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On the calibration of the W-Si electromagnetic calorimeter proposed for TESLA

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Abstract

The problem of the W-Si sampling calorimeter calibration is presented, together with possible solutions. A calibration at the level of few per mille seems possible, which is well in the range needed for the physics case of the LC.

1 Introduction

Due to the large number, about 32 10^6, channels in the proposed W-Si electromagnetic calorimeter, the calibration could be difficult. It is shown in this short note, that the overall calibration can be under control at the level of few per mille.

Because the response of a silicon diode is very stable with time , temperature (at least up to a per mille level), the W-Si calorimeter pad response to electron/photon is related to the overall read-out system (gain of the preamplifiers,...) and to the amount of tungsten in front of the pad, the silicon diode depletion thickness. The first point is expected to be controled directly by the DAQ chain [1].

The second point is a constant of the detector, while the depletion length and the overall read-out system could change with time. The first point to check is the impact of the pad to pad calibration (intercalibration) on the energy resolution. Figure 1 shows the impact on the energy resolution for different intercalibration uncertainties, obtained for 3 GeV photon, using GEANT4 simulation. One can conclude that in fact a relatively poor knowledge (about 1-2 %) of the amount of tungsten as well as the depletion length pad to pad has no impact on the energy resolution. This weak impact is related to the large number of pads hit by a shower. To reach an intercalibration uncertainty of about 1-2% is relatively easy as it is shown in the next sections.

Now it remains only the overall calibration of the ECAL, which do not present any problem with the large sources of electrons in the physics processes.

2 Tungsten calibration

The thickness and density of the tungsten in front of a pad determine the electromagnetic response of the device. The measurement of the thickness and density can be made at the time of construction, using ultrasonic method for the thickness, or gammagraphy which controls directly the radiation length of tungsten in front of a pad. This measurement would lead to a mapping of the tungsten over the whole calorimeter, which is used to correct on-line, the pad response. Since the impact is small, a rough measurement could be sufficient. In addition, the use of "physics events", such as W/Z decays with electrons, or Bhabha events, could give a check in-situ of the intercalibration.

3 The use of cosmics muons for the barrel

In order to know the flux of cosmics muons crossing the detector, we have to calculate the number of interaction lengths that a muon has to passing through to reach the internal part of the detector. That is 3 meter of concrete ($9\lambda_I 0$), 1.5m of steel for the return yoke ($9\lambda_I 0$), 2 λ_I for the coil and 6 λ_I for the ECAL/HCAL and 1 λ_I for the ECAL after the crossing the center part of the detector. The total number of interaction lengths is about

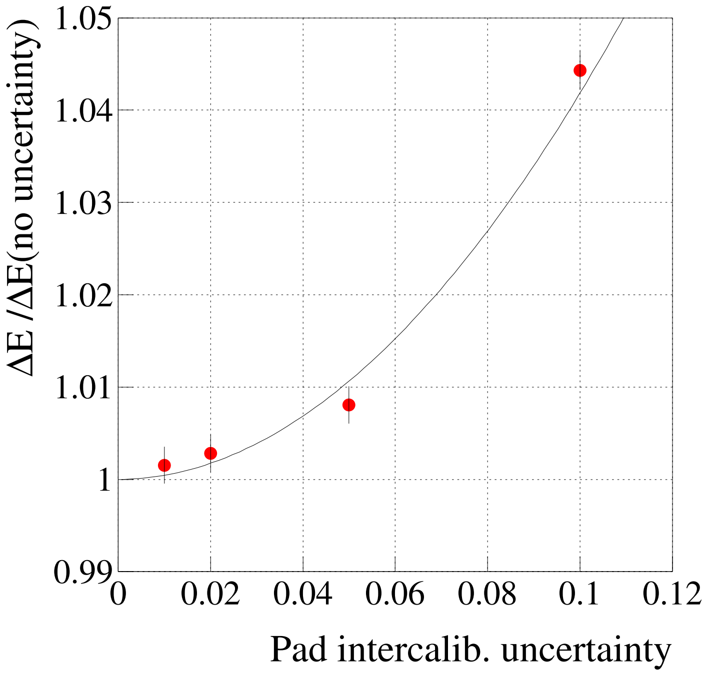

Figure 1: Impact of the pad's intercalibration on the energy resolution. points with error bars are obtained with GEANT4 simulation of 3 GeV photon

27 λ_I, corresponding to about 22m of water equivalent, as used in the figure 7 of reference [2], which gives a flux of $I_\mu \sim 2.\ 10^{-3}$ mu $s^{-1}sr^{-1}cm^{-2}$.

