Background from CR

P. Bobik

Institute of Experimental Physics SAS Košice

23. june 2010 *7th international JEM-EUSO meeting, Huntsville*

Production of JEM EUSO background

Approach of cosmic rays to the top of the atmosphere is depending on geomagnetic cut-off rigidity → background will be different at different places of ISS orbit

We need to know intensity of geomagnetic field and spectra on the top of atmosphere for different places of Earth surface (top of atmosphere)

IGRF model is enough to describe geomagnetic field, we do not need external model field

AMS spectra are probably best choice for particle spectra (i.e. published AMS spectra for 10 geomagnetic regions).

Production of JEM EUSO background

Particle spectrum in Corsika is described by input parameter ESLOPE PSLOPE - power law spect.

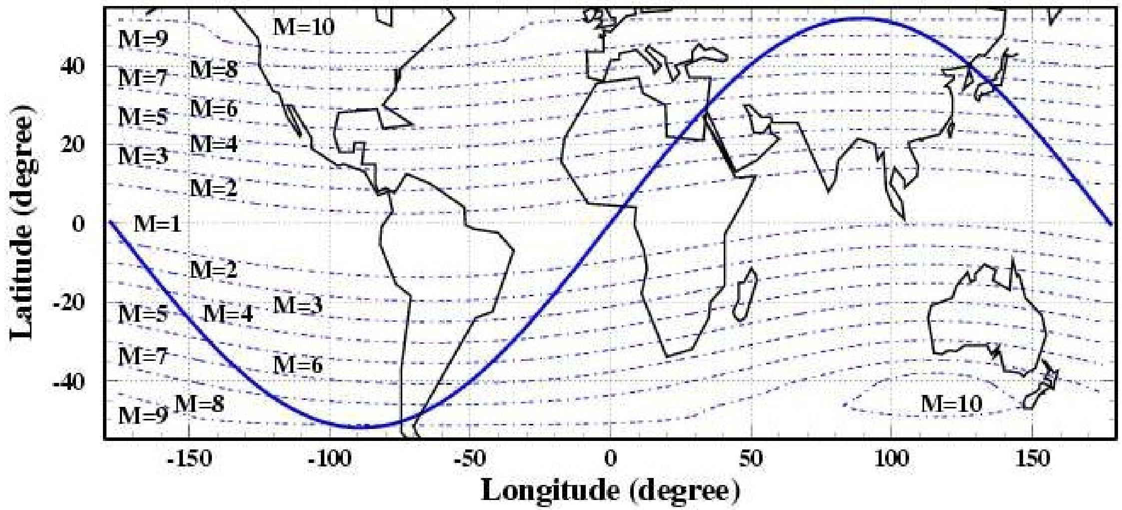
This mean that spectrum can precisely describe situation at 1AU for energies >60GeV

- 60Gev are energies not modulated by heliosphere
- we can assume that modulation can be neglected for particles with energies >10GeV and we still be quite OK
- but what about energies <10GeV ? – where we have most of all particles

We apply next scheme:

1. calculate a results (in Corsika) for set of single energies (AMS bins)
2. use AMS spectra in different regions as spectra on the top of atmosphere
3. By combination of Corsika results for discrete energies and AMS spectra evaluate results inside of atmosphere

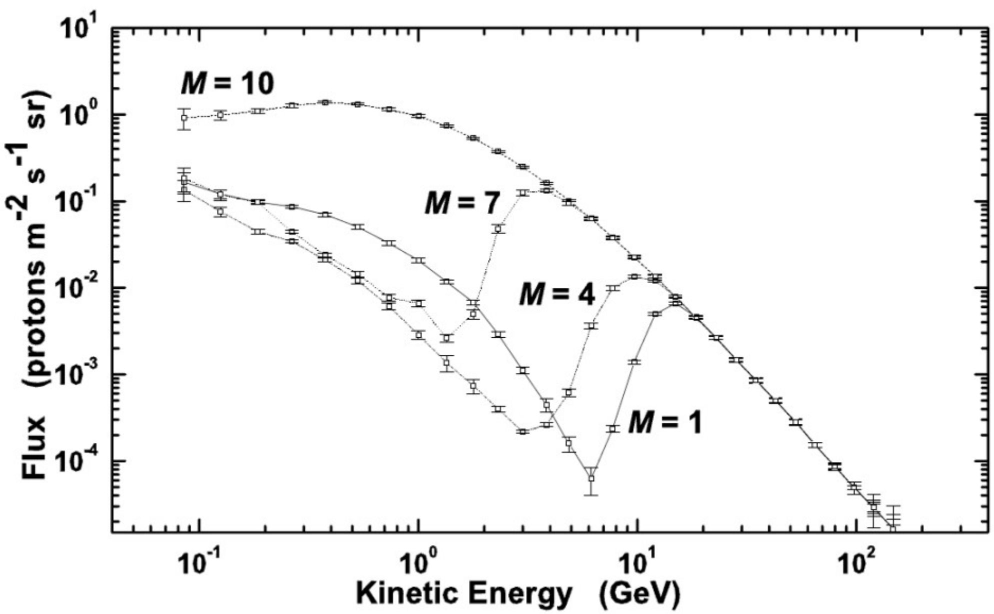
Production of JEM EUSO background



The 10 geomagnetic regions (M) covered by AMS-01, defined in Table 1, are shown on the background of the Earth surface. A typical trajectory of AMS-01 detector on board of the space shuttle, at an altitude of about 400 km, is also plotted. The space shuttle trajectory shifts with time and covers almost uniformly the Earth surface inside a geographic latitude Θ≤51,6º.

Region (M)	CGM latitude θ_M (rad)
1	$\lvert\theta_M\rvert \leq 0.2$
2	$0.2 \leq \lvert\theta_M\rvert \leq 0.3$
3	$0.3 \leq \lvert\theta_M\rvert \leq 0.4$
4	$0.4 \leq \lvert\theta_M\rvert \leq 0.5$
5	$0.5 \leq \lvert\theta_M\rvert \leq 0.6$
6	$0.6 \leq \lvert\theta_M\rvert \leq 0.7$
7	$0.7 \leq \lvert\theta_M\rvert \leq 0.8$
8	$0.8 \leq \lvert\theta_M\rvert \leq 0.9$
9	$0.9 \leq \lvert\theta_M\rvert \leq 1.0$
10	$\lvert\theta_M\rvert \geq 1.0$

Table 1. Geomagnetic regions covered by AMS-01 measurements and kinetic energies corresponding to the dip for each geomagnetic zone (see [*AMS Collaboration*, 2000a; *AMS Collaboration*, 2002]). The regions are dened using the Corrected Geomagnetic latitude (CGM).



Left down panel: Normalized fluxes per units of solid angle are shown for the geomagnetic regions M = 1, 4, 7 and 10 as functions of the proton kinetic energies.

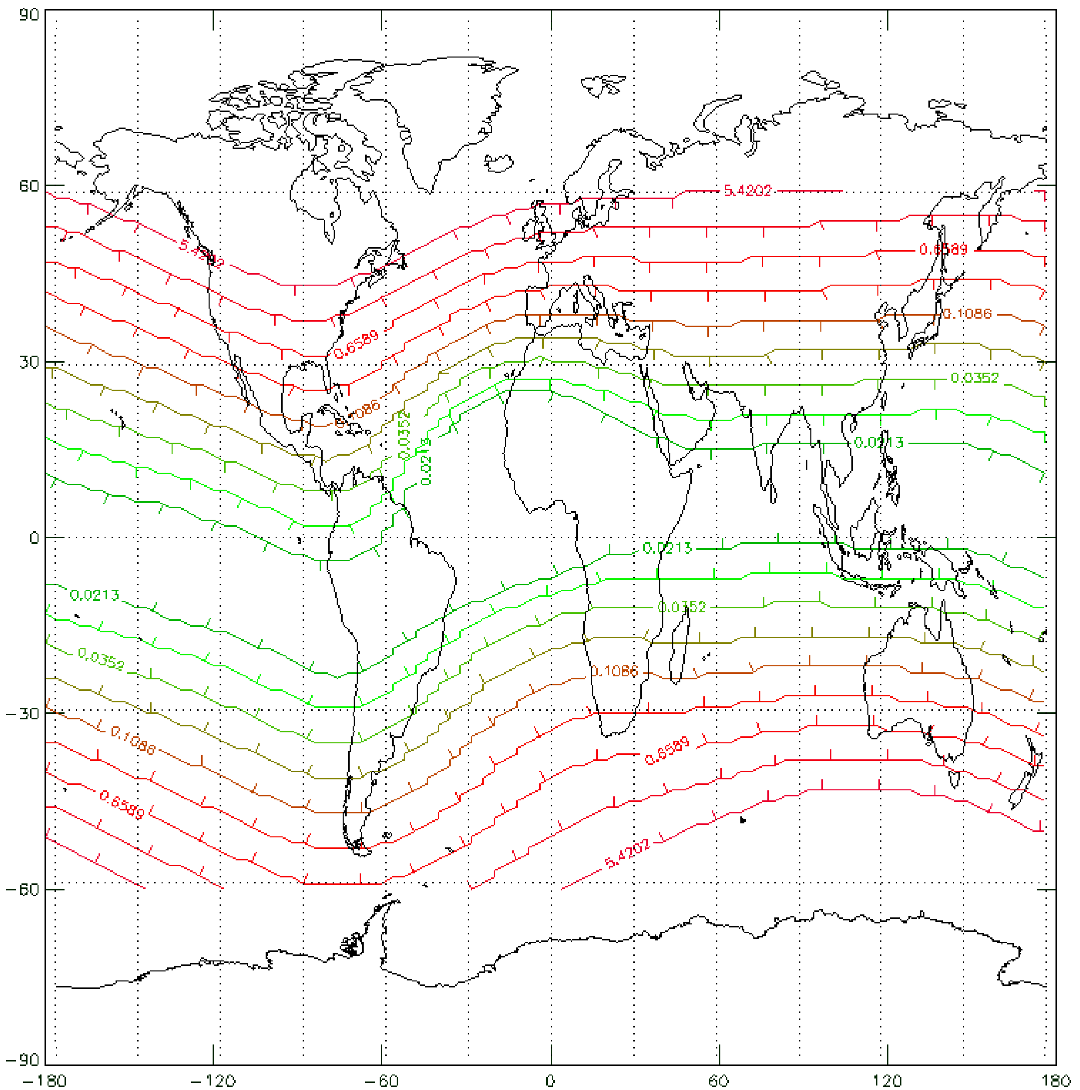
Q: Why we choose AMS spectra?

A: Because it is most precise measurement of CR spectra yet.

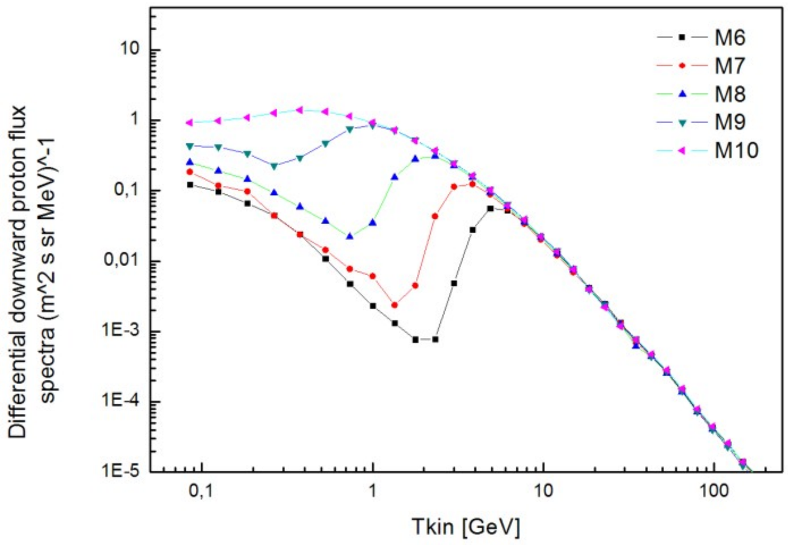
All figures are from: *Bobik P., Boella G., Boschini M. J., Gervasi M., Grandi D., Kudela K., Pensotti S., Rancoita P. G., Magnetospheric transmission function approach to disentangle primary from secondary cosmic ray fluxes in the penumbra region, JGR, 111, Issue A5, A05205, 2006*

Production of JEM EUSO background

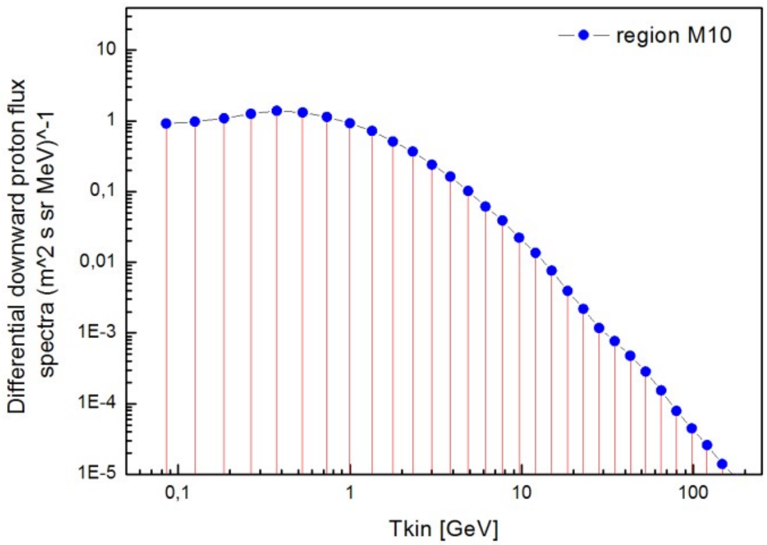
AMS downward proton total flux in $(m^2\ s\ sr\ MeV)^{-1}$ - evaluated from spectra published in article *Protons in near earth orbit, Physics Letters B, Volume 472, Issues 1-2, 13 January 2000, Pages 215-226*



Production of JEM EUSO background



AMS fluxes in region M = 6,7,8,9,10



AMS differential downward proton flux spectra $(m^2 s\ sr\ MeV)^{-1}$ in region 10.

