Output of CORSIKA

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Input (steering) File

```
File  Edit  View  Terminal  Help
/home/pierog/corsika/corsika-6970/run : cat all-inputs
RUNNR   1                           run number
EVTNR   1                           number of first shower event
NSHOW   1                           number of showers to generate
PRMPAR  14                          particle type of prim. particle
ESLOPE  -2.7                        slope of primary energy spectrum
ERANGE  1.E3  1.E3                  energy range of primary particle
THETAP  20.  20.                    range of zenith angle (degree)
PHIP    -180.  180.                 range of azimuth angle (degree)
SEED    1   0   0                   seed for 1. random number sequence
SEED    2   0   0                   seed for 2. random number sequence
OBSLEV  110.E2                      observation level (in cm)
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   0.3  0.3  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
LONGI   T  20.  T  T                longit.distr. & step size & fit & out
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  6  F  1000000            debug flag and log.unit for out
EXIT                                terminates input
/home/pierog/corsika/corsika-6970/run :
```

CORSIKA to be used via standard input (keyboard) or by a steering text file redirected in CORSIKA

- `./corsika6970Linux_QGSJET_gheisha < all-inputs`

3 Types of controls :

- shower parameters
- options parameters
- output parameters

End steering :

- EXIT

Shower Parameters (1)

```
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```

EVTNR

- event number of first shower

NSHOW

- Number of showers to simulate

PRMPAR

- primary particle

ERANGE and ESLOPE

- primary energy

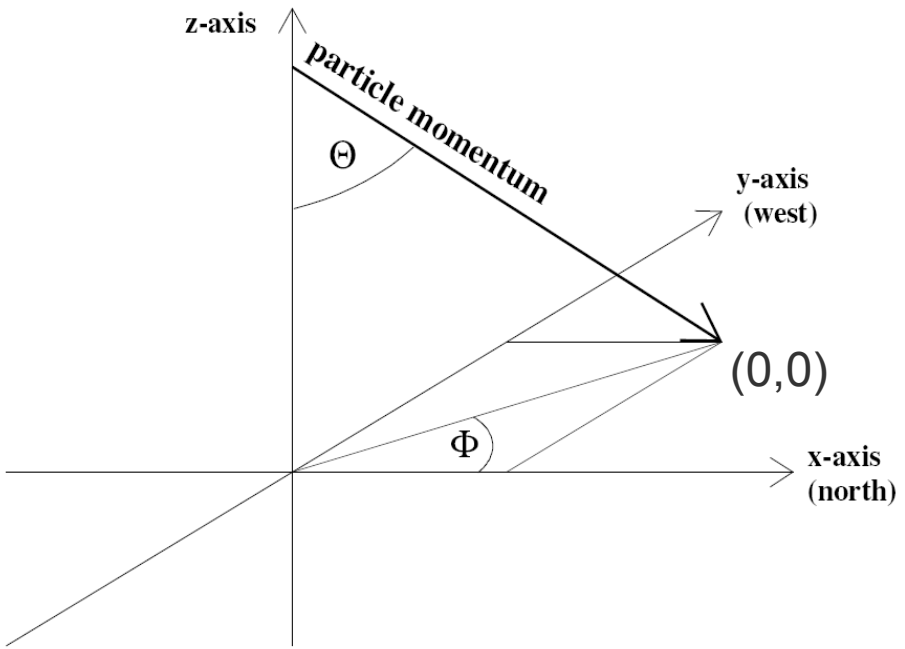
THETAP

- zenith angle (limits depend on CURVED and UPWARD options)

PHIP

- azimuth angle

Shower Parameters (1)



EVTNR

- event number of first shower

NSHOW

- Number of showers to simulate

PRMPAR

- primary particle

ERANGE and ESLOPE

- primary energy

THETAP

- zenith angle (limits depend on CURVED and UPWARD options)

PHIP

- azimuth angle

Shower Parameters (2)

