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CMS DP -2025/004

The Compact Muon Solenoid Experiment

CMS Performance Note

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03 February 2025

Performance of a new Beam halo tagger for the ECAL endcap

CMS Collaboration

Abstract

Beam halo can be a huge background for analyses that search for the presence of a single photon accompanied by missing transverse energy in the detector. It can be rejected in the ECAL barrel (EB) by requiring the timing of the photon within a certain window. In addition, the requirement $\mathrm{MIP_{tot}} < 4.9$ GeV is applied to photons detected in the EB, where $\mathrm{MIP_{tot}}$ is the maximum of the total calorimeter energy summed along all possible paths of beam halo particles passing through the cluster. The same strategy used in the EB to remove beam halo is ineffective in the ECAL endcap (EE) due to its geometry. In this region, beam halo particles hit the detector nearly parallel to the beamline, making it challenging to distinguish them from genuine photons produced at the interaction point. Due to the presence of various magnets (dipoles, quadrupoles, etc), the beam halo peaks around $\varphi = 0$ and $\varphi = \pm\pi$ of the photons.

Performance of a new Beam halo tagger for the ECAL endcap

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https://cms-results.web.cern.ch/cms-results/public-results/detector-performance/

Abstract

Beam halo can be a huge background for analyses that search for the presence of a single photon accompanied by missing transverse energy in the detector. It can be rejected in the ECAL barrel (EB) by requiring the timing of the photon within a certain window. In addition, the requirement MIP_{tot} < 4.9 GeV is applied to photons detected in the EB, where MIP_{tot} is the maximum of the total calorimeter energy summed along all possible paths of beam halo particles passing through the cluster. The same strategy used in the EB to remove beam halo is ineffective in the ECAL endcap (EE) due to its geometry. In this region, beam halo particles hit the detector nearly parallel to the beamline, making it challenging to distinguish them from genuine photons produced at the interaction point.

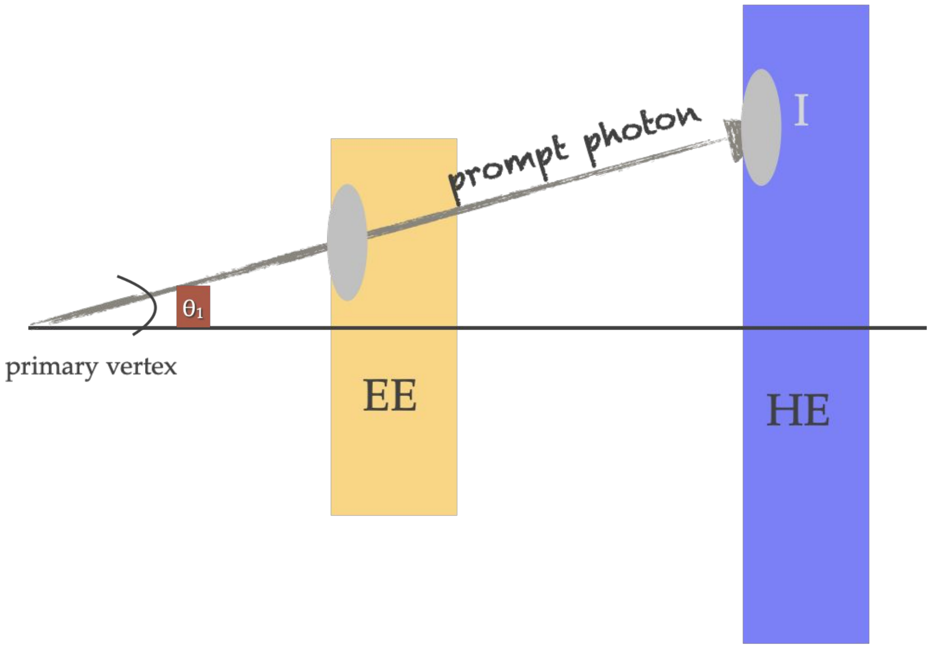
Due to the presence of various magnets (dipoles, quadrupoles, etc), the beam halo peaks around $\varphi=0$ and $\varphi=+/-\pi$ of the photons.

