Collaboration, Big Data and the search for the Higgs Boson

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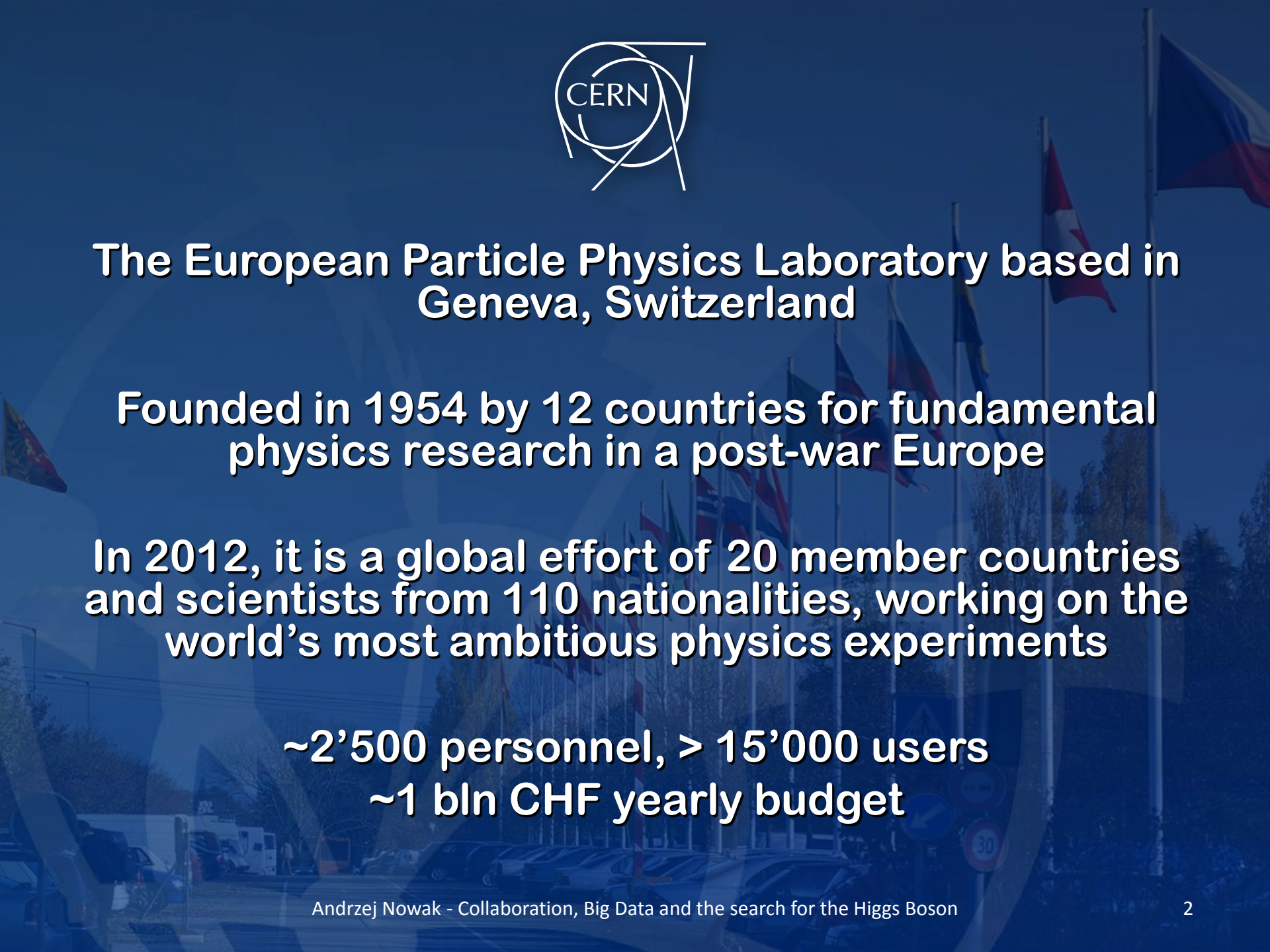


