The SCintillator-ECAL Beam Test  
at DESY, 2007  
— Update 1 —  

The CALICE collaboration

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Abstract

A beam test of the SCECAL prototype module was performed in the period Feb 26 - Mar 28 2007 using 1-6 GeV positron beams at the DESY-II electron synchrotron.  

This is an update of a previous note [1], presenting the results of further analysis of the collected data, mainly the results of position scans with MIP and EM shower events and a comparison of the three detector configurations.  

The results presented in this note will be shown at the 2007 ALPCG meeting at FNAL.
1 Introduction

This note should be read in conjunction with [1]. It describes further progress in the analysis of the data collected at the SCECAL testbeam at DESY in 2007. The alignment of the tracking is described. The performance of the three detector configurations are compared. The tracking system is then used to study the position dependence of the detector response to MIPs and positron showers.

2 Trigger requirements

The selection applied to the trigger and veto counters (TC1, TC2, VC1, VC2) were similar to those used previously [1], and was based on the signals read by the PMTs attached to the counters. It is designed to select events in which a MIP passed through the entire detector without showering. The requirements on PMT ADC counts are summarised below.

<table>
<thead>
<tr>
<th>TC1 R</th>
<th>TC2 R</th>
<th>VC1 U</th>
<th>VC1 D</th>
<th>VC2 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 1300</td>
<td>≥ 1500</td>
<td>≤ 810</td>
<td>≤ 970</td>
<td>≤ 850</td>
</tr>
</tbody>
</table>

3 Alignment of drift chambers

The tracking system consists of four drift chambers, each of which measure the beam position in the $x$ and $y$ directions, giving a total of 8 measurements. Drift chamber “3” is that closest to the ECAL detector, “0” is that furthest away (i.e. most upstream). The tracking detectors have been aligned by an optical survey to a nominal accuracy better than 1 mm.

The high voltage applied to the four chambers was not necessarily equal, so the drift velocity also needed to be measured. The $x$ and $y$ measurements in each chamber are made in the same gas volume, with the same applied voltage, so the drift velocity was assumed to be the same for the two measurements.

TDC distributions in typical triggered events for these eight channels are show in Fig. 1. There is often more than one signal measured per channel. We assume that the first signal on each wire is that due to the charged particle, while other signals are mainly due to “after-pulses”. The $y$ measurement of chamber 3 is seen to be very noisy.

We select events from a few runs taken with a 6 GeV/c positron beam: this is the highest energy beam used, minimising the effect of multiple scattering. We require most channels to have registered exactly one hit, except for the $x$ measurement in chamber 0, and the $y$ measurements in chambers 1 and 3.
Figure 1: Number of hits per event on each drift chamber wire. Top row: wire measuring the $x$-coordinate in chambers 0 → 3, bottom row: wire measuring the $y$-coordinate in chambers 0 → 3.

which we require at least one hit, since these channels are seen to be rather noisy and often register more than one hit. In the case of multiple hits in these channels, we consider only the earliest one. The number of selected tracks considered is about 30k.

Since the sense wires are placed in opposite ends of the chamber in successive chambers, we assume the sum of the $x$ ($y$) drift distances in adjacent chambers is constant, assuming negligible beam divergence. Assuming that the drift velocities in the different chambers are similar, we also expect the sum of the drift times in adjacent chambers to be approximately constant. In Fig. 2 we show the distribution of the sum of drift times in adjacent chambers. Based on these plots, we make an additional selection, removing events where an incorrect hit time has been measured. A significant “tail” is observed in distributions involving the $y$ measurement of chamber 3, which is removed by this cut. The tails in other distributions are much smaller.

We now plot the correlation between the $x$ ($y$) drift times in adjacent chambers. This allows us to extract the drift velocities in the following way:

$$W_{eff} = d_\alpha + d_\beta$$
where $d_i$, $t_i$ and $v_i$ are respectively the drift distance, drift time and drift velocity in chamber $i$, and $W_{eff}$ is the effective total drift distance, i.e. the chamber width modified by the relative misalignments of the two chambers. A plot of $t_β$ versus $t_α$ will therefore have the ratio of the two drift velocities as its gradient, and the effective total drift distance divided by $v_β$ as its intercept. Assuming that the initial misalignments are small with respect to the chamber width (as expected: $≈ 1\text{mm}$ vs. $72\text{mm}$), we assume that $W_{eff}$ is always equal to the total drift distance, $72\text{mm}$.

