ATLAS Trigger Performance and Initial Running

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on behalf of the ATLAS Trigger/DAQ community

cHarged 2008
Uppsala, Sweden
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Outline

- Charged Higgs trigger menu
- The ATLAS electron and muon triggers
- Commissioning of the ATLAS trigger
- From startup to physics trigger menus
- Expected performance of lepton triggers
- Measuring trigger efficiencies from data
- Towards higher luminosities

Reference (unless stated otherwise):
ATLAS Collaboration, Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics, CERN-OPEN-2008-020, Geneva, 2008, to appear.

Charged Higgs “trigger menu”

- **Possible trigger signatures for a charged Higgs:**
  - For m(H^+) above/below top mass, we can look for these signatures:

$$tt \rightarrow 2b(W_{lep},W_{had})(\tau_{lep},\tau_{had})$$
$$tbH^+ \rightarrow 2b(W_{lep},W_{had})(\tau_{lep},\tau_{had})$$
$$tbH^+ \rightarrow 4b(W_{lep},W_{had})(W_{lep},W_{had})$$

(fully leptonic decays omitted due to small branching ratio)

  - This talk will concentrate on the lepton (e, μ) triggers (see the following talk by Richard Brenner for hadronic tau triggers)
- **Strategy**
  - Use unprescaled lepton triggers with lowest thresholds where possible
  - At higher luminosity use multi-object triggers. Example of a H+ “trigger menu” with rate estimates based on 7 million minbias events:

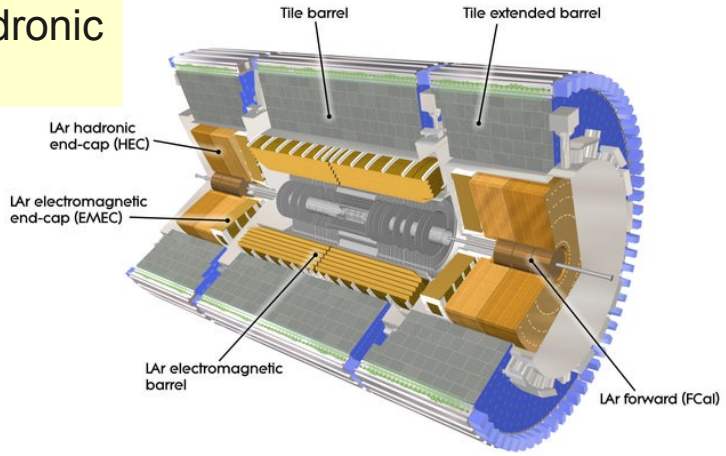
10^{31} Signature	Rate/Hz	10^{33} Signature	Rate/Hz
xe70	0.2 ± 0.1	xe80	< 10
e25i tight	0.7 ± 0.3	e55	10 ± 10
		e25i+xe30	10 ± 10
mu20	1.7 ± 0.4	mu40	10 ± 10
		mu20+xe30	20 ± 15
tau20i+xe30	5.8 ± 0.8	tau35i+xe50	< 10
tau15i+xe20+3j18	5.4 ± 0.8	tau35i+xe40+3j18	< 10

For much more details see Chris Potter's talk yesterday.

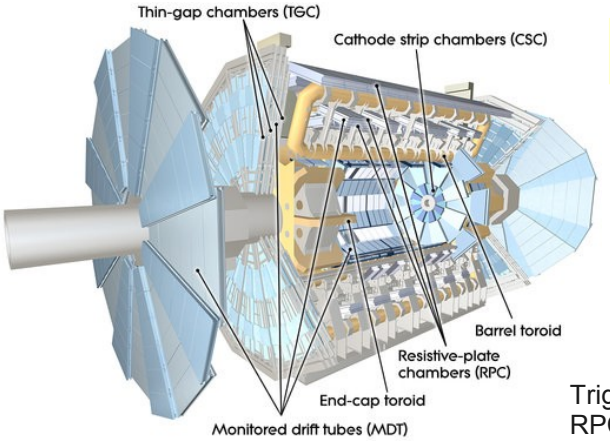
Example signatures from an earlier study. Menus have evolved since then. ATL-COM-PHYS-2008-026

ATLAS Level-1 triggers

EM and hadronic calorimeter



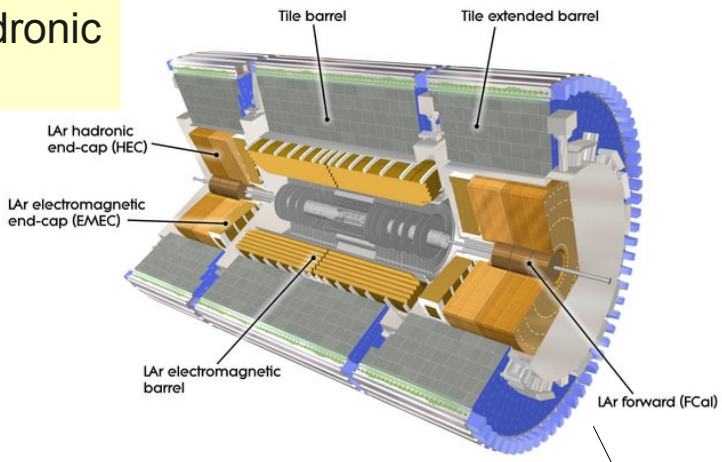
Muon system



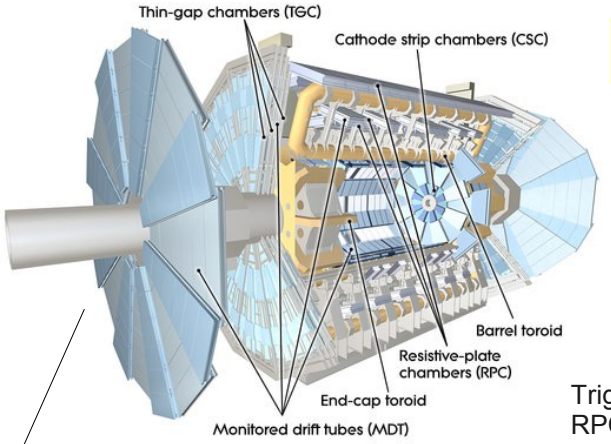
Trigger chambers:
RPC (barrel),TGC (endcap)

