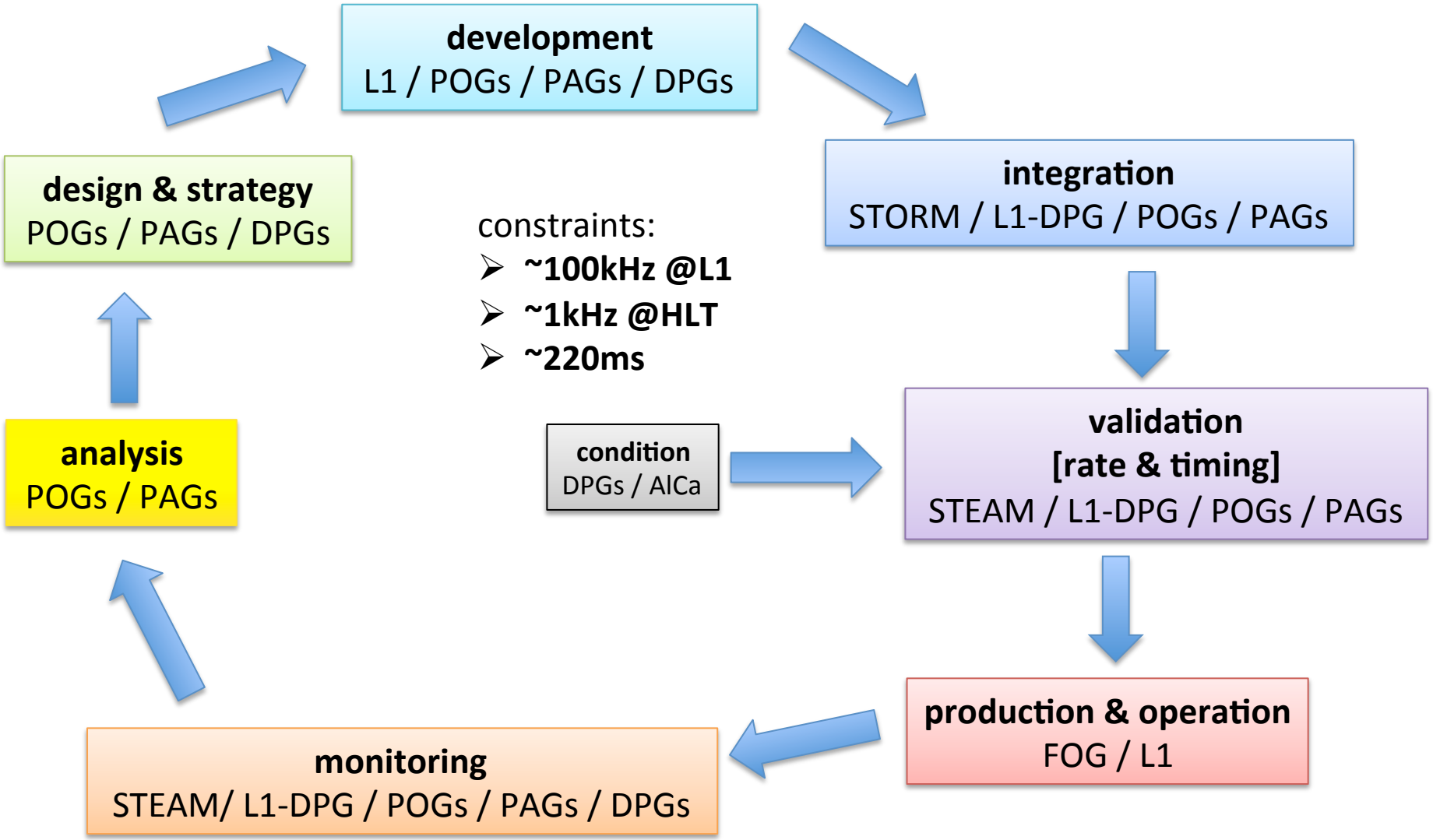
trigger stato e prospettive

mia tosi

-- Riunione CMS Italia 2016 --

Spoleto, Dec 14th-16th, 2016

trigger


development
L1 / POGs / PAGs / DPGs
integration
STORM / L1-DPG / POGs / PAGs
validation
[rate & timing]
STEAM / L1-DPG / POGs / PAGs
production & operation
FOG / L1
monitoring
STEAM/ L1-DPG / POGs / PAGs / DPGs
analysis
POGs / PAGs
design & strategy
POGs / PAGs / DPGs
condition
DPGs / AlCa
constraints:
~100kHz @L1
~1kHz @HLT
~220ms

trigger in 2016

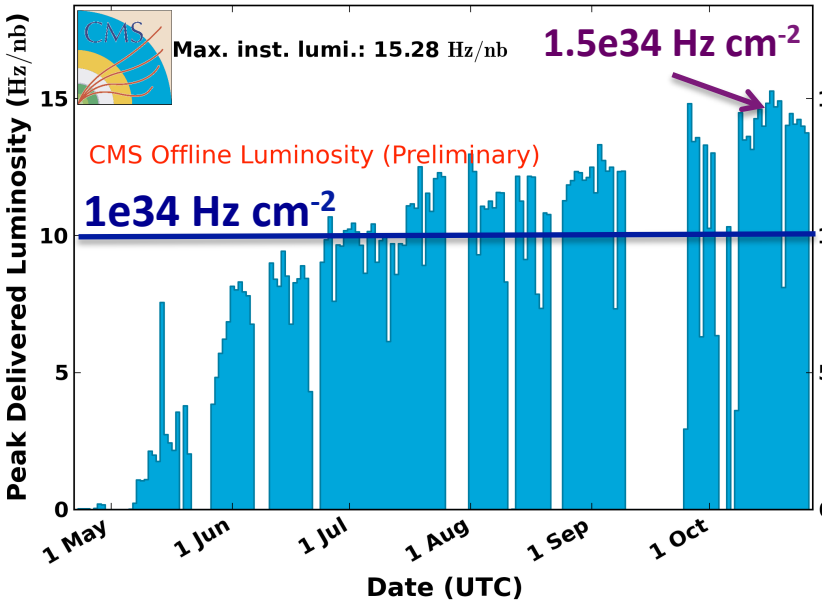
very, very busy year !

- big changes in 2016 → **Phase I L1 Trigger Upgrade**
  - ✓ new Barrel, Overlap and Endcap Muon Track Finders
  - ✓ new (micro) Global Muon Trigger
  - ✓ new Layer 1 Calo Trigger
  - ✓ new Layer 2 Calo Trigger
  - ✓ new (micro) Global Trigger

allows
- to define > 128 bits ;)
- to define more advanced operations
  (deltaR, di-object mass, deltaBX, …)

- lots of special runs to accommodate
  [vdM, strip Virgin Raw, high PU, low PU]

- very high luminosity
  highest peak lumi: **1.5e34 Hz cm^{-2} → PU~50** !
- very high LHC duty cycle
  from 2015 menus,
  already quite ready for lumi upto 1e34 Hz cm^{-2}
  [new menu for lumi >1e34 Hz cm^{-2} after ICHEP]

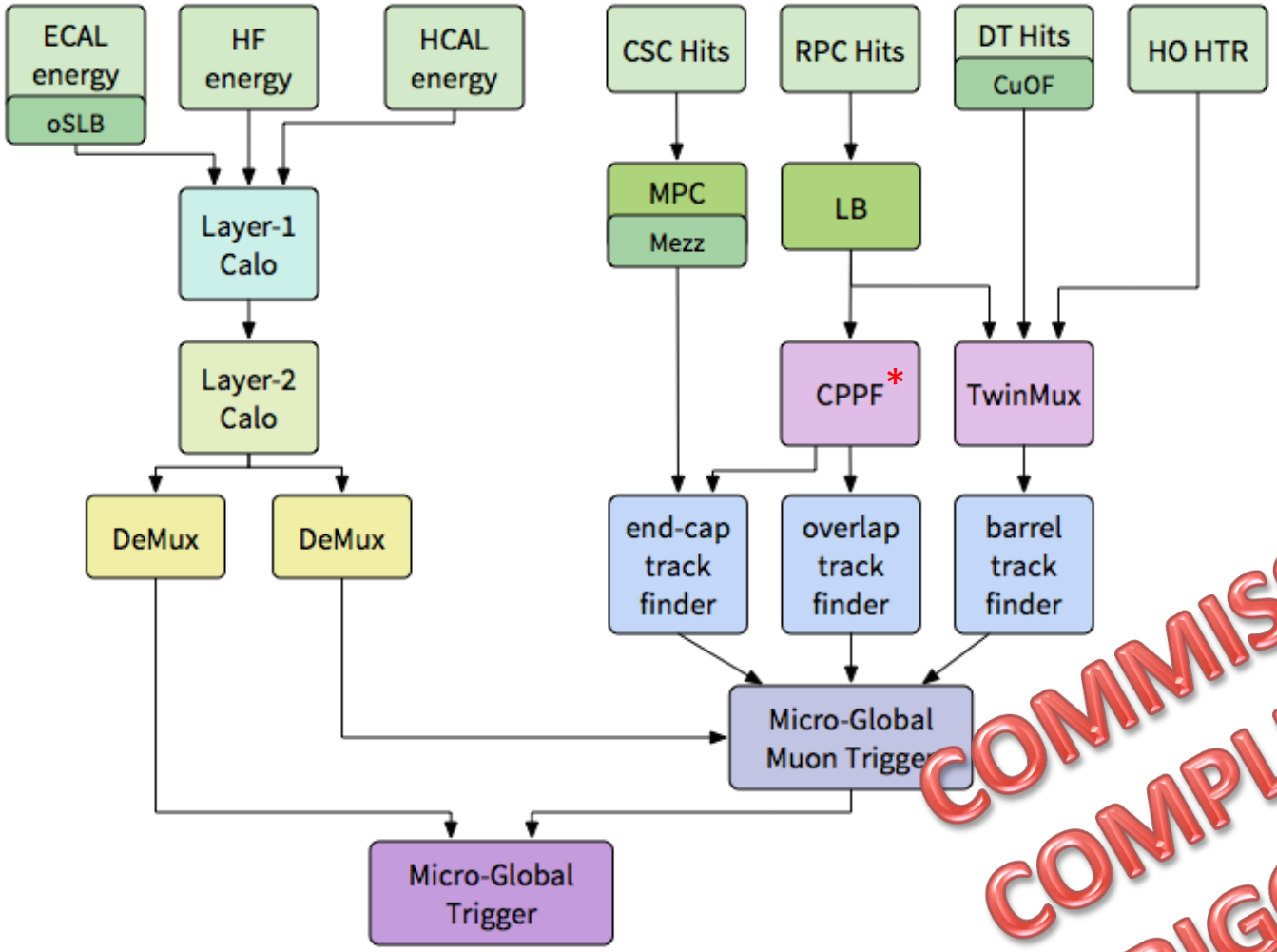


- unexpected strip dynamic inefficiency

evolutionary changes to the HLT
- lots of small updates/bugs fixes needed in order to accommodate the L1 upgrade
- better matching w/ offine reconstruction
- keep pileup dependence under control
- take advantage of the “APV fix”

L1 trigger in 2016

Alessandro Thea
Ivan Cali
Pierluigi Bortignon
Giuseppe Codispoti
Gian Michele Innocenti
Andrea Triossi



COMMISSIONED A COMPLETELY NEW TRIGGER SYSTEM

*install in 2017

L1 trigger in 2016

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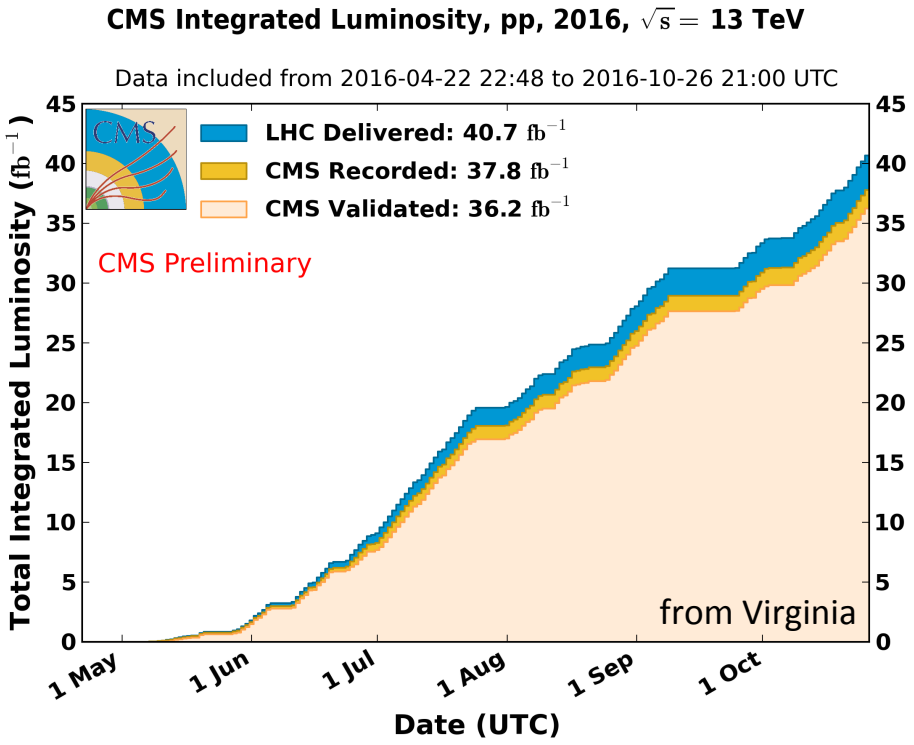
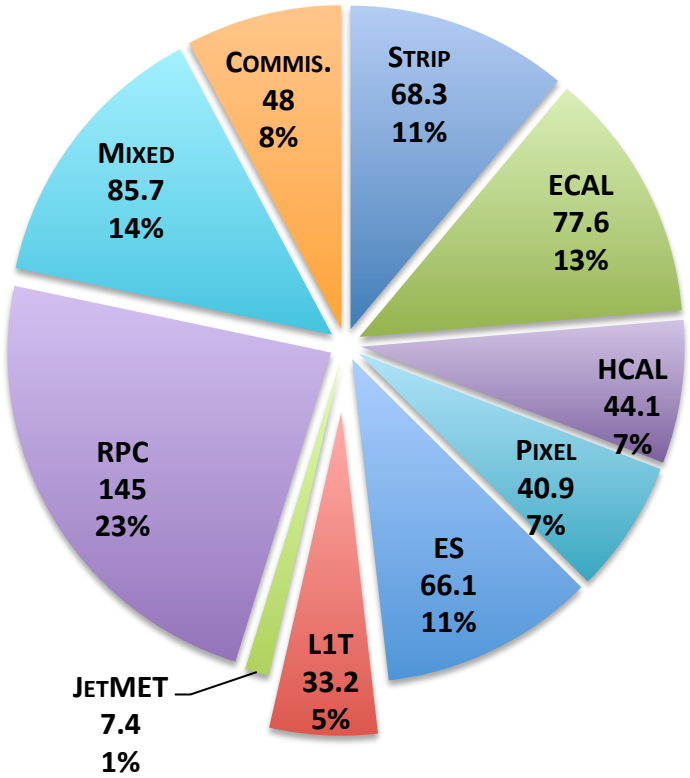
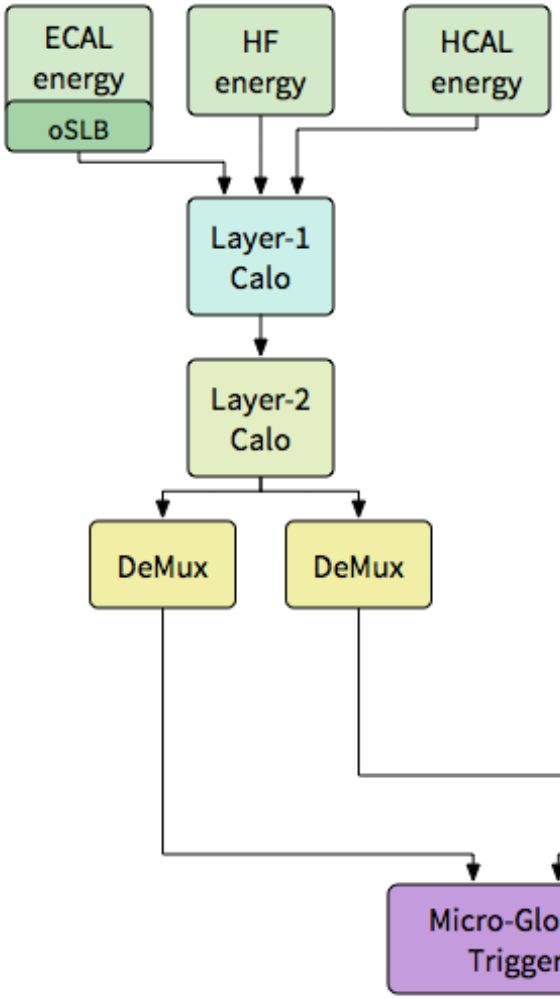


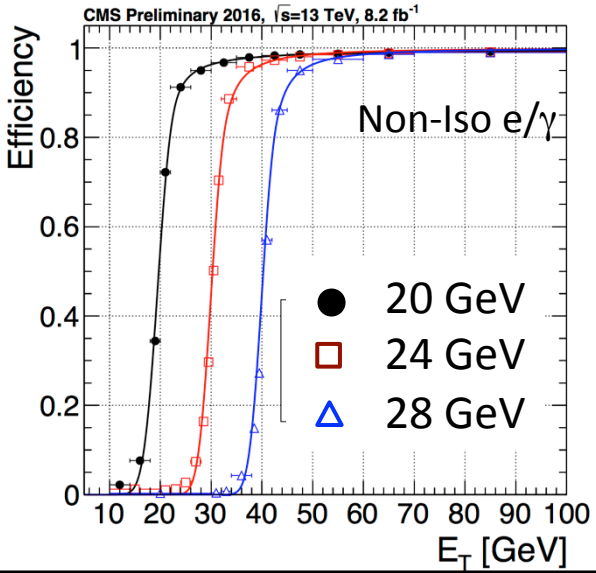
data GOOD for Physics: 36.20 fb^{-1}
[96% w.r.t. recorded]
loss: ~1.5 fb^{-1} = 0.8 (HV) + **0.7**

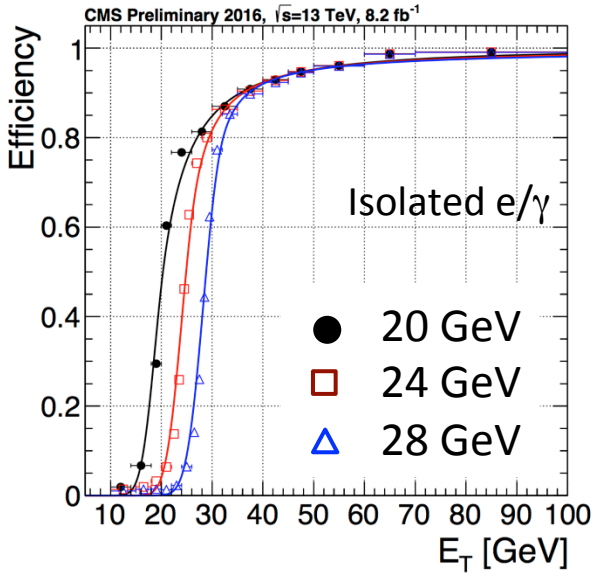


Delivered, Recorded and Validated luminosity are calculated using normtag_DATACERT.json

L1 trigger in 2016: e/γ



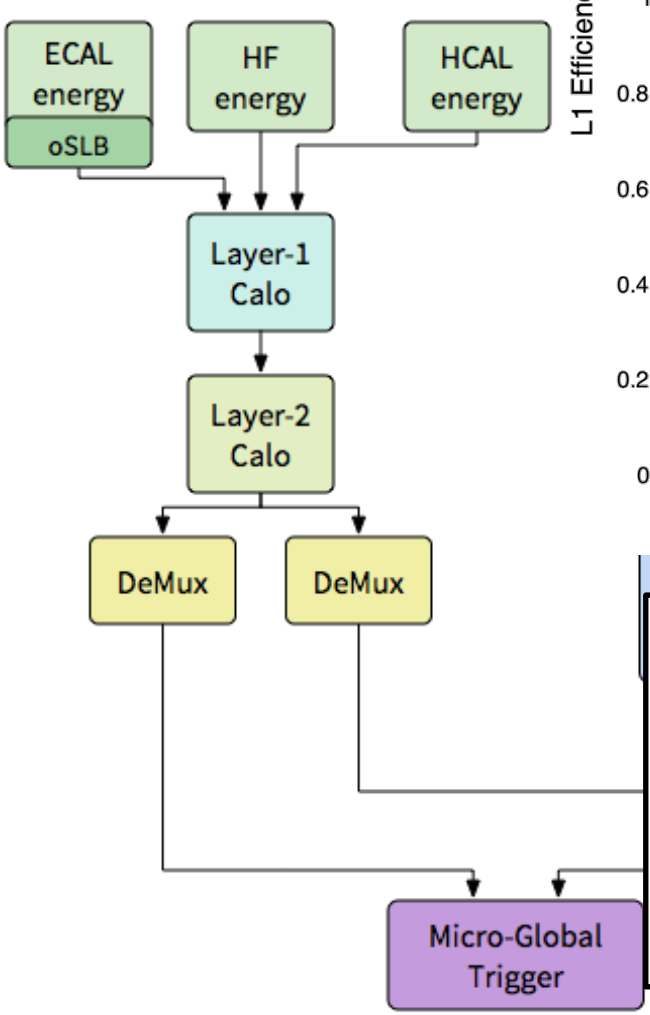


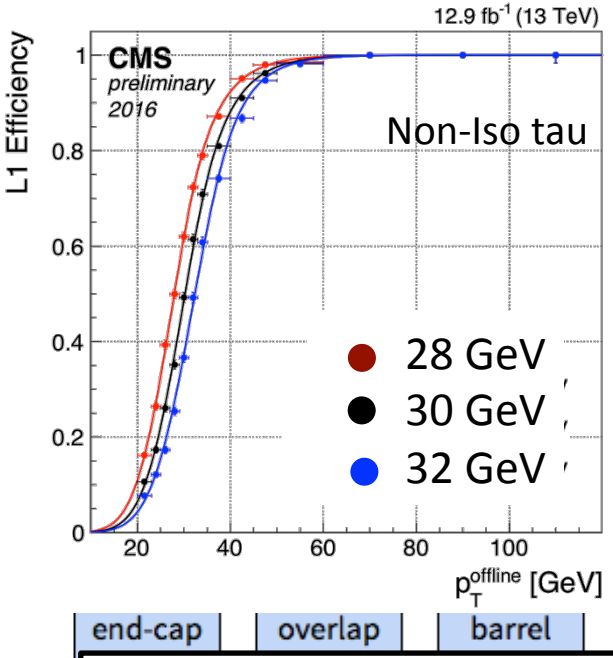


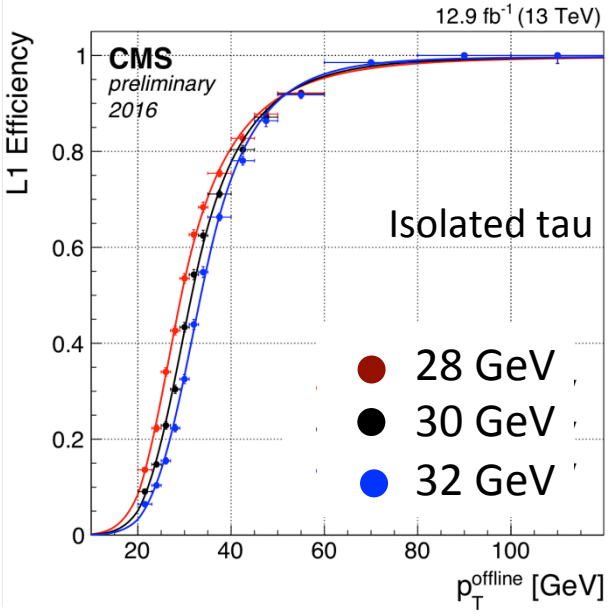
- ✓ consistent performance throughout 2016
  w/ weekly laser corrections
- ✓ no strong dependence on PU for IsoEG
  → rate has ~linear PU dependence
- ✓ new Layer-1 correction and isolation reoptimization
- ✓ new spike killing threshold
  → ~50% reduction in spike contamination
- ✓ improve performance vs η
- TODO re-optimize the Iso working point for limiting the rate
- TODO need a more systematic approach to optimization

L1 trigger in 2016: tau

new L1 Tau algorithm deployed in 2016



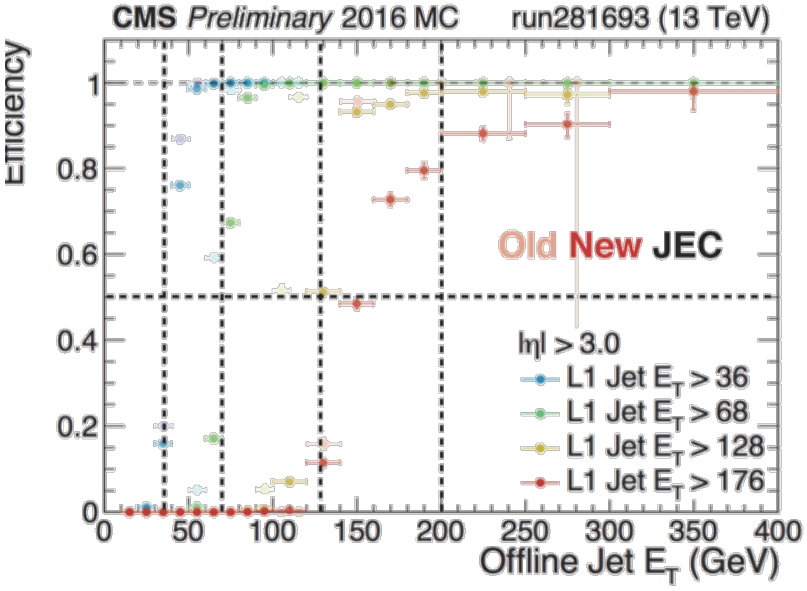


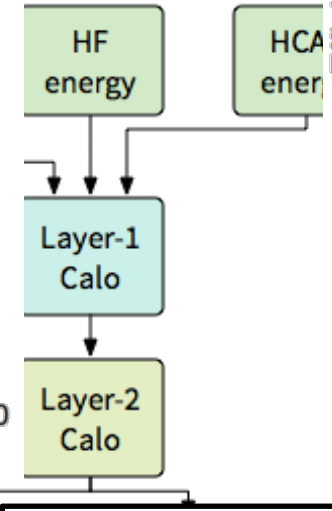


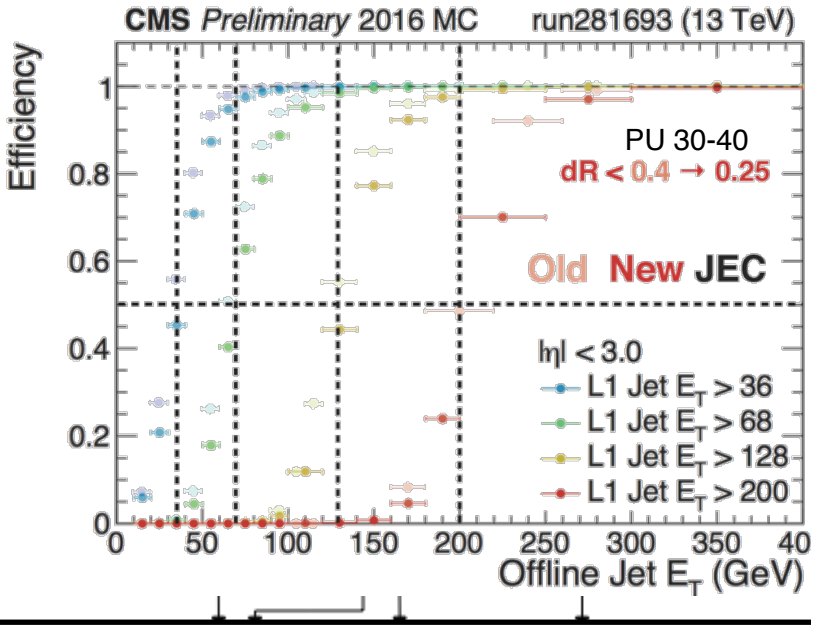
part of Stage-2 L1 Calo trigger upgrade

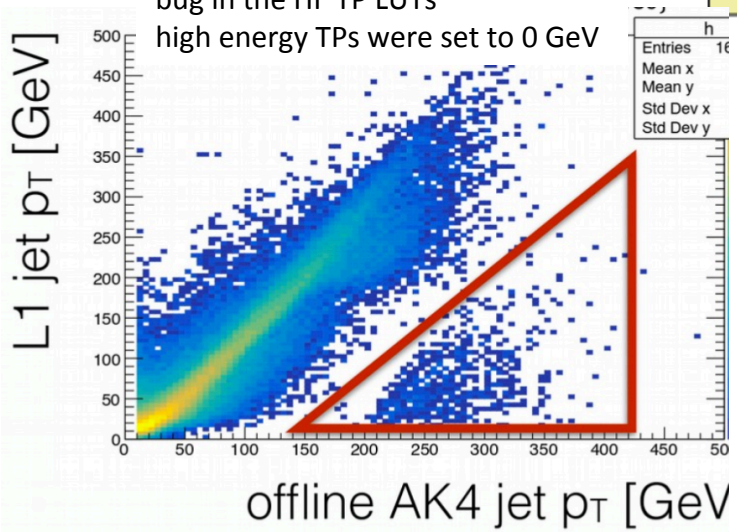
- ✓steep turn on, isolated plateaus at 60 GeV
- ✓good resolution in η and φ
- ✓rate has ~linear PU dependence
- TODO need a more systematic approach to optimization
- TODO comparison of firmware and emulator in DQM

L1 trigger in 2016: jet



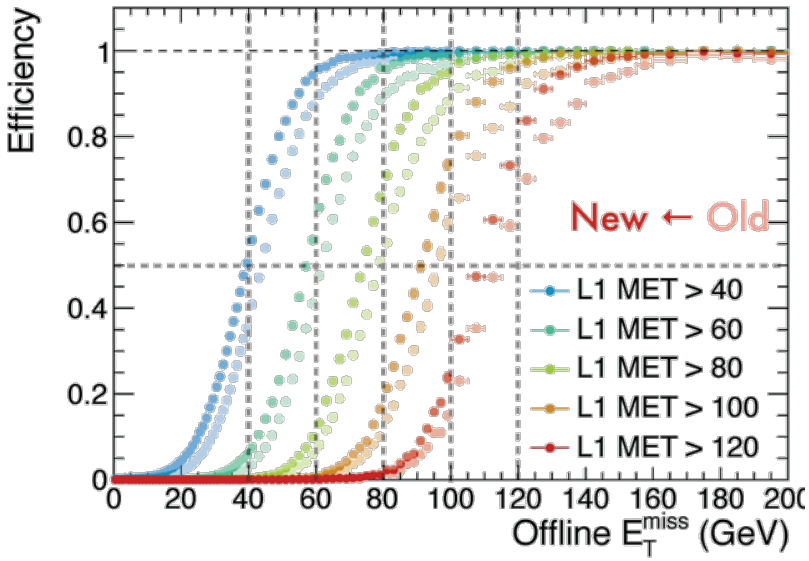


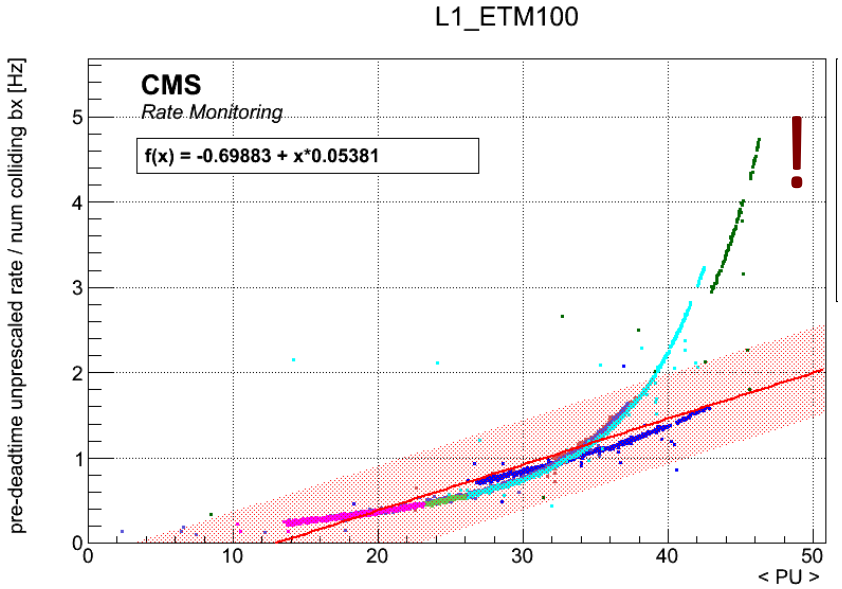


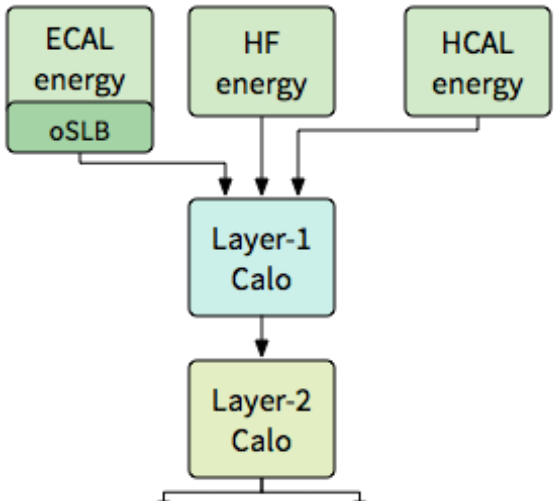


- ✓ new JEC re-derived [in production in Run2016H]
- ✓ good turn on (G – old, H – new)
- ➢ L1 Jet E_T > 128 - issue w/ saturation in HF
  some recovery by saturating jet, if jet seed saturated
- ✓ rate has ~linear PU dependence
- TODO study low p_T response
- TODO optimiztion jet seed threshold
- TODO data-driven calibration, using BDT
- TODO HCAL depth segmentation
- TODO HF trigger primitives (TP) dynamic range
- TODO add wide jets

