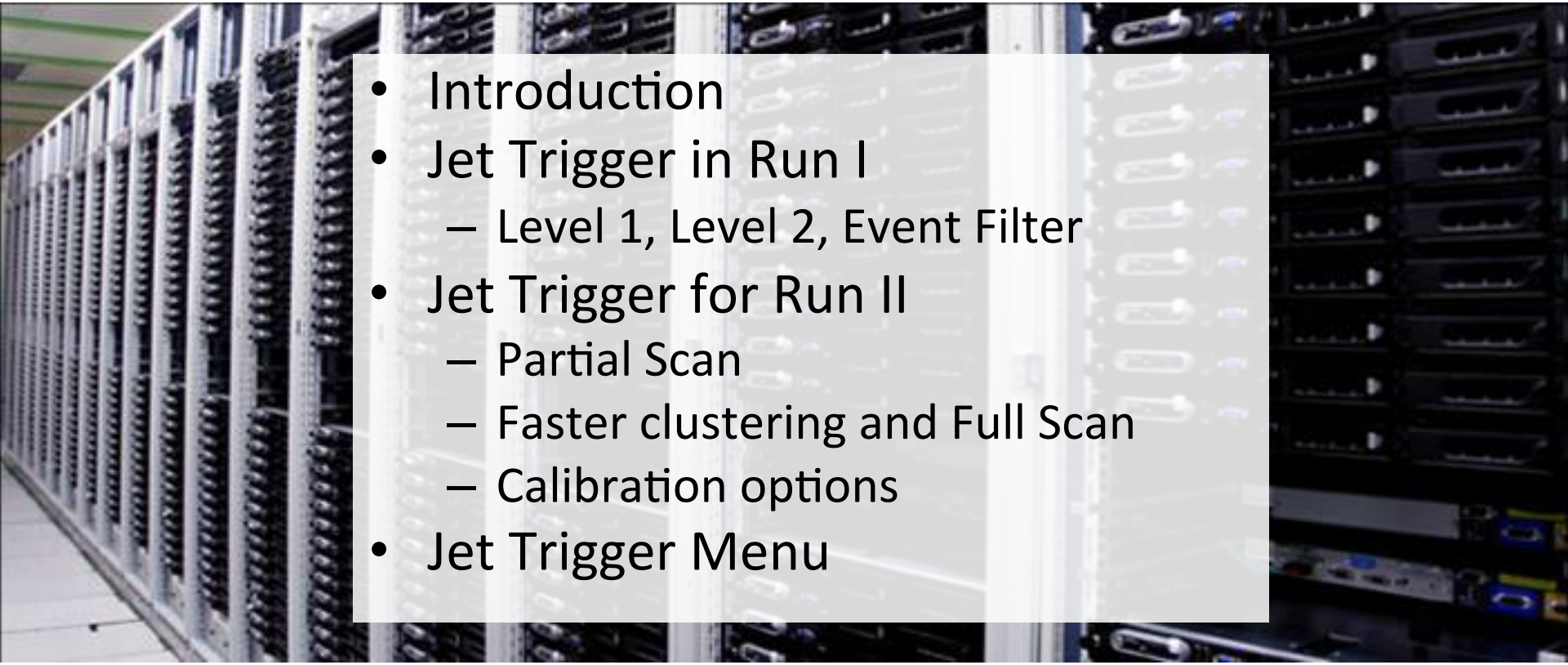
Jet Trigger and changes for Run II

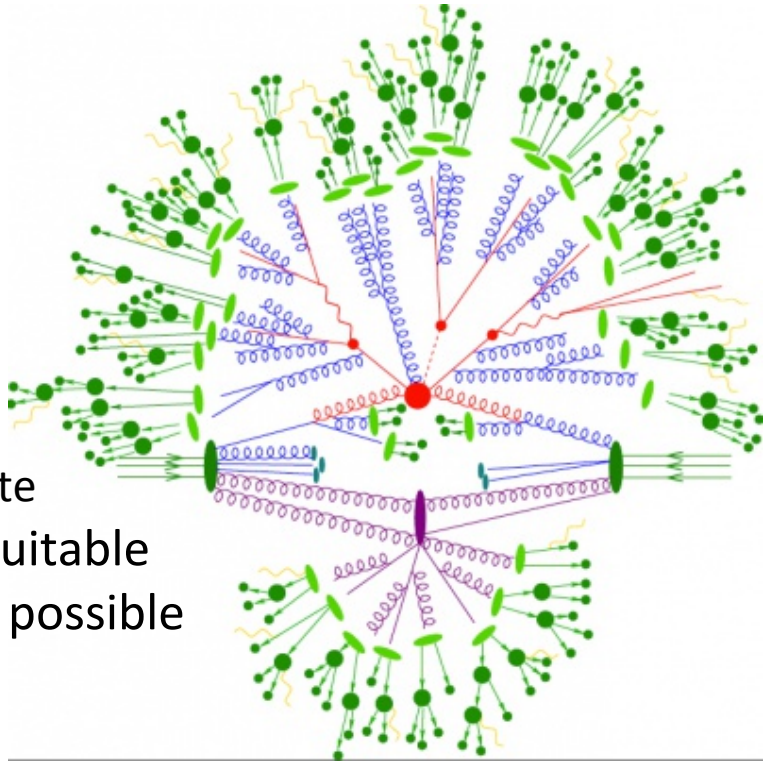
Ricardo Gonçalo (LIP), David Miller (Chicago)
On behalf of the Jet Signature Group people who did the hard work
ATLAS Weekly Meeting - 2 December 2014

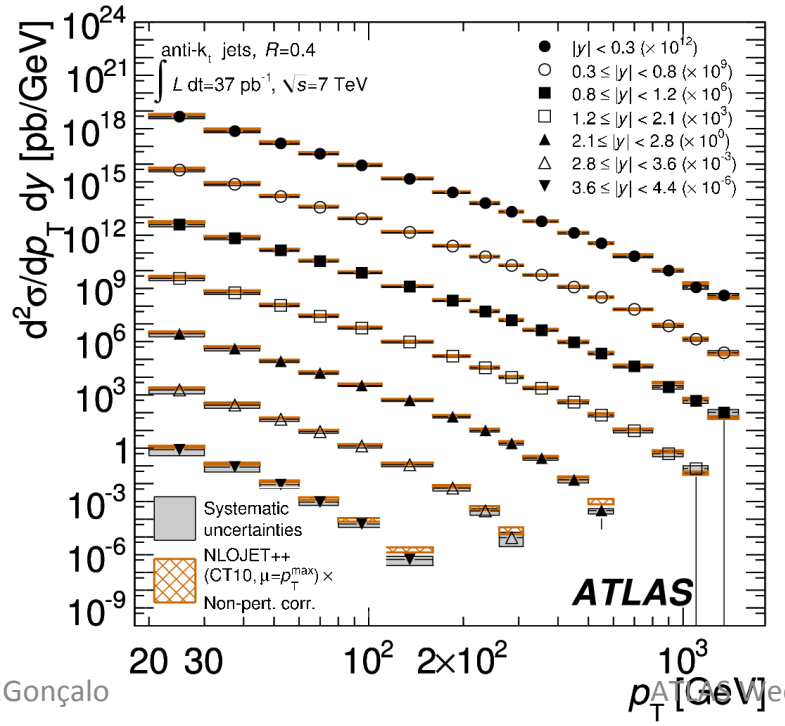
Outline



- Introduction
- Jet Trigger in Run I
  - Level 1, Level 2, Event Filter
- Jet Trigger for Run II
  - Partial Scan
  - Faster clustering and Full Scan
  - Calibration options
- Jet Trigger Menu

- Unusual trigger…
  - Jets *defined* by jet algorithm
  - Jets have non-negligible size in detector
  - Nearby jets influence reconstruction
  - Signal is *same* as background
  - Just selecting phase space (i.e. physics!)
  - Very steeply falling spectrum
  - Jet p_T resolution determines "background" rate
- Region of Interest (RoI) approach not really suitable
- Reproduce offline reconstruction as much as possible

