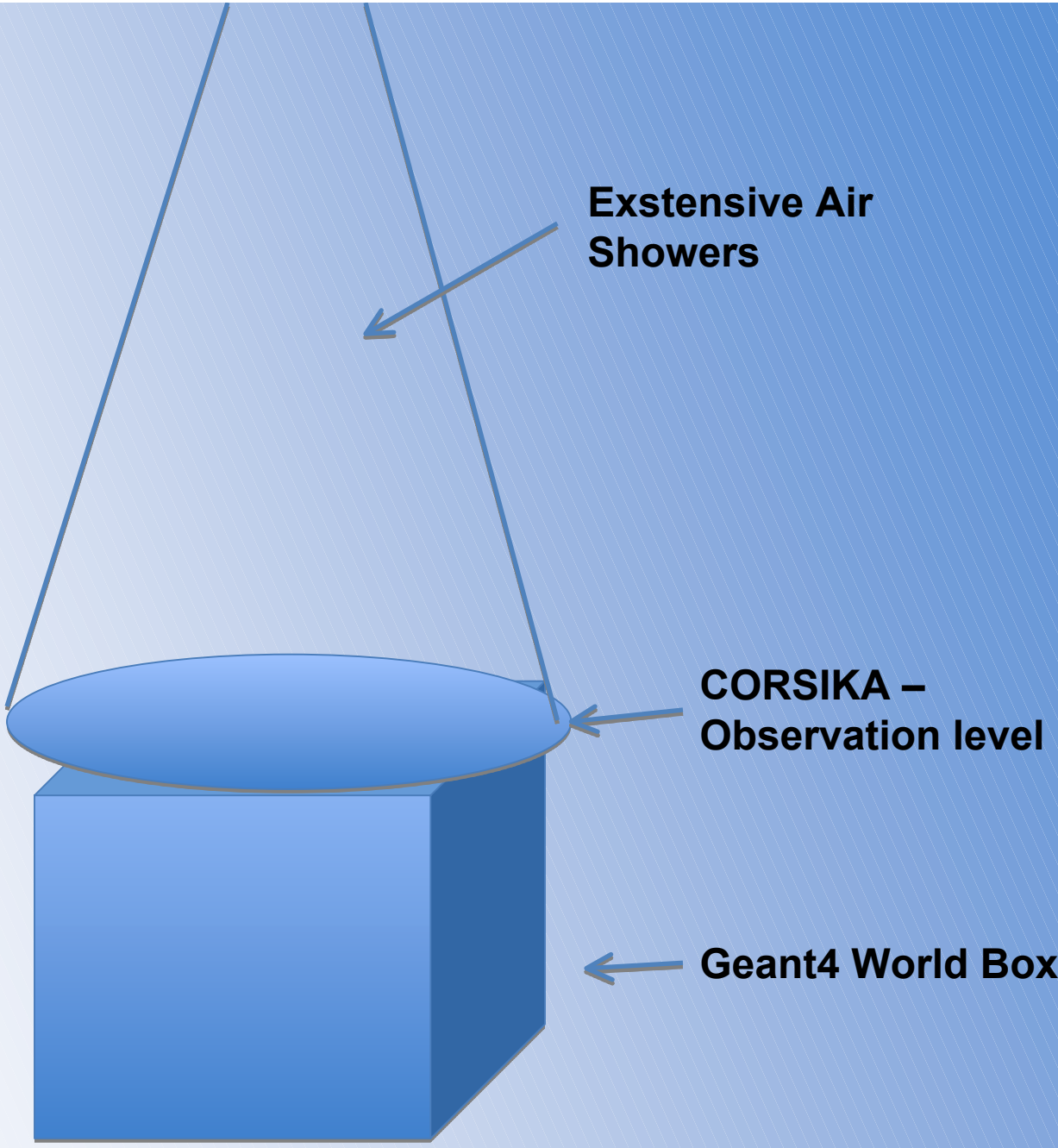
Extensive Air Shower Simulation with CORSIKA+Geant4 @ Institute of Physics and Faculty of Physics guide

D. Maletic, IF

INTRODUCTION



Za kompletiranje simulacija sa XP-a su vam potrebni:

1. putty - terminal za windows (http://www.putty.org/)
2. Xming - X server for Windows (http://sourceforge.net/projects/xming/)
3. WinSCP - program za kopiranje fajlova sa linux masina na windows (http://winscp.net/eng/download.php)

Svi ovi programi su besplatni i lako dostupni na internetu.

Potrebno je da se u konfiguraciji putty-ja otvori X11 forwarding;
(Levi deo pocetnog prozora: Category->SSH->X11->Enable X11 forwarding).

Prvo se startujete X server (Xming) a potom putty.Ako zelite da prebacujete falove sa/na
linux masinu koristite WinSCP.

Parametri za konekciju u putty-ju:
corsika@147.91.68.103
sifra corsika

(konektovanje na masinu (sa linux-a):
ssh corsika@147.91.68.103 -Y

Po otvaranju terminala treba:

doci u direktorijum za rad:
cd /home/corsika/CORSIKA/corsika-6960/run

#pokrenuti simulaciju
./corsika6960Linux_QGSJET_fluka < all-inputs > out.txt
Rad u pozadini- mozete iskljuciti terminal…
(nohup ./corsika6960Linux_QGSJET_fluka < all-inputs > out.txt &)

promeniti parametre menjanjem all-inputs fajla

gedit all-inputs

#ili, alternativno npr: pico all-inputs

otvraranje izlaznog fajla u root programu na linux-u

root .l DAT000001.root

u pokrenutom root programu, pokrenuti graficki interfejs sa:
TBrowser b;
#...

```
RUNNR   1031                    run number
EVTNR   1100001                 number of first shower event
NSHOW   100000                  number of showers to generate
PRMPAR  14                      particle type of prim. Particle
ESLOPE  -2.7                    slope of primary energy spectrum
ERANGE  10.  1.E4               energy range of primary particle
THETAP  0.  60.                 range of zenith angle (degree)
PHIP    -180.  180.             range of azimuth angle (degree)
SEED    103   1   0             seed for 1. random number sequence
SEED    201   1   0             seed for 2. random number sequence
OBSLEV  116.E2                  observation level (in cm) // treba 80 za Zemun
FIXCHI  0.                      starting altitude (g/cm**2)
MAGNET  20.0  42.8              magnetic field centr. Europe
HADFLG  0  0  0  0  0  2        flags hadr.interact.&fragmentation
ECUTS   0.05  0.05  0.003  0.003    energy cuts for particles
MUADDI  T                       additional info for muons
MUMULT  T                       muon multiple scattering angle
ELMFLG  T   T                   em. interaction flags (NKG,EGS)
STEPFC  1.0                     mult. scattering step length fact
.RADNKG  200.E2                 outer radius for NKG lat.dens.distr.
ARRANG  0.                      rotation of array to north
QGSJET  T  0                    nesto
ECTMAP  1.E3                    cut on gamma factor for printout
MAXPRT  100                     max. number of printed events
DIRECT  ./                      output directory
DATBAS  T                       write .dbase file
PAROUT  T F                     write DAT file
USER    you                     user DEBUG   F  11  F  1000000          debug flag and log.unit
      for out
EXIT                            terminates input
```

```
RUNNR   1031                run number
EVTNR   1100001             number of first shower event
NSHOW   100000              number of showers to generate
PRMPAR  14                  particle type of prim. Particle
ESLOPE  -2.7                slope of primary energy spectrum
ERANGE  10.  1.E4           energy range of primary particle
THETAP  0.  60.
PHIP    -180.  180.
SEED    103  1  0
SEED    201  1  0
OBSLEV  116.E2
FIXCHI  0.
MAGNET  20.0  42
HADFLG  0  0  0  0
ECUTS   0.05  0.05
MUADDI  T
MUMULT  T
ELMFLG  T   T
STEPFC  1.0
.RADNKG  200.E2
ARRANG  0.
QGSJET  T  0
ECTMAP  1.E3
MAXPRT  100
DIRECT  ./
DATBAS  T
PAROUT  T F
USER    you
    for out
EXIT
```

