Time dependent GCR intensity with Neutron Monitor, PAMELA and AMS02 measurements

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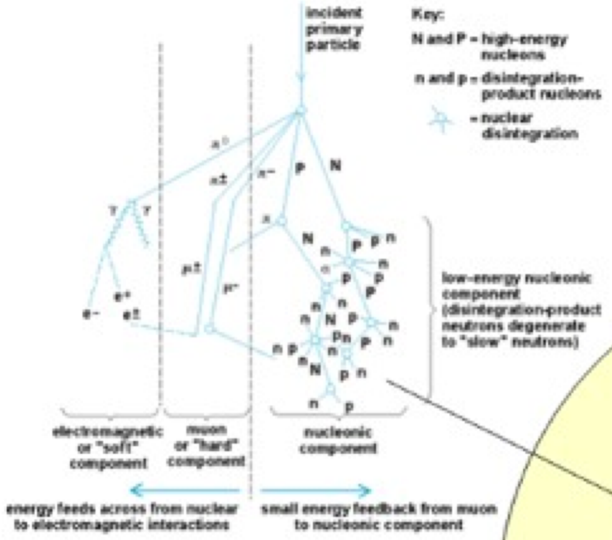
Neutron Monitors

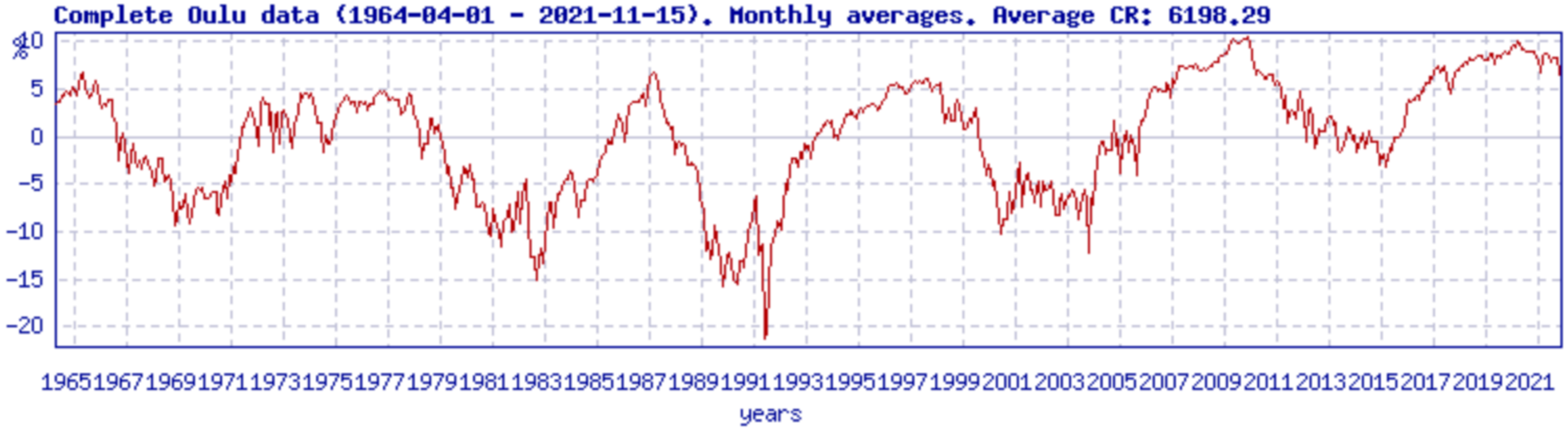
Different designs:

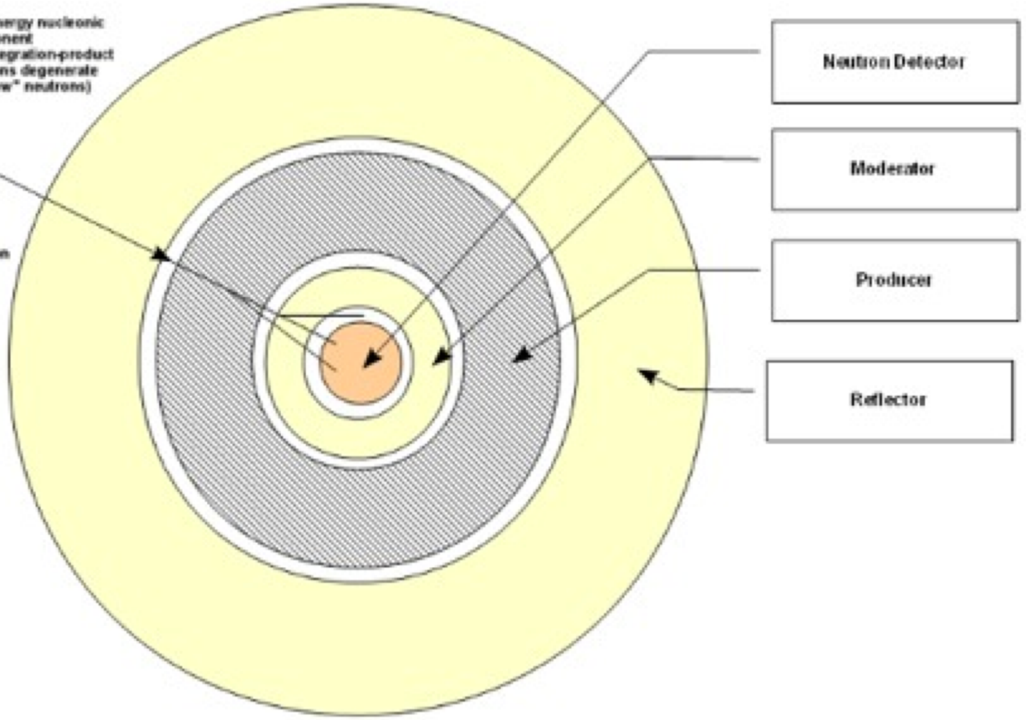
original IGY proposed by Simpson 1950

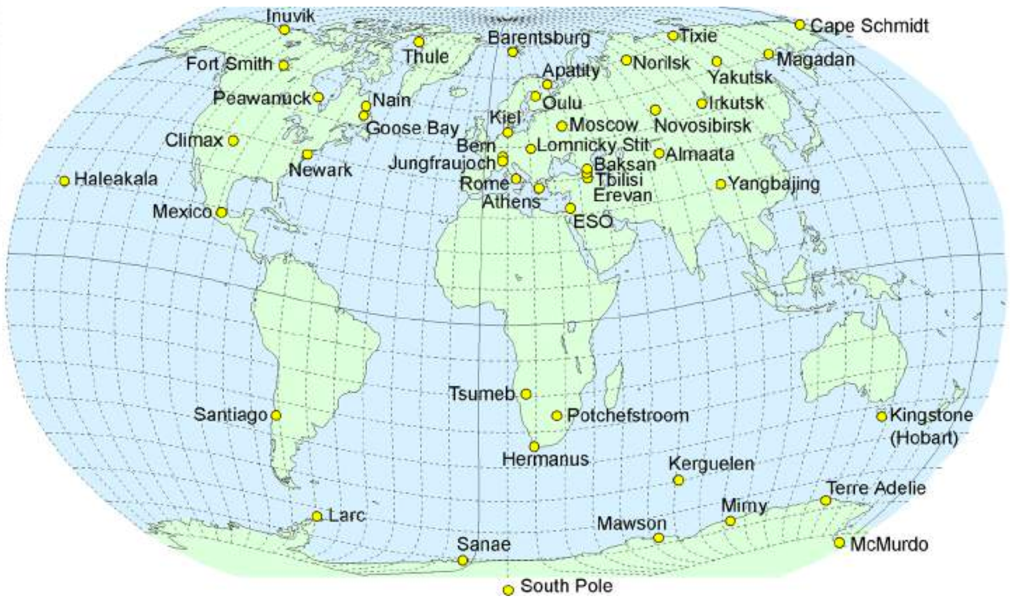
NM64 proposed by Carmichael and Hatton 1964