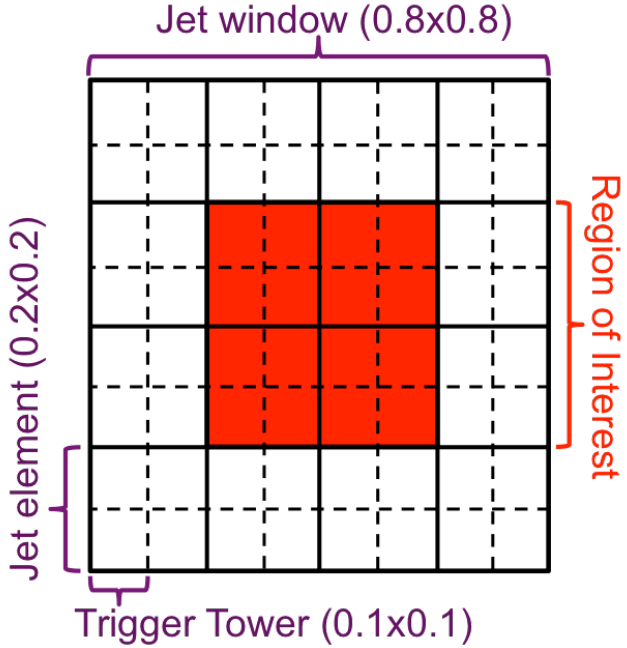


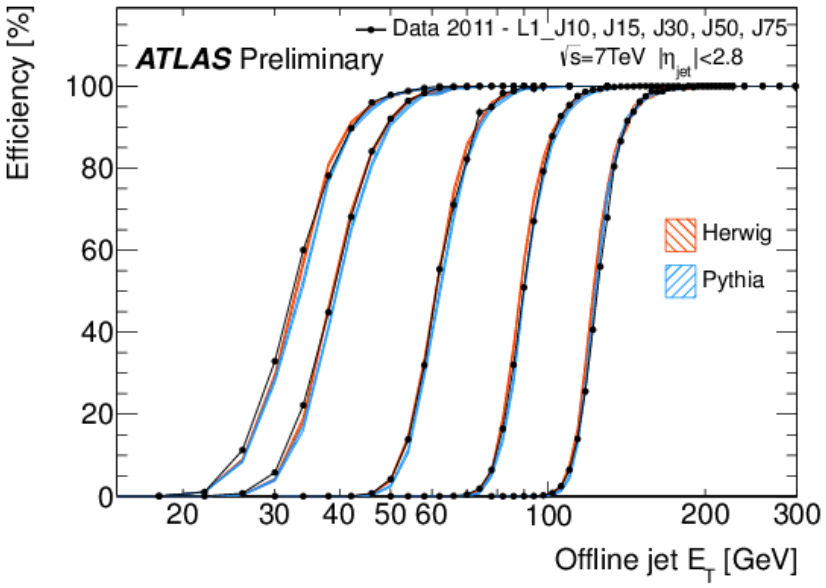


Jet Trigger in Run-I

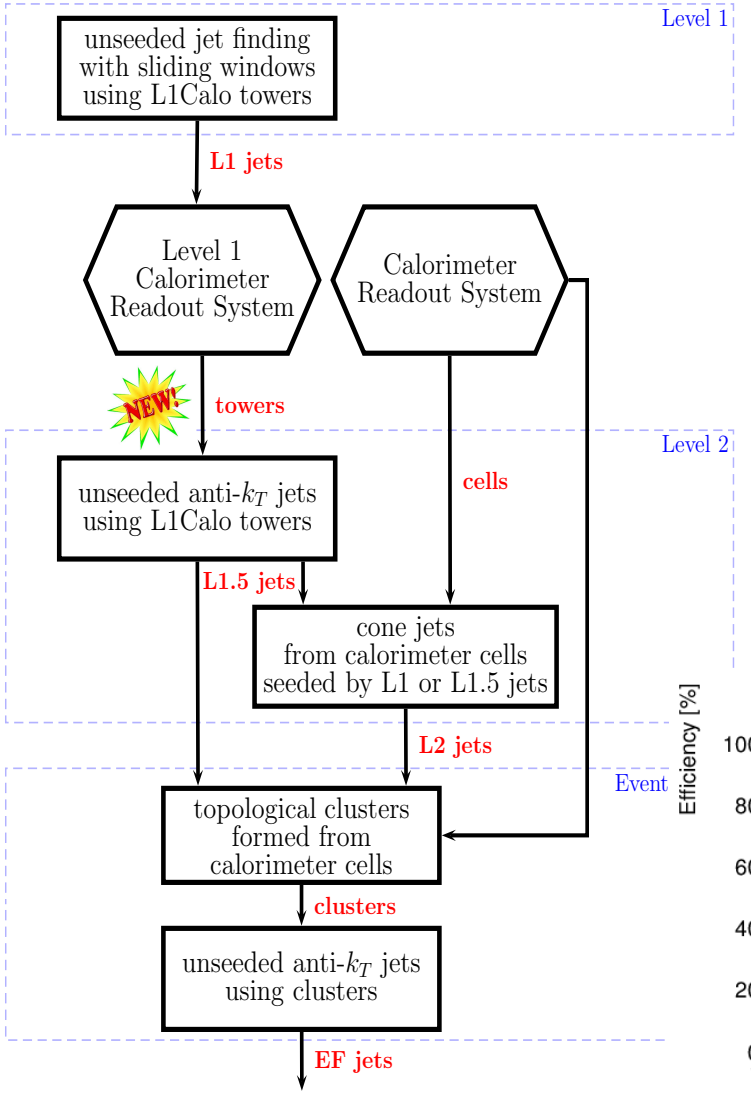
Level 1 Jet Trigger

- Jet Elements built from 2x2 Trigger Towers
- Sliding Window jet algorithm
- Identifies L1 jet RoI if local E_T maximum found and above threshold
- Trigger Tower ET resolution around 1GeV (digital)
- Very slow turn-on due to poor resolution (J15 reaches 100% efficiency at ≈50GeV)
- NOTE: expect significant improvements for Run II from nMCM calibration





Jet trigger in Run 1

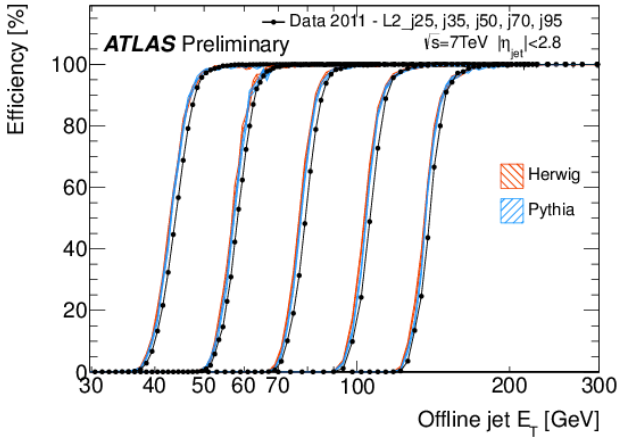


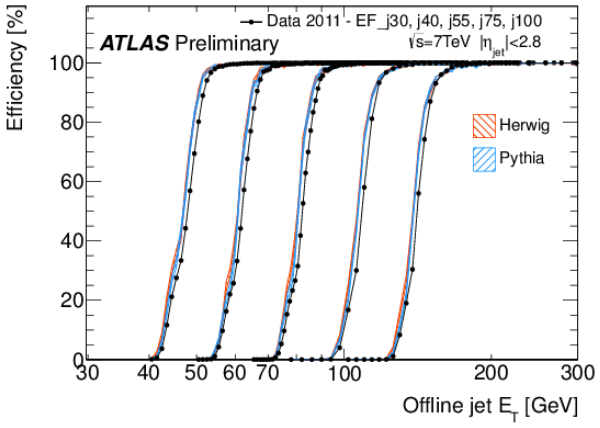
Level 2:

- Cone algorithm in RoI's
- Anti-kt jets from Trigger Towers (**Level 1.5**)
  - ≈L1 granularity and resolution but full calo scan
  - Partially recover close-by jet/jet splitting bias from L1 sliding window
- Much faster turn-on than L1

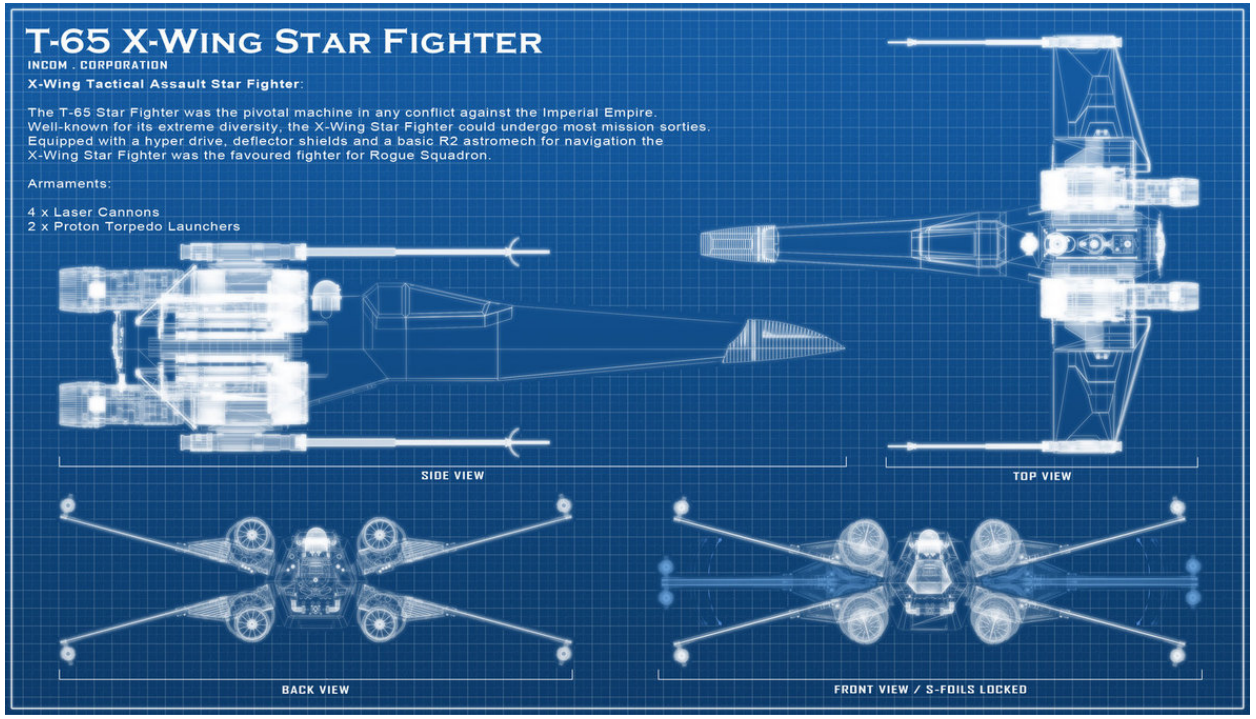
Event Filter:

- Offline-like jet reconstruction
  - Anti-kt jets starting from TopoClusters
- Offline-like performance (on surviving events)



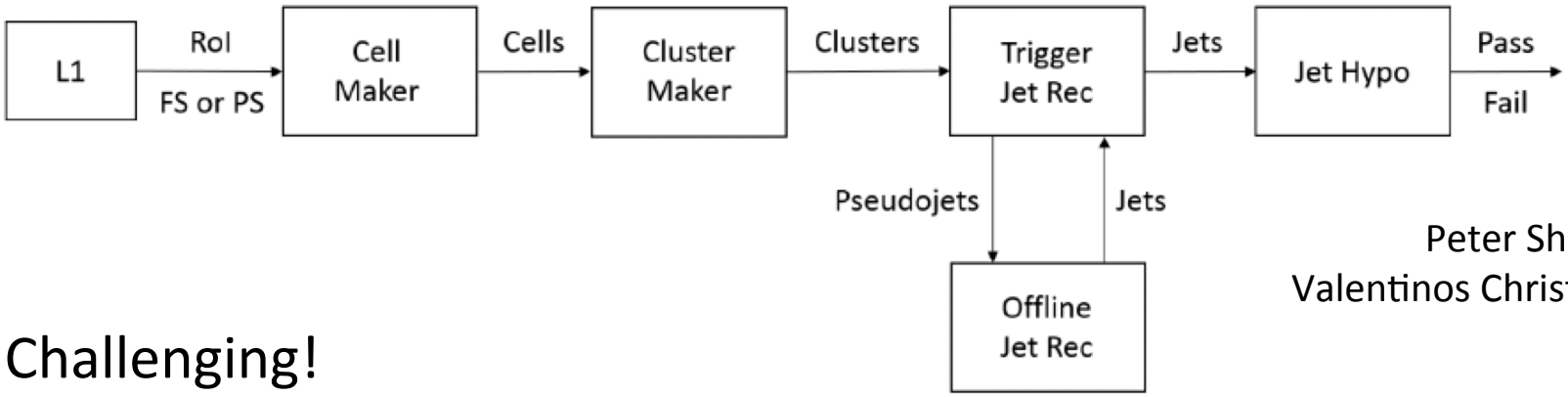


Jet Trigger plans and difficulties



Architecture & SW changes for Run II

- Merged High Level Trigger instead of separate L2 & Event Filter
- L1Topo topological processor at Level 1 (see later slides)
- Migration to xAOD led to major software changes

