tγq Round table

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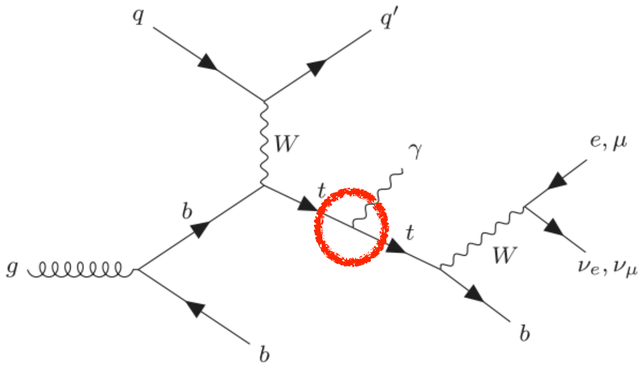
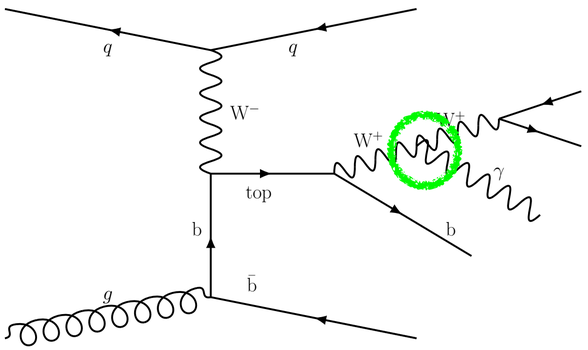
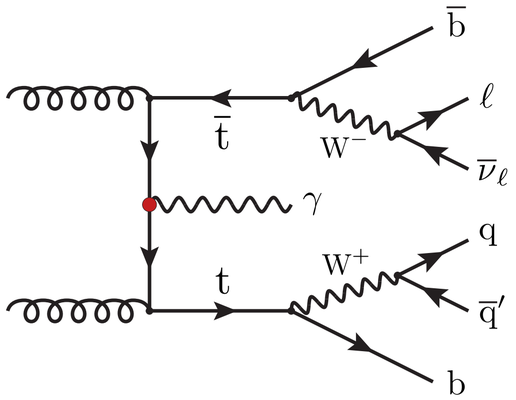
tγq measurement







- The tγq process is observed by ATLAS and not hasn't been observed by CMS yet, also no differential cross section results
  - We could seek for the CMS observation and cross section measurements (plus tWγ as signal for more stats if possible)
- This process represents a direct probe of the top-photon coupling
  - Anomalous top coupling (top-photon electroweak) by top EFT fit is interesting (tγq+ttγ EFT)
  - Could perform the EFT interpretation for tγq+ttγ or even plus tWγ

Simultaneous fit for tγq+ttγ

- Obtains full set of correlations between the two processes
- Possible for a more straightforward EFT interpretation
- High precision ttγ results (precision is similar between CMS full Run2 and ATLAS 2016 data)

$t\gamma q$ strategy

Background estimation/constraint:

- Data-Driven background: j→γ, j→ℓ, e→γ
- Define $t\bar{t}\gamma$ CR and Wγ CR
  - Float normalisation of the $t\bar{t}\gamma$ and Wγ in the fit

Separate signal and background

- Train **DNN** to separate tγq, ttγ, and others

Object selection

Good Muon
- Cut-based-tight muon ID and isolation
- $p_T > 30$ GeV for $|\eta| < 2.4$
- Muon rochester correction

Good Electron
- Cut-based-medium electron ID
- $p_T > 35$ GeV for $|\eta| < 2.5$ (remove gap)
- Energy scale and smearing

Veto Lepton
- Muon is with loose ID and loose isolation
- Electron is with veto ID
- $p_T > 15$ GeV and $|\eta| < 2.5$

MET
- MET pT > 20 GeV

Good Photon
- Cut-based-medium photon ID
- Pixel seed veto
- $p_T > 20$ GeV for $|\eta| < 2.5$ (remove gap)
- Energy scale and smearing