L1 trigger in 2016: MET



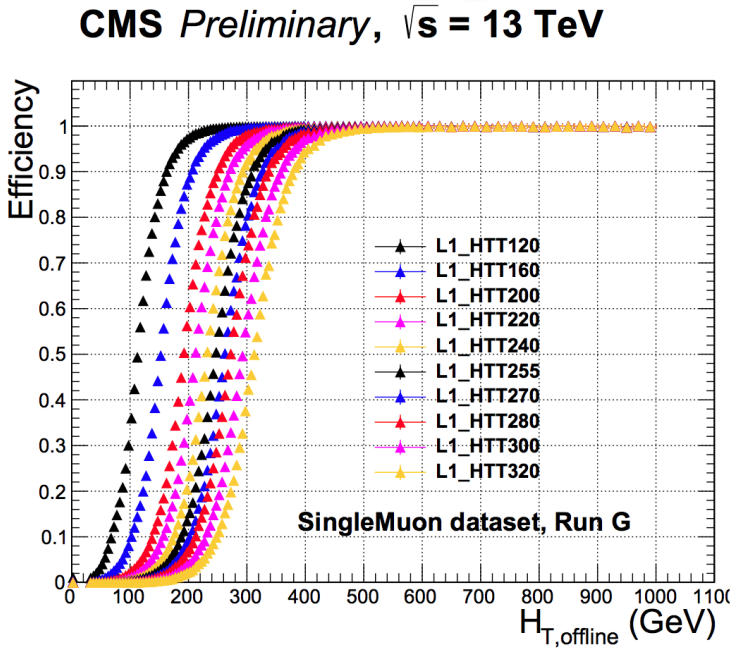


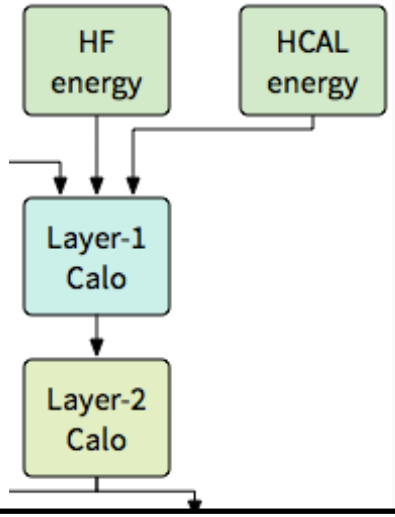


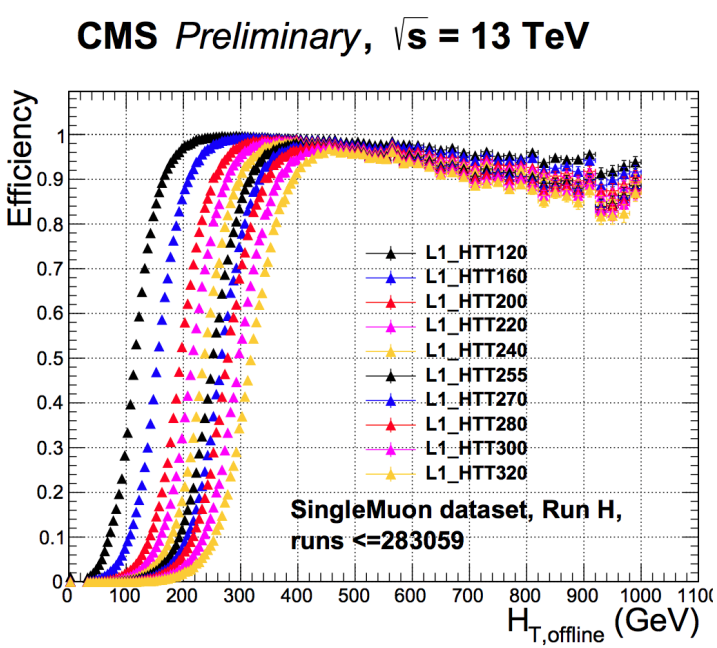
- ✓ efficiencies improved w/ layer1 calibration
  - ⚠ rates increased significantly [up to 30%] !
  - ⚠ more PU dependence

- TODO calibrate using LUTs
- TODO PU subtraction
- TODO more extensive workflow for validation

L1 trigger in 2016: MET/HTT



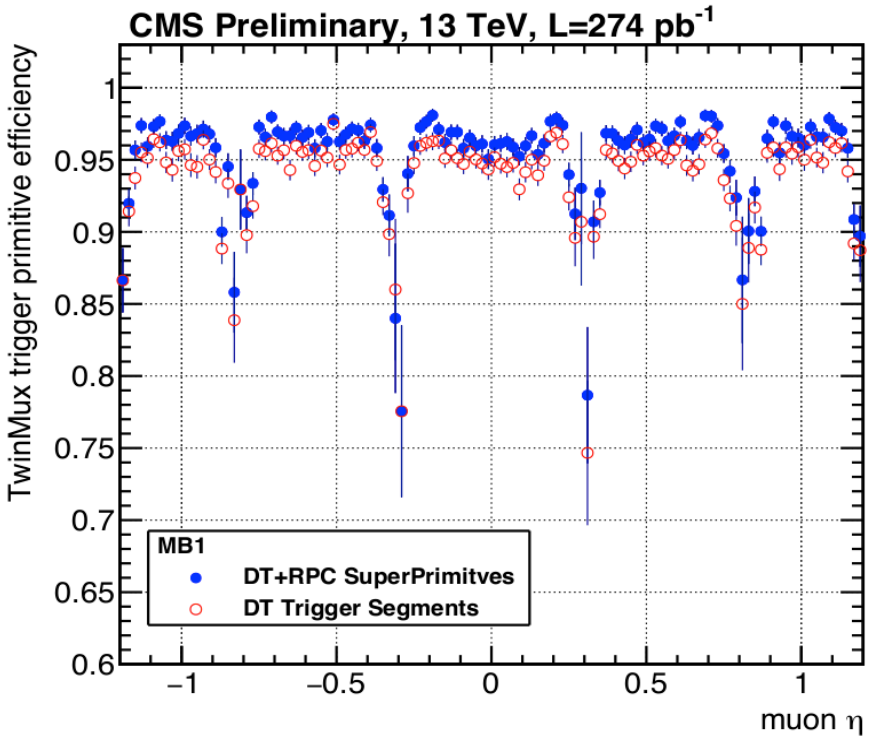


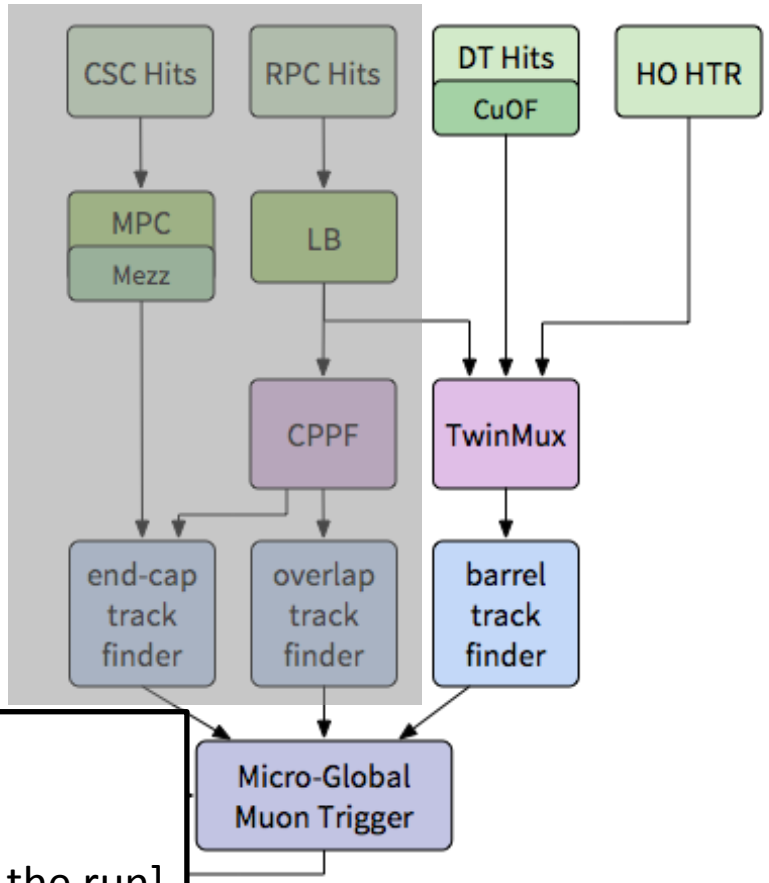


- ⚠ HTT inefficient @high HT after layer1 calibration
- ⚠ rates increased significantly [up to 30%] !
- ⚠ more PU dependence
  - ➢ can be partly recovered using HLT paths seeded by single jets
  - ➢ weakness in the prompt monitoring

- TODO work on saturation
- TODO more extensive workflow for validation !

L1 trigger in 2016: muon





some issues and bugs resolved ~quickly
overall efficiency stable at 92±1%

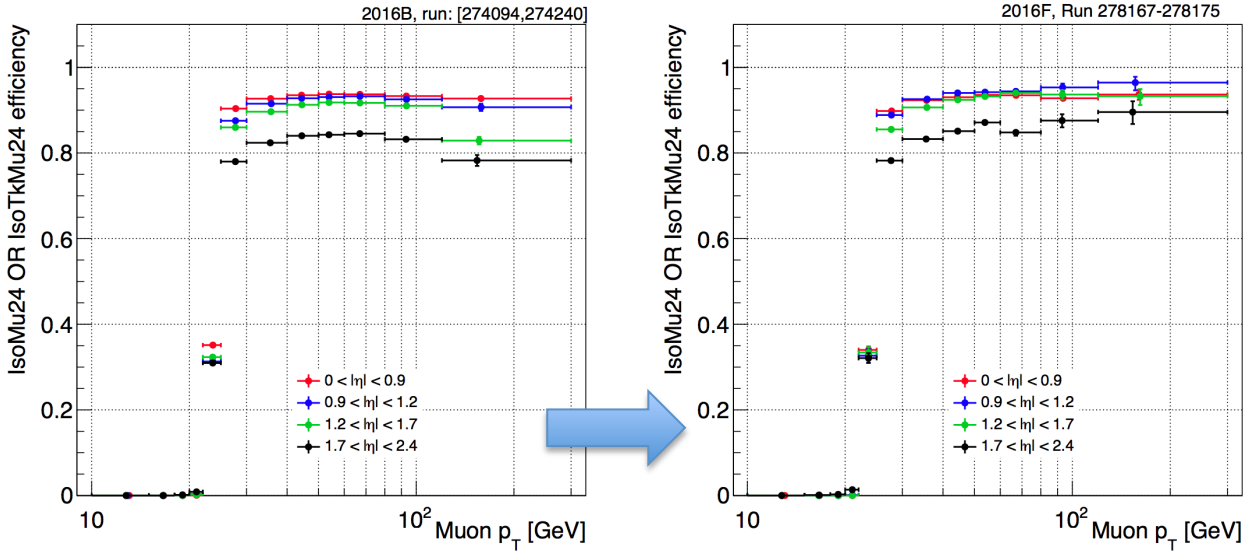
DT-RPC matching [implemented at the end of the run]

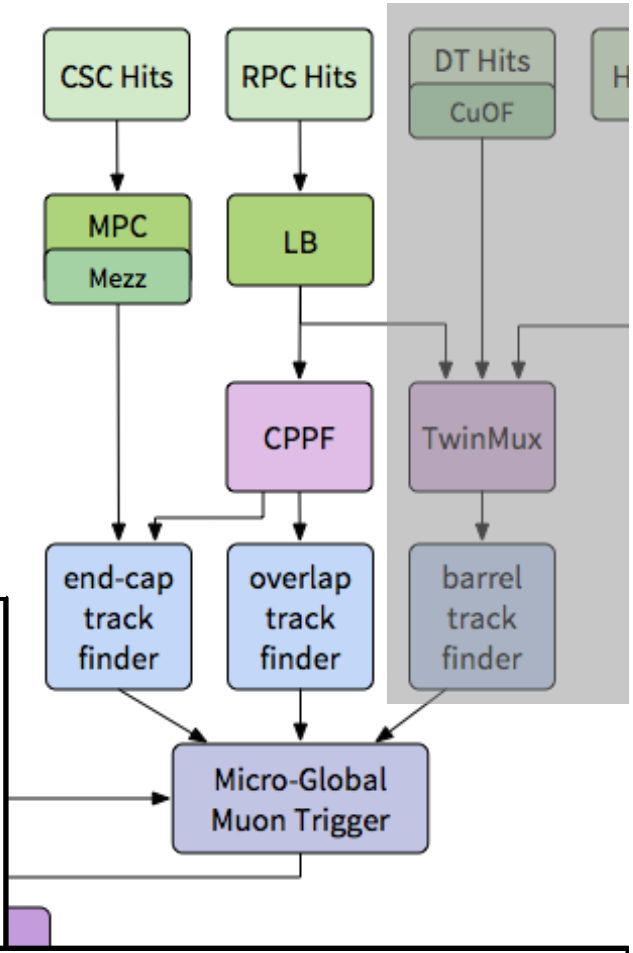
- ✓ **reduces out of time triggers**
- ✓ **local efficiency increased by ~1.3%**

TODO generation of RPC-only trigger primitives

TODO inclusion of HO in the trigger algorithm ?

L1 trigger in 2016: muon



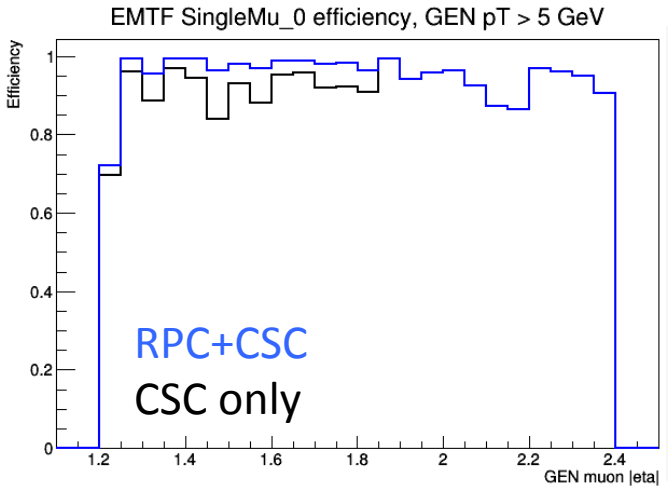


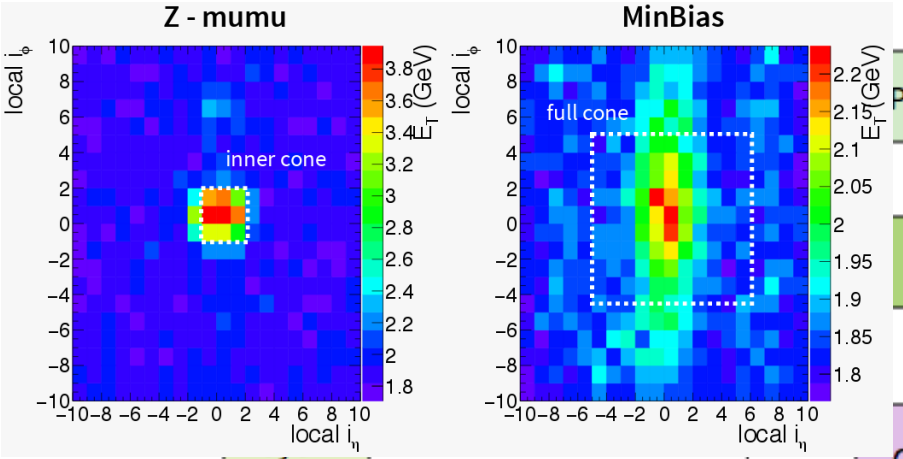
- ✓ many issues and bugs resolved
  - ➢ configuration error:
    EMTF only assigned pT to highest-quality track in a 60° sector
    [others got pT = 0]
  - ➢ firmware error:
    track in BX=0 was sometimes mis-assigned the pT
    from a track in the same sector in BX=-1
  - ➢ algorithm tuning:
    showering muons can produce tracks w/
    3 LCTs in a straight line + 1 outlier LCT
    → EMTF assigns low pT
  - → many improvements in performance algorithms

TODO offline DQM

TODO never forget the high p_T region !!

L1 trigger in 2016: muon





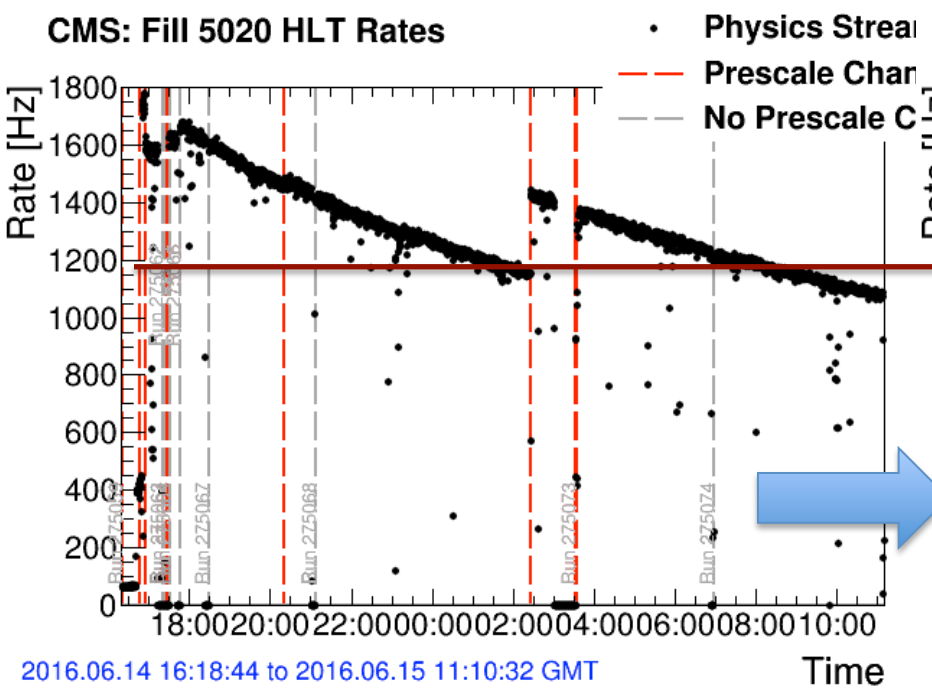
- TODO BMTF and EMTF
  - new p_T assignment algos (early stages)
- TODO CPPF(Concentration, Pre-Processing, and Fan-out)
  - RPC hits to EMTF (and OMTF)
- TODO TwinMux
  - use H0 information for TPs sent to BMTF
  - include RPC-only primitives
- TODO μGMT
  - calo info from layer 2 for μ isolation
  - muon ϕ extrapolated back to vertex (better angle and mass resolution)

HLT trigger in 2016

Roberta Arcidiacono
Elisabetta Gallo
Simone Gennai
Andrea Perrotta
Marina Passaseo
Sandro Ventura
Nazar Bartosik
Andrea Bocci
Silvio Donato
Sara Fiorendi
Gian Michele Innocenti
Riccardo Manzoni
Lorenzo Russo
Mia Tosi

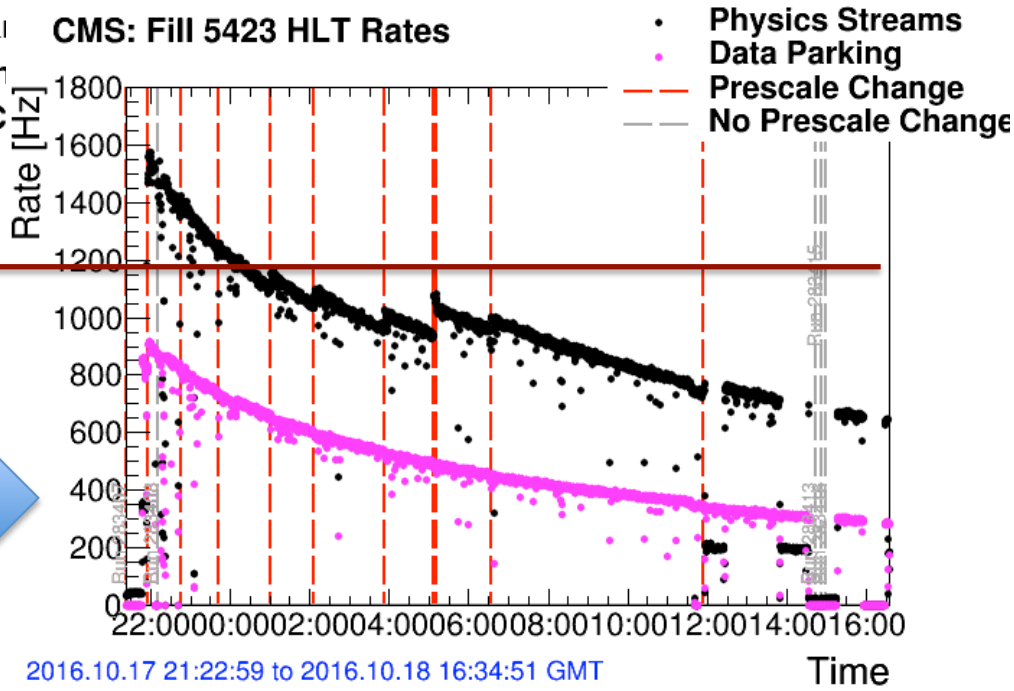
- lots of small updates/bugs spotted and fixed needed in order to accommodate the L1 upgrade
- wrote on average >~1000 Hz of Physics stream at Tier-0 and ~600 Hz of Parked Physics

peak PU = 30



June 2016

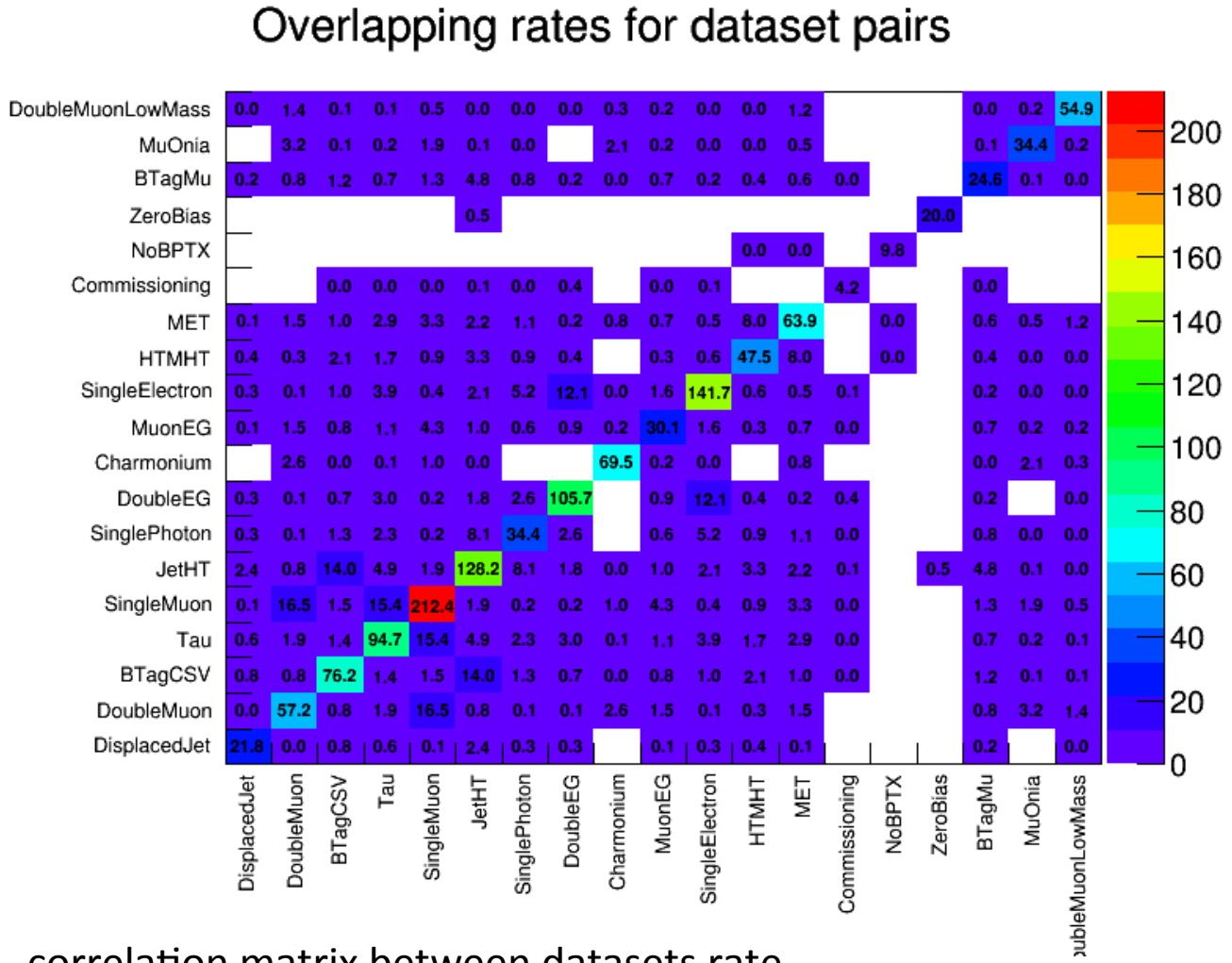
peak PU = 50



October 2016

rate : overlap between PDs

HLT menu v4.2
PS column 1.35e34
PU~42



correlation matrix between datasets rate
shows that **dataset definition is rather optimal in terms of overlaps**

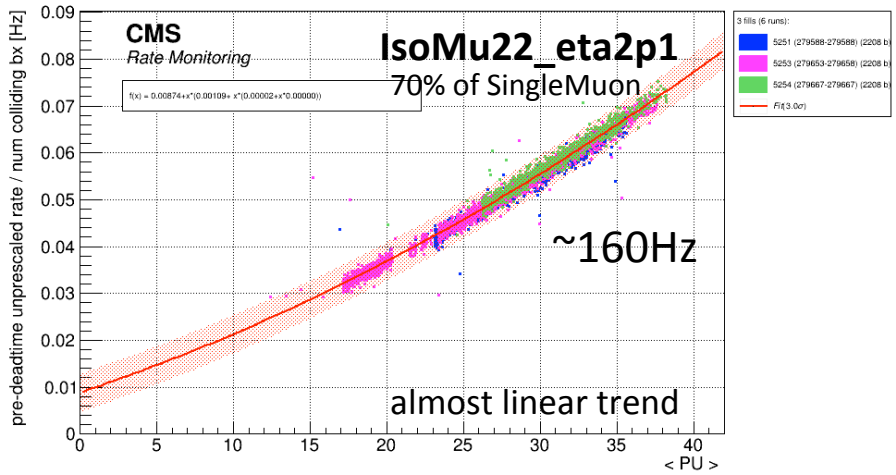
some considerable rate overlaps for pairs:

{SingleMuon ; DoubleMuon}, {JetHT ; BTagCSV}, {SingleMuon, Tau}

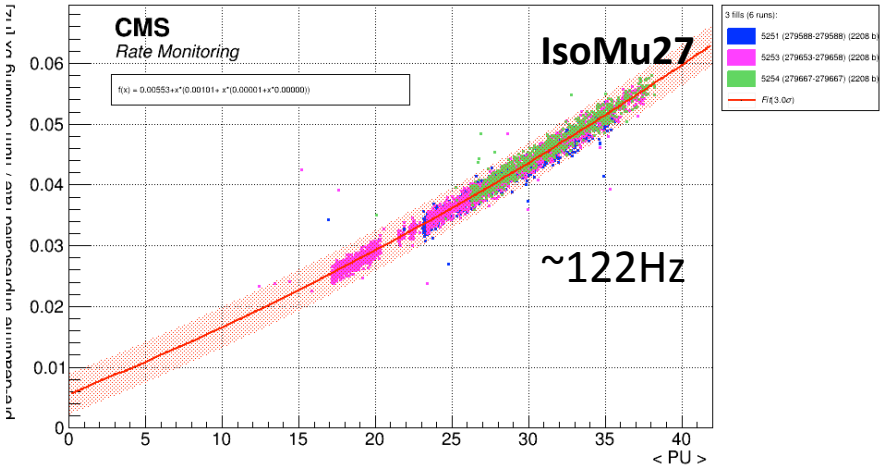
rate : PU dependence

Rates evolution with PU for some highest consumers:

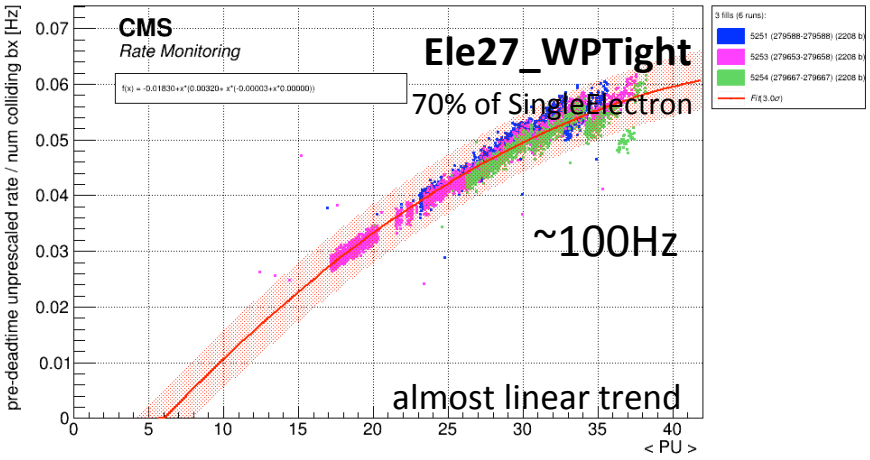
HLT_IsoMu22_eta2p1



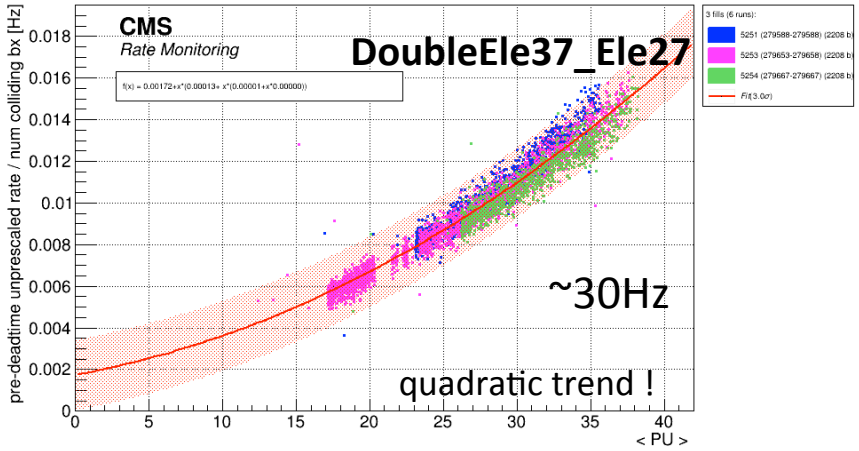
HLT_IsoMu27



HLT_Ele27_WPTight_Gsf



HLT_DoubleEle37_Ele27_CaloIdL_GsfTrkIdVL

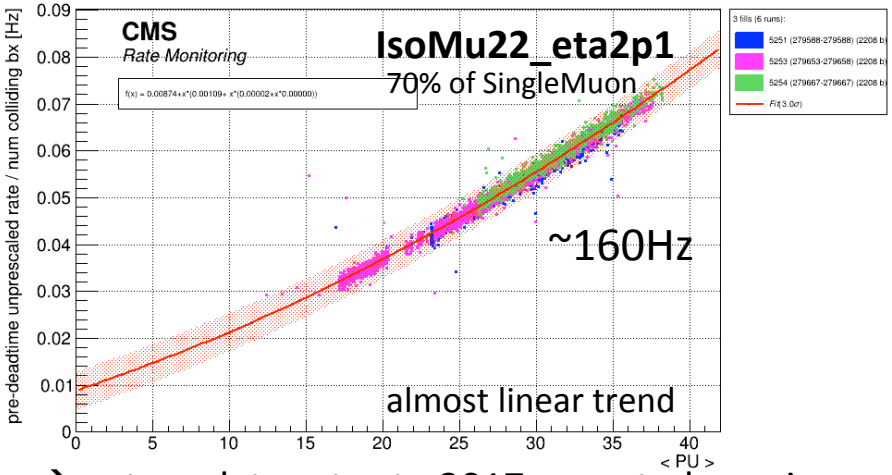


http://awightma.web.cern.ch/awightma/STEAM_plots/All_Triggers/Fills_5251-5254/

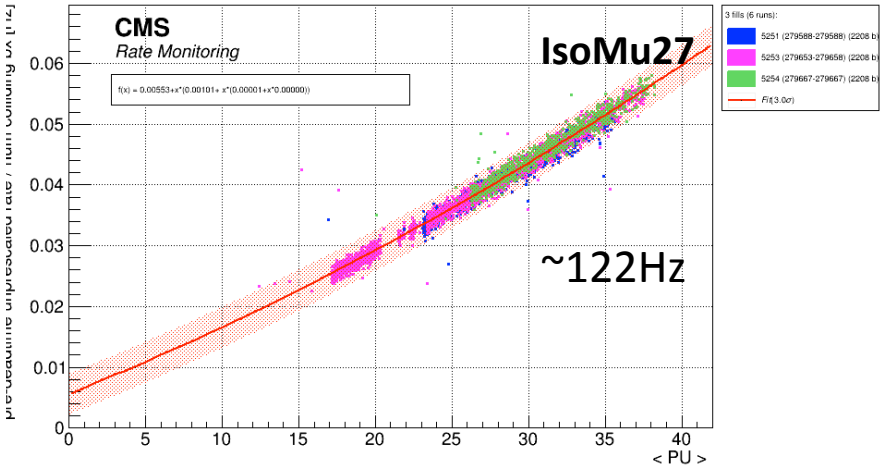
rate : PU dependence

Rates evolution with PU for some highest consumers:

HLT_IsoMu22_eta2p1



HLT_IsoMu27



→ extrapolate rates to 2017 expected running conditions: 1.6e34 – 2.0e34 @ PU ~(46 – 58)

	rate [Hz]				
	1.2e34	1.4e34	1.6e34	1.8e34	2.0e34
IsoMu22_eta2p1	160	190	220	250	280
IsoMu24	150	180	200	230	260

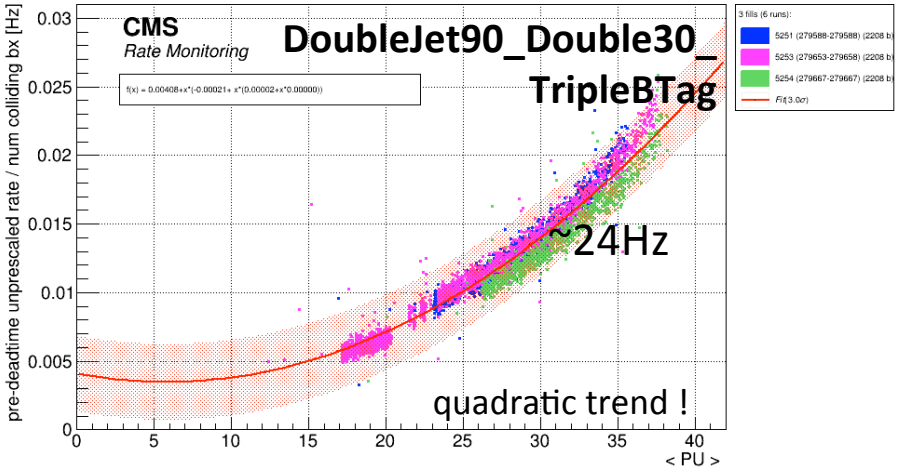
	threshold [GeV]				
	1.2e34	1.4e34	1.6e34	1.8e34	2.0e34
IsoMuXX_eta2p1	22	22	26	28	30
IsoMuXX	24	27	28	30	32

!

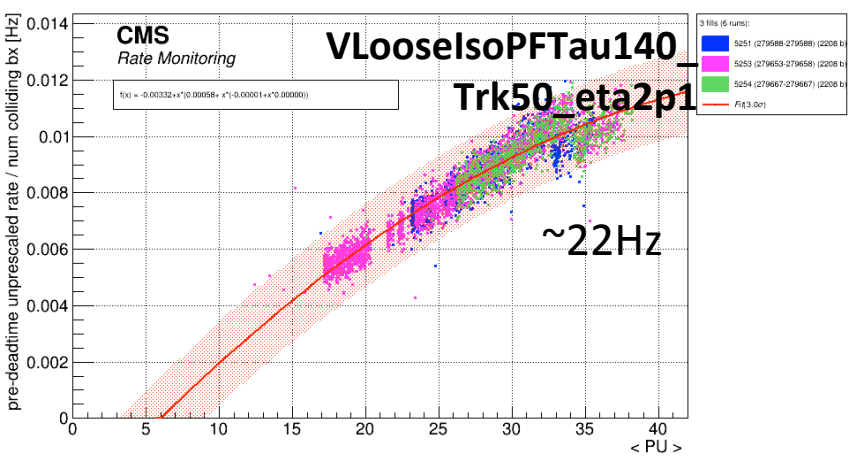
rate : PU dependence

Rates evolution with PU for some highest consumers:

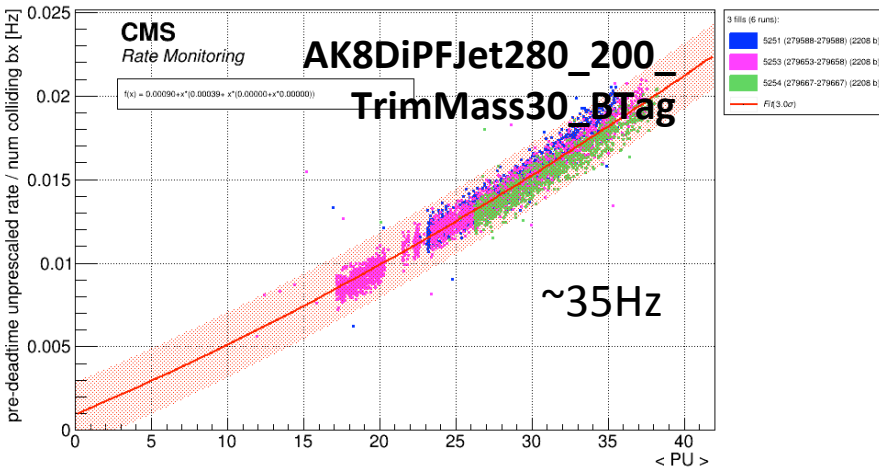
HLT_DoubleJet90_Double30_TripleBTagCSV_p087



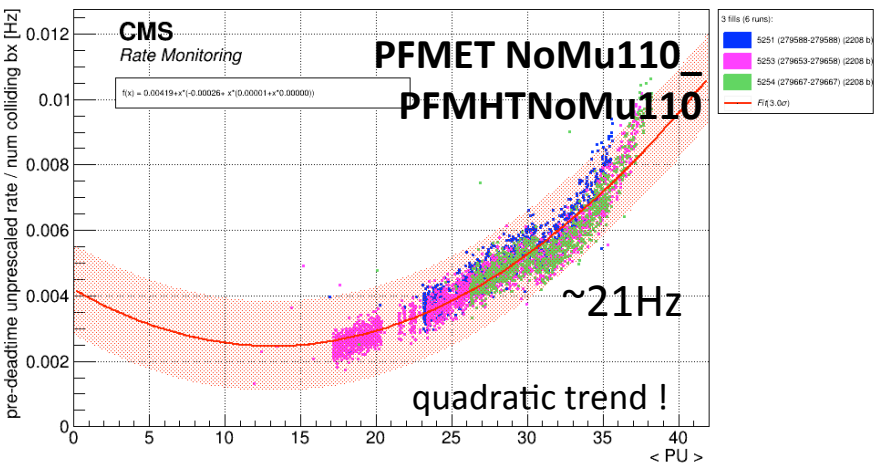
HLT_VLooseIsoPFTau140_Trk50_eta2p1



HLT_AK8DiPFJet280_200_TrimMass30_BTagCSV_p20



HLT_PFMETNoMu110_PFMHTNoMu110_IDTight



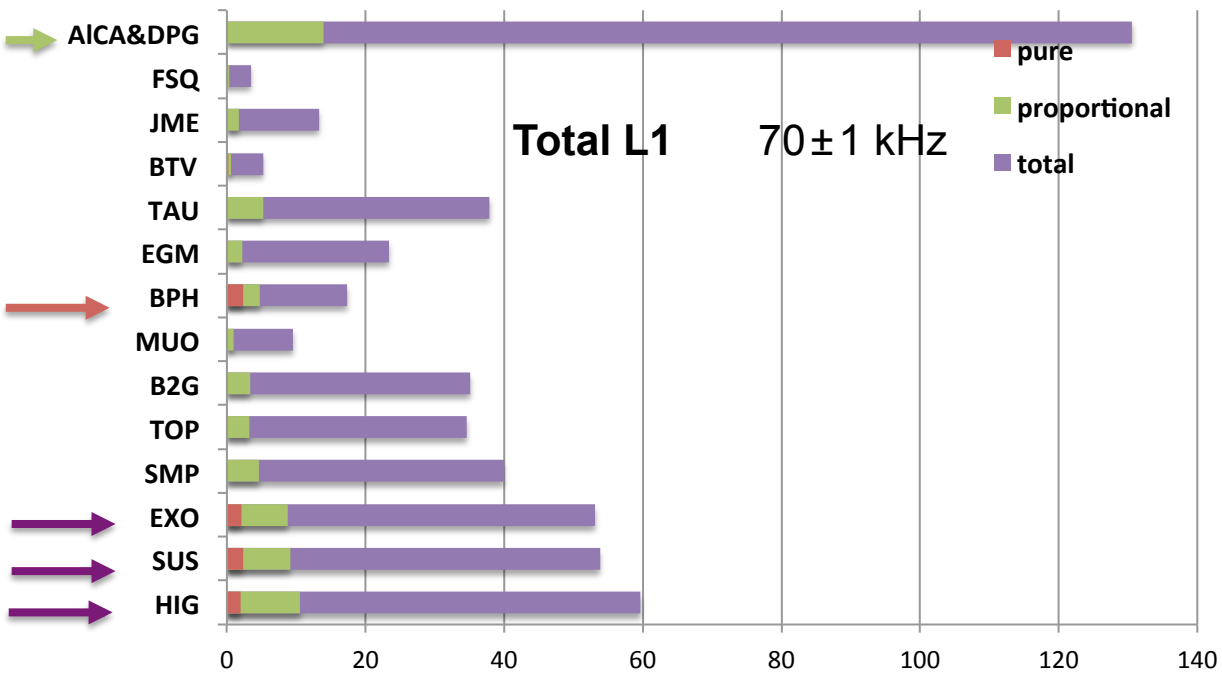
→ extrapolate rates to 2017 expected running conditions: 1.6e34 – 2.0e34 @ PU ~(46 – 58)

http://awightma.web.cern.ch/awightma/STEAM_plots/All_Triggers/Fills_5251-5254/

L1 trigger in 2016: rate

HLT menu v4.2
PS column 1.35e34
PU~42

Group	Rate [kHz] Total	Prop.	Pure
HIG	60 ± 1	11 ± 1	2 ± 1
SUS	54 ± 1	9 ± 1	2 ± 1
EXO	53 ± 1	9 ± 1	0 ± 1
SMP	40 ± 1	5 ± 1	0 ± 1
TOP	35 ± 1	3 ± 1	0 ± 1
B2G	35 ± 1	3 ± 1	0 ± 1
MUO	10 ± 1	1 ± 1	0 ± 1
BPH	17 ± 1	5 ± 1	2 ± 1
EGM	23 ± 1	2 ± 1	0 ± 1
TAU	38 ± 1	5 ± 1	0 ± 1
BTV	5 ± 1	1 ± 1	0 ± 1
JME	13 ± 1	2 ± 1	0 ± 1
FSQ	3 ± 1	0 ± 1	0 ± 1
AlCa & DPGs	131 ± 1	14 ± 1	0 ± 1

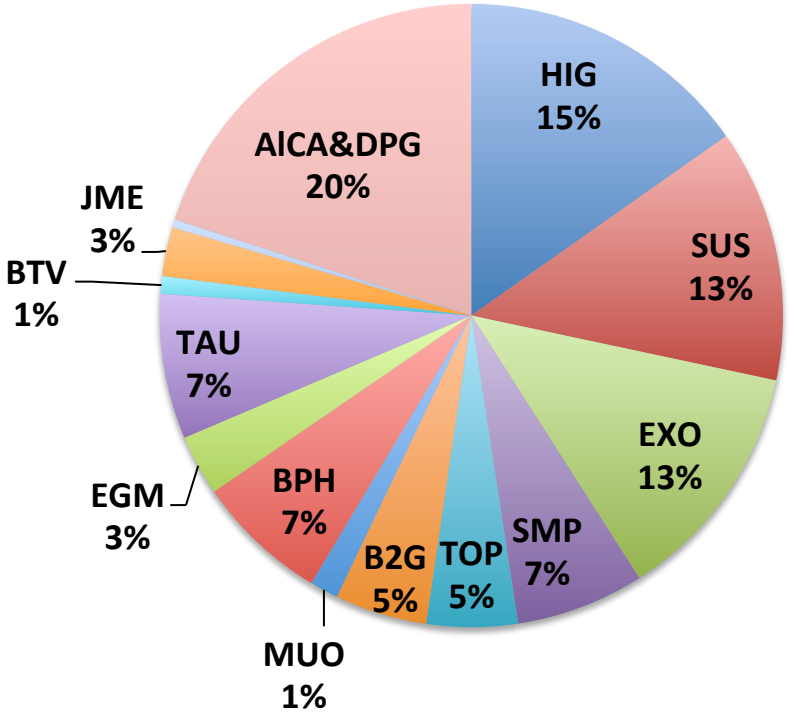


- **Total rate per group** := sum of the triggers rate used by group
  - the biggest consumers are the **HIG**, **SUS** and **EXO** PAGs (~ 50% of the total rate)
  - **TAU** makes use of larger bandwidth
  - **AlCA & DPG** make use of a lot of L1 rate → special streams for calibration
- **Proportional rate per group** := rate from single-group triggers → rate takes into account co-owenership
  - **HIG** , **SUS** and **EXO** are again the main consumer (~15-20%)
- **Pure rate per group** := rate from single-group triggers
  - **HIG**, **SUS** and **EXO** and **BPH** groups are the only ones w/ pure rate
    → dedicated strategy already @L1

L1 trigger in 2016: rate

HLT menu v4.2
PS column 1.35e34
PU~42

Group	Rate [kHz] Total	Prop.	Pure
HIG	60 ± 1	11 ± 1	2 ± 1
SUS	54 ± 1	9 ± 1	2 ± 1
EXO	53 ± 1	9 ± 1	0 ± 1
SMP	40 ± 1	5 ± 1	0 ± 1
TOP	35 ± 1	3 ± 1	0 ± 1
B2G	35 ± 1	3 ± 1	0 ± 1
MUO	10 ± 1	1 ± 1	0 ± 1
BPH	17 ± 1	5 ± 1	2 ± 1
EGM	23 ± 1	2 ± 1	0 ± 1
TAU	38 ± 1	5 ± 1	0 ± 1
BTV	5 ± 1	1 ± 1	0 ± 1
JME	13 ± 1	2 ± 1	0 ± 1
FSQ	3 ± 1	0 ± 1	0 ± 1
AlCa & DPGs	131 ± 1	14 ± 1	0 ± 1

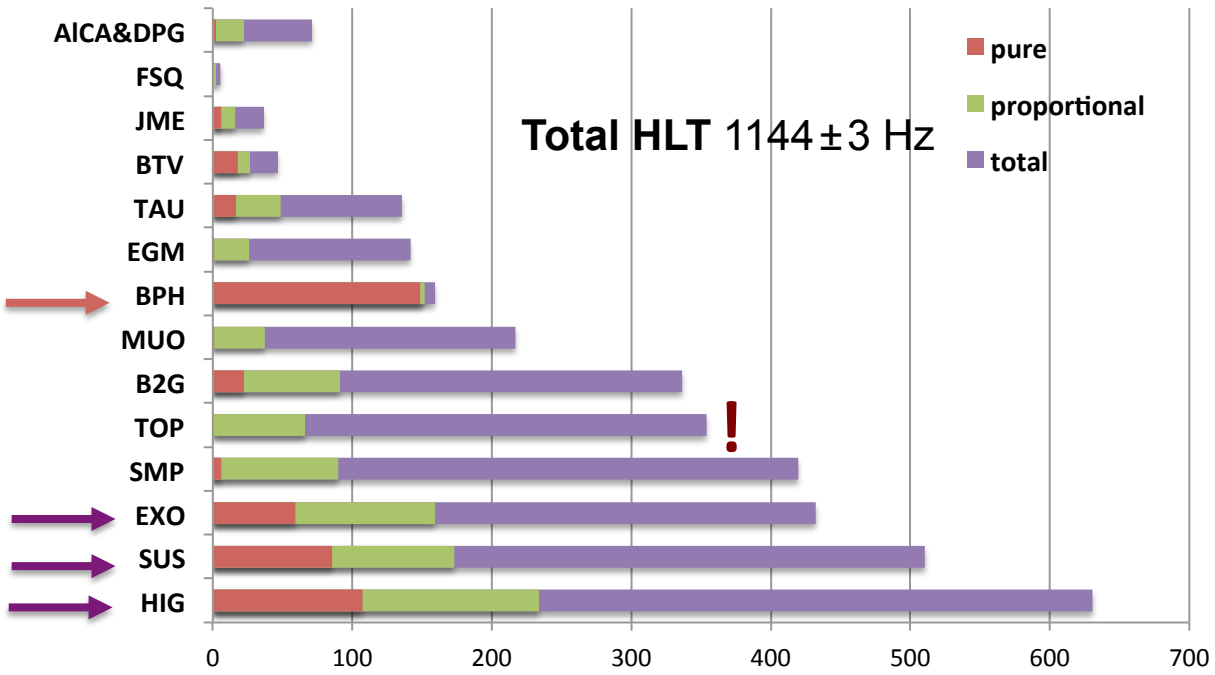


- **Total rate per group** := sum of the triggers rate used by group
  - the biggest consumers are the **HIG**, **SUS** and **EXO** PAGs (~ 50% of the total rate)
  - **TAU** makes use of larger bandwidth
  - **AlCA & DPG** make use of a lot of L1 rate → special streams for calibration
- **Proportional rate per group** := rate from single-group triggers → rate takes into account co-owenership
  - **HIG** , **SUS** and **EXO** are again the main consumer (~15-20%)
- **Pure rate per group** := rate from single-group triggers
  - **HIG**, **SUS** and **EXO** and **BPH** groups are the only ones w/ pure rate
    → dedicated strategy already @L1

HLT trigger in 2016: rate

HLT menu v4.2
PS column 1.35e34
PU~42

Group	Rate [Hz] Total	Prop.	Pure
HIG	630 ± 2	234 ± 1	107 ± 1
SUS	510 ± 1	173 ± 1	86 ± 1
EXO	432 ± 1	159 ± 1	59 ± 1
SMP	420 ± 1	90 ± 1	6 ± 1
TOP	354 ± 1	66 ± 1	0 ± 1
B2G	336 ± 1	91 ± 1	22 ± 1
MUO	216 ± 1	37 ± 1	1 ± 1
BPH	159 ± 1	152 ± 1	149 ± 1
EGM	141 ± 1	26 ± 1	1 ± 1
TAU	136 ± 1	49 ± 1	17 ± 1
BTV	47 ± 1	27 ± 1	18 ± 1
JME	36 ± 1	16 ± 1	6 ± 1
FSQ	6 ± 1	2 ± 1	0 ± 1
AICa & DPGs	71 ± 1	22 ± 1	2 ± 1



- **Total rate per group** := sum of the triggers rate used by group
  - the biggest consumers are the **HIG**, **SUS** and **EXO** PAGs (~ 50% of the total rate)
- **Proportional rate per group** := rate from single-group triggers → rate takes into account co-owenership
  - **HIG** is again the main consumer (~30%)
  - the top 5 is very similar to that of total rates, except for **BPH** (very particular phase space)
- **Pure rate per group** := rate from single-group triggers
  - **BPH** group is here the biggest consumer due to phase-space (~95% of its total rate)
  - **HIG**, **SUS** and **EXO** are again among the biggest consumers (~16% of their total rate)
  - **TOP** group has no pure rate

HLT trigger in 2016: rate

HLT menu v4.2
PS column 1.35e34
PU~42

Group	Rate [Hz]		
	Total	Prop.	Pure
HIG	630 ± 2	234 ± 1	107 ± 1
SUS	510 ± 1	173 ± 1	86 ± 1
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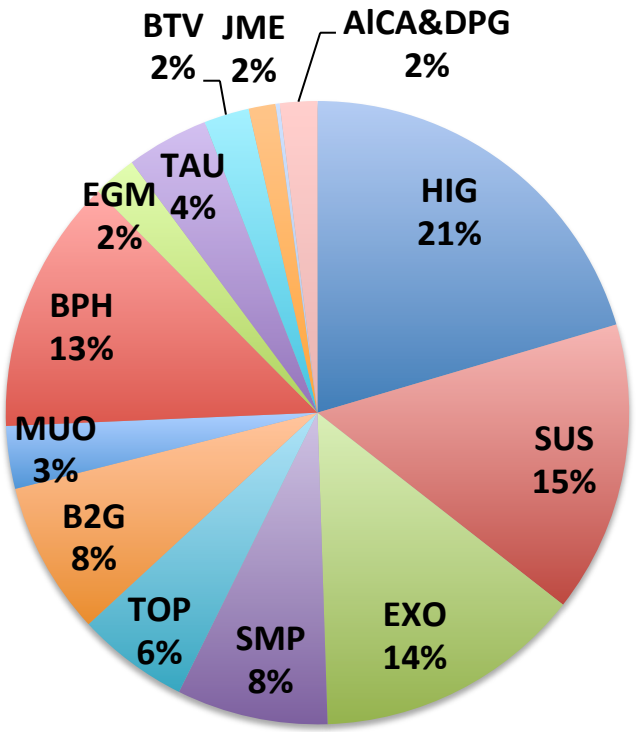
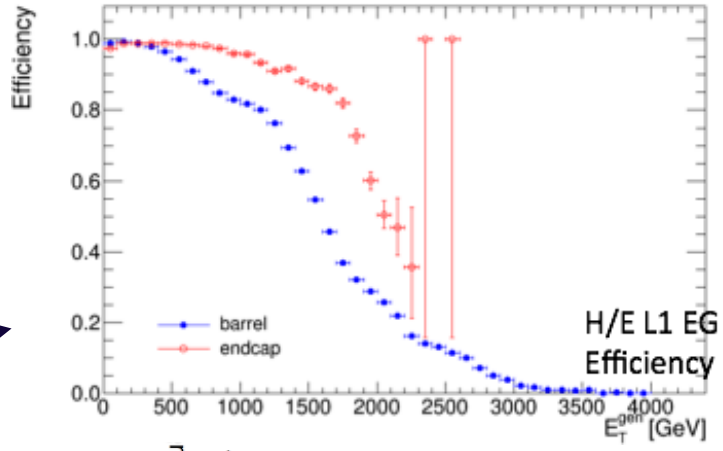
AlCa & DPGs	71 ± 1	22 ± 1	2 ± 1

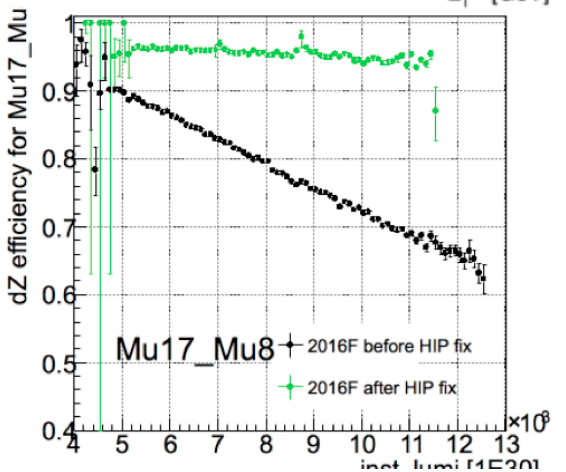


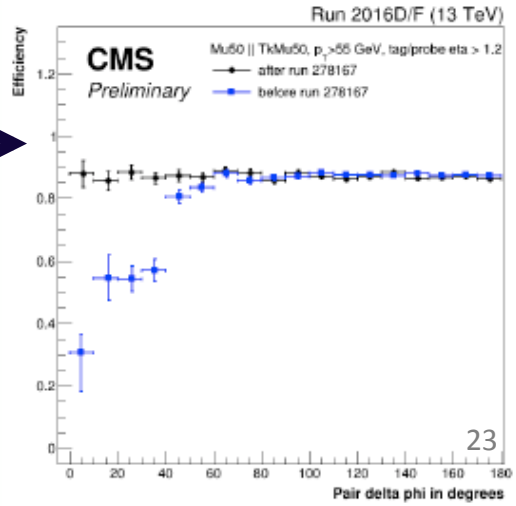
- **Total rate per group** := sum of the triggers rate used by group
  - the biggest consumers are the **HIG**, **SUS** and **EXO** PAGs (~ 50% of the total rate)
- **Proportional rate per group** := rate from single-group triggers → rate takes into account co-owenership
  - **HIG** is again the main consumer (~20%)
  - the top 5 is very similar to that of total rates, except for **BPH** (very particular phase space)
- **Pure rate per group** := rate from single-group triggers
  - **BPH** group is here the biggest consumer due to phase-space (~95% of its total rate)
  - **HIG**, **SUS** and **EXO** are again among the biggest consumers (~16% of their total rate)
  - **TOP** group has no pure rate

HLT issues

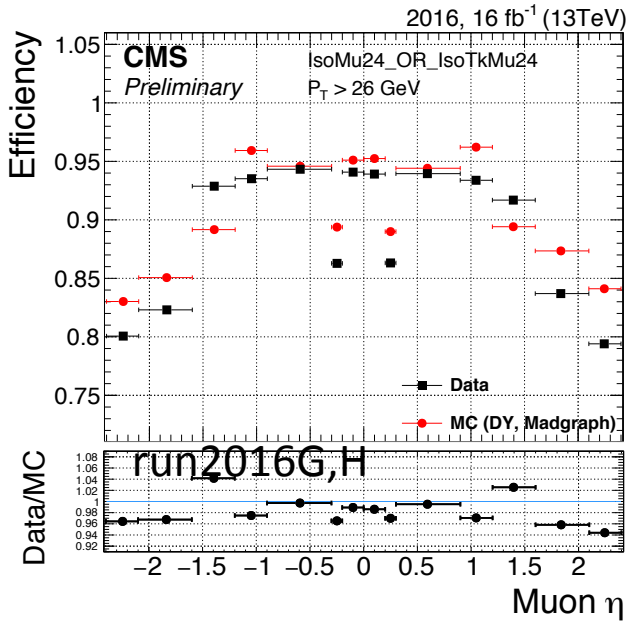
- Run2016B - bug in L1-HLT objects matching
- Run2016C - bug in H/E for L1 e/γ
  - all EG objects had cut H/E < 3.125% (6.25%)
    in the barrel (endcap),
    w/o taking into account the p_T
- up to Run2016F – strip dynamic inefficiency
  - large effect on lepton dZ and lepton efficiency
  - Small effect on paths with btag
- Few bugs in EMTF, up to 2016F
  - Highest impact bug was a firmware bug assigning the p_T only to highest-quality track in a 60° sector
  - See also https://twiki.cern.ch/twiki/bin/view/CMS/EndcapHighPtMuonEfficiencyProblem

