



Li and Be Isotopes in the PAMELA Experiment 2006-2008

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GEANT4 Simulation of Isotopes Separation

- PAMELA acceptance
- Nuclei cross S1-S3, Tracker, Calorimeter without nuclear interactions (interactions - background)
- Truncated selection in Si X,Y- detectors for ionization loss. Energy scale step of E_{Si} distributions by simulation – 2 or 10 keV (V. Formato data)
- Rigidities and angular data from Tracker

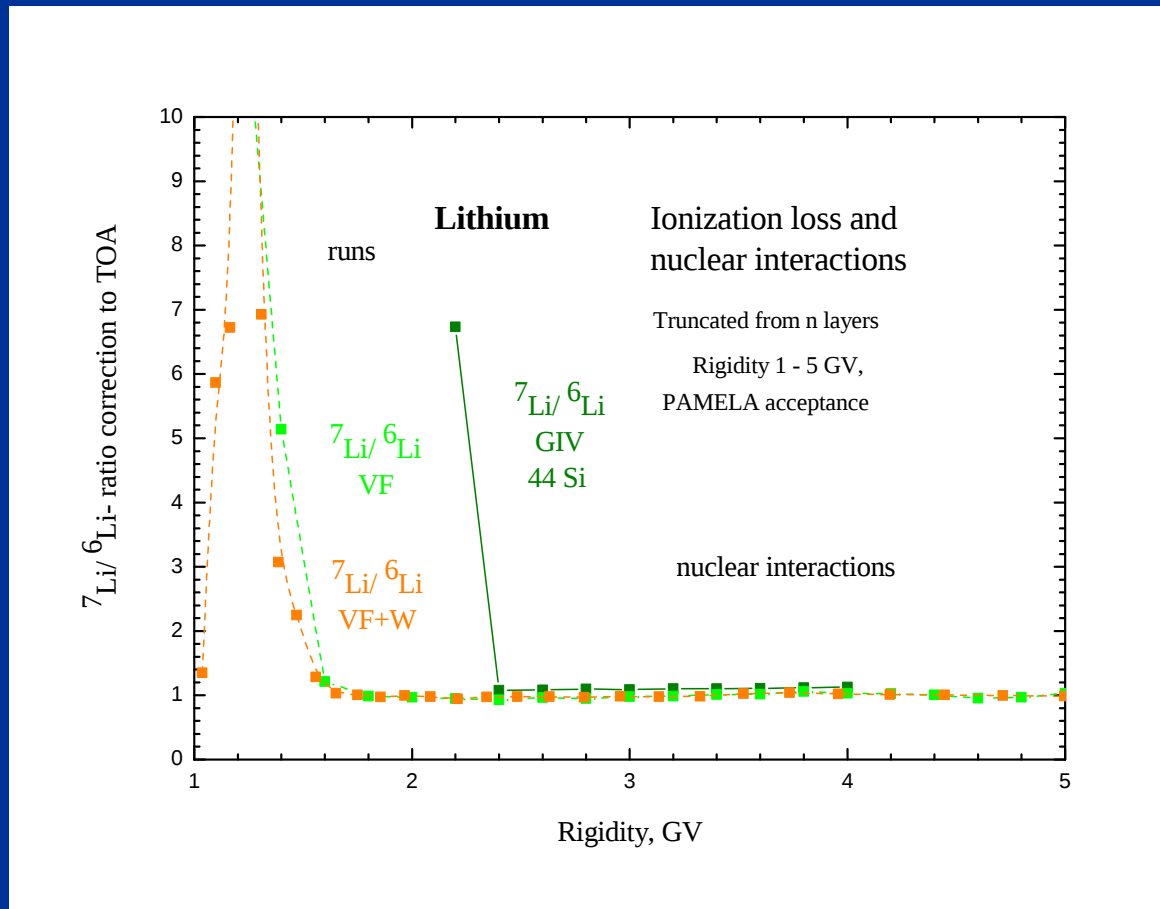
PAMELA Flight Data 2006-2008

Lithium and Beryllium

- Li and Be PAMELA data are need without signals in CARD, CAT and CAS. Signal in Si layer of the Calorimeter before nuclear interaction is equal or more than one in 1st Si.

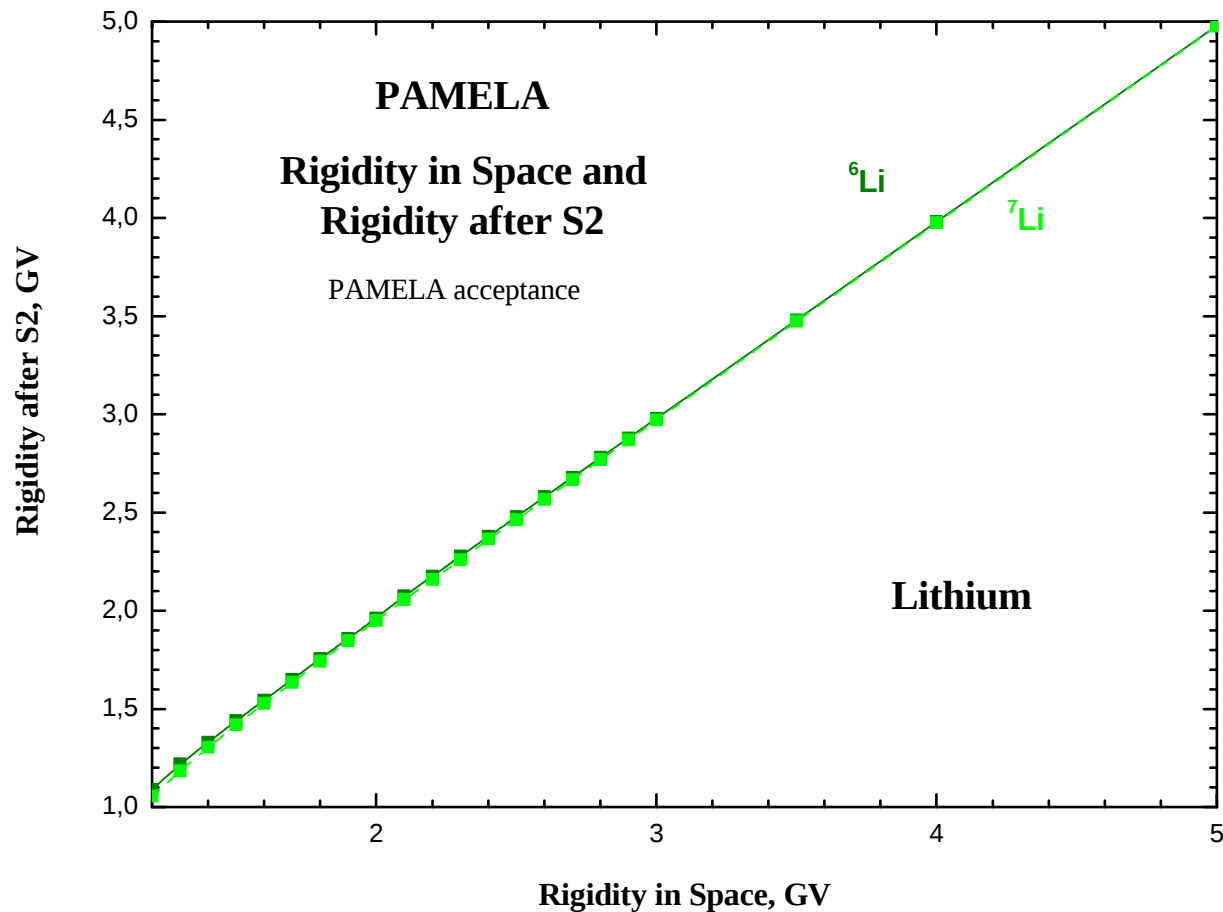
Lithium Isotopes and PAMELA

Correction of measurements data for $^7\text{Li}/^6\text{Li}$ ratio to space (TOA). Runs and nuclear interactions.

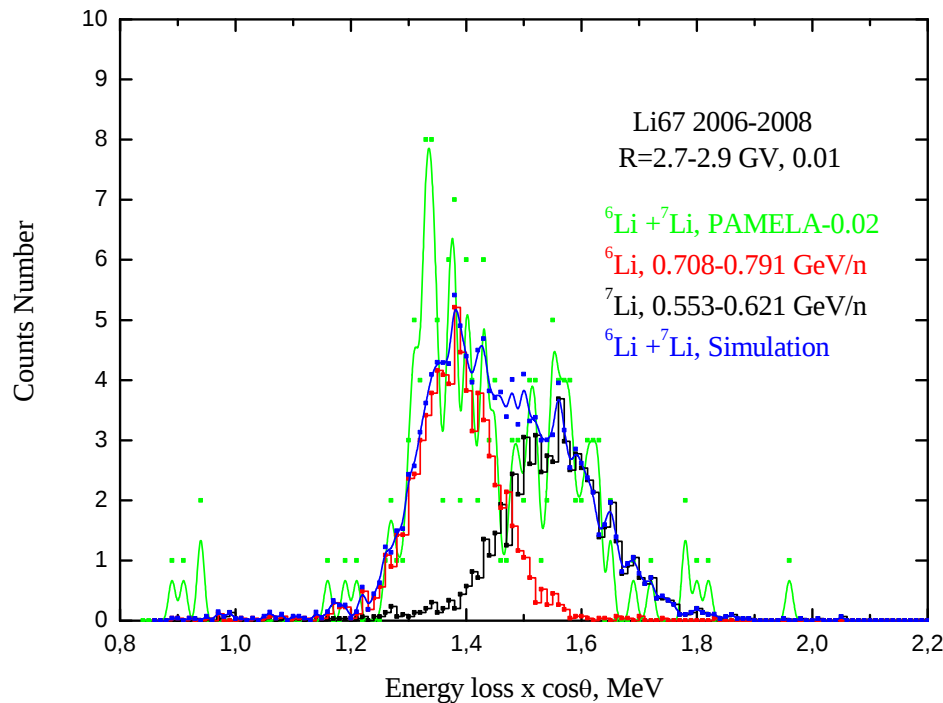


V. Formato from VMC with W. Menn selection criteria of experimental data

Correction of rigidity in the Tracker to space (TOA)



