

# FCNC $t \rightarrow q\gamma$ with FCC-hh

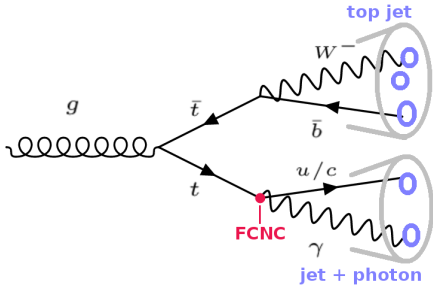
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Sensitivity of the experimental search of FCNC at FCC-hh collider is estimated for:



- FCNC in  $tq\gamma$  vertex
- boosted  $t\bar{t}$  production with  $t \rightarrow \gamma q$  decay where  $q$  is  $u$  or  $c$  quarks
- Final-state signature with top-jet and light-jet with photon

### Motivation:

- Top decays through FCNC is a hot topic for BSM searches at LHC and for HL-LHC projections. Top decays through FCNC are enhanced in many BSM but are strongly suppressed in SM  $\Rightarrow$  observation of any excess would indicate new physics.
- Study of the boosted top and boosted photon + light quark jets substructure

## Signal:

- MadGraph5\_aMC@NLO v.2.5.5,  
 $p_T(t) > 1000$  GeV
- $t \rightarrow \gamma u$ ,  $\bar{t} \rightarrow \gamma c$
- No pileup assumed

## Event selection:

- Exactly one photon with  $|\eta| < 3$ ,  $p_T > 200$  GeV
- Exactly one b-tagged jet with cone  $R = 0.4$ ,  $|\eta| < 3$ ,  $p_T > 30$  GeV
- At least one light jet with cone  $R = 0.4$ ,  $|\eta| < 3$ ,  $p_T > 30$  GeV
- At least two fatjets with cone  $R = 0.8$ ,  $|\eta| < 3$ ,  $p_T > 30$  GeV
- One or zero leptons ( $e$  or  $\mu$ ) with  $|\eta| < 3$ ,  $p_T > 25$  GeV
- $\Delta R(\gamma, b\text{-jet}) > 0.8$

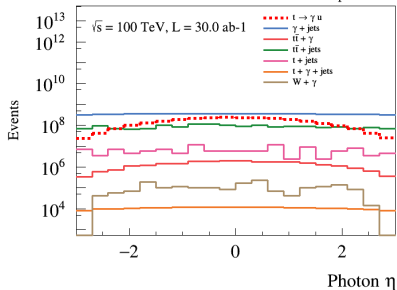
## Selection efficiency:

- $\sim 0.33$  for signal
- $< 0.01$  for most of the backgrounds

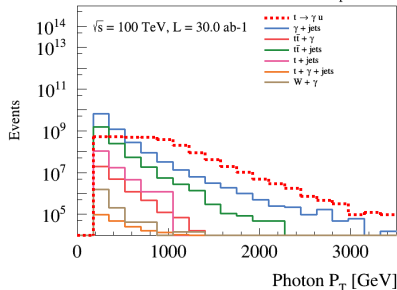
## Backgrounds:

- $t\bar{t}$ ,  $t\bar{t} + jets$ ,  $t\bar{t} + \gamma$
- $t + jets$ ,  $t + \gamma$
- $Z + jets$ ,  $W + jets$ ,  $W + \gamma$
- $\gamma + jets$

