# Проникновение солнечных протонов 1-100 МэВ в магнитосферу во время магнитных бурь


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## СОДЕРЖАНИЕ

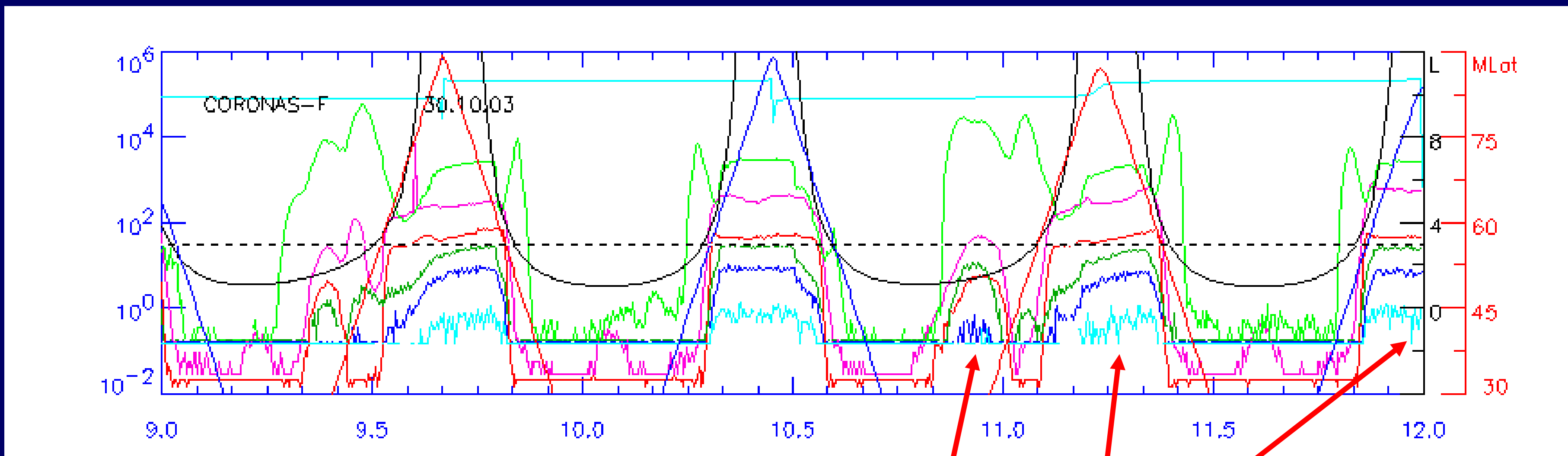
- Измерения на низковысотных спутниках
- Полярная шапка, хвост и область квазизахвата
- Динамика и структура границы проникновения (ГП) СКЛ
- Эффекты магнитных бурь и суббурь

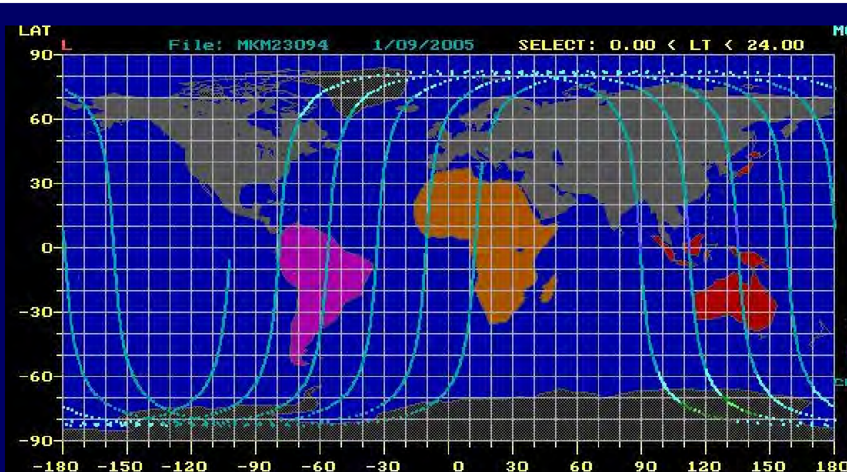
## CONTENT

- CORONAS-F measurements
- Polar cap, magnetotail & quasitrapping region
- Penetration Boundary (PB) dynamics & structures
- Magnetic storms & substorm effects
- Conclusion

CORONAS_F August 2001 – July 2005

Alt = 500 km   Incl= 87 deg  Electrons 0.3-9 MeV  Protons 1-100 MeV




Полярная шапка

Бразильская аномалия

# Stormer theory

$$\frac{d}{dt}m\vec{v} = \frac{e}{c}\left[\vec{v} \times \vec{H}\right]$$

$$mv^2 = \text{const}$$

Действие силы Лоренца

Particle motion by Lorents force

Энергия частицы не меняется

Constant particle energy

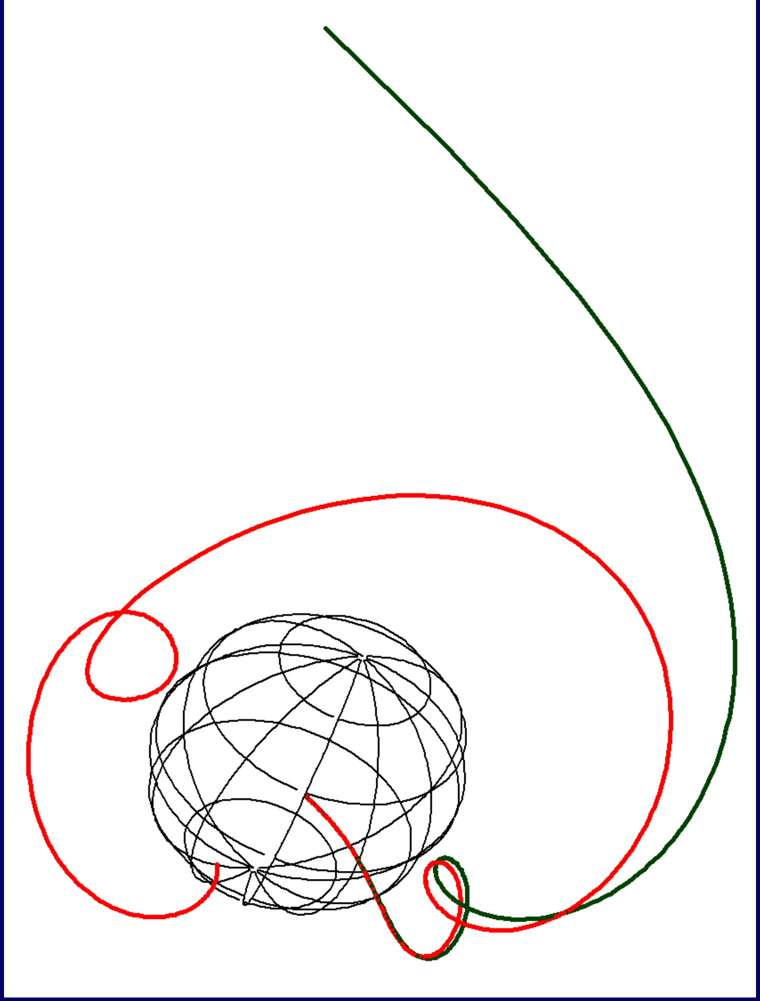
$$R = \frac{pc}{Ze},$$

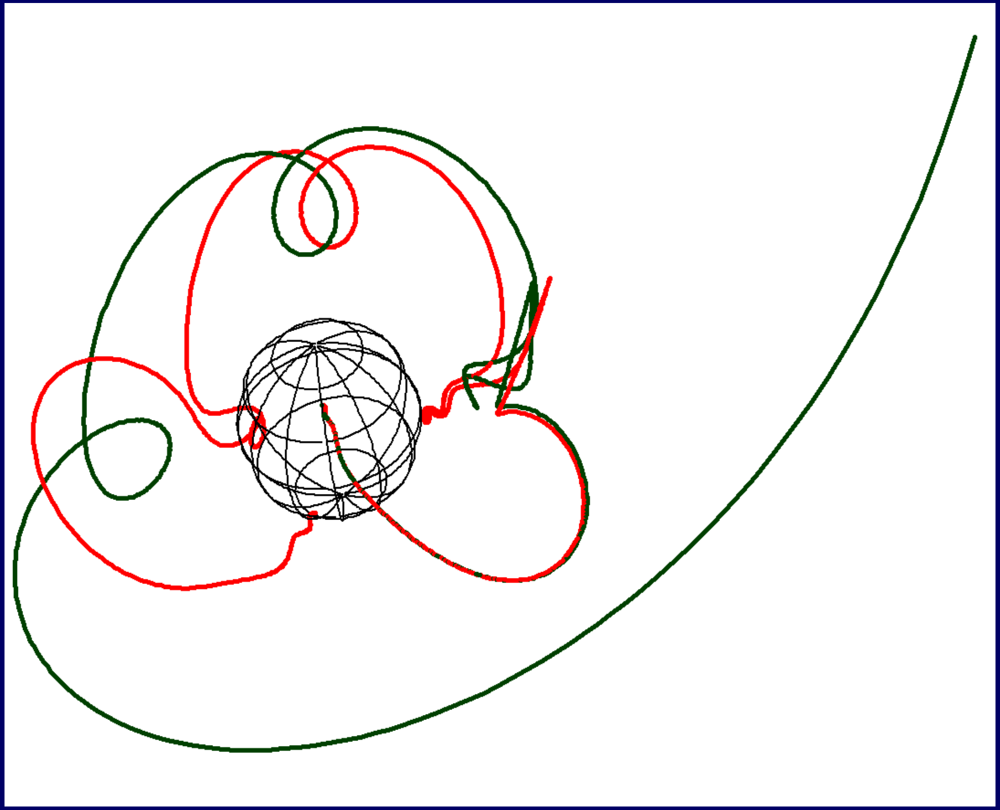
Частицы с равной жесткостью движутся одинаково

Particles with equal rigidity have the same trajectory

Сочетание двух сил – Лоренца и электрическое поле - создают множество эффектов динамики частиц в магнитосфере. Для частиц высоких энергий влияние Е-поля незначительно.

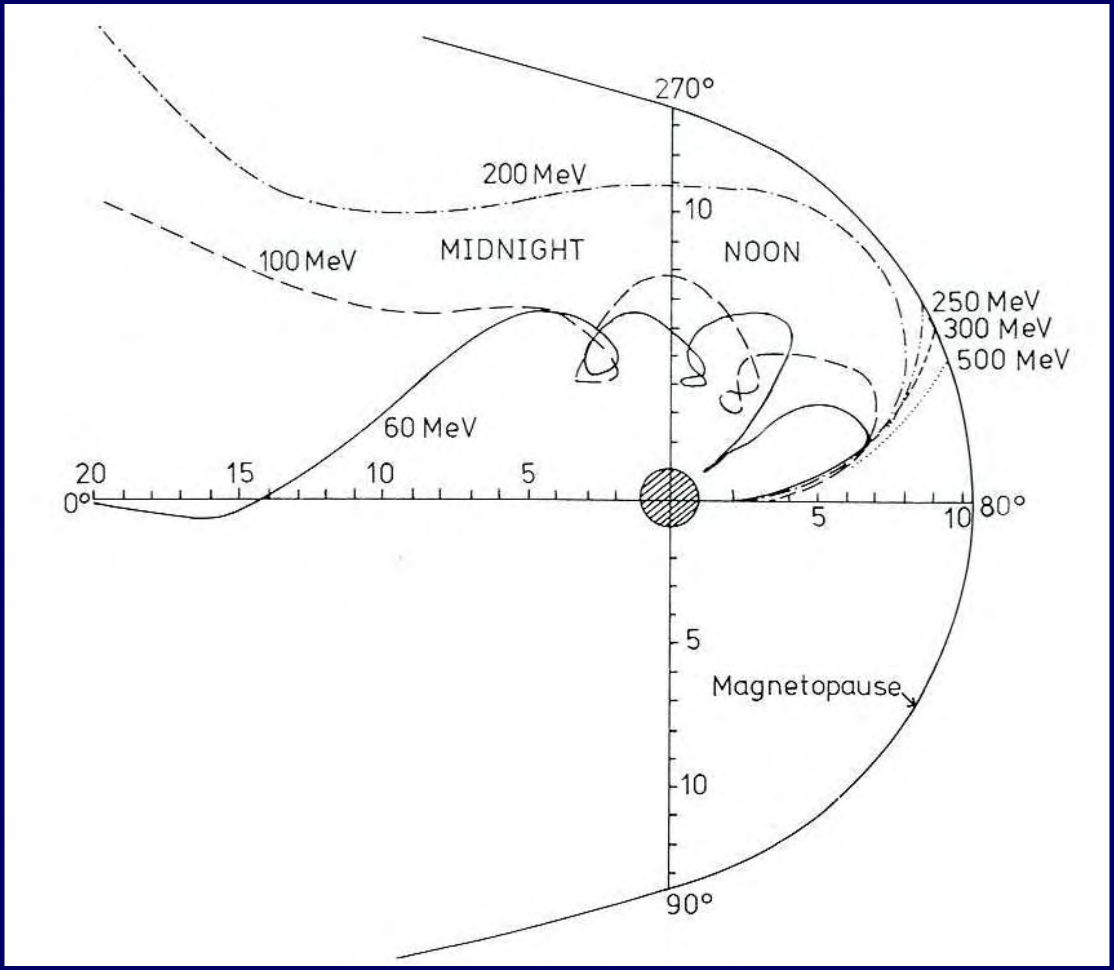
Electric field and Lorents forse create large variety of the particle effects in the magnetosphere. For high energy particle influence of the electric field may be ignored.





