

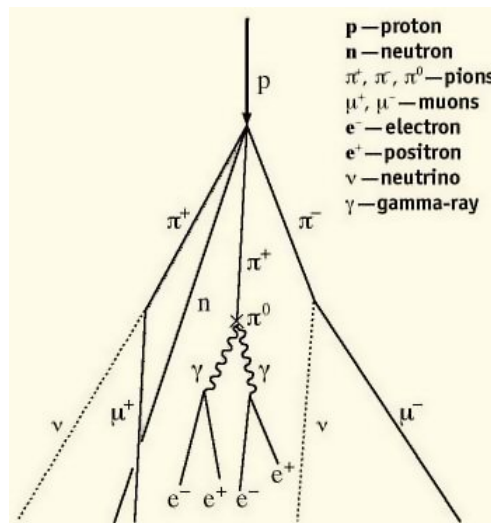
# 1 Worksheet 6: Shower Study

The sections uses the detectors in an unstacked configuration to detect cosmic ray showers. Once again, it requires about 10 hours of data to see many showers, but more accurate results can be obtained with more data. For each shower detected, the cosmic e-lab can provide information about the number of particles in the shower and the direction of the shower. Once again this is a great opportunity for pupils to write their own research proposal and investigate their own research question.

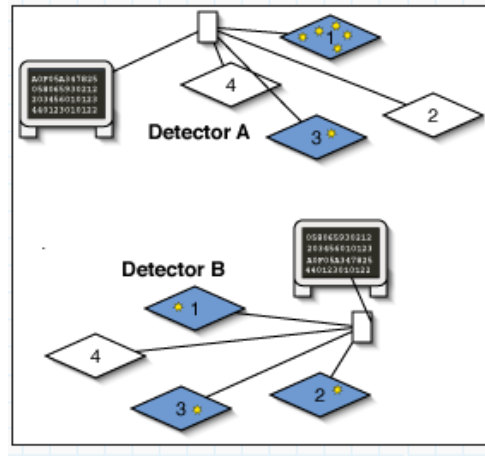
## 1.1 Aim

The aim of this worksheet is to investigate large cosmic ray showers and to find out where they come from and how they are produced.

## 1.2 What are air showers?



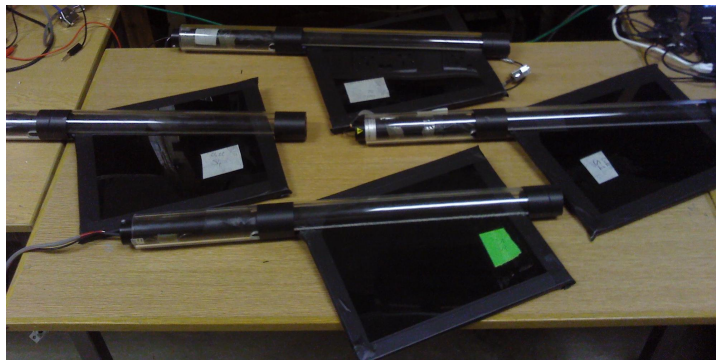
We have already discovered that cosmic ray muons are produced when primary cosmic rays interact in the atmosphere. However, there is often more than one particle produced in an interaction. Each of the particles which are produced will then interact with other molecules in the atmosphere to produce even more particles. With each interaction, the particles end up with a lower energy, until eventually there is not enough energy left to create more particles. The particles then decay, and you have a handful of muons produced by a single primary cosmic ray. This is called an Air Shower.



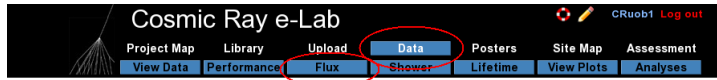
The muons will spread out as they travel towards Earth, but since they are all produced at the same time, they will reach sea level within about 100ns of each other. We can therefore spread our counters out flat, and see if we can detect a handful of muons arriving at the same time. We can then use the Cosmic e-lab website to analyse the data, and it will tell us how many muons were in the shower and what direction the shower came from.

The size of the air shower and the number of particles in the shower are determined by the energy of the primary cosmic ray. The higher the energy of the primary cosmic ray, the more particles there are and the further the shower spreads. There are sources of cosmic rays which produce particles with such high energy that the showers created are the size of a small town. The origin of these ultra high energy cosmic rays are still not fully known to physicists, but you can investigate them. If you know of some schools near you using the cosmic ray muon detector (CRMD) then you can organise yourself to take data at the same time. If you see a coincidence between signals in the detectors from different schools, then it is likely that you are detecting particles which are a part of the same large air shower, produced by an ultra high energy cosmic ray.

