Status of Geant4 in CMS

David Lange, Mike Hildreth, Vladimir Ivanchenko

for the CMS collaboration

Geant4 Technical Forum 11 January 2017

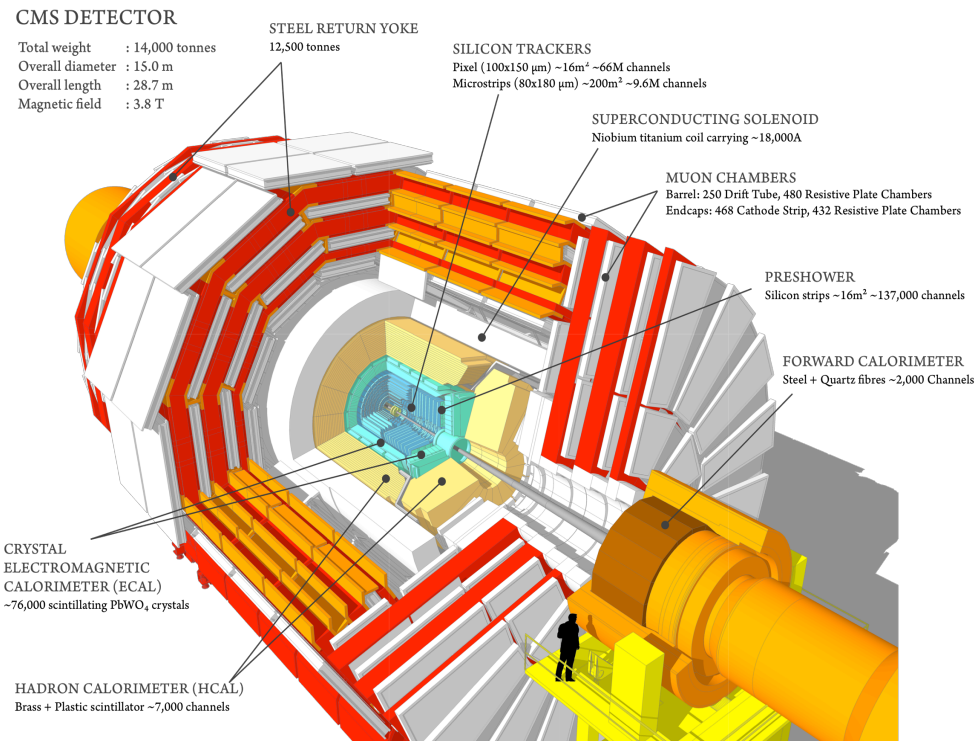
CMS simulation faces significant challenges for both today and tomorrow

Higher LHC luminosity means:

- Need for more accurate simulations
- Need for more events (ideally more events/CHF)
- More demanding pileup simulation requirements

Major detector upgrades in 2017, during LS-2 and for HL-LHC mean:

- New detector concepts to develop, benchmark and validate
- The need to make reliable simulations for HL-LHC luminosities



Increases in LHC luminosity and CMS detector upgrades push our simulation capabilities