Particles trajectory calculations. Two types of the trajectory: trapping and escaping from the magnetosphere

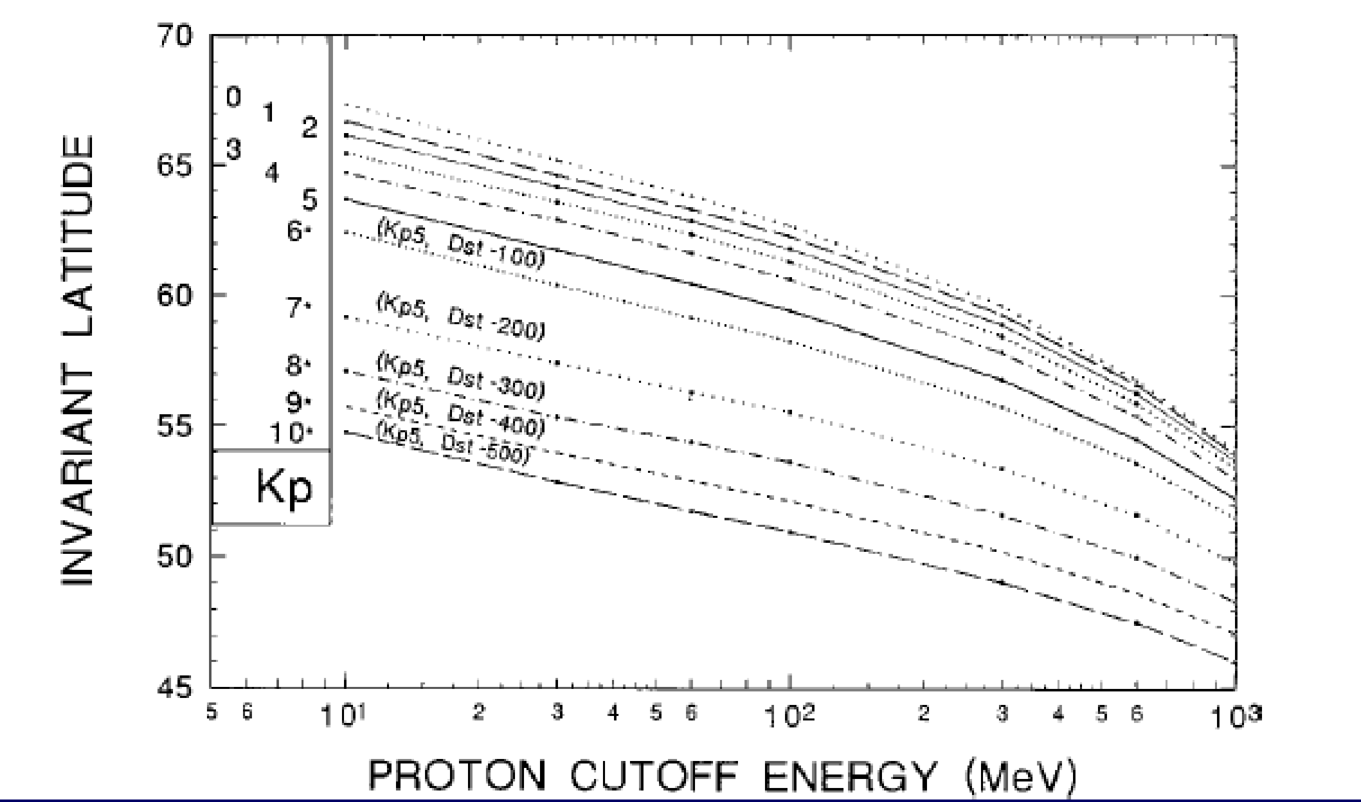
Два типа траекторий частиц в магнитосфере. Захваченные и уходящие.




For the protons with energy bellow 100 MeV entrance from the nightside became most important.

Протоны 1-100 МэВ входят через хвост.

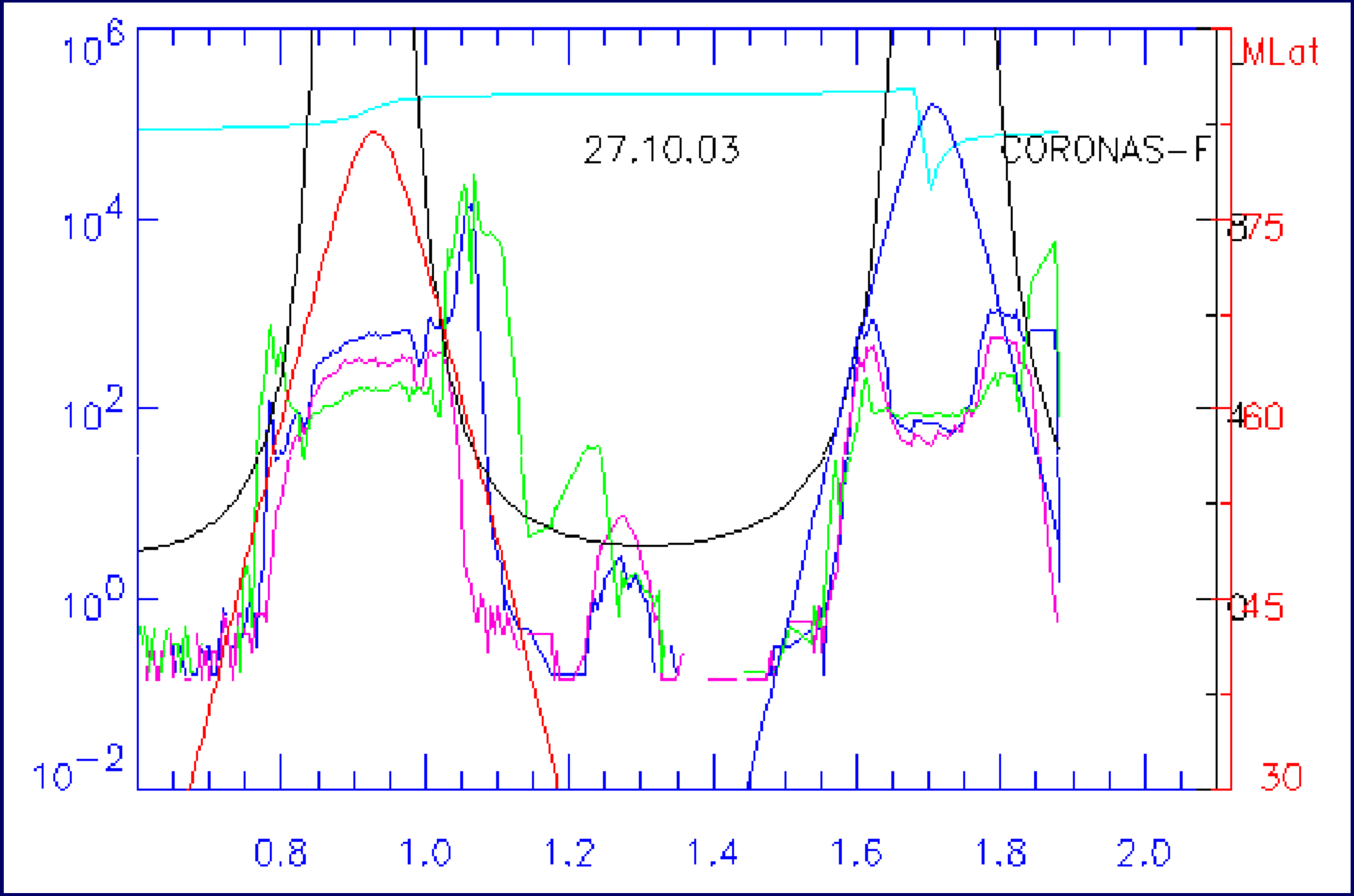
Пример расчета ГП. Чем больше энергия частицы и уровень возмущенности, тем ближе к Земле



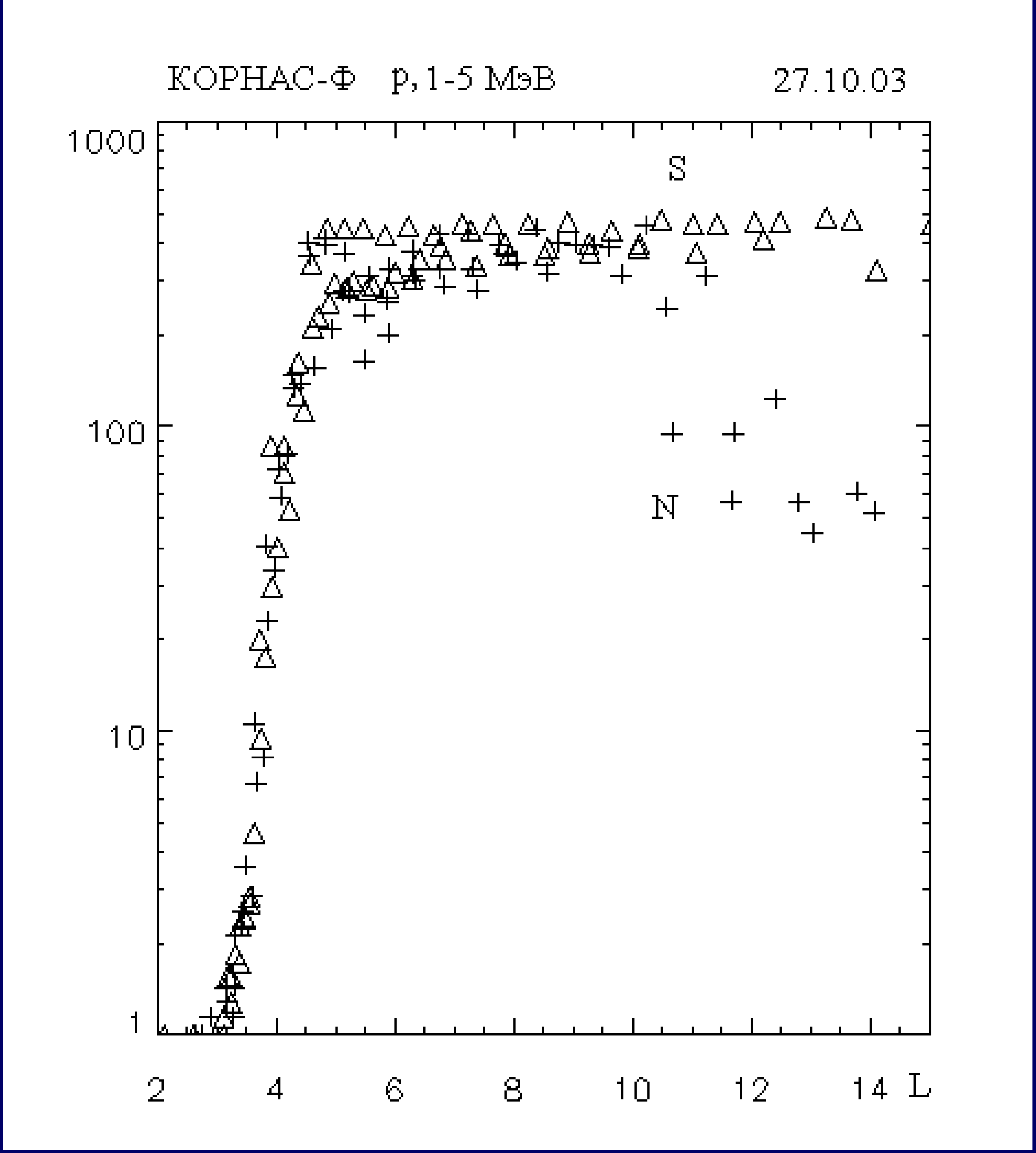

Gradual improvement of the traectory calculation process and magnetic field models used allow to reach acceptable agreement with experimental data but only for small or moderete disturbance conditions.

