Vertex identification in the search for the Higgs boson decaying to two photons

Moriond EWK, Young Scientist Forum, La Thuile 2016

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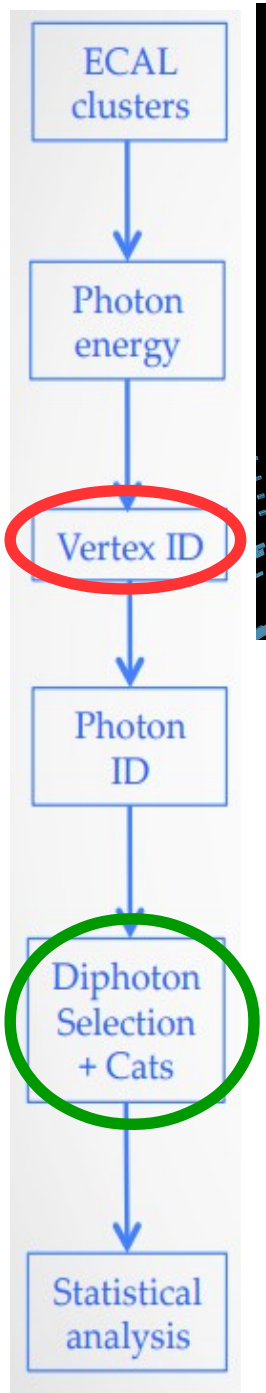
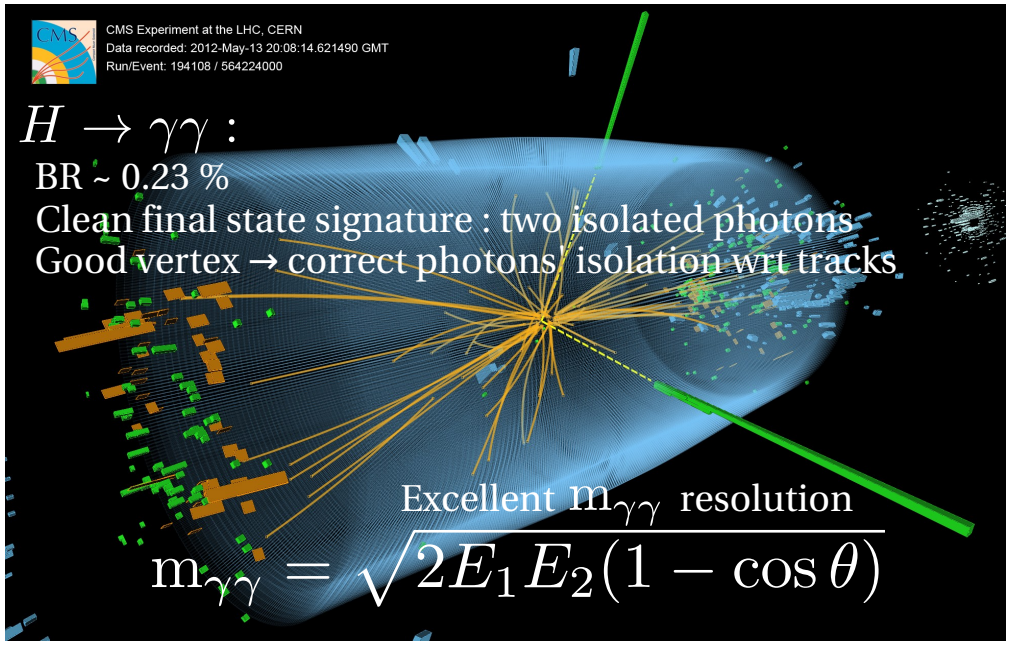
on behalf of the CMS collaboration

