



Сравнение долговременных изменений потока космических лучей по данным наземных детекторов, Pamela и AMS-02

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Земля и Небо



PAMELA 15 June 2006 - beginning of the 2016



Protons	0.08-1000 GeV
Antiprotons	0.06-350 GeV
Electrons	0.05-650 GeV
Positrons	0.05-250 GeV
anti-core	0.1-45 GeV/nuc.

<i>Mass</i>	450 kg
<i>Size</i>	1 m × 1 m × 1.25 m
<i>Magnetic field induction</i>	0.48 T
<i>Electric power</i>	350 Watt
<i>Geometric factor</i>	21.5 cm ² sr

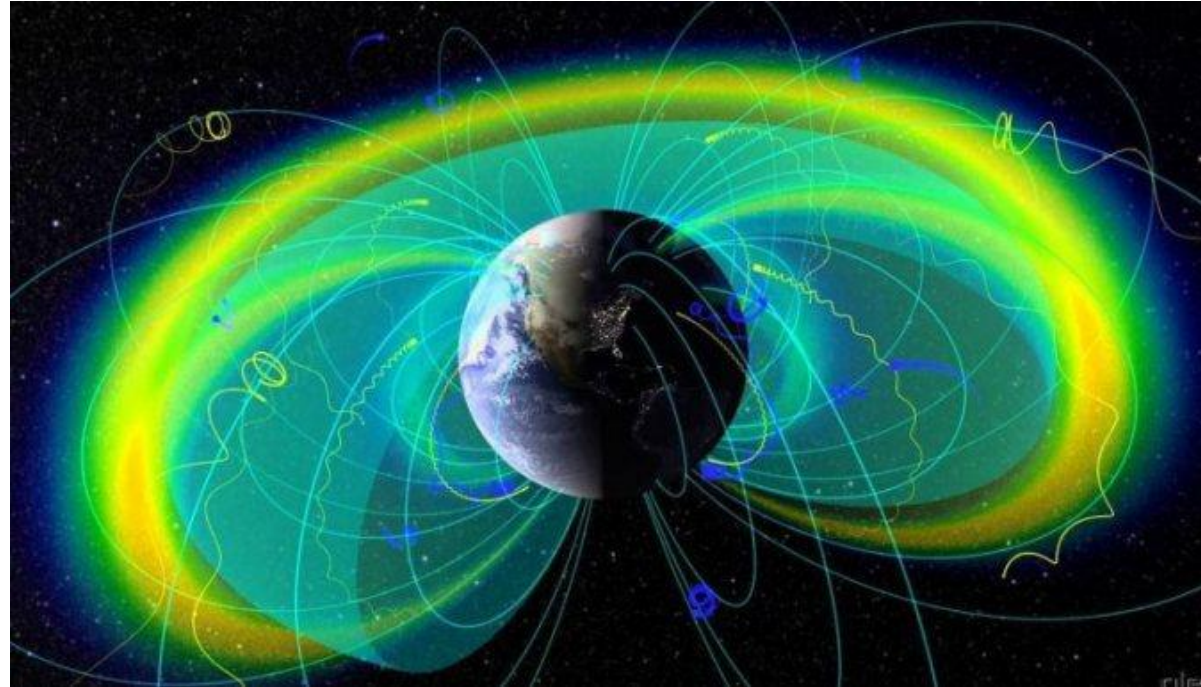
AMS-02 Start 16 May 2011



- ▶ Official website ams02.space
- ▶ Repair AMS Outside ISS on 2020-01-25
- ▶ Space manipulator
- ▶ The most powerful cosmic magnet **NASA**

Ground monitoring and global survey method - GSM

The Earth, with its magnetosphere and atmosphere, is a gigantic natural spectrometer, which allows the separation of primary charged particles by rigidity. Therefore flux of secondary cosmic rays is so different at various depths in the atmosphere and on different latitudes.



The isotropic part of the variations observed by the ground-based detector is related to the spectrum of primary variations $\delta J / J (R)$ by the integral equation :

$$v^i = \delta N / N \Big|_{R_c} = \int_{R_c^i}^{\infty} W(R_c^i, h_0^i, R) \cdot \delta J / J \cdot dR$$

Here, as a kernel, is the response function W for secondary CR, and as an unknown function, the spectrum of variations $\delta J / J (R)$.

Плюсы и Минусы

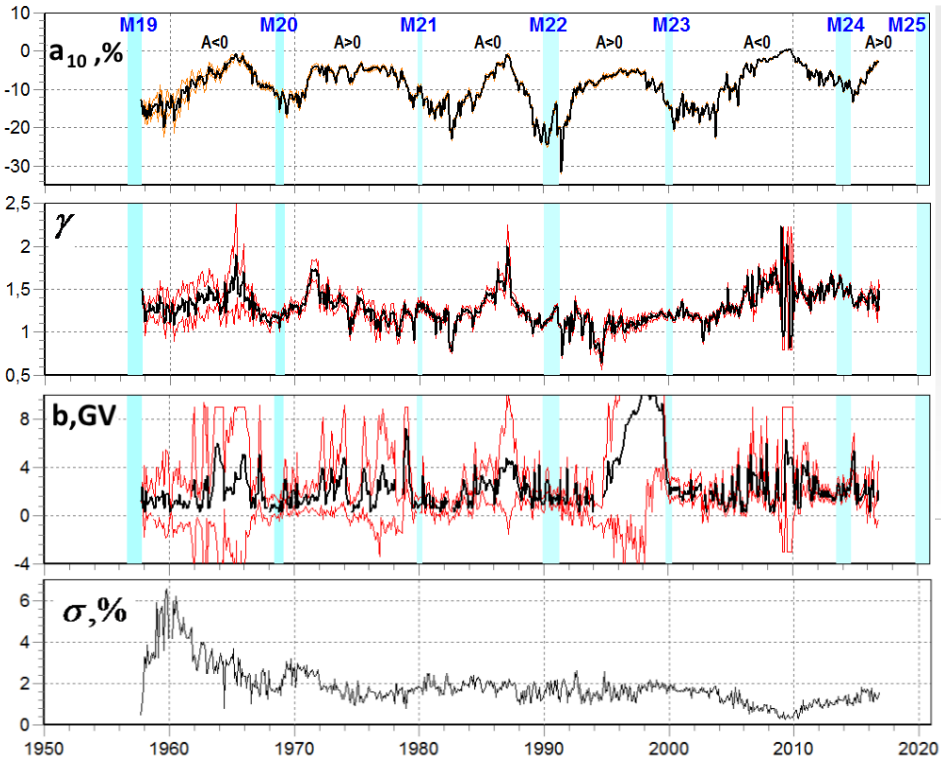
Наземные измерения

- + Большие размеры детекторов, высокая точность
- + Длинные однородные ряды
- + Легко контролировать и настраивать
- Только вторичные КЛ
- Изменения локальных условий
- Мало данных про химсостав и энергию

