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# Simulation studies on precise timing information during High Luminosity LHC.

The Issue

High Luminosity LHC: luminosity greater than 10^{34} cm^{-2}s^{-1} (about 10 times more than the design value for LHC) → Signal pileup in the detector caused by 140 concurrent interactions per bunch crossing.

Issue for the trigger and the object reconstruction. Fundamental to tag and remove hits from pileup.

The idea

Tracker is fundamental in pileup removal, but…
→ limited in acceptance
→ limited to charged particles.

Precise timing measurement in the electromagnetic calorimeter (ECAL) discriminate pileup vertices and improve particle reconstruction.

ECAL crystals
beam-axis
hard vertex   pileup
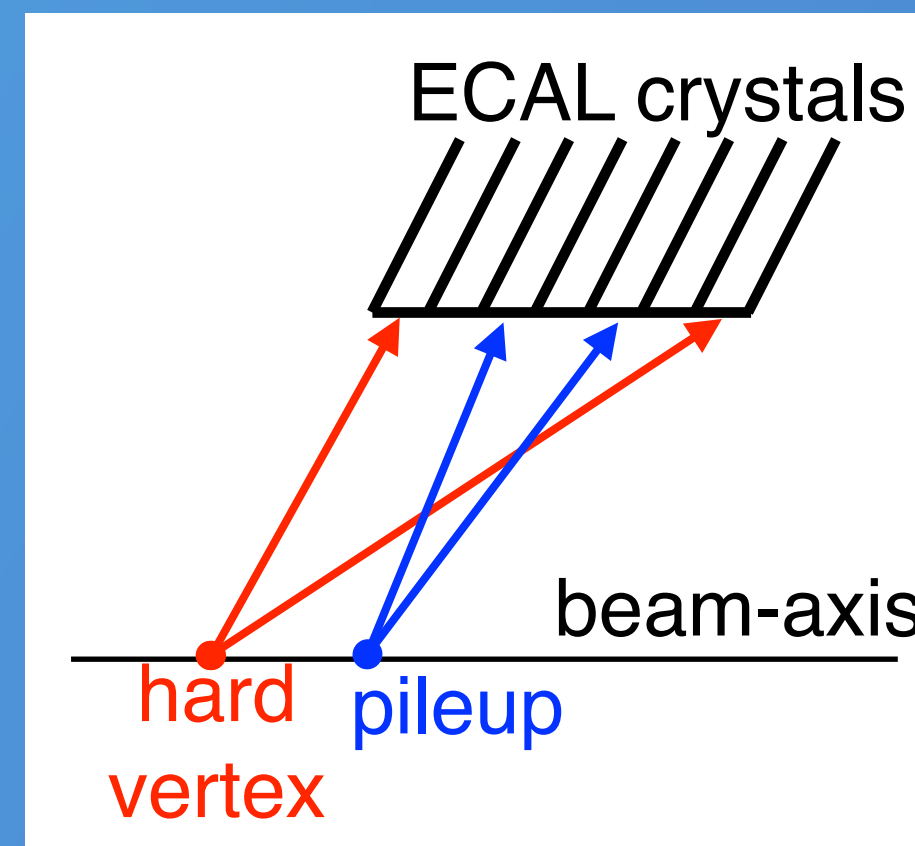
Time-Time Of Flight: different between the hard vertex and pileup
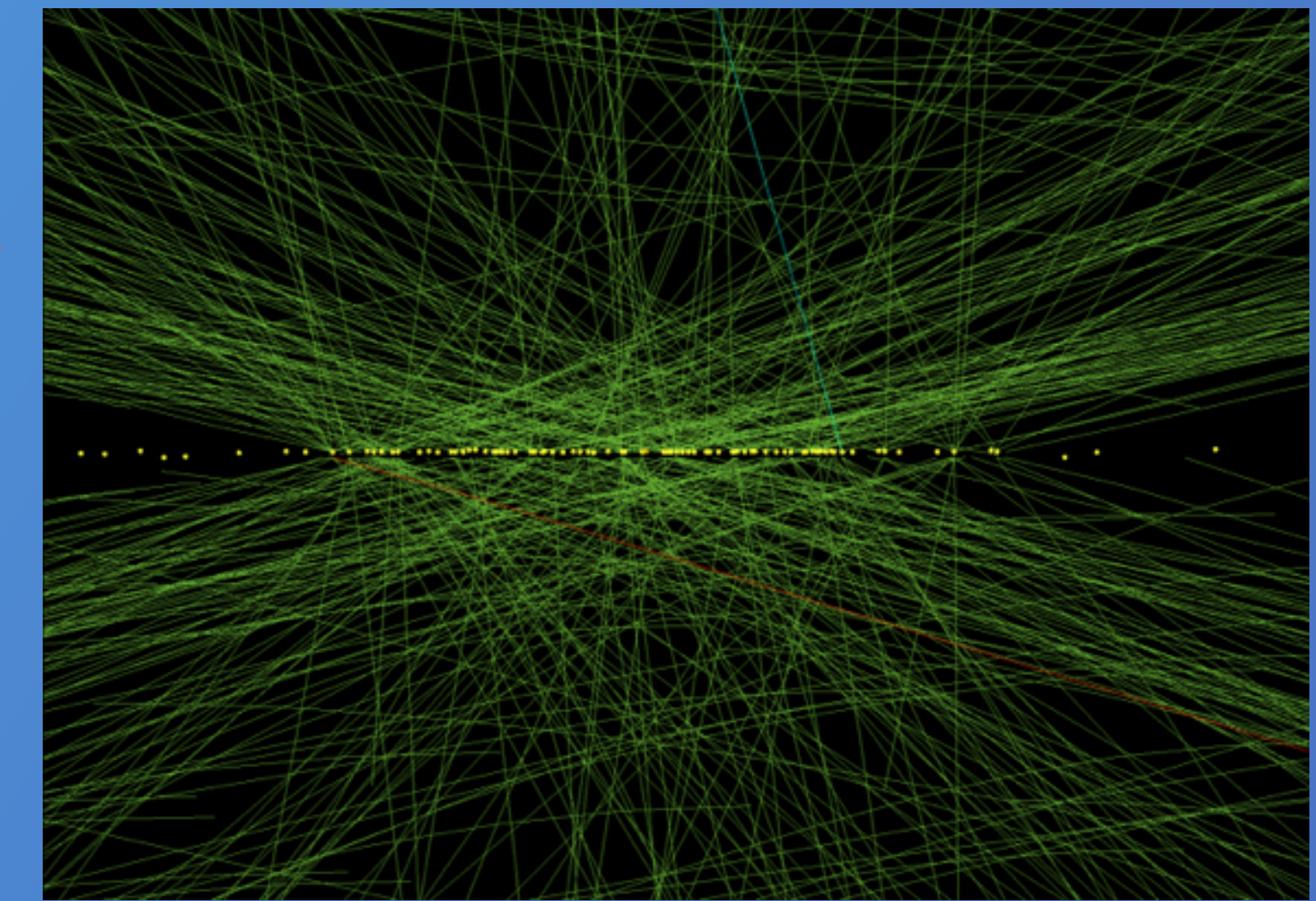
78 simultaneous collisions at CMS