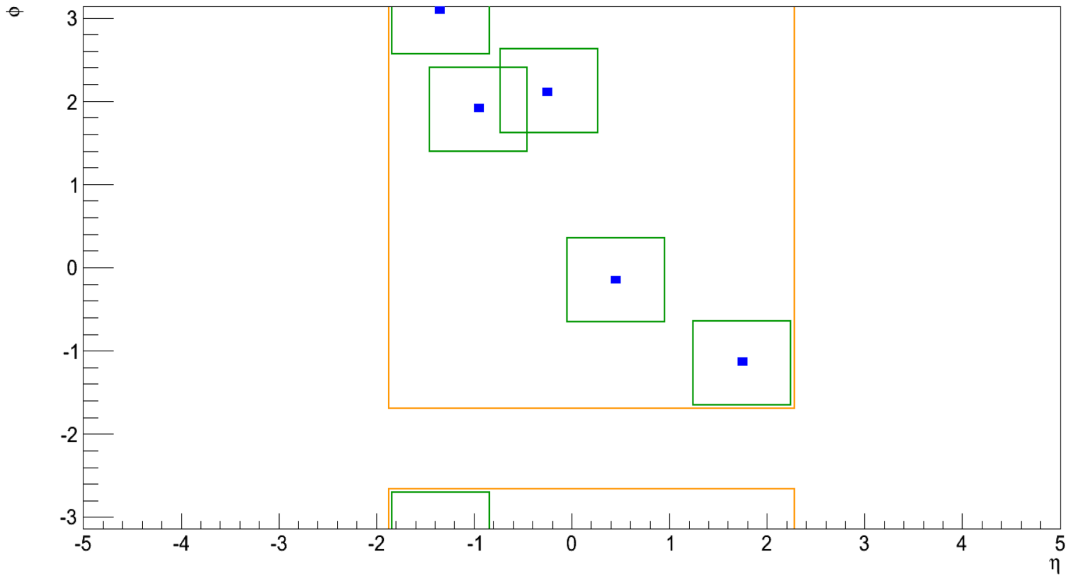


Peter Sherwood
Valentinos Christodolou

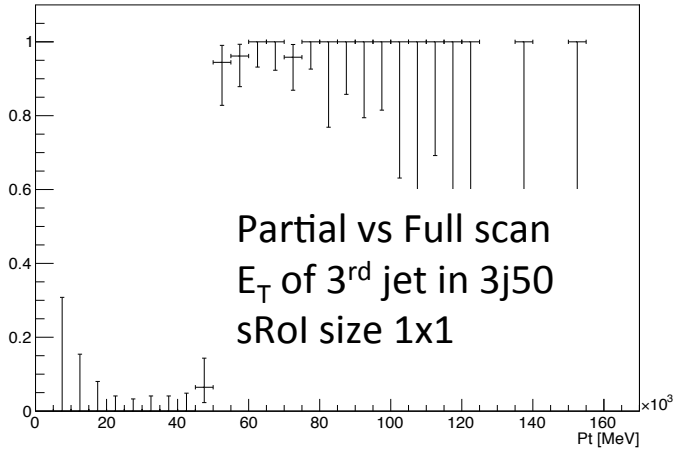
- Challenging!
  - Re-writing of jet trigger software and config, updated monitoring, etc
- Opportunities!
  - Improve on RoI-based jet reconstruction in Level 2
  - Greater re-use of offline jet reconstruction and calibration
  - Good collaboration with HLTCalo and offline jet groups (thanks!)
- Main obstacle: CPU time, mainly clustering

Partial solution: Partial Scan

Ademar Delgado, Mark Sutton

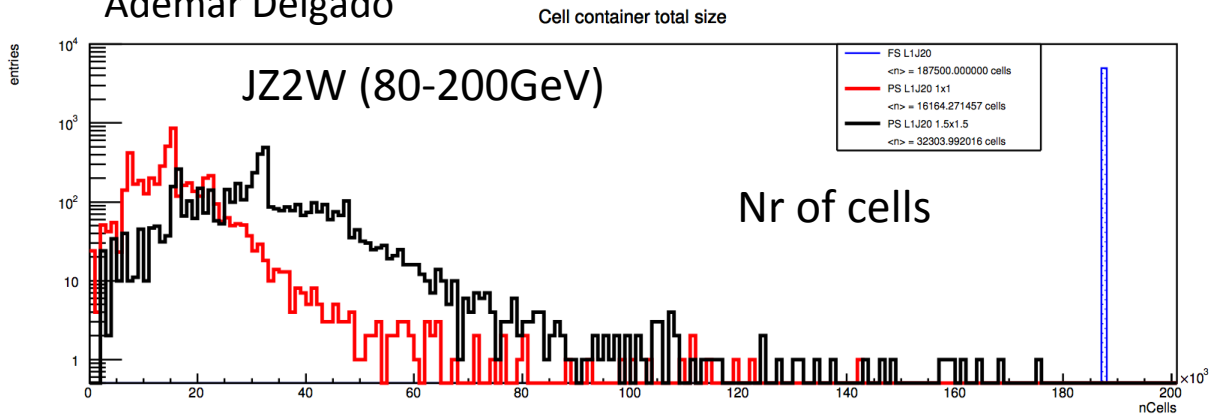


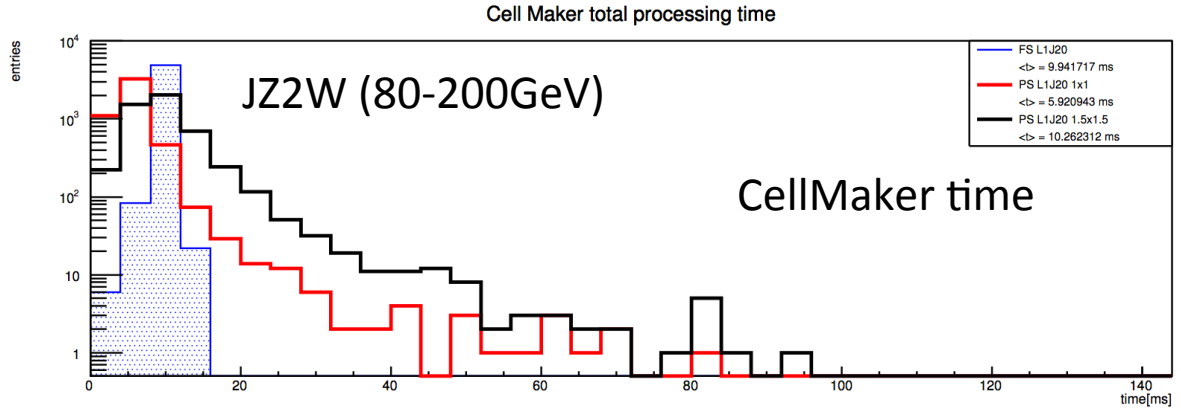
David Freeborn

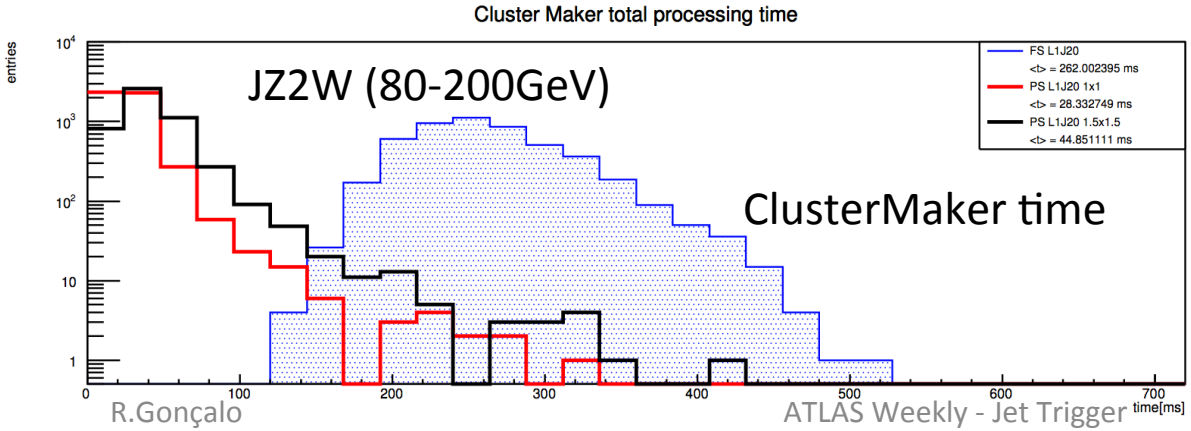


- HLT jet finding on **Super RoI** built from union of all L1 RoIs
  - Or better alternative: start from Trigger Tower full scan (L1.5)
  - Tuneable parameters: L1_Jx (or L1.5 seed), size of RoIs making sRoI
  - Good jet reconstruction performance and costs
  - Efficiency: (L1_J20) ≈ 99.5% wrt Full Scan (j110)
- **Major downside**: no jet area subtraction of pileup

Ademar Delgado







Cost…

Full Scan : <n> ≈ 190k cells

Partial Scan: L1_J20 1x1 :

<n> ≈ 16k cells

Partial Scan: L1_J20 1.5x1.5 :

<n> ≈32k cells

Full Scan : <t> ≈ 10ms

Partial Scan: L1_J20 1x1:

<t> ≈ 6ms

Partial Scan: L1_J20 1.5x1.5 :

<t> ≈ 10ms

Full Scan : <t> ≈ 260ms

(actually… this was a glitch)

Partial Scan: L1_J20 1x1:

<t> ≈ 30ms

Partial Scan: L1_J20 1.5x1.5 :

<t> ≈ 45ms

Improvements in clustering time

Updates to TopoCluster lead to much **improved CPU time**

TopoCluster:

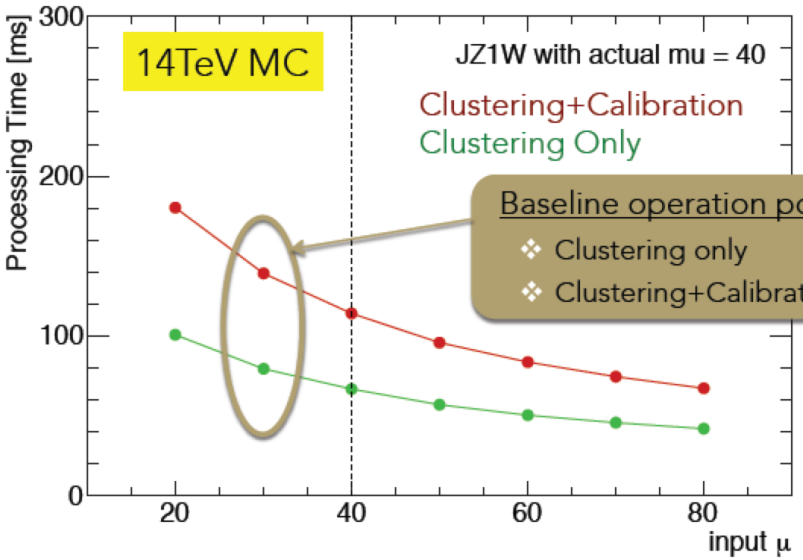
- Clustering
- Splitting
- Moment calculation
- Calibration

