13th LAGO Workshop

LAGO ARTI & Meiga
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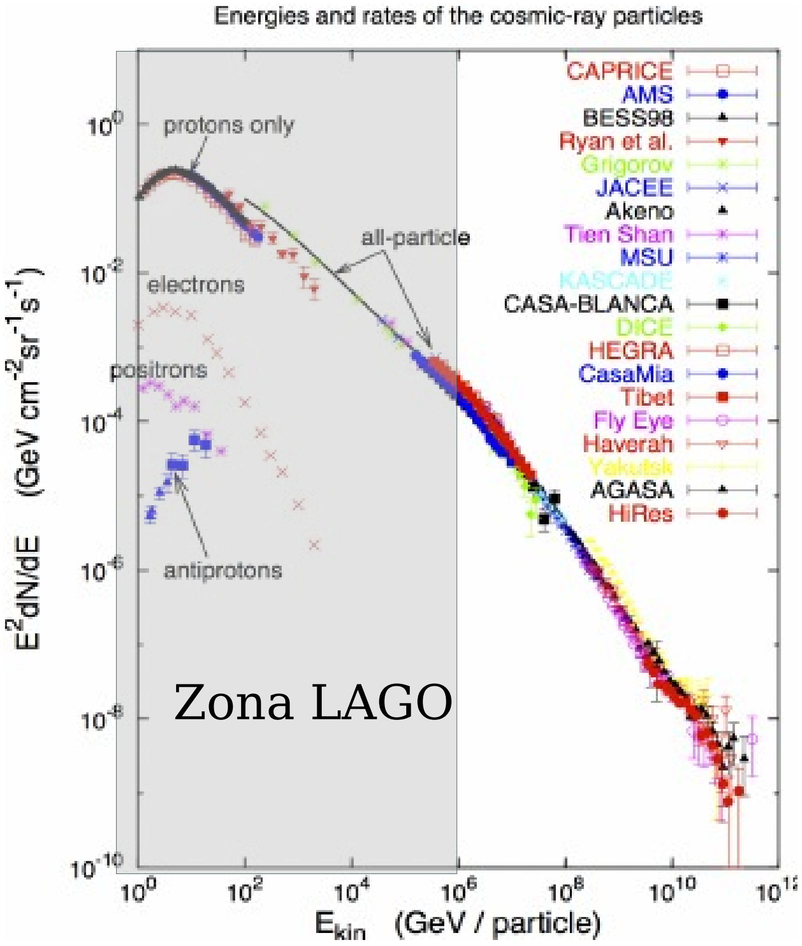
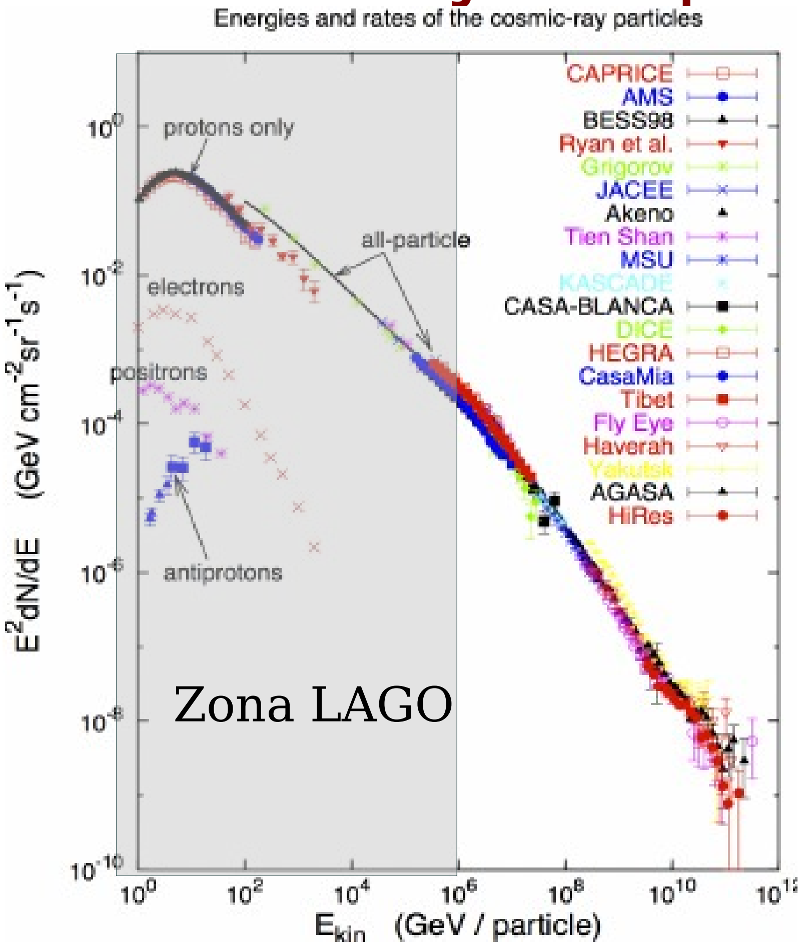
Sinopsis:

- Flujo de rayos cósmicos
- Cadena de simulación LAGO
- Simulación del flujo

Introducción a los Rayos Cósmicos



Flujo de partículas secundarias

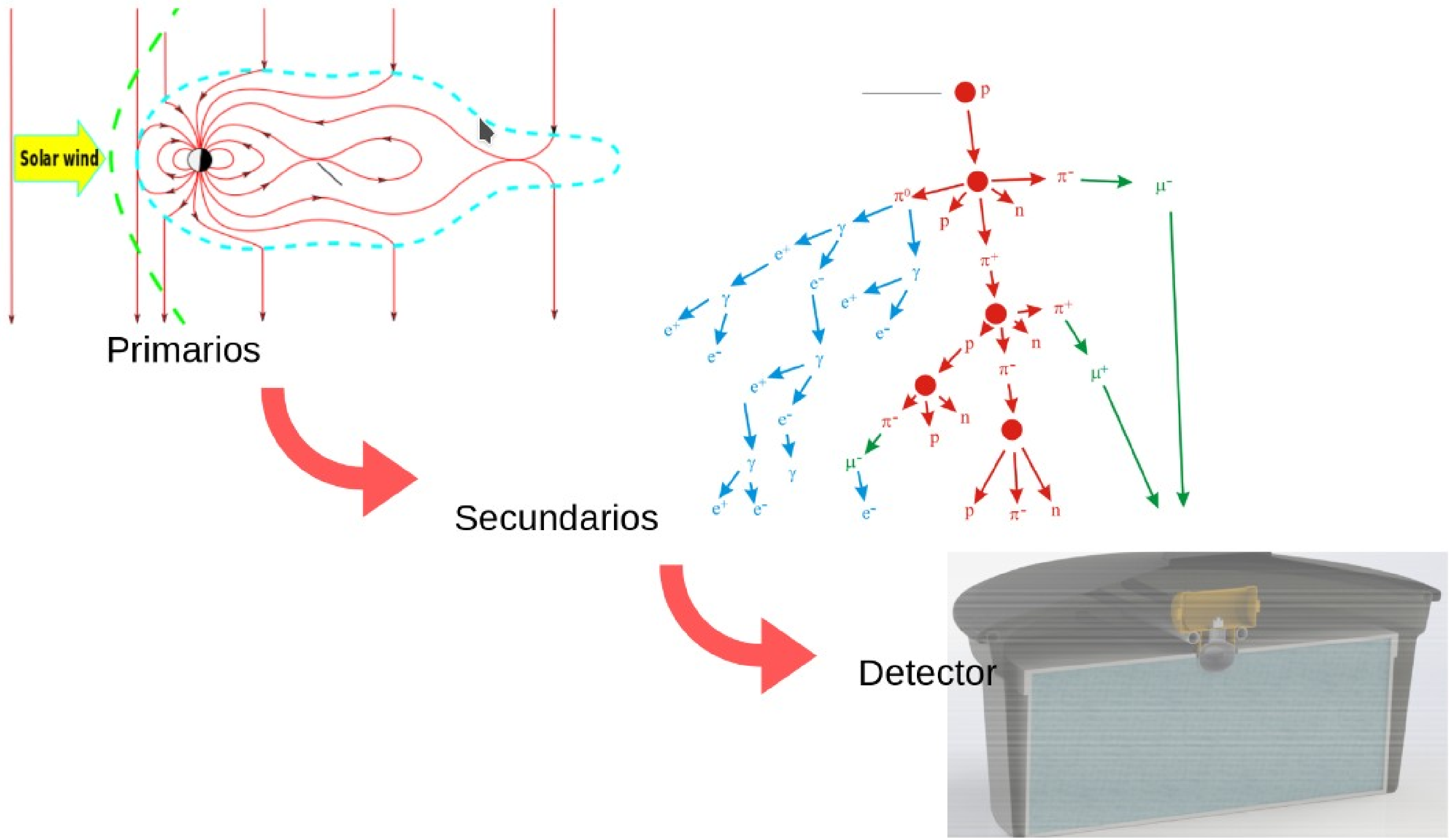


$$j(E) = j_0 E^{\alpha},$$

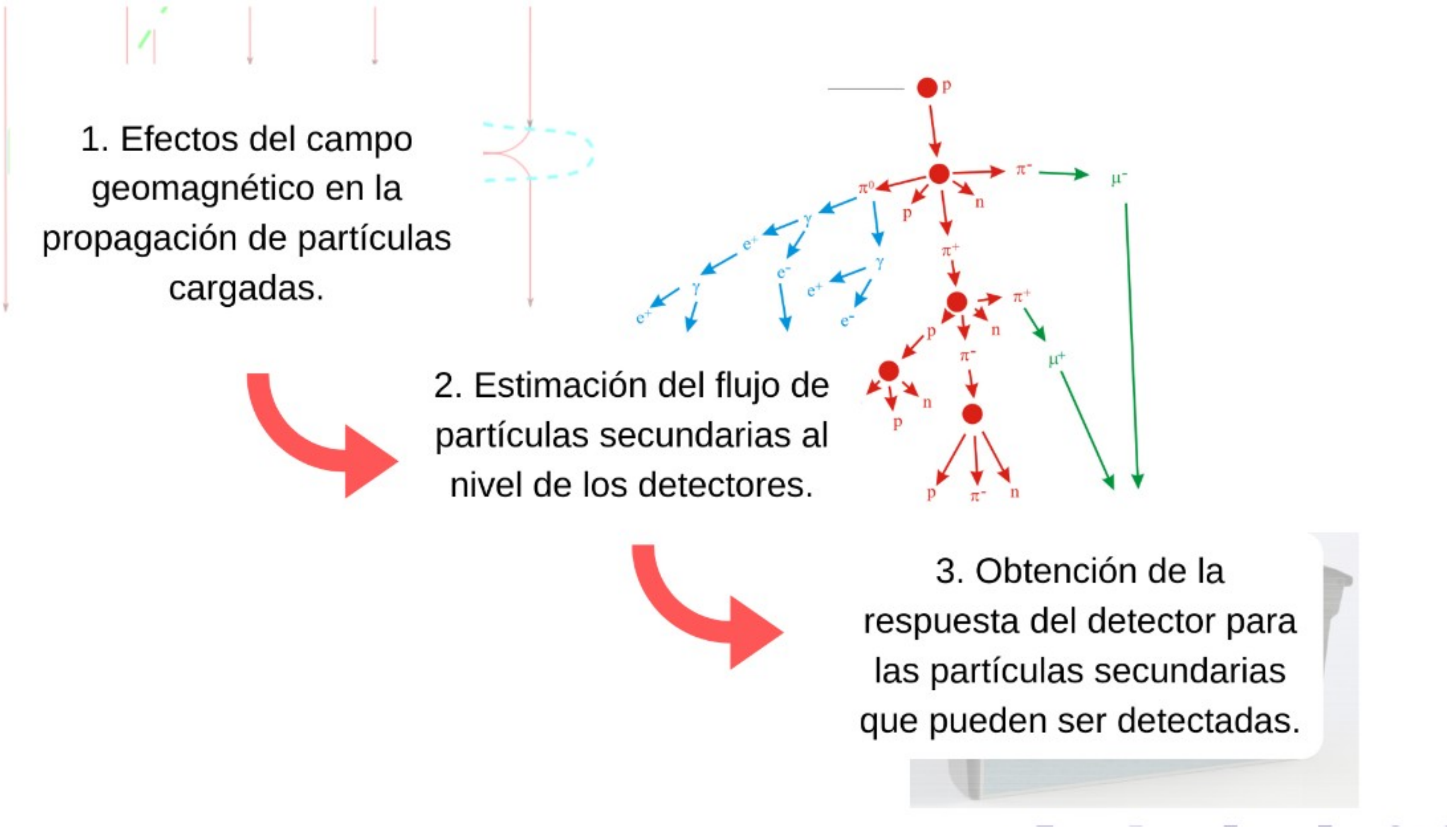
$$j(E) = \frac{dJ}{dE} = \frac{dN(E)}{dS\, d\Omega\, dt\, dE},$$

