Performance of the ATLAS Tau Trigger system with 7 TeV pp collisions at the LHC

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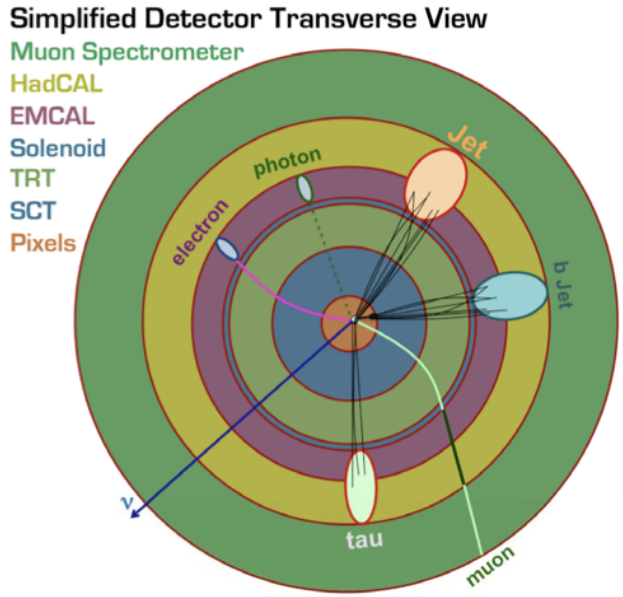
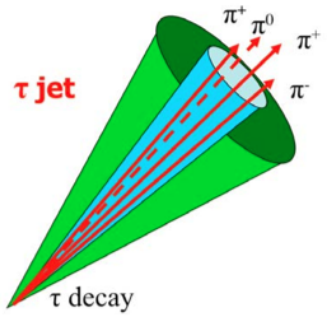
Identification of hadronic tau lepton decays

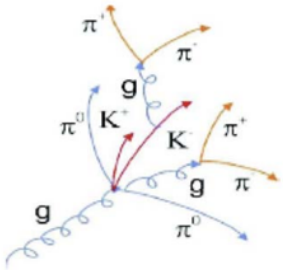
What do taus look like in the detector?



A tau jet (signal)...



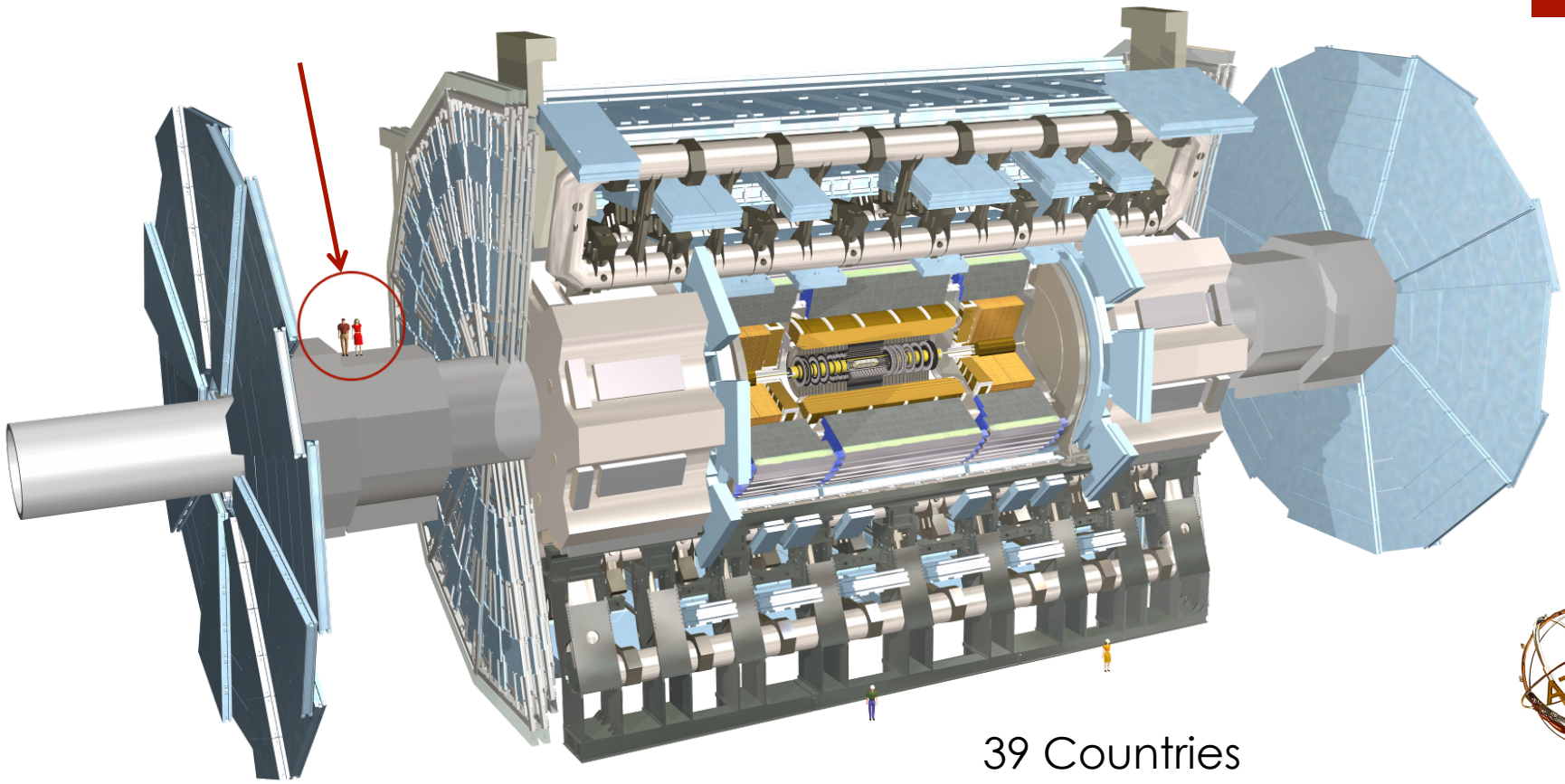
...vs. a QCD jet (background)



Tau Decay Mode			B.R.
Leptonic		$\tau^{\pm} \to e^{\pm} + \nu + \nu$	17.8%
		$\tau^{\pm} \to \mu^{\pm} + \nu + \nu$	17.4%
Hadronic	1-prong	$\tau^{\pm} \to \pi^{\pm} + \nu$	11%
		$\tau^{\pm} \to \pi^{\pm} + \nu + n\pi^0$	35%
	3-prong	$\tau^{\pm} \to 3\pi^{\pm} + \nu$	9%
		$\tau^{\pm} \to 3\pi^{\pm} + \nu + n\pi^0$	5%
	other		~5%

Identification of hadronic tau lepton decays requires input data from the calorimeter and the tracking detectors

