Measurement of the lepton-identification efficiencies for searches for Supersymmetry in events with two taus in the final state

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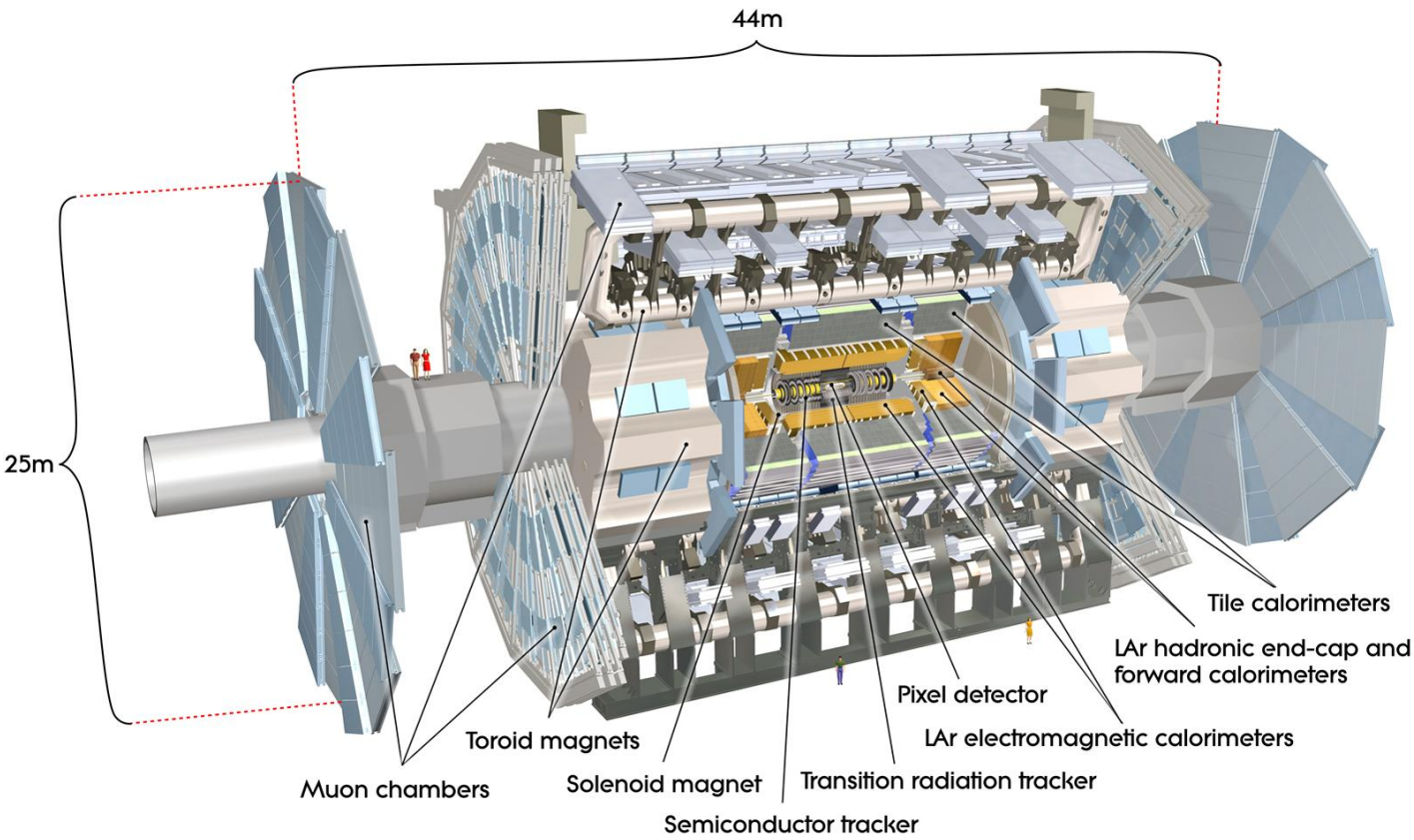
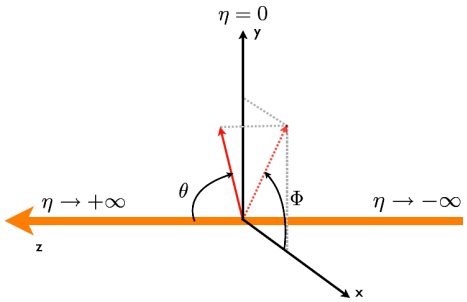
ATLAS Experiment





The pseudorapidity is defined as $\eta = -ln\tan(\theta/2)$

Supersymmetry

Space-time symmetry between bosons and fermions that turns a bosonic state into a fermionic state, and vice versa.

$$Q\,|Boson\rangle = |Fermion\rangle \qquad Q\,|Fermion\rangle = |Boson\rangle \qquad (1)$$

Bosons		Fermions	
gluon	g	gluino	$\tilde{g}$
weak	$W^{\pm}$, Z	wino, zino	$\tilde{w}^{\pm}$, $\tilde{z}$
hyper-charge	B^0	bino	$\tilde{B}^0$
sleptons	$\tilde{\nu}_L$, $\tilde{e}_L$	leptons	ν_L, e_L
	$\tilde{e}_R$		e_R
squarks	$\tilde{u}_L$, $\tilde{d}_L$	quarks	u_L, d_L
	$\tilde{u}_R$		u_R
	$\tilde{d}_R$		d_R
Higgs	H_1	higgsinos	H_1
	H_2		H_2

Particle Content of the MSSM

Electroweak Production

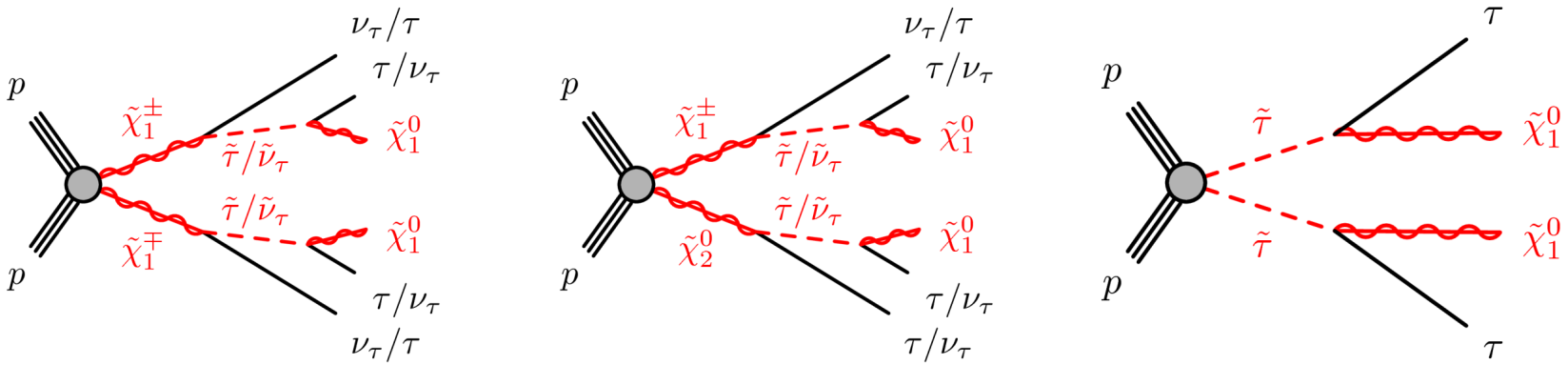
Electroweak symmetry breaking process mix the higgsinos and the electroweak gauginos.

