Search for $WH \to l\tau\tau$ in CMS

$m_{\tau\tau}$ Workshop Würzburg

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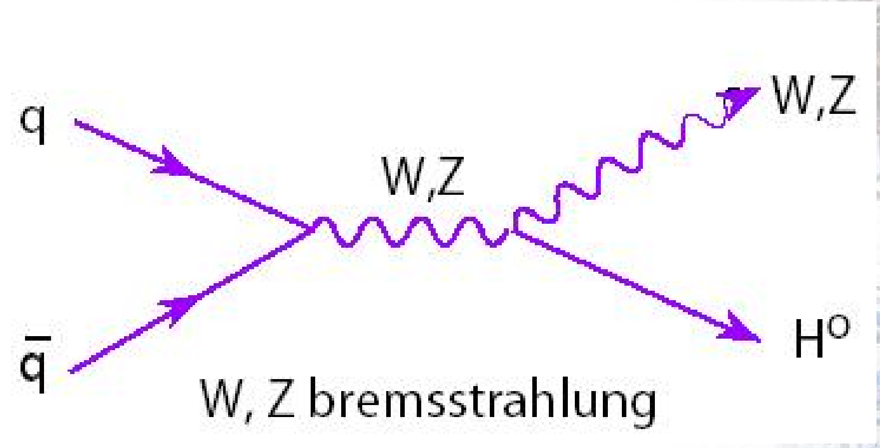
Introduction

- Why search for associated production?
  - Measure VH cross-section
  - Extra leptons from W or Z simplify triggering and reduce background
    - Also low signal rate



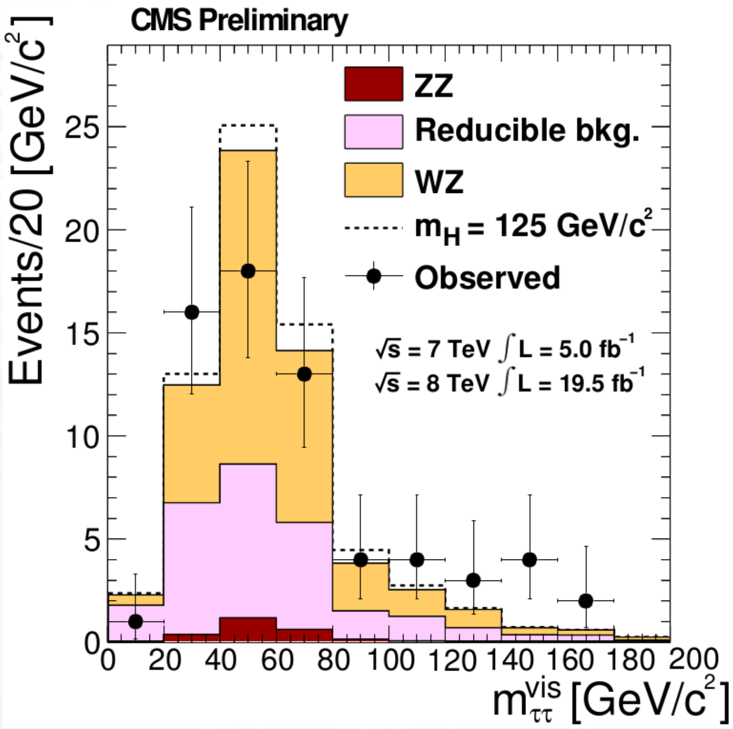
- Three channels studied in CMS
  - WH → $l\ \tau_l\ \tau_h$
  - WH → $l\ \tau_h\ \tau_h$ ← **this talk**
  - ZH → $l\ l\ \tau\ \tau$

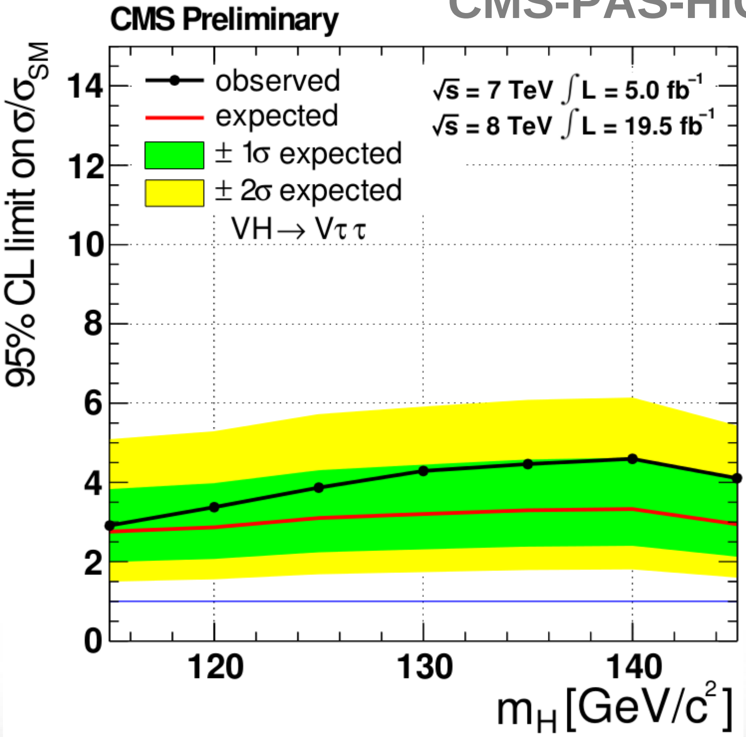
l = e, μ

Public Results

- Results made public together with H → ττ for Moriond 2013
  - Can exclude ~3x Standard Model cross section
  - Combination with H → ττ improve expected limit by ~5%

