UNIVERSITA' DEGLI STUDI DI PERUGIA
Dipartimento di Fisica e Geologia
XXX PhD "Scienza e Tecnologia per la Fisica e la Geologia"

Cosmic Rays and Solar Activity

Federico Donnini

13 February 2015

Curriculum

- *Bachelor degree (2011)*

  Continuous monitoring of the Radon concentration indoor

  Tutors *Prof. Francesco Sacchetti*
  Dr Alba Rongoni

→ *Tested a new device for the radon measurement*

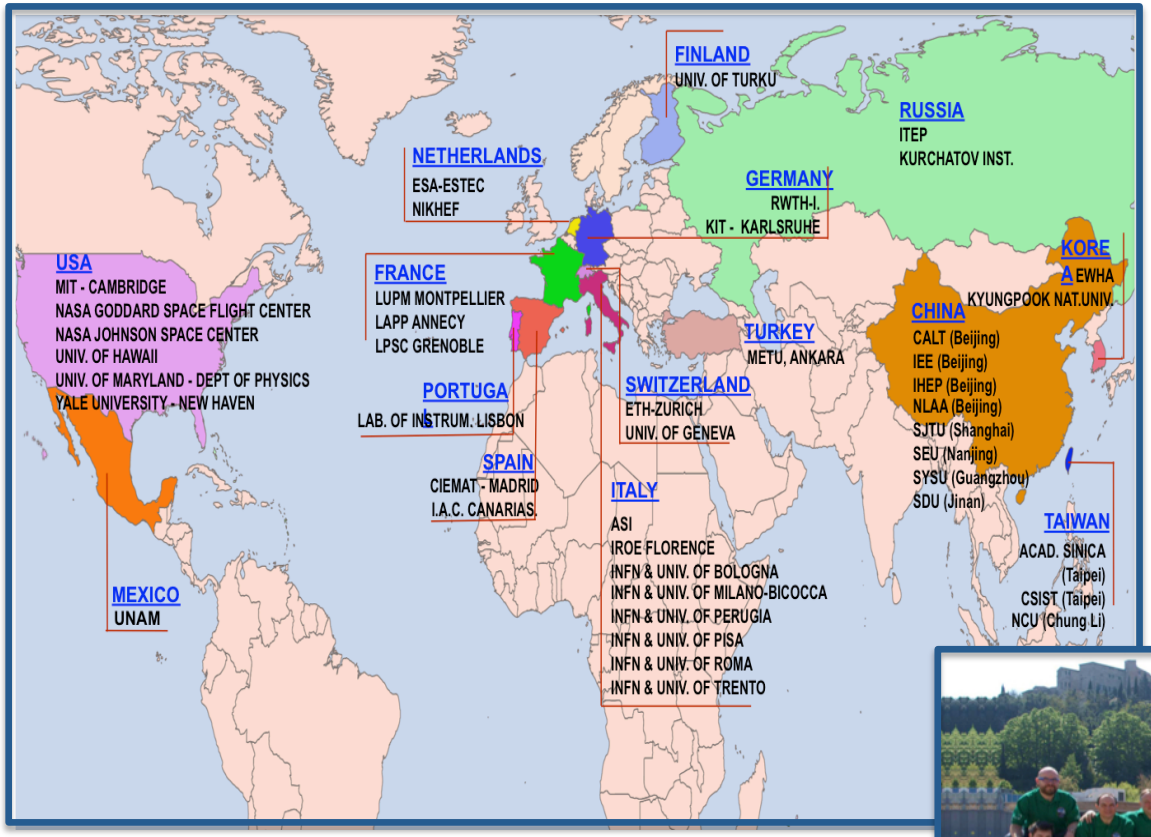
- *Master degree (2014)*

  Measurements of protons flux in Cosmic Ray at low energy with AMS-02 experiment

  Tutors *Dr. Emanuele Fiandrini*
  Dr. Domenico D'Urso

→ Analyzed AMS detector's data . *First work with AMS*

AMS Collaboration



Leader :

