Precision Measurement of the Helium Flux in Primary Cosmic Rays from Rigidities of 1.9 GV to 3 TV with the Alpha Magnetic Spectrometer on the International Space Station Supplemental Material

(AMS Collaboration)

TABLE I: The helium flux Φ as a function of rigidity at the top of AMS in units of $[\mathrm{m}^2 \cdot \mathrm{sr} \cdot \mathrm{s} \cdot \mathrm{GV}]^{-1}$ including errors due to statistics (stat.); contributions to the systematic error from the trigger (trig.); geomagnetic cutoff, acceptance, and background contamination (acc.); the rigidity resolution function and unfolding (unf.); and the absolute rigidity scale (scale); and the total systematic error (syst.).

Rigidity [GV]	Φ	$\sigma_{\mathrm{stat.}}$	$\sigma_{\mathrm{trig.}}$	$\sigma_{\mathrm{acc.}}$	$\sigma_{\mathrm{unf.}}$	σ_{scale}	$\sigma_{\mathrm{syst.}}$	
1.92 – 2.15	(6.031	0.007	0.002	0.106	0.054	0.012	0.120	)$\times 10^{1}$
2.15 – 2.40	(5.657	0.006	0.001	0.087	0.046	0.008	0.098	)$\times 10^{1}$
2.40 – 2.67	(5.174	0.005	0.001	0.073	0.036	0.004	0.082	)$\times 10^{1}$
2.67 – 2.97	(4.694	0.004	0.001	0.063	0.031	0.003	0.070	)$\times 10^{1}$
2.97 – 3.29	(4.176	0.004	0.001	0.055	0.026	0.004	0.061	)$\times 10^{1}$
3.29 – 3.64	(3.650	0.003	0.001	0.048	0.022	0.005	0.053	)$\times 10^{1}$
3.64 – 4.02	(3.145	0.003	0.001	0.041	0.018	0.005	0.045	)$\times 10^{1}$
4.02 – 4.43	(2.671	0.002	0.001	0.035	0.014	0.005	0.038	)$\times 10^{1}$
4.43 – 4.88	(2.250	0.002	0.001	0.029	0.012	0.005	0.032	)$\times 10^{1}$
4.88 – 5.37	(1.876	0.001	0.001	0.024	0.010	0.004	0.027	)$\times 10^{1}$
5.37 – 5.90	(1.555	0.001	0.001	0.020	0.008	0.004	0.022	)$\times 10^{1}$
5.90 – 6.47	(1.282	0.001	0.001	0.016	0.007	0.003	0.018	)$\times 10^{1}$
6.47 – 7.09	(1.054	0.001	0.001	0.013	0.006	0.003	0.015	)$\times 10^{1}$
7.09 – 7.76	(8.646	0.006	0.005	0.108	0.046	0.026	0.120	)$\times 10^{0}$
7.76 – 8.48	(7.081	0.005	0.004	0.087	0.038	0.022	0.098	)$\times 10^{0}$
8.48 – 9.26	(5.786	0.004	0.003	0.071	0.031	0.019	0.079	)$\times 10^{0}$
9.26 – 10.1	(4.740	0.004	0.003	0.058	0.025	0.016	0.065	)$\times 10^{0}$
10.1 – 11.0	(3.866	0.003	0.002	0.047	0.020	0.013	0.053	)$\times 10^{0}$
11.0 – 12.0	(3.138	0.003	0.002	0.038	0.017	0.011	0.043	)$\times 10^{0}$
12.0 – 13.0	(2.566	0.002	0.001	0.031	0.014	0.009	0.035	)$\times 10^{0}$
13.0 – 14.1	(2.100	0.002	0.001	0.025	0.011	0.008	0.029	)$\times 10^{0}$
14.1 – 15.3	(1.711	0.002	0.001	0.020	0.009	0.006	0.023	)$\times 10^{0}$
15.3 – 16.6	(1.395	0.001	0.001	0.017	0.007	0.005	0.019	)$\times 10^{0}$
16.6 – 18.0	(1.134	0.001	0.001	0.014	0.006	0.004	0.015	)$\times 10^{0}$
18.0 – 19.5	(9.241	0.010	0.007	0.110	0.049	0.036	0.126	)$\times 10^{-1}$
19.5 – 21.1	(7.485	0.009	0.006	0.089	0.040	0.029	0.102	)$\times 10^{-1}$
21.1 – 22.8	(6.100	0.007	0.005	0.073	0.032	0.024	0.083	)$\times 10^{-1}$
22.8 – 24.7	(4.963	0.006	0.004	0.059	0.026	0.020	0.068	)$\times 10^{-1}$
24.7 – 26.7	(4.045	0.005	0.003	0.048	0.021	0.016	0.055	)$\times 10^{-1}$
26.7 – 28.8	(3.295	0.004	0.003	0.039	0.017	0.013	0.045	)$\times 10^{-1}$
28.8 – 31.1	(2.686	0.004	0.002	0.032	0.014	0.011	0.037	)$\times 10^{-1}$
31.1 – 33.5	(2.194	0.003	0.002	0.026	0.012	0.009	0.030	)$\times 10^{-1}$
33.5 – 36.1	(1.797	0.003	0.002	0.022	0.010	0.007	0.025	)$\times 10^{-1}$
36.1 – 38.9	(1.469	0.002	0.001	0.018	0.008	0.006	0.020	)$\times 10^{-1}$
38.9 – 41.9	(1.198	0.002	0.001	0.014	0.006	0.005	0.017	)$\times 10^{-1}$
41.9 – 45.1	(9.824	0.018	0.010	0.119	0.052	0.041	0.136	)$\times 10^{-2}$