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62 / 137 161% eslope

this limit a simple superposition model is used. ULIMIT $\leq$ 1.E11 GeV for primary and electrons (but keep in mind that no LPM-effect is included in NKG!); for primary and nuclei no upper limit is recommended, but **the user should take care not to ove the selected hadronic interaction model**. See also Ref. [21]. It is recommended fo ULIMIT $\leq 1 \cdot 10^{17}$ eV and for VENUS: ULIMIT $\leq 2 \cdot 10^{16}$ eV.
This keyword is not available in the STACKIN option.

4.7 Slope of Spectrum

`ESLOPE PSLOPE`

Format = (A6, F), Default = 0.
PSLOPE : Exponent γ of differential primary energy spectrum. The primary energy i random from an exponential energy spectrum of the form $dN/dE_0 \propto E_0^{\gamma}$. PSLOI meaning in case of fixed primary energy. The energies are total energies and include th rest mass.
This keyword is not available in the STACKIN option.

4.8 Zenith Angle Definition

`THETAP THETPR(1) THETPR(2)`

Format = (A6, 2F), Defaults = 0., 0.

```
RUNNR   1031                run number
EVTNR   1100001             number of first shower event
NSHOW   100000              number of showers to generate
PRMPAR  14                  particle type of prim. Particle
ESLOPE  -2.7                slope of primary energy spectrum
ERANGE  10.  1.E4           energy range of primary particle
THETAP  0.  60.             range of zenith angle (degree)
PHIP    -180.  180
SEED    103  1
SEED    201  1
OBSLEV  116.E2
FIXCHI  0.
MAGNET  20.0
HADFLG  0  0  0
ECUTS   0.05  0.
MUADDI  T
MUMULT  T
ELMFLG  T   T
STEPFC  1.0
.RADNKG  200.E
ARRANG  0.
QGSJET  T  0
ECTMAP  1.E3
MAXPRT  100
DIRECT  ./
DATBAS  T
PAROUT  T F
USER    you
        for out
EXIT
```

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4.6 Energy Range

ERANGE LLIMIT ULIMIT

Format = (A6, 2F), Defaults = 1.E4, 1.E4
LLIMIT : Lower limit and
ULIMIT : Upper limit of the primary particle energy range (in GeV). The primary en
selected at random out of this interval. If LLIMIT = ULIMIT, the primary energy is fixe
value.
The energies are total energies and include the particle rest mass.
Limits are: LLIMIT > HILOW (by default 80 GeV/nucleon for nuclei, see page 64);
this limit a simple superposition model is used. ULIMIT $\leq$ 1.E11 GeV for primary p
and electrons (but keep in mind that no LPM-effect is included in NKG!); for primary l
and nuclei no upper limit is recommended, but **the user should take care not to over-
the selected hadronic interaction model**. See also Ref. [21]. It is recommended for I
ULIMIT $\leq$ $1 \cdot 10^{17}$ eV and for VENUS: ULIMIT $\leq$ $2 \cdot 10^{16}$ eV.
This keyword is not available in the STACKIN option.

```
RUNNR   1031
EVTNR   1100001
NSHOW   100000
PRMPAR  14
ESLOPE  -2.7
ERANGE  10.  1.E4
THETAP  0.  60.
PHIP    180.  180.
SEED    103   1   0
SEED    201   1   0
OBSLEV  116.E2
FIXCHI  0.
MAGNET  20.0  42.8
HADFLG  0  0  0  0  0
ECUTS   0.05  0.05  0
MUADDI  T
MUMULT  T
ELMFLG  T   T
STEPFC  1.0
.RADNKG  200.E2
ARRANG  0.
QGSJET  T  0
ECTMAP  1.E3
MAXPRT  100
DIRECT  ./
DATBAS  T
PAROUT  T F
USER    you
     for out
EXIT
```

run number

number of first shower event

number of showers to generate

particle type of prim. Particle

slope of primary energy spectrum

energy range of primary particle

range of zenith angle (degree)

range of azimuth angle (degree)

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62 / 137 161% eslope

Format = (A6, F), Default = 0.

PSLOPE : Exponent γ of differential primary energy spectrum. The primary ener
random from an exponential energy spectrum of the form $dN/dE_0 \propto E_0^{\gamma}$. PSI
meaning in case of fixed primary energy. The energies are total energies and includ
rest mass.

This keyword is not available in the STACKIN option.

4.8 Zenith Angle Definition

`THETAP  THETPR(1)  THETPR(2)`

Format = (A6, 2F), Defaults = 0., 0.

