Performance of the ATLAS Presampler Prototype of June 1996

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Abstract
A presampler prototype has been tested together with a liquid argon accordion shaped calorimeter in beam in June 1996. The presampler granularity was matching the calorimeter one and the presampler only provided for an energy measurement. In this note we present the energy resolution of the combined presampler-calorimeter system with different amounts of dead material upstream of the calorimeter. The uniformity of the presampler response in the $\eta$ and $\phi$ directions was also studied.
1 Introduction

During the summer of 1996 a presampler prototype was tested together with an accordion electromagnetic calorimeter prototype [1]. The presampler prototype had the following new characteristics compared to the previous one described in [2]:

- a coarse granularity $\Delta \eta \times \Delta \phi = 0.02 \times 0.08$,
- it had been assembled using the gluing technique selected for ATLAS.

The data taken during this beam test at CERN allowed the important features of the combined presampler-electromagnetic calorimeter device to be determined. The energy resolution reached by this device with electron beams at 200 GeV and 287 GeV and the uniformity of the presampler response in the $\eta$ and $\phi$ directions are presented in this note.

![Diagram](image)

**Figure 1:** Sketch of the two presampler modules tested in June 1996. Note that the modules are not at scale and in particular that the real ones were almost squares.

2 The Presampler Prototype of June 96

The June 1996 presampler prototype was composed of two modules each approximately 19 cm wide in $\phi$ and 24 cm long in $\eta$. The size of each module was made to match the calorimeter granularity. These modules had coarse granularity, obtained by grouping 8 elementary cells into one readout cell (see figure 1). The granularity in $\phi$ was two cells per module. The depth of the active layer was 10 mm, instead of the 11 mm planned for ATLAS.
3 The Calorimeter Prototype

The large scale accordion prototype is a cylindrical sector spanning 27° in \( \phi \) and 2 meters along the \( z \) axis which corresponds to the pseudorapidity range \( 0 \leq \eta \leq 1.08 \). The total thickness is \( 25X_0 \) at \( \eta=0 \), divided into three longitudinal compartments (front, middle and back) of \( 9X_0 \), \( 9X_0 \), \( 7X_0 \) respectively. The absorbers are made of lead plates (1.8 mm thick for \( \eta \leq 0.7 \) and 1.2 mm in the rest of the coverage) sandwiched in between two 0.2 mm stainless steel sheets to ensure a higher mechanical strength. The electrodes are multilayer copper-Kapton boards separated from the converter plates by a 1.9 mm liquid argon gap. Three consecutive kapton boards are grouped together in the same readout channel, giving an effective granularity \( \Delta \phi = 0.020 \), while the transverse segmentation \( \Delta \eta = 0.018 \) was obtained by etching projective strips on the conductive layer of the electrodes.

4 Beam Test Set-up

The 1996 tests used an electron beam provided by the SPS at CERN. The energies studied were 200 GeV and 287 GeV. Three beam chambers were installed in front of the calorimeter allowing to extrapolate the tracks of the particles into the calorimeter.

During the beam tests the two modules were mounted in front of the calorimeter as shown in figure 1 to cover 16 cells of the calorimeter in \( \phi \) and 8 cells in pseudo-rapidity from cell 26 to cell 34 in electromagnetic calorimeter cell numbers (from \( \eta=0.46 \) to \( \eta=0.62 \)). The whole detector was located in a cryostat filled with liquid argon.

The amount of dead material upstream of the presampler was 0.79 \( X_0 \) (mainly the cryostat wall) at \( \eta=0.60 \). To investigate the behavior of the presampler with larger amount of material in front, data has been taken with an additional 6 mm lead wall in front of the presampler. The resulting 1.87 \( X_0 \) of dead material thus simulates the amount of dead material found in ATLAS at \( \eta \approx 0.7 \).

