Analog Trigger Tower Adders for the Tilecal: Radiation Tolerance and Production Tests

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Topics:

- Introduction
- The Circuit
- Lab. Tests
- Radiation Tolerance
- Pre-Production
- Testbeam Results
- Conclusions

Introduction

- The Tile Calorimeter (Tilecal) is being developed to perform hadronic calorimetry for the Atlas detector on LHC environment.

- The Tile calorimeter is composed of one barrel and two extended barrels.

- Radially, the Tile calorimeter is segmented into three layers. Azimuthally, the barrel and extended barrels are divided into 64 modules. The rapidity coverage of the barrel is $|\eta| < 1.0$, whereas the extended barrel covers the range $0.8 < |\eta| < 1.7$.

- The first level trigger system requires trigger tower signals (η) from both electromagnetic (Liquid Argon) and hadronic calorimeters (Tilecal). The first level system uses this information for on-line event validation in Atlas.

Introduction

- A trigger tower signal for the Tilecal is built by combining linearly 5 signals from the three sampling layers: 2 from the first, 2 from second and 1 from the last layer.

- Two towers are grouped together on the extended barrel and requires the sum of 6 signals.

- Due to compatibility reasons, the 6-input topology for the level-one adder design was decided to be kept for the overall detector.

- More than 2500 adders are needed to build the trigger tower signals for the Tilecal.

Tile Calorimeter

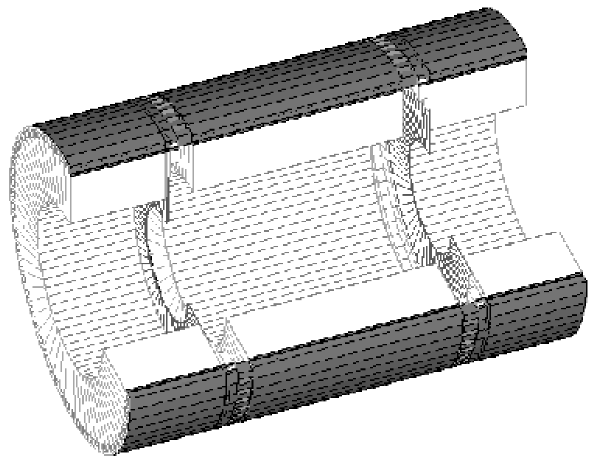

Figure 1: Tile Calorimeter.

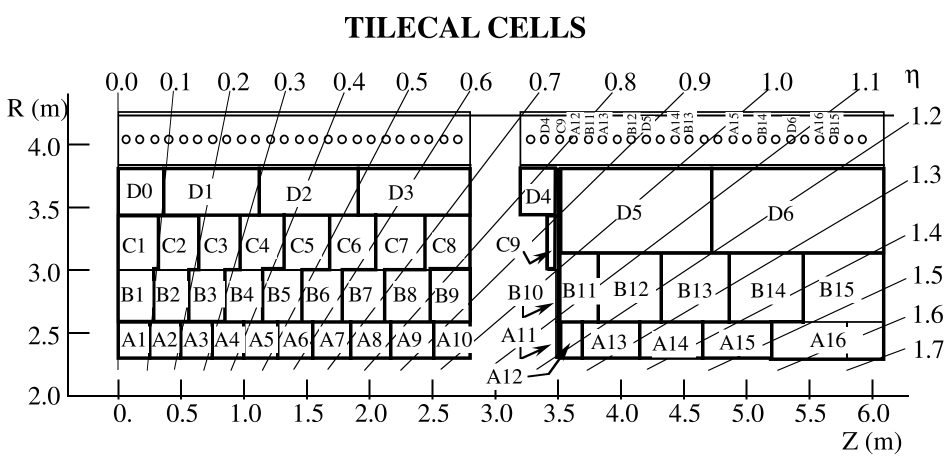

Figure 2: Tilecal Cells.

The Circuit

Input Signal Specifications:

- Furnished by the 3-in-1 cards.
- Differential (50 Ω matched).
- Unipolar, 50 ns FWHM.
- Calibration, +/- 0.5 mV/GeV.
- Time aligned to within +/- 1.5 ns.
- Noise input signals may be removed via an enable switch in the 3-in-1 units.

Output Signal Specifications:

- To provide differential signal output able to drive 50 Ω loads.
- Calibration, $+/-$ 4 mV/GeV.
- Maximum voltage swing of 4.0 V (500 GeV).
- Noise level smaller than 2 mV (250 MeV) (10-bit dynamic range).
- Voltage gain: 8.
- Gain dispersion: 2%.
- Linearity $< 2\%$.
- Fast overload recovery for 1000 GeV.
- Signals from the third sampling layer directly available at a specific adder output (muon trigger).

