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# The endcap accordion calorimeter prototype simulation.

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## Abstract

The results of MC simulation for the endcap accordion prototype are presented followed by comparison with beam test results. The $\phi$ -modulation and the energy resolution measured in the beam test are well reproduced by simulation.

## 1 Introduction

The present note describes the MC simulation of the endcap accordion calorimeter prototype which has been built by the RD3 collaboration and tested in october 1993 and may 1994 at the H8 beam line at the CERN SPS [2]. The main goal of the note is to verify that the simulation is capable to reproduce the behaviour of this type of calorimeter and can be used for design optimisation of the ATLAS e.m. endcap.

## 2 Prototype design

The prototype has been designed as a sector of inner wheel of the ATLAS endcap calorimeter. It consits of a sixth of a full wheel nominally built out of 348 absorbers and as many kapton readout borders. All plates are accordion shaped and arranged radially between inner radius $R = 40cm$ and outer radius $R = 96cm$. Each plate has 8 waves along beam axis with total length of 48 cm in this direction. Openning angle is decreasing from $110^0$ at $R = 40cm$ to $55^0$ at $R = 96cm$. Absorber was made of lead with a thickness changing lineary between 1.3 and 2.3 mm and 2 layers of stainless steel 0.2 mm thick glued to the lead plate by epoxy glue layer of 0.15 mm. Readout electrodes were made of multilayer material containning 2 kapton layers, 3 copper and 4 glue layers. Total thickness of the electrode is 0.3 mm including 0.06 mm of copper. Prototype granularity was $\Delta\eta \times \Delta\phi = 0.03 \times 0.05$ it contained 24 cells in $\eta$, 12 cells in $\phi$ and 3 longitudinal compartments $(9X_0, 9X_0, 6X_0)$. As this prototype was designed in the end of 1992, there are some differences in geometry with respect to technical proposal design, which was reoptimised in November 1994 according to recent changes in eta coverage, number of absorbers, total thickness etc. [3].

## 3 Prototype geometry description for GEANT simulation

As it was shown in [3] the accordion with variable openning angle has the wave height which varies nonlineary with radius. This makes necessary to cut each absorber in radial direction into several parts in order to well reproduce its geometry using the existing GEANT shapes. For the simulation of beam test configuration one don't need the description of a whole prototype, but only a cylindrical layer large enough to contain a shower taking into account a projective direction of the beam. This approach was used in the first version of the simulation program ("standalone" version) where the inner and outer radii of the simulated cylindrical layer calculated as a function of the beam incidence position and then the geometrical parameters are tuned to well reproduce the corresponding part of the real prototype. Later the correct geometry description of the whole calorimeter was also written and now it is included in the DICE95 software for general ATLAS simulation.

In the standalone version the cylindrical layer (TUBE shape) is divided along z direction into 8 similar wheels. Each of them (see fig. 1) includes 2 volumes 'ROUE' containning "plane" parts of accordions and 4 volumes 'RCRB' containning their folded parts. The view of an absorber part, represented by GEANT description is shown on fig. 2.

Absorber's composition of different GEANT elements is shown on fig. 3 The plane part of each accordion is represented by the volume ABSO having general trapezoid shape (GTRA). Folded part is represented by a cone sector ARND and a trapezoid CONJ for junction with a plane part. The layers of stainless steel and glue are represented by corresponding daughter volumes inside each part of an absorber (see fig. 4).

Because of variable openning angle one cannot avoid some overlapping of a cone sector with trapezoid in the fold region which increases the absorber thickness. To eliminate this effect the cone sector is declared 'MANY' and an addition volume of liquid argon is added to supress extra lead.

