ATLAS Trigger Menus

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Introduction

This note presents a set of trigger menus that has been produced as a joint effort of the Trigger Performance and Physics working groups of ATLAS. They are used in the Trigger/DAQ related documents [1], [2] and [3] submitted to the LHCC. As in the ATLAS Technical Proposal (TP) [4], it has been possible to write down a very simple set of menus that covers the vast majority of main stream 'discovery' physics. While it is clear that trigger menus will continue to evolve up to and during the experiment, it is timely to produce this document now. It serves as both a summary of the current state of Trigger Performance studies and a focus for the continuation of this work in the context of the forthcoming Physics TDR and the Trigger/DAQ work plans.

The main changes with respect to the menus presented in the ATLAS TP are:

- It has been recognised that there is no specific physics requirement for an inclusive missing E_T trigger. Instead, E_T^{miss} is used as an additional trigger with leptons or jets. Inclusive E_T^{miss} is retained as a specialised trigger.
- A tau/hadron trigger has been added for use in coincidence with other signatures.
- Most trigger rates have been updated from more recent studies. It should be understood that all the rates in this note are still under review.
- Menus are now split into two groups:
  1. Basic physics-motivated menus — a very simple set of menus covering the majority of main stream 'discovery' physics.
  2. Specialised triggers — those that are not needed directly for the main stream physics, but are needed to cover standard physics such as jet cross section measurement, other QCD studies and background studies. They also include monitoring and calibration triggers to read out data relating to the trigger and detector subsystems for technical studies.

Much of the content of the second group was not explicitly listed in the menus in the ATLAS TP although it was foreseen.

The first set of menus is an update of those published in the ATLAS TP. The vast majority of main stream physics is covered by a very simple list of triggers. The trigger menus eventually used by ATLAS will be far more complex than those presented here and will include triggers that are not required for any specific physics analysis. Some of these are covered in the second set of menus. The specialised triggers are those that are needed to understand thresholds, pile-up and to take data for the standard physics studies. They will make use of a range of prescale factors to limit the rate, because the results they provide are likely to be limited by systematic rather than statistical errors. The Detector Interface and Event Filter groups are collecting the information on triggers for monitoring and calibration [5].

Rates

The physics-oriented trigger menus are determined by the best compromise between efficiency for physics channels and tolerable trigger rate. The LVL1 trigger rate is dominated by background physics processes:

- jet events faking isolated $e/\gamma/\tau$;
- muons from $b/c \to \mu X$, $\pi/K \to \mu\nu$.

The rate target for LVL1 is ~40 kHz. This allows a safety factor of almost two, compared to the initial design capability of 75 kHz. The estimated uncertainty in the pp inelastic cross-section is about 30%.The total uncertainty on the main background processes could be as large as a factor of two (inclusive jet production at low p_T) to five ($b,c \to \mu$ events). Rate calculations have been made with PYTHIA; the rate predicted for multi-jet events by the NJETS model is a factor of about three higher at low p_T [6]. No K-factor correction has been used. Corrections for biases resulting from the η and p_T (hard scatter) cuts applied to the production at particle level in many cases are also only approximate. More details on the cross-sections and simulation tools can be found in Chapters 2 and 4 of [2].

The rate target for LVL2 is around 1 to 2 kHz, but it depends on the optimum separation between LVL2 and the Event Filter, which will not be determined for some time. The majority of LVL2 muon triggers will be genuine prompt muons, whereas the LVL2 isolated e/γ rate is still dominated by jet events. The expected rates for inclusive $W \to e\nu$ and $Z \to ee$ with $p_T(e) > 30$ GeV are about 50 Hz and 5 Hz respectively at design luminosity (10^{34} $cm^{-2}s^{-1}$).

Regions of Interest

Information on each LVL1 object in an event is communicated to LVL2 as a Region of Interest (RoI). Normally only the data in these regions of the detector are analysed by LVL2, except in the case of candidate B-physics triggers.

There are two types of RoI:

- Primary or ‘trigger’ RoIs are any objects found at LVL1 that have been used in accepting the event.
- Secondary or 'non trigger' RoIs are objects from LVL1 with transverse energies too low to contributed to the trigger. They are passed to LVL2 purely as additional information about the event.

