Beam Test 2012
Update of TASC data analysis
by
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CALET TIM, Pisa June 2015
Outline

• TASC calibration with muons

• TASC response with electrons beams at 10, 20, 30, 50, 80, 100, 150, 200, 250 and 290 GeV:

total energy deposit
longitudinal profile
comparison with Fluka and Epics MC simulations
energy deposit vs primary particle energy
energy resolution
variation of APD gain with temperature
study of calibration of 250 and 290 GeV electrons as a function of temperature
TASC calibration: channel calibration with MIPs

- 150 GeV muon beam;
- Use IMC tracking to select particles crossing the PWO crystal under study
- Selection cuts applied on $\chi^2$ and on fit parameters

- Pedestal (green curve), physics events (blue curve) and MIPs selection (red curve)
- Fit with a landau convoluted with a gaussian (langaus)
- Fitted MPV used as calibration coefficient
- Sigma used to reproduce the channel spread in MC simulation
TASC calibration - second step: APD High/Low stitching

- **High gain vs Low gain plot in each channel**
- **fit** to a break line
- **Fit parameters used to connect the two signal ranges**

![Graph showing Electron runs with data points and fit parameters]

- **Entries**: 389616
- **Mean**: 2757
- **Mean y**: 1.694e+04
- **RMS**: 4658
- **RMS y**: 2.452e+04
- \( \chi^2 / \text{ndf} \): 79.58 / 62
- **Offset**: -7.544 ± 4.836
- **Slope**: 9.189 ± 0.002
- **Breakpoint**: 7091 ± 0.8
Monte Carlo Simulation of Beam Test

Beam test apparatus simulated with Fluka

The simulated energy deposit is without any fluctuation caused by a detector

An event-by-event gaussian fluctuation (noise) event-by-event added

The noise of each TASC channel is simulated using the fitted sigma from MIP data
Data vs MC: Mean Longitudinal Profile at 150 GeV

2\textsuperscript{nd} layer (readout by BBM3 electronics) cannot be calibrated using MIPs; not possible to measure the MIP peak values to overcome this problem and calibrate this layer, we applied a two steps procedure.
**2nd Layer calibration : logs equalization**

- 100 GeV electron runs
- The beam illuminated all three logs
- Each plot is fitted to a gaussian function to obtain the peak value
- The peaks have been equalized to the average
2\textsuperscript{nd} layer calibration: MC rescaling

MC average longitudinal profile fitted to a $\Gamma$-function;

using the fitted curve a \textit{conversion factor (ADC to MIP units)} for the 2\textsuperscript{nd} layer is calculated.

\[
\frac{dE}{dt} = \frac{E_0 b}{\Gamma(b t_{\text{max}} + 1)} \left( b t \right)^{bt_{\text{max}}} e^{-bt}
\]
The peaks of two distributions differ less than 1%.

The energy resolution of data is ~2% against ~1.7% of MC.

That discrepancy probably due to calibration problem in 2nd layer.
150 GeV Electrons: Data vs MC

Pulse height in each channel

Energy layer deposit
150 GeV Electrons: Data vs MC

Pulse height in each channel

Energy layer deposit
150 GeV Electrons: Data vs MC

Pulse height in each channel

Energy layer deposit
150 GeV Electrons: Data vs MC

Pulse height in each channel

Energy layer deposit
10 GeV Electrons: Data vs MC

Data

MC

10 GeV Electrons Longitudinal Profile

Legend

- Data
- Fluka
- Epics
- Data Fit
- Fluka Fit

Energy Deposit [mip]

Entries: 3876
Mean: 379.1
RMS: 35.94
\(\chi^2/\text{ndf}: 83.68/75\)
Constant: 90.76 ± 1.94
Mean: 377.5 ± 0.6
Sigma: 32.45 ± 0.49

Entries: 13643
Mean: 371.1
RMS: 27.27
\(\chi^2/\text{ndf}: 10.72/52\)
Constant: 94.03 ± 2.23
Mean: 371.8 ± 0.6
Sigma: 27.31 ± 0.54

Total Energy Deposit [mip]
20 GeV Electrons: Data vs MonteCarlo

Data

<table>
<thead>
<tr>
<th>Entries</th>
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<tr>
<td>Mean</td>
<td>776.3</td>
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<tr>
<td>RMS</td>
<td>45.64</td>
</tr>
<tr>
<td>$\chi^2 / \text{ndf}$</td>
<td>69.44 / 56</td>
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<tr>
<td>Constant</td>
<td>381.1 ± 4.7</td>
</tr>
<tr>
<td>Mean</td>
<td>776.8 ± 0.5</td>
</tr>
<tr>
<td>Sigma</td>
<td>43.56 ± 0.37</td>
</tr>
</tbody>
</table>

MC

<table>
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<th>Entries</th>
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<tr>
<td>Mean</td>
<td>774.3</td>
</tr>
<tr>
<td>RMS</td>
<td>40.08</td>
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<tr>
<td>$\chi^2 / \text{ndf}$</td>
<td>51.69 / 38</td>
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<tr>
<td>Constant</td>
<td>371 ± 5.1</td>
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<tr>
<td>Mean</td>
<td>775.8 ± 0.5</td>
</tr>
<tr>
<td>Sigma</td>
<td>39.49 ± 0.43</td>
</tr>
</tbody>
</table>

