

DDAp - ITeDA+KIT

Física de Astropartículas - 2017

- **Unidad** 02 – Lluvias atmosféricas extendidas
- **Clase** UO2
- **Cont** EAS
- **Cátedra** Asorey
- **Web** <https://github.com/asoreyh/astroparticulas>

- **Unidad 1:** Fenomenología de Astropartículas.
- **Unidad 2:** Lluvias Atmosféricas Extendidas (EAS).
Laboratorio: Simulaciones en CORSIKA
- **Unidad 3:** Técnicas de detección de Astropartículas.
- **Unidad 4:** Aplicaciones en LAGO y análisis de datos.
Laboratorio: Análisis de datos de meteorología del espacio y del decaimiento del muón en un detector Cherenkov en agua.



<https://github.com/lagoproject/astroparticulas>

La idea detrás de la clase de hoy

WALLPAPERDETV.BLOGSPOT.COM



Lluvias Atmosféricas Extendidas (EAS)

Generalidades

- **EAS** Cascada de partículas originada en la interacción de un RC con la atmósfera
- X Profundidad atmosférica (masa atravesada)
- X_0 Punto de primera interacción
- $N_{\text{máx}}$ Número máximo de partículas en la lluvia: $N_{\text{máx}} \propto E_p$
- $X_{\text{máx}}$ Profundidad del máximo: $X_{\text{máx}} \propto \ln(E_p)$

EM

- Decaimiento de π^0 :

$$\pi^0 \rightarrow \gamma\gamma$$

$$\pi^0 \rightarrow \gamma e^+ e^-$$
- Bethe-Heitler:

Frenado: $e^\pm \xrightarrow{\gamma} e^\pm \gamma$

Pares: $\gamma \xrightarrow{\gamma} e^+ e^-$
- Domina $N_{\text{máx}} \rightarrow X_{\text{máx}}$
- $E_{\text{EM}} = (80\% - 90\%)E_p$

Muónica

- Dec. de K^\pm y π^\pm :

$$K^+ \rightarrow \mu^+ \nu_\mu$$

$$K^+ \rightarrow \pi^+ \pi^0$$

$$\pi^+ \rightarrow \mu^+ \nu_\mu$$
- Procesos radiativos

$$\mu^\pm \xrightarrow{\gamma} \mu^\pm e^+ e^-$$

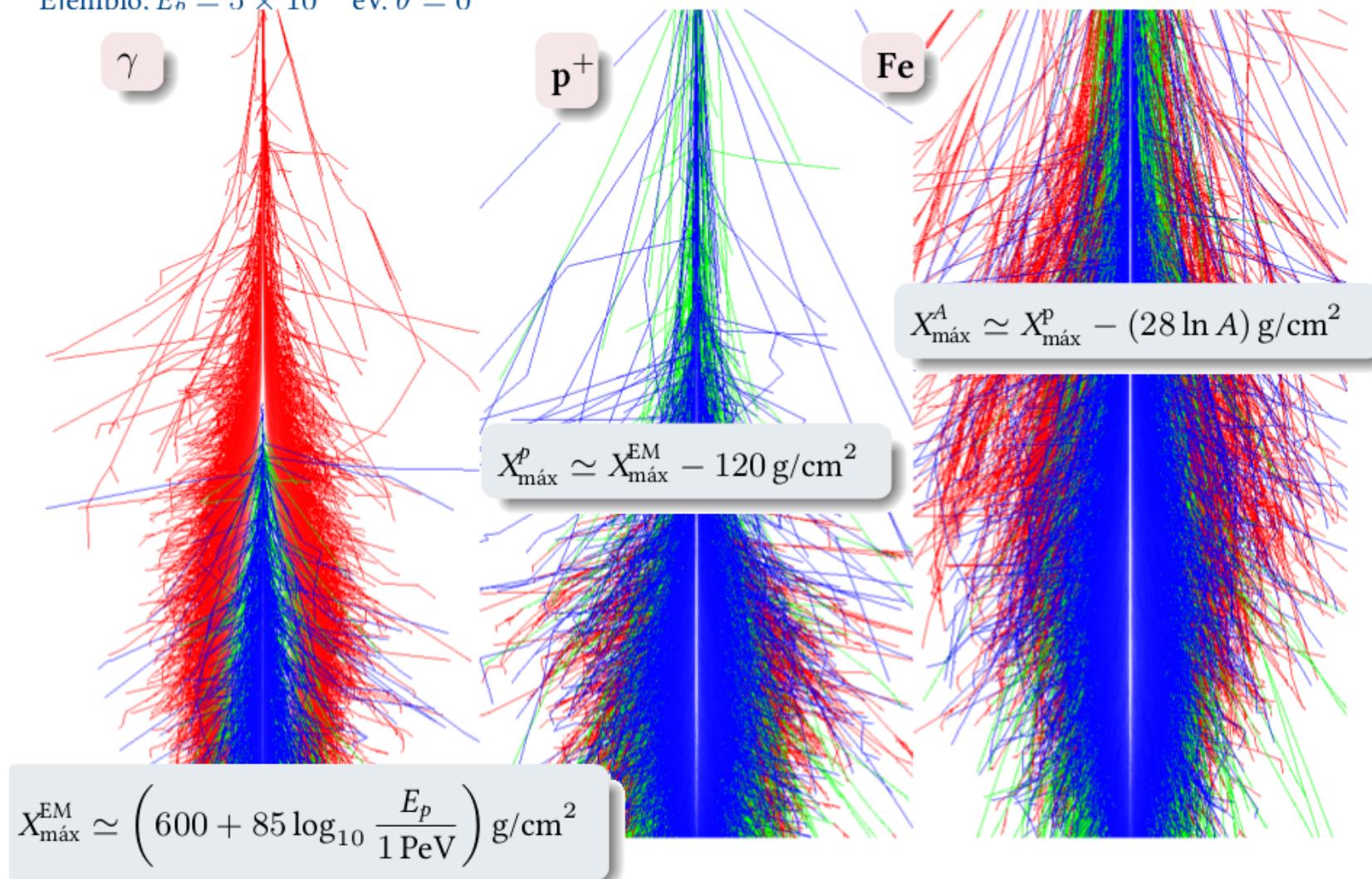
$$\mu^\pm \xrightarrow{\gamma} \mu^\pm + \text{had}$$
- $N_\mu \propto A^{0,1} E_p^{0,9}$

Hadrónica

- Fragmentos nucleares
- p, n, π^\pm, K^\pm
- Mesones encantados
- *Leading particle effect*
- Concentrada en el eje de la lluvia
- $N_h \propto N_e^{0,95}$
- $N_h/N_e \sim 10^{-2} - 10^{-4}$

Cascadas atmosféricas

Ejemplo. $E_n = 5 \times 10^{14}$ eV. $\theta = 0^\circ$

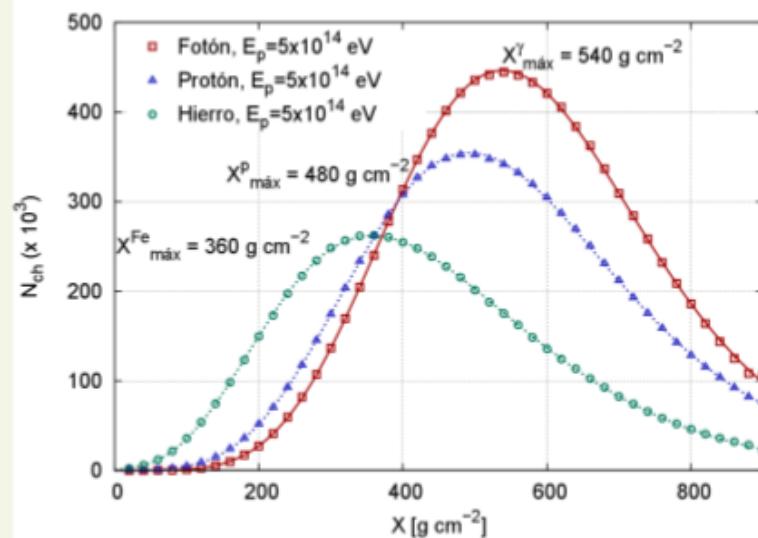


Repaso...

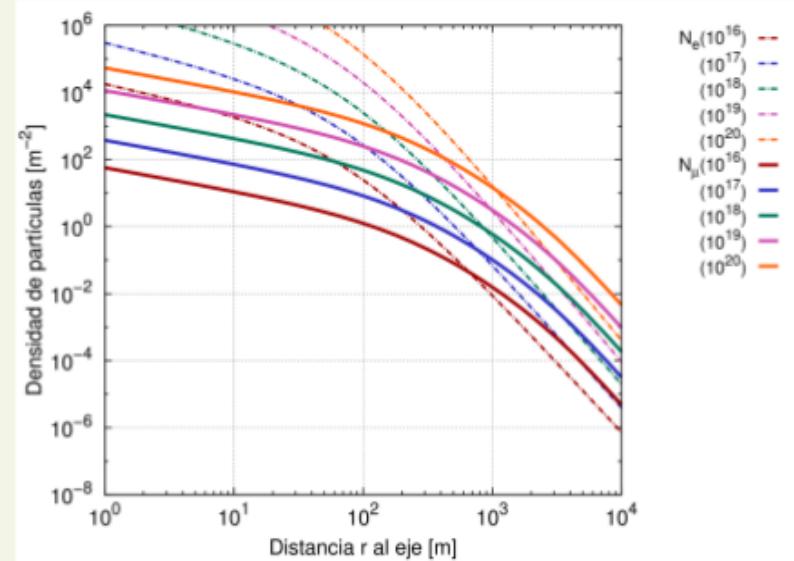
$$E_d^{\text{atm}} + E_d^{\text{suelo}} = E_p$$

