Early observation of ttbar events with hadronically decaying taus with ATLAS at 10 TeV

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TTBAR PROCESS WITH TAU LEPTONS: PHYSICS MOTIVATIONS

ttbar decaying modes/branching ratios

category	decay mode	branching ratio (BR)	
dileptonic	$t\bar{t} \to e\nu be\nu\bar{b}$	1/81	4/81 (5%)
	$t\bar{t} \to \mu\nu b\mu\nu\bar{b}$	1/81	
	$t\bar{t} \to e\nu b\mu\nu\bar{b}$	2/81	
	$t\bar{t} \to e\nu b\tau\nu\bar{b}$	2/81	5/81 (6%)
	$t\bar{t} \to \mu\nu b\tau\nu\bar{b}$	2/81	
	$t\bar{t} \to \tau\nu b\tau\nu\bar{b}$	1/81	
1 lepton + jets	$t\bar{t} \to q\bar{q}be\nu\bar{b}$	12/81	24/81 (30%)
	$t\bar{t} \to q\bar{q}b\mu\nu\bar{b}$	12/81	
	$t\bar{t} \to q\bar{q}b\tau\nu\bar{b}$	12/81	12/81 (15%)
full hadronic	$t\bar{t} \to q\bar{q}bq\bar{q}\bar{b}$	36/81	36/81 (44%)

- **Tau** lepton:
  - m = $1776.99^{+0.29}_{-0.26}$ MeV
  - $\tau = (290.6 \pm 1.0) 10^{-15}$ s
  - $c\tau = 87.11$ μm
- Comissioning Tau reconstruction & TauID algorithms (along with W->τν & Z->ττ)
- Standard Model(**SM**)
  - Cross section measurements
  - Higgs searches
    - ttH → tt ττ (100-150 GeV)
    - qqH → qq ττ
- **New physics**
  - SUSY
  - Extra dimensions
  - MSSM Higgs
    - A/H → ττ
    - H^+ → τν

$$R = \frac{t \to \tau \nu_\tau b}{t \to l \nu_l b} \; (l = e, \mu)$$

EXPERIMENTAL SIGNATURES OF TAU LEPTONS IN HADRON COLLIDERS

- Leptonic decay modes:

$\tau \rightarrow \nu_\tau + \nu_e + e$	(17.4%)	~35 %
$\tau \rightarrow \nu_\tau + \nu_\mu + \mu$	(17.8%)	

- Hadronic decay modes:

~ 65 %

~77 %

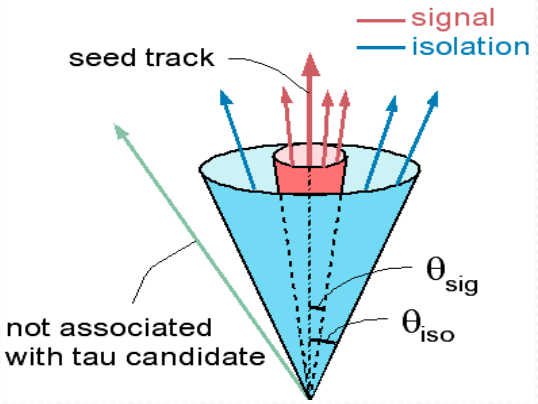
1 prong

$\tau \rightarrow \nu_\tau + \pi^\pm$	(11.0%)
$\tau \rightarrow \nu_\tau + \pi^\pm + \pi^0$	(25.4%)
$\tau \rightarrow \nu_\tau + \pi^\pm + \pi^0 + \pi^0$	(10.8%)
$\tau \rightarrow \nu_\tau + \pi^\pm + \pi^0 + \pi^0 + \pi^0$	(1.4%)
$\tau \rightarrow \nu_\tau + K^\pm + n\pi^0$	(1.6%)

~23 %

3 prong

$\tau \rightarrow \nu_\tau + 3\,\pi^\pm + n\pi^0$	(15.2%)



τ lepton signature at LHC

- Collimated jet (90% in a cone 0.2)
- Low track multiplicity (1p,3p)
- Energy deposition in EM (π^0) & Hadronic ($\pi^\pm$) calorimeters
- Fake tau sources
  - QCD jets, e, μ

