Computing Challenges of the Future

Simone Campana (CERN)
Before I even start, I thank people for the fruitful discussions and material in preparation for this presentation. And apologies if I forgot someone

Tim Bell, Doug Benjamin, Latchezar Betev, Tommaso Boccali, Concezion Bozzi, Ian Bird, Predrag Buncic, Federico Carminati, Marco Cattaneo, Davide Costanzo, Xavier Espinal, Joao Fernandes, Maria Girone, Bob Jones, Gavin Mccance, Bernd Panzer-Steindel, David Rohr, Stefan Roiser, Jamie Shiers, Daniele Spiga, Graeme Stewart, Ikuo Ueda, Sofia Vallecorsa

Of course the selection of the material and they way I present it is my responsibility
Introduction

The HEP Software Foundation delivered in 2018 a Community White Paper identifying the HEP computing challenges in the 2020s and defining a roadmaps for Software and Computing evolution.

The HSF CWP is a bottom up approach. Scientific projects prioritize topics from the CWP based on their future needs and specific challenges. See for example the WLCG Strategy Document for HL-LHC.

Those documents drive today a lot of the activity around future challenges in HEP. This presentation is an overview. Dedicated discussion on Wednesday morning.
HEP computing embraced a large scale distributed model since early 2000s
Based on grid technologies, federating national and international grid initiatives

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.
HEP Computing Today

Grid resources are shared among many experiments and sciences

LHC experiments consume 95% of the accounted computing capacity

Non HEP sciences rely a lot on HPCs (not accounted here)

Today LHC is in a leading position steering the evolution of the scientific Grid infrastructure
Today LHC generally gets the requested computing resources. Extra opportunistc compute capacity is available.

The LHC data volume challenge

ALICE and LHCb will increase considerably the data rates in 2022 (LHC Run-3)

ATLAS and CMS will increase the event rates by a factor 10 and the event complexity in Run-4 (HL-LHC)

No expected increase of funding for computing: “flat budget”

Use of Pledges

C. Bozzi (LHCb) @ HOW 2019

Run-3

HL-LHC

HSF CWP

WLCG RRB Apr. 2019

WLCG YEAR


Pledge Evolution Data MC Buffer & User Pledge

Disk

obsoleted, see later

obsoleted, see later

Simone.Campana@cern.ch - ESPP

13/05/2019
The HE(N)P data volume challenge

Several experiments will require relatively large amount of compute and storage resources. Several factors less than HL-LHC

DUNE foresees to produce ~70PB/year in the mid 2020s

J. Eschke @ ESCAPE kick-off

Y. Kato @ HOW 2019
Heterogeneous Facilities

Up to 25% of resources currently used by LHC experiments comes from non-Grid facilities

- Cloud Computing
- High Performance Computing
- HLT farms

Today contributing to the “opportunistic” pool of available capacity

Efficient usage of those resources will be a key challenge in the future
Clouds and HPCs

**High Performance Computing** centers: very heterogeneous in hardware and policies. Large pools of resources and growing. **Strengthen the link between HEP and HPC communities**: find effective common and scalable solutions to the challenges of data intensive processing

**Commercial Clouds**: virtually infinite resources and flexibility, cost effectiveness still to be demonstrated. Challenges: interfaces, vendor locking, networking, procurement, economic model

- **Google**, Amazon via HepCloud
- **Azure** via DoDas

![# prod running jobs @ T1s (2016)](image)

- **# cores used on HPCs in 2018**
  - Leadership Class Facilities
  - Other HPCs

![# prod running jobs @ T1s (2016)](image)
Storage and Data Management

Storage: the main challenge in the 2020s ...

- No opportunistic storage
- Data is THE main asset of HEP, but storage needs are hard to fulfill
- Storage service are challenging to operate

... but also a great opportunity

We have decades of experience in developing and operating large storage solutions and managing large data volumes

DOMA projects
(Data Organization, Management, Access)

- A set of R&D activities evaluating components and techniques to build a common HEP data cloud

Simone.Campana@cern.ch - ESPP
13/05/2019
There is an opportunity to leverage commonality across HEP and beyond. This is happening already. Compromise between experiment specific and common solutions.

