1st Meeting of LIA - Subatomic Physics: from theory to applications

Cosmic radiation transport for aerospace applications

Technological Institute of Aeronautics - Brazil
Institute for Advanced Studies - Brazil
National d'Etudes et de Recherches Aérospatiales - France
University of Seville - Spain

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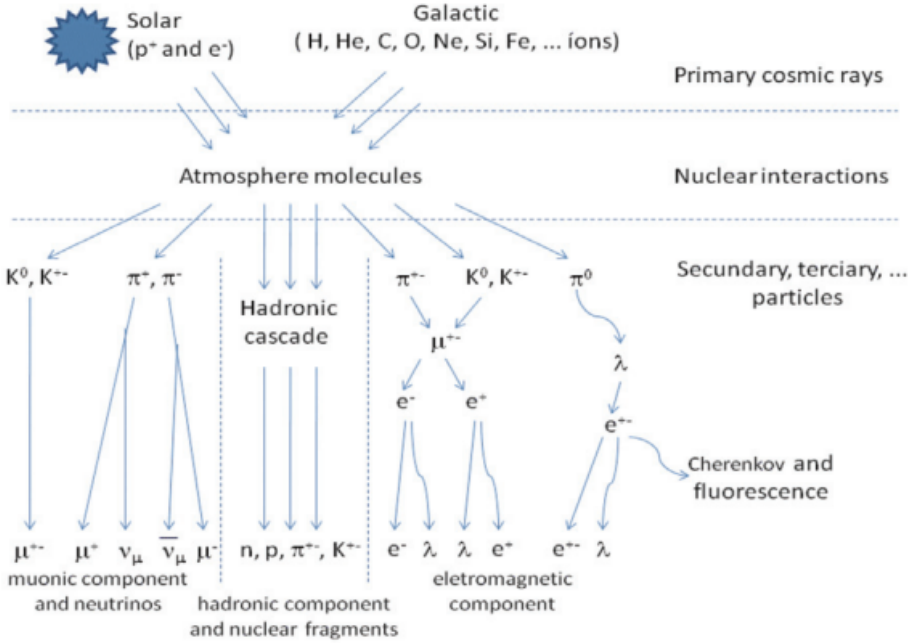
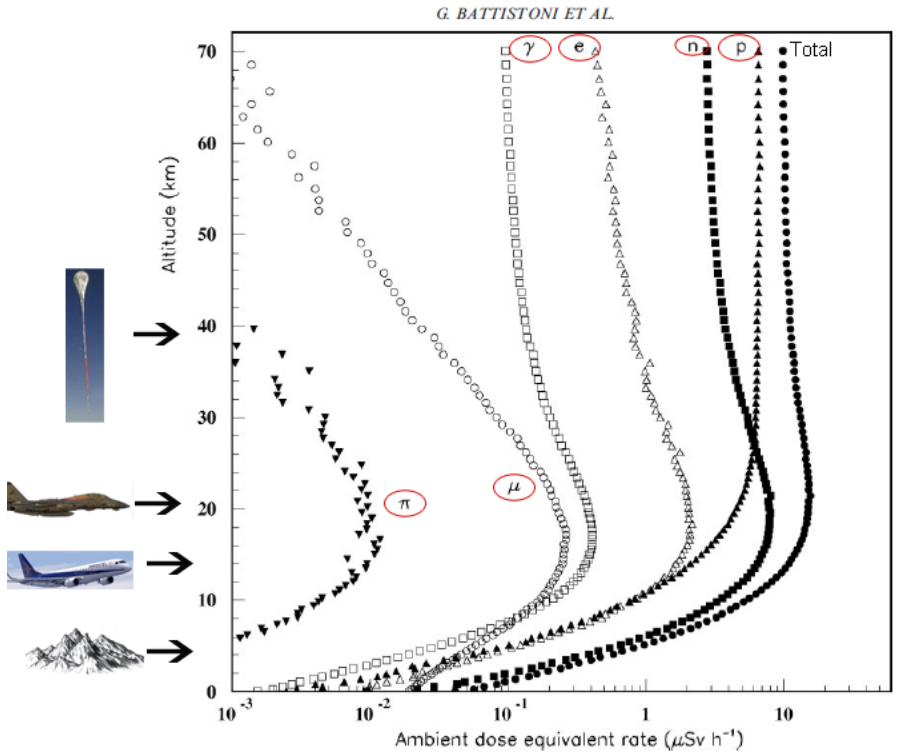
Introduction

- Aeronautics environment
  - Both the human being and onboard devices are inserted in this environment