20 GeV Electrons Longitudinal Profile

Legend
- Data
- Fluka
- Epics
- Data Fit
- Fluka Fit

Energy Deposit [mip]

$x_0 [\text{r.l.}]$
30 GeV Electrons: Data vs MonteCarlo

30 GeV

Entries: 5433
Mean: 1182
RMS: 51.81
$\chi^2 / \text{ndf}$: 87.74 / 55
Constant: 175.6 ± 3.1
Mean: 1183 ± 0.7
Sigma: 47.51 ± 0.57

Entries: 96401
Mean: 1185
RMS: 49.33
$\chi^2 / \text{ndf}$: 10.31 / 48
Constant: 180 ± 3.2
Mean: 1187 ± 0.8
Sigma: 48.04 ± 0.68

Data
MC

30 GeV Electrons Longitudinal Profile

Legend
- Data
- Fluka
- Epics

Energy Deposit [mip]

Total Energy Deposit [mip]

$X_0$ [r.l.]
50 GeV Electrons: Data vs MonteCarlo

### Data
- Entries: 3074
- Mean: 2014
- RMS: 62.58
- $\chi^2 / \text{ndf}$: 90.39 / 53
- Constant: 120.9 ± 2.8
- Mean: 2016 ± 1.2
- Sigma: 57.86 ± 0.83

### MC
- Entries: 63251
- Mean: 2016
- RMS: 63.54
- $\chi^2 / \text{ndf}$: 7.515 / 42
- Constant: 132.1 ± 3.0
- Mean: 2019 ± 1.2
- Sigma: 61.86 ± 1.06

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**Graph 1:**
- Title: 50 GeV Electrons Longitudinal Profile
- Legend:
  - Data
  - Fluka
  - Epics
  - Data Fit
  - Fluka Fit
- X-axis: $X_0 [\text{r.l.}]$
- Y-axis: Energy Deposit [mip]
- Data points and fitted curves.
100 GeV Electrons: Data vs MonteCarlo

![Graph showing 100 GeV Electrons: Data vs MonteCarlo comparison](image)

**Data**
- Entries: 7691
- Mean: 4105
- RMS: 101.7
- $\chi^2$/ndf: 58.96/36
- Constant: 380.4 ± 5.7
- Mean: 4110 ± 1.2
- Sigma: 92.89 ± 0.93

**MC**
- Entries: 63914
- Mean: 4112
- RMS: 90.42
- $\chi^2$/ndf: 19.55/28
- Constant: 396.9 ± 6.1
- Mean: 4116 ± 1.2
- Sigma: 87.6 ± 1.1

**Legend**
- Data
- Fluka
- Epics
- Data Fit
- Fluka Fit
200 GeV Electrons: Data vs MC

Entries: 1756
Mean: 8344
RMS: 154.3
$\chi^2$/ndf: 63.27/47
Constant: 93.73 ± 2.85
Mean: 8345 ± 3.5
Sigma: 140.7 ± 2.6

Entries: 59434
Mean: 8331
RMS: 129.9
$\chi^2$/ndf: 8.13/28
Constant: 112.3 ± 3.5
Mean: 8336 ± 3.1
Sigma: 123.1 ± 2.6

Legend:
- Data
- Fluka
- Epics
- Data Fit
- Fluka Fit
MIP peak position in each channel depends on the temperature (about -10 ADC/°C)

the calibration table cannot be applied to 250 GeV and 290 GeV electrons because taken at different temperature (greater than 1 °C) wrt previous runs

using muon runs at different temperatures, we measure the MIP peak variation with temperature in each channel

from the fit results, we calculated two calibration tables for 250 and 290 GeV electrons

the RMS of each channel remains stable as the temperature changes;
the peaks of two distributions differ by less 1%;

the energy resolution of data is about 1.8% against 1.4% of MC;
The peaks of two distributions differ by less 1%;

the energy resolution of data is about 1.5% against 1.3% of MC;
Difference between data and MC

\[(\text{Data peak} – \text{MC peak})/\text{MC peak}\]

except for 10 GeV electrons, the difference between Data peak and MC peak is always less than 1% (also at 250 and 290 GeV)

\[\text{Data resolution} – \text{MC resolution}\]

except for 10 GeV electrons, the difference between Data resolution and MC resolution is always less than 0.5%
The TASC response is linear: except for 10 GeV electrons, the residual value is always less than 2% (also at 250 and 290 GeV)
The points at 10 and 20 GeV not used to fit the curves.

\[ f(E) = p_0 \oplus \frac{p_1}{\sqrt{E \text{[GeV]}}} \]

