Barcelona Institute of Science and Technology

BIST Founding Conference
Barcelona, Spain
31 March 2017

The Worldwide LHC Computing Grid

Frédéric Hemmer
CERN – IT Department Head

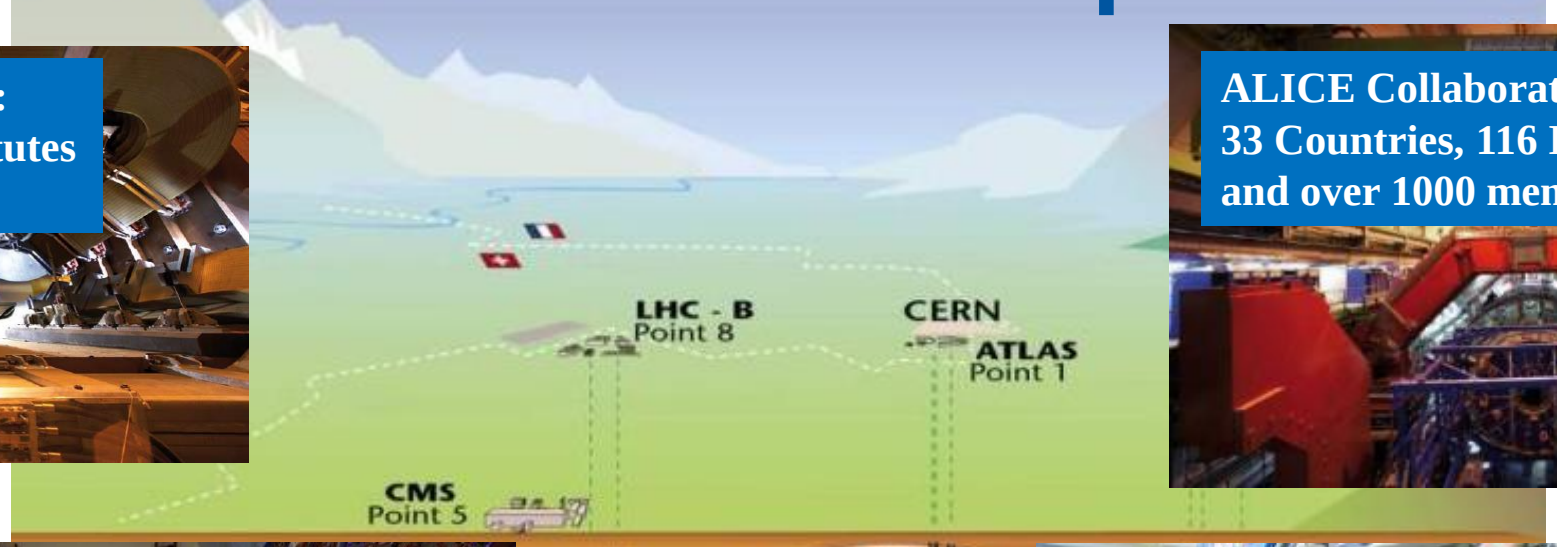
Outline

- CERN & LHC
- LHC Computing
- Data Preservation & Open Access

LHC: an accelerator of 27 km

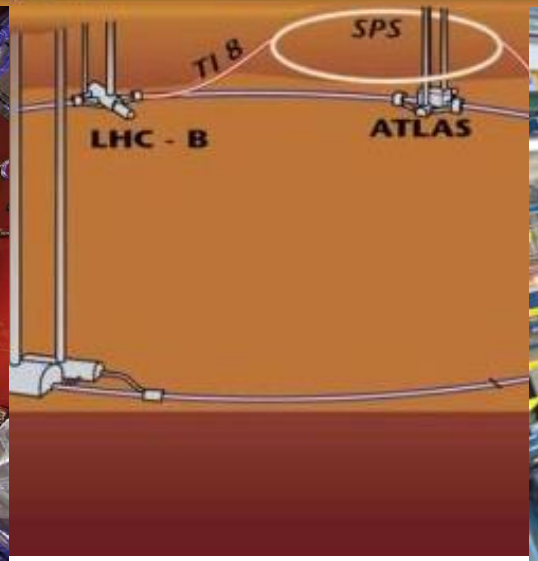
Four experiments : **the coopetition**

LHCB Collaboration :
15 Countries, 54 Institutes and 754 members



ALICE Collaboration :
33 Countries, 116 Institutes and over 1000 members

CMS Collaboration :
39 Countries, 169 Institutes and 3170 members



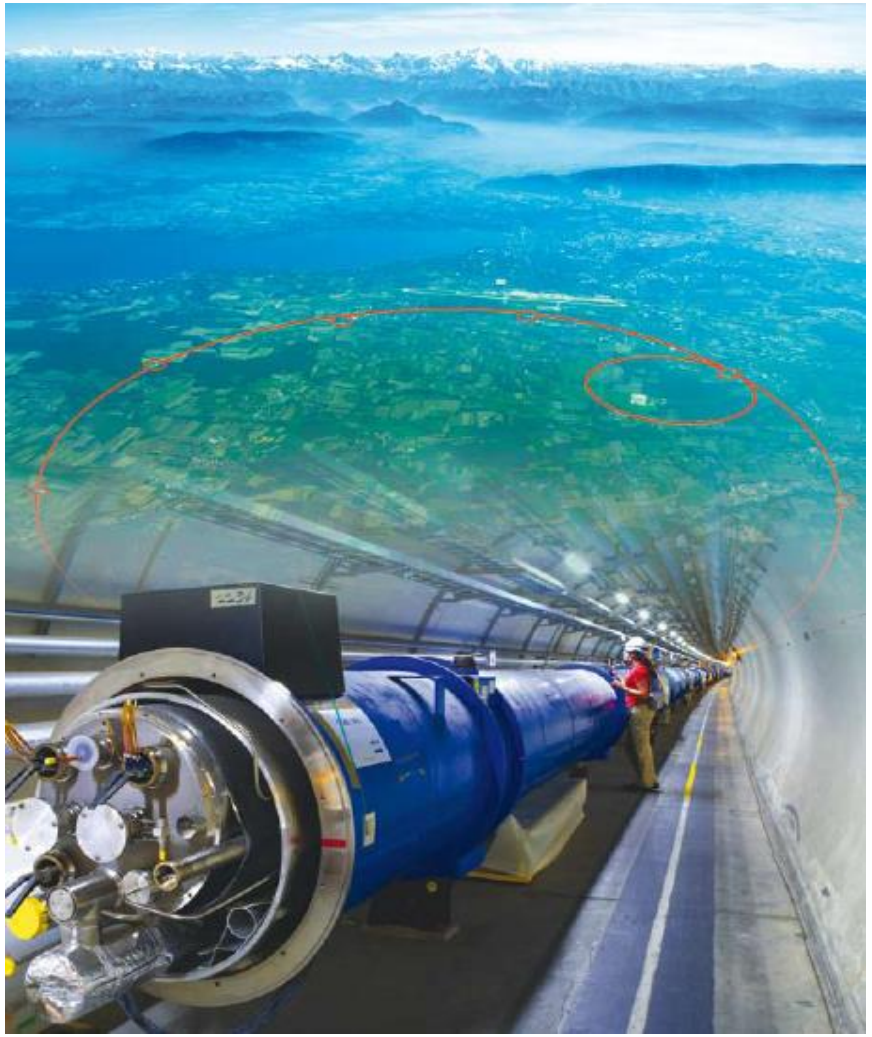
ATLAS Collaboration :
38 Countries, 174 Institutes and 3000 members

LHC (Large Hadron Collider)

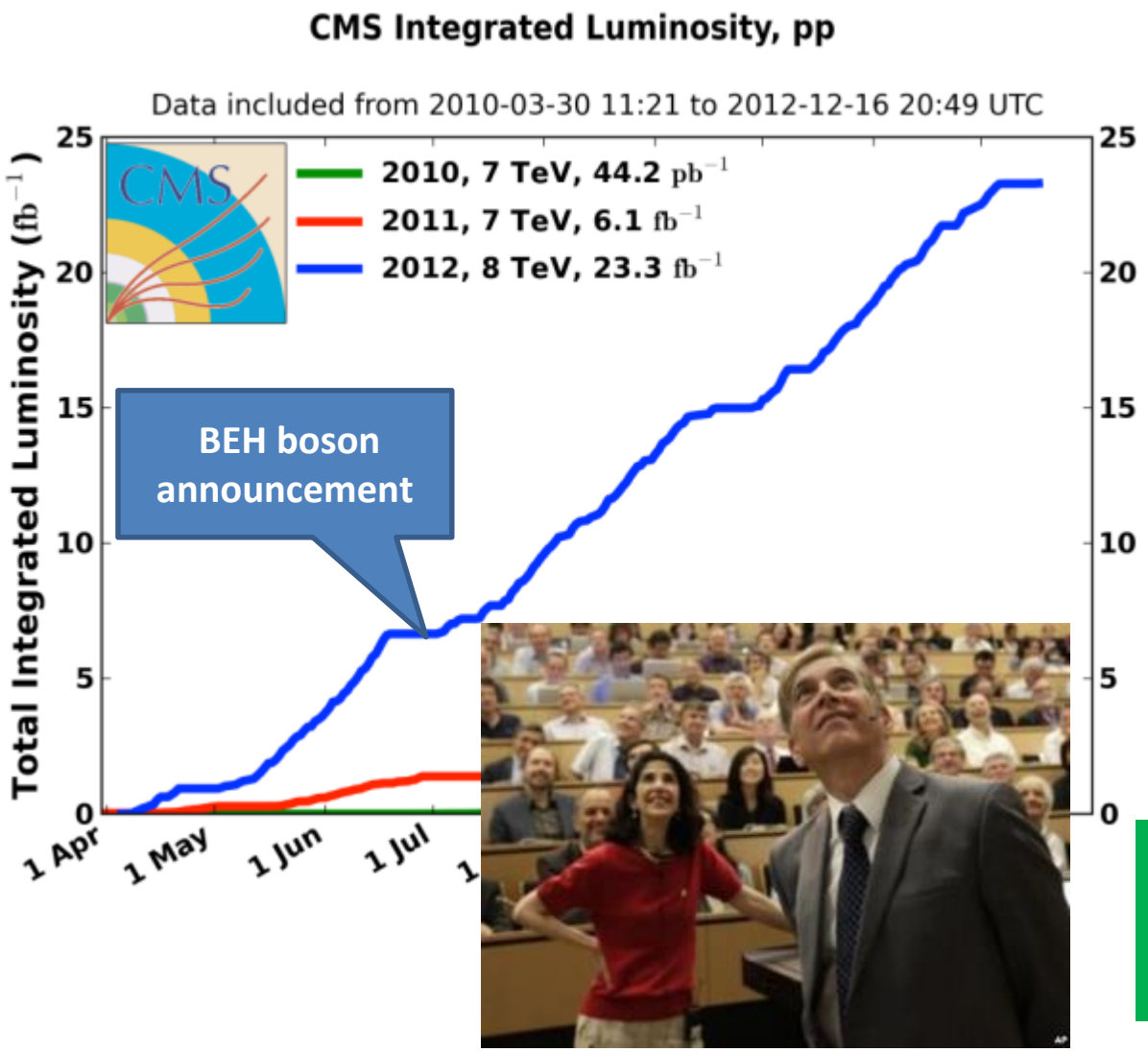
14 TeV proton-proton accelerator-collider built in the LEP tunnel (+ Lead-Lead collisions)

1983 : First studies for the LHC project
1988 : First magnet model (feasibility)
1994 : Approval of the LHC by the CERN Council
1996-1999 : Series production industrialisation
1998 : Start of civil engineering
1998-2000: Placement of the main production contracts
2004-2009: Installation & Commisioning

2010-2035…: Physics exploitation
2010 – 2012 : Run 1 ;7 and 8 TeV
2015 – 2018 : Run 2 ; 13 TeV
2021 – 2023 : Run 3 (14 TeV)
2024 – 2025 : HL-LHC installation
2026 – 2035… : HL-LHC operation



