Trigger Discussion

Higgs Tasting Workshop

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ATLAS EXPERIMENT

Trigger Challenges for Run2

Energy:
8 TeV → 13 TeV
Cross section increase for all processes.

Bunch spacing:
50ns → 25ns
Increased out-of-time pileup

Luminosity:
8e33 → 1.4e34 cm-2s-1
Higher rate from higher peak luminosity.

Overall, trigger rates expected to increase by at least a factor of ~5
More severe for triggers involving multiple objects (combinatorics)

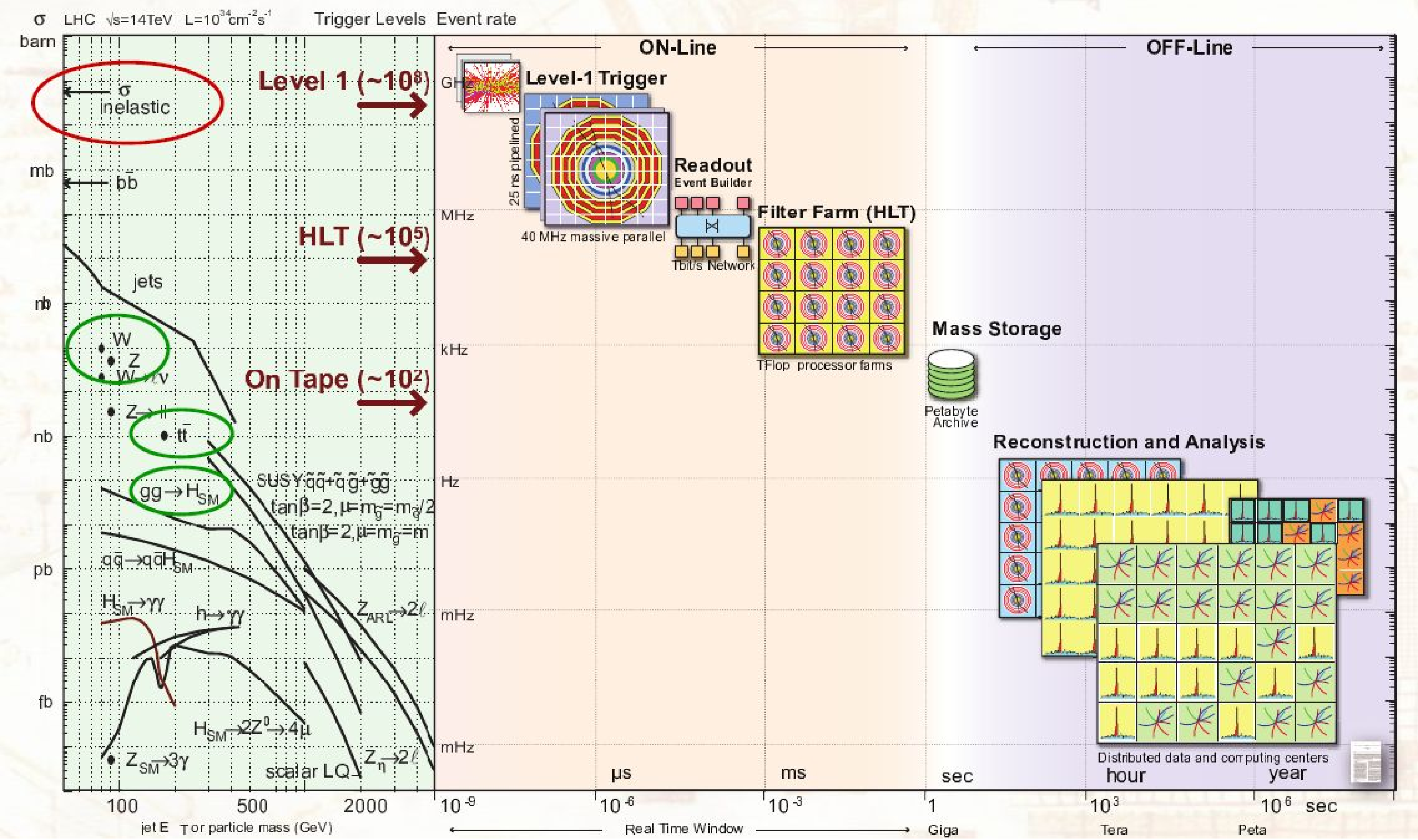
Improve hardware:
more sophisticated FPGA (L1),
additional CPU and storage (HLT)

Improve performance of algorithms

Increase thresholds for accepting physics objects

Two years of hard work on all these fronts.