Cutof position or penetration boundary (PB) closer to the Earth for grater disturbances and higher particle energy.

# North-South asymmetry effect



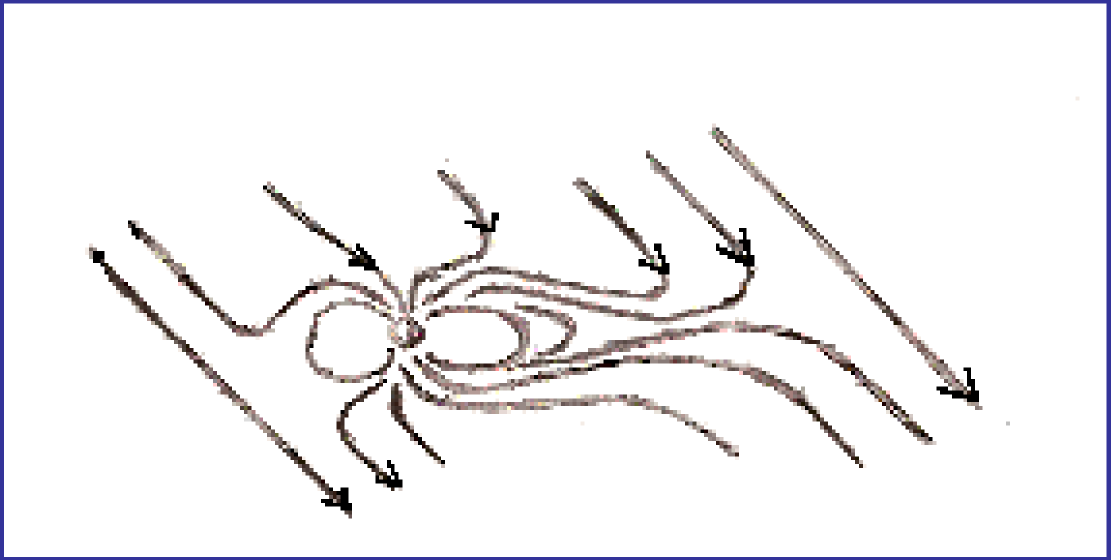

Северо-южная ассиметрия потока протонов в полярной шапке



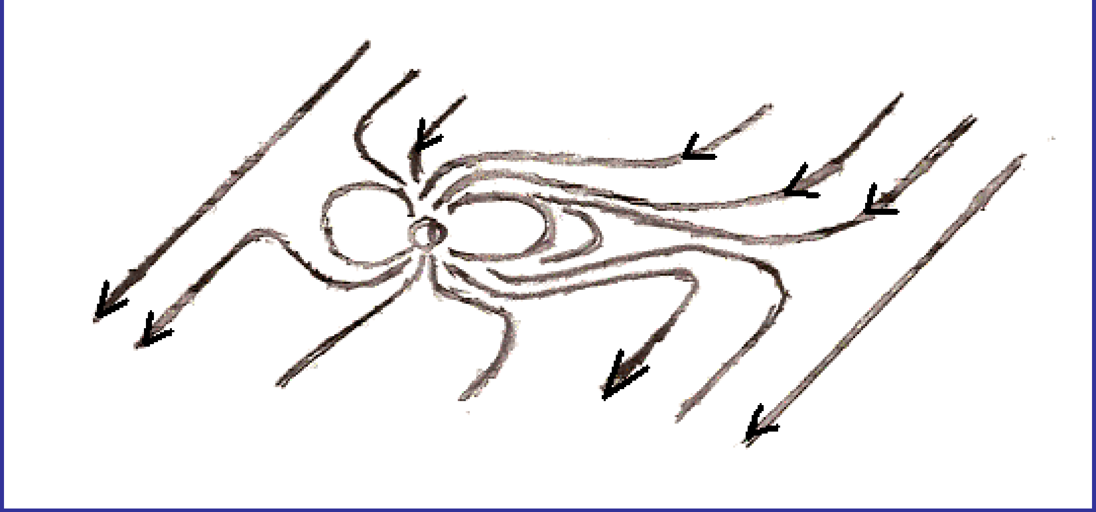

От границы полярной шапки на L=11 до ГП на L~4 расположена область квазизахвата с замкнутыми силовыми линиями.

Здесь вероятна диффузия через границы маг-сферы.

Diffusion through the boundaries and inside the magnetosphere are as important as a direct propagation.



Bx >0 Bz <0



Bx < 0, Bz <0

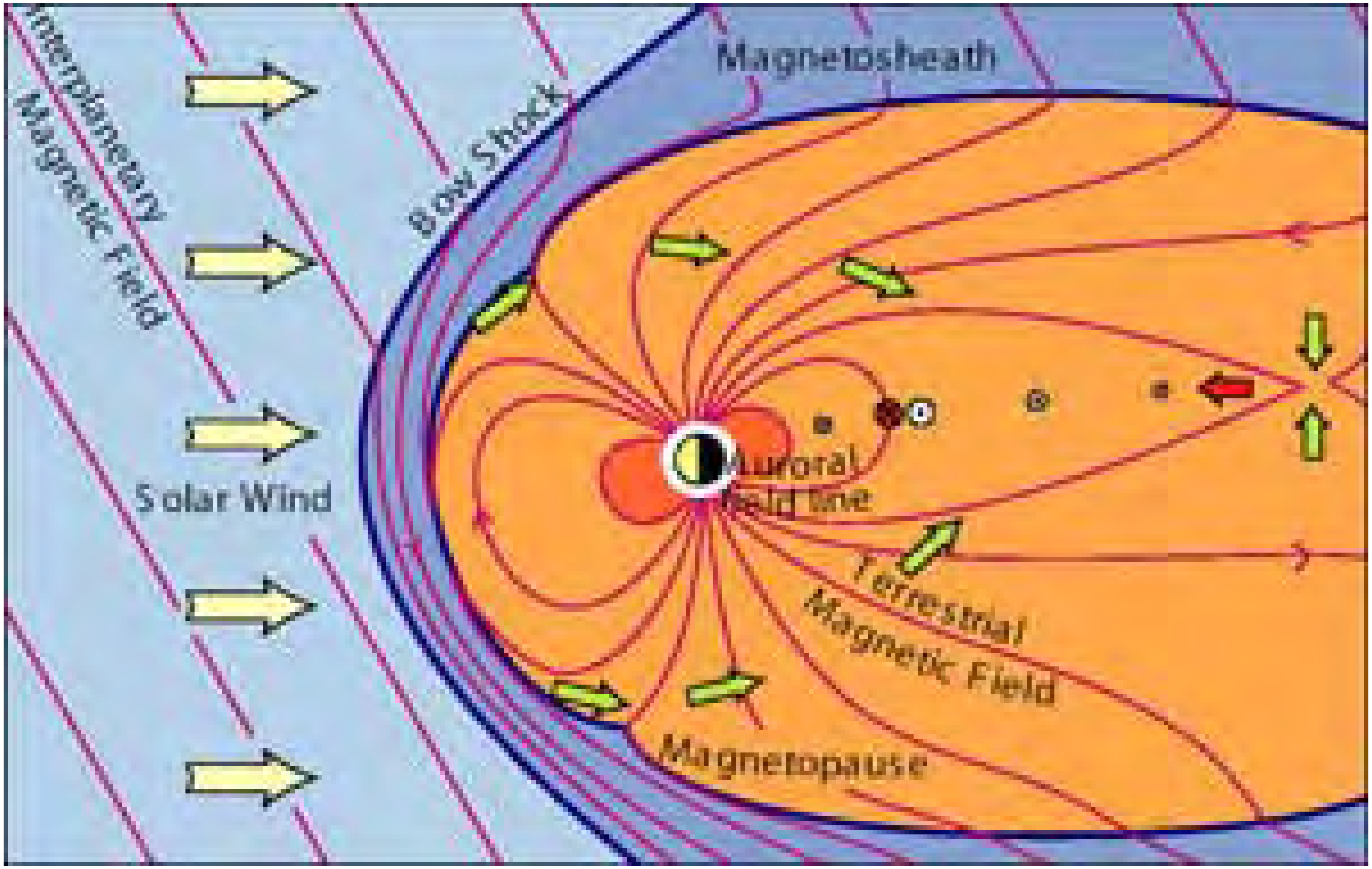
How 1-100 MeV particles penetrate into magnetotail? There are two possibilities:

- Diffusion

- Field line reconnection.

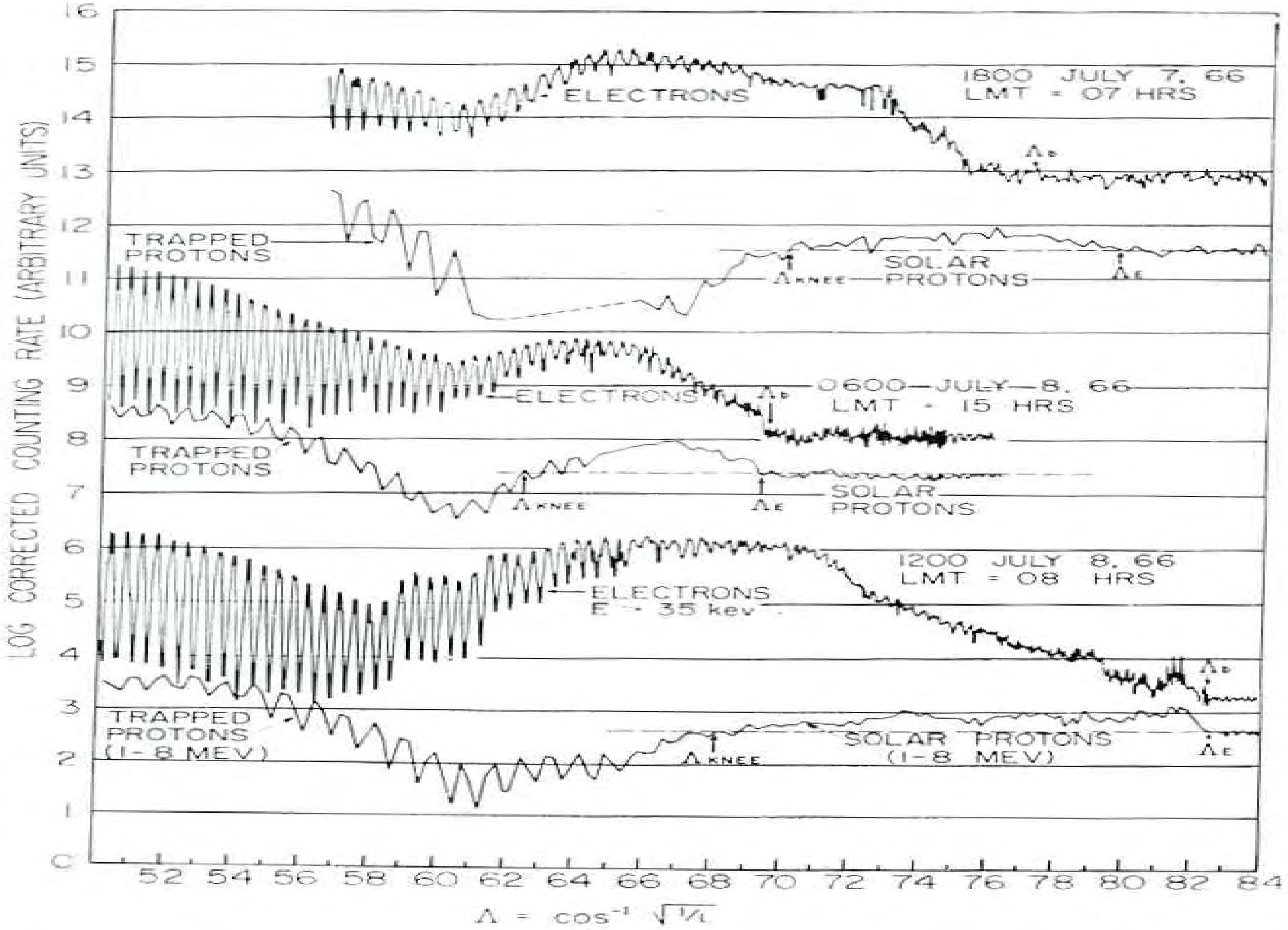
- Particles are oriented along the magnetic field lines. In case of the reconnection they enter into the magnetosphere. It is vald for 1 MeV , for higher energies diffusion is important.