ATLAS Level-1 triggers

EM and hadronic calorimeter



Muon system



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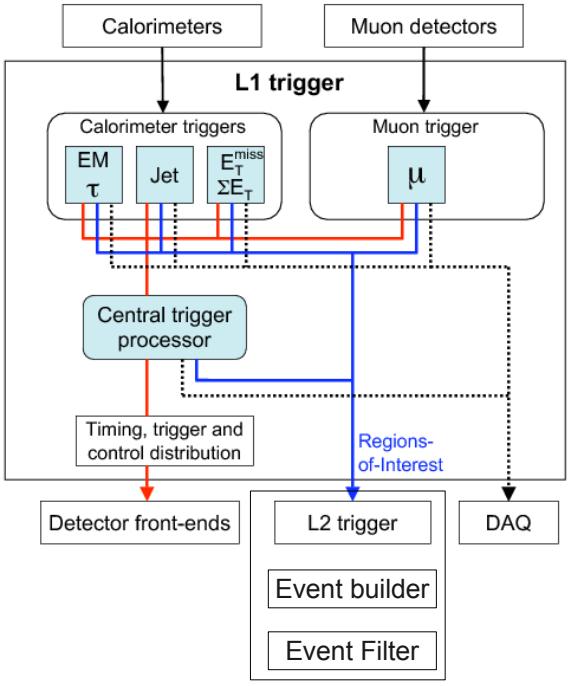

ATLAS Level-1 triggers

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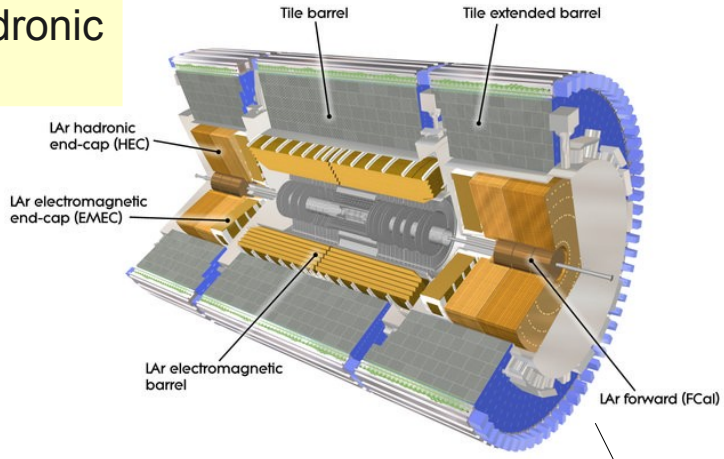
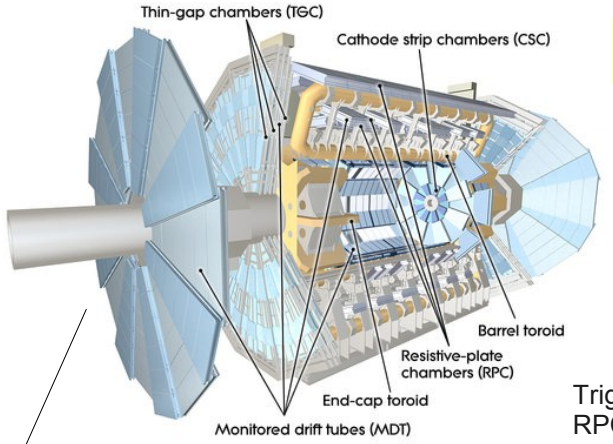
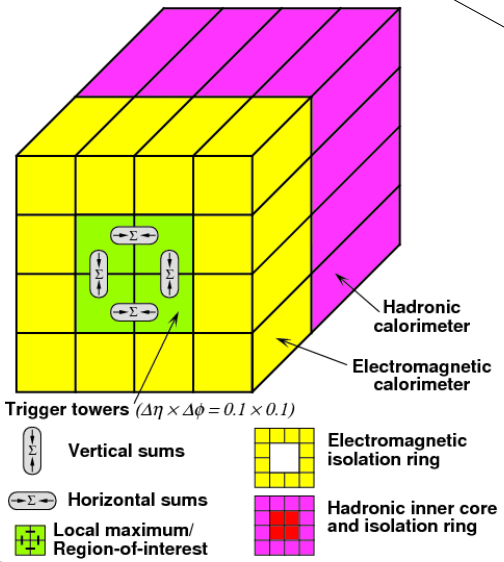


Muon system

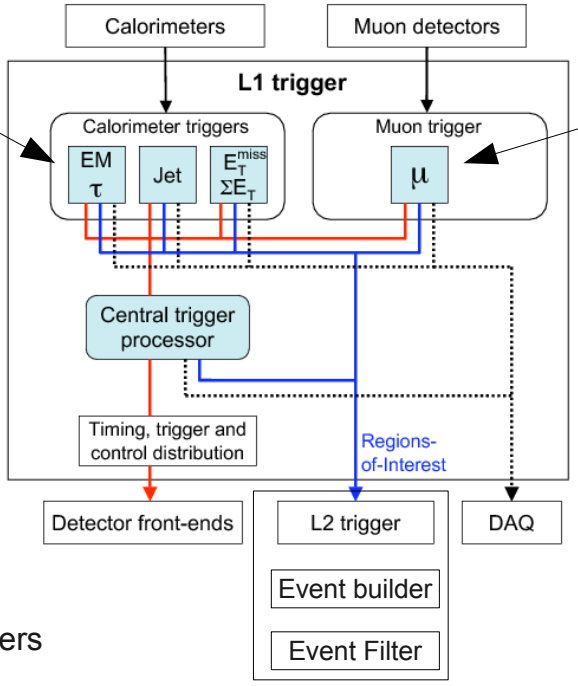


Trigger chambers:
RPC (barrel),TGC (endcap)

EM trigger algorithm

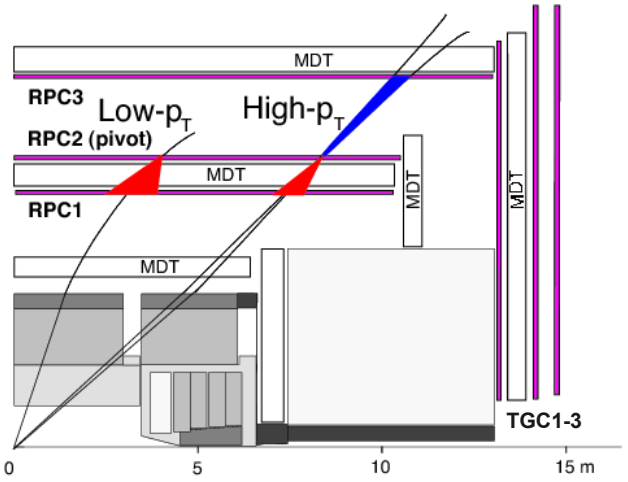


4x4 sliding window across trigger towers
Isolation vetos (EM and hadronic)