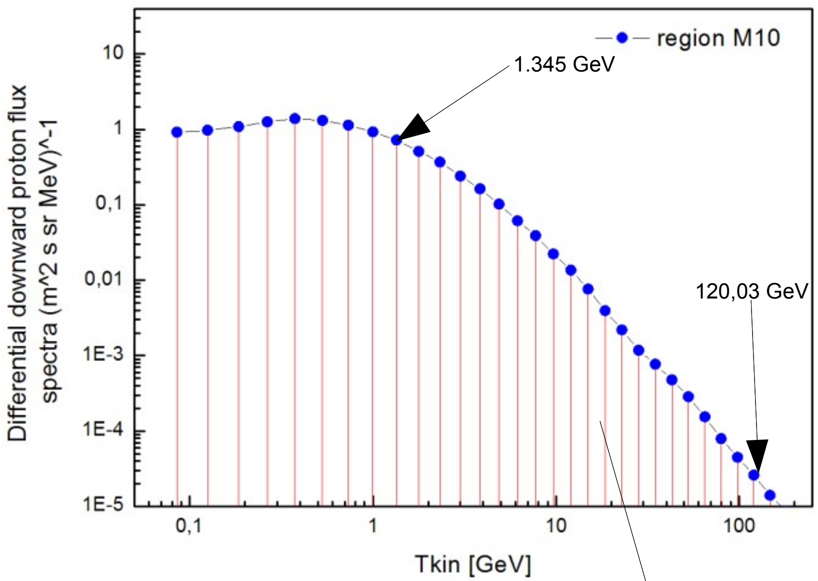
I_x (λ) – intensity of x (x herein is Cherenkov light) at λ depth in atmosphere

Formaly :

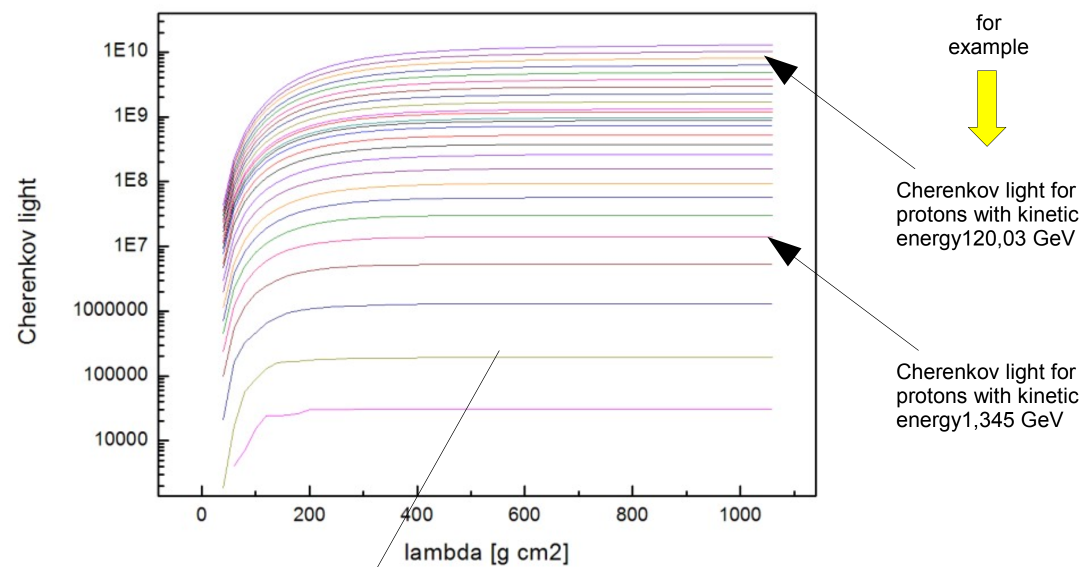
$$I_x(\lambda) = \sum_{i=1}^{31} I_{AMS,i}(\Re) * b_w * I_{Corsika,normalized,x}(\Re, \lambda)$$

- where b_w is width of AMS bin

Production of JEM EUSO background



AMS differential downward proton flux spectra $(m^2 s\ sr\ MeV)^{-1}$ in region 10.



Cherenkov light, simulation results for 31 AMS energies for region M = 10 (latitude 50°, longitude 100° - Bx = 20.3 μT, Bz = 56.2 μT), Θ = 0° – 70°, Φ = -180° – 180°.

$$I_x(\lambda) = \sum_{i=1}^{31} I_{AMS,i}(\Re) * b_w * I_{Corsika,normalized,x}(\Re,\lambda)$$

Production of JEM EUSO background

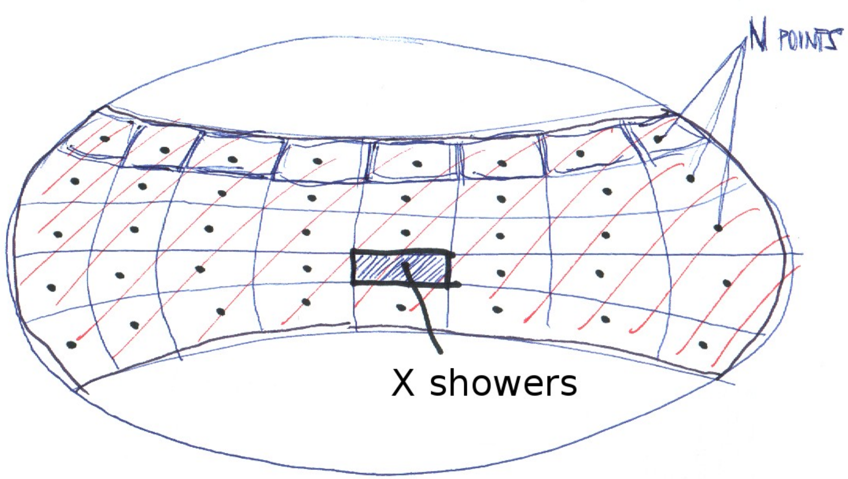
Corsika – simulation for

- N point at Earth (regions with equal area)

    - evaluation of Bx and Bz for net of points

- for every point X showers will be generated for every of 31 AMS bins

At all N * X * 31 showers



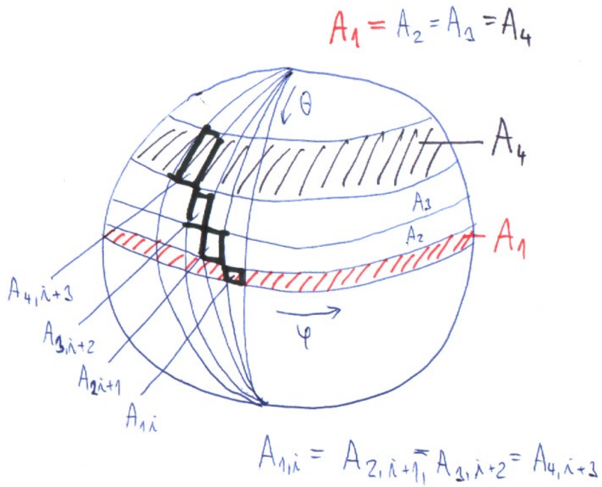
Latitude-longitude grid of points covering all ISS orbit.
Every point of grid should cover same area at the Earth.

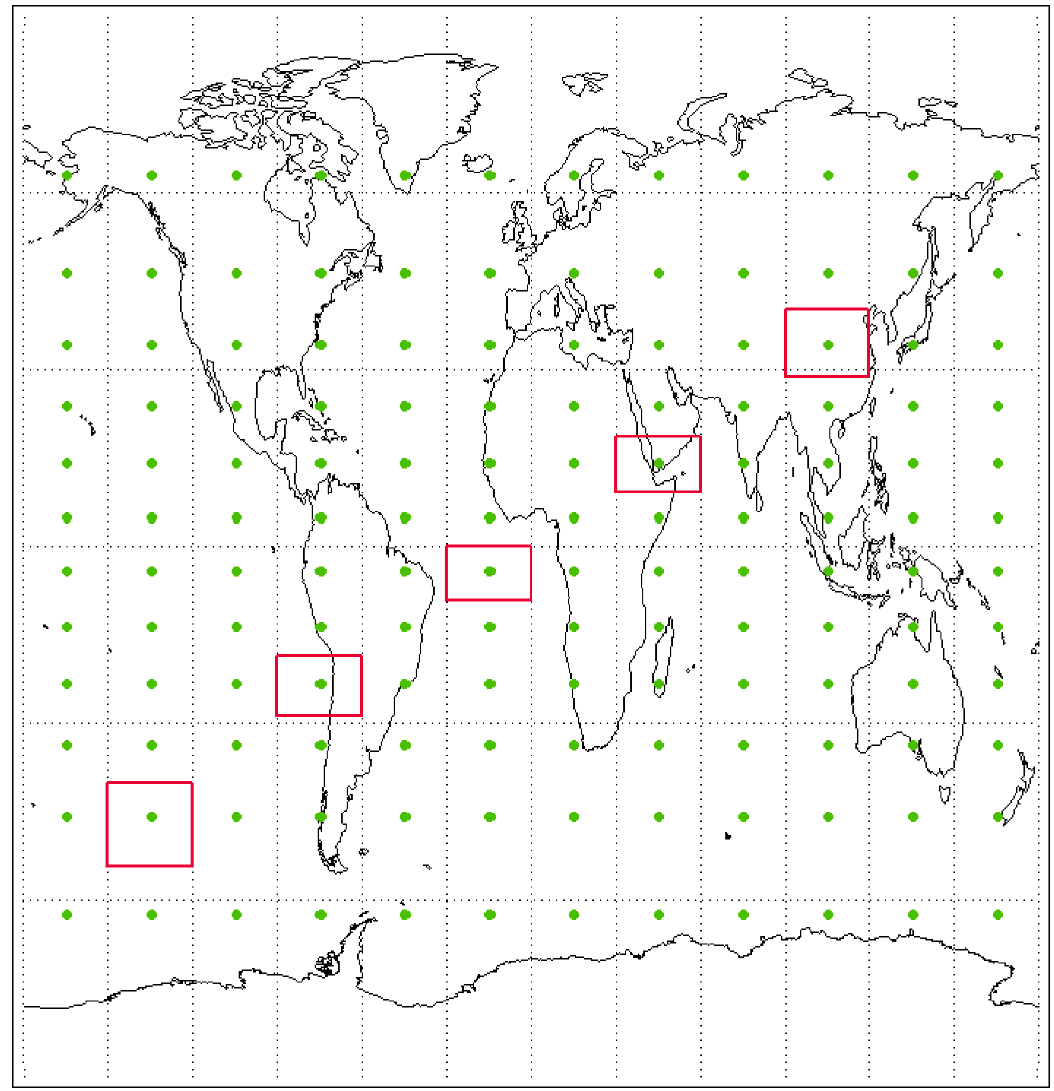
Example of input file for shower in region 7 and AMS bin 7

```
RUNNR    10                                    run number
EVTNR    1                                     number of first shower event
NSHOW    10000                                 number of showers to generate
PRMPAR   14                                    particle type of prim. particle
ESLOPE   -2.7                                  slope of primary energy spectrum
ERANGE   2.718E0  2.718E0                      energy range of primary particle
THETAP   0.   70.                              range of zenith angle (degree)
PHIP     -180.   180.                          range of azimuth angle (degree)
SEED     1   0   0                             seed for 1. random number sequence
SEED     2   0   0                             seed for 2. random number sequence
OBSLEV   110.E2                                observation level (in cm)
FIXCHI   0.                                    starting altitude (g/cm**2)
MAGNET   27.1   36.2                           magnetic field M = 7, AMS region
HADFLG   0  0  0  0  0  2                      flags hadr.interact.&fragmentation
ECUTS    0.3  0.3  0.003  0.003                energy cuts for particles
MUADDI   T                                     additional info for muons
MUMULT   T                                     muon multiple scattering angle
ELMFLG   T   T                                 em. interaction flags (NKG,EGS)
STEPFC   1.0                                   mult. scattering step length fact.
RADNKG   200.E2                                outer radius for NKG lat.dens.distr.
ARRANG   0.                                    rotation of array to north
LONGI    T  20.   T  T                         longit.distr. & step size & fit & out
ECTMAP   1.E3                                  cut on gamma factor for printout
MAXPRT   100                                   max. number of printed events
DIRECT   /home/EUSO/corsika/corsika-6735/run/pavol/ams_back7/          output directory
DATBAS   T                                     write .dbase file
THIN     1.E-6 1.E5   0.E0                     thinning electron
THINH    0.1  10.                              hardon thinning
CERARY   10 8 1200. 1500. 80. 50.              Cherenkov detector grid (cm)
CWAVLG   300. 450.                             Cherenkov wavelength band (nm)
CERSIZ   5.                                    bunch size Cherenkov photons
CERFIL   F                                     Cherenkov output file
CSCAT    5 1000. 1000.                         scatter Cherenkov events (cm)
USER     pavol                                 user
DEBUG    F  6  F  1000000                      debug flag and log.unit for out
EXIT                                           terminates input
```