Secondary RoIs do not contribute to the LVL1 accept/reject decision in any way. The lowest possible thresholds for the trigger objects will generally be secondary RoIs, for example J15 or J40, and EM7I. Secondary RoIs are expected to increase the flexibility and rejection capability of LVL2, but further studies are required. The efficiency for triggering on secondary RoIs at very low thresholds while limiting the number of fake secondary RoIs to a minimum has not yet been estimated reliably. This applies particularly to J15, but this does not appear to be required by the physics even at LVL2.

The LVL1 trigger also provides LVL2 with the values calculated for the missing E_T vector and the total scalar E_T (summed over jets or over the whole calorimeter).

Key to the Menus

The notation used in the menus is described in this section. Figures 1 and 2 summarise the notation used to formulate the trigger menus and define the trigger objects at the various levels.

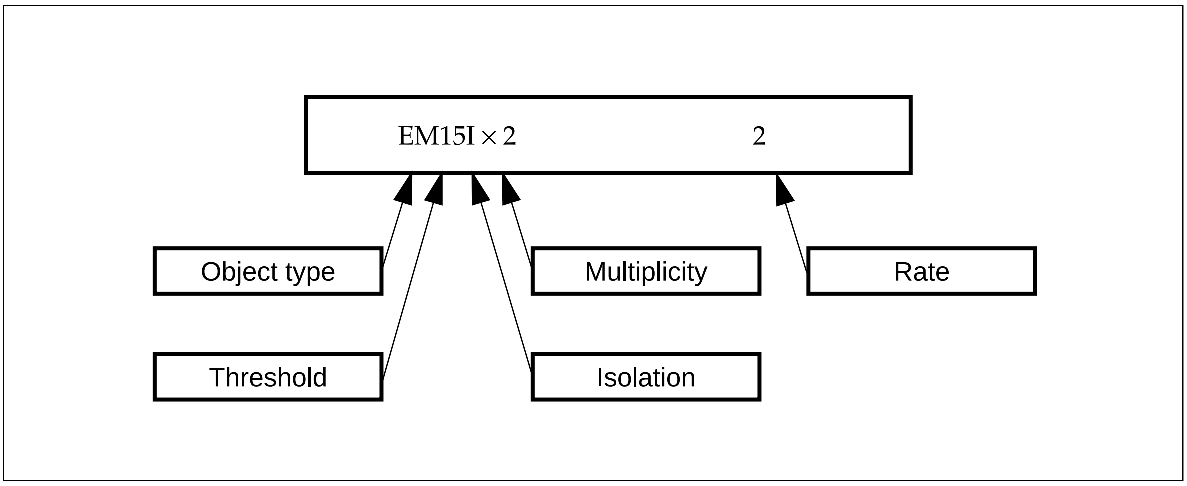

Figure 1 Notation used in the menus.

LVL1 Trigger Objects		**LVL2 Trigger Objects**		**LVL2 B-Physics Trigger Obj.**	
MU	muon	μ	muon	h	track reconstructed in inner detector
EM	electromagnetic	e	electron		
J	jet	γ	photon	e	track identified as electron candidate
T	tau/hadron	j	jet		
XE	missing energy	τ	tau	μ	track identified as muon candidate
		xE	missing energy		

Figure 2 Key to trigger objects.

LVL1 trigger objects are shown in capital letters. The E_T threshold and the requirement of isolation are indicated after the object code. The thresholds are generally given at the point where the LVL1 (LVL2) algorithms are 95% (90%) efficient. Exceptions include the E_T^{miss} trigger, where the actual cut is given, and the muon triggers which are given at ~90% efficiency for LVL1. The muon triggers have an additional inefficiency due to the geometric detector acceptance, which is approximately 90%, averaged over the fiducial η coverage. Full details of the efficiencies can be found in the relevant sections of [2].

The isolation thresholds will change with the p_T of the trigger object, becoming more loose for higher p_T candidates and being completely removed at very high p_T. At LVL2 the trigger objects may be constrained by additional requirements, like mass cuts. As shown in Figure 2, more complex objects are used at LVL2 for B-physics triggers. The exact definition of the low p_T electron and muon trigger objects is still under study. Typically, an electron is identified using the TRT and the EM calorimeter, whereas a muon is identified in the muon system for $p_T > 5$ GeV and possibly in the Inner Detector and Hadron Calorimeter for 3 GeV $< p_T <$ 5 GeV.

