Trigger challenges for Run II

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Mini-workshop on Scalar search and study in Belgium

ULB, 23-24 january 2014

The challenge

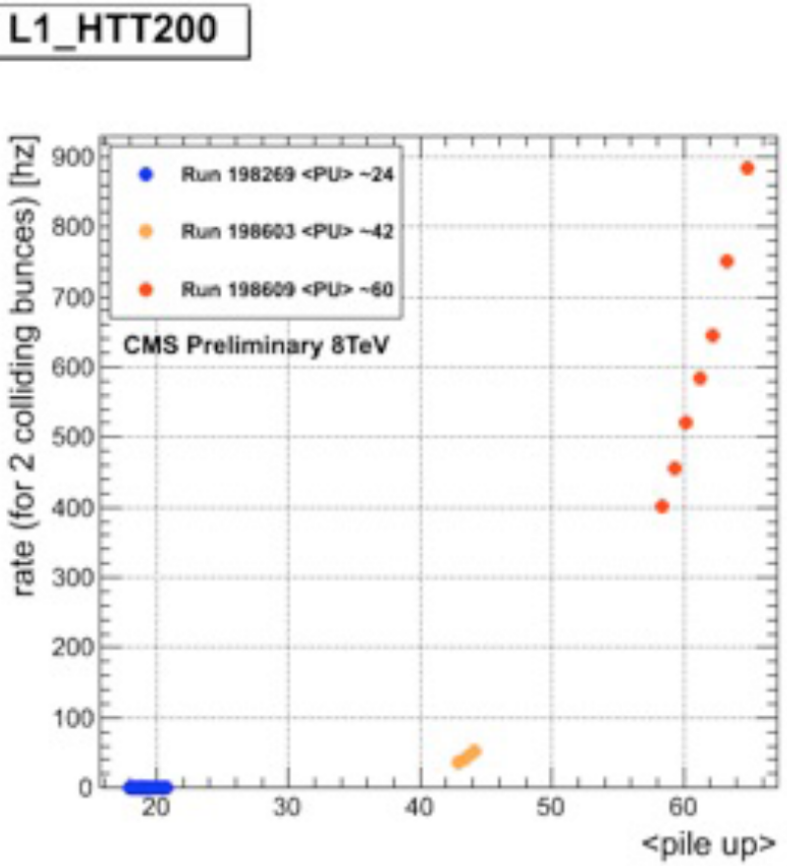
In Run II, maintain:

- 100 kHz L1 output rate
- 1 kHz HLT output rate

Given that:

- cross sections increase at 13 TeV
  - ~1.7 for W/Z
  - x4-5 for high-pT jets
  - https://indico.cern.ch/getFile.py/access?subContId=1&contribId=5&resId=0&materialId=slides&confId=282365
- luminosity increases
  - X2 at 1.6E34

- Rate non-linearity with pile-up e.g. of jet/MET paths



Thresholds

- **L1 managed to keep reasonable thresholds**

L1 Trigger / Column	6E33	7E33	8E33	9E33
Single EG	20	20	22	22
Single MU (η<2.1)	12	12	14	14
Double MU	10, 0pen	10, 0pen	10, 3.5	10, 3.5
Double MU HighQ (BPH)	0,0	0,0	3, 0	disabled
HT	150	150	175	disabled
MET	36	40	40	50
ET	300	300	300	disabled
Double-Jet (central)	56	64	64	64
Quad-Jet (central)	36	40	40	disabled
Triple-Jet VBF	64,48,28	64,48,32	64,48,32	disabled

- **But we are quite close to runaway**

Never used

Super emergency

L1 upgrade and the scalar

- Improve e/γ object isolation using calorimeter energy distributions with Pile-Up (PU) subtraction

  → Better isolation at L1 –> lower threshods on the SingleEG seeds
- Improve jet finding with PU subtraction

  → Save the Jets / MET – only triggers (Hbb/HiggsEXO)
- Improve hadronic τ ID with a smaller fiducial area

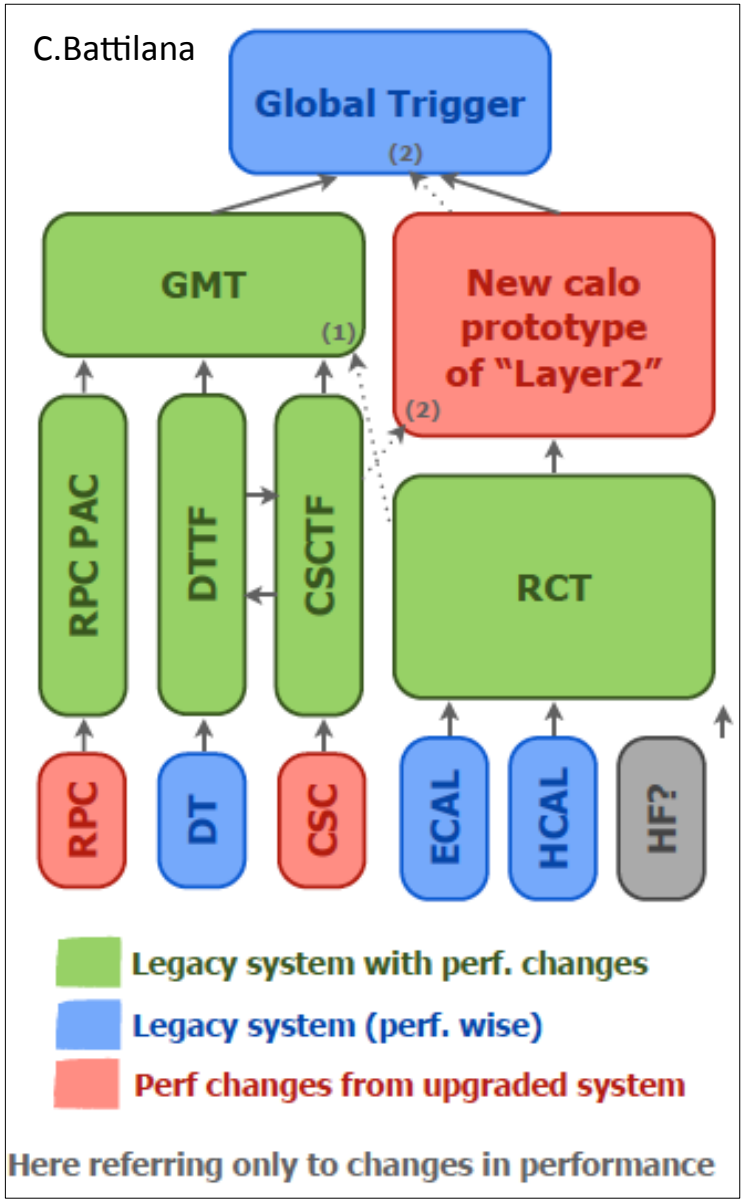
  →Critical for H2Tau!
- Improve muon p_T resolution (below 2.1 only 2016)

  → Improved L1_Muon seeds
- Improve global Level-1 trigger menu
  - Allow greater number of triggers (2016)
  - Allow more sophisticated algorithms (2016)

  →More (and more flexible) multi object triggers at L1 will allow to lower thresholds"

From M.Cepeda

L1 upgrade & 2015



- Muon system changes will require optimizations to legacy muon trigger:
  - CSC ME1/1(a) un-ganging and ME4/2 stations added
  - RPC RE4/2 RE4/3 stations added
- In addition other "purely L1" tuning is foreseen:
  - New DTTF LUTs (optimized for rate reduction)
  - New TFs quality definitions & GMT pT ass. Optimizations
  - L1 muon isolation @ GMT (1) or in endcap region (2) (NOT in 2015!)
- New prototype of Layer2 will operate on top of optimized RCT algos to provide:
  - More efficient tau triggers
  - Better EG/tau isolation
  - PU subtraction algorithms @ L1
- Most of the system is legacy one with some modifications
- Improvements for HI running (not discussed here)

HLT ½ rate menu

1 kHz -> need factor 2 rate reduction on average

P_T thresholds for a factor 2 reduction on each HLT path:

2012	2015
HLT_Mu**17**_Mu**8**	HLT_Mu**23**_Mu**10**
HLT_Ele**17**_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_Ele**8**_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL	HLT_Ele**30**_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL_Ele**27**_CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoV !!
HLT_IsoMu**24**_eta2p1	HLT_IsoMu**34**_eta2p1
HLT_IsoMu**20**_WCandPt**80**	HLT_IsoMu**25**_WCandPt**90**
HLT_IsoMu**18**_CentralPFJet**30**_CentralPFJet**25**	HLT_IsoMu**22**_CentralPFJet**35**_CentralPFJet**30**
HLT_Ele**27**_WP80	HLT_Ele**36**_WP80
HLT_Ele**27**_WP**80**_CentralPFJet**80**	HLT_Ele**36**_WP80_CentralPFJet**95**
HLT_Ele**24**_WP80_CentralPFJet**35**_CentralPFJet**25**	HLT_Ele**36**_WP80_CentralPFJet**40**_CentralPFJet**30**
HLT_IsoMu**17**_eta2p1_LooseIsoPFTau**20**	HLT_IsoMu**30**_eta2p1_LooseIsoPFTau**45**
HLT_IsoMu**15**_eta2p1_L1ETM20	HLT_IsoMu**25**_eta2p1_L1ETM20
HLT_DoubleMediumIsoPFTau**30**_Trk1_eta2p1_Reg_Jet**30**	HLT_DoubleMediumIsoPFTau**45**_Trk1_eta2p1_Reg_Jet**30**
HLT_Photon**26**_R9Id85_OR_CaloId10_Iso50_Photon**18**_R9Id85_OR_CaloId10_Iso50_Mass70	HLT_Photon**34**_R9Id85_OR_CaloId10_Iso50_Photon**24**_R9Id85_OR_CaloId10_Iso50_Mass70
HLT_Photon**36**_R9Id85_Photon**22**_R9Id85	HLT_Photon**42**_R9Id85_Photon**28**_R9Id85
HLT_PFMET**150**	HLT_PFMET**200**
HLT_QuadPFJet**82_65_48_35**_BTagCSV_VBF	HLT_QuadPFJet**95_75_55_40**_BTagCSV_VBF

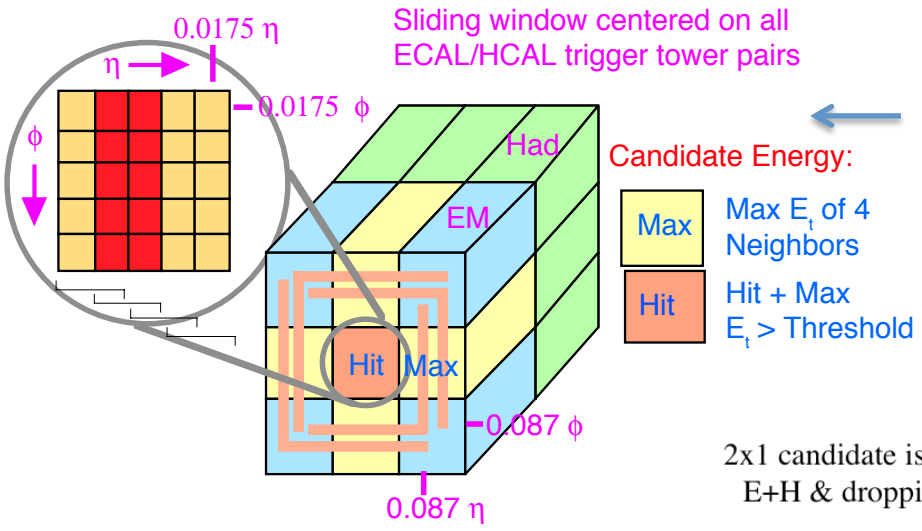
Z.Demiragli

+ need to account for more paths (Run I parked triggers; new / HiggsExo signals)

HLT objects and the scalar

- Better consistency of offline and HLT reconstruction
  - Electrons: PF clustering; H/E; fbrem; laser corrections
  - PF isolation
    - Tighter cuts in single-lepton paths
      - WH->lnubb; H->WW->lnujj
- Improved muon efficiency vs. pile-up and for nearby muons
- MET cleanup
  - save MET-based paths (VBF H->invis.; ZH->nunubb)
- Improved tau ID and isolation
  - Purer lepton+tau_h and di-tau_h paths to keep low p_T thresholds
- Improved PFJets at HLT
- Improved b-tagging
  - ZH->nunubb; WH->lnubb (l+b-tag; w/ single-top)

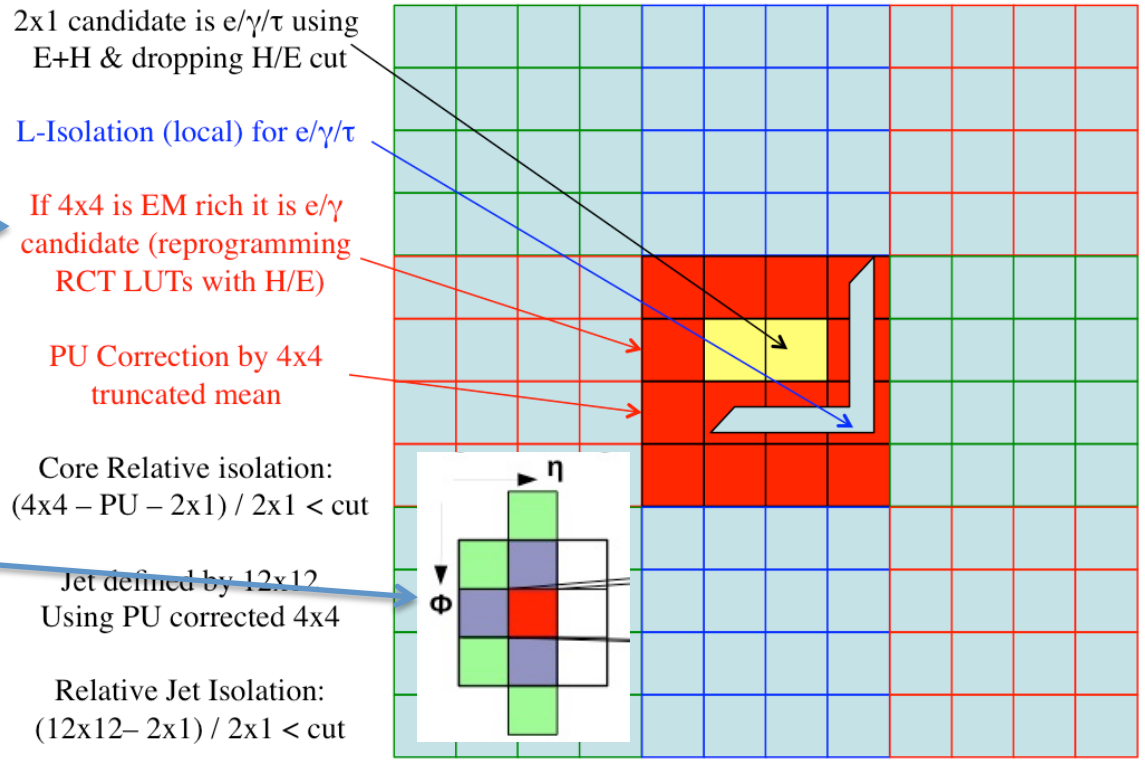
Egamma L1



Current: regional ID; absolute local isolation in 3x3 tower region

Upgrade (also for taus):

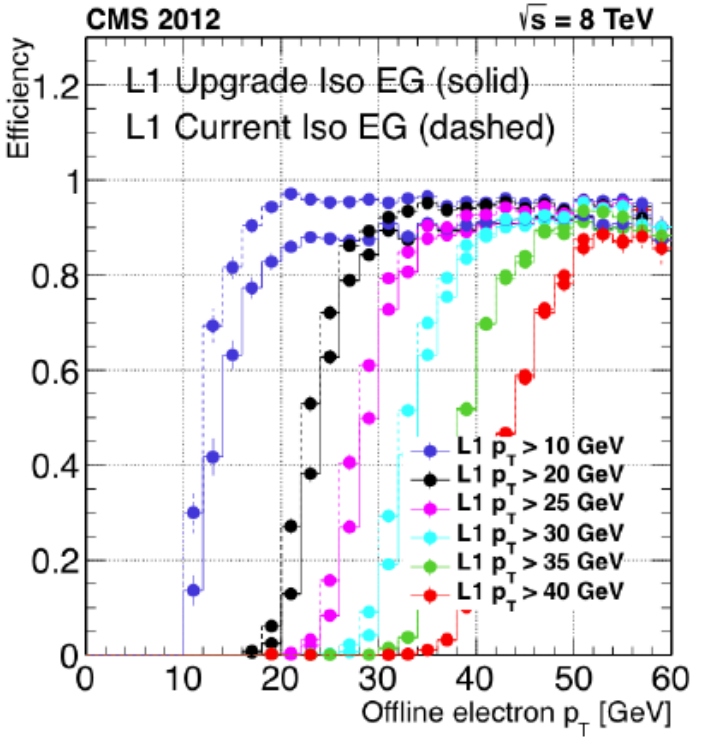
- relative isolation in 12x12 region (2015)
  - (E12x12-E2x1)/E2x1 < cut
  - PU corrected
- Mid-run: wider cluster than 2x1