1 point is ⟶ ~ 6GB data

Production of JEM EUSO background





A_i = 1 sr $\rightarrow$ i.e. Earth is covered by 12 rings, every ring cover/has area 1 sr

Δ lat = 30^o $\rightarrow$ every ring is divided to 12 part

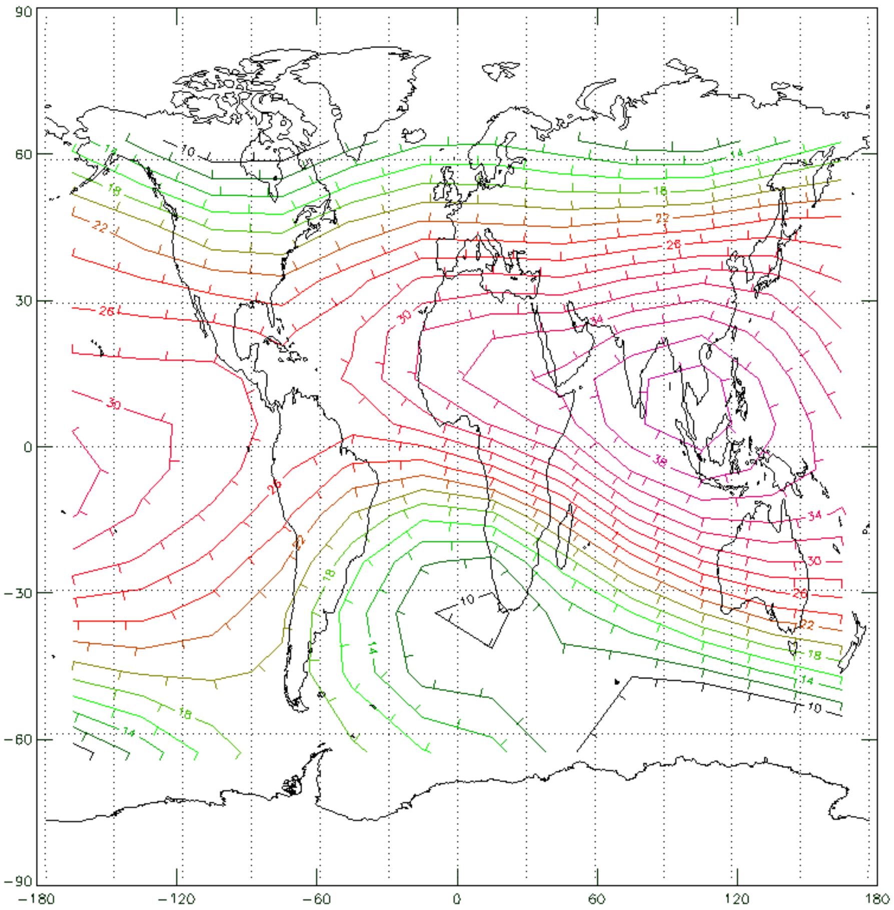
N = 12 x 12 = 144 points

Selected points – marked by green dots

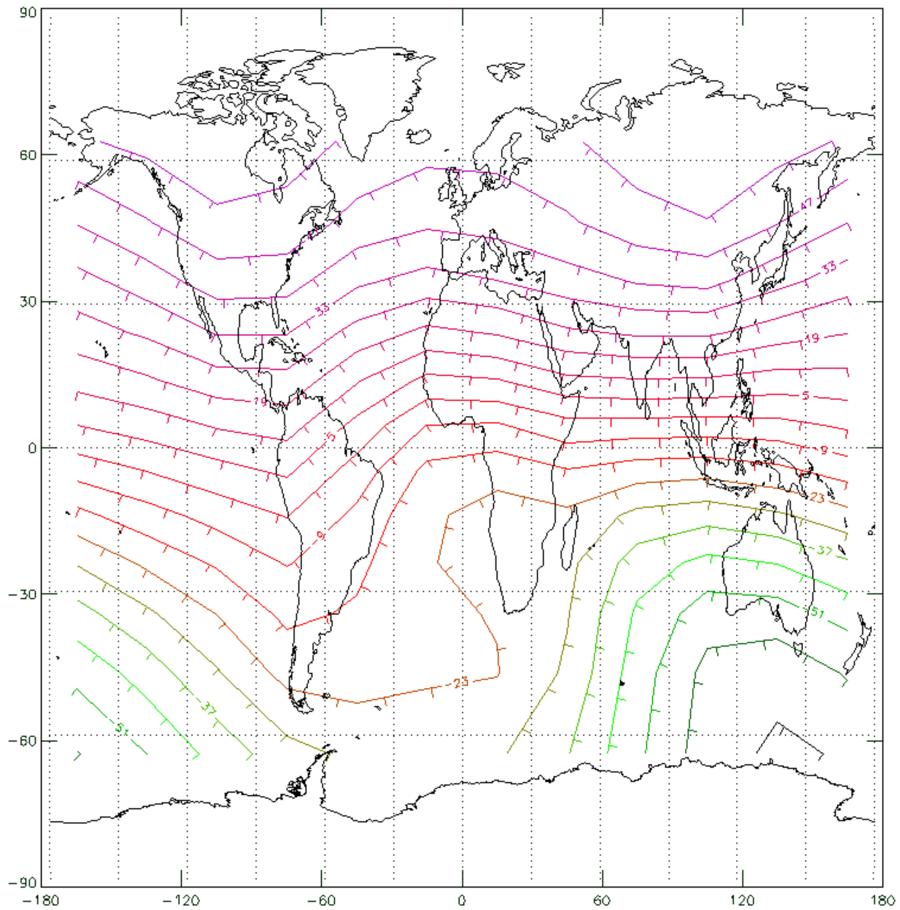
Red squares have 1/12 steradian everyone

Production of JEM EUSO background

Geomagnetic field – model GRF11



B_x [μG]



B_z [μG]

Production of JEM EUSO background

Presented Corsika simulations was done by code compiled with

-QGSII model

- fluka model

- cerenkov light

  - parameter CERARY 10 8 1200. 1500. 80. 50.

- thining

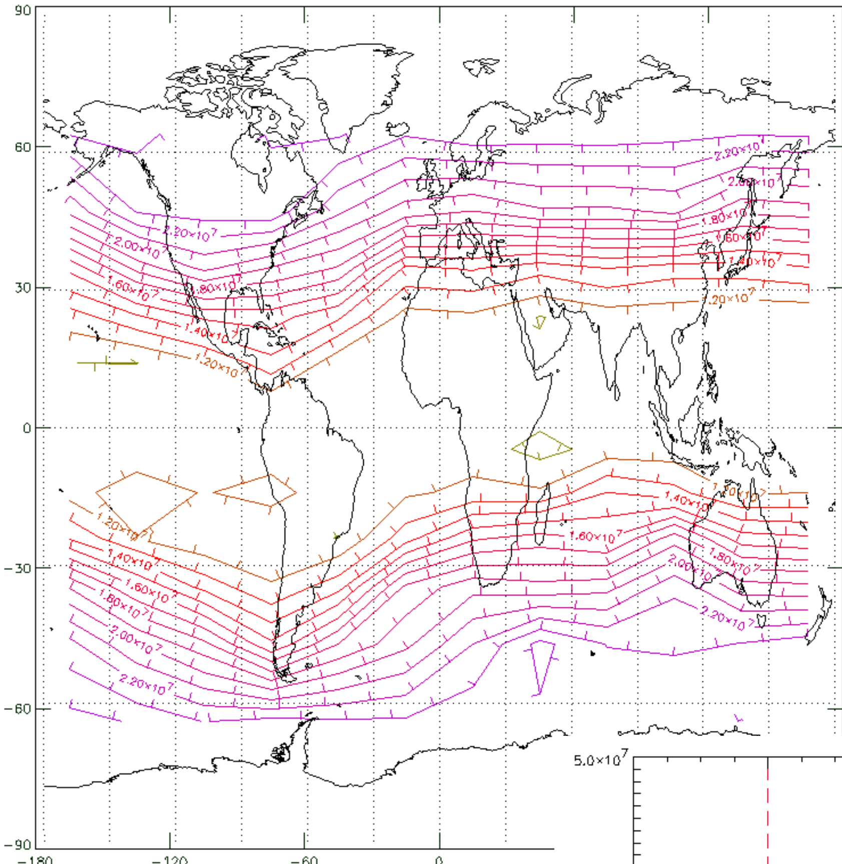
  - parameter THIN 1.E-6 1.E5 0.E0

  - parameter THINH 0.1 10.

- NSHOW – 100 showers for every energy (monoenergetic injection of AMS bins energies) for range of angles $\Theta = 0^o – 70^o$, $\Phi = -180^o – 180^o$ is averaged from *.long output file* to one average shower which is used in evaluation of background.

Selection of QGSII and Fluka for code compilation and input parameters of thining and Cherenkov light detector (detector grid) for Corsika simulation are maybe not optimal – was choose just as possible combination of parameters for method testing.