Table continued

TABLE I – *(Continued).*

Rigidity [GV]	Φ	$\sigma_{\text{stat.}}$	$\sigma_{\text{trig.}}$	$\sigma_{\text{acc.}}$	$\sigma_{\text{unf.}}$	σ_{scale}	$\sigma_{\text{syst.}}$	
45.1 – 48.5	(8.071	0.016	0.008	0.098	0.043	0.034	0.112	)$\times 10^{-2}$
48.5 – 52.2	(6.566	0.014	0.007	0.080	0.035	0.027	0.091	)$\times 10^{-2}$
52.2 – 56.1	(5.415	0.012	0.006	0.066	0.029	0.023	0.076	)$\times 10^{-2}$
56.1 – 60.3	(4.446	0.011	0.005	0.054	0.024	0.019	0.062	)$\times 10^{-2}$
60.3 – 64.8	(3.642	0.009	0.004	0.044	0.019	0.016	0.051	)$\times 10^{-2}$
64.8 – 69.7	(2.984	0.008	0.004	0.036	0.016	0.013	0.042	)$\times 10^{-2}$
69.7 – 74.9	(2.456	0.007	0.003	0.030	0.013	0.011	0.034	)$\times 10^{-2}$
74.9 – 80.5	(2.015	0.006	0.003	0.024	0.011	0.009	0.028	)$\times 10^{-2}$
80.5 – 86.5	(1.654	0.005	0.002	0.020	0.009	0.008	0.023	)$\times 10^{-2}$
86.5 – 93.0	(1.357	0.005	0.002	0.016	0.007	0.006	0.019	)$\times 10^{-2}$
93.0 – 100	(1.113	0.004	0.002	0.014	0.006	0.005	0.016	)$\times 10^{-2}$
100 – 108	(9.068	0.034	0.015	0.110	0.048	0.044	0.129	)$\times 10^{-3}$
108 – 116	(7.328	0.030	0.013	0.090	0.039	0.037	0.105	)$\times 10^{-3}$
116 – 125	(5.977	0.026	0.011	0.073	0.032	0.030	0.086	)$\times 10^{-3}$
125 – 135	(4.905	0.022	0.010	0.061	0.027	0.026	0.072	)$\times 10^{-3}$
135 – 147	(3.898	0.018	0.009	0.048	0.021	0.021	0.058	)$\times 10^{-3}$
147 – 160	(3.104	0.015	0.007	0.039	0.017	0.018	0.047	)$\times 10^{-3}$
160 – 175	(2.433	0.013	0.006	0.031	0.014	0.015	0.037	)$\times 10^{-3}$
175 – 192	(1.888	0.010	0.005	0.024	0.011	0.012	0.030	)$\times 10^{-3}$
192 – 211	(1.481	0.009	0.004	0.019	0.009	0.010	0.024	)$\times 10^{-3}$
211 – 233	(1.121	0.007	0.004	0.015	0.007	0.008	0.019	)$\times 10^{-3}$
233 – 259	(8.621	0.056	0.030	0.116	0.060	0.064	0.149	)$\times 10^{-4}$
259 – 291	(6.312	0.043	0.024	0.087	0.048	0.051	0.113	)$\times 10^{-4}$
291 – 330	(4.614	0.033	0.018	0.065	0.038	0.041	0.087	)$\times 10^{-4}$
330 – 379	(3.199	0.024	0.014	0.046	0.029	0.032	0.065	)$\times 10^{-4}$
379 – 441	(2.158	0.018	0.010	0.032	0.022	0.024	0.047	)$\times 10^{-4}$
441 – 525	(1.397	0.012	0.007	0.022	0.015	0.018	0.033	)$\times 10^{-4}$
525 – 643	(8.738	0.081	0.047	0.142	0.110	0.134	0.229	)$\times 10^{-5}$
643 – 822	(4.682	0.048	0.028	0.081	0.068	0.091	0.142	)$\times 10^{-5}$
822 – 1130	(2.288	0.025	0.015	0.042	0.040	0.060	0.085	)$\times 10^{-5}$
1130 – 1800	(7.980	0.100	0.060	0.161	0.182	0.310	0.398	)$\times 10^{-6}$
1800 – 3000	(2.147	0.038	0.019	0.047	0.069	0.134	0.159	)$\times 10^{-6}$

