H → Zγ updates

National Central University, Taiwan

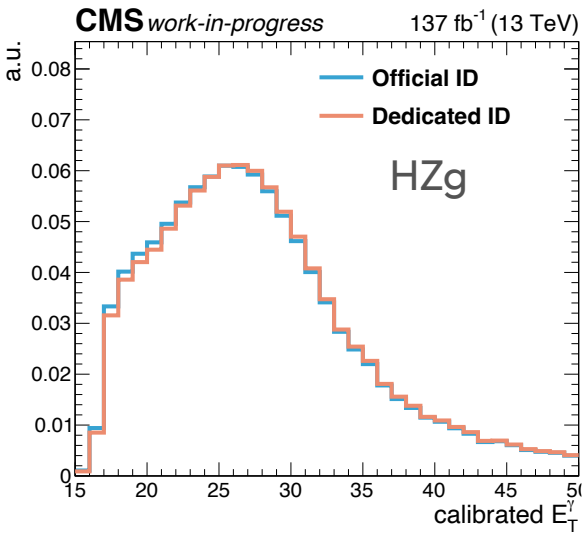
Yu-Hsuan Chou, Chia-Ming Kuo,
Prasant Kumar Rout, Debabrata Bhowmik

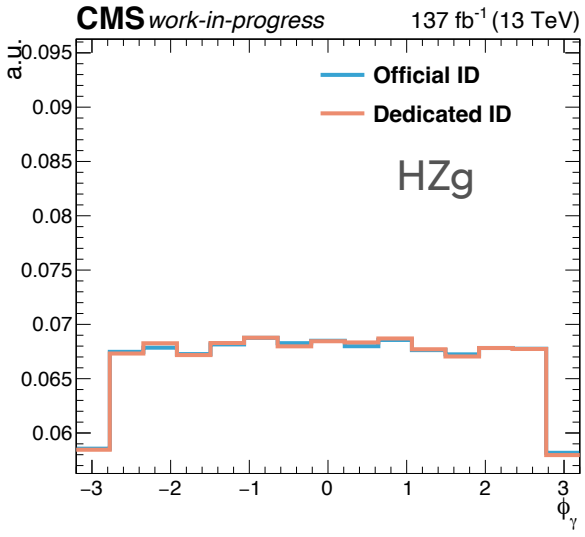
Status

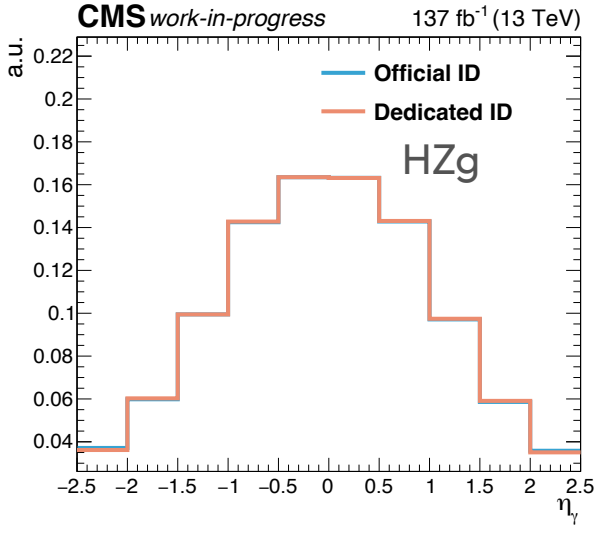
- Dedicated photon identification is implemented due to its strong discrimination between signal and background based on previous studies (by Yu-Sheng).
- MVAs are trained to separate the signal and background events by their kinematic differences.
  - $M_{ll\gamma}$ resolution is considered as the weight of signal samples in training.
  - The training is done by XGBoost in combined channel(e+μ).
  - The results with official/dedicated photon ID are compared.