5 Energy Resolution

To estimate the energy resolution, an event selection was applied to remove pion and muon events. The usual biasing effects, namely leakage due to the finite size of the cluster and \( \phi \)-modulation due to the accordion shape of the calorimeter [1] were corrected. Thereafter the combination of the signal in the calorimeter and the presampler is optimised to make the energy resolution as good as possible. The treatment of the data from the calorimeter (presampler) is described in section 5.1 (section 5.2) and the energy resolution obtained is presented in section 5.3.
5.1 Event Selection and Corrections

5.1.1 Event Selection

The following event selection were applied:

- Selection of beam particles events,

- Removal of pion and muon events: only events whose energy deposited in the calorimeter is above a certain threshold were used. This threshold was set to about 40 GeV below the energy peak in the calorimeter. Table 1 presents the energy threshold chosen for the different beam energies.

<table>
<thead>
<tr>
<th>Beam Energy</th>
<th>Peak Energy in the Calorimeter</th>
<th>Threshold Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>287 GeV</td>
<td>~ 260 GeV</td>
<td>220 GeV</td>
</tr>
<tr>
<td>200 GeV</td>
<td>~ 170 GeV</td>
<td>130 GeV</td>
</tr>
</tbody>
</table>

Table 1: Beam energy, corresponding peak energy observed in the calorimeter and corresponding threshold.

- Removal of the particles in the halo of the beam and the low statistics regions of the beam. The particles contained in the halo of the beam may have undergone some interactions or may have a slightly different energy. It is also necessary to cut the low statistics region of the beam since the distributions of energy versus $\eta$ and versus $\phi$ will be fitted and low statistics points lead to large uncertainty in the fits. The cuts on the halo and the low statistics regions of the beam are made by only accepting particles in a certain window in $\eta$, $\phi$. The $\eta$, $\phi$ position of the particle is given by three beam chambers upstream of the calorimeter which were used during the beam tests.

The position in the calorimeter could be calculated by using either the three beam chambers or only two beam chambers in cases where one beam chamber was not working correctly.

- Cuts on the time sum information given by the beam chambers. The signal induced by a particle propagates along the cathode wires and splits into two equal parts when it reaches the delay line. These two signals arrive at times $t_a$ and $t_b$ at the ends of the delay line. Thus $t_a-t_b$ gives the position of the particle and the $t_a+t_b$ distribution is a peak centered on a time proportional to the length of the delay line. This peak exhibits a tail corresponding to mismeasured events or events containing more than one particle due to an upstream reaction. These events are removed.

These cuts have been applied to only one beam chamber which was found to be working correctly in all cases. No improvement was observed when applying these cuts to more than one beam chamber.
Figure 2: Energy deposited in a 3×3 cluster of the electromagnetic calorimeter versus η given by the calorimeter before correction of the η-leakage (a), after correction of the η-leakage (b). Energy deposited in a 3×3 cluster of the electromagnetic calorimeter versus φ given by the calorimeter before φ-correction (c) and after φ-correction (d). These data are from 287 GeV electrons, and the energy is normalized to the mean energy of the events remaining after the cuts described in section 5.1.1. The η coordinate used in these plots is relative to the center of the cell and the φ coordinate is in calorimeter cell number.
<table>
<thead>
<tr>
<th>Treatment Stage</th>
<th>287 GeV $e^-$</th>
<th>200 GeV $e^-$</th>
<th>200 GeV $e^-$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Treatment</td>
<td>(1.79±0.04)%</td>
<td>(1.94±0.04)%</td>
<td>(1.35±0.05)%</td>
</tr>
<tr>
<td>+ Cuts</td>
<td>(1.40±0.09)%</td>
<td>(1.57±0.06)%</td>
<td>(1.11±0.03)%</td>
</tr>
<tr>
<td>+ $\eta$ and $\phi$ corrections</td>
<td>(0.83±0.04)%</td>
<td>(1.20±0.07)%</td>
<td>(1.02±0.03)%</td>
</tr>
<tr>
<td>+ Presampler</td>
<td>(0.75±0.05)%</td>
<td>(0.89±0.04)%</td>
<td>(0.87±0.04)%</td>
</tr>
</tbody>
</table>

Table 2: Energy resolution $\sigma_{E}$ at the different stages of the analysis. The errors are at most overestimated by 0.015 because of the rounding and the non computation of the covariance of $\sigma$ and $<E>$. The covariance is less or equal than the error on $\sigma$ times the error on $<E>$.

