, 11 flights including **2 flights over Antarctica** (called the **BESS-Polar**) has successfully completed
- Fully developing instrument for the BESS-Polar
  → longer observation time, improved detector performance
- The second flight over Antarctica in 2007-2008 (**BESS-Polar II**)
  → higher statistics, sufficient particle identification capability **to identify beryllium isotopes**.
- **Use the BESS-Polar II data** for the beryllium analysis
- In this contribution, **report the analysis process of the Be isotope**


Balloon launch of the BESS-Polar II payload

The BESS-Polar II

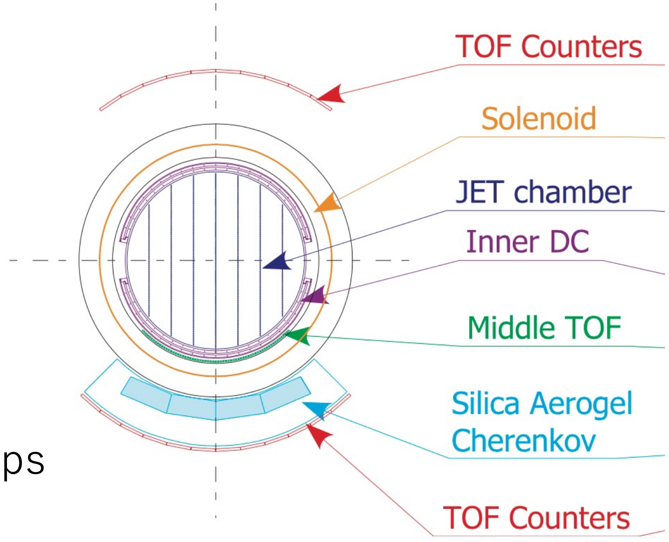
Flight condition

- Launched on Dec. 22, 2007, Observation time: **24.5 days**
- Flight altitude 34-38 km (residual air ~5.8 g/cm^2 on average)
- Cutoff rigidity < 0.5 GV
- About **4.7 billion** events



Instrument

- Uniform magnetic field (0.8 T) generated by a superconducting solenoid (~0.9 m diameter)
- Tracker on a concentric axis in a solenoid
  - ✓ Larger geometrical acceptance (0.23 m^{2}sr)
  - ✓ Better rigidity resolution (0.4% at 1 GV)
- Time-of-flight counters, 10 in the upper (UTOF) and 12 in the lower (LTOF) with a timing resolution of 120 ps
- High-precision track reconstruction with JET chamber



Data Analysis

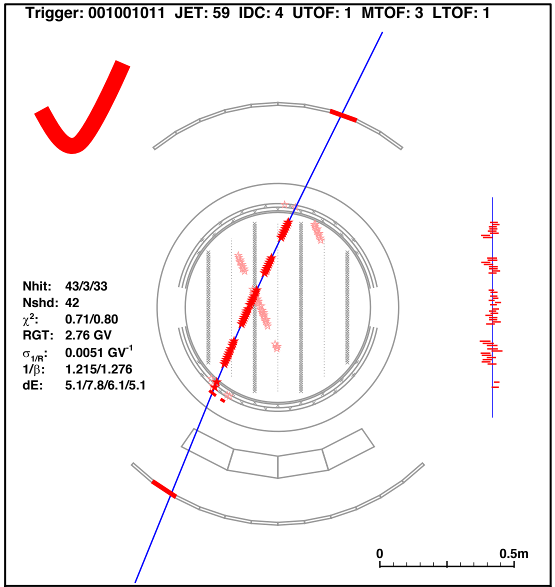
Track reconstruction

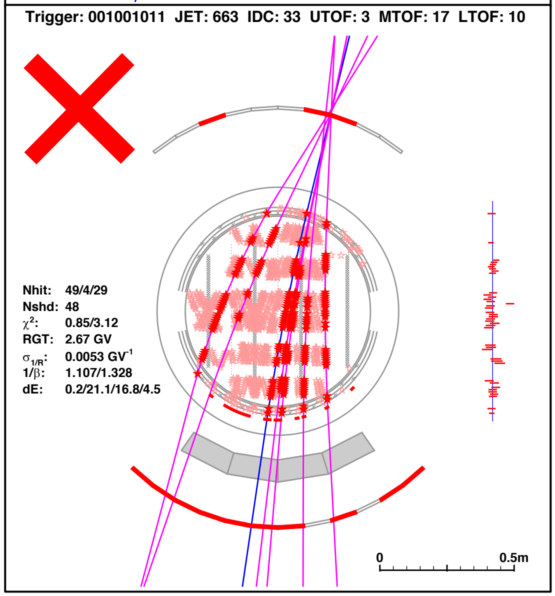
- Only events with **1 hit** each for UTOF and LTOF and 1 reconstructed track
- Fiducial cuts and quality cuts to obtain appropriate measurements