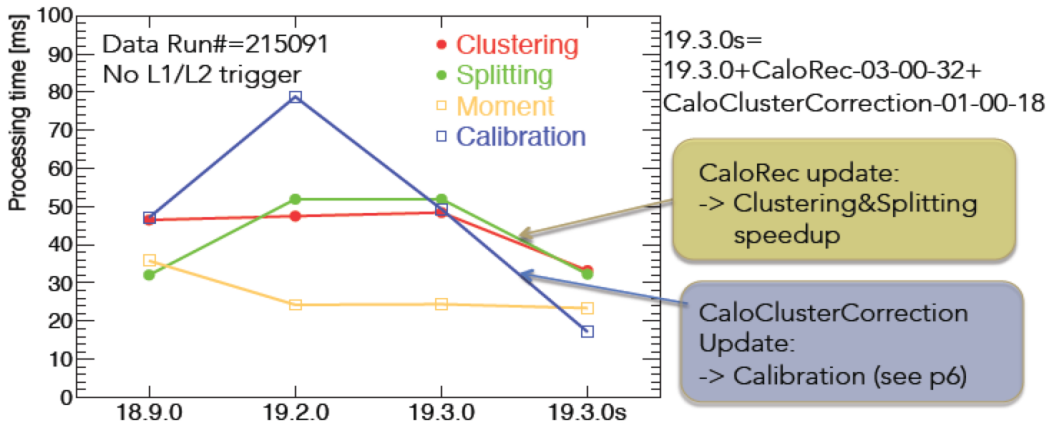
Full calorimeter scan in HLT

- Cluster making:
  - 80ms/evt
- Cluster+Calibration (LCW):
  - 140ms/evt

New baseline plan:

- **Full calorimeter scan**
- Keep Partial Scan: **plan B**
- Plan to use **L1.5** to reduce rate for TopoCluster scan (in progress)





	Pre-xAOD(18.9.0)	Post-xAOD(19.3.0s)
Clustering only	78ms	65ms (-17%)
Clustering+calibration	161ms	106ms (-35%)

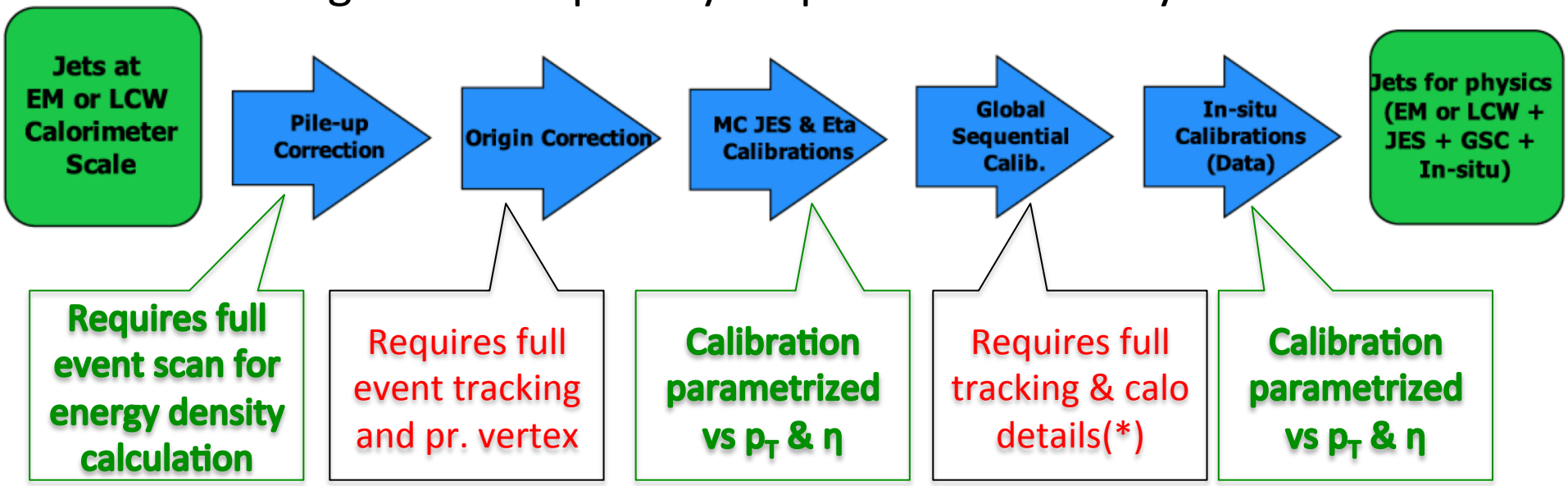
* (NOTE) They are simple sums of timing cost in the above 4 processes

Naoko Kanaya, Craig Wigglesworth, Walter Lampl

The road ahead

Jet Calibration in HLT

- Apply as much as possible of offline jet calibration
- Concentrate on steps leading to larger improvements
- Essential:
  - Pileup (jet area) subtraction and Jet Energy Scale: working
- In progress/plans:
  - Global Sequential Calibration: some factorizable steps possible
  - Tracking-based steps may be possible but not yet addressed



Peter Sherwood, Nuno Anjos

Key

- Jet Algorithm:
  - **a4** = anti-kt jet finding algorithm with R parameter of 0.4
  - **a10** = anti-kt jet finding algorithm with R parameter of 1.0
- Input objects used for jet finding:
  - **tc** = TopoClusters reconstructed from calorimeter cells
  - **TT** = Level 1 TriggerTowers read out in HLT to allow fast but coarse full calo scan (a.k.a. Level 1.5)
- Calorimeter scan:
  - **PS** = partial calorimeter scan seeded by L1 RoI or L1.5
  - **FS** = full calorimeter scan (default)
- Pseudorapidity range:
  - **xxETAyy =** jets in interval xx < |η| < yy – default is **0eta32** (old central jets)
- Cluster Energy Scale correction:
  - **em** = no weights applied
  - **lcw** = local cluster weighting
- Jet Energy Scale correction:
  - **jes** = JES calibration factors without pileup subtraction
  - **sub** = pileup subtraction applied but no JES factors
  - **subjes** = both pileup subtraction and JES factors

- Some possible combinations:
  - **a4tcem** = jets built from EM-scale clusters with no jet level calibration
  - **a10tcemsubjes** = jets built from EM-scale clusters with pile-up subtraction and jet-level calibration
  - **a10TTem** = jets built from TriggerTowers with no jet level calibration
  - **a4tclcwsub** = jets built from LC-scale clusters with only a pile-up subtraction applied at the jet level
  - **a10tclcw_PS** = jets built from LC-scale clusters found in a SuperRoI seeded by all L1_Jx items

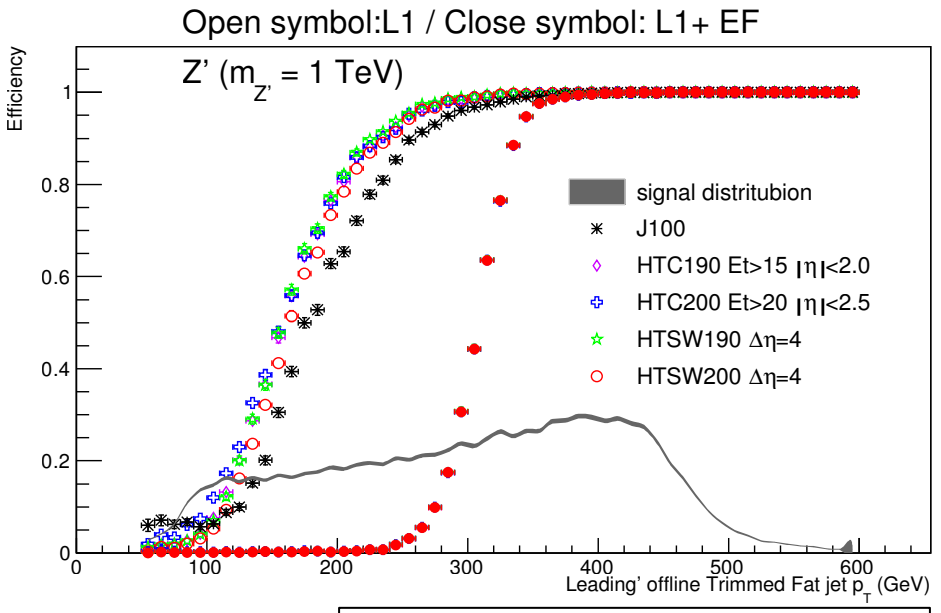
Primary Jet Menu Items at low & high lumi

- Menu for MC15 under final discussion right now
  - $5x10^{33}$ menu: j360, fatjet360, 4j85, 5j60, 6j50.0ETA24, ht800
  - $2x10^{34}$ menu: j400, fatjet450, 4j100, 5j85, 6j50.0ETA24, ht1000
- Default calibration: **emsubjes**
  - Calibrated + pileup subtract jets EM-scale clusters
- "Cross-check" chains with alternative calibrations for a few strategic thresholds
  - E.g.: j360_a4tcemjes/j380_a4tcemsubjes/j380_a4tcemjes/j380_a4tclcwsubjes

Chain Type	L1 Seed at $0.5x10^{34}$	HLT Item at $0.5x10^{34}$	L1 Seed at $2x10^{34}$	HLT Item at $2x10^{34}$
Single jet	J75	j360	j100	j400
Single fat jet	HT150	j360_a10	HT190	j450_a10
4 jets	3J40	4j85	3J50	4j100
5 jets	4J15	5j60	4J20	5j85
6 jets	5J15.0ETA24	6j50.0ETA24	5J15.0ETA24	6j50.0ETA24
HT trigger	HT190	ht800	HT190	ht1000

L1Topo, Fat Jets, et al.

- L1Topo allows to cut on complex quantities using L1 objects
- Example here:
  - Optimization of fat-jet L1 seed
  - HTC: E_T sum of all jets with E_T>20GeV within $|\eta|$<2.5
- Several other studies, like:
  - HT trigger for stop searches
  - Fat-jet trigger for VV->jj
  - Razor triggers for resonances decaying to jets+invisible particles



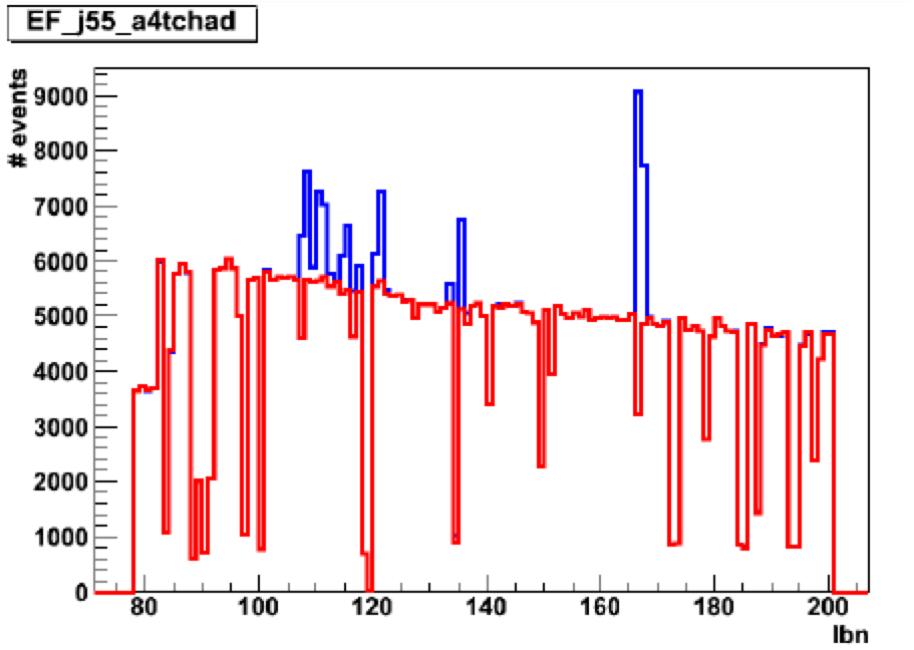
UBA (Devesa, Reisin, Otero, Piegaia)

