Tentative plan for the low-energy positron beam test with the Calibration Unit

As requested by Eduardo, I prepared a few slides for last Friday's vrvs conference, but because of technical problems with our local network, I was unable to present them. My apologies about that. I have thus written this short note to summarize my views on the low-energy positron beam test, so that it can be discussed on the next meeting. I may have missed many important issues to be addressed in this test, so this note should just be considered as a starting point to the definition of the test's objectives and how to reach them.

Objectives

Determining the Calibration Unit' s response to positrons offers the opportunity to obtain a more exhaustive set of data than can be obtained with γ-rays because of the limited beam time available. Although this beam test is evidently of lower importance than the γ-ray one (no mention of EGRET being exposed to e^+ is made in their paper devoted to the calibration), the high e^+ flux makes it possible to study the response to electromagnetic showers under many different conditions. The main objectives (from my point of view) are listed below.

1) One objective is to obtain an accurate cross-calibration of the 4 towers of the Calibration Unit, only one reference point per tower being planned to be measured with γ-rays. This will allow a homogeneous grasp of the towers' response to be obtained and the reproducibility of the measurements to be tested. Although there are alternatives to positrons, heavy ions for instance, using the positron beam at SLAC is the most convenient way to reach this objective, given the technical constraints.
2) A systematic study of the response as a function of E, impact position, polar and azimuth angles, Θ and Φ, can be carried out . A special emphasis could be put on the study of events involving several towers, in particular for small off-axis angles, where the effect of the losses in dead material is the most detrimental to the energy resolution (Fig. 1). This comprehensive set of data may enable a more stringent benchmarking of the Monte-Carlo simulation that will generate the different response tables mentioned by B. Hartman.
3) Another important objective is the test of the rejection of the soft electron background in orbit.
4) 'Special conditions', such as particles passing through cracks…, which are not worthy of wasting the precious γ-ray beam time, can be investigated.

Time considerations

A 30 Hz beam with one e^+ per spill on average would lead to an accumulation of 20000 one-e events in 32 min (the probability of having exactly one e in a spill is 0.37). The pile-up events (8 Hz) will easily be rejected by using the CAL information, the e beam being monoenergetic. 20 days of beam test with positrons are currently foreseen, enabling the use of 5 energies (for example, 1-2-5-10-20 GeV) with about 3 days per energy : up to 150 different conditions per energy could be potentially explored.

Systematic study

There have been several beam tests with positrons in the past. The test with the Calibration Unit will allow a fairly complete determination of the LAT response to EM showers traversing several towers. As mentioned above, only the trajectories intersecting the CAL are useful, so as to allow the pile-up rejection. The energy deposition in the CAL essentially concerns only a few crystals per layer (Fig. 2), as the Molière radius, $R_{M,}$ (3.8 cm in CsI) is comparable to the crystals' width (2.7 cm). For the present purpose, one assumes (to be ascertained by Monte-Carlo) that the pile-up discrimination will be sufficient provided that the minimal distance of the trajectory to the CAL border is greater than 2 R_M. Among the two envisaged configurations, 2x2 and 4x1, only the former will be considered here as it offers more possibilities regarding the scan in azimuth angle. Only the Φ=0° and Φ=45° cases are detailed thereafter, but the intermediate Φ=22.5° case can readily be interpolated from these cases.
Monte-Carlo simulations are underway to confirm these views.

1) Particles coming in through the entrance plane

Fig. 3 and Fig.4 display the different proposed entry points on the top of the towers, for different conditions in Θ and Φ . These points were chosen so as to allow a homogeneous sampling of the impact position, with a typical pitch of 8.5 cm, i.e. close to 2 R_M (7.6 cm).
The color coding is as follows: red: needed, blue: lower interest, green: redundant since similar to reds. For Θ=0°, because of symmetry, the measurement corresponding to the red points in Fig.3 provides all the necessary information, as all inter-tower configurations are explored. Four points located near the border of a tower seem useful in order to sample this region more finely and get a better handle on the loss in inert materials. For Φ=45° (Fig.3) , Θ=20°-40°, measuring only the 9 lowest red points should be sufficient. Note that for Θ>0° and Φ=45°, the showers may involve up to 3 towers. For Φ=0° (Fig.4) , one could again limit oneself to the points depicted in red. For Θ=40°, only the trajectories passing through the 5 lowest red points intersect the CAL.

2) Particles coming in from the side

These conditions are suitable for investigating the multi-tower response at large off-axis angles. Fig.5 and 6 exhibit the simplified geometries of two towers of the Calibration Unit for Φ=0° and 45° (along the diagonal) respectively, along with a few representative trajectories. A large range of conditions can be explored, with polar angles reaching or exceeding 70°. One could study 3 vertical positions, (the top position in Fig. 5 and 6 leads to results very similar to those obtained when the trajectory crosses the upper entrance face, and can be ignored) with three horizontal positions over the tower side and two polar angles each.

