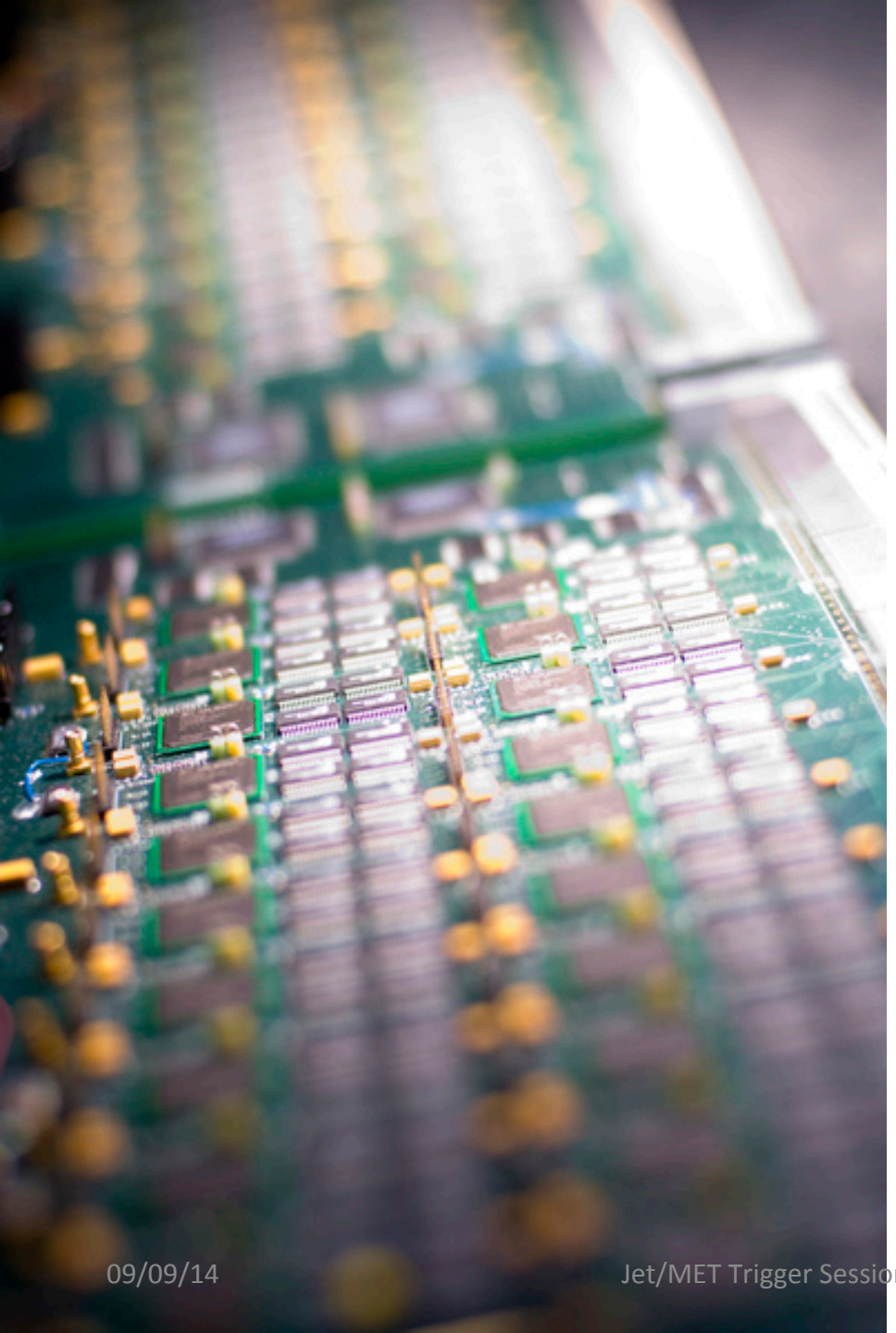
Jet & MET Trigger Session

(the **first** – but not last – dedicated trigger session at HCW!)

Hadronic Calibration Workshop 2014
Munich, Germany

Hugo Beauchemin, Florian Bernlochner,
Ricardo Goncalo, David Miller

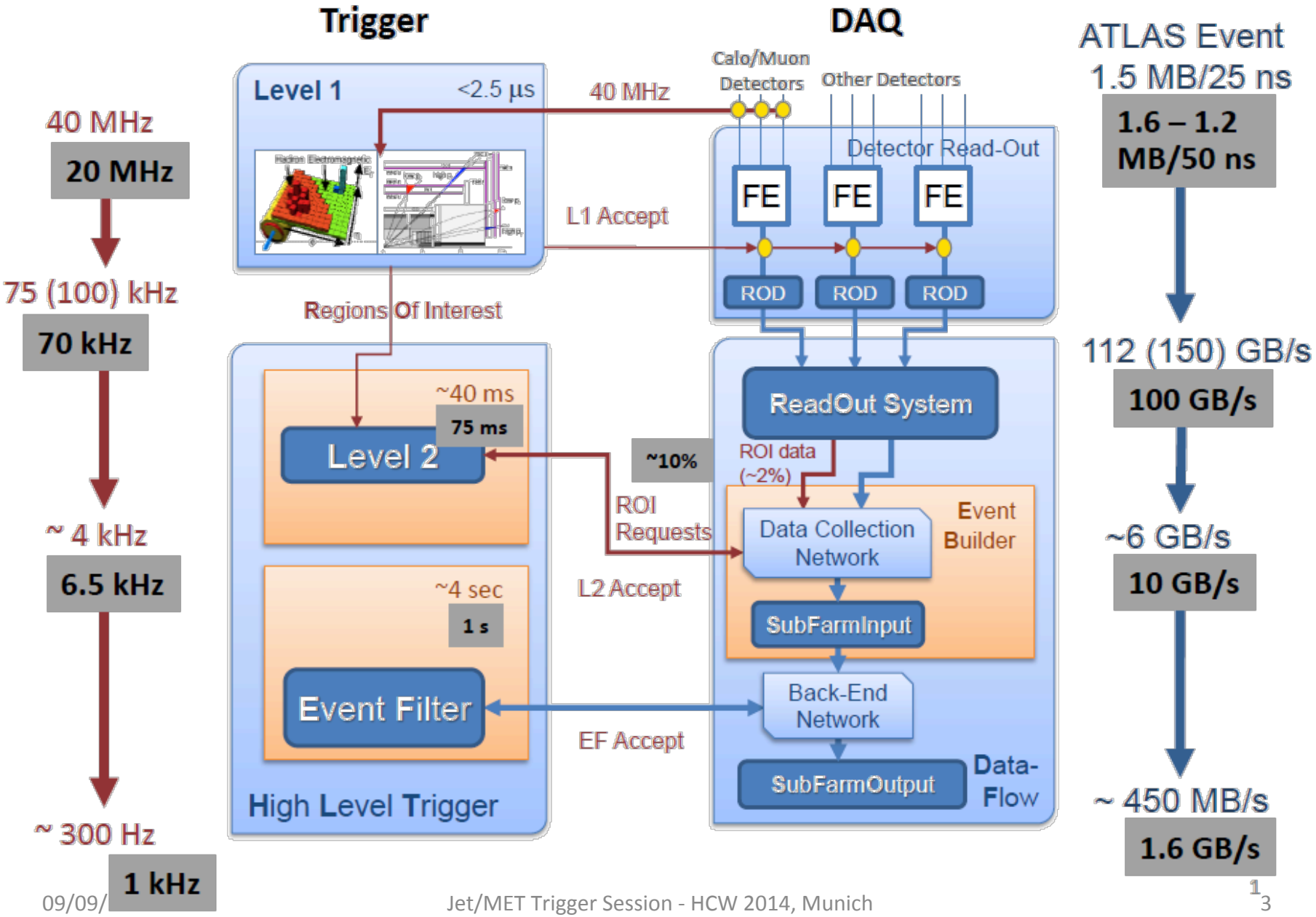


Introduction & background

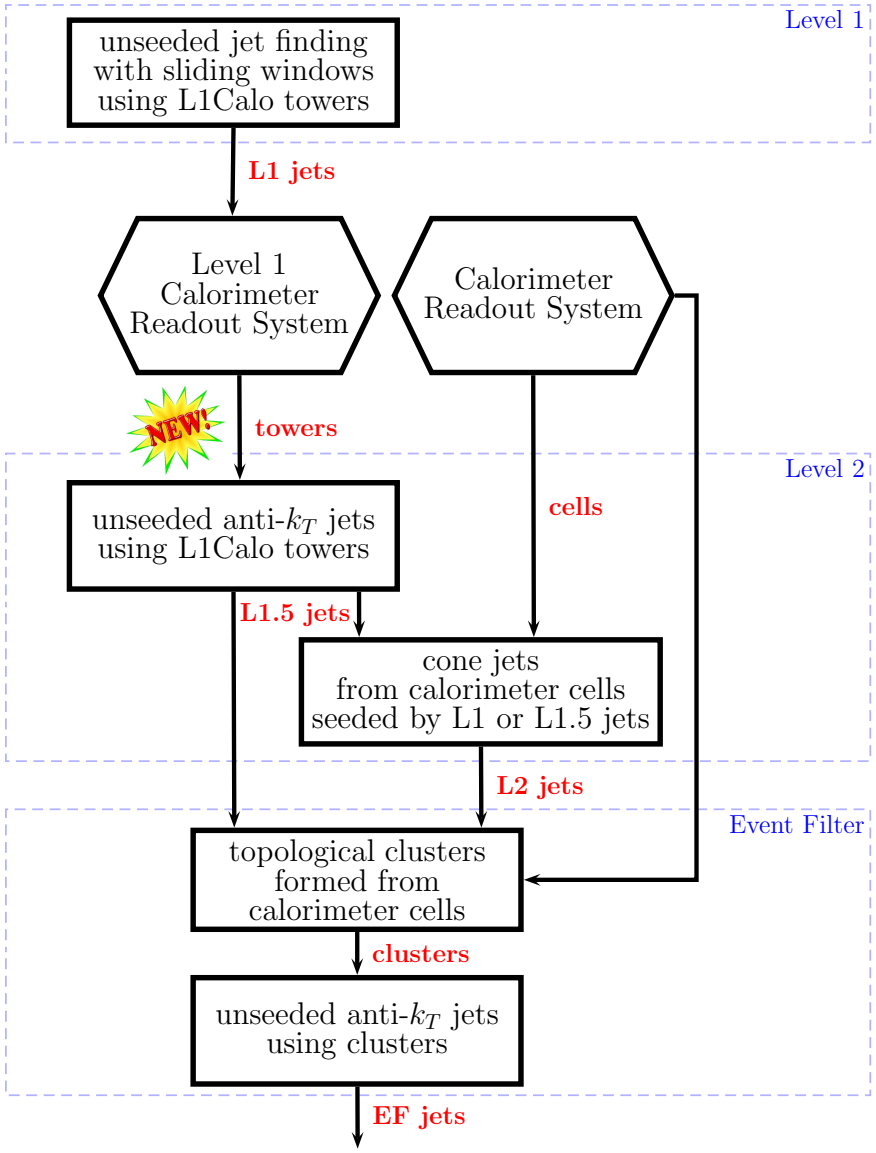
TDAQ in 2012

2012

ATLAS Data Trigger Info



Run I jet trigger scheme



Coarse square “jets”

Full event jets using tower

ROI cone jets from cells

Full event jets from clusters

E_T^{miss} Trigger in 2011 & 2012

2011

L1 → L2 → HLT ~10 Hz

Trigger Towers | Trigger Towers | Cells

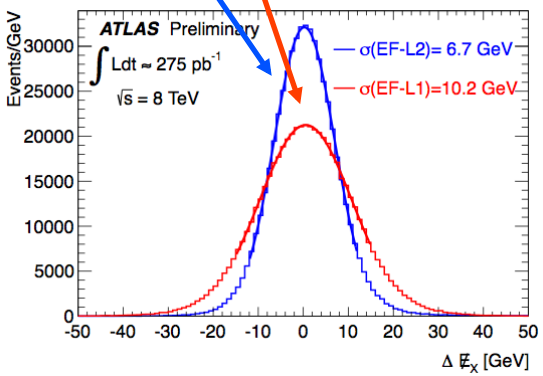
Lowest unprescaled chain: L1_XE50 → L2_xe55 → xe60

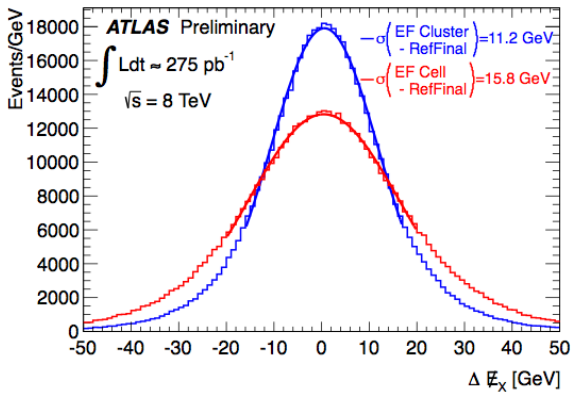
2012

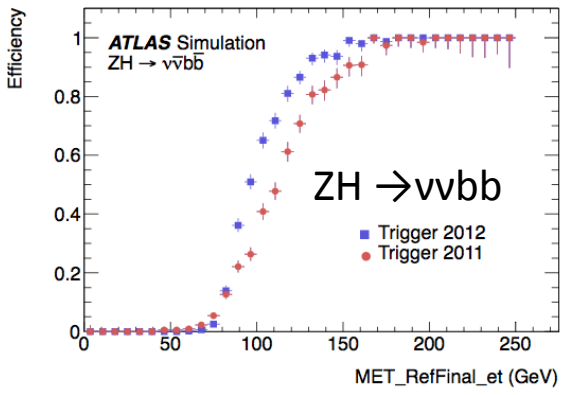
L1 → L2 → HLT ~10 Hz

Trigger Towers | Front-End-Board sums | LCW Clusters

lowest unprescaled chain: L1_XE40_BGRP7 → L2_xe45 → xe80_tclw

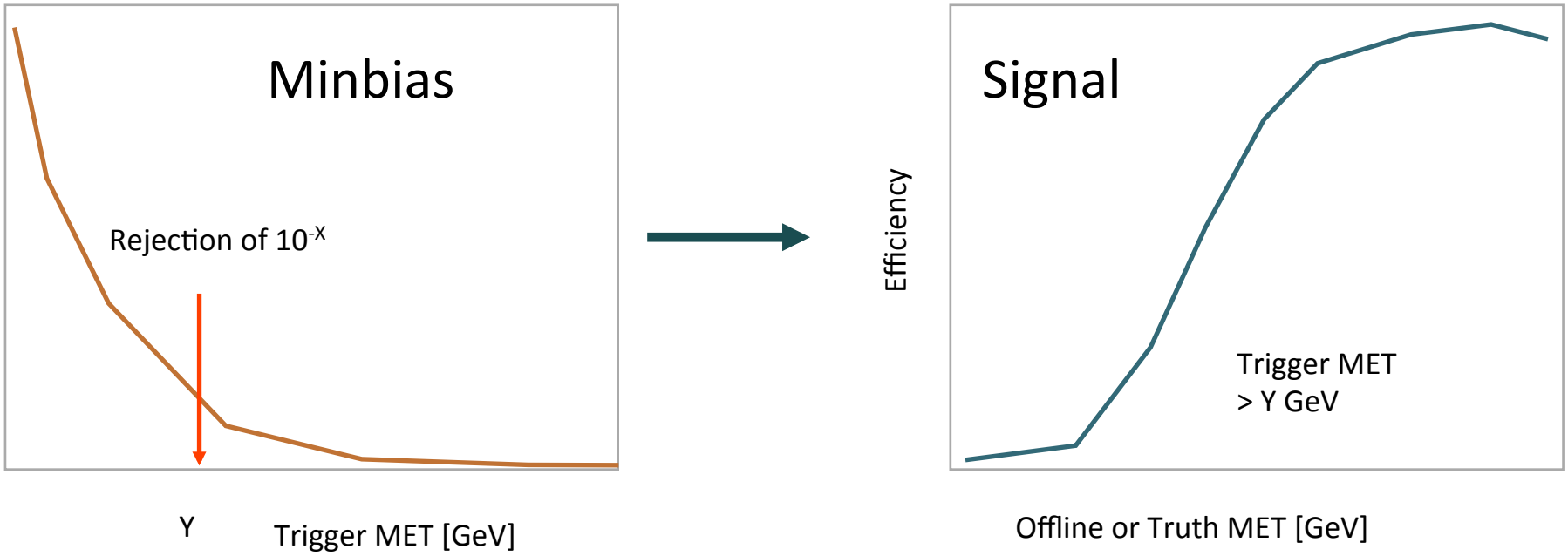




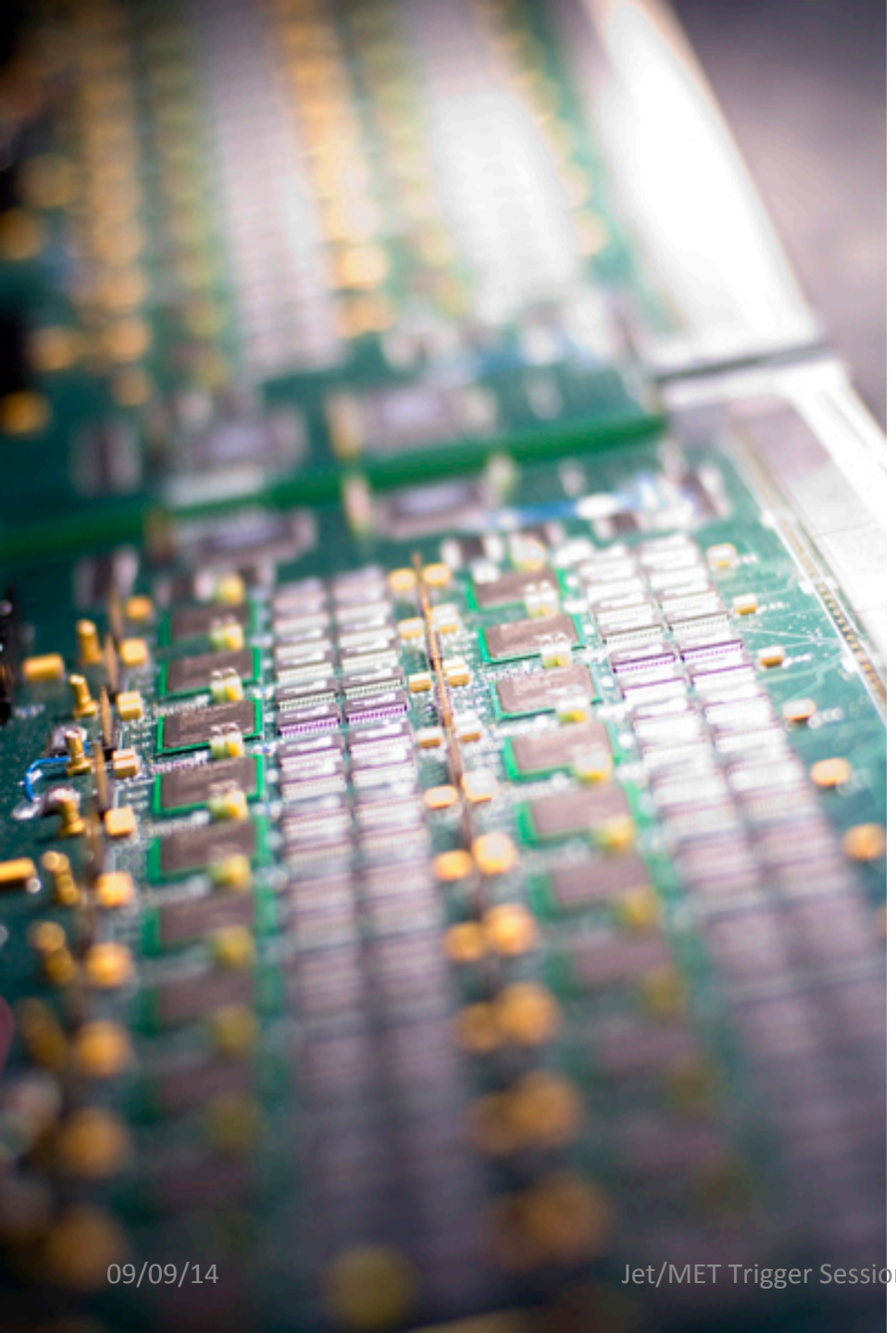


How to judge performance at the trigger?