The Circuit

- The adder circuit is functionally composed by three stages: the input buffers, the signal addition and the output buffer.

- The input buffers match the cable impedance and prevent inter-channels crosstalk. They are implemented by transconductance amplifiers (MAX435), which provide an output current proportional to the input voltage.

- The signal addition is implemented by gathering all channel currents together to an electrical node and the total current is then transformed into voltage by a resistive load.

- The output buffer is implemented as an instrumentation amplifier (OPA4650), in order to drive differentially the LVL1 signal cable.

- An extra output channel is also provided, with independent input and output buffers (for the muon trigger).

The Circuit

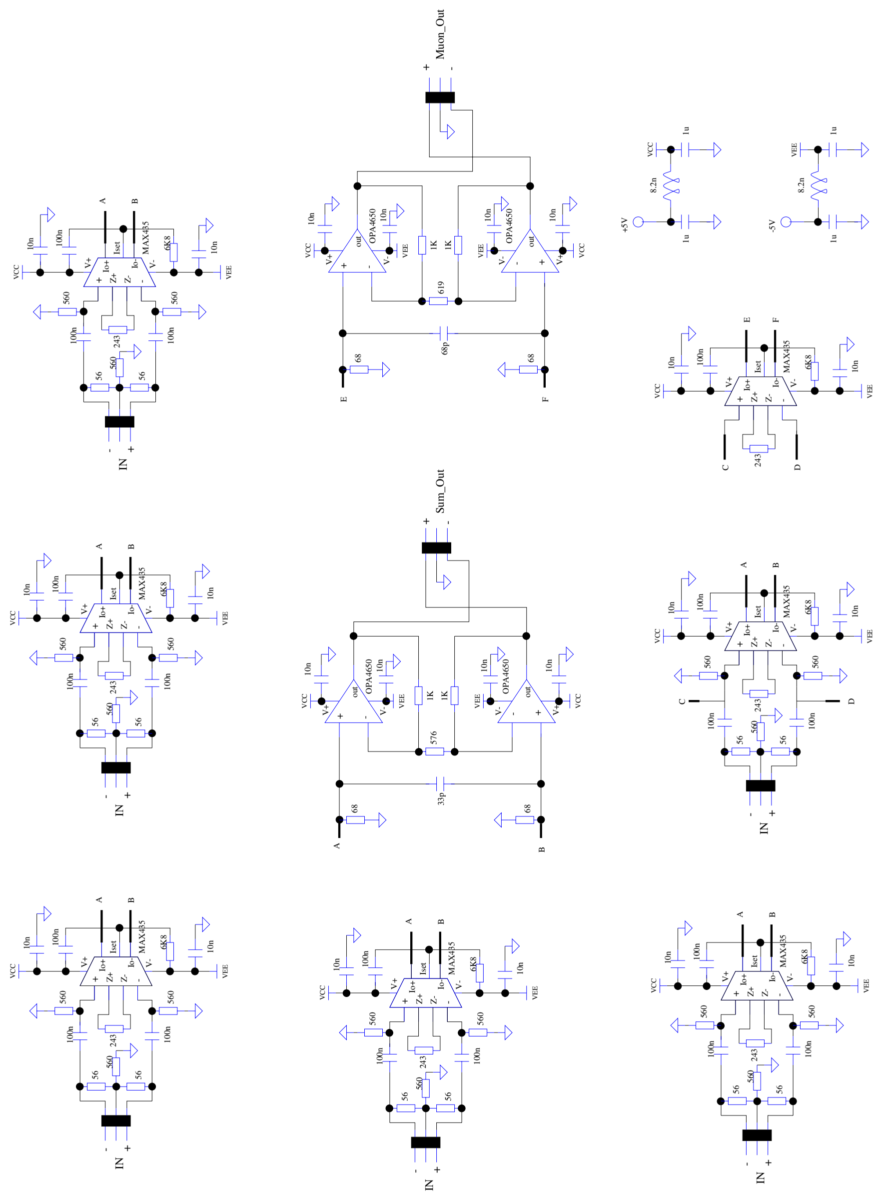

Figure 3: Trigger Summing Board schematic.

Lab. Tests

Setup:

- One adder board and five 3-in-1 cards were connected at the mother board.

- Charge was injected at the five 3-in-1 cards by a charge injection system.

- The adder output was either read out by a 12 bit ADC and by a digital storage oscilloscope (2 Gsamples/s, 500 MHz bandwidth).