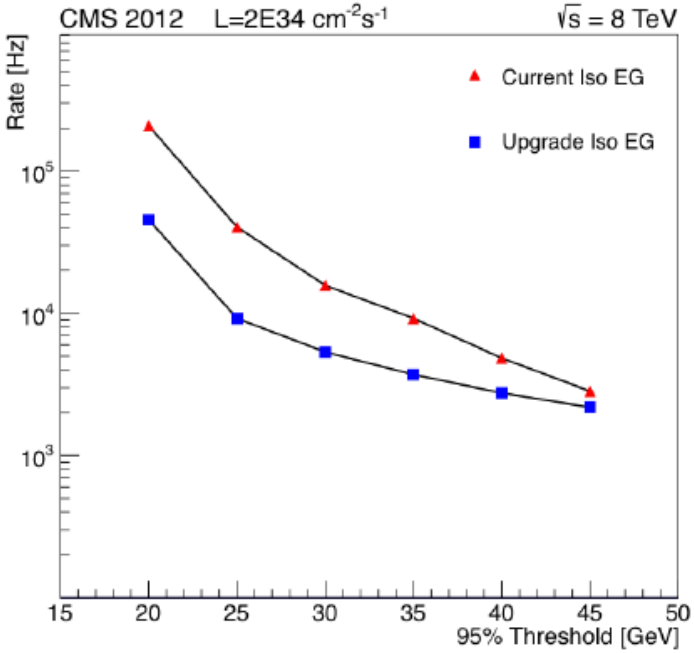


J.B. Sauvan https://indico.cern.ch/getFile.py/access?contribId=13&sessionId=1&resId=0&materialId=slides&confId=276893

Egamma L1 (2)

- **2x1 cluster with regional ID**
- Identical performance to the one in 2012 Egamma for relaxed electrons
- Improved Isolation performance (enhanced flexibility, factor of 2-3 reduction in rate with minimal impact in performance)
- **Details:**
  - Regional ID → Reprogrammed RCT LUTs and HCAL feature bit. Configurable thresholds (LUTs).
  - Isolation: (12x12-2x1)/2x1. Enhanced flexibility of algos compared to old RCT.
  - Dynamical range extended from (0-63) → (0,255) GeV

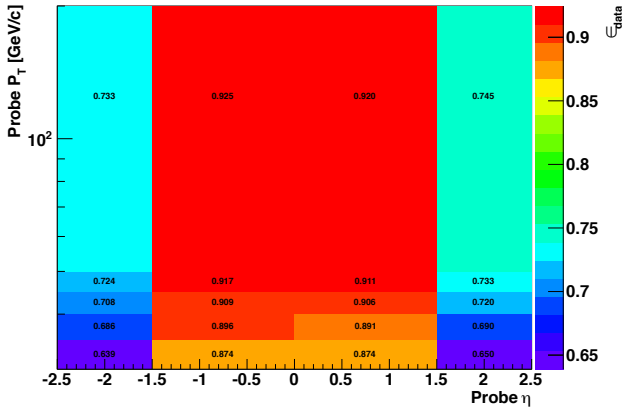




Egamma HLT

Main single-e path: *HLT_Ele27_WP80*

Rate in 2012D: 45Hz - ½ rate menu: *Ele36*



NB: e+jet cross triggers used single non-iso L1 EG seed during Run I

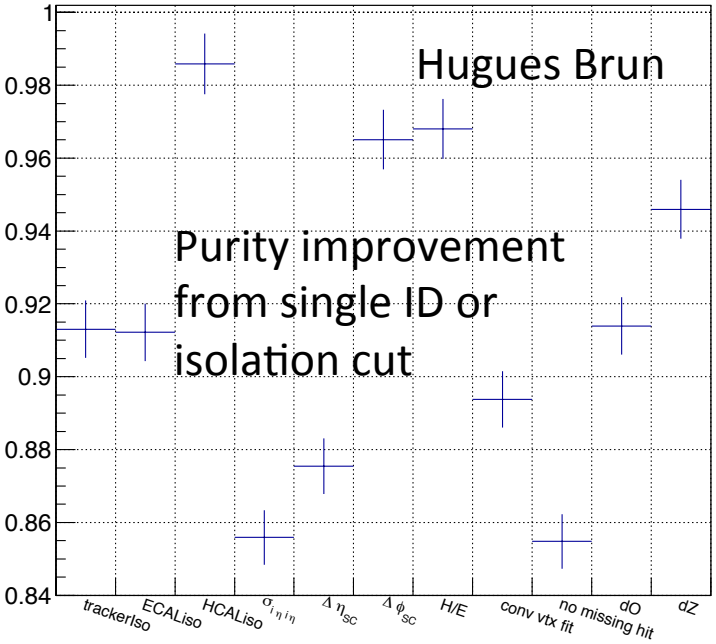
Main double-e path:

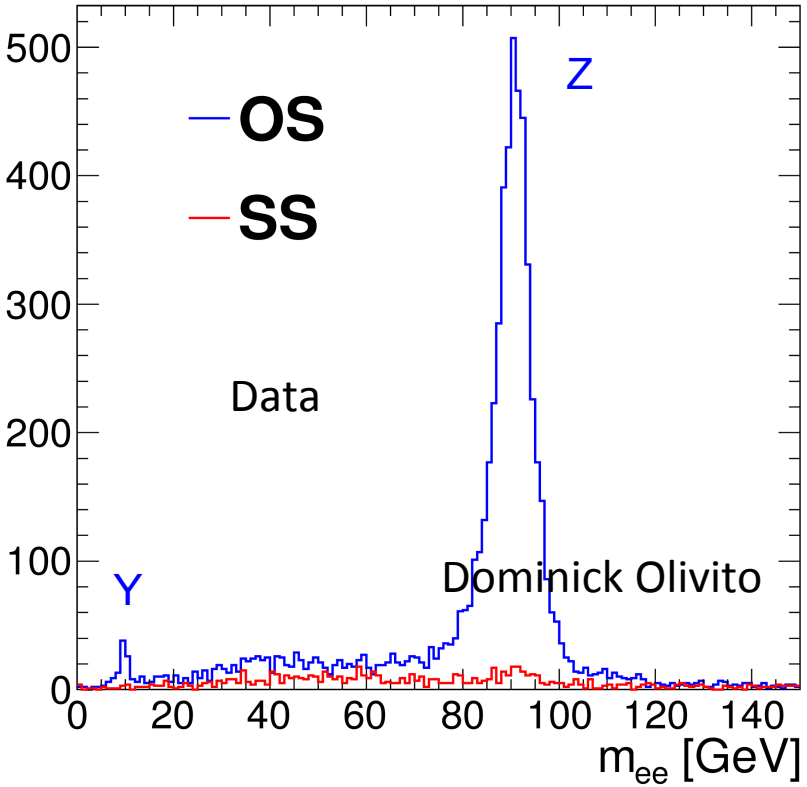
HLT_Ele17_Ele8; on each leg *CaloIdT_CaloIsoVL_TrkIdVL_TrkIsoVL*