Bare and mini neutron monitors









NM data: where to get? and stability

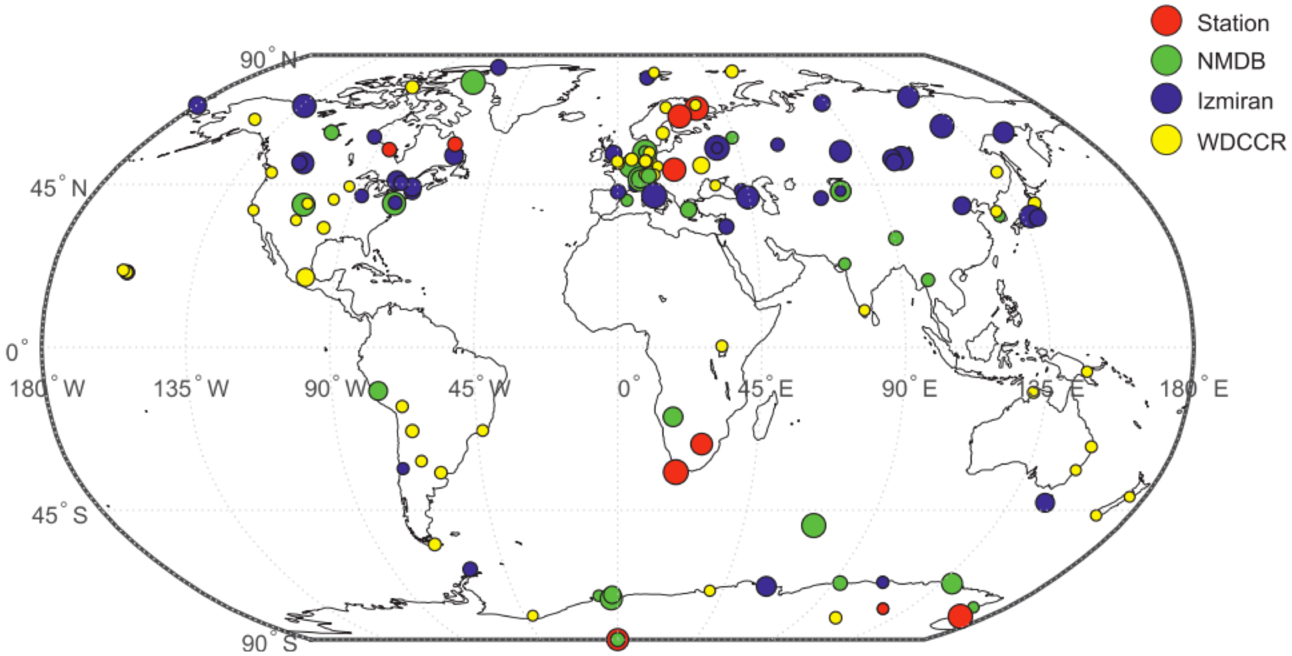
NMDB: http://www02.nmdb.eu/nest

WDC: https://cidas.isee.nagoya-u.ac.jp/WDCCR/readme.html

IZMIRAN: http://cr0.izmiran.ru/common

Dedicated NM databases

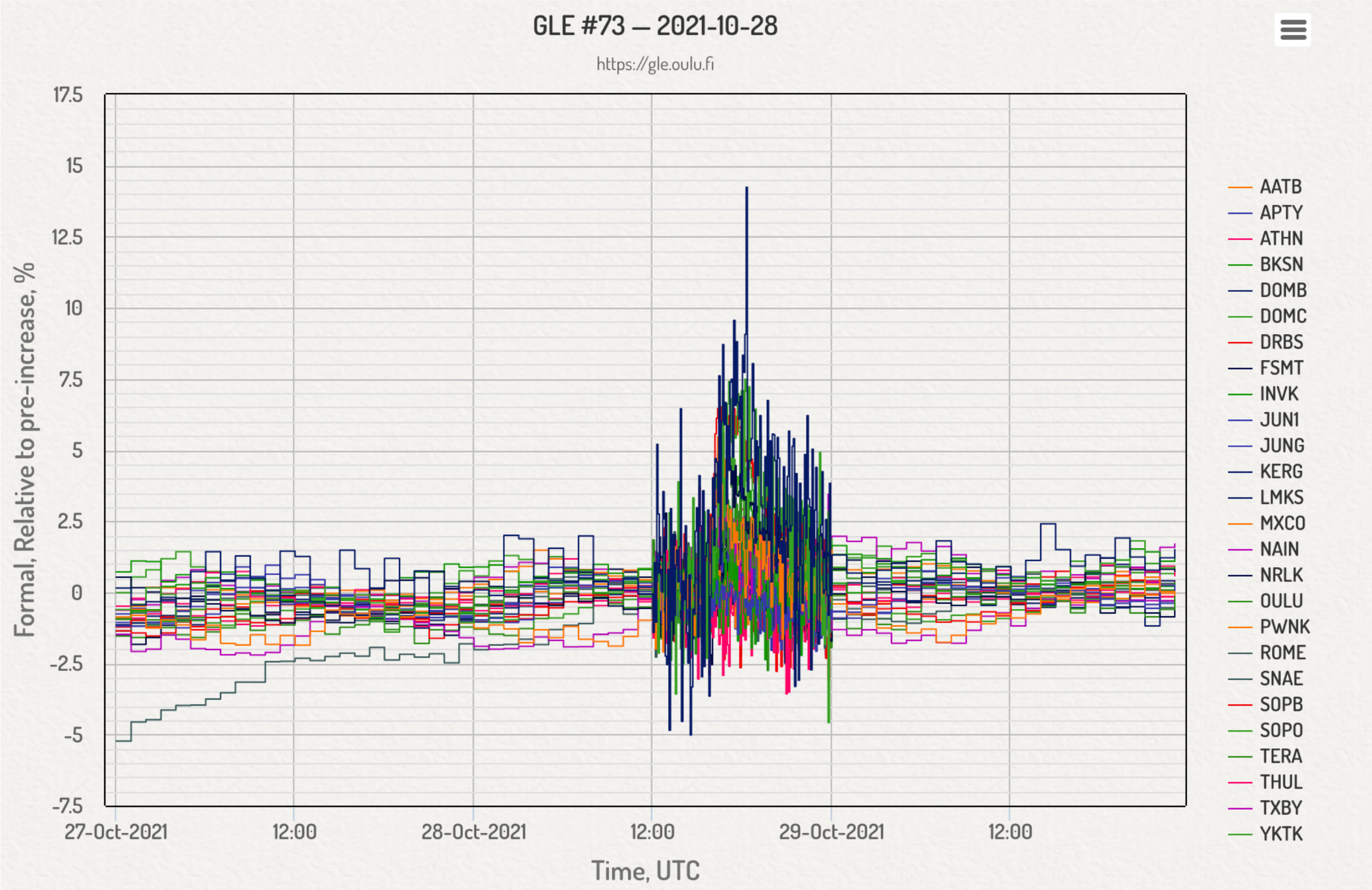
Väisänen et al. JGR:SP 2021



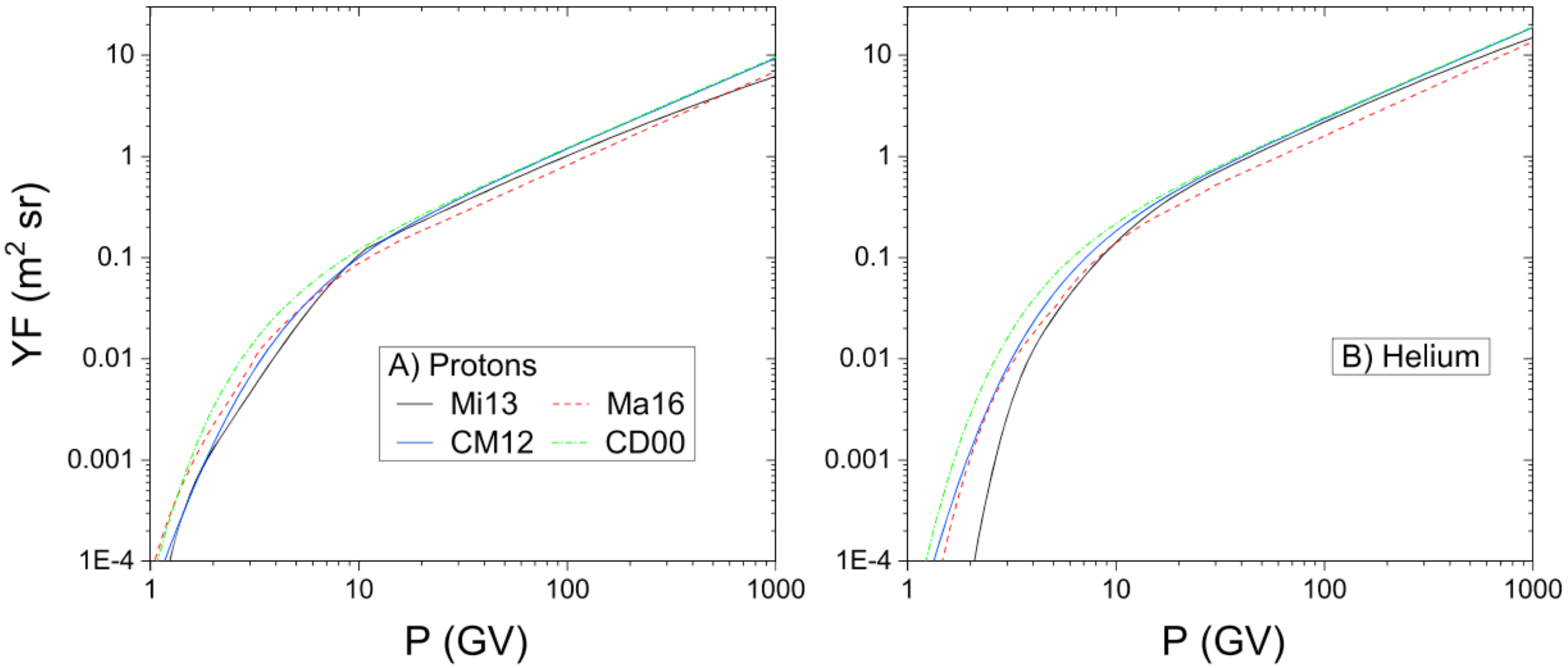
Direct measurements of CR databases:
https://tools.ssdc.asi.it/CosmicRays/
https://lpsc.in2p3.fr/crdb/

