Performance of the CMS Zero Degree Calorimeter for PbPb and pp running

for the CMS Collaboration

Sercan Sen, P. Debbins, Duane Ingram, Edwin Norbeck, Yasar Onel, Taylan Yetkin
University of Iowa

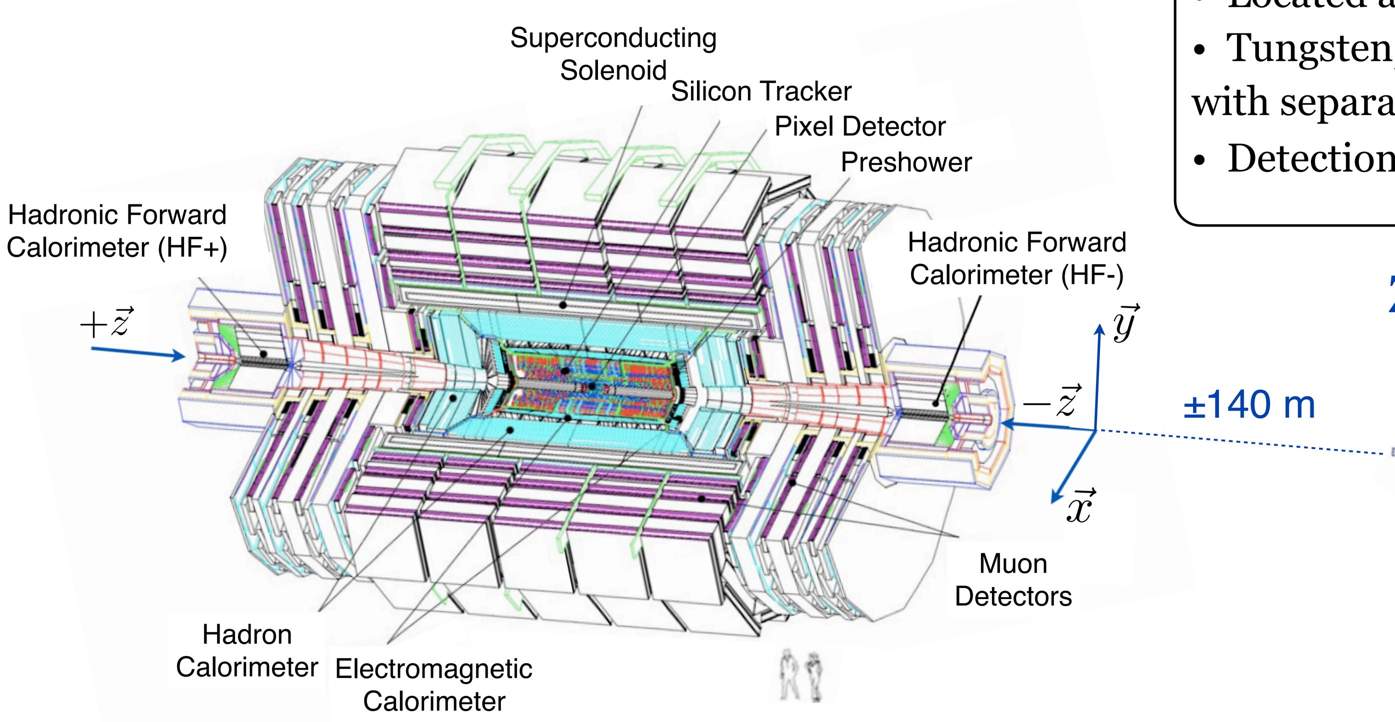
Oleg Grachov, Patrick Kenny, Michael Murray, Jeffery Wood
University of Kansas

Marguerite Tonjes
University of Maryland

E-mail: Sercan.Sen@cern.ch

Introduction

The Zero Degree Calorimeter (ZDC) for the CMS experiment at the Large Hadron Collider is located between the incoming and outgoing beam lines at a distance of 140 m on each side of the interaction point. It measures primarily neutral particles that go in the direction of the original proton or heavy ion beam. With p-p reactions these are mostly neutrons produced by a charge exchange of the original proton. During heavy ion running the ZDC measure forward neutrons produced in both electromagnetic and nuclear interactions. The number of neutrons provides a measure of the amount of overlap of the interacting heavy ions. Over the last year the ZDC has collected data from p-p reactions at center of mass energies of 0.9, 2.36, and 7.0 TeV and Pb-Pb reactions at center of mass energies $\sqrt{s_{NN}}$ = 2.76 TeV.