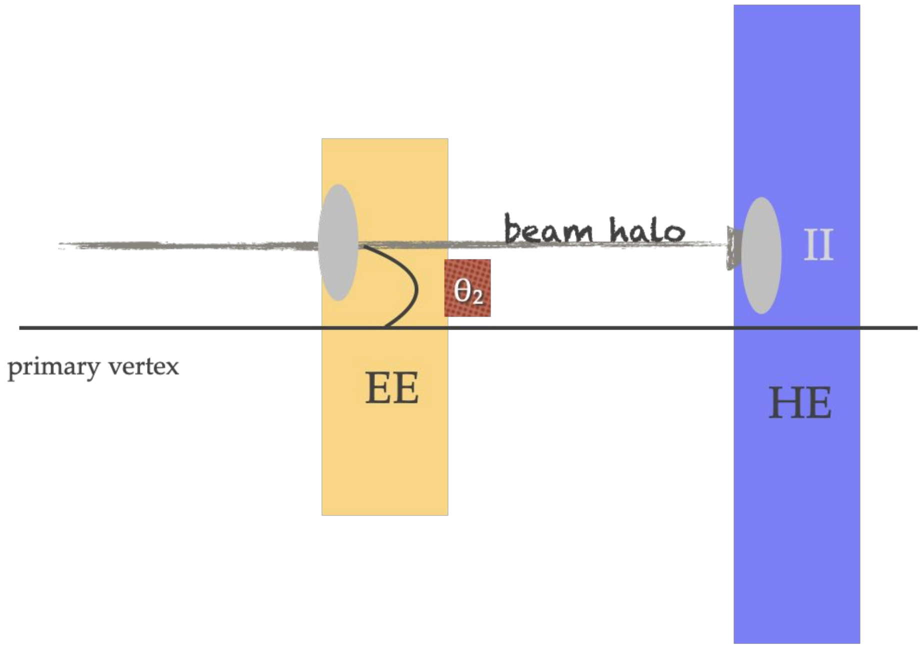
Beam halo tagger in the EE

To identify this background in the EE, a dedicated BDT using the directional information from the energy deposits in EE, HCAL Endcap (HE), and preshower (ES) was used. For a candidate photon, two hypotheses are defined: a prompt photon arising from the collision vertex, and a beam halo photon traveling parallel to the proton beam. For each hypothesis, two variables are constructed. The first variable is the angle between a line joining the hits in the EE and either in the HE or in the ES, and the beam line. The second variable is the energy deposit in either the HE or the ES. These variables, along with ECAL shower shape variables, are given as input to a BDT and a selection on the output score is used to reject beam halo photons.

This tagger is trained for photons with transverse momentum > 200 GeV. All the plots shown are with photons with transverse momentum > 200 GeV.

Two hypothesis of a photon using ECAL endcap (EE) and HCAL endcap (HE)