Jet
- PF AK4CHS Jets, tight jet ID
- $p_T > 30$ GeV and $|\eta| < 4.7$
- JES & JER correction
- Loose pileup jet ID (for $p_T < 50$ GeV)

b-jet
- $|\eta| < 2.5$
- Medium deepjet working point

Event selection

- Event pass high-level trigger HLT_IsoMu24 for muon channel and HLT_Ele32_WPTight_Gsf for electron channel
- Exactly one lepton
  - Reject events containing extra leptons with veto lepton requirement
- At least one photon
- At least one jet
- At least one b-jet
- $\Delta R(\ell,\gamma) > 0.4, \Delta R(\ell,j) > 0.4, \Delta R(\gamma,j) > 0.4$

Correction

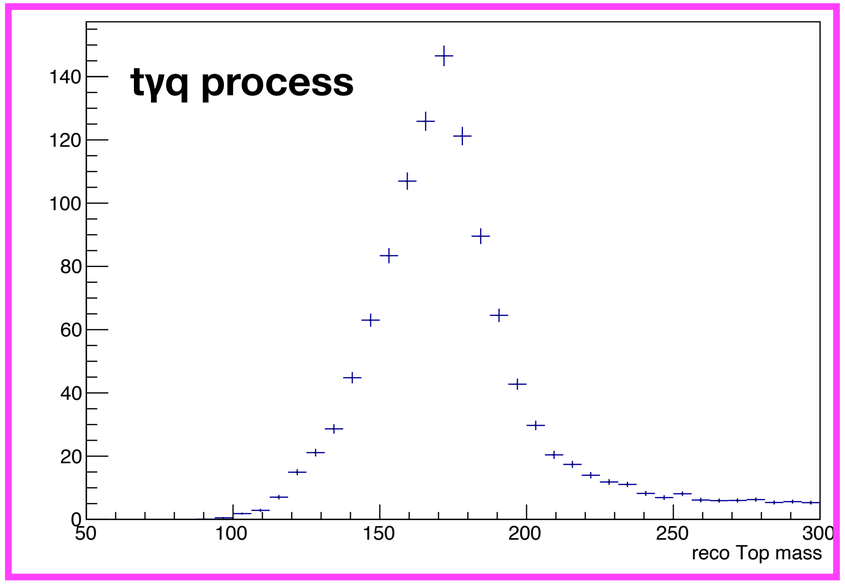
- Pileup reweighing
- Lepton energy correction → muon Rochester and electron energy scale/smearing
- Lepton ID/ISO/RECO/HLT scale factors
- Photon energy scale/smearing
- Photon ID/Pixel Seed Veto scale factors
- Jet energy correction
- ~~Jet pileup ID scale factors~~
- b-jet ID scale factors