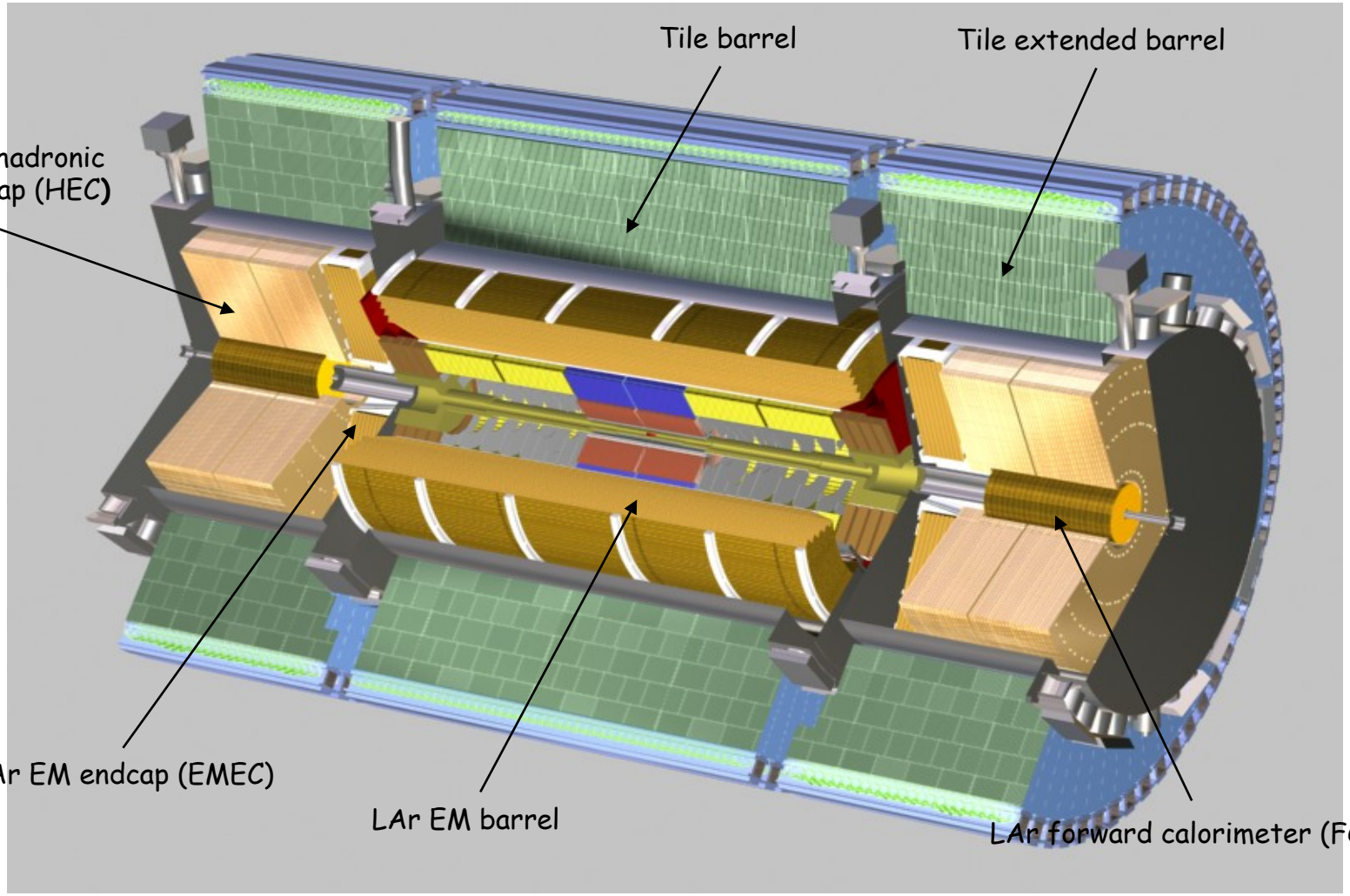
The ATLAS Experiment



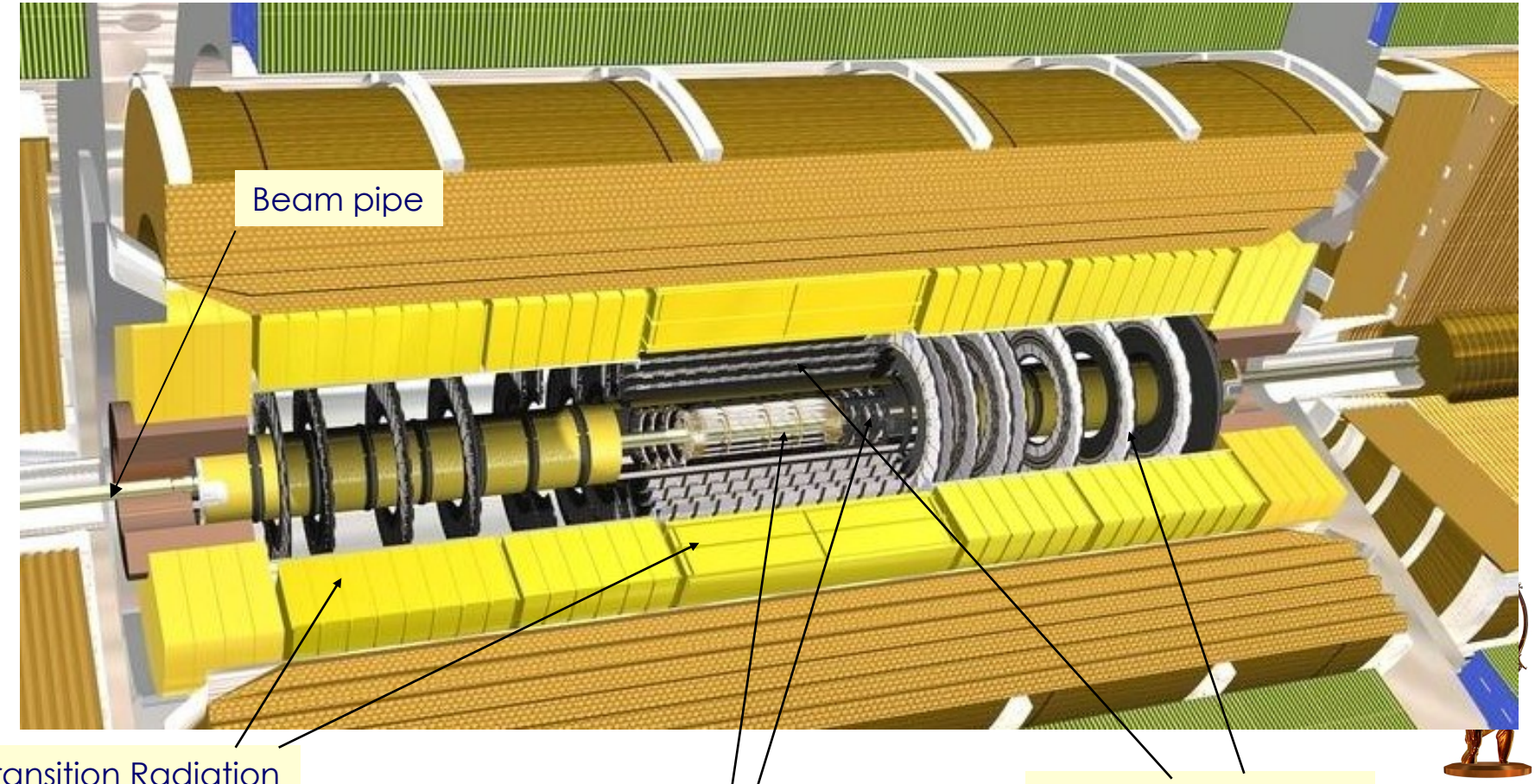
… a BIG experiment :

39 Countries
176 Universities
3000 Physicists
(more than 1000 students)

ATLAS calorimeter



ATLAS tracking detector



ATLAS Trigger

Background rate

40 MHz

online

Higgs rate (eg. VBF, 120 GeV)

10 mHz

Level 1 trigger
fast and simple first selection

Stepwise approach

75 KHz

High Level trigger
more complex analysis

offline

200 Hz

Max speed at which you can save data to disk (1 event = 1.5 MBytes)

disk

Reconstruction & Analysis

1 - 0.1 mHz

Trigger design constrained by several aspects :
- Rate of input data
- Amount of processors, available disk capacity (cost)
- Speed of data transfer (to disk, or internal)
- Speed of processors
- Efficiency to save new physics to disk for later analysis