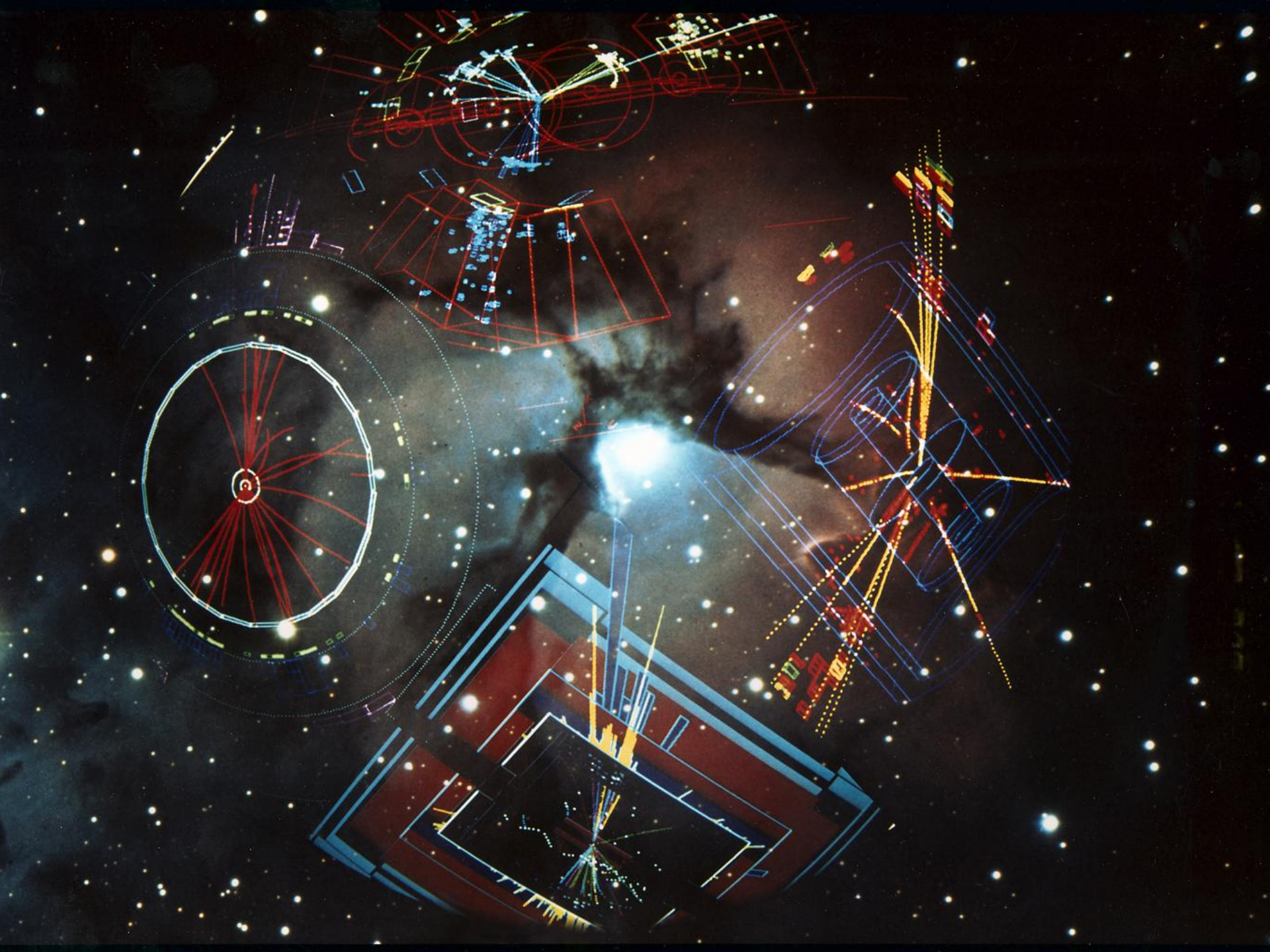
The European Particle Physics Laboratory based in Geneva, Switzerland

