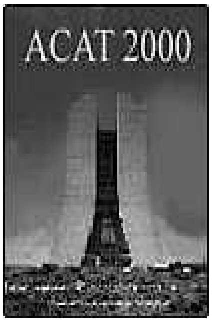

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An Hybrid Training Method for Neural Energy Estimation in Calorimetry

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- **Motivation**
- **Calorimeter and Experimental Setup**
- **The Hybrid Method**
- **Linearity and Resolution**
- **Conclusions**

INSTITUTO SUPERIOR TÉCNICO

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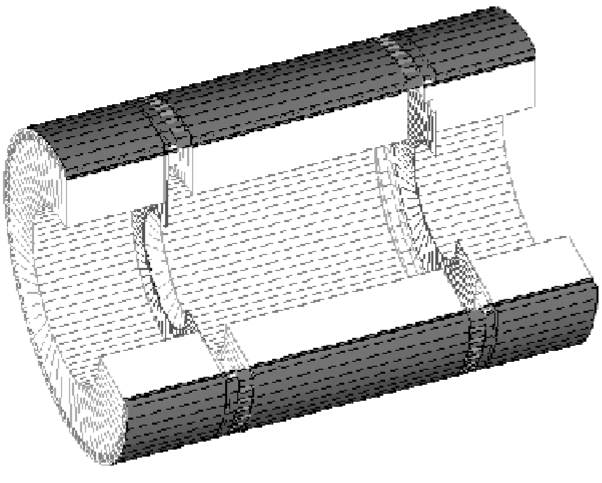
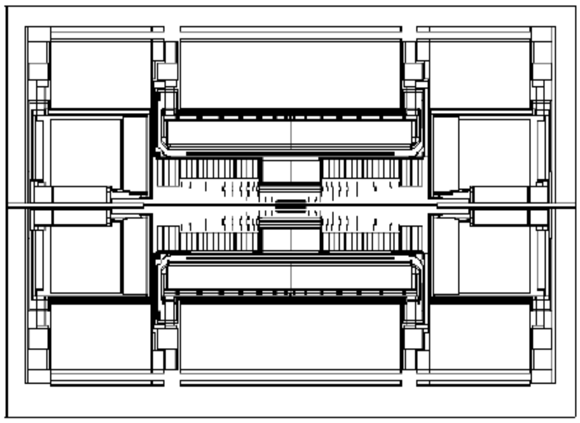
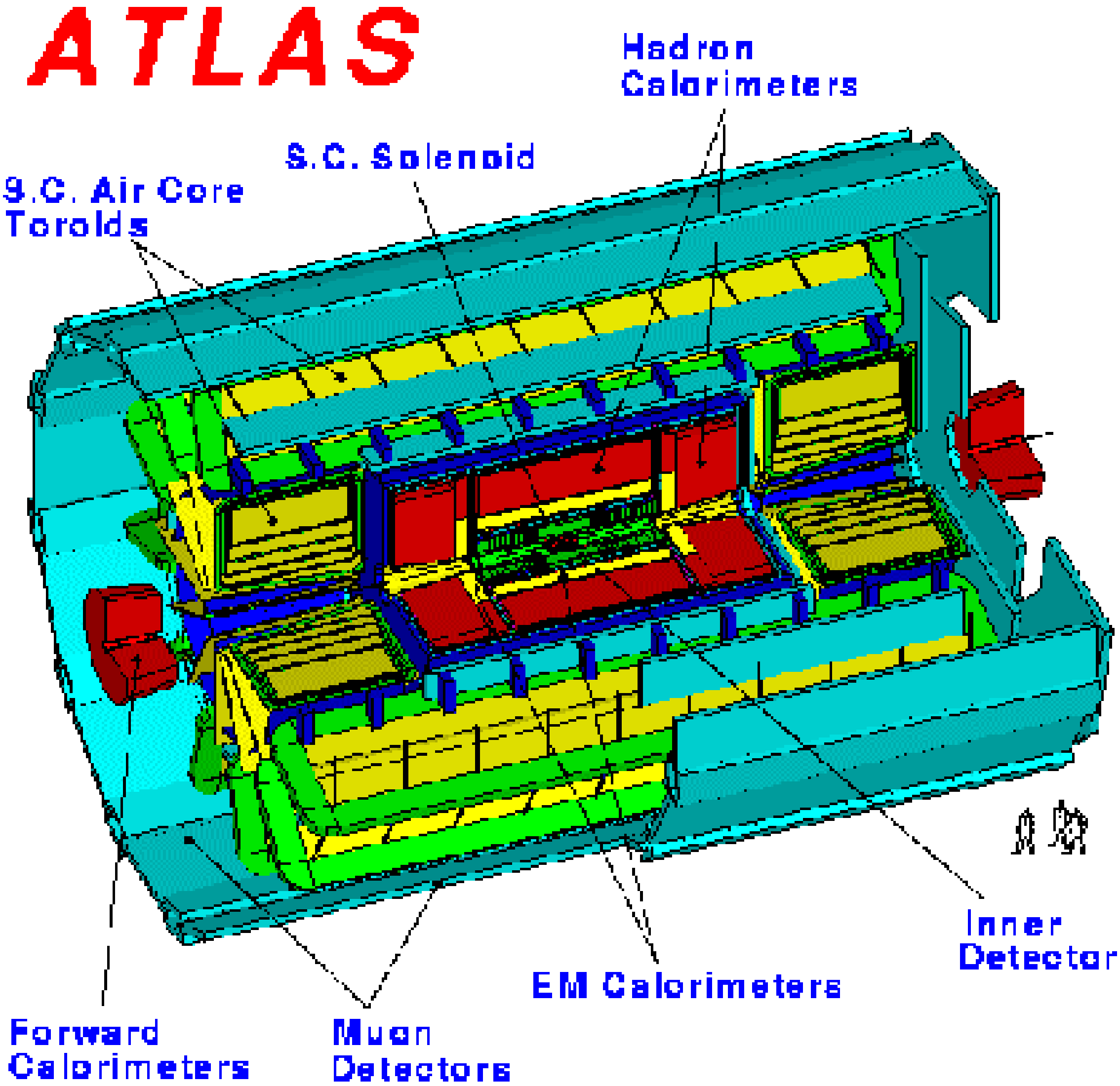
Introduction

- **LHC PROJECT / ATLAS DETECTOR**
- **CALORIMETER SYSTEM**
  - Eletromagnetic and hadronic parts
  - Very important in high energy experiments