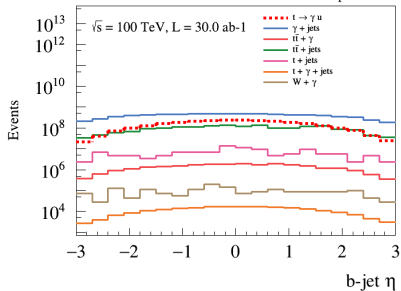
RECO: Delphes-3.4.2



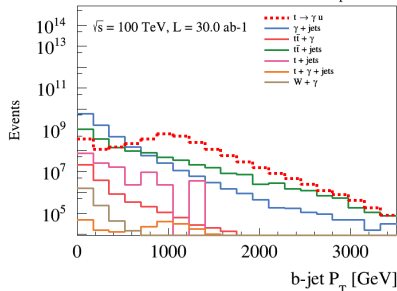
RECO: Delphes-3.4.2

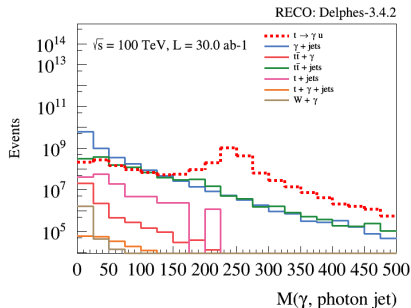
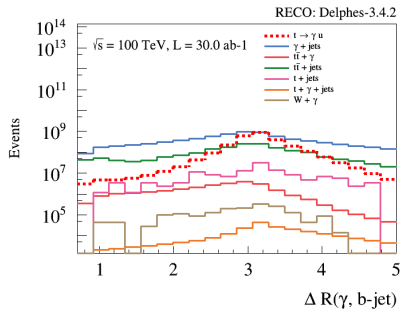
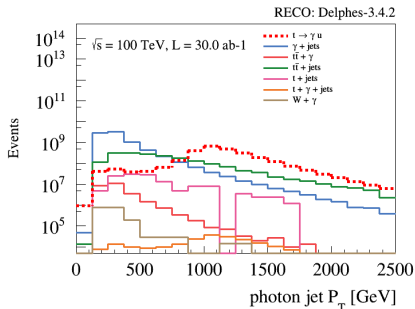


RECO: Delphes-3.4.2



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↑ We will apply a following cut for TMVA analyses: the  $p_T$  of the jet closest to the photon  $> 400 \text{ GeV}$   
 Mass of the photon + nearest jet might be corrected  $\Rightarrow$

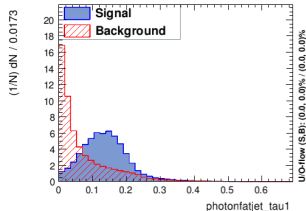
**Analysis** could be divided into three parts:

- Boosted photon + light quark FCNC jet tagging, information from:
  - ① photon
  - ② the jet and fatjet closest to the photon
- Top jet tagging, information from:
  - ① b-tagged jet
  - ② fatjet closest to b-tagged jet
  - ③ lepton
  - ④ MET
- Selections based on photon and top-jet kinematics correlations, information from:
  - ① photon
  - ② the jet and fatjet closest to the photon
  - ③ b-tagged jet and fatjet closest to b-tagged jet

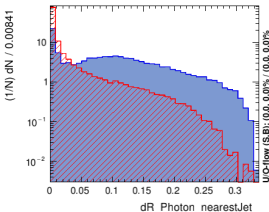
At the final step we will combine all results in order to separate signal from background.

# Boosted photon + light quark FCNC jet tagging, some variables:

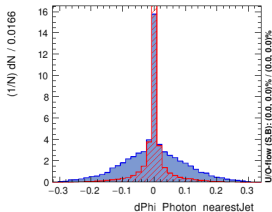
Input variable: photonfatjet\_tau1



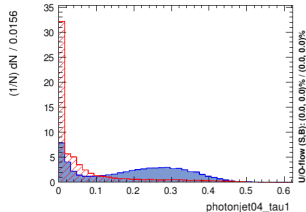
Input variable: dR\_Photon\_nearestJet



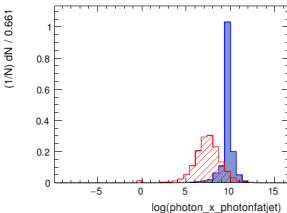
Input variable: dPhi\_Photon\_nearestJet



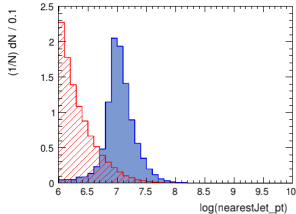
Input variable: photonjet04\_tau1



Input variable: log(photon\_x\_photonfatjet)

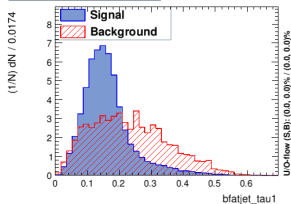


Input variable: log(nearestJet\_pt)