Figure of merit: cost (= rate) versus phase space accessible by signal

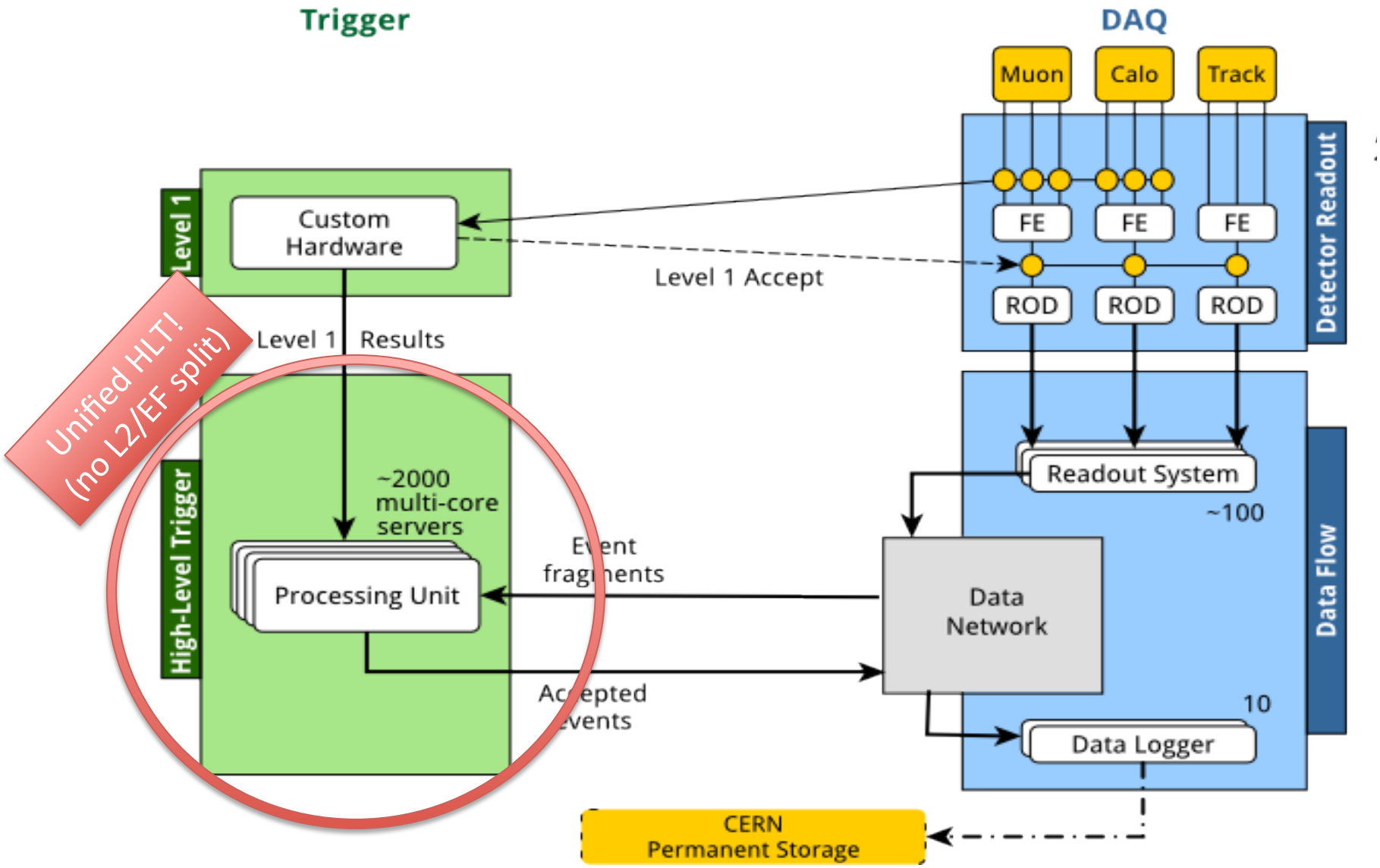


Interplay of performance of algorithms in presence of fake and real MET crucial.



Run II Concepts and Changes

Changes for Run II



E_T^{miss} Trigger for 2015

Several scenarios considered:

*** L1 MET calibration: Jets & LUT**

* MHT versus MET (with LUT to calibrate Jets)

* SET based calibration

* …

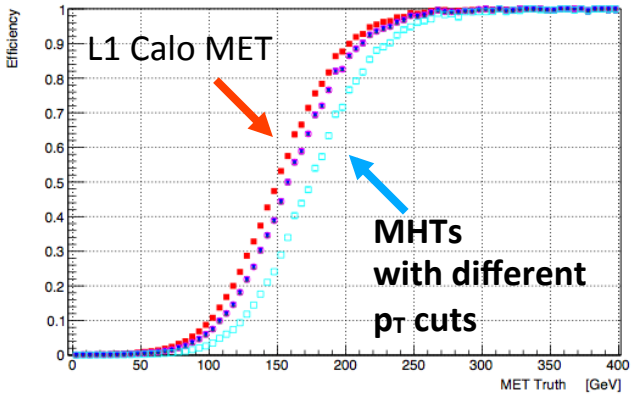
Several scenarios on the table:

* **MHT + Clusters (eventually FTK)**

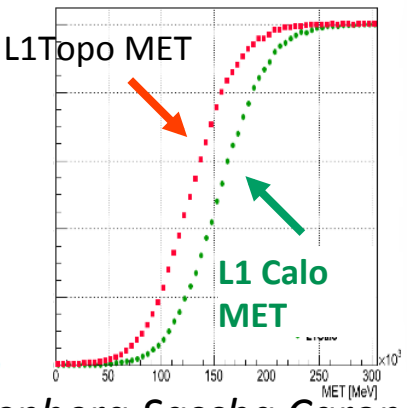
* Clusters

* Cells

10-3 reduction

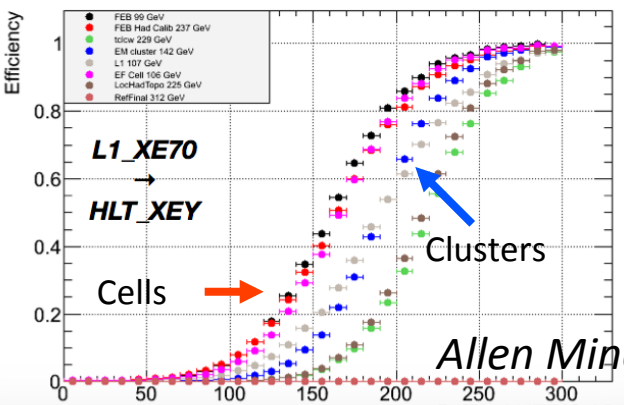


10-4 reduction



L1 & HLT combined 10-5 reduction

'Disaster' Plot



Allen Mincer

Antonia Strübig, Jeroen Schouwenberg,Sascha Caron

Preliminary Jet/MET Menu for Run II

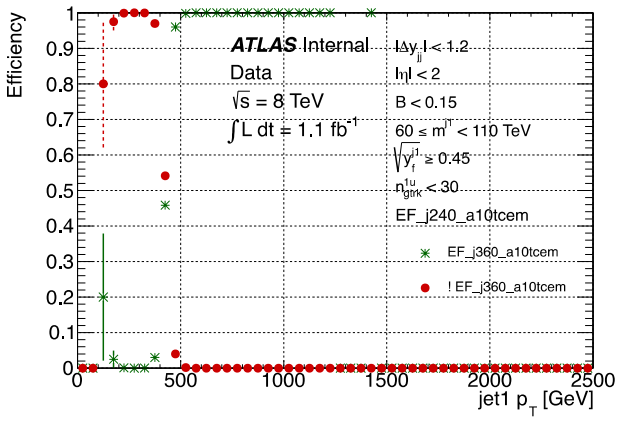
	Run1 L1	HLT	Run2 L1	HLT
Single jet	J75	360 GeV	J100	400 GeV
Multi-jets	4J15	5×55 GeV	4J20	5×85 GeV
				5×75 GeV, |η|<2.5
		6×45 GeV	5J15_ETA25	6×50 GeV, |η|<2.5
Jet + MET	J30_XE50	80 GeV (j), 100 GeV (MET)	J75_XE40	150 GeV (j), 90 GeV (MET)

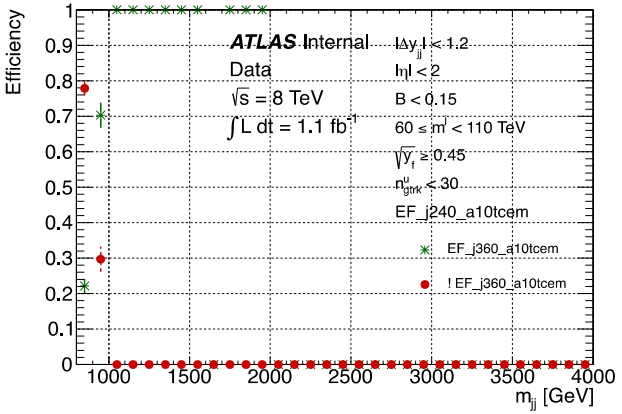
	Run1 L1	HLT	Run2 L1	HLT
MET	XE40	80 GeV	XE70	100 GeV
b-jets	4J15	45 GeV (b), 3×45 GeV(j)	4J20	75 GeV (b), 3×75 GeV (j)
		2×35 GeV (b), 145 GeV (j)		2×60 GeV (b), 200 GeV (j)
b-jet + (jets) + MET	J75	45 GeV (b), 145 GeV (j), 60 GeV (MET)	J100	70 GeV (b), 175 GeV (j), 70 GeV (MET)
		45 GeV (b), 110 GeV (j), 60 GeV (MET)	J75_XE40	120 GeV (b), 70 GeV (MET)

Run I Trigger Performance and Use Cases

Single jet triggers in the hadronic diboson resonance search (VV->JJ)

- Use events triggered by EF_j240_a10tcem (prescaled)
  - Study EF_j360_a10tcem trigger turn-on as a function of
    - Dijet mass
    - Leading jet-pt
    - Tagged dijet mass
    - Leading tagged jet pT





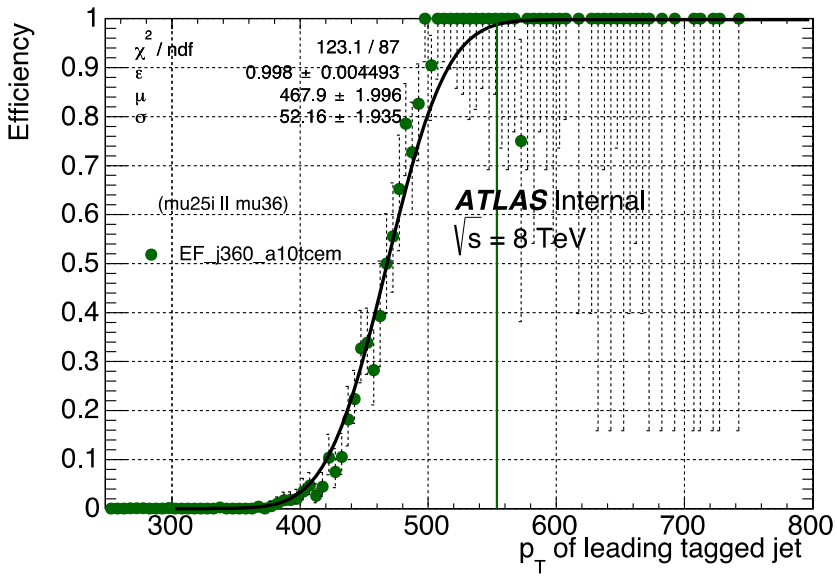
* Tagged jets

VV->JJ team (Enrique Must)

Single jet triggers in the hadronic diboson resonance search (VV->JJ)

- Use events triggered by a muon trigger
  - Study EF_j360_a10tcem trigger turn-on as a function of
    - Leading jet-pt
    - Leading tagged jet pT

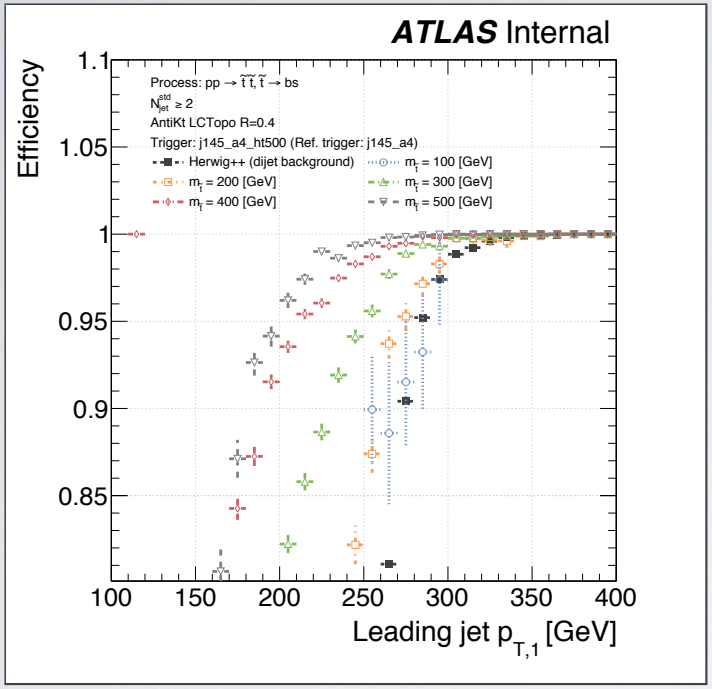
VV->JJ team (Enrique Must)



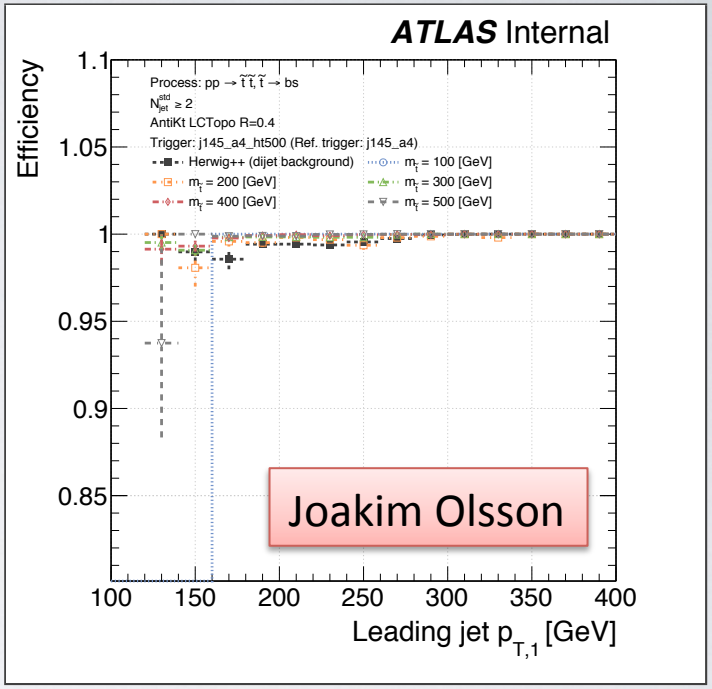
(Ungroomed pT)

Jet-H_T Triggers

Turn-On Curves: `EF_j145_a4tchad_ht500_L2FS_delayed`



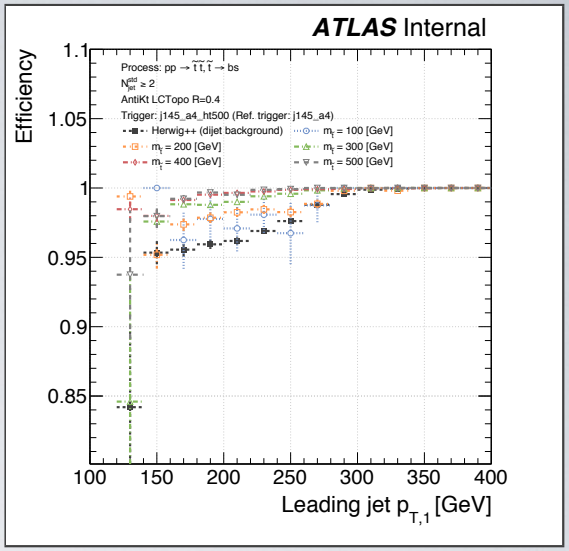
(a) jet p_{T1}, no H_T cut



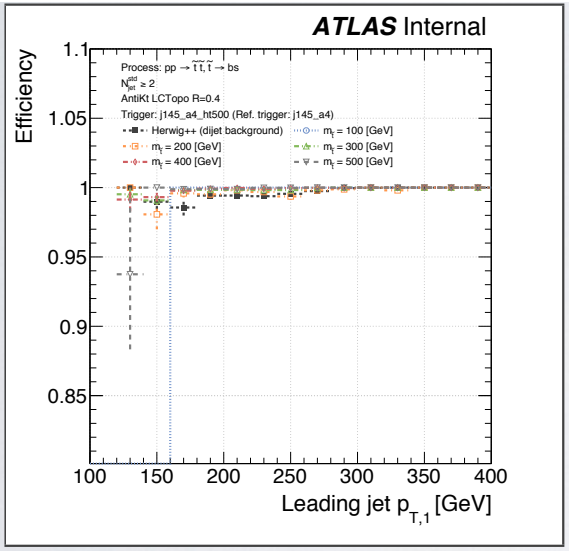
(b) jet p_{T1}, $H_T > 650$ GeV

- An offline cut of $H_T^{\Sigma} > 650$ GeV makes the `EF_j145_ht500` trigger fully efficient around $p_{T1} > 175$ GeV
  - This is a critical observation since a $p_{T1} \gtrsim 300$ GeV, as seems necessary in figure (a), would have made us much less sensitive to low stop masses down to 100 GeV

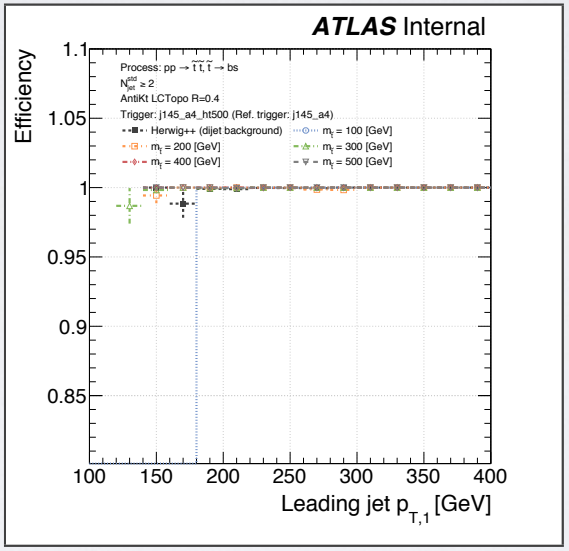
Jet+HT turn-on curves for SUSY



$H_T^{\Sigma} > 600$ GeV

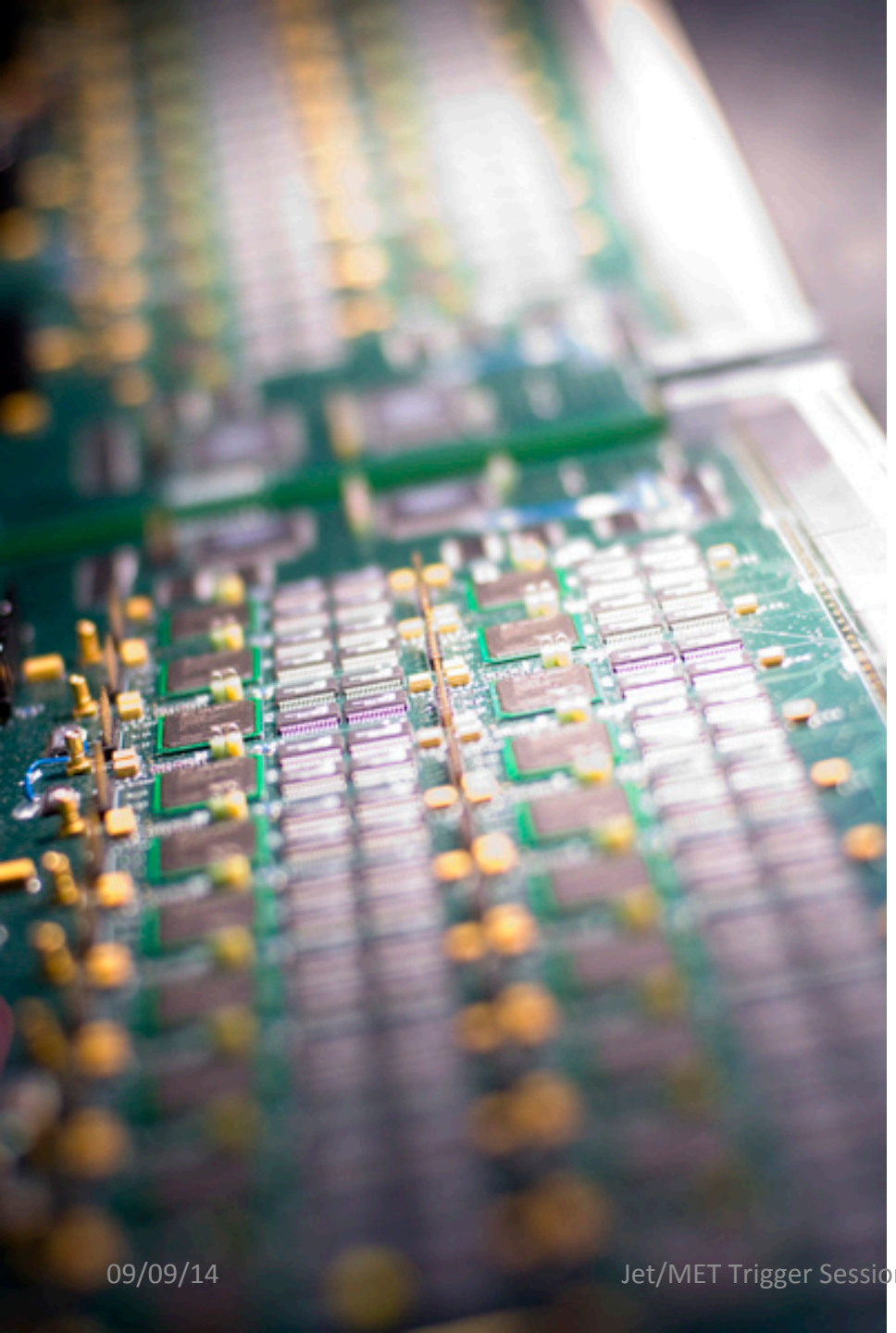


$H_T^{\Sigma} > 650$ GeV



$H_T^{\Sigma} > 700$ GeV

Joakim Olsson



L1Topo for Run II

L1 Calo Calib and Simul for Run 2 (I)

- Many new features added to calibration at L1
  - New hardware: nMCM, L1Topo
  - New firmware: Cluster Processor
    - More realistic pulse shape and finer granularity
  - New strategies : Autocorrelation FIR filter coefficients, noise cuts, BCID dependent pedestal corrections, isolation, Met calibration (other slide)
    - Adapted to luminosity conditions to cope with pile-up dynamically
  - Dual LUT option allowing for different calib for Tau/EM and Jet/Met

