14th LAGO Workshop

LAGO ARTI & Meiga

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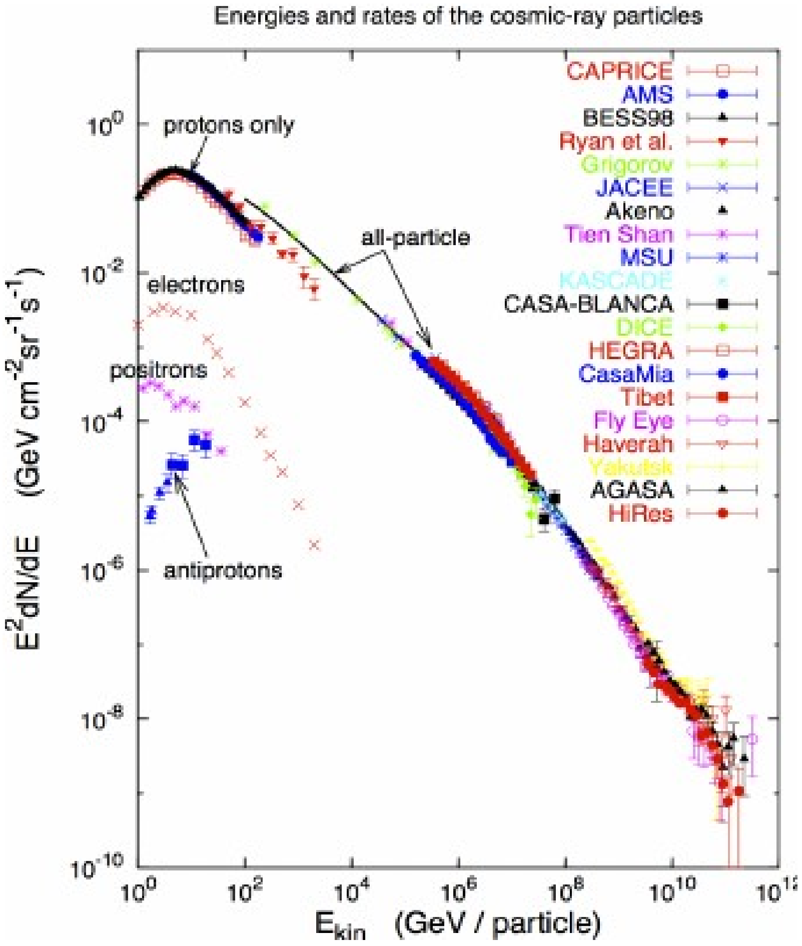
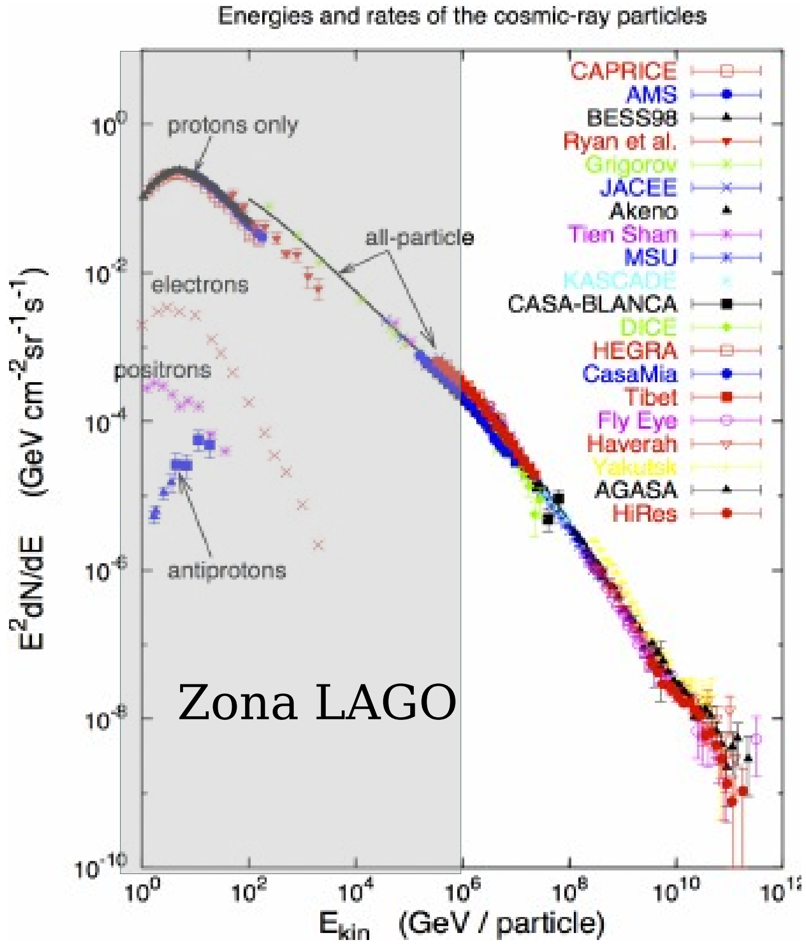
Sinopsis:

- Introducción a los Rayos cósmicos
- Corsika
- ARTI
- Simulación de RC
- Perfil longitudinal y lateral

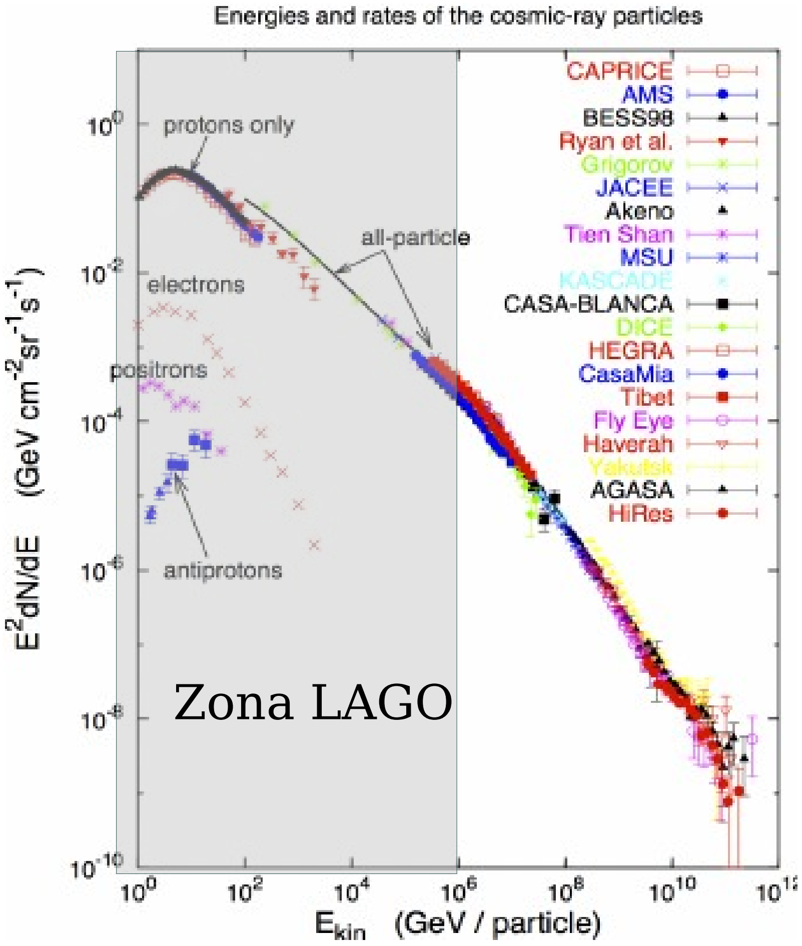
Introducción a los Rayos Cósmicos

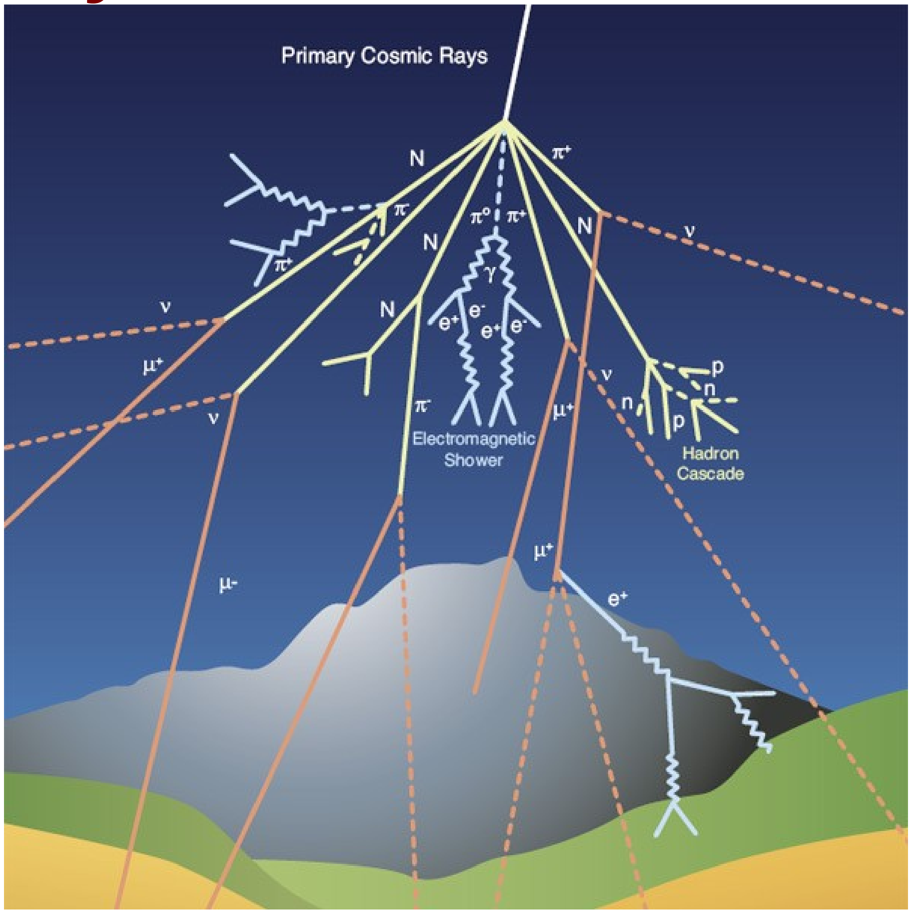


Introducción a los Rayos Cósmicos

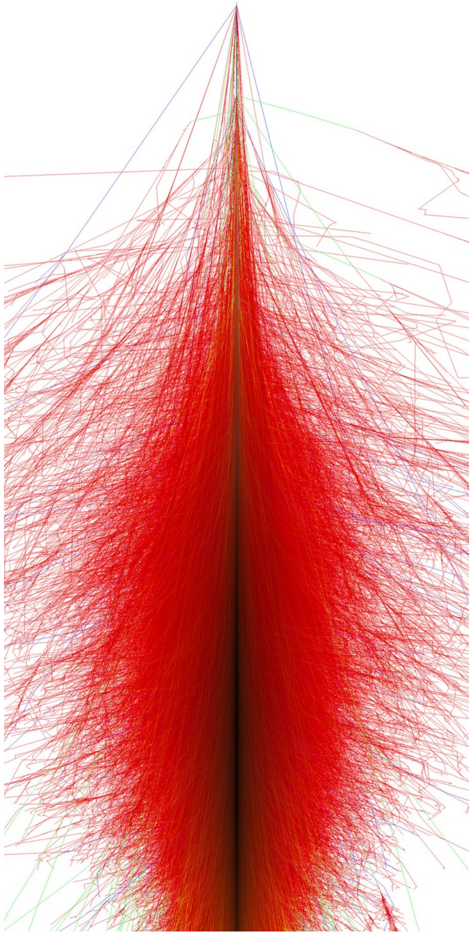


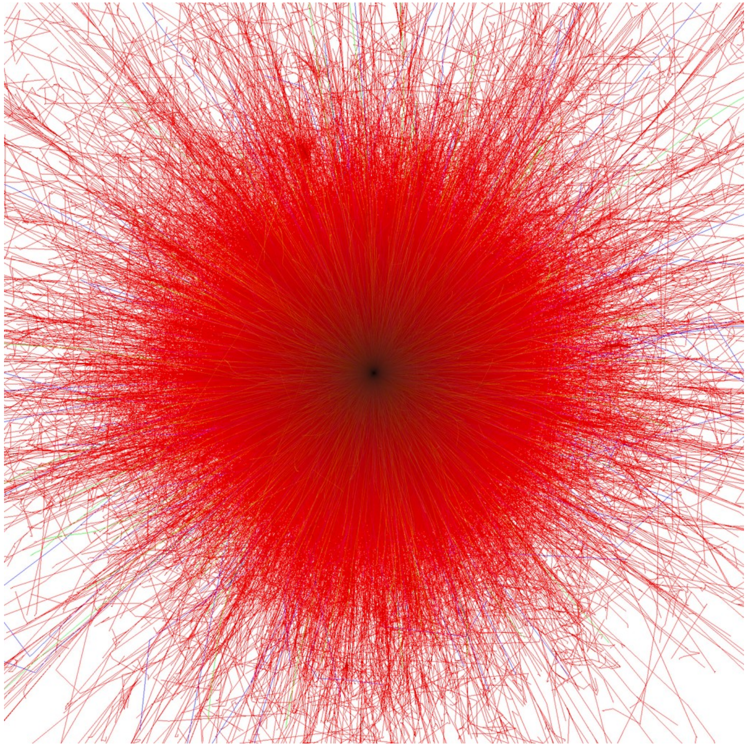
Introducción a los Rayos Cósmicos