### 1.3 Performing a Shower Study



We will first analyse data which has already been recorded by the University of Birmingham to show you how a shower study is done. The counters were unstacked, as in the picture above, and covered an area of about  $0.5\text{m}^2$ . The data was recorded for about 24hours.



**Shower: Choose data for shower study.**

The universe is a big place. Cosmic ray primaries drift around and get energy boosts from multiple sources. Some primaries attain enormous energies. When they strike the upper atmosphere, these create Extended Area Showers. These events create thousands of particles that simultaneously reach a small section of Earth's surface. More energetic primaries affect larger sections of the surface. Can you find out how often nearby detectors simultaneously "light up" with cosmic rays? If they do, is it a randomness or a measurement of one of these showers?

Gain confidence by watching a [shower analysis](#) done.

Quick Searches: Univ of Birmingham Birmingham GBR All

School: Univ of Birmingham Search Data

Advanced Search

Please enter dates in MMdd/yyyy format (e.g. 08/25/2011). You may leave one or both date fields blank.

Start Date: 08/13/2011 to 08/13/2011

Stacked: All Blessed: All

**Search for School "Univ of Birmingham" on 13th August 2011**

Help: [Tutorial on shower study](#), [Step-by-step instructions](#), [FAQs](#)

States include provinces and countries

Related Milestones: [Analyze Data](#), [Correct Data](#), [Assemble Evidence](#)

Legend



**Choose data for shower study.**

The universe is a big place. Cosmic ray primaries drift around and get energy boosts from multiple sources. Some primaries attain enormous energies. When they strike the upper atmosphere, they create Extended Area Showers. These events create thousands of particles that simultaneously reach a small section of Earth's surface. Can you find out how often nearby detectors "light up" with cosmic rays? If they do, is it a random coincidence or a measurement of violent conditions in another galaxy?

Gain confidence by running a practice search.

Quick Searches: Univ of Birmingham Birmingham GBR All

City: Search Data

Advanced Search

Results 1 - 1 of 1 for school Univ of Birmingham (Searched 1 files in 0.023 seconds)

[Clear selected data](#)

Univ of Birmingham Birmingham, GBR

1 data files: 0 blessed, 0 stacked, 5,338,249 total events.

August 2011, 1 file

Detector: 6411, 1 file

**6411 5,338,249 events**

**Select data from 13/08/2011 and click "Run shower study"**

Analyze: [Run shower study](#)

Help: [Tutorial on shower study](#), [Step-by-step instructions](#), [FAQs](#)

States include provinces and countries

Related Milestones: [Analyze Data](#), [Correct Data](#), [Assemble Evidence](#)

Log into the cosmic e-lab website and select "Shower" from the "Data" tab. Change the dropdown menu to school and search for "Univ of Birmingham". Select data from 13/08/2011 from detector 6411 and click on "Run shower Study", as shown in the figures above.

Click **Analyze** to use the default parameters. Control the analysis by expanding the options below.

**Click on ? for information**

**Analysis Controls**

? Center of graph view: Univ of Birmingham, Birmingham, GBR (6411) ⌵

? Event Gate (ns): 100

? Detector Coincidence: 1

? Channel Coincidence: 4

? Event Coincidence: 4

**Set the Event Gate and coincidence levels**

**Plot Controls**

? X-min:

? X-max:

? Y-min:

? Y-max:

? Z-min:

? Z-max:

Plot Size: Medium ⌵

Plot Title: Shower Study

Figure caption: Data: Univ of Birmingham Aug 12, 2011 00:00:00 UTC  
Detector: 6411  
Event Coincidence: 4  
Detector Coincidence: 1

**Execution Mode ?**

Local (estimated time: 00:10:55)

I2U2 Cluster (estimated time: 00:21:47)

Grid (temporarily disabled)

Automatic (estimated time: 00:17:02)

**Analyze** — **Click on Analyze**

You can then change the coincidence levels. Click on the question mark by each setting for find out what it means. The detector coincidence is the number of different detector (i.e. different schools) you want the shower to have hit. Since we are just looking at one detector, set this to 1. The channel coincidence is the number of counters which need to be hit. Since we want all 4 counters to be hit to define an air shower, set this to 4. The event coincidence is the number of signals which are detected among the 4 counters within the gate width. Set this to 4 also. The value of the gate width should not affect how many particles you see in a shower, since they should all arrive within 100ns. Having a gate width which is too high can mean that you detect particles which are not part of the shower. Set the gate width to 100ns. You should not need to change the plot controls except to change the title of the plot. Once you have set the coincidences, click on “Analyze”.