This allows us to fit for each drift velocity four times, using the two different combinations of different polarity chambers, separately in the $x$ and $y$ measurements. The velocities calculated are shown in table 1. The multiple measurements of each drift velocity agree to better than 5%. The reasons for the remaining discrepancies is not clear, but may be due to the ignored misalignments. In this analysis we take the average of the four measurements of each drift velocity.

We now measure the misalignments of the chambers. Since we are only concerned with the relative alignment of the four chambers, we take two chambers to be fixed, and align the remaining two with respect to them. Ideally we would use
Table 1: The fitted velocities and misalignments of the drift chambers.

<table>
<thead>
<tr>
<th>chamber</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>velocities [mm/ns]</td>
<td>0.0331</td>
<td>0.0315</td>
<td>0.0327</td>
<td>0.0285</td>
</tr>
<tr>
<td></td>
<td>0.0345</td>
<td>0.0310</td>
<td>0.0318</td>
<td>0.0296</td>
</tr>
<tr>
<td></td>
<td>0.0331</td>
<td>0.0320</td>
<td>0.0313</td>
<td>0.0292</td>
</tr>
<tr>
<td></td>
<td>0.0345</td>
<td>0.0322</td>
<td>0.0321</td>
<td>0.0299</td>
</tr>
<tr>
<td>average velocity</td>
<td>0.0338</td>
<td>0.0317</td>
<td>0.0320</td>
<td>0.0293</td>
</tr>
<tr>
<td>misalignments [mm]</td>
<td>0</td>
<td>-0.09</td>
<td>-2.13</td>
<td>0</td>
</tr>
<tr>
<td>x</td>
<td>0</td>
<td>-0.40</td>
<td>-1.63</td>
<td>0</td>
</tr>
</tbody>
</table>

the first and last chambers, which have opposite polarity and are separated by
the greatest distance, however chamber 3 did not operate so well. We therefore
consider chambers 0 and 1 to be fixed, and determine the relative misalignments
of chambers 2 and 3.

To reconstruct a track, we perform a straight line fit to the four measurements
in \( x \) (\( y \)), assuming the previously determined drift velocities and some assumed
misalignments, and calculate the \( \chi^2 \) of the fit in \( x \) and \( y \), assuming some arbitrary
position measurement error, taken to be equal for all measurements. We sum the
\( \chi^2 \) of a large sample of tracks. We vary the assumed misalignments, minimising
this \( \chi^2 \) to determine the true misalignments of the chambers. The results of this
procedure are reported in table 1.

A number of cross checks of this alignment procedure were performed. Figure
3 shows the track residuals before and after this alignment, showing that the
alignment procedure has indeed reduced the track residuals, as expected. The
dependence of the residuals on the drift time in the different channels is shown
in figure 4. This distribution is expected to be flat. Some non-flat regions
are observed towards the chamber edges, probably due to the non-uniform drift
velocity in this region. We do not make explicit cuts on these regions, however
the large majority of tracks are not affected, since the beam is quite well centred
in the drift chambers, and the beam’s width is relatively small. Other than this,
the distributions look flat on the scale of a few 100\( \mu \)m, sufficient for our purposes.

In later analysis, we discard the \( y \) measurement of the third chamber, which is
rather noisy. The distributions of the number of track hits, the track \( \chi^2 \) and the
distributions and slopes of the beam in \( x \) and \( y \) in triggered events are shown in
Fig. 5. We apply the following track selection in the analysis: at least 3 hits in
both the \( x \) and \( y \) directions, and a track fit \( \chi^2 \) of less than 15 (3) in \( x(y) \).
4 Alignment of the calorimeter detector to the tracking system

To align the calorimeter to the drift chambers, we examine data taken without absorber plates. We consider each layer of the calorimeter in turn, looking for cases in which the (pedestal subtracted) MPPC signal is greater than 100 in exactly one of the 18 strips in that layer. The pedestal width is around 18, so this selects events in which it is clear through which strip the MIP passed. By considering the distribution of the track position (as determined by the drift chambers and the reading from the movable stage) separately in each strip, we can align each layer of the detector with the tracking system. We assume that the calorimeter is internally perfectly aligned, and measure its shift and tilt with respect to the drift chamber reference frame. We estimate the accuracy of the position determination by considering the RMS of the strip position measurements in a single layer. The measured tile angle is rather small, around $0.36^\circ$ in $x$ and $0.15^\circ$ in $y$. 
Figure 3: Track residuals before (black) and after (red) alignment, in the eight channels. Upper row: $x_0 \rightarrow x_3$, lower row: $y_0 \rightarrow y_3$. 