$\tilde{H}_u^0$, $\tilde{H}_d^0$ and $\tilde{B}^0$, $\tilde{z} \longrightarrow$ **neutralinos** $\tilde{\chi}_i^0$ (i=1,2,3,4)

$\tilde{H}_u^+$, $\tilde{H}_d^-$ and $\tilde{w}^\pm \longrightarrow$ **charginos** $\tilde{\chi}_i^\pm$ (i=1,2)

The lightest neutralino, $\tilde{\chi}_1^0$, is assumed to be the LSP.

The dominant EW channels:



light stau models

The Di-tau Channel

- Chargino-chargino production
- Direct stau production

One τ decays **hadronically** and the other τ decays **leptonically**.

Identification of a leptonically decaying tau is done via the final lepton.

$\Longrightarrow$ Search for events with:

- one hadronically decaying **tau** (T)
- one **light lepton**: muon (M) or electron (E)
- **missing energy**

TE - one tau and one electron TM - one tau and one muon

SM Background

The main background to the di-tau channel arises from five different SM processes:

- W+jets processes
- Z+jets processes
- Diboson processes
- $t\bar{t}$ processes
- Multi-jet processes

Events Selection

- **Single lepton trigger (muon/electron trigger)**
- **Cosmic muon veto**
- **2 OS leptons cut**: tau + electron / tau + muon

- P_T **cuts**:
  - **electron/muon** - $p_T > 25 GeV$
  - **tau** - $p_T > 20 GeV$
- η **cuts**:
  - **electron** $|\eta| < 2.47$
  - **muon** - $|\eta| < 2.4$
  - **tau** - $|\eta| < 2.47$

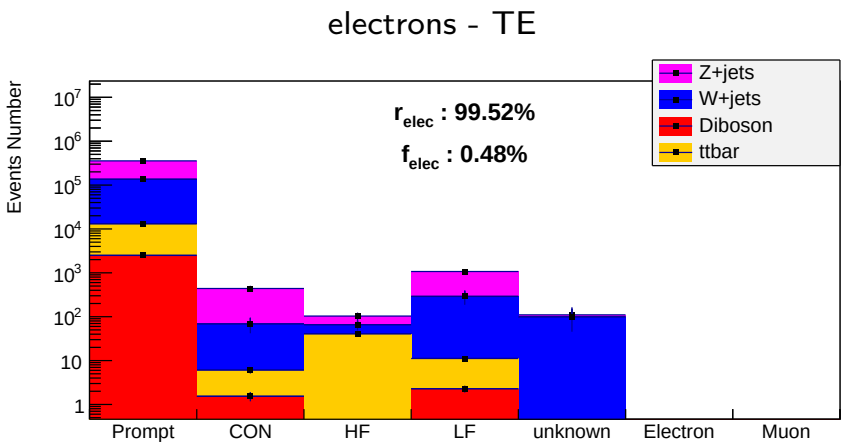
Origin of reconstructed leptons in MC simulations

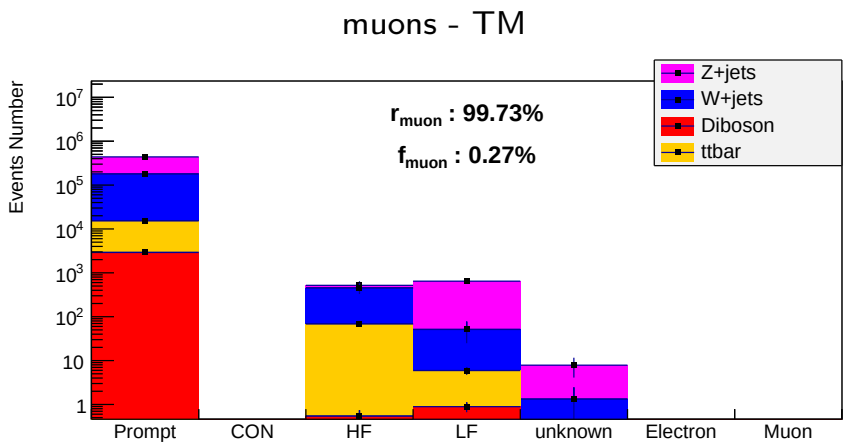
The possible origins of the reconstructed leptons are split into seven categories:

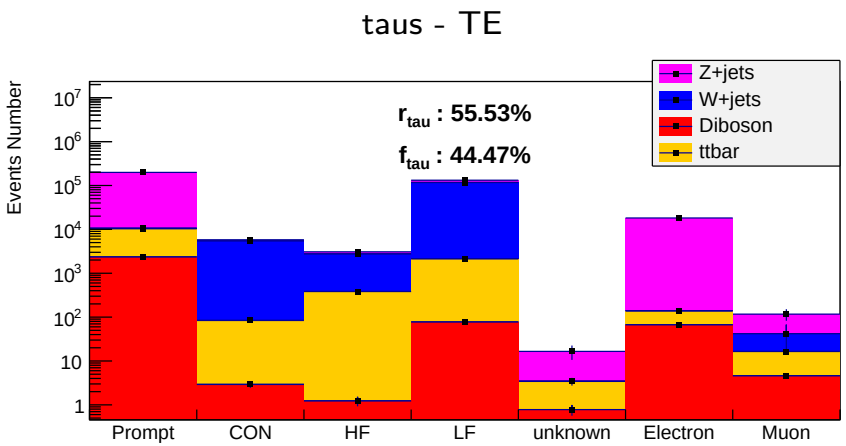
1. Prompt lepton - real lepton
2. Conversion (CON) - electrons from photon conversion.
3. Light flavour (LF) - Light flavour hadron
4. Heavy flavour (HF)- Heavy flavour hadron or semi-leptonic heavy quark decays.
5. Electron - prompt electron (only for taus).
6. Muon - prompt muon (only for taus).
7. Unknown - the reconstructed lepton does not match any other category.

