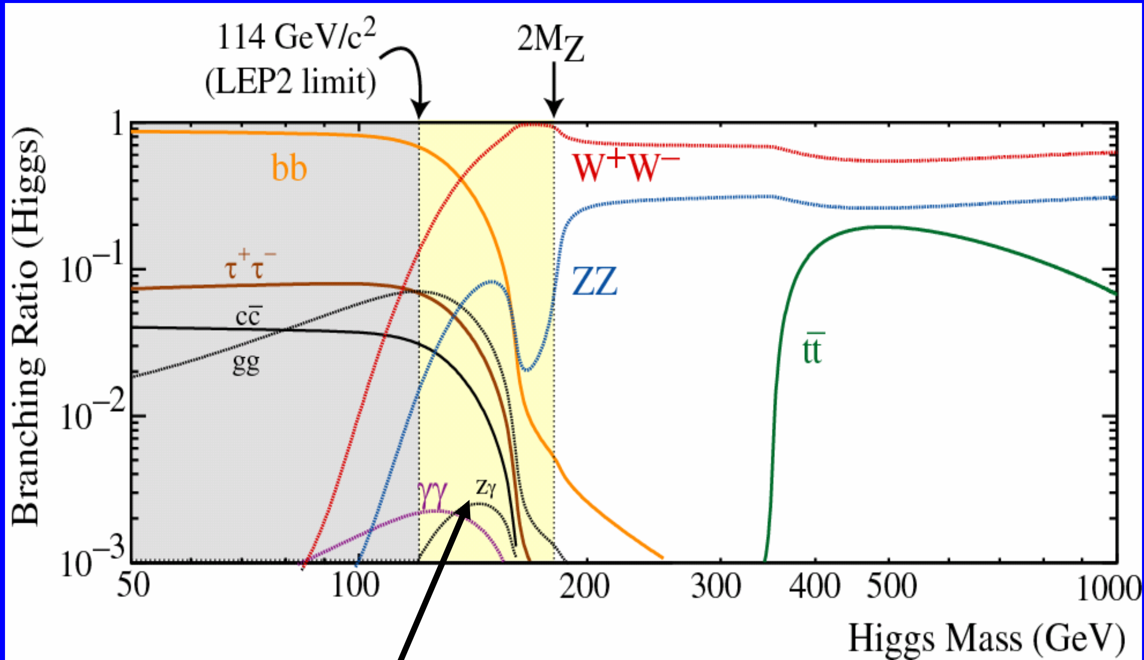
ATLAS: Triggering for Higgs

Valeria Perez Reale
University of Bern

On behalf of the ATLAS Collaboration

- SM Higgs Discovery Channels
- ATLAS High Level Trigger
- Trigger & Physics Selection
- Higgs Channels: Physics Performance

Higgs Discovery Channels



Dominant BR for $m_H < 2m_Z$:

σ (H → bb) ≈ 20 pb;

σ (bb) ≈ 500 μb

for m(H) = 120 GeV

→ no hope to trigger or extract fully had. final states

→ look for final states with ℓ, γ (ℓ = e,μ)