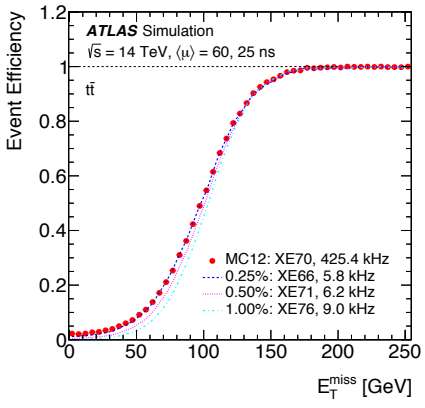
➔Improve Jet and Met performance in 2015 conditions compare to 2012 configuration in same conditions
  - Some optimization and calorimeter status dependence still needed

- Studies done:
  - Compare MC12 (matched coefficient + 2012 noise cuts) to MC15 (Autocorrelation coefficients + pedestal correction + 0.5% occupancy) using $<\mu>$ = 60 minbias and ZH signal samples

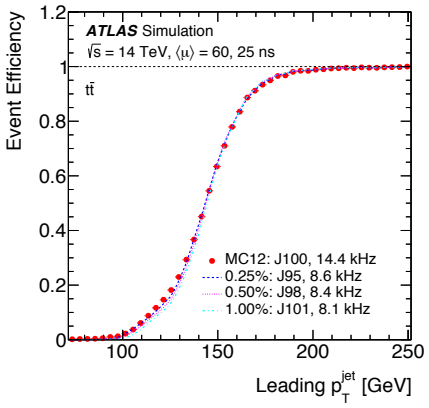
L1 Calo Calib and Simul for Run 2 (II)

- Noise cut optimization:

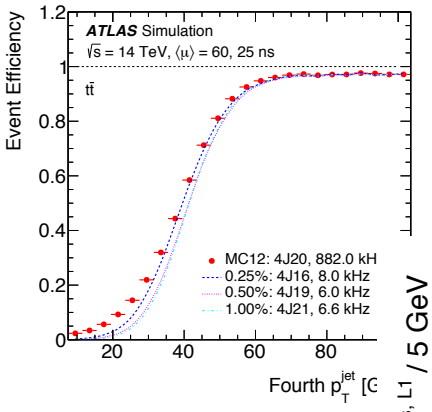
  Huge rate reduction with no loss of efficiency
  - overall best working point at 0.5% occupancy
  - Reduction of: MET – 98.5%, JET – 42%, 4J – 99.3%



MET

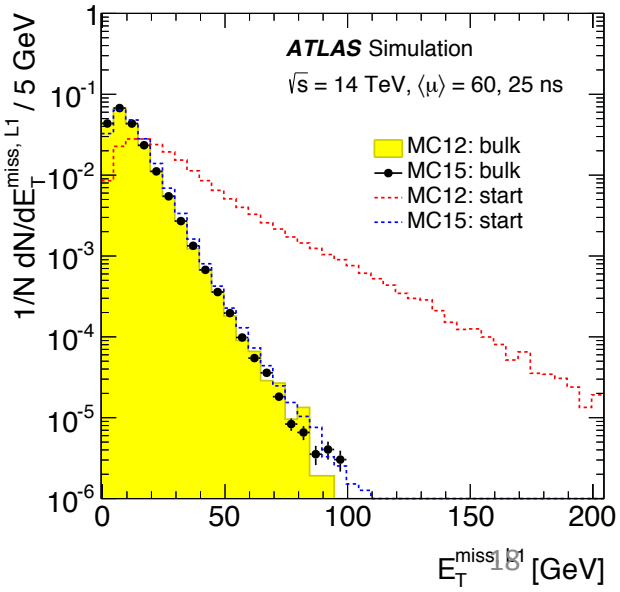


Single Jet



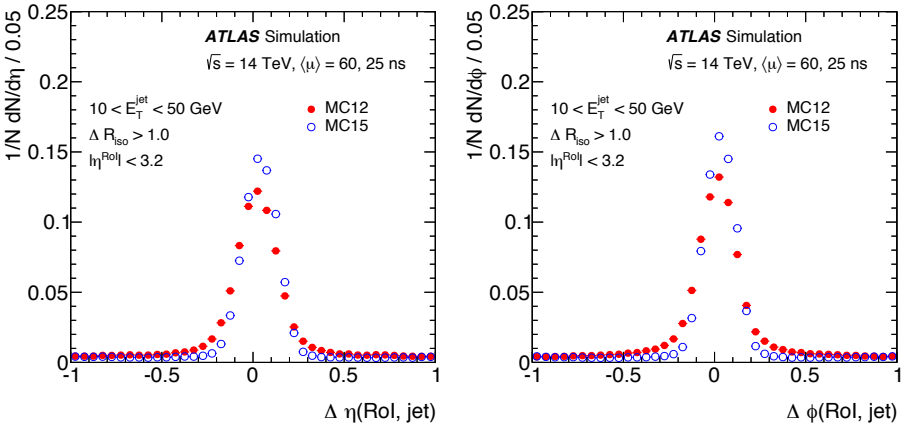
Multi Jet

- Met distribution:
  - Non-exponential tail removed
  - Shifts at start of bunch train reduced and corrected

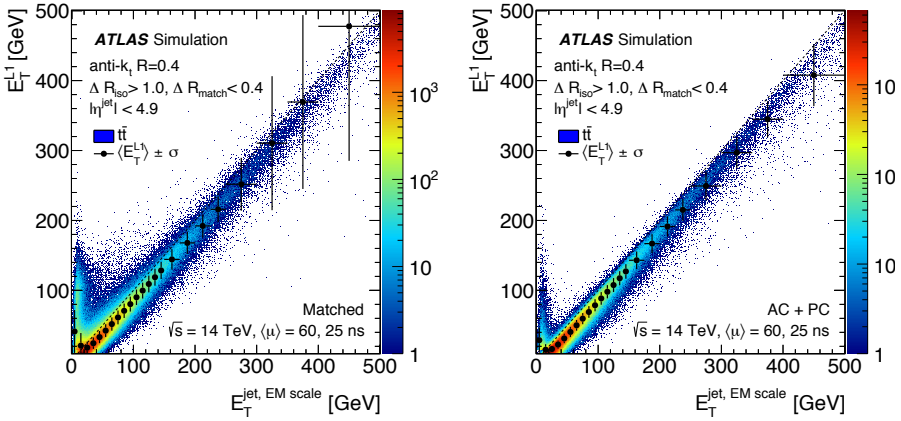


L1 Calo Calib and Simul for Run 2 (III)

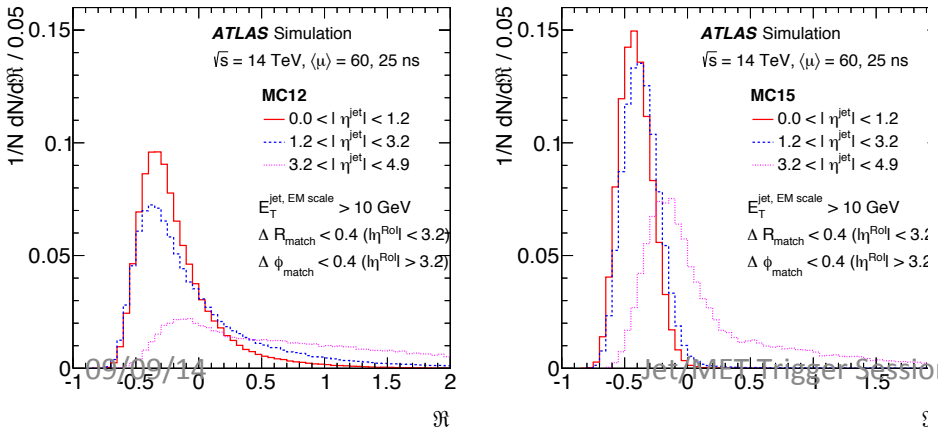
- Jet position resolution sharper in central region



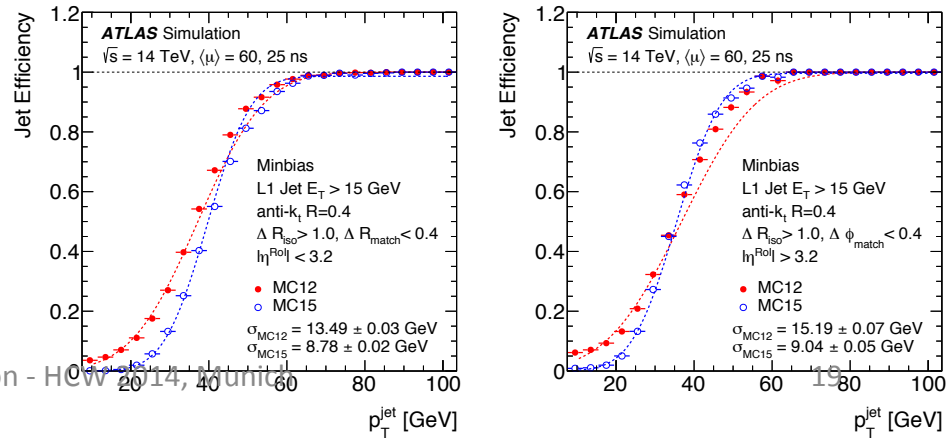
- Jet ET correlation shows reduced overestimate at low ET due to start of bunch train correction



- Jet linearity sharper with reduced tail



- Efficiency: sharper turn-on with similar plateau



Improvement of L1Met with L1Topo I

- Objective: Use L1Topo to calibrate Met using offline information on L1 within look-up tables ➔ maximize correlation to real Met

$$(E_T^{miss})^2 = (\Sigma_i \ \vec{E}_{T,i} * C_i)^2 \ | \text{ for all i with } w_i > \text{cut value}$$

- Method: Find C_i that minimize $\Delta p_{x,y} = (p_{x,y\ reco} - p_{x,y\ true})$, using Kalman filter

current estimation

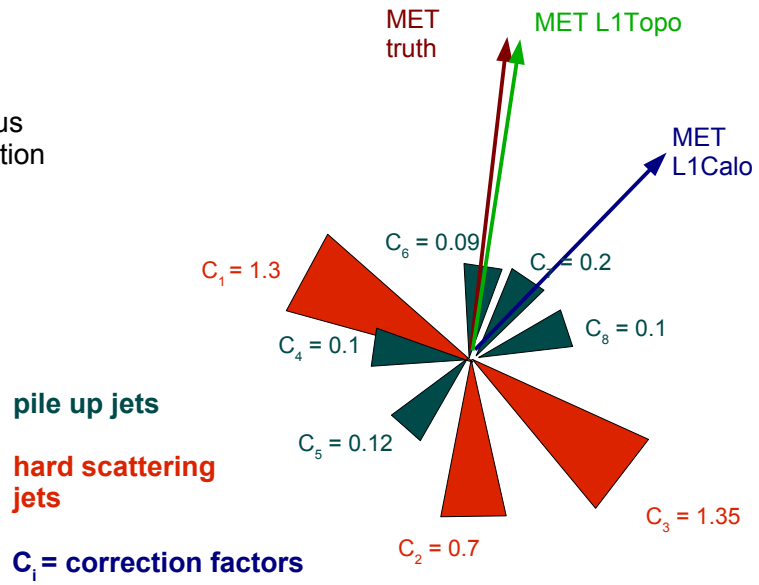
$$\vec{C}_n = \vec{C}_{n-1} + \boldsymbol{K_n}\left(\vec{y}_n - \vec{f}_n\left(\vec{C}_{n-1}\right)\right)$$

truth value $E_{x,y\ T}$

previous estimation

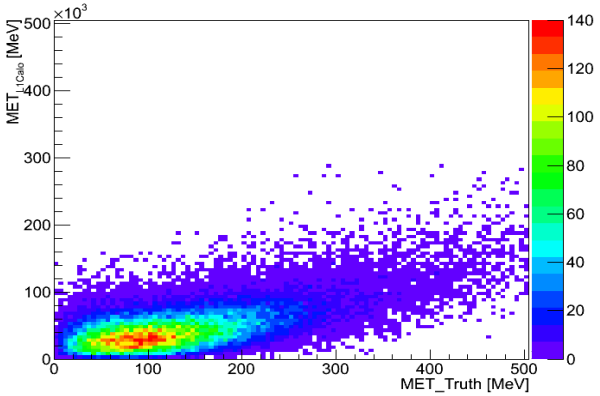
$\mathbf{K_n}$:= Kalman Gain (product of measured $E_{x,y\ T}$, error and covar. matrix)

- Two approaches:
  - Met = Σ jets
  - Correction to L1Met

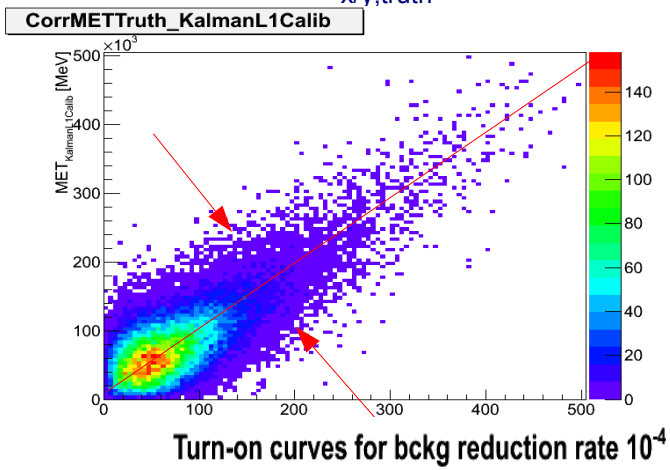


Improvement of L1Met with L1Topo II

L1Calo MET

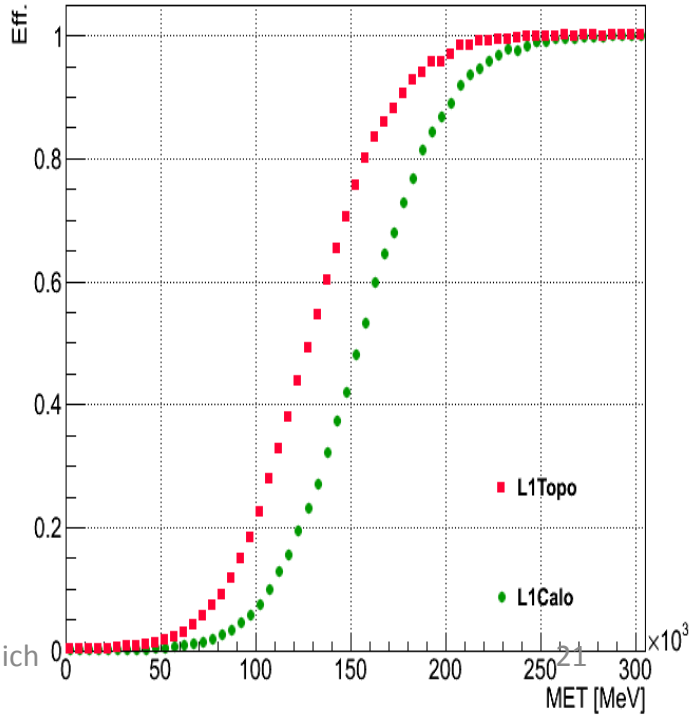


L1 MET calib. $\sigma(p_{x/y,truth})$

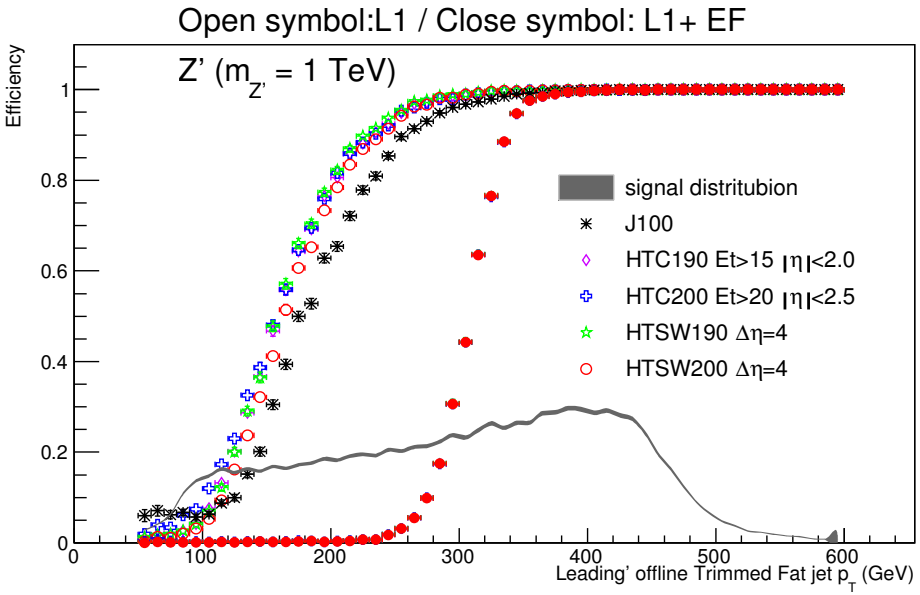


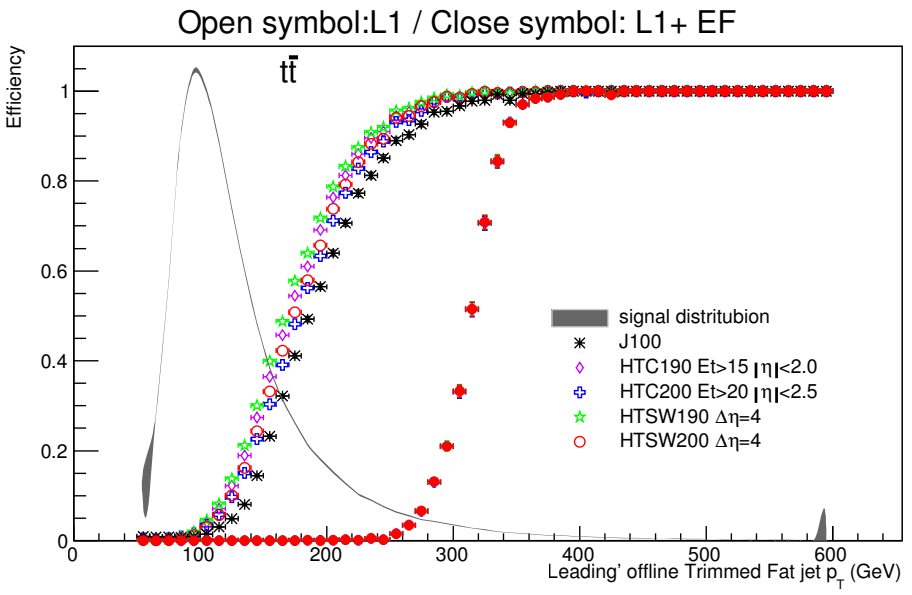
Turn-on curves for bckg reduction rate 10^{-4}

- Implementation:
  - LUT with 16 bins in η and 10 bins in E_T (1-1023 GeV)
  - Test on FPGA: less than 18% of resources
- Results:
  - Correlation significantly improved
  - Better efficiency and plateau gain (~30 GeV)
  - Doesn't depend much on signal
- Need to redo with new L1 noise cuts



L1 HT triggers for fat jets: signal





UBA (Devesa, Reisin, Otero, Piegaia)

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.

Studied di-jet, and three signal samples ($t\bar{t}$, $Z' \to t\bar{t}$, $W' \to tb$):

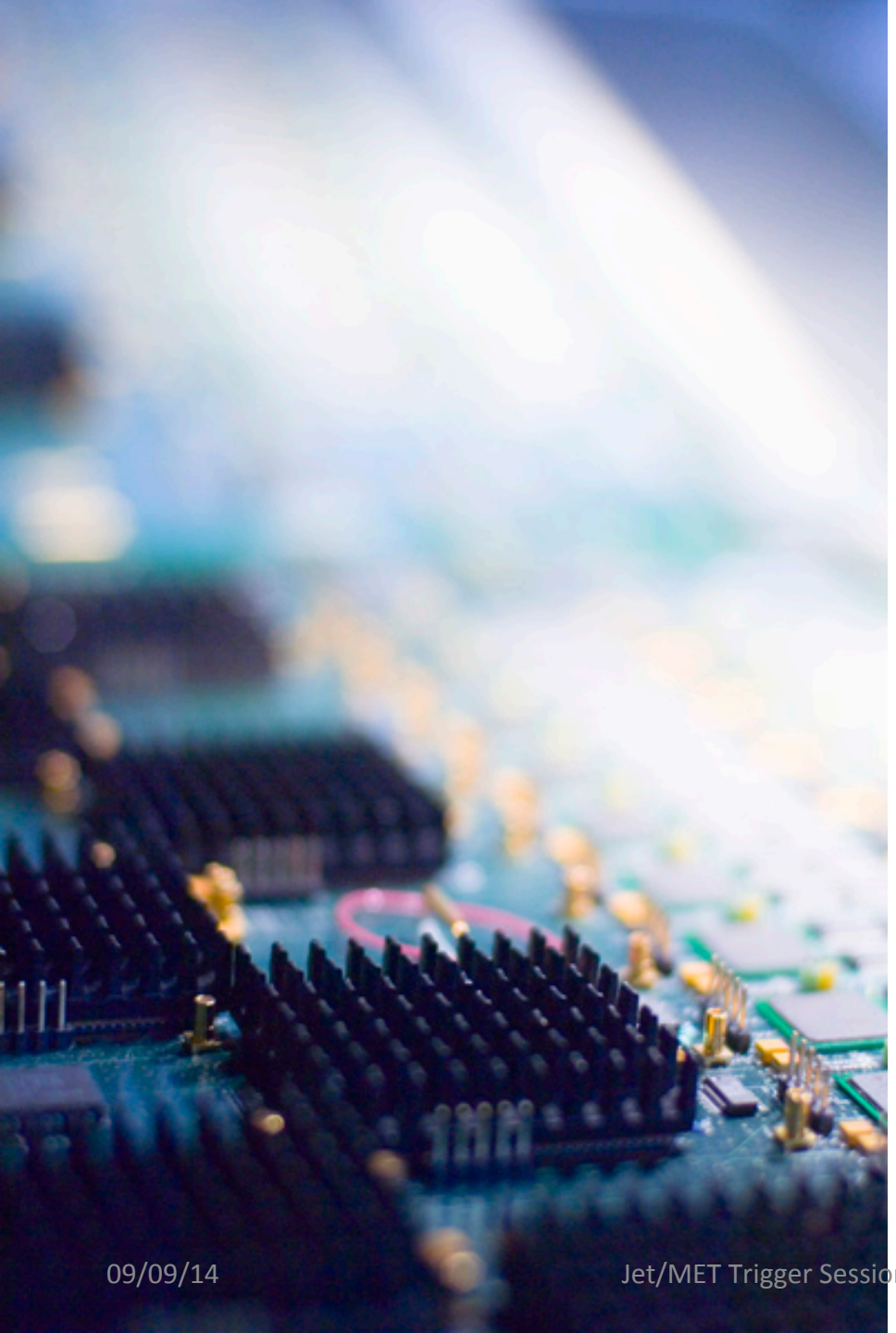
- mc12_8TeV.117050.PowhegPythia_P2011C_ttbar.merge.NTUP_COMMON.e1728_s1581_s1586_r3658_r3549 p1625
- mc12_8TeV.110903.Pythia8_AU2MSTW2008LO_zprime1000_tt.merge.NTUP_COMMON.e1345_s1499_s1504 r3658_r3549_p1562
- mc12_8TeV.110722.MadGraphPythia8_AU2CTEQ6L1_Wprime_right_tb_hadronic_M1250.merge.NTUP_TOP.e1817_s1499_s1504_r3658_r3549_p1400
- mc12_8TeV.159111.Herwigpp_EE3CTEQ6L1_jetjet_JZ*W.merge.NTUP_COMMON.e1373 s1499_s1504_r3658_r3549_p1562
- Note: These are 8TeV samples. Haven't adressed the impact of 14 TeV samples.