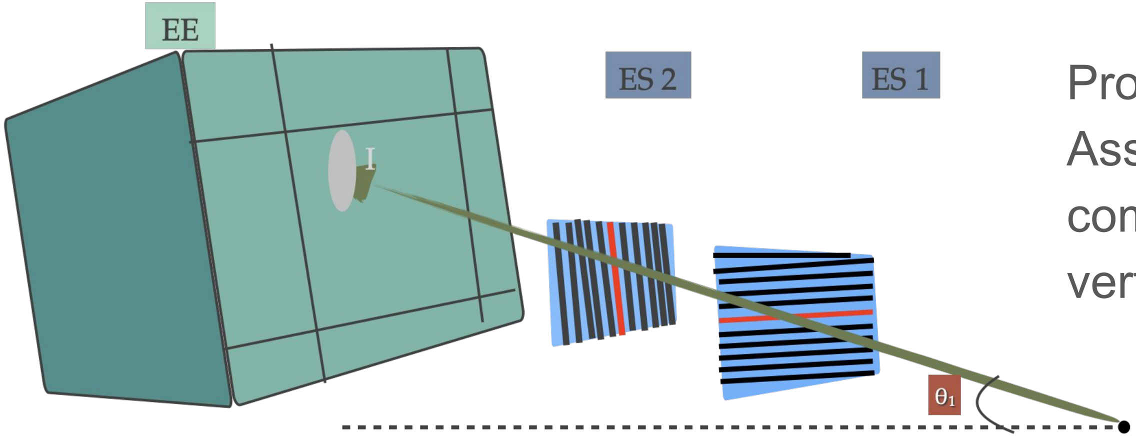




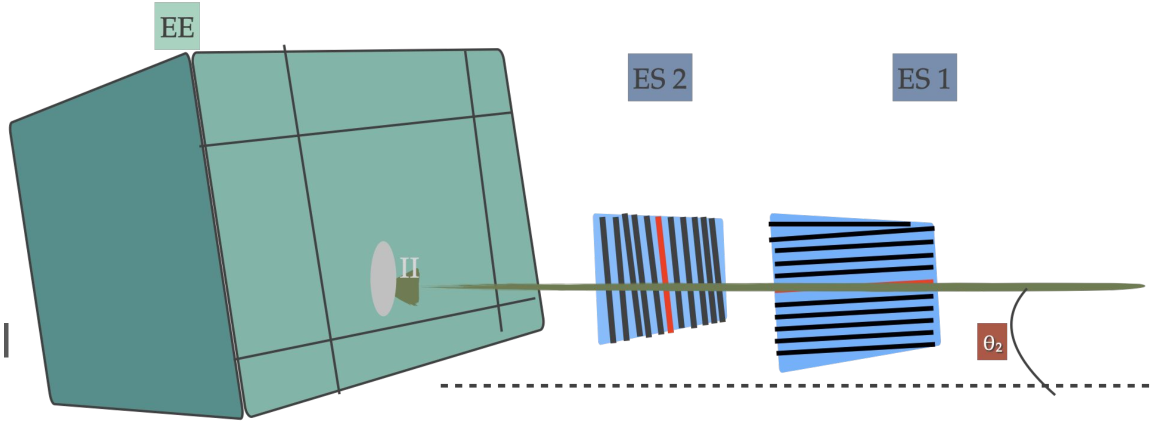
Prompt photon hypothesis: Assumes that the photon is coming from the primary vertex

Beam halo photon hypothesis: Assumes that the photon is a beam halo photon and travels parallel to the beam

Two hypothesis of a photon using ECAL endcap (EE) and Preshower (ES)