High Level Trigger

Muon trigger algorithm

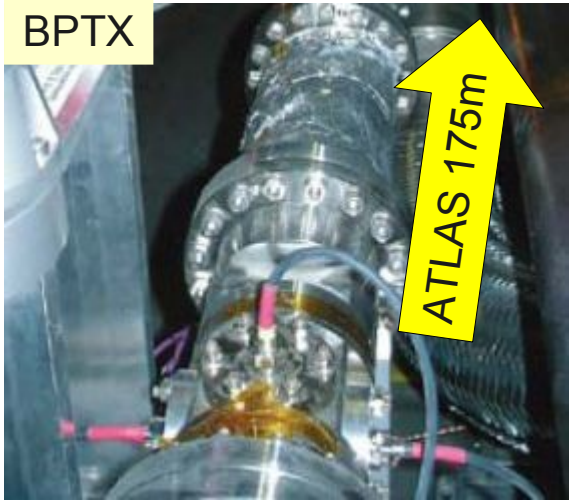


Coincidence within road in R/η and ϕ
Width of road determined by p_T cut

The less known ATLAS triggers

- Triggers relevant during startup period:

BPTX

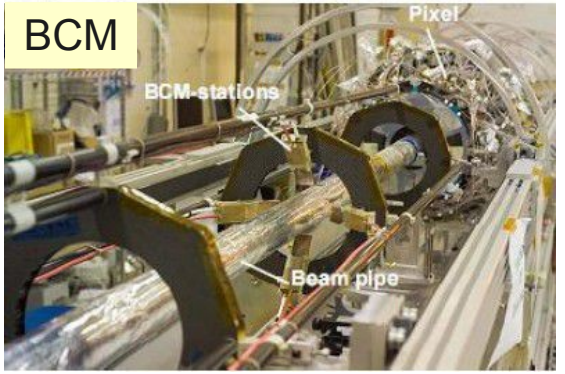


Beam Pickup Triggers
at ±175m from ATLAS
Trigger on filled bunches
Provides reference timing

MBTS

Minbias Trigger Scintillators
mounted on LAr cryostat
32 sectors (individual or multiplicity triggers)
Main trigger for initial running period

BCM



Beam Conditions Monitor
Diamond senors next to Pixel
1ns resolution
complements MBTS

LUCID

Luminosity monitor
within forward shielding (η~6)
can complement MBTS

in addition:

Random triggers
Bunch group triggers

Commissioning of the ATLAS trigger

- Many competing needs for the trigger during startup
  - Timing-in of detectors, trigger and DAQ
  - Detector commissioning
  - Commissioning of Level-1 trigger and HLT
  - Provide calibration and alignment samples
  - Provide samples for initial physics studies
  - Tier-0 (reconstruction) commissioning
  - ...
- All of the above while following the LHC beam conditions

Commissioning of the ATLAS trigger

- Many competing needs for the trigger during startup
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  - Provide calibration and alignment samples
  - Provide samples for initial physics studies
  - Tier-0 (reconstruction) commissioning
  - ...
- All of the above while following the LHC beam conditions
  - no beam
  - single beam clockwise
  - single beam counter-clockwise
  - beam on collimator
  - beam through ATLAS
  - one turn
  - many turns
  - two beams
  - Not to mention two colliding beams... ;-)

Four phases of commissioning

- 4 phases for commissioning
  - Rates controlled by Level-1 prescales, HLT mostly in pass-through mode

	Level 1	High Level Trigger
1	Random, BPTX, MBTS, BCM, LUCID Muon triggers in “coincidence mode” Low threshold L1Calo items	Empty HLT menu (re-run offline to check algorithms)
2	*In case luminosity higher than expected use higher thresholds*	Simple HLT algorithms (pass-through) Seeded from MBTS or full reconstruction

Single beam
O(2 weeks)

Four phases of commissioning

- 4 phases for commissioning
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2	*In case luminosity higher than expected use higher thresholds*	Simple HLT algorithms (pass-through) Seeded from MBTS or full reconstruction
3	Muon triggers now in physics mode	use higher thresholds
4	Enable higher thresholds in L1Calo Multi-object signatures	Full L2/EF menu (mostly pass-through) Check rates

Single beam
O(2 weeks)

First collisions

Gradually enable HLT filtering and remove Level-1 prescales.

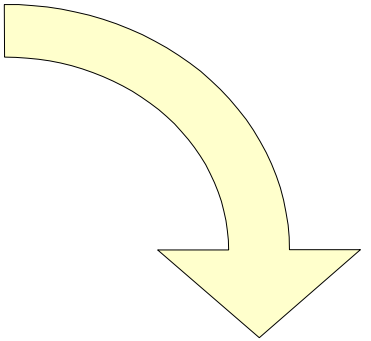
First physics run

Example: Calorimeter triggers

- From commissioning to physics menu:

Trigger	L1 item	Rate w/o prescale [Hz]	Pre-scale	HLT Rate [Hz]
em5_passHLT	EM3	40000	20000	2
em10_passHLT	EM7	5000	1300	4
em15_passHLT	EM13	800	200	4
em15i_passHLT	EM13I	390	100	4
em20_passHLT	EM18	280	70	4
em20i_passHLT	EM18I	100	25	4
em25i_passHLT	EM23I	41	10	4
em105_passHLT	EM100	1	1	1
2em5_passHLT	2EM3	6500	1600	4
2em15_passHLT	2EM13	80	20	4
2em20_passHLT	2EM18	35	10	4

From “Level1-only selection” with HLT in pass-through mode ...