rate: 5.5 Hz @ 7^E33

<u>Quite pure already</u>

½ rate menu: *Ele30_Ele27 ???*

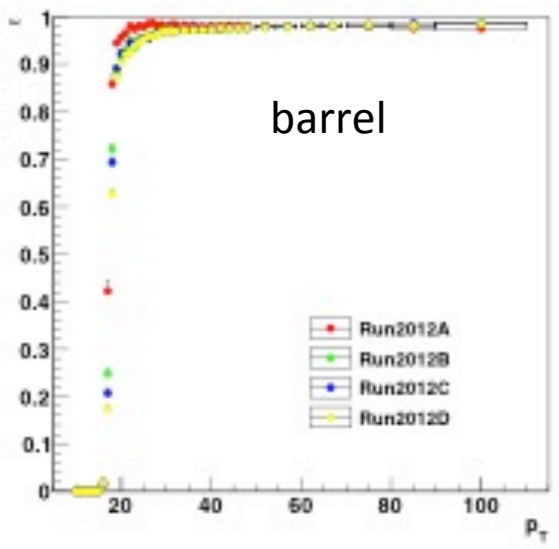




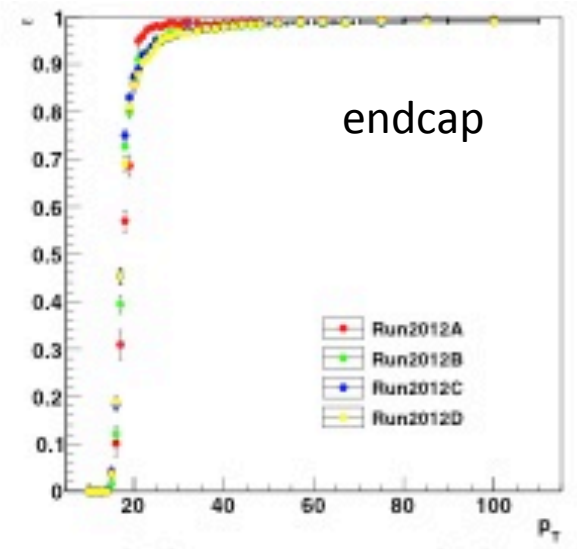
Double-e HLT_Ele17_Ele8

- **T&P efficiency**

Leading leg



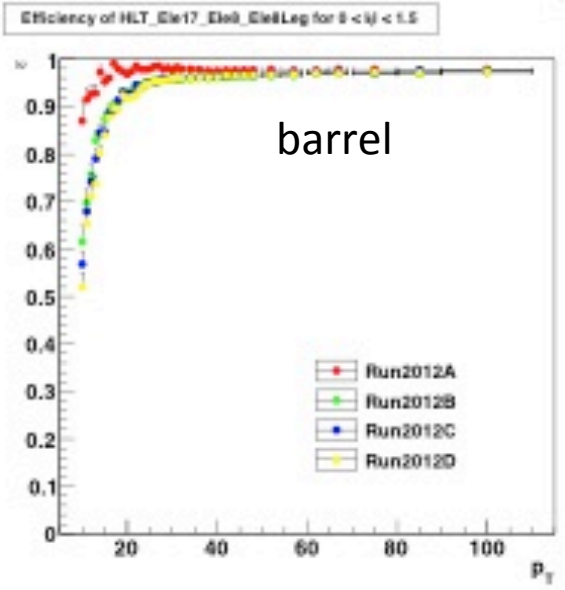
(a) leading leg, barrel

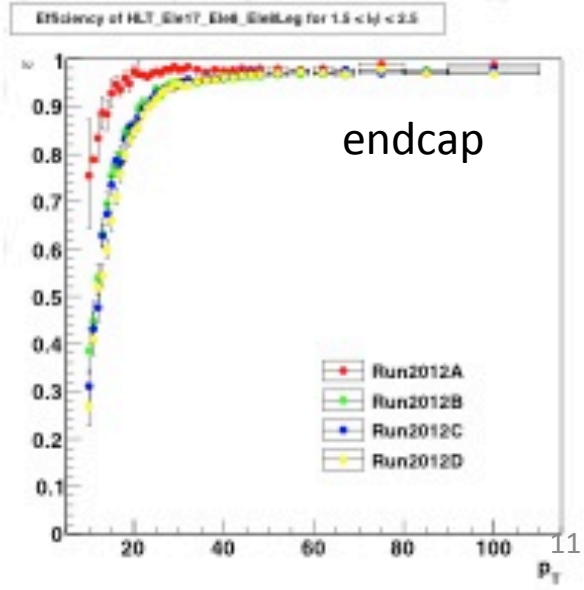


(b) leading leg, endcap

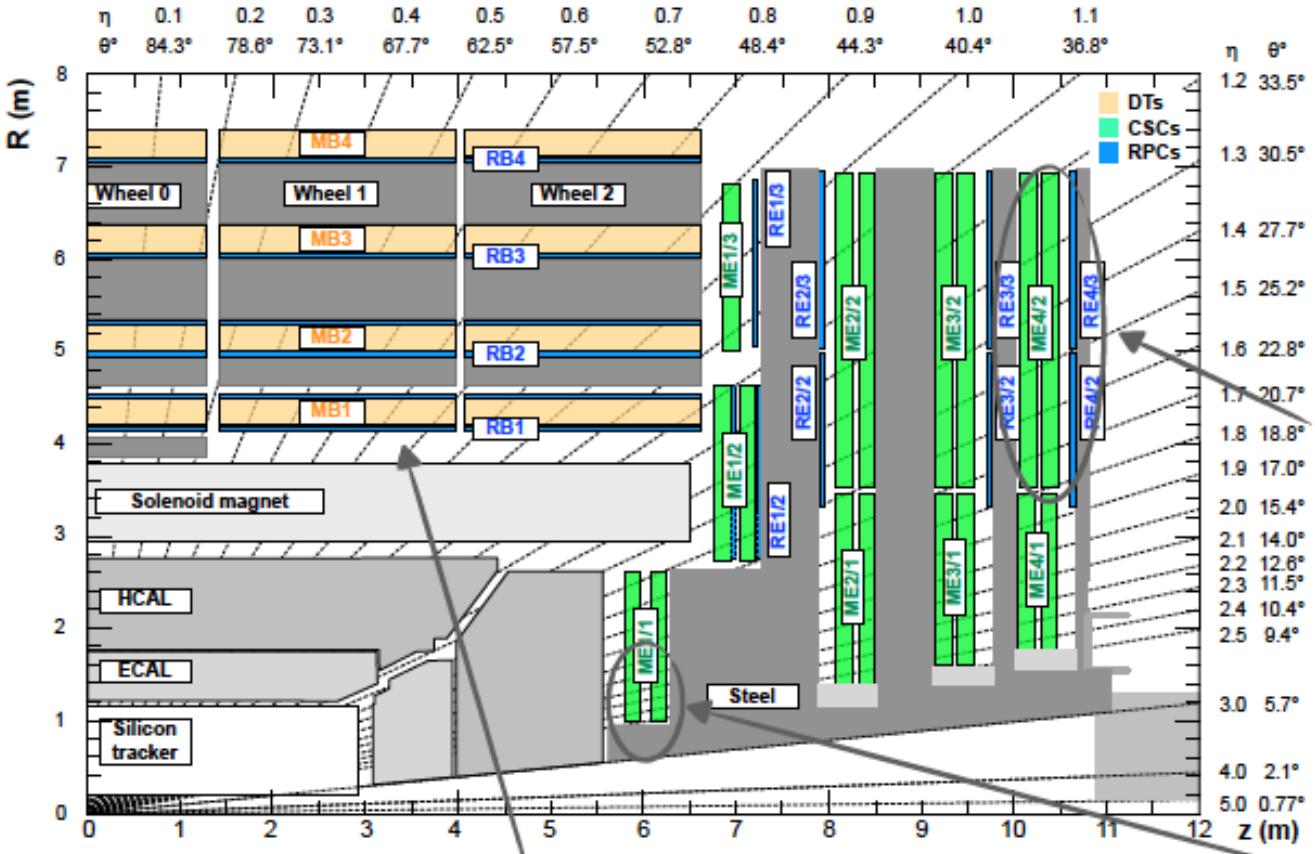
Trailing leg

Slow turn-on esp. in runs B,C,D





Muon L1



ME4/2 and RE4/2-RE4/3 chambs will add redundancy to the muon spectrometer (1.2<|η|<1.8)

- Will increase CSCTF/RPC PACT efficiency in that |η| region
- Can turn into optimisation of TFs quality assignments and GMT combinatorial logic

No detector changes (with major impact on performance) in the muon barrel

- However a **first version** of new DTTF LUTs aimed at reducing rate has been worked out

