Designing triggers for BSM physics

February 24, 2017

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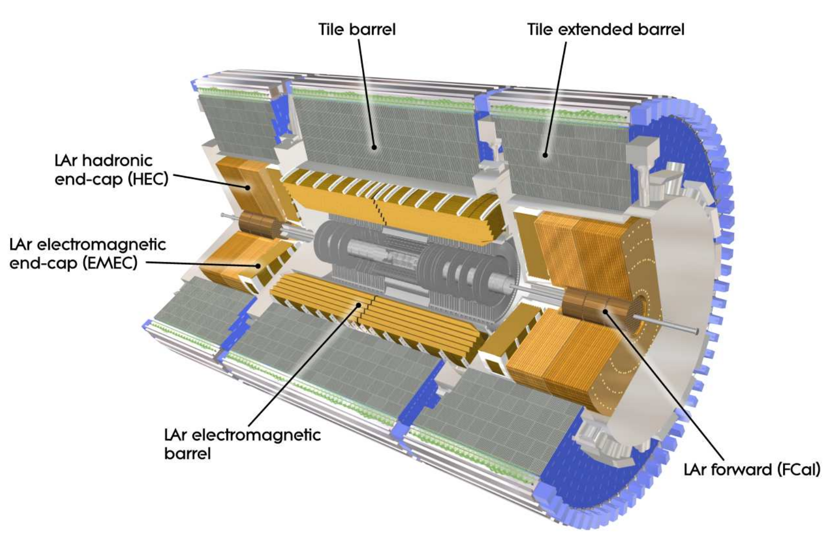

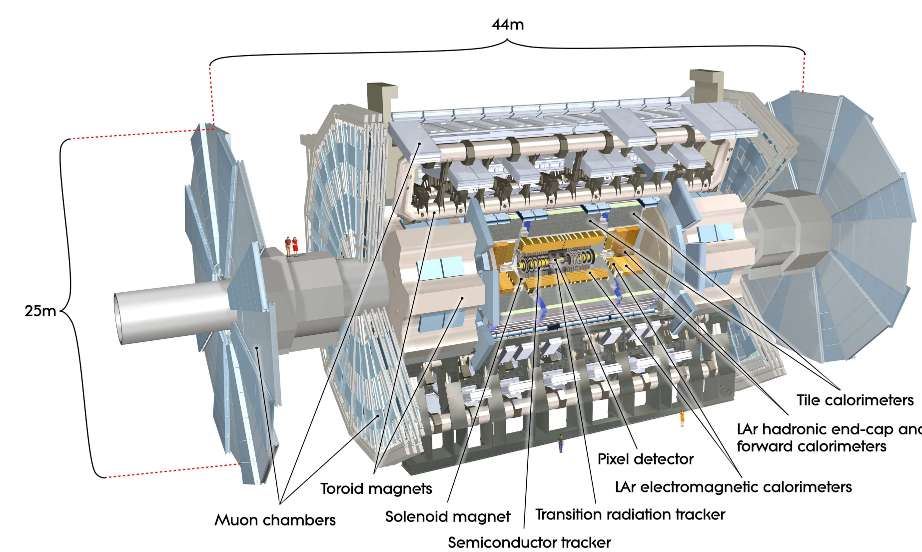

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Outline

Goal of this talk: solicit feedback on ideas for what we should include in the trigger to *dig deeper during the LHC run 2*

Trigger overview

- Why a trigger and how does it work
- What we actually trigger on

Can we improve?

Examples of triggers starting from physics

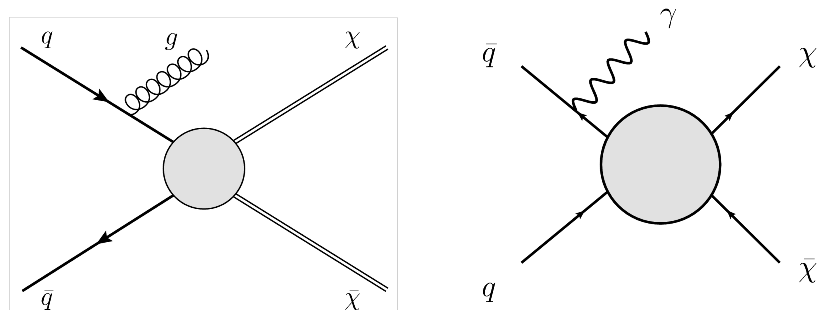
- Examples from BSM Higgs: E_T^{miss}, VBF, VBF + $\boldsymbol{\gamma}$
- Examples from diHiggs: multijet
- Examples from heavy resonances: boosted jets

What I won't discuss in detail

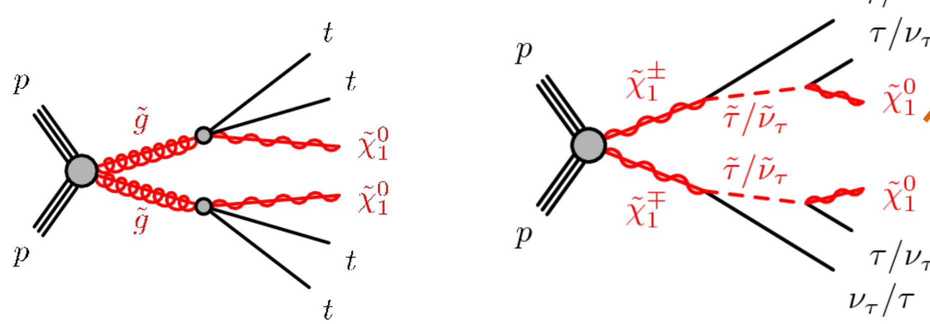
- $\boldsymbol{\tau}$'s, electrons, muons, long-lived particles

Physics→trigger signatures

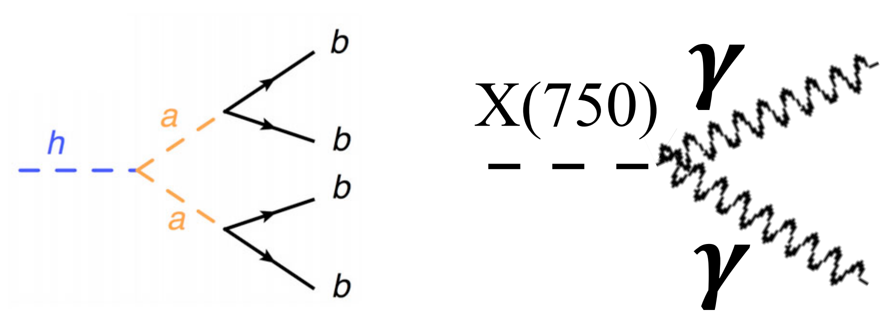
Dark Matter



SUSY



Exotic Higgs
(+ production modes)



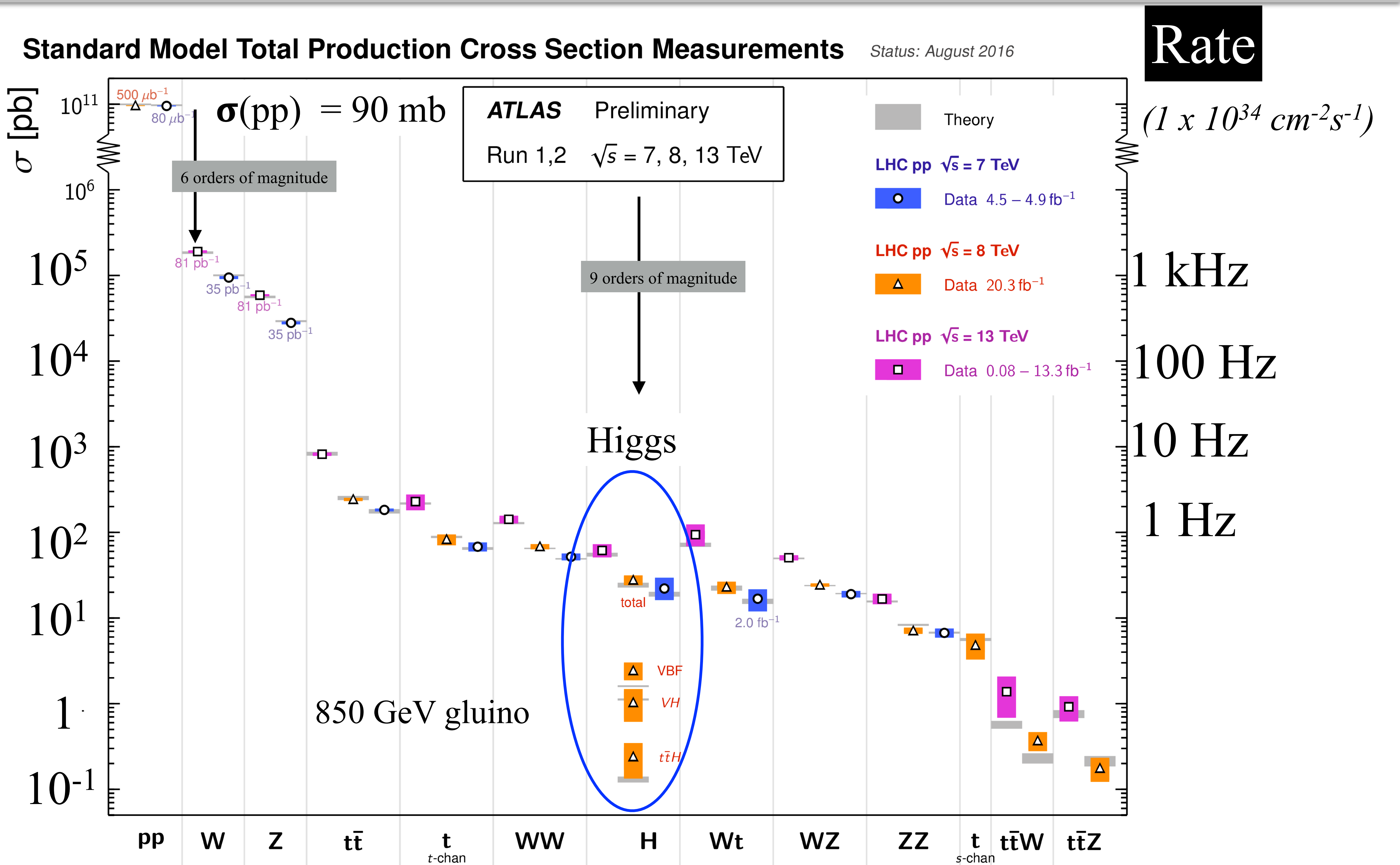
Not yet thought of

Triggers signatures

- Electrons
- Muons
- Taus
- Photons
- Jets (p_T, multijets, H_T, b-jets)
- E_T^{miss}
- Not yet implemented

Maximize coverage, minimize the not yet implemented!

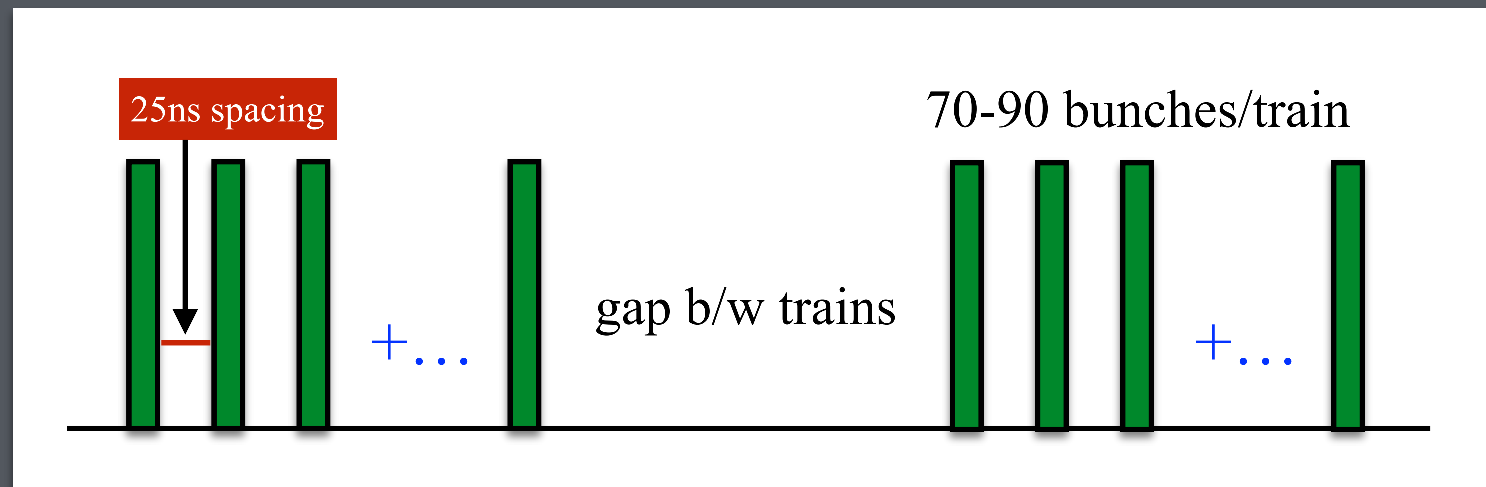
Why a trigger?



Pileup

Proton bunches are formed in trains around the LHC ring

bunch crossing rate: ~40 MHz (1/25ns)



~2200 total bunches (2016)

3564 maximum

Pileup: multiple interactions per bunch crossing

$\langle\mu\rangle$

- In time pileup: interactions in one bunch crossing
- Out of time pileup: interactions from previous bunch crossing

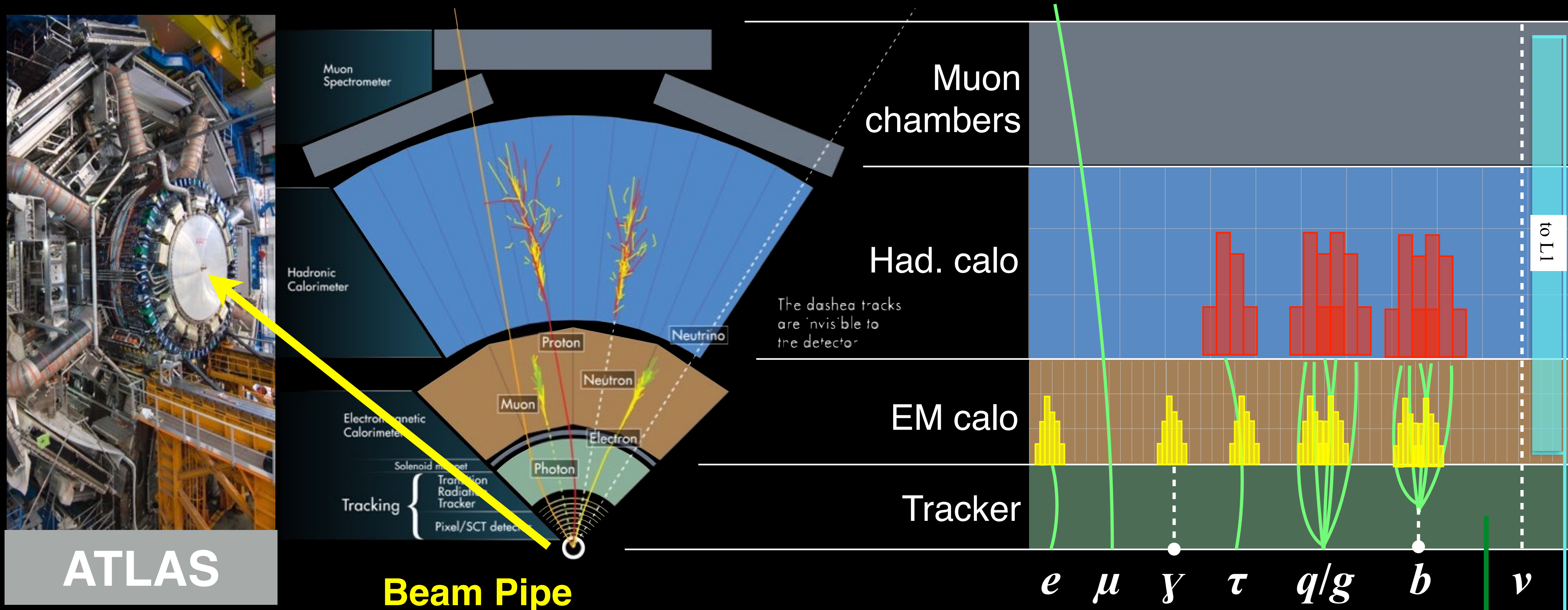
$\langle\mu\rangle$ in 2016: 20-40

Interaction rate (effective number of pp collisions) ~ 1 GHz

- B.C. rate = 40 MHz, $\langle\mu\rangle$ = 25,
- 40 MHz x 25 = 1 GHz

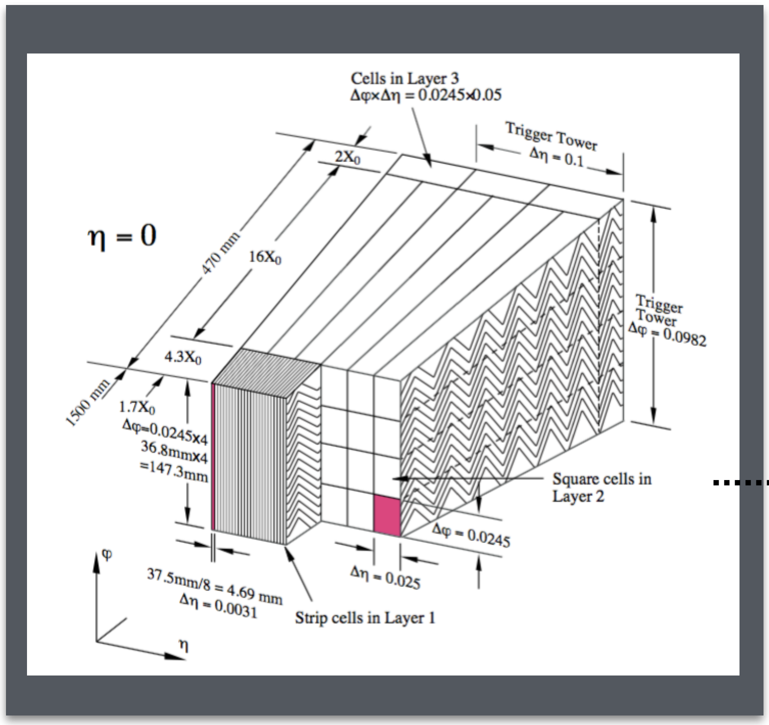
Effects of pileup must be mitigated in the trigger

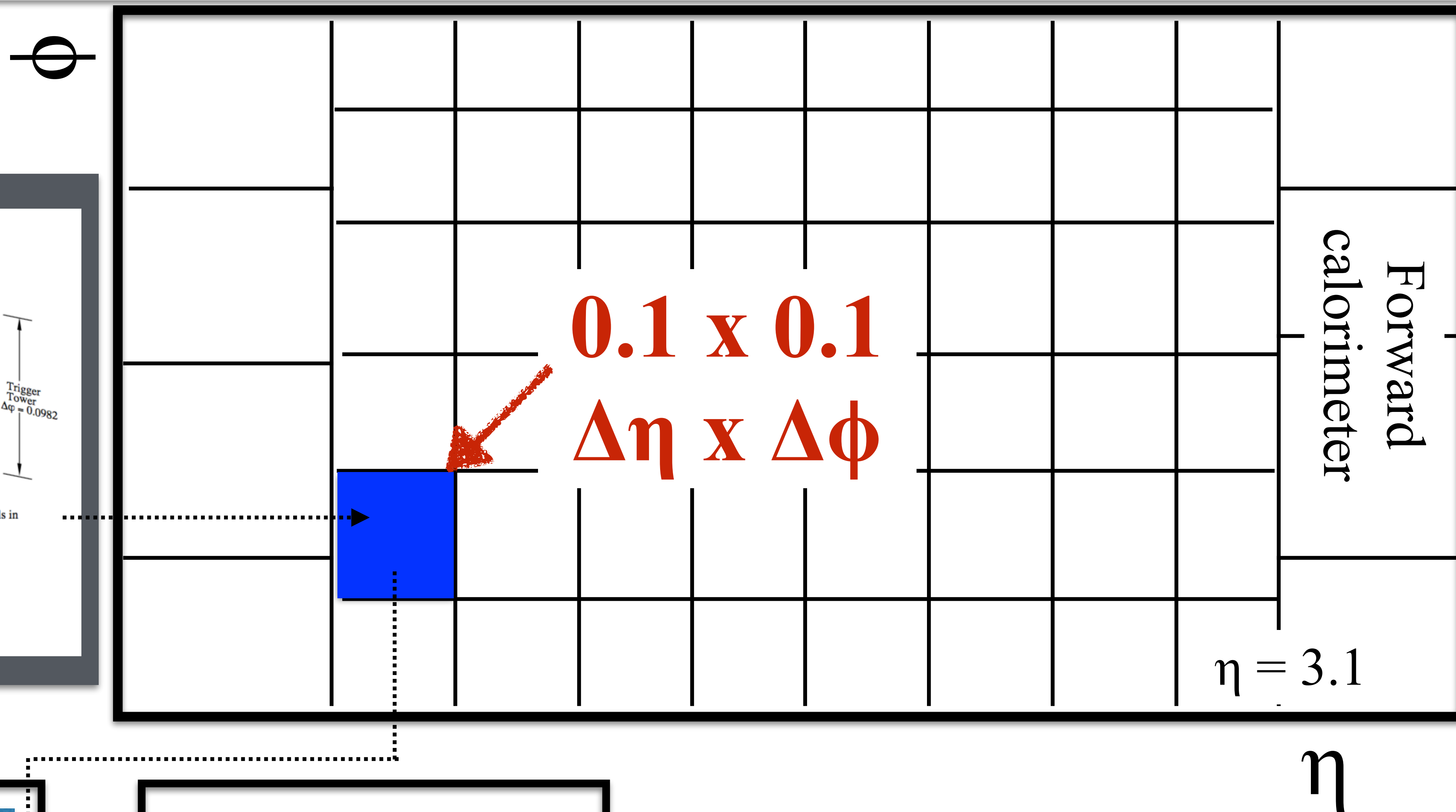
ATLAS detector

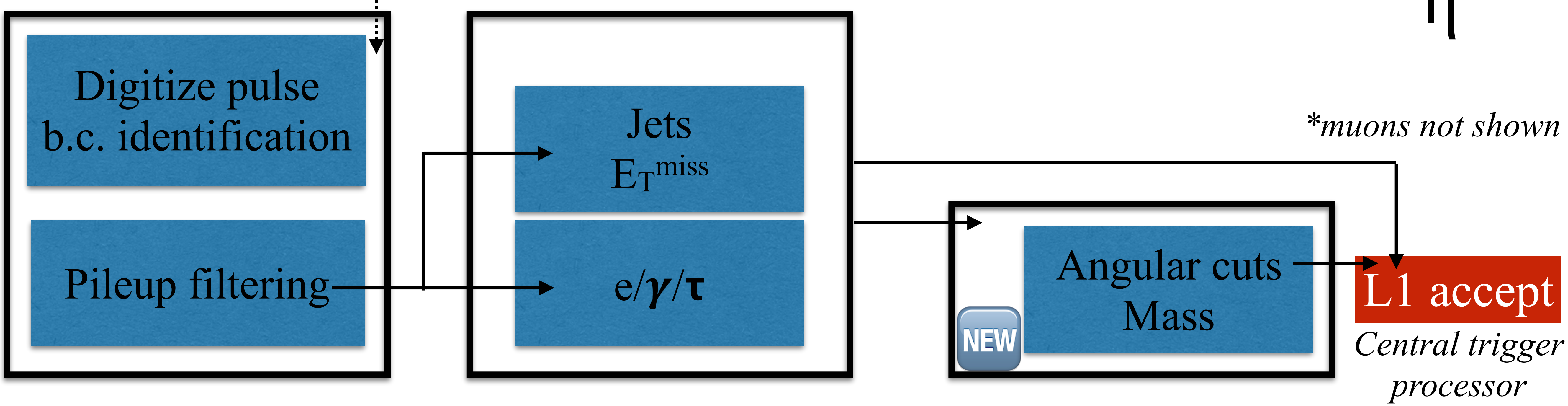


L1 calorimeter trigger

Trigger towers: Analog sum of pulses from calorimeter cells





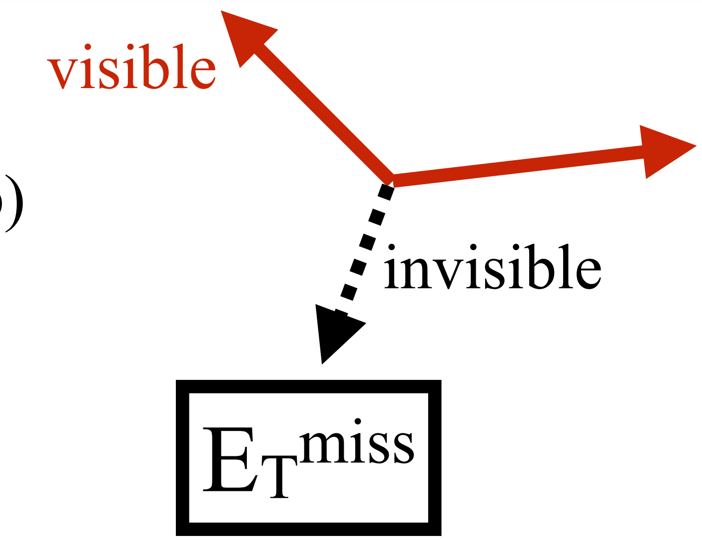


Reference: link, link

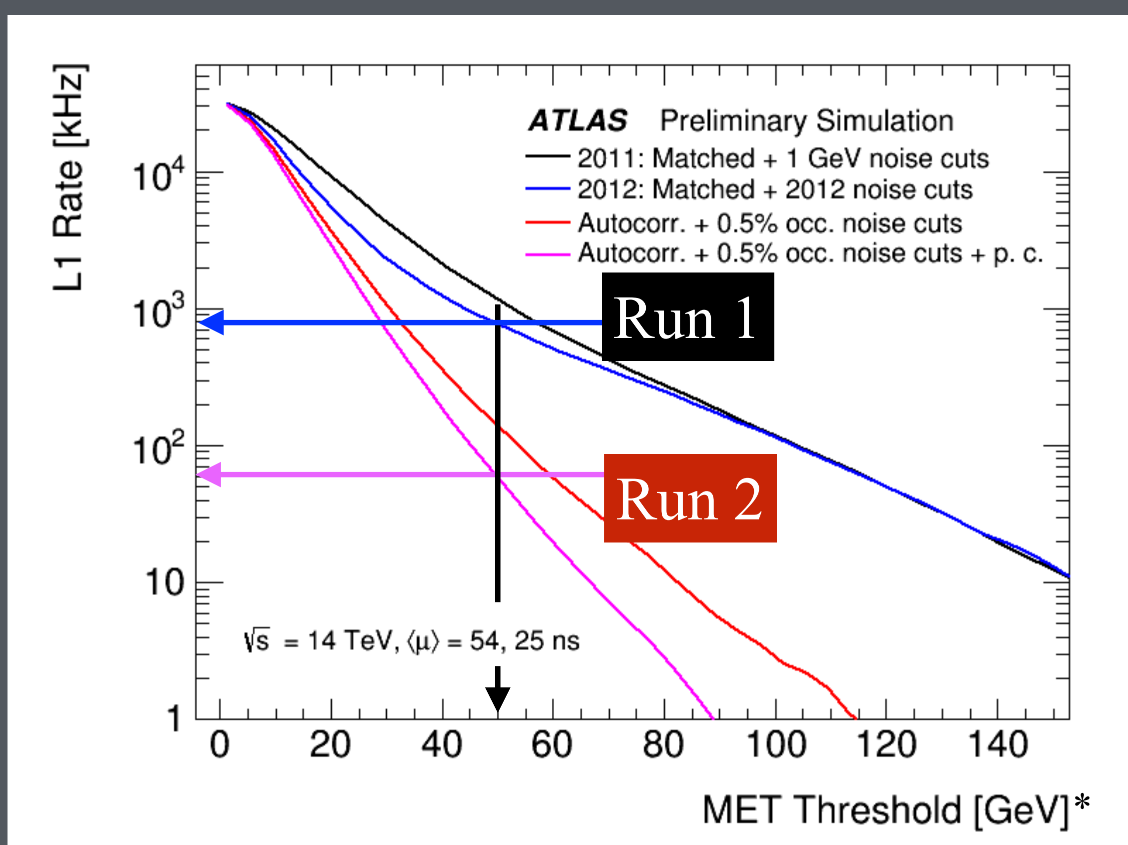
Improvements to L1Calo

Upgrades after run 1 needed for hadronic triggers

- Improved pileup filters reduce impact of out of time pileup (left, backup)
- Pedestal correction removes dependence on position in bunch train and reduces exponential dependence (right)

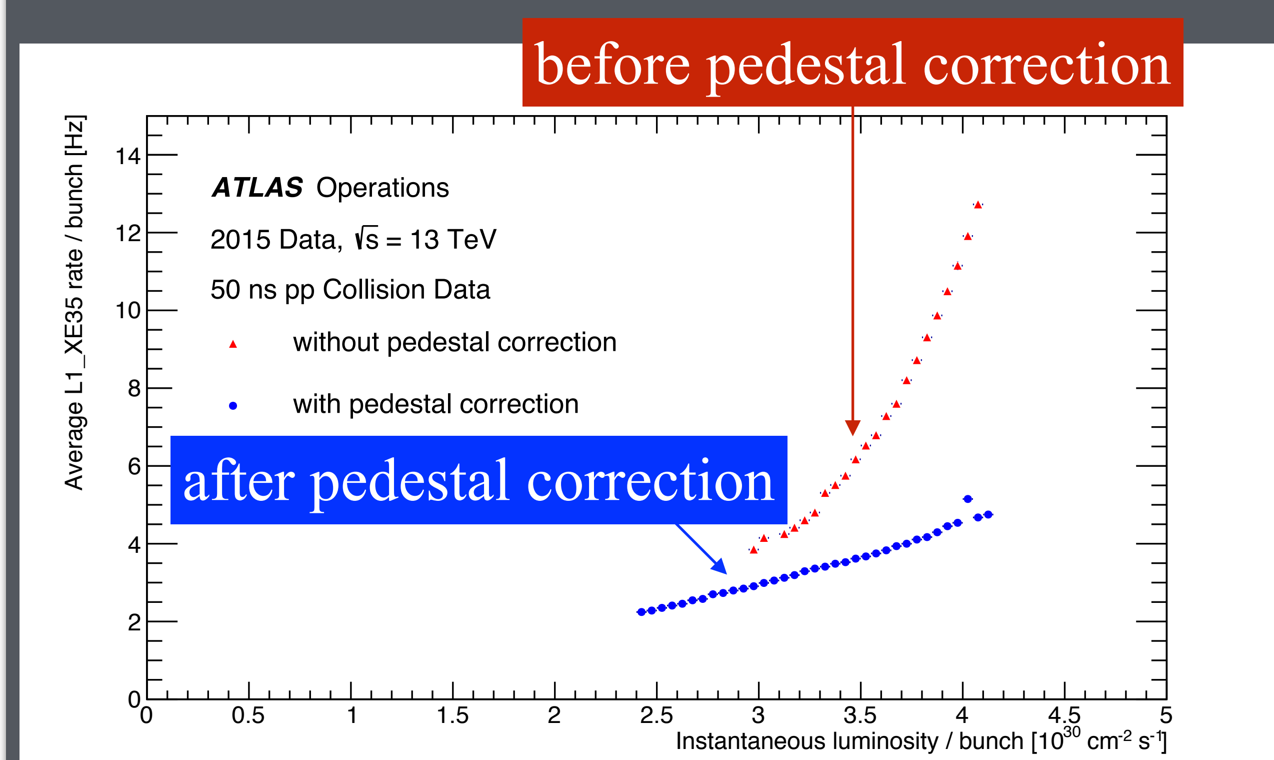


L1 rate vs. E_T^{miss} threshold



*Threshold at L1 not equivalent to offline E_T^{miss}

Rate / bunch vs. pileup



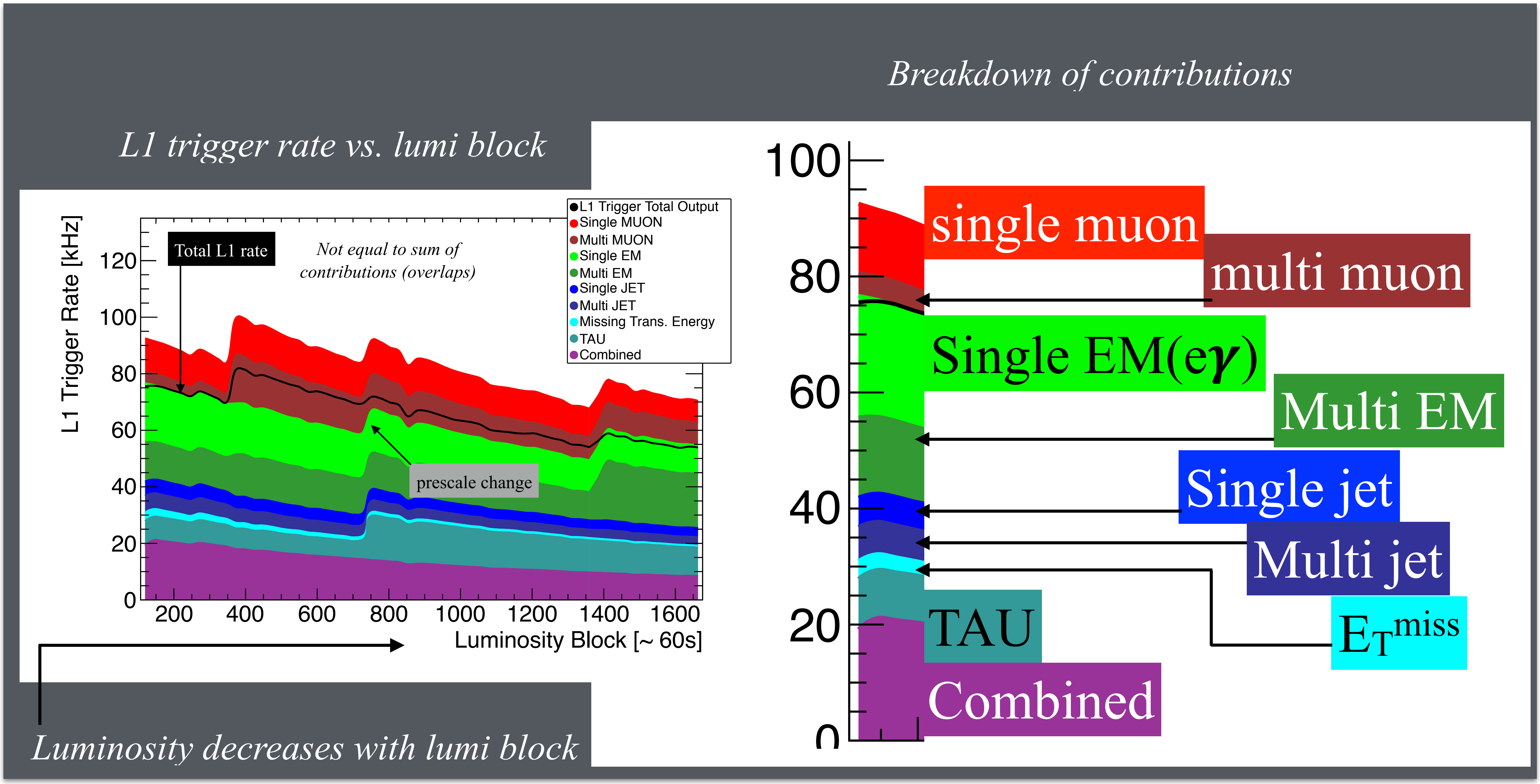
luminosity ~ pileup

ATL-COM-DAQ-2015-150 ATL-COM-DAQ-2013-150

What we trigger on (L1)

