



Universidad
Autónoma de
Bucaramanga



Reunión LAGO 2025

LAGO ARTI & Meiga

C. Sarmiento-Cano^{1*}

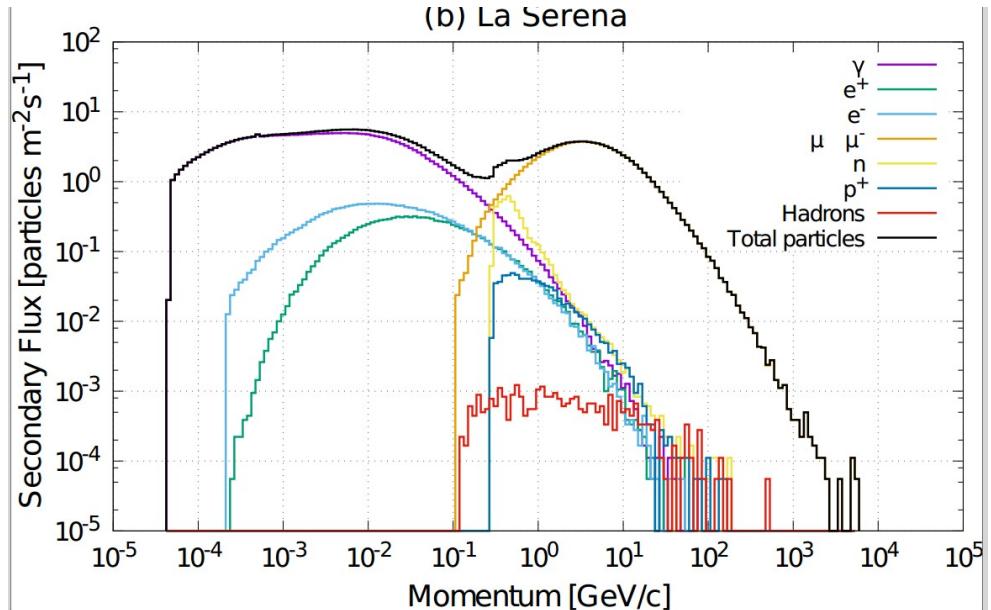
¹Universidad Industrial de Santander