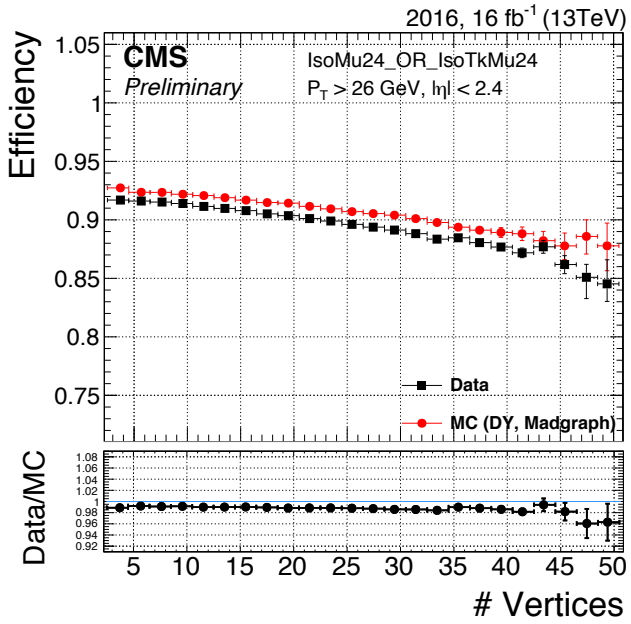


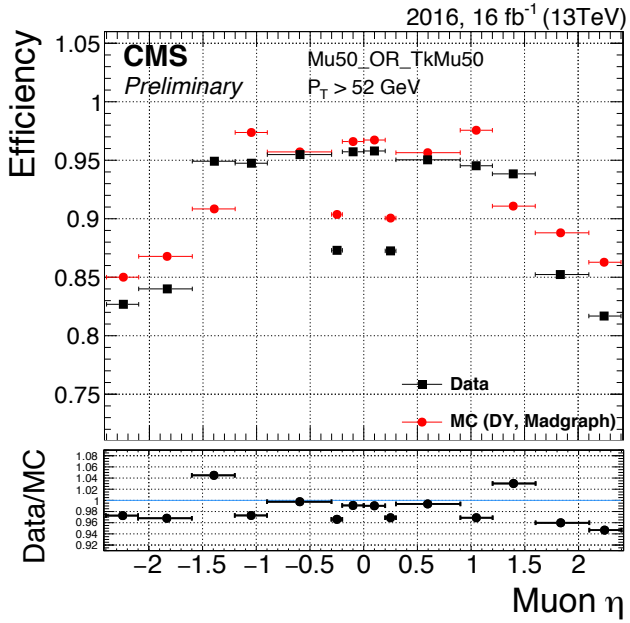


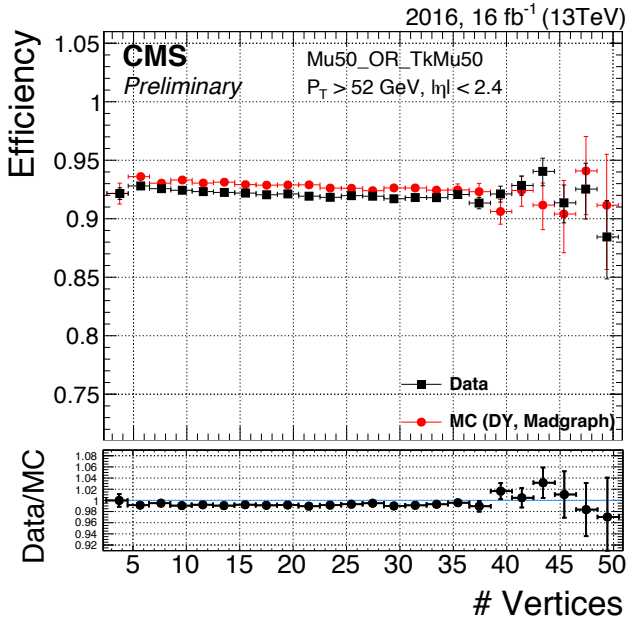


HLT trigger in 2016: performance



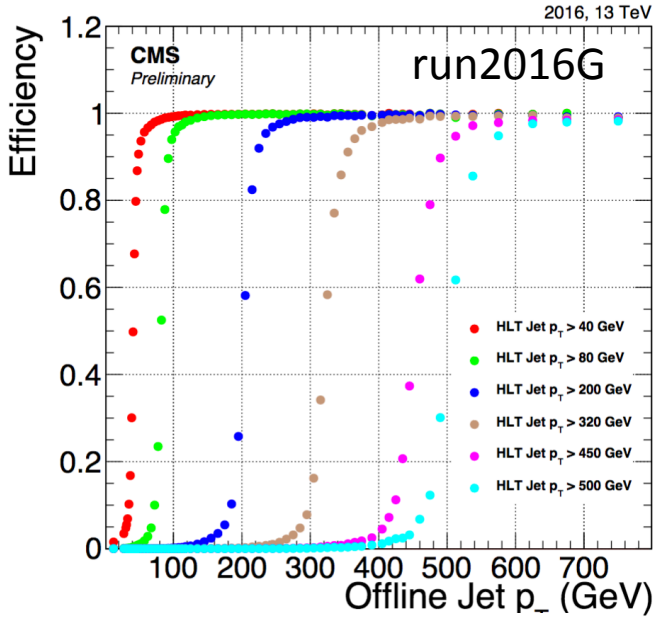


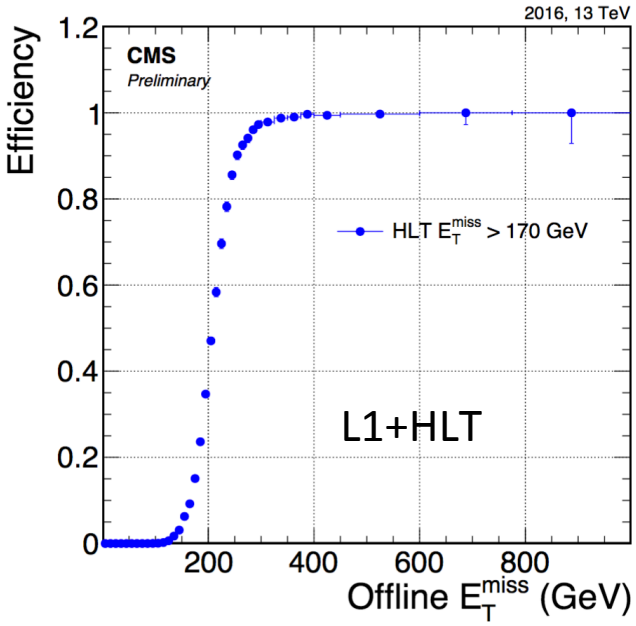




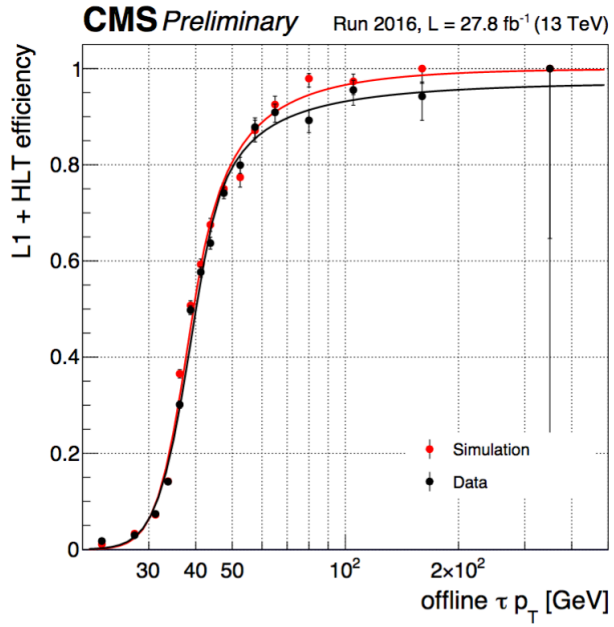
- absolute value
  mainly driven by L1
- trend vs PU
  driven by HLT (isolation)

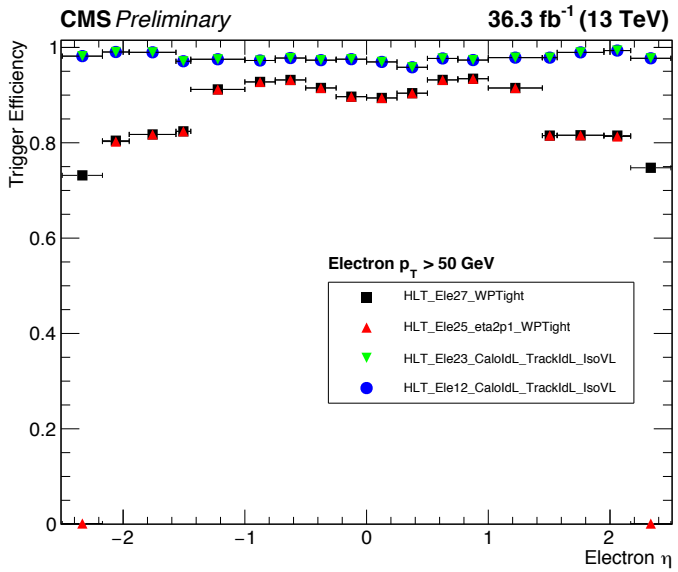
HLT trigger in 2016: performance





- jet energy resolution makes the turnON worst at high p_T

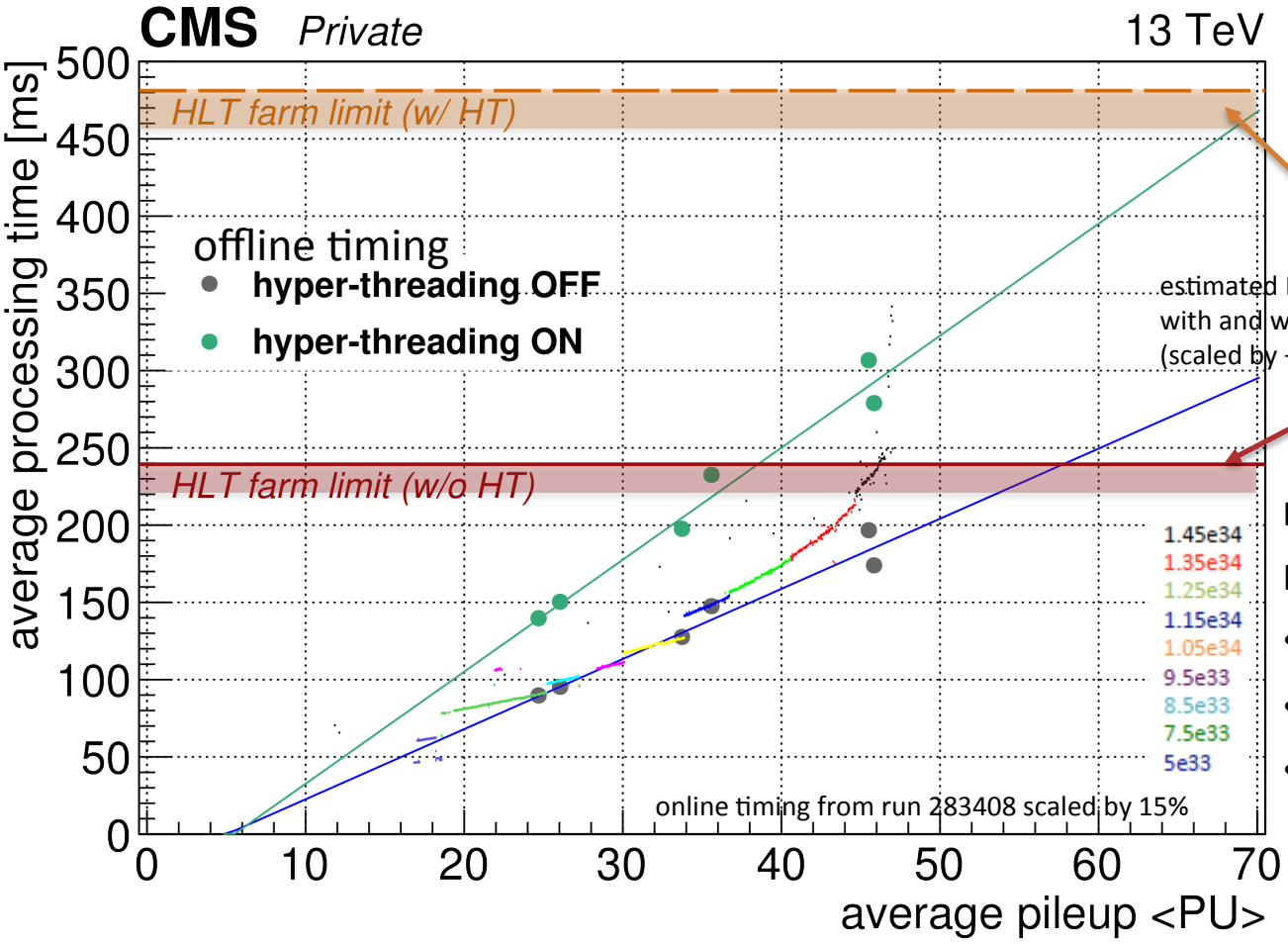




main sources of inefficiency:

- L1 threshold > HLT one @high PU
- selection on H/E
- calorimetric isolations
- GSF track fit χ^2 in EE

timing in 2016



L1 selections change event topology

higher the PS column [for ~fixed PU]

- higher the thresholds
- larger the particle multiplicity
- larger is the average HLT timing

new HCAL readout and new pixel detectors might have a not neglible impact on the timing in 2017 …

HLT Menu v4.2 on HLTPhysics Run2016H (6 skims based on both PU and PS column)
machines vocms003/004

2017 scenario

parameter	2016	BCMS	BCMS β* 33cm
Beta*	40 cm	40 cm	33 cm
Half crossing angle	140 µrad	155 µrad	170 µrad
Number of colliding bunches	2208	2448	2448
Proton per bunch	*~ 1.1e11*	1.25e11	1.25e11
Transverse emittance into SB	*~ 1.9 µm*	2.3 µm	2.3 µm
Bunch length	1.05 ns	1.05 ns	1.05 ns
Peak luminosity	~ 1.5e34 $cm^{-2}s^{-1}$	~ 1.8e34 $cm^{-2}s^{-1}$	~ 1.9e34 $cm^{-2}s^{-1}$
Peak pile-up	~ 49	~ 52	~ 56

outcome of the discussion at the trigger workshop:

- 1.6e34 $cm^{-2}s^{-1}$ (pileup ~ 46) to study the impact of lumi levelling
- 1.8e34 $cm^{-2}s^{-1}$ (pileup ~ 52) as the initial luminosity for 2017
- 2.0e34 $cm^{-2}s^{-1}$ (pileup ~ 58) as the ultimate luminosity for 2017
- 2.2e34 $cm^{-2}s^{-1}$ (pileup ~ 64) as the “emergency column”

optimise the menu and studies for 2.0e34 $cm^{-2}s^{-1}$ (pileup 55-58)

L1 menu in 2017 (draft)

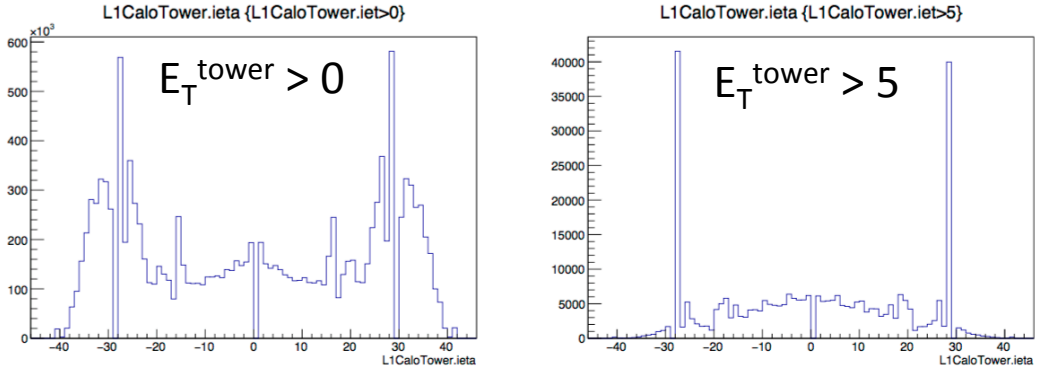
L1 trigger	1.45e34 (2016)	1.7e34 (2017)	2.0e34 (2017)
Muon triggers			
L1_SingleMu20er OR L1_SingleMu22	1	1	1
L1_SingleMu22er OR L1_SingleMu25	1	1	1
L1_DoubleMu_12_5	1	1	0
L1_DoubleMu_12_8 OR 13_6 OR 15_5	1	1	1
L1_TripleMu_5_0_0	1	0	0
L1_TripleMu_5_5_3	1	1	1
L1_QuadMu0	1	1	1
L1_DoubleMu0er1p25_dEta_Max1p8_OS	1	1	1
L1_DoubleMu0er1p4_dEta_Max1p8_OS	1	1	1
L1_Mu3_JetC120_dEta_Max0p4_dPhi_Max0p4	1	1	1
E/Gamma triggers			
L1_SingleIsoEG32er OR IsoEG34 OR EG36	1	0	0
L1_SingleIsoEG34er OR IsoEG36 OR EG38	1	1	0
L1_SingleIsoEG36er OR IsoEG38 OR EG40	1	1	1
L1_DoubleEG_24_17	1	1	1
L1_DoubleEG_25_12	1	1	1
L1_TripleEG_18_17_8	1	1	1
Tau triggers and cross-triggers			
L1_SingleTau120er	1	1	1
L1_DoubleTau50er	1	1	0
L1_DoubleTau70er	1	1	1
L1_DoubleIsoTau30er	1	1	0
L1_DoubleIsoTau33er	1	1	1
L1_Mu18er_Tau20er	1	1	1
L1_Mu20er_IsoTau26er	1	1	1
L1_IsoEG22er_IsoTau26er_dEta_Min0p2	1	1	1

L1 trigger	1.45e34 (2016)	1.7e34 (2017)	2.0e34 (2017)
Jet triggers			
L1_SingleJet180	1	1	1
L1_DoubleJetC112	1	1	1
L1_TripleJet_92_76_64_VBF	1	1	1
L1_QuadJetC50	1	1	1
Energy sum triggers			
L1_ETM100	1	0	0
L1_ETM105	1	1	0
L1_ETM115	1	1	1
L1_HTT300	1	0	0
L1_HTT320	1	1	0
L1_HTT360	1	1	1
Mu + EG cross-triggers			
L1_Mu20_EG15	1	1	1
L1_Mu20_IsoEG6	1	1	1
L1_Mu23_EG10	1	1	1
L1_Mu23_IsoEG10	1	1	1
L1_Mu5_EG23	1	1	1
L1_Mu5_IsoEG20	1	1	1
L1_DoubleMu7_EG7	1	1	1
L1_Mu6_DoubleEG10	1	1	0
L1_Mu6_DoubleEG17	1	1	1
Energy sum cross-trigger			
L1_DoubleMu0_ETM65	1	0	0
L1_DoubleMu0_ETM70	1	1	0
L1_DoubleJetC60_ETM60	0	0	0
L1_Mu6_HTT200	1	1	1
L1_EG27er_HTT200	1	1	0
L1_DoubleEG6_HTT255	1	0	0

- IsoEG**36**er OR IsoEG**38** OR EG**40** !
- ETM**115**
- HTT**360**

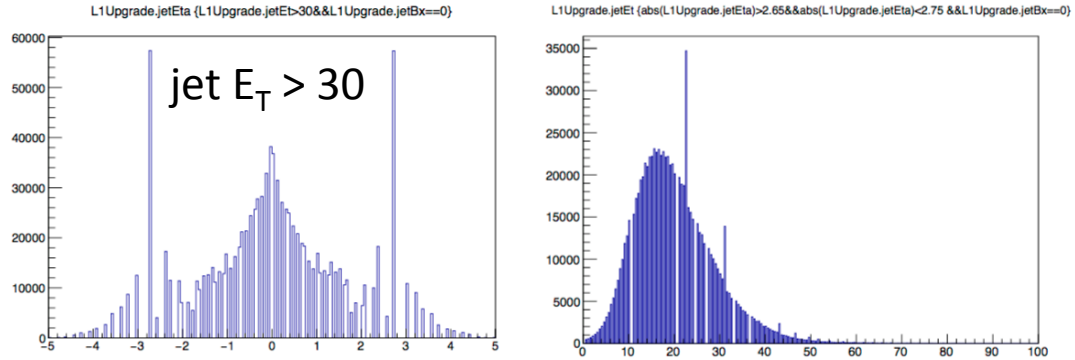
on HTT and MET ..

- some spikes observed in tower 28 (last endcap tower)



- many L1 jets observed at $|\eta| = 2.7$

  these jets seem to have a fishy E_T distribution



..apparentely, old layer1 calibration (derived by MC) available up to $|\eta| = 2.7$

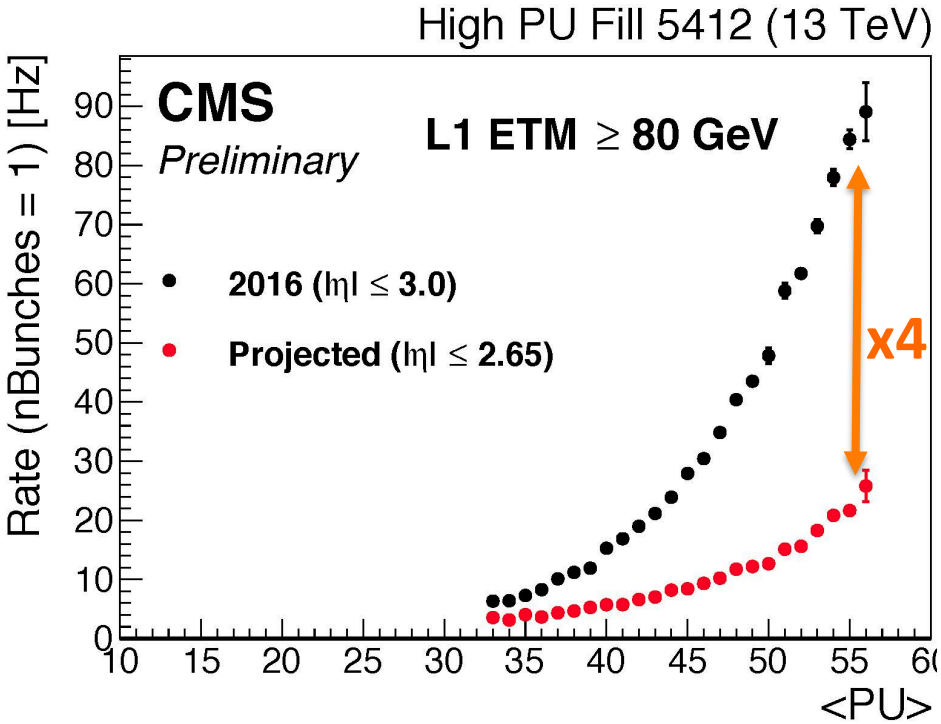
and remaining eta bins corrected by applying SFs derived by last available bin (both in ECAL and HCAL)

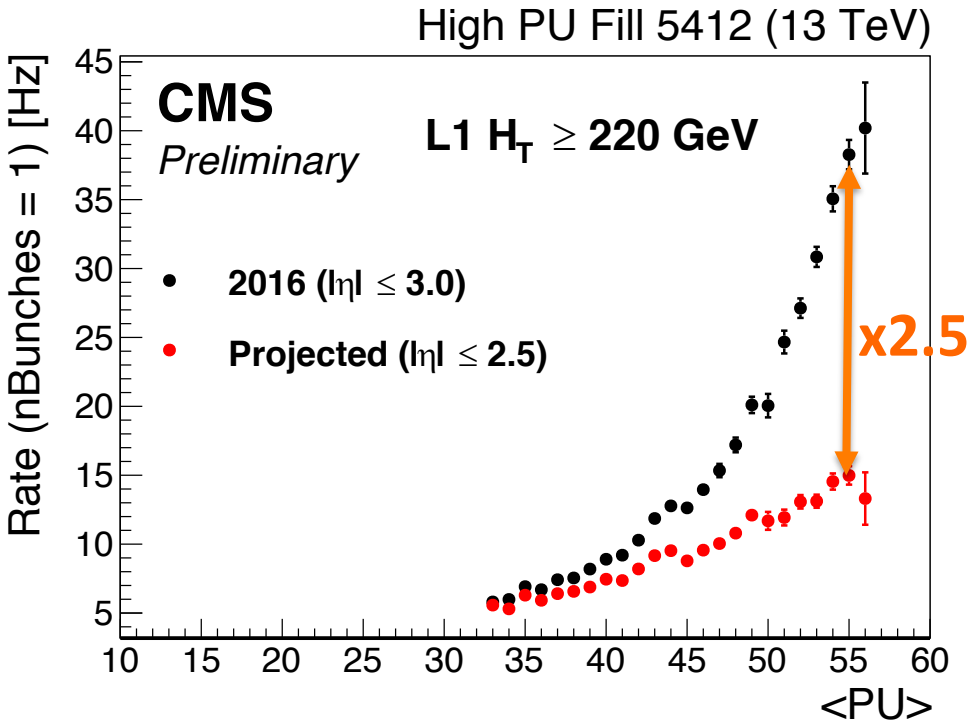
- over correction of tower energy for trigger tower 28 (TT28)

  [which is even eider in η]

on HTT and MET ..

- by removing TT28, we get better L1 ETM rate behavior vs PU
  option for 2017, depending on the understanding of TT28
- by reducing jet eta, we get better L1 HTT rate behavior vs PU
  most analysis use eta cut in the HTT, likely for 2017

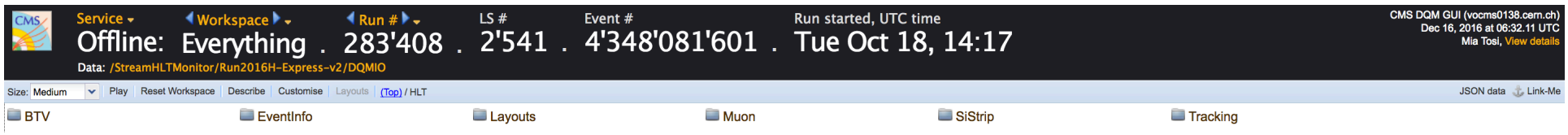




conclusion

- ✓ deployed and commissioned a new L1 trigger system
- ✓ ~neglible loss of data (both delivered and recorded) due to the trigger systems
  - about 125 pb^{-1} lost due to trigger issues, 8% of all down time
    - …in 2012 we lost 149 pb-1, 14% of all down time!
- ✓ good performance, specially at the end of the data taking (exept for HTT ..)
- ✓ rate w/in budget (even if it took a while to fit it …)
- ➢ many updates and configuration changes
  - ⚠ even “small” changes caused unexpected behavior !
    - not always obvious at first glance (some changes were not announced)
  - ➧ be ready to roll back in case of problems
  - ➧ but above all, improve

VALIDATION AND PROMPT MONIROTING !!!

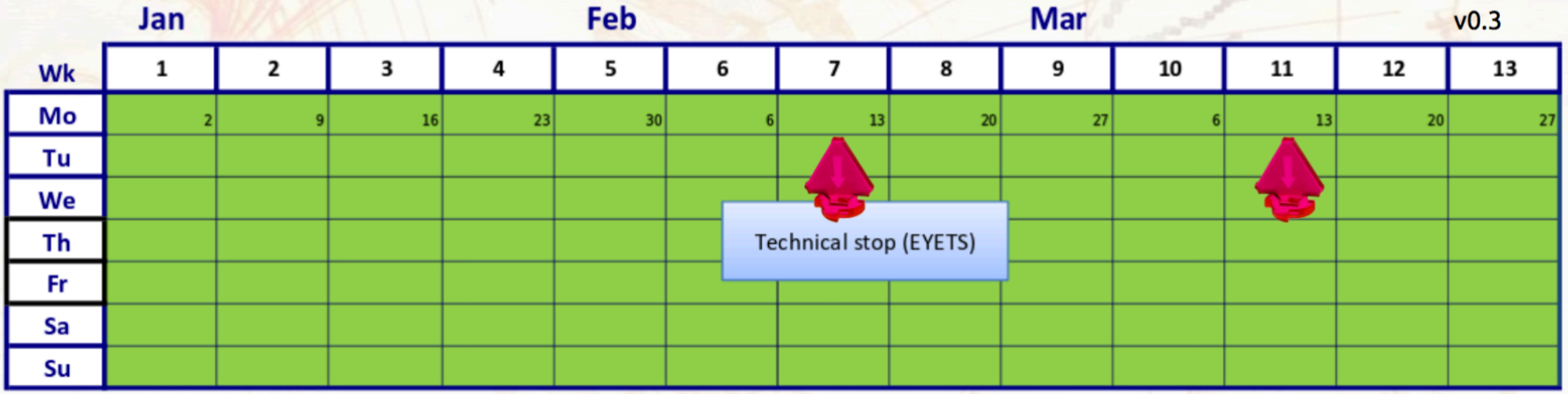


currentely, very few groups have a monitoring tool based on DQM
… we are working on it ;)

PS:
ATLAS has an HLT trigger w/ 2 b-tag unPS’d !!!

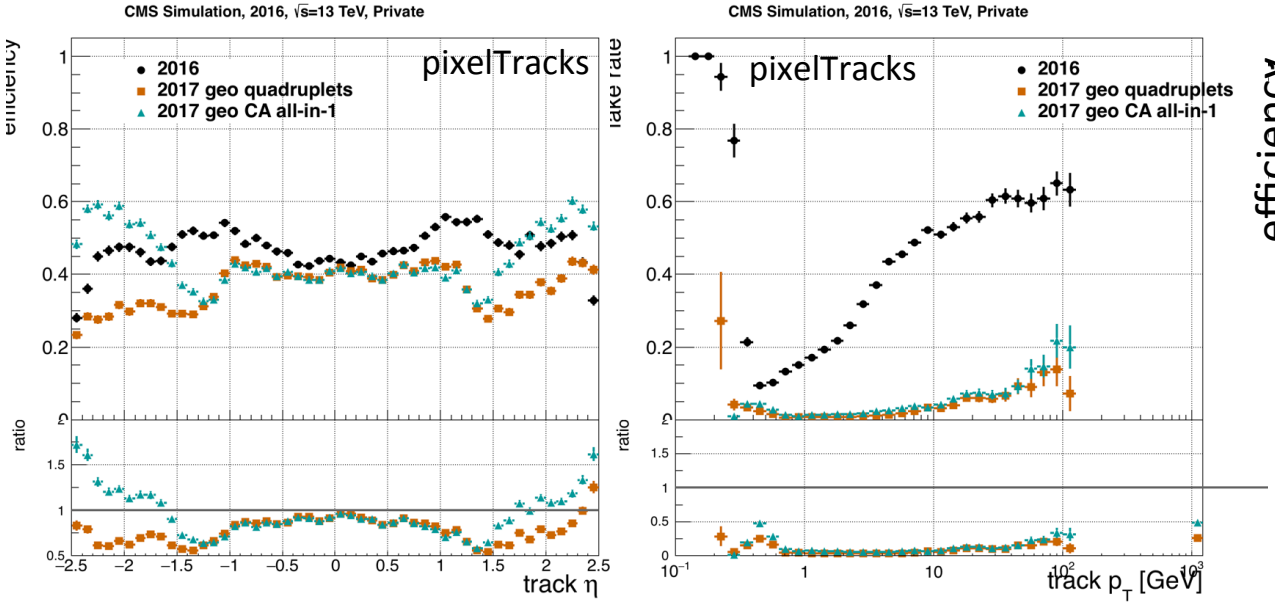
towards next year upgrades

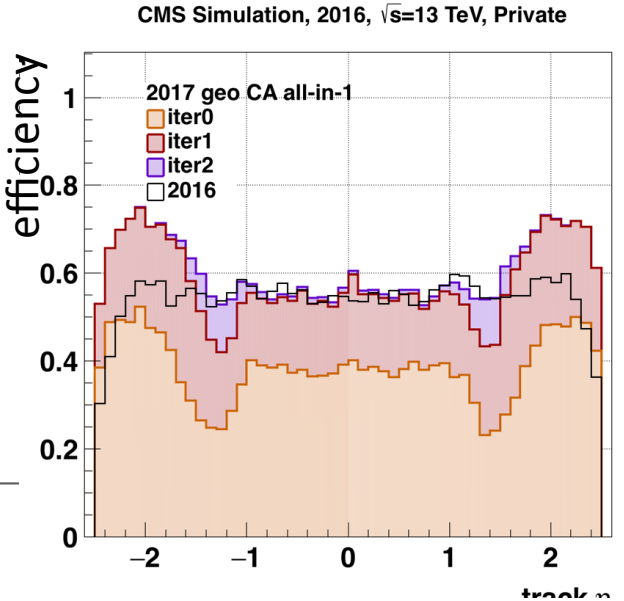
~~a~~ schedule for 2017

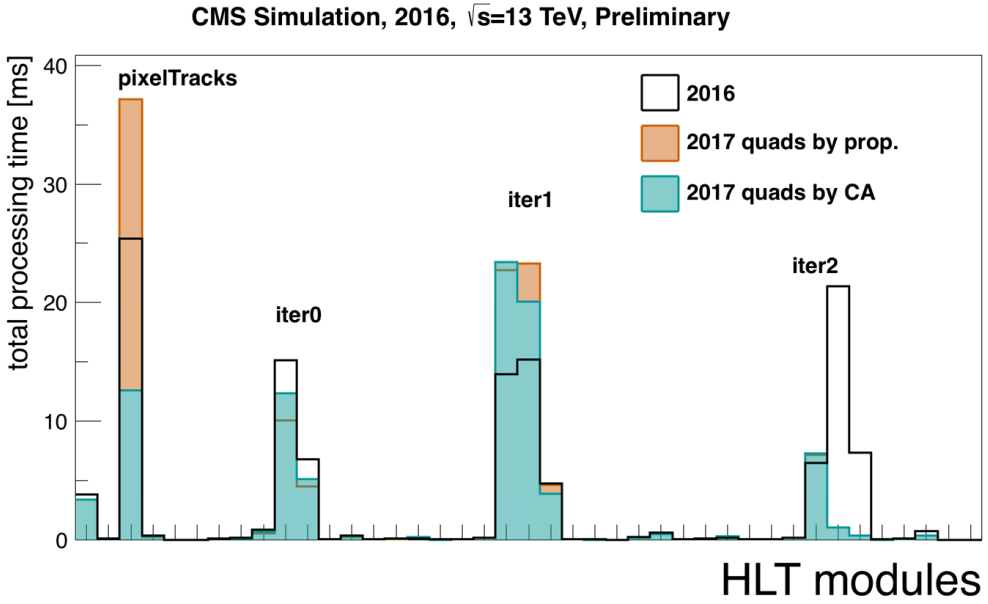


- February 15th
  - finalise tracking and local reconstruction (including HCAL method 3)
  - prepare preliminary calibrations
- March 15th
  - freeze tracking and local reconstruction
  - finalise POG reconstruction
  - derive final calibrations

towards next year upgrades



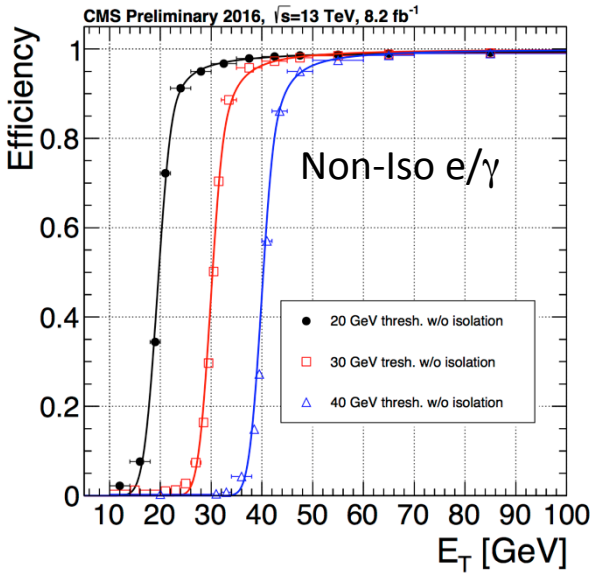


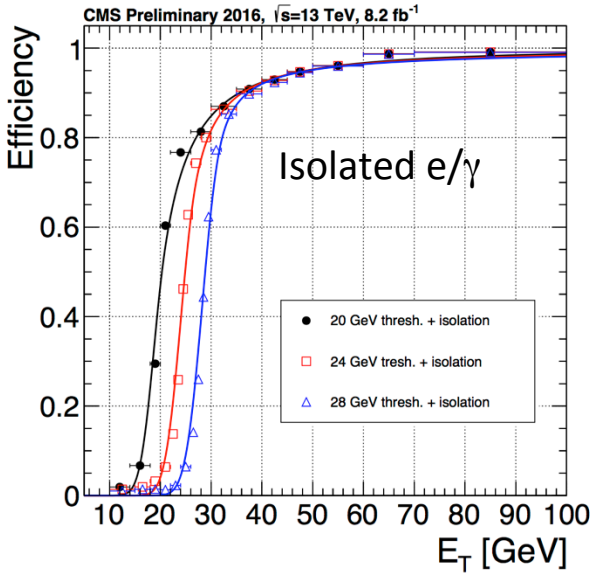


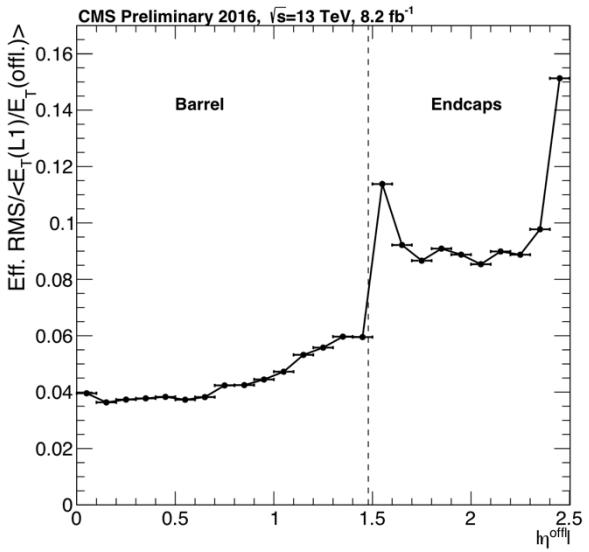
	average timing / event [ms]	
	all tracking	pixelTracks
2016	172	**25.4**
2017 geo quadruplets	153	37.1
2017 geo CA all-in-1	129	12.6


