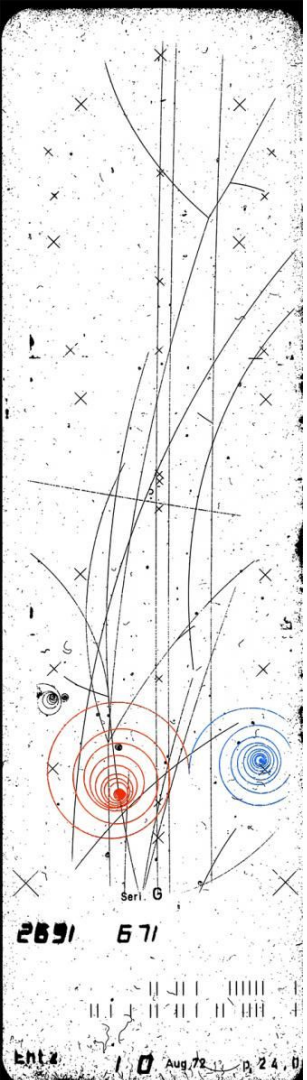


Computing at CERN

Xavier Espinal (CERN)

Computing at CERN: the big picture

Data

Detector

CMS

ATLAS EXPERIMENT

ALICE

LHCb

Data Acquisition (trigger)

Data Recording and Archive

CPU GPU

Data Reconstruction and Derivation

Simulated Data

Quantum Theory

PYTHIA

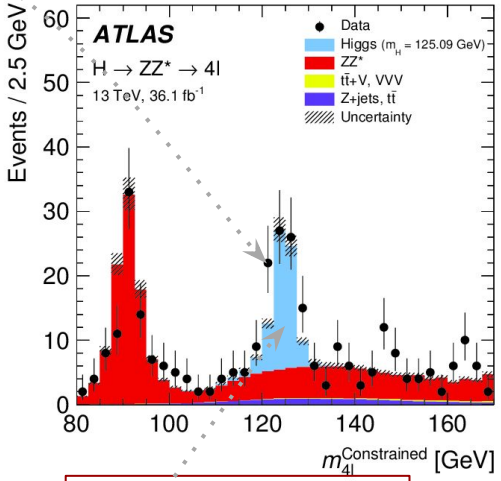
Event Generation(part. inter.) Simulation(int. w/ det.) Digitization(simul detector resp)

GEANT4

Data Analysis

SSD SSD

HPCs

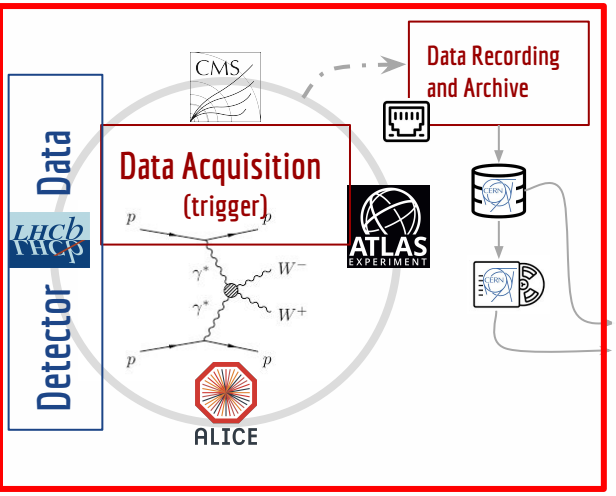


Preservation: Data and Analysis

SCIENCE

CPU

Computing at CERN: the big picture



Data Reconstruction and Derivation

Data Analysis

Preservation: Data and Analysis

Simulated Data

Event Generation
Simulation
Digitization
Quantum Theory
PYTHIA

Computing at CERN - International Teachers Program

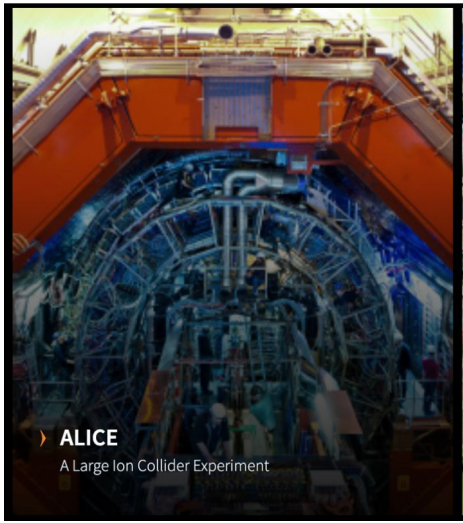
Our Data *Generators*

Experimental physics is about **DATA**!

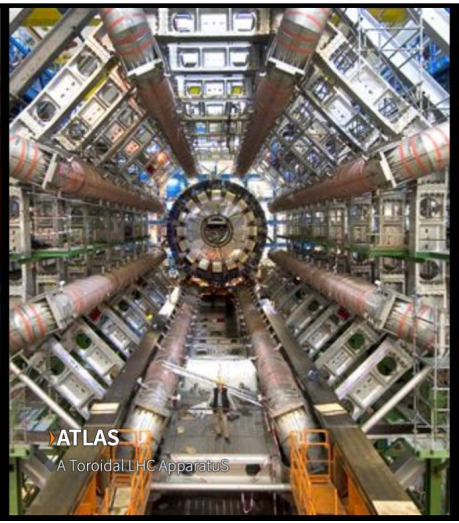
CERN experiments transfer all data to the Computing Center

Data is stored and ready to be processed, analyzed and shared

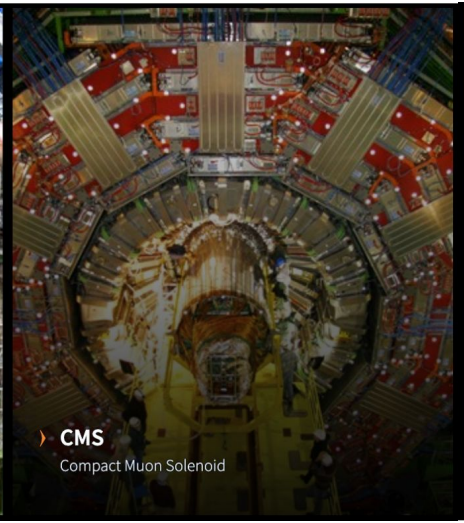
LHC Experiments: the *big* 4



heavy-ion physics, strongly interacting matter at extreme energy densities (quark-gluon plasma)



General-purpose:Higgs boson, extra dimensions, dark matter



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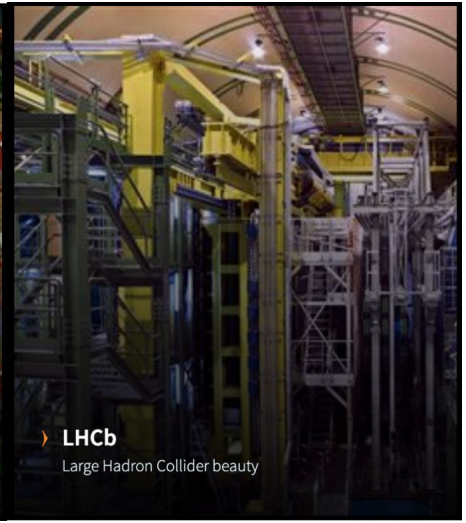
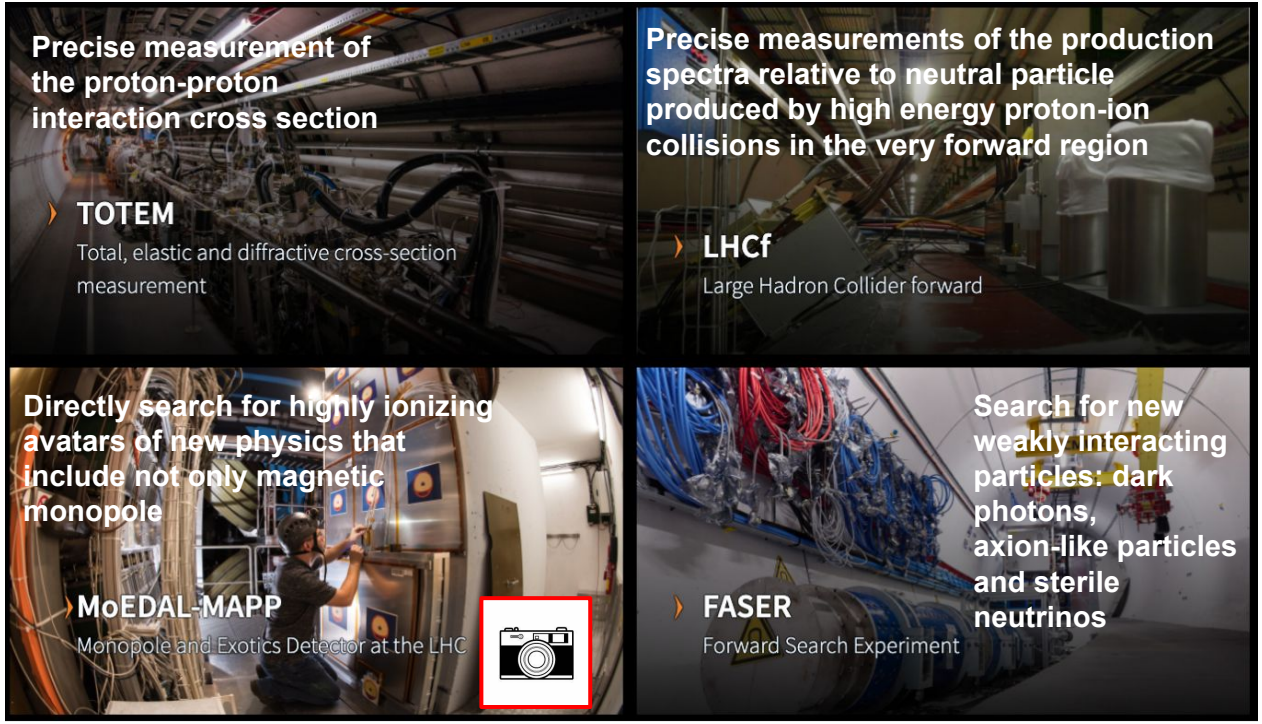


