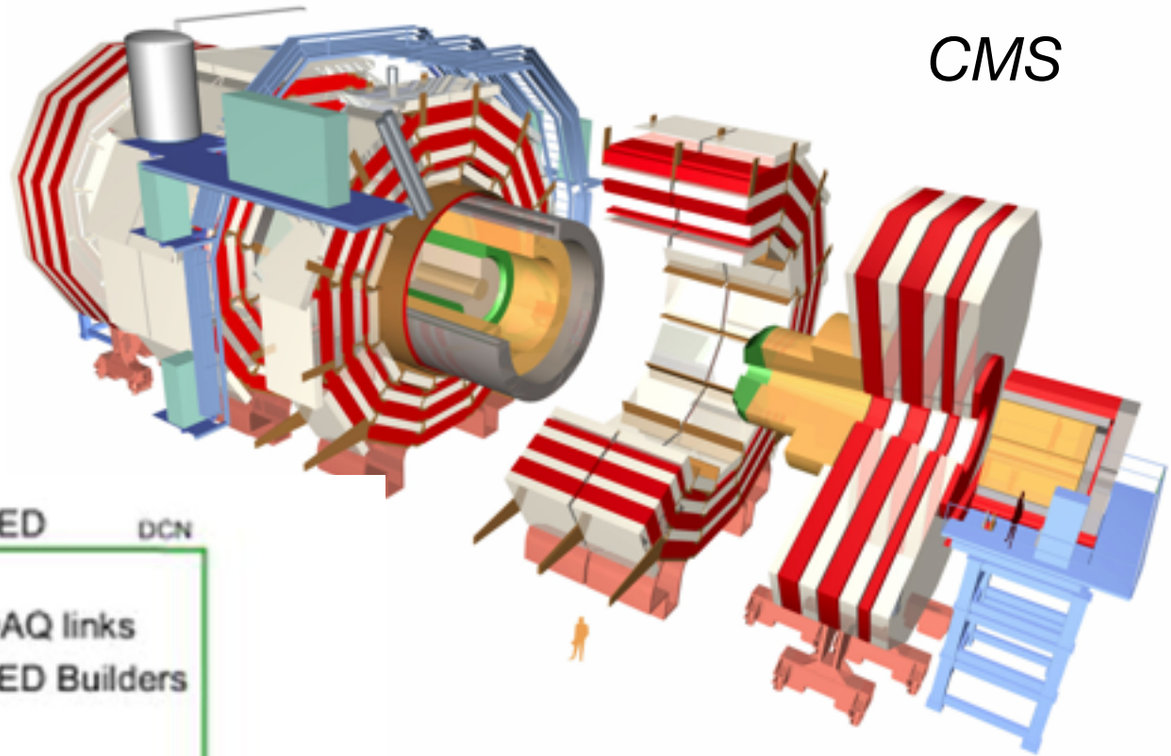
Performance of the CMS Level-1 Trigger

Jim Brooke, for the CMS Collaboration

Overview

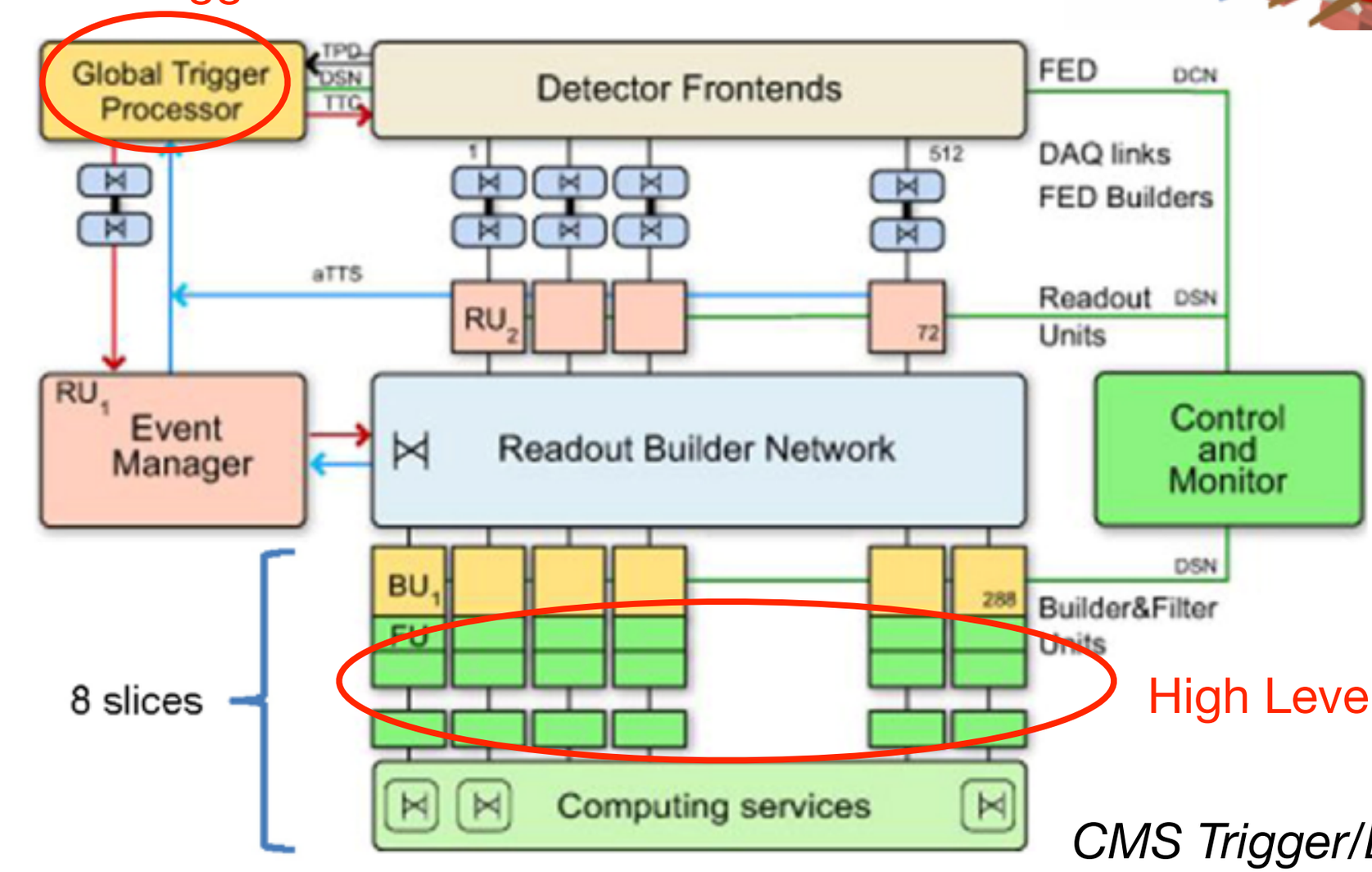
Three talks today :

- L1 Trigger Performance - J. Brooke
- High Level Trigger Performance - S. Beauceron
- Evolution of the CMS Trigger - I. Furic



CMS

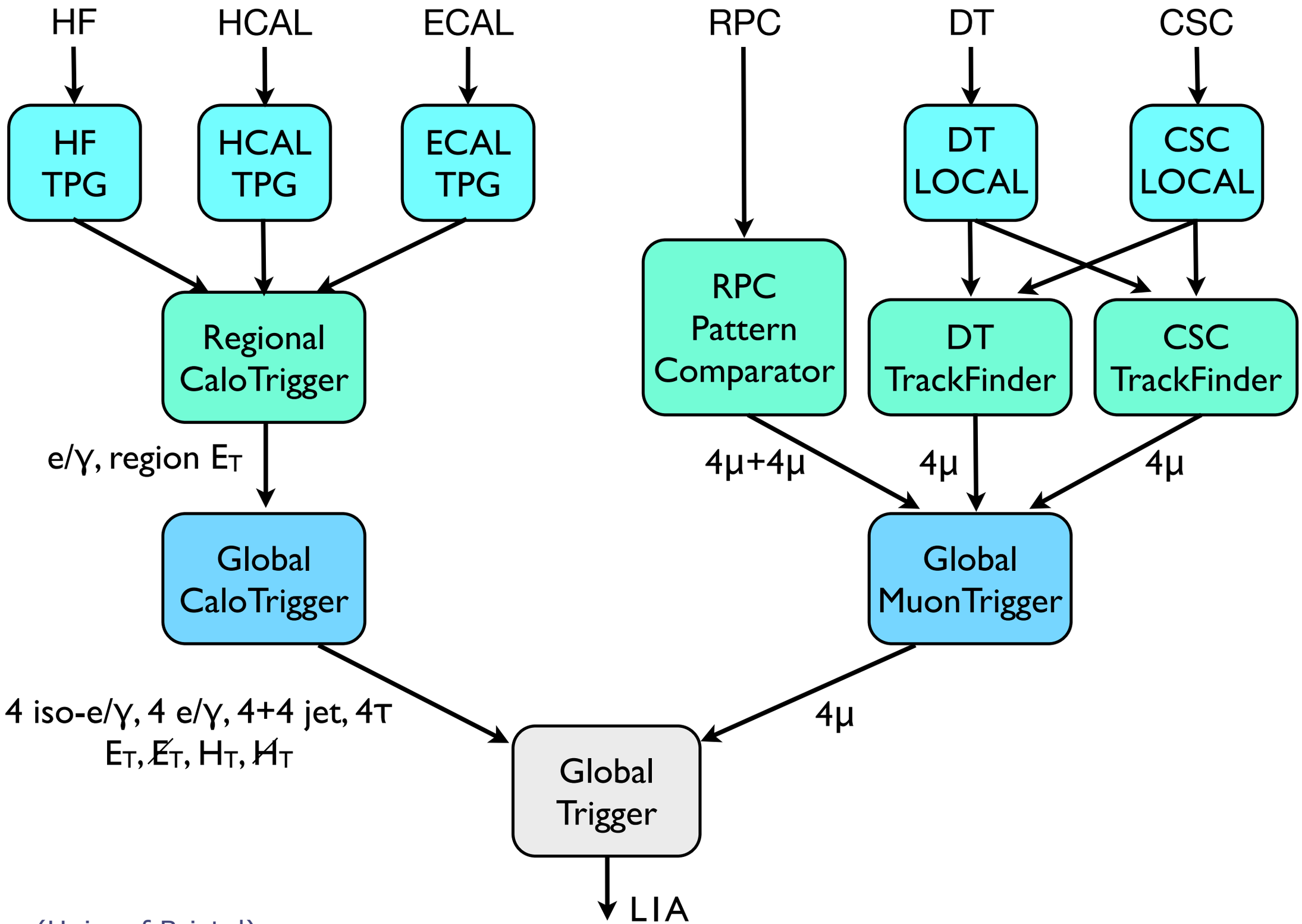
Level 1 Trigger



High Level Trigger

CMS Trigger/DAQ Architecture

Level-1 Trigger Architecture



L1 Trigger Menu

Snapshot of most important triggers in the “6E33” menu

- 10 sets of prescale factors, for different conditions and purposes

Peak L1 rate is close to 100kHz at the start of a fill ($L=6.6\times10^{33}$ $cm^{-2}s^{-1}$)

