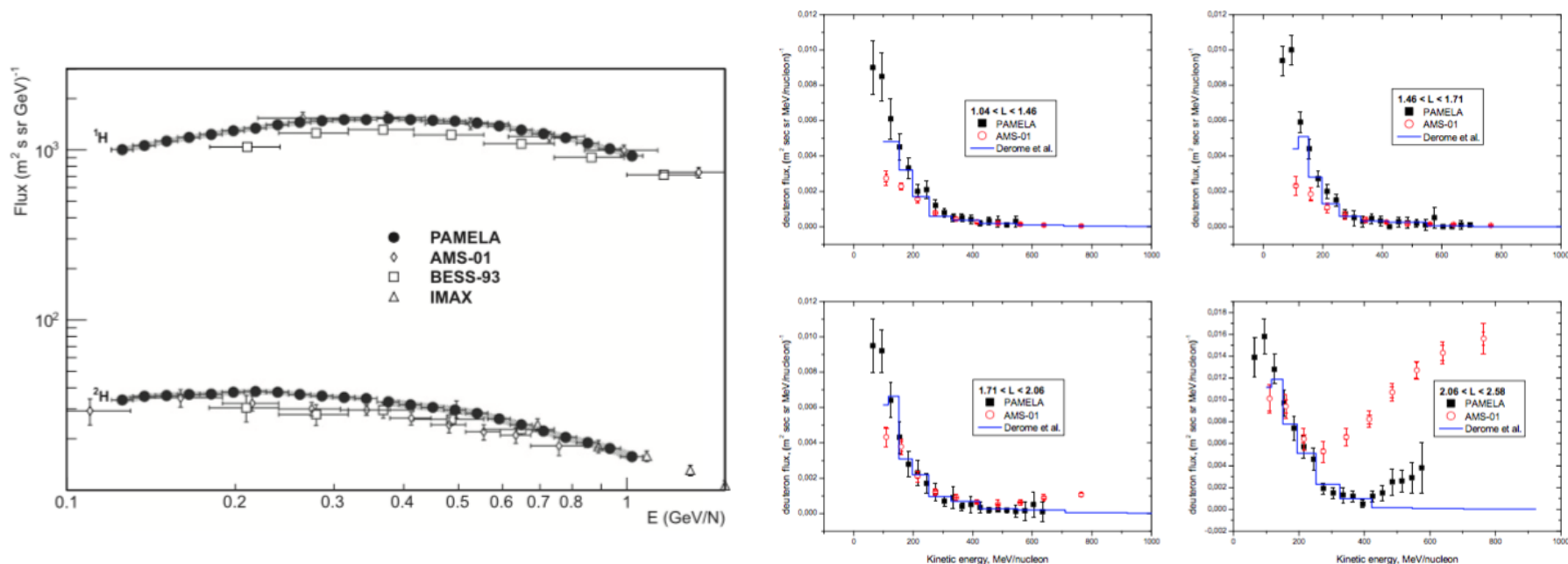


Solar modulation of deuterons in the PAMELA experiment

Koldobskiy Sergey A. on behalf of PAMELA collaboration

Deuteron spectra measurements in PAMELA



The analysis of PAMELA experimental data allowed to reconstruct both galactic deuteron spectrum (last work: *O. Adriani et al., Astrophysical Journal, 2016, 818 (1), 68*) and re-entrant albedo deuterons (last work: *Koldobskiy S.A. et al., Nuclear and Particle Physics Proceedings, 2016, 273-275, pp. 2345-2347*)

Solar modulation of GCR deuterons: BESS

Experimental data

A set of flights on balloons:

K.C. Kim et al // Proc. of 30th ICRC, Vol. 2
(OG part 1), pages 71 - 74

- BESS collaboration was able to reconstruct the deuteron spectra in period from 1992 to 2000 and therefore they show the influence of solar modulation to spectrum of galactic deuterons