$$N = \int_{\Delta E}\int_{\Delta\Omega}\int_{\Delta t}\int_{S}\left(\frac{dN(E)}{dS\, d\Omega\, dt\, dE}\right) dS\, dt\, d\Omega\, dE,$$

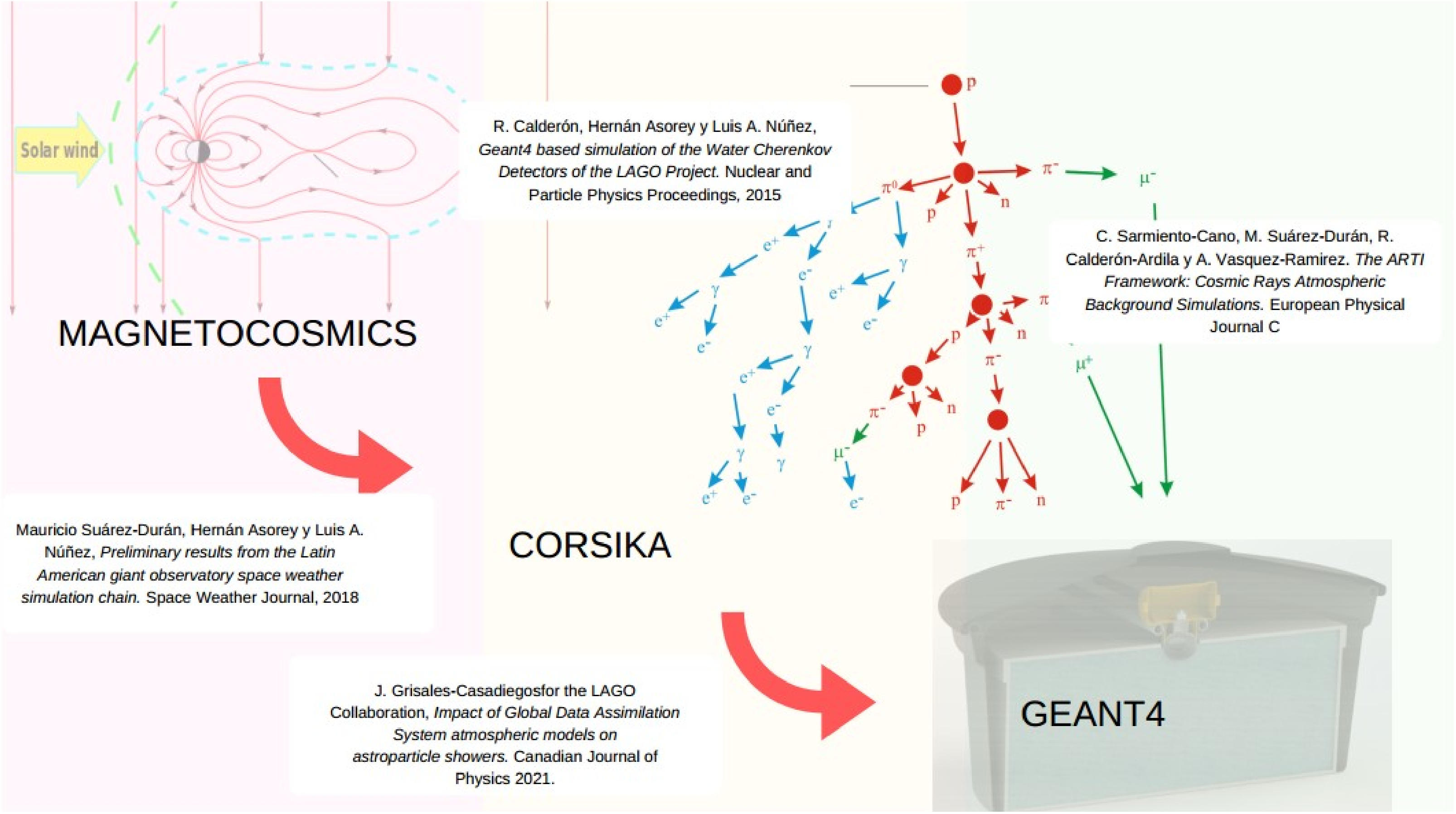
Flujo de partículas secundarias



Flujo de partículas secundarias



Flujo de partículas secundarias



ARTI(Corsika)

./do_sims.sh -?

```
USAGE ./do_sims.sh:
Simulation parameters
  -w <working dir>                    : Working directory, where bin (run) files are located
  -p <project name>                   : Project name (suggested format: NAMEXX)
  -v <CORSIKA version>                : CORSIKA version
  -h <HE Int Model (EPOS|QGSII)>      : Define the high interaction model to be used
  -u <user name>                      : User Name.
  -j <procs>                          : Number of processors to use
Physical parameters
  -t <flux time>                      : Flux time (in seconds) for simulations
  -m <Low edge zenith angle>          : Low edge of zenith angle.
  -n <High edge zenith angle>         : High edge of zenith angle.
  -r <Low primary particle energy>    : Lower limit of the primary particle energy.
  -i <Upper primary particle energy>  : Upper limit of the primary particle energy.
  -a <high energy ecuts>              : High energy cuts for ECUTS; (if set value in GV = enabled).
  -y                                  : Select volumetric detector mode (default=flat array)
Site parameters
  -s <site>                           : Location (several options)
  -k <altitude, in cm>                : Fix altitude, even for predefined sites