L1 HT triggers for fat jets: rates

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

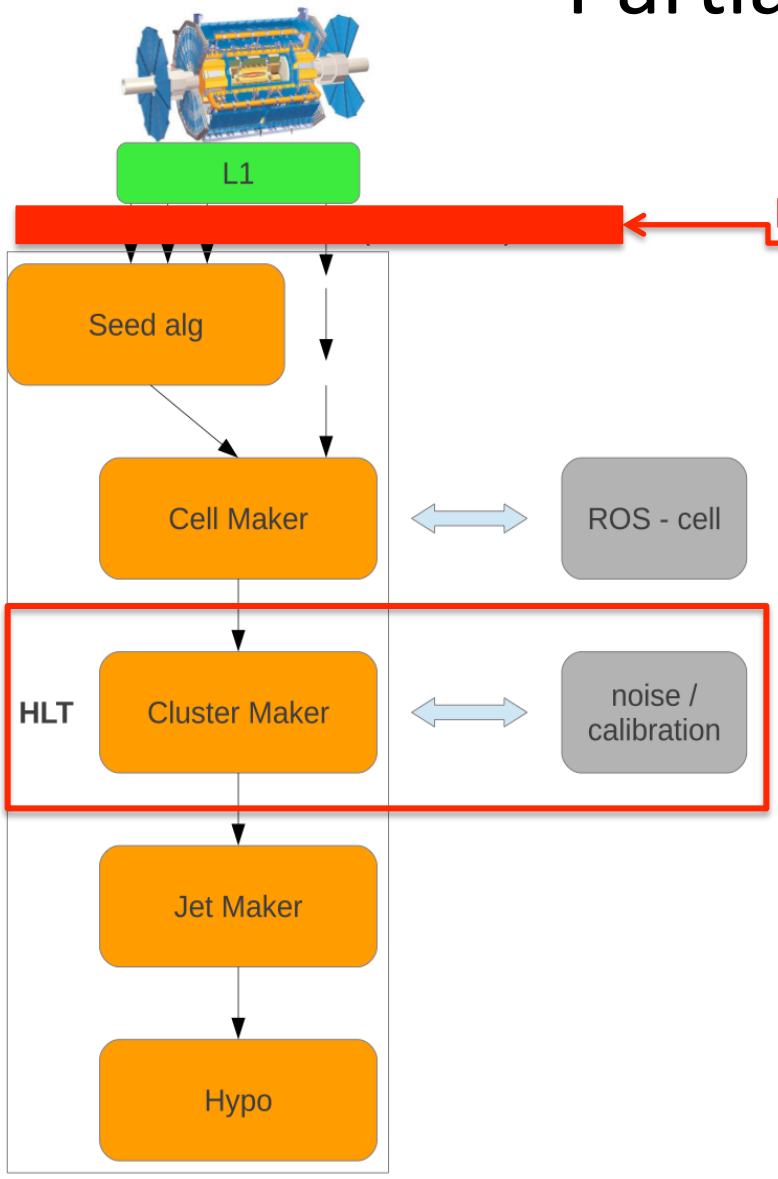
UBA (Devesa, Reisin, Otero, Piegaia)

- New proposed HT triggers have 25% unique rate despite having a lower total rate than the “default” J100 single jet trigger
- Higher efficiency at L1 for boosted objects



Partial and Full Scan

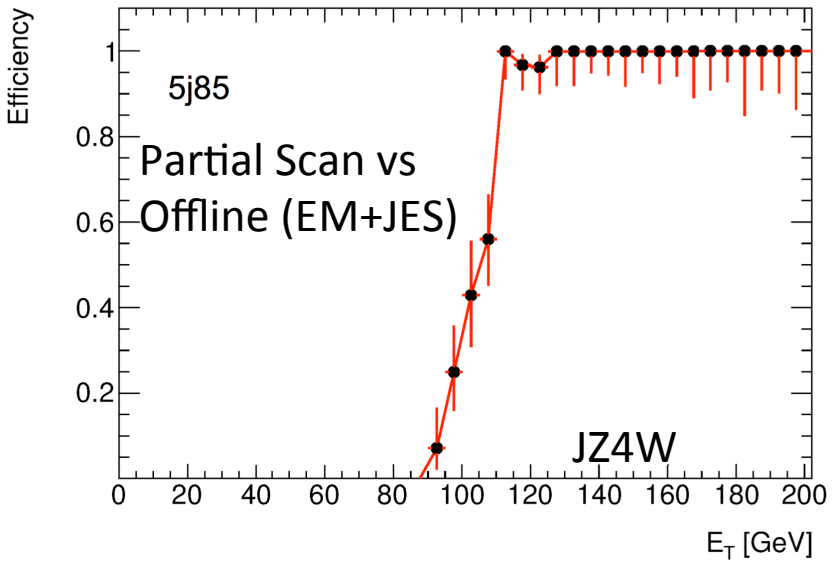
Partial versus Full Scan



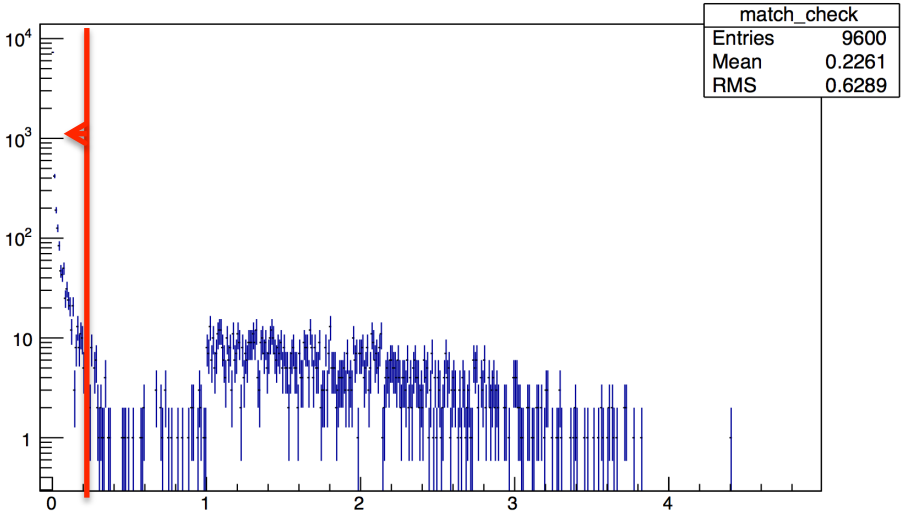
- No Level 2 trigger anymore!
  - I.e. take full L1 rate as HLT input
- Run full-scan on TriggerTowers (aka **Level 1.5**) to identify jet positions
  - Avoids L1 bias from close-by jets
  - Runs Anti-kt instead of cone
  - <t> ≈ 12ms (from Run-I typical run)
  - L1-like E_T resolution
  - Not yet tested for new data
- HLT jet finding on **Super RoI**
  - Union of all regions identified by L1.5
  - Assuming full-scan is too expensive
    - **Only <t> ≈ 40-50ms available***
- Evaluating performance and costs of new scheme
  - Tuneable parameters: L1_Jx seed, size of RoIs making sRoI
  - Data: 14TeV <μ>=80
- Efficiency:
  - PS (L1_J20) ≈ 99.5% wrt Full Scan (j110)

(*) depends on money spent on trigger CPU

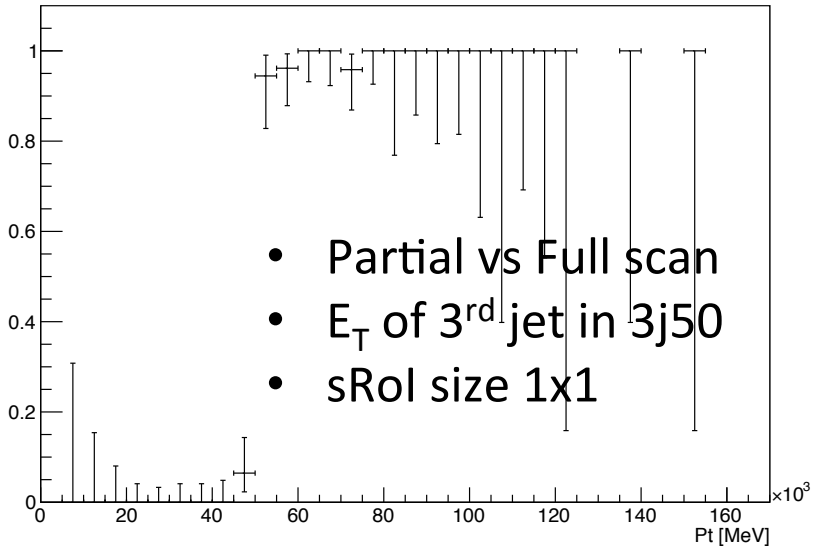
Performance



Delta_R offline/online

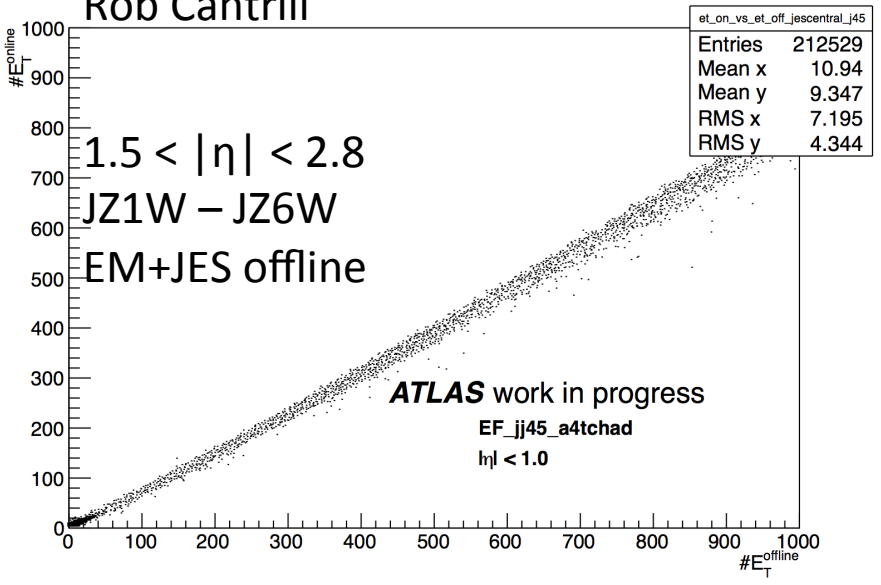


David Freeborn

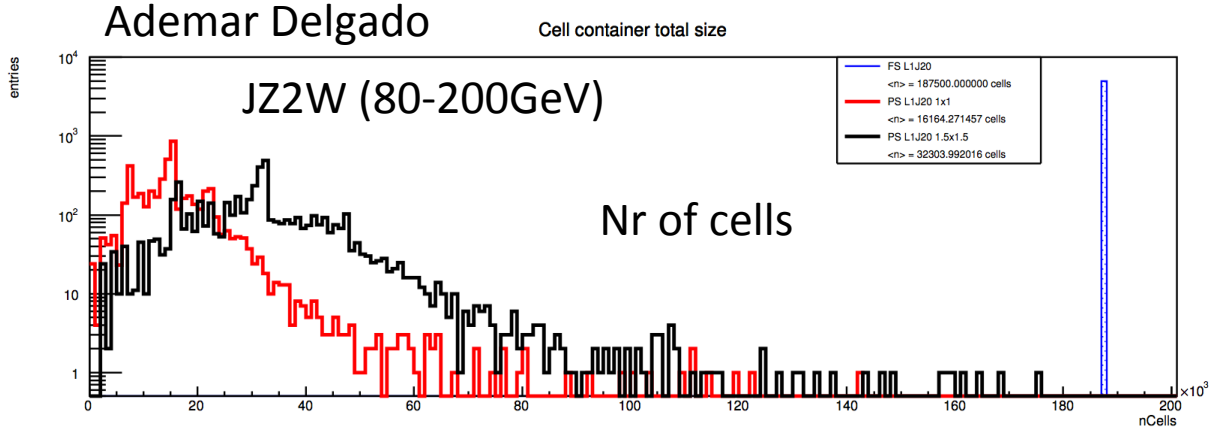


- Partial vs Full scan
- E_T of 3rd jet in 3j50
- sRoI size 1x1

Rob Cantrill



Cost…



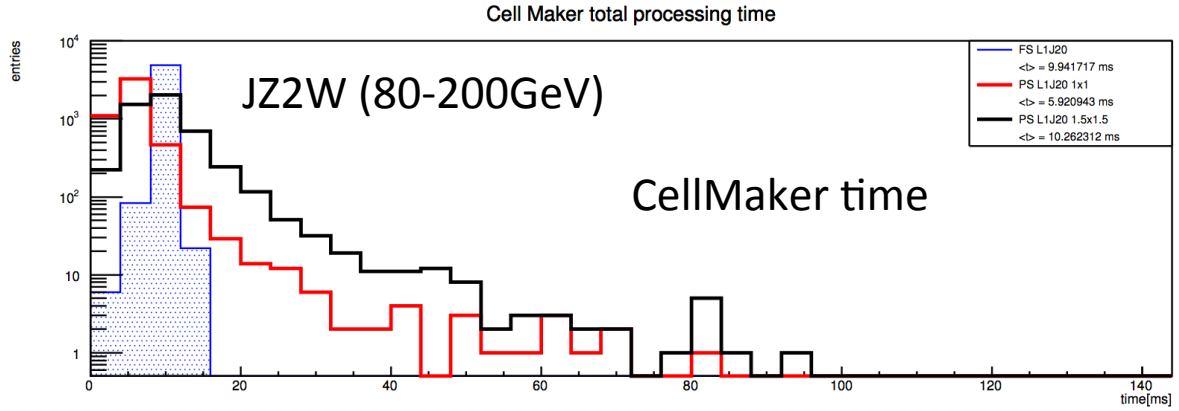
Full Scan : <n> ≈ 190k cells

Partial Scan: L1_J20 1x1 :

<n> ≈ 16k cells

Partial Scan: L1_J20 1.5x1.5 :

<n> ≈32k cells



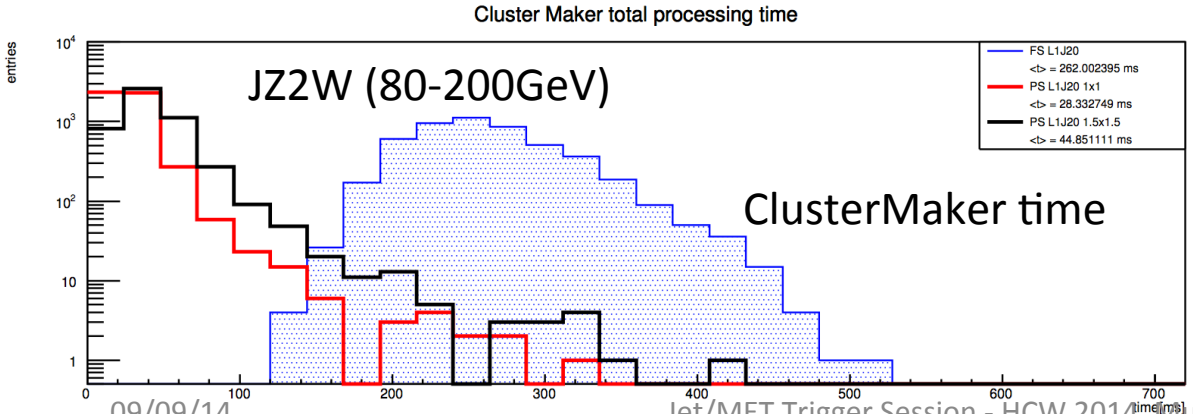
Full Scan : <t> ≈ 10ms

Partial Scan: L1_J20 1x1:

<t> ≈ 6ms

Partial Scan: L1_J20 1.5x1.5 :

<t> ≈ 10ms



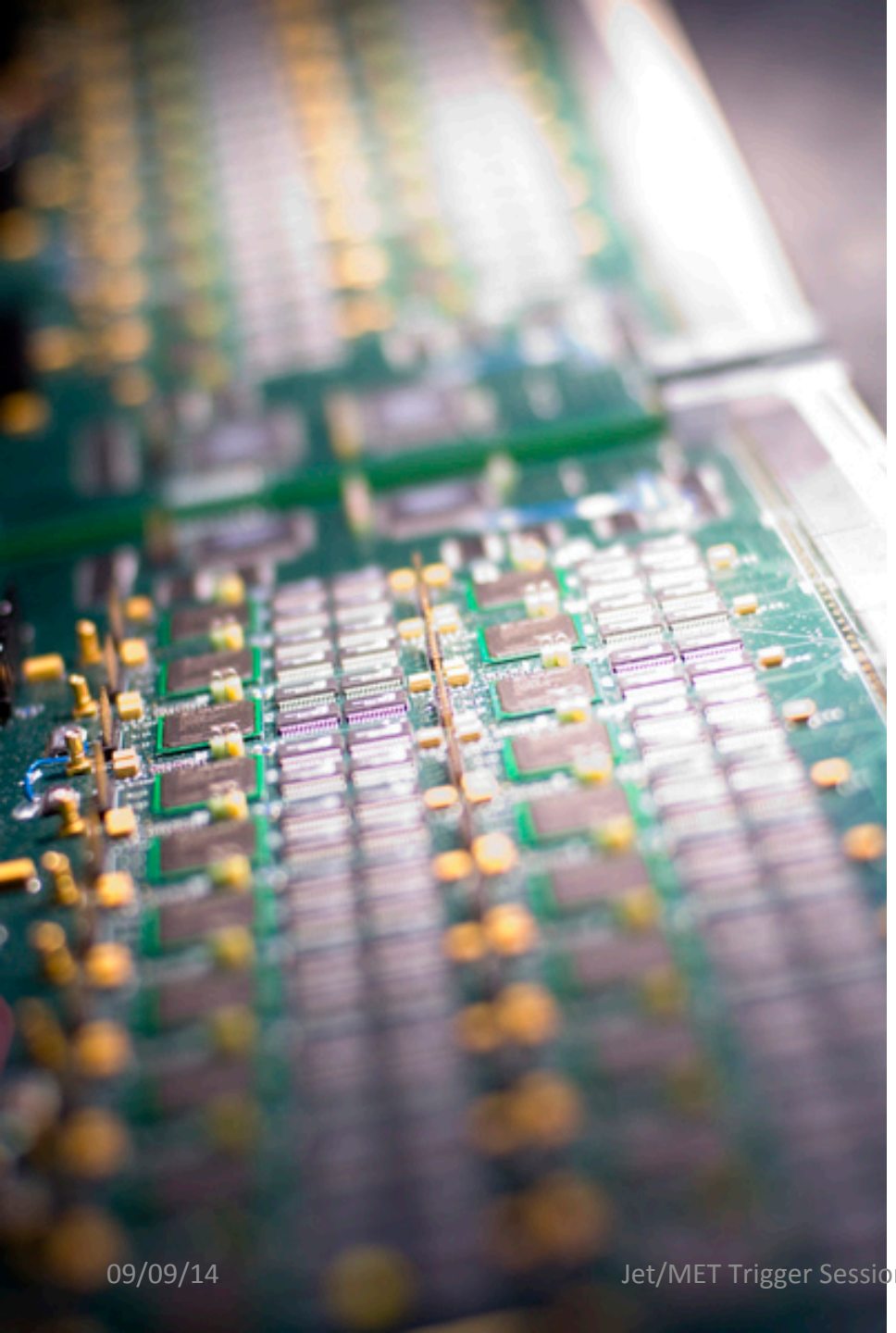
Full Scan : <t> ≈ 260ms

Partial Scan: L1_J20 1x1:

<t> ≈ 30ms

Partial Scan: L1_J20 1.5x1.5 :

<t> ≈ 45ms



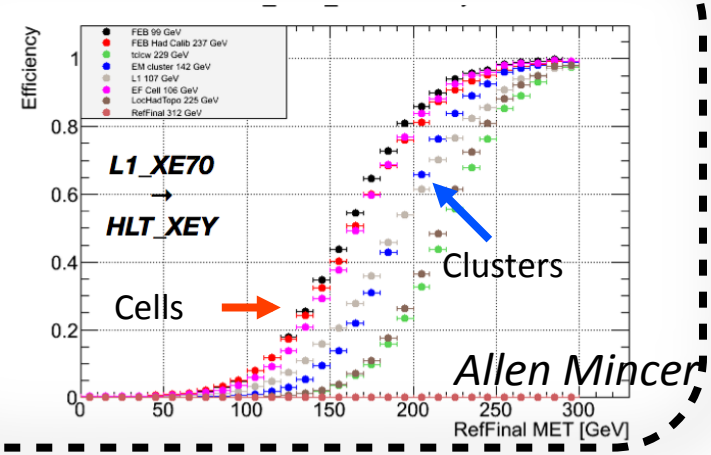
TOPOCLUSTERS IN THE HLT

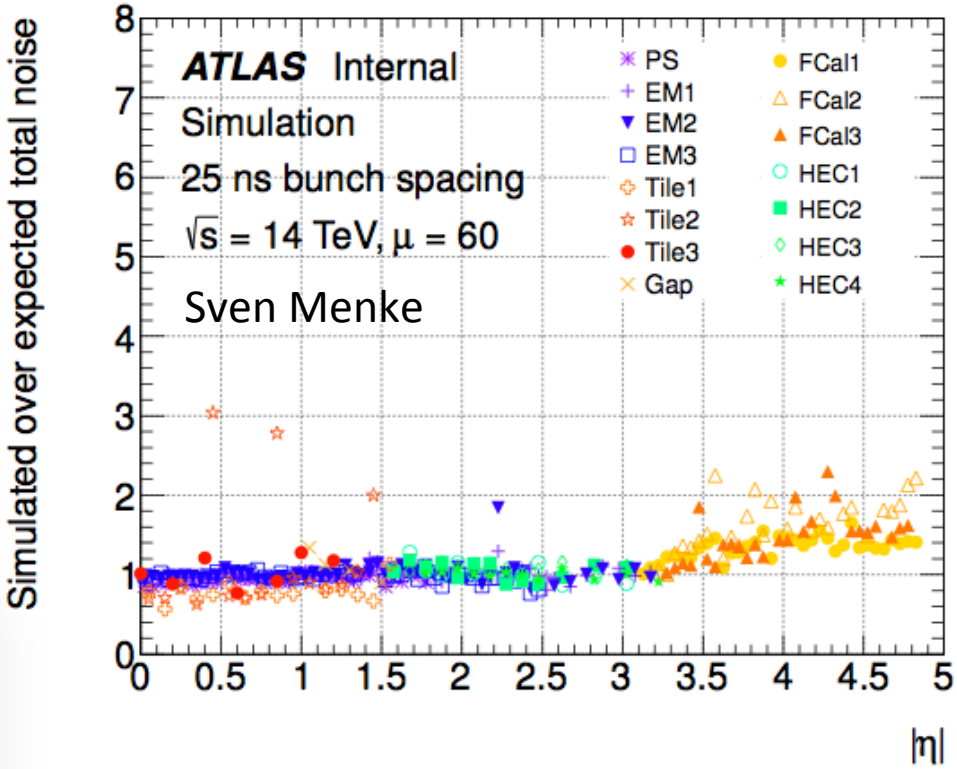
Clustering ‘Saga’ and the ‘Disaster’ Plot

History:

* Requested samples to study 2015 performance 1 year ago.
* The samples arrived in February, and we in essence saw the same thing (and on top problems with L1)
* After talking to HLT calo & L1 and both gave their heads up we requested a second production.

