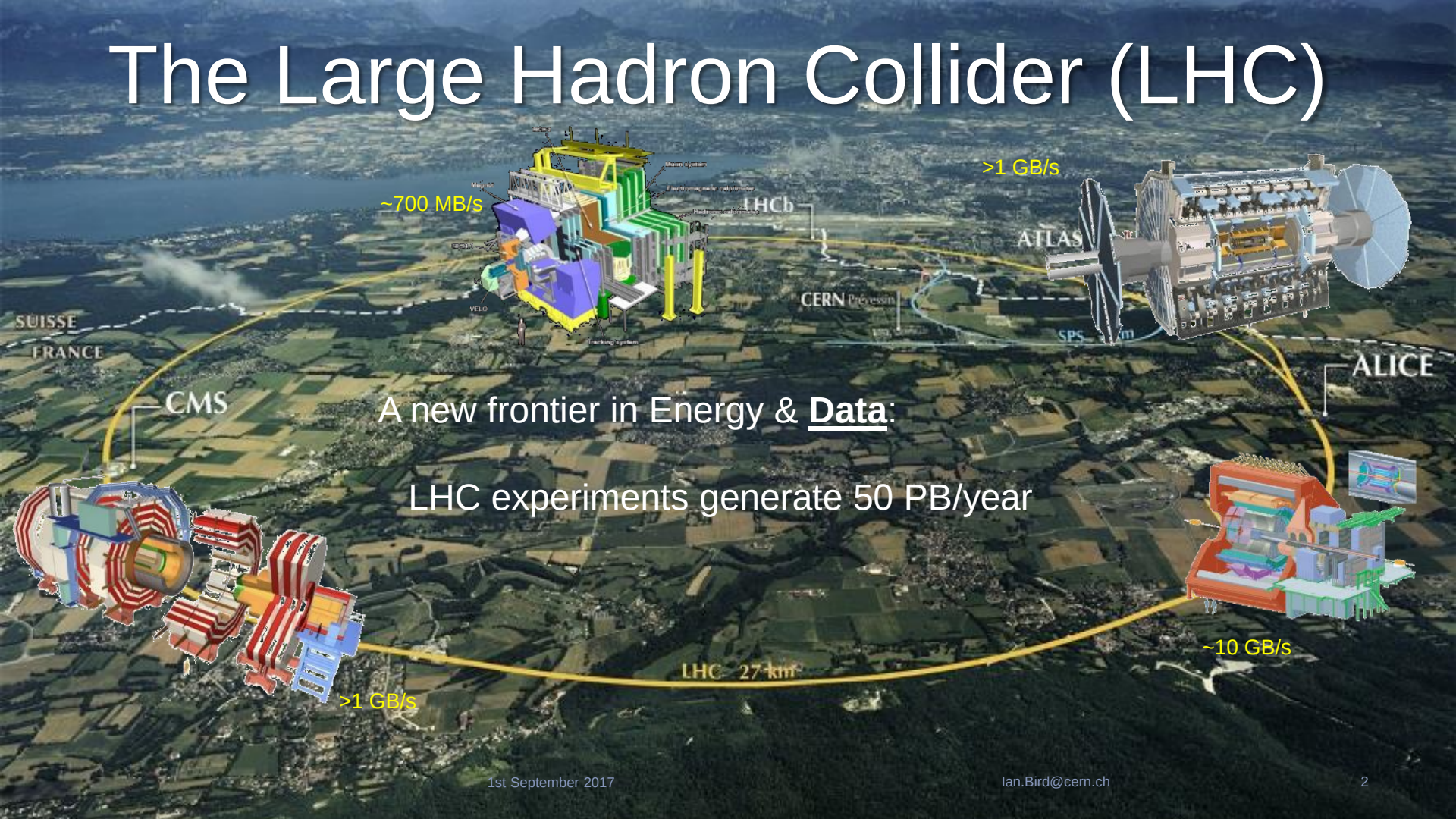
Dr. Ian Bird
CERN
LHC Computing Project Leader

CERN-GW Meeting
CERN, 1st September 2017

Computing for LHC

The Large Hadron Collider (LHC)



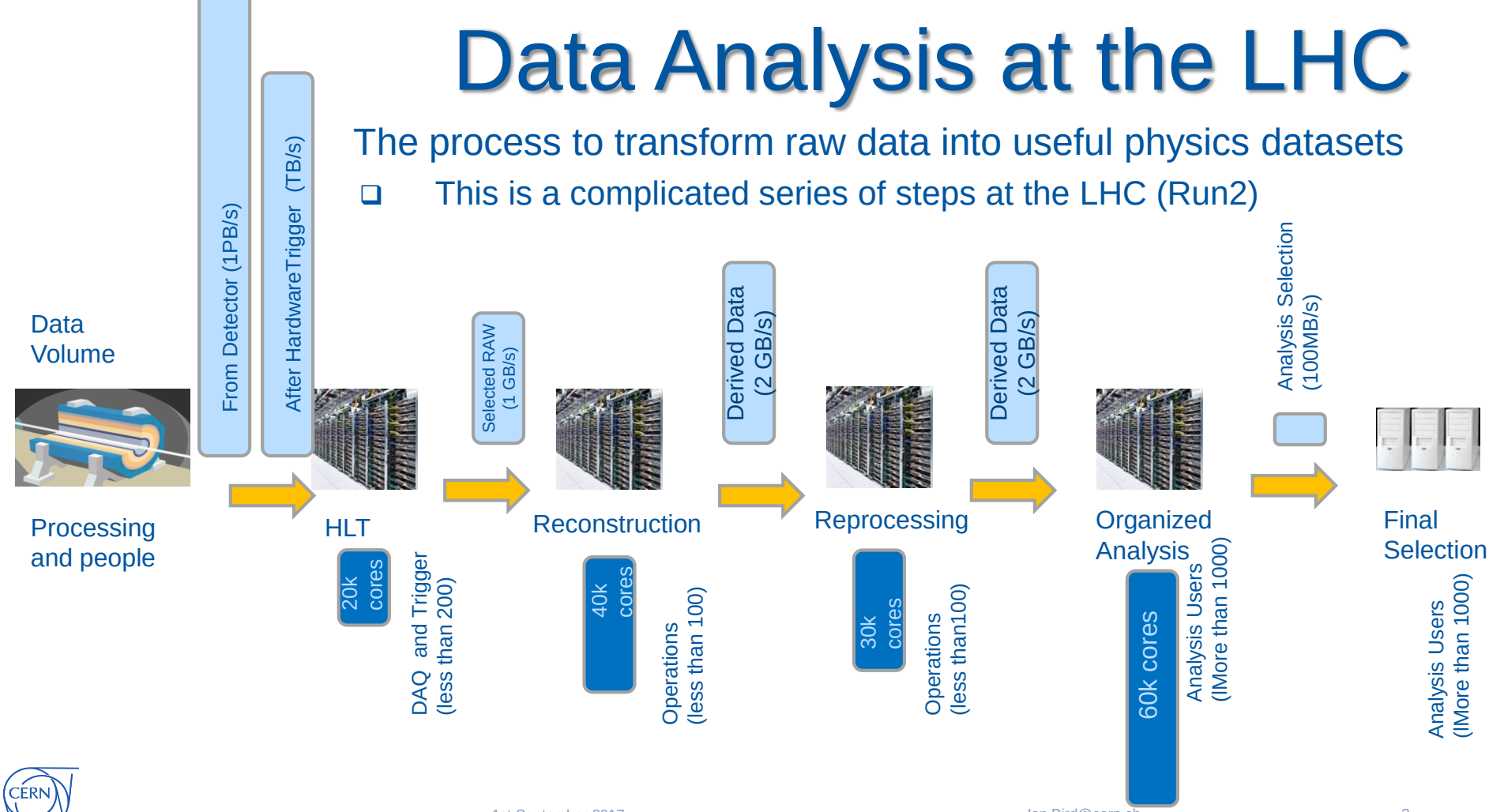
A new frontier in Energy & **Data**:

LHC experiments generate 50 PB/year

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)