Detector upgrades push continued simulation development in CMS

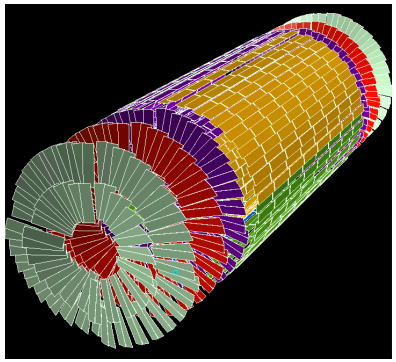
2017 upgrades

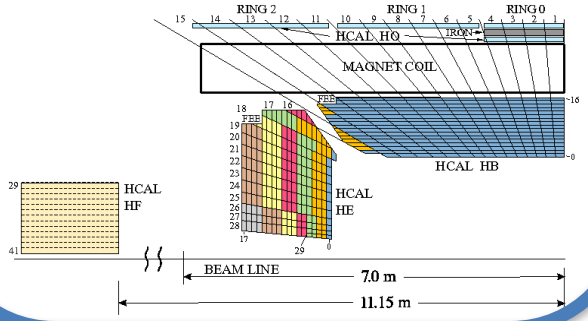
HL-LHC upgrades

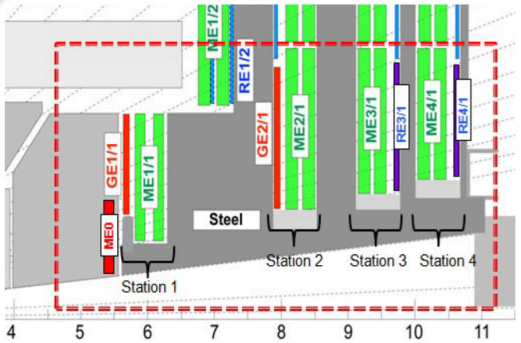
Muon ID

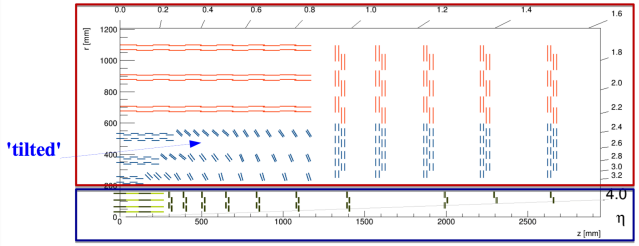
Tracking

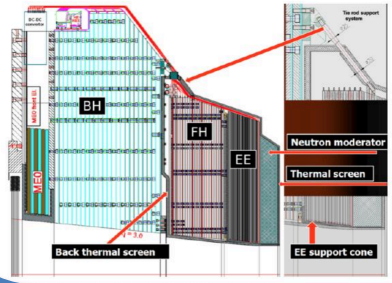
Calorimetry



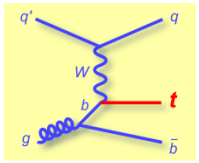






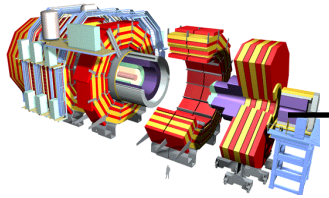


CMS Monte Carlo Simulation approach



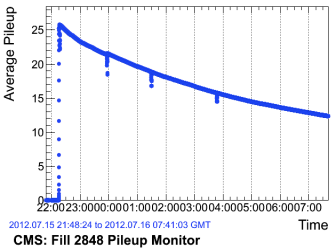
Physics Generators

Particle 4-vectors



Geometry/ Material Description

Geant 4



Simulated Hits from Pileup Interactions

Simulated Hits

Noise Model

Electronics Simulation

Simulated Raw Data

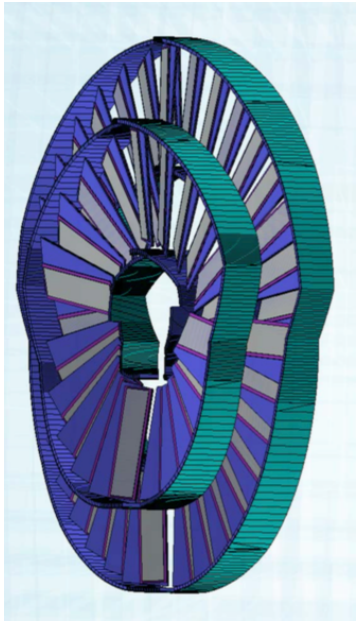
= “Digitization”

Recap from Run 1:
Simulation improvements for Run 2

- Geometry updates: Improvements to Run 1 detector model and integration of Run 2 detector changes
- Migration from Geant4 9.4p03 to 10.0p02
- Introduced Russian roulette method for sampling low energy particles
- New forward hadron calorimeter parameterized simulation (shower library instead of GFlash)
- Improved simulation library packaging
- Total number of events simulated for Run2 is ~16 billions
- Developed simulation for multi-threaded CMSSW framework

Together these improvements gained a factor of 2 in simulation time/event for 2015/2016 MC

What have we changed since then?