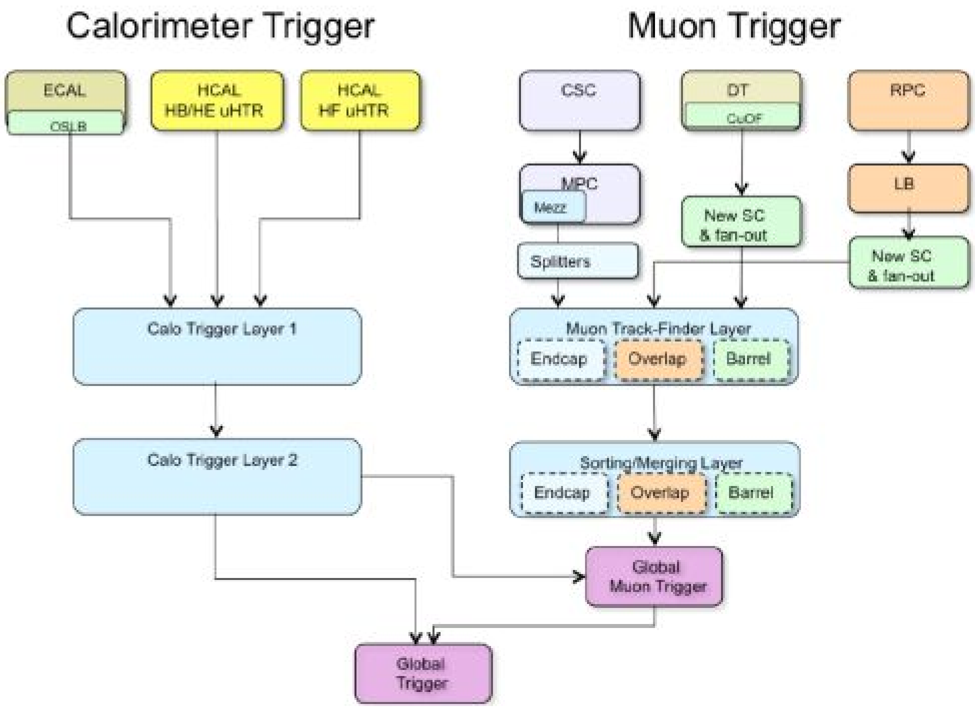
CMS Trigger Overview

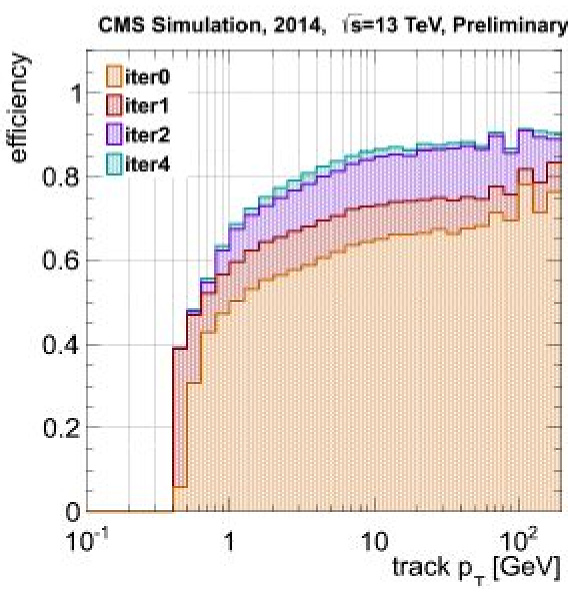


CMS: Trigger Improvements

L1

- Two-level L1Calo: improved pileup subtraction
- Additional endcap muon chambers
- Improved muon track-finder (larger FPGA, more hits, iso)

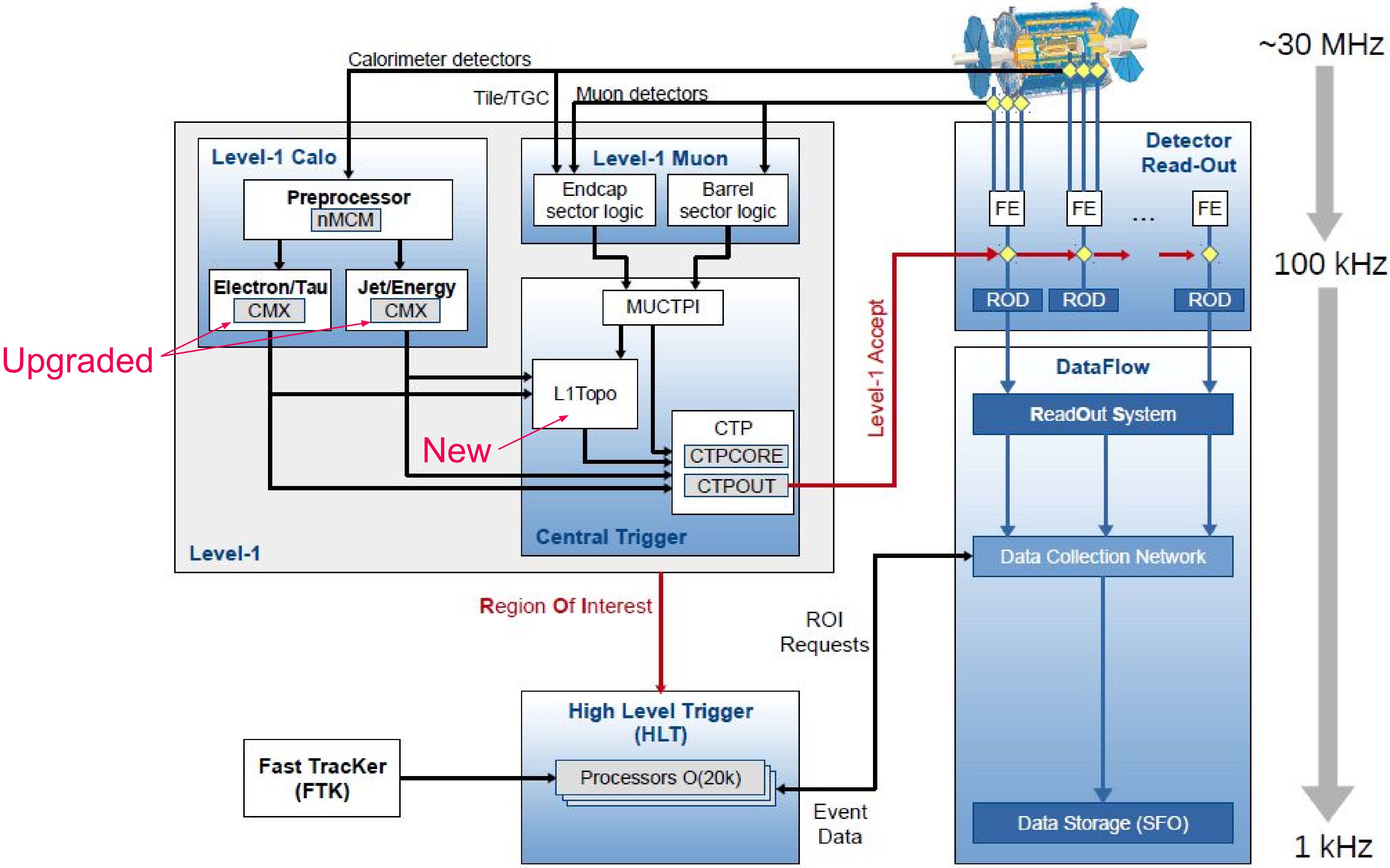




HLT

- All algorithms use Particle Flow object reconstruction
- Iterative track reconstruction
- Improved primary vertex finding
- Improved b-tagging