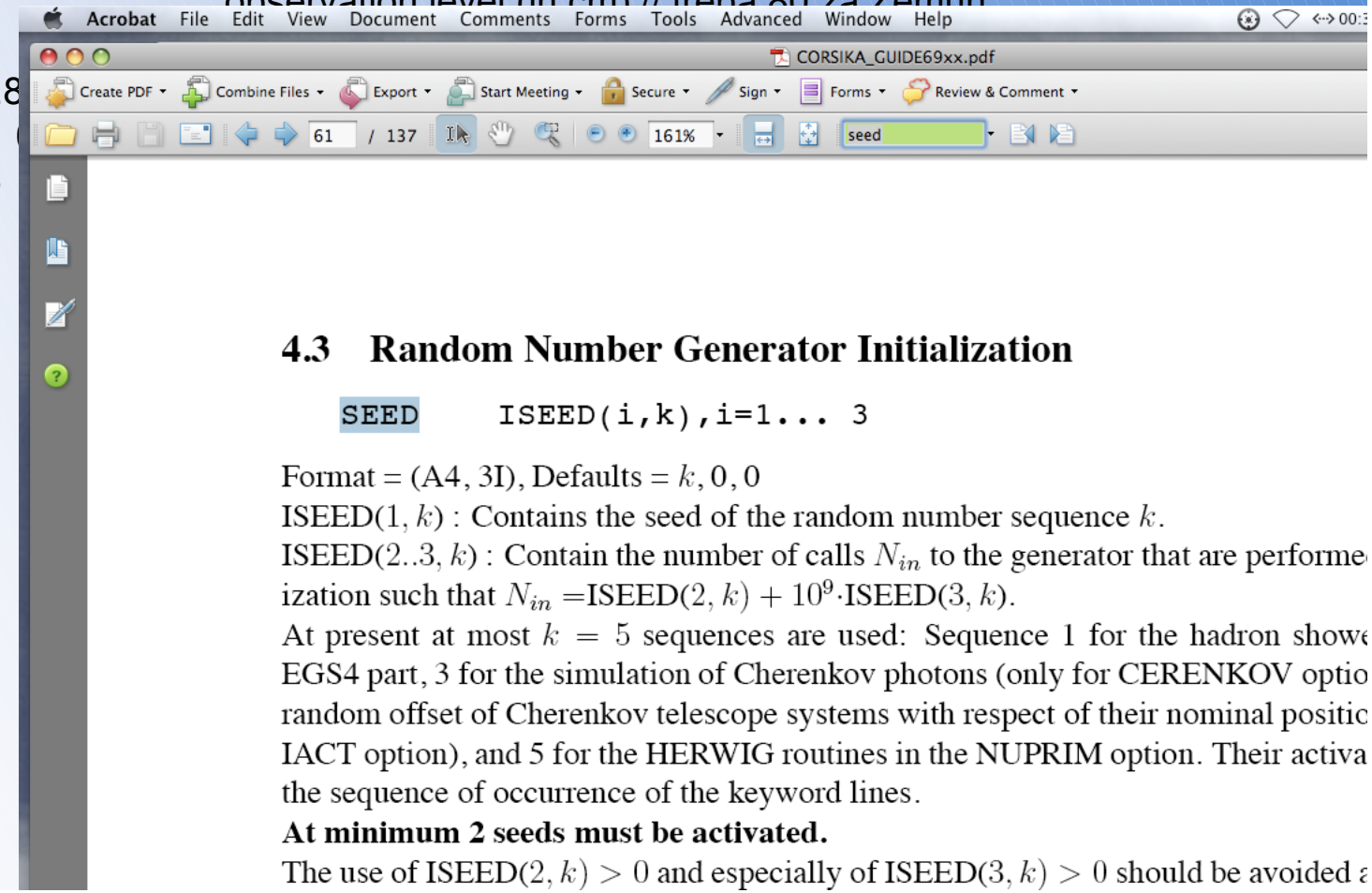
THETPR(1) : Low edge of zenith angle range of primary particle (in °).

THETPR(2) : High edge of zenith angle range of primary particle (in °).

The zenith angle is selected at random out of this interval in a manner which re
particle fluxes from all solid angle elements of the sky and a registration by a h
detector arrangement[47]. THETPR is the angle of incidence at a horizontal detector

[47] In the case you use a volume detector (sphere) or a vertical long string detector instead of a fla
tector, you should respect this by selecting the preprocessor option VOLUMEDET (for sphere) or V
(for vertical long string) to get the angular dependence of the shower intensity as observed with suc
Sect. 3.5.23 page 48).

```
RUNNR   1031                run number
EVTNR   1100001             number of first shower event
NSHOW   100000              number of showers to generate
PRMPAR  14                  particle type of prim. Particle
ESLOPE  -2.7                slope of primary energy spectrum
ERANGE  10.  1.E4           energy range of primary particle
THETAP  0.  60.             range of zenith angle (degree)
PHIP    -180.  180.         range of azimuth angle (degree)
SEED    103  1   0          seed for 1. random number sequence
SEED    201  1   0          seed for 2. random number sequence
OBSLEV  116.E2              observation level (in cm) // treba 80 za Zemun
FIXCHI  0.
MAGNET  20.0  42.8
HADFLG  0  0  0  0
ECUTS   0.05  0.05
MUADDI  T
MUMULT  T
ELMFLG  T   T
STEPFC  1.0
.RADNKG  200.E2
ARRANG  0.
QGSJET  T  0
ECTMAP  1.E3
MAXPRT  100
DIRECT  ./
DATBAS  T
PAROUT  T F
USER    you
     for out
EXIT
```



4.3 Random Number Generator Initialization

SEED ISEED(i,k),i=1... 3

Format = (A4, 3I), Defaults = $k, 0, 0$
ISEED$(1, k)$: Contains the seed of the random number sequence k.
ISEED$(2..3, k)$: Contain the number of calls N_{in} to the generator that are performe
ization such that N_{in} =ISEED$(2, k) + 10^9 \cdot$ISEED$(3, k)$.
At present at most $k = 5$ sequences are used: Sequence 1 for the hadron showe
EGS4 part, 3 for the simulation of Cherenkov photons (only for CERENKOV optio
random offset of Cherenkov telescope systems with respect of their nominal positic
IACT option), and 5 for the HERWIG routines in the NUPRIM option. Their activa
the sequence of occurrence of the keyword lines.
At minimum 2 seeds must be activated.
The use of ISEED$(2, k) > 0$ and especially of ISEED$(3, k) > 0$ should be avoided a