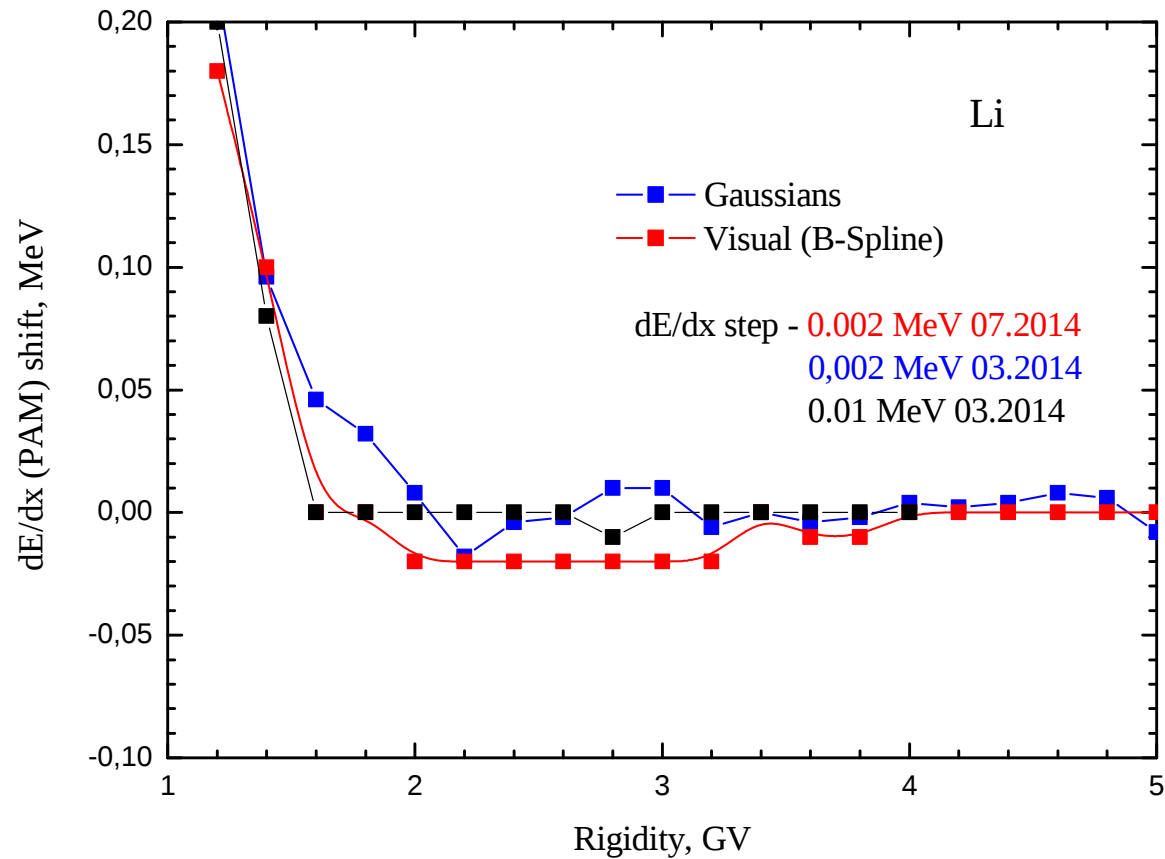
Approach to data analysis



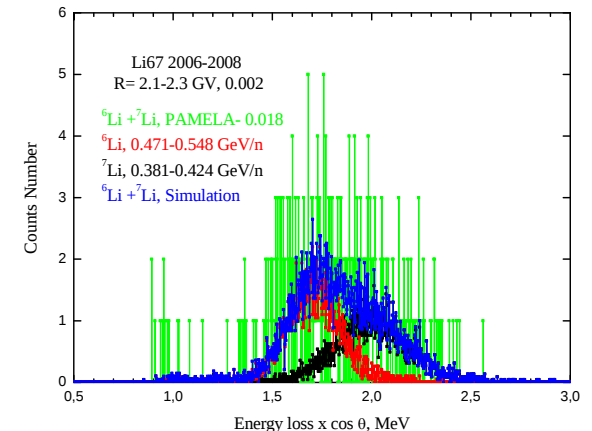
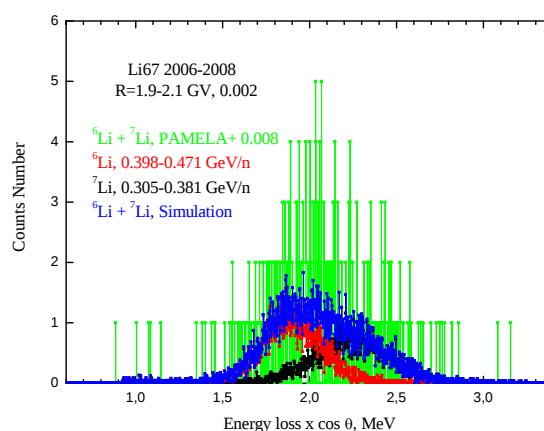
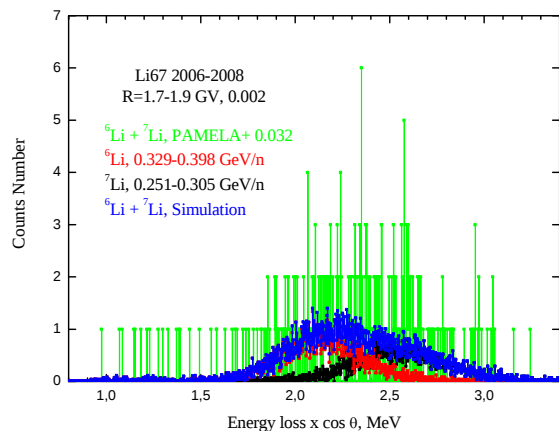
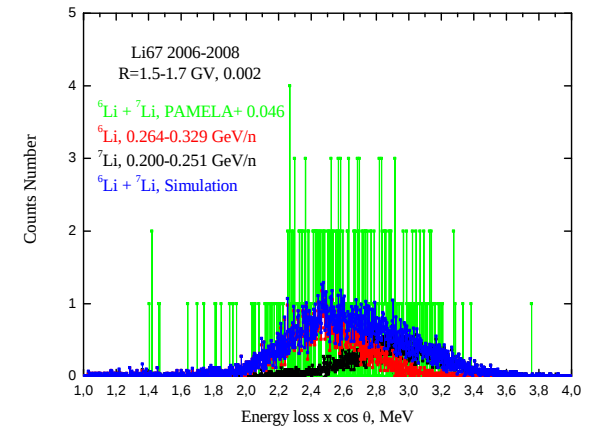
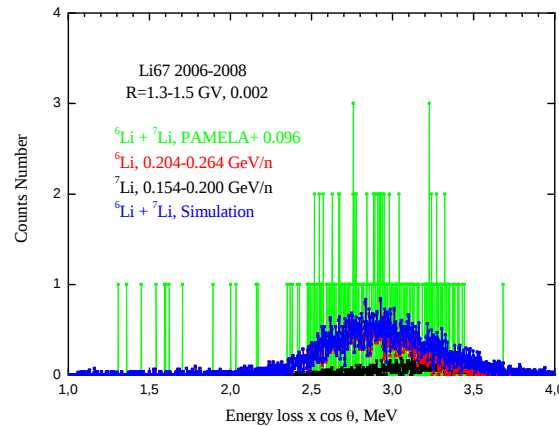
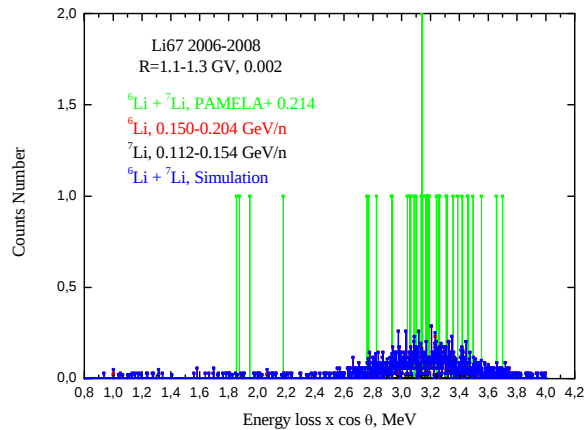
1. Simulation: $N(^6\text{Li}+^7\text{Li}) = N(\text{PAM})$ – normalization.
2. Shift of experimental distribution for dE/dx with use of B-Spline from OPJ and Gaussians up to superposition of simulation & experimental data ($\sim 2-10$ keV on the whole), using distributions with steps 0.04, 0.02, 0.01 and 0.002 MeV.
3. Area of ^6Li (PAM) dE/dx is up to $N(^6\text{Li}) = N(^7\text{Li})$ in cross distributions from simulation.
4. Exclusion of events with big deflections in dE/dx (PAM) distributions.

Exempl of distributions of the PAMELA data in B-Spline and simulation with step 0.01 MeV.
Data with steps 0.002 MeV were used in analysis.

Shift for dE/dx of the PAMELA data and simulation for Li.

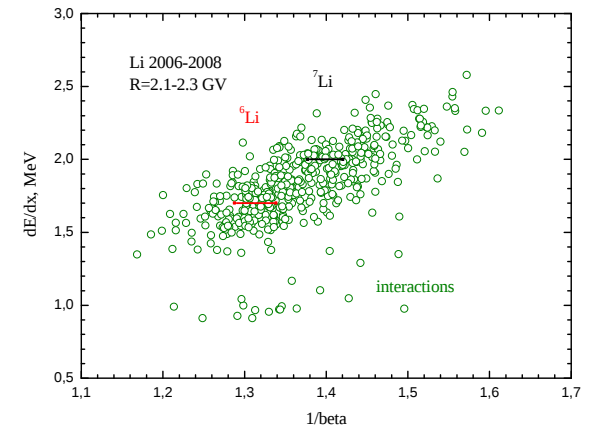
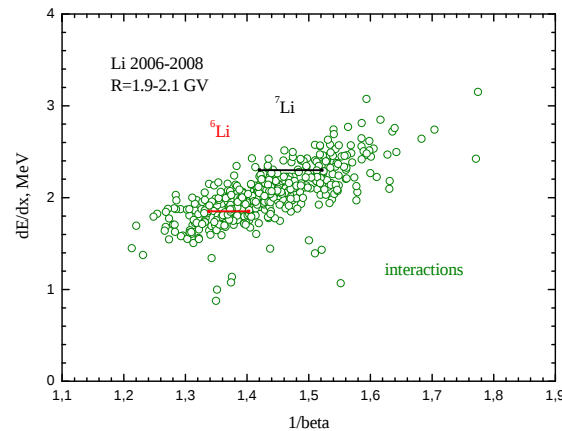
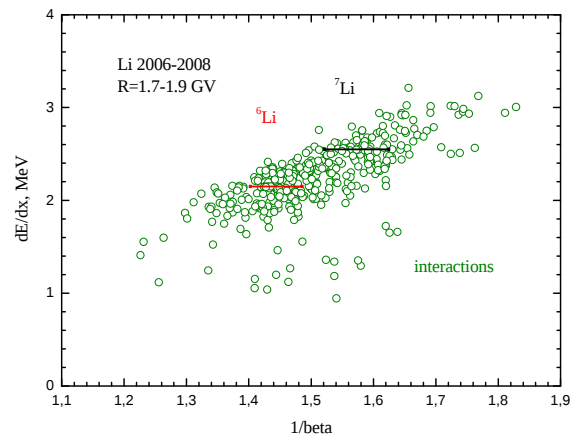
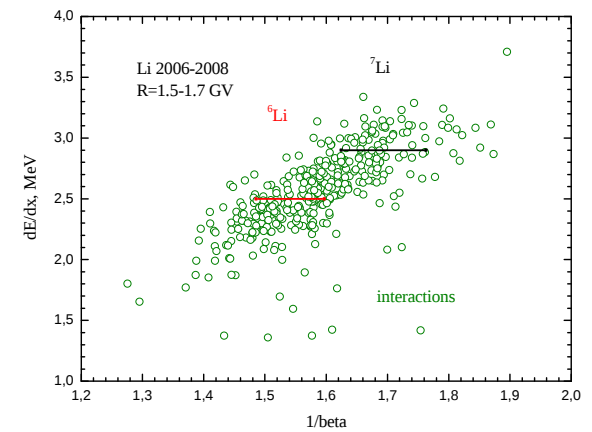
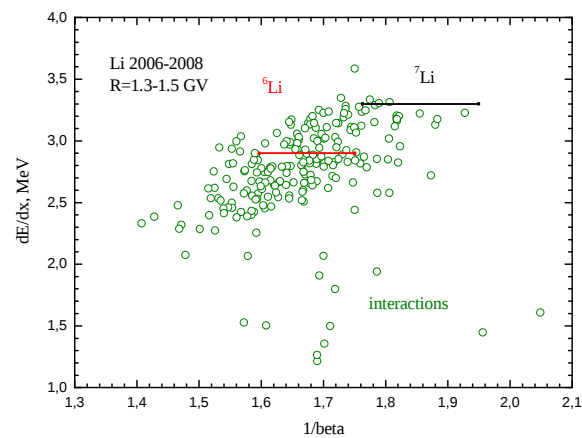
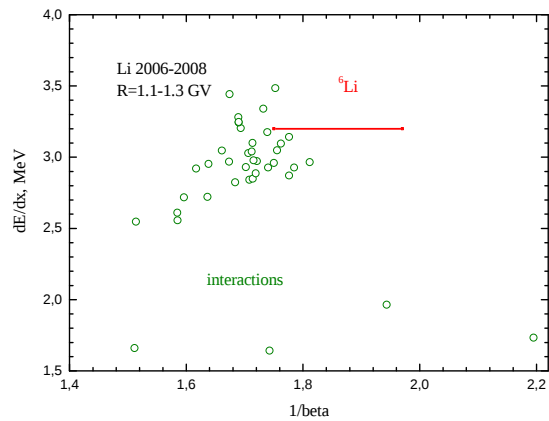


Lithium 1.1-2.3 GV. 2006-2008 data. dE/dx with step 0.002 MeV

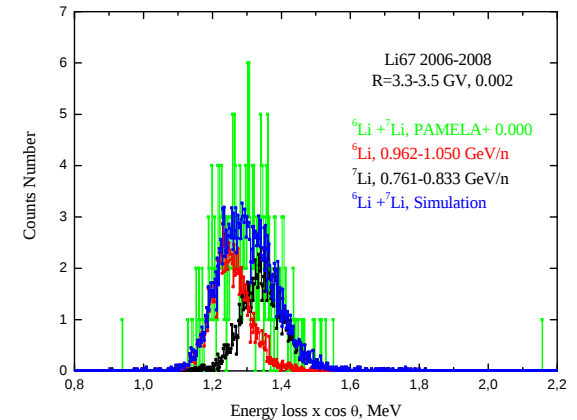
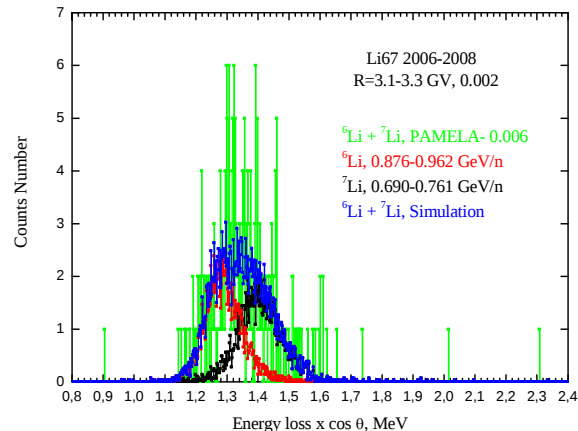
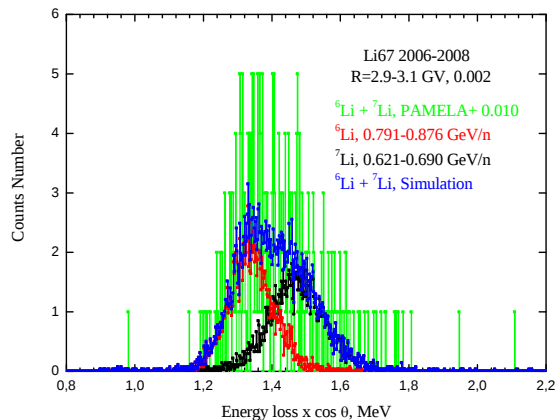
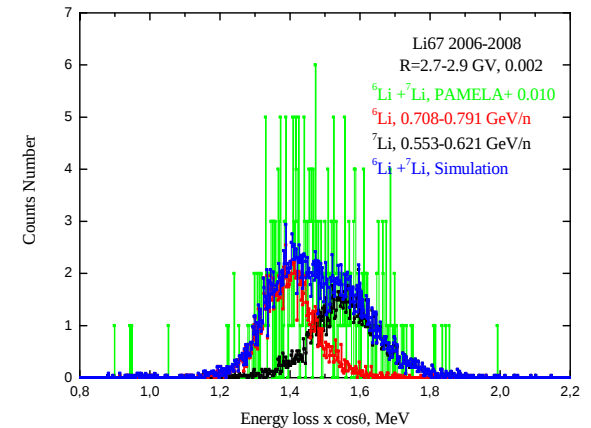
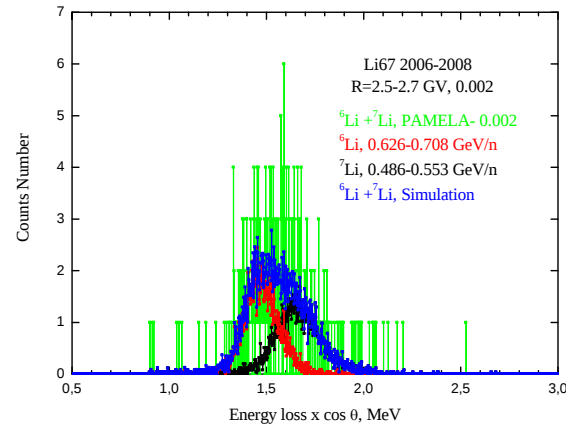
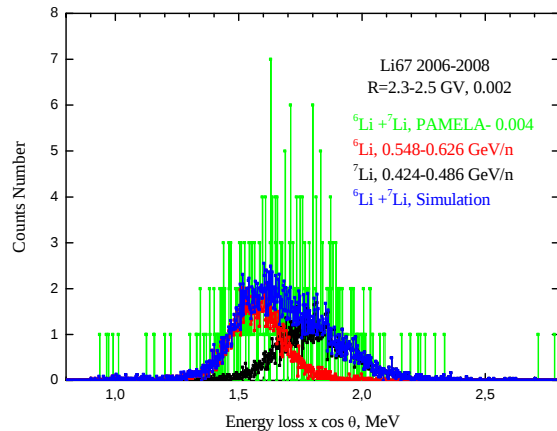


NB. Simulation: 7Li/6Li from GALPRPOP, $N(7\text{Li}+6\text{Li}, \text{simulation}) = N(\text{PAMELA})$

