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## **A new parameter in the description of SCR events - the energy of balance between solar and galactic protons**

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*International Symposium on Cosmic Rays and Astrophysics*

*МИФИ 2017*

## **In a statistical study of solar cosmic ray events, their comparison is carried out according to different criteria:**

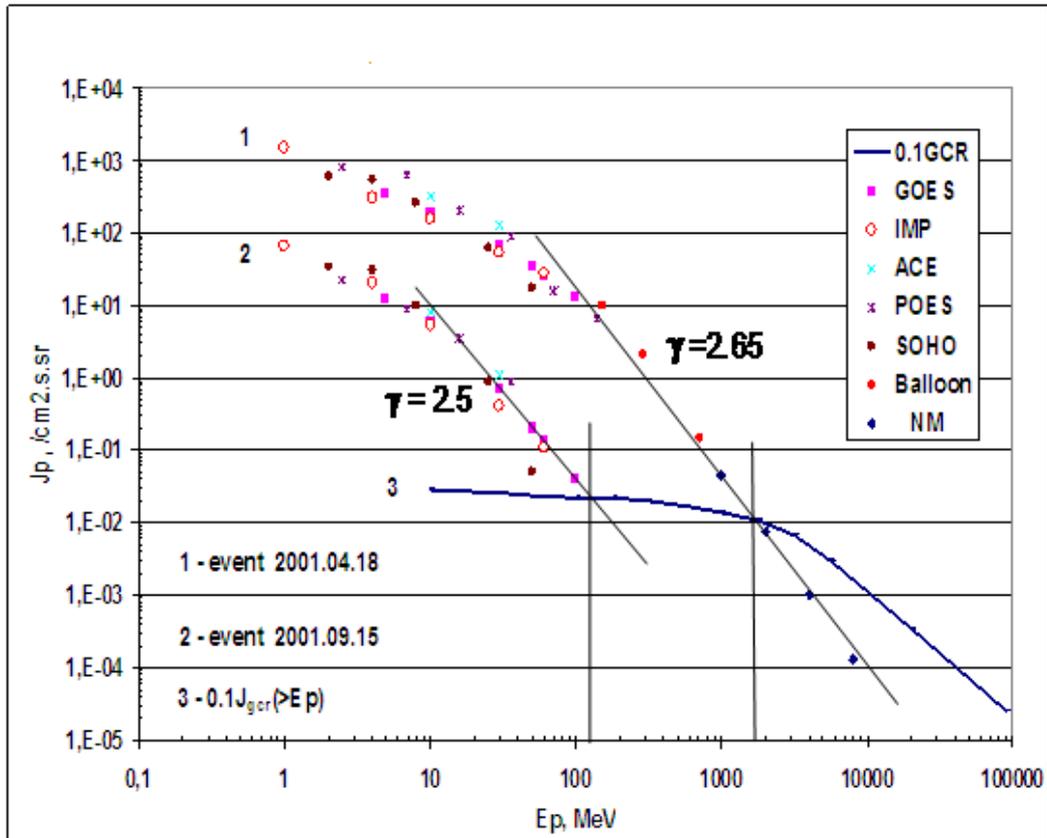
- by the maximum flux of accelerated particles of a certain energy (for example, over protons  $E_p > 10$  MeV);
  - by the power of the accompanying soft X-ray radiation;
  - by the duration of the event;
  - by the front steepness of rising of the flux;
  - by the longitude and latitude of the parent flare on the Sun and other parameters.
- special class of events are those with the highest energies registered by ground level installations, GLE events (Ground Level Enhancement) with  $E_{\text{Max}} > 10$  GeV. The highest value of  $E_{\text{Max}}$  was registered in event 29.09.1989 (GLE 42) according to the Baksan Underground Scintillation Telescope, whose threshold energy for primary protons was  $E_p = 500$  GeV.
- The value of  $E_{\text{Max}}$  in the SEP event is of particular interest

## Conventionality of the concept of $E_{max}$ .

There is no guarantee that in the event there were no particles with energy higher than the registered one.