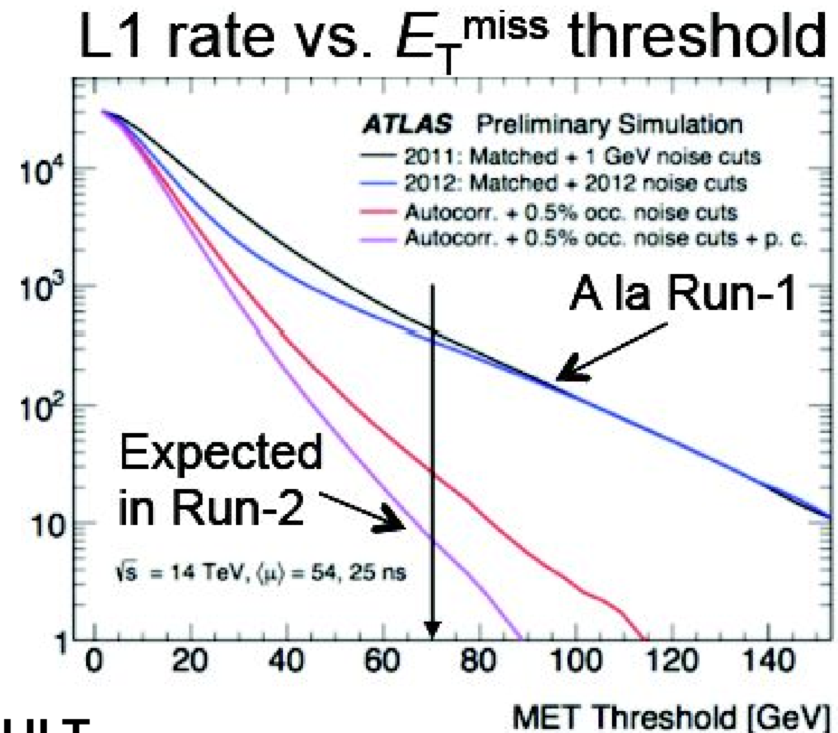
ATLAS Trigger Overview

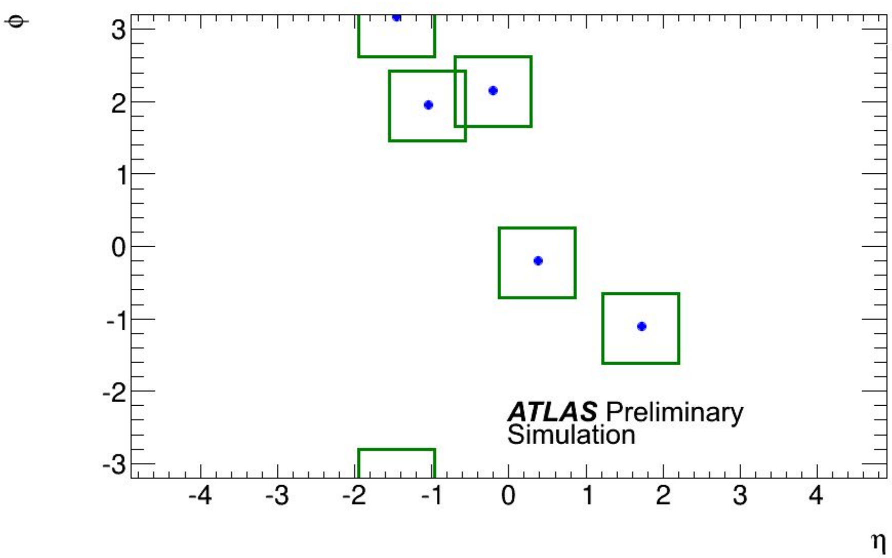


ATLAS: Trigger Improvements

L1

- L1Calo: dynamic pedestal subtraction → reduction in ETmiss rates and more flexible signal processing
- Muons in forward region: require coincidence with inner detectors
- L1 topological processor



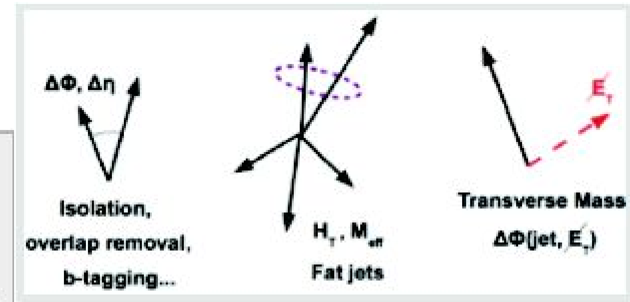


HLT

- merge L2 and EF in a unique HLT farm → dynamic sharing of resources
- jet area pileup suppression and jet finding on merged regions of interest
- multi-step tracking
- multivariate b-taggers online (JetFitter, MV1, MV2)

ATLAS New L1Topo Module

L1 hardware receiving and combining inputs from L1Calo and L1Muon → trigger decisions based on event topology



Angular Requirements

$$\Delta\eta, \Delta\varphi, \Delta R^2, \Delta\eta + \Delta\varphi$$

Mass Requirements

$$M^2 = 2 E_T^1 E_T^2 (\cosh \Delta\eta - \cos \Delta\varphi)$$

$$M_T^2 = 2 E_T^1 E_T^{miss} (1 - \cos \Delta\varphi)$$

Event Requirements

$$H_T = \sum p_T(jets)$$

$$H_{CT} = \sum p_T(central\ jets)$$

L1Topo MET

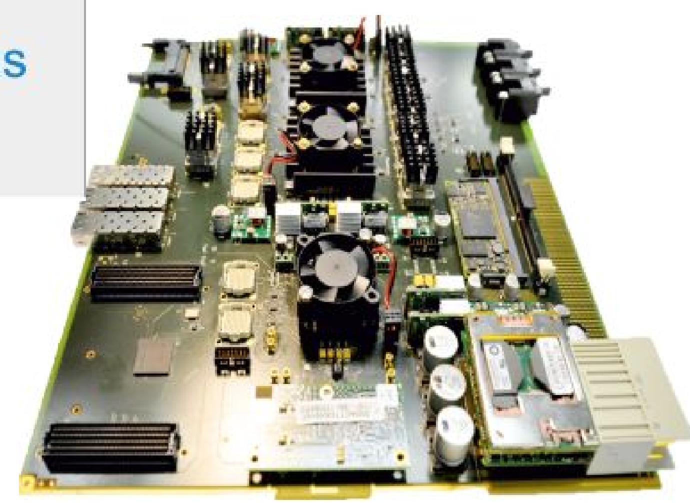
Dedicated Algorithms

Calorimeter Ratio
Delayed Particles

Constraints:

- up to 128 bits
- only fixed latency FPGA algorithms (max latency: 3bx)
- input collections limited to N(~10) objects

Currently being commissioned



Examples:

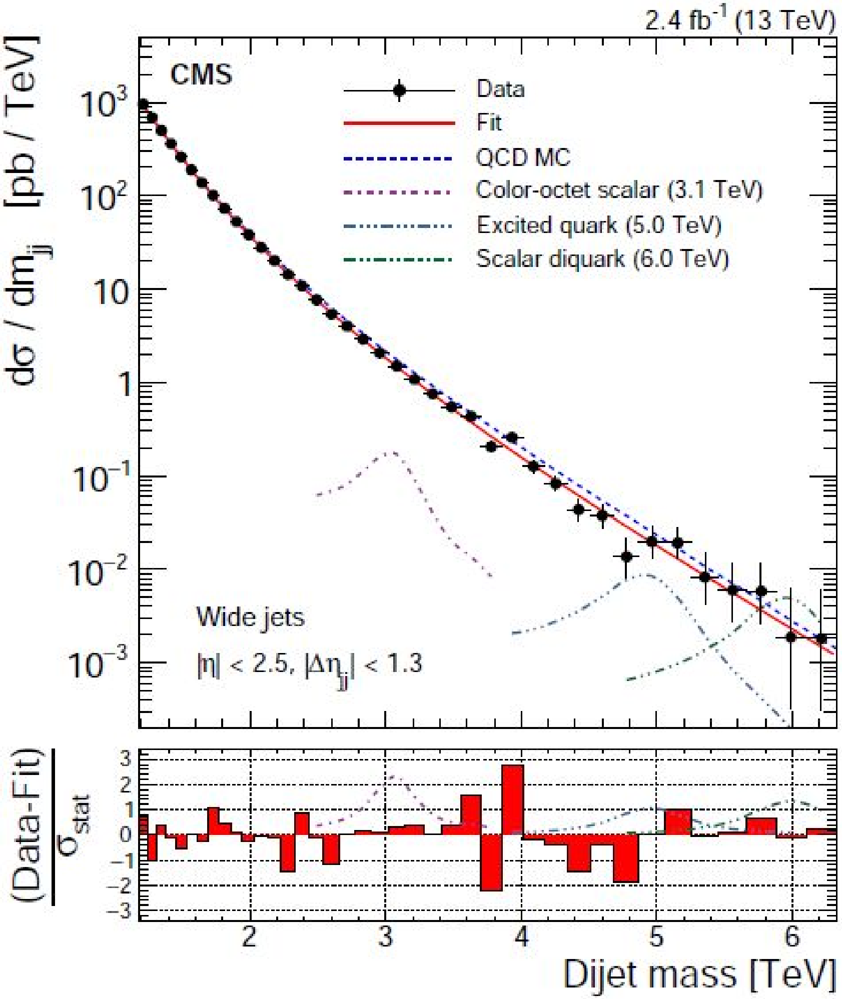
- "b-tag"
- VBF
- di-jet (and 4-jet) with mass requirements