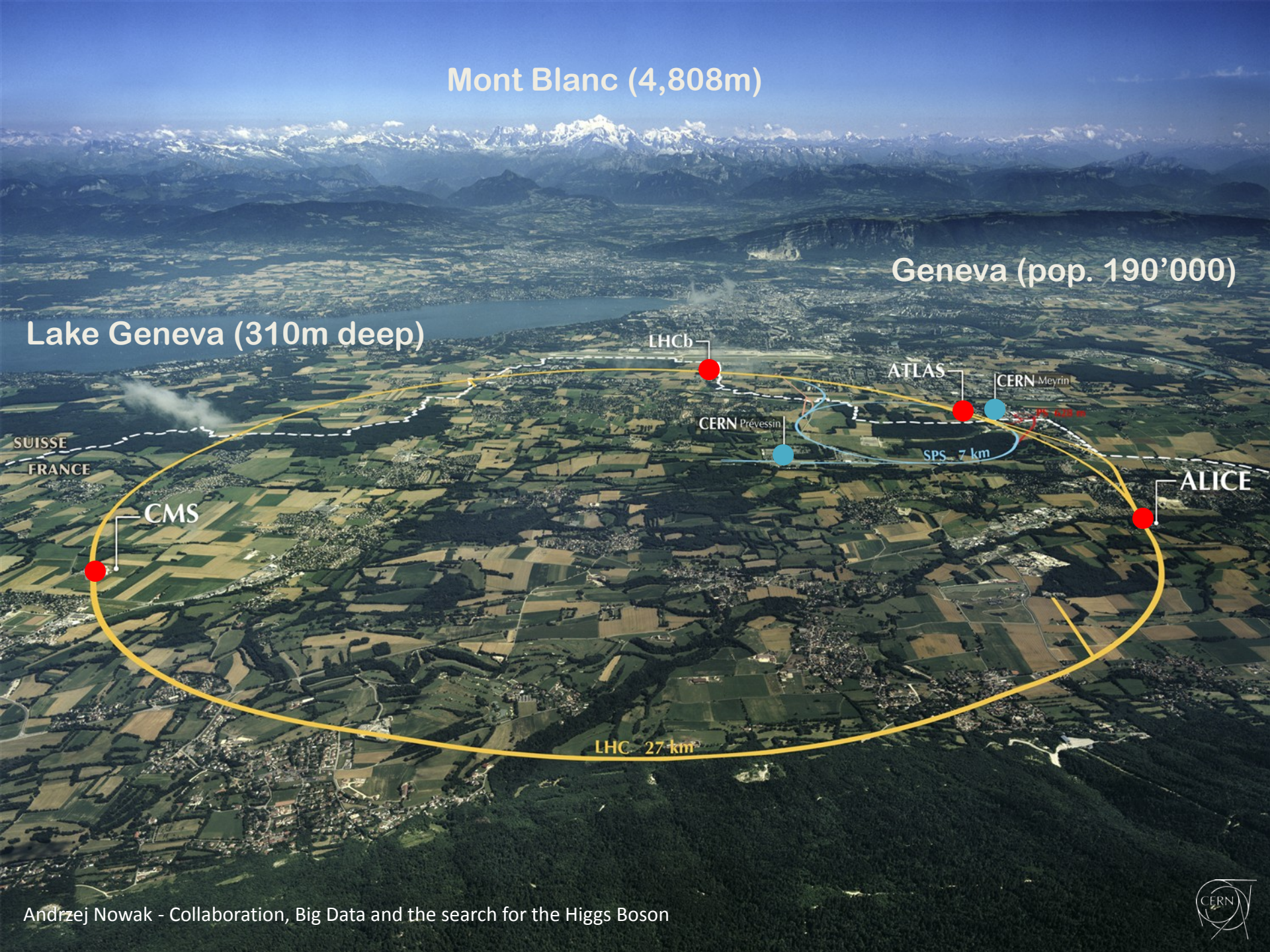
Founded in 1954 by 12 countries for fundamental physics research in a post-war Europe

In 2012, it is a global effort of 20 member countries and scientists from 110 nationalities, working on the world's most ambitious physics experiments