Desarrollo Longitudinal y Transversal

$E_d^{\text{atm}} \rightarrow$ Gaisser-Hillas

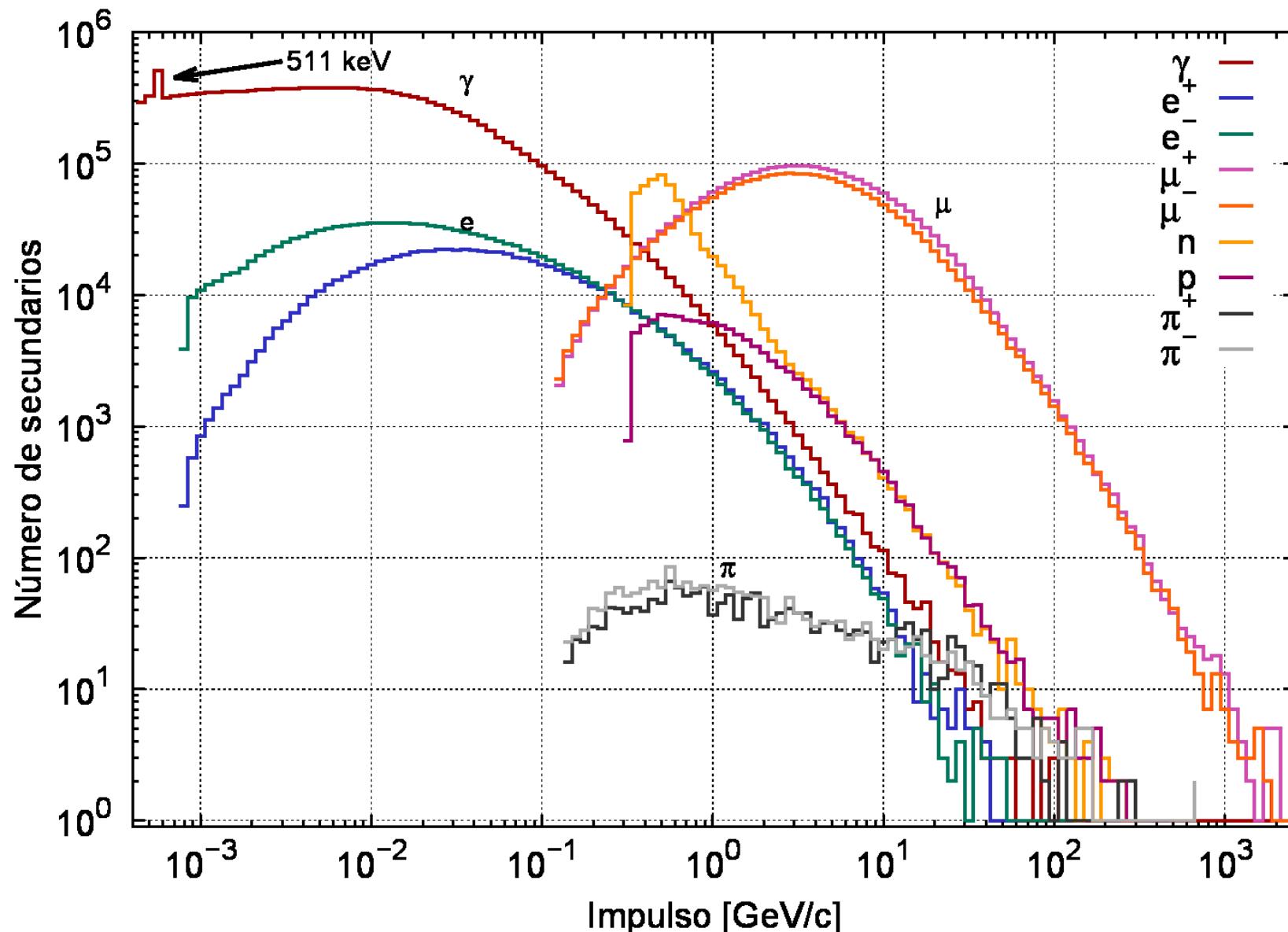


$E_d^{\text{suelo}} \rightarrow$ LDF: $\rho_e(r)$ y $\rho_\mu(r)$



- Desarrollo longitudinal
- $N_c h(X) \propto E_d(X)$
- Desarrollo transversal
- Función Distribución Lateral
- $\rho(r) = \sum_i \rho_i(r) \xrightarrow{\text{Detector}} S_m(r)$

Objetivo final → Flujo de secundarios



**Abandonad toda esperanza los
que atraveséis este umbral...**



CORSIKA, an Air Shower Simulation Program

- CORSIKA (COsmic Ray SImulations for KAscade) is a program for detailed simulation of extensive air showers initiated by high energy cosmic ray particles. Protons, light nuclei up to iron, photons, and many other particles may be treated as primaries. The particles are tracked through the atmosphere until they undergo reactions with the air nuclei or - in the case of unstable secondaries - decay. The hadronic interactions at high energies may be described by several reaction models alternatively: The VENUS, QGSJET, and DPMJET models are based on the Gribov-Regge theory, while SIBYLL is a minijet model. The neXus model extends far above a simple combination of QGSJET and VENUS routines. The most recent EPOS model is based on the neXus framework but with important improvements concerning hard interactions and nuclear and high-density effect. HDPM is inspired by findings of the Dual Parton Model and tries to reproduce relevant kinematical distributions being measured at colliders. Hadronic interactions at lower energies are described either by the GHEISHA interaction routines, by a link to FLUKA, or by the microscopic UrQMD model. In particle decays all decay branches down to the 1 % level are taken into account. For electromagnetic interactions a taylor made version of the shower program EGS4 or the analytical NKG formulas may be used. Options for the generation of Cherenkov radiation and neutrinos exist. CORSIKA may be used up to and beyond the highest energies of 100 EeV.

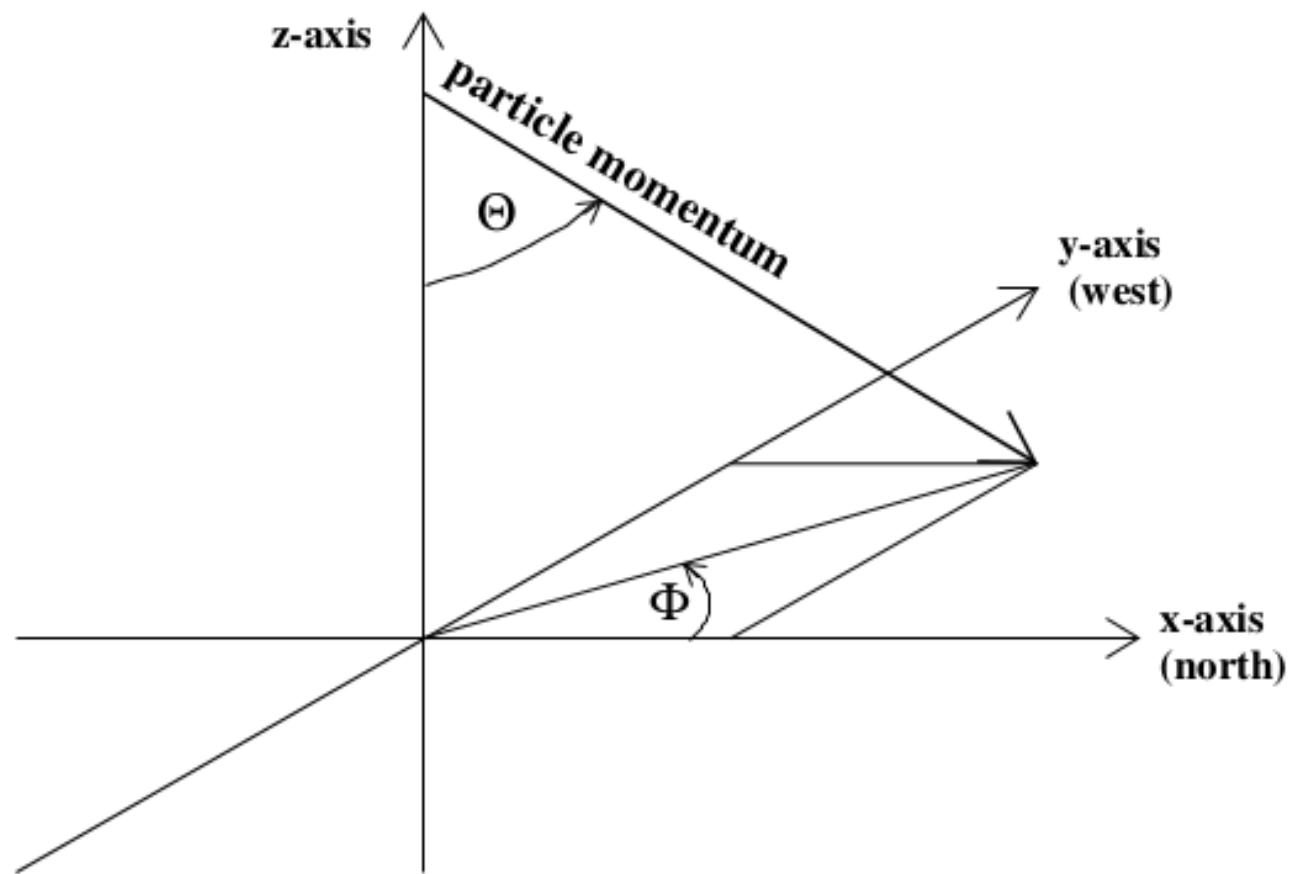


Instalación de corsika

- LAGO pre-compila y prepara versiones de CORSIKA para uso interno
- La versión actual es CORSIKA 7.5600 (Agosto 2016)
- Disponible en la **wiki** de LAGO y en la máquina virtual
- **Wiki LAGO → <http://wiki.lagoproject.org>**
- La configuración **estándar** de LAGO-CORSIKA es:
 - options: QGSJETII GHEISHA TIMEAUTO VOLUMEDET
 - selection: ATMEXT LPM EFIELD BERNLOHRDIR CURVED
- Para compilar con esta configuración, en la terminal

```
$ ./coconut -b
```
- **Una vez compilado, el directorio run/ es portable y autocontenido, i.e., todo lo necesario para realizar las simulaciones está en /run.**

Sistema de Coordenadas en CORSIKA



Quantity	CORSIKA	EGS4	FLUKA GHEISHA UrQMD	SIBYLL	DPMJET EPOS NEXUS QGSJET VENUS
length	cm	cm			
energy	GeV	MeV	GeV	GeV ³⁾	GeV
mass	GeV	MeV	GeV	GeV	GeV
time	sec ¹⁾	sec			
magn. field	μ T				
density	g/cm ³	g/cm ³			
mass overburden	g/cm ²				
angle	rad ²⁾	rad			
wavelength	nm				
	¹⁾ For output files also nsec is used. ²⁾ For in- and output files also ° is used. ³⁾ In some subroutines also TeV is used.				

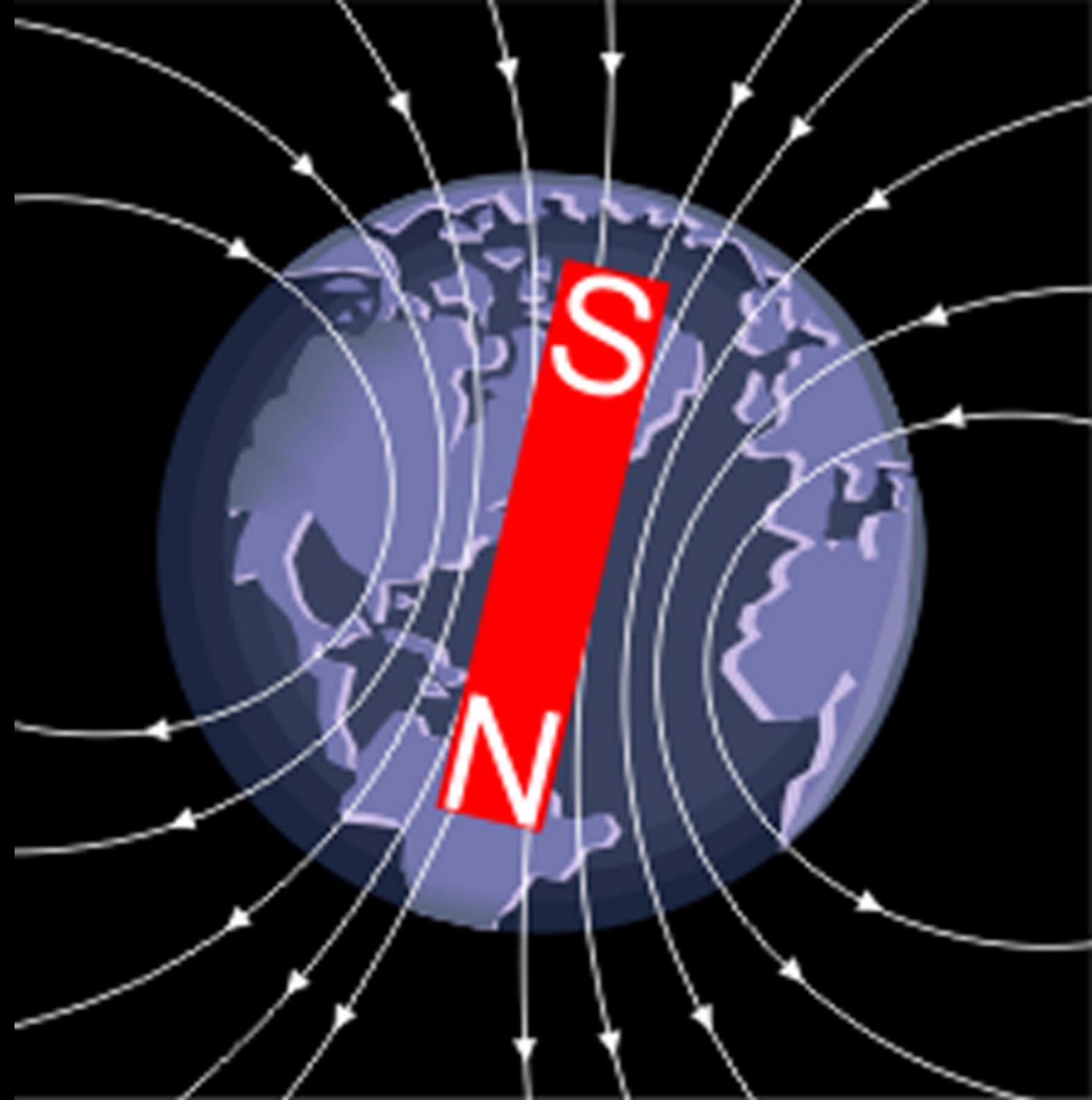
Table 3: Units used in CORSIKA and the coupled programs.