Physics Menus

The first set of menus covers the majority of LHC physics studies. They are intended to provide a common focus for physics studies and trigger performance studies. The menus in this note have been derived from the requirements of simulated physics analyses. They are designed to be simple, inclusive and to satisfy the physics requirements with as short a list of trigger items as possible. The one exception to this is B-physics, where semi-inclusive selection of particular decay modes must be done in the LVL2 trigger.

Where isolation of objects is indicated, it should be understood that the isolation criteria are relaxed as object E_T increases. For very high E_T, isolation is not required.

LVL1, Low Luminosity

The LVL1 menu for low luminosity is shown in Table 1. The MU6 trigger selects events for B-physics studies; clearly, higher-p_T muons relevant for other physics studies are included in this.

The threshold for the two EM object trigger is set as low as possible to maximise the efficiency for $H \rightarrow \gamma\gamma$ and $Z \rightarrow e^+e^-$ decays. If possible the threshold will be lowered further to give some acceptance for J/ψ and Υ decays to e^+e^-. This will be the subject of some future trigger performance studies.

The inclusive-jet threshold has been raised compared to the one given in the ATLAS TP to reduce the rate and make more room for other triggers. This is because the additional jet rejection available at LVL2 is small, so the useful LVL1 threshold is effectively limited by LVL2 rate requirements. Multi-jet and jet + E_T^{miss} are given priority when sharing out the rate budget for these types of triggers. The thresholds of the multi-jet triggers are also chosen to give an acceptable rate for LVL2. No specific requirements from the physics have been stated which would dictate explicit values for these triggers. The rate for the low p_T jets cannot be predicted reliably due to large theoretical uncertainties.

Studies of the J50 + XE50 and T20 + XE30 triggers are preliminary so the thresholds and rates given should only be taken as indicative of what may be possible. These triggers are intended to provide efficient inclusive triggers for SUSY production, and also for calibration via $W \rightarrow \tau\nu$ / $Z \rightarrow \tau\tau$. The additional requirement of missing energy allows lower thresholds than are possible with the jet and tau/hadron inclusive triggers. The aim for these triggers is a missing energy threshold of around 30–50 GeV and the lowest possible jet and tau thresholds that give an acceptable rate at both LVL1 and LVL2. The tau thresholds refer to the hadronic part of the tau energy. It should be noted that there is no direct physics need for the LVL1 tau trigger.

Table 1 LVL1 low luminosity menu.

Trigger	Rate (kHz)	Reference
MU6	23	Chapter 5 of [2]
EM20I	11	Chapter 6 of [2]
EM15I × 2	2	Chapter 6 of [2]
J180	0.2	Chapter 6 of [2]
J75 × 3	0.2	Chapter 6 of [2]
J55 × 4	0.2	Chapter 6 of [2]
J50 + XE50	0.4	Chapter 6 of [2]
T20 + XE30	2	Chapter 6 of [2]
Other triggers	5	Section "Menus for Specialised Triggers"
Total	**44**	

Table 2 LVL1 high luminosity menu.

Trigger	Rate (kHz)	Reference
MU20	3.9	Chapter 5 of [2]
MU6 × 2	1	ATLAS TP [4]
EM30I	22	Chapter 6 of [2]
EM20I × 2	5	Chapter 6 of [2]
J290	0.2	Chapter 6 of [2]
J130 × 3	0.2	Chapter 6 of [2]
J90 × 4	0.2	Chapter 6 of [2]
J100 + XE100	0.5	Chapter 6 of [2]
T60 + XE60	1	Chapter 6 of [2]
MU10 + EM15I	0.4	see text
Other triggers	5	Section "Menus for Specialised Triggers"
Total	**40**	

The table entry ‘Other triggers’ indicates the rate budget which is reserved for specialised, monitoring and calibration triggers that are described later in this document.