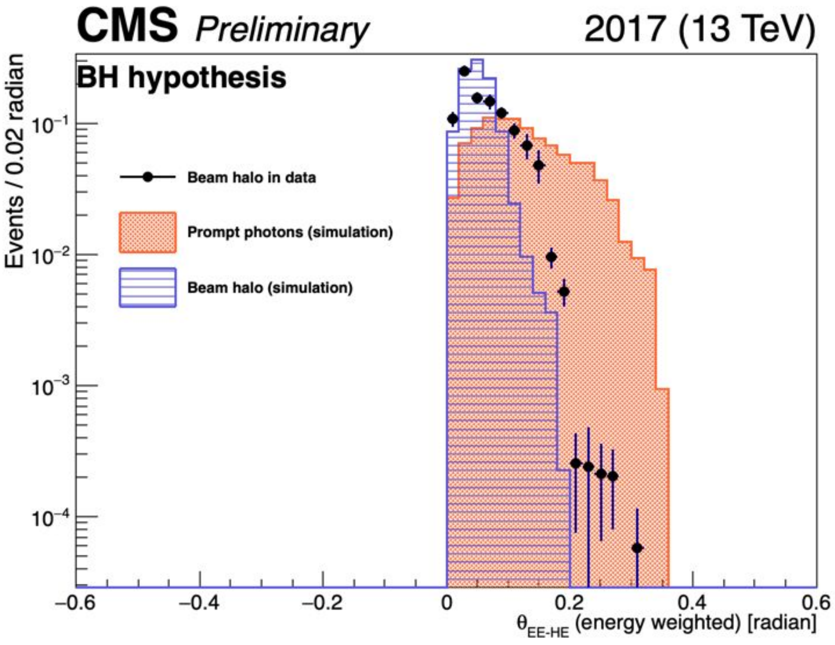


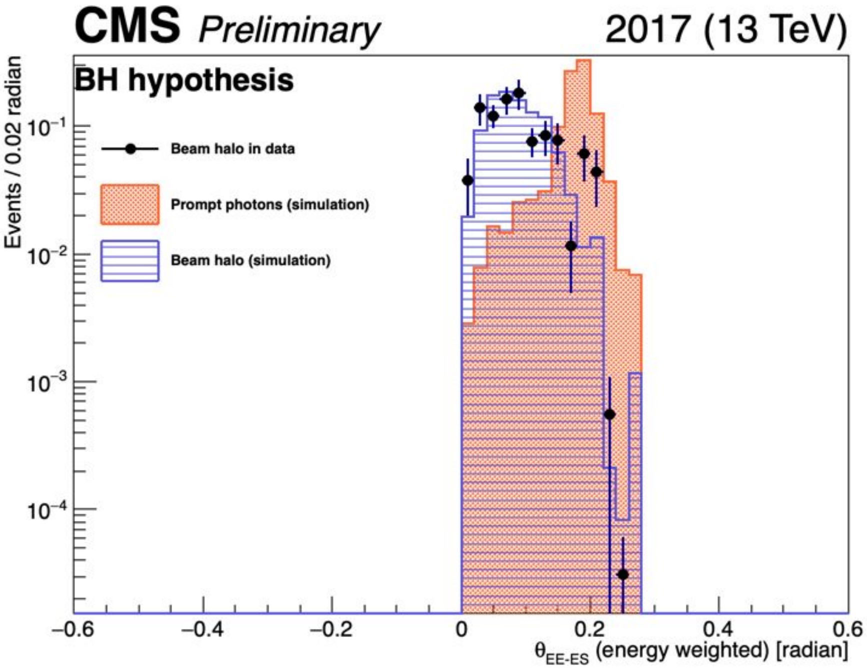
Prompt photon hypothesis: Assumes that the photon is coming from the primary vertex



Beam halo photon hypothesis: Assumes that the photon is a beam halo photon and travels parallel to the beam

Angle variables in the beam halo hypothesis





Angle variables in the beam halo hypothesis

Photon energy weighted angle between the line joining the photon super-cluster in the EE and the cluster in the HE/ES and the z-axis.

Left plot shows the angle between the EE and the HE where the cluster of energy in the HE is at the same φ as the photon in the EE.