CMS-PAS-HIG-12-053





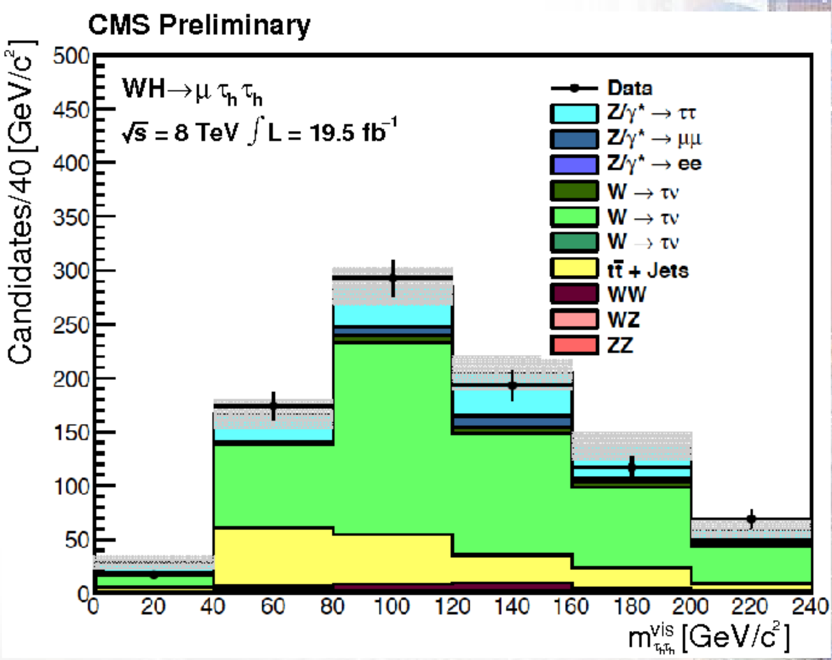
Analysis Strategy

- Select lepton-tau-tau final states
- Apply **topological selections** to reduce background
- Estimate reducible background (where τ is faked by jet) from a **sideband**
- Take irreducible background (WZ, ZZ) from **Monte Carlo simulation**
- **Statistical interpretation** using the shape of the visible di-tau mass

Background Estimation

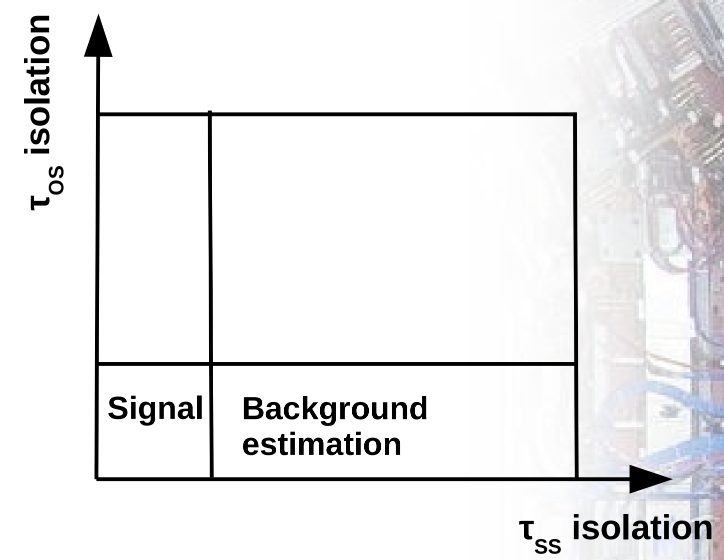
- Very **low statistics** in simulated samples for major backgrounds
- Major background from jets with **misidentified taus**
  - $W + 2\text{Jets} \rightarrow l + 2\text{jets}$
  - $Z + 1\text{jet} \rightarrow \tau\tau + 1\text{jet} \rightarrow l\tau_h + 1\text{jet}$
  - $Z + 1\text{jet} \rightarrow ee + 1\text{jet} \rightarrow e\text{"}\tau_h\text{"} + 1\text{jet}$
  - $t\bar{t} \rightarrow l + \tau_h + b\bar{b}$
- In all cases the tau with **same charge** as the light lepton is misidentified
  - ➔ Extract reducible background from **sideband with same sign tau anti-isolated**

CMS-PAS-HIG-12-053



The Fake Rate Method

- Measure the **probability** that a "tau-like" jet passes the tau isolation ("Fake Rate")
- Weigh events in anti-isolated region with the Fake Rate



- <u>Remaining ingredient:</u> **Measurement of the Fake Rate** in data
  - Measured in regions with no genuine taus

Fake Rate Measurement

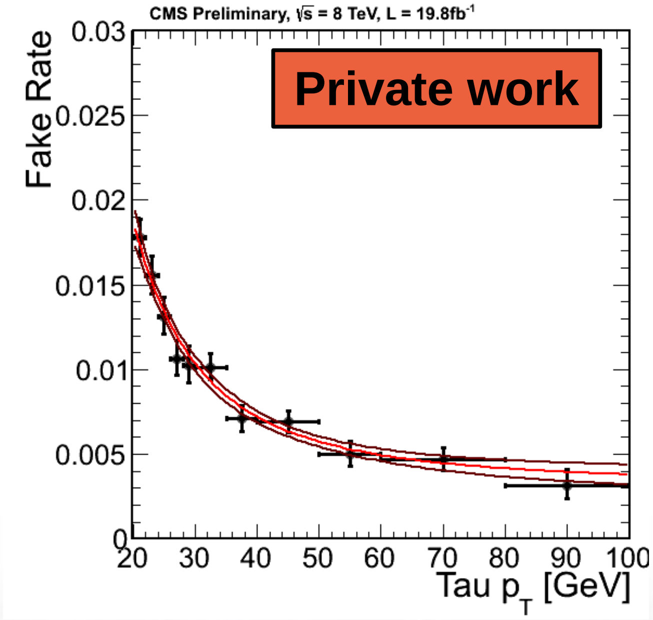
- Fake Rate is measured in **two different regions**

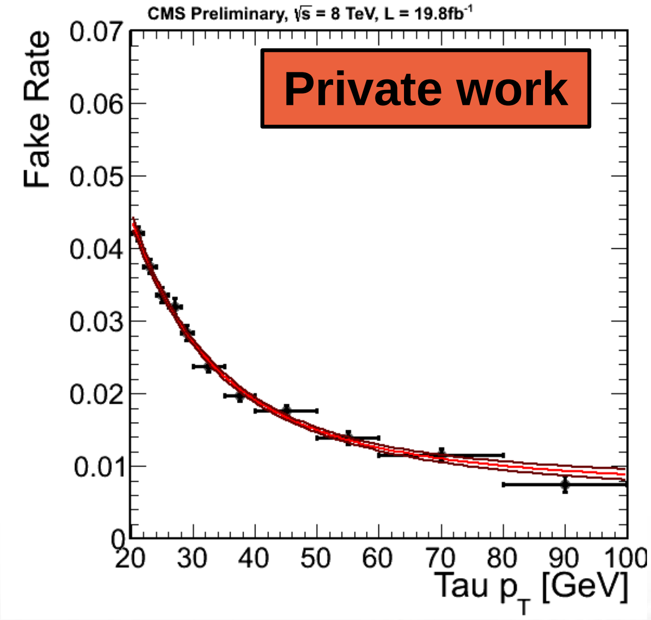
W + Jets Enriched Region:

- Select μ-τ-τ events
- M_T(μ, MET) > 40 GeV
- Require same sign between taus
- Require same sign between tau and muon

Z + Jets Enriched Region:

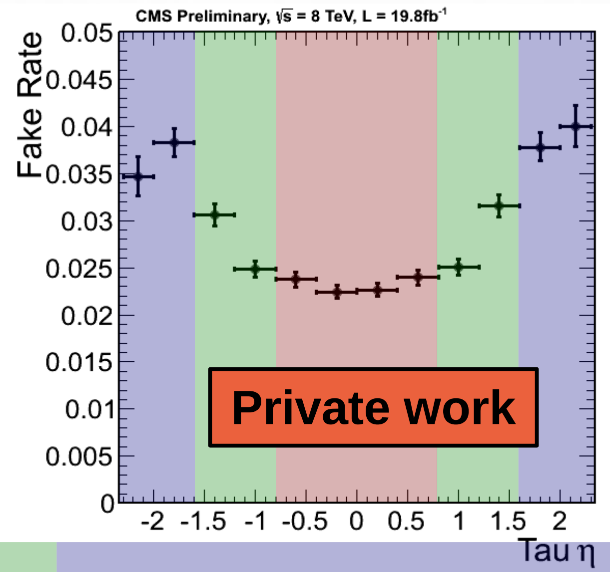
- Select μ-μ-τ events
- Opposite sign muons
- 80 < $M_{\mu\mu}$ < 100 GeV

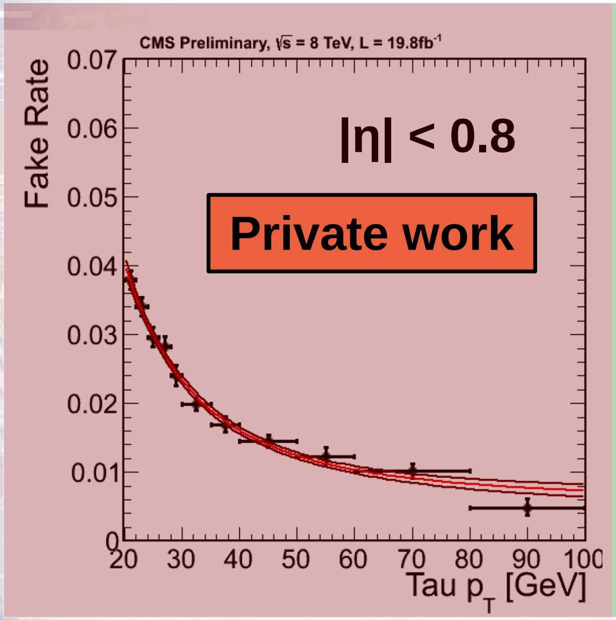


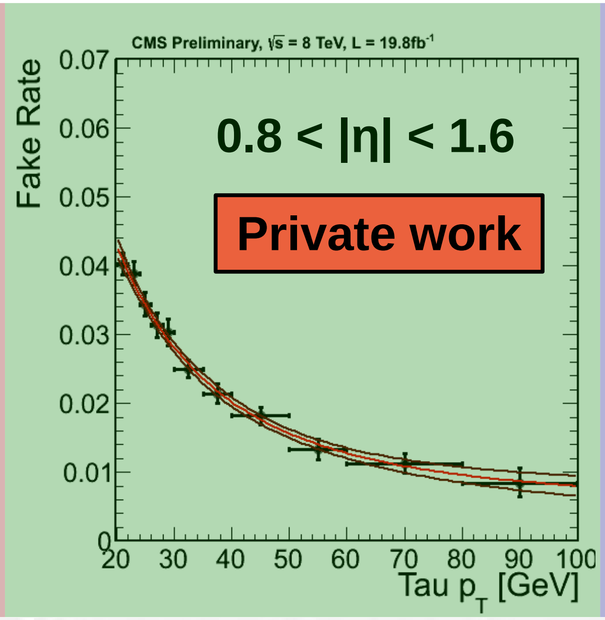


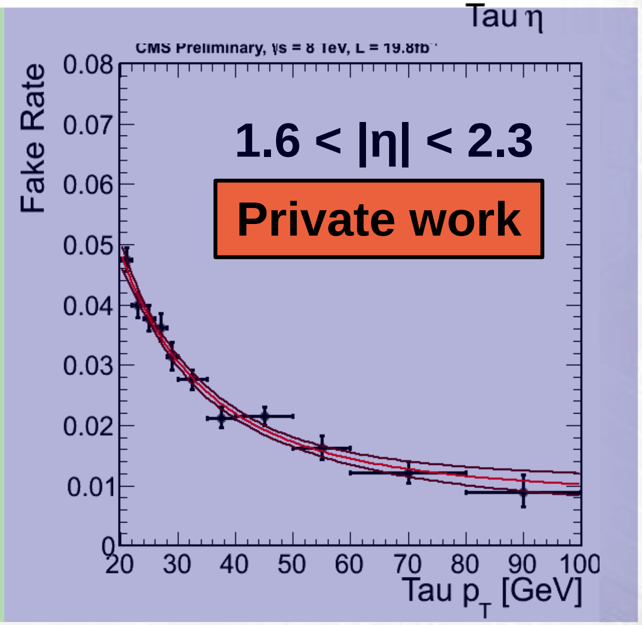
Fake Rate as a Function of η

- The Fake Rate also depends on the **pseudo-rapidity** of the tau-like jet
- Measure the Fake Rate in three **bins of |η|** as a function of p_T