CP violation in the interactions of b-hadrons: matter-antimatter asymmetry of the Universe.

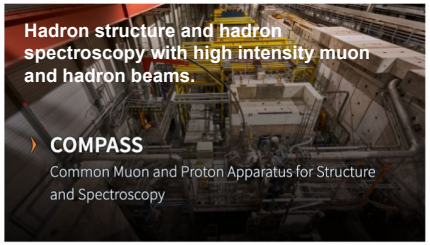
A computing perspective: O(10-100) Pb/year, 0.5M running jobs (continuous), fat and long-haul networks

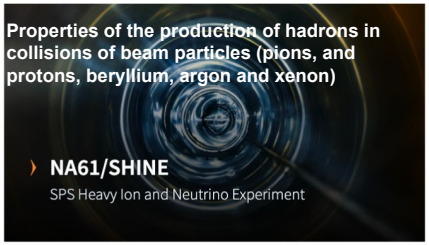
LHC Experiments

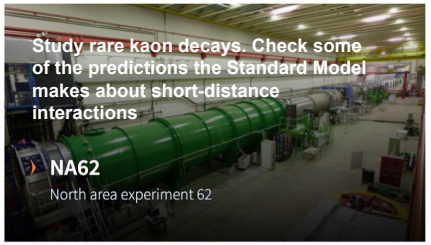


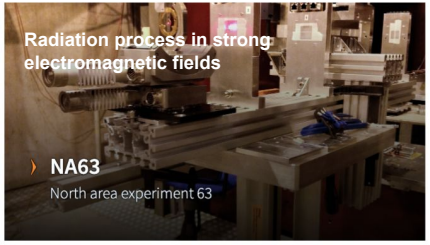
A computing perspective: ‹ Pb/year, data preservation, availability, shareability

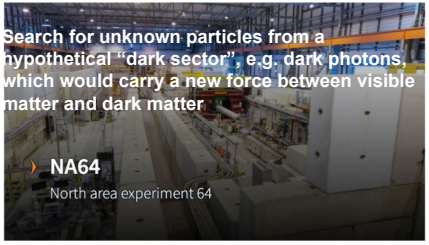
The *fixed target* Experiments

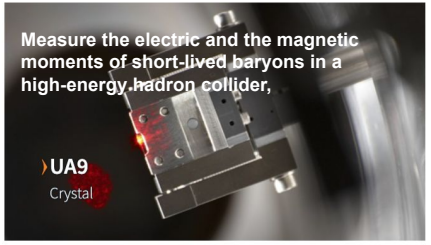








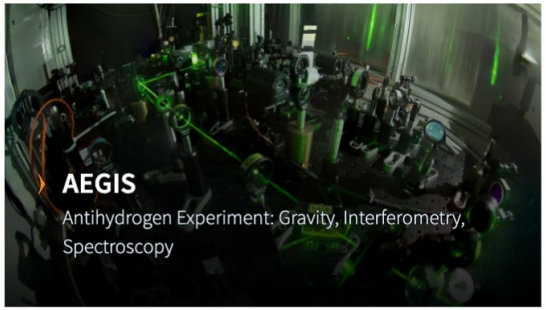


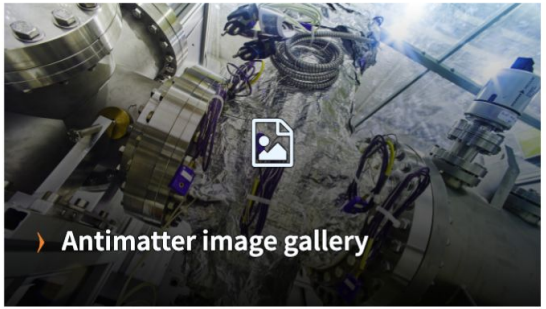


A computing perspective: from TeV/y to PB/y, small to large data processing needs, integration of external resources (HPC), workflow synchronisation turnarounds (data quality monitoring)

Antimatter Experiments

A computing perspective

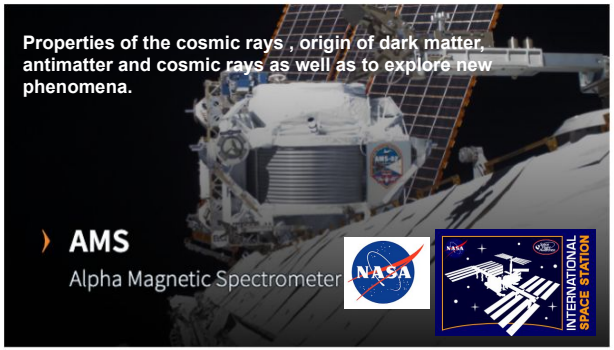


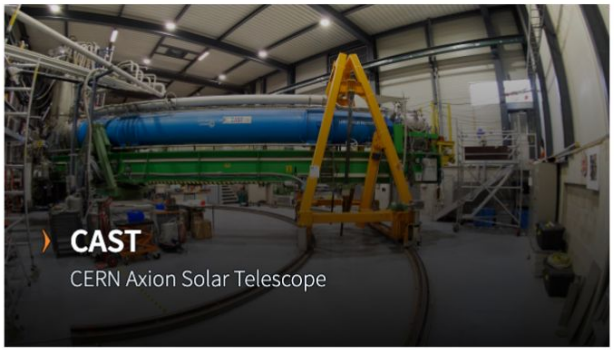


A computing perspective: modest computing requirements, challenge in preservation/reproducibility, data accessibility/shareability

Non-Accelerator Experiments

A computing perspective

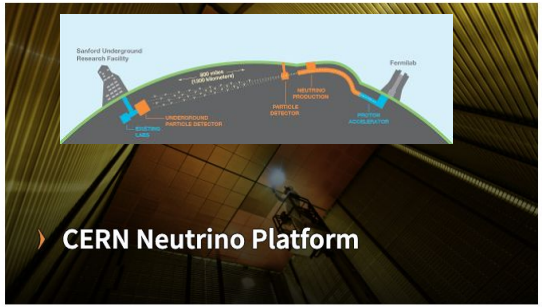




A computing perspective: data orchestration, consolidation and custody, from TeV/y to PB/y, some large data processing needs, international collaborations, workflow synchronisation turnarounds (data quality monitoring)

