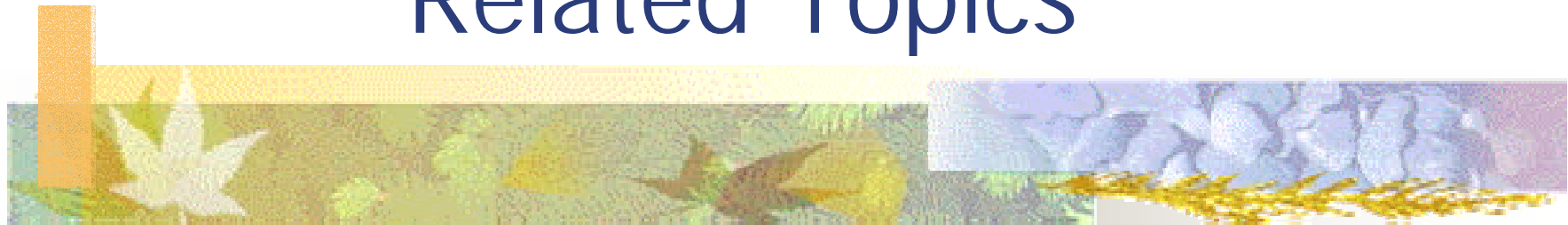


Final Results of RUNJOB and Related Topics



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Makoto Hareyama**

**Aoyama Gakuin Univ.
Toru Shiabta**

and RUNJOB collaboration

Aspen, 28 April 2005



Out Line

■ Final results of RUNJOB experiment

- individual elements spectra
- all-particle spectrum and average mass

V.A.Derbina et al., submitted to ApJL

■ Comparison to propagation models

- diffusion + no halo edge galaxy (Shibata et al., ApJ, 2004)
- leaky box (Gupta and Webber, ApJ, 1989)
- diffusion + reacceleration (Seo and Ptuskin., ApJ, 1994)



RUNJOB

RUssia-**NI**ppon **JO**int **B**alloon experiment

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T.Kobayashi, V.Kopenkin, S.Kuramata, A.K.Managadze, H.Matsutani,
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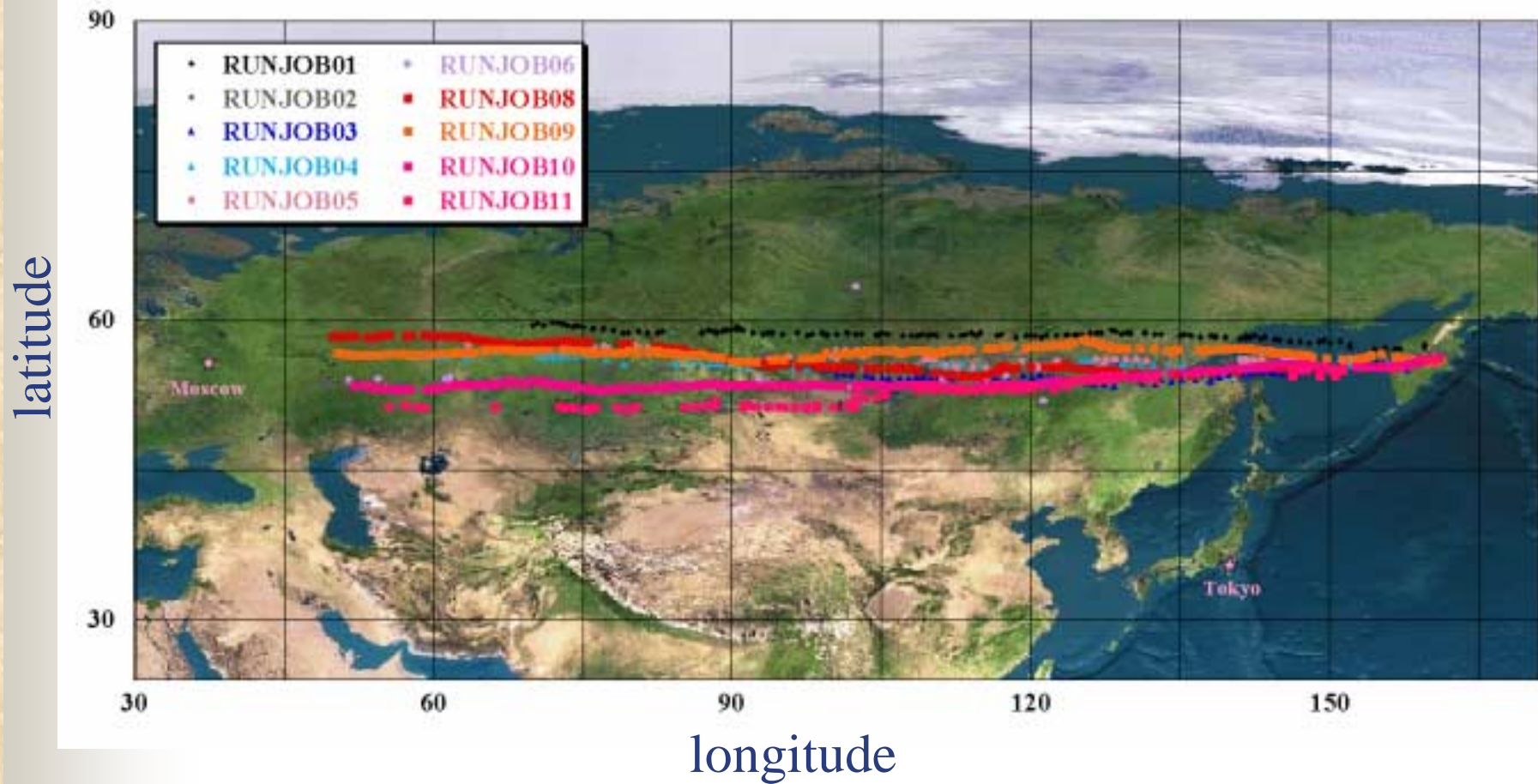
Multimedia Information Research Division, National Institute of Informatics The Ministry of Education,
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Department of Management, Urawa University, Urawa 337-0974, Japan