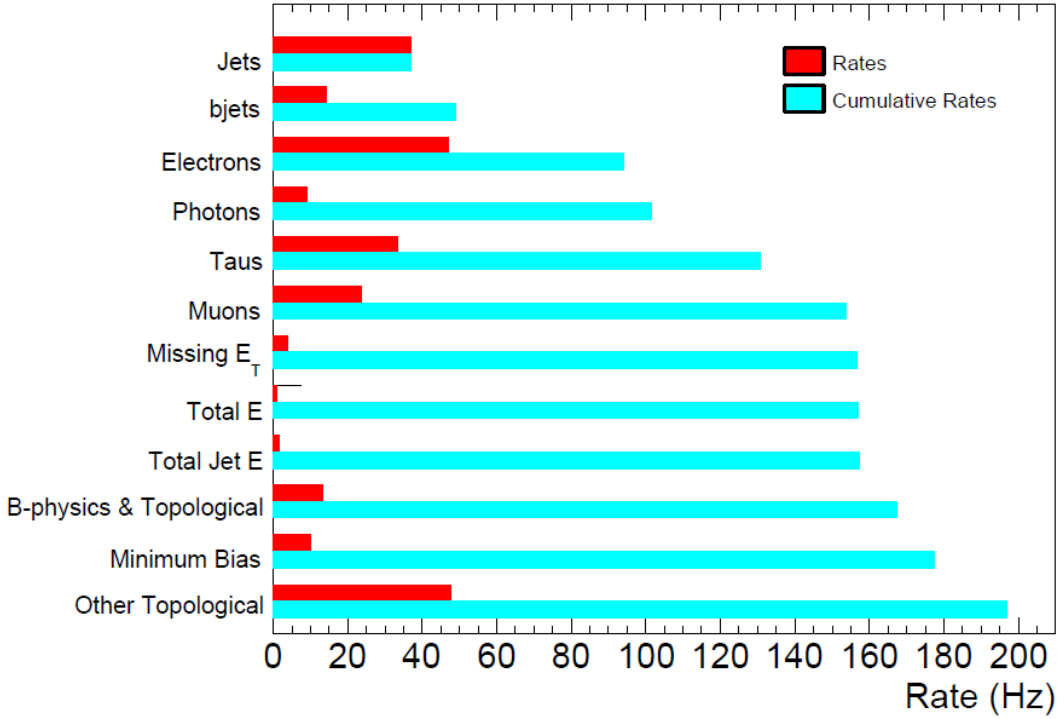


... to “10^{31} physics menu” without prescales

Signature	L1 item	EF selection	L1 Rate	Pre-scale	HLT Rate	Motivation
e10	EM7	medium	5.0 kHz	1	21 Hz	$e^{\pm}$ from b,c decays, E/p studies
γ20	EM18	loose	0.3 kHz	1	5.4 ± 0.2 Hz	direct photon production, jet calibration using γ-jet events, high-p_T physics
e20	EM18	loose	0.3 kHz	1	4.3 ± 0.2 Hz	high-p_T physics, $Z \rightarrow ee, W \rightarrow e\nu$
em105_passHLT	EM100		1 Hz	1	1.0 ± 0.1 Hz	New physics, check for possible problems
2e5	2EM3	medium	6.5 kHz	1	6 Hz	$J/\psi \rightarrow ee$, $Y \rightarrow ee$, Drell-Yan production
2γ10	2EM7	loose	0.5 kHz	1	< 0.1 Hz	di-photon cross-section
2e10	2EM7	loose	0.5 kHz	1	0.4 ± 0.2 Hz	$Z \rightarrow ee$

First menu for physics running at 10^{31} $cm^{-1}s^{-1}$

- Comprehensive studies have been done for a "10^{31} menu"
  - Contains ~130 Level-1 items and ~180 HLT selection chains
  - e/γ and muon triggers are unprescaled, except EM3
  - Rates estimated using 7 million minbias events (σ ~70 mb)
  - Already contains high and multi-object thresholds for debugging/testing
- Expected trigger rates for different trigger groups:



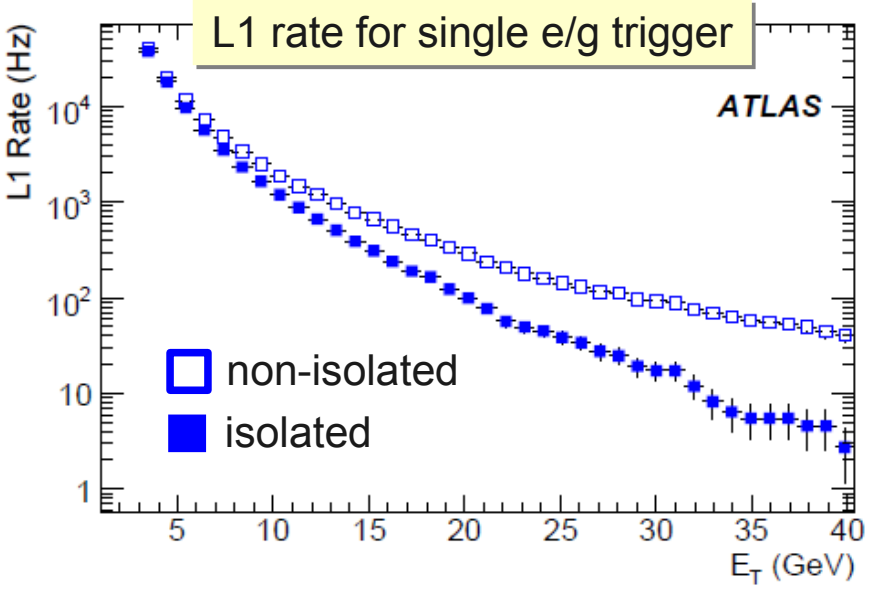
The exact thresholds and prescales to achieve these rates will have to be adjusted as soon as we get the first data.

Cheat sheet
Running 24h at 10^{31} $cm^{-2}s^{-1}$:
- integrated lumi ~ 0.86 pb^{-1}
- 10 Hz trigger ~ 1M events / pb^{-1}

Electron trigger rates

- Expected electron trigger rates in 10^{31} menu
  - Optimized to select events with at least 1 electron above 10 GeV and 1 photon above 20 GeV
  - In addition double object triggers for J/ψ, Υ, Z → ee and very high p_T trigger
  - J/ψ and Υ decays are challenging for the L1 trigger (noise ~ 0.5 GeV/region-of-interest)

L1 rate for single e/g trigger

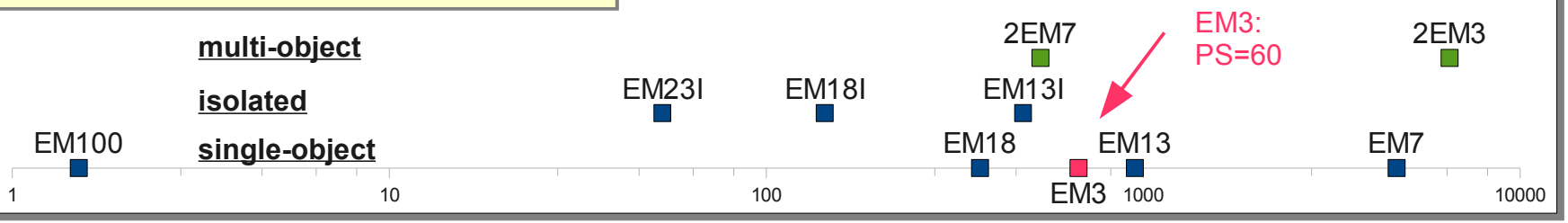


Important processes

Expected events		2 pb^{-1}	5 pb^{-1}	10 pb^{-1}
J/ψ → ee	no cuts	160k	420k	840k
	"typical" cuts	3.3k	8.3k	16.5k
Z → ee	no cuts	2.5k	6.5k	13k
	"typical" cuts	0.7k	1.8k	3.5k
W → eν	no cuts	25k	65k	130k
	"typical" cuts	6.3k	16k	31k

Expected number of events without any offline selection and a "typical" event selection for the 2e5 and e10 trigger items.