```
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/home/pierog/corsika/corsika-6970/run :
```

SEED

- fix the sequence of random numbers
- each line correspond to a subpart of CORSIKA (min 2)
  - 1 – Hadron
  - 2 – EGS4 (e/m)
  - 3 – Cherenkov
  - 4 – IACT
  - 5 – HERWIG

OBSLEV

- observation level in cm
- 1 line / level (up to 10)

Shower Parameters (3)

```
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```

FIXCHI (g/cm^2)

- starting point of shower primary
- not effective if FIXHEI is used

MAGNET

- magnetic field

HADFLG

- first 5 numbers related to HDPM
- last fix the nuclear fragmentation
  - 0 – None
  - 1 – Full
  - 2 or more – Realistic

Shower Parameters (4)

```
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/home/pierog/corsika/corsika-6970/run :
```

ECUTS

- lower kinetic energy of particle in GeV

MUADDI

- additional informations on muon mother particle

MUMULT

- muon multiple scattering type
  - F – Gauss approx.
  - T – Moliere's theory

Shower Parameters (5)

File Edit View Terminal Help

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```

ELMFLG

- NKG : approximation for LDF
- EGS : real MC for e/m particles

STEPFC

- electron multiple scattering length factor : better not to change

RADNKG

- maximum radius for NKG LDF

ARRANG

- rotation of frame at observation level
  - x-axis do not point to North

Options Parameters

All compilation options have their corresponding steering options ... most important ones :

- THIN F_{Ethr} W_{max} R_{max}
  - F_{Ethr} : if $E < F_{ethr} \times E_{prim}$ thinning is used
  - W_{max} : maximum weight for thinned particles
  - R_{max} : maximum radius for inner radius thinning
    - only to save disk space in DATnnnnnn file
- THINH T_{had} W_{had}
  - define $F^{h}_{Ethr} = F_{Ethr} / T_{had}$ and $W^{h}_{max} = W_{max} / W_{had}$ for hadrons

or

- THINEM T_{em} W_{em}
  - define $F^{em}_{Ethr} = F_{Ethr} \times T_{em}$ and $W^{em}_{max} = W_{max} \times W_{em}$ for e/m particles

Output Types

4 different types of output files :

- Control output (text file)
- Particle list (binary files)
  - DAT file for secondary particles of shower
  - CER file for Cherenkov photons
- Histograms
  - ANAHIST (CERNLIB)
  - AUGERHIST (CERNLIB)
  - First Interaction (CERNLIB)
  - COAST (ROOT) (see R. Ulrich talk)
- Infos on shower production
  - DBASE
  - INFO (Auger)

Control Output

Text appearing on screen during CORSIKA runs

- Can be saved in a text file using the “>” sign
  - `./corsika6970 < all-inputs > output.txt`
- Content all input parameters, how they are used and general informations on simulated showers
  - time
  - number of particles and interactions
  - distributions (longitudinal, energy, ...) per shower and/or averaged
- Should be used to control if all parameters are correct (please sent it in case of problem during simulation)
- Part of the content can be controlled by steering file

Output Parameters : screen

```
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PAROUT  T F                             write DAT file
USER    you                             user
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EXIT                                    terminates input
/home/pierog/corsika/corsika-6970/run :
```

ECTMAP

- printout option (for check)

MAXPRT

- detailed printout on screen

DEBUG

- switch on/off debug output

Output Parameters : files (1)

```
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```

RUNNR

- identification of run number (number in all output file names)

DIRECT

- path for output files
  - `/dev/null` suppress output

USER / HOST

- user and host name for identification in `.log` or `.dbase` files

Output Parameters : files (2)

```
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```

LONGI

- switch on/off longitudinal profile and fit
- last flag for extra `.long` file

PAROUT

- switch on/off `DATnnnnnn` file
- switch on/off `.tab` file

DATBAS

- switch on/off `.dbase` or `.info` file

(CERFIL

- switch on/off `CERnnnnnn` file)