Mass reconstruction

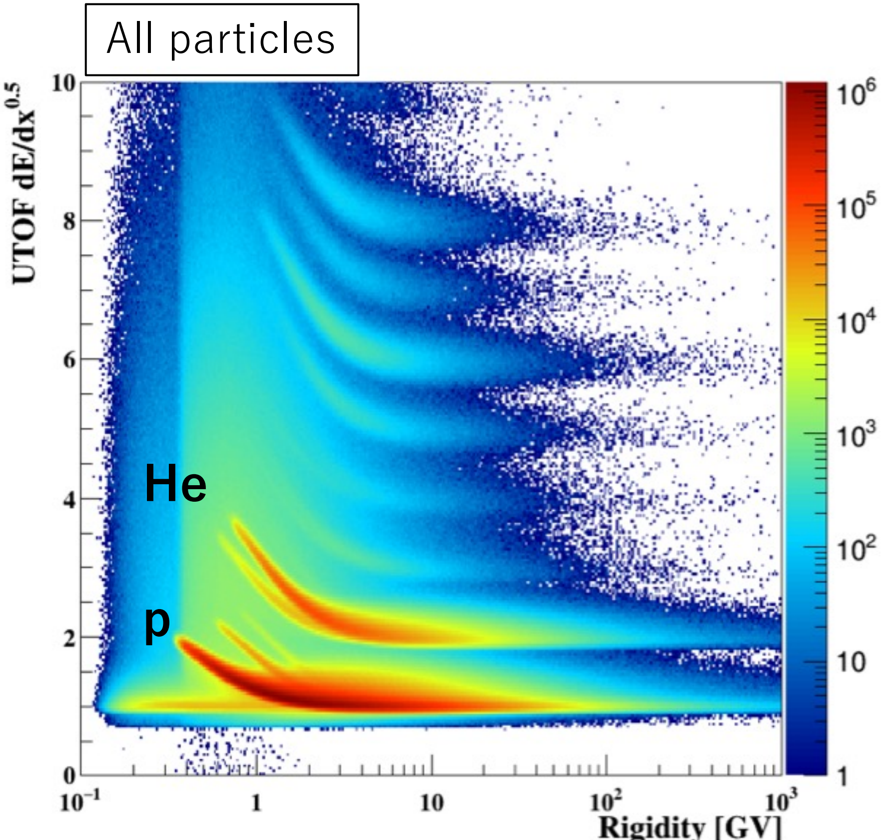
$$M^2 = (ZeR)^2\left(\frac{1}{{\beta_{\mathrm{UL}}}^2} - 1\right)$$

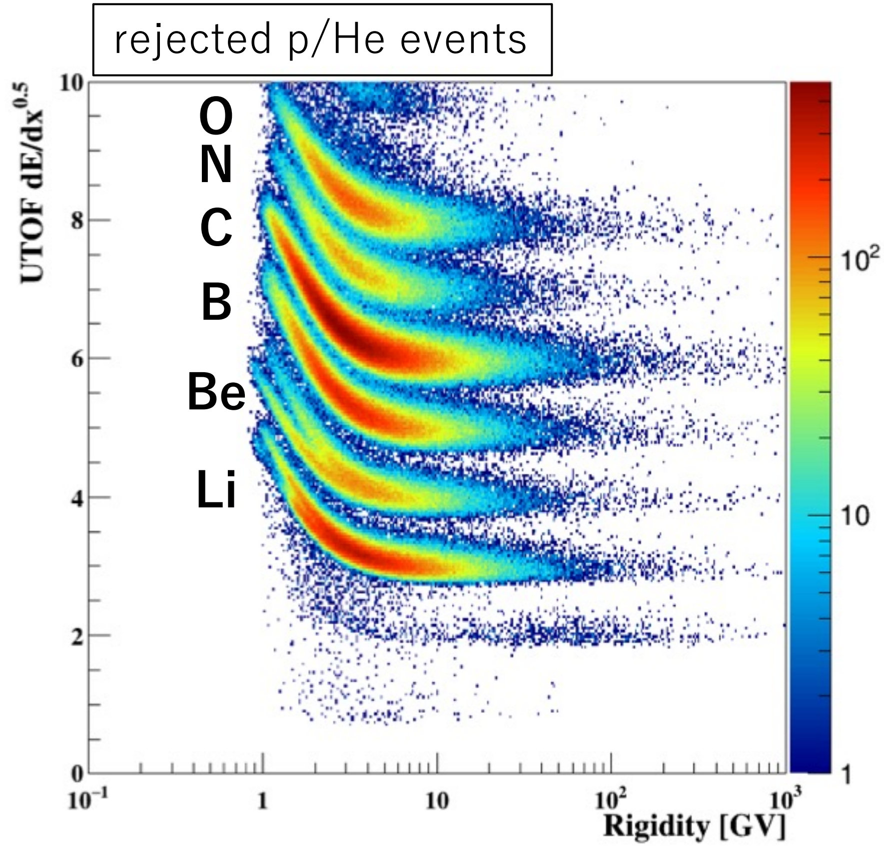
- R : Rigidity (momentum per charge), measured by the reconstructed particle track
- Ze : Charge, obtained from dE/dx measured by the TOF counters and the JET chamber
- β_{UL} : Velocity, derived from the time-of-flight and the path length between the UTOF and LTOF