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Balloon Trajectory



Flight Summary

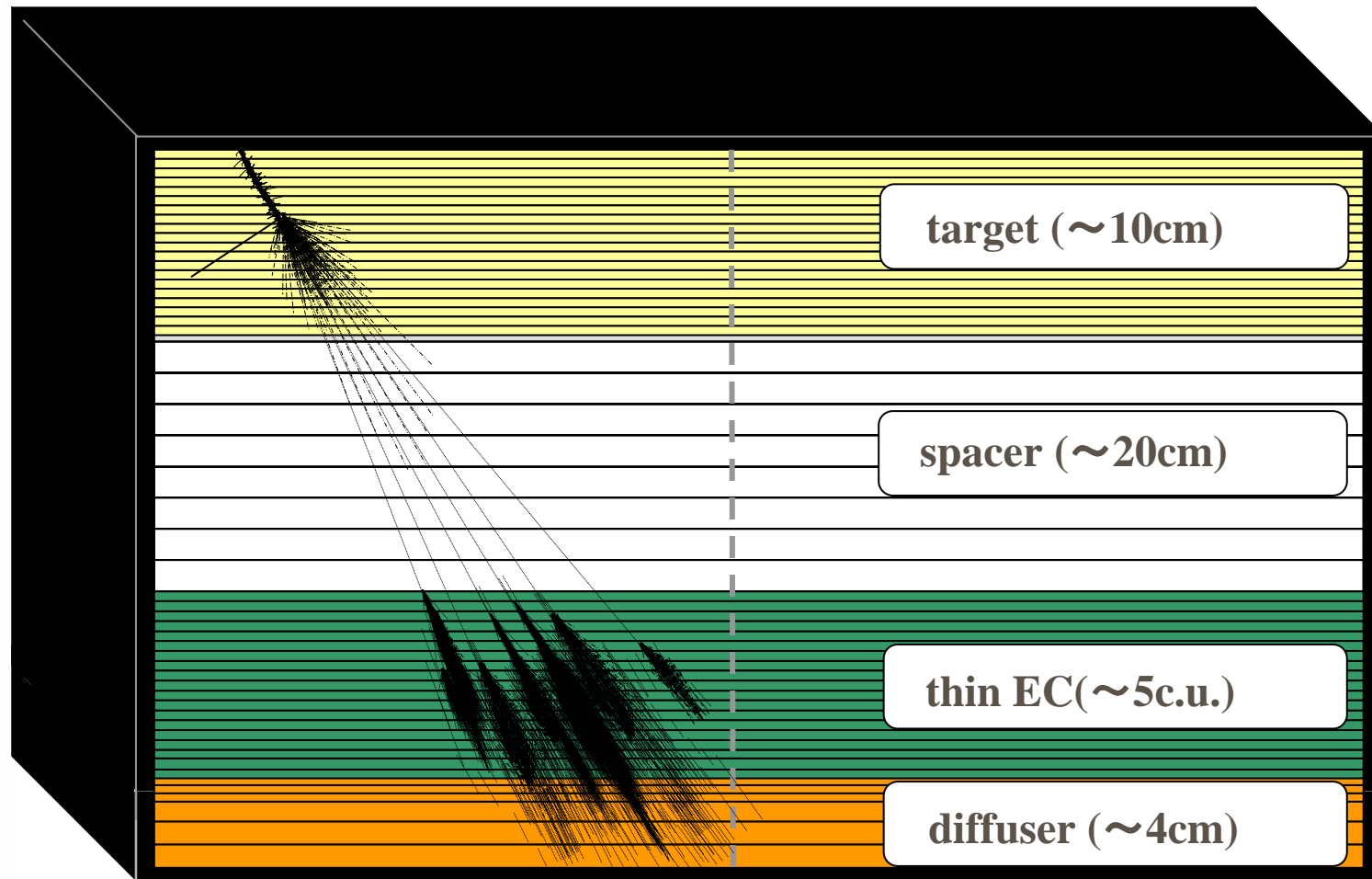
Flight Number	1995		1996		1997		
	1	2	3	4	5	6	7
Exposure time[hour]	130.0	167.0	134.0	147.5	139.5	139.5	failure
altitude[g/cm ²]	10.0	9.6	9.8	10.2	10.5	10.7	
Chamber area [m ²]	0.4	0.4	0.4	0.4	0.4	0.4	
Chamber weight [kg]	230.0	230.0	260.0	254.0	260.0	260.0	

Flight Number	1999			
	8	9	10	11
Exposure time[hour]	141.0	145.0	148.0	146.0
altitude[g/cm ²]	9.5	9.2	9.2	9.0
Chamber area [m ²]	0.4	0.4	0.4	0.4
Chamber weight [kg]	227.0	227.0	227.0	227.0

Total flight time = 1437.5 [hour] ~ 60 days

Total exposure factor = 575[m²·hour]