Structure of Binary Files

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

Normal or Cherenkov output files without(with) THIN

- information stored unformatted in a fixed block structure
  - block length = 22932(26208) bytes
  - 1 block = 5733(6552) words (4 bytes)
    = 21 sub-blocks of 273(312) words
  - sub-block are
    - RUN HEADER (273(312) words)
    - EVENT HEADER (273(312) words)
    - DATABLOCK (39*7(8) words)
    - LONG (13+26*10(+39) words)
    - EVENT END (273(312) words)
    - RUN END (273(312) words)
  - if less than n*21 sub-blocks used, end of block filled with 0
- example to read the files : `src/corsikaread.f` (`src/corsikaread_thin.f`)

Content of Binary Files (1)

Particle data sub-block : (up to 39 particles, 7 words each)	
No. of word	Contents of word (as real numbers R*4)
$7 \times (n-1)+1$	particle description encoded as: part. id$\times 1000$ + hadr. generation[76] $\times 10$ + no. of obs. level
$7 \times (n-1)+2$	px, momentum in x direction in GeV/c
$7 \times (n-1)+3$	py, momentum in y direction in GeV/c
$7 \times (n-1)+4$	pz, momentum in -z direction in GeV/c
$7 \times (n-1)+5$	x position coordinate in cm
$7 \times (n-1)+6$	y position coordinate in cm
$7 \times (n-1)+7$	t time since first interaction (or since entrance into atmosphere)[77] in nsec [for additional muon information: z coordinate in cm]
	for $n = 1 \ldots 39$ if last block is not completely filled, trailing zeros are added

Table 9: Structure of particle data sub-block.

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: $99.E5 + 10\times$NINT(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 to x axis
$7 \times (n-1)+5$	v direction cosine to y axis
$7 \times (n-1)+6$	t time since first interaction (or since entrance into atmosphere)[77] in nsec
$7 \times (n-1)+7$	height of production of bunch in cm
	for $n = 1 \ldots 39$ if last block is not completely filled, trailing zeros are added

Table 10: Structure of Cherenkov photon data sub-block.

Different type of info per sub-block :

- HEADER
  - general informations (options and primary) on run and events
- END
  - end of event (including NKG output) and run
- DATABLOCK
  - list of particles at observation level
    - id, generation and observation level
    - momentum
    - position
    - time
    - (weight)
  - only list of Cherenkov photons in CERnnnnnn file

Content of Binary Files (2)

'Longitudinal' sub-block: (up to 26 depth steps/block)	
No. of word	Contents of word (as real numbers R*4)
1	'LONG'
2	event number
3	particle id (particle code or $A \times 100 + Z$ for nuclei)
4	total energy in GeV
5	(total number of longitudinal steps)$\times$ 100 + number of longitudinal blocks/shower
6	current number m of longitudinal block
7	altitude of first interaction in g/cm^2
8	zenith angle θ in radian
9	azimuth angle ϕ in radian
10	cutoff for hadron kinetic energy in GeV
11	cutoff for muon kinetic energy in GeV
12	cutoff for electron kinetic energy in GeV
13	cutoff for photon energy in GeV
$10 \times n + 4$	vertical (resp. slant) depth of step j in g/cm^2
$10 \times n + 5$	number of γ-rays at step j
$10 \times n + 6$	number of e^+ particles at step j
$10 \times n + 7$	number of e^- particles at step j
$10 \times n + 8$	number of μ^+ particles at step j
$10 \times n + 9$	number of μ^- particles at step j
$10 \times n + 10$	number of hadronic particles at step j
$10 \times n + 11$	number of all charged particles at step j
$10 \times n + 12$	number of nuclei[78] at step j
$10 \times n + 13$	number of Cherenkov photons at step j
	for $n = 1, 26$ and for j longitudinal steps for 1st 'LONG' block: 1 ... j ... 26 for 2nd 'LONG' block: 27 ... j ... 52 ..... for m^{th} 'LONG' block: $(m-1) \cdot 26 + 1$ ... j ... $m \cdot 26$ if last block is not completely filled, trailing zeros are added