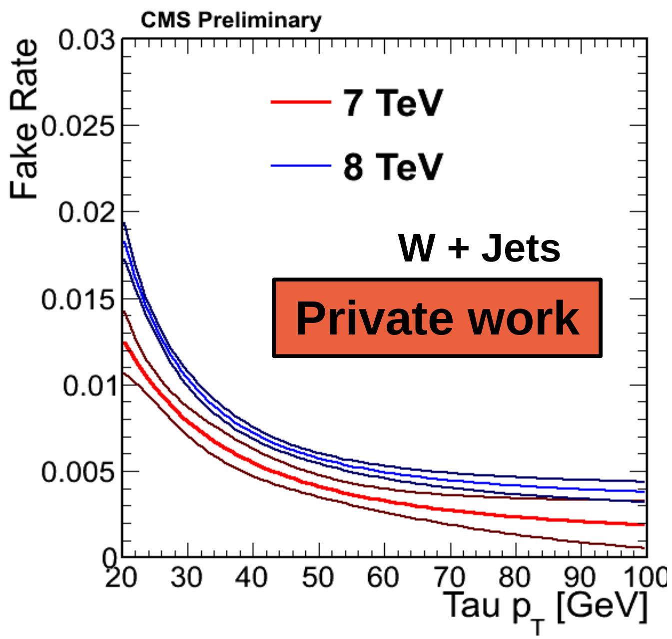


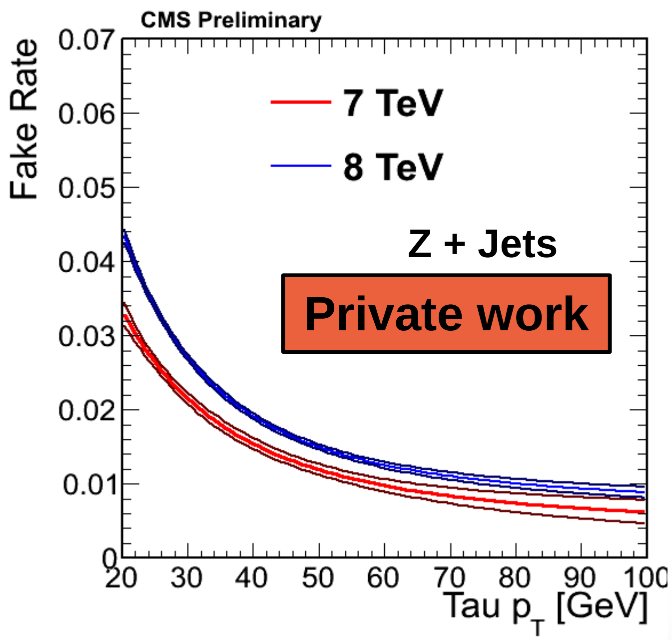




Fake Rate in 7 and 8 TeV

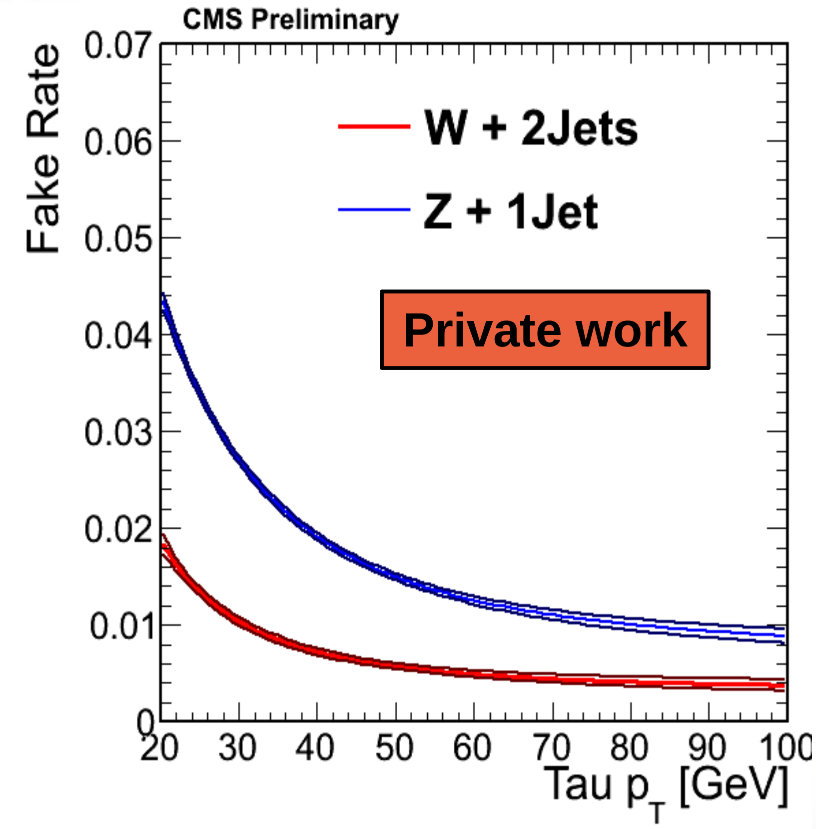
- The Fake Rate is a function of **Pile-Up**
  - Additional event content makes it harder to tell a hadronic tau from a jet
- Measure Fake Rate **separately** for 7 TeV and 8 TeV data





Comparing W+Jets and Z+Jets

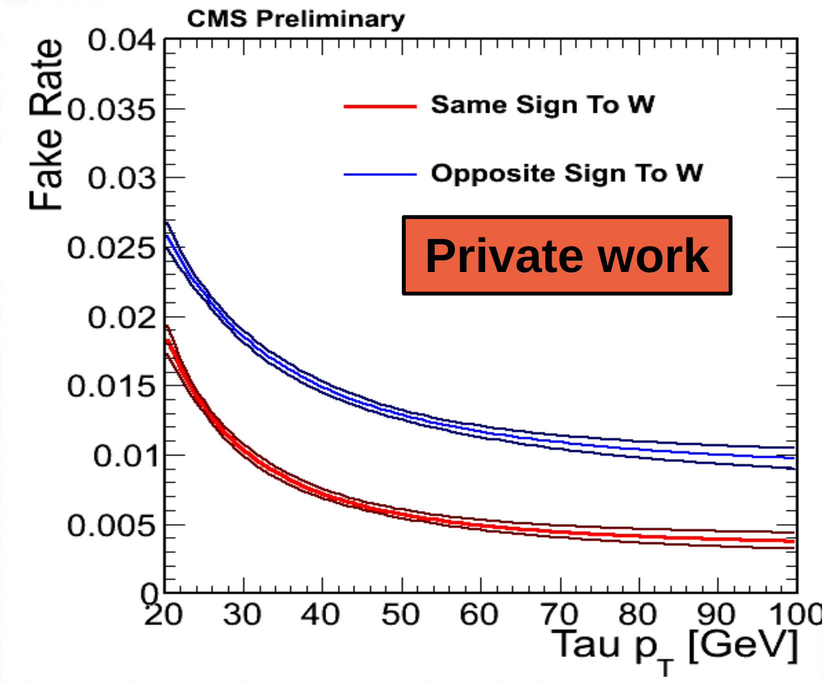
- The Fake Rates measured in W+Jets and Z+Jets events are **different** by a **factor of 2**!