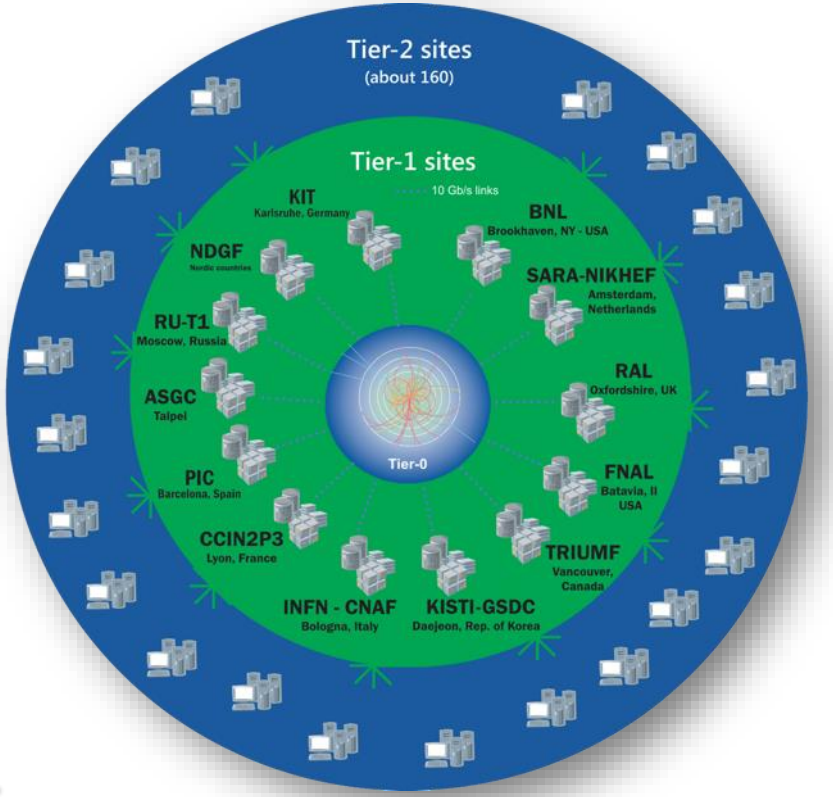


The Worldwide LHC Computing Grid

Tier-0 (CERN and Hungary): data recording, reconstruction and distribution

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

Tier-2: Simulation, end-user analysis



~170 sites, 42 countries

~750k CPU cores

~1 EB of storage

> 2 million jobs/day

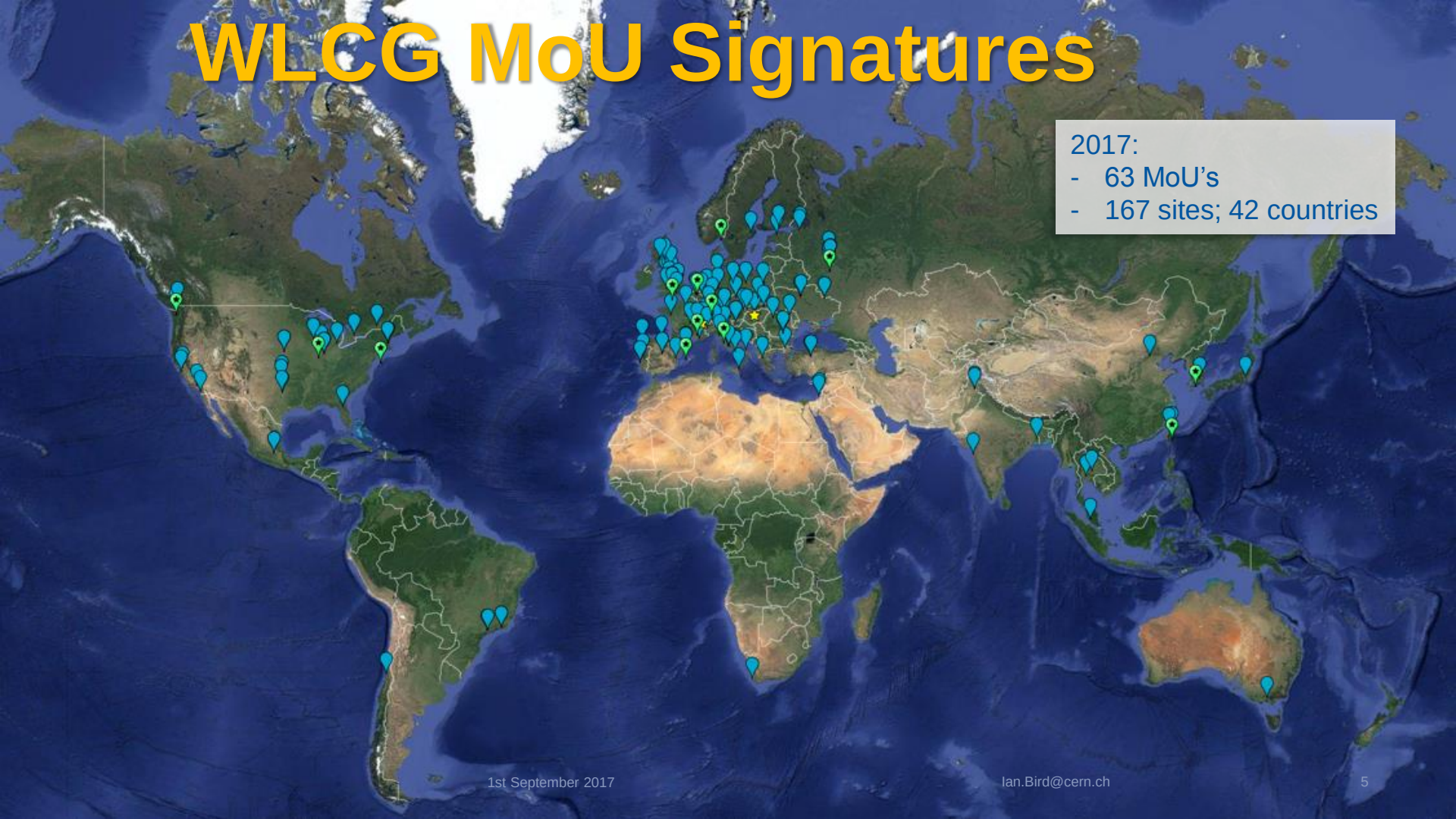
10-100 Gb links

WLCG:
An International collaboration to distribute and analyse LHC data

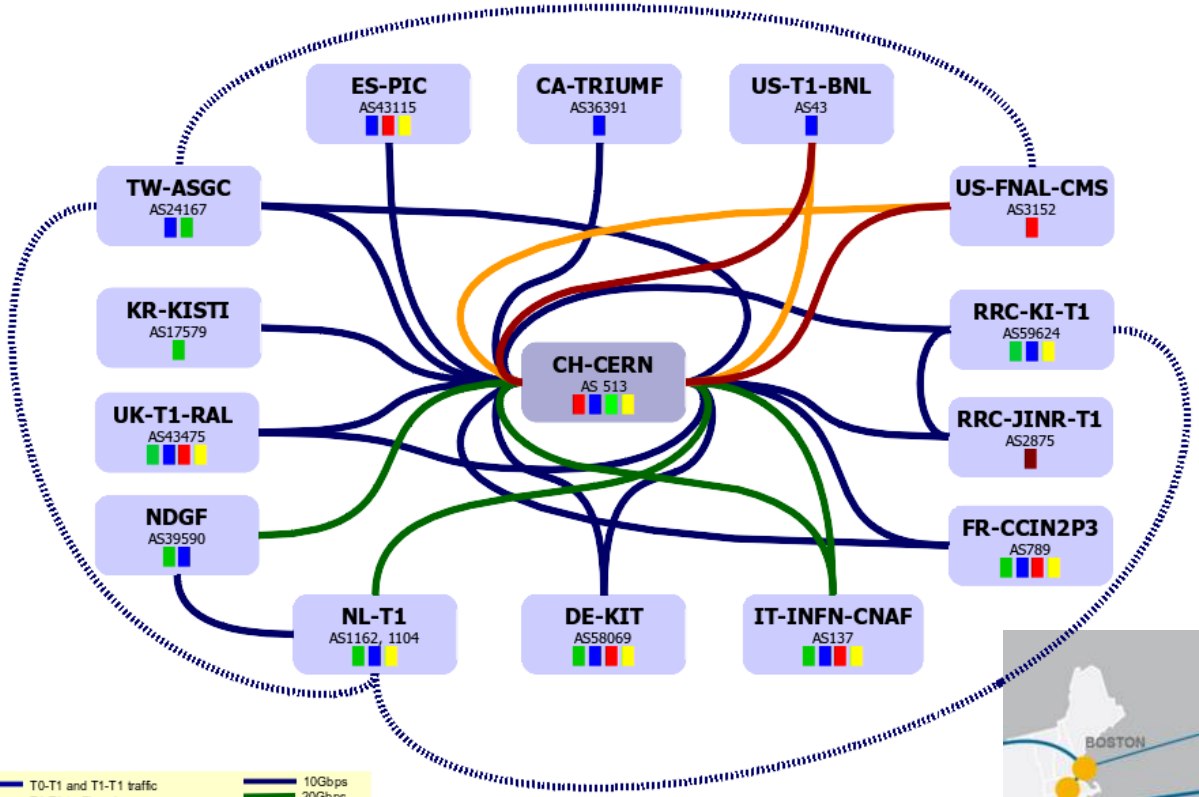
Integrates computer centres worldwide that provide computing and storage resource into a single infrastructure accessible by all LHC physicists