LHC 2010-2012: a rich harvest of collisions



Σ ~30 fb^{-1}
~ 2 10^{15} collisions

2010: **0.04 fb^{-1}**
7 TeV CoM
Commissioning

2011: **6.1 fb^{-1}**
7 TeV CoM
… exploring limits

2012: **23.3 fb^{-1}**
8 TeV CoM
… production

7 TeV and 8 TeV in 2012

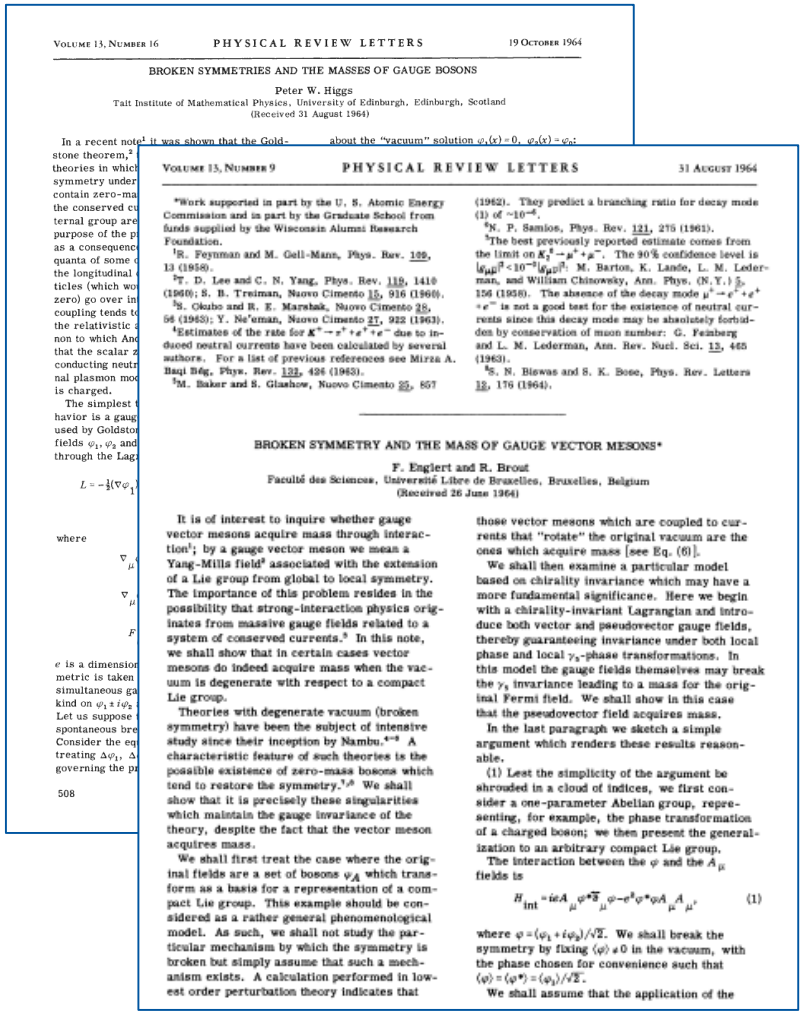
Up to 1380 bunches with1.5 10^{11} protons

Nobel Prize in Physics 2013

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".*

From **individual** theoretical physicist **idea**….

…to **collective innovation** !



VOLUME 13, NUMBER 16 PHYSICAL REVIEW LETTERS 19 OCTOBER 1964

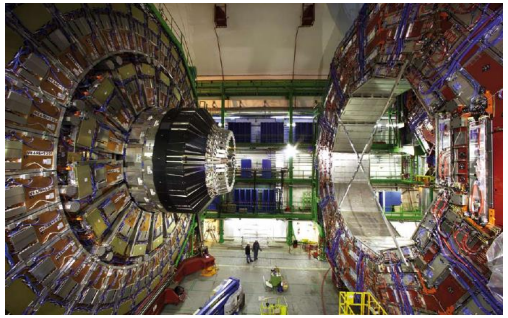
BROKEN SYMMETRIES AND THE MASSES OF GAUGE BOSONS

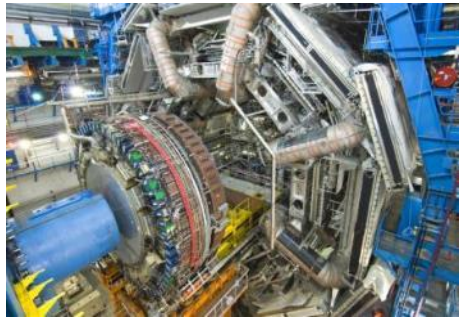
Peter W. Higgs
Tait Institute of Mathematical Physics, University of Edinburgh, Edinburgh, Scotland
(Received 31 August 1964)

VOLUME 13, NUMBER 9 PHYSICAL REVIEW LETTERS 31 AUGUST 1964

BROKEN SYMMETRY AND THE MASS OF GAUGE VECTOR MESONS*

F. Englert and R. Brout
Faculté des Sciences, Université Libre de Bruxelles, Bruxelles, Belgium
(Received 26 June 1964)

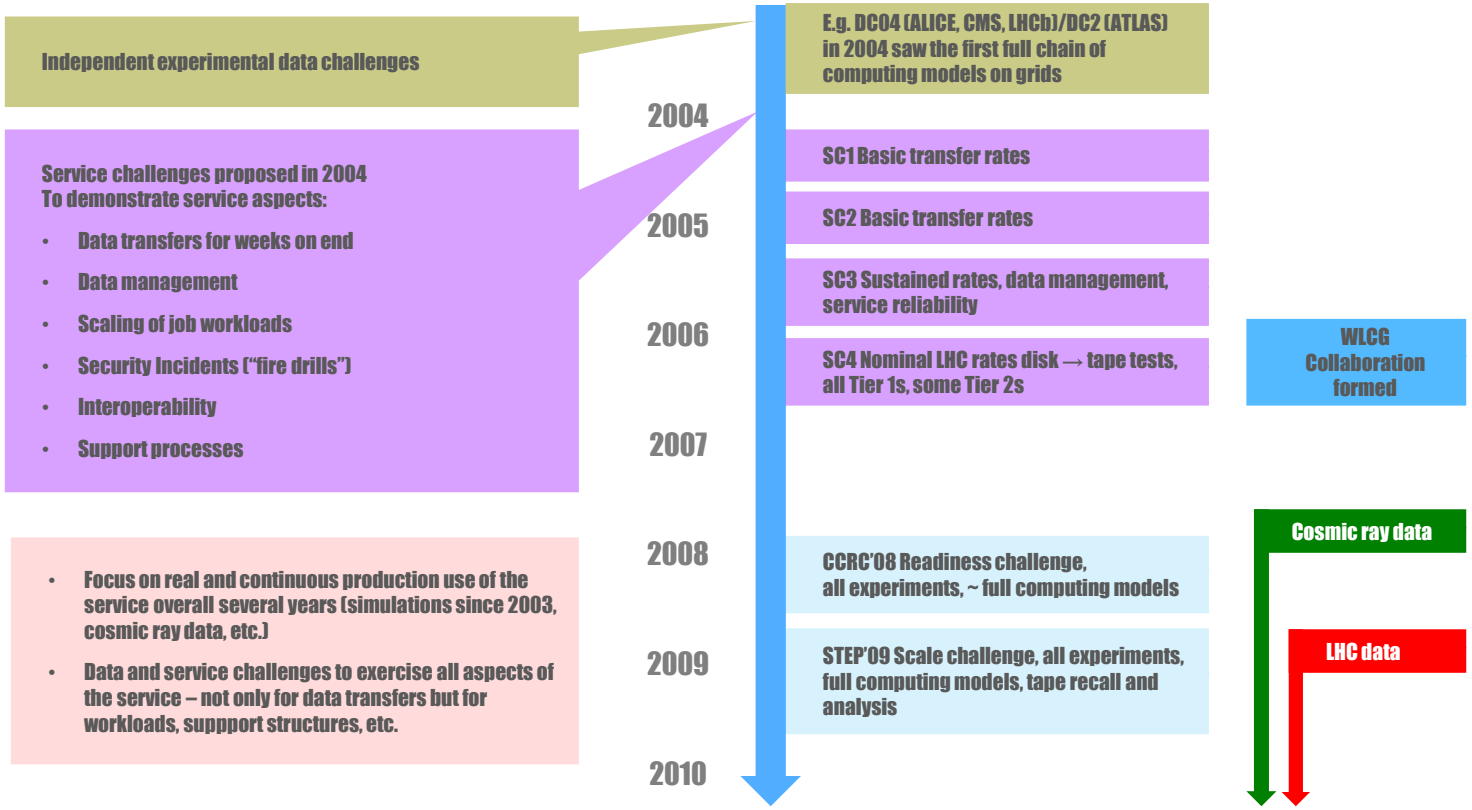




Worldwide LHC Computing

16 Years of (W)LCG

- CERN Council approval in September 2001 following the initiative of Manuel Delfino (CERN IT Division Leader) and Les Robertson (Project Leader)
- LCG Project began in 2002, with support from several countries – including significant funding from UK & Italy and several others
- First small grid deployments late 2002/early 2003
- Real production use and program of data challenges started in 2004