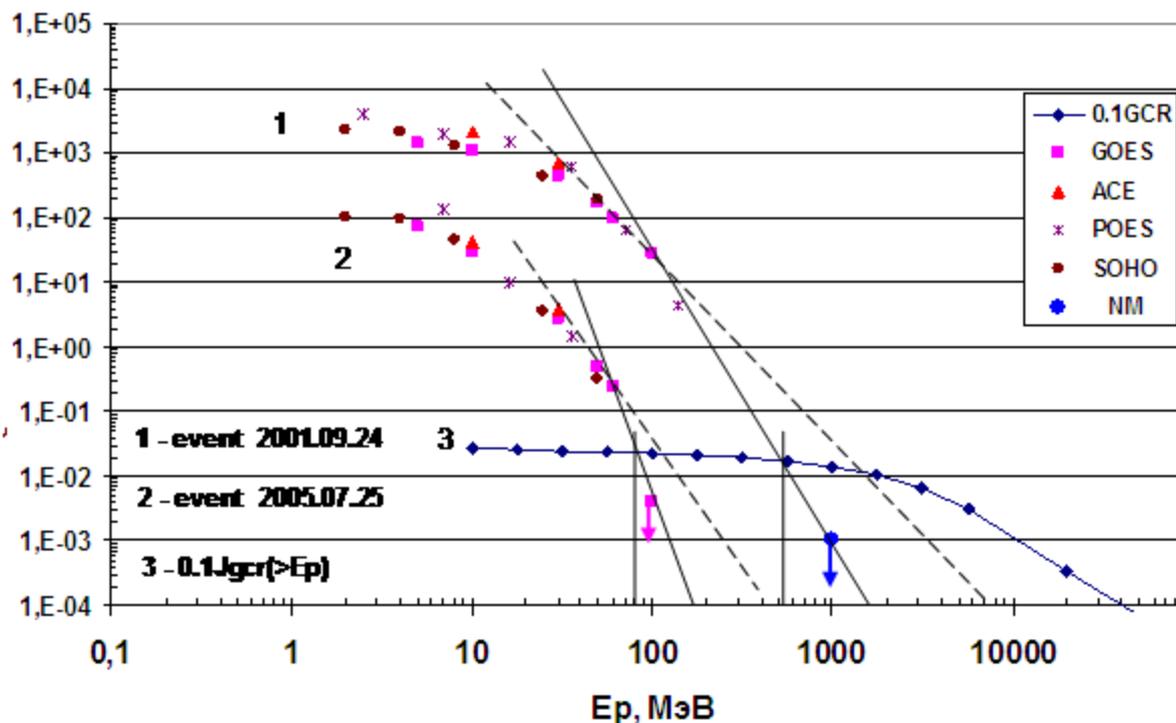
We propose to introduce one more parameter characterizing the power of the event, the energy of the flux balance of solar proton and galactic cosmic rays,  $E_b$ , which gives an idea of estimation of the maximum energy,  $E_{max}$ , of accelerated protons.

To determine the value of  $E_{max}$ , the integral spectrum of protons in the SEP is compared with 0.1 of the integral spectrum of GCR protons. The point of intersection of these spectra gives the value of  $E_{max}$  and the magnitude of the proton flux  $J (> E_{max})$ .



