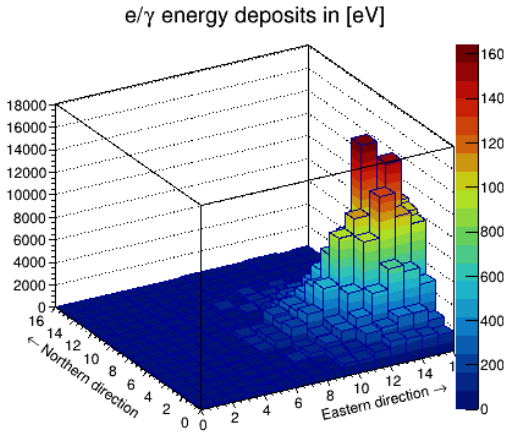
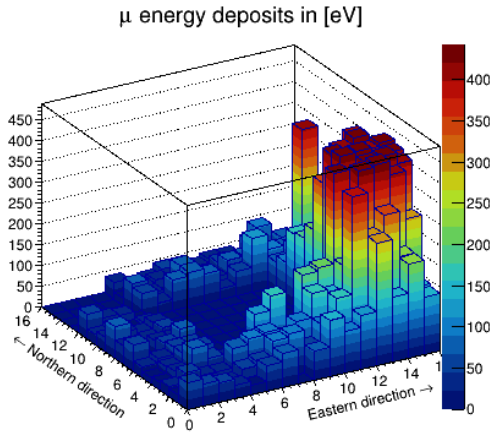
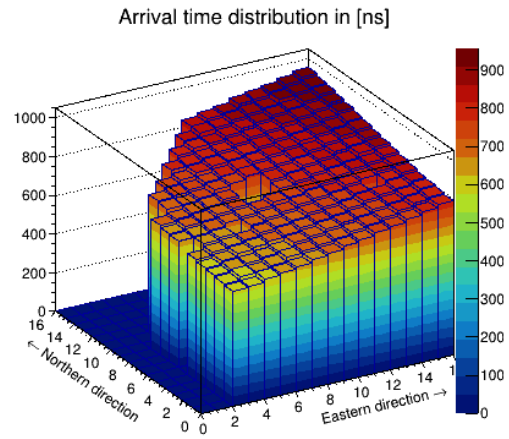
Event Display Manual







KASCADE Event Information

Run Nr.	6586
Event Nr.	169407
$lg(E_o)$	17.06 eV
Zenith Angle	27.35°
Azimuth Angle	254.61°
X-Core Position	78.90 m
Y-Core Position	-44.38 m
$lg(N_e)$	6.80
$lg(N_\mu)$	6.02
Number e/γ-Stations	232
Number μ-Stations	175
Number timing Stations	195
Event Date	2008-11-17
Event Time	23:47:23

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Version:	V-1.1
Last update:	2023-01-17

TABLE OF CONTENTS

1 INTRODUCTION

The EventDisplay Manual provides information how to display events recorded by the KASCADE and GRANDE detectors. In addition to measured data, simulated data can also be displayed.

For details regarding the KASCADE-Grande experiment and KCDC please consult the 'KCDC User Manual' or in case of simulations, the 'KCDC Simulations Manual'

1.1 THE IDEA BEHIND IT

Our goal is to visualize cosmic ray events measured and reconstructed in KASCADE-Grande. The displays should give an impression of what the events look like in different energy ranges and how different the distributions of deposited energy and arrival times can be, even if the events occur in similar energies and angular bins. Therefore, we have prepared a large number of reconstructed events to be displayed.

1.2 THE TOOLS

Within the KCDC web portal, we offer two ways to display events;

- random events from predefined displays (not from simulations);
- EventDisplays of data sets downloaded via the KCDC DataShop and associated '*Preselections'* or '*Simulations'* by means of C-programs provided via the 'Materials' menu item.

As our EventDisplay is done with the CERN ROOT framework, only root files can be analysed and displayed.

1.3 WHAT IS DISPLAYED

The EventDisplays show Energy Deposits and Arrival Times recorded in each detector station of the KASCADE or GRANDE detectors. In case of simulated events, the Energy Deposits and Arrival Times of air showers, simulated with the air shower simulation code CORSIKA and the detector simulation code CRES are displayed.

2 DISPLAY RANDOMLY SELECTED EVENTS

The menu bar item '*Event Display*' opens a page in where simple cuts can be applied and randomly selected events are displayed (fig. 2.1.).

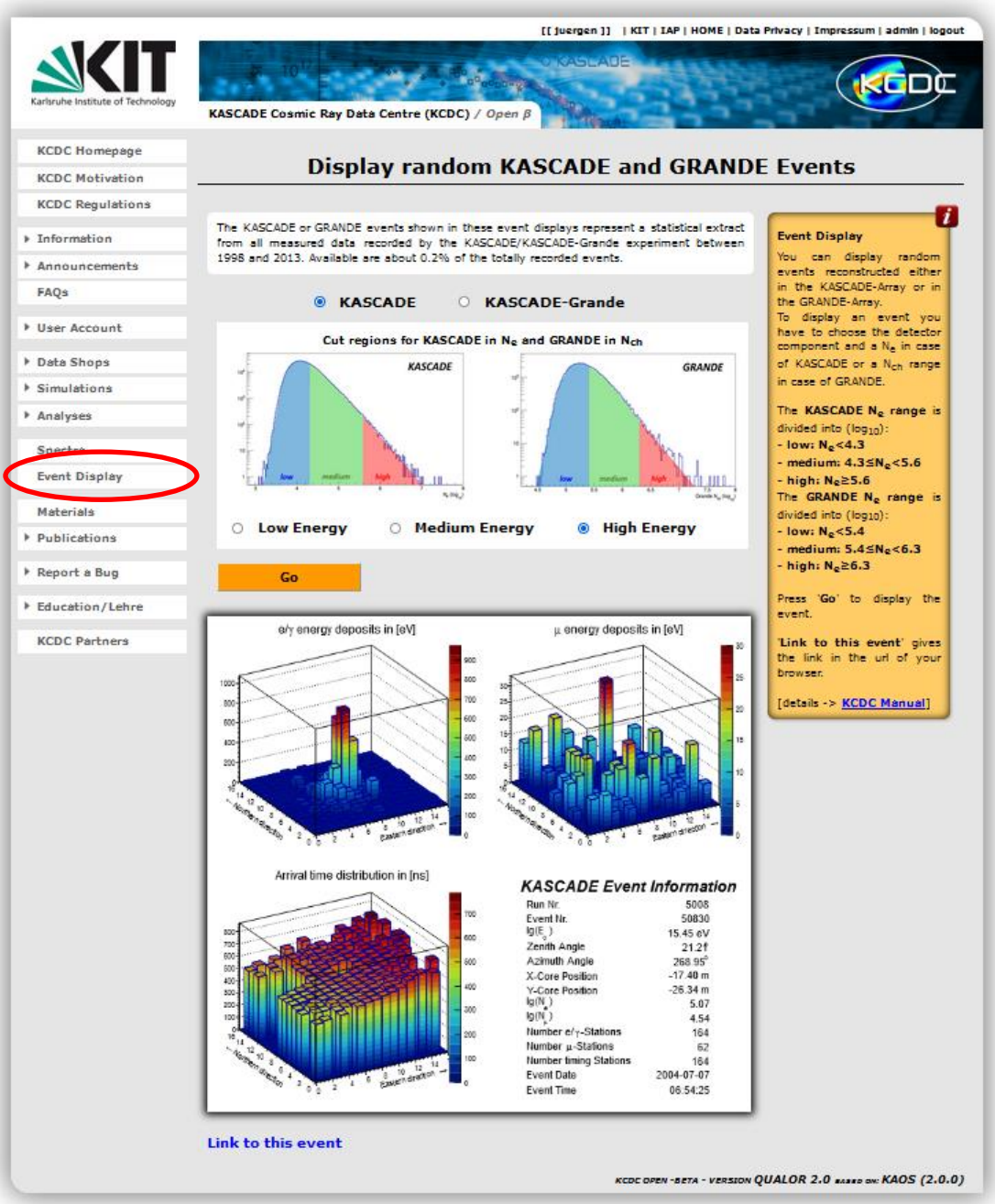

fig. 2.1. *Random Event Display*

2.1 AVAILABLE EVENTS

From the entire data sample recorded with the KASCADE-Grande detector system, which consists of over 433 million events, we offer more than 210.000 events for random display. This selection represents a uniform distribution of the measured data in the energy range 10^{14} – 10^{18} eV. In case of KASCADE, about 123.000 events are available, while for GRANDE more than 88.000 events can be displayed.