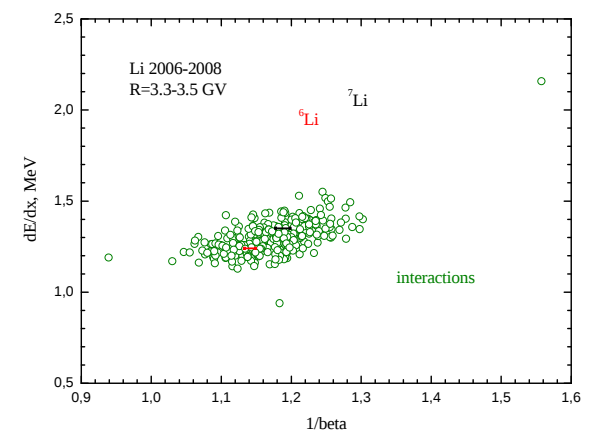
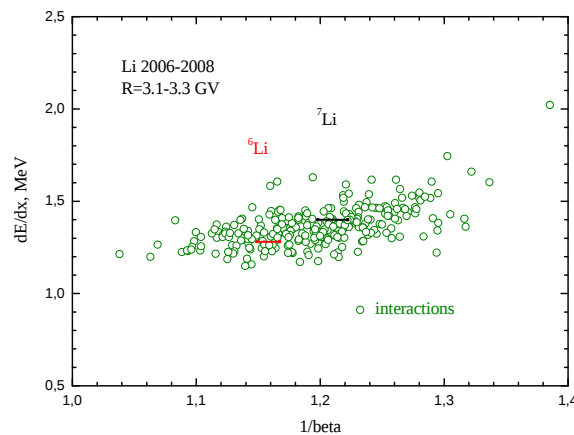
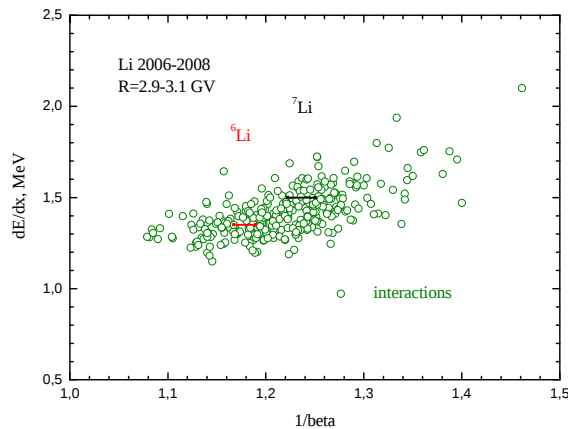
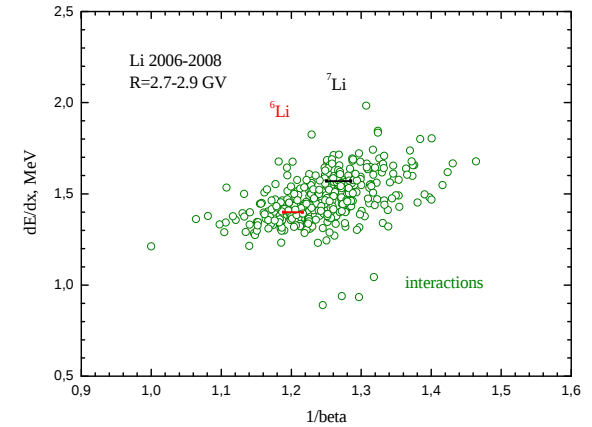
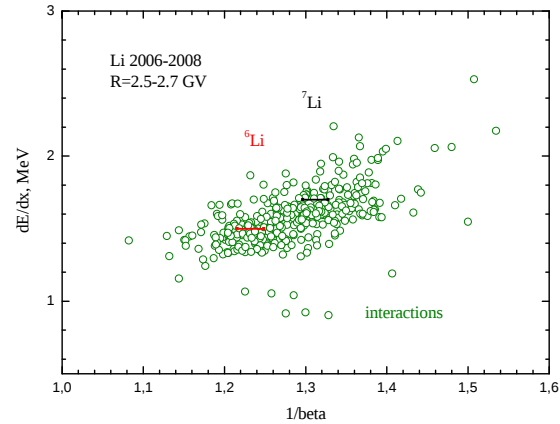
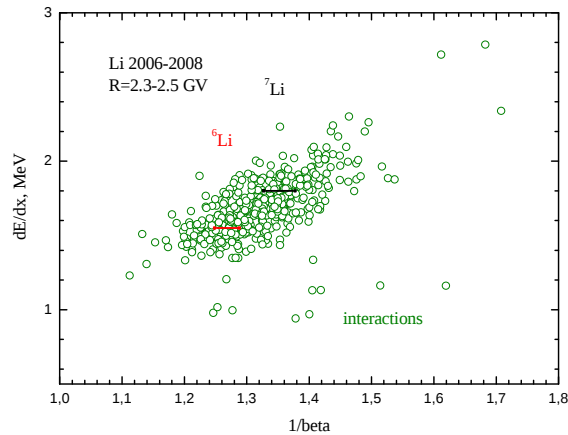
Lithium 1.1-2.3 GV. 2006-2008 data. 2D-analysis.



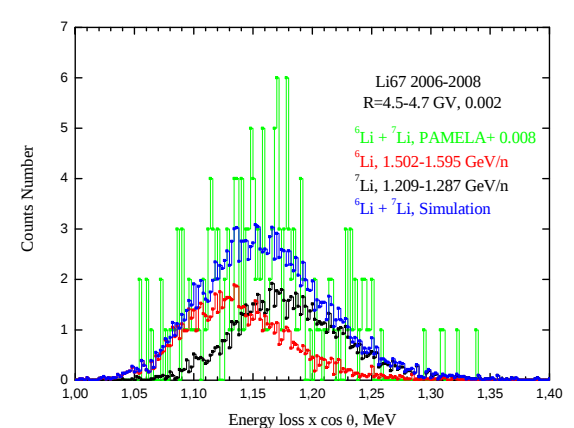
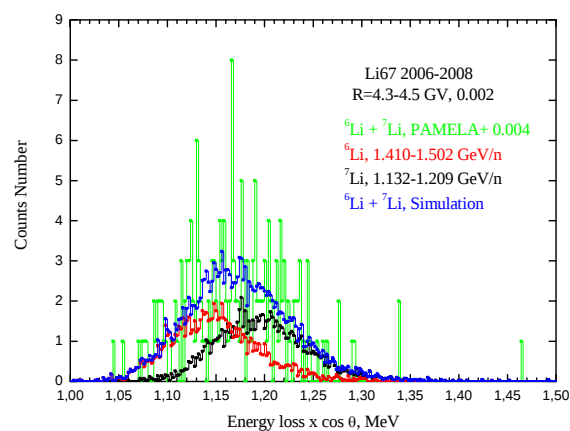
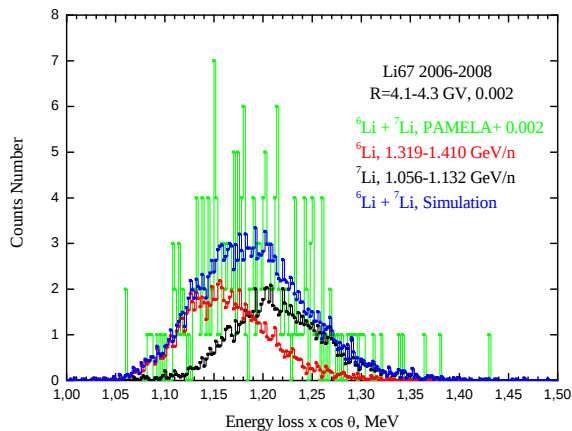
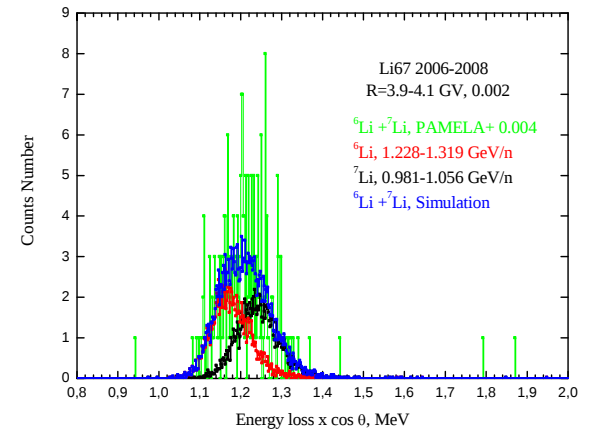
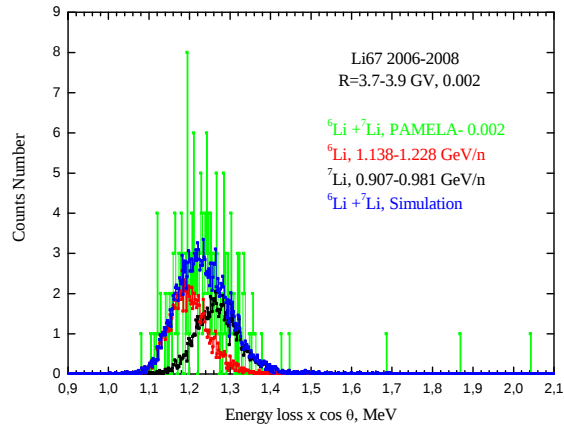
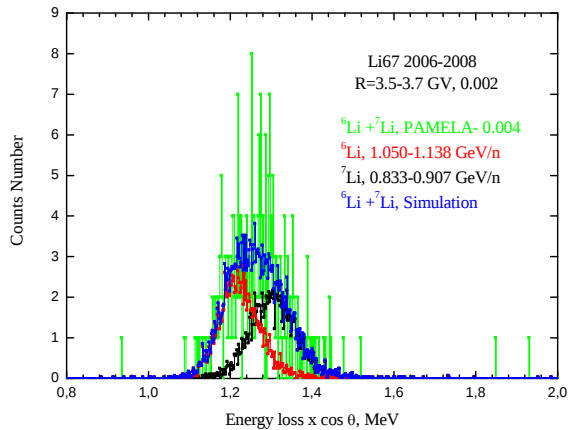
Lithium 2.3-3.5 GV. 2006-2008 data. dE/dx, 0.002 MeV



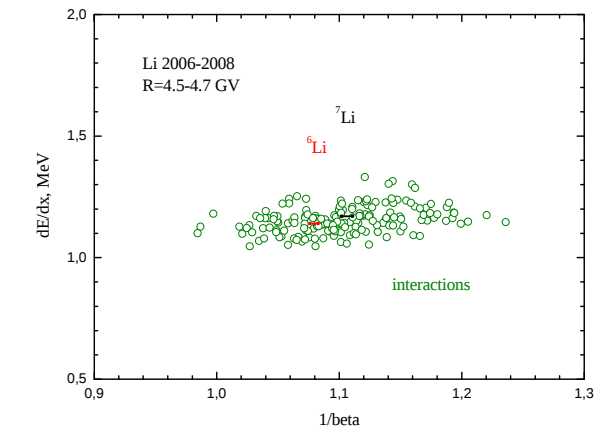
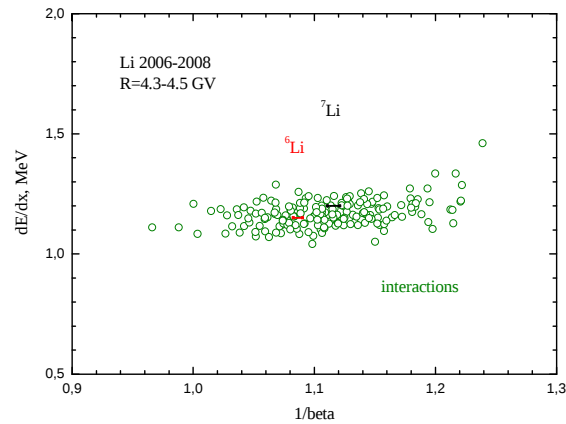
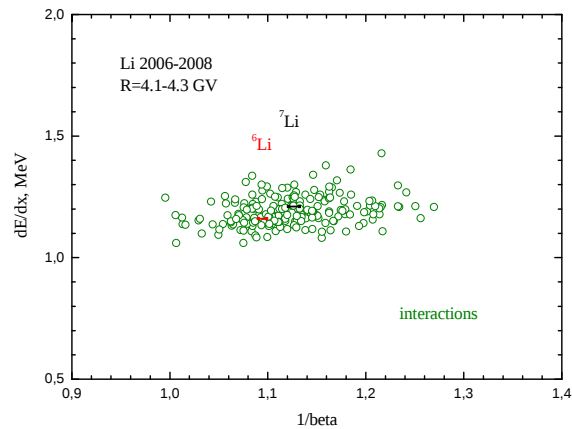
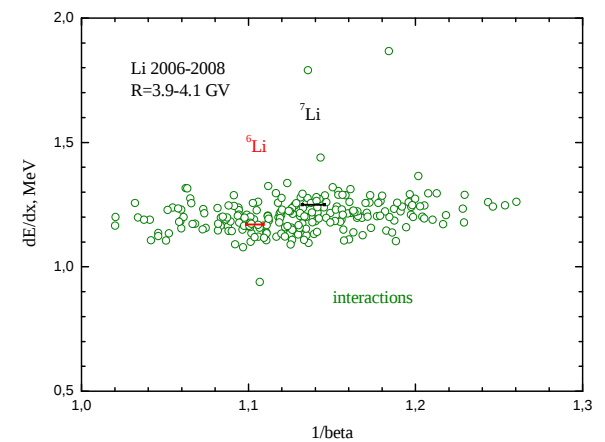
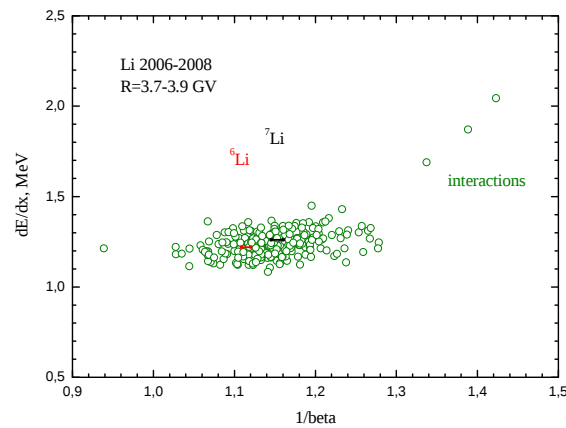
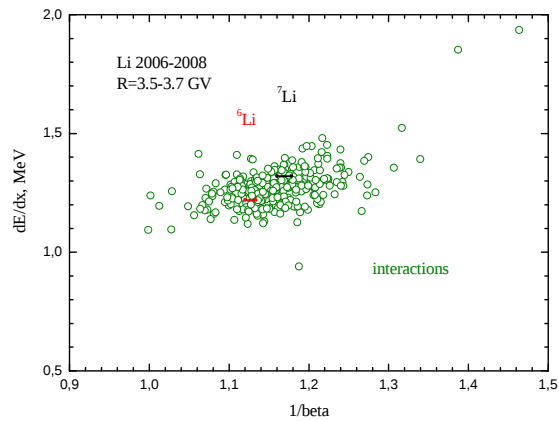
Lithium 2.3-3.5 GV. 2006-2008 data. 2D-analysis.



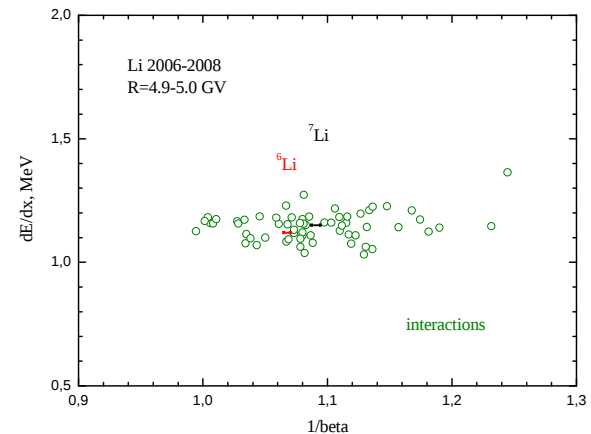
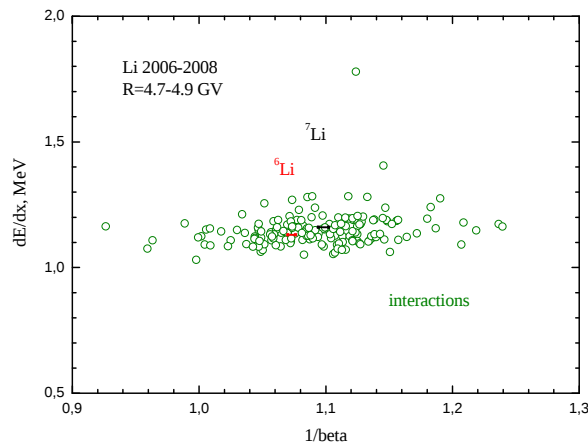
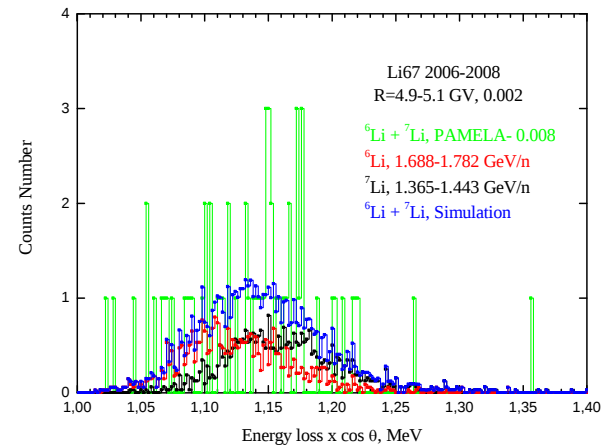
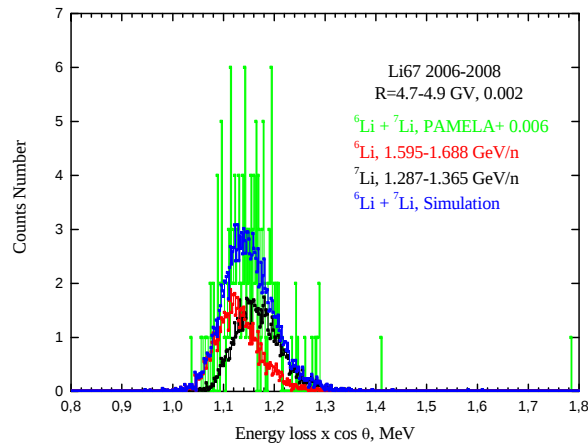
Lithium 3.5-4.7 GV. 2006-2008 data. dE/dx, 0.002 MeV



Lithium 3.5-4.7 GV. 2006-2008 data. 2D-analysis.