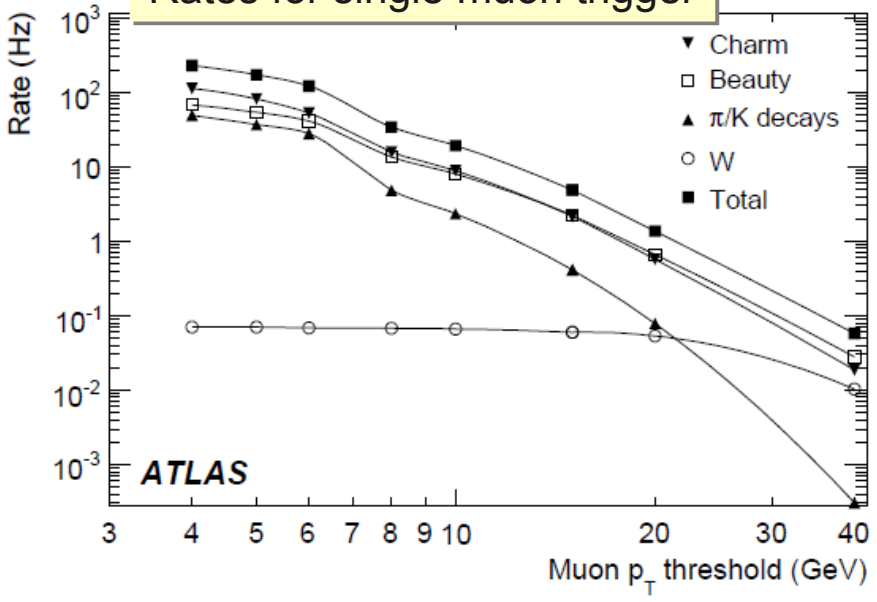
Level-1 EM threshold and rates (Hz)



Muon trigger rates

- Expected muon trigger rates in 10^{31} menu
  - All muon thresholds are unprescaled (both L1 and HLT)
  - Largest source of muons are b/c quarks and π/K in-flight decays

Rates for single muon trigger

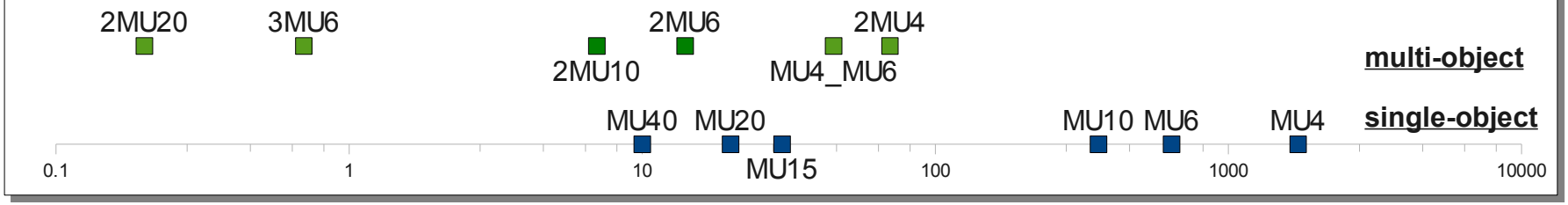


Muon rates with p_T>6 GeV and the fraction of events with $J/\psi \rightarrow \mu\mu$

	p_T > 6 GeV	$J/\psi \rightarrow \mu\mu$	Fraction
Level-1	380 Hz	0.21 Hz	0.05%
Level-2	3 Hz	0.19 Hz	6%

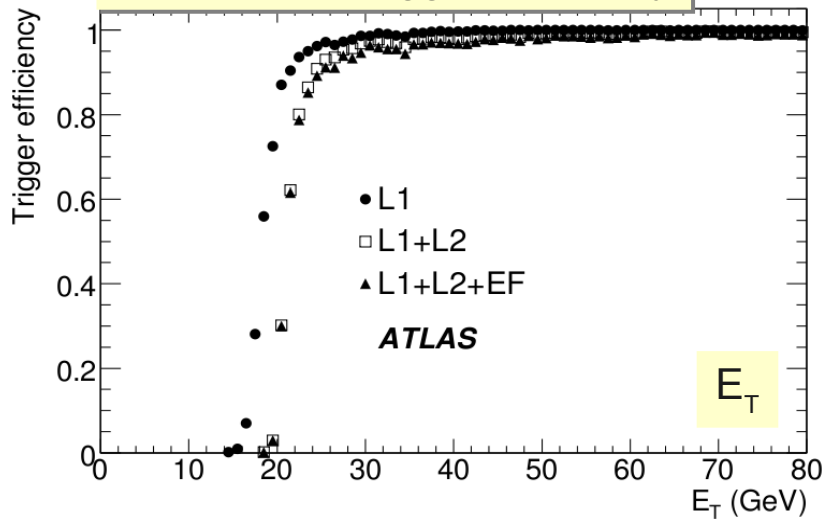
19k events / pb^{-1} @ 10^{31}

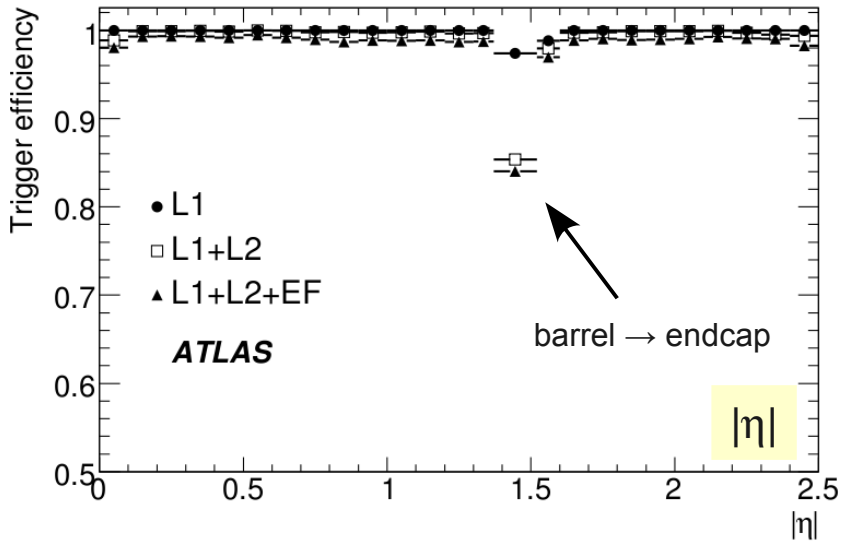
Level-1 muon thresholds and rates (Hz)



