Update on FCNC $t \to q\gamma$

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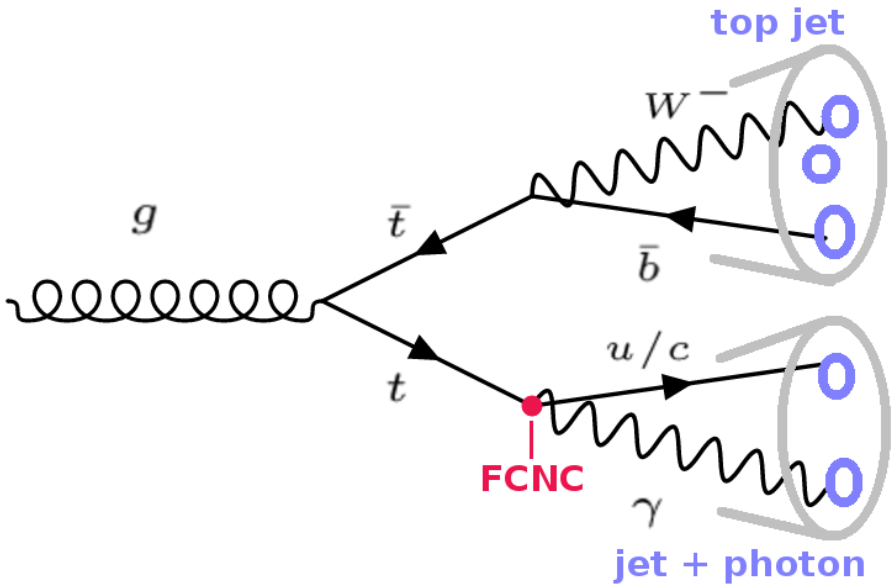
Sensitivity of the experimental search of FCNC at FCC-hh collider is estimated for:



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

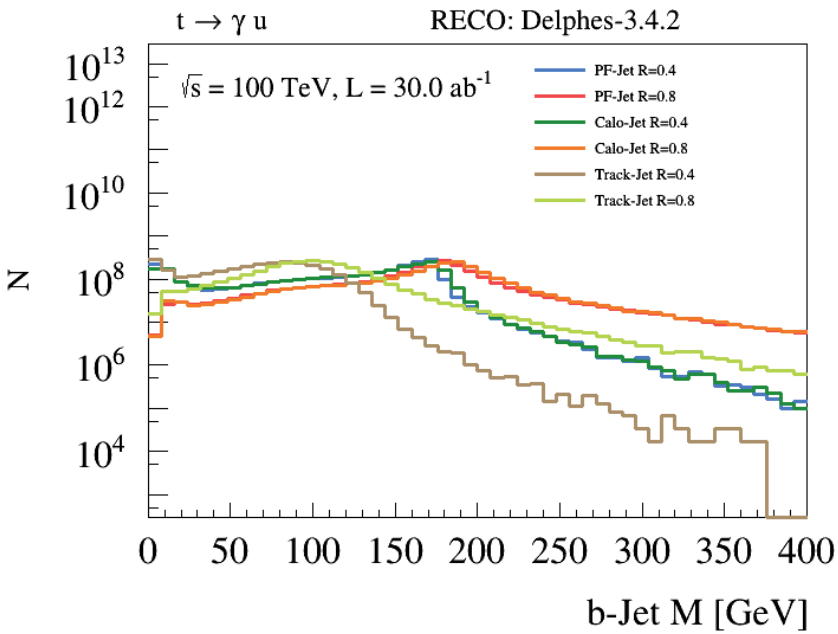
Signal:

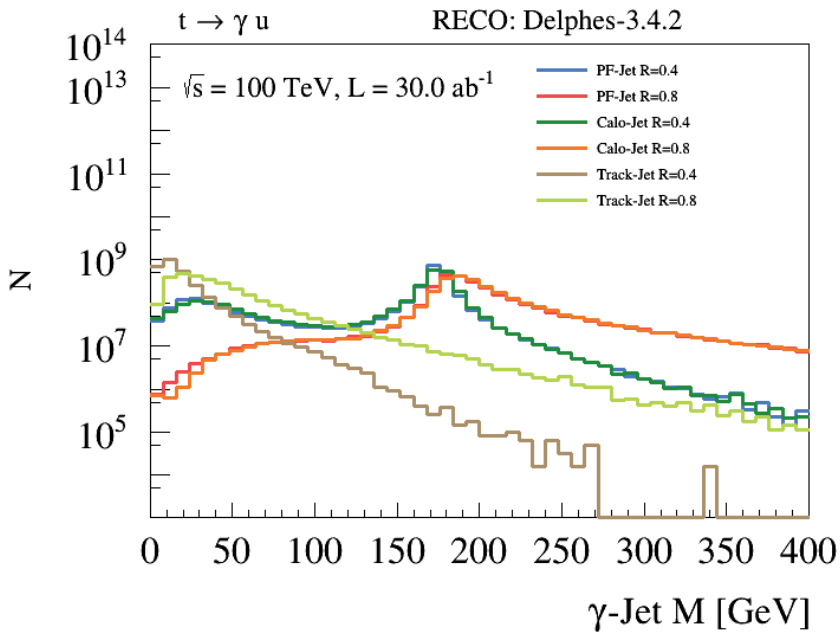
- MadGraph5_aMC@NLO v.2.5.5, $p_T(\bar{t}) > 1000$ GeV
- $t \to \gamma u$, $t \to \gamma c$
- No pileup assumed

Backgrounds:

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

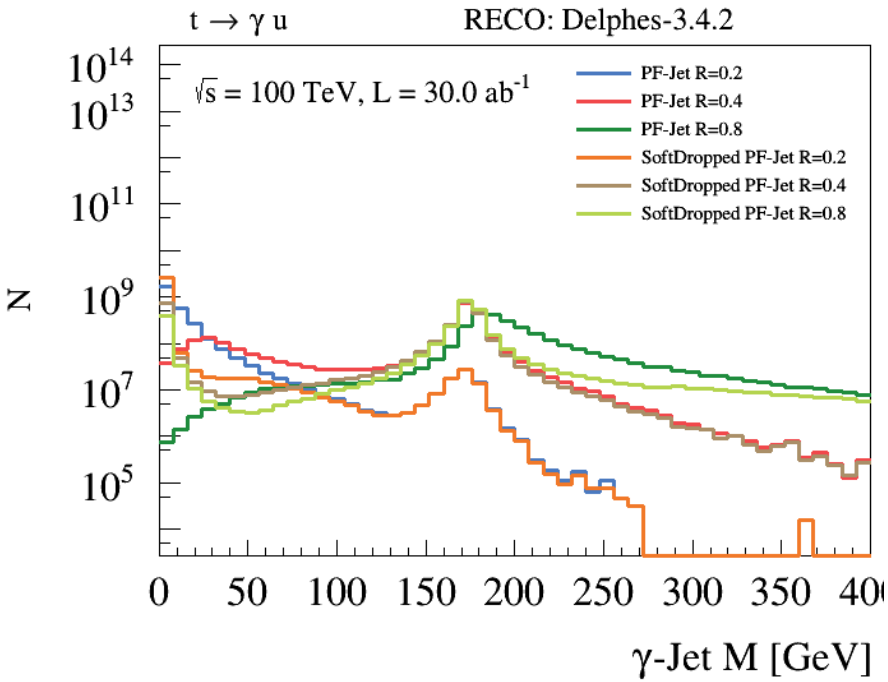
Jet Type



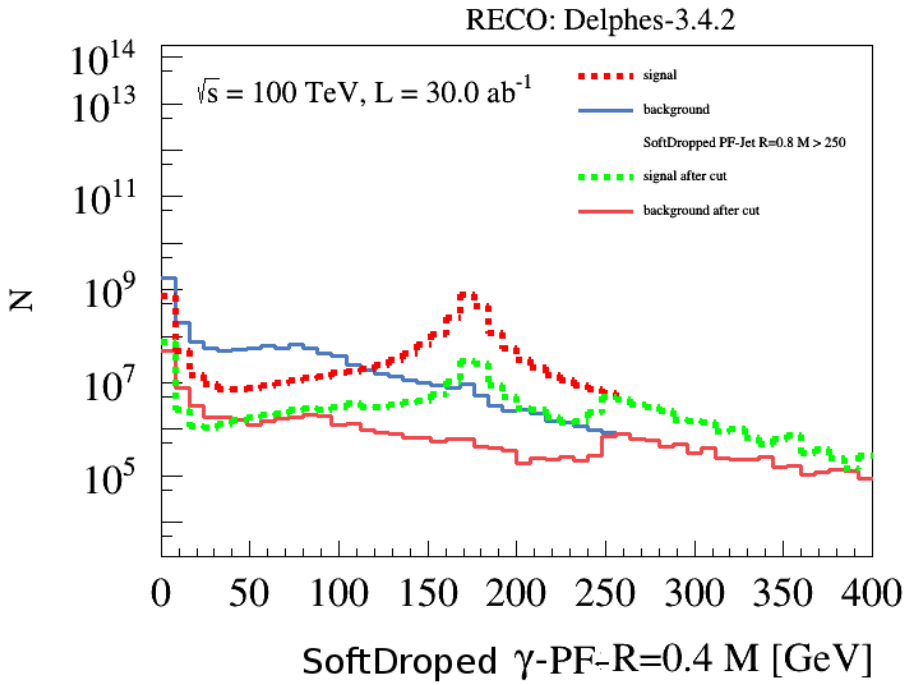


⇒ While Track jets do not look suitable for our analyse the PF and Calo jets show a quite similare perfomance. We will use PF jets to estabilishe the workflow.