Trigger	Data (14 TeV)	Unique (wrt J100)	Unique (wrt J100+4J20)
J100 (default)	5.8±0.7	-	-
HTC190 w/E_T >15 $\|\eta\|$ <2.0	4.3±0.8	2.9±1.8	1.4±1.0
HTC200 w/E_T >20 $\|\eta\|$ <2.5	3.8±0.6	1.0±0.4	0.9±0.7
HTC210 w/E_T >15 $\|\eta\|$ <3.0	3.8±0.6	0.6±0.2	0.4±0.2
$\sum E_T$ >110 ΔR<1.0	4.3±0.7	0.3±0.2	0.2±0.2
$\sum\sum E_T$ >120 ΔR<1.5	3.1±0.5	0.1±0.0	0.0±0.0
$\sum E_T$ >110 ΔR<1.5	4.7±0.7	0.6±0.3	0.2±0.2
HTSW>190 $\Delta\eta$=4	5.3±0.8	1.9±0.6	1.1±0.5
HTSW>200 $\Delta\eta$=4	4.3±0.7	1.2±0.5	0.8±0.4

Other loose ends…

Several other studies/improvements not mentioned here time:

- Impact of pileup subtraction (Erich Varnes)
- Impact of pileup in resolution and bias (Annabelle Chuinard)
- Jet offline analysis framework (Rob Cantrill, Lourenço Lopes)
- Lots of work in Monitoring and validation (Lee Sawyer, Sebastien Prince, Aparajita Dattagupta, et al)
- Jet menu studies in SUSY, SM, Higgs, Exotics, etc
- Jet cleaning (Nuno Anjos, liaising with Caterina Doglioni)
- Etc…



Conclusions

- Big changes in Jet Trigger for Run II
- Baseline plan:
  - Trigger Tower full scan to reduce input rate
  - Full calorimeter scan – Partial Scan as plan B
  - Jet area subtraction and as much as possible of offline calibration
- Long road to get here – but main features working
  - Much room for improvement! Volunteers (very) gladly accepted!

We're (almost) ready for new run!

Bonus slides

Inclusive single jet chains

Level 1 seed	Rate @ 0.5 & 2x10^{34}	HLT chain	Rate @ 0.5 & 2x10^{34}	Prescale@2x10^{34}	Clients
L1_RD0		j55_a4tcemsubjes	O(Hz)	?	bootstrap
		j60_a4tcemsubjes	O(Hz)	?	bootstrap
J12	0.95 / 3.8 MHz	j55_a4tcemsubjes	150 / 600 kHz	600,000 – 1 Hz	taus
J15	0.53 / 2.1 MHz	j60_a4tcemsubjes	100 / 400 kHz	400,000 – 1 Hz	taus, btag
J20	240 / 970 kHz	j85_a4tcemsubjes	21 / 85 kHz	85,000 – 1 Hz	taus, multi-j
		j85_a4tcemjes			
		j85_a4tclcwsubjes			
		j85_a4tclcwjes			
J25	130 / 510 kHz	j100_a4tcemsubjes	10 / 41 kHz	41,000 – 1 Hz	taus
J30	75 / 300 kHz	j110_a4tcemsubjes	6.5 / 26 kHz	26,000 – 1 Hz	LAr calib
J40	32 / 130 kHz	j150_a4tcemsubjes	1.6 / 6.5 kHz	6500 – 1 Hz	J+MET
J50	15 / 60 kHz	j175_a4tcemsubjes	0.75 / 3 kHz	3000 – 1 Hz	multijet
		j175_a4tcemjes			
		j175_a4tclcwsubjes			
		j175_a4tclcwjes			

Inclusive single jet chains

Level 1 seed	Rate @ 0.5 & $2x10^{34}$	HLT chain	Rate @ 0.5 & $2x10^{34}$	Prescale@$2x10^{34}$	Clients
J60	7.5 / 30 kHz	j200_a4tcemsubjes	0.4 / 1.6 kHz	1600 – 1 Hz	btag
J75	4 / 17 kHz	j260_a4tcemsubjes	140 / 400 Hz	400 – 1 Hz	btag, low Lumi
J85	2.5 / 10 kHz	j300_a4tcemsubjes	67 / 270Hz	200 – ≈1 Hz	multijet, medium Lumi
		j320_a4tcemsubjes	43 / 170 Hz	150 – ≈1 Hz	multijet, medium Lumi
J100	1.3 / 5 kHz	j360_a4tcemjes	22 / 90 Hz	100 – ≈1 Hz	unprescaled at $1x10^{32}$ or lower: aim for 1-2 points during year to change lowest unprescaled chain
		j380_a4tcemsubjes	16 / 65 Hz	50 – ≈1 Hz	
		j380_a4tcemjes			
		j380_a4tclcwsubjes			
		j380_a4tclcwjes			
		j400_a4tcemsubjes	9 / 35 Hz	unprescaled	Also re-think set of cross-check chains with different calibrations if needed
		j400_a4tcemjes			
		j400_a4tclcwsubjes			
		j400_a4tclcwjes			
J120	1.3 / 2.7 kHz	j460_a4tcemjes + cross-check chains	<1 / 2.8 Hz	unprescaled	High Lumi
J400	0 / 0 Hz	noAlg	5.5 Hz	unprescaled	Passthrough

Multi-jet and fat jet chains

Level 1 seed	@ 0.5 & 2x10^{34}	HLT chain	@ 0.5 & 2x10^{34}	Prescale@2x10^{34}	Clients
3J40	0.4 / 1.6 kHz	4j85_a4tcemsubjes	45 / 180 Hz	180 – 1 Hz	
3J50	0.3 / 1.0 kHz	4j100_a4tcemsubjes	12 / 50 Hz	unprescaled	SUSY, SM, top, jets
4J15	2.4 / 9.5 kHz	5j55_a4tcemsubjes	65 / 260 Hz	260 – 1 Hz	
4J20	0.5 / 1.9 kHz	5j60_a4tcemsubjes	40 / 170 Hz	170 – 1 Hz	
4J20	0.5 / 1.9 kHz	5j85_a4tcemsubjes	4 / 15 Hz	unprescaled	SUSY, SM, top, jets
		5j85_a4tcemjes			
		5j85_a4tclcwsubjes			
		5j85_a4tclcwjes			
5J15.0ETA24	0.1 / 0.3 kHz	6j45.0eta24_a4tcemsubjes	25 / 100 Hz	100 – 1 Hz	SUSY, SM (*)
5J15.0ETA24	0.1 / 0.3 kHz	6j50.0eta24_a4tcemsubjes	10 / 40 Hz	unprescaled	SUSY, SM (*)
5J15.0ETA24	0.1 / 0.3 kHz	6j55.0eta24_a4tcemsubjes	8 / 30 Hz	30 – 1 Hz	SUSY, SM (*)
HT150	3 / 12 kHz	j360_a10tcemsubjes	14 / 60 Hz	60 – 1 Hz	exotics, jets
HT190	1.2 / 5 kHz	j450_a10tcemsubjes	2 / 8 Hz	unprescaled	exotics, jets

(*) A new study from SUSY indicates that 6j chains can/should start from 4J20 to save bandwidth – need to understand if this is also ok for SM

Forward jet and HT chains

Level 1 seed	Rate @ 0.5 & 2x10^{34}	HLT chain	Rate @ 0.5 & 2x10^{34}	Prescale@2x10^{34}	Clients
J15.24ETA49	?	j60.24eta49	?	? – 1 Hz	egamma
J15.28ETA32	?	j60.28eta32	?	? – 1 Hz	SUSY, SM, top, jets
J20.28ETA32	?	j85.28eta32	?	? – 1 Hz	jets
J15.32ETA49	?	j60.32eta49	?	? – 1 Hz	jets
J20.32ETA49	?	j85.32eta49	?	? – 1 Hz	jets
J30.32ETA49	?	j110.32eta49	?	? – 1 Hz	jets
J50.32ETA49	?	j175.32eta49	0	unprescaled	Jets, SM
J75.32ETA49	?	j260.32eta49	0	unprescaled	SM
J100.32ETA49	?	j360.32eta49	0	unprescaled	SM

- Default R parameter and calibration is a4tcemsubjes
- Add cross-check chains (a4tcemjes, a4tclcwsubjes, a4tclcwjes) for:
  - j85.28eta32, j85.32eta49, j175.32eta49, j260.32eta49, j360.32eta49

Level 1 seed	Rate @ 0.5 & 2x10^{34}	HLT chain	Rate @ 0.5 & 2x10^{34}	Prescale@2x10^{34}	Clients
HT190	1.2 / 5 kHz	ht1000	3.5/14 Hz (0 unique)	unprescaled	
HT150		Ht500(?)		prescaled	

Bonus: rates with pileup correction

Erich Varnes

- Conditions:
  - L=2x10^{34}
  - 4j45 rate
  - No event weighting
- Only fixed **ρ=6** here
- ρ calculation works in private code so far
- **Top**: no areas subtraction
- **Bottom**: with ρ=6 area subtraction

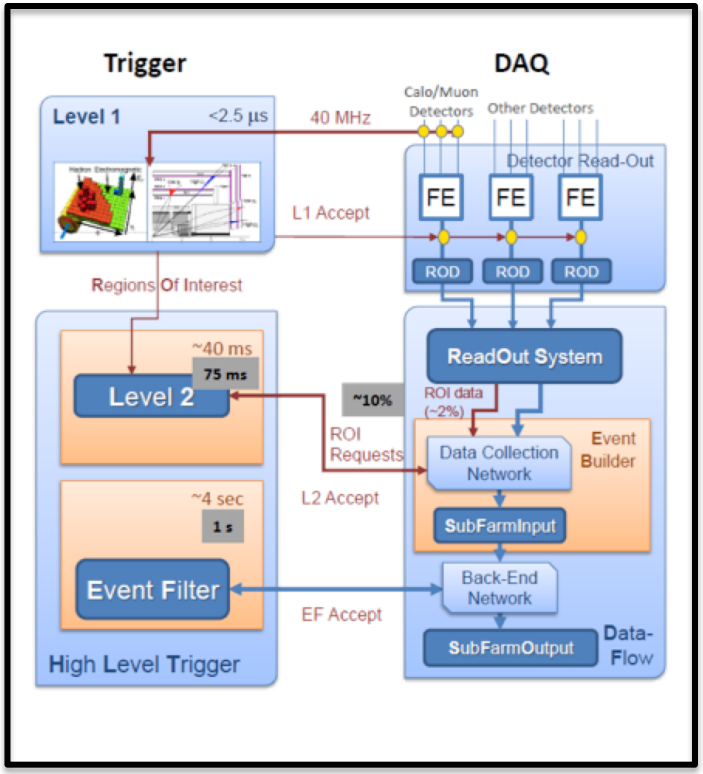
Sample	Cross section	Filter eff	nevents	npass	rate
JZ0W	7.90E+07				
JZ1W	7.93E+07	3.11E-04	2800	18	3.17E+03
JZ2W	6.41E+04	5.39E-03	2900	18	4.29E+01
JZ3W	1.66E+03	1.90E-03	1700	7	2.60E-01
JZ4W	2.76E+01	1.49E-03	2100	26	1.02E-02
JZ5W	3.03E-01	5.51E-03	2400	52	7.23E-04
JZ6W	7.51E-03	1.52E-02	2600	83	7.29E-05
total rate (Hz)					3214.03

