CRYOGENIC GaAs FRONT-END SYSTEM FOR THE LIQUID ARGON HADRONIC ENDCAP CALORIMETER OF ATLAS DIGITAL READOUT FOR MODUL 0

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A. Kiryukin, L. Kurochkin

presented by
J. Fent

Abstract

- Motivation for the System
- Concept of the Frontend
- Choice of Technology
- Performance of the GaAs Chips
- Results of Massmeasurements
- Results of Radiationhardness Tests
- Investigations about Bubbles in the LARG
- Beamtests at CERN with „Module 0“
HEC ‘Active Pads’ CONCEPT

HEC Tasks
- Measure hadronic energy in presence of high pile-up.
- Provide trigger energy sums for LVL1 trigger.
- Identify muons, measure their energy loss in HEC.

Specific Conditions
- Parallel plate calorimeter of large dimensions.
- Large detector capacities ($<4 \text{ nF}$) varying with $\eta$.
- Low sampling fraction.
- Low maximal signals.
- Summation over large volume for jet measurement, high sensitivity to coherent noise.

Strategy
- Use amplifiers with lowest noise.
- Avoid pick-up, place preamps close to read-out pads.

Baseline Solution
- Monolithic GaAs amplifiers operated in LAR
- Position at wheel circumference (Moderate radiation)
- One PA serves two consecutive pads
- Up to eight PAs summed to one readout channel
- Drivers send summed signals out of cryostat (shaper)
ATLAS - HEC Frontendelectronic (Blockdiagram)
Chip MPI 96B n.02 at LN temperature
Cables 1m in warm. Peak time 40 ns
Chip 96A, n.07, driver 2, LN temperature
ENI of 4 preamps and driver for 5 values of Cd (per preamp)

ENI, nA

Peak time, ns
### Results of Massmeasurements

**Definitions:**

- Normal PAM: amplitude 230 mV
- Bad Chip: something is bad
- Dead PAM: amplitude below 20 mV
- Bad PAM: amplitude below 170 mV
- Bad Group: one or more PAMs are dead or bad
- Bad driver: all four PAMs are dead or bad
- Bad Group, bad PAMs: gain variation of PAMs in a group above 2%
- Bad Group, bad Driver: output noise above 1.5 mV

<table>
<thead>
<tr>
<th></th>
<th>Chip</th>
<th>Group1</th>
<th>Group2</th>
<th>Preamps</th>
<th>Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>606</td>
<td>606</td>
<td>606</td>
<td>4848</td>
<td>1212</td>
</tr>
<tr>
<td><strong>Dead or bad preamps</strong></td>
<td>127</td>
<td>72</td>
<td>77</td>
<td>131</td>
<td>47</td>
</tr>
<tr>
<td><strong>Large gain variation</strong></td>
<td>36</td>
<td>19</td>
<td>22</td>
<td>164</td>
<td>0</td>
</tr>
<tr>
<td><strong>Large noise</strong></td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td><strong>Good</strong></td>
<td>444</td>
<td>515</td>
<td>506</td>
<td>4553</td>
<td>1164</td>
</tr>
<tr>
<td><strong>Yield, %</strong></td>
<td>73.27</td>
<td>84.98</td>
<td>83.50</td>
<td>93.92</td>
<td>96.04</td>
</tr>
</tbody>
</table>
Same measurements after five (5) times cooling down and warming up.

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</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>444</td>
<td>444</td>
<td>444</td>
<td>3552</td>
<td>888</td>
</tr>
<tr>
<td>Dead or bad preamps</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Large gain variation</td>
<td>20</td>
<td>10</td>
<td>12</td>
<td>88</td>
<td>0</td>
</tr>
<tr>
<td>Large noise</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Good</td>
<td>420</td>
<td>431</td>
<td>429</td>
<td>3458</td>
<td>885</td>
</tr>
<tr>
<td>Yield, %</td>
<td>94.59</td>
<td>97.07</td>
<td>96.62</td>
<td>97.35</td>
<td>99.66</td>
</tr>
</tbody>
</table>

69.3
Set of Chips 2: Signal R.M.S. in Measurement 1

All drivers

Drivers no. 1
Set of Chips 2: Average Peaking Time in Measurement 1

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**All drivers**

- Entries: 1021
- Mean: 54.31
- RMS: 1.842
- UDFLW: .0000E+00
- OVFLW: .0000E+00

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**Drivers no.1**

- Entries: 515
- Mean: 54.23
- RMS: 1.828
- UDFLW: .0000E+00
- OVFLW: .0000E+00

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**Drivers no.2**

- Entries: 506
- Mean: 54.38
- RMS: 1.854
- UDFLW: .0000E+00
- OVFLW: .0000E+00
Set of Chips 2: Equivalent Noise in Measurement 1