Dijet searches and triggers

CMS [1512.01224 [hep-ex]](https://arxiv.org/abs/1512.01224)

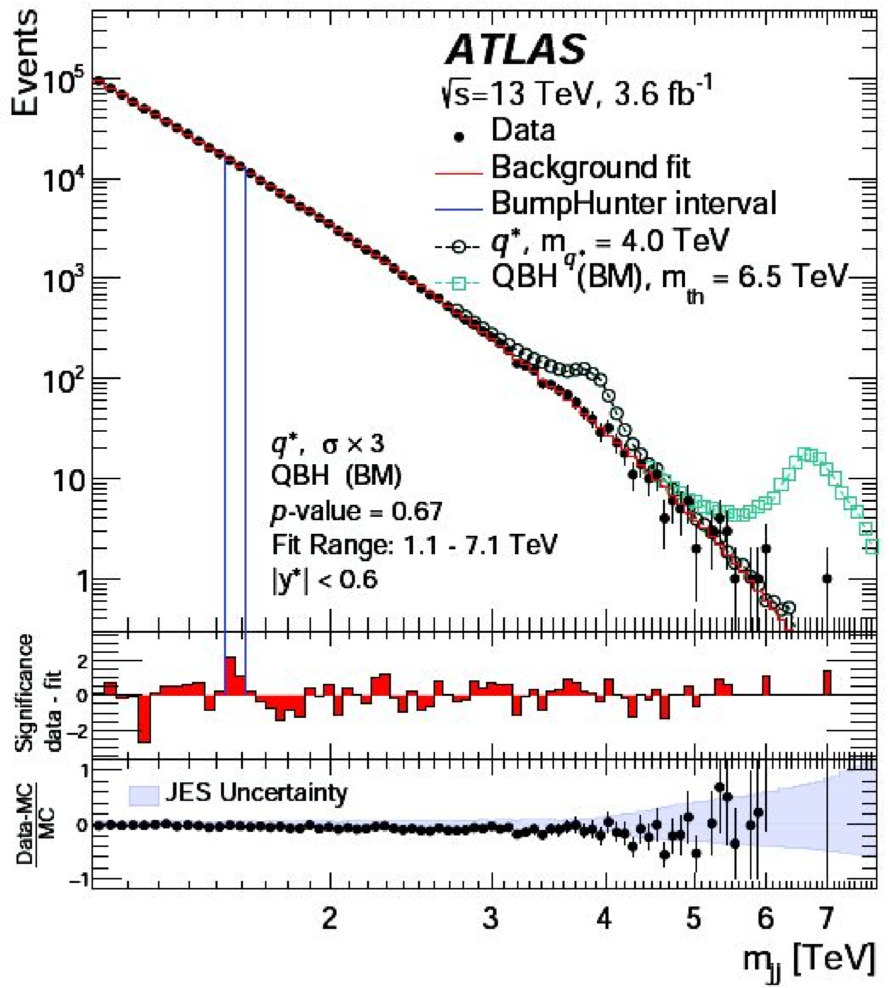
Trigger: H_T>800GeV or $p_{T,jet}$>500GeV

Fully efficient at m_{jj}>1.2 TeV



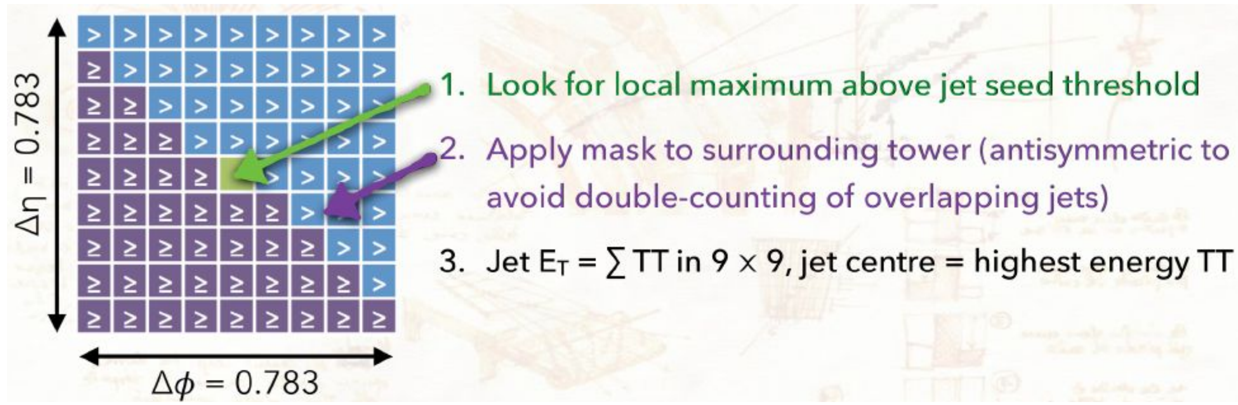
ATLAS [1512.01530 [hep-ex]](https://arxiv.org/abs/1512.01530)

