The commissioning and first results on the performance of the CMS Preshower detector

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• Summary
One of the main physics goals of CMS is search for SM Higgs. If $m_H < 150$ GeV, the best chance is through $\gamma\gamma$ decay. But large reducible background from $\pi^0$ faking single photons.

Idea of Preshower:

- Single incident photon
- Two closely-spaced incident photons

By adding a Preshower in front of endcap crystals, the reducible backgrounds to $H \rightarrow \gamma\gamma$ search can be further reduced by about 50%.
Physical Location

- 2.5m diameter discs, less than 20cm thick, containing 2 layers of:
  - lead absorber ($2X_0 + 1X_0$)
  - silicon strip sensors + front-end electronics
  - mechanical supports, cooling etc.
Preshower assembly

- The heart of CMS ECAL Preshower: 4288 silicon μ-modules
- Silicon sensor: 6.3 x 6.3 cm$^2$, 310 μm thick, 32 strips
- Custom front-end electronics

17m$^2$ of silicon sensors arranged in an X-Y grid
The largest EM sampling calorimeter based on silicon ever built!
Readout electronics scheme

• Number of channels: 137216

• Amplified & shaped; sampled every 25 ns (S1 for pedestal subtraction and S2, S3 for signal reconstruction)

• Digitized by 12-bit ADCs

• Two switchable gains
  • **High gain** (0→70 MIPs) for absolute calibration and low energy LHC running. S/N is about 10 for a MIP.
  • **Low gain** (0→450 MIPs) for “high” energy running. S/N is about 3 for a MIP.

MIP: the energy deposited by a high energy charged particle traversing the 310μm silicon sensor.
First commissioning: Noise level

- > 99.88% of channels functioning perfectly (64 strips are not biased and 100 strips have intrinsic noise > 15 ADC counts in high gain so are masked from the readout)

- agrees with test beam performance (presented in Calor ’08)
• Beam splash: beam was deliberately dumped on collimators 150m away from CMS, producing spray of secondary particles.

• Average particle flux is about 5 muons per cm$^2$ for a “splash” event. Preshower signals:
  - Consistent with results from other detectors
  - Isolated hot spots attributed to muon bremsstrahlung

• Improve Preshower timing adjustment

• Improve EE crystals inter-calibration
Timing Alignment

- Started with CMS cosmic ray data taking
- Beam splash data provided time synchronization of Preshower silicon sensors and used for LHC startup
- Improved with collision data
Cluster matching between two Preshower planes and ECAL crystals

- start from the significant amount of energy deposit in CMS EE crystals
- extrapolate back to the origin and find the intersection on Preshower planes
- open a search window and find the energy deposit within it
Energy deposit on Preshower planes

900 GeV

2.36 TeV

7 TeV
Position Correlation of EE-ES clusters

- Each ES plane measure X or Y with good resolution
- Residual distribution between most energetic Preshower (ES) cluster and seeded EE basic cluster shows alignment between EE and ES better than 2mm
- Residual widths dominated by low-energy particles in clusters - will decrease to less than 1mm when samples of high energy electrons/photons available
• The occupancy is defined as the percentage of strips with a signal at least $4 \times \sigma_{\text{noise}}$

• The occupancy increases as a function of $\eta$ and $\sqrt{s}$
First in-situ MIP calibration

- The accuracy of MIP pre-calibration using cosmic rays: 2.5% (requirement: 5%)
- Use charged tracks with $p > 1\text{GeV}$ to point to Preshower and find the associated hits
- Signals are corrected by the incidence angle
- Precision of first in-situ calibration is around 3.3% w.r.t. the pre-calibration
Summary

• CMS ECAL Preshower is fully operational at the CERN LHC
  • Installation and commissioning done in April 2009, according to schedule
  • 99.8% of channels are functioning perfectly

• Data recorded during cosmic ray data taking and beam splash used to provide initial time adjustment in preparation for LHC beam
  • Improved with LHC collisions

• Preshower successfully recorded collision events at LHC
  • Nice agreement between data and MC for energy deposit on Preshower planes and position correlation of Preshower-crystal
  • Occupancy grows as a function of $\eta$ and $\sqrt{s}$, as expected
  • First in-situ MIP calibration has been carried-out, achieving required accuracy
Supplement Materials
Physics Objective

- By adding a Preshower in front of endcap crystals, the reducible backgrounds to \( H \rightarrow \gamma \gamma \) search can be further reduced by about 50%
Internal Structure

19.52 cm

Silicon Micromodules

Cooling screens

front plane

rear plane

Particles

Window

Insulating Foam

Absorber

Motherboards

Heating films

Total $3X_0$ for particles at $|\eta| = 1.7$
MIP Pre-calibration before installation

• MIP calibration requirement: 5%
  • MIP varies from sensor to sensor and strip to strip due to silicon thickness, the particle incidence angle, the gain of electronics and the charge collection efficiency

• As part of our extensive testing procedure
  • Operating temperature: -15°C

• All silicon modules underwent “cosmic-ray calibration” for 24 hours (also serves as a first burn-in)

• MIP calibration accuracy estimated to be 2.5% for 24-hours of running
Position Correlation of EE-ES clusters

CMS Preliminary 2009
\( \sqrt{s} = 900 \text{ GeV} \)

EE Basic Cluster
E 7.0 GeV
\( \eta \ 2.4; \phi \ 0.1 \)
X 59.3; Y 4.6

1 ES X cluster
3 ES Y cluster
Combine (ESX1, EXSY1)