CSC ME1/1(a) (2.1<|η|<2.4) un-ganging

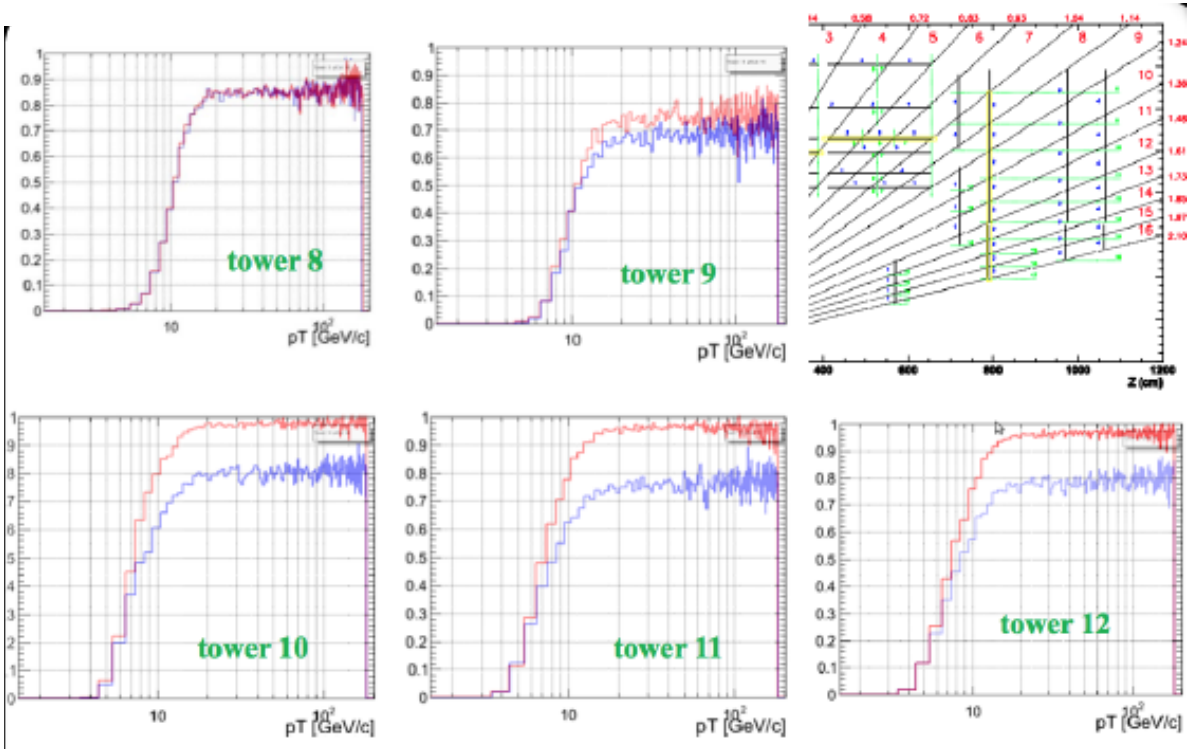
- Resolving 3->1 ambiguity due to ganging will ensure better rate reduction for CSCTF @ high |η|

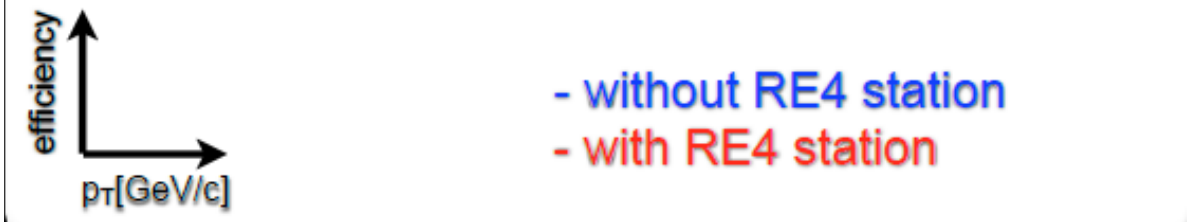
RPC PACT: new RE4 chambers

Improvement of PAC trigger efficiency (3 out of 4 layers to generate and RPC trigger candidate)

We are not aiming for better pT resolution with RE4.

Further studies to optimize rate reduction/efficiencies testing different GMT muon qualities



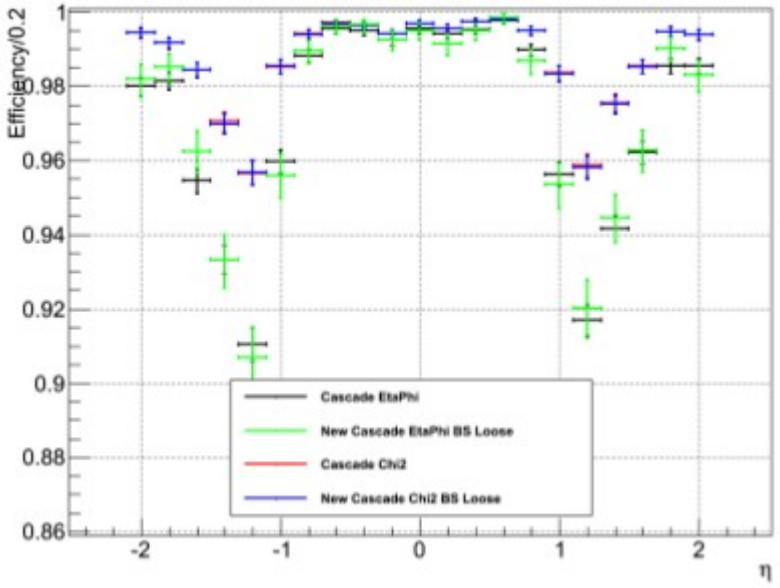


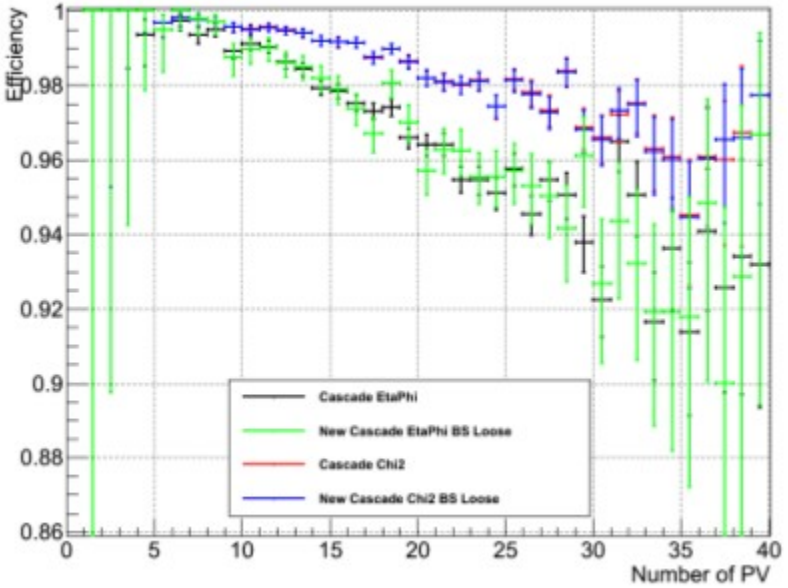
MC data efficiency study for 16 GeV L1T muons.

Muon HLT

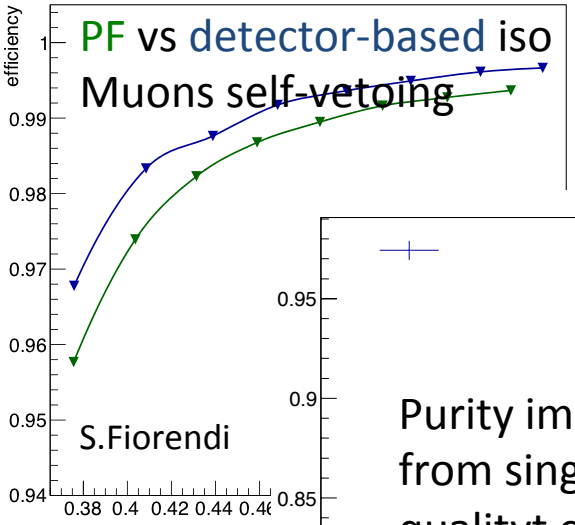
Fixed pile-up dependence; feedback from PAGs requested
Performance for cuts as in 2012 shown below