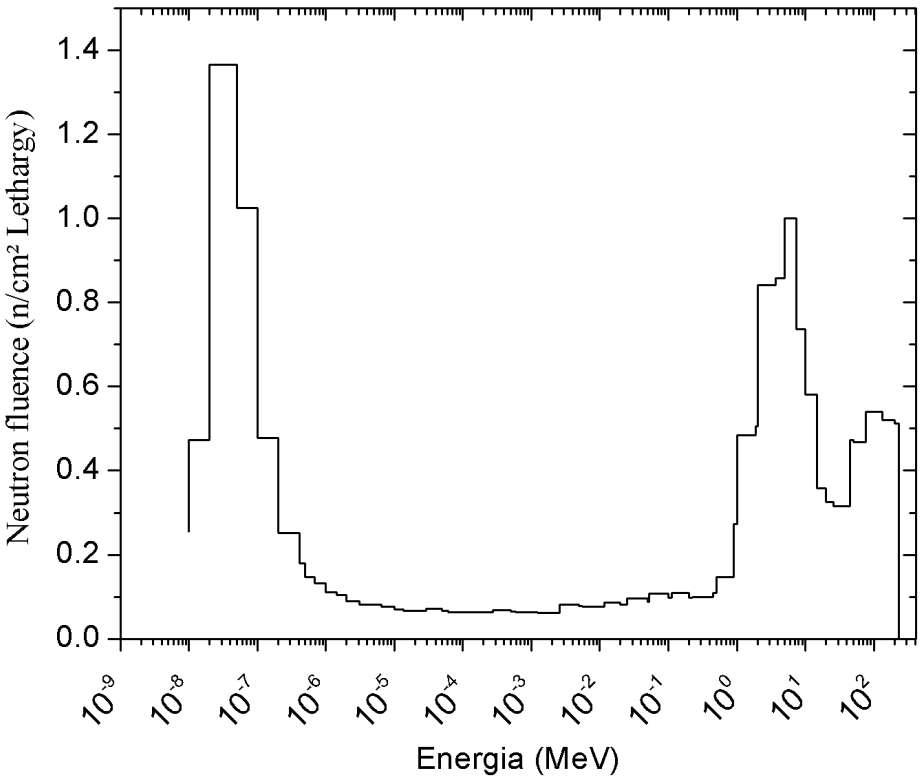


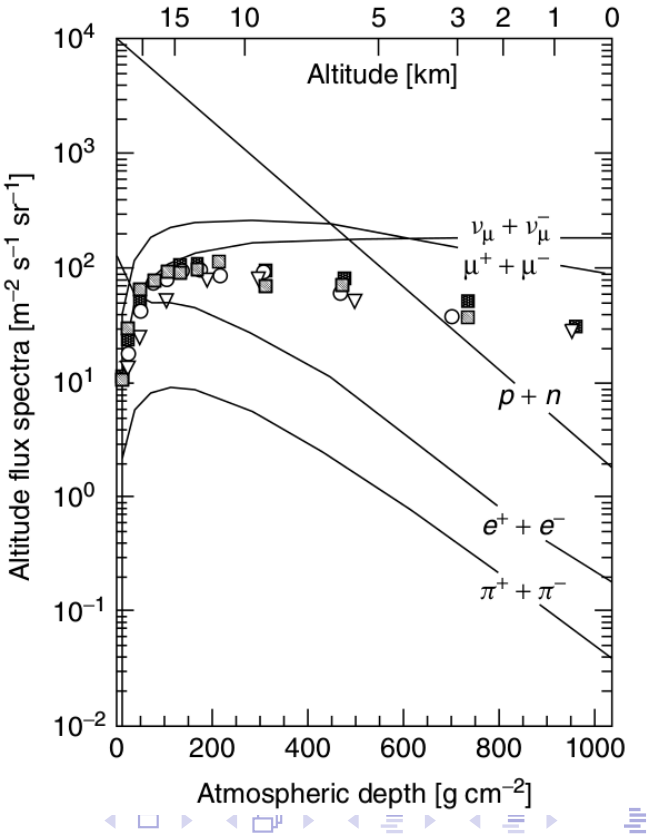


Neutrons are an important particle in dose levels received by aircraft crews and sensitive equipment

Motivation

- The interaction of primary cosmic rays with atmospheric atoms produces neutrons with high energy;
- Secondary neutrons produced with high energy are moderated by the atmosphere;
- The result is a wide spectrum of neutron energy.





Motivation

Great part of Brazil is subjected to the South Atlantic Magnetic Anomaly (SAMA).