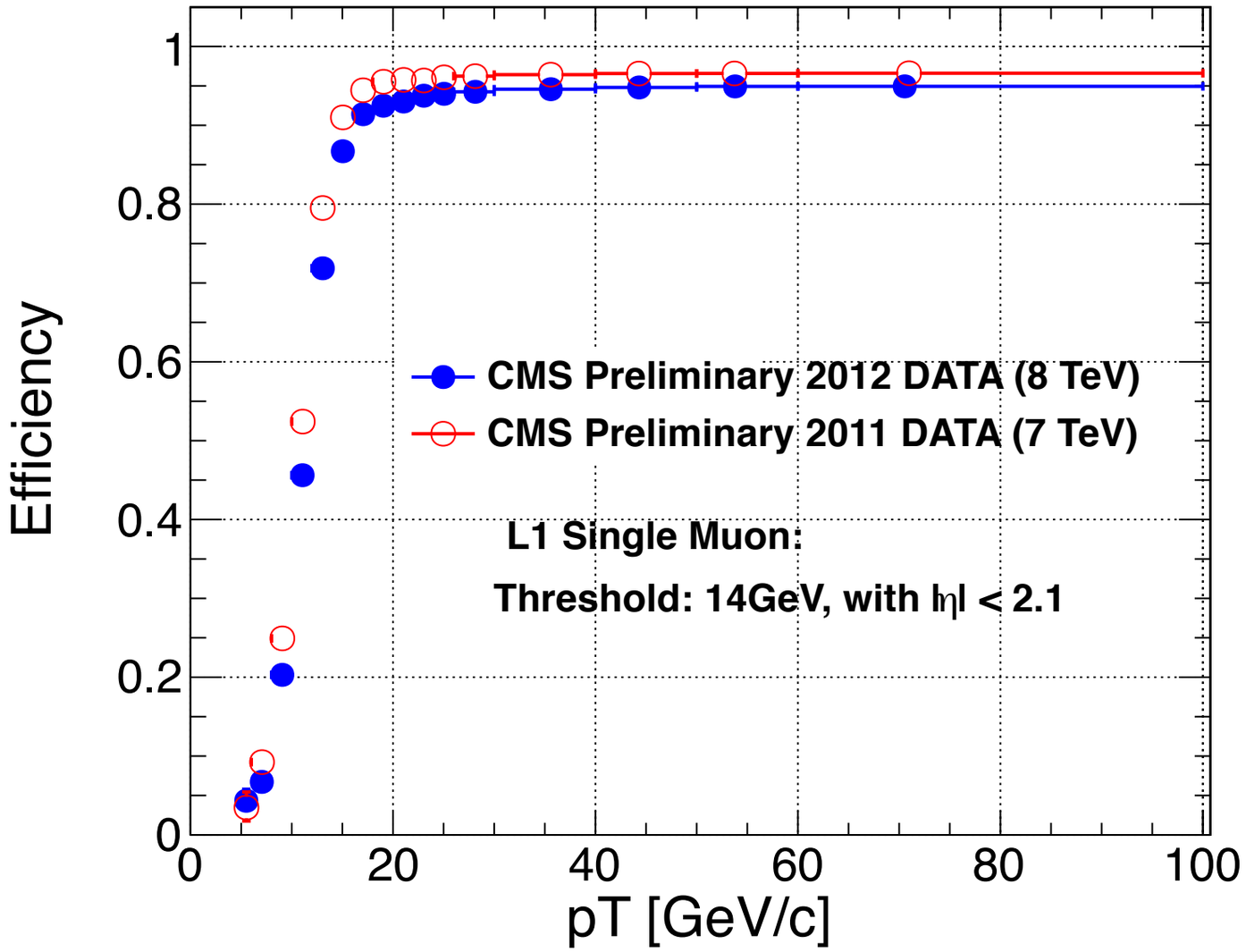
Total deadtime ~3%

Trigger	Threshold (GeV)	Rate (kHz)	Physics
Single e/γ	20	13	Higgs, SM, EXO
Double e/γ	13,7	8	Higgs, SM, SUSY, EXO
Single μ	14 (|η|<2.1)	7	Higgs, SM, SUSY, EXO
Double μ	10, 0	6	Higgs, SM, EXO
e/γ + μ	12, 3.5	3	SM, SUSY, EXO
μ + e/γ	12, 7	1.5	SM, SUSY, EXO
Single Jet	128	1.5	SM, EXO
Quad Jet	36	3.5	SM, SUSY, EXO
H_T	150	5	SUSY, EXO
E_T^{miss}	36	8	SUSY, EXO

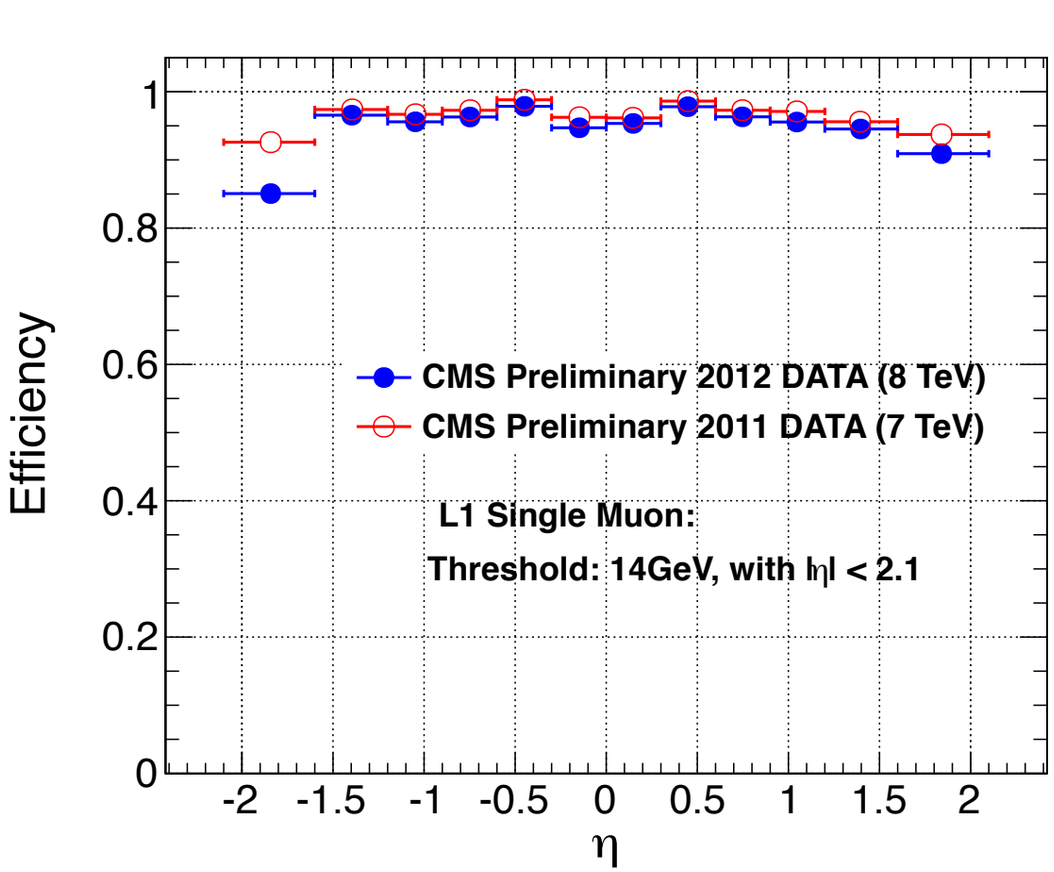
Muon Trigger Performance

Significant work done to reduce rate between 2011 and 2012

- Improved p_T assignment in CSC Track Finder
- Optimised merging (use of p_T information) in Global Muon Trigger
- **~50% rate reduction** for full pseudorapidity (30% for $|\eta| < 2.1$)