Lithium 4.7-5.1 GV. 2006-2008 data. dE/dx, 0.002 MeV and 2D-analysis.



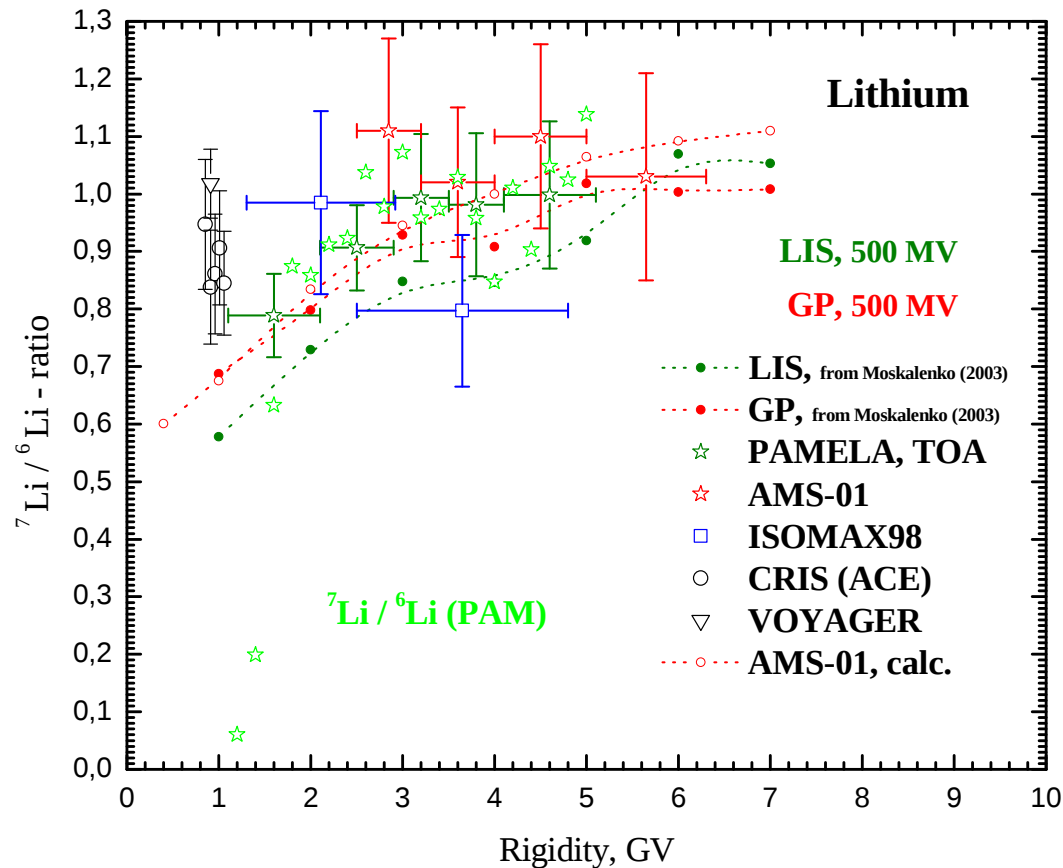
Results of Li isotopes selection

R(TRK), GV	${}^7\text{Li}+{}^6\text{Li}+\text{BG}$	${}^7\text{Li}/{}^6\text{Li}$	${}^6\text{Li}$, MeV	${}^6\text{Li} = {}^7\text{Li}$
1.1-1.3	2+33 +4+0	2/33	3.646	1.7
1.3-1.5	34+171+11+0	34/171	3.232	20.7
1.5-1.7	136+215+16+1	136/215	2.724	35,7
1.7-1.9	180+206+16+0	180/206	2.342	36.9
1.9-2.1	200+223+ 5+2	200/223	2.058	41.8
2.1-2.3	227+249+16+0	227/249	1.836	45.3
2.3-2.5	203+220+ 5+2	203/220	1.676	39.1
2.5-2.7	195+188+ 3+1	195/188	1.560	34.9
2.7-2.9	174+178+ 4+1	174/178	1.472	31.1
2.9-3.1	164+153+ 1+2	164/153	1.402	29.6

Results of Li isotopes selection

R(TRK), GV	${}^7\text{Li}+{}^6\text{Li}+\text{BG}$	${}^7\text{Li}/{}^6\text{Li}$	${}^6\text{Li}$, MeV	${}^6\text{Li} = {}^7\text{Li}$
3.1-3.3	138+144+1+2	138/144	1.346	26.1
3.3-3.5	145+149+1+1	145/149	1.299	29.8
3.5-3.7	143+139+1+2	143/139	1.262	38,1
3.7-3.9	113+118+0+3	113/118	1.234	28.1
3.9-4.1	105+124+1+2	105/124	1.210	29.4
4.1-4.3	103+102+0+1	103/102	1.188	28.5
4.3-4.5	84+93+0+1	84/93	1.171	25.7
4.5-4.7	88+84+0+4	88/84	1.156	27.4
4.7-4.9	84+82+0+2	84/82	1.146	26.4
4.9-5.0	33+29+0+1	33/29	1.140	10.6

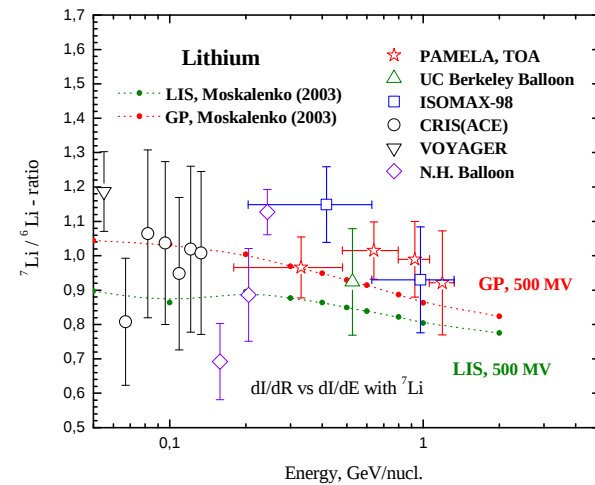
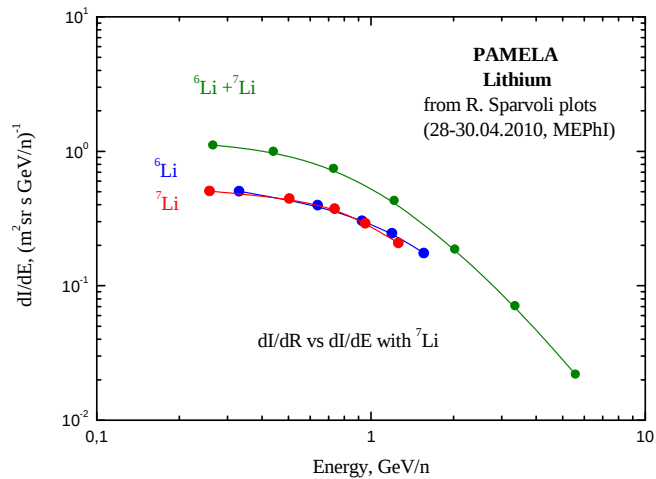
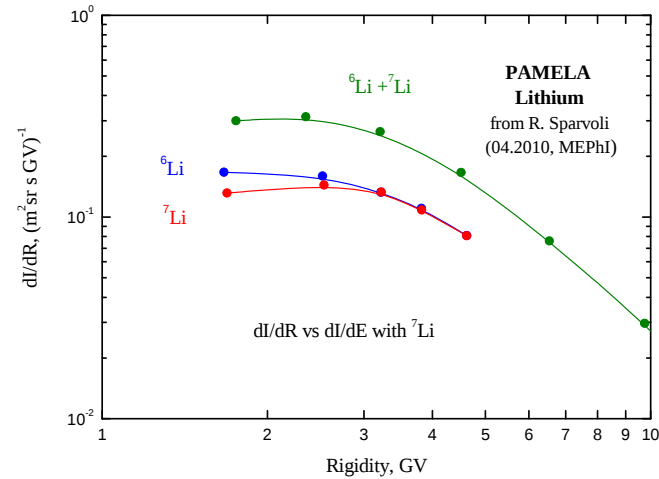
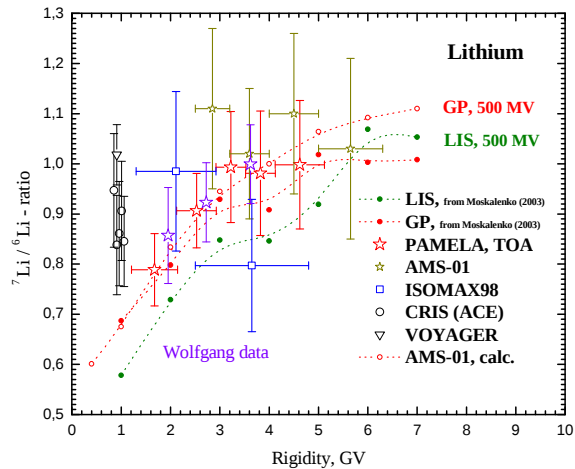
$^7\text{Li}/^6\text{Li}$ -ratio from the Calorimeter. PAMELA data, 2006-2008



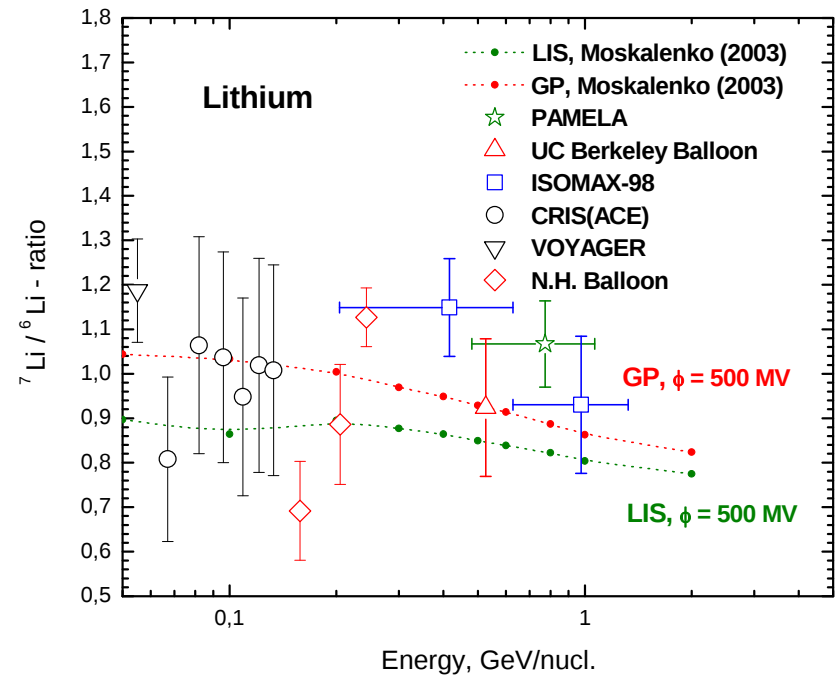
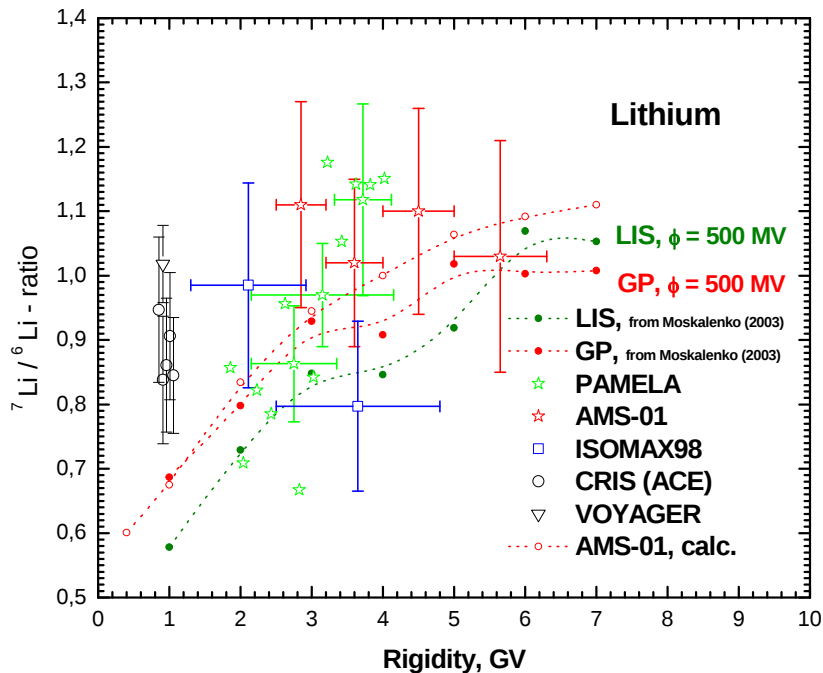
$${}^7\text{Li}/{}^6\text{Li}(R) > dI/dR > dI/dE > {}^7\text{Li}/{}^6\text{Li}(E_{\text{kin}})$$

- If to use data for ${}^7\text{Li}/{}^6\text{Li}(R)$ -ratio and $dI({}^7\text{Li}+{}^6\text{Li})/dR$ spectrum from PAMELA data can receive $dI({}^7\text{Li})/dR$ and $dI({}^6\text{Li})/dR$ spectra for $R > 1.1$ GV.
- If to use $dI/E = dI/dR \times dR/dE = dI/dR \times (A_i/Z^2) \times (E_{\text{tot}}/R)$ can receive $dI({}^7\text{Li})/dE$, $dI({}^6\text{Li})/dE$ spectra and ${}^7\text{Li}/{}^6\text{Li}(E)$ -ratio in the energy range $\sim 0.2\text{-}1.3$ GeV/n.

Lithium 2006-2008. Results status.



