The measurement of various efficiencies with $Z \to \mu\mu\gamma$

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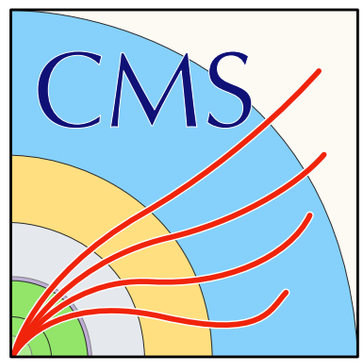

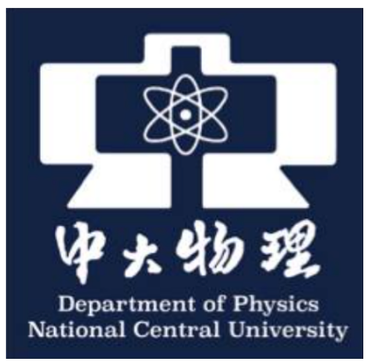

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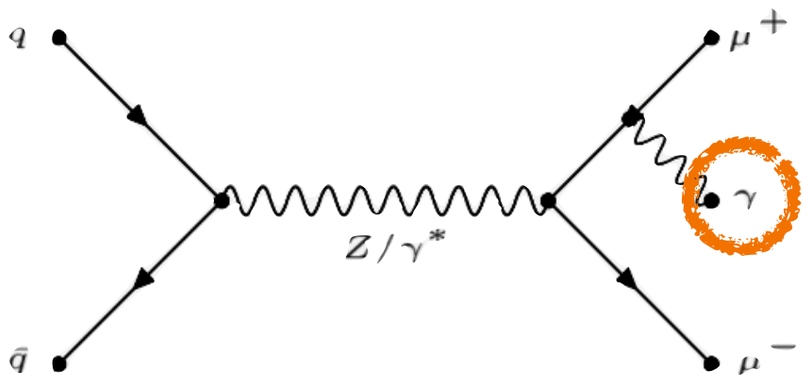
Introduction

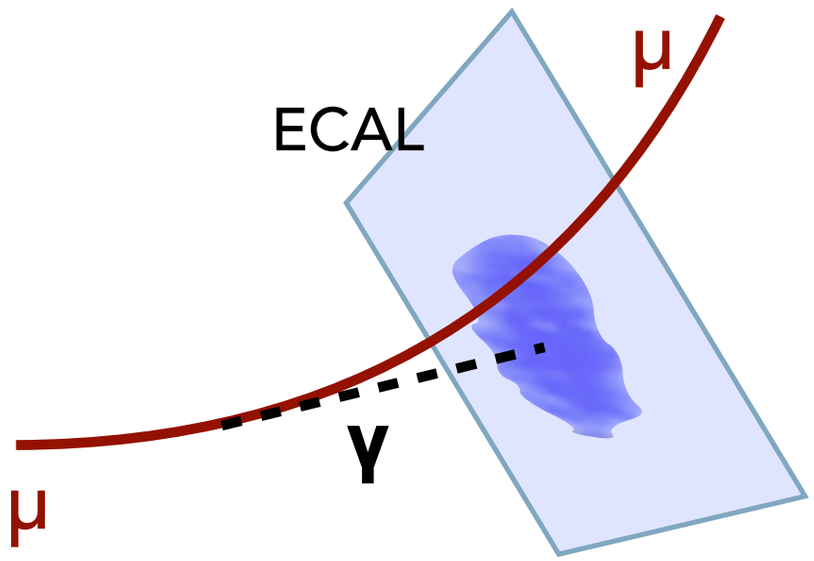
- Efficiency measurement needs a high-purity sample.
- $Z \rightarrow \mu\mu\gamma_{FSR}$ events provide us a **high-purity (~97%)** control sample, where γ_{FSR} is the photon coming from **final state radiation (FSR)**.
- We can use this control sample to perform the following efficiency measurements.
  1. Electron veto efficiency
  2. Trigger efficiency as the photon is involved
  3. Photon identification (ID) efficiency



FSR

Advantage	Disadvantage
It provides a pure control sample.	Most of the γ_{FSR}'s pT are low.