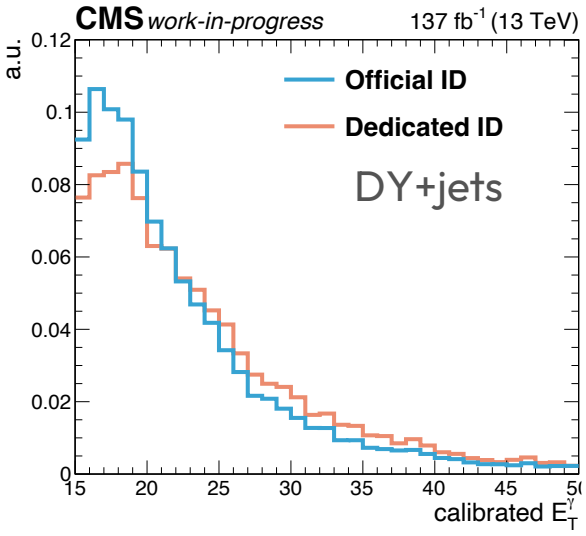
Photon kinematics

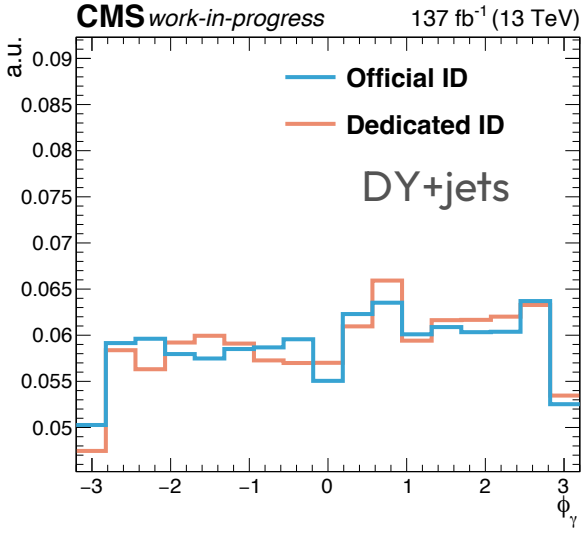
- More hard and forward photons are selected from dedicated ID.

