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CMS-DP-2014/011: ECAL Timing Performance Run1

Abstract:

The CMS electromagnetic calorimeter (ECAL) is made of about 75000 scintillating lead tungstate crystals arranged in a barrel and two endcaps. The scintillation light is read out by avalanche photodiodes in the barrel and vacuum phototriodes in the endcaps, at which point the scintillation pulse is amplified and sampled at 40 MHz by the on-detector electronics. The fast signal from the crystal scintillation enables energy as well as timing measurements from the data collected in proton-proton collisions with high energy electrons and photons. The stability of the timing measurement required to maintain the energy resolution is on the order of 1ns. The single-channel time resolution of ECAL measured at beam tests for high energy showers is better than 100 ps. The timing resolution achieved with the data collected in proton-proton collisions at the LHC is presented. The timing precision achieved is used in important physics measurements and also allows the study of subtle calorimetric effects, such as the timing response of different crystals belonging to the same electromagnetic shower. In addition, we present prospects for the high luminosity phase of the LHC, where we expect an average of 140 concurrent interactions per bunch crossing (pile-up). It is speculated that time information could be exploited for pileup mitigation and for the assignment of the collision vertex for photons. In this respect, a detailed understanding of the time performance and of the limiting factors in time resolution will be important.

CDS entry

Information:

At test beam, in 2008, the ECAL time intrinsic resolution was measured to be better than 100 ps. For collisions there are several effects that can worsen the resolution: run by run variations, intercalibration, effects vs energy, radiation, etc... The calorimeter has been properly calibrated to take care of part of such effects. The goal is now to estimate the resolution and compare it with the design one coming from TB.

For the following plots we use high pt photon-like ECAL deposits by using the following selection criteria: 1) they pass cluster shape strict requirements to look like a real em deposit based on Sminor and Smajor variables, 2) no isolation requirements (0 are fine) are applied

We use a method which is almost identical to the one of the TB analysis. We compare the timing of neighbouring crystals of an ECAL cluster which have a very similar energy. This is to minimize shower propagation effects. We require:

- E1,E2 < 120GeV (to avoid gain switch effects)
- |E1/E2| < 1.2

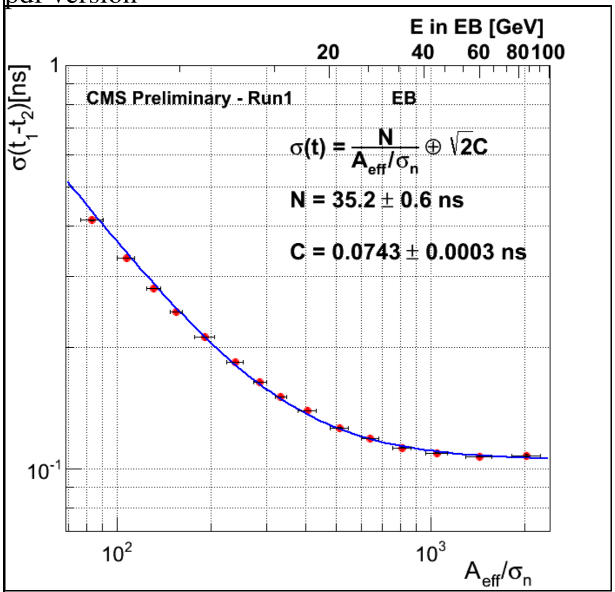
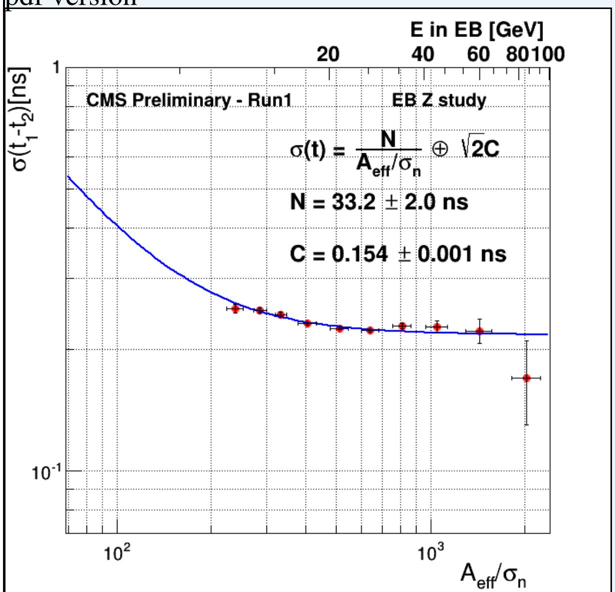
The resolution is estimated from a gaussian fit, taking the core of the distribution. The fit is in the range mean±2RMS.