Breakdown of rate by physics

- L1 total: ~100 kHz
- Dominant fraction used by lepton triggers



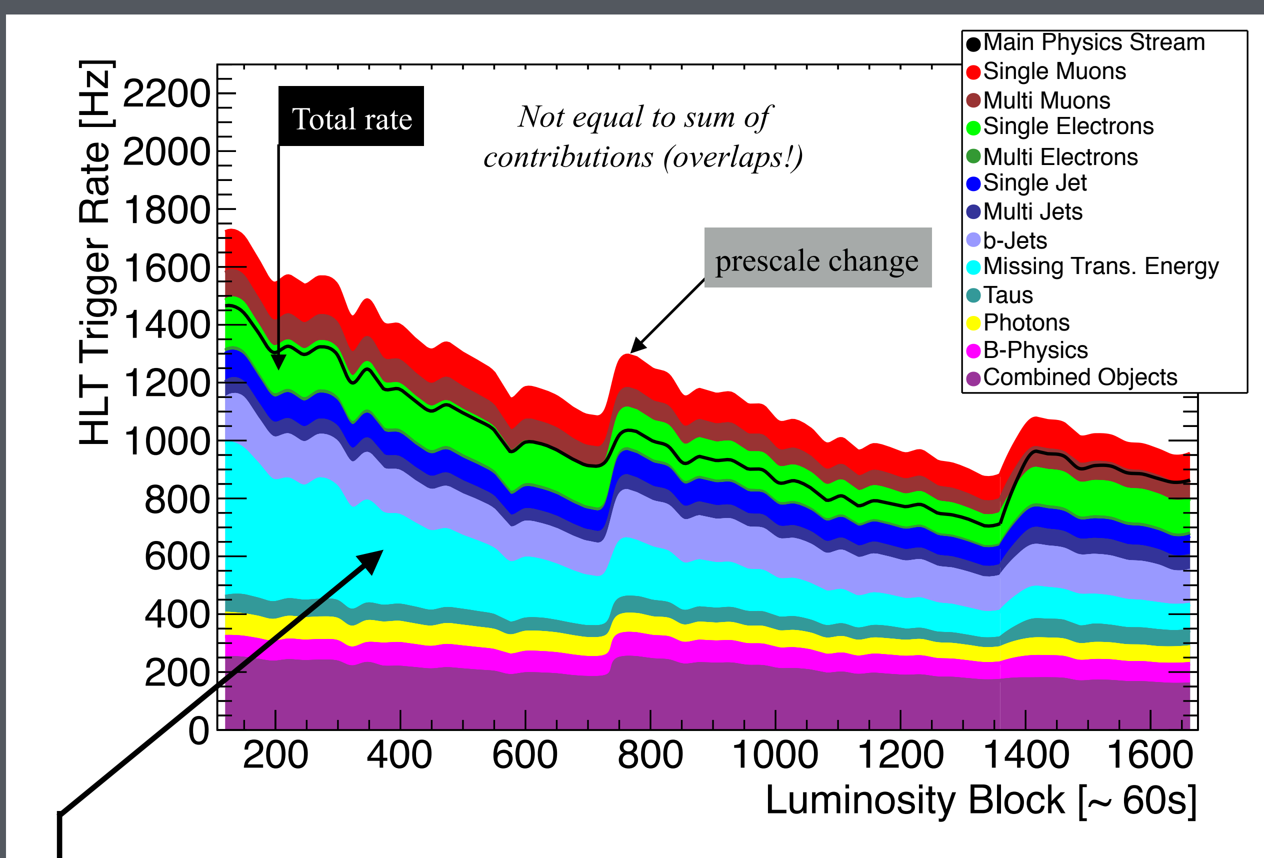
Reference, link

What we trigger on (HLT)

Breakdown of rate by physics

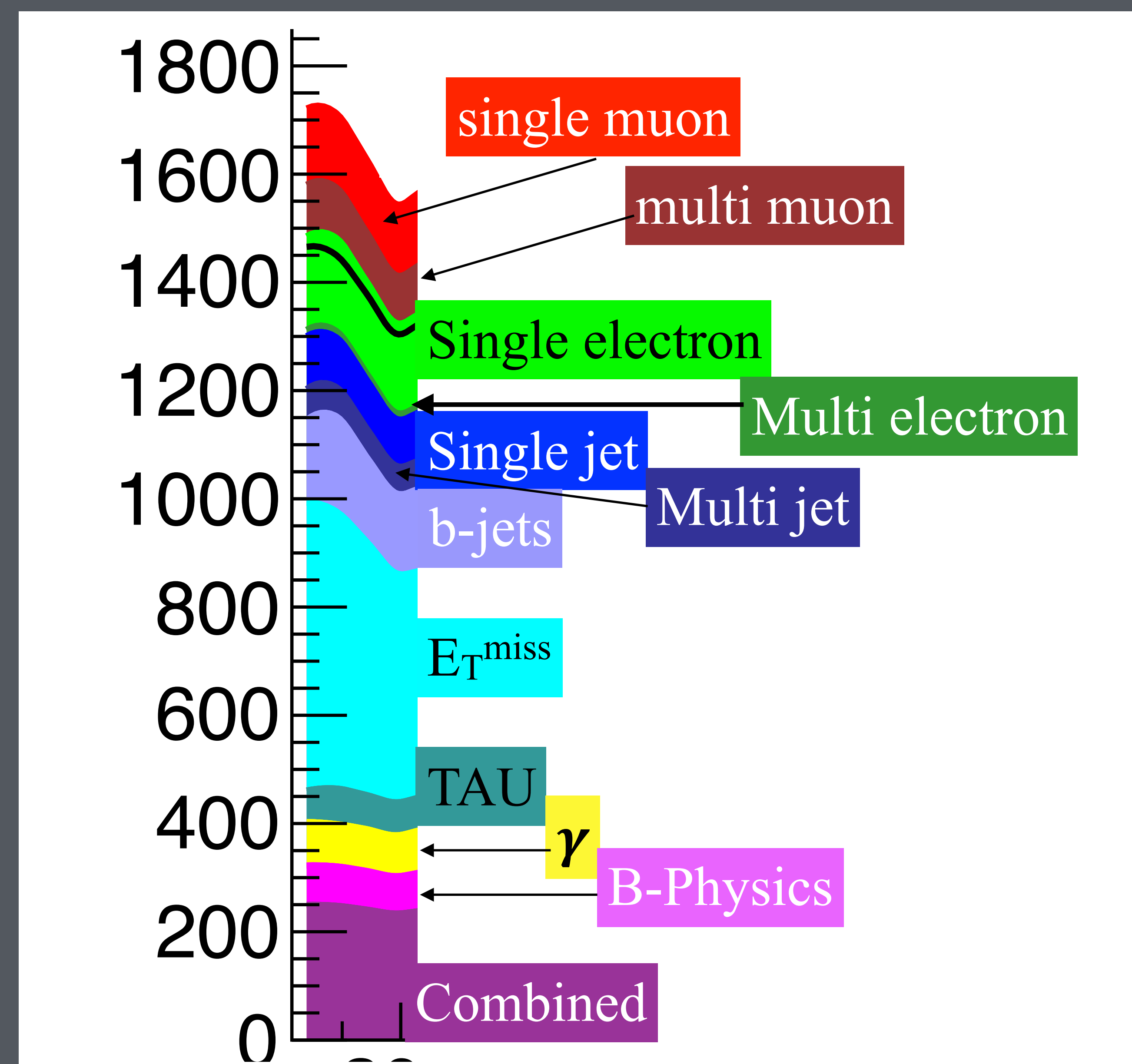
- HLT total: ~1 kHz
- E_T^{miss} fraction substantial because of pileup dependence

HLT trigger rate vs. lumiblock



Significant pileup dependence

Breakdown of contributions (overlaps included)

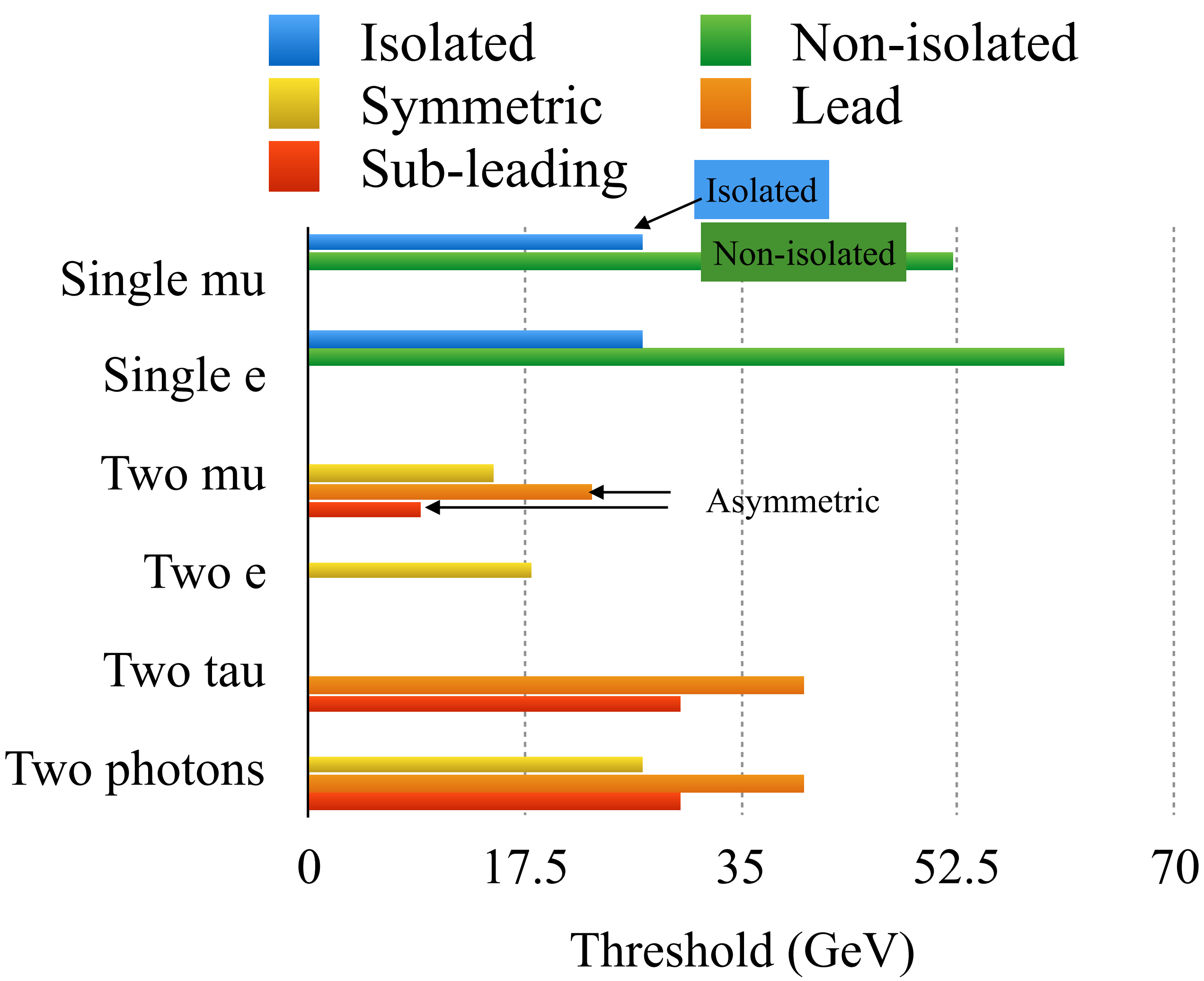


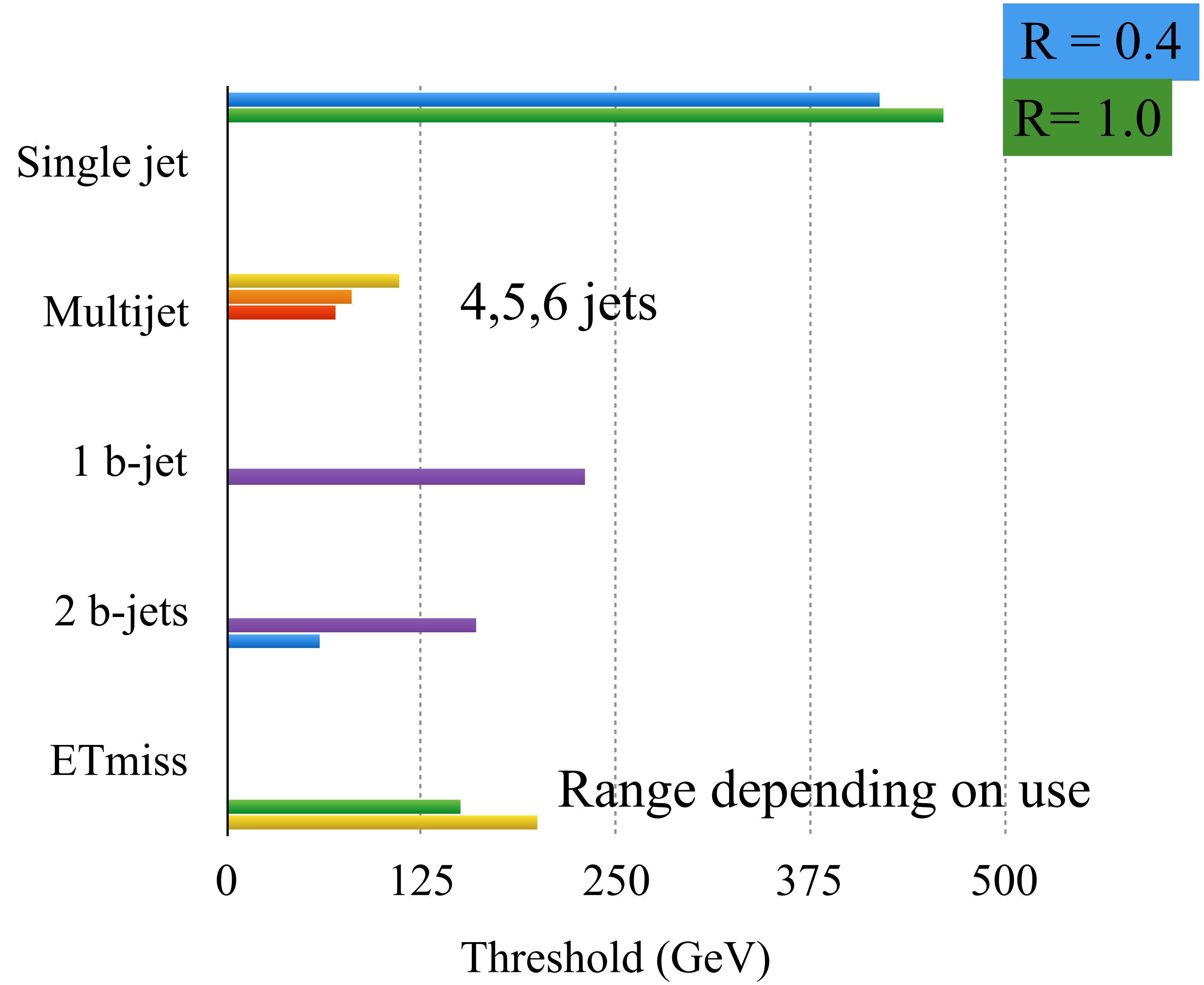
Reference, link

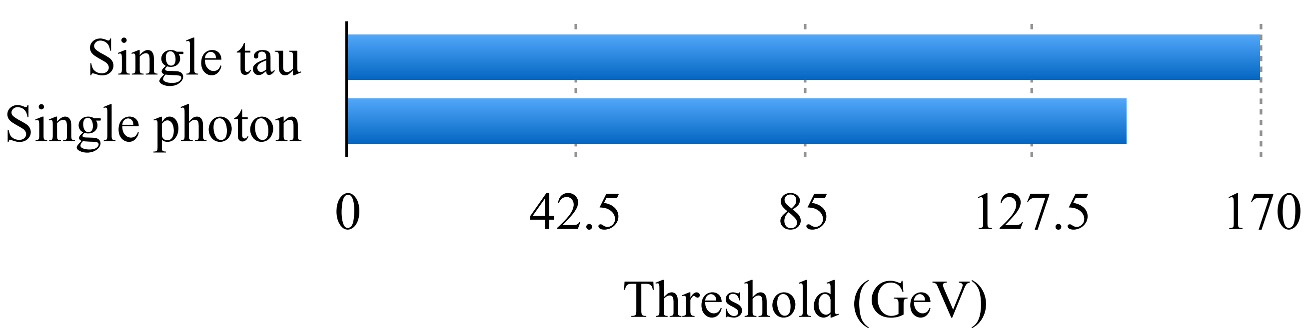
Trigger thresholds (2016)

Most of the rate goes to inclusive triggers (backup for more complete table)

- Triggers targeting specific processes tend to be lower rate







**dedicated triggers with more complicated kinematic requirements not shown here*

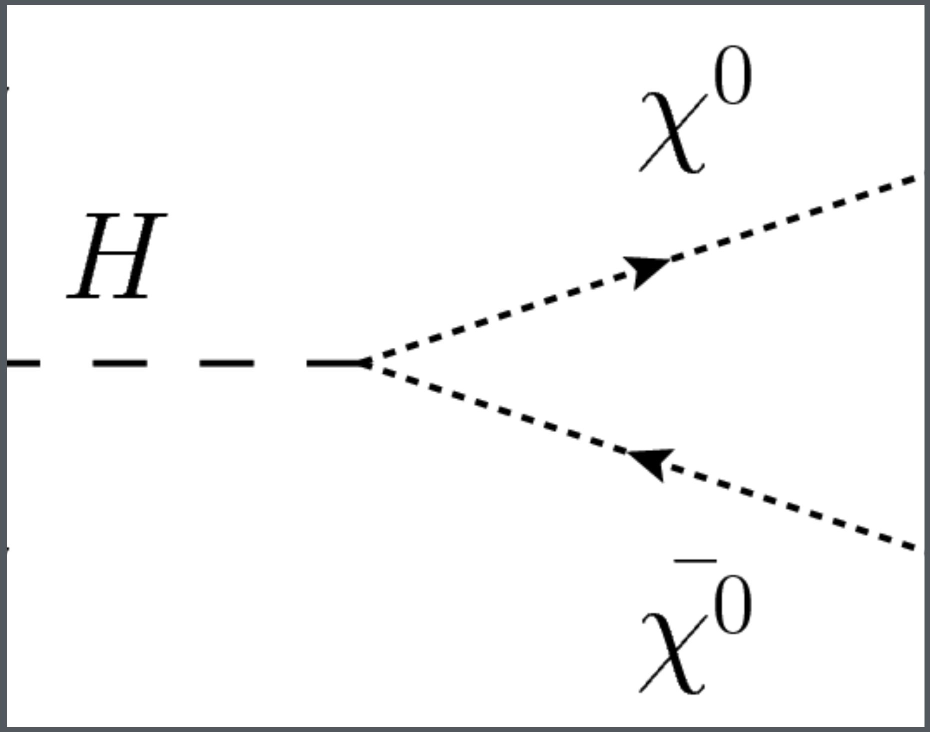
ATL-COM-DAQ-2017-001

BSM Higgs decays

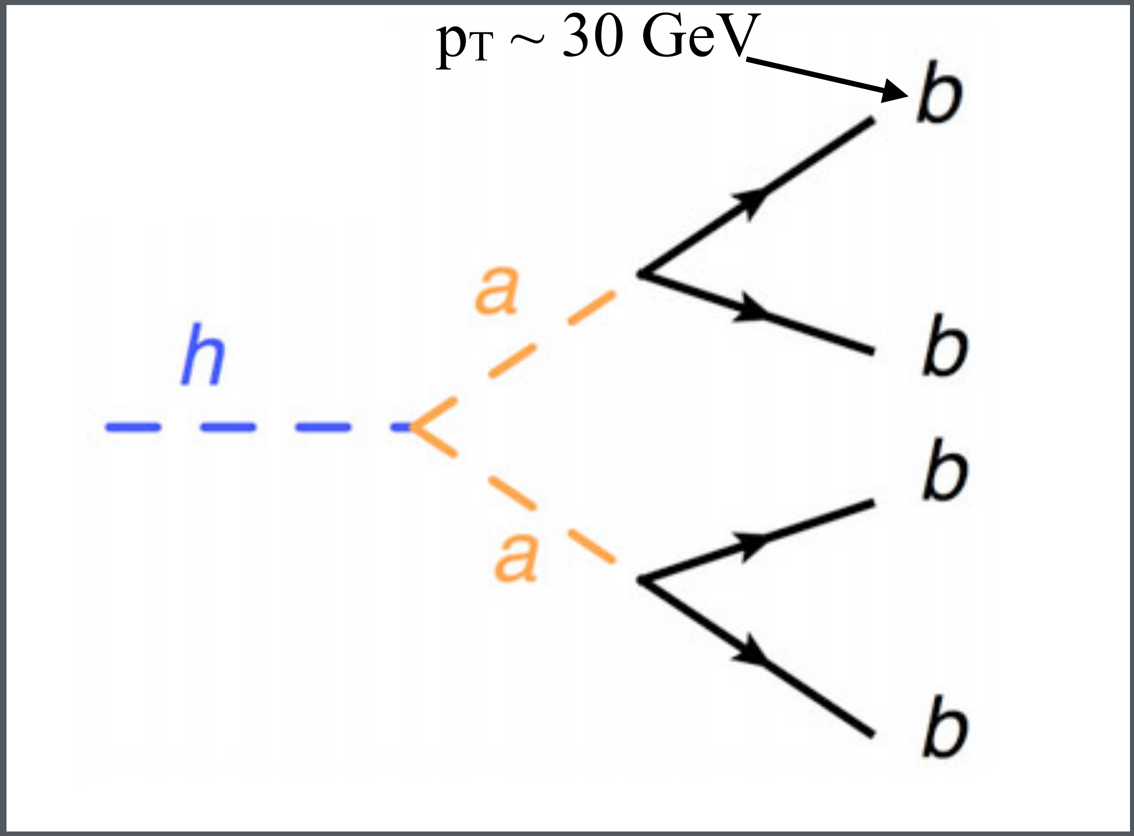
Higgs could have significant fraction of decays to BSM

- Decay to invisible (left)
- Many final states where Higgs couples to a scalar *a* (right)

Higgs to invisible

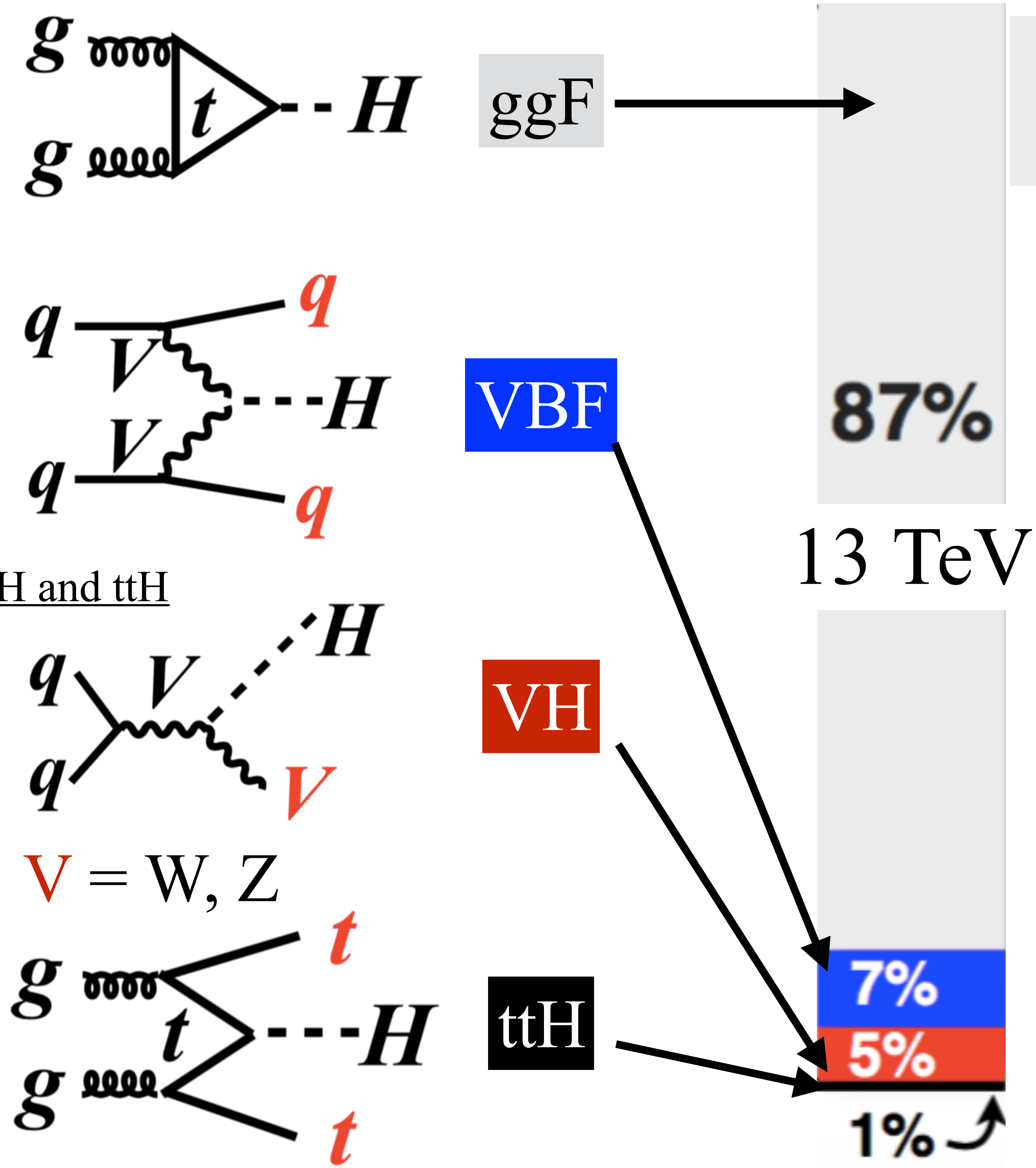


Higgs to 4b, largest Br decay



Why VBF?

hadron collider production modes



Br hit inVH and ttH

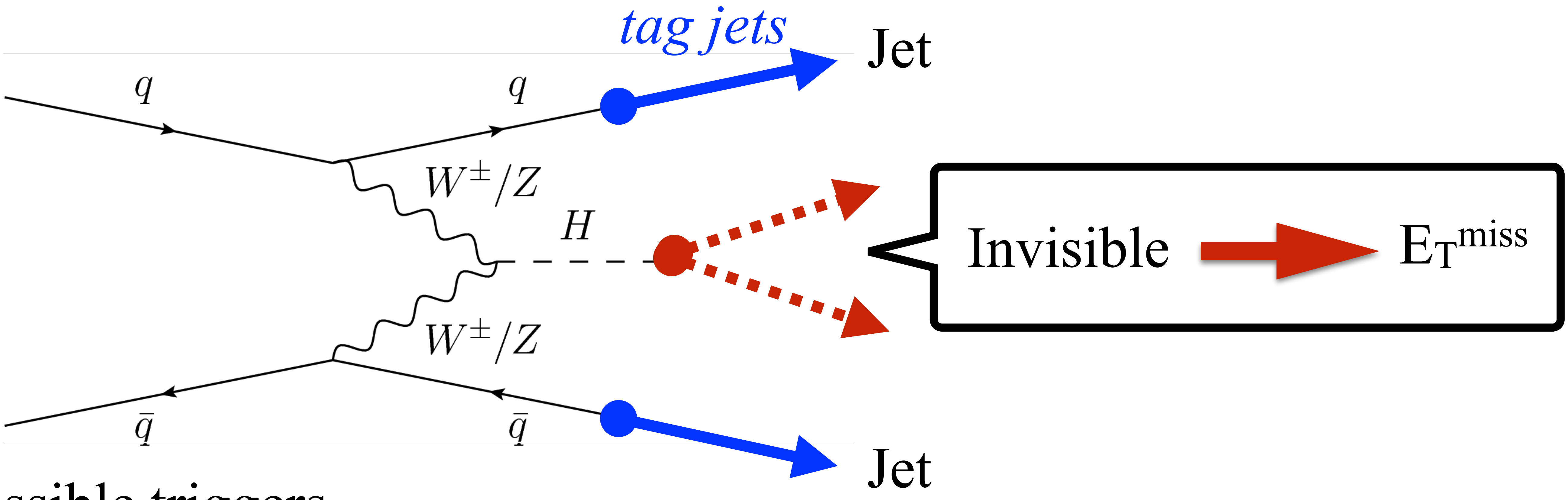
largest Br, but trigger / backgrounds make this intractable for some final states

(e,μ,ee,μμ)

$\boldsymbol{\sigma}(\mathrm{VBF})/\boldsymbol{\sigma}_{\mathrm{VH}} \times \mathrm{Br} \sim 10$

Possible to gain significant stats for hadronic final states

Triggers for VBF H→inv



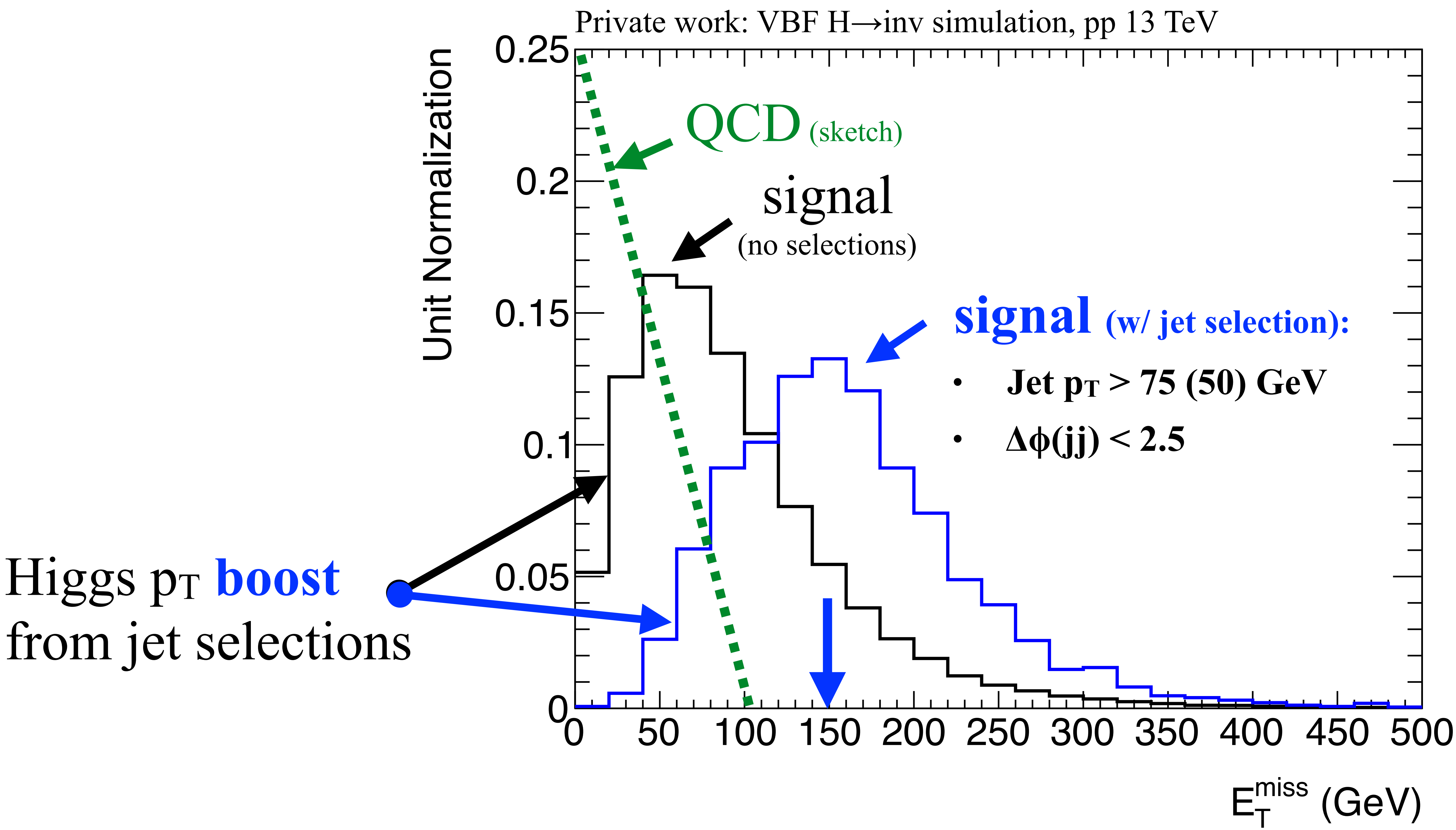
Possible triggers

- Jets: difficult to get out of L1 if only require two jets above p_T threshold *(until recently only counting of jets above threshold possible at L1)*