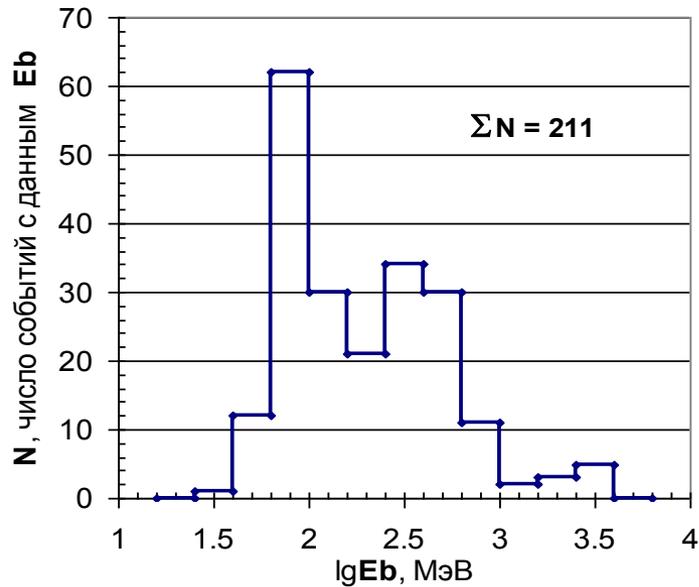
**Examples of determination of  $E_b$  according to intersection of SEP integral spectrum with the 10% spectrum of GCR.**

## Определение $E_b$ при укручении спектра



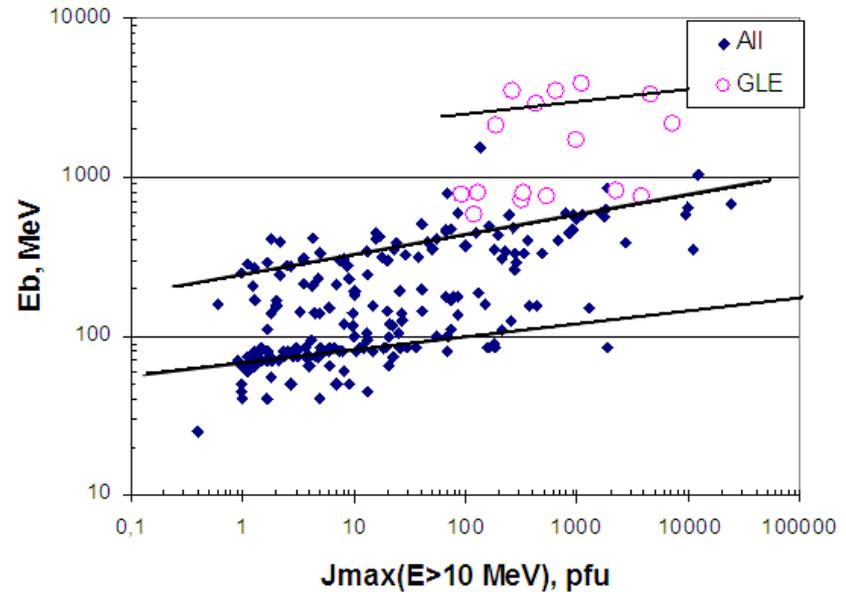
Determination of  $E_b$  for the SEP events 2001.09.24 and 2005.07.25. Shown are: approximation of a part of the integral spectra of protons by a power law, based on the results of measurements by spacecraft (dashed lines), and steeper spectra, obtained taking into account the absence of solar protons as measured by s/c GOES and neutron monitors (solid lines); the integral spectrum of 0,1 GCR flux (rhombs).  $E_b$  is indicated by vertical bars.