Efficiency of Single Muon Trigger
$p_T > 14$ GeV, $|\eta| < 2.1$

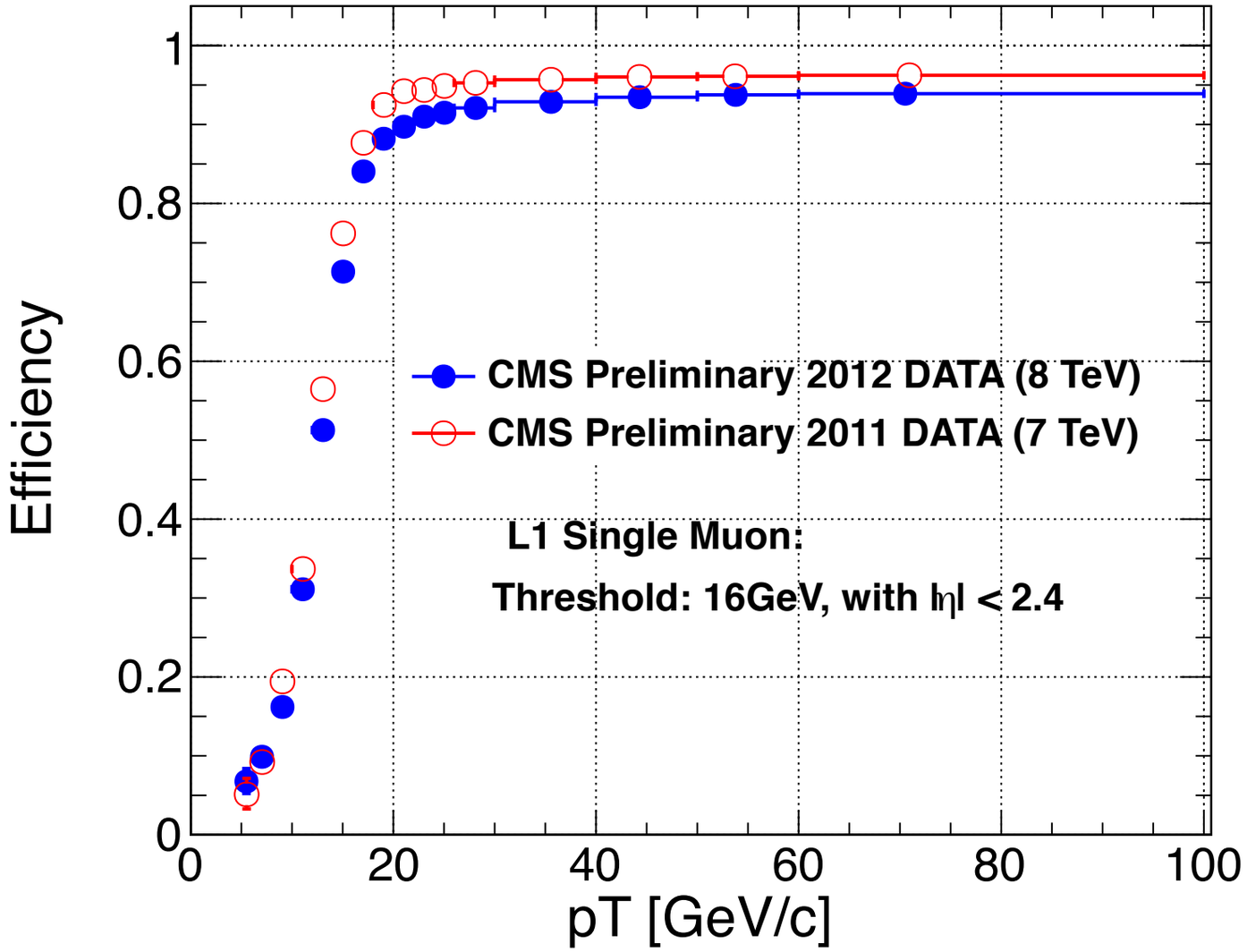


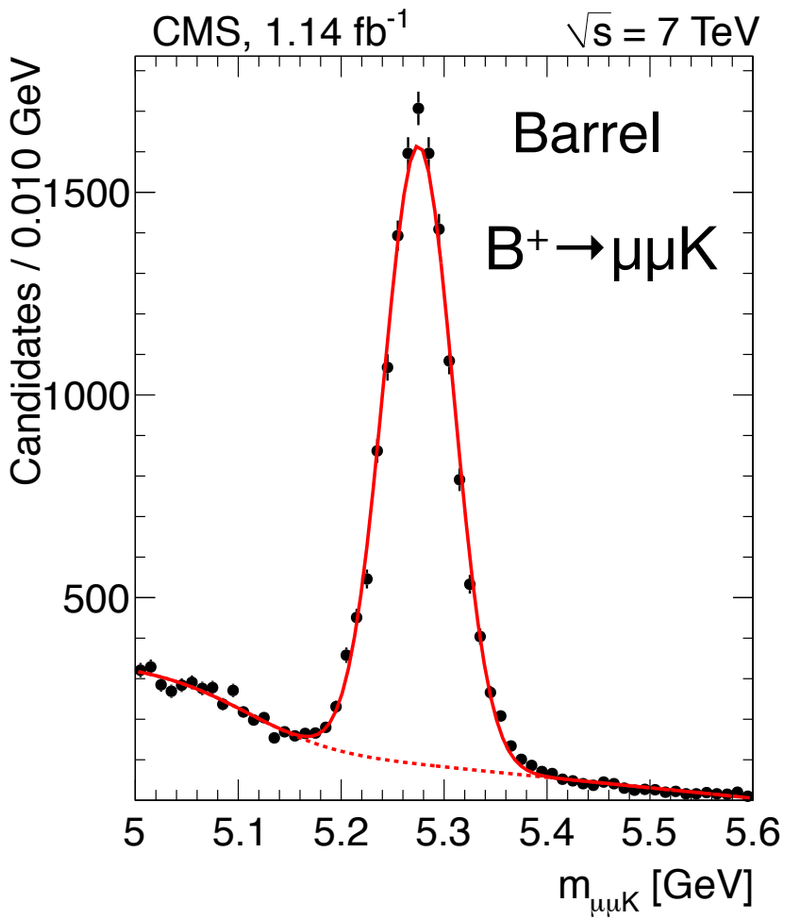
Muon Trigger Performance

Triggers with full acceptance in pseudorapidity

- Workhorse single muon with $p_T > 16$ GeV
- Di-muon trigger with high quality requirements, **no p_T threshold**

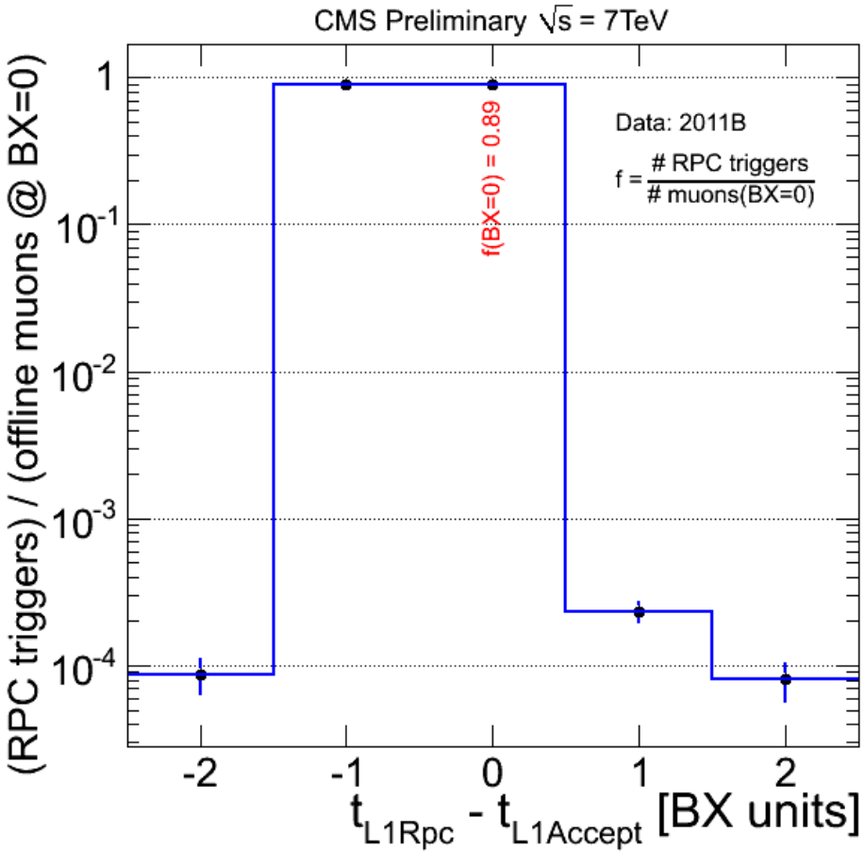
Efficiency of Single Muon Trigger
$p_T > 16$ GeV, $|\eta| < 2.4$





Di-muon trigger critical for $B_S \rightarrow \mu\mu$
Apply invariant mass cuts at HLT

Muon Trigger Performance

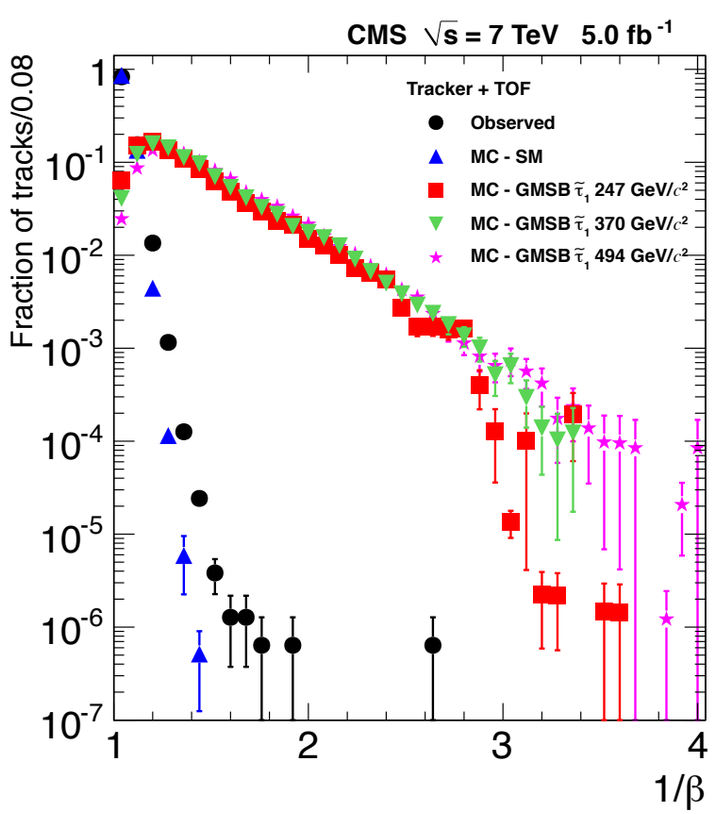


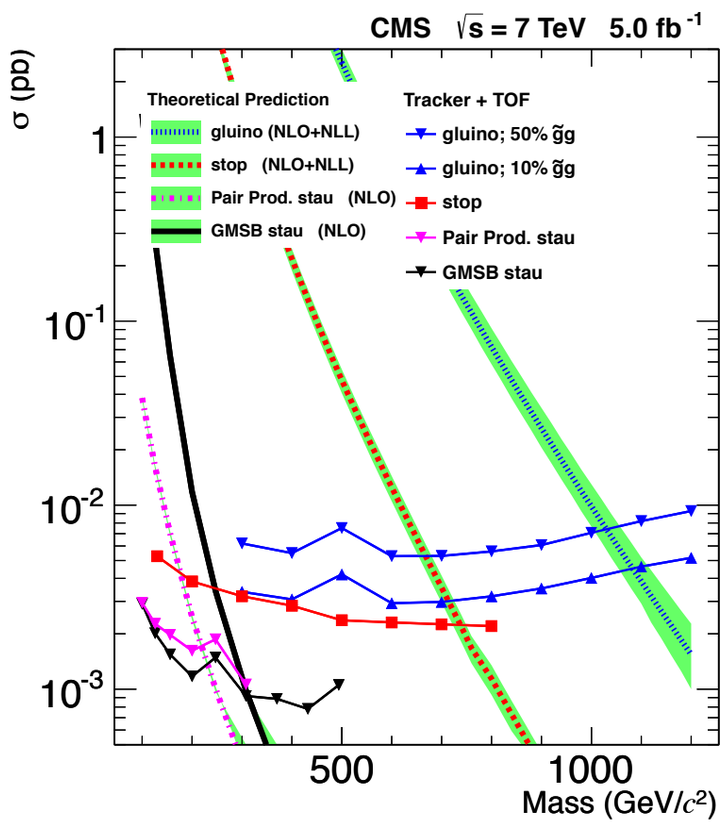
Special trigger for Heavy Stable Charged Particle searches

- Implemented during 2011 run
- Possible due to 50ns LHC bunch spacing

Synchronisation in RPC pattern comparator

- Expand the pulse width to cover two BX
- Muon arriving 1 BX after collision will produce trigger in time with the collision