Cherenkov light

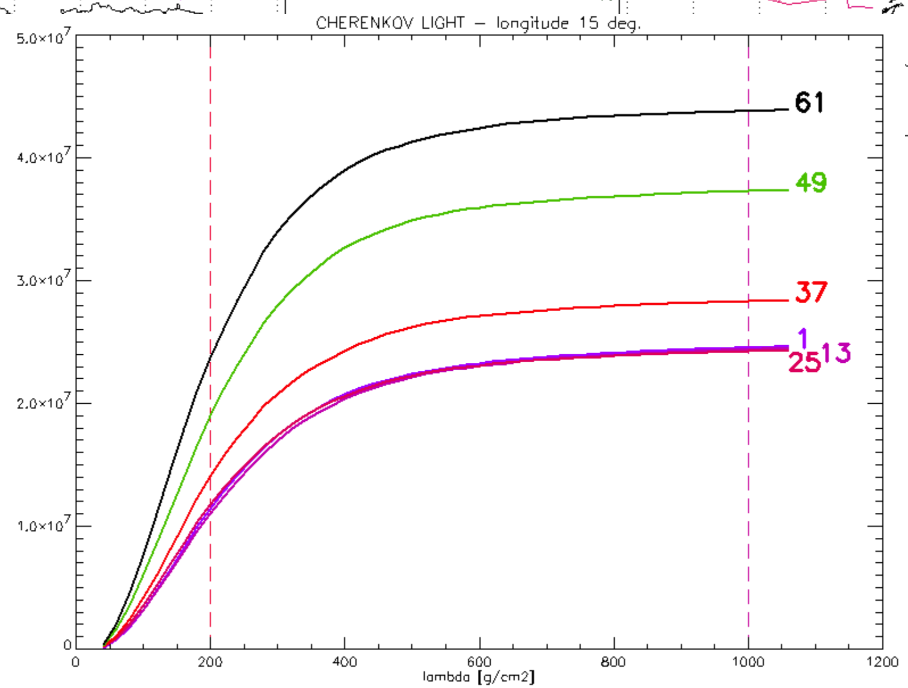


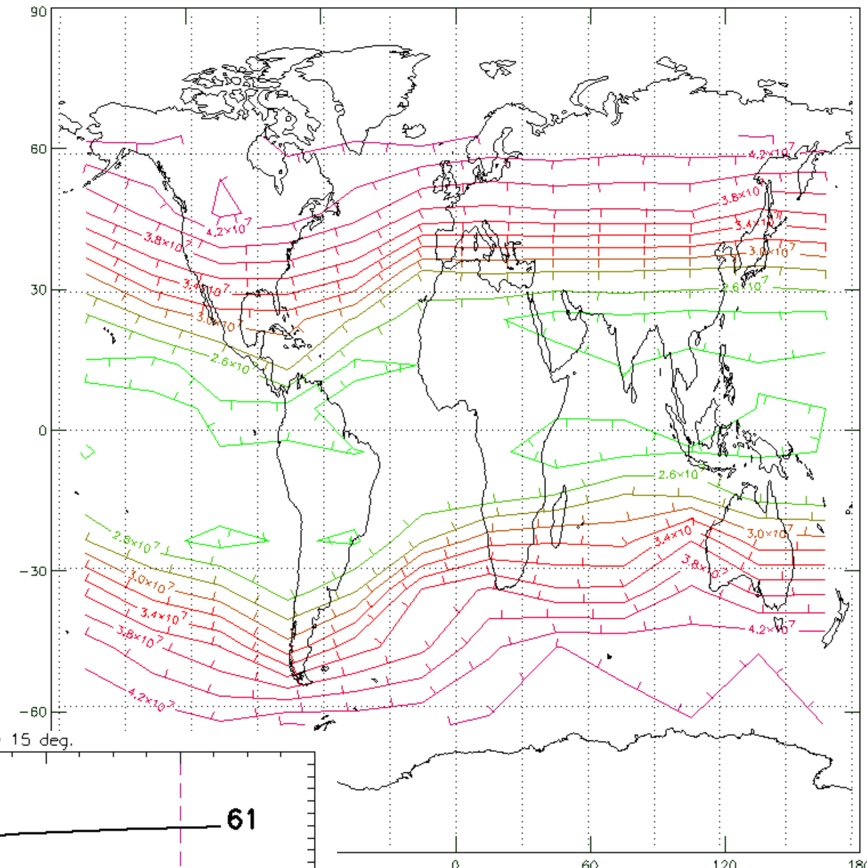
200 g/cm^2

Cherenkov light at 200 g/cm^2 upleft here.

Cherenkov light at set of selected points on Earth with geographic longitude 15° and latitudes in center of 1 steradians ring i.e. geo. latitudes = 4.58°, 13.86°, 23.54°, 34.03°, 46.13°, 62.73°

(bottom center figure)

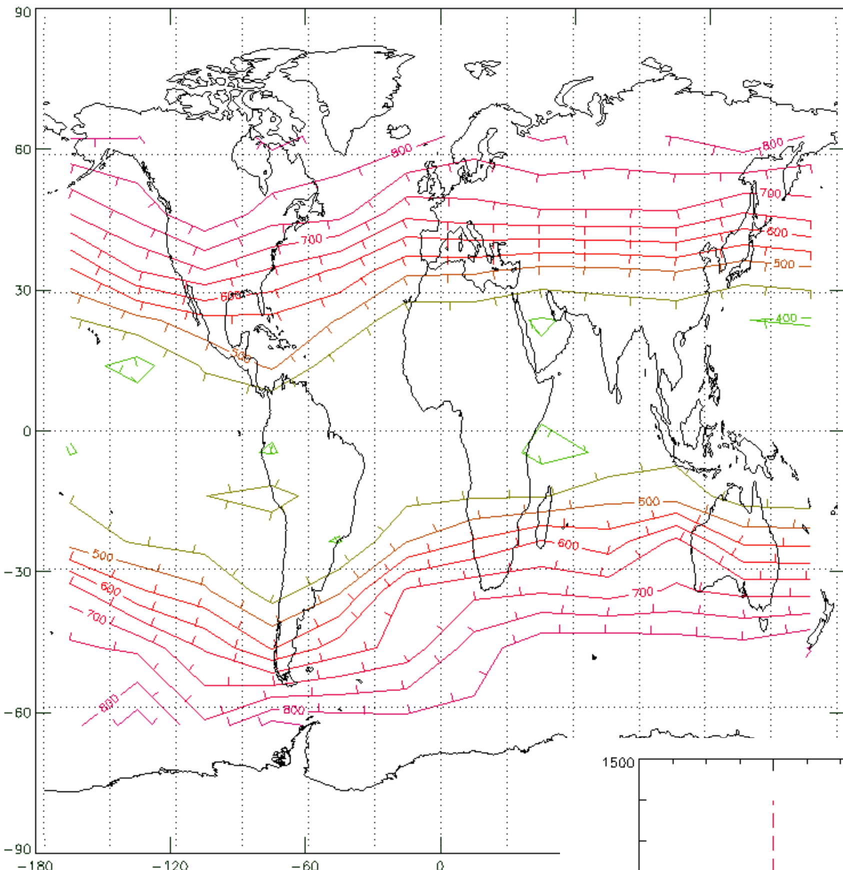




1000 g/cm^2

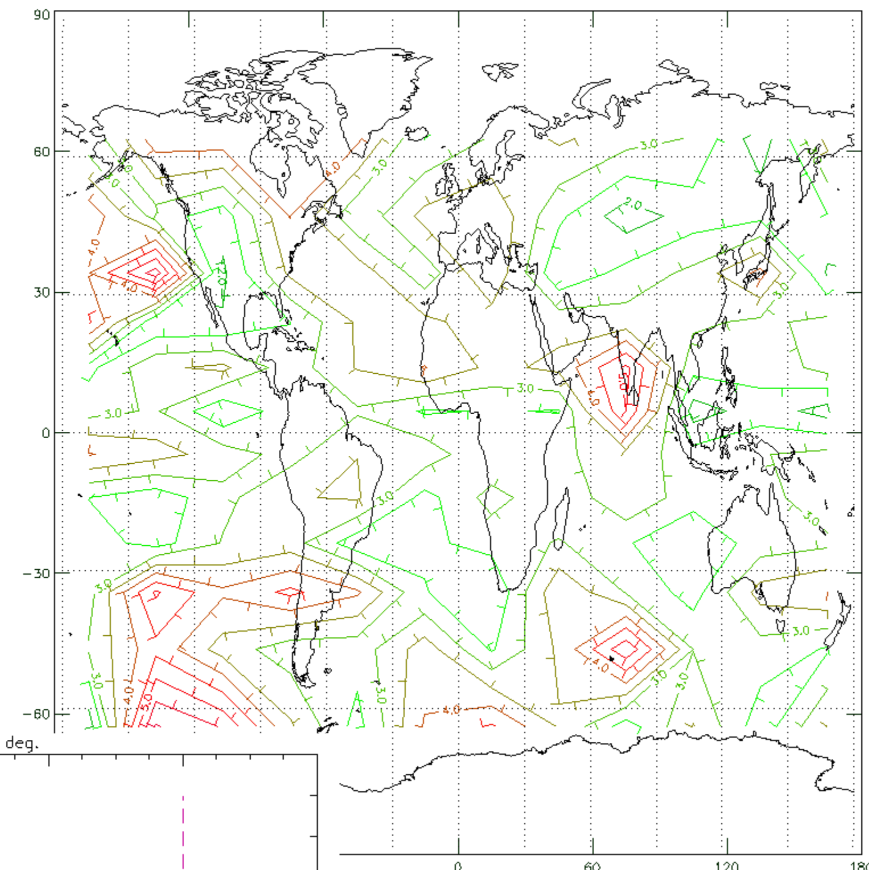
Cherenkov light at 1000 g/cm^2 upright here.

Electrons



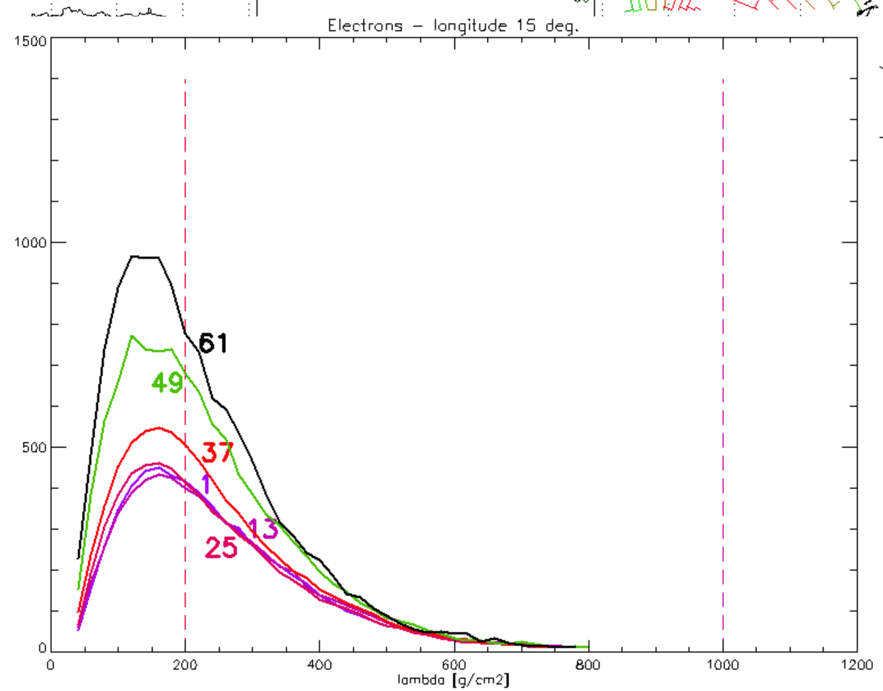
$200\ g/cm^2$

e^- at $200\ g/cm^2$ upleft here.



$1000\ g/cm^2$

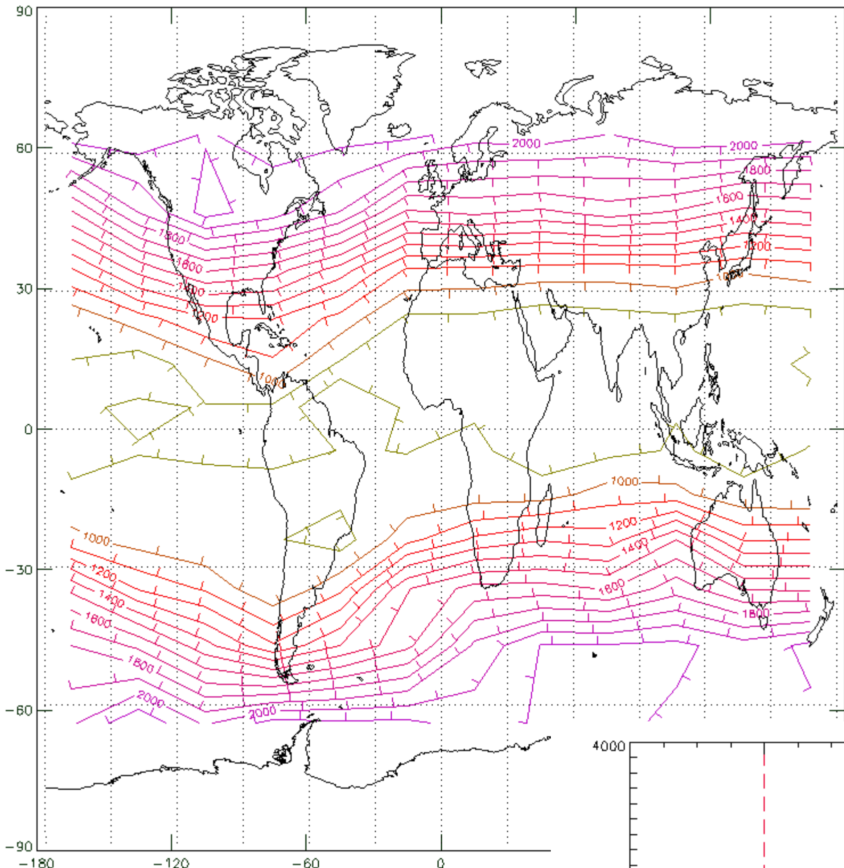
e^- at $1000\ g/cm^2$ upright here.



e^- at set of selected points on Earth with geographic longitude 15° and latitudes in center of 1 steradians ring i.e. geo. latitudes = 4.58°, 13.86°, 23.54°, 34.03°, 46.13°, 62.73°

(bottom center figure)