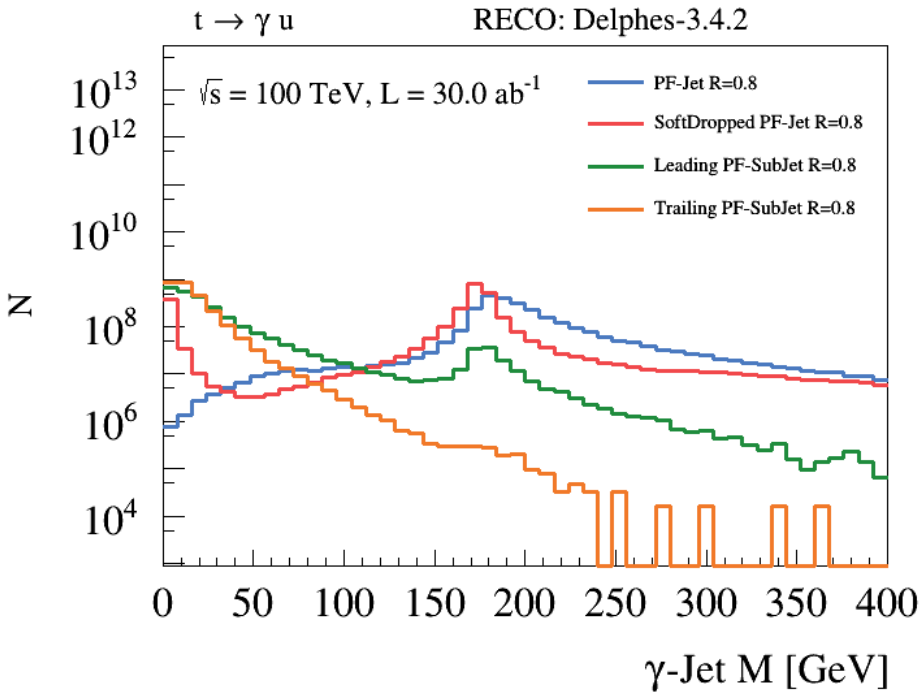
SoftDrop



$\Longleftarrow$ mass of jet closest to the photon before and after softdrop

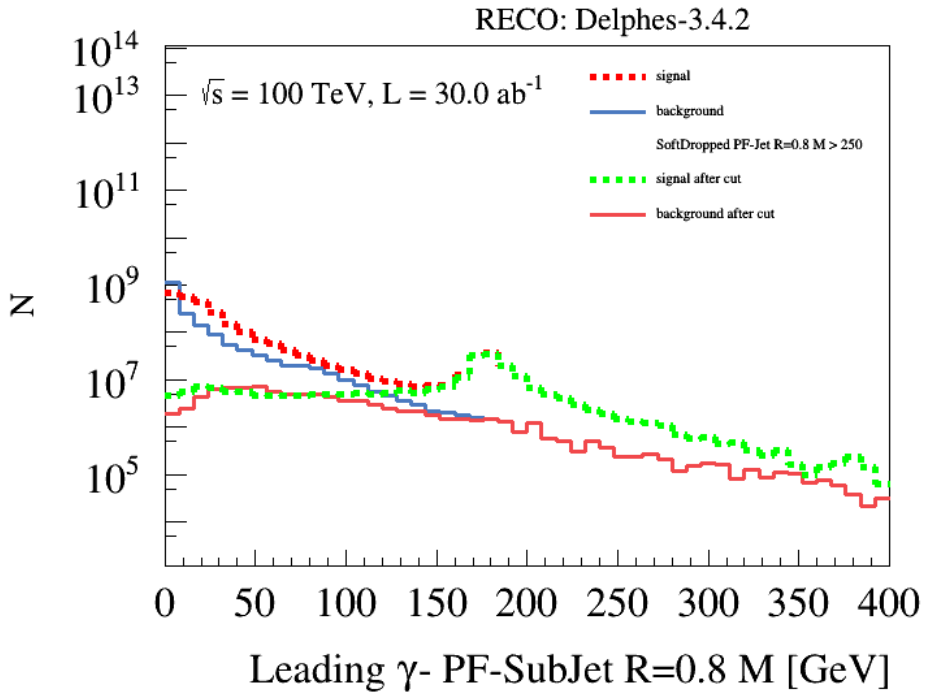


mass of the softdroped PF-jet ($R = 0.4$) after cut on $M > 250$ GeV of the PF-jet ($R = 0.8$) $\Longrightarrow$ **may use information from different collections**

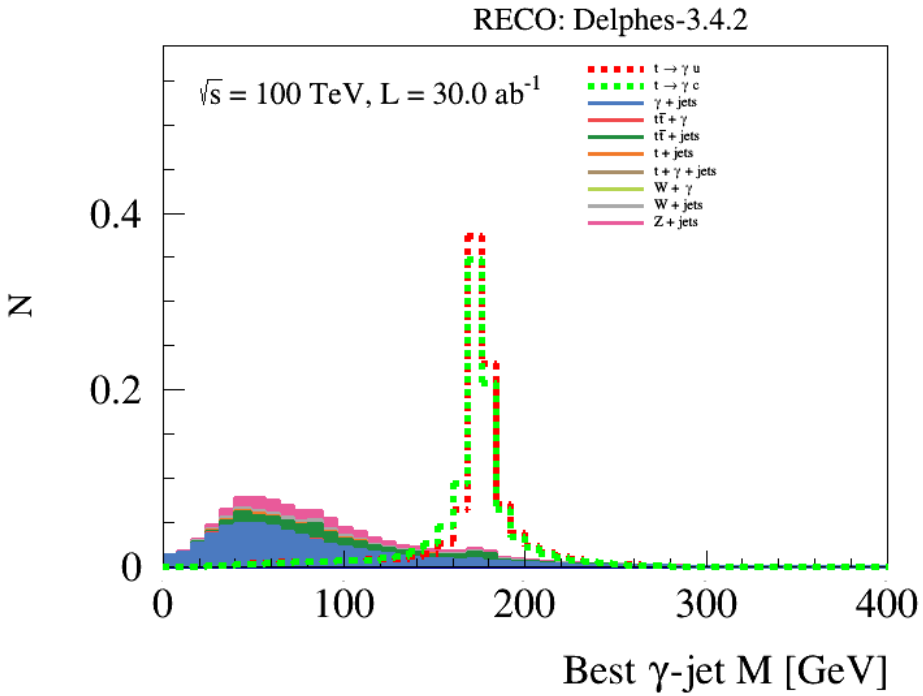


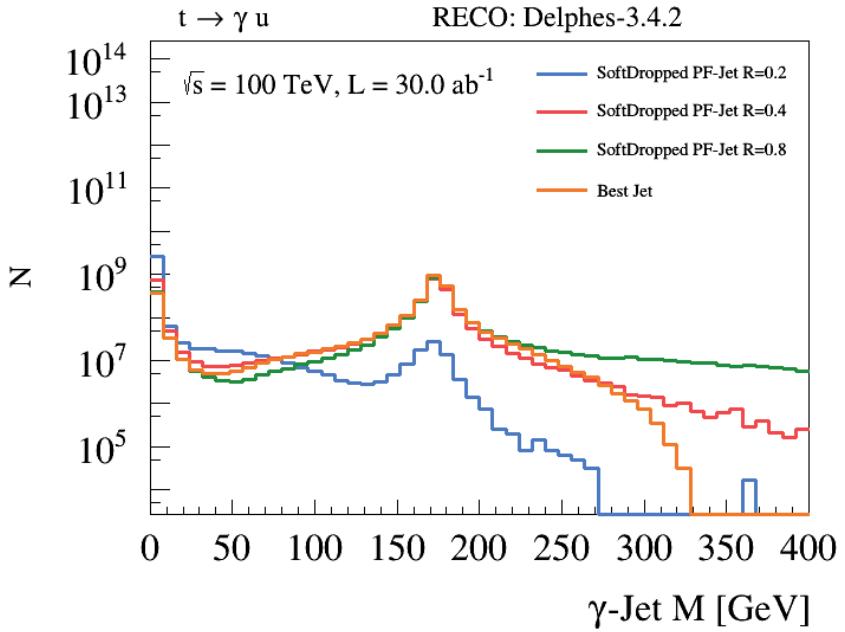
$\Longleftarrow$ mass of the leading and trailing subjets in comparison with jet mass

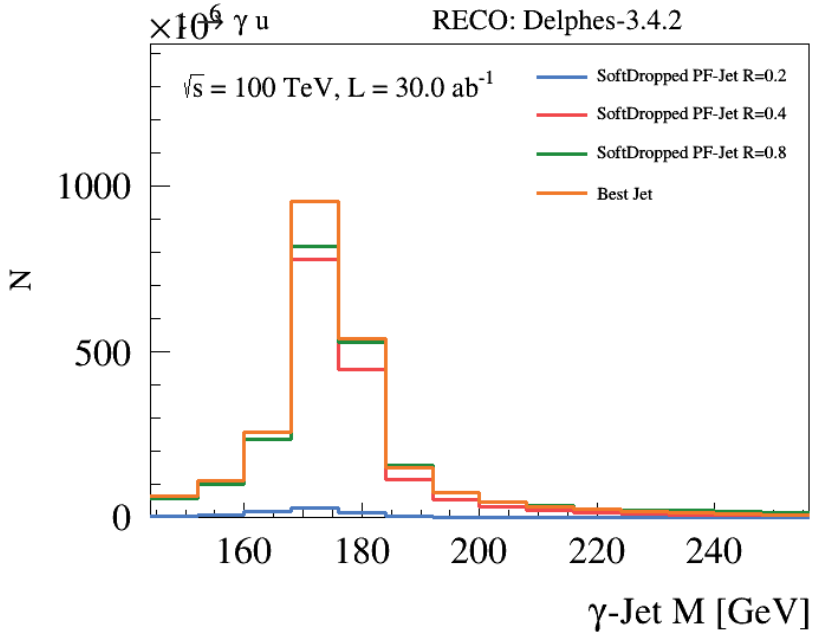
mass of the leading subjets after cut on $M > 250$ GeV of the jet $\Longrightarrow$ **information from subjets could be usefull too**