Nobel Laureate

Prof. Samuel Ting

16 Nations

57 Institutes

About 600 scientists

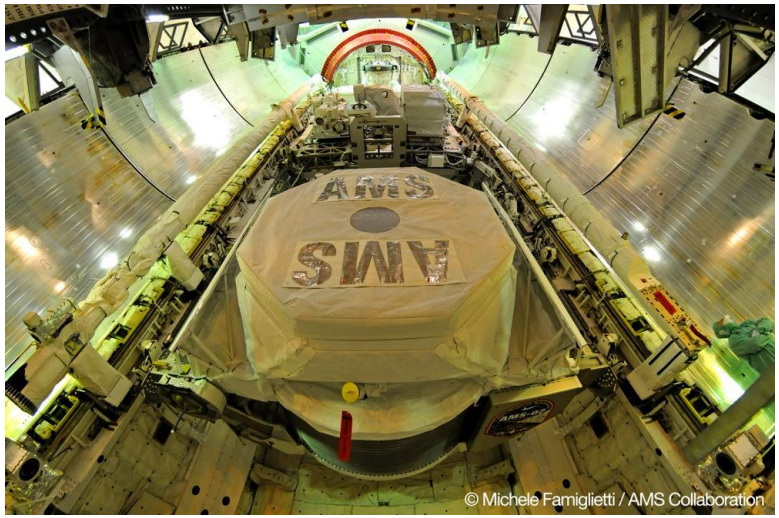
The importance of AMS Collaboration

- ***Important international context***
- ***To improve my background of Cosmic Ray physics***
- ***To improve my data analysis skills***
- ***Contribution to the publication of 1 paper***

PhD with AMS Collaboration

The AMS-02 Experiment

The main goal of AMS Collaboration is the study of the universe and its origins, searching for primordial antimatter and dark matter, and a precise measurement of Cosmic Ray fluxes up to Fe.



AMS-02 (Alpha Magnetic Spectrometer) is a particle detector designed to operate onboard the International Space Station (ISS).
Installed on ISS on May 2011.

Cosmic Rays

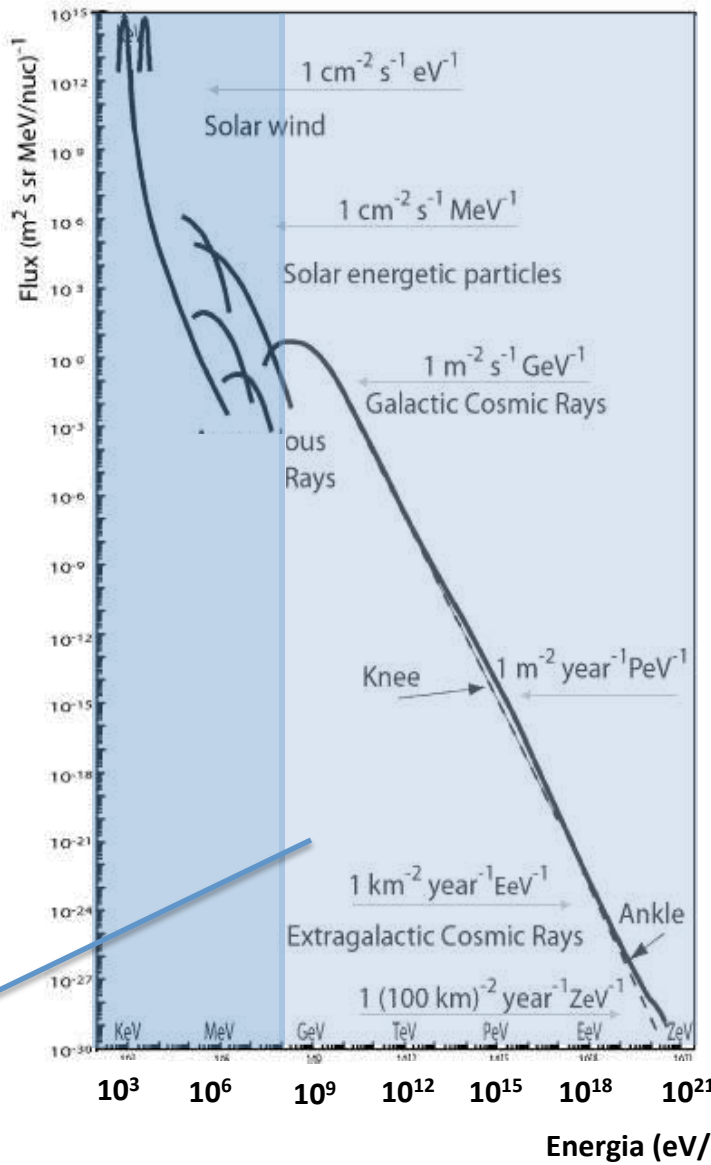
Isotropic and continuous flux of particles from:

Solar component
composed by protons, electrons, small tracks of nuclei

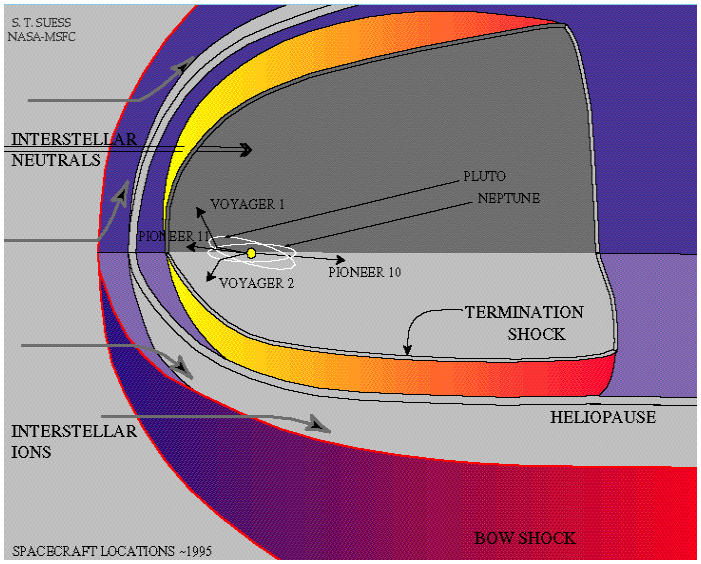
Galactic and extra-galactic component
composed by 90% protons, 8% helium, 2% electrons, positrons and nuclei with Z>2

Trapped in the geomagnetic field
(protons and electrons)

Interesting range (0.5-30 GeV) for my Analysis ; range influenced by Solar Activity



Solar Cycles and Modulation



- Solar wind generates a cavity in the interstellar medium: heliosphere
- Solar wind changes in time according to Solar Activity

Cosmic Rays must propagate in the heliosphere: time variations of the Solar wind cause variations of the intensity of the cosmic ray flux as a function of position at energies < 30 GeV

SOLAR MODULATION of Cosmic Rays

… First Year

- Monitoring of the detector POCC (Payload Operation Control Center) situated at CERN

- Development of tools for the geomagnetic cutoff calculation to separate Galactic and local Trapped Cosmic Rays components at the AMS orbit

- Follow with profit the PhD courses and PhD Schools

… Next years

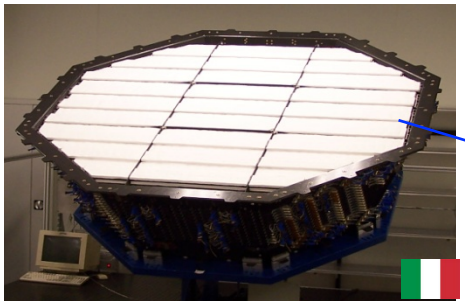
- measure the absolute flux of protons at very low energy as a function of time
- separation of the populations of galactic and trapped particles
- correlation with the parameters of solar activity
- measure of the flux of protons trapped in the geomagnetic field