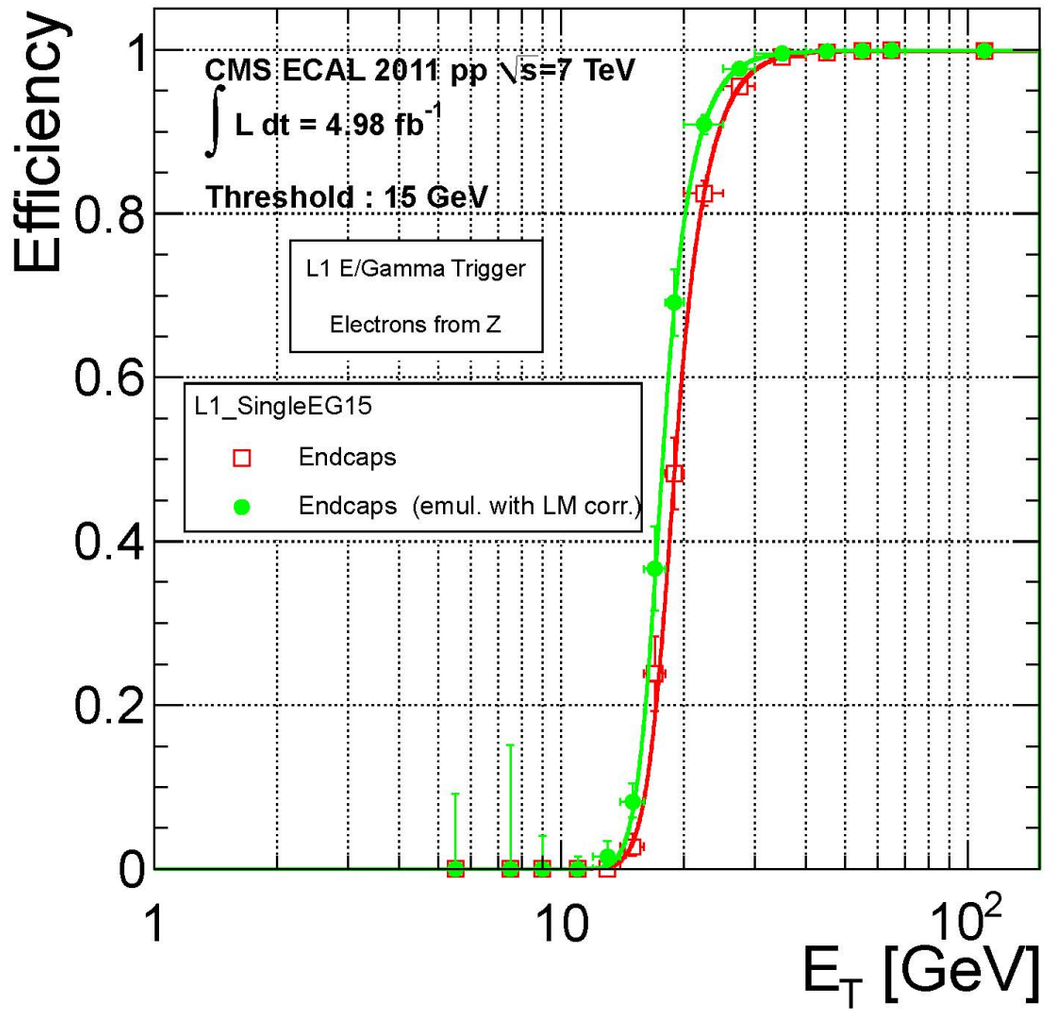




e/γ Trigger Performance

Much work done to improve performance between 2011 and 2012

- Irradiation of ECAL crystals results in significant reduction in transparency, and hence light yield
- Corrections for this are now applied
- 95% efficiency point (for 15 GeV threshold) improves from 35 to 30 GeV

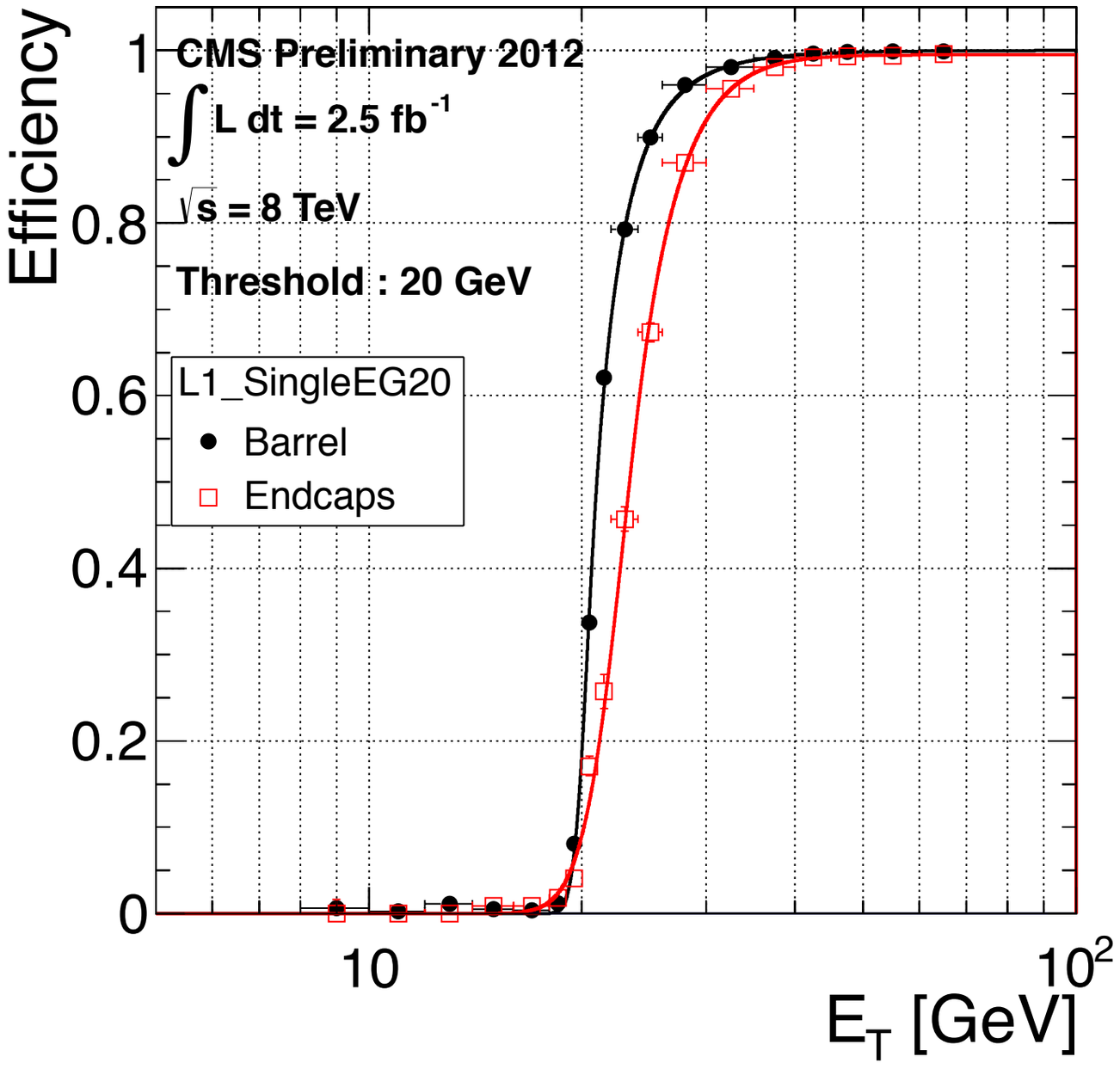


Anomolous signal rejection

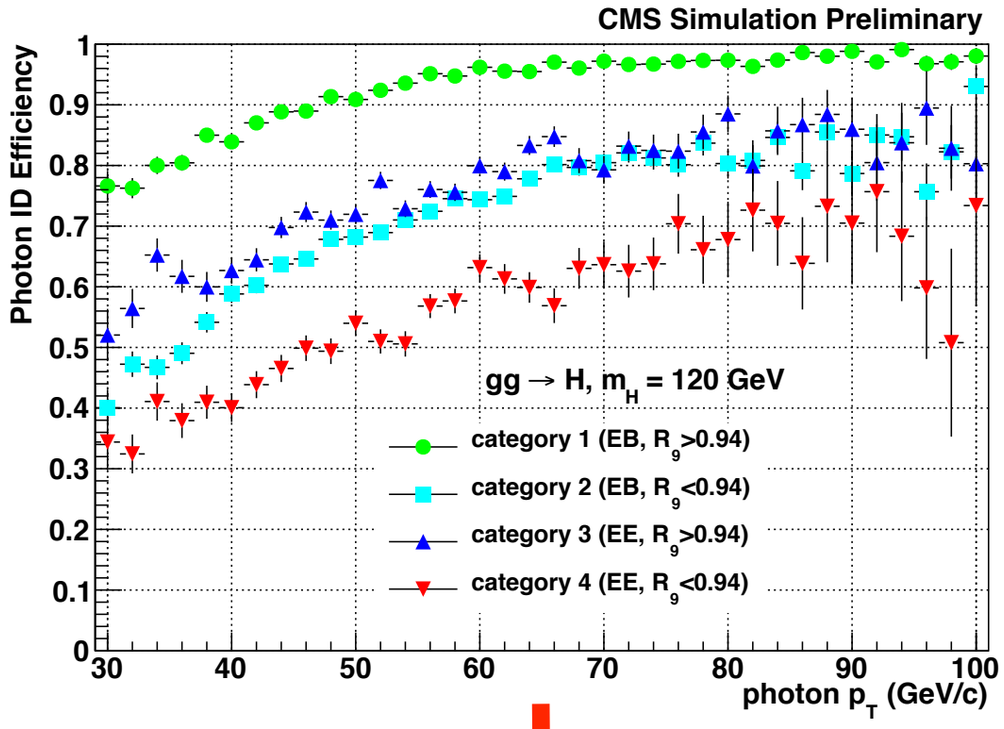
- Direct ionisation in APD - single crystal with large E
- Algorithm optimised to improve performance at high PU