Lab. Tests

Results:

- Power Consumption: 2.4 Watts.
- Linearity better than 0.6 %.
- Voltage Swing $\sim$ 4.0 V.
- Gain $\sim$ 8 for both outputs.
- Recover from saturation: 24.2 ns.
- Signal speed of the level of the 3in1 card.
- Noise level at the sum output: 926 uVrms (no 3in1 connected), 1.925 mVrms (one 3in1 connected), 4.744 mVrms (five 3in1 connected).
- Noise level at the muon output: 614 uVrms (no 3in1 connected), 1.71 6 mVrms (3in1 connected).

Lab. Tests

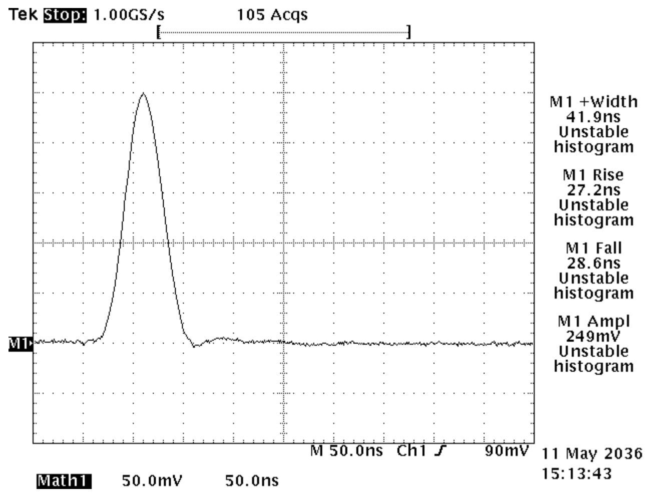

Figure 4: 3-in-1 output signal (250 GeV).

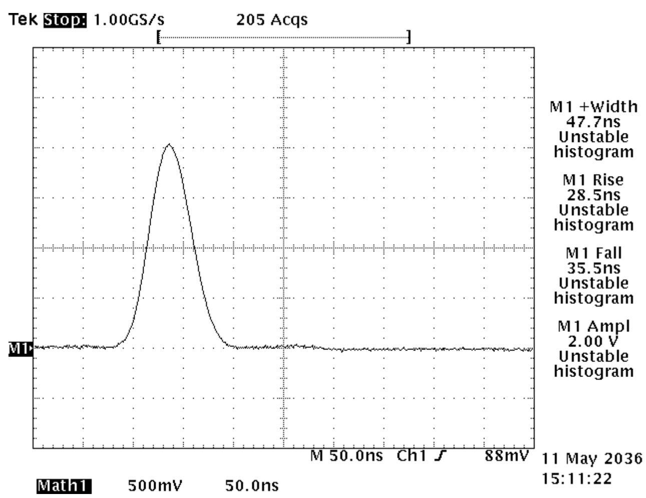

Figure 5: Adder output signal (250 GeV).

Radiation Tolerance

- The Tilecal electronics will receive a dose from ionizing radiation of 2 Gy/year (0.2 Krad/year) (total lifetime dose of 20 Gy).

- And a neutron fluence of 10^{11} 1-MeV-equivalent neutrons/cm2/year (lifetime dose of 10^{12} 1-MeV-equivalent neutrons/cm2/year). The relevant neutron energy spectrum ranges from $\sim$100 KeV to $\sim$2 MeV.

- A safety factor of 5 must be applied for uncertainties in the flux and because the actual exposure is at a much lower dose rate than the test exposure, an additional factor of 1.5 must be applied to the neutron exposure and a factor of 5 to the ionizing particle.

- The planned exposures are 500 Gy (50 Krad) for ionizing radiation and $7.5 * 10^{12}$ 1-MeV-equivalent neutrons/cm2.

Radiation Tolerance

- Two boards were tested (continuously monitored) with ionizing radiation. The total dose was 536 Gy (Co 60) for a period of 6 hours.

- The two boards had worked well during the entire test. There wasn't any change on the circuit performance.

- Two boards were tested with neutron fluence. The media dose for the board was $1.5 * 10^{12}$ neutrons/cm2 and $2.0 * 10^{13}$ for the integrated circuit MAX435, which was the specific goal of the test (the other components had already been tested).

- The test was performed in a period of 120 hours. It was used a Californium 252 source of $1.14 * 10^{8}$ neutrons/s. The two boards had worked well during the entire test.

Pre-Production

- 78 boards were assembled.

- Up to now, 59 boards were already tested with only one failure (the failure's nature was not determined yet).

- 24 were used at August testbeam.