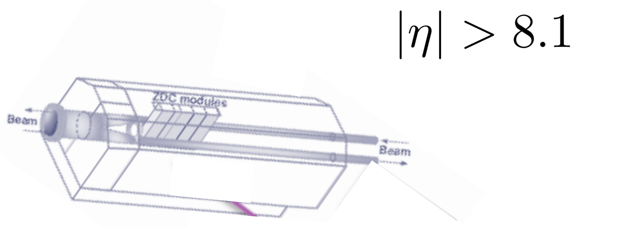


- Located at ±140 m from IP5
- Tungsten/quartz Cherenkov calorimeter with separated EM and HAD sections
- Detections of neutral particles (γ, π°, n)

Zero Degree Calorimeter

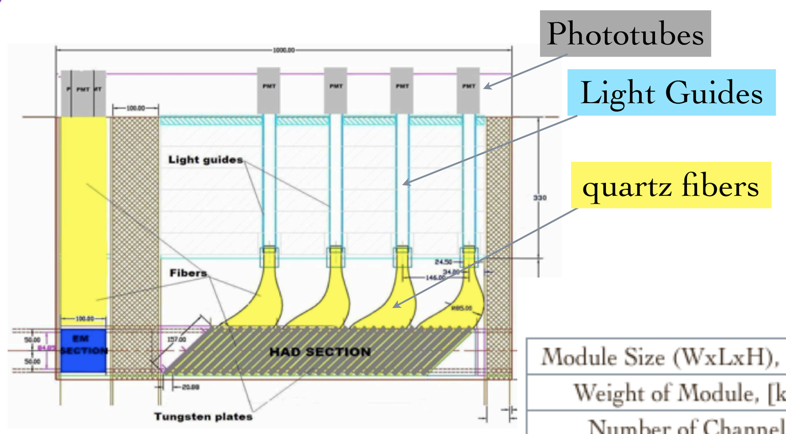
$|\eta| > 8.1$

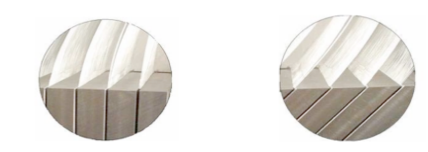
±140 m



Compact Muon Solenoid

Mechanical and Optical Design



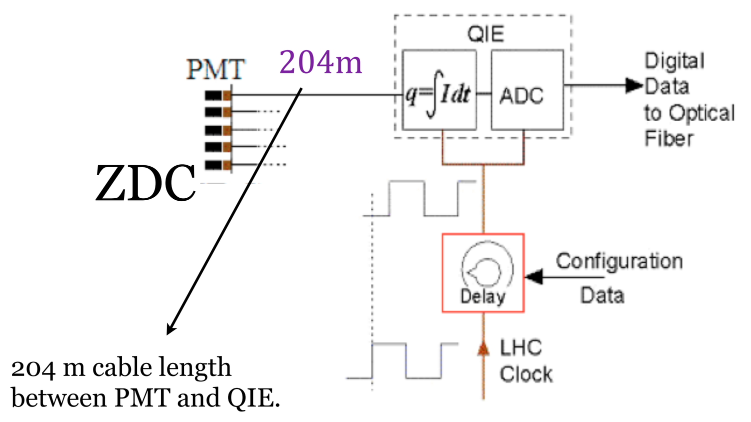


90°-orientation geometry for electromagnetic (EM) section.

45°-orientation geometry for hadronic (HAD) section.

	Electromagnetic Section	Hadronic Section
Module Size (WxLxH), [mm]	92 x 121 x 990	92 x 711 x 990
Weight of Module, [kg]	~65	~300
Number of Channels	5 transverse towers	4 longitudinal segments
PMT	5 Hamamatsu R7525	4 Hamamatsu R7525
Interaction (Rad.) Lenght	~1λo	5.6λo

Read-out System



The signals collected from the PMTs are integrated over each LHC clock period and then sampled.