Rate ~ **σ**(QCD dijet) x L_{inst} ~ 10^7pb x 10^{-2}pb^{-1}s^{-1} = 100 kHz

- E_{Tmiss}: efficient for > 150 GeV, with L1 rate ~5kHz

E_T^{miss} distribution



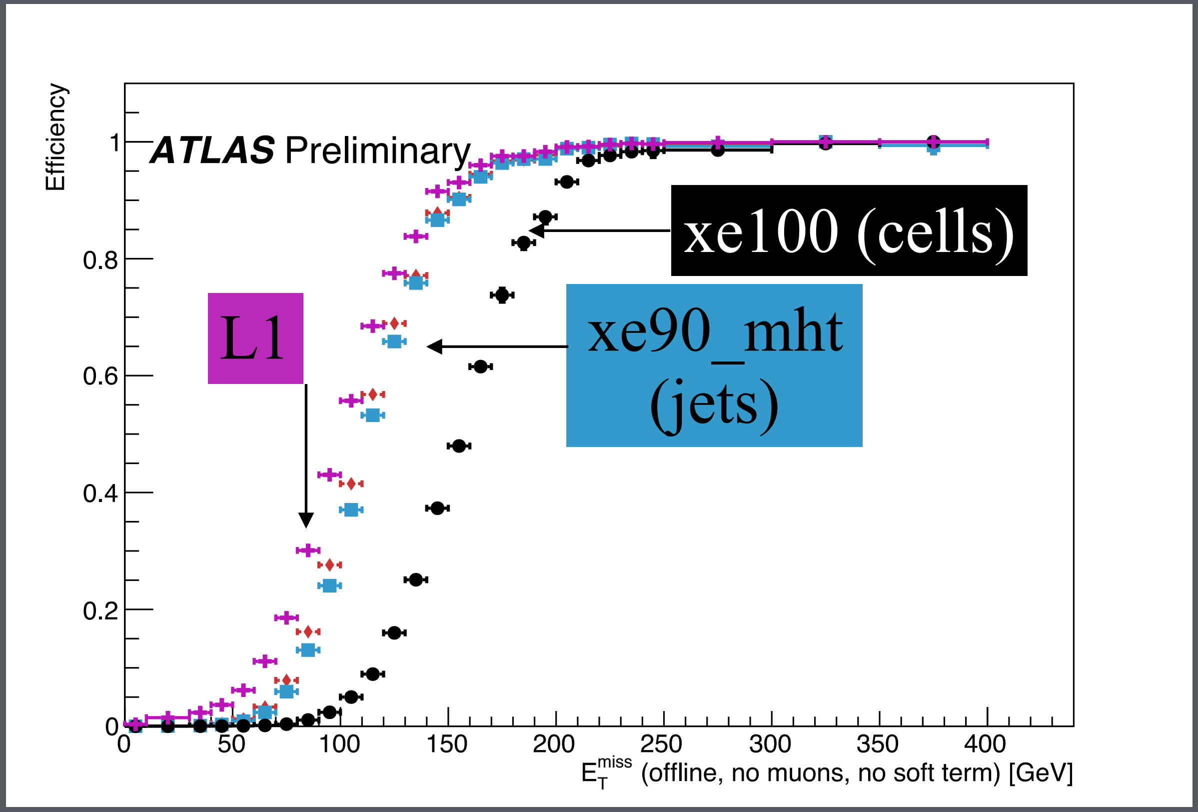
- After (loose) selections, E_T^{miss} distribution peaks at ~150 GeV

E_T^{miss} trigger performance

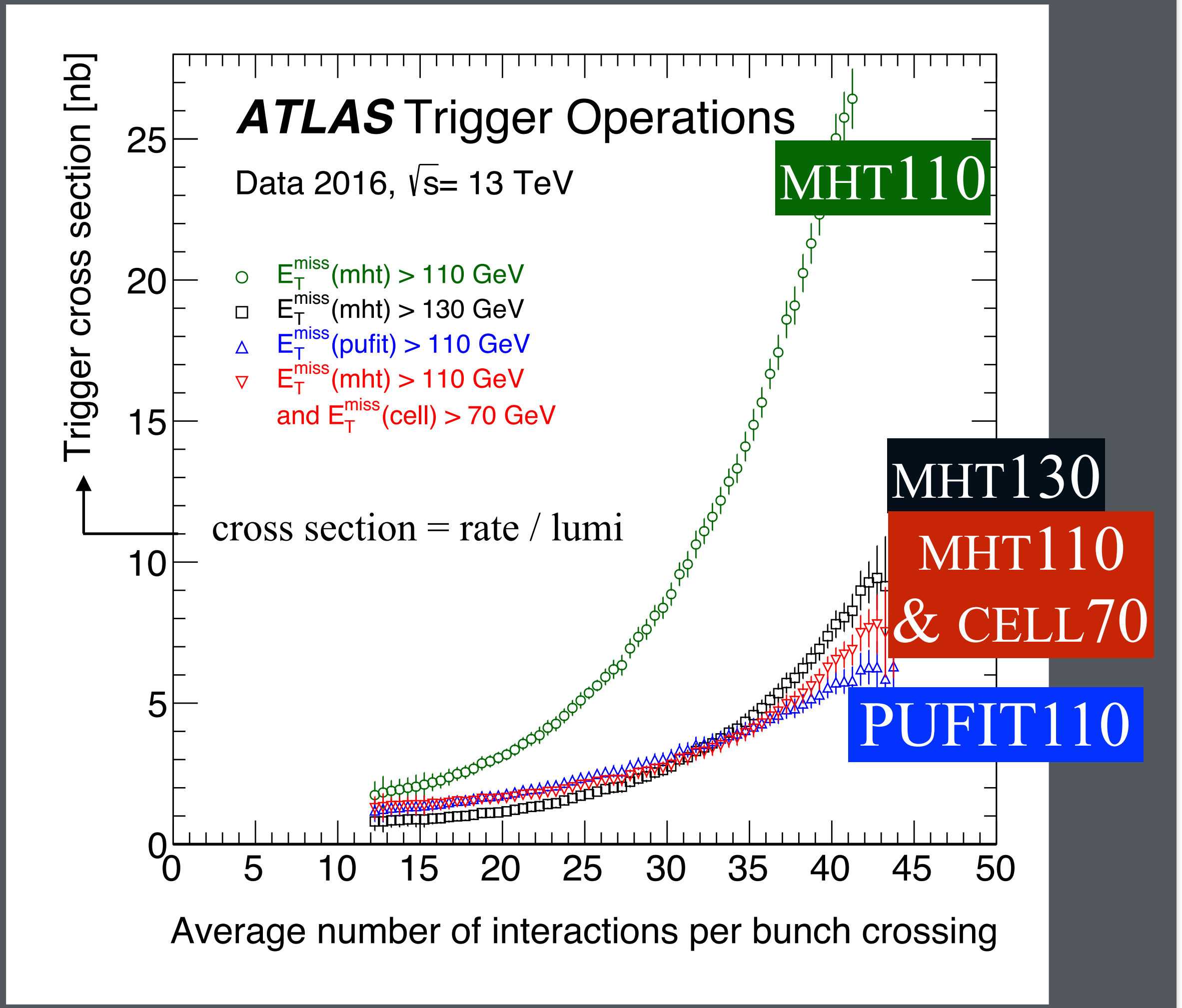
E_T^{miss} triggers

- Several algorithms available at HLT (backup), mht uses **calorimeter jets**
- E_T^{miss}: offline threshold ~ 150 GeV, approximately L1 limited (left)
- Dramatic rate increase with <μ>, but are constantly improving (right)

Efficiency curves for E_T^{miss}, reference events selected with lepton triggers



Trigger cross section vs. <μ>



Reference, link

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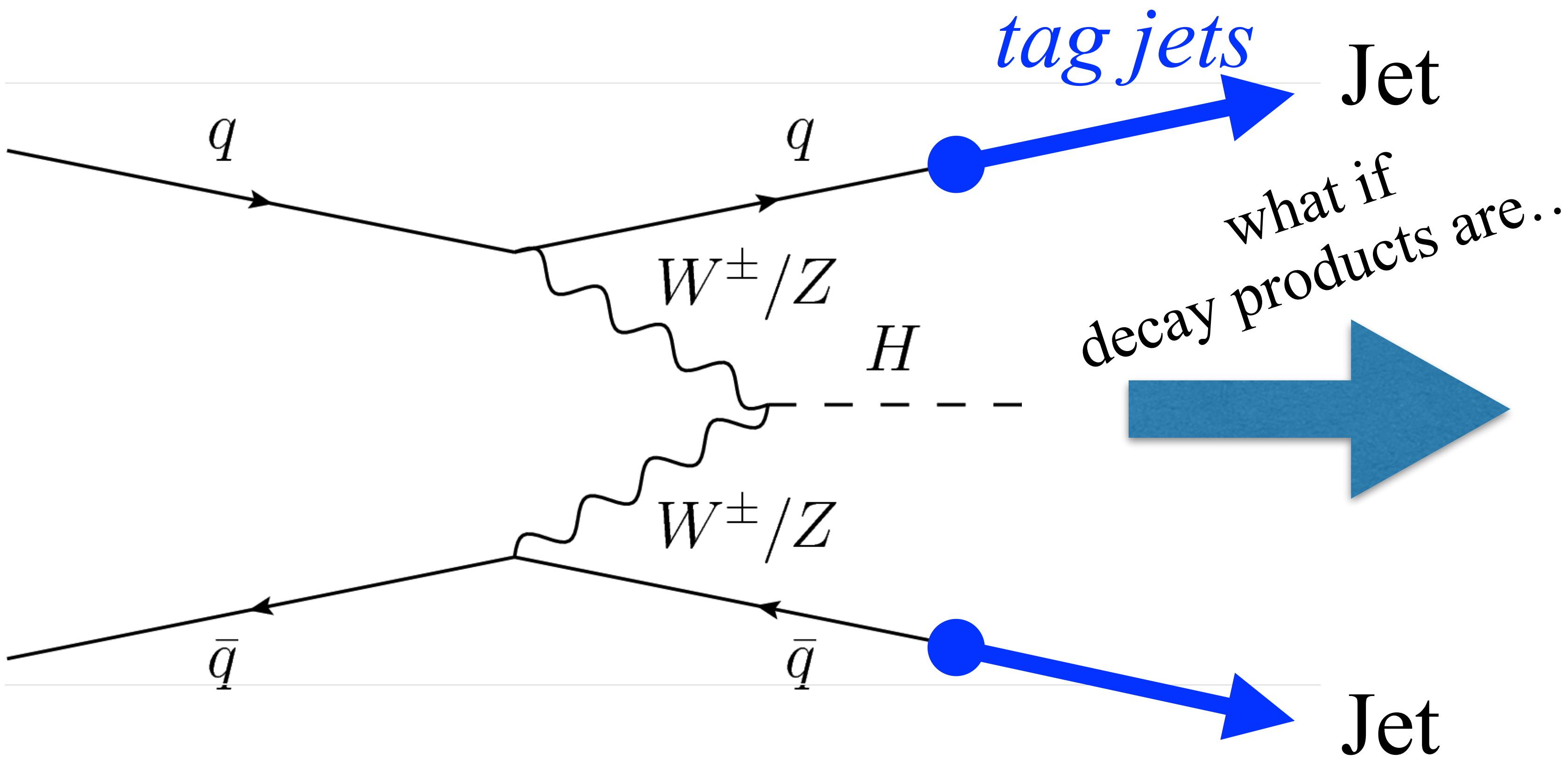
Why a VBF trigger



- low-p_T jets
- low-p_T e,μ,**τ**
- Many soft particles
- Long-lived (?)

Trigger on the tag jets

Trigger on the jet kinematics at L1

- Need handle in addition to jet p_T
- m(jj) or kinematic quantities to reduce background

dijet mass:

$$m^2(jj) \sim p_T(j_1) \bullet p_T(j_2) \bullet e^{\Delta\eta(jj)}$$

← *L1 trigger variable*

Reducing the rate

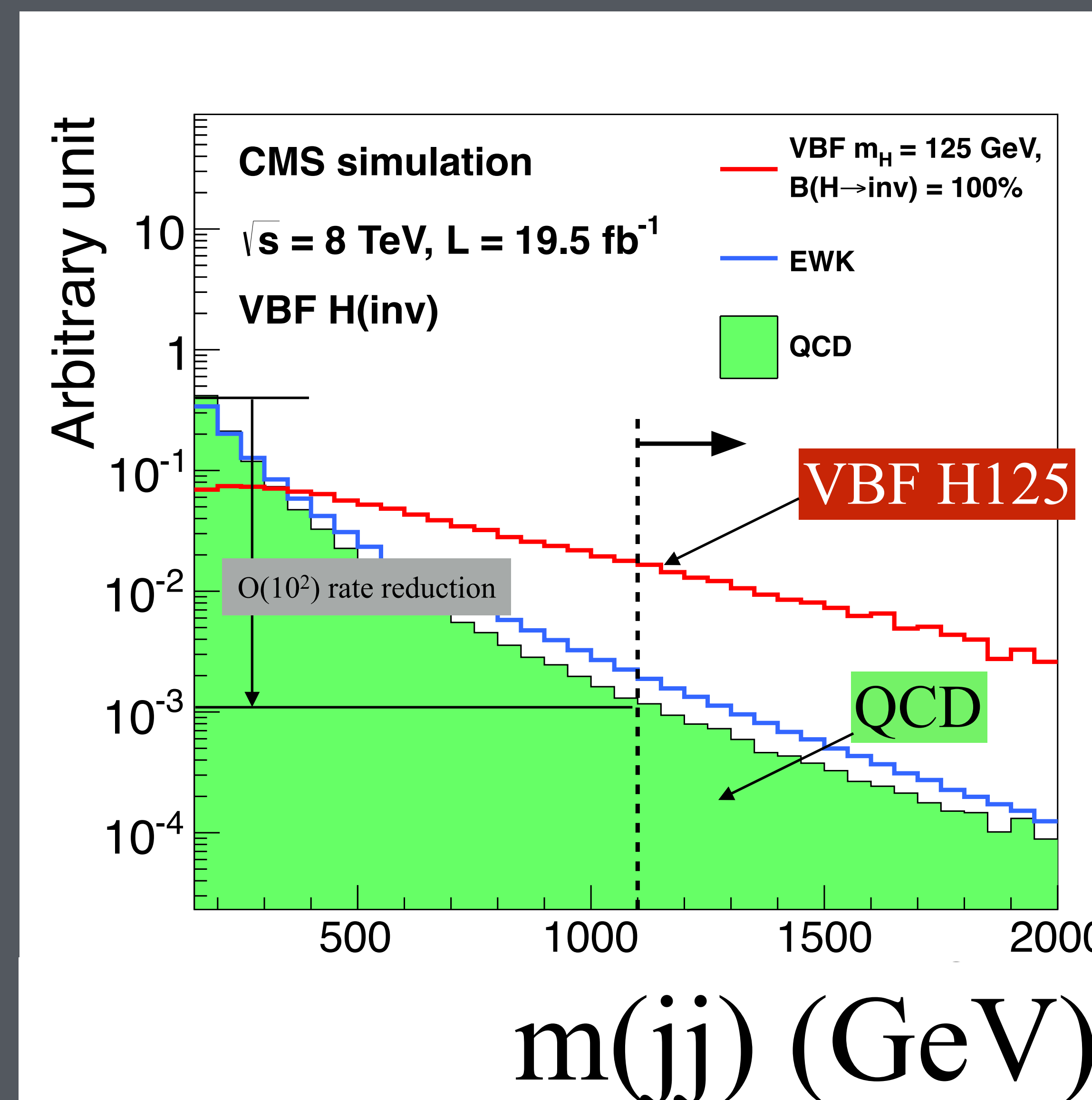
Trigger events with m(jj) to reduce QCD

- Orders of magnitude background reduction to help with rate
- Also used in offline selections to remove QCD

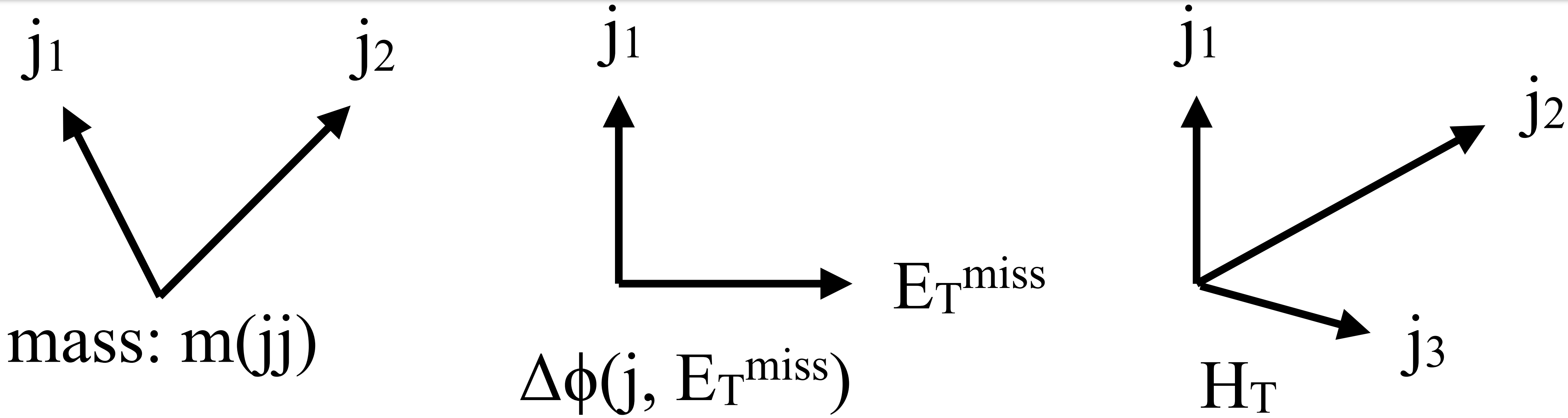
Illustrative plot from CMS, note some selections

$p_T > 50$ (50) GeV
(opposite hemi.)
m(jj) > 150 GeV
$E_T^{miss} > 130$ GeV

QCD background falls rapidly with m(jj)



Kinematics at L1



Additional flexibility at L1 possible

- Compute variables from truncated lists of inputs (jets, muons, EM, +…)

Possible m(jj) trigger at L1

- Two lists of up to six jets, $p_T > 60(50)$ GeV (offline)
- Compute m(jj) for all combinations

Rate driven up by combinatorics and pileup in fwd region

- Restrict $|\eta|$ ranges in m(jj) combination

Reduce combinatorics

To reduce the rate, restrict |η| for combinations

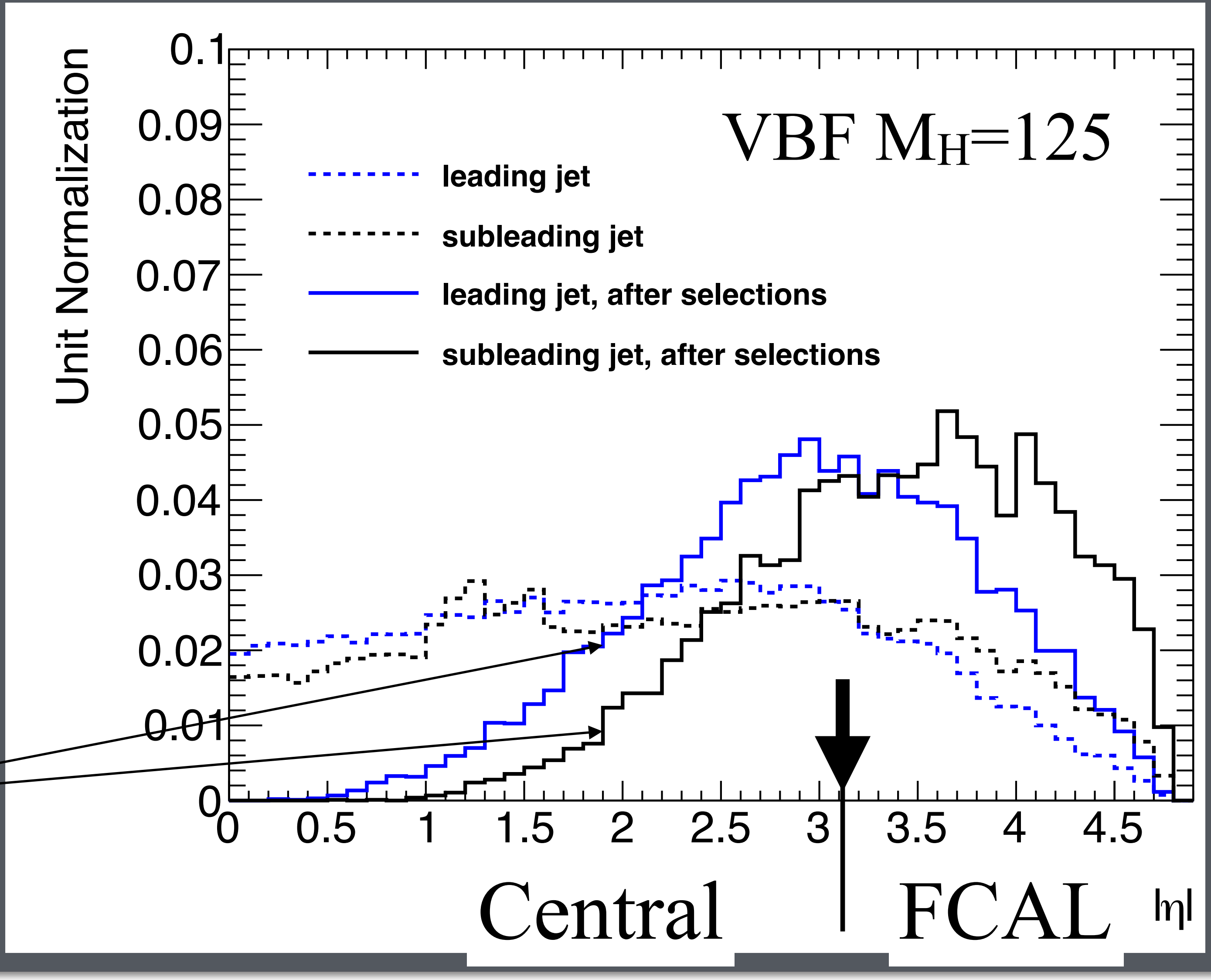
- ~50% of signal events have central-forward combination
- Significant rate reduction makes this a plausible strategy

Fraction of events split into combinations of central/forward (central defined as |η| < 3.1)

leading	subleading	**Fraction [%]**
Central	Central	**25**
Forward	Central	**18**
Central	Forward	**46**
Forward	Forward	**11**
	Total	**100**

Includes selections
p_T > 75 (50) GeV
m(jj) > 1 TeV, |Δη| > 4.8

Jet |η| distribution for VBF tag jets



VBF heavy scalar

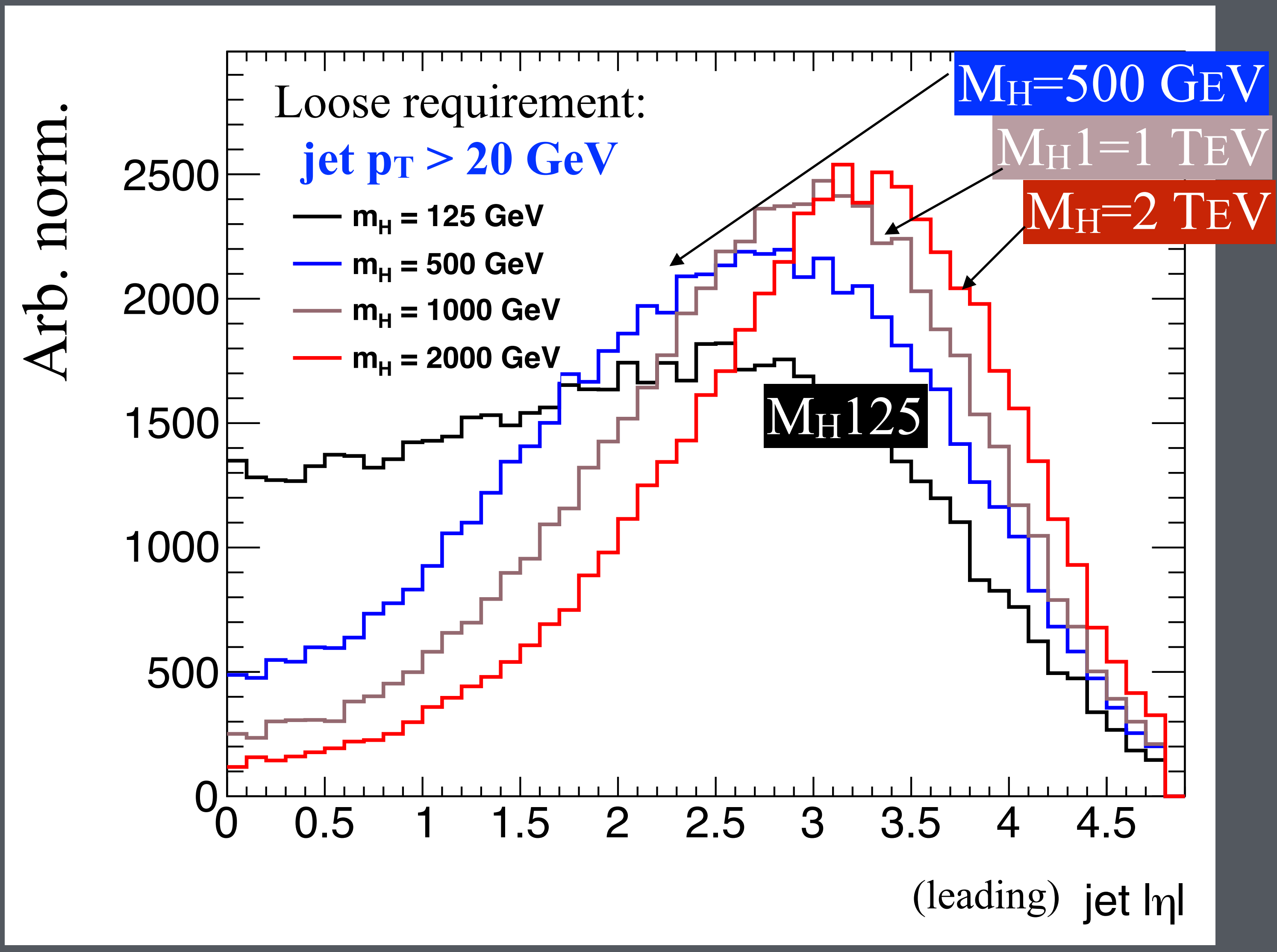
Physics in the forward-forward category?

- Jets from a heavy scalar are even more forward
- Significant fraction of these events will be lost by central-forward requirement

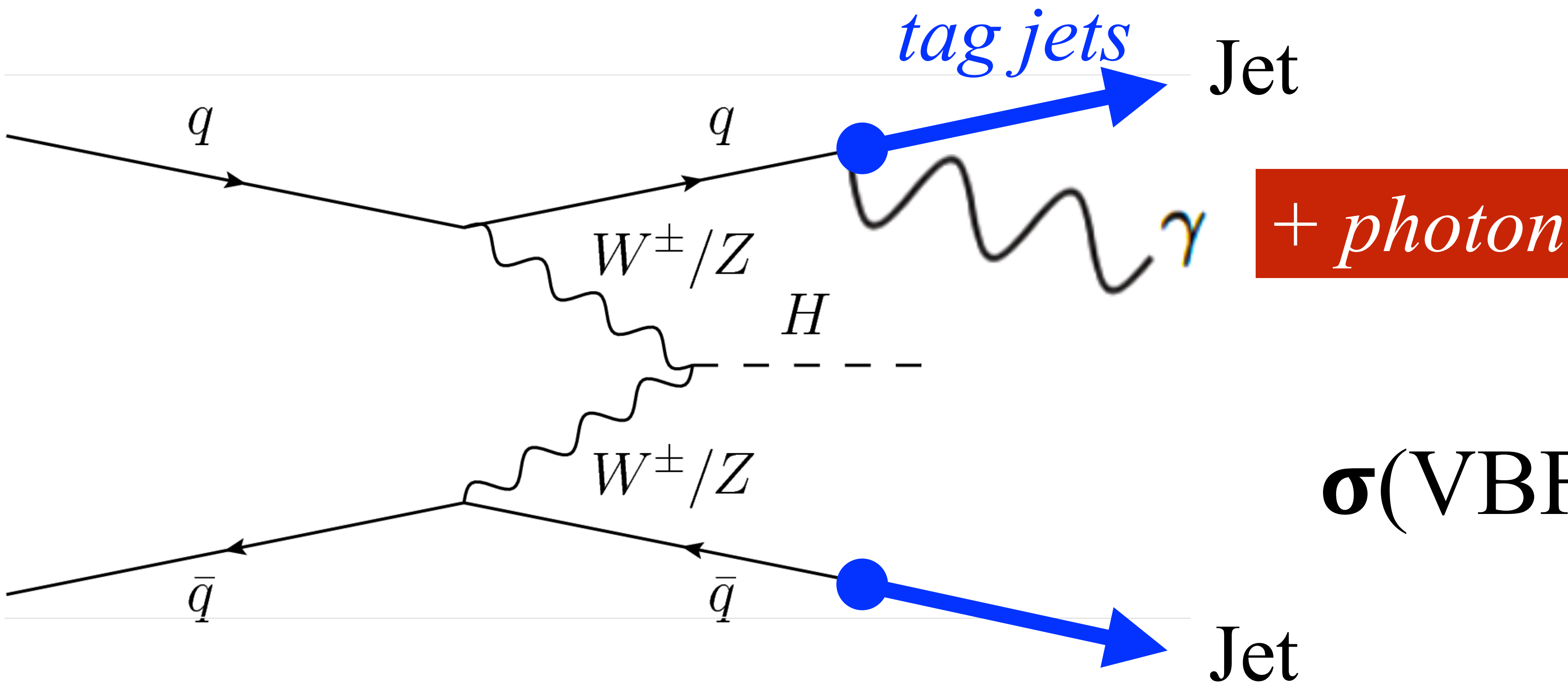
Also trigger on FF category?