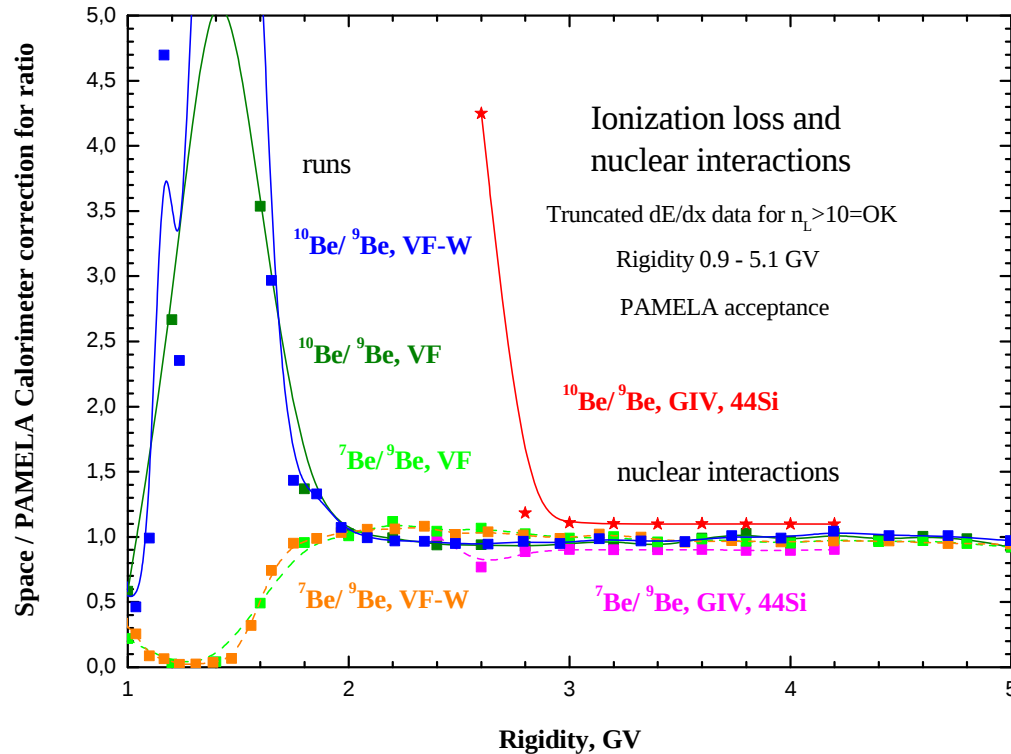
Lithium 2006-2008. Results status in 2012.



Basis: a little another PAMELA data and IPTI GEANT4 simulation for ${}^{44}\text{Si}$...

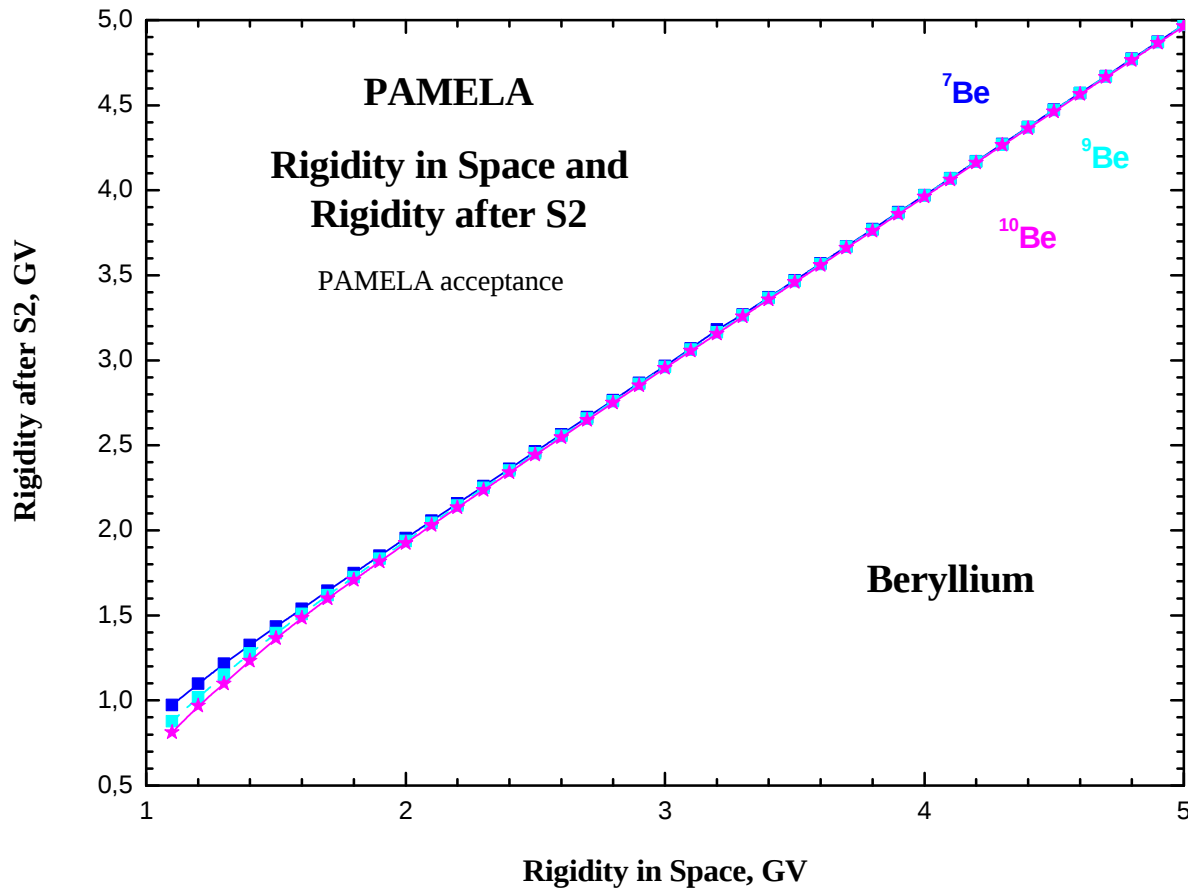
Beryllium Isotopes and PAMELA

Correction of measurements data for $^7\text{Be}/^9\text{Be}$ and $^{10}\text{Be}/^9\text{Be}$ ratio to space (TOA). Runs and nuclear interactions.

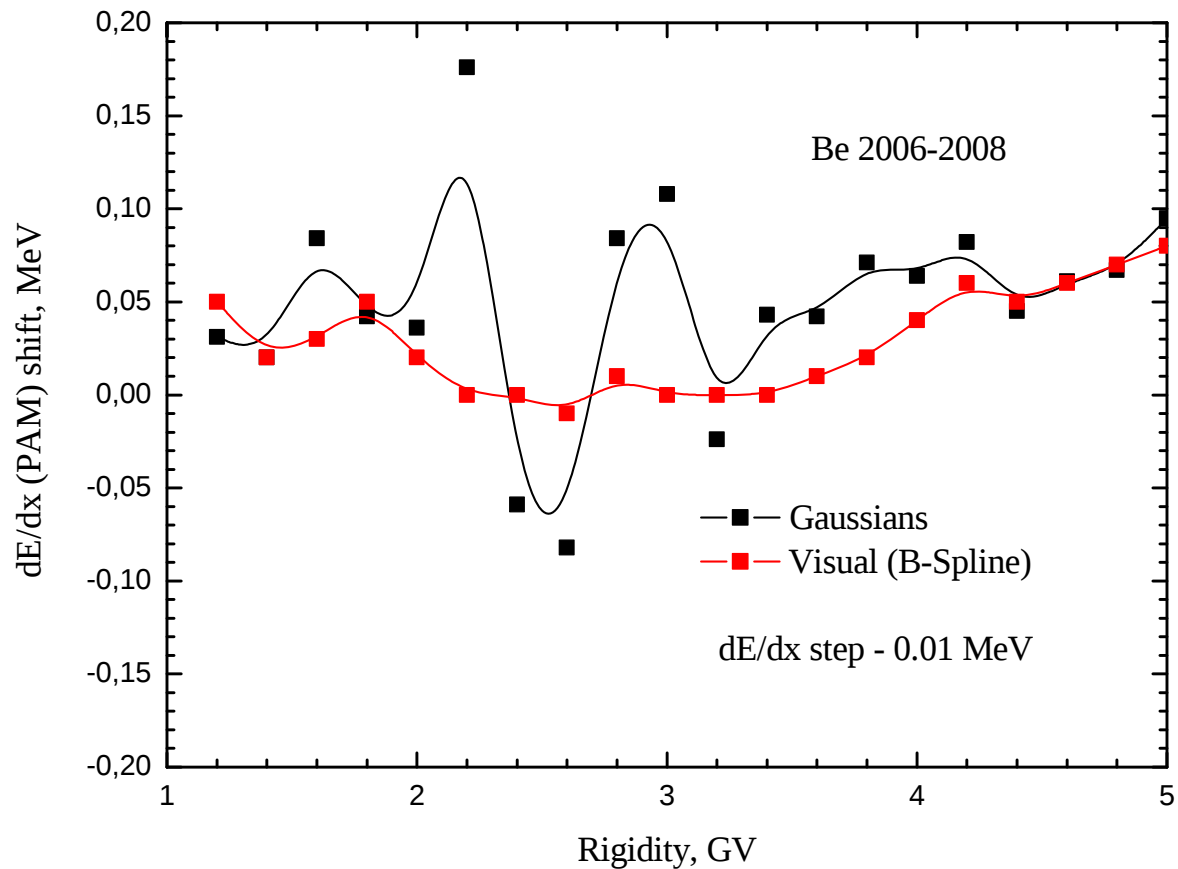


V. Formato from VMC with W. Menn selection criteria of experimental data

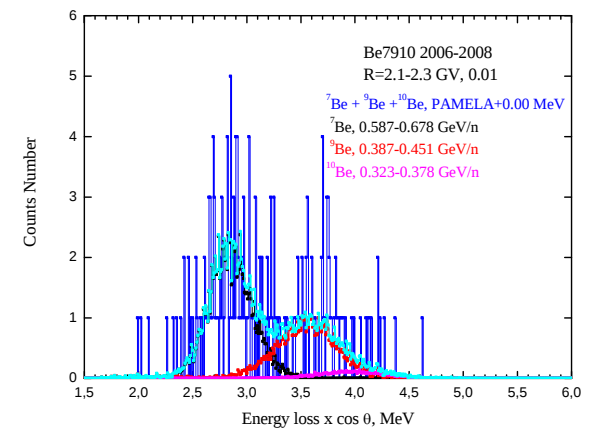
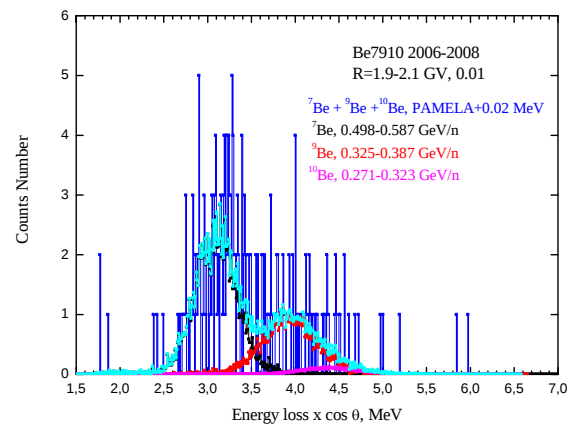
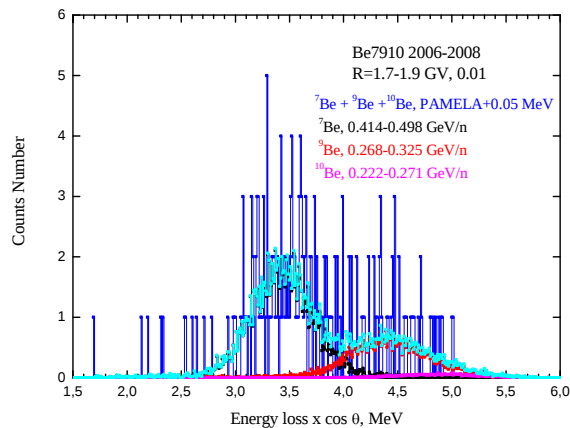
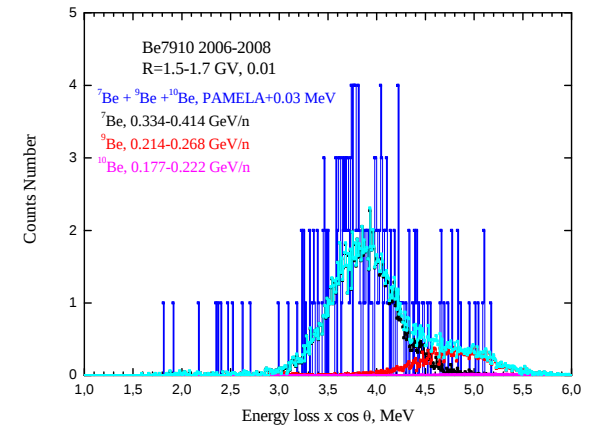
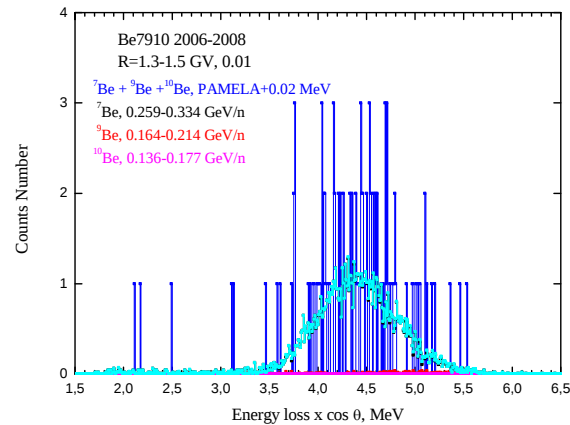
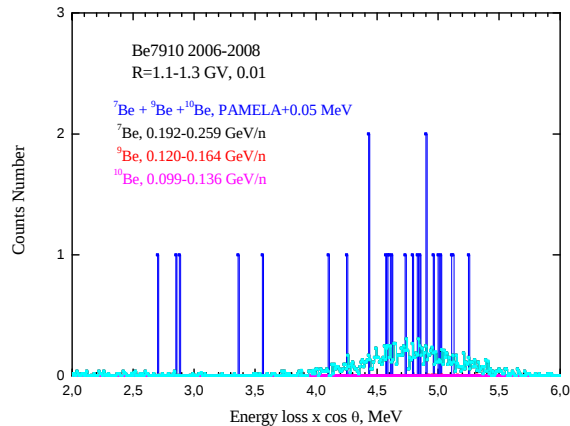
Correction of rigidity in the Tracker to space (TOA)



Shift for dE/dx of the PAMELA data and simulation for Be.