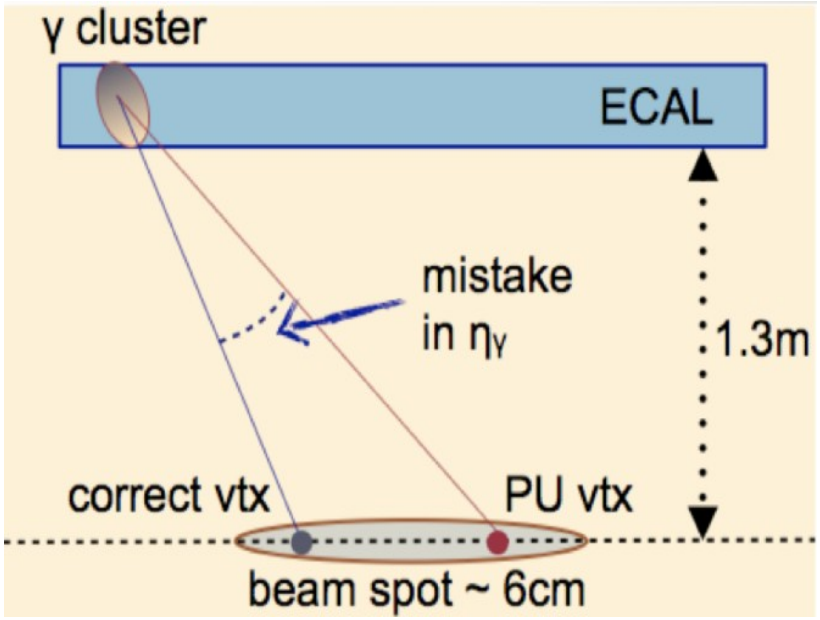
Outline:

- Motivation
- Vertex identification
- Per-event correct vertex probability estimate

Motivation







Vertex identification

- <Pileup> = 11 (spread in z ~ 6cm) in 2015
- CMS ECAL : non-pointing calorimeter
- Unconverted photons are not detected in the tracker

Per-event correct vertex probability

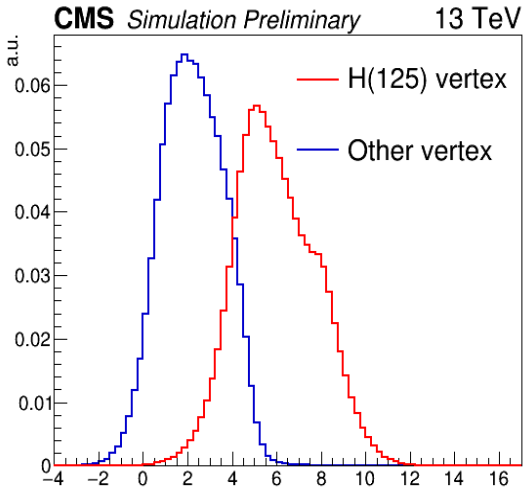
- Used for event categorization to fully benefit from ECAL mass resolution: ~ 1 GeV