5.1.2 Corrections

Corrections [1] are applied for the $\eta$-leakage and $\phi$-leakage due to the shower noncontainment and the $\phi$-modulation due to the accordion geometry [9] (cf figure 2). The $\eta$-leakage is corrected for by fitting a parabola to the curve of the energy deposited in the calorimeter versus $\eta$ given by the calorimeter. The $\phi$-modulation and $\phi$-leakage are corrected using the following expression:

$$f(\phi) = p_1 \sin(6\pi\phi + p_3) + p_2 \sin(12\pi\phi + p_4) + p_5 (\phi - \text{int}(\phi + 0.5))^2 + p_6$$

which is the sum of a leakage correction and a modulation correction. Here the $\eta$ and $\phi$ considered are the position of the barycenter of the shower in the first sampling layer of the calorimeter in cell units. These corrections allow significant improvement of the energy resolution since typically the energy resolution for events at 287 GeV is around 1.4% after the cuts and between 0.9% and 0.8% after the $\eta$ and $\phi$ corrections as shown in table 2.

Another parameter of importance in the analysis is the cluster size in the calorimeter. In the following a $n \times m$ cluster refers to a cluster made of $n$ cells in $\eta$ and $m$ cells in $\phi$. Two sizes of calorimeter clusters were used in this analysis:

- 3x3 cells in the two first sampling layers and 2x3 cells in the third sampling layer which has a coarser granularity in $\eta$,
- 5x5 cells in the two first sampling layers and 3x5 cells in the third sampling layer.

The results obtained with the two sizes of clusters are compared in table 3.

It appears that for data taken with 0.79 $X_0$ material upstream of the calorimeter the energy resolution is not affected by the size of the cluster (see comparison between 3x3 and 5x5 cluster in table 3).

With 1.87 $X_0$ material before the calorimeter and a 3x3 cluster the energy resolution is slightly worse than with a 5x5 cluster. It also appears that the ratio between the energy
Table 3: Energy resolution $\Gamma\_{\gamma}$ at 200 GeV with 0.79 $X_0$ and 1.87 $X_0$ and at 287 GeV with 0.79 $X_0$ obtained with 3x3 and 5x5 clusters. The errors are at most overestimated by 0.015 because of the rounding and the non computation of the covariance of $\sigma$ and $<E>$.

<table>
<thead>
<tr>
<th>Cluster size</th>
<th>200 GeV 0.79 $X_0$</th>
<th>200 GeV 1.87 $X_0$</th>
<th>287 GeV 0.79 $X_0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3x3 cluster</td>
<td>(0.90±0.05)%</td>
<td>(0.99±0.04)%</td>
<td>(0.75±0.05)%</td>
</tr>
<tr>
<td>5x5 cluster</td>
<td>(0.87±0.04)%</td>
<td>(0.89±0.04)%</td>
<td>(0.76±0.06)%</td>
</tr>
</tbody>
</table>

Figure 3: Energy deposited in the presampler cluster (3 cells in $\eta$) by 200 GeV electrons, with 0.79 $X_0$ of upstream material (on the left) and 1.87 $X_0$ of material (on the right). The noise and the electron signals have been normalised to the same number of events.

deposited in the 3x3 cluster and the energy deposited in the whole calorimeter decreases by more than 1% when the 6 mm lead wall is added, while the ratio between the energy deposited in the 5x5 cluster and the energy deposited in the whole calorimeter is constant.