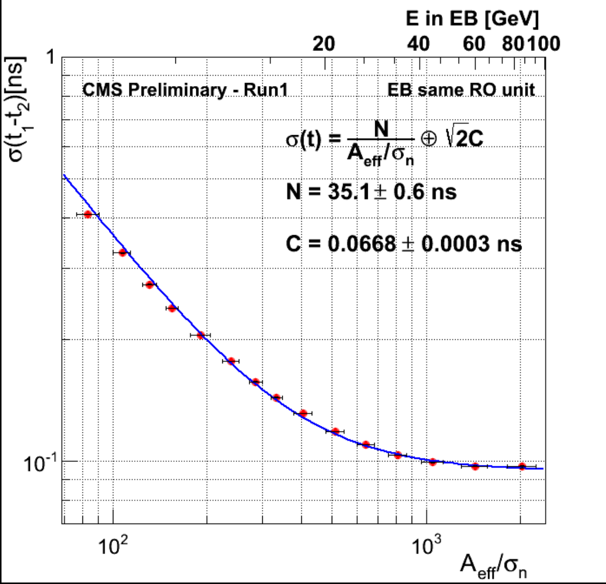
Results are for 2011 + 2012 data. Barrel only results are shown.

A study based on Z reconstruction has been also performed. For electrons we apply

- simple isolation and cluster shape requirements.
- E1,E2 > 10GeV
- E1,E2 < 120GeV (to avoid gain switch effects)
- 60GeV<m_inv(e1,e2)<150GeV

The time of the electron corresponds to the time of the cluster seed crystal. When comparing the time of the two electrons we correct for time of flight differences due to primary vtx position.

Figure	Caption
pdf version 	Resolution of time difference between the two most energetic crystals of an ECAL cluster as a function of the effective amplitude, normalized to the noise in the ECAL Barrel for 2011+2012 data. The selection applied and the resolution are the ones specified in the introduction. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. Bottomline: noise term consistent with TB. Constant term about 70ps.
pdf version 	Resolution of time difference between the two electrons from Z->ee decays, as a function of the effective amplitude, normalized to the noise in the ECAL Barrel for 2011+2012 data. The selection applied, the method and the resolution are the ones specified in the introduction. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. Bottomline: noise term consistent with TB. Constant term about 150ps, much larger than the one obtained with the neighbouring crystals method.
pdf version	Resolution of time difference between the two most energetic crystals of an ECAL cluster as a function of the effective amplitude, normalized to the noise in the ECAL Barrel for 2011+2012 data, for crystals belonging to the same readout unit (trigger tower). The selection applied and the resolution are the ones specified in the introduction. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. Bottomline: noise term consistent with TB. Constant term smaller than 70ps.