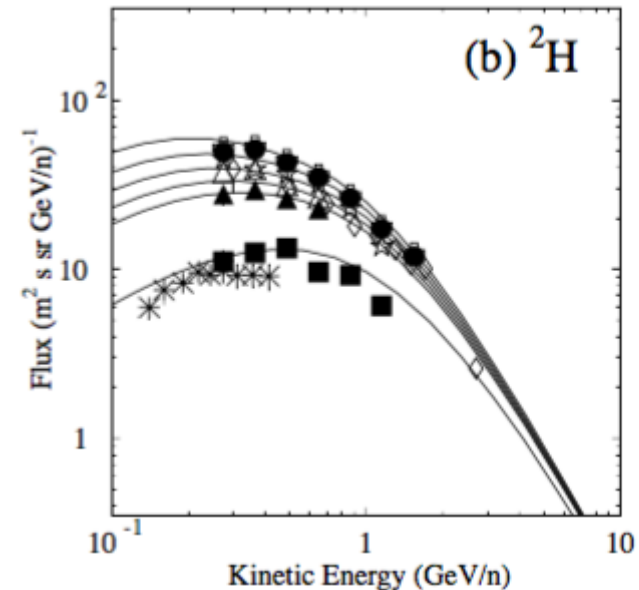
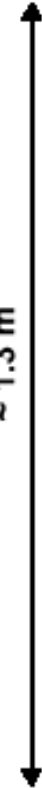


Figure 1: The absolute fluxes of ^1H and ^2H . The solid lines are theoretical predictions of the Reacceleration model. Modulation parameters are 500, 600, 700, 800, 900 and 1500 MV from top to bottom. (a) ^1H fluxes from BESS (93(solid triangle), 94(open triangle), 95(open star), 97(open cross), 98(solid