FSR selection



μ track points to the cluster

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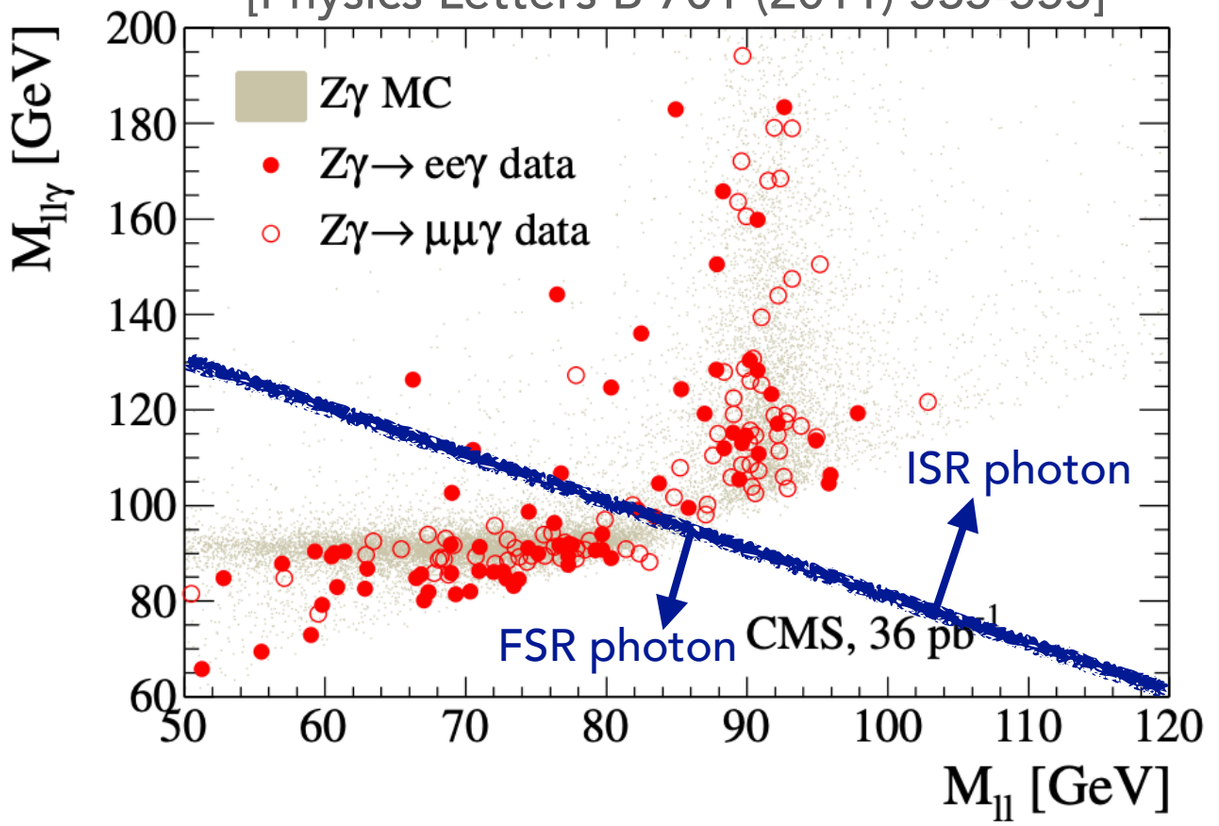


FSR selection:

1. $\Delta R(\mu_1,\gamma) > 0.1$ **and** $\Delta R(\mu_2,\gamma) > 0.1$
2. $\Delta R(\mu_1,\gamma) < 0.8$ **or** $\Delta R(\mu_2,\gamma) < 0.8$
3. $M_{\mu\mu} + M_{\mu\mu\gamma} < 180$ GeV
4. Three body mass must be close to Z mass (91.18 GeV)

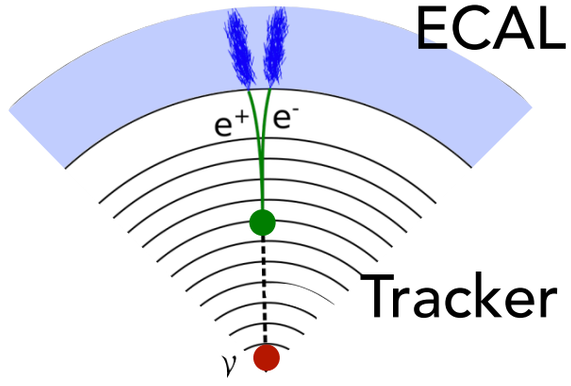
To avoid the photon picking up the track from one of the muons.