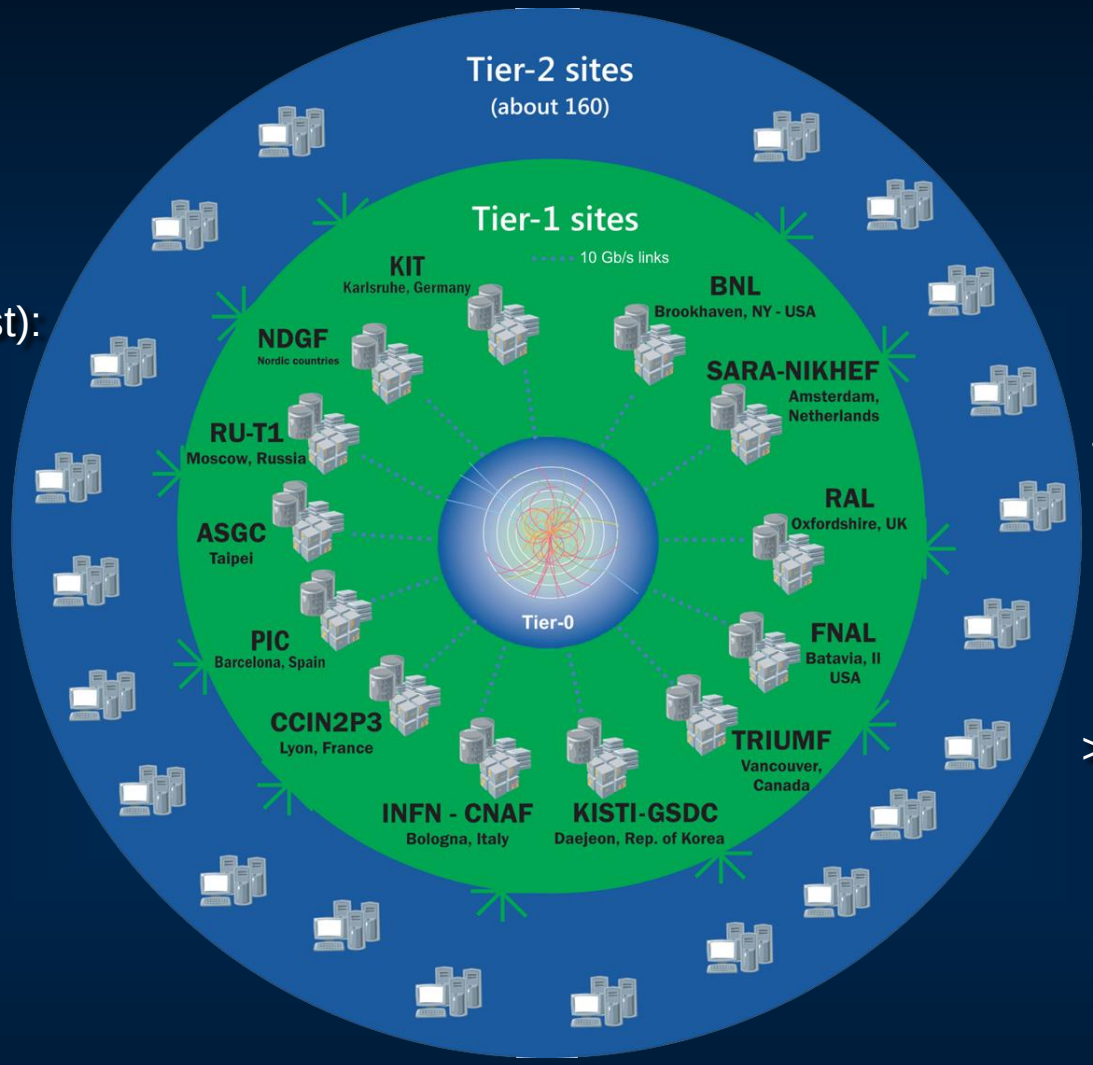


The Worldwide LHC Computing Grid

CERN Tier-0 (Geneva & Budapest): data recording, reconstruction and distribution

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

Tier-2: Simulation, end-user analysis



~170 sites, 40 countries

~500k CPU cores

500 PB of storage

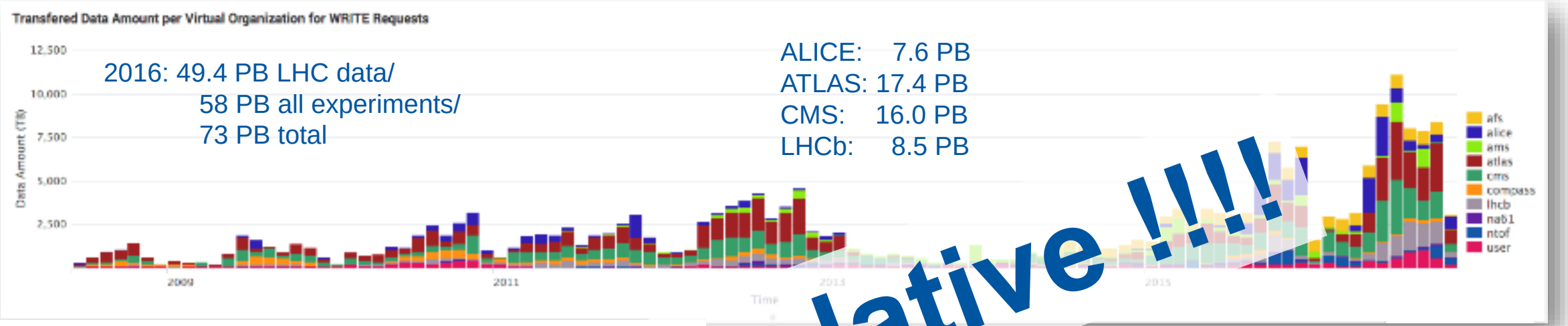
> 2 million jobs/day

10-100 Gb links

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

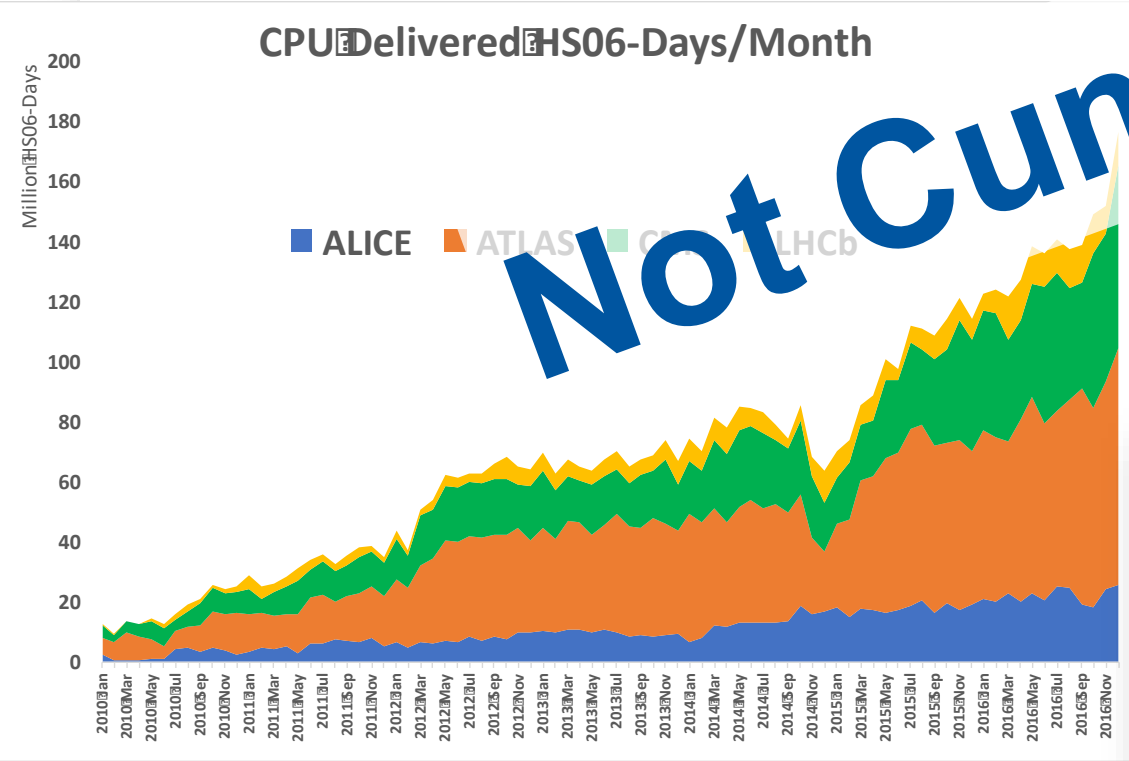
LHC Computing Summary

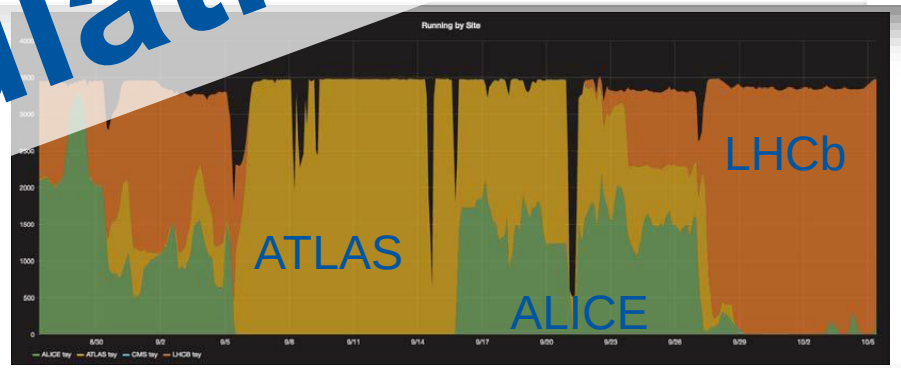


2016: 49.4 PB LHC data/
58 PB all experiments/
73 PB total

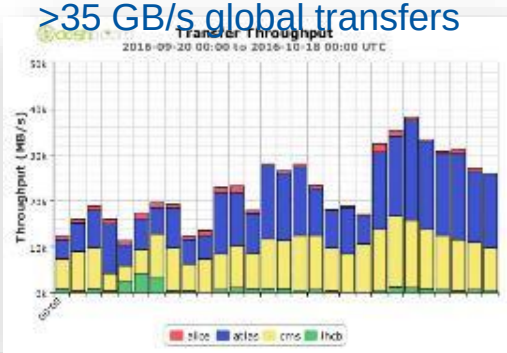
ALICE: 7.6 PB
ATLAS: 17.4 PB
CPU: 16.0 PB
LHCb: 8.5 PB

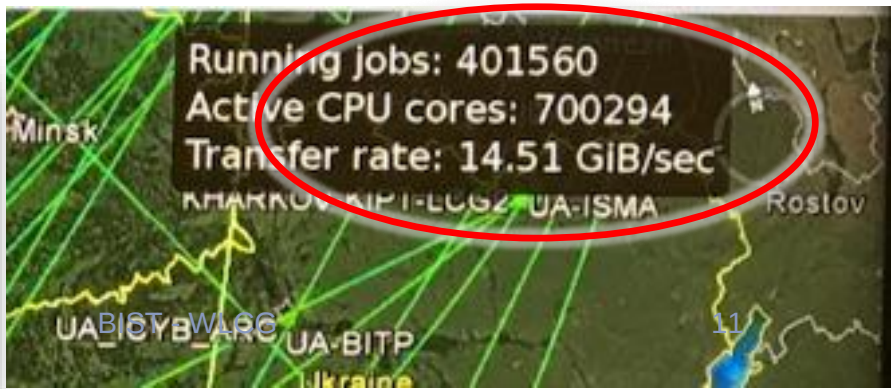
Not Cumulative !!!!





>35 GB/s global transfers

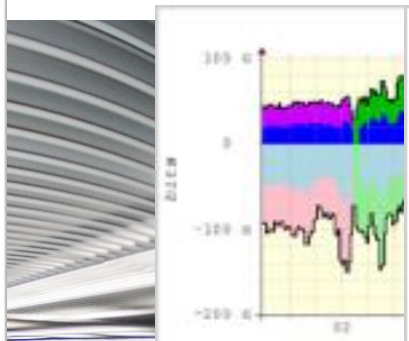


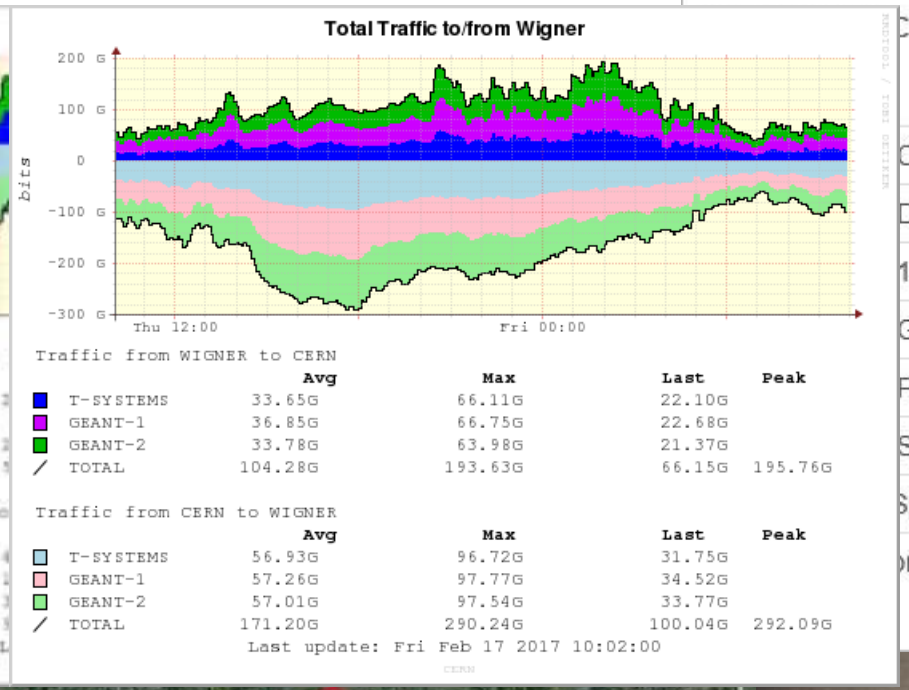


CERN Tier 0 - 2017

MEYRIN DATA CENTRE

	last_value
Number of Cores in Meyrin	121,806
Number of Drives in Meyrin	56,252
Number of 10G NIC in Meyrin	11,020
Number of 1G NIC in Meyrin	12,621
Number of Processors in Meyrin	16,640
Number of Servers in Meyrin	9,036
Total Disk Space in Meyrin (TB)	144,588
Total Memory Capacity in Meyrin (TB)	617