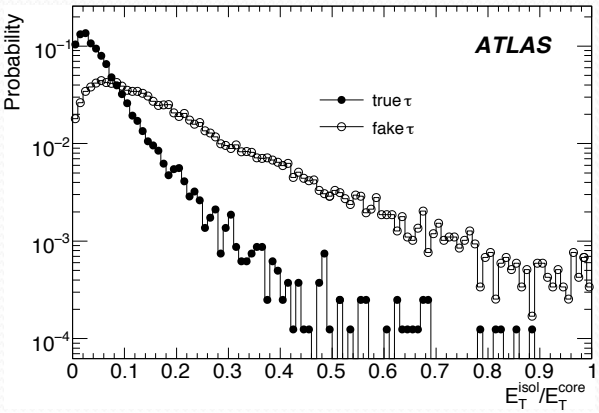
OFFLINE RECONSTRUCTION ALGORITHMS

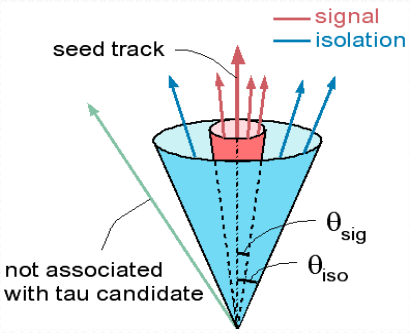
Tau1p3p

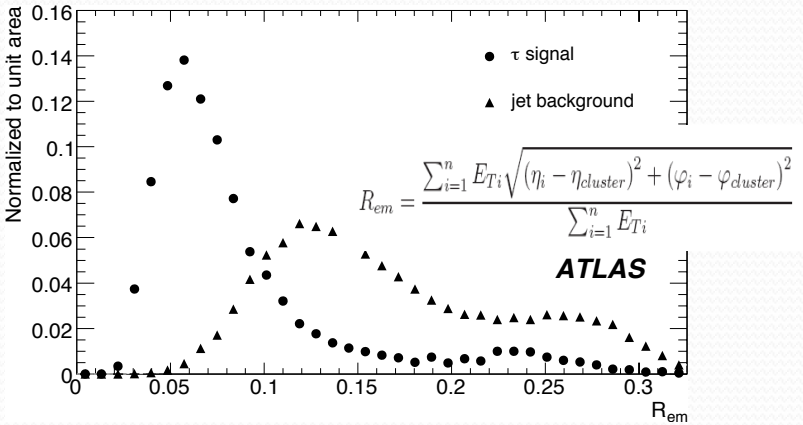
- track based
- **Seed** → 1 track P_t> 9 GeV
- Search for tracks with P_t> 2 GeV around the seed in a cone ΔR < 0.2
  - 0 tracks → 1p
  - 2 tracks → 3p
- Build **discriminant** variable using tau identification variables (tracker+calorimeter info)

TauRec

- Calorimeter based
- **Seed** → clusters reconstructed with E_t> 10 GeV y |η| < 2.5 in both calorimeters
- Search for tracks around the seed in a cone ΔR < 0.2
- Candidates with 1,2 & 3 tracks are selected
- Discriminant variable (**Likelihood**) build using tau identification variables (tracker+calorimeter info)







TAU ID WITH SAFE VARIABLES

With early data, tau-ID will be cut-based, and use variables that are more easily understood (safe variables):

Calo based

- EM radius
- Isolation Fraction
- width in the η strip layer
- $E_T(EM)/E_T$

Calo+Track based (**MERGED**)

- 4 calo based variables
- E_T/p_T leading track
- width of track momenta
- $\Sigma p_T/E_T$
- $E_T(EM)/\Sigma p_T$
- $E_T(HAD)/\Sigma p_T$

PHYSICS ANALYSIS: SIGNAL & MAIN BACKGROUNDS

$$t\bar{t} \rightarrow bW(l+\nu_l)bW(\tau_{had}+\nu_\tau) \rightarrow l+\tau_{had}+2\,jets+\not{E}_T \qquad l := e,\mu$$

W+jets	Z → ττ + jets	Single Top

PHYSICS ANALYSIS: SIGNAL & MAIN BACKGROUNDS

$$t\bar{t} \rightarrow bW(l+\nu_l)bW(\tau_{had}+\nu_\tau) \rightarrow l+\tau_{had}+2\,jets+\not{E}_T \qquad l := e,\mu$$