WLCG MoU Signatures

2017:
- 63 MoU's
- 167 sites; 42 countries



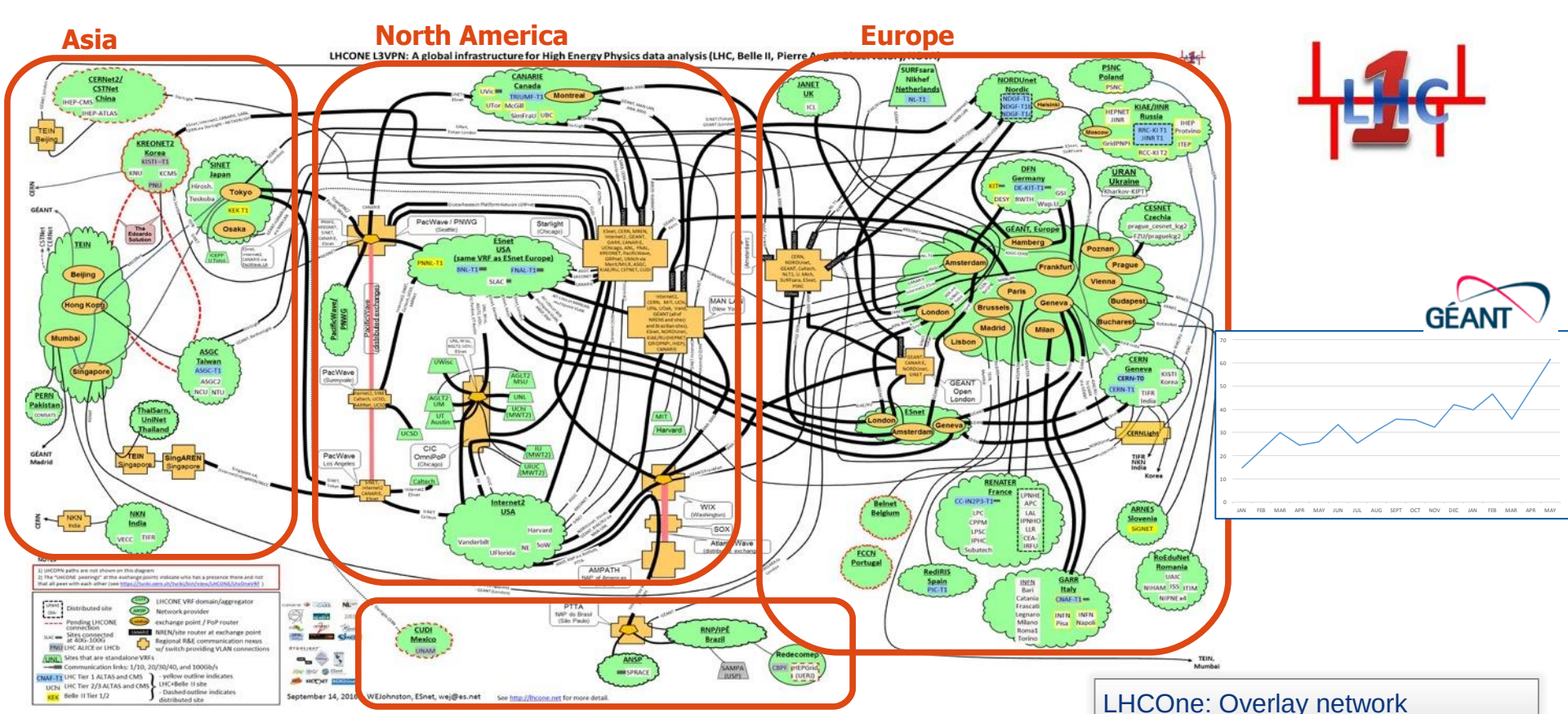
LHCOPN Networks



Optical Private Network
Support T0 – T1 transfers
& T1 – T1 traffic
Managed by LHC Tier 0 and
Tier 1 sites

Up to 340 Gbps transatlantic

T0-T1 and T1-T1 traffic
T1-T1 traffic only
= Alice = Atlas = CMS = LHCb
edoardo.martelli@cern.ch 20161010
10Gbps
20Gbps
40Gbps
100Gbps