Distinction between upgoing and downgoing particles

Since the LAT has no direct capability of distinguishing upgoing from downgoing

particles,
it is crucial to test the algorithms that will be used for rejecting the albedo electron background. In principle, if the particles leave enough energy within the CAL, the rejection of upgoing particles can be made via a crude profile fitting. If particles enter through cracks in the CAL, the direction of the shower "opening angle" as provided by the tracker can be used.

Proposed test matrix (tentative)

One considers 5 energies (1-2-5-10-20 GeV, for example). If one wishes to use finer steps in Φ, 3 energies only could be investigated (1-5-20 GeV for example).

1) The intercalibration of the 4 towers could require 9 points for each tower (Fig.7) with Θ=0°. Total: 36 points
2) Entrance face:
   Θ=0°: 13 points (depicted in red in Fig. 3)
   Φ=0°, 22.5°, 45°, Θ=20°: 9 points, Θ=40°: 5 points
   Total: 55 points
3) Side face:
   3 vertical positions x 3 horizontal positions x 2 polar angles x 2 azimuth angles
   Total: 36 points
4) Back face: Θ=0°, particles injected in the CAL: 5 points.
   Particles injected in the tracker trough cracks in the CAL: 10 points (?)

In this proposition, one reaches a total of 142 points, so very close to the maximum possible estimated in the beginning (150). This is probably far too many, as no margin is left for important tests overlooked here. Monte-Carlo simulations are needed to confirm which points are truly necessary.

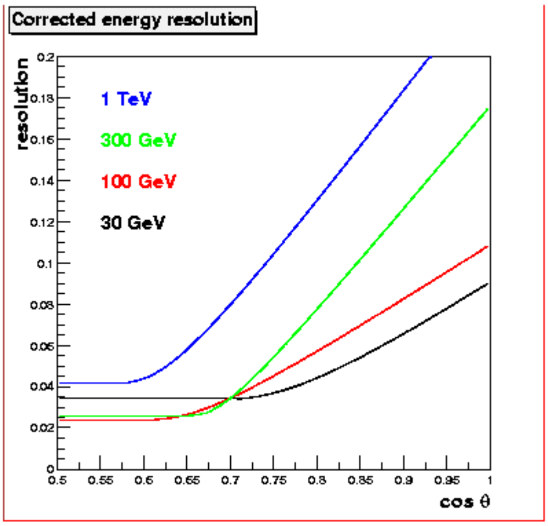

Figure 1. Theoretical energy resolution as obtained with the “last-layer correlation” method. (R. Terrier et al., Gamma 2001 Symposium)

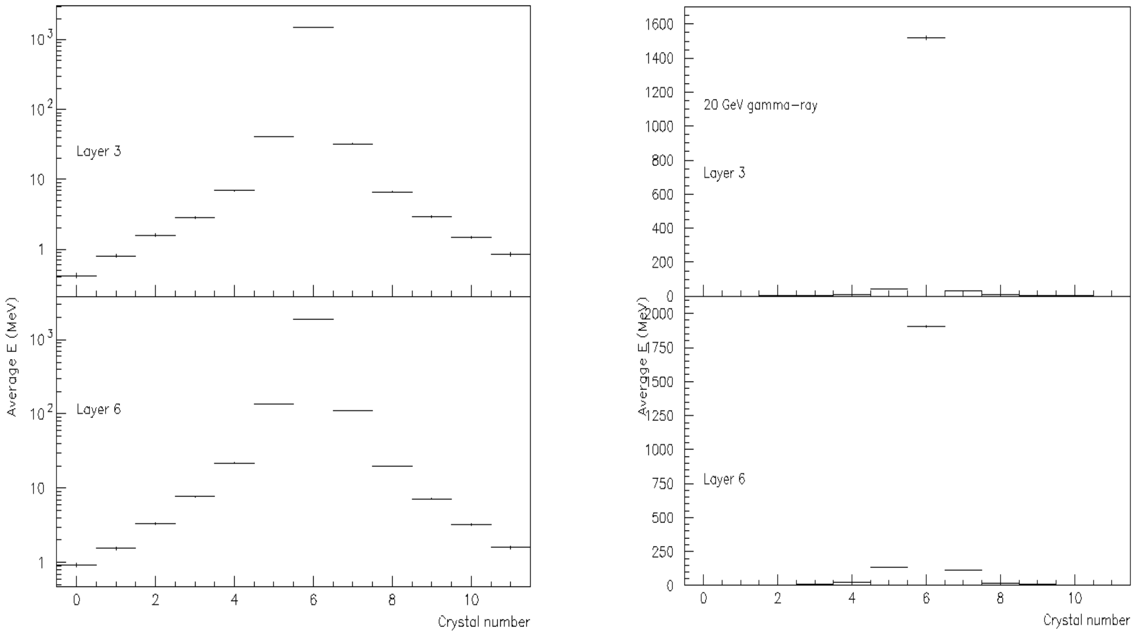

Figure 2. Transverse shower profile for a 20 GeV gamma-ray impinging on-axis on the LAT, for two different crystal layers of the CAL, as predicted by Geant3, in logarithmic (left) and linear (right) scales.