The effective area is given by the upper half of the barrel, which is 2.7 10^5 cm^2. The effective opening angle is taken as π steradian. The flux of useable muons is therefore 1.7 10^3 per second. Taking into account the total number of pads in the barrel (23 10^6), and the 80 pads crossed by a muon, we obtain about 3600 muons/pad per week. The ECAL and HCAL hits could be used to fit the track and extract the effective length crossed by the muon in each pad, and therefore to normalise the m.i.p. response to a vertical crossing.

Fitting the Landau peak with the sample of muons from *one week of cosmics data*, allows to reach a precision of about $\pm$ 5.3 10^{-3}, for the intercalibration of the m.i.p, well under the limit of 2% discussed previously.

Therefore, for the barrel, the uncertainty on the intercalibration has a totally negligible effect on the energy resolution.

4 Intercalibration of the end-caps

It is foreseen to do a "calibration" run at the Z peak at the begining of each year of data taking. Taking into account the area covered by a shower of such energy (in terms of Molière radius) and the polar angular distribution of the Bhabha, a week of such data will produce about 350 electrons/shower area. With the expected energy resolution for electron of $\Delta E/E = 14\%/\sqrt{E}$, one can conclude that a mapping of the end-cap can be made with a precision of about 7. 10^{-3}, *with only one week of data*. Here again, the level of precision with one week is largely smaller than the limit of 2% given in the introduction.

It must be noted that such physics processes could also be applied to the barrel. For a month of data a precision of about 1.2% could be reach. This is a cross-check for the method using the cosmics muons. Even with 1.2%, the impact on the energy resolution is negligible.

5 Conclusion on the intercalibration

A week of cosmics data for the barrel and a week of running at the Z peak for the end-cap are largely sufficient to reach a value of the intercalibration uncertainty which has essentially *no effect on the energy resolution*.

6 Pedestals and zero suppress control

The pedestals for each pad are foreseen to be controlled directly by the front-end chip, as described in [1]. The dispersion of the discrimator of the front-end chip is directly related to the efficiency for a m.i.p. particle. Assuming the track fit is done correctly in the special DAQ dedicated to the cosmics muons, any tail and/or unexpected dispersion of the discrimator values would create innefficiency on the m.i.p., and would be seen by the control of the number of pads fired by cosmics muons. To conclude, the control of the discriminator level, as well as the pedestals for each pad, will be under control and do not need any dedicated runs.

7 Global calibration of the ECAL

The remaining problem of the overall ECAL calibration is a very classical one, not specific to the W-Si calorimeter with its large number of channels. Any effect with polar angle, module number, phi angle, etc... can be made using the full electrons statistics and do not present any problem. For the overall calibration, the full statistics of electrons can be used, that is about 3 10^9 electrons with energy runing from few GeV ($\gamma\gamma \rightarrow e^+e^-$) to 45 GeV (Bhabha at the Z peak) and 250 GeV for Bhabha at $\sqrt{s}$=500GeV.

In this condition, there is no reason to have an overall calibration uncertainty larger than a per mille.

8 Conclusion

Although the number of channels in the proposed tungsten-silicon ECAL is large, the calibration do not present any challenge. The pad to pad intercalibration uncertainty is expected to have a negligible impact on the energy resolution. A precision on the overall calibration smaller than 10^{-3} is foreseen.

References

[1] Silicon diode, readout and front-end electronics on the proposed W-Si electromagnetic calorimeter. A.Karar and Ch. de la Taille , LC-DET-2001-059

[2] Atmospheric muon flux at sea level,underground and underwater
E.V. Bugaev et al, hep-ph/9803488