**Распределение событий по значениям  $E_b$  в 23 цикле СА**



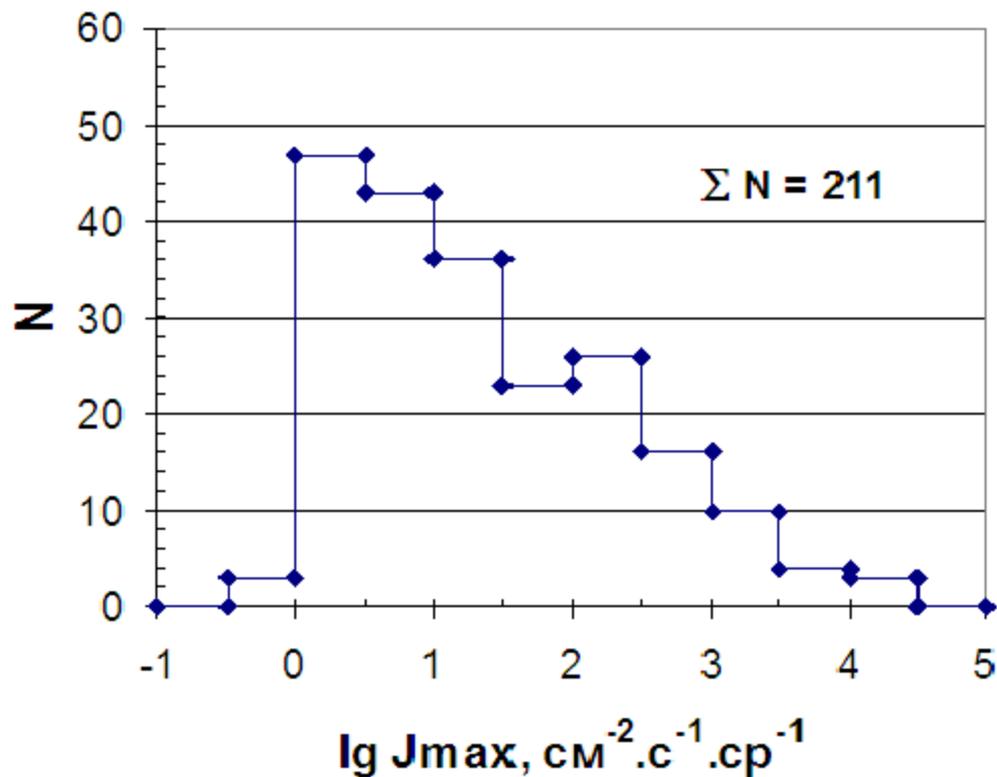
**Distribution of the values of  $E_b$  in the 23 - rd cycle of the solar activity. A low-energy group with a maximum of  $E_b \sim 80$  MeV, a medium group with a maximum of  $E_b \sim 800$  MeV, a high-energy tail with  $E_b > 1000$  MeV is due to the powerful GLE events.**

**$E_b$  в зависимости от  $J_{\max}$**



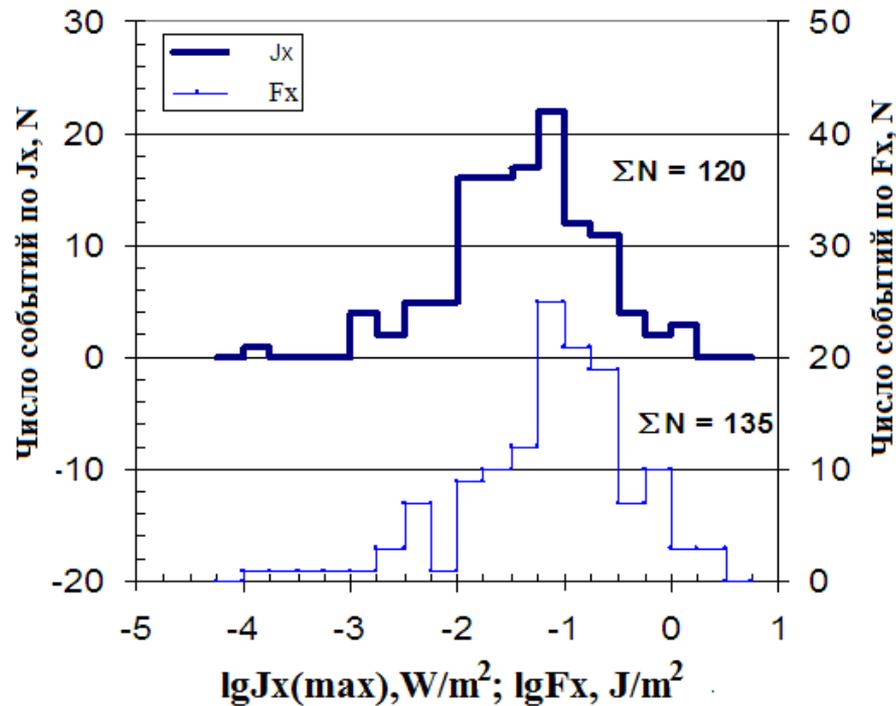
**Separation of all events into three groups: weak events with  $E_b \leq 200$  MeV, medium with  $200 \leq E_b \leq 1000$  MeV. And powerful with  $E_b > 800 - 1000$  MeV. GLE events are equally divided between groups of medium and powerful events.**

