The CMS
High Level Trigger

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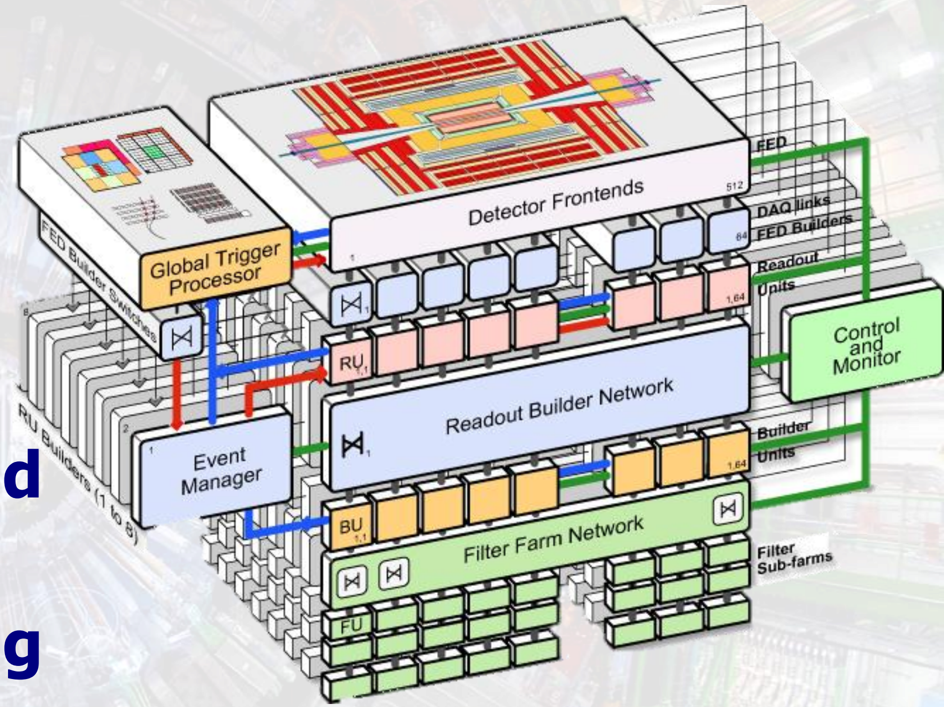
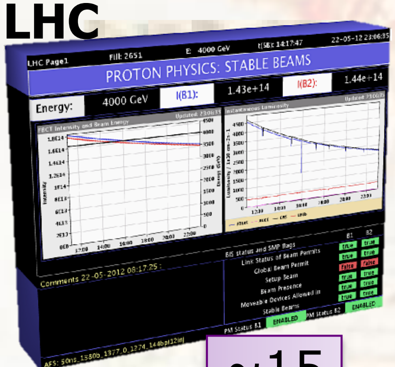
Outline

- **HLT Description**
- **2011 vs 2012: Challenges:**
  - **Pile Up**
  - **Particle Flow**
  - **Ecal Light Corrections**
- **Performance on Physics and HLT summary**
- **Data Parking/Data Scouting**
- **Conclusion**



High Level Trigger

LHC



~15 MHz

FPGA and custom ASIC technology

Level 1
(Jim Brooke talk)

~100 kHz

High Level Trigger

software on a filter farm of commercial rack-mounted computers, comprising over 13000 CPU

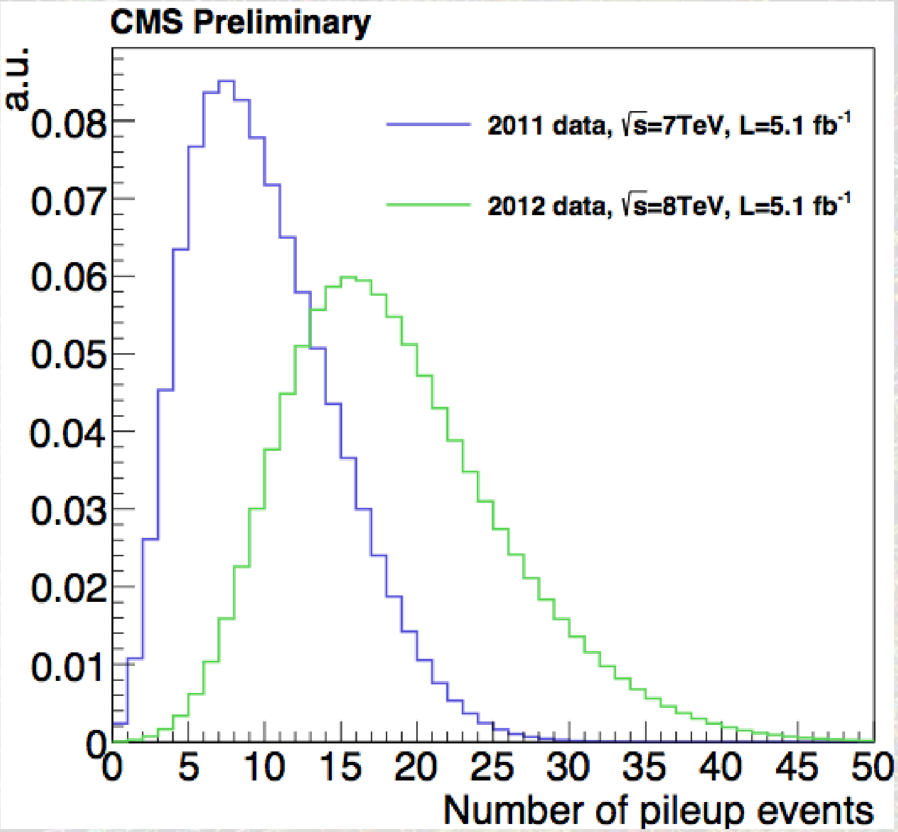
Alignment, Calibration and Luminosity (Event Size ~kB)
- 500Hz LumiPixel
- 10 kHz Pi0/Eta
- 1.5 kHz EcalPhiSym
- 1.5 kHz RPCMonitoring
- 100 Hz Calibration

Physics (Full Event Content), Scouting (Event Size ~kB)
- 1 kHz Stream A
- 40 Hz Express
- 1.2kHz Data Scouting

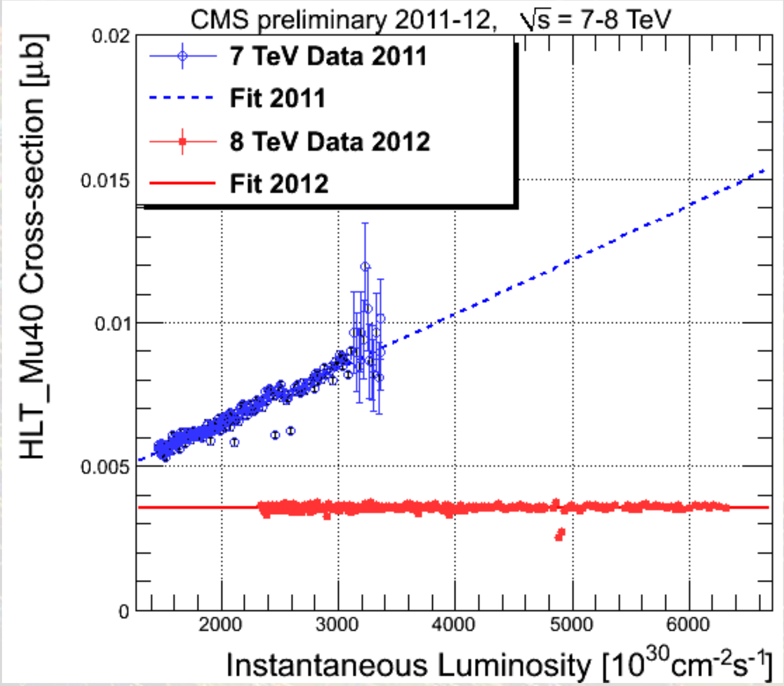
Trigger Studies (Event Size ~kB)
- 10 kHz NanoDST