Furthermore, to increase the number events in the interesting high-energy region, we provide about 11.700 events for GRANDE in the region $N_{ch} \geq 6.3$ [$\log_{10}$] and 10.224 events in case on KASCADE in the region $N_e \geq 5.6$ [$\log_{10}$] (marked red).

2.2 SIMPLE CUTS ON KASCADE EVENTS

The cut areas for the measured events reconstructed within the KASCADE-Array are shown in the left picture. We decided not to cut on the 'Energy' but on N_e, the reconstructed number of electrons in KASCADE, because N_e is a measured quantity, while 'Energy' is an estimated value, which also depends on the simulation model used.

The selected cut regions are in $\log_{10} N_e$ with events available (fig.: 2.2.1):

- low energy: $N_e < 4.3$ 80.005 ev blue area
- medium energy: $4.3 \leq N_e < 5.6$ 42.587 ev green area
- high energy: $5.6 \leq N_e$ 492 ev red area

additionally for the high-energy range:

- high energy plus: $5.6 \leq N_e$ 10.224 ev

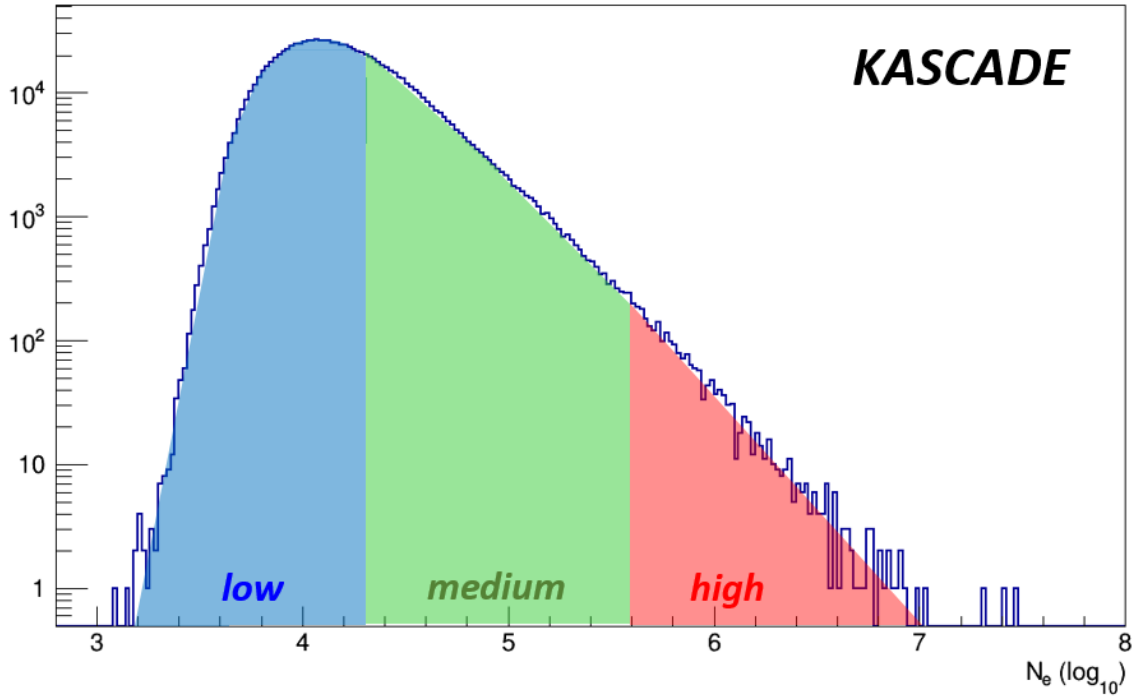

fig. 2.2.1. *Cut regions for KASCADE Event Display in N_e*

2.3 SIMPLE CUTS ON GRANDE EVENTS

The cut areas for the measured events reconstructed within the GRANDE-Array are shown in the right picture. As there is no energy estimation available for GRANDE reconstructed events, we decided to cut on N_{ch}, the reconstructed number of charged particles in GRANDE, which is a measured quantity and does not depend on simulation models.

The selected cut regions are in $\log_{10} N_{ch}$ with their relative abundancies (fig.: 2.3.1):

- low energy: $N_{ch} < 5.4$ 54.769 ev blue area
- medium energy: $5.4 \leq N_{ch} < 6.3$ 33.038 ev green area
- high energy: $6.3 \leq N_{ch}$ 530 ev red area

additionally for the high-energy range:

- high energy plus: $6.3 \leq N_{ch}$ 11.677 ev

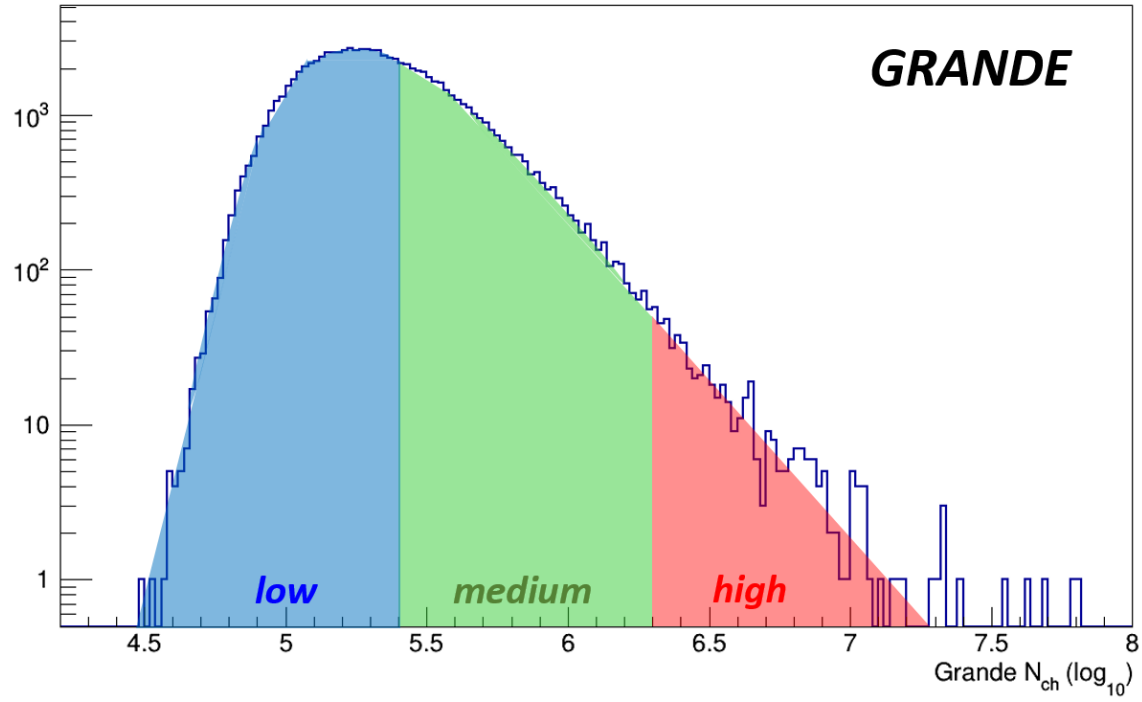

fig. 2.3.1. *Cut regions for GRANDE Event Display in N_{ch}*

2.4 DISPLAYED EVENT

If the detector component and the desired energy range have been selected, press 'Go' to display the event.

2.4.1 KASCADE EVENT

In case of a KASCADE event, three plots are displayed (fig. 2.4.1), showing the energy deposits in the 252 e/γ-detectors of the KASCADE-Array (top left) and in the 192 μ-detectors in *eV* (top right). The arrival time distribution in 252 detector stations (bottom left) is given in *ns* and represents the first time stamp of each detector station that has been hit by a charged particle.

A list of the event properties like run- and event numbers and event time, reconstructed shower parameters like core position and arrival direction as well as the respective number of stations contributing to this event is shown in the bottom right corner.

Since the KASCADE detector array consists of 252 stations in a regular grid with a grid spacing of approx. 13m, the plots are given in '*relative grid numbers*' ranging from 1-16 in x-

and y axis (see fig. 2.4.2). In the centre of the array, four stations are missing, blocked by the Central Calorimeter.