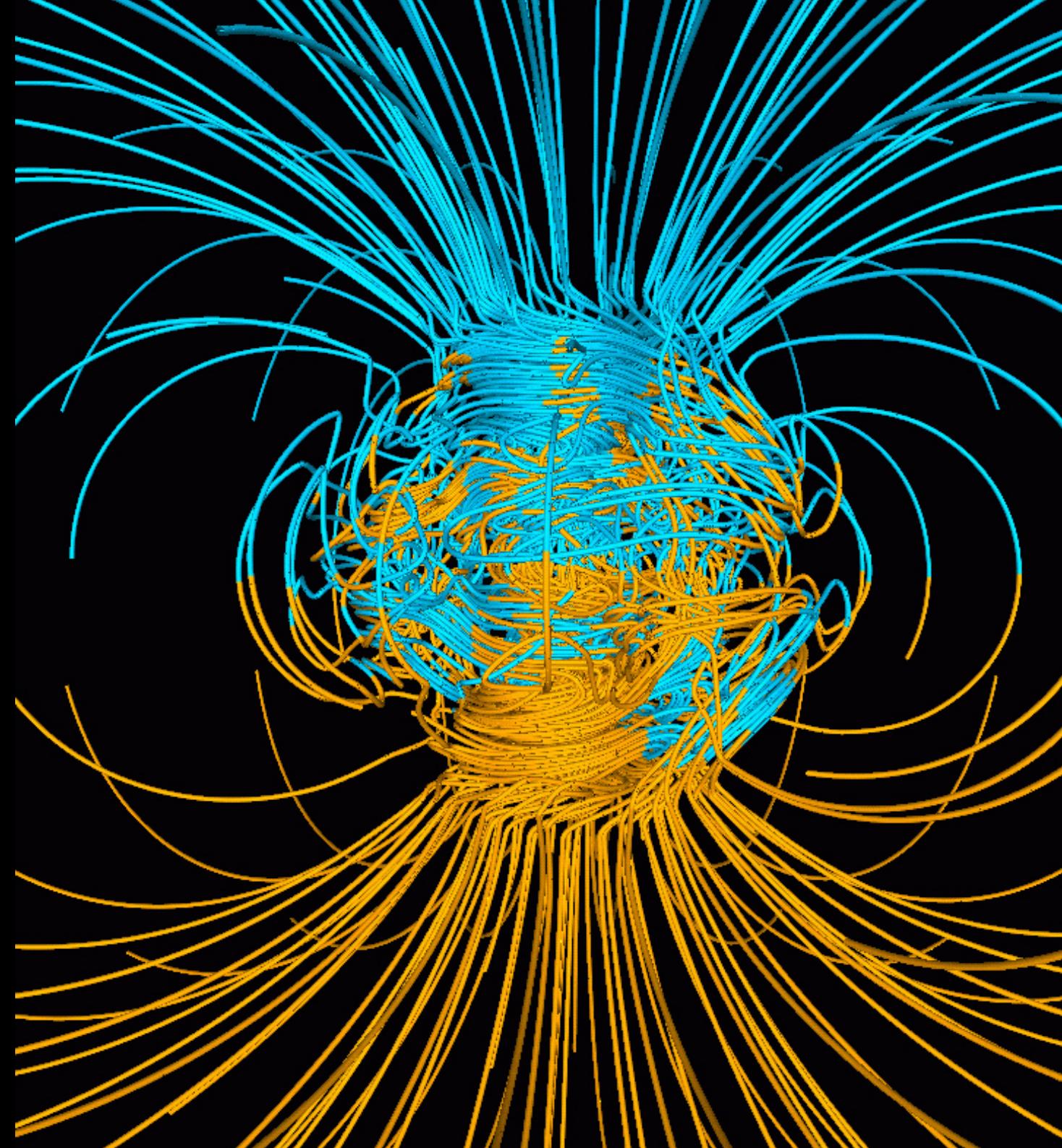
Partículas: CORSIKA Id

Particle identifications			
Identification	Particle	Identification	Particle
1	γ	51	ρ°
2	e^+	52	ρ^+
3	e^-	53	ρ^-
		54	Δ^{++}
5	μ^+	55	Δ^+
6	μ^-	56	Δ°
7	π°	57	Δ^-
8	π^+	58	$\overline{\Delta}^-$
9	π^-	59	$\overline{\Delta}^\circ$
10	K_L°	60	$\overline{\Delta}^+$
11	K^+	61	$\overline{\Delta}^+$
12	K^-	62	K^{*0}
13	n	63	K^{*+}
14	p	64	K^{*-}
15	\bar{p}	65	$\overline{K^{*0}}$
16	K_S°	66	ν_e
17	η	67	$\overline{\nu}_e$
18	Λ	68	ν_μ
19	Σ^+	69	$\overline{\nu}_\mu$
20	Σ°		
21	Σ^-	71	$\eta \rightarrow \gamma\gamma$
22	Ξ°	72	$\eta \rightarrow 3\pi^\circ$
23	Ξ^-	73	$\eta \rightarrow \pi^+\pi^-\pi^\circ$
24	Ω^-	74	$\eta \rightarrow \pi^+\pi^-\gamma$
25	\bar{n}	75	μ^+ add. info.
26	$\bar{\Lambda}$	76	μ^- add. info.
27	$\overline{\Sigma}^-$		
28	$\overline{\Sigma}^\circ$		
29	$\overline{\Sigma}^+$		
30	$\overline{\Xi}^\circ$		
31	$\overline{\Xi}^+$		
32	$\overline{\Omega}^+$		
50	ω		

Particle identifications (continued)			
Identification	Particle	Identification	Particle
116	D°	149	$\overline{\Lambda}_c^-$
117	D^+	150	$\overline{\Xi}_c^-$
118	\overline{D}^-	151	$\overline{\Xi}_c^\circ$
119	\overline{D}°	152	$\overline{\Sigma}_c^-$
120	D_s^+	153	$\overline{\Sigma}_c^\circ$
121	\overline{D}_s^-	154	$\overline{\Sigma}_c^0$
122	η_c	155	$\overline{\Xi}'_c^-$
123	D^{*0}	156	$\overline{\Xi}'_c^\circ$
124	D^{*+}	157	$\overline{\Omega}_c^\circ$
125	\overline{D}^{*-}		
126	\overline{D}^{*0}	161	Σ_c^{*++}
127	D_s^{*+}	162	Σ_c^{*+}
128	\overline{D}_s^{*-}	163	Σ_c^{*0}
130	J/ψ	171	$\overline{\Sigma}_c^{*-}$
131	τ^+	172	$\overline{\Sigma}_c^*$
132	τ^-	173	$\overline{\Sigma}_c^*$
133	ν_τ		
134	$\overline{\nu}_\tau$		
137	Λ_c^+		
138	Ξ_c^+		
139	Ξ_c°		
140	Σ_c^{*++}		
141	Σ_c^{*+}		
142	Σ_c^{*0}		
143	Ξ'_c^+		
144	Ξ'_c°		
145	Ω_c°		
$A \times 100 + Z$		nucleus of Z protons and $A - Z$ neutrons ($2 \leq A \leq 59$)	
9900		Cherenkov photons on particle output file	

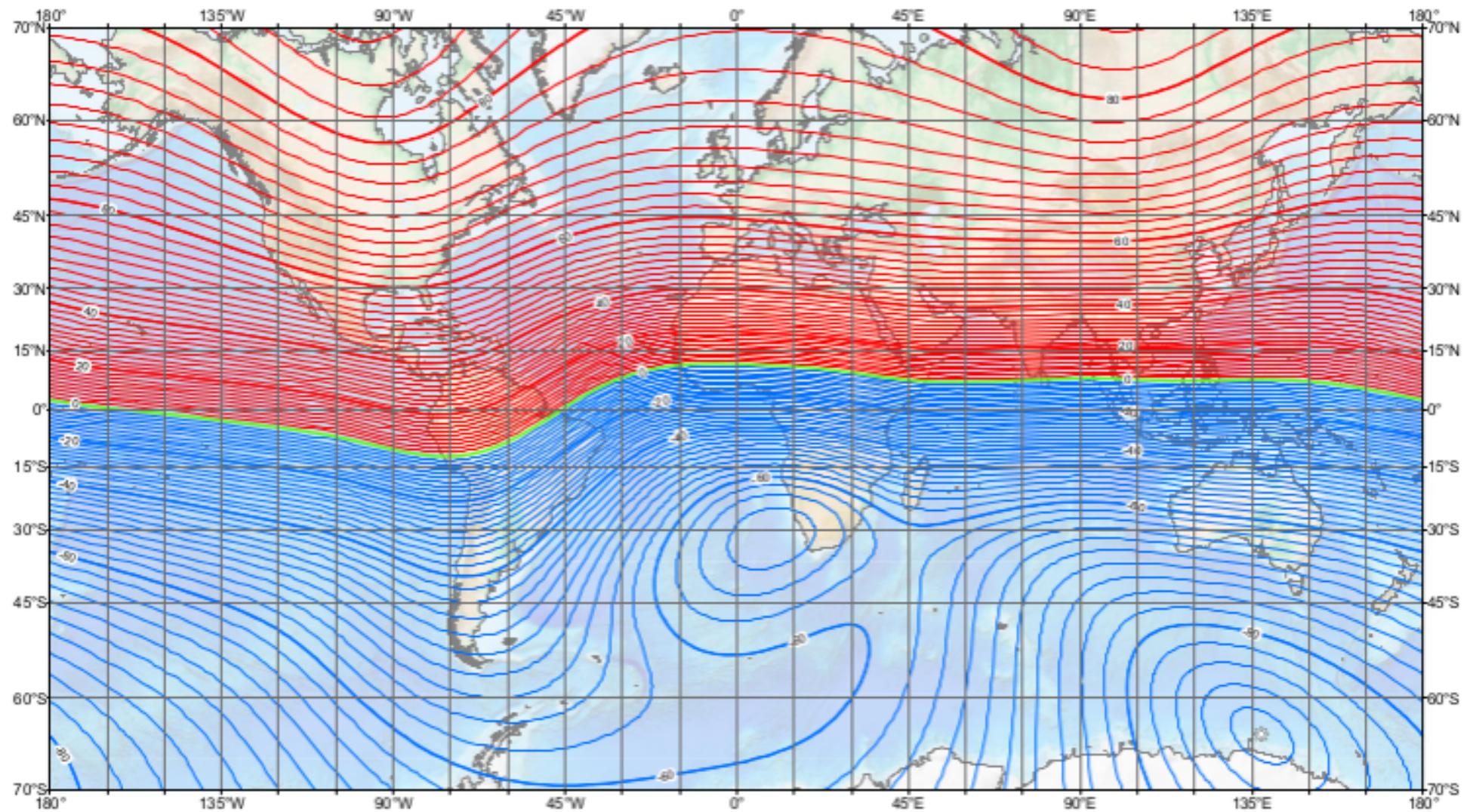
Table 4: Particle identifications as used in CORSIKA (to be continued).