Thanks

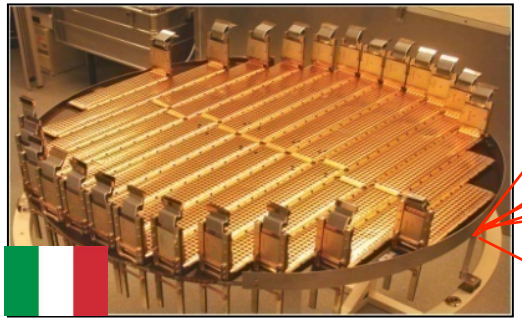
BACKUP

The AMS-02 detector

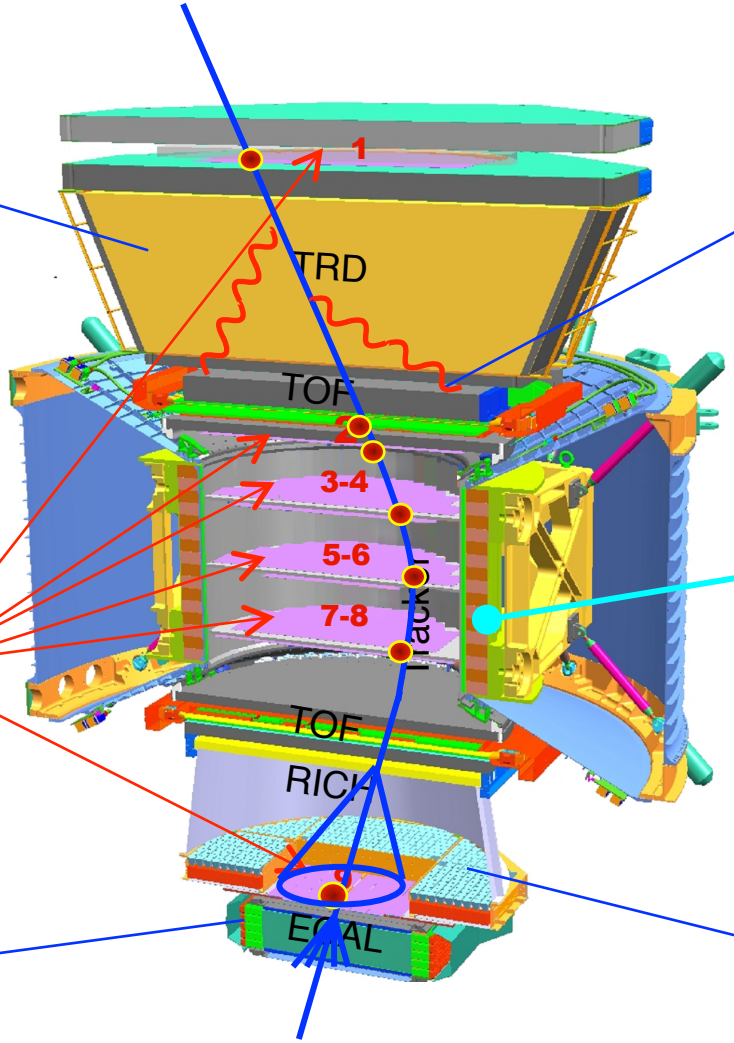
TRD (|Q|, e/p)



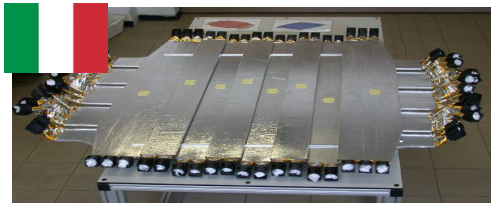
Silicon Tracker (±Q,R)



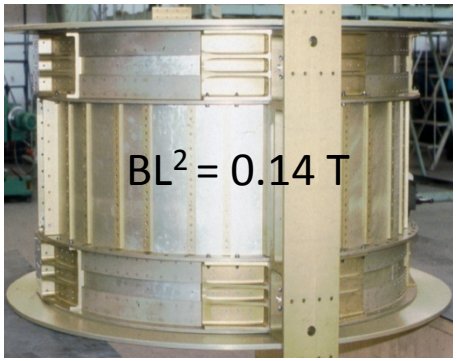
ECAL (E, e/p)



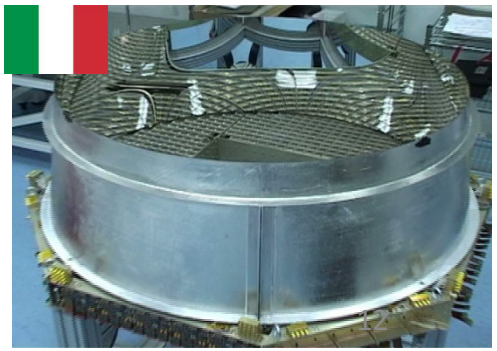
TOF (v, |Q|, trigger)