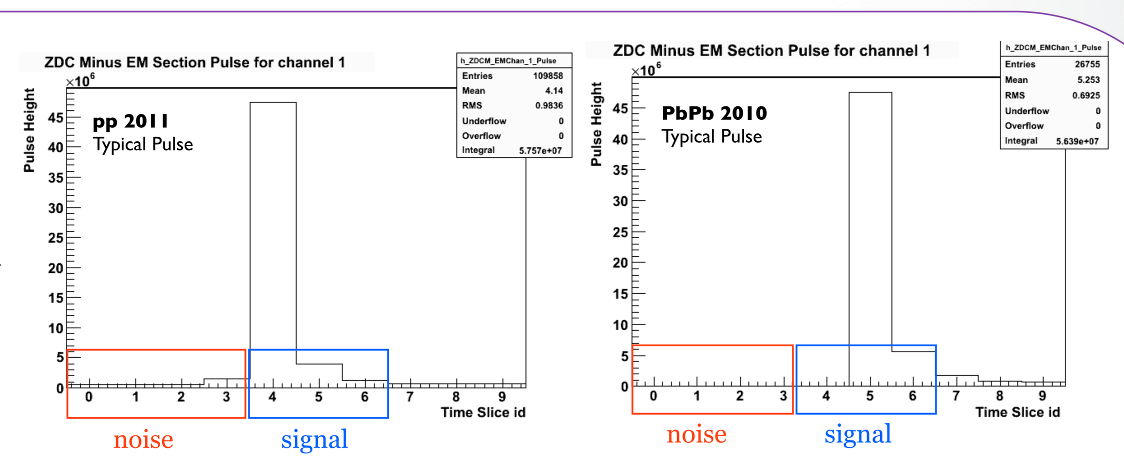
The integration clock can be delayed with respect to the LHC clock.

Signal and Noise Calculation

$$\text{Signal} = \sum_{TS=4}^{6} \text{Energy[TS]} \qquad \text{Noise} = \sum_{TS=0}^{3} \text{Energy[TS]}$$

TS = Time Slice.

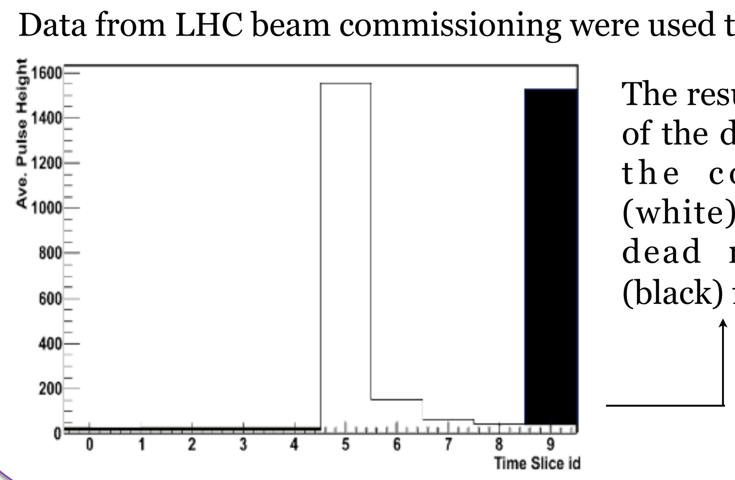
Different noise algorithms, QIE saturation, relative timing of ZDC channels and so on, were studied with the first LHC beam data.



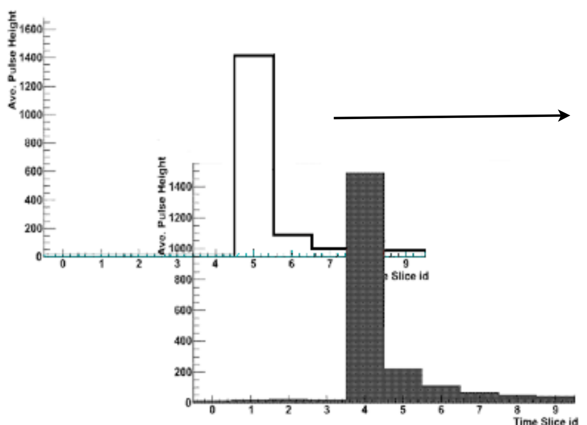
ZDC Timing Adjustment with the first circulating beam at the LHC

$$\text{Timing} = \frac{\sum_{TS=3}^{7}(\text{TSmax}-1)*\text{Energy[TSmax}-1] + \text{TSmax}*\text{Energy[TSmax]} + (\text{TSmax}+1)*\text{Energy[TSmax}+1]}{\sum_{TS=3}^{7}\text{Energy[TSmax}-1] + \text{Energy[TSmax]} + \text{Energy[TSmax}+1]}$$

Data from LHC beam commissioning were used to validate the ZDC sampling delay settings derived from dead reckoning estimation.