  - Barrel $-1.0<\eta<1.0$, Extended barrels $0.8<|\eta|<1.7$


ATLAS
Hadron Calorimeters
S.C. Solenoid
S.C. Air Core Toroids
Inner Detector
EM Calorimeters
Forward Calorimeters
Muon Detectors

- **ENERGY RESOLUTION**

  - Is usually modeled by :

$$\frac{\sigma}{E} = \frac{A}{\sqrt{E}} + B$$

  - When combining linearly the calorimeter cells the energy resolution was measured to be (raw data, no corrections) :

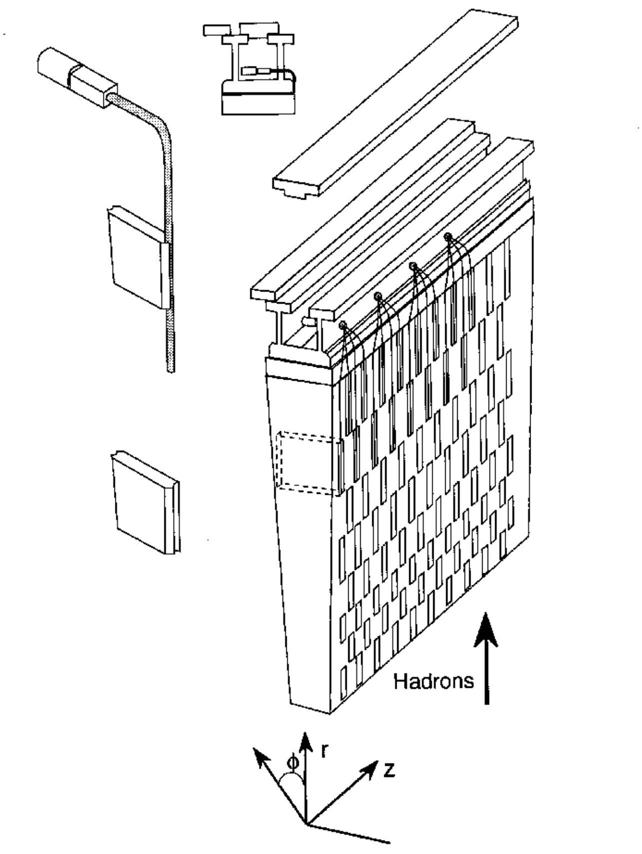
$$\frac{\sigma}{E} = \frac{44\ \%}{\sqrt{E}} + 6.0\ \%$$

- **THE NEURAL MAPPING**

  - Practical calorimeters present non-linearities in their response. From raw experimental data a maximum non-linearity of 10.6% was obtained for Tilecal (no corrections)
  - Multiparametric functions too complex (energy dependent)
  - A neural mapping can be used for correcting such nonlinearities

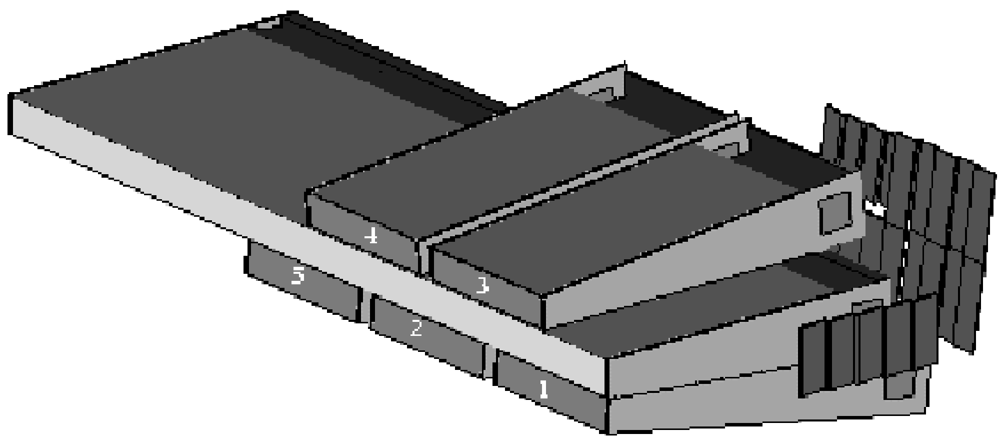
➢ THE TILE CALORIMETER

- Highly segmented (3 sampling layers,10k cells)
- Iron as absorber
- Scintillanting tiles as active material
- Signal carried by optical fibers
- Photomultipliers convert the optical signal into eletrical signal



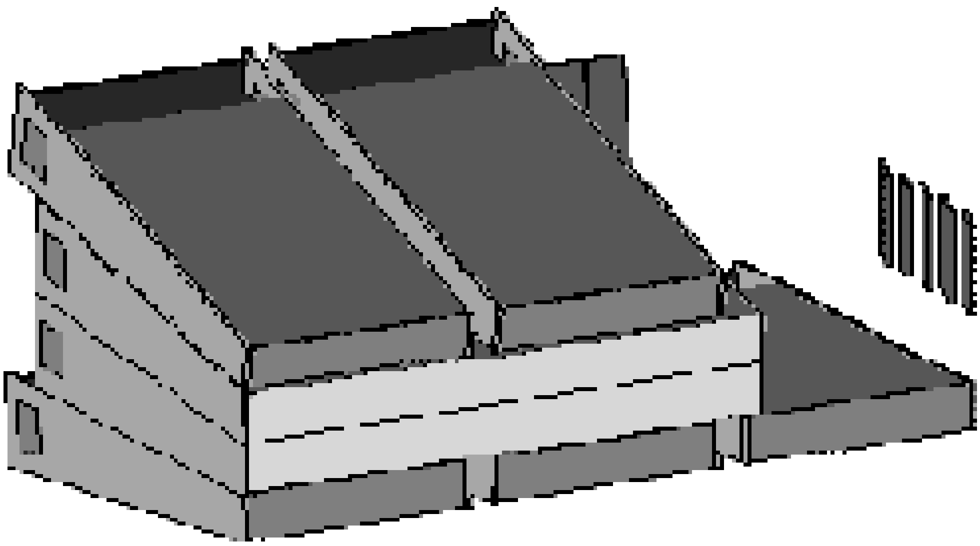
Barrel-Module 0 Prototype

- Prototype of one of the 64 modules of the actual detector
- Half of the prototype was instrumented, providing 46 readout channels
- Energy range (pions) : 10, 20, 50, 60, 80, 100, 150, 180, 300 and 400 GeV (Experimental)
- 5 adjacent modules of a previous generation of prototypes (leakage compensation)
- Muon Wall for muon rejection