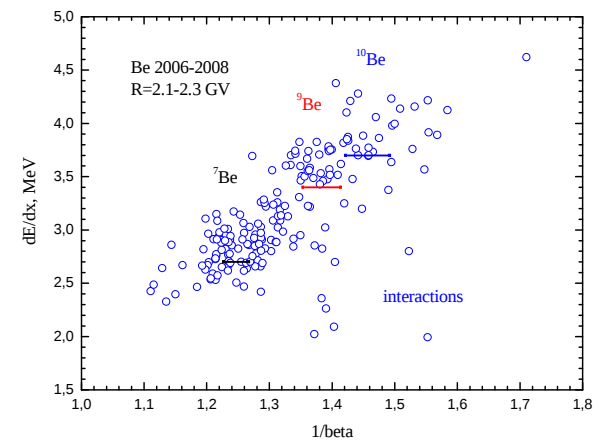
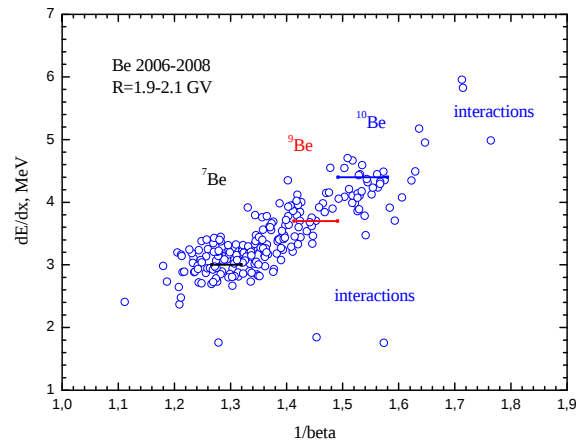
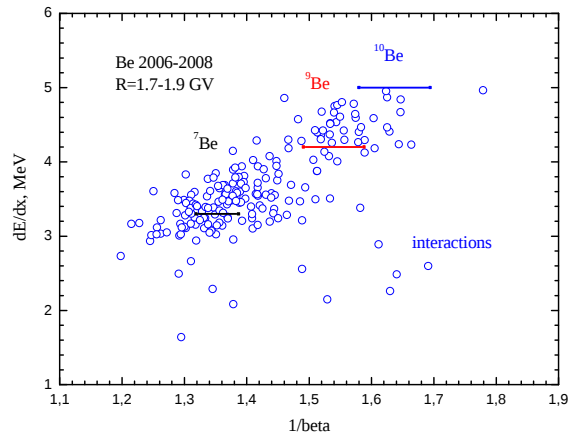
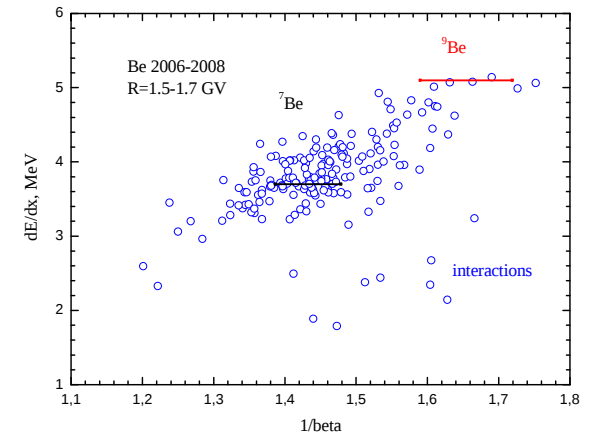
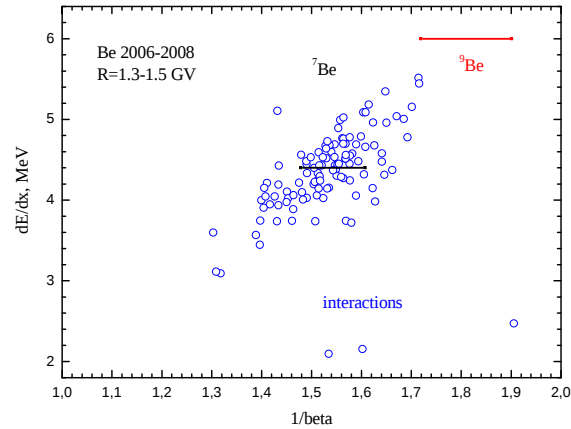
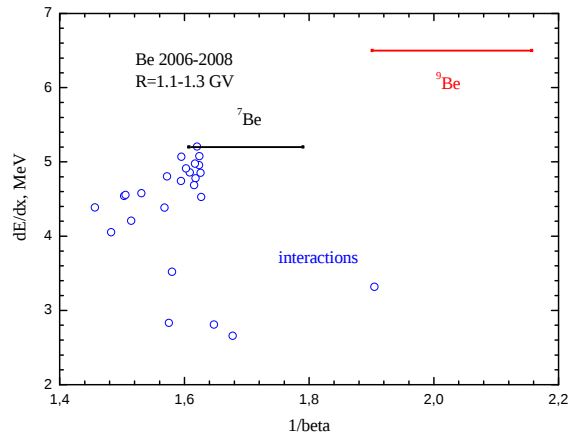


Beryllium 1.1-2.3 GV. 2006-2008 data. dE/dx with step 0.01 MeV.

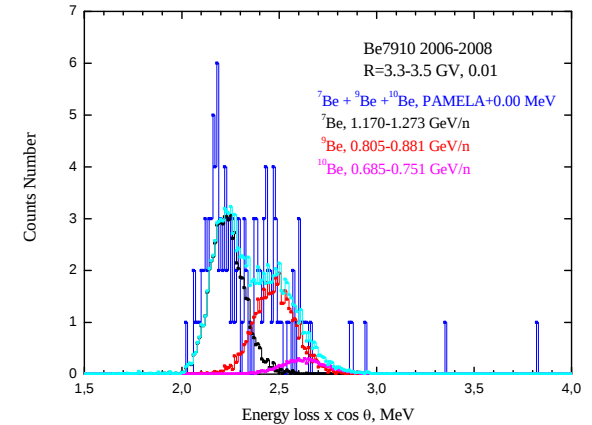
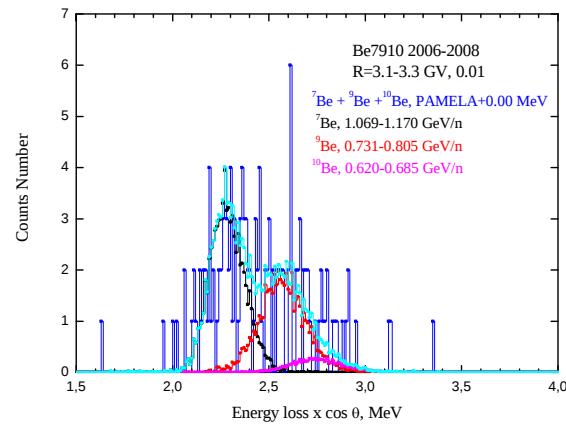
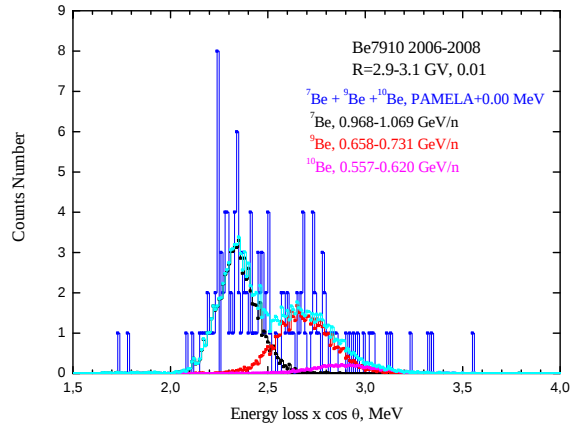
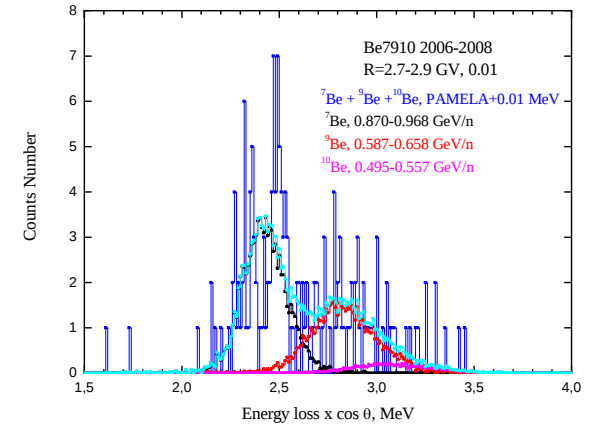
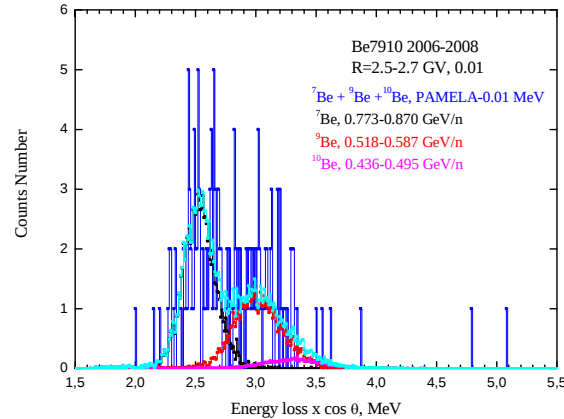
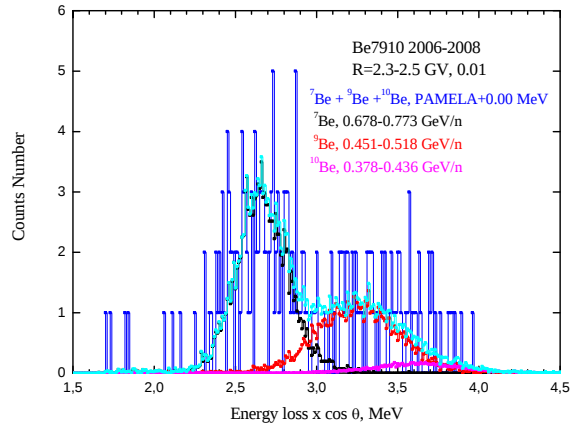


NB. Simulation: ${}^7\text{Be}/{}^9\text{Be}$, ${}^{10}\text{Be}/{}^9\text{Be}$ from GALPRPOP, $N({}^7\text{Be}+{}^9\text{Be}+{}^{10}\text{Be}, \text{simulation}) = N(\text{PAMELA})$

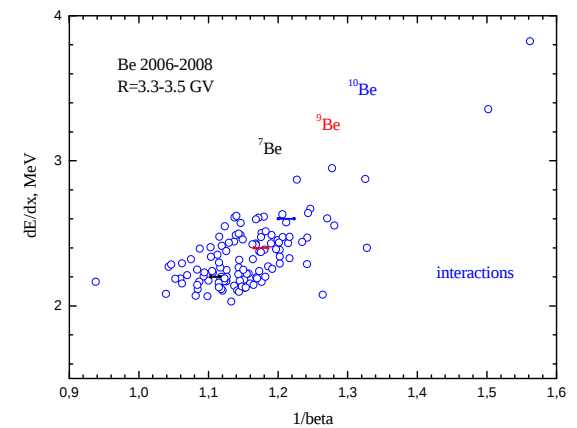
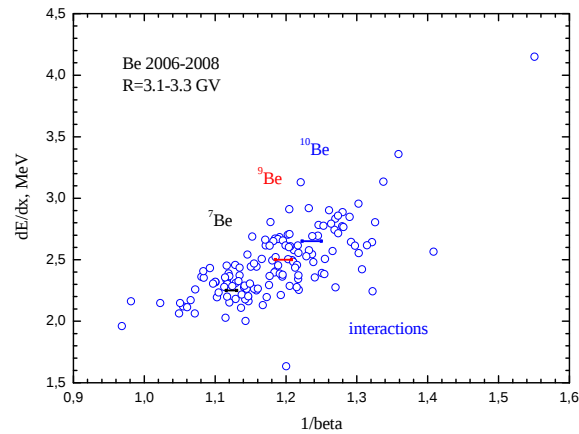
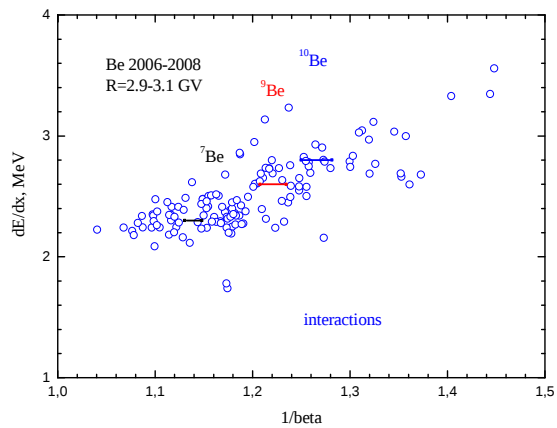
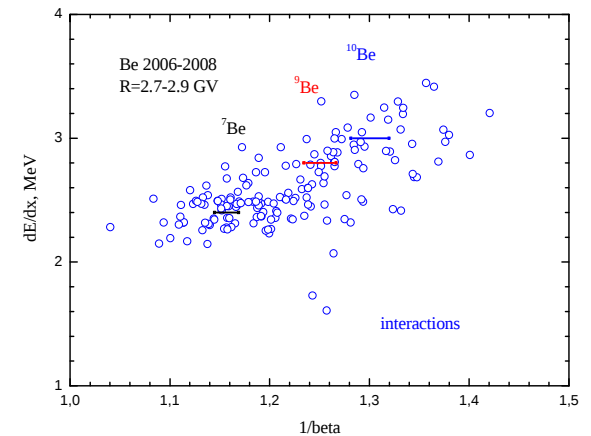
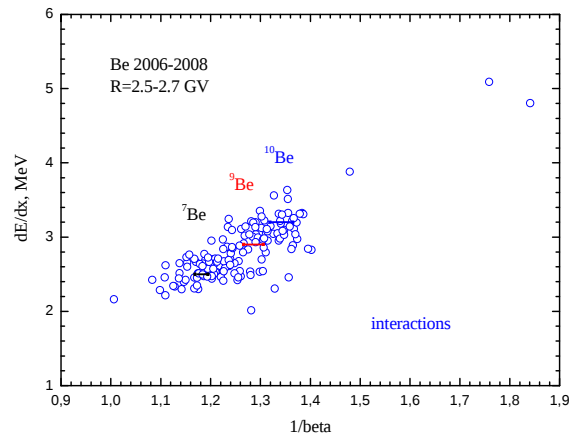
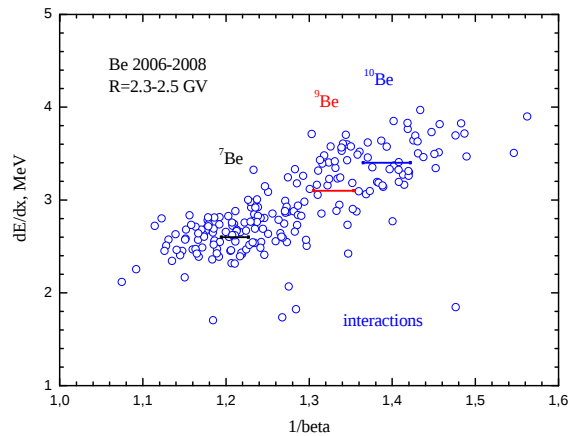
Beryllium 1.1-2.3 GV. 2006-2008 data. 2D-analysis.



