Study of tt-bar events in the dilepton channel with tau lepton in ATLAS

- Physics motivations
- Physics Analysis
  - Main Backgrounds
  - Event Selection
  - Offline tau reconstruction algorithms
- Results at 14 TeV

XXXII BIENAL DE FÍSICA
7-11 September 2009
Ciudad Real

Mª Teresa Pérez García-Estañ
on behalf of the ATLAS collaboration
IFIC (CSIC – Universidad de Valencia)

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
  - $c\tau = 87.11\ \mu m$
- 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%)
$\tau \rightarrow \nu_\tau + \nu_\mu + \mu$ (17.8%)
} ~35 %

- Hadronic decay modes:

~ 65 %

~77 %

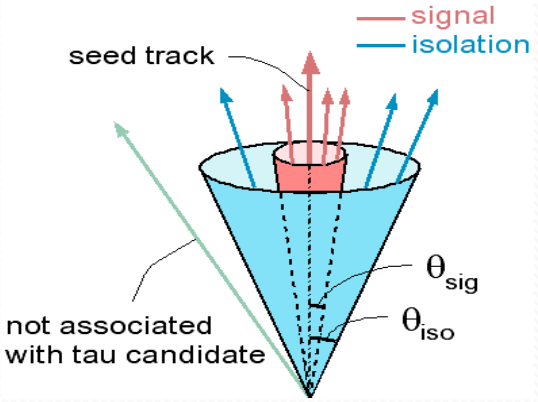
1 prong

$\tau \rightarrow \nu_\tau + \pi^\pm$ (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%)