The resulting distribution of the difference between the corrected time (white) and predicted dead reckoning time (black) for ZDC+.



Offset in timing between the positive (upper plot) and negative (lower plot) ZDC, were studied with the beam splash data from both directions. The timing for ZDC+ before any corrections, shows an average time difference is 16 ns later than ZDC-.

Physics with ZDC

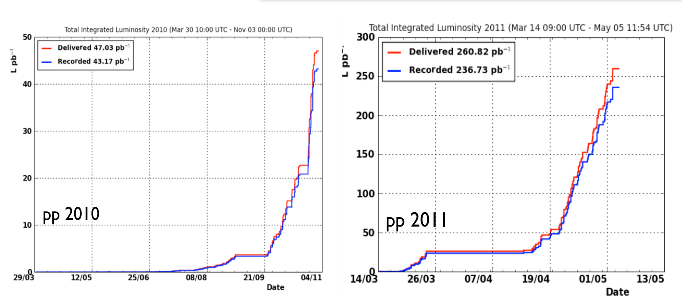
Accelerator Physics [pp, PbPb]
- Luminosity monitoring/calibration, beam tuning, IP5 crossing angle.

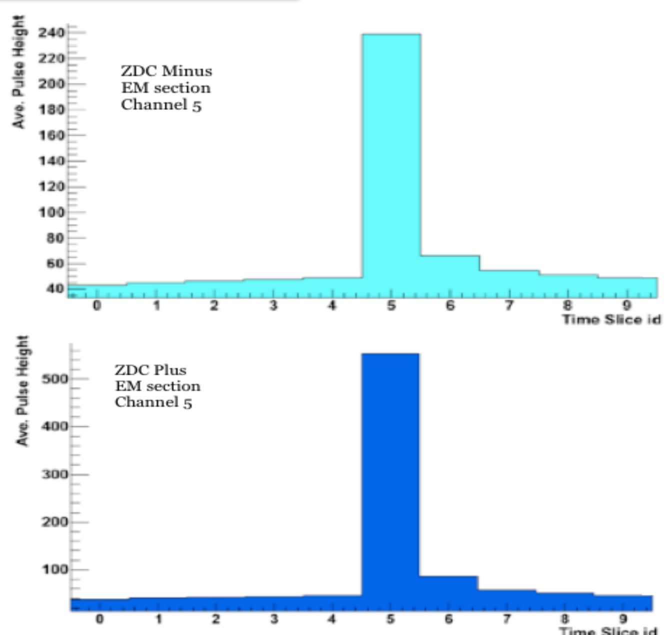
High-energy nuclear physics [pp, PbPb]
- Online: minimum bias trigger, vertex.
- Global event characterization: centrality, reaction-plane.
- Absolute luminosity

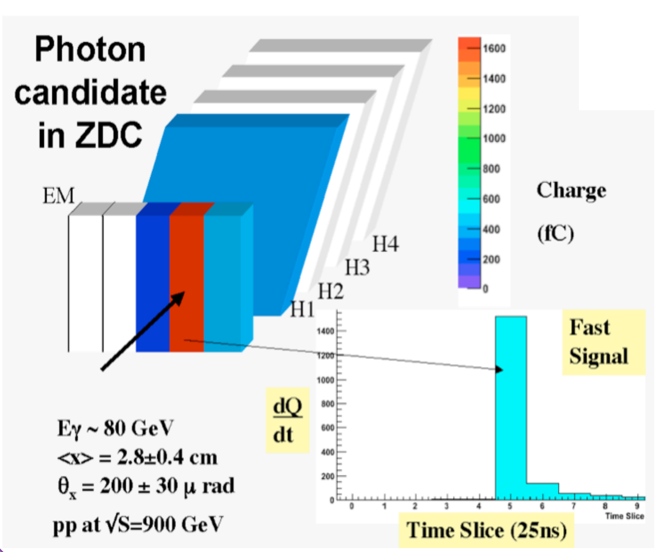
Diffractive Physics [pp, PbPb]
- Tagging of rapidity gaps in central hard diffraction
- ϒ + ϒ: Neutron-tagging of QED processes.