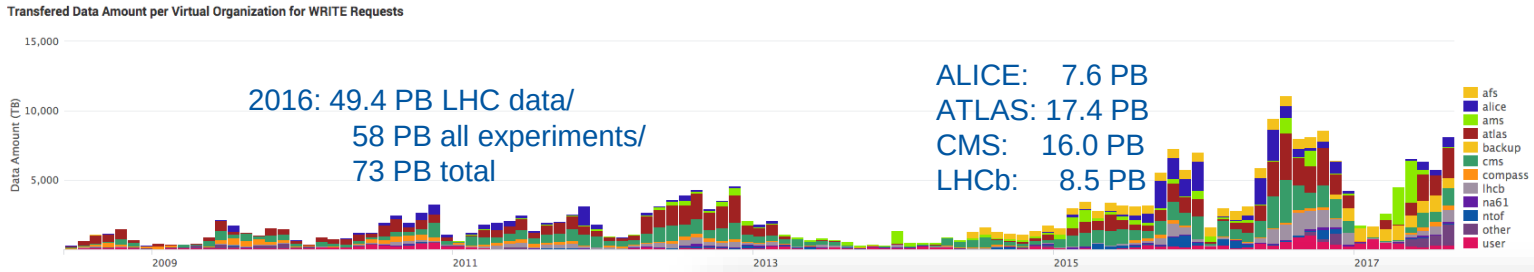
South America

LHCOne: Overlay network

Allows NREN's to manage HEP traffic on general purpose network

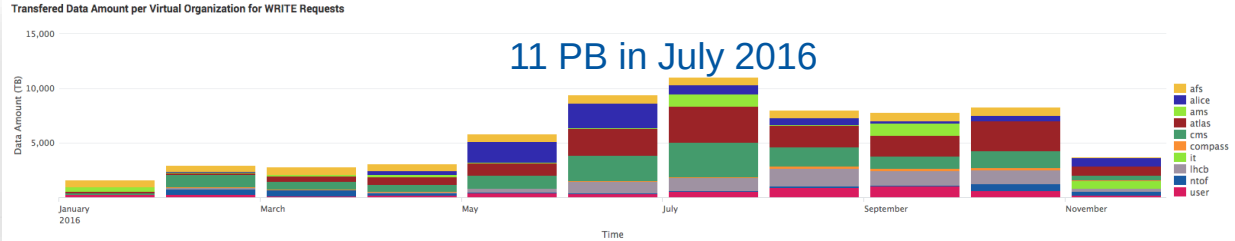
Managed by NREN collaboration

Data at CERN

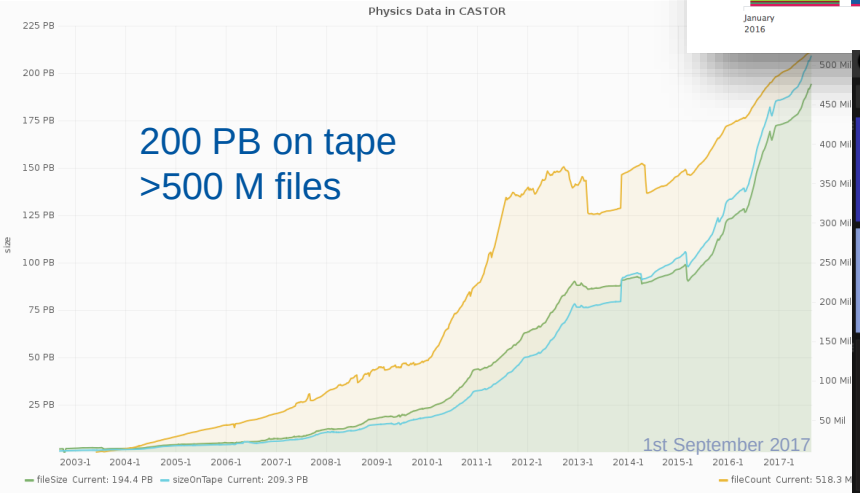


2016: 49.4 PB LHC data/
58 PB all experiments/
73 PB total

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

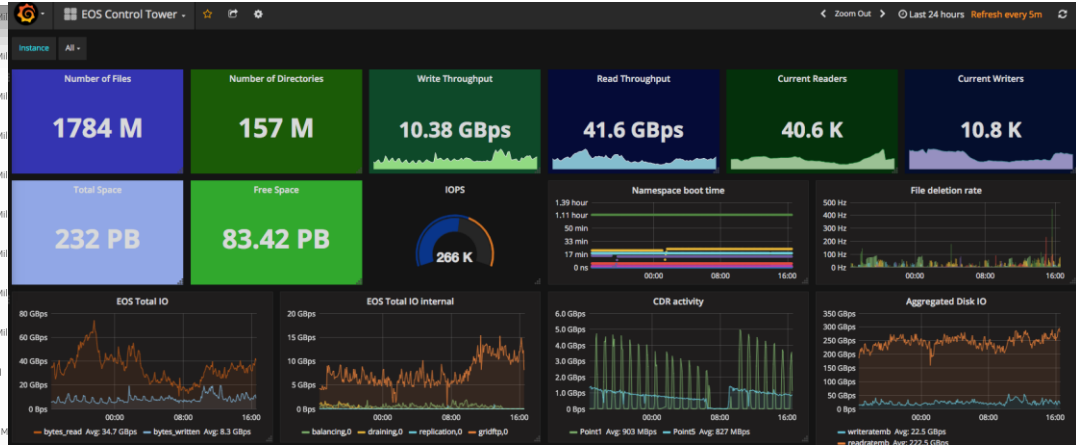


11 PB in July 2016



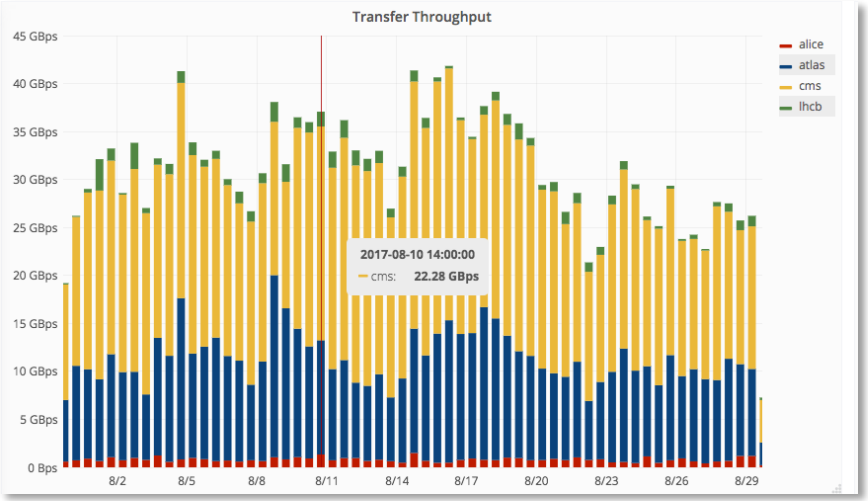
200 PB on tape
>500 M files

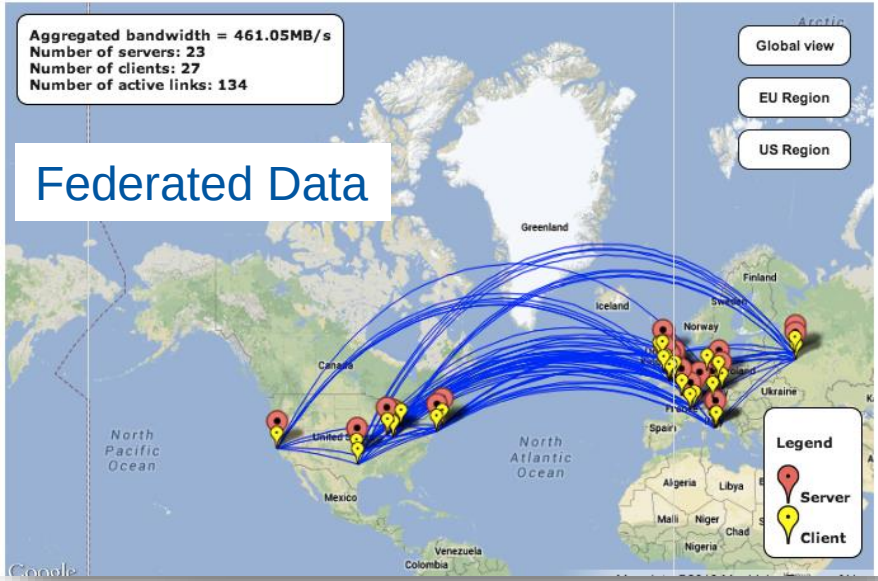
1st September 2017

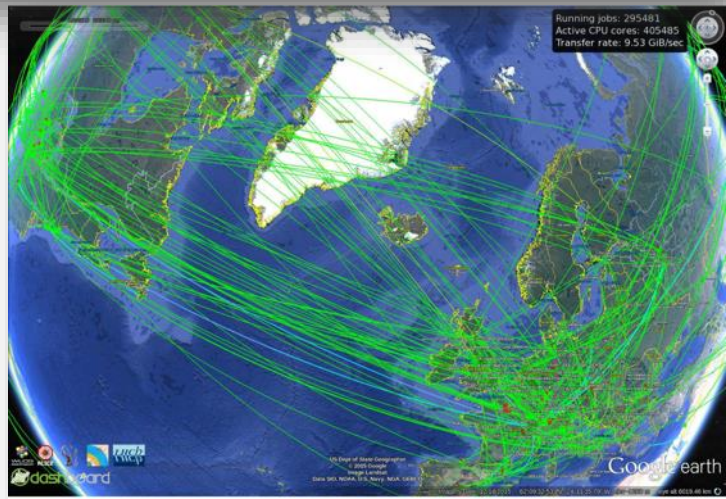


Data distribution

- Global transfer rates increased to 30-40 GB/s (>2 x Run1)





