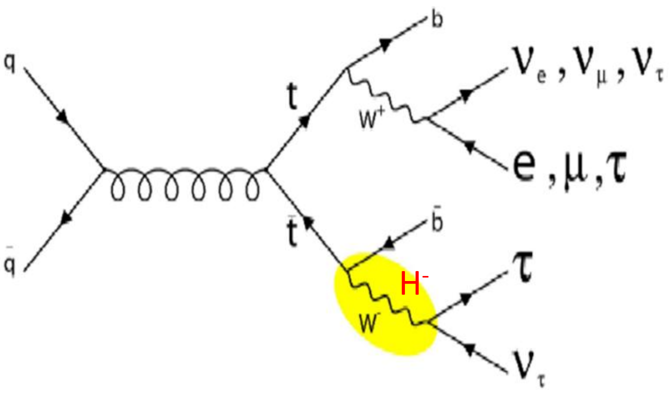
Top in tau and impact on the low mass Higgs sector at CDF

On behalf of Matteo Corbo, Aurore Savoy-Navarro and Stephan Lammel

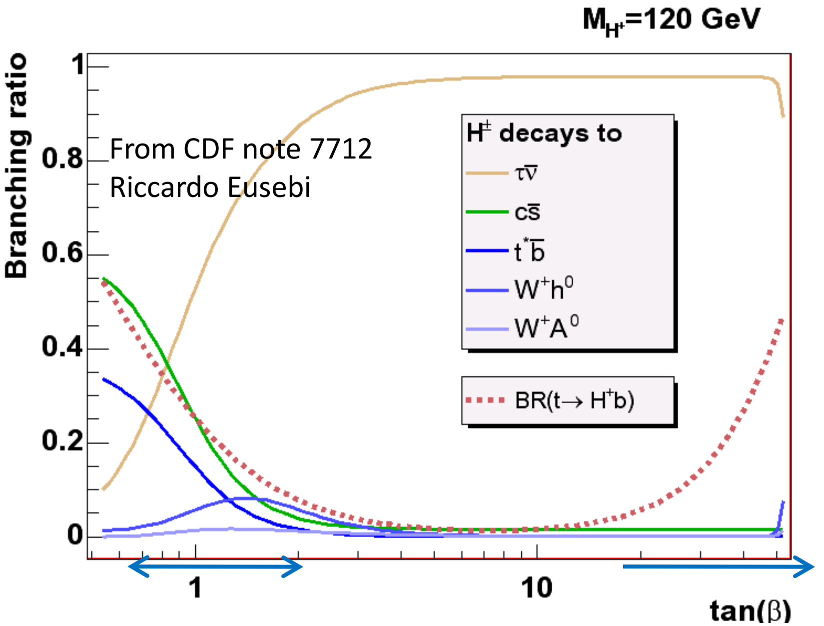
Theoretical Interest

- Standard Model
  - Lepton universality in EW
- Standard Model extensions:
  - Adding two (or more) Higgs doublet fields
  - The models provide at least:
  1. Two parity even and one parity odd neutral Higgs particles
  2. A charged Higgs

