Computing challenges of the CMS experiment

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on behalf of the CMS Collaboration

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Outline

- Present and future computing needs in
  - LHC Run 2 and HL-LHC

- How to full-fill the computing needs
  - cloud computing, High-Performance Computing
WLCG landscape

- Over 170 computing centers in 42 countries
- CPU: \(~350,000\) of today’s fastest cores (3.8 million HEPSpec06)
- Storage: Disk: 310 PB, Tape: 390 PB
LHC Run 2 computing needs

- LHC Run 2 performance is above expectations
  - all factors driving computing have increased above expected levels
  - p-p collisions

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<tbody>
<tr>
<td>Peak Luminosity (10^{34} cm^{-2}s^{-1})</td>
<td>1.0</td>
<td>1.5</td>
<td>1.7-1.9</td>
<td>1.7-1.9</td>
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<tr>
<td>Integr. Luminosity (fb^{-1})</td>
<td>25</td>
<td>40</td>
<td>~45</td>
<td>~45</td>
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- For 2016, the available resources were sufficient
  - More tapes at CERN have been needed

- Analysis for 2017, 2018
  - Expectations are increased, the requirements are ~20% above previous estimates
LHC Run 2 computing needs

- WLCG estimates made in 2014 for LHC Run 2 up to 2018
- Growth of 20%/year starting in 2016 (“flat budget”)

- 2016→2018
  - CPU 3.8→6.3 (million HEPSpec06)
  - Disk 310 PB→520 PB
  - Tape 390 PB→850 PB

Ian Bird, CWP Workshop, Jan. 2017
HL-LHC data analysis

- To extract physics results requires to handle/analyze a lot more data!
- Tests started with new technologies
  - "Big Data" technology (new toolkits and systems to support analysis of datasets in industry)
  - Cloud Computing
  - High Performance Computing (HPC)
- Educates our community to use industry-based technologies
- Use tools developed in larger communities reaching outside of our field
Future computing cost drivers

- Detector design, trigger rates, etc.
- Optimization of reconstruction, simulation, etc.
- Experiment parameters
- Experiment Algorithms
- Software Performance
- Infrastructure
- New grid/cloud models; optimization of CPU/disk/network
- Architecture, memory, ...
Initial studies on computing needs for HL-LHC

CPU needs (kHS06)

- Data Reprocessing
- MC Reconstruction
- MC Simulation Full
- Evgen
- Flat Budget
- CPU need

Disk Needs (PB)

- DAOD (MC)
- AOD (MC)
- DAOD (DATA)
- AOD (DATA)
- Disk Needs
- Flat Budget

HS06....HEPSpec 2006 based on SpecInt 2006

Frédéric Hemmer CERN School of Computing, Aug. 2016
Computing: Growth > x 50

Data: ~25 PB/year → 400 PB/year, x 16

- Simple model based on today’s computing models, but with operating parameters (pile-up, trigger rates, etc.)
- Technology at ~20%/year will bring x 6-10 in 10-11 years
- At least x 10 above is realistic to expect from technology with reasonable constant cost
Possible Model for future HEP computing

ATLAS
HLT

CMS
HLT

LHCb
HLT

ALICE
O2

Reconstruction facility (calibration, alignment, reconstruction)

Archive at “AOD” level

Distribute

LHC Data cloud
Storage and computing

Simulation resources

Cloud users: Analysis

Frédéric Hemmer, CERN School of Computing, Aug. 2016
HL-LHC computing needs will be > 50 x current capacity

Commercial clouds can provide increased capacities for decreased costs compared to the past

Elasticity usage needed – Usage not steady-state

Burt Holzman, CHEP 2016
Classes of Resource Providers

GRID
- Virtual Organizations (VOs)
- Pledges

Cloud
- Community Clouds and Commercial Clouds
- Rented resources

HPC
- Researcher granted access to High-Performance Computing installations
- Exploit opportunistic resources
Fermilab HEPCloud and CMS use case (2016) - Amazon Web Services (AWS)

- Reaching ~60k slots
- 25% of CMS global capacity
- CMS simulation
  - 2.9 million jobs, 15.1 million wall hours
  - 518 million events generated

Oliver Gutsche, HSF CWP, Jan. 2017
Fermilab HEPCloud and CMS use case (2016) – Google Cloud Platform

- Double the size of global CMS computing resources
- Aiming to generate 1 billion events in 48 hours
- 730,000 simulation jobs, 6.35 million wall hours used
- 205 million physics events generated, yielding 82 TB of data
On-premises vs. cloud cost comparison

- Amazon Web Services (AWS)
  - Average cost per core-hour
    - On-premises resource: 0.9 cents per core-hour (includes power, cooling, staff)
    - Off-premises at AWS: 1.4 cents per core-hour (ranged up to 3 cents per core-hour at smaller scale)
  - Benchmarks - specialized (“ttbar”) benchmark focused on HEP workflows
    - On-premises: 0.163 ttbar/s (higher = better)
    - Off-premises: 0.158 ttbar/s

Computing performance roughly equivalent
Cloud costs higher – but approaching equivalence
Helix Nebula Science Cloud

- European hybrid cloud platform that will support high-performance, data-intensive scientific computing
- for end-users from many research communities: High-energy physics, astronomy, life sciences,…

- sponsored by 10 of Europe’s leading public research organizations and co-funded by the European Commission (H2020). Procurers: CERN, CNRS, DESY, EMBL-EBI, ESRF, IFAE, INFN, KIT, SURFSara, STFC
  - Funds (> 1.6 MEuro), manpower, use-cases with applications & data, in-house IT resources

- November 2016 the 4 winning consortia for the Helix Nebula Science Cloud have been presented
Challenges on HL-LHC computing
- HEP computing much more capacity is needed
- New computing models and more efficient software have to be developed
- Additional resources are needed – cloud computing, High-Performance computing

Commercial cloud resources
- Tests performed by Fermilab and CMS on Amazon Web Services and Google Cloud Platform
  - Proven capability to execute efficiently both data intensive and CPU intensive workflows
  - Cloud resources are much more competitive in terms of cost than in the past
  - Potentially an interesting resource to supplement to the existing resources