W+jets | **Z → ττ + jets** | **Single Top**

1. $W+3p \rightarrow l+\nu_l+3\,jets \neq l+2\,jets+\not{E}_T+\tau_{had} \qquad l := e,\mu$
   - 1 e,μ + 2 jets + MET + 1 fake hadronic tau
   - Tau identification cuts for reduction
2. W(→eν)+bb :
   - 1 e,μ + MissingEt + 2 b-jets + 1 quark-gluon-jet passing tau ID cuts

PHYSICS ANALYSIS: SIGNAL & MAIN BACKGROUNDS

$$t\bar{t} \rightarrow bW(l+\nu_l)bW(\tau_{had}+\nu_\tau) \rightarrow l+\tau_{had}+2jets+\not{E}_T \qquad l := e,\mu$$

W+jets | **Z → ττ + jets** | **Single Top**

$$Z+2p \rightarrow \tau\tau+2p \rightarrow l+\nu_l+\nu_\tau+\tau_{had}+2p \rightarrow l+\tau_{had}+2jets+\not{E}_T \qquad l := e,\mu$$

- 1 e,μ + 1 hadronic tau + 2 jets + MET
- Identical signal in the detector → Physic background
- Reduction through kinematic and angular criteria

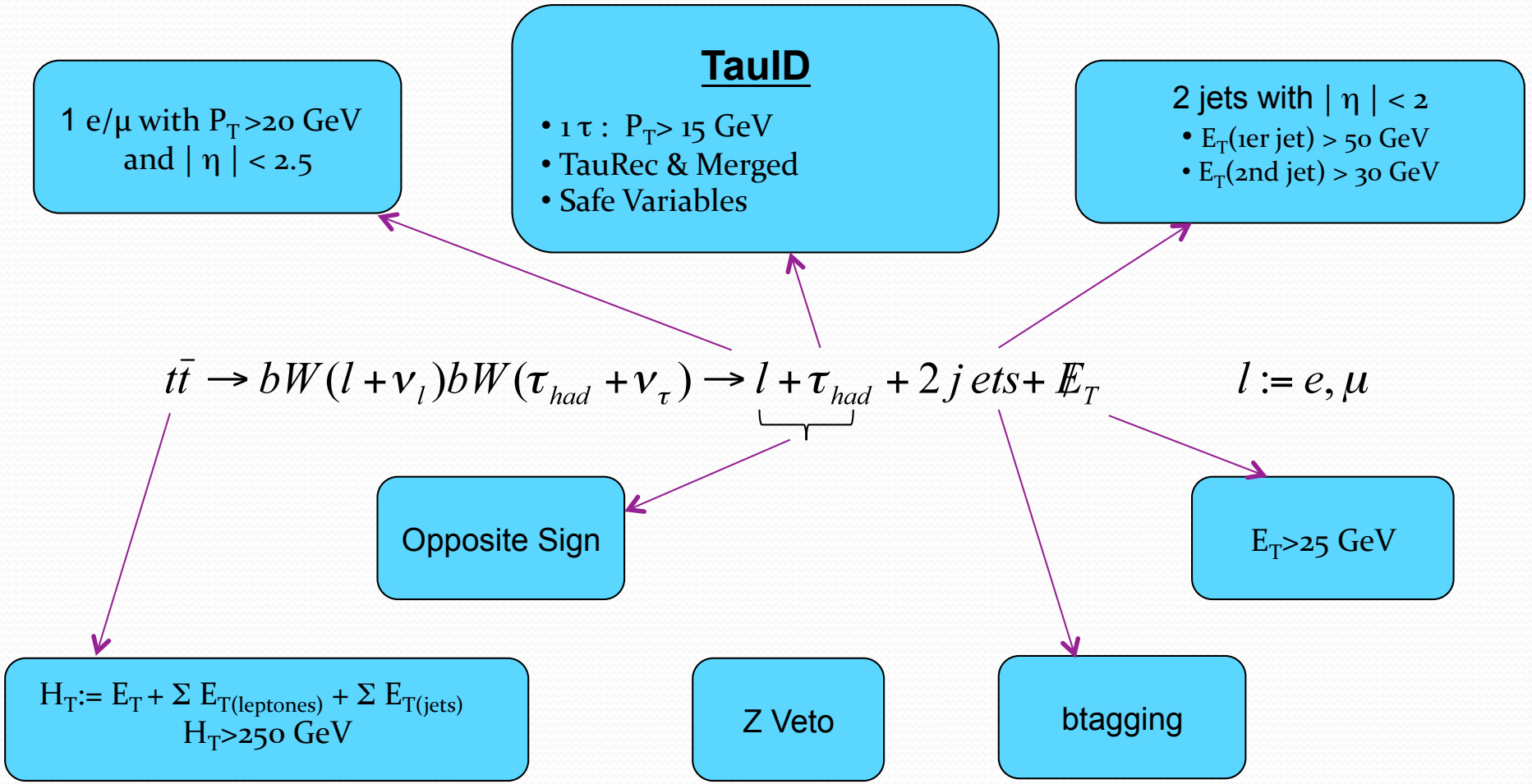
PHYSICS ANALYSIS: SIGNAL & MAIN BACKGROUNDS