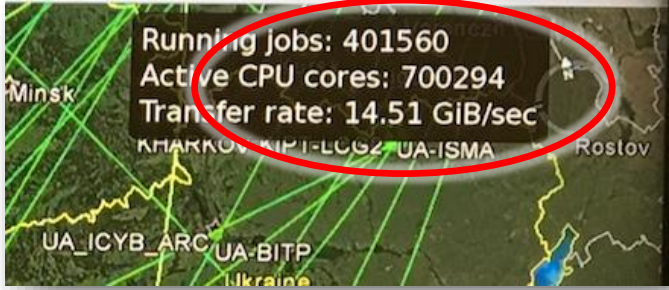


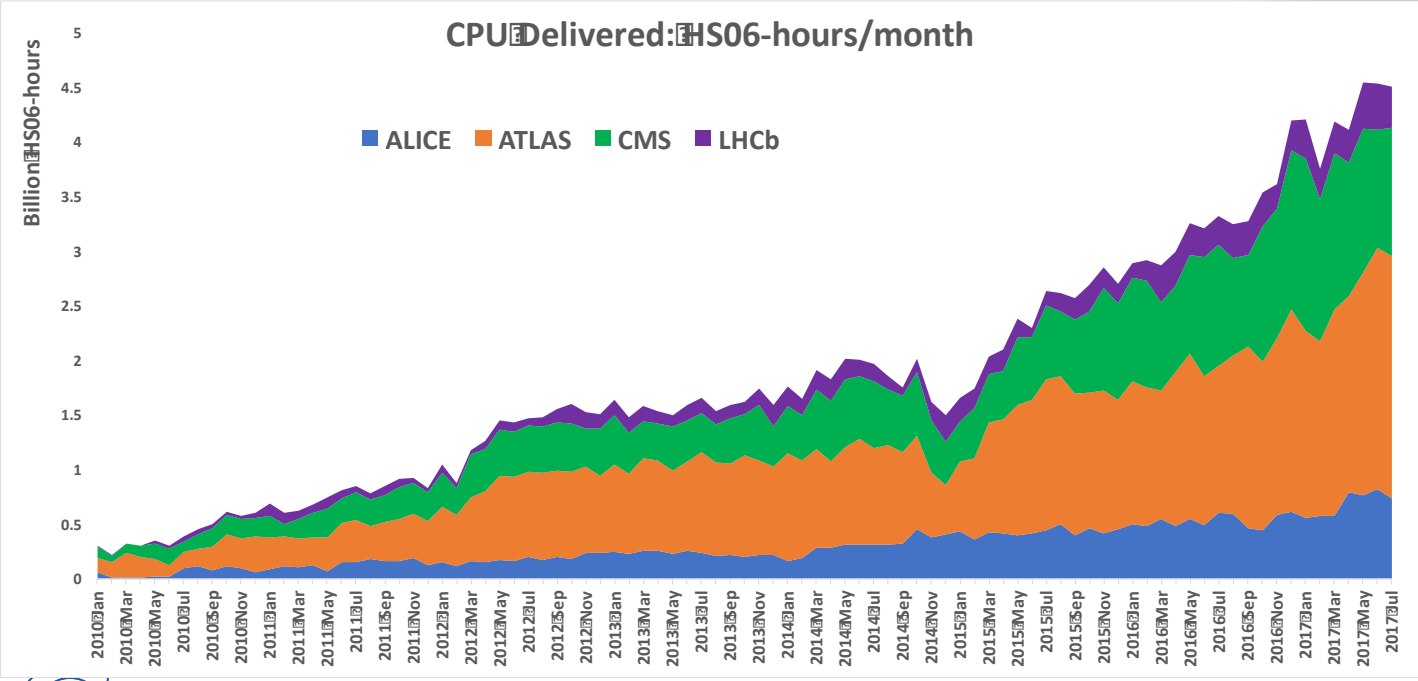
Increased performance everywhere:

- 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

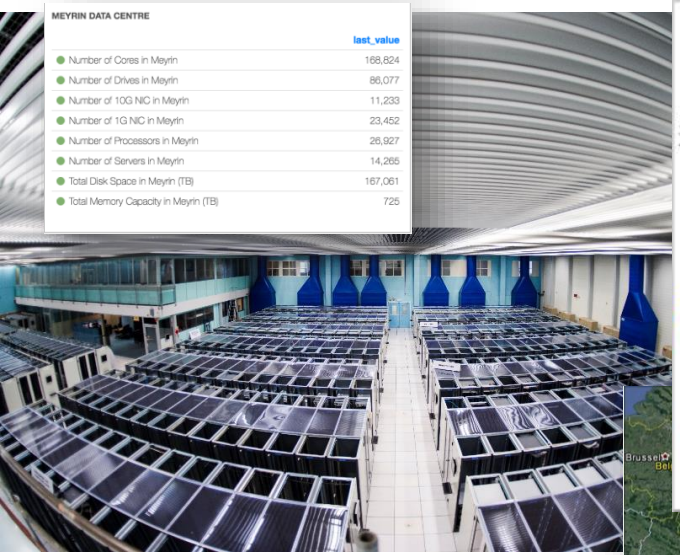




Peak delivery:

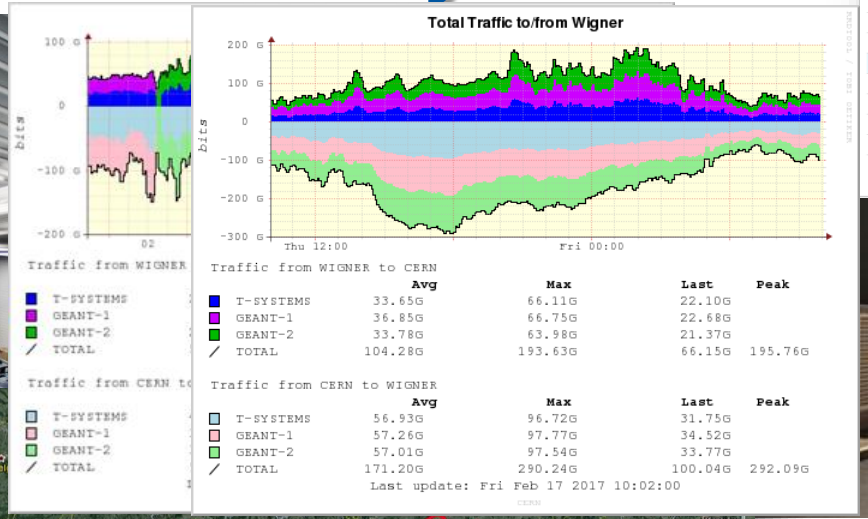
190M core-days/month
(~ 600k cores permanently)

CERN Facilities today



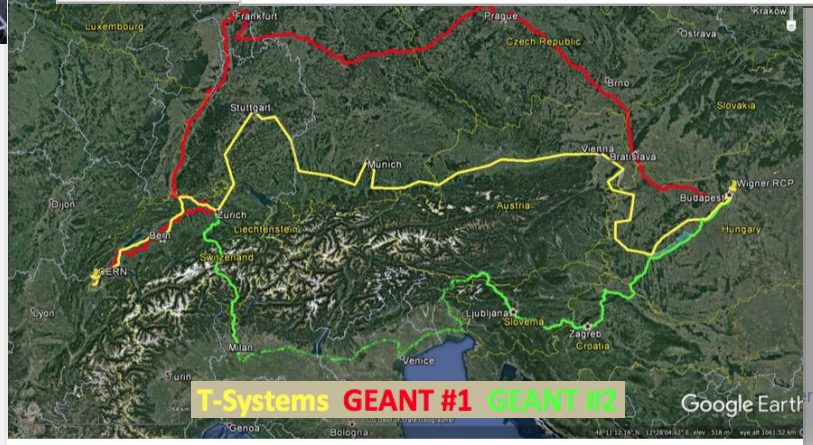
MEYRIN DATA CENTRE

	last_value
Number of Cores in Meyrin	168,824
Number of Drives in Meyrin	86,077
Number of 10G NIC in Meyrin	11,233
Number of 1G NIC in Meyrin	23,452
Number of Processors in Meyrin	26,927
Number of Servers in Meyrin	14,265
Total Disk Space in Meyrin (TB)	167,061
Total Memory Capacity in Meyrin (TB)	725



WIGNER DATA CENTRE

	last_value
Number of Cores in Wigner	56,000
Number of Drives in Wigner	29,694
Number of 10G NIC in Wigner	2,981
Numer of 1G NIC in Wigner	6,579
Number of Processors in Wigner	7,002
Number of Servers in Wigner	3,504
Total Disk Space in Wigner (TB)	97,315
Total Memory Capacity in Wigner (TB)	221