Compromise in adopting products from open source community projects and in-house development.

Openness and collaboration are the key. Watch for sustainability!

Common access layers to HPC and Clouds.
Different Sciences, Shared Infrastructure

Most of the facilities supporting HEP and other science projects are the same. The Funding Agencies do not want to deploy several computing infrastructures.

Several HEP and Astro-Particle projects indicated their wish to share many aspects of the computing global infrastructure and services, while maintaining flexibility to adopt what suites them more. E.g. APPEC [ID-84], DUNE [ID-126].

The idea to generalize the infrastructure related aspects of WLCG and open them to more scientific communities has been presented [ID-53] and generally well perceived. It is being prototyped with DUNE and Belle-2.
Goals:
Prototype an infrastructure adapted to the Exabyte-scale needs of the large science projects.

Driven by the sciences

Address FAIR data management

Science Projects
- HL-LHC
- FAIR
- KM3Net
- ELT
- EURO-VO
  (LSST)
- SKA
- CTA
- JIVE-ERIC
- EST
- EGO-VIRGO
  (CERN,ESO)

Data centres: CERN, INFN, DESY, GSI, Nikhef, SURFSara, RUG, CCIN2P3, PIC, LAPP, INAF
Challenges from hardware trends

- Cost of hardware decreasing exponentially vs time 😊 ... but not as steeply as before 😱
- In general, trends driven by market (revenues) rather than technology

**B. Panzer @ Scientific Computing Forum**
Challenges from Hardware Trends

New Summit HPC @ ORNL:
9.96 Pflops in CPU (non X86_64)
215.7 Pflops in GPUs

We need to take advantage of the huge GPU capacity at HPCs (also to get good allocations)

In general, we need to continue to modernize our applications to take advantage of hardware evolution

https://www.karlrupp.net
Software is probably the biggest opportunity to address the possible future HEP shortage of computing resources. See HSF input [ID-79]

Multithreading allows flexibility to optimize memory usage and throughput

Speed up from GPU usage + from algorithmic improvements + tuning on CPUs

Modern GPU replaces 40 CPU cores @ 4.2 GHz
Algorithm speed-up on CPU 20-25x v.s. to Run 2 Offline

CMS reconstruction MT+MP

D. Rohr @ HOW 2019
Increasing gap in skills between early career physicists and the profile needed for programming on new architectures, e.g. parallelization. Collaboration between physics and SW engineers communities on core components (see e.g. see [ID-114] from MCNET)

Lot of legacy in HEP software. To implement radical changes need a multi-year planning and institutional commitment as we have in other areas

Career prospects for those who specialize in software should be as bright (or no more gloomy) than anyone else in HEP. SW development is a critical part of our future success, let’s reward it!

Following HFS CWP, several funded initiatives: IRIS-HEP (US), IRIS (UK), IDT-UM (DE)
Preliminary discussions on the idea of a Scientific Computing Institute. See also [ID-5] for a Deep Learning focused proposal

Innovation, collaboration with other sciences and industry, access to and experience with modern technologies is a key to motivate our community.
Machine Learning

A concrete example of technology attracting interest and showing great potential

• Adopted in HEP since the 90s e.g. Multivariate Analysis
• Rapid recent development of tools and techniques in last years driven by industry
  • optimized and even specialized for modern hardware
• Different ML applications in HEP in different phases of maturity

ML Applications and R&D *(from the HSF CWP)*

1. Simulation
2. Real Time Analysis and Triggering
3. Object Reconstruction, ID, and Calibration
4. End-To-End Deep Learning
5. Sustainable Matrix Element Method
6. Matrix Element Machine Learning Method
7. Learning the Standard Model
8. Theory Applications
9. Uncertainty Assignment
10. Data Quality Monitoring
11. Operational Intelligence

S. Vallecorsa @ CERN IT Technical Forum
Example of Collaboration with Industry

CERN openlab [ID-162]

A science – industry partnership to drive R&D and innovation

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

Training

Dissemination and outreach

Besides aforementioned R&D activities, allows investigations of long term disruptive technologies e.g. Quantum Computing [ID-59] and [ID-128]
Aspects of data stewardship

**Data Preservation:** preserving data and associated “information” for designed purposes
- E.g. ANALYSIS and educational outreach