TABLE II: The proton to helium flux ratio p/He as a function of rigidity including errors due to statistics (stat.); contributions to the systematic error from the trigger (trig.); geomagnetic cutoff, acceptance, and background contamination (acc.); the rigidity resolution function and unfolding (unf.); the absolute rigidity scale (scale); and the total systematic error (syst.).

Rigidity [GV]	p/He	$\sigma_{\text{stat.}}$	$\sigma_{\text{trig.}}$	$\sigma_{\text{acc.}}$	$\sigma_{\text{unf.}}$	σ_{scale}	$\sigma_{\text{syst.}}$
1.92 – 2.15	8.279	0.010	0.008	0.207	0.092	0.018	0.228
2.15 – 2.40	7.814	0.009	0.007	0.175	0.081	0.008	0.193
2.40 – 2.67	7.495	0.008	0.006	0.154	0.073	0.000	0.171
2.67 – 2.97	7.156	0.007	0.006	0.137	0.067	0.006	0.153
2.97 – 3.29	6.902	0.006	0.006	0.127	0.062	0.005	0.142
3.29 – 3.64	6.721	0.006	0.006	0.120	0.060	0.003	0.135
3.64 – 4.02	6.575	0.006	0.006	0.115	0.057	0.002	0.128
4.02 – 4.43	6.480	0.005	0.006	0.111	0.054	0.002	0.124
4.43 – 4.88	6.391	0.005	0.006	0.108	0.053	0.002	0.120
4.88 – 5.37	6.311	0.005	0.006	0.105	0.052	0.002	0.117
5.37 – 5.90	6.234	0.005	0.006	0.102	0.050	0.001	0.114
5.90 – 6.47	6.167	0.005	0.006	0.099	0.049	0.001	0.111
6.47 – 7.09	6.089	0.005	0.006	0.097	0.048	0.001	0.108
7.09 – 7.76	6.011	0.005	0.006	0.094	0.048	0.001	0.106
7.76 – 8.48	5.932	0.005	0.006	0.092	0.047	0.001	0.103
8.48 – 9.26	5.852	0.005	0.006	0.090	0.046	0.000	0.101
9.26 – 10.1	5.747	0.005	0.005	0.088	0.045	0.000	0.098
10.1 – 11.0	5.665	0.005	0.005	0.086	0.044	0.000	0.097
11.0 – 12.0	5.603	0.005	0.005	0.085	0.043	0.000	0.096
12.0 – 13.0	5.522	0.006	0.005	0.084	0.043	0.000	0.094
13.0 – 14.1	5.467	0.006	0.005	0.083	0.043	0.000	0.093
14.1 – 15.3	5.415	0.006	0.006	0.082	0.042	0.000	0.092
15.3 – 16.6	5.347	0.006	0.006	0.081	0.042	0.000	0.091
16.6 – 18.0	5.285	0.006	0.006	0.080	0.042	0.000	0.090
18.0 – 19.5	5.229	0.006	0.006	0.079	0.041	0.000	0.089
19.5 – 21.1	5.202	0.006	0.006	0.078	0.041	0.000	0.089
21.1 – 22.8	5.165	0.007	0.006	0.078	0.041	0.000	0.088
22.8 – 24.7	5.114	0.007	0.006	0.077	0.041	0.000	0.088
24.7 – 26.7	5.043	0.007	0.006	0.076	0.040	0.000	0.086
26.7 – 28.8	5.008	0.007	0.006	0.075	0.040	0.000	0.086
28.8 – 31.1	4.971	0.007	0.006	0.075	0.040	0.000	0.085
31.1 – 33.5	4.931	0.008	0.007	0.074	0.040	0.000	0.085
33.5 – 36.1	4.891	0.008	0.007	0.074	0.039	0.000	0.084
36.1 – 38.9	4.853	0.009	0.007	0.074	0.039	0.000	0.084
38.9 – 41.9	4.836	0.009	0.007	0.074	0.039	0.000	0.084
41.9 – 45.1	4.800	0.010	0.007	0.073	0.039	0.000	0.083