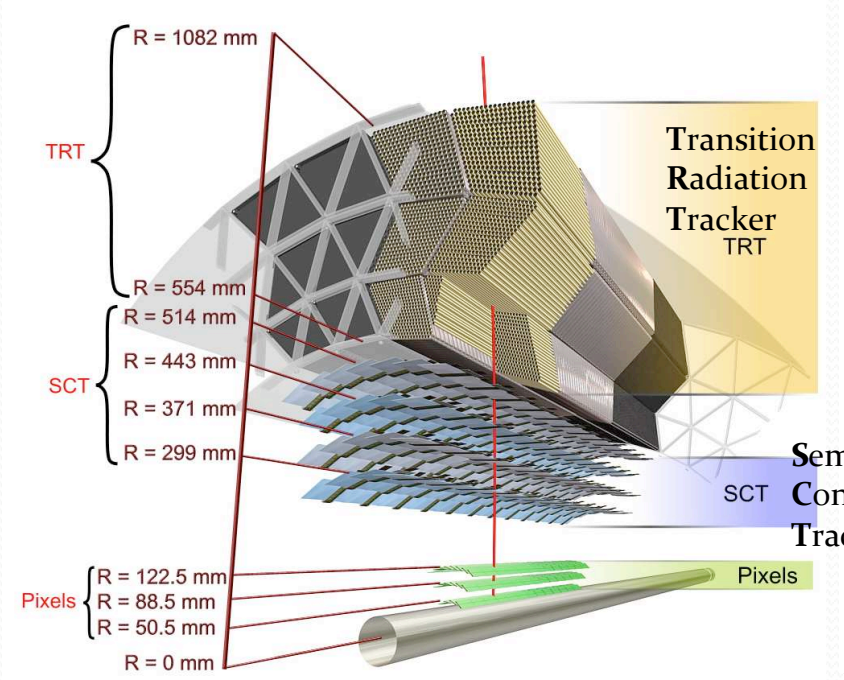


τ lepton signature at LHC

- 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

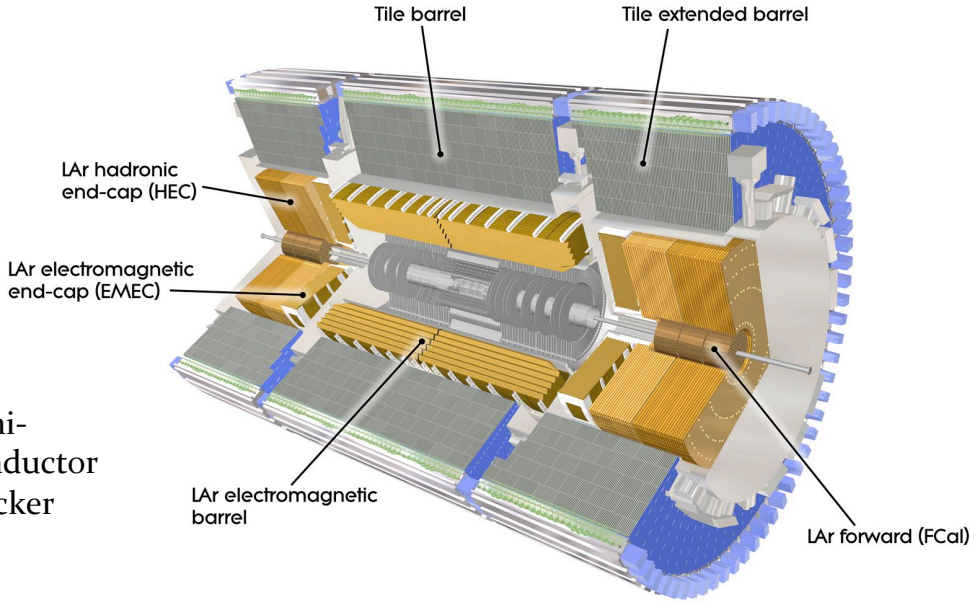
The ATLAS experiment: Ingredients for tau identification

Tracking:
ATLAS Inner Detector



Reconstruction of charged hadronic tracks originated by the charged pions

Calorimetry:
ATLAS EM & Had calorimeters



Measurement of the energy deposition from the visible decay products (excluding neutrinos): narrow showers in EM calorimeter (π^0)

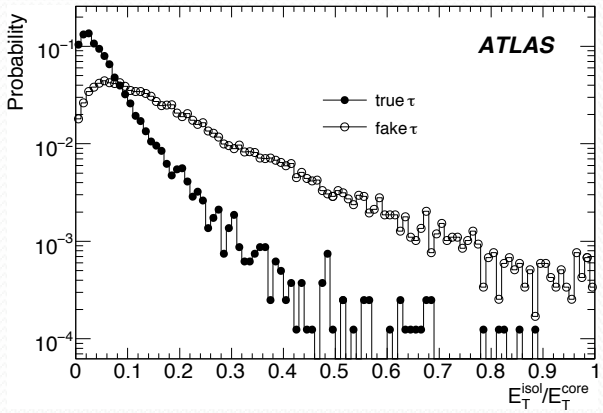
OFFLINE RECONSTRUCTION ALGORITHMS

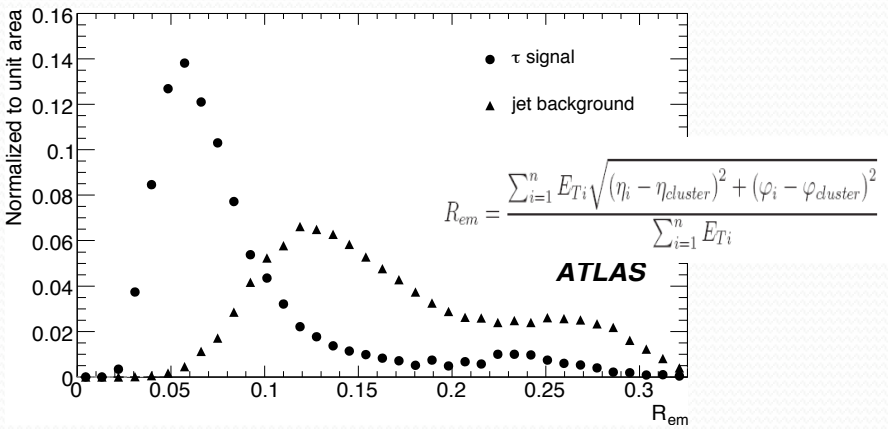
Tau1p3p

- 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)