²Instituto en Tecnologías de Detección y Astropartículas

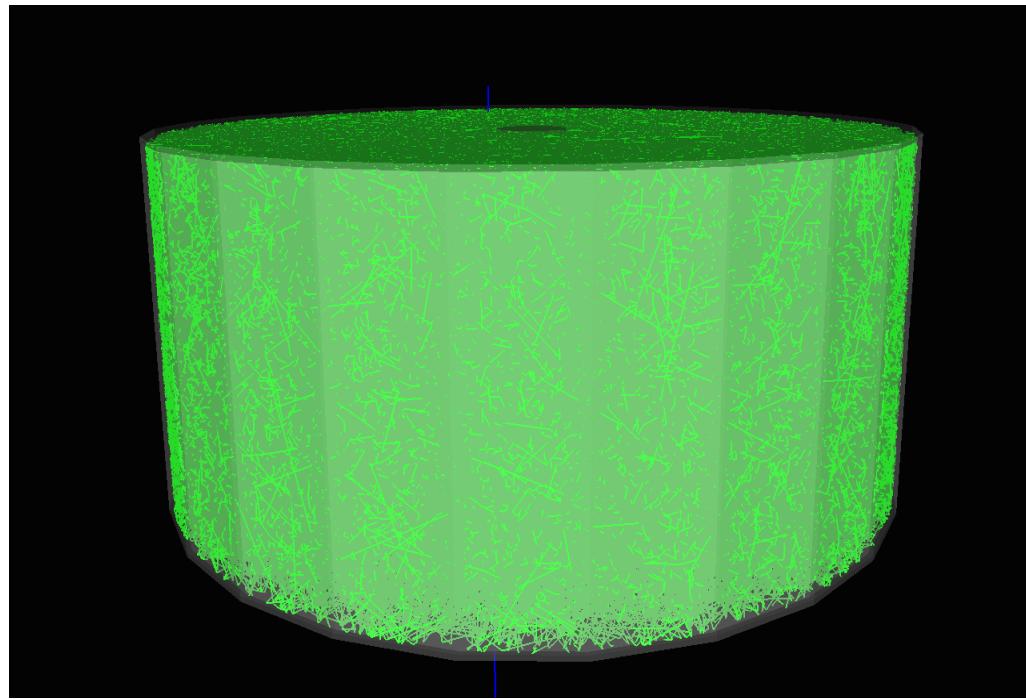
*csarmiento32@unab.edu.co

ARTI & MEIGA

Corsika & Geant4



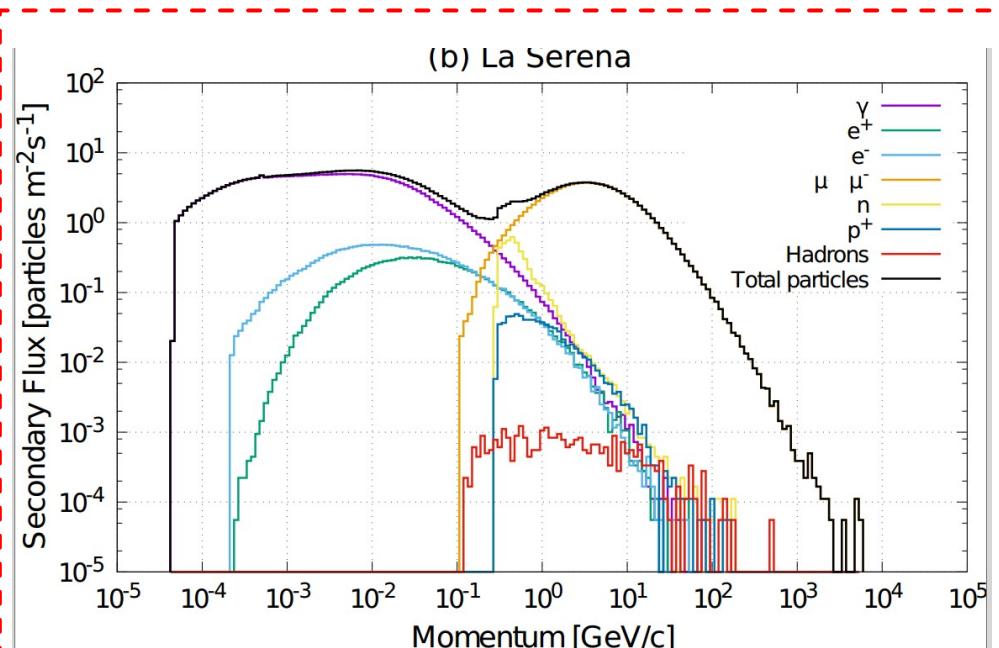