$$t\bar{t} \rightarrow bW(l+\nu_l)bW(\tau_{had}+\nu_\tau) \rightarrow l+\tau_{had}+2\,jets+\not{E}_T \qquad l := e,\mu$$

W+jets | **Z → ττ + jets** | **Single Top**

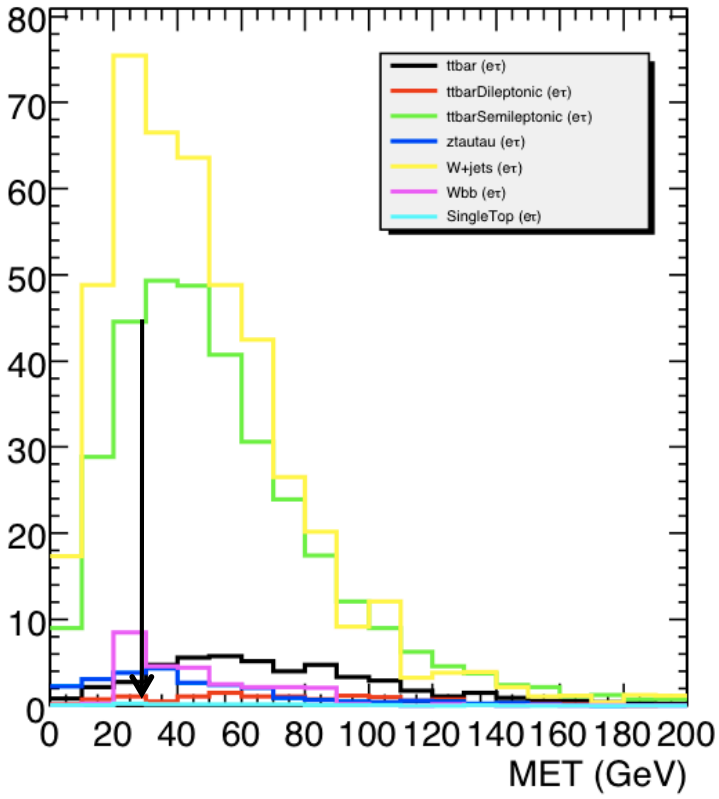
- Wt:
  - W(→e/μ/+τ,ν),t→W(→qq´)b
  - 1 leptón (e/μ) + 1 b-jets + 0,2 non-b jets + MET + 1 fake/real tau
- s-channel:
  - [t→W(→e/μ+ν)b]b
  - 1 lepton (e/μ) + 2 b-jets + MET + 1 fake tau
- t-channel:
  - [t→W(→e/μ+ν)b]b,q´
  - 1 lepton (e/μ) + 1,2 b-jets + 1 non-b jet + MET + 1 fake tau