-When SCR flux is anisotropic in the interplanetary space, we can observe effect named South-North asymmetry..



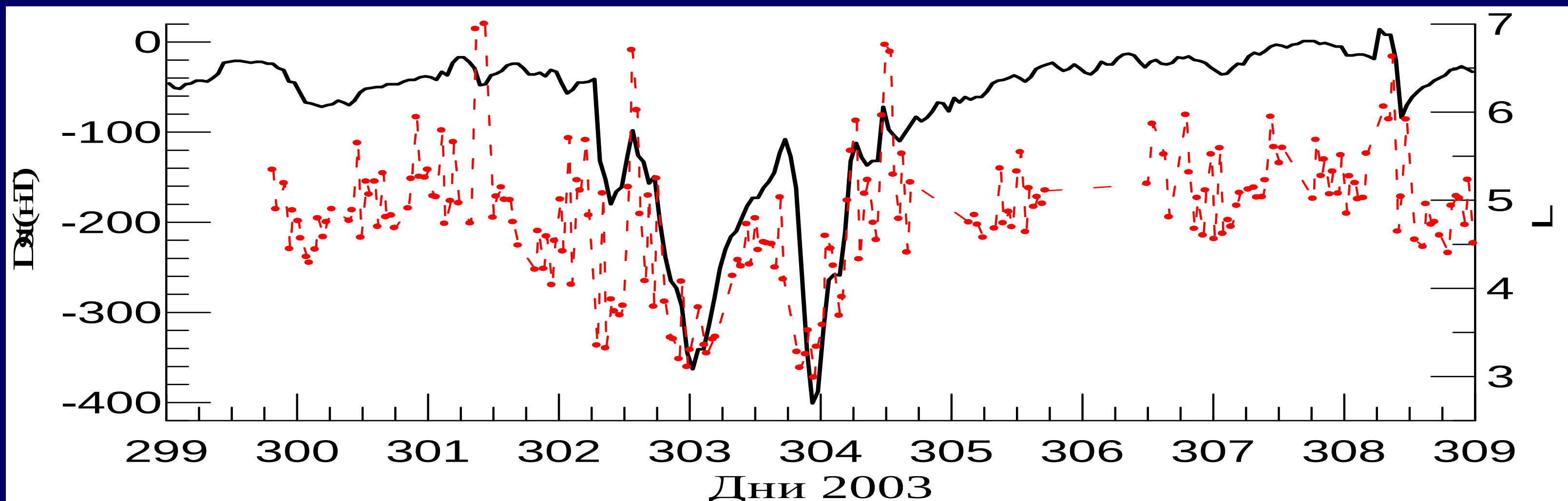
Interplanetary Magnetic Field
Bow Shock
Magnetosheath
Solar Wind
Auroral field line
Terrestrial Magnetic Field
Magnetopause

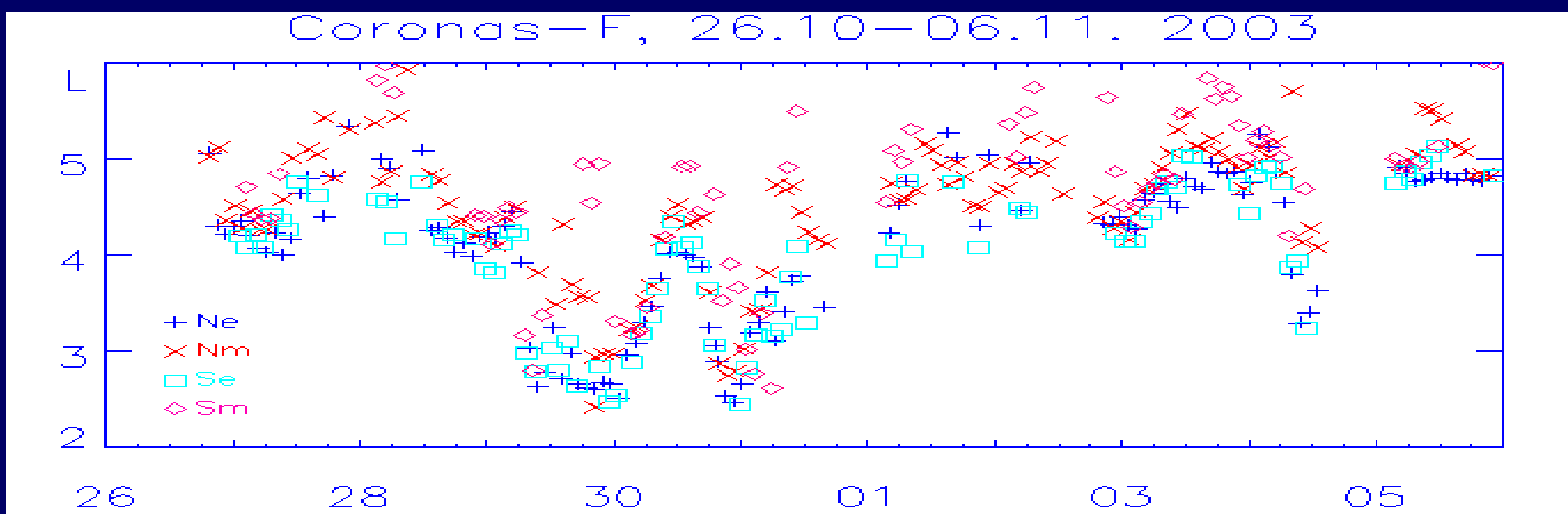
SCP PAD inside the magnetosphere

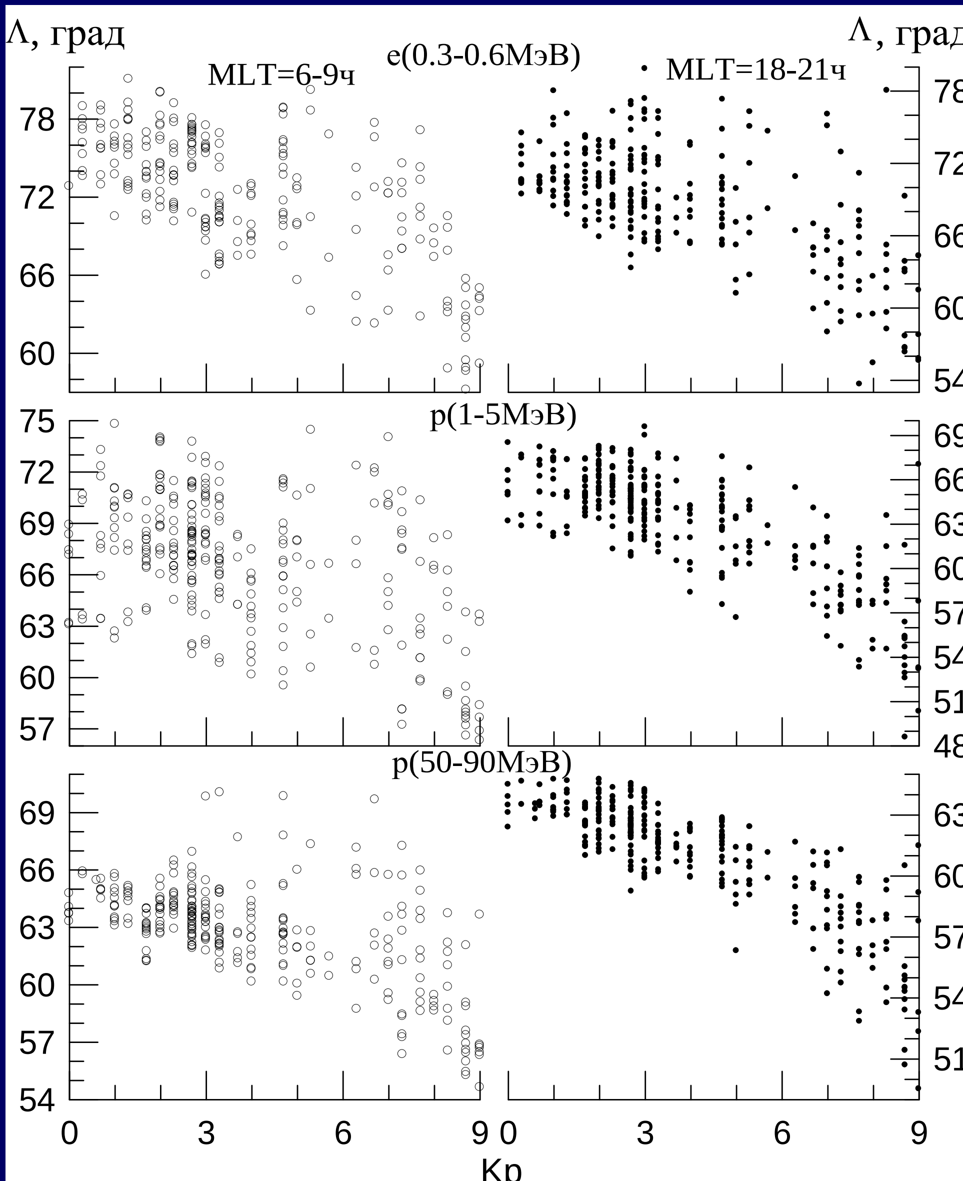



on and proton latitude profiles during a solar proton event in July, 19
on flux is enhanced over the polar cap value can be seen at latitudes betw
$\Lambda_E$ (McDiarmid and Burrows, 1969).

# Penetration boundary – structure and dynamics



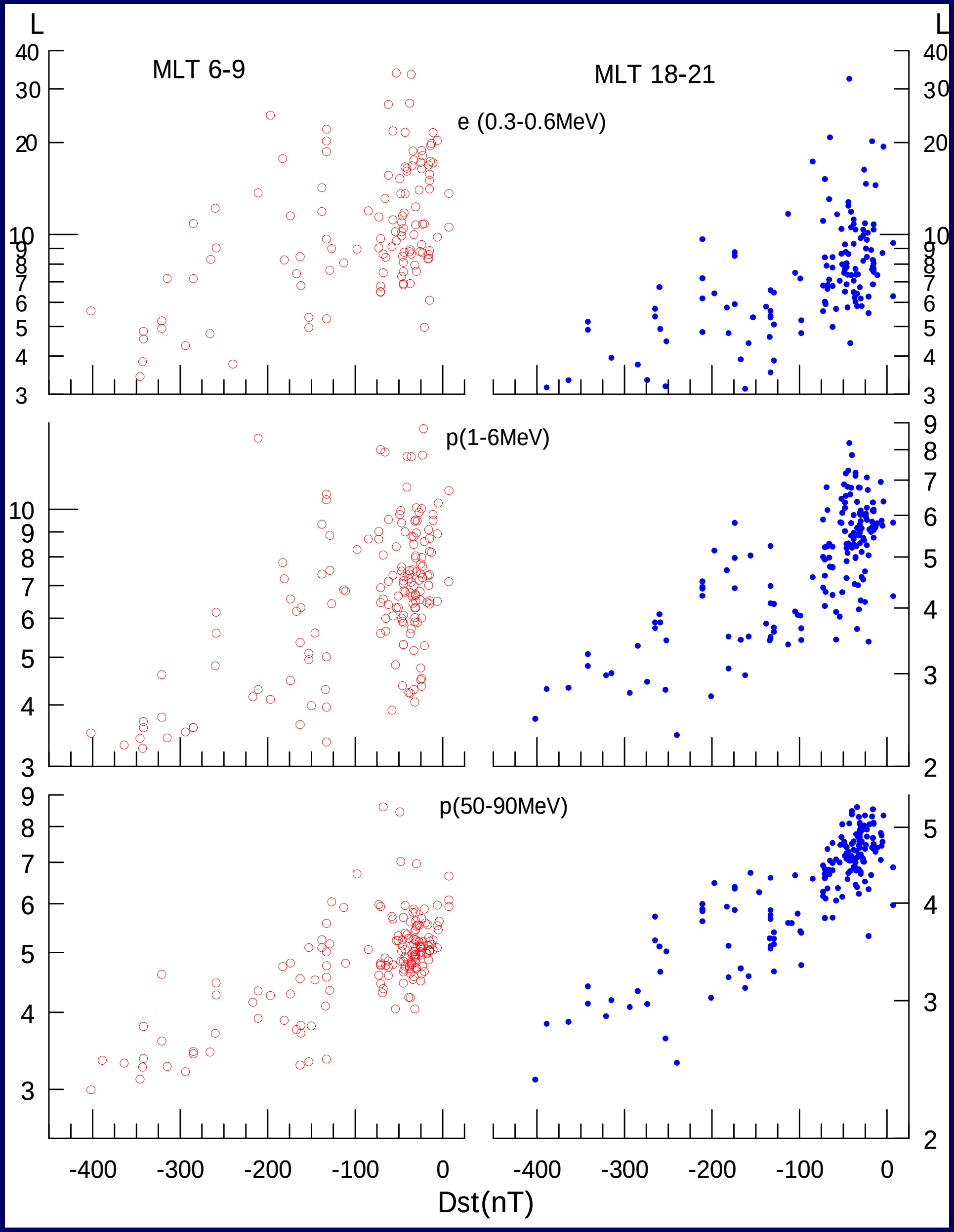






PB position vs. Kp in the morning (left) and the evening (right) sectors. (CORONAS-F)