For Physics Online:
- Minimum bias trigger, vertex.
- Trigger on electromagnetic events

pp Running







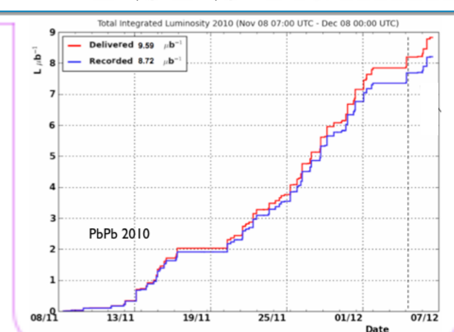
During the pp data taking, the synchronization between ZDC plus and minus side was good.

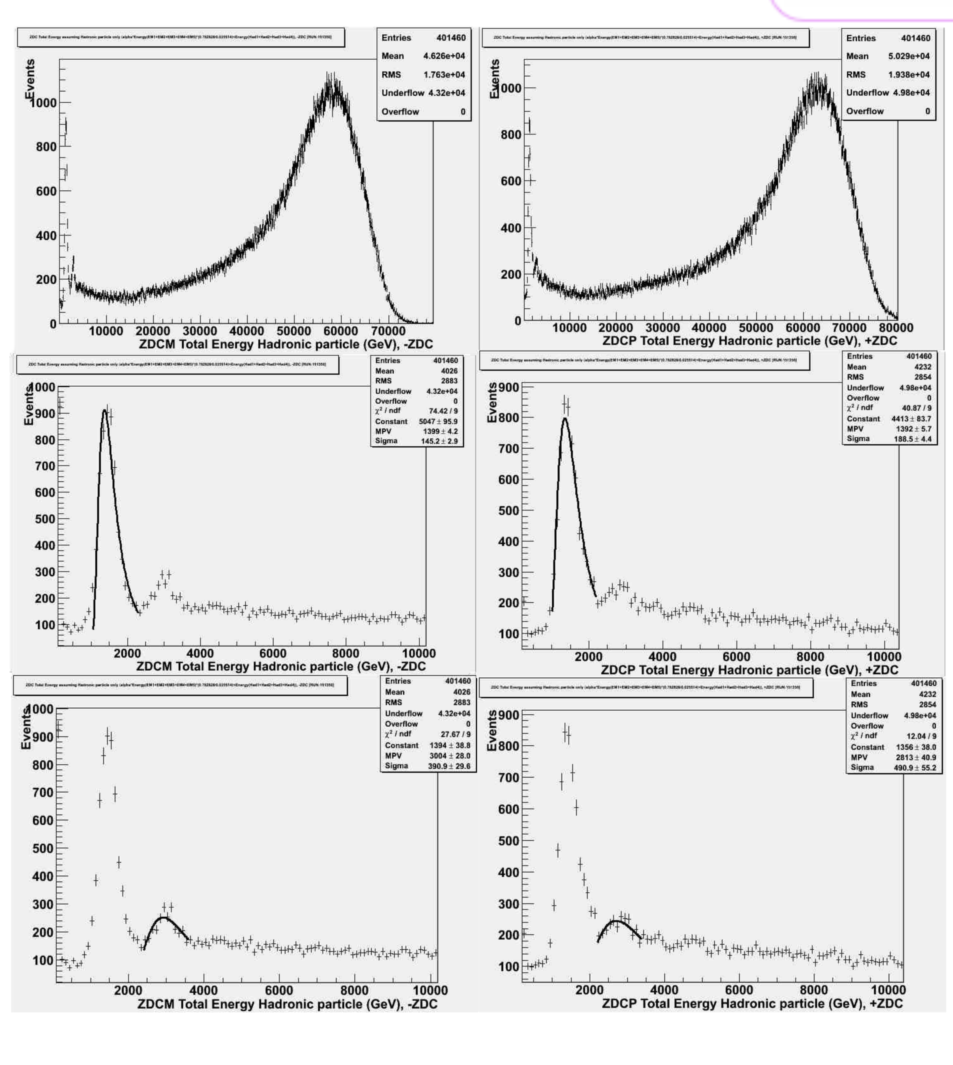
With the first pp collisions data @900 GeV, a photon-like signal was observed in ZDC.