Data Quality and Monitoring (Various Event Content)
- 25 Hz Stream B
- 75 Hz DQM
- 1 kHz HLTDQMResults
- 150 Hz HLTDQM
- 20 Hz HLTMonitoring

New Challenges



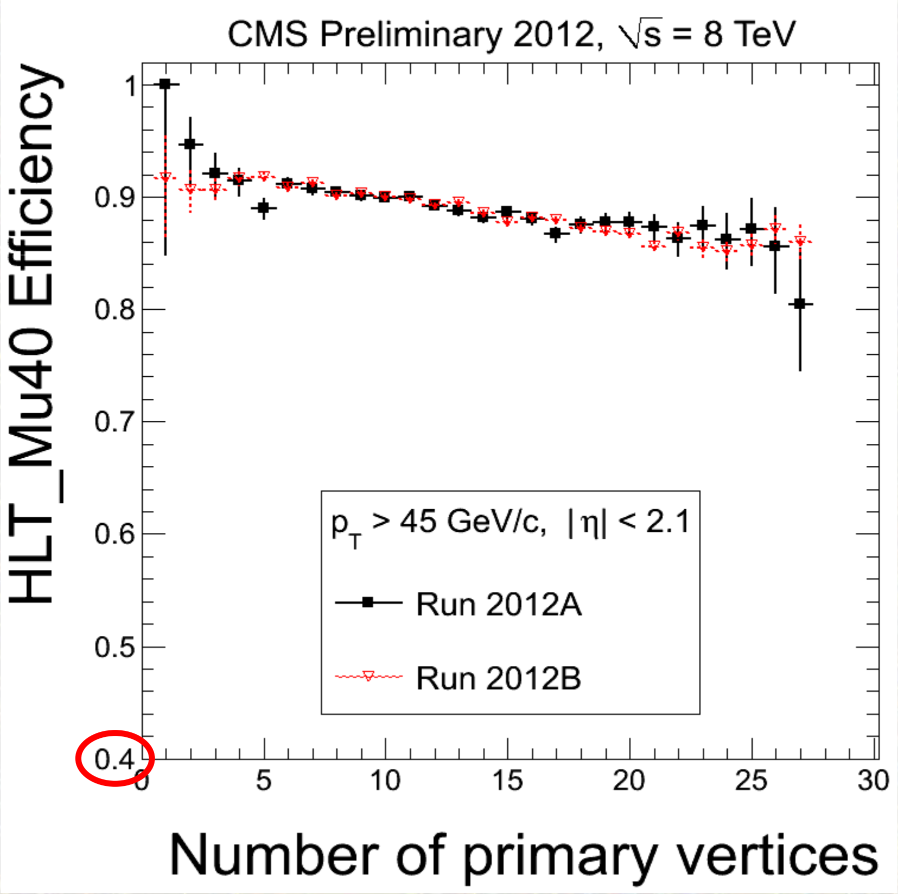
2011: $\mathscr{L}$ up to 3.5 Hz/nb
2012: $\mathscr{L}$ up to 6.5 Hz/nb
→ Code improved to reduce pile up dependence

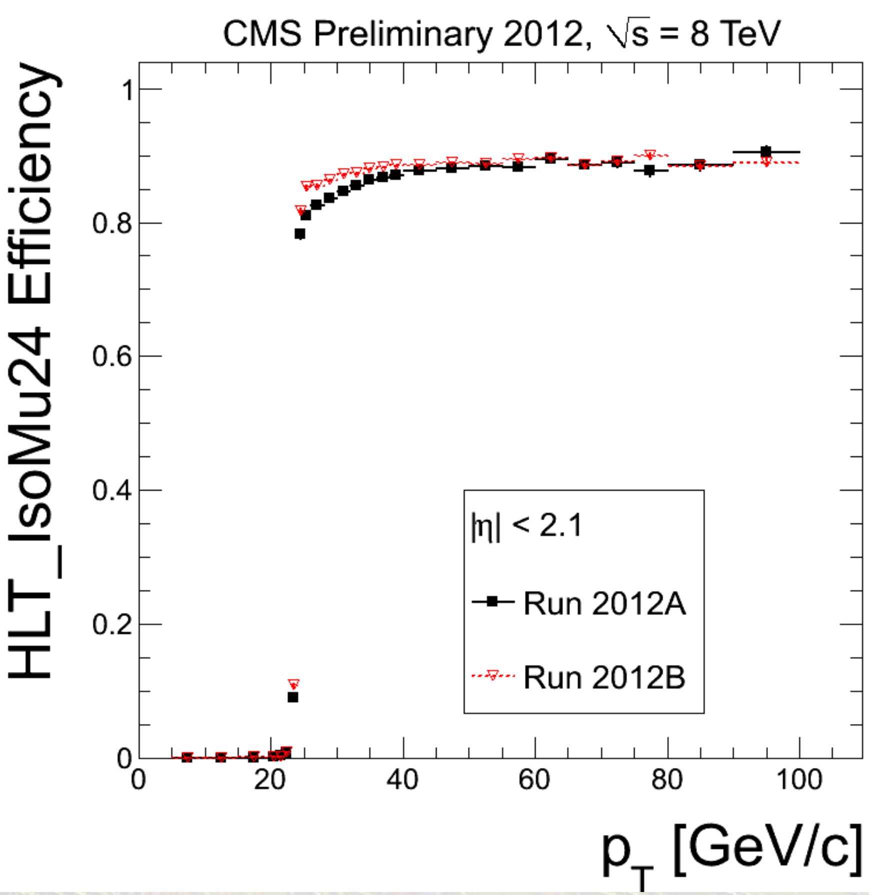


Muon cross section at HLT with p_T> 40 GeV
→ Lower and flat in 2012 thanks to better track quality cuts

