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CMS-DP-2014/012: ECAL Timing Studies for Upgrade

Abstract: ECAL upgrade performance plots for 2013 LHCC and ECFA.

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.

NB: There is no associated detector note.

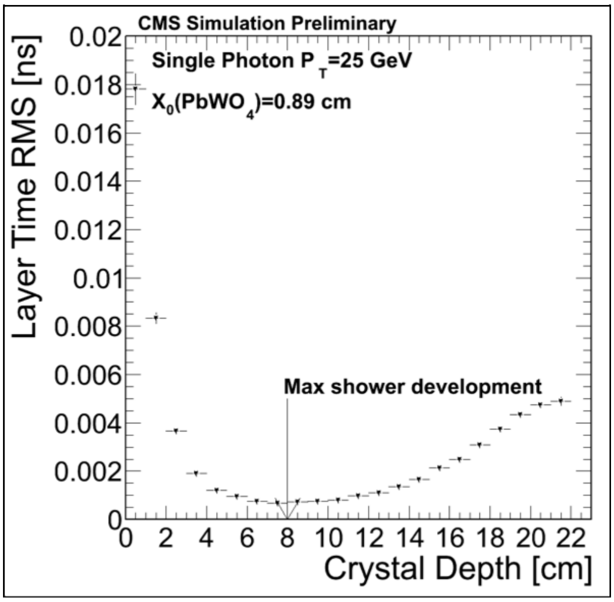
Information: Simulation and performance of a fast timing ECAL in full sim and full reco

The results proposed here are aimed to determine the physics performance of a precision timing detector integrated in the electromagnetic calorimeter. They start from a very basic study at Geant level to understand

- radiation-matter interaction timing-wise
- time response and time propagation for different particles
- effect of different longitudinal segmentations
- effect of material in front of detector

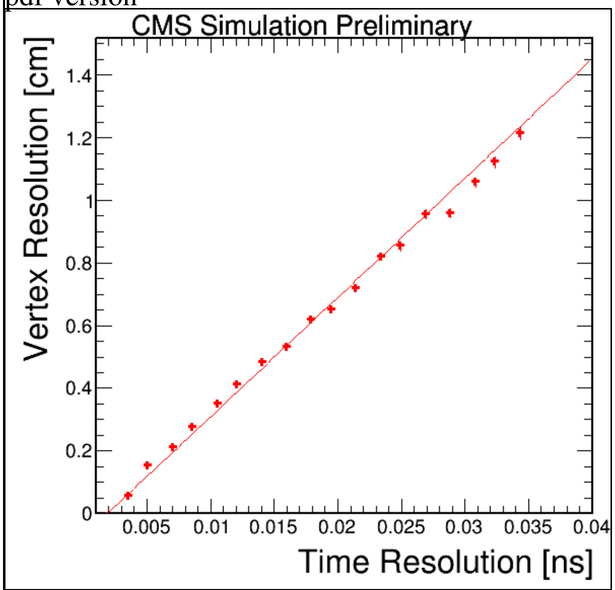
These are aimed to find the best information to be stored in Digis and Reco in order to use a possible new timing determination for PU mitigation purposes. This approach has the advantage of integrating this new timing information with full reconstruction and the particle flow algorithm. Clearly, the use of full simulation makes the conclusions on the physics performance more realistic.