This can be explained by the large distance between the lead wall and the calorimeter (about one meter) which leads to a larger transverse extension of the shower. The 3x3 cluster was not sufficient to reconstruct the energy with a resolution better than $\sim$1.0% for data taken with 1.87 $X_0$ material upstream of the calorimeter.

5.2 Signal from the Presampler

The last step toward the optimal energy resolution is the use of the presampler signal in an optimised combination with signals from the three sampling layers of the electromagnetic calorimeter. It is therefore necessary to make sure that the presampler gives a usable signal (figure 3), corresponding to the energy deposition.

5.2.1 Energy Scale in the Presampler

To compute the energy scale one considers a minimum ionising particle (MiP) going through the presampler. A MiP is an imaginary particle which loses energy only by ionisation and whose energy loss per unit length is equal to the minimum average value for the material concerned. A MiP deposits an energy of 2.11 MeV/cm in liquid argon. The resulting current is calculated [3]. Each presampler cell is pulsed with current pulses of
Runs at 287 GeV, $\phi=6.3$ and 200 GeV, $\phi=5.7$

<table>
<thead>
<tr>
<th>$\eta$-cell</th>
<th>29</th>
<th>30</th>
<th>31</th>
<th>32</th>
<th>33</th>
<th>34</th>
</tr>
</thead>
<tbody>
<tr>
<td>287 GeV</td>
<td></td>
<td></td>
<td>0.74±0.04</td>
<td>0.78±0.04</td>
<td>0.75±0.05</td>
<td>0.77±0.04</td>
</tr>
<tr>
<td>200 GeV</td>
<td>0.89±0.04</td>
<td>0.90±0.04</td>
<td>0.89±0.04</td>
<td>0.90±0.04</td>
<td>0.89±0.03</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Energy resolution $\sigma_E$ in % for 200 and 287 GeV electrons. Note that the 200 GeV data (287 GeV) were taken with 1.87 (0.79) radiation length of material upstream of the presampler. The errors are at most overestimated by 0.015 because of the rounding and the non computation of the covariance of $\sigma$ and $<E>$. 

defined amplitudes equivalent to a certain number of MiPs. The response of the presampler cell is measured and gives the conversion between the energy in MeV and the cell response measured in number of Analog to Digital Converter (ADC) counts.

5.2.2 Clustering in the Presampler

A clustering algorithm based on selecting the cell with the largest energy can easily pick up a noisy cell and artificially produce a cluster. Therefore a cluster based on the presampler cell pointed to by the beam chambers was used. For runs with 0.79 $X_0$ of upstream material where the presampler signal was small (average smaller than $\sim 20$ MeV) only a small $\eta$ and $\phi$ range was illuminated by the beam and a single cell was used as the cluster. This gave a better signal to noise ratio for the study of the presampler performance. Beam particles not hitting clearly within a single presampler cell were removed.

With 1.87 $X_0$ of upstream material the shower is wider as explained in section 5.1.2. It also results in a larger presampler signal with an average energy signal of about 80 MeV, well separated from the noise. In this case a large $\eta$ range was scanned by the beam and the regions between cells were also studied. Therefore a 3-cell cluster consisting of the cell pointed to by the track and its two neighbours in $\eta$ was used.

5.3 Energy Resolution

The final energy is

$$E = k(\alpha E_{PS} + \beta E_1 + E_2 + E_3)$$

where $E_1$, $E_2$, $E_3$ are the signals from the three sampling layers of the electromagnetic calorimeter and $E_{PS}$ is the signal from the presampler. The coefficients $\alpha$ and $\beta$ are optimised to achieve the best energy resolution. The parameter $k$ is a global calibration factor which does not affect the energy resolution.

The coefficients $\alpha$, $\beta$ are optimised by a FORTRAN program using MINUIT routines for minimisation [8]. The minimisation is done with respect to $\frac{\sigma_E}{E}$. The table 5 shows the optimised coefficients for different positions and different energies. The energy resolution is obtained by fitting a Gaussian to the distribution of the final energy $E$ between $<E>$ $\pm 2\sigma$.