LVL1, High Luminosity

The high luminosity menu in Table 2 contains mostly the same objects as the low luminosity menu, but with higher thresholds and/or rates. An additional trigger at high luminosity is

MU10 + EM15I. Another extra trigger EM20I + XE is being studied. The additional physics that might be caught by these triggers at high luminosity (e.g. $W \rightarrow e\nu$ and $Z \rightarrow \tau\tau$ for calibration purposes) is already included in the lower-threshold, single-object triggers at low luminosity. The rate given for MU10 + EM15I is based on a preliminary study of $b \rightarrow \mu X$ events with pile-up added, so the rate and thresholds should only be taken as indicative of what may be possible.

LVL2, Low Luminosity

Most of the menu items in the low-luminosity LVL2 trigger menu, Table 3, follow directly from the LVL1 items in Table 1. EM triggers can be refined at LVL2 into candidates for electrons and/or photons. It is possible to apply isolation criteria to the muon triggers to help reduce the rate. The inclusive, non-isolated μ6 trigger is not preserved at LVL2; the threshold for the inclusive muon trigger is raised to 20 GeV. Events that satisfy the MU6 LVL1 trigger and are confirmed by the LVL2 μ6 pre-selection are passed to the B-physics menu, described in the next section. The rate of events passing the inclusive LVL2 μ6 pre-selection is estimated to be 9 kHz (see Chapter 10 of [2]). The inclusive single-muon trigger μ20 does not require isolation. An additional single muon trigger with a lower p_T threshold may be possible with isolation; this is being studied. An inclusive di-muon trigger μ6 + μ5 can be found in the B-physics menu (Table 4).

Table 3 LVL2 low luminosity menu.

Trigger	Rate (Hz)	Reference
μ20	200	ATLAS TP [4]
e20i	100	Sections 8.2.2 and 9.3 of [2]
e15i × 2	~few Hz	see text
γ40i	100	Sections 8.2.2 and 9.2 of [2]
γ20i × 2	5	Sections 8.2.2 and 9.2 of [2]
j180	100	Section 8.2.4 of [2] and see text
j75 × 3	80	Section 8.2.4 of [2] and see text
j55 × 4	40	Section 8.2.4 of [2] and see text
j50 + xE50	250	Section 8.2.4 of [2] and see text
τ20 + xE30	400	Section 9.4 of [2] and see text
μ6i + e15i	15	see text
B-physics	1130	Table 4
Other triggers	100	Section "Menus for Specialised Triggers"
Total	**2400**	

The trigger μ6i + e15i allows lower thresholds than are possible for the inclusive single-object triggers. It is an example of the use of a secondary RoI (in this case EM15I) which would not in itself constitute a LVL1 trigger. The rate given here is based on a preliminary study of $b \rightarrow \mu X$ events, so the rate and thresholds should only be taken as indicative of what may be possible. Muon isolation, which would further reduce the rate, has not yet been taken into account.

The thresholds of the jet triggers in the table are the actual thresholds applied. As discussed in Section 8.2.4 of [2], the corresponding nominal threshold for 90% efficiency could vary slightly, depending on the choice of reference jet.

The rate for the trigger τ20 + xE30 is estimated by taking a rejection factor of 5 with respect to the LVL1 tau trigger. This reduction has been shown to be feasible in Section 9.4 of [2].

As at LVL1, the additional requirement of missing energy in the SUSY/calibration triggers (j50 + xE50, τ20 + xE30), allows lower thresholds than would be possible for the inclusive triggers. It is not necessarily expected that E_T^{miss} will be recalculated at LVL2, but the LVL1 value could be refined, for example by including any muon E_T and correcting for LVL1 ADC saturation. For the rates given here, no LVL2 refinement has been taken into account.

Some rates presented in the table are limited by statistics, due to the size of data sets that are currently available. For example the rate given for the trigger γ20i × 2 is the 90% upper confidence limit based on 2 events. No events survive the cuts for the trigger e15i × 2, and the data sets available are biased by a 17 GeV cut in E_T (see Section 4.4 of [2]). However, from consideration of the other e/γ triggers it can be concluded that the rate will be of the order of a few Hz, which is a negligible contribution to the total LVL2 rate.

LVL2, Low Luminosity B-Physics

The low-luminosity B-physics trigger menu will only be used in the following case:

- the LVL1 trigger includes a MU6;
- the LVL2 trigger confirms a μ6 trigger.