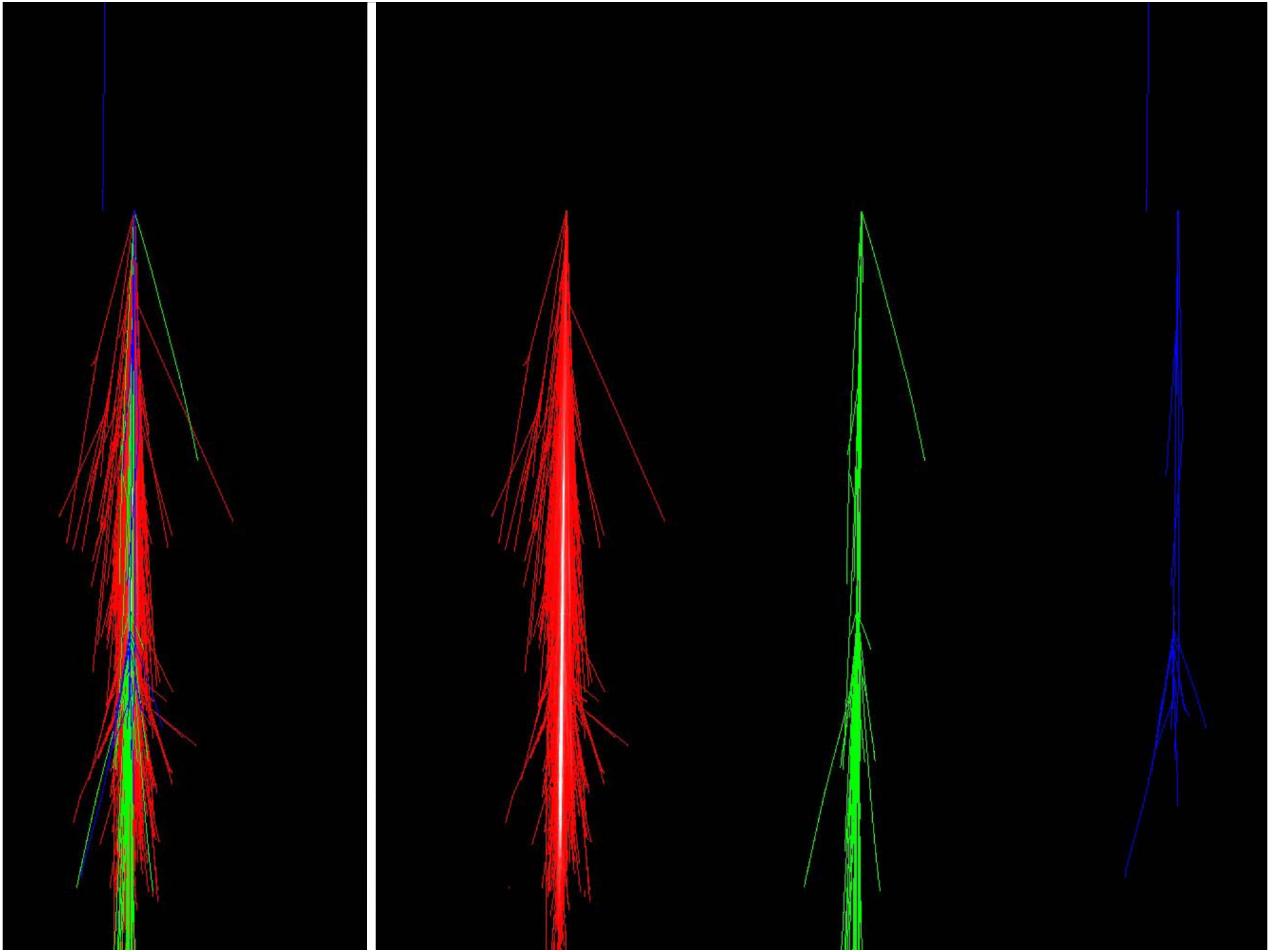
```
RUNNR   1031
EVTNR   1100001
NSHOW   100000
PRMPAR  14
ESLOPE  -2.7
ERANGE  10.  1.E4
THETAP  0.  60.
PHIP    -180.  180.
SEED    103   1   0
SEED    201   1   0
OBSLEV  116.E2
FIXCHI  0.
MAGNET  20.0  42.8
HADFLG  0  0  0  0  0
ECUTS   0.05  0.05  0.003  0.003      energy cuts for particles
MUADDI  T                  additional info for muons
MUMULT  T                  muon multiple scattering angle
ELMFLG  T   T              em. interaction flags (NKG,EGS)
STEPFC  1.0                mult. scattering step length fact
.RADNKG  200.E2                outer radius for NKG lat.dens.distr.
ARRANG  0.                 rotation of array to north
QGSJET  T  0               nesto
ECTMAP  1.E3                cut on gamma factor for printout
MAXPRT  100                 max. number of printed events
DIRECT  ./                 output directory
DATBAS  T                  write .dbase file
PAROUT  T F                 write DAT file
USER    you                user DEBUG   F  11  F  1000000          debug flag and log.unit
     for out
EXIT                       terminates input
```