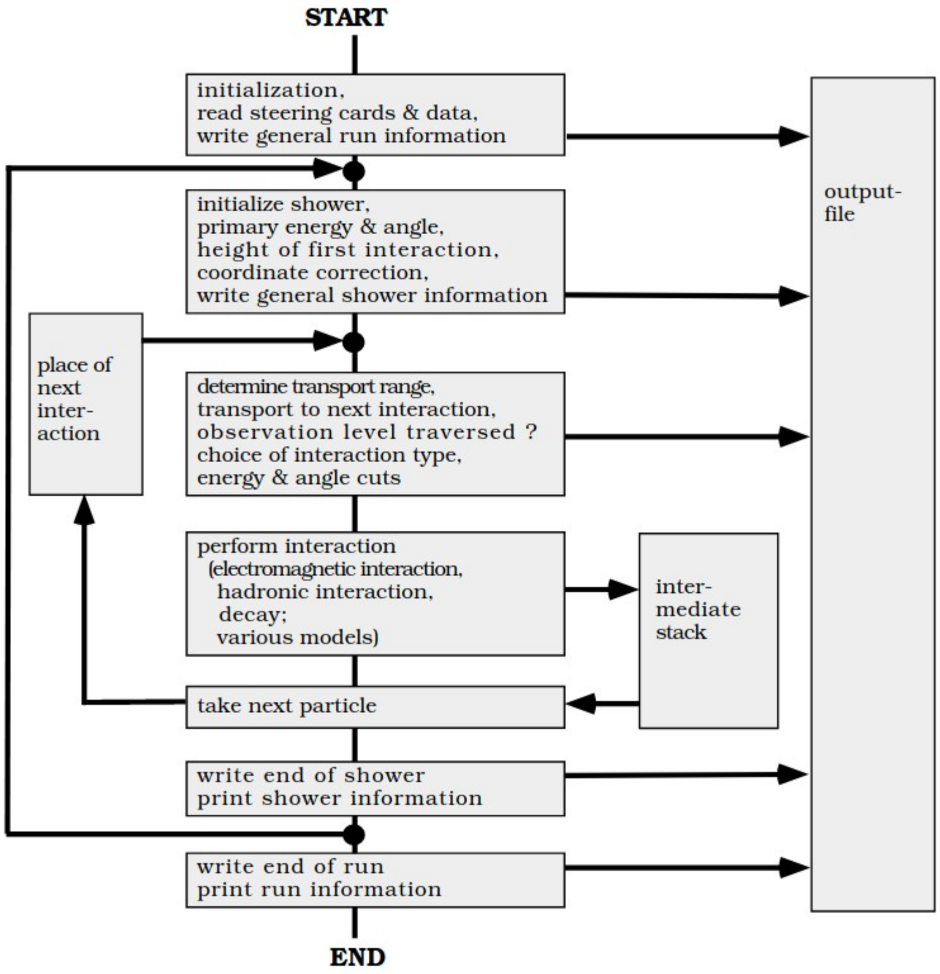
CORSIKA: COsmic Ray SImulations for KAscade





https://www.iap.kit.edu/corsika/

CORSIKA


START
initialization,
read steering cards & data,
write general run information
output-
file
initialize shower,
primary energy & angle,
height of first interaction,
coordinate correction,
write general shower information
place of
next
inter-
action
determine transport range,
transport to next interaction,
observation level traversed ?
choice of interaction type,
energy & angle cuts
perform interaction
(electromagnetic interaction,
hadronic interaction,
decay;
various models)
inter-
mediate
stack
take next particle
write end of shower
print shower information
write end of run
print run information
END