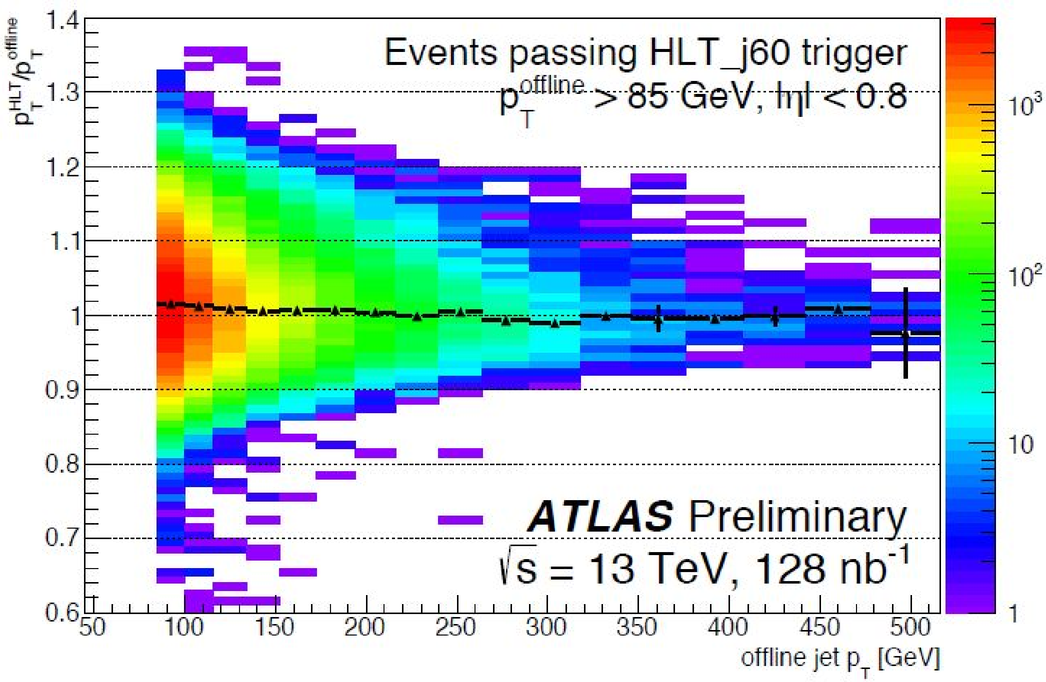
Trigger: at least one jet with p_T > 360 GeV.



Trigger Jets are not Offline Jets

L1 jets are "rectangular jets"
→ trigger bias when they are closeby





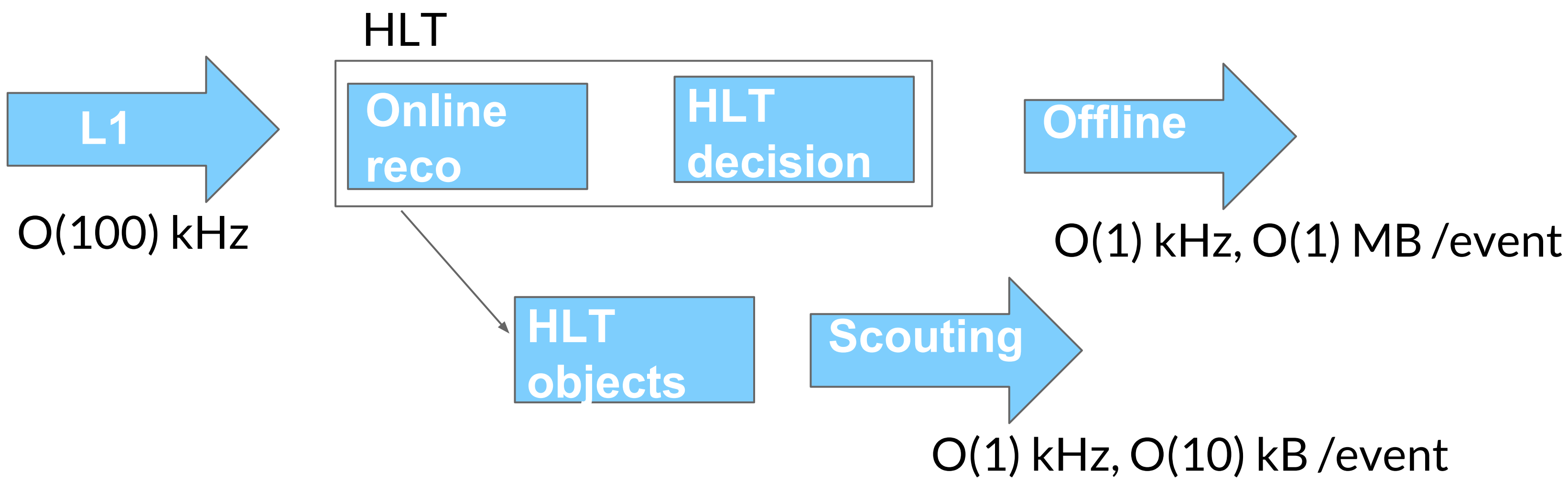
HLT jets have small remaining differences wrt. offline jets:

- calibrations
- pileup removal

Although experiments try hard to get as close as possible to their offline algorithms