Theoretical justification would help here…

Jet |η| distribution for a heavy scalar, VBF production



VBF + γ



σ(VBF H + γ) ~ 70 fb

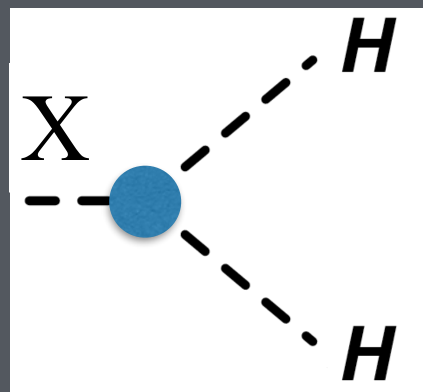
Clean events with a photon (initially implemented for H→bb, but generally useful)

- 60% L1 bandwidth already goes to EM
- 2016 trigger seeded from EM item at L1:
  γ p_T > 22 GeV, m(jj) > 700 GeV
- *Future trigger will require L1 m(jj) as well*

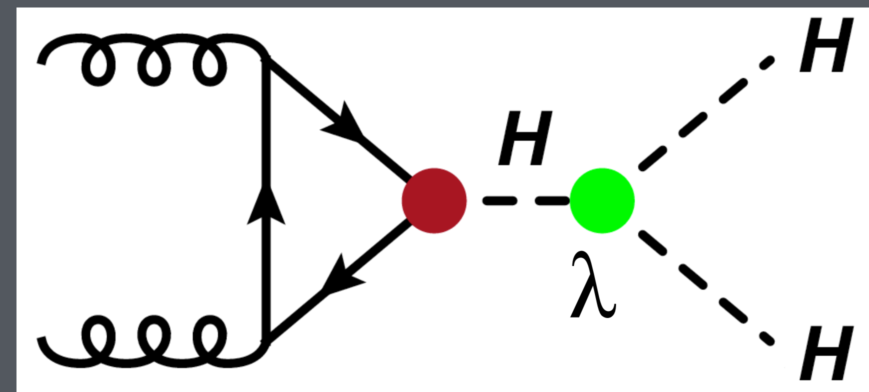
ATLAS-CONF-2016-063

Dihiggs

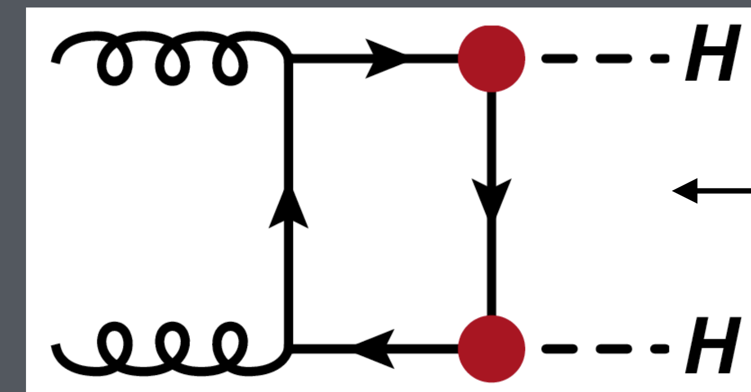
X coupling to HH



Trilinear self-coupling



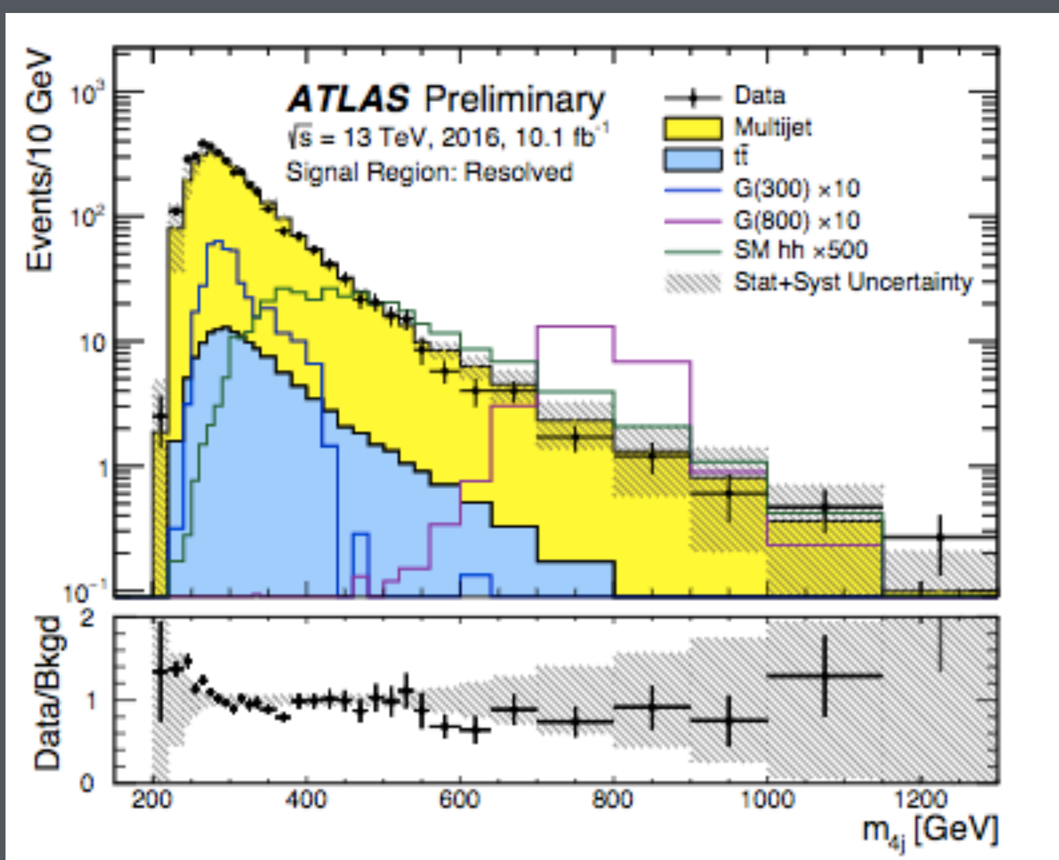
Box diagram



cross section ~ 40fb

Proposed trigger strategy for 4b similar between run 2 and HL-LHC, but contingent on trigger upgrades

All hadronic X→HH, m4j distribution



(b) 2016 dataset

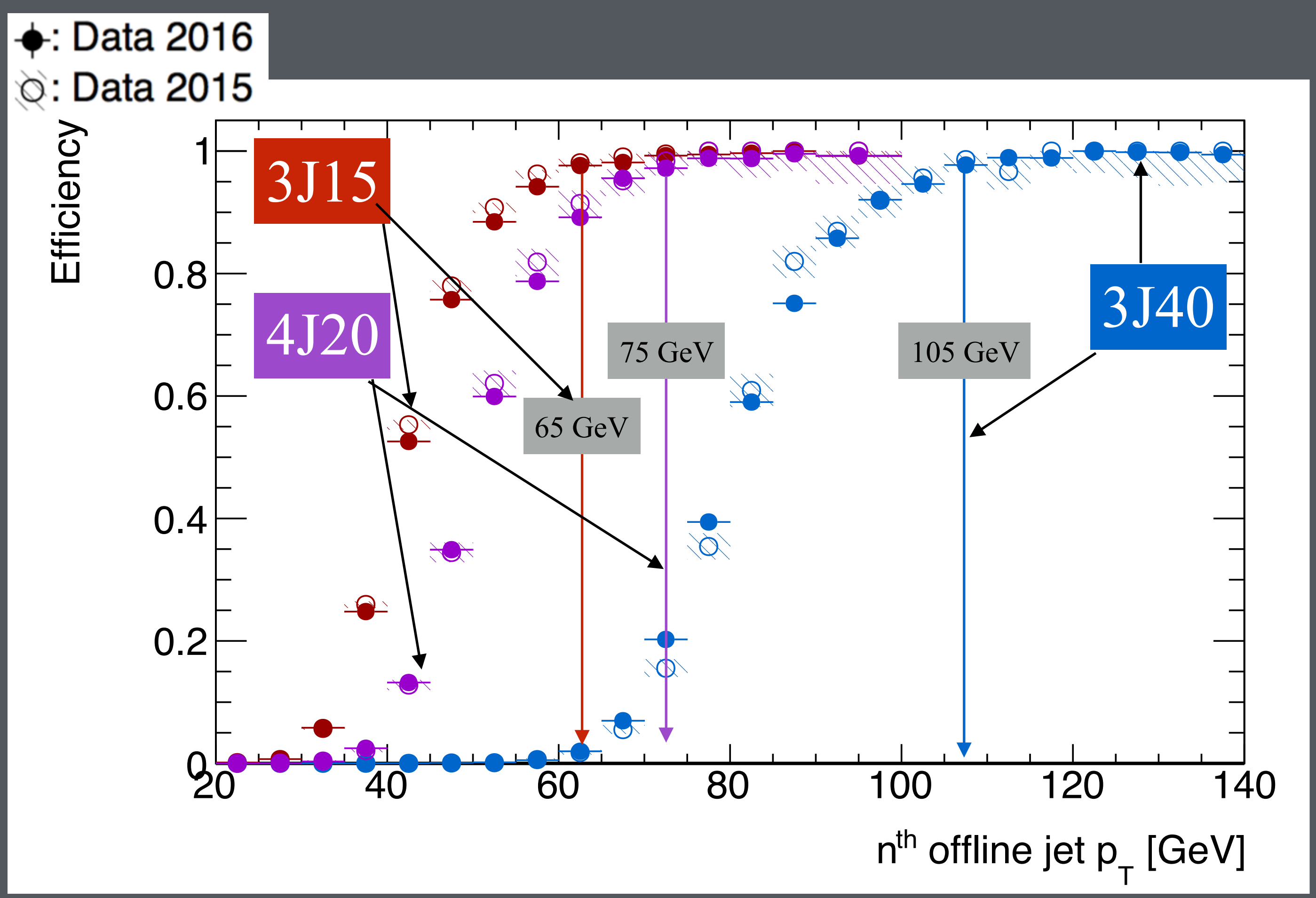
- Run 2 analysis uses combination of several jet triggers
- Most important trigger: multijet
- *Many users of multi jet triggers*

Multijet triggers

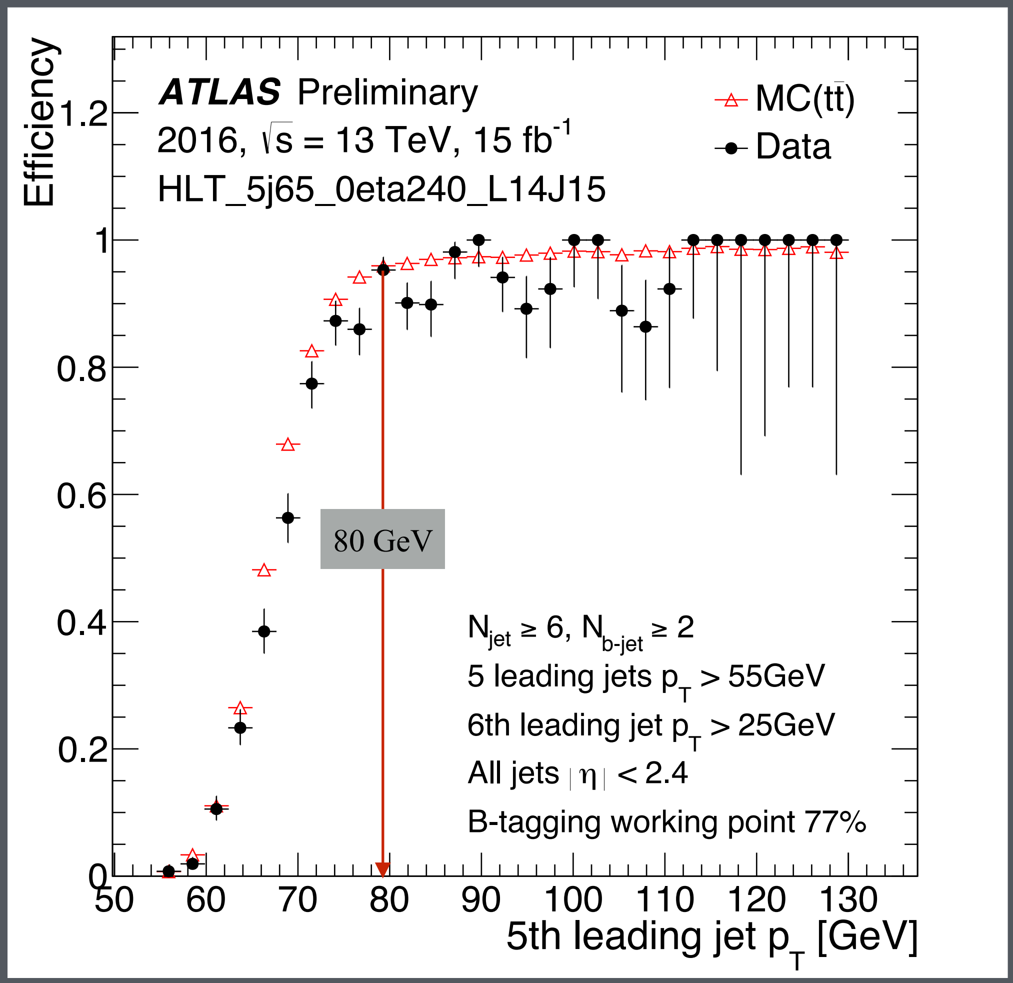
Lowest unprescaled triggers: 4J15, 3J50

- Efficiency curves for L1 multijet triggers (left)
- Efficiency curve for HLT 5-jet trigger (right)
- Approximately L1 limited

Efficiency of L1 3(4) jet triggers offline, |η| < 2.8



Efficiency of HLT 5 jet trigger



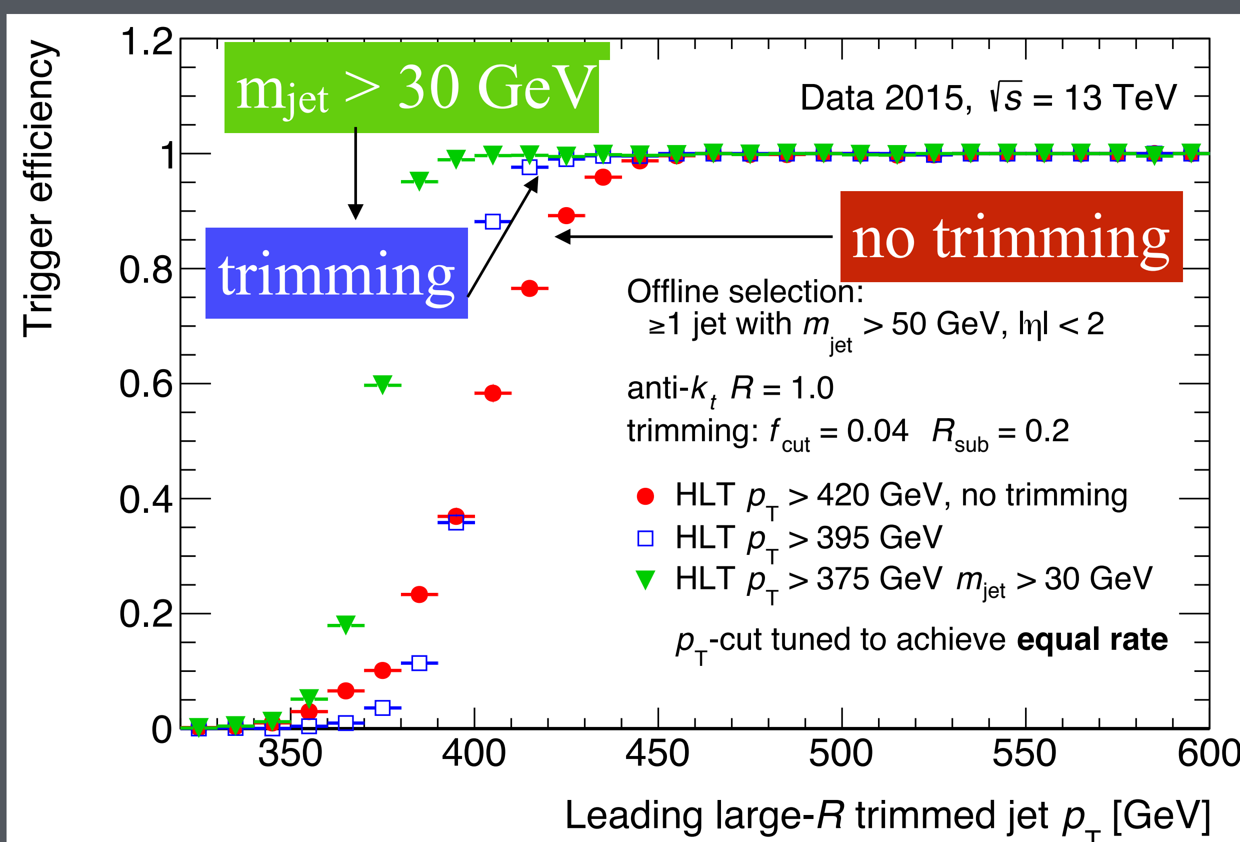
ATL-COM-DAQ-2016-130 (link)

Large-R single jet

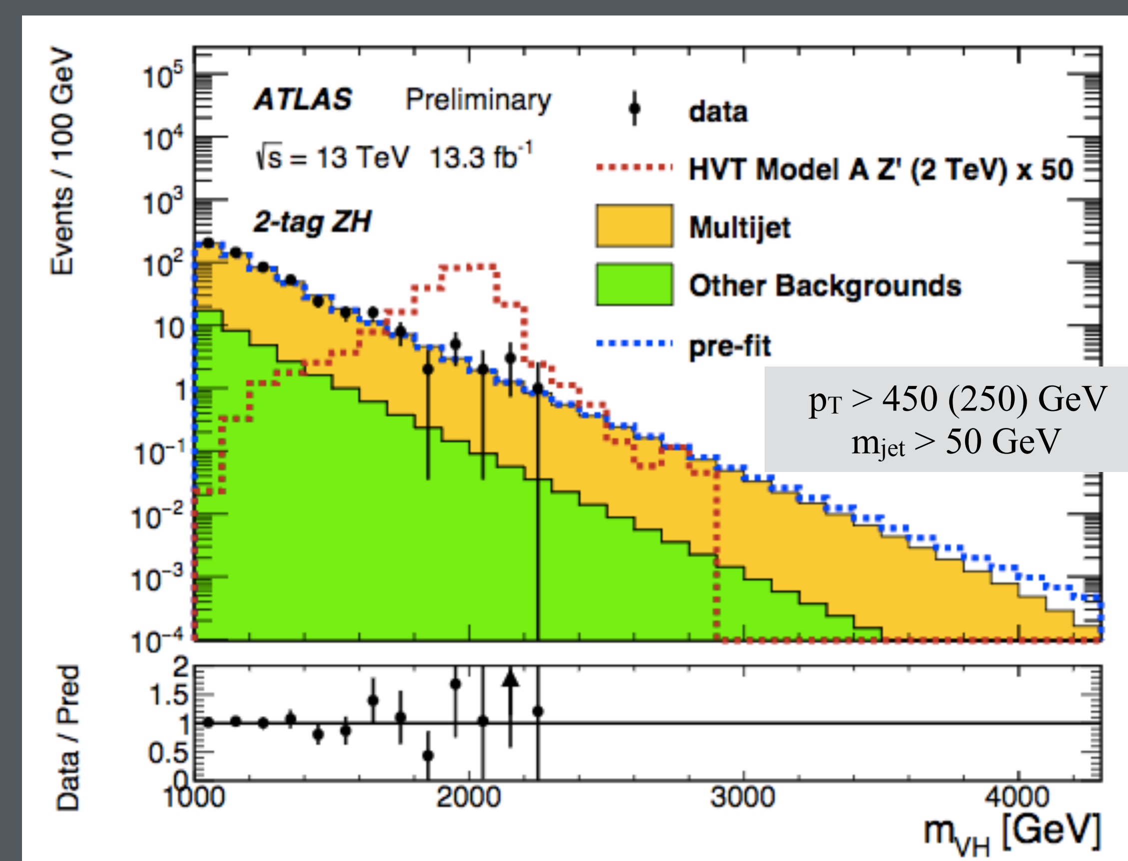
Boosted jets reconstruct resonances, V'→VH

- Trigger: single R = 1.0 jet, $p_T > 420$ GeV, m_{VH} distribution (right)
- Trigger threshold can be improved using jet mass requirement (left)

Efficiency curves (equal rate) demonstrating improvements to large-R jet triggers



Distribution of m_{VH} formed from two large-R jets

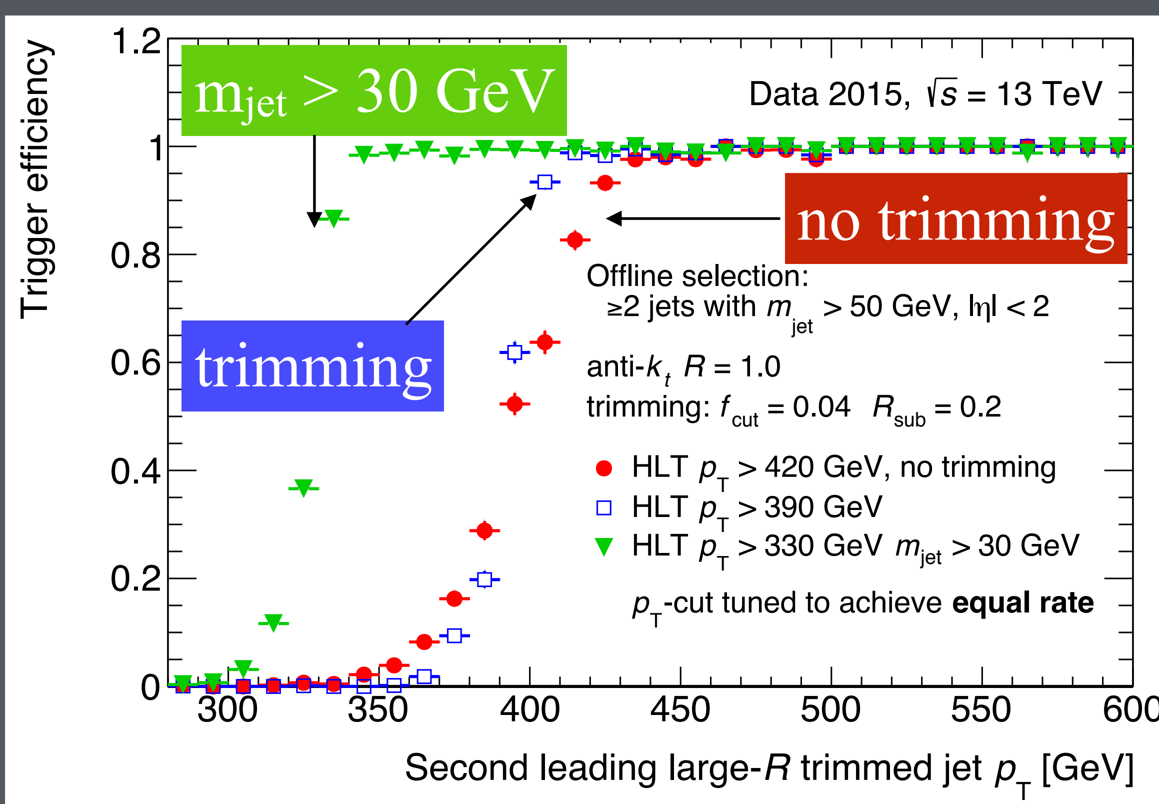


Large-R dijet

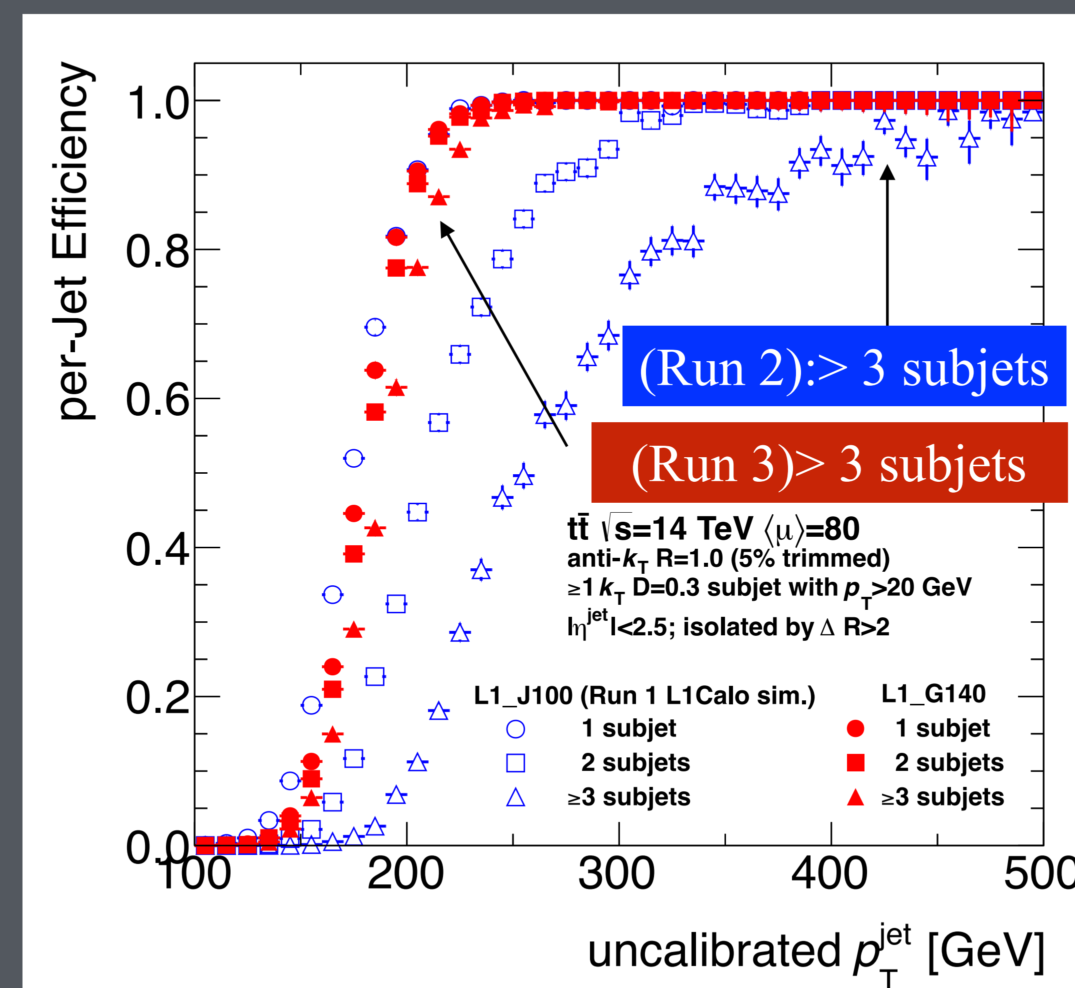
Jet mass requirement reduces threshold

- L1 seed fully efficient by 220 GeV (offline): HLT limited
- However, L1 inefficient for >2 sub-jets (see right, backup)
- Run 3: global feature extractor to target this, but opportunity also in run 2

Efficiency curves (equal rate) demonstrating improvements to large-R jet triggers



Turn-on curve for boosted jet trigger



ATL-COM-DAQ-2017-007

ATL-COM-DAQ-2014-087

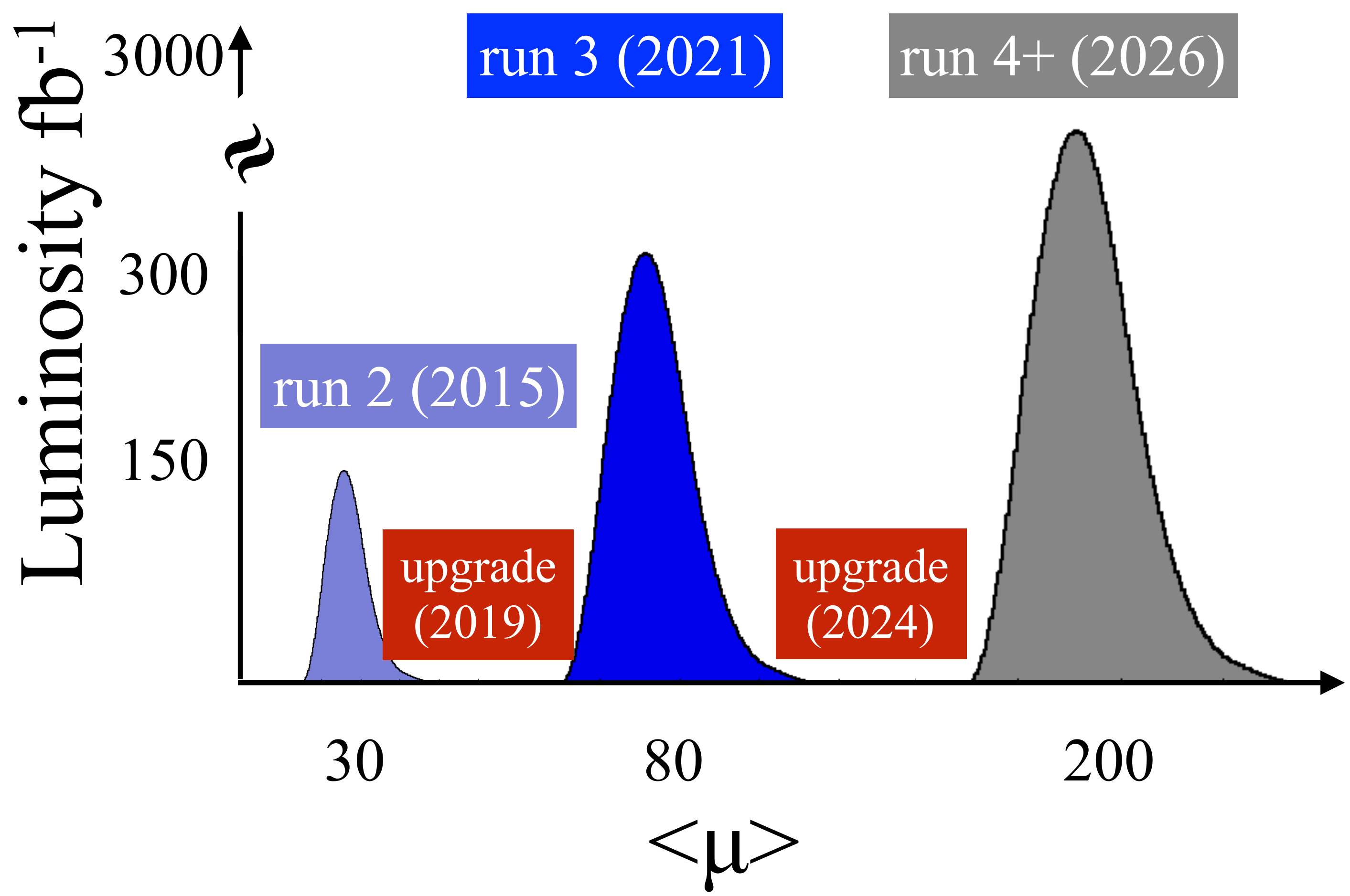
Conclusions

The ATLAS trigger system

- Remarkable system with a great deal of flexibility
- Many improvements implemented already

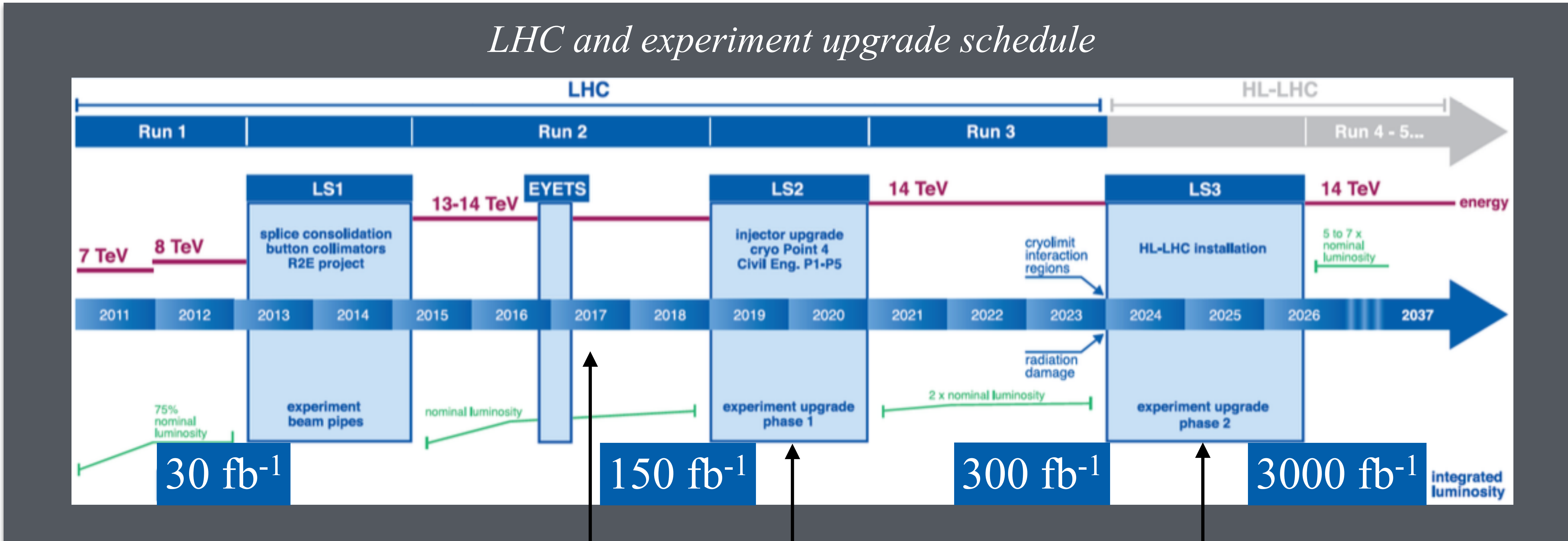
Examples of triggers motivated by physics use cases

- E_T^{miss}
- VBF
- Multijet triggers
- Boosted jet triggers



Backup

Timeline for upgrades



2017

Upgrade 2019

Upgrade 2024

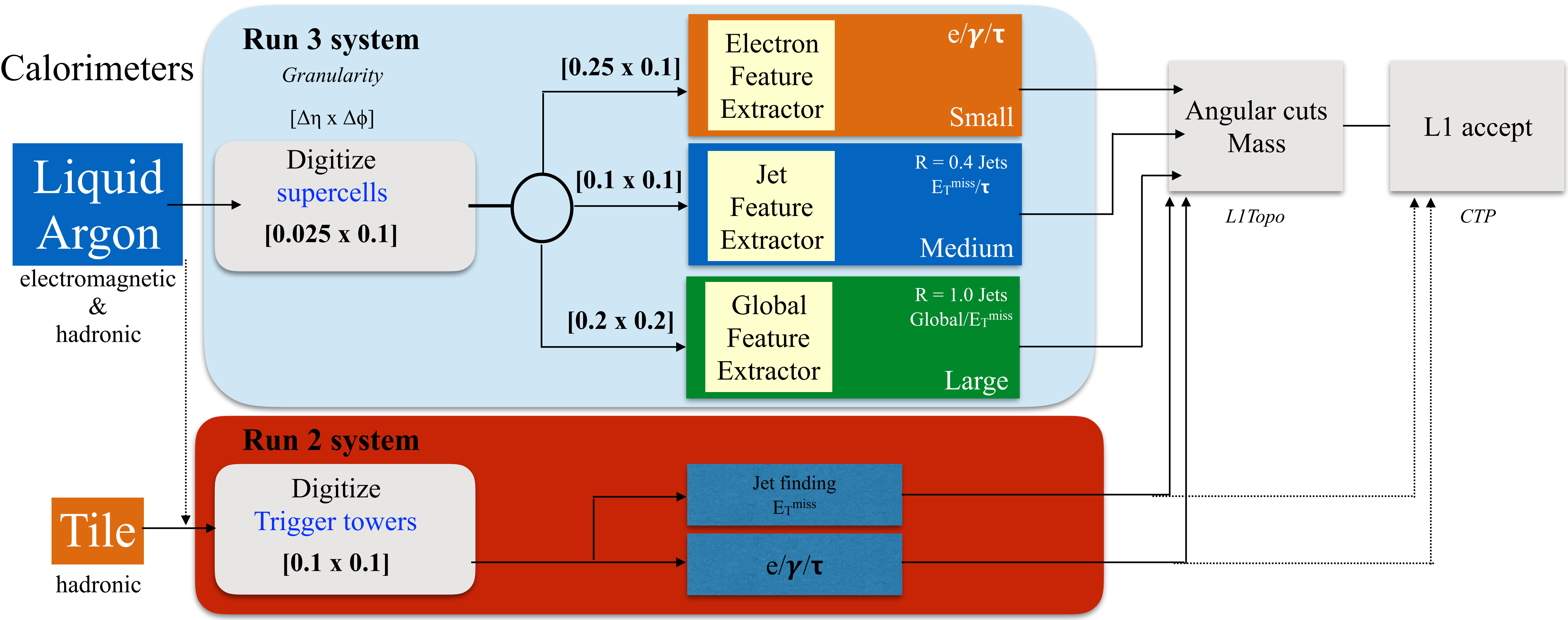
ATLAS upgrade

- *2019: significant upgrades in trigger readout electronics and L1 trigger electronics*
- *2024: upgrades to tracker, calorimeters, muon system and trigger*

Needed to cope with increasing pileup & add new features

Reference: link, link

Trigger upgrade overview



**muons not shown*

Digitize trigger readout path and increase physics capability

- Global feature extractor [gFEX]: no direct analog in existing system
- Run 2 system also will operate during commissioning of run 3 system

ATLAS-TDR-023

Detector upgrade

Calorimeters

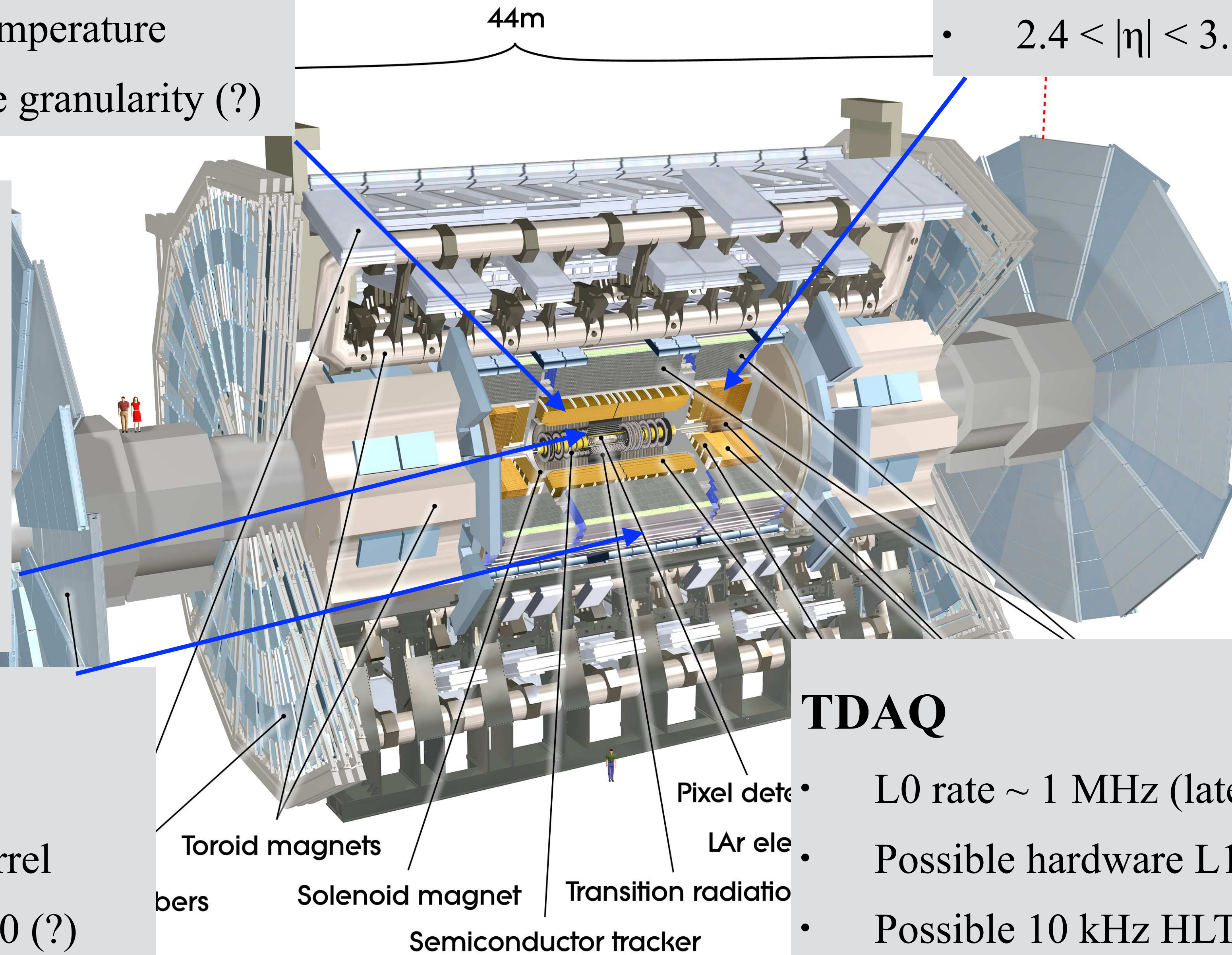
- New BE/FE electronics
- New HV power supplies
- Lower LAr temperature
- Additional tile granularity (?)