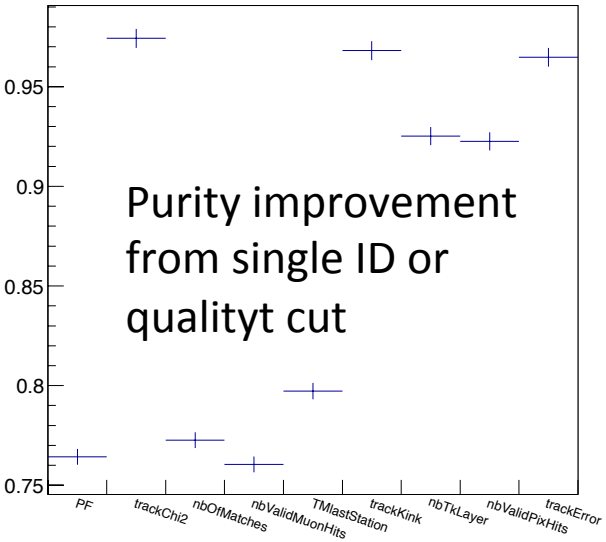
- current cuts are on transverse impact parameter and track χ^2
- each PAG should consider which paths may be affected by these cuts (e.g. displaced vertex? b-tagging?) and check our proposal → we'll provide a recipe for the new algorithm
- for now, the New Cascade was put in a pull request with loose cuts (9E99) that reproduce the old behaviour: https://github.com/cms-sw/cmssw/pull/1521



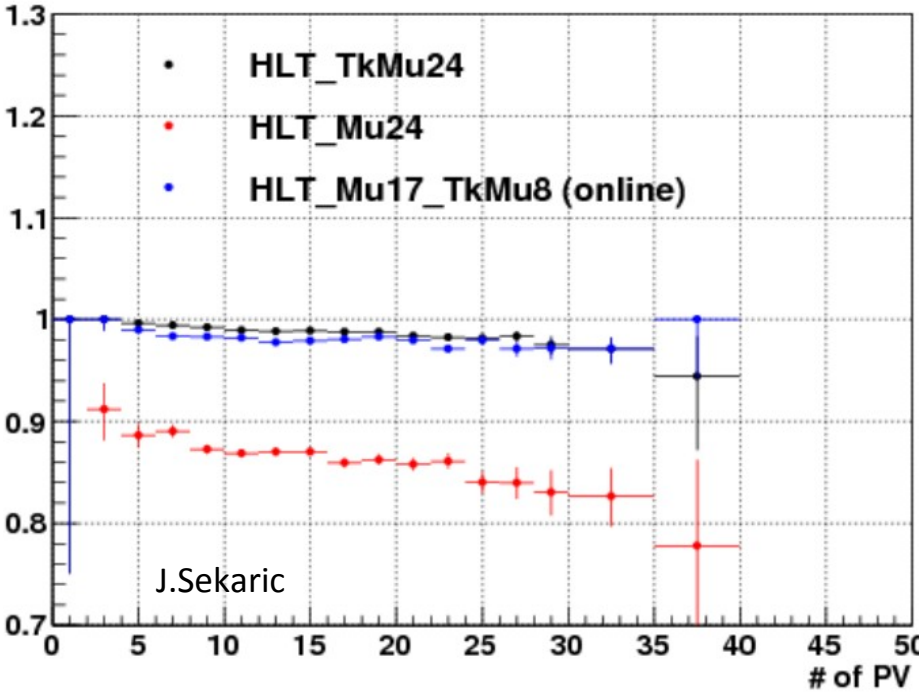


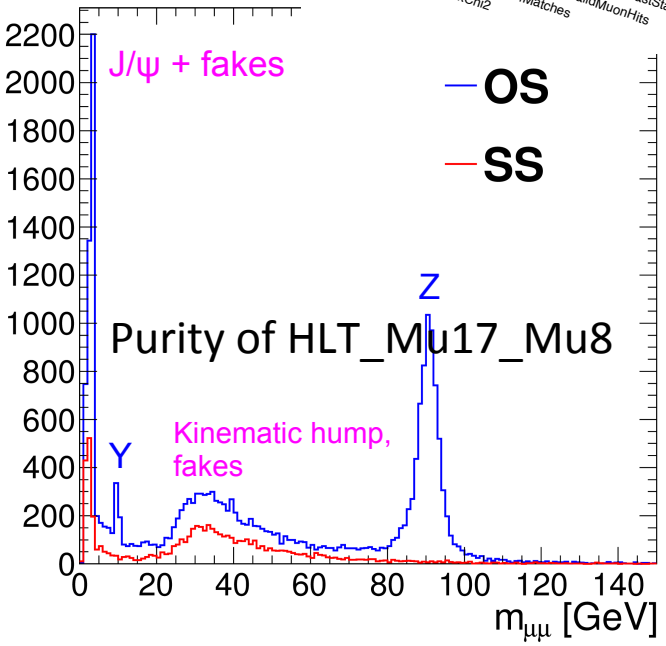
Muon HLT (2)





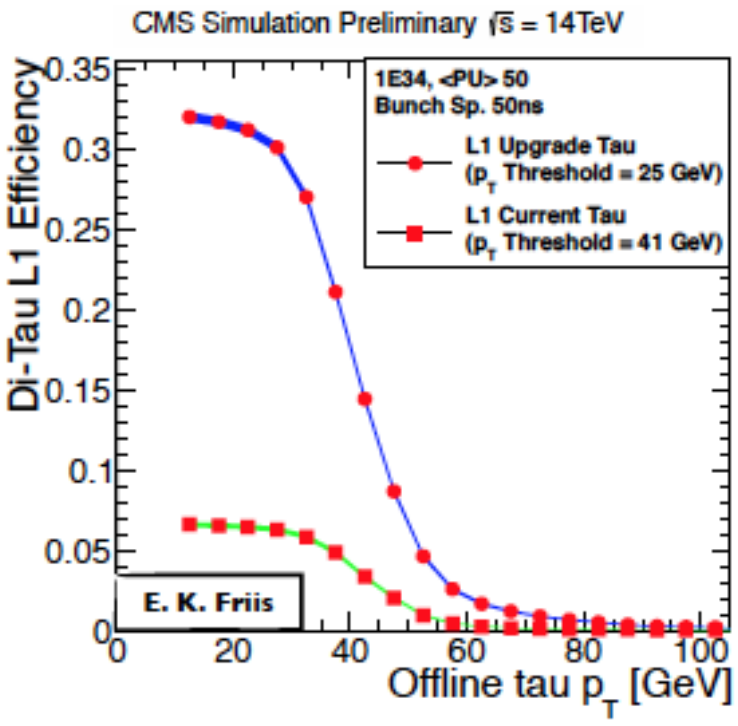
TkMuon studies
CPU consuming path – gain for H ?



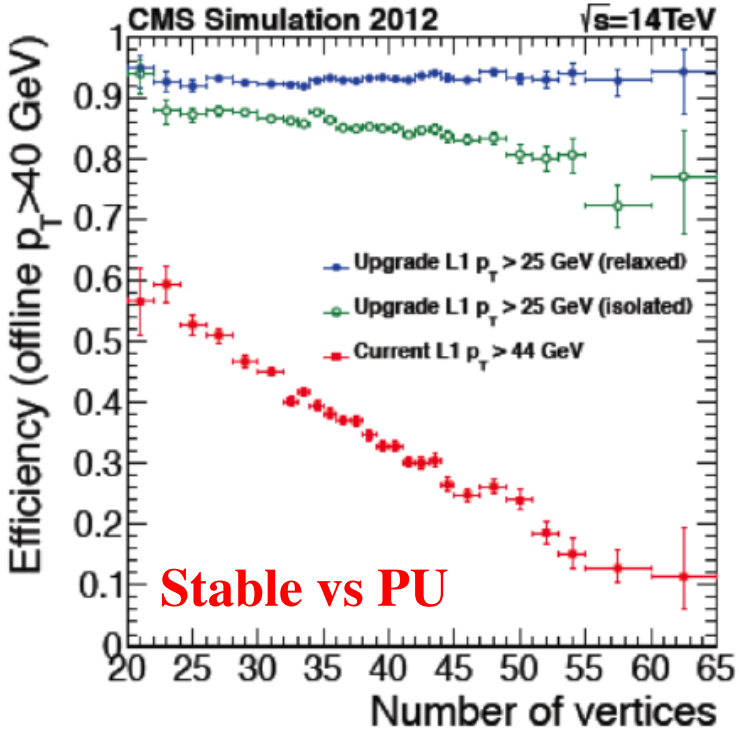



```
HLT_TkMu24_v1 = cms.Path( HLTBeginSequence
+ hltL1sMu16 + hltPreTkMu20 + hltL1fL1sMu16L1Filtered0
+ HLTL2muonrecoSequence + hltL2fL1sMu16L1f0L2Filtered16Q
+ HLTL3muonrecoSequence + hltL3fL1sMu16L1f0L2f16QL3Filtered24Q
+ HLTTrackerMuonSequence
+ hlTkfL1sMu16L1f0TkFiltered24Q
+ HLTEndSequence )
```