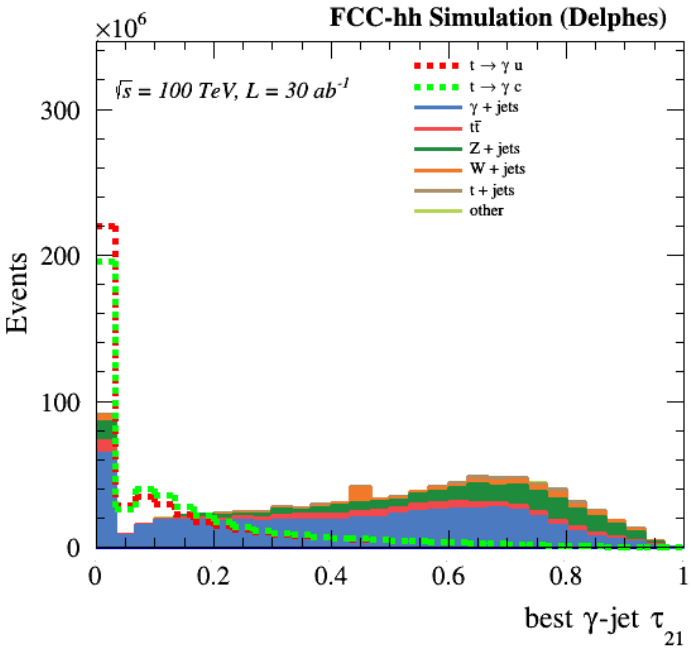
We will use the information from the jet with better fitted mass from all avilable collections:

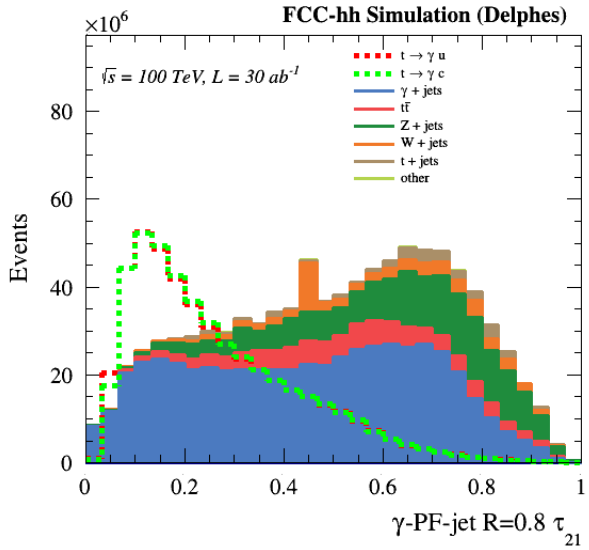






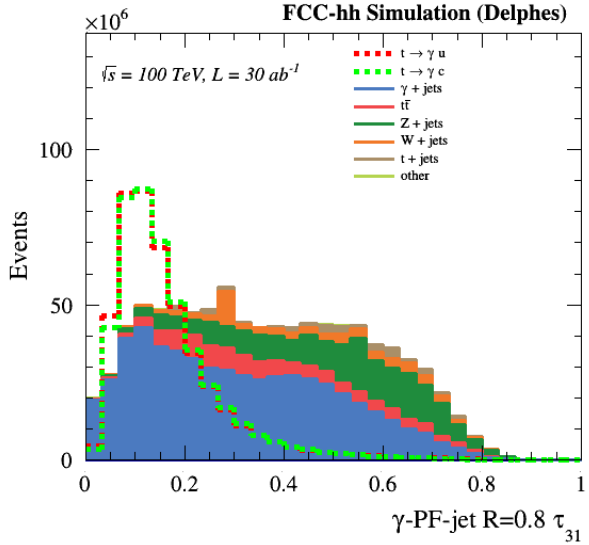
TMVA Input Variables

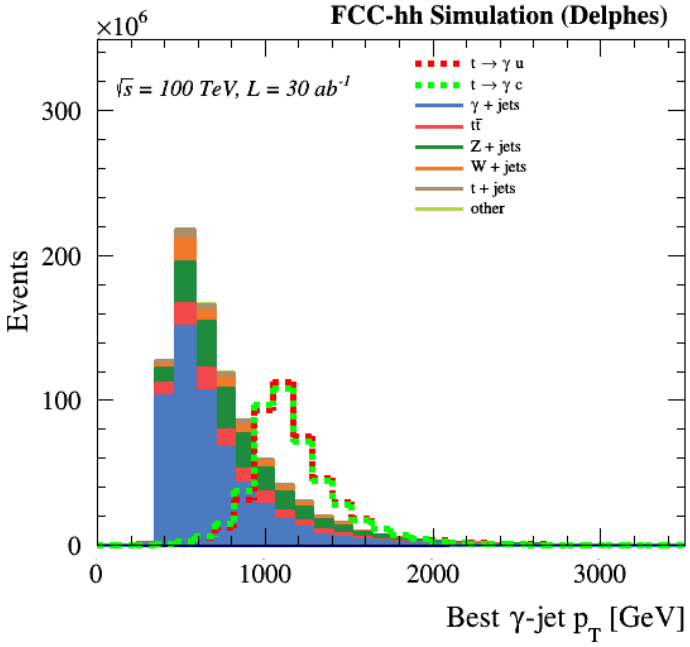


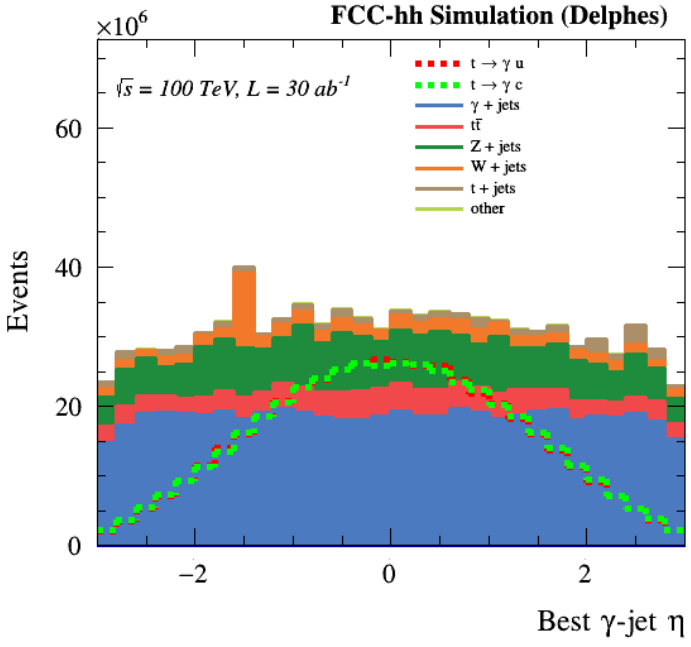


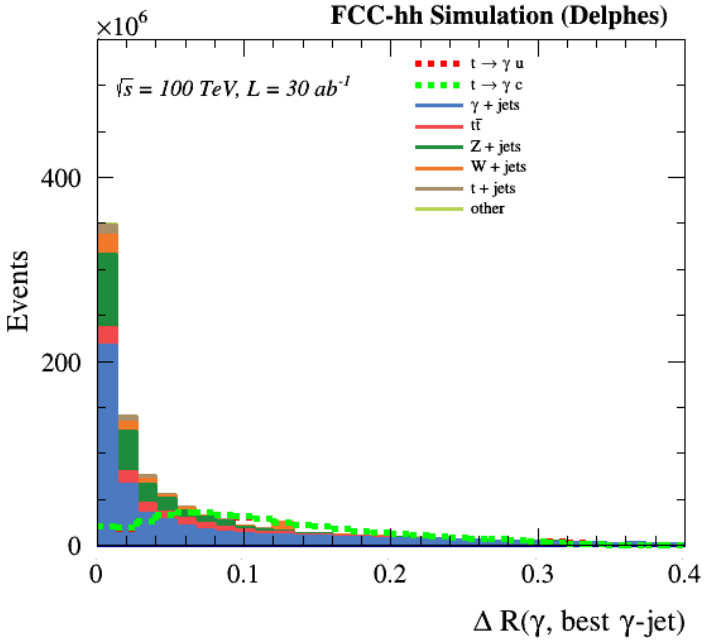
⇑ a lot of jets (softdroped, subjets) do not have τ_1

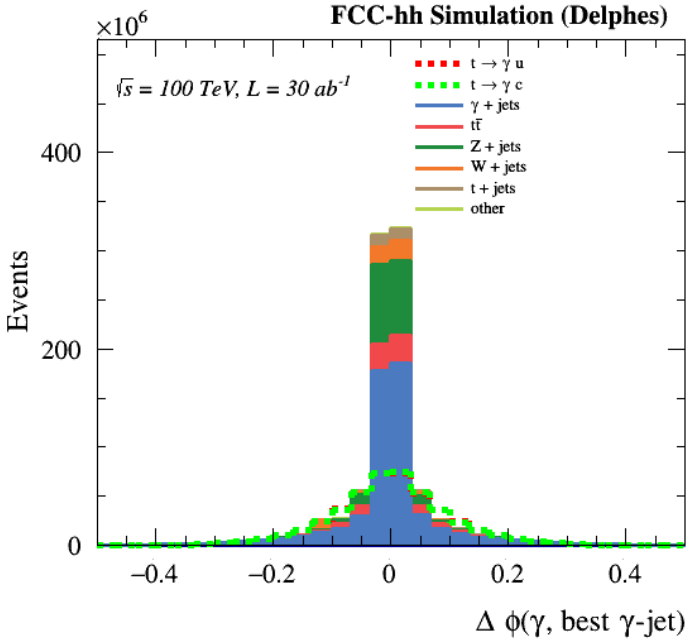
τ_{31} looks similare $\Longrightarrow$

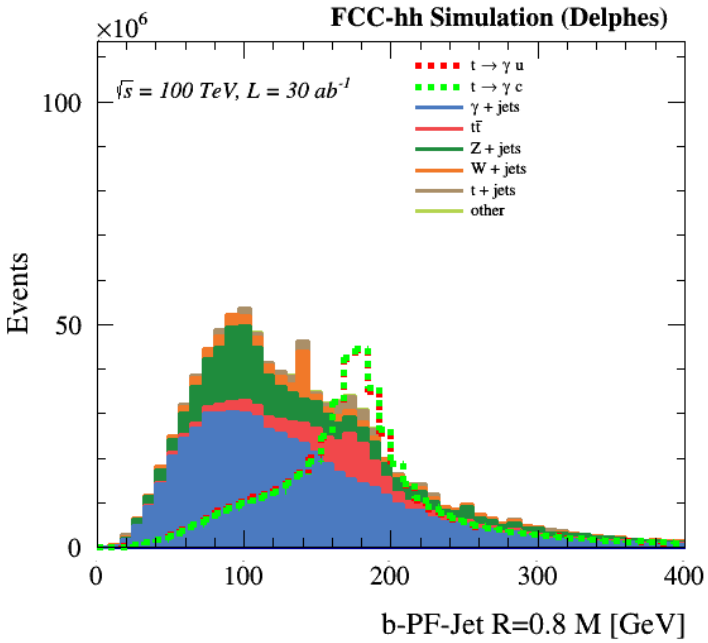


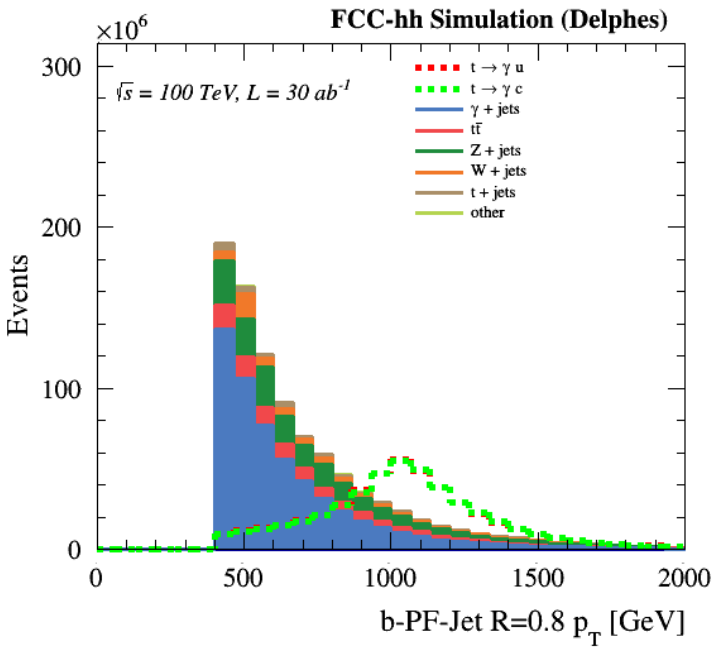

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
Best γ-jet p_T [GeV]