Expected performance of lepton triggers

e20 electron trigger efficiency



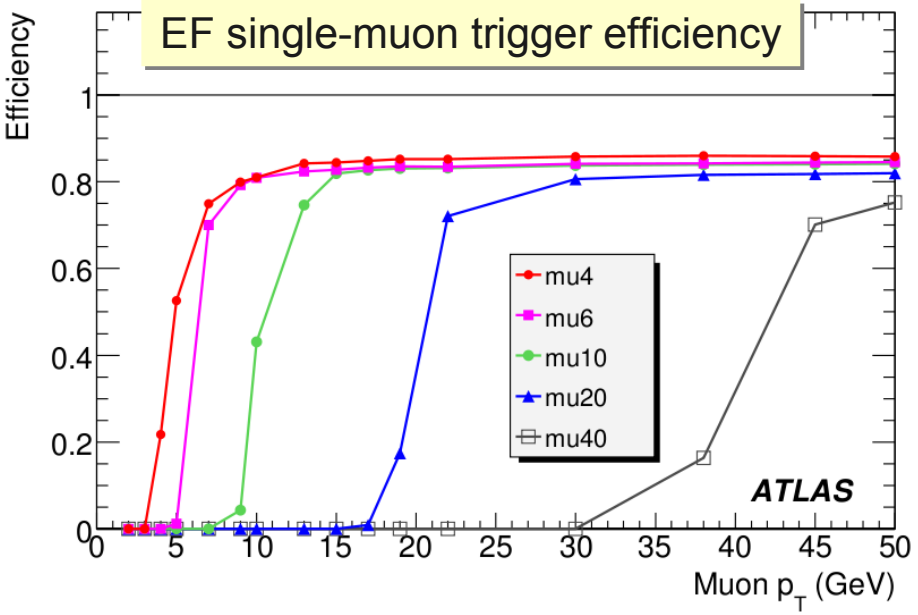


Trigger efficiencies for e20 with respect to offline reconstruction selection.

Level-1 muon efficiency
barrel ~ 80%
endcap ~ 94%

Almost exclusively due to geometrical acceptance. Level-1 muon algorithm expected to be almost 100% efficient.

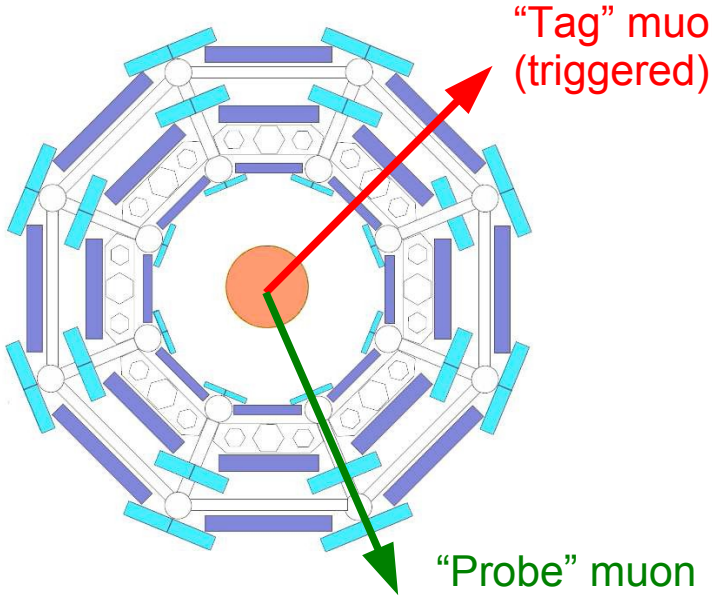
EF single-muon trigger efficiency



Event filter efficiencies for different thresholds with respect to generated truth muons.

Measuring trigger efficiencies from data

- Possible definitions of trigger efficiencies
  - Absolute: with respect to MC truth (useful to check reconstruction improvements)
  - Relative to another trigger (e.g. muon with respect to minbias trigger)
  - Relative to offline reconstruction
- Both e/gamma and muon groups are using “Tag & Probe” method:
  - Other methods (e.g. orthogonal triggers) used as cross-check



(1) Clean signal sample ($Z, J/\psi \rightarrow l^+l^-$)

(2) Select track that triggered the event (“Tag”)

(3) Find other track using offline criteria (“Probe”)

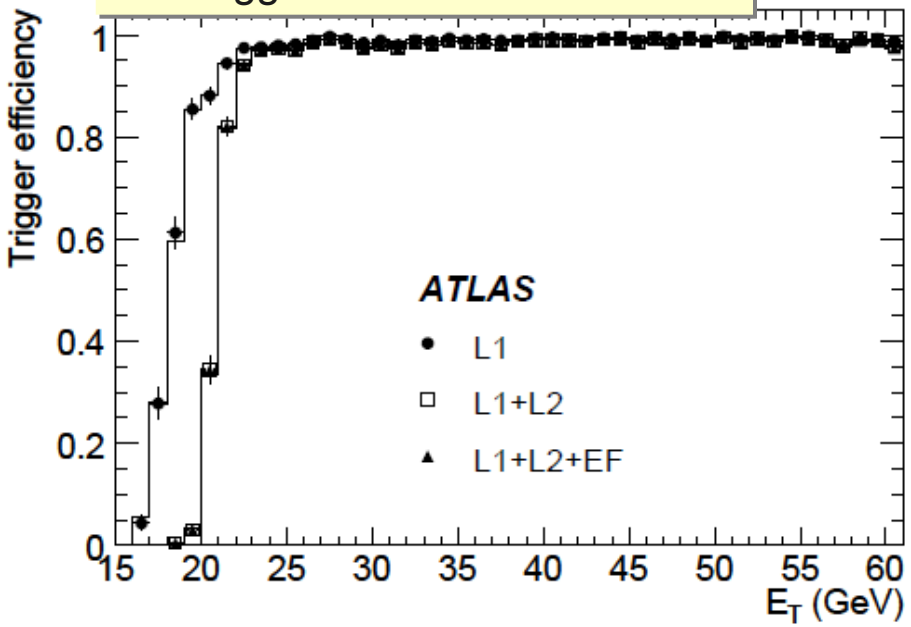
(4) Determine efficiency by applying trigger selection on Probe