BACKUP

L1T e/γ



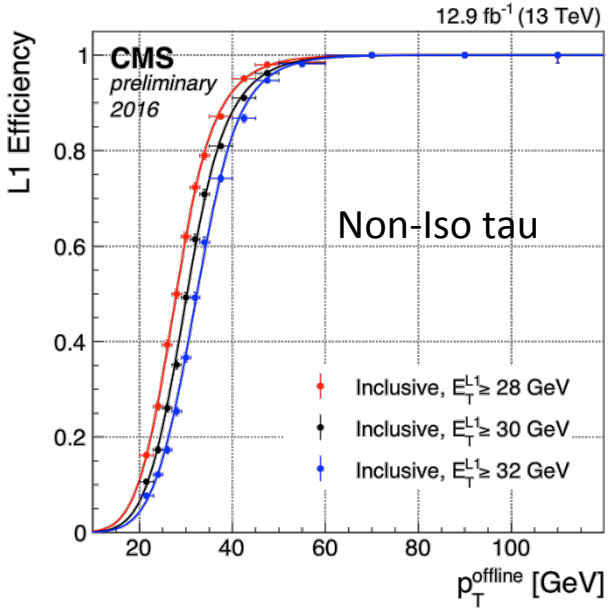


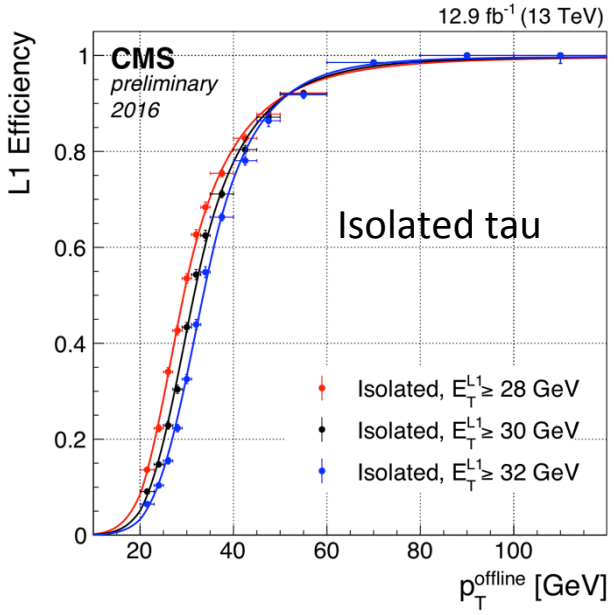


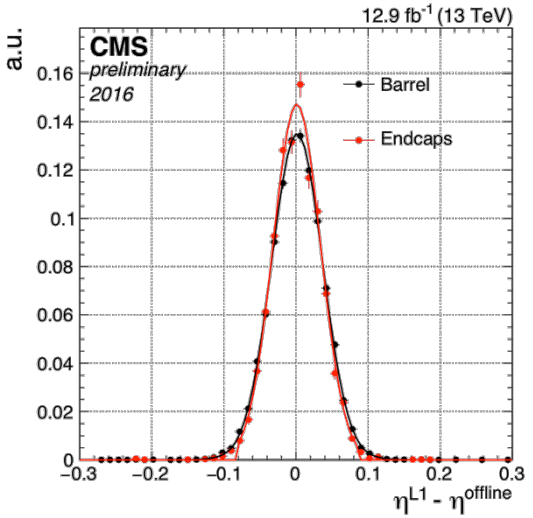
- Efficiency for single e/γ with E_T > L1 threshold vs offline E_T
  - Consistent performance throughout 2016 with Weekly laser corrections
  - No strong dependence on PU for IsoEG
  - New Layer-1 correction and isolation reoptimization
  - New spike killing threshold ~50% reduction in spike contamination
  - 2017 – numerous improvements expected
    - SK, FG, PU, shape veto, iso. reopt., trimming and calibration, etc.

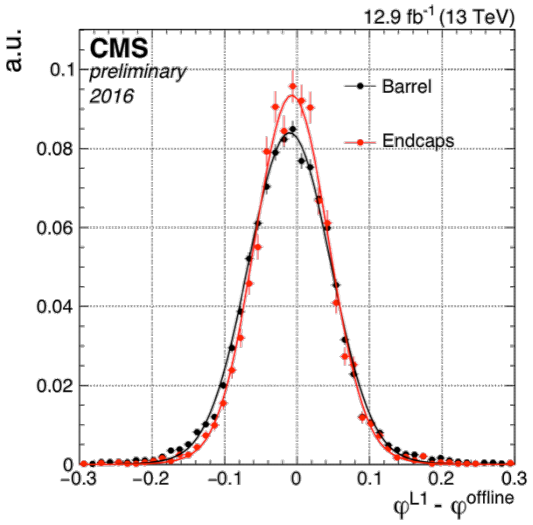
T. Sinthuprasith

L1T Tau





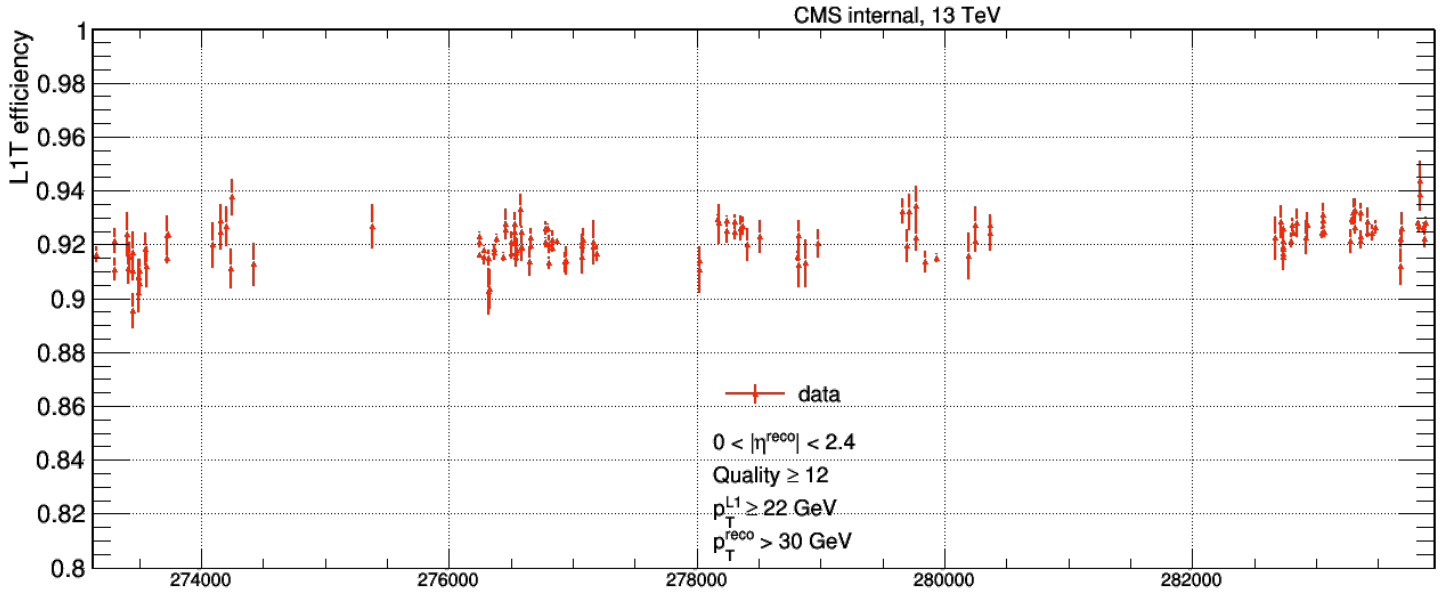




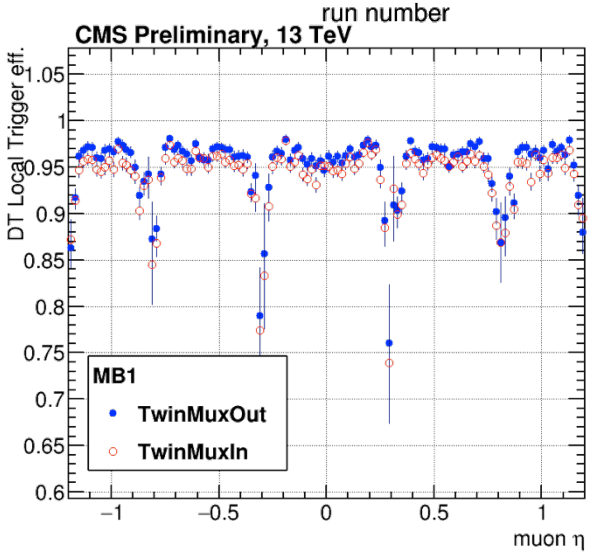
- New L1 Tau algorithm deployed in 2016
  - Part of Stage-2 Level-1 Calo trigger upgrade
  - Steep turn on, isolated plateaus at 60 GeV
  - Good resolution in η and φ
  - 2017 improvements
    - Iso. reopt. (loose and tight), shape veto, new correlation seed

O. Davignon

L1T Muon



- Overall Efficiency Stable at 92±1%
  - Muon trigger commissioned a new system
    - Parts of were installed early 2016
  - Many issues and bugs resolved quickly
  - Many improvements in performance, algorithms



A. Brinkerhoff and T. Reis

Menu in 2016

	1.05E34	1.15E34	1.25E34	1.35E34	1.45E34	1.6E34
L1_SingleMu	20	22	22	22	22	22
L1_SingleMuer	18	20	20	20	20	20
L1_DoubleMu	11,4	11,4	12,5	12, 5	12, 5	12, 5
L1_SingleEG	30	32	34	34	36	38
L1_SingleEGer	28	30	32	32	34	36
L1_SingleIsoEGer	26	28	30	30	32	34
L1_DoubleEG	23, 10	23,10	23,10	23,10	25,12	25,12
L1_SingleJet	150	160	170	170	180	180
L1_DoubleJetC	100	100	100	100	112	112
L1_QuadJetC	50	50	50	50	50	50
L1_DoubleIsoTauer	30	30	30	30	30	30
L1_HTT	280	300	300	300	300	320
L1_ETM	85	85	90	95	100	110
L1_DoubleMu0_ETM	55	55	55	65	65	70

- Tuned with rates from LS with expected pileup or extrapolated from fits to pileup
- Feedback from L1 & HLT used to adjust balance of triggers

Z. Wu

Preliminary Menu in 2017

- L1Menu rate
  - 1.5 kHz ZeroBias,
  - 4kHz EXO NotBptxOR
  - 5kHz Buffer
  - Tuned to ~89 kHz
- 1.7e34
  - Expect 83 kHz
- 2e34
  - Expect 89 kHz
  - Thresholds may be higher
  - Almost no x-triggers

	1.6E34	1.7E34	2E34
L1_SingleMu	22	22	25
L1_SingleMuer	20	20	22
L1_DoubleMu	13, 6	13, 6	13, 6
L1_SingleEG	38	38	42
L1_SingleEGer	36	36	40
L1_SingleIsoEGer	34	34	38
L1_DoubleEG	25,12	25, 12	25, 13
L1_SingleJet	180	18	18
L1_DoubleJetC	112	112	112
L1_QuadJetC	50	50	50
L1_DoubleIsoTauer	30	30	33
L1_HTT	320	340	380
L1_ETM	110	120	NA

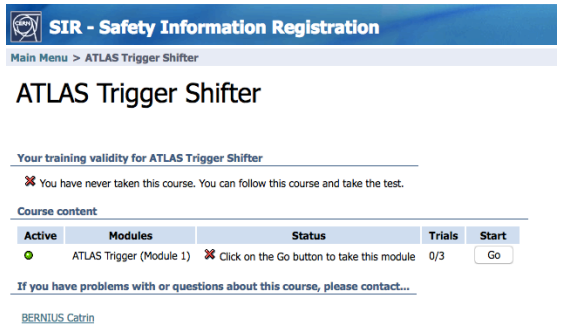
Note: 0^{th} iteration – no retuning for higher lumi or PU, or L1 improvements

Z. Wu

Lessons Learned 2016

& Wish List…

- Shifter (continued)
  - Wrong prescale column
    - μGT preserve column between runs, shifter training
  - Shifters in general
    - Selection more stringent this year
    - Trainer a bit burnt out
      - Maybe migrate some training to sir.cern.ch
      - ATLAS (right) has already done this
      - Advantage - quizzes
      - Disadvantage – no personal interaction



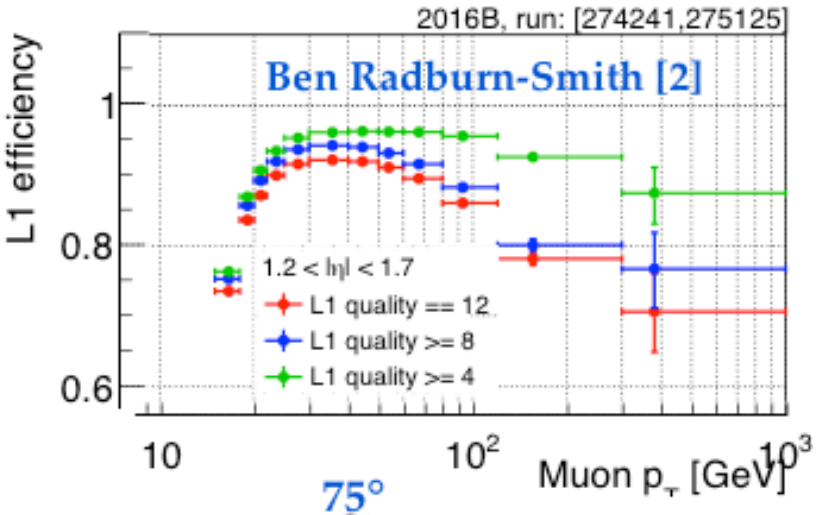
- Trigger Objects
  - Tracked on CMS TWiki: L1KnownIssues
  - e/γ
    - Need a more systematic approach to optimization
    - DQM firmware emulator comparisons to be implemented
    - Run certification to be automated

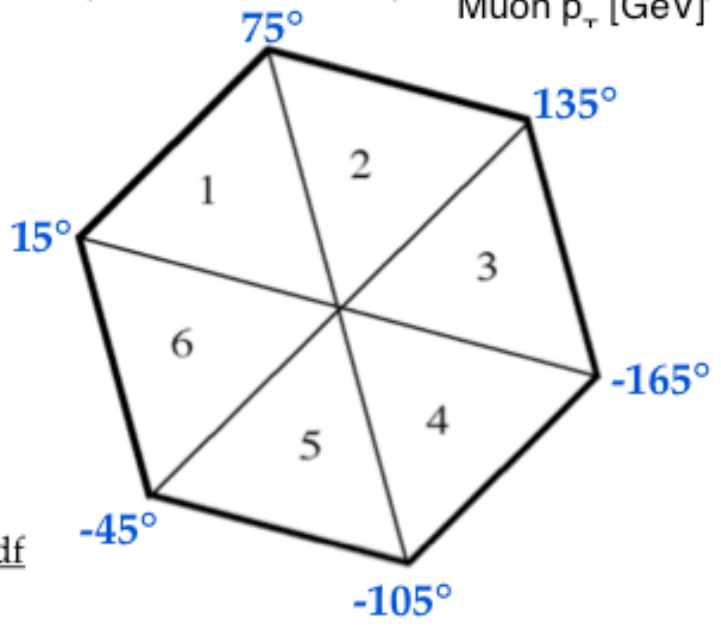
Lessons Learned 2016 & Wish List…

- Trigger Objects (continued)
  - Tau
    - Need a more systematic approach to optimization
    - Comparison of firmware and emulator in DQM to be implemented
    - Run certification to be automated
  - Jet, ME_T & H_T
    - Careful when deploying firmware fixes online
    - Better testing, MC samples for edges
    - Studies at end of fill
    - Hardware and firmware comparisons in DQM
  - Muon
    - Better communication/more contact with HLT colleagues
    - Basic set muon performance & kinematics plots for reference
    - Offline DQM, better emulator DQM
    - Zero Suppression (lose the fat event filter) more stats for DQM
    - Never forget the high p_T region of the energy spectrum!

EMTF "high-pT" issue

- Starting in June [1], noticed a drop in efficiency for high pT muons in endcap
- Eventually traced down to cases where there were two EMTF tracks in the same sector, and one was thrown away
- In the end, "high-pT" inefficiency was determined to be an artifact of the Z→μμ tag-and-probe method - not real
  - Muons from boosted Z's often land in same sector. Tag must fire trigger, so probe cannot.
- Small DoubleMu inefficiency for low-dϕ





[1] https://indico.cern.ch/event/536777/contributions/2181157/attachments/1284799/1910292/2016_06_03_L1T_muon_efficiency.pdf
[2] https://indico.cern.ch/event/555889/contributions/2241895/attachments/1308264/1956360/L1PlotsMuonHLTPOG.pdf

high-rate paths per PD

Paths per dataset which cover more than 50% of the dataset rate:
Single + Double Ele/Mu

Dataset	**Dataset Rate [Hz]**				
HLT Path	Rate [Hz]			Shared Rate [Hz]	Fraction of dataset rate
SingleMuon	**212,38**	**+/-**	**0,99**		74% (IsoMu22)
HLT_IsoMu22_eta2p1_v4	156,93	+/-	0,85	26.16 +/- 0.14	
HLT_IsoMu27_v7	122.84	+/-	0.75	24.57 +/- 0.50	
SingleElectron	**141,72**	**+/-**	**0,81**		76%
HLT_Ele27_WPTight_Gsf_v7	107,41	+/-	0,70	17.90 +/- 0.12	
DoubleMuon	**57,17**	**+/-**	**0,51**		36%
HLT_TkMu17_TrkIsoVVL_TkMu8_TrkIsoVVL_DZ_v3	20,76	+/-	0,31	6.92 +/- 0.10	
DoubleEG	**105,69**	**+/-**	**0,70**		66%
HLT_DoubleEle37_Ele27_CaloIdL_GsfTrkIdVL_v7	31,25	+/-	0,38	15.63 +/- 0.19	
HLT_Diphoton30_18_R9Id_OR_IsoCaloId_ AND_HE_R9Id_Mass90_v7	24,27	+/-	0,33	24.27 +/- 0.33	
HLT_DoubleEle33_CaloIdL_MW_v8	14,04	+/-	0,25	14.04 +/- 0.25	

high-rate paths per PD

Paths per dataset which cover more than 50% of the dataset rate:
BTagCSV, Tau, JetHT, MET

Dataset	**Dataset Rate [Hz]**				
HLT Path	Rate [Hz]			Shared Rate [Hz]	Fraction of dataset rate
BTagCSV	**76,22**	**+/-**	**0,59**		60%
HLT_DoubleJet90_Double30_TripleBTagCSV_p087_v5	23,90	+/-	0,33	23.90 +/- 0.33	
HLT_QuadJet45_TripleBTagCSV_p087_v6	22,08	+/-	0,32	22.08 +/- 0.32	
Tau	**94,71**	**+/-**	**0,66**		71%
HLT_DoubleMediumCombinedIsoPFTau35_Trk1_eta2p1_Reg_v3	44,55	+/-	0,45	14.85 +/- 0.15	
HLT_VLooseIsoPFTau140_Trk50_eta2p1_v5	22,33	+/-	0,32	22.33 +/- 0.32	
JetHT	**128,15**	**+/-**	**0,77**		89%
HLT_AK8DiPFJet280_200_TrimMass30_BTagCSV_p20_v5	35,81	+/-	0,41	35.81 +/- 0.41	
HLT_AK8DiPFJet300_200_TrimMass30_v1	32,32	+/-	0,39	32.32 +/- 0.39	
HLT_AK8PFHT700_TrimR0p1PT0p03Mass50_v8	22,90	+/-	0,32	22.90 +/- 0.32	
HLT_PFHT400_SixJet30_DoubleBTagCSV_p056_v6	22,89	+/-	0,32	11.45 +/- 0.16	
MET	**63,87**	**+/-**	**0,54**		64%
HLT_PFMETNoMu110_PFMHTNoMu110_IDTight_v8	21,80	+/-	0,32	7.27 +/- 0.11	
HLT_DoubleMu3_PFMET50_v6	19,34	+/-	0,30	19.34 +/- 0.30	

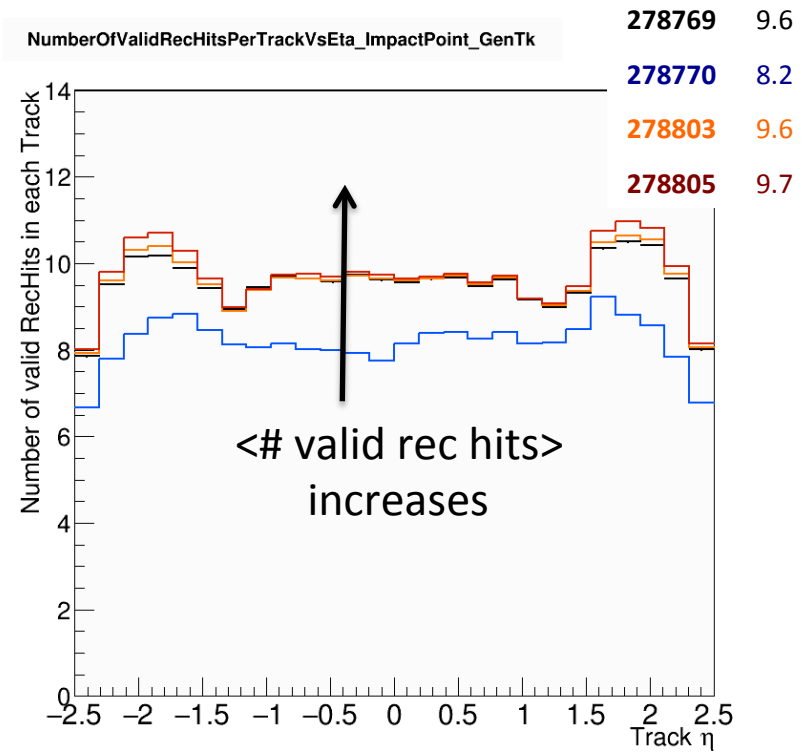
tracking @HLT

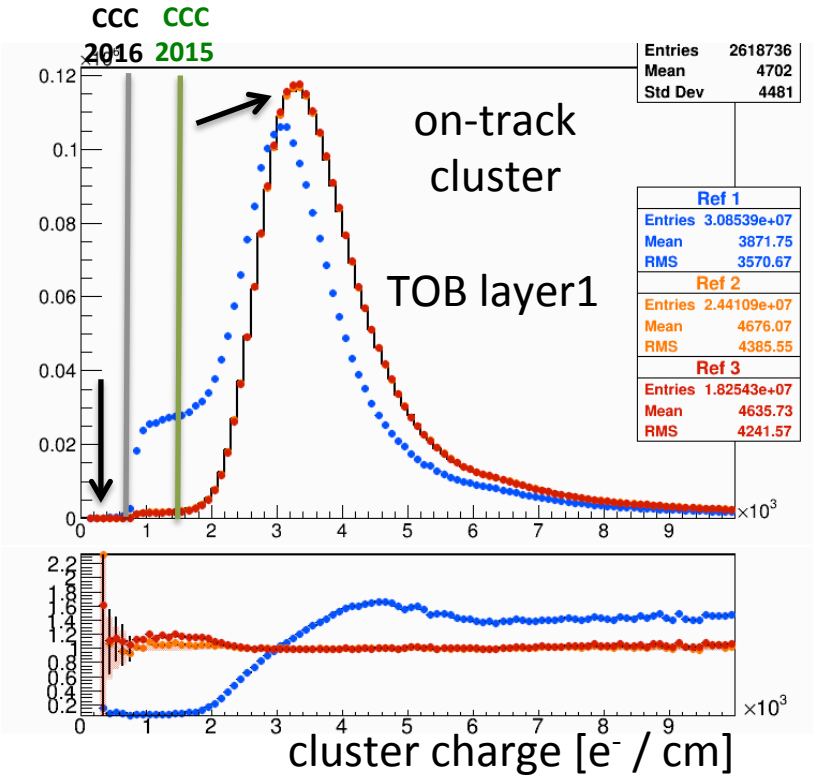
Mia Tosi

impact of the APV fix:

- ☑ similar to what is observed offline
- roll back to 2015 strip cluster charge cut (CCC) configuration
  for tracking used in PF jets and lepton isolation
  expect a reduction by 10-15% in fake rate and 2-3% in CPU usage

run	<PV>	APV setting
278769	12.8	new
278770	11.2	old
278803	12.1	new
278805	11.1	new



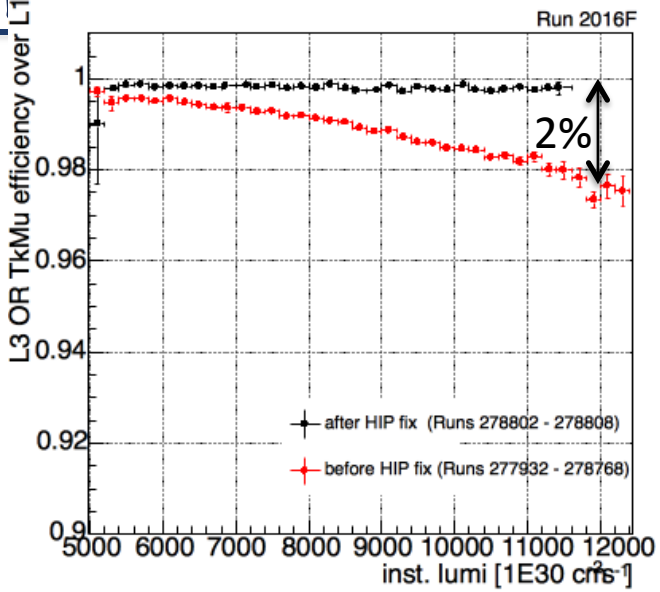


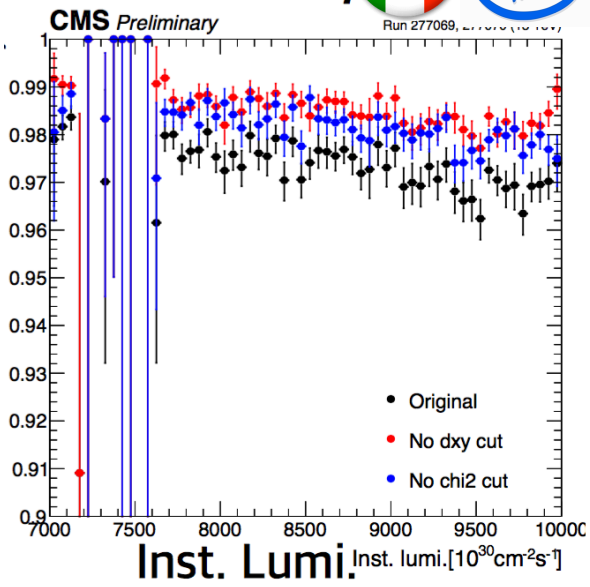
muon @HLT

Sara Fiorendi

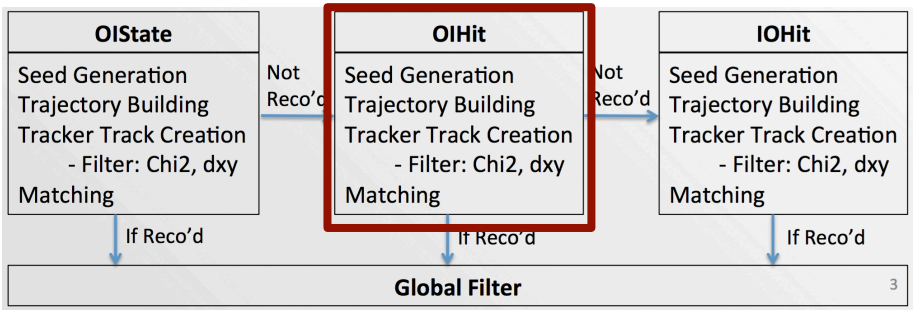
impact of the APV fix

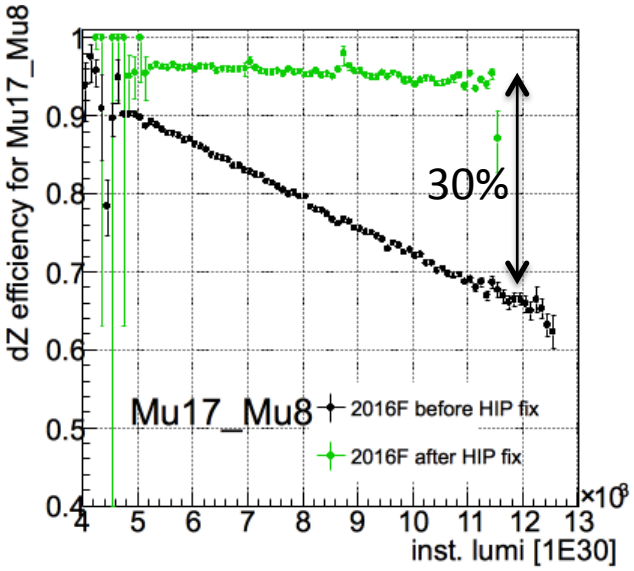
- ☑ **recovers full efficiency**
  in HLT muon reconstruction
  - ➢ up to 2% at 1.2e34 Hz cm^{-2}
  - ➢ efficiency is now flat and better than 99.5%