Electron veto efficiency

- The rejection of electron is important in the photon identification in CMS. There are two commonly used methods - **Conversion-safe** and **Pixel-seed electron veto**.

Conversion-safe veto:

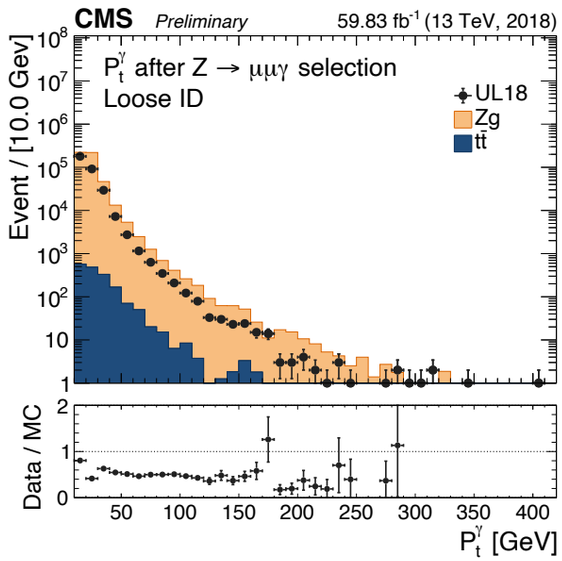
The photon candidate will be rejected when the **innermost hit** in the pixel detector is **NOT** matched to the **reconstructed conversion vertex.**

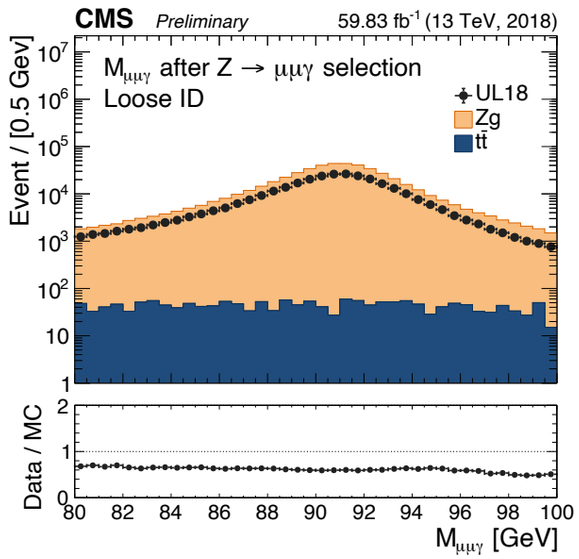


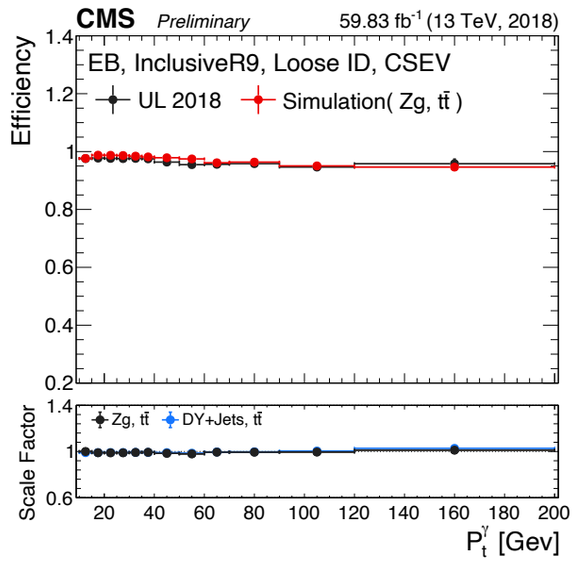
Pixel-seed veto:

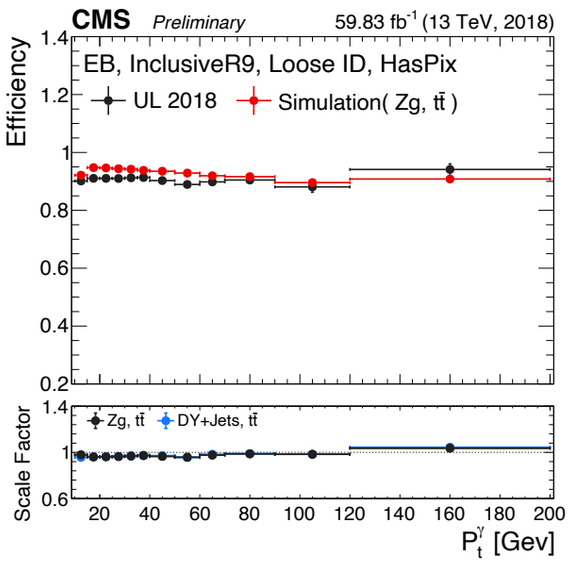
The photon candidate will be rejected when there are at least **TWO** hits in the pixel detector points to the ECAL cluster.

$$Eff = \frac{N_{Z\to\mu\mu\gamma + veto}}{N_{Z\to\mu\mu\gamma}}$$









Mu17Pho30 trigger efficiency

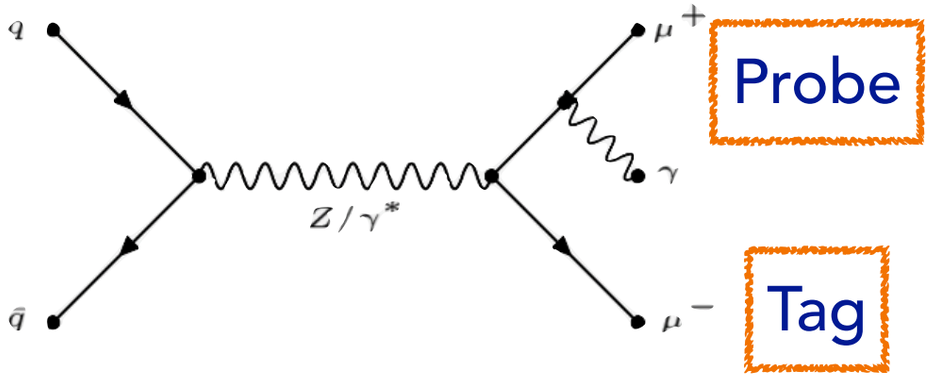
- The strategy of measuring the trigger efficiency is **the tag-and-probe method**.
- To see if the probe μ & γ_{FSR} can fire the corresponding μ & γ_{FSR} filters in the Mu17Pho30 trigger.

Tag μ:

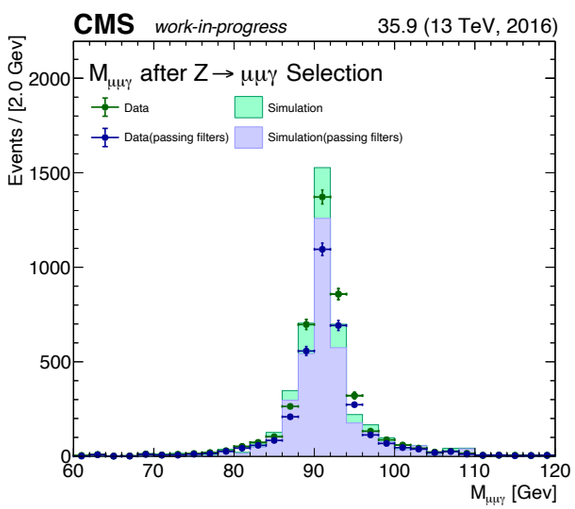
The muon passes tight cut-based ID and Isolation.