Algorithms revised for Run II conditions

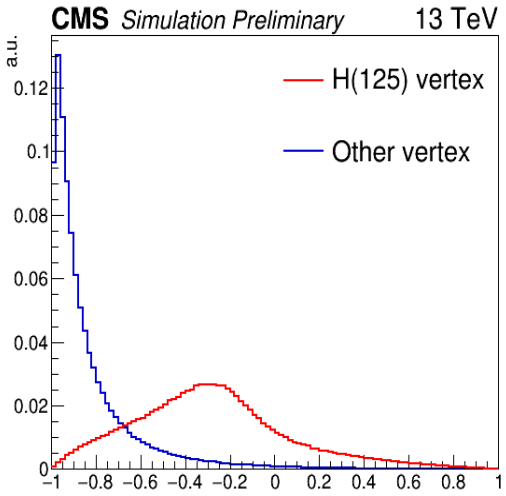
Vertex identification

Information : recoiling tracks and their balance with the $p_T^{\gamma\gamma}$

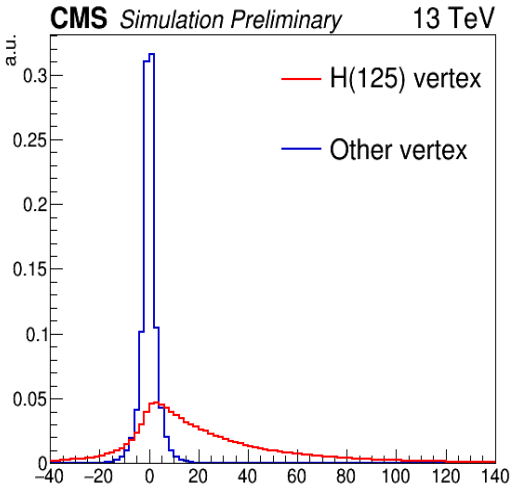
H(125) vertex
Other (random) vertex



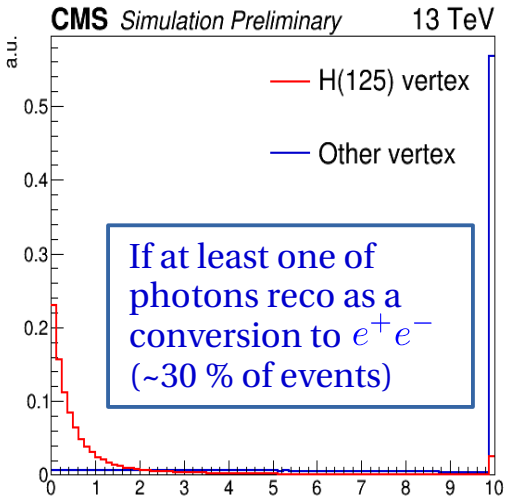
$$\sum_i |\overrightarrow{p}_T^{\,i}|^2$$



$$\frac{|\sum_i \overrightarrow{p}_T^{\,i}| - p_T^{\gamma\gamma}}{|\sum_i \overrightarrow{p}_T^{\,i}| + p_T^{\gamma\gamma}}$$



$$-\sum_i (\overrightarrow{p}_T^{\,i}) \cdot \frac{\overrightarrow{p}_T^{\gamma\gamma}}{|\overrightarrow{p}_T^{\gamma\gamma}|}$$



$$\frac{z_{PV} - z_{PV}^{conv}}{\sigma_{conv}}$$

Principle : combine discriminating variables using MVA method - BDT

- Samples : all Higgs production modes weighted according to the cross-section
- The vertex with the most signal-like BDT output is chosen

Performance : Efficiency - fraction of events with $|z_{chosen\ vtx} - z_{true\ vtx}| \leq 1\ cm$

→ where the photons opening angle makes a negligible contribution to the diphoton mass resolution

The efficiency ~ 83% for $H \to \gamma\gamma$ simulation, averaged over the $p_T^{\gamma\gamma}$ spectrum with all production modes reweighted to the cross-sections and to the data <PU> = 11

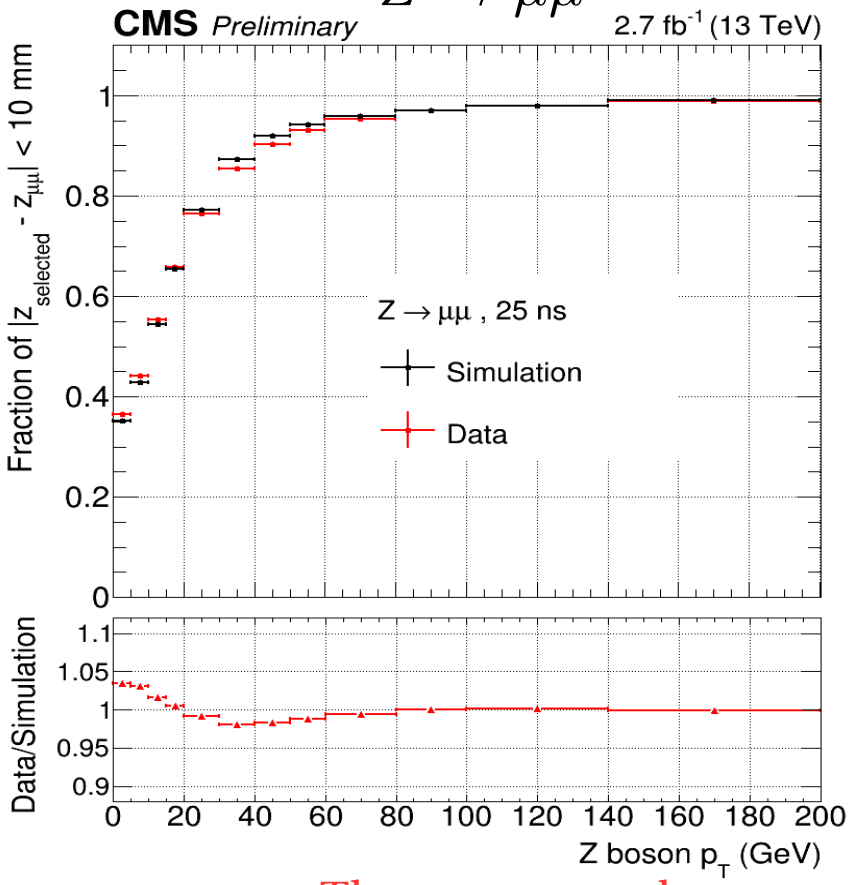
Vertex identification: validation

$Z \to \mu\mu$ events for unconverted photons and $\gamma + jets$ events for converted photons