The precision muon detector and the inner detector are used to confirm the muon RoI at LVL2. If these conditions are true, an unguided track search will be performed in the inner detector. Without the constraints of RoI guidance, tracks can be found down to very low p_T. These tracks are the objects required in addition to μ6, in Table 4. It is assumed that the LVL2 muon RoI confirmation will reduce the muon rate from the 23 kHz provided by LVL1 to 9 kHz. The rates in the table depend on this assumption and include the effect of pile-up at low luminosity.

The rates after the LVL2 selection are given in Table 4. They are all taken from Chapter 10 of [2]. There is little overlap between the trigger items so the total rate is approximately equal to the sum of the rates for the individual triggers.

Regarding the first three items in Table 4, channels with a J/ψ include the decays $B_d \to J/\psi\, K_S$, $B_s \to J/\psi\, \phi$, $B_d \to J/\psi\, K$, $B_d \to J/\psi\, K^{*0}$, which are important for CP violation studies, as well as $\Lambda_b \to \Lambda\, J/\psi$, $B_c \to J/\psi\, X$. The first item also covers rare decays such as $B \to \mu\mu$ and $B \to \mu\mu K^{0*}$.

The rates and thresholds in the table are still under review. It may be possible to reduce the p_T cut on the $B_d \to \pi^+\pi^-$ trigger to 3 GeV by using a tighter mass cut to maintain the rate; this is currently being investigated. Soft muons with $p_T < 6$ GeV are identified by matching inner detector tracks to the calorimeter and/or muon detector. Lowering the threshold for the soft muon from 5 GeV to 3 GeV increases the rate of the di-muon channel to 600 Hz. Electrons with $p_T > 5$ GeV, as used in the $B \to eX$ trigger, can be identified using the ECAL in addition to the TRT signature.

Table 4 Example of B-physics trigger menu.

Trigger Signature	Rate (Hz)	Example Channel
$\mu6$ + additional $\mu5$	170	Inclusive $J/\psi \rightarrow \mu^+\mu^-$
$\mu6 + e0.5 \times 2 + m_{ee}$	310	$b \rightarrow \mu X$, $B \rightarrow J/\psi\ X \rightarrow ee$
$\mu6 + e5$	100	$b \rightarrow eX$, $B \rightarrow J/\psi\ X \rightarrow \mu\mu$ (second μ not required in trigger)
$\mu6 + h5 \times 2 + m_B$	60	$b \rightarrow \mu X$, $B_d \rightarrow \pi^+\pi^-$
$\mu6 + h1.5 \times 3 + m_\phi + m_{Ds}$	190	$b \rightarrow \mu X$, $B_s \rightarrow D_s(\phi^0(K^+K^-)\pi)X$
$\mu6$ + ...	300	reserved for additional B channels
Total	**1130**	

LVL2, High Luminosity

Most menu items in the LVL2 high-luminosity menu, Table 5, follow directly from the LVL1 items inTable 2. Compared to low luminosity, thresholds have generally been raised and the requirement of isolation has been added to the inclusive muon trigger. The di-muon triggers without isolation requirements are mainly for B-physics. In addition to the di-muon trigger $\mu10 \times 2$, a lower threshold with isolation is under study as a possible additional trigger. The rate of the di-lepton trigger $\mu10i + e15i$ is estimated from a preliminary study of $b \rightarrow \mu X$ events, with the same caveats as at low luminosity.

Table 5 LVL2 high luminosity menu.

Trigger	Rate (Hz)	Reference
$\mu20i$	200	ATLAS TP [4] and Section 9.1 of [2]
$\mu6 \times 2 + m_B$	10	ATLAS TP [4]
$\mu10 \times 2$	80	ATLAS TP [4]
e30i	600	Sections 8.2.2 and 9.3 of [2]
$e20i \times 2$	20	see text
$\gamma60i$	400	Sections 8.2.2 and 9.2 of [2]
$\gamma20i \times 2$	200	Sections 8.2.2 and 9.2 of [2]
j290	120	Section 8.2.4 of [2] and see text
$j130 \times 3$	80	Section 8.2.4 of [2] and see text
$j90 \times 4$	80	Section 8.2.4 of [2] and see text
j100 + xE100	~few 100	see text
$\tau60$ + xE60	~few 100	see text
$\mu10i + e15i$	20	see text
Other triggers	100	Section "Menus for Specialised Triggers"
Total	**2000**	

The rate for the di-electron trigger e20i $\times$ 2 is calculated using the same cuts as the single e30i trigger (Section 9.3 of [2]). The rate is estimated from the one event that survives these cuts. Anyway, this trigger is almost a complete subset of γ20i $\times$ 2, so the rate is not included in the total.