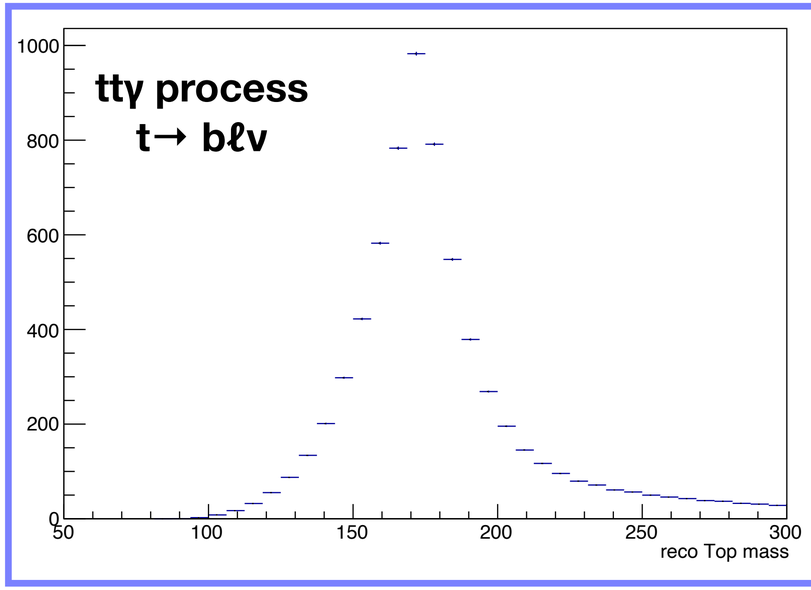
Top reconstruction

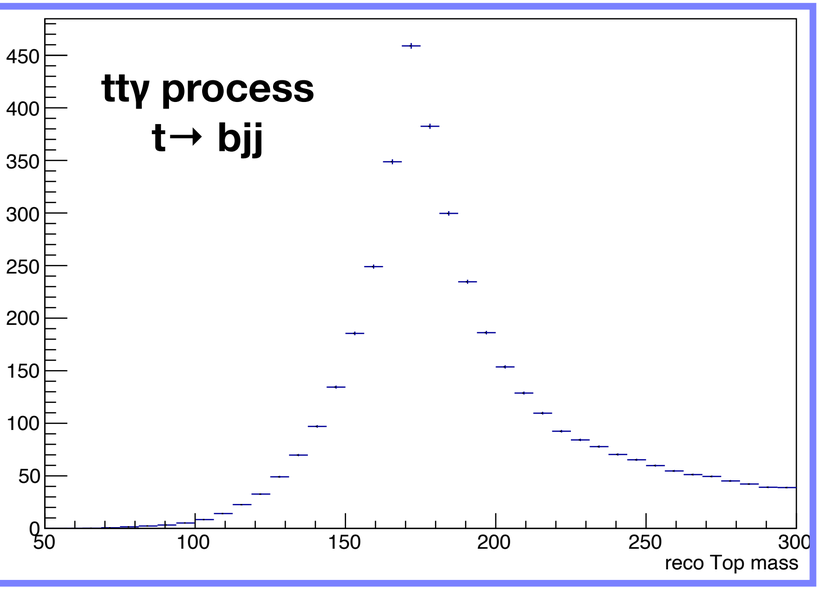
Chi-square minimisation is performed to minimise distance between jets/ leptons inv. mass combinations and top/W mass

Top is reconstructed in two cases:

- t → bW → bℓν
- t → bW → b j j

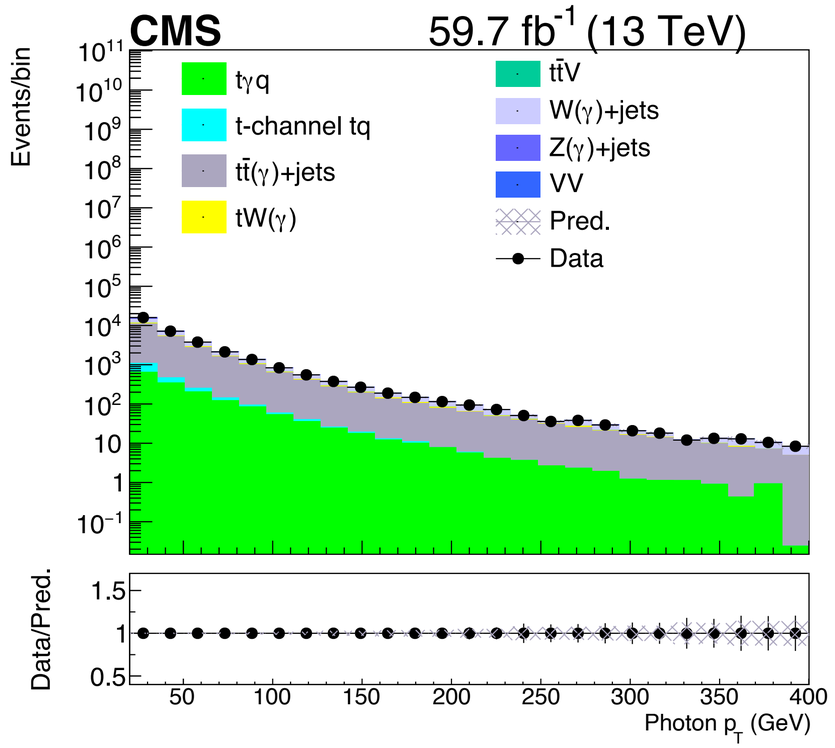


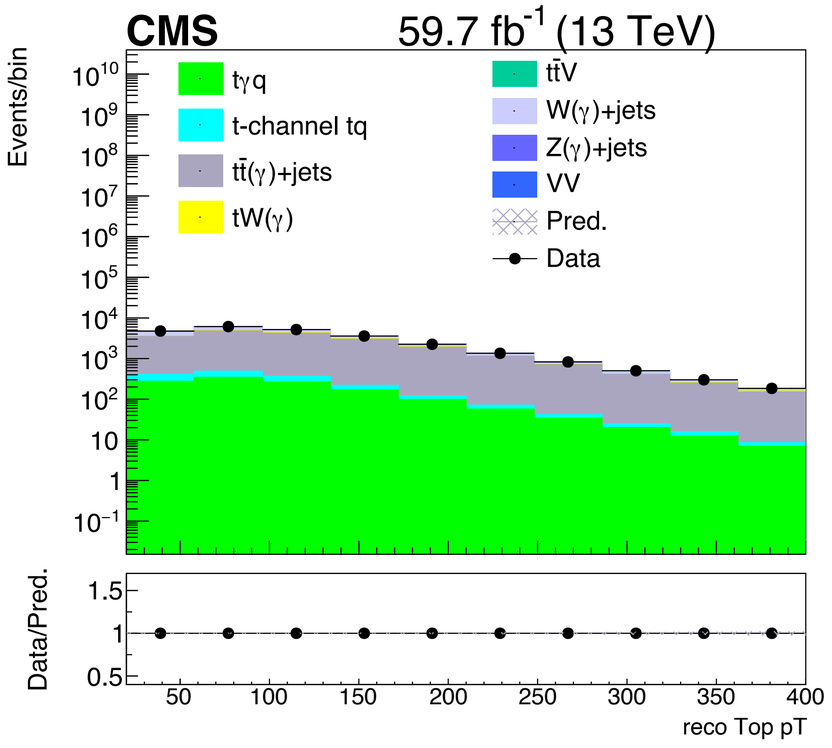


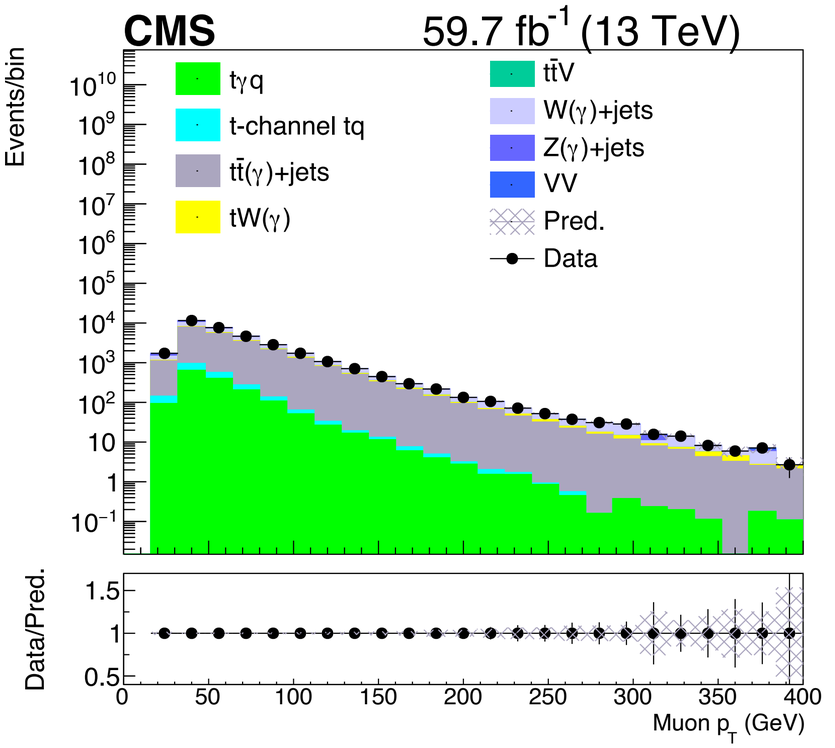


SR plot show (MC only)