SEP physics using NM data

http://gle.oulu.fi/#/



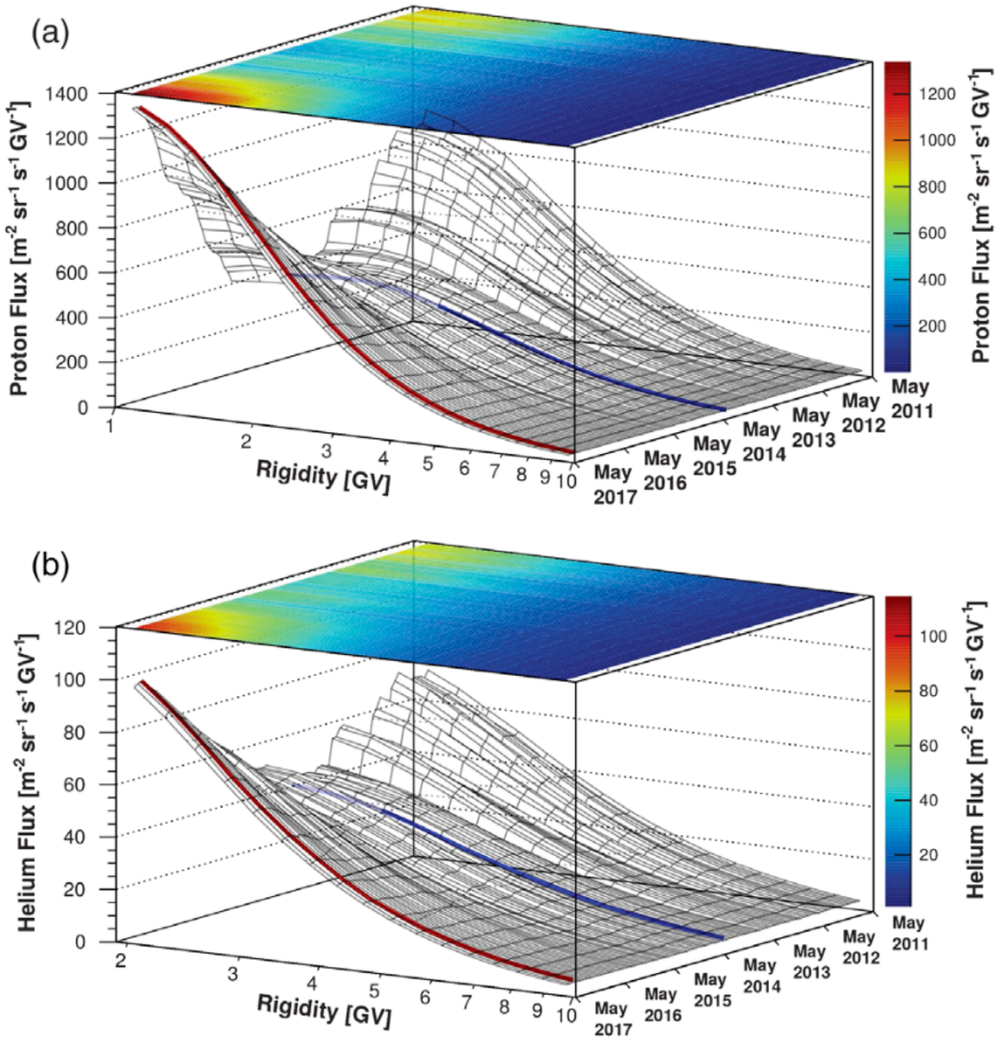
NM yield functions

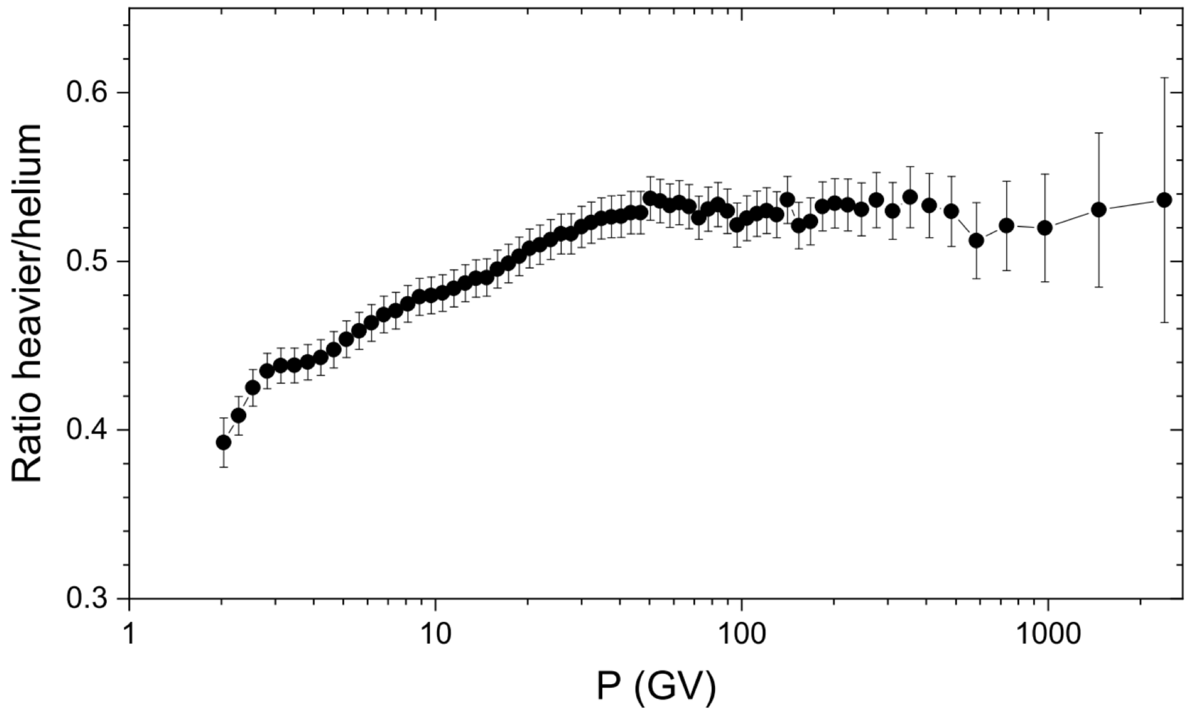


$$N(t,h) = \frac{1}{\kappa} \sum_i \int_{P_c}^{\infty} J_i(P,t) \cdot Y_i(P,h) \cdot \mathrm{d}P$$