CENTRE

	last_value
Cores in Wigner	56,000
Drives in Wigner	29,684
10G NIC in Wigner	2,981
G NIC in Wigner	6,579
Processors in Wigner	7,002
Servers in Wigner	3,504
Space in Wigner (TB)	97,279
ory Capacity in Wigner (TB)	221

2017:
- 225k cores → 325k
- 150 PB raw → 250 PB

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

Clouds …

The Helix Nebula Science Cloud public-private partnership

HELIX NEBULA THESCIENCECLOUD

Strategic Plan

- Establish multi-tenant, multi-provider cloud infrastructure
- Identify and adopt policies for trust, security and privacy
- Create governance structure
- Define funding schemes

Updated October 2016

CERN: To support the computing capacity needs for the ATLAS experiment

EMBL: Setting up a new service to simplify analysis of large genomes, for a deeper insight into evolution and biodiversity

esa, cnes: To create an Earth Observation platform, focusing on earthquake and volcano research

PIC port d'informació científica: To improve the speed and quality of research for finding surrogate biomarkers based on brain images

Additional Users: cnrs, CRS4, DESY, ECMWF, ESO, ESRF, INFN, Science & Technology Facilities Council, SCC, SURF SARA

Suppliers: PROZETA, Q-LEAP NETWORKS, SAFESWISS CLOUD, TIXEL, Atos, CGI, CLOUDEO, CloudSigma, Cloudwatt, DataCentred, DEUTSCHE BÖRSE CLOUD EXCHANGE, egi, exoscale, GÉANT, INNOVO CLOUD, ITER, Prologue, sixsq, SWITCH, T-Systems, the SERVER LABS, ultimum technologies

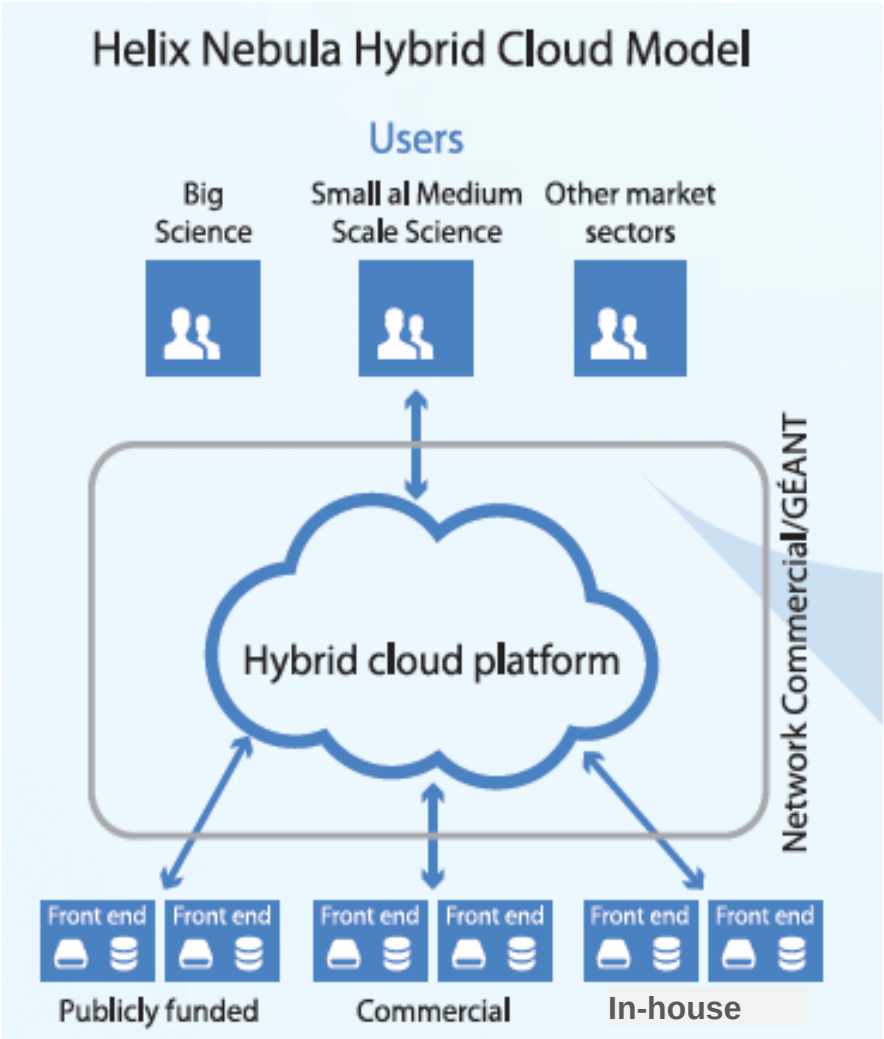
Adopters: AWST, CSA cloud security alliance, deac, Ifremer, MEMSET, orange Business Services, RHEA, UNICO Europe, Strategic Blue, terradue 2.0, THALES, vito, VU, Yandex

The Hybrid Cloud Model

Brings together

- research organisations,
- data providers,
- publicly funded e-infrastructures,
- commercial cloud service providers

In a hybrid cloud with procurement and governance approaches suitable for the dynamic cloud market



Major challenges

1. **Cloud computing is disrupting the way IT resources are provisioned**
2. **In-house resources, publicly funded e-infrastructure and commercial cloud services are not integrated** to provide a seamless environment
3. Current **organisational and financial models** are **not appropriate**
4. The new way of **procuring cloud** services **is also a matter of skills and education**
5. **Legal impediments exist**

Helix Nebula Science Cloud Joint Pre-Commercial Procurement (PCP)

Procurers: CERN, CNRS, DESY, EMBL-EBI, ESRF, IFAE, INFN, KIT, STFC, SURFSara
Experts: Trust-IT & EGI.eu

The group of procurers have committed
- Procurement funds
- Manpower for testing/evaluation
- Use-cases with applications & data
- In-house IT resources

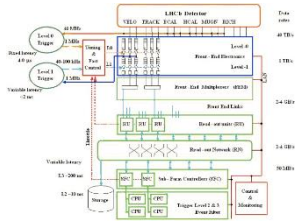
Resulting services will be made available to end-users from many research communities

Co-funded via H2020 Grant Agreement 687614

Total procurement budget >5.3M€

Data Preservation

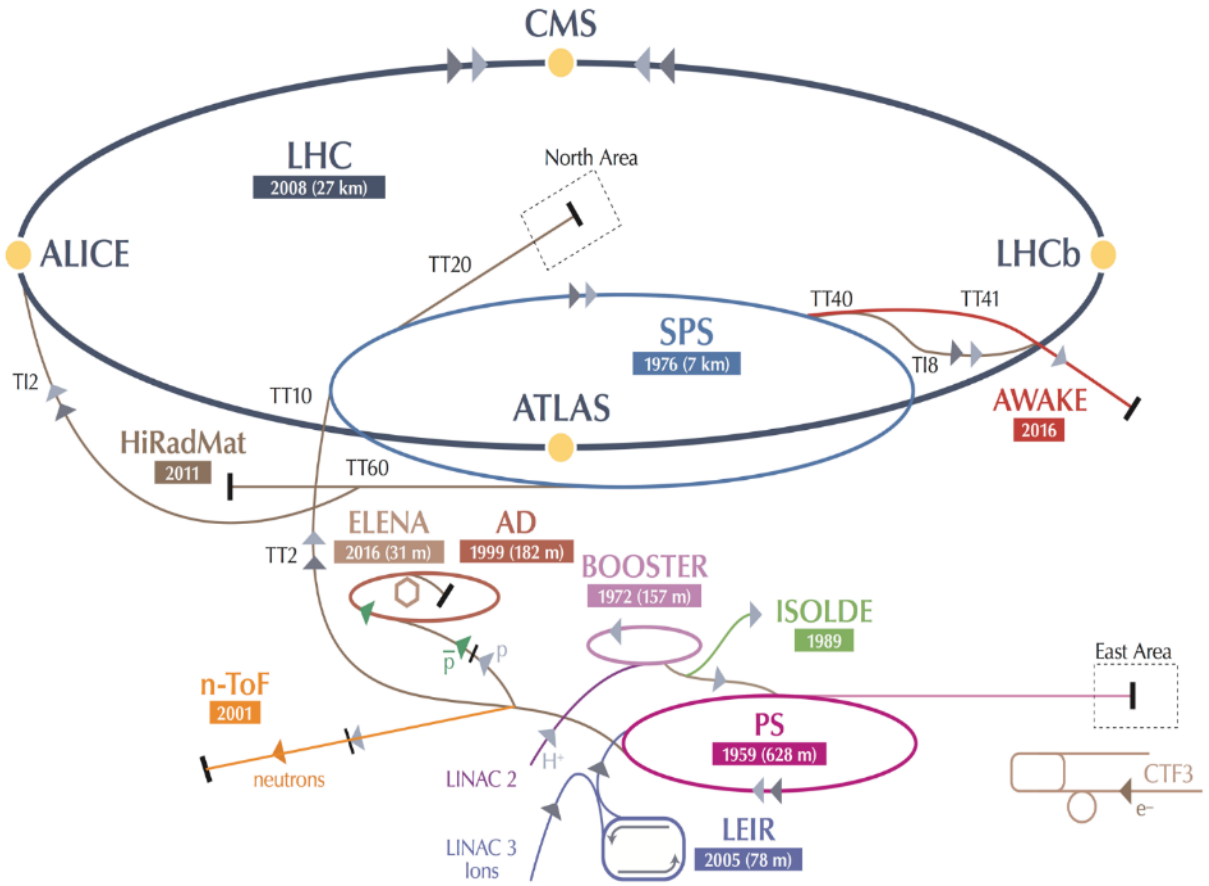
Characteristics specific to particle physics



- We **throw away** most of our data before it is even recorded – "triggers"
- Our detectors are **relatively stable** over long periods of time (years) – not "doubling every 6 or 18 months"
- We make "**measurements**" – not "**observations**"
- Our projects typically last for **decades** – we **need** to keep data usable during at least this length of time
- We have **shared** "data behind publications" for more than 30 years… (HEPData)

CERN's scientific diversity programme

CERN accelerators



~20 experiments, > 1200 physicists

AD: Antiproton Decelerator for antimatter studies

AWAKE: proton-induced plasma wakefield acceleration

CAST, OSQAR: axions

CLOUD: impact of cosmic rays on aeorosols and clouds → implications on climate

COMPASS: hadron structure and spectroscopy

ISOLDE: radioactive nuclei facility

NA61/Shine: heavy ions and neutrino targets

NA62: rare kaon decays

NA63: radiation processes in strong EM fields

NA64: search for dark photons

Neutrino Platform: ν detectors R&D for experiments in US, Japan

n-TOF: n-induced cross-sections

UA9: crystal collimation

CERN Archive current numbers

Data:

- ~190 PB physics data (CASTOR)
- ~7 PB backup (TSM)

Tape libraries:

- IBM TS3500 (3+2)
- Oracle SL8500 (4)