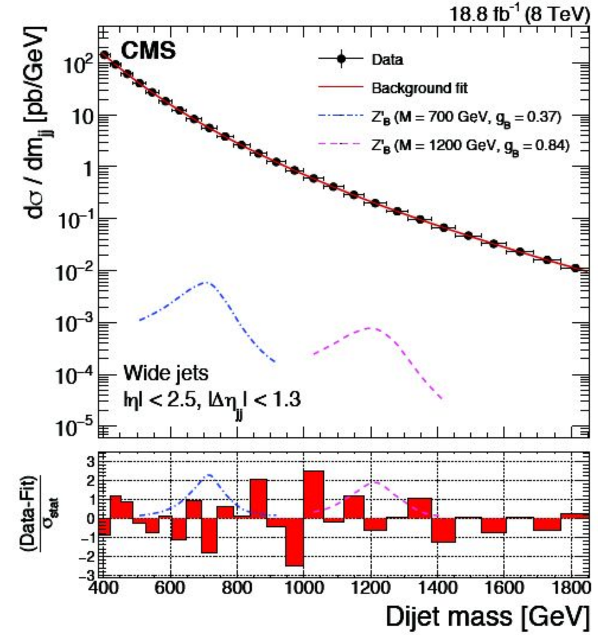
Data scouting

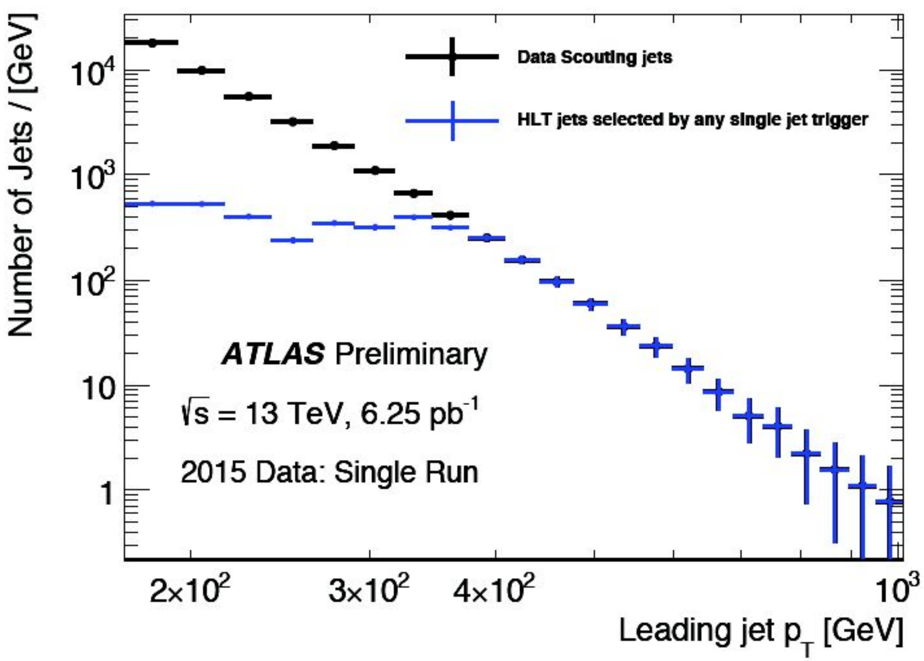
- Motivation: the dijet trigger rate is very large → cannot look for light resonances with small cross sections
- Some low-mass regions of the xsec vs. m plane have not been explored since UA1 and CDF
- The bottleneck is in MB/s, not in event/s → write only what is needed: jet 4-momenta and cleaning information
- Introduced by CMS in Run1 and by ATLAS in Run2

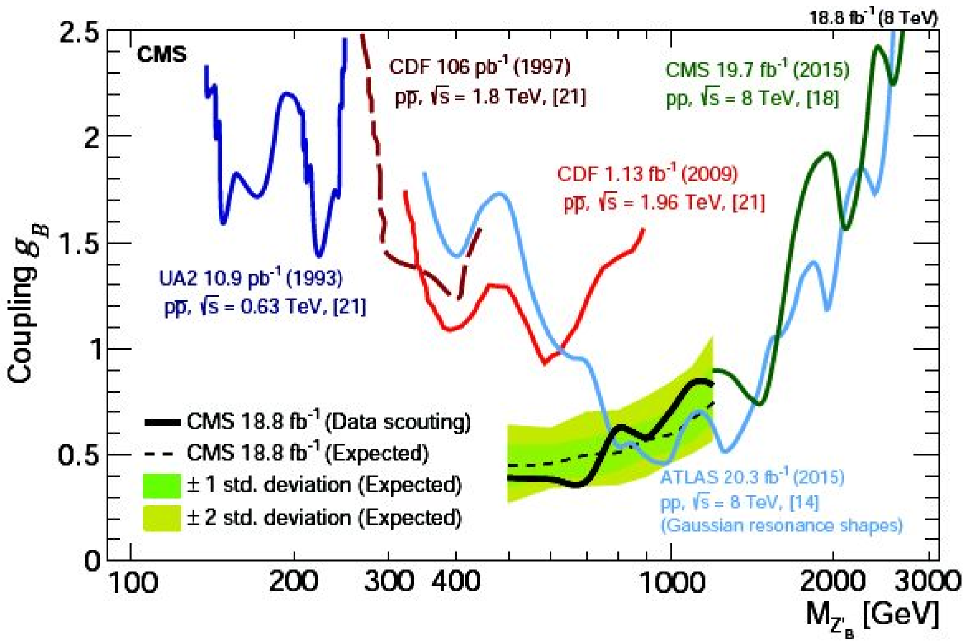


Data scouting

- Reconstruct at HLT all physics objects needed for an offline analysis
- Apply a loose trigger selection, then save the HLT objects
- Some low-mass regions of the xsec vs. m plane have not been explored since UA1 and CDF
- Example ATLAS: scouting stream triggered by unprescaled L1_J75