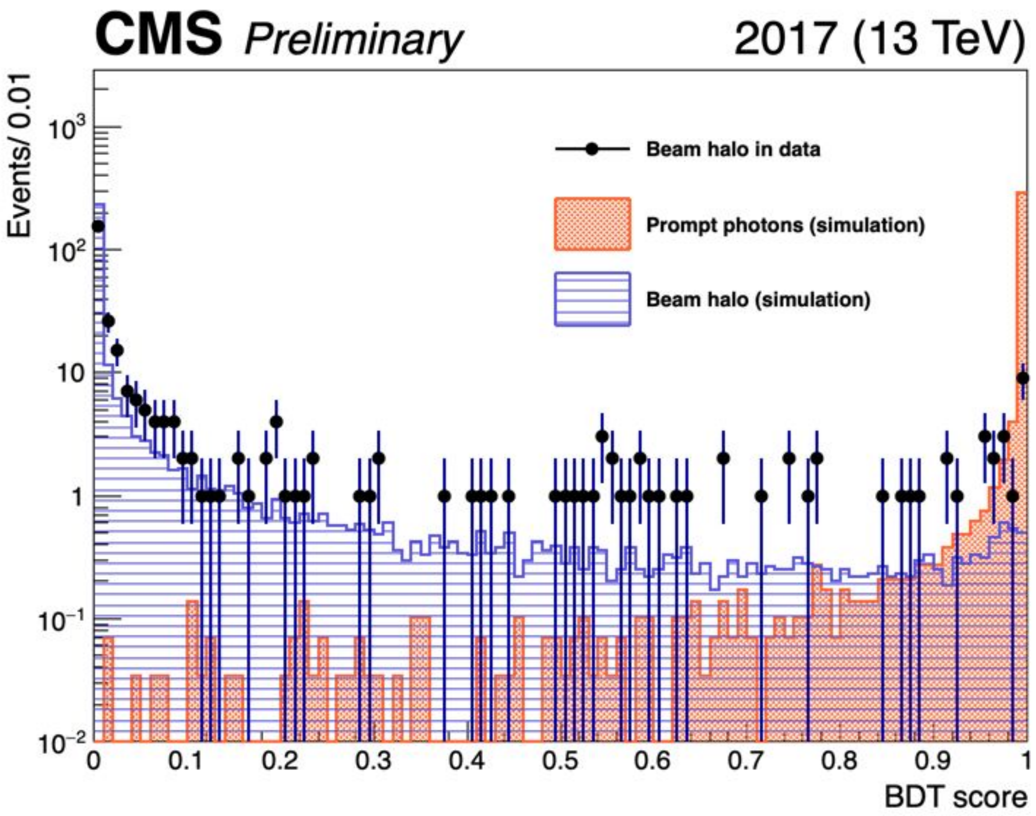
Right plot shows the angle between the EE and the ES where the cluster of energy in the ES is at the same φ as the photon in the EE.

Black points show the control region of beam halo photons collected in 2017 pp collision data and selected using information from the cathode strip chambers (CSC) where the hits in the CSCs are aligned with the super-cluster in the EE. Red histogram shows the distribution of the prompt photons obtained from $Z(\nu\nu)\gamma$ simulation. Blue histogram shows the distribution of beam halo photons obtained from simulation.

Variables used in the training

- XGboost is used for the training.
- Signal is represented by prompt photons from Z(νν)γ simulation and background is from simulated samples of beam halo photons.
- 16 variables are used in the training:
  - 6 are shower shape variables in the EE and ES.
  - Scalar sum of pT of all the tracks at the primary vertex.
  - Energy density in the event.
  - Remaining are the variables formed using EE-HE and EE-ES:
    - Angle between the beam axis and the line joining the EE and HE in both prompt photon and beam halo photon hypotheses.
    - Angle between the beam axis and the line joining the EE and ES in both prompt photon and beam halo photon hypotheses.
    - Energy deposited in the HE behind the EE supercluster in both prompt photon and beam halo photon hypotheses.
    - Energy deposited in the ES behind the EE supercluster in both prompt photon and beam halo photon hypotheses.