- 8 boards have participated in a burn-in test without any failure.

Pre-Production

Lab. Tests Results:

- Sum output gain (45 boards): 8.2 +/- 0.2.
- Muon output gain (1 board) (100 measurements): 7.8 +/- 0.1.
- Linearity better than 0.6 %.
- Power Consumption 2.4 W +/- 0.1 W.
- Noise level at the sum output (45 boards): 738 uVrms +/- 110 uVrms.
- Noise level at the muon output (45 boards): 990 uVrms +/- 270 uVrms.

Pre-Production

Lab. Tests Results:

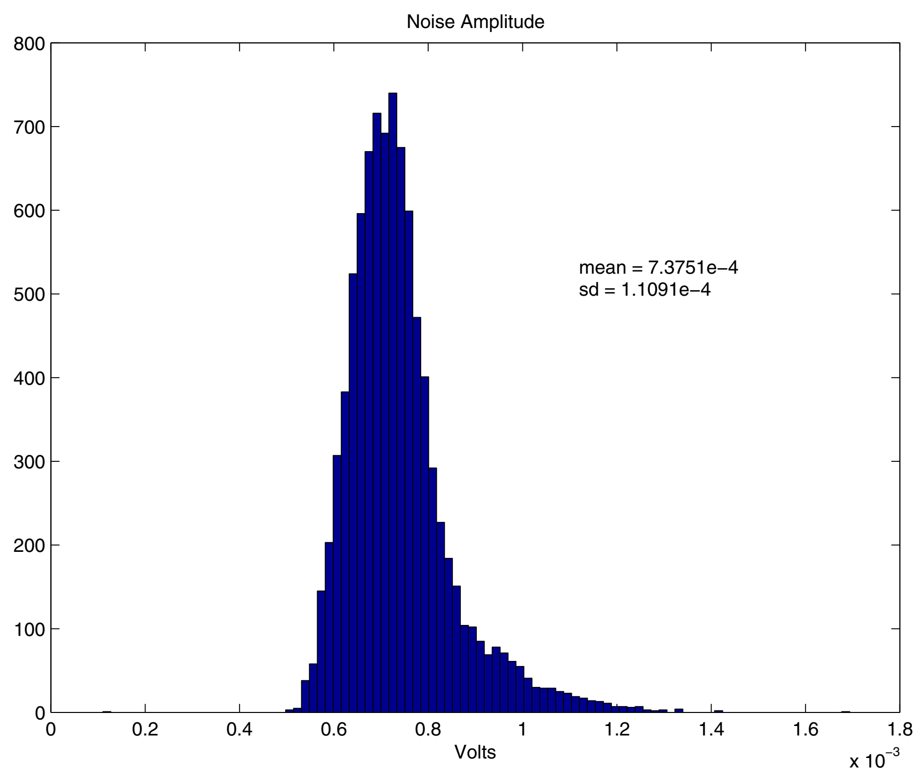

Figure 6: Noise fluctuations on the sum output from the 45 boards tested.

Testbeam (August 2000)