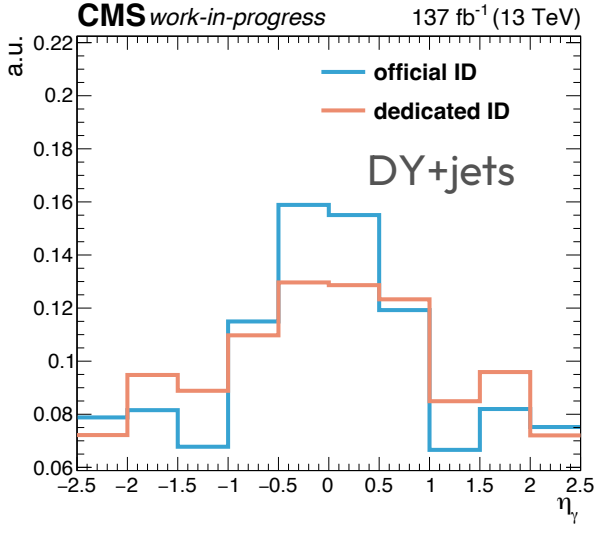






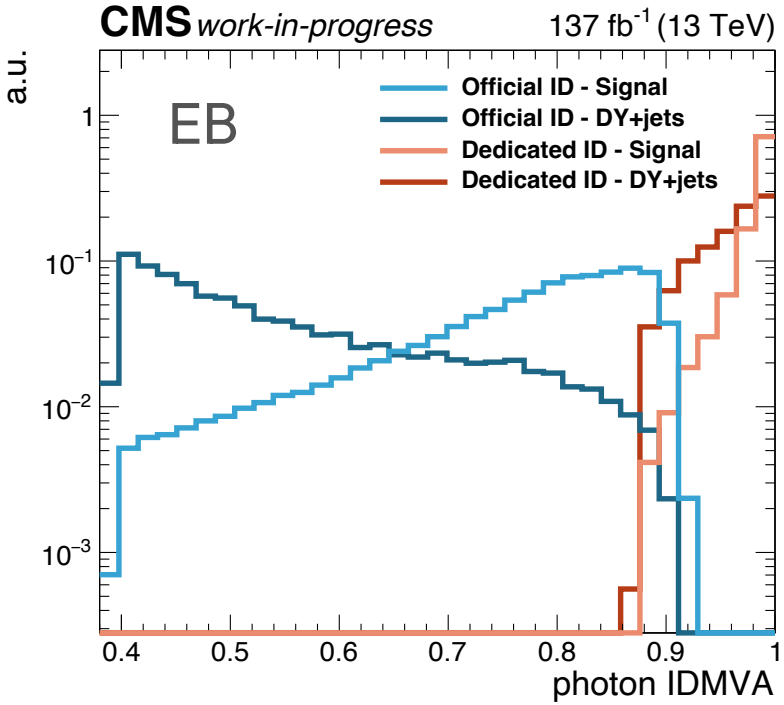


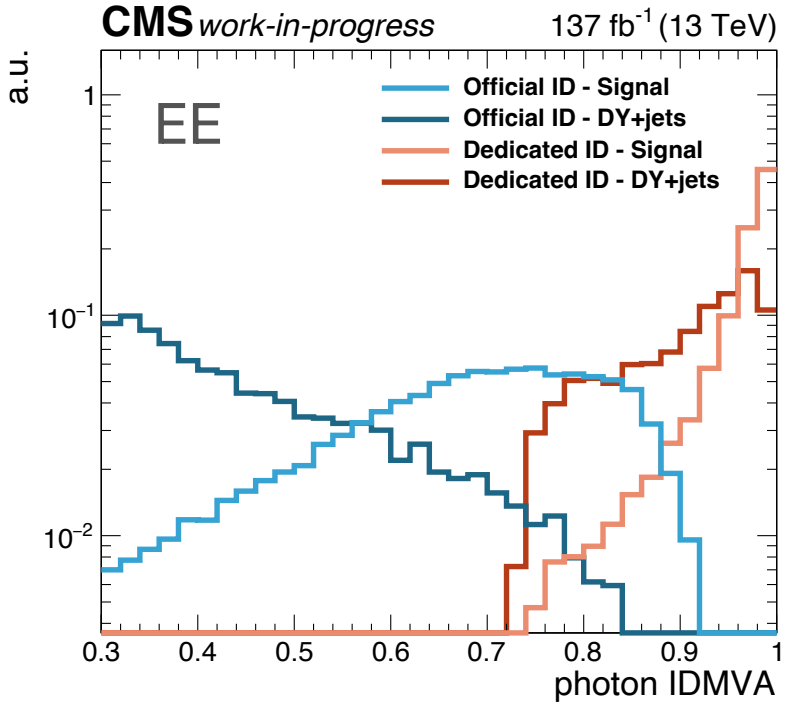




Photon ID comparison

- The signal and DY+jets distributions with official and dedicated photon ID are compared.





Kinematic MVA - setup

- Run-2 UL(Summer20) MC samples are used:
  - **signal samples**: ggF, VBF, WH, ZH, ttH
  - **background samples**: SM Zg, Z+jets
- The events are required to pass Run-2 event selection and $m_{ll\gamma}$ in 105-170 GeV.
  - The untagged events are excluded from the lepton-tagged and dijet-tagged events.

booster parameters

n_estimators
learning_rate
max_depth
min_child_weight
gamma
subsample

Training Features

Angle between the final state particles	Kinematics of final state particles	Photon related var Boosted Higgs
$\cos\theta$	η_{l1}	σ_γ/E_γ
ϕ	η_{l2}	photon ID MVA
$\cos\Theta$	η_γ	$p_T^{ll\gamma}/m_{ll\gamma}$
$\Delta R(l,\gamma)$		