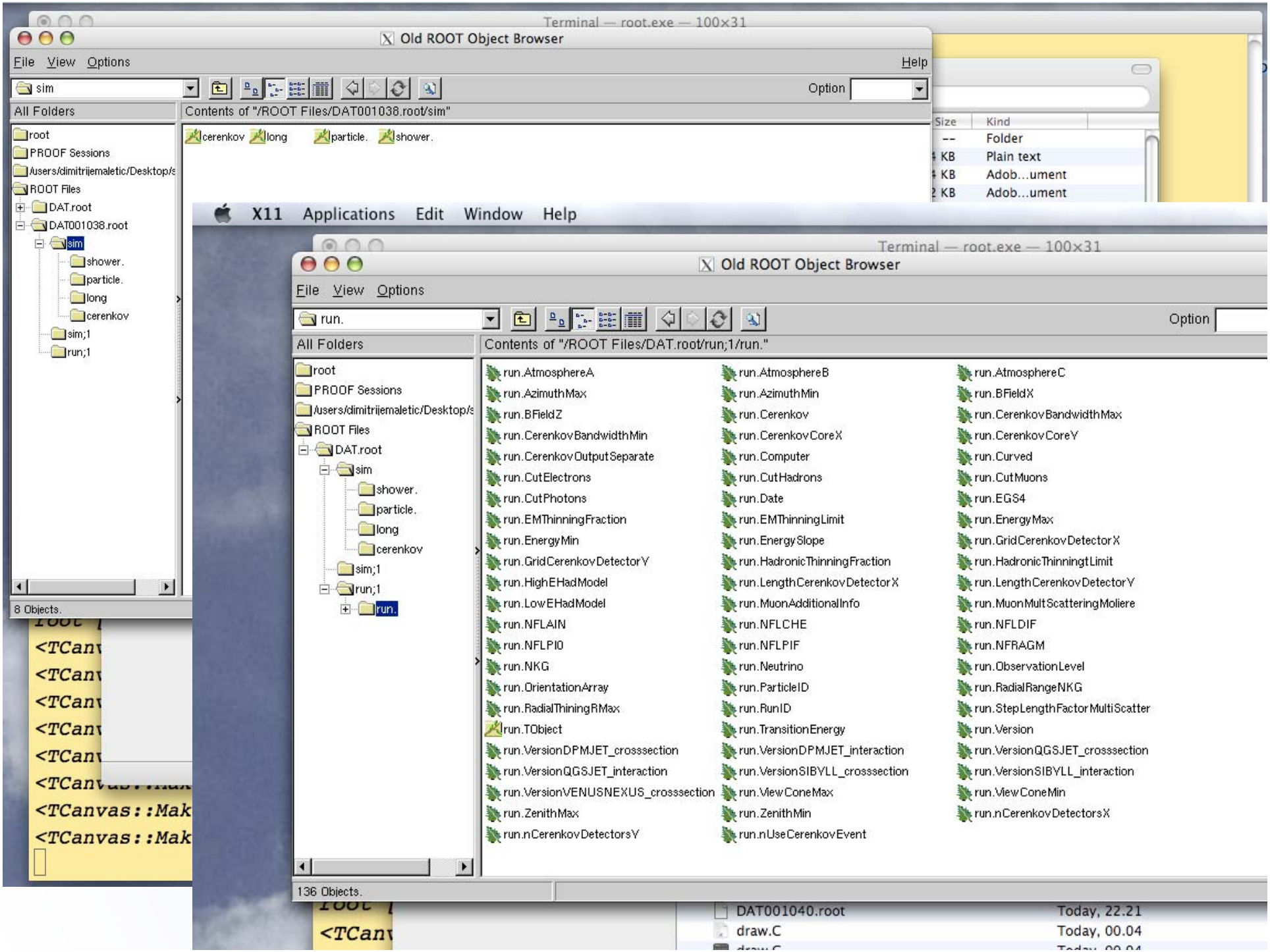
4.47 Energy Cut-Offs

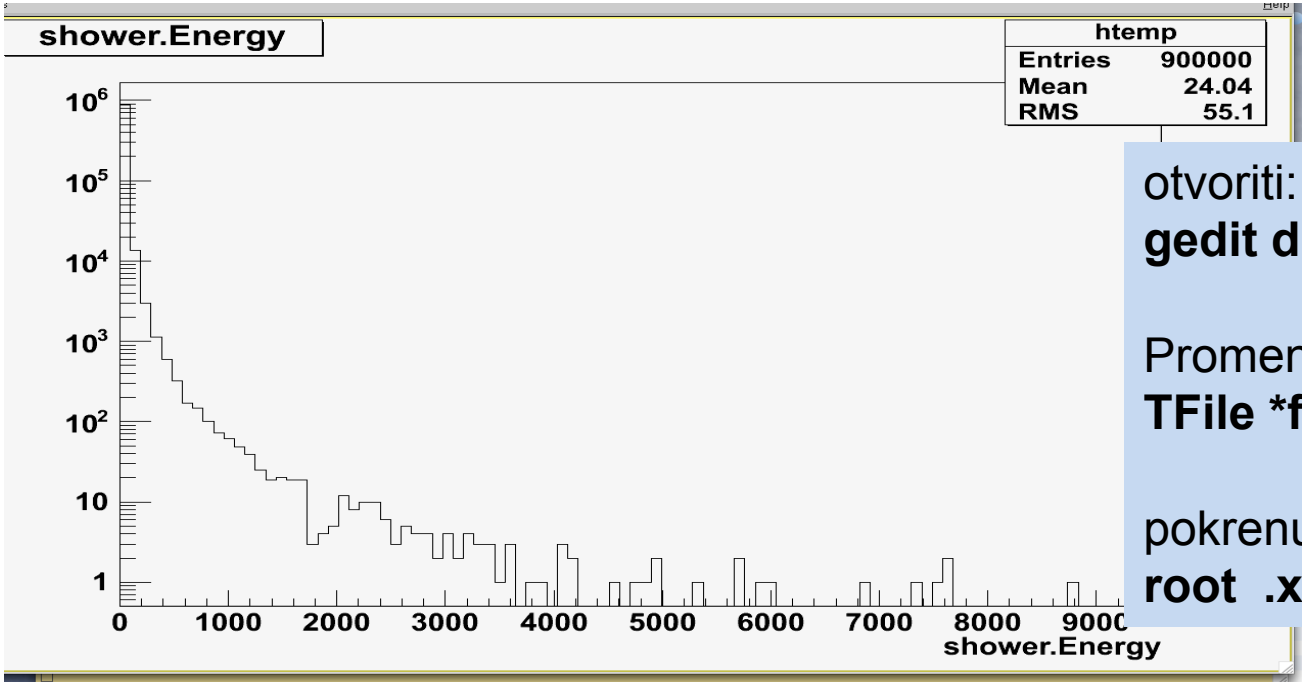
ECUTS ELCUT(i), i=1... 4

Format = (A5, 4F), Defaults[57] = 0.3, 0.3, 0.003, 0.003
ELCUT(i) : The low energy cut-off (in GeV) of the particle kinetic energy ma
differently for hadrons (without π^0's) ($i = 1$), muons ($i = 2$), electrons ($i = 3$),
(including π^0's) ($i = 4$). For nuclei ELCUT(1) is applied to the energy per nucleo
It is in the responsibility of the user to choose the cut-off values in a reasonabl

[56] In the Slowenian thinning [45] an ϵ is defined which gives the inverse of WEITRAT. There t
w_{max} is defined for em-particles and from this the weight limit for hadrons and muons is derived b
[57] For the INTTEST option: Defaults = 0., 0., 0., 0. and all limits are ELCUT(i) $\geq$ 0.