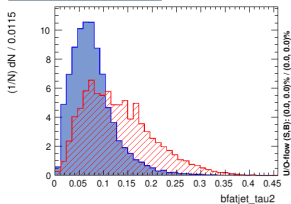


# Top jet tagging, some variables:

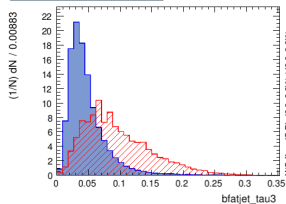
Input variable: bfatjet\_tau1



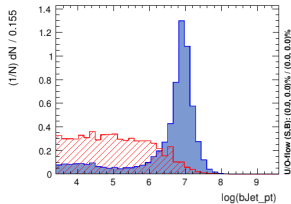
Input variable: bfatjet\_tau2



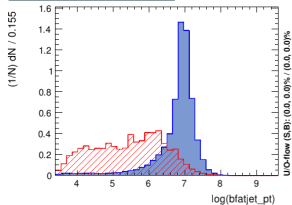
Input variable: bfatjet\_tau3



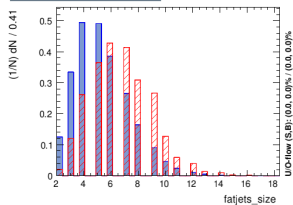
Input variable: log(bJet\_pt)



Input variable: log(bfatjet\_pt)

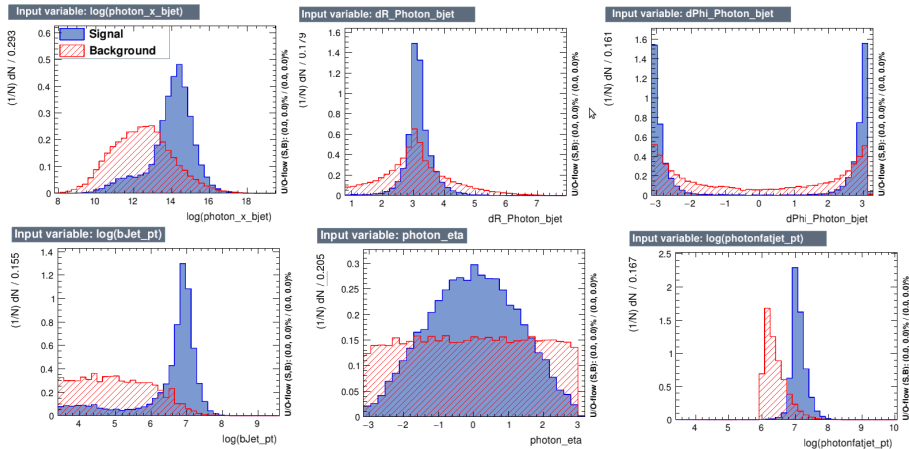


Input variable: fatjets\_size

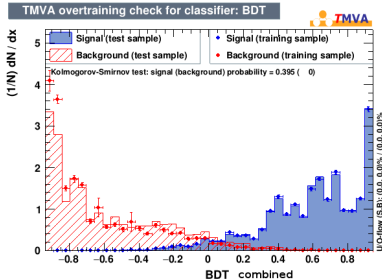
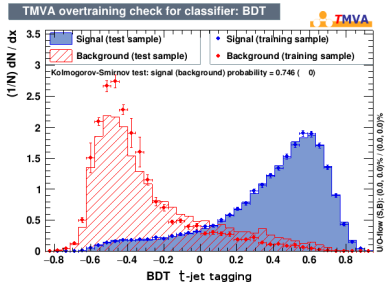
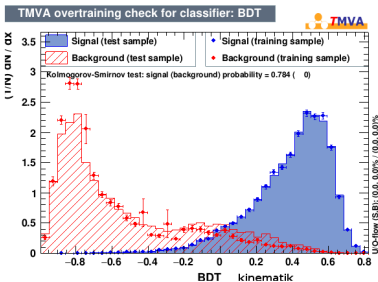
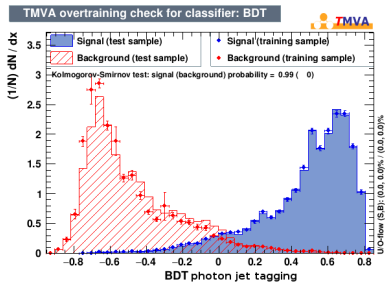




