B-tagging at High Level Trigger in CMS

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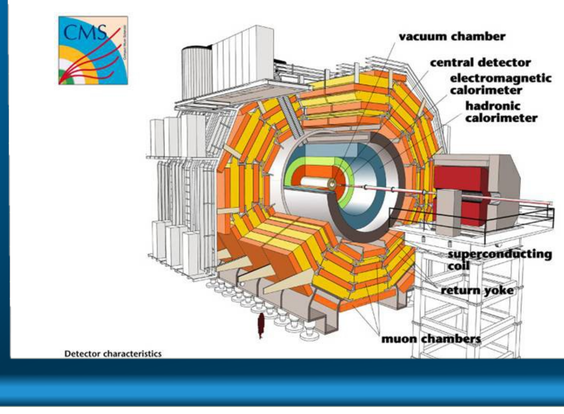
Scientific context



LHC run I (2012 conditions)

- √s=**8** TeV
- Bunch spacing = **50** ns
- Luminosity up to **7x10^{33}**cm^{2}s^{-1}
- <Pile up (PU)> : **~ 20**

LHC run II (2015)

- √s=**13**TeV
- Bunch spacing = **25** ns (50 ns at restart)
- Luminosity up to **1.6x10^{34}**cm^{2}s^{-1}
- <Pile up (PU)> : **~ 40**
- **Increase of out-of-time PU**

Consequences :

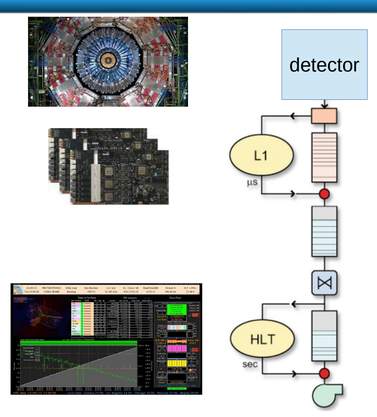
- Event rate will increase by a factor 4 to 8
- High PU will increase the timing of HLT algorithms

Ex : more combinatorics in the tracking algorithms

Goals for HLT @ run II

- Reduce CPU-time
- Decrease the sensitivity to PU (especially out-of-time PU)
- Gain in signal eff. & background rejection
- Bring online physics object reconstruction closer to offline

CMS Trigger system



Level 1 Trigger

- **Hardware** level implemented using FPGA and custom ASIC technology
- Goal is to select events at a maximum rate of **~100 kHz**
- This upper limit is imposed by the CMS data acquisition electronics

High Level Trigger

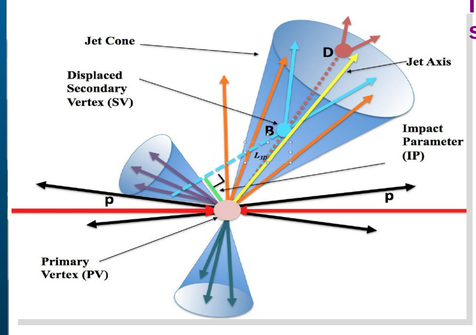
- **Software** level runs on a cluster of commercial rack-mounted computers : 13000 CPU cores
- Goal is to reduce the rate to **~800 Hz** on average, for offline data storage.
  - 400 Hz used for prompt reconstruction (within 48 hours)
  - 400 Hz used for data parking (delayed reconstruction)

HLT main constraints:

- Run with a peak CPU time: 200 ms/evt @ 100 kHz input rate
- Maximize the efficiency while keeping CPU-time and rate low
- Same software framework and most of the same reconstruction codes than used offline
- Performances should be robust w.r.t alignment, calibration constants and PU

b-tagging

Identification of jets originating from the hadronization of b-quarks is a crucial step for many new physics searches (SUSY, b', t', …) and many measurements of standard model processes as the ones involving top quarks. It also plays a leading role in Higgs physics as this boson can be studied via its decay into two b-quarks