<u>Low mass region: m(H) < 2 m_Z :</u>

H → γγ : small BR, but best resolution

H → bb : good BR, poor resolution ➔ ttH, WH

H → ττ : via VBF

H → ZZ* → 4ℓ

H → WW* → ℓνℓν or ℓνjj : via VBF

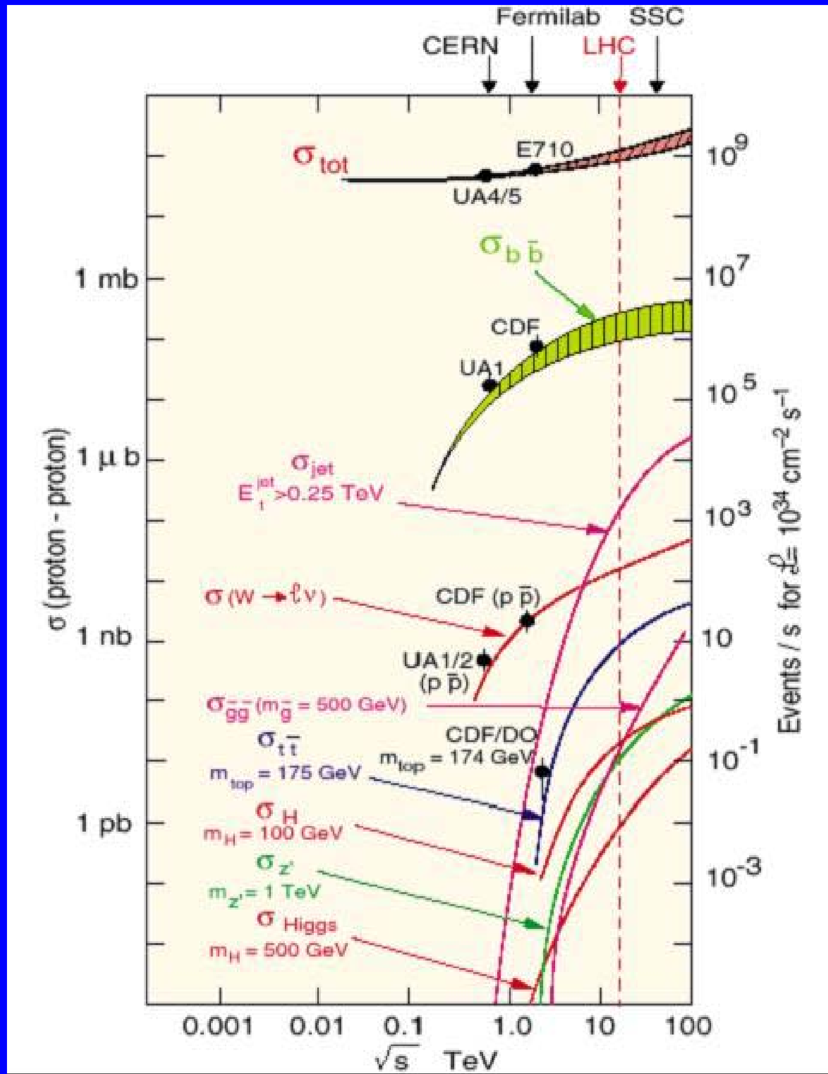
LHC Physics and Trigger Requirements

- Highly hermetic and granular detectors ⊕ large particle multiplicity → huge data volume!
  Average event size 1.5 MB
- 25 ns bunch spacing → high rates!

