Study of fake-tau background with the ATLAS experiment

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Introduction

- Introducing the Fake Factor method for estimation of fake-tau background
- Measuring FFs in $Z \to \mu\mu +$ jets events

Tau lepton and fake-tau

- τ decays
  - 35% leptonical ($\tau \rightarrow \nu_\tau \nu_l l, l = e, \mu$)
  - 65% hadronical ($\tau \rightarrow \nu_\tau \, hadrons$)
    - 72% one charged particle (1-prong)
    - 22% three charged particles (3-prong)
    - 68% at least one neutral pion
- fake-tau – jet misidentified as hadronically decaying τ
  - crucial source of background for analyses with τs in final-state

Fake Factor method

- Data-driven method of the fake-tau background determination
- $N_{\mathrm{passID}}^{\mathrm{SR}} = N_{\mathrm{failID}}^{\mathrm{SR}} * FF$
- Fake Factor $FF = \frac{N_{\mathrm{passID}}}{N_{\mathrm{failID}}}$
  - Can/must be determined in fake-enriched CR

FF determination Data	FF application Data
CR Pass ID	SR Pass ID
CR Fail ID	SR but Fail ID

Fake Factor method

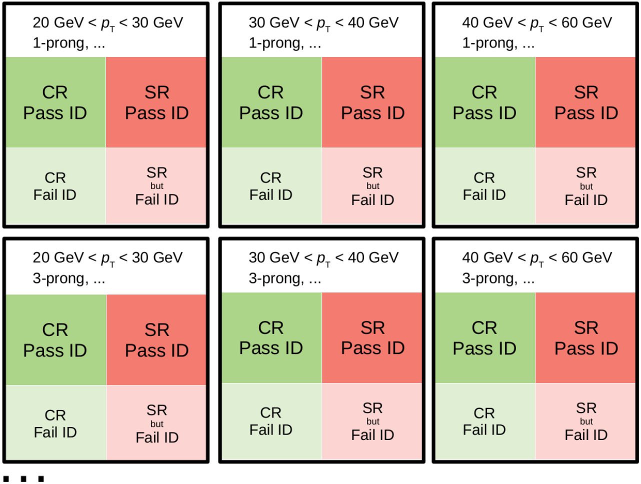
- Complication: some true taus sneak into the CR and the “SR but fail ID” regions
  - Subtracted with the use of MC:

$$N^{\mathrm{SR}}_{\mathrm{passID}} = (N^{\mathrm{SR}}_{\mathrm{failID}} - N^{\mathrm{SR}}_{\mathrm{failID,\ true\ }\tau}) * FF$$

$$FF = \frac{N_{\mathrm{passID}} - N_{\mathrm{passID,\ true\ }\tau}}{N_{\mathrm{failID}} - N_{\mathrm{failID,\ true\ }\tau}}$$

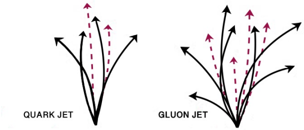
Fake Factor method

- FF depends on p_{T}, prongness, η, μ,...
  - ...need to split each region into subregions



FF method & fake tau composition

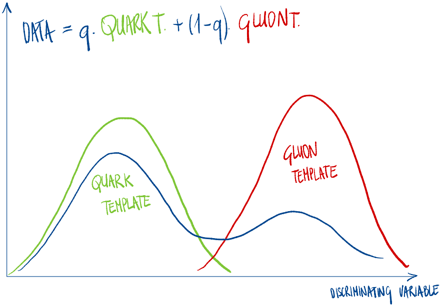
- Fake Factors depend on the fake tau origin



- Use universal FF for q- and g-jets
  - $N^{\mathrm{SR}}_{\mathrm{passID}} = N_q * FF_q + N_g * FF_g = N^{\mathrm{SR}}_{\mathrm{failID}} * FF_{comb}$
  - $FF_{comb} = FF_q * q + FF_g * (1 - q)$

q/g composition determination

- Fitting jet width MC templates to data



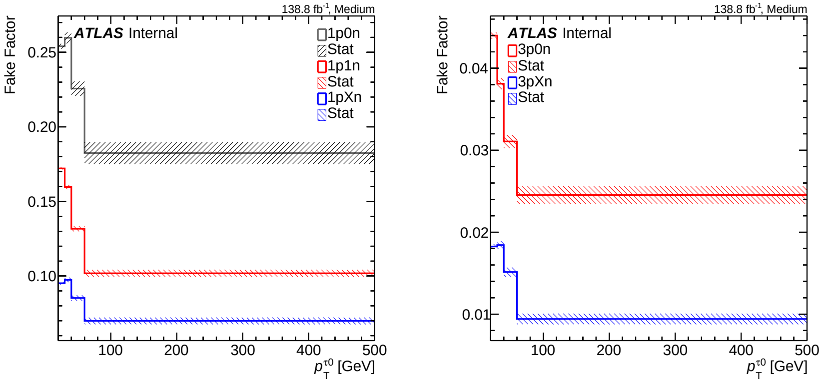
- $\text{JetWidth} = \frac{\sum_{\text{constituents}} \Delta R^i p_{\mathrm{T}}^i}{\sum_{\text{constituents}} p_{\mathrm{T}}^i}$
- Each analysis has to determine q for its fail-ID "SR"

