The ATLAS tau trigger

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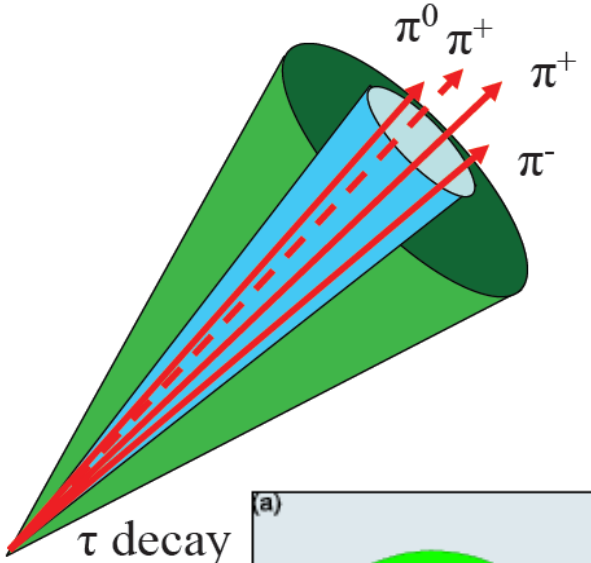
on behalf of ATLAS collaboration

Challenge of tau trigger

Identifying the hadronic tau lepton at trigger.

Our challenge : **combined performance of tracking, EM and Hadronic calorimeters.**



Tracking :

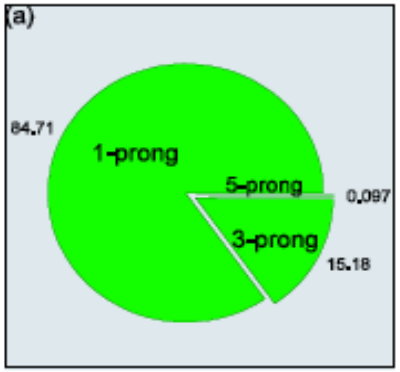
- Collimated tracks (1-3-prong) in core region.
- Isolation from other tracks.
- non zero impact parameter ($c\tau$~87μm).

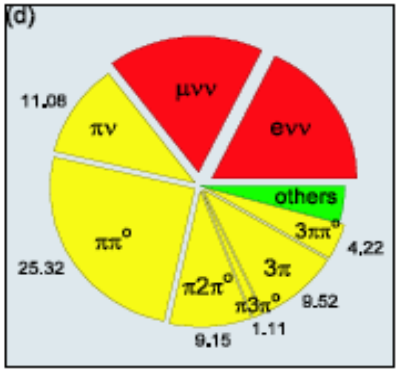
Calorimeters :

- Collimated deposition in EM. (50% of energy by π^0 in 1-prong τ)
- Use shower shape.
- Both EM and HAD component.
- Isolation cone.
- Reconstruction of π^0 sub-cluster.

τ decay

- Leptonic Decay Modes
  $e/\mu\nu_{e\mu}\nu_\tau$ 35%
- 1Prong Hadronic Decay Modes
  $\pi^-\nu_\tau$ 11%
  $\pi^-\pi^0\nu_\tau$ 25%
  $\pi^-\pi^0\pi^0\nu_\tau$ 9%
  $\pi^-\pi^0\pi^0\pi^0\nu_\tau$ 1%
  K^- + Neutrals 1.5%
- 3Prong Hadronic Decay Modes
  $\pi^-\pi^+\pi^-$ 9%
  $\pi^-\pi^+\pi^-\pi^0$ 4.5%
  $K^-\pi^+\pi^-$ 0.4%
- Other Modes ($\sim$ 3%)





Relatively high QCD jet rejection can be achieved.

Physics motivation

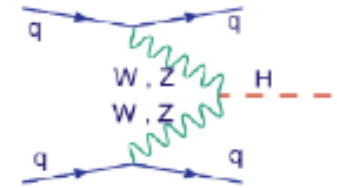
LHC is "QCD jets" collider.

The tau trigger will play an important rule to suppress the rate by exploring the combined menu.