Time Simulation → **Time in reconstruction** → **Physic improvements**

A time information is extracted from the simulation and it is associated to each calorimeter crystal.

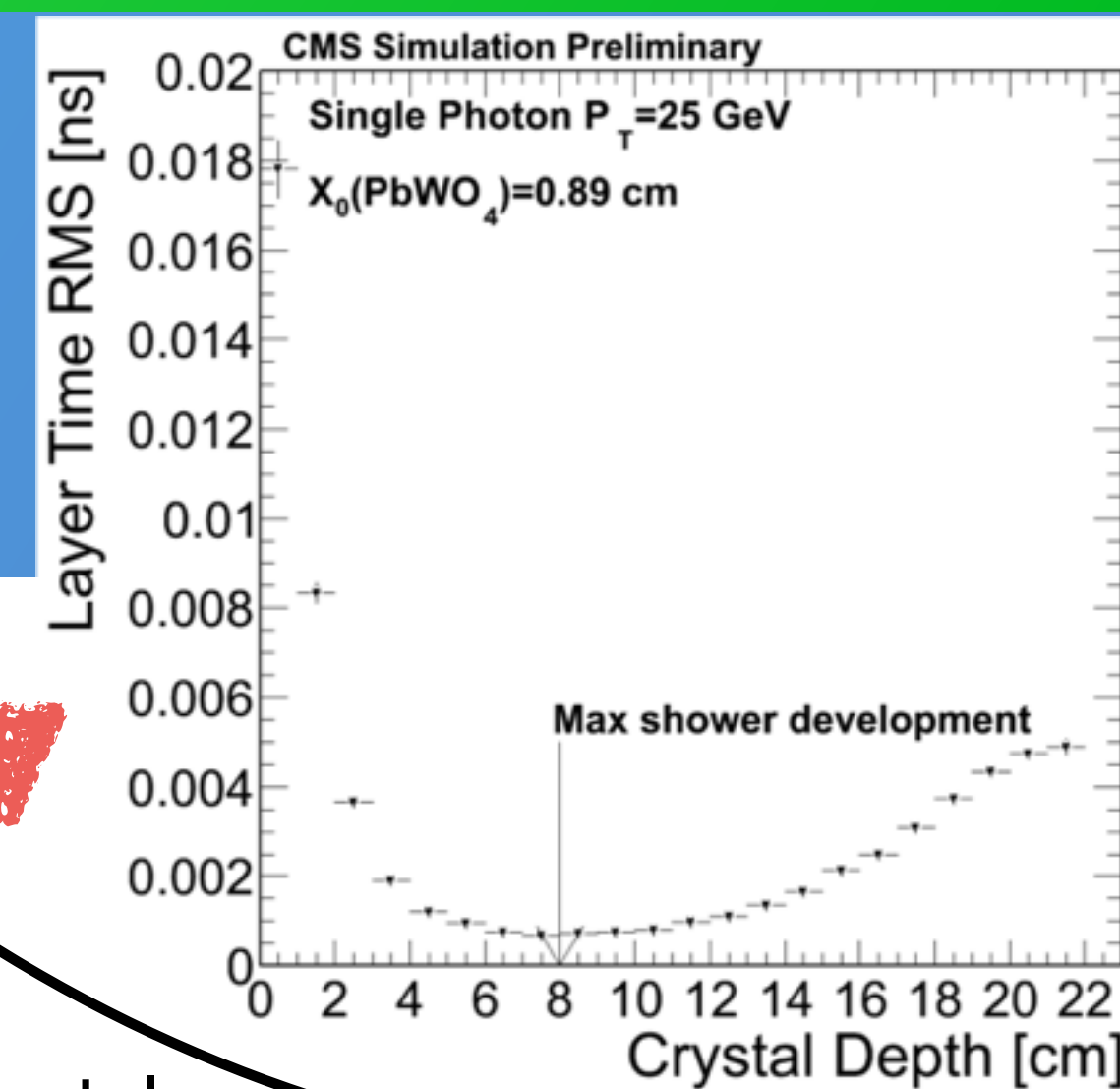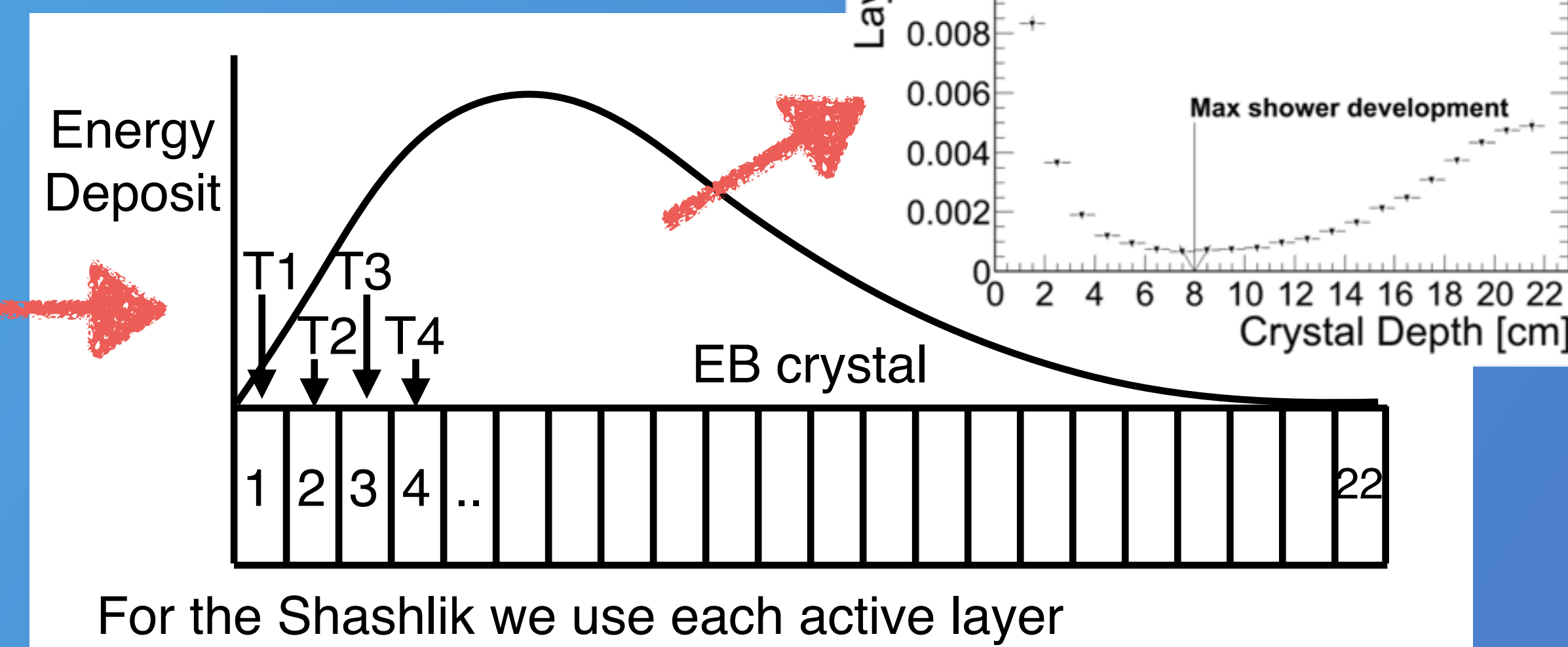The time information is associated to the reconstructed particles.