CORSIKA

```
RUNNR   1                           number of run
EVTNR   100400                      no of first shower event
SEED    100401   0   0              seed for hadronic part
SEED    100402   0   0              seed for EGS4 part
SEED    100403   0   0              seed for Cherenkov part
NSHOW   10                          no of showers to simulate
PRMPAR  5626                        primary particle code (iron)
ERANGE  2.00E4   4.00E4             energy range of primary (GeV)
ESLOPE  -2.7                        slope of energy spectrum
THETAP  0.   10.                    range zenith angle (deg)
PHIP    -180.   180.                range azimuth angle (deg)
QGSJET  T   0                       QGSJET for high energy & debug level
QGSSIG  T                           QGSJET cross-sections enabled
HADFLG  0   0   0   0   0   2       HDPM interact.flags & fragmentation flag
ELMFLG  T   T                       elmag. interaction flags NKG, EGS4
STEPFC  1.                          multiple scattering step length factor
RADNKG  200.E2                      outer radius (cm) of NKG elect. distrib.
MAGNET  20.4   43.23                magnetic field central Europe (/uT)
ECUTS   .3   .3   .015   .015       energy cuts: hadr. muon elec. phot. (GeV)
LONGI   T   20.   T    T            longitud, stepsize(g/cm^2), fit, out
MUMULT  T                           muon multiple scattering by Moliere
MUADDI  T                           additional muon information
OBSLEV  110.E2                      observation level (cm)
ARRANG  18.25                       angle between north to array-grid (deg)
MAXPRT  10                          max. no of printed events
ECTMAP  1.E2                        printout gamma factor cut
DIRECT  /home/user/corsika/run/     directory of particle output
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  1                           Cherenkov output file
CSCAT   5   1000.   1000.           scatter Cherenkov events (cm)
DATBAS  T                           write data base file
USER    you                         user name for data base file
HOST    your_host                   host name for data base file
DEBUG   F   6   F   999999999       debug flag, log. unit, delayed debug
EXIT
```

ARTI(CORSIKA)

- Compilar Corsika
  - Modelo hadrónico
  - Incluye campo geomagnético
  - Configurar la salida
  - etc

- Steering file
  - Energía
  - Tipo de partícula
  - Altura del sitio
  - Ecut
  - Modelo atmosférico
  - Semillas del MC

- Análisis de los datos
  - LDF
  - Espectro de energía

¡Vamos a la acción! (Docker)

- Corsika
- ARTI

Instalación:

- sudo docker build --no-cache --build-arg ARTI_BRANCH="master" -t arti:2022.01 - < Dockerfile-arti

Verificamos la existencia la imagen
- sudo docker images -a

Para correrlo
- sudo docker run -it arti:2022.01

Para conocer el ID
- sudo docker ps -a

Para pararlo
- sudo docker stop ID
- sudo docker cp ID:path/to/file path/to/host

¡Vamos a la acción!
(ARTI)

```
cd /opt/arti/sims/

./do_sims.sh -?
```

¡Vamos a la acción! (ARTI)

```
cd /opt/arti/sims/

./rain.pl -?
```

```
    ./rain.pl v1r0

    A simple input files generator for CORSIKA
    (C) 2013 - H. Asorey - asoreyh@cab.cnea.gov.ar
    Usage: See ./rain.pl -?  - If you enjoy it, please send me an email

    ./rain.pl

    -b                                   Activates batch mode
    -i                                   Disable PLOTSH and PLOTSH2 modes (usual simms production)
    -d                                   Debug mode: only shows what it should do. Don't start simulation
    -r  <working directory>              Specify where corsika bin files are located
    -v  <version>                        Corsika version number
    -h  <high energy interaction model>  High energy interaction model used for compilation of CORSIKA (EPOS|QGSII|SIBYLL)
    -l                                   Enables SLURM cluster compatibility (with sbatch).
    -t  <EFRCTHN> <WMAX> <RMAX>          Enables THIN Mode (see manual for pg 62 for values)
    -th <THINRAT> <WEITRAT>              If THIN Mode, select different thining levels for Hadronic (THINH) ...
    -te <THINRAT> <WEITRAT>              ... and electromagnetic particles (THINEM)
    -a <high energy ecuts (GeV)>         Enables and set high energy cuts for ECUTS
    -z                                   Enables CHERENKOV mode
    -mu                                  Enables additional information from muons and EM particles
    -g                                   Enables GRID mode
    -s <site>                            Choice site for simulation (some predefined sites: hess|sac|etn|ber|bga|lim|glr|mch|mge|and|mpc|cha|cid|mor|ccs|lsc
|mbo)
    -m <energy>                          Defines energy (in GeV) for monoenergetic showers (CHERENKOV)
    -q <theta>                           Defines zenith angle (in degs) for fixed angle showers (CHERENKOV)
    -p <prmpar>                          Defines primary particle (see table 4 pg 87) (CHERENKOV)
```