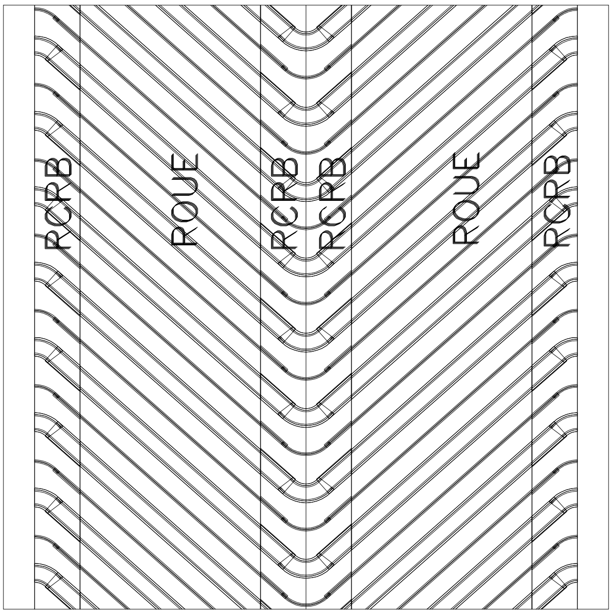


Figure 1: *A cut of 1/8 of calorimeter by a plane transversal to radius*

## 4 Charge collection effects

Nonuniformity of a charge collection near the fold region was taken into account using the same method as for barrel accordion [1]. The electric field map was calculated for gap geometries corresponding to several different radii. The signal produced by an elementary charge deposed in a certain point in a gap was calculated by numerical integration of the field along the ionization drift taking into account the drift velocity variation and the shaping time. For each readout cell the signal calculation was performed using the beam test high voltage values.

## 5 Segmentation

The prototype segmentation in $\phi$ , $\eta$ and z direction was simulated on the readout level. It was done in the subroutine GUSTEP where the cell number in each direction was determined from the coordinates of the energy deposition. Number of $\eta$ cell was used also to chose appropiate charge collection map.

## 6 Results and their comparison with test beam data

Simulated calorimeter response as a function of $\phi$ has periodical modulations due to two effects : a) non-uniformity of the sampling fraction near the absorber fold and b) non-uniformity of the electric field near the absorber or the electrode fold. The sum of these two effects produces two sets of peaks with different amplitudes and widths at the position of the absorber and the electrode folds.

The height of the peak produced by absorber folds is sensitive to the overlapping of absorbers. From the other side, the overlapping of absorbers is affected by geometry changing in the cold, by mecanical tolerances on absorbers positionning etc. To take into account these effects the value of the openning angle used for the simulation was tuned with respect to designed value to get better agreement with data. The $\phi$-modulation obtained from data for two different cells of the calorimeter together with corresponding simulation results are shown on fig. 5 and fig. 6.

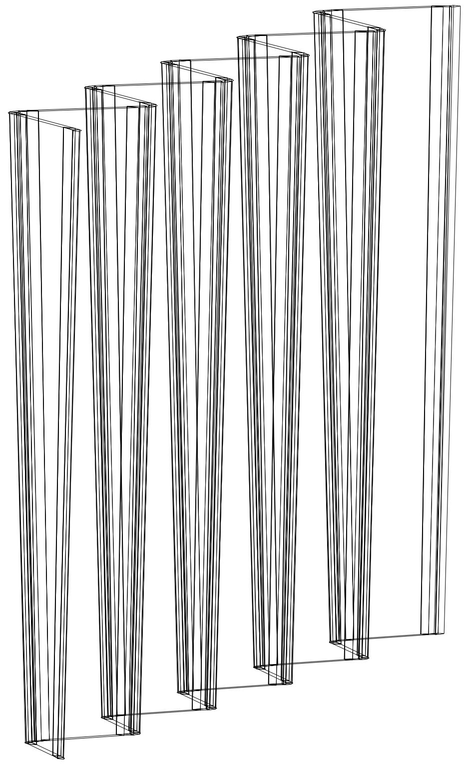

Figure 2: *A part of the accordion with variable openning angle, represented by GEANT*

The simulation of the first one was done with openning angle $\alpha = \alpha_0 - 1^0$, where $\alpha_0$ is the designed value for openning angle. For the second one the openning angle was $\alpha = \alpha_0 - 2^0$ This increases the overlapping of absorbers by $\Delta h = 0.5mm$ and 1 mm respectively. These values are in agreement with measurements of absorber shrinking in the cold.

In order to define the sampling and the constant term for the energy resolution the simulation was done for 20, 50, 100 and 300 GeV electrons. As we expected for this prototype higher *phi*-modulations for smaller $\eta$ values and possible deterioration of the resolution due to residual $\phi$-modulation, simulation was done for $\eta = 2.22$ (cell number $N_\eta = 22$).

Due to relatively small number of radiation length in this prototype ($25X_0$) there is visible effect of backward leakage for 300 GeV electrons. One can see this effect at fig. 7 where the correlation between total energy deposition in the calorimeter and the energy in the third sampling is shown.

The slope parameter which is equal to 0.3 and independent of the initial electron energy was then used to correct the energy response of the calorimeter.