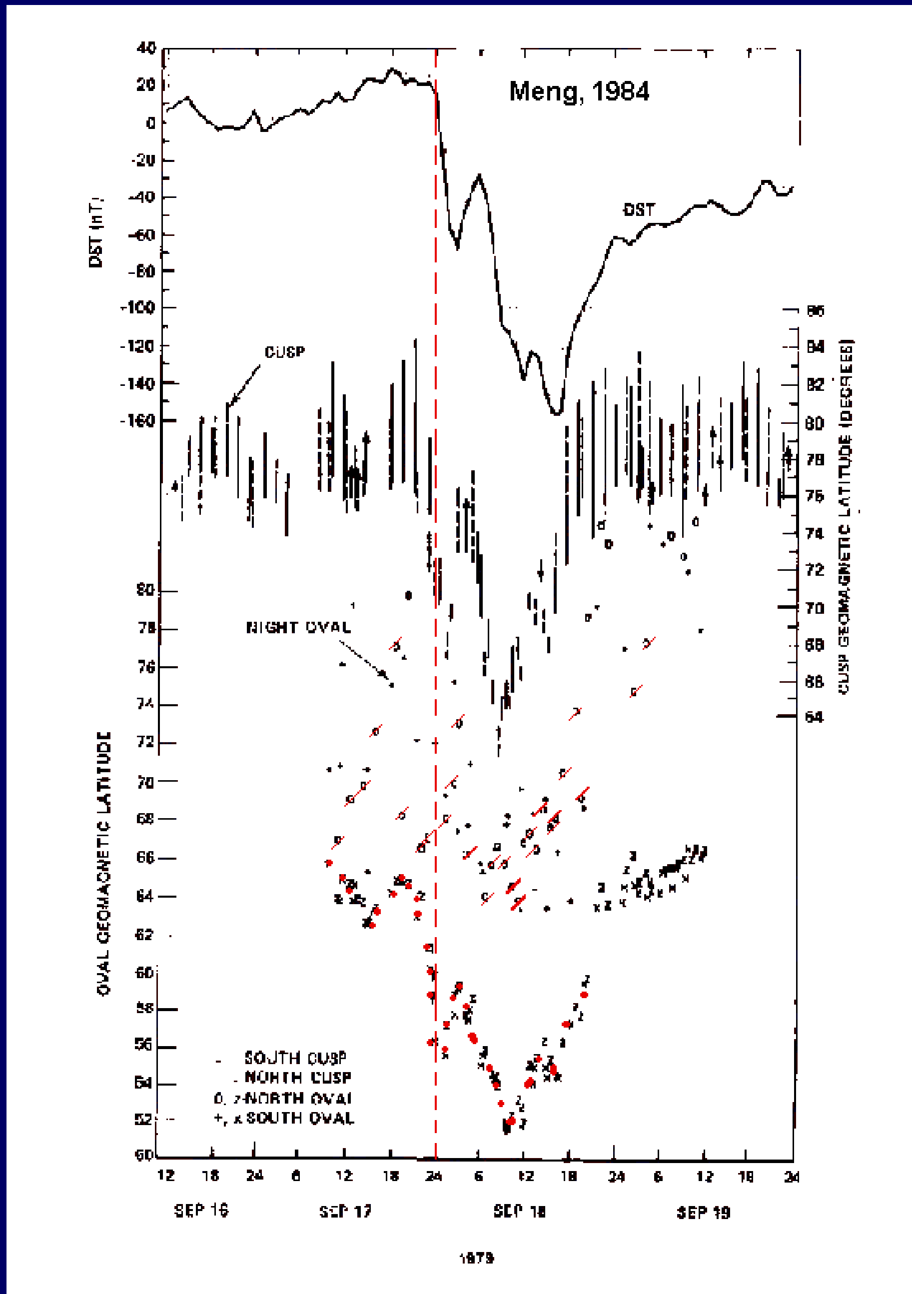
Best correlation coefficient ( 0.9)

for the 50 MeV protons at the nightside.




PB position vs. Dst
in the morning (left)
and the evening (right)
sectors.

(CORONAS-F)



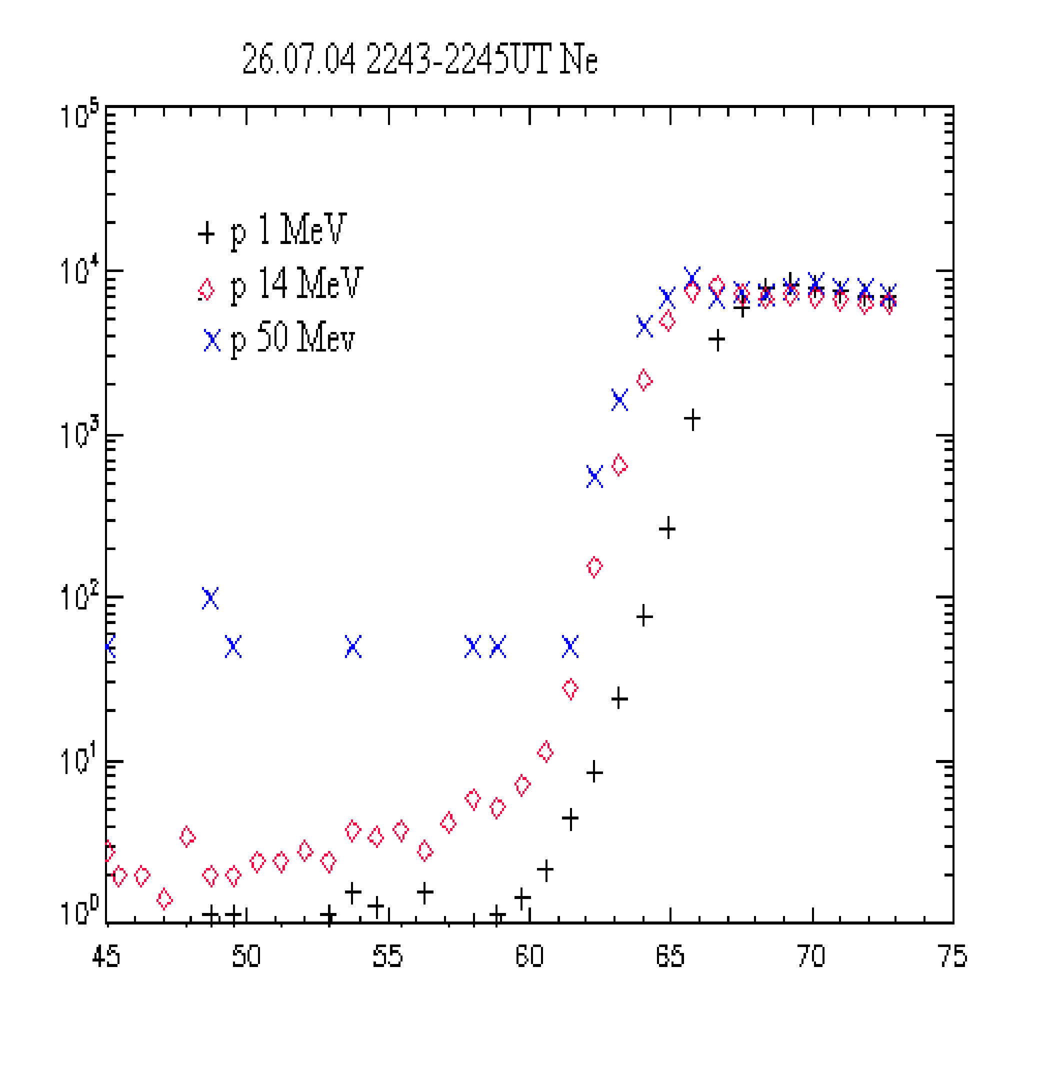

PB shifts Earthward

before the beginning of the storm main phase.

SW pressure and negative Bz are more

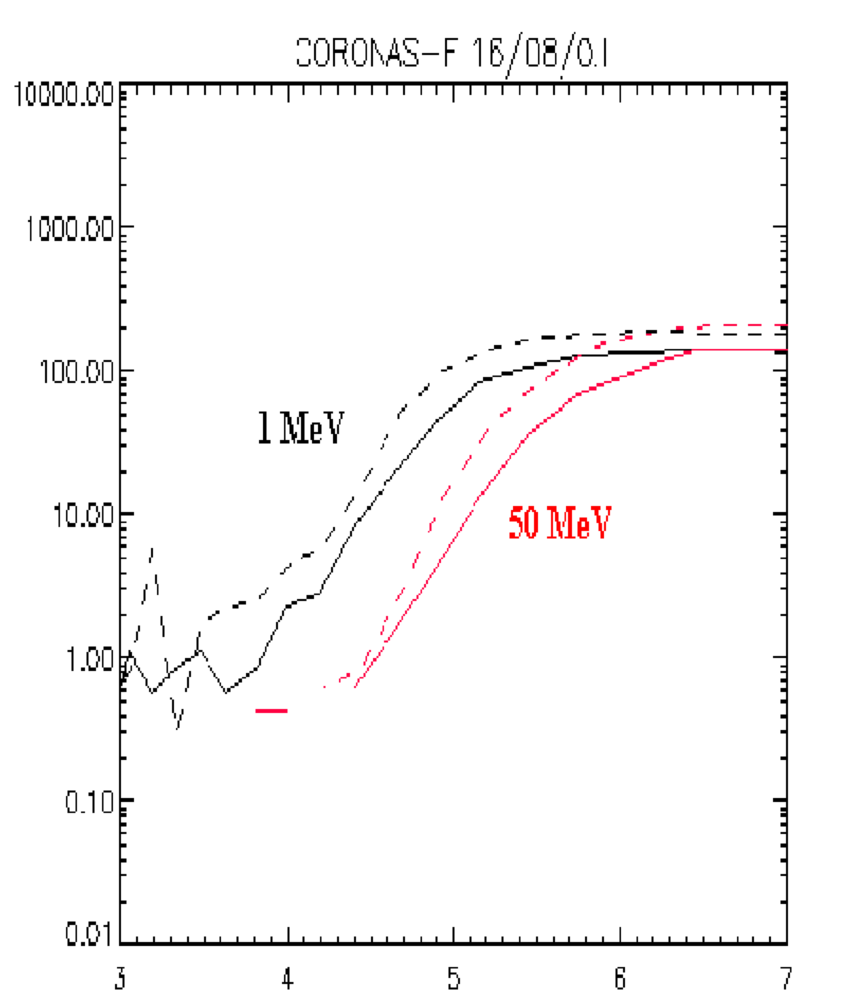
important dor the initial shift.

# PB STRUCTURE




Normal PB radial profile:

Energeic protons penetrates deeper than low-energy ones.