PbPb Running

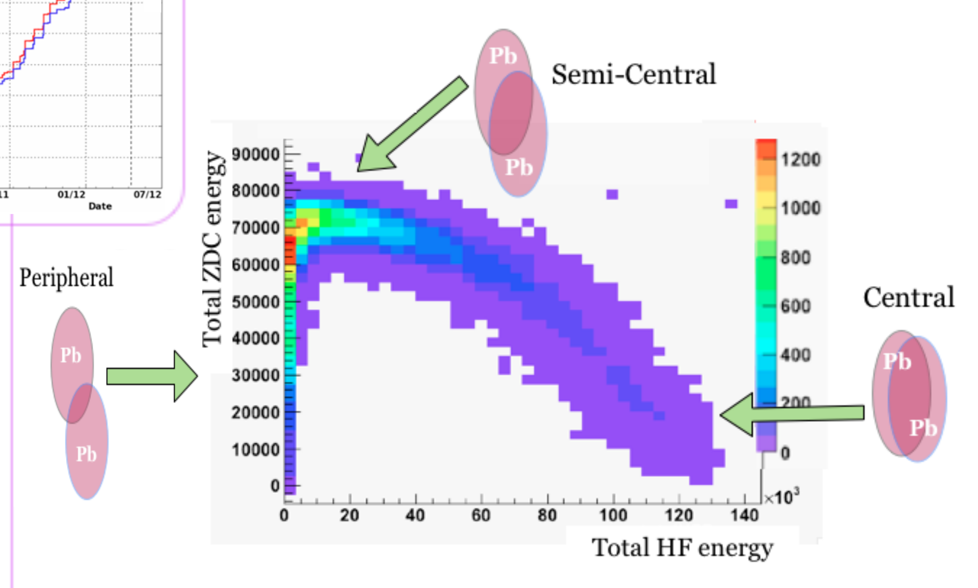
Single Neutron Peak in ZDC

This spectra is a sample of all the events recorded by CMS not necessarily a minimum bias sample.





Centrality Determination



In order to improve the centrality determination for peripheral events, a correlation of the HF transverse energy with the total neutral energy deposited in the Zero Degree Calorimeters (ZDCs) is foreseen.

ZDC improves resolution at large b (like RHIC)

By combining information from various independent measurements, such as the ET measurements in both HF (on each side of the interaction point) and, plus the forward energy of spectator forward neutrons measured in both ZDCs, the impact parameter of the reaction **can be determined** with an improved experimental resolution of a few tenths of fm.

Conclusion

- The ZDC was fully operational during the pp and PbPb data taking in 2009 and 2010.
- The first running experience and commissioning of ZDC with the first collision events were successful. The read-out timing and channel-to-channel gain variation were measured and corrected for uniform response.
- The ZDC showed that it has sufficient energy resolution and linearity to meet our physics goals. It has provided significant information during the collision data taking and has been used in CMS physics analyses.

References

[1] O Grachov et al., "**Commissioning of CMS zero degree calorimeter using LHC beam**", 2011, *J. Phys.: Conf. Ser.* 293 012040 doi: 10.1088/1742-6596/293/1/012040.
[2] The CMS Collaboration, "**Preliminary Results from collisions at 900 and 2360 GeV**", 2010, *CMS DP* 2010/001.
[3] The CMS Collaboration, "**Pseudo-rapidity dependence of energy flow in sqrt(s_NN) = 2.76 TeV Pb+Pb collisions**", 2011, *CMS PAS* HIN-11-003.
[4] O A Grachov et al., "**Performance of the combined zero degree calorimeter for CMS**", 2009, *J. Phys.: Conf. Ser.* 160 012059 doi: 10.1088/1742-6596/160/1/012059.
[5] A.S.Ayan et al., "**CMS Zero Degree Calorimeter Technical Design Report**", 2006, *CMS IN* 2006/054.

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