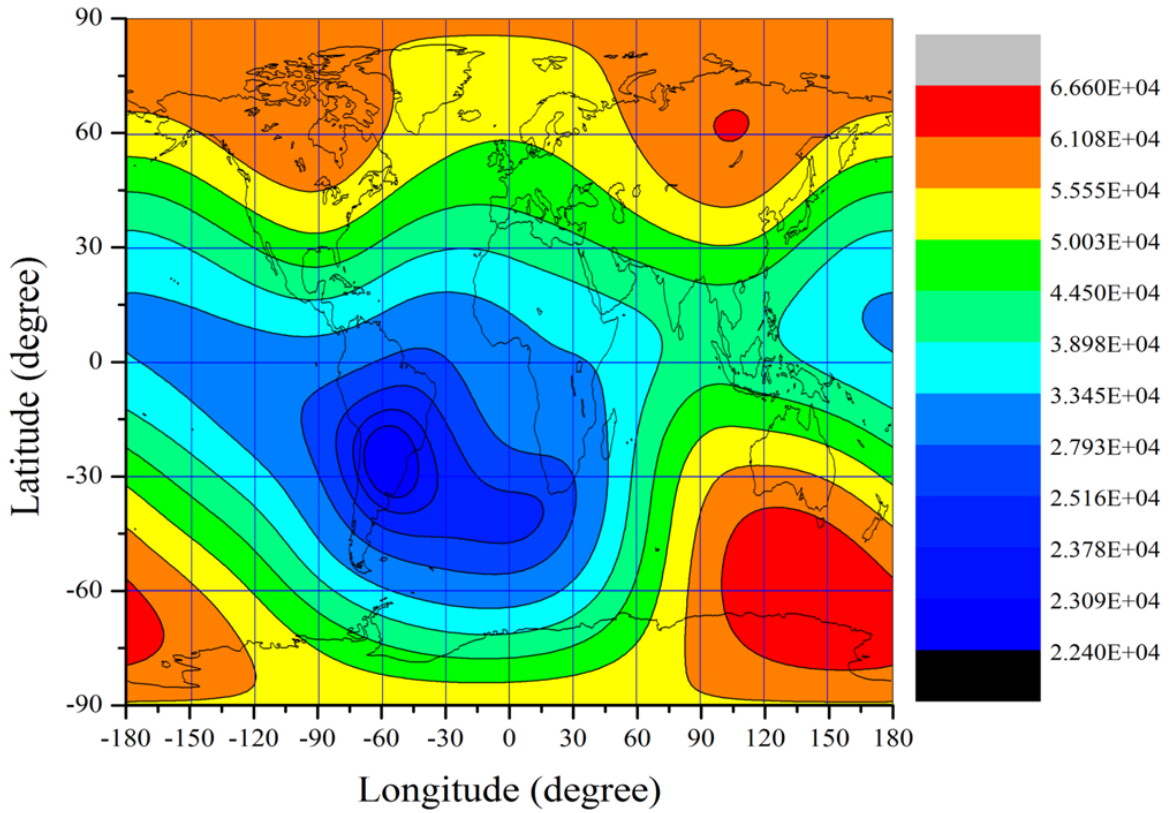
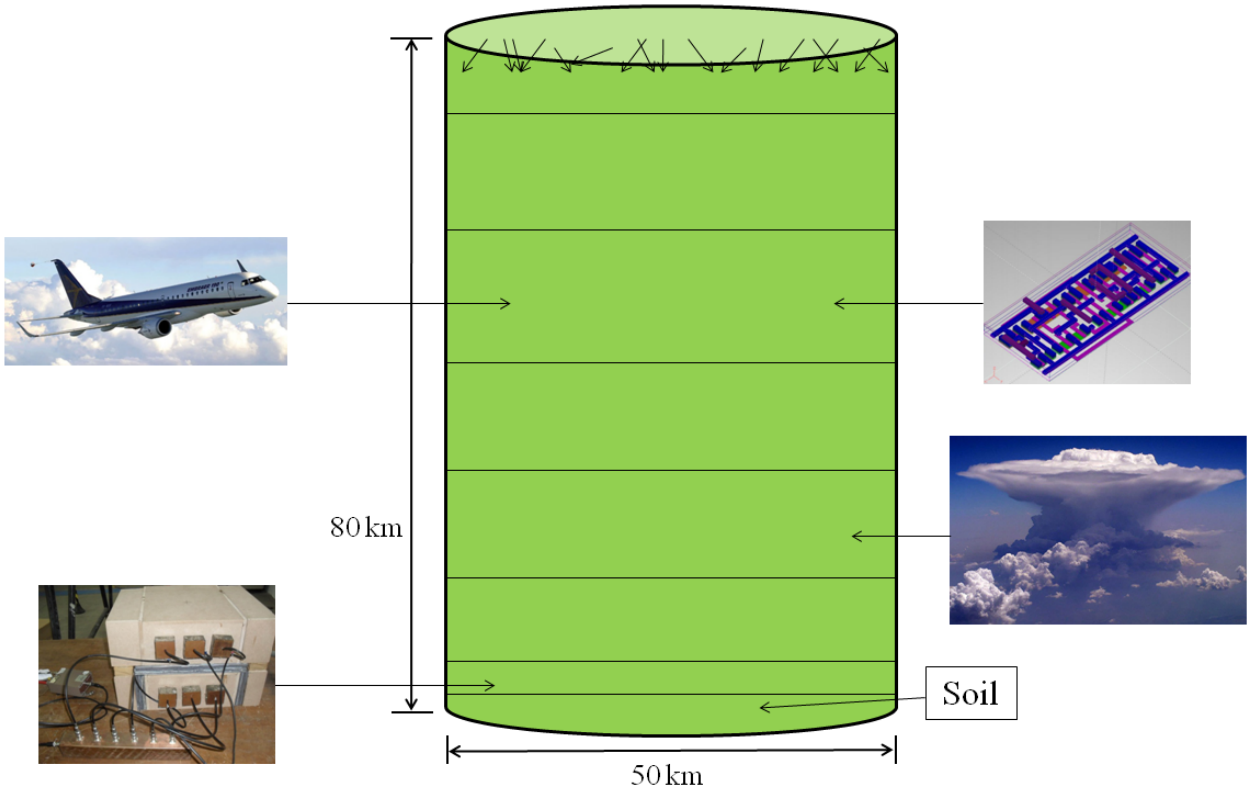


Figure: Earth's magnetic field (nT) map at 12 km altitude, for 10/01/2010 taken from IGRF2011.

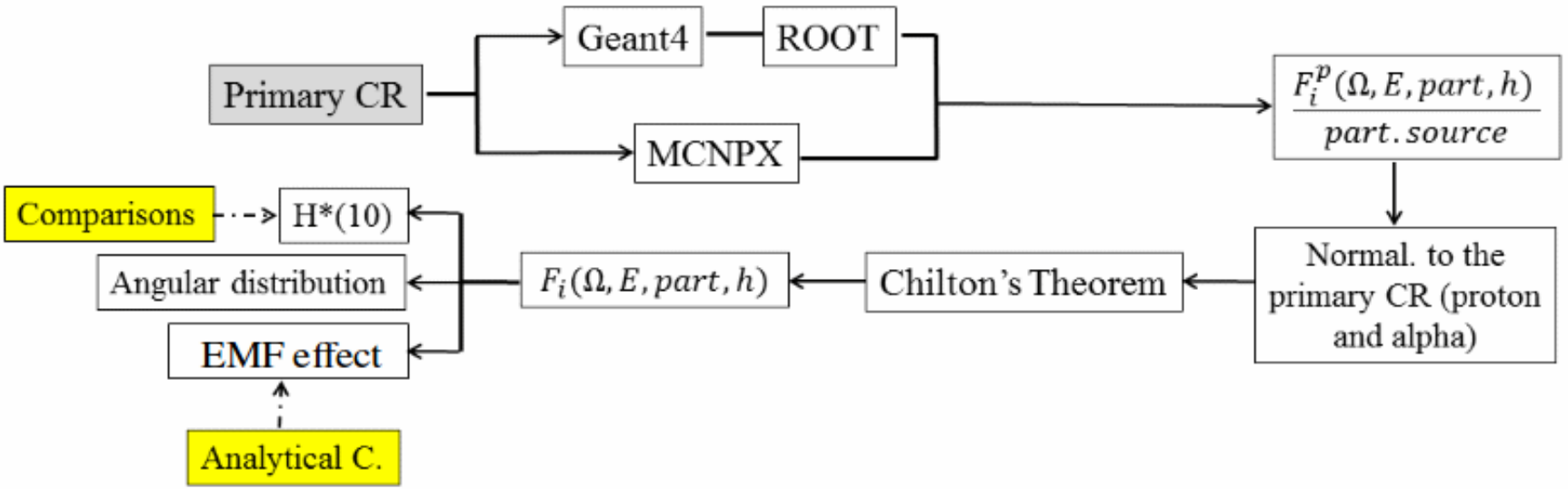
Atmospheric modeling

There is interest in modeling the atmosphere in the South Atlantic Magnetic Anomaly with MCNPX and GEANT4 in order to obtain the cosmic-ray-induced spectra as a function of altitude and develop further applications.