Chamber Structure



emulsion chamber

actual event in RUNJOB chamber



RJ09 B-block

event no.11

primary charge: CNO

zenith angle : 50 deg

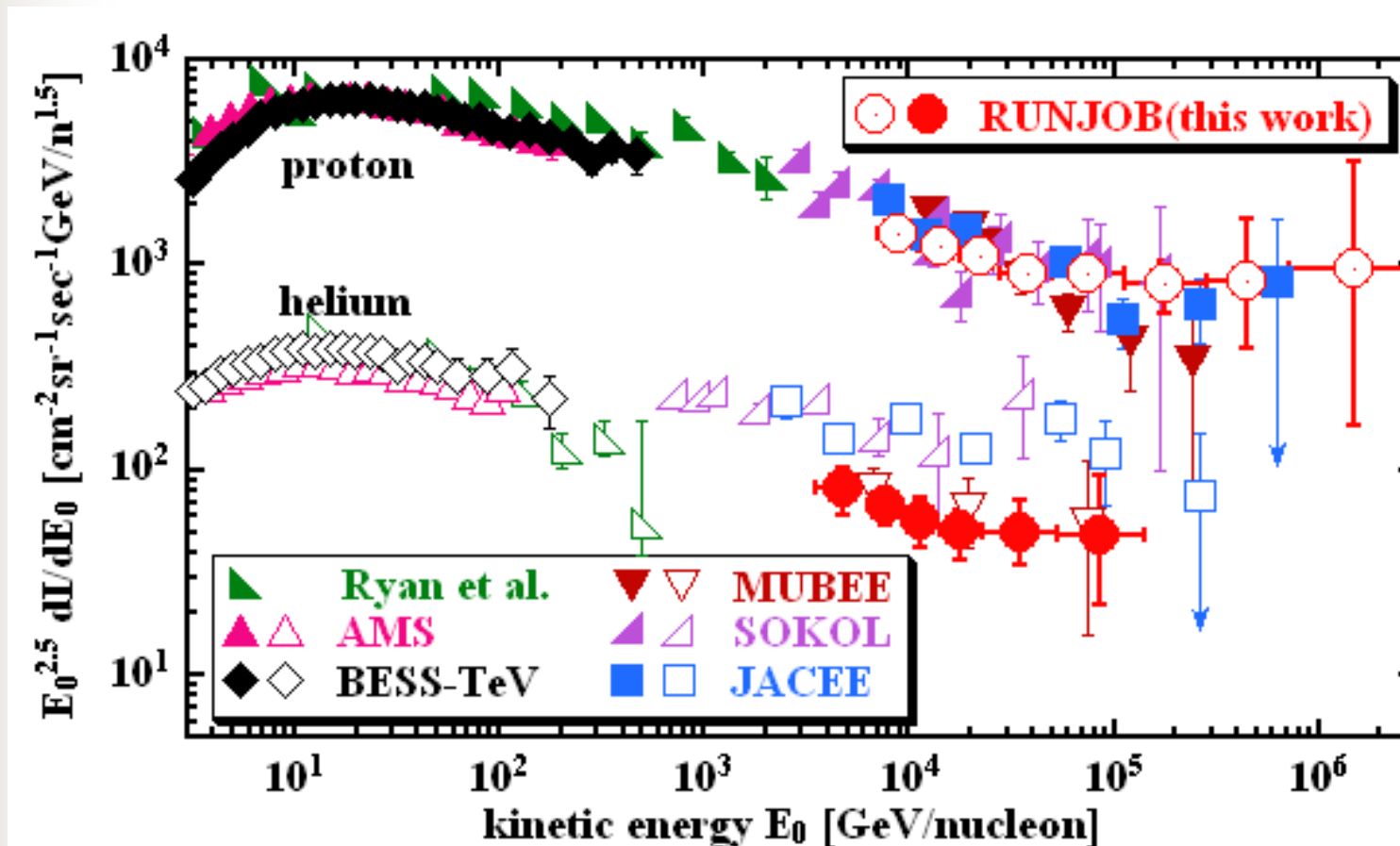
shower energy : 15.5 TeV

Analysis methods of RUNJOB

Apanasenko et al., Astrop. Phys, 2001

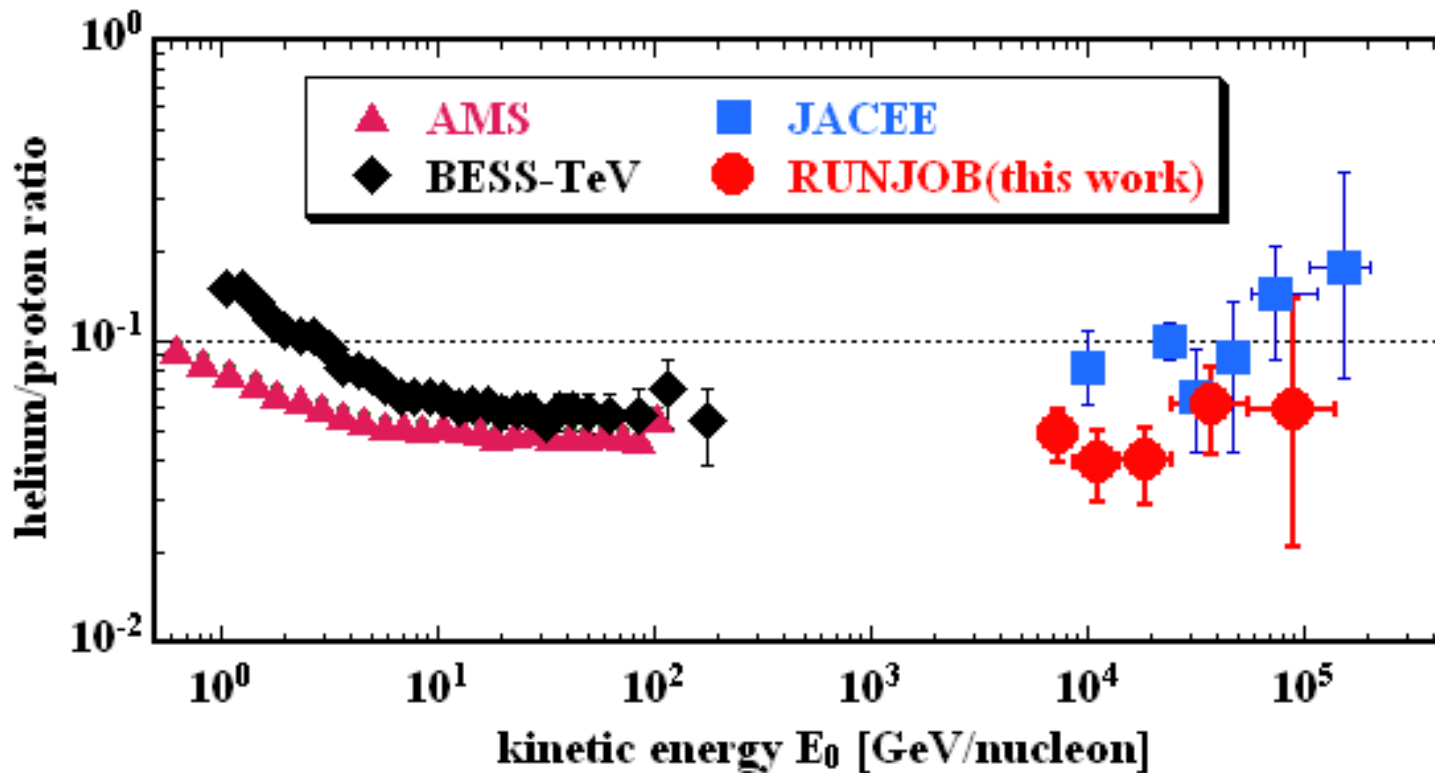
Hareyama et al., NIM, 2003

proton and helium spectra



- a PeV proton was detected in 1995
- parallel spectra
- He flux is half of those given by JACEE and SOKOL, while MUBEE is consistent.