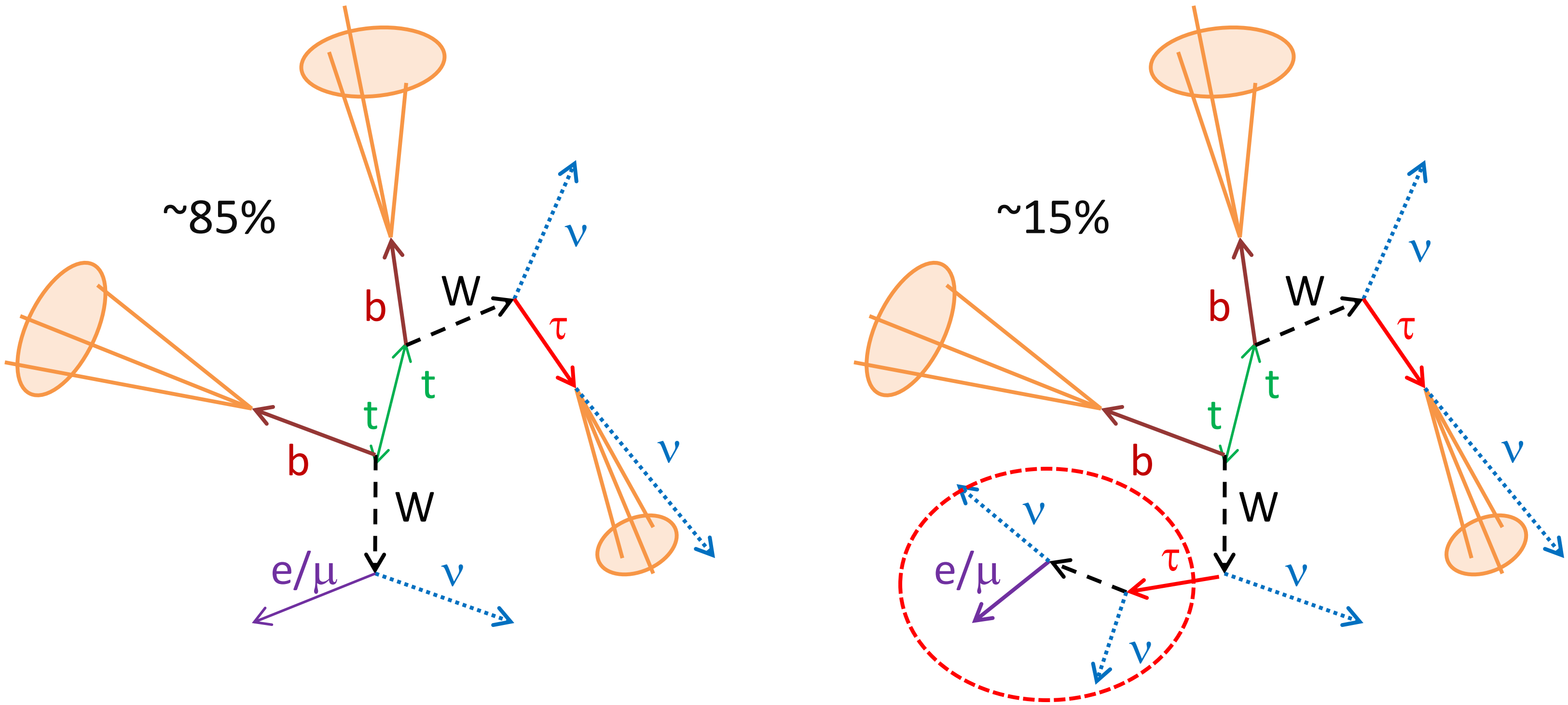


- In the low mass regime top decay in $H^\pm$ competes with W channel
- In MSSM $H^\pm$ decay in tau becomes dominant with tan(β) > 1
- $H^\pm$ enhances top decay in tau
  - tan(β) ≈ 1 and tan(β) >> 1
  - Deviation from SM predictions

- Top decay in tau test for SM
  - Less explored channel



Signature and Triggers



- Previous analysis explored "High Pt Lepton" samples
  - With 20 GeV electrons or muons
- More acceptance in "Lepton plus isolated track"
  - Leptons with Pt > 8 GeV
  - Thus sensitive to tau into e/μ decays
  - "Isolated track" for tau preselection

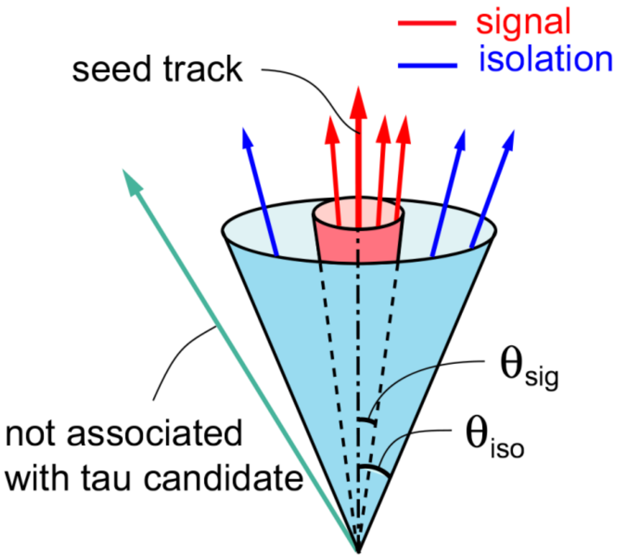
Previous Studies

- Previous analysis done with small statistic
  - Tourneur, Savoy-Navarro (note 8627) 1 fb^{-1}
  - Amerio, Gresele, Lazzizzera (note 8443) with 311 pb^{-1}
  - Frisch, Levy (note 8287) with 335 pb^{-1}
- D0 latest result with 1 fb^{-1}
  - Phys. Lett. B 682, 278 (2009)
- Expecting 10 fb^{-1} integrated luminosity soon available
  - Starting to be sensitive to small SM deviations in this channel
  - SM predictions ≈ 2500 events of top pair decay with hadronic tau

Tau Offline Reconstruction

- Tau decay modes
  - 35.2 % in leptons not separable from prompt leptons
  - 64.8 % in hadrons
    - One or three charged tracks + neutrals
    - Neutrals made mostly by π_0's

- Standard CDF strategy for tau reconstruction:
  - Starting point narrow cluster few calorimetric towers
  - Higher Et tower, "seed tower"
  - Track pointing to the tower, "seed track"
  - "Seed track" as reference
  - Signal cone $\theta_{sig} = \min\left(0.17, \frac{5.0\text{rad}/GeV}{E^{cl}}\right)\text{rad}$
  - Cluster energy as indication of tau boost
  - Signal tracks and π_0's
  - Iso cone $\theta_{iso} = 0.52\text{rad}$
  - Isolation tracks and π_0's for vetoing QCD



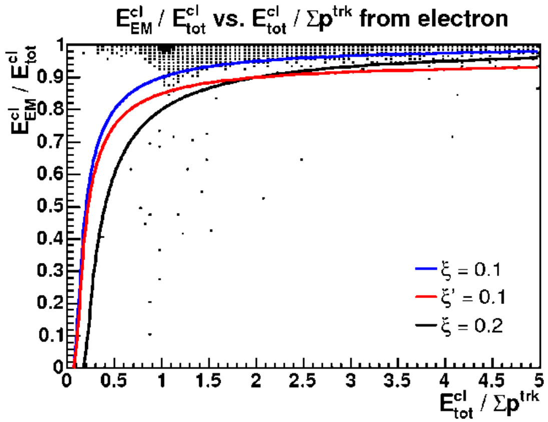
- Tau Reconstruted in the central region
  - In CDF tau momentum: π_0's energy and track Pt

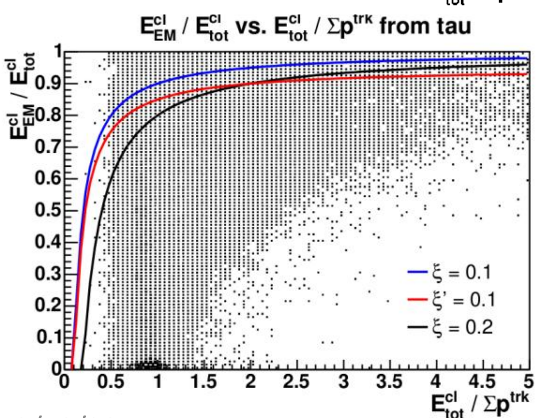
Tau Idetification

- Electron removal

$$\xi = \frac{E_{had}}{\sum|\vec{p}|} = \frac{E_{tot}}{\sum|\vec{p}|}\left(1 - \frac{E_{EM}}{E_{tot}}\right)$$

$$\xi^1 = \frac{E_{tot}}{\sum|\vec{p}|}\left(0.95 - \frac{E_{EM}}{E_{tot}}\right)$$