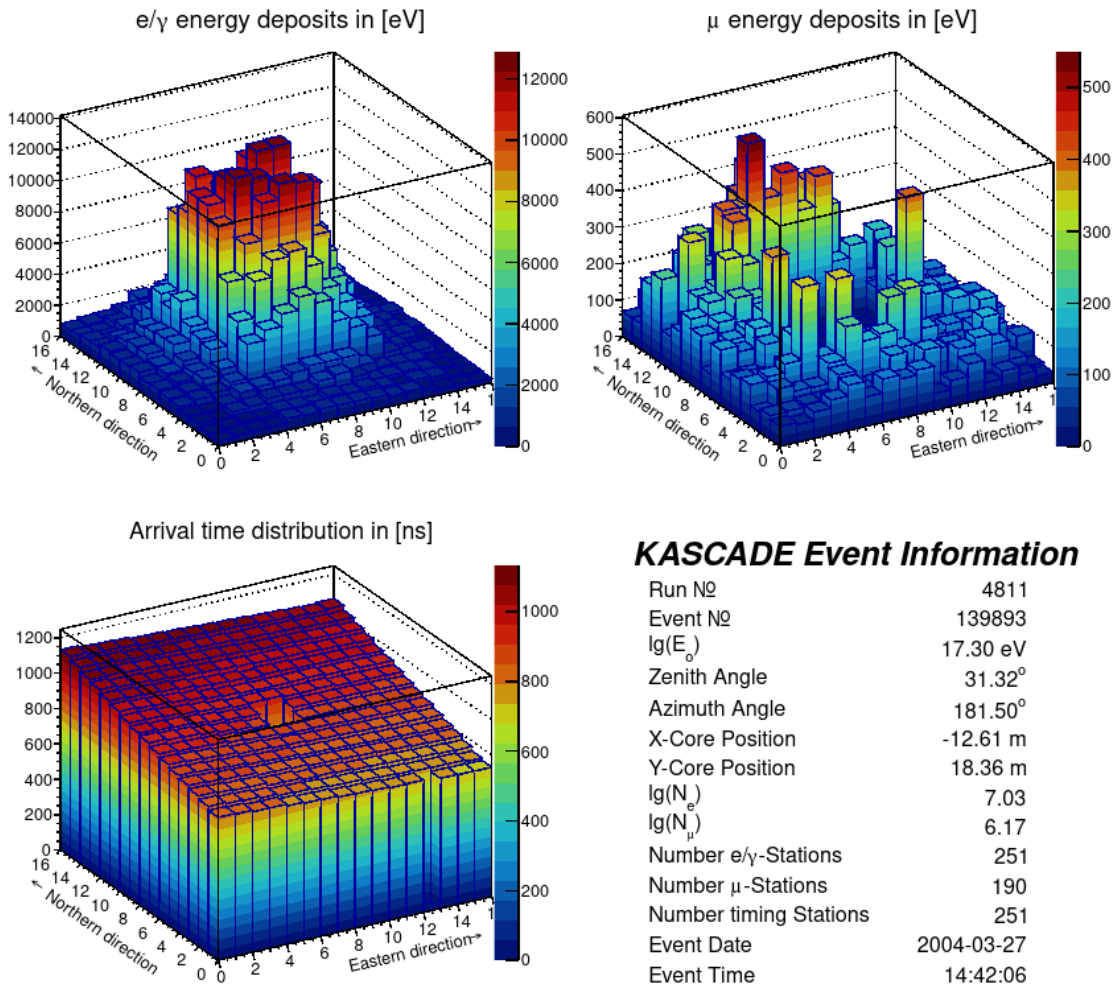

fig. 2.4.1. *Event Display for a high-energy KASCADE Event*

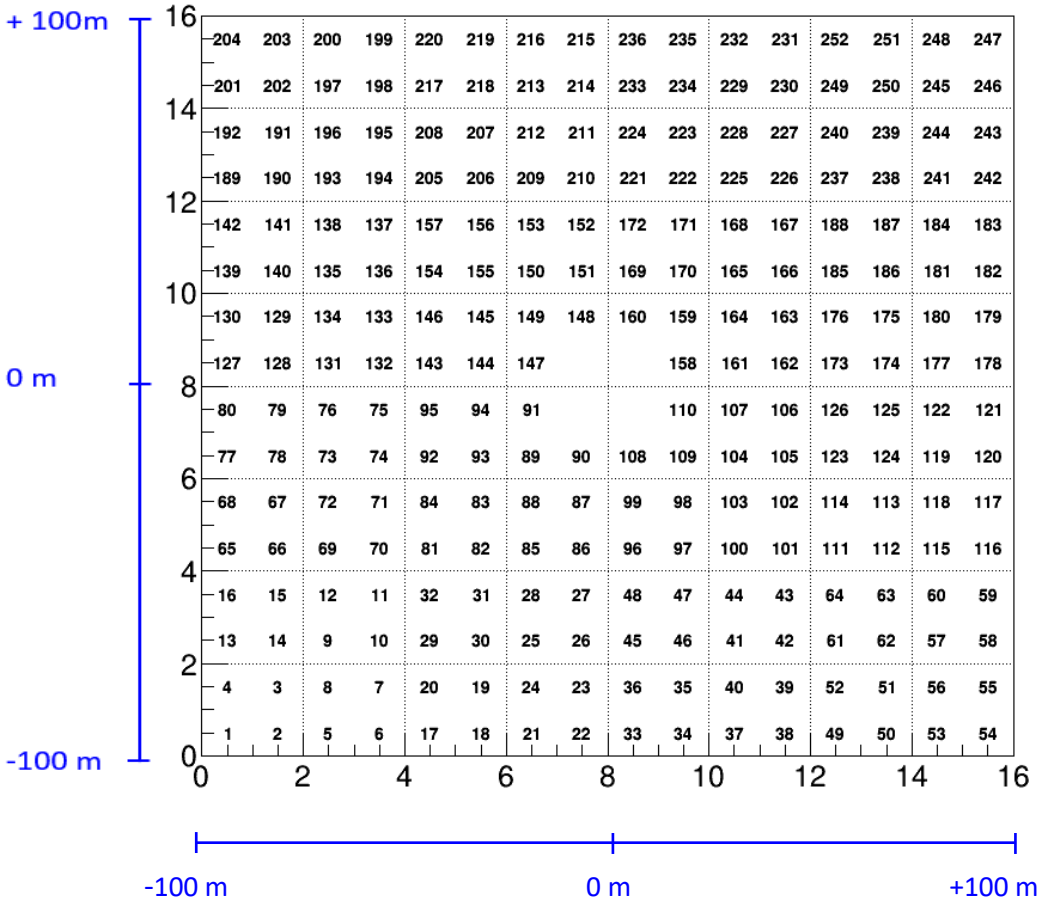

fig. 2.4.2. *KASCADE station numbers naming convention and the 'relative grid numbers' on the x- and y-axis. The four central stations are blocked by the Central Hadron Calorimeter. The blue scales indicate the real distance scale in [m].*

2.4.2 GRANDE EVENT

In case of a GRANDE event, three plots are displayed (fig. 2.4.3), showing the charged energy deposits in the 37 stations of the GRANDE-Array (top) in 'lego' and in 'colour' plots. The arrival time distribution in 37 detector stations (bottom left) is a relative time given in *ns* and represents the first time stamp of each detector station that has been hit by a charged particle.

Shown in the colour plot (top right) are the station numbers of the GRANDE detector stations and the location of the KASCADE detector array (see also fig. 2.4.4).

A list of the event properties like run- and event numbers and event time, shower parameters reconstructed by GRANDE like core position and arrival direction as well as the respective number of stations contributing to this event is shown in the bottom right corner.

The GRANDE detector array consists of hexagons that are not arranged quite as regularly as is the case with KASCADE, since the local conditions in the KIT-CN do not allow this.

Thus, the locations of the station are only plotted relative to each other.