The energy resolution obtained after correction for the $\phi$ modulations and the backward leakage is shown (Fig. 8) as a function of the initial particle energy. The fit gives a sampling term of $10 \pm 0.2\%$ and a constant term of $0.25 \pm 0.1\%$. These values should be compared with results of data analysis presented in [4] with sampling term $9.9 \pm 0.5\%$ and constant term $0.5 \pm 0.05\%$ for this $\eta$ value.

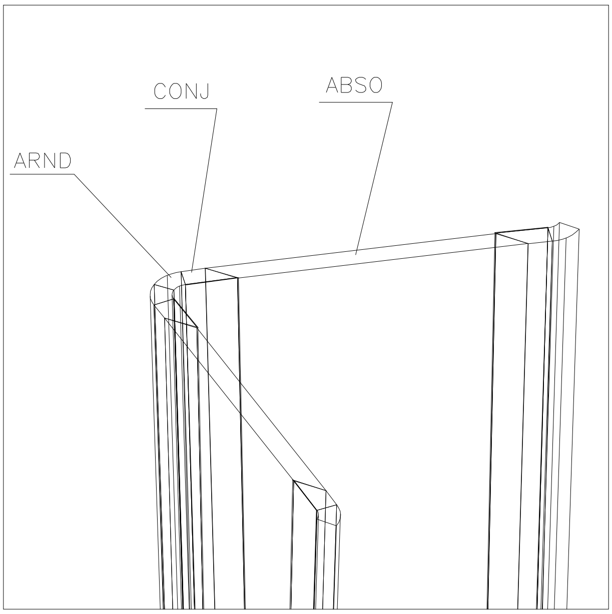


Figure 3: *Endcap accordion composition of GEANT elements: ABSO (shape GTRA), ARND (shape CONS) and CONJ (shape GTRA)*

## 7 Conclusion

As one could see in previous section, the Monte Carlo simulation of the endcap accordion prototype explains well the $\phi$-modulation shape and the energy resolution dependence on incident particle energy. This justifies the use of this simulation program for endcap design optimisation.

## References

[1] M.Lefebvre, G.Parrour, P.Petroff. RD3 note 41 (1993).
[2] A.Chekhtman et al. ATLAS internal note CAL-NO-67 (1994)
[3] A.Chekhtman et al. ATLAS internal note LARG-NO-004 (1994)
[4] L.Serin et al. Proceedings of the 5th international conference on calorimetry in high energy physics. BNL, September 1994.

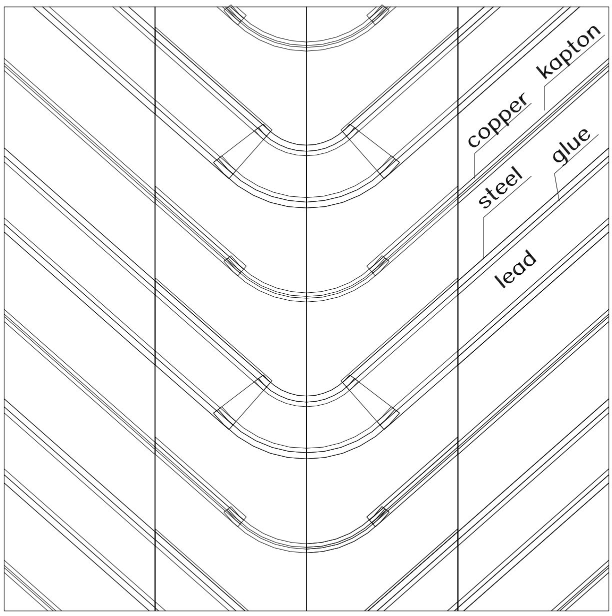


Figure 4: *Detailed geometry of absorbers and electrodes*

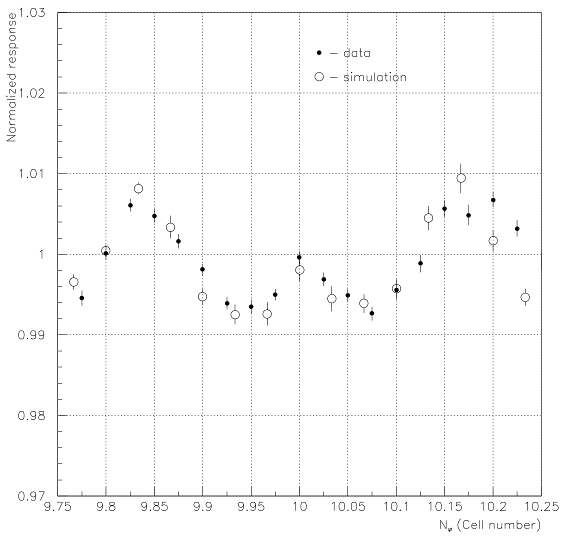


Figure 5: Φ-*modulation, data for* $N_\eta = 10$, $N_\phi = 10$, *simulation with openning angle* $\alpha = \alpha_0 - 1^0$