Charged particles

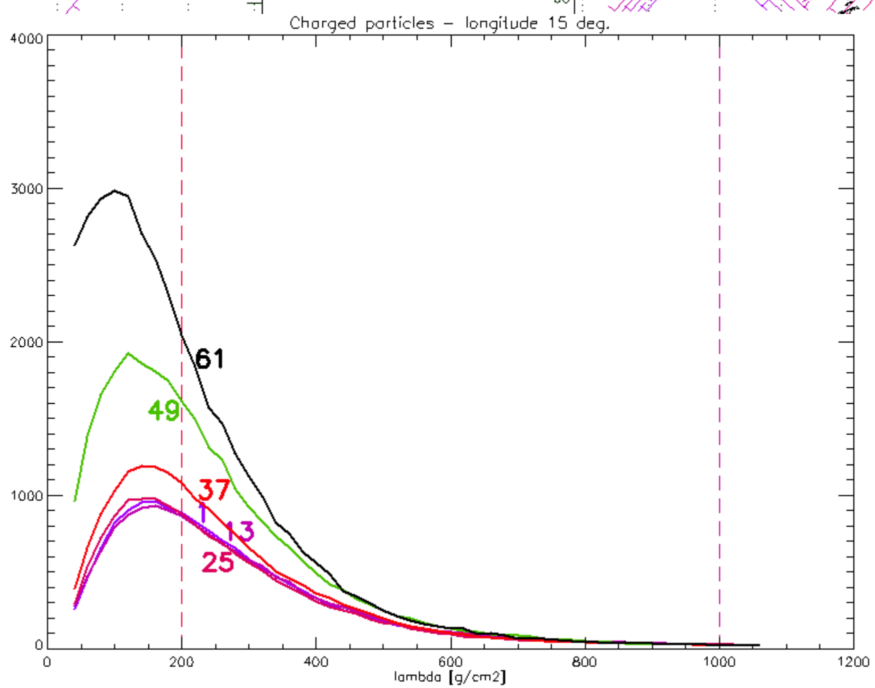


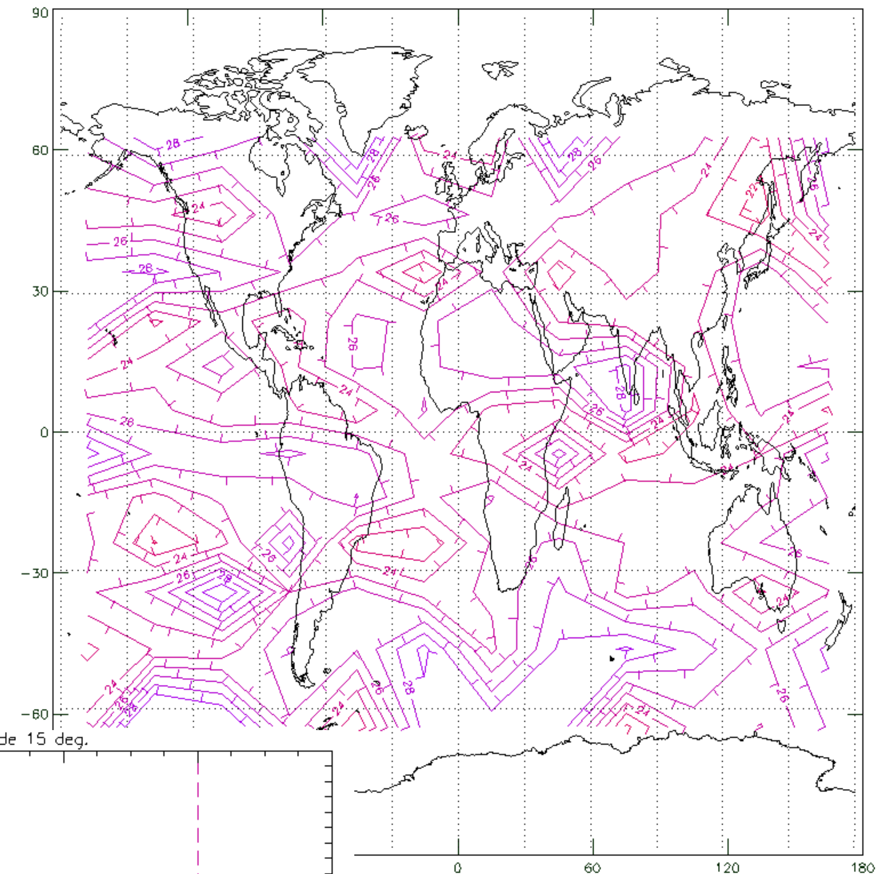
200 g/cm^2

Charged particles at 200 g/cm^2 upleft here.

Charged particles at set of selected points on Earth with geographic longitude 15° and latitudes in center of 1 steradians ring i.e. geo. latitudes = 4.58°, 13.86°, 23.54°, 34.03°, 46.13°, 62.73°

(bottom center figure)

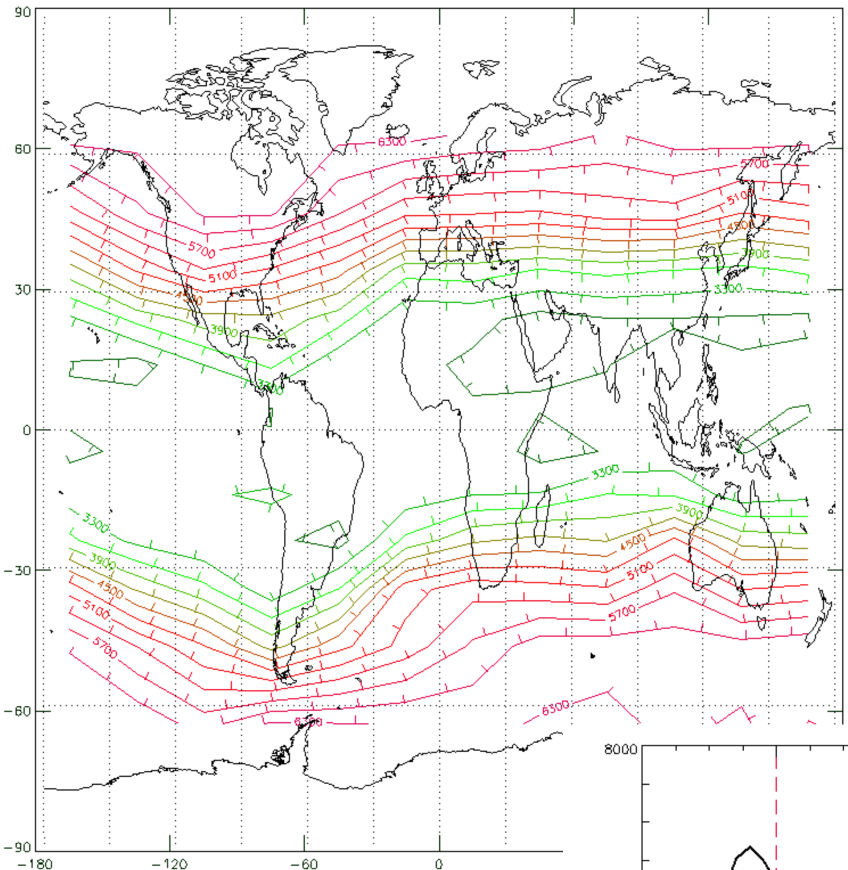




1000 g/cm^2

Charged particles at 1000 g/cm^2 upright here.

Gamma

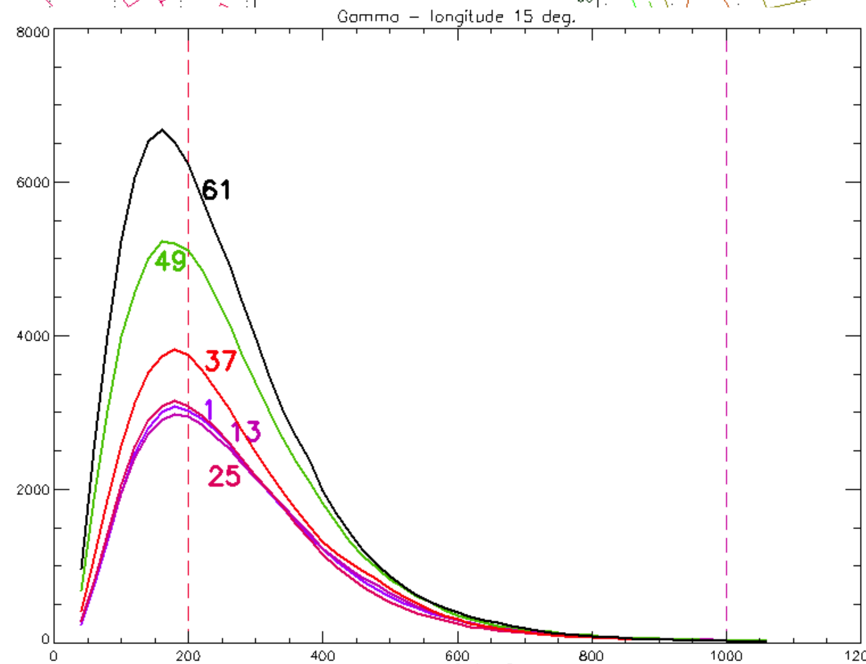


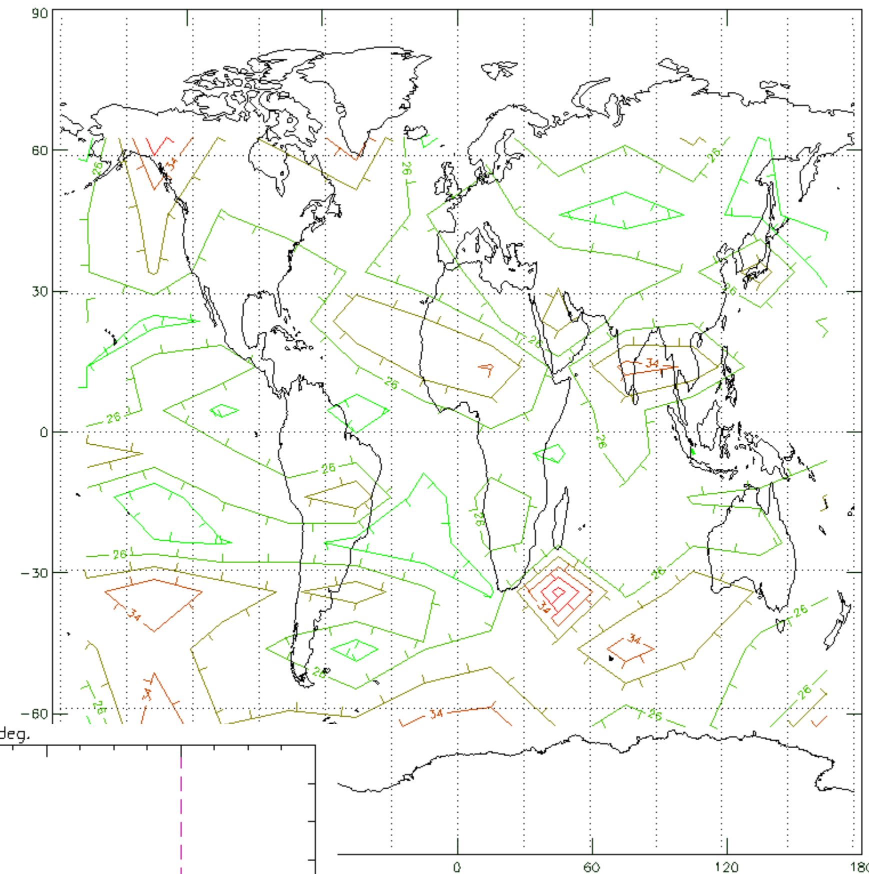
$200\ g/cm^2$

Charged particles at 200 g/cm^2 upleft here.