## Распределение СПС по Jmax

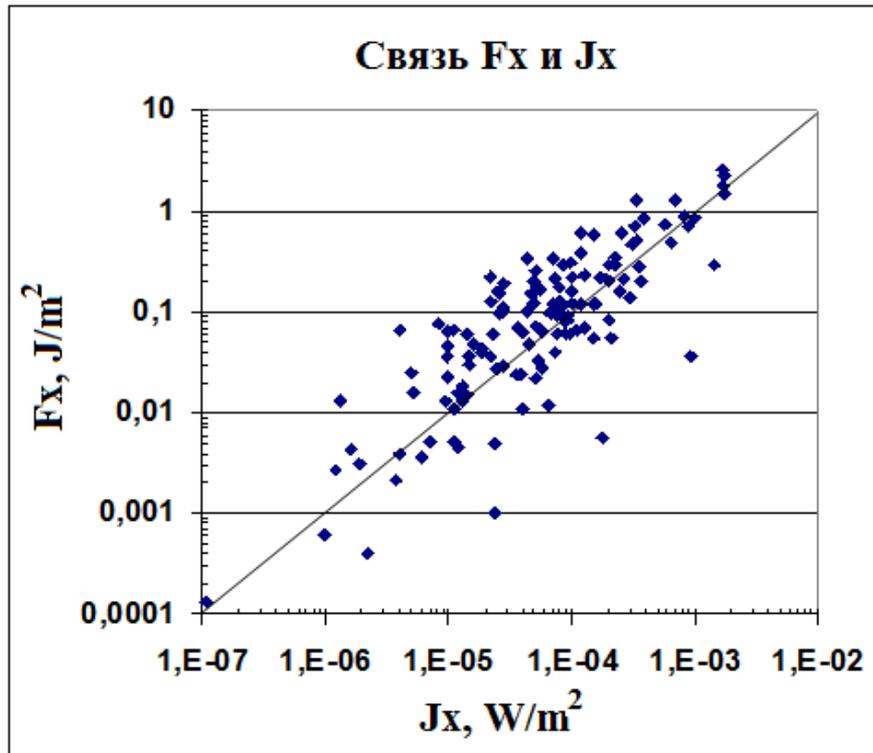


**Distribution of events over  $J_{\max}$ (>10 MeV), the values of peaks in the intensity-time profiles in the 23-rd solar activity cycle.**