- **initial_residual_x_0**: Entries 29569, Mean 1.157, RMS 1.164
- **initial_residual_x_1**: Entries 29569, Mean -0.6019, RMS 0.8487
- **initial_residual_x_2**: Entries 29569, Mean -0.2536, RMS 0.7063
- **initial_residual_x_3**: Entries 29569, Mean 0.881, RMS 0.9273
- **initial_residual_y_0**: Entries 29569, Mean 0.9745, RMS 1.207
- **initial_residual_y_1**: Entries 29569, Mean -0.373, RMS 0.8273
- **initial_residual_y_2**: Entries 29569, Mean -0.4703, RMS 0.7784
- **initial_residual_y_3**: Entries 29569, Mean 0.9967, RMS 1.058
<table>
<thead>
<tr>
<th>Drift Time [ns]</th>
<th>Residual [mm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>-4</td>
</tr>
<tr>
<td>900</td>
<td>-2</td>
</tr>
<tr>
<td>1000</td>
<td>0</td>
</tr>
<tr>
<td>1100</td>
<td>2</td>
</tr>
<tr>
<td>1200</td>
<td>4</td>
</tr>
</tbody>
</table>

### Mean

- **x0**
  - Mean x: 949 mm
  - Mean y: -0.001506 mm
  - RMS x: 65.59 mm
  - RMS y: 1.175 mm

- **x1**
  - Mean x: 1292 mm
  - Mean y: -0.0006933 mm
  - RMS x: 73.94 mm
  - RMS y: 0.8486 mm

- **x2**
  - Mean x: 973.6 mm
  - Mean y: 0.009252 mm
  - RMS x: 78.06 mm
  - RMS y: 0.7083 mm

- **x3**
  - Mean x: 1382 mm
  - Mean y: -0.03372 mm
  - RMS x: 91.66 mm
  - RMS y: 0.9403 mm

### Figure 4: Track residuals vs. drift time in the eight channels. Upper row: $x_0 \rightarrow x_3$, lower row: $y_0 \rightarrow y_3$. 
Figure 5: Track parameters after alignment. Upper: number of hits (left) and track fit $\chi^2$ (right); Lower: track position (left) and slope (right).

Figure 6: First configuration alignment of calorimeter to tracking detectors. Left plot shown the track position distributions when different strips of a particular layer have been hit. The centre (right) plot shows the reconstructed position of a fixed point on each of the detector layers in $x$ ($y$), showing the small slope of the detector.
5 MIP event selection

This section describes the selection of events in which a positron passed through a particular strip, in cases where no absorber plates were in the detector.

We first require that the reconstructed track intersects the strip in question. We then also require that almost all similar strips in the other detector layers with the same polarity have registered a MPPC signal inconsistent with the pedestal (at least 80 ADC counts above pedestal); we allow no more than two such strips not to satisfy this condition, excepting known dead strips. We also require that no other strips in the same layer as the strip being considered have a MPPC signal greater than 80 ADC counts above pedestal.

6 Calibration

We consider strips selected by the above MIP selection, and use the reconstructed track to determine which part of the strip was hit by the positron. We split the strip into five regions, each of length 9mm, along the length of the strip. We consider the distribution of the MPPC signal in each of these regions.

We fit these distributions with a Gaussian–convoluted Landau distribution, and extract several values:

- the mean of the underlying ADC histogram, calculated in the range 0 → 1000 ADC counts (“mean”);
- the most probable value of the Landau component of the fitted function (“MPV”);
- the most probable value of the full, convoluted, fitted function (“peak”).

We test the use of different values as calibration constants: the mean, MPV or peak measured in the central region of the strip; or the average of the mean, MPV or peak in the five strip regions.

We then used these calibration constants to reconstruct the energy of EM showers in the detector (now with absorber plates). Events in which the beam was directed at the centre of the detector were used, and the energy response linearity and the energy dependence of the resolution were measured. To reconstruct the energy deposited in a particular strip, we simply divide the pedestal–subtracted signal by the calibration constant for that strip. The total energy deposited in the calorimeter is the obtained by summing this over all strips, giving an energy in units of “MIP-equivalents”.
Table 2: Fitted statistical and constant terms of the energy resolution for different calibration strategies.