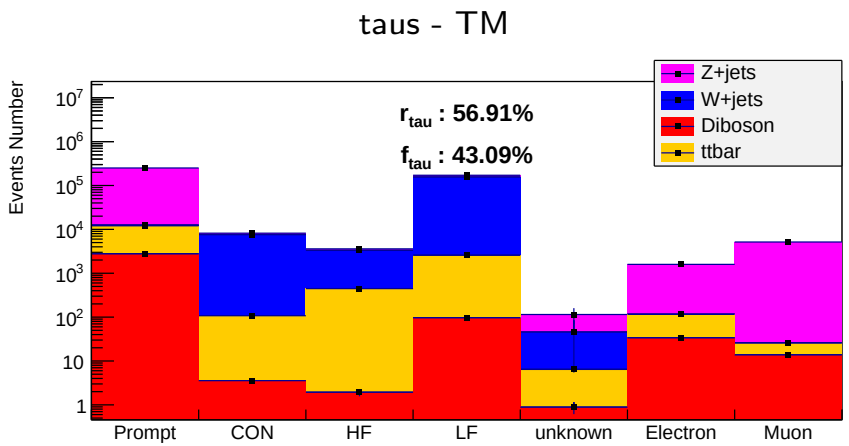
prompt leptons $\longrightarrow$ '**real leptons**'
other origins $\longrightarrow$ '**fake leptons**'

Origin of Leptons in the Tau+light lepton Events in SM Background Processes









Light lepton is real, fake taus are mostly from the W+jets

Goal

Measurement of the SM background originating from fake taus

Assumption: The light lepton is always real.

Method: Semi-data driven method - Matrix method.

Data: the full datasets recorded in 2012 at $\sqrt{s} = 8$ TeV with an integrated luminosity of approximately 20.3 fb^{-1}.

Definitions

Two sets of selection criteria for taus are defined:
loose taus and **tight** taus.

Efficiency definitions:

Real efficiency:

The probability of a real, prompt lepton to pass the tight selection criteria. $r = \frac{N_{real}^{tight}}{N_{real}^{loose}}$

Fake efficiency:

The probability of a fake, non- prompt lepton to pass the tight selection criteria. $f = \frac{N_{fake}^{tight}}{N_{fake}^{loose}}$

Matrix Method:

$$N^{loose} = N_{real}^{loose} + N_{fake}^{loose}$$

$$N^{tight} = N_{real}^{tight} + N_{fake}^{tight} = r\ N_{real}^{loose} + f\ N_{fake}^{loose}$$

$$\boxed{N_{fake}^{tight} = \frac{f}{r-f}(N^{loose} r - N^{tight})}$$

Matrix Method in the **TM** Channel:

Fake efficiencies:

Weighted average fake efficiency for taus: $\boxed{f^{\tau} = \Sigma_j (sf \times R_f^j \times f^j)}$

- **Light-flavor** fake efficiency is the most dominant type of fake taus.
  It is evaluated in the **W+jets CR**, which is rich in fake taus.
- measuring fake efficiency in process j from truth information in MC: $f^j = \frac{N_f^{tight}}{N_f^{loose}}$
- Calculating process independent scale factors in WCR: sf$= \frac{f_{data}}{f_{mc}}$
- Measuring in MC the fraction of fake efficiency in process j in WCR from MC: $R^j = \frac{f^j}{f^{all\_processes}}$

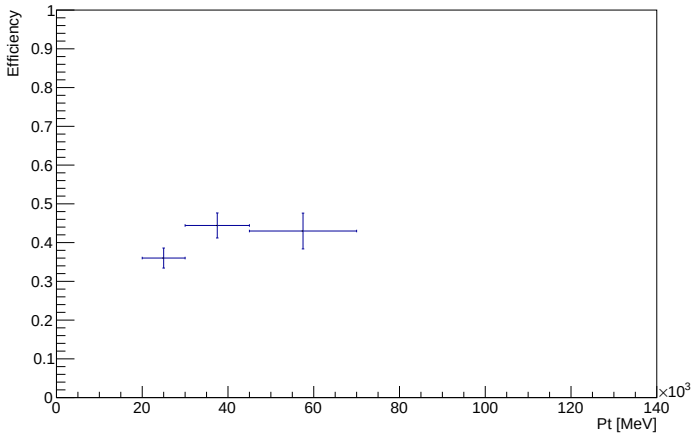
Real efficiencies:

Weighted average real efficiency for taus: $\boxed{r^{\tau} = \Sigma_j (sf \times R_r^j \times r^j)}$

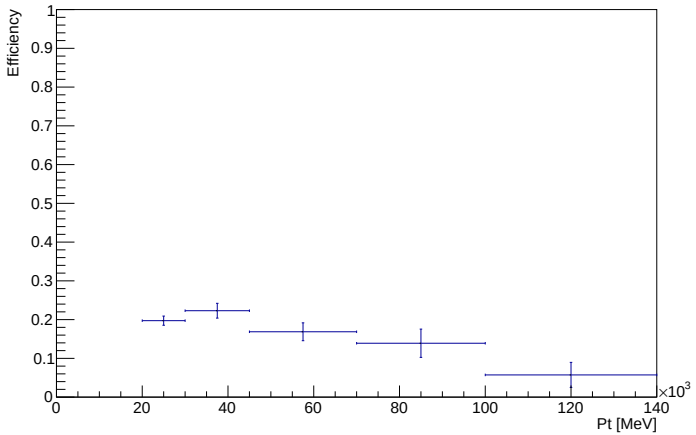
- Evaluating real efficiencies in **Z+jets CR**.
- measuring real efficiency in process j from truth information in MC: $r^j = \frac{N_r^{tight}}{N_r^{loose}}$
- ...