The comments made on the jet, tau and missing energy triggers in the low luminosity menu apply here too. The rates of j100 + xE100 and τ60 + xE60 are estimated from the rate reductions expected of LVL2 at low luminosity and depend on the tau efficiency aimed for. Hence only an approximate indication of the rate is given. As at LVL1, a trigger on an isolated electron plus missing energy is also under study.

Menus for Specialised Triggers

The main stream physics programme does not have a direct requirement for the specialised trigger items that are discussed in this section. Physics topics covered here include QCD studies and Standard Model cross section measurements. There are also redundant triggers for cross checks. Inclusive triggers are prescaled with lower thresholds to understand thresholds, collect background samples, and to take low p_T data. The rate will be controlled by choice of threshold and prescale factors. We allow rate budgets of 5 kHz at LVL1 and 100 Hz at LVL2 for these triggers. At this stage, the most important aspect is to know the number of thresholds required as this has implications for the design of the LVL1 trigger.

The possibility of implementing a b-jet tag trigger based on impact-parameter information at LVL2 is under study (Section 9.6 of [2]). Issues to be addressed include the feasibility (beam-position stability, alignment, etc.) and comparing the merits of making the selection at LVL2 or in the Event Filter, where more complex algorithms and better alignment constants might be available. No strong physics case for this trigger has been established [6], but it would add to the flexibility of the trigger. For example, if a factor of 10 rejection were to be available at LVL2 with high enough efficiency with respect to the offline algorithms, the multi-jet thresholds of Tables 1 and 2 could be lowered at LVL1 and thus provide possibly better acceptance for multi-jet final states containing b-jets.

Additional Inclusive Triggers with High Thresholds and Low Rates

These are not prescaled.

1. Tau/Hadron
2. E_T^{miss}
3. Sum E_T
4. Sum Jet E_T

A localised forward energy trigger is also under consideration.

Prescaled Triggers with a Range of Thresholds

Prescaled triggers are foreseen with a range of thresholds. Typically, these would have four to six thresholds per trigger, each with a different prescale factor. Prescaled triggers will include the following:

1. Jet
2. Muon
3. Di-Muon
4. Electron/Photon
5. Tau/Hadron
6. 3 Jet
7. 4 Jet
8. E_T^{miss}
9. Sum E_T
10. Sum Jet E_T
11. Forward energy (under consideration)

Other Specialised Triggers

In addition to the specialised physics triggers listed above, some more technical triggers are foreseen. These include a random trigger and triggers on empty bunch crossings, as well as detector calibration triggers (approximately one per subsystem).

Physics Coverage of the Trigger Menus

It is believed that the set of triggers proposed in Tables 1 to 5 covers most of the physics goals of the ATLAS experiment very well. This conclusion follows several dedicated meetings between the Trigger Performance group and the Physics groups. It is also based on detailed feedback requested by the Trigger Performance group from the Physics groups concerning the cuts used for physics analysis.

In fact, many processes will be selected through multiple trigger signatures, thus providing optimal efficiency and several means of controlling the crucial aspects of the trigger efficiency. This trigger strategy remains basically the same as at the time of the ATLAS Technical Proposal, but the physics studies performed since (most prominently in the areas of B-physics, MSSM Higgs physics and supersymmetry) warrant a justification of the statement that the ATLAS trigger strategy still covers most of the physics goals.

Inclusive lepton and di-lepton triggers provide $W \rightarrow l\nu$ and $Z \rightarrow l^+l^-$ selections, where l designates an electron or a muon. They therefore give an unbiased trigger for many Standard Model physics processes and also for many searches for physics beyond the Standard Model. At low luminosity, $W \rightarrow l\nu$ decays are selected by the MU6/EM20I LVL1 triggers and the μ20/e20i

LVL2 triggers; $Z \rightarrow l^+l^-$ decays are selected by the MU6/EM15I × 2 LVL1 triggers and the μ6 + μ5 / e15i × 2 LVL2 triggers.