L3 muon reconstruction





- ☑ **recovers large inefficiency in di-muon triggers delta-Z cut**
  - requires muons to come from the same PV
  - useful to reduce the rate from combinatorics

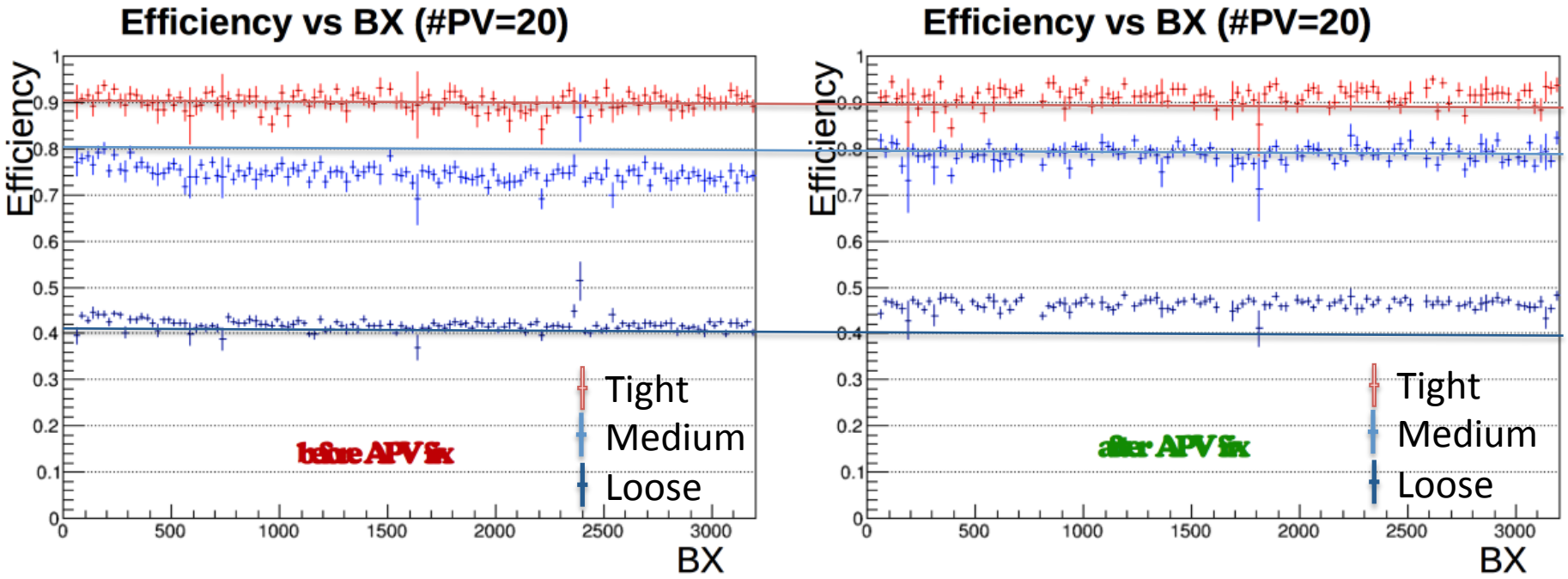
➡ <u>dZ cut can be safely applied</u>
on most di-muon and electron-muon triggers ;)

b-tagging @HLT

Silvio Donato

impact of the APV fix

- ☑ **higher b-tagging efficiency for all working points**
- ☑ flat efficiency w/in the orbit
- ☑ **lower b-tagging fake rate (not shown here)**

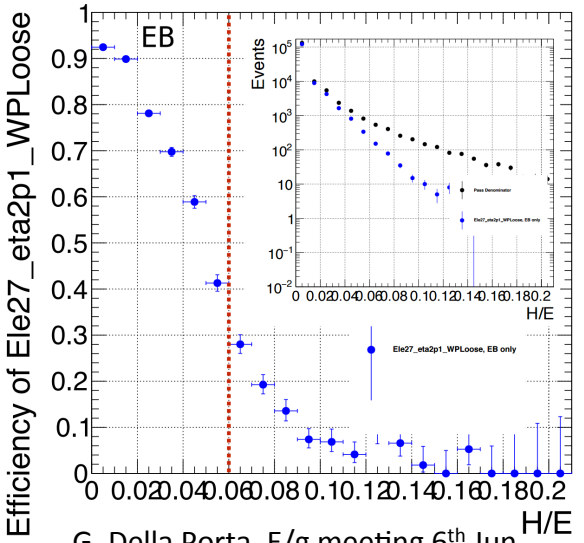


NB: online b-tagging has been less affected by this issue then offline one, because of the very loose selection on the #hits per track

HLT H/E Issues

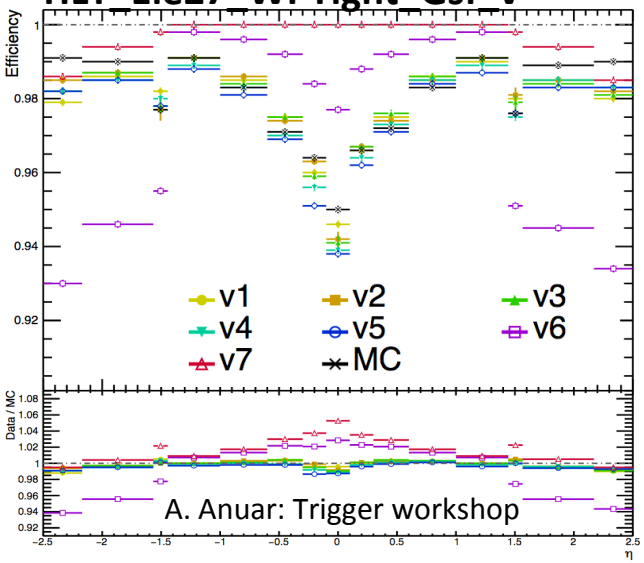
- Online / offline agreement
  - Method 2 HCAL mitigation of out of time pile-up used at RECO slow, developed method 3 for HLT
  - Two methods have little to no correspondence for low energy deposits (from PU/noise) which are the relevant contributions to H for H/E at the trigger
  - RECO and HLT H/E variables were individually efficient but cutting out different events → overall inefficient
  - Fixed by going to method 2 locally (in a cone of 0.25 around e/γ candidates) for HLT H/E
  - Now almost perfect agreement for H
- Miss-configuration of single electron trigger (no rho correction) in period F-G ("v6") after new WPTight tune went online, fixed in period H ("v7")

Method 3 HLT to offline



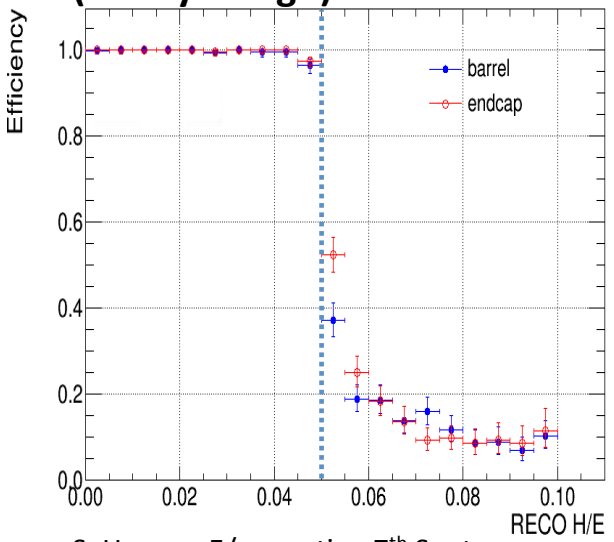
G. Della Porta, E/g meeting 6th Jun

H/E filter efficiency HLT_Ele27_WPTight_Gsf_v



A. Anuar: Trigger workshop

Method 2 HLT H/E to offline (tail by design)



S. Harper: E/g meeting 7th Sept

Operational Plans for 2017

- Software
  - Configuration Editor
    - New version to be deployed
    - Better key deprecation mechanism
    - Better display of keys
    - Comparison of keys with more useful results
  - New L1 Page
    - More descriptive alarms and alerts
    - No more embedded TWiki mess
      - Instead a sort of bulletin board with expiration dates
    - Better clarity regarding subsystem status
      - Subsystem text and process dot is not always clear to shifter
- WBM
  - More L1 responsibilities – L1 data needs to be stable
  - Beginning to look into improvements for L1/HLT synchronicity

Lessons Learned 2016

& Wish List…

- Updates and configuration changes
  - Even “small” changes caused unexpected behavior
    - Not always obvious at first glance
    - Test vectors/patterns should be enhanced
    - Do tests at end of fill before final deployment
    - Some changes were not announced
      - Experts need to stay in touch with L1 DOCs and Trig. Tech. Coord.
  - Coupling changes not ideal
    - e.g. New layer-1 corrections
      - Improved tau and e/gamma, but caused PU dependent ME_T behavior
  - Careful with keys (L1 DOCs and Experts)
    - The wrong key used for update, typos in XML, etc.
    - Need better ways to spot problems (“diff”, non-XML view)
      - L1 Online SW group is thinking about this
  - Be ready to roll back in case of problems

Lessons Learned 2016

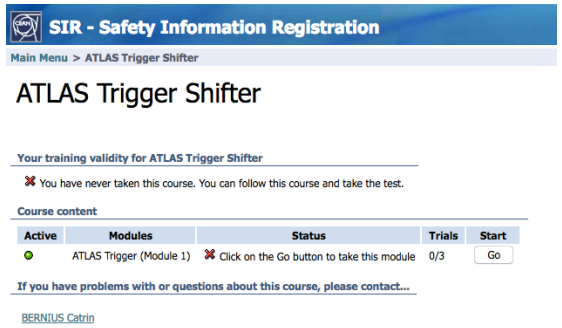
& Wish List…

- Updates and configuration changes (continued)
  - Menus, including prescale tables, algo mask, BX mask…
    - Workflow well defined, need an L1 DOC checklist…
      - Lots to update when menu changes, can be confusing
    - Mostly smooth, some issues:
      - "Compatible" menu had a bit missing, triggers added, no prescales
      - Menus tested without warning – errors in HLT, etc.
    - **Communication is key!**
- Shifter
  - Timing issues not noticed
    - Timing plots now in L1T Quick Collection (Trigger shifter view)
    - Additional emphasis in tutorial
  - Holes in detectors not noticed
    - More plots in QC, L1T groups should use main L1T DQM Summary
    - Also more emphasis in tutorial

Lessons Learned 2016

& Wish List…

- Shifter (continued)
  - Wrong prescale column
    - μGT preserve column between runs, shifter training
  - Shifters in general
    - Selection more stringent this year
    - Trainer a bit burnt out
      - Maybe migrate some training to sir.cern.ch
      - ATLAS (right) has already done this
      - Advantage - quizzes
      - Disadvantage – no personal interaction

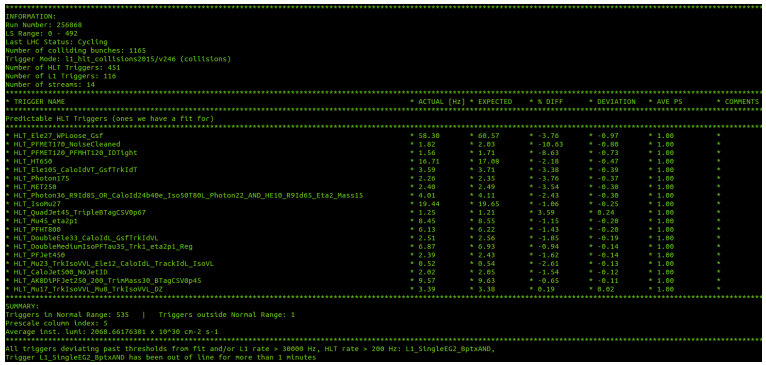


- Trigger Objects
  - Tracked on CMS TWiki: L1KnownIssues
  - e/γ
    - Need a more systematic approach to optimization
    - DQM firmware emulator comparisons to be implemented
    - Run certification to be automated

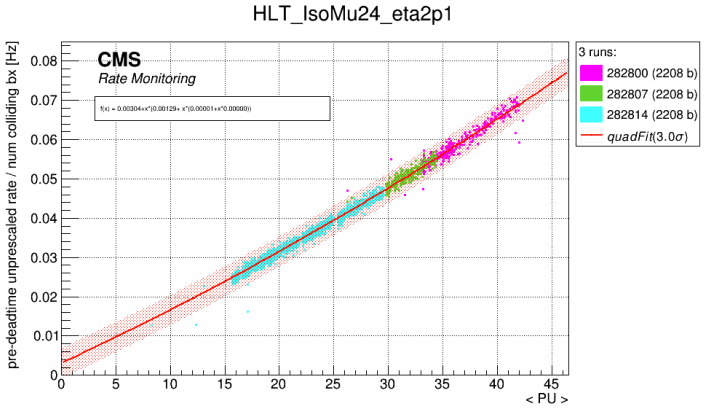
List of Operational Issues and Improvements (1)

- Occasionally a problem with L1 menu update
  - Wrong releases used for the upload, error in manual operations, O2O performed without notice, etc.
- Many improvements to the rate monitor
  - Rate warnings appear for the trigger shifter
  - Full suite of plots of rate vs PU available to trigger expert after just one lumi-section from the beginning of run

Rate Monitor



Rate vs. Pileup



List of Operational Issues and Improvements (2)

- Regardless, we are still far from spotting some kind of issues/ topologies
  - As those affecting high p_T objects with the rate monitoring for example.
    - Further improvements to the validation and monitoring of the data and trigger paths are under study.
- All the many any changes/tests done during the year revealed it is not straight forward to structure streams (calibrations, event content, etc.)
  - For example, the High PU menu we had in October contained several problems
    - Missing streams, wrong prescales...
  - To take care of that: we improved considerably the MenuChecker we run on Hilton during the year
- Full list - CMS TWiki: KnownHLTIssuesOnline2016

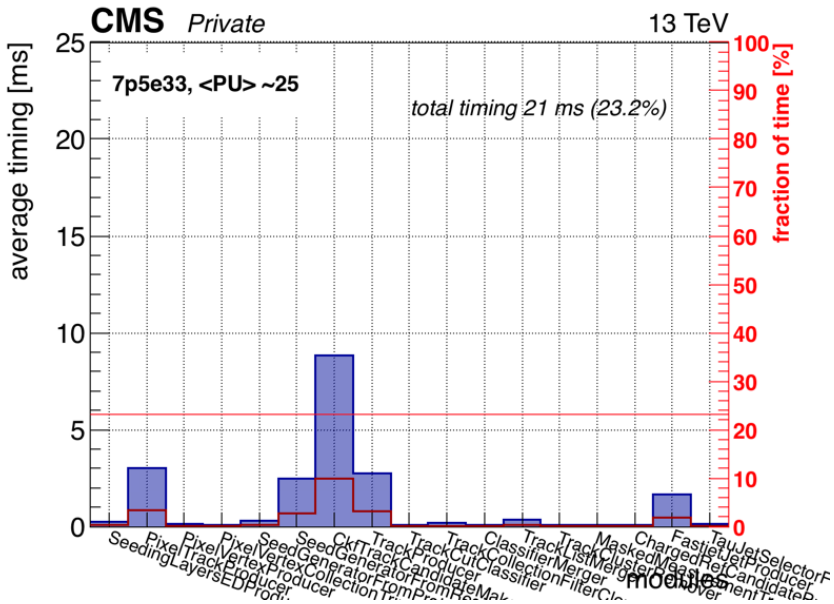
L1/HLT Prescales

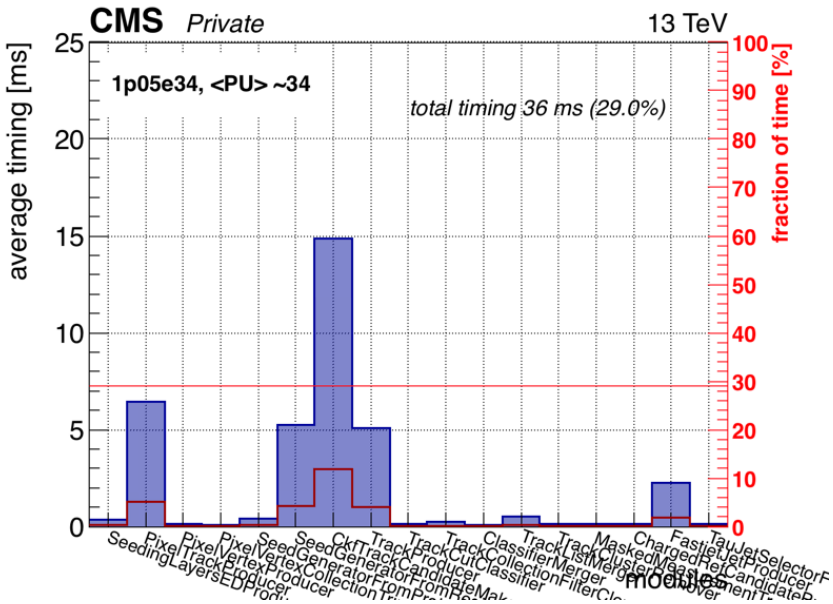
- We often had problem with is the set of L1 and HLT prescale columns
  - The procedure involved 4 players
    - L1 DOC
    - HLT DOC
    - TSG STORM/STEAM group (offline)
    - L1 DPG
- The regular way of proceeding is
  1. L1 DPG group proposes a set L1 prescales and columns
  2. TSG/STEAM elaborate on those, revise and propose modifications, plus compiles the HLT prescales
  3. STORM implement in confdb and put in the offline menu, i.e. ready for next menu
  4. FOG apply it online for HLT and passes the Google Doc with prescale to the L1 DOC
     - As L1 and HLT DOC con make changes on the fly, many problems are raised when these changes are not communicated back, for example to STORM
- <u>We need to think of a possible improvement in the workflow to prevent these kinds of mistake from happening</u>

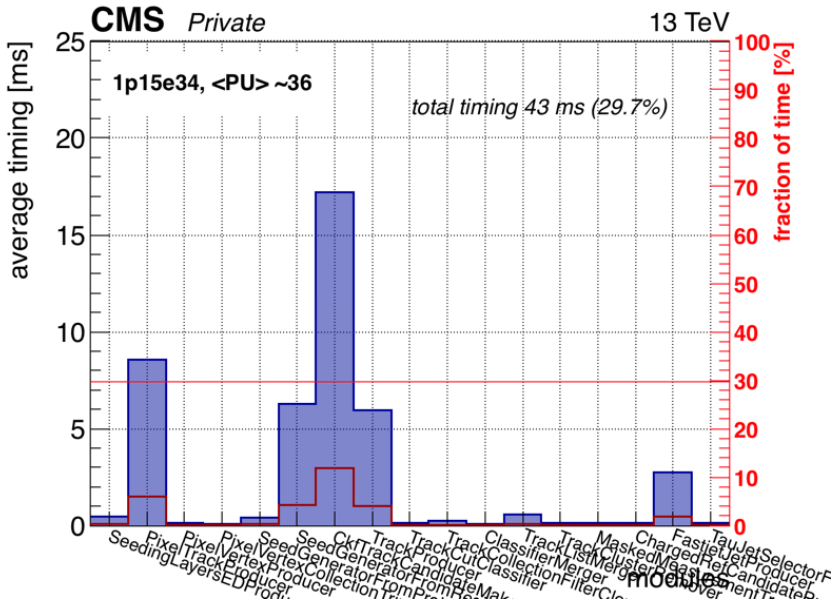
Summary

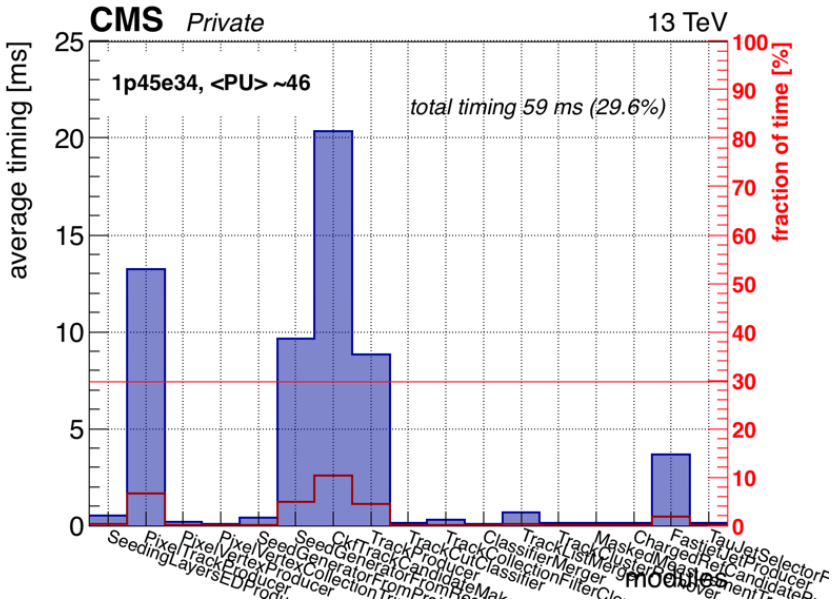
- 2017 needs to be a consolidation year for L1
  - Need to be stricter and stick to workflows for
    - Updates and improvements (including menus)
    - DQM – get updates online more quickly
  - Software – additional safety checks, monitoring, alarms
- L1 and HLT should improve workflow for menus
  - Particularly during deployment
  - Communication!
- HLT
  - Further improvements to data validation and checking
- L1T and HLT ran very reliably in 2016!
  - About 125 pb^{-1} lost due to trigger issues, 8% of all down time.
    - In 2012 we lost 149 pb-1, 14% of all down time!
    - Trigger was completely new in 2016!

tracking timing

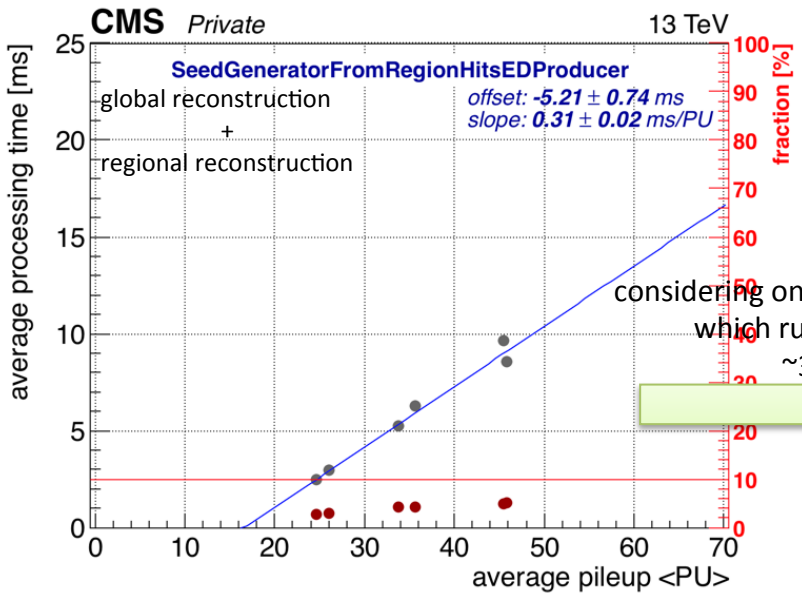




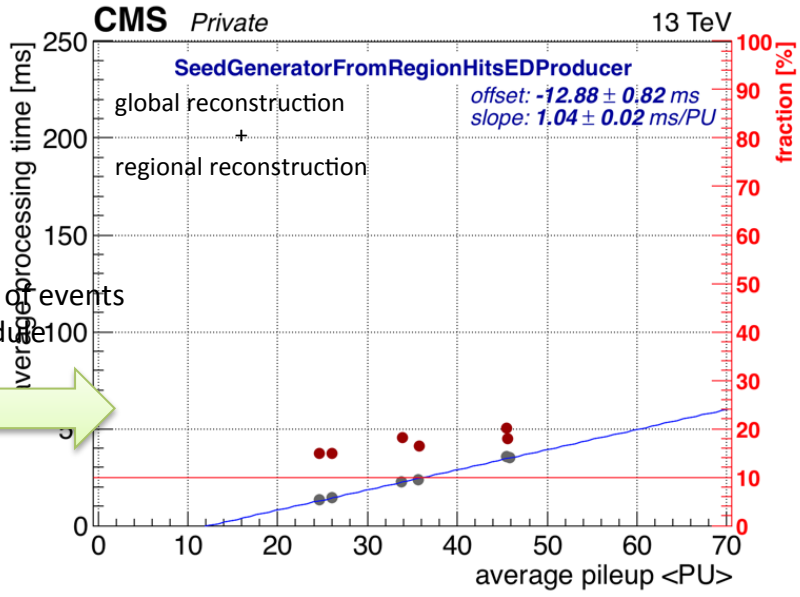


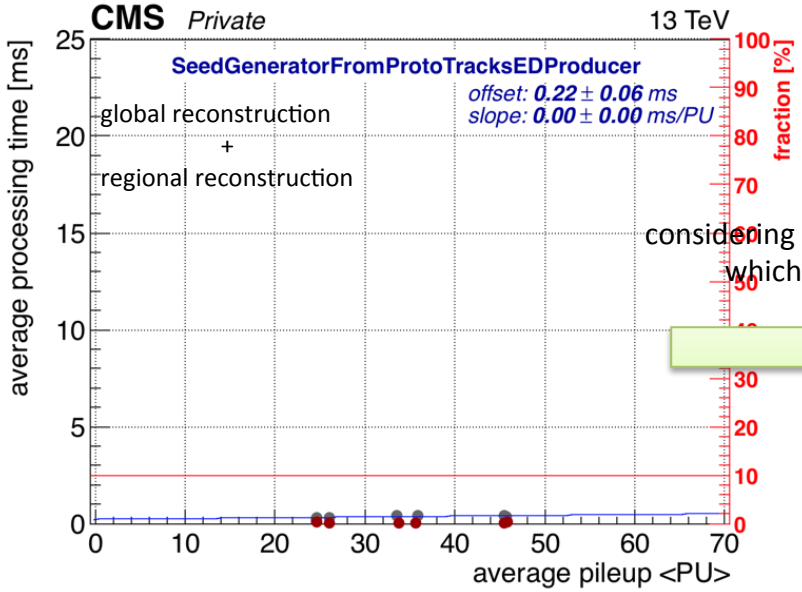


track reconstruction

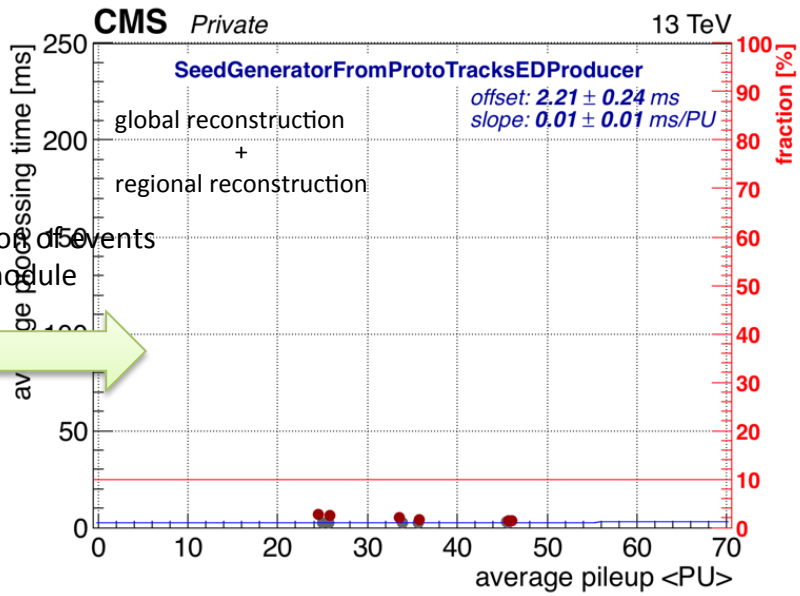


considering only fraction of events which run this module ~30-40%

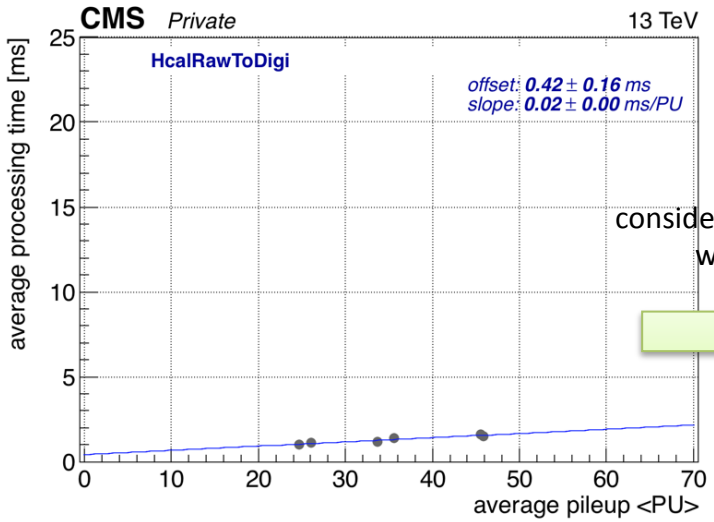




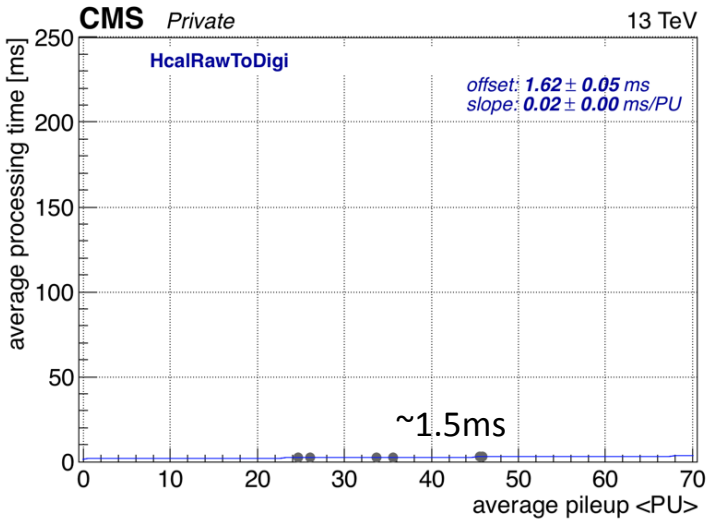
considering only fraction of events which run this module ~30-40%