**Cosmic Ray e-Lab**

CRuob1 [Log out](#)

[Project Map](#) [Library](#) [Upload](#) [Data](#) [Posters](#) [Site Map](#) [Assessment](#)  
[View Data](#) [Performance](#) [Flux](#) [Shower](#) [Lifetime](#) [View Plots](#) [Analyses](#)

**Shower study candidates (58)**

Event Date	Event Coincidence	Detector Coincidence
Aug 12, 2011 05:22:27 UTC	8	1 (6411)
Aug 12, 2011 00:38:44 UTC	7	1 (6411)
Aug 11, 2011 13:55:13 UTC	7	1 (6411)
Aug 11, 2011 17:58:58 UTC	6	1 (6411)
Aug 12, 2011 09:17:48 UTC	6	1 (6411)
Aug 11, 2011 16:09:37 UTC	6	1 (6411)
Aug 12, 2011 07:20:04 UTC	6	1 (6411)
Aug 12, 2011 05:18:26 UTC	6	1 (6411)
Aug 12, 2011 05:10:13 UTC	6	1 (6411)
Aug 11, 2011 15:28:58 UTC	6	1 (6411)
Aug 12, 2011 03:29:14 UTC	6	1 (6411)
Aug 11, 2011 16:32:38 UTC	5	1 (6411)
Aug 12, 2011 11:28:10 UTC	5	1 (6411)
Aug 12, 2011 10:08:02 UTC	5	1 (6411)
Aug 12, 2011 09:51:37 UTC	5	1 (6411)
Aug 12, 2011 09:39:48 UTC	5	1 (6411)
Aug 12, 2011 01:42:29 UTC	5	1 (6411)
Aug 12, 2011 01:14:14 UTC	5	1 (6411)
Aug 12, 2011 01:09:23 UTC	5	1 (6411)
Aug 12, 2011 01:08:44 UTC	5	1 (6411)
Aug 12, 2011 00:21:41 UTC	5	1 (6411)
Aug 12, 2011 00:07:22 UTC	5	1 (6411)
Aug 11, 2011 21:57:36 UTC	5	1 (6411)
Aug 11, 2011 21:28:57 UTC	5	1 (6411)
Aug 11, 2011 16:27:44 UTC	4	1 (6411)
Aug 11, 2011 16:17:09 UTC	4	1 (6411)

Click on an event to view the plot and information

Click on image for a larger view

View raw data or geometry for Aug 12, 2011 08:22:27 UTC for detector ID 6411

Plot datapoints:

East/West (meters)	North/South (meters)	Time (nanosec)	Detector Channel
-1.0	-7.6	0.0	6411 3
-0.9	-8.3	2.5	6411 1
-1.0	-8.8	3.7	6411 2
-1.1	-8.3	3.7	6411 4
-1.0	-8.8	23.8	6411 2
-0.9	-8.3	27.5	6411 1
-1.1	-8.3	38.8	6411 4
-1.0	-7.6	41.3	6411 3

Information about events in shower

View more events

Analysis run time: 00:11:44; estimated: 00:19:37

Show [shower analysis directory](#) or [event plot analysis](#). [Change parameters of study](#)

[Change your parameters](#)

You will then see a page with all of the events which match your select criteria. They should therefore all be air showers. At the top of the page you will see the number of shower candidates. The list below tells you the date of the shower and the event coincidence, i.e. the number of particles in the shower. By clicking on an event, it will produce a plot of that event on the right hand side of the page. Click on the plot to make it larger.

**Plot of position and arrival time of each event in shower**

Data: Univ of Birmingham Aug 11 2011 13:48:02 UTC  
 Univ of Birmingham Aug 12 2011 00:00:00 UTC  
 Detector: 6411

Event Coincidence: 4  
 Detector Coincidence: 1  
 Event Gate (ns): 100

Plot datapoints:

East/West (meters)	North/South (meters)	Time (nanosec)	Detector Channel
-1.0	-7.6	0.0	6411 3
-0.9	-8.3	2.5	6411 1
-1.0	-8.8	3.7	6411 2
-1.1	-8.3	3.7	6411 4
-1.0	-8.8	23.8	6411 2
-0.9	-8.3	27.5	6411 1
-1.1	-8.3	38.8	6411 4
-1.0	-7.6	41.3	6411 3

Data for each event including position, arrival time and channel. The position of first event tells you the direction of the shower

To save this plot permanently, enter the new name you want.