NMs are energy-integrating detectors

Neutron monitor and AMS-02 data

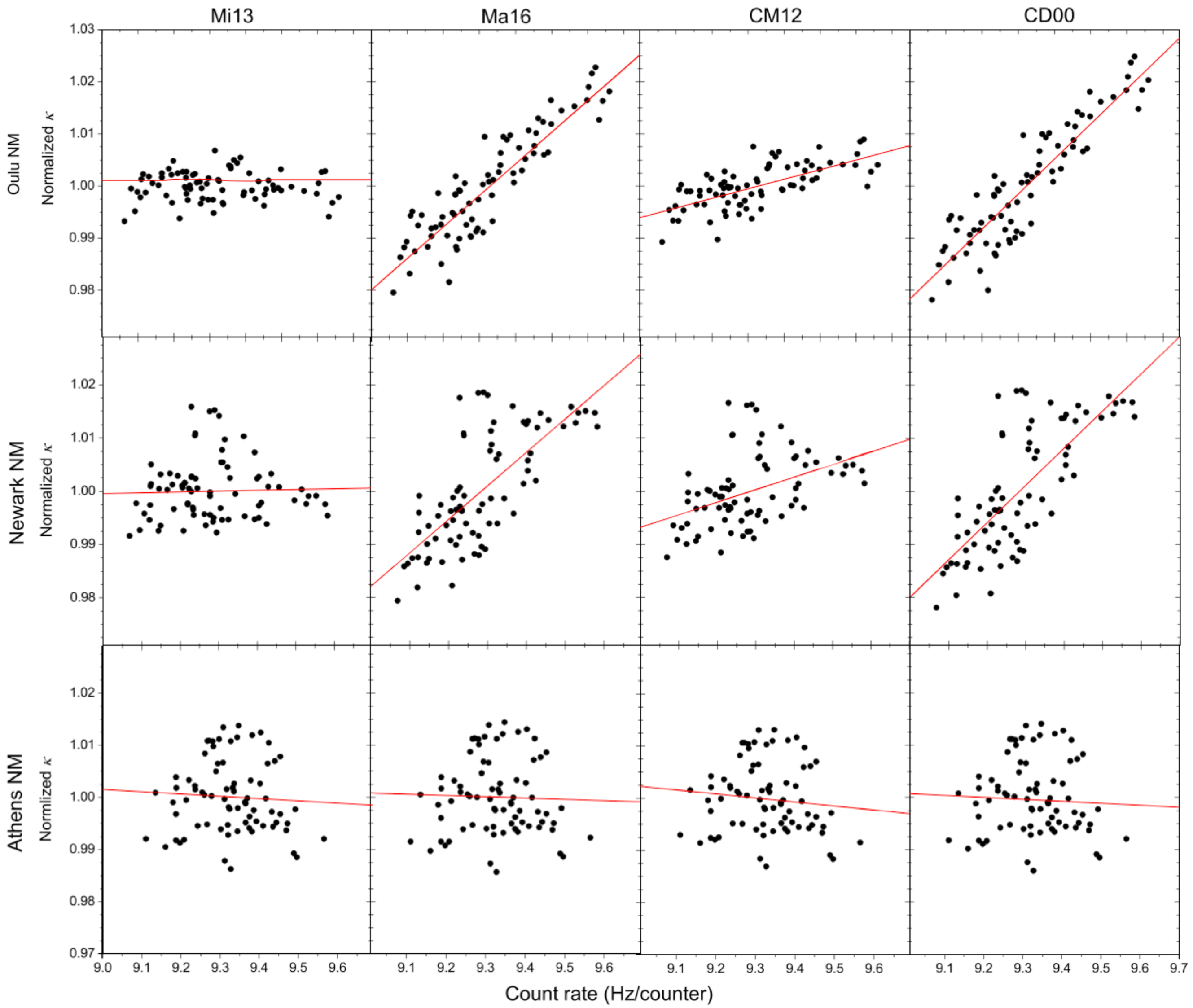




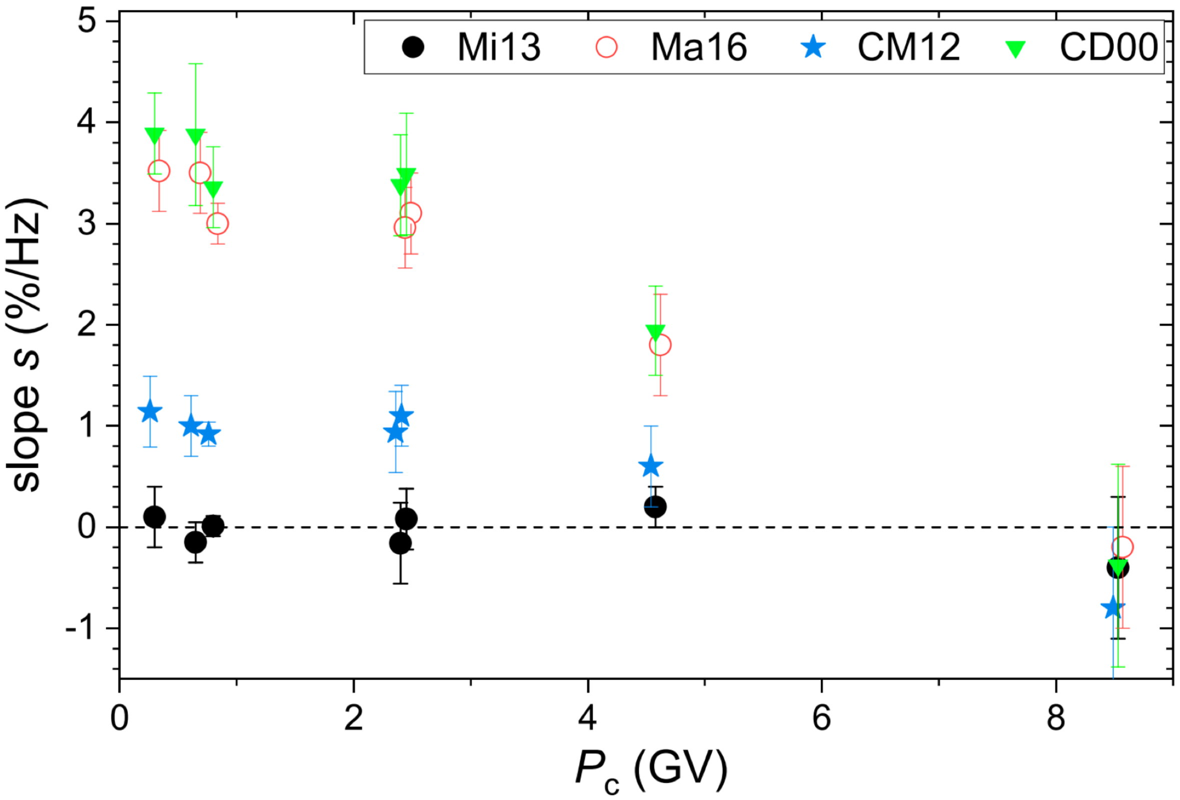
Neutron monitor count rate:

$$N(t,h) = \frac{1}{\kappa} \sum_i \int_{P_c}^{\infty} J_i(P,t) \cdot Y_i(P,h) \cdot \mathrm{d}P$$

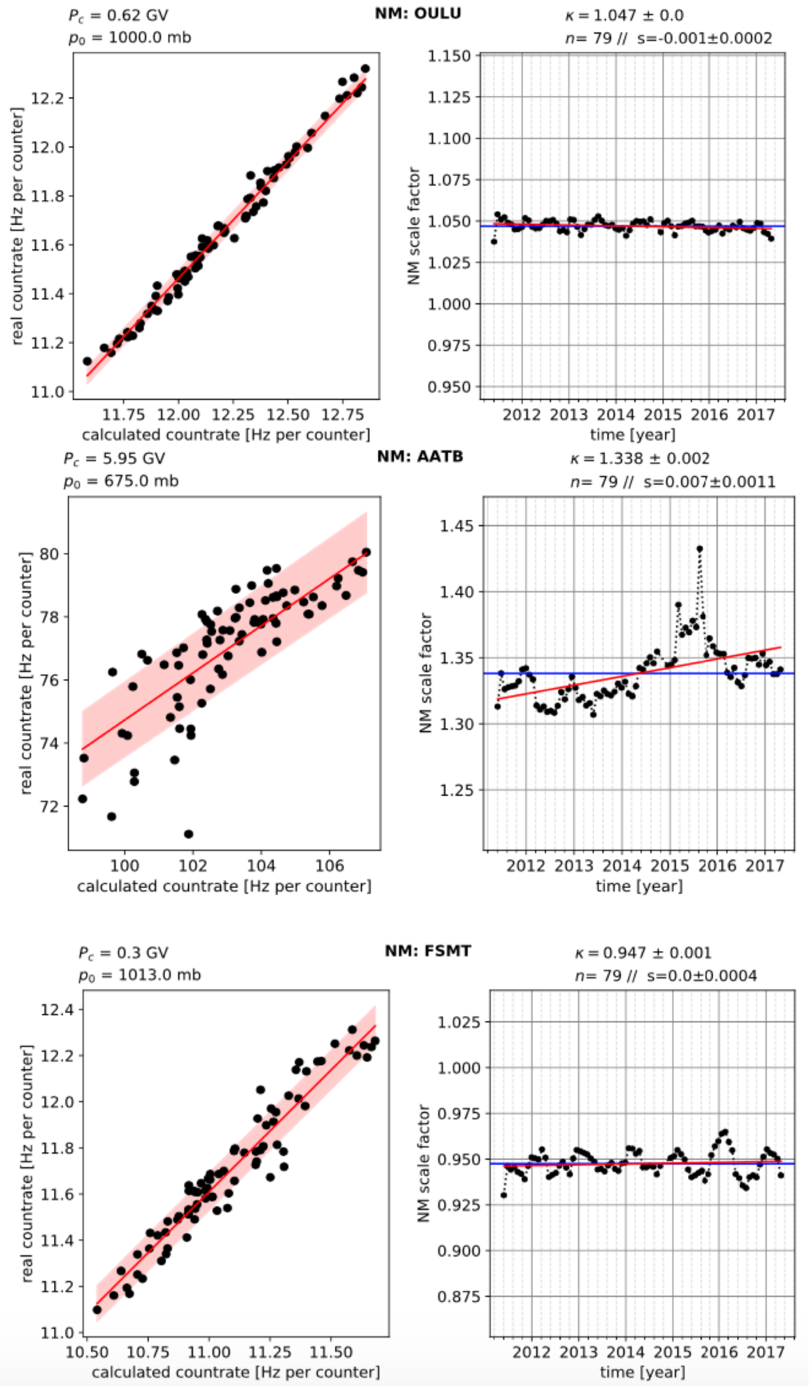
Neutron monitor yield function verification



