An Integrated UV preshower

in the RD3 Liquid Argon Accordion Calorimeter:

First Test Beam Results *

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ABSTRACT

In this paper we report on the construction and the tests of an integrated UV preshower within the RD3 Liquid Argon (LAr) accordion electromagnetic calorimeter (EM). Both design and construction followed the same techniques as for the EM calorimeter: no problem was encountered. Beam tests were performed during summer 1994 and good performances of the integrated preshower have been measured: no energy resolution loss, position resolution better than 300 μm and angular resolution better than 6 mrad for electrons with energy above 100 GeV.

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1. Introduction

In the framework of the ATLAS EM calorimeter elaboration and following the idea of the GEM collaboration to integrate the preshower in the first sampling of the EM calorimeter, the RD3 collaboration decided to build and test an integrated stereo UV preshower. The RD3 collaboration has also tested a separate preshower and results were presented at this conference. So were results of an integrated \( \eta \) preshower in an accordion Liquid Krypton calorimeter.

1.1. Physics requirements

Most of the constraints on the EM calorimeter requirements come from the necessity for the ATLAS experiment to be able to search for the Higgs boson in the mass region \( M_H \geq 80 \text{ GeV} \). For \( M_H \leq 130 \text{ GeV} \) the search of the Higgs decaying into 2 \( \gamma \) seems to be the only possible way to extract the signal over the QCD background. The \( \gamma \gamma \) mass resolution has two contributions: one from the energy and one from angular measurements; in ATLAS, both benefit from the use of a preshower:

- due to the amount of dead material in front of the calorimeter (tracker, cryostat, coil, clearance), an early sample of the EM shower allows to correct for the energy loss in this material (\( \approx 1.2 \times X_0 \) at \( \eta = 0 \) to \( \approx 2.5 \times X_0 \) at \( \eta = 1.4 \)).
- the angular resolution benefits from a highly segmented first sampling, where the EM shower is still narrow.
- a good position resolution improves the \( \pi^0 \) rejection, important when fighting the background to single photons.

1.2. Construction constraints

When building a large detector as ATLAS, ease of construction is an important aspect; the main advantage of an integrated preshower is that it does not involve extra mechanical structure as it is part of the EM calorimeter; it is therefore intrinsically aligned with it. Having two views (U and V) is also an apriori advantage as it should improve \( \pi^0 \) rejection.

In the next section, the construction of the two sectors of the RD3 EM prototype, equipped with UV electrodes, will be described and the noise figures summarized. In the third section, the test-beam setup and the analysis will be described leading to the position and angular resolution measurements. In the last section conclusions will be drawn and prospects presented.

2. Construction

2.1. Ideas

The RD3 EM prototype is segmented in three samplings in depth; in this test, the depth of the first sampling was reduced and the transverse segmentation modified to draw the strips of the integrated preshower.

In the GEM design, the integrated preshower had a fine segmentation in the \( \eta \) direction but a very coarse one in \( \phi \). The RD3 collaboration has developed the idea of a stereo segmentation in the U and V directions: making use of the accordion geometry (\( \phi \neq cte \)), two sets of strips with borders following the equations of Fig. 1 were
drawn on the kapton electrodes; then, when stacking the module, U and V electrodes were interleaved. The rest of the construction follows the procedure described in §.

To limit the number of electronic channels, six U (V) strips, with the same \( \eta - (+) \phi \), were connected together. The total number of channels in the preshower sampling is twice the number of the middle sampling.

The strip width is \( \simeq 5 \text{ mm} \). The segmentation is \( \Delta \eta \times \Delta \phi = 0.00441 \times 0.0784 \) to be compared to \( \Delta \eta \times \Delta \phi = 0.00176 \times 0.0196 \) for the middle sampling.

2.2. High voltage

In the RD3 EM prototype, the high voltage (HV) was distributed from the front face of the calorimeter for the front sampling, and from the back face for the middle and the back samplings. In order to reduce the number of connections on the front face, the HV for the preshower sampling was also brought from the back using resistive ink. The aim was to have a resistance of \( \simeq 100 \, k\Omega \) for these connections; only \( \simeq 10 \, k\Omega \) were achieved; this low resistance probably explains the cross-talk between the middle and the preshower sampling that was measured at the level of 1% per cell.