Campo geomagnético: el “dipolo”

US/UK World Magnetic Model -- Epoch 2010.0
Main Field Inclination (I)



Main field inclination (I)
Contour interval: 2 degrees, red contours positive (down); blue negative (up); green zero line.
Mercator Projection.
Position of dip poles

Map developed by NOAA NGDC & ORES
<http://hgdcc.noaa.gov/geomag/WMM>
Map reviewed by NGA/BGS
Published January 2010

El modelo IGRF

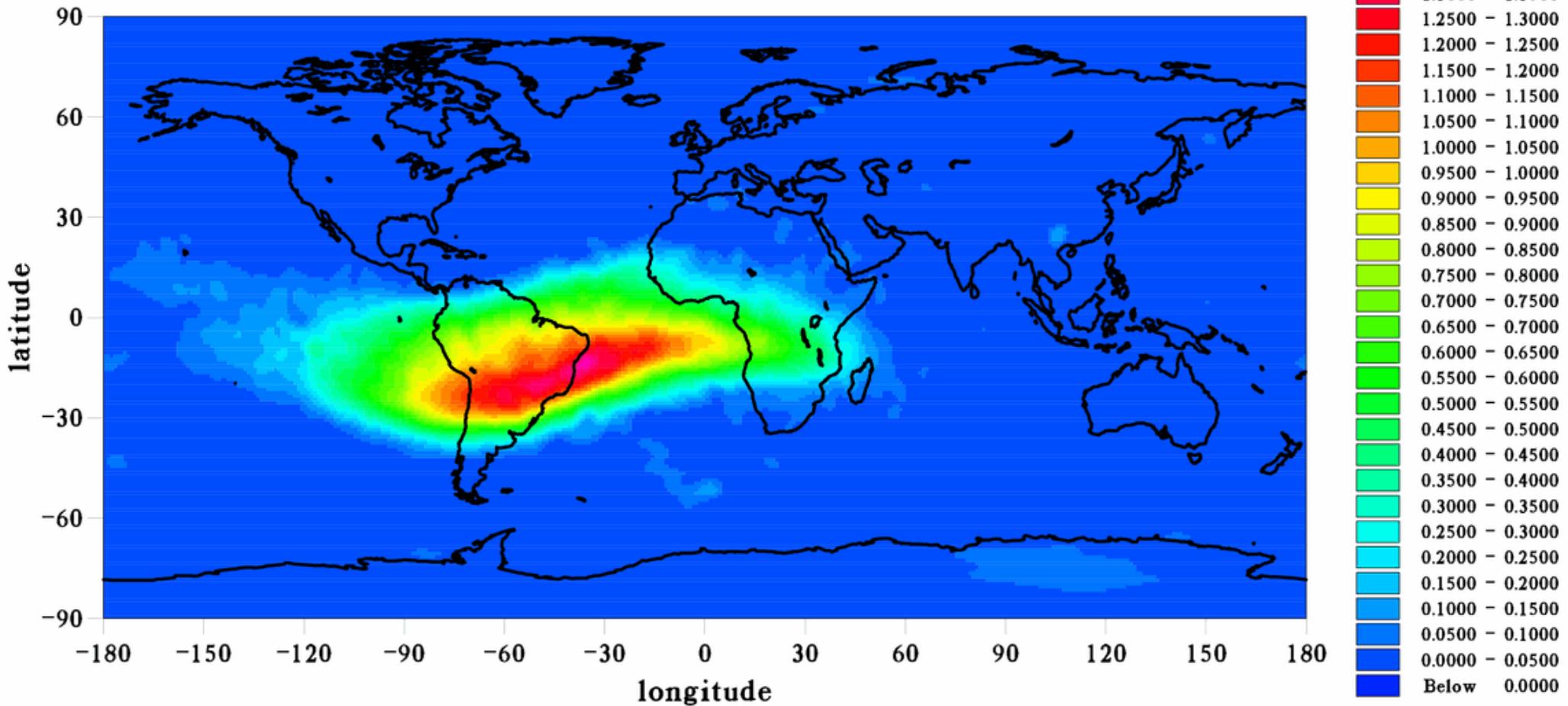
- Expansión multipolar de armónicos esféricos del campo magnético

$$V(r, \phi, \theta) = a \sum_{\ell=1}^L \sum_{m=-\ell}^{\ell} \left(\frac{a}{r}\right)^{\ell+1} (g_{\ell}^m \cos m\phi + h_{\ell}^m \sin m\phi) P_{\ell}^m(\cos \theta)$$

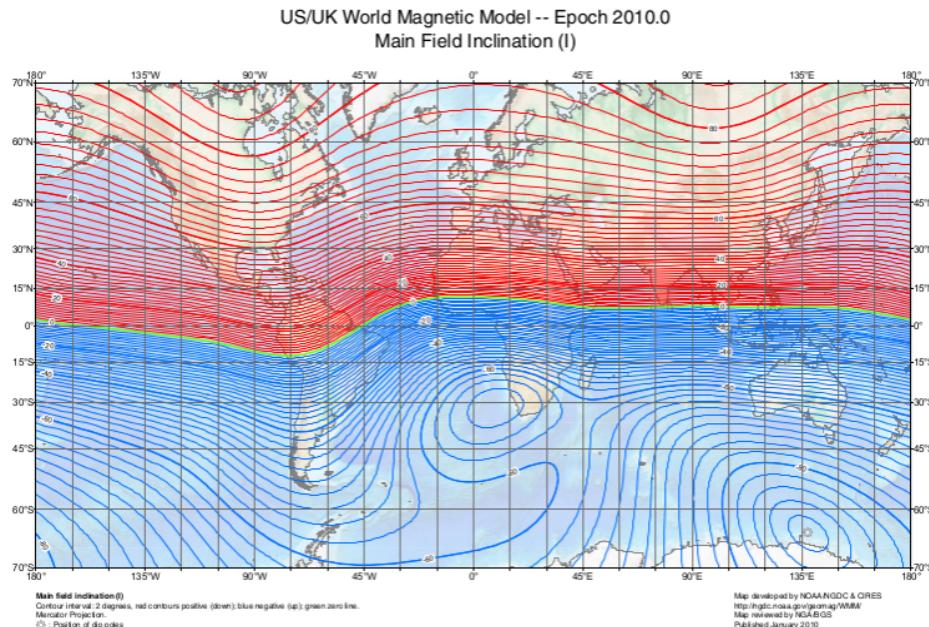
- L es el máximo multipolo considerado en la expansión
- ϕ es la longitud Este, θ es la colatitud (ángulo polar)
- a es el radio terrestre
- g_{ℓ}^m y h_{ℓ}^m son los coeficientes de Gauss de la expansión
- $P_{\ell}^m(\cos \theta)$ son las funciones de Schmidt (Legendre) de orden l y m
- Descarga de coeficientes y explicación detallada
 - Ver <http://wdc.kugi.kyoto-u.ac.jp/igrf/> y <http://www.ngdc.noaa.gov/IAGA/vmod/igrf.html>

Anomalía del Atlántico Sur

(rms : 0.2560 / moy : 0.1117 / min : 0.0010 / max : 1.4814)



Campo Geomagnético



(X component/1000) en IGRF2011 → BX (Horizontal)
(Z component/1000) en IGRF2011 → BZ (Vertical)

MAGNET BX BZ

Format = (A6, 2F), Defaults = 20.40, 43.23

BX : Is the horizontal component of the Earth's magnetic field (in μT) to the x-direction of the detector (North) and

BZ : Is the vertical component of the Earth's magnetic field (in μT) downwards.

Modelo Campo Magnético

<http://www.ngdc.noaa.gov/geomag-web/#igrfwmm>

Magnetic Field							
Model Used: IGRF12							
Latitude: 29.90° S							
Longitude: 71.25° W							
Elevation: 28.0 m Mean Sea Level							
Date	Declination (+ E - W)	Inclination (+ D - U)	Horizontal Intensity	North Comp (+ N - S)	East Comp (+ E - W)	Vertical Comp (+ D - U)	Total Field
2017-02-17	0.4706°	-30.0538°	20,283.0 nT	20,282.4 nT	166.6 nT	-11,735.8 nT	23,433.5 nT
Change/year	-0.1657°/yr	-0.1130°/yr	-78.7 nT/yr	-78.2 nT/yr	-59.3 nT/yr	-7.9 nT/yr	-64.2 nT/yr

Cuidado con las unidades (nT vs μ T)

Horizontal Intensity: The horizontal intensity is the intensity of the component of the magnetic field is tangent to the Earth surface at a given point.

North Component: The North component is the portion of the magnetic field that is directed horizontally northward. A southward directed field would have a negative value for the North component.

East Component: The East component is the portion of the magnetic field that is directed horizontally eastward. A westward directed magnetic field has a negative value for the East component.

Vertical Component: The vertical component is the portion of the magnetic field that is directed perpendicular to the Earth's surface at a given location. Down is measured as positive and up as negative.

Total Field: The total field is the intensity (or strength) of the entire magnetic field at a given location. Geometrically, it is the length of the magnetic field vector.

Input files

```
RUNNR      756014
EVTNR      0
NSHOW      1

PRMPAR     14
ESLOPE    -2.77
ERANGE    1.00e+04 1.00e+04
THETAP     30. 30.
PHIP       90. 90.

OBSLEV     2800.
ATMOSPHERE 2 Y
MAGNET    20.29 -11.74
FIXCHI     0.

SEED       6215087  0  0
SEED       7466722  0  0
SEED       4220892  0  0
SEED       7906236  0  0

ECUTS      0.05 0.05 0.00005 0.00005

CURVOUT    T
MUADDI    F
MUMULT    T
MAXPRT    0
ELMFLG    F T
LONGI     F 10. T T
ECTMAP    1.E3

DIRECT    ./
DATBAS    T
PAROUT    T F

USER      lago
EXIT
```

Ejemplo

Protón

$10 \text{ TeV} < E^{-2.7} < 10 \text{ TeV}$

$30^\circ < \theta < 30^\circ$

$90^\circ < \phi < 90^\circ$

$h=28 \text{ m snm}$

Atmosfera Tropical

La Serena

Semillas

Corriendo la simulación manual

1) Escribir el archivo input: proton-lago.input

2) cd /path/to/corsika-75600/run

3) ejecutar la simulación:

```
$ ./corsika75600Linux_QGSII_gheisha < proton-lago.input >  
proton-lago.lst &
```