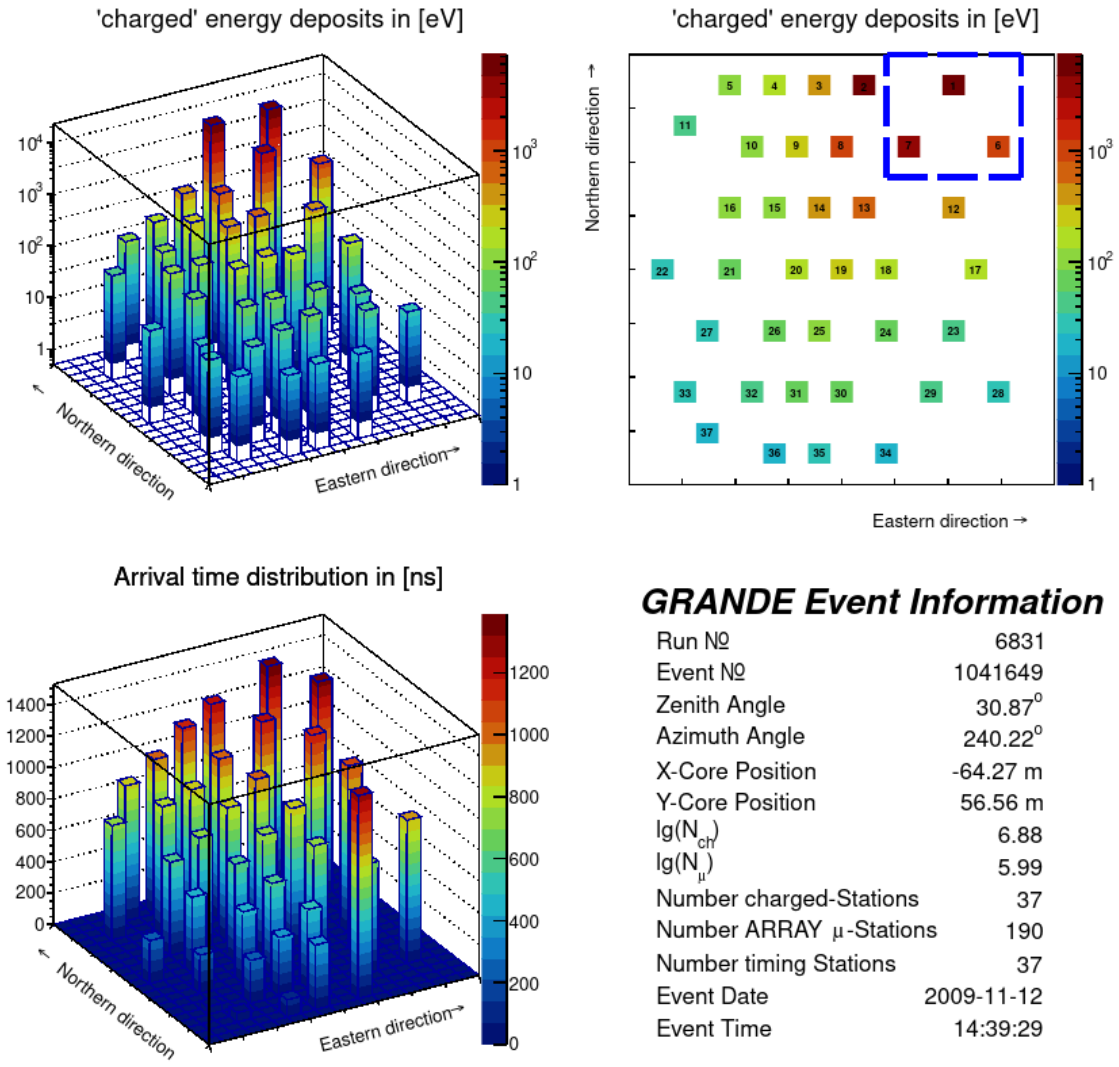

fig. 2.4.3. *Event Display for a high-energy GRANDE Event*

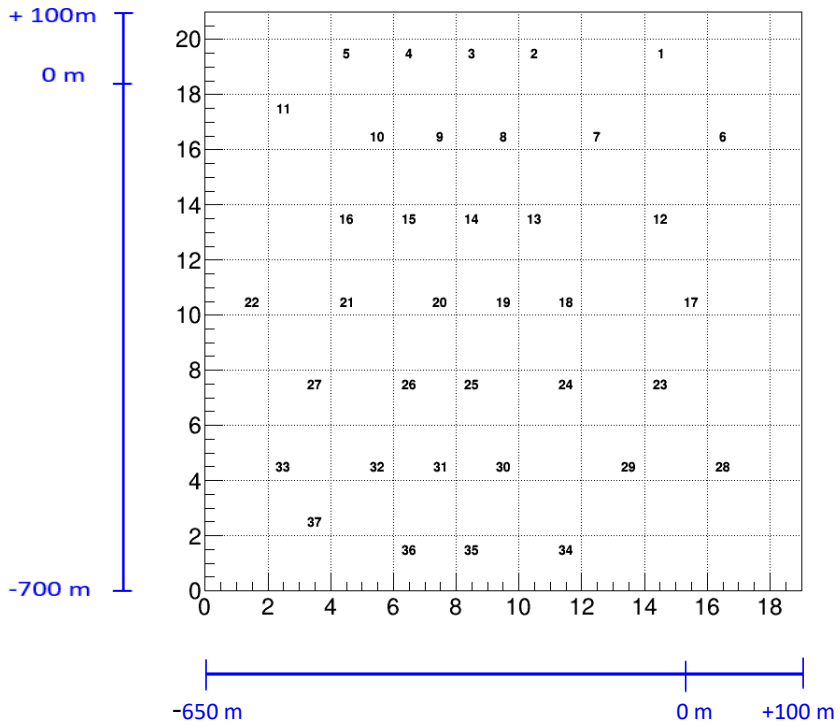

fig. 2.4.4. *GRANDE station numbers naming convention. The blue scales indicates the real distance scale in [m].*

3 GENERATING YOUR OWN EVENT DISPLAYS

Through the menu item *'Materials*', we provide four C++ programs for download to help you generate your own Event Displays. By means of these programs, you can easily visualize Events measured by the KASCADE and GRANDE detectors and downloaded via the KCDC web portal.

Furthermore, simulations that are available for download in the KCDC web portal can be displayed.

Running these programs requires a CERN ROOT installation.

3.1 AVAILABLE PROGRAMS

For measured data and simulations different programs are necessary**,** since the data sets from KCDC have different ROOT branches and in some cases different variable declarations. Thus, four programs are provided for the different applications.

All programs have a similar structure, they only differ in their input parameters.

EventDisplay_KASCADE-raw.C	to display measured KASCADE-Array events downloaded via the KCDC DataShop 'KASCADE'
EventDisplay_GRANDE-raw.C	to display measured GRANDE-Array events downloaded via the KCDC DataShop 'KASCADE'
EventDisplay_KASCADE-sim.C	to display data simulated for KASCADE-Array downloaded via the KCDC menu item 'Simulations'
EventDisplay_GRANDE-sim.C	to display data simulated for GRANDE-Array downloaded via the KCDC menu item 'Simulations'

Included in each download zip are four files (for example: 'KASCADE-raw.zip'):

- EventDisplay_KASCADE-raw.C C++-program code
- example_KASCADE-raw.root example ROOT data file
- ED_KA_R5008E0050830-org.svg example svg picture
- ED_KA_R5008E0050830-org.info example Info File
- ED_KA_R5008E0050830-org.info example Info File

3.1.1 What is shown in the KASCADE event Display

In the KASCADE Event Displays, three plots are shown (see p.e. fig. 3.1.3). The energy deposits in the 252 e/γ-detector stations of the KASCADE-Array (top left) and in the 192 μ-detectors in *eV* (top right). The arrival time distribution in 252 detector stations (bottom left) is given in *ns* and represents the first time stamp of each detector station that has been hit by a charged particle.

A list of the event properties like run- and event numbers, reconstructed shower parameters like core position and arrival direction as well as the respective number of stations contributing to this event is shown in the bottom right corner. The contents of this box differs between measured an simulated data in the sense that for simulations additional information like true primary energy and particle ID is given, while information on event date and time are without meaning and skipped.

Since the KASCADE detector array consists of 252 stations in a regular grid with a grid spacing of approx. 13m, the plots are given in '*relative grid numbers'* ranging from 1-16 in x- and y axis (see fig. 3.1.1). In the centre of the array, four stations are missing, blocked by the Central Calorimeter.

The real distance scale is shown in blue in fig 3.1.1.