Longitudinal profile in binary output file

- LONG
  - only number of particles (no energy deposit)
  - for each depth bin, 10 numbers
    - different particle types
  - 26 depth bins per sub-block
    - for 20 gr/cm^2 per bin, at least 2 sub-blocks needed per event
  - depth bin = vertical depth
    - use SLANT option to have slant depth

Alternative for longitudinal profile

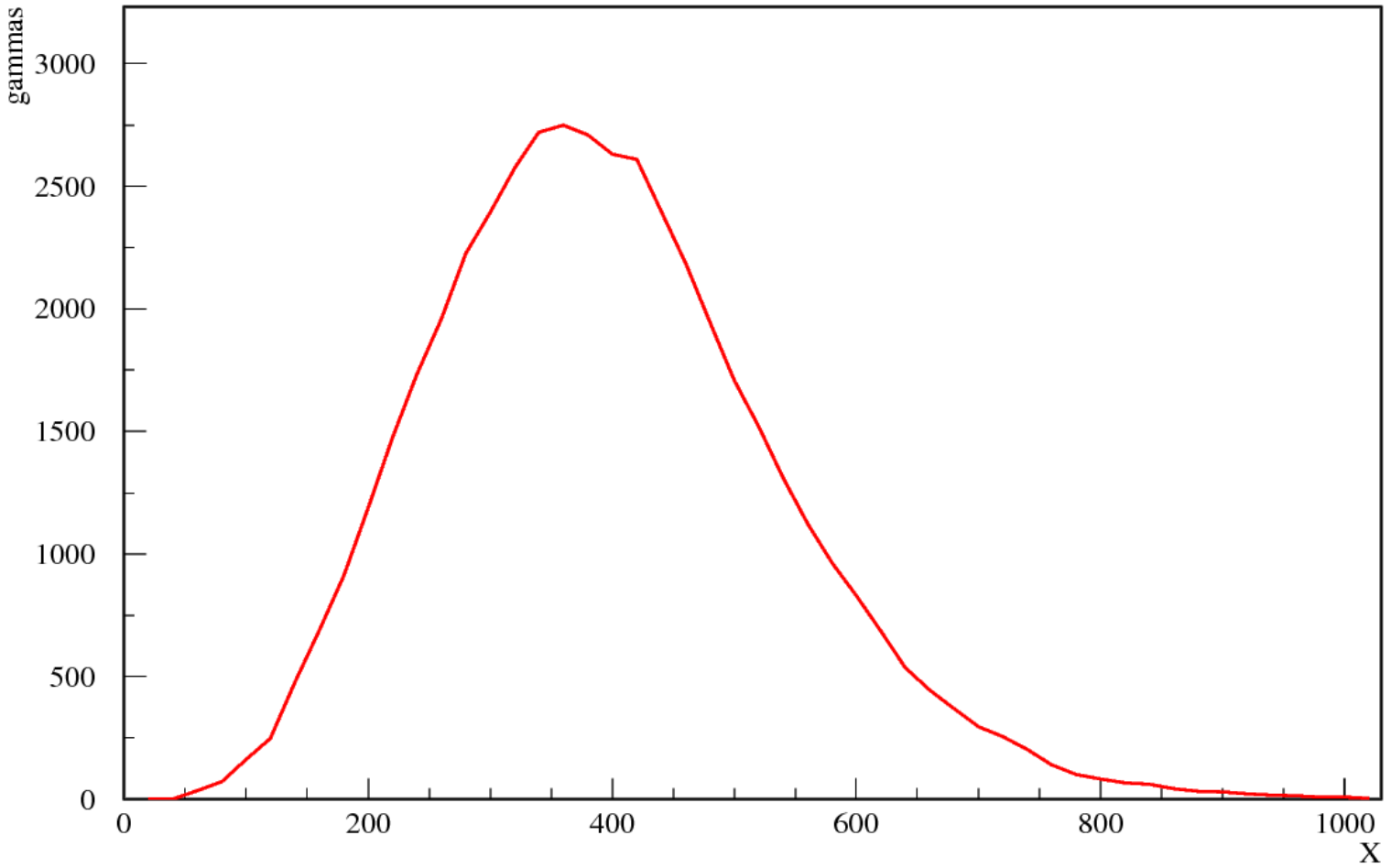
- `.long` file
  - text file
  - include energy deposit and particle number