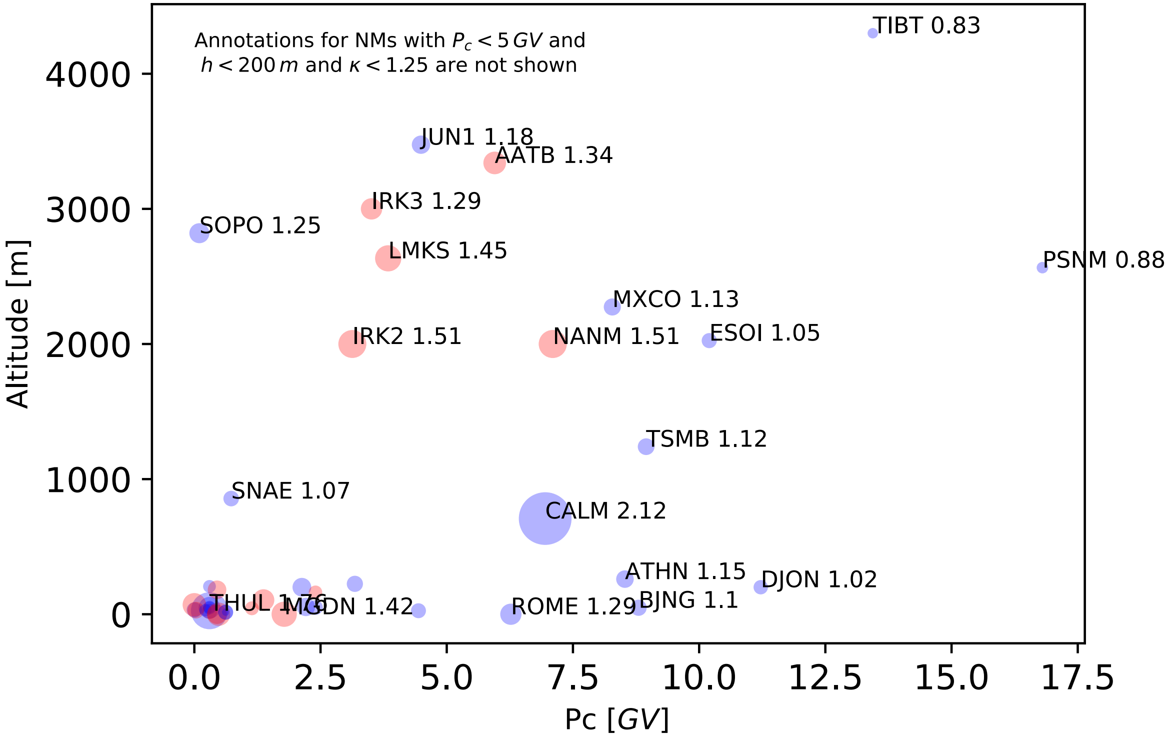
Koldobskiy et al. JGR:SP 2019



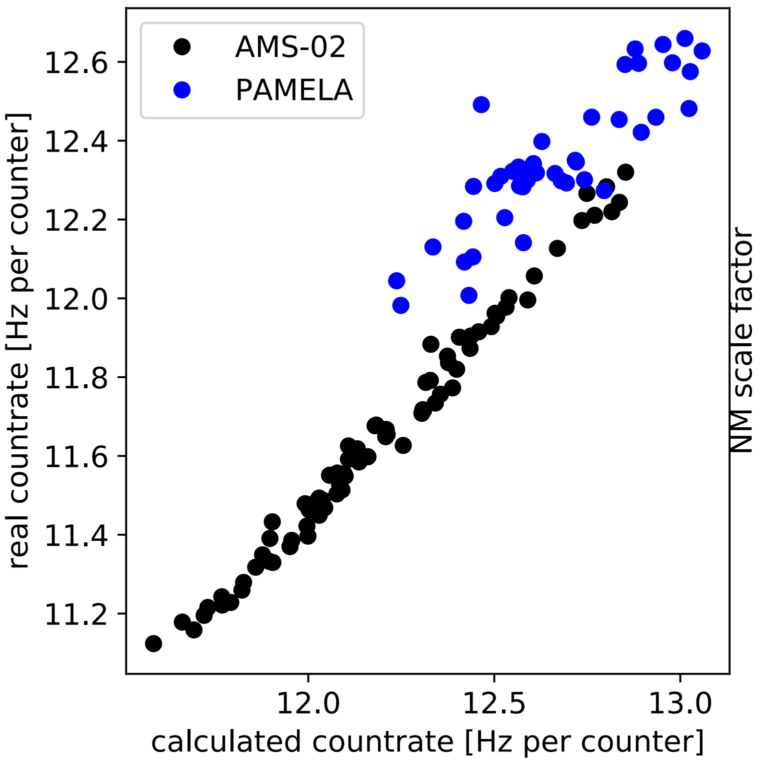
Mishev et al. JGR:SP 2020

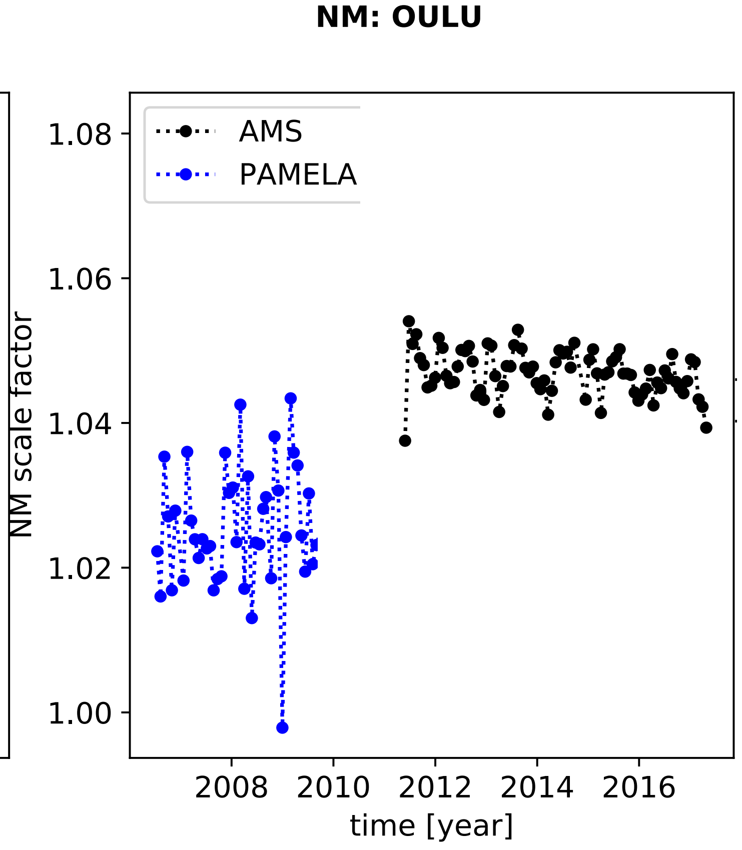


AMS-02 allowed to check the stability of neutron monitors and to compute the scale factors for NM operating in 2006—2017.



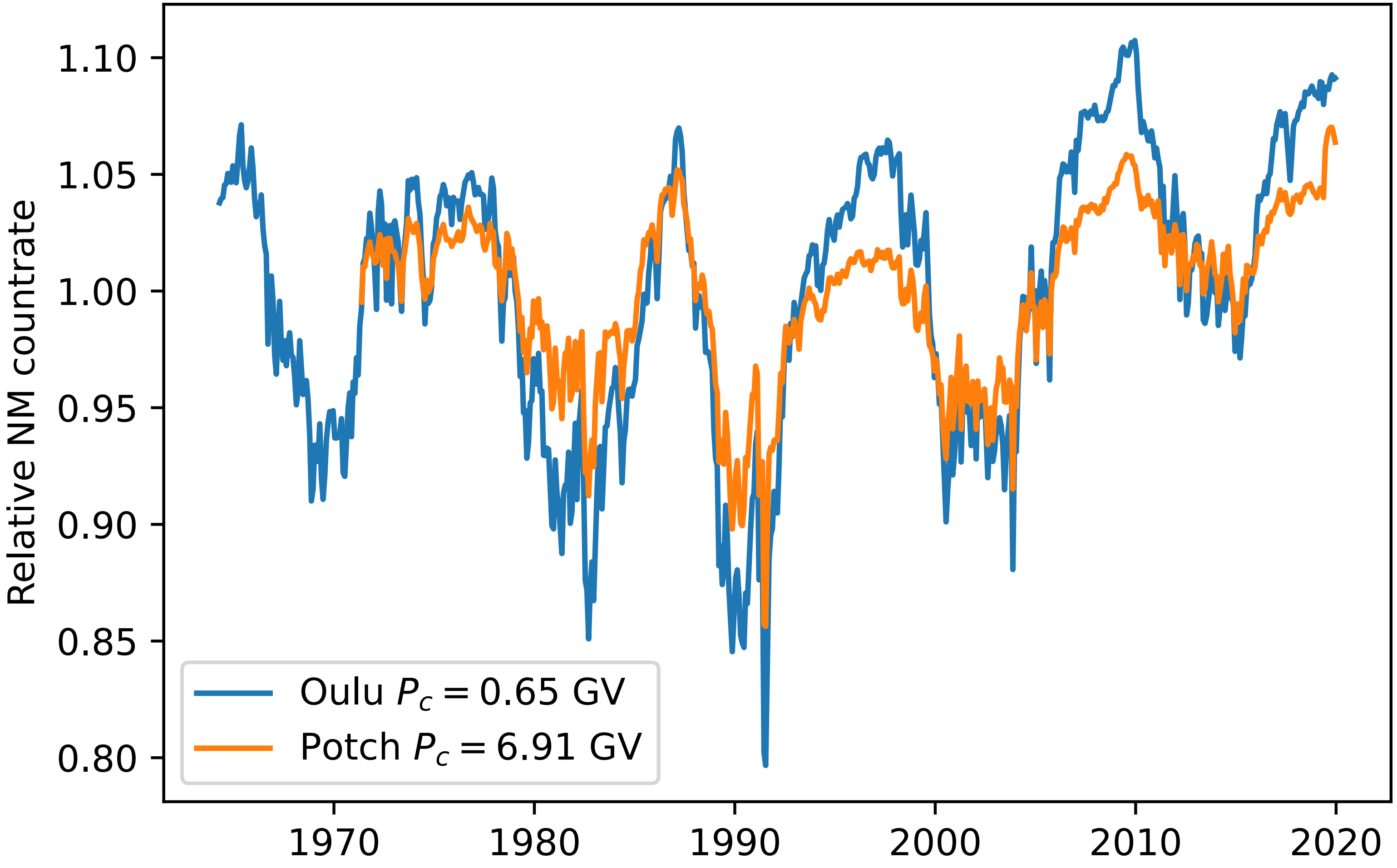
PAMELA vs AMS-02 calibration with NM



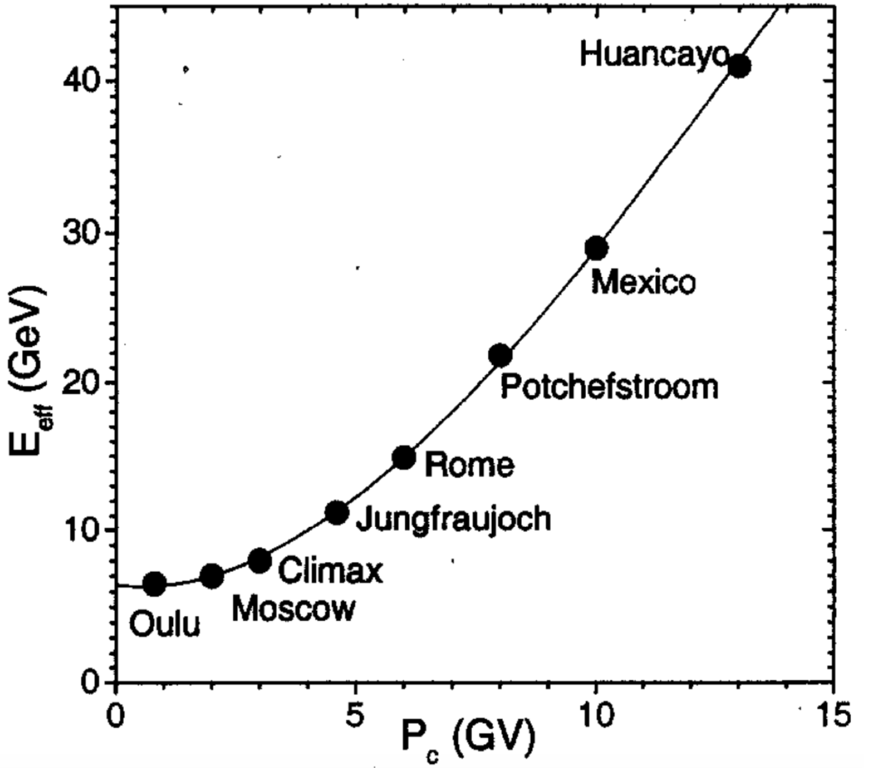


The systematic difference is visible (but not big!) as discussed yesterday. Again we are not able to say which experiment has better data.

