Performance, Calibration and Alignment of CMS Preshower Detector

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Outline

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• Detector Performance with LHC beam
• Calibration and Alignment of Preshower
• Summary
Introduction

- Preshower is designed as a pre-sampling detector of CMS Endcap Calorimeter
- Measure “shower shape” in front of Endcap crystal calorimeter.
- Identify single or multiple photons
- Physics requirement:
  - Energy resolution within 5%
  - Position resolution at sub-mm for 60 GeV e/γ

Low mass SM Higgs decays to two isolated photons

But large reducible background from π0 faking single photon
Preshower in CMS

- 2 layers of
  - lead absorbers ($2X_0$, $1X_0$)
  - Silicon strip detectors + front-end electronics
  - mechanical support and service (cooling, power)
Preshower Detector

- Total of 4288 Silicon strip detectors with custom-made chips and hybrids
- Detector thickness of $310\mu m$ with strip area of $1.9mm \times 61mm$ and 32 strips per detector.
- $17m^2$ of detector surface with detector strips arranged in X-Y grid.
  - front plane, closer to IP, has strip segmented in X
  - rear plane has strips segmented in Y.

A detector module
A ladder contains 7~10 modules
Front-end Readout Electronics

- Total of 137,216 channels
- Amplified and shaped as shown
- Read out every 25ns (LHC clock) for 3 samples ($S_1-3$)
- Digitized by 12-bit ADCs
- Two switchable gains
  - High Gain: with $S/N \approx 10$ for a MIP for calibration and LHC low energy run
  - Low Gain: with $S/N \approx 3$ for a MIP, for high luminosity LHC run

MIP: an approximate term for a charged hadron or muon leaving $dE/dx$ on silicon

IRPD10, Siena

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Detector Performance
Detector Commissioning

- Detector is installed on Apr. 2009
- More than 99.8% of channels functioning. (64 strips are not biased and around 100 channels have intrinsic noise > 15 ADC in high gain. Therefore, they are masked in readout)
- The noise performance agrees with earlier test beam results and meets with requirement

![Graphs showing intrinsic noise per strip for high and low gain modes]
Beam was deliberately dumped on collimators 150m upstream of CMS producing secondary particles

Average flux is about 5 muons/cm² for the event

- consistent with other detectors
- Isolated hot spots due to muon bremsstrahlung

First time seeing LHC beams. Data used to tune ES timing
Performance - LHC Collisions

- Observing clusters linked between Preshower and EE
- Start from EE clusters with significant energy deposit
- Extrapolate back to IP and find the intercept points on Preshower planes
- Look for preshower signal in the search window
Performance - LHC Collisions

- Observed clusters linked between Preshower and EE
- 3 EE clusters found in an example event
- Linked ES clusters were found on both planes.
• Energy deposits in Preshower planes show consistent results as expected.

• More energy deposits in rear plane due to the more material in front.
Occupancy in Collision events

- The occupancy is defined as number of strips with energy greater than 4 times the noise.
- Occupancy increases as function of $\eta$ and collision energy.
- Expect to have a few % of occupancy at high $\eta$ with 14TeV and $10^{34}$ LHC luminosity.

$\sqrt{s} = \text{center of mass energy of LHC collisions}$
Calibration and Alignment
Energy Pre-Calibration

- All sensors went through burn-in, thermal cycles and cosmic-ray pre-calibration
- Pre-calibration using MIPs with correction applied on sensor thickness, temperature, and crossing angle.
- Accuracy at 2.5% with 24 hours of data taking.
- 5% of resolution is needed.

Energy deposit on Preshower in Cosmic data

Pulse shape from Cosmic data

Layer_3_x_1_y_4_combined

$\chi^2 / \text{ndf}$: 9.559 / 19
$\sigma_L$: 0.08228 ± 0.00237
MPV: 0.9957 ± 0.0018
Area: 1016 ± 8.8
$\sigma_0$: 0.116 ± 0.003
In-situ Energy Calibration

- In-situ calibration looks at the energy deposit from charged hadrons passing through Preshower.
- Results from first in-situ calibration is within 3.3% of pre-calibration value.
- 5 % of energy resolution is needed
Alignment with EE

- Look for Preshower (ES) signal in front of EE cluster.
- Event display shows correlation between EE and ES clusters.
- Residual distribution shows alignment better than 2mm.
- With early data and lack of high energy e/γ, the width is dominated by low energy particles. Will decrease to less than 1mm with high energy electrons/photons.
Alignment w.r.t. Tracker

- Extrapolate track trajectory from Tracker to Preshower.
- Select high purity track and match with Preshower signal.
- Minimizing residuals between track trajectory and Preshower hits while floating Preshower in 3-D space.
Alignment Results

- Consistent alignment constants between 2 planes in same endcap.
- Plots show only the measurement with good resolution in X or Y for each plane.
- After alignment, residual is narrower with mean at zero ± 70μm
- A few mm misalignment can be accounted by software
Preshower-Tracker matching efficiency

- Measure the matching efficiency between track trajectory and Preshower measurement.

- Inefficiency due to fake track, fake ES signal or multiple scattering.

- Agree with prediction from simulation.

![Graph showing the efficiency of tracking and comparison with simulation](image)
Summary

- CMS ECAL-Preshower detector has been commissioned and fully operational taking LHC collision data.
- The performance agrees with expectation from earlier test beam studies and Monte-Carlo simulation matching with requirement.
- The calibration and alignment procedures were performed.
  - First in-situ calibration achieves required accuracy
  - Alignment with EE and Tracker improves the position measurements.
Backup Slide
Preshower
The Timing of Preshower was adjusted using cosmic-ray, beam-splash and later by Collision data.
Energy resolution - beam test

Total energy of electron $\equiv EE + \alpha \times (ES_1 + 0.7 \times ES_2)$

$\alpha$ is constant when the beam energy is above 20 GeV

Fitted by the linear least-squares
Spatial Resolution - beam test

Front plane
0 degree incident angle

Rear plane
0 degree incident angle