Космические измерения

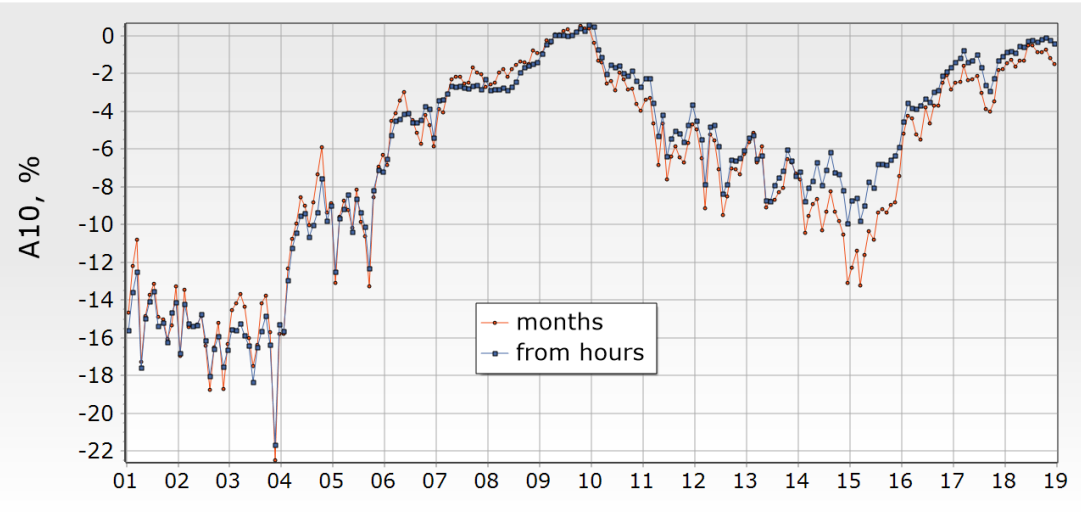
- + Первичные КЛ
- + Данные про химсостав и энергии
- + Стабильность локальных условий
- Маленькие детекторы, низкая точность
- Ряды короче
- Трудно контролировать и настраивать

GSM results



Parameters of variations of GCR density
[Belov, Gushchina, Yanke 2018].

$$a_{10}, \gamma, R_0$$

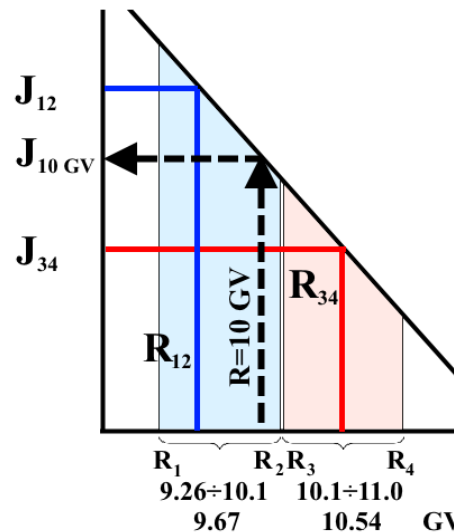


Variations of CR density (10 GV), obtained by
different GSM versions
from hourly [Belov et al., Sol. Phys., 2018]
and monthly data.

Used channels of PAMELA and AMS-02

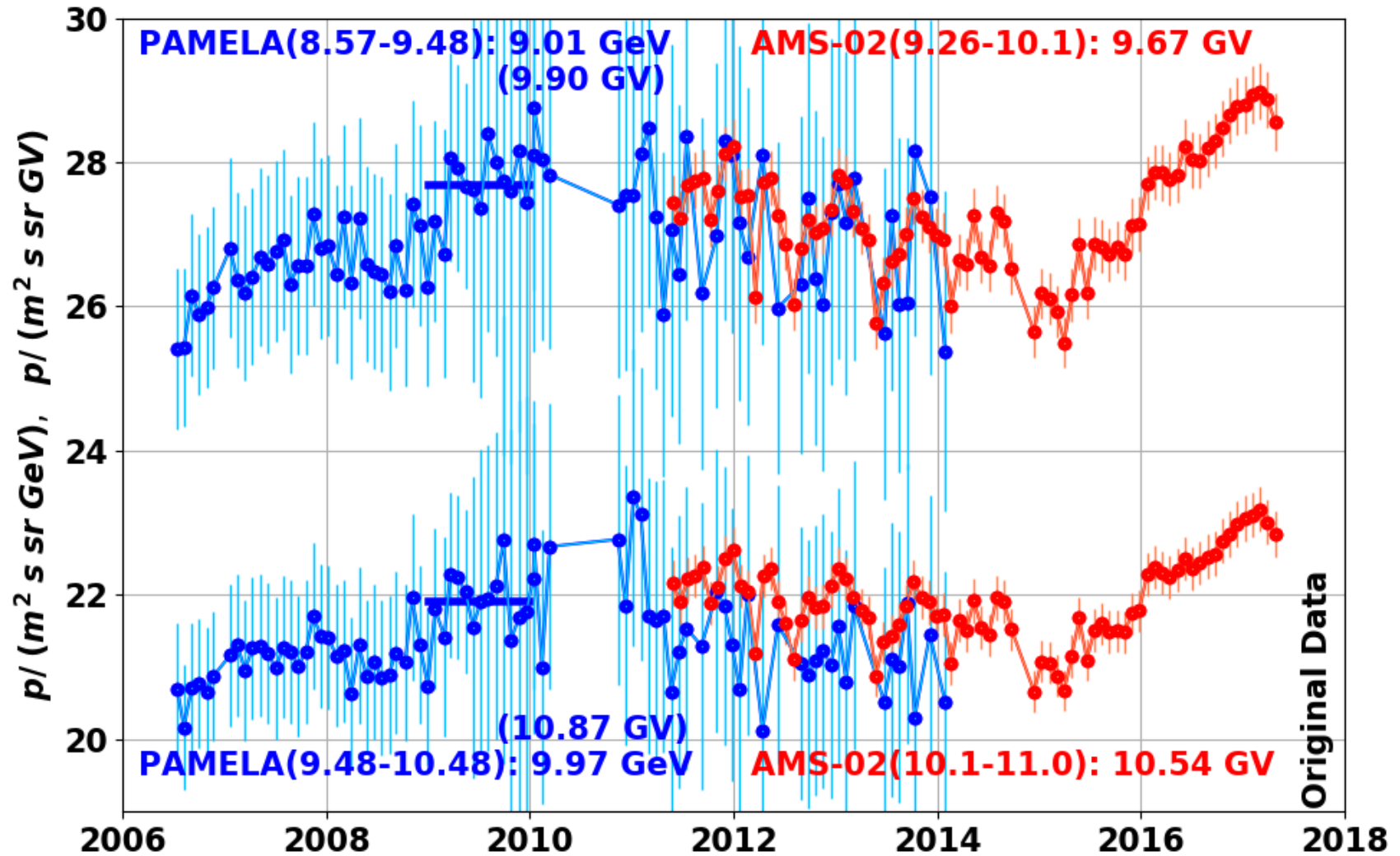
PAMELA		AMS-02	
диапазон, GeV	$E_{\text{evr}}, \text{GeV}/R_{\text{evr}}, \text{GV}$	диапазон, GV	$R_{\text{evr}}, \text{GV}$
8.57 ÷ 9.48	9.01/9.90	9.26 ÷ 10.1	9.67
9.48 ÷ 10.48	9.97/10.87	10.1 ÷ 11.0	10.54