The energy resolution is given in tables 3 and 4 for different energies, positions, calorimeter clusters and amounts of material in front of the presampler.
Figure 4: Total energy deposited in the electromagnetic calorimeter versus the energy deposited in the third sampling layer of the calorimeter ($E_3$). Here the nominal beam energy is 287 GeV and $\eta=33$. The total number of events on this plot is 2144 while the number of events below 260 GeV is 19 events.

5.3.1 Energy Leakage

In equation 1 a third coefficient in front of the energy deposited in the third sampling layer ($E_3$) is sometimes used to compensate a possible energy leakage through the rear face of the electromagnetic calorimeter. The energy leakage is expected to be small at large $\eta$ where the presampler is located. Furthermore an energy leakage would cause a decrease of the total energy deposited in the calorimeter for events with large energy deposit in the third sampling layer. Plots of the total energy deposited in the calorimeter versus the energy in the third sampling layer ($E_3$) (cf figure 4) show a slight decrease of 7-10 GeV in the third layer, but the decrease is not statistically significant. Therefore the coefficient to weight the energy deposited in the third sampling layer was always equal to 1.

5.3.2 Comparison with 1995 Data

The values of the energy resolution can be compared to previous results obtained with an earlier prototype tested in 1995 [10]. The energy resolution quoted was:

$$\frac{\sigma}{E} = \frac{(11.2\pm0.2)\%}{\sqrt{E}} \oplus \frac{0.282 GeV}{E} \oplus (0.26\pm0.04)\%$$

(2)

at $\eta$ equal 0.59, with 0.79 $X_s$ of material. From this the expected energy resolution at 200 GeV and 287 GeV without the additional 6 mm of lead can be computed. The energy resolution expected at $\eta=33$, 287 GeV is $(0.78 \pm 0.03)\%$ and the energy resolution measured in this analysis is $(0.75 \pm 0.05)\%$. At 200 GeV the expected energy resolution at the same $\eta$-position is $(0.90 \pm 0.03)\%$ and the measured energy resolution is $(0.87 \pm 0.03)\%$. The 1996 results are in good agreement with the 1995 results. Note that the contribution
of the momentum spread of the beam has been substracted in the data presented in this work as well as in the results of the 1995 tests.

It must be pointed out that the presampler well fulfils its task when the amount of material upstream of the calorimeter increases. As it is shown in table 2 the energy resolution of the electromagnetic calorimeter alone is worsened by \( \sim 0.2\% \) with the lead wall at 200 GeV. However, after the use of the presampler with optimised coefficients, the energy resolution is identical within the statistical errors.

### 6 Uniformity

#### 6.1 Scan of the Presampler in \( \eta \)

A position scan in the \( \eta \) direction of the presampler over 5 readout cells, with 200 GeV electrons and 1.87 \( X_e \) of material upstream of the presampler was carried out. These data allow the uniformity of the presampler response in the \( \eta \) direction to be verified. The presampler signal was taken to be the energy deposited in the cell pointed to by the beam chambers plus the energy of the closest two neighbour cells. To scan the calorimeter-presampler system over 5 adjacent readout cells the cryostat was moved to five different positions.

#### 6.1.1 Coordinate System

The physical granularity of the presampler in the \( \eta \) direction is 0.125 of a readout cell. A position resolution better than 0.125 is therefore required to study the uniformity of the presampler response at the scale of the physical cells.

Two position informations are available:

- The position measured with the calorimeter, by computing the barycenter of the cell cluster. The position given by the calorimeter is biased by the so called S-shape due to the discrete structure of the calorimeter.
- The position measured by the beam chambers. The beam chambers have a position resolution of about 0.3 mm.