B-jet characteristics

Large lifetime : 1.5 ps, cτ ~ 450 mum
mean path length @ 50 GeV : ~ 5 mm

High mass : about 5.2 GeV →decay products have a large transverse momentum (p_T) relative to the jet axis

Muon/Electron : can be produced in semi-leptonic b-hadron decays

High charged track multiplicities : ~5 on average

Observables

Track information :
Displaced tracks with a large impact parameter (IP)

Secondary vertex information :
- Displaced vertex
- Vertex mass
- Track multiplicity

Soft lepton information :
Presence of a soft muon/electron with a large p_T rel

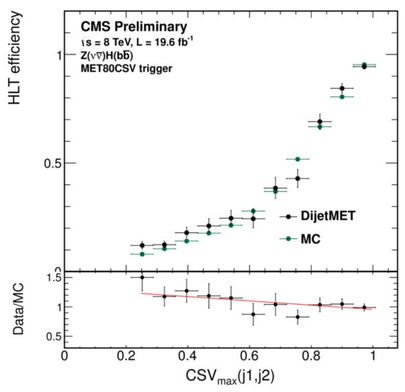
B-tagging algorithm

CMS uses several b-tagging algorihms **CMS-PAS-BTV-13-001**
The « **Combined Secondary Vertex** » (**C.S.V**) algorithm is used online :
- used in many papers published by CMS.
- based on a **Likelihood Ratio** technique
- **Inputs :** secondary vertices, tracks measurements, jet kinematics.
- **Performances** :
  ~70 % b-tagging efficiency for a light flavor jet efficiency of ~ 1 %

B-tagging sequence @ HLT

B-tagging sequence @ HLT has been used in many published analyses during Run I :

ZH (Z→νν,H→bb)	Phys.Rev. D89 (2014) 012003
ZH (Z→bb, H invisble)	CMS-PAS-HIG-13-028
VBF Higgs ,H→bb	CMS-PAS-HIG-13-011
MSSM Higgs→bb into H→bb	Phys. Lett. B 722 (2013) 207
	CMS-PAS-SUS-13-022



Efficiency of MET80+CSV07 trigger as function of CSV1 for data and MC. Results taken from Phys.Rev. D89 (2014) 012003

Sequence applied in 2012

L1 Calo Jet

Pixel clusters

Fast Primary Vertex
Resolution ~ 2 mm

Use all compatible pixel clusters along the jet direction
Search for a peak in their z-projection

Fast P.V. constraint

Pixel tracks

Pixel Primary Vertex
Resolution ~ 100 μm

Regional tracking w/ Pixel P.V. constraint

Full tracks (Pixel+Strips)

b-tagging algorithm similar to the one used offline fed with **online quantities**

C.S.V. algorithm

Inputs : *Pixel PV + Full Regional Tracks*

Improved sequence for Run II

Regional clustering

Extend the range of pixels clusters considered :
|η|<1.6→|η| <2.4
Weighting of the clusters using several quantities

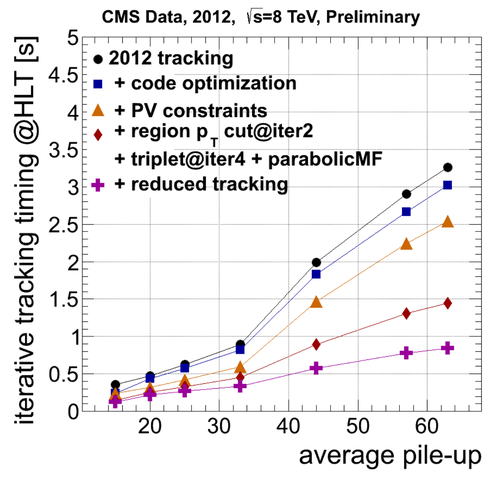
Regional tracking (around the jets)
Fast P.V. constraint

Use an iterative tracking in three steps :
- high pT prompt tracks seeded by pixelTracks applying PV constraint
- low pT prompt tracks seeded by pixel triplets
- recover high pT prompt tracks seeded by pixel pairs