Sample	Cross section	Filter eff	nevents	npass	rate
JZ0W	7.90E+07				
JZ1W	7.93E+07	3.11E-04	1610	5	1.53E+03
JZ2W	6.41E+04	5.39E-03	1400	8	3.95E+01
JZ3W	1.66E+03	1.90E-03	1500	4	1.68E-01
JZ4W	2.76E+01	1.49E-03	1500	22	1.21E-02
JZ5W	3.03E-01	5.51E-03	1400	27	6.44E-04
JZ6W	7.51E-03	1.52E-02	300	9	6.85E-05
total rate (Hz)					1571.49

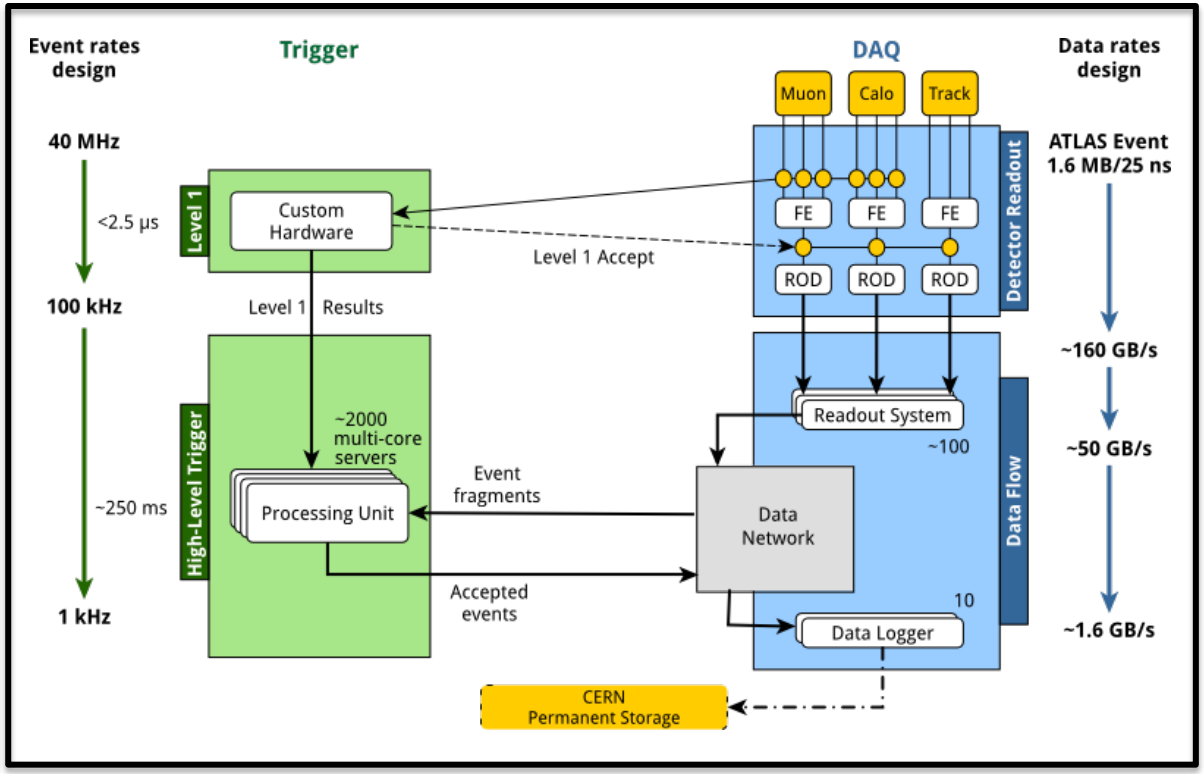
Architecture Changes in Run-II

- Main change is merged HLT instead of separate L2 & EF

Run I



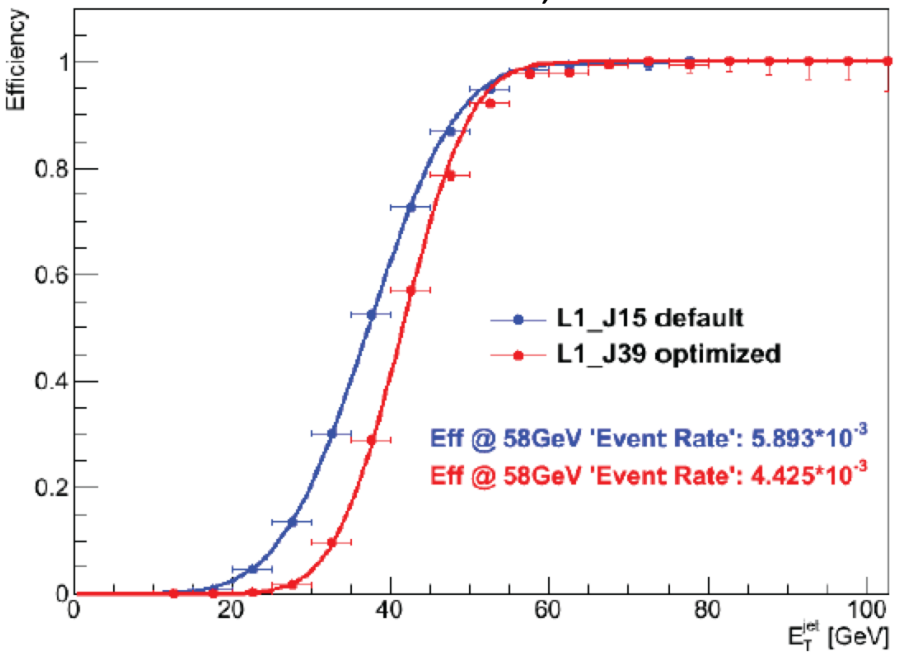
Run II

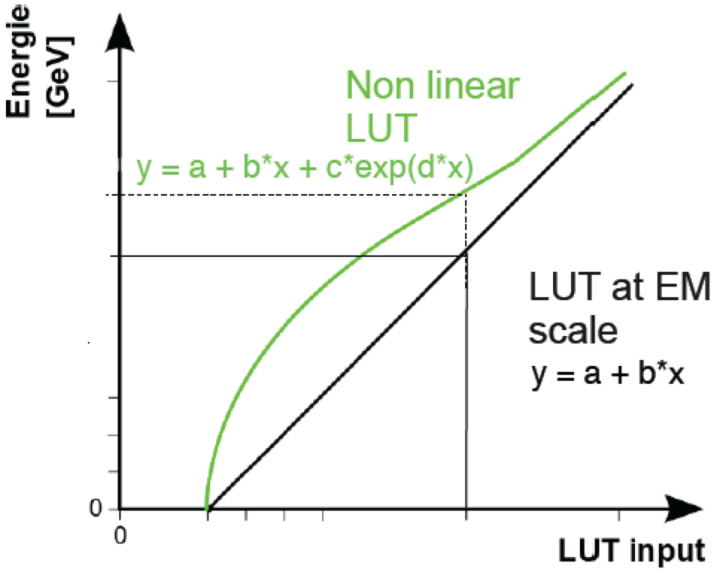


New L1 LUT calibration

Alessandra Baas, Stanislav Suchek

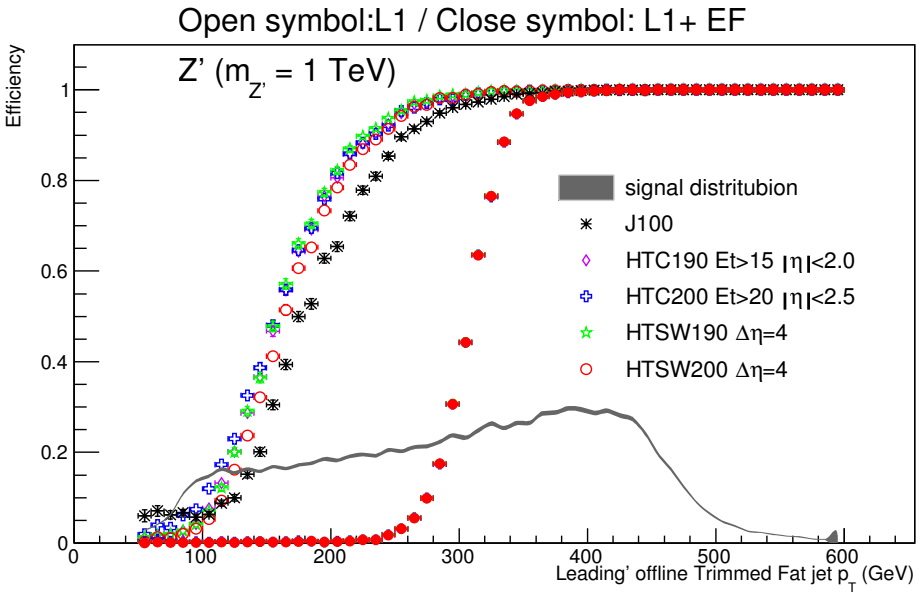
- Improved jet calibration in Level 1 Look Up Table
- Applied in new nMCM L1Calo boards
- Add small non-linear term to optimize resolution