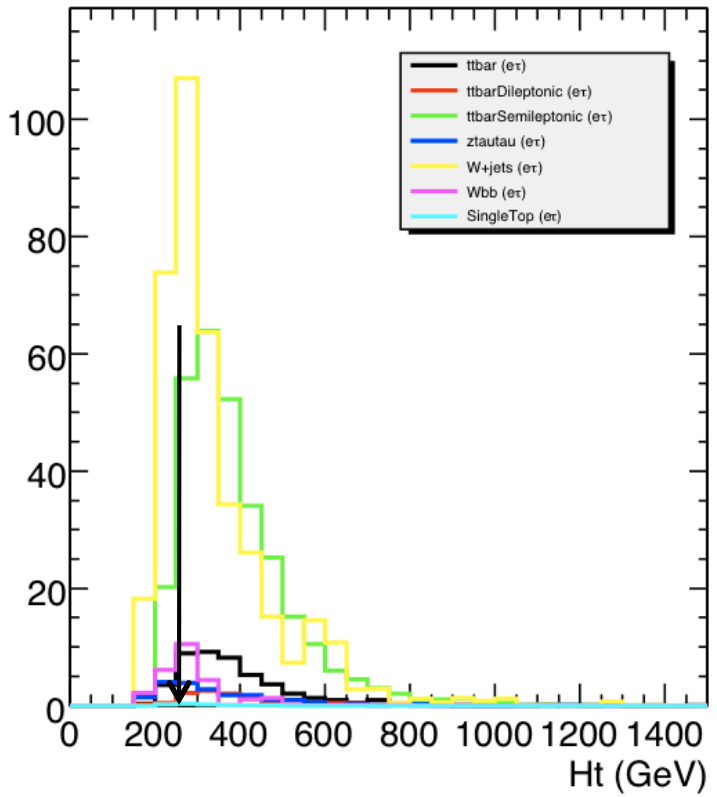
PHYSICS ANALYSIS: EVENT SELECTION



Physics Analysis: results at 10 TeV with 100 pb^{-1}

After Tau ID & Jet E_T (eτ)





Physics Analysis: results at 10 TeV with 100 pb^{-1}

	$t\bar{t}$ (e/τ_{had})	$t\bar{t}$ BKG (e/τ_{had})	W(e+ν)+Np	W(τ_e+ν)+Np	Z(τ_e+τ_{had})	Wbb(e+ν)+Np	SingleTop (e/τ_{had})
	509.8 ± 4.1	5300.7 ± 13.1	504156.0 ± 1381.0	348360.4 ± 860.8	40633.8 ± 181.1	2016.5 ± 17.1	275.0 ± 3.3
1 e/μ $P_T > 20$ GeV	264.3 ± 2.9	2725.0 ± 9.4	221726.3 ± 919.3	42640.8 ± 303.4	5882.3 ± 68.9	840.3 ± 11.1	137.7 ± 2.3
1 τ $P_T > 15$ GeV	263.7 ± 2.9	2721.9 ± 9.4	172470.9 ± 882.9	39527.3 ± 295.8	5746.8 ± 68.2	768.6 ± 10.6	135.0 ± 2.3
1 τ ID (Tight)	59.6 ± 1.4	324.6 ± 3.2	16272.8 ± 273.2	3602.8 ± 89.5	1363.9 ± 33.1	41.8 ± 2.3	8.9 ± 0.6
$E_T^{1st\ jet} > 50$ GeV	38.9 ± 1.1	271.2 ± 3.0	2732.3 ± 96.1	247.4 ± 22.0	333.3 ± 16.2	8.7 ± 0.9	3.9 ± 0.4
$E_T^{2nd\ jet} > 30$ GeV	36.0 ± 1.1	259.5 ± 2.9	2336.7 ± 88.7	207.5 ± 20.0	267.2 ± 14.5	7.4 ± 0.8	3.7 ± 0.4
$\not{E}_T > 25$	33.9 ± 1.0	230.9 ± 2.7	2004.2 ± 82.6	179.1 ± 18.6	200.8 ± 12.5	7.0 ± 0.8	3.5 ± 0.4
$\Sigma E_T > 250$ GeV	31.0 ± 1.0	214.3 ± 2.6	1557.2 ± 72.2	123.1 ± 15.2	128.1 ± 9.8	5.3 ± 0.7	2.9 ± 0.3
VetoZ	24.6 ± 0.9	170.9 ± 2.4	1231.6 ± 64.0	67.0 ± 11.2	19.3 ± 3.8	4.0 ± 0.6	2.5 ± 0.3
OS	26.7 ± 0.9	96.9 ± 1.8	635.9 ± 46.4	47.1 ± 9.4	103.3 ± 9.0	2.4 ± 0.5	1.2 ± 0.2