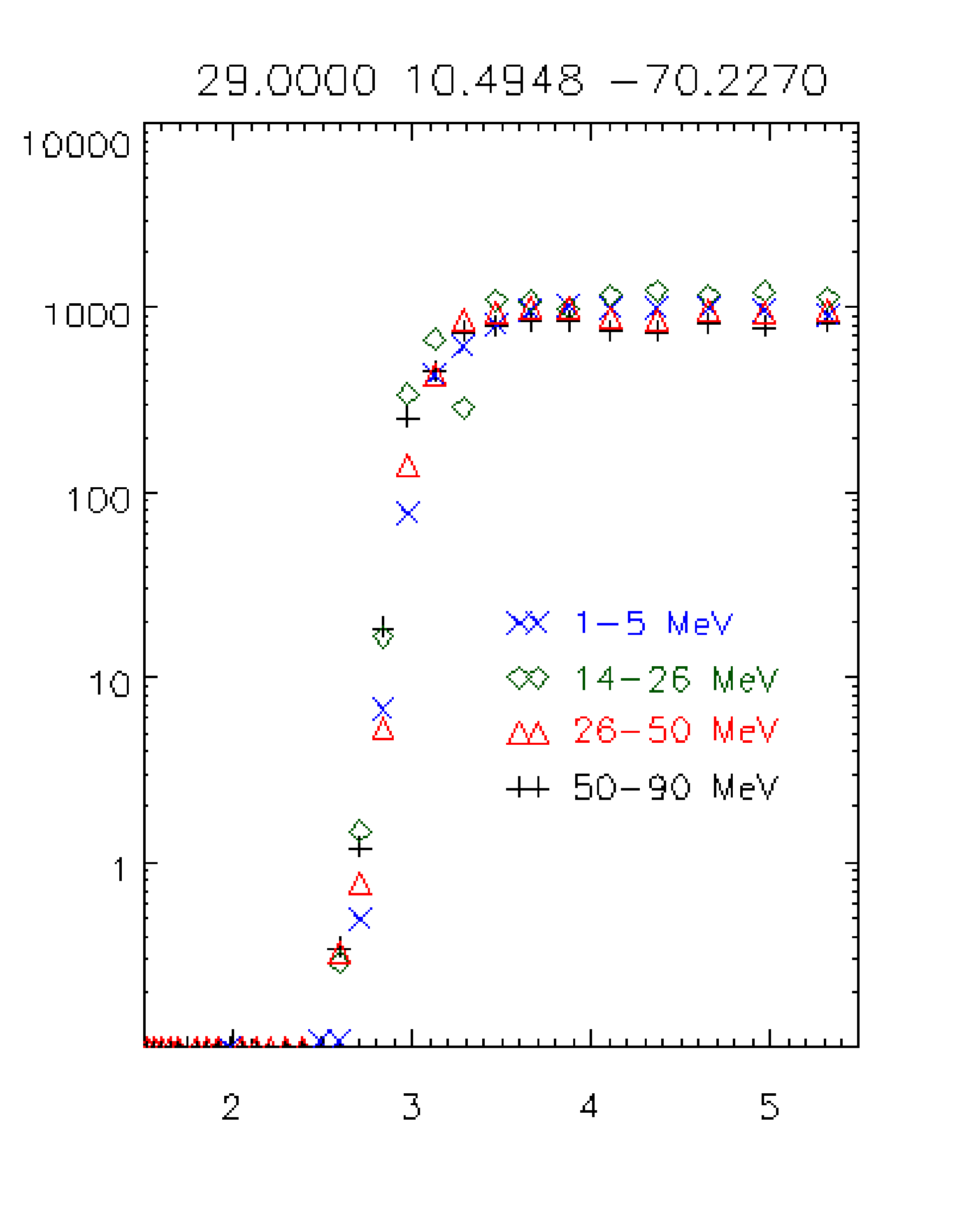



Reverse PB energy dependence

Possible explanation:

Radial ExB drift velocity greater as compared with magnetic drift velocity for low-energy protons.

As a result low-energy particles penetrate deeper before they leave nightside magnetosphere.



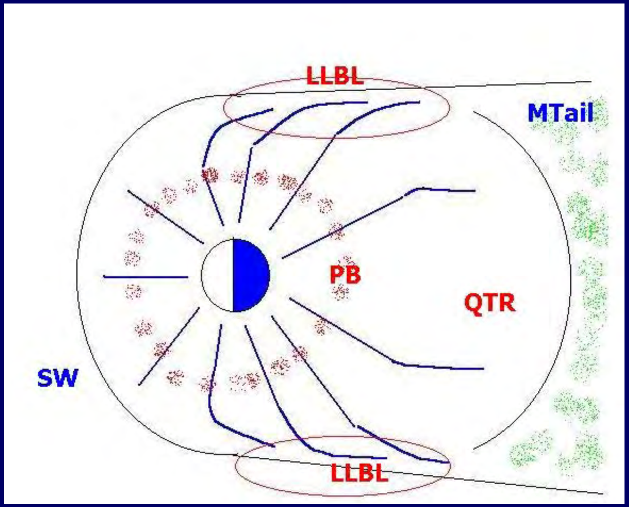

Energy independent PB profile.

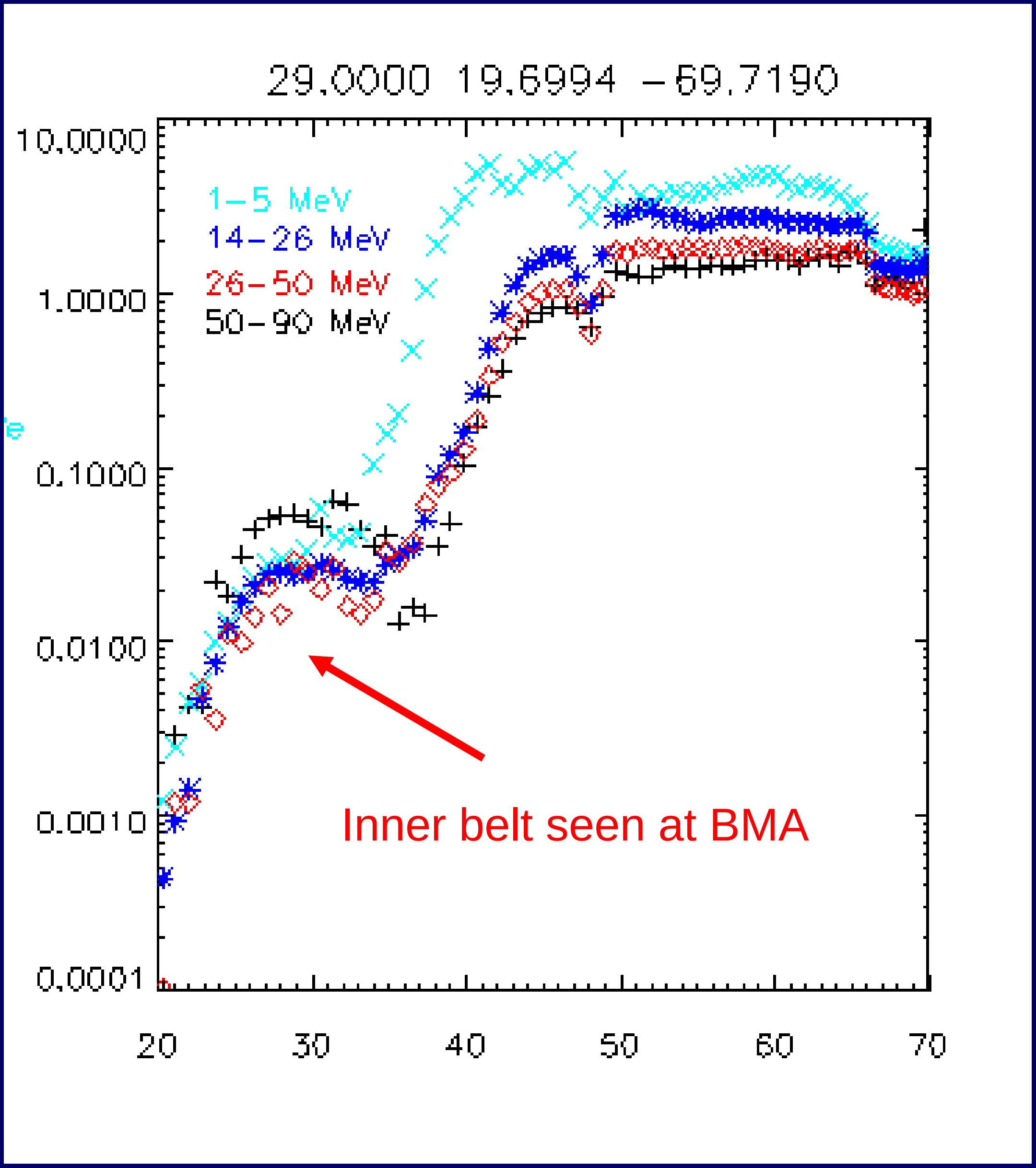
Usually at the peak of the main phase of the strong magnetic storm.

Usually deeper than L = 3.5

Intensity equal to that in interplanetary space.

Proposed explanation: strong diffusion through the LLBL

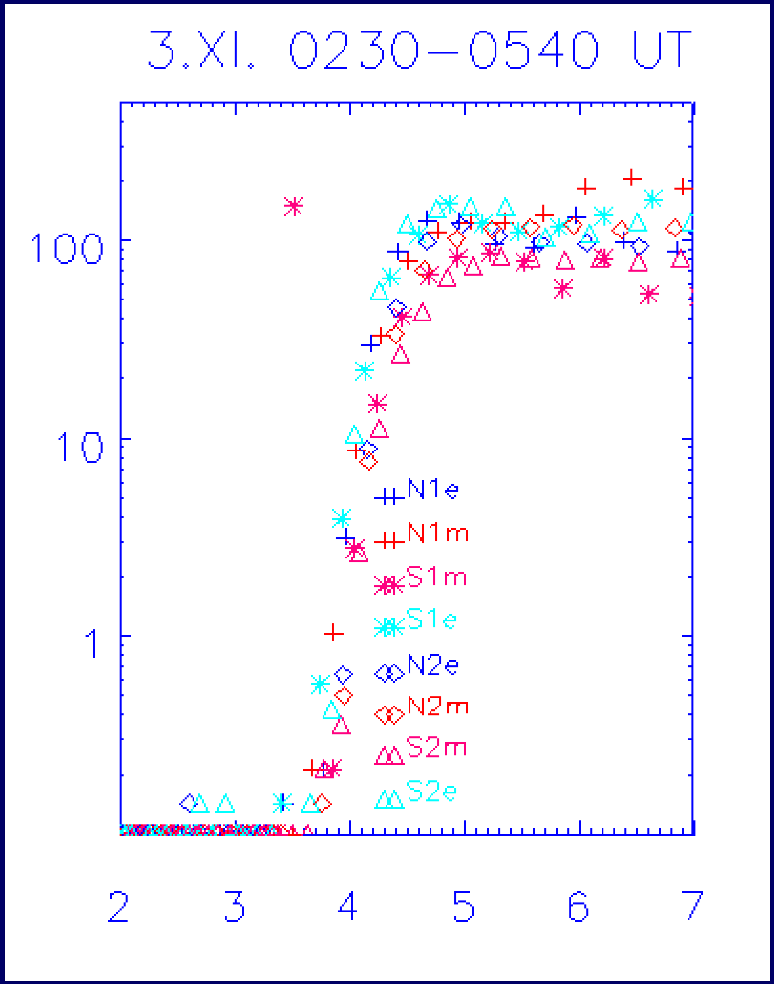


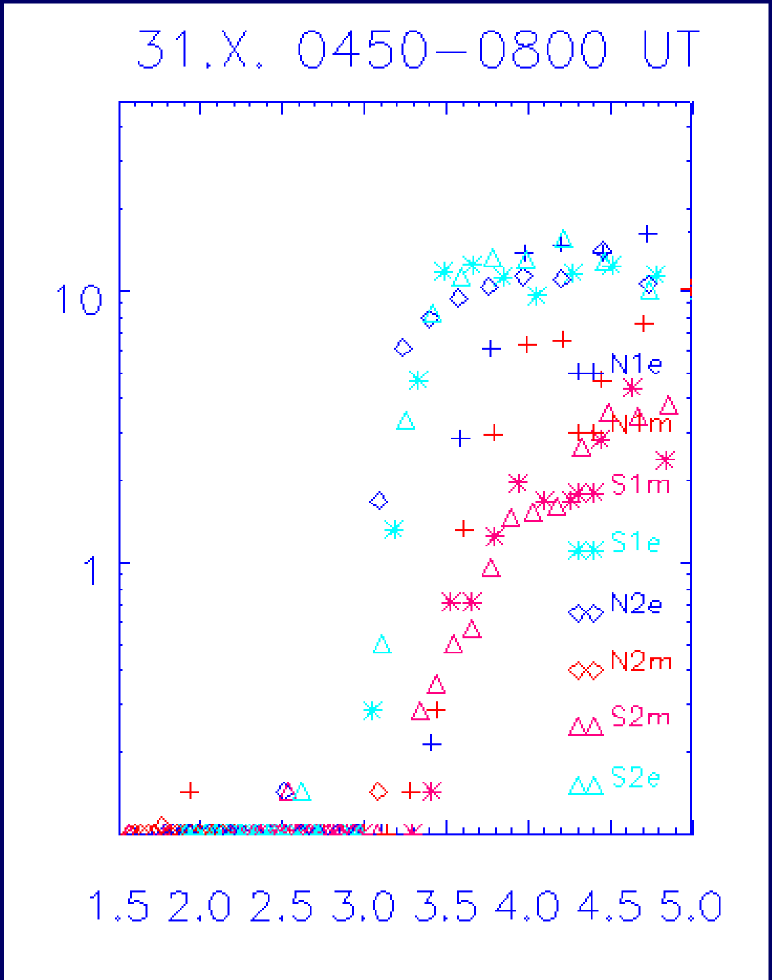



1-5 MeV PB deeper than PB of the protons with E>15 MeV.