Much More Options ...

Please read the user guide for details and particular options ...

Exercice 1

1) Using `all-inputs`, reproduce the following plot :



Plotting can be done by ROOT, PAW, GNUPLOT (`plot 'filename' u x:y w l`), ...

How to Read DAT file

- corsikaread (corsikaread_thin)

```
C=====================================================================
C
C                    CORSIKAREAD  (without THINNING)
C
C            ===================================================
C                  READ  AND  PRINT  CORSIKA  SHOWER  DATA
C            ===================================================
C
C     output format for particle output (blocklength = 22932+8 fixed)
C     each block consists of 21 subblocks of 273 words.
C     How to use this program:
C     1) Generate a file 'input' containing the path and name of the
C        DATnnnnnn file to be analyzed by this program.
C        The name should not contain leading blanks but filled up
C        by trailing blanks to get a total length of >70 characters.
C     2) Execute this program with the file 'input' as standard input:
C              corsikaread <input >output
C     3) The file 'output' will contain a short overview of the
C        content of the DATnnnnnn file to be analyzed.
C     4) The file fort.8 will contain a detailed print out of the
C        content of DATnnnnnn.
C
C     D. Heck       FZKA, May 14, 2004
C=====================================================================
```

fort.8 file

`corsikaread` translate the DAT file into the `fort.8` ASCII file containing all informations

- RUNH identified by 1.11111E+07 followed by 272 floats
  - 39 lines of 7 numbers in the file

Repeated for each event in run

- EVTH identified by 3.33333E+07 followed by 272 floats
  - 39 lines of 7 numbers in the file
- DATABLOCK, each line correspond to one particle
  - id, generation and observation level (1 float)
  - momentum (3 floats)
  - position (2 floats)
  - time (1 float)
- LONGBLOCK identified by 5.55555E+07 followed by 272 floats
  - 39 lines of 7 numbers in the file for 26 steps in depth * (# of steps/26)
- EVTE identified by 7.77778E+07 followed by 272 floats
  - 39 lines of 7 numbers in the file
- RUNE identified by 1.00000E+08 followed by 272 floats
  - 39 lines of 7 numbers in the file

Exercices 2 and 3

2) Using `all-inputs`, plot scattering plot of muons at ground.

