Detector Powering in the 21st Century
Why stay stuck with the Good old 20th Century methods?

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Agenda
CMS ECAL - powering
ECAL readout system was:
designed in ~2000
produced in 2001-2007
commissioned in 2006-2007

20th Century State of Power Distribution – *LHC Detectors*

FE produces distributed heat low W/sq cm
Power Boards High W/sq cm. use heat spreaders
CMS ECAL Super modules
Power Chain Efficiency for CMS ECAL

- Transformer 18 KV 3 Phase
  - UPS Batteries
  - Isolation Transformer 220 V 3 Phase
  - Rectifier & PFC 385 V
  - Wiener Maraton PS 6.3 V
  - Load 125 KW

$\text{Power delivery Efficiency} = 30\%$

$\text{with Power for Heat Removal} = 20\%$

It takes 2 watts of power to remove 1 watt of heat load

From Experts Efficiency %
Guess work Efficiency %

Representing the efficiency of power delivery to a physics detector, e.g. ECAL
Power Efficiency _ Inefficiency _ Wasted Power

Input Power

315 kW

Power Supply
380 VDC input

6.3 V

30 meters
50K Amps

100 kW

LDO
1.8 V drop

4.3 V

90 kW

10 cm
50K Amps

2.5 V

Load Power

Front End Electronics

125 kW

---------- in Hall ----------

-------- on Detector --------

CMS – ECAL Power Delivery System
Collider Detector Magnetic Field & Radiation
Sub-Systems operate:
Main 1.5 to 4 Tesla
Fringe Magnetic field 0.1 to 1 Tesla
Radiation Tolerance: Highest for trackers ~ 100 Mrads
~ 1 Mrads for outer sub systems

Collider Detector Power Essential
Sub-Systems operate:
Main 1.5 to 4 Tesla
Fringe Magnetic field 0.1 to 1 Tesla
Radiation Tolerance: Highest for trackers ~ 100 Mrads
~ 1 Mrads for outer sub systems
### TABLE III Radiation Testing Matrix for GaN Devices

<table>
<thead>
<tr>
<th>Company</th>
<th>Device</th>
<th>Neutron Fluence (cm⁻²)</th>
<th>Proton Fluence (cm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitronex</td>
<td>25015</td>
<td>5 x 10¹⁴</td>
<td>1 x 10¹⁵</td>
</tr>
<tr>
<td>Cree</td>
<td>40010</td>
<td>5 x 10¹⁴</td>
<td>1 x 10¹⁵</td>
</tr>
<tr>
<td>Eudyana</td>
<td>EGNB010</td>
<td>43 Mrad</td>
<td>1 x 10¹⁵</td>
</tr>
<tr>
<td>EPC</td>
<td>EPC1015</td>
<td>64 Mrad</td>
<td>1 x 10¹⁵</td>
</tr>
</tbody>
</table>

**XySemi MOSFET Radiation Effects**

**Nitronex 25015**

- Neutron Fluence: 5 x 10¹⁴ Neutrons/cm²
- Graph showing I_out (Amps) vs Vgs (Volts)

**EPC 1015 Clocked**

- Before and After 10¹⁵ protons
- Graph showing I_out (Amps) vs Vgs (Volts)

**Eudyana EGNB010, SN243**

- Before and After 60Co Radiation
- Graph showing I_out (Amps) vs Vgs (Volts)

**Poly-Si**

- SiO₂
- Si

**Hole removal process by tunneling in thin-oxide MOS Structures**

- 5 nm Tunneling Region

**Coupled Air Core Inductor**

- Inductance: 0.8 μH
- Diagram showing the inductor connected in series
Overall efficiency - Silicon = 65%  
- GaN = 88%

Total losses = 157 Watts  
Total losses = 54 Watts

Ultra High Efficiency PFC

- Integrated Magnetics
  Volume / Loss Reduction
- New MOSFETs / Diodes
- Ceramic Capacitors
- Low Power DSP
Line → Power factor correction (PFC) → Switched Mode Power Supply (SMPS) → Point of Load (PoL)

87% 85% 89%

Typical conversion efficiency today

- Ultra Low Voltage Drop
- Temperature Stable

- Zero charge storage
- Temperature Stable
Figure 1: Conversion Current Density for a four phase 120 A, 12 Vin to 1.2 Vout buck converter vs switching frequency.

M.A. Briere IEDM 2010
Bus Losses = 0.2%
Improve Efficiency
1 Billion Dollar Data centers
DC Distribution

ETSI standard entering EN public enquiry by July 11.
Safety and EMC, that are out of the scope of the standard should be covered by IEC.
ITU-T should also relay efficiently this work at international level.

Mandate 462 - ICT to enable efficient energy use in information and communication networks
A Standardisation mandate addressed to CEN, CENELEC and ETSI in the field of ICT to enable efficient energy use in fixed and mobile information and communication networks has been published. CEN, CENELEC and ETSI, as well as other standardisation organisations, have identified energy efficiency as a key area for standardisation. For the execution of this mandate, particular attention will be given to the involvement of all relevant parties.

**European Commission Mandates**

*ETSI* performs energy efficiency related work in support of European Commission Mandates. The current Mandates in this domain are:

- Mandate 439: Standardization in the field of standby and off modes power consumption measurement for energy using products
- Mandate 450: Standardisation in the field of measurements of no-load condition electric power consumption and average active efficiency of external power supplies
- Mandate 451: Standardization in the field of power consumption measurement of simple set-top boxes in active and standby modes
- Mandate 462: ICT to enable efficient energy use in fixed and mobile information and communication networks
Efficiency Improvement with DC 380 Volts

90% x 97% = 67%

97% x 99% = 76%
END

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Heat Spreader

Cooling Plate on Top

Thermally Conducting Gap Filler for LDO’S

Heat Spreader

Plenty of material to remove heat