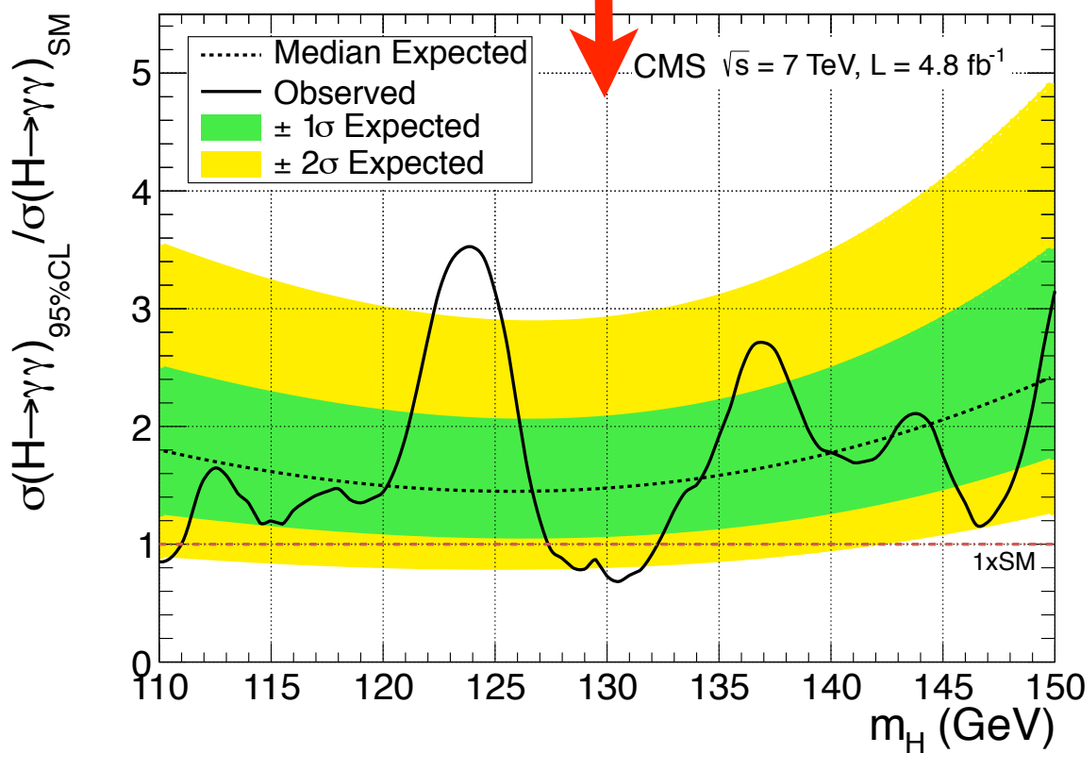
e/γ Trigger Performance

L1 Single EG efficiency

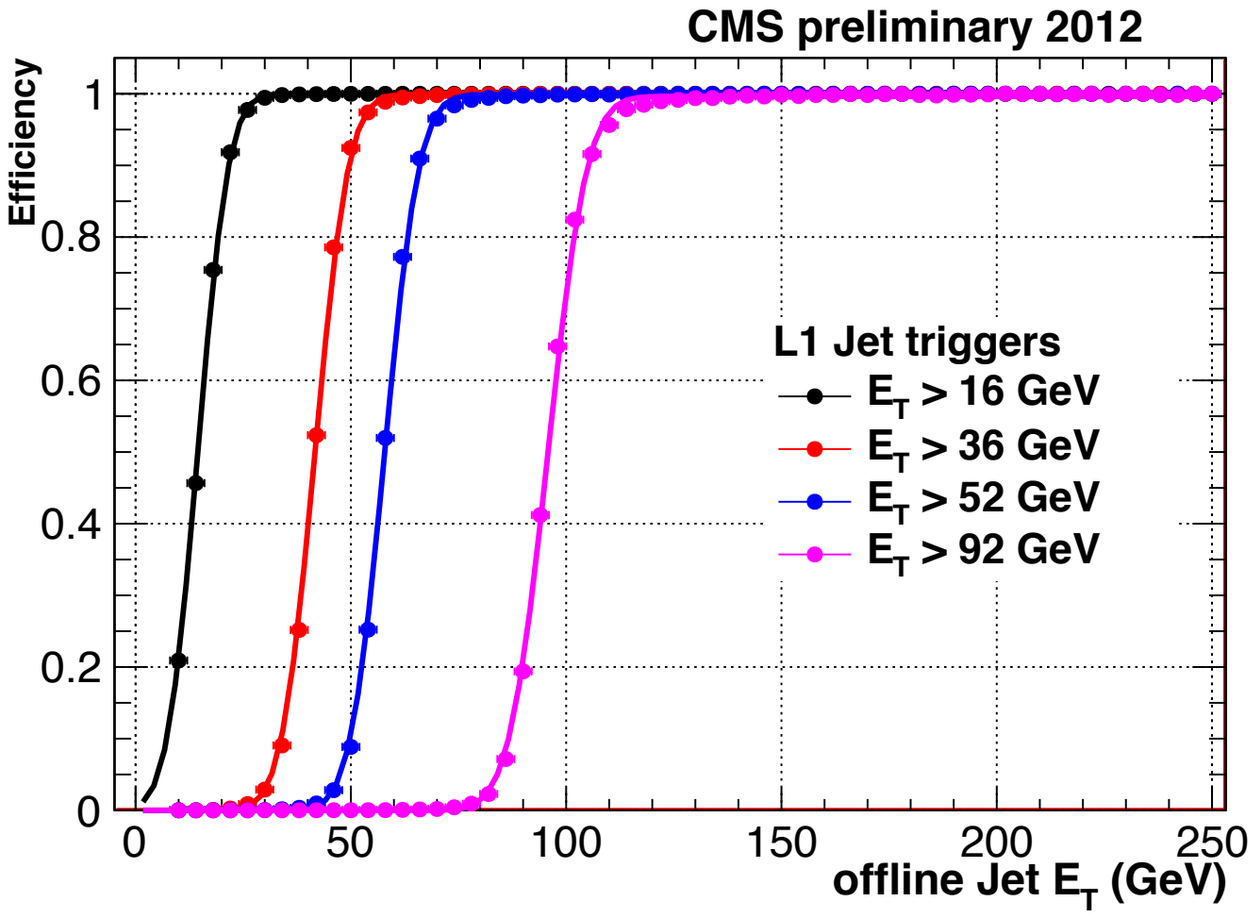


Di-photon e/γ trigger (13,7 GeV) is critical for H→γγ



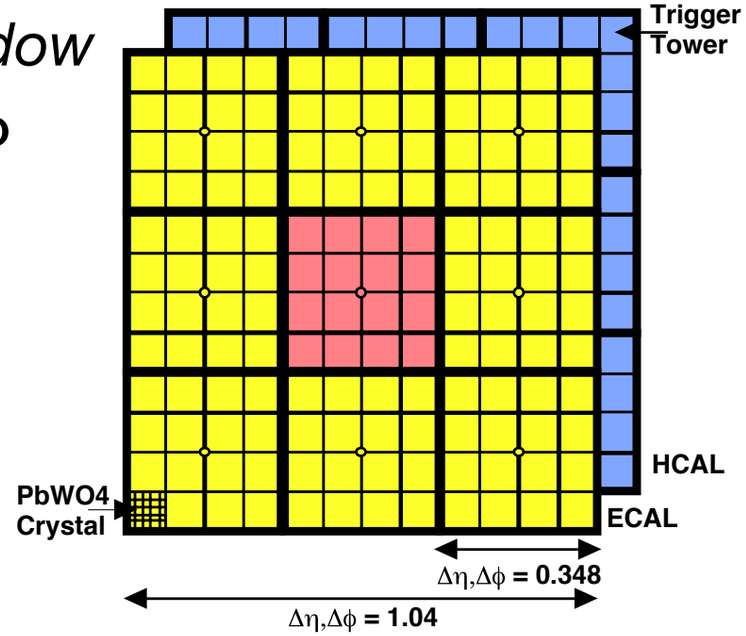


Jet Trigger Performance



L1 Jet Window

*1.0*η × *1.0*Φ



Perform jet finding out to |η| < 5.0

Apply MC-based JES corrections

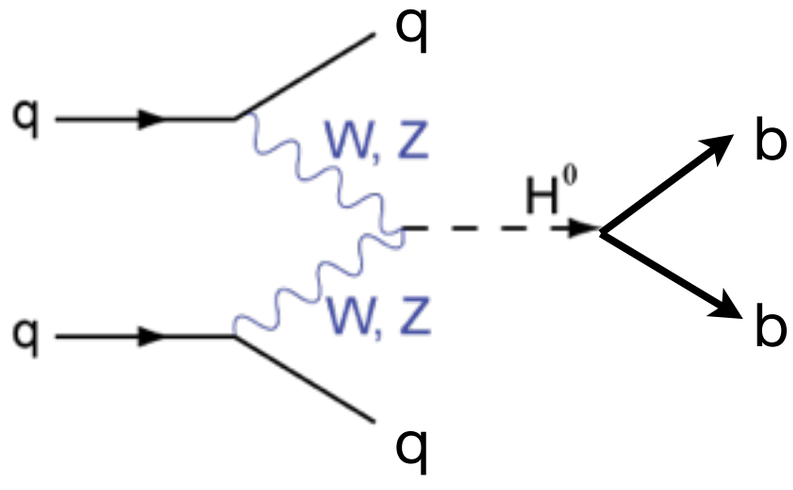
Topological conditions in Global Trigger

For H→bb in VBF

- TriJet trigger with E_T > 68, 48, 28 GeV (~7 kHz)
- Require all central, or one forward and two central