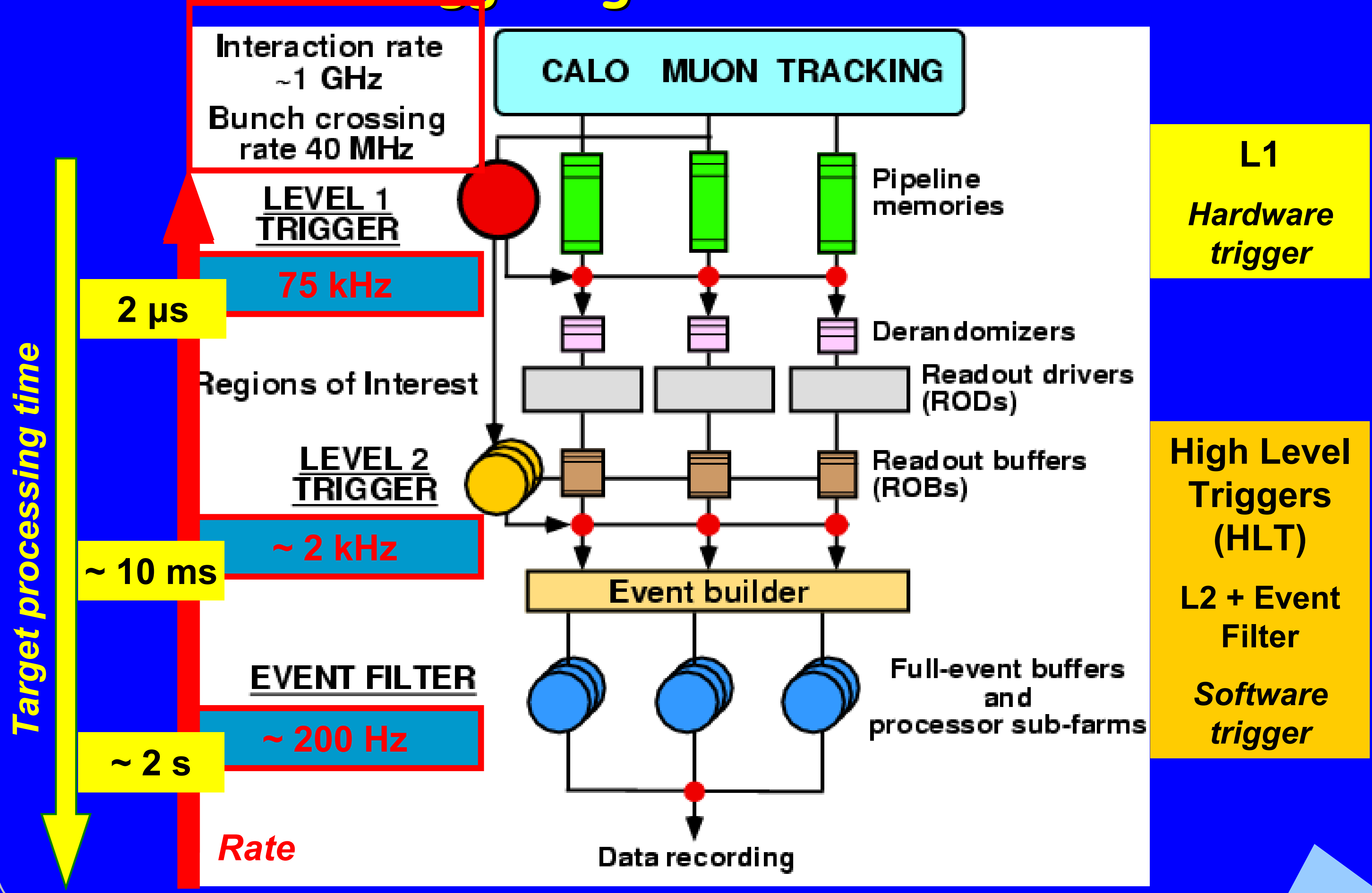
  Data throughput

At detectors (40 MHz) (equivalent to)	PB/s
--> LVL1 Accepts	100 GB/s
--> Mass storage	300 MB/s

- Number of overlapping events per bunch crossing: 23 ($1 \cdot 10^{34}\ cm^{-2}s^{-1}$)
- Low cross sections for discovery physics (e.g., Higgs production) → Rejection power 10^{13} ($H \to \gamma\gamma$ 120 GeV)



ATLAS Triggering



Trigger Requirements

Mostly inclusive high p_T trigger selections with relatively low-p_T thresholds for fundamental objects (e.g leptons)

- ✓ Cover all SM topologies and those expected from new physics
- ✓ Be sensitive to presently unknown new physics
- ✓ Keep safety margin against uncertainties
  - Knowledge of (background) cross-sections (factor 2-3)
  - Real detector behavior, beam-related (and other) backgrounds
  - Performance of the selection software

Trigger Item:

1e25i

1: Minimum number of objects required

25: transverse energy value in GeV at which we want to be efficient

e: type of object

i: isolation

Inclusive Trigger Selection (HLT)