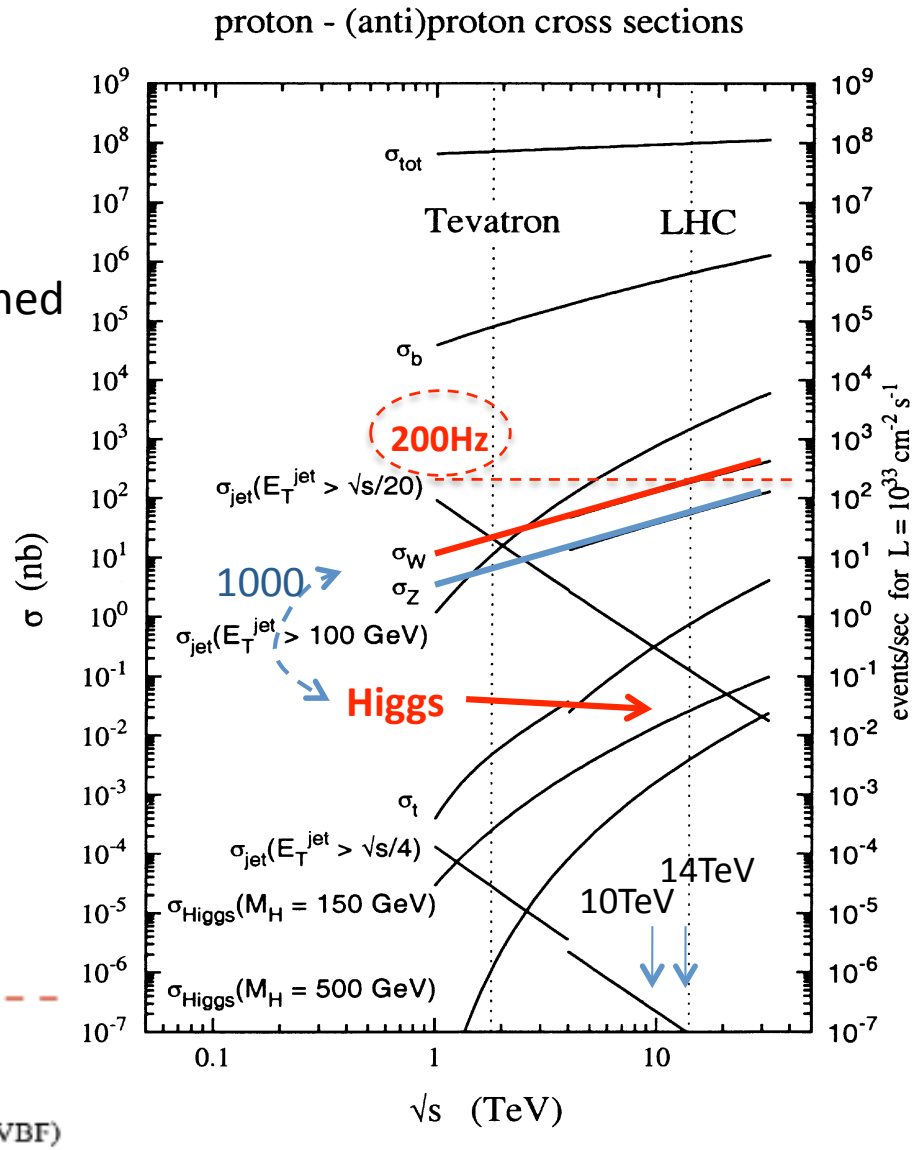
Need to suppress QCD background with order ~10^6 .

To suppress the trigger rate,

- double hadronic taus ($\tau_h\tau_h$)
- lepton + tau ($l+\tau_h$)
  VBF Higgs -> $\tau\tau$ -> hh / lh
- tau + Missing E_T (τ_h + MET)
  MSSM Charged H^+
- high p_T tau
  Z' / W' searches.



Vector Boson Fusion (VBF)



~300 VME modules

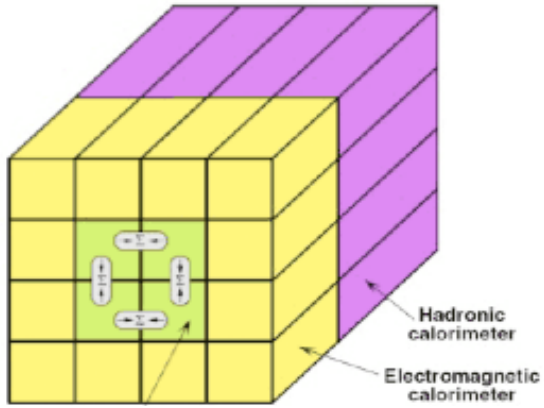
Level 1 tau trigger

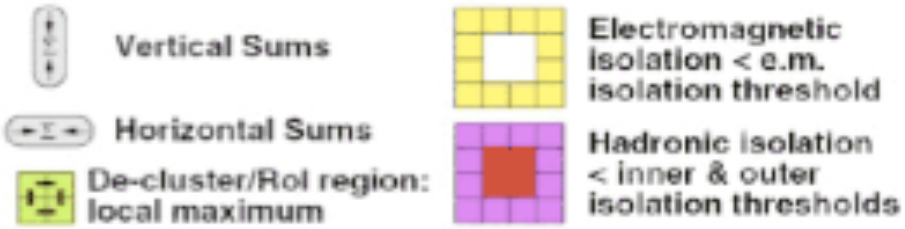
Basic spec : L1 Calorimeter

- Hardware : ASICS / FPGA
- latency < ~2.5 μs, operates on 40MHz,
- L1 acceptance : 75kHz,
- 7200 coarse projective trigger towers ($\Delta\phi x\Delta\eta$=0.1x0.1)
- 10bits ADC (1 ADC count = 250MeV)

Cluster processor :

- RoI Core : 2x2 tower EM and Had E_T maximum,
- Tau cluster is formed as 1x2 EM + 2x2 Had towers.
- EM/Had isolation : total 16 towers around RoI Core.