Single Muon Efficiency

→ **Keep good performances wrt 2011**

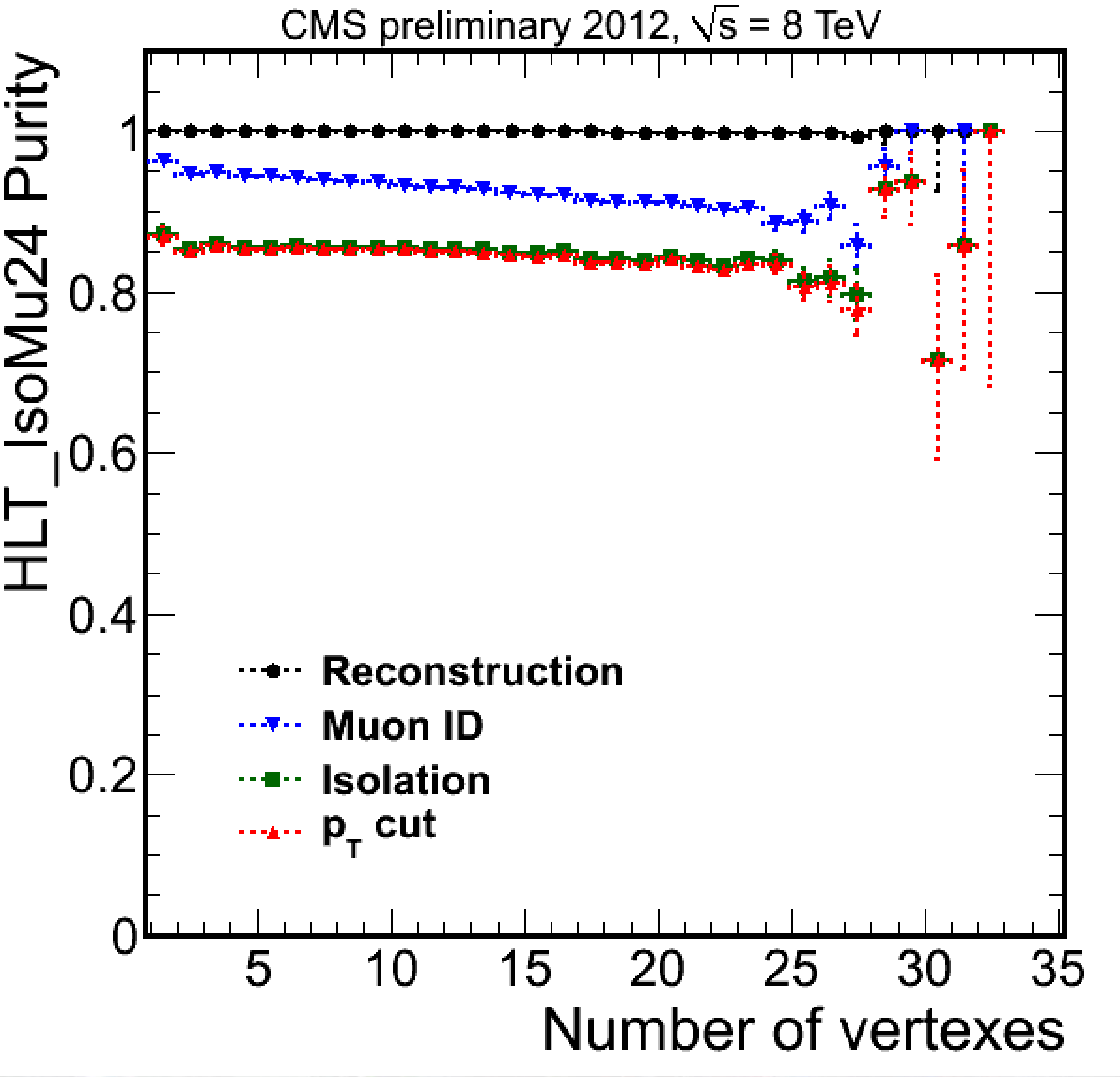




2012B trigger shows higher efficiency due to introduction of pileup corrections for isolation.

Sharp turn on curve, efficiency plateau at ~90% and stable with Pile Up.

Purity of HLT paths



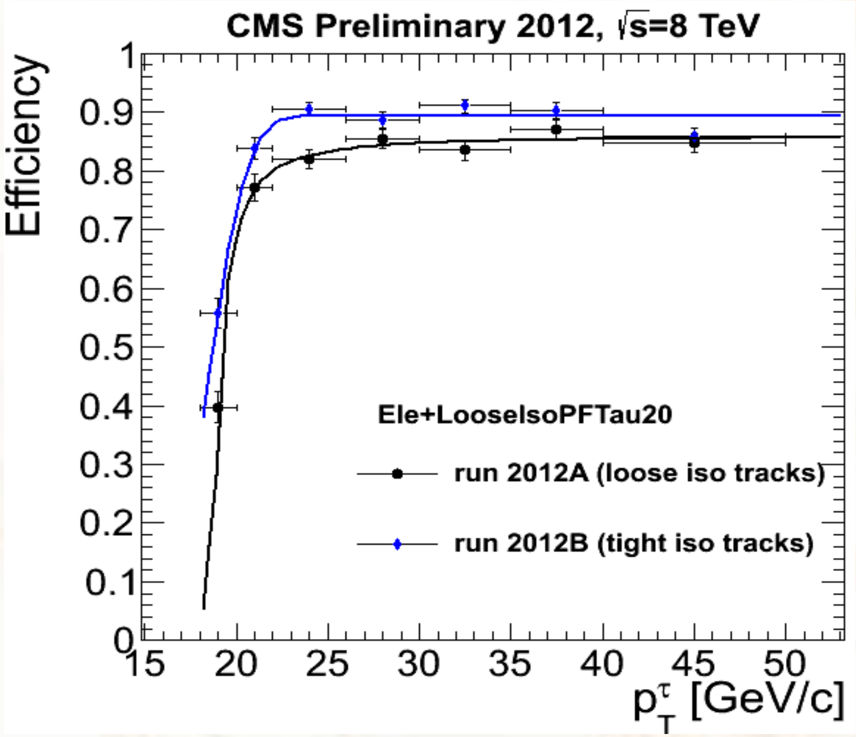
Purity is preserved with respect to pile up.

Above 80% purity in for muons.

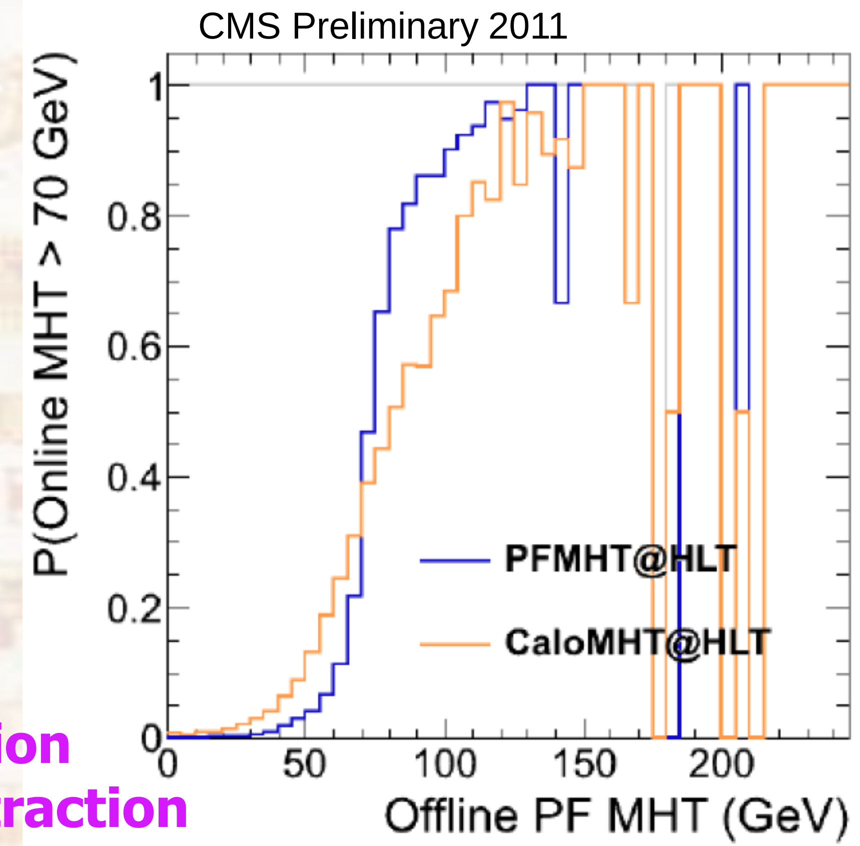
➔ Quite pure selection of objects at HLT