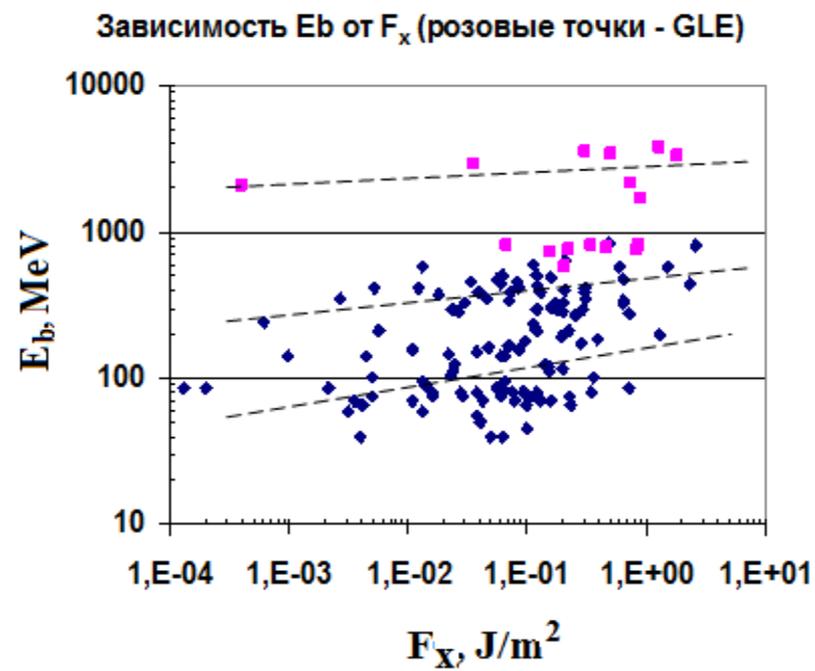
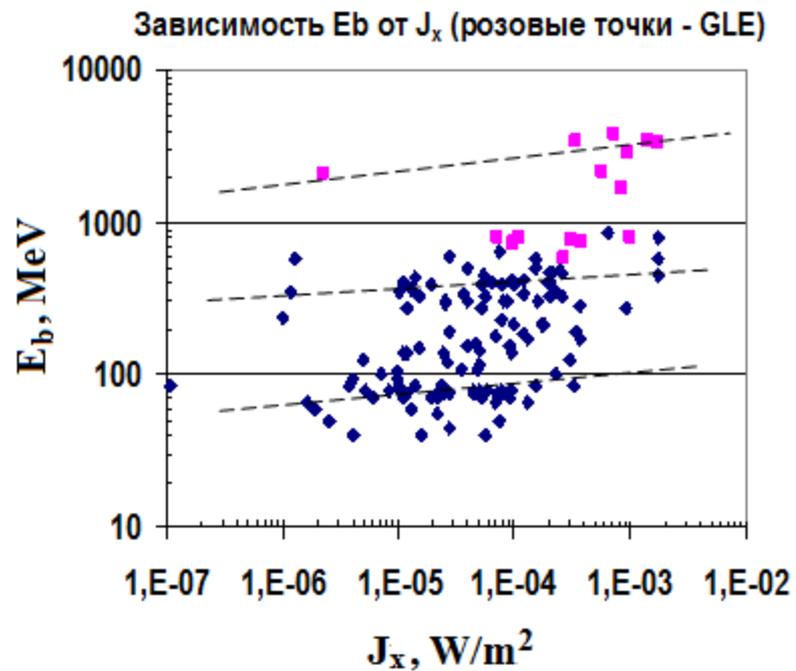
- Распределения событий по  $J_x$  и  $F_x$  в 23 цикле СА



**Distributions of the maximum fluxes and the total energy of the soft X-ray bursts for all proton events in the 23-rd cycle of solar activity.**