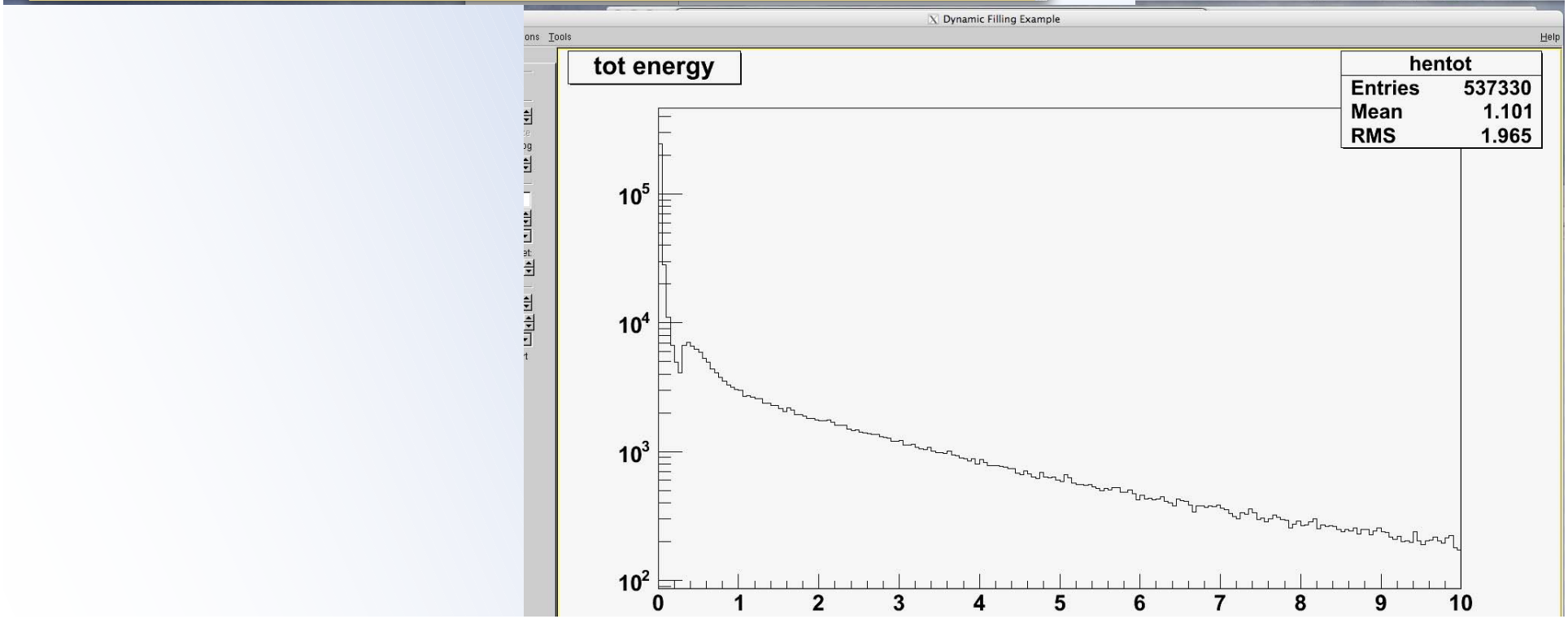

Terminal — root.exe — 100×31
Old ROOT Object Browser
File View Options
Help
sim
Option
All Folders
Contents of "/ROOT Files/DAT001038.root/sim"
root
PROOF Sessions
/users/dimitrijemaletic/Desktop/s
ROOT Files
DAT.root
DAT001038.root
sim
shower.
particle.
long
cerenkov
sim;1
run;1
cerenkov
long
particle.
shower.
8 Objects.
Size
Kind
-- Folder
KB Plain text
KB Adob...ument
KB Adob...ument
X11 Applications Edit Window Help
Terminal — root.exe — 100×31
Old ROOT Object Browser
File View Options
run.
Option
All Folders
Contents of "/ROOT Files/DAT.root/run;1/run."
root
PROOF Sessions
/users/dimitrijemaletic/Desktop/s
ROOT Files
DAT.root
sim
shower.
particle.
long
cerenkov
sim;1
run;1
run.
run.AtmosphereA
run.AtmosphereB
run.AtmosphereC
run.AzimuthMax
run.AzimuthMin
run.BFieldX
run.BFieldZ
run.Cerenkov
run.CerenkovBandwidthMax
run.CerenkovBandwidthMin
run.CerenkovCoreX
run.CerenkovCoreY
run.CerenkovOutputSeparate
run.Computer
run.Curved
run.CutElectrons
run.CutHadrons
run.CutMuons
run.CutPhotons
run.Date
run.EGS4
run.EMThinningFraction
run.EMThinningLimit
run.EnergyMax
run.EnergyMin
run.EnergySlope
run.GridCerenkovDetectorX
run.GridCerenkovDetectorY
run.HadronicThinningFraction
run.HadronicThinningtLimit
run.HighEHadModel
run.LengthCerenkovDetectorX
run.LengthCerenkovDetectorY
run.LowEHadModel
run.MuonAdditionalInfo
run.MuonMultScatteringMoliere
run.NFLAIN
run.NFLCHE
run.NFLDIF
run.NFLPI0
run.NFLPIF
run.NFRAGM
run.NKG
run.Neutrino
run.ObservationLevel
run.OrientationArray
run.ParticleID
run.RadialRangeNKG
run.RadialThiningRMax
run.RunID
run.StepLengthFactorMultiScatter
run.TObject
run.TransitionEnergy
run.Version
run.VersionDPMJET_crosssection
run.VersionDPMJET_interaction
run.VersionQGSJET_crosssection
run.VersionQGSJET_interaction
run.VersionSIBYLL_crosssection
run.VersionSIBYLL_interaction
run.VersionVENUSNEXUS_crosssection
run.ViewConeMax
run.ViewConeMin
run.ZenithMax
run.ZenithMin
run.nCerenkovDetectorsX
run.nCerenkovDetectorsY
run.nUseCerenkovEvent
136 Objects.
<TCanv
<TCanvas::Mak
DAT001040.root
Today, 22.21
draw.C
Today, 00.04

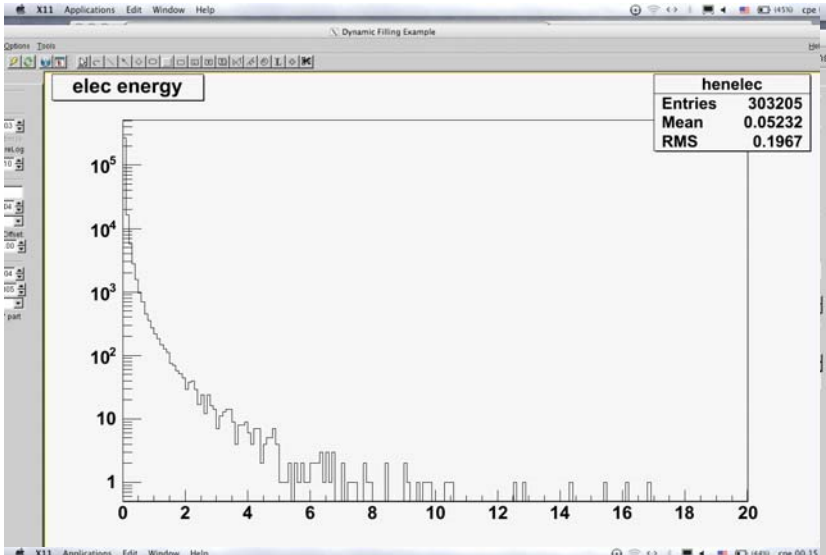


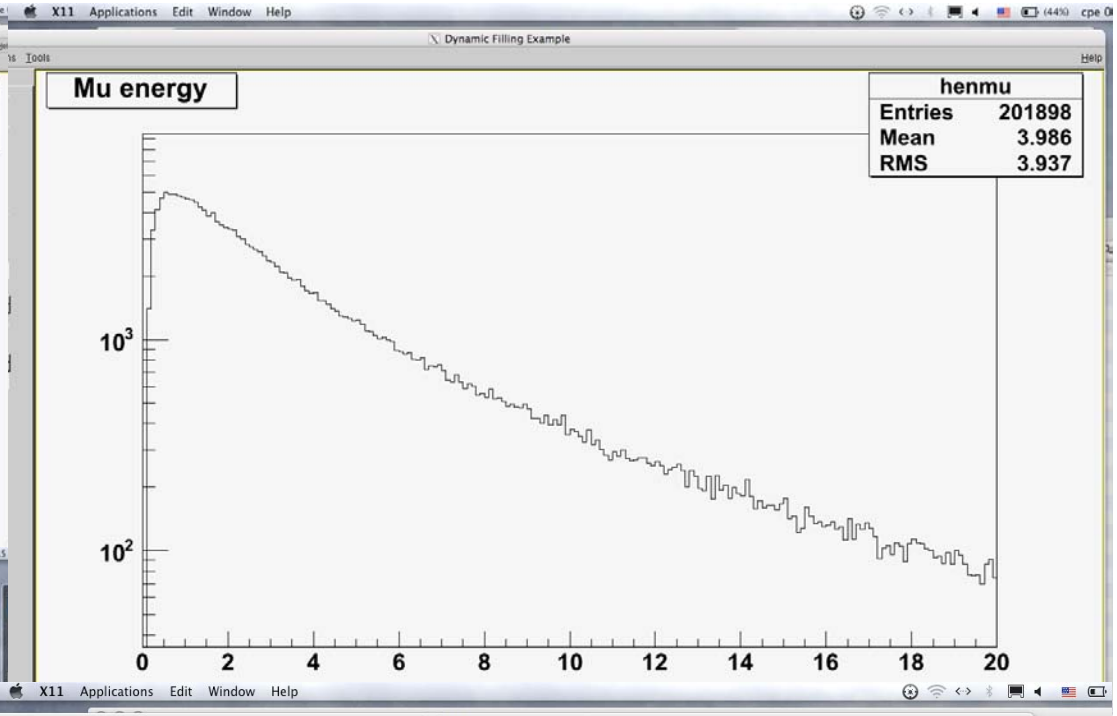
otvoriti:
gedit draw.C

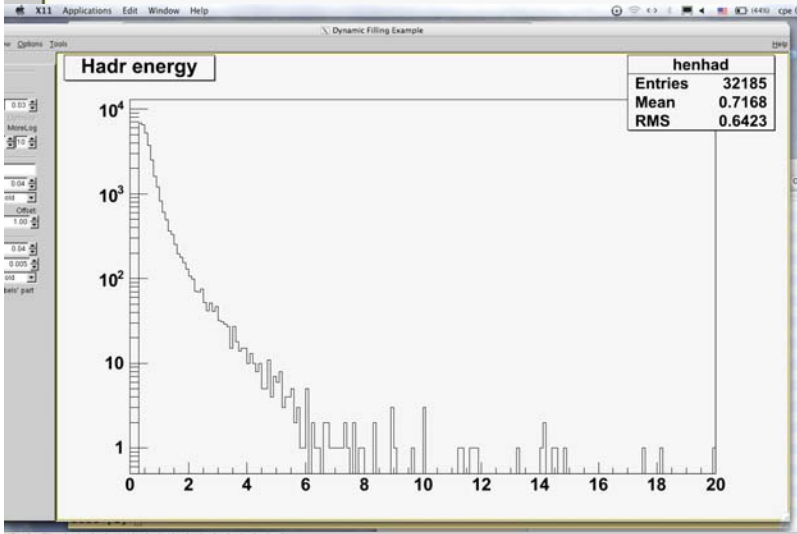
Promeniti liniju:
TFile *f = TFile::Open("DAT.root");