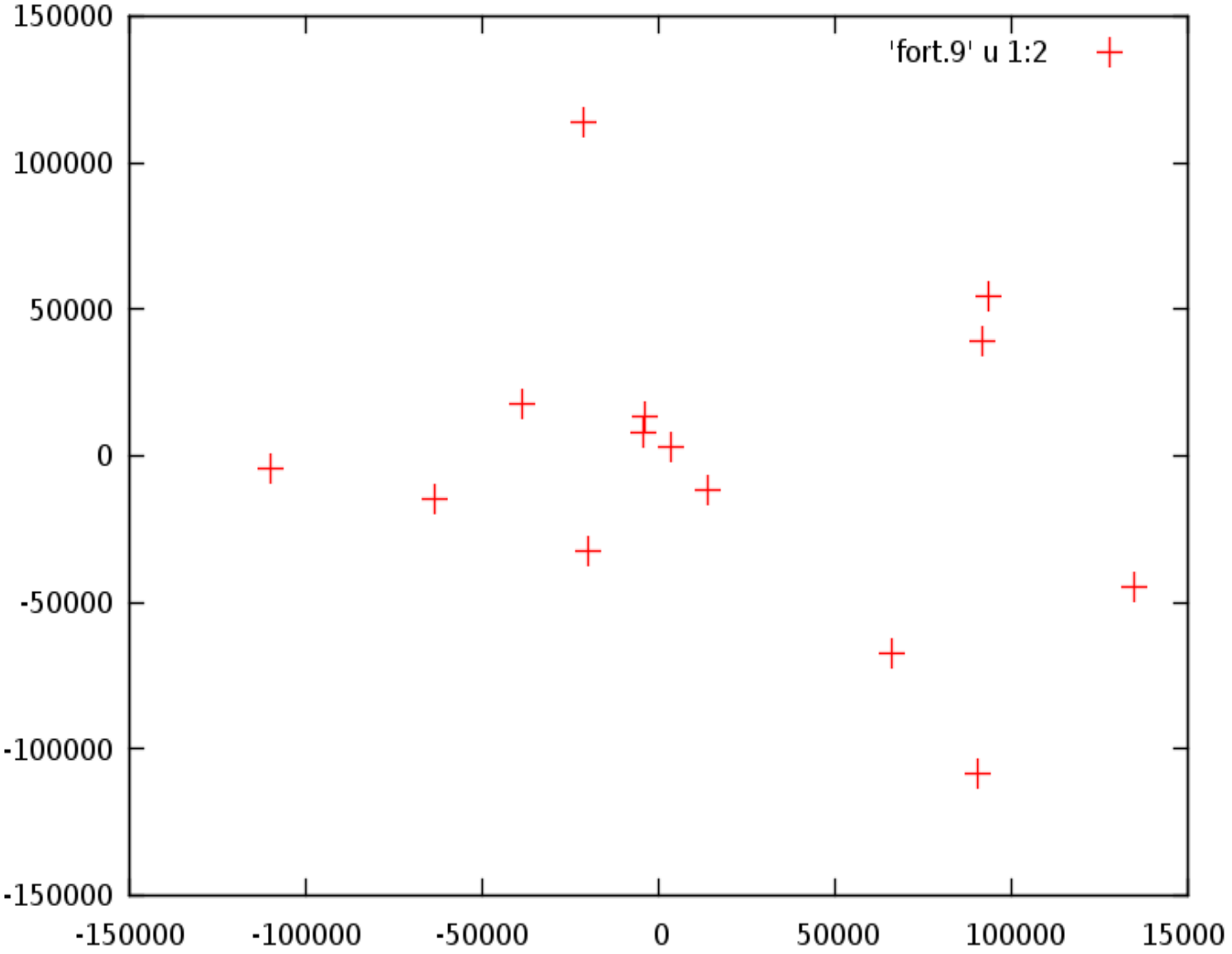
- read `fort.8` file
- or change `corsikaread` to save only needed informations

3) Using `all-inputs`, plot lateral distribution density of muons

- read `fort.8` file and analyse data
- or change `corsikaread` to save distribution directly

You can recompile `corsikaread` after modifications simply by using `make install` in `corsika-6970/`