For MSSM bbH→bbbb

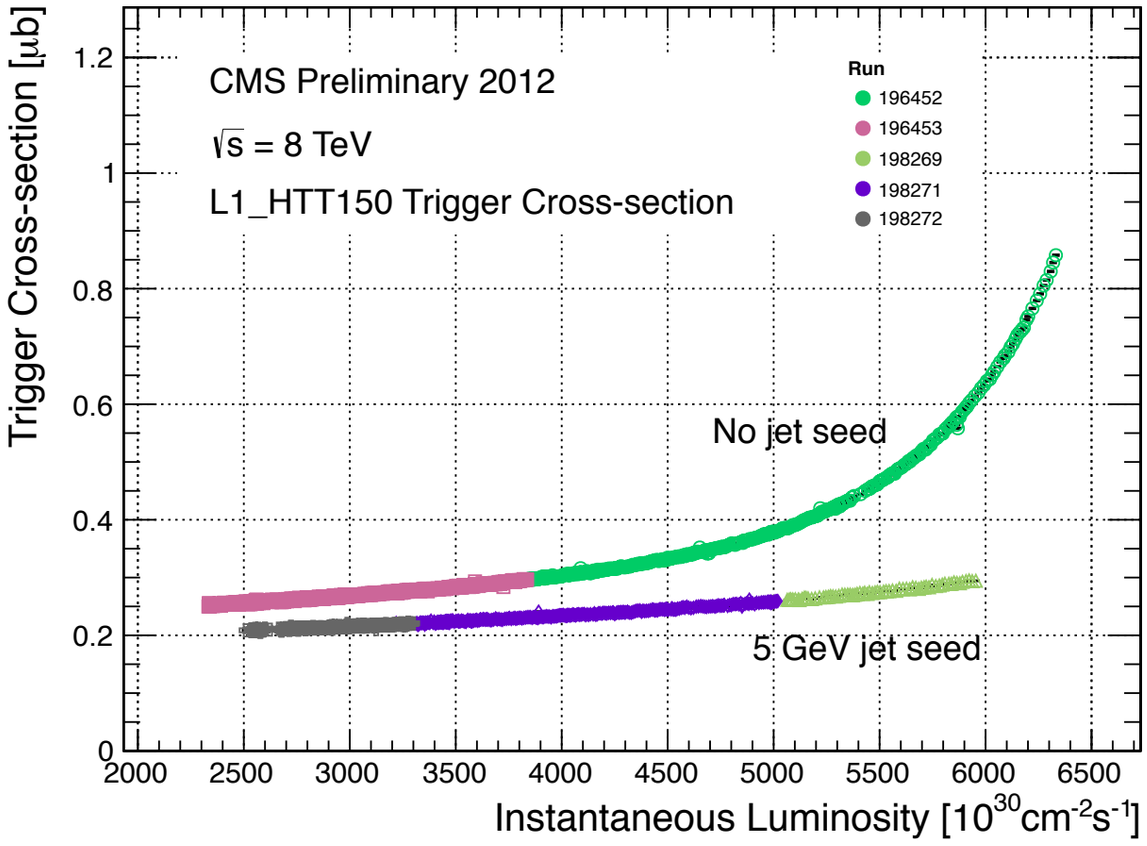
- TriJet trigger with **E_T > 20, 12, 12 GeV**
- Require **one jet within ΔΦ<50°, Δη<1.3 of a muon** (p_T > 10 GeV)

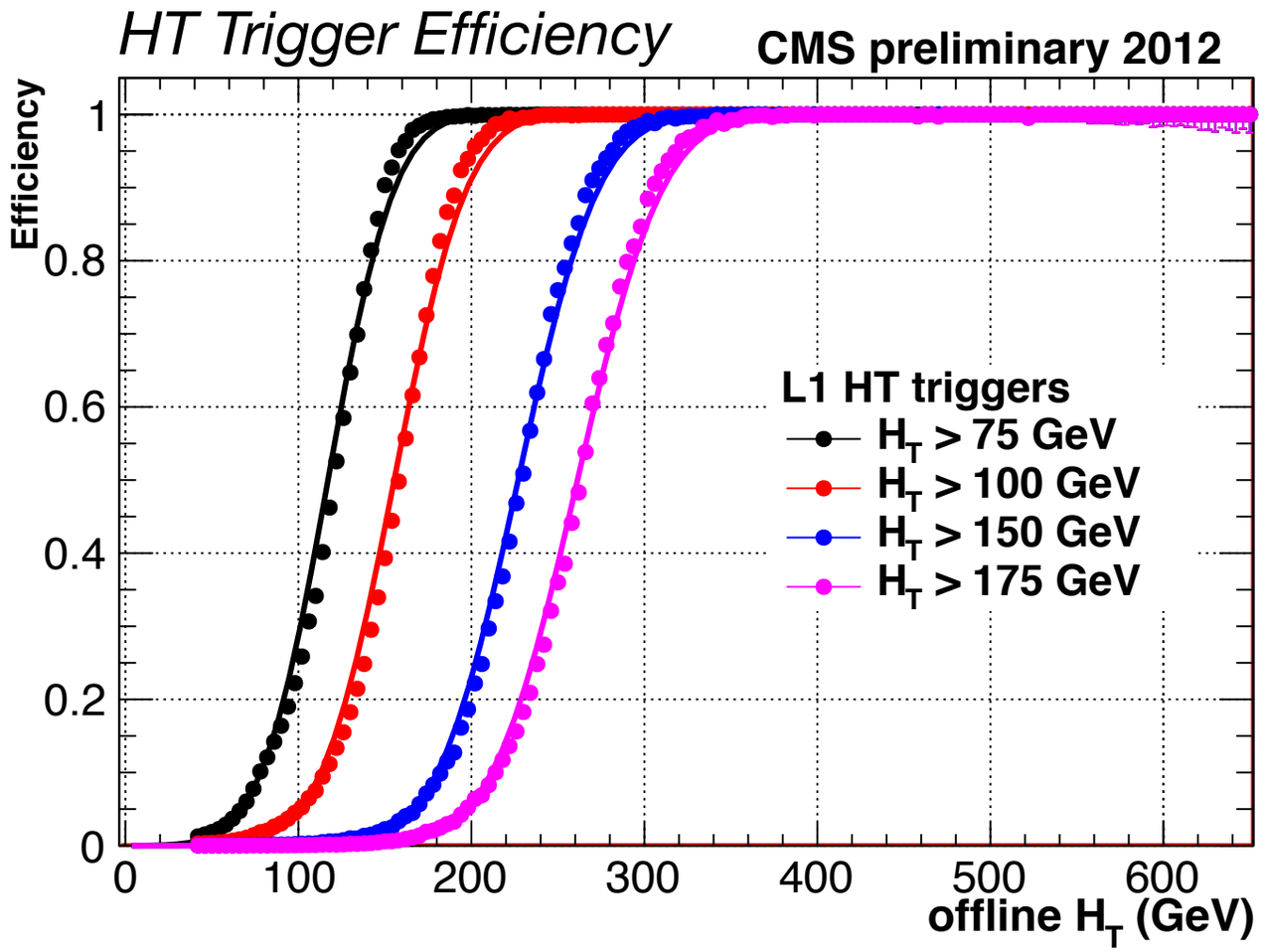


Energy Sums Performance

H_T

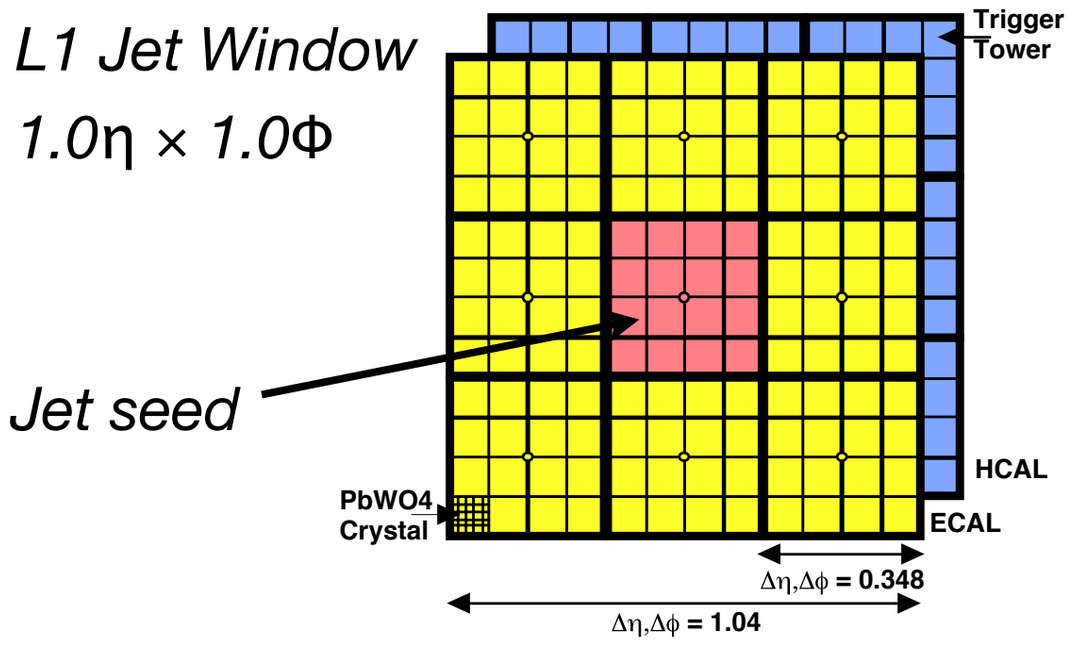
- E_T sum over jets with E_T > 10 GeV, $|\eta| < 3$
- Used extensively by searches





Pile-up

- Low E_T jet multiplicity increases with PU
- H_T trigger rate **strongly dependent on PU**
- Mitigate by using a **threshold on the "jet seed"**