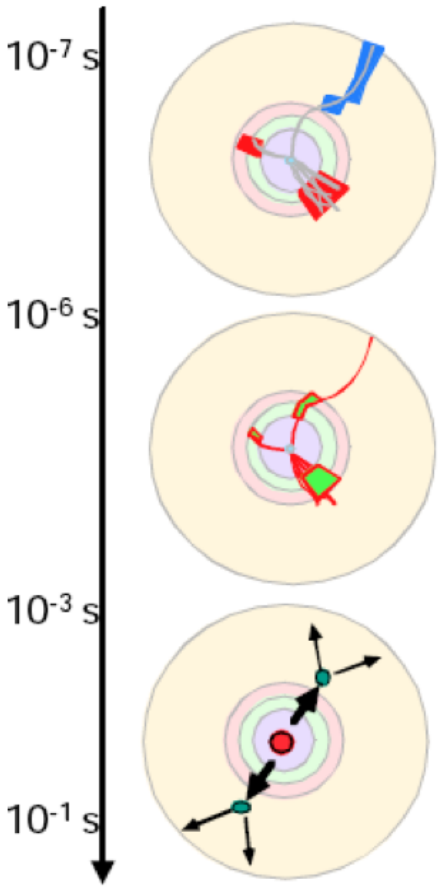
10 -1 μ Hz

μ s(L1)

msec(L2)/sec(L3)

min++
Processing time/event

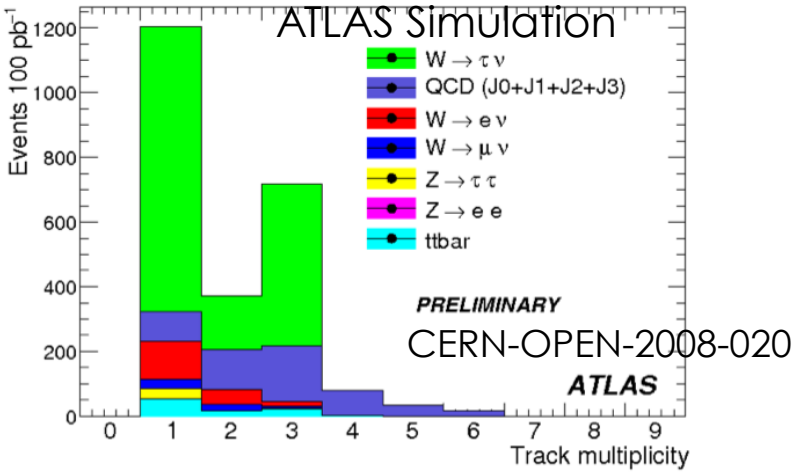
ATLAS Trigger



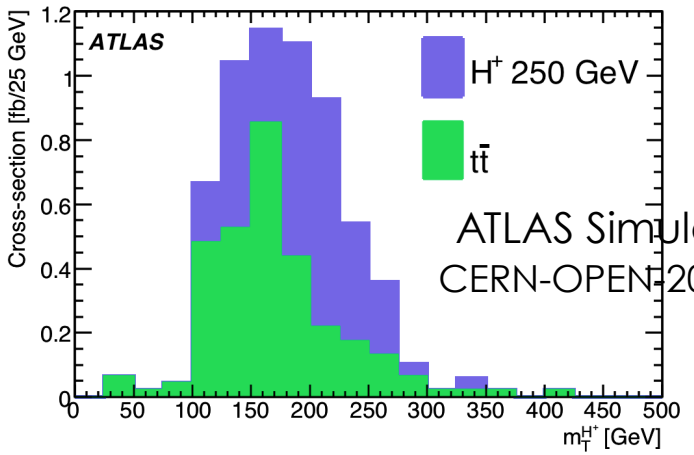
- The first level trigger (L1) finds regions of activity in the detector (muon detector or calorimeter), and passes this information to the second level trigger (L2). Simple, fast selection applied.
- The second level accesses the data in the region of activity determined by L1 (a few percent of the total). Noise subtraction in calorimeter can be applied. Dedicated tracking algorithms are run.
- The third level trigger (or Event Filter, EF) can operate in the region determined by L2 or on the full event. Offline reconstruction algorithms are run online. Sophisticated selection can be applied.

Tau trigger focuses on final states with one or more **hadronic decays** of tau leptons. This allows **efficient detection** of Standard Model (SM) and Beyond the SM **physics processes** like H-> $\tau\ \tau$, H^+ -> $\tau\ \nu$, Z' -> $\tau\ \tau$, ...

ATLAS tau trigger motivation



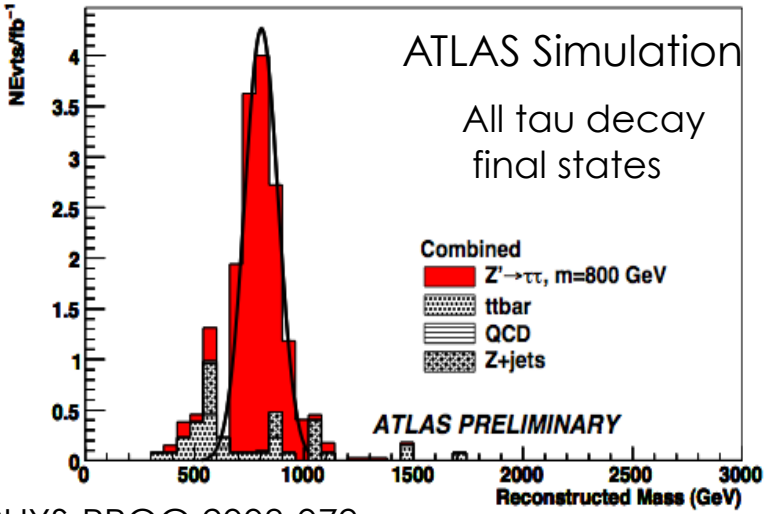
CERN-OPEN-2008-020



ATLAS Simulation

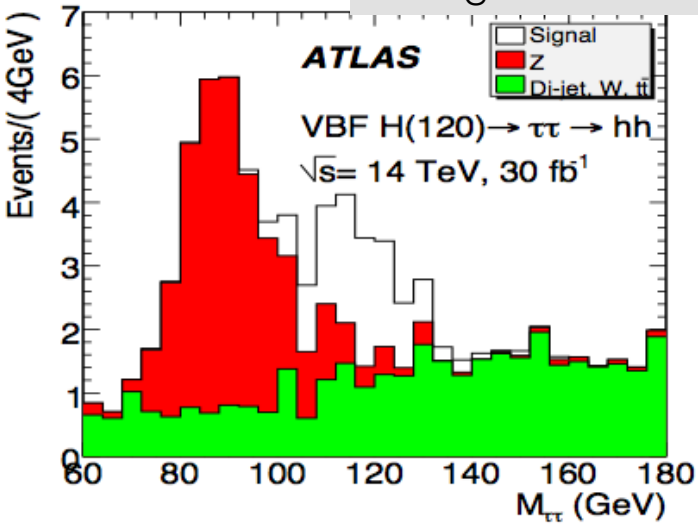
CERN-OPEN-2008-020

Note: safety factor 5 for QCD background not included



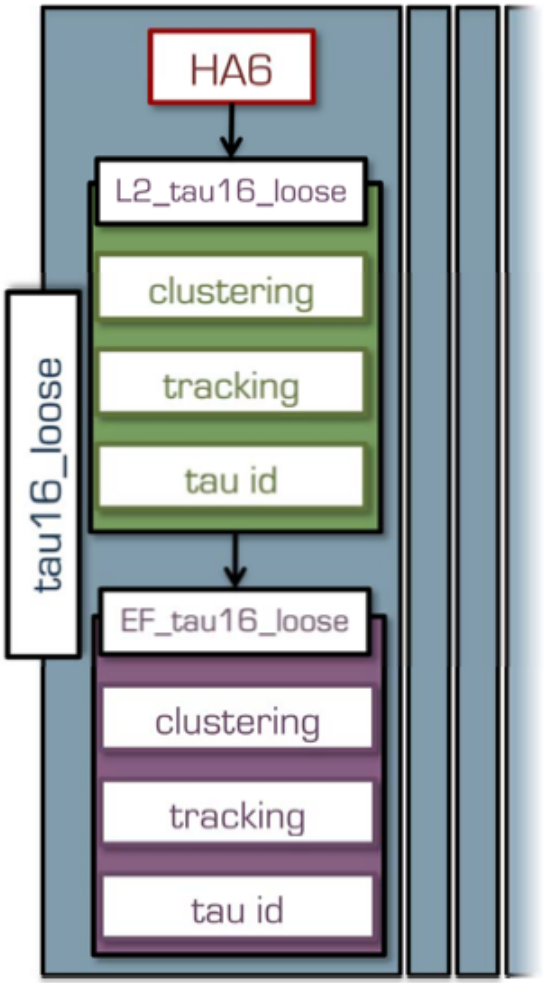
ATL-PHYS-PROC-2008-079

ATLAS Simulation

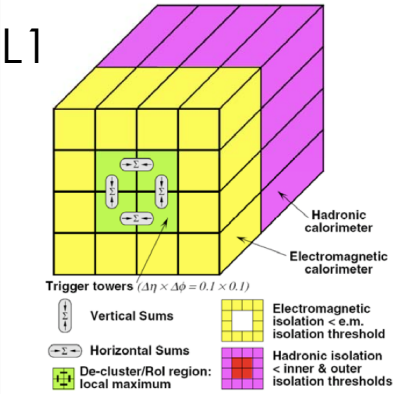


ATL-PHYS-PROC-2009-001

ATLAS Tau Trigger Implementation



L1



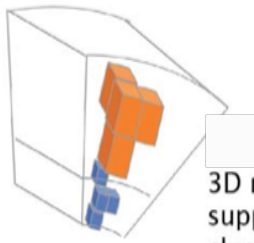
Trigger Tower = 0.1 x 0.1 η xΦ
Sum of several calorimeter cells

Local maximum (0.2 x 0.2 core region) should be above threshold e.g. HA6 means threshold is 6 GeV

$|\eta| < 2.5$

Track and calorimeter cell information are combined, for the first time tau dedicated selection on number of tracks, isolation and lateral shape in calorimeter is applied. No noise suppression applied.

L2



3D noise-suppressed clusters of cells

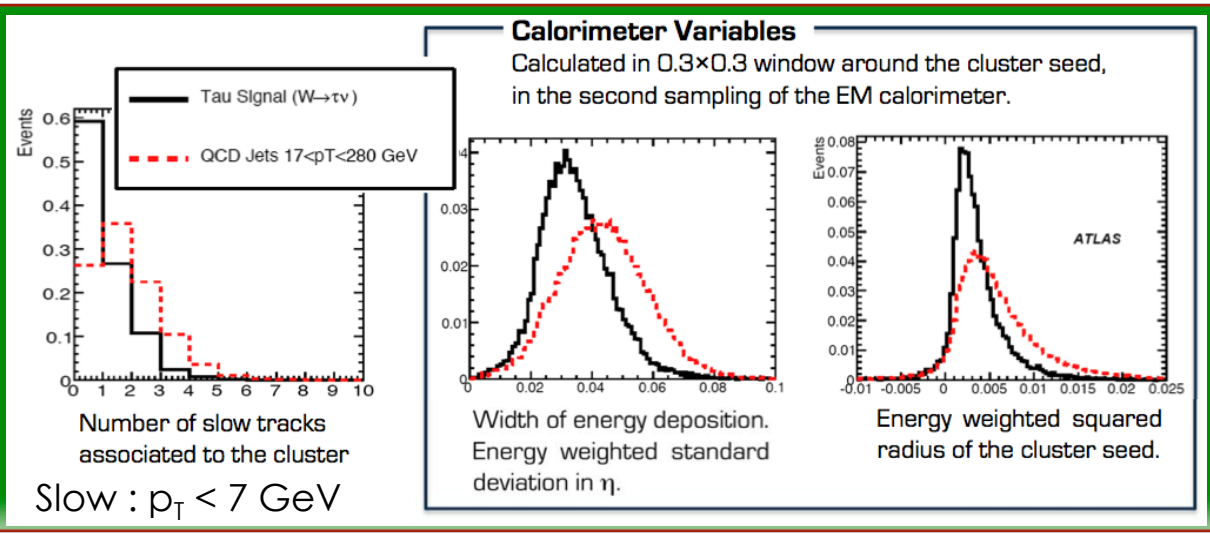
Noise suppression using topological clustering algorithm and offline calibration procedure is applied.

EF

Run identification algorithms online, then use cut-based selection optimized in simulation wrt offline identified tau leptons.

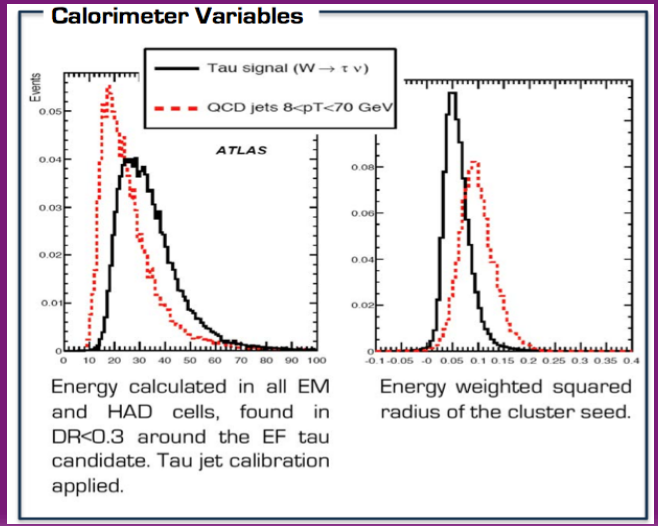
HLT tau trigger identification

L2



Slow : $p_T < 7$ GeV

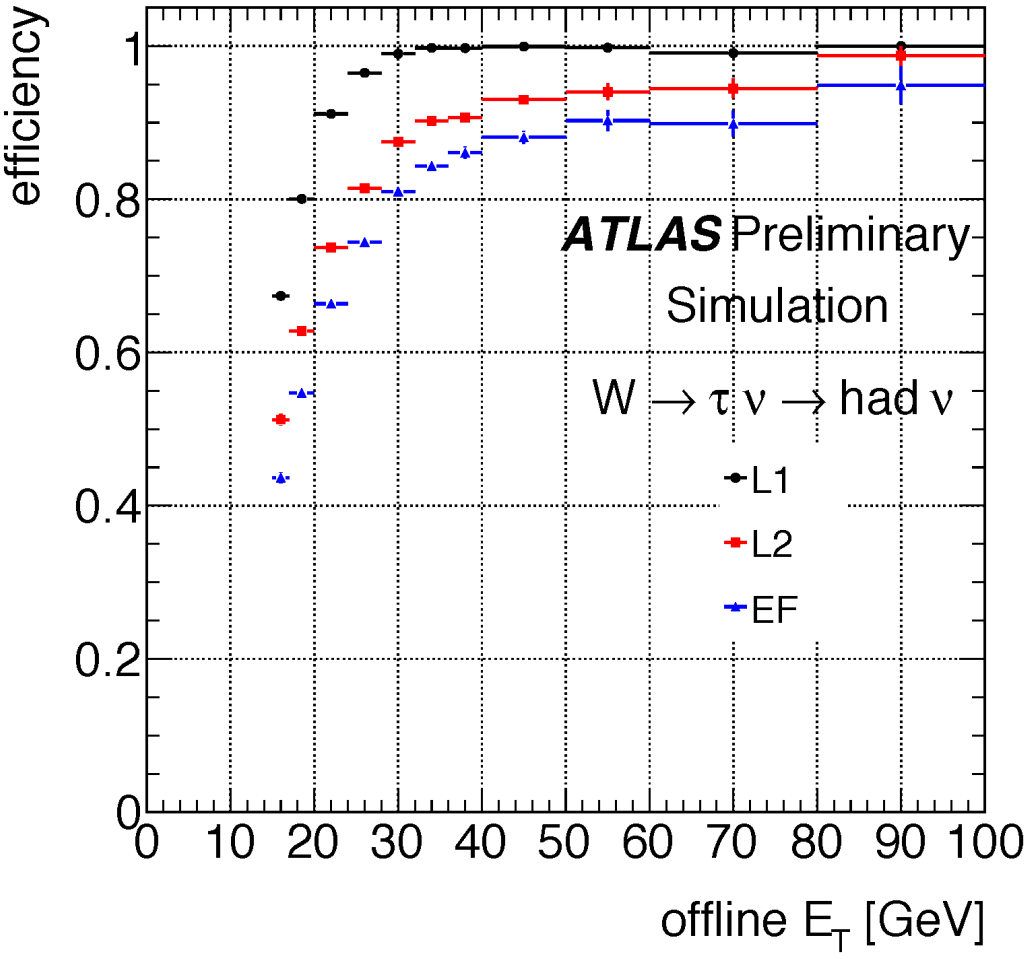
EF



Typical rejection of L2 + EF with respect to L1 rate is > 10

Tau Trigger performance

Efficiency = N true taus passing tau trigger && reconstructed as offline tau jets / N true taus reconstructed as offline tau jets



Fraction of offline reconstructed tau candidates passing L1, L2 and EF **tau12_loose** trigger , as a function of the E_T of the offline tau candidate. Distributions are done on Monte-Carlo (MC) W -> τ (had) ν events. Requirements for E_T are 5 GeV at L1, 7 GeV at L2 and 12 GeV at EF.

No identification applied to offline tau candidates. Tau trigger candidates are matched to true tau candidates in the simulated events.

tau12_loose

E_T cut at EF

Efficiency wrt true taus offline reconstructed with E_T > 12 GeV is ~ 80%

Tau Trigger menu

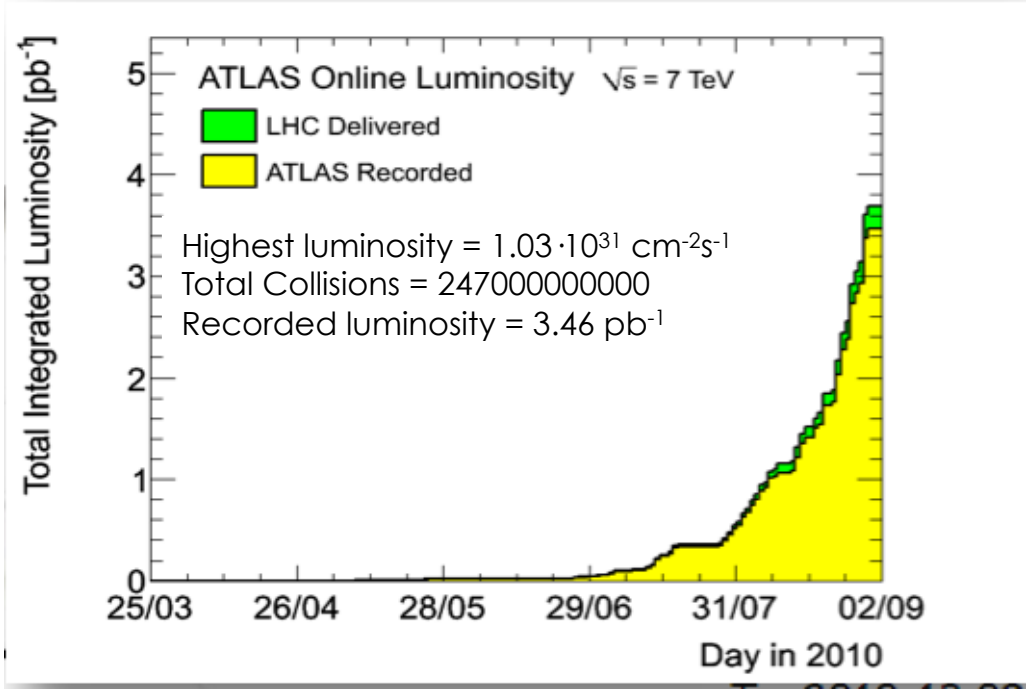
The list of tau triggers running online (tau trigger menu) includes

- primary physics triggers for various luminosities : single tau triggers or tau triggers combined with other triggers like missing E_T , etc..
- monitoring triggers to verify during each run the performance of the detector components needed for optimal online tau identification
- calibration triggers

Type	Motivation	Example of Trigger
Single	H+ -> tau nu	tau38_loose
Double	H, Z' -> tau tau	2tau12_loose
Combined	H/H+ , tt, W, Z	tau12_loose_xe15 tau12_loose_e10_loose tau12_loose_2b15
HLT monitoring only	Monitor L2+EF variables	tauNoCut
Calibration	Hadronic	trk9_loose

10^{31} cm^{-2} s^{-1}

ATLAS tau trigger performance in real data



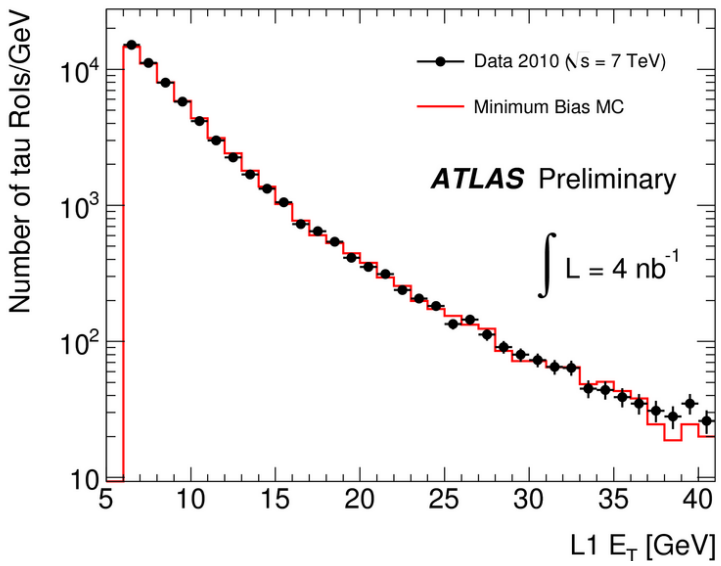
ATLAS tau trigger has been running online during whole 2010

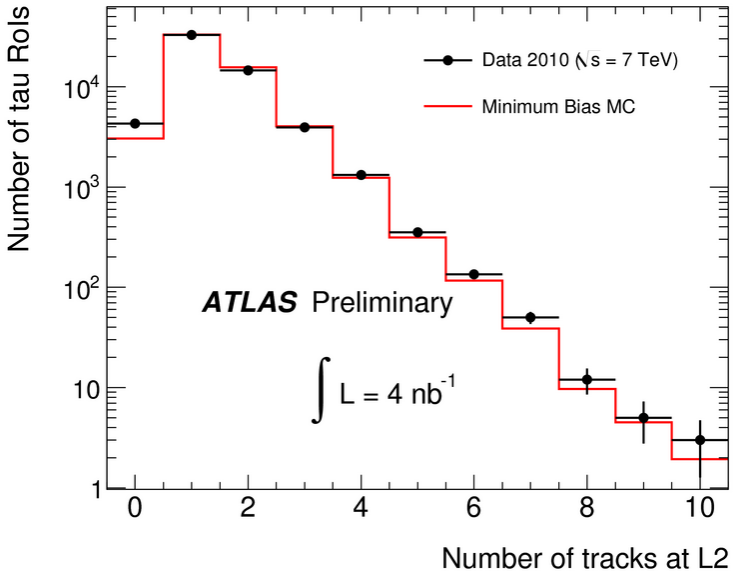
At first, the HLT tau trigger was in monitoring mode, which means no rejection was applied online

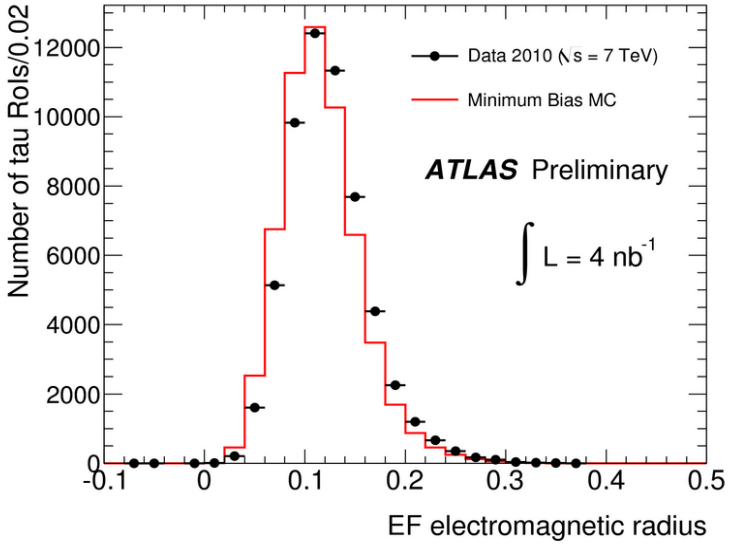
This has allowed to study the HLT performance before it was needed actively online

Since April 2010, with increasing LHC luminosity, the L1 output rate has become too high to be saved directly to tape , so tau trigger HLT has become active.

ATLAS tau trigger variables





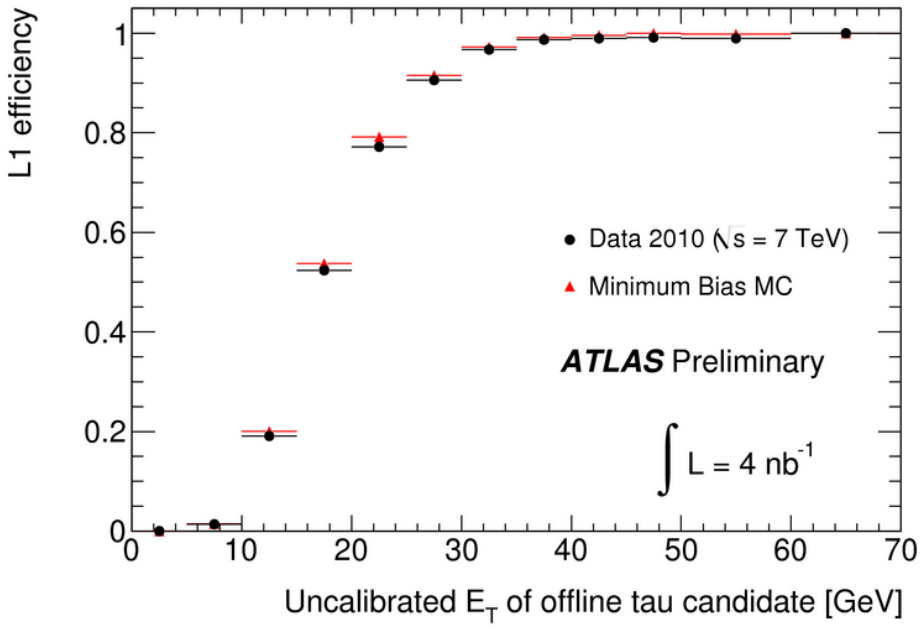


Variables for L1 and HLT selection well described over several orders of magnitude of E_T without yet tuning Monte-Carlo simulations for underlying event or other effects.

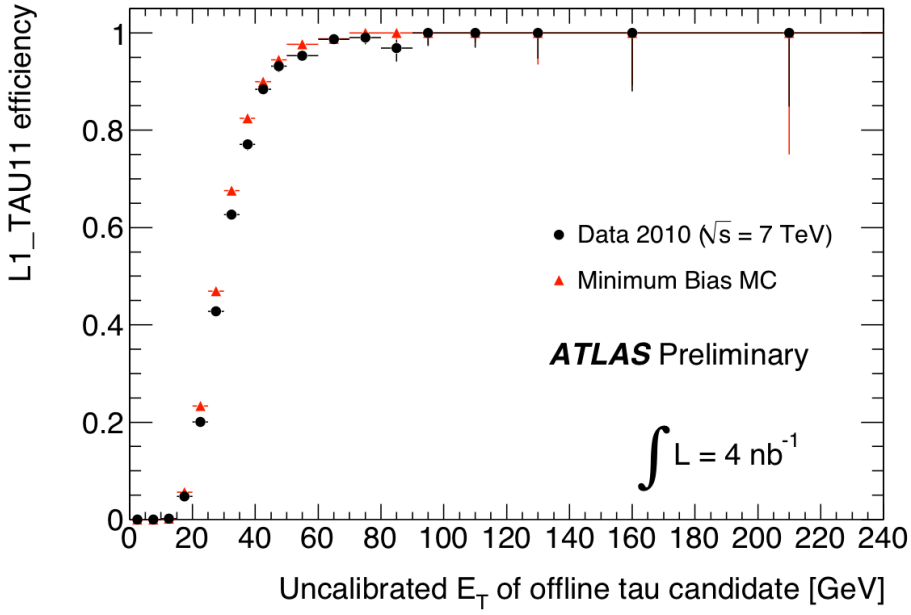
Shape variables are most sensitive to Imperfect simulation of underlying event

ATLAS tau trigger L1 background efficiency

HA5



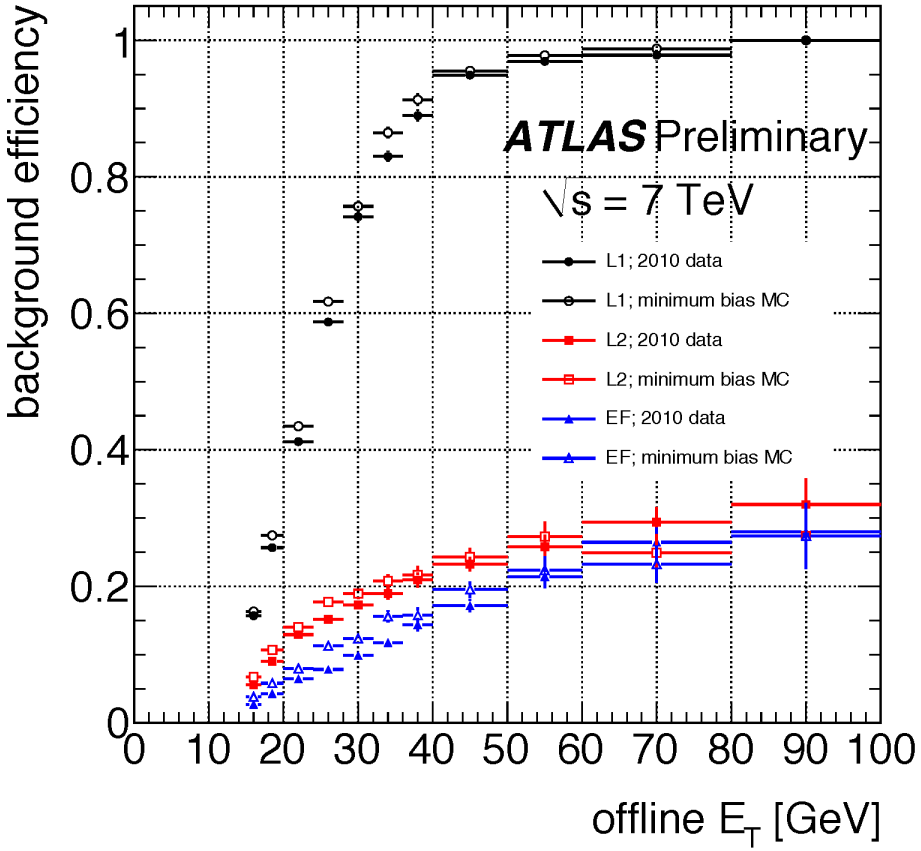
HA11



Fraction of the offline tau reconstructed candidates matched to a L1 trigger object with E_T > 5 and 11 GeV as a function of the uncalibrated E_T of the offline tau candidate. The small differences at low E_T can be attributed to inefficiencies in the forward region of the detector.

8 different L1 tau thresholds are present in the ATLAS trigger menu

ATLAS tau trigger HLT background efficiency



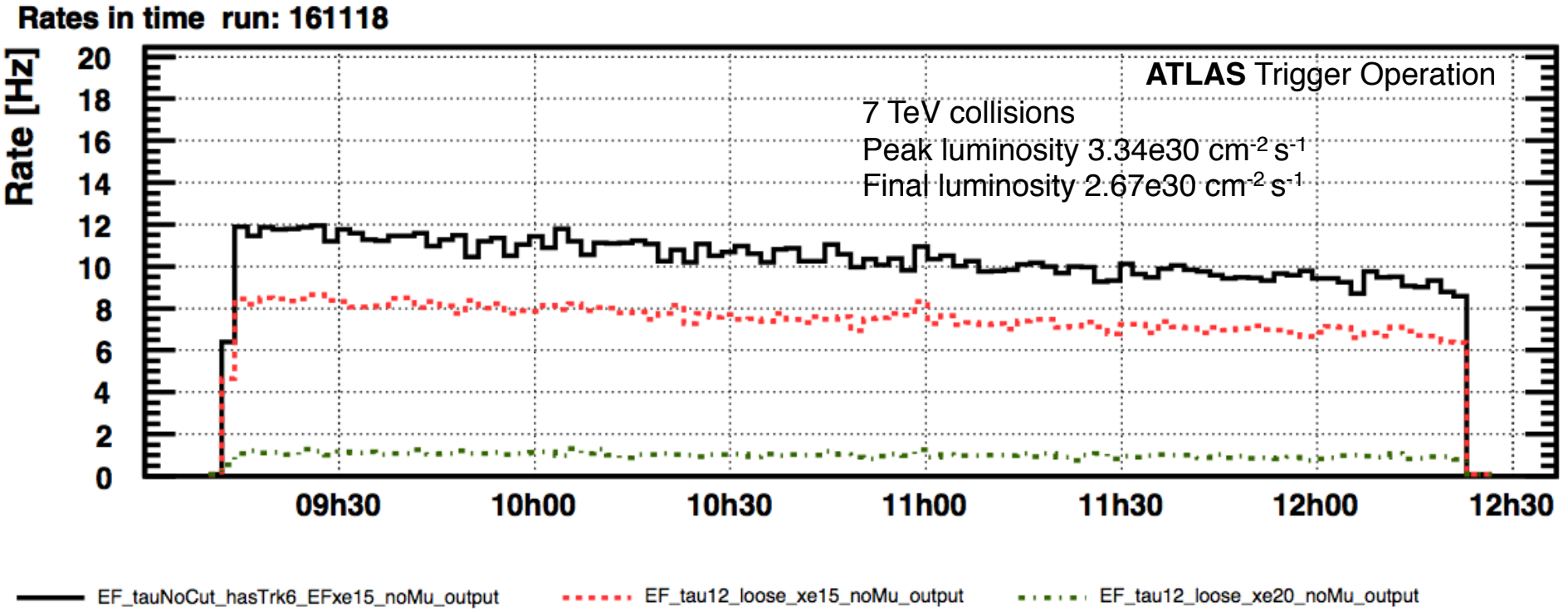
Fraction of the background offline tau candidates passing L1, L2 and EF **tau12_loose** trigger as a function of the E_T of the offline tau candidate.

Requirements for E_T are : > 5 GeV at L1, ≥ 7 GeV at L2 and ≥ 12 GeV at EF.

Distributions are done on Monte-Carlo (MC) Minimum Bias simulated with PYTHIA and on data from Minimum Bias stream.

Without any ATLAS-specific tuning for underlying event, the PYTHIA simulation reproduces remarkably well the observed background rejection performance in the data. Tuned PYTHIA simulations are expected to show better agreement with data results, as observed in recent tau identification offline studies.

ATLAS tau trigger online rates

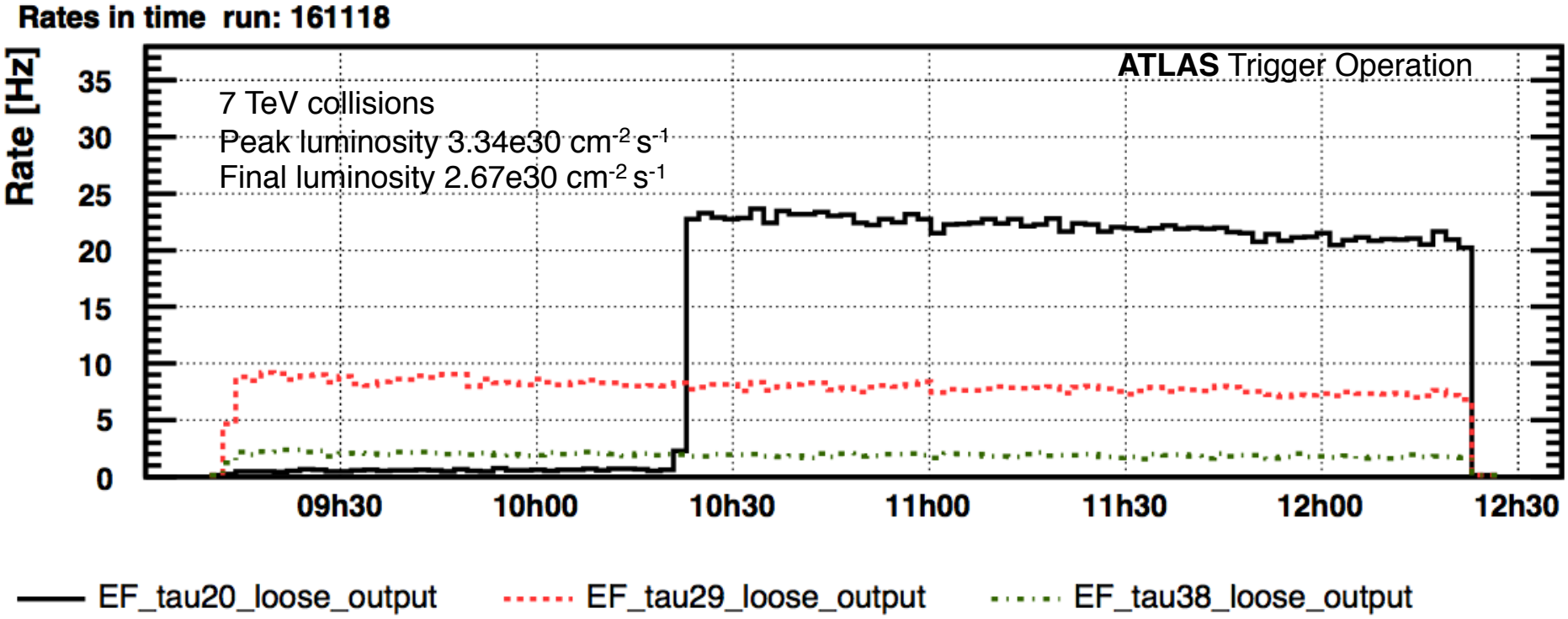


Primary tau trigger items for physics analyses requiring final states with tau leptons decaying hadronically and large missing transverse energy.