<table>
<thead>
<tr>
<th>( \eta )-position</th>
<th>200 GeV 1.87 ( X_e ), ( \phi=5.7 )</th>
<th>200 GeV 0.79 ( X_e ), ( \phi=5.7 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>31.6 35.4 31.9 30.4 32.7</td>
<td>25.0</td>
</tr>
<tr>
<td>( \beta )</td>
<td>1.025 0.942 1.04 1.01* 1.024</td>
<td>1.02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>( \eta )-position</th>
<th>287 GeV 0.79 ( X_e ), ( \phi=6.3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>22.2 30.4 33.2 30.5</td>
</tr>
<tr>
<td>( \beta )</td>
<td>1.03 1.00* 1.02 0.99</td>
</tr>
</tbody>
</table>

**Table 5:** Optimised coefficients \( \alpha, \beta \) for different positions and energies. The stars mean that these coefficients were determined by a “handmade” optimisation in case where the minimisation routine only found a local minimum.
The position given by the beam chambers is extrapolated into the calorimeter knowing the position of the cryostat and the calorimeter. The position of the cryostat which is moved by a motor is given by an encoder. The encoder translates the movement of the motor into the position of the cryostat. The errors on the position of the calorimeter, the beam chambers and the position given by the encoder implies that the position extrapolated from the beam chambers into the calorimeter ($\eta_{bc}$) is shifted and scaled with respect to the true position ($\eta_{true}$). As a matter of fact it appears that one cell in the calorimeter ($\Delta\eta_{calo}=1$) corresponds to less than one unit in the coordinates computed with the beam chambers (typically $\Delta\eta_{bc}=0.95$ for one cell in the calorimeter). There is a linear relation (to a good approximation) between the true position ($\eta_{true}$) and the position given by the beam chambers ($\eta_{bc}$):

$$\eta_{true} = \alpha + \beta \eta_{bc}$$  \hspace{1cm} (3)

where $\alpha$ is an offset and $\beta$ is a scale factor.

To study the uniformity of the presampler response, the presampler energy is plotted versus the “true” position. The true position is based on $\eta_{bc}$ corrected for the offset and the scale factor. Because of the movement of the calorimeter, $\alpha$ and $\beta$ are computed for each position of the calorimeter in the following manner.

For each cryostat position $\eta_{bc}$ is plotted versus $\eta_{calo}$ (see figure 5). The beam spot only covers slightly more than a half calorimeter cell. Therefore it is necessary to parametrise $\eta_{bc}$ versus $\eta_{calo}$ to be able to compute a correspondence between them at the middle and the edges of a calorimeter cell. $\eta_{bc}$ versus $\eta_{calo}$ is fitted with a S-shape function \cite{1, 7}:

$$f(\eta_{calo}) = a_1 + a_2 \text{int}(\eta_{calo} + 0.5) +$$

$$\frac{a_2}{2 \arctan \frac{a_3}{2}} \arctan \{ a_3 (\eta_{calo} - \text{int}(\eta_{calo} + 0.5)) \}$$  \hspace{1cm} (4)

The position at the center of a calorimeter cell given by the calorimeter itself is called $\eta_{calo}^{Center}$ and the same position given by the beam chambers is called $\eta_{bc}^{Center}$. $\Delta\eta_{bc}$ is the width of a calorimeter cell when measured with the beam chambers.

With these notations we have $\eta_{bc}^{Center} = f(\eta_{calo}^{Center})$ and $\Delta\eta_{bc} = f(\eta_{calo}^{Right})-f(\eta_{calo}^{Left})$ where $\eta_{calo}^{Right}$ and $\eta_{calo}^{Left}$ are the coordinates given by the calorimeter for the right and left edges of a calorimeter cell respectively and $f$ is the S-shape function given by equation 4. $\eta_{true} = \eta_{calo}$ at the middle and the edges of a calorimeter cell where there is no S-shape. With relation 3 this gives:

$$\eta_{true} = \eta_{calo} + \frac{\eta_{bc} - \eta_{bc}^{Center}}{\Delta\eta_{bc}}.$$  \hspace{1cm} (5)