Table continued

TABLE II – *(Continued).*

Rigidity [GV]	p/He	$\sigma_{\text{stat.}}$	$\sigma_{\text{trig.}}$	$\sigma_{\text{acc.}}$	$\sigma_{\text{unf.}}$	σ_{scale}	$\sigma_{\text{syst.}}$
45.1 – 48.5	4.757	0.010	0.007	0.073	0.039	0.000	0.083
48.5 – 52.2	4.764	0.011	0.007	0.073	0.039	0.001	0.083
52.2 – 56.1	4.707	0.012	0.007	0.072	0.038	0.001	0.082
56.1 – 60.3	4.678	0.012	0.008	0.072	0.038	0.001	0.082
60.3 – 64.8	4.671	0.013	0.008	0.072	0.038	0.001	0.082
64.8 – 69.7	4.668	0.014	0.008	0.072	0.038	0.001	0.082
69.7 – 74.9	4.610	0.015	0.008	0.071	0.038	0.001	0.081
74.9 – 80.5	4.598	0.015	0.009	0.071	0.038	0.001	0.081
80.5 – 86.5	4.553	0.016	0.009	0.071	0.037	0.001	0.080
86.5 – 93.0	4.530	0.017	0.009	0.070	0.037	0.001	0.080
93.0 – 100	4.514	0.018	0.010	0.070	0.037	0.002	0.080
100 – 108	4.505	0.019	0.010	0.070	0.038	0.002	0.080
108 – 116	4.495	0.021	0.011	0.071	0.038	0.002	0.081
116 – 125	4.514	0.022	0.011	0.071	0.038	0.002	0.082
125 – 135	4.432	0.022	0.012	0.071	0.038	0.003	0.081
135 – 147	4.431	0.023	0.012	0.071	0.039	0.003	0.082
147 – 160	4.376	0.024	0.013	0.071	0.039	0.003	0.082
160 – 175	4.377	0.025	0.014	0.072	0.040	0.004	0.083
175 – 192	4.350	0.027	0.015	0.072	0.040	0.004	0.084
192 – 211	4.254	0.028	0.016	0.072	0.040	0.005	0.084
211 – 233	4.274	0.030	0.017	0.073	0.041	0.006	0.086
233 – 259	4.181	0.030	0.018	0.073	0.042	0.006	0.087
259 – 291	4.194	0.032	0.019	0.075	0.044	0.008	0.089
291 – 330	4.083	0.033	0.020	0.075	0.044	0.008	0.090
330 – 379	4.026	0.035	0.022	0.076	0.046	0.009	0.092
379 – 441	4.029	0.037	0.024	0.079	0.049	0.009	0.096
441 – 525	3.970	0.039	0.027	0.081	0.052	0.009	0.100
525 – 643	3.842	0.041	0.029	0.082	0.055	0.011	0.104
643 – 822	3.973	0.046	0.035	0.090	0.063	0.014	0.116
822 – 1130	3.745	0.047	0.040	0.092	0.073	0.015	0.125
1130 – 1800	3.676	0.053	0.052	0.101	0.095	0.018	0.150