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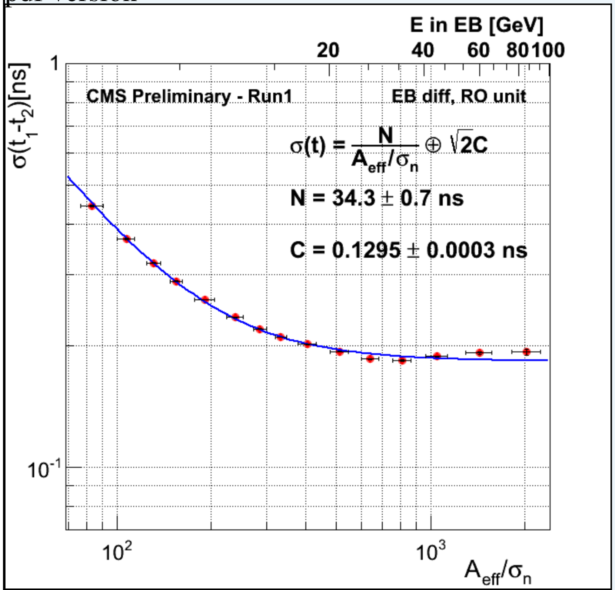
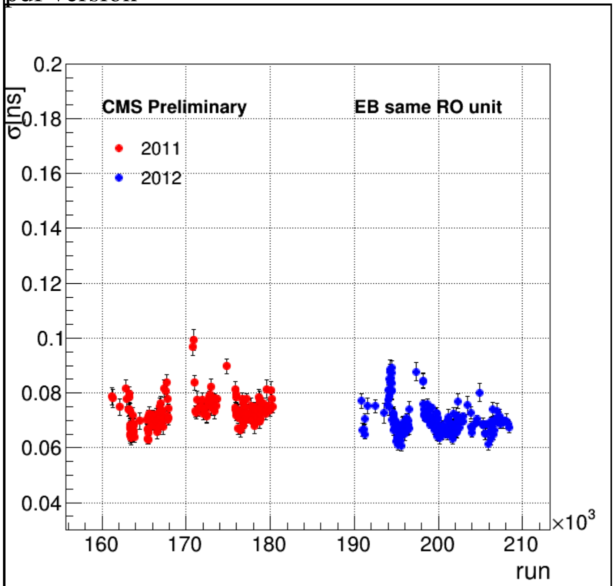
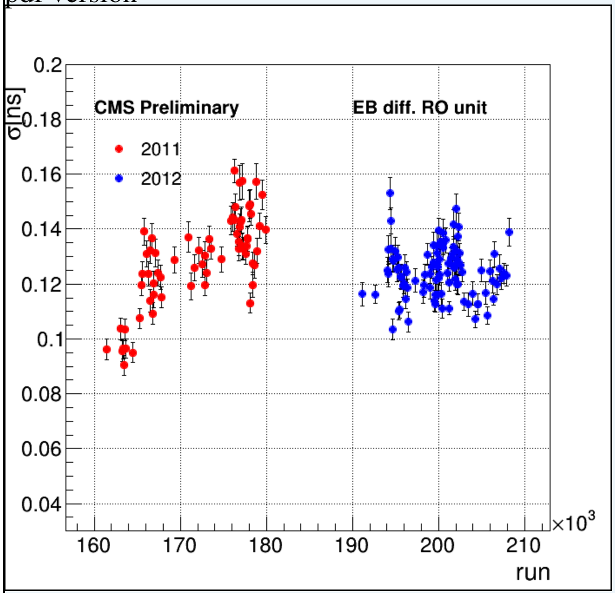
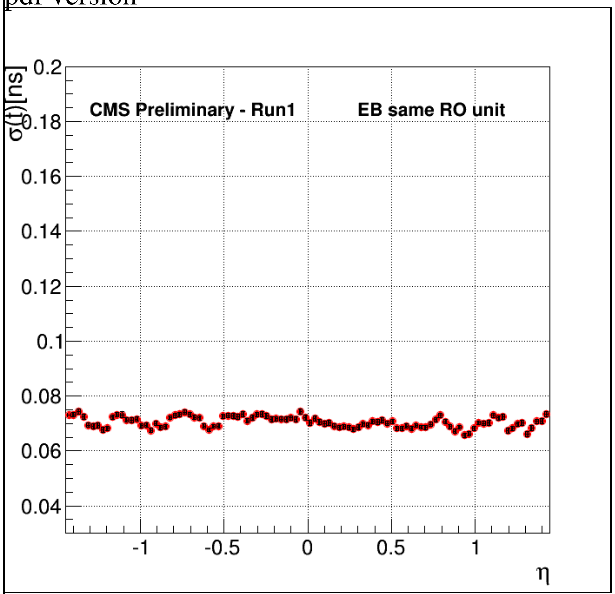
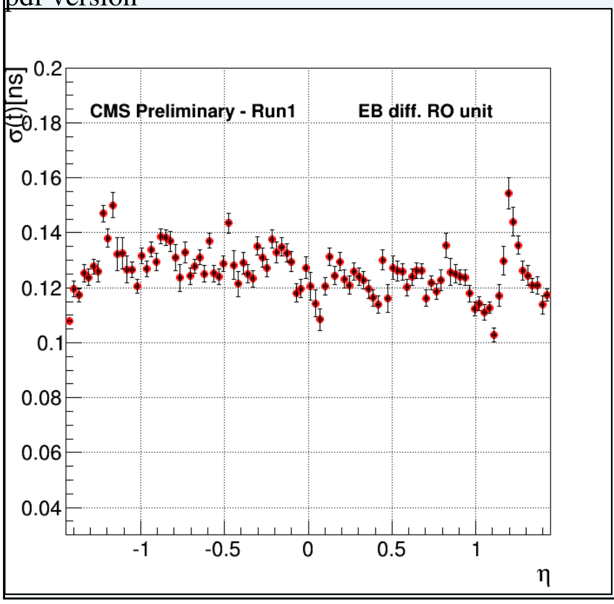