2.3. Electronics and read-out

Standard motherboards § equipped with hybrid GaAs preamplifiers were used for the middle and the back samplings. Multi-layers (10) cards, equipped with monolithic GaAs preamplifiers 7 were developped for this test; the total thickness of the electronics on the front face (summation+preamps+calibration) was \( \simeq 27 \, \text{mm} \). The standard acquisition chain was then used (shapers with \( \tau_s \simeq 20 \, \text{ns} \), track and hold and ADC); standard calibration was used.
2.4. Electronics noise and muon signal

Using the test-pulse system, the gains were measured to be 10 MeV/ADC for the preshower strips and 40 MeV/ADC for the middle and back samplings. The noise figures are respectively 15, 60 and 40 MeV (differences with 8 come from oscillations in the preamplifiers of the middle sampling). The cross-talk between adjacent U(V) strips was measured at the level of 2.5%.

Using muon data, the ratio of a mip signal to noise could be measured; summing the signal in two U and two V strips (chosen according to the beam impact), the ratio was found to be 3.3 (for a shaping time $\tau_s = 20\,\text{ns}$).

2.5. Conclusions on the construction

In summary, both design, construction and performances of the integrated UV preshower followed expectations: no major problem arose building the two sectors and the noise figures are as naively predicted; the operation of such a device is identical as of the calorimeter.

The design of the device could not be fully optimized as there were existing constraints from the already existing prototype: there was no massless gap, the overlap between cell definition and the kapton electrodes was odd (cf Fig. 1 and 3), the cross-talk was not studied in details.

Improvements are forseen for the HV connections between the middle and the preshower samplings and also a thinner summation system is under study as dead material before the calorimetr is critical for both energy and angular resolutions.

3. test-beam setup and analysis

3.1. Test-beam setup

The prototype was installed in the H8 beam at the CERN SPS; details about the installation can be found in 8. The integrated preshower covers the region 0.42 to 0.85 in rapidity and 0.31 to 0.47 in azimuth. Energy scans with electrons of energies 10, 20, 50, 100, 150, 200 and 300 GeV were performed at $\eta = 0.53$ and $\eta = 0.61$.

The analysis presented here concentrates on data at $\eta = 0.53$ where the amount of dead material before the active part of the calorimeter amounts to 1.4 $X_0$ (beam line, cryostat, dead LAr), the depth of the three samplings being 5.6, 14.6 and 9.1 $X_0$ from front to back.

3.2. Energy reconstruction and shower profile

The preshower sampling is thin enough to be used to correct for the shower energy loss in the dead material (cf Fig. 2). The EM shower is reconstructed, in the preshower sampling, as 11 strips around the strip with maximum energy for U and V strips independantly; in the middle sampling the cluster is 3 x 3 cells and 2 x 3 in the back sampling. The total energy is calculated as $E_{\text{total}} = \alpha(S_U + S_V) + S_{\text{middle}} + S_{\text{back}}$, where $S$ is the signal in the cluster for the given sampling, calibrated using the test-pulse system and the expected ionisation electrons yield in LAr. After corrections for the $\phi$ modulation (absorber vs electrodes) and the lateral leakage on the side of the cluster, the energy resolution for 300 GeV electrons is measured at $\frac{\Delta E}{E} = 0.9\%$ (cf Fig. 2), before unfolding the beam energy resolution contribution. This is comparable
to what will be published in 8 without a preshower.

The fine granularity can be used to measure the shower width after 7 $X_0$. On Fig. 3 is shown the shower profile measured with the V strips, for 200 GeV electrons, the beam spread unfolded. The fit of the distribution gives a measurement of the shower width of 4 mm.

**Fig. 3.**

![Shower Profile](image)

**Electrons 300 GeV**

- **a)** $\alpha = 1.11$
- **b)** $\Phi (\text{Unit Cell})$
- **c)** $\eta (\text{rod})$
- **d)** $\sigma_E = 2.8 \text{ GeV}$

**Fig. 2.** Energy reconstruction: a) $E_{\text{cluster}}^{\text{tot}}$ vs $E_{\text{cluster}}^{U+V}$; the slope is fitted to 1.1. b) $\phi$ modulation across a cell of the middle sampling (18.0 corresponds to the middle of the cell); the fitted curve is a sum of sinusoids. c) lateral leakage across a cell in $\eta$; the fitted curve is a parabola. d) $E_{\text{cluster}}^{\text{corrected}}$, the beam energy resolution has not been unfolded.