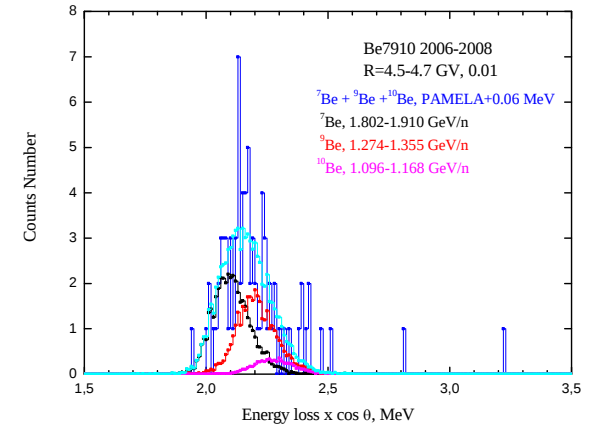
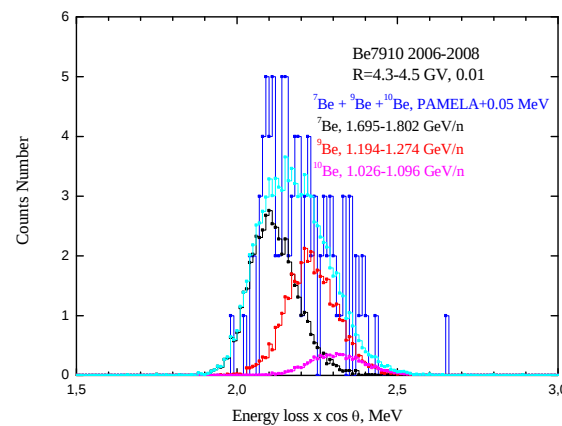
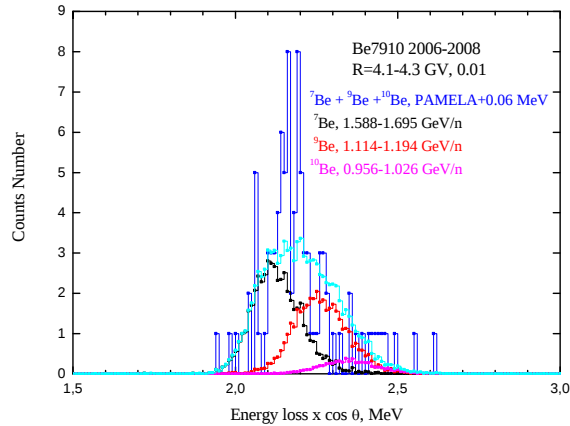
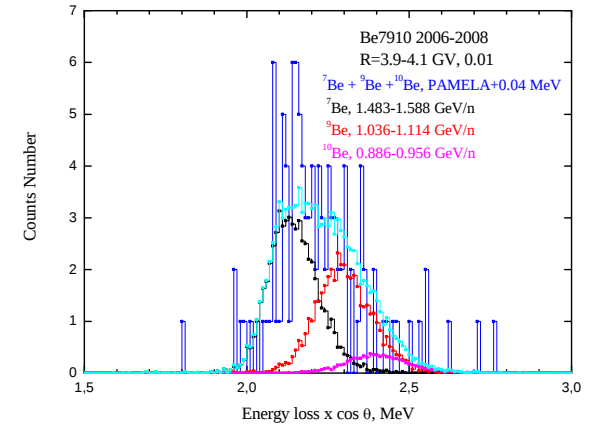
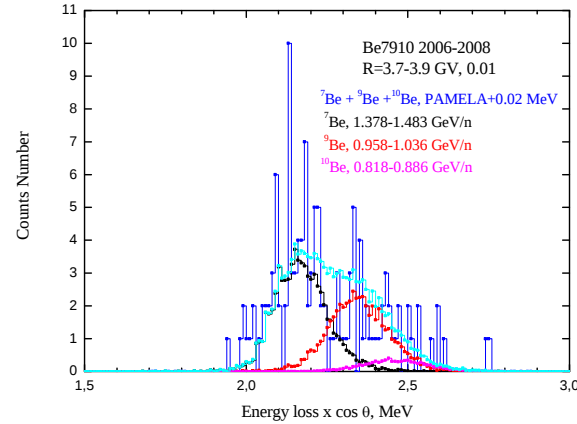
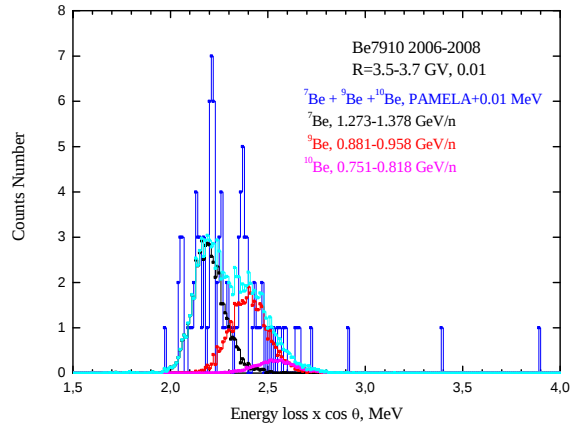
Beryllium 2.2-3.5 GV. 2006-2008 data. dE/dx, 0.01 MeV.



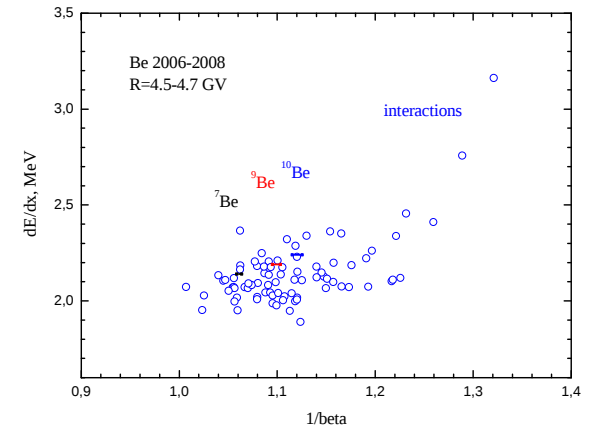
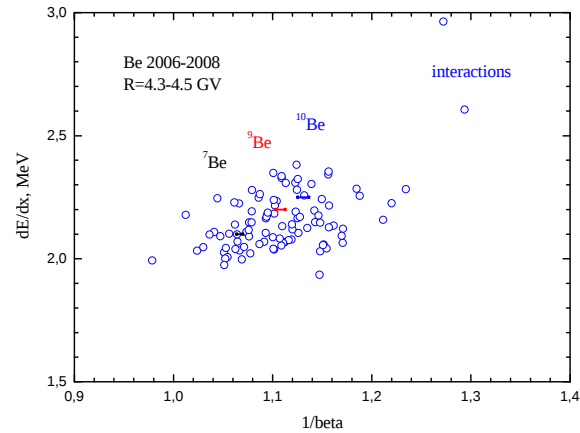
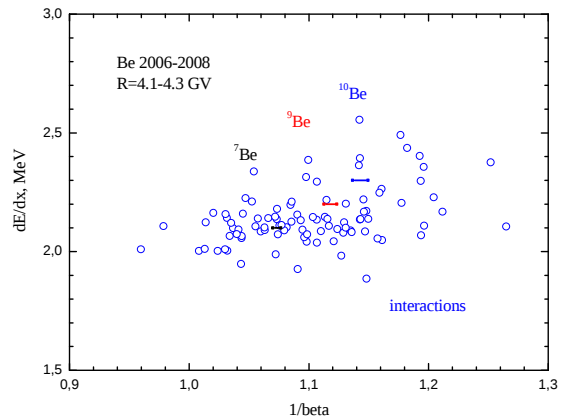
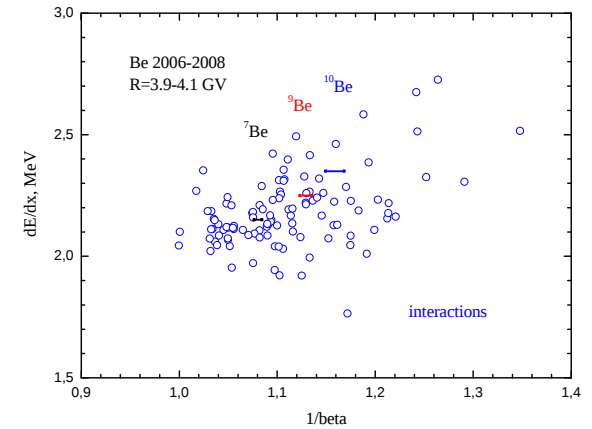
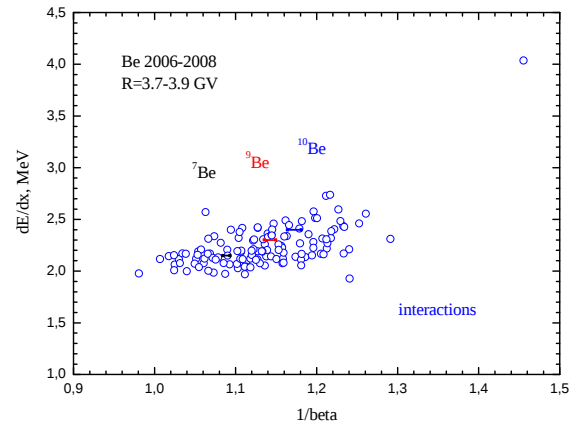
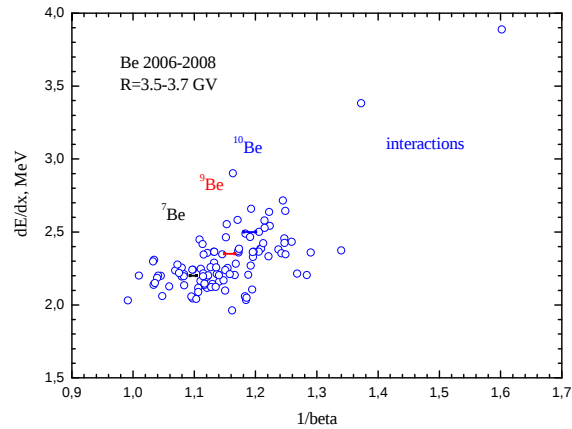
Beryllium 2.3-3.5 GV. 2006-2008 data. 2D-analysis.



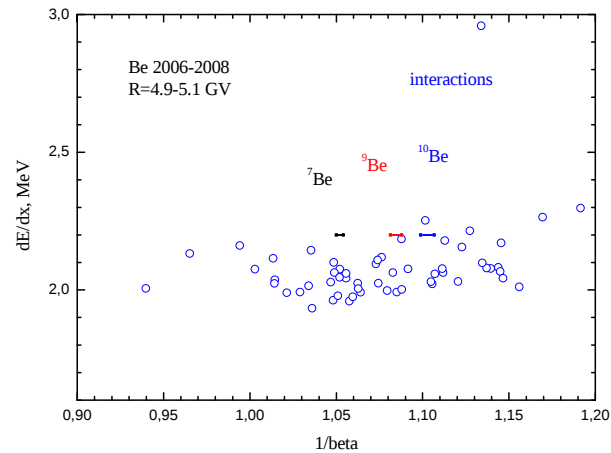
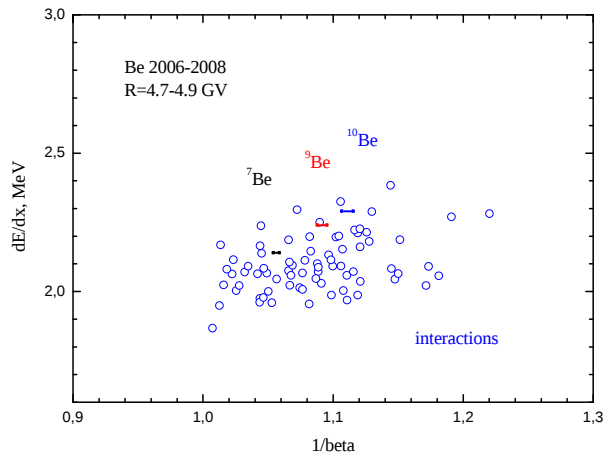
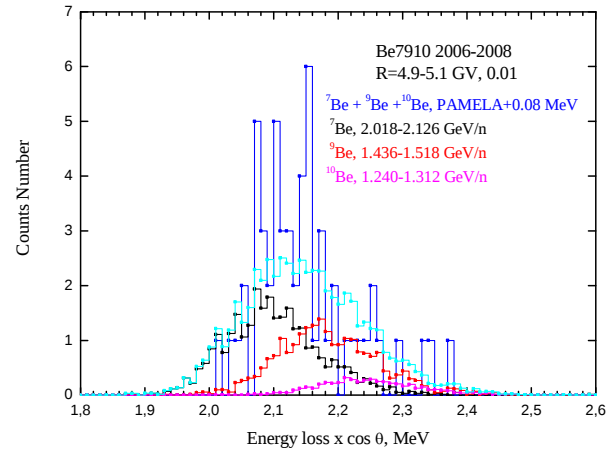
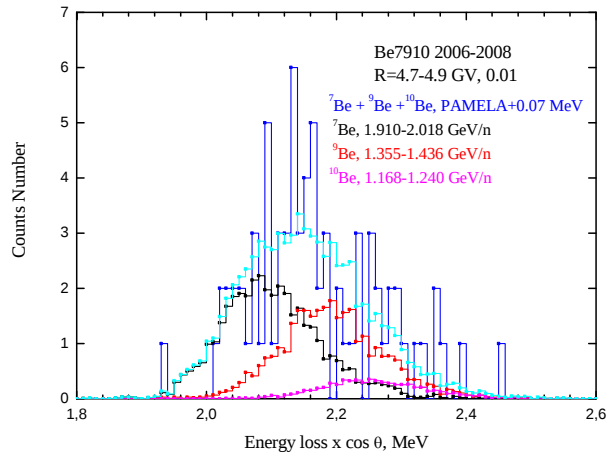
Beryllium 3.5-4.7 GV. 2006-2008 data. dE/dx, 0.01 MeV.



Beryllium 3.5-4.7 GV. 2006-2008 data. 2D-analysis.



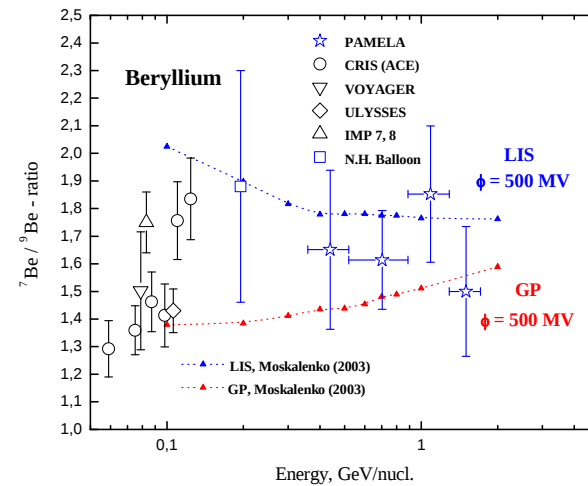
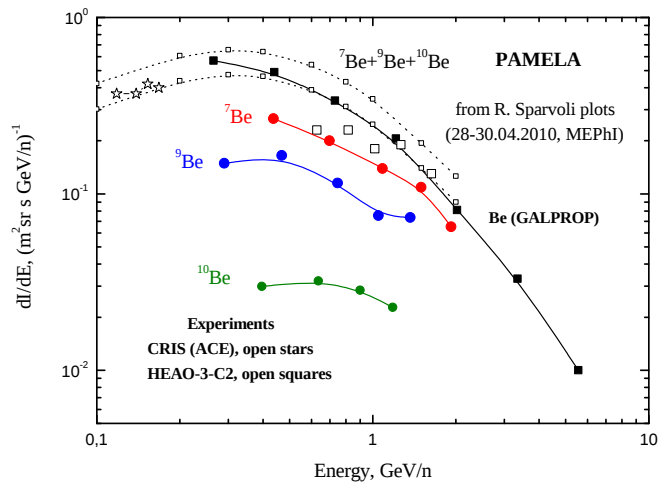
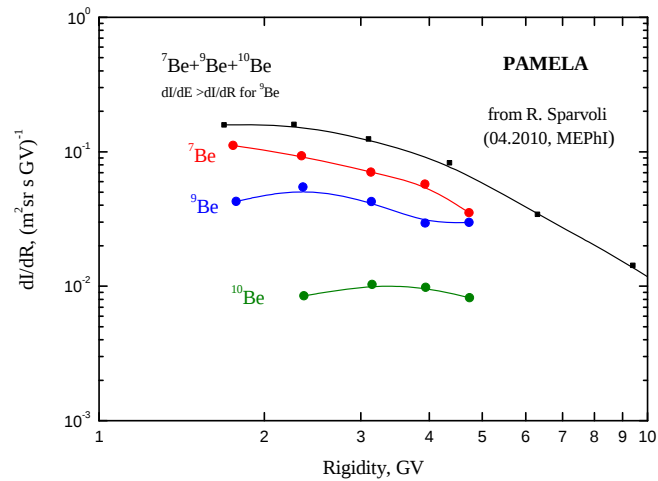
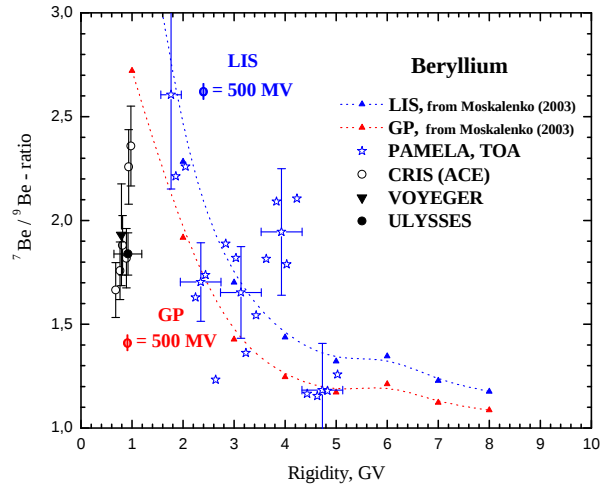
Beryllium 4.7-5.1 GV. 2006-2008 data. dE/dx, 0.01 MeV and 2D-analysis.



