Dispersion in the energy response of GLAST's CsI logs

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Abstract

This note presents the different data at hand regarding the dispersion in the energy response of the CAL logs.

1 Introduction

The dispersion in the energy response of GLAST's CsI logs is a crucial quantity in determining the resolution of the whole calorimeter. The relevant case for GLAST is course that of electromagnetic showers, but it is also important to establish this dispersion in the case of particles used for calibration, like muons, protons or heavy ions. This note presents the available data regarding the different cases and discusses the results.

2 Dispersion for MIPS: protons and muons

Only the case of mono-energetic beam particles will be considered here, to avoid any ambiguity relative to the proper modeling of the energy distribution of atmospheric muons. Three cases will be addressed: 20 GeV muons at CERN with the minical, 1.7 GeV protons at GSI with the minical and EM. Let us recall that while the crystals are the same and underwent similar processing for the minical and EM, the electronics are different: the noise level and linearity are better for the minical, but probably more important in the present case, the minical makes use of peak-sensing ADCs, while the EM uses sample-and-hold circuits. In the latter case, the digitization took place at a fixed delay time with respect to the trigger, which was externally provided by the FRS detection system at GSI. Since we were dealing with extended beams (several cm in diameter), the energies were averaged over the two ends on an event-by-event basis to correct for the light tapering effect.

It was first noticed in the analysis of the 2002 CERN experiment that the experimental muon deposited-energy distributions were slightly broader than those predicted by GEANT. For orientation, the FWHM and mode of the GEANT distribution are about 1.8 MeV and 11.6 MeV, respectively. The best agreement

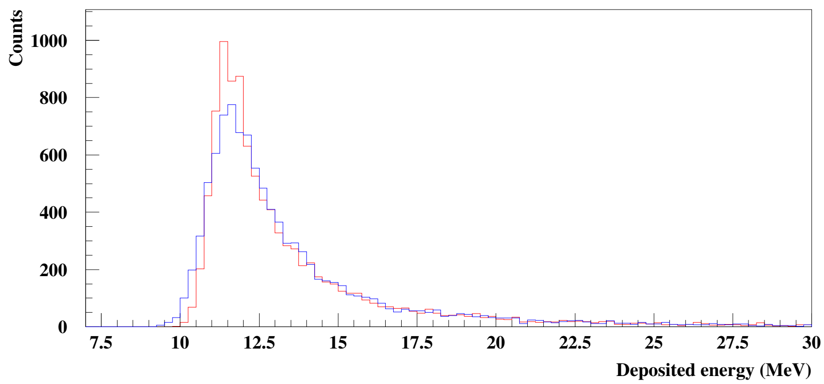

Figure 1: Comparison between the deposited-energy distribution (red) predicted by GEANT4 for 20-GeV muons and that resulting from a convolution of this distribution with a gaussian function with a 0.6 MeV width (blue).

with the data was found when the GEANT distribution was convolved with a gaussian distribution with a width of about 0.6 MeV. The effect of this smearing is displayed in Fig. 1. A comparison between the resulting distribution and experimental one measured at CERN in 2003 with the minical is displayed in Fig. 2.

The same effect was observed at GSI both with the minical (Fig. 4) and the EM (Fig.3). The width of the gaussian smearing is 0.65 MeV in both cases. This value was determined independently by Frederic Piron from fits of the data and simulation results using a Landau function and a sum of Laudau and Gaussian functions, respectively. One can note the good reproduction of the experimental distributions in Figs 4 and 3 when this effect is taken into account.

What is responsible for this effect? It may be due to inhomogeneity in the light collection. In that case, the smear should be proportional to the amount of the measured energy, and should remain close to the 5% figure observed with MIPs. This would impact the overall energy resolution of the calorimeter.