$$J(R) = J(K) \frac{\sqrt{K(K + 2M_p)}}{K + M_p}$$



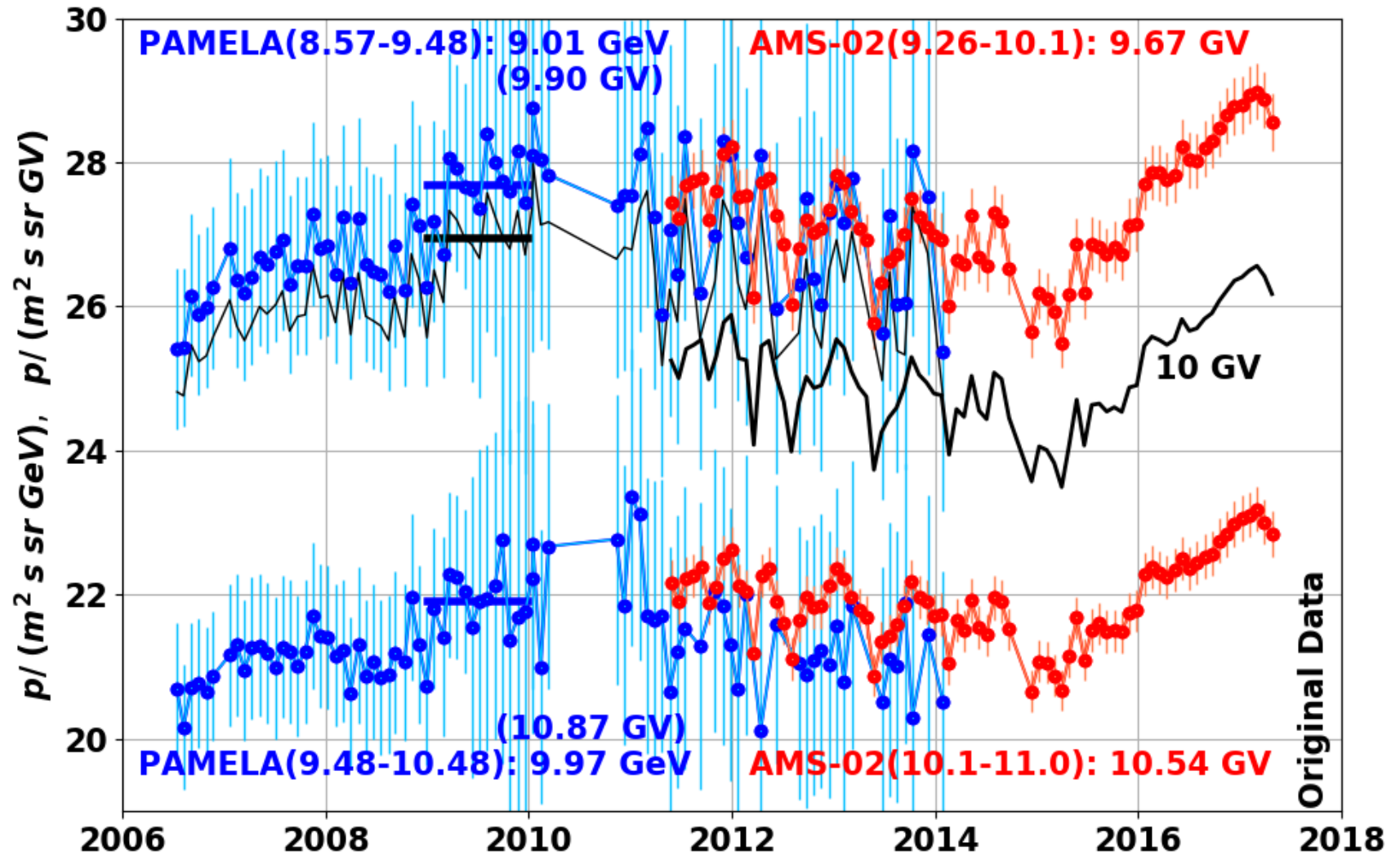
Evaluation of effective rigidities

Pamela and AMS data



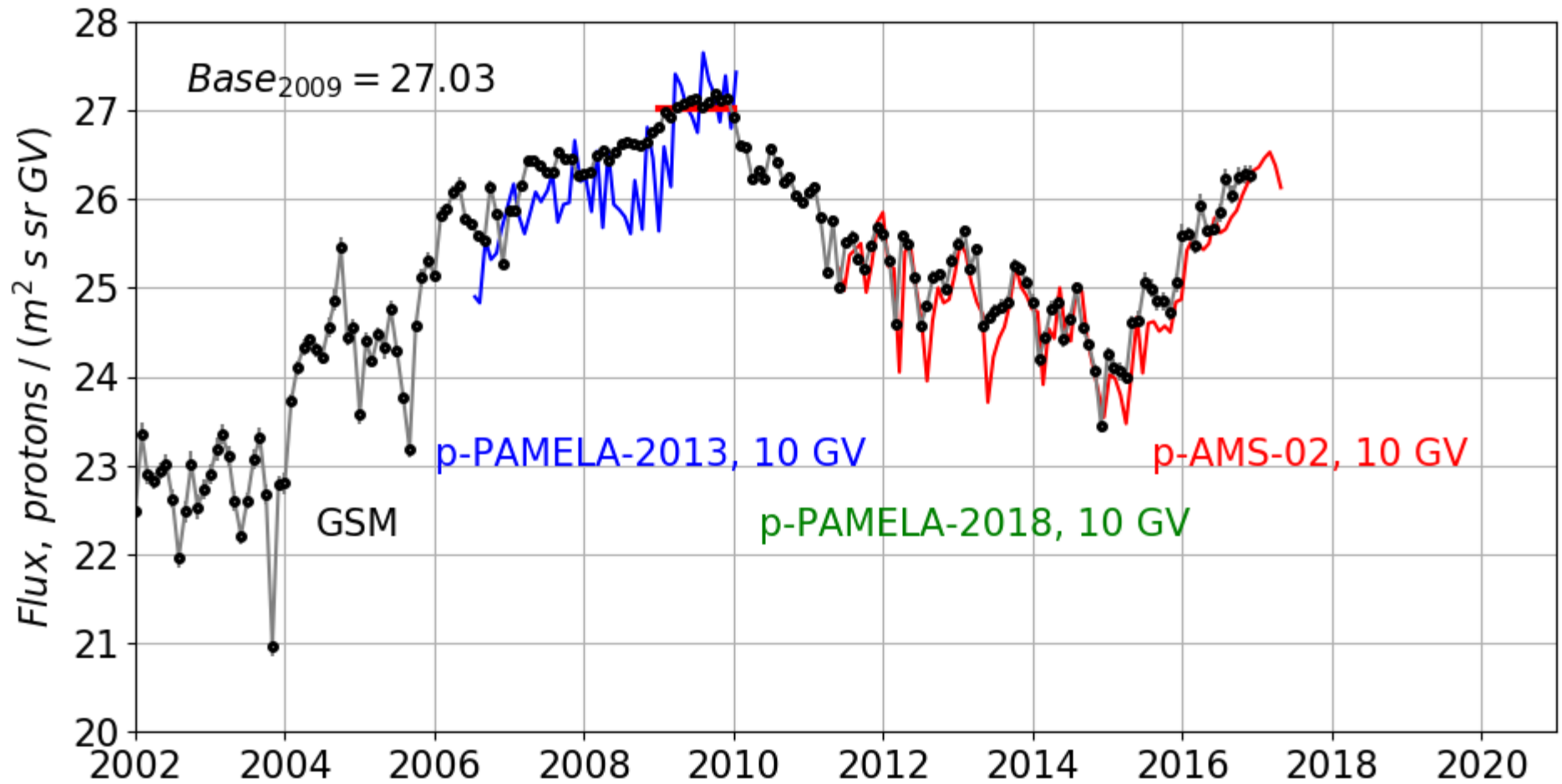
Original PAMELA and AMS-02 data for channels nearest to 10 GV rigidity. Statistical errors for PAMELA – 4% and 8% from 2009; for AMS-02 – 1.5%