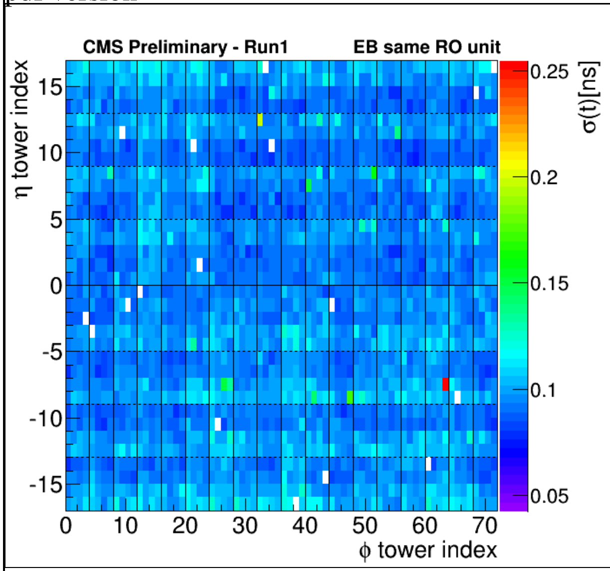
Resolution of time difference between the two most energetic crystals of an ECAL cluster as a function of the effective amplitude, normalized to the noise in the ECAL Barrel for 2011+2012 data, for crystals belonging to different neighbouring readout units (trigger towers). The selection applied and the resolution are the ones specified in the introduction. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. Bottomline: noise term consistent with TB. Constant term about 130 ps, quite larger than the one obtained when the two crystals belong to the same readout unit. This explains why Z method and neighbouring crystals method give such a different constant term.

pdf version



Resolution of time difference between the two most energetic crystals of an ECAL cluster as a function of the run number for crystals belonging to the same readout unit (trigger tower). The selection applied and the resolution are the ones specified in the introduction. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. The resolution here is estimated by the spread of t1-t2 distribution after placing a cut on Aeff (Aeff > 30GeV). This is because there is not enough statistics to perform the sigma vs Aeff/sigma_n fits per run. As a consequence, it can be slightly larger than the constant term. Bottomline: resolution quite stable vs run.

pdf version 	Resolution of time difference between the two most energetic crystals of an ECAL cluster as a function of the run number for crystals belonging to different neighbouring readout units (trigger towers). The selection applied and the resolution are the ones specified in the introduction. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. The resolution here is estimated by the spread of t1-t2 distribution after placing a cut on Aeff (Aeff > 30GeV). This is because there is not enough statistics to perform the sigma vs Aeff/sigma_n fits per run. As a consequence, it can be slightly larger than the constant term. Bottomline: resolution seems to increase with time in 2011. At the beginning of 2011 it was not very different from the one obtained for crystals in the same readout unit.
pdf version 	Resolution of time difference between the two most energetic crystals of an ECAL cluster as a function of the pseudorapidity for crystals belonging to the same readout unit (trigger tower). The selection applied and the resolution are the ones specified in the introduction. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. The resolution here is estimated by the spread of t1-t2 distribution after placing a cut on Aeff (Aeff > 30GeV). This is because there is not enough statistics to perform the sigma vs Aeff/sigma_n fits per run. As a consequence, it can be slightly larger than the constant term. Bottomline: resolution is quite stable vs eta.
pdf version 	Resolution of time difference between the two most energetic crystals of an ECAL cluster as a function of the pseudorapidity for crystals belonging to different neighbouring readout units (trigger towers). The selection applied and the resolution are the ones specified in the introduction. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. The resolution here is estimated by the spread of t1-t2 distribution after placing a cut on Aeff (Aeff > 30GeV). This is because there is not enough statistics to perform the sigma vs Aeff/sigma_n fits per run. As a consequence, it can be slightly larger than the constant term. Bottomline: resolution is quite stable vs eta.

pdf version 	Resolution of time difference between the two most energetic crystals of an ECAL cluster for crystals belonging to same readout unit (trigger tower), for each readout unit. The selection applied here differs from the previous plots and it is much looser (no requirement on E1/E2 and loose isolation) to increase statistics. The effective amplitude, Aeff, corresponds to A1A2/sqrt(A1^2+A^2), where A1 and A2 are the amplitude of the two crystals. The noise corresponds to 42MeV. The resolution here is estimated by the spread of t1-t2 distribution after placing a cut on Aeff (Aeff > 15GeV). This is because there is not enough statistics to perform the sigma vs Aeff/sigma_n fits per run. As a consequence, it can be slightly larger than the constant term. White spots correspond to dead towers. Bottomline: resolution is quite stable vs the full barrel, there are local variations which show that regions of the detector (in particular some SMs) seem to behave better.

-- ToyokoOrimoto - 17 Oct 2014

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Topic revision: r3 - 2014-12-03 - EmanueleDiMarco