Matrix Method Results

real efficiency



fake efficiency

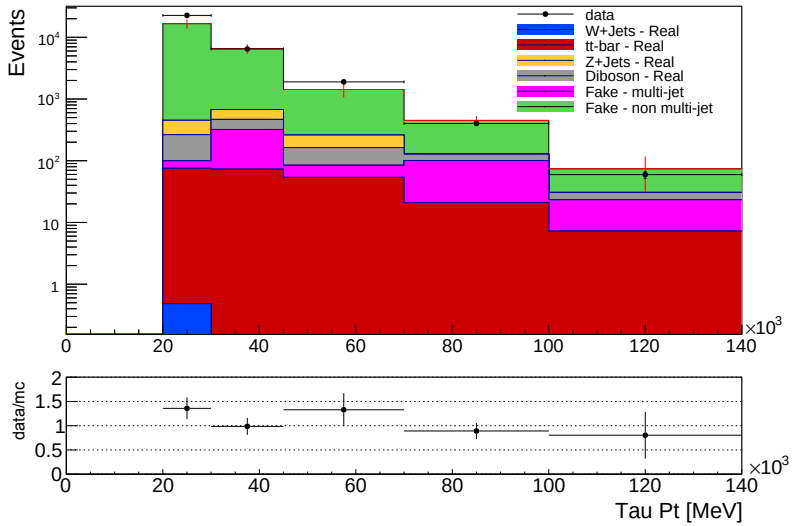


Average values

Real efficiency: 0.40 ± 0.09

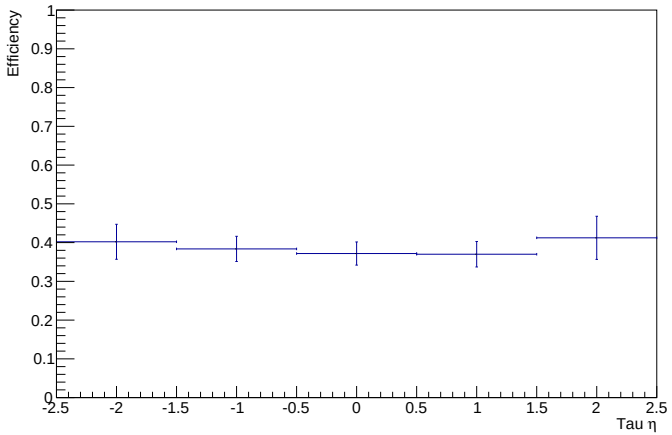
Fake efficiency: 0.18 ± 0.05

fake background

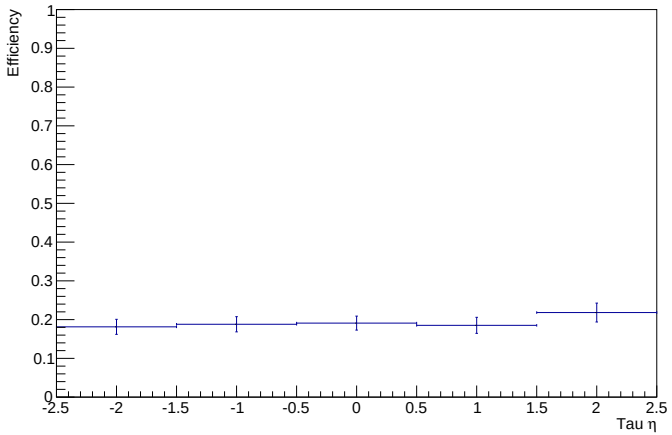


Matrix Method Results

real efficiency



fake efficiency



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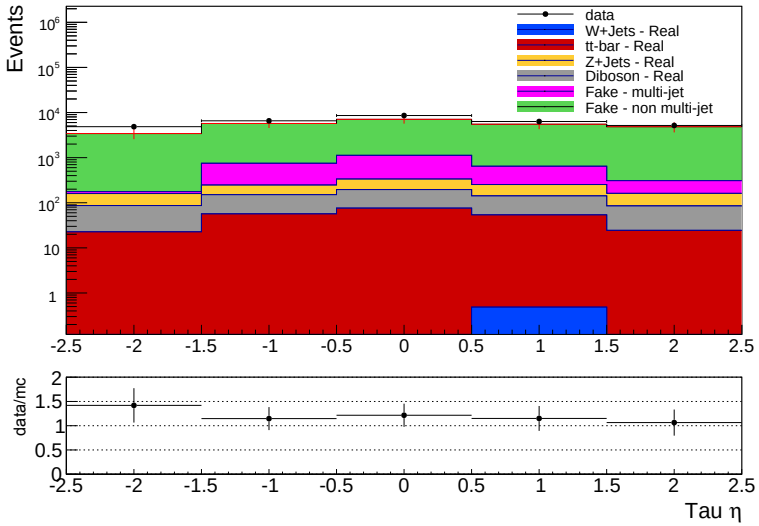


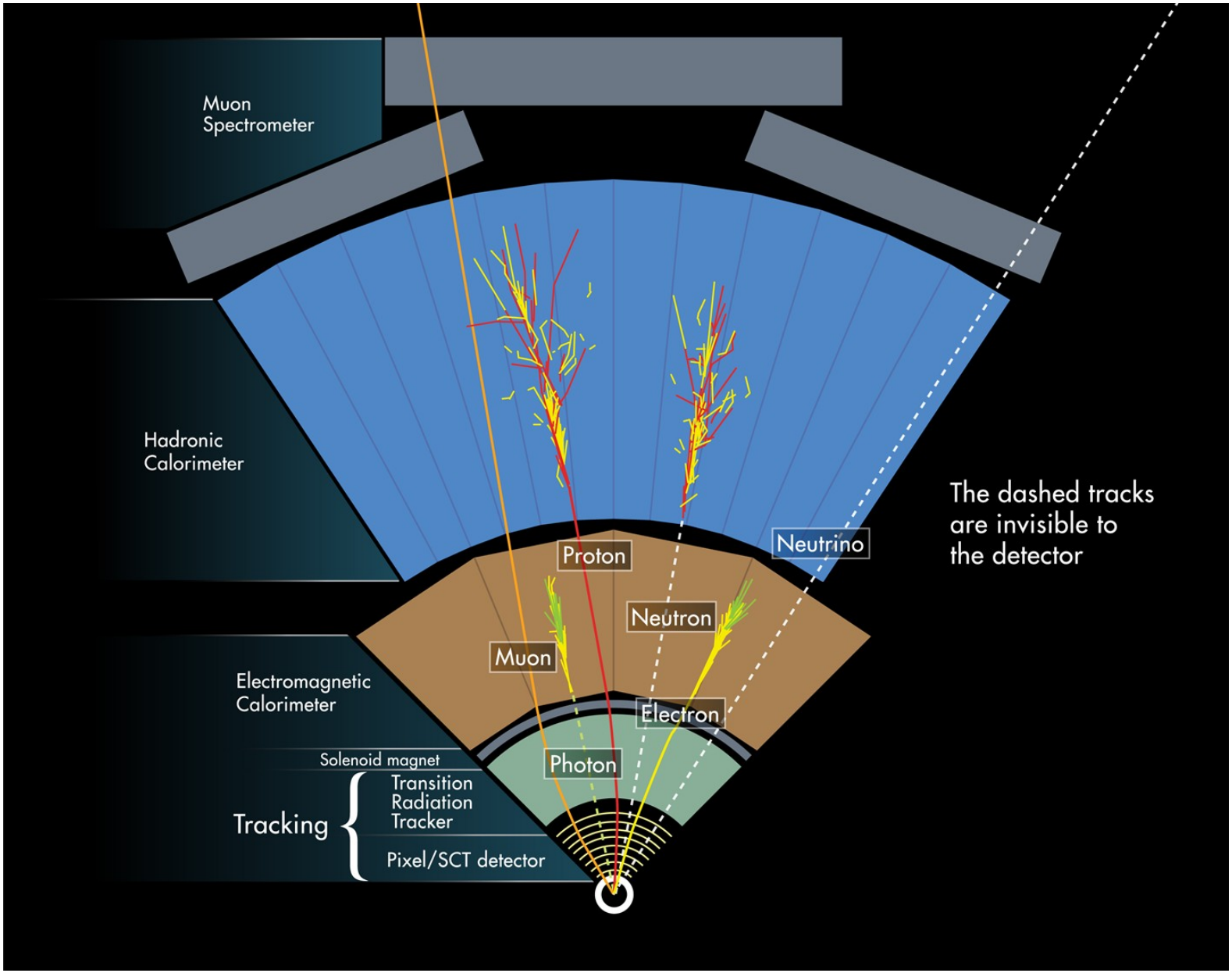
Summary:

In the search for events with two taus (hadronically decaying tau and leptonically decaying tau) in the final state:

- The origin of the reconstructed leptons in SM background processes has been evaluated through the MC simulations.
  1. 99% of light leptons are real.
  2. most of the fake taus are from light flavour jets.
  3. most of the fake background is in W+jets processes.
- Real and fake efficiencies of taus have been measured in data and MC.
- This study proves that the fake background can be estimated via the Matrix Method.
- The method is proposed for LHC run-2, which will start in 2015.

Thank you for your attention.

Backup


Muon
Spectrometer
Hadronic
Calorimeter
Electromagnetic
Calorimeter
Solenoid magnet
Tracking
Transition
Radiation
Tracker
Pixel/SCT detector
Proton
Neutrino
Neutron
Muon
Electron
Photon
The dashed tracks
are invisible to
the detector

- The transverse missing energy $\vec{E}_T^{miss}$: the vectorial sum of the transverse energy of all the particles in the event multiplied by (-1), $\vec{E}_T^{miss} = -\sum_{i \in particles} \vec{E}_{T\,i}$.
- The transverse mass:
$m_T = \sqrt{2 \cdot E_T^{miss} \cdot p_T(lepton) \cdot (1 - \cos\Delta\phi(\vec{E}_T^{miss}, \vec{p}_T(lepton)))}$.

W+jets CR (loose taus)

WCR optimized for purity and statistics.

W+Jets CR definition:

TM Channel

B-jet veto

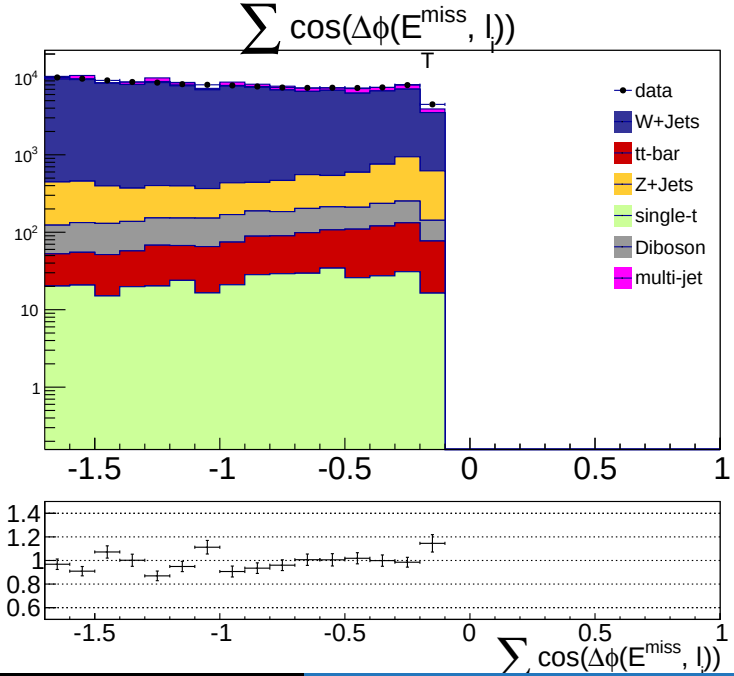
$m_T(muon, E_T^{miss}) > 60 GeV$

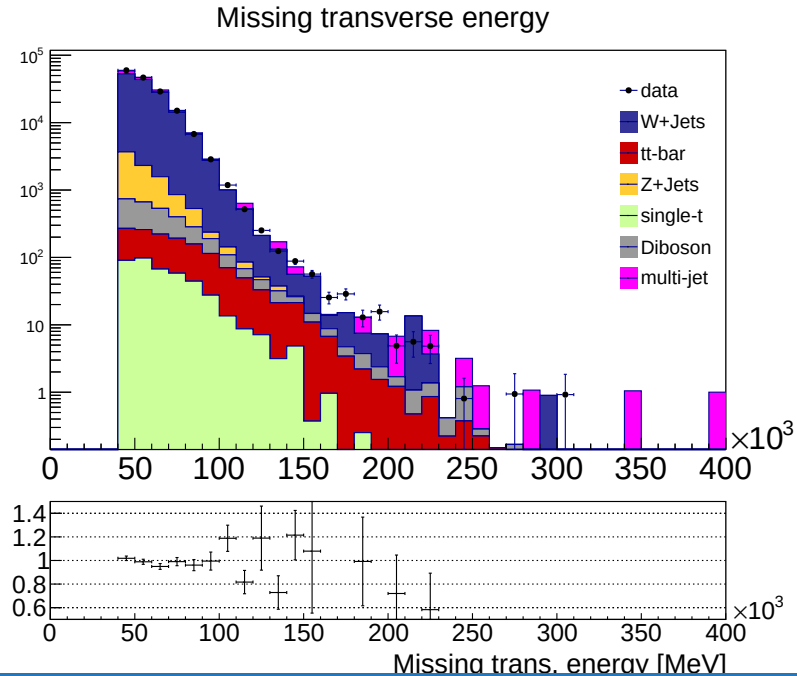
$\Sigma_{lep} cos(\Delta\phi(E_T^{miss}, lep)) < -0.15$

$\Delta R(muon, tau) > 0.3$

The transverse missing energy$> 40 GeV$

	Events number
W+jets	140979±1776
Multi-jet	13001±1410
Z+jets	6439±152
Diboson	1692±14
tt-bar	1014±14
Single-t	424±17
SM total	163551±2273
Data	162304±400
Purity	0.861±0.001





Z+jets CR (loose taus)

ZCR optimized for purity and statistics.