- Two effects:
  - Different **Number of Jets**
  - Fake Rate in W+Jets depends on relative **charge** of Jet and W

Charge Correlation

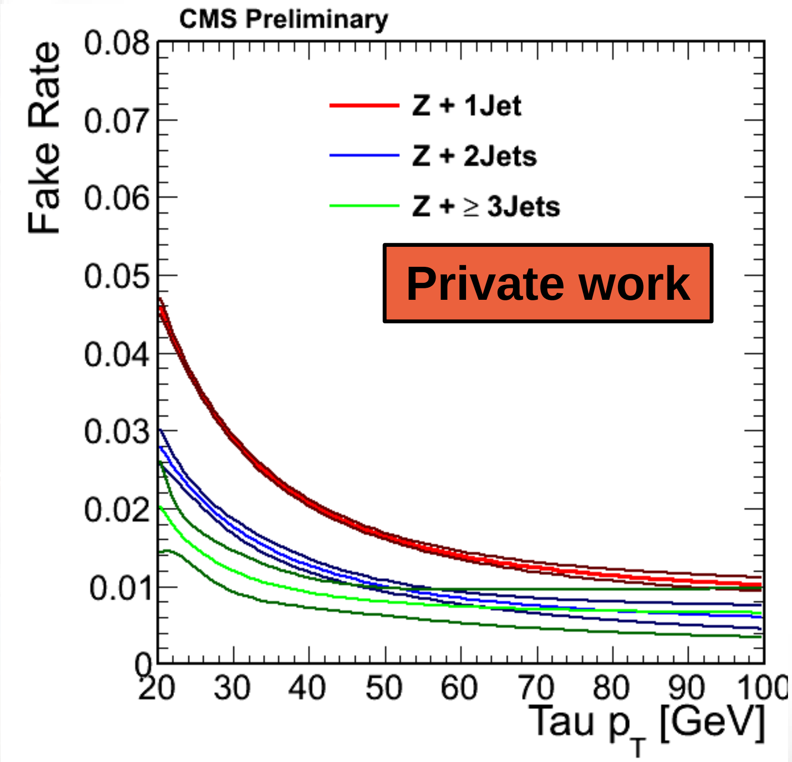
- In the W+Jets region we require the jets to have the **same charge** as the lepton from the W boson
- How does the Fake Rate change when looking at jets that are opposite sign to the lepton from the W boson?



→ **Significant Difference!**

Jet Multiplicity

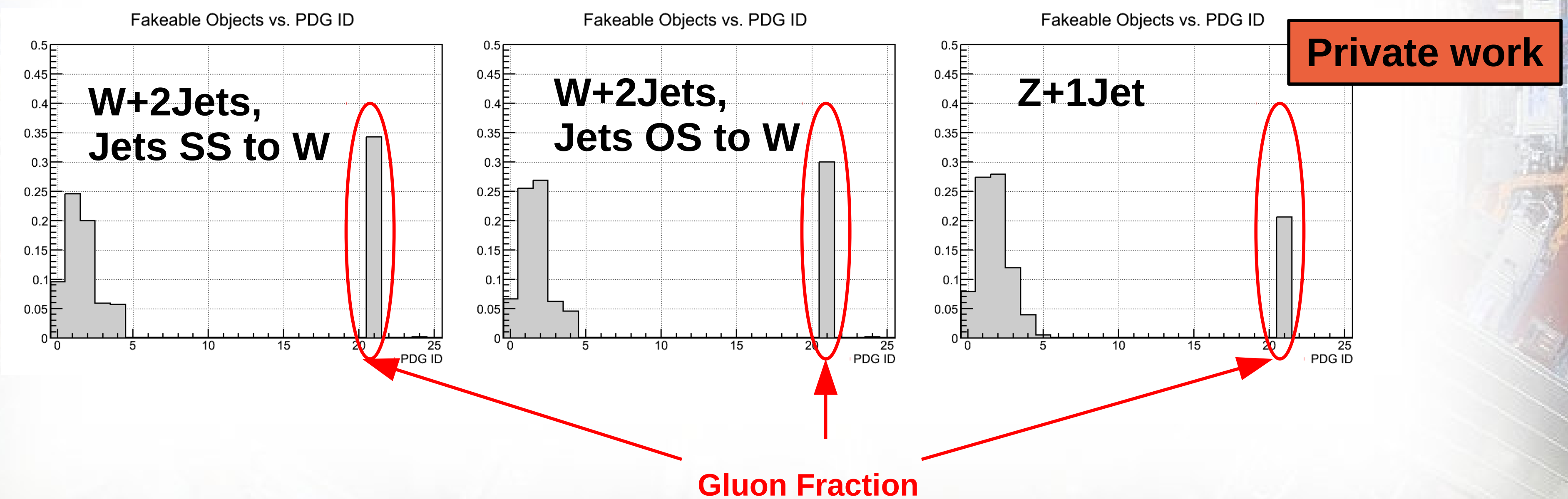
- In the W region we select W + 2Jets events
- In the Z region we select Z + 1Jet events
- How does the Fake Rate depend on the Jet Multiplicity?