Charged particles at set of selected points on Earth with geographic longitude 15° and latitudes in center of 1 steradians ring i.e. geo. latitudes = 4.58°, 13.86°, 23.54°, 34.03°, 46.13°, 62.73°

(bottom center figure)

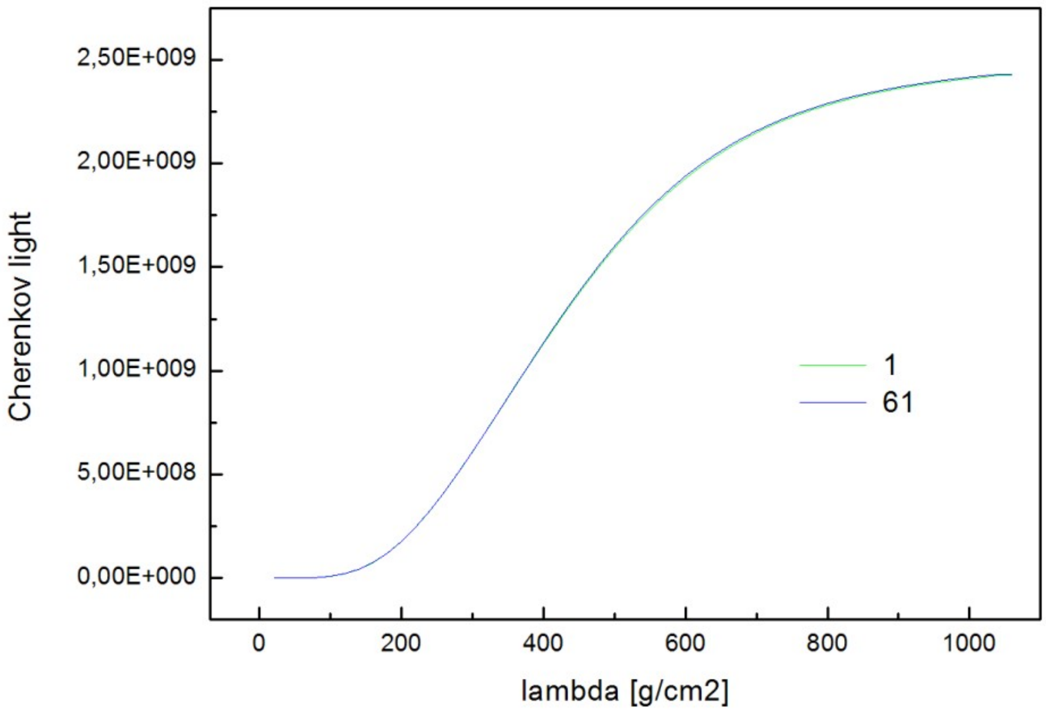


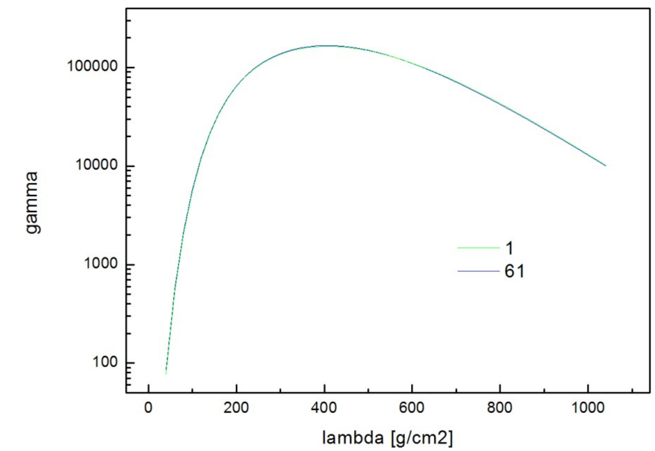


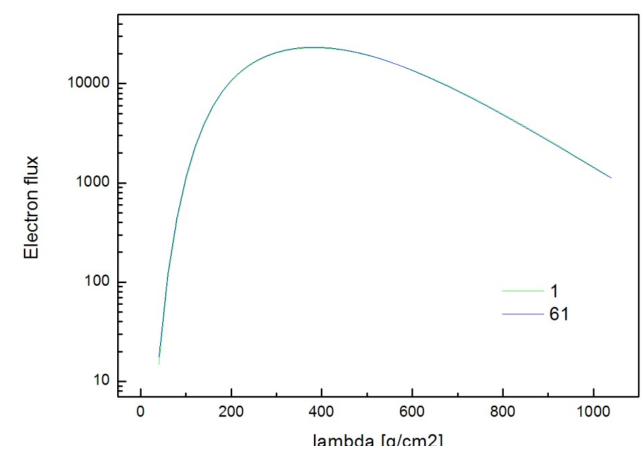
$1000\ g/cm^2$

Charged particles at 1000 g/cm^2 upright here.

Production of JEM EUSO background

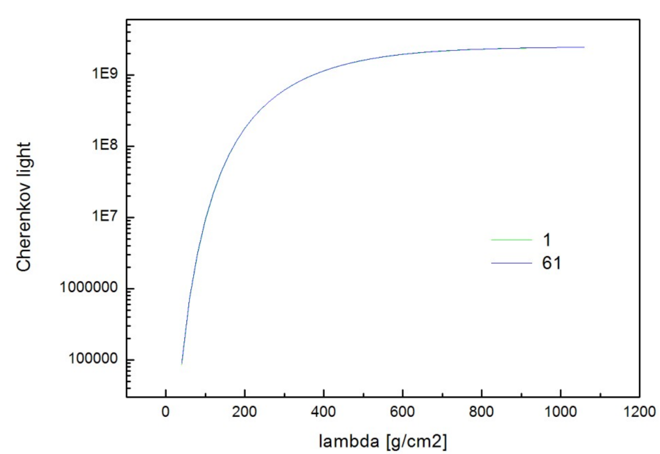


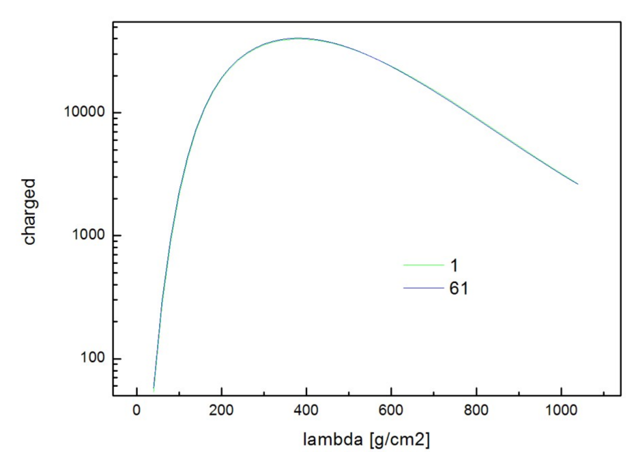




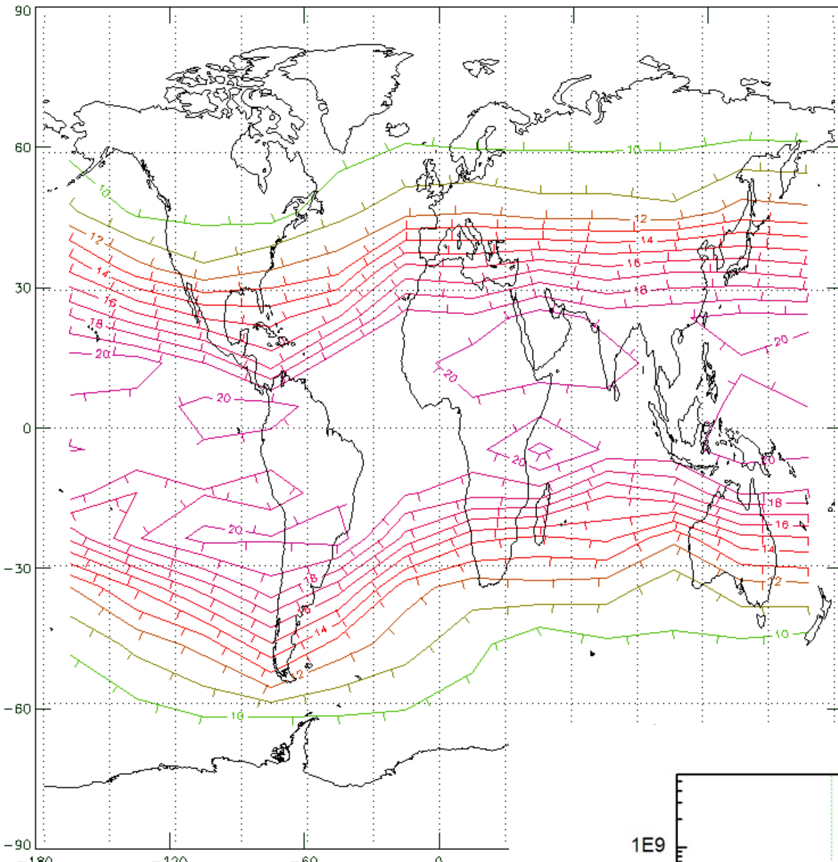
Comparison of Cherenkov light (up left), gamma (up right), electrons (middle right) altitude profile for points 1 and 61 for incoming particle with energy 1e14 eV – difference is negligible = just few percent due to statistics.

We can say/conclude that for energies over 1e14 is influence of Earth magnetosphere negligible.





Cherenkov light – background vs. 1e14 eV proton ratio

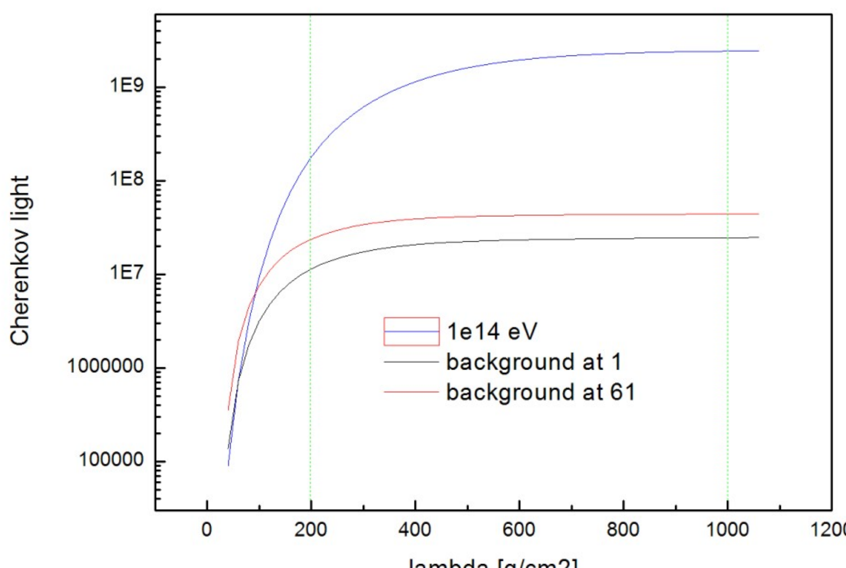


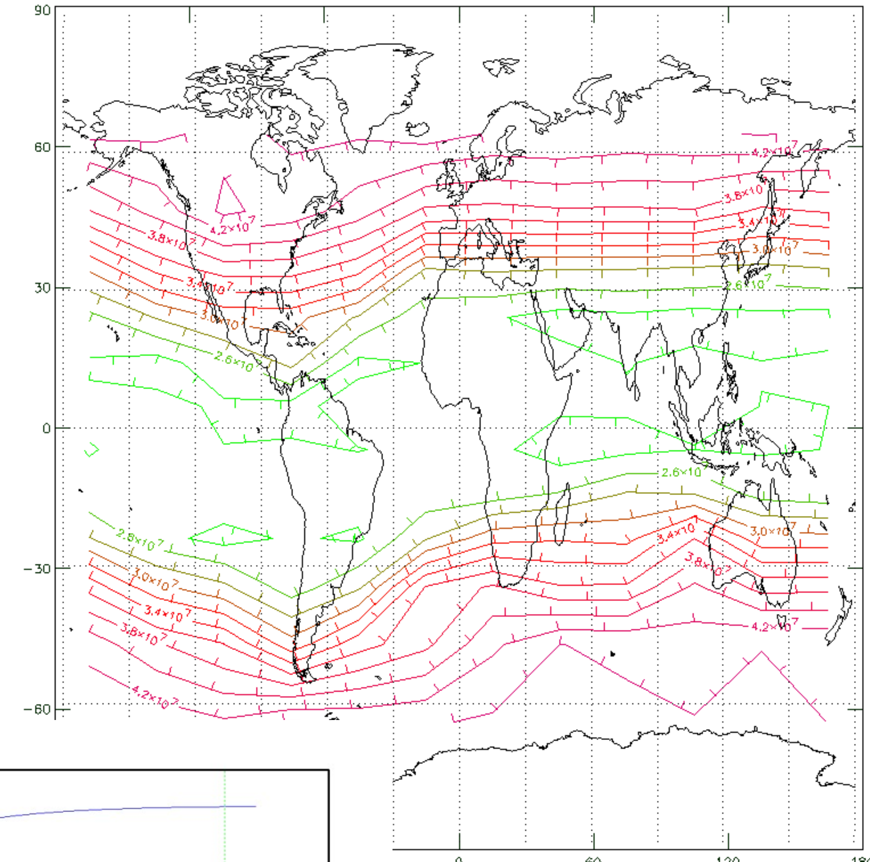
200 g/cm^2

Ratio between Cherenkov light flux at 200 g/cm^2 from background and from 1e14 eV proton, upleft here.