	$t\bar{t}$ (μ/τ_{had})	$t\bar{t}$ BKG (μ/τ_{had})	W(μ+ν)+Np	W(τ_μ+ν)+Np	Z(τ_μ+τ_{had})	Wbb(μ+ν)+Np	SingleTop (μ/τ_{had})
	502.4 ± 4.0	4641.0 ± 12.3	1262143.5 ± 2022.1	344561.6 ± 856.1	39775.3 ± 179.1	2046.7 ± 17.3	265.5 ± 3.2
1 e/μ $P_T > 20$ GeV	328.0 ± 3.3	3725.2 ± 11.0	738571.8 ± 1546.3	60254.8 ± 360.6	8187.8 ± 81.4	1132.9 ± 12.9	164.3 ± 2.5
1 τ $P_T > 15$ GeV	327.5 ± 3.3	3716.8 ± 11.0	685493.6 ± 1496.2	55941.0 ± 351.9	7971.0 ± 80.4	1030.4 ± 12.2	160.6 ± 2.5
1 τ ID (Tight)	74.0 ± 1.5	434.5 ± 3.8	64254.3 ± 457.4	5100.6 ± 106.3	1891.1 ± 39.1	62.3 ± 2.9	10.6 ± 0.6
$E_T^{1st\ jet} > 50$ GeV	49.9 ± 1.3	356.4 ± 3.4	1718.7 ± 64.0	382.4 ± 27.3	384.5 ± 17.5	15.8 ± 1.3	3.9 ± 0.4
$E_T^{2nd\ jet} > 30$ GeV	46.4 ± 1.2	341.9 ± 3.3	1317.1 ± 55.4	321.7 ± 25.0	314.2 ± 15.7	13.8 ± 1.2	3.4 ± 0.4
$\not{E}_T > 25$	43.7 ± 1.2	307.2 ± 3.2	1134.9 ± 51.4	272.1 ± 23.0	226.7 ± 13.3	12.5 ± 1.2	3.1 ± 0.3
$\Sigma E_T > 250$ GeV	39.3 ± 1.1	285.1 ± 3.0	713.0 ± 39.3	186.1 ± 19.0	152.1 ± 10.8	8.8 ± 0.9	2.7 ± 0.3
VetoZ	30.9 ± 1.0	232.1 ± 2.7	564.7 ± 34.9	106.2 ± 14.4	24.4 ± 4.2	7.6 ± 0.9	2.2 ± 0.3
OS	33.4 ± 1.0	128.0 ± 2.0	279.9 ± 24.3	58.9 ± 10.6	129.4 ± 10.0	3.9 ± 0.6	1.1 ± 0.2

WORK IN PROGRESS…

- Btagging with early b-taggers (JetProbe)
- Tau ID fake rates from QCD dijets
- AnalyzeTopMixing Sample → apply fake rates

- Actual main challenge:
  - **ttbar bkg** **HIGHER** than ttbar **signal** even after btagging (preliminary results, work ongoing)

Backup Slides

OFFLINE RECONSTRUCTION ALGORITHMS

variables

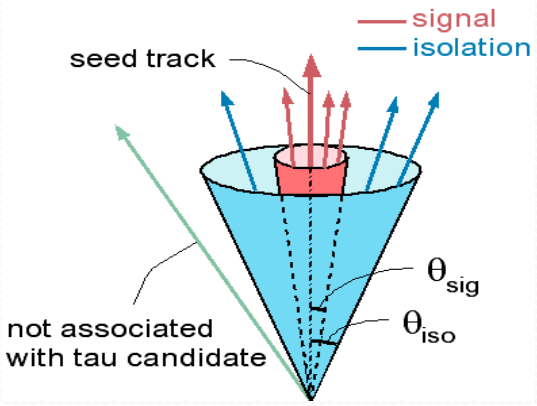
- electromagnetic radius, R_{em}

$$R_{em} = \frac{\sum_{i=1}^{n} E_{Ti}\sqrt{(\eta_i - \eta_{cluster})^2 + (\varphi_i - \varphi_{cluster})^2}}{\sum_{i=1}^{n} E_{Ti}}$$

- Isolation in the calorimeter

$$\Delta E_T^{12} = \frac{\sum_{j=1}^{n'} E_{Tj}}{\sum_{i=1}^{n} E_{Ti}}$$

- Number of associated tracks, N_{tr}
- Tau charge



- Transverse energy width in the η strip layer

$$\Delta\eta = \sqrt{\frac{\sum_{i=1}^{n} E_{Ti}\,(\eta_i - \eta_{cluster})^2}{\sum_{i=1}^{n} E_{Ti}}}$$

- Lifetime signed pseudo impact parameter significance

$$\sigma_{IP} = \frac{d_0}{\sigma_0} \times sign\left(\sin(\phi_{cl} - \phi_{tr})\right)$$

- E_T/p_T leading track
- Number of hits in the η strip layer