Data Analysis



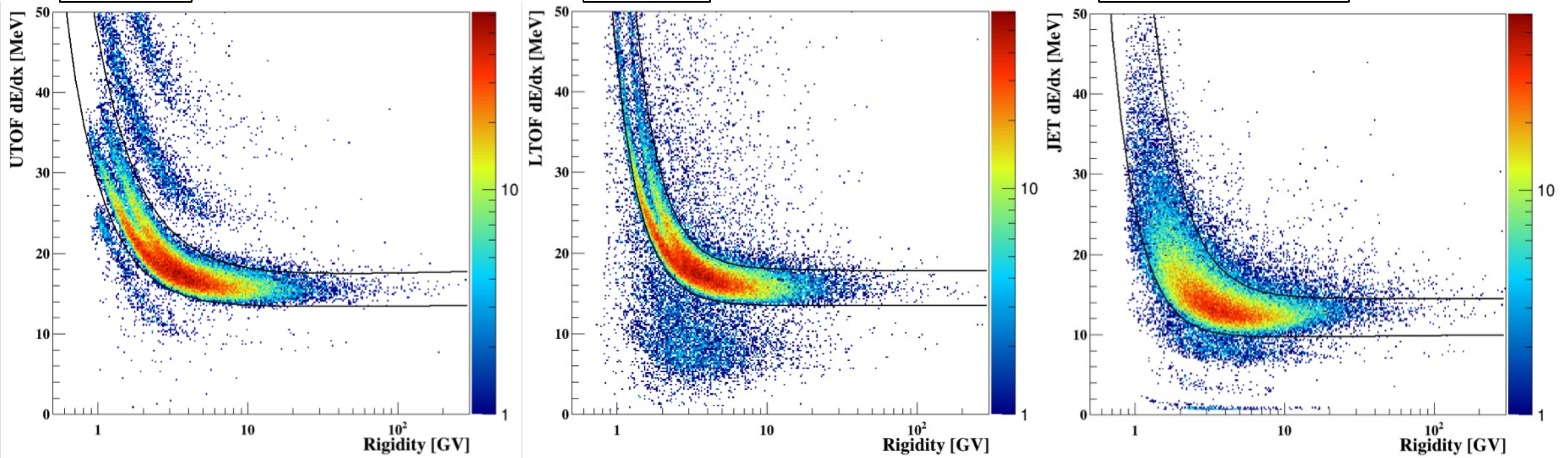


dE/dx distribution

- The plots of UTOF dE/dx vs R under selection criteria applied
- Confirmed that the dE/dx, R and timing resolution **for high-charge (Z ≧ 3) events were stable** throughout the flight

