The Worldwide LHC Computing Grid

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LHC accelerator and detectors

Ultra high vacuum, colder than outer space

LHC ring: 27 km circumference
The ATLAS experiment

7000 tons, 150 million sensors generating data 40 millions times per second
Collisions Produce 1PB/s
Pick the interesting events

• 40 million per second
  • Fast, simple information
  • Hardware trigger in a few micro seconds

• 100 thousand per second
  • Fast algorithms in local computer farm
  • Software trigger in <1 second

• Few 100 per second
  • Recorded for study
Pick the interesting events: Data size

• 40 million per second
  • Fast, simple information
  • Hardware trigger in a few micro seconds

• 100 thousand per second
  • Fast algorithms in computers
  • Software trigger

• Few 100 per second
  • Recorded for study

ニュースマイルドペルセント

1 Petabyte per second?

• Cannot afford to store it
  • 1 year’s worth of LHC data at 1 PB/s would cost few hundred trillion dollars/euros

• Have to filter in real time to keep only “interesting” data
• We keep 1 event in a million
  • Yes, 99.9999% is thrown away

>>6 Gigabytes per second
CERN Data Centre

- Built in the 70s on the CERN site (Meyrin-Geneva), 3.5 MW for equipment
- Extension located at Wigner (Budapest), 2.7 MW for equipment
- Connected to the Geneva CC with 3x100Gb links (24 ms RTT)
- Hardware generally based on commodity
- 15,000 servers, providing 190,000 processor cores
- 80,000 disk drives providing 250 PB disk space
- 104 tape drives, providing 140 PB
Worldwide computing

2017:
- 63 MoU’s
- 167 sites; 42 countries
When we started LHC computing (~2001)

- There were no internet companies, **no cloud computing** – Google was a search engine, Amazon, etc. did not exist

We had to invent all of the tools from scratch

- At CERN we had no tools to manage a data centre at the scale we thought was needed (no commercial or OS tools existed)
- Initial tools developed through EU Data Grid – **Open Source** from the beginning

Grid ideas from computer science did not work in the real world at any reasonable scale

- We (EU, US, LHC grid projects) had to make them work at scale
- We had to invent trust networks to convince funding agencies to open their resources to federated users

Our users were not convinced that any of this was needed ;-)
Data - 2018

2018: 88 PB
ATLAS: 24.7
CMS: 43.6
LHCb: 7.3
ALICE: 12.4
inc. parked b-physics data

14 PB in August

Data transfers

HI Run

~ 860 k cores continuous
Heterogenous computing

- The majority of today’s HEP processing is performed on dedicated clusters of commodity processors ("x86")
- Recently: opportunistic use of many types of compute, in particular HPC systems, and HLT
- In future, this heterogeneity will expand; we must be able to make use of all types:
  - Non-x86 (esp GPU), HPC, clouds, HLT farms (inc FPGA?)

HPC Use is challenging
HEP engagement with DOE & NSF in USA and (together with SKA) with PRACE and EuroHPC in Europe and participating in BDEC2 workshops
Heterogenous compute

- Requires:
  - Common provisioning mechanisms, transparent to users
  - Facilities able to control access (cost), appropriate use, etc

- HPC, Clouds, HLT will not have (affordable) local storage service (in the way we assume today)
  - Must be able to deliver data to them when they are in active use

Deployed in a hybrid cloud mode:
- Procurers’ data centres
- Commercial cloud service providers
- GEANT network and EduGAIN Federated Identity Management
The HL-LHC computing challenge

- HL-LHC needs for ATLAS and CMS are above the expected hardware technology evolution (15% to 20%/yr) and funding (flat)
- The main challenge is storage, but computing requirements grow 20-50x

ATLAS: simulation for HL-LHC with 200 vertices

CMS: event from 2017 with 78 reconstructed vertices
Google
Internet archive
~15 EB