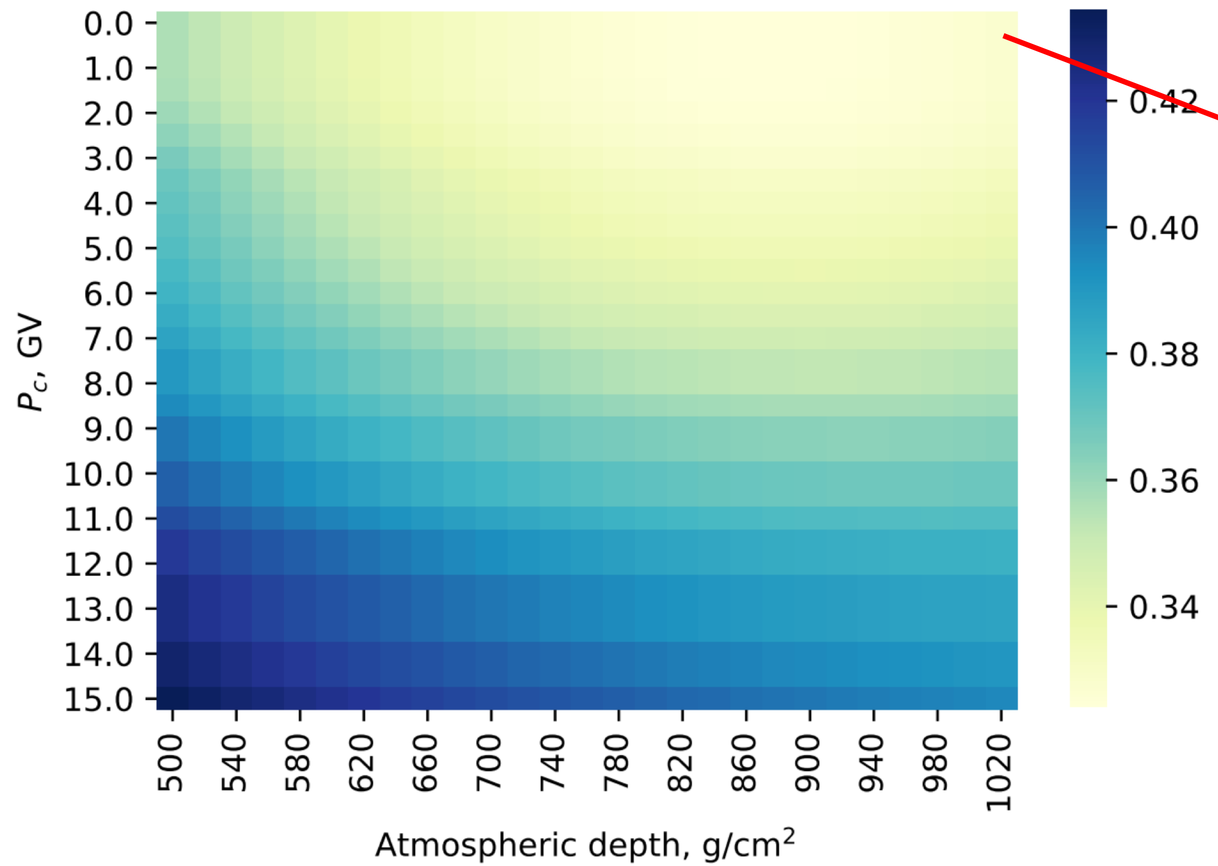
NM cutoff rigidity dependence

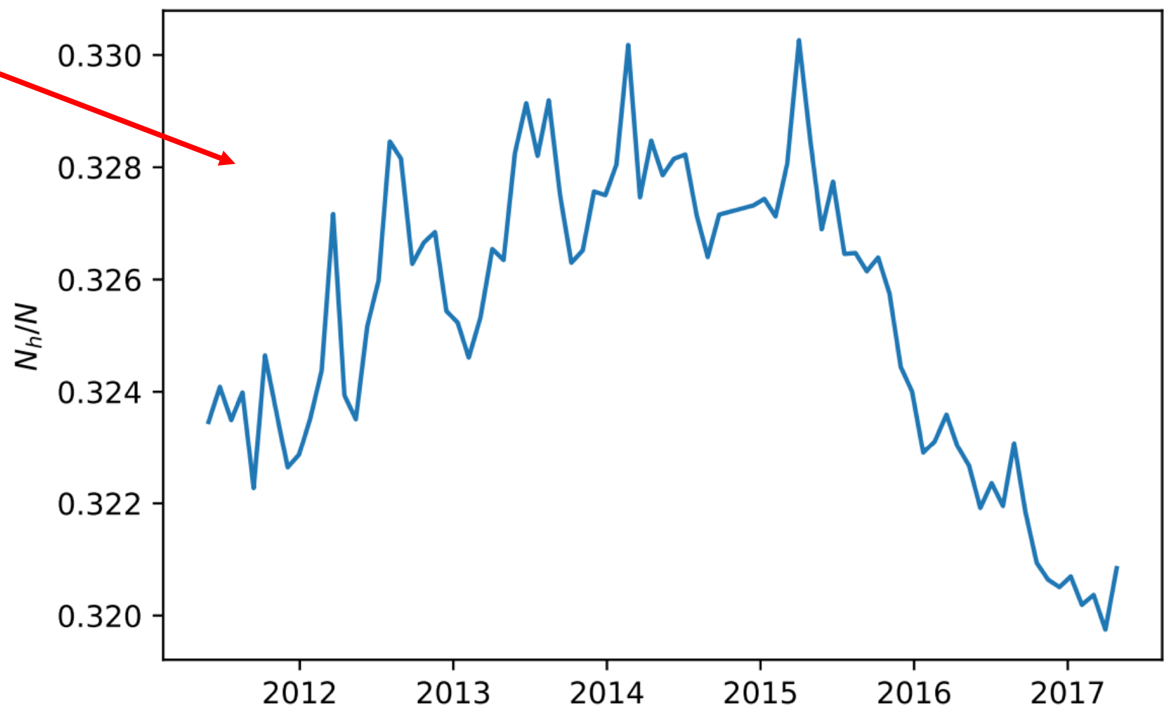


Alanko et al. 2003



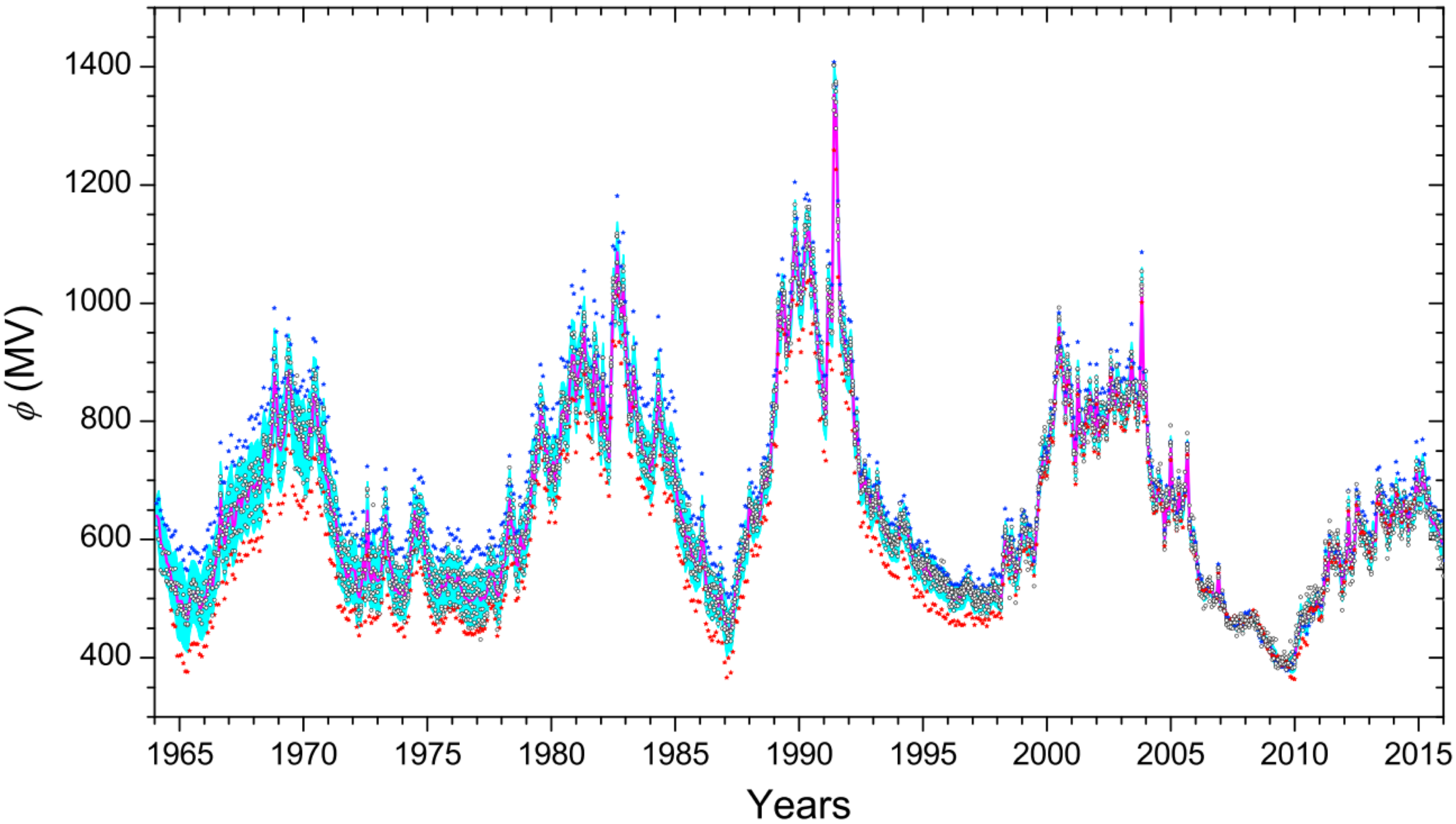
Heavy nuclei in NM response



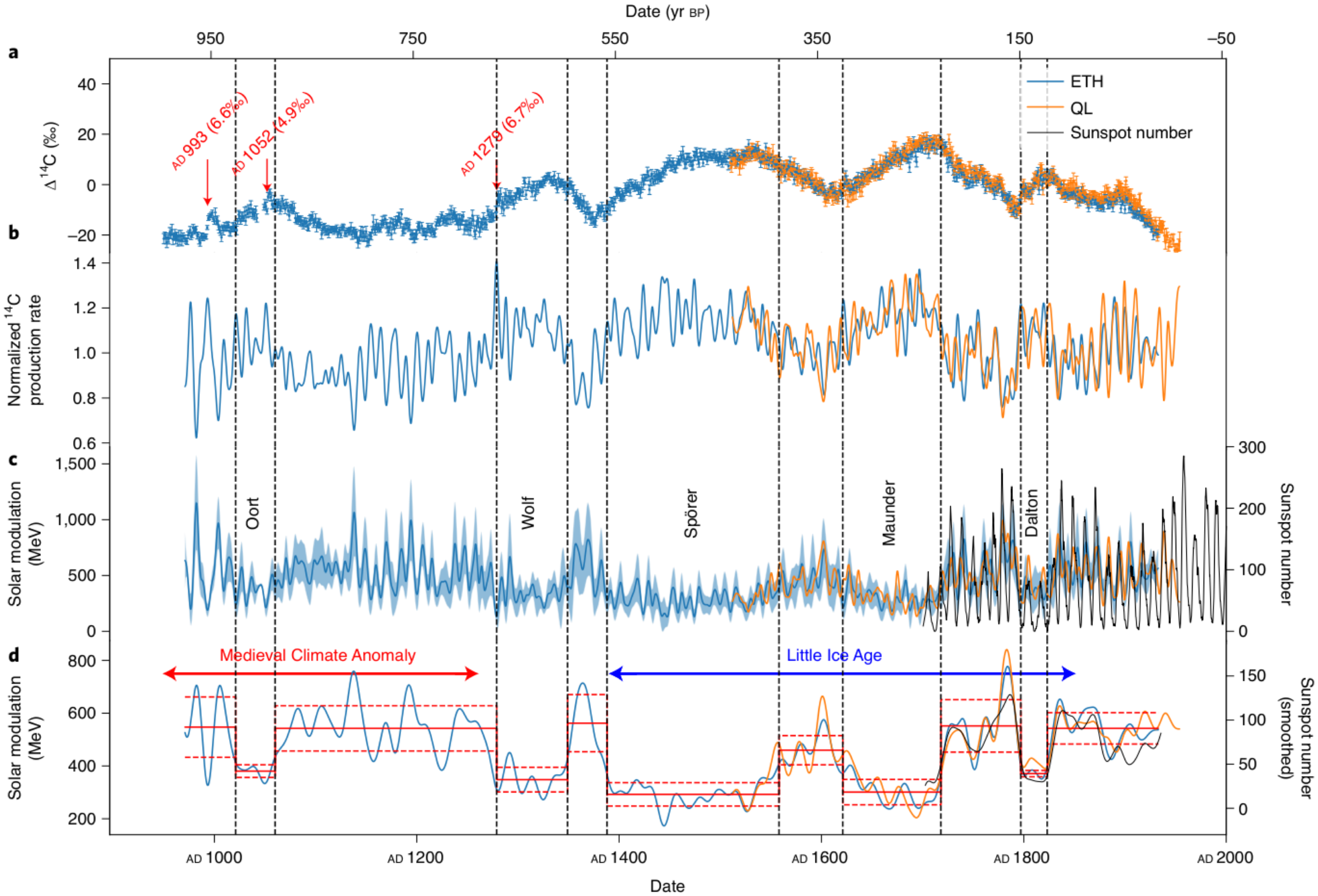


Force-field approximation I

$$J_i(T,\phi) = J_{\mathrm{LIS}_i}(T+\Phi_i)\frac{T(T+2T_\mathrm{r})}{(T+\Phi_i)(T+\Phi_i+2T_\mathrm{r})}$$



Force-field approximation II



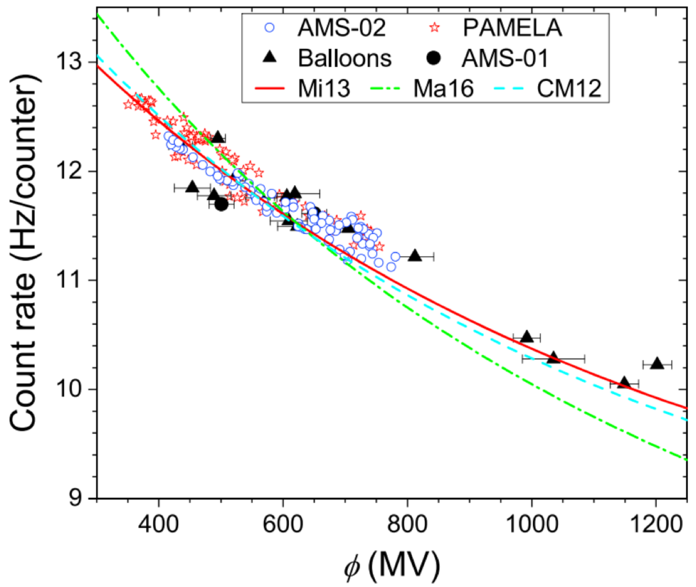
14C

+

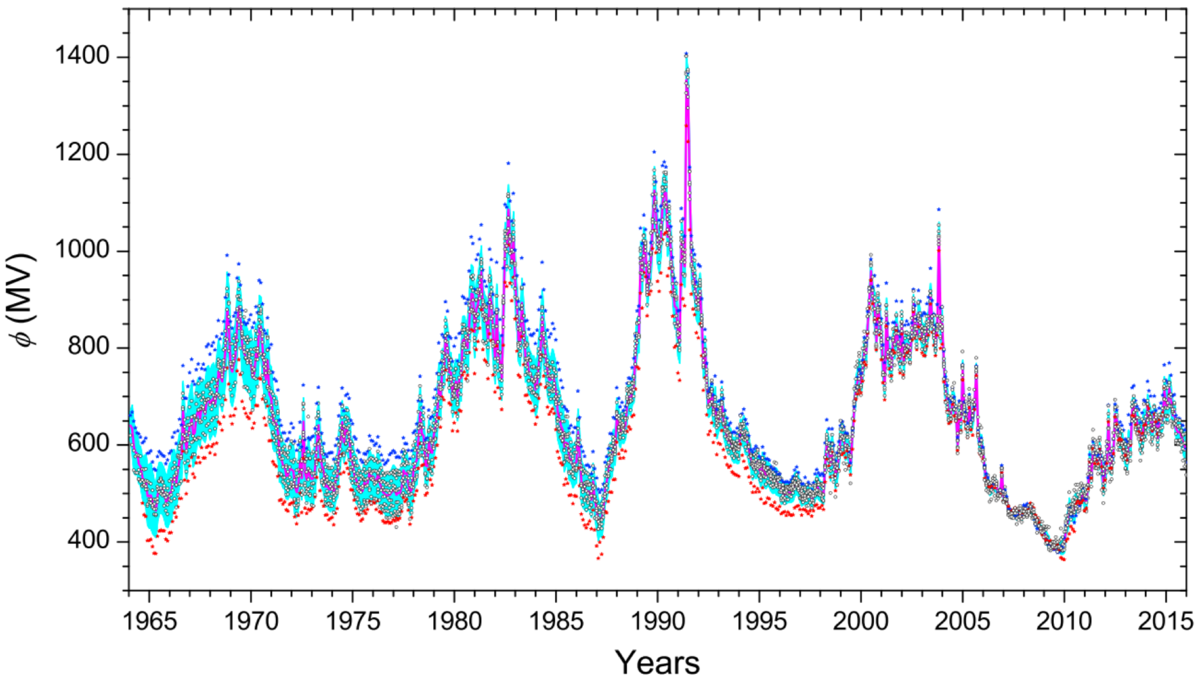
10Be

36Cl

Force-field approximation and NMs



Usoskin et al. JGR:SP 2017



Another reconstructions:
Ghelfi et al. ASR 2017,
Kobelev et al. BRAS 2021

Pros:
Simple, that makes it super useful for practical application and quantification of the solar modulation strength;
Cons:
- Too simple, it is not possible to get an understanding of different solar modulation processes;
- Exact value of solar modulation potential is depended on LIS (can be corrected).
- Erroneous in low energies.

Force-field modifications

Corti et al. ApJ 2016

$$\phi(R) = \begin{cases} \phi_L, & R < R_L \\ f(R, \phi_L, \phi_H), & R_L \leqslant R \leqslant R_H \\ \phi_H, & R > R_H, \end{cases}$$