Lluvia monocromática

```
./rain.pl v1r0

A simple input files generator for CORSIKA
(C) 2013 - H. Asorey - asoreyh@cab.cnea.gov.ar
Usage: See ./rain.pl -?  - If you enjoy it, please send me an email

./rain.pl

-b                                  Activates batch mode
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-te <THINRAT> <WEITRAT>             ... and electromagnetic particles (THINEM)
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|mbo)
-m <energy>                         Defines energy (in GeV) for monoenergetic showers (CHERENKOV)
-q <theta>                          Defines zenith angle (in degs) for fixed angle showers (CHERENKOV)
-p <prmpar>                         Defines primary particle (see table 4 pg 87) (CHERENKOV)
```

```
./rain.pl -r ../../lago-corsika-77402/run/ -v 77402 -s vcp -m 1E3 -q 0 -p 1
```

Archivo de salida en Corsika

Dependiendo de la configuración del steering se crearan distintos archivos:

- En este caso tendremos 3 archivos:

DATNNNNNN ← toda la info de los secundarios (archivo binario)

DATNNNNNN.dbase ← librerías e info de la lluvia

DATNNNNNN.lst ← archivo 'log' para controlar la salida

- Otro tipo de archivos

.long .tab .info ...

→ ver el capitulo. 10 Corsika guide

Análisis de los datos

- Extraer información del binario:

```
for i in DAT??????.bz2; do j=$(echo $i | sed -e 's/.bz2//'); u=$(echo $j | sed -e 's/DAT//'); bzip2 -d -k $i; echo $j | ../../../arti/analysis/lagocrkread | ../../../arti/analysis/analysis -p -v $u; rm $j; done
```

- Analisis de los secundarios:

```
bzcat *sec.bz2 | ../../../arti/analysis/showers -a 10 -d 10 -c 5100. -n 1 1 -v salida_apx
```

Análisis de los datos

- Extraer información del binario:

```
for i in DAT??????.bz2; do j=$(echo $i | sed -e 's/.bz2//'); u=$(echo $j | sed -e 's/DAT//'); bzip2 -d -k $i; echo $j | ../../../arti/analysis/lagocrkread | ../../../arti/analysis/analysis -p -v $u; rm $j; done
```

- Analisis de los secundarios:

```
bzcat *sec.bz2 | ../../../arti/analysis/showers -a 10 -d 10 -c 5100. -n 1 1 -v salida_apx
```

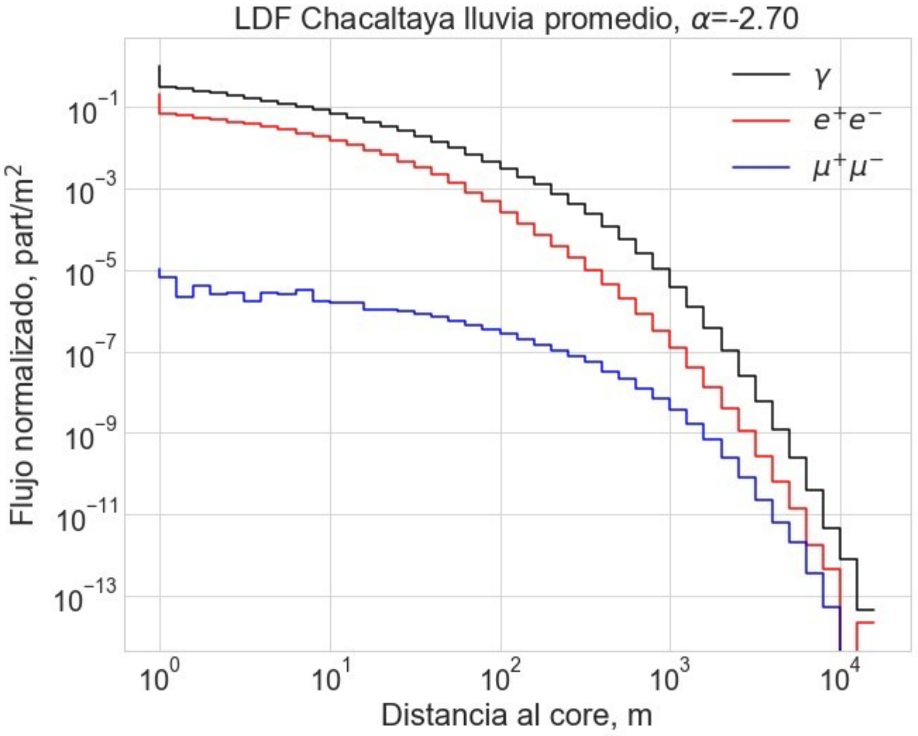
- Salida:

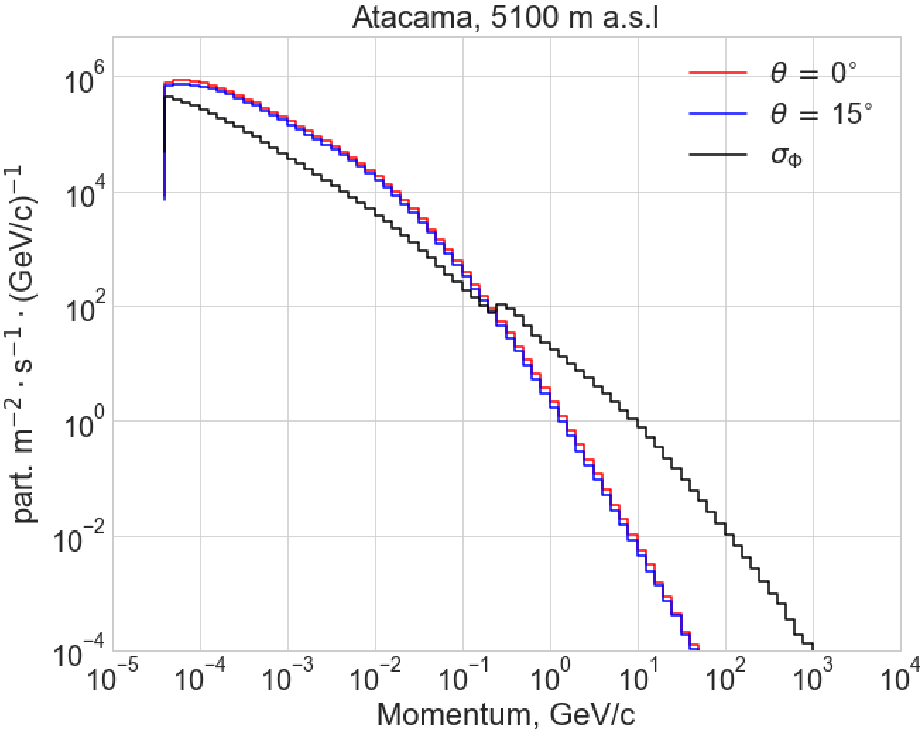
salida_apx.dst→ Distribución lateral de los secundarios en el piso

salida_apx.hst→ Distribución de la energía de los secundarios

salida_apx.dse→ Distribución de la energía de los secundarios con respecto a la distancia.