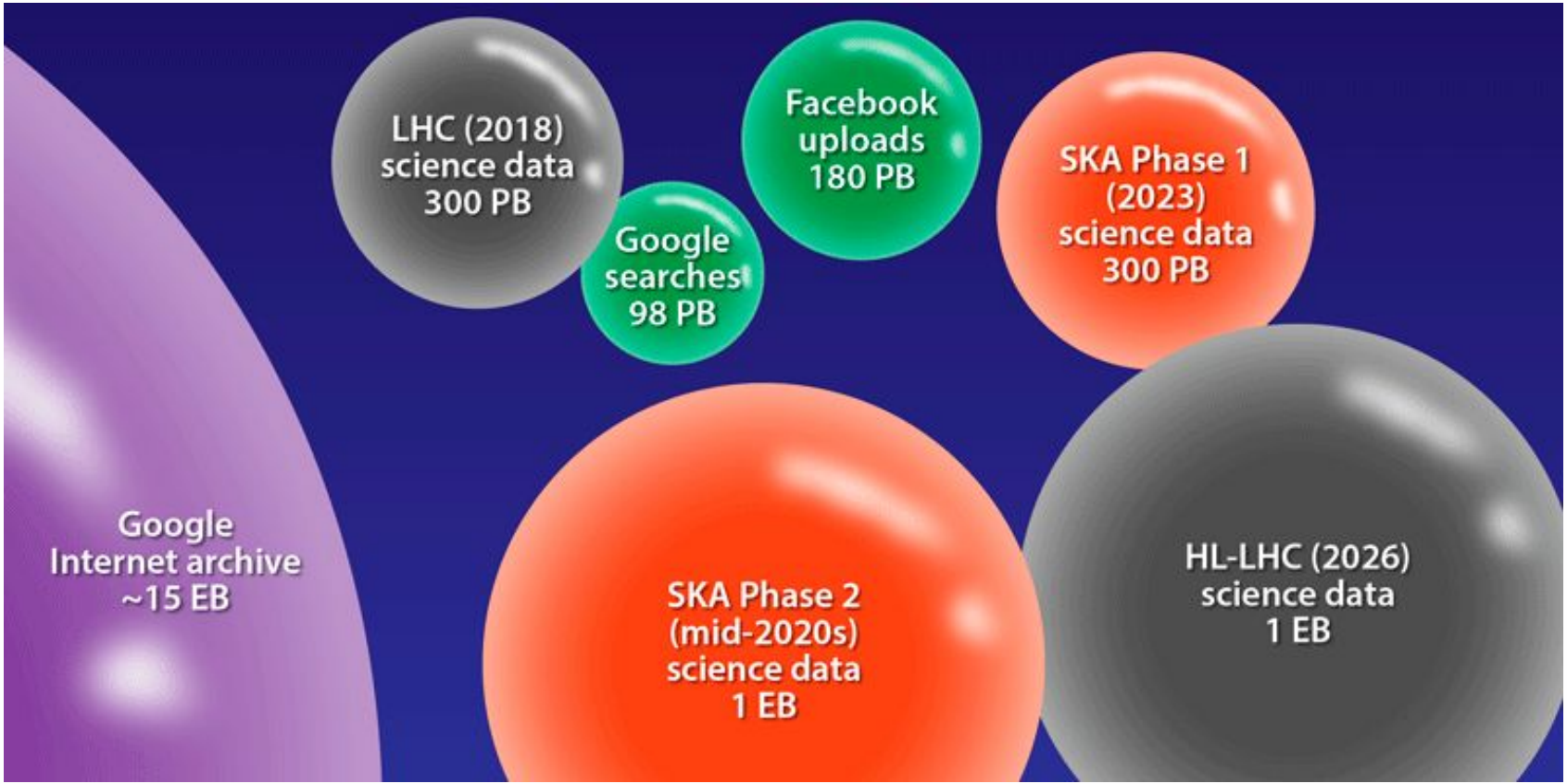
Experimental Facilities

A computing perspective



A computing perspective: from TeV/y to PB/y, small to large data processing needs, integration of external resources (HPC), workflow synchronisation turnarounds (data quality monitoring)

A comparison of the yearly data volumes of current and future projects:



Credits: APS/Alan Stonebraker and V. Gülzow/DESY

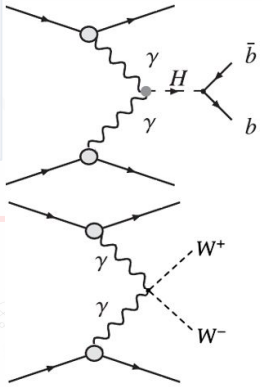
Astroparticle Physics and Radio Astronomy

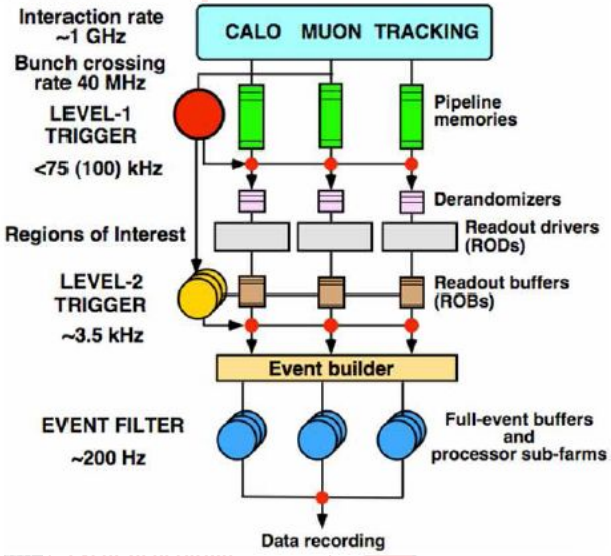
Knowledge transfer and expertise sharing among large ESFRIs on scientific computing

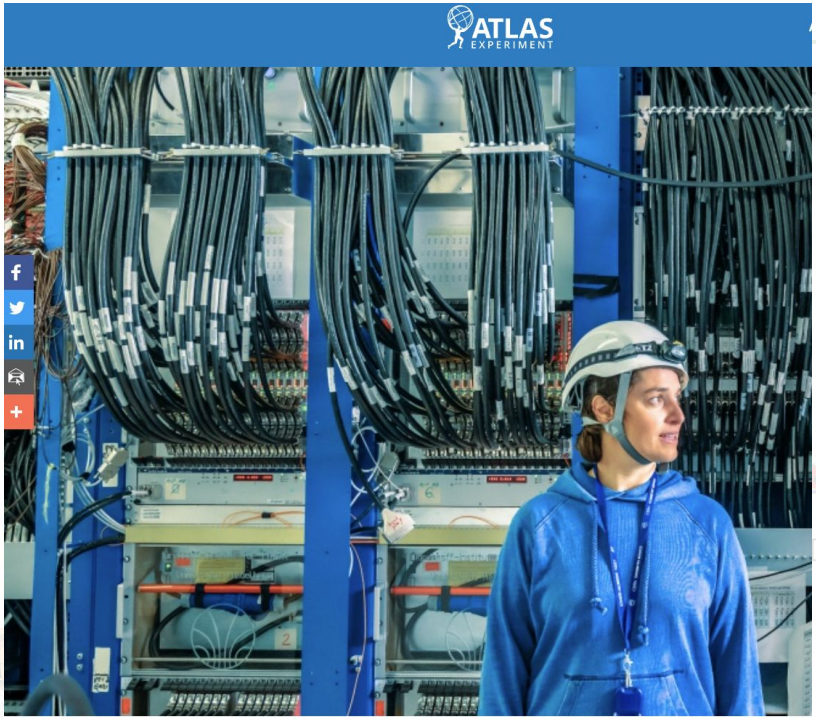
Data Recording from remote sources

Computing at CERN: the big picture

Data Acquisition
(trigger)