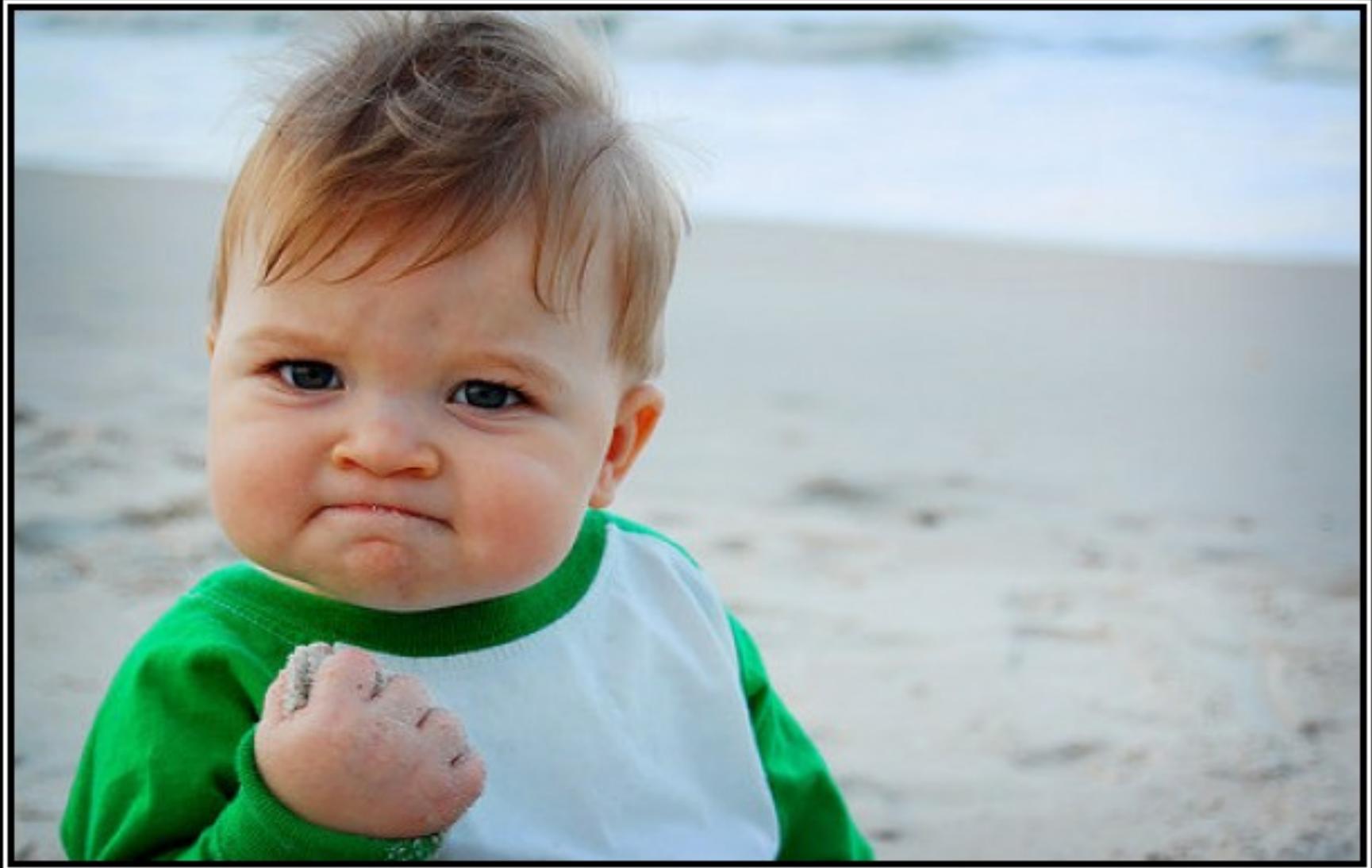
4) verificar avance

```
$ tail -f proton-lago.lst
```

5) esperar la finalización

```
PRESENT TIME : 18.01.2017 11:48:36
```

```
===== END OF RUN =====
```



SUCCESS

Because you too can own this face of pure accomplishment

Depende de la configuración de CORSIKA y del input

3 archivos básicos: NNNNNNN = RUNNR

DATNNNNNN ← Secundarios + info

DATNNNNNN .dbase ← Para librería de lluvias

nombre .lst ← Output de control

Otros archivos

.long .tab .info ...

Ver Cap. 10 Manual del Usuario

Atmospheric profile with 50 levels read from file atmoprofil.dat

Results of the atmosphere fit:

Layer 1: 0.00 km < h < 10.00 km: a = -135.708, b = 1174.01, c = 994186
 Layer 2: 10.00 km < h < 19.00 km: a = +22.0191, b = 1261.58, c = 721829
 Layer 3: 19.00 km < h < 42.50 km: a = 0.587399, b = 1350.34, c = 636143
 Layer 4: 42.50 km < h < 105.00 km: a = -0.000577176, b = 560.655, c = 772170
 Layer 5: 105.00 km < h < 116.20 km: a = 0.00124205, b = 1, c = 9.35523e+09

[...]

AAA

```

    OOO      OOO      0000      0000      00      0      0      0
    O   O      O   O      O   O      O   O      OO      O   O
    O      O      O   O      O   O      OO      O   O      O   O
    O      O      O   O      O   O      OO      O   O      O   O
    O      O      O   O      O   O      OO      O   O      O   O
    O   O      O   O      O   O      O   O      OO      O   O
    OOO      OOO      O   O      OOOO      OO      O   O      O
  
```

COSMIC RAY SIMULATION FOR KASCADE

[...]

===== USERS RUN DIRECTIVES FOR THIS SIMULATION =====

DATA CARDS FOR RUN STEERING ARE EXPECTED FROM STANDARD INPUT

RUNNR 1

[...]

AVERAGE NUMBER OF PARTICLES PER EVENT :

FROM LEVEL NUMBER	1
HEIGHT IN CM	9.000E+04
HEIGHT IN G/CM**2	9.374E+02
NO OF PROTONS	= 0.0 +- 0.0
NO OF ANTI PROTONS	= 0.0 +- 0.0
NO OF NEUTRONS	= 0.0 +- 0.0
NO OF ANTI NEUTRONS	= 0.0 +- 0.0
NO OF GAMMAS	= 0.000000E+00 +- 0.000000E+00
NO OF ELECTRONS	= 0.000000E+00 +- 0.000000E+00
NO OF POSITRONS	= 0.000000E+00 +- 0.000000E+00
NO OF MU -	= 0.0 +- 0.0
NO OF MU +	= 0.0 +- 0.0
NO OF PI 0	= 0.0 +- 0.0
NO OF PI -	= 0.0 +- 0.0
NO OF PI +	= 0.0 +- 0.0
NO OF K0L	= 0.0 +- 0.0
NO OF K0S	= 0.0 +- 0.0
NO OF K -	= 0.0 +- 0.0
NO OF K +	= 0.0 +- 0.0
NO OF STR. BARYONS	= 0.0 +- 0.0
NO OF DEUTERONS	= 0.0 +- 0.0
NO OF TRITONS	= 0.0 +- 0.0
NO OF 3HELIUM	= 0.0 +- 0.0
NO OF ALPHAS	= 0.0 +- 0.0
NO OF OTHER PART.	= 0.0 +- 0.0
NO OF DECAYED MUON	= 5.0 +-

PRESENT TIME : 02.05.2013 11:29:53

===== END OF RUN =====

Block structure

```
RUN HEADER nrun
  EVENT HEADER 1
    DATABLOCK
    DATABLOCK
    ...
    ...
    (LONG 1:1)
    ...
    (LONG 1:n)
  EVENT END 1
  EVENT HEADER 2
    DATABLOCK
    DATABLOCK
    ...
    ...
    (LONG 2:1)
    ...
    (LONG 2:n)
  EVENT END 2
  ...
  ...
  EVENT HEADER nevt
    DATABLOCK
    DATABLOCK
    ...
    ...
    (LONG nevt:1)
    ...
    (LONG nevt:n)
  EVENT END nevt
RUN END nrun
```

Outputs (ver Cap. 10)



Block structure	
RUN HEADER nrun	Run header sub-block: (once per run)
EVENT HEADER 1	No. of word Contents of word (as real numbers R *4)
DATABLOCK	1 'RUNH'
DATABLOCK	2 run number
...	3 date of begin run (yyymmdd)
...	4 version of program
(Long 1:1)	5 number of observation levels (maximum 10)
...	5 + i height of observation level i in cm
(Long 1:n)	16 slope of energy spectrum
EVENT END 1	17 lower limit of energy range
EVENT HEADER 2	18 upper limit of energy range
DATABLOCK	19 flag for EGS4 treatment of em. component
DATABLOCK	20 flag for NKG treatment of em. component
...	21 kin. energy cutoff for hadrons in GeV
...	22 kin. energy cutoff for muons in GeV
(Long 2:1)	23 kin. energy cutoff for electrons in GeV
...	24 energy cutoff for photons in GeV
(Long 2:n)	physical constants and interaction flags:
EVENT END 2	24 + i $C(i), i = 1, 50$
...	75 XPINCL X-displacement of inclined observation plane
...	76 YPINCL Y-displacement of inclined observation plane
EVENT HEADER nevt	77 ZPINCL Z-displacement of inclined observation plane
DATABLOCK	78 THINCL θ angle of normal vector of inclined observation plane
DATABLOCK	79 PHINCL ϕ angle of normal vector of inclined observation plane
...	79 + i 0, $i = 1, 15$ (no longer used)
...	94 + i CKA(i), $i = 1, 40$
(Long nevt:1)	134 + i CETA(i), $i = 1, 5$
...	139 + i CSTRBA(i), $i = 1, 11$
(Long nevt:n)	150 + i 0, $i = 1, 97$ (no longer used)
EVENT END nevt	248 XSCATT scatter range in x direction for Cherenkov
RUN END nrun	249 YSCATT scatter range in y direction for Cherenkov
	249 + i HLAY(i), $i = 1, 5$
	254 + i AATM(i), $i = 1, 5$
	259 + i BATM(i), $i = 1, 5$
	264 + i CATM(i), $i = 1, 5$
	270 NFLAIN
	271 NFLDIF
	272 NFLPI0+100×NFLPIF
	273 NFLCHE+100×NFRAGM

Table 7: Structure of the run header sub-block.

Block structure		Run header sub-block: (once per run)		Event header sub-block: (once per event)	
		No. of word	Contents of word (as real numbers)	No. of word	Contents of word (as real numbers R*4)
RUN HEADER nrun	EVENT HEADER 1	1	'RUNH'	1	'EVTH'
	DATABLOCK	2	run number	2	event number
	DATABLOCK	3	date of begin run (yyymmdd)	3	particle id (particle code or $A \times 100 + Z$ for nuclei)
	...	4	version of program	4	total energy in GeV
	(LONG 1:1)	5	number of observation levels (max)	5	starting altitude in g/cm ²
	...	5 + <i>i</i>	height of observation level <i>i</i> in cm	6	number of first target if fixed
	(LONG 1:n)	16	slope of energy spectrum	7	z coordinate (height) of first interaction in cm (negative, if tracking starts at margin of atmosphere, see TSTART)
	EVENT END 1	17	lower limit of energy range	8	px momentum in x direction in GeV/c
	EVENT HEADER 2	18	upper limit of energy range	9	py momentum in y direction in GeV/c
	DATABLOCK	19	flag for EGS4 treatment of em. con	10	pz momentum in -z direction in GeV/c (pz is positive for downward going particles)
	DATABLOCK	20	flag for NKG treatment of em. con	11	zenith angle θ in radian
	...	21	kin. energy cutoff for hadrons in G	12	azimuth angle ϕ in radian
	...	22	kin. energy cutoff for muons in Ge	13	number of different random number sequences (max. 10)
	(LONG 2:1)	23	kin. energy cutoff for electrons in C	11 + 3 × <i>i</i>	integer seed of sequence <i>i</i>
	...	24	energy cutoff for photons in GeV	12 + 3 × <i>i</i>	number of offset random calls (mod 10 ⁶) of sequence <i>i</i>
	(LONG 2:n)		physical constants and interaction f	13 + 3 × <i>i</i>	number of offset random calls (/ 10 ⁶) of sequence <i>i</i>
	EVENT END 2	24 + <i>i</i>	C(<i>i</i>), <i>i</i> = 1, 50	44	run number
	...	75	XPINCL X-displacement of inclin	45	date of begin run (yyymmdd)
	...	76	YPINCL Y-displacement of inclin	46	version of program
	EVENT HEADER nevt	77	ZPINCL Z-displacement of inclin	47	number of observation levels
	DATABLOCK	78	THINCL θ angle of normal vector	47 + <i>i</i>	height of level <i>i</i> in cm
	DATABLOCK	79	PHINCL ϕ angle of normal vector	58	slope of energy spectrum
	...	79 + <i>i</i>	0, <i>i</i> = 1, 15 (no longer used)	59	lower limit of energy range in GeV
	...	94 + <i>i</i>	CKA(<i>i</i>), <i>i</i> = 1, 40	60	upper limit of energy range in GeV
	(LONG nevt:1)	134 + <i>i</i>	CETA(<i>i</i>), <i>i</i> = 1, 5	61	cutoff for hadrons kinetic energy in GeV
	...	139 + <i>i</i>	CSTRBA(<i>i</i>), <i>i</i> = 1, 11	62	cutoff for muons kinetic energy in GeV
	(LONG nevt:n)	150 + <i>i</i>	0, <i>i</i> = 1, 97 (no longer used)	63	cutoff for electrons kinetic energy in GeV
	EVENT END nevt	248	XSCATT scatter range in x directic	64	cutoff for photons energy in GeV
	RUN END nrun	249	YSCATT scatter range in y directic	65	NFLAIN
		249 + <i>i</i>	HLAY(<i>i</i>), <i>i</i> = 1, 5	66	NFLDIF
		254 + <i>i</i>	AATM(<i>i</i>), <i>i</i> = 1, 5	67	NFLPI0
		259 + <i>i</i>	BATM(<i>i</i>), <i>i</i> = 1, 5	68	NFLPIF
		264 + <i>i</i>	CATM(<i>i</i>), <i>i</i> = 1, 5	69	NFLCHE
		270	NFLAIN	70	NFRAGM
		271	NFLDIF		
		272	NFLPI0+100×NFLPIF		
		273	NFLCHE+100×NFRAGM		