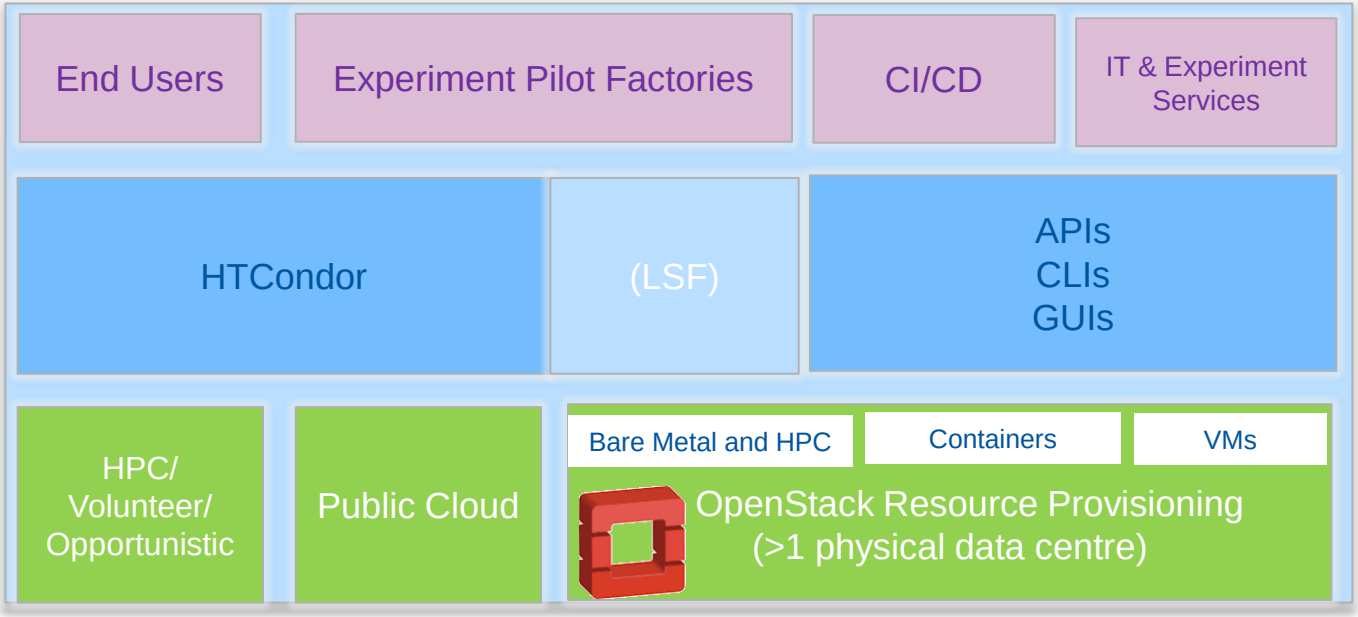
2017:

- 325 k cores
- 250 PB raw disk

2017-18/19

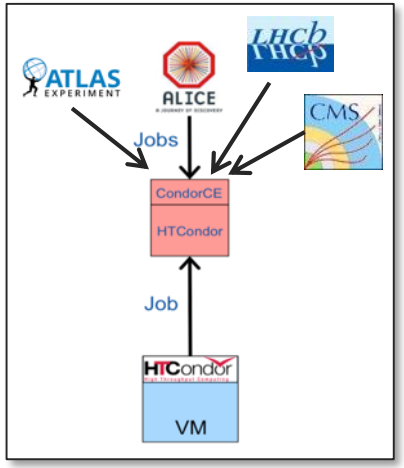
- Upgrade internal networking capacity
- Refresh tape infrastructure

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



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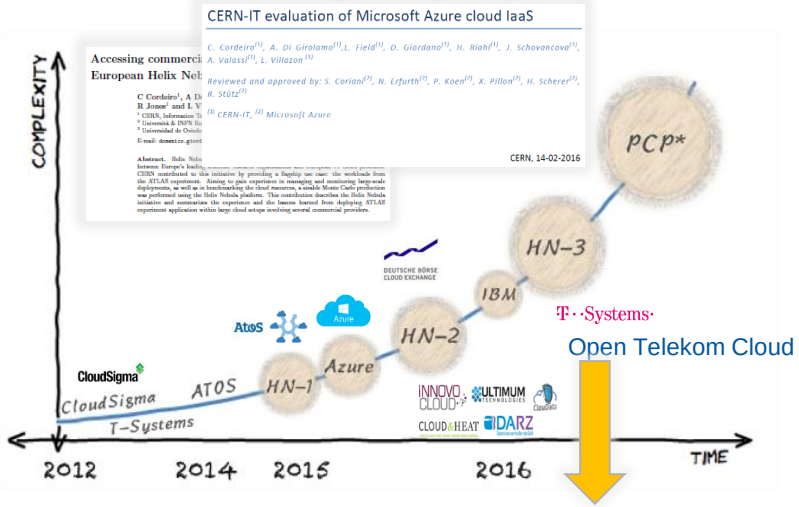
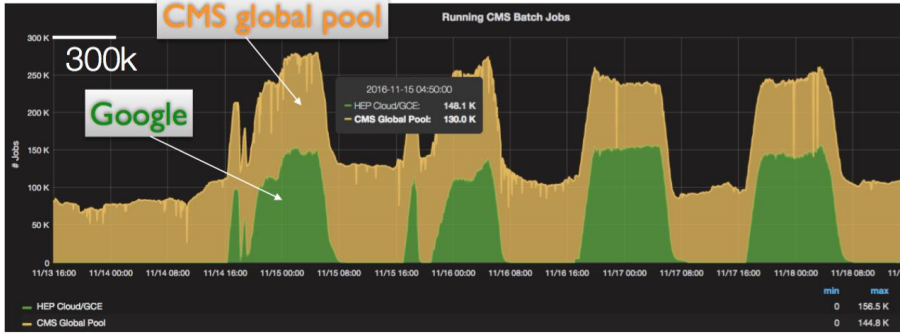
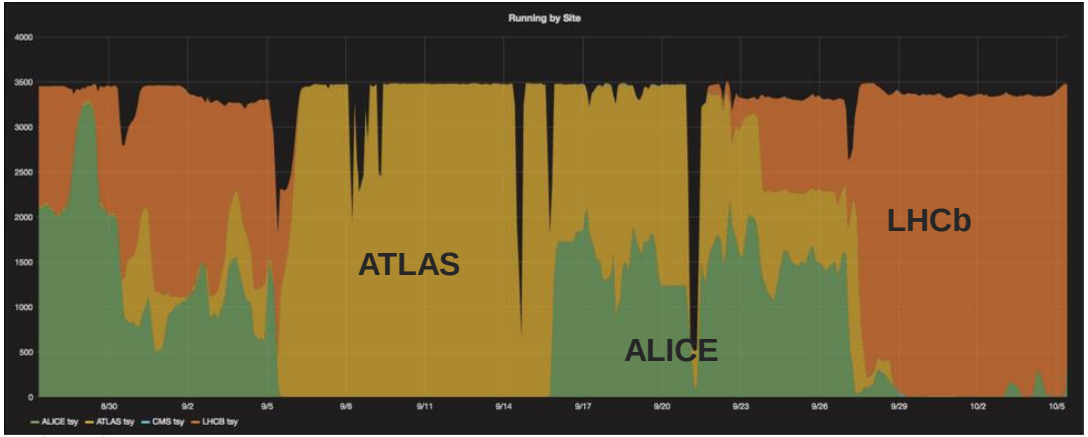
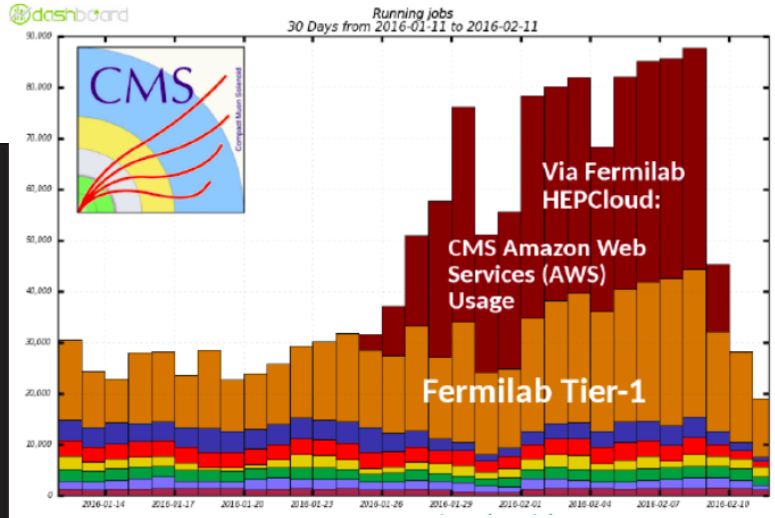
Commercial Clouds