Extended Barrel Prototype

- The prototype comprised 2 modules with 28 readout channels each
- Energy range (pions) : 10, 20, 40, 50, 80, 100, 180, 300 and 400 GeV (Experimental)
- Like the barrel, 5 adjacent modules were used for containment



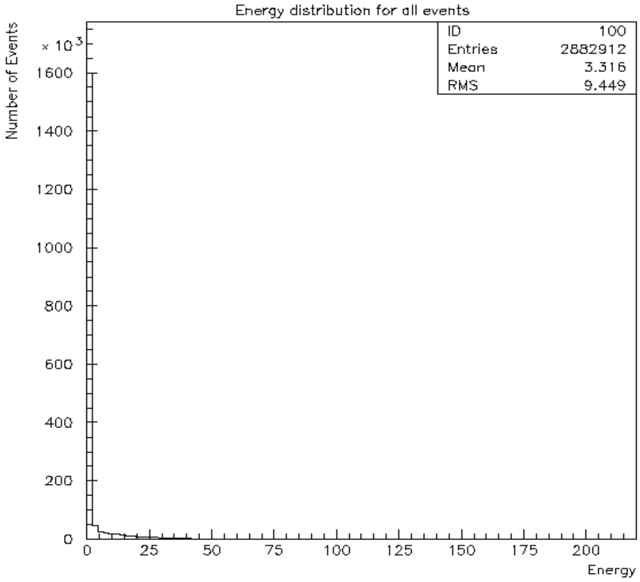
➢ THE NEURAL NETWORK

TOPOLOGY

- Feed-forward – 3 layers (good for achieving linearity for low energies)
- Activation Function
  Sigmoid – Hidden Layers
  Linear – Output Layer (energy reconstrution)
- Backpropagation

NORMALIZATION

- The input data was normalized by a **constant factor** (independent of the particle energy)



➢ THE HYBRID MODEL

- Combines the high linearity achieved by a network trained using the nomimal beam energy as target with the resolution of the original calorimeter response (neural mapping reproducing the linear combination of cells)

- Alternated Training :

  - Determination of the number of training cycles for each phase of the training procedure
  - Final configuration → 30000 cycles having nominal energy as target and 7500 cycles with "calorimeter" target

- Same topology, 3 layers

CONCLUSIONS

- A hybrid model was developed for training a neural estimator for the energy deposited on a calorimeter

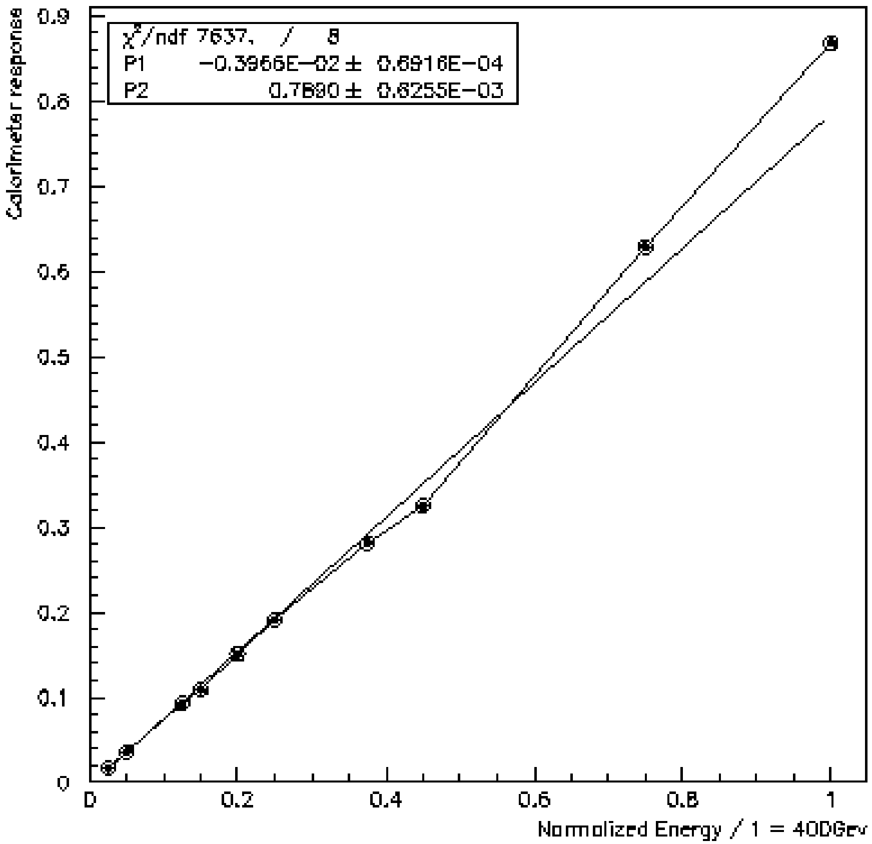
- The neural mapping envisages to correct for nonlinearities on pratical calorimeter designs