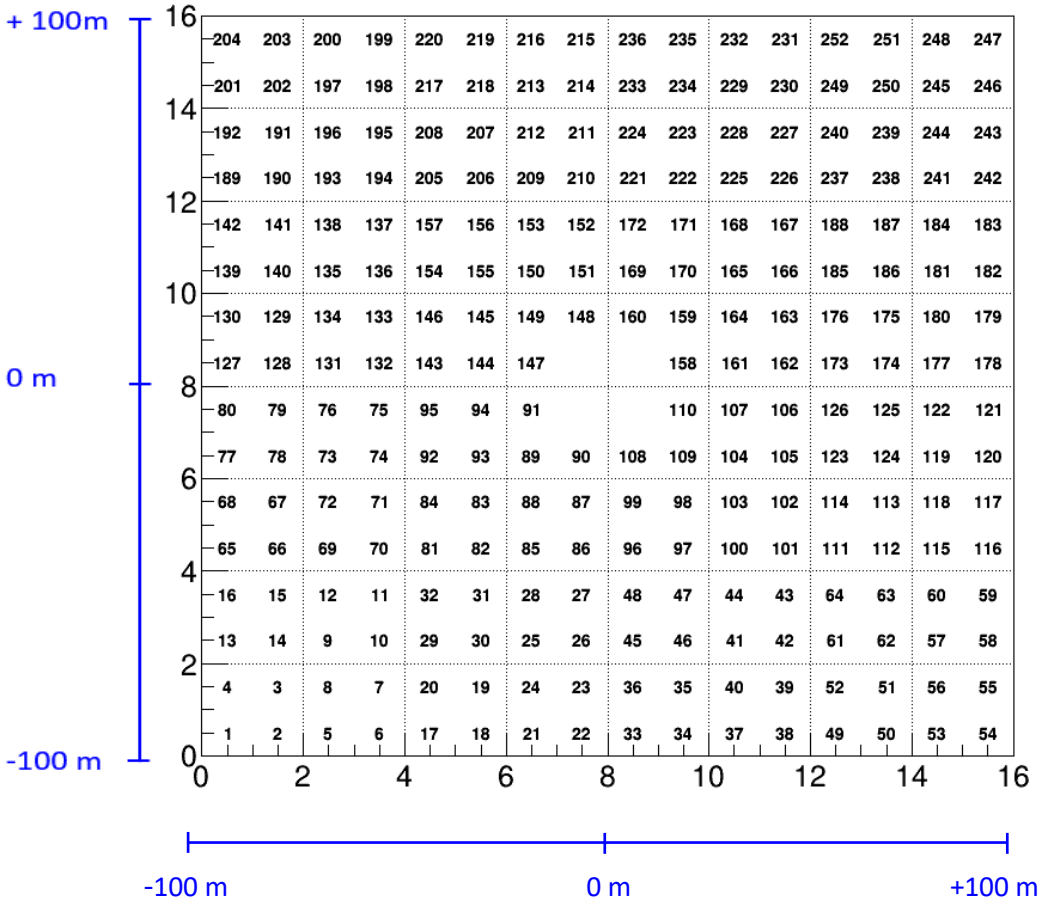

fig. 3.1.1. *KASCADE station numbers naming convention and the 'relative grid numbers' on the x- and y-axis. The four central stations are blocked by the Central Hadron Calorimeter. The blue scales indicate the real distance scale in [m].*

3.1.2 WHAT IS SHOWN IN THE GRANDE EVENT DISPLAY

In case of a GRANDE event, three plots are displayed (p.e. fig. 3.1.4), showing the charged energy deposits in the 37 stations of the GRANDE-Array (top) in 'lego' and in 'colour' plots. The arrival time distribution in 37 detector stations (bottom left) is a relative time given in *ns* and represents the first time stamp of each detector station that has been hit by a charged particle.

Shown in the colour plot (top right) are the station numbers of the GRANDE detector stations and the location of the KASCADE detector array (red in fig. 3.1.2.).

A list of the event properties like run- and event numbers, reconstructed shower parameters like core position and arrival direction as well as the respective number of stations contributing to this event is shown in the bottom right corner. The contents of this box differs between measured an simulated data in the sense that for simulations additional information like true primary energy and particle ID is given, while information on event date and time are without meaning and skipped.

The GRANDE detector array consists of hexagons that are not arranged quite as regularly as is the case with KASCADE, since the local conditions in the KIT-CN do not allow this.

Thus, the locations of the station are only plotted relative to each other (see fig. 3.1.2.).

The real distance scale is shown in blue in fig 3.1.2.

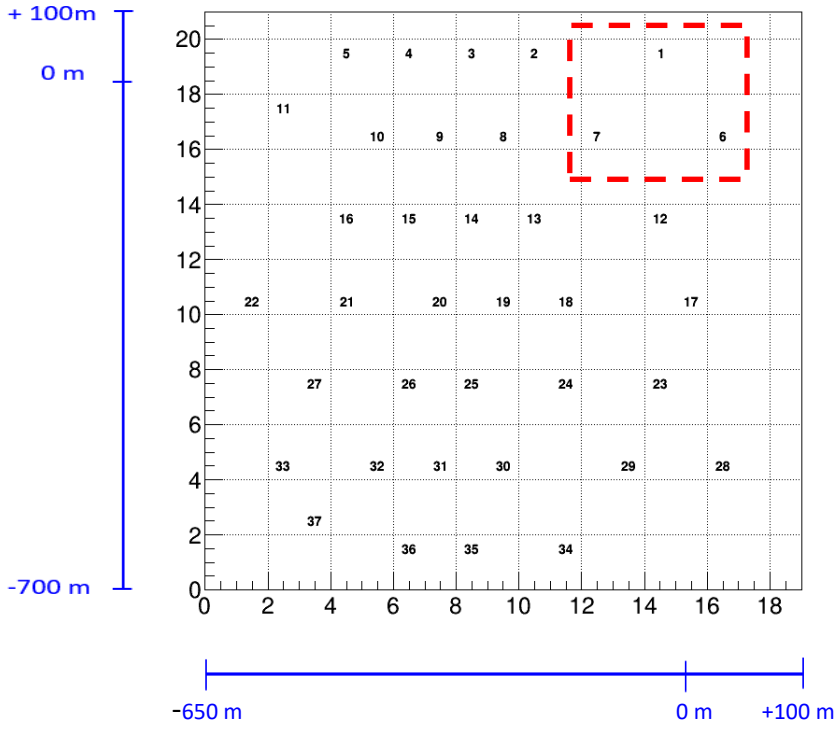

fig. 3.1.2. *GRANDE station numbers naming convention. The blue scales indicates the real distance scale in [m].*

3.1.3 DISPLAY MEASURED KASCADE EVENTS

To display events measured with the KASCADE detector array we recommend using the program '*EventDisplay_KASCADE-raw.C*'. There the frame necessary to correctly read the e/γ- and μ-energy deposits as well as the arrival times in the 252 detector stations is provided.
An example for a measured high-energy KASCADE event is given in fig 3.1.3.

A 'svg' file is produced with the plot displayed and an 'info' file keeping the information from the box and some more quantities for the present event. Naming convention for the files is p.e. '*ED_KA_R7281E0802630.svg'* or '*ED_KA_R7281E0802630.info'* for the text file.
svg-file ‚*ED_KA_R7281E0802630.svg*' :