LHC – 2016
50 PB raw data

LHC Science
data
~200 PB

Google searches
98 PB

Facebook uploads
180 PB

SKA Phase 1 –
2023
~300 PB/year
science data

Yearly data volumes

SKA Phase 2 – mid-2020’s
~1 EB science data

HL-LHC – 2026
~1 EB Physics data

HL-LHC – 2026
~600 PB Raw data

10 Billion of these
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Many software challenges

- Improved algorithms, Machine Learning (ML)
  - “ML” as Neural Networks used for more than 20 years in HEP
  - A lot of development in the IT industry in this area, scope for re-use and improvements
- Vectorisation, GPUs, FPGAs, other processor architectures
- Data Analysis model and software changes
- Visualisation
- Storage and preservation
Grid vs Cloud

• “Cloud computing” everywhere
  – Web based solutions (http/https and RES)
  – Virtualisation, containers….

• GRID has mainly a scientific user base
  – Complex applications running across multiple sites, but works like a cluster batch system for the end user
  – Mainly suitable for parallel computing and massive data processing

• Technologies converging
  – “Internal Cloud” at CERN – OpenStack
  – Xbatch – extending to external cloud providers
  – CernVM – virtual machine running e.g. at Amazon
  – Google Cloud Kubernetes Higgs Challenge
  – “Volunteer Cloud” - LHC@home 2.0
**Volunteer grid - LHC@home**

- **LHC volunteer computing**
  - Allows us to get additional computing resources for e.g. accelerator physics and theory simulations
- **Based on BOINC**
  - “Berkeley Open Infrastructure for Network Computing”
  - Software platform for distributed computing using volunteered computer resources
  - Uses a volunteer PC’s unused CPU cycles to analyse scientific data
  - Virtualization support - CernVM
  - Other well known projects
    - SETI@Home
    - Climateprediction.net
    - Einstein@Home
You can help us!

As a volunteer, you can help us by donating CPU when your computer is idle.

Connect with us on:
- [http://cern.ch/lhcathome](http://cern.ch/lhcathome)
The Balance between Academic Freedom, Operations & Computer Security

http://cern.ch/security
Open Data
http://cds.cern.ch
http://opendata.cern.ch
http://zenodo.org
Open Data – Open Knowledge

CERN & the LHC experiments have made the first steps towards Open Data (http://opendata.cern.ch/)

- Key drivers: Educational Outreach & Reproducibility
- Increasingly required by Funding Agencies
- Paving the way for Open Knowledge as envisioned by DPHEP (http://dphep.org)
  - ICFA Study Group on Data Preservation and Long Term Analysis in High Energy Physics

CERN has released Zenodo, a platform for Open Data as a Service (http://zenodo.org)¹

- Building on experience of Digital Libraries & Extreme scale data management
- Targeted at the long tail of science
- Citable through DOIs, including the associated software
- Generated significant interest from open data publishers such as Wiley, Ubiquity, F1000, eLife, PLOS

¹Initially cofunded by the EC FP7 OpenAire series of projects
Training
Welcome to the CERN School of Computing. This year’s event, CSC:2016, will provide around 50 hours of lectures and hands-on component includes projects and mini-challenges carried out in groups. We have an in-depth programme of advanced, interesting topics which will provide ECTS university credits upon successful completion.

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A science – industry partnership to drive R&D and innovation with over a decade of success
Evaluate state-of-the-art technologies in a challenging environment and improve them
Test in a research environment today what will be used in many business sectors tomorrow
Train next generation of engineers/employees
Disseminate results and outreach to new audiences
IT at CERN – more than the Grid

- **Physics computing – Grids (this talk!)**
- **Administrative information systems**
  - Financial and administrative management systems, e-business...
- **Desktop and office computing**
  - Windows, Linux and Web infrastructure for day to day use
- **Engineering applications and databases**
  - CAD/CAM/CAE (Autocad, Catia, Cadence, Ansys etc)
  - A number of technical information systems based on Oracle, MySQL
- **Controls systems**
  - Process control of accelerators, experiments and infrastructure
- **Networks and telecom**
  - European IP hub, security, telephony software...

More information: [http://cern.ch/it](http://cern.ch/it)
Thank You!

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