Table 7: Structure of the run header sub-block.

Table 8: Structure of event header sub-block (to be continued).

1.00100E+03	-5.46885E-03	-4.30982E-04	8.00286E-03	-1.09995E+05	2.67416E+04	3.65921E+05	per event)
3.00100E+03	3.36570E-03	-3.16320E-03	1.09089E-02	2.59059E+04	-9.41258E+03	3.65278E+05	rd (as real numbers R*4)
1.00100E+03	1.39548E-02	1.44308E-03	5.08759E-02	1.52463E+05	9.26423E+03	3.65832E+05	
1.00100E+03	1.98270E-03	1.18373E-03	6.73459E-03	3.56049E+04	6.99683E+04	3.65540E+05	
1.00100E+03	2.70109E-04	5.36199E-03	2.54889E-02	-4.02150E+03	8.87279E+04	3.65494E+05	
1.00100E+03	1.60414E-03	-1.38442E-03	8.80514E-03	7.86012E+03	7.17196E+02	3.65272E+05	article code or $A \times 100 + Z$ for nuclei)
1.00100E+03	1.31139E-03	-4.13751E-04	7.60755E-03	1.93719E+04	-6.21680E+03	3.65321E+05	GeV
1.00100E+03	4.52887E-04	4.59891E-04	8.79854E-03	5.27229E+03	7.75617E+03	3.65250E+05	in g/cm ²
1.00100E+03	-4.74282E-04	3.71646E-04	2.47985E-02	-4.33793E+03	1.95580E+03	3.65243E+05	target if fixed
1.00100E+03	9.15386E-05	2.78302E-03	5.88027E-03	-1.79104E+04	2.31367E+04	3.65377E+05	height) of first interaction in cm
1.00100E+03	-1.92442E-03	-4.20737E-04	9.12530E-03	-2.14523E+04	-5.10769E+03	3.65317E+05	king starts at margin of atmosphere, see TSTART)
1.00100E+03	-4.72408E-03	-6.27047E-03	9.72252E-02	-5.45996E+03	-6.97886E+03	3.65253E+05	in x direction in GeV/c
1.00100E+03	4.96364E-04	4.78332E-04	4.78139E-03				
1.00100E+03	2.14301E-03	-6.12580E-04	3.94709E-03				
1.00100E+03	1.03227E-03	6.72250E-03	4.26197E-02				
1.00100E+03	1.87294E-04	-1.30695E-04	9.84595E-02				
1.00100E+03	1.02055E-02	3.00120E-03	9.61462E-02				
1.00100E+03	6.20602E-04	-3.99478E-04	8.32675E-03				
1.00100E+03	-1.15495E-03	-1.72205E-03	5.94811E-02				
1.00100E+03	-5.04701E-04	-1.57059E-03	3.35787E-03	-3.66002E+03	-1.77579E+04	3.65368E+05	get random calls (mod 10 ⁶) of sequence <i>i</i>
1.00100E+03	-3.02525E-06	2.10781E-03	7.28154E-03	9.29422E+02	1.79657E+04	3.65323E+05	get random calls (/ 10 ⁶) of sequence <i>i</i>
1.00100E+03	-2.47017E-04	5.55099E-03	2.74278E-02	4.24123E+02	1.29336E+04	3.65283E+05	

EVENT HEADER	nevt
DATABLOCK	76
DATABLOCK	77
...	78
...	79
(LONG nevt:1)	79 + <i>i</i>
...	94 + <i>i</i>
(LONG nevt: <i>n</i>)	134 + <i>i</i>
EVENT END	139 + <i>i</i>
RUN END	150 + <i>i</i>
	248
	249
	249 + <i>i</i>
	254 + <i>i</i>
	259 + <i>i</i>
	264 + <i>i</i>
	270
	271
	272
	273

Id, px, py, pz, x, y, t
Con thin son 8: weight
Multiple OBSLEV → data blocks ordered

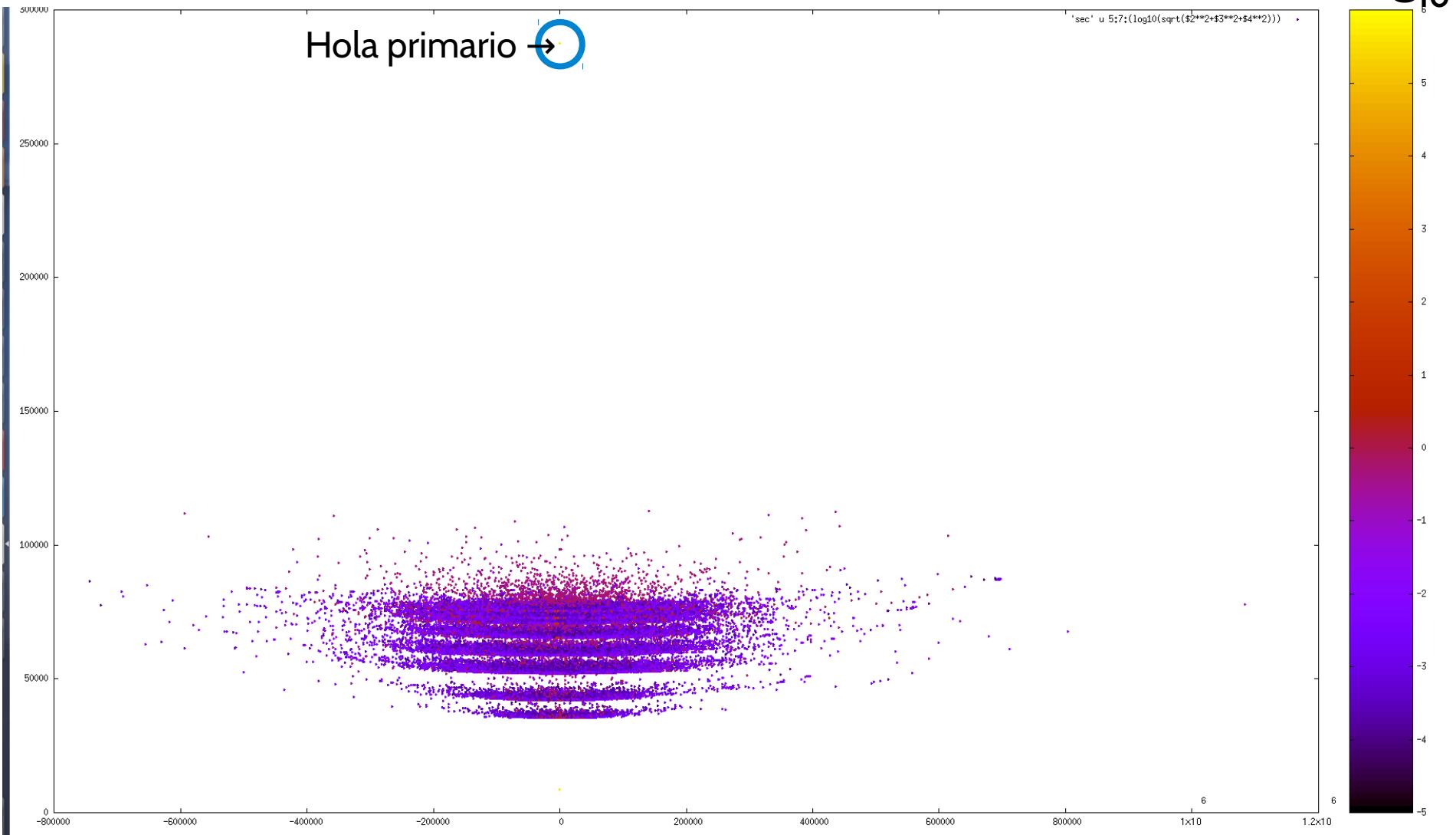
Particle data sub-block : (up to 39 particles, 7 words each)	
No. of word	Contents of word (as real numbers R*4)
7 × (<i>n</i> - 1) + 1	particle description encoded as: part. id × 1000 + hadr. generation ⁸⁴ × 10 + no. of obs. level
7 × (<i>n</i> - 1) + 2	px, momentum in x direction in GeV/c
7 × (<i>n</i> - 1) + 3	py, momentum in y direction in GeV/c
7 × (<i>n</i> - 1) + 4	pz, momentum in -z direction in GeV/c
7 × (<i>n</i> - 1) + 5	x position coordinate in cm
7 × (<i>n</i> - 1) + 6	y position coordinate in cm
7 × (<i>n</i> - 1) + 7	t time since first interaction (or since entrance into atmosphere) ⁸⁵ in nsec [for additional muon information: z coordinate in cm]
	for <i>n</i> = 1 ... 39 if last block is not completely filled, trailing zeros are added

Table 10: Structure of particle data sub-block.