Skimming		
ξ'	< 0.1	→ Electron removal
E/P	< 0.4	→ Muon removal
$Et_{seedtwr}$	> 6 GeV	
Ntwr	<= 6	
$Pt_{seedtrk}$	> 6 GeV	Energy, momentum cuts
$Et_{cluster}$	> 10 GeV	Energy, momentum cuts
Ptvis	> 15.0 GeV	Energy, momentum cuts
|ΔZ|	< 5 GeV	
CES |Z|	$9 < \|Z_{CES}\| < 230$ cm	
COT Ax Seg	>= 3	
COT St Seg	>= 2	
ρ_{COT}	< 140 cm	
M_t	< 1.8 GeV	→ Mass constraint
ΣPt_{iso}	< 2.0 GeV	Isolation veto
$\Sigma Et_{\pi 0 iso}$	< 1 GeV	Isolation veto
Pt_{isotrk}	< 1.5 GeV	Isolation veto
N_{trksig}	1,3	
|Q|	1	

Triggers, Data Set

- Triggers
  - Central leptons: CMUP, CMX
  - Central isolated tracks
- Trigger track isolation: no 1.5 GeV tracks in the isolation annulus
- Low energy/momentum thresholds without prescaling
  - CMX after period 12 dinamicaly prescaled
- Current data sample 8.5 fb^{-1}
- Good run requirement
  - Good electromagnetic measurement (Without b-tagging no Silicon tracker required)
  - ~95% efficiency

Ex: up to trigger table 4_00_v-3

TAU_CMUP8_TRACK5_ISO
TAU_CMX8_TRACK5_ISO
TAU_ELECTRON8_TRACK5_ISO

Ex: current trigger table, 5_05_v-3

TAU_CMUP8_TRACK5_ISO
TAU_CMX8_TRACK5_ISO_DPS
TAU_ELECTRON8_TRACK5_ISO

Physical Backgrounds

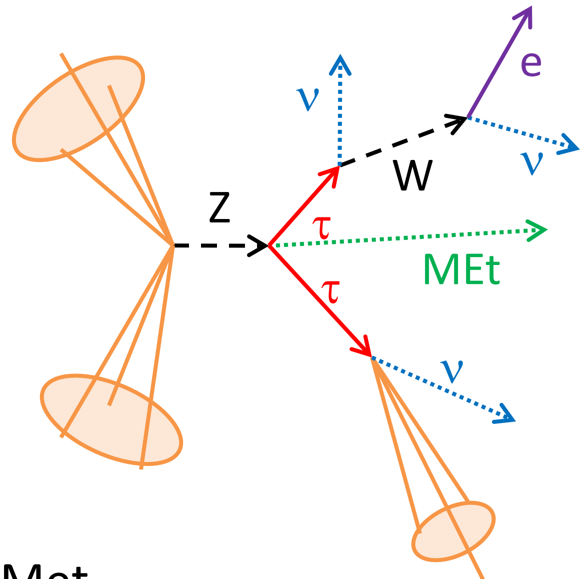
- Selecting τ_h and e
  - Z → ττ
  - Di-boson production

Processes	σ	Expected in 8 fb^{-1}
WW	11.7 pb	97
WZ	3.46 pb	21
ZZ	1.51 pb	5.4
Z→ $\tau_h\tau_e$	355 pb	9'700
tt → t_h + e	100 fb	72
tt → t_h + t_e	20 fb	8.0

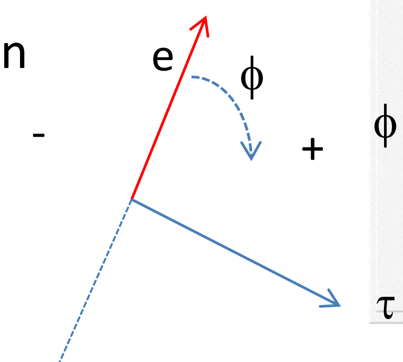
- Preselection for
  - 2 jets with corrected Et > 15 GeV and |η| < 2.4
  - MEt > 20 GeV
- MEt corrected for jets with:
  - Raw Et > 10 GeV
  - |η| < 2.4

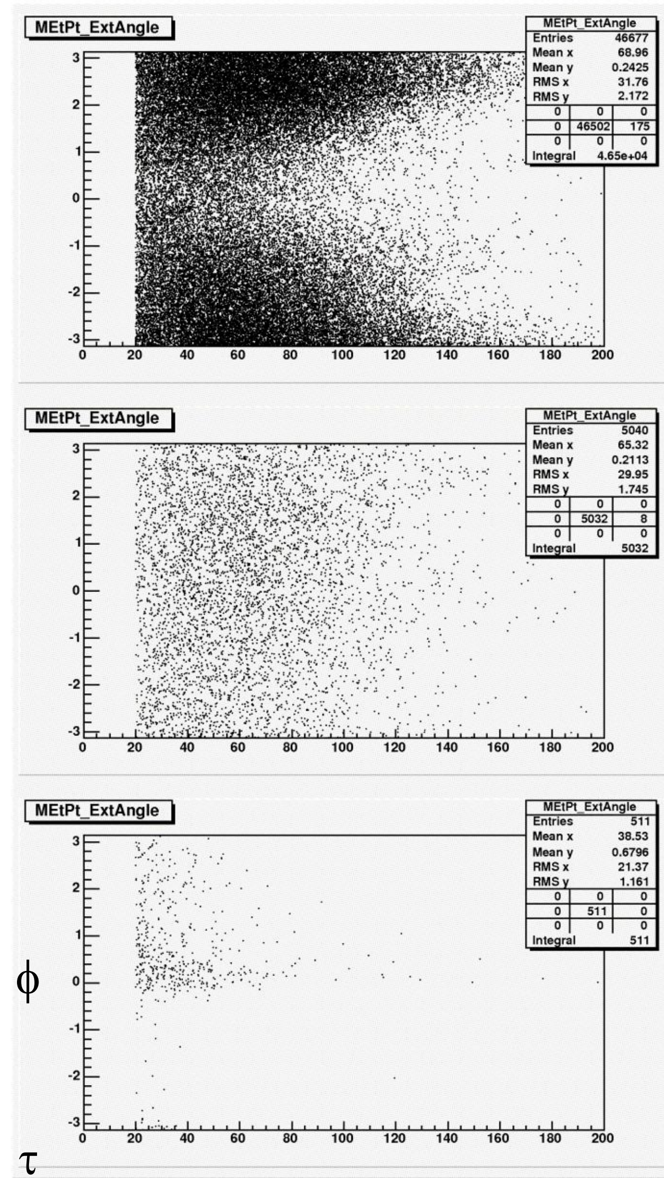
Processes	Exp. Events in 8 fb^{-1}
WW	2.6
WZ	3.8
ZZ	1.8
Z→ ττ	210
tt → τ_h + e	57.6
tt → τ_h + τ_e	6.4