Dijet MVA - setup

- Run-2 UL(Summer20) MC samples are used:
  - **signal samples**: VBF
  - **background samples**: SM Zg, Z+jets, ggF
- The events are required to pass Run-2 event selection and $m_{ll\gamma}$ in 105-170 GeV.
  - The events with additional dijet are used in this MVA study.

booster parameters

n_estimators
learning_rate
max_depth
min_child_weight
gamma
subsample

Training Features

Kinematic MVA variables

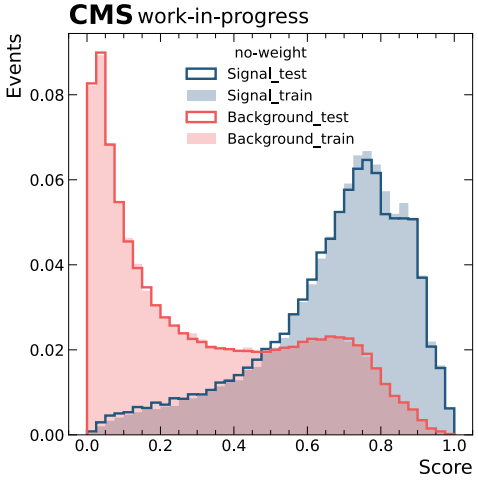
Dijet variables

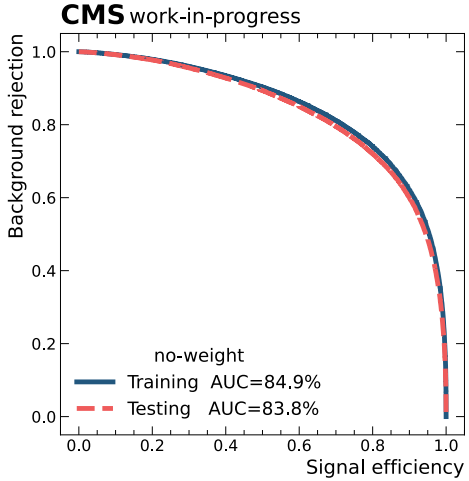
$p_T^{jet1/2}$	
$\|\Delta\phi(Z\gamma,jj)\|$	
min $\Delta R(\gamma,j)$	
$\|\Delta\eta(j,j)\|$	
$\|\Delta\phi(j,j)\|$	

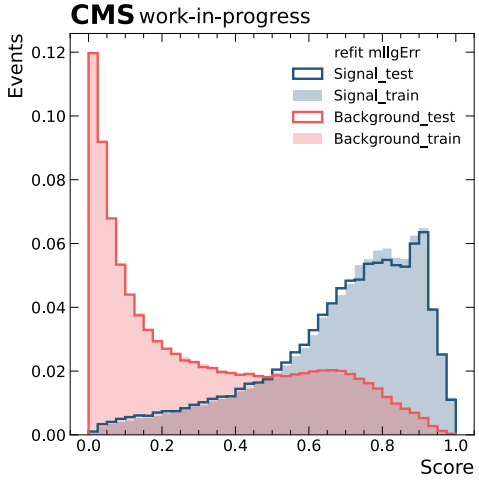
γ Zeppenfeld	$\|\eta_\gamma - (\eta_j^{(1)} + \eta_j^{(2)})/2\|$
System balance	$\|\sum_{Z,\gamma,j^{(1)},j^{(2)}} \vec{p_T} / \sum_{Z,\gamma,j^{(1)},j^{(2)}} p_T\|$
p_T^t	$\frac{(2\|p_T^Z(x)p_T^\gamma(y) - p_T^Z(y)p_T^\gamma(x)\|)}{p_T^H}$