3 Dispersion for heavy ions

The GSI data [1]provide a very convenient way to investigate this problem since the deposited energy through ionization varies between about 500 MeV for Carbon ions to over 8 GeV for Fe ions (Fig.**??**) and the distributions are narrow. In contrast to the MIP case, the distributions assume a gaussian shape. Thanks to the information provided by the spectrometer detection system, it was possible to obtain individual distributions for each ion species. The widths

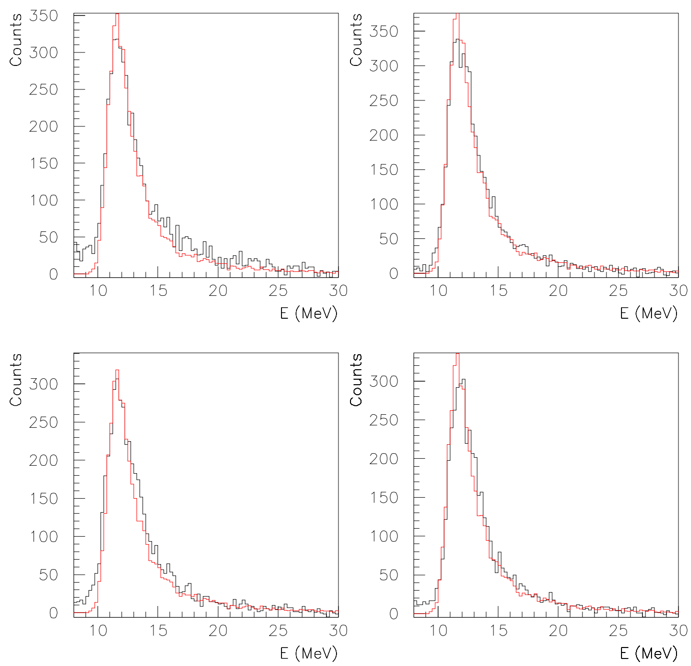

Figure 2: Comparison of the deposited-energy distributions measured at CERN (black histograms) with those predicted by GEANT4 (red histograms) for 4 different logs. The beam is 20 GeV muons.

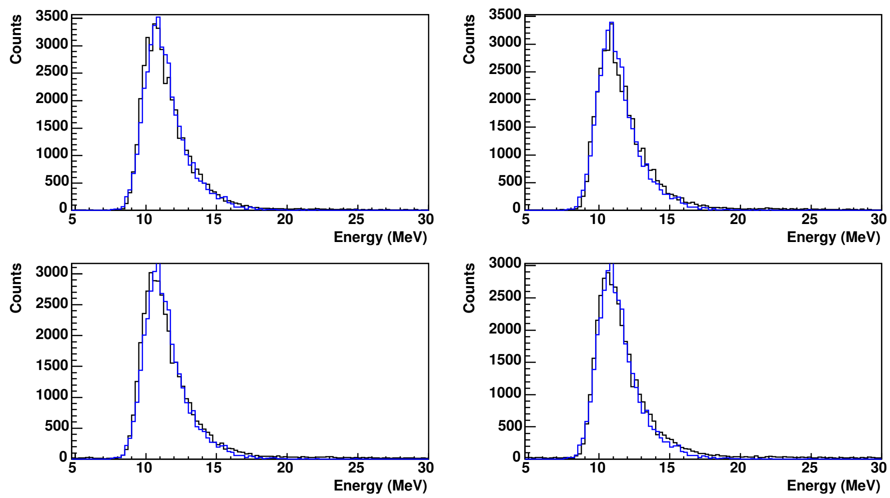

Figure 3: Calibrated deposited-energy distributions for 1.7 GeV protons (black histograms) compared to the corresponding GEANT4 predictions, spread by 0.65 MeV (blue histograms), for the first four EM layers.