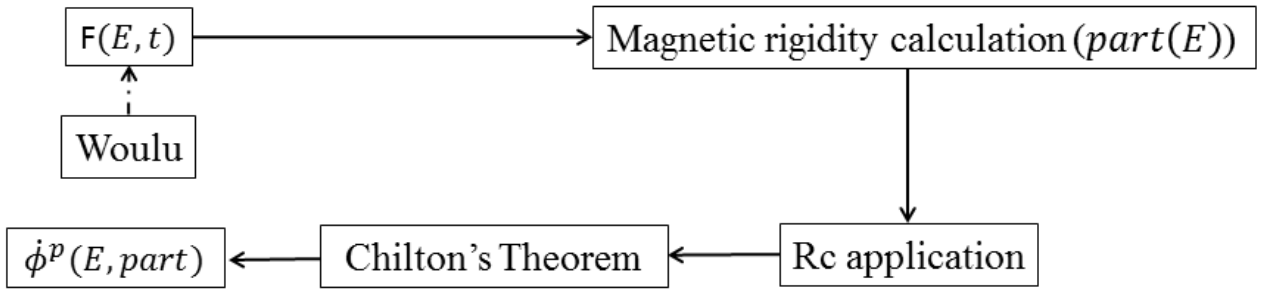


Computational modeling

The main aspects of the methodology developed for the computational modeling using Monte Carlo codes:

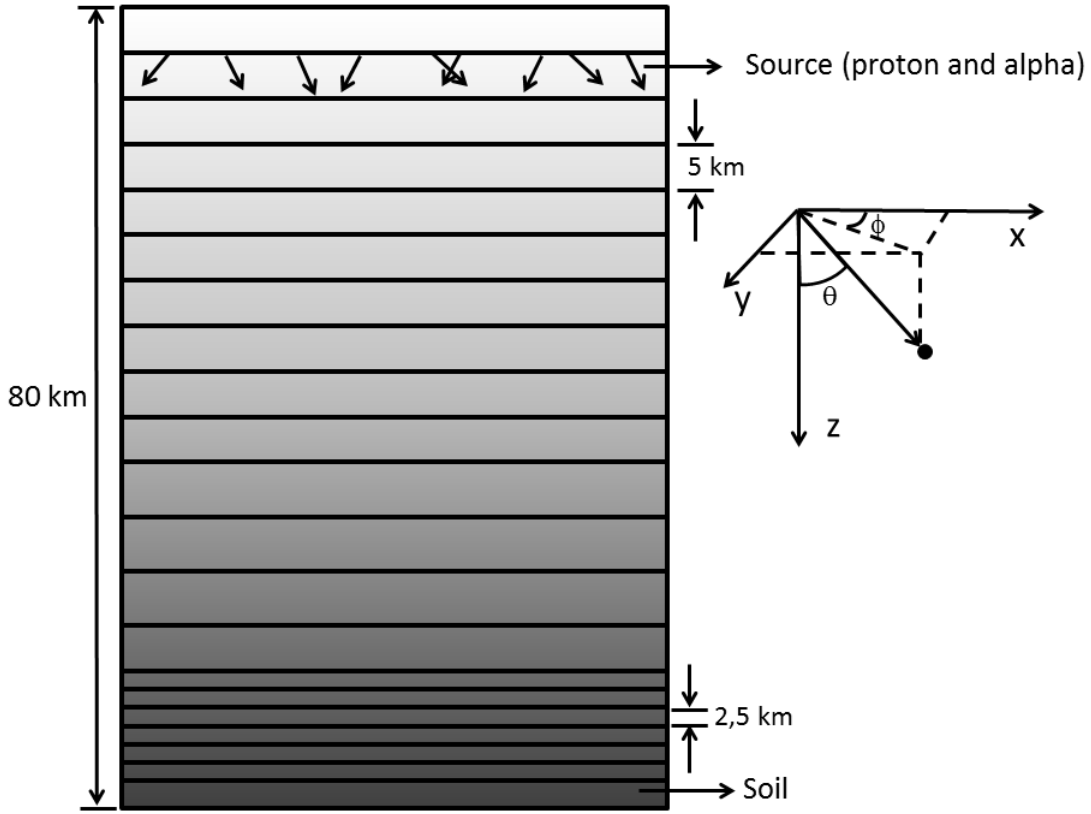


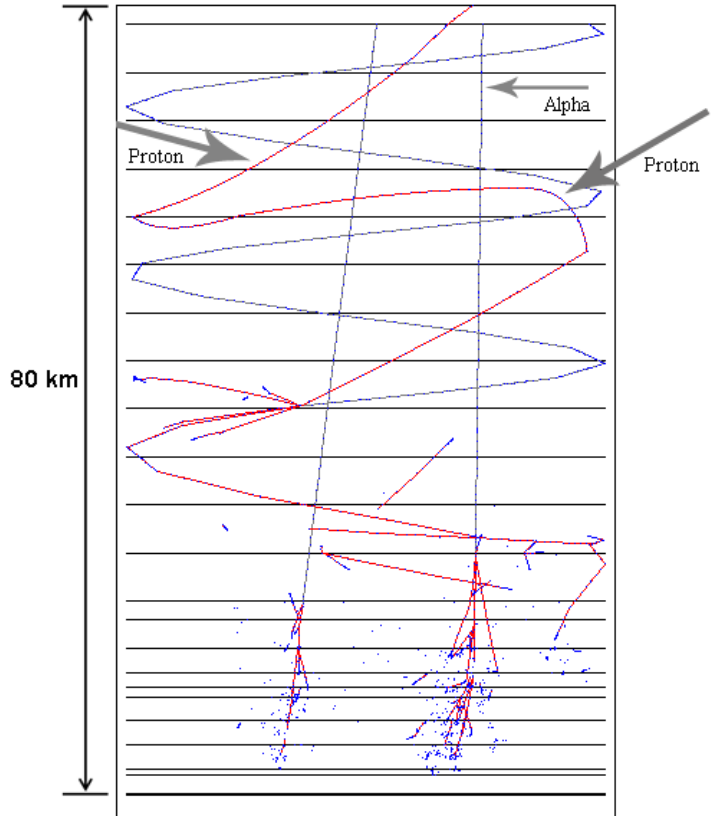
Generation of the primary cosmic radiation:



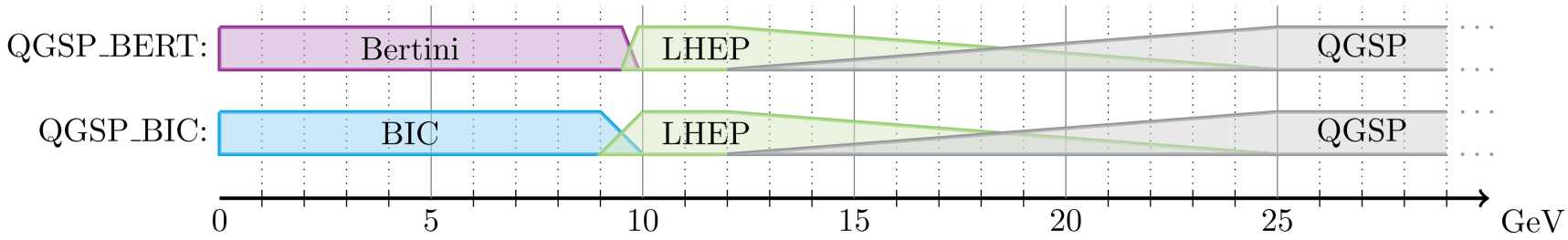
Modeling of the cosmic radiation propagation and the atmosphere

- Planar source (repreduce the isotropic radiation field (protons + alphas));
- Atmosphere modeling;
- Reflective sides;
- The Earth's magnetic field were considered.





Geant4 and MCNPX parameterization

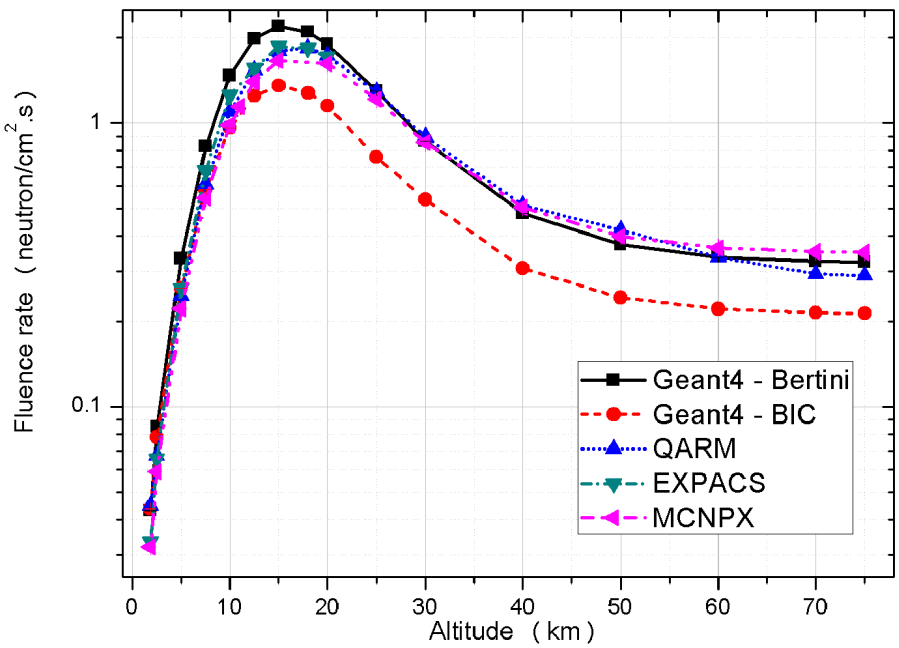


- ENDF/VII nuclear data library (Geant4)
- ENDF/VI nuclear data library (MCNPX)
- Scattering matrices S(α,β)
- Bertini model
- Binary Cascade model
- Neutron and proton elastic scattering
- Preequilibrium model after intranuclear cascade
- Quark-Gluon String Precompound model
- Experimental branching ratios were used.

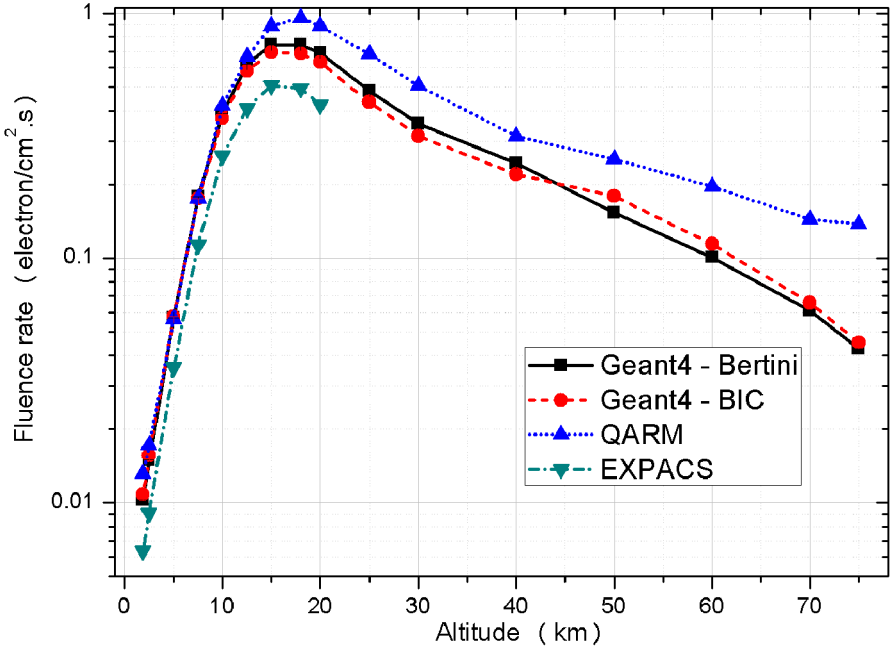
Geant4 - Classes

- New classes created: “G4WallReflection.cc”, “GNeutAtMagneticField.cc”, “GNeutAtMagneticFieldMessenger.cc”, “StackingMessenger.cc”;
- Storage data in ROOT files.