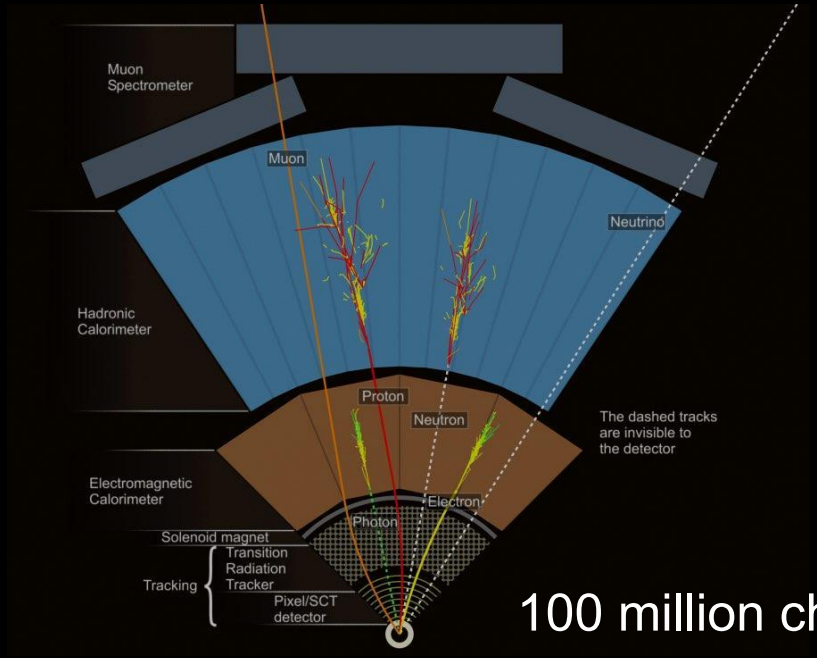


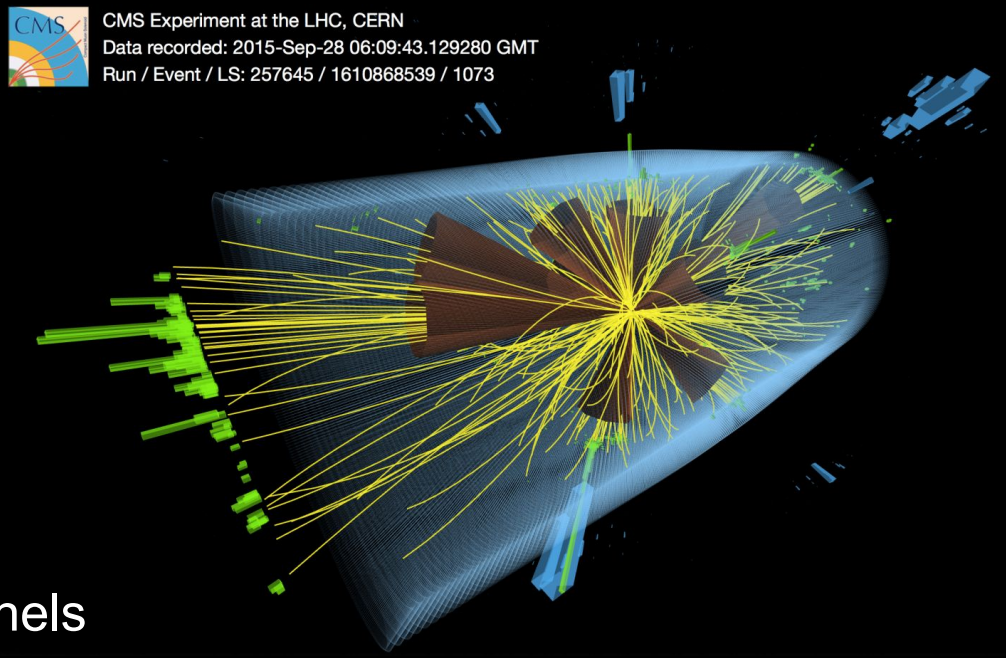




updates > briefing > ATLAS event selection system readies for LHC Run 3

From the Hit to the Bit: DAQ





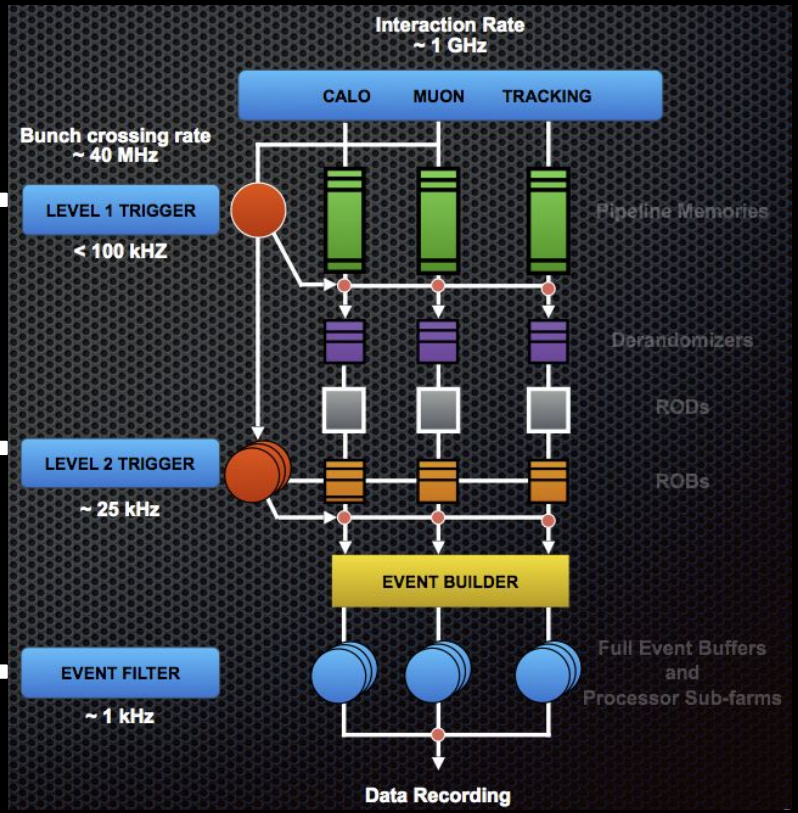
100 million channels

40 million pictures a second

Synchronised signals from all detector parts

From the Hit to the Bit: event filtering

- L1: 40 million events per second
  - Fast, simple information
  - Hardware trigger in a few microseconds
- L2: 100 thousand events per second
  - Fast algorithms in local computer farm
  - Software trigger in <1 second
- EF: Few 100 per second recorded for study



From the Hit to the Bit: event filtering

- L1: 40 million events per second

1PB/s: few hundred trillion euros/yr !!!

From 40 MHZ to 100kHz

- L2: 100 thousand events per second
  - Fast algorithms in local computer farm
  - Software trigger in <1 second
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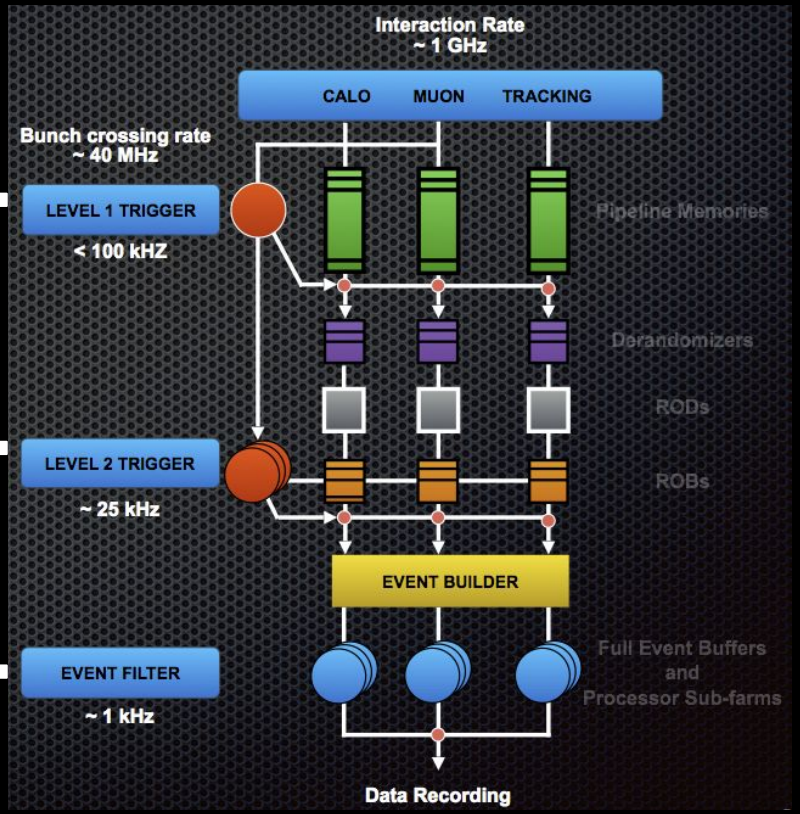