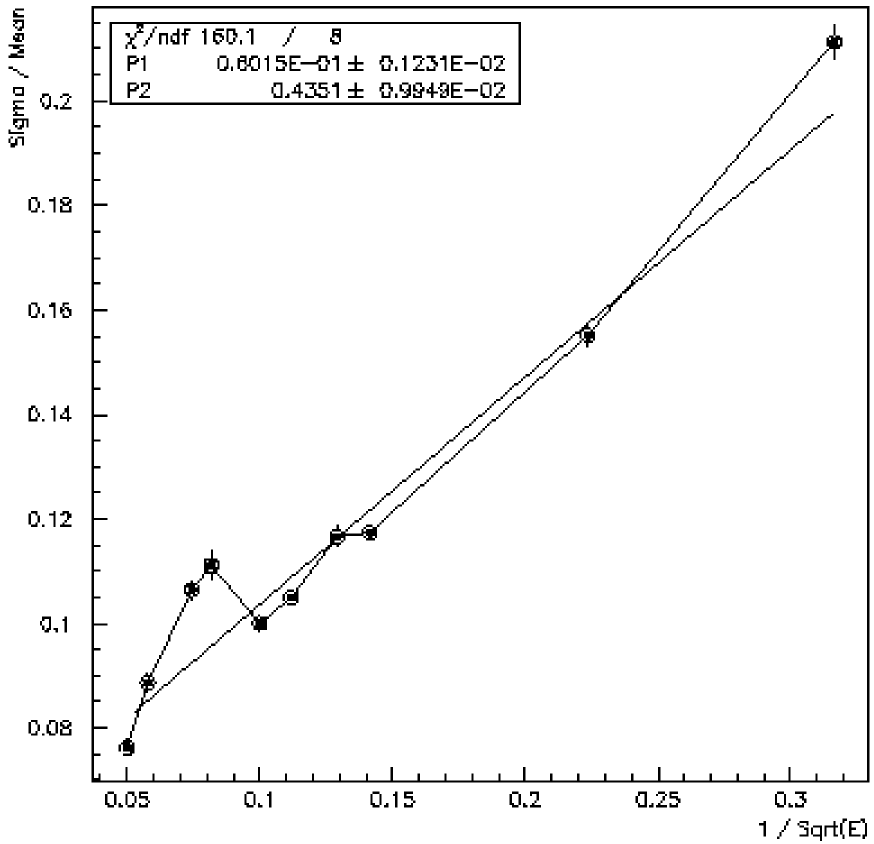
- Compromise : linearity x resolution

- Two segments for energy resolution : multi-neural mapping

- Fine-grain energy sampling required for more accurate estimator design

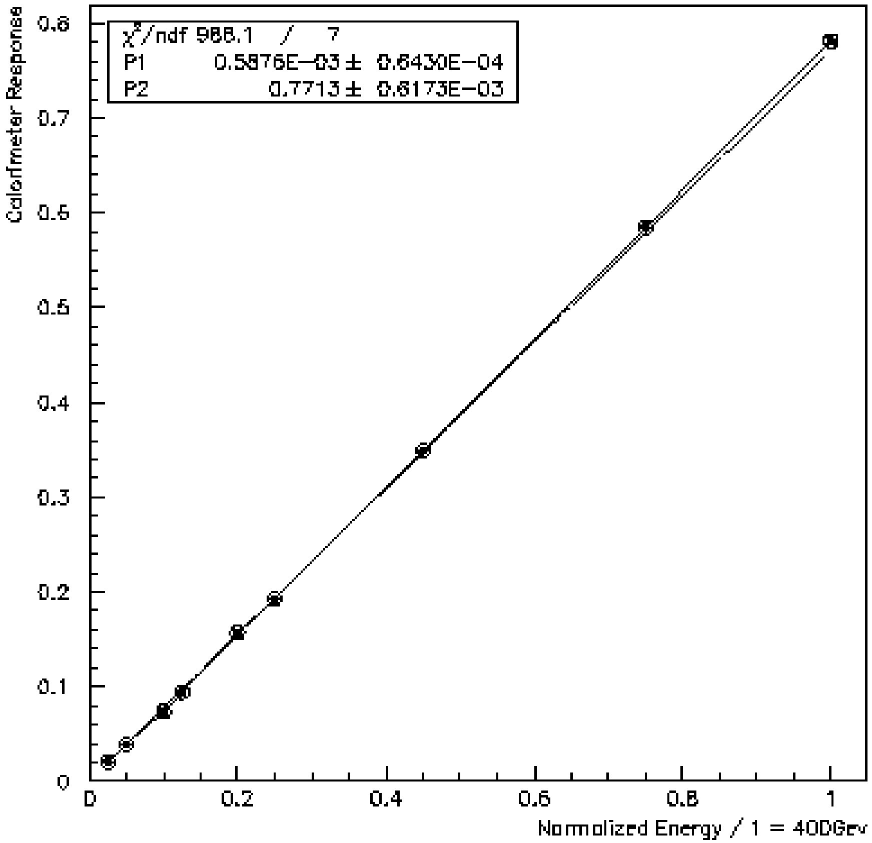
Barrel - Original Response

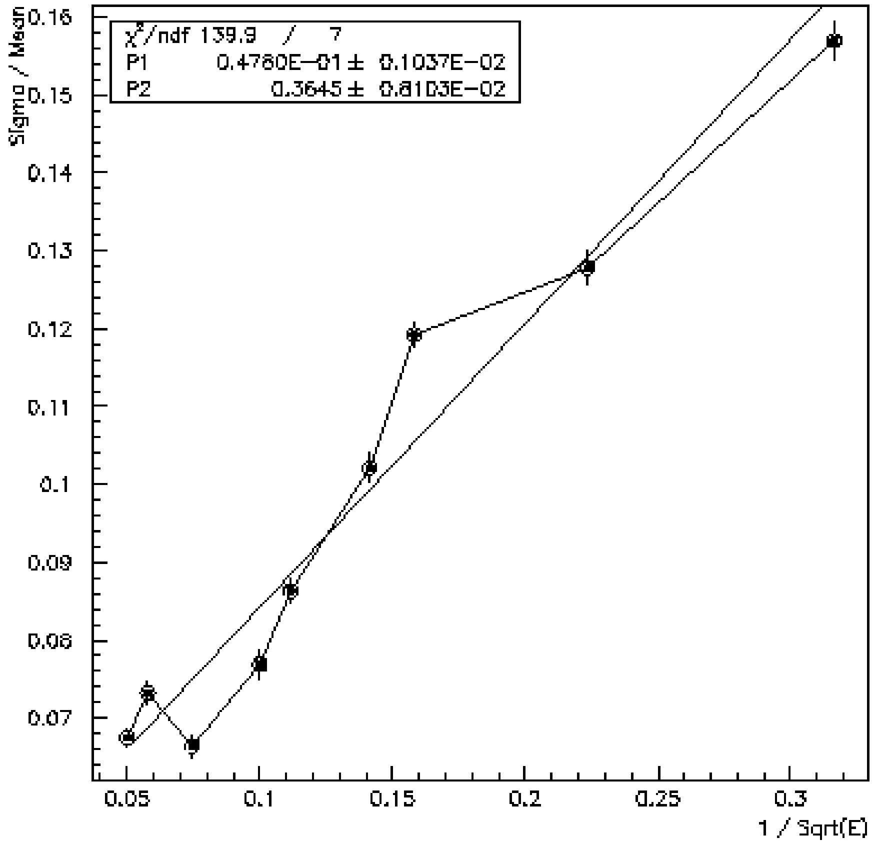