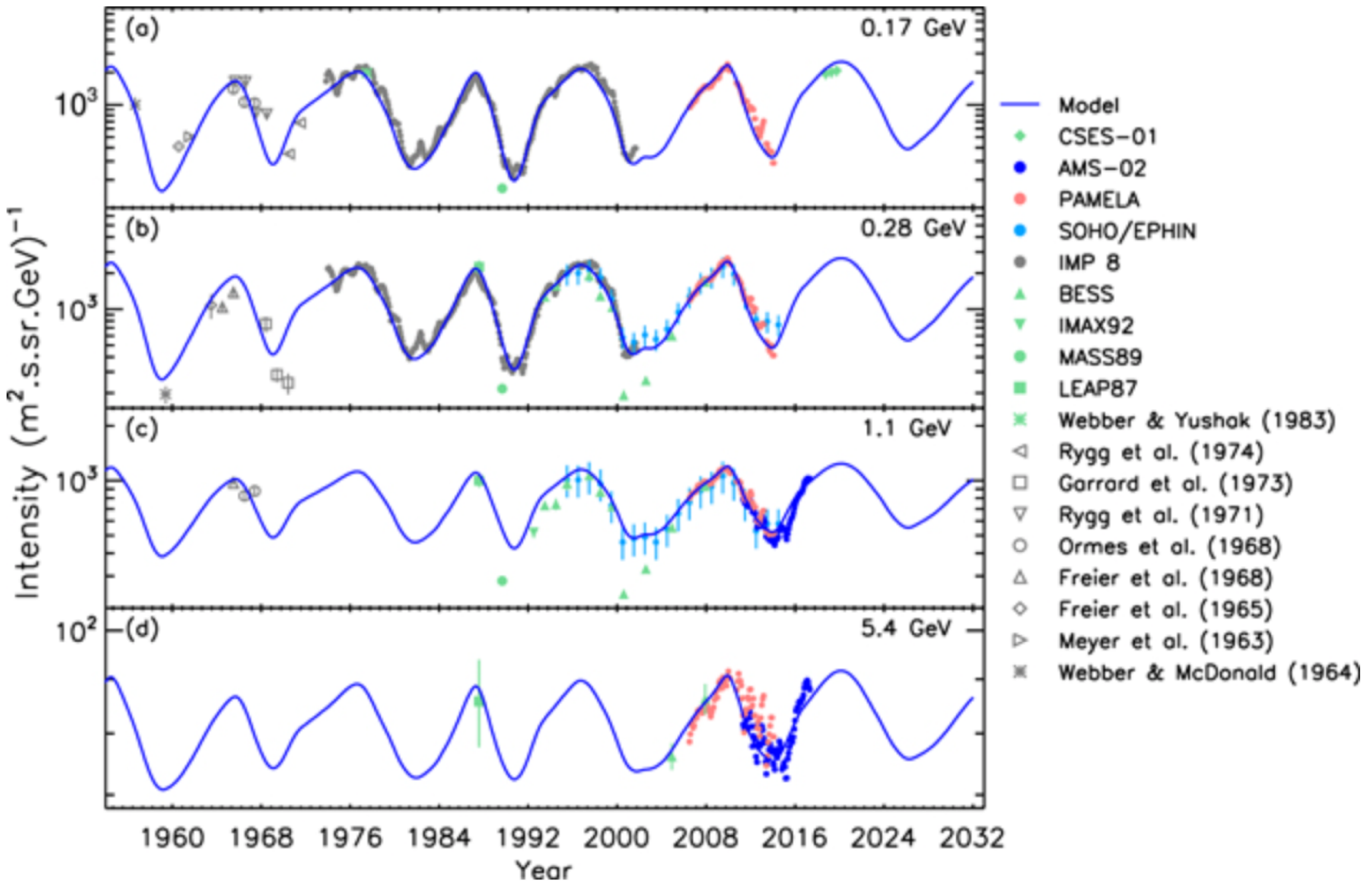
Gieseler et al. JGR:SP 2017

$$\phi(P) = \begin{cases} \frac{\phi_{\mathrm{Uso11}}-\phi_{\mathrm{pp}}}{P_{\mathrm{Uso11}}-P_{\mathrm{pp}}} \cdot (P - P_{\mathrm{pp}}) + \phi_{\mathrm{pp}} & \text{if } P < P_{\mathrm{Uso11}} \\ \phi_{\mathrm{Uso11}} & \text{if } P \geq P_{\mathrm{Uso11}} \end{cases}$$

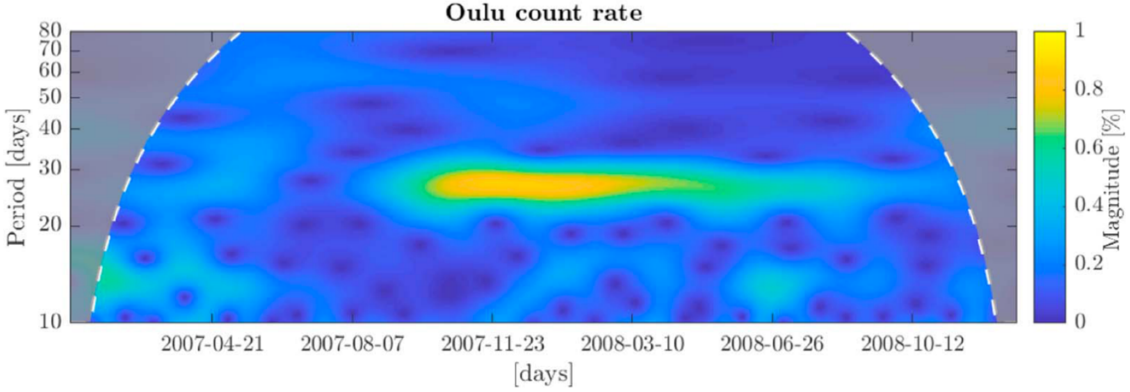
Shen et al ApJ 2021

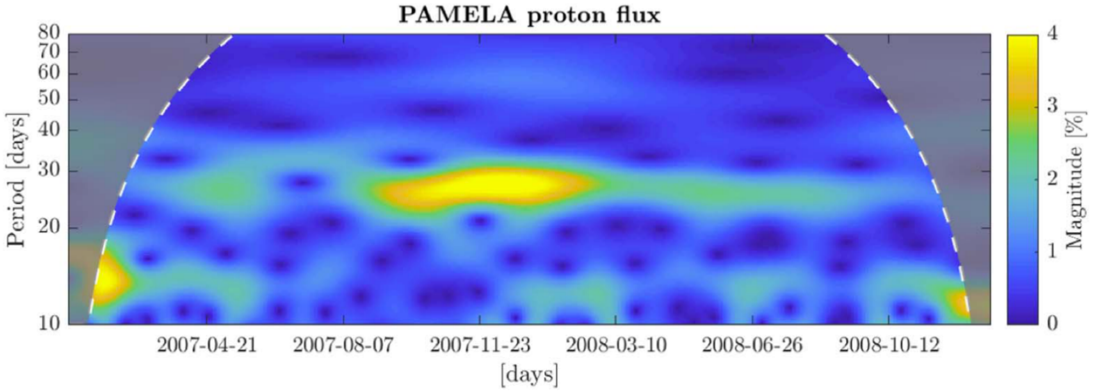
$$\phi = \phi_0 \beta^{-1} \left(\frac{E}{E_b}\right)^{\phi_1} \left[1 + \left(\frac{E}{E_{b1}}\right)^{b_1}\right]^{b_2}$$

Shen et al ApJ 2021

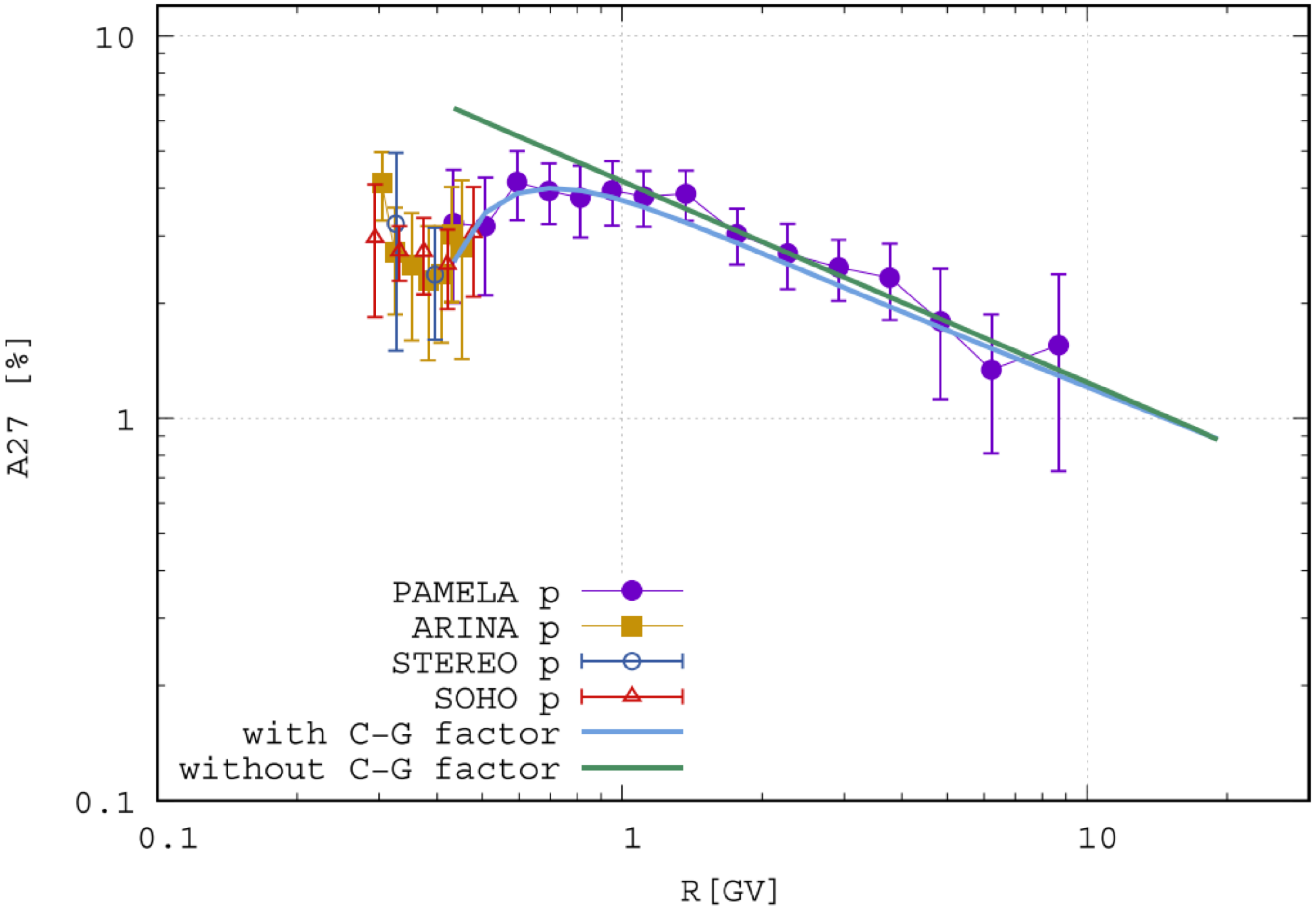


27-day variations of GCR flux





Modzelewska et al. 2021



Conclusions

- Neutron monitors are still very important for study of the long-term solar modulation and SEP physics;
- PAMELA and AMS-02 gave the opportunity to calibrate NM and check their stability;
- Force-field model is of course can not be used for detailed study of derailed “laboratory conditions” but only for measuring the average temperature.