  -c <atm_model>                      : Fix Atmospheric Model even for predefined sites.
  -o <BX>                             : Horizontal comp. of the Earth's mag. field.
  -q <BZ>                             : Vertical comp. of the Earth's mag. field.
  -b <rigidity cutoff>                : Rigidity cutoff; (if set value in GV = enabled).
Modifiers
  -l                                  : Enables SLURM cluster compatibility (with sbatch).
  -e                                  : Enable CHERENKOV mode
  -d                                  : Enable DEBUG mode
  -x                                  : Enable other defaults (It doesn't prompt user for unset parameters)
  -?                                  : Shows this help and exit.
```

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```

```
./do_sims.sh -w ../../lago-corsika-77402/run/ -p lagoW -v 77402 -u csarmiento -t 60 -s bga
```

ARTI(Corsika)

```
0 1 H 140581  ->  _______
4 2 He 14149  ->  _______
12 6 C 365  ->  _______
16 8 O 353  ->  _______
7 3 Li 144  ->  _______
11 5 B 99  ->  _______
24 12 Mg 84  ->  _______
28 14 Si 81  ->  _______
14 7 N 74  ->  _______
20 10 Ne 65  ->  _______
56 26 Fe 49  ->  _______
9 4 Be 42  ->  _______
55 25 Mn 15  ->  _______
52 24 Cr 14  ->  _______
32 16 S 13  ->  _______
51 23 V 12  ->  _______
27 13 Al 11  ->  _______
23 11 Na 10  ->  _______
48 22 Ti 9  ->  _______
40 20 Ca 8  ->  _______
19 9 F 7  ->  _______
45 21 Sc 6  ->  _______
40 18 Ar 5  ->  _______
39 19 K 4  ->  _______
31 15 P 3  ->  _______
35 17 Cl 2  ->  _______
```