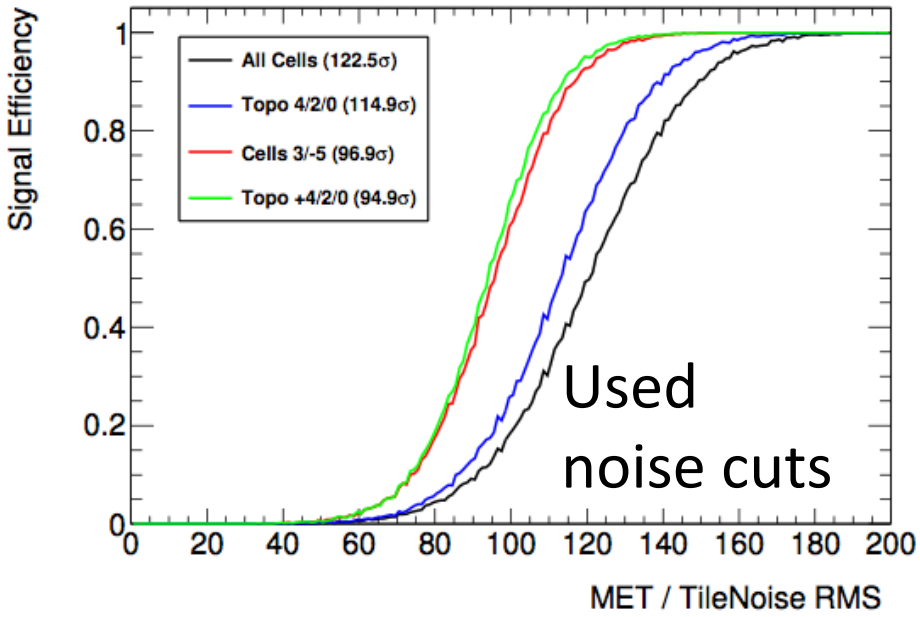
‘Disaster’ Plot

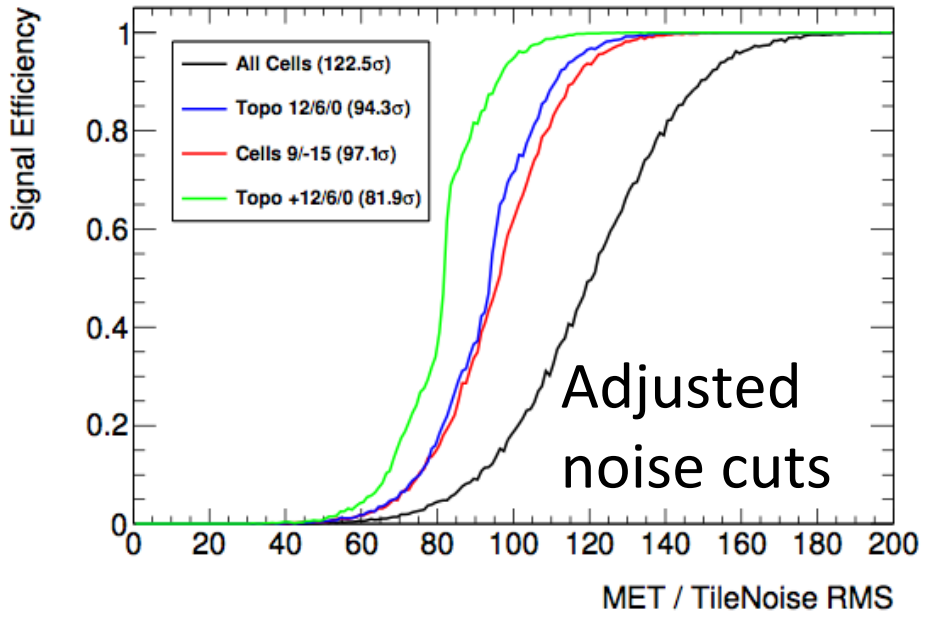




Sven Menke tracked down the problem at light speed; noise levels in Tile & FCal underestimated, hadronic calibration also not doing what it’s supposed to be doing.

Sven's toy

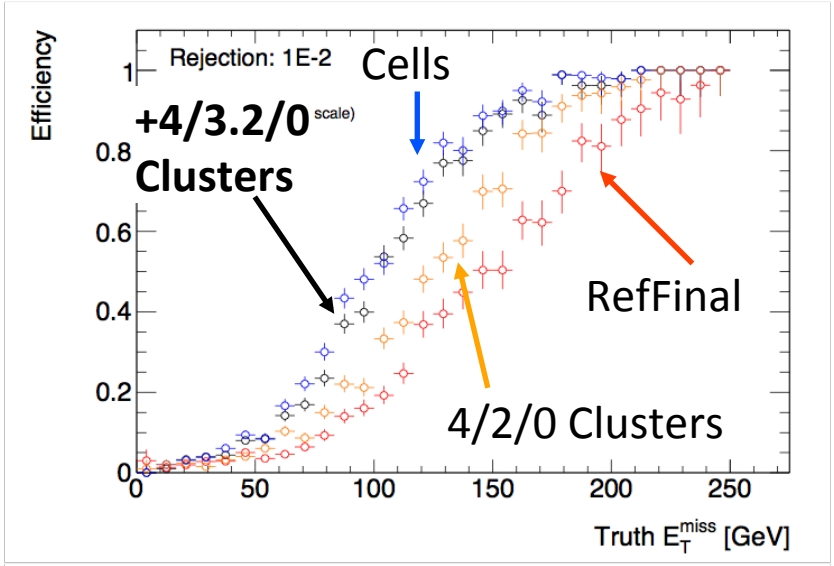


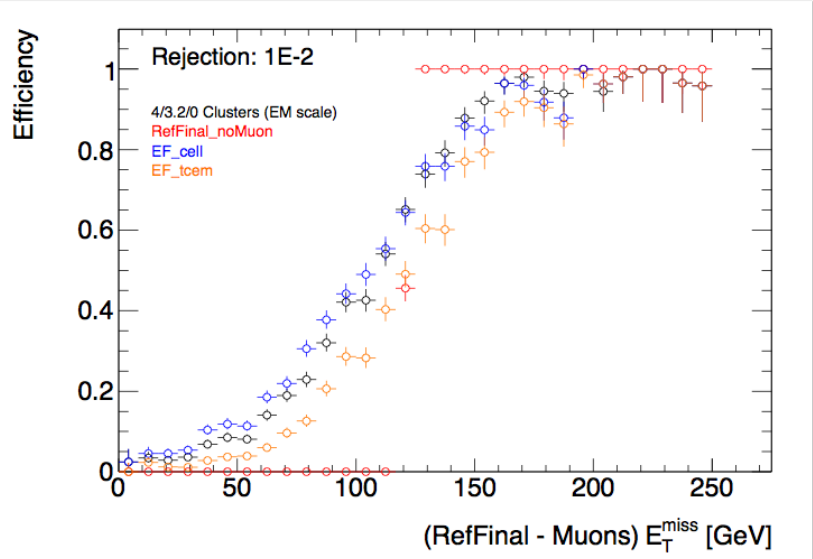


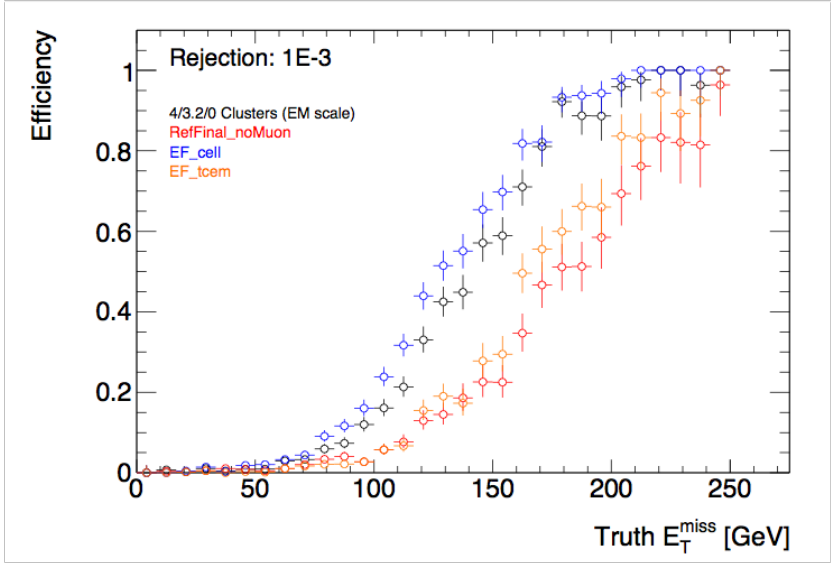
Noise plays a big role on the performance of the trigger

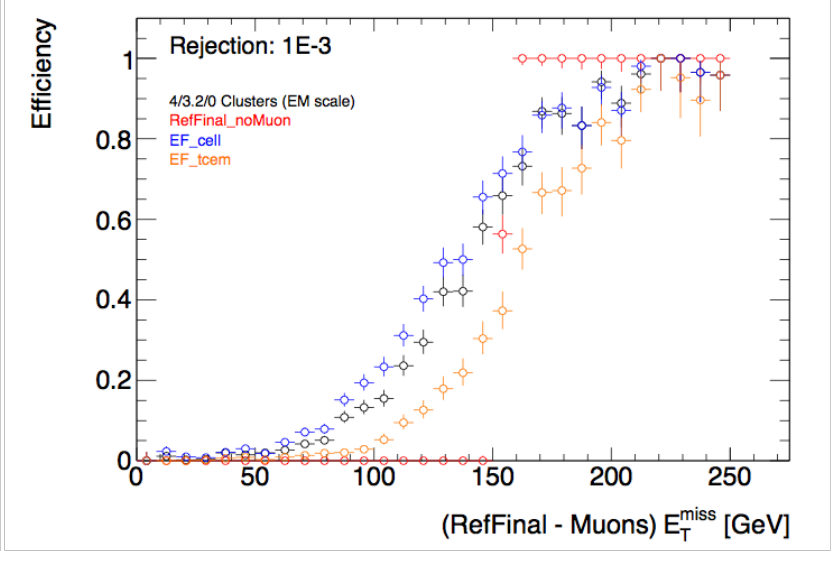
We should use one-sided noise cuts for clustering

Rerunning clustering with faulty samples



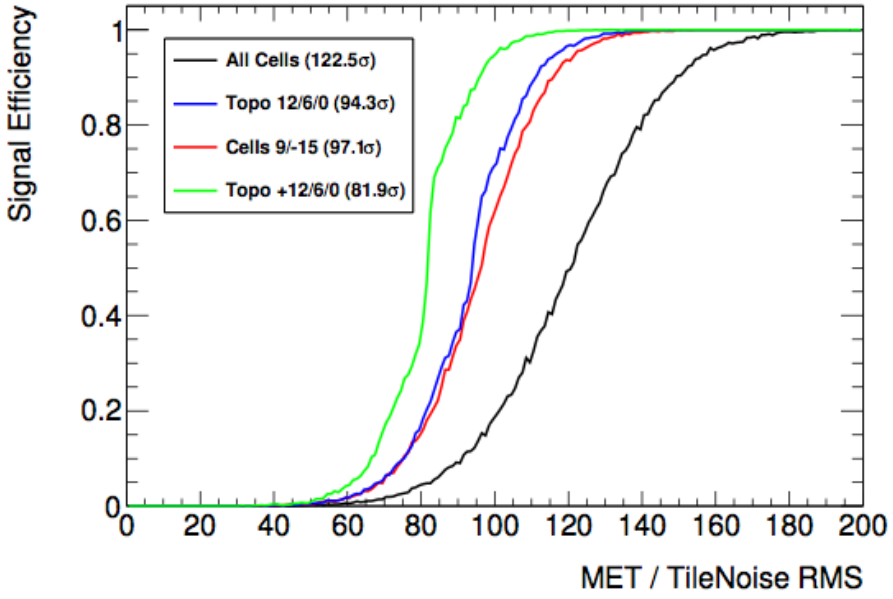


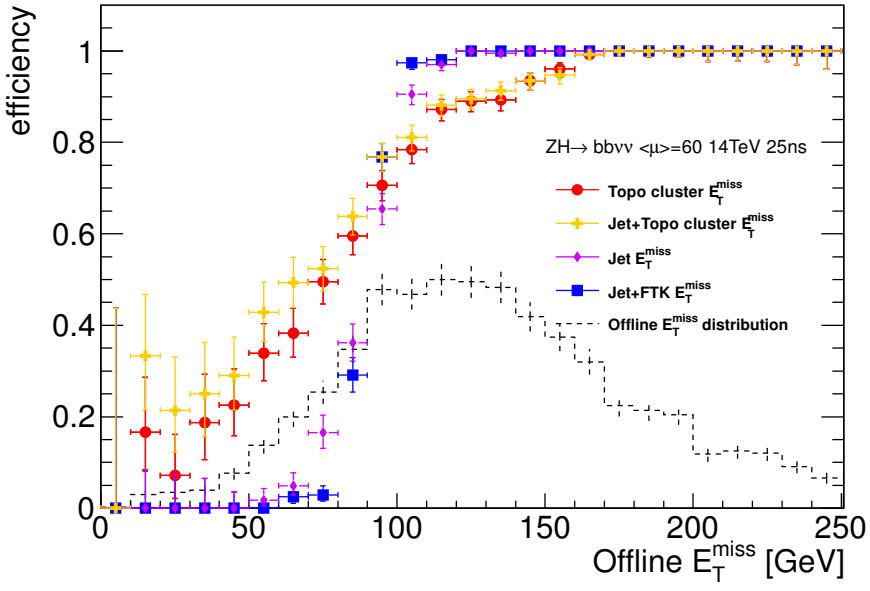


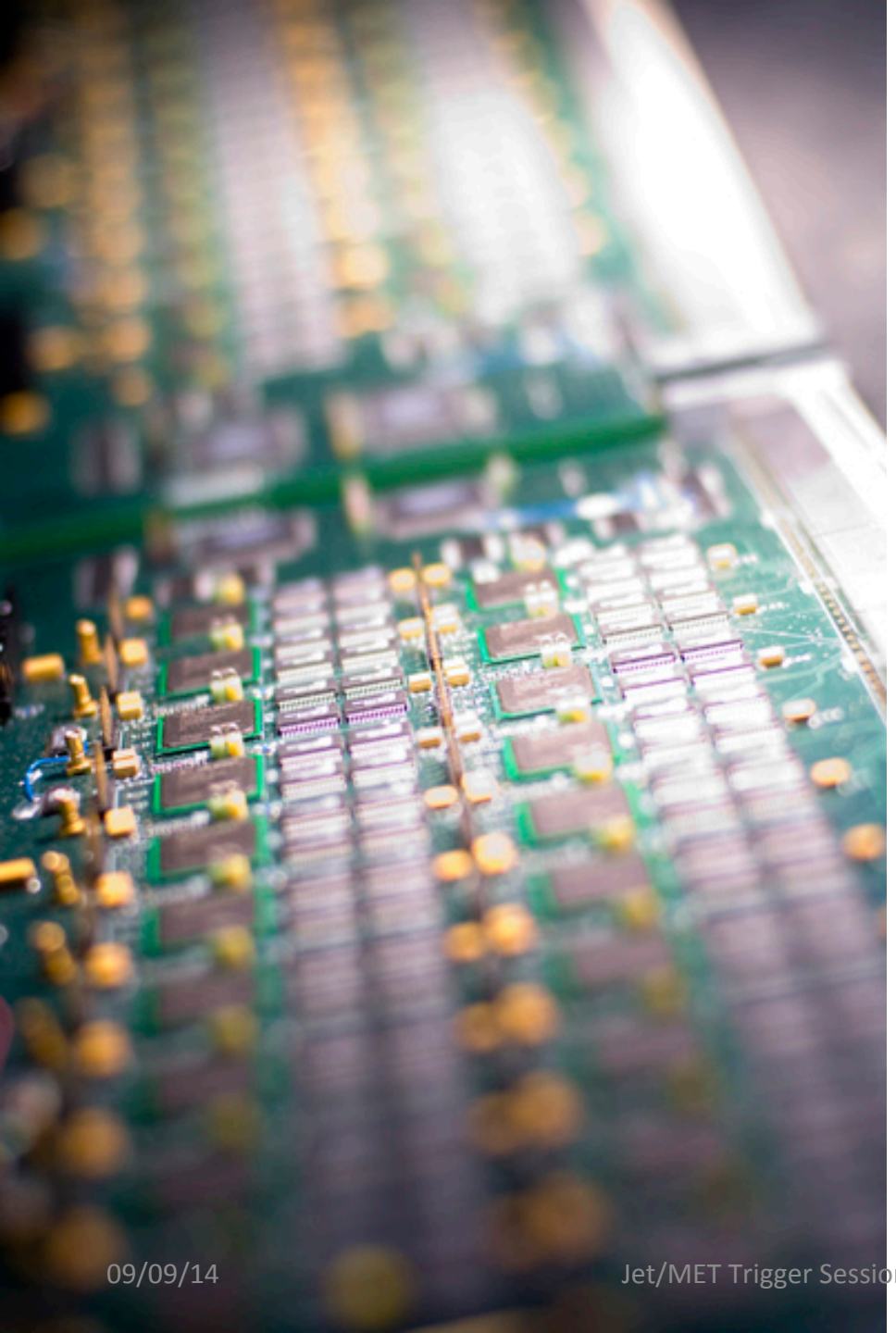


Ok, so what now?

- We will show this to the Trigger General Meeting.
- Samples are in physics validation, but a fixed version will arrive too late for the decision making process if additional CPU should be purchased.