Then click **Save Plot**. Remember to **save your plot**

.png

You will now see a graph and a table of data for that particular study. The graph is a 3-dimensional plot of the shower. For each particle in the shower, the North/South and East/West measurement are plotted on the x- and y-axes and is determined by which channel the event was recorded in, and the geometry which you uploaded for the counter in that channel. The time of arrival is then plotted on the z-axis. This is relative to the time of the first signal, which has a time of 0.0ns. The position of the first signal tells you the direction of the cosmic ray shower. So for the plot above, the shower originated from the north. You can see a plot like this for each of the shower candidates by clicking on them from the page of events.

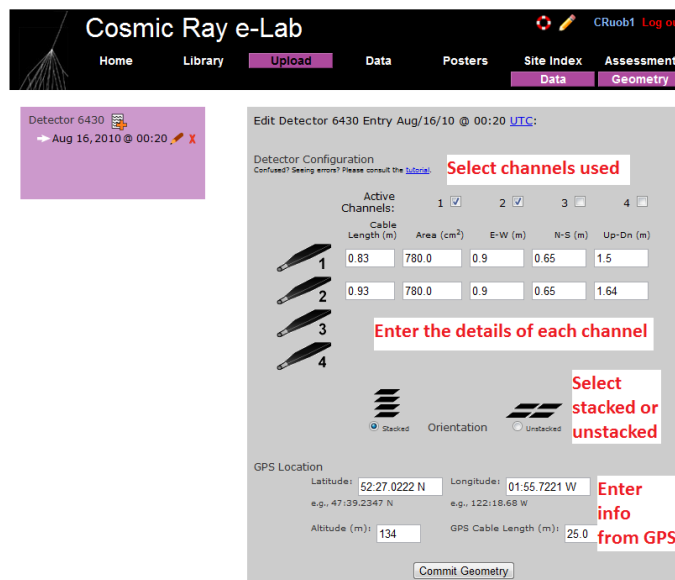
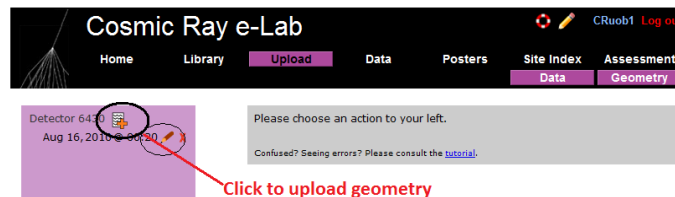
## 1.4 Your Own Investigation

Set up your counters in an unstacked configuration, as shown in section 1.3, and you can start your own shower study. You can be flexible with what it is you really want to investigate. Think about what might affect the air showers, or what properties of air showers you want to investigate, and come up with a research question. For example, what is the average number of particles in a shower? How is the shower affected if you move the counters further apart? Is there one particular direction that the showers tend to originate from? Is there a relationship between the number of particles in a shower and their direction? Try to come up with your own idea and then you are ready to start taking data. Open up Hyperterminal and follow the instructions below:

### 1.4.1 Upload Geometry

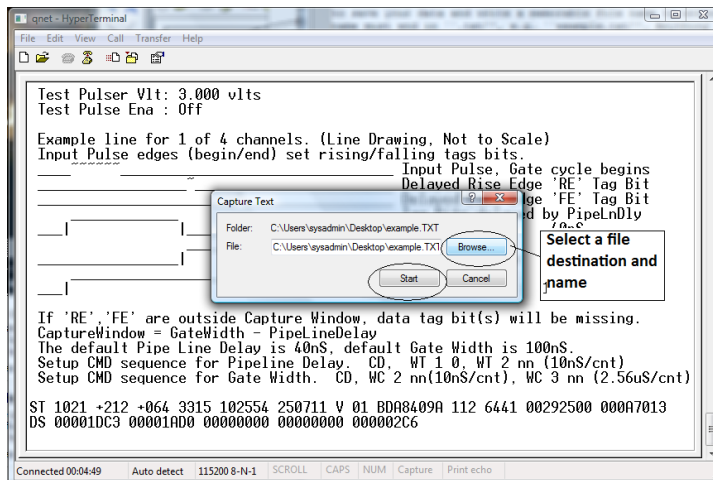
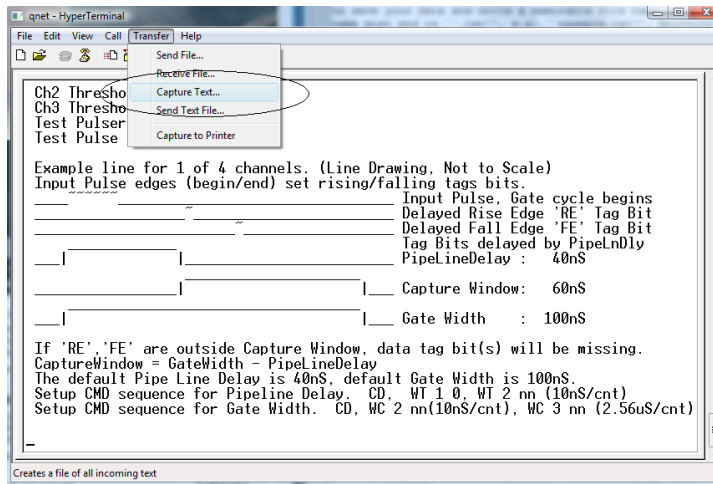
Before you start collecting data, be sure to upload your geometry with the new, unstacked configuration.