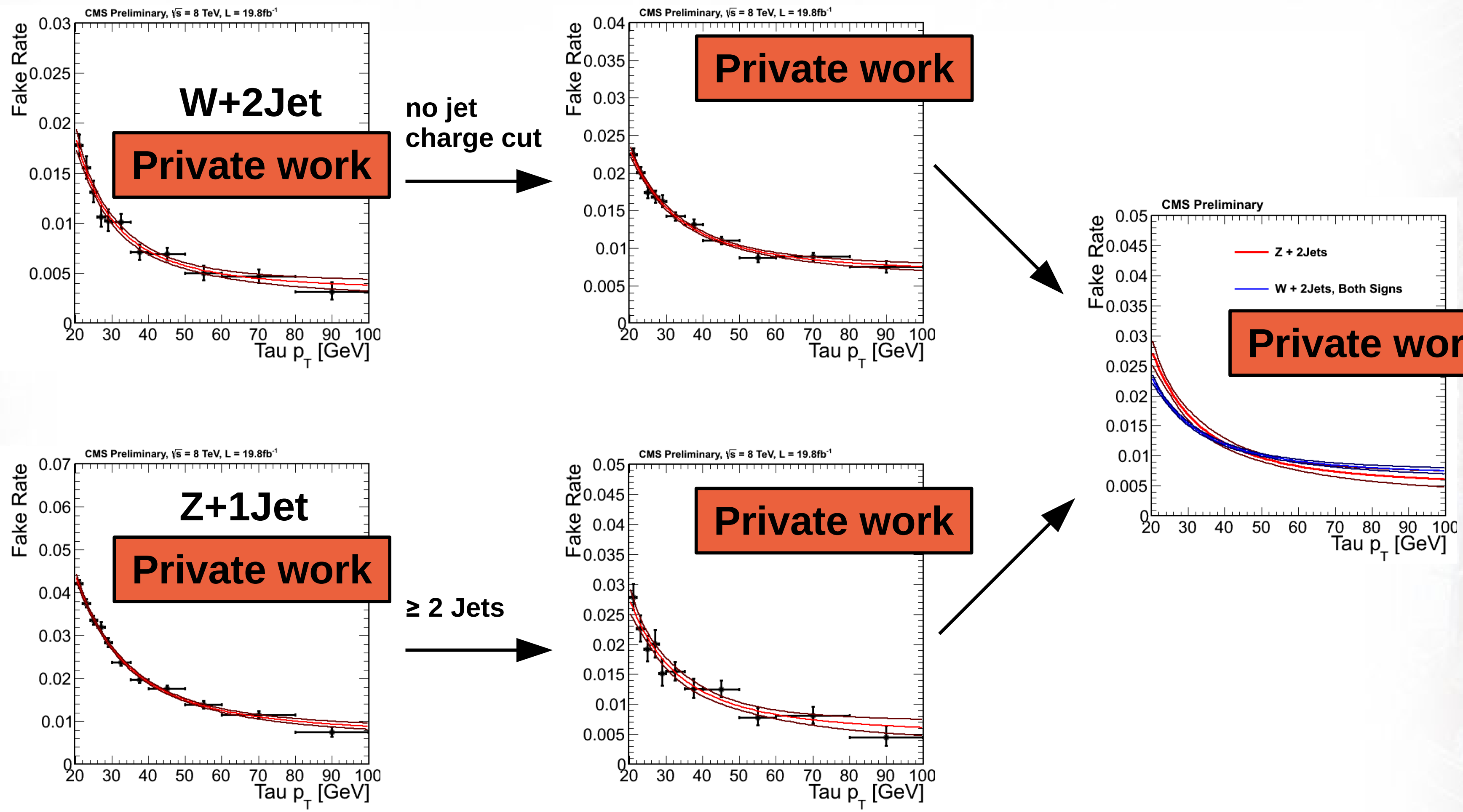
Significant Difference between Z+1Jet and Z+2Jets!

Quark/Gluon Fraction

- The different Fake Rates come from a different fraction of **quark-induced** and **gluon-induced** jets
  - Quark-induced jets are more tau-like than gluon-induced jets
- Look at **generator level parton** within $\Delta R < 0.3$ with highest p_T