At high luminosity, the $W \rightarrow l\nu$ decays can still be selected by inclusive lepton triggers, although with a somewhat high threshold in the case of electrons (MU20/EM30I at LVL1 and μ20i/e30i at LVL2). As stated in the Section "Physics Menus", a trigger on an isolated electron with a lower threshold and an additional E_T^{miss} requirement is being studied at high luminosity in LVL1 and LVL2 in order to recover the inclusive $W \rightarrow l\nu$ selection. In contrast the thresholds for the inclusive $Z \rightarrow l^+l^-$ decays remain comfortably low (MU6 × 2 / EM20I × 2 at LVL1 and μ10 × 2 / e20i × 2 at LVL2).

As mentioned above, many physics processes of interest are covered by the inclusive lepton/di-lepton triggers:

- Gauge-boson pair production, for the study of anomalous couplings and to investigate the behaviour of the production cross-section at high mass.
- Top-quark production (single top or $t\bar{t}$ pairs), for all cases except $t\bar{t}$ production with fully-hadronic top decays.
- Direct production of SM or MSSM Higgs bosons with $H \rightarrow ZZ^{(*)}$, $WW^{(*)}$ decays, over the full Higgs mass range of interest. Associated production of SM Higgs bosons through WH/ZH/$t\bar{t}$ H processes, with $H \rightarrow b\bar{b}$ or $H \rightarrow \gamma\gamma$, and $W \rightarrow l\nu$ or $Z \rightarrow l^+l^-$.
- Decays of MSSM Higgs bosons, such as $A \rightarrow Zh$, $H/A \rightarrow \mu\mu$, $H/A \rightarrow t\bar{t}$, and also $H/A \rightarrow \tau\tau$ with one leptonic τ decay. Production of $t\bar{t}$ with one top decay to bH, where the other top-quark decay provides the inclusive W trigger.
- Production of new vector gauge bosons (W′/Z′), with W′/Z′ decays to leptons. Also, resonance production at the TeV scale (strongly interacting Higgs sector), with resonance decays into gauge-boson pairs.
- Production of supersymmetric particles with final states containing:
  - at least one high-p_T lepton and large E_T^{miss} in the case of R-parity conservation;
  - at least one high-p_T lepton (e.g. from $\chi_2^0 \rightarrow ll\chi_1^0$ decay) with or without large E_T^{miss} in the case of R-parity violation with $\chi_1^0 \rightarrow 3$ jets, $\chi_1^0 \rightarrow l\nu\nu$, or $\chi_1^0 \rightarrow ll'\nu$.
- Searches for leptoquarks decaying into electrons or muons; searches for compositeness in the lepton sector through Drell-Yan production.

The remaining physics channels not covered by the inclusive lepton/di-lepton (and electron + E_T^{miss}) triggers discussed above are:

- B-physics, which is covered in a separate menu in Table 4. In this particular case, each class of exclusive channel of interest needs its own dedicated trigger study at LVL2, given the very high rate of inclusive B-hadron events containing a high-p_T muon used to trigger at LVL1. A certain budget has been foreseen at LVL2 for B decay channels that are not yet part of the studies. Under study at present, in case it should be necessary, is whether modest impact-parameter cuts could be used to reduce the trigger rate per individual channel and thereby further increase the flexibility of the trigger at LVL2.
- $H \rightarrow \gamma\gamma$ decays from direct Higgs production, which are covered at low luminosity by EM15I × 2 for LVL1 and by γ20i × 2 for LVL2, and at high luminosity by EM20I × 2 for LVL1 and by γ20i × 2 for LVL2. These triggers also cover possible MSSM Higgs boson decays such as $H \rightarrow hh \rightarrow b\bar{b}\gamma\gamma$.

- Searches for supersymmetry involving high-p_T jets with or without E_T^{miss}. At low luminosity the combination of J50 + xE50, J180, and J75 × 3/J55 × 4 triggers provides excellent coverage for all exclusive final states of interest not containing leptons.

  In the case of R-parity conservation, final states containing at least two high-p_T jets and large E_T^{miss} (typically two jets with E_T > 150 GeV and E_T^{miss} > 200 GeV) provide a broad inclusive sample for more exclusive searches. This also applies largely to SUSY searches in the framework of gauge-mediated SUSY-breaking models.