Particle Flow at HLT

Improve efficiency of algorithms via particle flow on the HLT farm as for offline

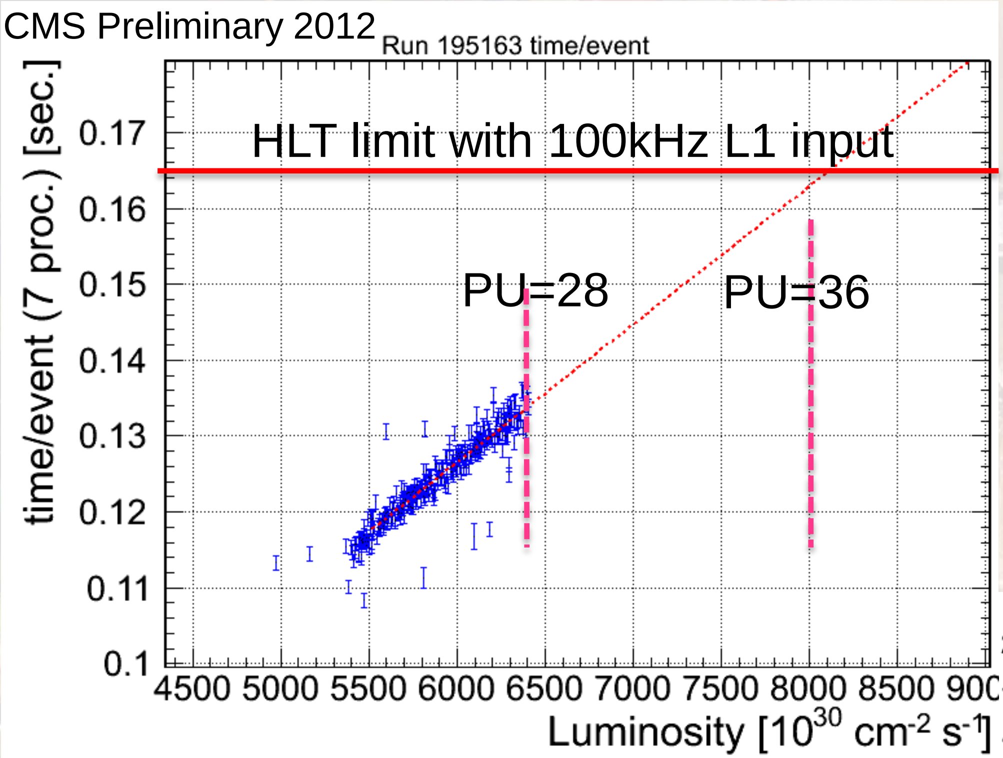


Particle flow algorithms:
- first implementation for Tau
- extension to Jets, Met, Missing HT



Particle flow algorithms:
→ Better resolution on object
→ Optimization of CPU consumption
→ Refine technics for pile up subtraction

CPU & Cross Section



HLT CPU time/evt grows linearly with Pile Up

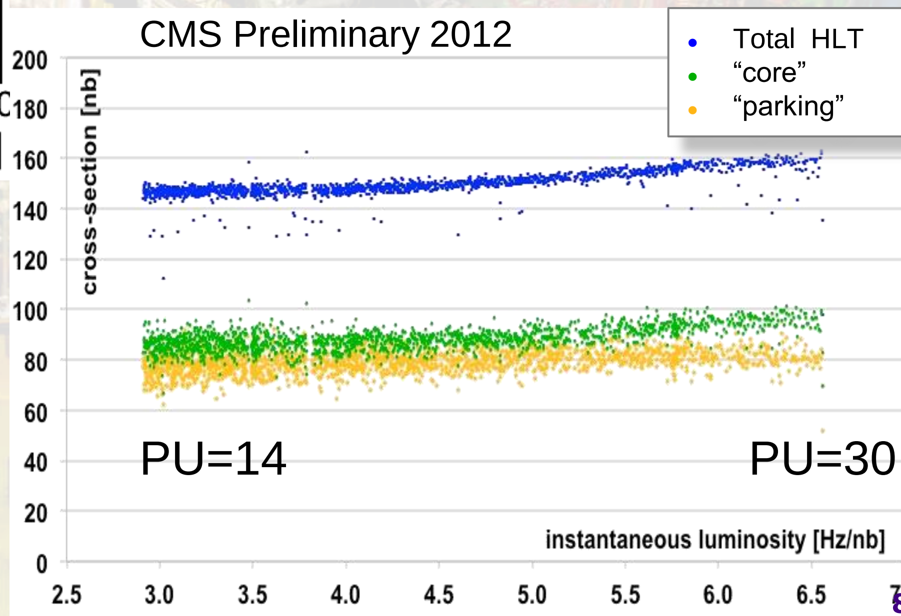
> 5 Hz/nb use extension of HLT farm

Current HLT farm [13k core] cope up to 8 Hz/nb

Cross Section almost constant among a run (=with pile up)

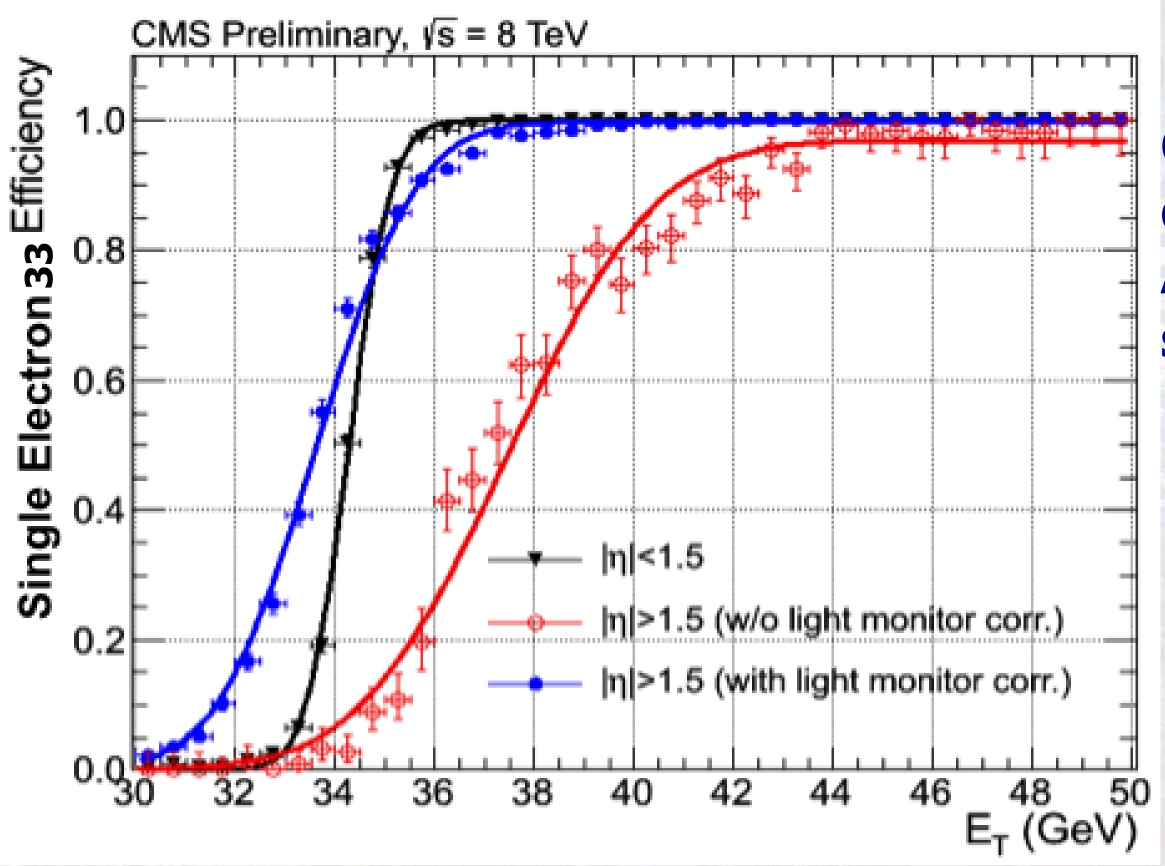
- No degradation of signal/background wrt to pile up