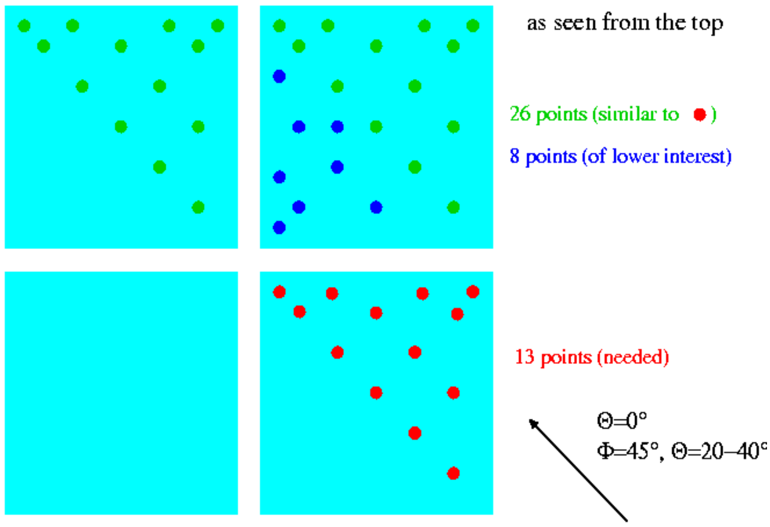

Figure 3. Possible entry points for Θ=0 or Φ=45°

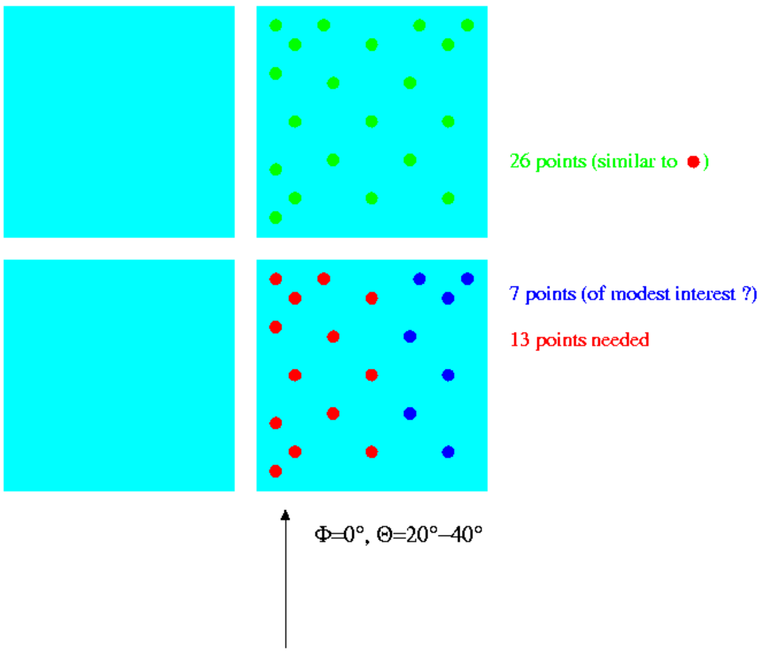

Figure 4. Possible entry points for ϕ=0°

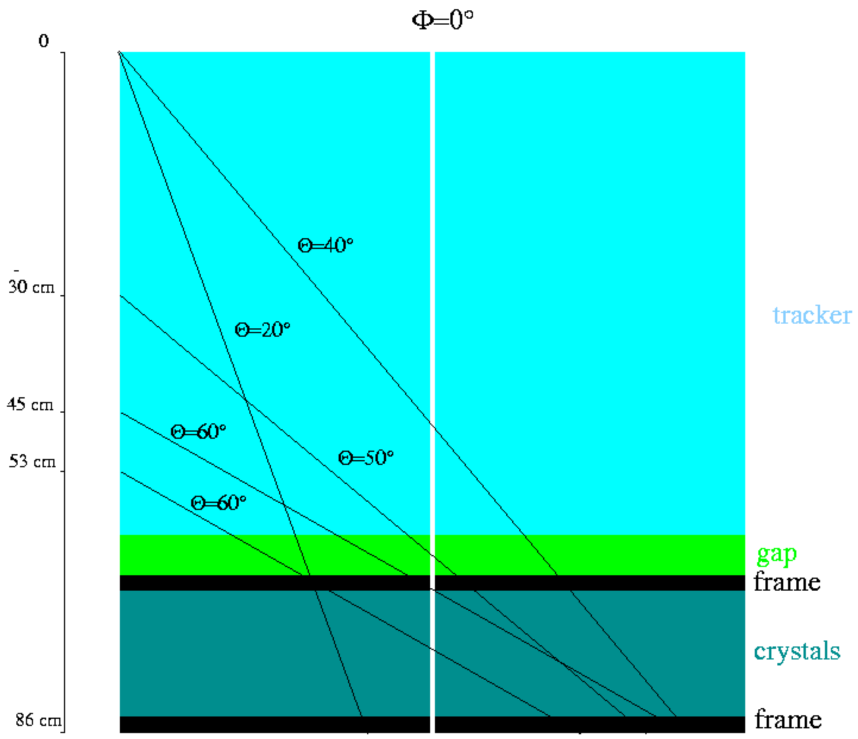