**Open Data** – data released for re-use
- Data that is “open” is not necessarily accessible with zero latency

**Significant resource/support requirements involved**

(FAIR) **Data Management Plans:** bring the above together:
- Findable, Accessible, Inter-operable, Re-usable

DPMs must describe how data is preserved (including resource requirements)
- are increasingly an (EU) funding agency requirement
- need to be produced and updated at regular intervals

Do you have a Data Management Plan?
Computing resources for HEP in the 2020s will be more constrained w.r.t. the current decade: existing projects entering in a challenging phase, many new projects, competition from other sciences

We have the possibility leverage this intellectual challenge and turn it into opportunity. Innovation is the key aspect as it offers:

- an occasion for young (and not so young) generations of physicists to master modern computing technologies and specialize

- solutions of our problem, maximizing the physics we get for our computing and software
Conclusions (2/2)

We faced the 2010s compute challenge with success. The 2020s present a new one. A lot of work has been done for LHC Run-3 (e.g. Alice/LHCb): now under control HL-LHC work started, there is a concrete plan and lots of opportunities.

The plan needs to be implemented. Everyone on board!
CERN, update on the Higgs Boson searches at the LHC, 4th July 2012

https://www.youtube.com/watch?v=0Tnd8bxDYOs

Global Effort → Global Success

Results today only possible due to extraordinary performance of accelerators – experiments – Grid computing

Observation of a new particle consistent with a Higgs Boson

S. Campana
Backup Material
Compute Cloud Resources

Commercial Clouds still need to demonstrate cost effectiveness when compared with on-premise capacity. However:

- Offer elastic capabilities to absorb peak of activities for compute
- Price is decreasing ...

Challenges: heterogeneous interfaces, networking, procurement and economic model, operational effort, **DATA MANAGEMENT**

Deployed in a hybrid cloud mode:

- Procurers’ data centers
- commercial cloud service providers
- GEANT network and EduGAIN Federated Identity Management

**B. Jones, J. Fernandes**

*# prod running jobs @ T1s (2016)*
High Performance Computers

**HPCs are** in HEP computing, to stay and **grow**. HPCs are very heterogeneous. Major funding agencies are mandating a **very high profile for HPCs**

See e.g.  *J. Siegrist (US DOE), Status of the DOE High Energy Physics Program (May 2018)*

Leveraging HPCs requires **dedicated investment** of effort:

- **stable allocations**, not just backfill, to make the investments pay; resource acquisition model is important
- **edge services** and tools for software distribution, provisioning, data handling. Negotiating policies is important

HEP and HPC centers need to engage:

find effective common and scalable solutions to the challenges of data intensive processing

Mutual benefit if the link between HEP and HPC communities is strengthened. In Europe this would be through PRACE/EUROHPC
Aspects of data stewardship

**Data Preservation** – the (well established) active task of **preserving data and associated “information”** – even across significant changes in technology – for **designed purposes** such as ANALYSIS and educational outreach

**Open Data** – data that has been released for re-use / sharing typically with s/w + doc to make this possible. Data that is “open” is not necessarily accessible with zero latency

**Significant resource/support requirements involved**

(FAIR) **Data Management Plans**: a relative newcomer but a way of tying the above together:
- Findable, Accessible, Inter-operable, Re-usable
- DMPs must describe (inter-alia) how data is preserved and can (should) include resource requirements
- (FAIR) DMPs are increasingly an (EU) funding agency requirement
- DMPs need to be produced and updated at regular intervals!

Do you have a Data Management Plan?
X. Zhao @ WLCG DOMA

Store on cheaper high latency media (tape today). Process in organized campaigns

T. Boccali, M Klute

<table>
<thead>
<tr>
<th>Data Tier</th>
<th>Size (kB)</th>
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<tbody>
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<tr>
<td>NANOAOD(SIM)</td>
<td>1 (50x reduction)</td>
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Comments and Recommendations: 2017

- The experiments have worked to mitigate the impact of the increased LHC live time, but it is unreasonable to expect them to be able to keep pace with the rapid increase in LHC performance within a flat budget.
- C-RSG considers the requests of the experiments adequate for the physics program approved by LHCC.