Need a high purity signal sample
Biases must be checked carefully

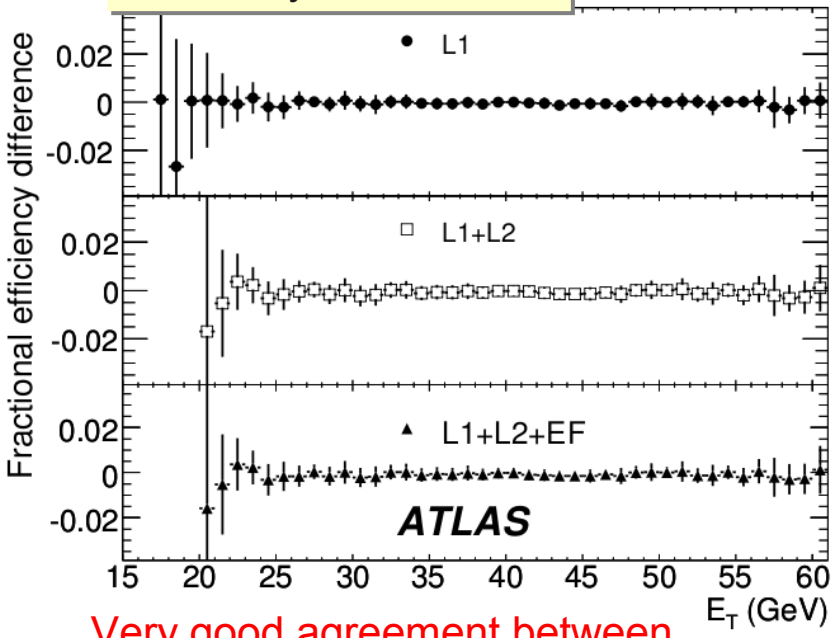
Efficiencies with first data: e/gamma

- e20: Efficiencies using Tag&Probe for 50 pb^{-1}
  - A sample of Z → ee events (no background) was used to exercise the Tag&Probe method
  - Average overall efficiency (after EF) compared to offline is (99.41 ± 0.05) %
  - Expect similar numbers for J/ψ → ee (more signal and background)
  - But expect much larger error (1-2%) for initial running with not well understood detector

e20 trigger efficiencies vs. offline



Efficiency vs. MC-truth

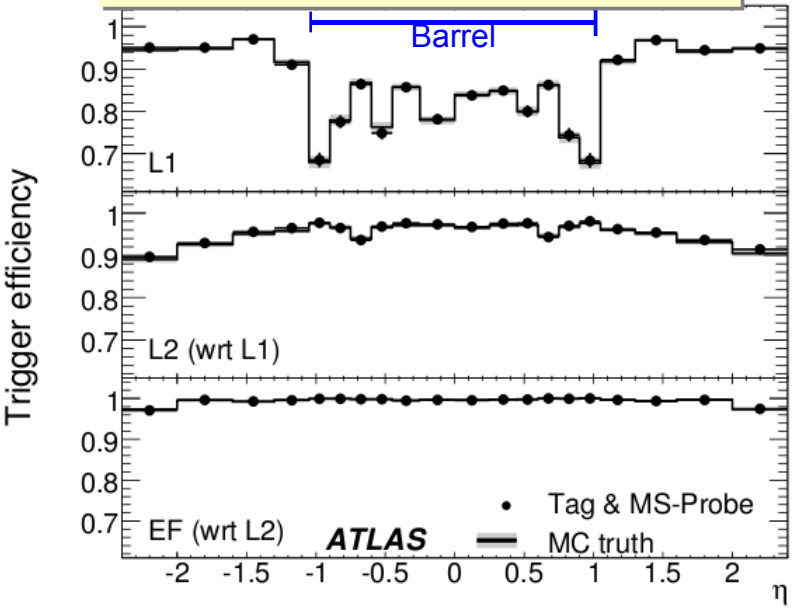


Very good agreement between
Tag&Probe efficiency and "true" efficiency

Efficiencies with first data: muons

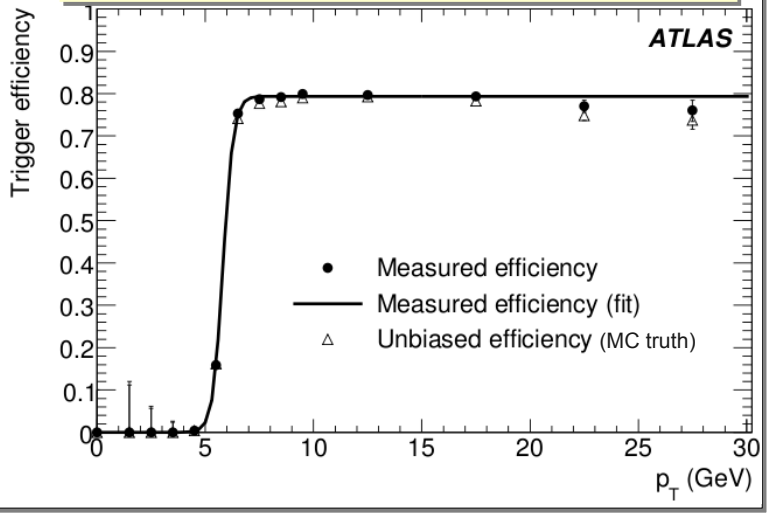
- Tag&Probe using $Z \rightarrow \mu\mu$
  - Study with ~50 pb^{-1}.Require p_T > 20 GeV
  - Use inner detector (ID-Probe) or muon spectrometer (MS-Probe) as probe system
  - Overall efficiency (77.4 ± 0.4) %
  - Very good agreement between Tag&Probe and MC truth (~99%)

Tag&Probe efficiency in $Z \rightarrow \mu\mu$



- Tag&Probe using $J/\psi \rightarrow \mu\mu$
  - Study with 300k J/ψ events (~100pb^{-1}), p_T > 6 GeV
  - Achieve better than 5% precision
  - But need a dedicated calibration trigger for this

Tag&Probe efficiency in $J/\psi \rightarrow \mu\mu$



Towards higher luminosities (in 2009)