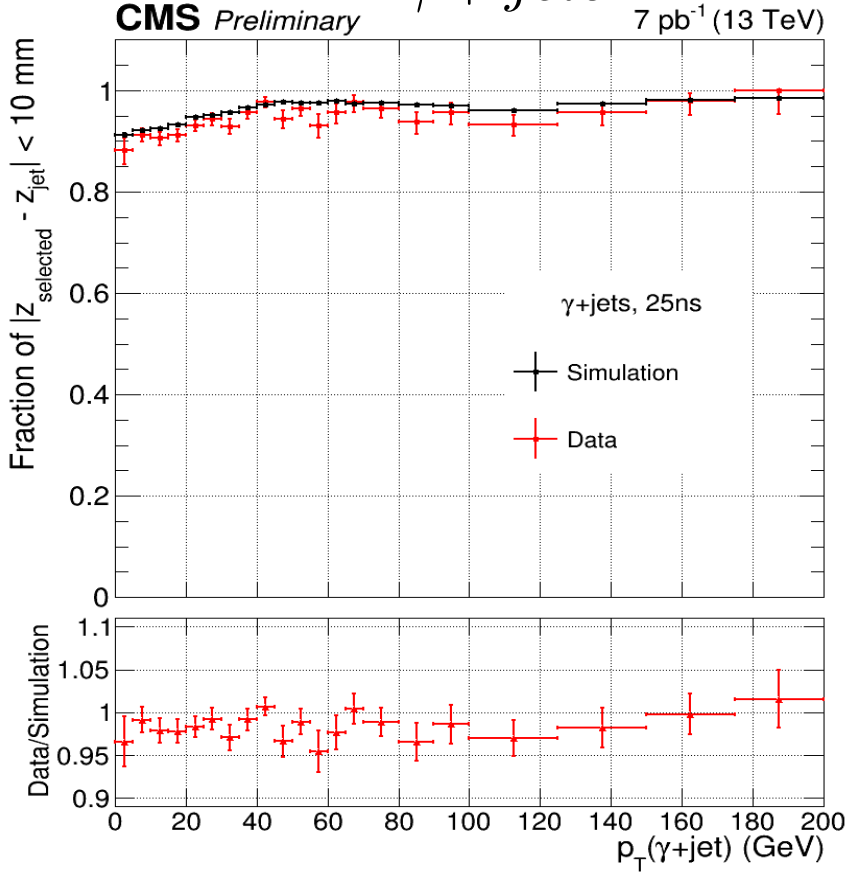
The same procedure for data and simulation :

→ remove muon (jets') tracks and re-reco vertices (only in $Z \to \mu\mu$ case)
→ choose the primary vertex with vertex ID algorithm

$Z \to \mu\mu$



$\gamma + jets$



The agreement between data and simulation is good

$Z \to \mu\mu$ data/simulation vs p_T used to correct simulation and compute systematic uncertainty