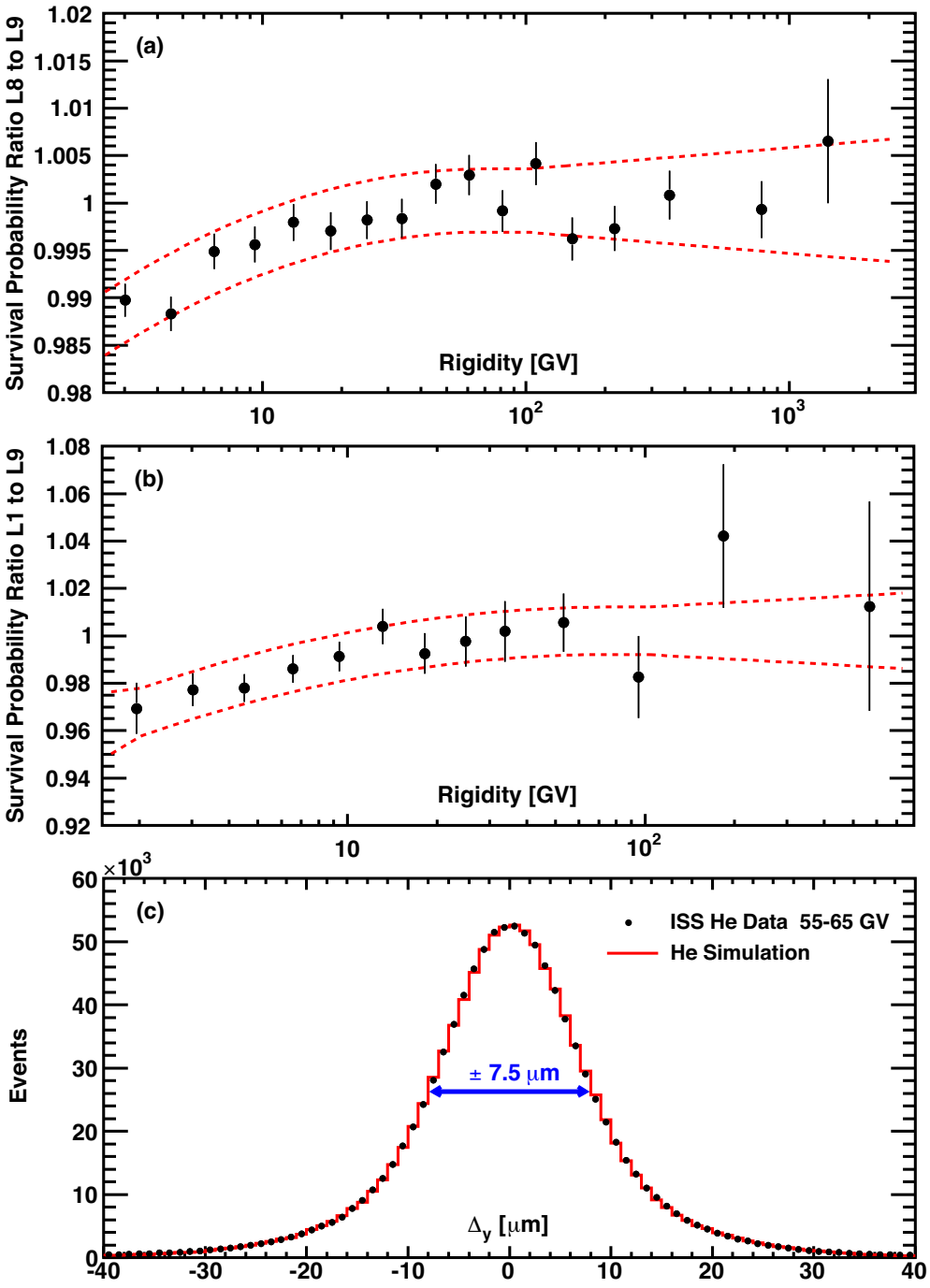

FIG. SM1. (a) Ratio of the He survival probabilities from L8 to L9 between the best scaled simulation and data when traversing the lower TOF and RICH. (b) Ratio of the He survival probabilities from L1 to L9 between the best scaled simulation and data when traversing the entire detector. In (a) and (b) the dashed curves indicate the corresponding systematic errors. (c) The differences Δ_y of the bending plane y coordinates measured in L3 or L5 to those obtained from the track fit using the measurements from L1, L2, L4, L6, L7, L8, and L9 for data and simulation. The blue arrow indicates that the width at half height is ± 7.5 μm.