Kinematic



- Met
  - Z into tau MEt in betweem the leptons
  - In top pair preferentially opposite to electron
- Angle between electron and MEt





tt → τ_h + e

tt → τ_h + τ_e

Z→ ττ

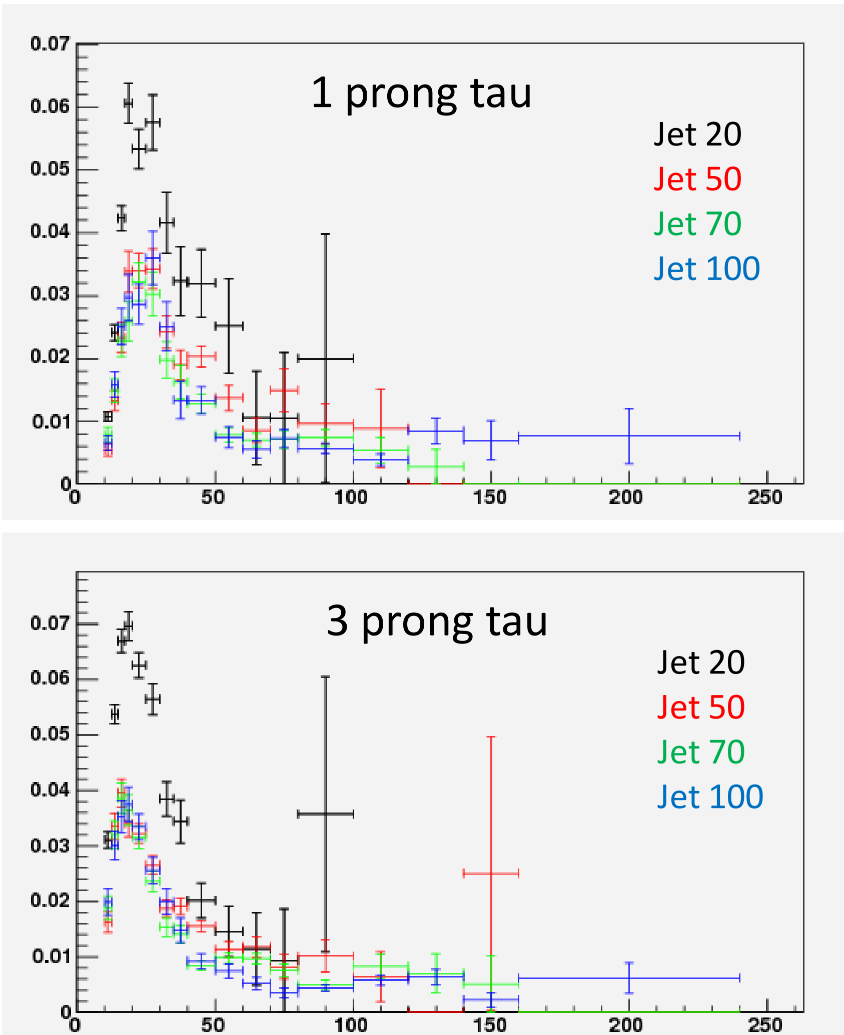
MEt

Background with Fakes

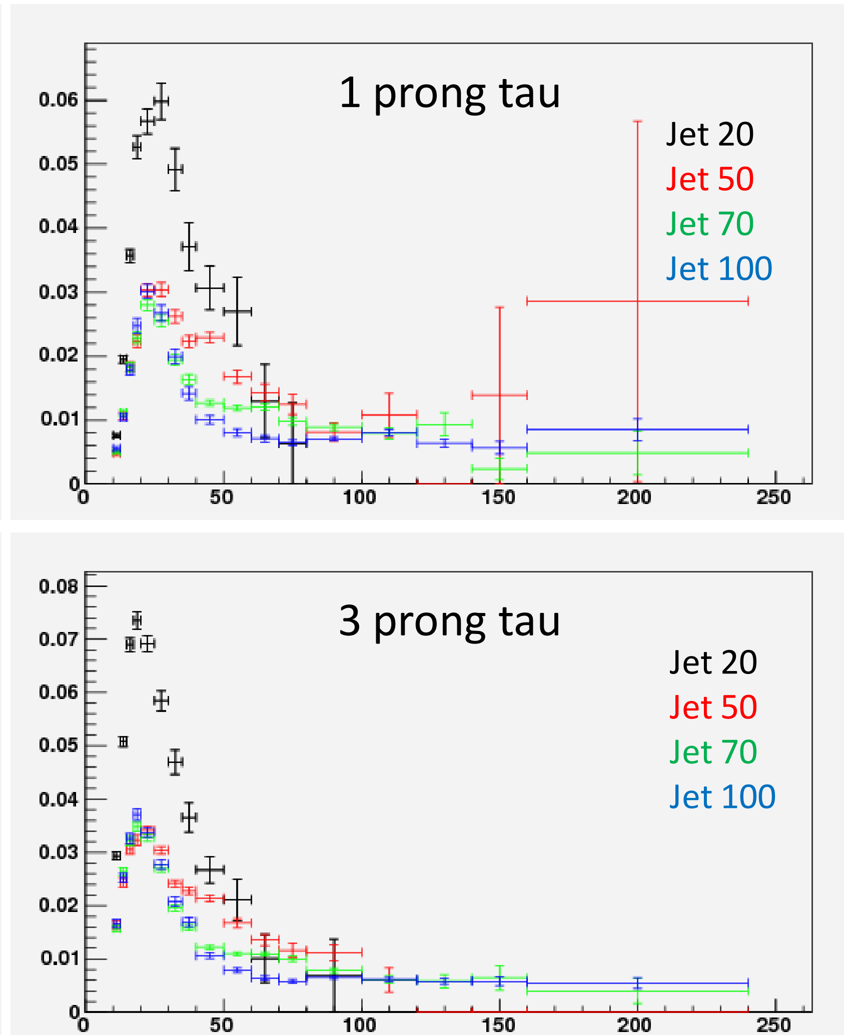
- Background with misidentified objects (fakes)
  - Mainly from jet identified as taus
- In the electron and muon channels
  - $W \rightarrow e/\mu + \nu + 3$ jets
  - $Z/\gamma^* \rightarrow ee/\mu\mu + 3$ jets
- Type of fakes