High granularity timing detector (?)

- $2.4 < |\eta| < 3.8$

Tracker (ITk)

- All silicon tracker (strip & pixel)
- Radiation tolerant
- High granularity
- Low material budget
- Coverage to $|\eta| = 4.0$



Muon

- New BE/FE electronics
- New RPC layer in inner barrel
- Muon tagging $2.7 < |\eta| < 4.0$ (?)

TDAQ

- L0 rate ~ 1 MHz (latency up to 10 μs)
- Possible hardware L1Track
- Possible 10 kHz HLT output

Primary focus of upgrade physics on performance of phase II

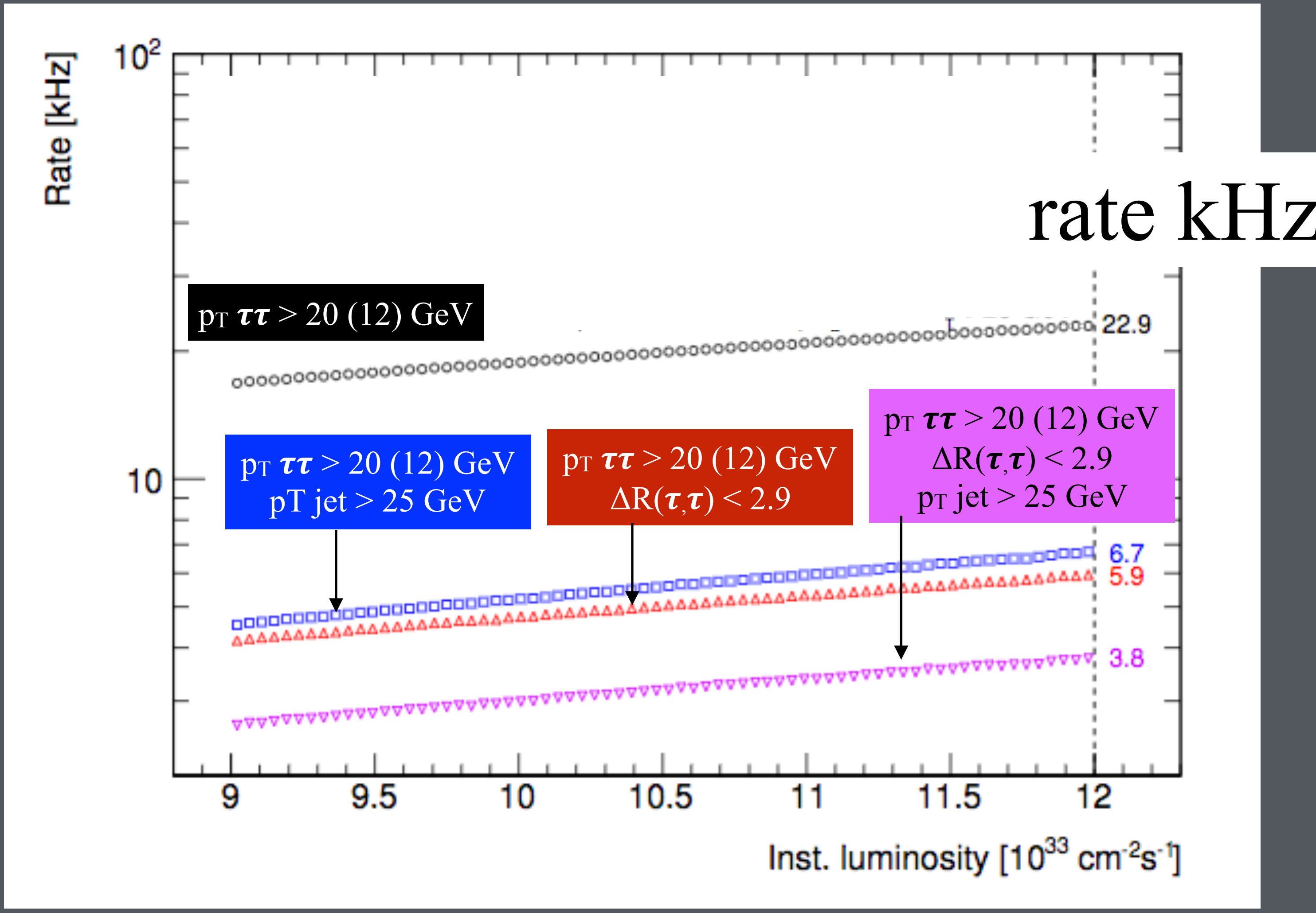
Trigger for H→$\tau\tau$

Unsustainable rates τ rates reduced with $\Delta R(\tau,\tau)$ & jet requirement

- Factor ~5 rate reduction (below), with negligible signal loss, targeting H→$\tau\tau$ (backup)
- Full requirement: p_T $\tau\tau$ > 20 (12) GeV, $\Delta R(\tau,\tau) < 2.9$, p_T jet > 25 GeV
  [offline: p_T $\tau\tau$ 40 (30) GeV, 60 GeV jet]

Additional kinematic requirements needed?

Rate reduction for τ_{had} triggers with angular and jet requirements



Missing some $\tau\tau$ decays, where $\tau\tau$ pair is back to back

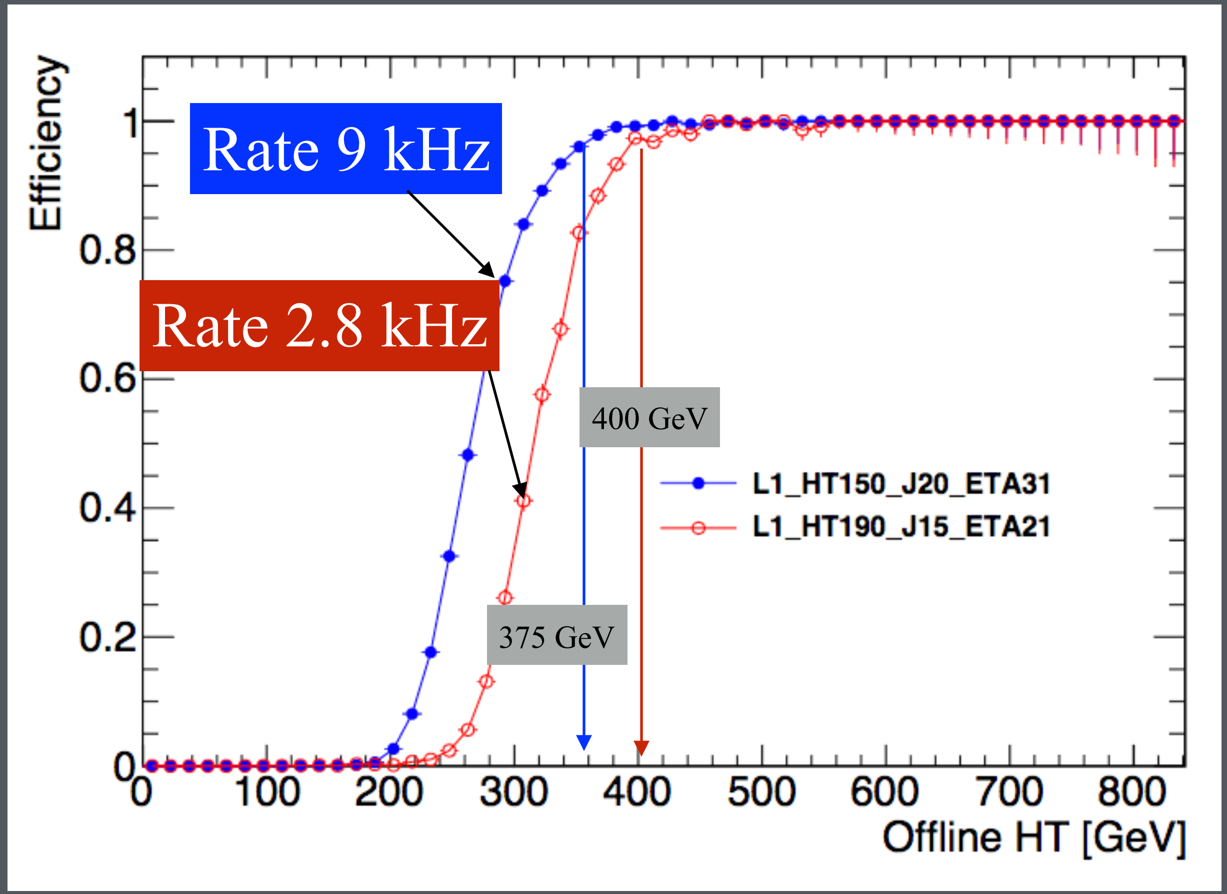
ATL-COM-DAQ-2017-001

H_T trigger

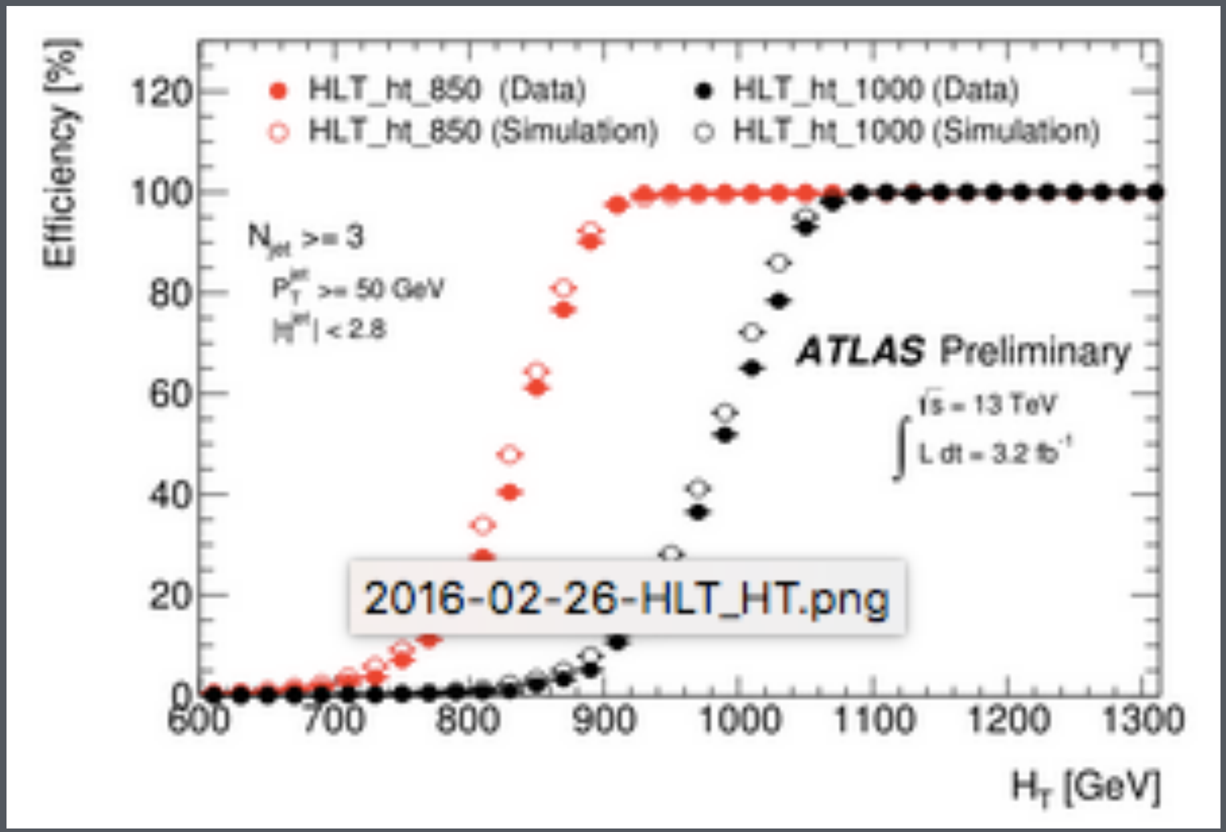
H_T: scalar sum of jet p_T (central)

- L1 fully efficient by H_T = 400 GeV (offline) with reasonable rate (left)
- HLT fully efficient by H_T = 1 TeV (offline), could be updated with new L1 seed

Efficiency curves for H_T, rates for $2x10^{34}cm^{-2}s^{-1}$



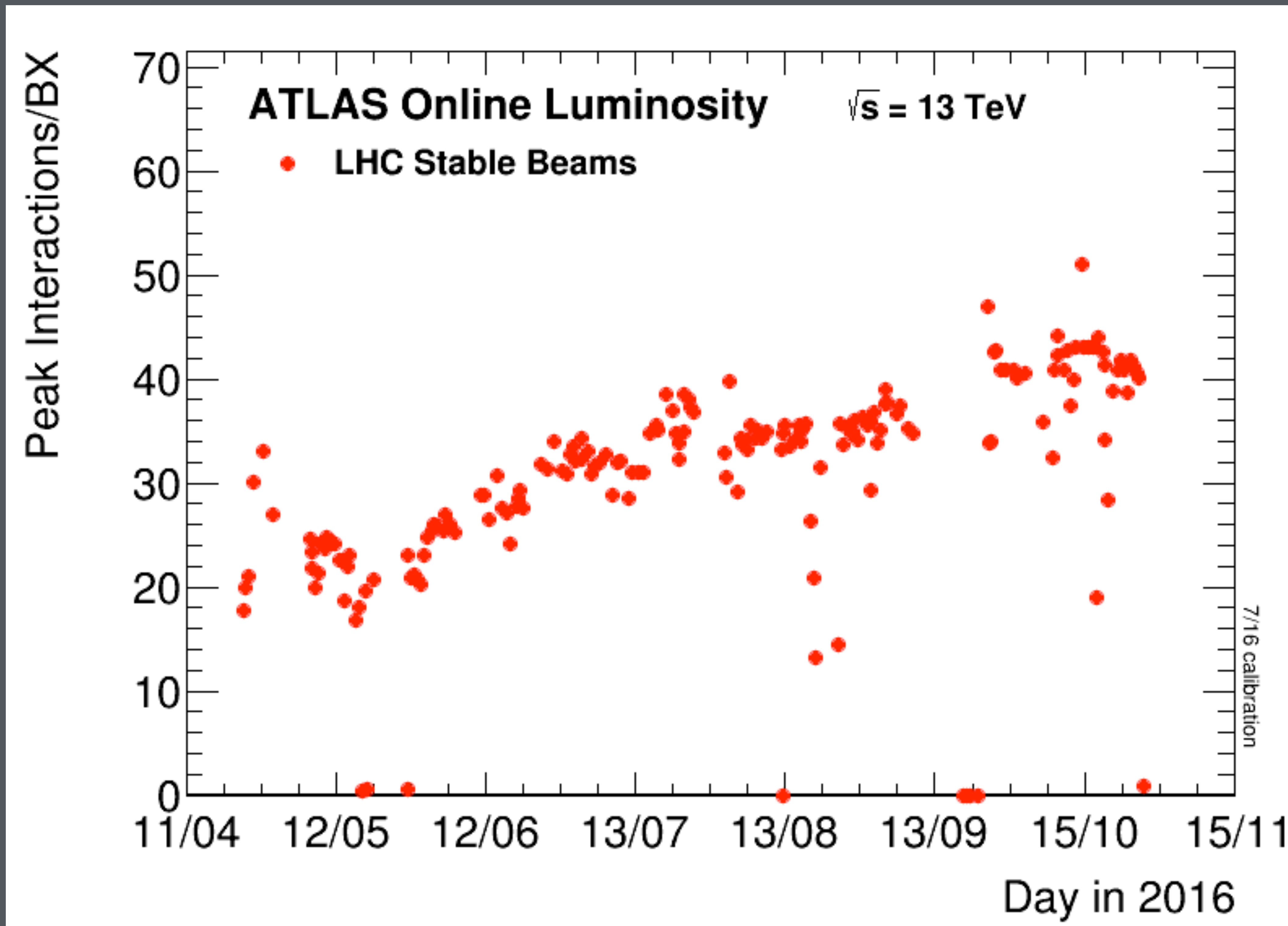
Efficiency (HLT) for ht trigger.
Note, seeded by L1_J100, as L1_HT was not yet available



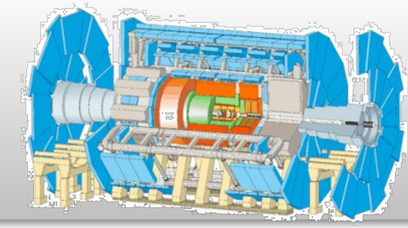
ATL-COM-DAQ-2017-001

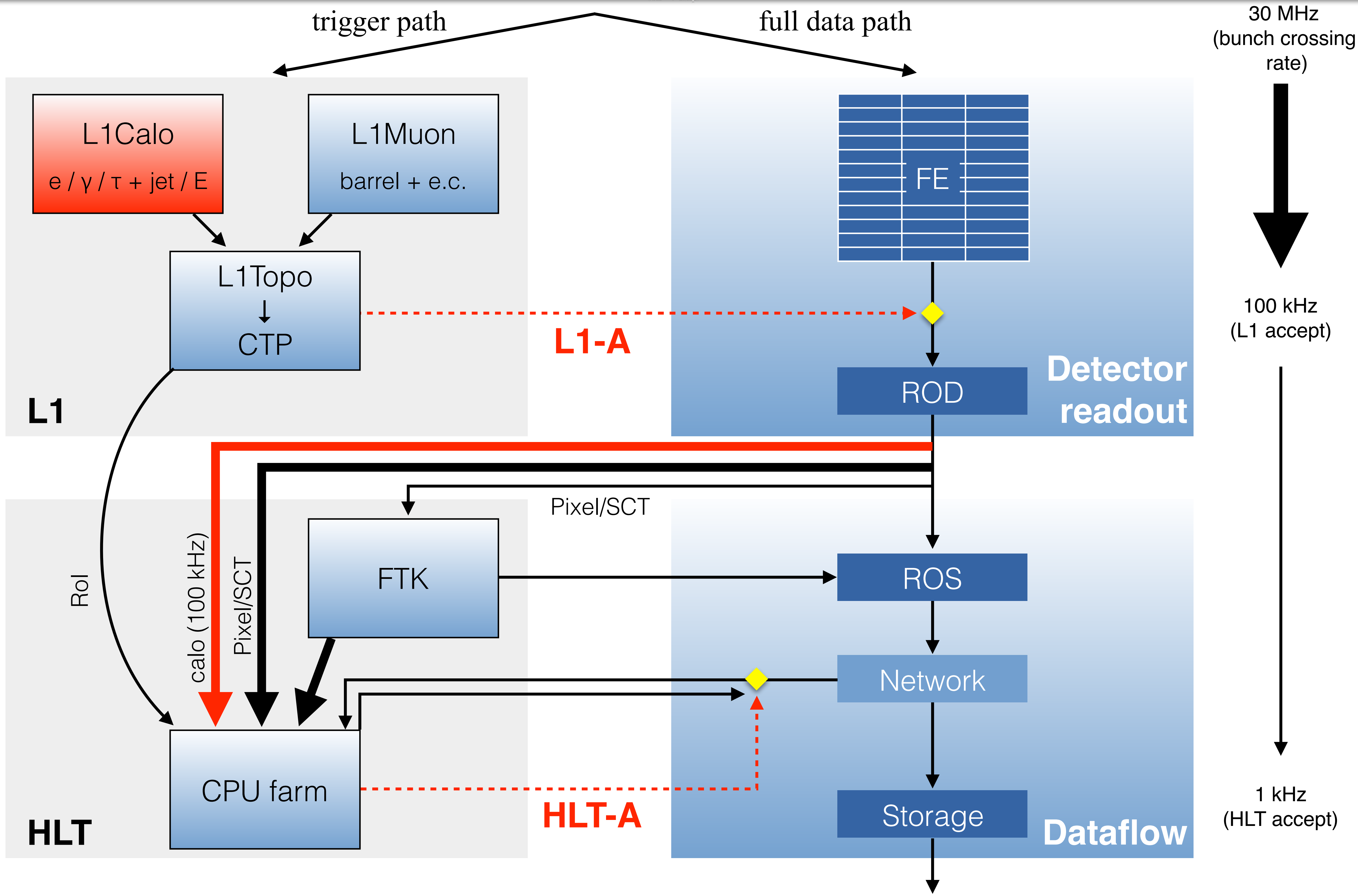
UPDATE ME!!!!

Profile of <μ> vs. time (2016)



Data readout





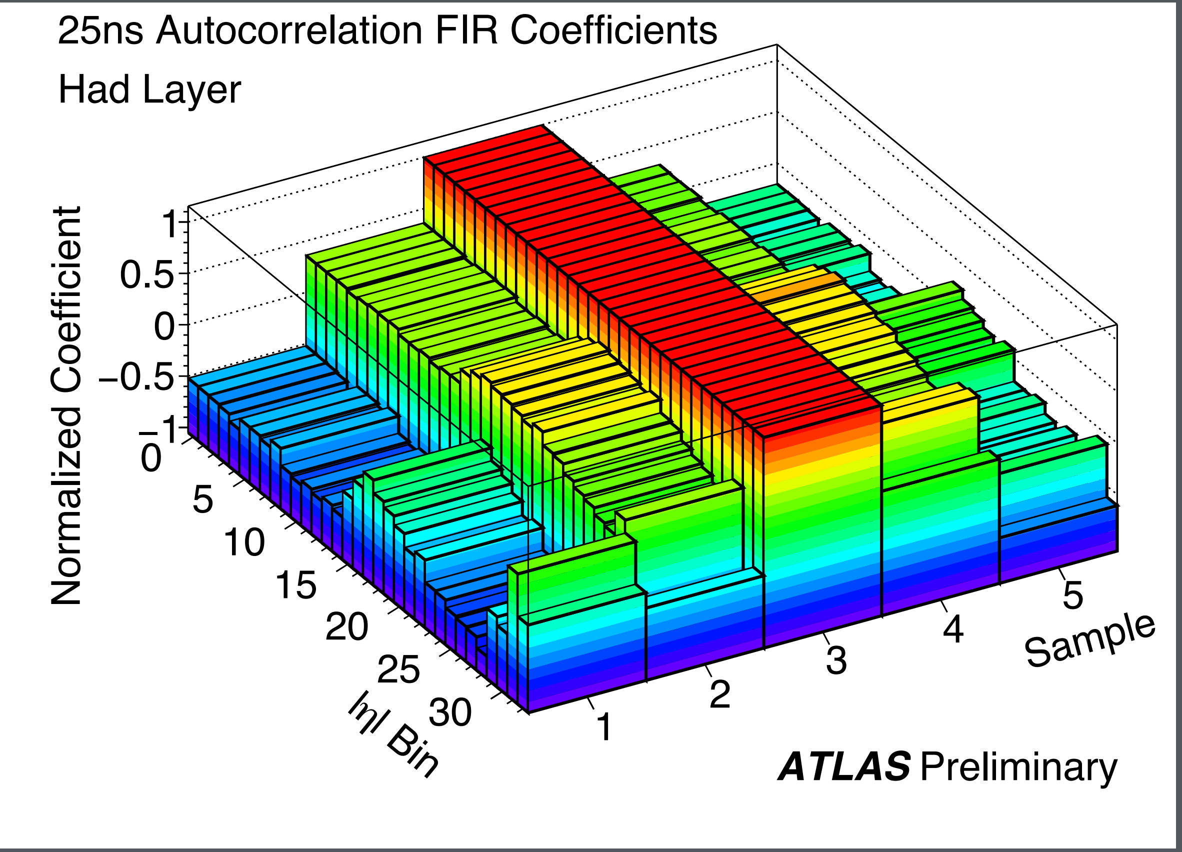
Derived from "Performance of the ATLAS Trigger System in 2015" arXiv: 1611.09661

Autocorrelation filter

Apply several techniques to mitigate pileup

- *Pedestal correction* Removes bunch train dependence
- ***Autocorrelation filter*** Removes sensitivity to previous bunches

Filter coefficients



- Negative coefficients reduce impact of out of time pileup

ATL-COM-DAQ-2015-150

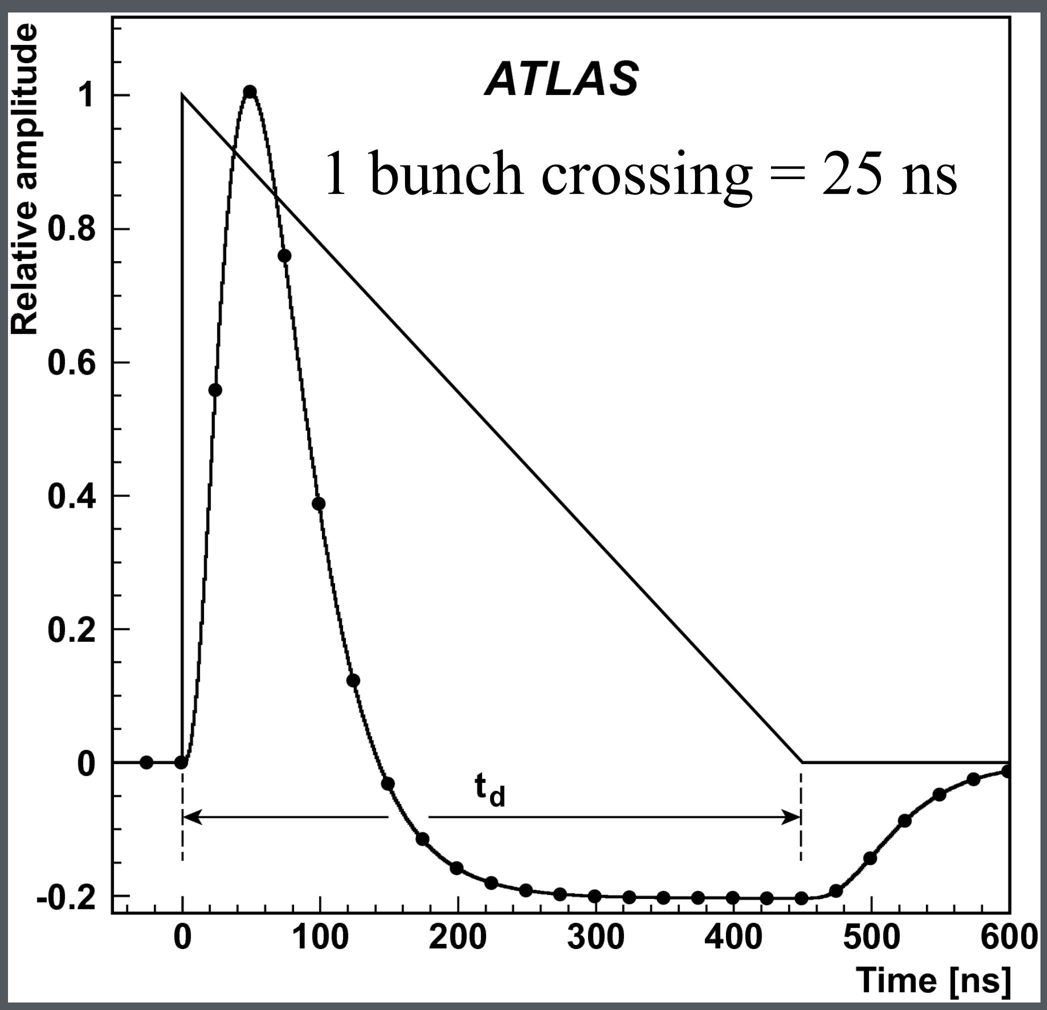
Dealing with pileup

Apply several techniques to mitigate *pileup*

multiple pp collisions per bunch crossing

- ***Pedestal correction*** Removes bunch train dependence
- *Autocorrelation filter* Removes sensitivity to previous bunches *(out of time pileup)*

Calorimeter pulse shape

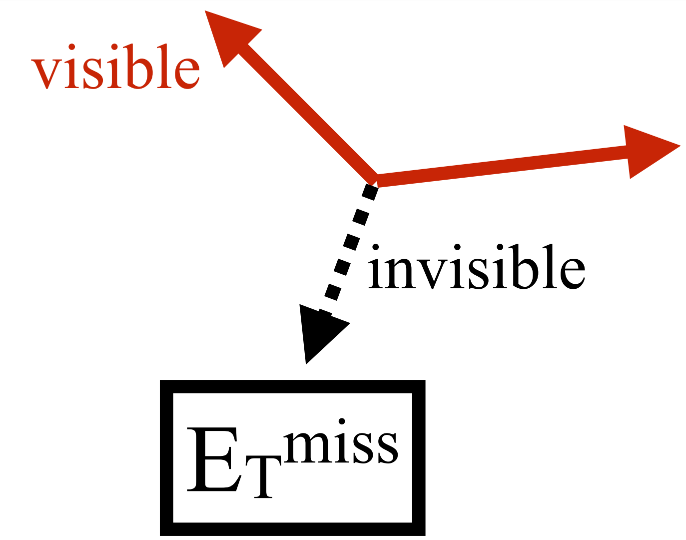


- Sum over 24 bunch crossings is 0: cancels out of time pileup
- Leading edge of pulse tends to increase trigger rate for first few bunches
- Pedestal correction removes this artifact
- Also corrects for differences in luminosity for each bunch

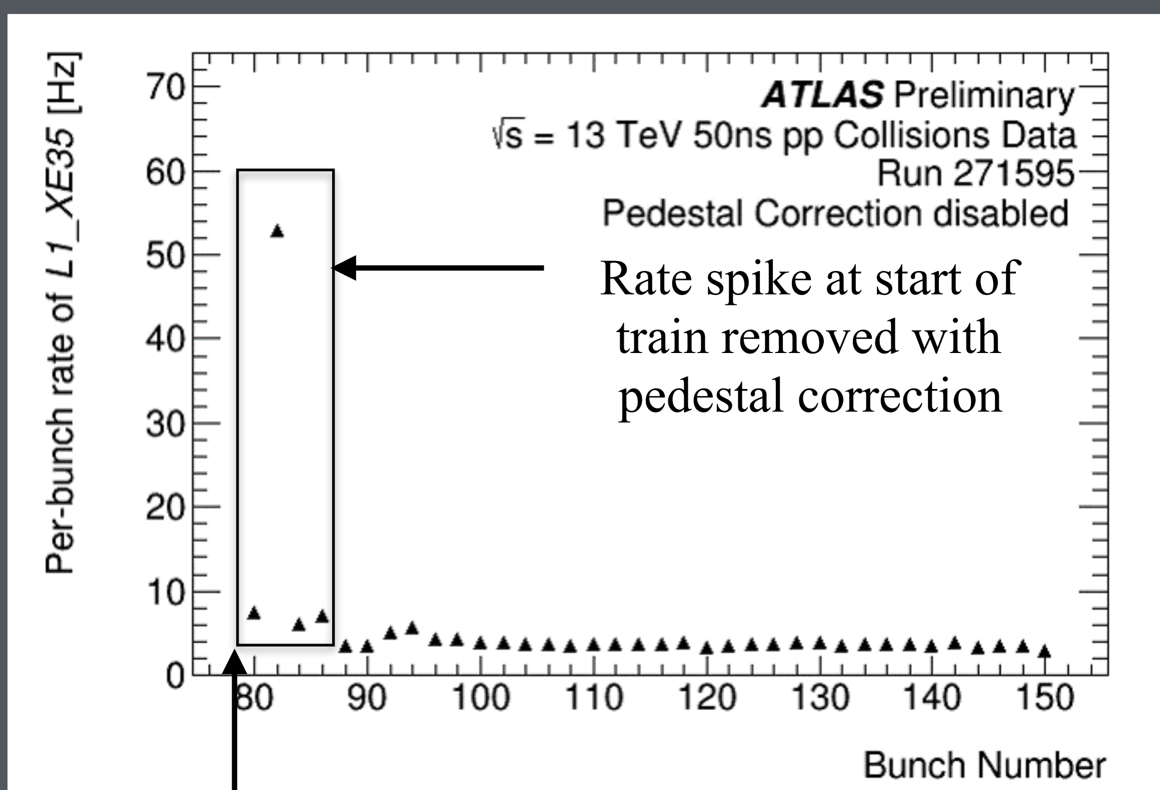
Pedestal correction: E_T^{miss}

E_T^{miss} trigger requires a pedestal correction

- Rate significantly higher for first few bunches
- Remove spike at start of bunch trains (left)
- Pedestal correction reduces exponential dependence on pileup (right)