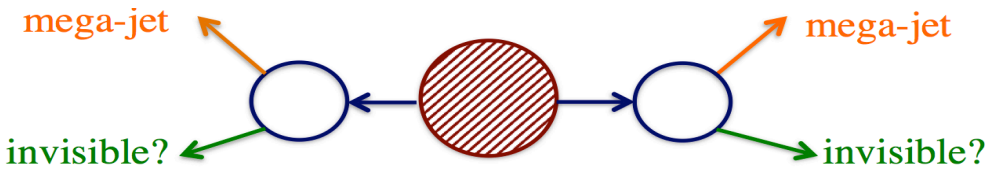






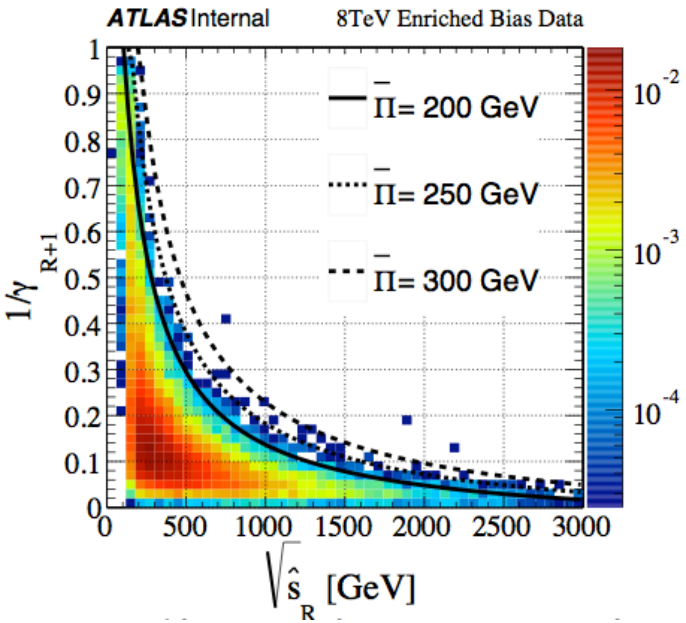
Performance Expectations for Run II

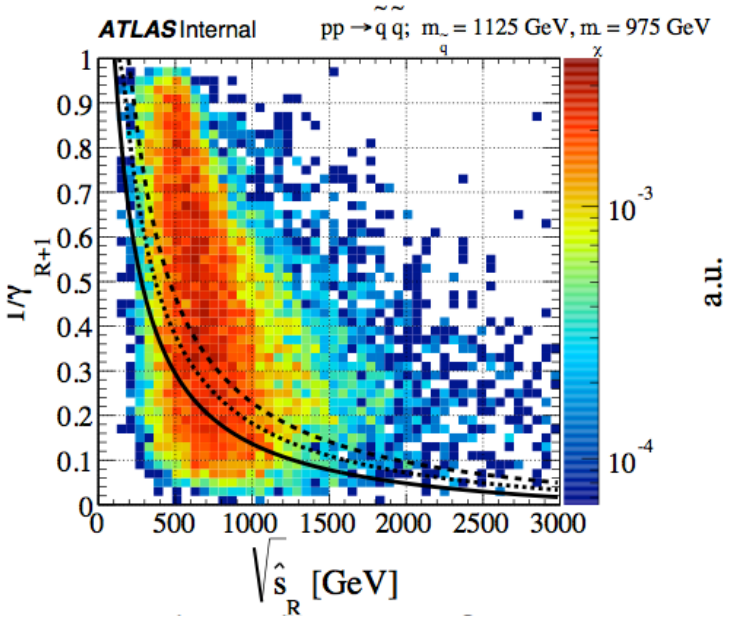
Razor triggers at HLT



- 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



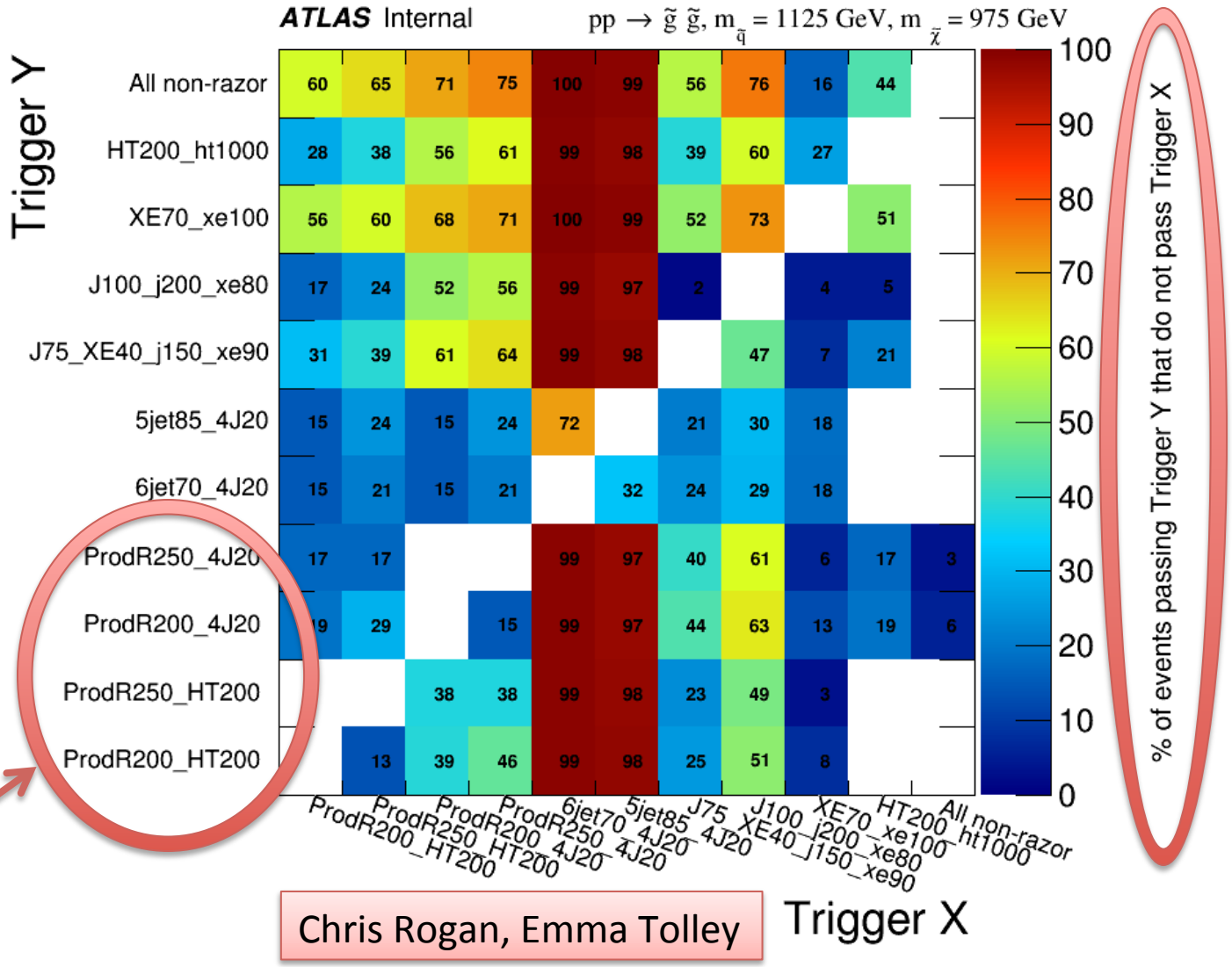


- Suppress background with hyperbolic cut:

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

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*

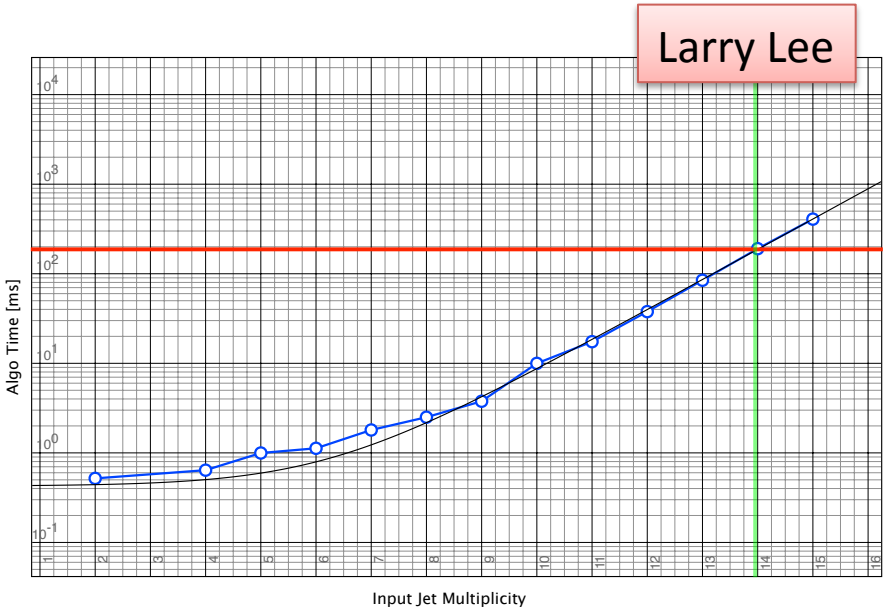


Razor triggers with Different L1 seeds (HT and multijet)

Chris Rogan, Emma Tolley

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

Trigger for ZH ($\nu\nu bb$) in Run 2 (I)

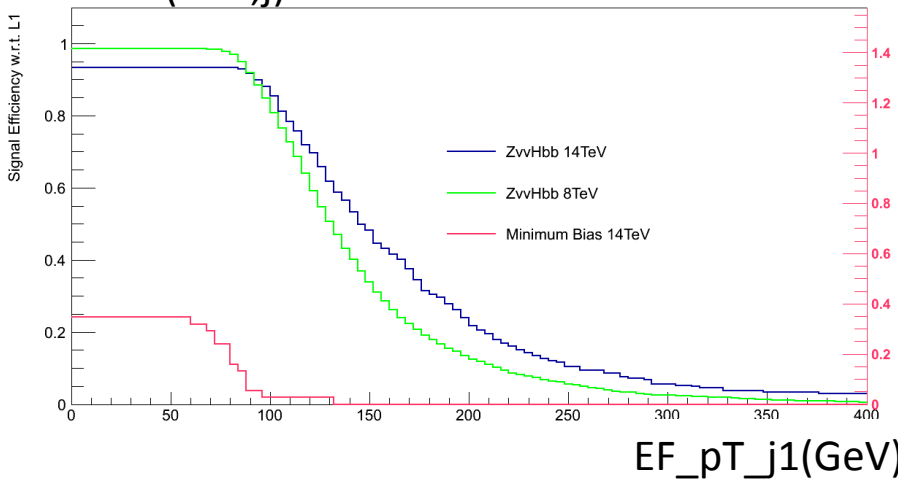
- One of the biggest costumer for Met trigger
  - Use Met-Jet cuts to improve performance
- New L1 triggers:
  - Offline Met > 120 GeV
  - Offline $\Delta\phi$(met-jet), $\Delta\phi(Met_{calo}, Met_{track})$, $\Delta R(j_1,j_2)$

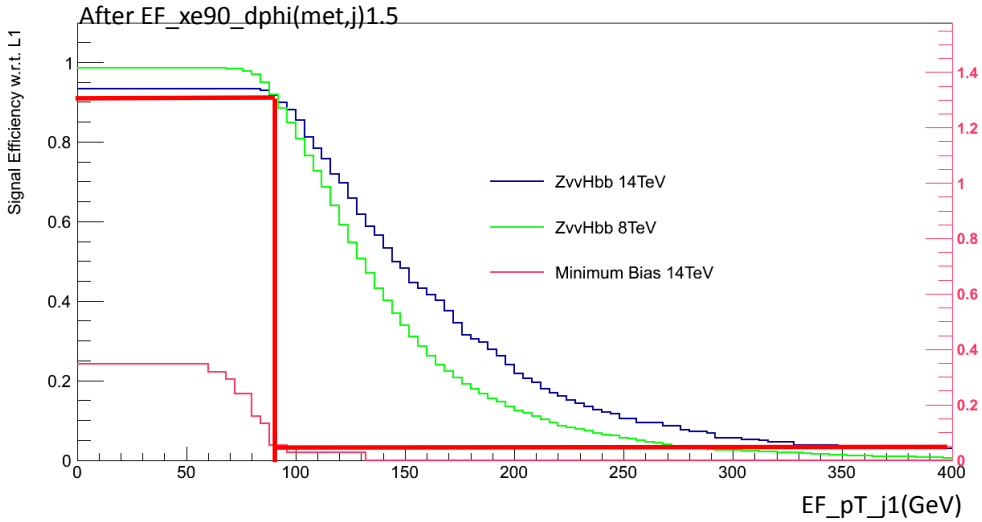
Trigger	Trigger Rate(kHz)	Signal Efficiency w.r.t. offline(%)	
		8TeV	14TeV
XE50_J40_dPhi1	5.3	91.9 ± 0.3	91.5 ± 3.3
XE60_J30	4.1	89.9 ± 0.4	93.9 ± 2.6
XE50_J40_dPhi1||L1_XE60_J30	7.6	96.3± 0.2	95.1±2.4
XE70	5.6	78.8 ± 0.5	79.3 ± 4.5
XE40_J75	5.5	51.7 ±0.6	48.8 ±5.5

Trigger for ZH (ννbb) in Run 2 (II)

- Strategy:
  - Assume L1 trigger passed (take L1_XE50_J40_dPhi1)
  - Remove 12 first bunches on 14 TeV samples
  - Apply EF_xe90 (high efficiency, trigger rate of 1khz) as starting point
  - Consider combination of cuts on: jet P_T, min $\Delta\phi$(Met,J), $\Delta\phi$(Met,J_{12}), $\Delta\phi(j_1,j_2)$

dPhi(met,j)>1.5

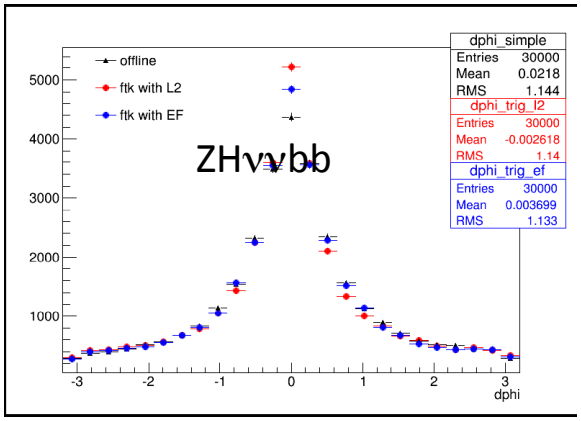


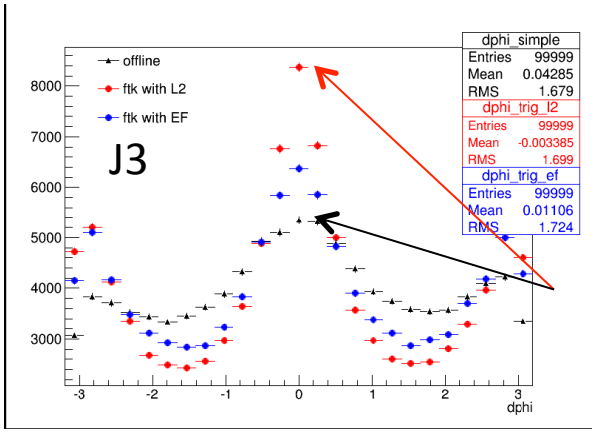


- Efficiency w.r.t. L1: 89.5% (14 TeV); EF Trigger Rate: 53 ± 37 Hz
- Still not low trigger rate, but based on low statistic samples…

Preliminary look at FTK based p_T^{miss} use in MET trigger

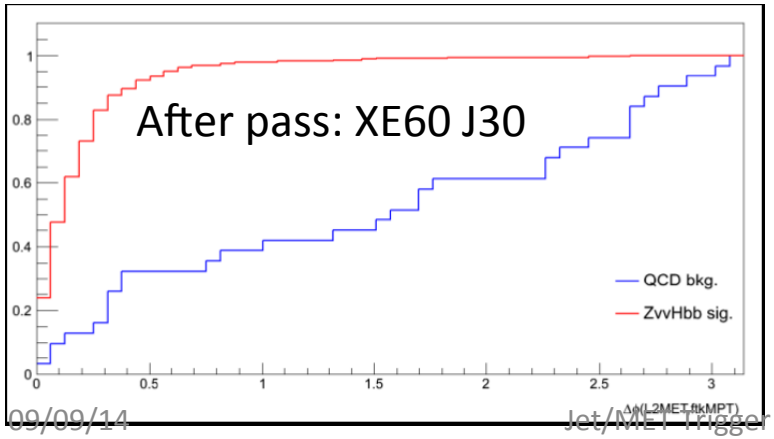
- Pure track-based p_T^{miss} very useful in offline event selection. Can it be used online to reject events with badly measured or fake MET?
- Use FTK tracks to estimate p_T^{miss} online and compare to online MET





Difference was tracked down to online MET
More MC samples are needed

- A simple study on ZHνν̄bb for trigger efficiency at EF



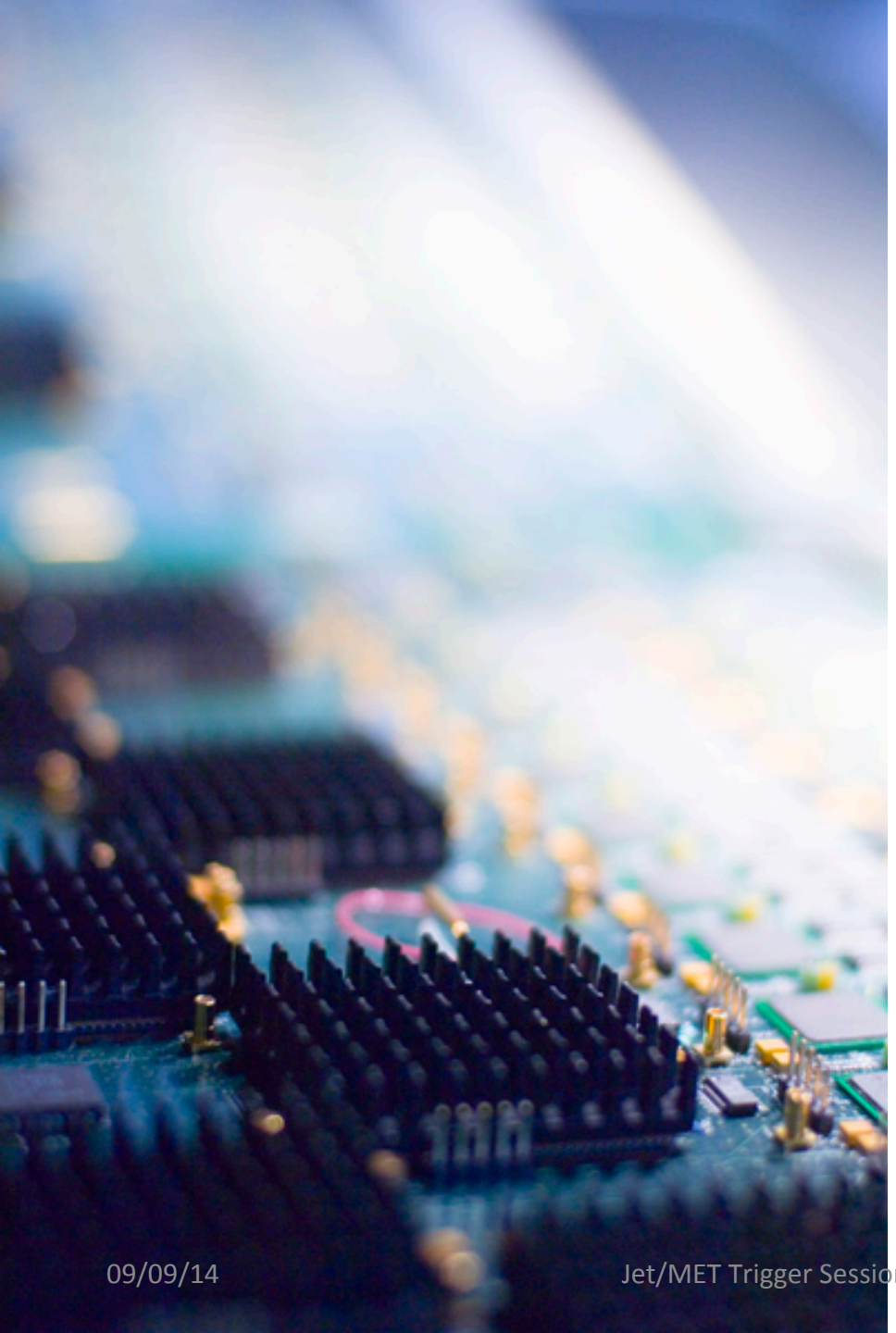
Online $\Delta\Phi$(MET, p_T^{miss})

Very preliminary results:

- Trigger: dPhi(L2(EF)_MET, ftkMPT)

Signal(ZvvHbb):
BCID:24914 Offline:403
XE50_J40_dPhi1:358 ==> L2:354(98.83%) EF:355(99.16%)
XE60_J30 :346 ==> L2:342(98.84%) EF:343(99.13%)

QCD:
BCID:82829
XE50_J40_dPhi1:33 ==> L2:18(54.55%) EF:19(57.58%)
XE60_J30 :31 ==> L2:14 (45.16%) EF:11(35.48%)



PILEUP STUDIES

Pileup Studies

Annabelle Chuinard

- Ongoing studies of pileup impact on trigger rate, turn-on and resolution
- Rates studied with:
  - (hacked) standard MenuFast tool
    - Uses enhanced bias 8TeV data, 8/14TeV MC
  - Jet trigger analysis package LIPJetTrigPerfAnalysis/JetTrigEff
    - Based on RootCore – will migrate to xAOD
    - Study turn-on, resolution, rate, etc
- Several pileup scenarios: <μ> = 20, 40, 60, 80

Trigger [Hz]:	8 TeV Data	8 TeV MC	Scaling	MC total 14 TeV	Data Scaled
EItight33_LoneEMH28	73.5+- 9.9	58.0+-10.8	(2.8+- 0.8)	117.4+-22.8	161.1+-22.7
Unique	73.5+- 9.9	57.9+-10.8	(2.8+- 0.8)	117.3+-22.8	161.1+-22.7
MUI24_LoneMU20	208.5+-16.7	0.0+- 0.0	(2.0+- 0.2)	0.0+- 0.0	403.3+-25.7
Unique	208.5+-16.7	0.0+- 0.0	(2.0+- 0.2)	0.0+- 0.0	403.3+-25.8
Total	282.0+-19.4	179.6+-14.3	(1.5+- 0.4)	263.6+-22.9	465.0+-70.0