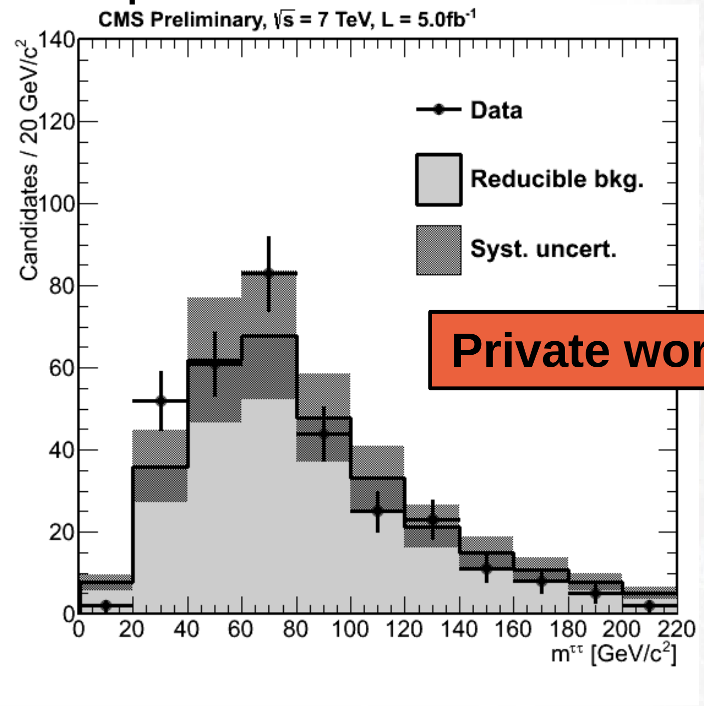
Putting known effects together

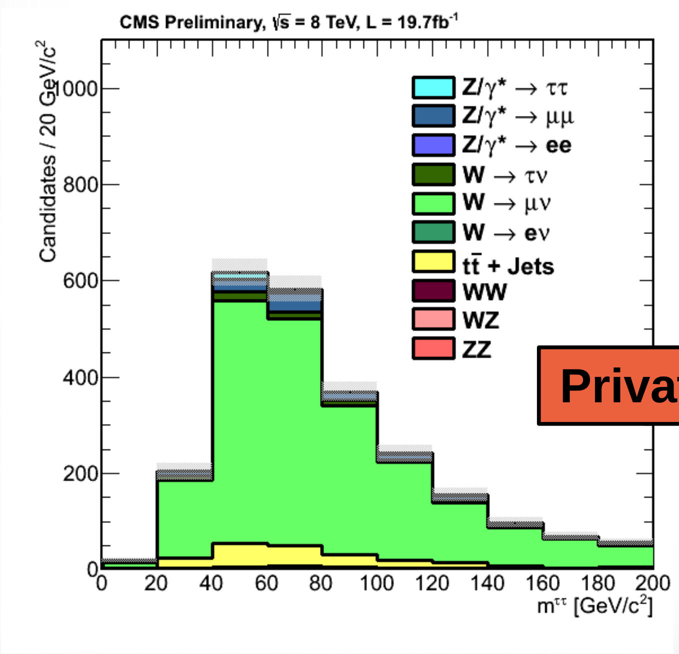


Fake Rates are very similar
Also, Gluon Fraction is the same

Validation

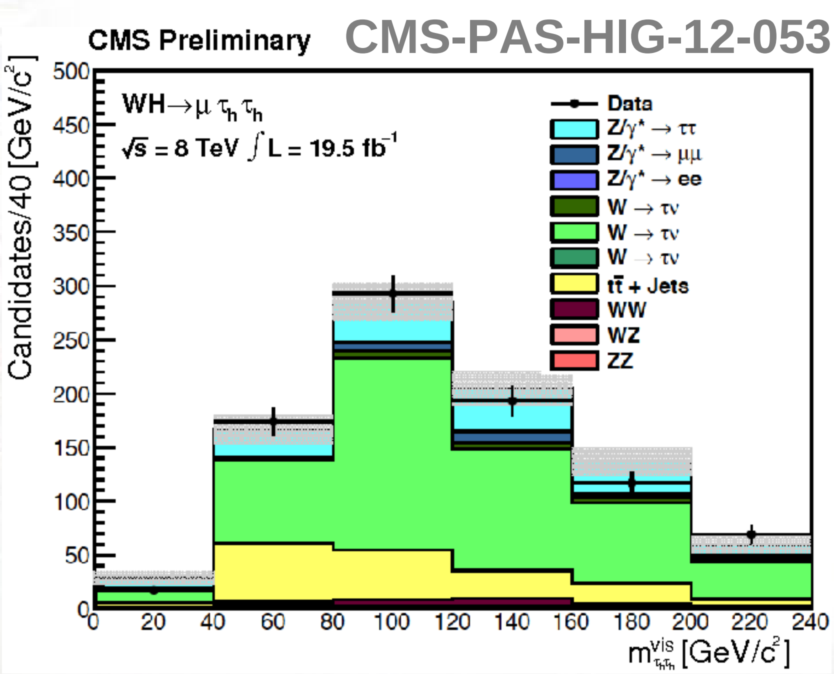
- The Background Estimation can be validated in a Control Region
  - Invert isolation of the tau OS to the lepton
  - Region dominated by W + Jets





Background Composition

- The two different Fake Rates are physical
- How to weigh anti-isolated events?
- Use a weighted average of the Fake Rate Functions



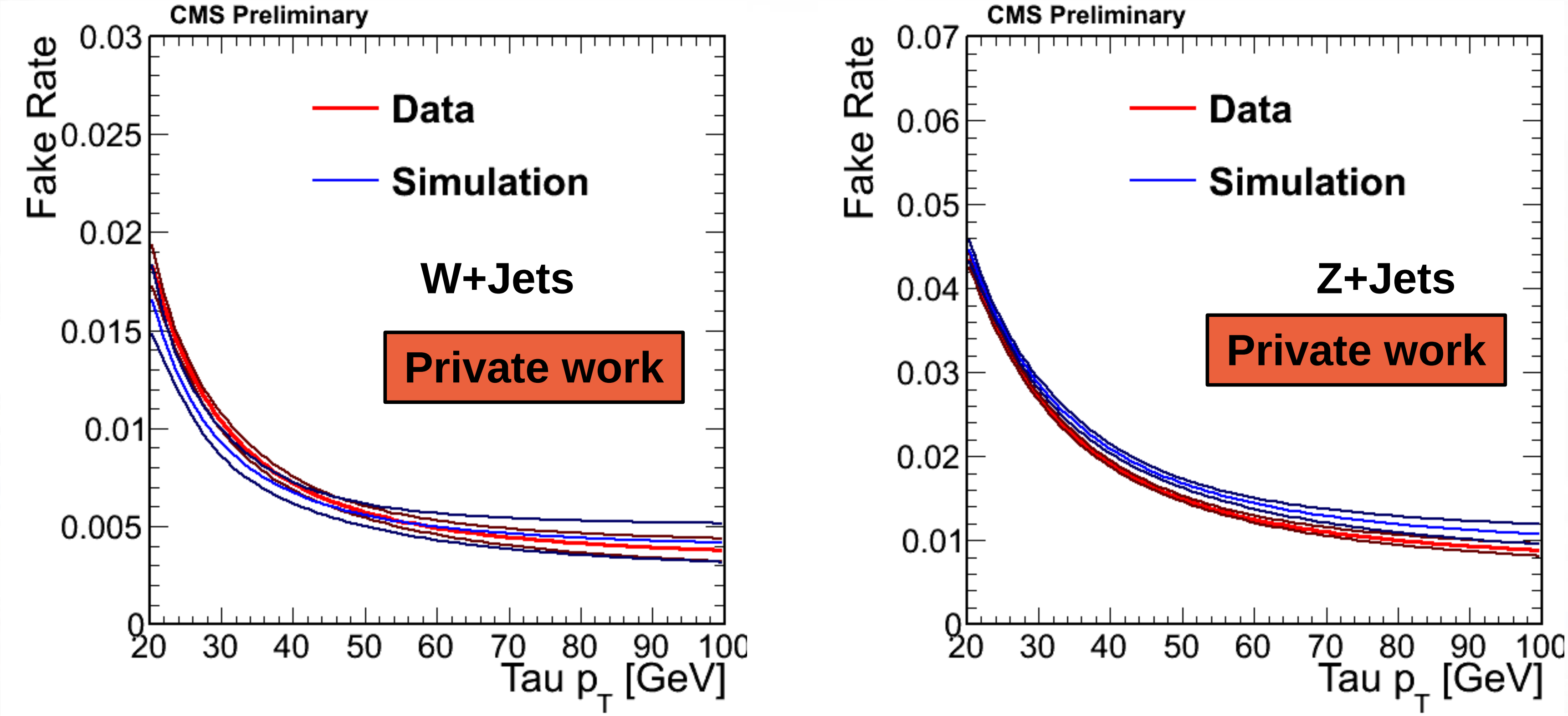
- Take weight from Monte Carlo Simulation
- Ratio of events with
  - 1 fake tau (Z+Jet, $t\bar{t}$+Jet)
  - 2 fake taus (W+Jets)