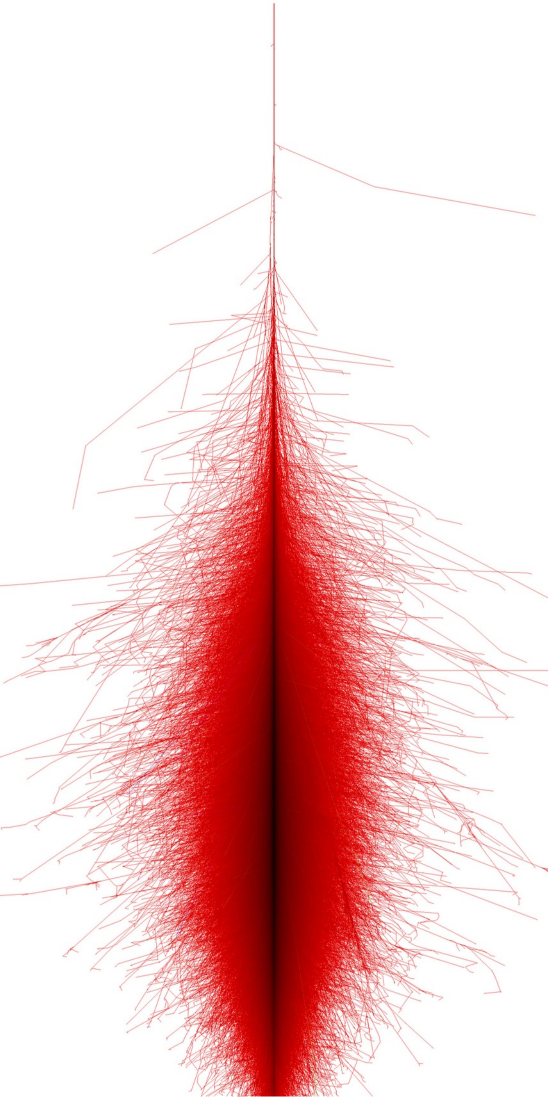
Análisis de los datos





Algunos enlaces de interés

- Manual de Corsika: https://www.iap.kit.edu/corsika/70.php
- Articulo sobre ARTI: https://arxiv.org/abs/2010.14591
- Procceding sobre GRBs LAGO: https://pos.sissa.it/395/929/pdf



¡Gracias por su atención!

#LDF lluvia monocromatica (dst)

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from matplotlib import pyplot

import os

plt.rc('axes', labelsize=22)
plt.rc('xtick', labelsize=20)
plt.rc('ytick', labelsize=20)

#A partir de aquí python sabe en que carpeta se encuentran los datos
os.chdir("/home/christian/MEGA/PostDoc_UIS/LAGO/Workshop_LAGO")
os.getcwd()

df= pd.read_table(r"salida_apx.dst", delimiter=" ", skiprows=7, skipinitialspace=True, skipfooter=7,
                 names=["distance_in_bin", "N_phot", "N_e+", "N_e-", "N_mu+", "N_mu-", "N_pi0",
                        "N_pi+", "N_pi-", "N_n", "N_p", "N_pbar", "N_others", "Total_per_bin"])

plt.figure(figsize=(10,8))
plt.step(df["distance_in_bin"], df["Total_per_bin"]/10, c="b", label=r"total")
plt.step(df["distance_in_bin"], df["N_phot"]/10, c="k", label=r"$\gamma$")
plt.step(df["distance_in_bin"], (df["N_e+"]+df["N_e-"])/10, c="r", label=r"$e^{+}e^{-}$")
plt.xscale("log")
plt.yscale("log")
#plt.xlim(0, 200)
plt.title(r"LDF La Serena, lluvia promedio", fontsize=22)
plt.xlabel("Distancia al core, m")
plt.ylabel(r"Flujo normalizado, part/m$^2$")
plt.legend(fontsize=20)
```

#LDF lluvia monocromatica (dse)

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from matplotlib import pyplot

import os

plt.rc('axes', labelsize=22)
plt.rc('xtick', labelsize=20)
plt.rc('ytick', labelsize=20)

#A partir de aquí python sabe en que carpeta se encuentran los datos
os.chdir("/home/christian/MEGA/PostDoc_UIS/LAGO/Workshop_LAGO")
os.getcwd()

de1= pd.read_table(r"salida_apx.dse", delimiter=" ", skiprows=7, skipinitialspace=True,
                 names=["distance_in_bin", "E_phot", "E_e+", "E_e-", "E_mu+", "E_mu-", "E_pi0",
"E_pi+", "E_pi-","E_n", "E_p", "E_pbar", "E_others", "Total_E_per_bin"])

plt.figure(figsize=(10,8))
plt.step(de1["distance_in_bin"], de1["Total_E_per_bin"]/10, c="b", label=r"$total$")
plt.step(de1["distance_in_bin"], de1["E_phot"]/10, c="k", label=r"$\gamma$")
plt.step(de1["distance_in_bin"], (de1["E_e+"]+de1["E_e-"])/10, c="r", label=r"$e^{+}e^{-}$")
plt.xscale("log")
plt.yscale("log")
#plt.xlim(0, 200)
plt.title(r"La Serena, lluvia promedio", fontsize=22)
plt.xlabel("Distancia al core, m")
plt.ylabel(r"Energy fluence, GeV/m$^2$")
plt.legend(fontsize=20)
```