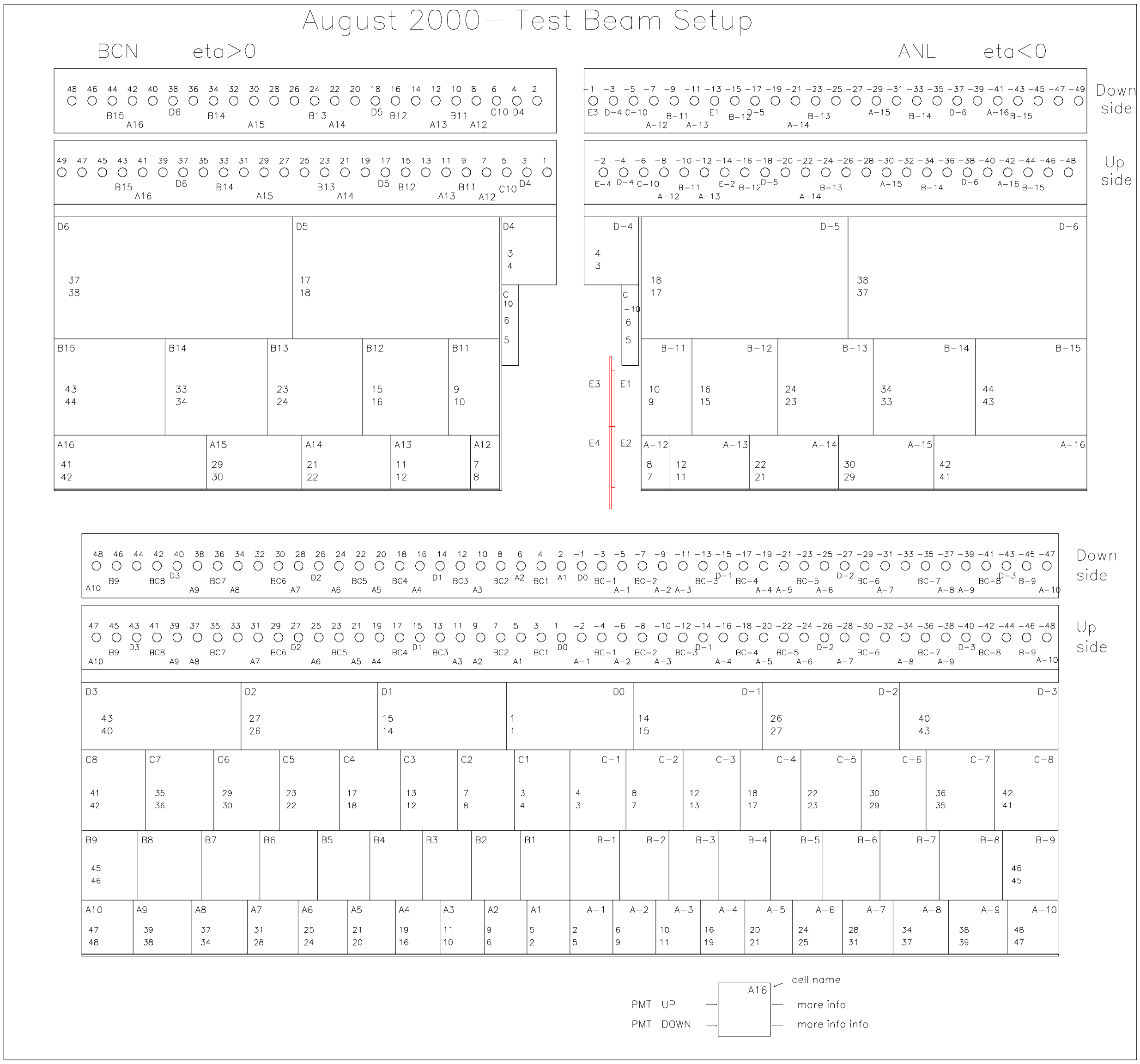

Figure 7: Cell PMT layout.

Testbeam (August 2000)

Ntuple	Eta	Status	Problem
adder(10)	0.0-0.1	OK	
adder(9)	0.1-0.2	OK	
adder(8)	0.2-0.3	no signal	cabling
adder(7)	0.3-0.4	OK	
adder(6)	0.4-0.5	OK	
adder(5)	0.5-0.6	OK	
adder(4)	0.6-0.7	OK	
adder(3)	0.7-0.8	OK	
adder(2)	0.8-0.9	OK	
adder(1)	0.9-1.0	OK	

Table 1: Adder status for the the barrel.

Testbeam (August 2000)

Ntuple	Eta	Status	Problem
adder(10)	0.8-0.9	OK	
adder(9)	0.9-1.0	OK	
adder(8)	1.0-1.1	OK	
adder(7)	1.2-1.3	OK	
adder(6)	1.1-1.2	OK	
adder(5)	1.3-1.4	OK	
adder(3)	1.4-1.6	OK	

Table 2: Adder status for the negative extended barrel.

Testbeam (August 2000)