  $e_f + \tau_f$
  $e + \tau_f$ } Starting from a sample of identified electrons and collecting fake taus we can count for both contributions
  $\tau + e_f$
- Probability of jet to pass the tau identification
  - Jet20, Jet50, Jet70, Jet100 samples
- Events without EW contribution
  - No ID electrons
  - No ID muons
  - MEt < max{10, 10+(SumEt-50)/20} GeV
    (Met < 20 GeV for high SumEt)
- Tau fakable objects definition
  - Offline tau objects with Et > 10 GeV
  - Electron and muon removal
    - $\xi' > 0.1$
    - $E/P > 0.4$
  - Geometrical fiduciality

Results



Periods 1 to 4



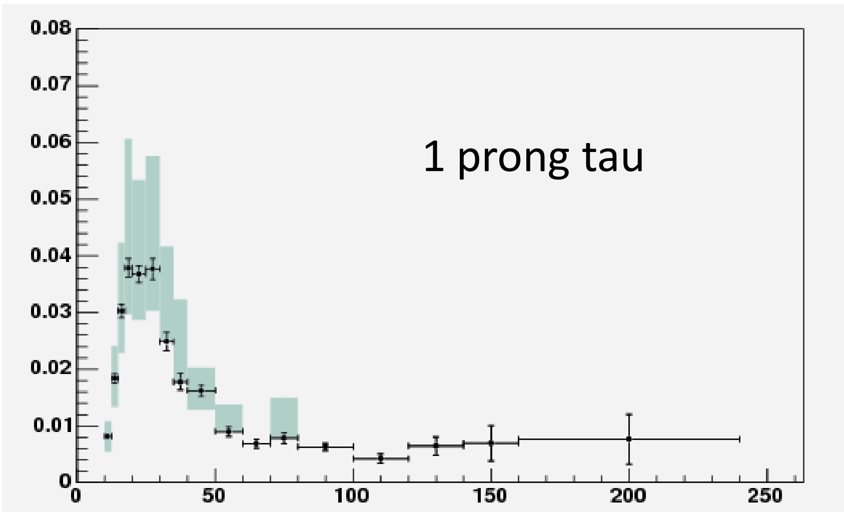
Periods 18 to 28

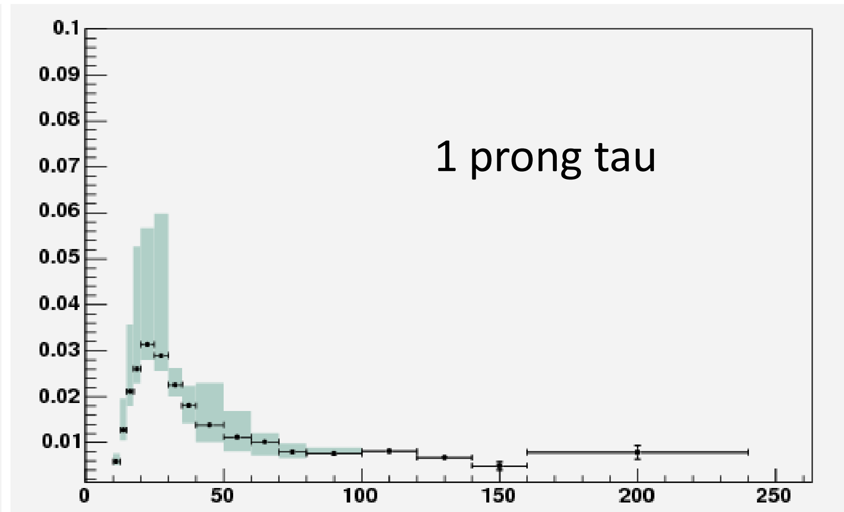
Statistics and Systematics

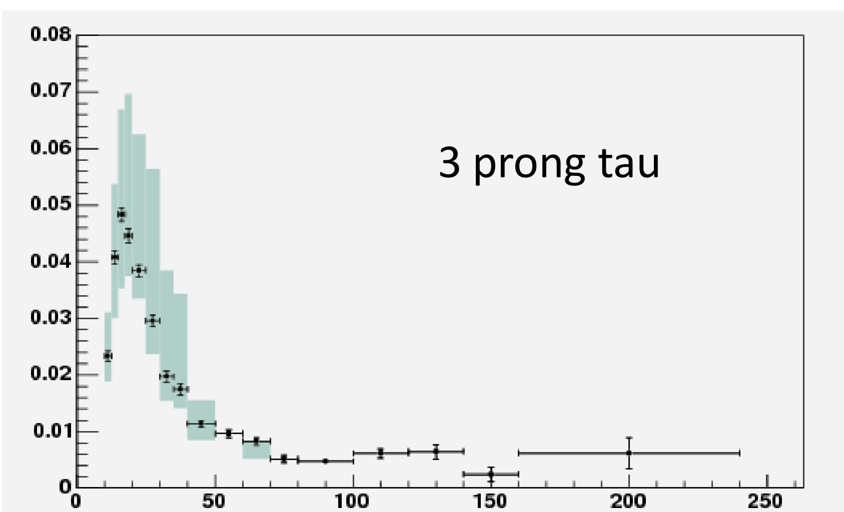
- Tau fake rate computed
  - Average between sample
  - With minimum χ^2 method
- Different jet samples give different fake rates
  - In the low energy region (Et < 50)
  - Motivation: three against two jet event topology
    - Better isolation in two jet topology (mostly in Jet 20)
    - Hard gluon emission can be the source of "third" jet
- Systematic uncertainty
  - If a fake rate is two standard deviations from the average