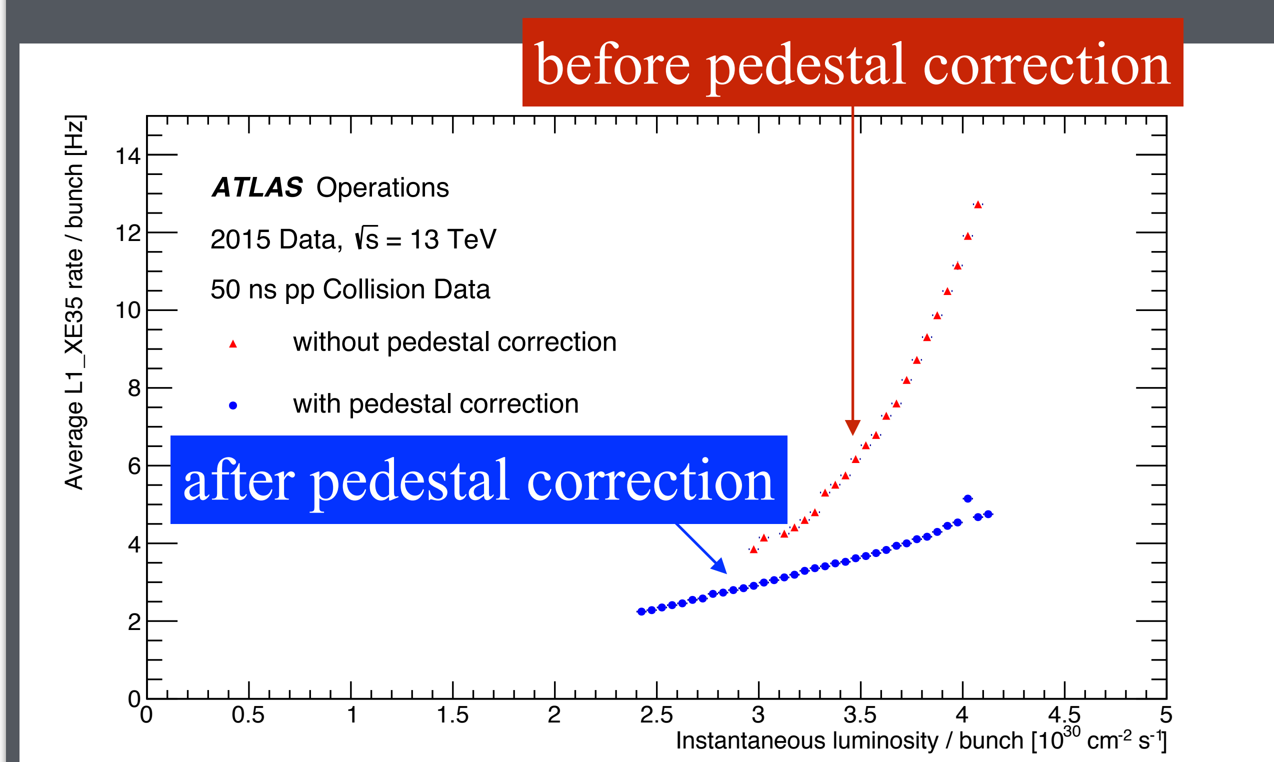


L1 rate vs. position in bunch train:
Rate rises at start of train



start of bunch train

Rate / bunch vs. pileup



luminosity ~ pileup

ATL-COM-DAQ-2015-150

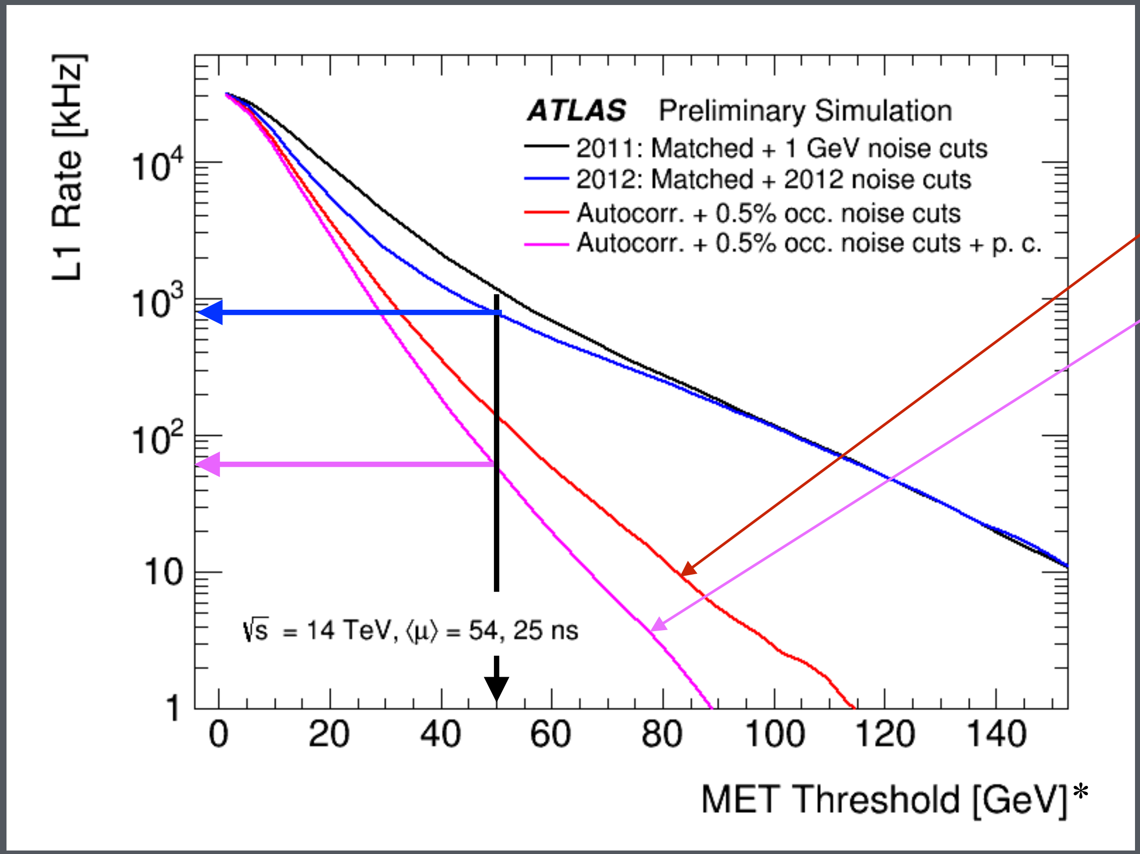
Impact of pileup mitigation

Apply several techniques to mitigate pileup

- *Pedestal correction* Removes bunch train dependence
- ***Autocorrelation filter*** Removes sensitivity to previous bunches

separate signal from pileup noise by deweighting previous bunches

L1 rate vs. E_T^{miss} threshold



**Threshold at L1 not equivalent to offline E_T^{miss}*

- Matched filter: 2011 settings
- Matched filter: 2012 settings
- Autocorrelation filter
- Autocorrelation filter + pedestal correction

- Autocorrelation and pedestal correction allow for *x*10 rate reduction

more on autocorrelation filter,
see Wikipedia!

ATL-COM-DAQ-2013-150

Trigger menu (2015)

Not a complete list..

Year	2012		2015		
$\sqrt{s}$	8 TeV		13 TeV		
Peak luminosity	7.7×10^{33} cm^{-2} s^{-1}		5.0×10^{33} cm^{-2} s^{-1}		
	p_T threshold [GeV], criteria				
Category	L1	HLT	L1	HLT	Offline
Single electron	18	24i	20	24	25
Single muon	15	24i	15	20i	21
Single photon	20	120	20	120	125
Single tau	40	115	60	80	90
Single jet	75	360	100	360	400
Single *b*-jet	n/a	n/a	100	225	235
E_T^{miss}	40	80	50	70	180
Dielectron	2×10	2×12,loose	2×10	2×12,loose	15
Dimuon	2×10	2×13	2×10	2×10	11
Electron, muon	10, 6	12, 8	15, 10	17, 14	19, 15
Diphoton	16, 12	35, 25	2×15	35, 25	40, 30
Ditau	15i, 11i	27, 18	20i, 12i	35, 25	40, 30
Tau, electron	11i, 14	28i, 18	12i(+jets), 15	25, 17i	30, 19
Tau, muon	8, 10	20, 15	12i(+jets), 10	25, 14	30, 15
Tau, E_T^{miss}	20, 35	38, 40	20, 45(+jets)	35, 70	40, 180
Four jets	4×15	4×80	3×40	4×85	95
Six jets	4×15	6×45	4×15	6×45	55
Two *b*-jets	75	35b,145b	100	50b,150b	60
Four(Two) (*b*-)jets	4×15	2×35b, 2×35	3×25	2×35b, 2×35	45
B-physics (Dimuon)	6, 4	6, 4	6, 4	6, 4	6, 4

From “Performance of the ATLAS Trigger System in 2015”
arXiv: 1611.09661

Trigger menu (2016)

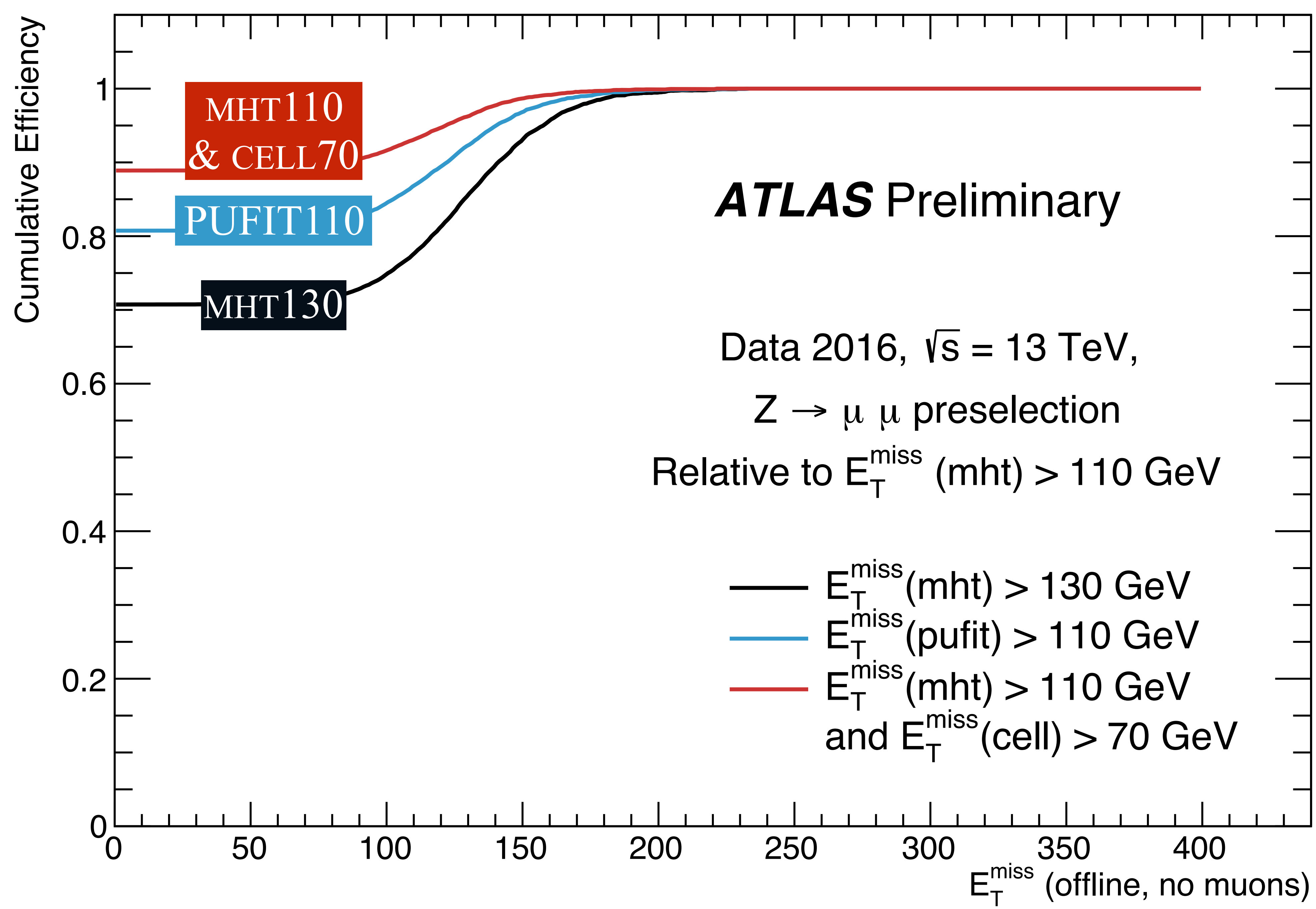
Not a complete list..

Trigger	Typical offline selection	Trigger Selection: Level-1 (GeV)	Trigger Selection: HLT (GeV)	Level-1 Peak Rate (kHz) $L = 1.2 \times 10^{34}$ cm^{-2}s^{-1}	HLT Peak Rate (Hz) $L = 1.2 \times 10^{34}$ cm^{-2}s^{-1}
Single leptons	Single isolated μ, $p_T > 27$ GeV	20	26 (i)	13	133
	Single isolated tight e, $p_T > 27$ GeV	22 (i)	26 (i)	20	133
	Single μ, $p_T > 52$ GeV	20	50	13	48
	Single e, $p_T > 61$ GeV	22 (i)	60	20	13
	Single τ, $p_T > 170$ GeV	60	160	5	15
Two leptons	Two μ's, each $p_T > 15$ GeV	2×10	2×14	1.5	21
	Two μ's, $p_T > 23, 9$ GeV	20	22, 8	13	30
	Two loose e's, each $p_T > 18$ GeV	2×15	2×17	8	7
	One e & one μ, $p_T > 8, 25$ GeV	20 (μ)	7, 24	13	2
	One loose e & one μ, $p_T > 18, 15$ GeV	15, 10	17, 14	1.5	2.6
	Two τ's, $p_T > 40, 30$ GeV	20 (i), 12 (i) (+jets)	35, 25	6	35
	One τ & one isolated μ, $p_T > 30, 15$ GeV	12 (i), 10 (+jets)	25, 14 (i)	1.5	7
	One τ & one isolated e, $p_T > 30, 18$ GeV	12 (i), 15 (i) (+jets)	25, 17 (i)	3	9
Three leptons	Three loose e's, $p_T > 18, 11, 11$ GeV	$15, 2 \times 8$	$17, 2 \times 10$	15	< 0.1
	Three μ's, each $p_T > 7$ GeV	3×6	3×6	0.1	3
	Three μ's, $p_T > 21, 2 \times 5$ GeV	20	$20, 2 \times 4$	13	4
	Two μ's & one loose e, $p_T > 2 \times 11, 13$ GeV	2×10 (μ's)	$2 \times 10, 12$	1.5	0.2
	Two loose e's & one μ, $p_T > 2 \times 13, 11$ GeV	$2 \times 8, 10$	$2 \times 12, 10$	1.1	0.1
One photon	One loose γ, $p_T > 145$ GeV	22 (i)	140	20	30
Two photons	Two loose γ's, $p_T > 40, 30$ GeV	2×15	35, 25	8	40
	Two tight γ's, $p_T > 27, 27$ GeV	2×15	2×22	8	16
Single jet	Jet ($R = 0.4$), $p_T > 420$ GeV	100	380	3	38
	Jet ($R = 1.0$), $p_T > 460$ GeV	100	420	3	35
E_T^{miss}	$E_T^{miss} > 200$ GeV	50	110	6	230
Multi-jets	Four jets, each $p_T > 110$ GeV	3×50	4×100	0.4	18
	Five jets, each $p_T > 80$ GeV	4×15	5×70	3.5	14
	Six jets, each $p_T > 70$ GeV	4×15	6×60	3.5	5
	Six jets, each $p_T > 55$ GeV, $\|\eta\| < 2.4$	4×15	6×45	3.5	18
b−jets	One b ($\epsilon = 60\%$), $p_T > 235$ GeV	100	225	3	24
	Two b's ($\epsilon = 60\%$), $p_T > 160, 60$ GeV	100	150, 50	3	20
	One b ($\epsilon = 70\%$) & three jets, each $p_T > 85$ GeV	4×15	4×75	3.5	19
	Two b ($\epsilon = 60\%$) & one jet, $p_T > 65, 65, 110$ GeV	$2 \times 20, 75$	$2 \times 55, 100$	2.7	25
	Two b ($\epsilon = 60\%$) & two jets, each $p_T > 45$ GeV	4×15	4×35	3.5	56
b−physics	Two μ's, $p_T > 6, 6$ GeV plus dedicated b-physics selections	6, 6	6, 6	4.7	20
Total				85	1500

ATL-COM-DAQ-2017-001

Comparison of E_T^{miss}

Comparison of efficiency for various E_T^{miss} algorithms



E_T^{miss} at HLT: methods

E_T^{miss} algorithms

- *mht* Vector sum of pileup-corrected jets with $E_T > 7$ GeV *(threshold at uncalibrated scale)*
- *cell* Calorimeter cells with cut on energy significance *s* *($s > 2$, $-5 < s < -2$)*
- *topocluster* Start with seed, add neighbors, then add their neighbors
- *pueta* p.u. sub. from density in η rings
- *pufit* p.u. sub. by χ^2 fit*

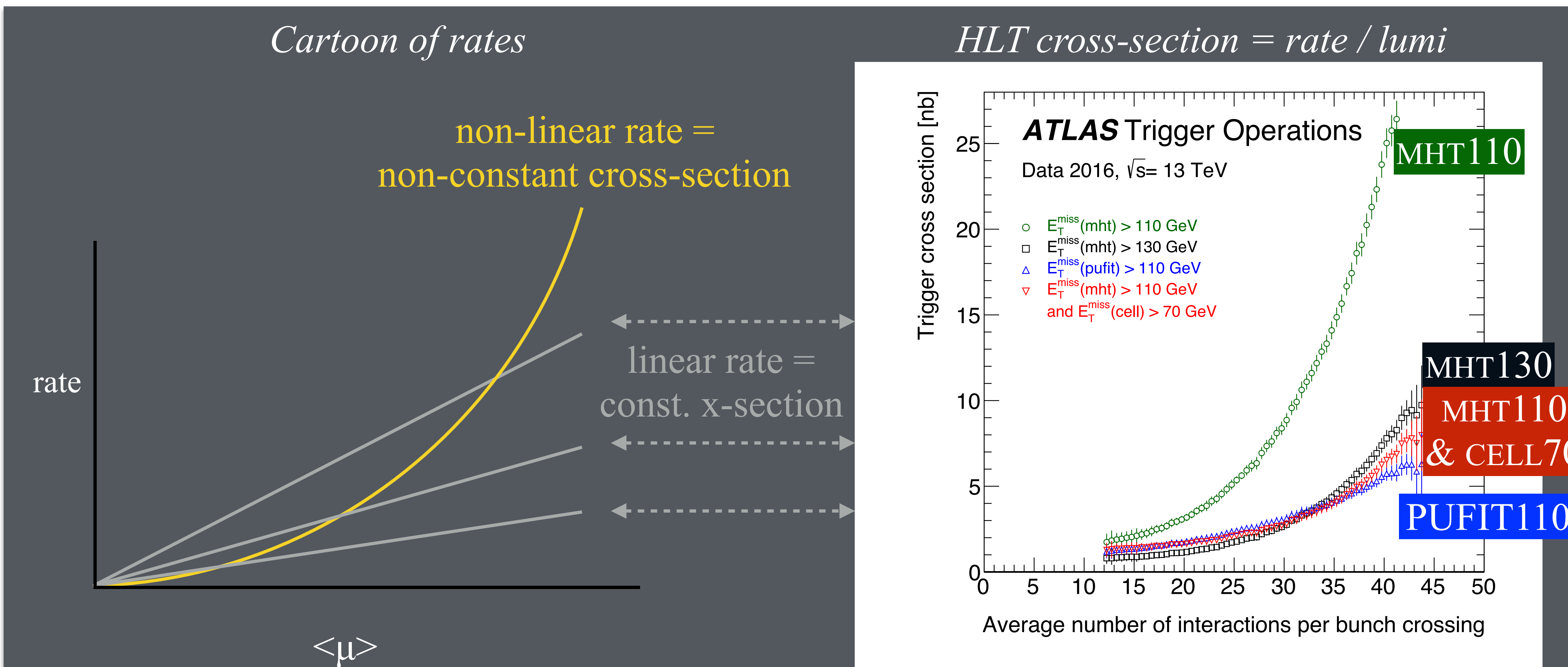
*Forces no E_T^{miss} from towers < threshold

From "Performance of the ATLAS Trigger System in 2015" arXiv: 1611.09661

Trigger cross section

Rates

- Conceptually, linear rate v. <μ> means “no pileup dependence,” see left cartoon
- Rates show non-linear <μ> dependence, see right plot



arXiv: 1603.02934

Forming topoclusters

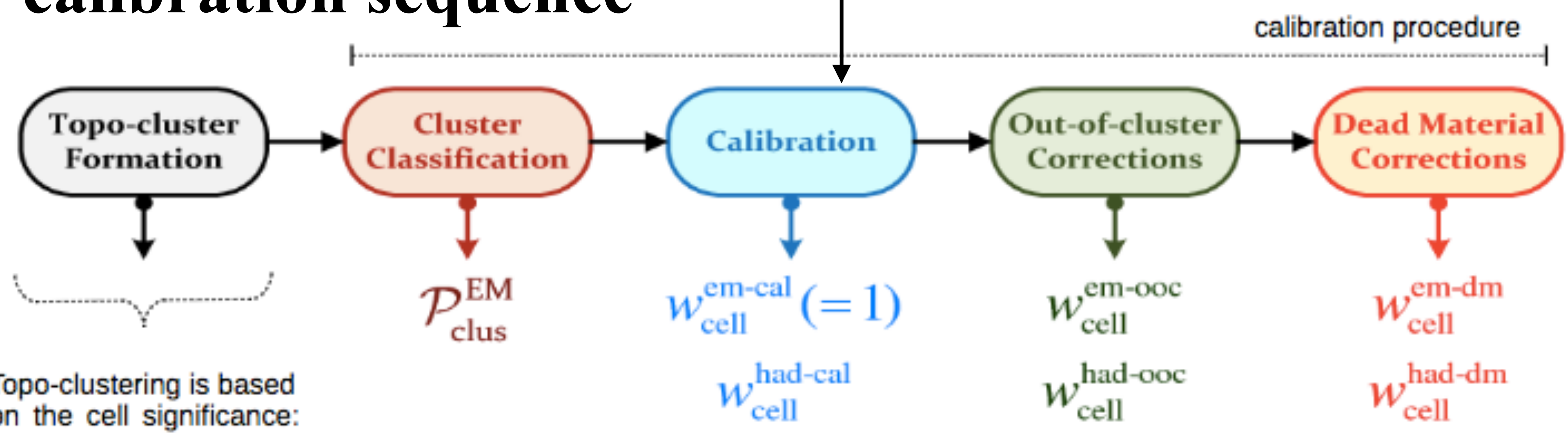
- Topoclusters: inputs for jets and E_T^{miss}
- **Same as offline: made for every event**

Iterative algorithm: 4/2/0
1. Seed: $|E| > 4\boldsymbol{\sigma}$
2. Add neighbors: $|E| > 2\boldsymbol{\sigma}$
3. Add cells on perimeter: $|E| > 0\boldsymbol{\sigma}$

$\boldsymbol{\sigma}$: *noise from electronics + pileup*

see event display

LCW calibration sequence



Corrects: *calorimeter response, losses in clustering, dead material*

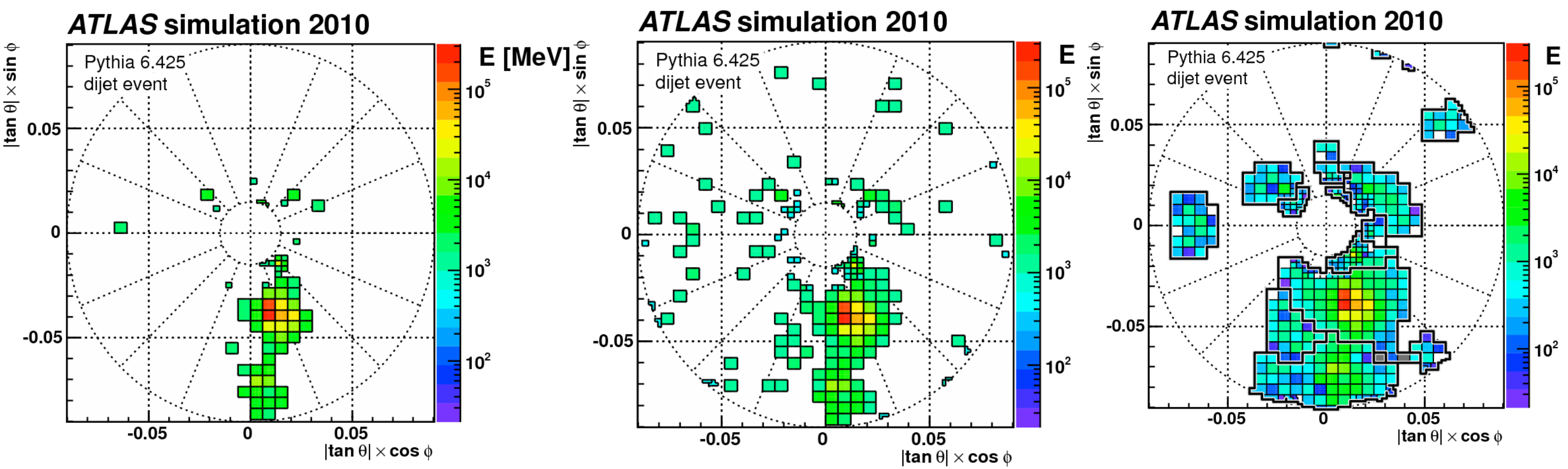
arXiv: 1603.02934

Forming topoclusters

- Sequential algorithm to combine cells
- Projection in one layer of FCAL

σ defined by *electronics* + *pileup* noise

Seed + neighbors ++ neighbors

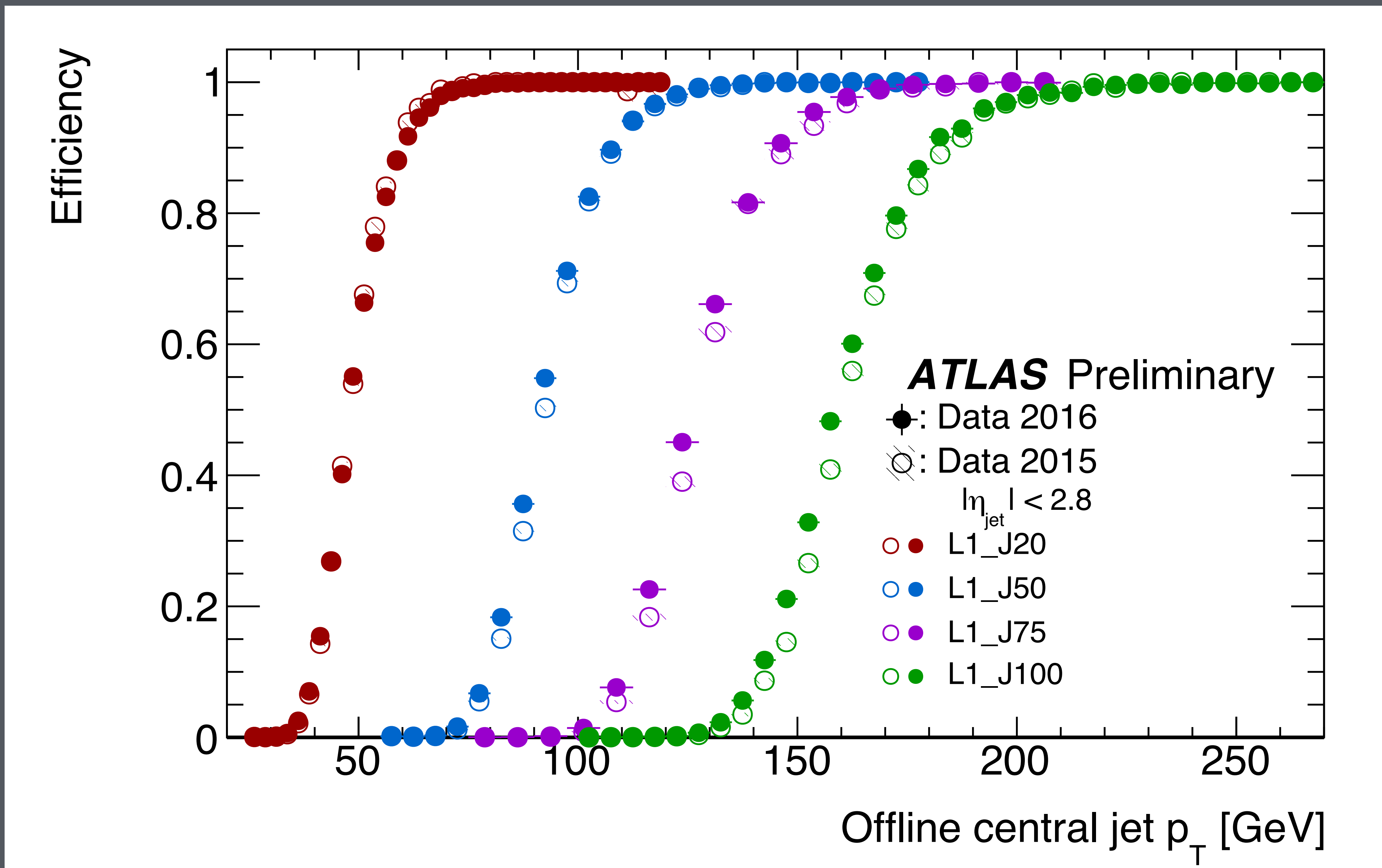


|E| > 4**σ** 2**σ** 0**σ**

Illustration of 4/2/0 scheme (can change thresholds)

L1 jet trigger efficiency

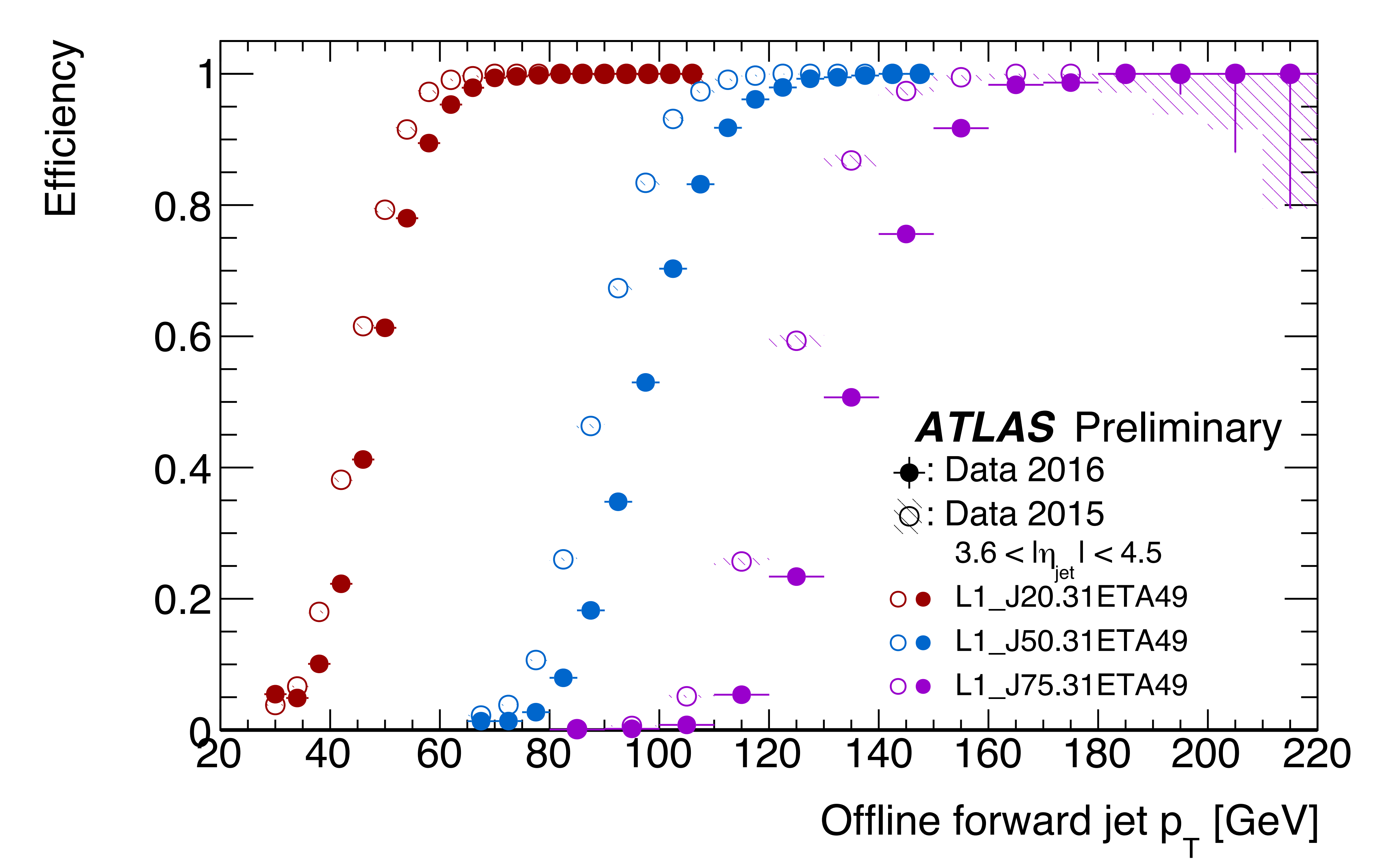
Turn-on curve for jet trigger



ATL-COM-DAQ-2016-087 (link)

