ALICE MUON TRACKING CHAMBERS
LOW-VOLTAGE POWER SYSTEM UPGRADE

Presented by

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ORCEL THYS

HEPP WORKSHOP 2019
Present Low-voltage system

230VAC, single phase

"PL500-F12"
LVPS
12Ch, 25A

μP

Water cooled

+2.5v
-2.5v
+3.3v

FILTER BOX

Low radiation & 0.7 T magnetic field tolerance

Muon Tracking Chambers

OPC Server
An analysis of the detector system for both the present and upgraded electronics was necessary to understand possible low-voltage power supply solutions that would meet the required specifications.

<table>
<thead>
<tr>
<th>Present detector electronics</th>
<th>Upgraded detector electronics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FEC</strong> MANU cards (4 X 16 channels)</td>
<td><strong>DualSAMPA</strong> (2 X 32 channels)</td>
</tr>
<tr>
<td>Voltage for FEC chips</td>
<td>1.25V digital and 1.25V analogue (2 low-voltages)</td>
</tr>
<tr>
<td>Power consumption for max low-voltage line</td>
<td>4.5mW/ch digital</td>
</tr>
<tr>
<td>Input voltage for FEC</td>
<td>1.7V digital and 1.7V analogue (2 low-voltages)</td>
</tr>
<tr>
<td>Read out electronics</td>
<td>CROCUS (requires 3.3V supply)</td>
</tr>
<tr>
<td>+/−2.5V, 3.3V (3 low-voltages)</td>
<td>1.25V digital and 1.25V analogue (2 low-voltages)</td>
</tr>
<tr>
<td>4mW/ch for each LV line</td>
<td>7mW/ch analogue</td>
</tr>
<tr>
<td>Implies: &lt;25A max for both slats and quadrants</td>
<td>4.5mW/ch digital</td>
</tr>
<tr>
<td>+2.5V, −2.5V, 3.3V</td>
<td>Implies: ~45A max for slats</td>
</tr>
<tr>
<td>1.7V digital and 1.7V analogue (2 low-voltages)</td>
<td>~85A max for quadrants</td>
</tr>
<tr>
<td>SOLAR (requires 5V from supply)</td>
<td></td>
</tr>
</tbody>
</table>
DC – DC CONVERTER
DC – DC Studies

• Input of DCDC to be powered by LVPS: 5V-7V
• Output of DCDC to supply 3.6V (1.7V+1.9V(drop)) to FEC with 45A current consumption at maximum
• DCDC must be able to perform well in magnetic field of 0.7T
• Various commercial DCDC modules were investigated at ITHEMBA LABS and CERN

Inside IThemba LABS laboratory

Inside CERN laboratory

- DC load
- Power supply
- Magnet (Magnetic field range 0T – 0.7T)
- Box for mounting DCDC
- Multi-meters for input measurements
- Fusion digital power designer from Texas software for output measurements (temperature, output voltage and current)
## DC - DC Studies - Summary

<table>
<thead>
<tr>
<th>DCDC Converters:</th>
<th>LMZ31710</th>
<th>LTM4650</th>
<th>ISL8272</th>
<th>TPS543C20</th>
<th>TPSM846C23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluation Board</td>
<td>2X 10A LMZ31710 @18A</td>
<td>1X 50A LTM4650</td>
<td>1X 50A ISL8272</td>
<td>2X 40A TPS543C20 @80A</td>
<td>2X 35A TPSM846C23 @70A</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Texas Instruments</td>
<td>Linear Technology</td>
<td>Intersil</td>
<td>Texas Instruments</td>
<td>Texas Instruments</td>
</tr>
<tr>
<td>Output Current</td>
<td>10A</td>
<td>50A</td>
<td>50A</td>
<td>40A</td>
<td>35A</td>
</tr>
<tr>
<td>Vout Range</td>
<td>0.6V - 5.5V (♣)</td>
<td>0.6V - 1.8V (♣)</td>
<td>0.6V - 5V (♣)</td>
<td>0.6V - 5.5V (♣)</td>
<td>0.6V - 2V</td>
</tr>
<tr>
<td>Vin Range</td>
<td>2.95V - 17V</td>
<td>4.5V - 15V</td>
<td>4.5V - 14V</td>
<td>4V - 16V</td>
<td>4.5V - 15V</td>
</tr>
<tr>
<td>Inductor</td>
<td>Integrated (Shielded)</td>
<td>Integrated (Unshielded)</td>
<td>Integrated (Shielded)</td>
<td>External (Shielded)</td>
<td>Integrated (Shielded)</td>
</tr>
<tr>
<td>Magnetic Field Test at 0.7T</td>
<td>Passed</td>
<td>Failed (@0.3T)</td>
<td>Failed (@0.3T)</td>
<td>Failed (@0.3T)</td>
<td>Passed (validated with Vout set to 4V) Tested at Vout =5V → output voltage does not stay in regulation → but we need only 3.6V at DCDC level so it is fine.</td>
</tr>
<tr>
<td>Comments</td>
<td>Matches ITS Studies for same DCDC module. Need five LMZ31710 modules in parallel to achieve 45A needed.</td>
<td>Inadequate shielding. Output of DCDC fails – goes to 0V</td>
<td>Inadequate shielding. Output of DCDC fails – goes to 0V</td>
<td>Inadequate shielding. Output of DCDC fails – goes to 0V</td>
<td>Gives best result compared to other DCDC modules – Test results presented in following slides</td>
</tr>
</tbody>
</table>
DCDC Studies - Conclusion

• **18A LMZ31710 DCDC** as a starting point yielded satisfactory results under magnetic field conditions – promising start to investigate higher current modules.