Z+Jets CR definition:

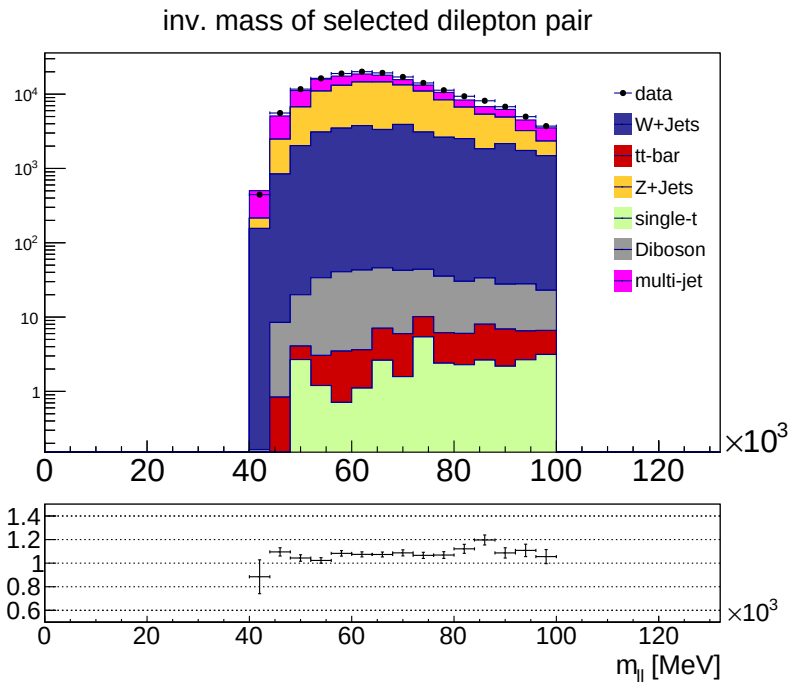
B-jet veto

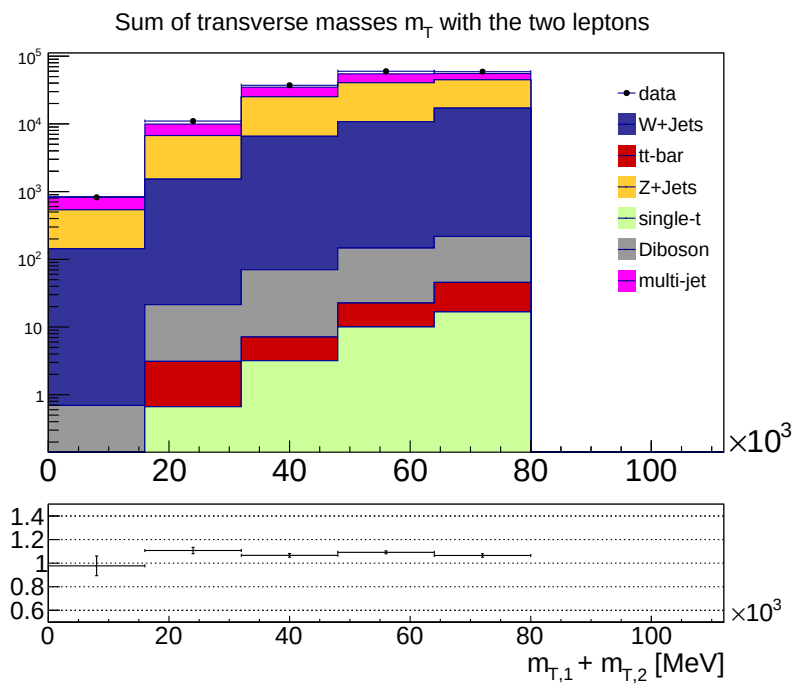
in Z window

$\Sigma_{lep} m_T < 80\text{GeV}$

$\Delta\phi_{ll} > 2.4$

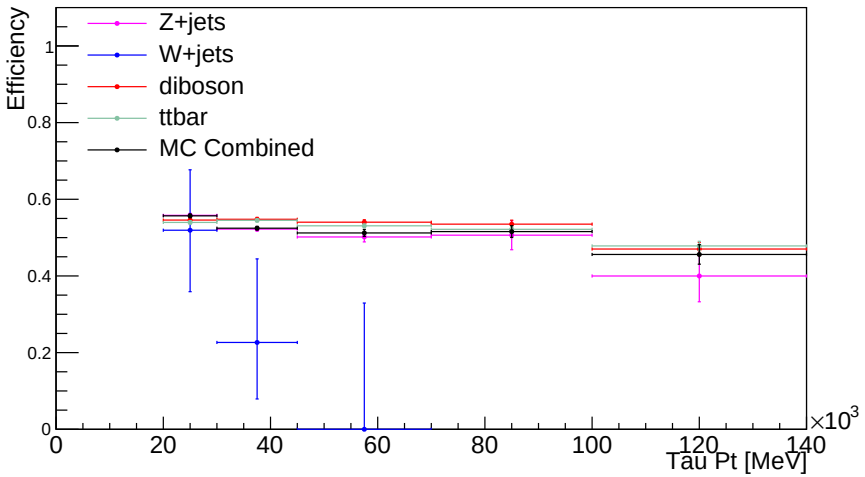
	Events number
Z+jets	81683±571
Multi-jet	38058±717
W+jets	35609±890
Diboson	378±6
tt-bar	48±3
Single-t	31±4
SM total	155806±1278
Data	167805 ±410
Purity	0.5242±0.0006