Clases 1 y 2



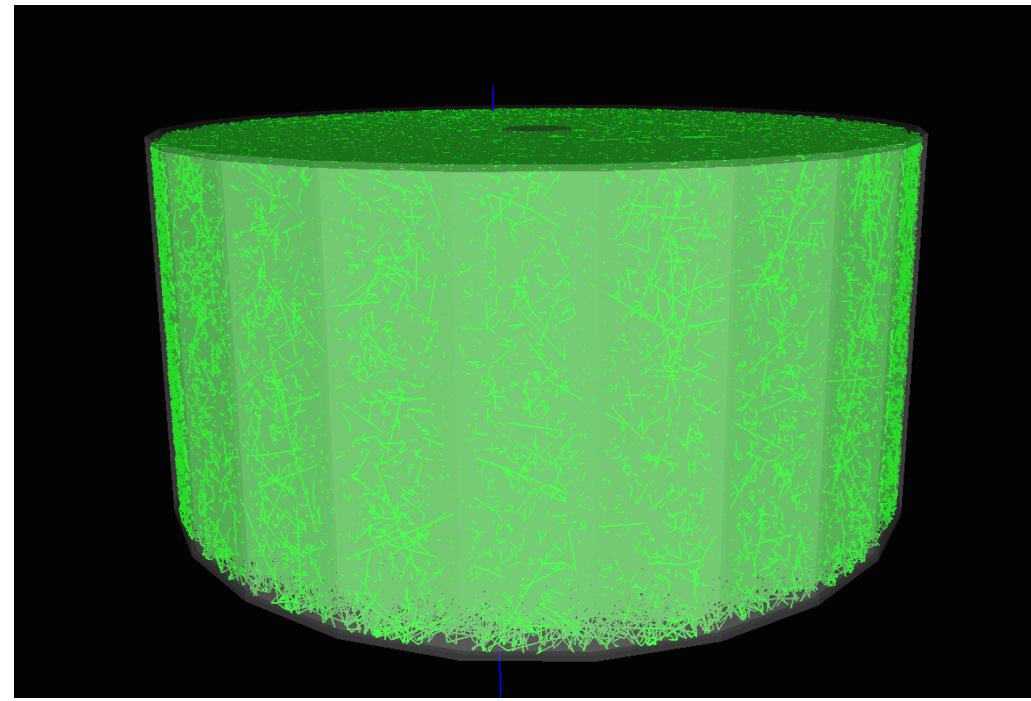
Clases 3 y 4

ARTI & MEIGA

Corsika & Geant4



Clases 1 y 2



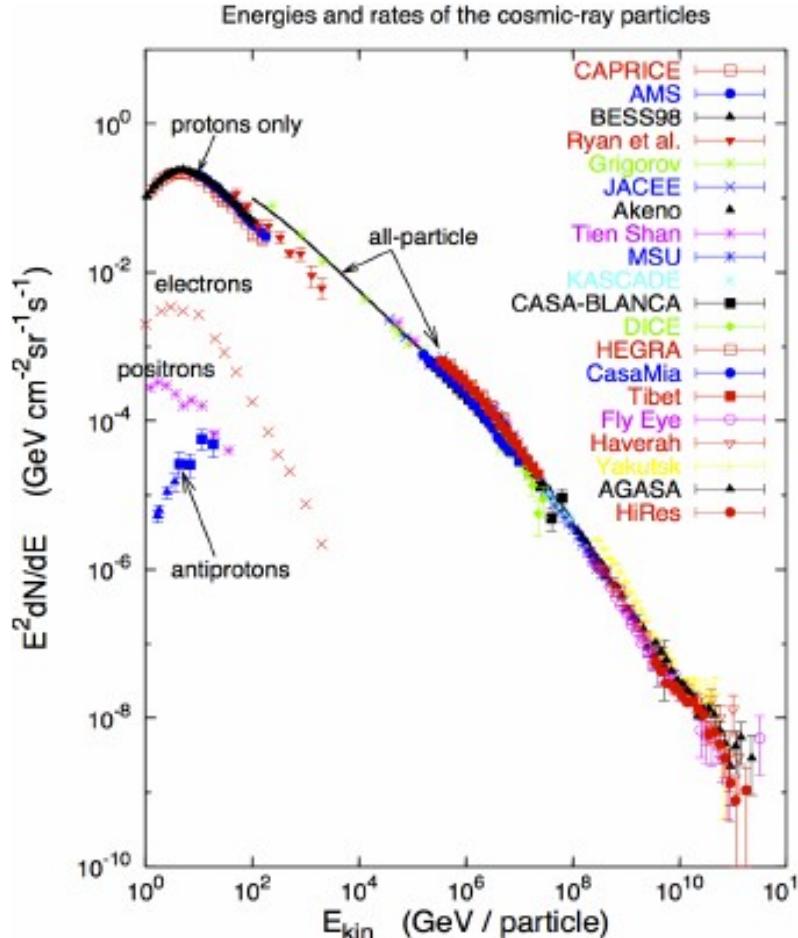
Clases 3 y 4

Sinopsis:

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

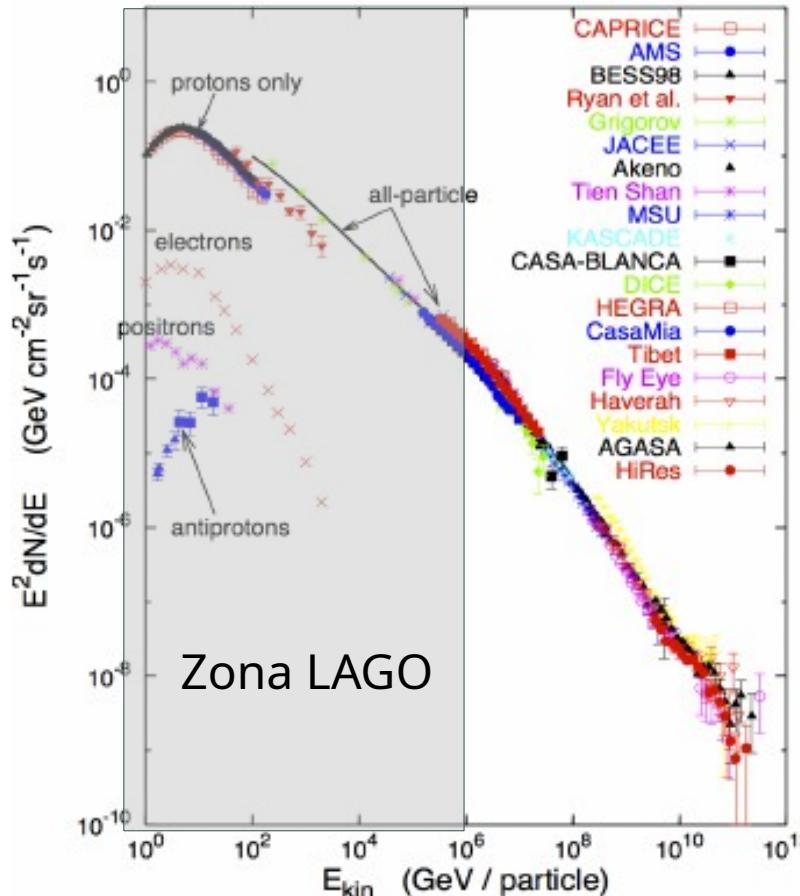


Introducción a los Rayos Cósmicos

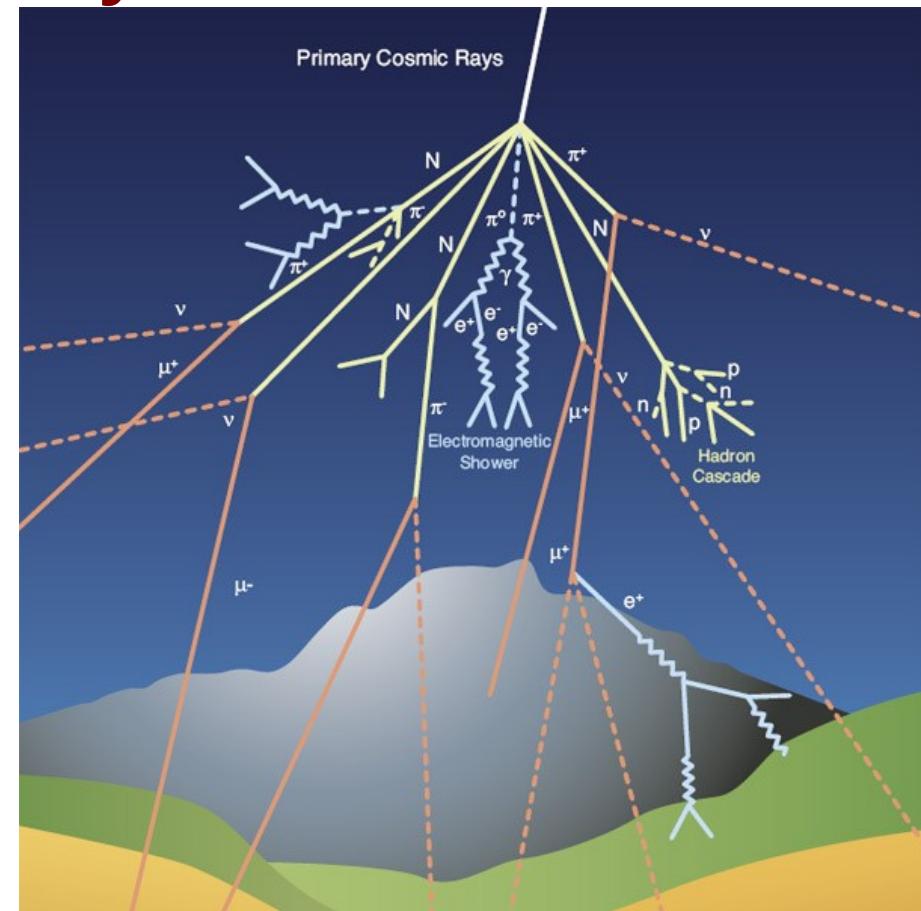
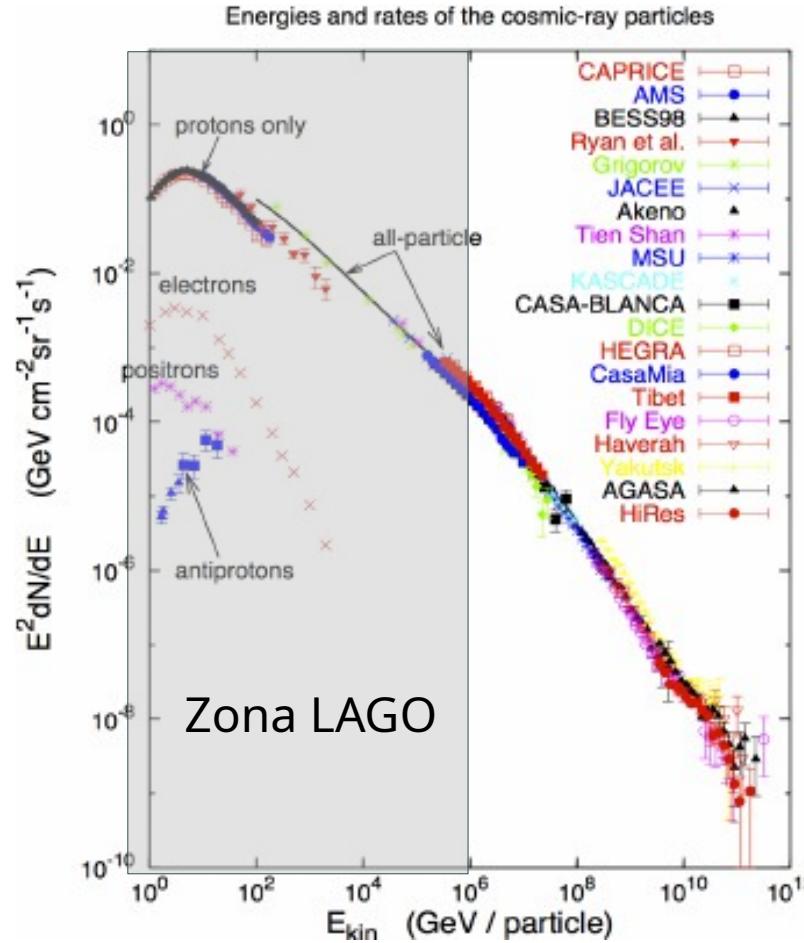