Cherenkov light from background at selected points on Earth with geographic longitude 15° and latitudes in center of 1 steradians ring i.e. geo. latitudes = 4.58°, 62.73° together with Cherenkov light from 1e14 eV proton

(bottom center figure)



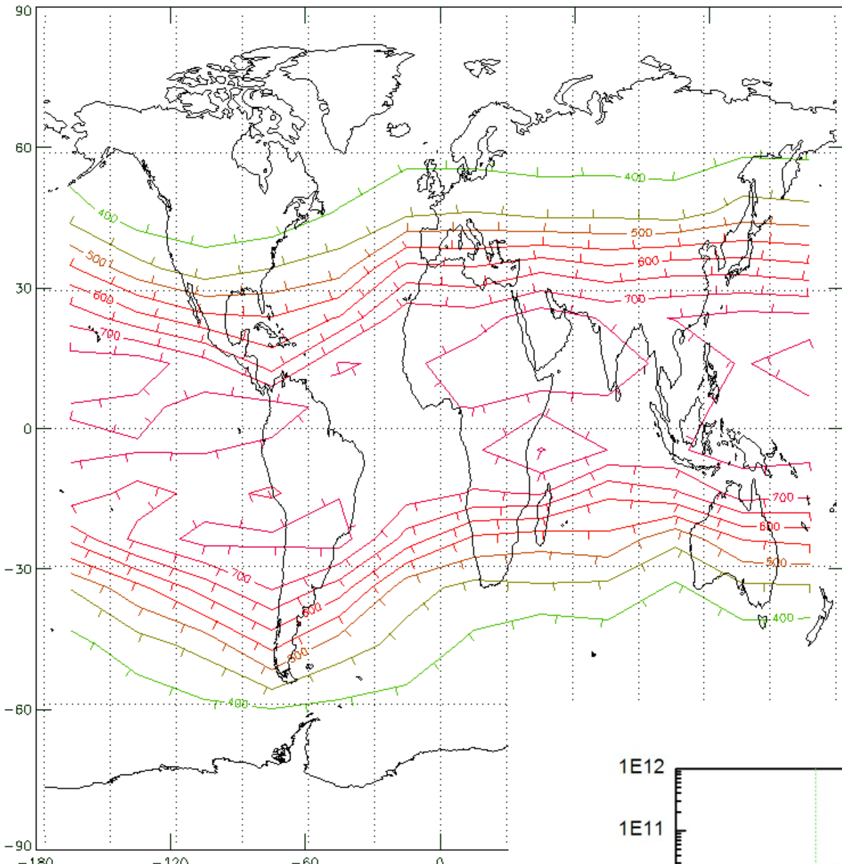


1000 g/cm^2

Ratio between Cherenkov light flux at 1000 g/cm^2 from background and from 1e14 eV proton

upright here.

Cherenkov light – background vs. 1e16 eV proton ratio

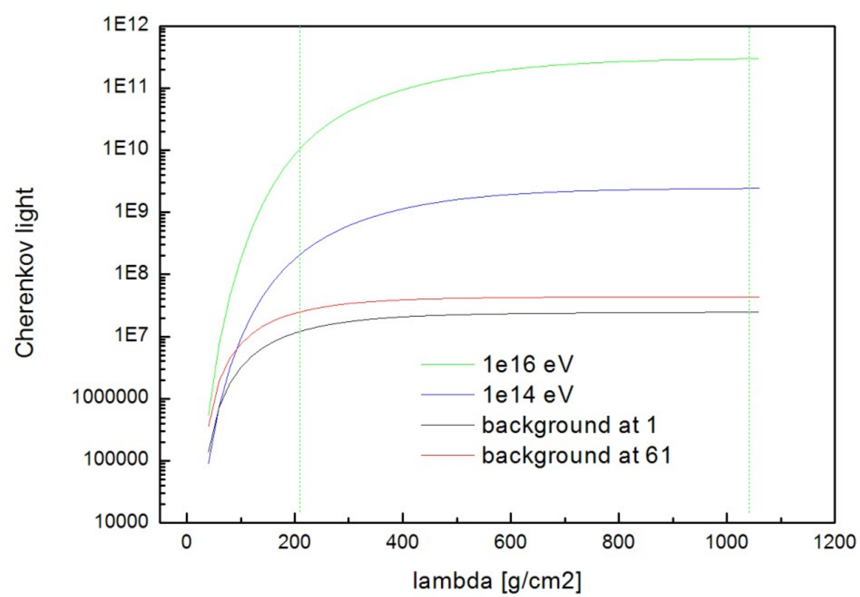


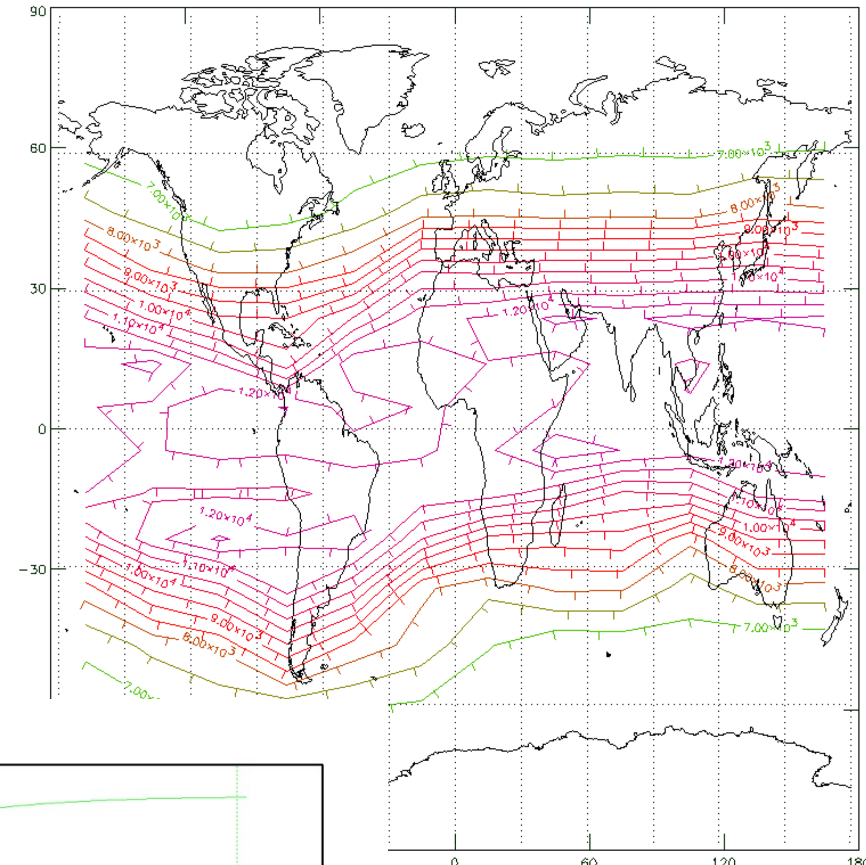
200 g/cm^2

Ratio between Cherenkov light flux at 200 g/cm^2 from background and from 1e16 eV proton, upleft here.

Cherenkov light from background at selected points on Earth with geographic longitude 15° and latitudes in center of 1 steradians ring i.e. geo. latitudes = 4.58°, 62.73° together with Cherenkov light from 1e14 eV and 1e16 eV proton

(bottom center figure)



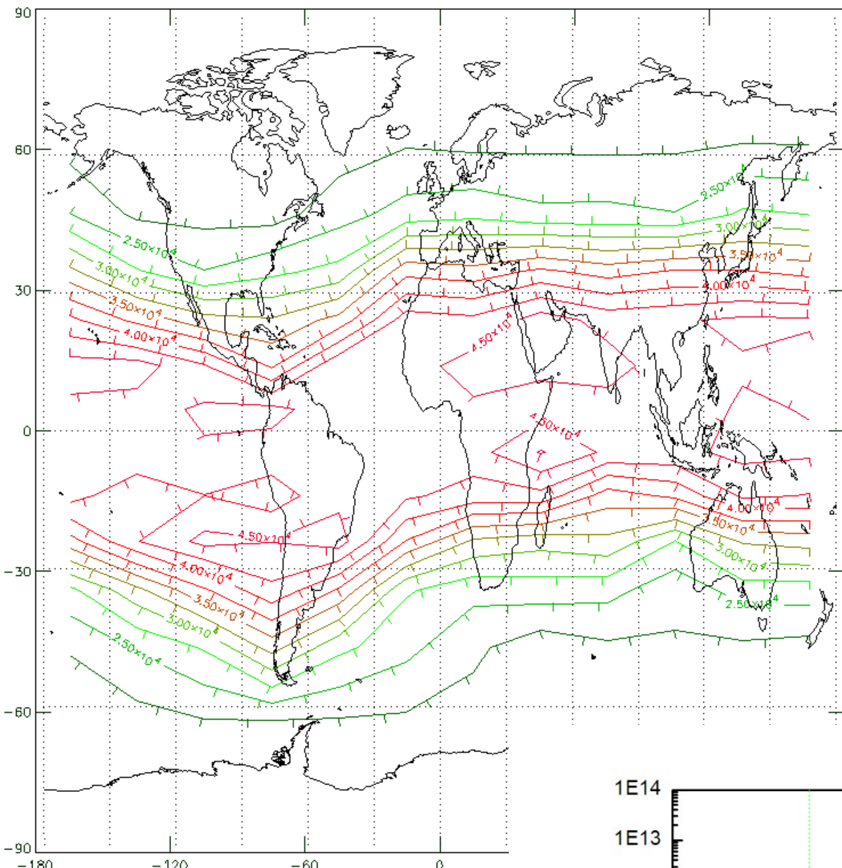


1000 g/cm^2

Ratio between Cherenkov light flux at 1000 g/cm^2 from background and from 1e16 eV proton

upright here.

Cherenkov light – background vs. 1e18 eV proton ratio

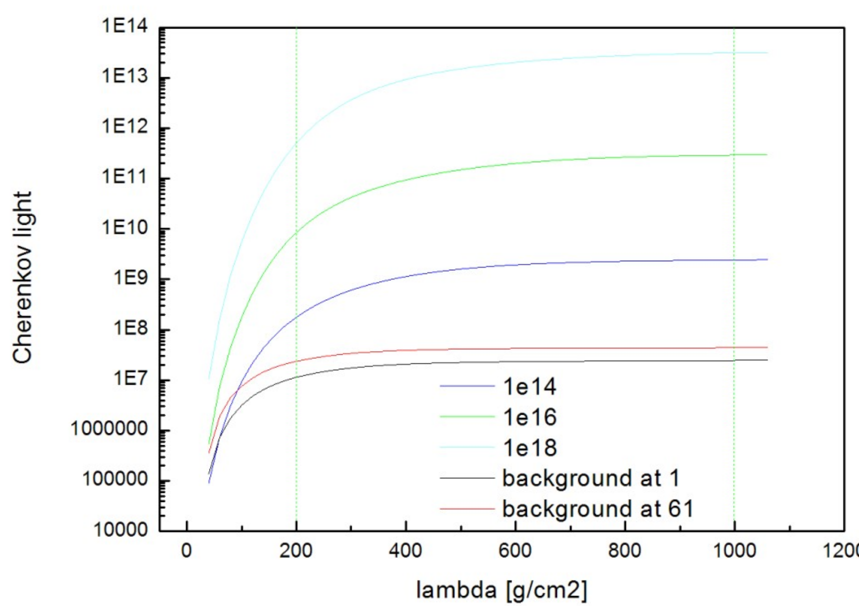


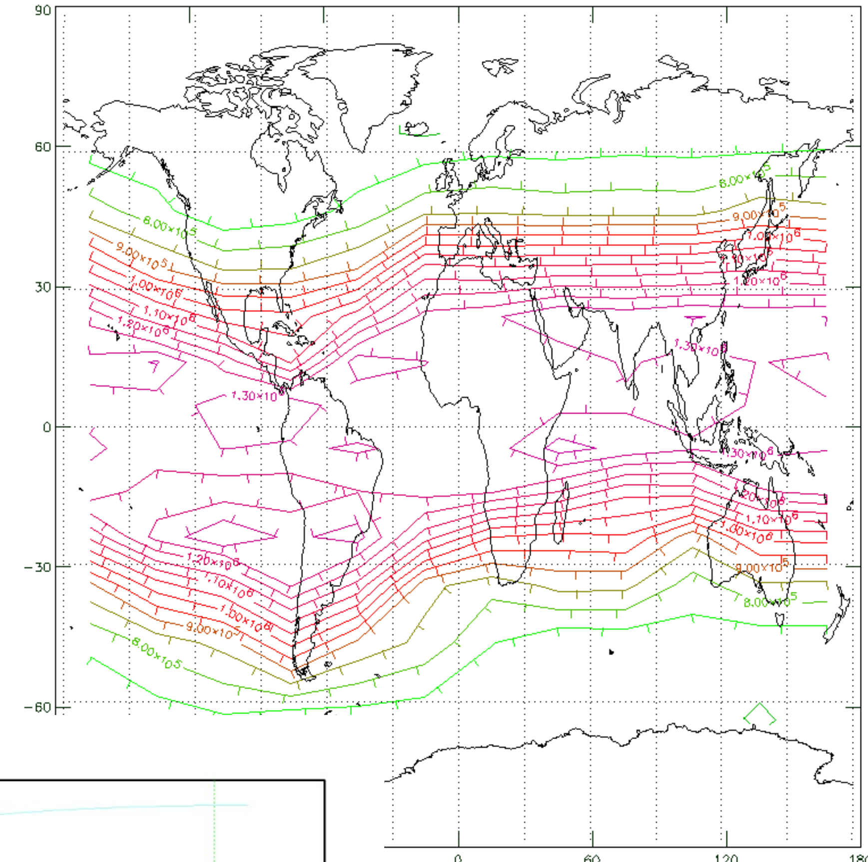
200 g/cm^2

Ratio between Cherenkov light flux at 200 g/cm^2 from background and from 1e18 eV proton, upleft here.