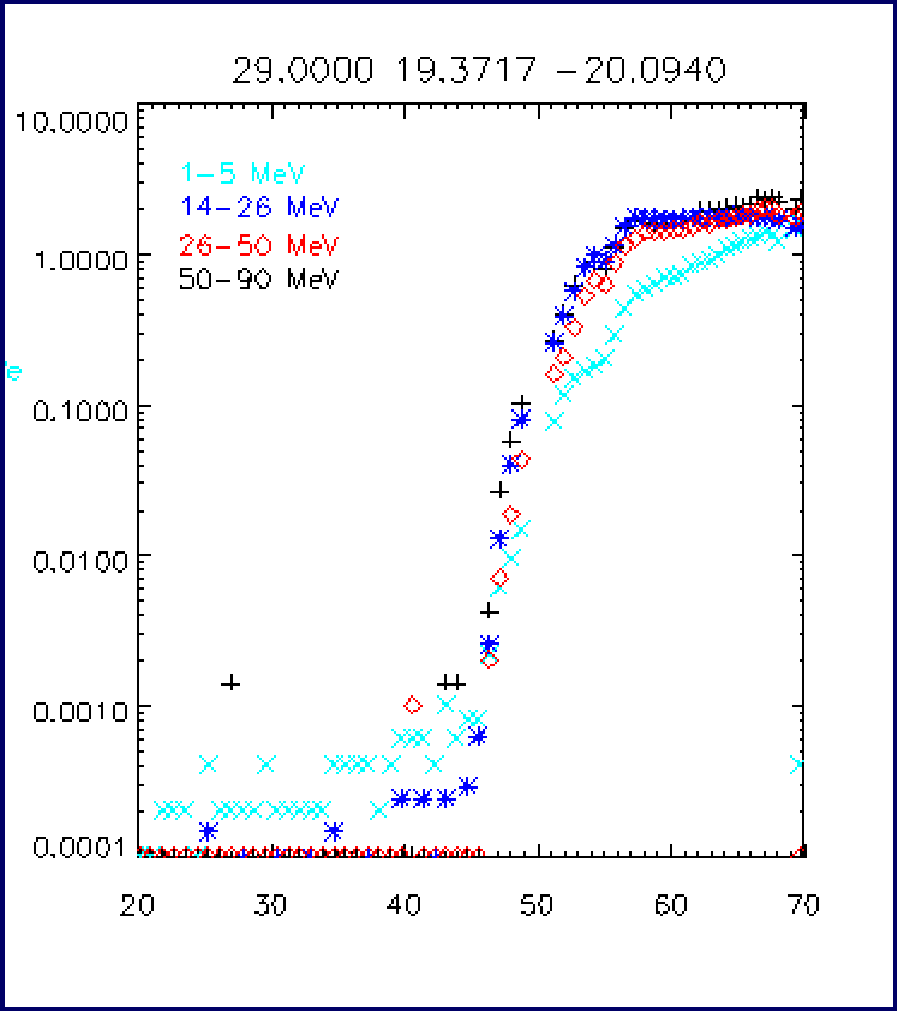
Special profiles due to the magnetosphere dynamics.

Will be considered in the special report.




Dayside PBs are shifted outward. Invalid L.

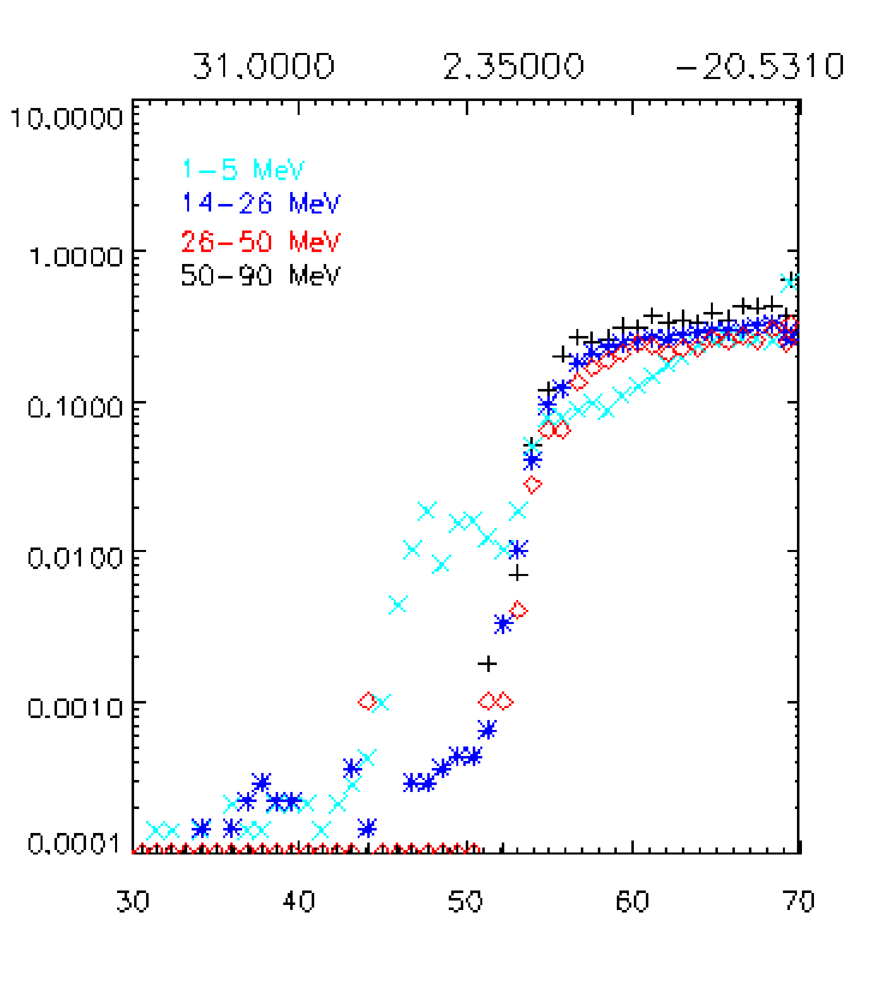



Gradual radial decrease of 1-5 MeV protons dayside profile created by PAD non-adiabaic effects.

At the night side magnetic field line curvature is compared with proton Larmor radii both for 1 and 50 MeV.

Therefore regime of the strong PA diffusion exists and loss cone is full.

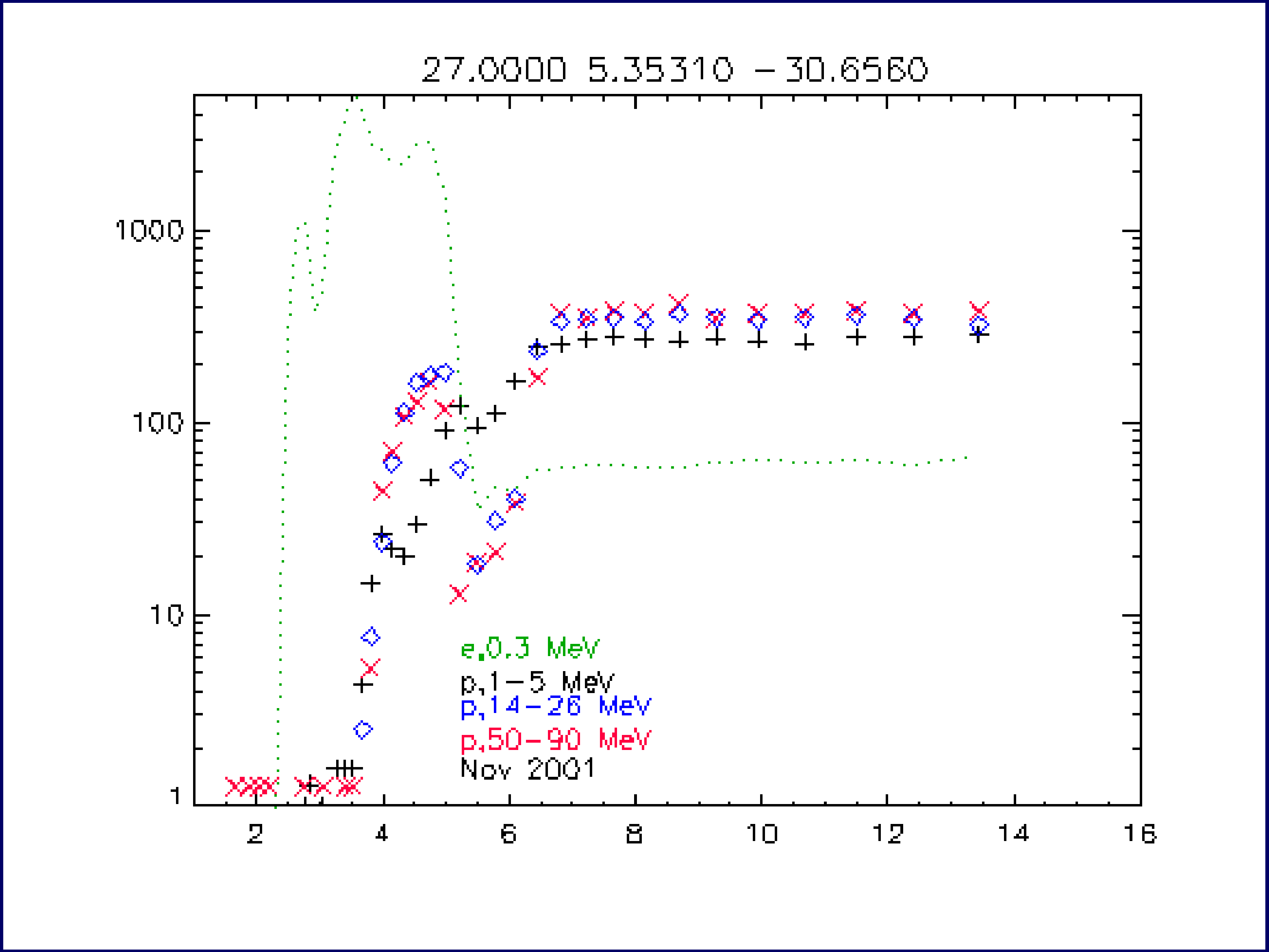
During magnetic drift to the dayside 2 MeV proton diffusion gradually decreases and loss cone became nearly empty.




Combined adiabatic and dynamic effects.

During the recovery of the magnetosphere configuration transition from the strong to low PAD occurs.