Introducción a los Rayos Cósmicos

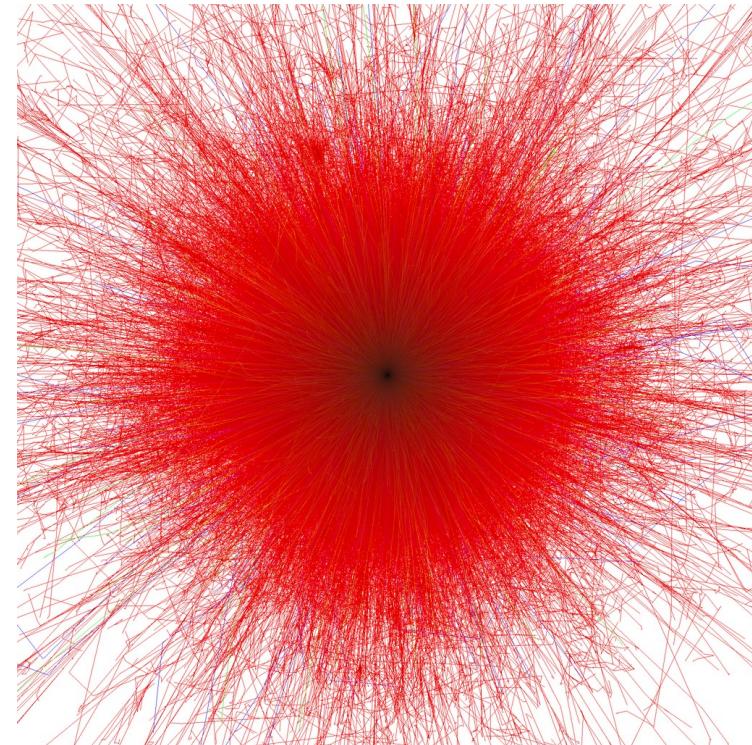
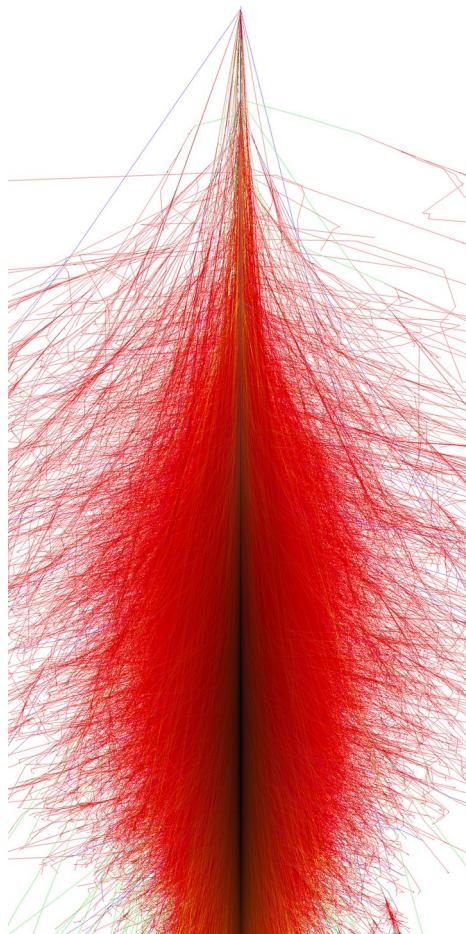
Energies and rates of the cosmic-ray particles