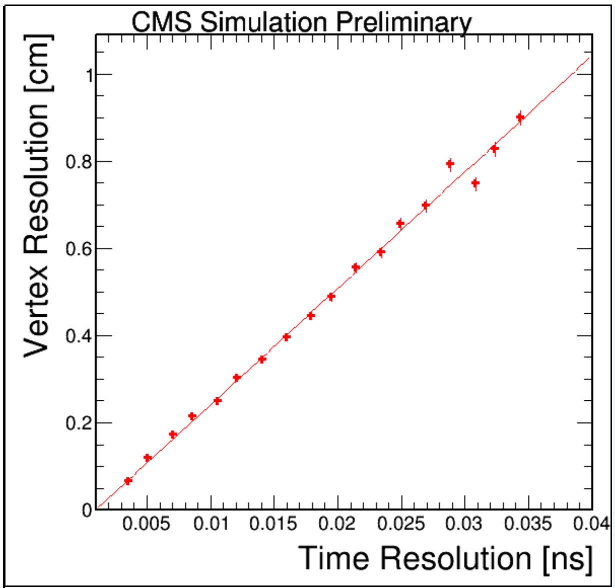
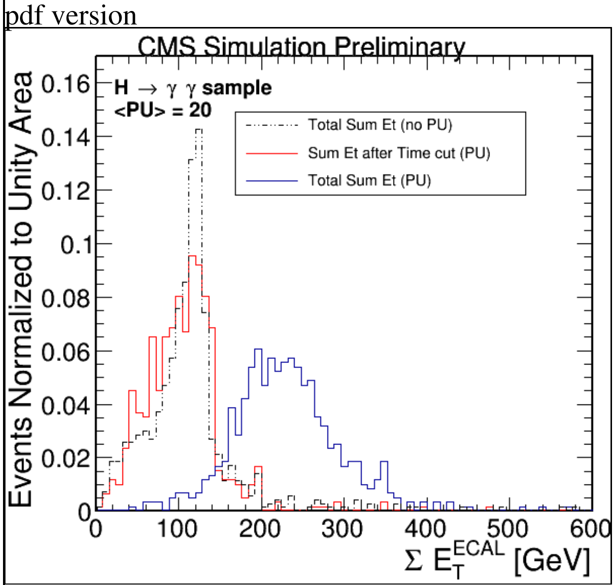
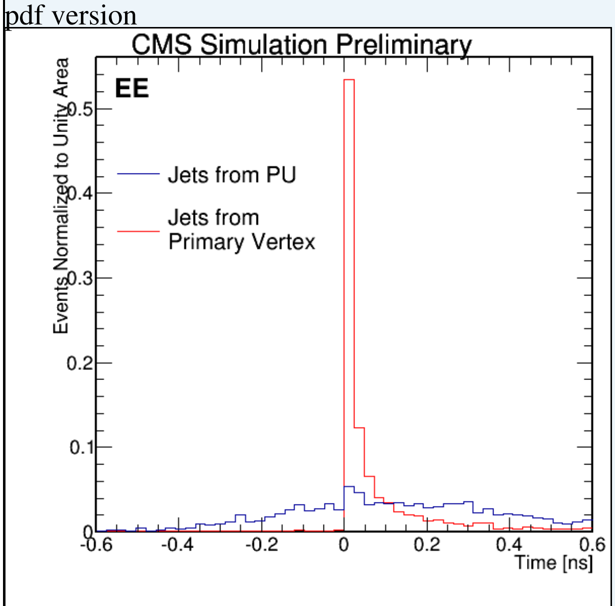
The current ECAL geometry is used. Crystals are divided in different longitudinal sub-cells. In each sub-cell the new timing information is extracted as the average of all Geant hits time within that volume, weighted by the energy of each deposit (only hits with E>5 KeV used).

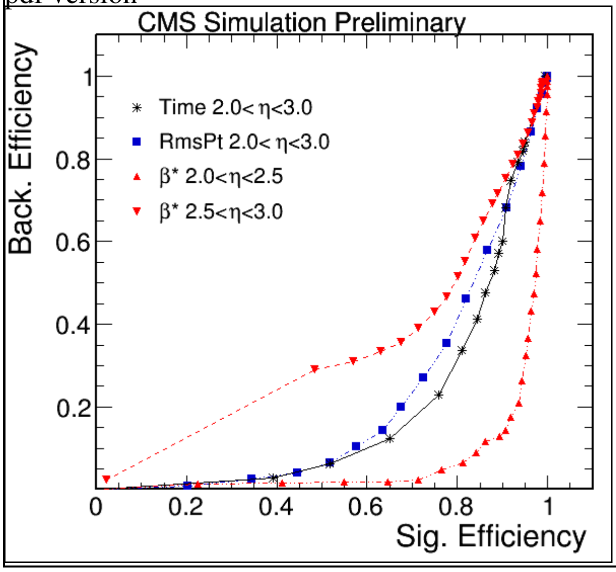
The thickness and the position of the subcell has been studied in terms of intrinsic spread of this new timing information. The smallest spread is obtained for 1 cm thick layer when there are about 8-10 radiation lengths in front of it, i.e. at the maximum of the shower. The dependence vs depth is shown in the plot below (already approved). 