<table>
<thead>
<tr>
<th>Calibration strategy</th>
<th>statistical term (%)</th>
<th>constant term (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No calibration</td>
<td>13.69</td>
<td>5.84</td>
</tr>
<tr>
<td>calibrated in centre of strip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak of fit function</td>
<td>13.57</td>
<td>3.01</td>
</tr>
<tr>
<td>MPV of Landau</td>
<td>13.62</td>
<td>3.32</td>
</tr>
<tr>
<td>Mean</td>
<td>13.48</td>
<td>2.71</td>
</tr>
<tr>
<td>averaged over 5 regions of strip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak of fit function</td>
<td>13.55</td>
<td>2.96</td>
</tr>
<tr>
<td>MPV of Landau</td>
<td>13.60</td>
<td>3.19</td>
</tr>
<tr>
<td>Mean</td>
<td>13.49</td>
<td>2.67</td>
</tr>
<tr>
<td>Mean (temperature correction)</td>
<td>13.48</td>
<td>2.50</td>
</tr>
</tbody>
</table>

The result of this study, performed using the first detector configuration (“fibre + direct”), is shown in fig. 7 and table 2. Better results are observed when the calibration is performed. The choice of calibration constant is seen to change the energy resolution of EM showers. In general, the statistical term does not vary much among the different calibration methods (by around 1%), while the constant term varies by up to 40% (not considering the “no calibration” case). Using the Landau MPV gives the worst performance, while using the mean of the ADC distribution gives the best, both for the statistical and constant terms. Using the average calibration of the five strip regions is seen to give a small improvement with respect to using just the calibration measured in the central region.

The non–linearity of the energy response is seen to be less than around 4% in the energy range being considered after these calibrations. This seems rather larger than that obtained by not applying any calibration. The reason for this is not yet understood.

We therefore choose to use the means of the ADC distributions, averaged over the five strip regions, as the calibration constants in further analysis.

7 Temperature dependence of calibration

MIP calibration runs were performed several times. This allows the data to be split according to the measured temperature of the detector. We measured the calibration constants of the first detector configuration separately in each run (which typically lasted no more than one hour), and obtained each strips’ calibration constant as a function of temperature. An example of the variation of calibration constants with temperature for the strips in a single layer is shown.
in Fig. 8. A clear trend is seen, the calibration constants tending to decrease with increasing temperature. The dependence was fitted with a linear function, separately for each MPPC.

The consistency of the temperature dependence of different MPPCs was investigated. The temperature dependence was fitted in two ways:

\[
C_\alpha = C_0 + \alpha \cdot (T - T_0) \tag{4}
\]
\[
C_\beta = C_0 \cdot (1 + \beta \cdot (T - T_0)) \tag{5}
\]

The distributions of the fitted temperature coefficients \(\alpha\) and \(\beta\) over the 468 MPPCs of the first configuration are shown in Fig. 9. Also shown in the figure is the dependence of the temperature coefficient on the fitted \(C_0\) value. Two bands
can be seen in these plots, corresponding to the two halves of the detector (fibre and direct) which have rather different calibration constants.

The temperature coefficients in the $\alpha$ scheme are seen to depend rather strongly on the calibration constants $C_0$, while in the $\beta$ scheme the coefficients are almost uncorrelated with $C_0$. The $\beta$ temperature coefficients are quite consistent among the various strips.

We therefore take an average of all MPPCs’ $\beta$ coefficient, which we then apply uniformly to all MPPCs. This average temperature coefficient corresponds to a variation of the MPPC response of 1.8% per degree.

$$C = C_0 \cdot (1 + 0.018 \cdot (T - T_0))$$  \hspace{1cm} (6)

where $C$ is the temperature corrected calibration constant, $C_0$ the average constant, measured using all runs, $T$ is the temperature, and $T_0$ the average temperature of the runs used to measure the calibrations, taken to be 20°C.