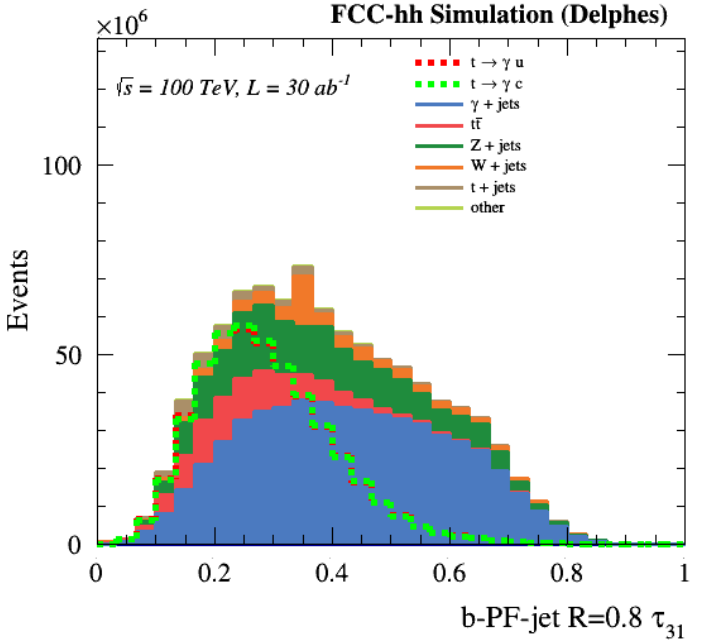

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
Best γ-jet η

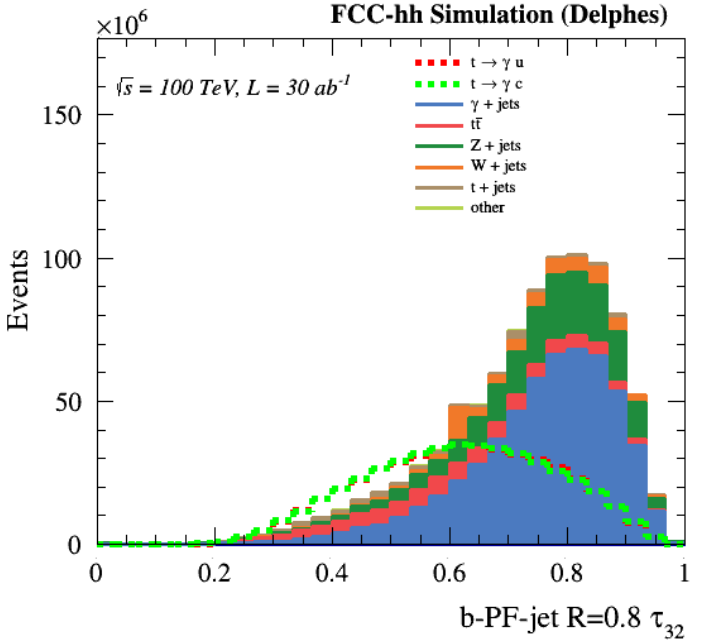

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
Δ R(γ, best γ-jet)

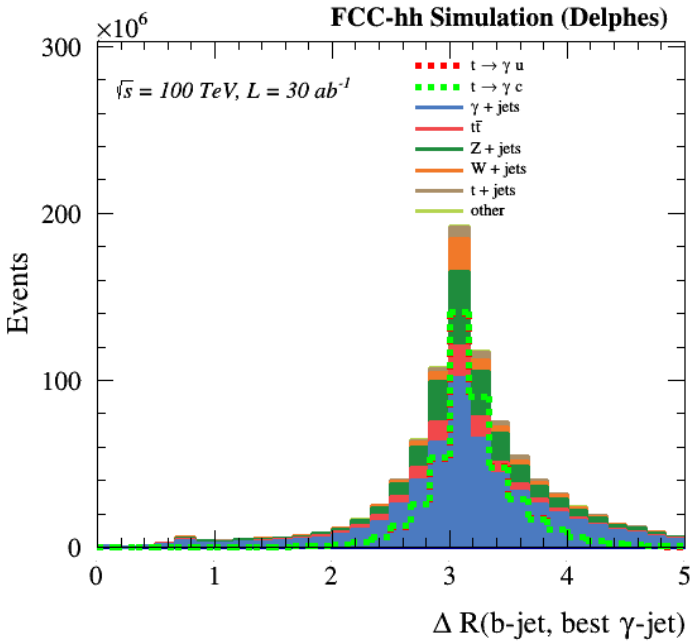

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
Δ φ(γ, best γ-jet)

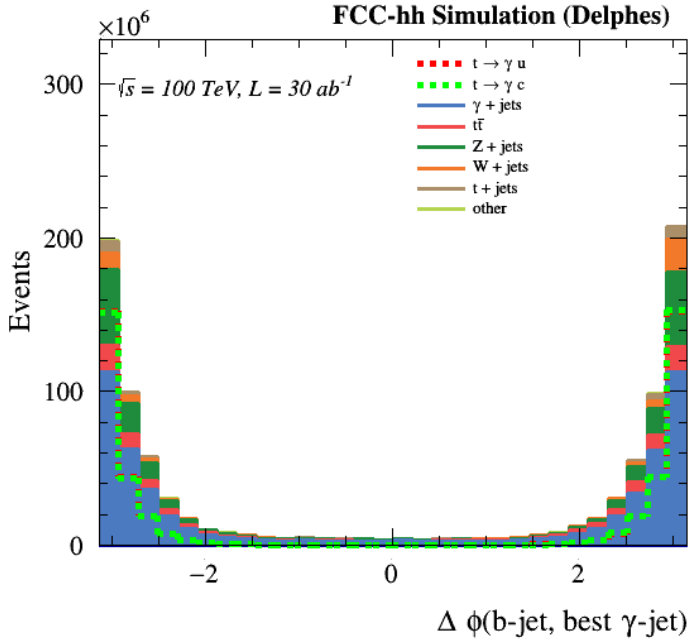

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
b-PF-Jet R=0.8 M [GeV]

