Phase-1 Upgrade of the CMS Hadron Calorimeter Endcaps

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October 26, 2018
CMS HCAL Phase 1 Upgrade

New photosensors
- Replace Hybrid Photo-Detectors (HPD) with Silicon Photomultipliers (SiPM)

New readout electronics
- QIE cards with custom QIE ASIC chips
Phase 1 Readout Module (RM)

- Optical Decoder Unit (ODU)
- Dry Gas Tube
- Megatile/CU cable connectors
- 4.8 gbps optical data links
- JTAG adapter board
- SiPM Control Card
- 4 QIE Cards
- Silicon Photomultipliers (SiPMs) and Peltier
- 4 QIE Cards
Phase 1 Readout Box (RBX)

- Megatile cables
- Clock and Control Module (ngCCM)
- Readout Modules (RM)
- Calibration Unit (CU)
- Dry Gas Tubes
- Optical data links
- Low Voltage and Bias Voltage Power Cables

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HCAL Endcap (HE)

- 2 HCAL Endcaps (±z)
- 18 wedges per Endcap
  - 1 Readout Box (RBX) per wedge
  - 20 deg. (φ) per wedge
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Motivation

- Radiation damage to Hybrid Photo-Detectors (HPD) occurred sooner and was more severe than expected.
- The HE HPDs were replaced with SiPMs in the Phase 1 upgrade in early 2018.

Talk: HCAL HE Status by Pawel De Barbaro

HPD Radiation Damage

- Response normalized to beginning of 2017
- Integrated luminosity (fb⁻¹)

HPD from HEP17/RM4, Dec 2017

Numbers on "fiber imprints" indicate layer# of tile

Scint/WLS

HPD

SiPMs
From HPDs to SiPMs

HPDs to SiPMs
- x 400 higher gain
- x 2.5 PDE
- Lower voltage (8kV to 70V)
- Reduced noise

Calorimeter response to muons from HE prototype wedge at H2 beamline
New Geometry

• Increase in number of channels.
• Increase in number of depths (each color is a depth).
• Provides better longitudinal segmentation.

Old geometry

New geometry
Installation

Procedure
• Remove existing electronics.
• Install new electronics.
• Test control and data links.
• Take FiberID, LED, and Laser data.
• Perform radiation sourcing scan with Co60.
• Calibrate using Co60 data.
Commissioning with Co60

- Radioactive source (Co60) is pushed with a wire through tubes in the detector.
- As the wire extends, the source passes near different scintillator tiles.
- Response measured in every channel.
- Used to verify end-to-end channel mapping and cable connections.
- Used for startup calibration of detector.

Co60 signal position inside megatile vs reel extension for one of the ~3000 tubes
A positive slope diagonal without missing spots means ALL OK

Radioactive Source on wire

Source Driver

Response (Lin. ADC)

Detector Response (Lin. ADC)
Commissioning with Co60

Before upgrade  
After upgrade

HEP Layer 1

2017 sourcing (HPD)  
2018 sourcing (SiPM)

Improved uniformity vs. phi after the upgrade!
Commissioning with Co60

- Comparison of 2017 sourcing (HPD) and 2018 sourcing (SiPM).
- Improved uniformity in 2018.

Co60 data:
2017/HPD
2018/SiPM

<table>
<thead>
<tr>
<th></th>
<th>2017 Phase 0</th>
<th>2018 Phase I</th>
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</thead>
<tbody>
<tr>
<td>Entries</td>
<td>16048</td>
<td>16670</td>
</tr>
<tr>
<td>Mean</td>
<td>-0.00</td>
<td>-0.00</td>
</tr>
<tr>
<td>Std Dev</td>
<td>0.22</td>
<td>0.07</td>
</tr>
</tbody>
</table>

(Charge - Mean) / Mean
Conclusion

• Installation and commissioning were completed on schedule during the 2017–18 year-end technical stop.
• The HE Phase 1 upgrade brings improved detector response and uniformity.
• The HCAL Barrel (HB) Phase 1 upgrade will be installed during Long Shutdown 2 (2019–2020).

Thank you for your time!
Backup
Commissioning with Co60

- [feynman.physics.uiowa.edu/HESourcing18/Others/SourceResponse_HEP.pdf](http://feynman.physics.uiowa.edu/HESourcing18/Others/SourceResponse_HEP.pdf)
- [feynman.physics.uiowa.edu/HESourcing18/Others/SourceResponse_HEM.pdf](http://feynman.physics.uiowa.edu/HESourcing18/Others/SourceResponse_HEM.pdf)
Commissioning with Co60

- Megatile cable is connected backwards
Commissioning with LED

- Low intensity LED runs were used to tune the SiPM gains.
- The bias voltages are selected such that the gains are tuned to 40 fC (charge measured for one electron).
Commissioning with Laser

- Laser to Megatile
  - Only measured by a subset of channels.

- Laser to Calibration Unit (CU)
  - HEP receives more light than HEM due to laser splitting.
Following power interlock on June 30, two endcap sectors are not functional.
- 40° in one endcap, 2% of HCAL coverage.

Five-week campaign led to full understanding:
- On power up after interlock, 10V power supply (PS) unable to read internal calibration.
- PS sent 22V/10ms pulse to detector
  - exceeded its own 14V max rating
  - damaged on-detector components with 12V rating.
HCAL endcap sectors 15/16 (cont'd)

- **HCAL installed secondary safety system** to mitigate risk of damage from potential future transients.

- **PS manufacturer** working to understand and address
  - why the PS fails to read its calibration
  - why the PS sends high voltage when the calibration fails

- **Physics impact:**
  - trigger rates are OK
  - effect on MET resolution is small but measurable
  - PF reconstruction reduces impact of loss.
  - Additional modifications of reconstruction in progress to minimize impact.

*Talk: CMS Status Report by Jim Hirschauer*
HCAL Endcap (HE)

- HCAL Endcap (HE)
- 18 wedges
  - 1 RBX per wedge
  - 20 deg. per wedge
- Colors correspond to power supplies
  - 1 or 2 RBX per power supply
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October 26, 2018
Electrons ($\eta$)

Talk: Check on HEM issue by Joe Pastika and Brooks McMaster

October 26, 2018

Phase-1 Upgrade of the CMS Hadron Calorimeter Endcaps
Electrons ($\phi$, $p_T$)

**Talk: Check on HEM issue by Joe Pastika and Brooks McMaster**

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Phase-1 Upgrade of the CMS Hadron Calorimeter Endcaps
Jets ($\eta$)

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Phase-1 Upgrade of the CMS Hadron Calorimeter Endcaps
Jets ($\phi$, $p_T$)

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Phase-1 Upgrade of the CMS Hadron Calorimeter Endcaps
MET and $H_T$

**Talk:** Check on HEM issue by Joe Pastika and Brooks McMaster

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