Neutron and electron fluence rate in the atmosphere



(a) Neutron fluence rate as function of altitude.

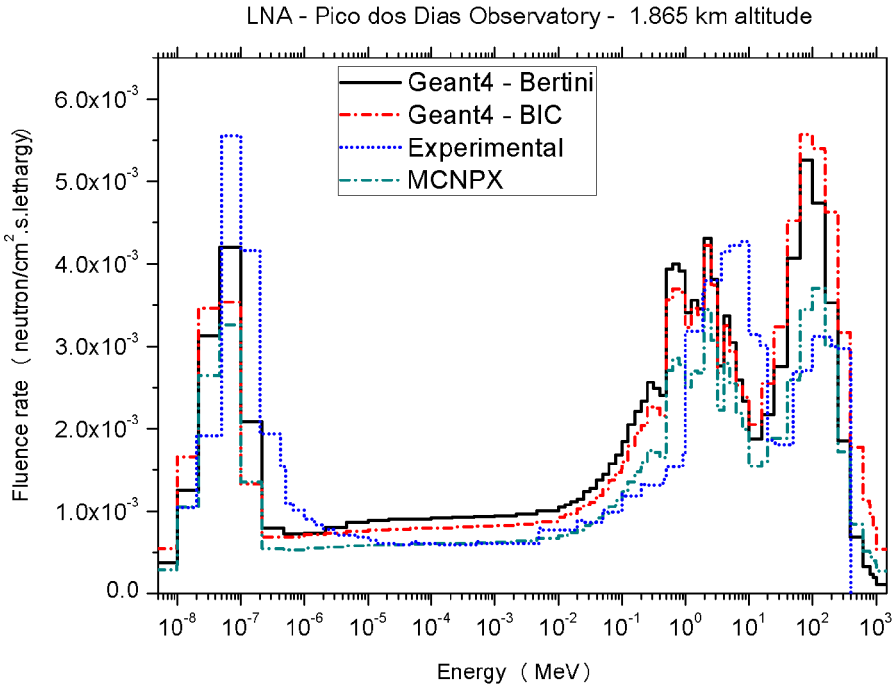


(b) Electron fluence rate as function of altitude.

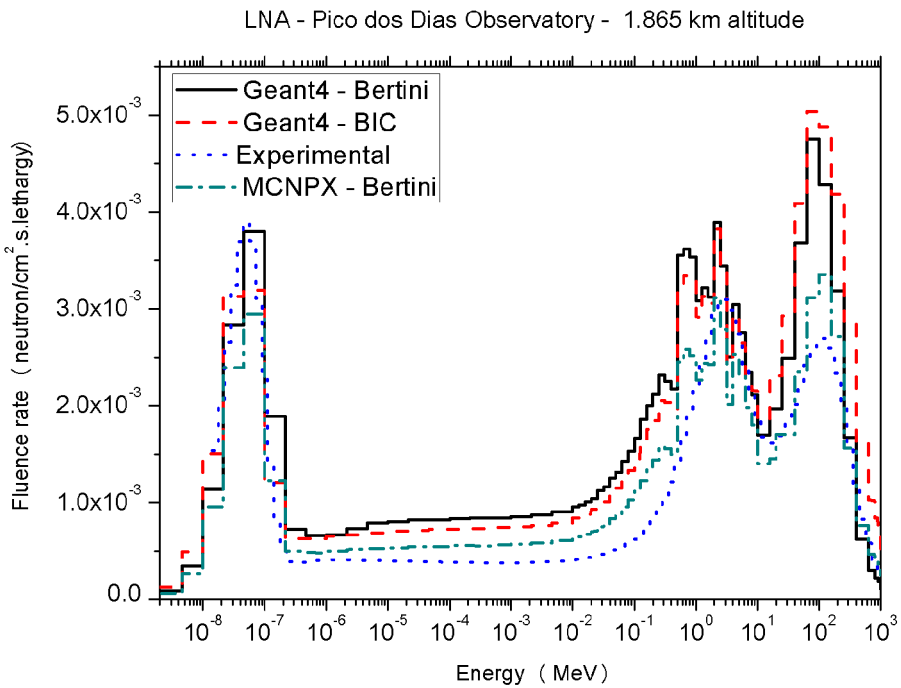
Conditions for the particle fluence simulation - OPD

- Date: (3-4)/8/2015
- Cutoff rigidity: 9.7 GV
- Solar potential: 683 MV; W_{OULU}: 6003 count/min
- Primary proton fluence rate: 1.02×10^{-1} prot/cm^2.s; alphas: 1.84×10^{-2} alpha/cm^2.s

Simulations and measurement at ground level - OPD (LNA)



(c) 2009



(d) 2015

Pazianotto, M. T., et al. Astroparticle Physics, v. 88, p. 17-29, 2016.

Lethargic interval: $lnE_{i+1} - lnE_i$

H*(10) comparison with flight measurement

Comparison of the ambient dose equivalent rate calculated from simulations, EXPACS and QARM codes, and experimental measurement at flight altitude in the Foz do Iguaçu region.

