The Large Hadron Collider (LHC)

A new frontier in Energy & Data:

LHC experiments generate 50 PB/year

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Data Analysis at the LHC

The process to transform raw data into useful physics datasets

- This is a complicated series of steps at the LHC (Run2)

Data Volume

From Detector (1PB/s)
After HardwareTrigger (TB/s)

Processing and people

Data Volume

HLT
Reconstruction
Reprocessing
Organized Analysis
Final Selection

Selected RAW (1 GB/s)
Derived Data (2 GB/s)
Derived Data (2 GB/s)
Analysis Selection (100MB/s)

20k cores
40k cores
30k cores
60k cores

DAQ and Trigger (less than 200)
Operations (less than 100)
Operations (less than 100)
Analysis Users (More than 1000)
Analysis Users (More than 1000)

From Detector (1PB/s)
Derived Data (2 GB/s)
Analysis Selection (100MB/s)

1st September 2017
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Tier-0 (CERN and Hungary): data recording, reconstruction and distribution

Tier-1: permanent storage, re-processing, analysis

Tier-2: Simulation, end-user analysis

WLCG: An International collaboration to distribute and analyse LHC data

Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists

~170 sites, 42 countries

~750k CPU cores

~1 EB of storage

> 2 million jobs/day

10-100 Gb links
WLCG MoU Signatures

2017:
- 63 MoU’s
- 167 sites; 42 countries
Optical Private Network
Support T0 – T1 transfers & T1 – T1 traffic
Managed by LHC Tier 0 and Tier 1 sites

Up to 340 Gbps transatlantic
LHCOOne: Overlay network
Allows NREN’s to manage HEP traffic on general purpose network
Managed by NREN collaboration
Data at CERN

2016: 49.4 PB LHC data/
      58 PB all experiments/
      73 PB total

ALICE:  7.6 PB
ATLAS: 17.4 PB
CMS:    16.0 PB
LHCb:   8.5 PB

11 PB in July 2016

200 PB on tape
>500 M files
Global transfer rates increased to 30-40 GB/s (>2 x Run1)

Increased performance everywhere:
- Data acquisition >10PB / month
- Data transfer rates > 35 GB/s globally

Regular transfers of >80 PB/month with ~100 PB/month during July-October
(many billions of files)
Worldwide computing

Peak delivery:
190M core-days/month
(~ 600k cores permanently)
2017:
• 325 k cores
• 250 PB raw disk

2017-18/19
• Upgrade internal networking capacity
• Refresh tape infrastructure
Provisioning services

Moving towards Elastic Hybrid IaaS model:
• In house resources at full occupation
• Elastic use of commercial & public clouds
  • Assume “spot-market” style pricing

End Users | Experiment Pilot Factories | CI/CD | IT & Experiment Services
---|---|---|---
HTCondor | (LSF) | APIs CLIs GUIs
HPC/ Volunteer/ Opportunistic | Public Cloud | Bare Metal and HPC | Containers | VMs
OpenStack Resource Provisioning (>1 physical data centre)
Commercial Clouds

CERN IT evaluation of Microsoft Azure cloud IaaS

Open Telekom Cloud

CMS global pool

Google

300k

ATLAS

LHCb

ALICE
LHC Schedule

- Run 3 (Alice, LHCb upgrades)
- Run 4 (ATLAS, CMS upgrades)

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Future Challenges

- Raw data volume for LHC increases exponentially and with it processing and analysis load
- Technology at ~20%/year will bring x6-10 in 10-11 years
- Estimates of resource needs at HL-LHC x10 above what is realistic to expect from technology with reasonably constant cost

Data:
- Raw 2016: 50 PB → 2027: 600 PB
- Derived (1 copy): 2016: 80 PB → 2027: 900 PB

CPU:
- x60 from 2016
10-year challenges

- HL-LHC will be a multi-Exabyte challenge
  - Storage and compute needs x10 above what naïve technology extrapolation will bring
  - Need to drive down costs: focus on performance, efficiency, operations, etc. ➔ changes in computing and infrastructure models are necessary

- But there is experience:
  - ~15 years of grid development and successful operation for science
  - CERN has been operating a distributed DC for >5 years
  - Large internet companies provide tools and experience that did not exist when we started WLCG
    - Tools for managing interconnected DCs, cloud provisioning, etc.
    - Starting to prototype federated structures for the future
Possible Model for future HEP computing infrastructure

HEP Data cloud
Storage and compute

HEP Data lake
Storage and compute

Simulation resources

A data lake is a place to put all the data enterprises (may) want to gather, store, analyze and turn into insights and action, including structured, semi-structured and unstructured data
The HEP Software Foundation (HSF) facilitates coordination and common efforts in high energy physics (HEP) software and computing internationally.

The HSF is now beginning community process to develop a consensus roadmap for HEP Software and Computing R&D for the 2020s. More information about this can be found on the Community White Paper (CWP) page on the HSF site.

Meetings
All our activities and ideas are discussed weekly in our HSF meeting. Feel free to participate!
• HSF Weekly Meeting #71, November 3, 2016
• HSF Weekly Meeting #69, September 15, 2016
• HSF Weekly Meeting #68, September 8, 2016

Full list of meetings »

Newsletter
If you would like to stay updated, please subscribe to our newsletter:
• Third HSF Workshop
• Sharing ideas and code
• HSF Newsletter - Logo Contest and Packaging Working Group

Older newsletters »

Activities
Our plenty of activities span from our working groups, organizing events to supporting projects as HSF projects, and channeling communication within the community with discussion forums, technical notes and a knowledge base.

How to get involved »

HSF Set up in response to recognition that software will be key to success for HL-LHC and the future
New analytics

- Big Data tools
- Machine/Deep learning

Machine Learning

ML in Atlas
- Machine Learning (or rather Multivariate Analysis as we used to call it) used almost since first data taking (2010) for reconstruction and analysis
- In most cases, Boosted Decision Tree with Root-TMVA, but recent explosion of usage and studies (see later)

Data taking
- Real time event categorization
- Data monitoring & certification robot

Data Reconstruction
- Calorimeter reconstruction
- Boosted object jet tagging

Data Processing
- Computing Resource Optimization
- Predicting data popularity
- Intelligent networking

Data Analysis
- CMS assistance service
- Big data reduction and analysis
- Model independent search

Machine learning and data analytics are hot topics at CERN openlab workshop
SWAN

- Provides a web-based analysis facility – via notebooks
- Transparent access to scalable back-end analysis infrastructure
  - Clouds, Spark, Hadoop, ML, etc.
- Performance is defined by the infrastructure
- Provides the analysis portal in a “data cloud” or “data lake” model
Conclusions

- WLCG has been very successful in providing the global computing environment for physics at the LHC
- Engagement and contributions of the worldwide community have been essential for that
- LHC upgrades over the coming decade will give new challenges and opportunities
  - Technology will change our computing models
- We see a lot of potential synergy with other sciences: leadership in scientific big-data in the next decade