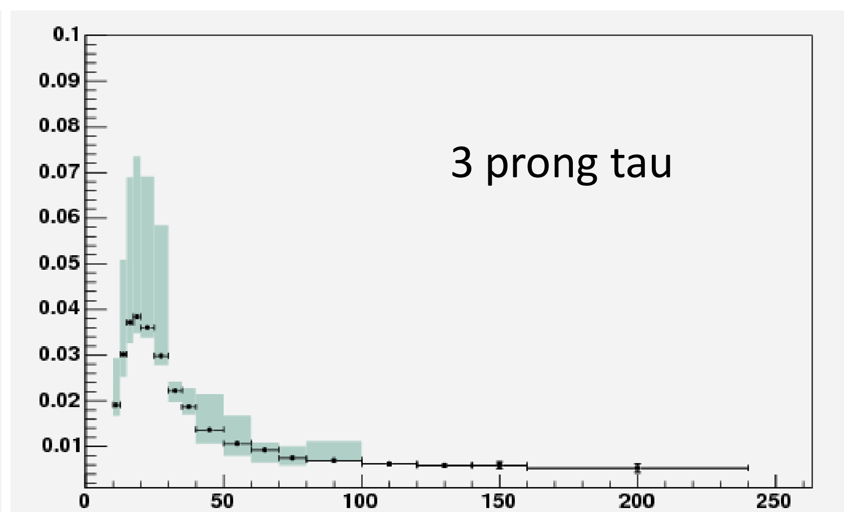
    (Standard deviation of the sample fake rate)

Fake Rate Average









Datasets -0h

Datasets -0m

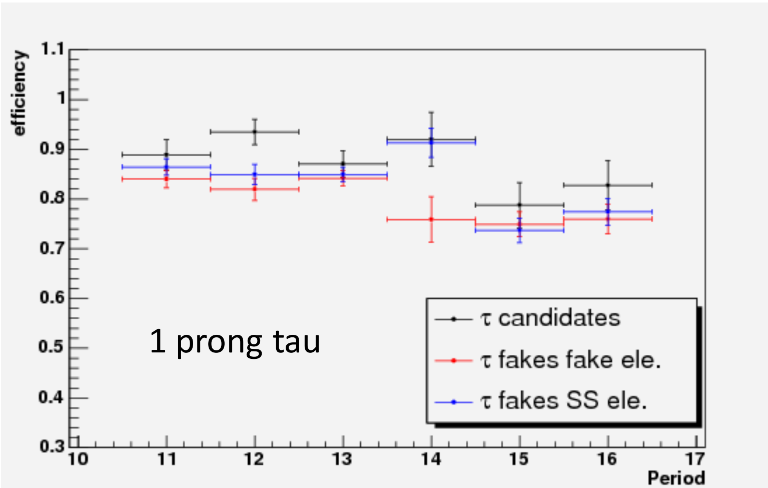
Trigger Efficiency for Taus

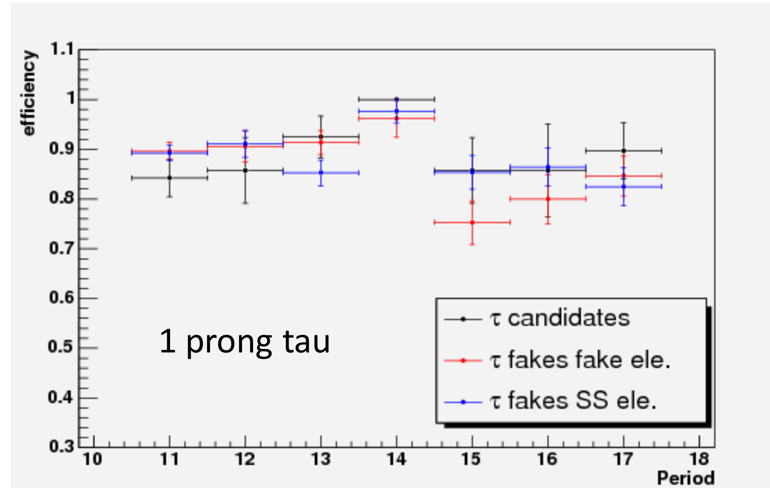
- Trigger efficiency for tau candidates studied
  - Separate identification and treatment of inefficiency sources:

- We intend to accomplish an independent study
- Inefficiency of the tau "leg" starting from a sample of events already passing the lepton requirements
  - Complementary to previous studies
  - Sensible effects external at the trigger algorithm

- Starting from "Calibration Lepton" or "High PT Lepton" samples
  - At L1 same requirements
  - At L2:
    - Similar to "Electron + Iso. Track"
    - "Calibration Muon" similar, but more relaxed
    - Differences removed accessing to the L2 trigger data bank
  - At L3 similar requirements
    - We intend to set common offline cuts
- Three tau samples
  - Tau identified together with identified leptons
  - Tau identified together with a loose lepton not passing the tight identification
  - Tau identified together with a tight lepton of the same sign