Cherenkov light from background at selected points on Earth with geographic longitude 15^o and latitudes in center of 1 steradians ring i.e. geo. latitudes = 4.58^o, 62.73^o together with Cherenkov light from 1e14 eV, 1e16 eV and 1e18 eV proton

(bottom center figure)



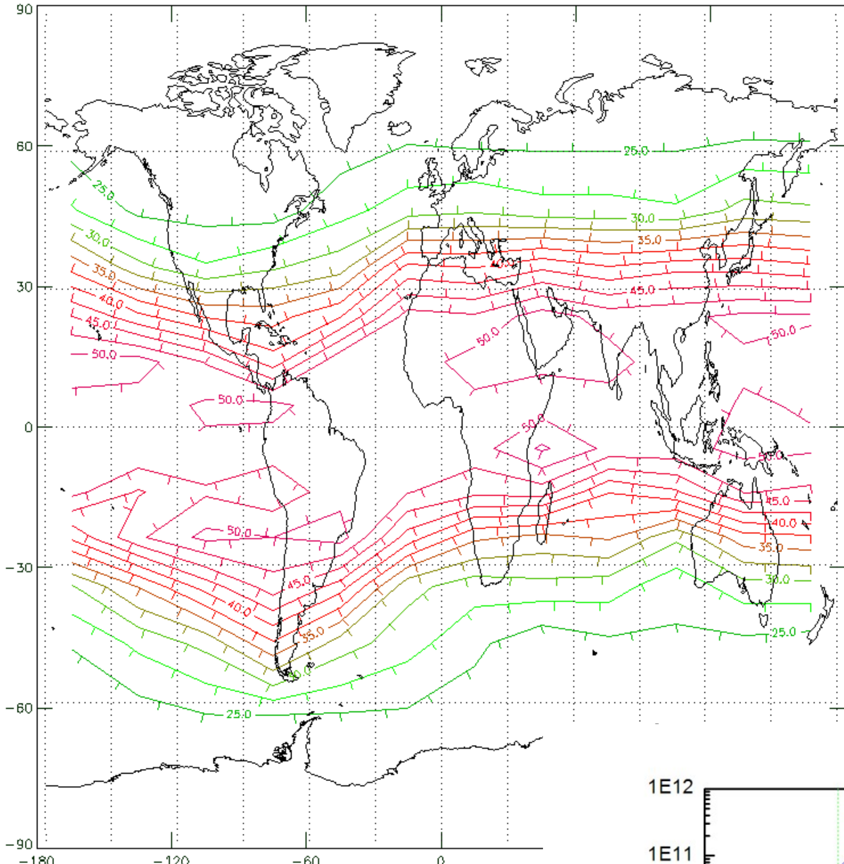


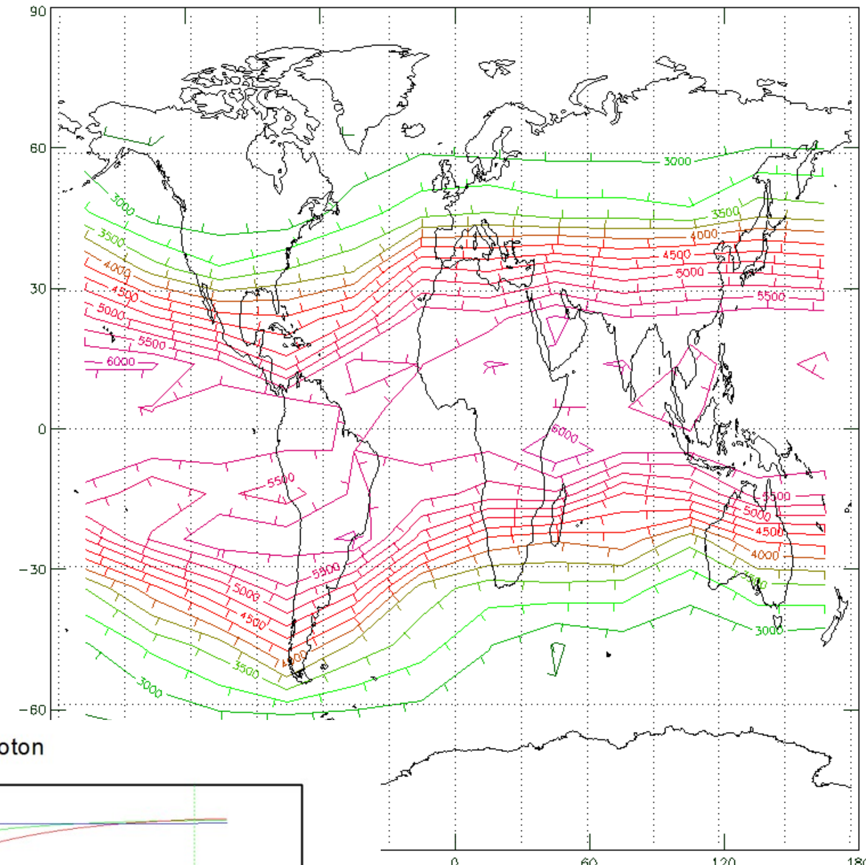
1000 g/cm^2

Ratio between Cherenkov light flux at 1000 g/cm^2 from background and from 1e18 eV proton

upright here.

Cherenkov light – 1e16 eV proton



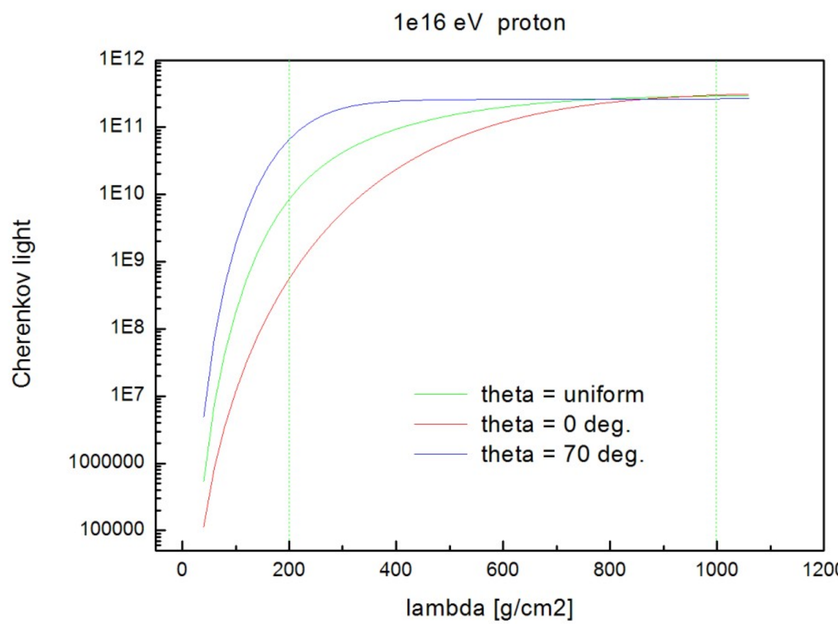


200 g/cm^2

Ratio between Cherenkov light flux at 200 g/cm^2 from background and from 1e16 eV proton for $\Theta = 0^{o}$ upleft here and $\Theta = 70^{o}$ upright here.

Cherenkov light from background for 1e16 eV proton for $\Theta = 0^{o},70^{o}$, and uniformly distributed in $\Theta = (0^{o},70^{o})$

(bottom center figure)



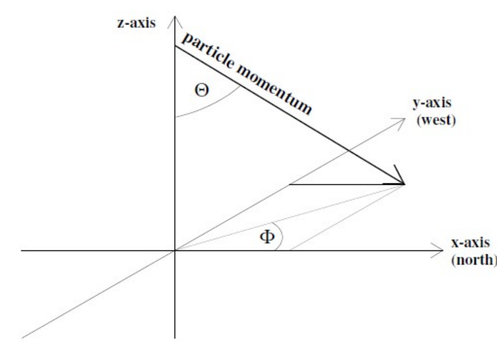


Figure 1: Coordinate system in CORSIKA.

Production of JEM EUSO background

Verification of method

1.6. DEFINITION OF COMMON OBSERVABLES 23

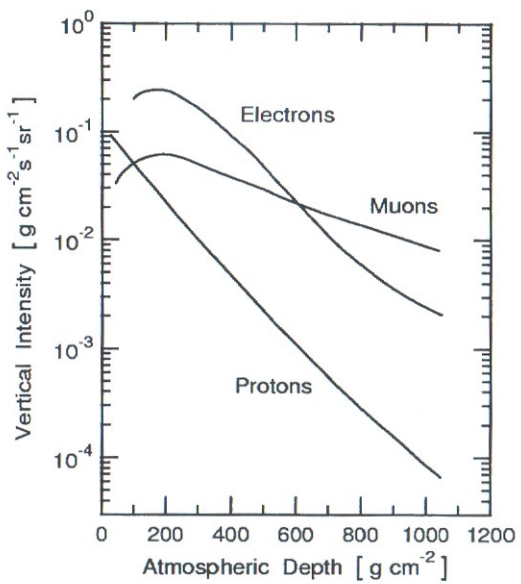
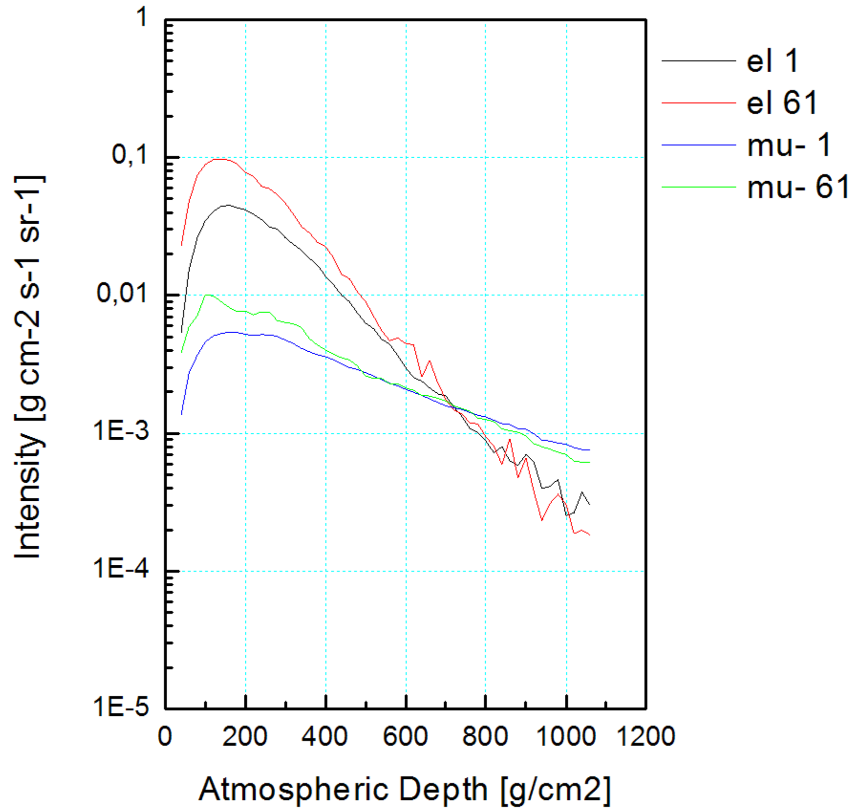


Figure 1.13: Altitude variation of the main cosmic ray components.

COSMIC RAYS AT EARTH, Researcher's Reference Manual and Data Book, Peter K. F. Grieder, Elsevier 2001, p. 23



Corsica background simulation for e^- an muons$^-$ near equatorial and near midle latitude position (geographic longitude 15° and latitudes in center of 1 steradians ring i.e. geo. latitudes = 4.58°, 62.73°)