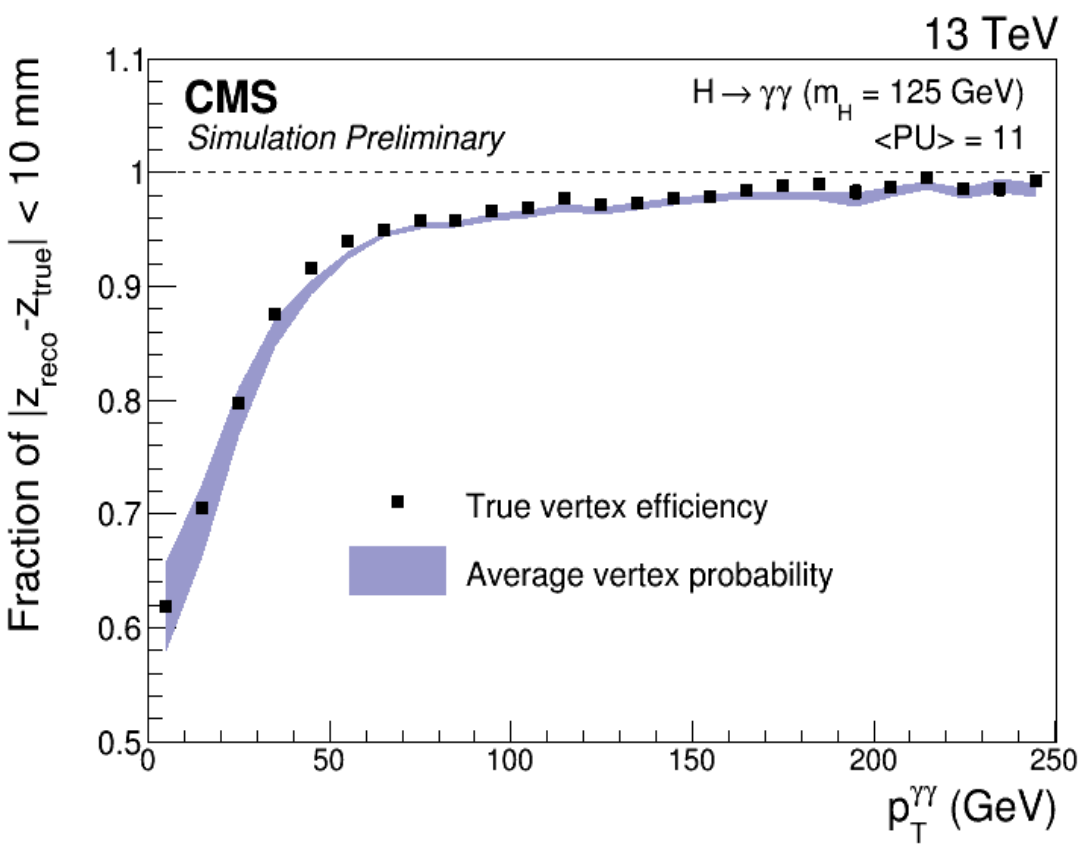
Vertex probability estimate

Method : 2nd BDT used to estimate the per-event correct vertex probability

Inputs : first BDT output for the three most likely vertices, number of vertices, $p_{T\gamma\gamma}$, distances between the chosen vertex and the 2nd and 3rd best vertices, number of converted photons

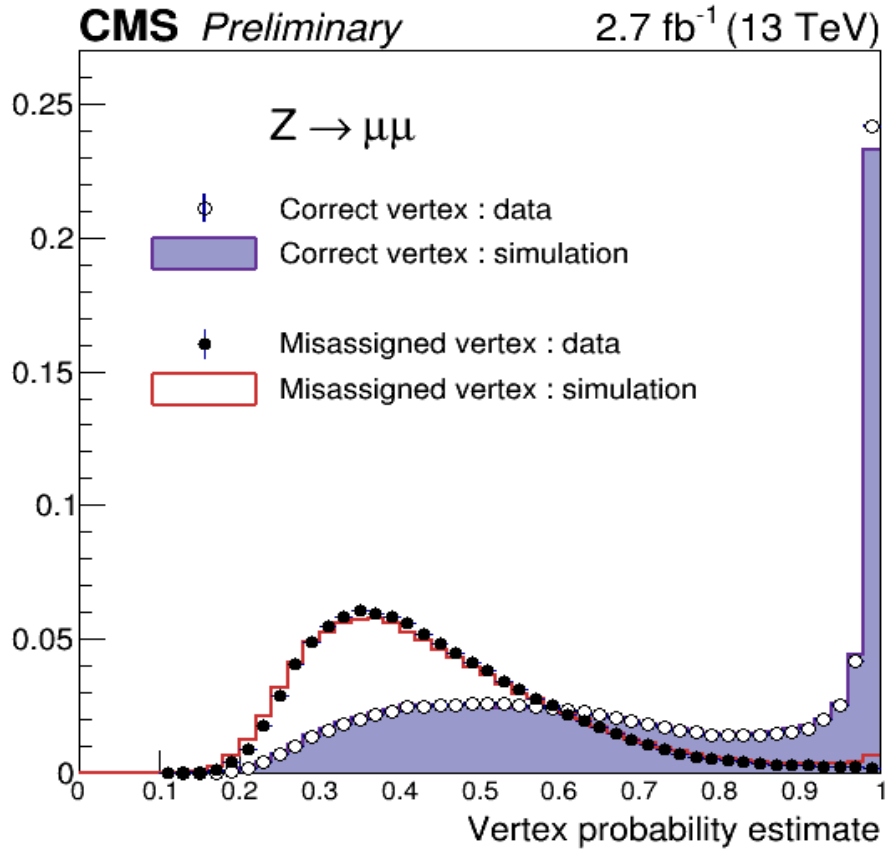
Per-event correct vertex probability : the vertex efficiency parametrized as a function of the MVA score