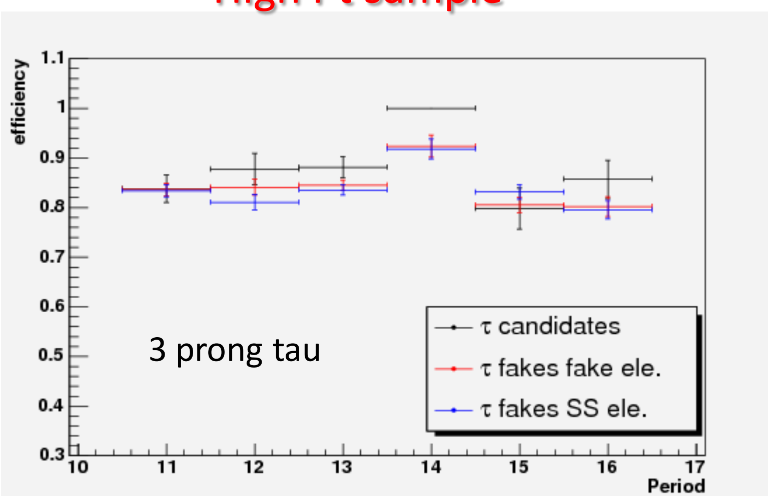
Results (Electron Samples)

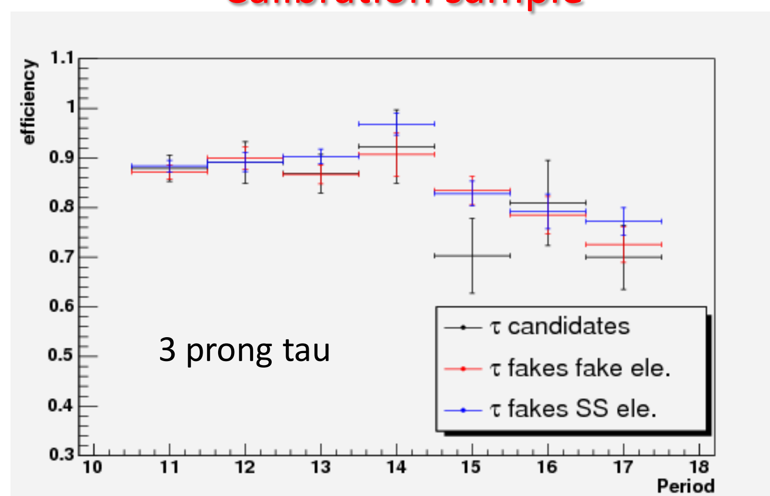




High Pt sample

Calibration sample

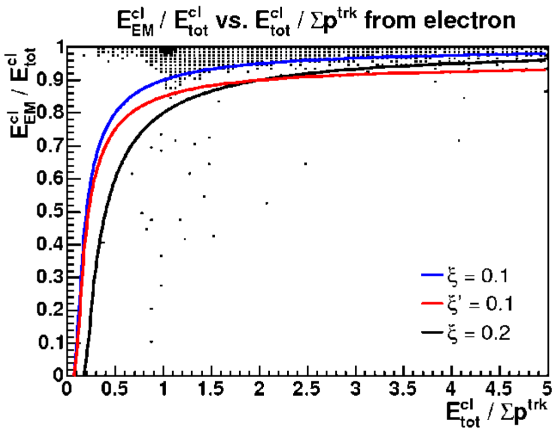




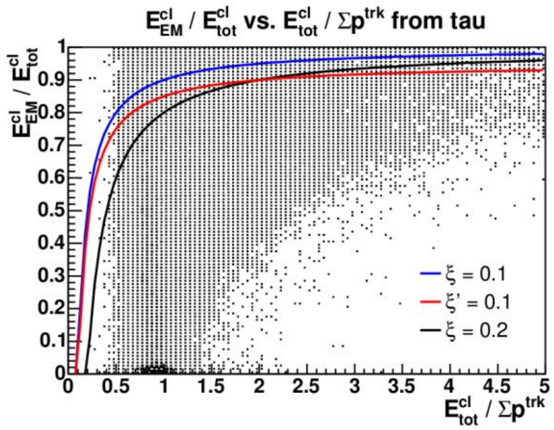
Conclusions

- We expect to improve the measurement of branching ratio of top pair decaying in tau
- We expect to measure the ditau component
- Tau selection tools under control
  - Jet misidentified as taus
  - Trigger efficiency (muon samples under study)
- Ready to compare distributions from data with signal and background expectations