OBSLEV (hasta 10) protón vertical, Bs As, $E_p=5 \times 10^{14}$ eV

H en km: 30; 20; 12; 10; 7; 5; 3; 1.4; 0.8; 0

$\log_{10}(p_s)$



Cherenkov light

Cherenkov photon data sub-block : (up to 39 bunches, 7 words each)

No. of words	Contents of word (as real numbers R*4)
$7 \times (n - 1) + 1$	number of Cherenkov photons in bunch [in case of output on the particle output file: $99.E5 + 10 \times \text{NINT}(\text{number of Cherenkov photons in bunch}) + 1$]
$7 \times (n - 1) + 2$	x position coordinate in cm
$7 \times (n - 1) + 3$	y position coordinate in cm
$7 \times (n - 1) + 4$	u direction cosine ⁹⁷ to x-axis
$7 \times (n - 1) + 5$	v direction cosine ⁹⁷ to y-axis
$7 \times (n - 1) + 6$	t time since first interaction (or since entrance into atmosphere) ⁹⁶ in nsec
$7 \times (n - 1) + 7$	height of production of bunch in cm
	for $n = 1 \dots 39$ if last block is not completely filled, trailing zeros are added

Adelgazamiento (THINning)

- **Compresión CON PÉRDIDA de información**
- Si la energía es menor que un umbral E_0 , cada partícula es reemplazada por una representante con un peso w (obviamente, w crece con el desarrollo)
- Por construcción, conserva la energía
- La energía umbral se define mediante el **nivel de thinning**, $\varepsilon_{th} = E_p / E_0$, valores típicos hoy: $10^{-7}, 10^{-8}$

THIN	ε_{th}	W_{max}	R_{max}
------	--------------------	-----------	-----------

Si $E_{sec} < \varepsilon_{th} E_p$, el secundario se pasa por el alg. Thinning

$W_{max} \rightarrow$ si $w > W_{max}$, el thinning se desactiva para ese bunch

Si $r < R_{max}$, las partículas se eligen con prob $p \sim (r/r_{max})^4$. Y $w^* = (1/p)$

USAR CON CUIDADO Y PRECAUCIÓN

- Dos opciones adicionales para THIN:

THINH ϵ_{thHad} W_{maxRat}

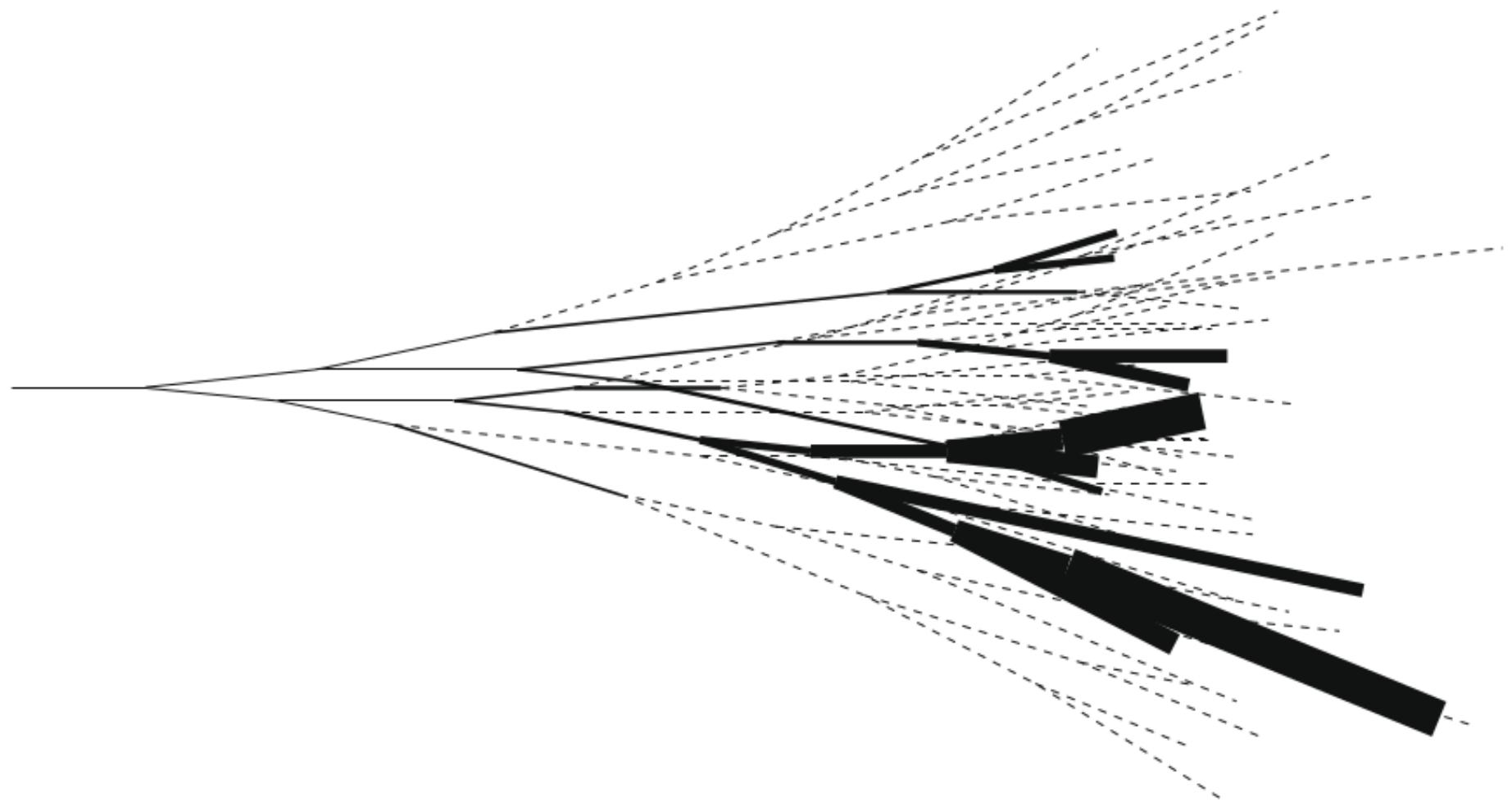
ó

THINEM ϵ_{thEM} W_{maxRat}

Manejo diferente de las partículas HAD y EM
 $\epsilon_{\text{thEM}} / \epsilon_{\text{thHad}}$ (default: 1.)



Thinning algorithm



El peso

- Estas dos condiciones se aplican sobre el grupo de los j secundarios considerados.

► Condición:

$$E_{\text{p}} \epsilon_{th} > \sum_{j=1}^n E_j \quad (1)$$

► Seguidas con una probabilidad:

$$P_i = E_i / \sum_{j=1}^n E_j \quad (2)$$

► Condición:

$$E_{\text{p}} \epsilon_{th} < \sum_{j=1}^n E_j \quad (3)$$

► Tienen una probabilidad:

$$P_i = E_i / E_{\text{p}} \epsilon_{th} \quad (4)$$

En ambos casos...

► Finalmente a las partículas se les asignará un peso estadístico igual a $w_i = 1/P_i$.



Unthinning

- La estrategia es resamplear la distribución de partículas al nivel del detector
- Recomiendo fuertemente ver:

Billoir, P. (2008). *A sampling procedure to regenerate particles in a ground detector from a “thinned” air shower simulation output*. Astroparticle Physics, 30(5), 270-285.

Método de Dethinning^a

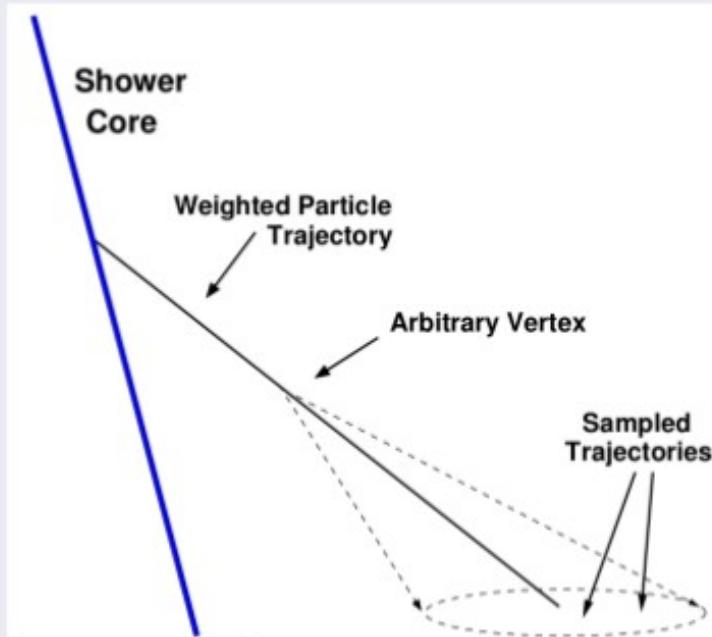


Figura 4: Cono gaussiano para una partícula madre inclinada $\theta \approx 30^\circ$

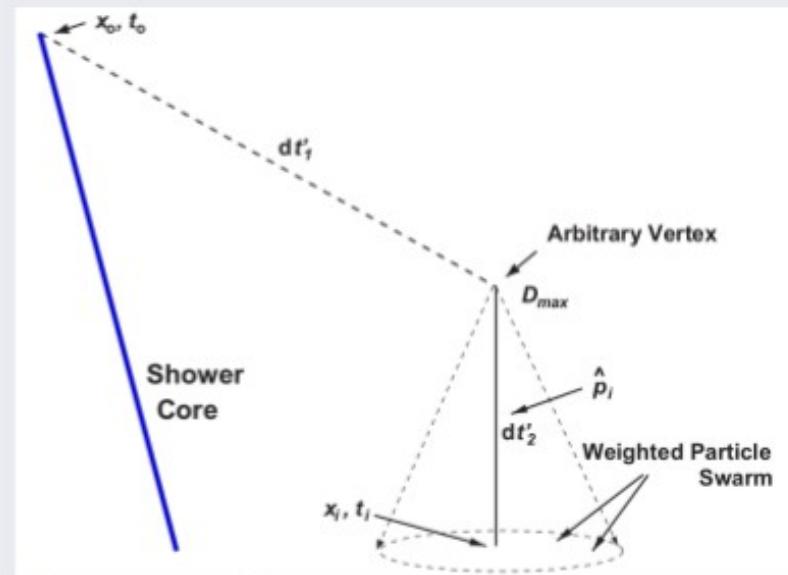


Figura 5: Cono gaussiano para una partícula madre vertical.

^aDethinning Extensive Air Shower Simulations B.T. Stokes, R. Cady, D. Ivanova, J. N. Matthews , G. B. Astropart. Phys. 35 (2012) pp. 759-766.

Reinyección de secundarios

Ajuste al ángulo del cono gaussiano

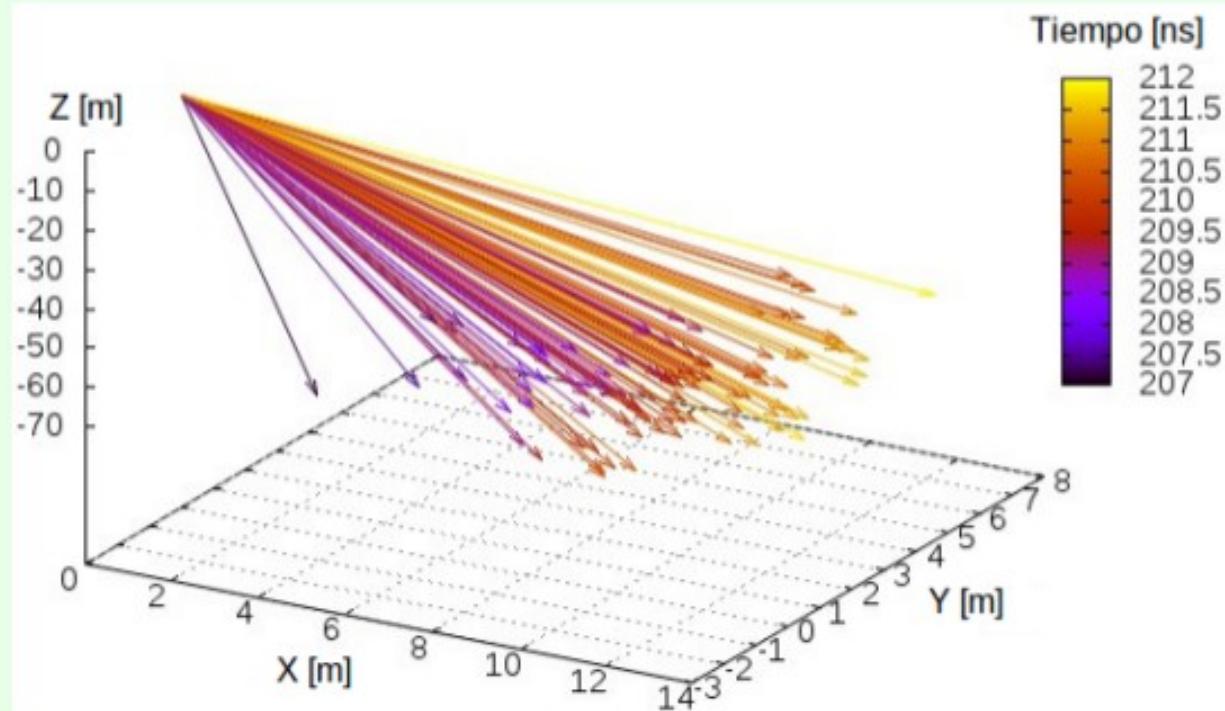


Figura 7: Trayectoria de las partículas secundarias hijas, donde la partícula madre es un fotón de 0.22 GeV.