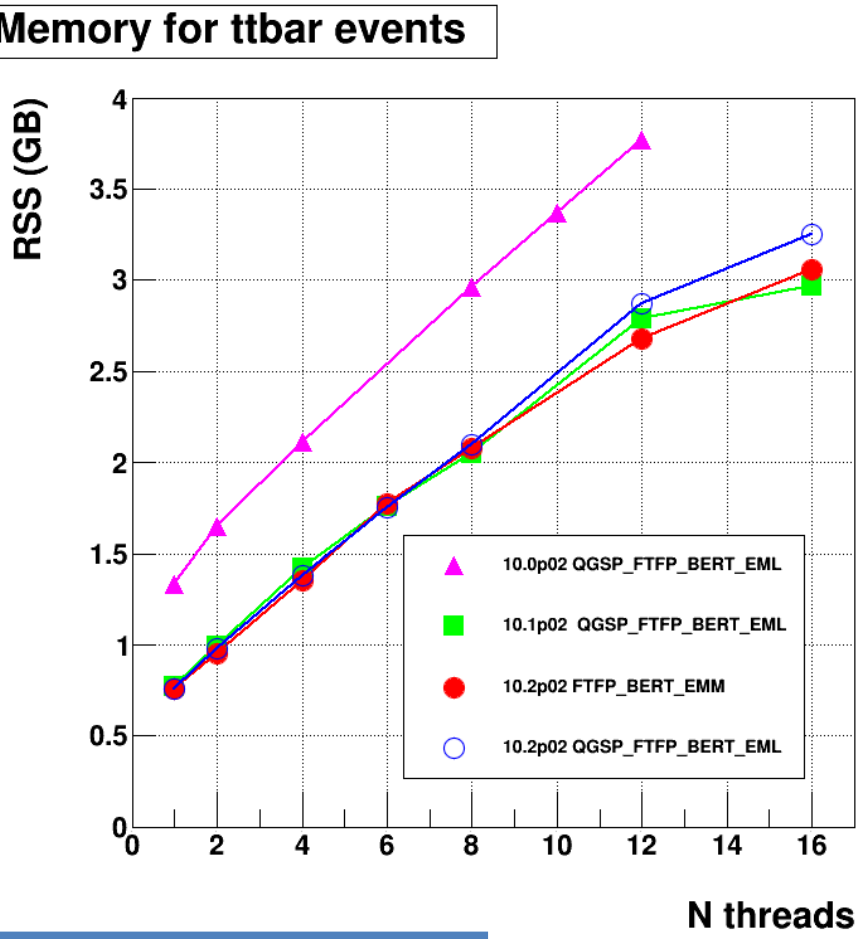
- New Geant4 10.2 built in multithreaded mode.
- Minor changes applied by CMS:
  1. FTF model parameters defined as in 10.1p03
  2. Fix to G4SubtractedSolid
  3. Fix to G4CutTubs
     - Our first use of this shape to model support structure of new pixel detector
- Production platform slc6_amd64_gcc530

What have we changed since then?

- Default physics list: FTFP_BERT_EMM
  - FTFP_BERT: Standard hadronic physics list
    - Bertini-style cascade for hadrons < 5 GeV
    - FTF (Fritiof) model for high energies (> 4 GeV)
  - EMM means:
    - Default EM physics in HCAL (“Option 0“) in order to get an unbiased response of the sampling calorimeter
    - EM “Option 1“ physics in other all detectors (increased multiple scattering step length limit)
  - This physics list choice and our choice to revert changes in FTFP made in recent 10.2 patches was based on comparisons of single particle response using test-beam (2006) and run-2 data (See details in S.Banerjee talk)