Introducción a los Rayos Cósmicos

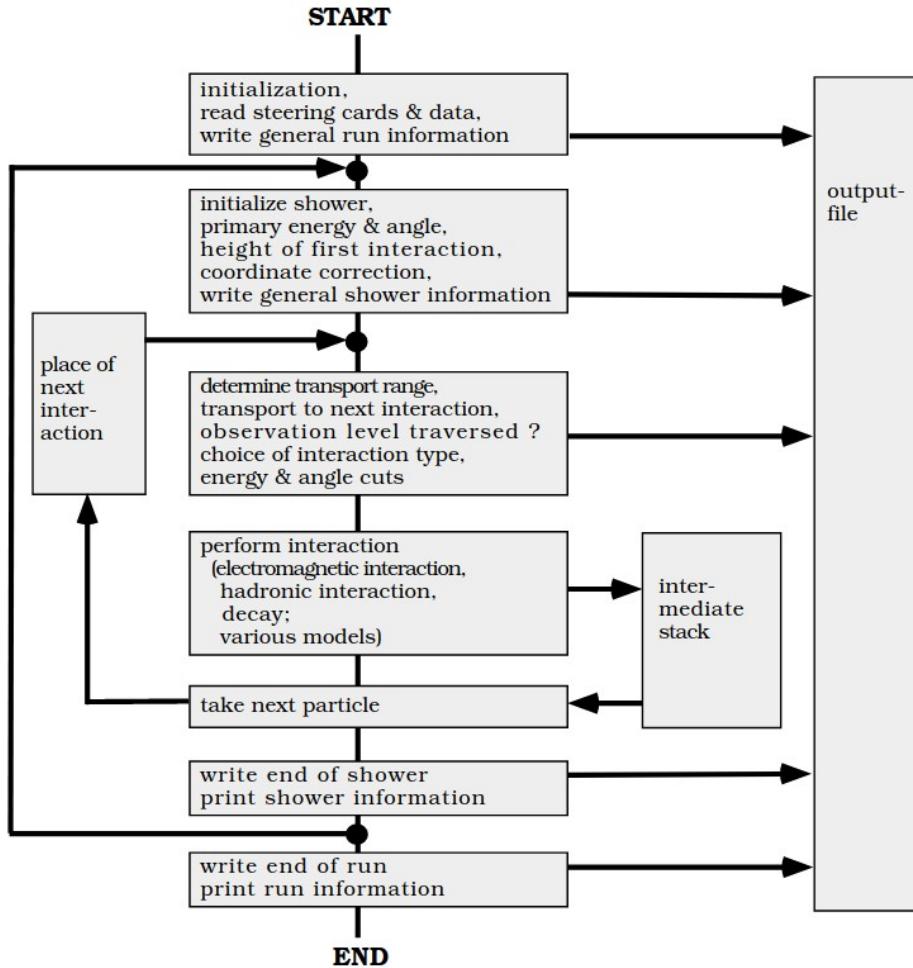


CORSIKA: COsmic Ray SImulations for KAscade



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

CORSIKA



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

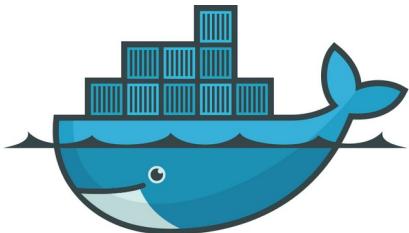
- Análisis de los datos
 - LDF
 - Espectro de energía

¡Vamos a la acción!

(Docker)

Instalación:

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



- Corsika
- 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 vlr0
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)
```

```