Data Selection for Be Events

UTOF LTOF JET chamber



dE/dx in JET adopted a truncated mean method

dE/dx-band cuts

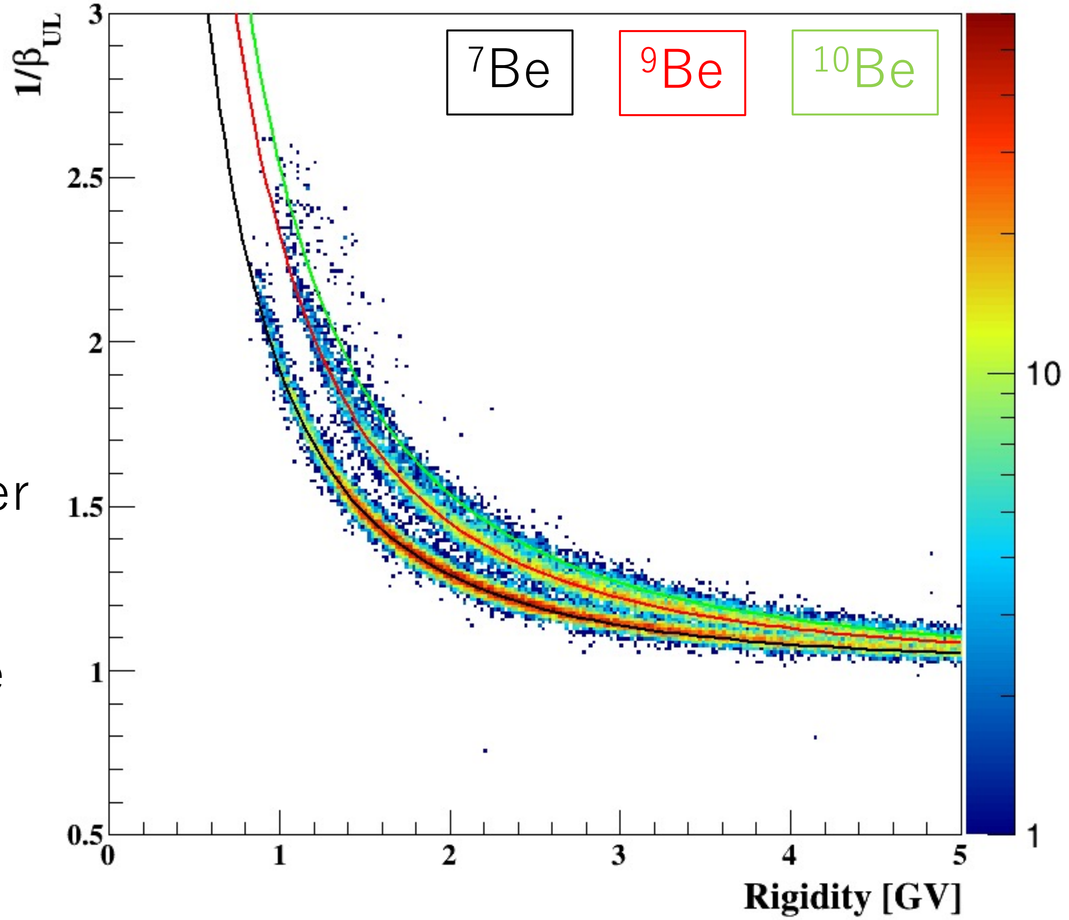
- ☐ dE/dx with all cuts except itself against rigidity
- ☐ dE/dx-band is determined to reject the other elements events

Data Selection for Be Events

$1/\beta_{UL}$ distribution

$$M^2 = (ZeR)^2 \left(\frac{1}{\beta_{UL}{}^2} - 1 \right)$$

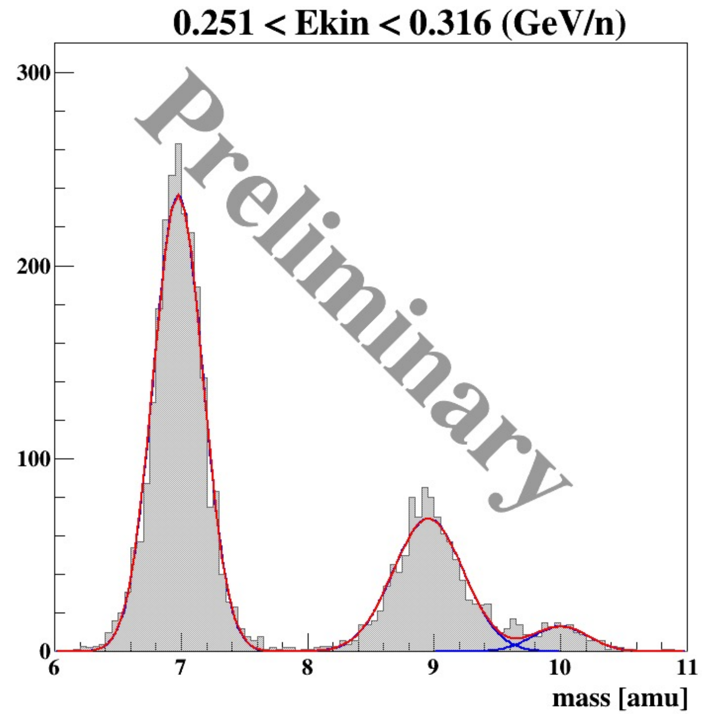
- $1/\beta_{UL}$ versus rigidity under dE/dx-band cuts applied
- **Good agreement** with the theoretical lines of $1/\beta_{UL}$



To Do List

^{10}Be/^{9}Be ratio at TOI

- Divide into several E_{kin} (TOI) ranges, perform fitting for the mass histograms
- Be isotope ratio at TOI is calculated
- Conversion from TOI to TOA is needed



↑ Quality cuts are not yet fully considered

Atmospheric correction

- Remove the effects of the residual atmosphere (the BESS-Polar II: ~5.8 g/cm^2)
- Estimated by performing atmospheric MC simulation with data from GALPROP
- ^{10}Be/^{9}Be ratio at TOA is calculated by this correction

Summary

- We demonstrated that the BESS-Polar II has
  - ✓ **superior instrument performance to identify the high-charge (Z≧3) events**
  - ✓ **enough statistics to calculate the Be isotope ratio**

- Since the analysis method for determining the number of Be isotope events in the BESS-Polar II has been established,
  detailed analysis such as optimization of selection cuts is **ongoing**