Muon channel







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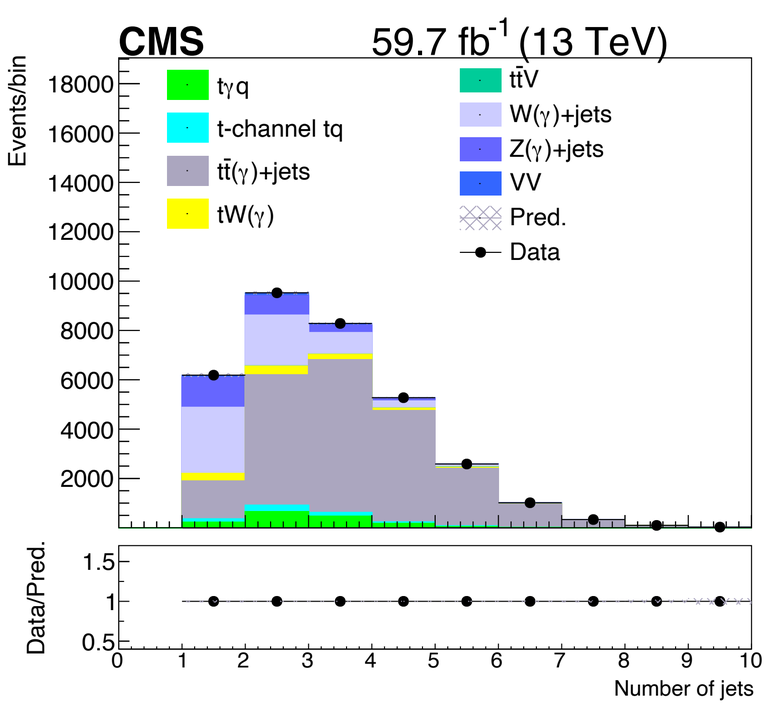