Object	Examples of physics coverage	Low Luminosity $2*10^{33}\ cm^{-2}s^{-1}$	Rates (Hz)
Electrons	Higgs (SM, MSSM), new gauge bosons, extra dimensions, SUSY, W, top	e25i, 2e15i	~40
Photons	Higgs (SM, MSSM), extra dimensions, SUSY	γ60, 2γ20i	~40
Muons	Higgs (SM, MSSM), new gauge bosons, extra dimensions, SUSY, W, top	μ20i, 2μ10	~40
	Rare b-decays ($B \rightarrow \mu\mu X$, $B \rightarrow J\Psi(\Psi')X$)	2μ6 + μ^+ μ^- + mass cut	~25
Jets	SUSY, compositeness, resonances	j400, 3j165, 4j110	~20
Jet+missing E_T	SUSY, leptoquarks	j70 + xE70	~5
Tau+missing E_T	Extended Higgs models (e.g. MSSM), SUSY	τ35i + xE45	~10
Others	Prescaled, calibration, monitoring		~20
Total HLT Output Rate			~200

Trigger menus will evolve continuously with time to reflect our best knowledge of the physics and the detector

Electron Trigger Selection

L1 calo

-Region of Interest (η,ϕ, pT and energy sum of candidate object)
-Coarse granularity info from calorimeter