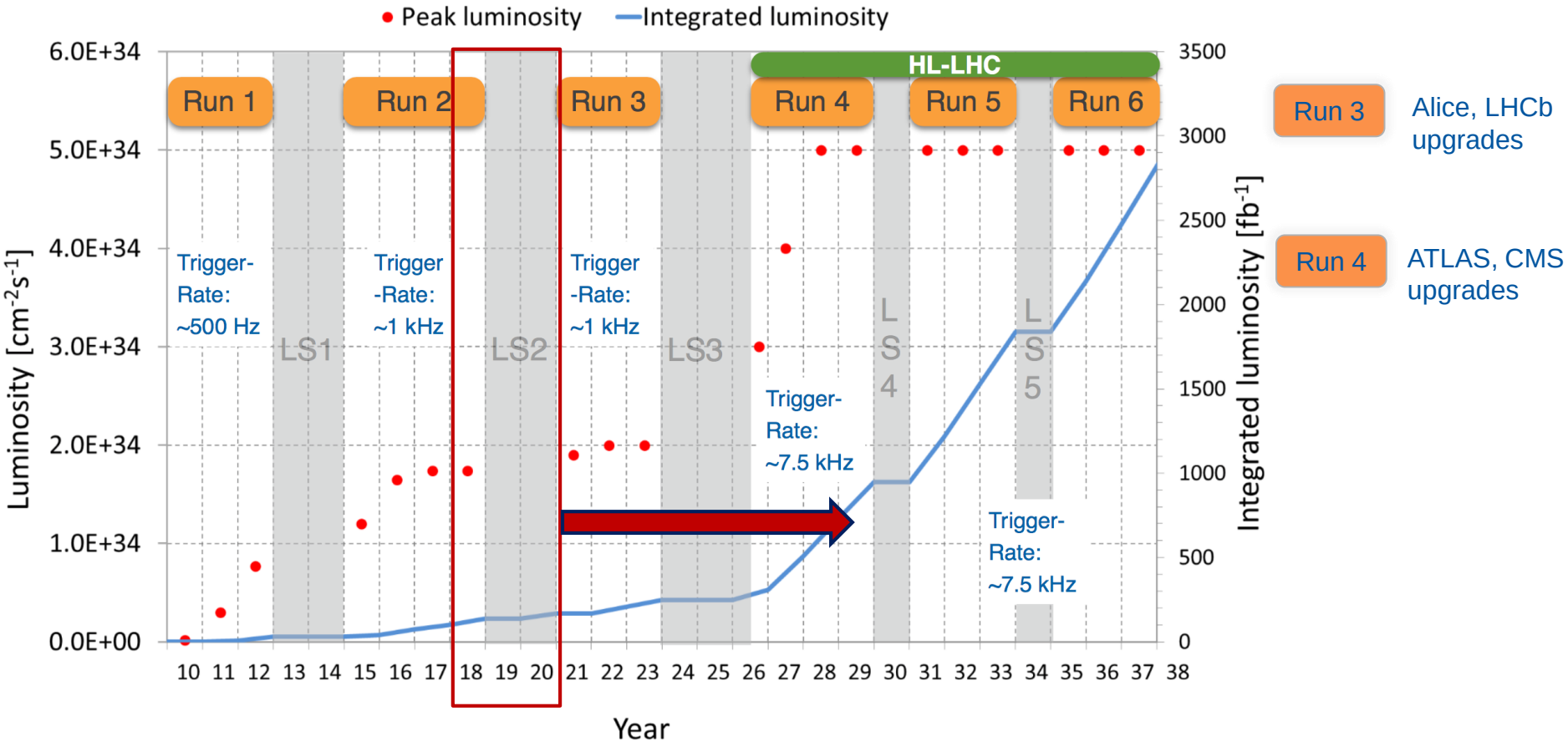








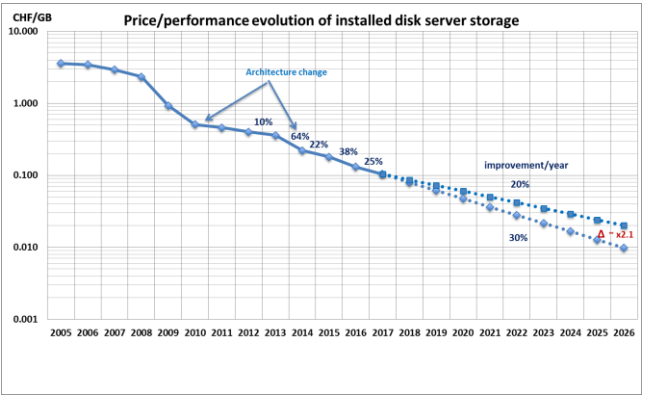
LHC Schedule

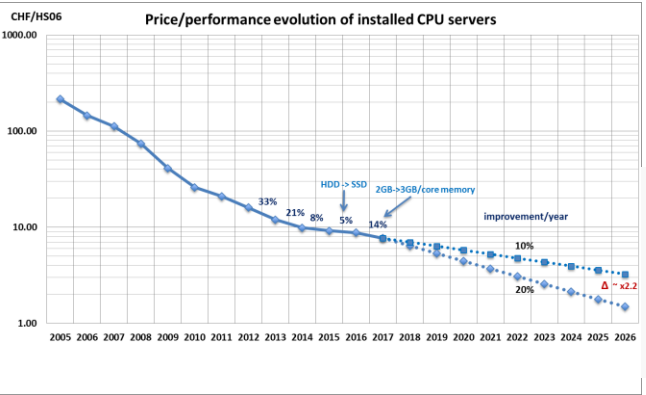


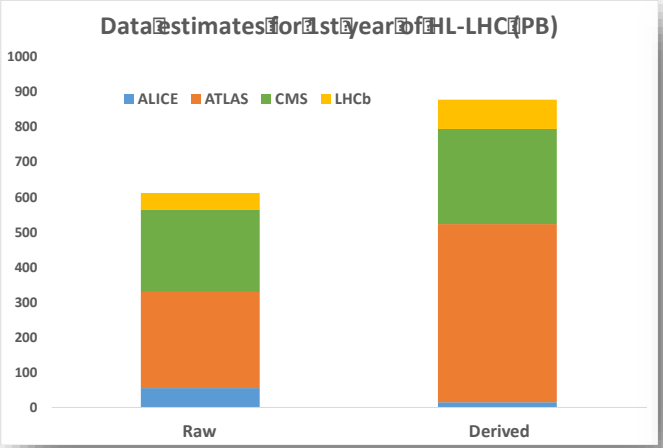
Future Challenges

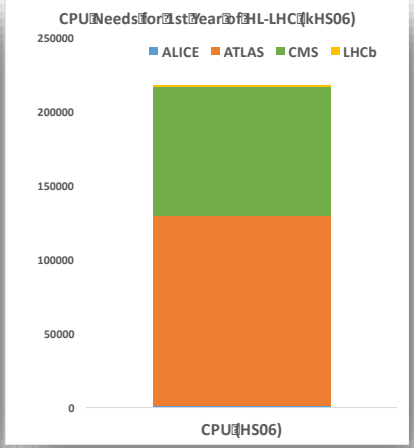
2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 …… 2030?

First run | LS1 | Second run | LS2 | Third run | LS3 | HL-LHC | FCC?









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

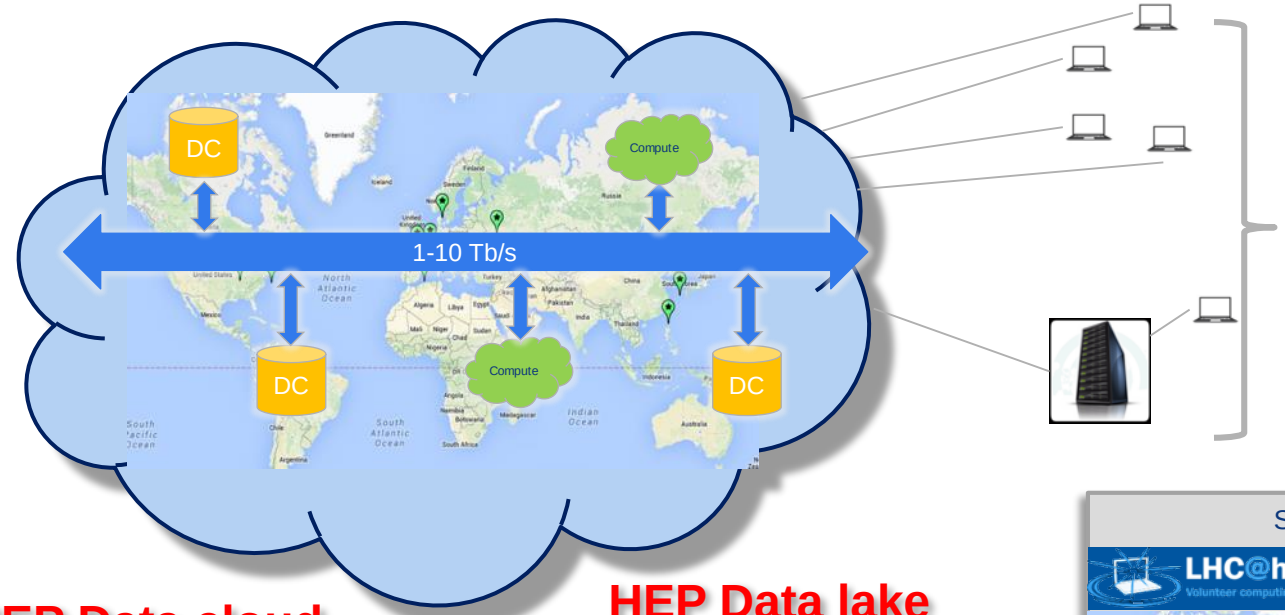
CPU:
- x60 from 2016

- 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

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



Cloud users:
Analysis

HEP Data cloud

Storage and compute

HEP Data lake

Storage and compute

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

Simulation resources

Software

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

HSF
HEP Software Foundation

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 infomation 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 »