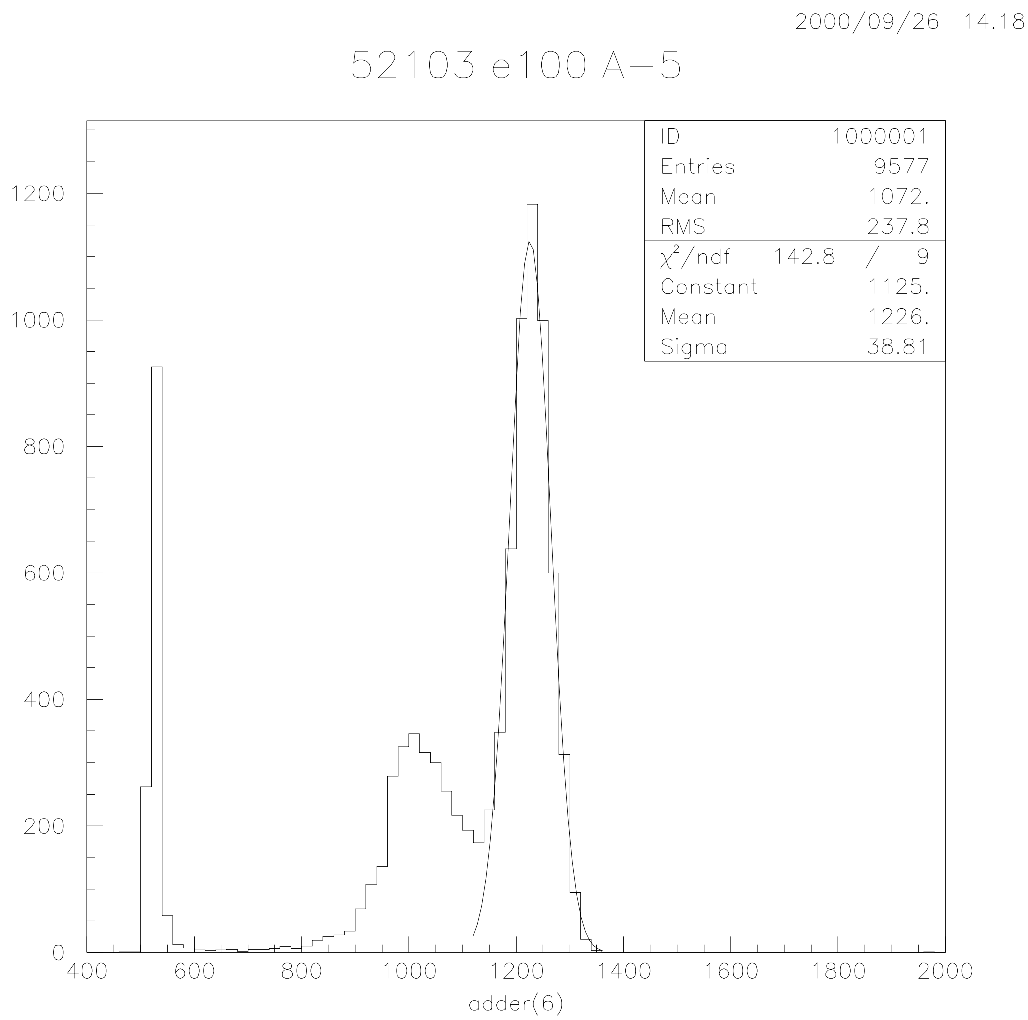

Figure 8: Adder response for electrons 100 GeV, Cell A-4, 20 degrees (trigger tower $0.3 < |\eta| < 0.4$).

Testbeam (August 2000)