From the Hit to the Bit: event filtering

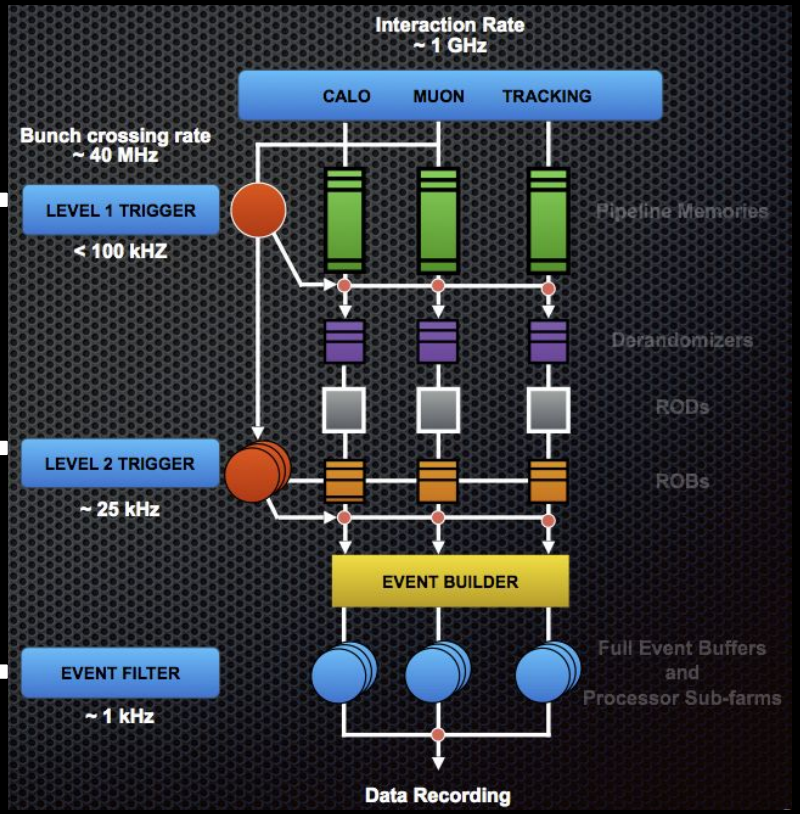
- L1: 40 million events per second

  1PB/s: few hundred trillion euros/yr !!!
  From 40 MHZ to 100kHz

- L2: 100 thousand events per second

  We keep ~1 event in a million
  From 100 kHZ to 25kHz

- EF: Few 100 per second recorded for study



From the Hit to the Bit: event filtering

- L1: 40 million events per second

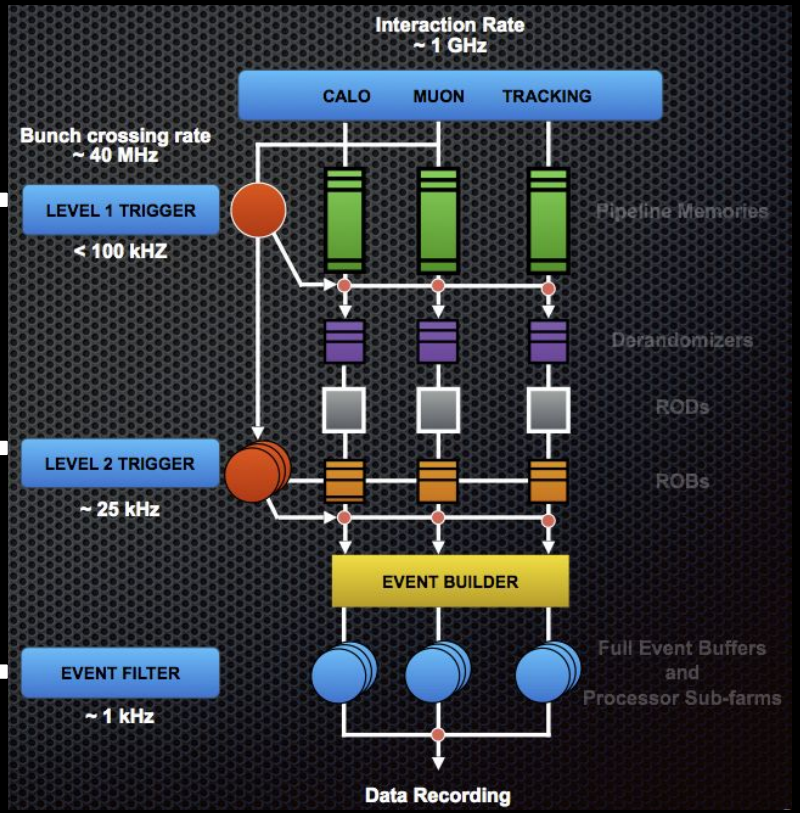
  1PB/s: few hundred trillion euros/yr !!!
  From 40 MHZ to 100kHz

- L2: 100 thousand events per second

  We keep ~1 event in a million
  From 100 kHZ to 25kHz

- EF: Few 100 per second recorded for study

  From 25 kHZ to few kHz
  Final data rates ~10 GB/s



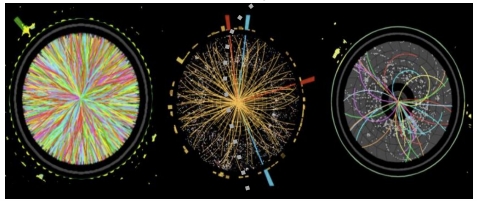
Computing at CERN: the big picture

Data Recording and Archive

Data Acquisition (trigger)

Data

Detector



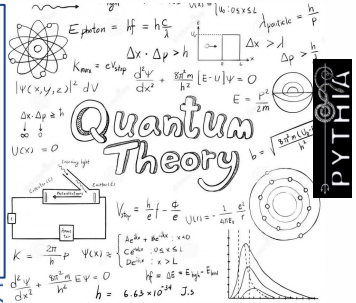
CPU GPU

Data Reconstruction and Derivation

SSD SSD

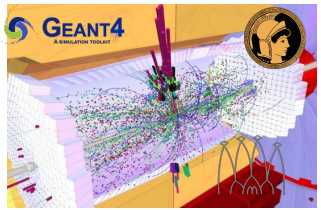
Data Analysis

Simulated Data



Event Generation(part. inter.) Simulation(int. w/ det.) Digitization(simul detector resp)