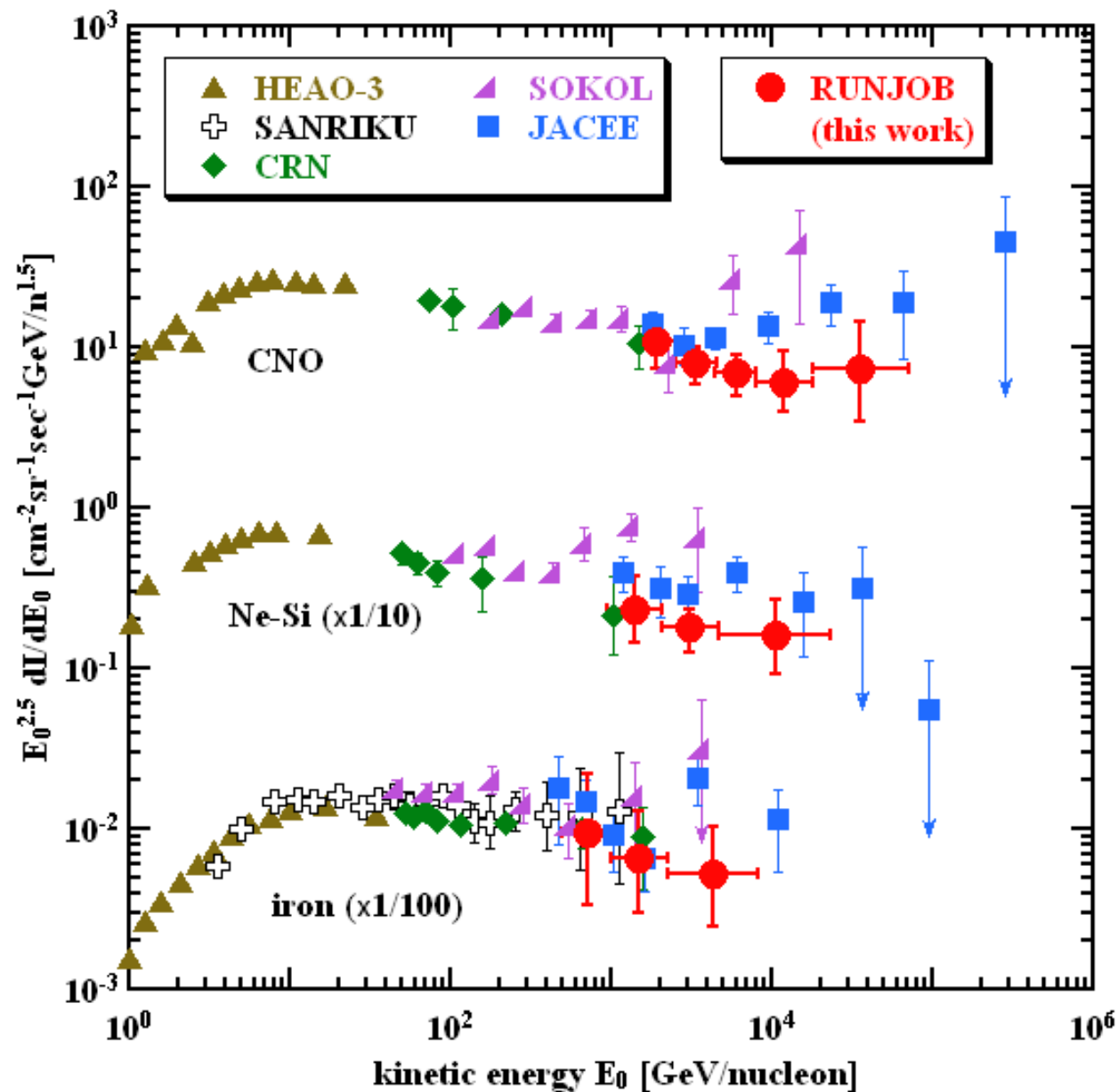
helium/proton ratio



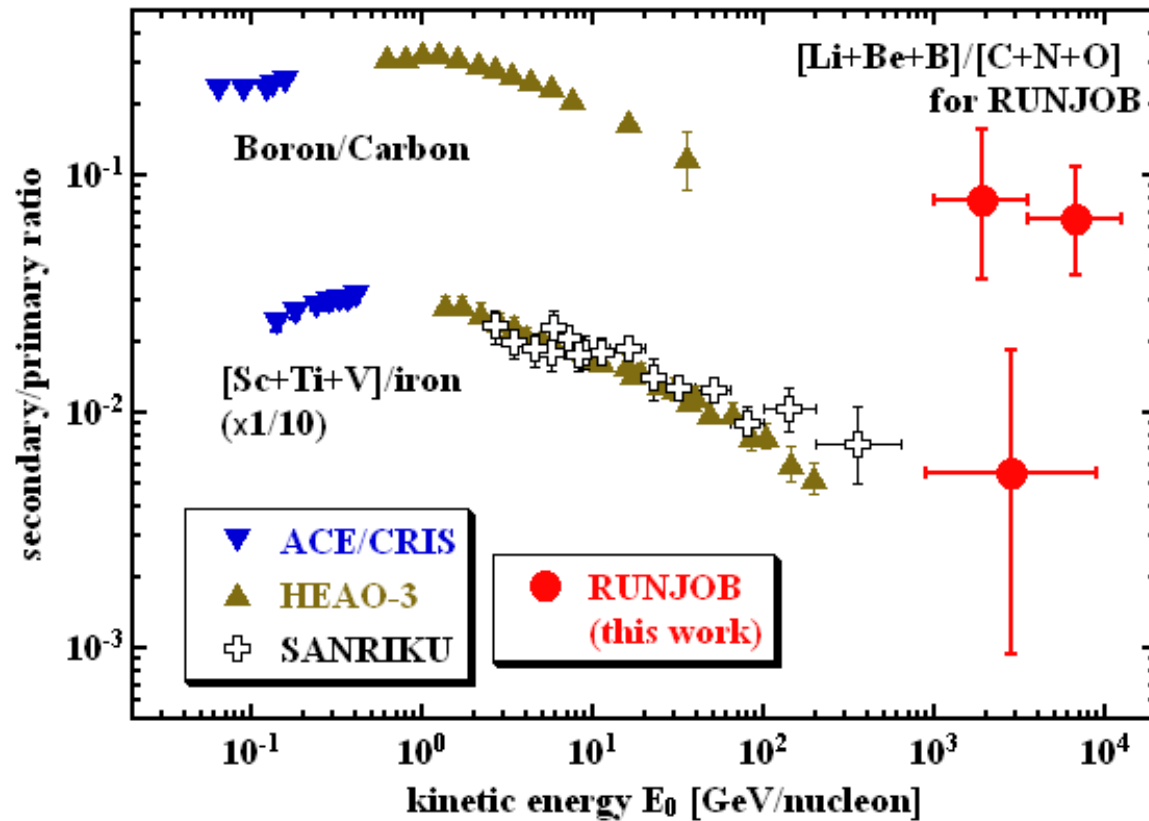
- constant ratio from 10GeV/n to 100TeV/n