Closure test in $H \to \gamma\gamma$ simulation



Probability estimate is modeling well the true efficiency

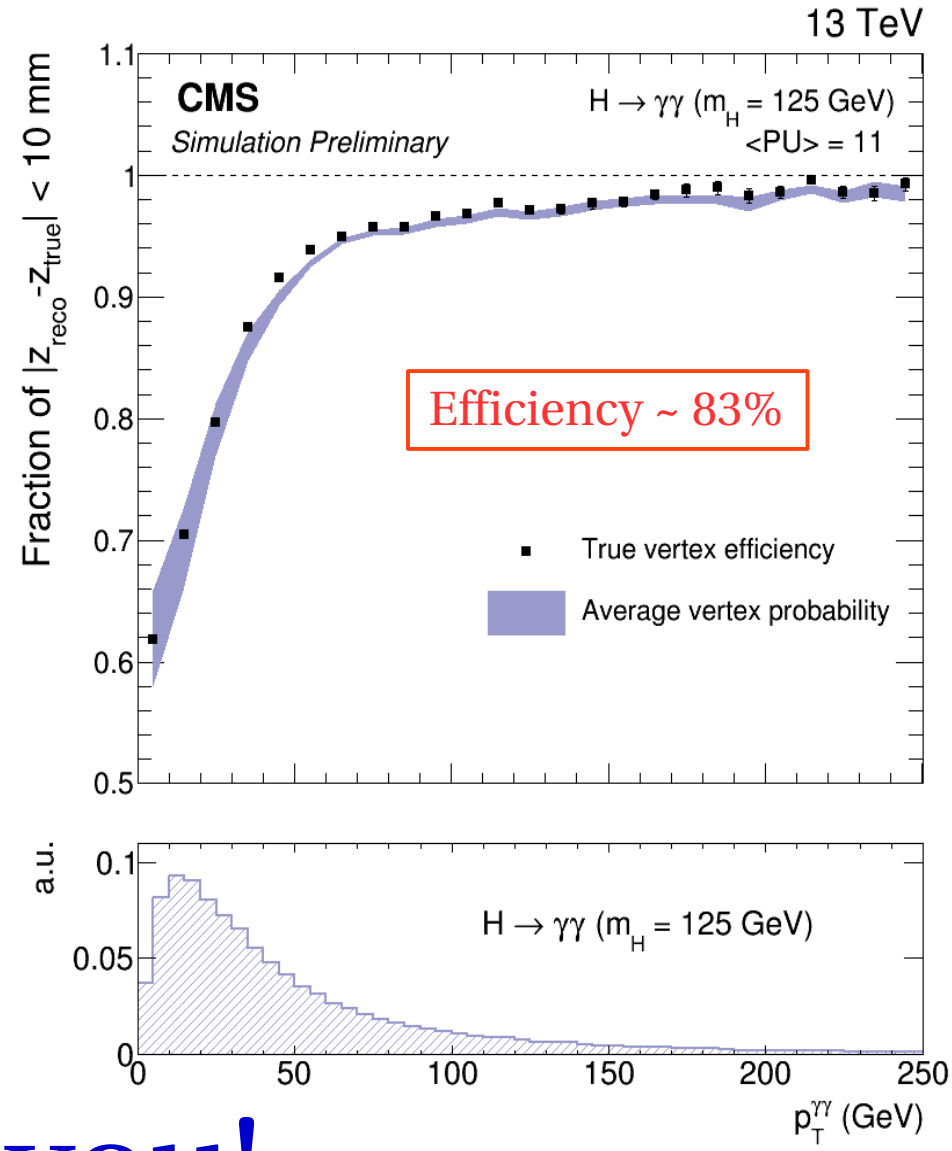
Validation with $Z \to \mu\mu$ events



The agreement between data and simulation is good

Summary

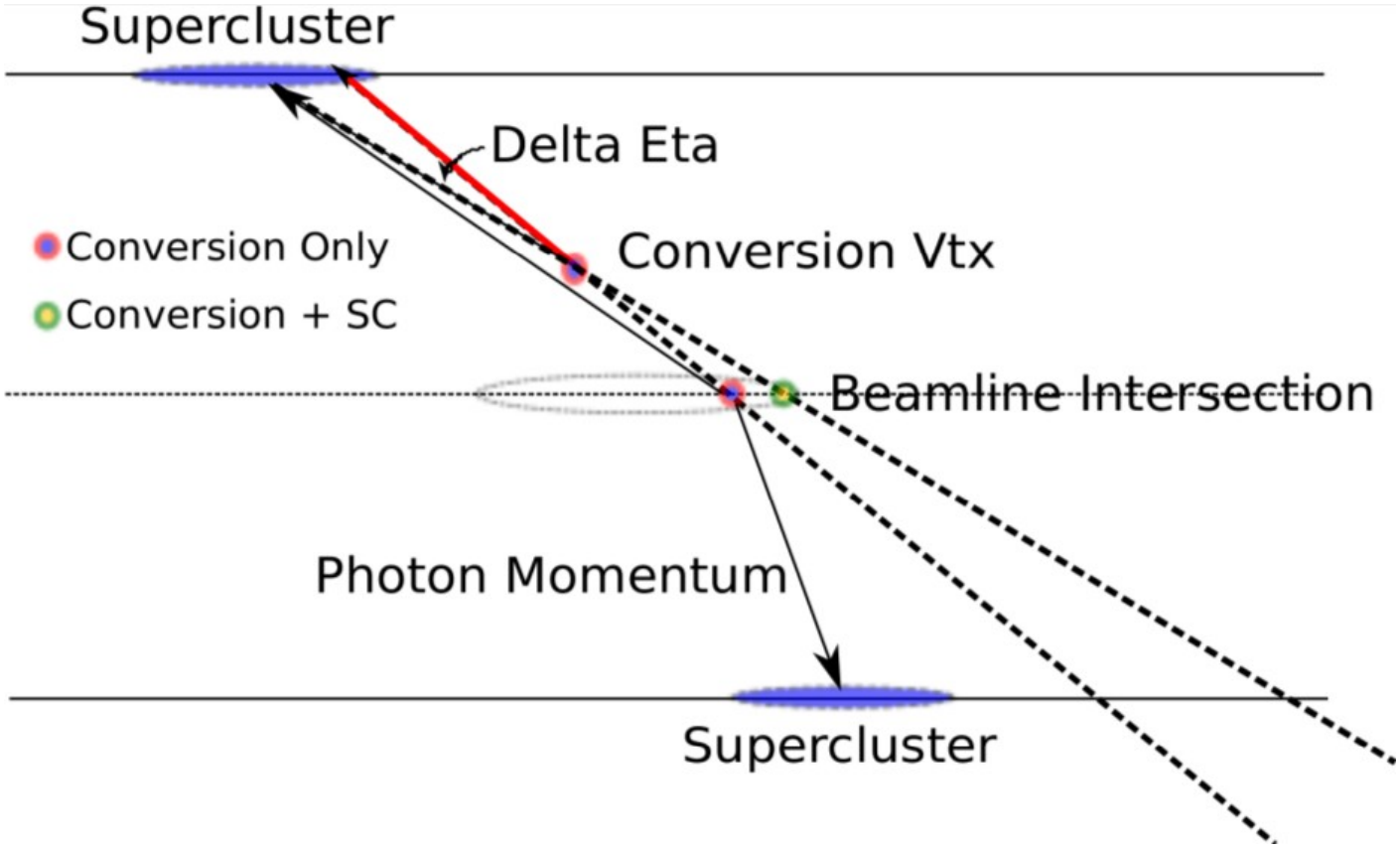
- Vertex identification and good vertex probability estimate algorithms revised for Run II and validated with data collected by CMS in 2015
- Important part of the $H \rightarrow \gamma\gamma$ Run II analysis (see Seth Zenz's talk)
- Expected performance in 2016 ~ 79 % with <PU> = 20



Thank you!

Backup slides

Conversion vertex position



z_{PV}^{conv} computed from the conversion vertex and the conversion momentum pointing to the z-axis or from the conversion vertex and the position of the super-cluster associated

The one with the best resolution for each tracker part is chosen.