- A few paths with non linear increase with luminosity (working on them)



Single Electron Efficiency

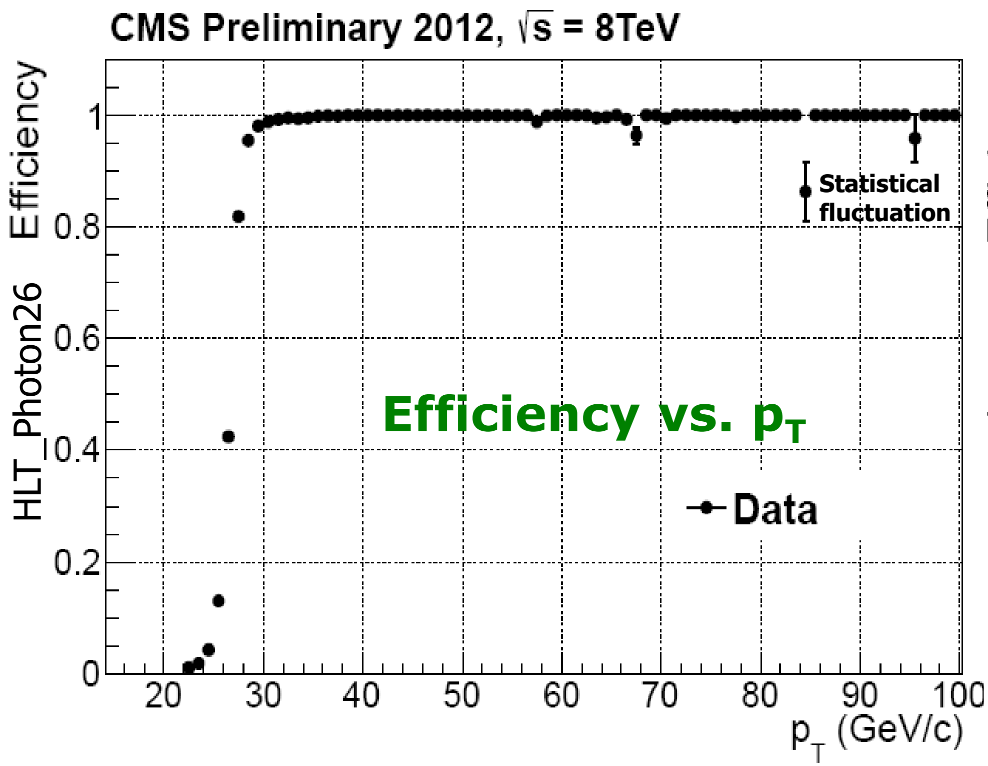
Increase of luminosity → increase of transparency losses in Electromagnetic calorimeter of CMS.

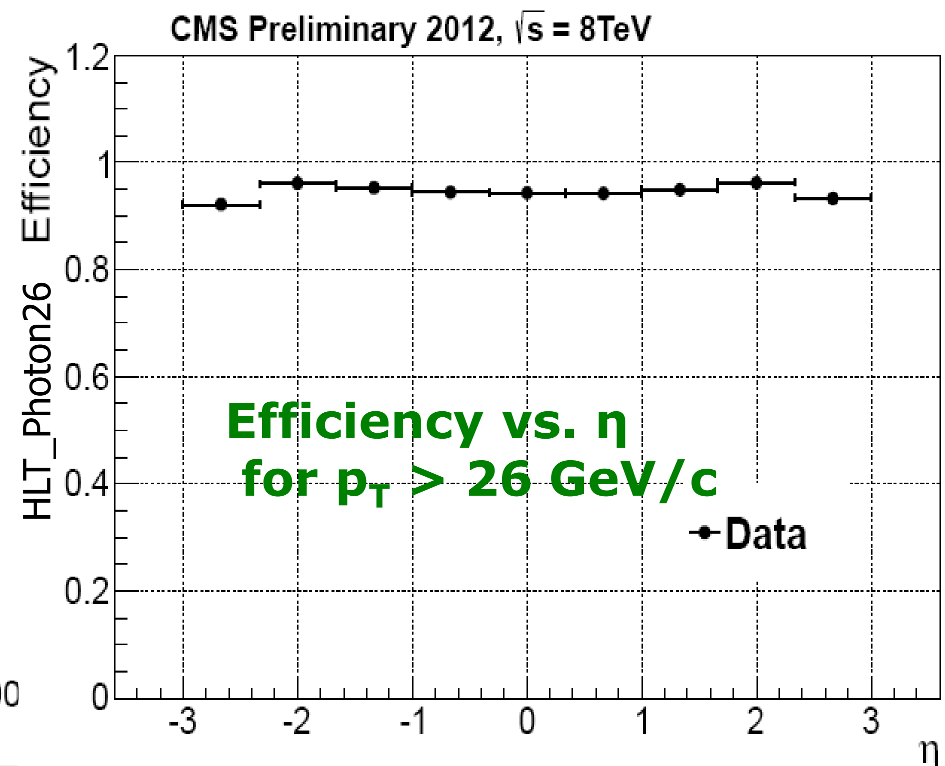


Correction to compensate derived every week in 2012. Application to Endcap only so far.

→ Improvement: steeper turn on curve and keep lower threshold than 2011 thanks to corrections.