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

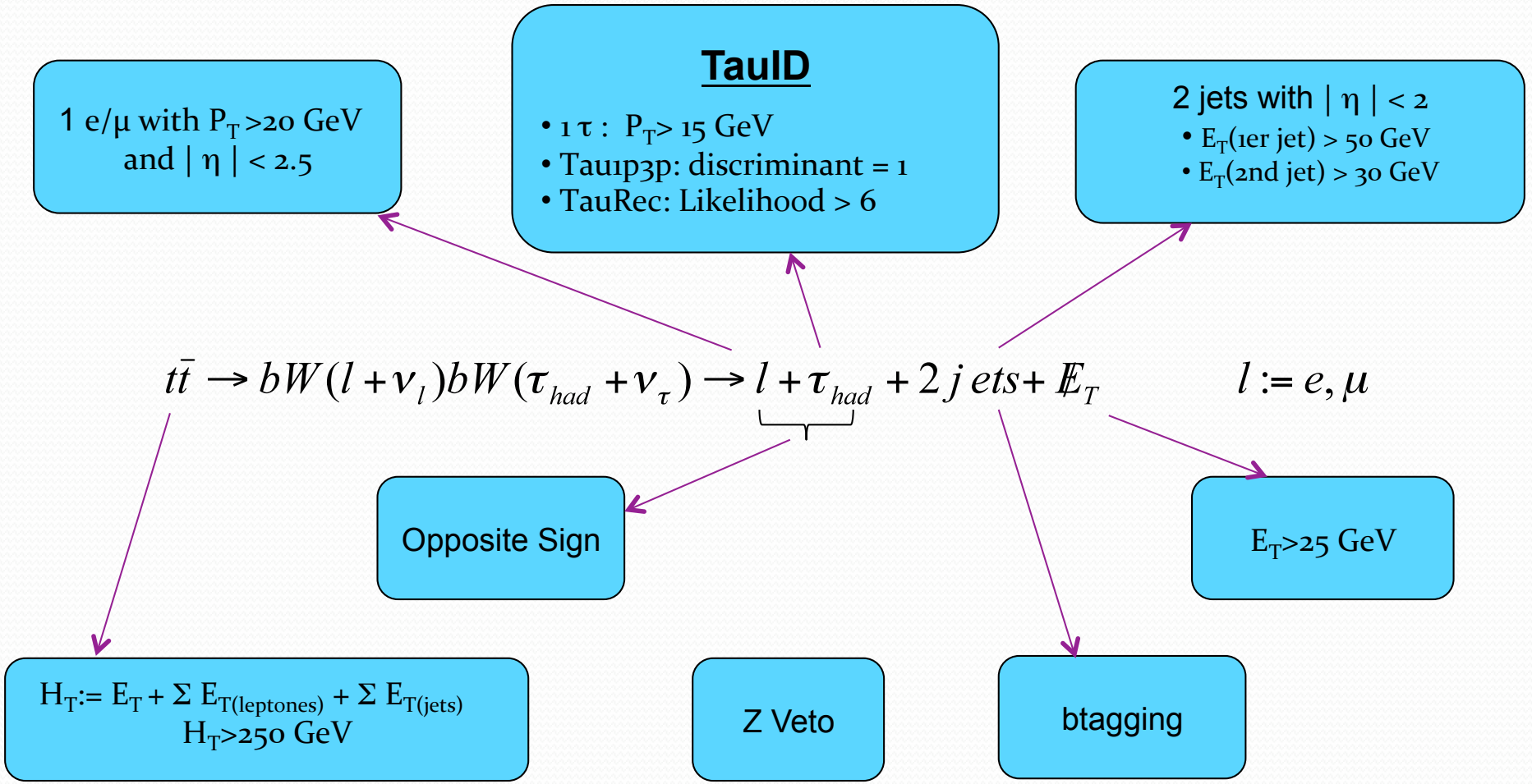
PHYSICS ANALYSIS: SIGNAL & MAIN BACKGROUNDS

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

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 14 TeV with 100 pb^{-1}

	Number of expected events in 100 pb^{-1}			
Selection	$t\bar{t}(\ell, \tau_{had})$	$W \rightarrow \ell\nu + 3\,jets$	single t	$Z \rightarrow \ell\ell$ + 2 jets
Isolated lepton $p_T > 20$ GeV	1300	$3.9 \cdot 10^5$	4300	630
Identified τ_{had} $p_T > 15$ GeV	190	22000	210	120
1st jet $E_T > 50$ GeV, 2nd jet $E_T > 30$ GeV	170	4000	170	35
$E_T^{miss} > 25$ GeV	150	3400	150	15
$\Sigma E_T > 250$ GeV	150	1750	130	10
Opposite-sign events	130	850	54	< 10
1 b-jet tag	67	28	20	

W+jets background dominant

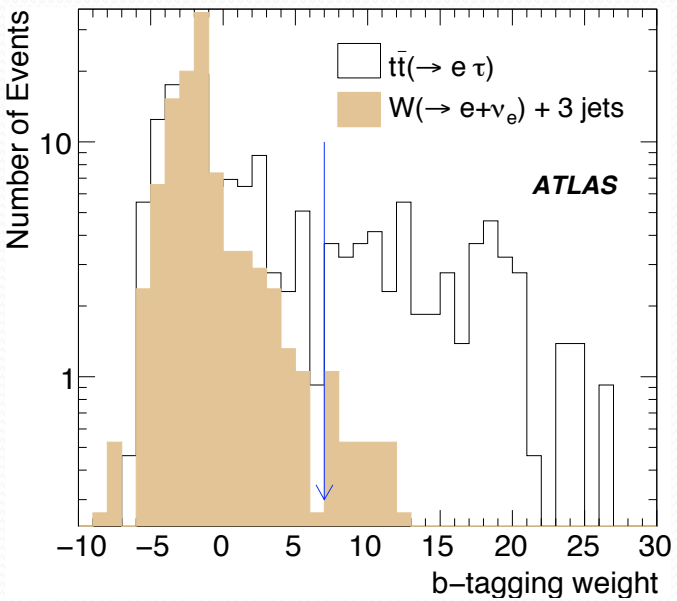
Btagging needed to get S/B > 1

Wbb negligible → not included

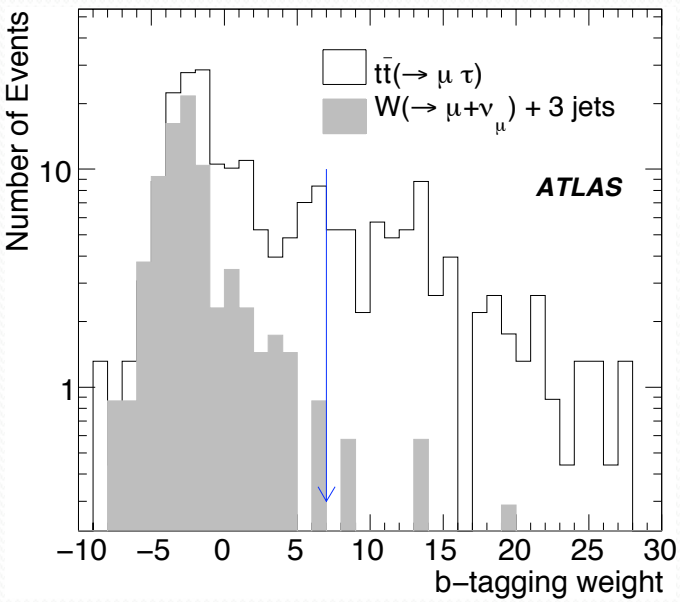
W+jets & SingleTop
Comparable after btagging