BDT output score

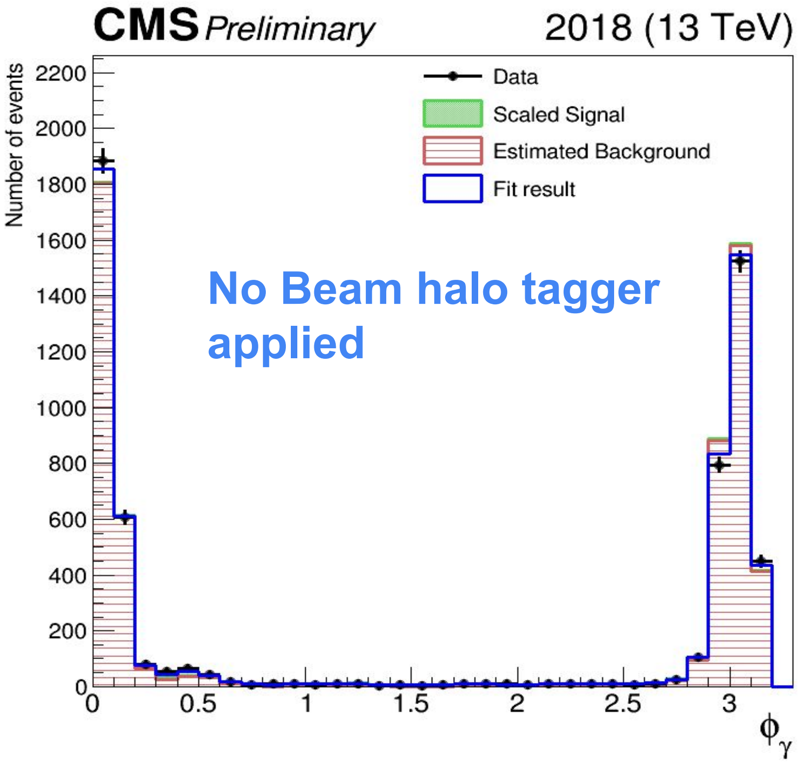


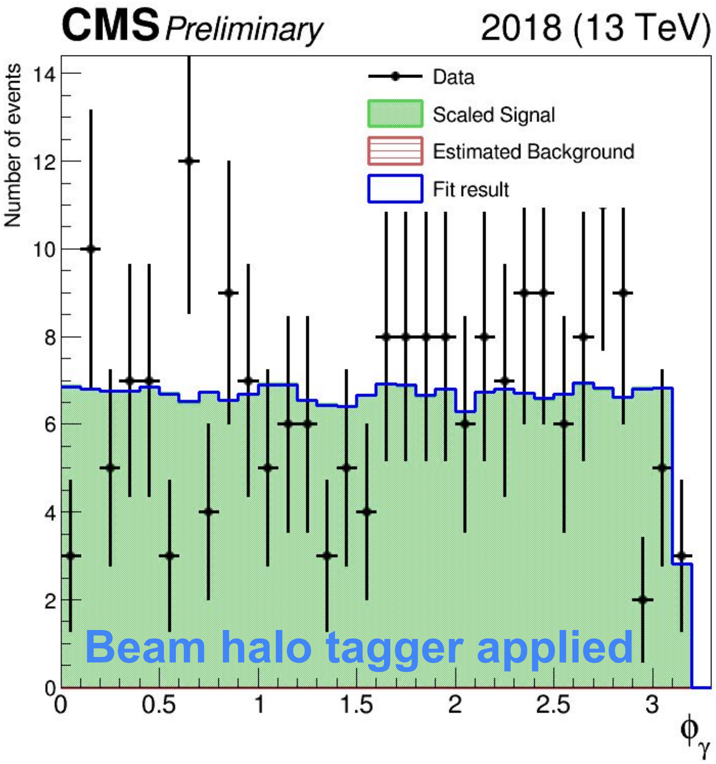
BDT output score

BDT output score of the photons.

Black points show the control region of beam halo photons collected in 2017 pp collision data and selected using information from the cathode strip chambers (CSC) where the hits in the CSCs are aligned with the super-cluster in the EE. Red histogram shows the distribution of the prompt photons obtained from Z(νν)γ simulation. Blue histogram shows the distribution of beam halo photons obtained from simulation.

Performance in 2018 data: Phi angle of the photons





Performance in 2018 data

Training is done in 2017 data. The plot shows the performance on 2018 data.

The events are collected by requiring the presence of one photon with a transverse momentum cut of 225 GeV and missing transverse energy > 200 GeV. No other objects are required to be present in the event.

Plot shows the phi angle distribution of the photons passing the above criteria.

Black points show the distribution of photons collected in 2018 pp collision data. These data points are fitted using a maximum likelihood fit method (TFractionFitter) with a phi angle template from prompt photons taken from simulation and beam halo photons taken from a control region in data. The fraction of prompt photons in the data is the fitted parameter.

Green distribution shows the contribution of the prompt photons obtained from Z(vv)γ simulation and red histogram shows the contribution of beam halo photons obtained after the likelihood fit to the data.

Left plot shows the distribution of phi angle of the photons when no criteria on the beam halo tagger is applied.

Right plot shows the distribution of phi angle of the photons when a tight criteria on the beam halo tagger is applied. The contribution from the beam halo photons has been reduced to almost 0.