L1 TAU :

Maximum 8 trigger thresholds,
EM isolation ≤ 6GeV

High Level Trigger (HLT)

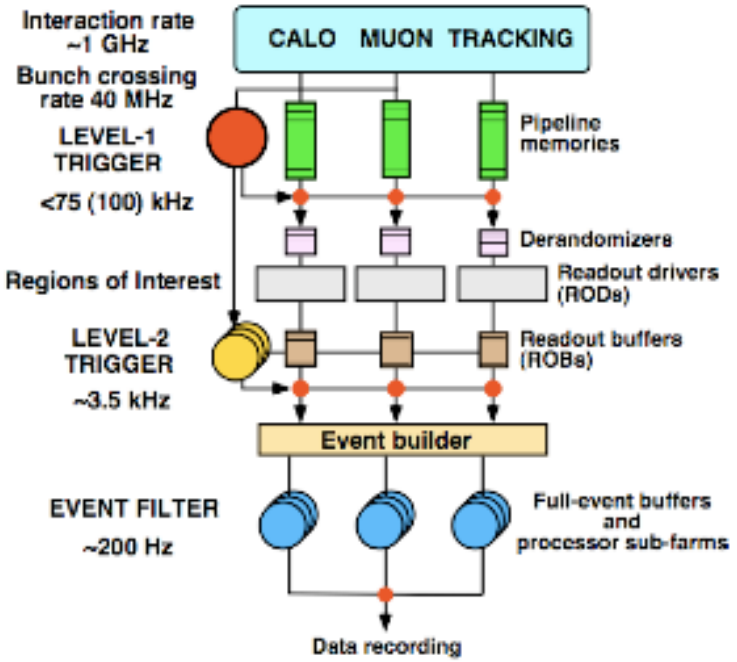
Software triggers :

- PC farm : 2300 PCs, SLC4->5, Intel 2.5GHz (4-core)
- Implementing on RoI/object,
- L2 operates 75kHz, processing time ~40ms,
- EF operates 3kHz, processing time ~4s,
- Accept 200Hz (go in tape, 1.6M bytes/evts).
- Full reconstruction at EF.

Tau algorithm performance : tau20i

	Level 2	Event Filter
RoI unpacking	~3.8 ms	---
Calorimeter	~8.0 ms	~13.4 ms
Tracking	~15.0 ms	~269.5 ms
Combined	~2.0 ms	~80.7 ms
Total time	~19.7 ms	~67.5 ms

Note : QCD jets sample was used. No prescale.
"Total" is ms/event, otherwise ms/RoI.



Tau identification at trigger

Level 2 / Event Filter
(normalized to 1)

At HLT (L2 and EF), the tau identification criteria is applied :

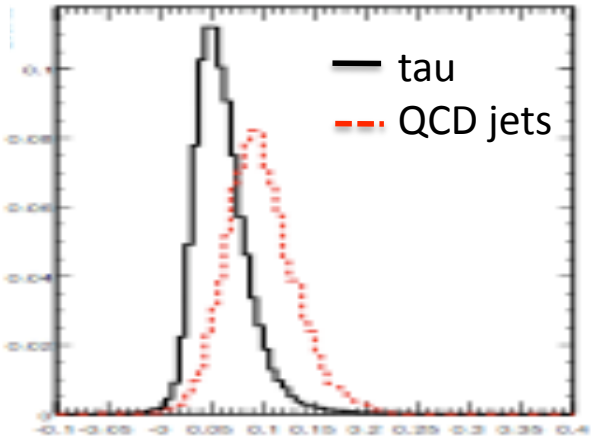
EMRadius : transverse EM shower profile,