Primary Vertex
Resolution 20-30 μm

Inputs : *PV + Full Regional Iterative Tracks*

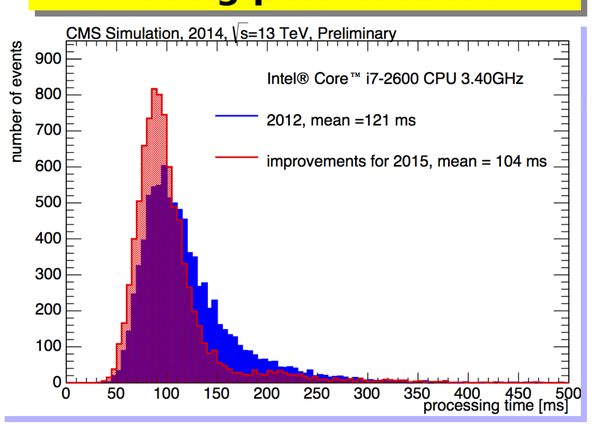
Tracking@HLT : improvements



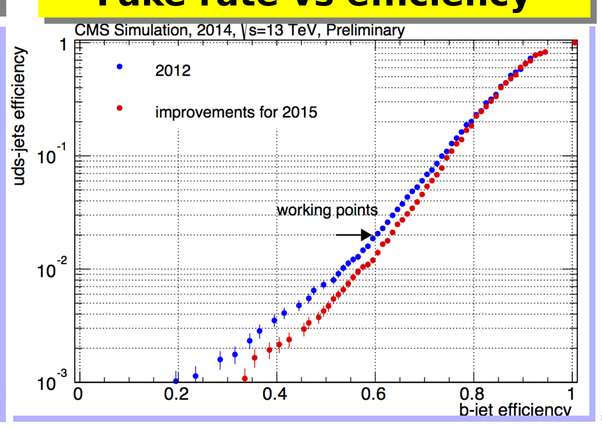
Performances

Comparison of the HLT b-tagging performances obtained with the version used in 2012 (in blue) and the new improved procedure that will be used when the LHC will restart in 2015 (in red).

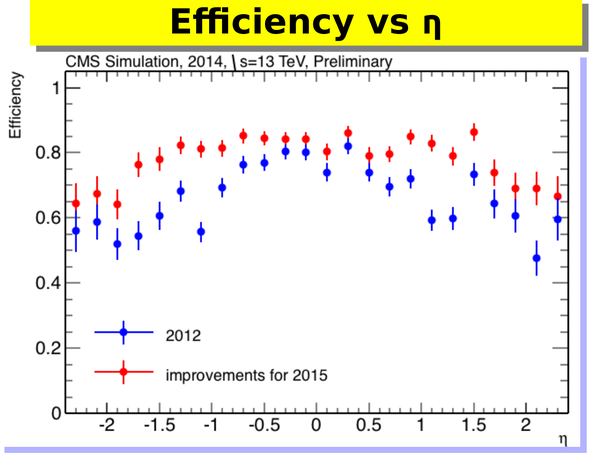
Timing performance



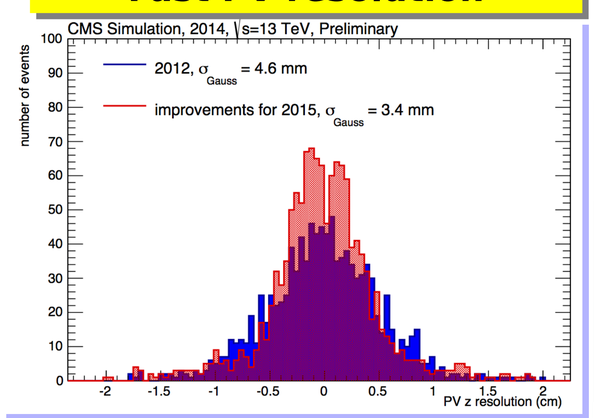
Fake rate vs efficiency



Efficiency vs η



Fast PV resolution



Results obtained on simulated top pair events - <PU> = 25

Results obtained on simulated Z→νν H→bb events - <PU> = 60