Test the possible improvements in pileup mitigation, vertexing… as a function of the time resolution.
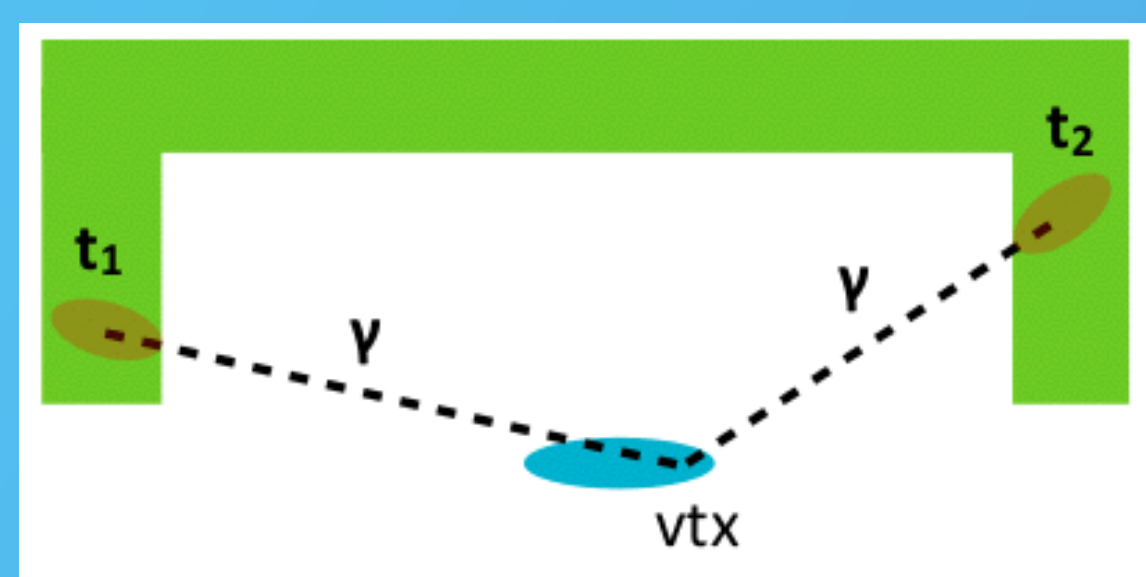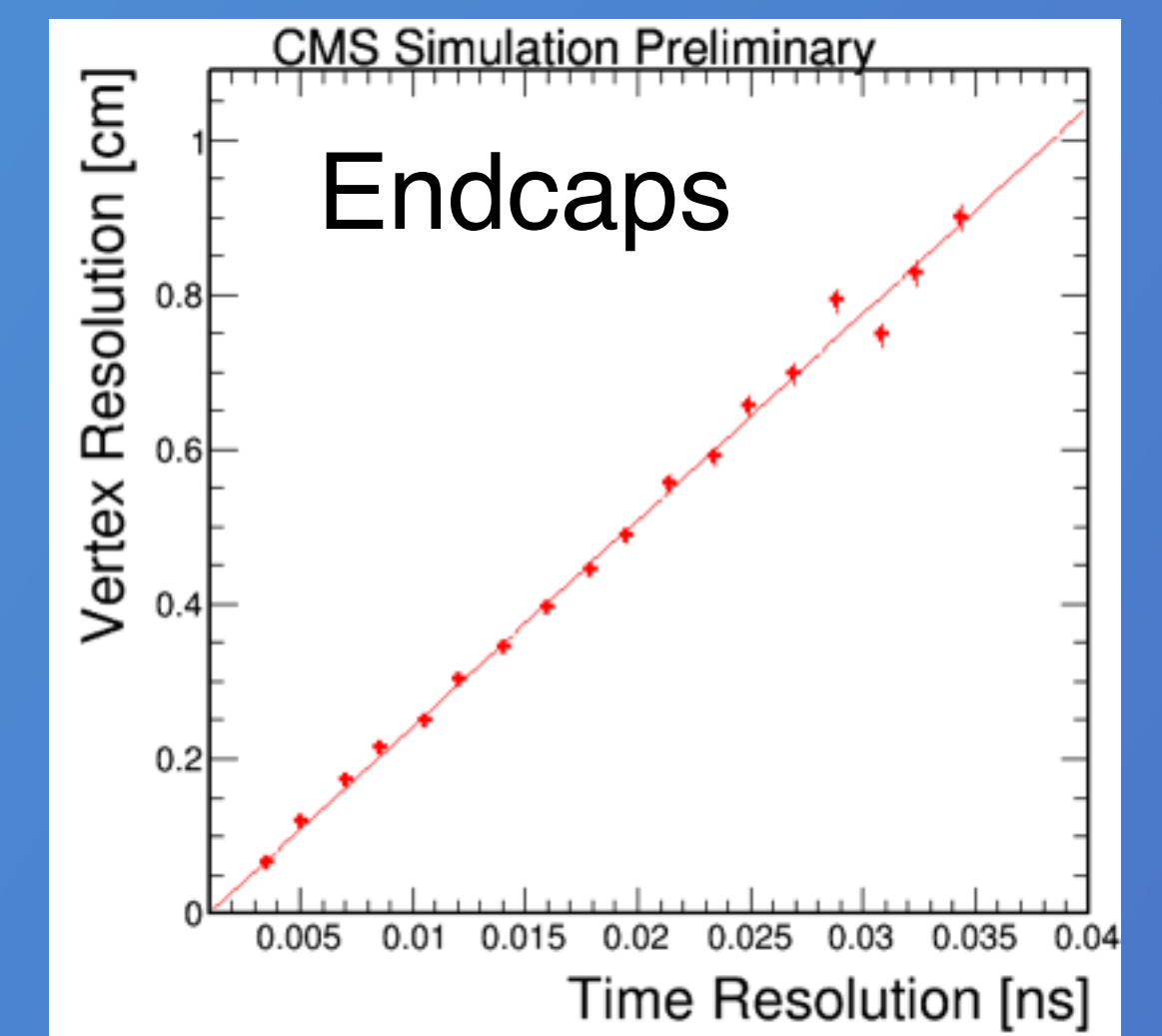