The effect of applying this temperature correction to the “mean” calibration constants is shown in fig. 7 and table 2. This temperature correction procedure is seen to give a small improvement in the energy resolution. It also improves the energy response linearity of the detector, giving a similar non-linearity as the “no calibration” case, at around the 1% level. The mean temperature at which these runs were taken, shown in fig. 7, seems correlated with the non-linearities observed after calibration without temperature correction, so we conclude that the non-linearity of the non-temperature corrected response is, at least in part, caused by temperature variations.
Figure 8: Variation of calibration constants with temperature for the 18 strips in the 3rd bre layer of the first configuration detector.
Figure 9: Distribution of calibration temperature coefficients (top) and their correlation with the calibration constant (bottom), in the $\alpha$ (left) and $\beta$ (right) schemes (see text).
The performance of the detector was measured in three configurations: “fibre + direct”, “direct + fibre” and “extruded + fibre”, according to the types of scintillator tile used in the two detector halves. The energy response, non-linearity and energy resolution of the three configurations is shown in Fig. 10. The response curves for the three configurations are all linear within around 2%. However, the slope of the curve for the third configuration is quite different to that of the other two. This is surprising: since we measure the energy in MIP-equivalents, the slopes are expected to be identical. The reason for this behaviour is not clear, and is presently being studied; we suspect that it is due to some feature of the calibration.

Figure 10: Performance of the three detector configurations. The top plots show the detector response and non-linearity, and the lower plots show the energy resolution in the measured energy range (left), and with an extended range to show the value of the fitted constant term (right).

The variation of the energy resolution with the beam energy is fitted by the
A quadratic sum of a statistical and constant term $\sigma_E/E = a/\sqrt{E} + b$. The results of the fits for the three configurations are shown below.

<table>
<thead>
<tr>
<th>configuration</th>
<th>statistical term “a” (%)</th>
<th>constant term “b” (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. fibre + direct</td>
<td>13.39 ± 0.05</td>
<td>2.50 ± 0.07</td>
</tr>
<tr>
<td>2. direct + fibre</td>
<td>13.51 ± 0.05</td>
<td>3.30 ± 0.05</td>
</tr>
<tr>
<td>3. extruded + fibre</td>
<td>14.55 ± 0.08</td>
<td>5.76 ± 0.05</td>
</tr>
</tbody>
</table>

The performance of the first two configurations are quite similar, the first being slightly better. The third configuration, however, shows significantly worse performance, in particular a much larger constant term. One possible reason for this larger constant term is the non-uniformity of the scintillator strip response, which is addressed in the next section.

9 Position dependence of MIP response

A variety of detector scans was performed during the beam test, including detailed scans over the surface of a single strip position, without absorber plates. These data were used to study the uniformity of the scintillator strips’ MIP response.

We analyse only the strips over which the beam was scanned, strip # 5 in the $x$ layers of the detector. We use tracking information to determine at which point the positron crossed this strip in each of the detector’s $x$ layers. If the beam actually crossed a different strip, we discard the event. We divided the strip into 20 (7) regions along the length (breadth) of the strip. Each region therefore has a size of $2.25 \times 1.43$ mm$^2$. We then look at the MPPC signal (the pedestal-subtracted ADC signal) distribution for events in which the positron was reconstructed to have passed through a particular region of a particular strip. By considering the mean of each of these distributions, we can map the strip response across the surface of the strip.

These mappings are shown in Fig. 11 for the three different types of scintillator strip. Since the HV supplied to the MPPCs was tuned to give a similar gain in each MPPC, the pedestal-subtracted ADC signal is strongly correlated to the number of photons detected by the MPPC. Figure 12 shows the projections of these distributions along the strip length, more clearly showing the effects of attenuation along the strip length.

The response of the fibre strips is seen to be high, around 450 ADC counts, and is relatively constant across the strip. The direct readout strips have a significantly lower response of around 200 ADC counts, and is also relatively constant over the strip, other than a “hot spot” very close to the MPPC position. The extruded strip, however, shows a rather non-uniform response, which is high near the
MPPC (at a similar level to that of the fibre strip), while much lower at the other end of the strip (about as low as the direct readout strips’ response).

The most likely reason for this non-uniformity of the extruded strips is bad optical coupling at either the scintillator-fibre or fibre-MPPC interface. Test bench studies suggest that the attenuation length observed at the beam test is consistent with that measured in extruded strips without fibre readout, but is significantly shorter than that obtained when a fibre is properly used to couple the scintillator and MPPC. We therefore suspect that the fibre is not efficiently channeling the light produced in the scintillator to the MPPC. Tests are ongoing to further understand this effect.