(sigma) of the distributions measured for the first minical layer are displayed in the top panel of Fig. 5 as a function of the ion atomic number (red dots). For comparison, also shown in the panel are the GEANT4 corresponding values (green dots). The experimental widths exceed the expected ones by a fairly constant factor of 30% (the line corresponds to a linear fit of the GEANT4 widths multiplied by 1.3). If the widths are normalized with respect to the actual measured (or calculated) energies, one obtains the relative widths plotted in Fig.5 bottom (let us recall that the normalizing energies are different for the data and the GEANT4 predictions because of the non-unity quenching factors). For Fe, the relative width is about 0.7%, much lower than the 5% value deduced above for MIPs. One can estimate the instrumental contribution to the relative widths by quadratically subtracting the calculated widths to the measured ones. The results are displayed in Fig. 6. The spread is fairly constant, lying below 0.6% over the whole the range of ion species (and thus of deposited energy) considered. The same exercise was repeated for the first layer of the EM, the results being shown in the same figure (blue squares). For the data associated with atomic numbers between 8 and 20 (HEX8 range), the electronic noise is not negligible, the contribution deduced from the pedestal width amounting to about 6 MeV for the energy summed over the two ends as considered here. The blue open squares in Fig. 6 correspond to the relative widths resulting of this contribution being quadratically subtracted. Once this effect is taken in account, there is a general fair agreement between the EM and minical values, although the former are systematically slightly higher.

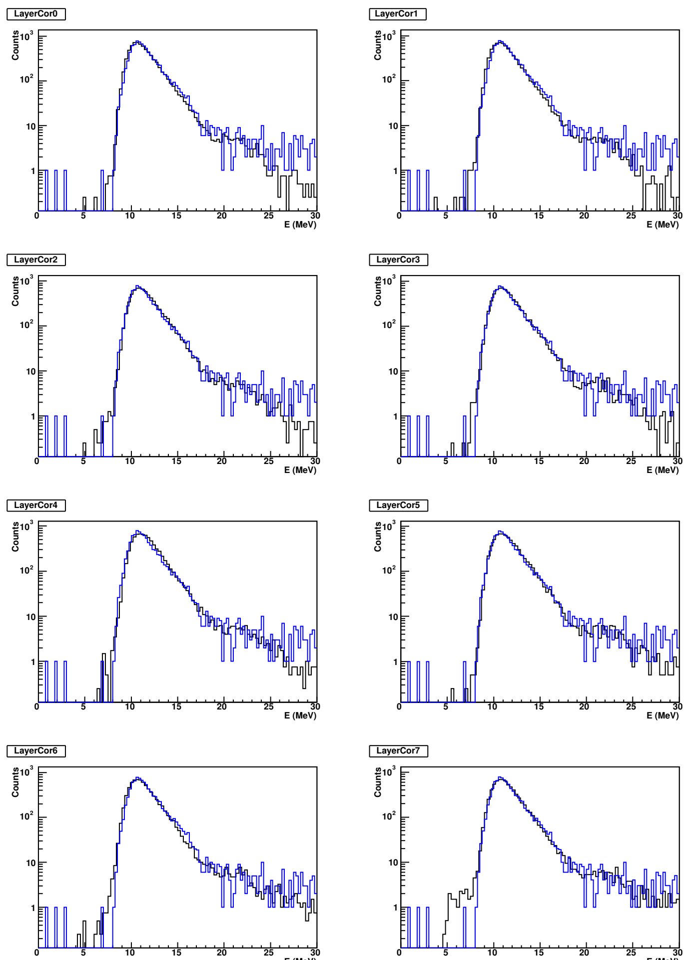

Figure 4: Same as previous figure for the 8 minical logs, but the beam is 1.7 GeV protons at GSI.

The uncertainty on these results is estimated to be at least 0.2%.

Conclusion

The heavy-ion data prove that the energy resolution of GLAST's logs is below 1% at high energy (E>500 MeV). This observation rules out that the 0.6 MeV spread observed with MIPs stems from inhomogeneity in the light collection. It may be due to an underestimation of the width of the deposited-energy distribution calculated by GEANT4.