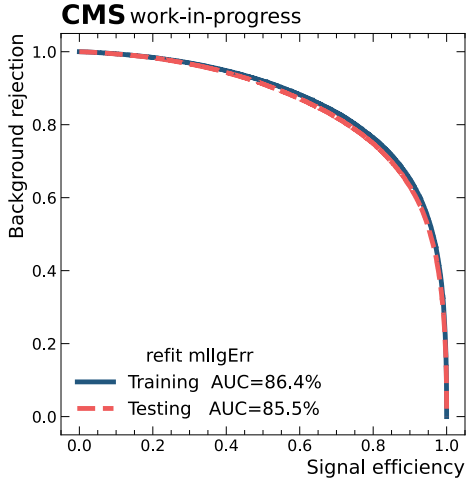
Kinematic MVA - BDT score & ROC curve

Official photon ID - with/without additional weight

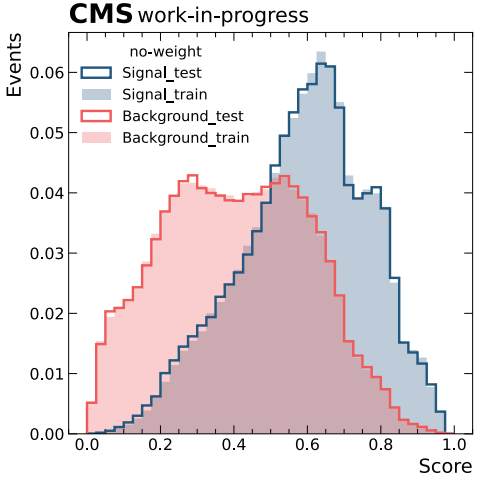


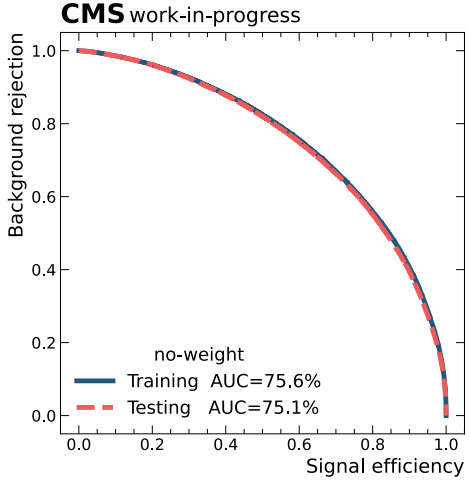


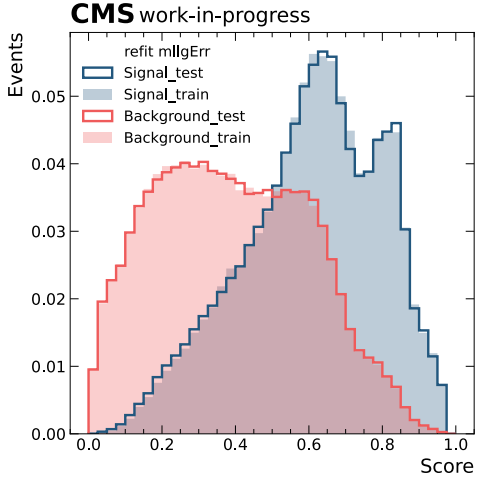


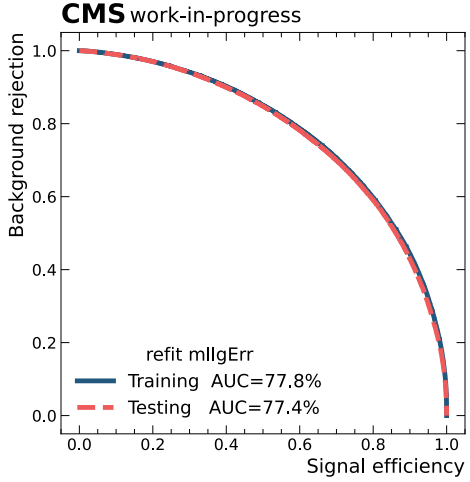


Dedicated photon ID - with/without additional weight



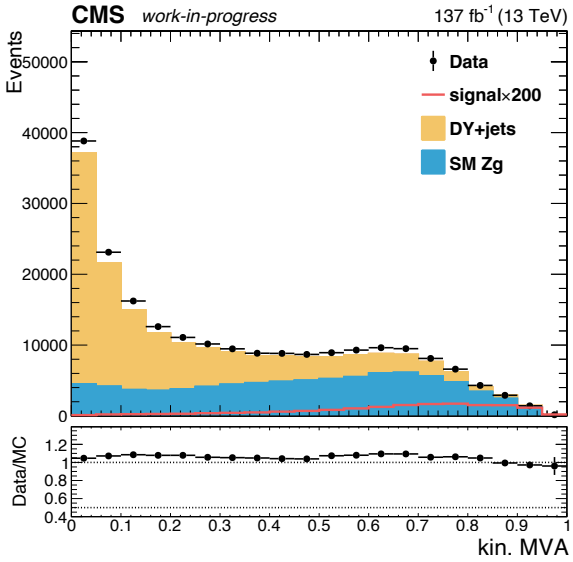


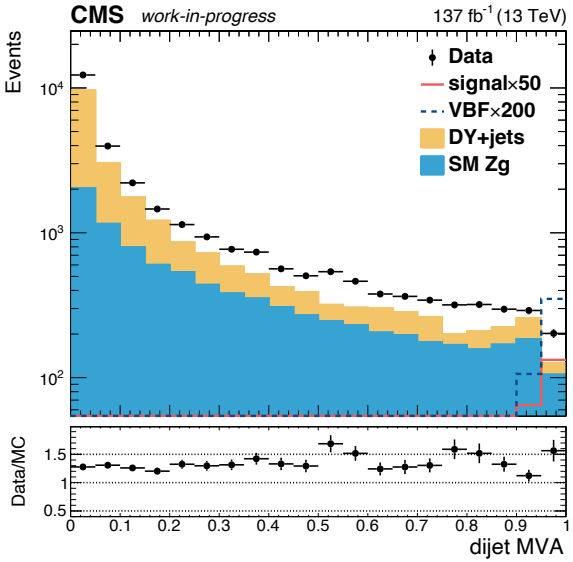




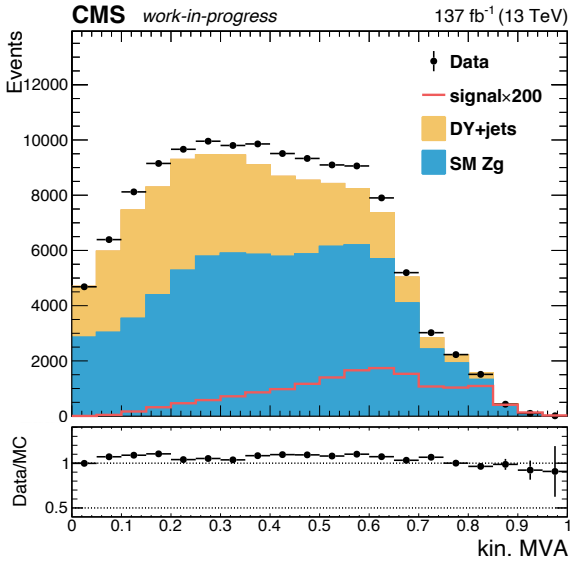
Kinematic/dijet MVA score

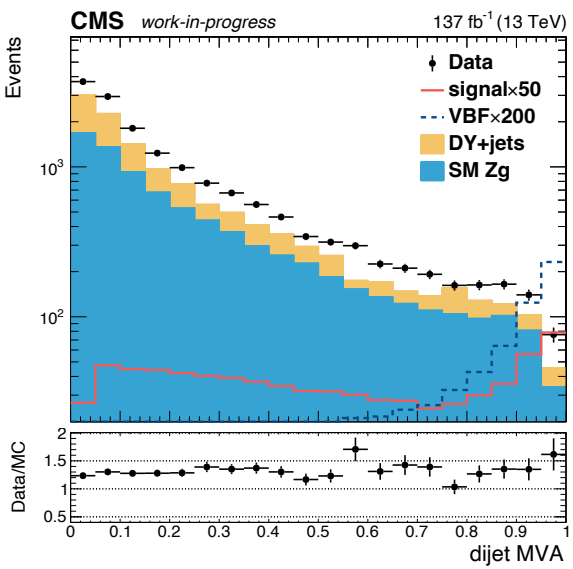
Results with official photon ID





Results with dedicated photon ID





Results

- The contribution from DY+jets process is significantly suppressed.
- After the categorization with kin./dijet MVAs, the combined signal and background ratio Z95 are increased in all categories.