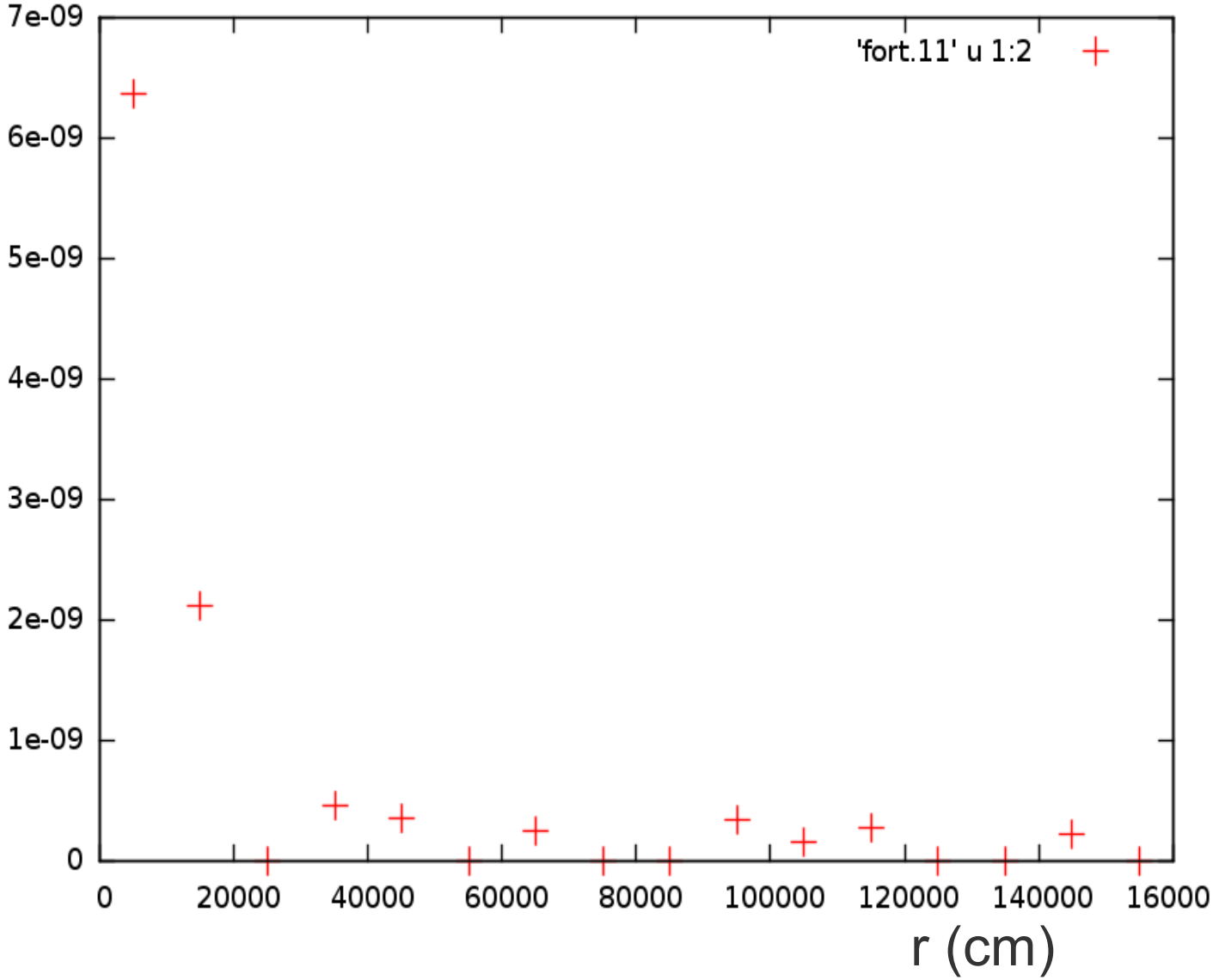
Result Exercise 2



Result Exercise 3

$dN_{mu}/dA(r)$ (cm^{-2})