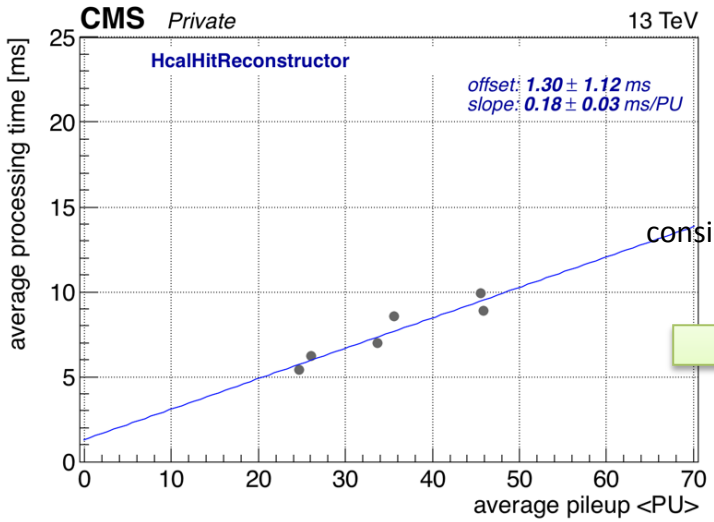


HCAL local reconstruction

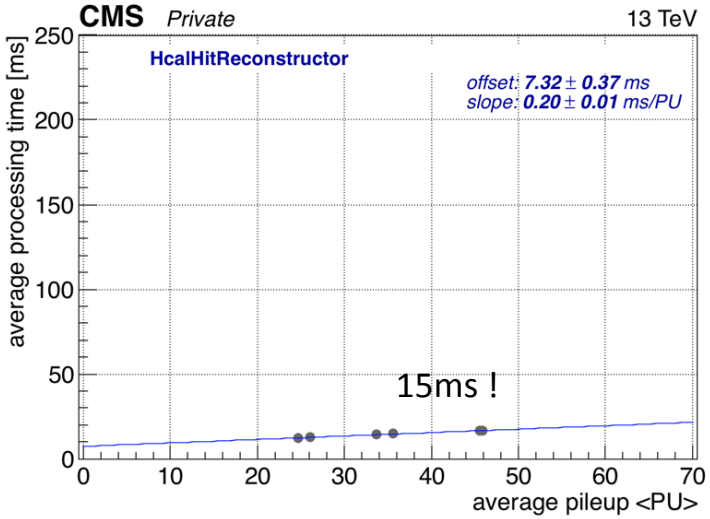


considering only fraction of events which run this module ~50%

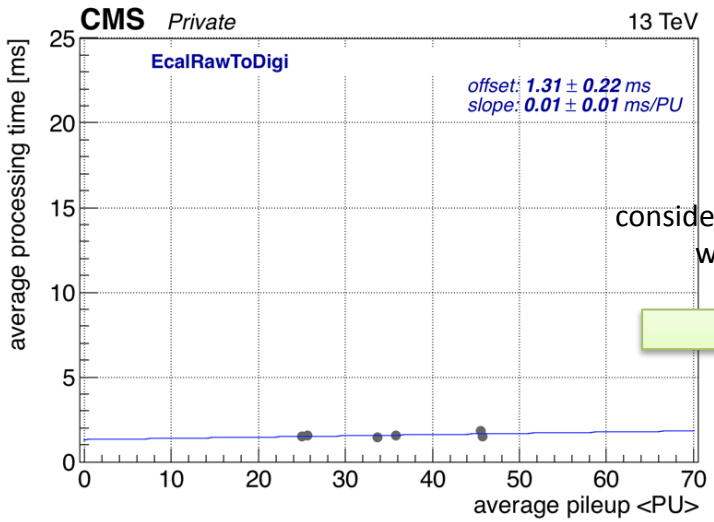




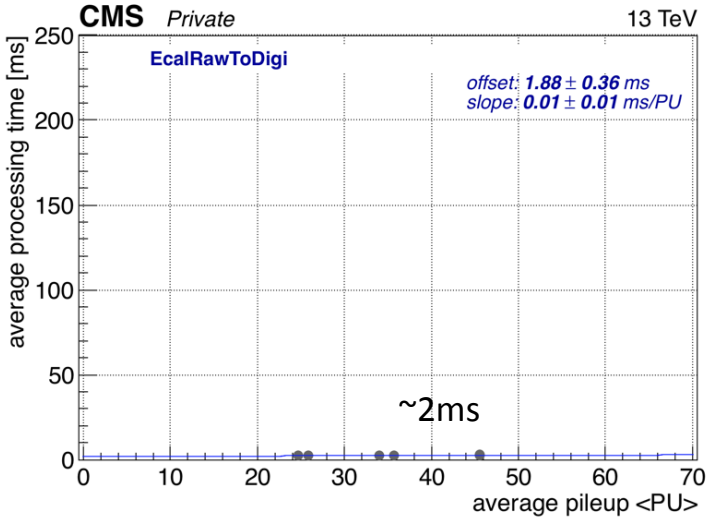
considering only fraction of events which run this module ~50%

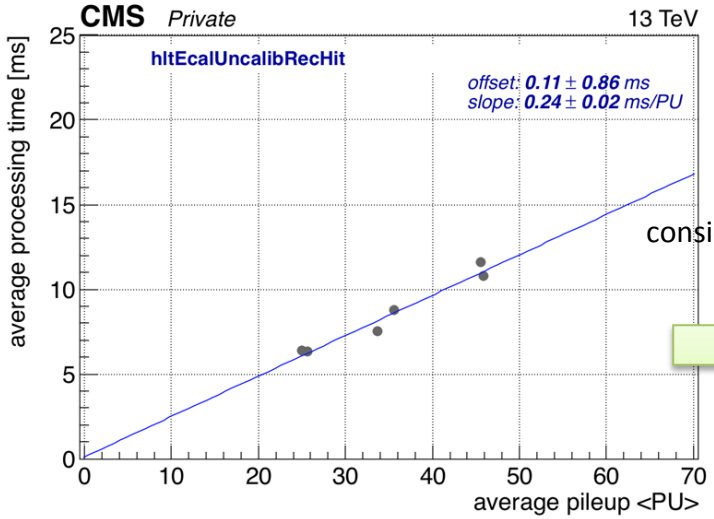


ECAL local reconstruction

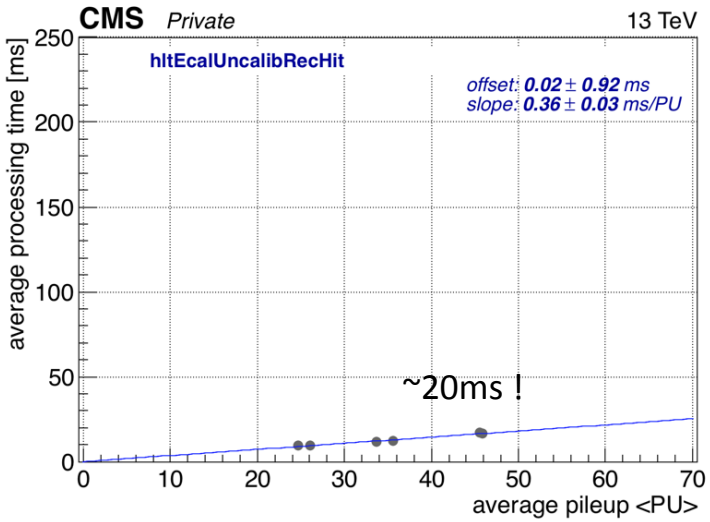


considering only fraction of events which run this module ~70%



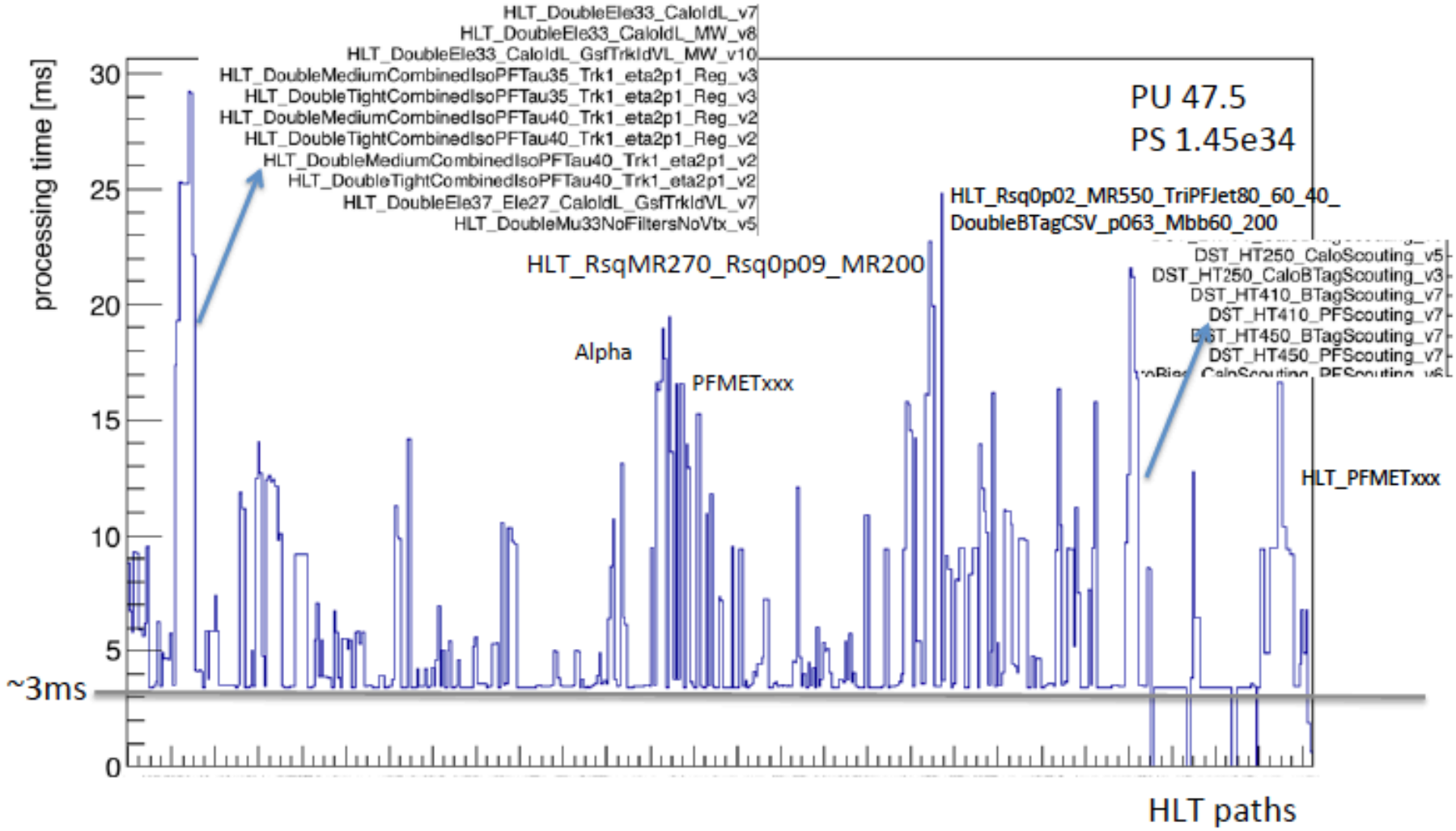


considering only fraction of events which run this module ~70%



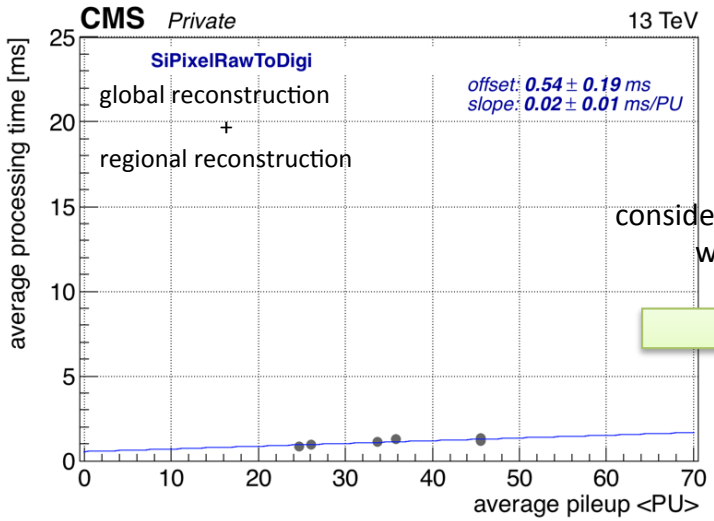
path total timing in 2016

offline timing

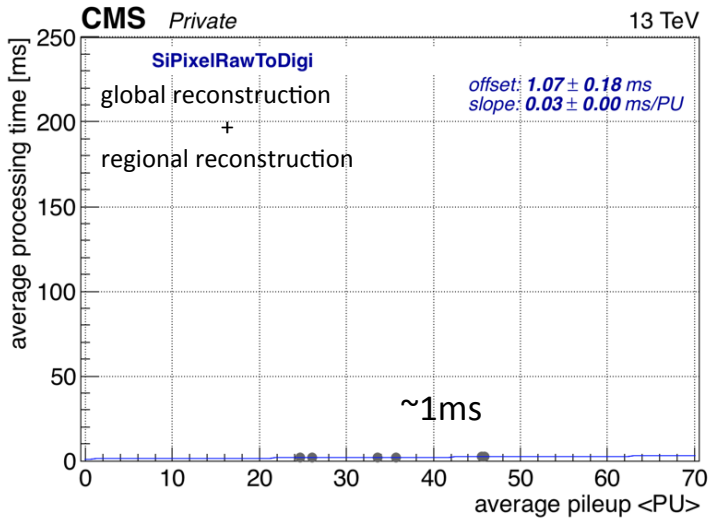


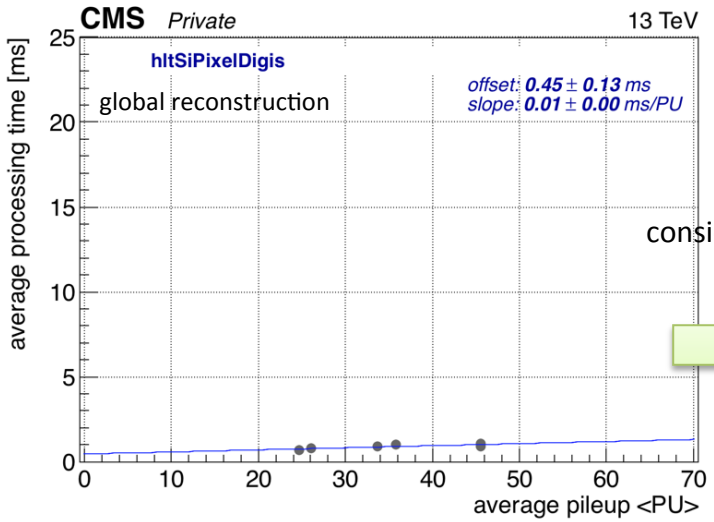
HLT Menu v4.2 on HLTPhysics Run2016H (6 skims based on both PU and PS column)
machines vocms003/004

pixel local reconstruction (I)

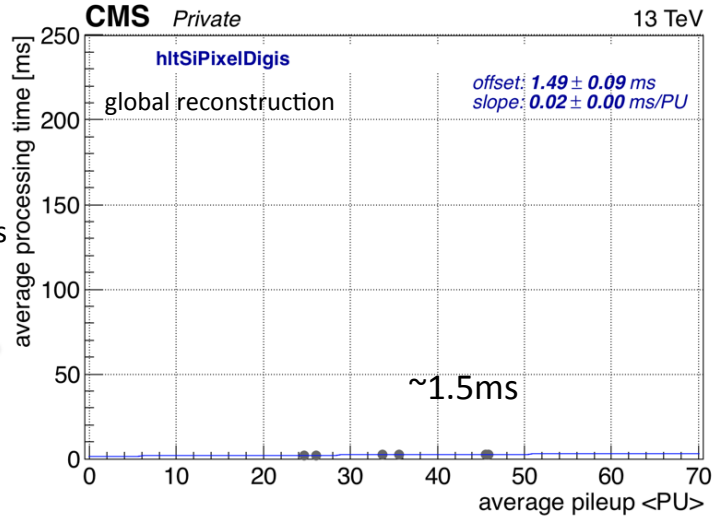


considering only fraction of events which run this module
~60%

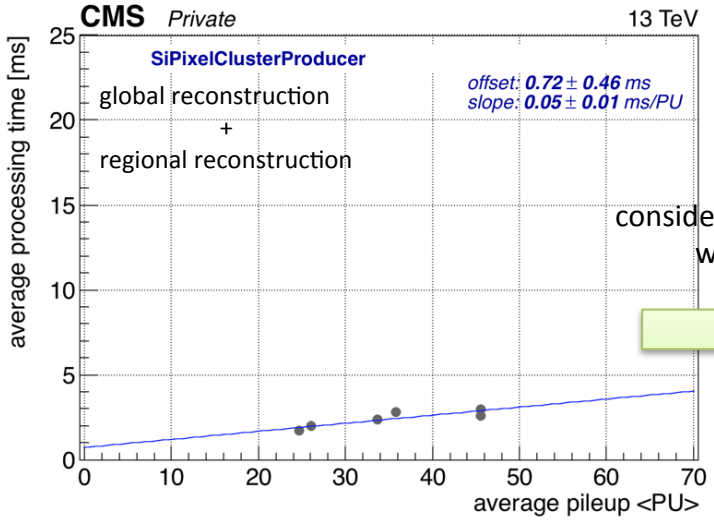




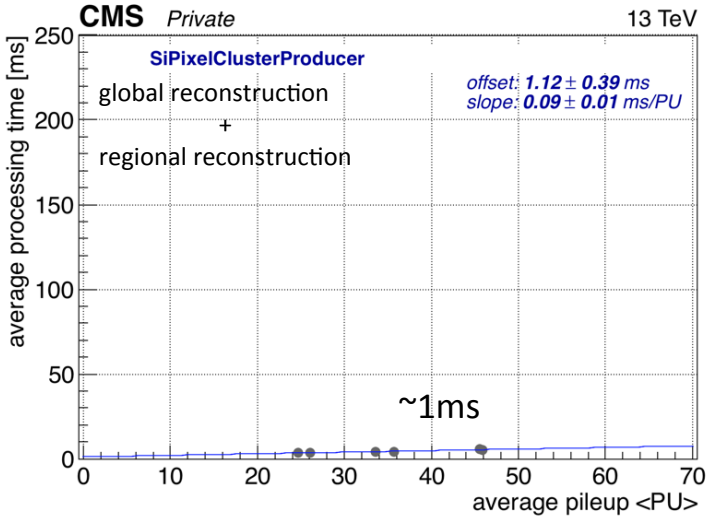
considering only fraction of events which run this module
~40%

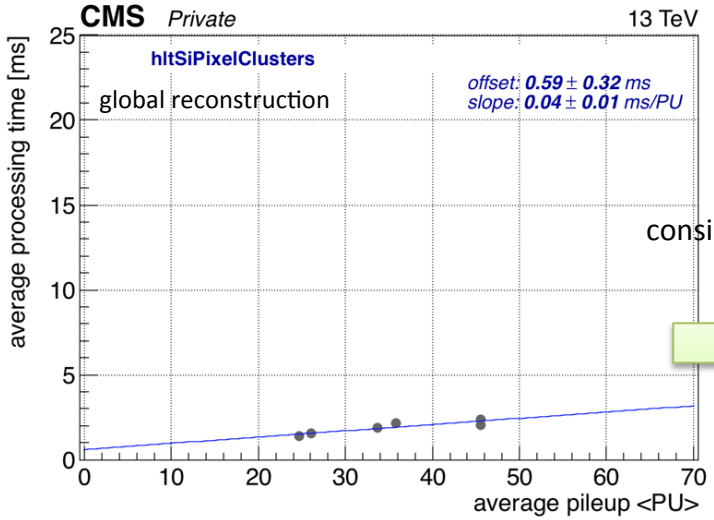


pixel local reconstruction (II)

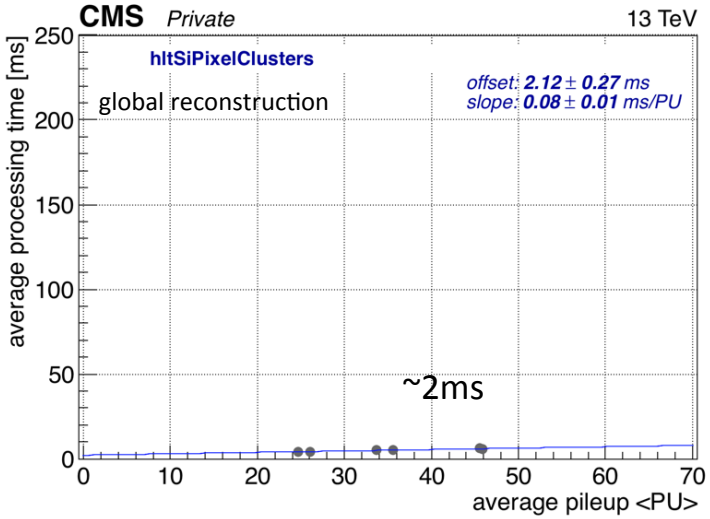


considering only fraction of events which run this module **~60%**

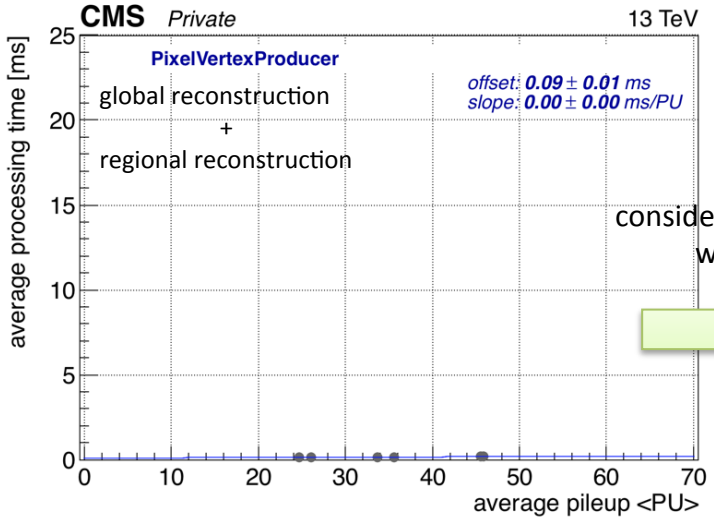




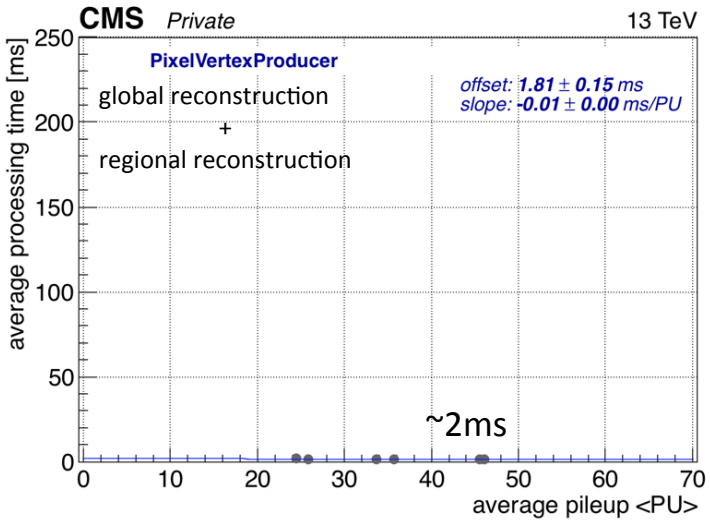
considering only fraction of events which run this module **~40%**

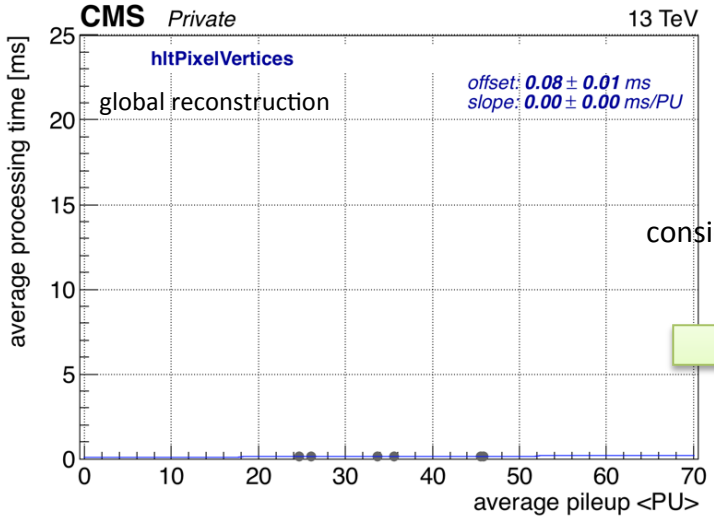


pixel vertex reconstruction

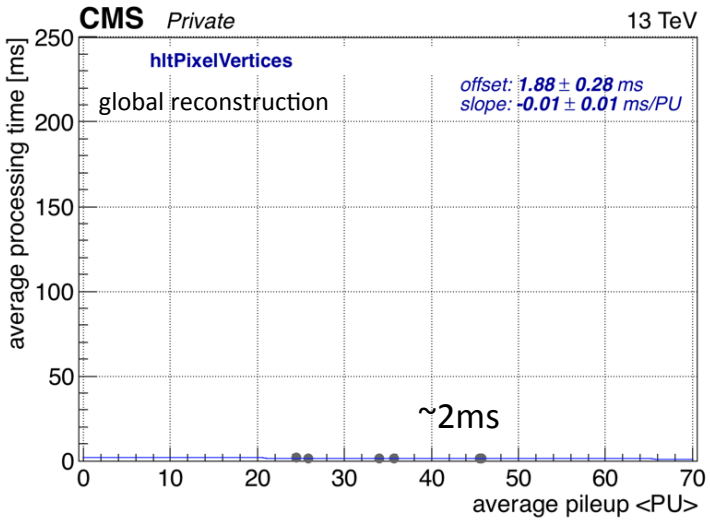


considering only fraction of events which run this module ~15%

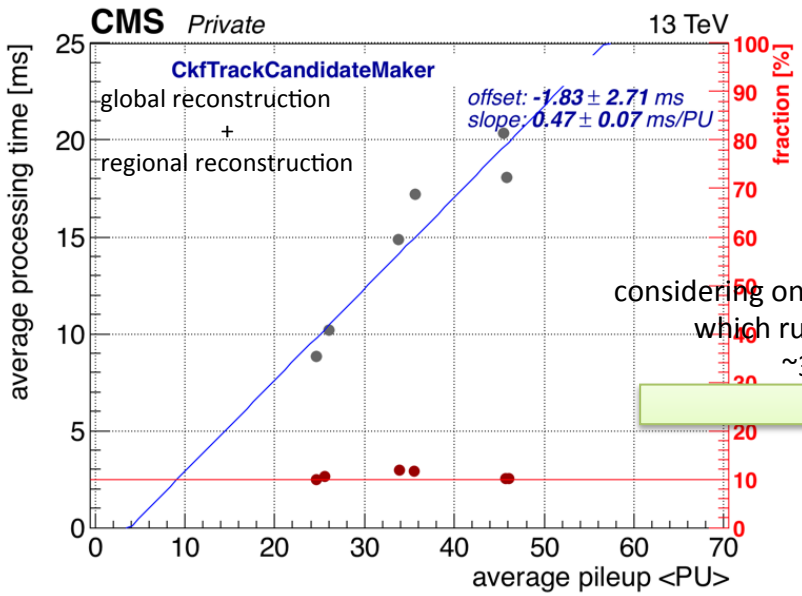




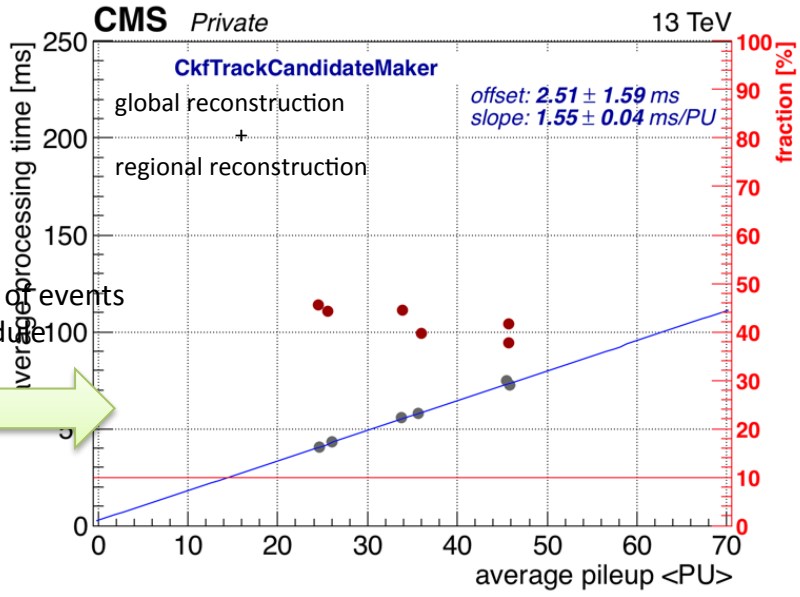
considering only fraction of events which run this module ~10-15%

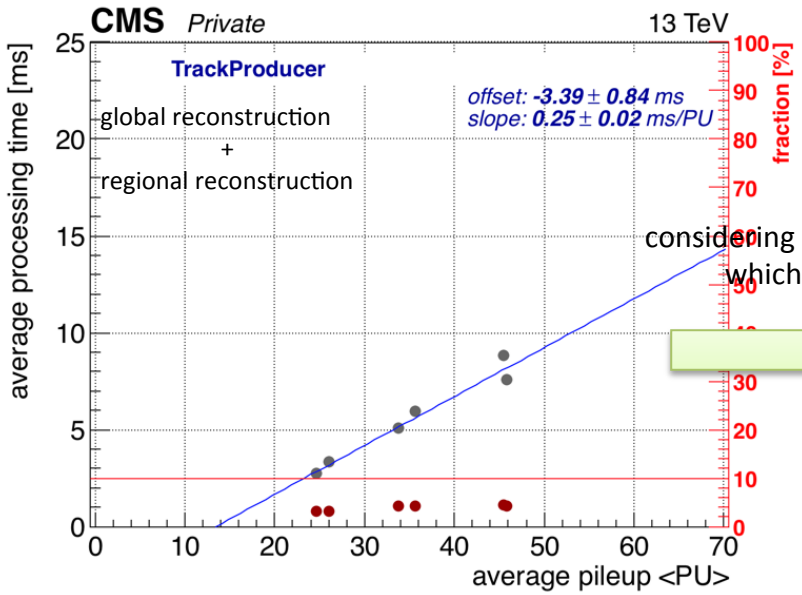


track reconstruction

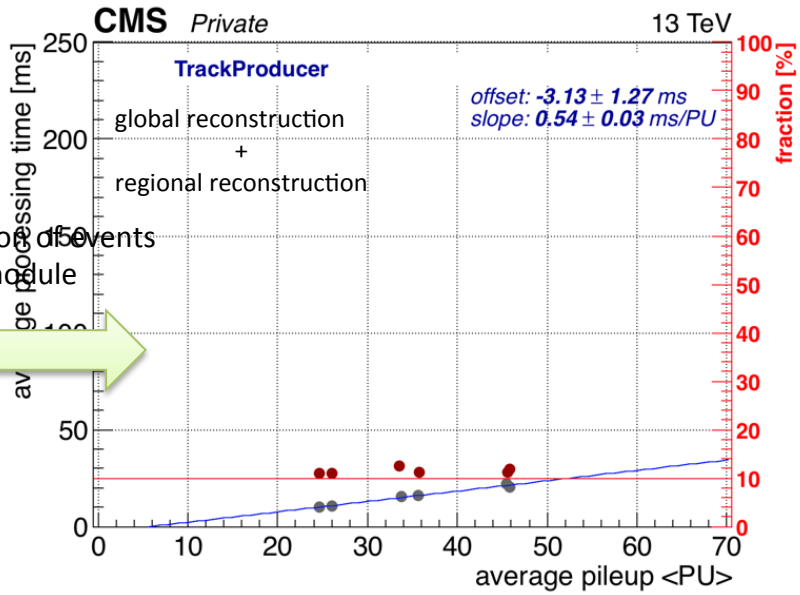


considering only fraction of events which run this module ~30-40%

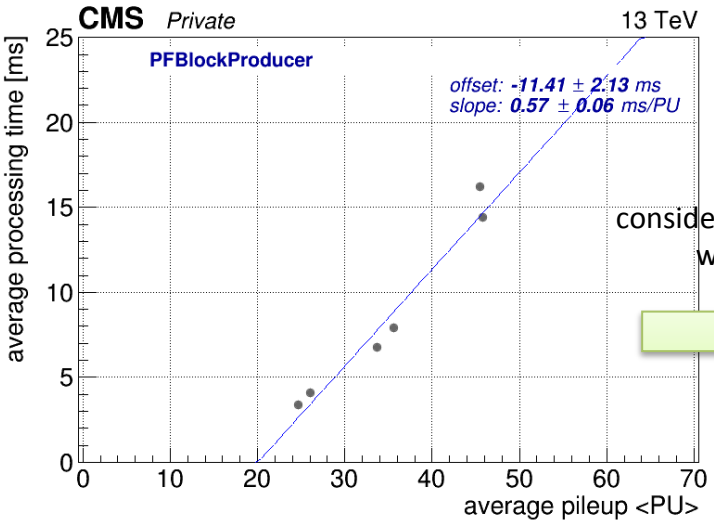




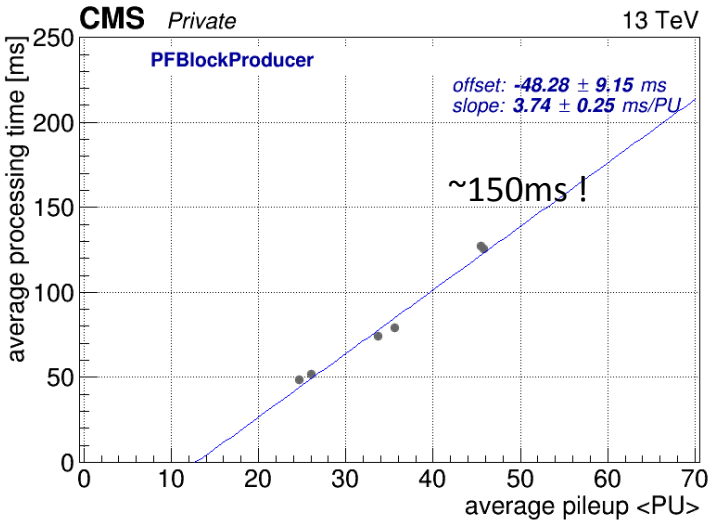
considering only fraction of events which run this module ~30-40%