L2 calo

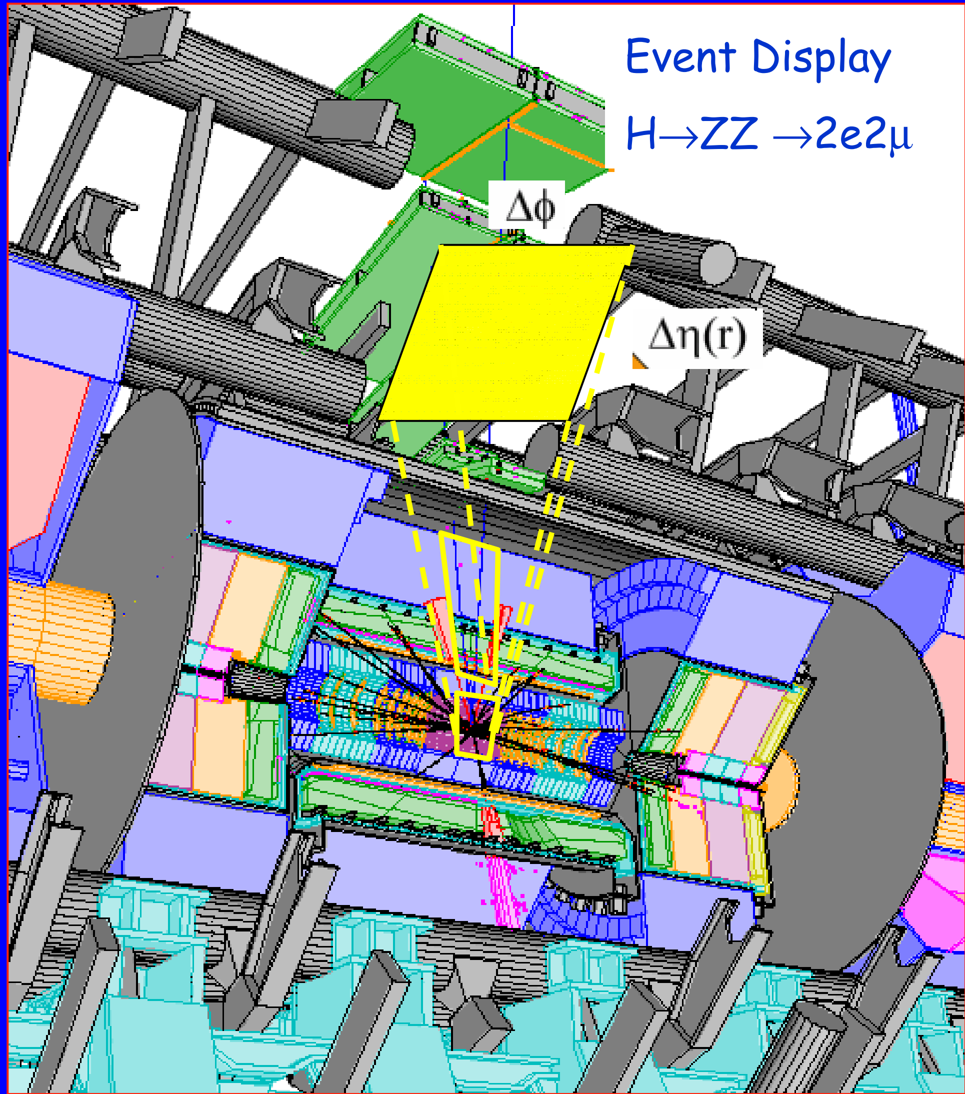
L2 tracking

-Seeded by L1 RoI
-Full granularity
-Calo (shower shape) and tracking

EF calo

EF tracking

-Seeded by L2 or full event access
-refined alignment and calibration data
-Calorimeter and tracking
- offline-like algorithms



Higgs Channels

The following SM Higgs channels in the low mass range with e/gamma decays have been studied:

Higgs Channel	Low Luminosity	High Luminosity
$H \rightarrow ZZ^* \rightarrow eeee$	e25i or 2e15i	e30i or 2e20i
$H \rightarrow ZZ^* \rightarrow 2e2\mu$	e25i , 2e15i	e30i or 2e20i
$H \rightarrow \gamma\gamma$	γ60i , 2γ20i	γ60i , 2γ20i

Low Luminosity: $2 \cdot 10^{33}\ cm^{-2}s^{-1}$

High Luminosity: $1 \cdot 10^{34}\ cm^{-2}s^{-1}$

General Remarks

- Event samples were simulated with Pythia 6.2 and with Geant3 full simulation of the ATLAS detector and fully reconstructed including electronic noise and pile-up:

    - 10^7 QCD dijet events for background optimization of rates/efficiencies and 10^4 signal events

- The trigger efficiencies of the Higgs processes are for the decay leptons in the geometrical acceptance of $|\eta| < 2.5$ (region of precision physics)

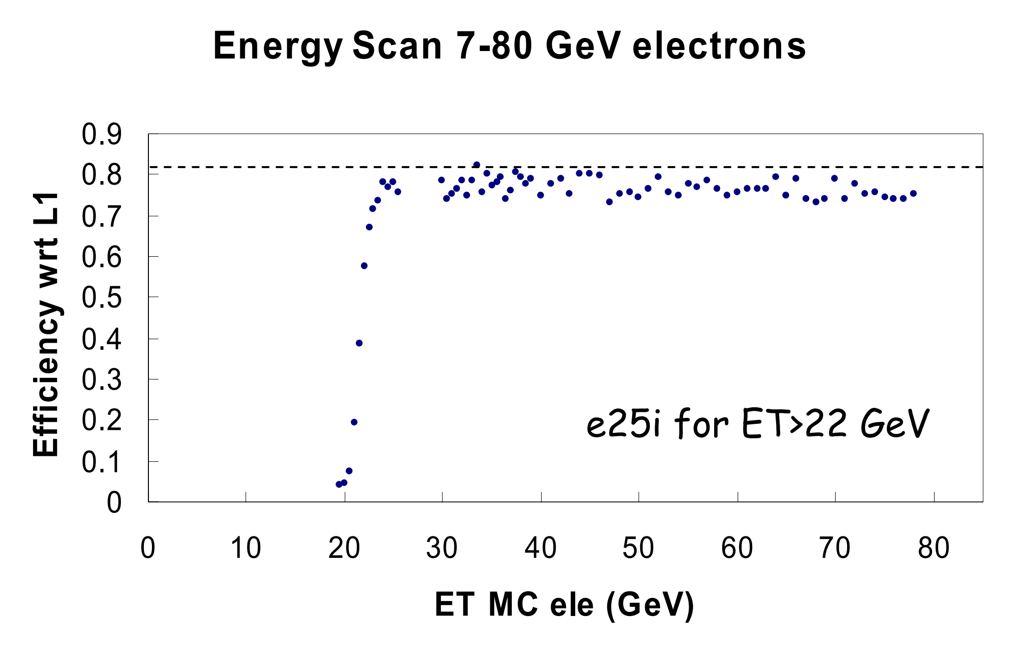
<u>Trigger efficiency</u>: e/γ accepted in a phase space region in η and p_T.