- Nonlinearity < 10.6 %
- Energy Resolution : 44% + 6.0%

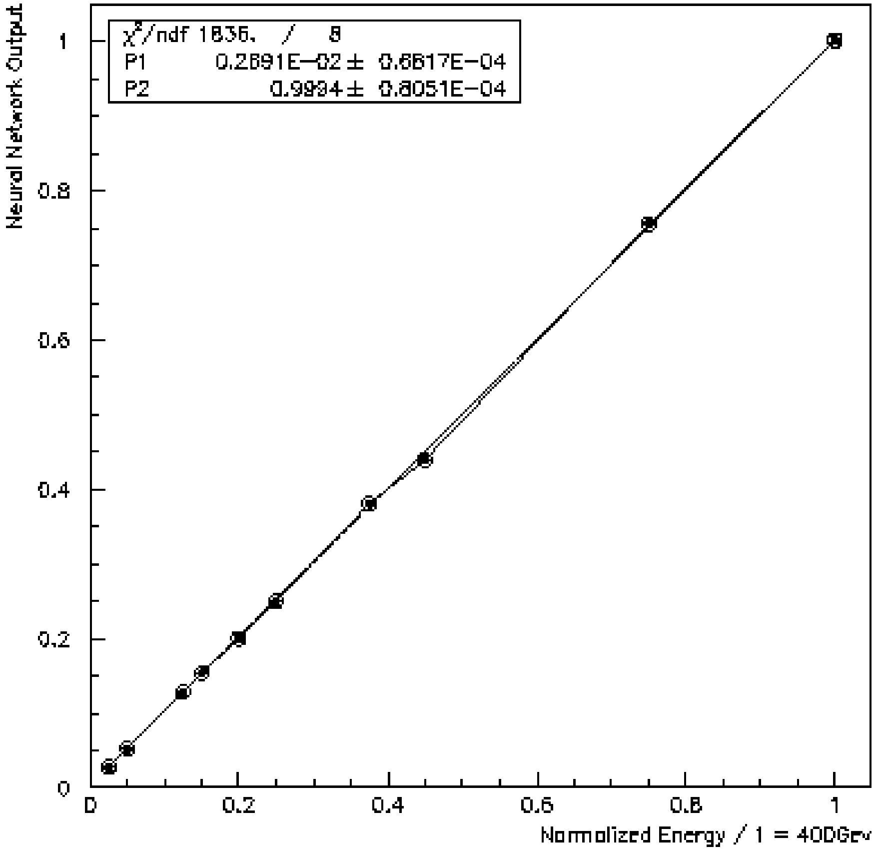
Extended Barrel - Original Response

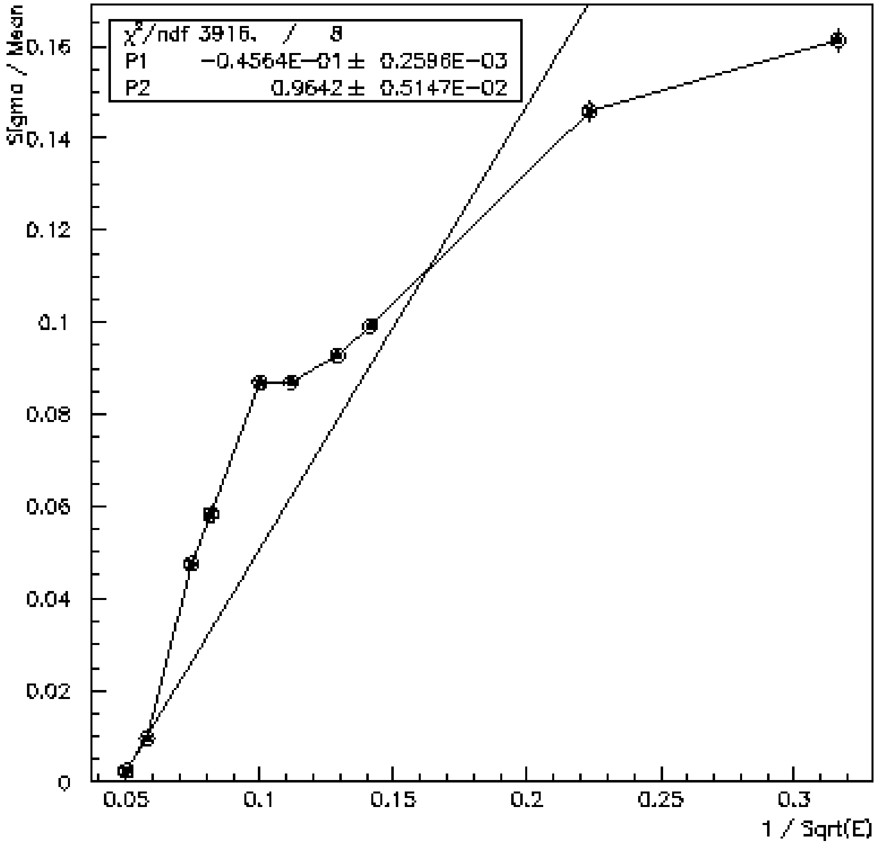




- Nonlinearity < 4.8 %
- Energy Resolution : 36% + 4.8%

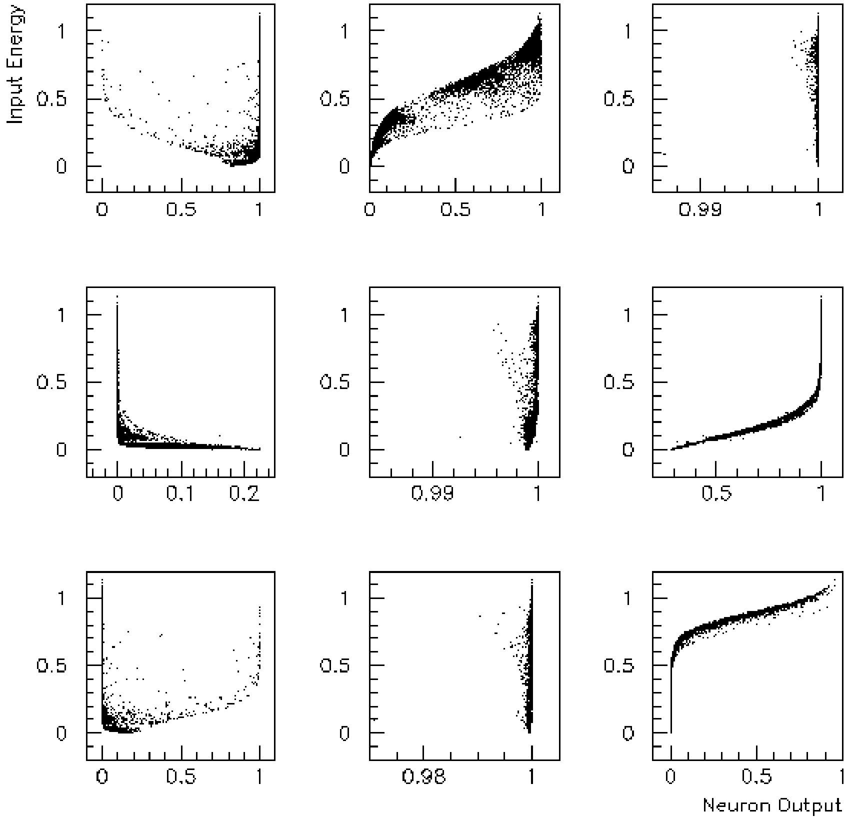
Single Network Response (Barrel)

