Digital versus semi-digital readout

Simulation and energy reconstruction
First trial on SDHCAL-RPC TB data

07/02/2013
Simulation

• Geometry
  – 100 Micromegas layers of 1x1 m²
  – SDHCAL absorbers

• Data set
  – 10000 pion events from 10 to 70 GeV, every 10 GeV

• Digitisation
  – Low threshold at 15 eV (gas ionisation potential)
  – Medium threshold at 5 MIP (set in keV from muon Landau distribution)
  – High threshold at 15 MIP (set in keV from muon Landau distribution)
Nhit distributions – 3 thresholds

Low thr.

Medium thr.

High thr.

Number of hits from pions - low threshold

Number of hits from pions - medium threshold

Number of hits from pions - high threshold

~ 0 MIP

5 MIP

15 MIP
Distribution moments

Get RMS and MEAN from smoothed distribution instead of fit parameters
→ MEAN not over-estimated
→ RMS not under-estimated

1. Fit Novosibirsk function to histo1
2. Fill histo2 from fit function (10^5 entries for a smooth histo)
3. Get MEAN and RMS of histo2

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**Nhit thr0 60 GeV Novosibirsk fit**

<table>
<thead>
<tr>
<th>Entries</th>
<th>10000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>607.4</td>
</tr>
<tr>
<td>RMS</td>
<td>78.53</td>
</tr>
<tr>
<td>(\chi^2 / \text{ndf})</td>
<td>493.7 / 446</td>
</tr>
<tr>
<td>p0</td>
<td>622.2 ± 1.4</td>
</tr>
<tr>
<td>p1</td>
<td>75.14 ± 0.63</td>
</tr>
<tr>
<td>p2</td>
<td>-0.1308 ± 0.0116</td>
</tr>
<tr>
<td>p3</td>
<td>50.94 ± 0.67</td>
</tr>
</tbody>
</table>

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**Nhit thr0 60 GeV from fit function**

Entries: 10000
Mean: 607.3
RMS: 77.05
Response to pions in Nhit

Fit function: \( N_0 = \frac{0}{[1]} \times \log(1 + [1] \times E) \)

Work only for the low threshold: medium thr. \( \sim \) linear while high thr. rises faster than linear

Very similar to Micromegas TB data
Energy reconstruction - pure digital

Inverse fit function: $E = \exp\left(\frac{[1]}{[0]} \times N_0 - 1\right) / [1]$

Reconstructed pion energy - pure digital
Performance for pure digital

Linearity almost perfect (no surprise, we used the inverse of the response)
However, corrections degrade the energy resolution above at 30 GeV
Degradation of the resolution

The EM fraction of hadron showers increases with energy. With a digital readout → saturation of Nhit → worse resolution.
Degradation of the resolution

The EM fraction of hadron showers increases with energy. With a digital readout → saturation of $N_{hit}$ → worse resolution.
Energy reconstruction - semi-digital

**Maximum likelihood method**

Calculate at each energy, the probability to observe \((N_0, N_1, N_2)\)
The best estimate of the energy is then the one for which the probability is maximum

**Hypothesis**

\(N_0, N_1, N_2\) are not correlated
(verified in 2D plots and with correlation coef. centred at 0)

\[ p(N_0, N_1, N_2) = p(N_0) \times p(N_1) \times p(N_2) \]

**Calculation of probability**

Parametrise the energy dependence of Novosibirsk fit parameters (\(\mu, \sigma, \text{tail}, \text{norm}\))
Normalised distributions \(\rightarrow p(N_i, E)\) at any energy in the parametrisation range
Correlation
Energy parametrisation - thr0

Calculation of probability

Parametrise the energy dependence of Novosibirsk fit parameters (mu, sig, tail, norm)
Normalised distributions → p(Ni,E) at any energy in the parametrisation range
Calculation of probability

Parametrise the energy dependence of Novosibirsk fit parameters \((\mu, \sigma, \text{tail}, \text{norm})\)

Normalised distributions \(\rightarrow p(N_i,E)\) at any energy in the parametrisation range
Energy reconstruction - semi digital

Distributions are more symmetrical!
Performance semi-digital

Linearity slightly worse than with pure digital (for which it had to be $\sim$ perfect)
No degradation of resolution: OFFLINE COMPENSATION works!
Comparison pure/semi digital

Semi-digital non linearity below 4% at 10 GeV, below 2% in 20-70 GeV
Energy resolution: improvement already at 20 GeV
Next steps

Apply semi-digital energy reconstruction method to RPC testbeam data (hoping the detector is proportional...)

Add more discrimination power to likelihood method

→ barycentre of hits along beam axis is correlated to the beam energy

→ also: radial position of hits?
SDHAL/RPC testbeam data

August-Sept. Period: H6, better beam conditions claimed by RPC group

Difference with simulation:
100 perfect layers $\rightarrow$ 47 layers $\rightarrow$ leakage (in addition to geom. saturation)
Environmental variations $\rightarrow$ systematics
Proportional signals $\rightarrow$ saturated signals (?)
Pure samples $\rightarrow$ electrons, pions, cosmics, muons $\rightarrow$ PID

Before parametrisation of Novo. function with energy for 3 thresholds $\rightarrow$ many checks!
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Leakage

Nhit VS Zstart 30 GeV

Nhit VS Zstart 50 GeV

Nhit VS Zstart 70 GeV
Leakage

Profile Nhit VS Zstart

→ Select shower starting in 12 first layers
(cut on Nhit in last layers not allowed, would bias the sample)
Sample purity

SDHCAL is ~ compensated at low energy → PID e/h based on Nhit useless. → Use transverse and longitudinal information → Centre of gravity radial and along Z (proved to work in simulation too)
At a given energy, the Novosibirsk parameters show some spread for 3 thr. The trends with energies are to be understood...
Conclusion

It seems that we have a method that improves the energy resolution by using the semi-digital information.

Lot of work still to understand the RPC data...
... hoping it is possible.