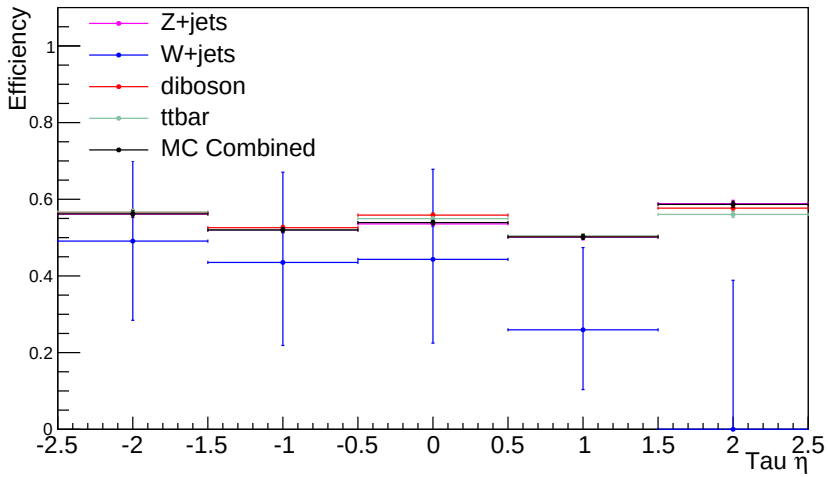


Efficiencies from MC (1 prong taus)