Isolation fraction: fraction of energy in iso.ring region,

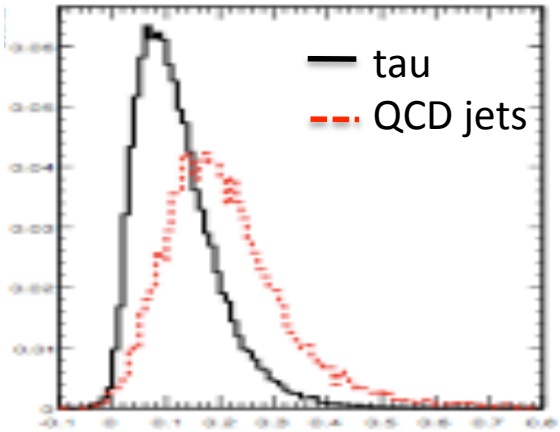
n tracks : # of tracks,

track isolation: fraction of tracks in core region,

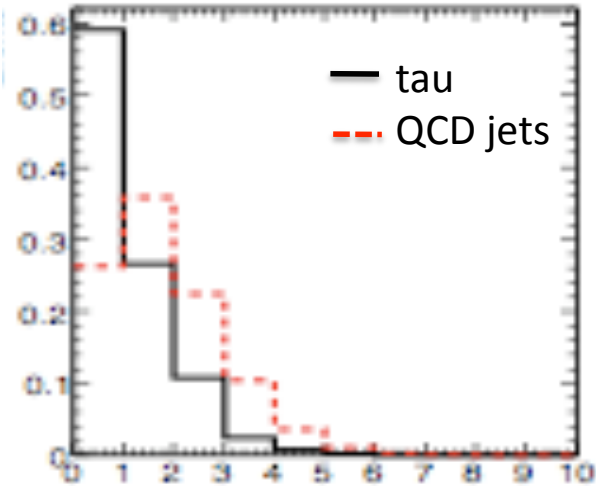
EM fraction: EM energy fraction,
isolation fraction,
leading track p_T , EM E_T …… etc.



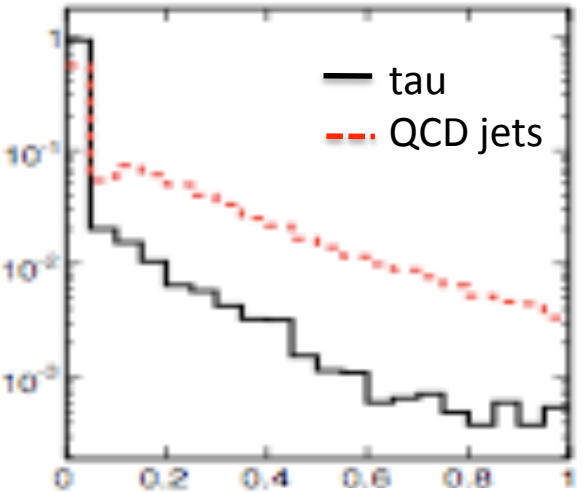
EMRadius



Isolation fraction



# of tracks



Track isolation

At EF, same reconstruction algorithm is used with offline tau reconstruction.

Tau trigger performance

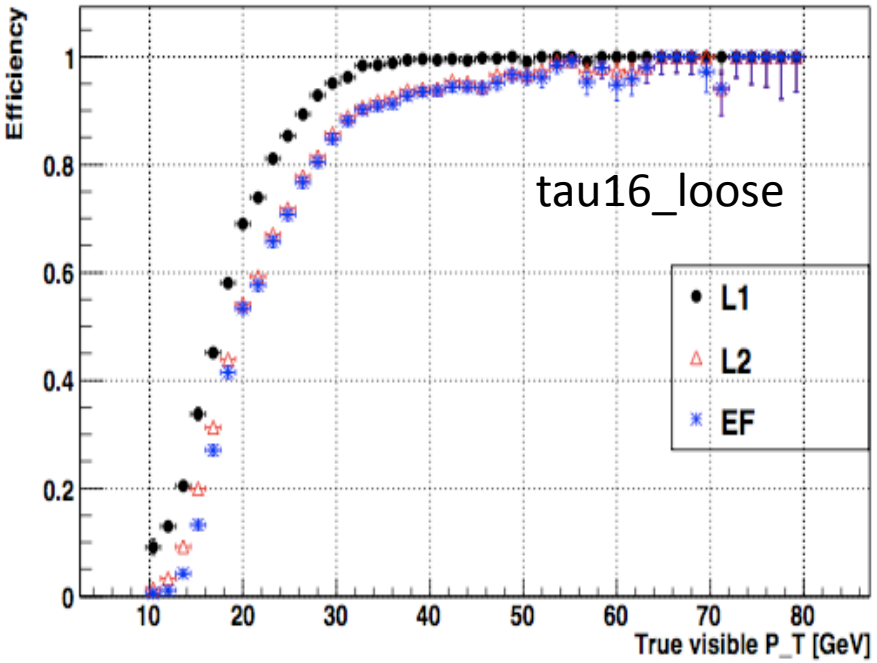
At each level, the trigger efficiency reaches fairly flat.