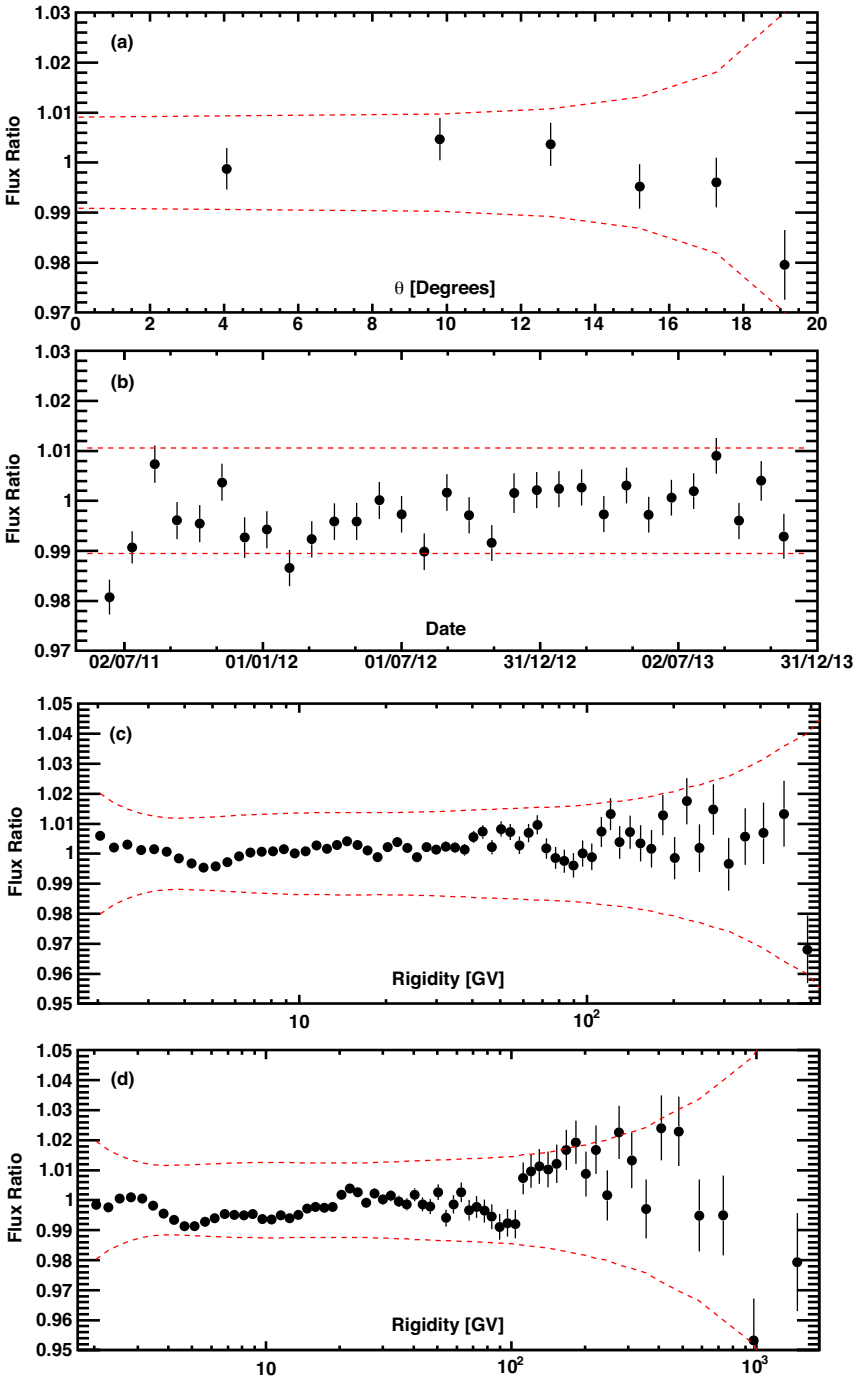

FIG. SM2. Independent verification of the systematic errors. The curves indicate the corresponding systematic errors. (a) Variation of the flux ratio above 30 GV vs the incident angle to the AMS central axis. This verifies the systematic errors on the acceptance. (b) Variation of the flux ratio above 45 GV vs time. This verifies that the detector performance is stable over time and that the flux above 45 GV shows no observable effect from solar modulation fluctuations. (c) Variation of the flux ratio measured using only the inner tracker vs the full tracker. (d) Variation of the flux ratio measured using tracker L1 to L8 vs the full tracker (L1 to L9). (c) and (d) verify the systematic errors from the acceptance, the unfolding procedure, the unfolding procedure and the rigidity resolution function.