• Failed DCDC converters from Linear Technology, Intersil and Texas Instruments tested in 0.7T Magnetic field were seen to be inadequately shielded.

• From the DCDC investigation and tests, it can be noted that the **70A TPSM846C23 DCDC** from Texas Instruments yielded the best results from all other DCDCs investigated. **Therefore, it is found to be a suitable solution for the LV System upgrade if implemented → however more tests with full chain need to be done using this Evaluation Board.**

• **The dc-dc solution was put on hold due to time constraints, we decided to look at other possible solutions to modify the actual LVPS.**

• **This will be discussed in the next section.**
PROPOSED LV SYSTEM PLAN
Low-voltage upgrade system

- **FEC**
  - Keep the existing LV cables and need a voltage of 1.7V @ 50A slats and 85A quadrants
  - Detectors supplied through the same LV busbars
  - Upgrade Currents 3-4 times higher than present setup

- **SOLAR BOARD**
  - Need a voltage of 5V @ 1A
  - 6 Solar boards per crate
  - 112 crates --> 112 channels

- **FILTER BOX**
  - Upgrade the capacitors (100A)
  - Modifications of the filter box

- **LVPS**
  - 38 (including spares) existing LVPS; 8V max, 25A max
  - Buy or/and modification of the LVPS with higher currents (mainly < 50A, but some channels < 100A)
1 FEC = 2 SAMPA = DualSAMPA
17000 + 2500 (spares)
FLEX (slats) / PCB (quadrants) + flat cable ~2500
Possible solution for quadrants of (CH1,Ch2,CH3,CH4), with PL512 6 modules (50/100A)

- 1 quadrant = 2 cathodes ; 1 half-chamber = 2 quadrants
- 1 cathode supplied by 1 for analog and 1 for digital voltage line
- Our LV system is divided in 2 sides (right and left), so by half-chamber
- In total 16 quadrants for the stations 1 & 2 = 8 on right side (INSIDE°) + 8 on left side (OUTSIDE)
- Need 32 LV lines, 6 LVPS PL512 6 modules (100A) on each side ⇒ 12LVPS in total
Possible solution for slats of station 3 (CH5,CH6), with PL512 6 modules (50/100A)

CH5 Left = CH5 Right
CH6 Left = CH6 Right
Possible solution for slats of station 4 & 5 (CH7, CH8, CH9, CH10), with PL512 6 modules (50/100A)

CH7/CH9 Left = CH7/CH9 Right  
CH8/CH10 Left = CH8/CH10 Right
LVPS crates location

### Present Configuration

<table>
<thead>
<tr>
<th></th>
<th>C08</th>
<th>C09</th>
<th>C10</th>
<th>C11</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1</td>
<td>CH5</td>
<td>CH7</td>
<td>CH9</td>
<td></td>
</tr>
<tr>
<td>CH2</td>
<td>CH5/CH6</td>
<td>CH7/CH8</td>
<td>CH9</td>
<td></td>
</tr>
<tr>
<td>CH3</td>
<td>CH6/CH7</td>
<td>CH8</td>
<td>CH10</td>
<td></td>
</tr>
<tr>
<td>CH4</td>
<td>CROCUS</td>
<td>CH10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**OUTSIDE: view from back**

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### Upgrade Configuration

<table>
<thead>
<tr>
<th></th>
<th>C08</th>
<th>C09</th>
<th>C10</th>
<th>C11</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLAR</td>
<td>CH1</td>
<td>CH4</td>
<td>CH7/CH8</td>
<td></td>
</tr>
<tr>
<td>SOLAR</td>
<td>CH1/CH2</td>
<td>CH5</td>
<td>CH8</td>
<td></td>
</tr>
<tr>
<td>SOLAR</td>
<td>CH2/CH3</td>
<td>CH5/CH6</td>
<td>CH9</td>
<td></td>
</tr>
<tr>
<td>SOLAR</td>
<td>CH3</td>
<td>CH6</td>
<td>CH9/CH10</td>
<td></td>
</tr>
<tr>
<td>SOLAR</td>
<td>CH4</td>
<td>CH7</td>
<td>CH10</td>
<td></td>
</tr>
</tbody>
</table>

**OUTSIDE: view from back**

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### Inside: view from back
LVPS FEC: Cabling modifications

**PRESENT CONFIGURATION**

1 cable = 1 LV Analog (+ Red) + 1 LV Analog (- Blue) + 1 LV Digital (+ Yellow) + 2 GND + 3 pairs of sense