<table>
<thead>
<tr>
<th></th>
<th>$P_0$</th>
<th>$P_1$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data</strong></td>
<td>(1.4±0.1)%</td>
<td>(18±1)%</td>
</tr>
<tr>
<td><strong>MC</strong></td>
<td>(0.3±0.3)%</td>
<td>(21±1)%</td>
</tr>
</tbody>
</table>
Energy Resolution vs Beam Energy (2)

\[ f(E) = p_0 + \frac{p_1}{\sqrt{E[GeV]}} + p_2 \frac{1}{E[GeV]} \]

- low signal to noise ratio
- we introduced a term to take into account the instrumental effects at low energies

<table>
<thead>
<tr>
<th></th>
<th>( P_0 )</th>
<th>( P_1 )</th>
<th>( P_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>((1.5 \pm 0.1)%)</td>
<td>((13 \pm 2)%)</td>
<td>((81 \pm 8)%)</td>
</tr>
<tr>
<td>MC</td>
<td>((0.4 \pm 0.3)%)</td>
<td>((21 \pm 1)%)</td>
<td>((37 \pm 17)%)</td>
</tr>
</tbody>
</table>
Fine calibration of 250 GeV electrons (1)

- Strong variation of calibration table wrt temperature used

Nominal temperature
Fine calibration of 250 GeV electrons (2)

the Mean energy deposit of MC is constant

Mean energy deposit as a function of temperature value used to build the calibration card

Residuals between data and MC mean value
Fine calibration of 250 GeV electrons (3)

Sigma of energy distribution as a function of temperature value used to build the calibration card

Energy resolution as a function of temperature value used to build the calibration card
Fine calibration of 250 GeV electrons (4)

We obtained the best fit between Data e MC using the calibration table built at $T = 31.0 \, ^\circ C$ (the nominal value is $31.1 \, ^\circ C$)
Fine calibration of 290 GeV electrons (1)

Nominal temperature

- As in case of 250 GeV electrons, there is a strong variation of calibration table wrt temperature used
Fine calibration of 290 GeV electrons (2)

Mean energy deposit as a function of temperature value used to build the calibration card

Residuals between data and MC mean value

the Mean energy deposit of MC is constant
Sigma calibration of 290 GeV electrons (3)

Sigma of energy distribution as a function of temperature value used to build the calibration card

Energy resolution as a function of temperature value used to build the calibration card
We obtained the best fit between Data e MC using the calibration table built at $T = 30.7$ °C (the nominal value is 30.6 °C)
Energy Deposit vs Beam Energy
after fine calibration for 250 Gev and 290 Gev electrons

The TASC response is linear:
except for 10 GeV electrons, the residual value is always less than 2% (also at 250 and 290 GeV)
Energy Resolution vs Beam Energy
after fine calibration for 250 Gev and 290 Gev electrons

\[ f(E) = p_0 \oplus \frac{p_1}{\sqrt{E[GeV]}} \oplus \frac{p_2}{E[GeV]} \]

- low signal to noise ratio
- we introduced a term to take into account the instrumental effects at low energies

\[ \chi^2 / \text{ndf} = 5.578 / 7 \]
\[ \text{Prob} = 0.5698 \]
\[ p_0 = 0.0142 \pm 0.0009175 \]
\[ p_1 = 0.1488 \pm 0.01813 \]
\[ p_2 = 0.7831 \pm 0.082 \]

\[ \chi^2 / \text{ndf} = 0.5616 / 7 \]
\[ \text{Prob} = 0.9992 \]
\[ p_0 = 0.004632 \pm 0.002626 \]
\[ p_1 = 0.2072 \pm 0.01383 \]
\[ p_2 = 0.3734 \pm 0.1712 \]

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<th>( P_2 )</th>
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<tbody>
<tr>
<td>Data</td>
<td>(1.4\pm0.1)%</td>
<td>(15\pm2)%</td>
<td>(78\pm8)%</td>
</tr>
<tr>
<td>MC</td>
<td>(0.5\pm0.3)%</td>
<td>(21\pm1)%</td>
<td>(37\pm17)%</td>
</tr>
</tbody>
</table>
Conclusions & Suggestions

TASC calibration method based on MIP works fine

Good agreement between beam test electron data and FLUKA MC

Good TASC linear behaviour up to 290 GeV

Calibration criticities:

possible bias on MIP fitted peaks due to low S/N ratio

a fine monitoring of temperature changes is mandatory
Appendix: list of files used

• 150 GeV muon beam for calibration:
  20120928_001904_mu-169
  20120928_022006_mu-172
  20120928_041941_mu-174

• 150 GeV + 200 GeV electron runs used for stitching:
  20120929_024721_ele150-222
  20120929_035339_ele150-224
  20120929_045728_ele150-226
  20120929_055351_ele150-228
  20120929_065237_ele150-230
  20120929_145535_ele200-249
  20120929_154957_ele200-251
  20120929_164448_ele200-254
  20120929_175114_ele200-257
  20120929_184809_ele200-259
  20120929_194208_ele200-261
  20120929_203636_ele200-264
  20120929_213939_ele200-266

• 100 GeV electron beam used to calibrate 2\textsuperscript{nd} layer:
  20120928_221415_ele100-211
  20120928_233425_ele100-213
  20120929_000357_ele100-215
  20120929_104250_ele100-241