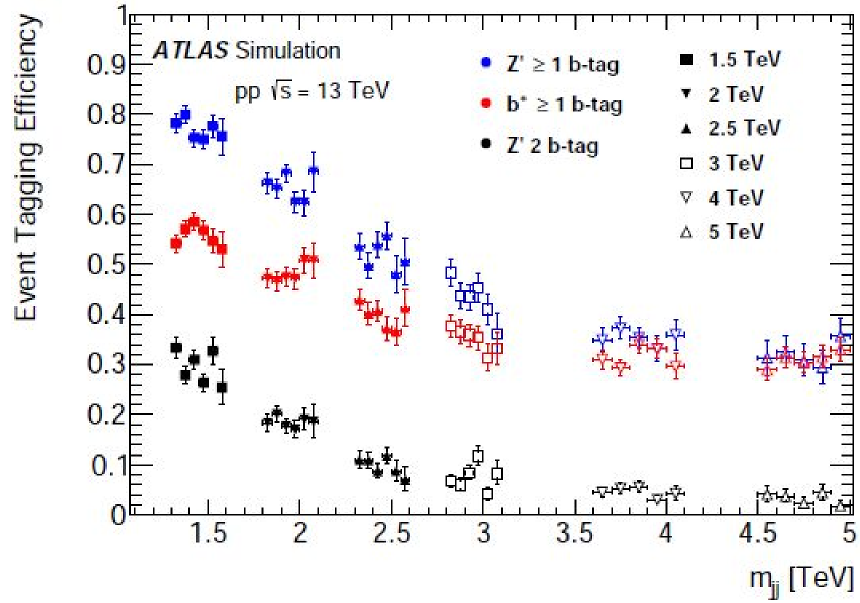


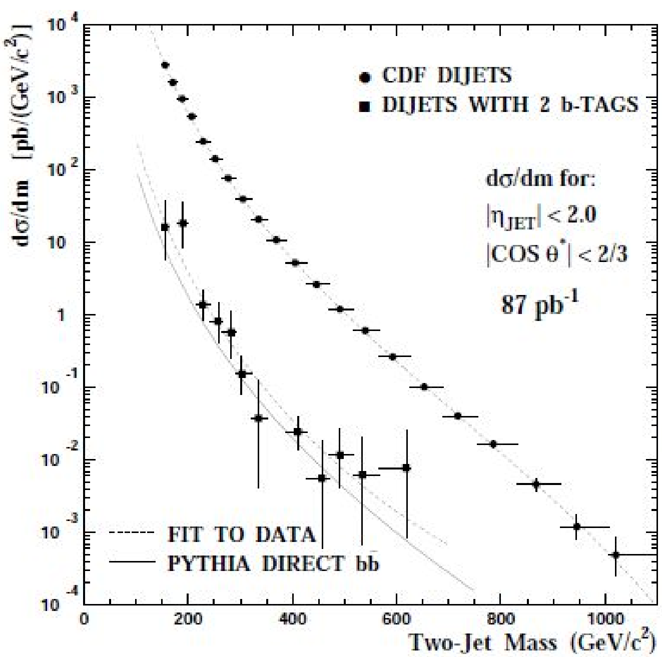


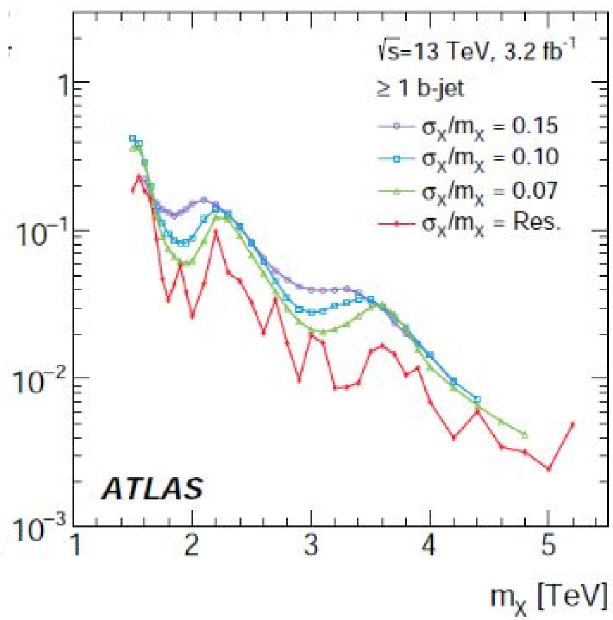
Dijet with b-tag

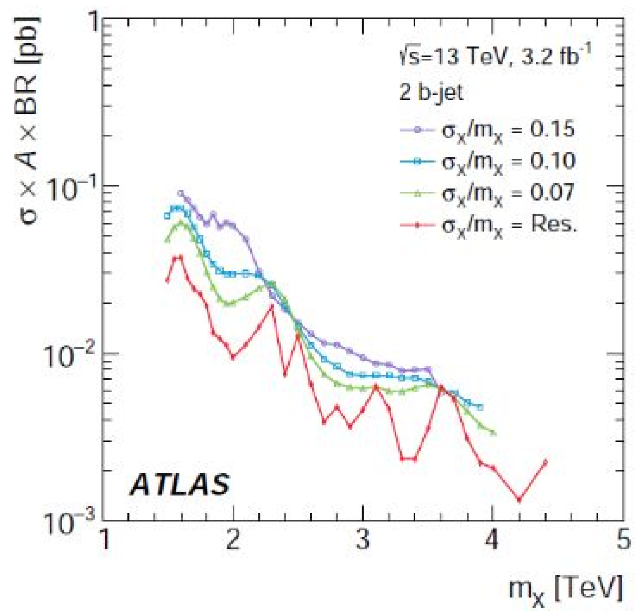
Adding b-tag requirements offline causes a hit in the efficiency.

Previously: CDF hep-ex/9809022, trigger jet p_T>20,50,70,100 GeV
ATLAS 1603.08791 [hep-ex]
“jet-based trigger requiring at least one jet with a transverse momentum pT of at least 360 GeV”







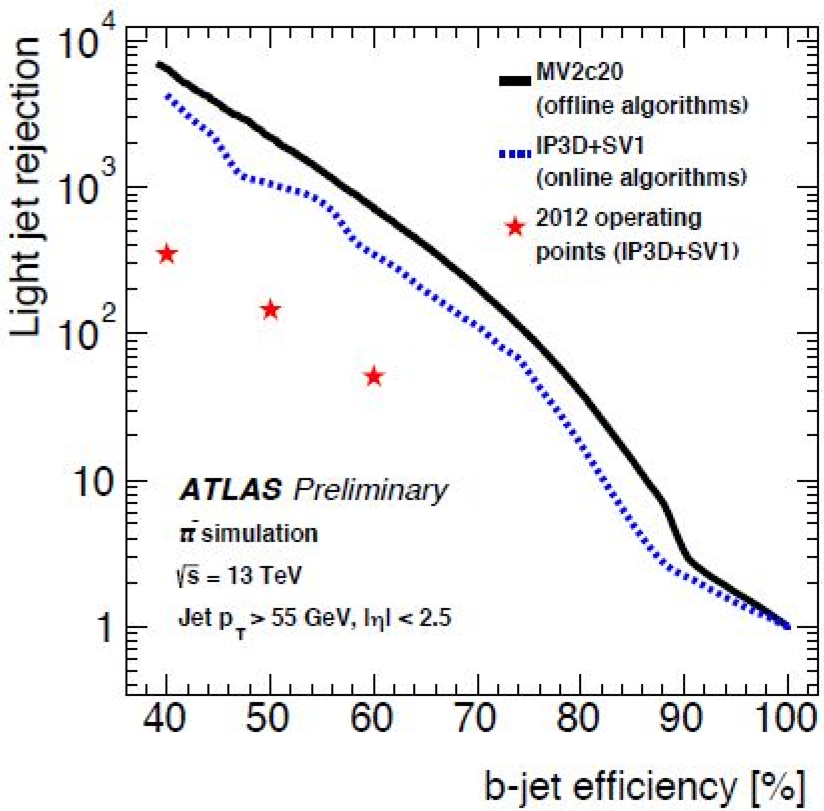


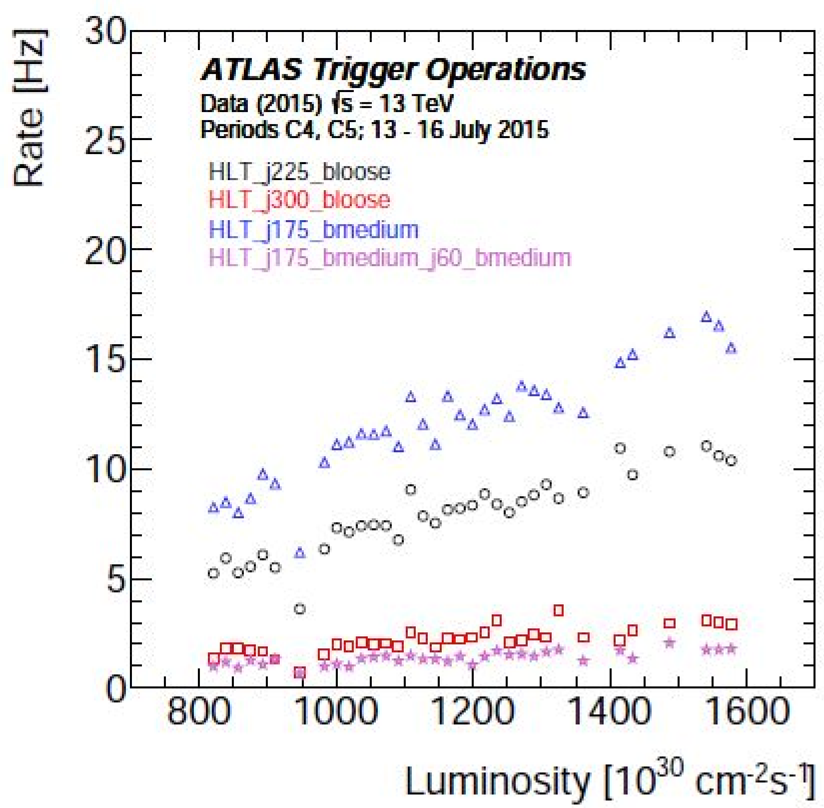
ATLAS Trigger: b-tag

Run2: improved b-tagging efficiency thanks to the insertion of a 4th innermost pixel layer (IBL)