6.1.2 Accuracy on $\eta_{true}$

The error on $\eta_{true}$ comes from the beam chamber resolution, the calorimeter position resolution at the center of a calorimeter cell (less than 0.012 cells according to \cite{1}) and from the estimation of $\eta_{bc}^{Center}$ and $\Delta\eta_{bc}$, as shown in table 6. The final error on $\eta_{true}$ has

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*The difference between the formula used here and the one given in the references comes from a continuity condition which has been imposed here. This allows one coefficient to be dropped.
Figure 5: $\eta$ given by the beam chambers ($\eta_{bc}$) versus $\eta$ given by the calorimeter ($\eta_{Calo}$) for one run at 200 GeV and $1.87X_0$ of material in front of the cryostat. The solid line shows the result of the fit with a S-shape function. The dashed line is the part of the function which has not been fitted to the data because of the lack of statistics in this region.
been computed in two cases: assuming that all errors are uncorrelated, assuming that all errors are maximally correlated. The final error is in the range 0.08 to 0.14 readout cell. The position resolution achieved here is about or slightly worse than the position resolution required to study the presampler granularity.

The main part of the error comes from the estimation of $\eta^{\text{Center}}_{bc}$ and $\Delta\eta_{bc}$. These parameters are not accurately estimated because of the lack of statistics and the narrowness of the beam spot in the calorimeter cell.

To allow a better precision on $\eta_{\text{True}}$ it would be necessary to have a beam spot as large as a calorimeter cell and a larger number of events. Those improvements would allow more precise estimation of $\eta^{\text{Center}}_{bc}$ and $\Delta\eta_{bc}$ which are the principal sources of errors on $\eta_{\text{True}}$.

Figure 6 shows the energy deposited in a presampler cluster consisting of three cells in $\eta$ by a beam of 200 GeV electrons at three different positions. The presampler energy in three cells is plotted versus $\eta_{\text{True}}$ in figure 7. No cut is applied on the presampler energy. Electron events are chosen by requiring an energy in the calorimeter larger than 130 GeV. The events hitting the wrong presampler module in $\phi$ are cut. The spread of the response over 40 physical cells is 5.9 MeV.

<table>
<thead>
<tr>
<th>Source of error</th>
<th>Contribution (in readout cell)</th>
</tr>
</thead>
<tbody>
<tr>
<td>beam chambers</td>
<td>0.010</td>
</tr>
<tr>
<td>calorimeter at the center of a cell</td>
<td>0.012</td>
</tr>
<tr>
<td>estimation of $\eta^{\text{Center}}_{bc}$</td>
<td>0.050</td>
</tr>
<tr>
<td>estimation of $\Delta\eta_{bc}$</td>
<td>0.100</td>
</tr>
</tbody>
</table>

**Table 6:** The different contributions to the error on $\eta_{\text{True}}$. The total error on $\eta_{\text{True}}$ is calculated according to the dependency of $\eta_{\text{True}}$ on $\eta_{bc}$, $\eta^{\text{Center}}_{bc}$, $\Delta\eta_{bc}$ and $\eta^{\text{Center}}_{Calo}$ according to the formula 5.

### 6.1.3 Increase of the Deposited Energy with $\eta$

When the cryostat is moved so that a higher $\eta$ position of the presampler is illuminated by the beam, the path length in liquid argon increases. The energy deposited in the presampler and therefore the presampler response are proportional to this length. An increase of the energy deposited in the presampler is thus expected. One finds that the presampler response should raise for this reason by 5.1 MeV over the five cells or by $\sim$ 1.0 MeV per cell.