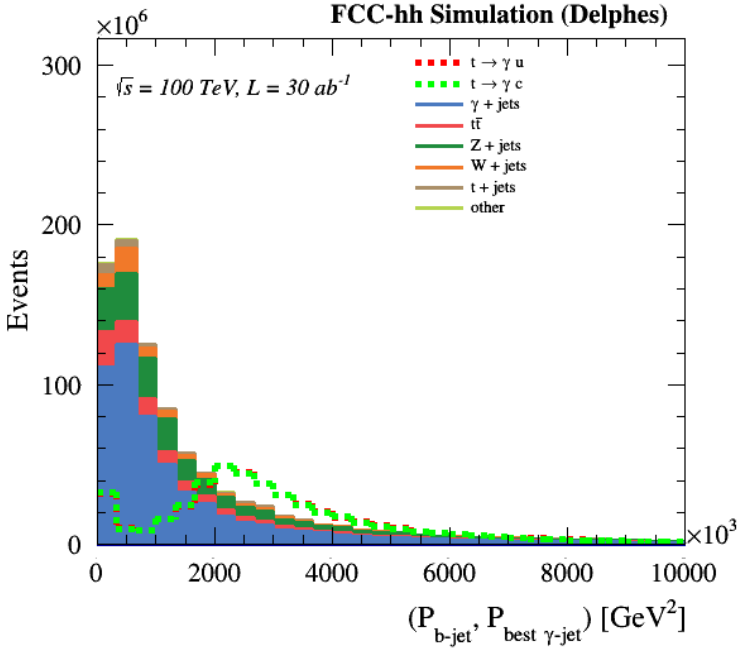

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
b-PF-Jet R=0.8 p_T [GeV]

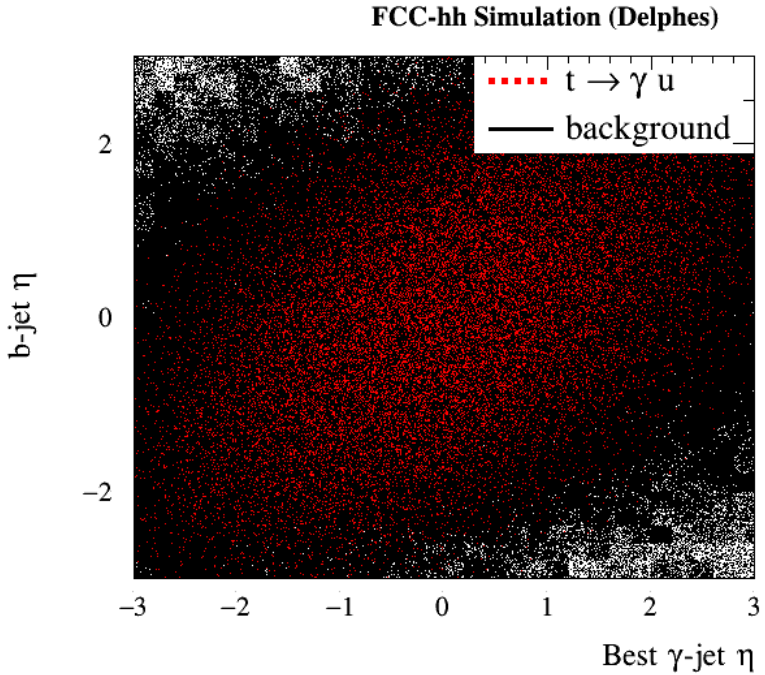

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
b-PF-jet R=0.8 τ31


FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
b-PF-jet R=0.8 τ32

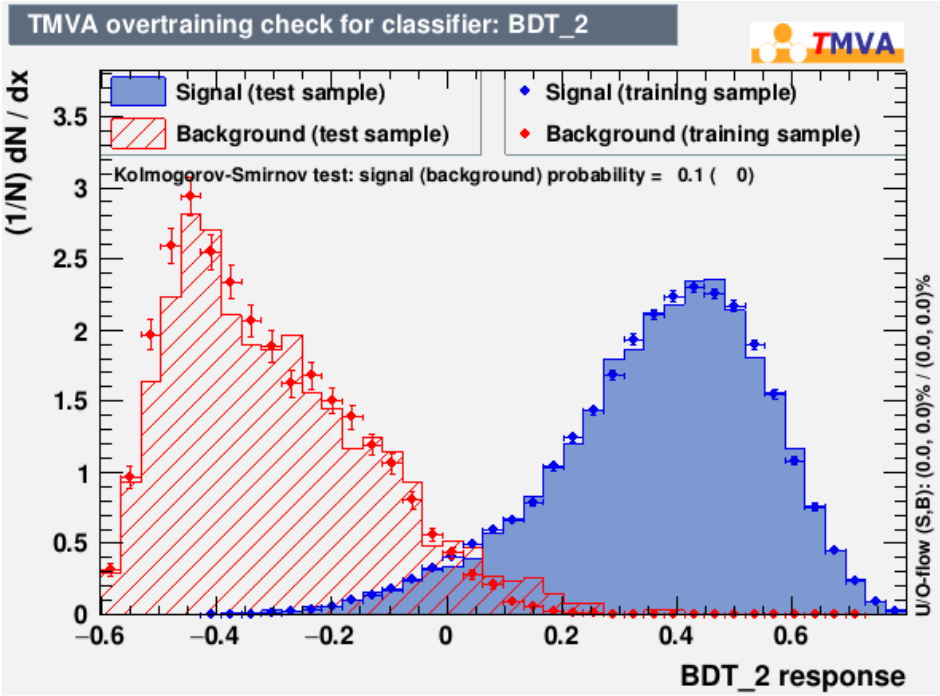

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
Δ R(b-jet, best γ-jet)