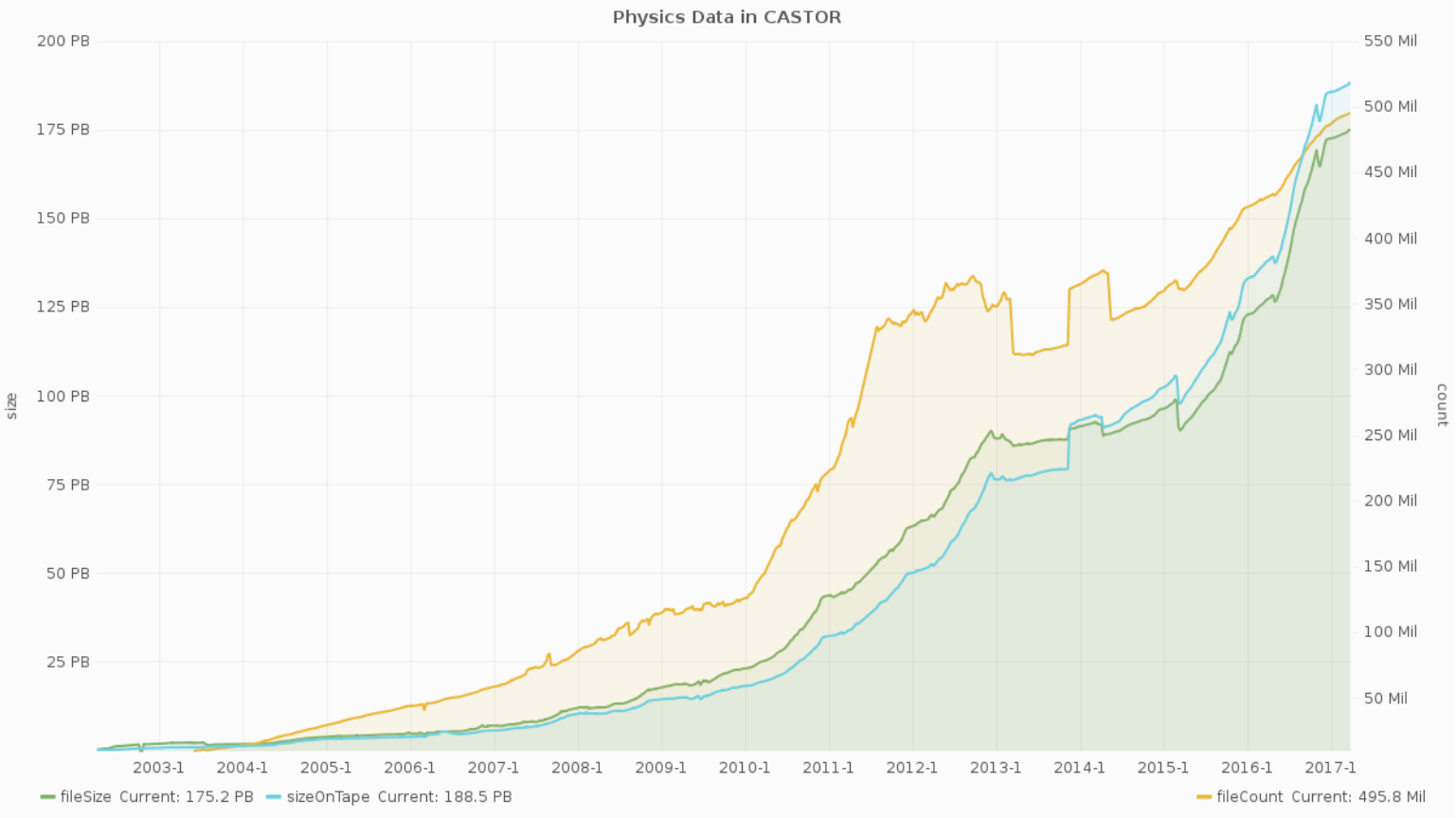
Tape drives:

- ~100 archive

Capacity:

- ~70 000 slots
- ~25 000 tapes

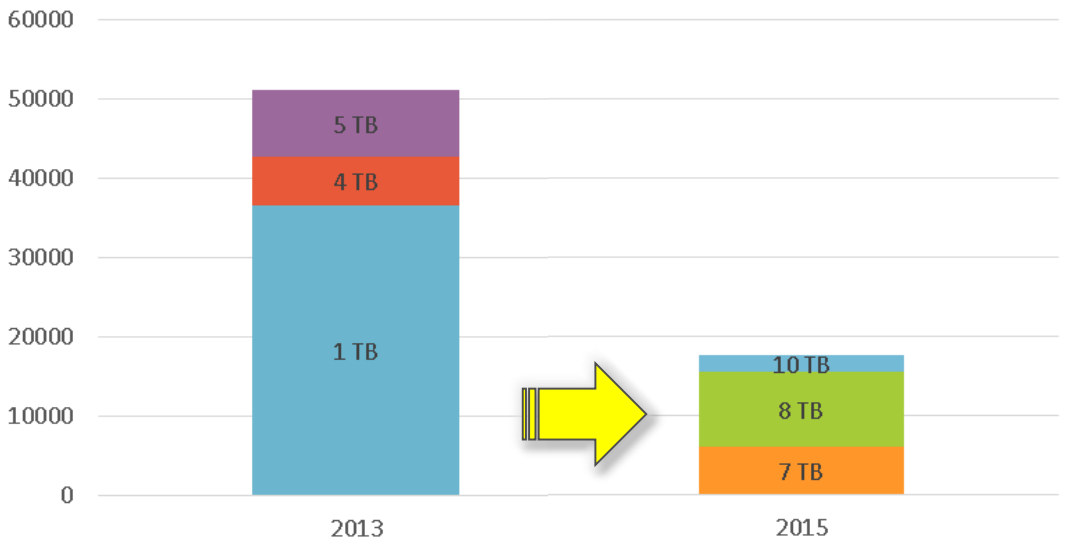
Data to CASTOR tape, 2002-2017



Document Classification: Public

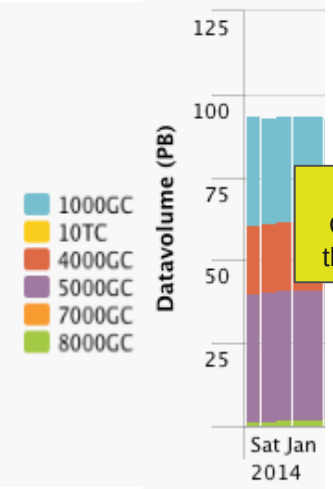
Large scale media migration

- Challenge:
  - ~85 PB of data
  - 2013: ~51 000 tapes
  - 2015: ~17 000 tapes
  - Verify all data after write
    - 3x (255PB!) pumped through the infrastructure (read->write->read)
  - Liberate library slots for new cartridges
    - Decommission ~35 000 obsolete tape cartridges



- Constraints:
  - Be transparent for user/experiment activities
  - Preserve temporal collocation
  - Finish before LHC run 2 start

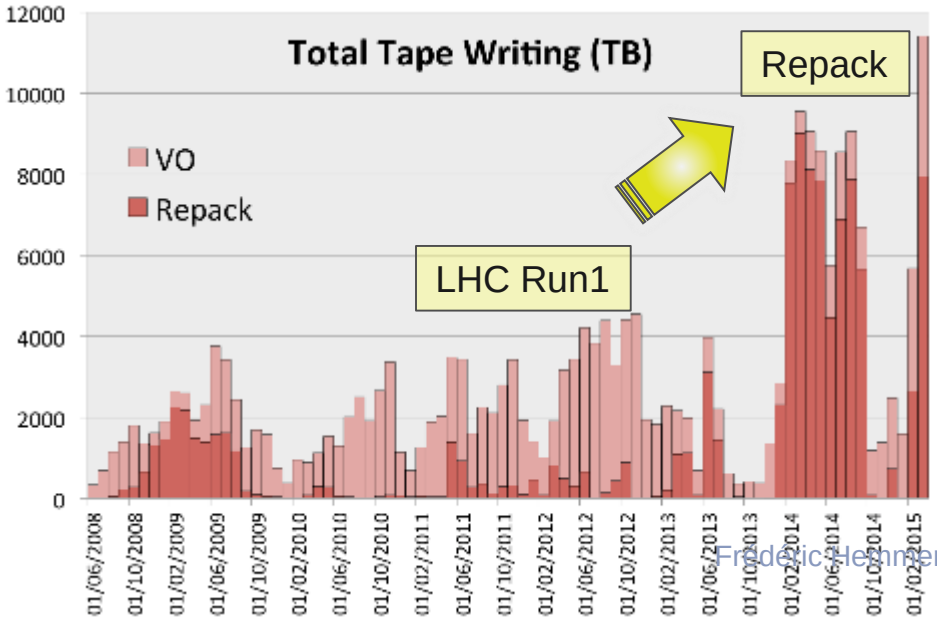
Large media migration: Repack

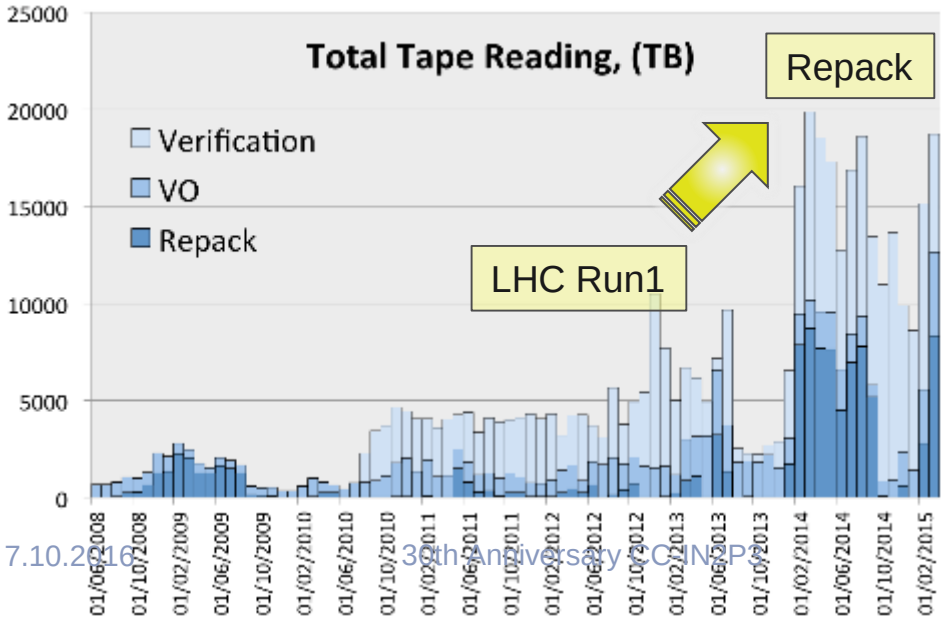


Part 1:
Oracle 5->8TB
then empty 1TB

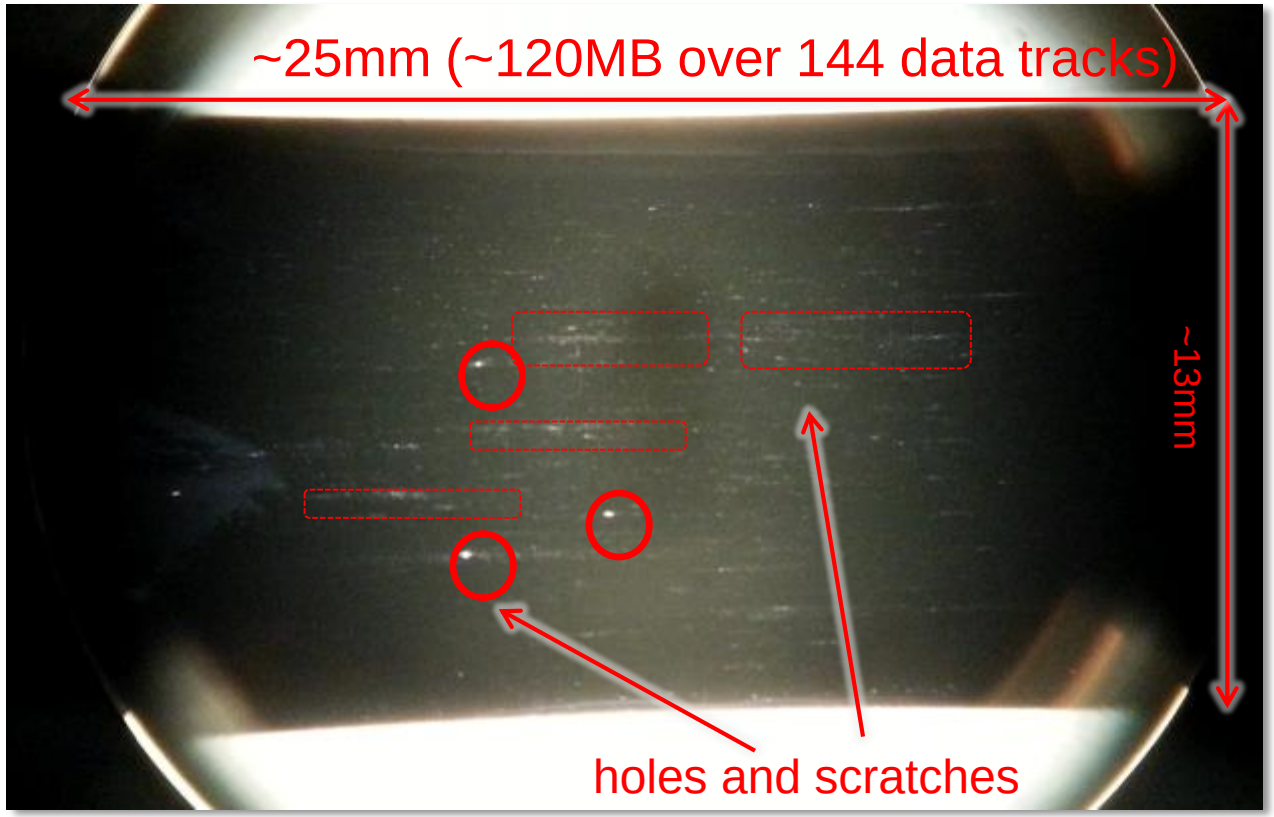
Part 2:
IBM 4->7TB
then 1TB

Completed !