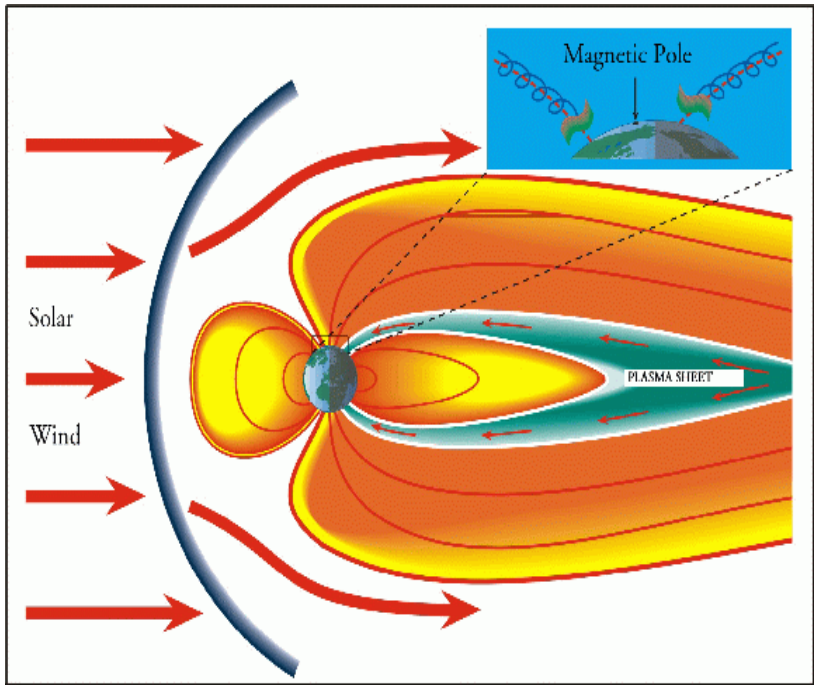
Permanent Magnet

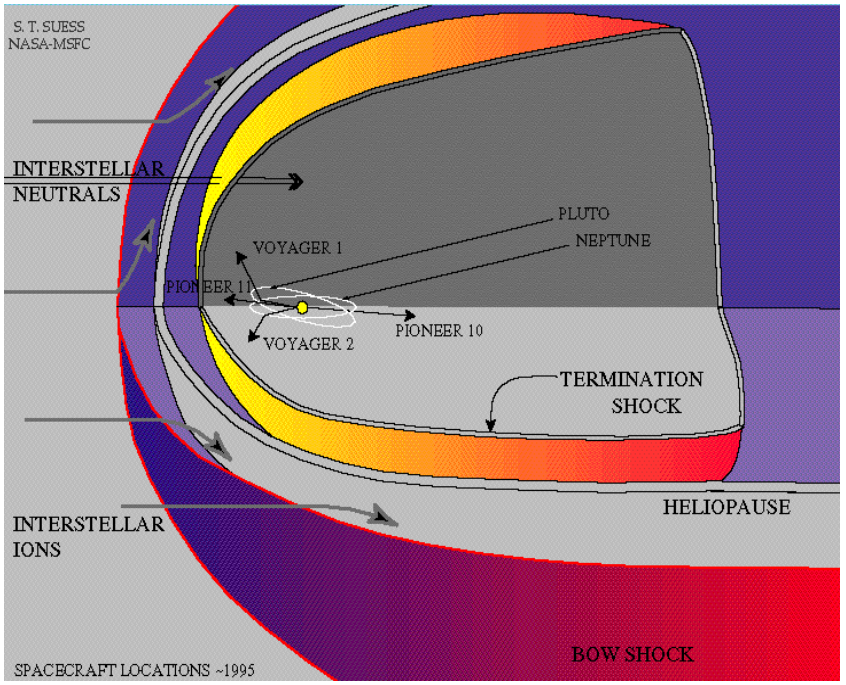


RICH (v,|Q|)



Heliosphere and magnetosphere





A cavity n the heliosphere where the Earth's magnetic field dominates

A cavity of the local interstellar medium in where the solar magnetic field dominates

Cosmic rays propagate through the heliosphere before arriving close to the Earth and have to cross the magnetosphere before get to the top of the atmosphere.

Rigidity Cut-off: allowed/forbidden trajectories

Driving force is the Lorenz force (in quiet sun conditions)