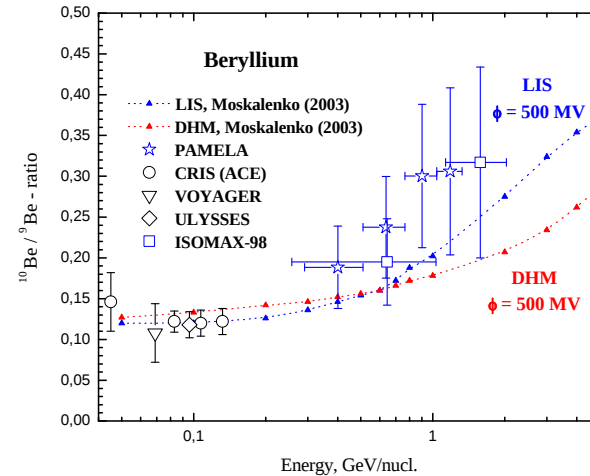
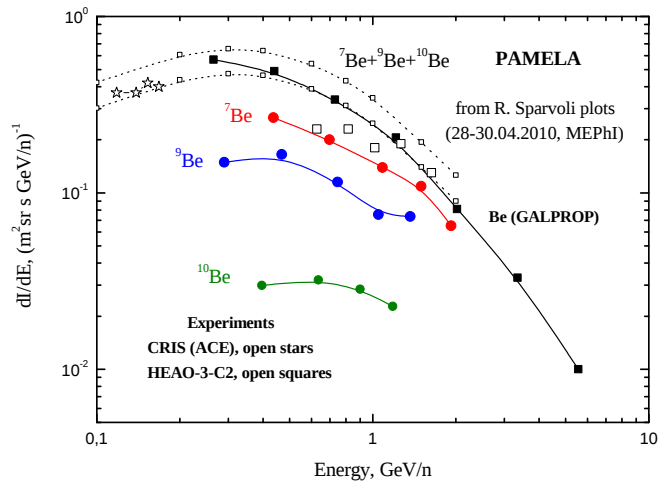
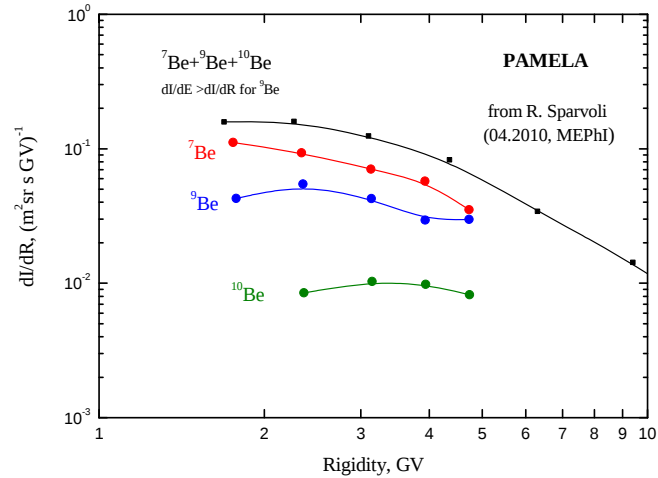
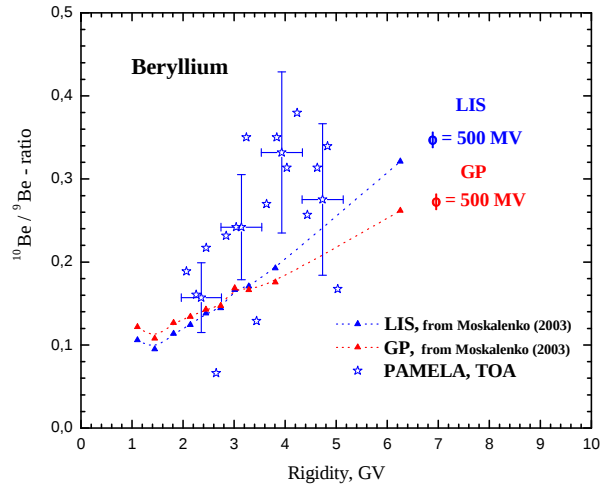
Results of Be isotopes selection

R(TRK),GV	${}^7\text{Be}+{}^9\text{Be}+{}^{10}\text{Be}+\text{BG}$	${}^7\text{Be}_{\text{max}}(\text{MeV})$	${}^7\text{Be} = {}^9\text{Be}+{}^{10}\text{Be}$	${}^{10}\text{Be}_{\text{min}}(\text{MeV})$	${}^{10}\text{Be} = {}^7\text{Be}+{}^9\text{Be}$
1.3-1.5	108+0+0+0+0				
1.5-1.7	157+21+0+9+0	4.60	6.2, 6.2	5.54	0.9, 0.9
1.7-1.9	132+57+0+9+0	3.93	5.9, 6.0	5.04	3.7, 3.6
1.9-2.1	146+65+12+3+3	3.50	7.2, 7.4	4.44	5.1, 5.3
2.1-2.3	99+68+11+6+1	3.17	6.9, 7.0	3.98	4.5, 4.5
2.3-2.5	115+69+16+5+0	2.92	7.8, 7.4	3.62	5.6, 5.3
2.5-2.7	82+71+5+1+2	2.76	5.1, 5.7	3.33	4.6, 4.8
2.7-2.9	96+52+13+3+0	2.61	5.6, 5.7	3.08	5.0, 5.0
2.9-3.1	79+43+11+2+3	2.50	4.9, 5.0	2.89	4.4, 4.0
3.1-3.3	68+50+18+1+1	2.42	5.5, 5.7	2.75	3.9, 4.4
3.3-3.5	69+43+6+0+2	2.36	5.2, 5.8	2.63	3.9, 4.0
3.5-3.7	61+33+9+0+2	2.30	6.3, 5.7	2.54	3.9, 3.4
3.7-3.9	78+36+13+0+1	2.26	9.5, 8.3	2.47	4.5, 5.4
3.9-4.1	64+34+11+1+0	2.23	8.3, 9.0	2.42	4.5, 4.6
4.1-4.3	58+27+10+0+0	2.20	9.1, 8.8	2.38	4.4, 4.0
4.3-4.5	46+38+10+0+2	2.18	9.5, 9.9	2.34	4.7, 4.2
4.5-4.7	38+32+10+0+2	2.16	9.7, 9.4	2.31	4.2, 4.3
4.7-4.9	36+29+10+0+0	2.15	9.2, 9.3	2.29	4.3, 4.1
4.9-5.1	30+22+4+0+1	2.14	7.8, 6.6	2.27	3.3, 3.6

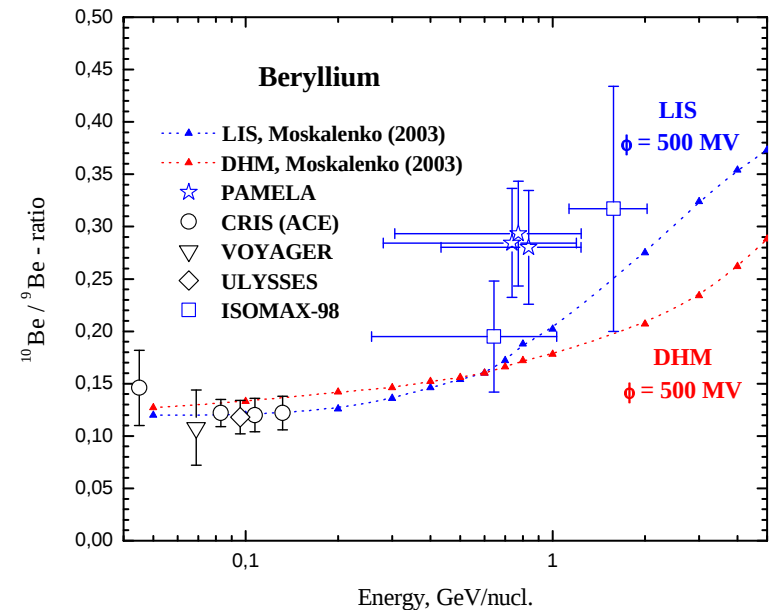
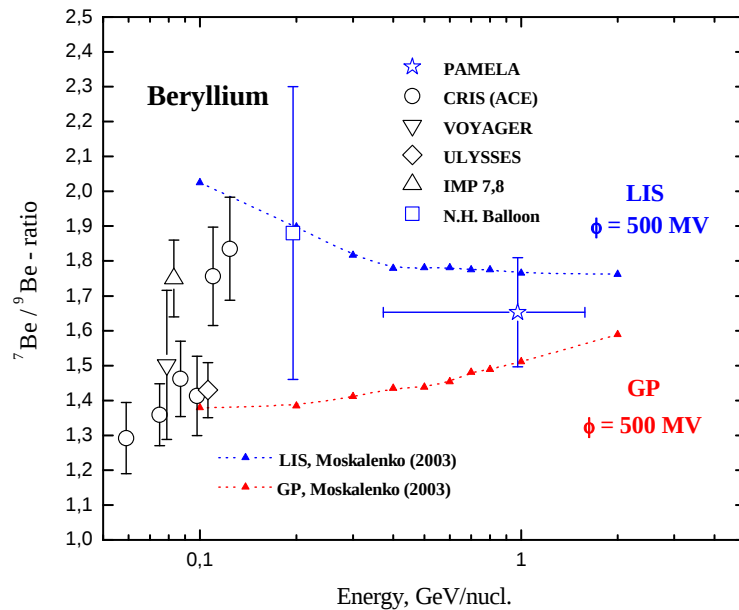
${}^7\text{Be}/{}^9\text{Be}$ 2006-2008. Results status.



$^{10}\text{Be}/^9\text{Be}$ 2006-2008. Results status.



Beryllium 2006-2008. Results status in 2012.



Basis: a little another PAMELA data and IPTI GEANT4 simulation for ${}^{44}\text{Si}$...

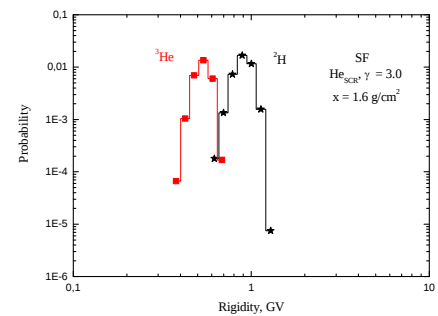
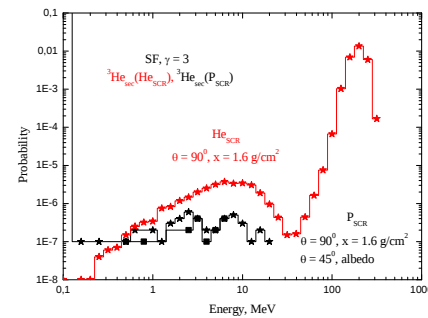
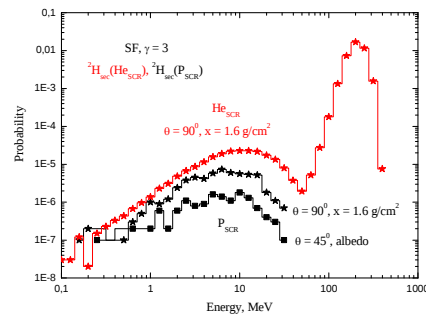
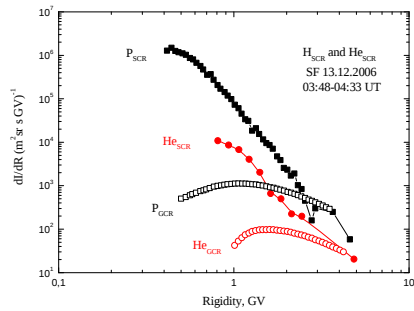
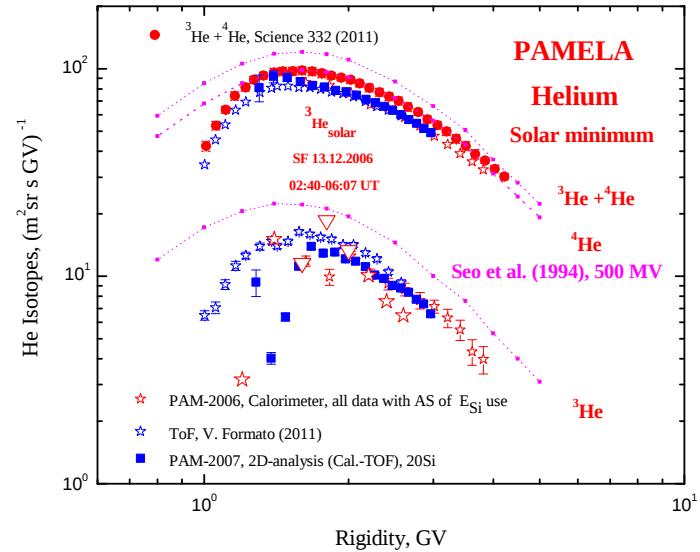
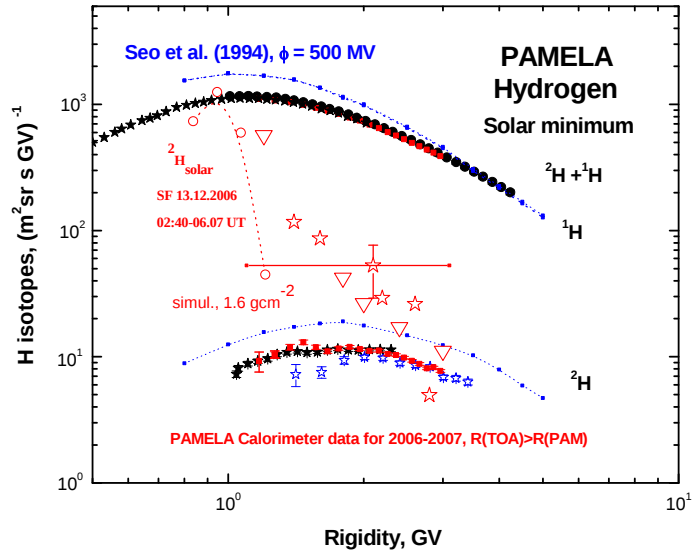
Conclusion

- Preliminary PAMELA data for Li and Be isotopes composition in galactic cosmic rays are in agreement with GALPROP model but contribution of LIS is possible...
- We have for Li good agreement of Edward and Wolfgang results by different approaches.
- **PAMELA dI/dR spectra for Li and Be are needed** for correct data of Li and Be isotopes ratio from energy. **(Roberta?)**.
- Statistics for Li and Be data can increase using 2009-2014 PAMELA data...
- I think it is needed to prepare the publications about Li and Be isotopes in ApJ during 2014-2015 before AMS-02...

May be it is interesting...

^2H and ^3He in SF 13.12.2006

(very preliminary...)



Thank you.

Best wishes from St. Petersburg :~)