Tape contamination incident

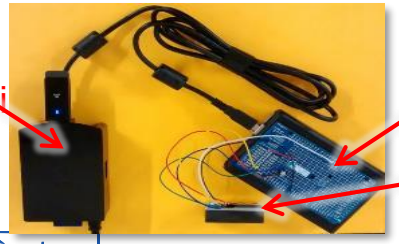


Over 30m³/min of airflows per library

- (Home vacuum cleaner: ~2m³/min)

Operating environment required for new-generation drives: ISO-14644 Class 8 (particles / m³):

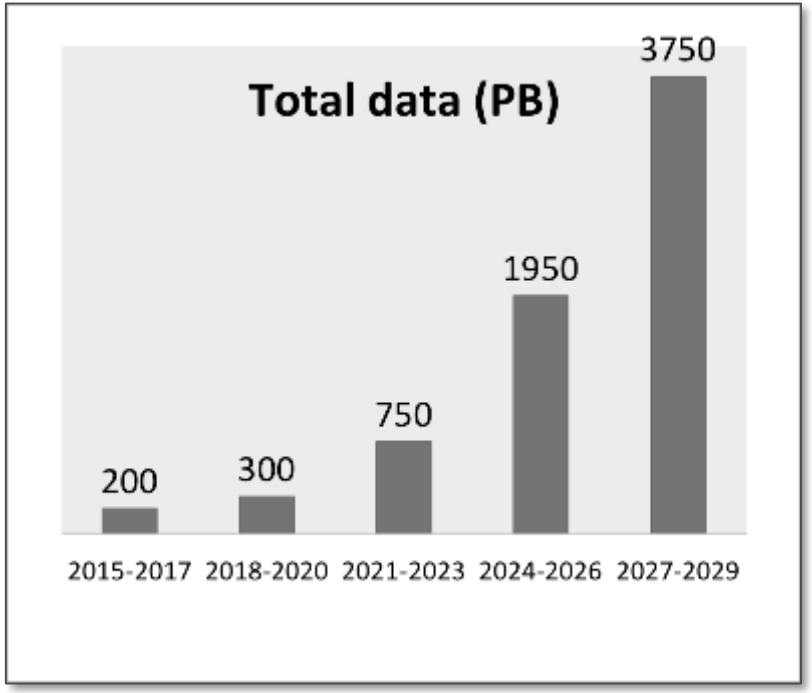
Class	>0.5 um	>1 um	>5 um
8	3 520 000	832 000	29 300

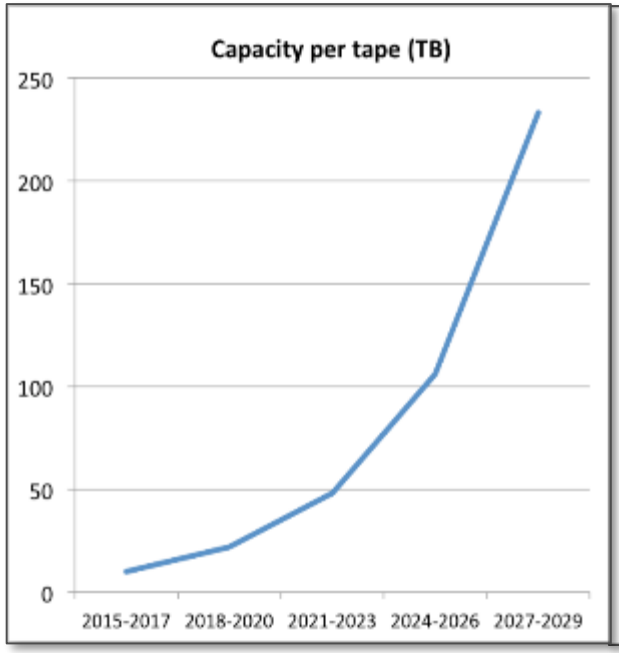


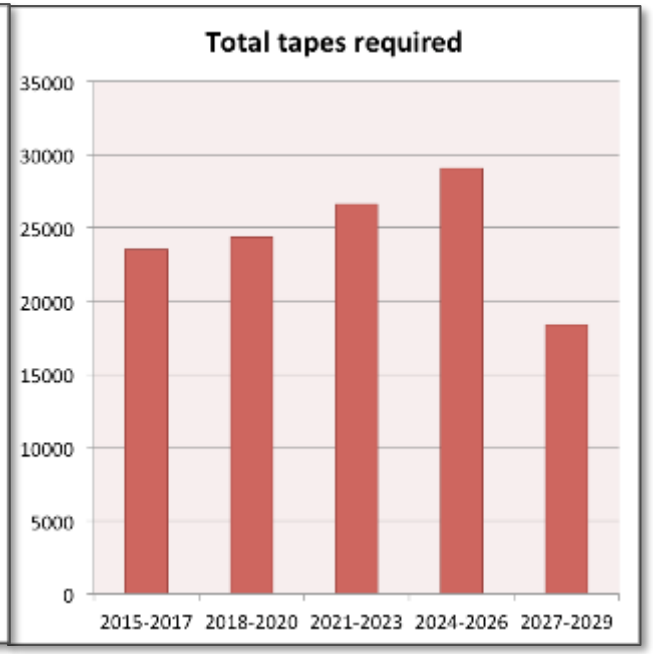
Document Classification: Public

Future…

- Run-2 (2015-2018): Expecting ~50-80PB/year of new data (LHC + non-LHC)
  - +7K tapes / year (~35'000 free library slots)
- Run-3 (-2022): ~150PB/year. Run-4 (2023 onwards): 600PB/year..
- ... tape technology grows faster
  - tape roadmaps at 30% CAGR for at least 10 years
  - demo for 220TB tape by IBM/Fujifilm in April 2015
- … but: market evolution is difficult to predict
  - Tape media: monopoly in shrinking market
  - Disk: "duopoly"
  - Cloud storage solutions
  - Disk capacity slowdown .. may slowdown tape products!
  - Storage slowdown == higher archiving costs

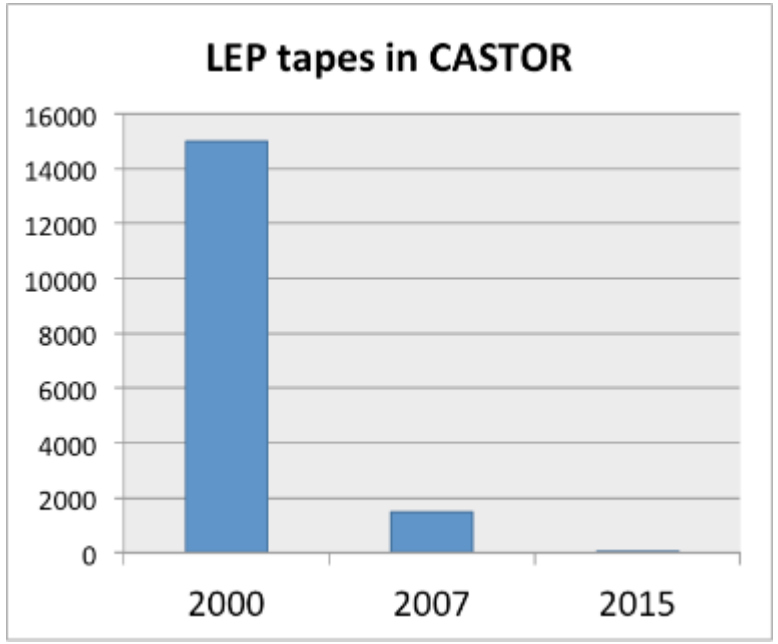






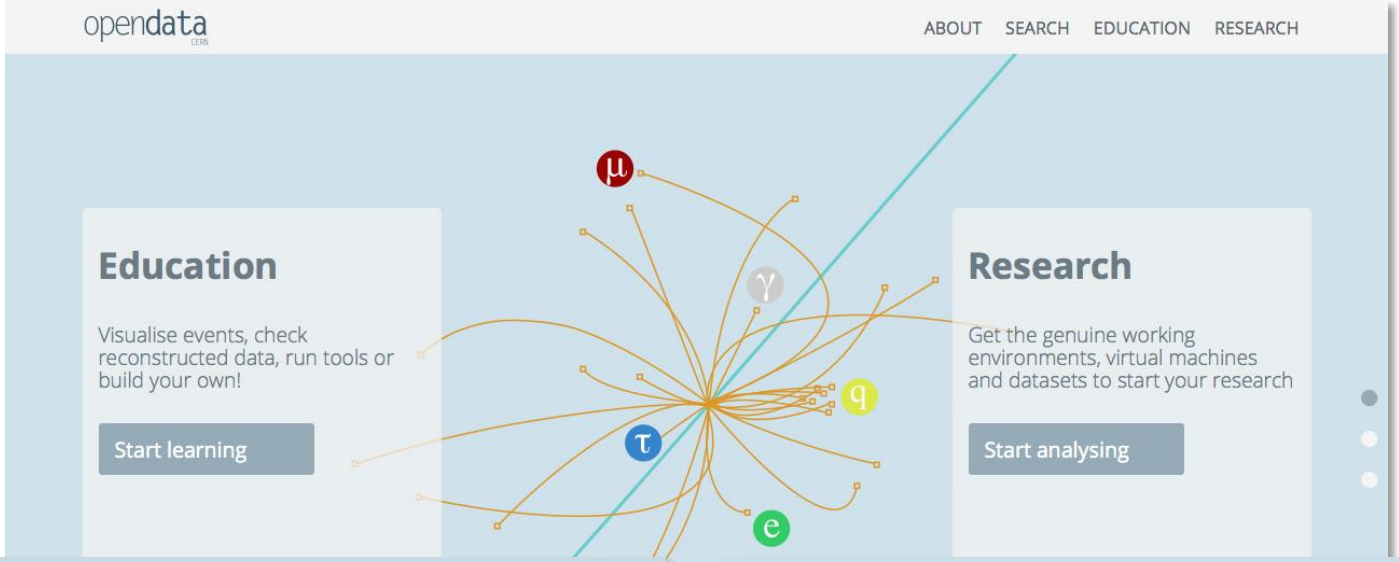
… and the past

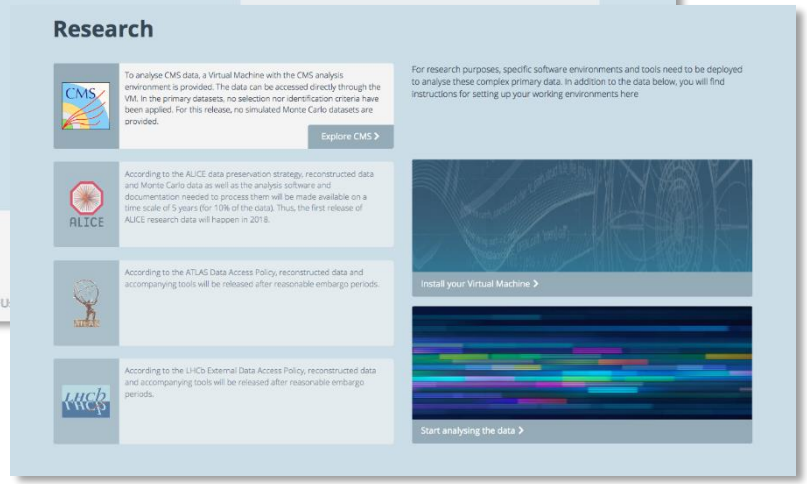
- LEP-era data: ~370TB
- 2000:
  - ~ 15’000 tapes
- 2007:
  - ~ 1500 tapes
- 2015:
  - 30 tapes… x 2 (replicated in separate buildings)
  - Cost:  … in the context of a large tape operation