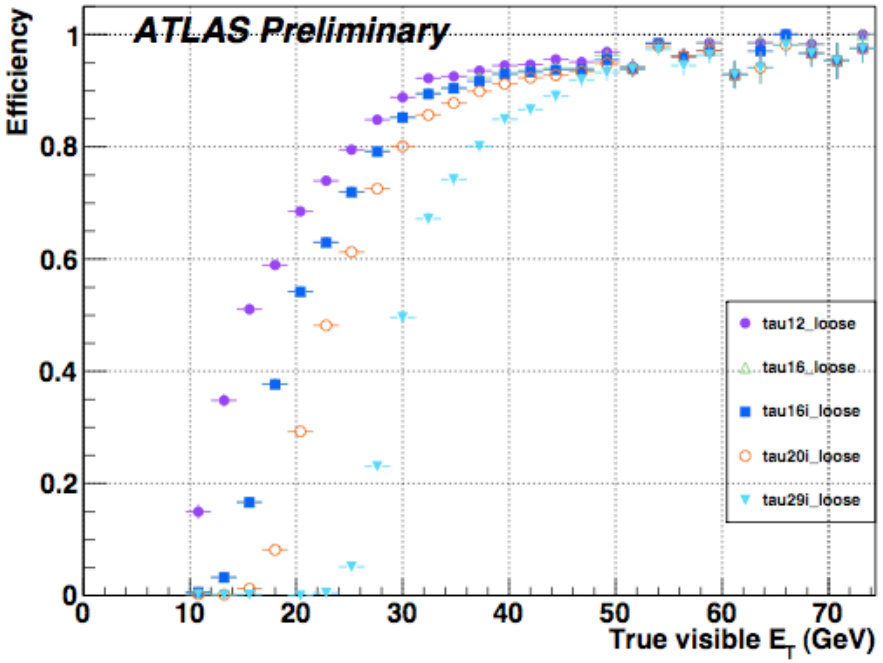
The “tau16” means the tau with p_T>16GeV.

The trigger rate at L=$10^{31}cm^{-2}s^{-1}$:

tau16_loose : L1/L2/EF = 1.9k / 408 / 265 Hz ⇐ Used in the combined menu

tau50_loose : 26 / 1.97 / 0.89 Hz ⇐ Acceptable as single menu





Tau trigger menu

Start up menu (L=10^{31}cm^{-2}s^{-1} , 10TeV)

- Validate trigger. Stay simple as much as possible.
- L1 : low p_T threshold, looser isolation,
- HLT : running with pass-through mode,
- Combined menu will be tighten.
- tau+MET will be studied for W->$\tau_h\nu$ xsec.

L=10^{31}cm^{-2}s^{-1} , 10TeV

Trigger	Prescale	Rate (Hz)
tau50	1	0.89±0.44
tau16i_EFxe30	1	5.8±0.70
2tau20i	1	1.1±0.5
tau12_e10	1	0.89±0.45
tau16i_mu6	1	0.11±0.03
tau16i_j120	1	0.22±0.22
tau16i_2j70	1	0.44±0.3
tau16i_3j23	1	0.44±0.3

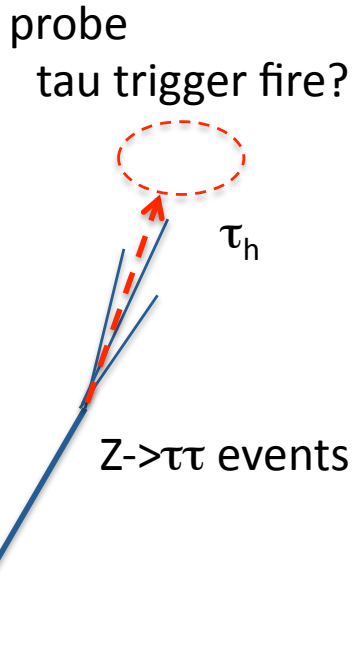
At L=10^{33}cm^{-2}s^{-1} , 14TeV

Complex signature and high p_T threshold will be necessary to achieve the physics goal.

Trigger rate and acceptance at L=10^{31}cm^{-2}s^{-1} ,14TeV, loose cut

Signature	Rate, Hz	Eff($W \to \tau\nu$)	Eff($Z \to \tau\tau$)	Eff($A(800) \to \tau\tau$)
offline tau	2667.969 ± 30.541	0.5670 ± 0.0017	0.7351 ± 0.0014	0.7342 ± 0.0014
tau16i	587.120 ± 19.229	0.7329 ± 0.0024	0.8602 ± 0.0014	0.9003 ± 0.0011
tau20i	327.125 ± 13.780	0.7577 ± 0.0027	0.8528 ± 0.0016	0.8968 ± 0.0011
tau29i	114.472 ± 7.641	0.7870 ± 0.0043	0.8324 ± 0.0022	0.8899 ± 0.0012
tau50	7.957 ± 1.975	0.7193 ± 0.0139	0.6796 ± 0.0072	0.9223 ± 0.0010
tau84	1.997 ± 1.086	0.7759 ± 0.0316	0.8059 ± 0.0165	0.8968 ± 0.0012
2tau16i	8.503 ± 1.569	0.0000 ± 0.0000	0.6082 ± 0.0055	0.6265 ± 0.0045
2tau29i	1.573 ± 0.286	0.0000 ± 0.0000	0.6067 ± 0.0147	0.6065 ± 0.0046
tau20i_xE30	2.233 ± 0.352	0.4044 ± 0.0059	0.5164 ± 0.0095	0.8252 ± 0.0016
tau29i_xE40	0.438 ± 0.166	0.3594 ± 0.0130	0.5650 ± 0.0174	0.7966 ± 0.0018
tau16i_e10	4.748 ± 1.706	0.0000 ± 0.0000	0.7478 ± 0.0053	0.7984 ± 0.0035
tau16i_e15i	0.045 ± 0.015	0.0000 ± 0.0000	0.5904 ± 0.0066	0.6350 ± 0.0042