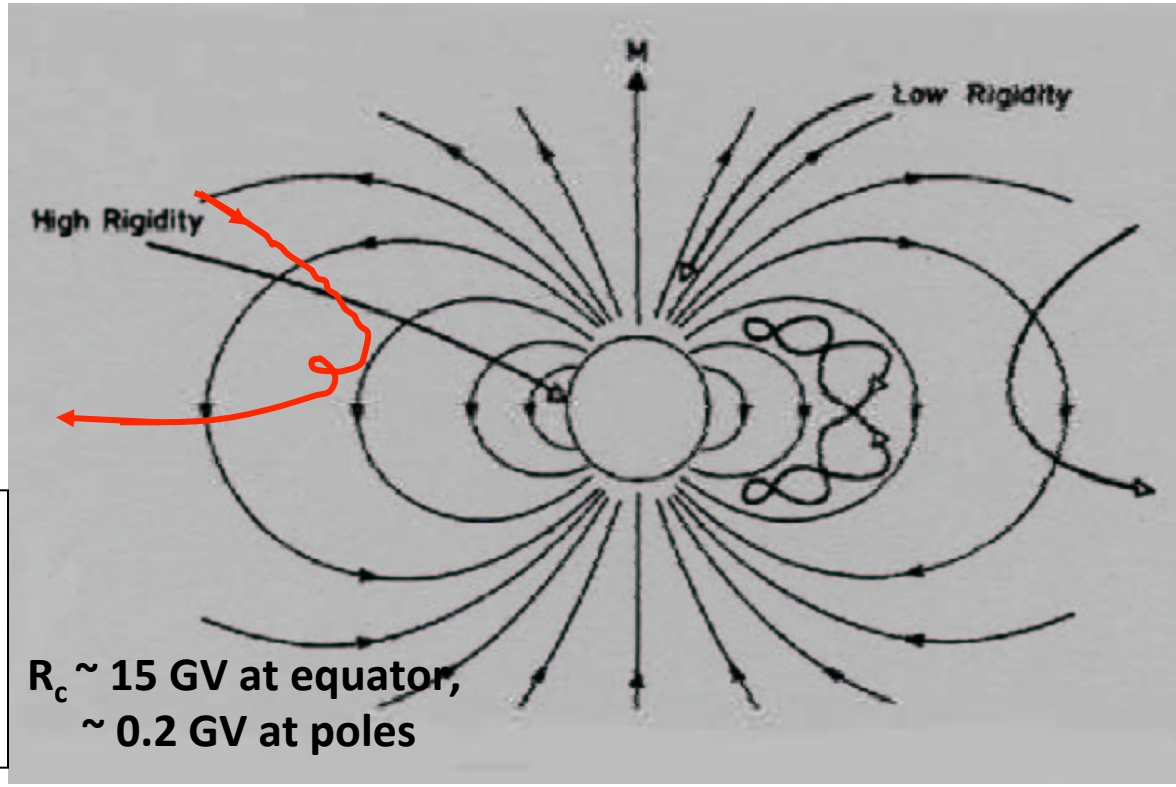
$d\underline{P}/dt=(q/c)(\underline{E}+\underline{v}x\underline{B})$

Typically $\underline{E}=0$ and given $R=P/q$, the magnetic rigidity ➔ $d\underline{R}/dt=\underline{\beta}x\underline{B}$

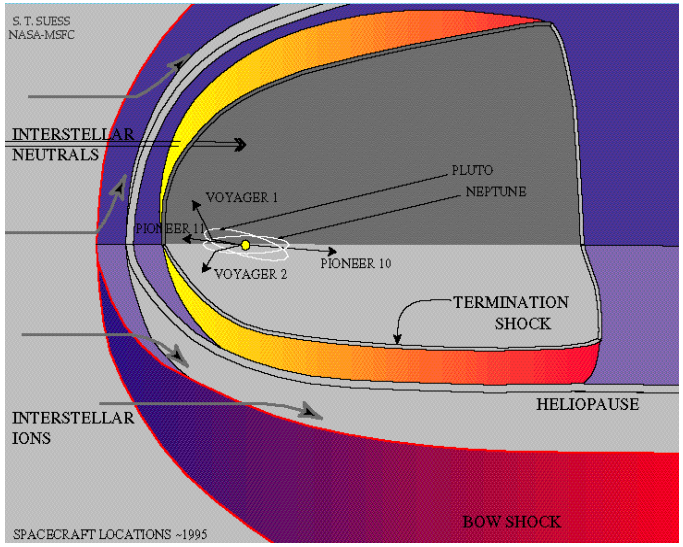
All particles with same R and β have same motion

Only particles with rigidity $\vec{R}$ greater than a minimum rigidity R_c can reach a given position from outside magnetosphere, because B field gradients bend particles trajectory as they approach earth.

R_c is a complex function of the position in the field and of particle momentum direction: $R_c(r,Q,F,p/p)$



Solar Cycles and Modulation



The Sun generates a supersonic wind variable of magnetized plasma that derives a cavity in the local interstellar medium, the heliosphere.

- Cycle of 11 years in which the Sun is in two minimum (maximum) of activity.
- Cycle of 22 years consisting of two 11-year cycles with polarity of the magnetic field reversed.