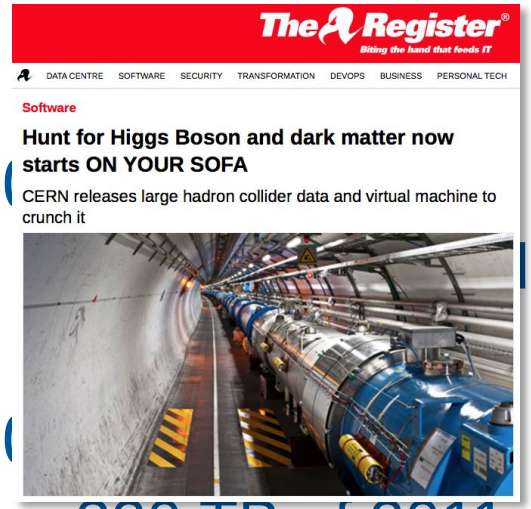


Open Access, open data

CERN Open Data Portal







- 2
- lata
- 2
- 320 TB of 2011 data
- se of
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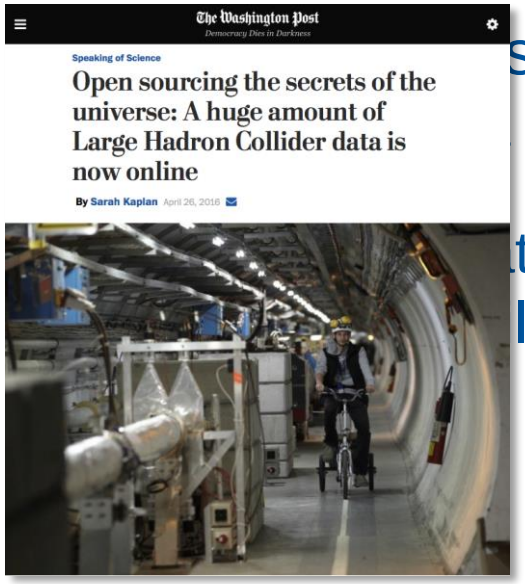

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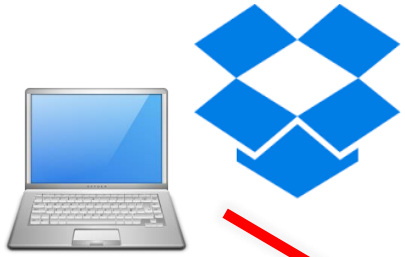
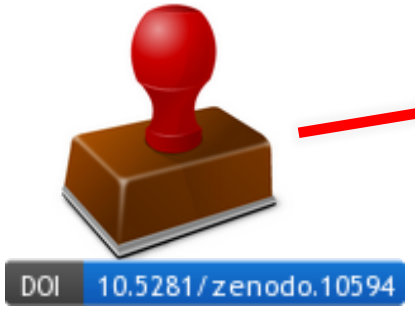
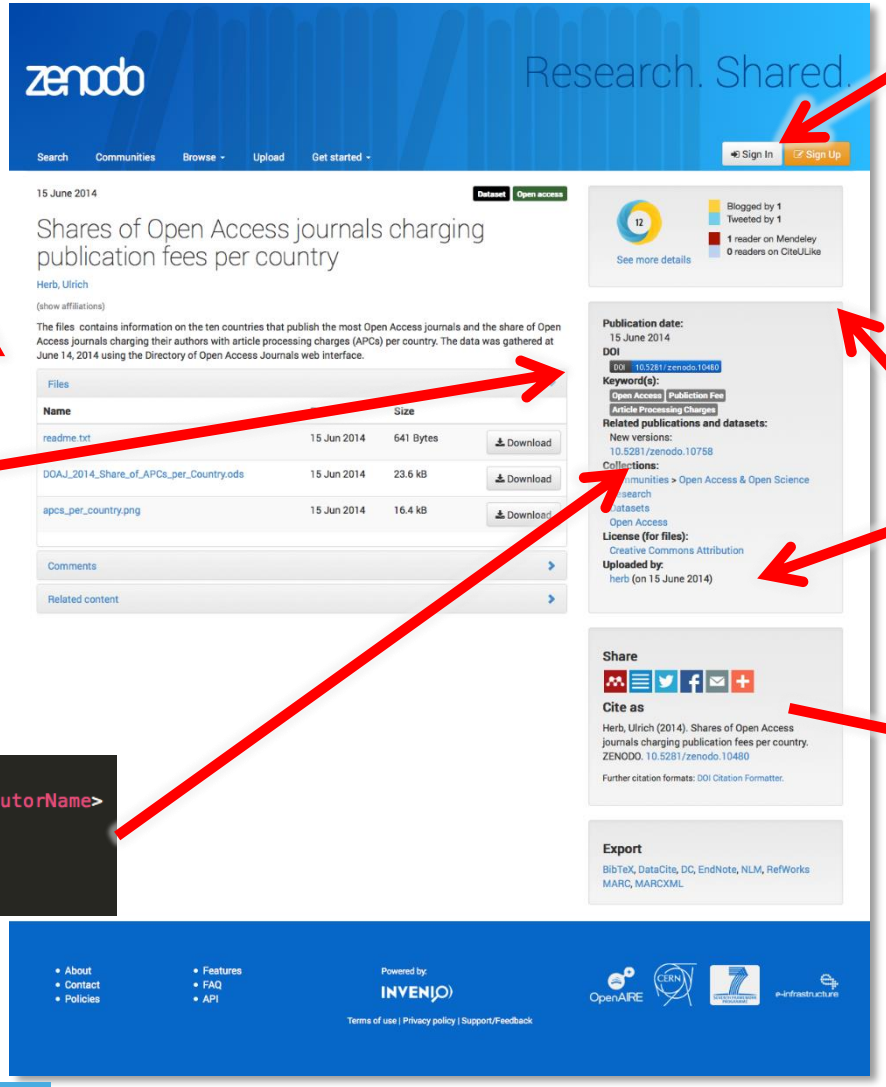
Open Data as a Service





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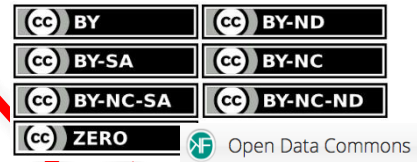


Some (Societal) Impact of CERN Computing

UNOSAT powered by CERN IT

- Hosting databases and Geographic Information System (GIS) data server
- 16 terabytes of data stored at CERN Computer Centre – benefiting from economies of scale (~150 petabytes at CERN), i.e. UNOSAT share: 1/10000
- >10 gigabit/second bandwidth
- IT-support and development
- Virtual machines in CERN-cloud
- Computer security
- Research environment, collaboration

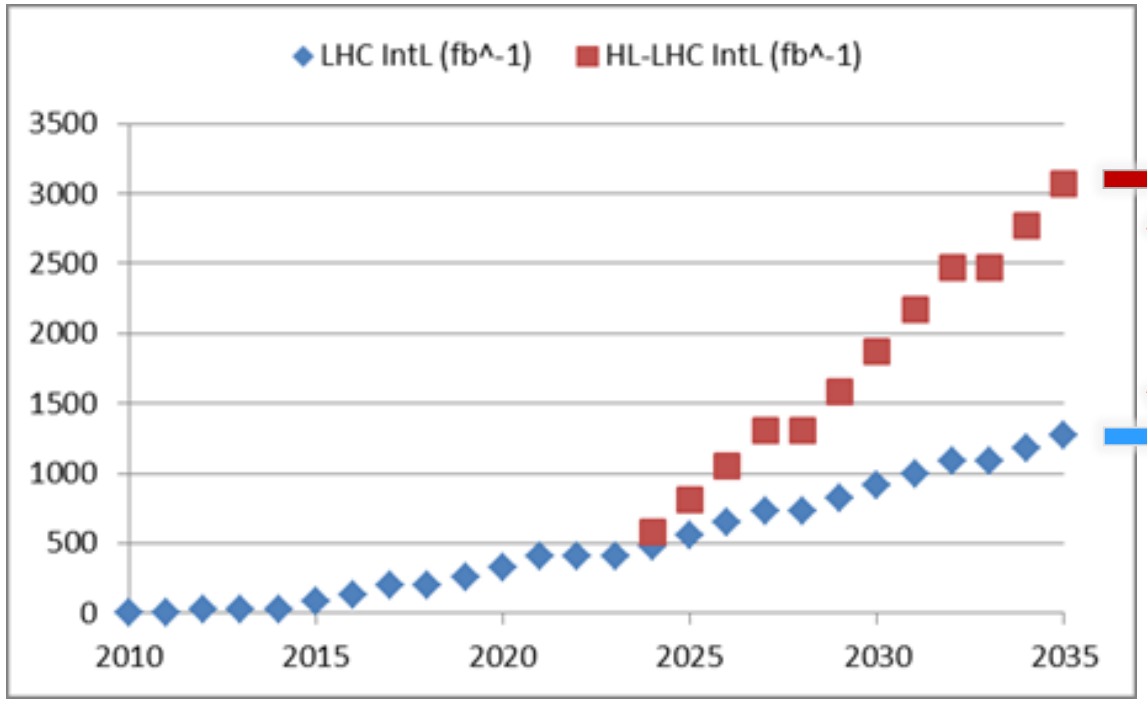
Hurricane Matthew: Haiti

May 2016

October 2016

The Future

Why High-Luminosity LHC ? (LS3)



By implementing HL-LHC

Almost a factor 3

By continuous performance improvement and consolidation

Around 300 fb^{-1} the present Inner Triplet magnets reach the end of their useful life (due to radiation damage) and must be replaced.