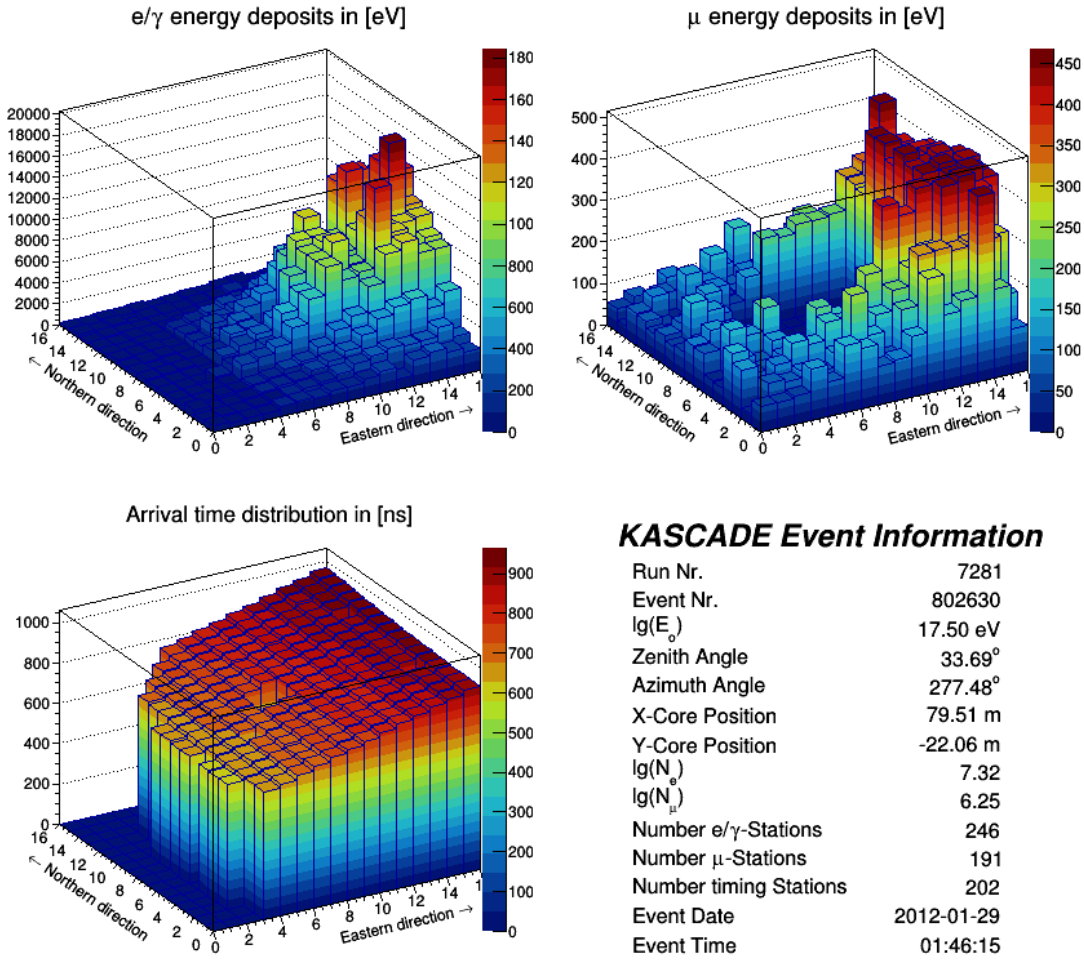

fig. 3.1.3. *KASCADE very high-energy measured event*

Info-file ‚*ED_KA_R7281E0802630.info*‘ :

Event Display KASCADE - Event information

Run Number	7281
Event Number	802630
Prim Energy (lg10)	17.50 eV
Zenith Angle	33.69°
Azimuth Angle	277.48°
X-Core Position	79.51 m
Y-Core Position	-22.06 m
lg(Ne)	7.32
lg(Nmu)	6.25
Number e/γ-Stations	246
Number μ-Stations	191
Number timing stations	202
Shower Age	0.86
Event Time	2012-01-29 01:46:15
Global Event Time	1327801575 (secs since 1.1.1970)
Air Pressure	1012.50 hPa
Air Temperature	1.66°

3.1.4 DISPLAY MEASURED GRANDE EVENTS

To display events measured with the GRANDE detector array we recommend using the program '*EventDisplay_GRANDE-raw.C*'. There the frame necessary to correctly read the charged energy deposits and the arrival times in the 37 detector stations is provided. Moreover, some KASCADE-Array data are read to complete the information in the info box.

An example for a measured high-energy GRANDE event is given in fig 3.1.4.

A 'svg' file is produced with the plot displayed and an 'info' file keeping the information from the box and some more quantities for the present event. Naming convention for the files is p.e. '*ED_GR_R6623E0078975.svg'* or '*ED_KA_R6623E0078975.info'* for the text file.

Example svg-file ‚*ED_GR_R6623E0078975.svg*' :

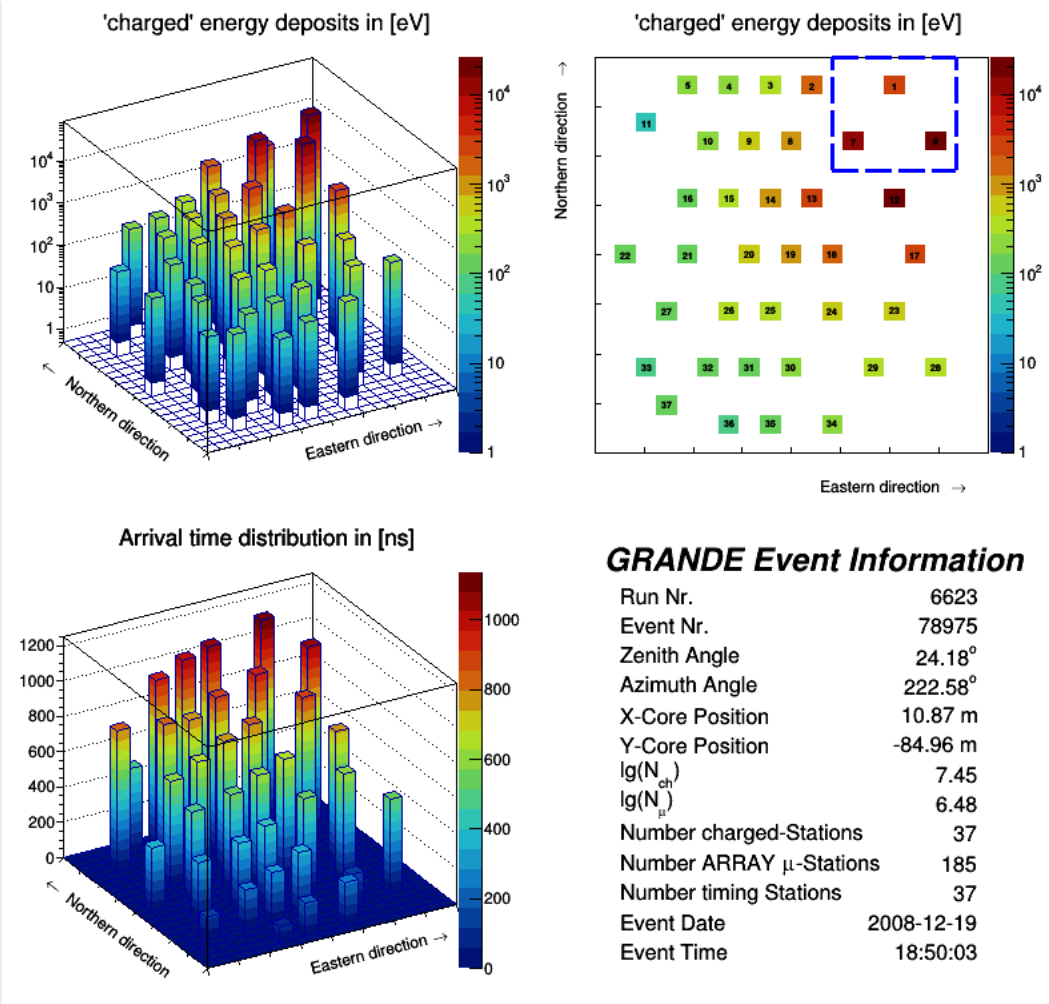

fig. 3.1.4. *GRANDE very high-energy measured event*

Info-file ‚*ED_KA_R6623E0078975.info*‘ :

Event Display GRANDE - Event information

Run Number	6623
Event Number	78975
Prim Energy (lg10)	-1.00 eV
Zenith Angle	24.18°
Azimuth Angle	222.58°
X-Core Position	10.87 m
Y-Core Position	-84.96 m
lg(Nch)	7.45
lg(Nmu)	6.48
Number charged-Stations	37
Number ARRAY µ-Stations	185
Number timing stations	37
Shower Age	0.99
Event Time	2008-12-19 18:50:03
Global Event Time	1229712603 (secs since 1.1.1970)
Air Pressure	1014.20 hPa
Air Temperature	1.45°

3.1.5 DISPLAY SIMULATED KASCADE EVENTS

To display events simulated for the KASCADE detector array we recommend using the program '*EventDisplay_KASCADE-sim.C'*. There the frame necessary to correctly read the e/γ- and μ-energy deposits as well as the arrival times in the 252 detector stations is provided. In addition to the reconstructed quantities, the true particle ID (in CORSIKA naming conventions-see chapter 3.1.7.) and the true energy of the primary particle are given in the info box.

An example for a simulated high N_e KASCADE event is given in fig 3.1.5.

A 'svg' file is produced with the plot displayed and an 'info' file keeping the information from the box and some more quantities for the present event. Naming convention for the files is p.e. '*ED_KAsim_R088041E000003.svg'* or '*ED_KAsim_ R088041E000003.info'* for the text file.