LV + GND = 16 mm²

**UPGRADE CONFIGURATION**

Example CH5

1 cable = 1 LV Analog (+ Red) + 1 LV Digital (+ Blue) + 2 GND (Black) + 2 pairs of sense

LV + GND = 16 mm²
LVPS SOLAR: New Cabling

UPGRADE CONFIGURATION

Example CH5

1 LV lines | Sense | Ground

1 cable = 1 LV (+ Red) + 1 GND (Black) + 1 pairs of sense

LV + GND = 3.3 mm²
### SOLAR LVPS cabling: racks C08 and C36

<table>
<thead>
<tr>
<th>C08</th>
<th>C36</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOLAR 1:</td>
<td>SOLAR 1:</td>
</tr>
<tr>
<td>4 cables for CH1 + 4 cables for CH2</td>
<td>4 cables for CH1 + 4 cables for CH2</td>
</tr>
<tr>
<td>(Station 1)</td>
<td>(Station 1)</td>
</tr>
<tr>
<td>SOLAR 2:</td>
<td>SOLAR 2:</td>
</tr>
<tr>
<td>4 cables CH3 + 4 cables CH4</td>
<td>4 cables CH3 + 4 cables CH4</td>
</tr>
<tr>
<td>(Station 2)</td>
<td>(Station 2)</td>
</tr>
<tr>
<td>SOLAR 3:</td>
<td>SOLAR 3:</td>
</tr>
<tr>
<td>5 cables CH5 + 5 cables CH6</td>
<td>5 cables CH5 + 5 cables CH6</td>
</tr>
<tr>
<td>(Station 3)</td>
<td>(Station 3)</td>
</tr>
<tr>
<td>SOLAR 4:</td>
<td>SOLAR 4:</td>
</tr>
<tr>
<td>7 cables CH7 + 5 cables CH8</td>
<td>7 cables CH7 + 5 cables CH8</td>
</tr>
<tr>
<td>(Station 4)</td>
<td>(Station 4)</td>
</tr>
<tr>
<td>SOLAR 5:</td>
<td>SOLAR 5:</td>
</tr>
<tr>
<td>2 cables CH8 + 8 cables CH9</td>
<td>2 cables CH8 + 8 cables CH9</td>
</tr>
<tr>
<td>(Station 4 + 5)</td>
<td>(Station 4 + 5)</td>
</tr>
<tr>
<td>SOLAR 6:</td>
<td>SOLAR 6:</td>
</tr>
<tr>
<td>8 cables CH10</td>
<td>8 cables CH10</td>
</tr>
<tr>
<td>(Station 5)</td>
<td>(Station 5)</td>
</tr>
</tbody>
</table>
LVPS racks under Muon platform

MCH SOLAR Cables

- SOL1+2-O : 8 cables CH1+2 station 1
- SOL3+4-O : 8 cables CH3+4 station 2
- SOL5-O : 5 cables CH5 station 3
- SOL6-O : 5 cables CH6 station 3
- SOL7-O : 7 cables CH7 station 4
- SOL8-O : 7 cables CH8 station 4
- SOL9-O : 8 cables CH9 station 5
- SOL10-O : 8 cables CH10 station 5

- INSIDE = OUTSIDE
- Total: 112 cables (56 on each side)

- 1 cable = 1 LV + 1 GND + 1 pair of sense
  = 2 x 3.3 mm² + 1 pair of sense

Right side of the detector in the UX25

Left side of the detector in the UX25
Global LVPS solution

- **On LVPS side**
  - SOL[Rack N°]-[LV Crate N°]-[Channel]
  - ex: SOLC36-1-1 corresponds to Rack 36, LV crate 1, channel 1
  - This channel will supply: CH1 Inside, SOLAR Crate 1

- **On Detector side (Quadrants)**
  - SOL[Chamber N°][Side]-C[Crate N°]
  - Ex: SOL5I-C1 SOL Chamber5 Inside – Crate 1

C1, C2 on Top

C3, C4 on Bottom

Idem for CH2, 3 and 4 Inside and Outside
Global LVPS solution

- **On Detector side (station 3)**
  - SOL[Chamber N°][[Side]-C[Crate N°]
  - Ex: SOL5I-C1 SOL Chamber5 Inside – Crate 1

- **On Detector side (station 4 and 5)**
  - SOL[Chamber N°][[Side]-C[Crate N°]
  - Ex: SOL9I-C1 SOL Chamber9 Inside – Crate 1

View from inside the dipole, looking at the yoke

CH7 and CH8 : 7 crates C1 → C7

CH9 and CH10 : 8 crates C1 → C8
Summary

- The new sample 100A LVPS from Wiener ordered and tested with Test bench at CERN – performed satisfactory 🔄

- New 100A LV Capacitors tested in DSF LAB under magnetic field (~0.7T) and with test bench at CERN – performed satisfactory 🔄

- Total capacity of LV capacitors ordered and received at CERN 🔄

- Removal and Modification of filter boxes to be done at Saclay – ongoing

- Awaiting full capacity of new LVPS from Wiener and modification of current LVPS to done within next couple months

- LV System project on track for installation for the coming year