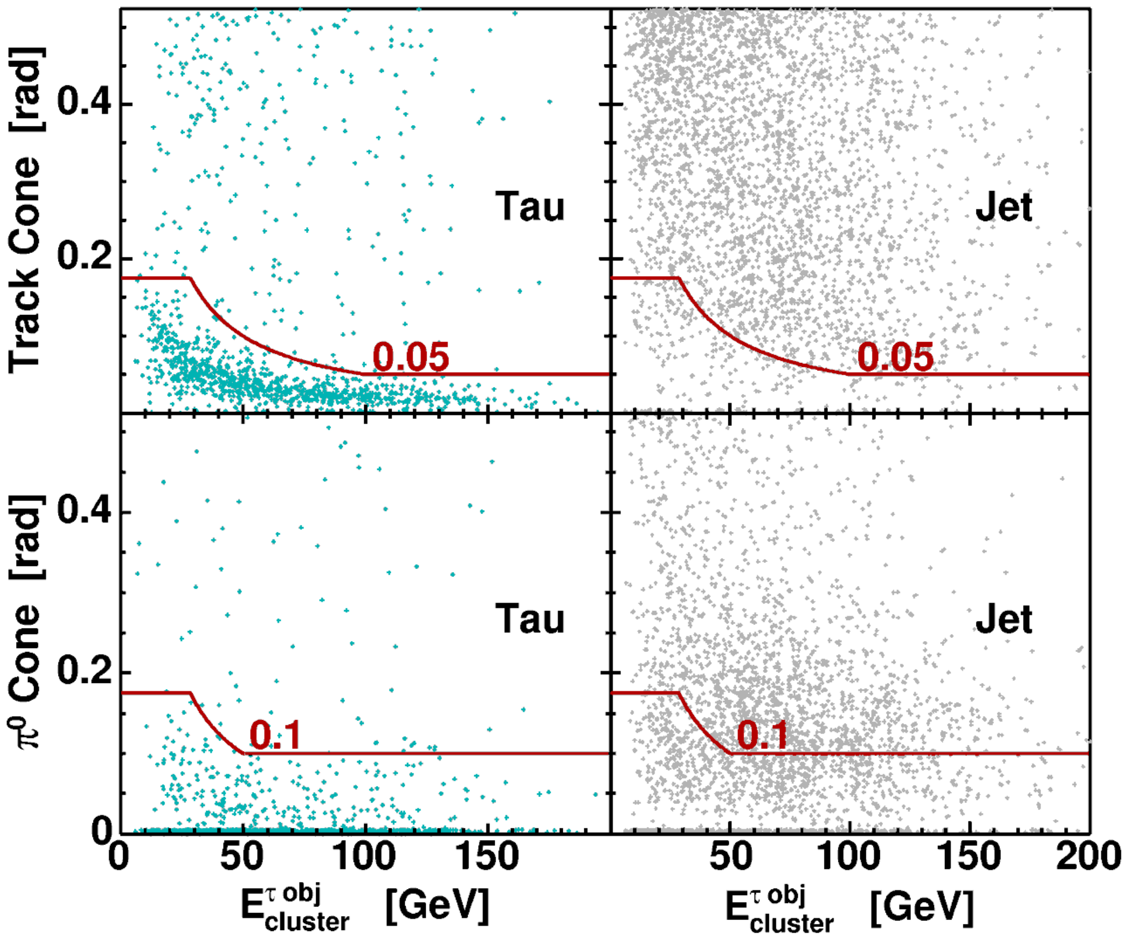
Back Up



$E^{cl}_{EM} / E^{cl}_{tot}$ vs. $E^{cl}_{tot} / \Sigma p^{trk}$ from electron
$E^{cl}_{EM} / E^{cl}_{tot}$
$E^{cl}_{tot} / \Sigma p^{trk}$
$\xi = 0.1$
$\xi' = 0.1$
$\xi = 0.2$



$E^{cl}_{EM} / E^{cl}_{tot}$ vs. $E^{cl}_{tot} / \Sigma p^{trk}$ from tau
$E^{cl}_{EM} / E^{cl}_{tot}$
$E^{cl}_{tot} / \Sigma p^{trk}$
$\xi = 0.1$
$\xi' = 0.1$
$\xi = 0.2$



Track Cone [rad]
π^0 Cone [rad]
Tau
Jet
0.05
0.1
$E^{\tau\ obj}_{cluster}$ [GeV]

Electron ID

- Loosening:
  - Energy and Pt
    - Include medium Et electron
    - Compatible with trigger requirements

- Full ID requirements validated through check with previous studies

	Tight electron ID
Region	CEM
Fiduciality	SMX fiducial
Et	> 20 GeV
Track Pt	>10 GeV
Track Z_0	< 60 cm
COT Ax. Seg.	> 3
COT St. Seg.	> 2
Conversion	= 0
Had/Em	< 0.055 + 0.0045xE
Isolation (Pt > 20 GeV)	< 0.1
Isolation (Pt < 20 GeV)	2 GeV
Lshr	< 0.2
E/P	< 2.0 (Pt > 50)
CES |DZ|	< 3 cm
CES qDX	-3 < qDX < 1.5 Qxcm
CES Strip c^2	$c^2 < 10$

Muon ID

- Medium Pt muons
- Identification checked
  - comparison with previous result

	Cuts
P_T	>10 GeV
$\|Z_0\|$	< 60 cm
Axial S.L.	>= 3
Stereo S.L.	>= 2
ρ_{COT}	< 140 cm (CMX only)
χ^2_{COT}	< 4
$\|d_0\|$	0.2 cm

	$P_T > 20$ GeV	$P_T < 20$ GeV
E^{iso}	< 0.1 (relative)	< 2 GeV
E_{EM}	< 2 + max(0, 0.0115*(p-100)) GeV	< 2 GeV
E_{HAD}	< 6 + max(0, 0.028*(p-100)) GeV	< 3.5 + (P_T/8.0)GeV
CMU stub	$\|\Delta x\| < 7$ cm	$\|\Delta x\| < 7$ cm or $\chi^2_{CMU} < 9$
CMP stub	$\|\Delta x\| < 5$ cm	$\|\Delta x\| < 5$ cm or $\chi^2_{CMP} < 9$
CMX stub	$\|\Delta x\| < 6$ cm	$\|\Delta x\| < 6$ cm or $\chi^2_{CMX} < 9$

Measurement

- Definition of loose electrons and muons
  - Choosing the tightest cuts between the trigger sample
  - Considering the tightest trigger path

	Loose muon
Stub	CMU + CMP
Pt	> 10 GeV (20 GeV)
$\lvert Z_0 \rvert$	< 60 cm
Rel. Iso. (Pt > 20 GeV)	< 0.2
Abs. Iso. (Pt < 20 GeV)	4 GeV
CMU stub	|Dx| < 15 cm
CMP stub	|Dx| < 20 cm

XFT_STEREO_CONFIRMATION = 1 requirement set using L2Databank

	Loose electron
Region	CEM
Et	> 10 GeV (20 GeV)
Track Pt	> 8 GeV (10 GeV)
Track Z_0	< 60 cm
Had/Em	< 0.055
Rel. Iso. (Pt > 20 GeV)	< 0.2
Abs. Iso. (Pt < 20 GeV)	4 GeV
Lshr	< 0.2
E/P	< 4.0 (Pt > 50)
CES |DZ|	< 5.0 cm
CES qDX	-3 < qDX < 3 cm