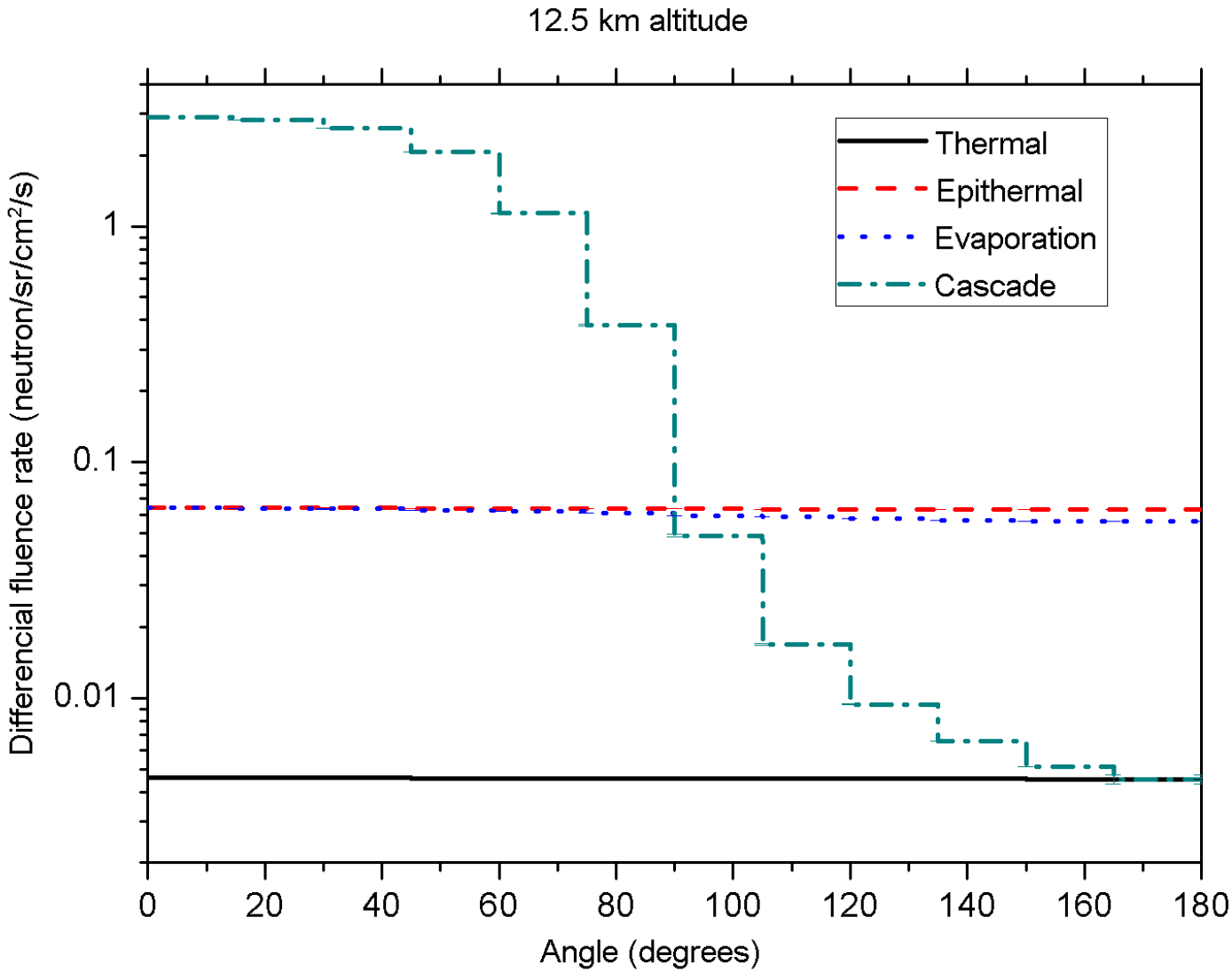
	H*(10) (μSv/hr)	Erro
Experimental	**1.57E+00**	**4.00E–02**
Geant4 - Bertini	**1.53E+00**	-
Geant4 - BIC	1.04E+01	-
MCNPX	1.03E+00	-
EXPACS	**1.48E+00**	-
QARM	1.10E+00	-

Conditions during the flight - Foz do Iguaçú

- Date: 29/06/2011
- Cutoff rigidity: 9.6 GV
- Solar potential: 517 MV; W_{OULU}: 6324 count/min
- Primary proton fluence rate (calculated): 1.08×10^{-1} prot/cm^2.s; alphas: 1.93×10^{-2} alpha/cm^2.s