10 Position dependence of energy response

Scans over the surface of the detector were also performed with absorber plates. Coarse scans were performed over the entire detector, using a wide range of beam momenta between 1 and 6 GeV/c. In the second and third configurations, a finer scan was also performed over a central slice of around $2 \times 9 \text{cm}^2$, at a fixed beam momentum of 3 GeV/c. The coarse scans were used to investigate the effect of lateral leakage from the detector, and the fine scans to look at variations of energy response within a strip.

For the investigation of lateral leakage, the front surface of the calorimeter was split into five concentric rectangular “frames”, each of width 10mm (the central section is a square of side 10 mm). Events were classified according to which detector section the beam hit, and the energy response was measured in each section, at a range of beam momenta between 1 and 6 GeV/c. The distributions of the reconstructed energy in the five sections are shown in Fig. 13, as are the measured energy resolutions in each section as function of beam energy. The effect of lateral leakage is clearly visible in the outer two sections, while the inner three sections have similar energy response and resolution.

The data collected during the fine detector scan runs were used to measure the variation of the detector response with much finer granularity. The central three pairs of vertical strips were scanned across, as shown in Fig. 14. Using the tracking information, the precise position at which the positron hit the front face of the detector was established. Each strip was divided into $x$ ($y$) sections along its length (width), giving a total of $z$ sections per strip. The distribution of reconstructed energy was considered separately in each section, allowing the variation of energy response and resolution across a single strip to be calculated. These are shown in Fig. 15. The detector response is seen to be higher when the positron enters the detector at the end of the strip closest to the MPPC, and lower when it enters at the far end.

The variation between the maximum and minimum energy response (not in-
cluding regions affected by lateral leakage) is around 10% in the second configuration, and around 30% in the third configuration. This is due to the strip non-uniformity also measured above in MIP events. The energy resolution does not vary significantly within a strip, except due to lateral shower leakage close to the detector edge.

11 Further improvements

The non-linearity of the MPPC is being studied, and a correction to account for its saturation is being developed.

Calibration studies are underway to understand various features mentioned above, particularly the different energy scale (in units of MIPs) of shower events observed in the different configurations.

12 Conclusions

This note describes an update to our analysis of the data taken at DESY with the SCECAL prototype.

The variation of the calibration constants with temperature were measured, and a correction procedure has been developed.

The position dependence of the MIP response within a strip has been measured, and shown to be significantly less uniform in the strips made of extruded scintillator.

This non-uniformity leads to the significantly worse energy resolution of the third configuration detector, with 13 layers of extruded scintillator strips. In particular, the constant term is almost doubled.

The detector also shows evidence of non-uniformity in its response to EM showers, strongly correlated to the proximity of the beam impact point and the positions of the MPPCs.

References

[1] CALICE analysis note 005.
Figure 11: Variation of MIP response within strip 5 of the $x$–layers in the second (top) and third (lower) configurations. The MPPC position is at the centre of the right–hand edge of the plots. Rows 1&2 are direct readout strips, 3&4 are fibre readout strips, measured in the second configuration. Rows 5&6 are extruded strips, and 7&8 are fibre readout strips, measured in the third configuration. The color shows the MIP response in a region of the strip: the color scale is identical in all plots.
Figure 12: Variation of MIP response along strip length, normalised to the maximum response. The MPPC position is at the right edge of the plot. The left (right) plots are measured in the second (third) configuration. The different colour curves are for scanned strips in different layers.

Figure 13: Energy response of the five detector regions (see text) to 3 GeV positrons. Region 0 is the centre of the detector, region 4 the edge.
Figure 14: Cartoon of the front face of the detector. The strip (MPPC) positions are shown by the open (filled) rectangles, the two orientations shown in black and red. The magenta shading shows the region subjected to a detailed position scan with 3 GeV positrons, shown in Fig. 15.
Figure 15: Detailed scan of energy response and resolution for 3 GeV positron showers. The considered region spans the central 2 strips of the detector in $x$, and the entire detector in $y$. The dotted red lines show the central axes of the detector, along which the MPPCs are positioned (the axes are in the same positions on the lower set of plots). Upper (lower) set of 4 plots are for configuration 2 (3). The top 2 plots of each set show the energy response (left) and resolution (right) in the region. The lower two plots are the projections of the top left plot onto the $x$ and $y$ axes respectively.