References

[1] B. Lott and F. Piron, "Probing the quenching effect in CsI for high-energy particles" http://www.cenbg.in2p3.fr/ftp/astropart/glast/note_quenching.pdf

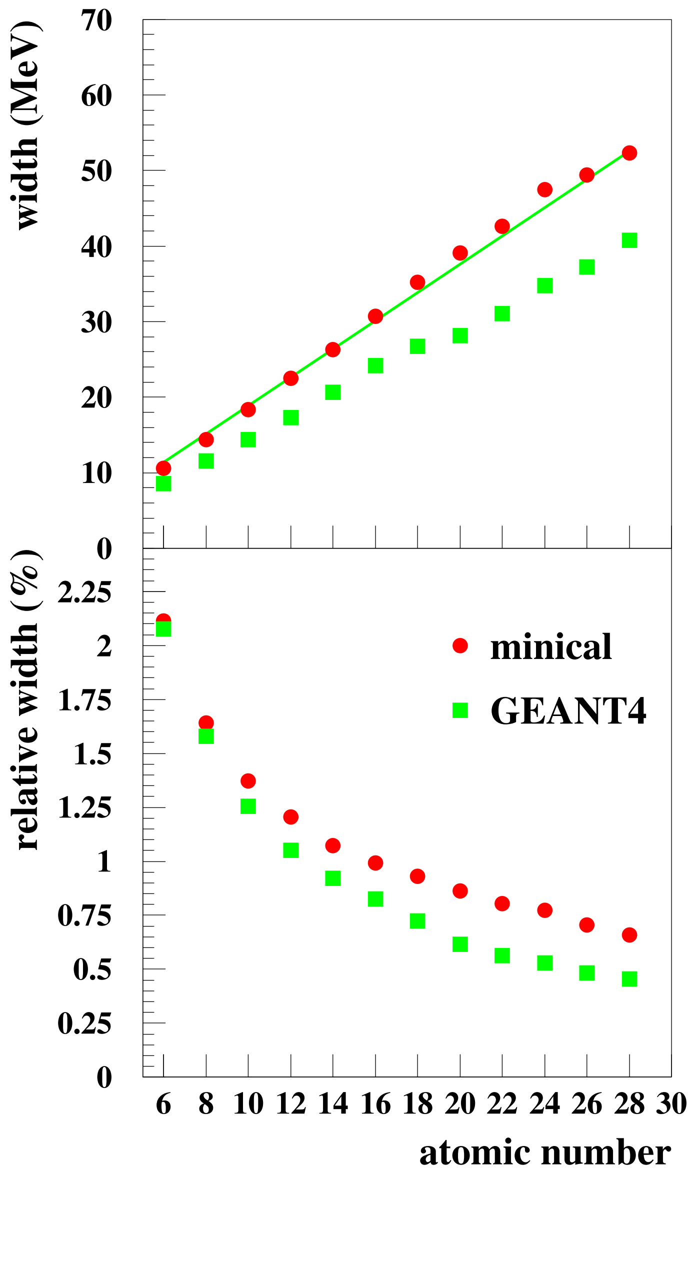

Figure 5: Top: Widths of the measured (red dots) and calculated (green squares) deposited-energy distributions plotted as a function of the ion atomic number. Bottom: same as top for the relative widths.

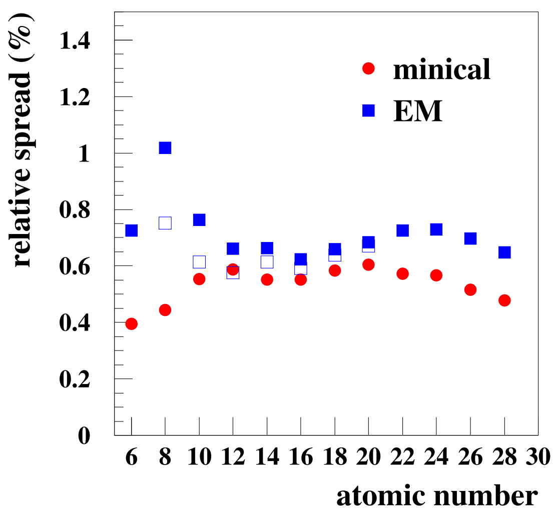

Figure 6: Relative spread obtained from the quadratic difference of the relative experimental and calculated widths, for the minical (red dots) and EM data (blue squares).