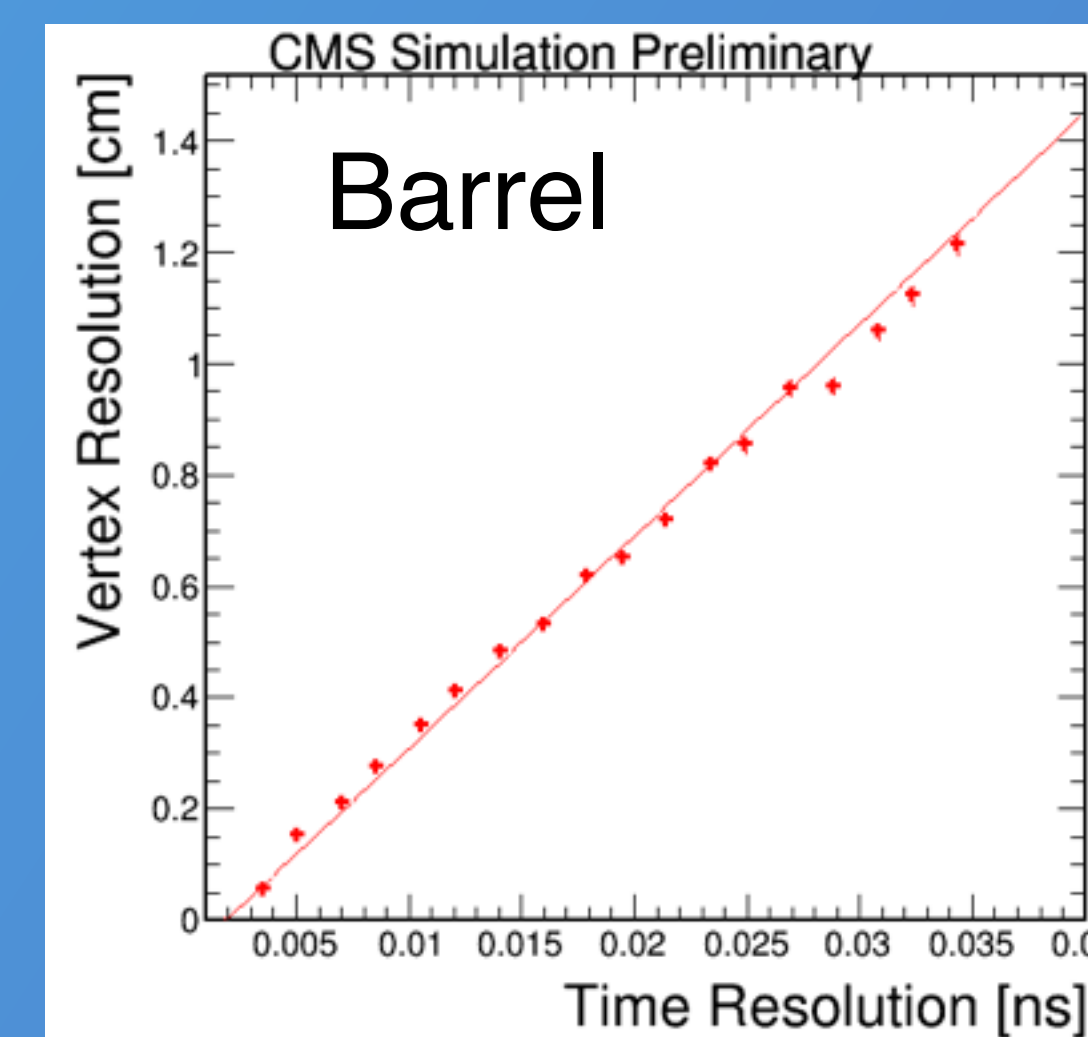
Time Simulation
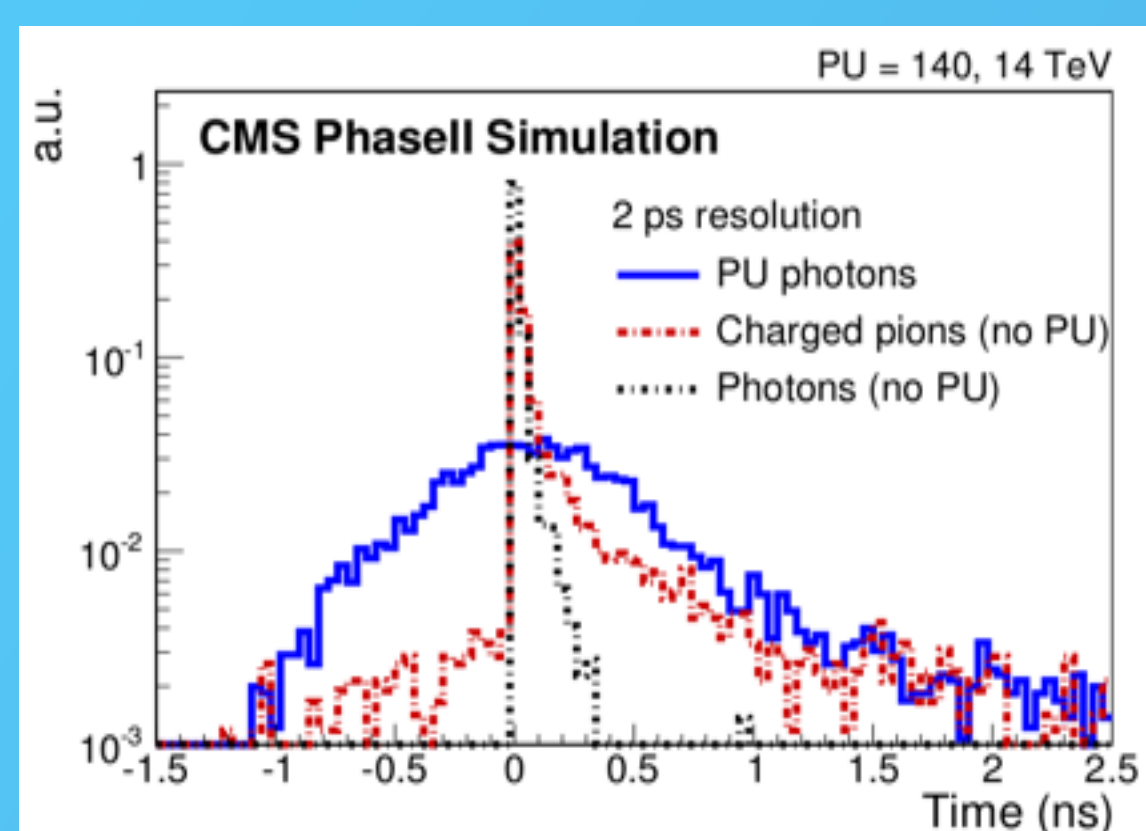
Time extracted from simulation. Electromagnetic shower causes several interactions between the crystal and the particles. Each interaction happens at a given time, at a given position inside the crystal and with an energy deposit.