**All drivers**

- Entries: 1021
- Mean: 93.58
- RMS: 5.185
- UDFLW: 0.0000E+00
- OVFLW: 0.0000E+00

**Drivers no.1**

- Entries: 515
- Mean: 93.01
- RMS: 5.208
- UDFLW: 0.0000E+00
- OVFLW: 0.0000E+00
EN\(\mathbf{I}\) (nA) vs. shaping time \(\tau\) (ns), channel 11, \(C_d = 330\) pF

- \(\text{rad} = 0.0 \times 10^{14}\ n / \text{cm}^2\) before irradiation
- \(\text{rad} = 0.5 \times 10^{14}\ n / \text{cm}^2\)
- \(\text{rad} = 1.0 \times 10^{14}\ n / \text{cm}^2\)
- \(\text{rad} = 1.6 \times 10^{14}\ n / \text{cm}^2\)
- \(\text{rad} = 2.0 \times 10^{14}\ n / \text{cm}^2\)
- \(\text{rad} = 2.5 \times 10^{14}\ n / \text{cm}^2\)
2. Transfer function

Output Voltage $\xrightarrow{TF}$ Input Current

$\tau = 50 \text{ns}$

$C_d = 0 \text{ pF}$

$\tau = 100 \text{ns}$

$C_d = 330 \text{ pF}$
ATLAS HEC FRONTEND ELECTRONICS QUALITY ASSURANCE PROCEDURE

TESTS of UNITS

PSB Frontend Boards

Preliminary Check

**FUNCTIONAL TEST WARM MPI**
*All PreAmp-(128) + Driver-(16) Channels, Amplitude Peak time Noise out RMS Oscillation Freq. Oscillation Factor*

**FUNCTIONAL TEST COLD MPI**
*All PreAmp-(128) + Driver-(16) Channels, Amplitude Peak time Noise out RMS Oscillation Freq. Oscillation Factor*

**TEMP. SHOCK MPI**
*Connected Board Liquid Nitrogen*

**TEMP. RISE MPI**
*Connected Board Room Temp.*

Repeat 3X (7 hours)

Full Measurements

**FULL MEAS. WARM MPI**
*All PreAmp-(128) + Driver-(16) Channels, Amplitude Peak time Noise out RMS X-Talk Nonlinearity*

**FULL MEAS. COLD MPI**
*All PreAmp-(128) + Driver-(16) Channels, Amplitude Peak time Noise out RMS X-Talk Nonlinearity*

**TEMP. SHOCK MPI**
*Connected Board Liquid Nitrogen*

**TEMP. RISE MPI**
*Connected Board Room Temp.*

**FUNCTIONAL TEST WARM MPI**
*All PreAmp-(128) + Driver-(16) Channels, Amplitude Peak time Noise out RMS Oscillation Freq. Oscillation Factor*
Digital Atlas-HEC Readout

AD CONVERTER

Burr-Brown ADS800

- Resolution: 12 Bit
- Sampling Rate: 40 MHz
- Linearity Error: ± 1.0 LSB
- Power Consumption: 485 mW (max.)
- Input: differential

<table>
<thead>
<tr>
<th>Differential Input</th>
<th>Output Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>IN - _IN</td>
<td>MSB</td>
</tr>
<tr>
<td>2 V</td>
<td>111111111111111</td>
</tr>
<tr>
<td>0 V</td>
<td>100000000000000</td>
</tr>
<tr>
<td>-2 V</td>
<td>000000000000000</td>
</tr>
</tbody>
</table>
Conclusion

We designed a multichannel preamplifier chip with summing stage and linedrivers. The performance tests showed the expected and simulated results.

The mass production reached a yield of 73% good chips. After five times fast cooling down in liquid nitrogen and warming up again, 5.5% additional chips were bad.

Then the chips were soldered onto motherboards and again cooled down measured in the cold and warmed up again. No additional bad chip was found.

150 readout channels (1200 amplifiers) are currently operational in a beamtest at CERN. They are read out via Flash-ADCs into digital pipelines. First data show the expected performance.