A fit to the data in figure 7 with a straight line gives a slope of $-1.0 \pm 0.5$ MeV/cell which is not compatible with the expected increase. The slope is clearly not seen.
Figure 6: Energy distribution in a 3×1 presampler cluster for three different η positions, at $\phi_{\text{Calo}}=5.7$, with a beam energy of 200 GeV and $1.87X_0$ of material in front of the presampler.

Figure 7: Average energy in a 3×1 presampler cluster as a function of $\eta_{\text{true}}$ over 5 presampler cells at $\phi_{\text{Calo}}=5.7$, with a beam energy of 200 GeV and $1.87X_0$ of material in front of the presampler.

6.2 Scan of the Presampler in $\phi$

A position scan of the presampler in the $\phi$ direction over 5 presampler cells, with 287 GeV electrons and $0.79X_0$ of material upstream of the presampler has been carried out allowing the uniformity of the presampler in the $\phi$ direction to be checked (cf figure 8). The $\phi$ coordinate chosen in the presampler is the position given by the beam chambers.

As shown in figure 8 there is an increase in the average presampler signal well above the noise, around the position $\phi = 2.7$ in presampler cell units. This increase suggests that there was an additional amount of material in front of the presampler in this region.
The increase of energy in the presampler is confirmed by the figure 9 which shows the energy deposited in the calorimeter.

The events depositing more energy in the presampler give less signal in the calorimeter, indicating that the increase in the energy in the presampler is not a defect and confirms that the electrons lose a certain amount of energy before the presampler, probably due to some additional amount of material in the cryostat wall.

The standard deviation of the presampler signal in a position range not affected by the increase of signal at $\phi=2.7$ (1.5 $\leq \phi \leq 2.2$ in presampler cell units) is 2 MeV.

![Figure 8: Average energy deposited in the presampler as a function of the $\phi$ position. The boundary between the 2 presampler modules is located at $\phi_{BeamChamber}=2.5$ (in presampler cell units). This plot was made using the data from 5 different runs, not always with the same number of events and not providing a perfect coverage of the presampler in $\phi$, the error bars are therefore varying. These data were taken at 287 GeV, $\eta_{Calo}=32$ and 0.79 $X_0$. The dashed lines represent the limits of the domains called “events near” and “events far” from the peak. The boxes near the $\phi$ axis show the representation of these domains used in the figure 9.](image)

7 Conclusion

The primary aim of this study was to estimate the energy resolution of the combined presampler-electromagnetic calorimeter system. The data taken during the summer of 1996 shows that this system achieves an energy resolution of 0.77% at 287 GeV and 0.90% at 200 GeV. These values are consistent with the data taken in 1995. A comparison of the energy resolution reached with and without additional material upstream of the presampler shows that the presampler well fulfils its task to compensate for the energy lost in the material before the electromagnetic calorimeter.

The uniformity of the presampler response at the scale of the physical cells has been studied. It can be characterised by a standard deviation of 5.9 MeV over 40 physical cells.
These plots show the energy deposited in the presampler and calorimeter by events with $2.6 \leq \phi_{BeamChambers} \leq 2.95$ or $2.75 \leq \phi_{BeamChambers} \leq 2.9$ (white histogram) and for events with $2.65 \leq \phi_{BeamChambers} \leq 2.75$ (squared histogram).

or 5 readout cells. The slope due to the increase of path length in liquid argon is not visible.

To achieve a more accurate measurement of the uniformity of the presampler at the scale of the physical cells it is necessary to have a larger beam covering the width of one calorimeter cell, and a larger number of events to allow a precise fit of the position given by the beam chambers versus the position given by the calorimeter.

The position scan in $\phi$ exhibits a significant increase in the energy deposited at $\phi=2.7$ (presampler cell units). The calorimeter data confirms that there was an additional amount of material in front of this region. This extra amount of material could come from the cryostat wall. Far from the peak the standard deviation of the energy deposited versus $\phi$ over 0.7 presampler $\phi$-cell (0.056 in $\phi$) is 2 MeV.
References