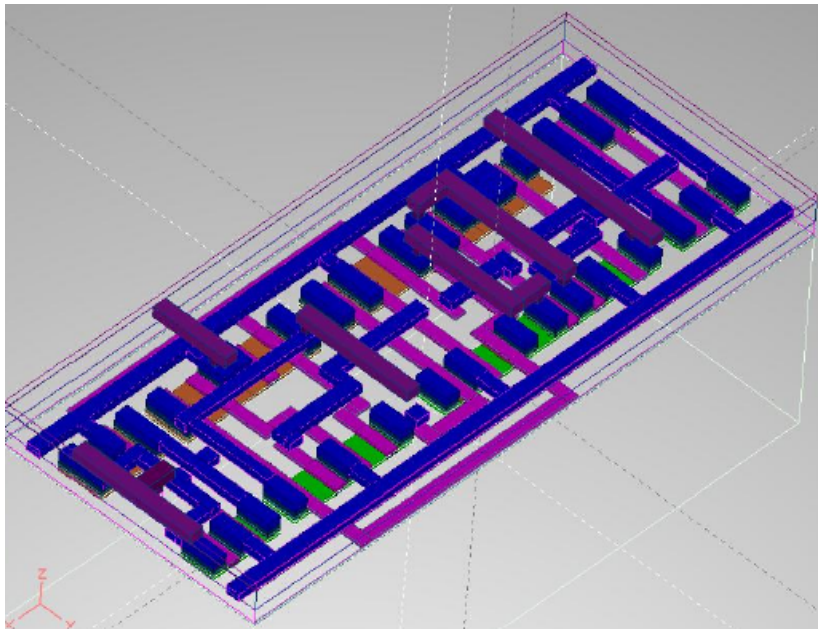
Angular distribution analyses

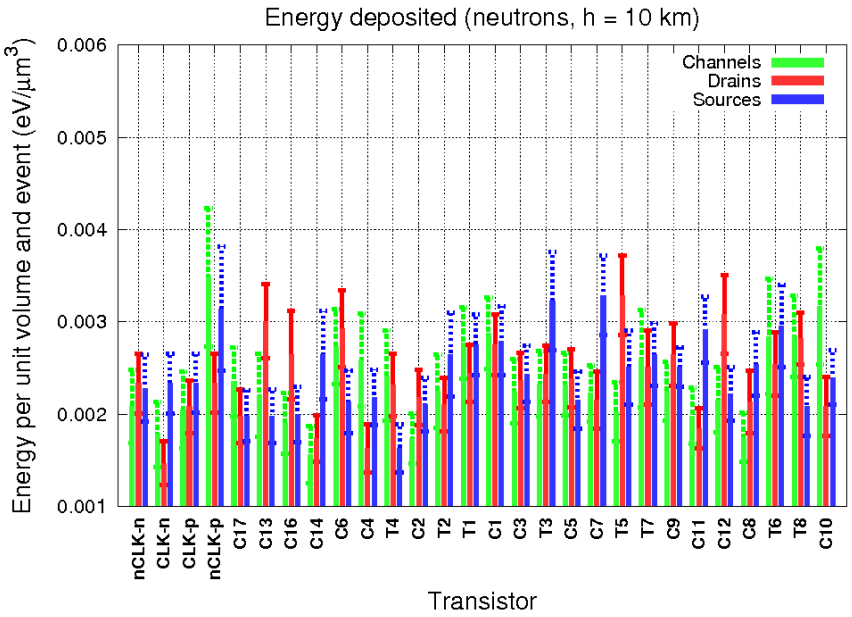
Neutron angular distribution for different energy ranges at 12.5 km altitude.



Embedded electronic

Irradiation application (CMOS flip-flop): Energy Deposited per unit volume and event in the flip-flop elements at 10 km altitude.



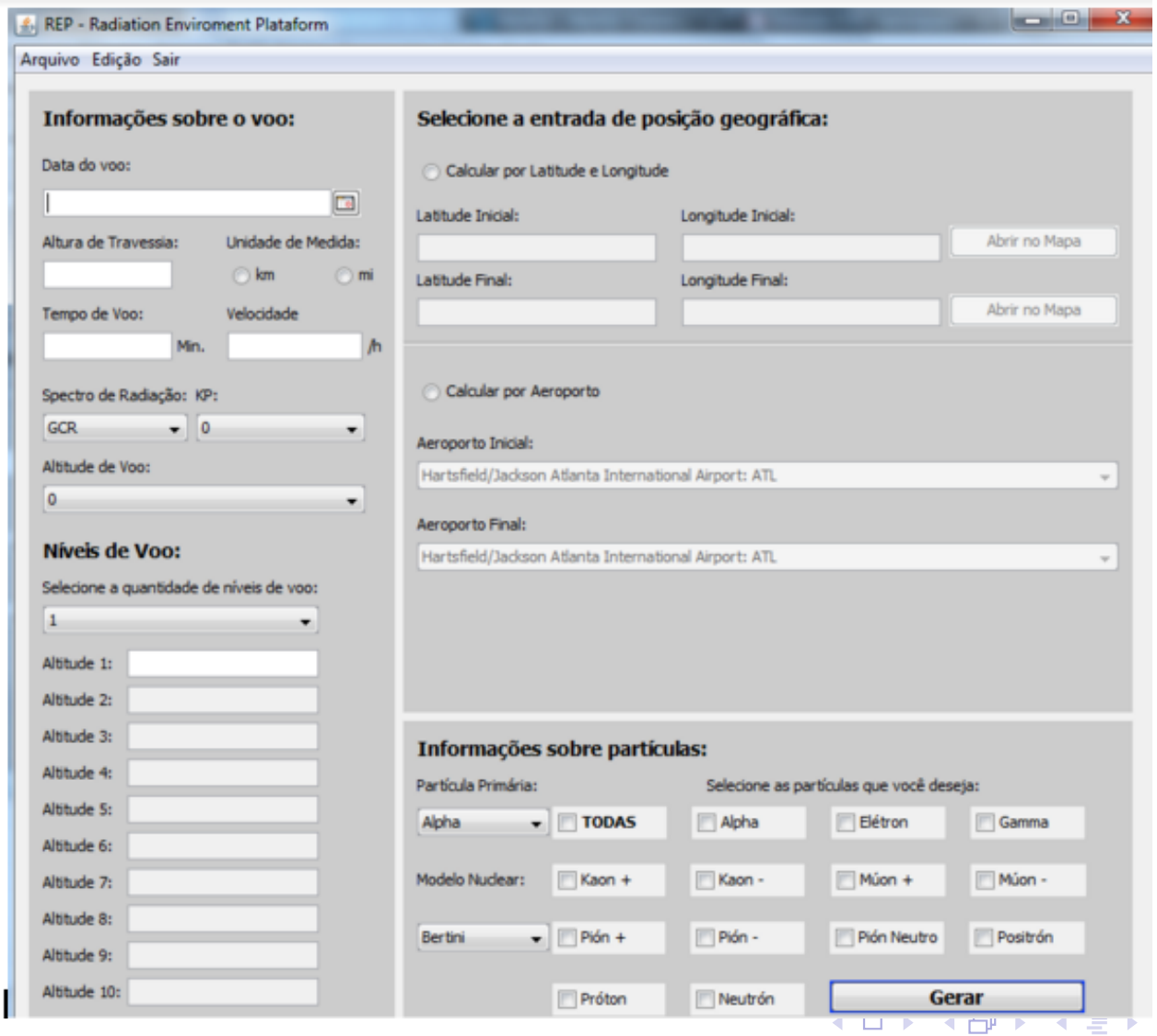


The histograms show values for channels, drains and sources.

Data from our simulations + MUSCA SEP3 platform (ONERA) $\Longrightarrow$ SEE estimations.

REP - (*Radiation Environment Platform*)

Web interface:



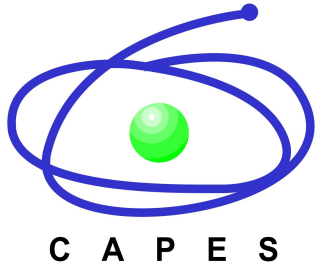
REP - (*Radiation Environment Platform*)

Primary particles parameterization

- Neutrons data measured at the ground level ⇒ primary cosmic radiation fluence rate ⇒ determine the cosmic-ray-induced particles;
- These neutron data is collected at different locations around the world:
- stations located at Pico dos Dias (Brazil), Concórdia Station (Antarctica) and Pic-du-Midi (France).

IEAv and ONERA cosmic ray stations

Financial sponsors:



Collaborators: