Implementation and Performance of the High-Level Trigger electron and photon selection for the ATLAS experiment at the LHC

Fernando G. Monticelli, on behalf of the ATLAS HLT e/gamma group

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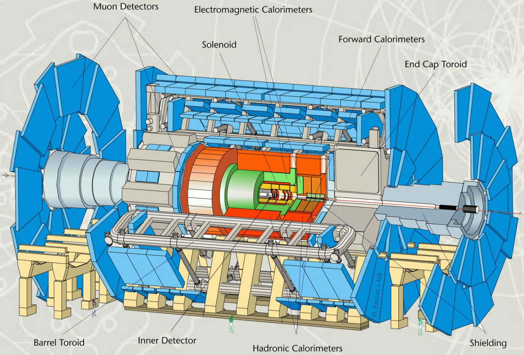
Outline

The ATLAS detector

The ATLAS detector is compose different subdetectors. For e/γ identification we use:

- Inner Detector
- EM and Had Calorimeter



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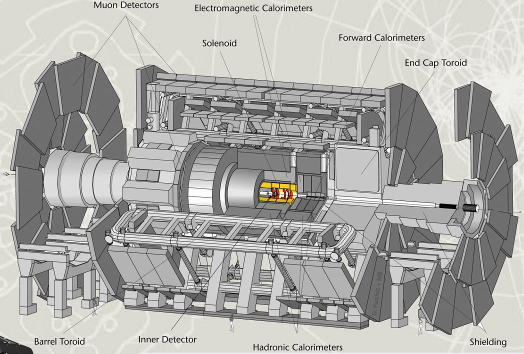

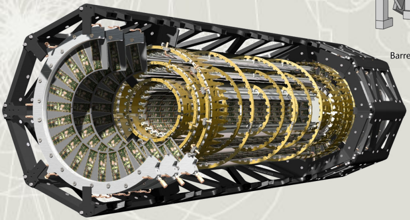

- ID $\longrightarrow$ Tracking: Already introduced by Esben

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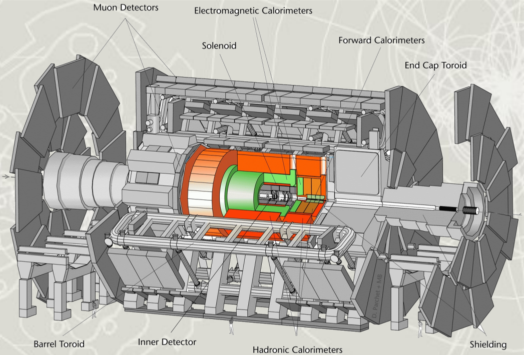

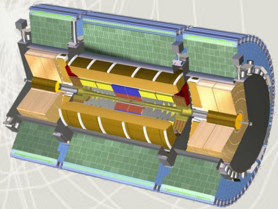

- LAr EM Calorimeter: reconstruct e/γ energy and shower shape
- Had Tile Calorimeter: separate e/π, isolation

The Atlas Trigger system

- In LHC → Bunch crossing @40MHz
- ∼ 23 interactions / bunch @ high luminosity
- In atlas a full event size ∼ 1.5MB
- Store every bunch to disk → ∼50 TB/sec
- Need to reduce the rate → ∼ 200Hz

- The task of the ATLAS Trigger System is to select the most interesting events and save them for later analysis.
- Only the trigger accepted events will be analyzed. Rejected by trigger means lost for ever!
- The ATLAS Trigger relays on a 3 level trigger system, that reduces LHC interaction rate (∼ 1GHz)→ Mass Storage:

1. HW based LVL1
2. SW based HLT: LVL2
3. SW based HLT: Event Filter

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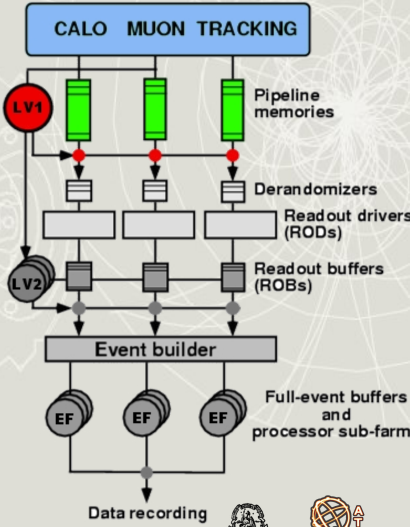
The ATLAS trigger system

LVL1 Trigger

- hardware based (FPGAs ASICs);
- coarse granularity calo/muon data;
- latency: 2.5μs
- output rate: 75kHz



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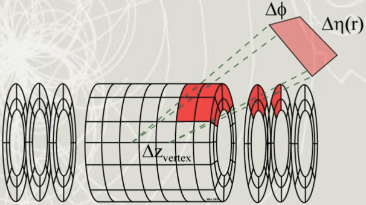
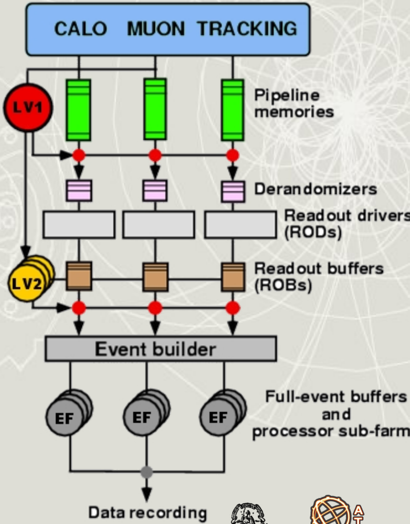
The ATLAS trigger system

LVL2 Trigger (HLT)

- seeded by LVL1 result;
- full granularity for all subdetectors;
- fast rejection steering;
- event processing time: $\lesssim$ 40ms;
- output rate: $<$ 2kHz





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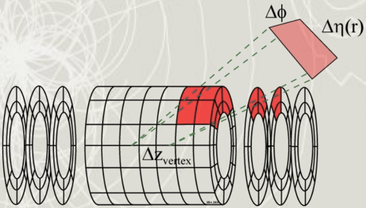
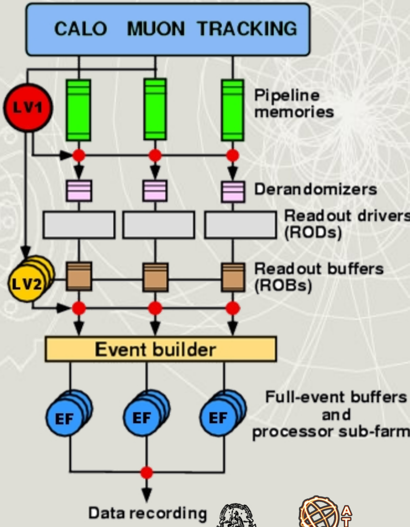
The ATLAS trigger system

Event Filter (HLT)

- seeded by LVL2 result;
- potential full event access;
- Offline-like algorithms;
- event processing time: $\sim$ 2s;
- output rate: $\sim$ 200Hz
- data storage: $\sim$ 300MB/s

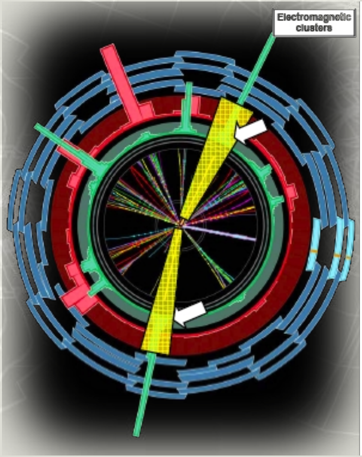




HLT Event Selection

The main ideas behind the ATLAS HLT event selection strategy are:

- Reconstruction in Regions Of Interest (just 2% of the detector!)
- alternate steps of feature extraction and hypothesis testing
- events can be rejected after any step if the reconstructed features do not fulfill required criteria (signature).
- goal: minimize processing time and network traffic.



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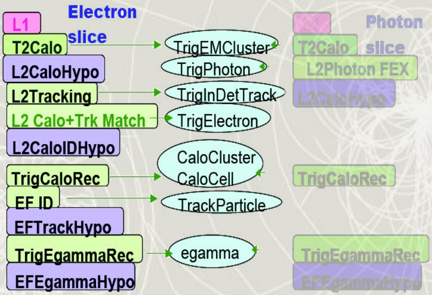
e/γ identification @HLT

e/γ identification and measurement uses combination of ID tracking and EM calorimeter data



Electron reconstruction

- isolated EM calo cluster:energy measurement
- ID track: p_T measurement
- track to cluster matching: bremsstrahlung recovery;
- identification (e/π separation): both using single detector (TRT LAr) or combined E/p.

electron trigger menus: 2e15i, e25i, e60

Photon reconstruction

- isolated EM calo cluster
- ID not used @HLT, but could be used for
  - track veto from the ID
  - tracking recovery of converted photons

photon trigger menus: 2g20i, g60

Trigger menus for $L = 10^{33} s^{-1} cm^{-2}$

e/γ identification @HLT

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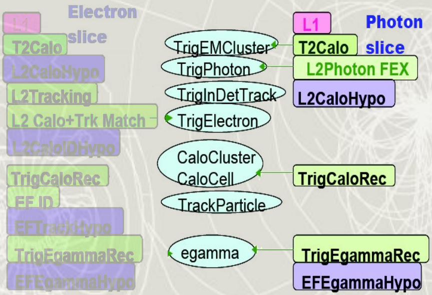

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LVL2 e/γ selection algorithms & Timings per RoI

T2CaloEgamma

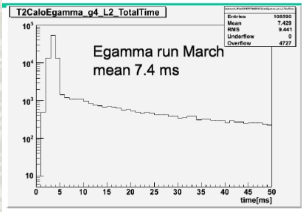
- Performs calorimeter cluster reconstruction
- Full detector granularity
- Shower shape variables to discriminate e/γ from jets

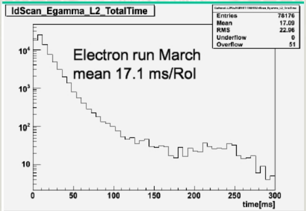
IDScan

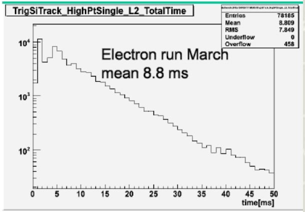
- zFinder: z position of pp collision
- hitFilter & groupCleaner: main pattern recognition step
- trackFitter: final track fit and outliers removal

SiTrack

- Space point sorting
- Track seeds formation
- Primary vertex reconstruction
- Track extension







Timings from the Technical Run in March 2007

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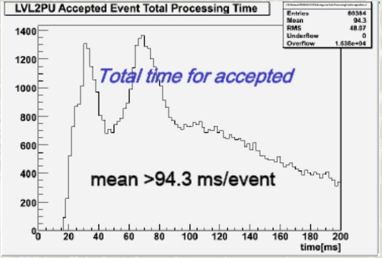
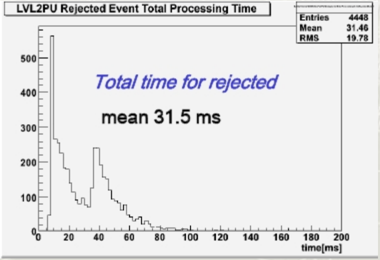
LVL2 e/γ selection algorithms & Timings per RoI

- LVL2 timing obtained in technical run in May 2007
- Not final hardware used!.





The LVL2 mean processing time $\sim$ 40ms.

EF e/γ selection & Timings

TrigCaloCellMaker + TrigCaloTowerMaker + TrigCaloClusterMaker

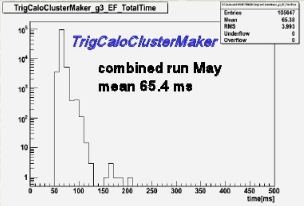
- Perform calorimeter cluster
- Wrap-up offline tools
- involved also in tau and jet slices

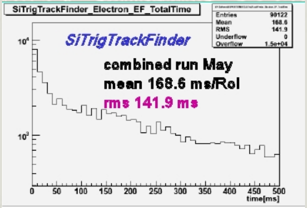
EFID

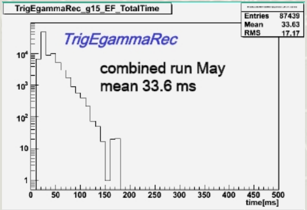
- Based on offline tools in a seeded mode
- Involved in tau, b-physics, b-tagging and muon slices also.

TrigEgammaRec

- Reconstructs the e/gamma object
- Wrap-up offline tools
- Combines ID and Calo information
- Includes bremsstrahlung correction



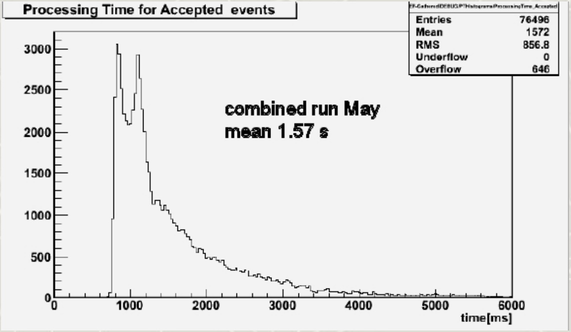




Timings from the Technical Run in May 2007

Processing time for accepted events

- EF timing obtained in the technical run in May 2007
- Not using the final implementation of the EF computers farm!



The EF mean processing time is $\sim$ 2s.

- Online measurement depends on many things (network layout, #of processors per node, slice, algorithms)
- The technical run was a snapshot of a particular setup (far away of the final implementation HLT)
- Optimization needs to be done in algorithms and HLT final hardware implementation.

Photon Trigger performance for $L = 10^{33} s^{-1} cm^{-2}$

$H_{120} \rightarrow \gamma\gamma$ photon trigger efficiencies

Trigger Level	2g20i Eff	2g20i Rate	g60 Eff	g60 Rate
L1	96.4±0.5%	150 ±10 Hz	92.9±0.4%	1200 ±80 Hz
L2	94.6±0.7%	5 ±1.7 Hz	86.8±0.6%	35 ±14 Hz
EF	93.8±0.8%	2 ±1 Hz	84.7±0.6%	16 ±9 Hz

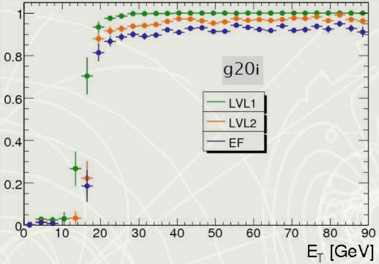
- Efficiencies w.r.t. offline reconstructed photons:

Efficiency triggering on Direct photon production

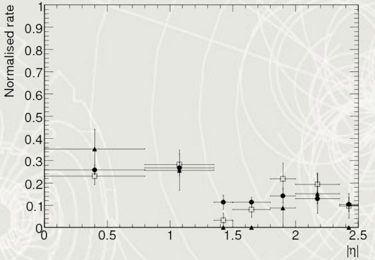
γ+Jet energy range	g20 efficiency
17-35 GeV	97.51±0.14 %
35-70 GeV	99.42±0.09 %
70-140 GeV	99.53±0.04 %
140-280 GeV	99.59±0.05 %
280-560 GeV	99.72±0.05 %
560-1120 GeV	99.60±0.04 %
Rate $L = 10^{31}$	5.11±0.45 Hz
Rate $L = 10^{33}$	429.16±21.51 Hz

Photon trigger efficiencies

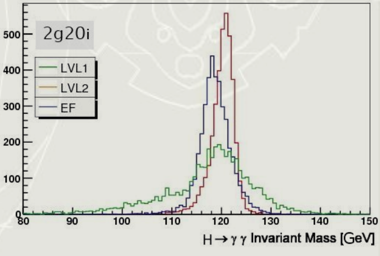
g20i photon trigger turn on curve



g20i bkgrnd rate vs $|\eta|$



$H_{120} \rightarrow \gamma\gamma$ Reconstructed invariant mass at each trigger stage



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Electron Trigger performance for $L = 10^{33} s^{-1} cm^{-2}$

$Z \rightarrow e^+ e^-$ electron trigger efficiencies

Trigger Level	e25i Efficiency
L1	96.0%
L2	84.4%
EF	84.0%

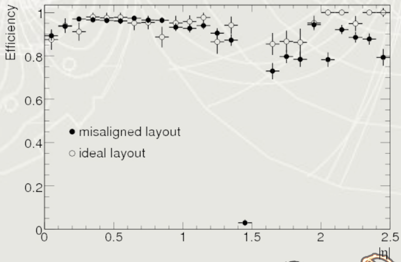
using SiTrack algorithm.

$G_{500} \rightarrow ee$ Non isolated electron triggers

Trigger Level	2e15 Eff (%)	e60 Eff (%)
L1	99.9 ± 0.1	99.9 ± 0.1
L2	84.4 ± 0.5	96.1 ± 0.2
EF	73.0 ± 0.6	92.1 ± 0.3

- Efficiencies w.r.t. offline reconstructed electrons:

Efficiency of e25i vs pseudorapidity



Photon and electron trigger menus for $L = 10^{31} cm^{-2} s^{-1}$

- Trigger menus have been extensively studied for $L = 10^{33}$
- For early running at $L = 10^{31}$ we plan to:
  - No LVL1 isolation
  - LOOSE selection for high-pT: photon and electron selection → same calo only selections
  - tighter (but still safe) selection for low-pT (rate constraints)
  - commissioning triggers (e.g. L2/EF pass-through)
  - backup triggers if rate is too high
  - lots of redundancy

Electron Menus

Signature	LVL1	EF Rate	Physics coverage
2e5	2EM3	10 Hz	J/ψ,Y → ee
e10	EM7	11 Hz	b/c decays, E/P studies
2e10	2EM7	1 Hz	Z→ e^+e^-
e20	EM18	3 Hz	High p_T physics, $W \rightarrow e\nu$, Z→ e^+e^-
e20_PassL2	EM18	10 Hz	If problems with LVL2
e20_PassEF	EM18	12 Hz	If problems with EF
EM105_PassHLT	EM100	1 Hz	New physics, or problems w. HLT
And more...			

Photon and electron trigger menus for $L = 10^{31} cm^{-2} s^{-1}$ Contd.

Photon Menus

Signature	LVL1	EF Rate	Physics coverage
g10	EM7	109 Hz	Hadronic Calibration, inclusive and di-photon cross section
g15	EM13	35 Hz	
g15i	EM13i	28 Hz	
g20	EM18	6 Hz	Hadronic Calibration di-photon cross section
g20i	EM18i	5 Hz	
g25i	EM23i	2 Hz	
g105	EM100	$<$1 Hz	Exotics, SUSY, unknown had calibration
2g10	2EM7	1 Hz	Di-photon cross section, Exotics, SUSY, trigg eff, direct γ
2g15	2EM13	$\sim 1 Hz$ Hz	
2g20	2EM18	0.1 Hz	
2g105	2EM100	$<<$ 1 Hz	

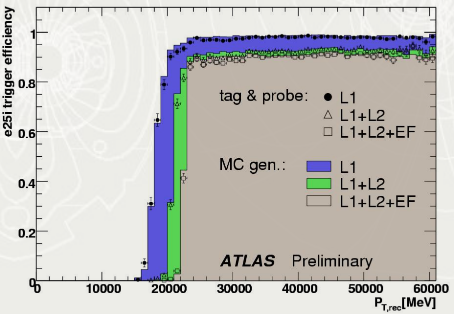
Measure trigger efficiency with Data

To measure the trigger efficiency with data, we will use the "Tag and probe" method:

Example with Z$\rightarrow e^+ e^-$

- Select events accepted by single e trigger (e15, e15i, e25, e25i) $\rightarrow$ TAG
- Events with $\geq$ 2 electrons $\rightarrow$ build inv. Mass & keep only those with inv. mass close to Z peak.
- For this selection, check how many times the 2nd electron also triggered (2e15, 2e15i, 2e25, 2e25i) $\rightarrow$ probe

Method tested with Montecarlo with good agreement:



Conclusions

- ATLAS will start data taking soon (LHC should start in 2008 offspring)
- The High Level Trigger algorithms for selecting electrons and photons are ready, and in good shape (timing and performance)
- Electron and photon trigger menus are well set up for trigger on events with high energy photons or electrons.
  - High efficiency triggering on signal
  - High background rejection
- Start up strategy and menu in place
  - includes both physics and commissioning needs
- HLT is in good shape to face the challenge of selecting interesting and new physics events @ ATLAS.