### 3.3. position resolution

The beam direction is measured with three MWPC 8 which resolution, both in $\eta$ and $\phi$ directions is between 250 and 300 $\mu m$. The shower position measured with the preshower is calculated as the energy weighted barycenter on three strips (one strip on each side of the strip with maximum energy) for both U and V; then $\eta = \frac{U+V}{2}$.
and $\phi = \frac{U-V}{2s}$ are calculated. Some geometrical corrections, illustrated by Fig. 3, are applied independently of the energy and relying only on the calorimeter. The beam chambers resolution is unfolded. The energy dependence of the position resolution in the $\eta$ direction (the relevant one for ATLAS) has been fitted between 10 and 200 GeV by the function:

$$\sigma_\eta = \frac{1.55 \pm 0.16}{E} + \frac{6.7 \pm 0.4}{\sqrt{E}} + 0.24 \pm 0.01 \text{ mm}.$$  

The value for the constant term is not yet understood; the cross-talk is probably one explanation. Work is going on to try to understand these numbers, in particular the difference between the measurement at 100 GeV of $\sigma_\eta = 360 \mu m$ and the prediction from a full Monte-Carlo simulation of 180 $\mu m$.

3.4. angular resolution

Using the preshower and the middle sampling, and knowing the level arm between the 2 samplings, one can compute the shower direction. The position in the middle sampling is computed also as the weighted baycenter in the $3 \times 3$ cluster. The level arm has been estimated by Monte-Carlo to be 10 cm. On Fig. 3 the energy dependence of the angular resolution is shown, together with the fitted function. The angular resolution in the $\eta$ direction is $8 \text{ mrad}$ at 50 GeV and better than $6 \text{ mrad}$ above 100 GeV.

4. Conclusions

The RD3 collaboration has built and operated with success an integrated UV preshower: no fundamental problem was encountered. It has been tested in July 94 with electrons of energies between 10 and 300 GeV and good performances were measured:

- The energy resolution is not degraded by the presence of the preshower.
- The position resolution in the $\eta$ direction is $380 \mu m$ for 50 GeV electrons, and better than $300 \mu m$ for energies above 100 GeV.
- The angular resolution, measured with the preshower and the middle sampling, is $8 \text{ mrad}$ at 50 GeV and better than $6 \text{ mrad}$ above 100 GeV.

Work is going on to understand better these numbers and to complete the analysis; the linearity, uniformity will be studied. Events with one $\gamma$ (with energy between 10 and 100 GeV) and one electron were taken in the UV preshower; their analysis should allow to measure the $\gamma \gamma$ separation and to estimate the $\pi^0$ rejection.
Fig. 3. a) The shower profile of a 200 GeV electron, measured in the preshower sampling using the V strips. The curve is the result of the fit of a function of the form \( \frac{1}{1 + (w/\phi)^2} \) where \( w \) is the width of the shower. \( w \) is found to be 0.8 which gives a width of 4 mm. b) Beam impact vs cluster position in \( \eta \) (radians). Two effects are visible: the clusterisation (only 3 strips are used) and barycenter definition "S-shape". c) \( \phi \) modulation; d) \( \eta_{\text{strip}} - \eta_{\text{beam}} \) in radians; e) the energy dependence of the angular resolution measured with the preshower and the middle sampling and a lever arm of 10 cm.
2. J. Collot for the RD3 collaboration, Performance of a high granularity preshower, contribution to this conference.
3. D. Lissauer, Precision Electromagnetic Calorimetry with Liquid Krypton, contribution to this conference.
5. D.M. Gingrich et al., The RD3 collaboration, Performance of a Large Scale Prototype of the ATLAS Accordion Electromagnetic Calorimeter, to be published in NIM.
7. D. Camin for the RD3 collaboration, Monolithic front-end electronic for the accordion LAr calorimeter, contribution to this conference.