- To upload the geometry of the detector click on the upload tab on the e-lab website and then click on the geometry tab.
- Click on “add entry”. You should see the following pages.



- Fill in the details of the detector setup.
  - First, tick the boxes corresponding to the channels which you are using.
  - Next, enter the required details for each counter.
  - The cable length is the length of cable from the PMT to the DAQ board.
  - The area is the surface area of the counter in units of  $\text{cm}^2$ .
  - The E-W (East-West), N-S (North-South) and Up-Down measurements are the distances of the counters from the GPS antenna. In the stacked configuration, the Up-Down measurements for all counters should be the same.
  - Next you need to select the orientation of the detector. Select unstacked for a shower study.
  - Finally, you need to enter details of the GPS antenna. The longitude, latitude and altitude measurements can be found by typing the DG command into Hyperterm.
  - The GPS cable length is the length of cable connecting the GPS module to the DAQ board.

### 1.4.2 Collecting Data



```

qnet - HyperTerminal
File Edit View Call Transfer Help
DG
DG
Date-Time: 25/07/11 10:30:20.031
Status: V (invalid)
PosFix#: 0
Latitude: 52:27.016426 N
Longitude: 001:55.716881 W
Altitude: 161.872m
Sats used: 2
PPS delay: +0064 msec (CE=1 updates PPS,FPGA data)
FPGA time: 49C56CAB
FPGA freq: 25000000 Hz (Cmd V3, freq history)
ChkSumErr: 0
ST 2 5
ST Enabled, with scalar data.
CE
53FC3102 AC 00 2B 00 00 00 00 00 52F8049A 103027.007 250711 V 02 0 -0040
53FC3102 00 00 3D 38 00 00 00 00 52F8049A 103027.007 250711 V 02 0 -0040
53FC3103 00 22 00 21 00 00 00 00 52F8049A 103027.007 250711 V 02 0 -0040
54332914 BA 00 38 00 00 00 00 00 52F8049A 103027.007 250711 V 02 0 -0040
54332915 00 00 00 24 00 00 00 00 52F8049A 103027.007 250711 V 02 0 -0040
54332915 00 2B 00 00 00 00 00 00 52F8049A 103027.007 250711 V 02 0 -0040
Connected 00:08:35 Auto detect 115200 8-N-1 SCROLL CAPS NUM Capture Print echo

```

1. For a shower study we want to record all of the signals coming from the counters, not just the ones with coincidences. Type WC 00 0F to look at all signals from all counters. We will use the analysis page of the website to search the data for coincidences at a later time.
2. From the “Transfer” menu select “Capture Text”
3. Choose a file name ending with “.txt” and save your file somewhere memorable. Then select “Start”
4. Anything which now appears in the Hyperterminal window will also be written to the “.txt” file. Start by typing the commands V1, V2, DG, TL, ST 2 5. This ensures your data file contains the necessary information about the detectors.
5. Type the command CE to enable the counters and start writing data to the “.txt” file. Leave this running for about 24 hours to collect enough data. Make sure that the computer you are using is set to never sleep, otherwise you will not continue to collect data.
6. Once you have collected enough data type the command CD to stop writing out data.
7. From the “Transfer” menu select “Capture Text” and “Stop”.

Now that you have your data recorded on a file, you can upload it to the e-lab website for analysis.

- Click on the upload tab, and then click on data.
- Now select the file that you recorded the data and on click on “upload”.

Repeat the steps in section 1.3 and use the data you have collected to answer your research question and write up some conclusions.