<u>Overall Trigger Efficiency</u>: acceptance in the whole phase space region

Electron/Photon Trigger

Trigger Selection is performed on an event basis and includes the double and single object trigger items for electrons and photons.

Trigger	Efficiency	Rate
e25i	76.2 %	46 ±4 Hz (low)



Efficiency has flat distribution for high E_T

e25i low luminosity		
Trigger Selection	Efficiency (%)	Rates
L1	95.5 ± 0.2	8.6 kHz
L2Calo	92.9 ± 0.3	1.9 kHz
EFCalo	90.0 ± 0.4	1.1 kHz
EFID	81.9 ± 0.4	108 Hz
EFIDCalo	76.2 ± 0.4	46 Hz

50% of the clusters come from real electrons

Trigger	Efficiency	Rate
2e15i	60 %	few Hz

H→ZZ*→4e (130 GeV)

Kinematical cuts: 2 isolated electrons
pt>20GeV & 2 isolated electrons pt> 7 GeV in $|\eta|$< 2.5
Trigger Items: e25i or 2e15i (low)
e30i or 2e20i (high)
Main background: ZZ → 4e and ττll Reducible: tt, Zbb.

Geometrical acceptance:
47 %

Trigger	Luminosity	Higgs eff. (%)
e25i	Low	96.5
2e15i	Low	95.8
e25i or 2e15i	Low	96.7
e30i	High	95.0
2e20i	High	94.5
e30i or 2e20i	high	95.5

Trigger Selection	Eff(%) low	Eff(%) high
LVL1	99.6	99.2
L2Calo	99.4	98.9
EFCalo	98.5	97.8
EFID	97.7	96.8
EFIDCalo	96.7	95.5

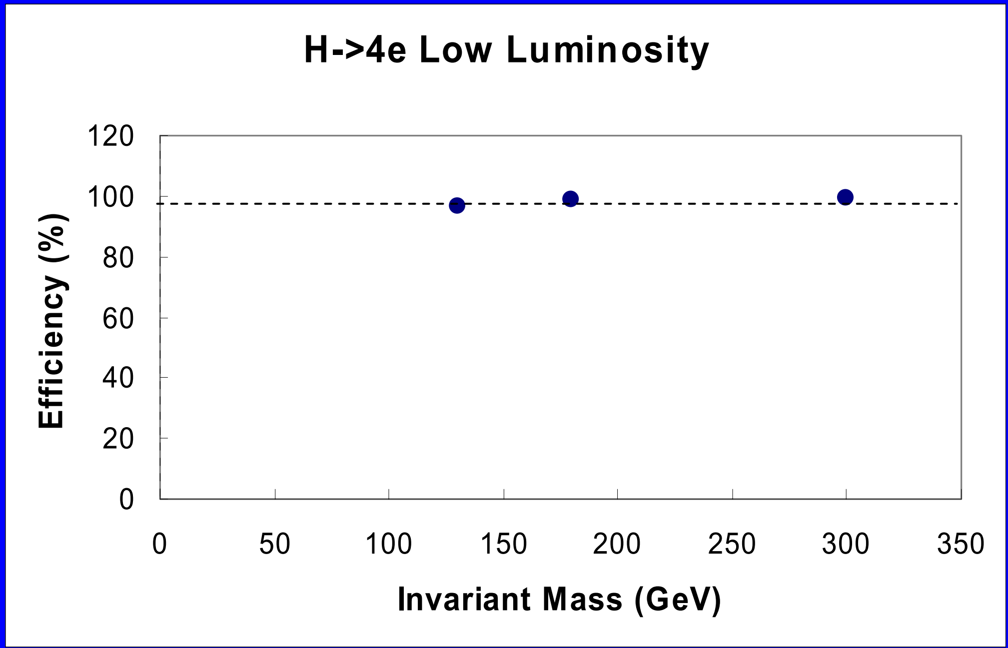
H→ZZ*→4e (130 GeV)