  In the case of R-parity violation, with χ_1^0 decaying predominantly to three jets, the final-state jet multiplicities range from 8 to 16, which completely suppresses the characteristic E_T^{miss} signature of SUSY events. Here the multi-jet triggers will cover most of the exclusive final states of interest. It is important to note that to date the only exclusive final states which have been proven to be observable above the huge potential QCD background are final states containing one or preferably two isolated high-p_T leptons.

  At high luminosity, the higher thresholds applied to the various jet triggers and to the jet + E_T^{miss} trigger will be well suited to searches for higher-mass SUSY particles. Further study would be needed to optimise the triggers for systematic studies of lower-mass SUSY particles, should they be discovered in the initial years of operation.

- Searches for leptoquarks decaying into jet and neutrino that rely on the jet + E_T^{miss} trigger.
- Searches for resonances decaying into jets and for compositeness in the quark structure. These rely largely on the inclusive single-jet trigger (e.g. additional vector bosons or technicolour resonances decaying to two jets) or on multi-jet triggers (e.g. purely hadronic decays of $t\bar{t}$ pairs), both at low and high luminosity. The thresholds quoted for this trigger at low and high luminosity will provide good coverage of these physics channels, given the expected reach of the Tevatron experiments in this field before the LHC starts operation.

As shown in the physics menus, a τ + E_T^{miss} trigger is foreseen at LVL1 and LVL2 to extract as large a fraction as possible of $W \to \tau\nu$ and $Z \to \tau\tau$ in view of detector calibration and monitoring. This trigger may increase the sensitivity to specific SUSY signatures for high values of tan β.

It is also hoped that the large variety of fairly inclusive triggers presented here would be sensitive to unexpected new physics.

Finally, it is important to emphasise, as stated in the section above on specialised triggers, that much of the early large cross-section physics (e.g. QCD jets, direct photons, etc.) will be studied using more inclusive triggers than the ones quoted explicitly in the menus of Tables 1–5.

Conclusions and Work Plan

The menus presented here have been used as a basis for all trigger menus and rates presented in the various Trigger and DAQ reports submitted to the LHCC in June 1998. To gain approval for this, they were examined and discussed at the June 98 Physics Coordination meeting and in specific trigger meetings during the ATLAS week of June 98, and presented in the Physics Plenary meeting of the same ATLAS week. The menus and rates will now be used as a common focus for continuing Trigger Performance studies, offline physics analysis studies, and as a basis for menus for more detailed studies of the LVL2 trigger and the Event Filter, both in terms of performance and of implementation, for example the test beds mentioned in the LVL2 Pilot Project [3]. An initial evaluation has been made of the detailed trigger menus needed for LVL2 implementation studies [7]. Work is in progress to prepare updated detailed menus consistent with the menus presented in this document.

Those trigger items that are considered particularly challenging or critical will be subject to detailed trigger performance studies using fully simulated data as input and offline reconstruction code as a reference. Wherever possible, the trigger performance results will be parameterised for use in fast simulations (ATLFAST [8]) with high-statistics background samples. A complete set of rates for the trigger menu tables can only be obtained through a combination of the above full-simulation studies and fast-simulation parameterisations.

References

1 *ATLAS Level-1 Trigger Technical Design Report*, CERN/LHCC/98-14, ATLAS-TDR-12, June 1998.

2 *Trigger Performance Status Report,* CERN/LHCC/98-15, June 1998.

3 *ATLAS DAQ, EF, LVL2 and DCS Technical Progress Report*, CERN/LHCC/98-16, June 1998.

4 *ATLAS Technical Proposal*, CERN/LHCC/94-43, December 1994.

5 *Detector Interface Working Group Summary Document*, Draft Version 3.0, 9 March 1998, http://atddoc.cern.ch/Atlas/DetfeIf/document/Detinfo.ps

6 E. Richter-Was and D. Froidevaux, *MSSM Higgs searches in multi-b-jet final states*, PHYS-NO-104, July 1997.

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8 E. Richter-Was et al, *ATLFAST 1.0: A package for particle-level analysis*, PHYS-NO-79, March 1996.