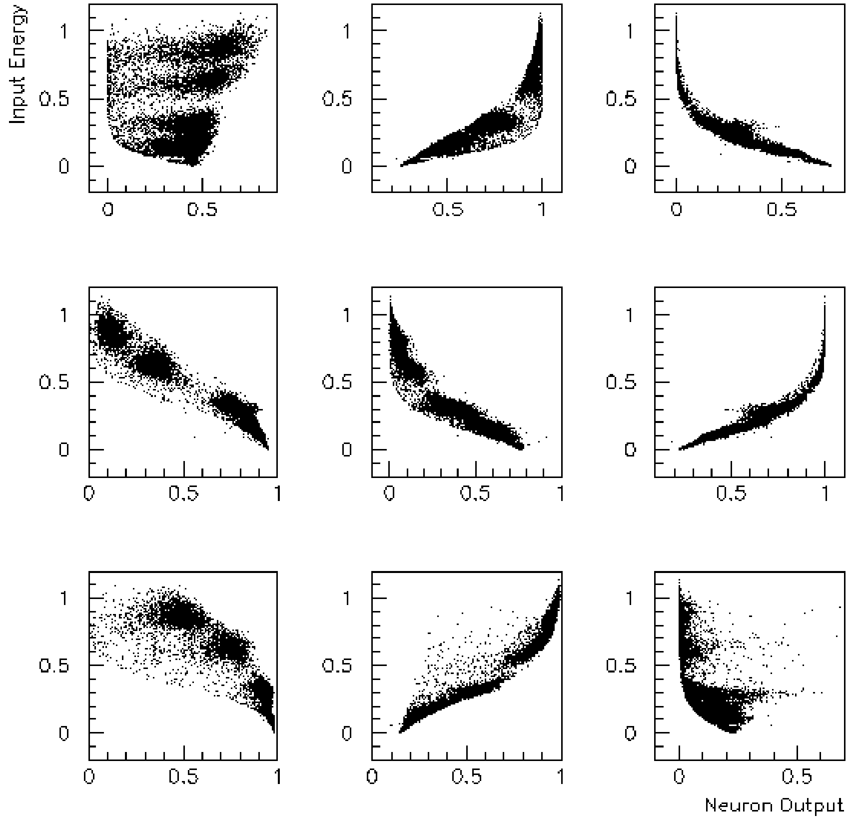




- Nonlinearity < 2.9 %
- Energy Resolution : 96.4% - 4.6%

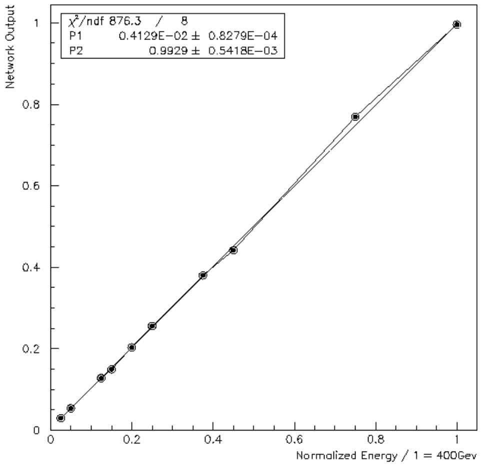
Neuron Saturation



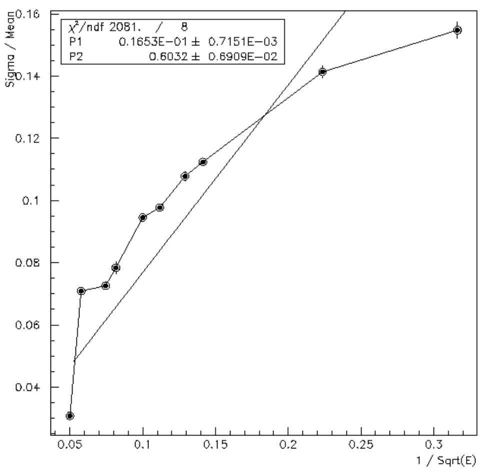


- Temperature = 1
- Temperature = 2

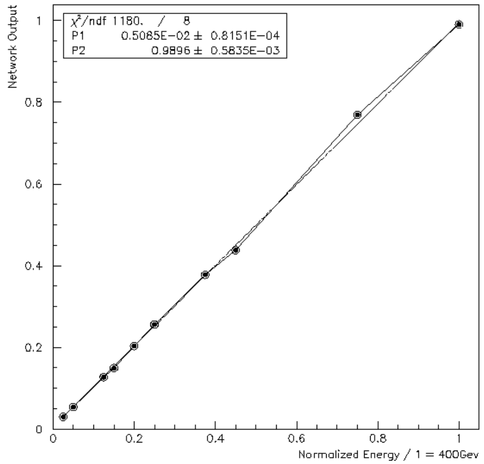
Neuron Saturation