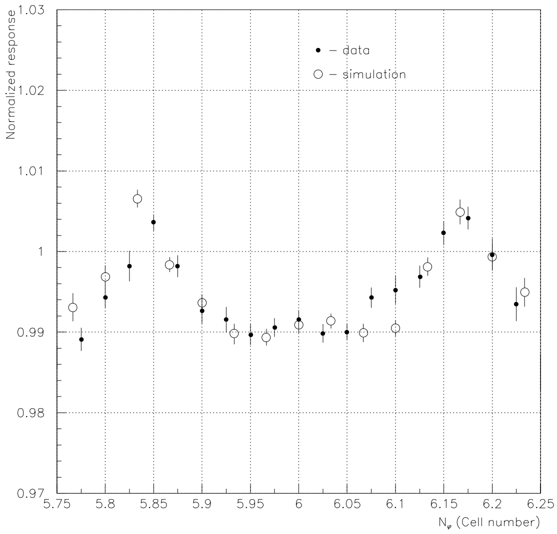


Figure 6: *Φ-modulation, data for* $N_\eta = 10$, $N_\phi = 6$, *simulation with opening angle* $\alpha = \alpha_0 - 2^0$

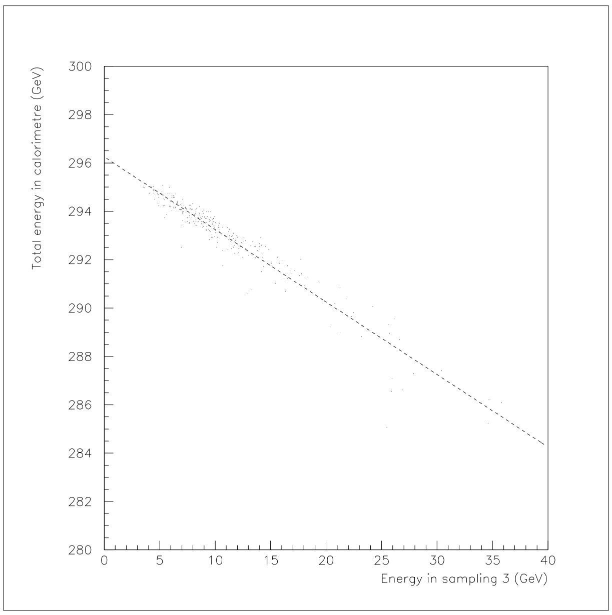


Figure 7: *Correlation between the total energy and the energy in sampling 3 (Monte Carlo data)*

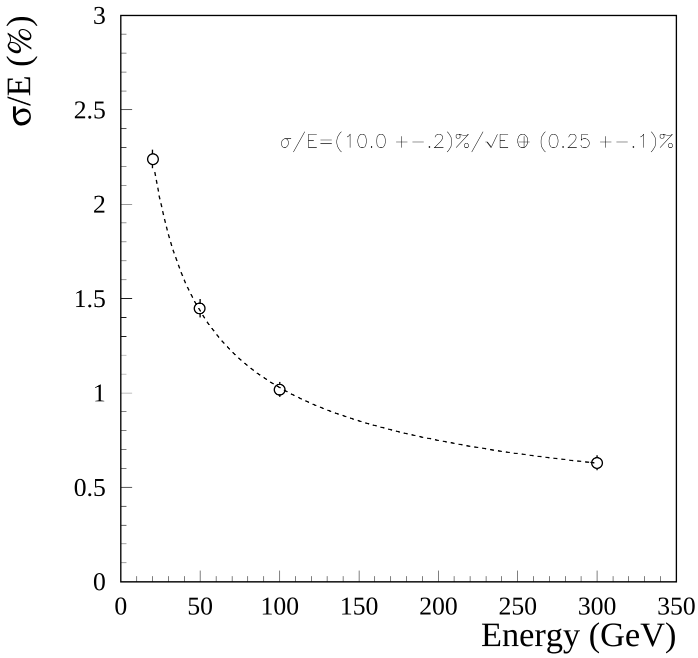


Figure 8: *Energy resolution (Monte Carlo)*