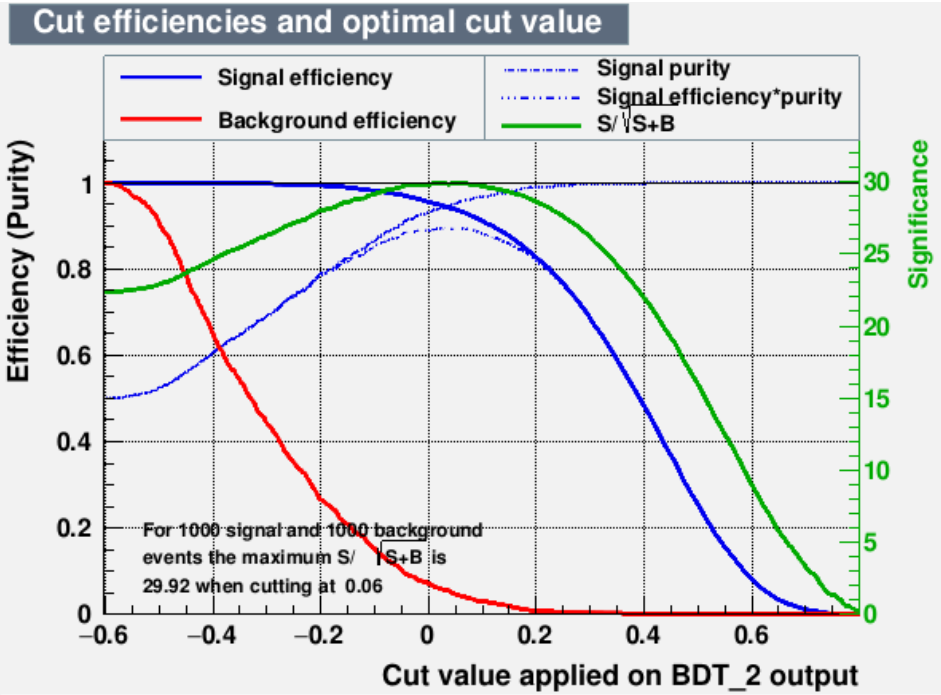

FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
Δ ϕ(b-jet, best γ-jet)


FCC-hh Simulation (Delphes)
×10^6
√s = 100 TeV, L = 30 ab^-1
t → γ u
t → γ c
γ + jets
tt̄
Z + jets
W + jets
t + jets
other
Events
×10^3
(P_b-jet, P_best γ-jet) [GeV^2]


FCC-hh Simulation (Delphes)
t → γ u
background
b-jet η
Best γ-jet η

BDT



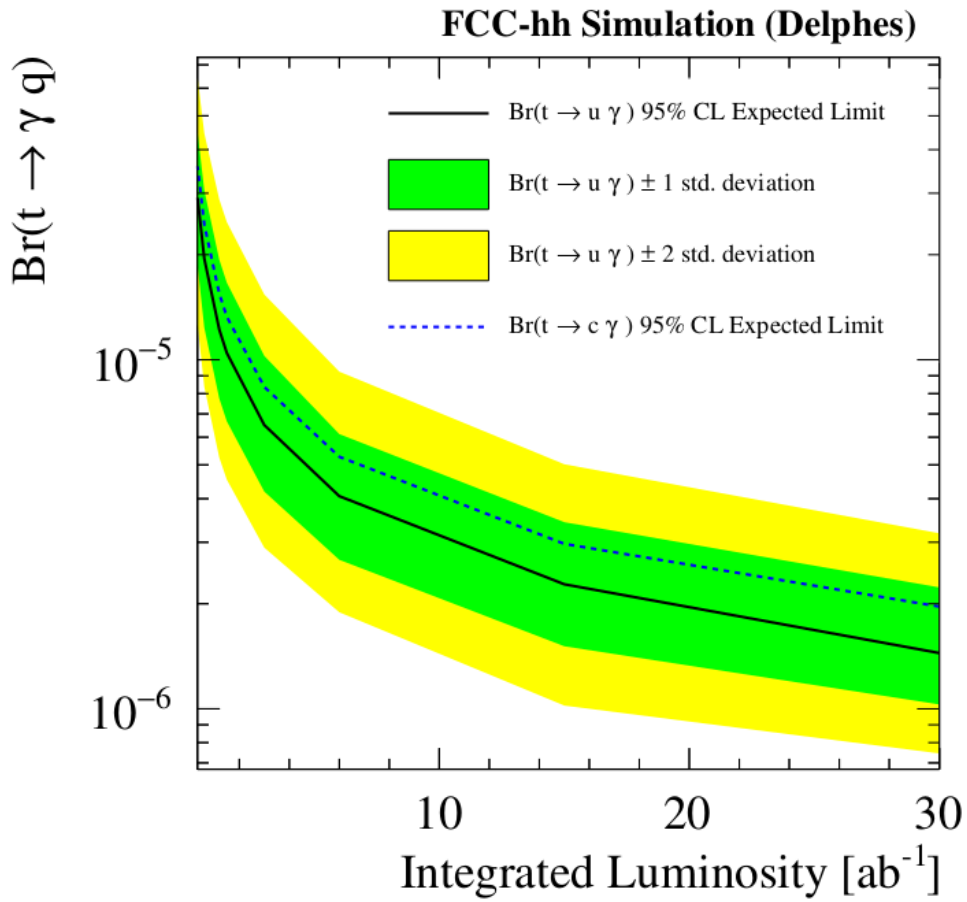


- 10% of events of samples with at least 10000 events is used in training
- BDTs with from 40 to 1000 trees is trained - 125 show the best performance
- different binning number from 15 to 30 is checked - limits show stable minimum around 25

Limits

- CombinedLimit package, cross checked with TRExFitter
- 30% normalisation uncertainty for each background

Process	Branching fraction	Coupling strengths λ [56]
$t \to u\gamma$	$1.44 \cdot 10^{-6}$	$1.70 \cdot 10^{-3}$
$t \to c\gamma$	$1.96 \cdot 10^{-6}$	$2.14 \cdot 10^{-3}$



- **8 TeV** [0]
  $Br(t \to u\gamma) < 1.3 \cdot 10^{-4}$
  $Br(t \to c\gamma) < 1.7 \cdot 10^{-3}$
- **HL-LHC** [1]
  $Br(t \to u\gamma) < 1.19 \cdot 10^{-5}$
  $Br(t \to c\gamma) < 7.25 \cdot 10^{-5}$

[0] arXiv:1511.03951
[1] CMS-TDR-17-007

Conclusions

- FCC-hh $\sqrt{s} = 100$ TeV high energies conditions open up the possibility for research and exploit the area of boosted kinematik
- A direct search for boosted $t \to u\gamma$ and $t \to c\gamma$ decays has been projected
- The 95% CL expected exclusion limits on the branching fractions demonstrate possibility for about two order of magnitude improvement in comparison with the best existing experimental limits on $t \to u\gamma$ branching fractions and about three order of magnitude improvement for $t \to c\gamma$ branching fractions

Backup

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 μ) with $|\eta| < 3$, $p_T > 25$ GeV
- $\Delta R(\gamma, b\text{-jet}) > 0.8$
- fatjet matched to photon must have $p_T > 400$ GeV
- fatjet matched to b-jet must have $p_T > 400$ GeV