Trigger efficiency measurement from data



Tag & probe method :

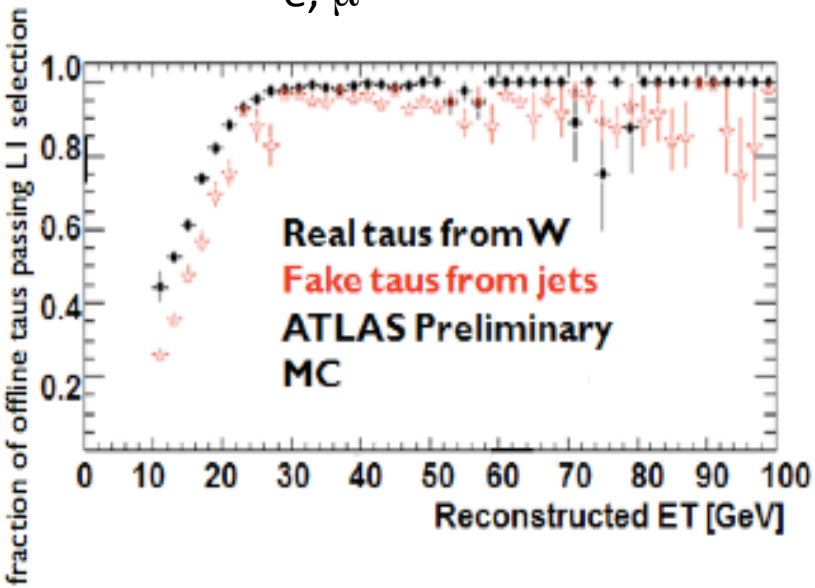
- Require tag lepton which passes single lepton trigger,
- Ask if tau trigger fires with respect to offline tau,
- Direct measurement from data,
- Suffer from the statistics, and limited p_T range.

Using QCD jets or electron :

- The tau is between “electron” and “jet”,
- Gain high statistics, extend high p_T region,
- Assume the transfer of jet/electron to tau by adjusting identification criteria.

Using ttbar events :

- The top event can be another control sample.
- Using three jets trigger, ask if one of W fire the tau trigger.



Tau trigger data quality monitoring

Data is monitored w.r.t. the reference.

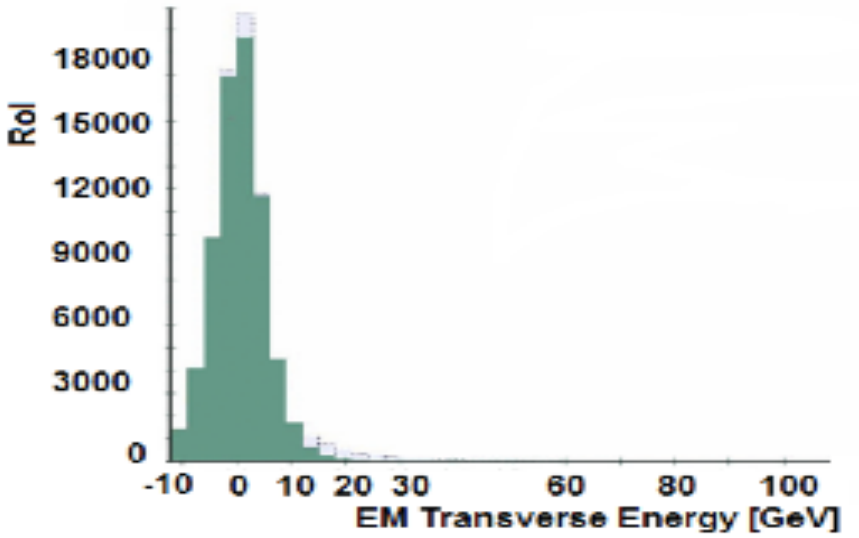
- GREY : reference
- GREEN : Good
- RED : Bad