Pamela and AMS data



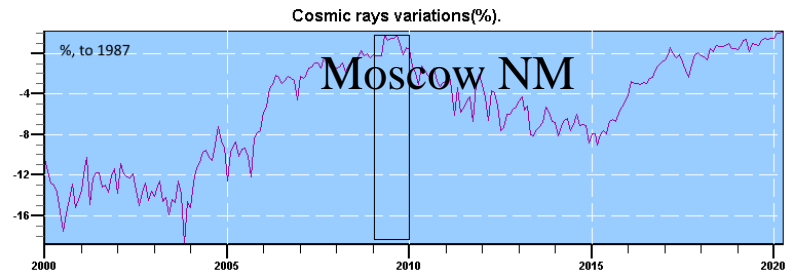
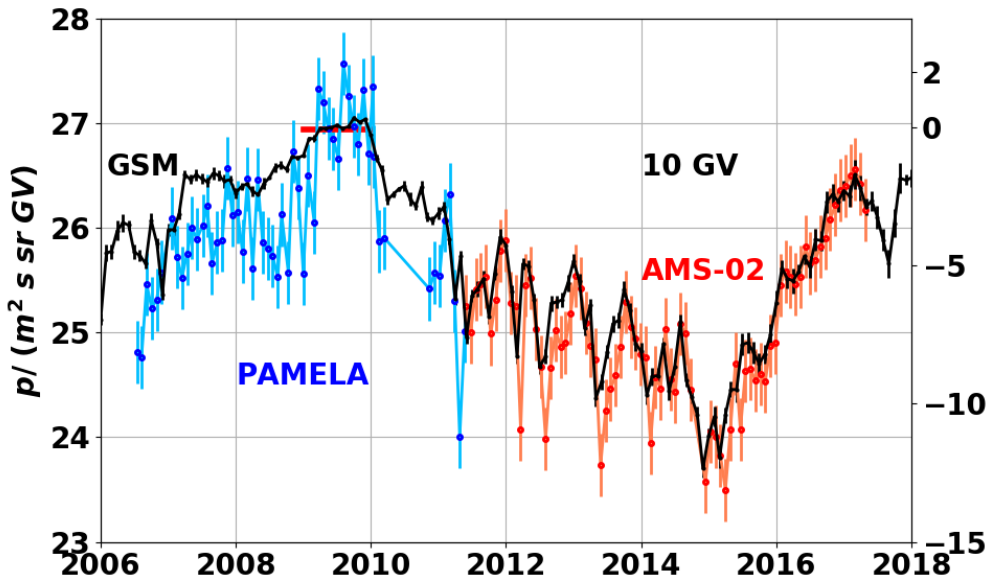
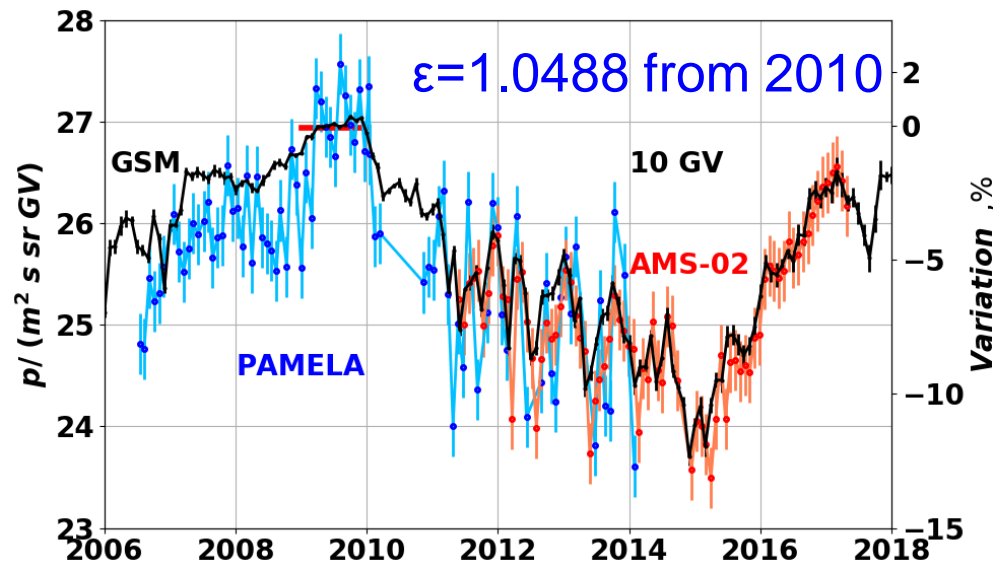
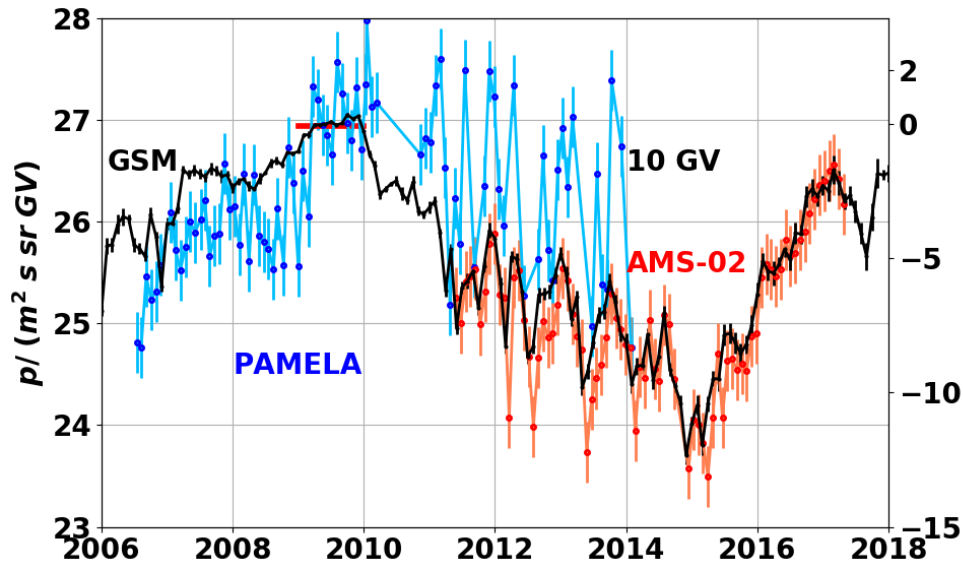
Original PAMELA and AMS-02 data for channels nearest to 10 GV rigidity and interpolation for 10 GV