./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:

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

DATNNNNNNN.dbase ← librerías e info de la lluvia

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

- Otro tipo de archivos

.long .tab .info ...

→ ver el capítulo. 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
```

- Análisis 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
```

- Análisis de los secundarios:

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

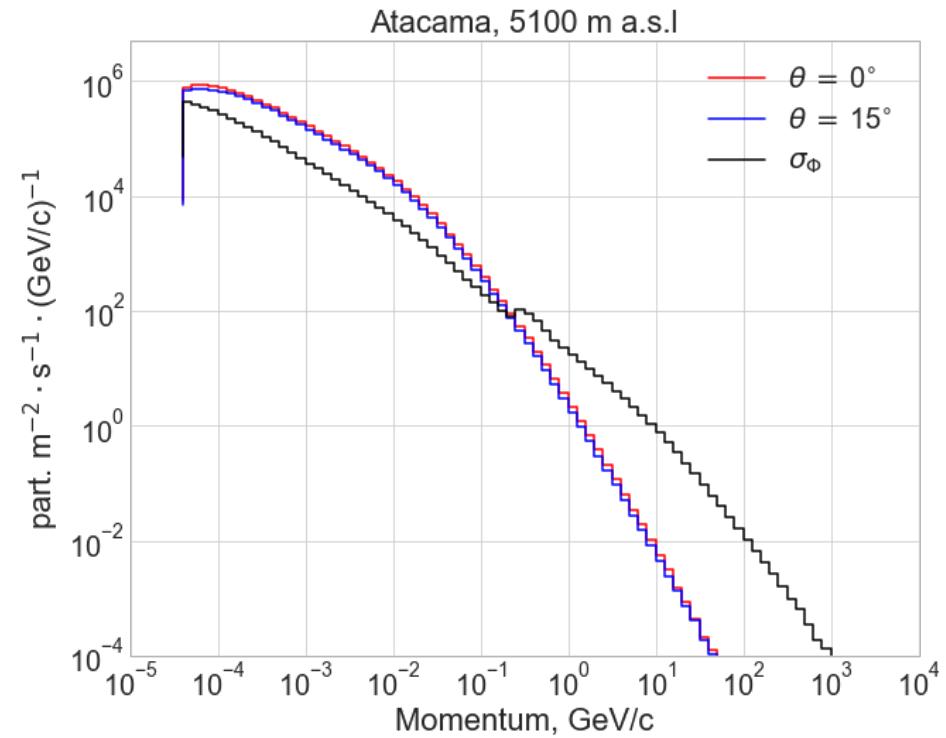
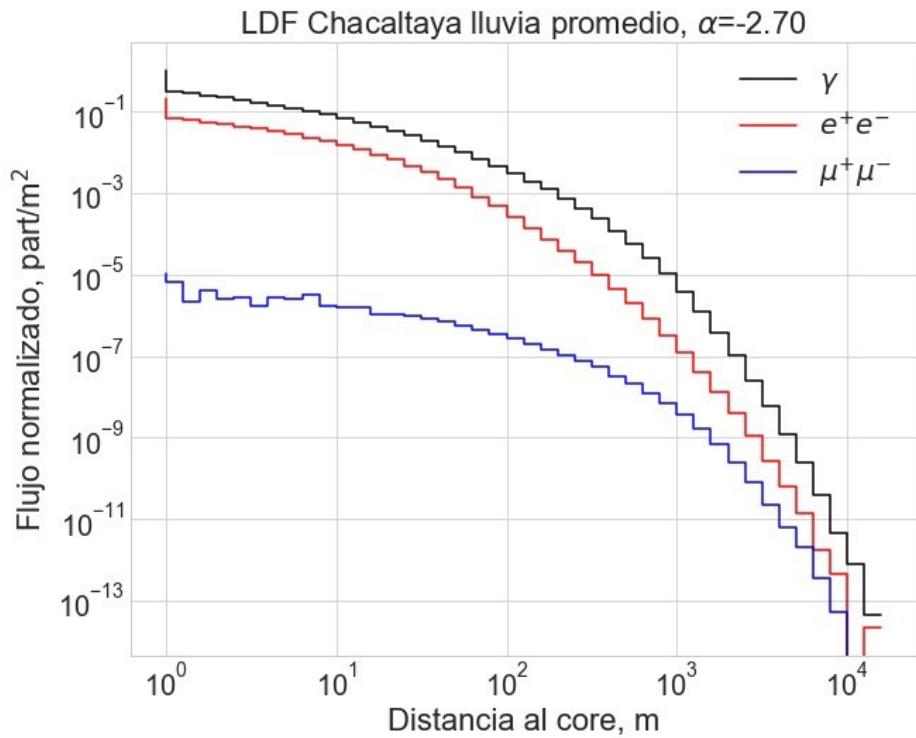
- Salida:

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

salida_apx.hst→ Distribución de la energía de los secundarios

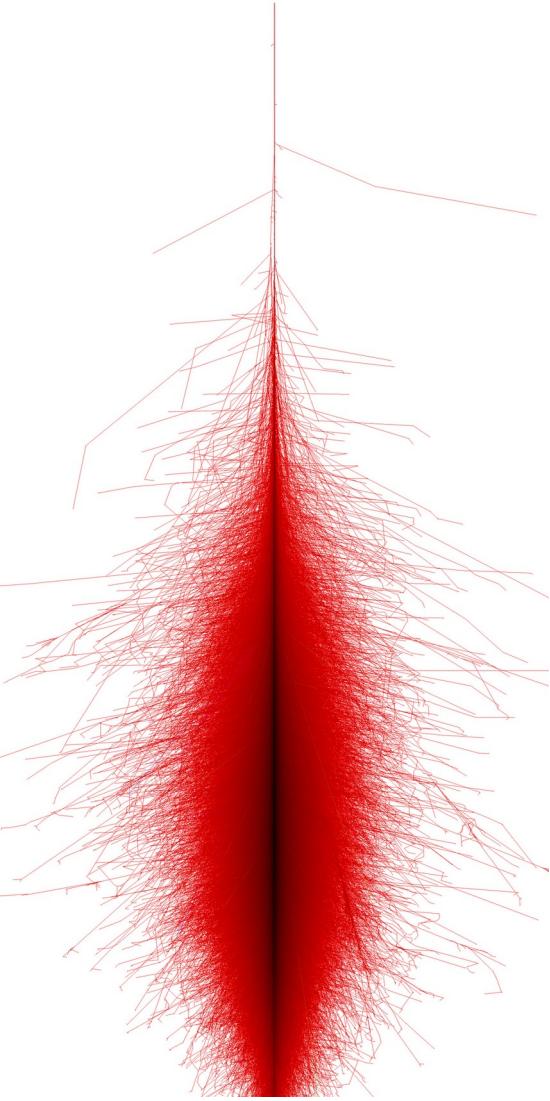
salida_apx.dse→ Distribución de la energía de los secundarios con respecto
a la distancia.

Análisis de los datos



Algunos enlaces de interés

- Manual de Corsika:
<https://www.iap.kit.edu/corsika/70.php>
- Artículo sobre ARTI:
<https://arxiv.org/abs/2010.14591>
- Proceding 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()

del= 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(del["distance_in_bin"], del["Total_E_per_bin"]/10, c="b", label=r"$total$")
plt.step(del["distance_in_bin"], del["E_phot"]/10, c="k", label=r"$\gamma$")
plt.step(del["distance_in_bin"], (del["E_e+"]+del["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)
```