heavy component spectra

- monotonically decrease
- on extrapolate line from CRN

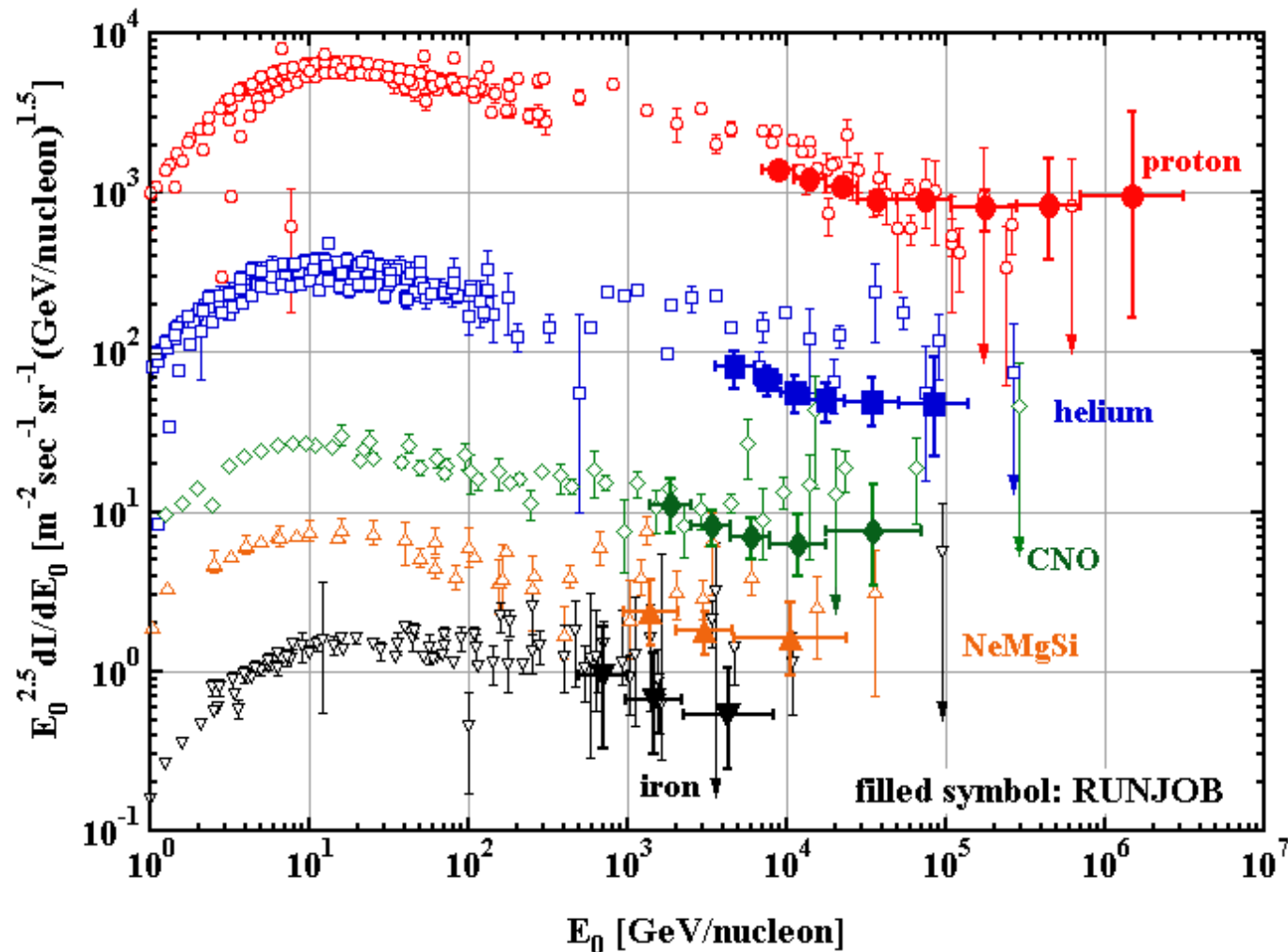


2-ry/1-ry ratio

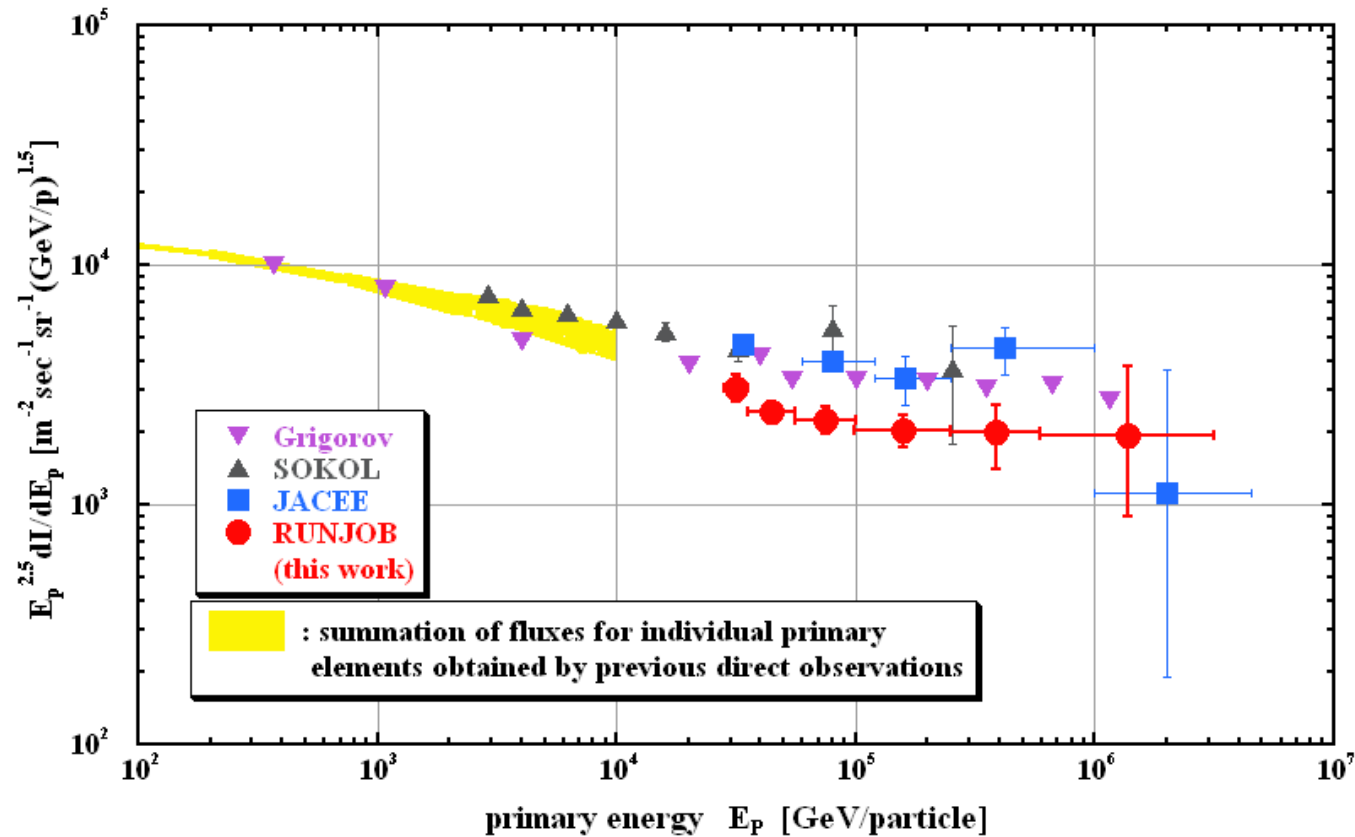


- TeV/n region data were shown
- but, big contamination correction for fragmentation in atmosphere (70% for Li-B and 45% for sub-Fe)

summary of individual spectra

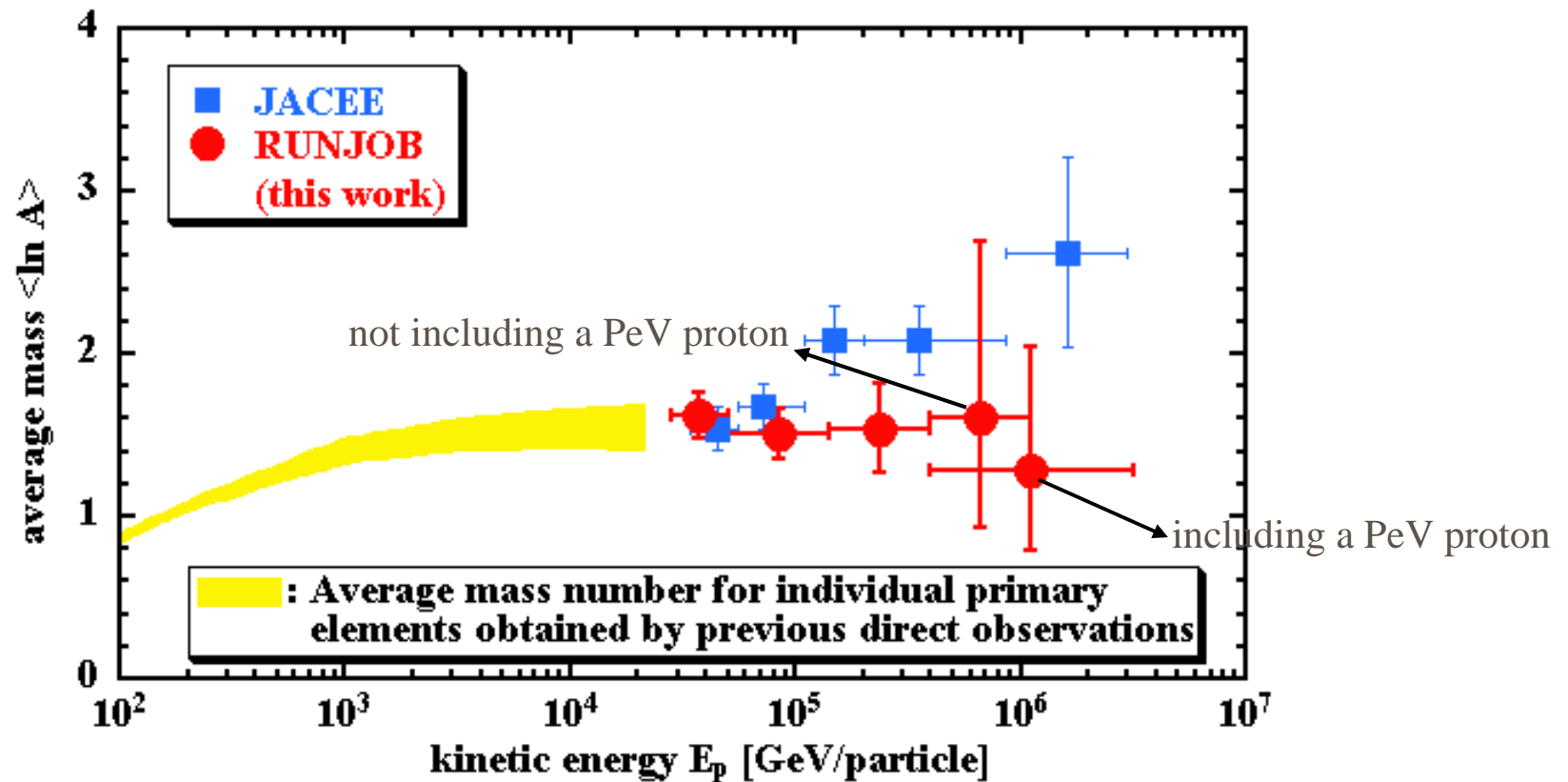


all particle spectrum



- 40% intensity less than other group
- spectral shape is almost same more than 50TeV region (flattering?)

average mass



- constant value (He ~ Li) from 1 to 1000 TeV/n



Comparison to propagation models

- Shibata et al., ApJ, 2004
diffusion model + no halo edge galaxy
 $\alpha = 1/2$ and $\alpha = 1/3$
- Gupta and Webber, ApJ, 1989
Standard Leaky Box Model, $\alpha = 0.6$
- Seo and Ptuskin., ApJ, 1994
diffusion model + reacceleration, $\alpha = 1/3$

α : index of energy (rigidity) dependency of propagation

propagation model

T.Shibata et al., ApJ, 612, 238–261, (2004)

no halo edge galaxy model

$$\text{Diffusion coefficient : } D(\mathbf{r}) \equiv D(r, z) = D_0 \exp \left[+ \left(\frac{r}{r_D} + \frac{|z|}{z_D} \right) \right]$$

$$\text{Gas density : } n(\mathbf{r}) \equiv n(r, z) = n_0 \exp \left[- \left(\frac{r}{r_n} + \frac{|z|}{z_n} \right) \right]$$