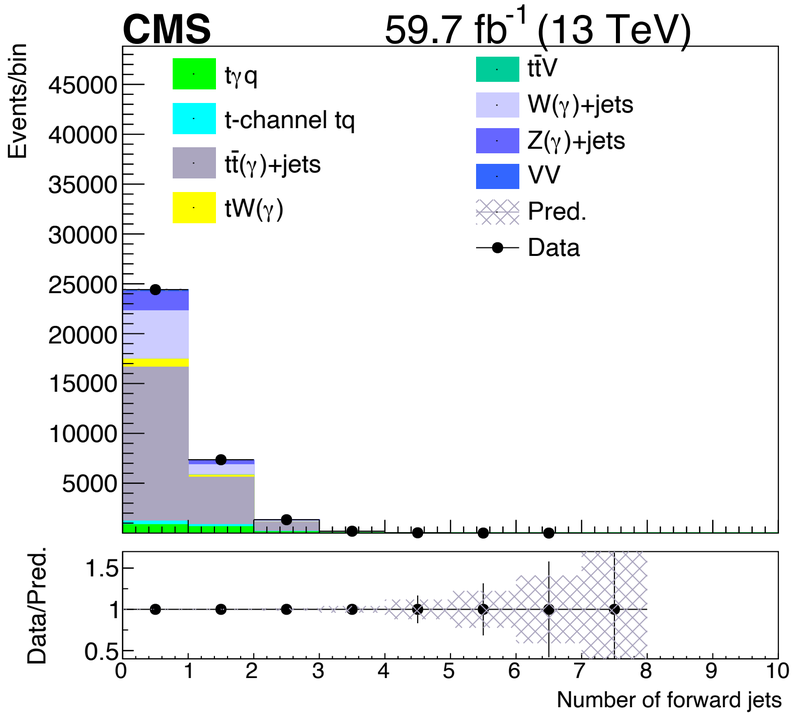
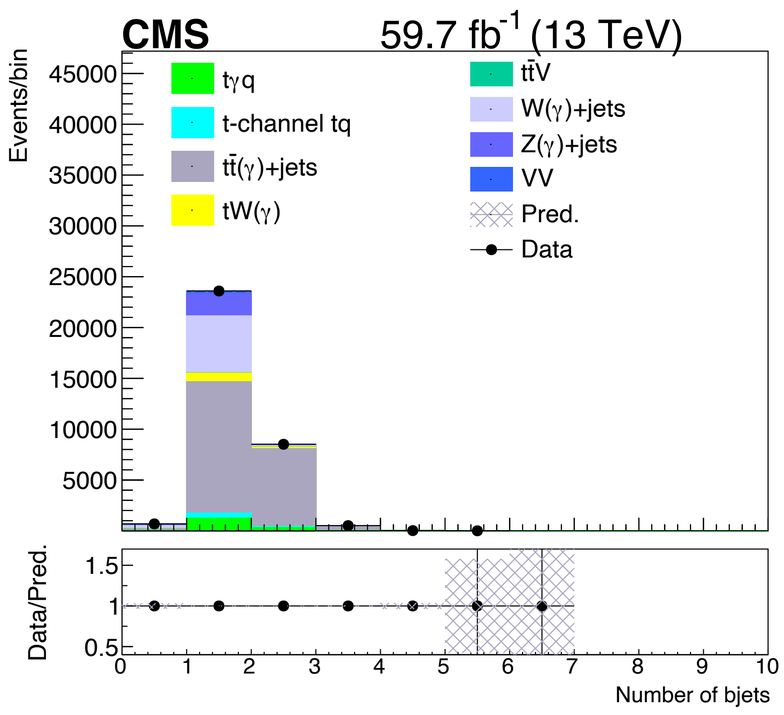
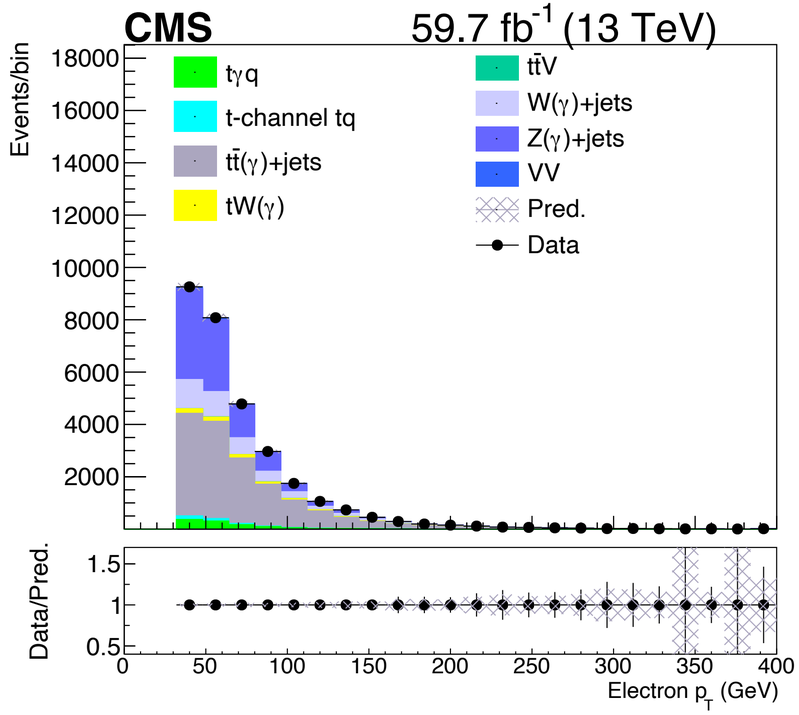