Photon Efficiency: H→γγ



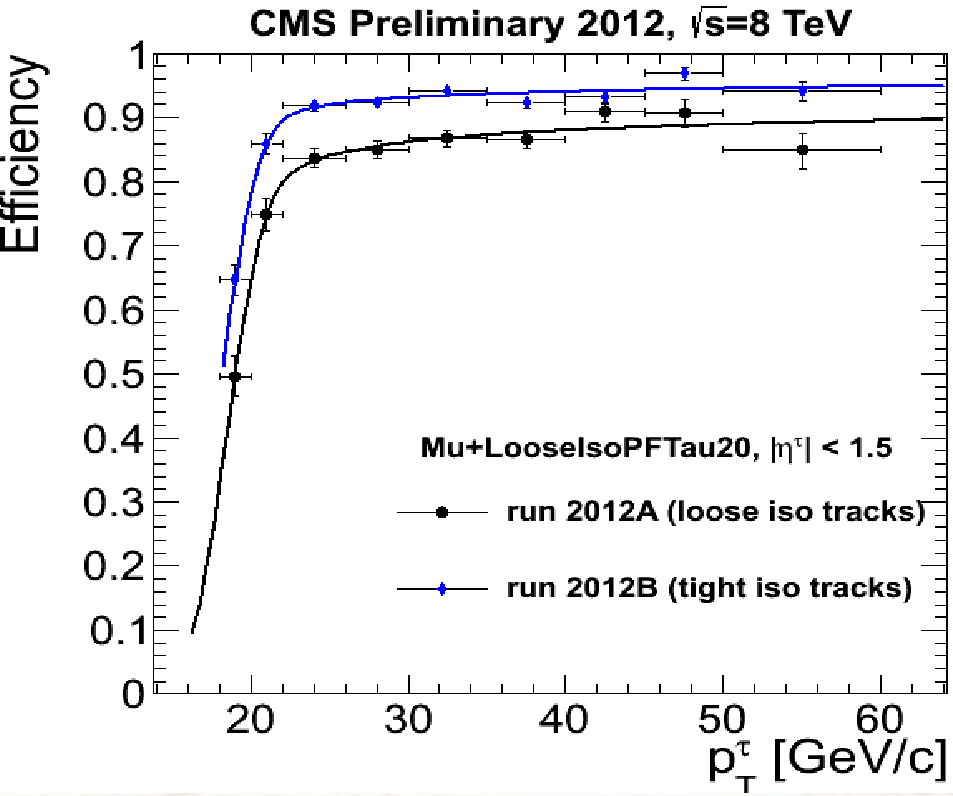


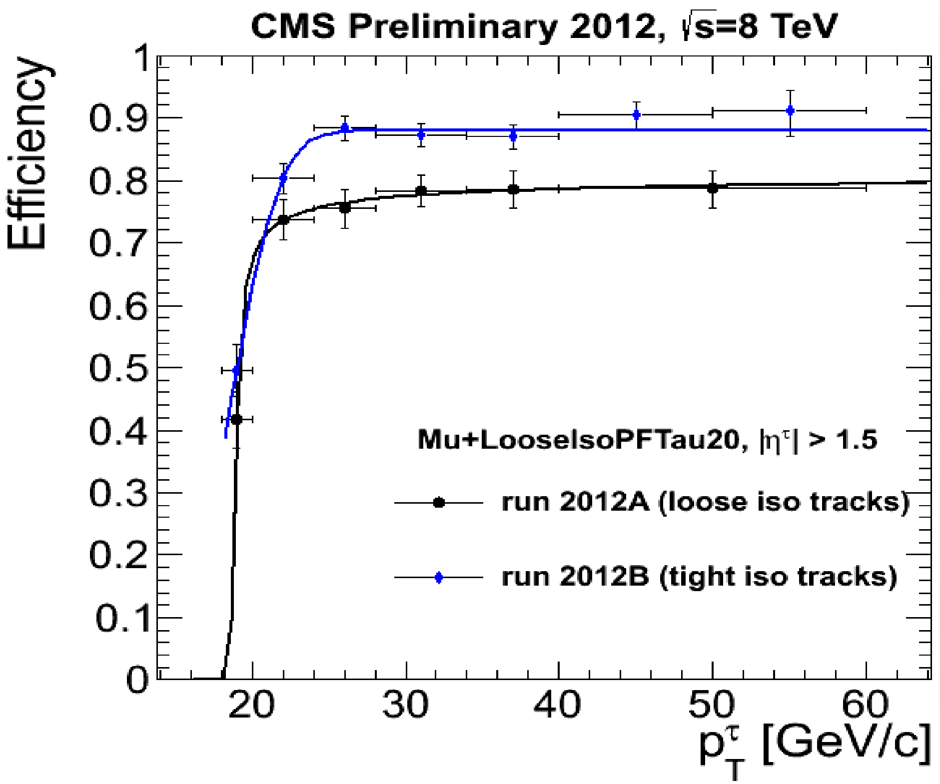
Efficiency of HLT reconstruction for photons above 26 GeV as a function of offline p_T & η.

Fully efficient at 30 GeV thanks to correction applied in endcap electromagnetic calorimeter.

→ Crucial triggers for Higgs searches.

Tau efficiency: H→ττ





Run 2012A < run 2012B: change quality criteria of isolation tracks
Difference between barrel (|η|<1.5) and endcap (|η|>1.5): due to detector effects and different real tau purity

➔ Very high performance which allow Higgs investigations

HLT Menu @ 6Hz/nb

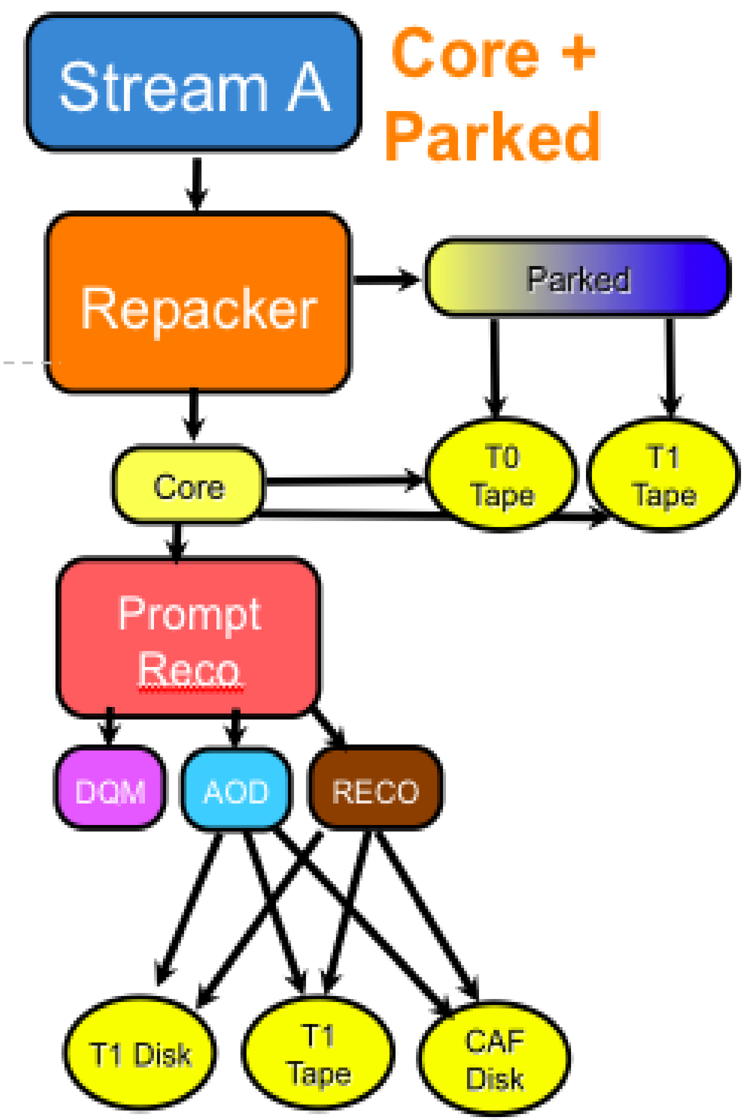
(Unprescaled) Object	Trigger Threshold (GeV)	Rate (Hz)	Physics
Single Muon	40	21	Searches
Single Isolated muon	24	43	Standard Model
Double muon	(17, 8) [13, 8 for parked data]	20 [30]	Standard Model / Higgs
Single Electron	80	8	Searches
Single Isolated Electron	27	59	Standard Model
Double Electron	(17, 8)	8	Standard Model / Higgs
Single Photon	150	5	Searches
Double Photon	(36, 22)	7	Higgs
Muon + Ele x-trigger	(17, 8), (5, 5, 8), (8, 8, 8)	3	Standard Model / Higgs
Single PFJet	320	9	Standard Model
QuadJet	80 [50 for parked data]	8[100]	Standard Model /Searches
Six Jet	(6 x 45), (4 x 60, 2 x 20)	3	Searches
MET	120	4	Searches
HT	750	6	Searches

Data Parking

LHC will stop in 2013/2014: Recording additional events to be studied at that time:

Vector Boson Fusion: M_{jj}>650 GeV , $\Delta\eta_{jj}$>3.5
MultiJet: 4 Jet with p_T>50 GeV
HT and MHT: For susy searches
MuOnia: low $M_{\mu\mu}$ (Jpsi, Psi`, ..)
DoubleMu: Mu13_Mu8
TauParked: ττ (with 3prong decays)
5% of parked data are promptly reconstructed for monitoring purpose

➔ **On average 350 Hz of "core physics" is promptly reconstructed and 300 Hz of data is parked for future reconstruction**

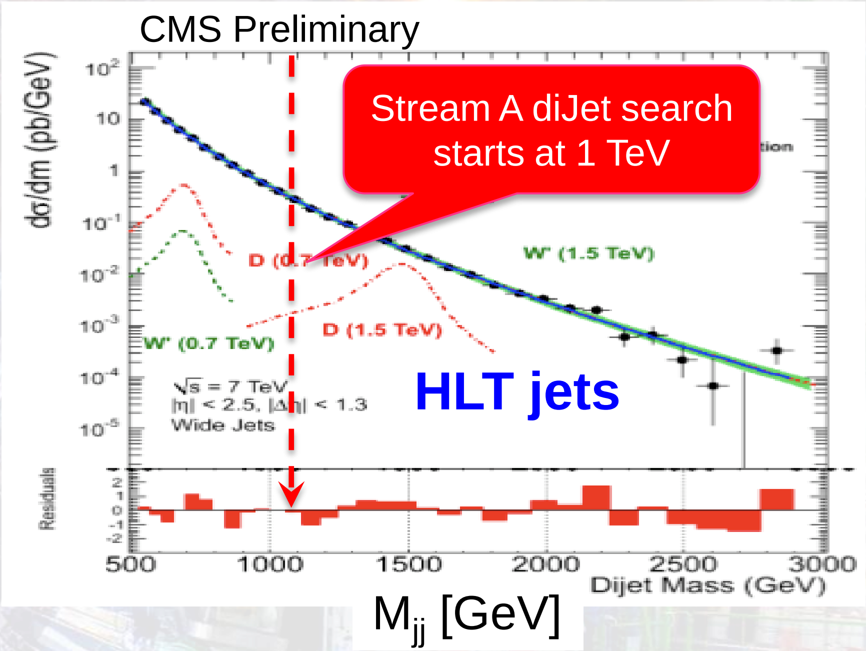


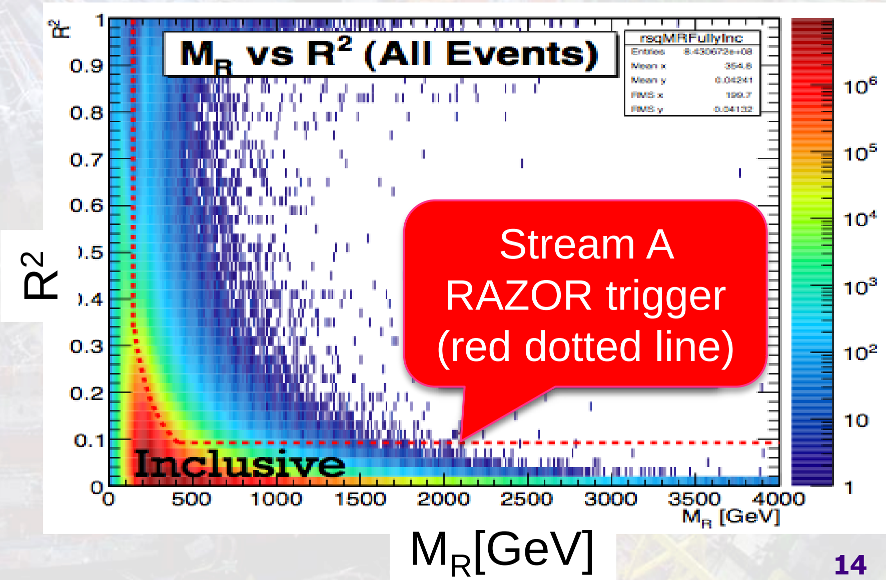
Data Scouting

Look at events not collected in main stream due to trigger constraints.
Scouting approach:
Trigger: H_T>250 GeV unprescaled
High rate (~1 kHz) + reduced event content (i.e. store HLT jets, no RAW data)

- → **Bandwidth (= rate x size) under control [a few MB/s]**
- → **Possibility to change stream A triggers in case something interesting is seen by "scouting"**

Analyses in Data Quality Monitoring-like framework for:
Exotica: Dijet search
SUSY: Razor, α_T





Conclusions

- **HLT is serving many purpose:**
  - **Various streams for detector maintenance**
  - **Large flexibility to record specific events for physics searches**
- **HLT remarkably stable wrt PU**
  - **Many improvements in code/tuning of corrections**
  - **Allows us to use refined algorithms online**
  - **Current HLT Farm able to cope with 165 ms/evt @ 100 kHz L1 → ~ 8 Hz/nb as instantaneous luminosity with no changes from current prescale setting at HLT**
  - **Efficiencies high, turn-on's sharp, rates stable**

→ Ready to record more data to hunt for/to study new particles

Back Up

High Level Trigger

The HLT: dedicated configuration of the CMS reconstruction software. We currently have ~13 000 cpu cores, and run ~20 000 event processors (exploiting the hyperthreading capability of the CPUs from 2011 and 2012).
The current machines are:

- **720 dual E5430 Xeon quad-core processors**
- **288 dual X5650 Xeon six-core processors (with HyperThreading)**
- **256 dual E5-2670 Xeon eight-core processors (with HyperThreading)**

With a nominal input rate of 100 kHz, each process has available an average of ~160 ms to read the input data run all the trigger algorithms (~400 currently) take the final accept/reject decision stream the data to the Storage Managers

Nominal output rate ~1 kHz

For comparison, offline reconstruction takes ~3 sec per event

HLT farm evolution

2009: 720x

May 2011 add: 72x

May 2012 add: 64x

	Original HLT System Dell Power Edge 1950	2011 extension Dell Power Edge c6100	2012 extension Dell Power Edge c6220
Form factor	1 motherboard in 1U box	4 motherboards in 2U box	4 motherboards in 2U box
CPUs per mother-board	2x 4-core Intel **Xeon E54**30 **Harpertown**, 2.66 GHz, 16GB RAM	2x 6-core Intel **Xeon X5650 Westmere**, 2.66 GHz, hyper-threading, 24 GB RAM	2x 8-core Intel **Xeon E5-2670 Sandy Bridge**, 2.6 GHz, hyper threading, 32 GB RAM
#boxes	720	72 (=288 motherboards)	64 (=256 motherboards)
#cores	5760	3456 (+ hyper-threading)	4096 (+ hyper-threading)
cumulative #cores	5.6k	9.1k	13.2k
cumulative #CMSSW	5k instances	11k instances	20k instances

(CPU budgets are on 1 core of an Intel Harpertown)