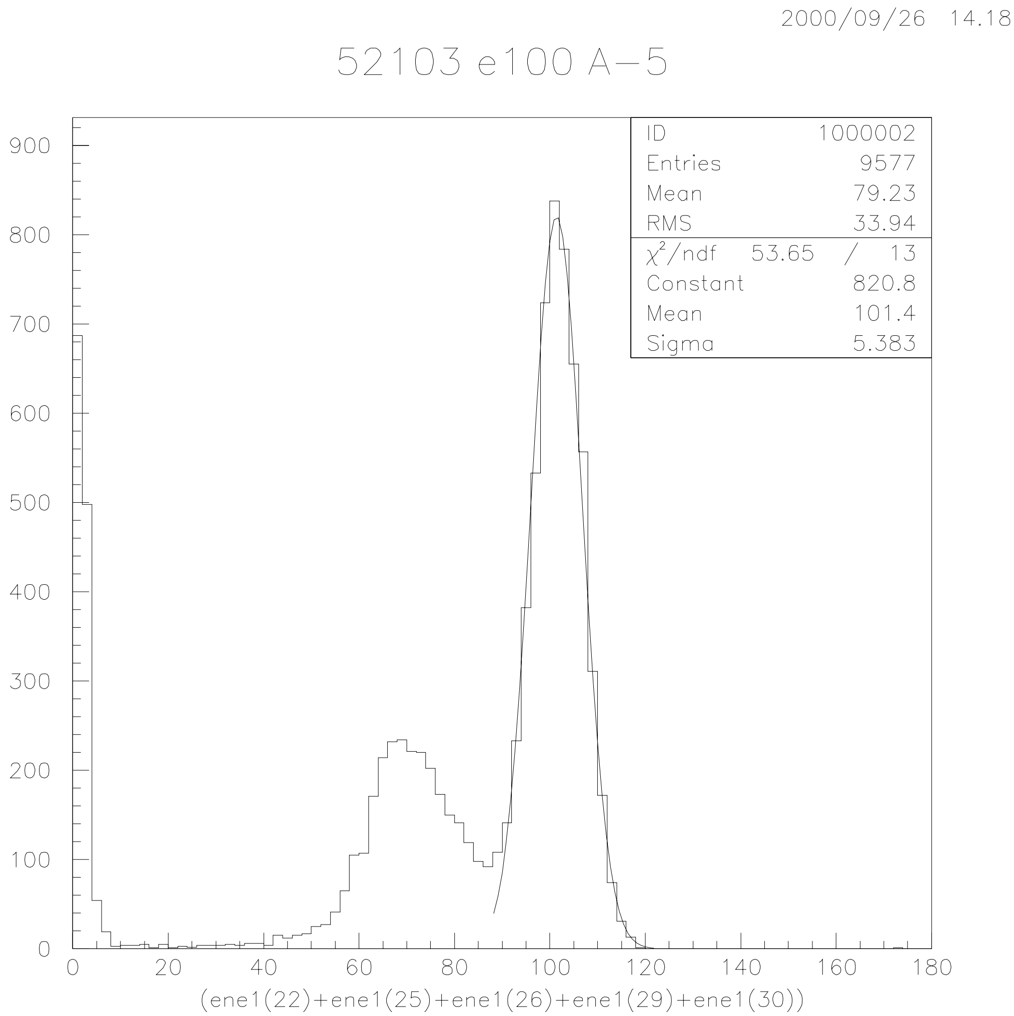

Figure 9: Software sum for electrons 100 GeV, Cell A-4, 20 degrees (sum of each PMT for the trigger tower $0.3 < |\eta| < 0.4$).

Testbeam (August 2000)

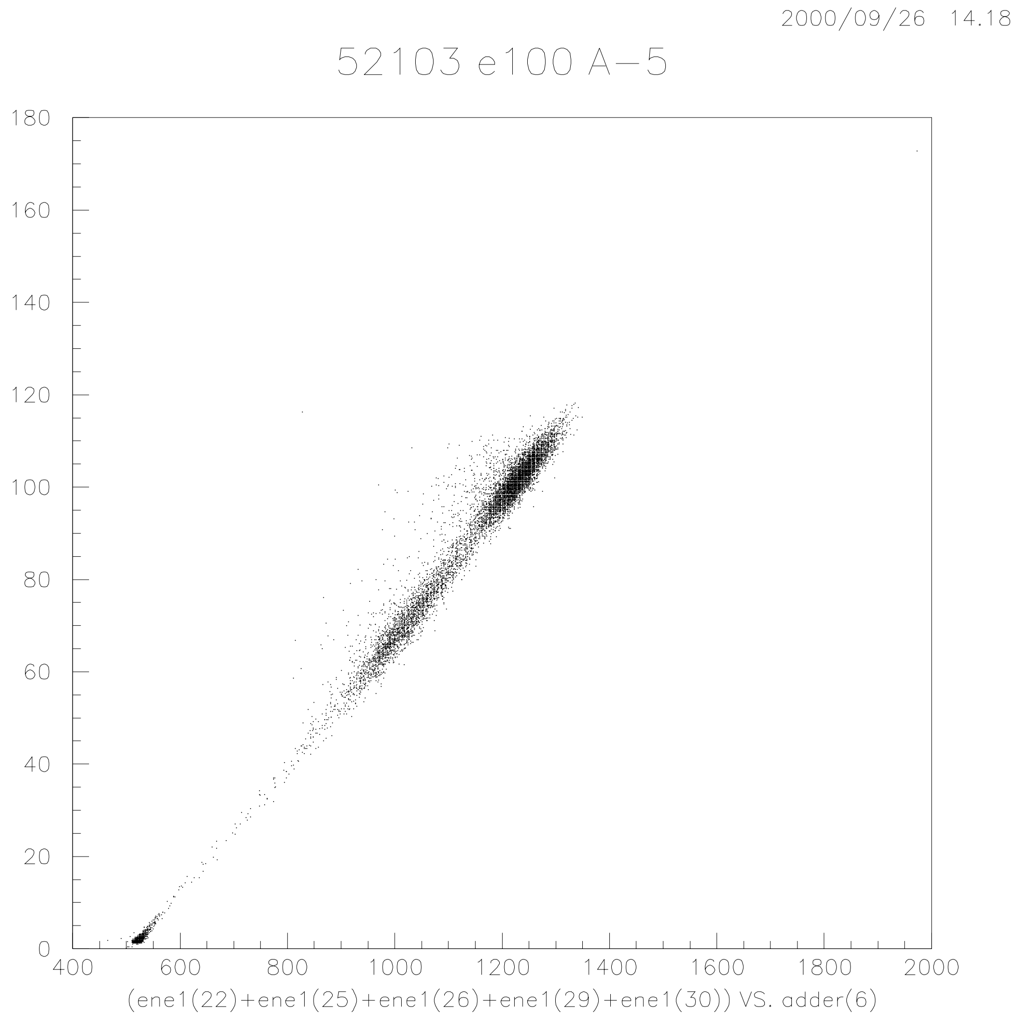

Figure 10: Correlation between the hardware and the software sums for electrons 100 GeV, Cell A-4, 20 degrees (trigger tower $0.3 < |\eta| < 0.4$).