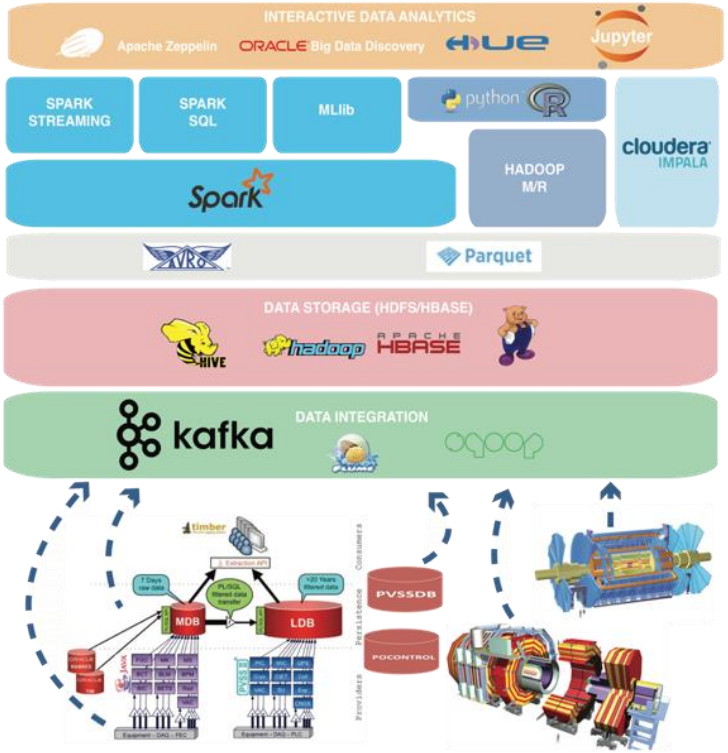
Activities

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.

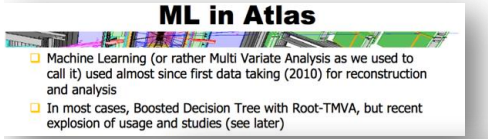
How to get involved »

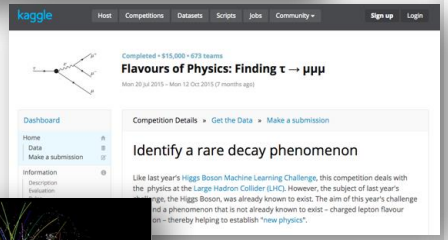
New analytics

- Big Data tools
- Machine/Deep learning

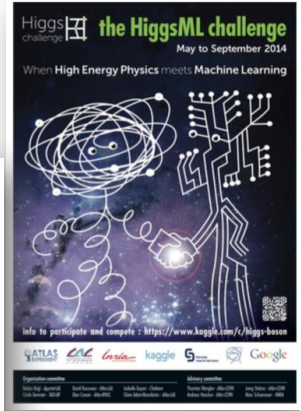


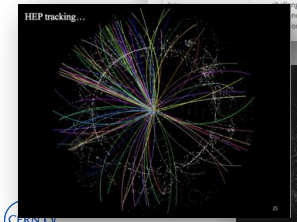
Machine Learning

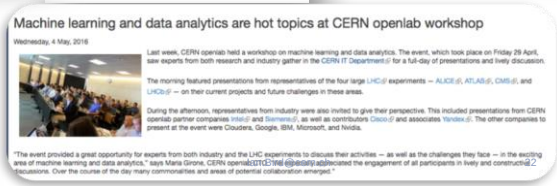




- Data taking
  - Real time event categorization
  - Data monitoring & certification robot
- Data Reconstruction
  - Calorimeter reconstruction
  - Boosted object jet tagging
- Data Processing
  - Computing Resource Optimization
  - Predicting data popularity
  - Intelligent networking
- Data Analysis
  - CMS assistance service
  - Big data reduction and analysis
  - Model independent search

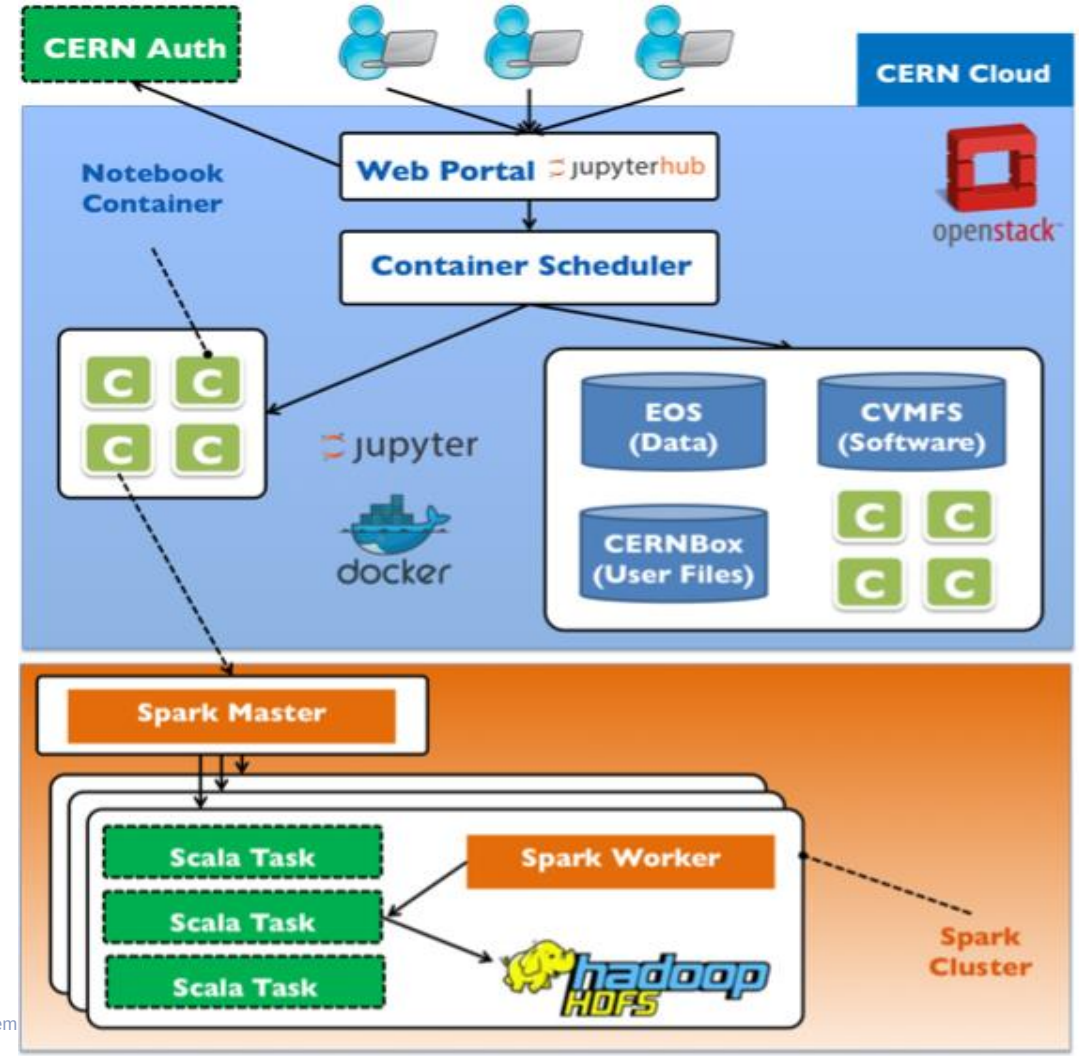






SWAN

- 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