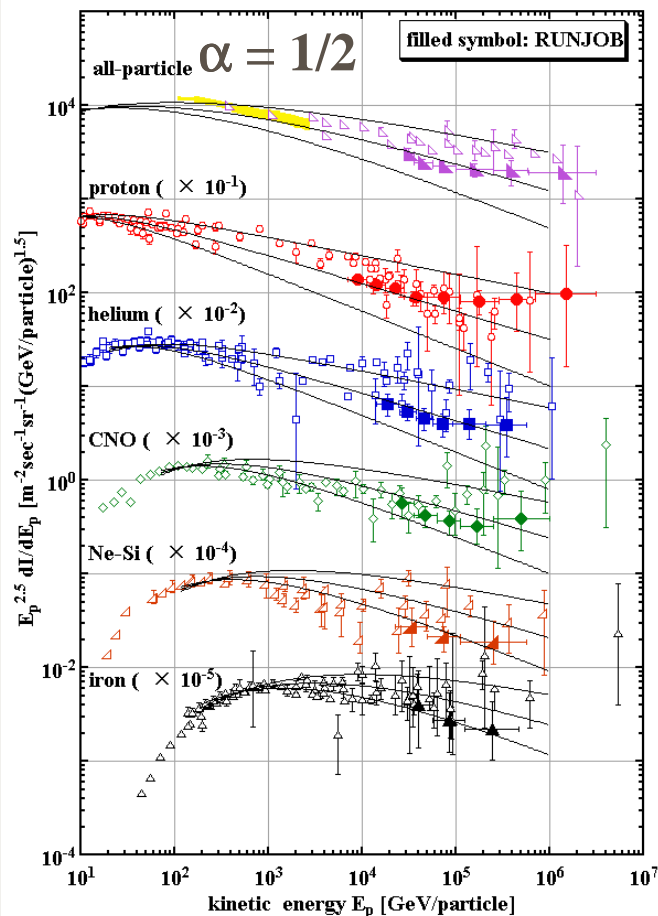
$$\text{Source density : } Q(\mathbf{r}) \equiv Q(r, z) = Q_0 \exp \left[- \left(\frac{r}{r_Q} + \frac{|z|}{z_Q} \right) \right]$$

$$\text{CR source spectrum} \quad \propto R^{-\gamma}$$

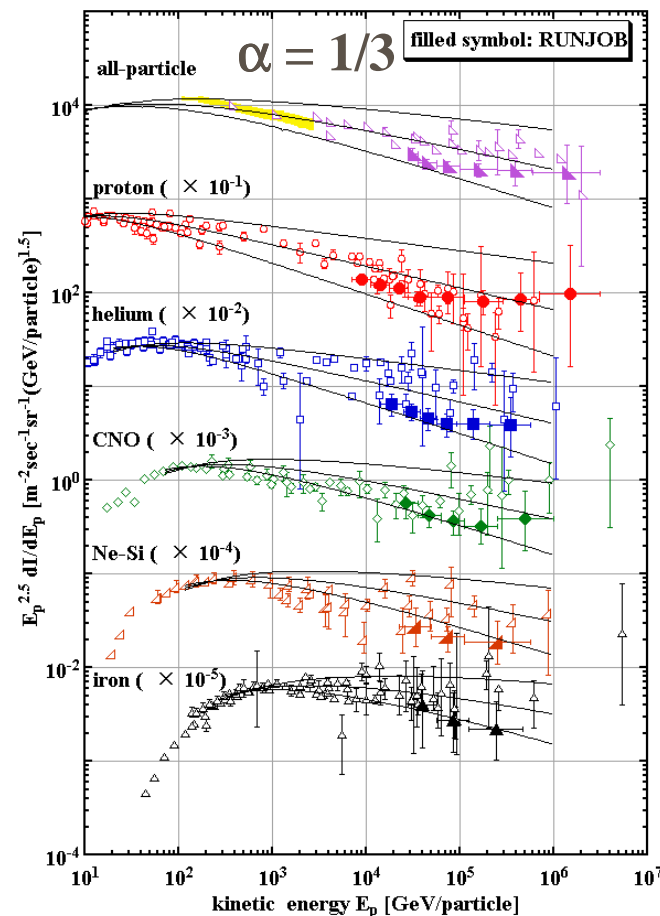
$$\text{rigidity dependency of } D_0 \quad \propto R^\alpha$$

Not taking account to low energy effect (ionization loss, reacceleration, solar modulation ...)

comparison with 1-ry spectra



γ :
2.2
2.3
2.4



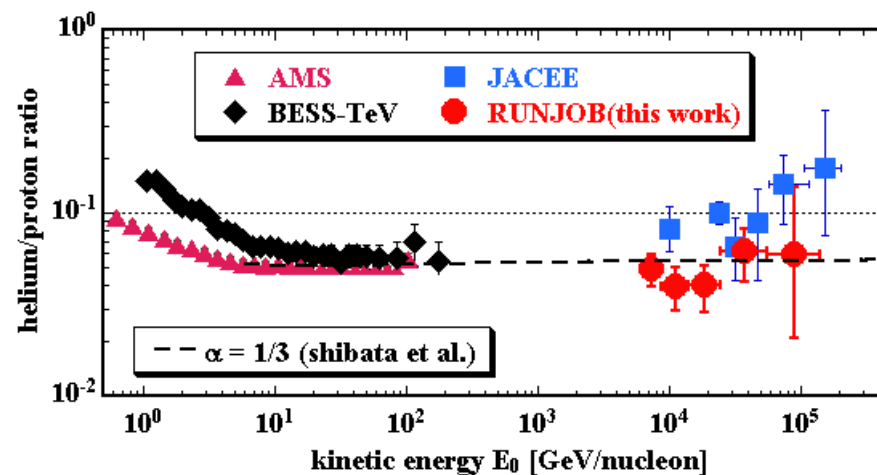
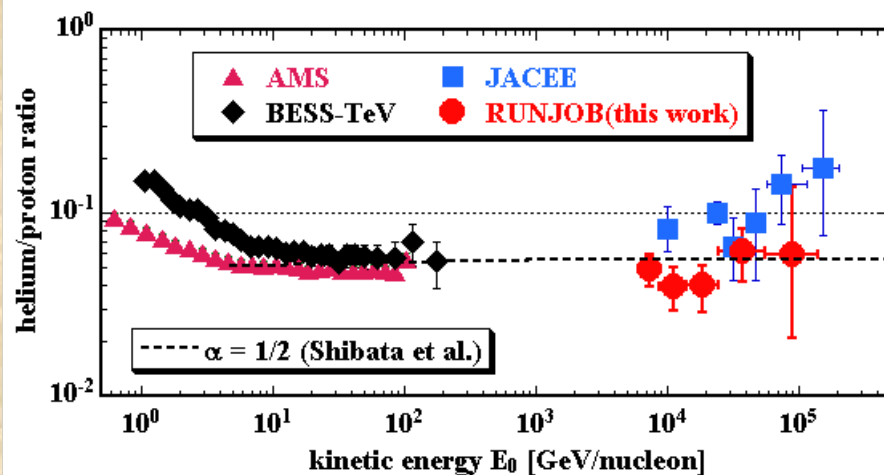
γ :
2.3
2.4
2.5