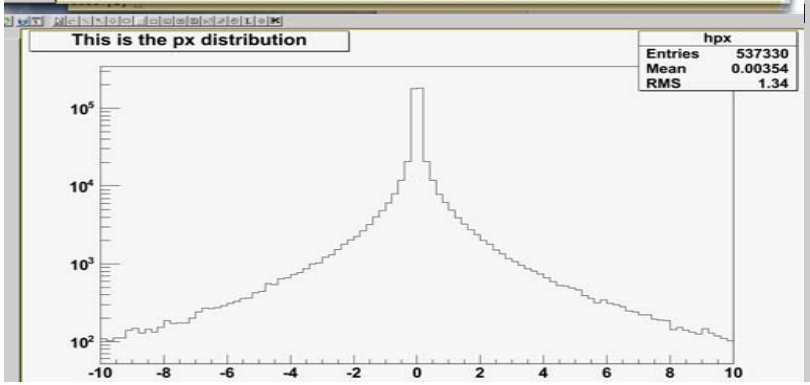
pokrenuti:
root .x draw.C

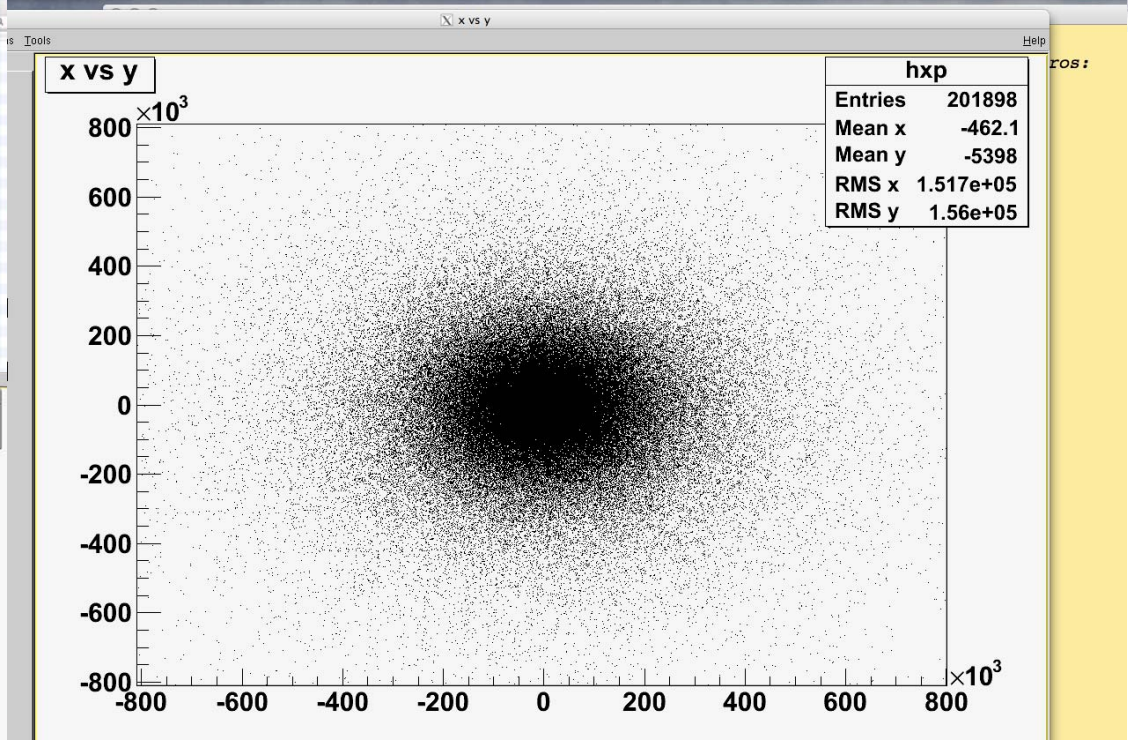


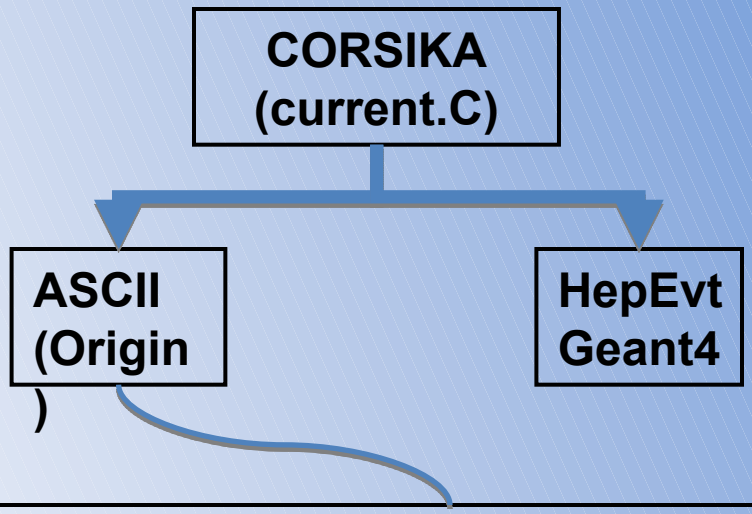

elec energy
henelec
Entries 303205
Mean 0.05232
RMS 0.1967


Mu energy
henmu
Entries 201898
Mean 3.986
RMS 3.937


Hadr energy
henhad
Entries 32185
Mean 0.7168
RMS 0.6423


This is the px distribution
hpx
Entries 537330
Mean 0.00354
RMS 1.34


x vs y
hxp
Entries 201898
Mean x -462.1
Mean y -5398
RMS x 1.517e+05
RMS y 1.56e+05



Evt PID(PDG) px[GeV] py[GeV] pz[GeV] mass[g] x[cm] y[cm] z[cm] t[ns]

3 11 -4.691787e-03 3.083721e-04 1.884782e-02 5.100000e-04 1.482645e+04 2.730096e+05 8.000000e+03 1.114538e+05

otvoriti:
gedit current.C

Promeniti linije:
TFile *f = TFile::Open("DAT001021.root");
FILE *fp = fopen("R1021.hepevt","w");
FILE *fp2 = fopen("R1021.hepevt2","w");
FILE *fp3 = fopen("R1021.dat","w");
pokrenuti:
root –b .x current.C > log.txt

Geant4 simulacija

(radni direktorijum: ~corsika/Geant4/WORK/LLL/run
pokretanje simulacije is gornjeg direktorijuma: ../../bin/Linux-g++/LLL)

- Osnova simulacija. Nekompletna. Razvijena prvenstveno za testiranje mogućnosti učitavanja izlaznih fajlova iz CORSIKA-e.