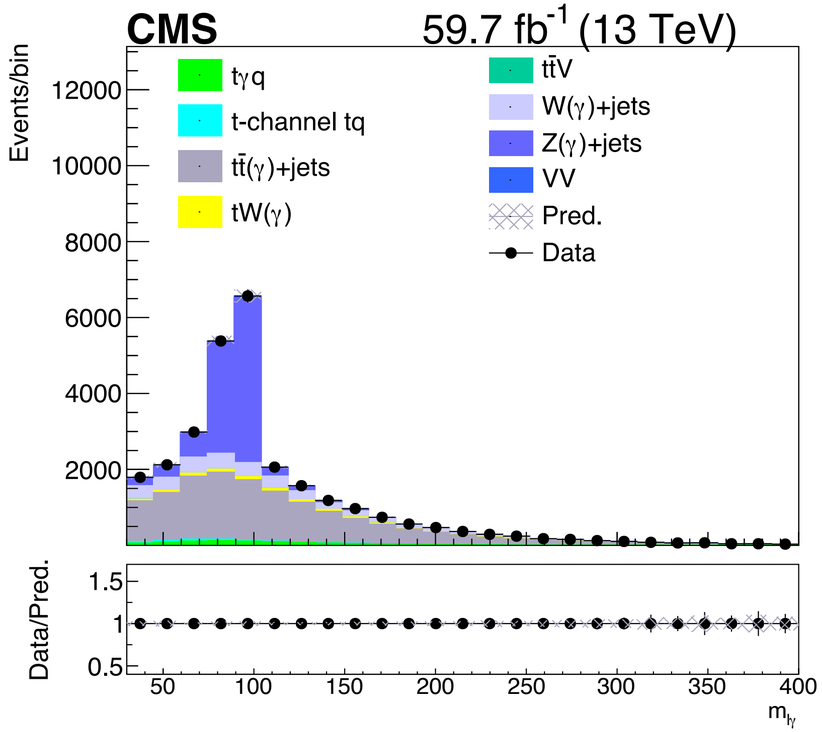


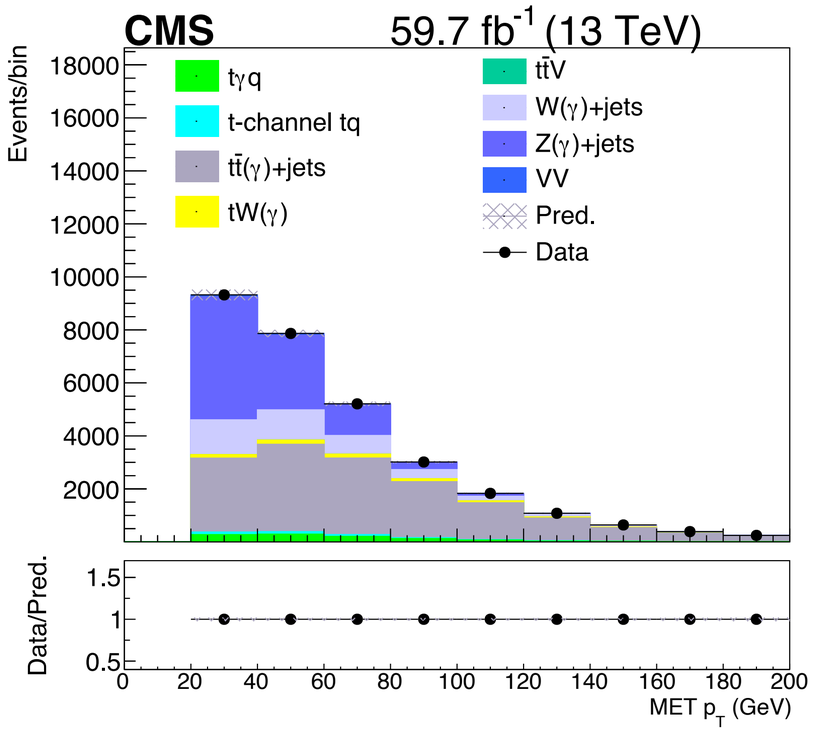


SR plot show (MC only)