Figure 5. Schematic geometry for the measurement at Φ=0°.

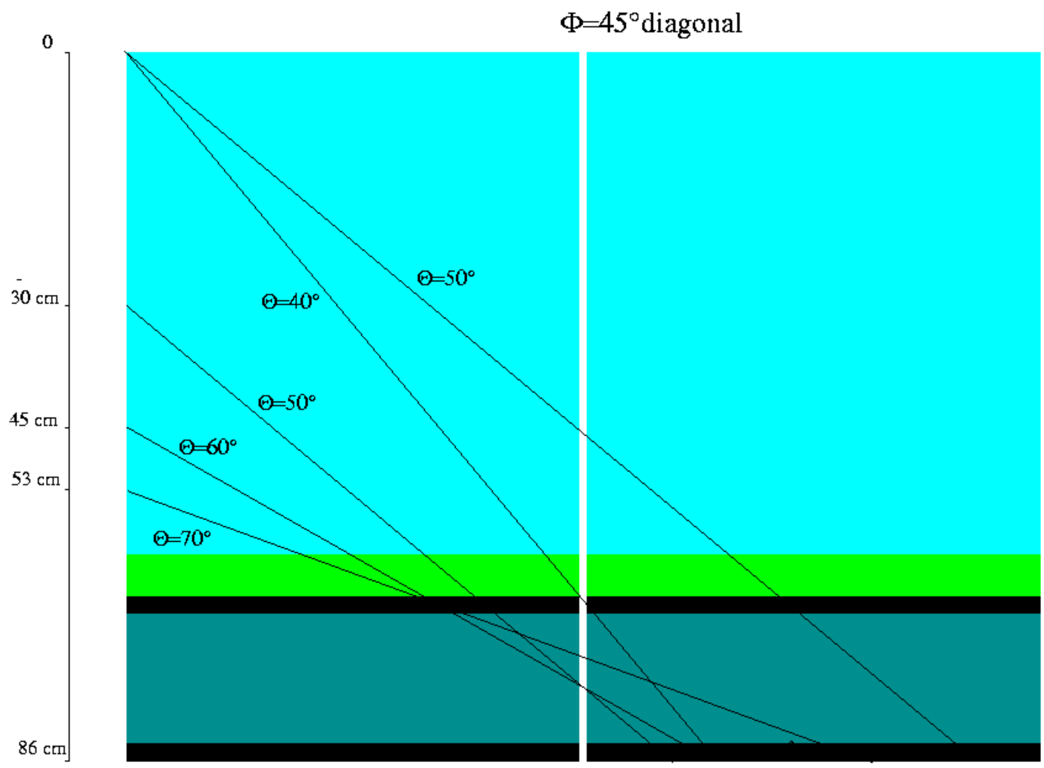

Figure 6. Schematic geometry for the measurement at Φ=45°, along the diagonal.

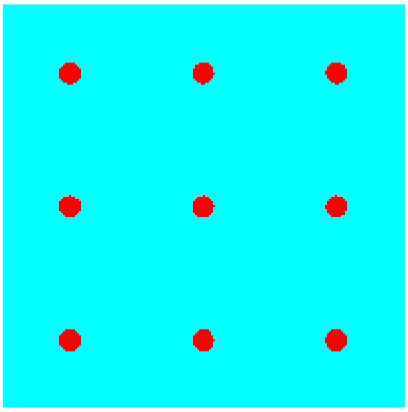

Figure 7. Proposed points for the tower calibration.