Fluctuación en la energía

Ajuste de la energía

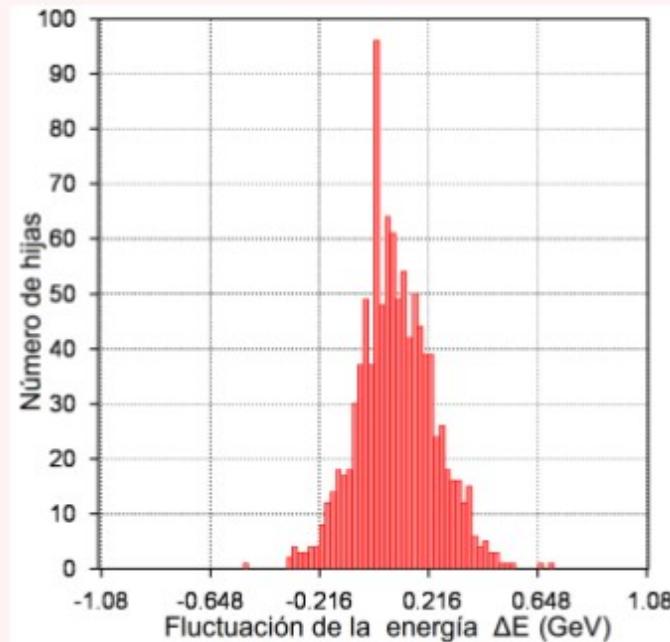


Figura 8: Fluctuación de la energía respecto a un electrón de energía ≈ 2 GeV.

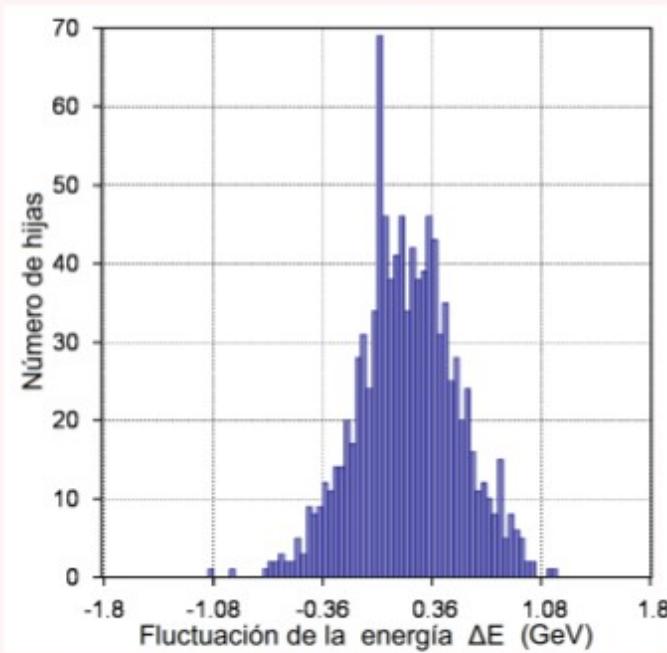


Figura 9: Fluctuación de la energía respecto a un positrón de energía ≈ 4 GeV.

Absorción en la atmósfera

Probabilidad de transmisión atmosférica

$$N = N_0 e^{-\Delta\chi/\epsilon} \quad (5)$$

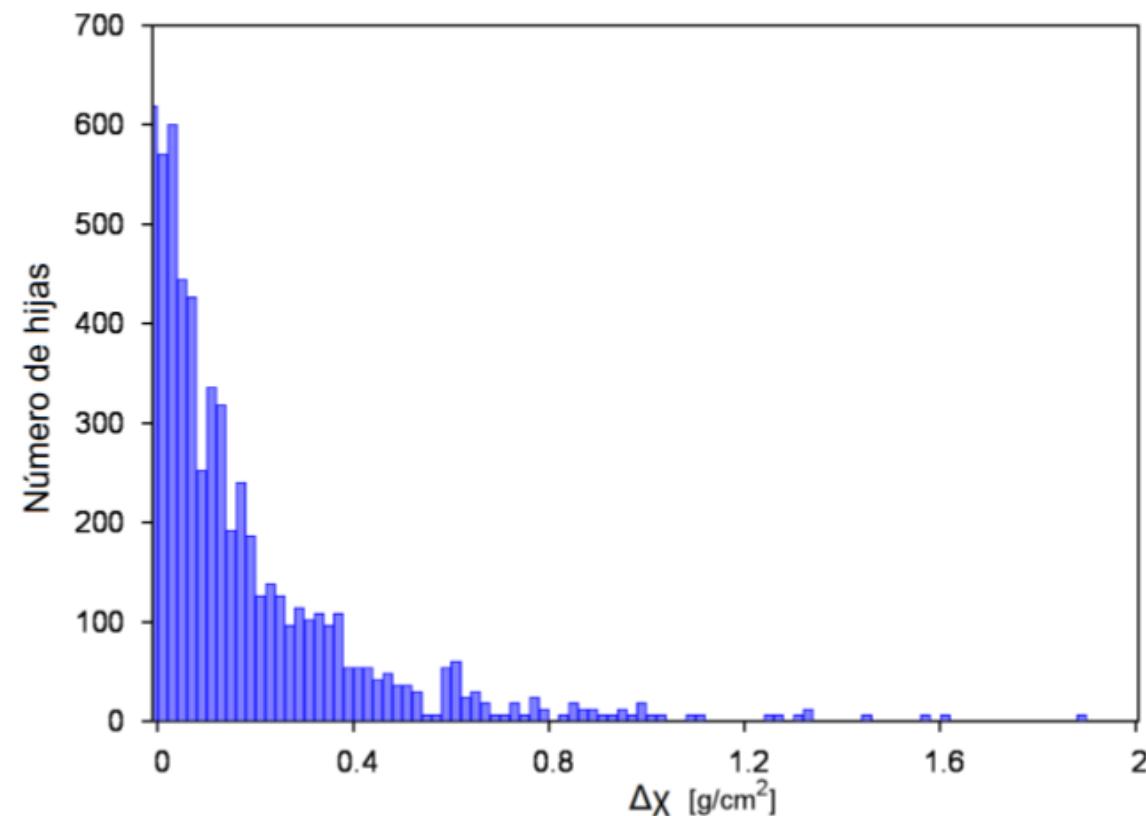


Figura 10: Histograma de Absorción Atmosférica de las partículas hijas que tienen por madre un electrón vertical de energía 0.18 GeV.

La wiki de LAGO

Latin American Giant Observatory [edit]

Bienvenidos a la Wiki interna del [Latin American Giant Observatory \(LAGO\)](#). Por favor, si usted tiene consultas y sugerencias envíe un correo a lagowiki@lagoproject.org. Antes de editar o modificar una página, por favor consulte el [Manual del Usuario](#).

Grupos de Trabajo [edit]

WG1: Física

Seminarios del Grupo de Trabajo de Física

[File:Fluencia-lago.pdf](#)

[File:Analisis CHA.pdf](#)

[File:Presentation 2.pdf](#)

WG2: Detectores

LAGO Adquisicion de datos: Quick Start

Bases del PAO

WG2.1: Electrónica

WG2.2: Calibración

WG3: Data

[El Repositorio de datos LAGO](#)

[El Programa LAGO Virtual](#)

[Respositorio de tesis y documentos de LAGO](#)

WG0: Project Management

La Organización del Proyecto LAGO

Objetivos Organizacionales Anuales

Meetings anuales de la colaboración

Comités: Coordinación, Científico, Editorial.

Comunidades: LAGO-Argentina, LAGO-Bolivia, LAGO-Brasil, LAGO-Colombia, LAGO-Ecuador, LAGO-España, LAGO-Guatemala, LAGO-Méjico, LAGO-Perú, LAGO-Venezuela.

Recursos [edit]

ACQUA: LAGO Data Acquisition

ACQUA: la *suite* de adquisición de datos de LAGO

Configuración Básica Raspberry Pi

Datos en LAGO-ACQUA

Metadatos en LAGO-ACQUA

ARTI: LAGO Simulations

ARTI: el paquete de simulaciones de LAGO

CORSIKA para LAGO

Géant4 en LAGO

Simulación WCD

Curso de simulaciones para cálculo de Fluencia

ANNA: LAGO Data Analysis

ANNA: el entorno de análisis de datos de LAGO

Uso de ANNA

Ejemplo de Análisis de Datos

ADVI: LAGO Documents

LAGO Virtual

Repositorio de datos LAGO

Repositorio de tesis y documentos de LAGO ([enlace directo](#))

(reservado para próximos recursos)

NETI: LAGO Clusters and grid

Cluster Halley

Cluster Guane

Cluster Sumo

LAGO Grid

<http://wiki.lagoproject.org/>

Proyectos Asociados [edit]

RACIMO: Red Ambiental Ciudadana de MOnitoreo

El Proyecto RACIMO

MuTe: Muon Telescope (for Volcanoes muongraphy)

El Proyecto MuTe

ESCARAMUJO

El Proyecto Escaramujo

Simulaciones en LAGO → ARTI™

ARTI™ es un paquete diseñado para automatizar y simplificar estas tareas

Instrucciones en la sección ARTI de la wiki de LAGO

<http://wiki.lagoproject.org/index.php?title=ARTI>

Con git, desde la terminal:

```
$ git clone https://github.com/lagoproject/arti.git
```

Simulaciones: do_sims.sh; rain.pl; do_grid.sh;
generate_espectra.pl

Análisis: lagocrkread.f; lagocrkthin.f; onlysecs.f;
analysis.cc; showers.cc;

Antes de usar → \$ git pull; make

Pequeño glosario

- Ejecución automatizada de las simulaciones (`./sims/`)
 - **rain.pl** → automatiza el método de generación de inmutas mediante una serie de preguntas y modificadores en linea de comando
 - **generate_espectra.pl** → integra numéricamente espectros de la forma E-g para obtener los flujos a partir del tiempo de simulación (1h, 1d, 1m, etc). Produce archivos que leerá el rain.pl para producir los inputs (27 especies en total, de protón a hierro)
 - **do_sims.sh** → Automatiza la producción de inputs combinando los códigos anteriores para producir los scripts finales de simulación y calcular la fluencia de cada sitio

Pequeño glosario

- Ejecución automatizada de los análisis (`./analysis/`)
 - **lagocrkread.f** → convierte los archivos DATNNNNNN de salida de CORSIKA en tablas ASCII (**lagocrkthin.f** es equivalente para simulaciones con thinning)
 - **onlysecs.f** → procesa los DATNNNNNN mostrando solo los bloques de secundarios, sin información
 - **analysis.cc** → lee los archivos ASCII producidos por lagocrkread.f y produce archivos de secundarios para cada tipo de primario
 - **showers.cc** → procesa las salidas de analysis.cc para obtener un único archivo con el *background* de secundarios, y archivos de análisis como el histograma de energias, distancias, etc

Seguimos en la terminal