At 10^{30} cm^{-2} s^{-1} , a simpler requirement of L1 tau E_T > 5 GeV with at least one track with p_T > 6 GeV at L2 and missing E_T > 15 at EF can be afforded (tauNoCut_hasTrk6_EFxe15_noMu).

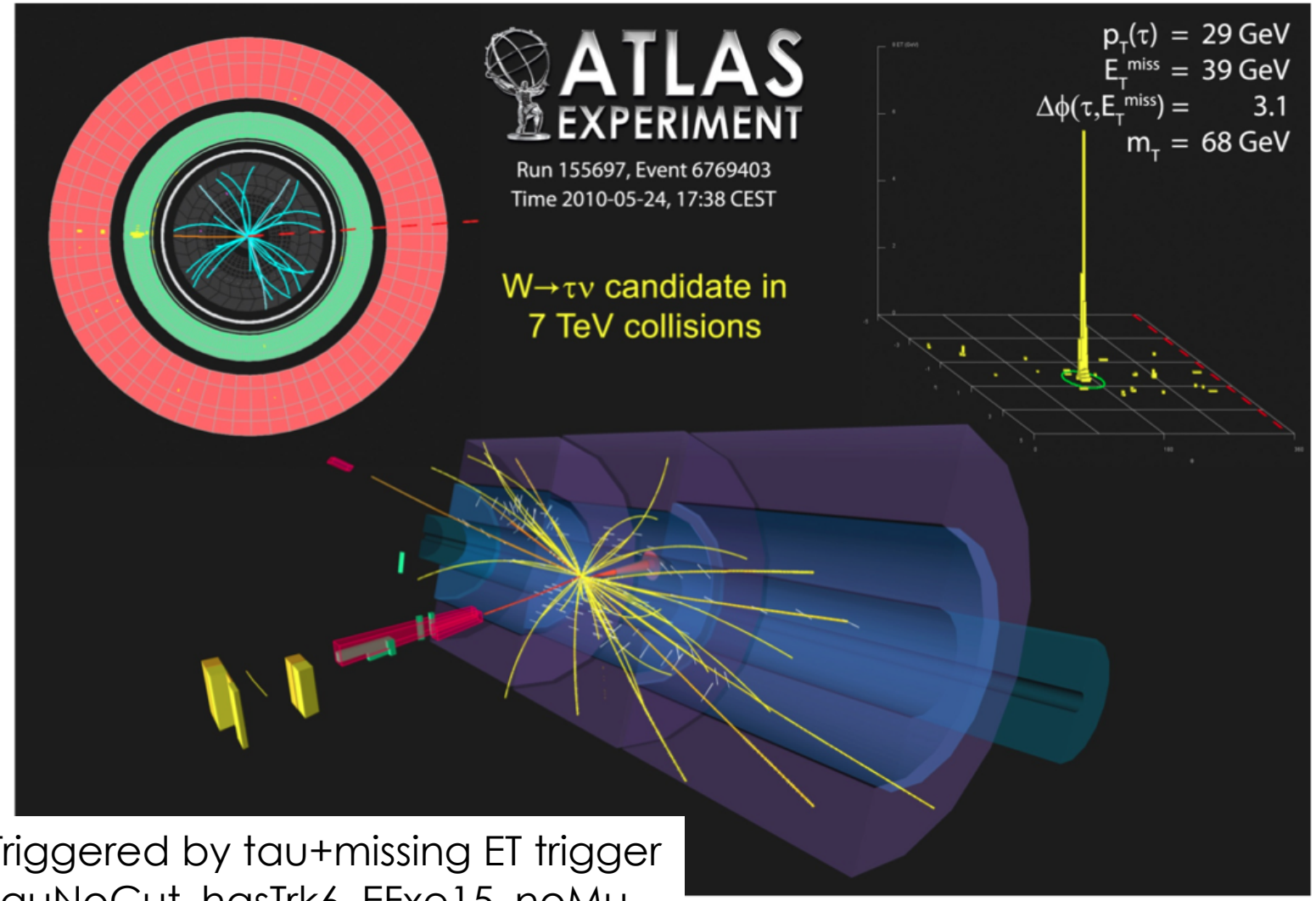
For higher luminosities, at L2 and EF trigger levels a more sophisticated tau identification and missing E_T thresholds at all trigger levels must be required (tau12_loose_xe15_noMu and tau12_loose_xe20_noMu).

ATLAS tau trigger online rates



Dynamical prescaling during a run allows to optimize efficiency of physics sample collection. Examples from a few single tau triggers.

ATLAS first W tau nu candidate event

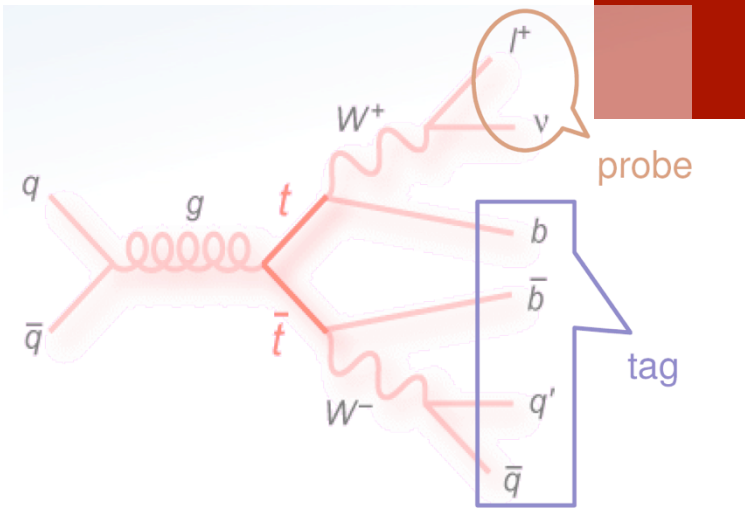


Triggered by tau+missing ET trigger
tauNoCut_hasTrk6_EFxe15_noMu

Tau trigger efficiency determination from data

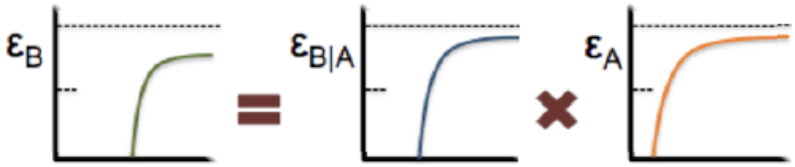
TAG and PROBE method

Single tau trigger efficiency:
Using Z-> tau tau events (~ 500 events in 100 pb^{-1}) triggered by electron or muon single trigger + offline basic selection applied. Tau trigger (probe) efficiency measured on the opposite side of the (tag) trigger.



Combined tau+missing E_T trigger :
Using ttbar events (~300 in 100 pb^{-1}), triggered by 4jets trigger.

Boostrap method



Eg. B = tau50_loose
A= tau12_loose

Requires one has a method for measuring the efficiency of A

Summary

ATLAS tau trigger focuses on efficient collection of physics processes involving a tau lepton decaying hadronically in the final state

A varied tau trigger menu is in place, with single high pT and combined lower pT tau trigger items, which allows to guarantee an ample spectrum of tau physics samples for future studies

The ATLAS tau trigger has been operational during the whole 2010 first in monitoring mode and then in active rejection mode, and its performance in real data is remarkably close to what was expected from past studies on simulated ATLAS data

Optimizations are being prepared, to account for what we learnt from real data background distributions.

We are ready to trigger on new physics !