CPU GPU



CPU CPU CPU GPU GPU GPU GPU GPU

HPCs

Preservation: Data and Analysis

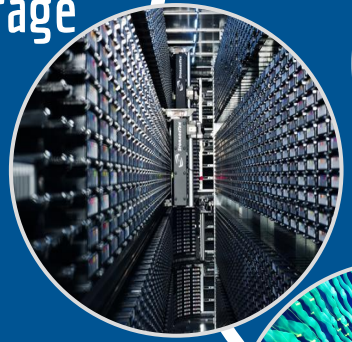
CERN IT Department

Facilities

Network

Data Processing

Data Storage



IT

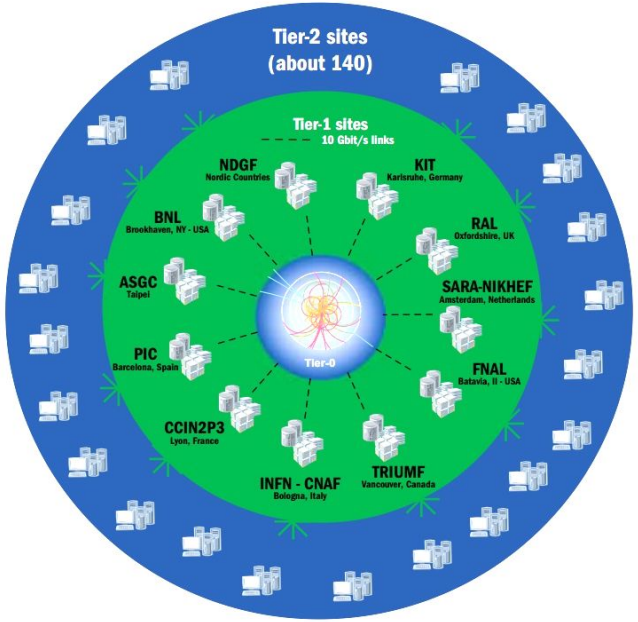
Distributed Computing

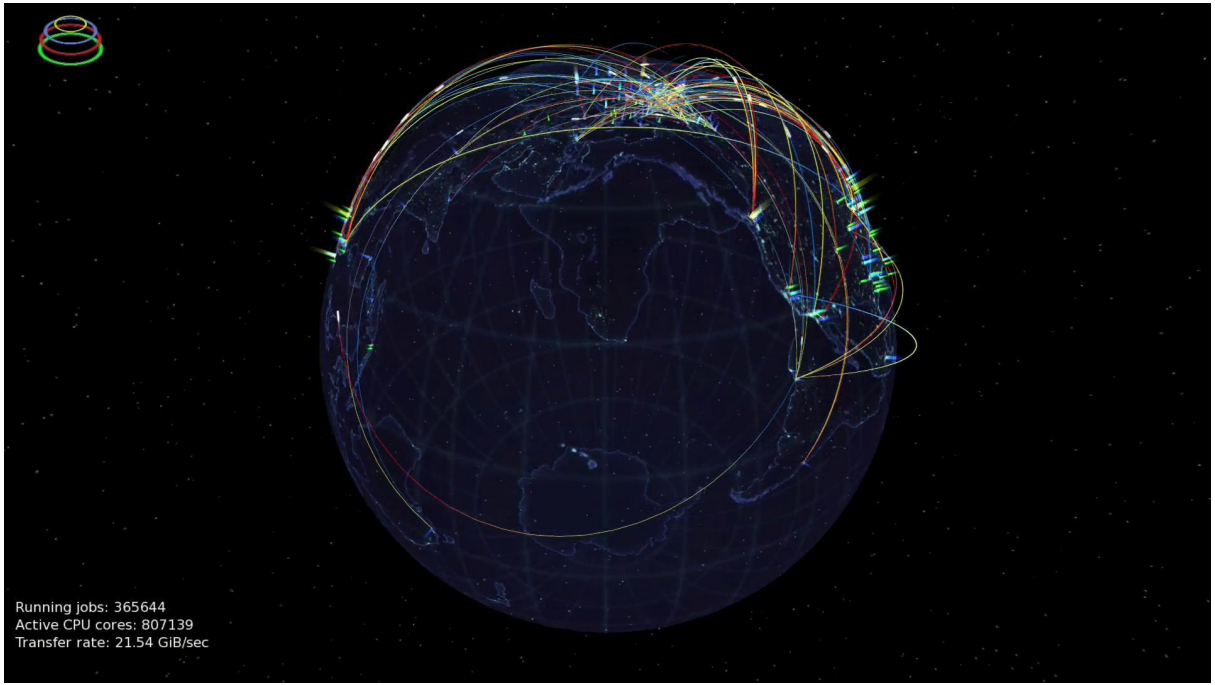
DataBases

Applications and devices

CERN IT Department

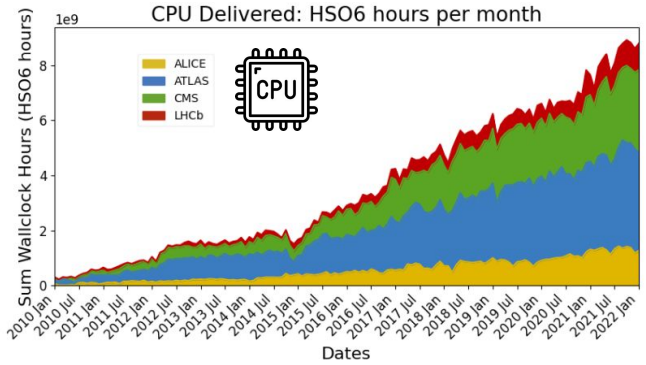
The Worldwide LHC Computing Grid

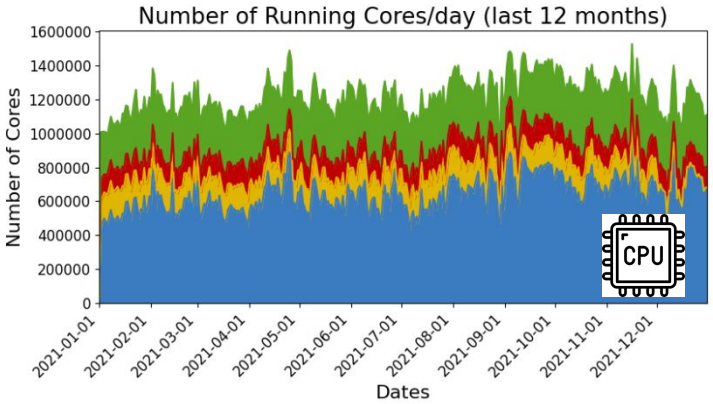


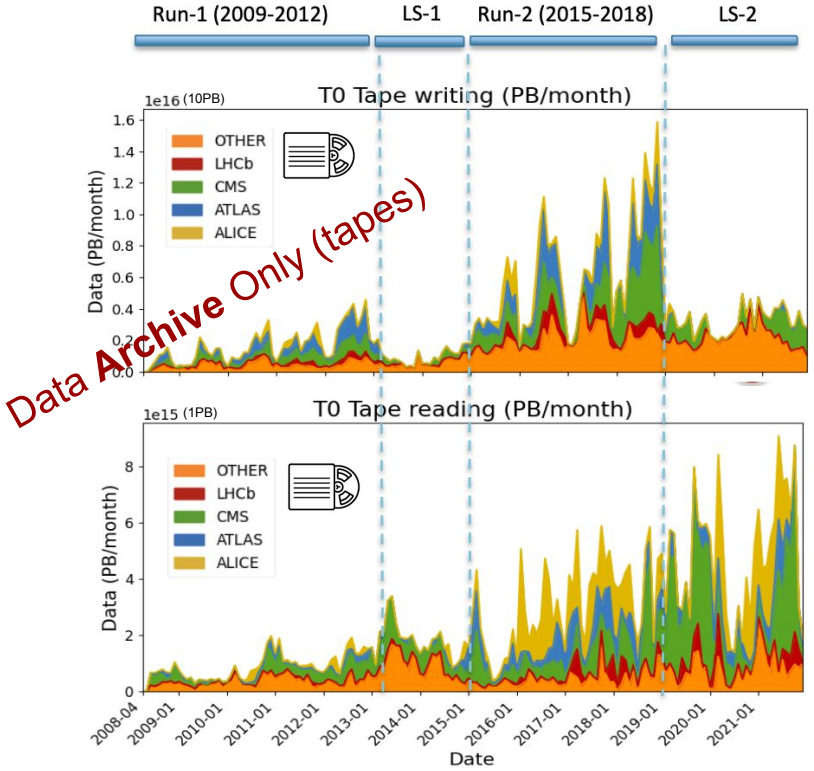


WLCG provides global computing resources to store, distribute and analyse the LHC data

