# Validation of CAL Calibrations

Motivated by the plots shown by Philippe in the last beam test VRVS meeting on the distribution of CalZDir (see http://polywww.in2p3.fr/~bruel/cernps_20060801.pdf) I spent some time inspecting the reconstruction of the direction of muons (which is far simpler than electrons) in the calorimeter of the calibration unit. In this page you find a comparison of the FRED event displays, as well as the distributions of Trk1ZDir, CalZDir and CalTransRms, for muon events detected with the **Calibration Unit (Pisa, July 2006)** and with the **Full LAT detector (SLAC, April-May 2006).**

## Muon events from Cosmic Ray runs taken with the Full LAT (SLAC, April-May 2006)

The data run used is **77003553**.

The events discussed below (both distributions and FRED images) were selected with the following criteria:

*TCut cut = "TMath::Abs((acos(Tkr1ZDir)*(180./3.14159))-180.) < 5 && CalEnergyRaw>10";*

The image MuonWithFullLAT shows the distribution of energy deposited in the calorimeter when a muon goes through it. **This is a typical image.** The muon deposites energy (11.2 MeV in average) in a crystal from each layer. A clear track is visualized, and consequently the direction of the muon event can be (up to some precision) reconstructed for a large fraction of the events using only information from the calorimeter. The distributions of the variables Trk1ZDir and CalZDir are shown in MuonSLACReconstruction.gif, MuonSLACReconstruction.ps and MuonSLACReconstruction.root (gif, ps and root files). Note that (for this data and selection applied) the muon direction in the calorimeter (CalZDir) is properly reconstructed for most of the events, as expected.

The distribution of CalTransRms for events with one track and 2 tracks are shown in figures MuonSLACCalTransRms.gif, MuonSLACCalTransRms.ps and MuonSLACCalTransRms.root (gif, ps and root files). Note that the Transverse RMS is substantially smaller than the width of a CsI crystal (26.7mm), as expected.

## Muon events from Cosmic Ray runs taken with the Calibration Unit (Pisa, July 2006)

The data run used is **700000460**.

The events discussed below (both distributions and FRED images) were selected with the following criteria:

*TCut cut = "TMath::Abs((acos(Tkr1ZDir)*(180./3.14159))-180.) < 5 && CalEnergyRaw>10";*

### Important Remark

The calibration of this run *is not perfect*, yet it is roughly ok (*within 10-20%, estimated from the location of the muons peaks*). I took this run because the calibration seems to be much better than in dedicated muon runs (700000276 to 286, 700000490 to 500). Details about this quick evaluation of the calibration constants for these specific runs can be found in the following two references:

- https://confluence.slac.stanford.edu/download/attachments/13893/Paneque_BeamTest_20060718.pdf?version=1
- https://confluence.slac.stanford.edu/display/BeamTest/CAL+Energy+Calibrations

The image MuonWithCU shows the distribution of energy deposited in the calorimeter when a muon goes through the Calibration Unit. **This is a typical image; not a rare event.** Note that the track is "brocken"; every other layer there is a "hole" in the track, and the energy deposited in that layer seems to located off the track. The FRED Images 1,2,3 and 4 show the first 4 consecutive events from that run (after the application of the selection criteria described above). You can see the same behaviour in all them. The FRED image Evt0_4Views shows the event 0 from 4 different perspectives. Note that the Z-X perspective is different from the Z-Y perspective. In the Z-X view the layers 2, 4, 6, 8 are alined and the layers 1, 3, 5, 7 are off; whereas in the Z-Y view the opposite occurs.

Anders and Leon atributed this effect to a **wrong crystal diode relative calibration;** since the position of the event along the crystal is determined comparing the signal produced in each of the diodes at the end of the crystal. Thus a wrong relative calibration of these two diodes will shift the position determined for that energy deposition. The fact that the positions determined in all layers are wrong (in a composed Z-Y and Z-X image) seems to point to a wrong relative calibration of all diode-pairs from each crystal.

This effect deteriorates the reconstruction of the direction of the event in the calorimeter; which is clearly observed in the distributions of the variables Trk1ZDir and CalZDir shown in MuonPisaReconstruction.gif, MuonPisaReconstruction.ps and MuonPisaReconstruction.root (gif, ps and root files). Note that (for this data and selection applied) the muon direction in the calorimeter (CalZDir) is properly reconstructed for ONLY a TINY FRACTION (about 3%) of the events.

This effects also deteriorates the transverse shape of the energy deposited in the calorimeter. The distribution of CalTransRms for events with 1 track and 2 tracks are shown in figures MuonPisaCalTransRms.gif, MuonPisaCalTransRms.ps and MuonPisaCalTransRms.root (gif, ps and root files). Note that the Transverse RMS is about 3 "crystal widths"; which is definitely not what we should have.

In the case of electron events, there is not a single particle crossing the calorimeter but a bunch (shower) of them distributed over a given region (at least two crystals wide) in the calorimeter. Therefore the impact of this effect on the reconstruction of CalZDir would be somewhat lower.

### Additional muon runs

From the list of muon runs in the Beam test data base, only 2 runs are shown as *Vertical Muon Runs*. I took run number **700000322**, which has 10^5 events (5962 seconds of data, taken on 2006/07/15). Before inspecting the data with FRED i applied the same selection criteria used above (vertical events within 5 deg which deposit some energy in teh cal) and ONLY 2 events survived. Later on i noticed that indeed, **most events are empty** (CalEnergyRaw < 10 MeV). **Does anybody know why ?**

Anyway, the FRED display for the two events which survived can be found at Evt0 and Evt1. Note that the behaviour is similar to the one described above.

## Electrons events @ 5 GeV from test beam

Data run used: **700000811**

The events discussed below (both distributions and FRED images) were selected with the following criteria:

*TCut cut = "TMath::Abs((acos(Tkr1ZDir)*(180./3.14159))-180.) < 5 && CalEnergyRaw>10";*

The images ElectronWithCU_1 and ElectronWithCU_2 show the distribution of energy deposited in the calorimeter when a electron goes through it. **This is a NOT a typical image in run 811.** Typically this run shows many events with more than one charge particle in the Calibration Unit. Therefore, these images with only one clean track have been carefully selected. The goal here is not to show a typical image, but to check whether the effect described previously occurred in run 811; and for that one needs events with only 1 electron traversing the calorimeter.

Note that the track of the electron in the calorimeter does not have the "holes" showed for the muon events from runs 460 and 322. Images ElectronWithCU_2_ZX ElectronWithCU_2_ZY show the second electron event from the ZX and ZY perspective. The track is well defined in both planes.

The distributions of the variables Trk1ZDir and CalZDir are shown in Electron811Reconstruction.gif, Electron811Reconstruction.ps and Electron811Reconstruction.root (gif, ps and root files). And the distribution of the variable CalTransRms is shown in Electron811CalTransRms.gif, Electron811CalTransRms.ps and ElectronCalTransRms.root. Note that the reconstruction fo these variables is not as "incorrect" as in the case muons events from runs 460.

Therefore, it seems that **run 811 is NOT suffering from the calibration problem described before.**

The differences in CalZDir and, specially CalTransRms observed in run 811 seem to have their origin in the presence of other charge particles (in addition to the 5 GeV electron) in the Calibration Unit. Scanning events from this run with FRED, one finds many events with more than 1 clear charge particle entering in the tracker of the Calibration Unit.

Typical images from run 700000811 with more than one incoming charge particle can be found HERE.