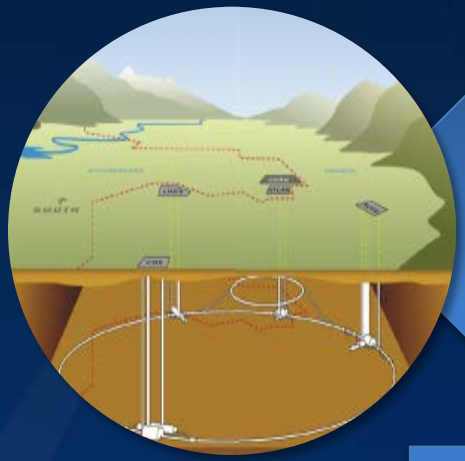
~2'500 personnel, > 15'000 users

~1 bln CHF yearly budget



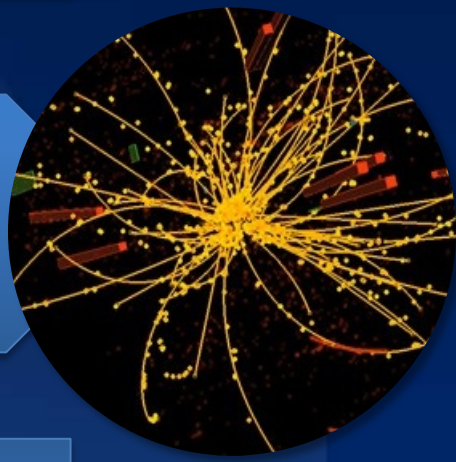

Mont Blanc (4,808m)
Geneva (pop. 190'000)
Lake Geneva (310m deep)
LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
CMS
ALICE
LHC 27 km