Pamela, AMS and GSM data

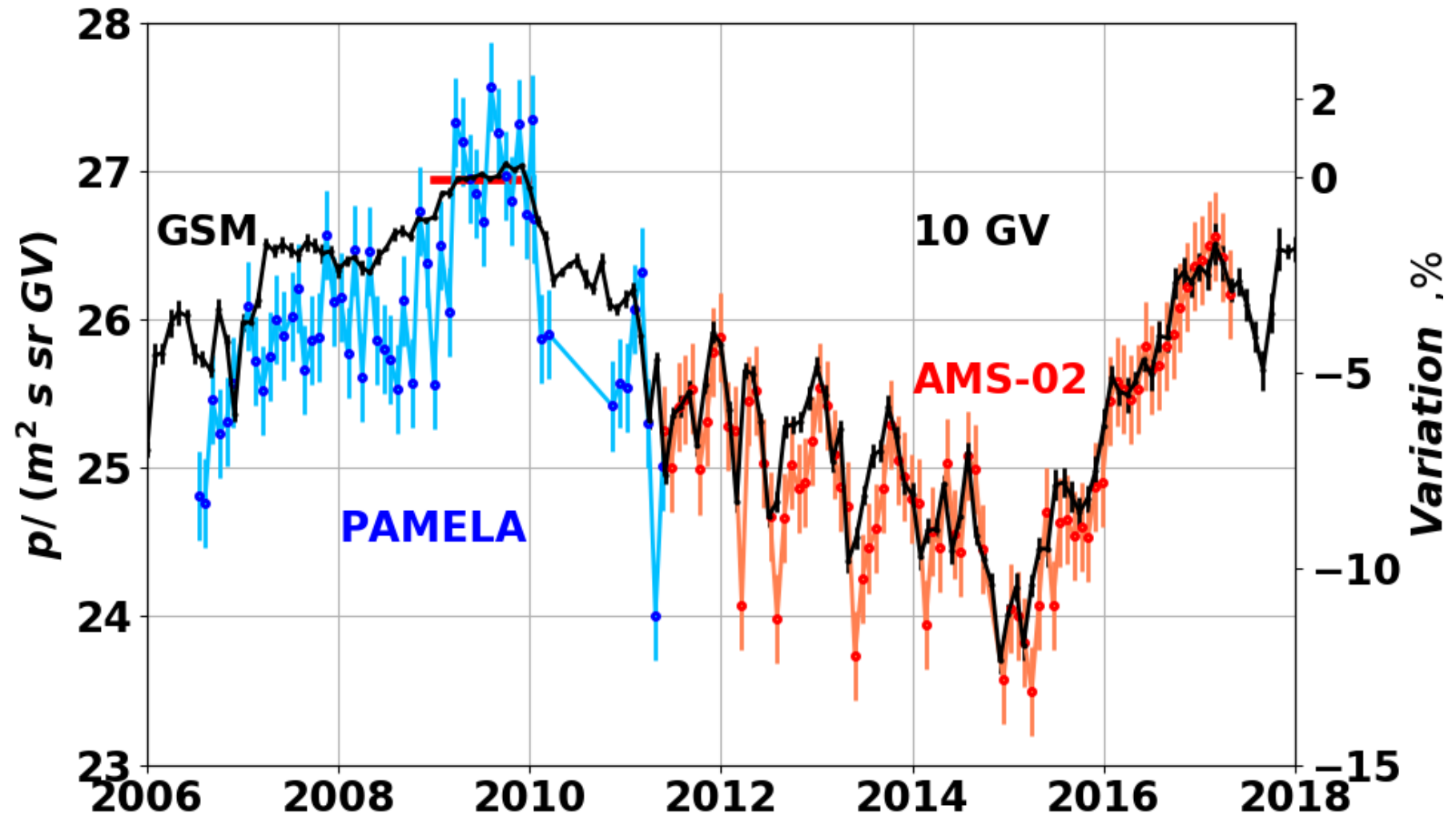


Without last PAMELA

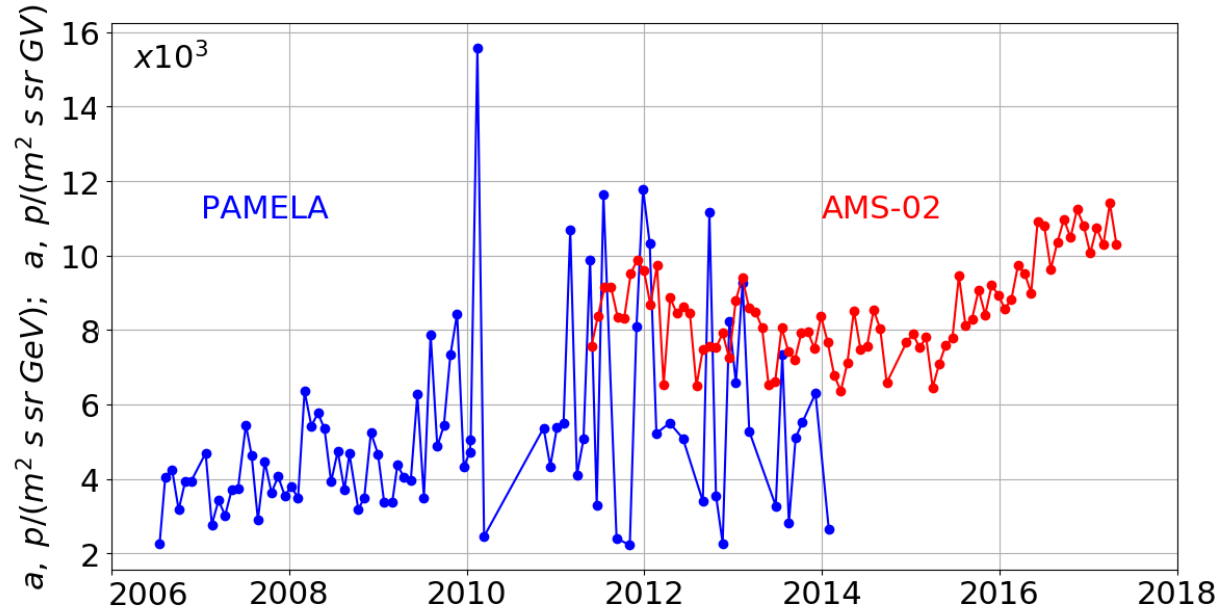
Pamela, AMS and GSM data



Pamela, AMS and GSM data

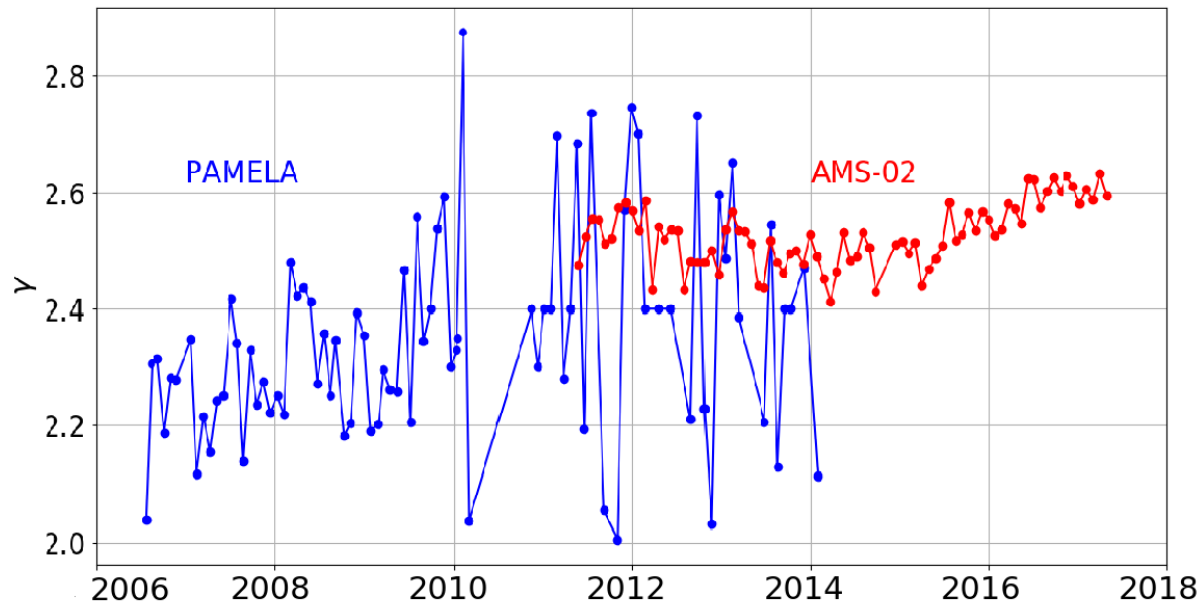


Results

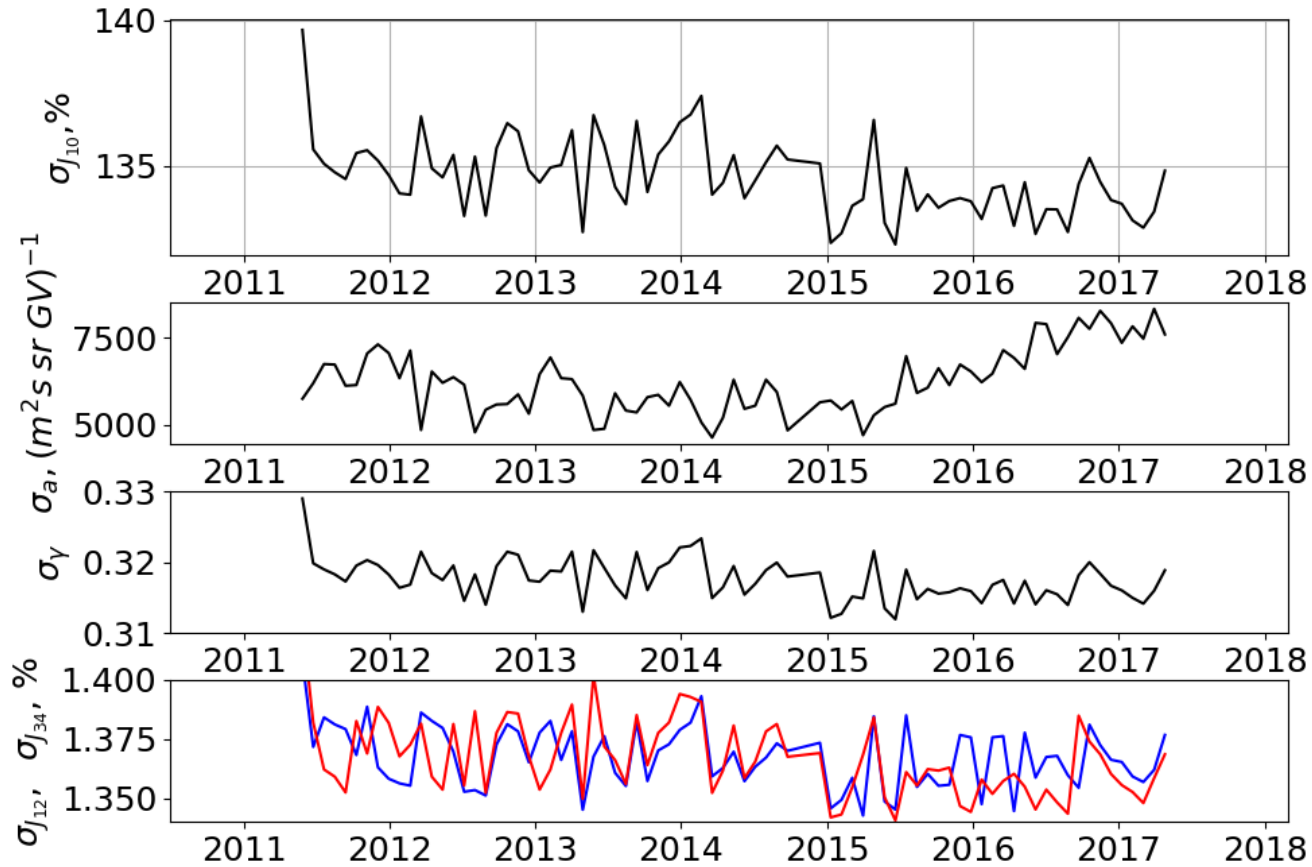


Changes a_{10} and γ for dependence

$$J = a_{10} (R/10)^{-\gamma}$$

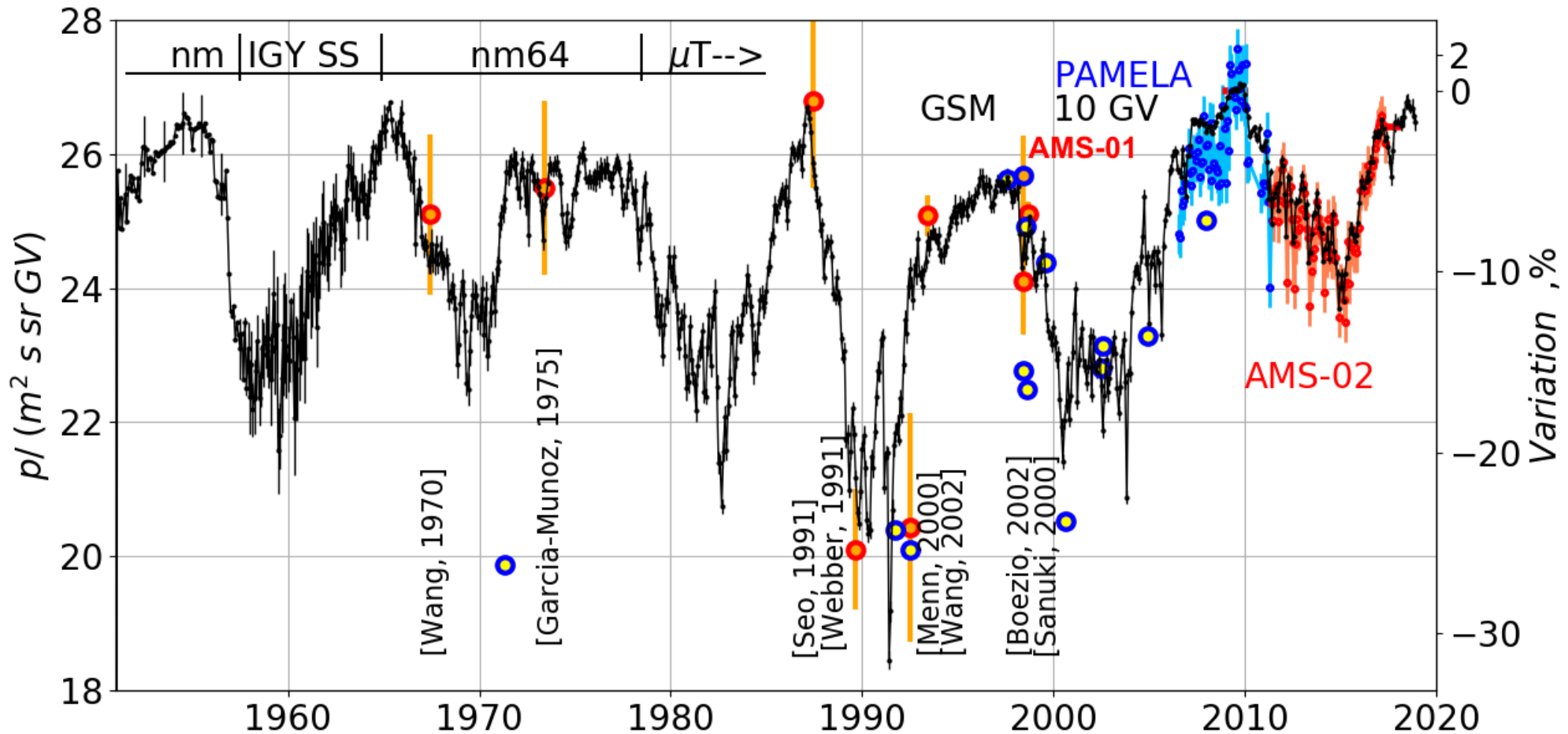


Evaluation of statistical errors



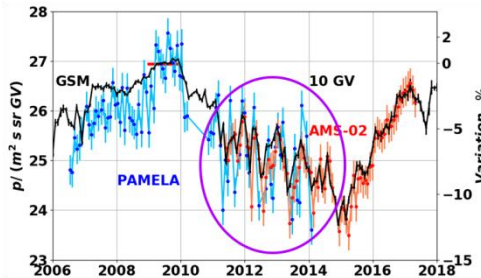
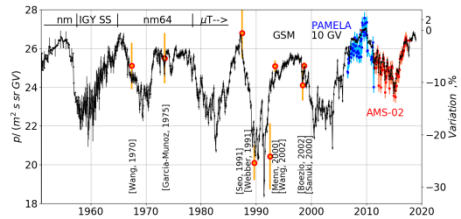
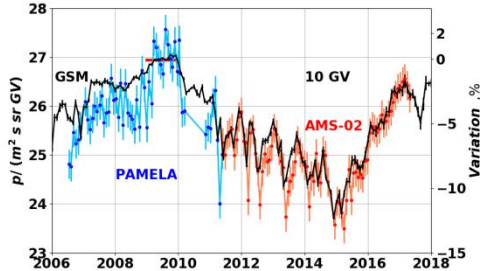
Evaluation of statistical errors J_{10} flux of AMS-02.

Results. Long time variations for 10 GV.



Base (PAMELA – 2009) = 26.94 $pI/(\text{m}^2 \text{s sr GV})$.
Separate points – stratospheric measurements.