Cosmic rays should propagate in the eliosphere → temporal variations of the intensity of the cosmic ray flux as a function of position

SOLAR MODULATION of Cosmic Rays

The local spectrum E <30 GeV is not representative of the interstellar spectrum. The calculation of the solar modulation is very important to extrapolate the spectrum at low energy

Flux and Normalized Flux

The relationship between rate of counts in a time interval T between (t, t + T) and the flux is given by:

$$\langle \Phi_0(E,t) \rangle_T = \frac{\Delta N(E, E+\Delta E)}{\Delta E \, \Delta T \, \langle G(E,t) \rangle_T \langle \epsilon(E,t) \rangle_T}$$

ΔN *number of counts with energy from E and E+ ΔE*
G(E,t) *acceptance of the detector*
ϵ(E,t) *total efficiency*

To measure changes in the flow of protons in time we use the Normalized Flux

$$\frac{\langle \Phi_0(t) \rangle_T}{\langle \Phi_0(t) \rangle_{tot}}$$

$\langle \Phi_0(t) \rangle_T$ *Average flow in a generic time interval*

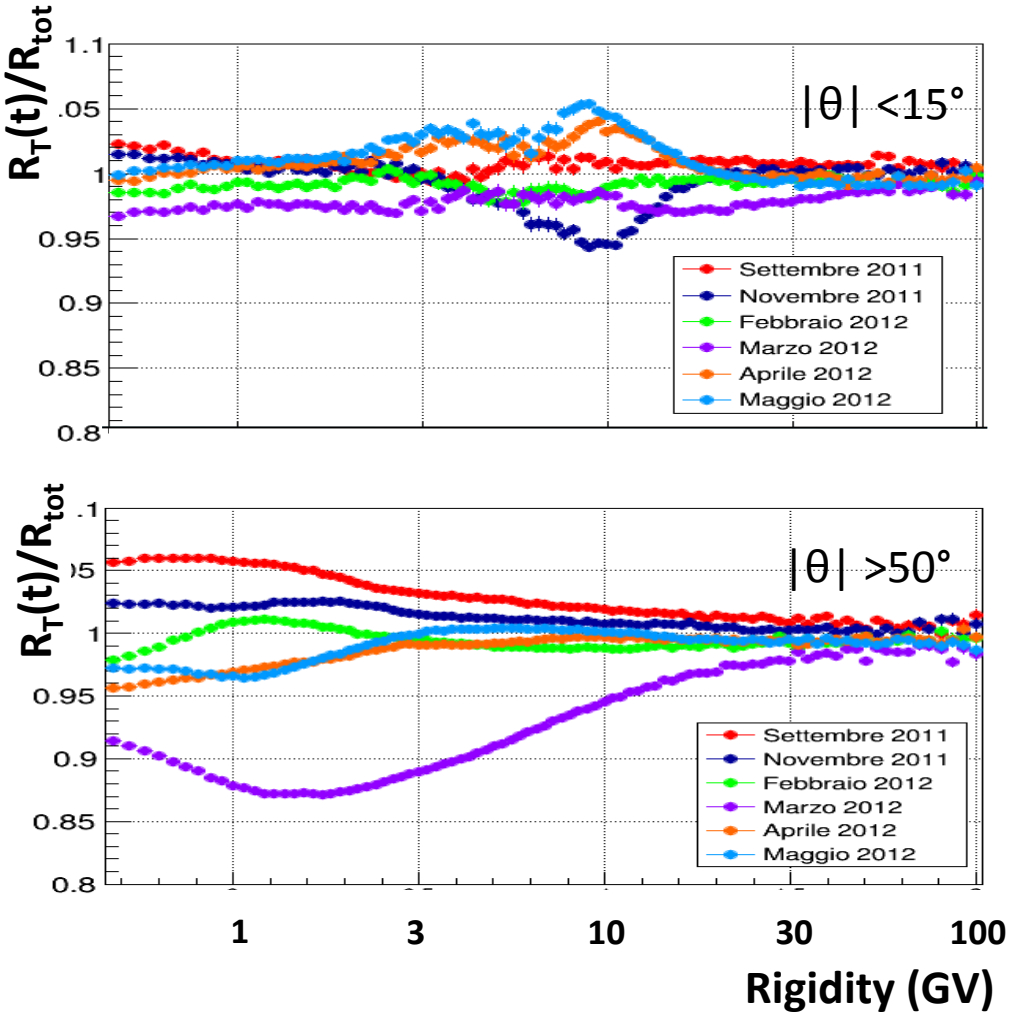
$\langle \Phi_0(t) \rangle_{tot}$ *Average flux in total time interval of the measure*

Since the variation in time of the two lsst terms a few of %, in first approximation they can be considered constant

$$\frac{\langle \Phi_0(t) \rangle_T}{\langle \Phi_0(t) \rangle_{tot}} \approx \frac{\langle R(t) \rangle_T}{\langle R(t) \rangle_{tot}}$$

In this way, the ratio of the average fluxes is approximately equal to the ratio of the average rate

