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The ATLAS hadronic tau trigger-performance and early running plans

Richard Brenner on the behalf of the ATLAS Tau Trigger Group

- Trigger motivation and description
- Use of tau trigger in searches for Higgs and exotica
- Trigger variables and performance
- Tau trigger menus
- Commissioning of tau trigger with first data

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Tau trigger motivation and description

- Tau (trigger) is especially important for searches in the Higgs sector because the tau is the heaviest in the lepton family
  - Triggering taus will be difficult at LHC due to high rate and occupancy however a trigger will increase the discovery potential.
  - This presentation will focus on the trigger for hadronic tau decays while leptonic decay of taus will be triggered by the electron and muon triggers

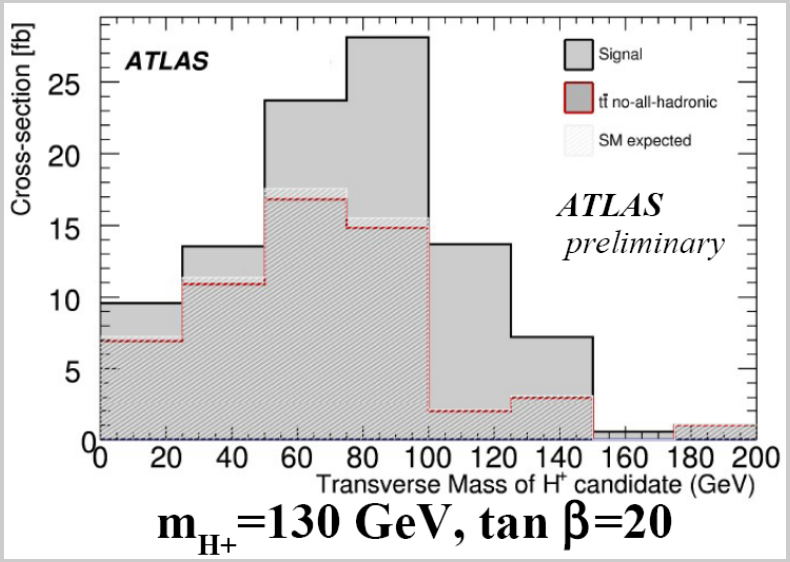
Tau trigger in charged Higgs searches

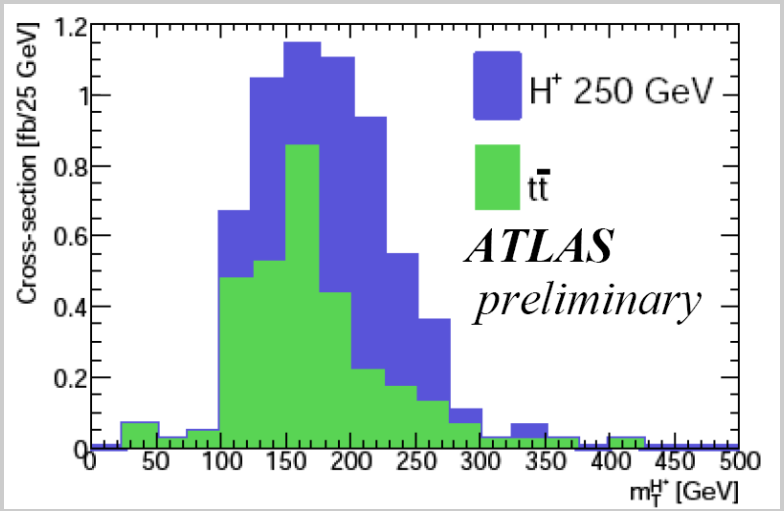
- Charged Higgs (*main customer for the tau trigger?*)
  - Light mass channel

    tt(bar) → bHbW →
    b τ(had)ν bqq
  - Heavy mass channel

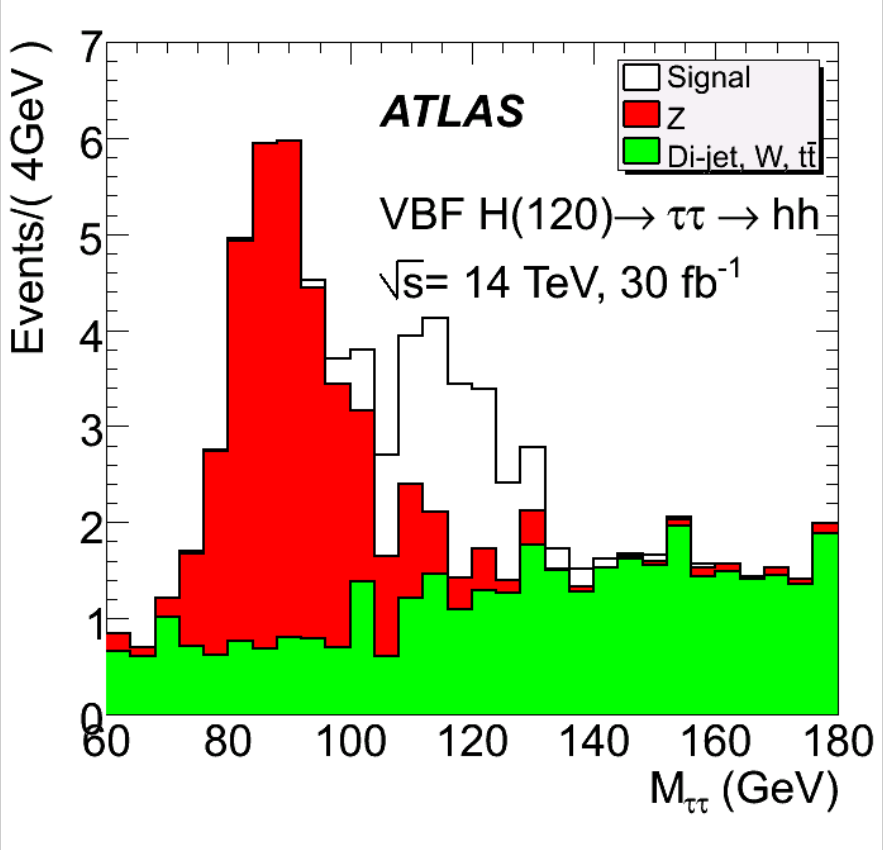
    gg/gb → tH → ttb →
    b lν bqqb

    gg/gb → tH →
    bqq τ(had)ν





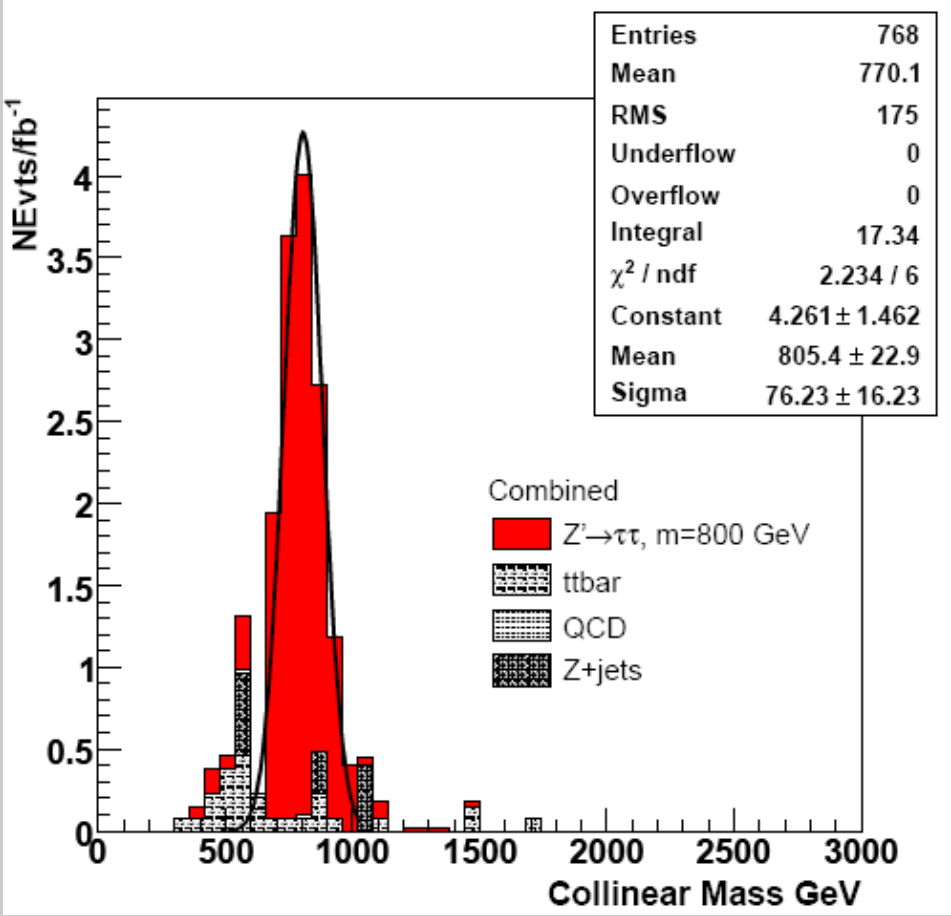
Tau trigger in neutral Higgs searches



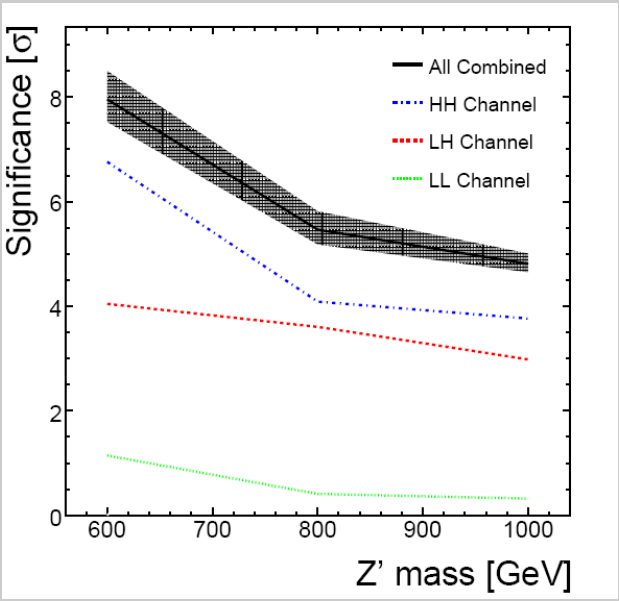
- SM H → ττ (VBF)
  - Study of all lepton, lepton-hadron and all hadron channels
  - Efficiency in all hadron channels comparable with other channels but sensitivity of QCD background to be studied with data.

(The A/H → ττ study didn't use tau trigger at the time of CSC)

And trigger for excotics?



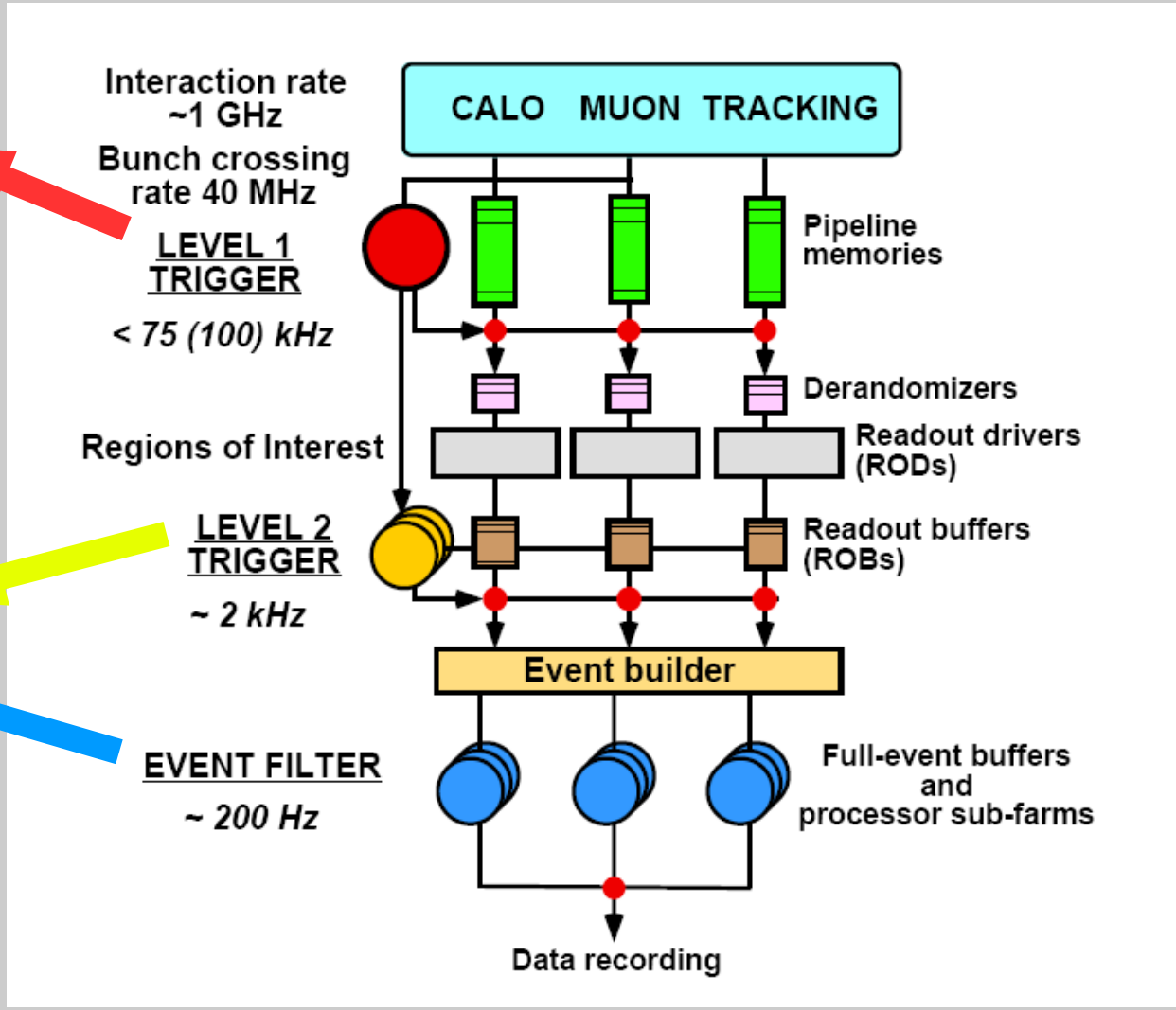
- Heavy vector bosons:
  $Z' \rightarrow \tau\tau$
  - double tau lepton final states.
  - discovery is enhanced including all hadron final states.



ATLAS trigger chain

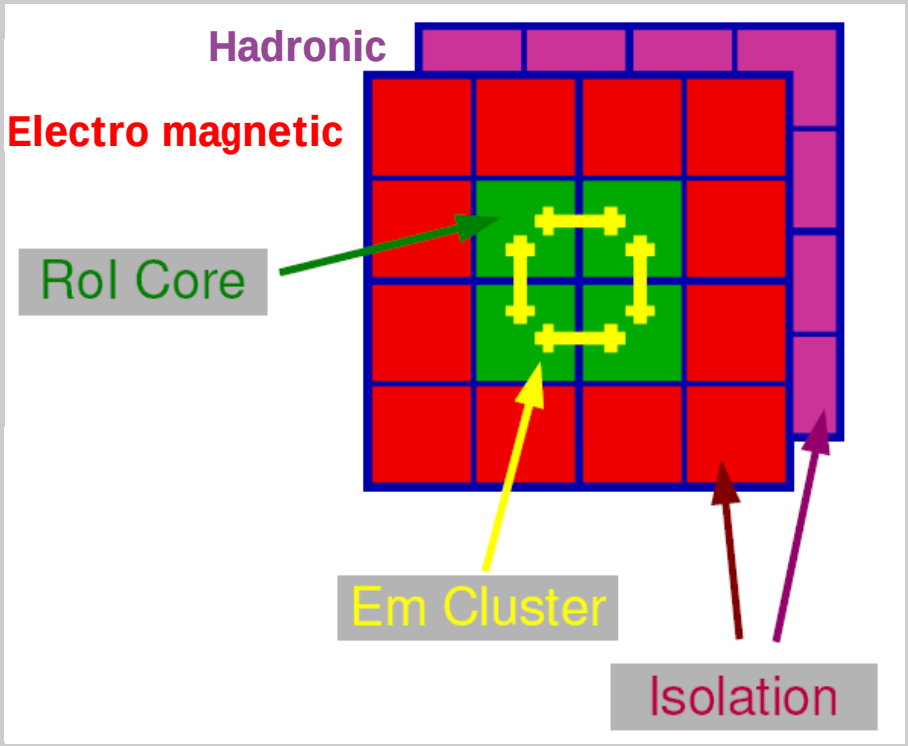
LVL1 trigger in USA15 counting room underground

High Level trigger in surface building SDX1



LVL1 trigger quantities

$\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$

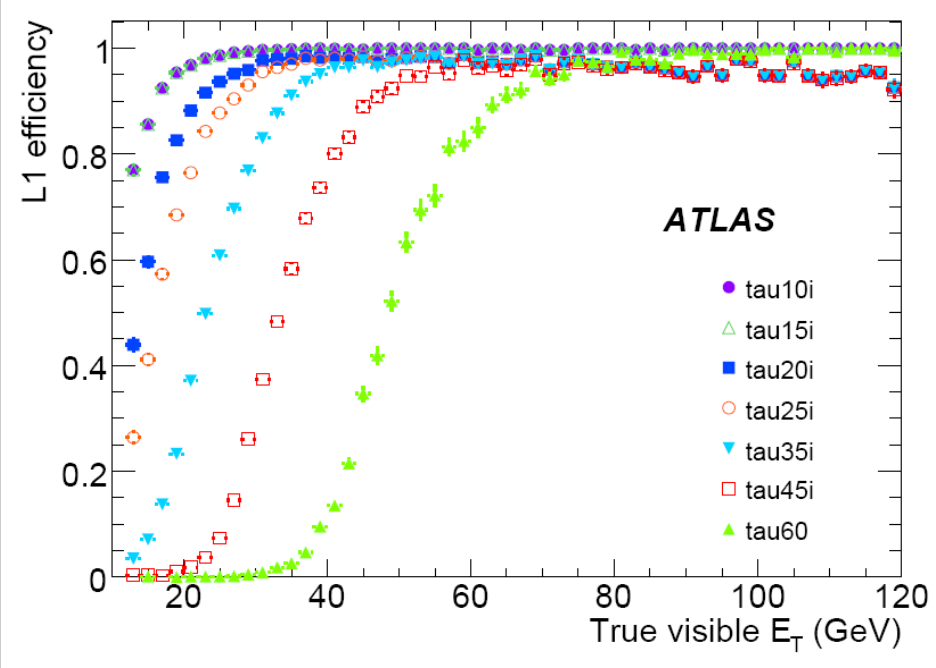


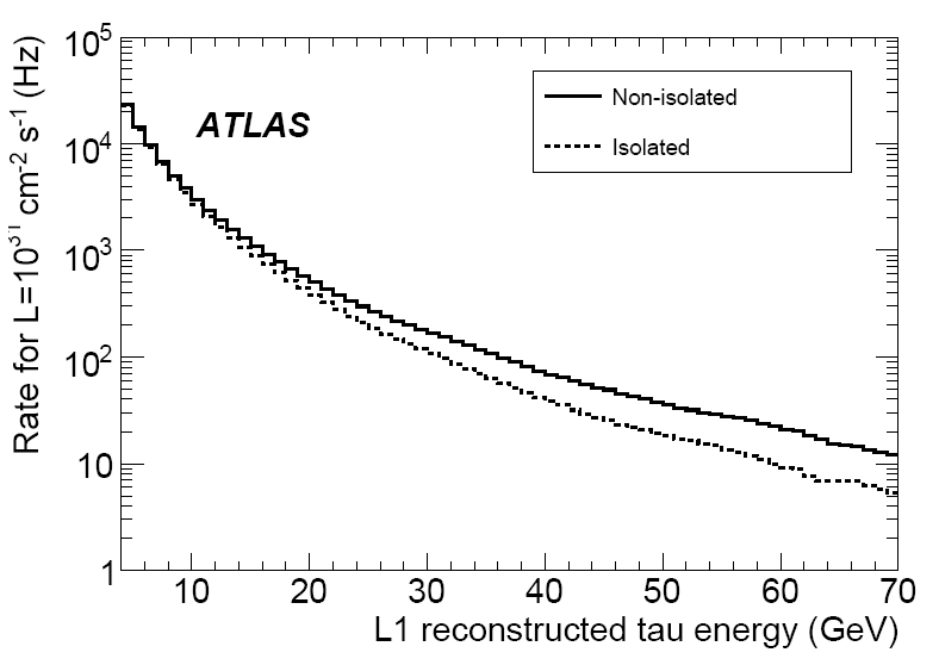
Coverage $|\eta| < 2.5$

- Central 2x2 core of both e.m. and hadronic towers
- Tau cluster=two most energetic neighboring e.m towers+ central 2x2 hadronic towers
- EmIsol=energy in the isolating ring 2x2 to 4x4 in e.m. calorimeter
- HadIsol=energy in the isolating ring 2x2 to 4x4 in hadronic calorimeter

Maximum 8 trigger thresholds

LVL1 trigger performance for single taus





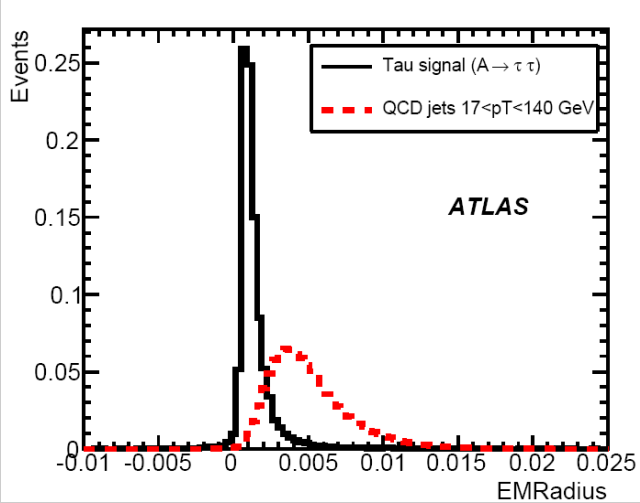
Tau efficiency $|\eta| \leq 2.5$

$\mathcal{L} = 10^{31}\ cm^{-2}s^{-1}$

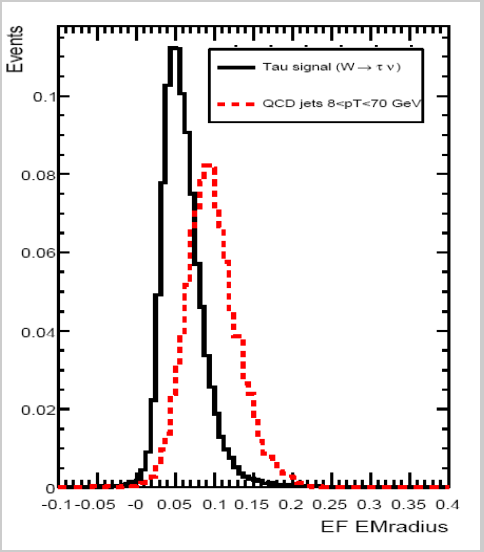
(Dijet sample $8 < pT < 140$ GeV)

HLT-L2 & EF

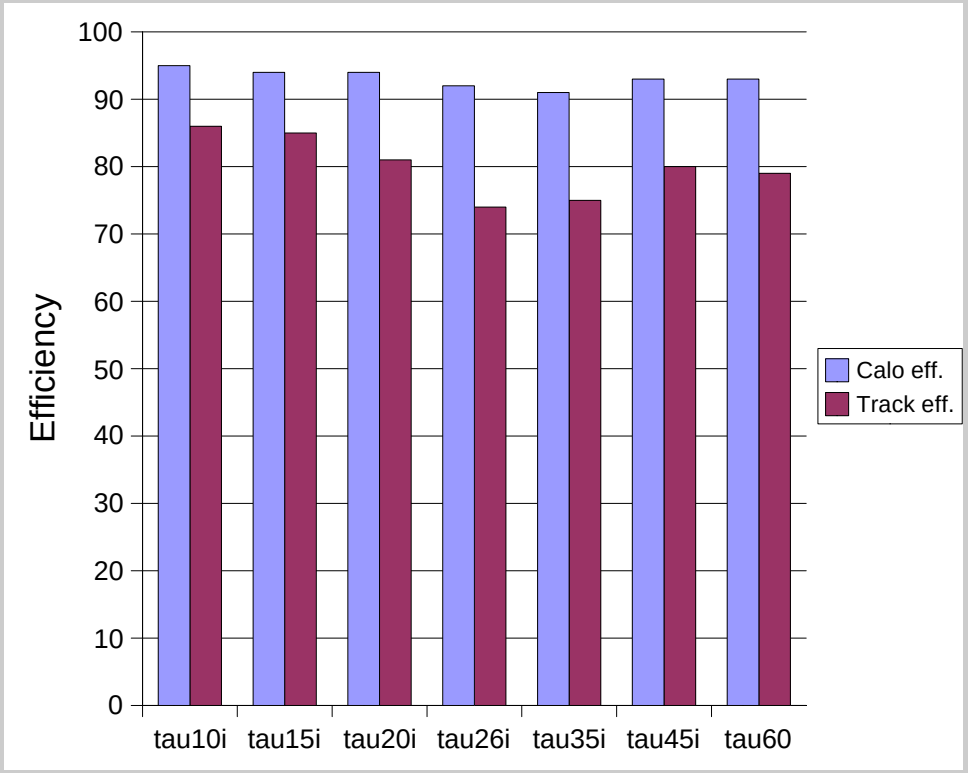
- Seeding ROI form L1
  - First, search for taus in calorimeter
  - Second, for taus in tracker
  - Extracted tau variables are shape variables



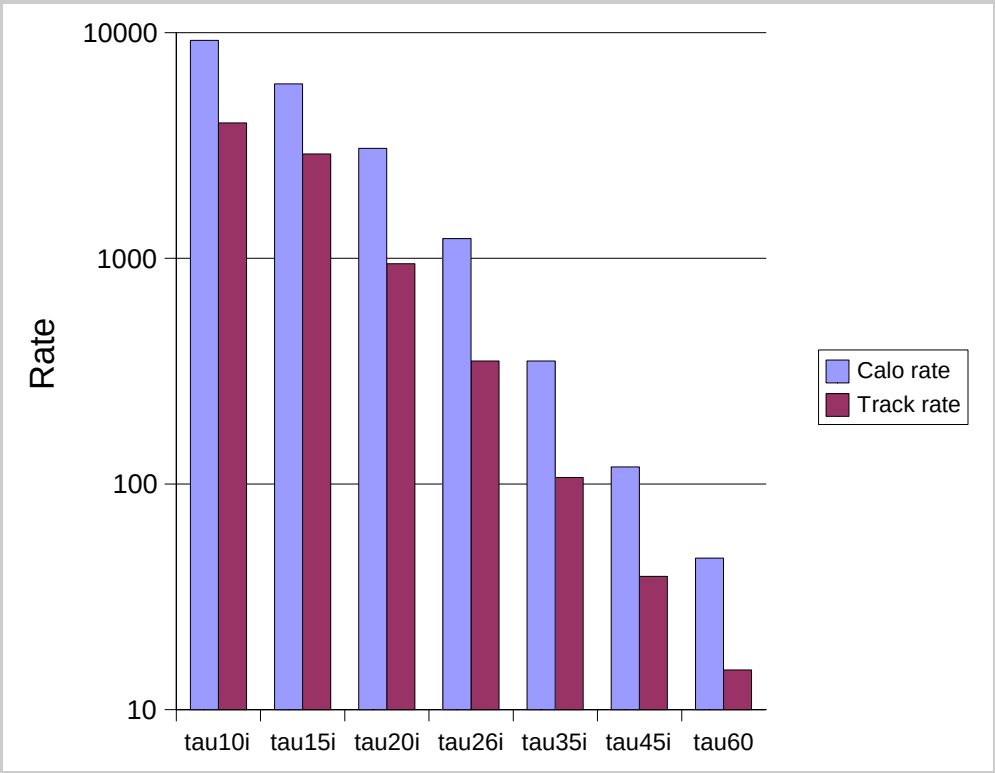
- Seeding from L2
  - EF is repeating the LVL2 steps but in a much more sophisticated tau identification algorithm taken from offline.
  - Shape variables extracted



LVL2 trigger performance for single taus

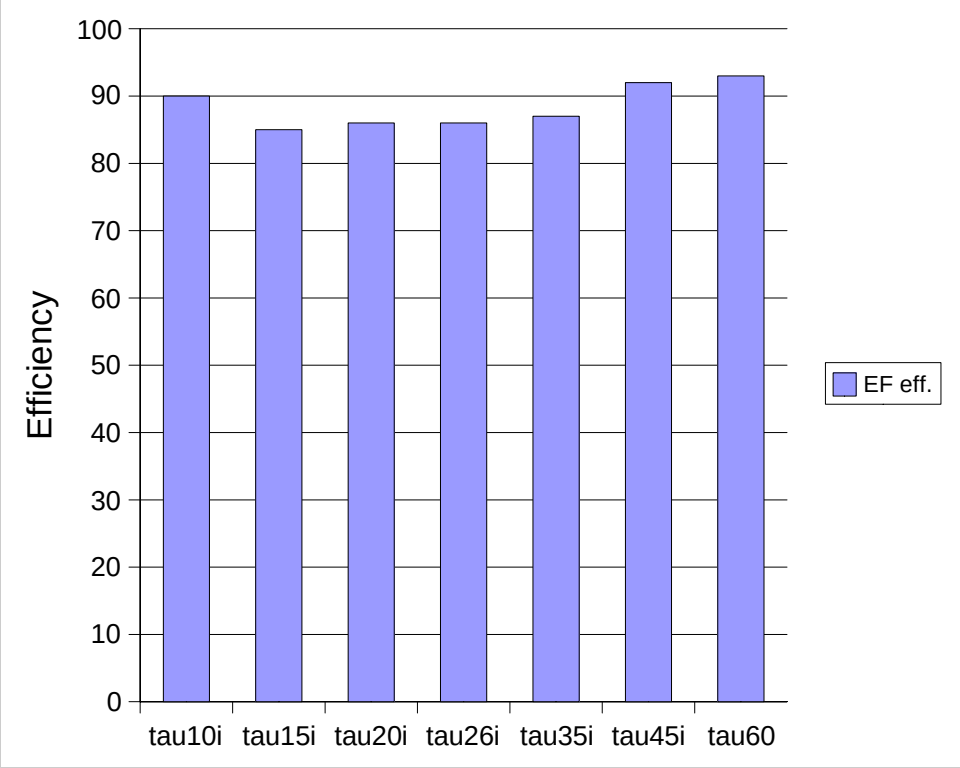


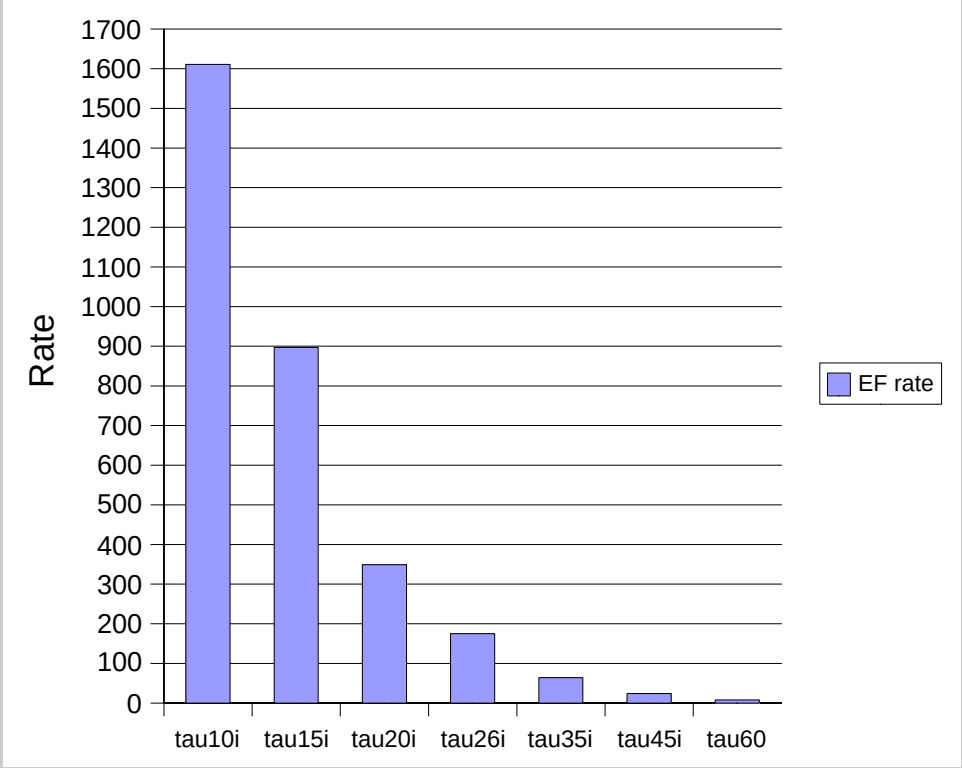
Efficiency for $W \rightarrow \tau \nu$



QCD rate at $L=10^{31}$ $cm^{-2}s^{-1}$

Event Filter performance for single taus





Efficiency for $W \rightarrow \tau \nu$

QCD rate at $L=10^{31}$ $cm^{-2}s^{-1}$

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Tau trigger items

- Tau only
  - Single tau: apart from very high E_T these triggers are to be use d in combination with other triggers.
  - Single track trigger: select RoI:s with only 1 track. Run parasitic without L1 trigger item.
- Combined triggers
  - tau+missing E_T: For W days and similar ($H^{\pm}$)

    $L=10^{31}$: XE30_L1_TAU13, XE20_3j20_L1_TAU13

    $L=10^{31}$: XE40_3j20_L1_TAU30, XE50_L1_TAU30
  - tau+l(+jets): Optimized for double tau decays (Z,H/A,...)

    L1_TAU30_XE40_softHLT
  - tau+tau(+jets): Like previous but all hadronic
  - tau+jets,tau+bjets: Option for tt -studies allowing lower threshold
  - Commissioning: Only a fraction will be recorded.

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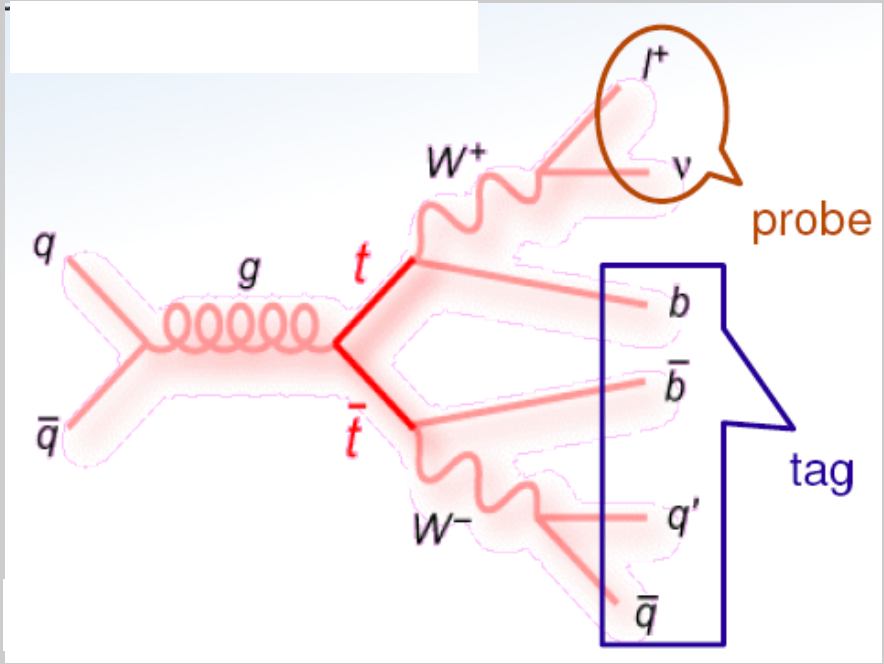
Tau trigger menu at start-up $L=10^{31}$ cm^{-2}s^{-1}

Trigger	Prescale	Rate (Hz)	Cumulative Rate (Hz)
tau100	1	2.4±0.5	2.4±0.5
tau60	1	10.7±1.0	10.7±1.0
tau45i	10	2.5±0.2	12.6±1.1
tau45	20	4.1±0.1	16.0±1.4
tau20i_xe30	1	4.9±0.7	20.1±1.4
tau20i_e10	1	1.2±0.4	21.2±1.5
tau20i_mu6	1	2.8±0.5	23.7±1.6
2tau25i	1	2.6±0.5	25.3±1.6
tau20i_4j23	1	0.1±0.1	25.4±1.6
tau20i_3j23	1	0.9±0.3	25.8±1.6
tau20i_j70	1	7.1±0.9	28.6±1.7

Note: The naming convention for menus have changed to effective threshold levels e.g. tau20 -> tau17

Commissioning of tau trigger with first data (studies in progress)

- Efficiency of Tau+XET with tt(bar) events
  - tag: 4jet25
  - make offline selection and probe
  - main background: QCD, single top
  - tt(bar) samples with an estimated background of 35% in the tagged sample
  - 3% statistical uncertainty for tau25i_xe20 with 100 pb^{-1} data



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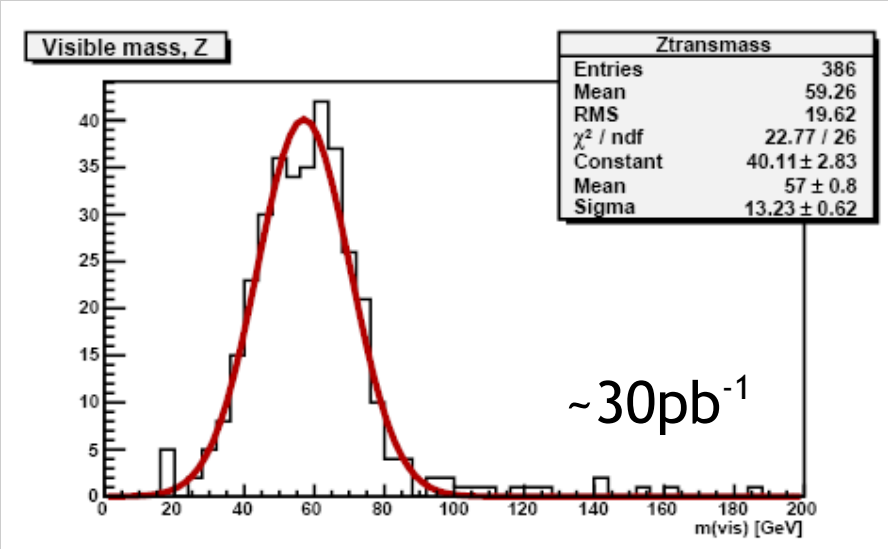
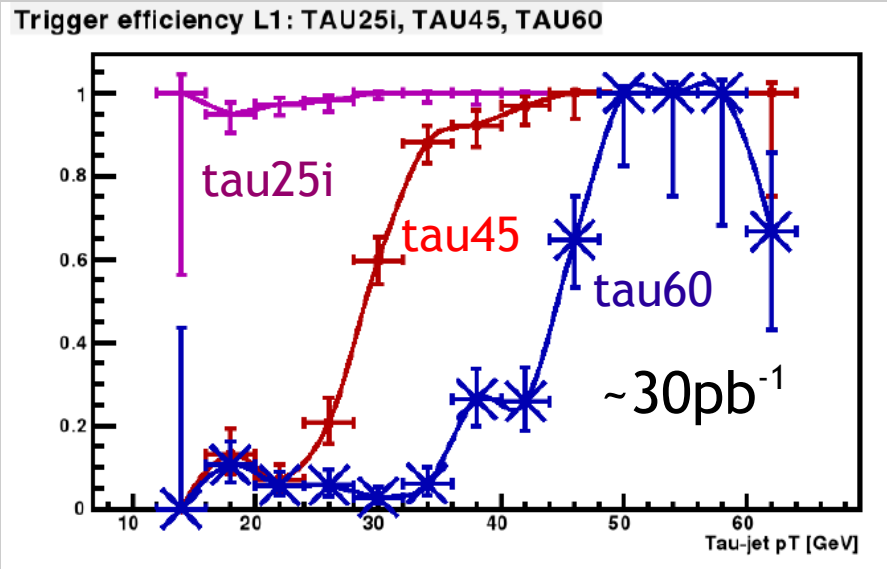
- Efficiency and turn-on curves with $Z \rightarrow \tau\tau$
  - Tag: e or μ
  - Reconstruct Z offline, study $\tau \rightarrow$ had
  - Background dominated by top and QCD
  - Expect ~1200 signal events in 100pb^{-1} with 30% background
  - First single tau trigger turn-on curves can be made.





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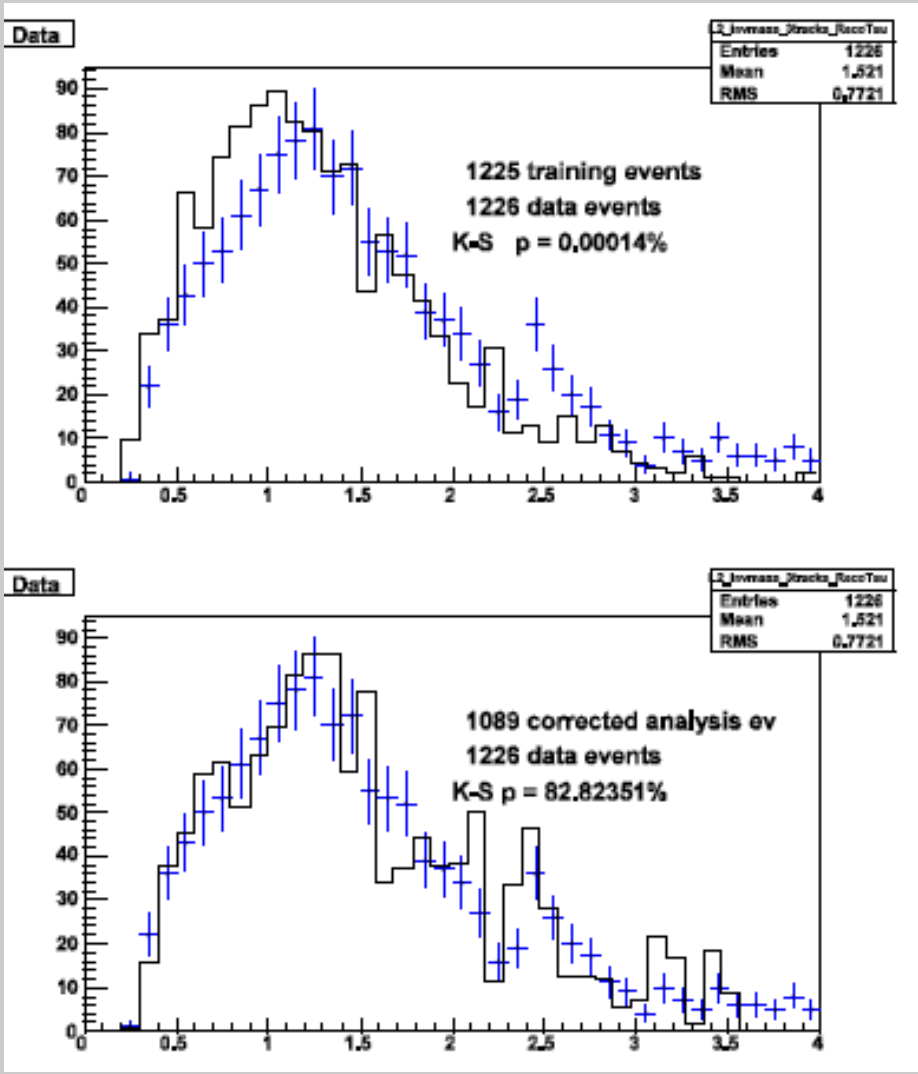
- Tuning of trigger variables with data
  - Develop methods for using data to correct single shape variables
    1. MC training sample vs. data -> correction parameters extracted
    2. MC with corrections (analysis sample) then used on data
  - Develop methods to get the MC contents to look like data, especially important to understand backgrounds



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Conclusions

- A full set of single tau and combined tau triggers has been defined for start-up of LHC
- Low threshold tau triggers need to be combined with other triggers to keep trigger rates low while high threshold trigger can be used as single tau triggers.
- Tau triggers has been used in the CSC work and the use of tau trigger menus are expected to increase in the future
- Tau trigger performance will be measured and tuned with first data.

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Conclusions

- A full set of single tau and combined tau triggers has been defined for start-up of LHC
- Low threshold tau triggers need to be combined with other triggers to keep trigger rates low while high threshold trigger can be used as single tau triggers.
- Tau triggers has been used in the CSC work and the use of tau trigger menus are expected to increase in the future
- Tau trigger performance will be measured and tuned with first data.

...may be as soon as this week-end when we expect first collisions

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Back-up slides

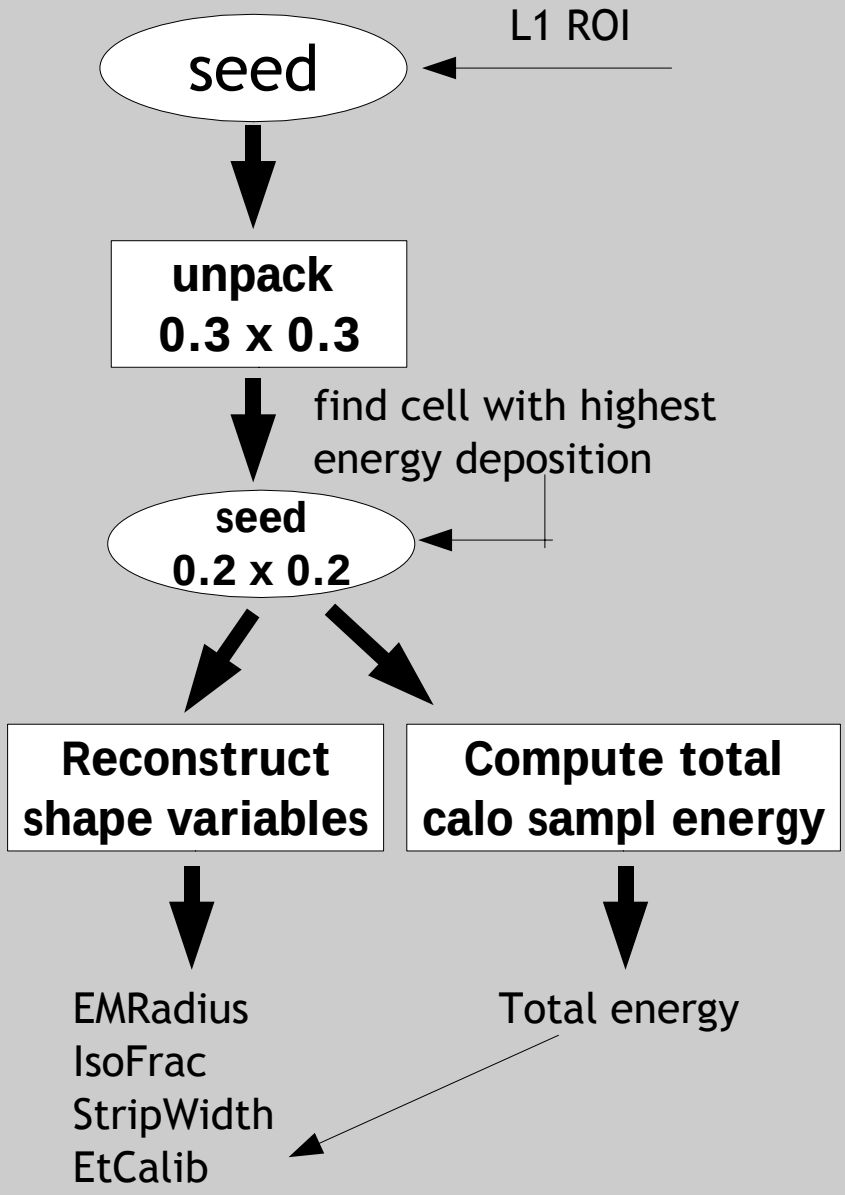
LVL2 trigger- calorimeter variables

- EMRadius:calculated in a window around the seed

$$EMRadius = \frac{\sum_{0.3x0.3} E_{cell} \cdot R_{cell}^2}{\sum_{0.3x0.3} E_{cell}}$$

- IsoFrac: Normalised difference in the energy between a 0.1x0.1 and 0.2x0.2 window

$$IsoFrac = \frac{\sum_{0.2x0.2} E_{cell} - \sum_{0.1x0.1} E_{cell}}{\sum_{0.2x0.2} E_{cell}}$$



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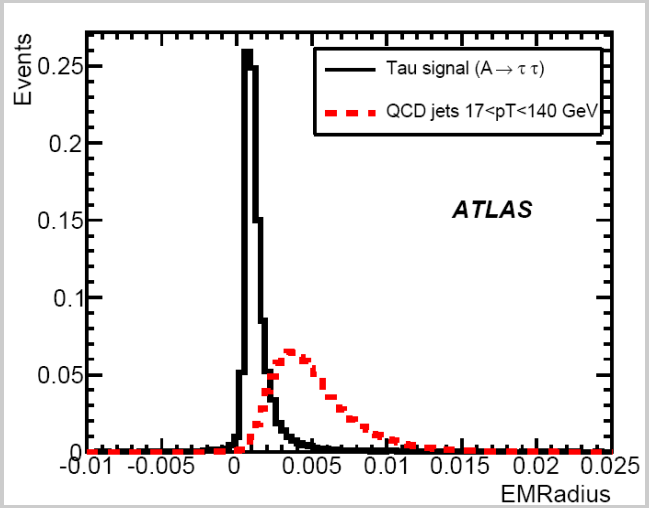
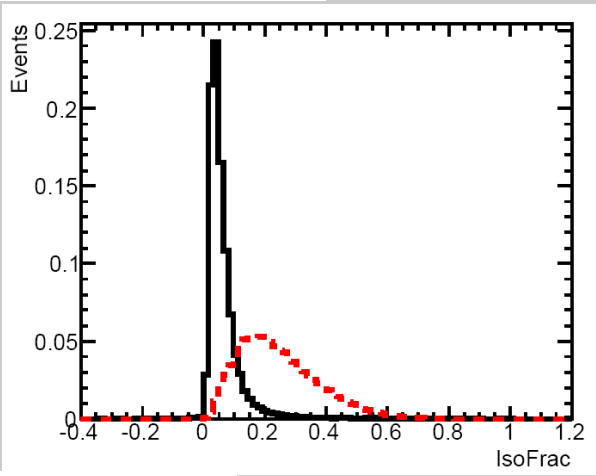
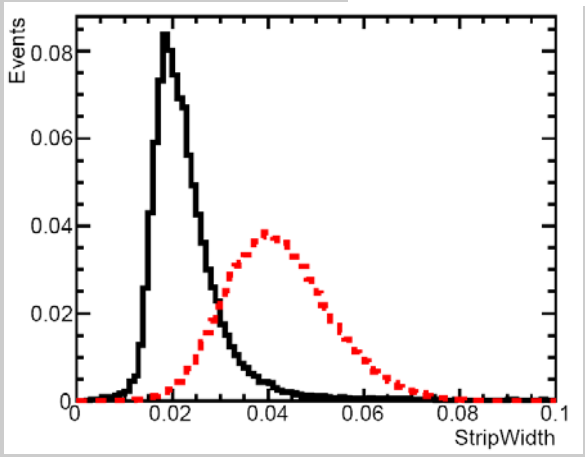
- StripWidth: Energy weighted width of the energy deposition in η

$$IsoFrac = \sqrt{\frac{\sum_{0.3x0.3} \eta_{cell}^2 \cdot E_{cell}}{\sum_{0.3x0.3} E_{cell}} - \left[\frac{\sum_{0.3x0.3} \eta_{cell} E_{cell}}{\sum_{0.3x0.3} E_{cell}}\right]^2}$$

- EtCalib: Total transverse momentum in both e.m. and hadronic calorimeters in 0.3x0.3 window







m_A = 800GeV

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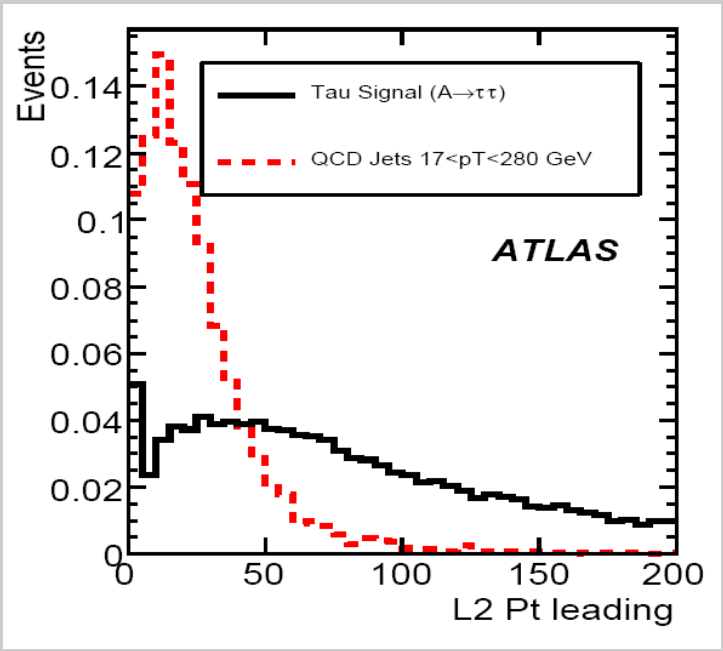
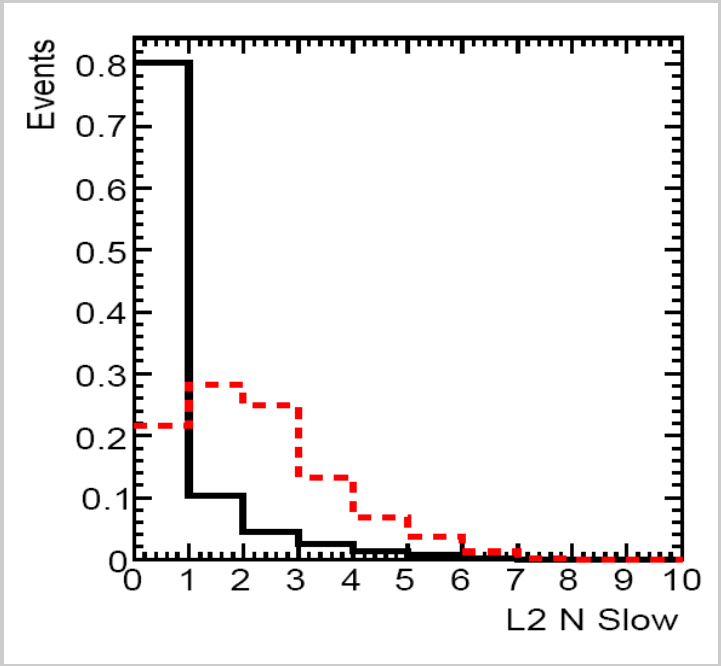
LVL2 trigger-tracking variables

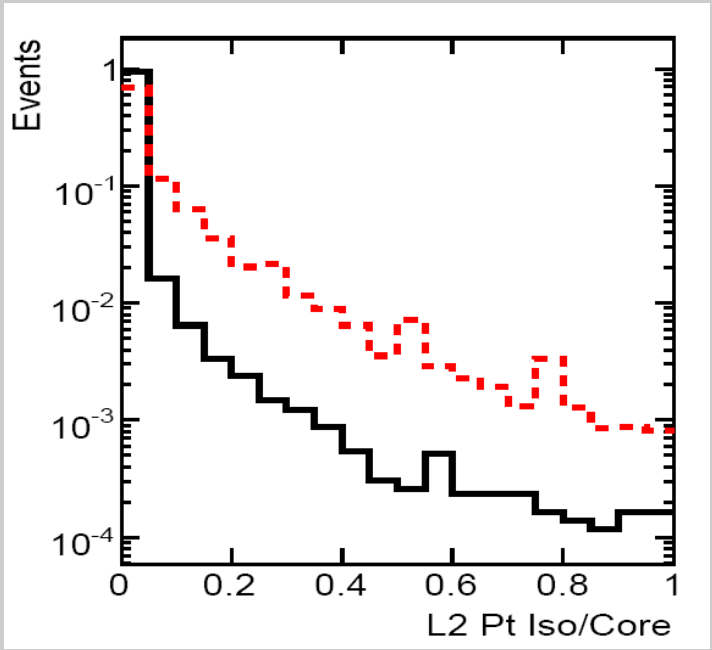
- The LVL2 track trigger is run after the calorimeter
- Tracks with pT>1.5GeV in 0.6x0.6 region around calorimeter seed (TRT not included)
- RoI around highest pT track 0.15 (core) and 0.3 (nor)
- Isolation ring between 0.15 and 0.3

- Pt leading: Highest pTtrack
- Pt Iso/Core: ratio of scalar sum of track pT in core and isolation regions
- N Slow tracks: Number of tracks in the core region with pT below a threshold (e.g. 7.5 GeV/c)
- Charge: Sum of charges of tracks in nor region
- N Tracks: total number of tracks in nor region


Events
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Tau Signal (A→ττ)
QCD Jets 17<pT<280 GeV
ATLAS
0
50
100
150
200
L2 Pt leading

m_A = 800 GeV


Events
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10
L2 N Slow


Events
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
0.2
0.4
0.6
0.8
1
L2 Pt Iso/Core

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Event Filter variables

- EF is repeating the LVL2 steps but in a much more sophisticated tau identification algorithm taken from offline.
- The seeding is taken from LVL2
- Main variables are: EMRadius, IsoFrac, N Tracks, Pt leading track and EtCalib.