$$\beta = \gamma + \alpha = 2.7 \sim 2.8$$

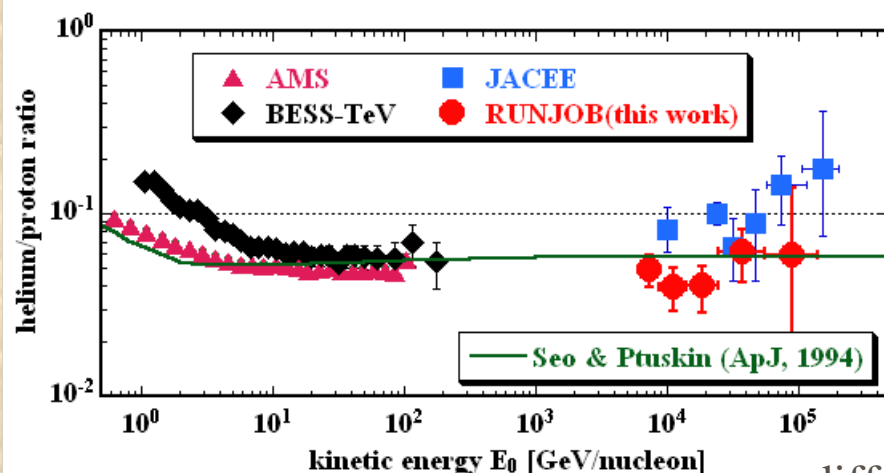
Model : diffusion + no halo edge galaxy (Shibata et al., 2004)

normalized to AMS for p and He and HEAO-3-C2 for heavies at 10 GeV/n

comparison with He/p ratio



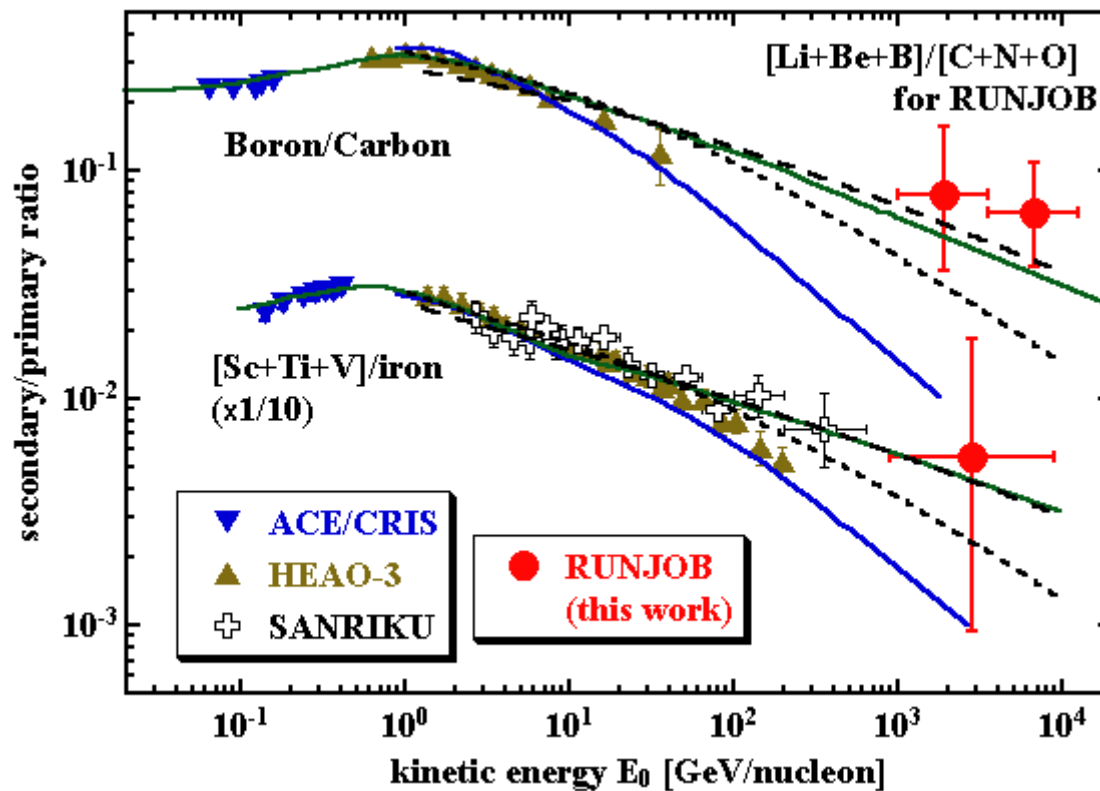
diffusion + no halo edge, normalized to AMS at 10GeV/n



If source spectra of p and He are parallel, He/p ratio is constant

diffusion + reacceleration

comparison with 2-ry/1-ry ratio



In order to confirm α , we need more data with good accuracy in $> 100\text{GeV}/n$ region.

- $\alpha = 0.6$, leaky box (Gupta and Webber, 1989)
- $\alpha = 1/3$, diffusion + reacceleration (Seo and Ptuskin, 1994)
- - - $\alpha = 1/3$, diffusion + no halo edge (Shibata et al., 2004)
- $\alpha = 1/2$, diffusion + no halo edge (Shibata et al., 2004)



Summary 1

Final results of RUNJOB observed by 10 long duration balloons (about 60 days).

■ Proton and Helium

- The both spectral index are almost parallel ($\beta = 2.7 \sim 2.8$)
- Helium flux of RUNJOB is half of those obtained by JACEE and SOKOL, while MUBEE is consistent.
- A PeV proton was detected directly.
- He/p ratio is good agreement with propagation models such as Seo-Ptuskin and Shibata et al.



Summary 2

- Heavy components
 - The intensities decrease monotonically with energy getting.
 - RUNJOB data are in good agreement with extrapolated line form CRN data
 - TeV region data of 2-ry/1-ry ratio are shown, though the ratio need to be viewed with large uncertainties in mind.

- All particle spectrum and average mass
 - RUNJOB is 40% of intensity less than one of other direct measurements.
 - Any spectra obtained by direct measurements look like same shape (flattering?) in the energy range more than 50TeV/particle.
 - Average mass is almost constant value , $\langle \ln A \rangle \sim 1.5$ corresponding to He or Li, in the energy rage from a few TeV to 1000 TeV.

RUNJOB

final results