circle), and 2000(solid square)) and IMAX-92(open diamond) data. (b) The absolute flux of ^2H from BESS and MASS-89(snow) data.



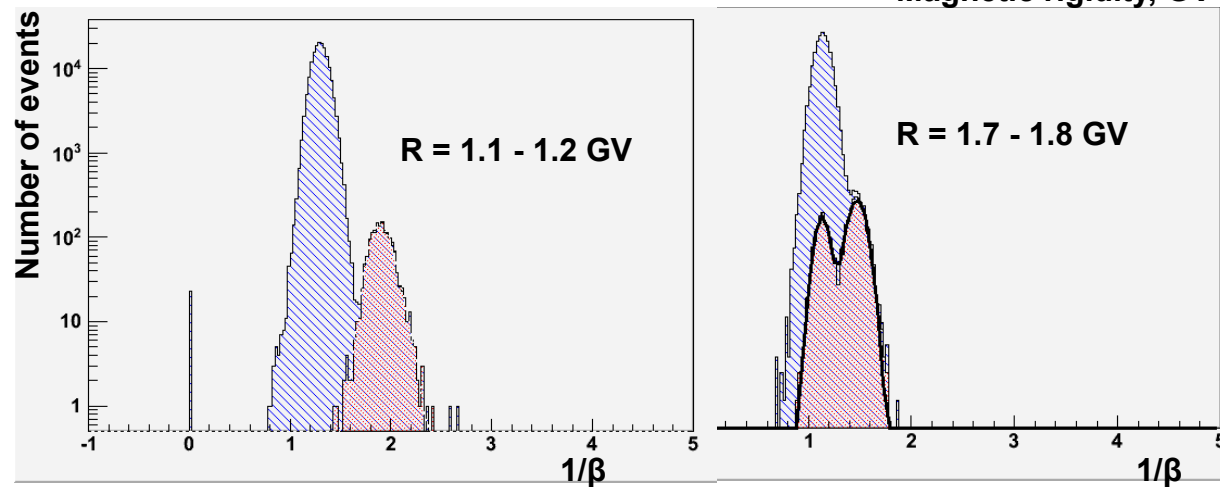
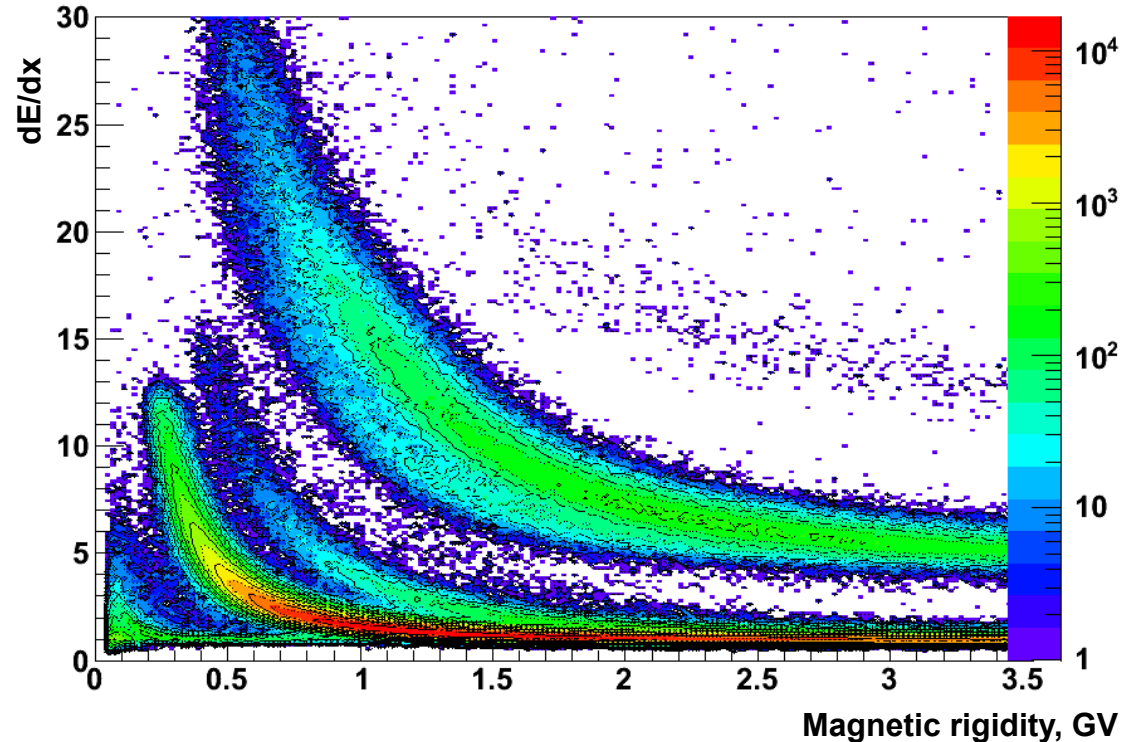
- Permanent magnet, 0.43 T
- 21.5 cm² sr
- 6 planes double-sided silicon strip detectors (300 μm)
- 3 μm resolution in bending view → MDR
~800 GV (6 plane) ~500 GV (5 plane)