Physics Analysis: results at 14 TeV with 100 pb^{-1}

e+τ



μ+τ



1 btag jet:
S:B 1:0.8

1 btag jet:
S:B 1:0.3

CONCLUSIONS & PLANS

- ttbar process with tau leptons are important to commission tau reconstructions & identification algorithms

- NEW APROACH: **ANALISIS AT 10 TEV**
  - lepton selection (e,μ,τ) + btagging before other selection cuts
    - btagging → early btaggers
  - TauID → safe variables

- Contribution:
  - Atlas Collaboration, *"Expected Performance of the ATLAS Experiment : Detector, Trigger and Physics"*. CERN-OPEN-2008-020.

Backup Slides

OFFLINE RECONSTRUCTION ALGORITHMS

variables

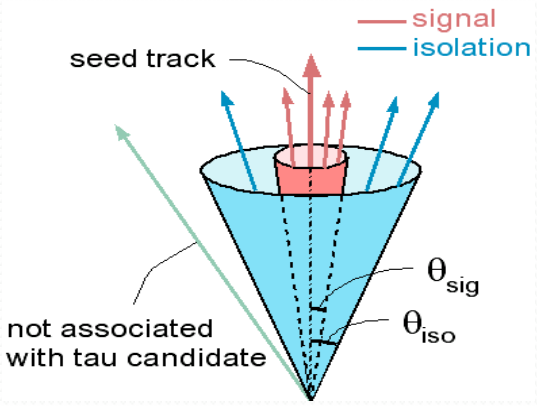
- electromagnetic radius, R_{em}

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

- 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

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

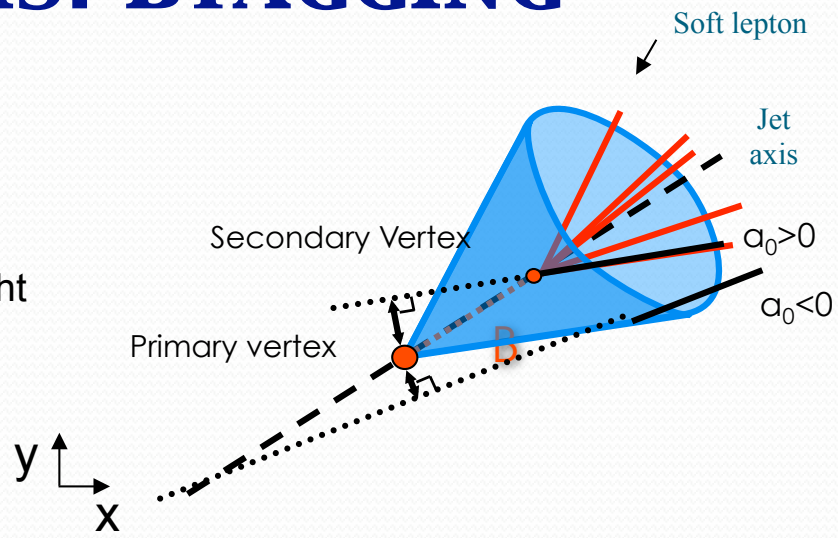
- Lifetime signed pseudo impact parameter significance

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

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

PHYSICS ANALYSIS: BTAGGING

- Spatial (life-time) tagging
  - L(B(50 GeV)) ~ 5mm
  - Secondary vertex (SV) in jets
  - tracks with positive high impact parameter (IP)
  - B-hadron → e,μ → likelihood discriminant againts light jets
- IP3D+SV1
  - transverse+longitudinal IP (IP3D)
  - mass/energy/vertices/track multiplicity (SV)



Weight(AOD) (IP3D+SV1) 1st OR 2nd JET >7