Taus L1



- **Based on 2x1 clusters**
- Pt assignment can take into account 2x1 + contiguous 4x4 regions (account for leaks)
- Isolation: 12x12 Jet vs Tau Pt, Relative
- Efficiency plateau reaches 100% efficiency



Critical for H2Tau

Tau HLT

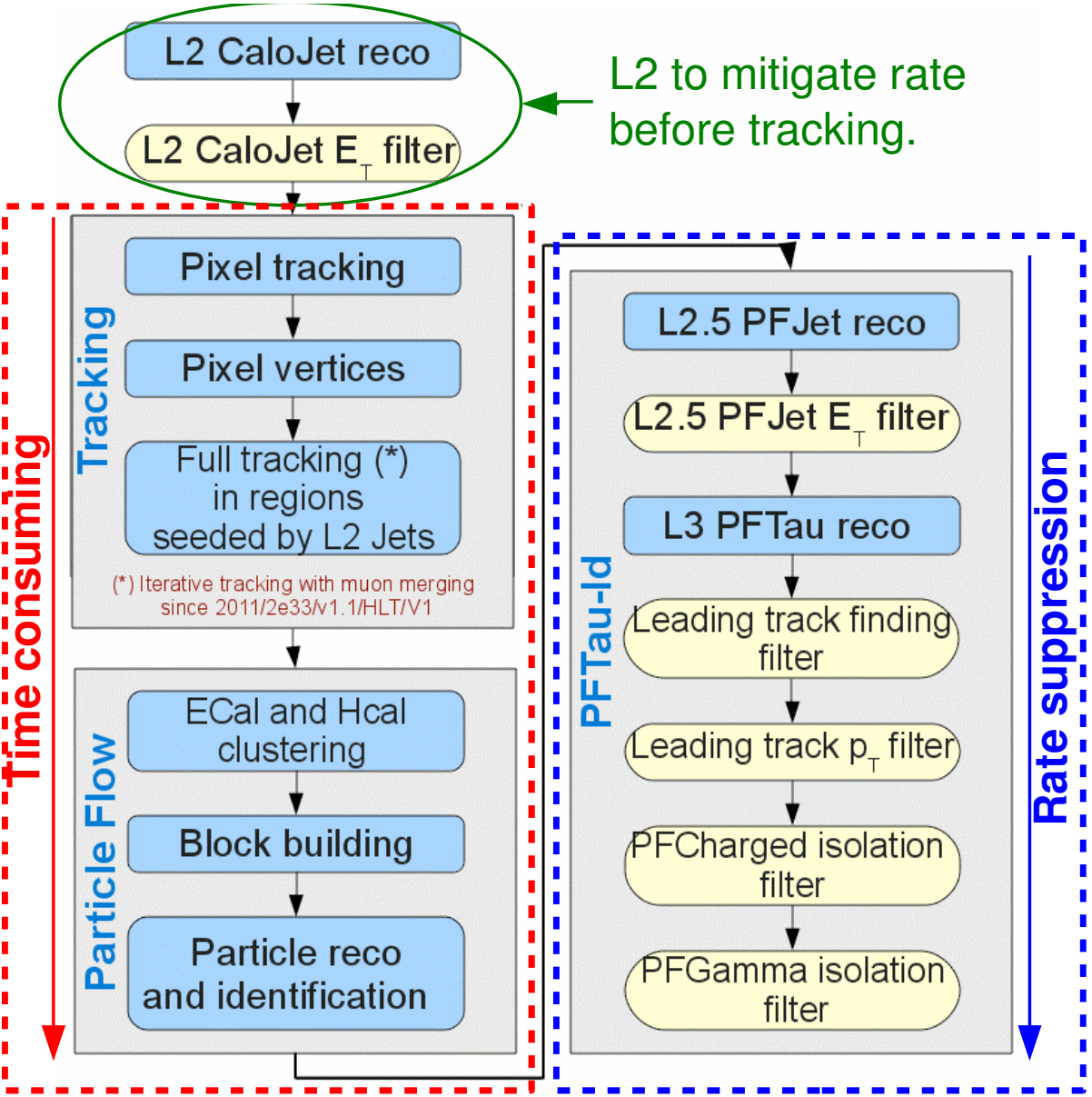
M.Bluj

Path name	Rate at 7e33 $cm^{-2}s^{-1}$		Rate reduction		"Half rate" threshold
	L1 [kHz]	HLT [Hz]	L2/L1	HLT/L2	
IsoMu17_LooseIsoPFTau20	7.7	13	1.2%	16%	30 / 45
Ele22_WP90Rho_LooseIsoPFTau20	~18†	30	0.5%	25%	30 / 45
DoubleMediumPFTau30_Trk1_Jet30	~9†	25	5.1%	6.0%	42
DoubleMediumPFTau35_Trk1 [Prong1/TauParked]	~9†	6/48	10%	0.8/6.5%	–

(†) For L1EG and L1DoubleTau with an OR between Iso and NoIso seeds

- Minimal requirement is to reduce current rate by 2 to compensate increase of luminosity and energy (they give factor of ~4)
- "Half rate" thresholds
  - ~30GeV for lepton (vs 20 GeV now), and ~45 GeV for tau (vs 20-30 GeV now)
    => Z-candle basically killed, also H125 affected
- Purity is a key to keep both acceptable rate and reasonable thresholds
  - Currently PFTau@HLT with isolation reduces rate by factor of ~5 compared to ~100 for tight e/mu (or offline tau)! => **it is a key issue!**
    - Where factor of ~2.5 from Pt cut, ~1.5 for track finding, and (only!) ~1.5 from isolation

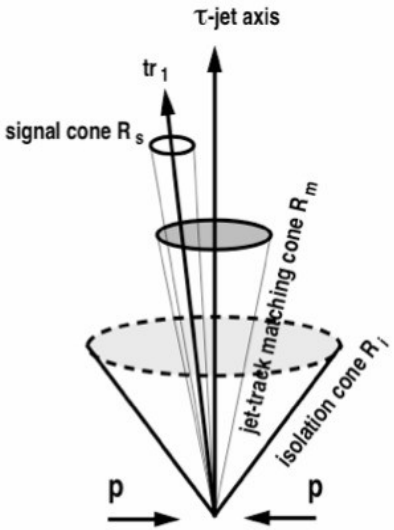
Tau HLT (2)



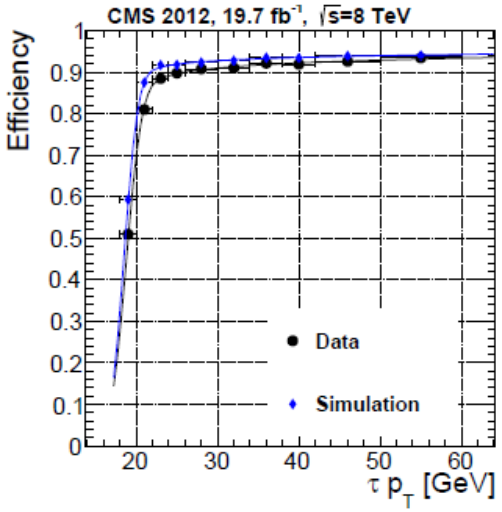
- PFlow used
  - Good resolution => narrow turn-on
  - High efficiency
- but time consuming
  - Full tracking
- Rate mitigated before tracking by L2
  - L2caloTaus (R=0.2) with pixel isolation
  - CaloMET
  - Lepton
- Simple Tau-Id HLT (old offline algo):
  - Leading track finding
  - Trk-based Isolation => high fake-rate
- **Main concerns**
  - Improve purity
  - Speed-up tracking (esp. for di-tau)