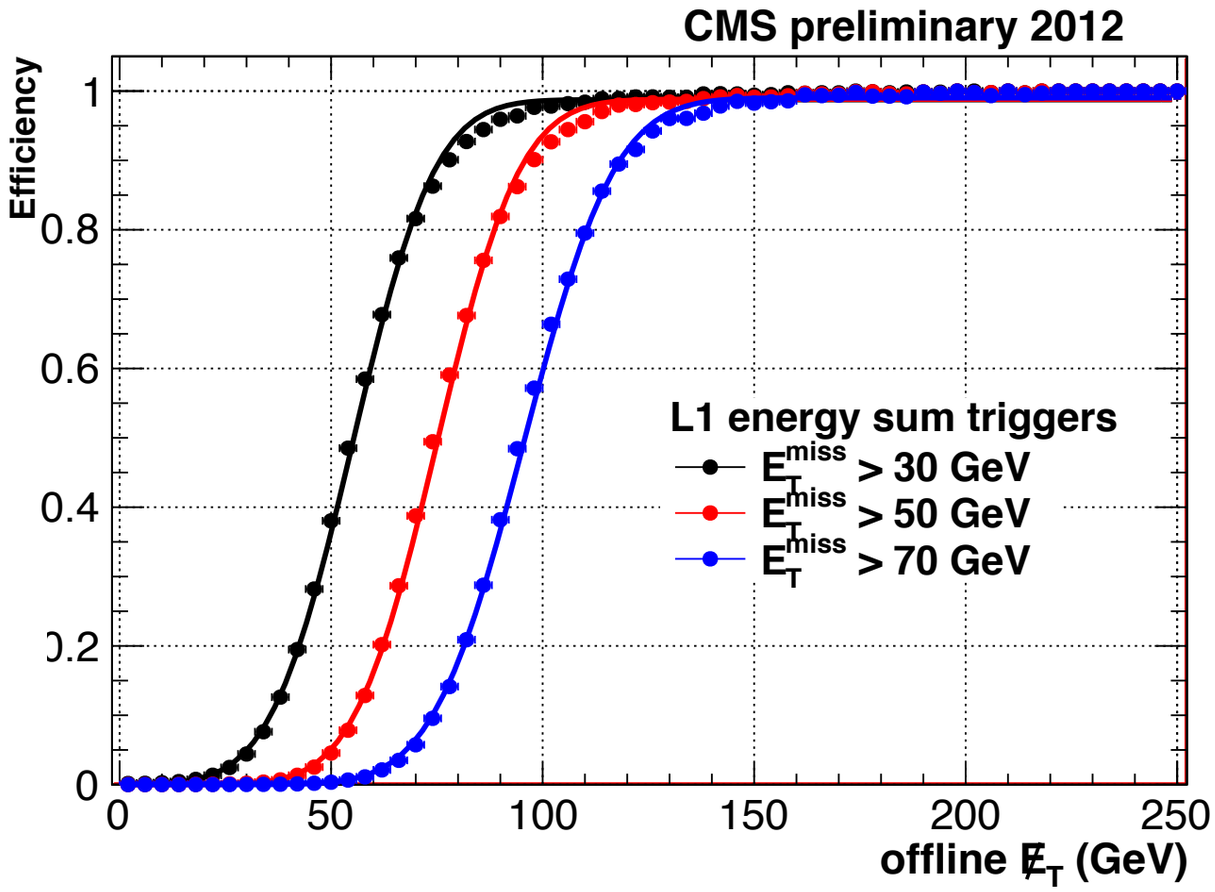


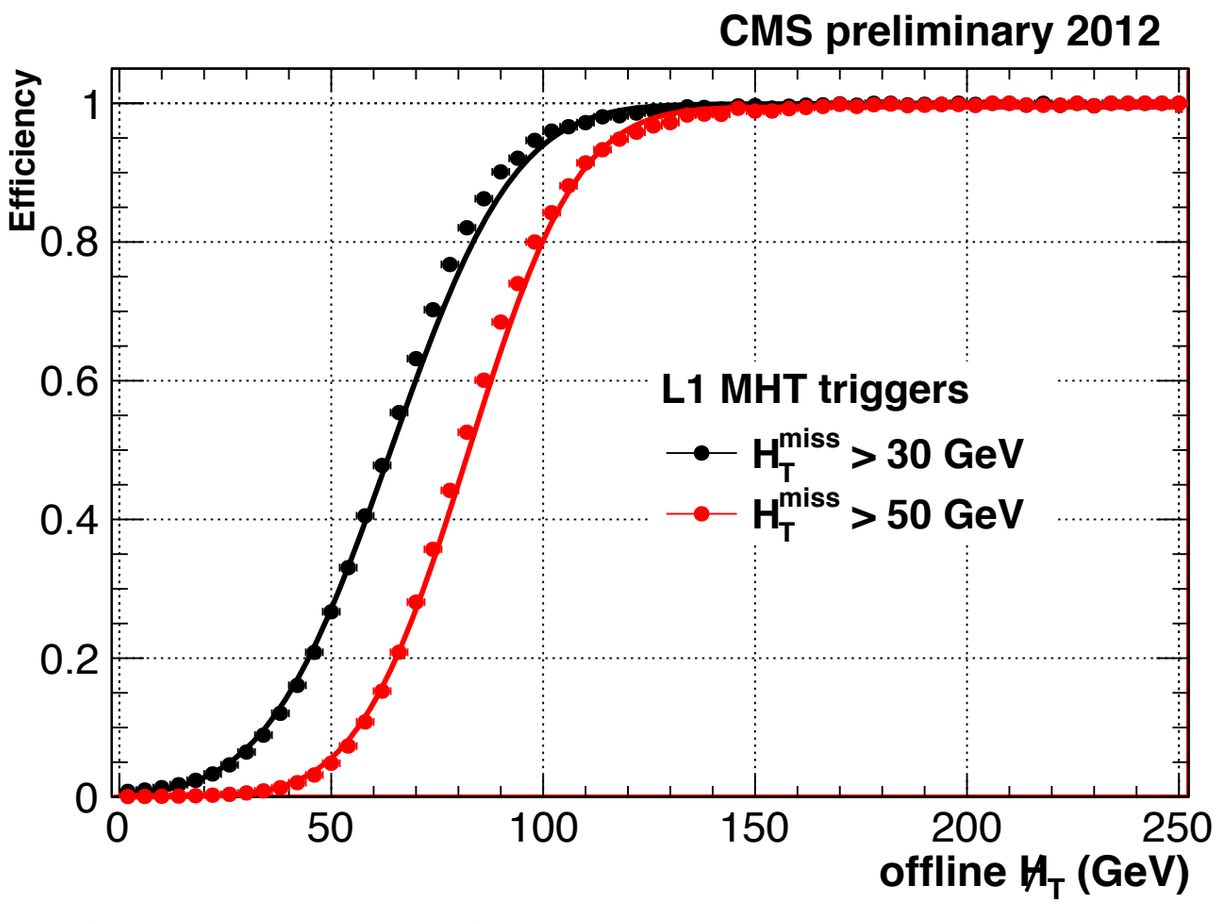
Energy Sums Performance

MET

- Sum over calorimeter towers with $\eta < 3$
- $E_T^{miss} > 36$ GeV

Used extensively by SUSY/EXO searches





Missing HT

- Vector sum over identified jets ($E_T > 10$ GeV, eta < 3.0)

Not currently in use, but may offer improved rate vs threshold over E_T^{miss}

Summary

CMS Level-1 Trigger is delivering events for physics

- Total rate up to 100 kHz, while maintaining low deadtime (~3%)

Much work has been done since 2011 to reduce rates and maintain low thresholds

- Currently running **single μ with E_T > 12 GeV** ($|\eta| < 2.1$)
- Maintain threshold for **single e/γ at E_T > 20 GeV**

Additional μ rate reduction during last technical stop!

Pile-up has been a challenge for jet and HT triggers

- Addressed by using a threshold on the jet seed

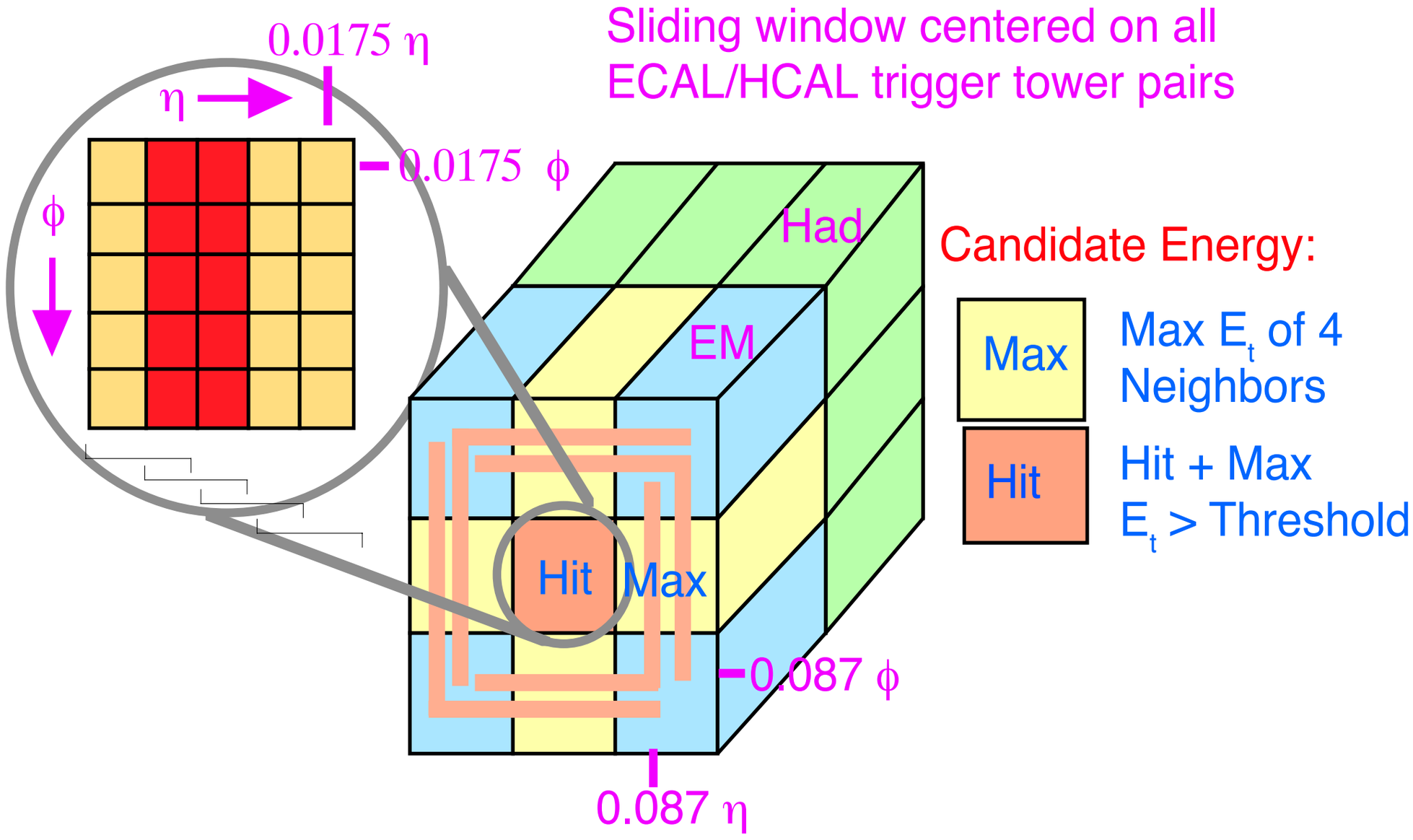
We run a variety of dedicated triggers to maximise physics

- High quality, low threshold **di-muon triggers for onia**
- **Delayed muon triggers**
- Topological triggers for difficult jet signatures
- And more...