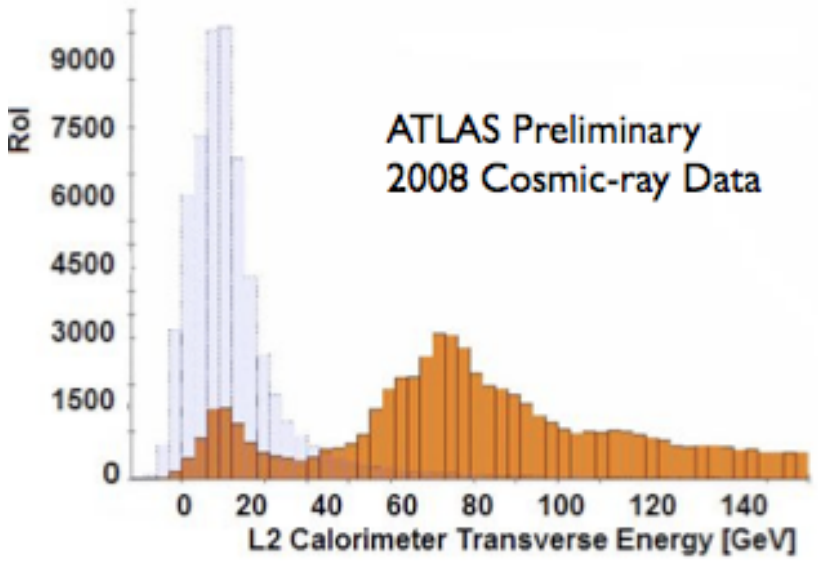
This example depicts

EM E_T is fine, but problem in total E_T.

Problem was in hadronic E_T.

It was configuration problem.