- **44 Si-x / W / Si-y planes (380)**
- **16.3 X0 / 0.6 L**
- **dE/E ~5.5 % (10 - 300 GeV)**
- **Self trigger > 300 GeV / 600 cm² sr**

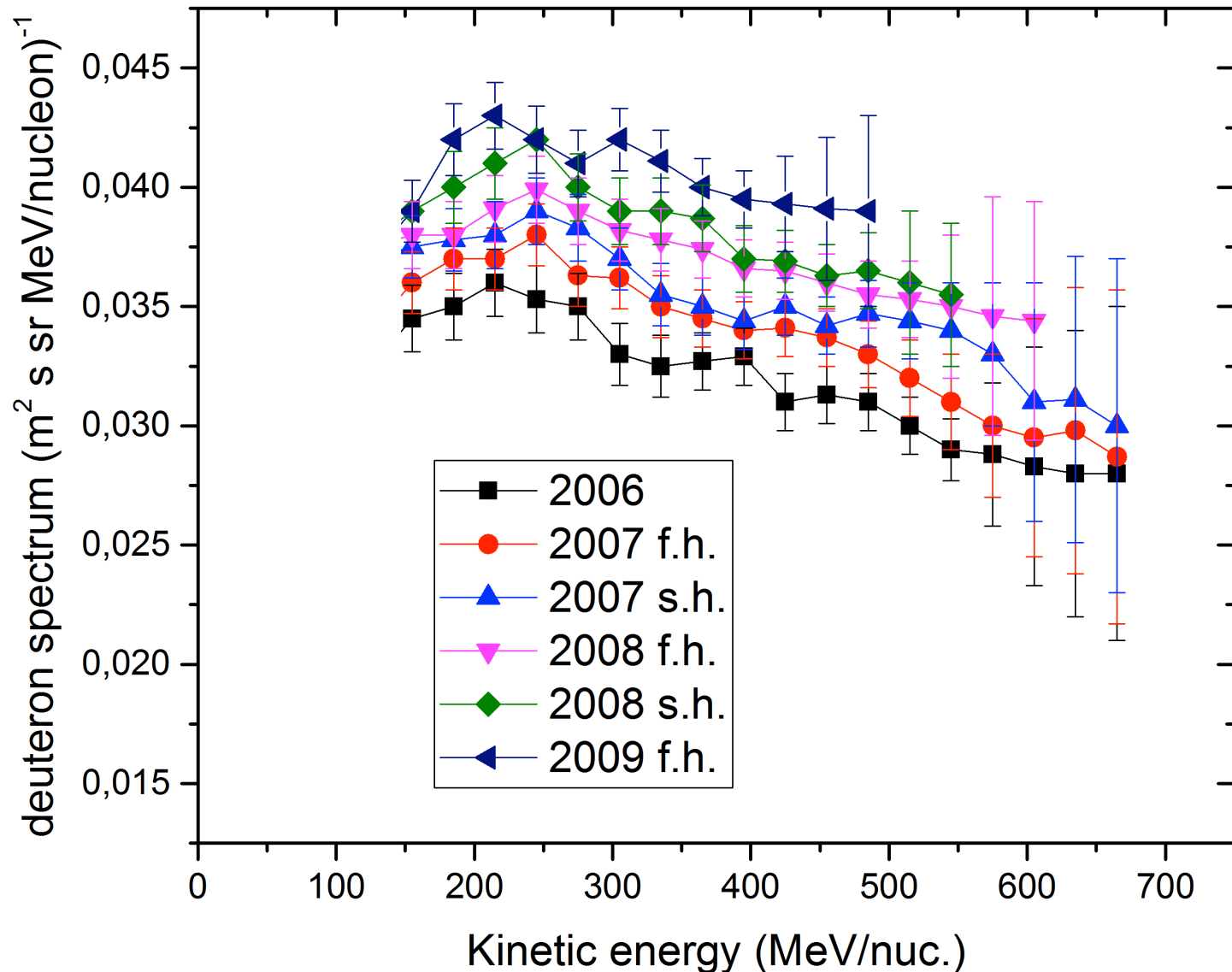
- 4

Deuteron selection

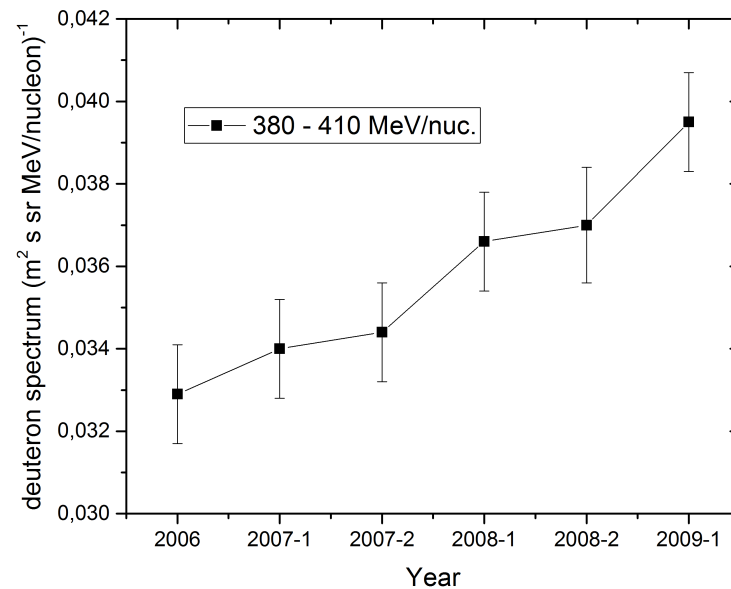
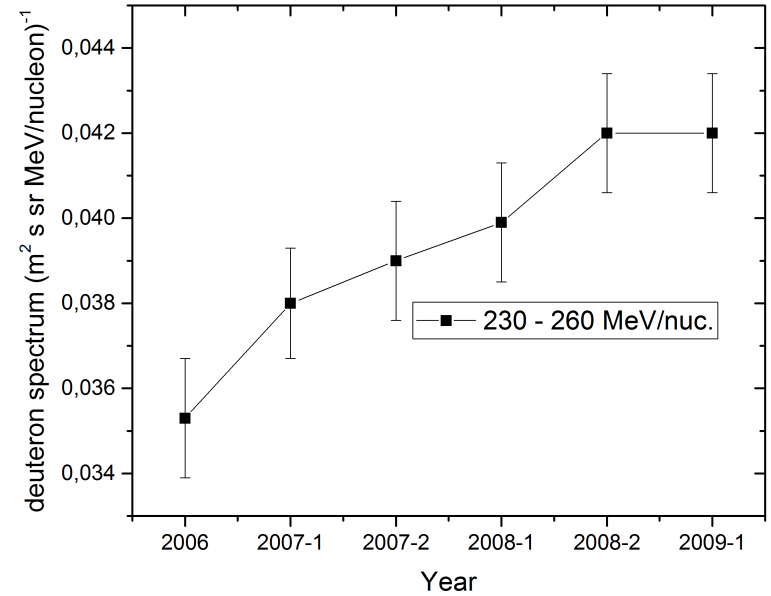
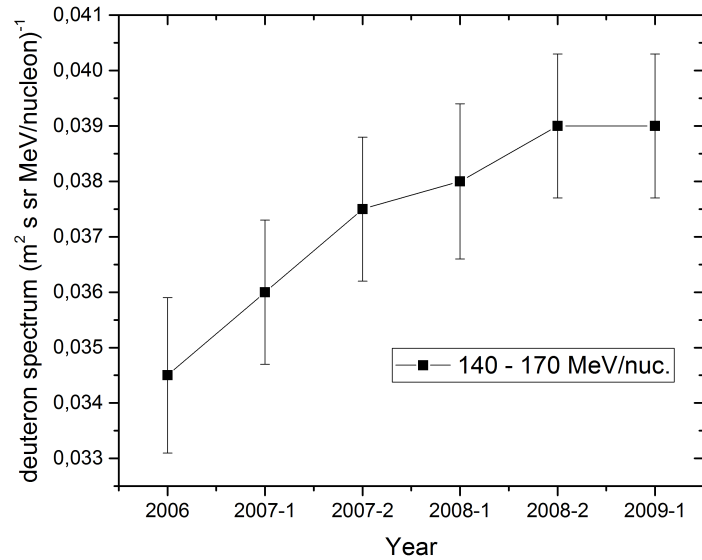
- Main problem: **enormous background of protons.**
- Deuterons were selected via multivariate correlation analysis.
- Rigidity, velocity and energy losses in magnetic spectrometer and detectors of ToF system allows to separate deuterons and protons with energies from 120 MeV/nucleon to 650 MeV/nucleon.



Preliminary results for GCR deuteron spectrum modulation in PAMELA experiment



Preliminary results for GCR deuteron spectrum modulation in PAMELA experiment



Conclusion

- PAMELA experimental data from June 2006 to June 2009 was analyzed and GCR deuteron spectra were reconstructed for this period of time with bin size in half year.
- It is clearly seen that the deuteron spectrum is dependent from solar modulation.
- Work not done, there is some additional efficiency evaluations are needed, moreover the main goal is to reconstruct the spectra for period from 2006 to 2015.

Thank you for attention!

Solar modulation of deuterons: theory

During the measurements the energy spectra of protons and helium nuclei it was found that the flux of galactic cosmic rays (GCR) varies in opposition with the 11 year cycle of solar activity. To describe this effect, called solar modulation of cosmic rays, Glisson and Exford in year of 1968 developed a simplified parametric force field model.

The main feature of this model is a diffusion equation describing the propagation of particles in a spherically symmetric heliosphere, with a diffusion coefficient which depends only on the particle rigidity R and the distance r from the Sun. The analytical expression for the measured flux and flux on the boundary of the heliosphere given by the following one-parameter formula:

$$J(E + \Phi, r) = J(E + \Phi, r \rightarrow \infty) \frac{E^2 - M^2}{(E + \Phi)^2 - M^2},$$

where E – total particle energy, M – particle mass, $J(E, r)$ – measured cosmic ray flux, $J(E + \Phi, r \rightarrow \infty)$ – interstellar cosmic ray flux, $\Phi = eZ\phi$, ϕ – model parameter, called as potential of solar modulation.

dE/dx distribution (tracker)