Conclusions

- Presented a Search for H → ττ in **Associated Production**
- Background Estimation with **Fake Rate Method**
- Understanding the Misidentification Rates is crucial
- The Rate depends on
  - Pile-Up
  - Jet p_T and η
  - Jet Multiplicity
  - Relative Charge of Jet and W boson
- Analysis has background with **two different kind of events**, with two different Fake Rates

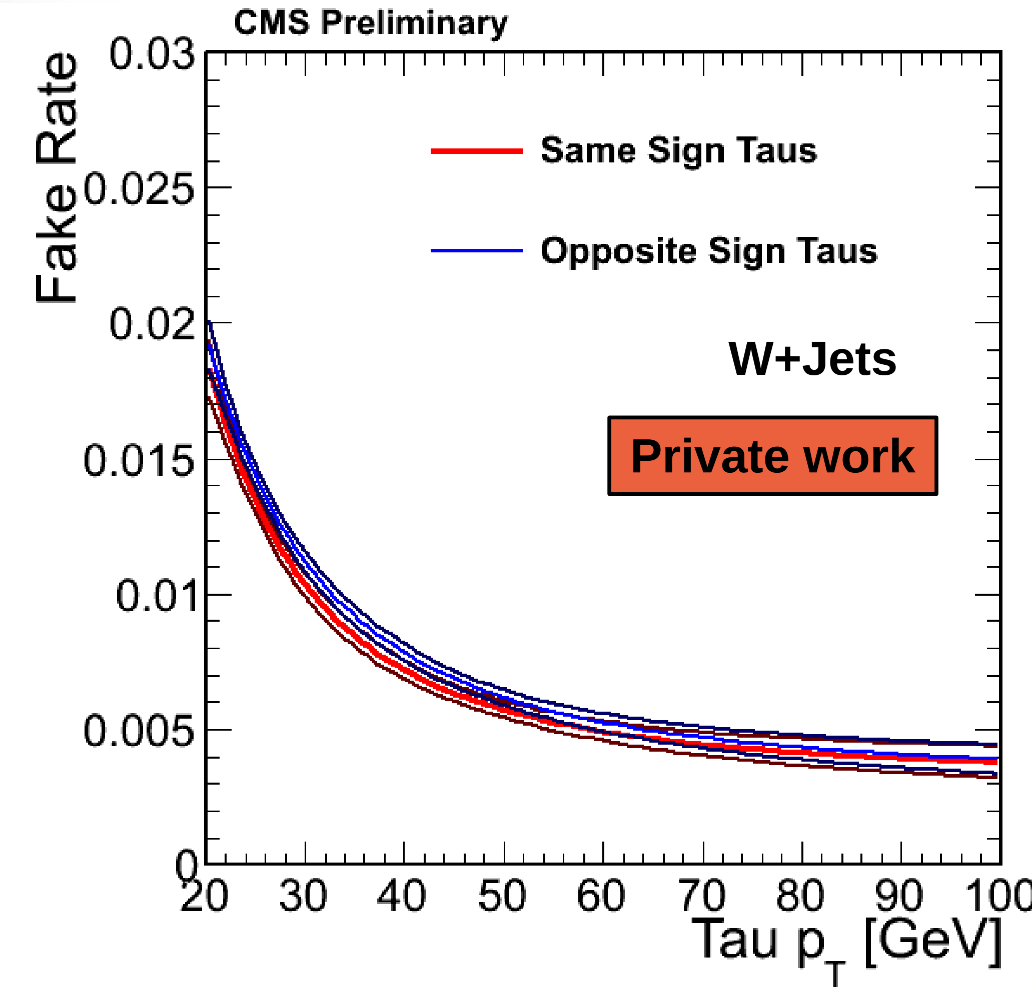
Backup

Fake Rates in Simulation



- The different Fake Rates in W + 2Jets and Z + 1Jet are reasonably **described by simulation**

SS Tau Pairs vs. OS Tau Pairs



- The Fake Rate only depends very weakly on the **relative charge between the two jets**

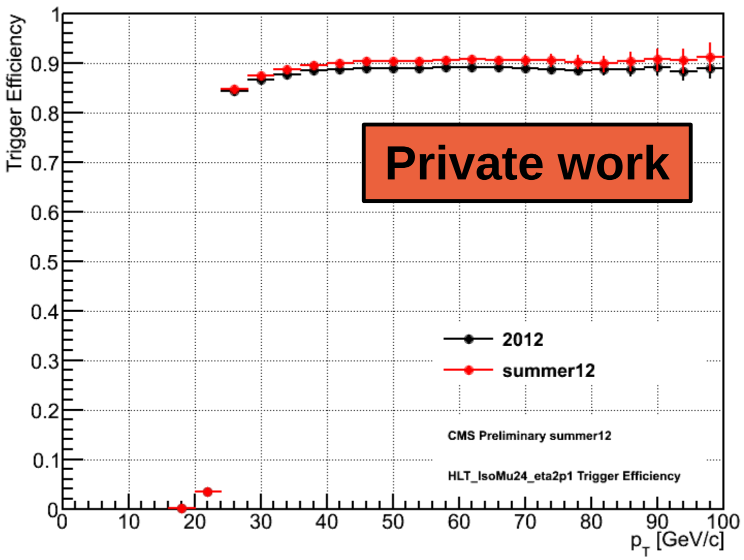
Event Selection

Leading Tau:

$p_T > 45$ GeV
|eta| < 2.3
Tight Isolation

Subleading Tau:

$p_T > 30$ GeV
|eta| < 2.3
Medium Isolation



Electron:

e+τ Cross Trigger
$p_T > 24$ GeV
|eta| < 2.1

Muon:

Single μ Trigger (24 GeV)
$p_T > 24$ GeV
|eta| < 2.1

Topological Selections:

Electron Channel:

$M_T(e, E_T^{miss}) > 50$ GeV **($Z \rightarrow \tau\tau$ veto)**

No two OS electrons with
$|m_Z - m_{ee}| > 25$ GeV **($Z \rightarrow ee$ veto)**

Muon Channel:

$p_T(\tau_1, \tau_2) > 50$ GeV

OR **($Z \rightarrow \tau\tau$ veto)**

$m(\mu, \tau_{OS}) > 80$ GeV