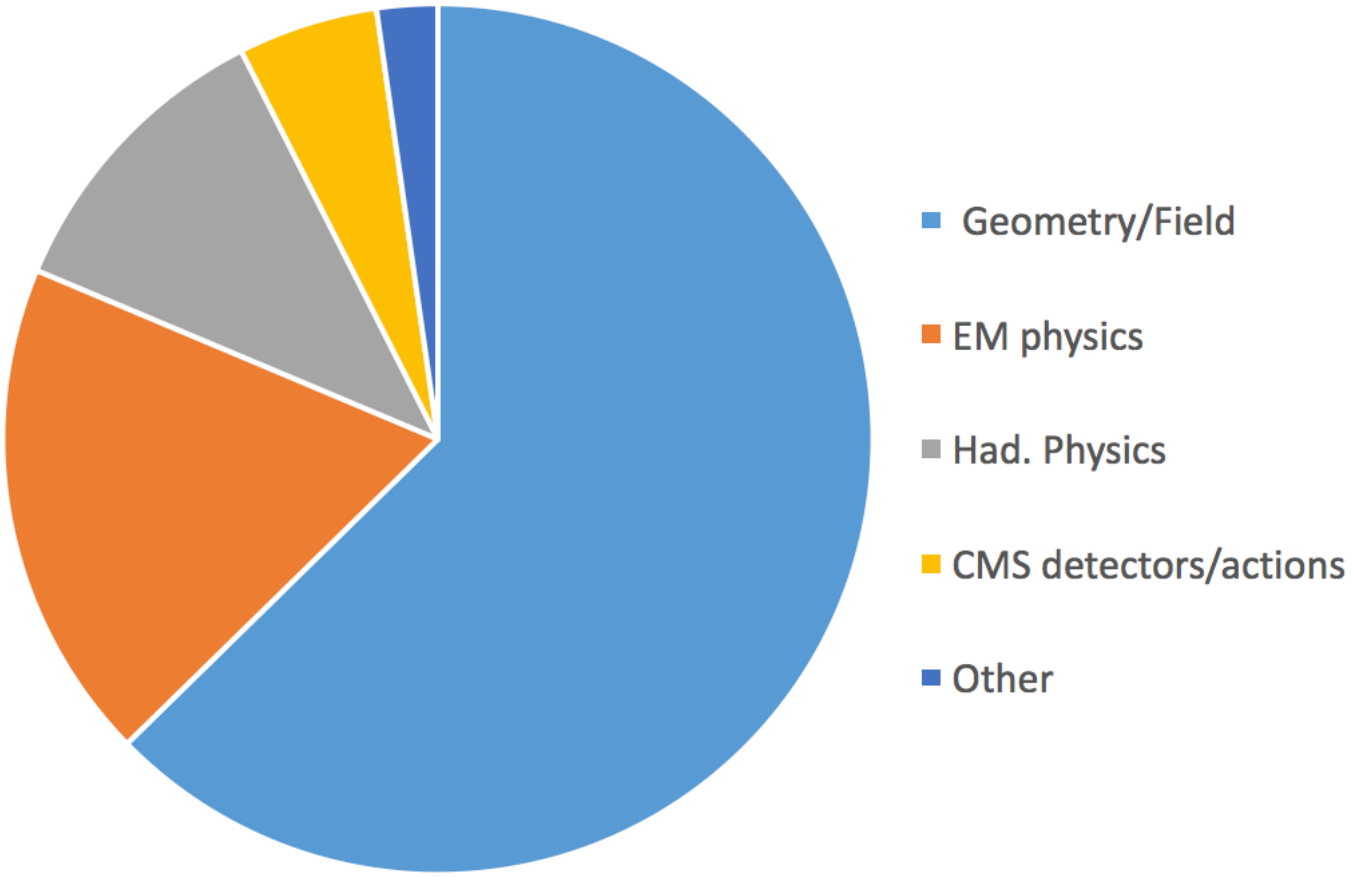
Memory for CMS run with Geant4 10.2p02

- A node with 12 Intel cores was used to study memory utilisation
- 13 TeV hard scattering event were simulated
  - Results after 1000 events are shown
  - CMS private patches to 10.0 include backports of fixes of memory leak and memory optimisation
  - Results for 10.1 and 10.2 are practically the same
  - No dependency on Physics List
- No problems to run CMS SIM production in the MT mode