The Higgs efficiency for this electron channel is independent from the Invariant Mass:

130 GeV -> 96.7%

180 GeV -> 98.6%

300 GeV -> 99.4%



- Trigger Efficiency in Acceptance Region: 96.7%
- Overall Trigger Efficiency: 45.8%

$H \rightarrow ZZ^* \rightarrow 4e$ (130 GeV)

Is the Trigger Analysis rejecting events prematurely?

If an offline analysis is performed less than 1% of the events passing the selection are rejected by the trigger:

- ✓ Main effect from L1 → L1 has poorer energy resolution and coarser granularity
- ✓Offline and trigger have slightly different e-ID selection strategy
- ✓ Better calibration available in offline compared to Level1 and Level2

Trigger selection rejects less than 1% of the events that pass offline analysis →Trigger is well setup !!

$H \to ZZ^* \to 2e\ 2\mu$ (130 GeV)

Kinematical cuts: 2 isolated leptons pt>20 GeV
& 2 leptons pt> 7 GeV in $|\eta|$< 2.5
Trigger Items: e25i or 2e15i (low)
e30i or 2e20i (high)
Main background: $ZZ \to 4e$ and $\tau\tau ll$ Reducible: tt, Zbb

Geometrical acceptance:

39 %

Trigger	Luminosity	Higgs eff. (%)
e25i	Low	76.2
2e15i	Low	63.7
e25i or 2e15i	Low	76.9
e30i	High	70.1
2e20i	High	59.4
e30i or 2e20i	high	71

✓Muon trigger not included.

✓If muon trigger μ20i, 2μ10 and electron + muon trigger μ10 + e15i were included eff. will rise.

- Trigger Efficiency in Acceptance Region: 76.9%
- Overall Trigger Efficiency: 29.9%

H→gamma gamma (120 GeV)

Kinematical cuts: 1 γ pt>40 GeV & 1 γ pt> 25 GeV in |η|< 2.4
barrel/endcap crack excluded

Trigger Thresholds: γ 60i or 2 γ 20i

Main background: jet-jet, γ-jet, γ γ

Trigger	Luminosity	Higgs eff. (%)
γ60i	Low	57
2γ 20i	Low	74
γ 60i or 2 γ 20i	Low	83

- Offline gamma/jet separation is tuned for 80% efficiency independent of η and pT
- Previous complete studies (with older detector layout) showed that less than 1% were rejected prematurely

- Trigger Efficiency in Acceptance Region: 83 %

Conclusions

- First complete study of trigger and offline selection of Higgs efficiencies with full detector simulation.
  - ✓ full reconstruction, access to raw data, electronic noise and pile-up, with "final" ATLAS reconstruction software
- Trigger Menus are well setup for the selected Higgs processes with lepton/gamma decays in the low mass region . e.g. H->4e has 97% efficiency.
  - ✓The Trigger Selection (L1-HLT) rejects less than 1% of the events prematurely.
- Work in progress to assess other Higgs channels with one leptonic decay and muon trigger:
  - ✓ ttH (H->bb), H->ZZ*->4μ, H->WW->lnujj
- Ensure that events are well triggered on for other channels or else investigate the possibility of a more exclusive trigger selection: e+Etmiss for VBF channels, Invisible Higgs