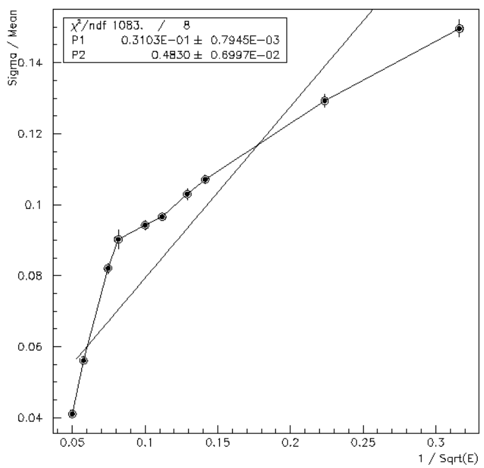
- Nonlinearity < 2,8 %



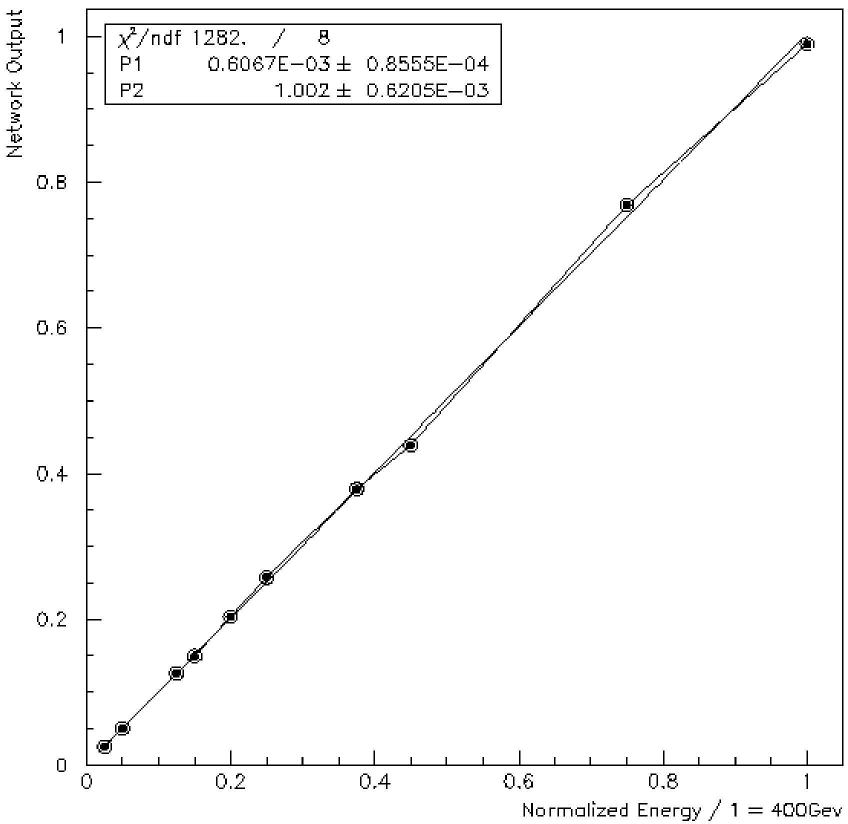
Correction

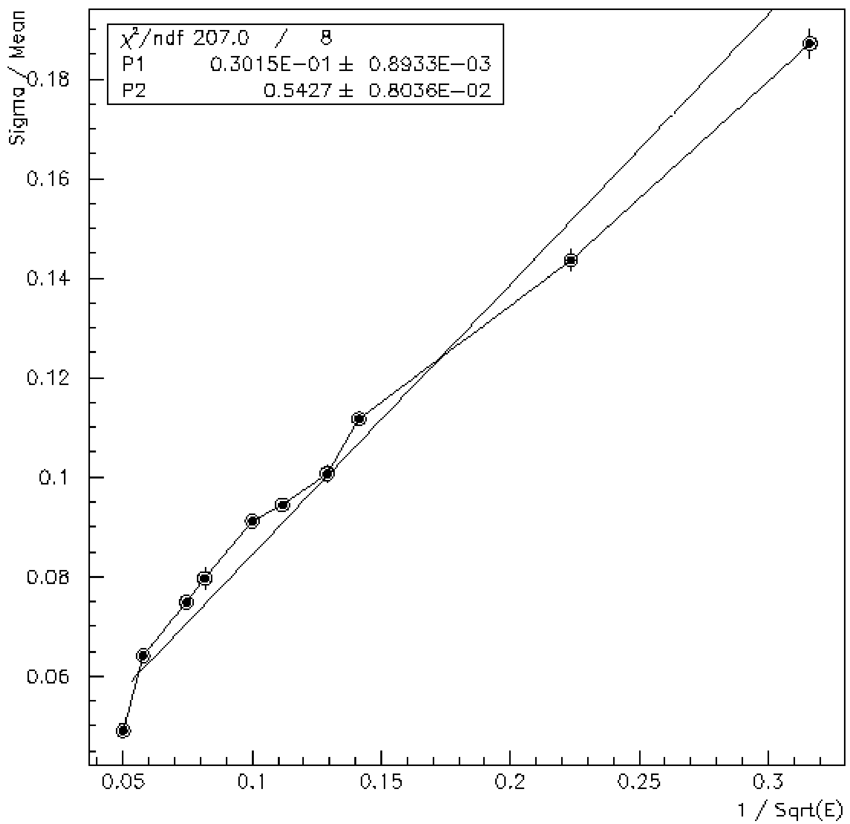


- Nonlinearity < 2,9 %

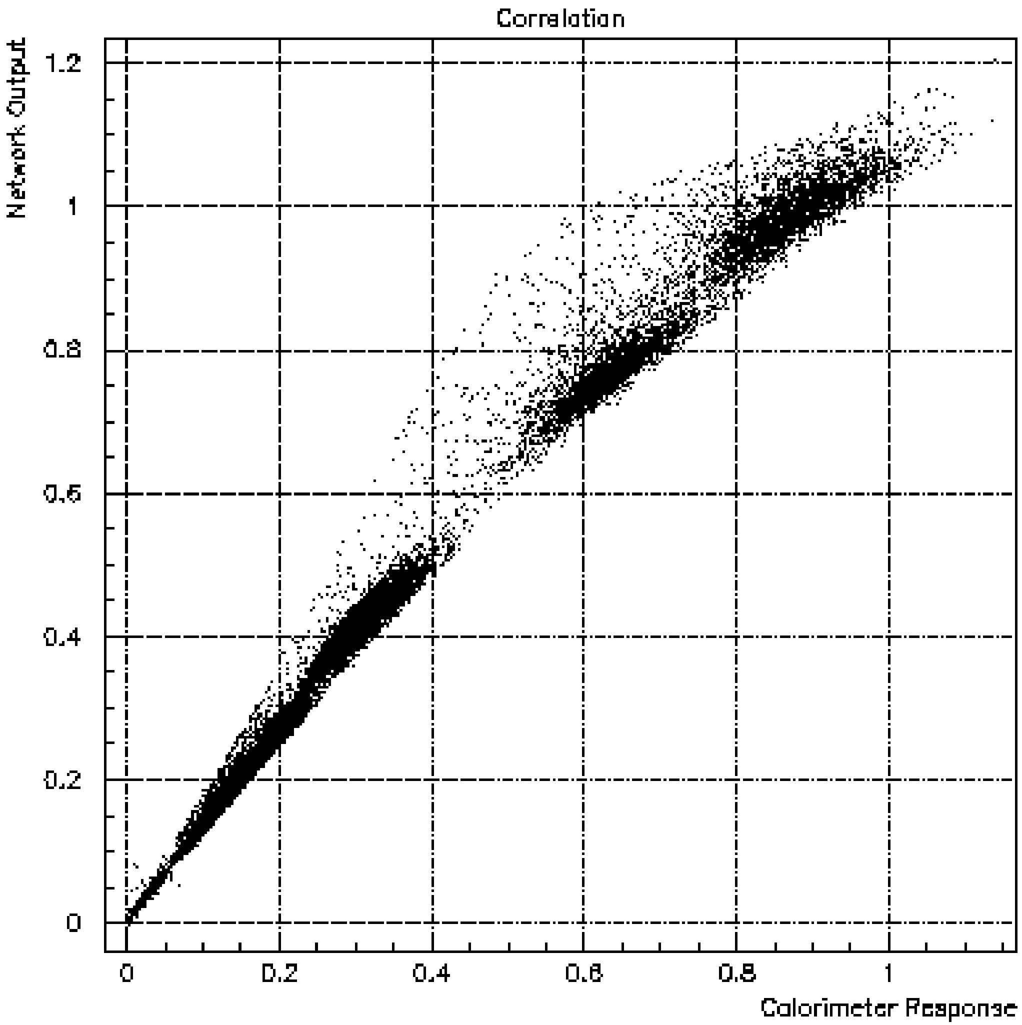


Neural Estimator (Barrel, 246 Readout Channels)

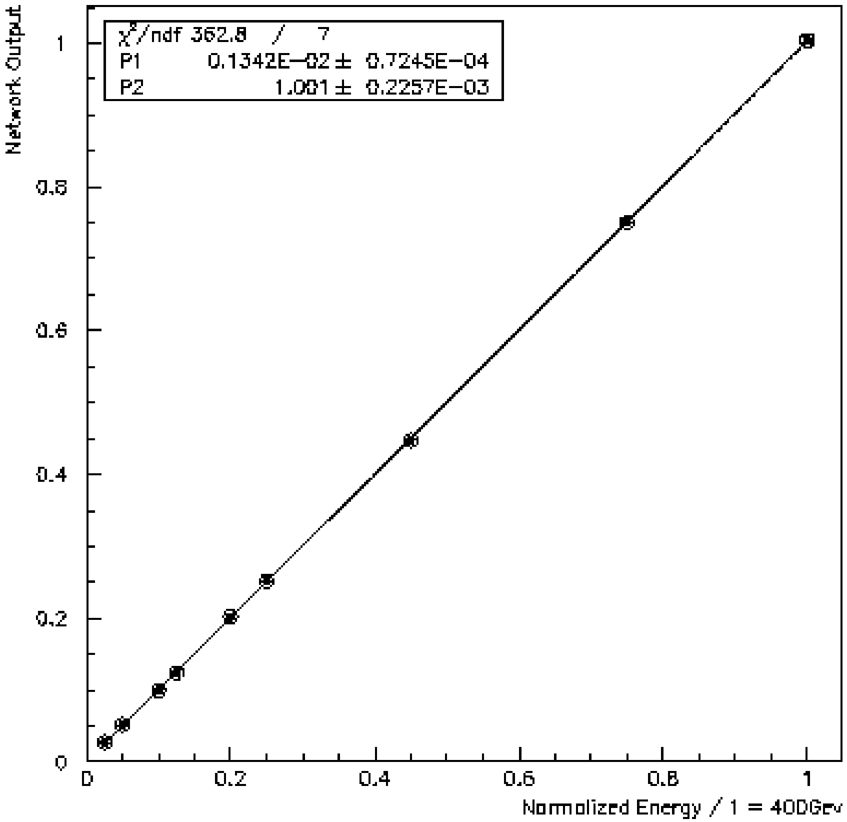