Example svg-file ‚*ED_KAsim_ R088041E000003.svg*' :

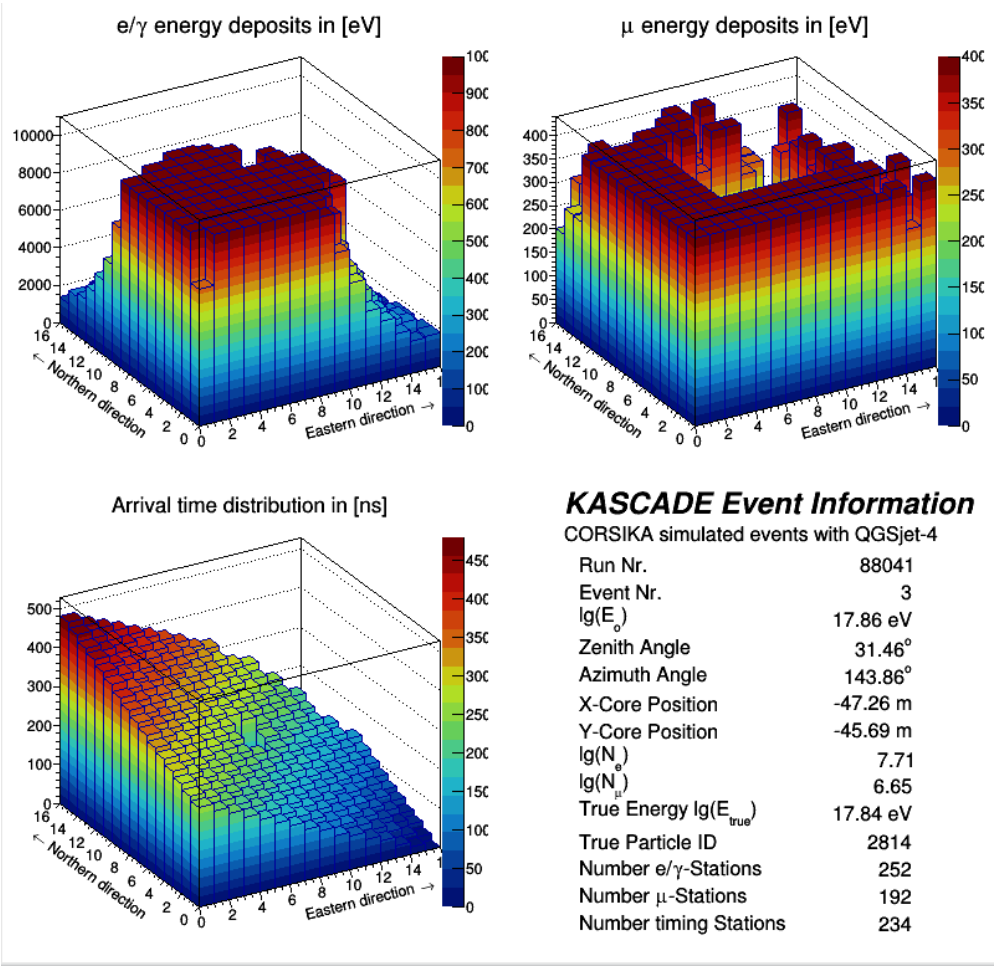

fig. 3.1.5. ***KASCADE very high N_e simulation event***

Example info-file*: 'ED_KAsim_R088041E000003.info'*

Event Display KASCADE - Simulated Event information

CORSIKA simulated event with QGSjet-4

Run Number	88041
Event Number	3
Prim Energy (lg10)	17.86 eV
Zenith Angle	31.46°
Azimuth Angle	143.86°
X-Core Position	-47.26 m
Y-Core Position	-45.69 m
lg(Ne)	7.71
lg(Nmu)	6.65
Number e/γ-Stations	252
Number μ-Stations	192
Number timing stations	234
Shower Age	0.89
True Primary Energy /lg10)	17.84 eV
Primary Particle ID	2814

3.1.6 DISPLAY SIMULATED GRANDE EVENTS

To display events simulated for the GRANDE detector array we recommend using the program '*EventDisplay_GRANDE-sim.C*'. There the frame necessary to correctly read the charged energy deposits as well as the arrival times in the 37 detector stations is provided. For GRANDE no energy reconstruction is available. In addition to the reconstructed quantities, the true particle ID (in CORSIKA naming conventions-see chapter 3.1.7.) and the true energy of the primary particle are given in the info box.

An example for a high-N_{ch} GRANDE event is given in fig 3.1.6.

A 'svg' file is produced with the plot displayed and an 'info' file keeping the information from the box and some more quantities for the present event. Naming convention for the files is p.e. '*ED_GRsim_R087918E000004.svg'* or '*ED_GRsim_ R087918E000004.info'* for the text file.

Example svg-file ,*ED_GRsim_ R087918E000004.svg*' :

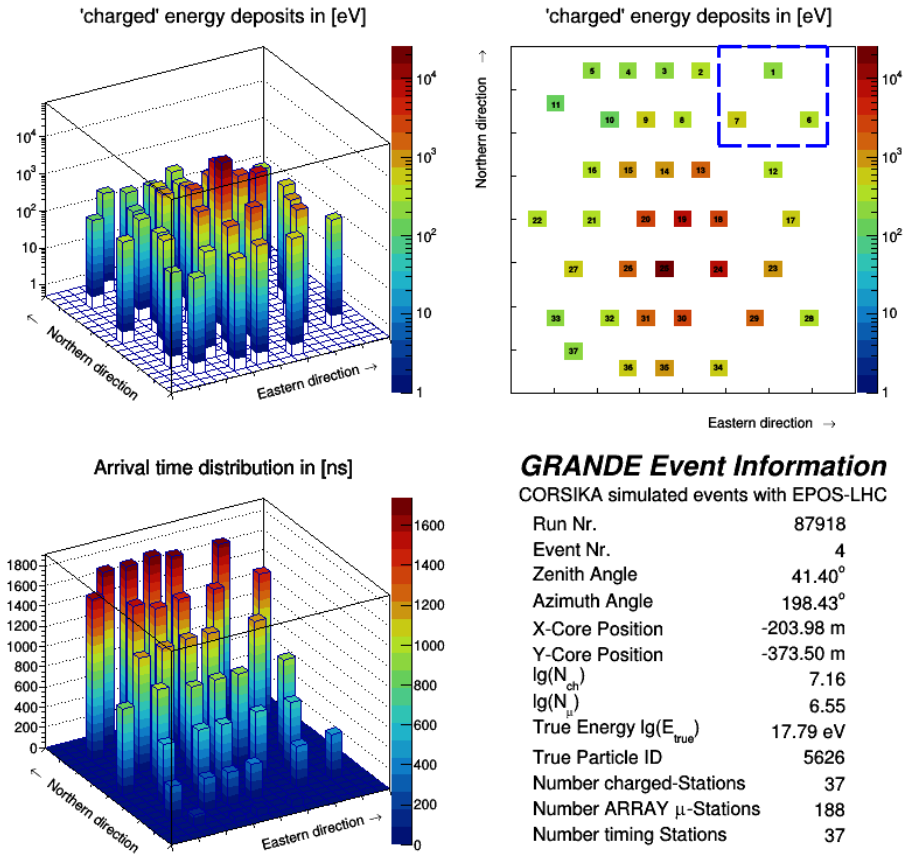

fig. 3.1.6. ***GRANDE high N_{ch} simulation event***

Example info-file*: 'ED_GRsim_ R087918E000004.info'*

Event Display GRANDE - Simulated Event information

CORSIKA simulated events with QGSjet-4

Run Number	87918
Event Number	4
Zenith Angle	41.40°
Azimuth Angle	198.43°
X-Core Position	-203.98 m
Y-Core Position	-373.50 m
lg(Nch)	7.16
lg(Nmu)	6.55
Number charged-Stations	37
Number ARRAY µ-Stations	188
Number timing stations	37
Shower Age	0.91
True Primary Energy /lg10)	17.79 eV
Primary Particle ID	5626

3.1.7 PARTICLE IDS

True CORSIKA particle IDs for the six primaries used in KASCADE and GRANDE simulations.

Particle ID	Particle
14	Proton – representing the lightest mass
402	Helium – representing a light mass group
1206	Carbon – representing the CNO-group
2814	Silicon – representing a medium heavy mass group
5626	Iron – representing a heavy mass group
1	Gamma – representing the photons

3.2 HANDLING THE PROGRAMS

The programs provided are intended to represent examples in which the correct framework for reading out and displaying an event is specified. You have to adapt the programs to your own requirements. However, with the example ROOT file included in the download zip, you can directly run the program to test the output.

3.2.1 REQUIREMENTS

- a local CERN ROOT installation;
- the ROOT files to be analysed were either downloaded from the KCDC DataShops '*KASCADE*', from the provided '*Preselections*' or from the '*Simulation*' pages;
- to download data sets from the KCDC DataShop and Preselections you need to register.