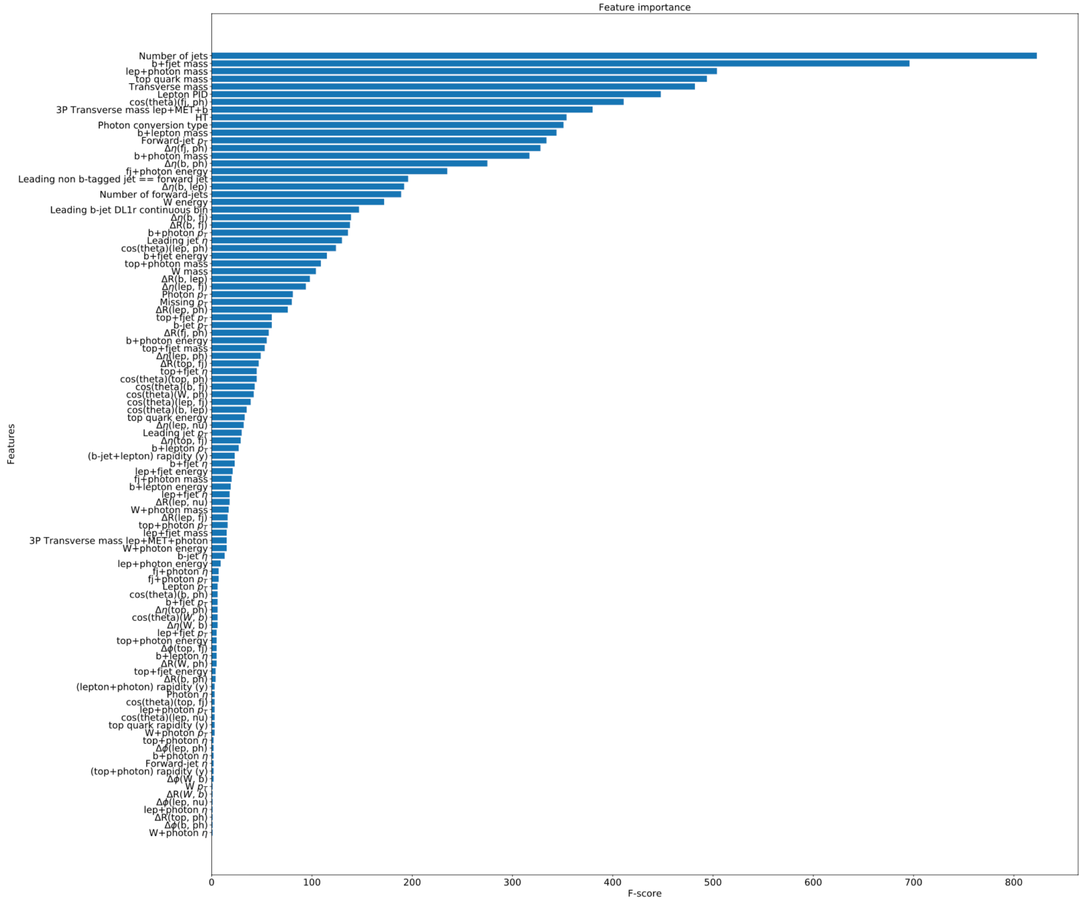
Electron channel







Feature importance (BDT)



- Simple BDT used to get ranking of feature importance of many variables
- Considering removing less importance ones when train DNN

Backup

Steps for $t\gamma q$ measurement

1. Data-driven background estimations are needed and validated in some CRs
2. Background overlap-removal between V($t\bar{t}$/t)+jets and V($t\bar{t}$/t)γ+jets
3. Control regions are needed to constrain some backgrounds for the final fit:
   - $t\bar{t}\gamma$ CR: to constrain $t\bar{t}\gamma$
   - Wγ CR: to constrain Wγ
   - They could also be used as validation Region for step1
4. Machine-learning model from Neutral-Network or Decision Tree is necessary for the final fit
5. Perform fit and extract cross sections

Pay attention to:

- e→γ method, didn't experience before
- Correctness of the overlap-removal
- Signal categorisation for the simultaneous fit of tγq+ttγ

Rough estimation for $t\gamma q$ full Run2

CMS $t\gamma q$ with 2016 data had significance 4.4 (3) σ in μ channel and only barrel photon

Simple calculation for sensitivity with full Run 2 data:

- It could be 8.5 (6) σ in μ channel
- If add e channel, it could be 10 (8) σ with precision 0.1
- If add endcap photon events, could increase a little bit more

Expected signal events should be 2 × (4×57+4×57×0.6) = 728 ~ 1000

CMS $t\gamma q$ post-fit yields table

Process	Event yield
$t\bar{t}+\gamma$	1401 ± 131
$W\gamma$+jets	329 ± 78
$Z\gamma$+jets	232 ± 55
Misidentified photon	374 ± 74
$t\gamma$ (s- and tW-channel)	57 ± 8
$VV\gamma$	8 ± 3
Total background	2401 ± 178
Expected signal	154 ± 24
Total SM prediction	2555 ± 180
Data	2535

ATLAS $t\gamma q$ post-fit yields table Particle level measurement

	≥ 1fj SR	0fj SR	$t\bar{t}\gamma$ CR	$W\gamma$ CR
$tq\gamma$	2360 ± 250	2450 ± 310	880 ± 120	1260 ± 140
$t(\rightarrow l\nu b\gamma)q$	500 ± 170	660 ± 210	180 ± 60	330 ± 120
$t\bar{t}\gamma$ (production)	3100 ± 400	4700 ± 700	4300 ± 600	2700 ± 400
$t\bar{t}\gamma$ (radiative decay)	3800 ± 600	9200 ± 1400	5600 ± 600	4200 ± 900
$W\gamma$+jets	2500 ± 400	9200 ± 1400	1170 ± 320	31 700 ± 3000
$Z\gamma$+jets	970 ± 310	2700 ± 800	430 ± 150	7700 ± 2400
$e \rightarrow \gamma$ fake photons	5100 ± 500	10 400 ± 800	4900 ± 400	5500 ± 500
$h \rightarrow \gamma$ fake photons	1100 ± 400	2700 ± 900	1300 ± 500	2600 ± 800
Other prompt γ	1340 ± 350	2600 ± 900	1400 ± 400	4000 ± 600
Fake leptons	390 ± 190	1000 ± 500	110 ± 50	3600 ± 1700
Total	21 250 ± 150	45 720 ± 240	20 180 ± 150	63 590 ± 280
Data	21 227	45 723	20 194	63 592

Planned $t\gamma q$ analysis

- Significance measurement (depending on the situation)
- Inclusive/differential measurements
- EFT interpretation or top QED dead cone study?? (Not sure)
- Add tWγ in simultaneous final fit or EFT if necessary/required (Not sure)