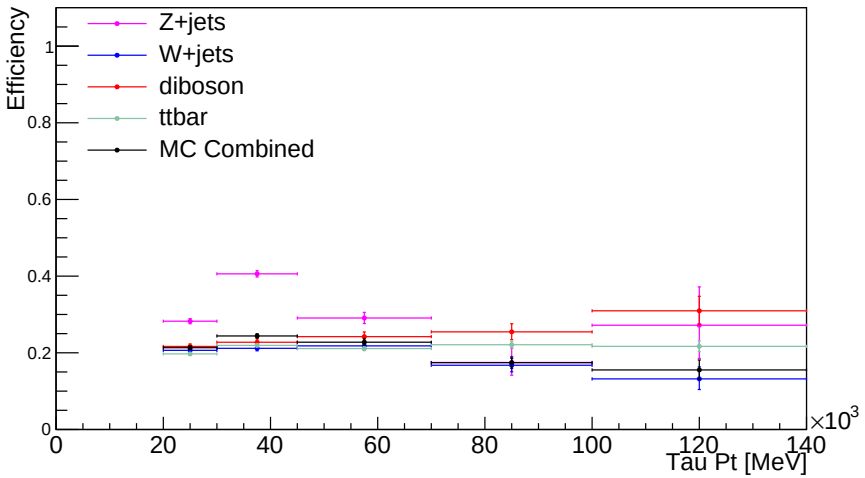
real efficiency vs tau momenta



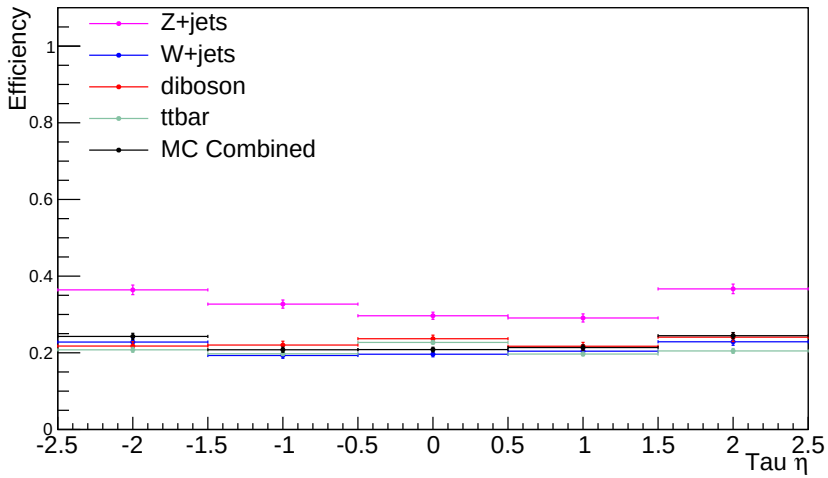
real efficiency vs tau eta



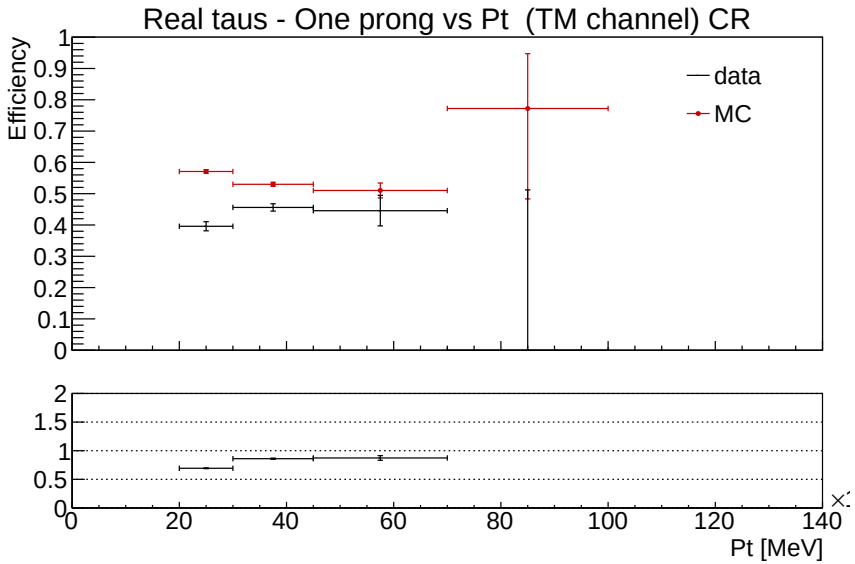
fake efficiency vs tau momenta

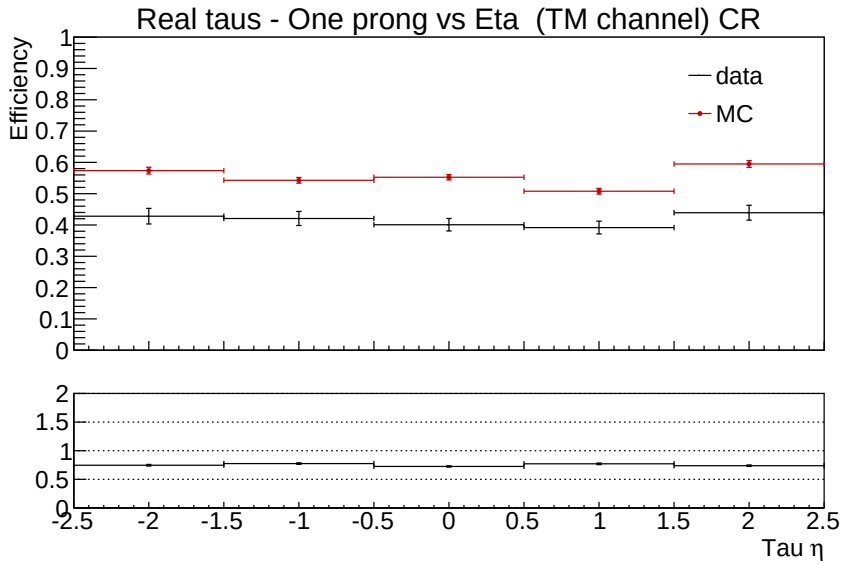


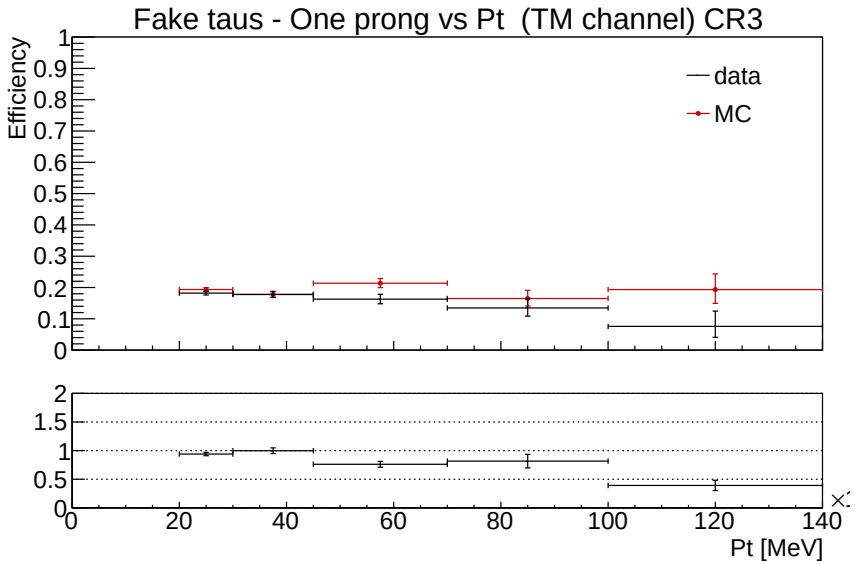
fake efficiency vs tau eta

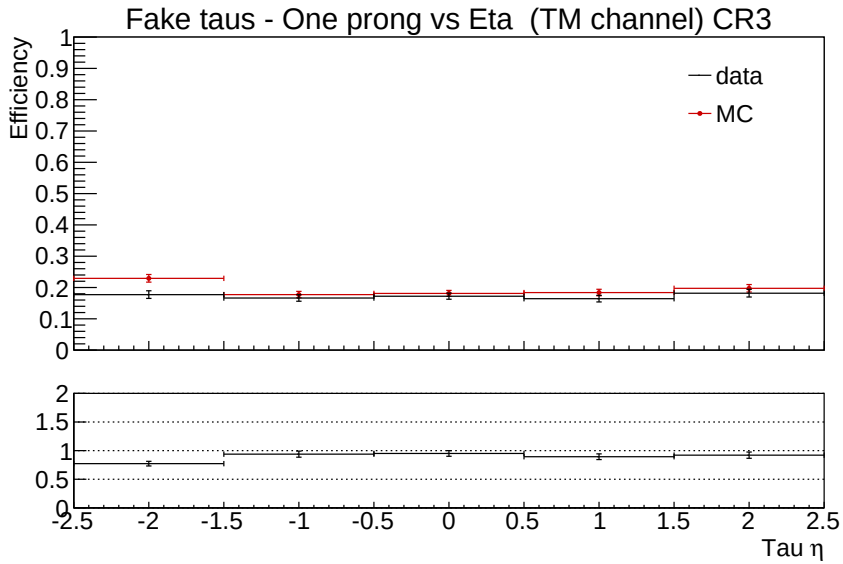


Scale Factors for **Real** and **Fake** Efficiencies (1 prong taus)



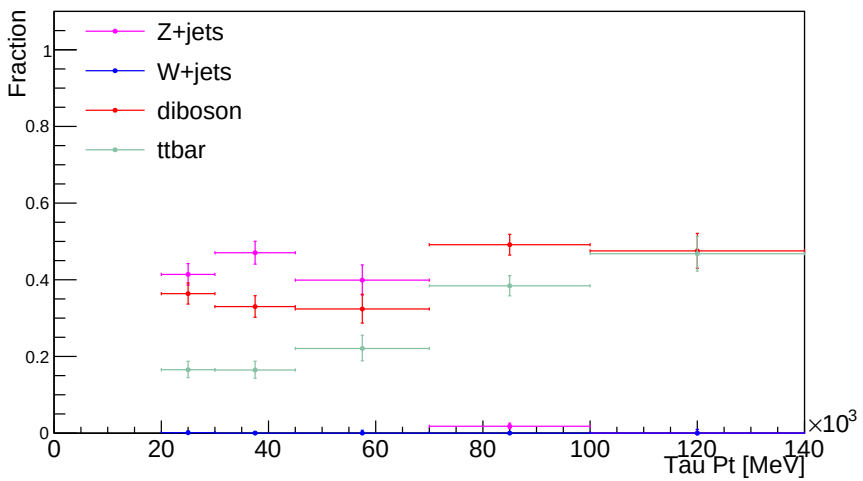




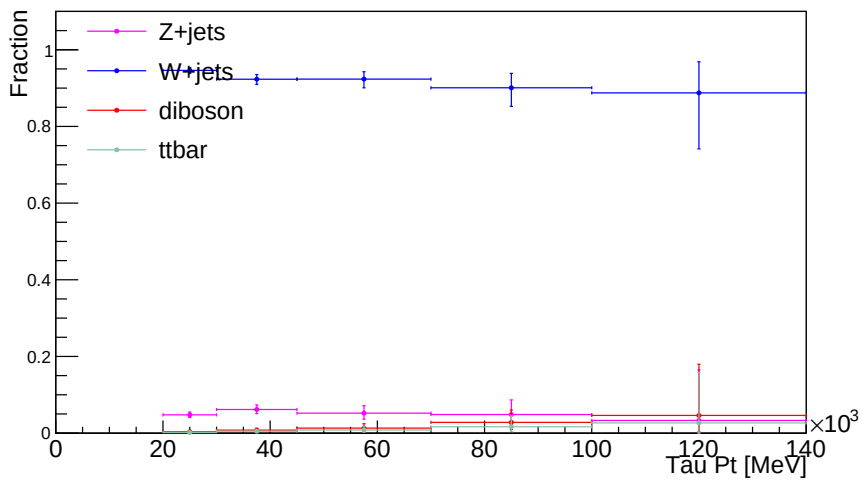


Fake/Real Fractions in WCR from MC (1 prong taus)

Real



Fake



Tight/Loose Events in WCR from Data (1 prong taus)