Use offline tagger (MV2): first fast tracking for PV (ΔR<0.2), then precision tracking for secondary vertex and b-tag (ΔR<0.4)

The operating points: efficiencies are 79% (bloose) and 72% (bmedium)





Conclusion / Discussion

- If the 750 GeV bump remains, the trigger capabilities (and its limitations) will play an important role in what can be studied
- $\gamma\,\gamma$ not limited by trigger → not discussed here
- Rich and complex trigger menu for both ATLAS and CMS
- Limitations (prescales or approximations) are mostly at L1 , where the rates are higher and the algorithms more primitive
- di-jet: data scouting a useful resource to probe low-mass resonances
- di-b-jet: allows for significantly lower pT thresholds than simple di-jet
- L1Topo: topological constraints can help deal with large multi-jet production

References

CMS

- Performance of the CMS High Level Trigger, A. Perrotta, CHEP 2015
- The Trigger of the CMS experiment, A. Bocci, KSETA 2016
- Performance of Tracking, b-tagging, and Jet/MET at the CMS High Level Trigger, M. Tosi, CHEP 2015

ATLAS

- The Run-2 ATLAS Trigger System, A. Ruiz-Martinez, ACAT 2016
- 2015 start-up trigger menu and initial performance assessment of the ATLAS trigger using Run-2 data, ATL-DAQ-PUB-2016-001, in preparation
- The ATLAS Trigger System: Ready for Run-2, Y.Nakahama, CHEP 2015

ATLAS Trigger Menu Summary

Trigger	Typical offline selection	Trigger Selection Level-1 (GeV)	Trigger Selection HLT (GeV)	Level-1 Peak Rate (kHz) $L = 5 \times 10^{33}$ cm^{-2}s^{-1}	HLT Peak Rate (Hz) $L = 5 \times 10^{33}$ cm^{-2}s^{-1}
Single leptons	Single iso μ, $p_T > 21$ GeV	15	20	7	130
	Single e, $p_T > 25$ GeV	20	24	18	139
	Single μ, $p_T > 42$ GeV	20	40	5	33
	Single τ, $p_T > 90$ GeV	60	80	2	41
Two leptons	Two μ's, each $p_T > 11$ GeV	2×10	2×10	0.8	19
	Two μ's, $p_T > 19, 10$ GeV	15	18, 8	7	18
	Two loose e's, each $p_T > 15$ GeV	2×10	2×12	10	5
	One e & one μ, $p_T > 10, 26$ GeV	20 (μ)	7, 24	5	1
	One loose e & one μ, $p_T > 19, 15$ GeV	15, 10	17, 14	0.4	2
	Two τ's, $p_T > 40, 30$ GeV	20, 12	35, 25	2	22
	One τ, one μ, $p_T > 30, 15$ GeV	12, 10 (+jets)	25, 14	0.5	10
	One τ, one e, $p_T > 30, 19$ GeV	12, 15 (+jets)	25, 17	1	3.9
Three leptons	Three loose e's, $p_T > 19, 11, 11$ GeV	15, 2×7	17, 2×9	3	< 0.1
	Three μ's, each $p_T > 8$ GeV	3×6	3×6	< 0.1	4
	Three μ's, $p_T > 19, 2 \times 6$ GeV	15	18, 2×4	7	2
	Two μ's & one e, $p_T > 2 \times 11, 14$ GeV	2×10 (μ's)	2×10, 12	0.8	0.2
	Two loose e's & one μ, $p_T > 2 \times 11, 11$ GeV	2×8, 10	2×12, 10	0.3	< 0.1
One photon	one γ, $p_T > 125$ GeV	22	120	8	20
Two photons	Two loose γ's, $p_T > 40, 30$ GeV	2×15	35, 25	1.5	12
	Two tight γ's, $p_T > 25, 25$ GeV	2×15	2×20	1.5	7
Single jet	Jet ($R = 0.4$), $p_T > 400$ GeV	100	360	0.9	18
	Jet ($R = 1.0$), $p_T > 400$ GeV	100	360	0.9	23
E_T^{miss}	$E_T^{miss} > 180$ GeV	50	70	0.7	55
Multi-jets	Four jets, each $p_T > 95$ GeV	3×40	4×85	0.3	20
	Five jets, each $p_T > 70$ GeV	4×20	5×60	0.4	15
	Six jets, each $p_T > 55$ GeV	4×15	6×45	1.0	12
b−jets	One loose b, $p_T > 235$ GeV	100	225	0.9	35
	Two medium b's, $p_T > 160, 60$ GeV	100	150, 50	0.9	9
	One b & three jets, each $p_T > 75$ GeV	3×25	4×65	0.9	11
	Two b & two jets, each $p_T > 45$ GeV	3×25	4×35	0.9	9
b−physics	Two μ's, $p_T > 6, 4$ GeV plus dedicated b-physics selections	6, 4	6, 4	8	52
Total				70	1400

CMS L1 Trigger Menu Summary

(Unprescaled) object	PT threshold 2012 (final lumi), GeV	PT threshold 2015 (50ns, L=5e33), GeV	PT threshold 2015 (25ns, L=14e33), GeV
Single Muon	16	16	20er(*) / 25
Double Muon	10+3.5	10+3.5	12+5
Single EGamma	22	25	40
Single Iso EGamma	20	22er(*)	30er(*)
Double EGamma	13+7	15+10	22+10
Muon + EGamma	12+7 / 3.5+12	12+10 / 5+15	20+10 / 5+20
Single Jet	128	128	200
Quad Jet	40	40	60
MET	40	50	70
HTT	175	125	175
Double Iso Tau	-	36er(*)	40er(*)

CMS HLT Trigger Menu Summary

(Unprescaled) object	PT threshold 2012 (final lumi), GeV	PT threshold 2015 (50ns, L=5e33), GeV	PT threshold 2015 (25ns, L=14e33), GeV
Single Muon	40	50 / 45er(*)	50 / 45er(*)
Single Iso Muon	24	20	27 / 24er(*)
Single Iso Electron	27	27	32
Single Photon	150	170	170
Single PF Jet	320	450	450
(PF) MET	120 (80 parked)	170	170
(PF) HT	750	900	900

Note: these are preliminary thresholds shown at CHEP2015.
Subject to later fine tuning.