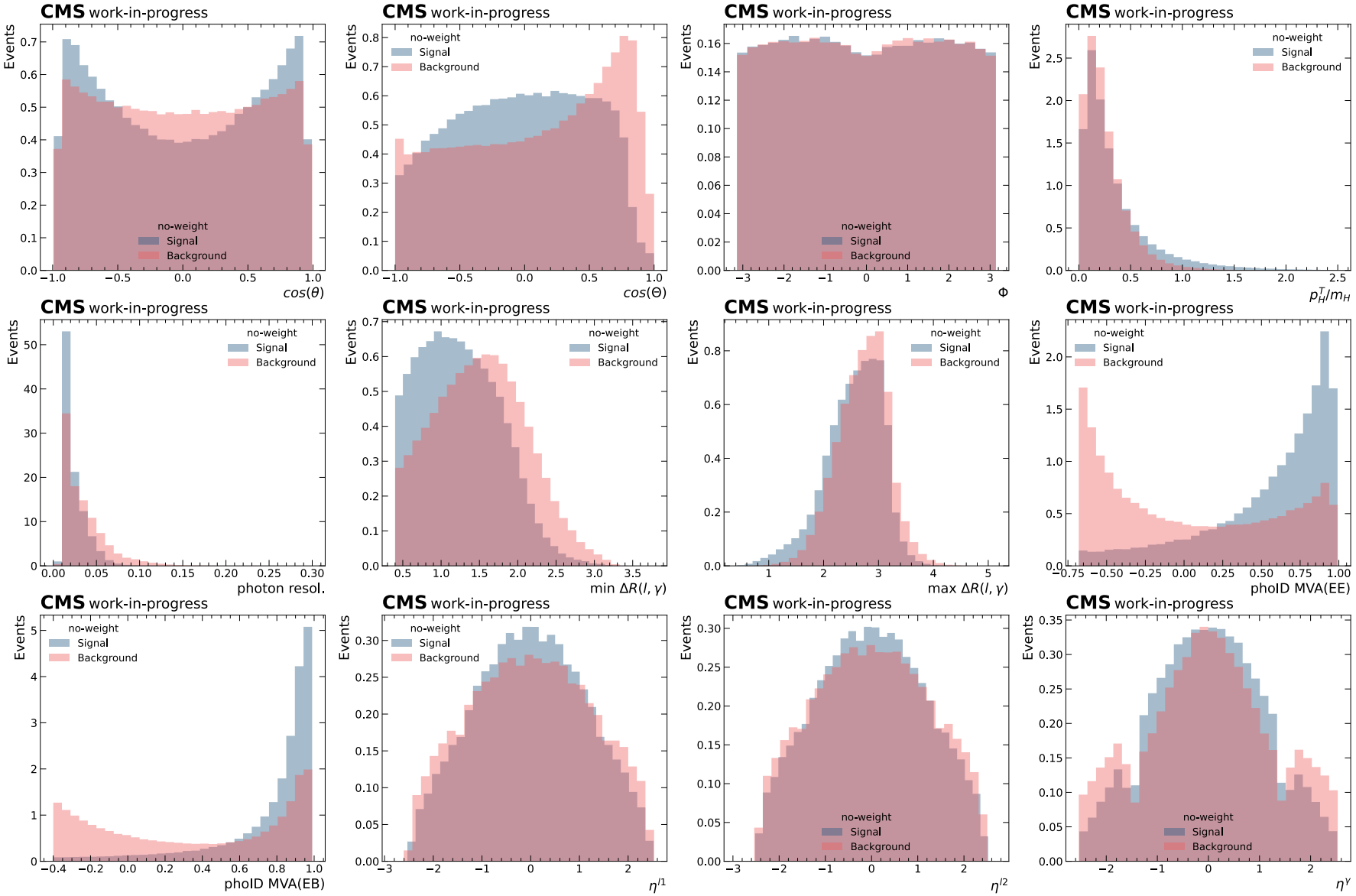
Yield		Lepton tag		Dijet tag		Untagged	
Signal (S_{95})		0.3	-7%	11.5	-5%	58.8	-5%
Background (B_{95})	DY+jets	32.2	-63%	453.4	-68%	5191.0	-66%
	SMZg	57.8	-14%	814.4	-11%	9692.6	-10%
$\sqrt{2((S+B)\ln(1+S/B)-S)}$ (Z_{95})		0.04	33%	0.24	63%	0.83	2%