Crystal time: average time of all the interactions in 1 cm layer, weighted by the energy deposit.

CMS PhaseII Simulation
PU = 140, 14 TeV
2 ps resolution
PU photons
Charged pions (no PU)
Photons (no PU)
Time (ns)

CMS Simulation Preliminary
Single Photon P_t=25 GeV
X_0(PbWO$_4$)=0.89 cm
Layer Time RMS [ns]
Max shower development
Crystal Depth [cm]

Energy Deposit
T1 T3
T2 T4
EB crystal
1 2 3 4 .. 22
For the Shashlik we use each active layer

Higgs Vertex

Higgs decay into 2 photons. The time of photon is estimated from the reconstructed time in the crystal with highest energy (associated to the photon shower) From a minimization we are able to determine:
→ vertex position along the beam-axis

t_1 t_2
γ   γ
vtx

CMS Simulation Preliminary
Barrel
Vertex Resolution [cm]
Time Resolution [ns]

CMS Simulation Preliminary
Endcaps
Vertex Resolution [cm]
Time Resolution [ns]

Occupancy Reduction

SumEt: scalar sum of the energy of the ECAL crystals.
Blue: SumEt for H→γγ without pileup.
Red: SumEt for H→γγ without pileup and time selection.
→ Time selection does not affect the signal (>90% eff.).
Black: SumEt for H→γγ with 140 pileup.
Green: SumEt for H→γγ with 140 pileup and time Celection.
→ Time selection bring the distribution closer to the signal.
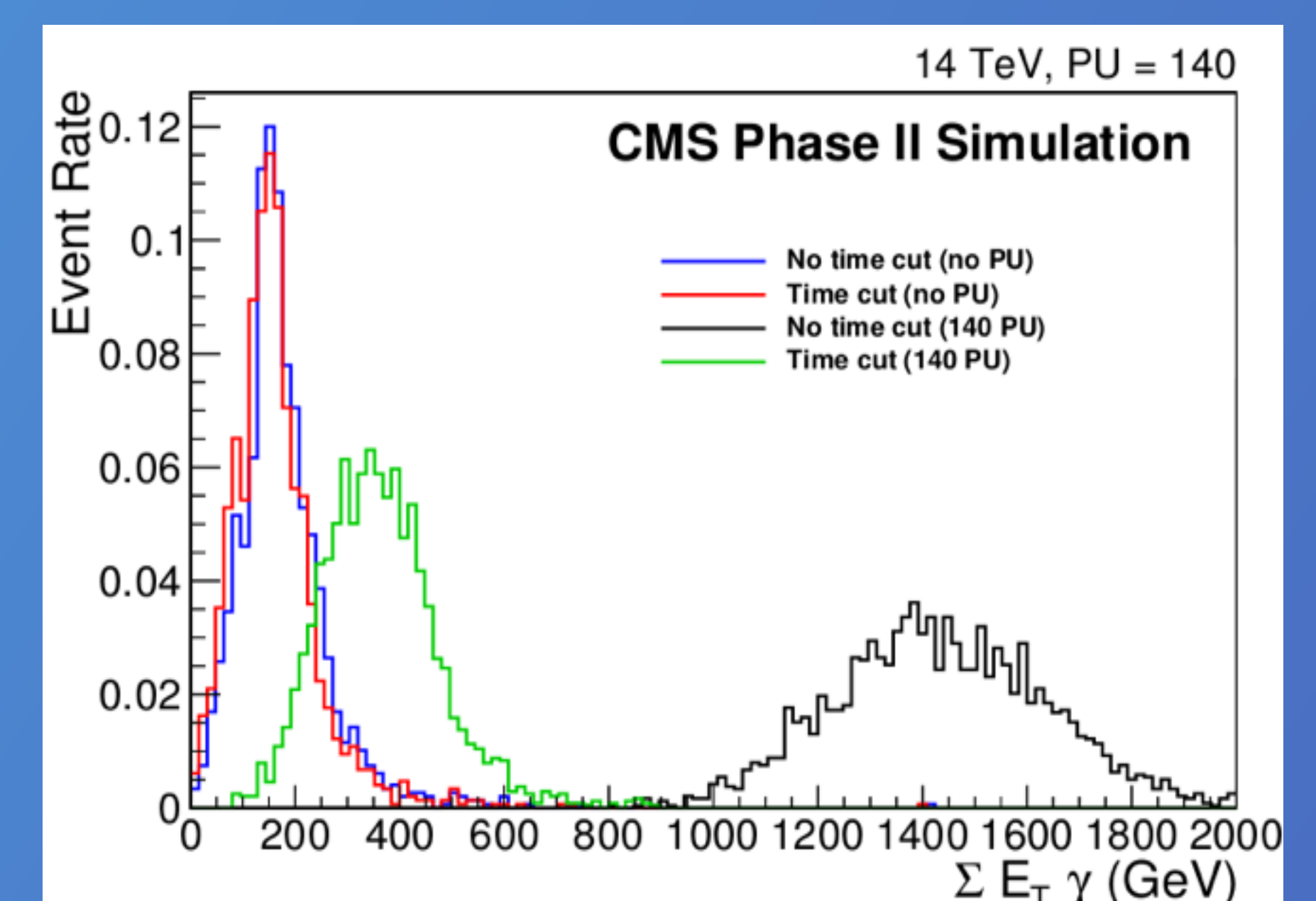
Conclusion

A proof of principle is provided of the advantage of precision timing in event reconstruction. Many other ideas to exploit precise timing: combination of the tracker and time information, jet re-clustering based on the time…

14 TeV, PU = 140
CMS Phase II Simulation
Event Rate
No time cut (no PU)
Time cut (no PU)
No time cut (140 PU)
Time cut (140 PU)
Σ E$_T$ γ (GeV)

Bibliography

DN-2014/006: Studies on a precision timing electromagnetic calorimeter for the CMS upgrade.
AN-2014/088: performance of jets and missing transverse energy with fast ECAL timing.