The FF measurements in $Z \to \mu\mu$ + jets events

Event/object selection

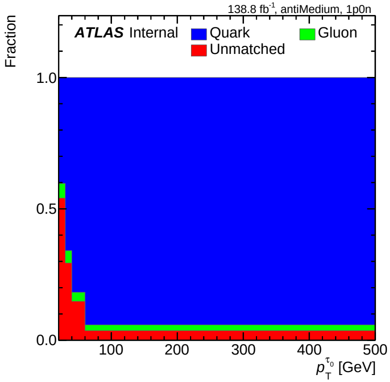
- Data: ATLAS Run 2, pp, 13 TeV, 138.8 fb^{-1}
- Trigger: Muon trigger used, p_{T} threshold 26 GeV
- Exactly two muons and at least one tau
- $m_{\mu\mu} \in (70, 110)$GeV
- Fake Factors measured for the Medium ID WP

Dependence of FFs on τ decay modes and p_{T}



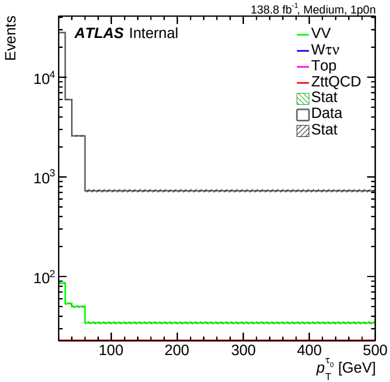
- Strong dependence on τ decay modes and p_{T}

Origin of leading fake-τ candidate in $Z \to \mu\mu$ + jets events



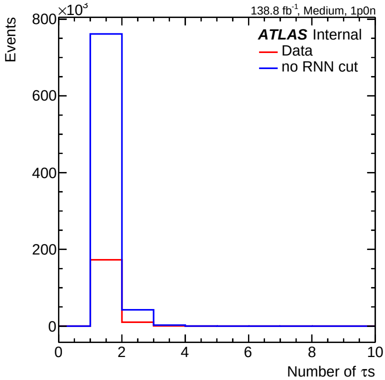
- Leading τ candidate originate mostly from quark-initiated jets
- Higher fraction for unmatched (pile-up) jets in lower p_{T} bins

True tau dilution of pass-ID region



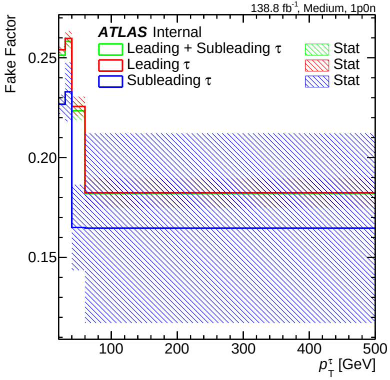
- Low true tau dilution in $Z(\mu\mu) + jets$ events

Number of fake-τ candidates in event



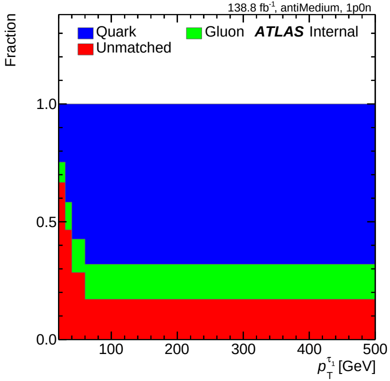
- Significantly lower number of events with two and more τs in the given event

FFs with contribution from leading and subleading τ



- Subleading τ - in given events we only care about properties of subleading candidate (no cuts on leading candidate)
- FFs for subleading τ are smaller + larger statistical uncertainty (small sample)
- FF measurement with contribution from leading τ only

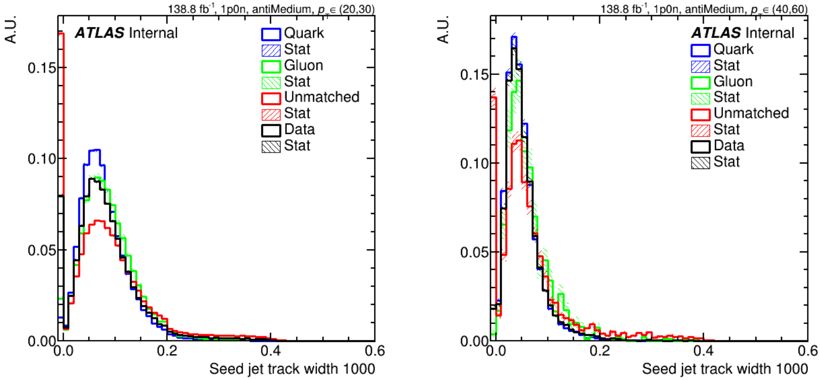
Origin of subleading fake-τ candidate in $Z \rightarrow \mu\mu$ + jets events