The Worldwide LHC Computing Grid

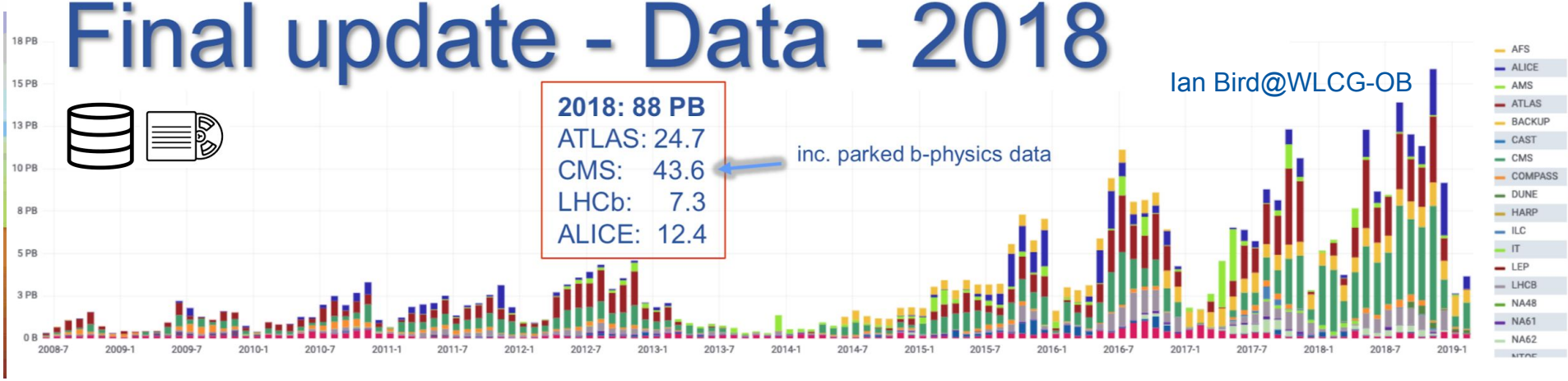






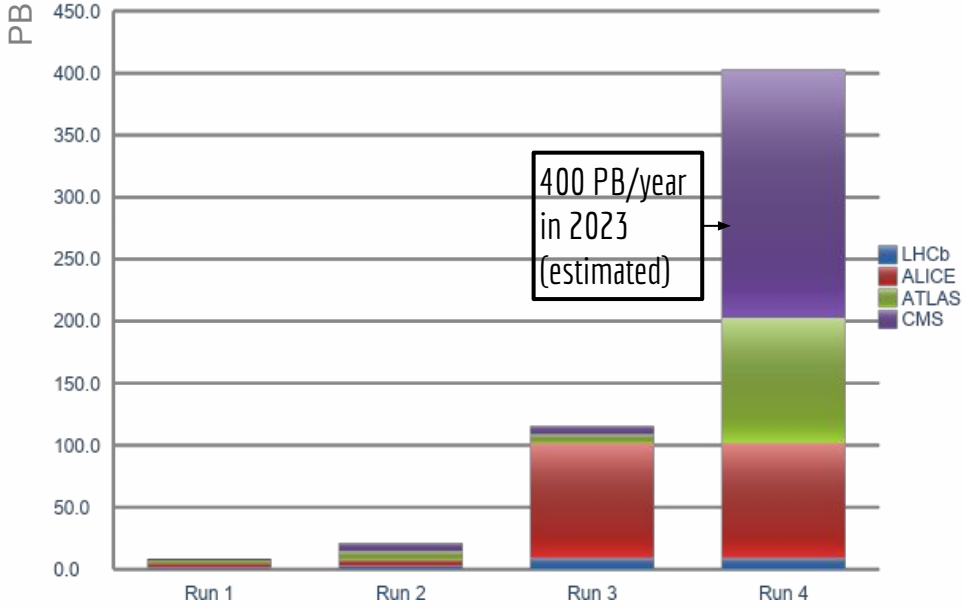
The last LHC Run: data recording

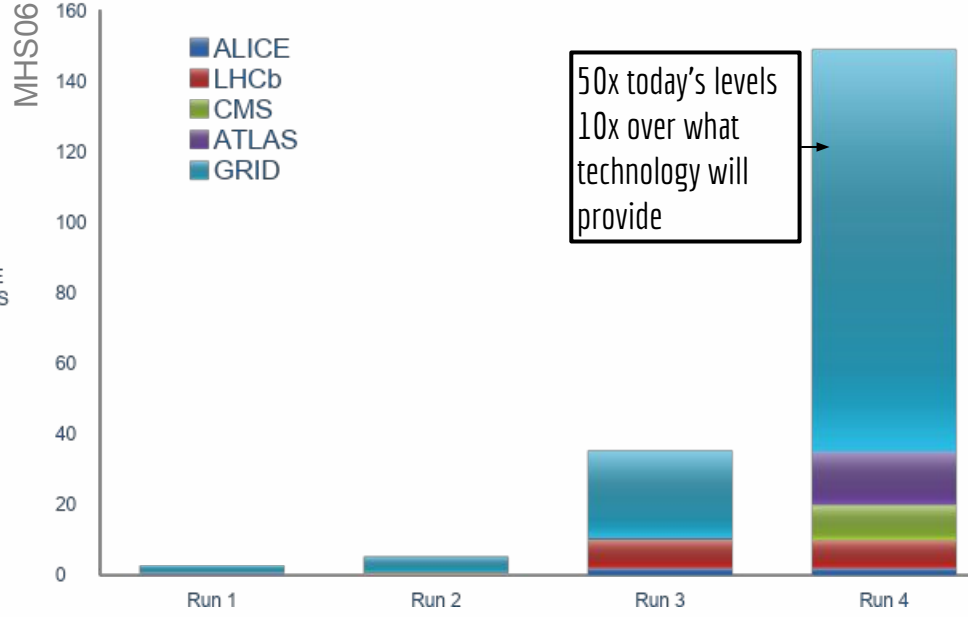
- LHC Experiments recorded 88 Petabytes of data in 2018 (15.8PB only in November)
- The LHC data is aggregated at the CERN data centre to be stored, processed and distributed



HL-LHC: a computing challenge

HL-LHC: a computing challenge





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Detector

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Simulated Data

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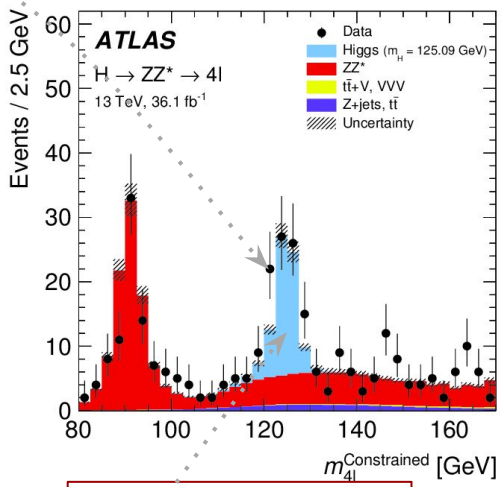
Data Analysis

HPCs

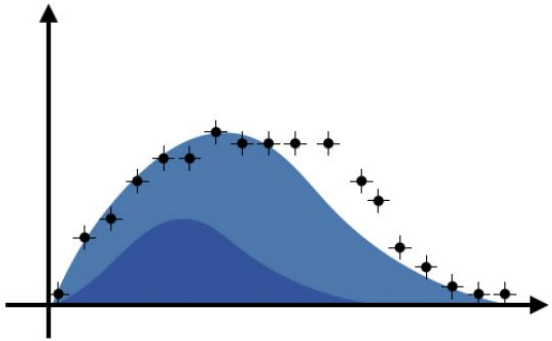


Preservation: Data and Analysis

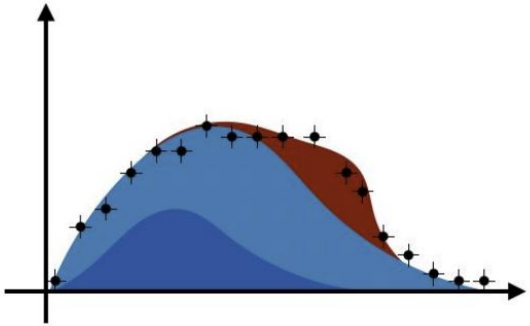
Data processing… and discovery!

Spawning a large cloud computing cluster at CERN for data processing using notebooks (70TB spread over 20k files). All processed in few minutes, real time!

Baseline only



Baseline +
New Physics



Baseline cannot describe data

… but baseline + new physics theory does -> Discovery!

Heinrich, Rocha @Kubecon and @CERN-ITTF

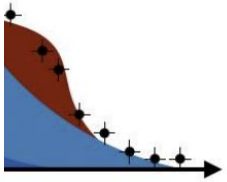
Keynote: Re-performing a Nobel Prize Discovery on Kubernetes

https://www.youtube.com/watch?v=CTfp2woVEkA (10:15 start, 14:30 populating plot)

Da[redacted]very!

Spawning a[redacted]ooks (70TB spread over 20k file[redacted]

Baseline on[redacted]



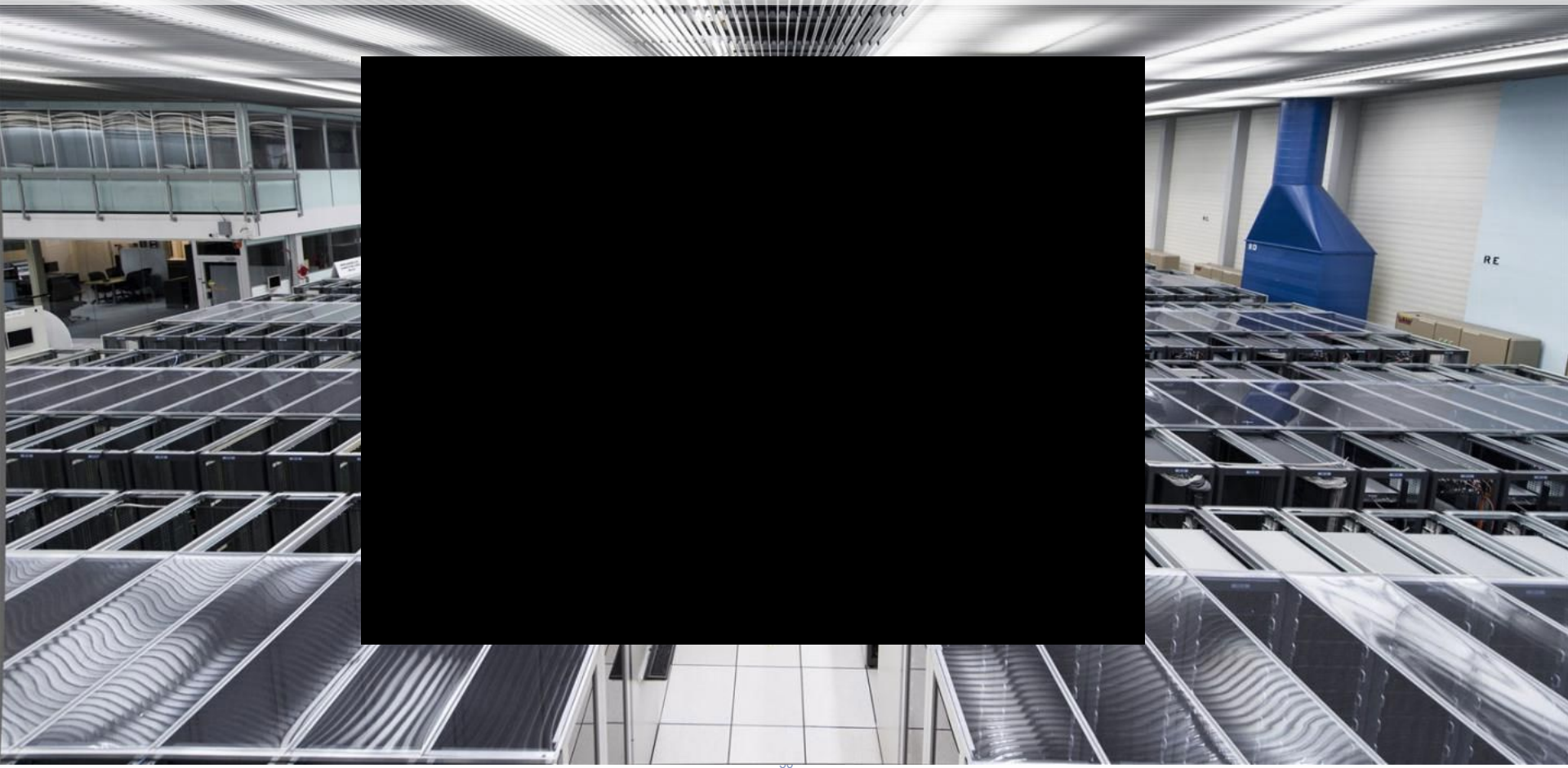
Hei[redacted]
Key[redacted]

https://www.youtube.com/watch?v=CTfp2woVEkA (10:15 start, 14:30 populating plot)