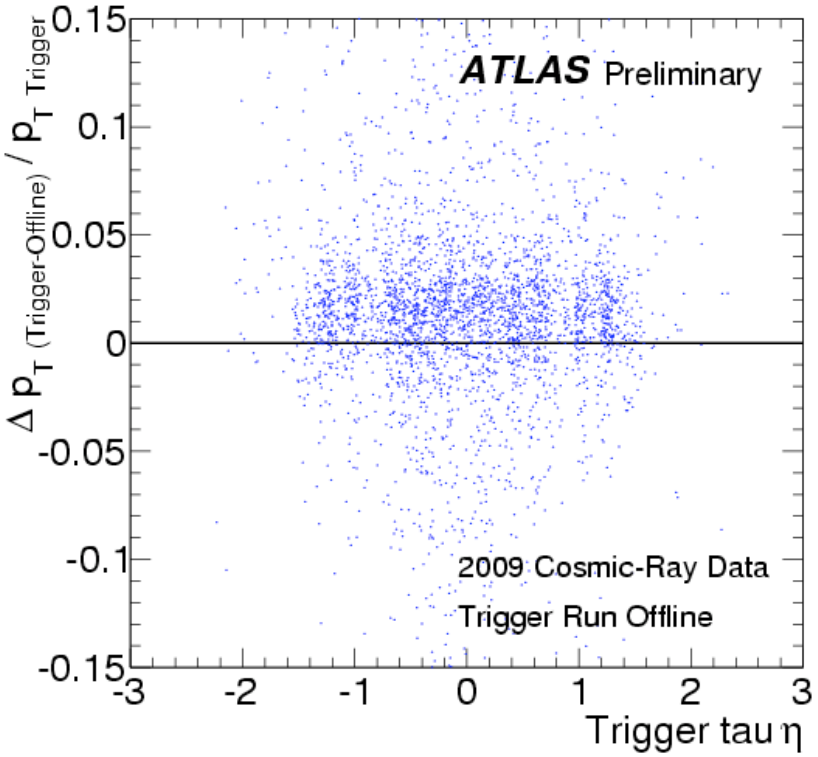


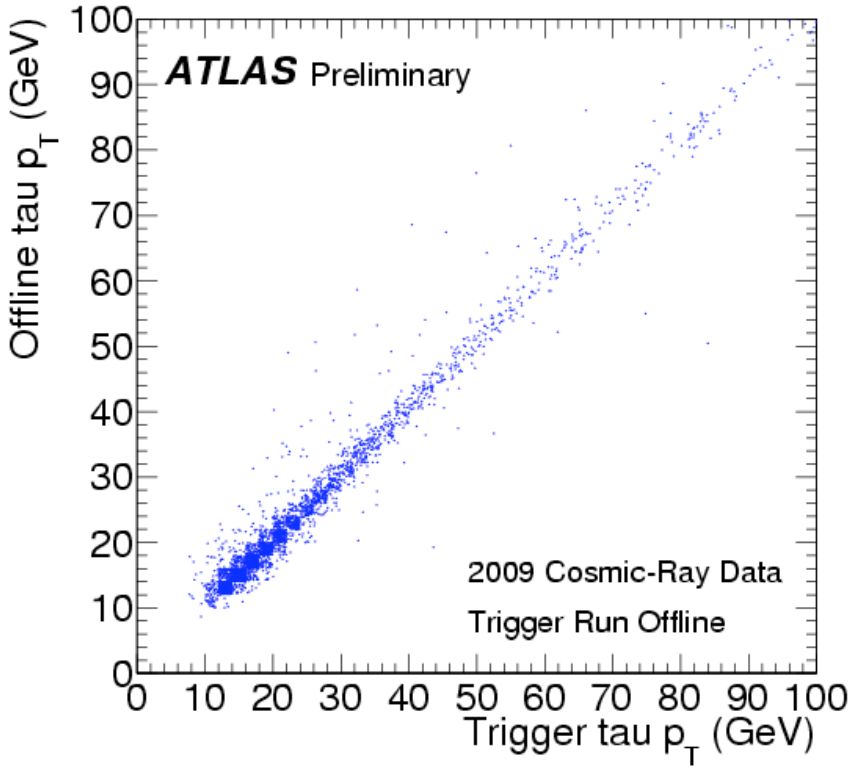


Tau trigger performance on cosmic data

The tau trigger performance is checked with respect to the offline reconstruction.
The plots show the pT difference as a function of EF tau (left) and the energy correlation between trigger and offline reconstructions (right).

No eta dependence was found. The difference is within the expected difference between trigger and offline reconstruction.





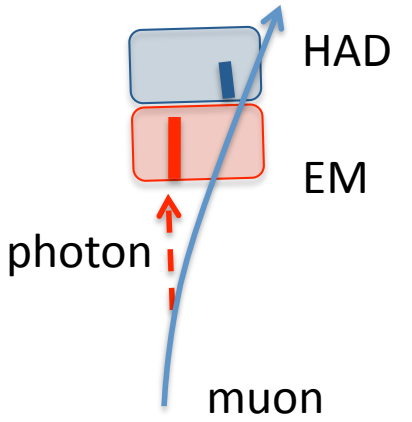
Hunting the MIP cluster

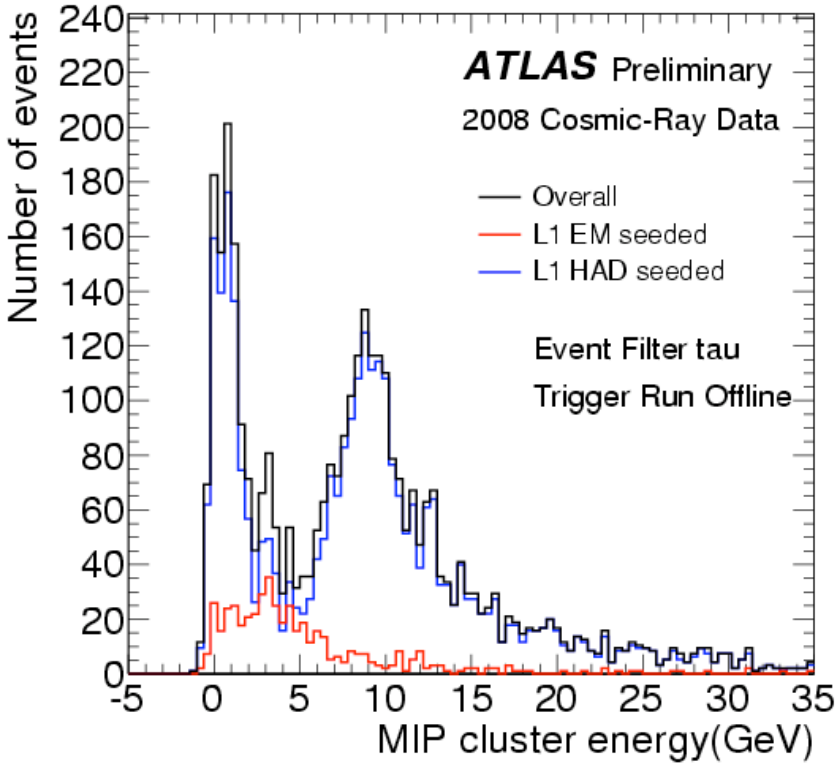
The tau signature gives an unique opportunity to hunt the MIP cluster in tau object.

The tau uses tracks and EM and hadronic energy.

Hunting the cluster associated in the muon track.

(The muon track is extrapolated on to calorimeter surface, then find a MIP cluster.)





Events are categorized as EM and HAD seeded events.

Source of the three peaks :

- The MIP cluster itself fires the tau trigger (~10GeV).
- MIP energy in Tile calorimeter (~3-4 GeV)
- MIP energy in LAr. (typically 200MeV), but cut off by the cell energy threshold (~1GeV).

Summary

Our challenge is to understand the combined performance of tracking, EM and hadronic calorimeters.

In the tau triggering,

Level 1 : narrow jet and isolation with coarse projective trigger tower,
Level 2 : fast tracking, fast clustering in RoI, fast identification,
Event Filter : sophisticated identification, same reconstruction with offline.

Performance is well-evaluated by the MC simulation :

- High rejection of QCD background,
- Combined menu (2tau, l+tau, tau+MET) explores sensitivities for new physics.

Tested, demonstrated on the cosmic muon data :

- Monitoring the data quality,
- Validated and understood with respect to the offline reconstruction.

We are eagerly waiting for DATA.