In the following studies we use such new timing information extracted for a 1 cm layer after 10 radiation lengths. To emulate a real detector timing is further smeared with different gaussian resolutions.

In the different MCs used for the following studies the simulated interaction region corresponds to the configuration which reproduces Run1 conditions, i.e. the spread in z is about 5-6 cm. In addition, no spread in the time of the interaction is simulated. This means that the time of the interaction is constant.

Figure	Caption
pdf version 	Vertex determination with timing in H -> gamgam events, when both photons are in the barrel. The timing corresponds to the new timing (see introduction) of the crystal seed of each of the two photon clusters. We require pT(photon)>5GeV. The vertex position is determined by imposing that the photons originate from the same primary vertex. In this sample the time of the primary interaction is constant. The resulting resolution (RMS of the z vertex) is plotted vs different smearing resolutions. Bottomline: with a 30ps detector the resulting resolution on the vertex is about 1cm.
pdf version	Vertex determination with timing in H -> gamgam events, when both photons are in the endcap. The timing corresponds to the new timing (see introduction) of the crystal seed of each of the two photon clusters. We require pT(photon)>5GeV. The vertex position is determined by imposing that the photons originate from the same primary vertex. In this sample he time of the primary interaction is constant. The resulting resolution (RMS of the z vertex) is plotted vs different smearing

	resolutions. Bottomline: with a 30ps detector the resulting resolution on the vertex is about 0.6 cm.
pdf version 	Effect of a timing cut on ECAL based SumET. SumET is here calculated by summing all ECAL hits with E>1GeV. In this sample the time of the primary interaction is constant. The three histograms correspond to: 1) no PU: here SumET is about ET(photon1)+ET(photon2) 2) ave nPU ~ 20 with no additional cut: clear bias due to PU additional energy 3) ave nPU ~ 20 with a requirement that hit timing has to be within a given 90ps window: most of the PU contribution is gone. A small fraction of the photon ET is also removed due to show propagation effects. This will be improved in the future when the shower propagation will be taken into account.
pdf version 	TOF-corrected timing for jets coming from the primary interaction and PU jets. The timing corresponds to new timing (defined in the introduction) of the ECAL crystal with the largest energy within a jet. This timing is subtracted of the TOF under the hypothesis that the jets come from the primary interaction. In this sample the time of the primary interaction is constant. We then expect this variable to be about zero for jets from primary vertex and wider for jets from PU. The asymmetric distribution for jets from the primary interaction is due, for instance, to charged tracks which are bent and arrive, in general, later than a photon. Bottomline: visually this variable can be used to reject PU jets.

pdf version 	Impact of a selection based on a TOF-corrected timing for jets compared to a tracker based selection (beta*). The timing corresponds to new timing (defined in the introduction) of the ECAL crystal with the largest energy within a jet. This timing is subtracted of the TOF under the hypothesis that the jets come from the primary interaction. The sample used corresponds to QCD events. In this sample the time of the primary interaction is constant. Different selections are applied based on this variable and the efficiencies for jets from primary vertex and PU are evaluated and shown in a ROC curve. beta* is the variable used in several CMS analysis and corresponds to the ratio of the sum of the pT of tracks of the jet not pointing to the primary vertex w.r.t. the sum of the pT of all tracks. This variable is evaluated in the endcap region where the tracker starts to be inefficient.

-- FedericoFerri - 20 Mar 2014

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