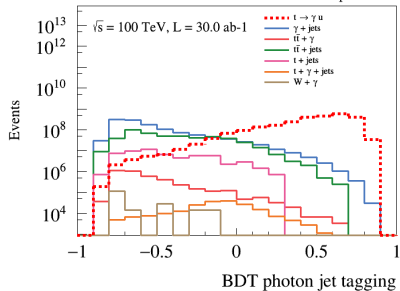
# Selections based on FCNC-jet and top-jet kinematics correlations, some variables:



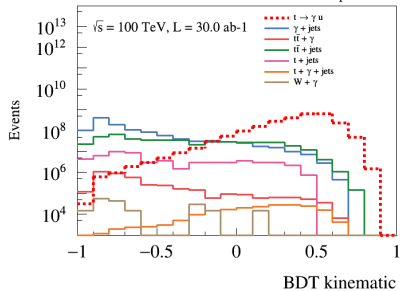
For every part a BDT classifier was trained and one additional BDT for combination:



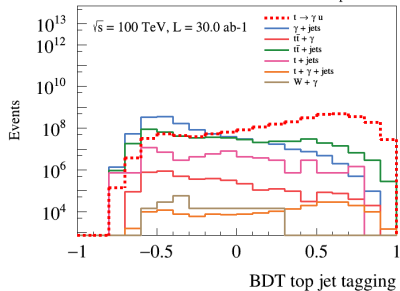
RECO: Delphes-3.4.2



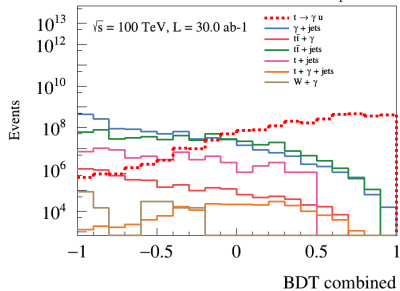
RECO: Delphes-3.4.2



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RECO: Delphes-3.4.2



# Limits

- 50% uncertainty assumed on the Backgrounds normalizations
- Expected limits on signal normalisation extracted from the Asimov dataset of background-only model using Bayesian inference:

BDT	95% CL Upper Limit
b-jet tagging	$32.905 \cdot 10^{-6}$
kinematics	$16.315 \cdot 10^{-6}$
photon jet tagging	$10.615 \cdot 10^{-6}$
combined	$1.565 \cdot 10^{-6}$

- $Br(t \rightarrow q\gamma) = 0.428 \cdot \lambda^2$  [1]  $\Rightarrow$   
 $Br(t \rightarrow q\gamma) = 0.428 \cdot \frac{\sigma_{exp}}{\sigma_{MG}} \cdot \lambda_{MG}^2$  - **should clarify the number!**
- $Br(t \rightarrow u\gamma) < 0.67 \cdot 10^{-8}$  for  $\lambda_{MG} = 0.1$  and combined BDT
- **SM**  $Br(t \rightarrow u\gamma) < 10^{-15}$
- **8 TeV**  $Br(t \rightarrow u\gamma) < 1.3 \cdot 10^{-4}$  [2]
- **HL-LHC**  $Br(t \rightarrow u\gamma) < 1.16 \cdot 10^{-5}$  [3]

[1] Acta Phys. Polon. B35 (2004) 2695–2710, [hep-ph/0409342]

[2] JHEP 02 (2017) 028

[3] CMS-TDR-17-007

# Conclusion

Workflow from the gridpack generation and events selection up to the settings of the limits is established.

## Future plans:

- Study additional CaloJet, TrackJets, SoftDrop (something else?) information for the top-jet and photon jet tagging
- Add second signal channel  $t \rightarrow c\gamma$  - Delphes events was generated
- Add missing backgrounds ( $W + jets$  was important in Run I analysis - the events already exist, Delphes events are currently generated)
- Increase statistics of some backgrounds ( $t + jets$ )