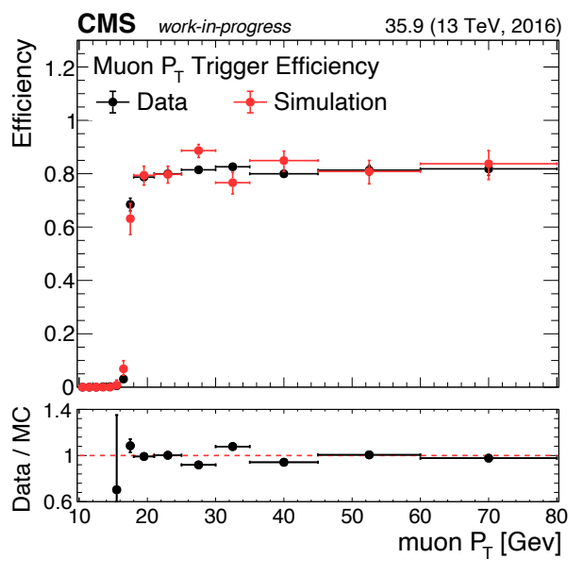
Probe μ & γ_{FSR}:

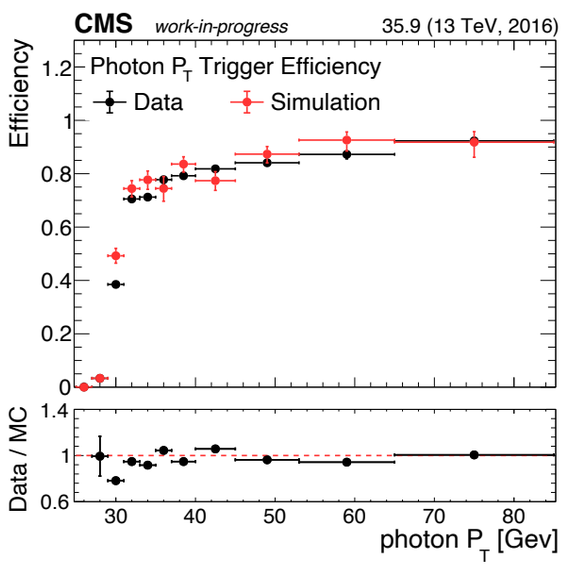
They are required to pass the **FSR selection** *(s3)* to ensure that they come from **$Z \rightarrow \mu\mu\gamma_{FSR}$**.



$$Eff = \frac{N_{Z\rightarrow\mu\mu\gamma + filters}}{N_{Z\rightarrow\mu\mu\gamma}}$$





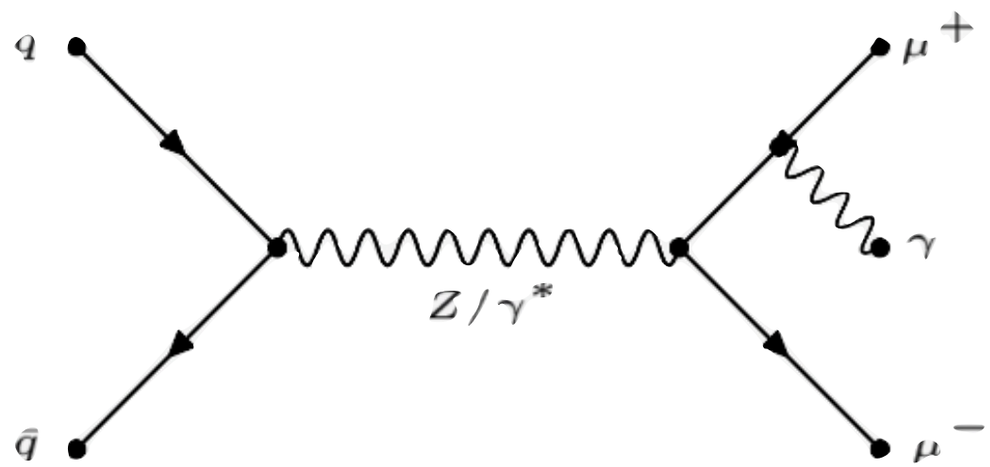


Summary

- Control samples with **FSR photons** enable us to perform efficiency measurements.

- This method has been widely used to measure the efficiencies of the different electron vetos and triggers involving photons

- This technique and results of electron veto were included in the CMS EGM-17-001 paper, which was submitted to JINST [arXiv:2012.06888].



Backup

CMS detector