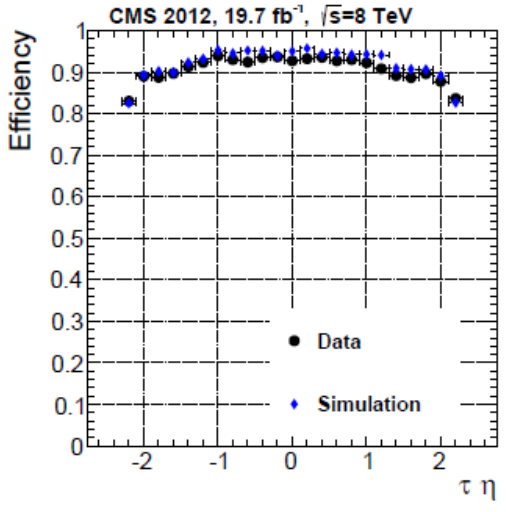
Current Tau-Id and isolation at HLT

- Cone-based Tau-Id (old offline algorithm) with PFlow
  - Leading track finding (close to jet axis)
    - Loose track quality to keep high efficiency
    - Fixed cone with size depending on trigger path (threshold) R=0.15-0.18
  - Track isolation in a ring around leading track
    - Track veto (Pt>1.5GeV for loose, Pt>1GeV for medium WP)
    - Tight track quality for PU-robustness (≥8hits, ≥3pixel hits)
  - No calo (ECal) based isolation to reduce PU-dependence
  - Signal track counting in some paths
    - No. of tracks <3 (“1-prong”) or <5 (“1+3-prongs”)
    - With very (too) loose track quality as for lead track finding
      → PU dependency esp. for “1-prong”
- Simple, fast and robust algorithm, but with high (fake) rate
  - Effective also for high-Pt taus



TRG-12-001
J. Swanson





Foreseen improvements to Tau@HLT

- Two options for Id
  - **Baseline**: Improve simple and fast track finding
    - Use shrinking cone (high efficiency for low Pt, suppressed rate)
    - Improved track counting (e.g. 1 or 3 tracks) → track quality to be studied
  - **Advanced**: Decay mode reconstruction (a la offline HPS algorithm)
    - CPU intensive due to combinatorics
    - potentially more sensitive on fakes/PU/quality of PFlow reco
    - A lot of tuning needed because of differences between offline/online tracking and PFlow,

      => postponed for now
- Isolation:
  - Currently: veto candidates with tracks with Pt>1.5(1.0) GeV in isolation ring for a loose(medium) isolation WP
  - Tight isolation track quality criteria
    - ≥8 hits and ≥3 pixel hits => should be relaxed
  - Check ECal for isolation → PU correction needed (rho)
    - Is it useful in high PU condition (<PU>~50)?

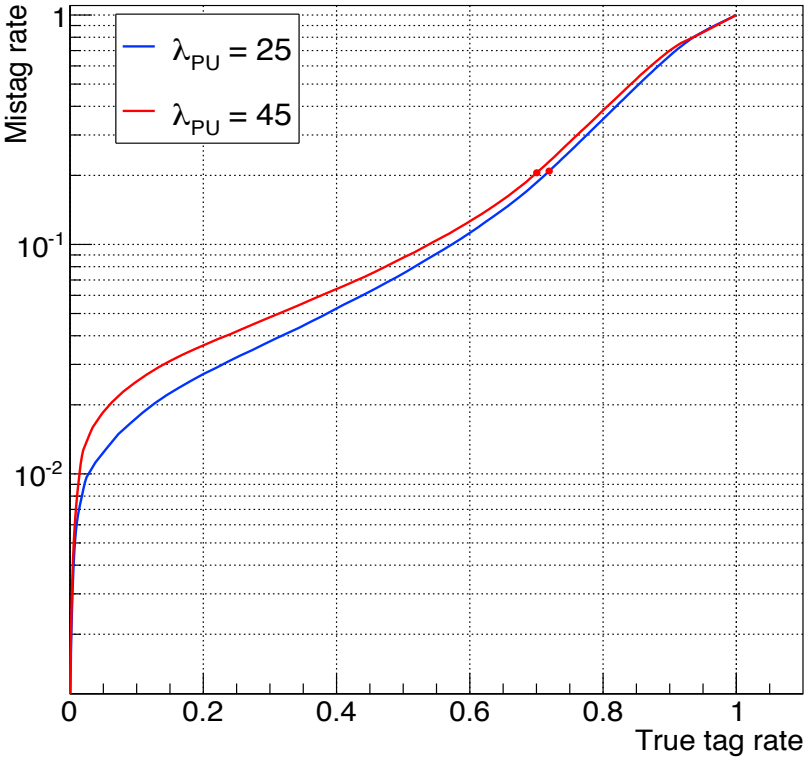
M.Bluj

B-tagging

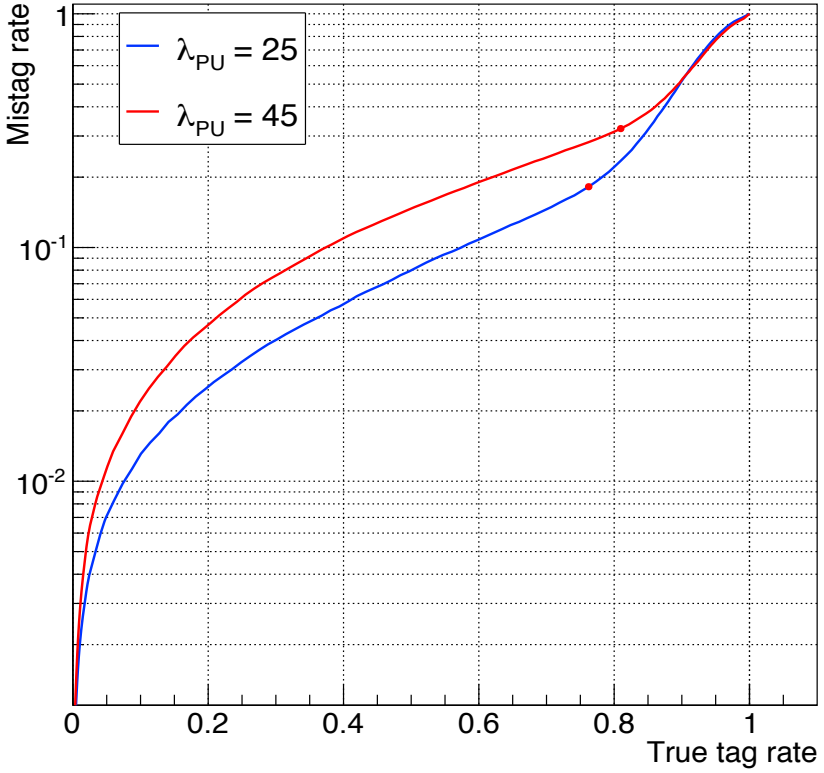
Pixel-hit based primary vertex finder (FastPV)
L2: pixel tracks / L3: pixel+sistrip tracks

Ttbar; 13 TeV; BX25; PU25 and PU45

FastPV @ L2, b vs g



FastPV @ L3, b vs g



A.-C. Le Bihan, I.Marfin; rates with data: A.Popov

Tools and samples

- New OpenHLT

https://twiki.cern.ch/twiki/bin/viewauth/CMS/NewOpenHLT
https://twiki.cern.ch/twiki/bin/view/CMS/OpenHLTReport

- 13 TeV samples in CMSSW62

https://twiki.cern.ch/twiki/bin/view/CMS/TriggerStudiesFall13MC62X#HIG_AN1
https://twiki.cern.ch/twiki/bin/view/CMS/TriggerStudiesFall13MC62X#L1T, #TSG, #TOP, #FSQ,…

  - PU 40, 25 ns => L = 1.40 x 1034 cm-2s-1(2508 bunches)
  - PU 20, 25 ns => L = 0.70 x 1034 cm-2s-1(2508 bunches)
  - PU 40, 50 ns => L = 0.75 x 1034 cm-2s-1 (different number of bunches)
  - Two samples with PU80BX50, not yet done: GG HToGG 125GeV and VBF HToTauTau 125GeV

- 8 TeV data


E
CMS Experiment at LHC, CERN
Data recorded: Mon May 28 01:16:20 2012 CEST
Run/Event: 195099 / 35438125
Lumi section: 65
Orbit/Crossing: 16992111 / 2295