Unique rate for given trigger line

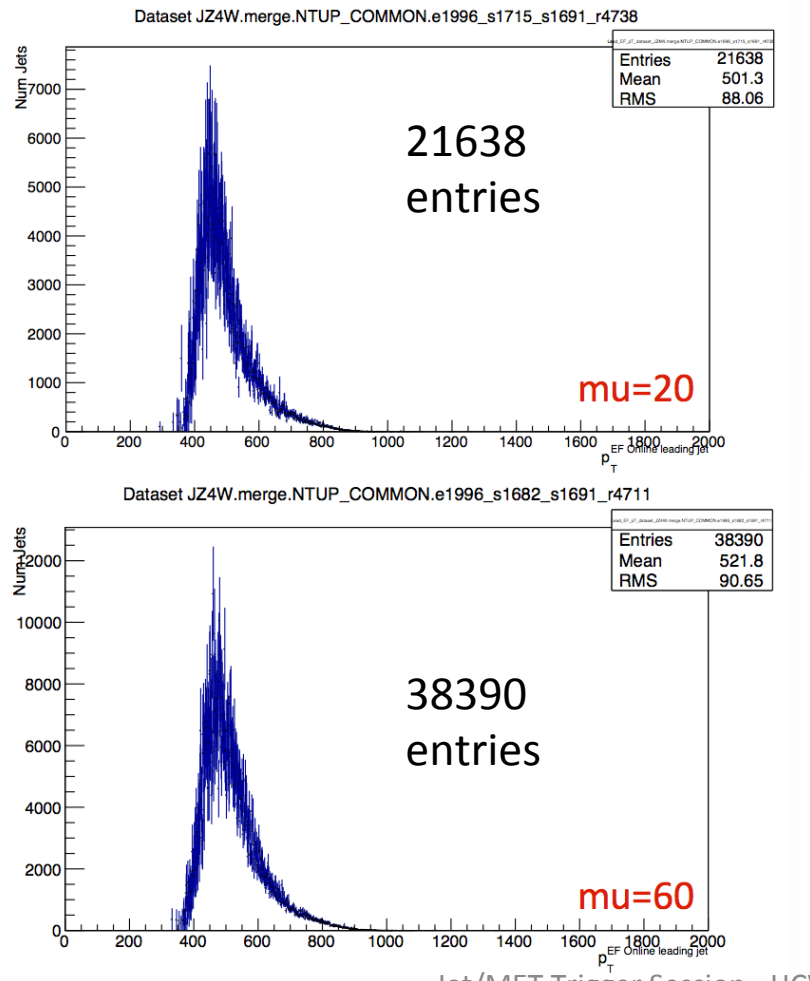
Total rates (pile-up included)

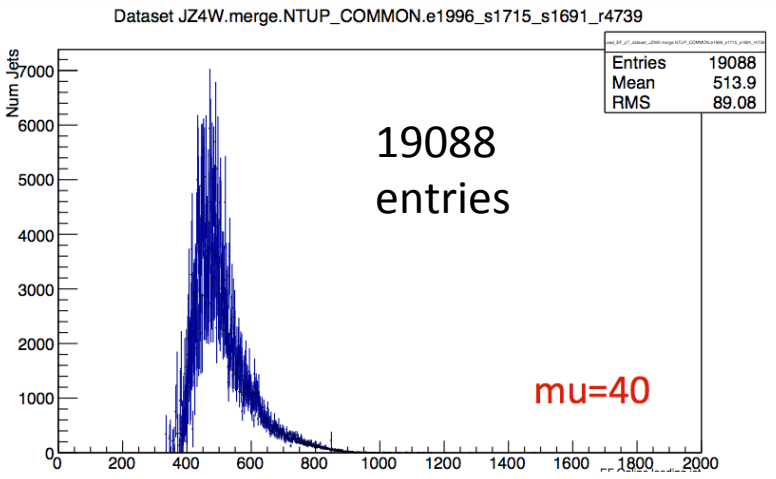
MenuFast example output
Pileup: μ = 60

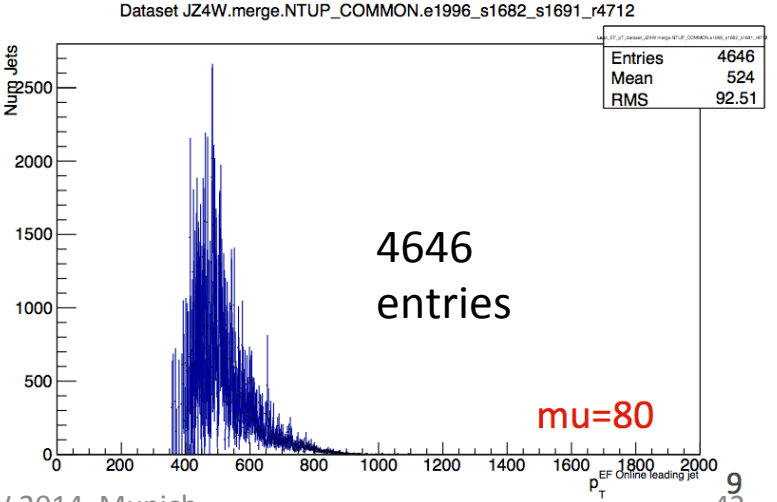
Effect on jet E_T – very preliminary

- Used JZ4W sample: truth jet 500 GeV < E_T < 1 TeV
- Antikt4_topo_calib_EMJES - no trigger cut, but E_T > 500GeV (truth)

Leading HLT jets



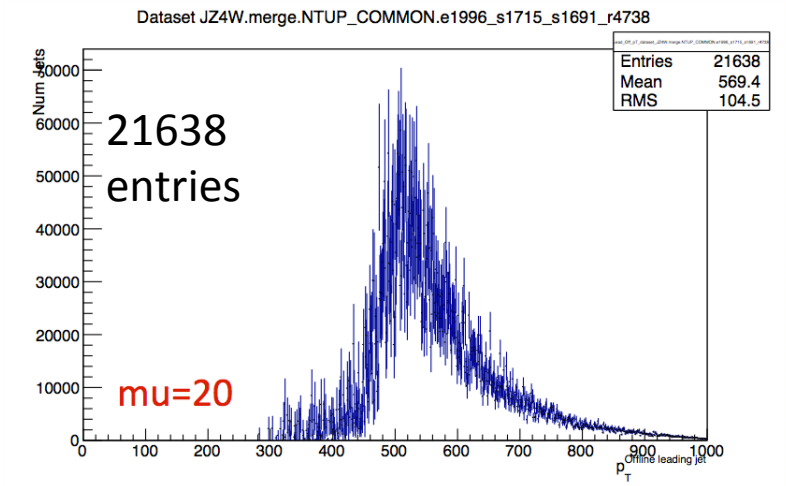


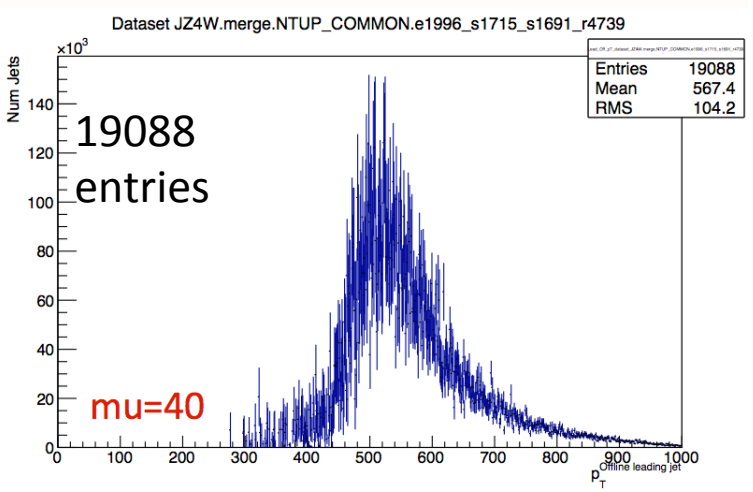


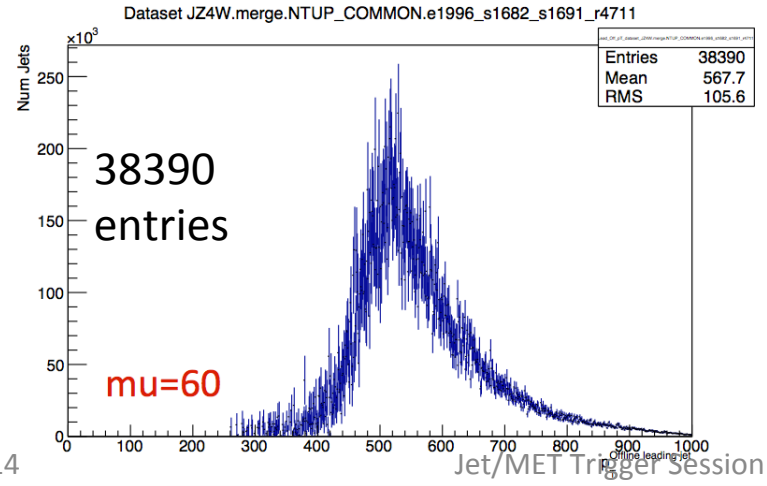
Effect on jet E_T – very preliminary

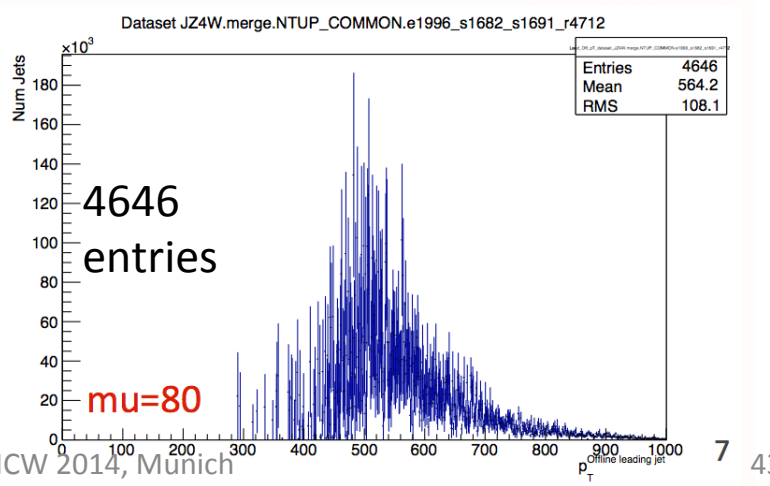
- Used JZ4W sample: truth jet 500 GeV < E_T < 1 TeV
- Antikt4_topo_calib_EMJES - no trigger cut, but E_T > 500GeV (truth)

Leading offline jets









Pileup subtraction in the HLT

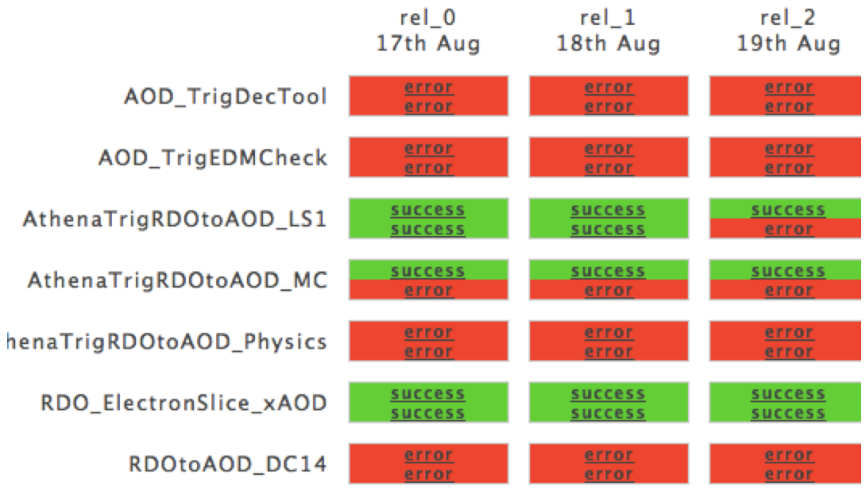
- Want to remain as close to the offline schema for jet calibration and pileup subtraction as possible
  - Rho calculation may become difficult in the HLT
  - Need to determine resource requirements (data volume and CPU time) for area calculation
  - Can we use Voronoi area for jets (both in rho calculation and application)
  - Could look at using trigger towers as well

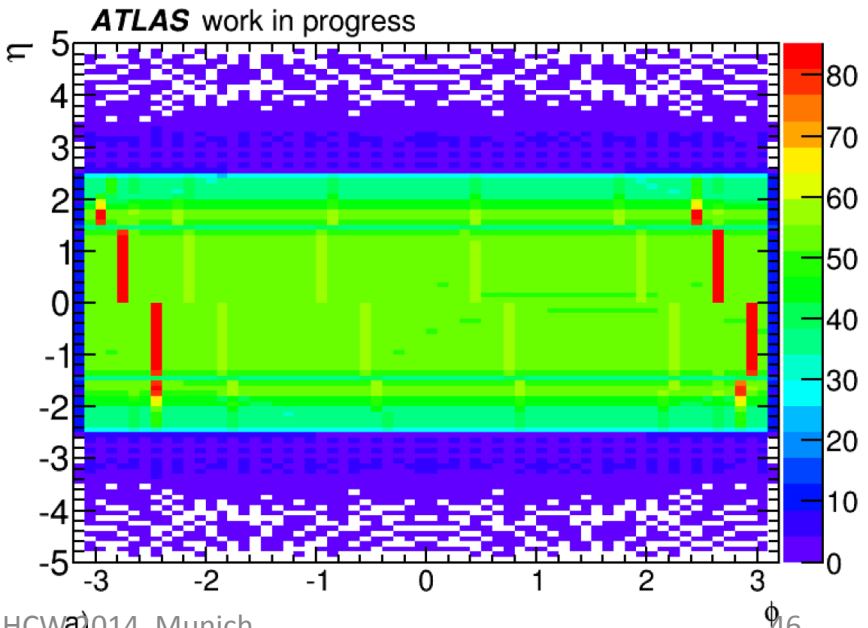
Monitoring and Validation

Monitoring and Validation

Several levels of scrutiny:

1. Software development validation
   - **Functional** validation (ATN/NICOS):
     - TriggerTest, TrigAnalysisTest, TrigP1Test
     - Regression tests on fixed reference: EDM, event counts, new menus, etc
   - **Performance** validation and infrequent errors (RTT)
     - Also runs same tests as ATN
     - Expanding tests as new developments are produced
     - Detailed validation: resolutions, cost monitoring, etc
   - Jet trigger **diagnostics**
     - Run in trigger chains for detailed studies
     - Allows greater access to input data as seen by trigger chains

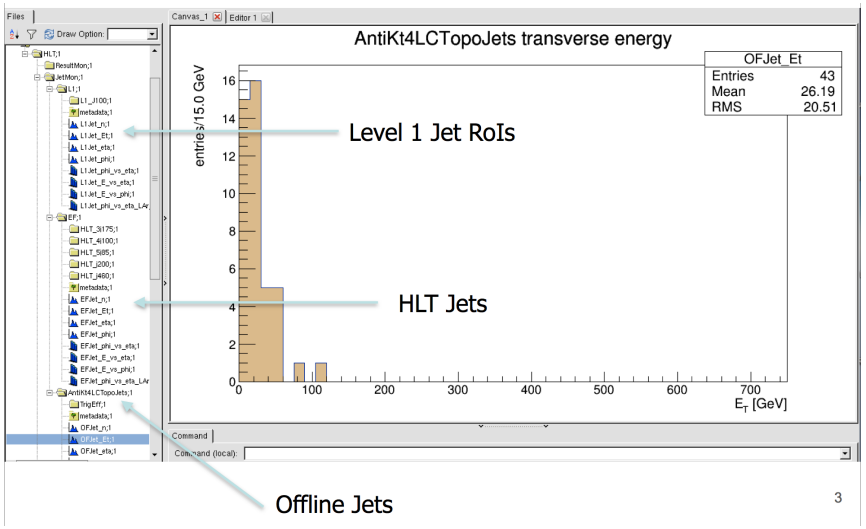


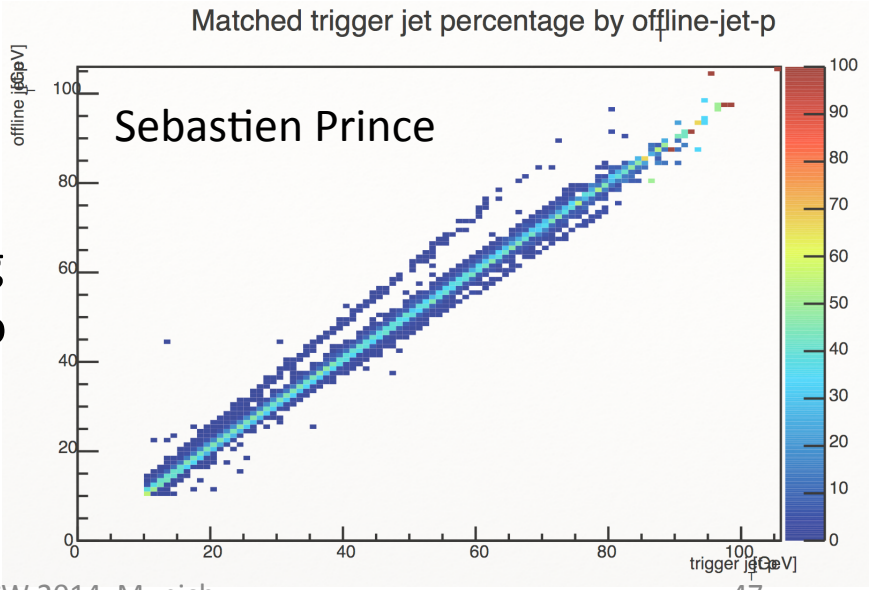


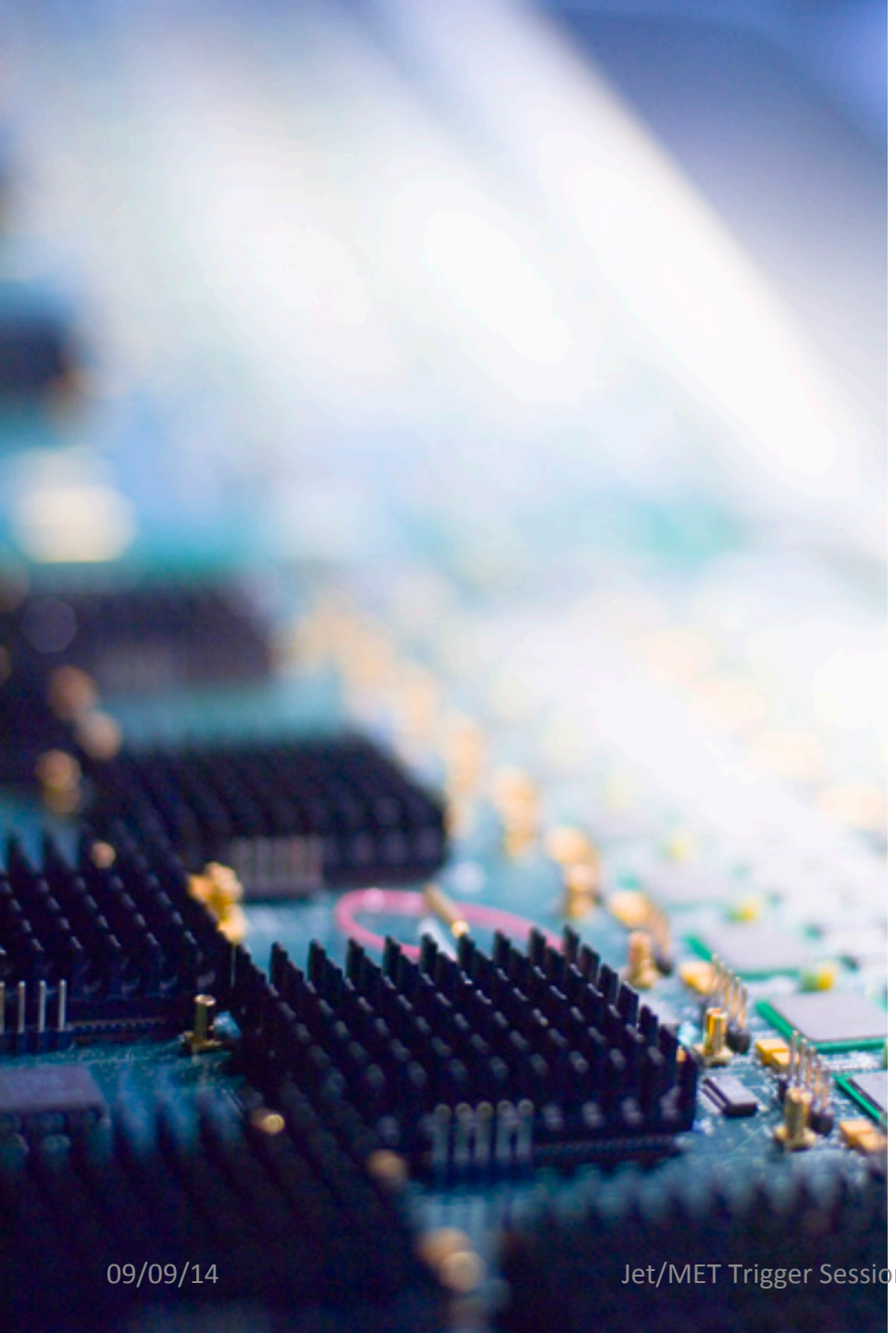
Monitoring and Validation

Lee Sawyer

1. **Software validation**
   - Previous slide
2. **Online monitoring**:
   - P1 operations
   - Fast detection of problems and fast response; not detailed analysis
   - Look for error situations affecting jet trigger performance
     - Hot towers, trigger rate, etc
3. **Offline monitoring**:
   - Examine data quality after Tier0 reconstruction
   - Comparison to offline jets
   - Harmonizing with offline monitoring
   - Trigger **menu awareness** essential to efficient operation
   - Migrated TrigJetMonitoring to xAOD
   - **Current priority/testing ground: M5**