L1 forward jet trigger efficiency

Turn-on curve for jet trigger



ATL-COM-DAQ-2016-087 (link)

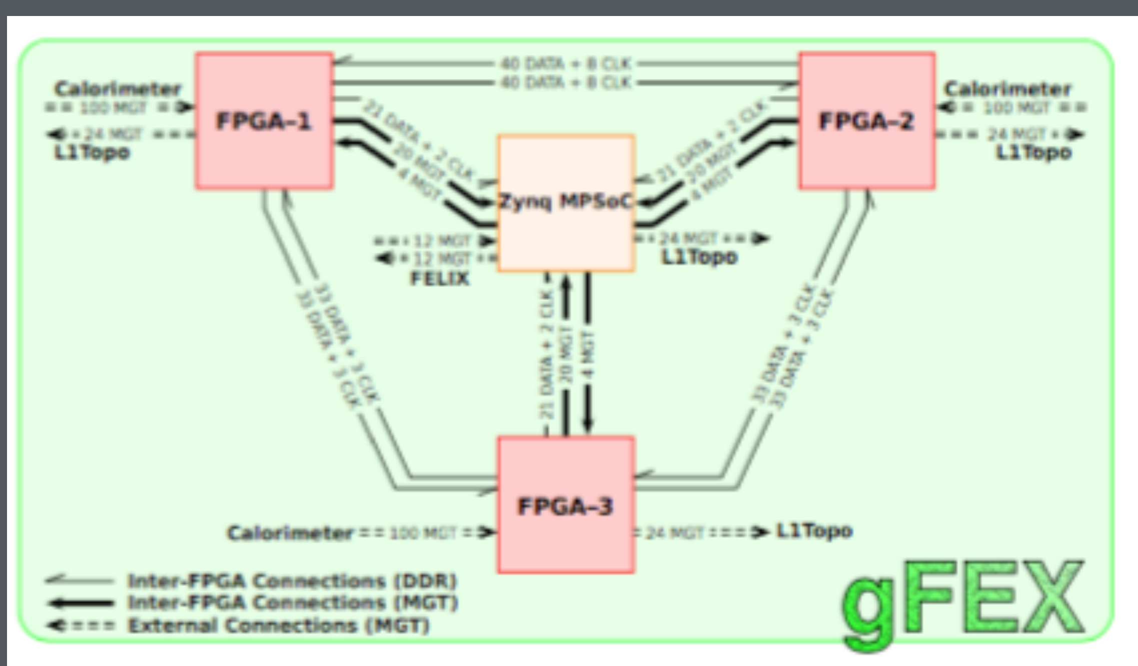
gFEX architecture

Global feature extractor: single board targeting boosted jets

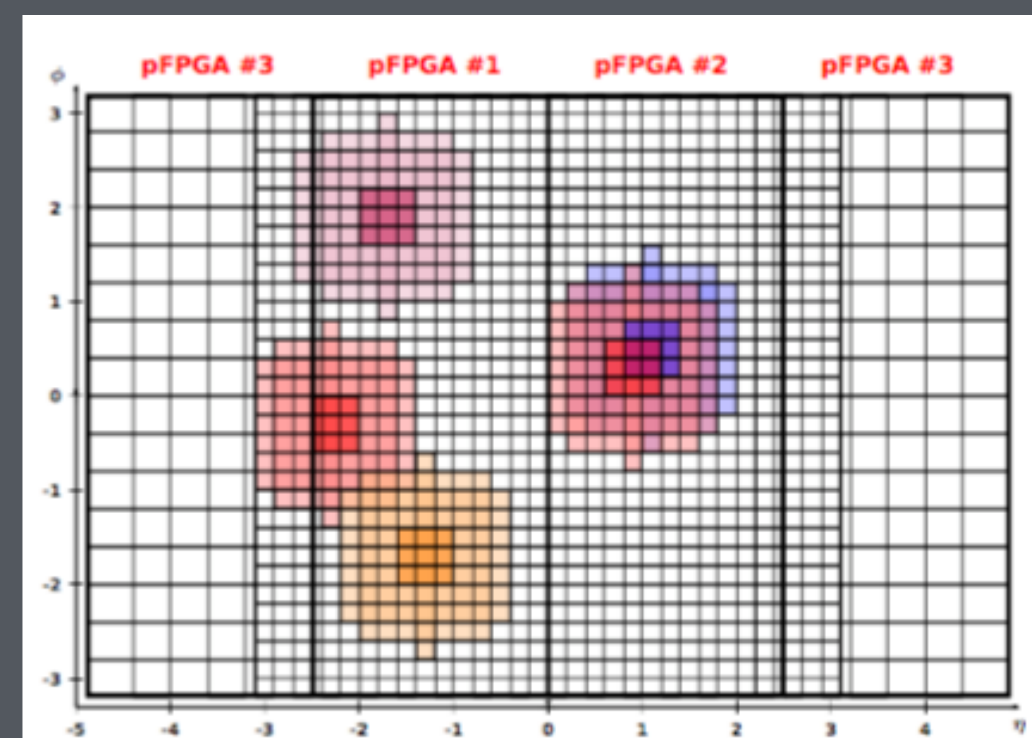
Details

- Detector split into three FPGAs
- Jet algorithm: like a cone jet
- Global variables: H_T, E_T^{miss}

gFEX layout



Event display



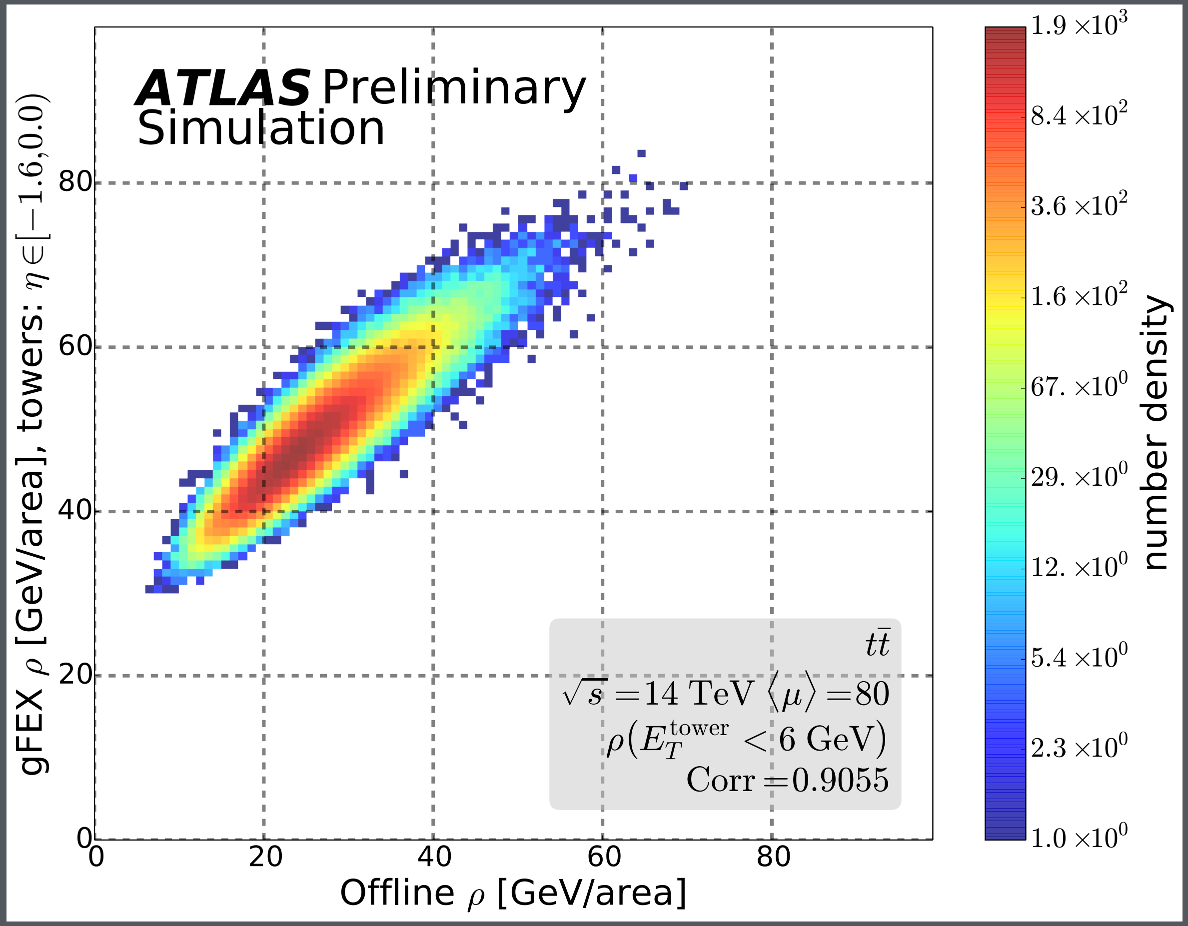
ATL-DAQ-PROC-2015-059

Large radius jets

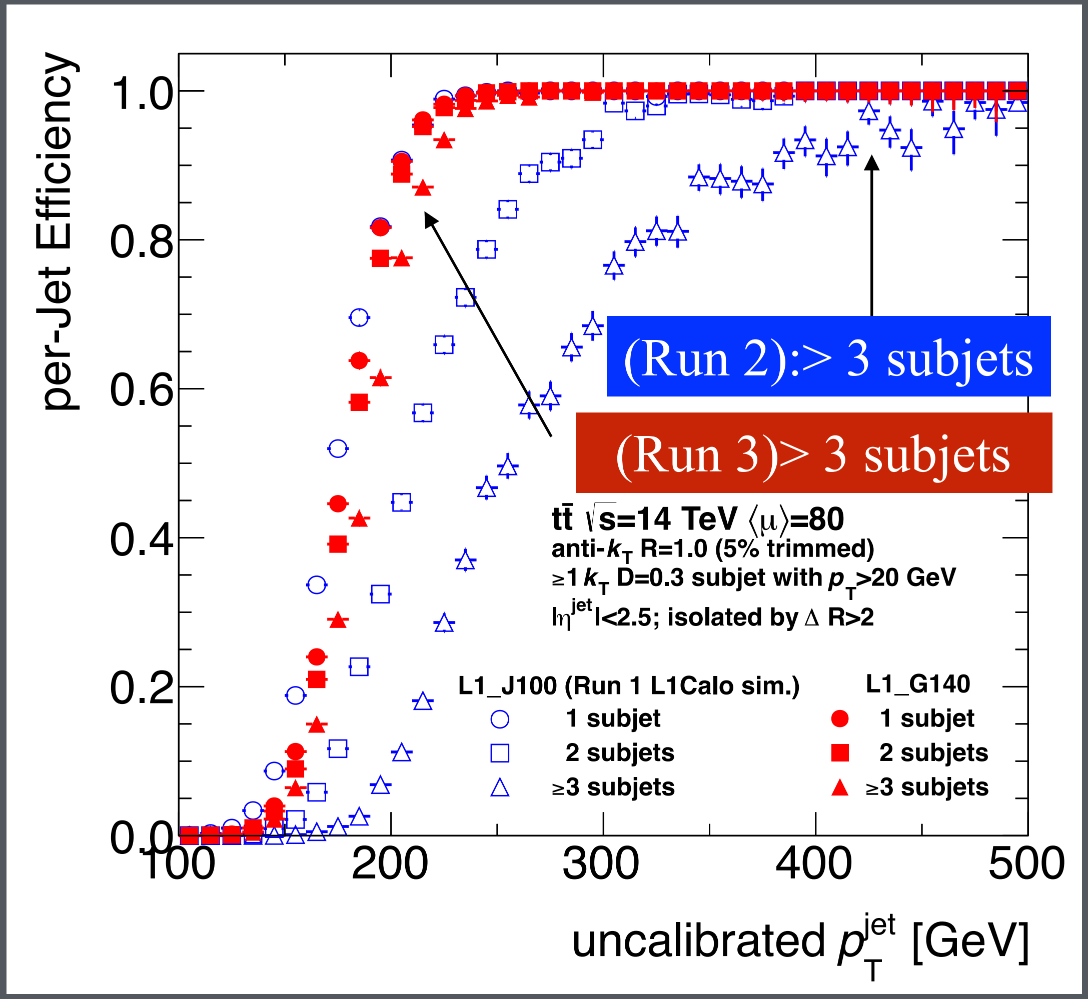
Global feature extractor: single board targeting boosted jets

- Event by event pileup subtraction: allow for lower rates at high pileup (left)
- Larger radius jets to trigger efficiently on boosted jets (right)

Online energy density (ρ) vs. offline ρ



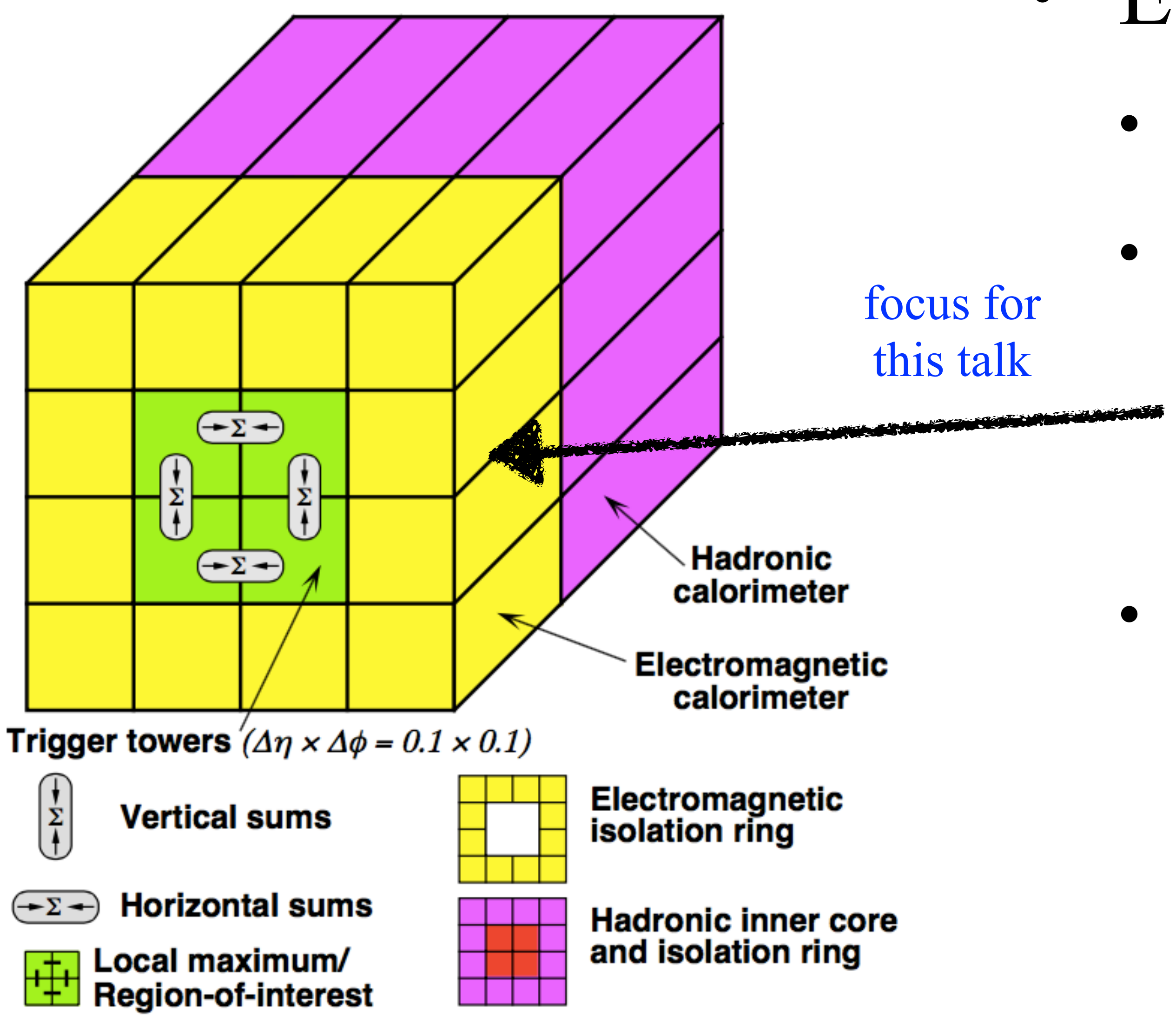
Turn-on curve for boosted jet trigger



ATL-COM-DAQ-2014-087

L1Calo EM algorithms

- Trigger towers (TT): $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$
- EM RoIs constructed using a sliding window algorithm over 4x4 TT



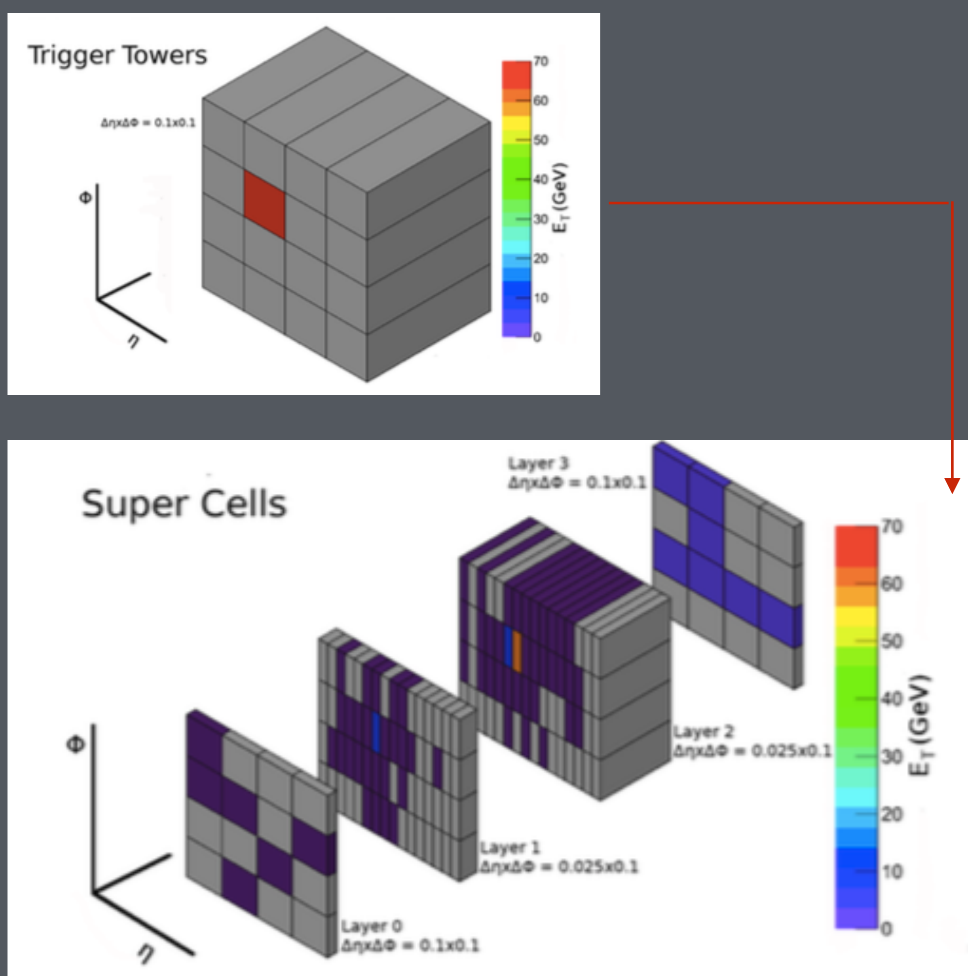
- Each EM RoI characterized by:
  - Core E_T
  - EM **isolation**
    - **Ring:** E_T in EM layer, 1 TT ring around core
  - Hadronic **isolation**
    - **Core**: E_T in hadronic layer behind core
    - **Ring**: E_T in hadronic layer, 1 TT ring around core

Improved run 3 resolution

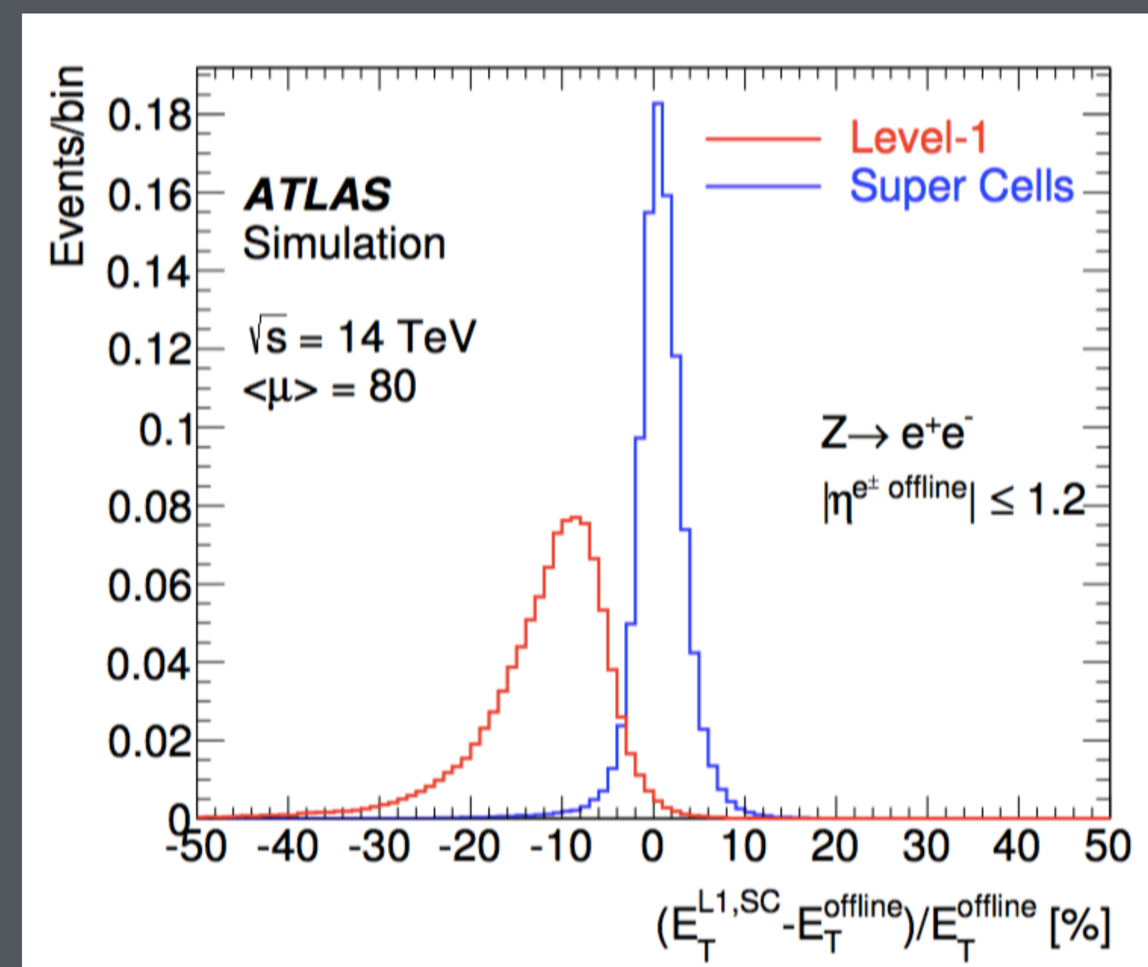
High granularity to improve resolution

- *Trigger tower resolution: 0.1 x 0.1*
- *Supercell resolution 0.025 x 0.1 (depending on layer)*

Granularity improvement

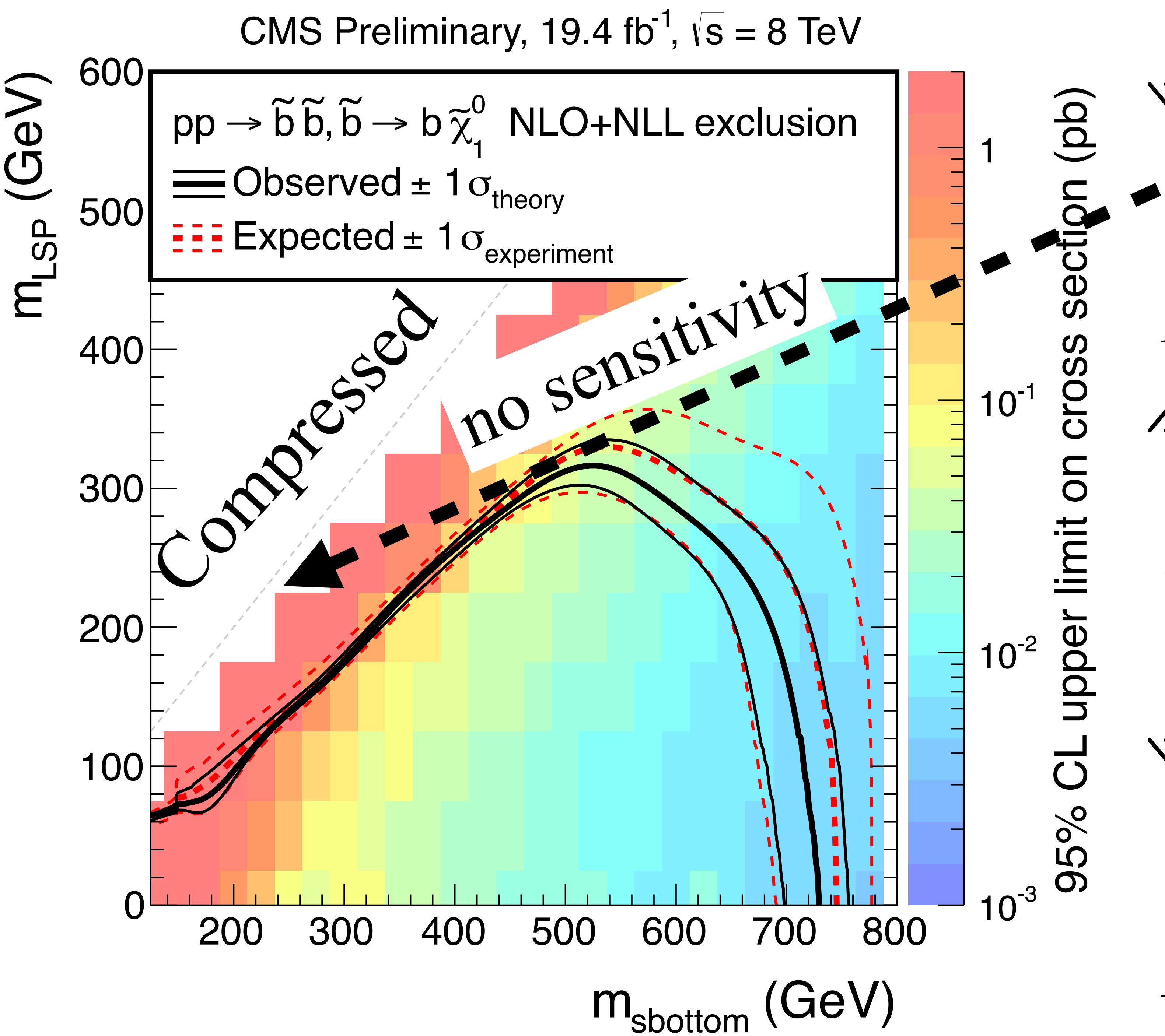


Resolution improves: higher granularity

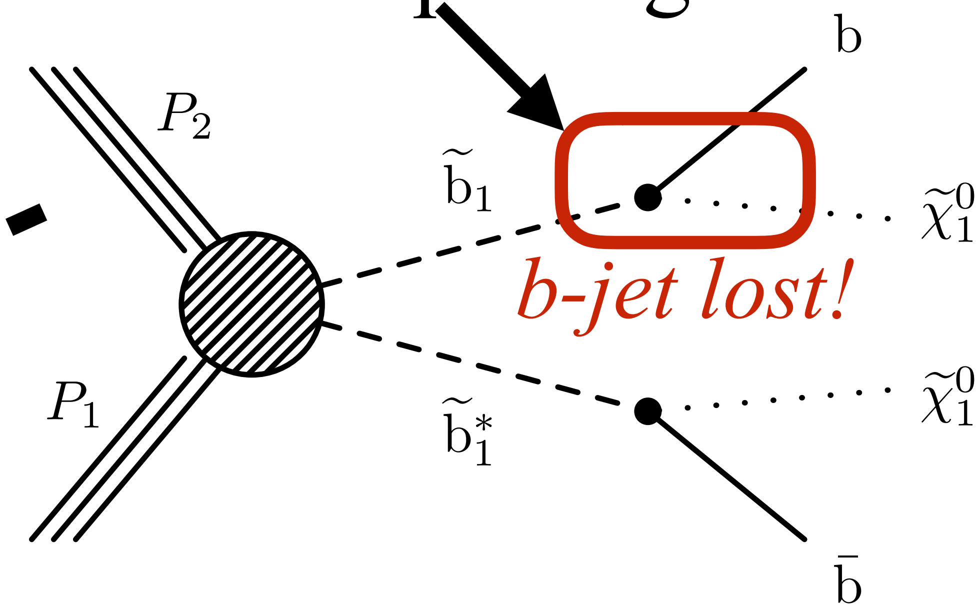


<u>ATLAS-TDR-022</u>

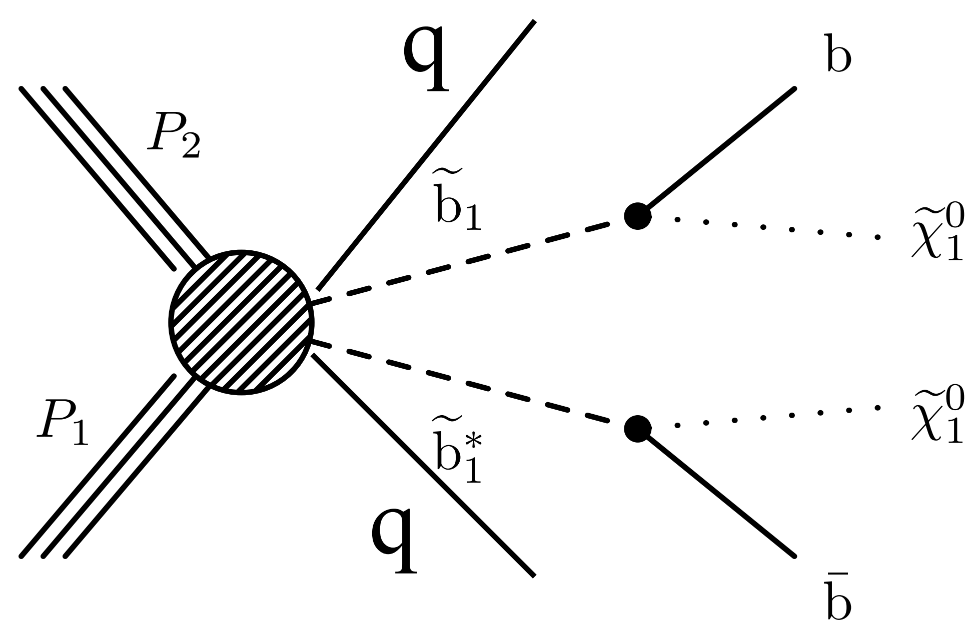
Compressed SUSY



Mass splitting ~5 GeV



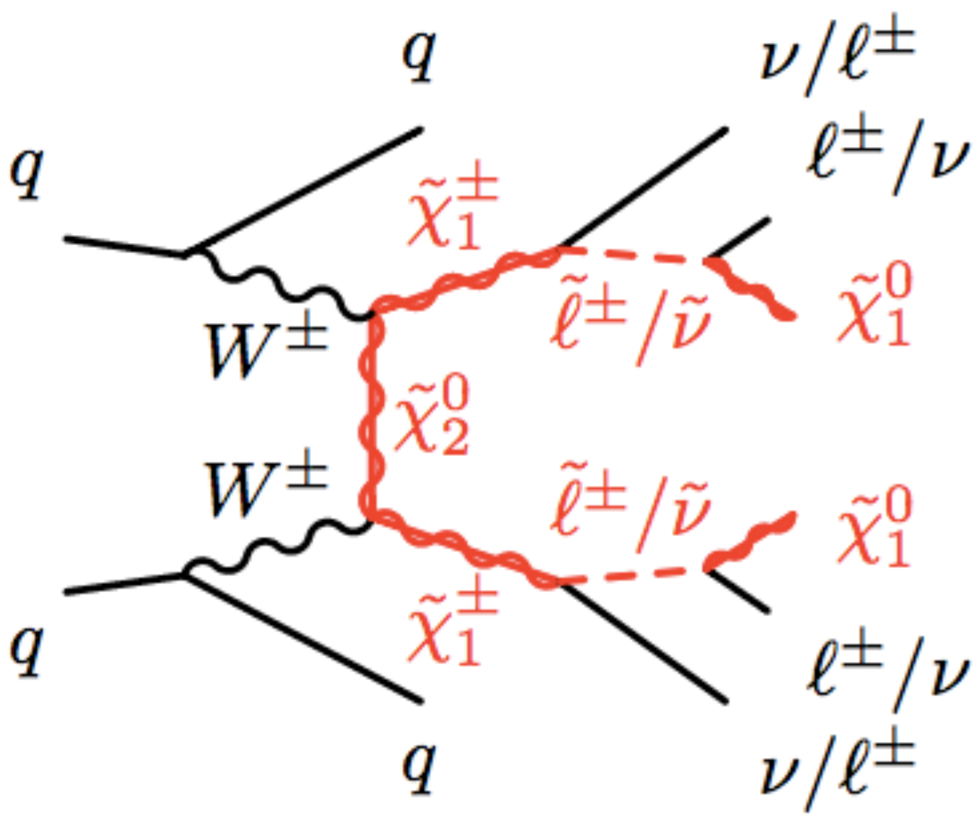
Consider VBF production

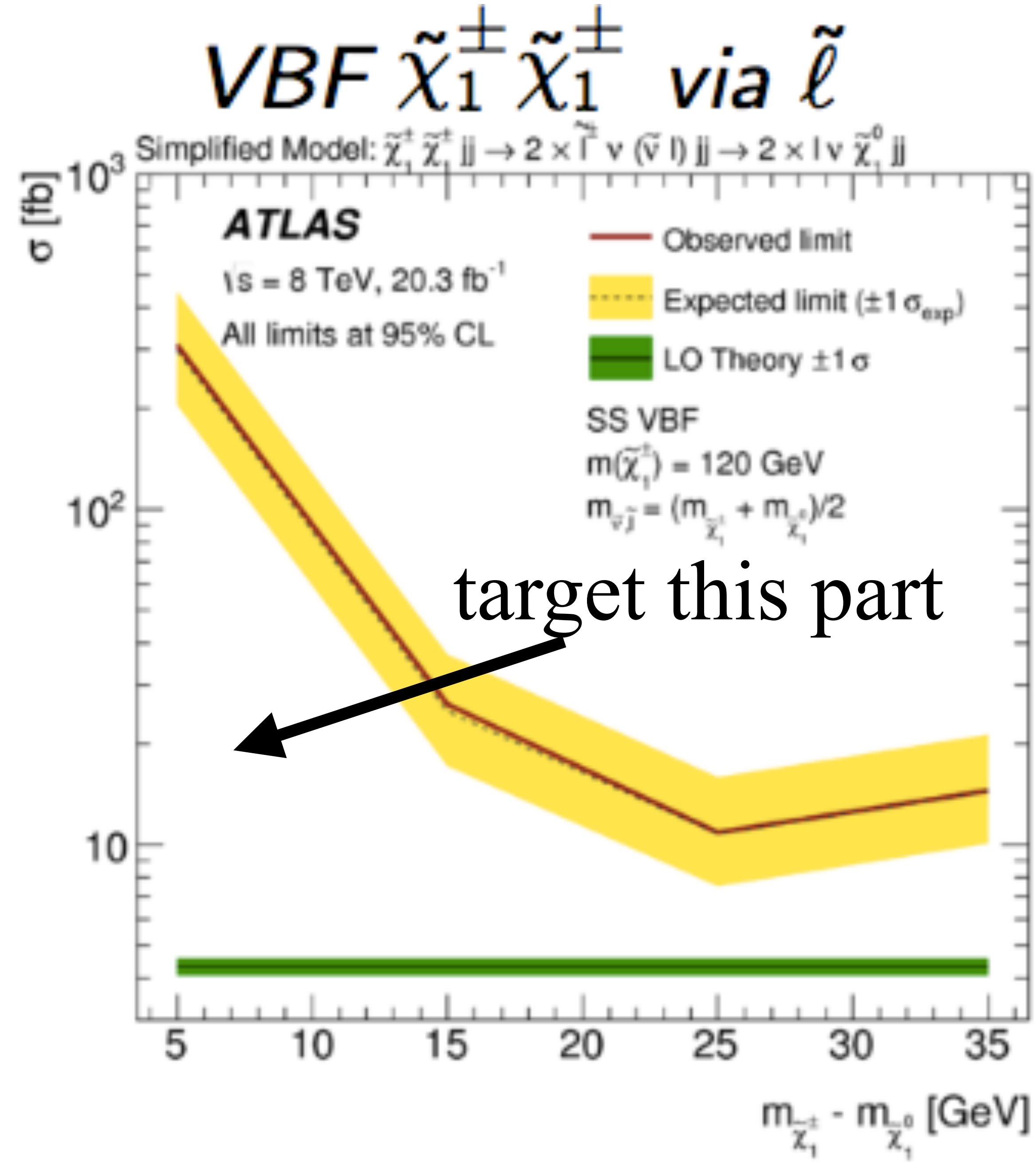


- Sensitivity by **VBF invisible**?