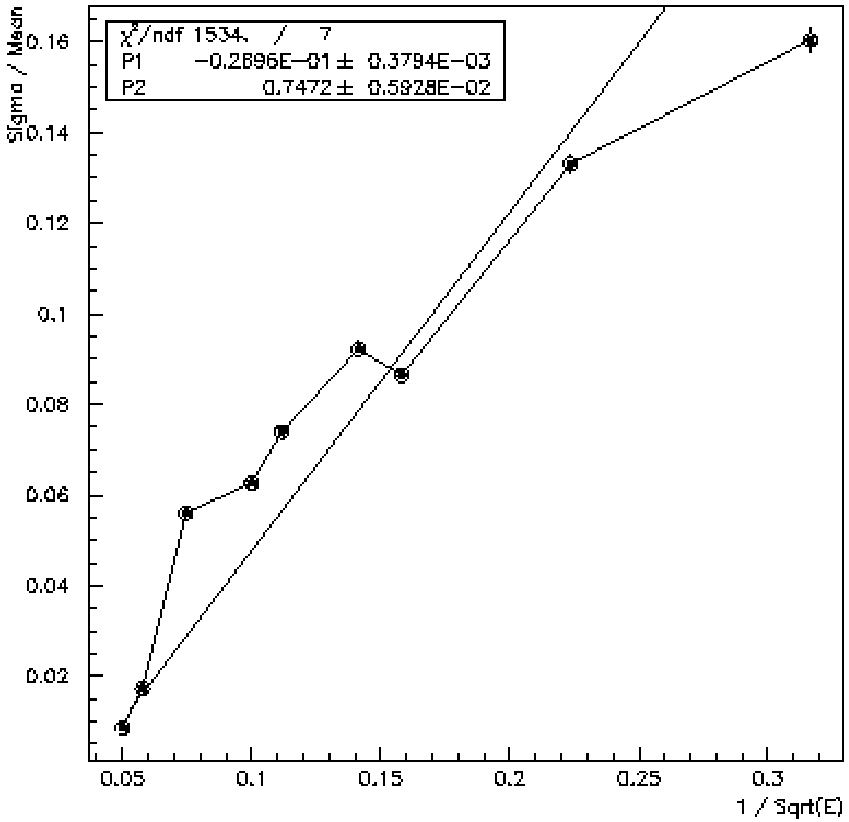


- Nonlinearity < 2.8 %
- Energy Resolution : 54% + 3.0%


Correlation
Network Output
1.2
1
0.8
0.6
0.4
0.2
0
0
0.2
0.4
0.6
0.8
1
Calorimeter Response

Preliminery Results (Extended Barrel)





- Nonlinearity < 2.9 %
- Energy Resolution : 75% - 2.7%

Neural Estimator (Barrel, 246 Readout Channels)