Summary

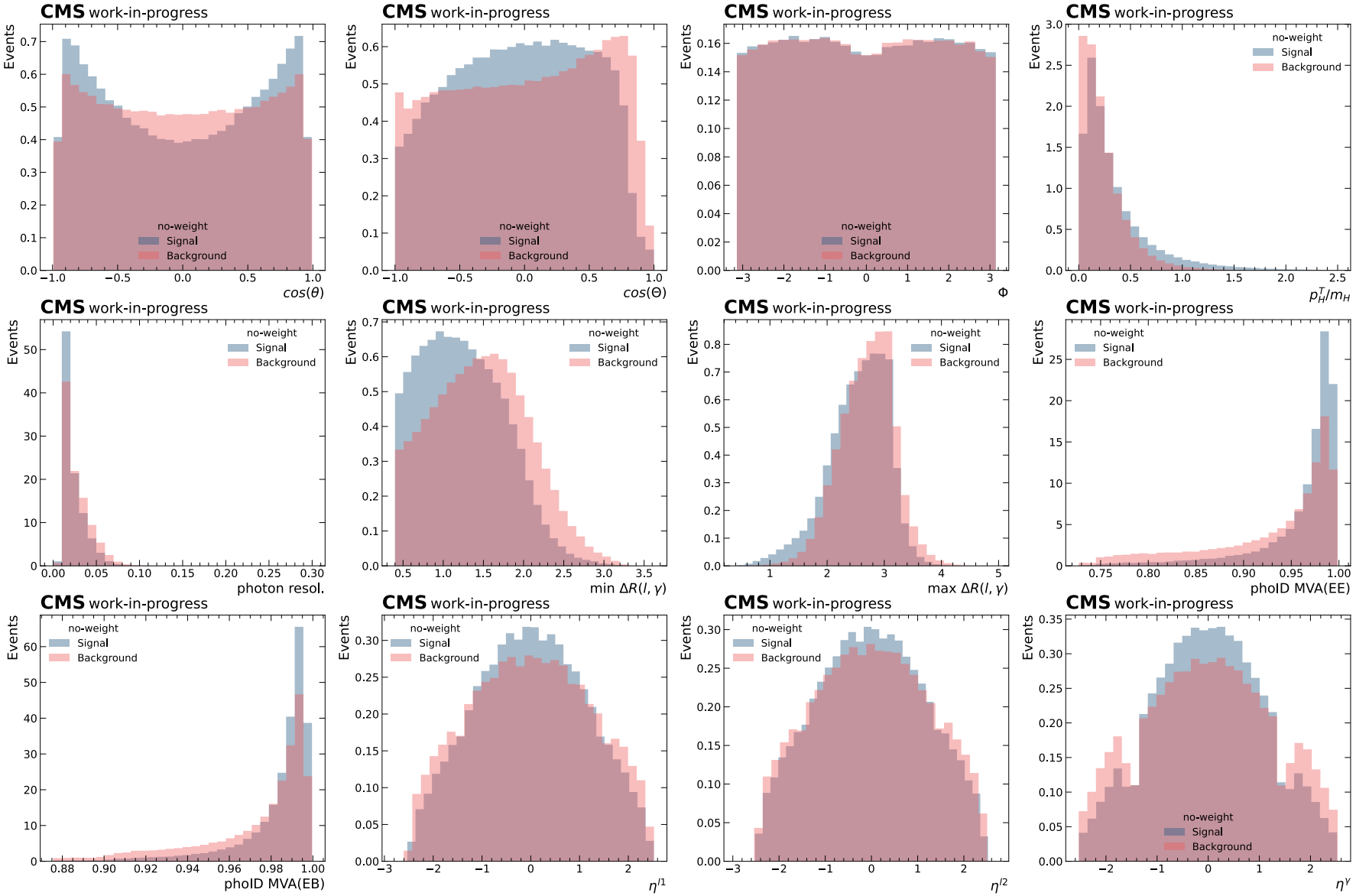
- Photon kinematics with 2 types of ID are shown.
- The kinematic and dijet MVA with the weight of mass resolution.
- The improvement after applying the dedicated photon ID and MVA studies is presented.

Backup

Features - Official ID



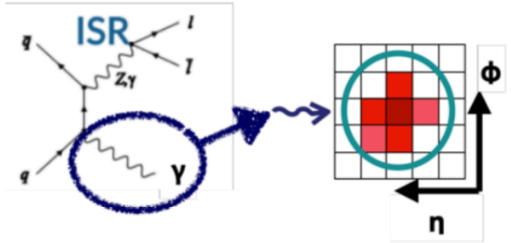
Features - dedicated ID



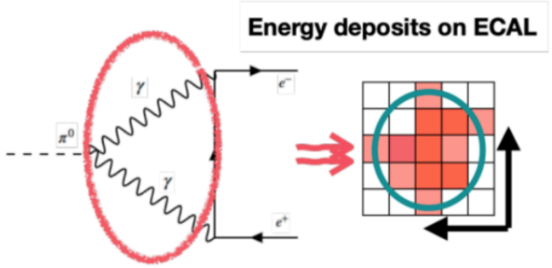
Dedicated photon MVA ID - overview

- A XGBoost binary classification was employed to classify the prompt photons and jet-fake photons.

  1. **Prompt photons (Signal)**: ISR photons (**H→Zγ**).



  2. **Jet-fake photons (Background)**: Photons from neutral meson or pile-up (**Z+Jets**).