Expect to maintain good performance throughout the 2012 run, at up to $L = 8\times10^{33}$ $cm^{-2}s^{-1}$

Backup

e/γ Algorithm



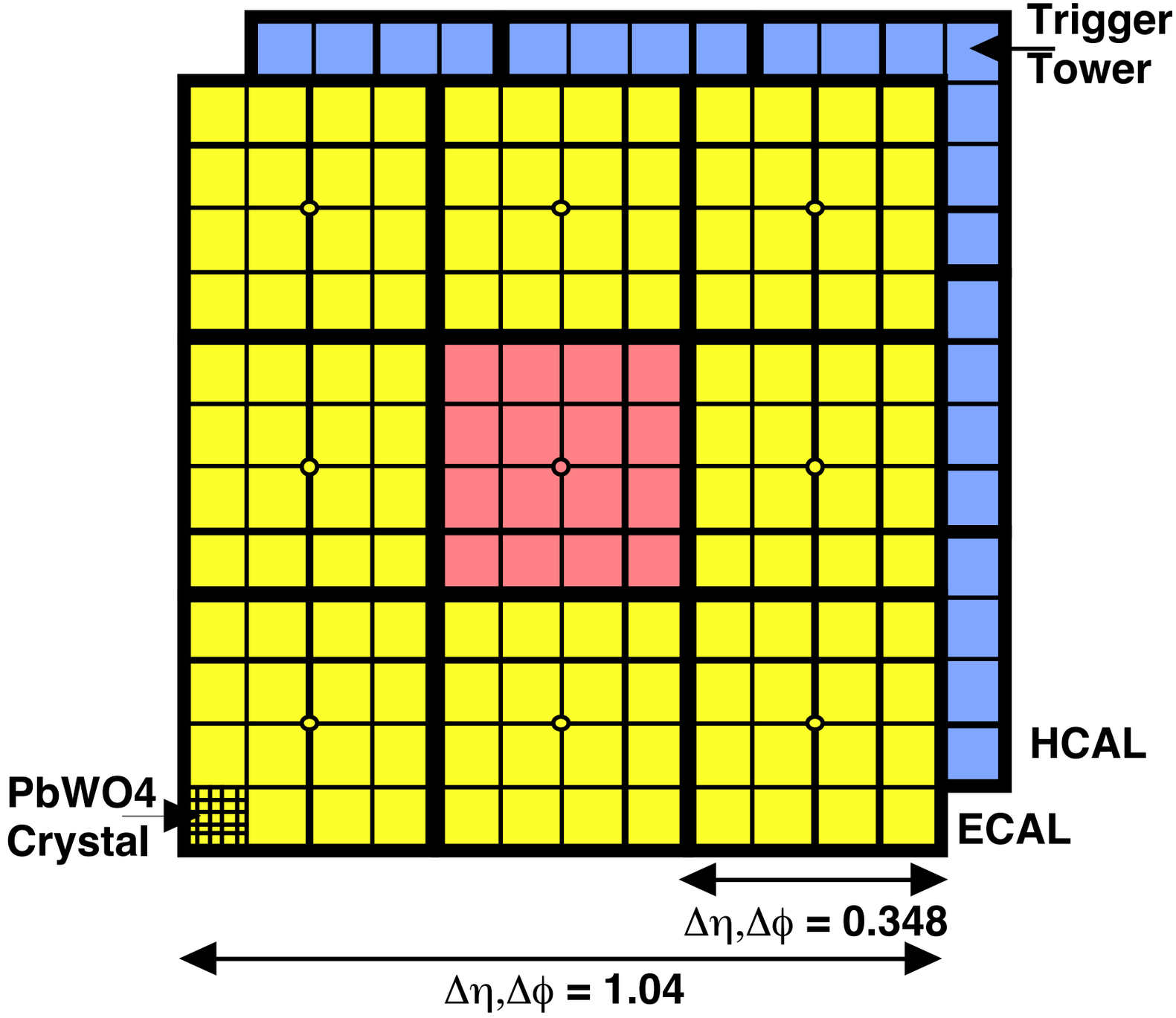
Sliding window centered on all ECAL/HCAL trigger tower pairs

Candidate Energy:

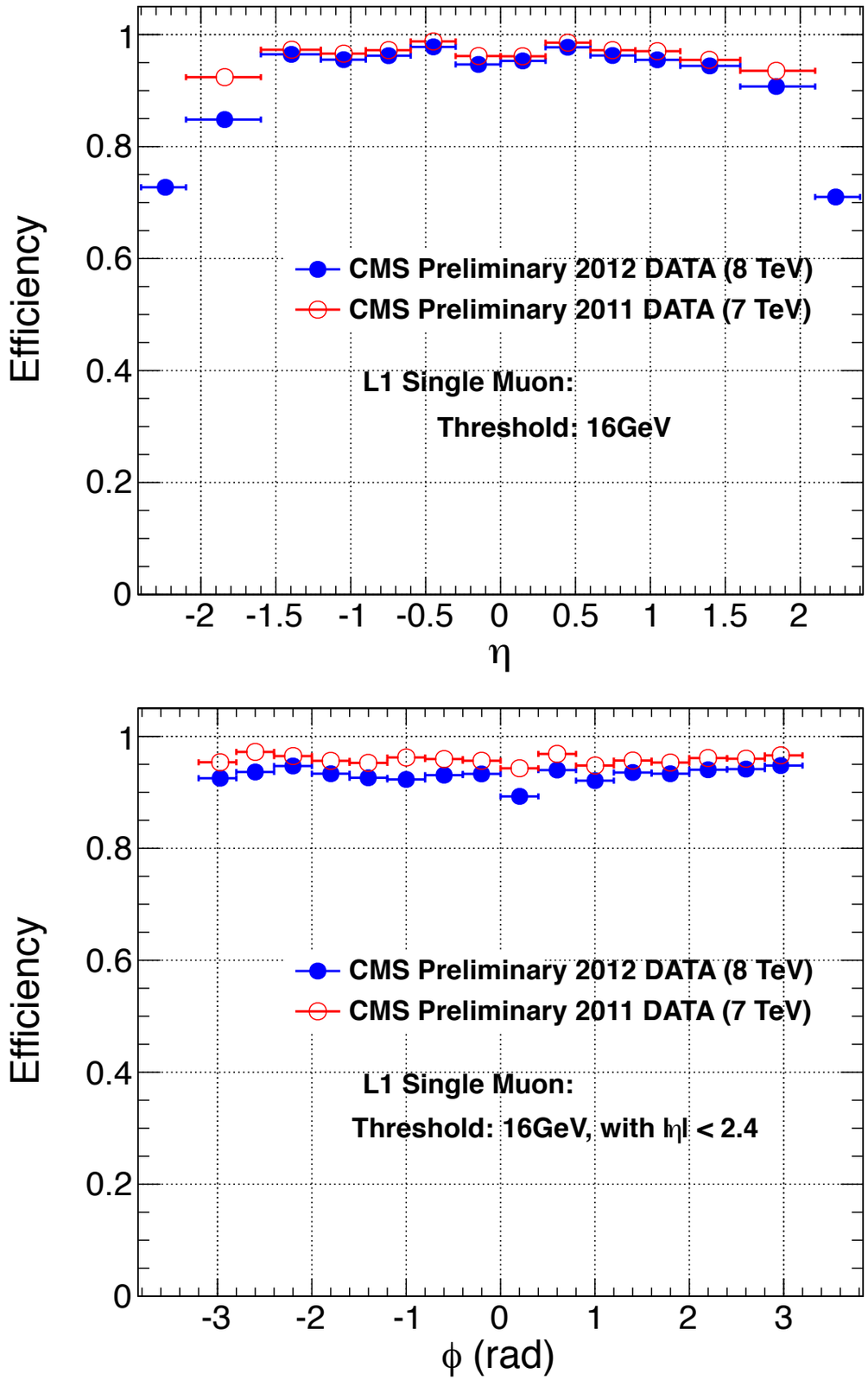
Max — Max E_t of 4 Neighbors

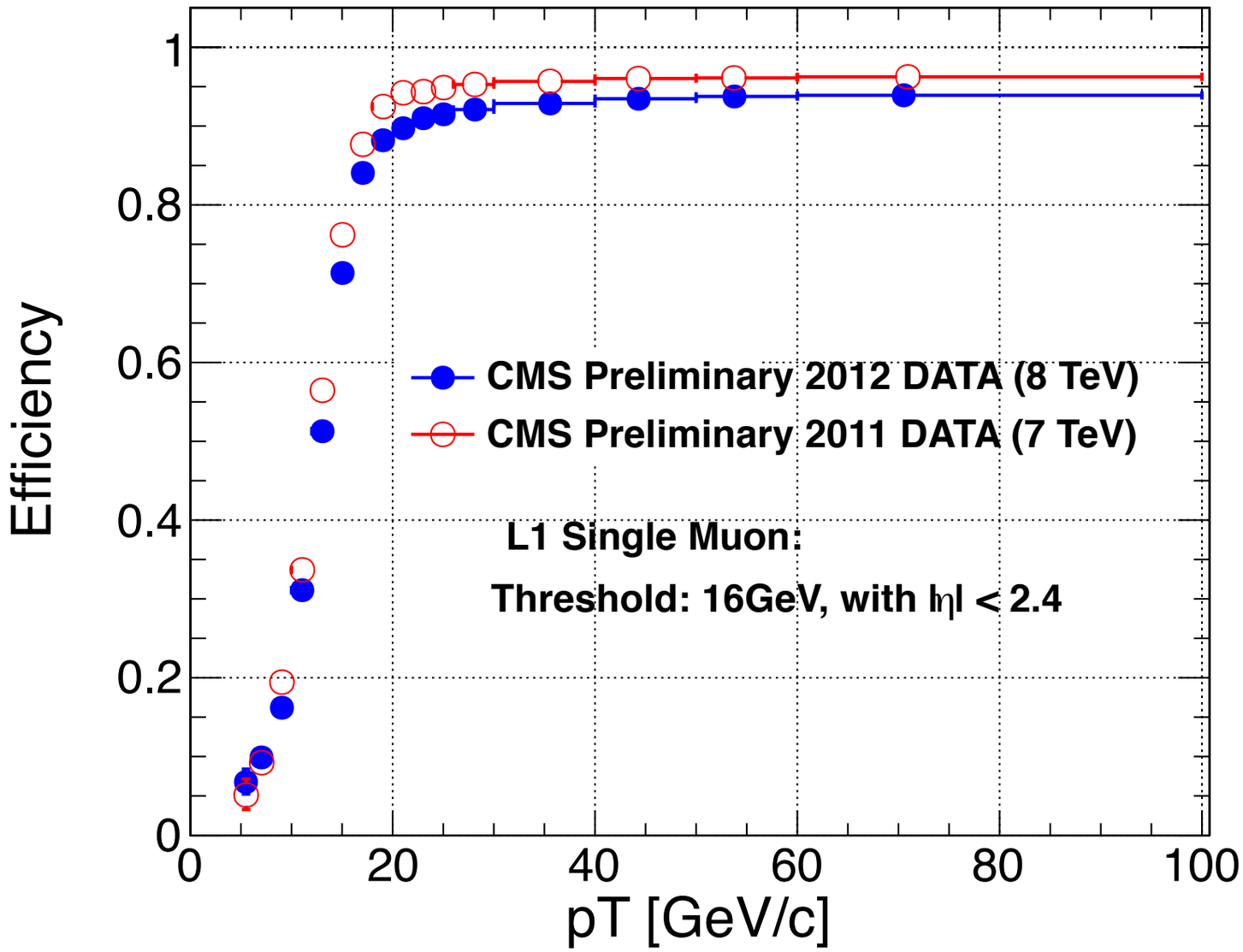
Hit — Hit + Max E_t > Threshold

Jet Algorithm



Muon Trigger Performance





L1 Single Muon Trigger Efficiency
p_T>16 GeV, |η|<2.4