Testbeam (August 2000)

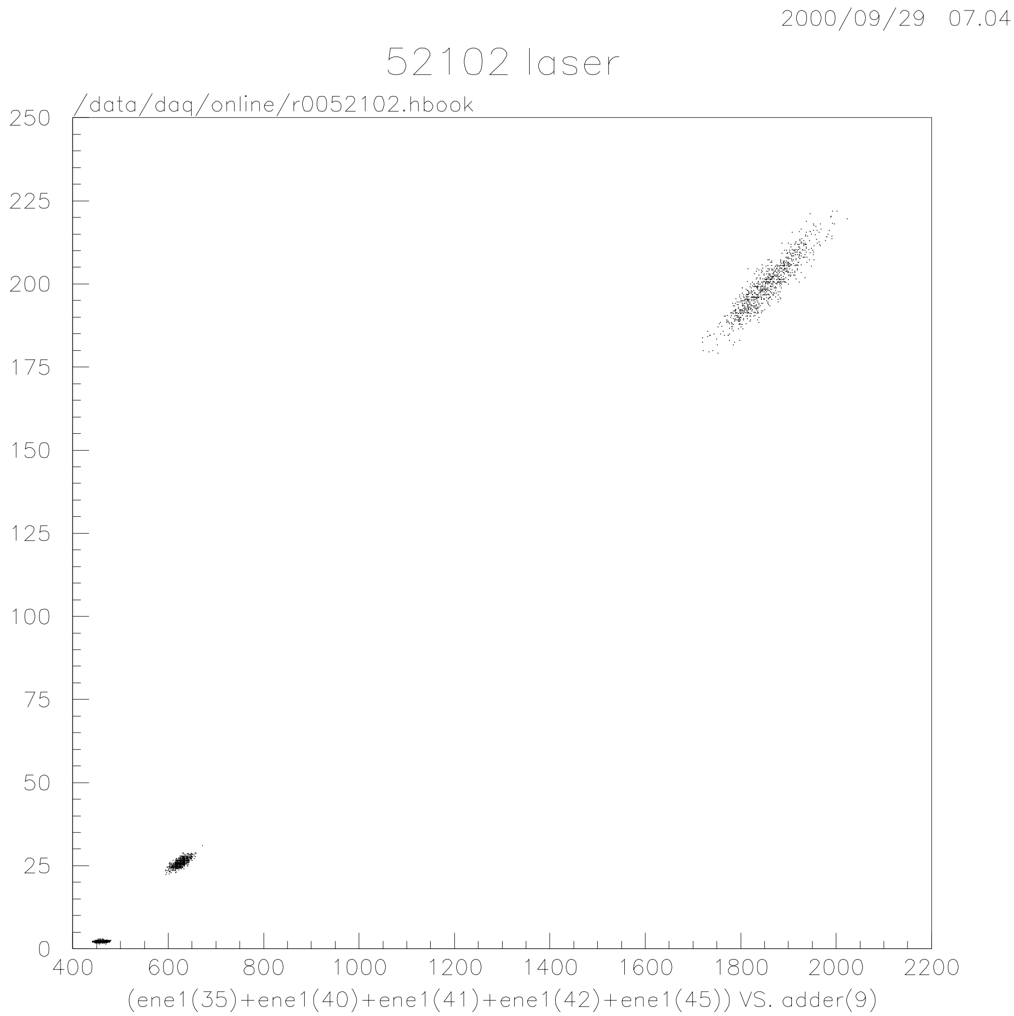

Figure 11: Correlation between the hardware and the software sums for laser events (trigger tower $0.1 < |\eta| < 0.2$).

Conclusions and Next Steps

- From the 78 boards produced, 59 were tested and 58 matched the specifications.
- 4 boards were exposed to radiation levels higher than the Atlas specifications without any failure and decrease of the performance.
- Small fluctuations and parameters according to specifications show that the preproduction was well succeeded.
- Good results on the August 2000 testbeam.
- We are ready for final production of the trigger tower adders.
- To be defined: all open issues concerning the integration (cables and connectors).