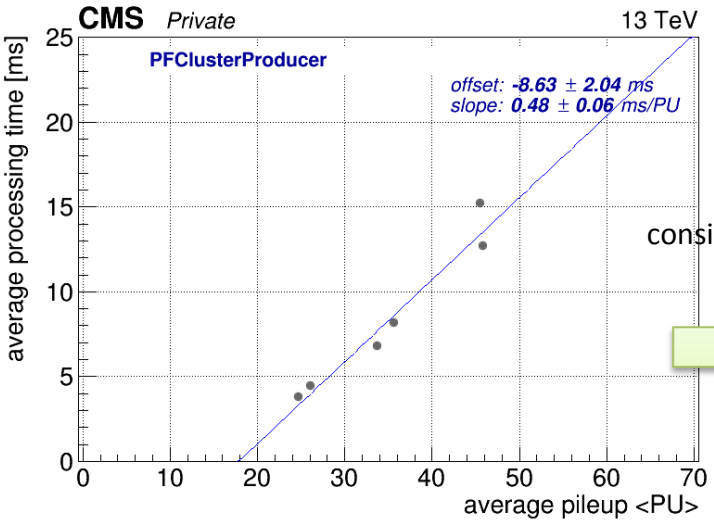


PF reconstruction (I)

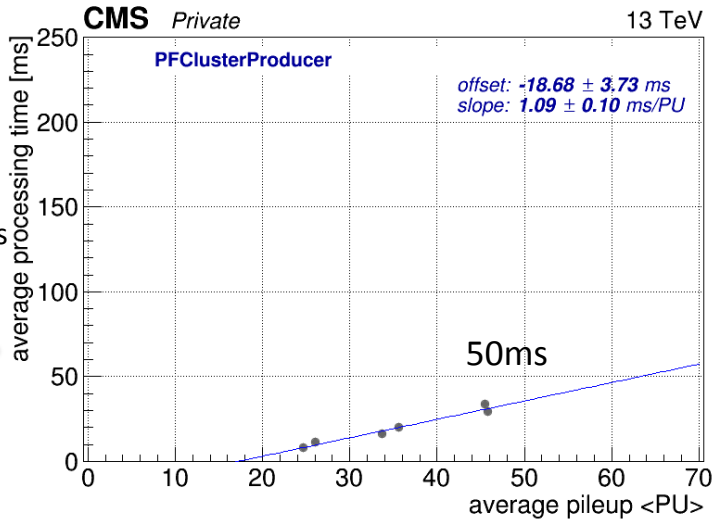


considering only fraction of events which run this module ~10-20%

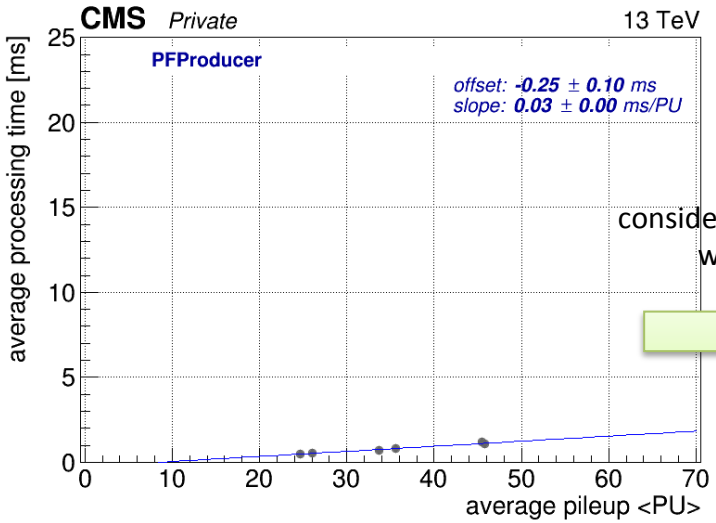




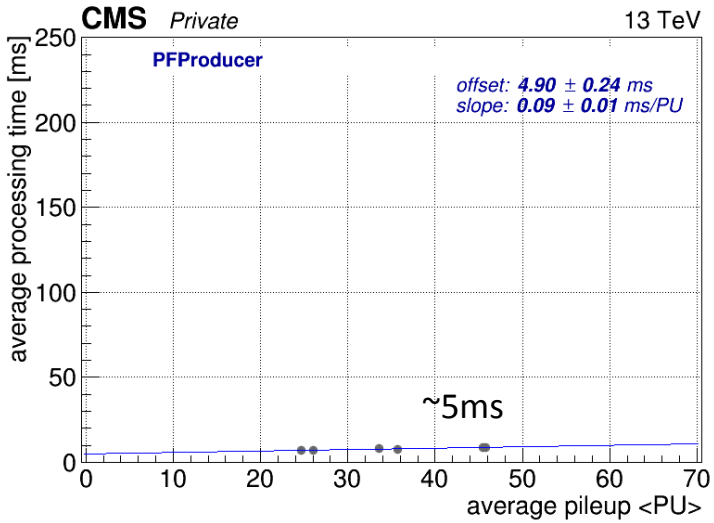
considering only fraction of events which run this module ~45%

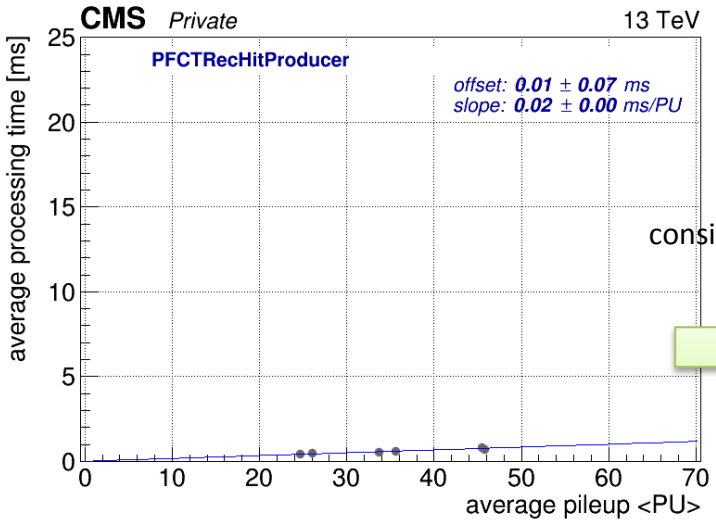


PF reconstruction (II)

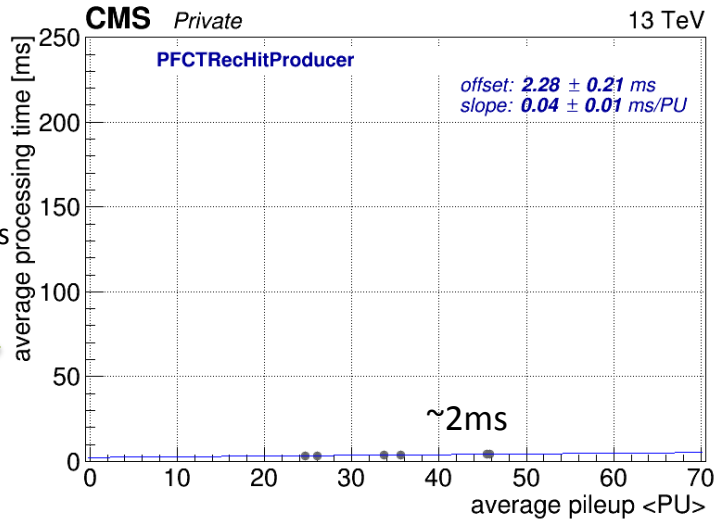


considering only fraction of events which run this module ~10%

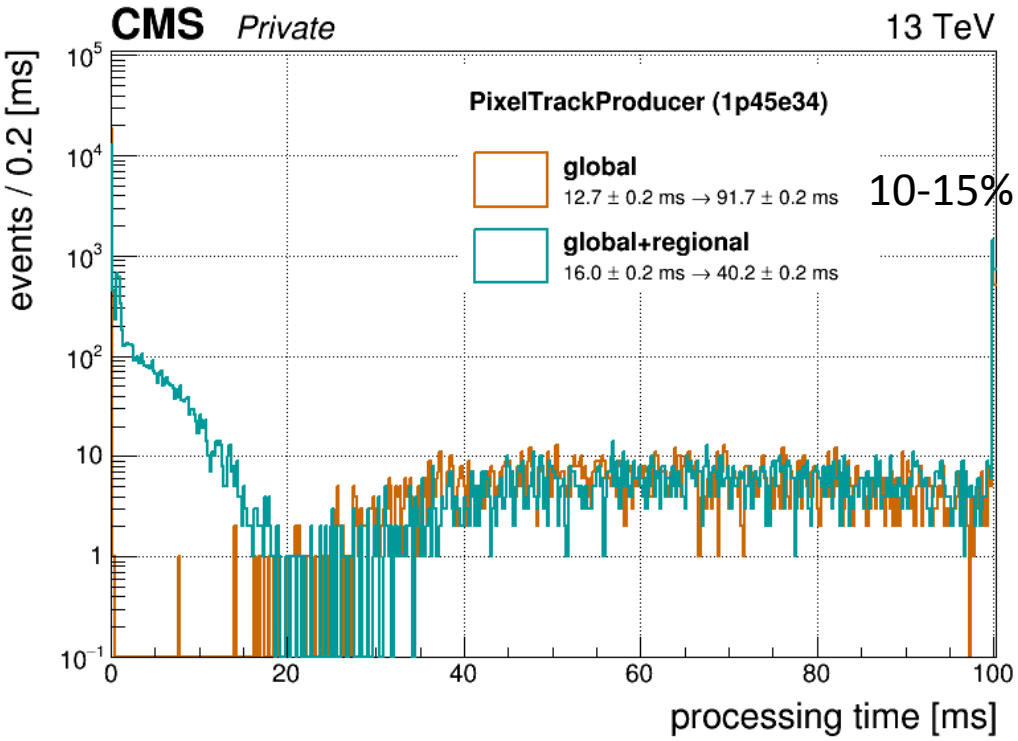




considering only fraction of events which run this module ~10-20%

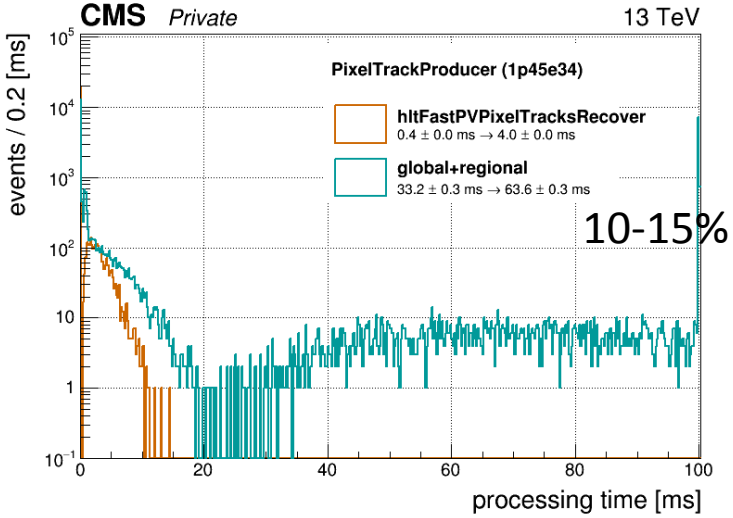


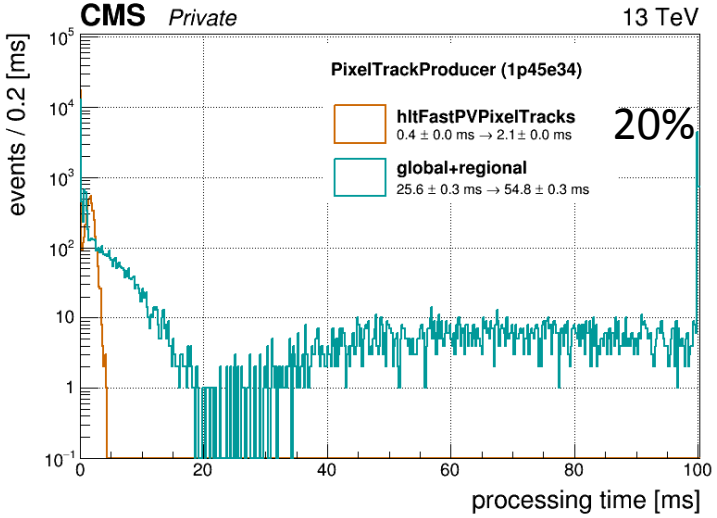
pixel track reconstruction (global)



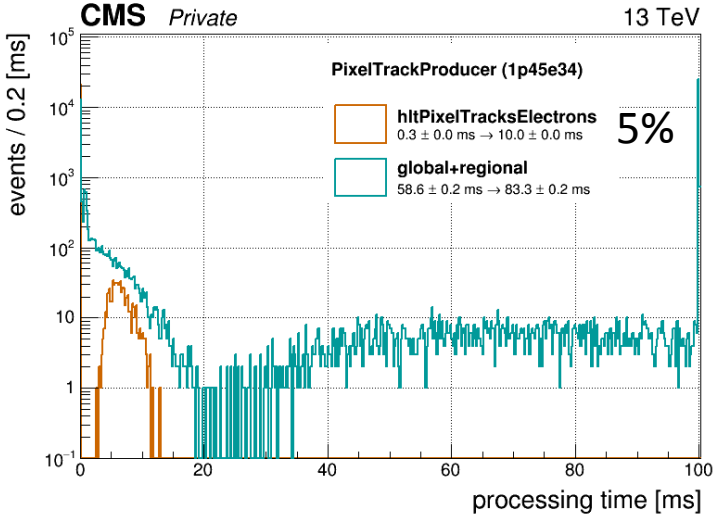
10-15%

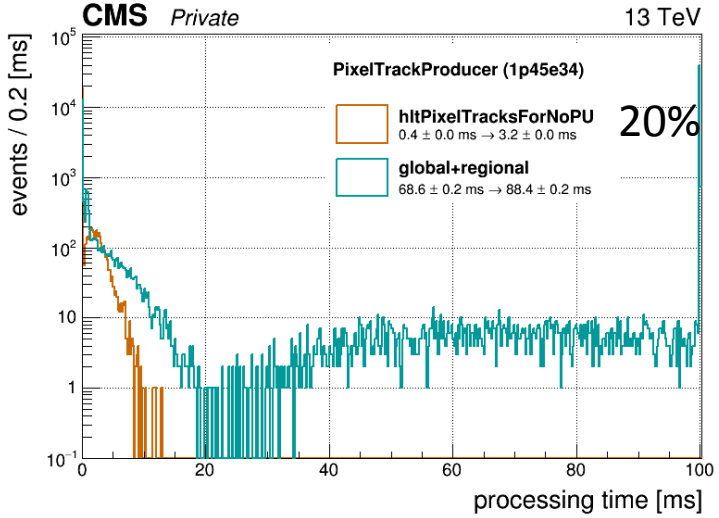
pixel track reconstruction (regional)

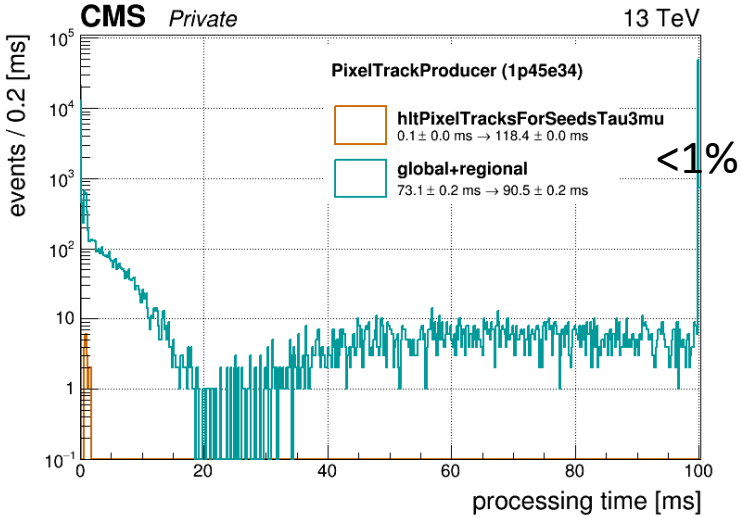


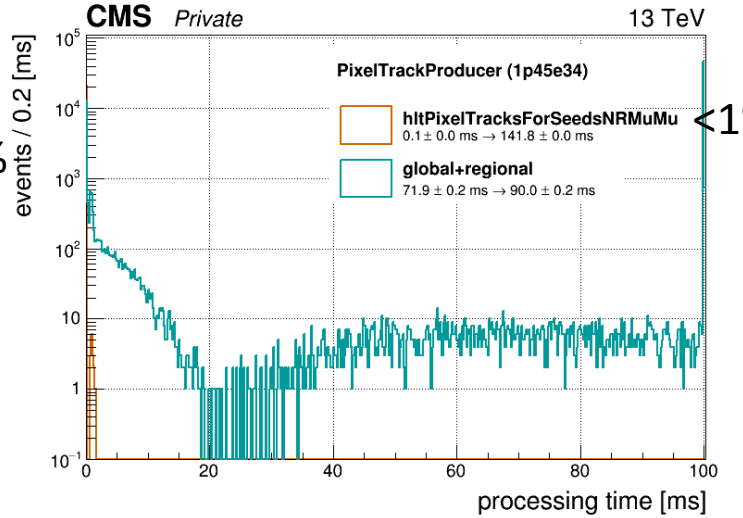


pixel track reconstruction (regional)

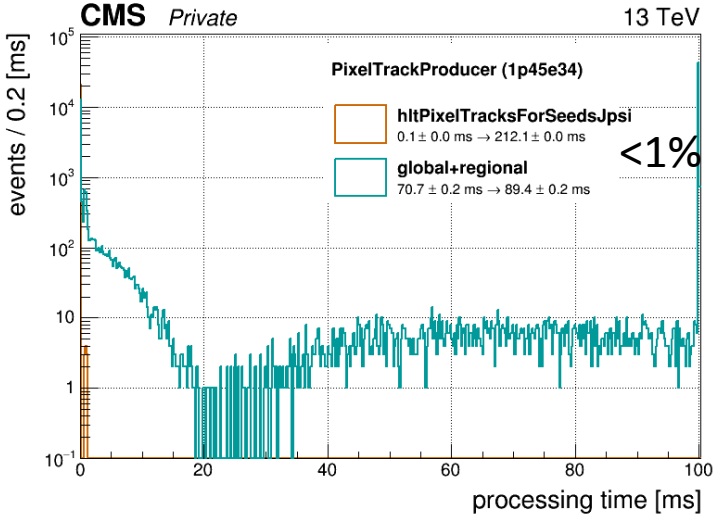








pixel track reconstruction (regional)



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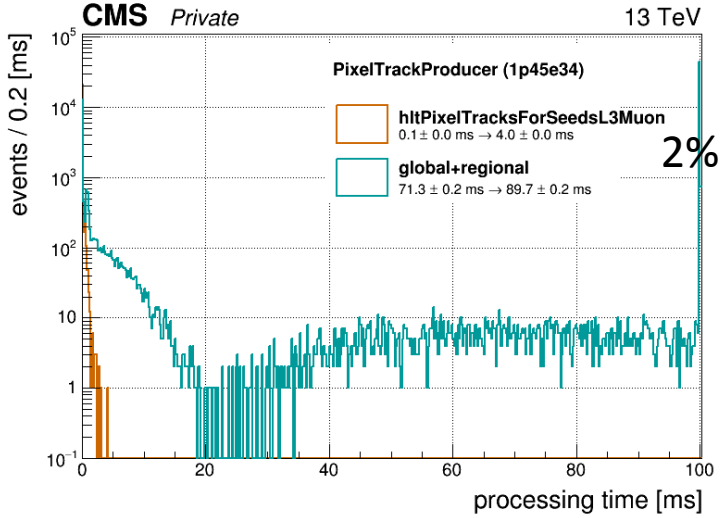
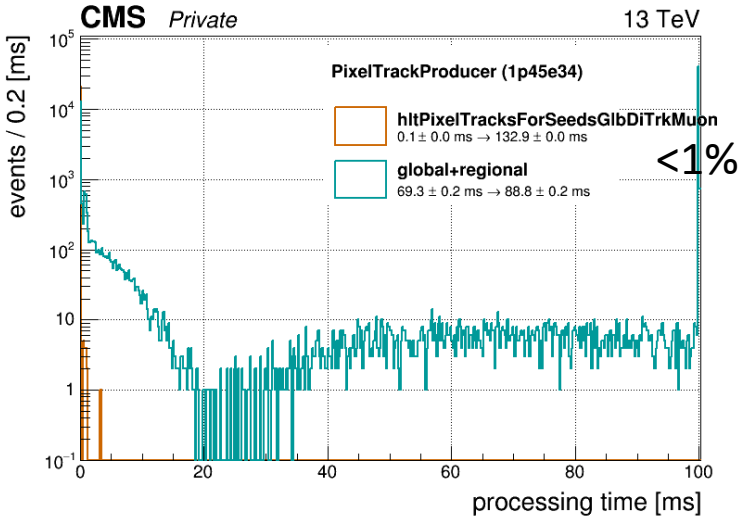
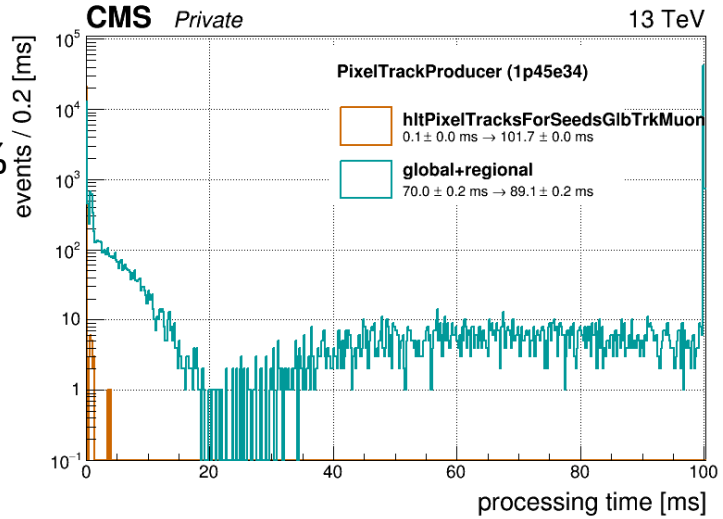


2%

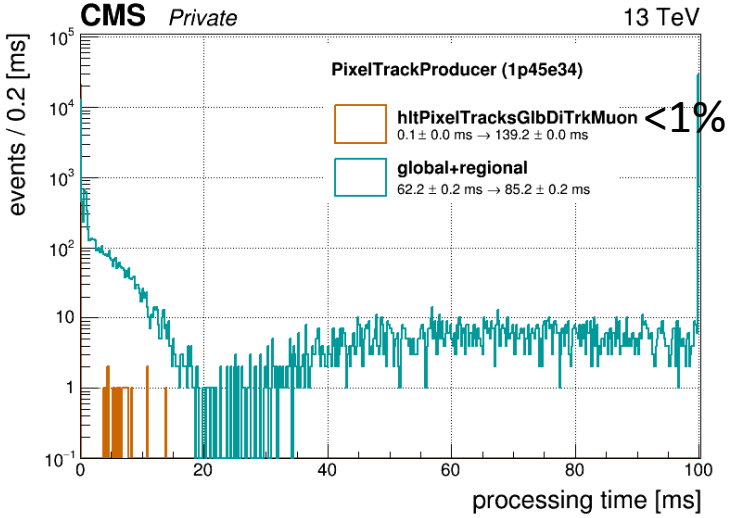


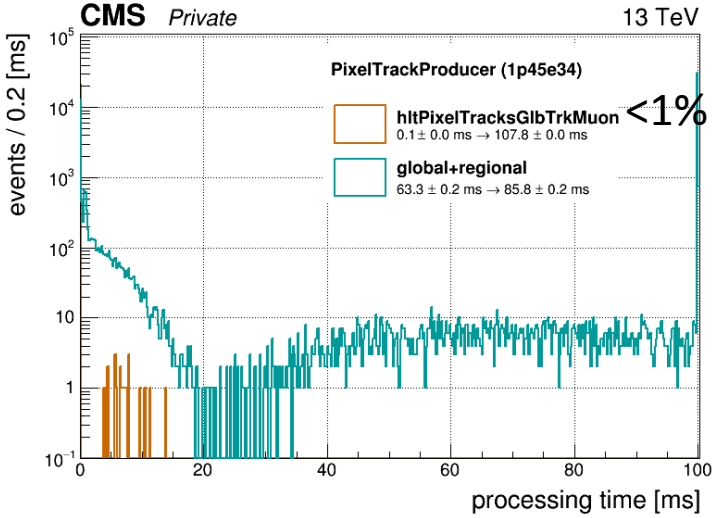
<1%



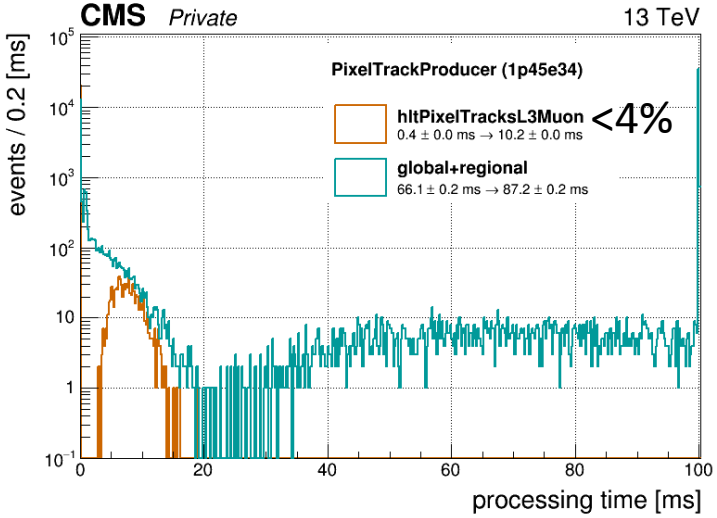
<1%

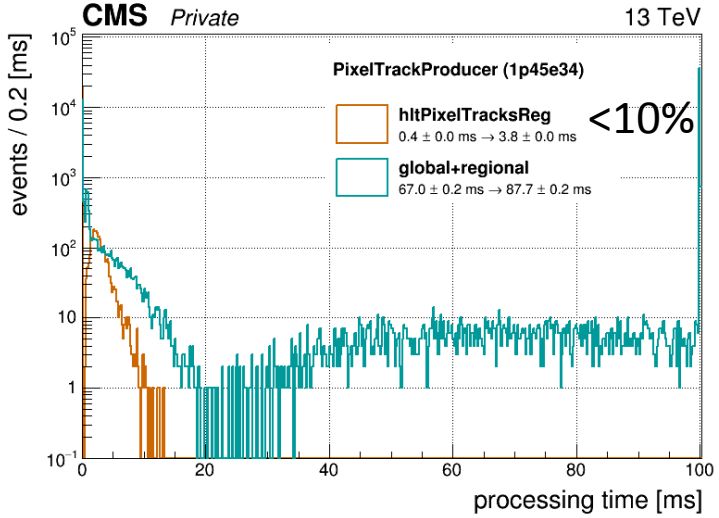
pixel track reconstruction (regional)

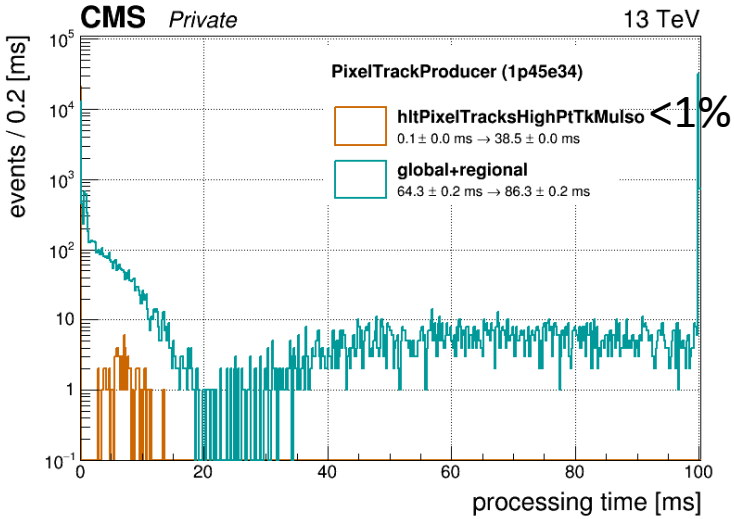


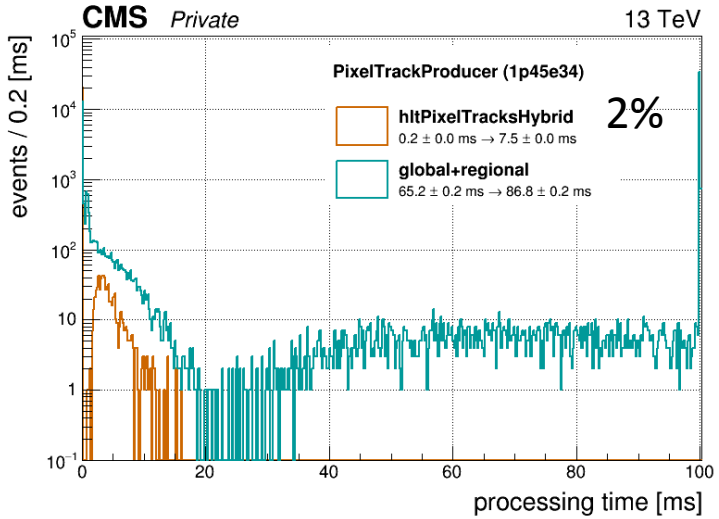


pixel track reconstruction (regional)









tracking timing