Issues and concerns for Run II

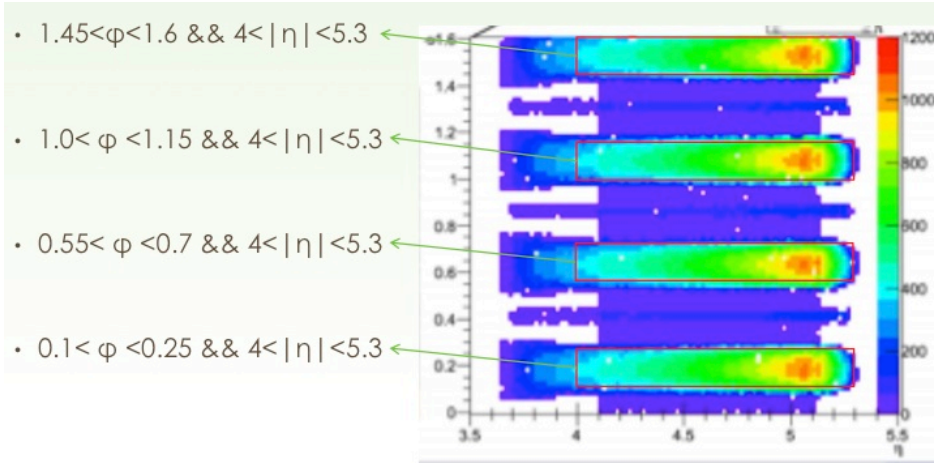
Issues to watch out for and planning for coping with trigger issues in Run II

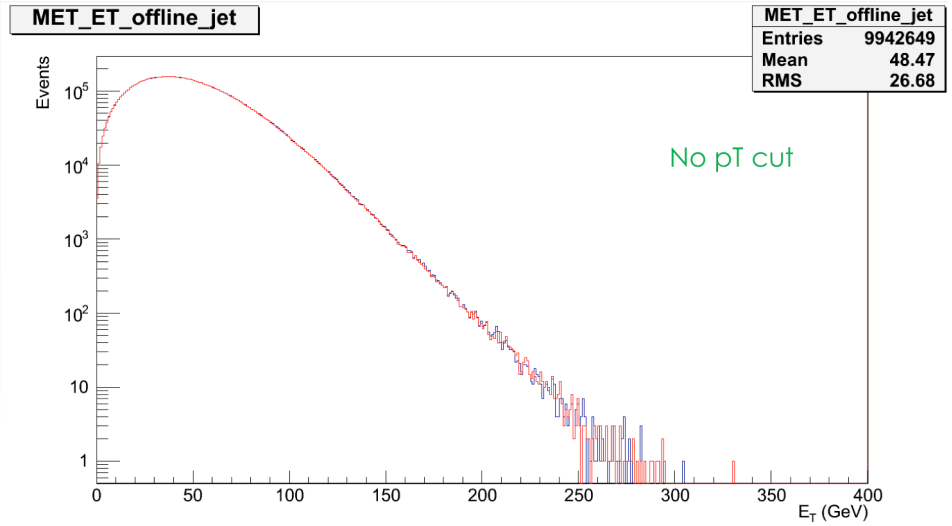
- Calibration of jets for the MET/MHT trigger
  - How important is the L1 jet calibration? Does the upgraded nMCM calibration proposal have a large impact?
  - How do we incorporate (technically) the jet area and rho calculations into the HLT?
  - How does calibration impact the Trigger Level Analysis (TLA)
- Fall back scenarios for jet/MET calibrations
  - What to do with errors/issues with calibrations in the trigger
  - How to handle missing calibration data or inputs (e.g. rho)?
- Impact of IBL material and services on MET trigger

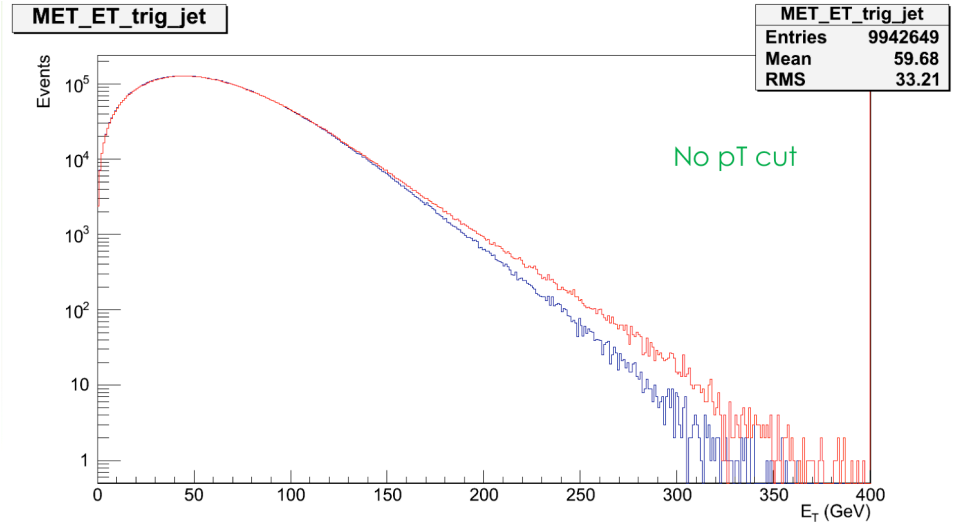
Impact of IBL service on Met

Hyungsuk Son

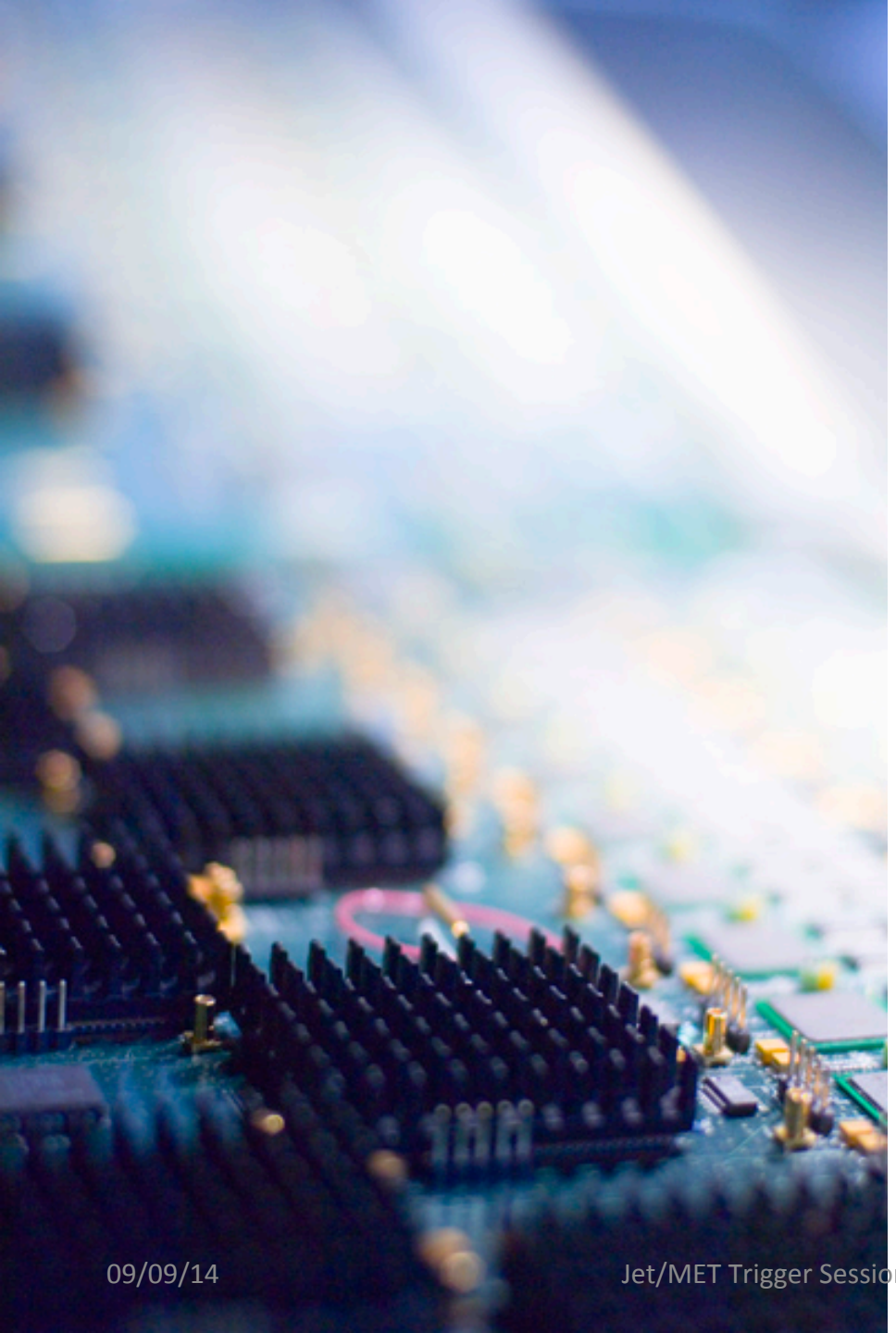
- Quick study:
  - Remove any object in high material region
  - Recalculate Met
  - Compare to Met without additional material







- Rate increases at trigger level due to soft jets falling in this region
  - Increases threshold by ~10% to keep trigger rate fixed



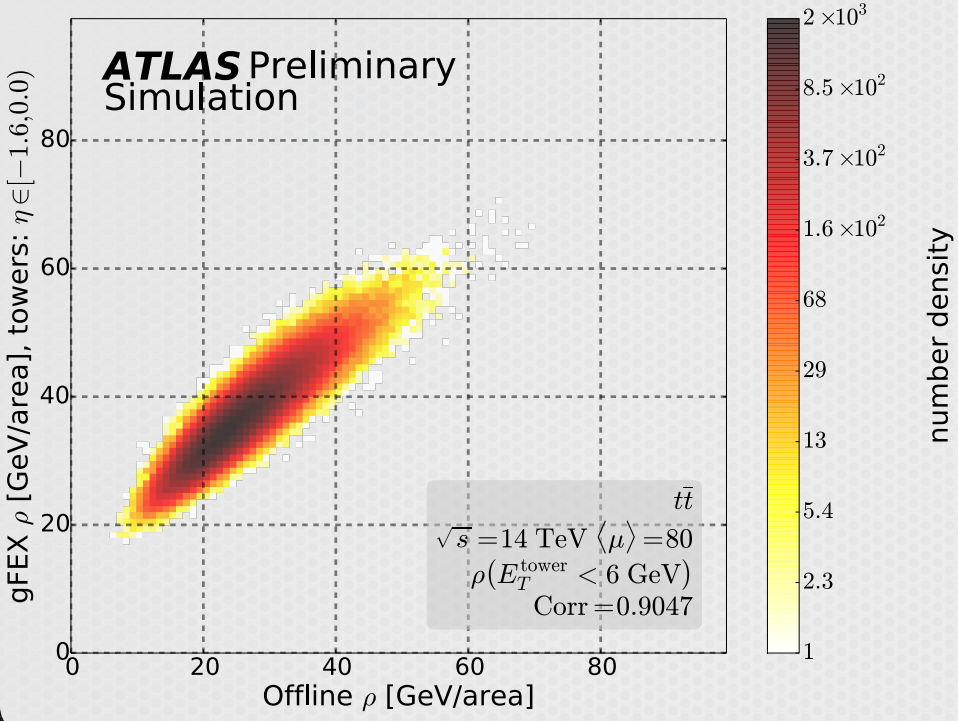
Looking towards Run III

Fat jet trigger at L1 for Run III

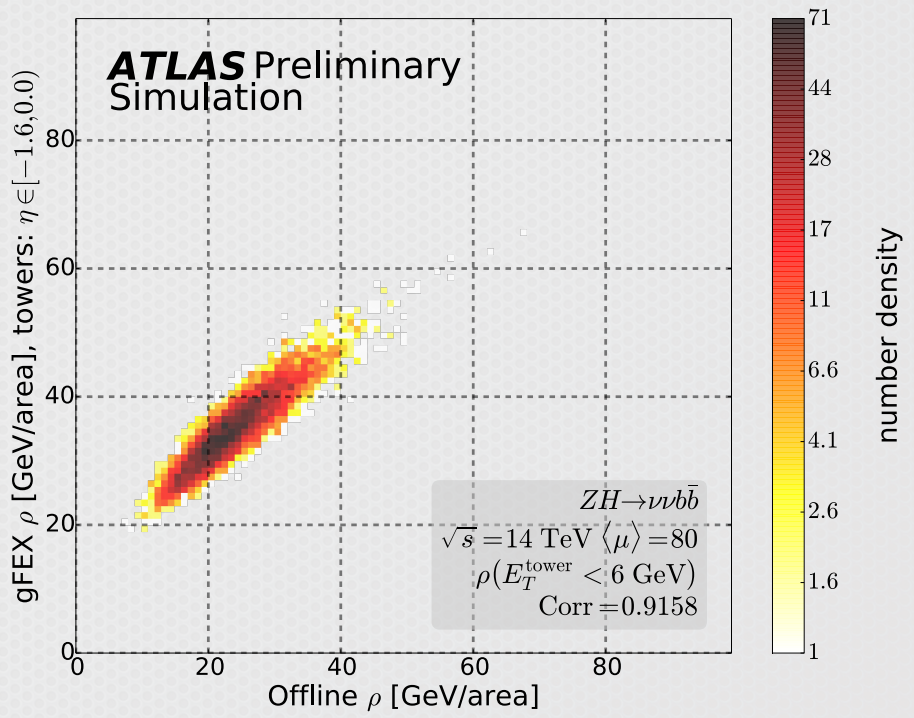
Level 1 trigger: gFEX Jet Pile-up Energy Density Correlation

Giordon Stark

$t\bar{t}$



$ZH \to \nu\nu b\bar{b}$

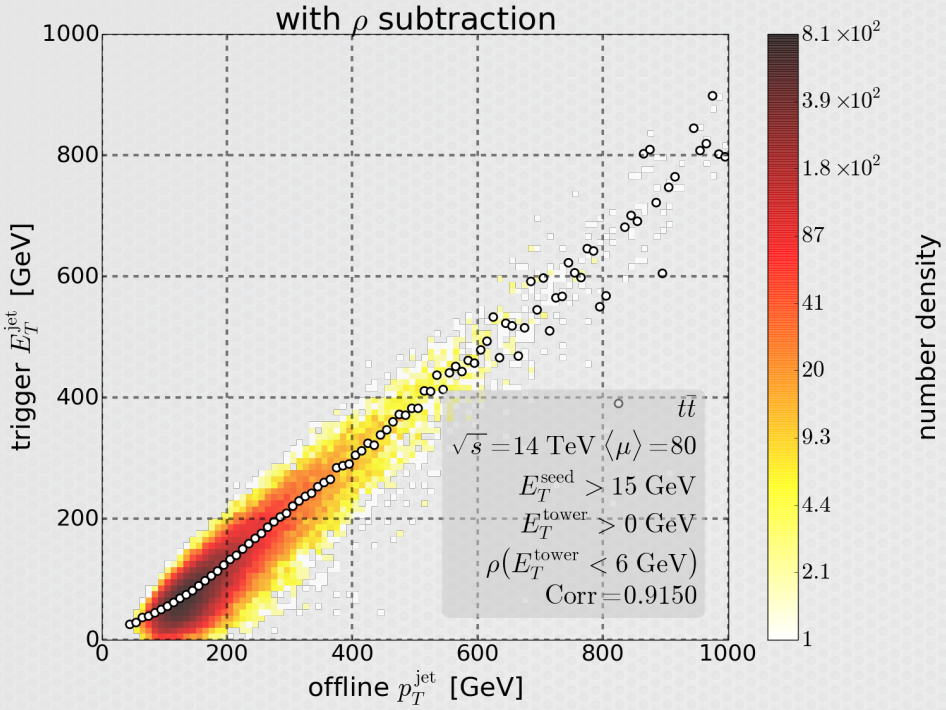


Fat jet trigger at L1 for Run III

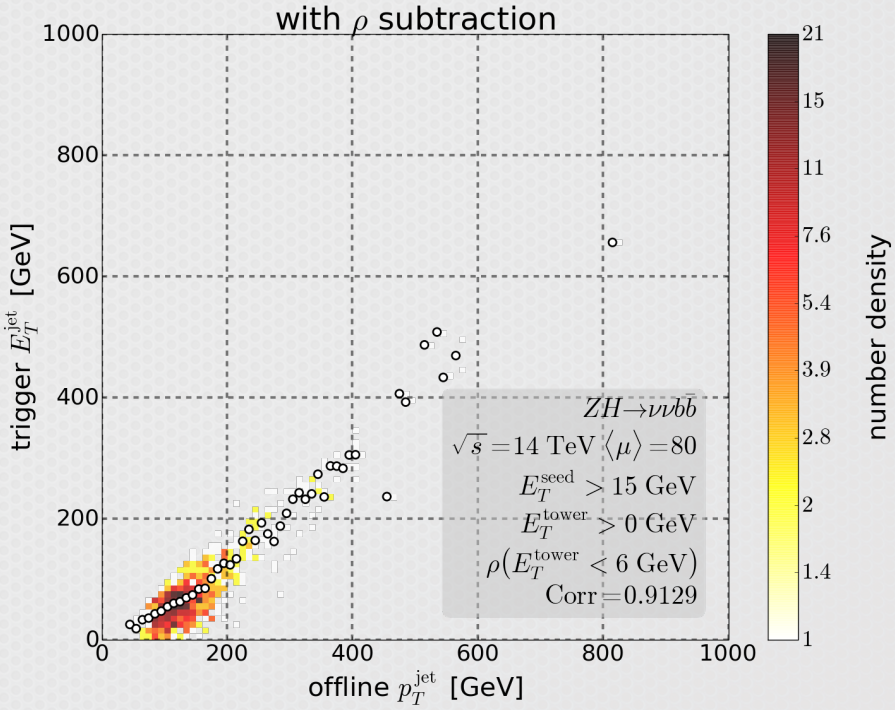
Level 1 trigger: gFEX Jet correlation with offline jet P_T

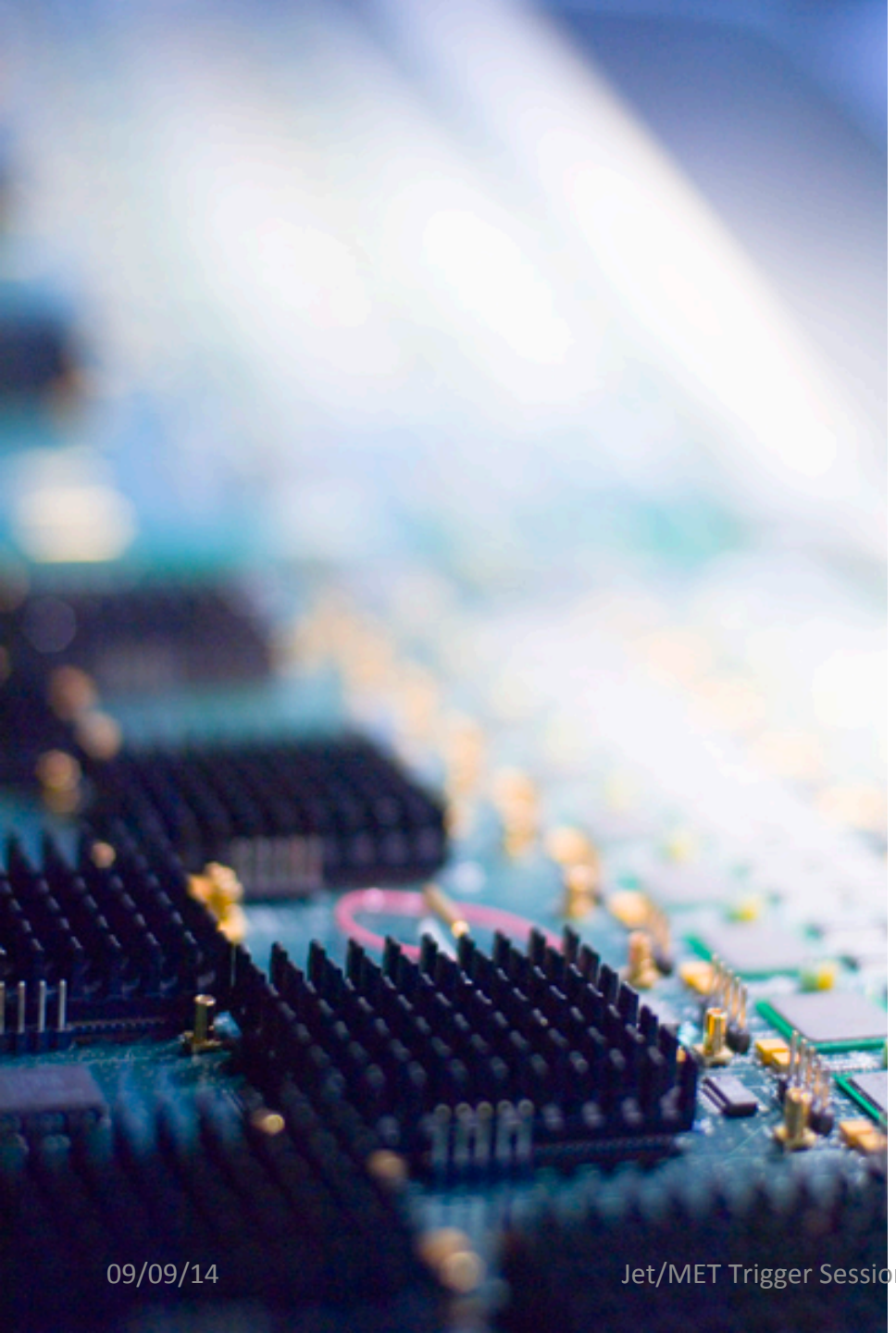
Giordon Stark

$t\bar{t}$



$ZH \to \nu\nu b\bar{b}$





Summary & Conclusions

Summary

- No conclusions, just lots of fun ahead ☺
  - Lots going on in the trigger
  - Great opportunities to make significant contributions!
- Many thanks to everyone contributing to Jet/MET triggers!