- Higher gluon fraction for subleading candidate

Track width

antiMedium ID



- Visible difference in track-based jet width shape of quark-, gluon-initiated and unmatched jets
- Many unmatched jets have no tracks below 1 GeV associated to the tau vertex
- With increasing p_{T}, the shape of the track-based jet width spectrum for data is more similar to the shape of the quark-initiated template

Conclusion

- The FF method for estimation of fake-tau background was introduced
- The FFs measured in Z + jets events
- Fake-τ candidates originate mostly from quark-initiated jets in Z + jets events
- Strong dependance on τ decay modes and p_{T}^{τ}

BACKUP

Event/object selection

- Data: ATLAS Run 2, pp, 13 TeV, 138.8 fb^{-1}
- Trigger: Muon trigger used, p_{T} threshold 26 GeV
- Exactly two muons and at least one tau
- $m_{\mu\mu} \in (70, 110)$GeV
- Muons:
  - $|\eta| < 2.5$, d_0, z_0 cuts
  - leading muon $p_{\mathrm{T}} > 27.3\mathrm{GeV}$
  - subleading muon $p_{\mathrm{T}} > 10\mathrm{GeV}$
  - Muon ID cut rejecting muons from light hadron decays
  - Muon isolation rejecting muons from heavy flavour hadron decays
- Taus: $p_{\mathrm{T}} > 20\mathrm{GeV}$, 1 or 3 tracks, $|\eta| < 1.37$ OR $1.52 < |\eta| < 2.5$, RNN> 0.01
- Fake Factors measured for the Medium ID WP

Monte Carlo samples

- Diboson samples:

```
[363356, 0],          # Sh221_PDF30_ZqqZll
[363358, 0],          # Sh221_PDF30_WqqZll
[363359, 0],          # Sh221_PDF30_WpqqWmlv
[363360, 0],          # Sh221_PDF30_WplvWmqq
[363489, 0],          # Sh221_PDF30_WlvZqq
[364250, 0],          # Sh221_PDF30_llll
[364253, 0],          # Sh221_PDF30_lllv
[364254, 0],          # Sh221_PDF30_llvv
[364255, 0],          # Sh221_PDF30_lvvv
```

- Top samples:

```
[410470, 0, 10],      # PhPy8EG_A14_ttb_nonallh
```

- W $\rightarrow \tau\nu$ samples

```
[364185, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV0_70_CFilterBVeto
[364186, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV0_70_BFilter
[364187, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV70_140_CVetoBVeto
[364188, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV70_140_CFilterBVeto
[364189, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV70_140_BFilter
[364190, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV140_280_CVetoBVeto
[364191, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV140_280_CFilterBVeto
[364192, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV140_280_BFilter
[364194, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV280_500_CFilterBVeto
[364195, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV280_500_BFilter
[364196, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV500_1000
[364197, 0], # Sherpa_221_NNPDF30NNLO_Wtaunu_MAXHTPTV1000_E_CMS
```

- Z$\rightarrow \tau\tau$ samples

```
[364128, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV0_70_CVetoBVeto
[364129, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV0_70_CFilterBVeto
[364130, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV0_70_BFilter
[364131, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV70_140_CVetoBVeto
[364132, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV70_140_CFilterBVeto
[364133, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV70_140_BFilter
[364134, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV140_280_CVetoBVeto
[364135, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV140_280_CFilterBVeto
[364136, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV140_280_BFilter
[364137, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV280_500_CVetoBVeto
[364138, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV280_500_CFilterBVeto
[364139, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV280_500_BFilter
[364140, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV500_1000
[364141, 0], # Sherpa_221_NNPDF30NNLO_Ztautau_MAXHTPTV1000_E_CMS
[364210, 0], # Sherpa_221_NN30NNLO_Ztt_Mll10_40_MAXHTPTV0_70_BVeto
[364213, 0], # Sherpa_221_NN30NNLO_Ztt_Mll10_40_MAXHTPTV70_280_BFilter
[364214, 0], # Sherpa_221_NN30NNLO_Ztt_Mll10_40_MAXHTPTV280_E_CMS_BVeto
[364215, 0], # Sherpa_221_NN30NNLO_Ztt_Mll10_40_MAXHTPTV280_E_CMS_BFilter
```

ZmmQCD MC samples

- ZmmQCD sample:

```
[361107, 20], # Powheg+Pythia 8, inclusive dimuon sample
```