ARTI(Corsika)

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40 18 Ar 5  ->  _______
39 19 K 4  ->  _______
31 15 P 3  ->  _______
35 17 Cl 2  ->  _______
```

```
cd ../../lago-corsika-77402/run/
```

```
go-lagoW-all-02.sh  go-lagoW-pr-3.sh
go-lagoW-all-03.sh  go-lagoW-pr-4.sh
go-lagoW-all-04.sh  go-lagoW-pr-5.sh
go-lagoW-all-05.sh  go-lagoW-pr-6.sh
go-lagoW-all-06.sh  go-lagoW-pr-7.sh
go-lagoW-he.sh      go-lagoW-pr-8.sh
go-lagoW-pr-1.sh    gr3.txt
go-lagoW-pr-2.sh    lagoW
```

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 de los binarios:

```
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
```

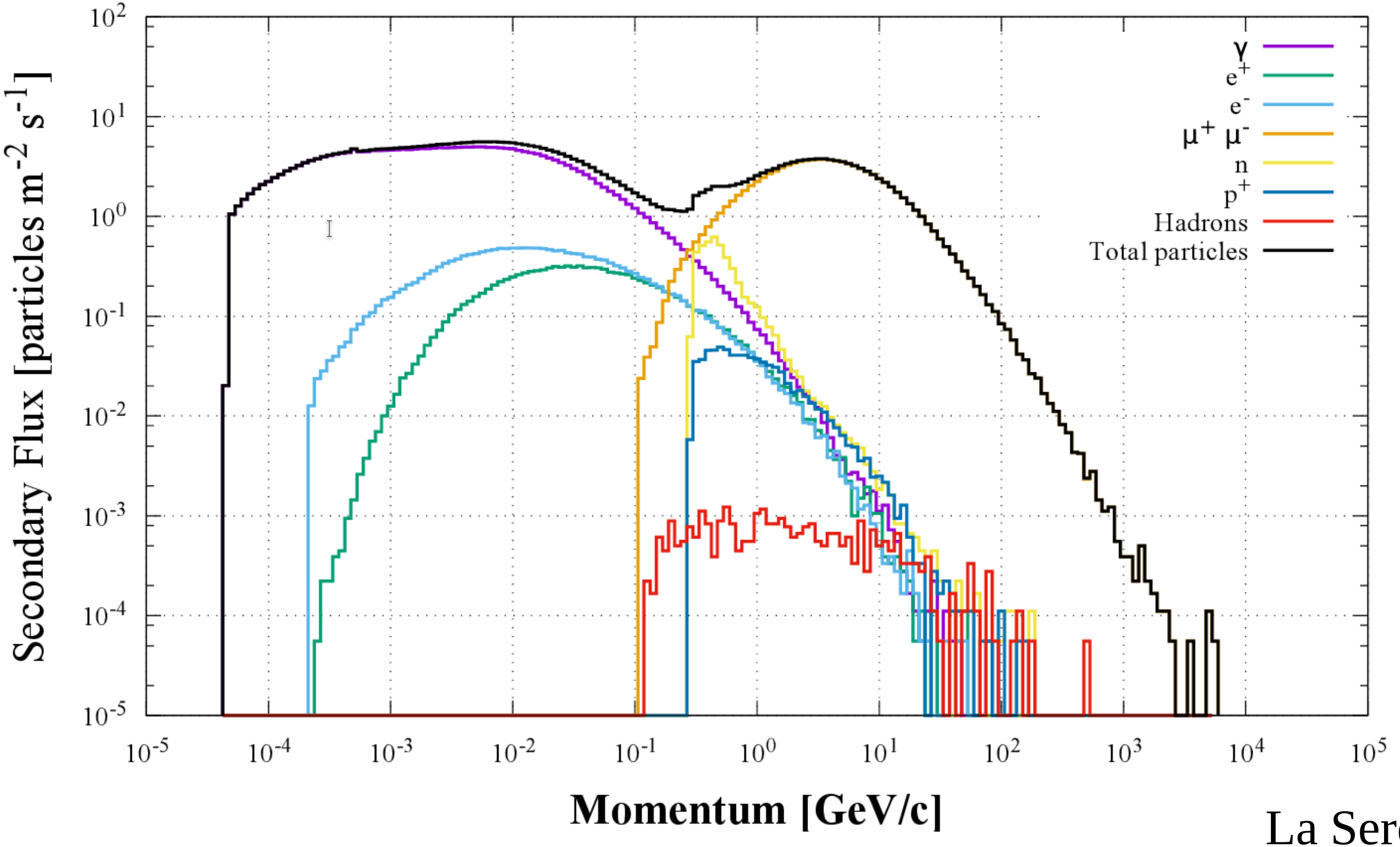
- Salida:

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.

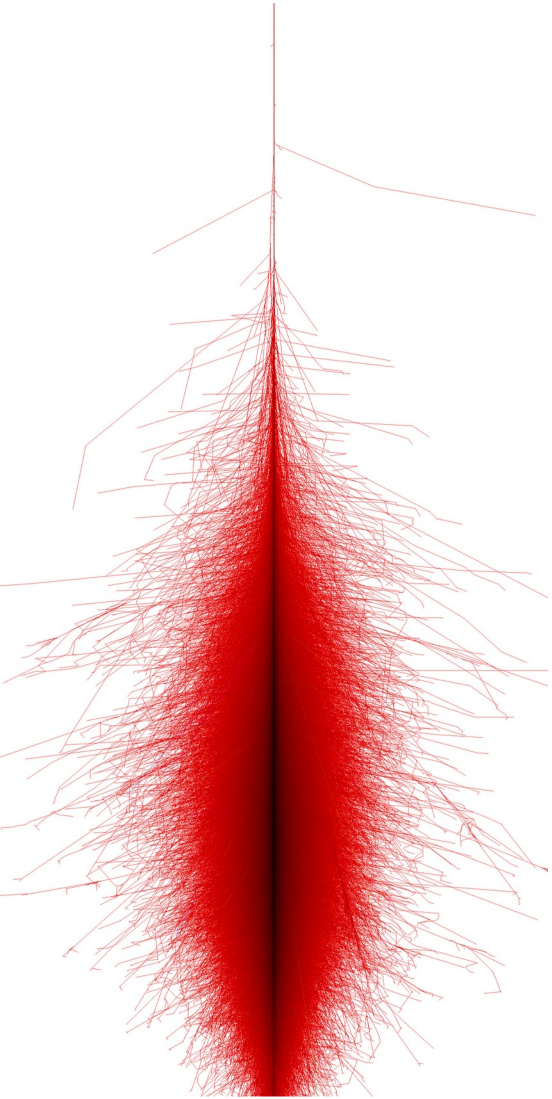
Análisis de los datos



La Serena, Chile

Algunos enlaces de interés

- Wiki LAGO: http://wiki.lagoproject.net
- 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!

```
#Espectro de energia del flujo de secundarios

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_flujo_bga60.hst", 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"]/60, c="b", label=r"total")
plt.step(df["distance_in_bin"], df["N_phot"]/60, c="k", label=r"$\gamma$")
plt.step(df["distance_in_bin"], (df["N_e+"]+df["N_e-"])/60, c="r", label=r"$e^{+}e^{-}$")
plt.step(df["distance_in_bin"], (df["N_mu+"]+df["N_mu-"])/60, c="g", label=r"$\mu^{+}\mu^{-}$")
plt.step(df["distance_in_bin"], (df["N_n"])/60, c="m", label=r"$n$")
plt.xscale("log")
plt.yscale("log")
plt.ylim(1, 30)
plt.title(r"Flujo para BGA", fontsize=22)
plt.xlabel("Momemtum, GeV/c")
plt.ylabel(r"part $\cdot$ m$^{-2}$ $\cdot$ s$^{-1}$")
plt.legend(fontsize=20)
```