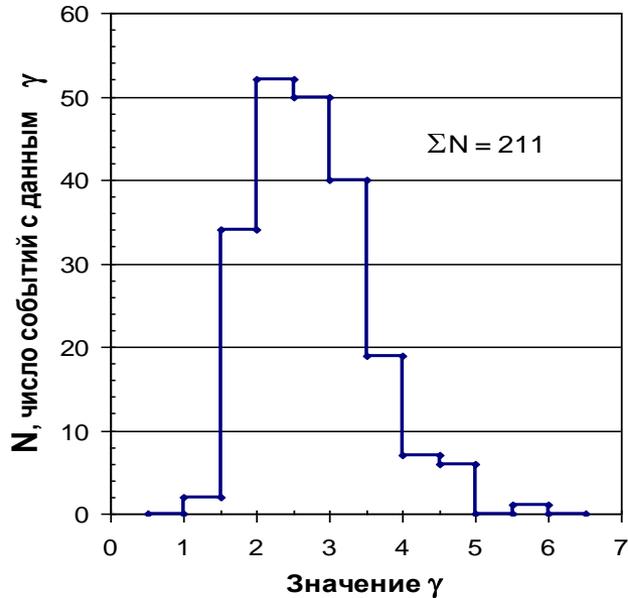


**Fx - Jx scatter plot**

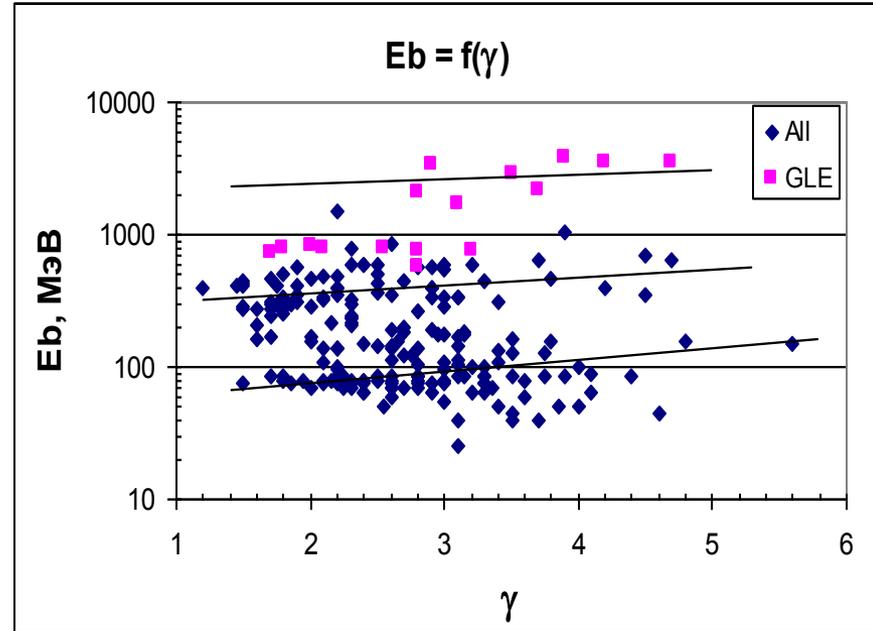


**$E_b$  vs.  $J_x$  and  $E_b$  vs.  $F_x$ . Magenta squares are GLEs.**

Распределение событий по  $\gamma$   
в 23 цикле СА



**Distribution of integral spectral index,  $\gamma$ , in the energy range 100÷300 MeV of SEP events in the 23-rd cycle of the solar activity.**



$\gamma$  -  $E_b$  scatter plot.

# Conclusions

A method for estimating the “quasi-maximal” energy of accelerated protons in SEP events is proposed. This quasi-maximal energy is the energy of balance between solar and 10% of galactic proton fluxes.

Investigations of solar proton events using the energy of balance,  $E_b$ , have shown that in the 23-rd cycle of the SA, all events may be divided into three groups according to the value of the “maximum” energy:

- weak events with  $E_b \leq 200$  MeV,
- medium events with  $200 \leq E_b \leq 1000$  MeV and
- powerful events with  $E_b > 800-1000$  MeV.

In this approach GLE events are equally divided between groups of medium and powerful events. Thus, the fact of registration of solar protons by ground-level neutron monitors itself, is not enough to be considered as powerful event.

This parameter is included in the: Logachev Yu.I., G.A.Bazilevskaya, E.V.Vashenyuk, E.I.Daibog, V.N.Ishkov, L.L.Lazutin, L.I.Miroshnichenko, M.N.Nazarova, I.E.Petrenko, A.G.Stupishin, G.M.Surova, O.S.Yakovchuk. Catalog of solar proton events in the 23rd cycle of solar activity (1996-2008). ESDB repository, GC RAS, Moscow, doi: 10.2205/ESDB-SAD-001