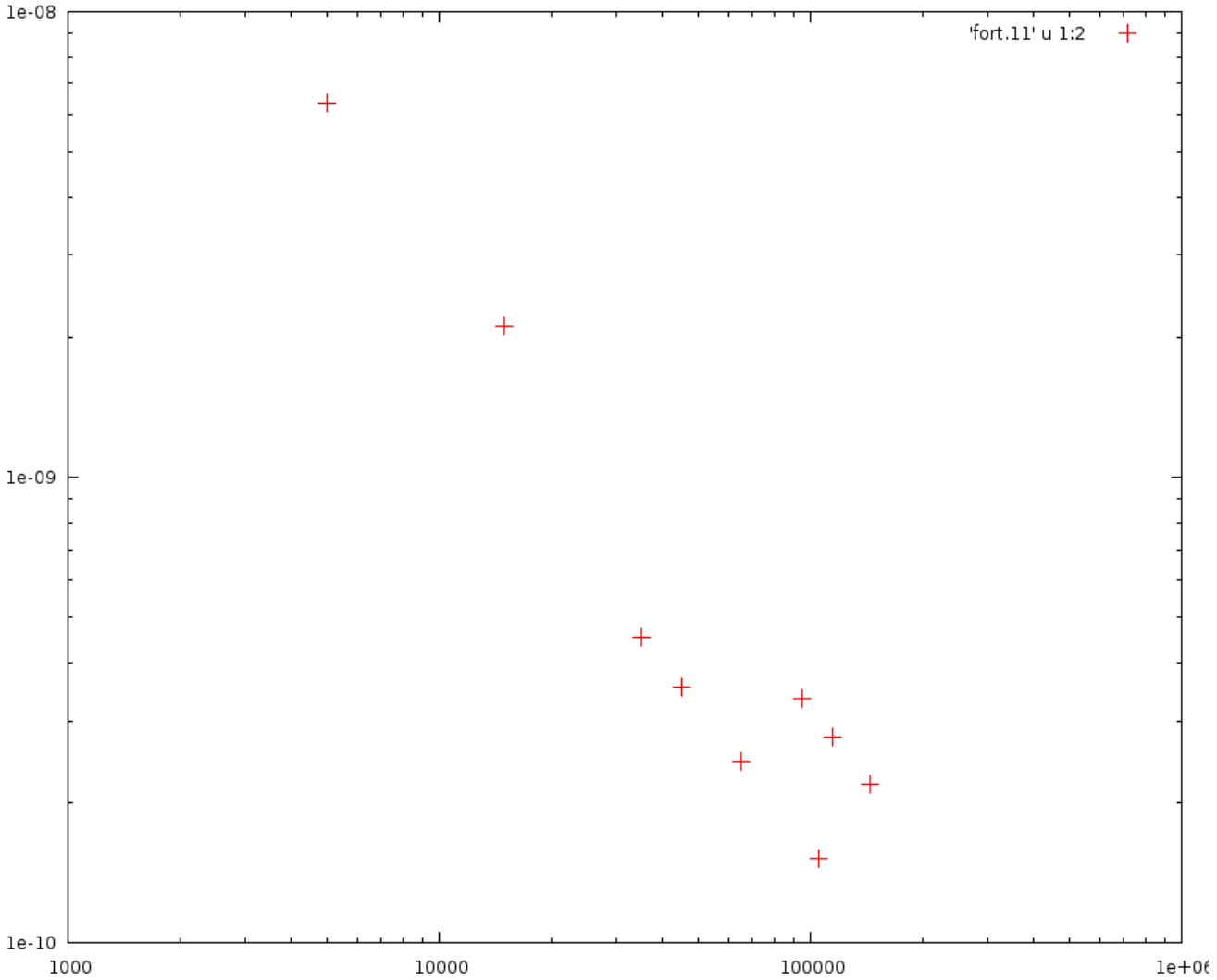
$A = \pi r^2$



Result Exercise 3

$dN_{mu}/dA(r)$ (cm^{-2})

$A = \pi r^2$



Exercise 4

4) Compile CORSIKA with EPOS and THIN and run `epos-inputs` at 10^{15} eV to compare NKG and real particles outputs (longitudinal profile and lateral distribution of electrons).

- `epos-inputs` has to be changed !