Direct EW SUSY: charged

VBF production

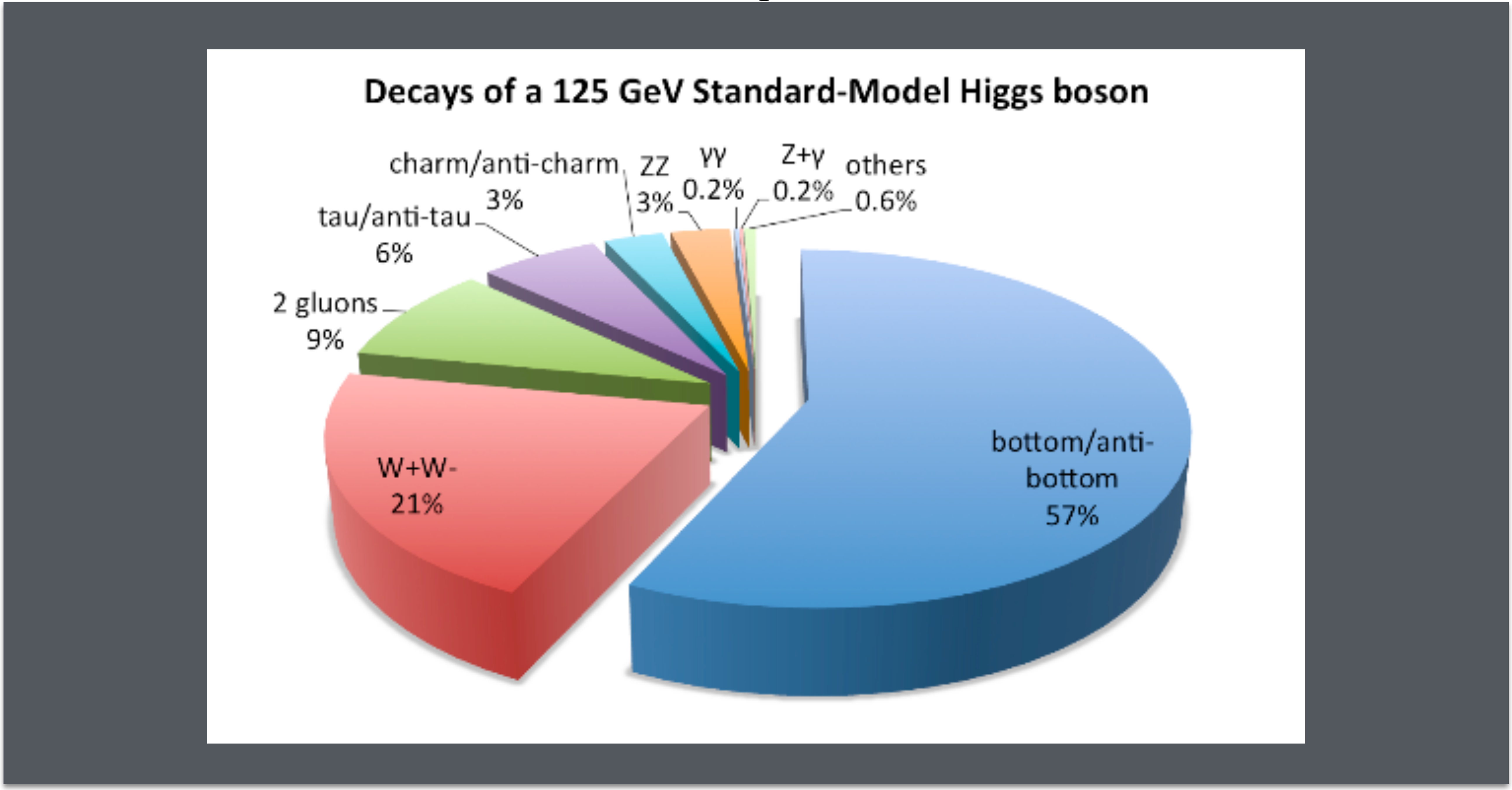




- Currently sensitive for the case where leptons missed?

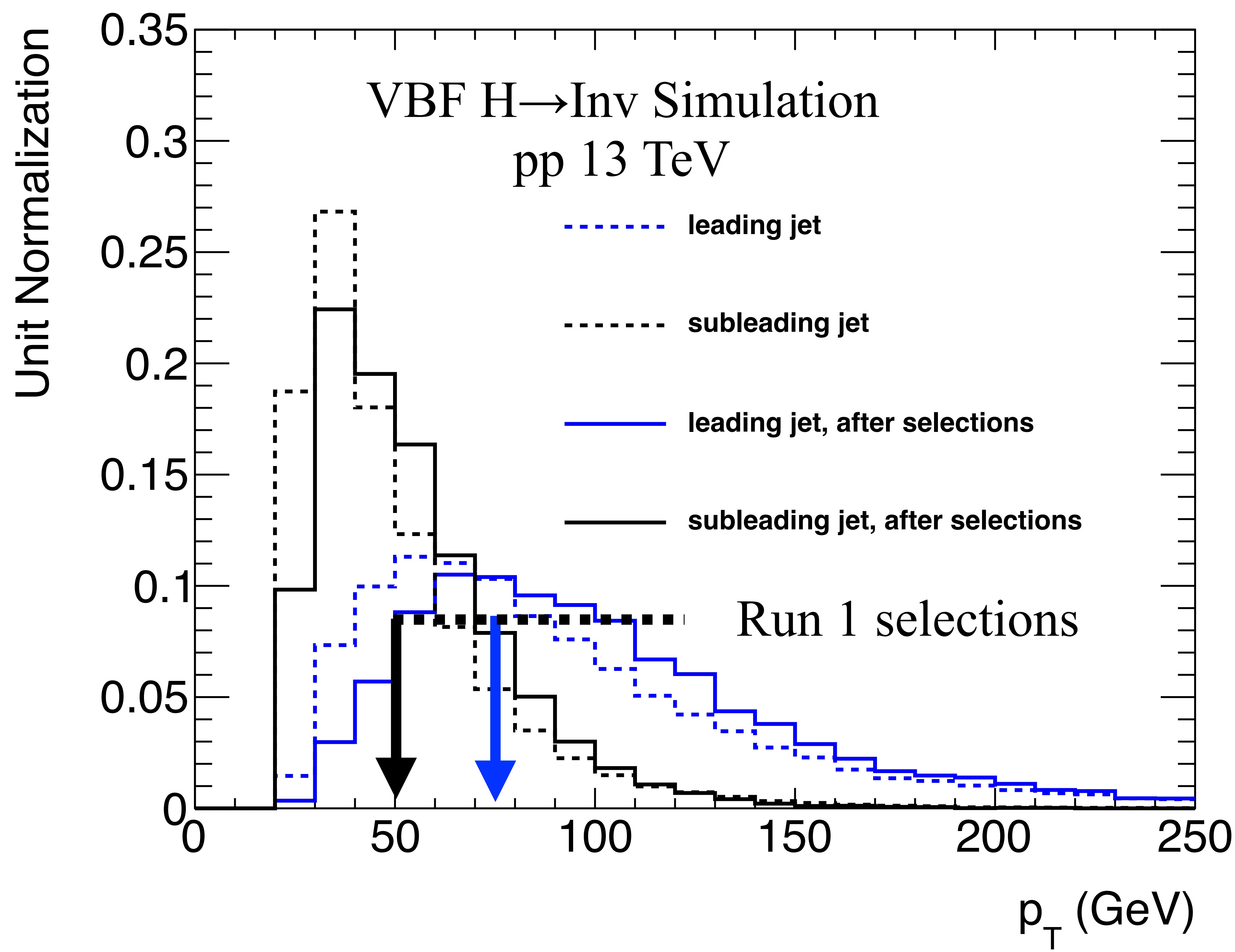
Decay modes

Branching fraction



p_T distribution of VBF jets

Jet p_T distribution for VBF tag jets

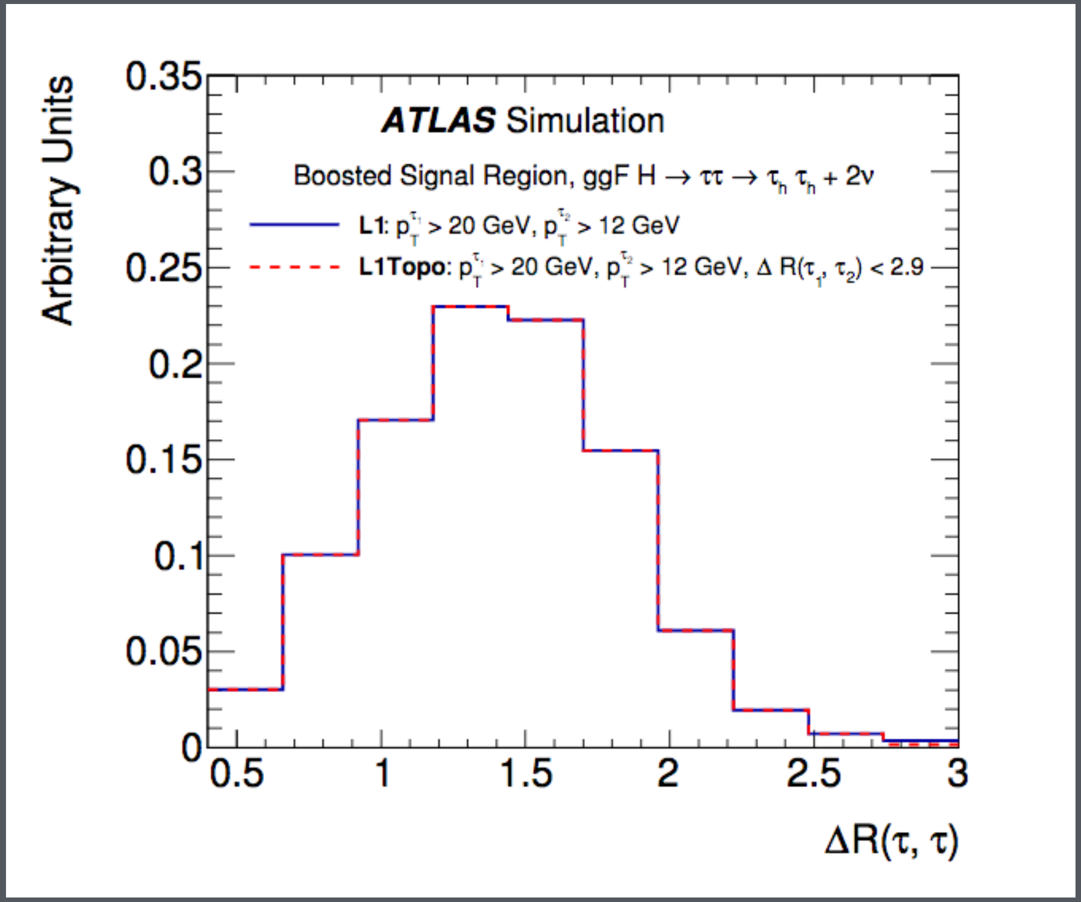


ΔR(τ,τ) efficiency

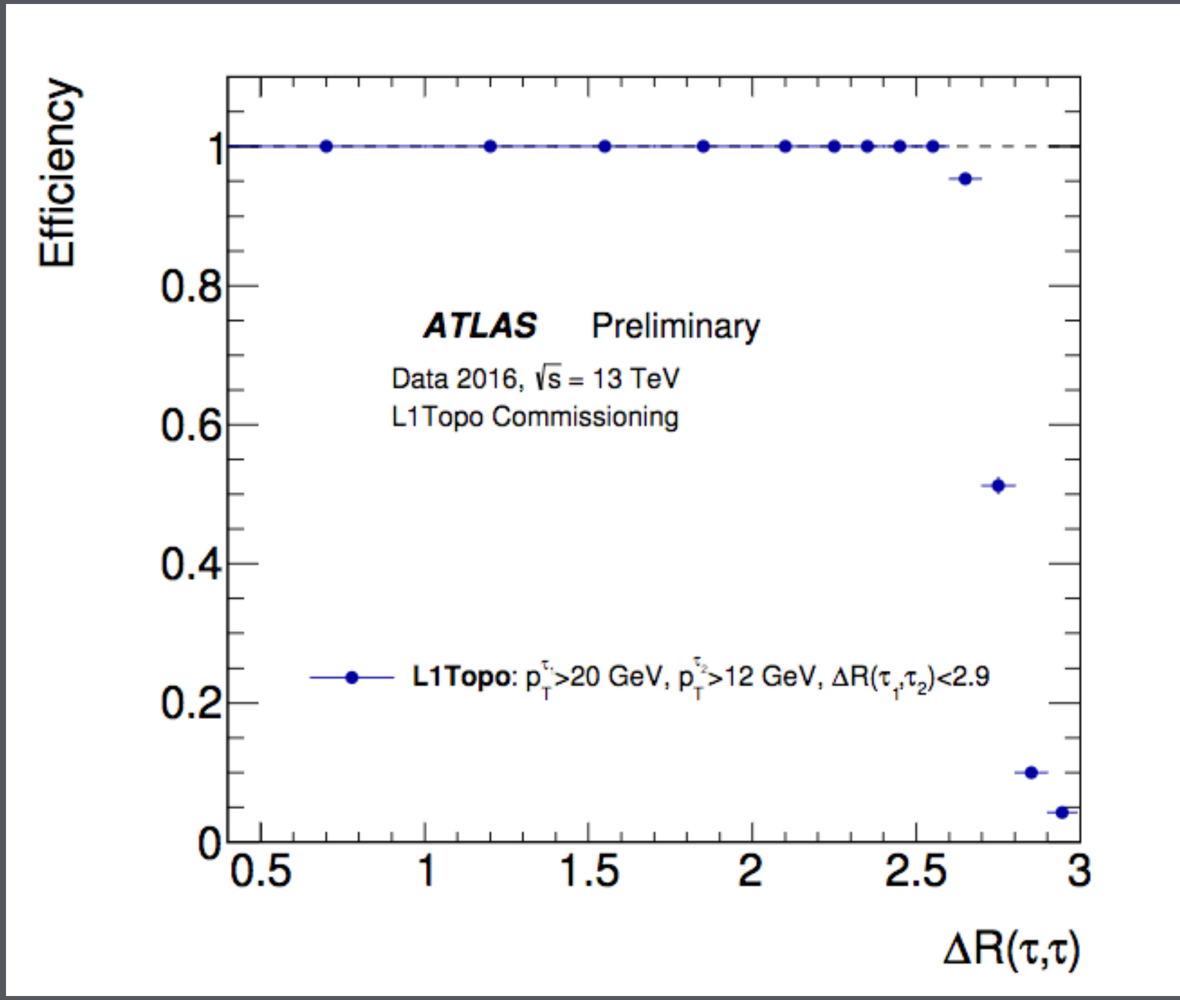
Impact of additional L1 requirements

- Excellent signal efficiency after offline requirements for H→ττ (left)
- L1 signal efficiency for ΔR(τ,τ) is fairly sharp (right)

Signal efficiency for H→ττ after cuts not impacted by ΔR(τ,τ) requirement



Efficiency of ΔR(τ,τ) requirement at L1



Trilinear self-coupling limits

3000 fb^{-1}

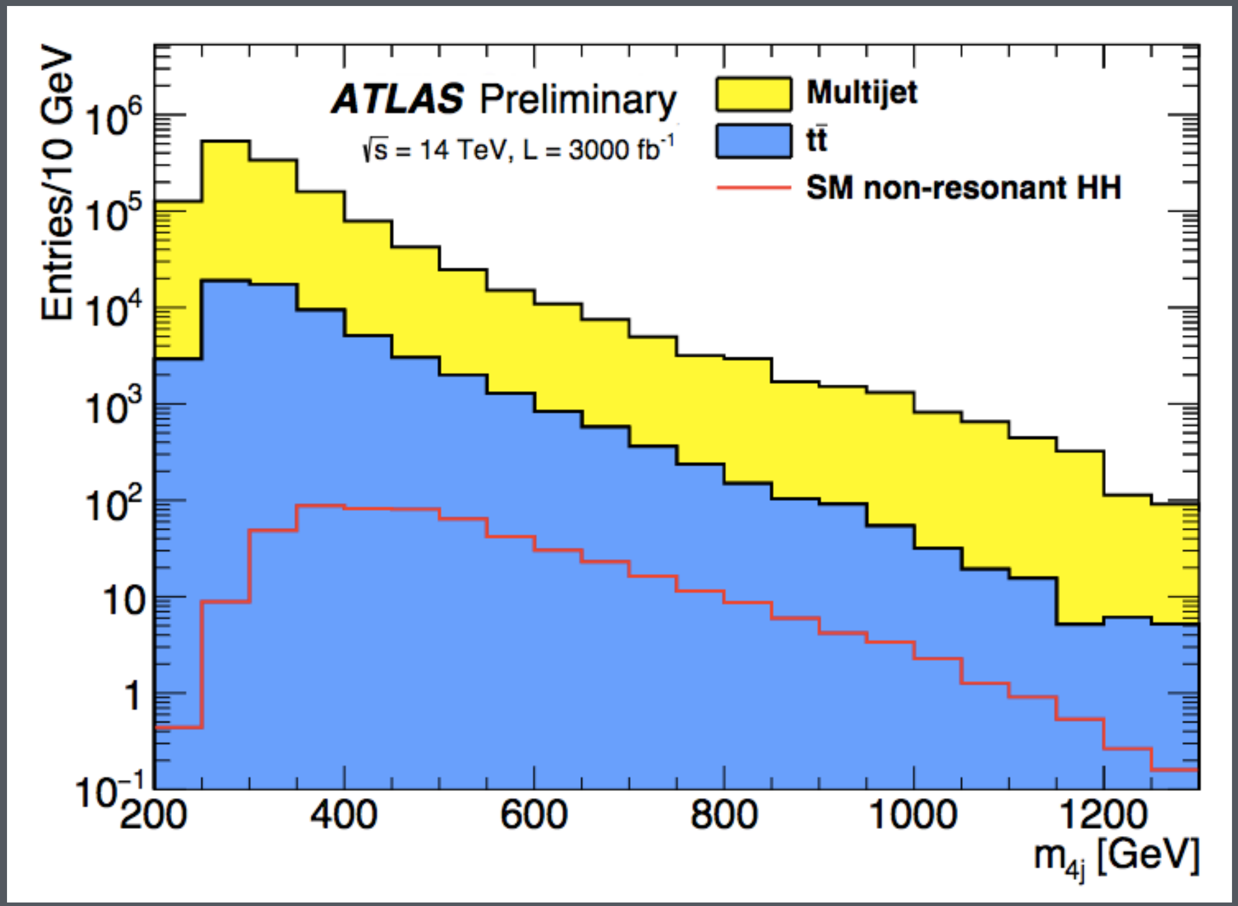
Decay	Br (%)	Yield	limit λ/λ_{SM}	Documentation
bb(bb)	33	40000	-3.5 - 11	ATL-PHYS-PUB-2016-024 (link)
bb(WW)	25	31000		-
bb($\tau\tau$)	7.3	8900	-4 - 12	ATL-PHYS-PUB-2015-046 (link)
ZZ(bb)	3.1	3800		
WW($\tau\tau$)	2.7	3300		-
ZZ(WW)	1.1	1300		
$\gamma\gamma$(bb)	0.26	320	-1 - 7	ATL-PHYS-PUB-2017-001 (link)
$\gamma\gamma$($\gamma\gamma$)	0.001	1.2		-

HH→4b

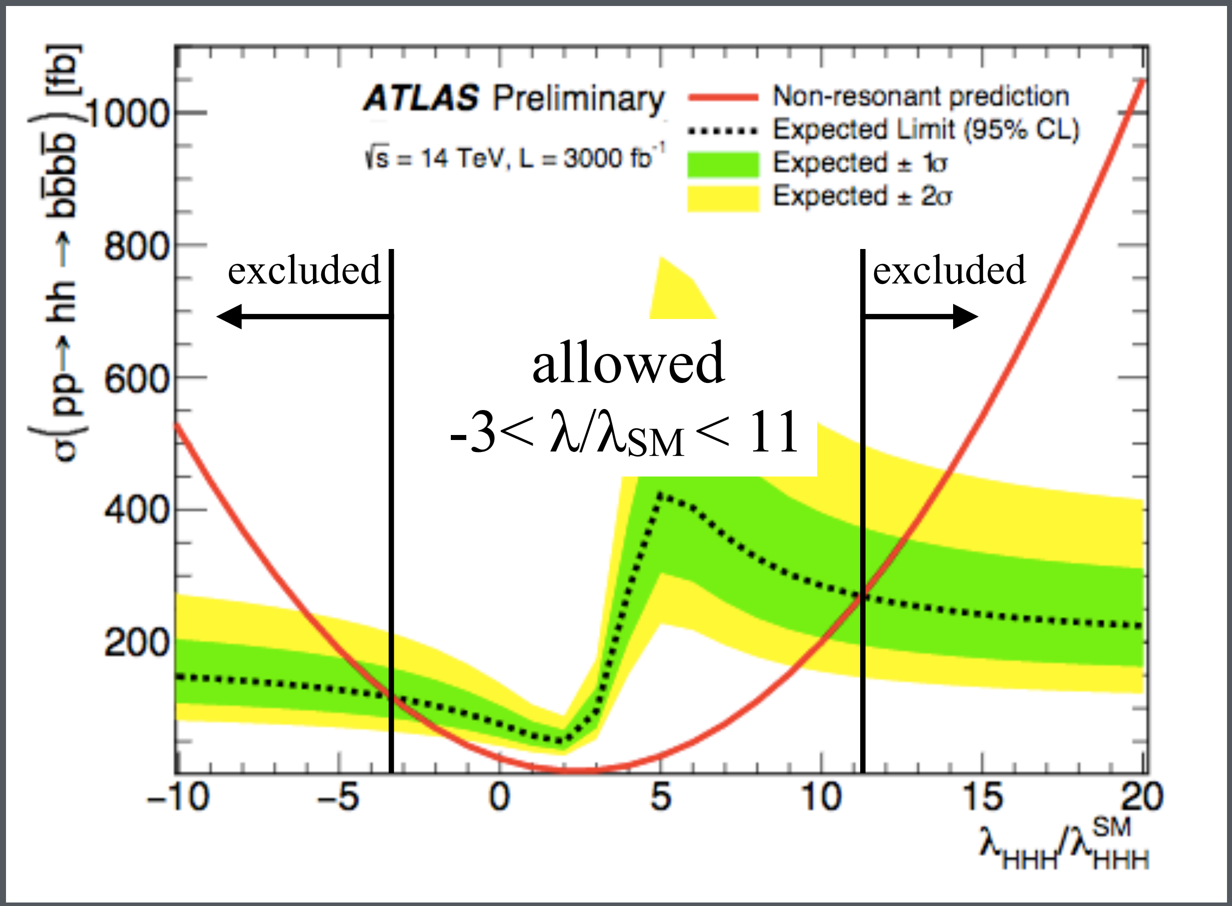
Run 2 extrapolation to $3ab^{-1}$

- Multijet background difficult to estimate (used data)
- Investigate various assumptions on background systematics and jet p_T threshold

m_{4j}: search distribution



Expected limit on λ/λ_{SM}



ATL-PHYS-PUB-2016-024 (link)

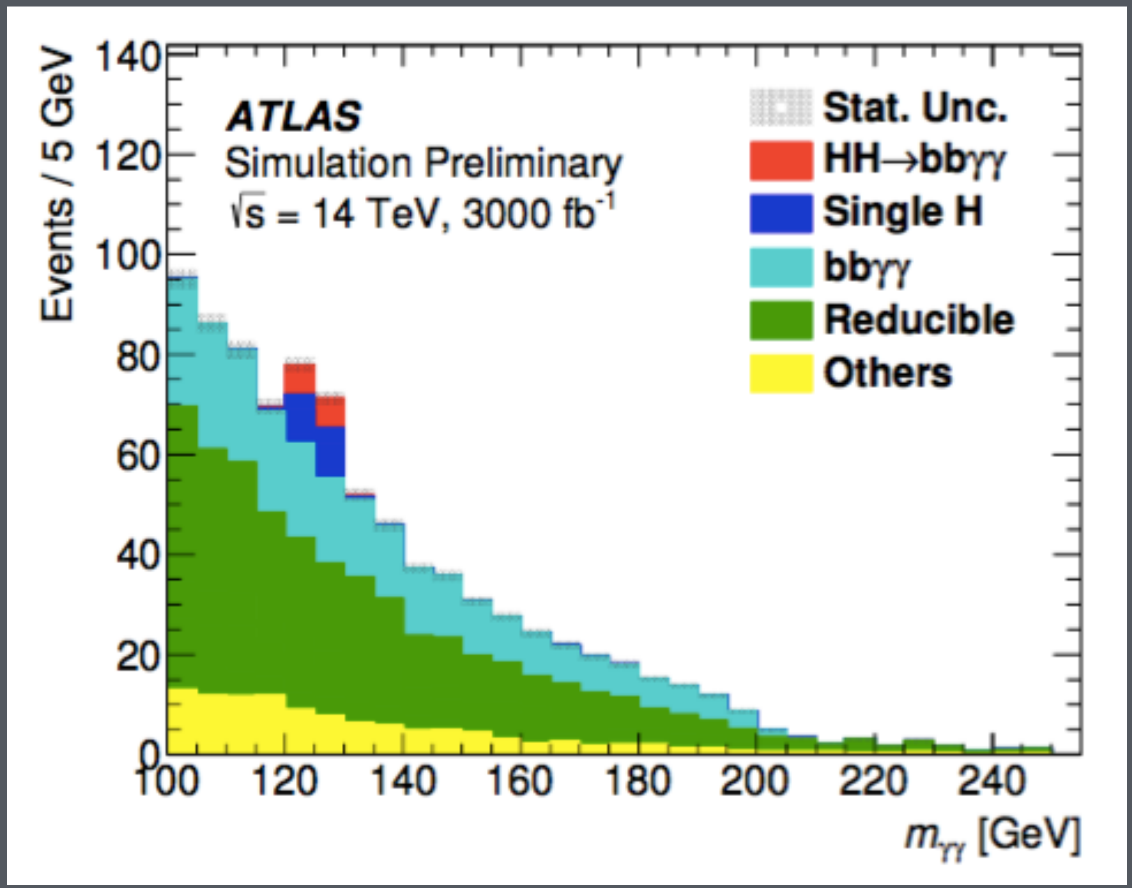
strip TDR

HH→bb($\gamma\gamma$)

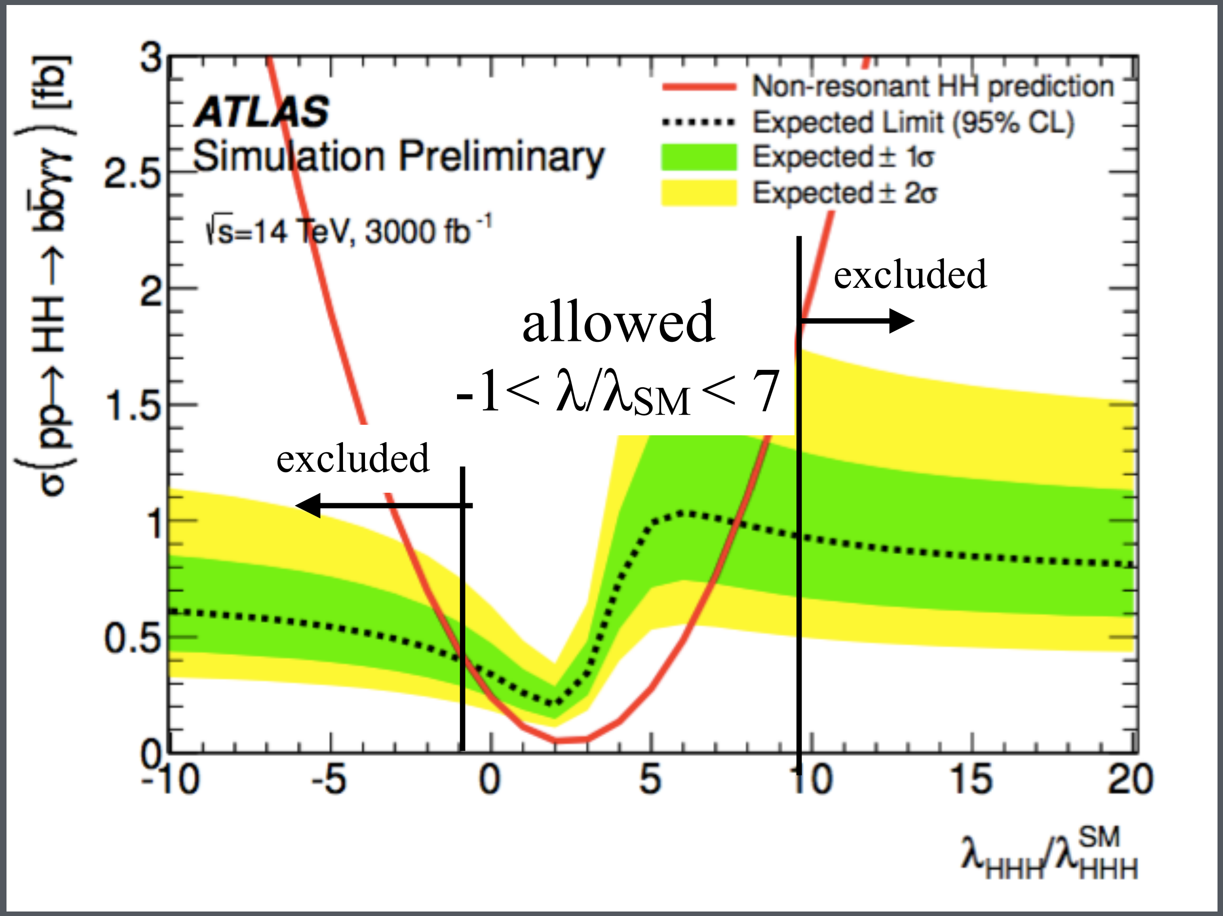
Extrapolation to 3ab^{-1} performed using smearing functions (link)

- New photon ID optimized for <μ> = 200
- Latest b-tagging function and pileup jet contribution used
- Main background, non-resonant QCD with at least one γ [bb$\gamma\gamma$] (left)
- [so far] most sensitive HH channel (right)

$m_{\gamma\gamma}$: search distribution



Expected 95% C.L. limit on λ/λ_{SM}



ATL-PHYS-PUB-2017-001 (link)