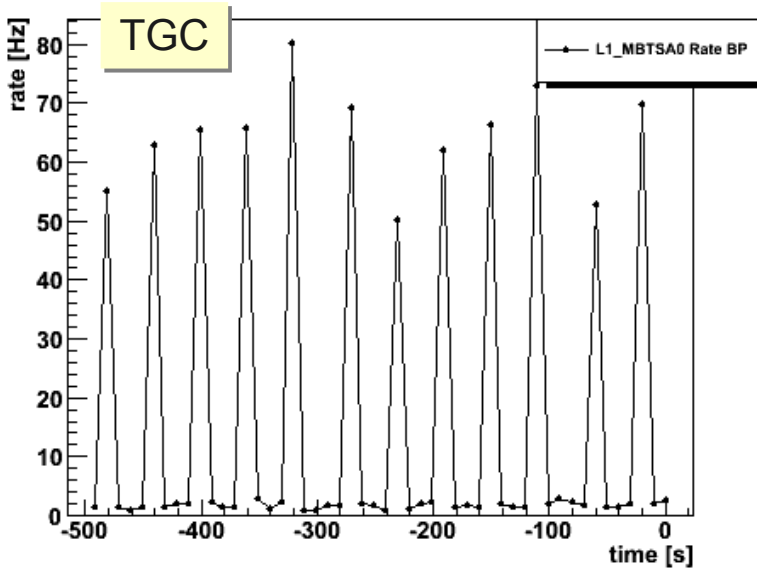
- General
  - Need to adjust trigger menus with LHC running conditions and luminosity
  - The first data will tell us in which direction the next menus need to evolve
- Level-1
  - Limited number of thresholds available per object type
  - Introduce higher Level-1 thresholds at cost of some of the lower ones
  - But keep most threshold identical to provide reference points across luminosities
- High Level Trigger
  - Average output rate is fixed at ~ 200 Hz
  - Cannot rely on Level-1 alone to control the rates. Need to apply tighter selections.
  - Pile-up effects become significant. Need to study this in detail.
  - Deploy selections (e.g. isolation, large missing E_T, flavor tagging) that were running in pass-through mode at lower luminosity.

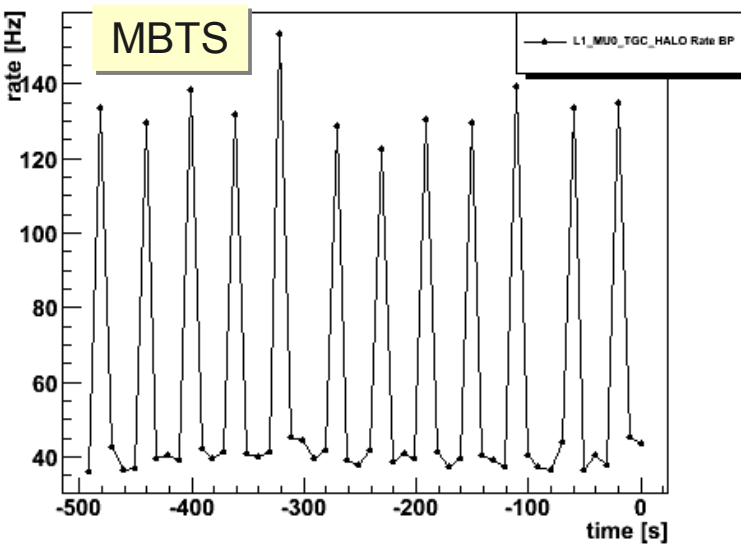
Summary

- Commissioning of the ATLAS trigger
  - Trigger needs commissioning with real data just like any other detector
  - Rates controlled by Level-1 prescales until HLT algorithms under control
  - Detailed program defined to go from commissioning to physics menu
- Trigger menus
  - Trigger menus defined and studied for 10^{31} and beyond
  - Will be adjusted as soon as we get first collisions
- Efficiency and performance of lepton triggers
  - First checks of performance of lepton triggers within a few pb^{-1}
  - Tag&Probe method used to measure trigger efficiencies from data
  - To achieve sub-percent level uncertainties need ~50 pb^{-1}
  - More detailed studies including pile-up and cavern background are needed

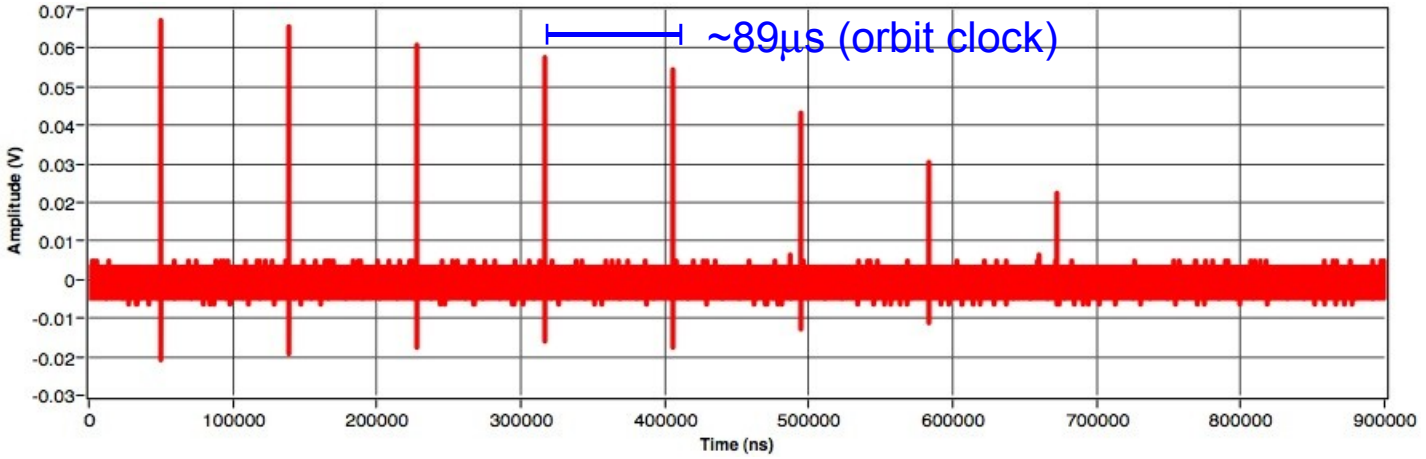
The first beam! triggers in ATLAS on Sept. 10th

- TGC (muon) and MBTS triggers during “injection-shots”:





- BPTX trigger of circulating beam (8 revolutions):



Backup slides

Example items of a 10^{33} menu

- Towards a 10^{33} trigger menu
  - Representative sample of Level-1 and HLT trigger items expected to be deployed without prescale factors at a luminosity of 2 x 10^{33} cm^{-2} s^{-1}

L1 item	Rate (kHz)
EM18I	12.0
2EM11I	4.0
MU20	0.8
2MU6	0.2
J140	0.2
3J60	0.2
4J40	0.2
J36_XE60	0.4
tau16I_XE30	2.0
MU10_EM11I	0.1
Others	5.0

HLT item	Rate (Hz)
e22i	40
2e12i	< 1
γ55i	25
2γ17i	2
μ20i	40
2μ10	10
j370	10
4j90	10
j65_xE70	20
τ35i_xE45	5
2μ6 for B-physics	10