3.2.2 USER APPLICATIONS

There are several ways to use the programs:

- provide a KCDC ROOT file with several events and display them one by one;
  - provide a root file from the KCDC DataShop '*KASCADE*' or '*Preselections*' or from '*Simulations*' respectively,
  - set number of events to be displayed '*ievents*' (0: all),
- display one event given by run- and event numbers;
  - provide a root file with the requested event included
  - set the '*single_switch*' to '*true*'
  - provide event number '*iev*' and run number '*irun*'
  - set number of events to be displayed '*ievents*' (0: all),

- apply cuts on parameters defined in the various ROOT branches,
  - provide a ROOTfile from the KCDC DataShop '*KASCADE*' or '*Preselections*' or from '*Simulations'* respectively,
  - set the '*cut_switch'* to '*true*'
  - define one or more cuts within the code

Most information are also included in the in-line documentation of the programs.

3.3 RUN THE PROGRAM

Run the program within CERN ROOT

```
root
.L EventDisplay_KASCADE-raw.C
run()
```

3.4 GETTING MEASURED EVENT DATA

This EventDisplay works only on data sets downloaded either from the KCDC DataShop 'KASCADE' or from the 'Preselections' and 'Simulations' pages. To have access you need to be a registered user in KCDC.

In order to display data in the EventDisplay downloaded from the KCDC web portal, you have to choose the following settings:

- select data arrays like 'E-Deposits' and 'Arrival Times' from the component 'General Info' (see fig 3.4.1);
- in case KASCADE-Array EventDisplay is chosen, select all quantities from the component 'KASCADE' (see fig 3.4.2.);
- in case GRANDE-Array EventDisplay is chosen, select all quantities from the component 'KASCADE' (see fig 3.4.2.) and from 'GRANDE' (see fig 3.4.3.);
- set output format to 'ROOT' (only ROOT format is supported by the EventDisplay programs.

Your submit request should look like displayed in fig 3.4.4.

Keep in mind that the data arrays like *'Energy Deposits*' or '*Arrival Times*' increase the amount of download data by a factor of 10. So please apply cuts not to exceed the download limit, which is presently set to 30 GB per request.

For further details, please refer to the '*KCDC User Manual*'.

An example of ROOT trees for measured data is given in fig 3.4.5. For simulations, another branch 'trmc' is defined holding information on true particle properties.

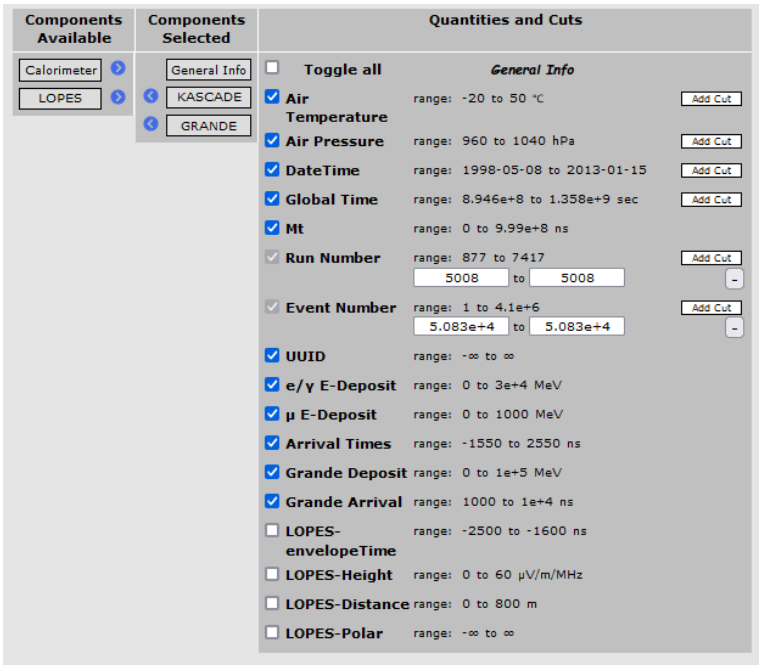

fig. 3.4.1. *Quantities selected from component 'General Info'*

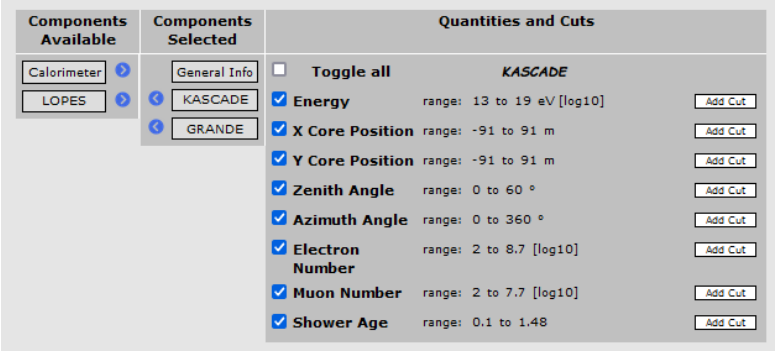

fig. 3.4.2. *Quantities selected from component 'KASCADE'*

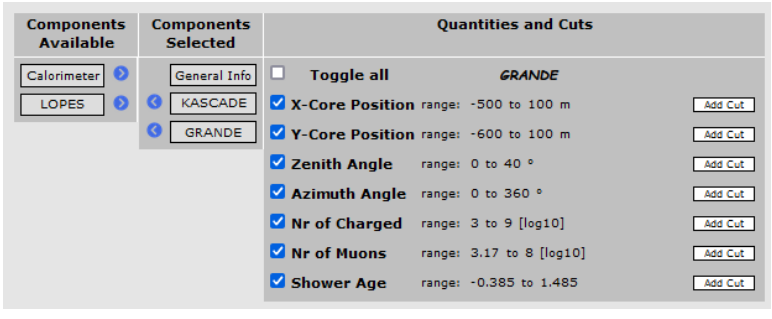

fig. 3.4.3. *Quantities selected from component 'GRANDE'*

Check your selections and submit request

General Info

Air Temperature	range:	**-20**	to	**50**	°C	full range
Air Pressure	range:	**960**	to	**1040**	hPa	full range
DateTime	range:	**1998-05-08**	to	**2013-01-15**		full range
Global Time	range:	**8.946e+8**	to	**1.358e+9**	sec	full range
Mt	range:	**0**	to	**9.99e+8**	ns	full range
Run Number	range:	**6623**	to	**6623**		user cut
Event Number	range:	**7.8975e+4**	to	**7.8975e+4**		user cut
UUID	range:	**-∞**	to	**∞**		full range
e/γ E-Deposit	range:	**0**	to	**3e+4**	MeV	full range
μ E-Deposit	range:	**0**	to	**1000**	MeV	full range
Arrival Times	range:	**-1550**	to	**2550**	ns	full range
Grande Deposit	range:	**0**	to	**1e+5**	MeV	full range
Grande Arrival	range:	**1000**	to	**1e+4**	ns	full range

KASCADE

Energy	range:	**13**	to	**19**	eV [log10]	full range
X Core Position	range:	**-91**	to	**91**	m	full range
Y Core Position	range:	**-91**	to	**91**	m	full range
Zenith Angle	range:	**0**	to	**60**	°	full range
Azimuth Angle	range:	**0**	to	**360**	°	full range
Electron Number	range:	**2**	to	**8.7**	[log10]	full range
Muon Number	range:	**2**	to	**7.7**	[log10]	full range
Shower Age	range:	**0.1**	to	**1.48**		full range

GRANDE

X-Core Position	range:	**-500**	to	**100**	m	full range
Y-Core Position	range:	**-600**	to	**100**	m	full range
Zenith Angle	range:	**0**	to	**40**	°	full range
Azimuth Angle	range:	**0**	to	**360**	°	full range
Nr of Charged	range:	**3**	to	**9**	[log10]	full range
Nr of Muons	range:	**3.17**	to	**8**	[log10]	full range
Shower Age	range:	**-0.385**	to	**1.485**		full range

Output Format: (•) **:ROOT** ( ) **:HDF5**

fig. 3.4.4. *Your submit request*

fig. 3.4.5. *ROOT tree example for measured data*

3.5 GETTING SIMULATED DATA

To have access to the simulated data sets you need to be a registered user in KCDC.

All simulated data sets contain the whole information necessary to be displayed via the Event Display C-programs provided. You cannot apply cuts to the data within the KCDC web portal.

Download the simulations via the 'Simulations' menu item, by choosing one of the high-energy interaction models and the primary particle.