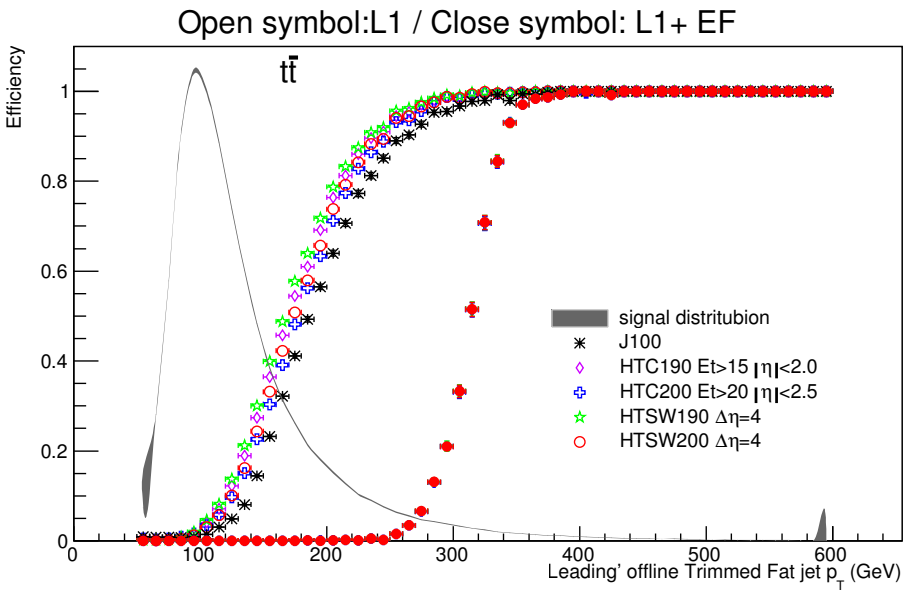




	L1_J15	L1_J39	
$N^{\text{events}} > \text{L1 thres}$	19553	14685	-25%
$N^{\text{all jets}}$	71038	9941475	x140
$N^{\text{all jets}}_{\text{matched}}$	52942	1543183	x30
$N^{\text{jets}} > \text{L1 thres}$	23488	18049	-30%
$N^{\text{jets}} > \text{L1 thres}}_{\text{matched}}$	17123	12770	-25%
$N^{\text{jets} > 99\%}_{\text{matched}}$	1550	1542	

L1 HT triggers for fat jets: signal





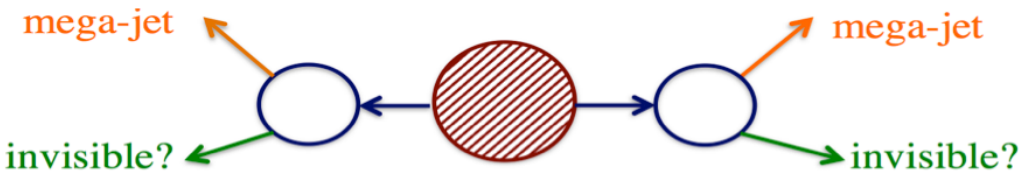
L1 selection	threshold	name
Sum of E_T of all jets with E_T >20 GeV and $\|\eta\|$ <2.5	200 GeV	HTC200
As above but for a Sliding Window in η, of size $\Delta\eta$=1.0	100 GeV	HTSW100
Sum of E_T for (up to 2) jets closer than ΔR =1.0	100 GeV	$\sum E_{T(2)}$100

Explored a large number of trigger configurations, varying parameters in blue.

UBA (Devesa, Reisin, Otero, Piegaia)

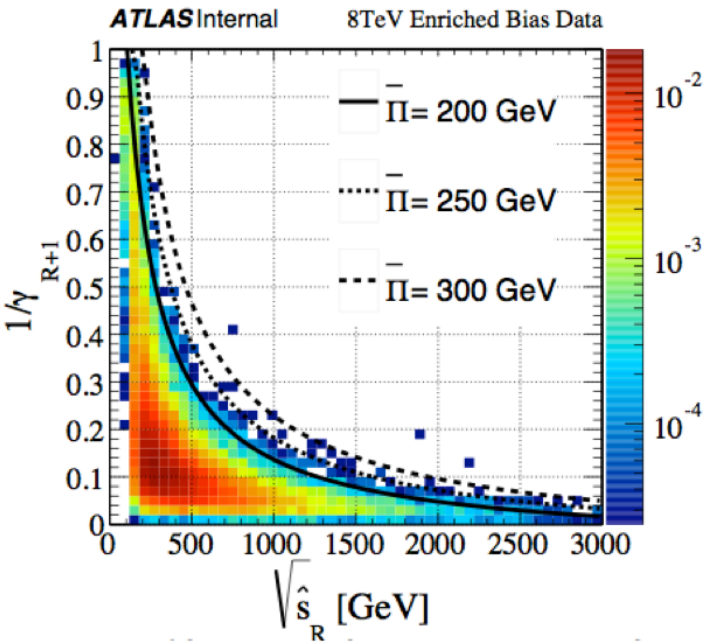
Trigger	Data (14 TeV)	Unique (wrt J100)	Unique (wrt J100+4J20)
J100 (default)	5.8±0.7	-	-
HTC190 w/E_T >15 $\|\eta\|$ <2.0	4.3±0.8	2.9±1.8	1.4±1.0
HTC200 w/E_T >20 $\|\eta\|$ <2.5	3.8±0.6	1.0±0.4	0.9±0.7
HTC210 w/E_T >15 $\|\eta\|$ <3.0	3.8±0.6	0.6±0.2	0.4±0.2
$\sum E_T$ >110 ΔR<1.0	4.3±0.7	0.3±0.2	0.2±0.2
$\sum E_T$ >120 ΔR<1.5	3.1±0.5	0.1±0.0	0.0±0.0
$\sum E_T$ >110 ΔR<1.5	4.7±0.7	0.6±0.3	0.2±0.2
HTSW>190 Δη=4	5.3±0.8	1.9±0.6	1.1±0.5
HTSW>200 Δη=4	4.3±0.7	1.2±0.5	0.8±0.4

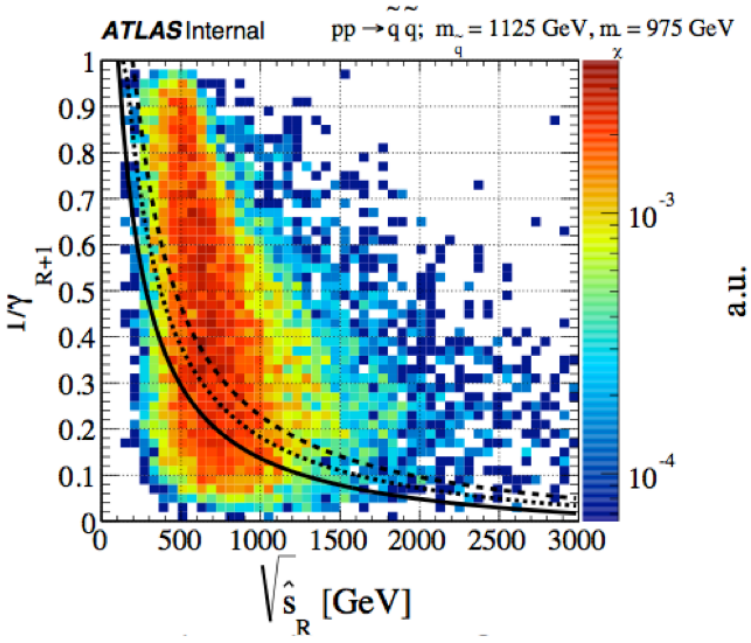
Razor triggers at HLT



- Interpret events as two mega-jets
- Build razor variables:
  - $\sqrt{\hat{s}_R}$ ~ mass scale
  - $1/\gamma_{R+1}$ ~ transverse event imbalance
  - $\cos\theta_{p_T,M_\Delta}$ ~ CM and mega jet mass imbalance

Chris Rogan, Emma Tolley



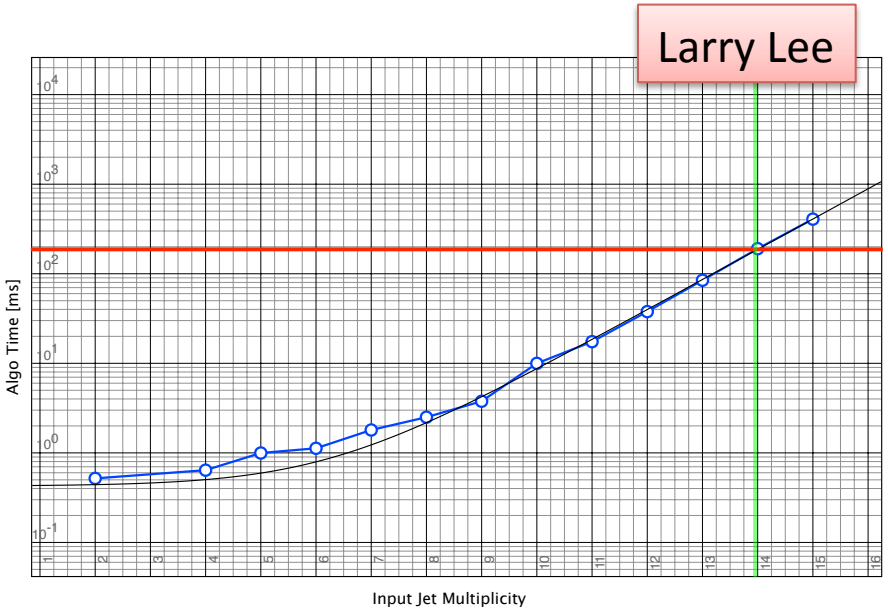


- Suppress background with hyperbolic cut:

$$\bar{\Pi} \equiv (\sqrt{\hat{s}}_R + 85\ \text{GeV})(1/\gamma_{R+1} + 0.048)$$

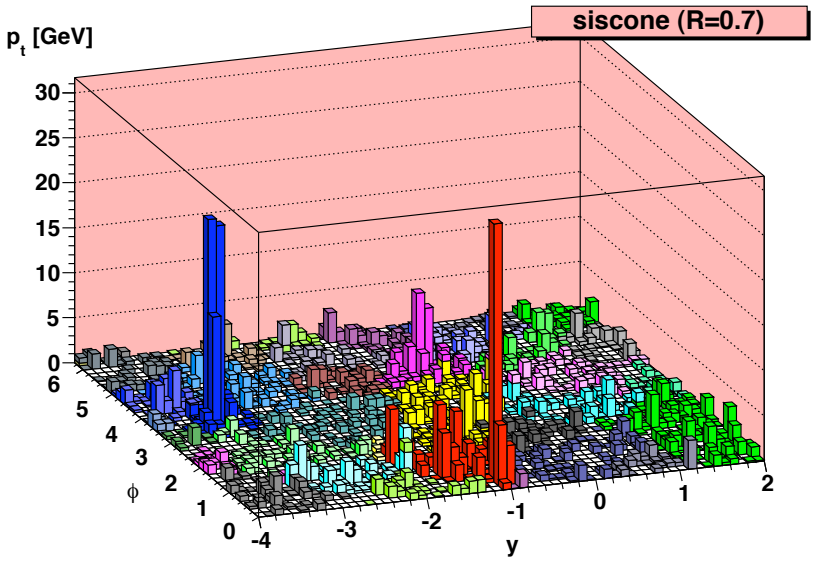
Razor trigger implementation

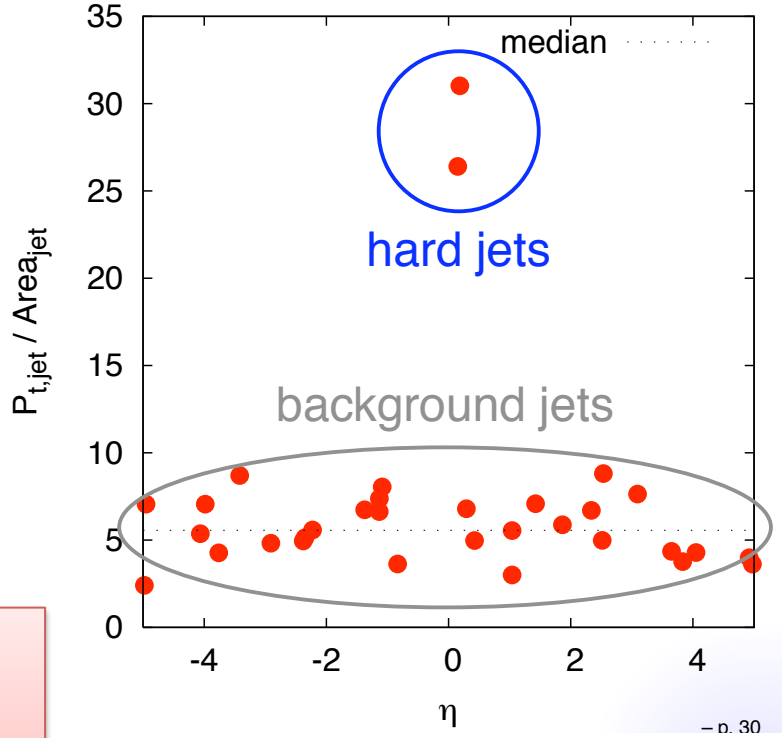
- Trigger/TrigAlgorithms/ TrigHLTJetHemisphereRec
  - HLT::FexAlgo, Modeled on TrigHLTJetRec. Takes in an xAOD jet collection and attaches a new jet collection of exactly 2 jets which represent the hemispheres to the TE
- Brute force - all combinations of N jets into two hemispheres
  - Running time grows as ~2^N logN so needs some passthrough at N_{Max} jets where a multijet trigger should take the event anyway (then offline OR)
- jobOptions configurable jet pT, eta, N_{Max}



- Timing results on lxplus node
- Must keep algorithm under 200ms → ~14 Jets
  - N_{Max} ~ 10-13 should be safe

Pile-up subtraction: rho





$$\rho = \text{median}\left\{\frac{p_{j,t}}{A_{j,t}}\right\}$$

Requires full event topoclusters for rho calculation

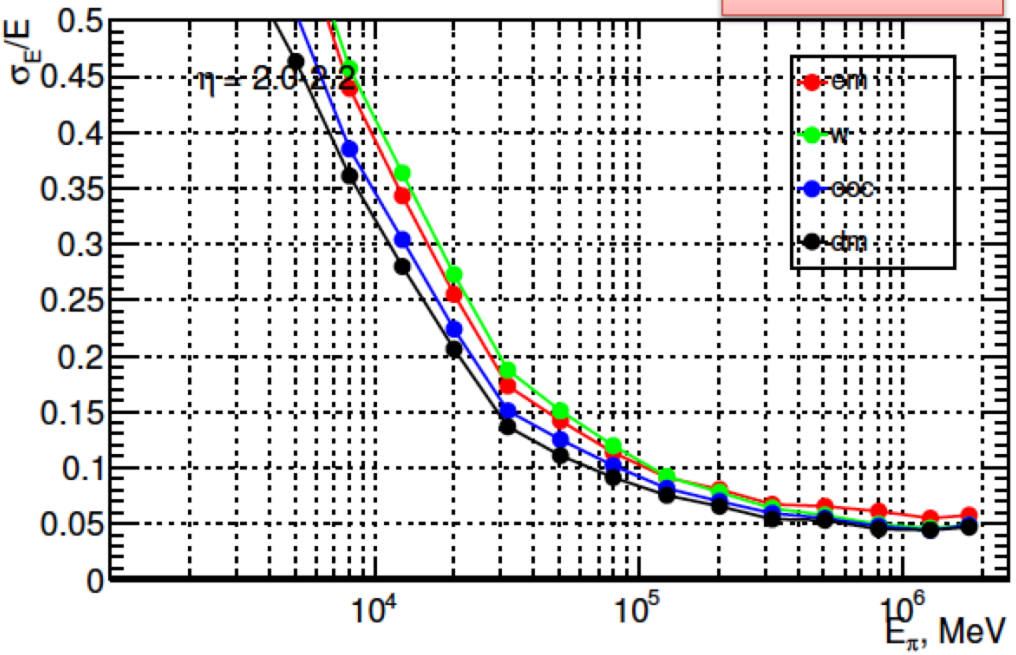
$$p_{t,\text{subtracted}} = p_{t,\text{jet}} - \rho_{\text{pileup}} \times \text{Area}_{\text{jet}}$$

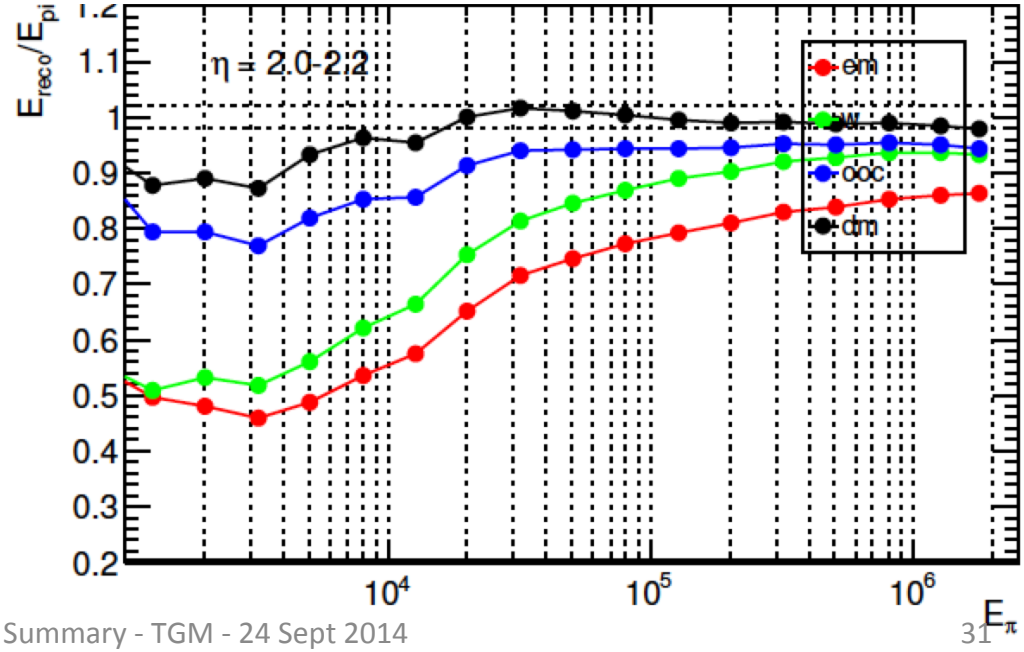
Cluster Calibration

- Resolution and linearity improvement for charged pions after each correction:
  - EM
  - LCW
  - Out of cluster
  - Dead material

- Conditions:
  - <μ>=0
  - IBL geometry
  - 2<|η|<2.2
  - 4 samplings

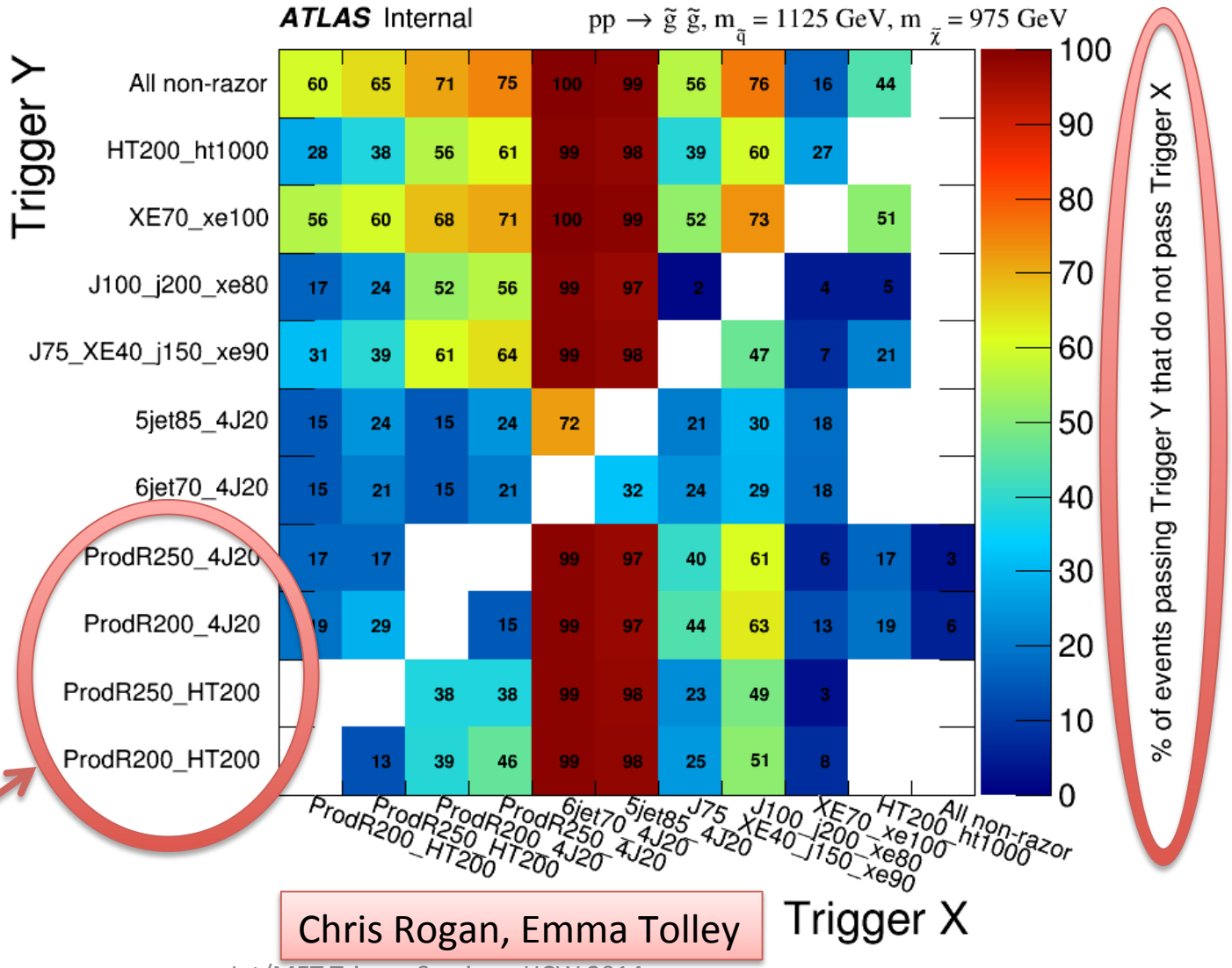
Sven Menke





Unique efficiencies of the razor triggers

*Read the **Y-axis** for a given trigger and then look at the value for any trigger on the X-axis to see the benefit*



Razor triggers with Different L1 seeds (HT and multijet)

Chris Rogan, Emma Tolley