PB profiles give us valuable information on particle dynamics and the magnetosphere configuration.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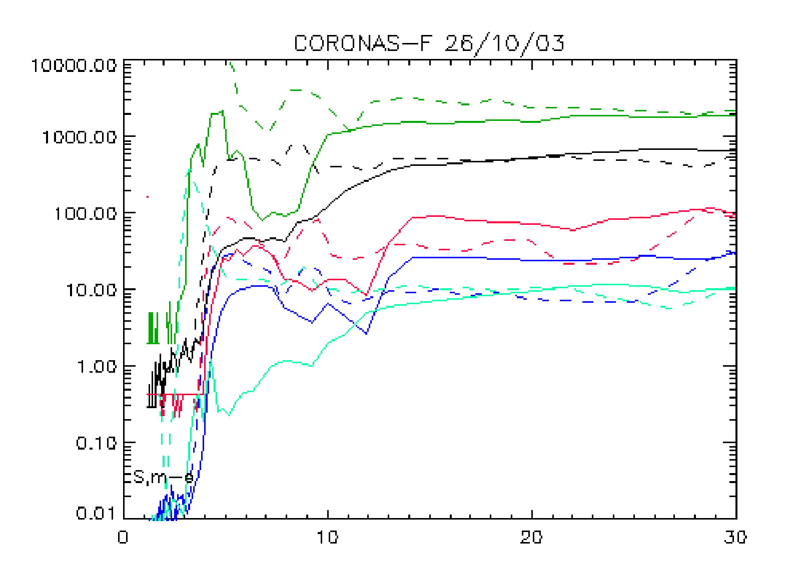
e,0.3 MeV
p,1-5 MeV
p,14-26 MeV
p,50-90 MeV
Nov 2001

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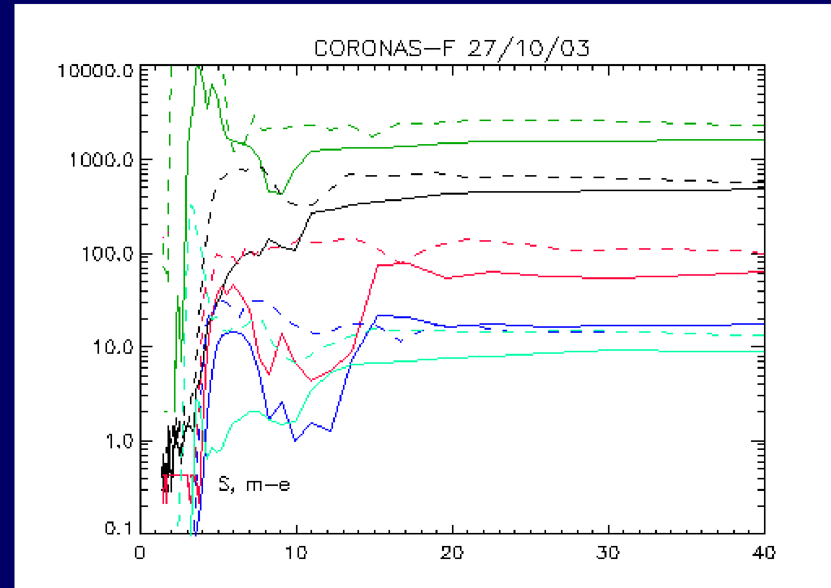


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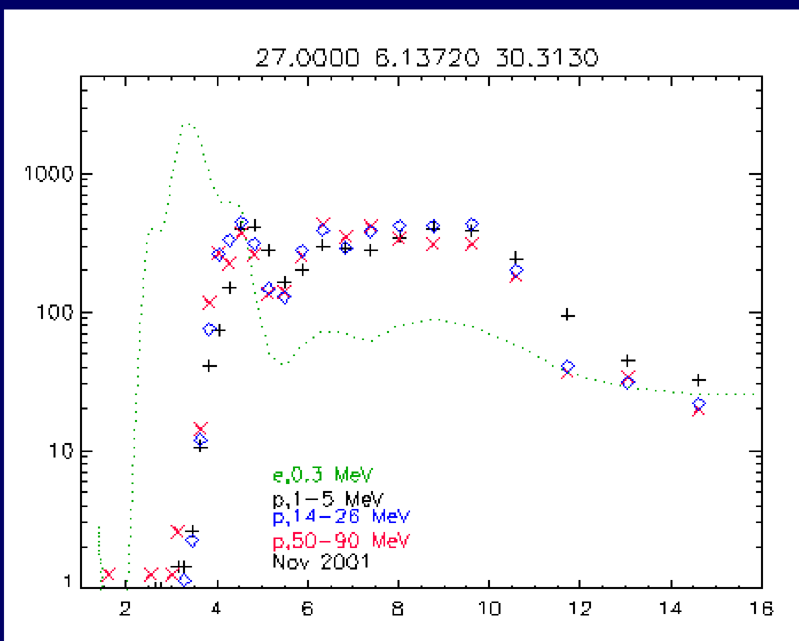
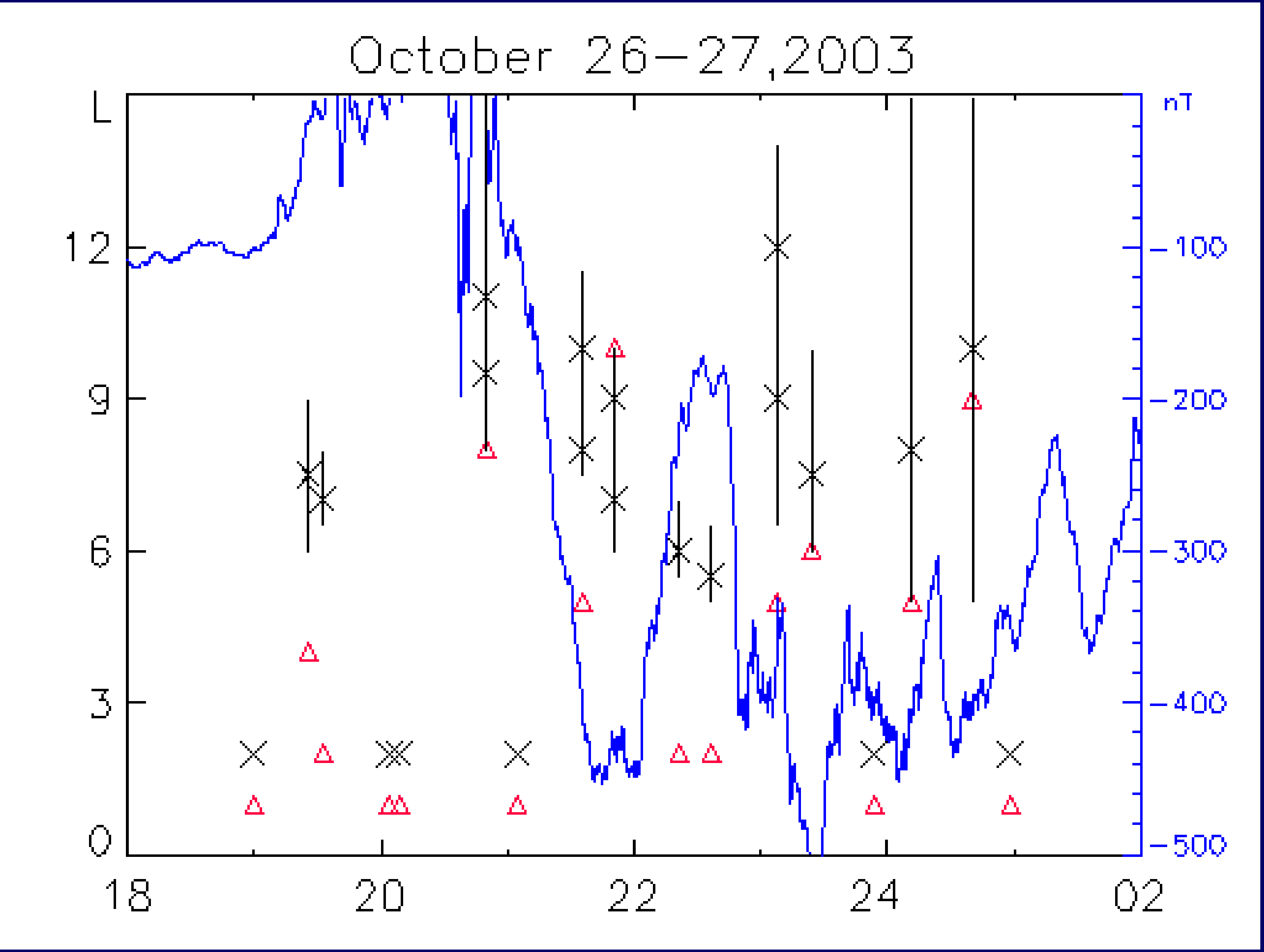



Several examples of the intensity dropouts inside the quasitrapping region. More strong effect for high energy protons.



October 26–27,2003
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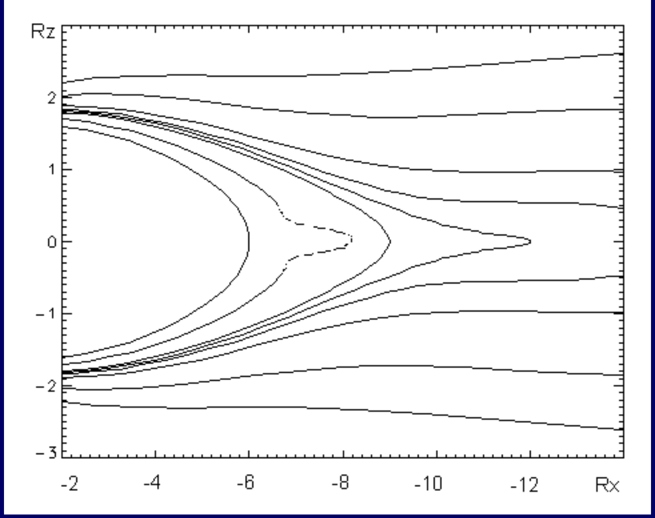
Rz
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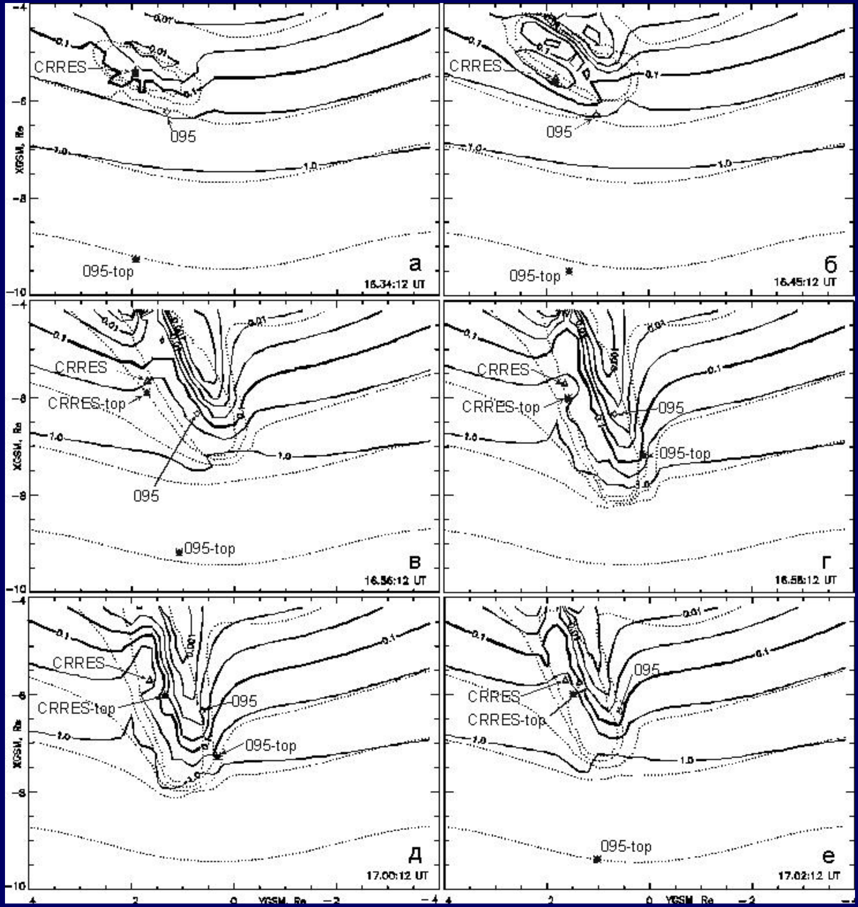
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# CONCLUSIONS

In general we do understand 1-100 MeV solar proton entrance and dynamics in the magnetosphere during small and moderate magnetic activity.

We do not know how exactly SCR penetrates deep inside during strong and extreeme magnetic storms. Why PB is the same for 1 and 50 MeV protons? Is there LLBL strong diffusion penetration and how it works?

We know that solar proton distribution can be used for the reconstruction of the strongly disturbed magnetosphere but not started yet quantitative estimations.

# ЗАКЛЮЧЕНИЕ

Проникновение СКЛ с энергией 1-100 МэВ во время слабых и умеренных бурь понятно в общих чертах.

Мы не знаем, как эти протоны проникают на L<3 во время сильных бурь. Почему ГП одинакова для 1 и 50 МэВ? Если это диффузия с границ прямо в область квазизахвата, как она работает?

Известно, что распледеление протонов в магнитосфере может быть использовано для диагностики магнитосферы. Но еще не приблизились к методам количественной оценки.