Conclusions



➤ The results of continuous ground-based monitoring of cosmic-ray variations and direct measurements of proton flux in PAMELA and AMS-02 experiments for the entire observation period are in good agreement.

Despite the doubled error of PAMELA for channels near 10 GeV and the changed efficiency, the total flow drift was not observed.

➤ The flux of cosmic rays obtained by the GSM method was estimated and calibrated using PAMELA data for all space era.

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1951	-	25.76	24.90	25.35	24.89	25.27	25.41	25.00	25.49	25.67	25.46	25.65	25.35
1952	25.46	25.37	25.65	25.31	25.88	26.11	26.11	26.08	25.78	25.95	25.95	25.72	25.78
1953	25.91	26.03	25.98	26.01	26.02	26.06	26.05	26.09	26.11	26.13	26.17	26.17	26.06
1954	26.17	26.28	26.45	26.39	26.43	26.41	26.46	26.61	26.56	26.54	26.46	26.38	26.43
1955	26.07	26.37	26.39	26.40	26.46	26.42	26.43	26.35	26.46	26.27	26.30	26.03	26.33
1956	26.22	26.21	25.60	25.59	25.37	25.35	25.55	25.53	25.35	25.76	25.05	24.22	25.48
1957	23.65	23.58	23.73	23.23	23.49	23.31	23.10	23.33	22.64	23.49	22.51	23.10	23.03
1958	22.38	22.86	22.19	22.38	22.77	23.21	22.35	22.70	23.10	23.01	23.27	23.15	22.78
1959	23.26	22.63	23.06	23.92	23.12	23.45	21.57	21.80	22.65	23.23	23.41	23.14	22.94
1960	22.94	22.91	23.81	23.28	22.06	22.81	22.79	23.19	23.46	23.63	22.96	23.59	23.12
...													
2015	24.01	24.20	23.80	24.21	24.46	24.45	24.89	24.90	24.81	24.70	24.79	24.98	24.52
2016	25.28	25.62	25.52	25.49	25.58	25.73	25.63	25.89	25.88	26.25	26.32	26.25	25.79
2017	26.36	26.30	26.51	26.38	26.20	26.26	26.11	25.88	25.66	26.05	26.47	26.46	26.22
2018	26.48	26.48	26.42	26.54	26.55	26.77	26.80	26.72	26.68	26.68	26.57	26.47	26.60

Статистические ошибки для периода:

до 1958 0.7 p/(m² s sr GV).

до 1965 0.5 p/(m² s sr GV).

после 1965 0.12 p/(m² s sr GV).

В течение долгого времени не было условий для сопоставления данных непрерывного наземного мониторинга сети нейтронных мониторов и прямых характеристик галактических космических лучей за пределами атмосферы, т.к. отсутствовали достаточно продолжительные в широком диапазоне жесткостей от нескольких GV до нескольких десятков GV экспериментальные данные. Только после публикации данных эксперимента PAMELA и данных AMS-02 это стало возможным.