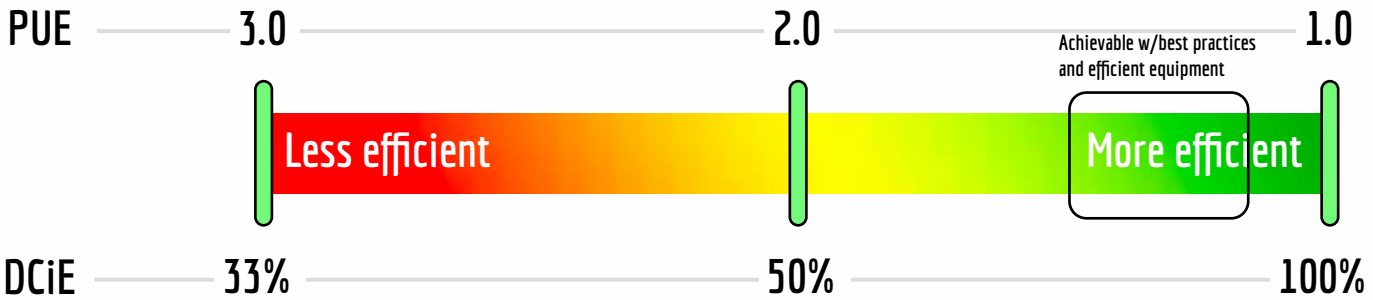
CERN Data Center

- Built in the 70s on the CERN site (Meyrin,Geneva)
  - 3.5 MW for equipment
- Hardware generally based on commodity
  - 10,000 servers, providing 500,000 processor cores (14.000 VMs)
  - 120,000 disk drives providing 0.6EB disk space (1EB=1000PB)
  - 40,000 tapes drives, providing 0.5EB capacity (1EB=1000PB)

CERN Data Center



Green IT



Power Usage Effectiveness (PUE): Total Facility Energy / IT Facility Energy

https://news.microsoft.com/features/under-the-sea-microsoft-tests-a-datacenter-thats-quick-to-deploy-could-provide-internet-connectivity-for-years/

Building work for CERN's new data centre in Prévessin begins

On Friday, 22 April, a ceremony was held to mark the beginning of construction of CERN's new energy-efficient data centre

22 APRIL, 2022 | By Andrew Purcell

Representatives of CERN and of the EQUANS France-Léon Grosse-Agapé consortium involved in the first-stone ce

An artist's impression of the CERN Data Centre in Prévessin. The facility will consist of three floors, to be progressively filled with computing equipment over the first ten years of operation. (Credit: + IMGS – Rocco Valantines)

Operational in the second half of 2023

"Computing is central to CERN's mission," says Charlotte Warakaulle, CERN Director for International Relations, who participated in the first-stone ceremony for the new data centre. "It turns data into knowledge, helping physicists unlock the secrets of the universe."

The CERN Data Centre in Prévessin will provide computing resources up to a total electrical power requirement of 12 megawatts. These resources will be delivered in three phases. Each phase corresponds to one of the three floors of the new data centre, with the first phase set to run from 2023 to 2025. It will see computing resources requiring up to 4 megawatts of electrical power installed; this is approximately the same as the power of the current CERN Data Centre in Meyrin for computing (excluding cooling).

Take-away (1/3)

- Computing is instrumental for science. Detectors and sensors evolving: growing IT demands.
- LHC raw data rates are PB/s scale but lowered to GB/s after data *filtering*
- 90PB of LHC data in 2018 (15.8PB in Nov only)
- 1EB data transferred world-wide
- Scientific data already at the **Exabyte scale**:
  - 1EB = 1.000PB = 1.000.000 TB = 1.000.000.000 GB

(1TB is your computer) (100 GB is your smartphone)

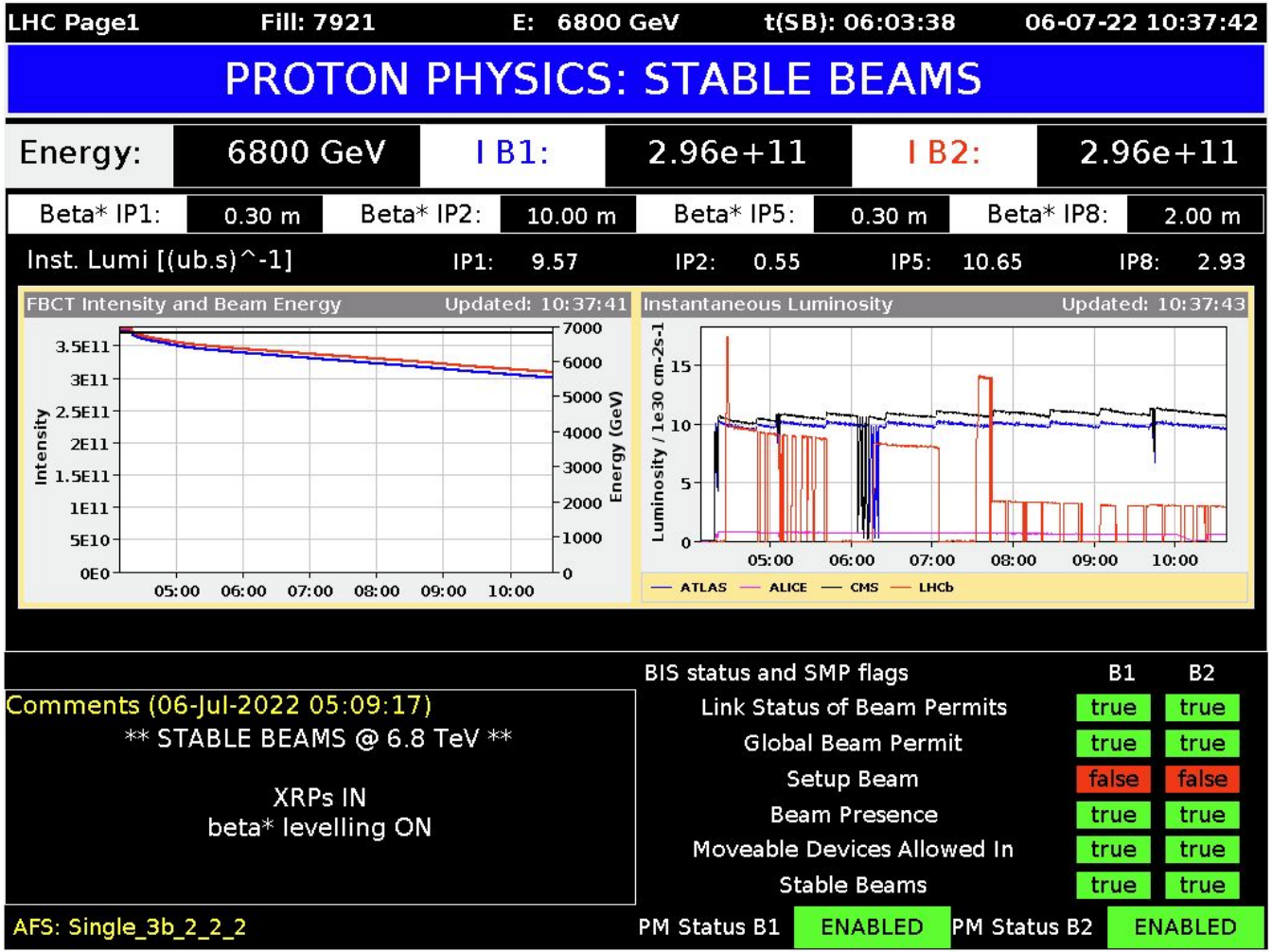
Take-away (2/3)

- Power and Heat management: PUE and Green-IT
- Data centers run on commodity hardware
- Big computing companies dominating the market: G, MS, DB, FB,...
- CERN remains largest scientific repository in the world

Take-away (3/3)

- High-Luminosity LHC brings new challenges in computing: time for **new ideas** and **R&D**!
- **Fundamental** science continue to be the main inspiration for **revolutionary** ideas, due to revolutionary needs
- Industry has well defined offer and demand. We do not. This is the key for **innovation**
- …and **innovation** foster technological advancements that percolates to the society

Thank you!



https://op-webtools.web.cern.ch/vistar/vistars.php