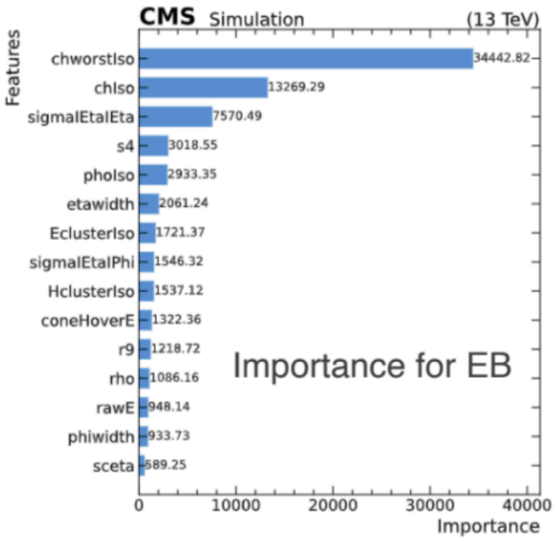
- Pre-selections:

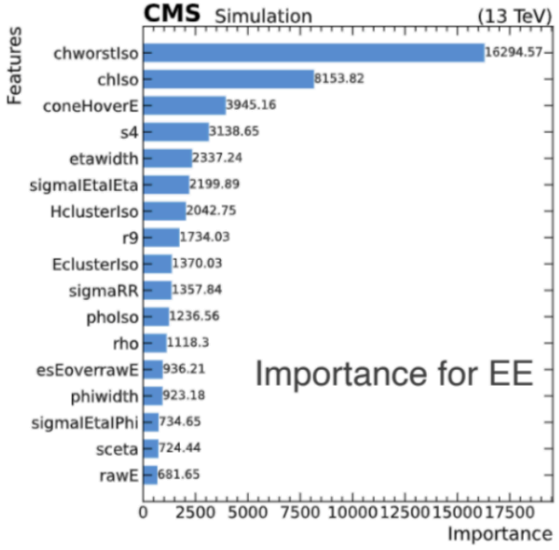
  1. Photon $p_T > 15$ GeV, exclude ECAL gap region.
  2. Conversion safe electron veto.
  3. **Δ**R(e or μ, **γ**) > 0.4.

Dedicated photon MVA ID - features

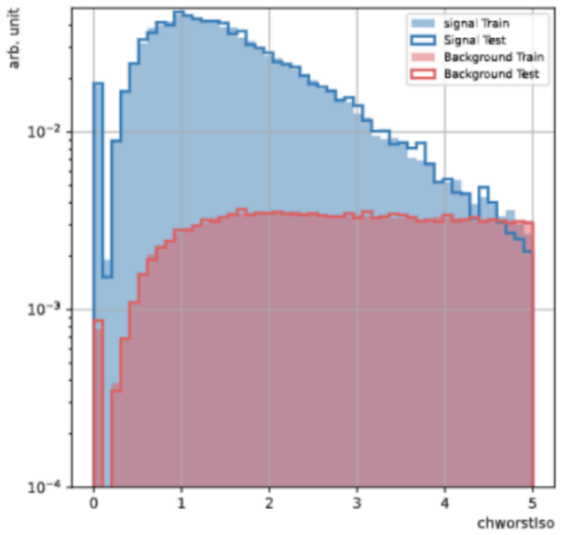
- Shower shape variables and isolation variables were applied in both dedicated photon MVA ID and official photon ID.
- New training features for dedicated ID: Iso_{ECAL}, Iso_{HCAL} and coned H/E.
- The most important feature is charge hadron isolation with worst vertex.

Importance: The contribution of a feature effecting the output MVA.





$Iso_{charge\ hadron,\ worst\ vertex}$



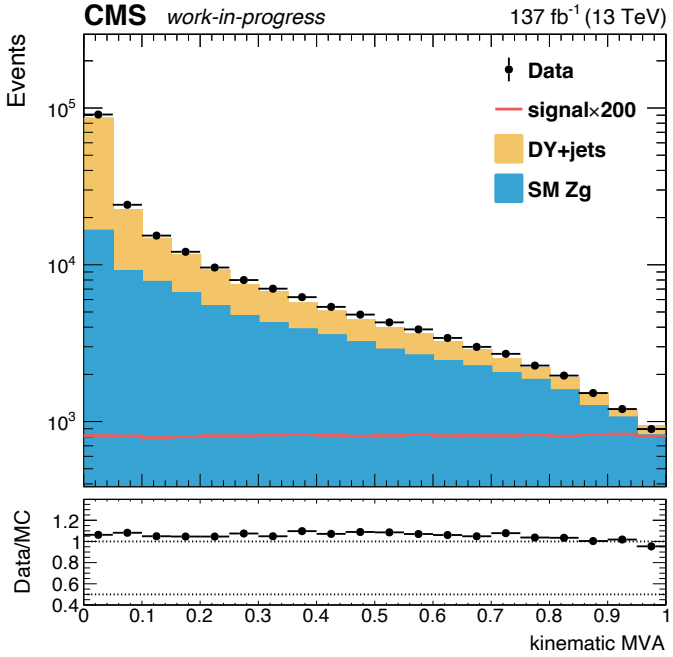
Blue: Signal

Red: Background

Transformed BDT score

- The transformed BDT distribution is used to do category optimization.
  - Calculate the S/√B values in the mass window 120-130 GeV to decide the category boundary.
  - Try to use Z_{95} and different mass window in optimization.

Official photon ID



Dedicated photon ID