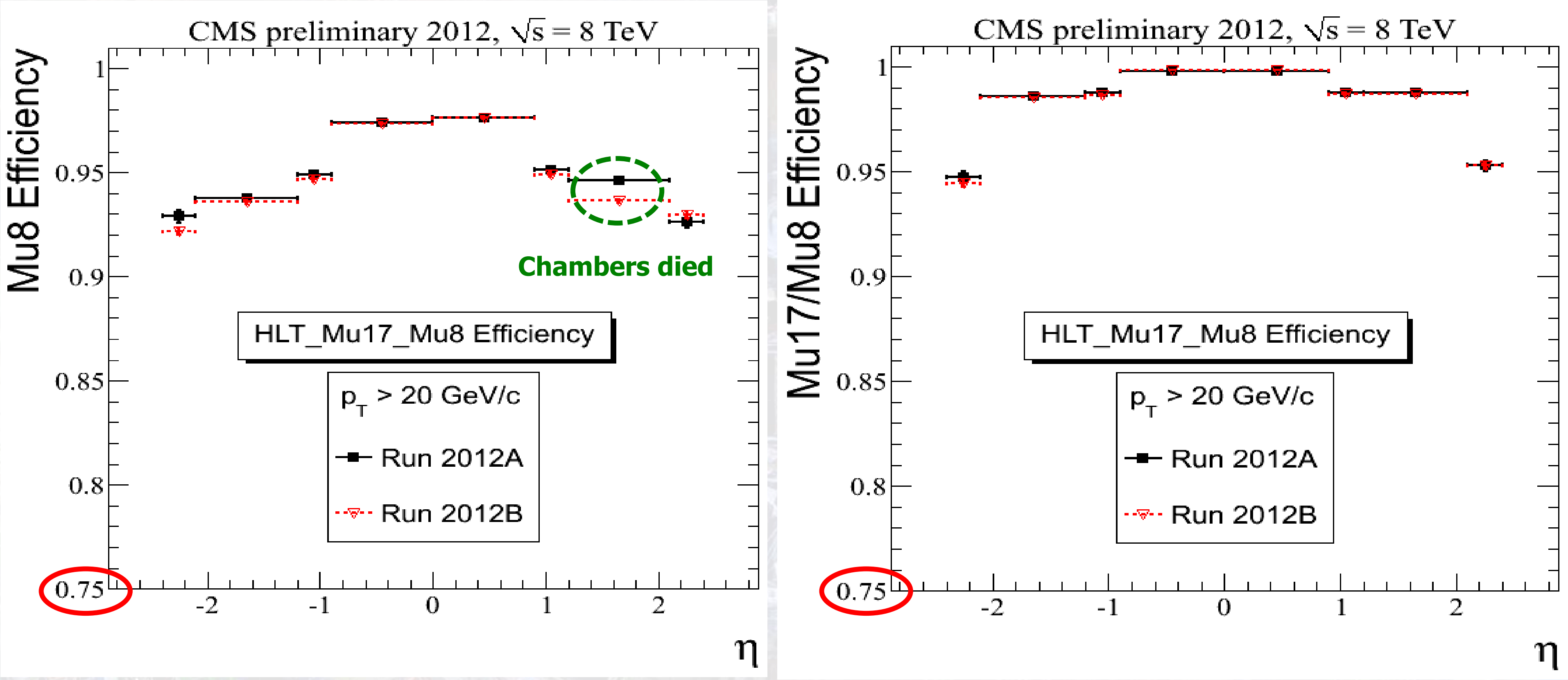
Per-event CPU budget @ 100 kHz:

2009: ~50 ms / evt

2011: ~100 ms / evt

2012: ~165 ms / evt

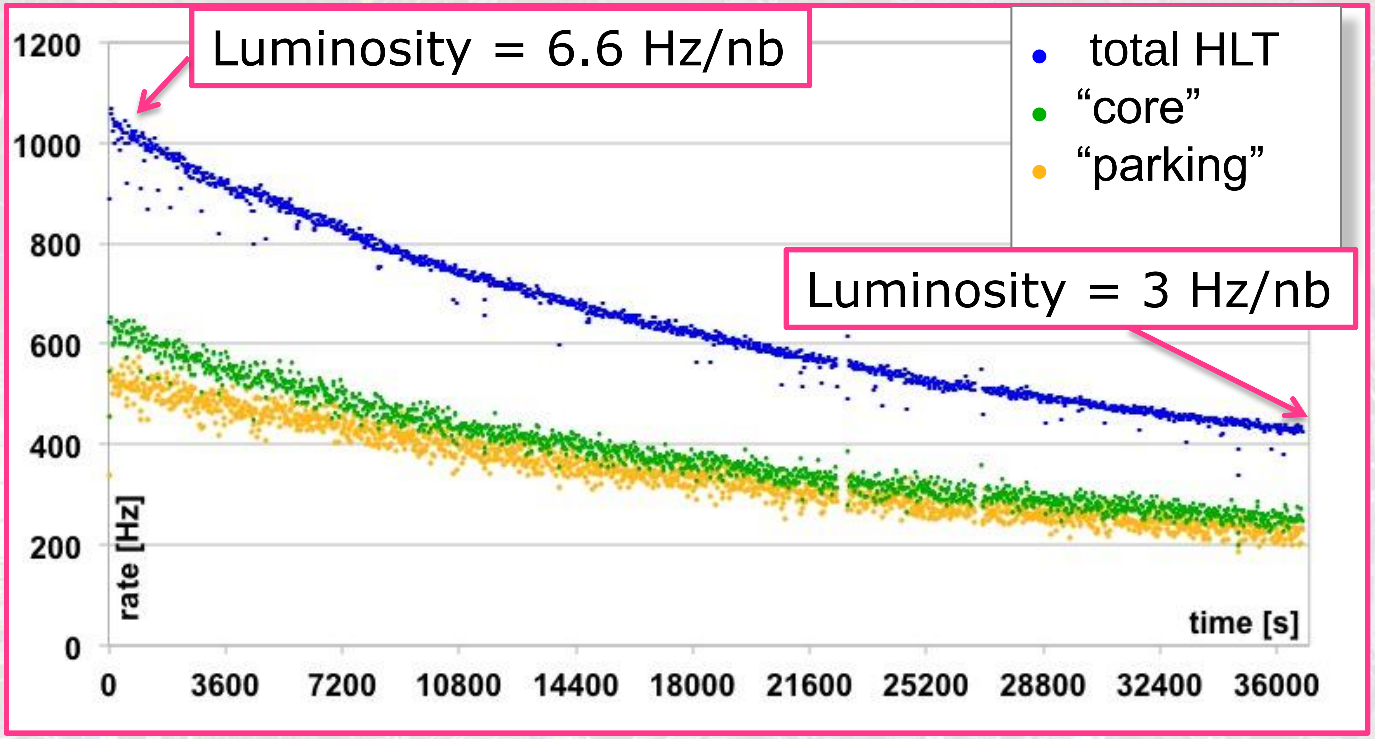
Dimuons Efficiency: H→WW



Very high efficiencies even for low threshold object

➔ Crucial for exploring H→ WW and H→ ZZ production mode

HLT Rates



HLT rate for first 10h of long recent fill

- **Average "core rate = 380 Hz in range shown (6.6 - 3 Hz/nb) = 340Hz from 6.5 - 2.5Hz/nb, when fill is usually dumped by operator**

- **Rate limit is set by offline resources, to 300-350Hz "core" physics on average.**
- **Goal: keep the average over the fill**
  - **If larger rates at the end → lower rates at start, with reduced physics acceptance**
  - **Physics like to have a constant set of thresholds throughout the data**

HLT Operations

- **Rate Monitoring:**
  - **Tools able to spot problems immediately during data taking.**
  - **Offline analysis identifies triggers with unexpected rate growth > instantaneous lumi**

Data Certification:

- **New, stream-lined certification process provides quicker feedback to operations.**
- **Improved HLT DQM utilities utilized by HLT secondary on-call**