Goal of HL-LHC project:

- 250 – 300 fb^{-1} per year
- **3000 fb^{-1} in about 10 years**

The European Strategy for Particle Physics
Update 2013

*Europe's top priority should be the **exploitation of the full potential of the LHC**, including the high-luminosity upgrade of the machine and detectors with a view to collecting **ten times more data than in the initial design, by around 2030**. This upgrade programme will also provide further exciting opportunities for the study of flavour physics and the quark-gluon plasma.*

HL-LHC from a study to a PROJECT

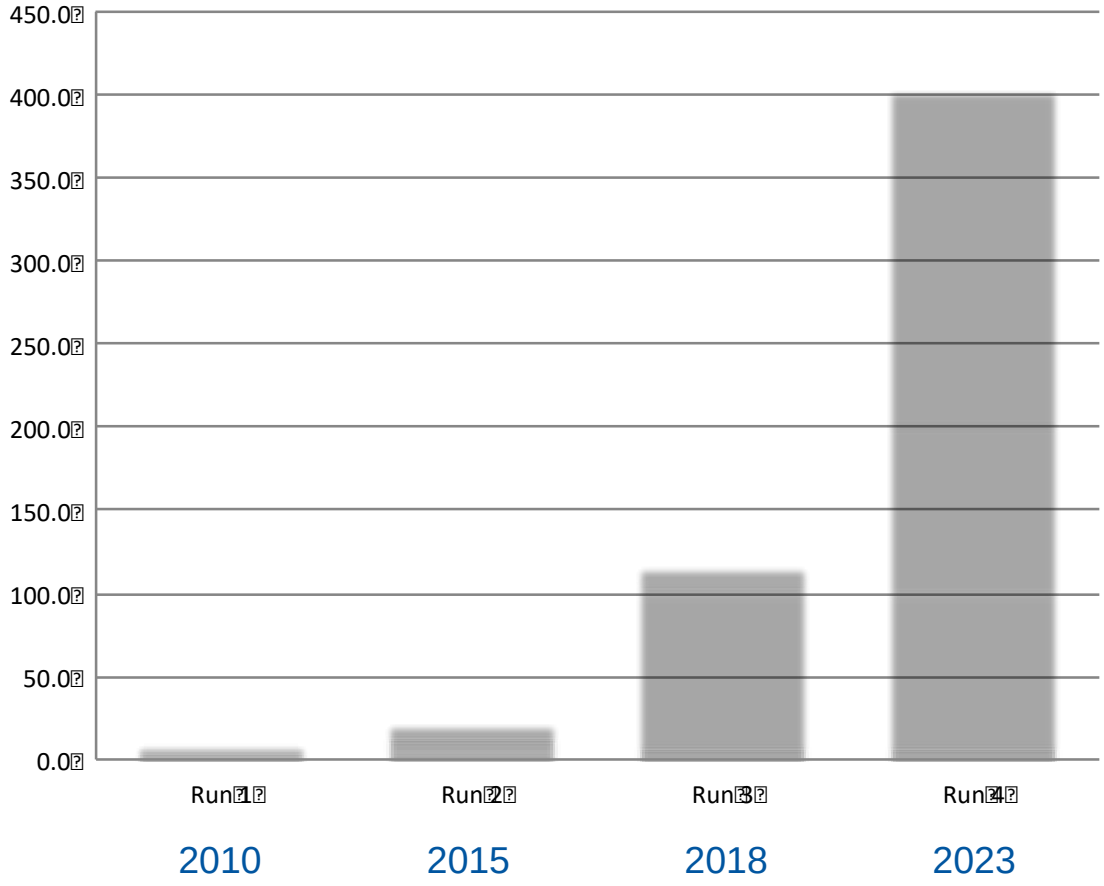
300 fb^{-1} → 3000 fb^{-1}

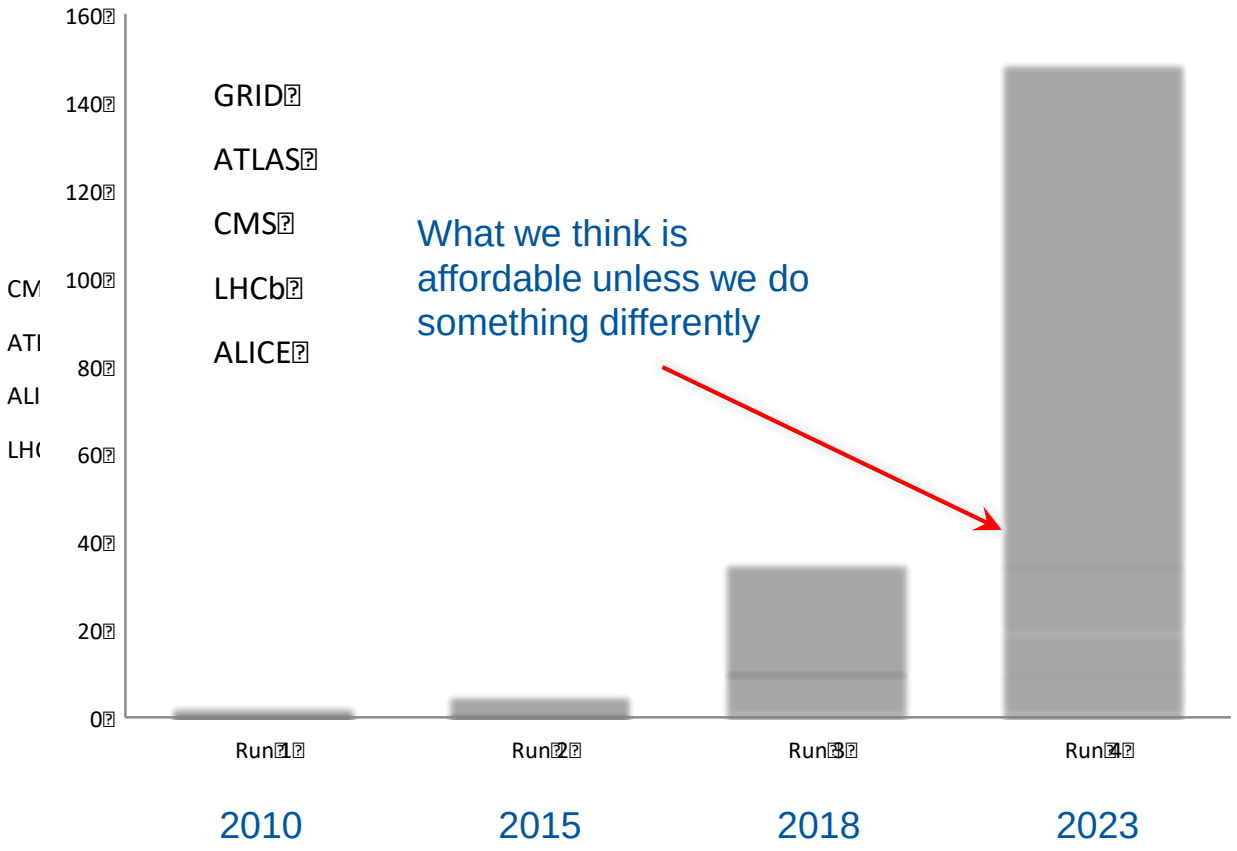
including LHC injectors upgrade **LIU**

(Linac 4, Booster 2GeV, PS and SPS upgrade)

Scale of data tomorrow …

10 Year Horizon

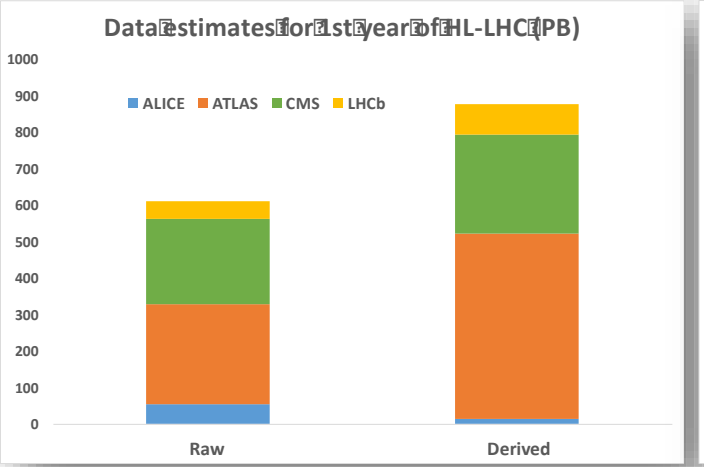


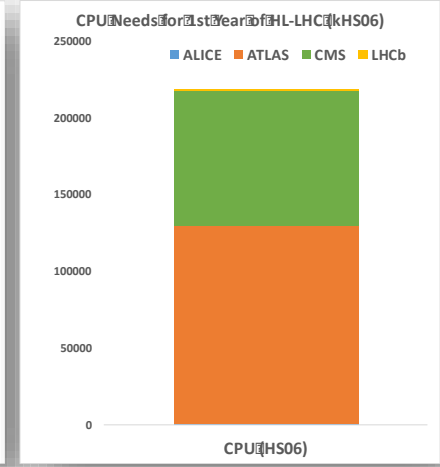


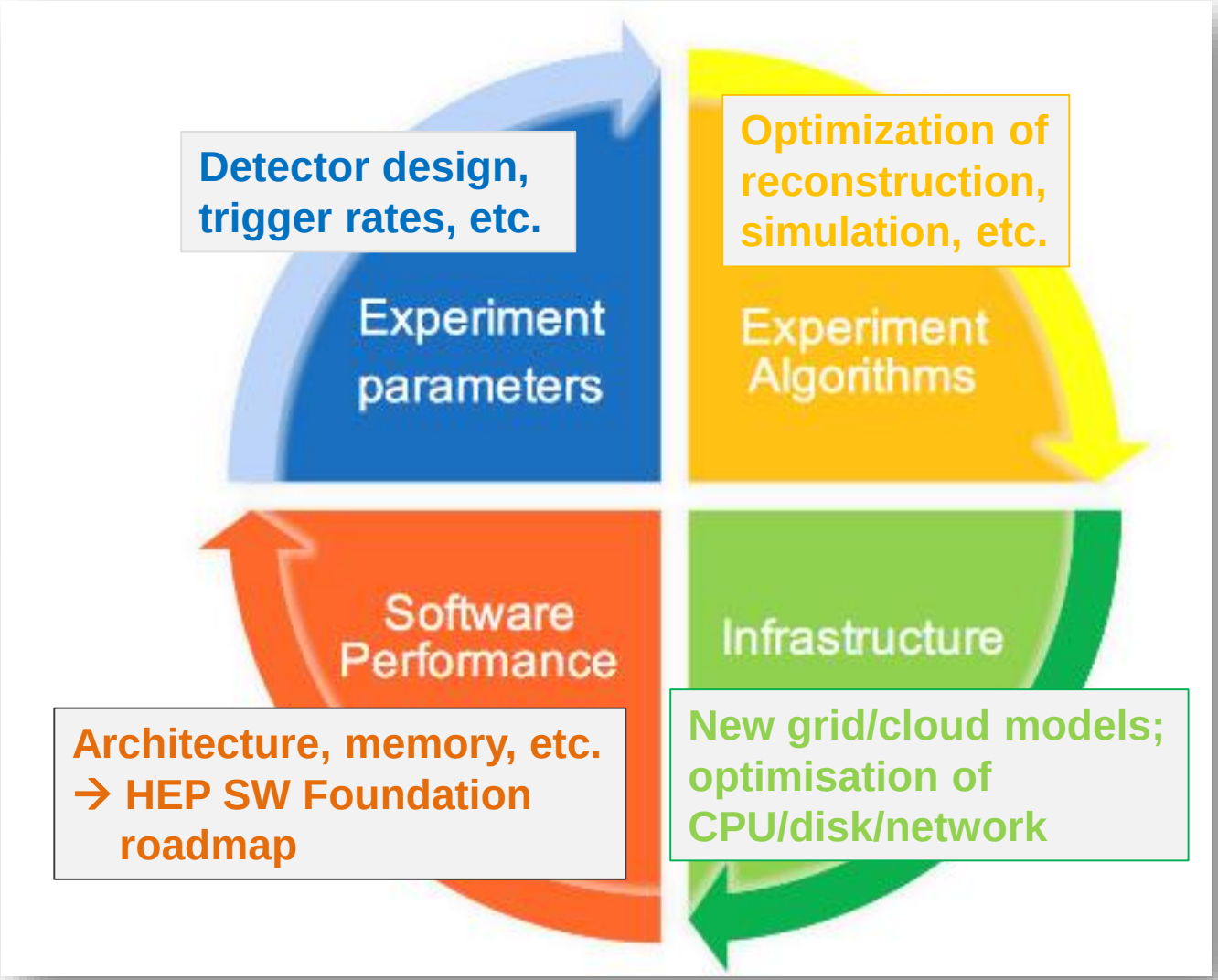
Data: ~25 PB/year → 400 PB/year

Compute: Growth > x50

WLCG preparations for HL-LHC







HSF
HEP Software Foundation

Summary

CERN & WLCG partners are

- World leaders in massive data handling
  - Using house & commercial services
  - Usable by other sciences as well
- Paving the way in Data Preservation & Open Access (incl. data)

Thank you for your attention

"The task of the mind is to produce future"

Paul Valéry