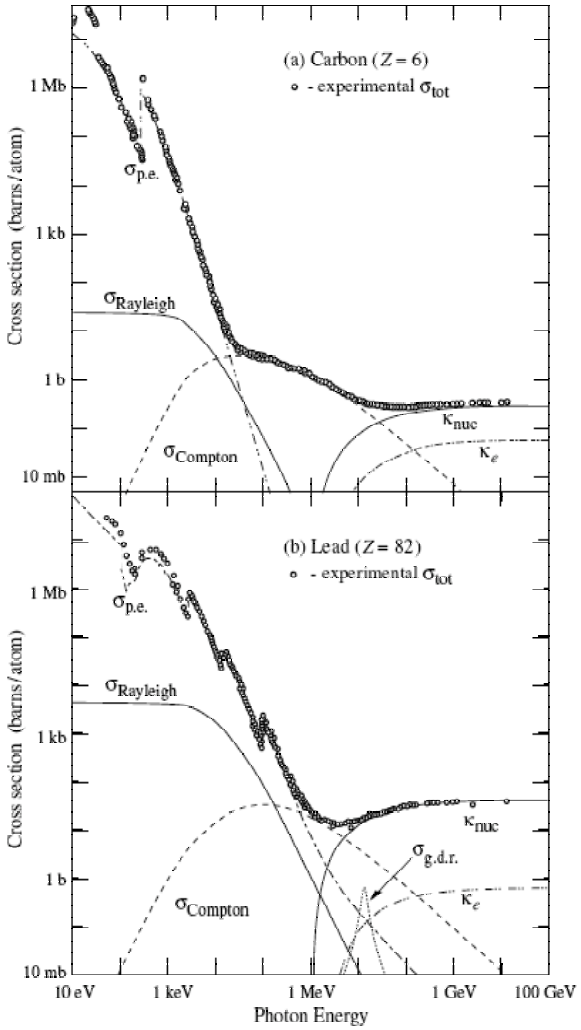
- **Novi interfejs koji omogućuje učitavanje proširenih HepEvt fajlova. Moguća opštija primena I na druge generatore događaja.** Prošireni HepEvt fajlovi = imaju uključenu informaciju o poziciji svake čestice I vremenu pojavljivanja u datoj tački.

-Prati optičke fotone koji dolaze do fotomultiplikatora.

- Interesantna još analiza pojedinih događaja HepRApp.jar aplikacijom.

-Sledi demonstracija…

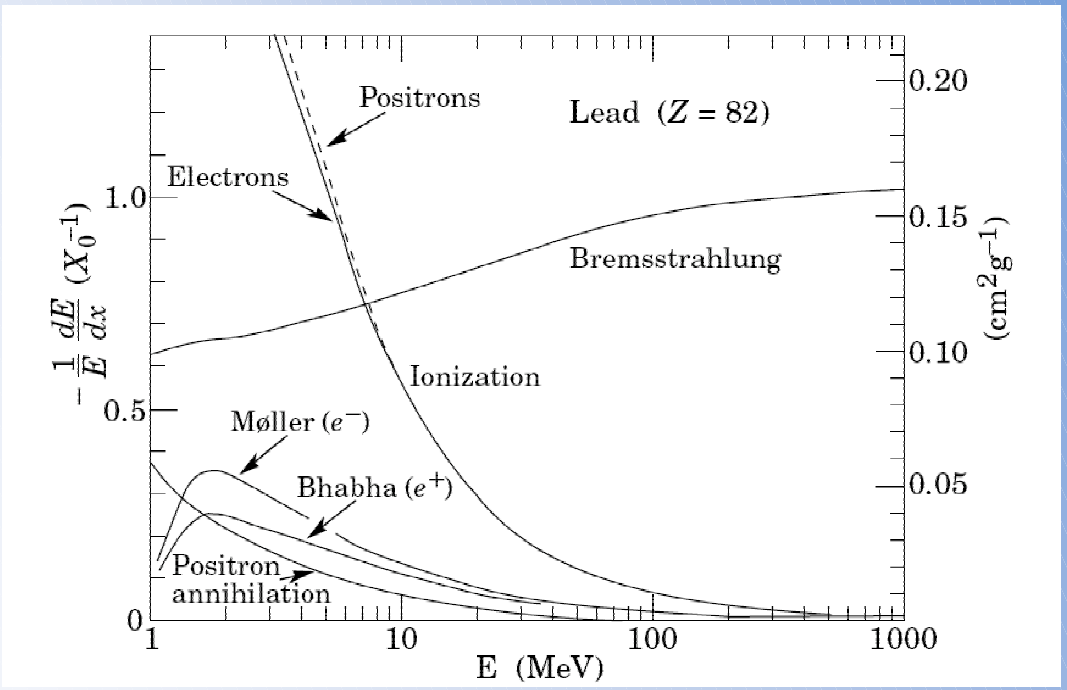
Initial Particle PDG code: 22 , momentum: (-2.65947,3.37838,13.8547) MeV, vertex: (9.85947,-8.49592,-100) cm, and time: 39351.3 ns. Total energy deposition in scintillator : 14506.552 (keV) Number of photons that hit PMTs in this event : 568 Number of photons produced by scintillation in this event : 163130



In physics, Compton scattering is a type of scattering that X-rays and gamma rays undergo in matter. The inelastic scattering of photons in matter results in a decrease in energy (increase in wavelength) of an X-ray or gamma ray photon, called the Compton effect. Part of the energy of the X/gamma ray is transferred to a scattering electron, which recoils and is ejected from its atom, and the rest of the energy is taken by the scattered, "degraded" photon.

The photoelectric effect is a phenomenon in which electrons are emitted from matter (metals and non-metallic solids, liquids or gases) as a consequence of their absorption of energy from electromagnetic radiation of very short wavelength, such as visible or ultraviolet light.

Initial Particle PDG code: -11 , momentum: (-10.8367,11.4697,33.214) MeV, vertex: (9.42918,-7.76341,-100) cm, and time: 39352.3 ns. Total energy deposition in scintillator : 7448.6185 (keV) Number of photons that hit PMTs in this event : 308 Number of photons produced by scintillation in this event : 85002



Bremsstrahlung is electromagnetic radiation produced by the acceleration of a charged particle, such as an electron, when deflected by another charged particle, such as an atomic nucleus.

Initial Particle PDG code: -13 , momentum: (29540.3,21061.3,70107.6) MeV, vertex: (0.401141,9.98769,-100) cm, and time: 47279.2 ns.□ Total energy deposition in scintillator : 45882.011 (keV)□ Number of photons that hit PMTs in this event : 1401□ Number of photons produced by scintillation in this event : 524240□