Normalized Rate



Time variation of the ratio

$$\frac{\langle R(t)\rangle_T}{R(t)\rangle_{tot}}$$

$R_T(t)$ = average rate of 30 days
R_{tot} (t) = average rate 1 year

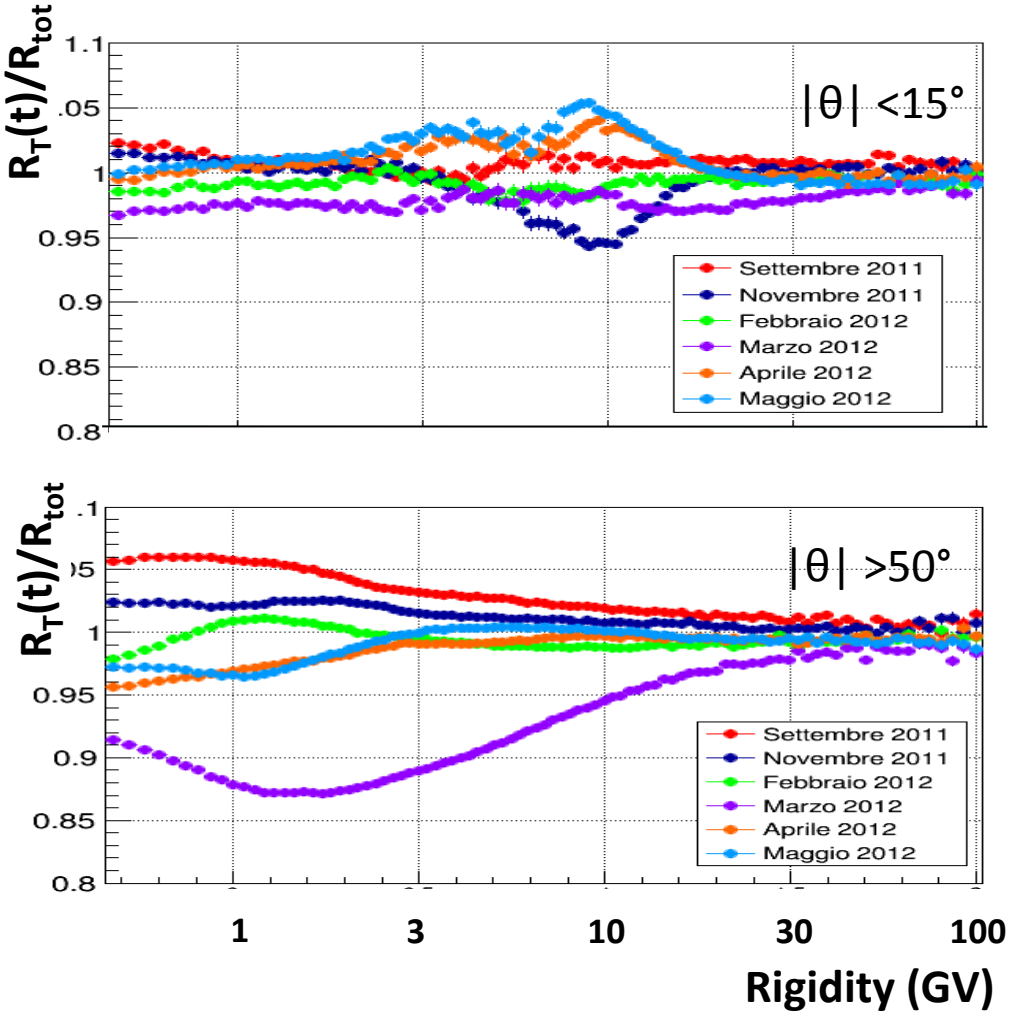
- Trapped CR at R< 5 GV are weakly affected by the variation of solar activity in the equatorial region
- GCR have Rigidity R > 20 GV in this region → **small modulation**
- Polar regions are accessible of low R GCR , population of trapped particles is negligible →**solar modulation more obvious, ~20%,**

The Master Degree Thesis

... purpose:

the observation of the effects of solar modulation, due to the interaction of cosmic rays with the heliosphere, with measurement of the relative variation in time of the protons flux

Normalized Rate



Time variation of the ratio

$$\frac{\langle R(t)\rangle_T}{R(t)\rangle_{tot}}$$

$R_T(t)$ = average rate of 30 days

$R_{tot}(t)$ = average rate 1 year

Solar Modulation increase from equatorial zone to polar zone