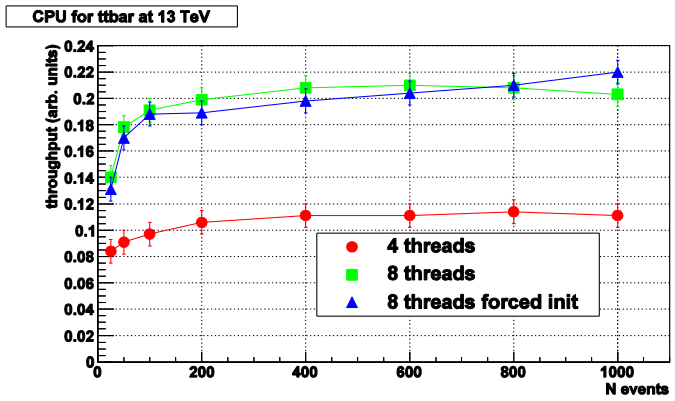


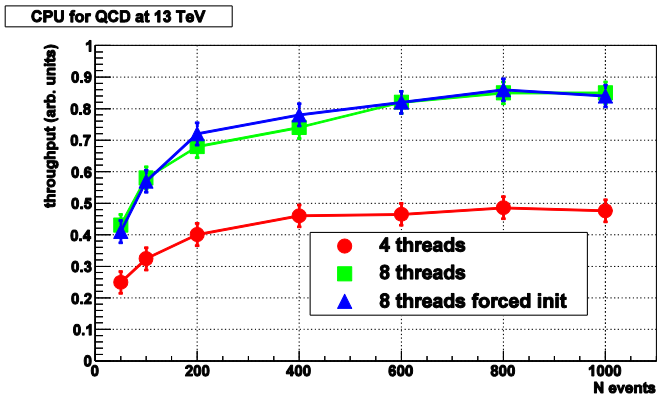
Release	1st thread (GB)	Delta per thread (GB)
10.0p02+CMS patches	1.33	0.23
10.2p02	0.76	0.19

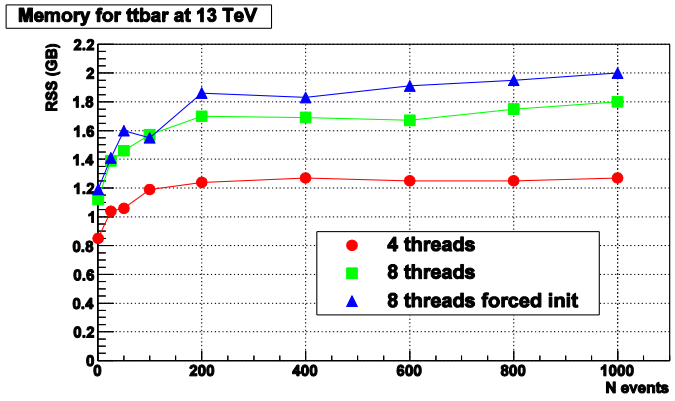
Where our simulation CPU goes

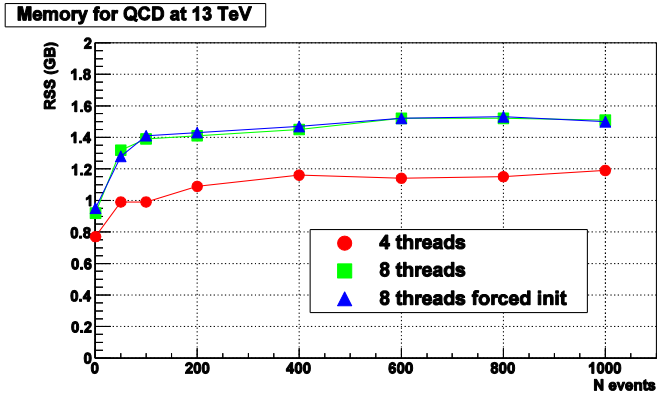


Dynamic of CPU and RSS for 13 TeV CMS simulation run in MT mode for Geant4 10.2p02









- Maxmum CPU efficiency is achieved after simulation ~500 events
  - The turnon shape is expected due to
    1. CMS and Geant4 initialisation before 1st event
    2. Lazy initialization of hadron physics in Geant4

CMS CPU performance for 2017

Geant4 version and configuration	Number of threads	CPU for ttbar (events/thread relative rate)	CPU for QCD (events/thread relative rate)
10.0p02 seq.	1	1	6.0
10.2p02 MT	1	1.07	5.7
10.2p02 MT	8	1.05	5.0
10.2p02 MT	8	0.97	4.5

CMS 2015/6

CMS 2017

- Overall, no substantial changes in our technical performance for hard scattered events since 2015
  - Modest improvements in CPU performance in Geant4 10.2p2 and in CMS sensitive detector code offset by other changes
- Minor performance loss with threading (up to 8 threads) - some performance loss due to new pixel geometry

Summary

- CMS are using 10.0p02 for Run-2 simulation
  - ~16 billion events are produced
- Geant4 10.2p02 have been prepared for 2017 production
  - Minor fixes are still possible
- The next big goal is Phase-2 upgrade simulation preparation