The Large Hadron Collider

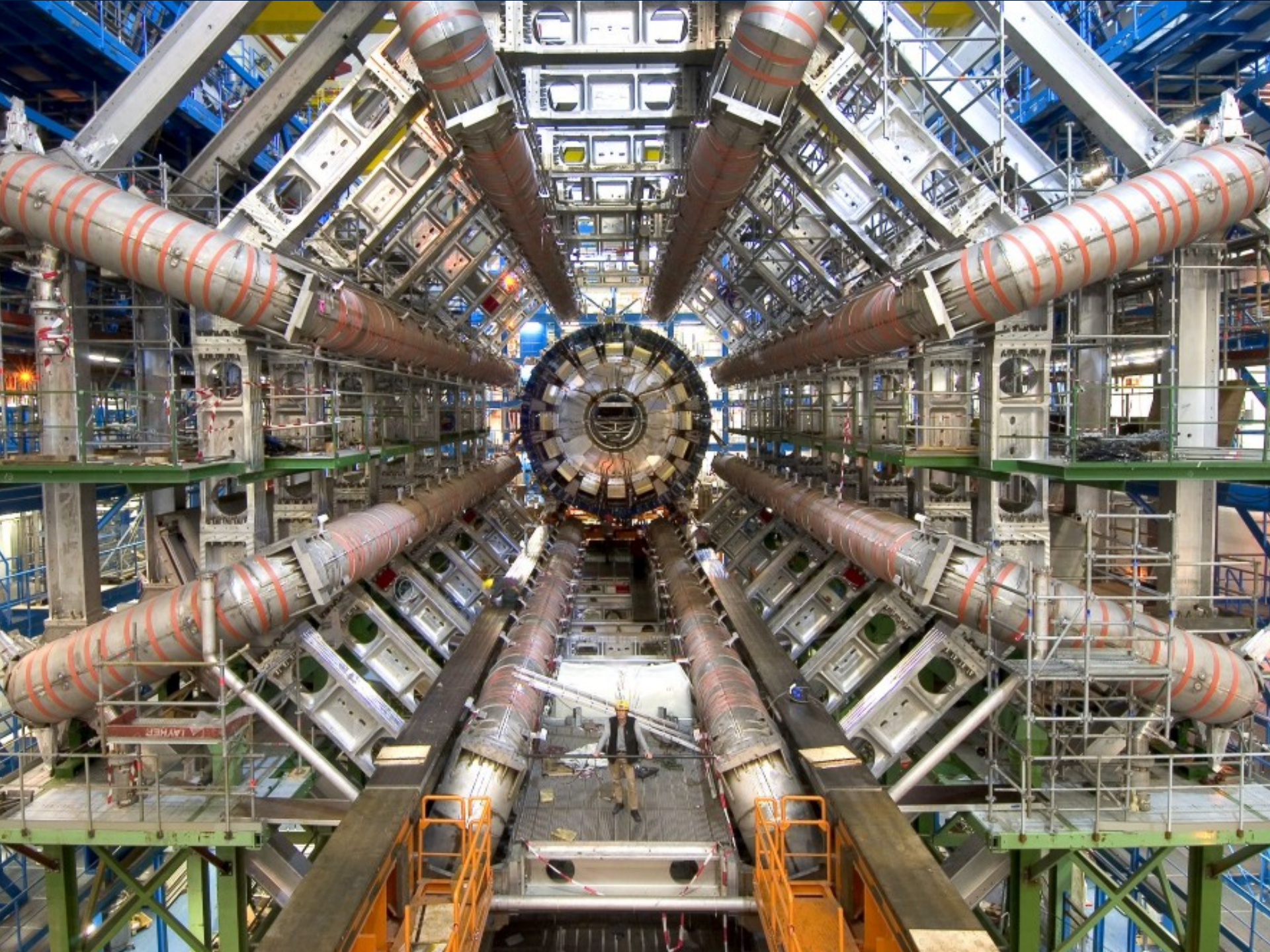


27 km underground superconducting ring – possibly the largest machine ever built by man

40 million collisions per second



150-200 MW power consumption



Charged-particle multiplicities in pp interactions at $\sqrt{s} = 900$ GeV measured with the ATLAS detector at the LHC ☆,☆☆

ATLAS Collaboration

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ABSTRACT

The first measurements from proton–proton collisions recorded with the ATLAS detector at the are presented. Data were collected in December 2009 using a minimum-bias trigger during coll at a centre-of-mass energy of 900 GeV. The charged-particle multiplicity, its dependence on trans momentum and pseudorapidity, and the relationship between mean transverse momentum and cha particle multiplicity are measured for events with at least one charged particle in the kinematic $|\eta| < 2.5$ and $p_T > 500$ MeV. The measurements are compared to Monte Carlo models of proton–p collisions and to results from other experiments at the same centre-of-mass energy. The charged-pa multiplicity per event and unit of pseudorapidity at $\eta = 0$ is measured to be 1.333 ± 0.003(st 0.040(syst.), which is 5–15% higher than the Monte Carlo models predict.

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1. Introduction

Inclusive charged-particle distributions have been measured in pp and $p\bar{p}$ collisions at a range of different centre-of-mass energi 13]. Many of these measurements have been used to constrain phenomenological models of soft-hadronic interactions and to p properties at higher centre-of-mass energies. Most of the previous charged-particle multiplicity measurements were obtained by sel data with a double-arm coincidence trigger, thus removing large fractions of diffractive events. The data were then further correc remove the remaining single-diffractive component. This selection is referred to as non-single-diffractive (NSD). In some cases, desig as inelastic non-diffractive, the residual double-diffractive component was also subtracted. The selection of NSD or inelastic non-diffr charged-particle spectra involves model-dependent corrections for the diffractive components and for effects of the trigger selecti events with no charged particles within the acceptance of the detector. The measurement presented in this Letter implements a dif strategy, which uses a single-arm trigger overlapping with the acceptance of the tracking volume. Results are presented as incl inelastic distributions, with minimal model-dependence, by requiring one charged particle within the acceptance of the measureme

This Letter reports on a measurement of primary charged particles with a momentum component transverse to the beam dire $p_T > 500$ MeV and in the pseudorapidity range $|\eta| < 2.5$. Primary charged particles are defined as charged particles with a mean li $\tau > 0.3 \times 10^{-10}$ s directly produced in pp interactions or from subsequent decays of particles with a shorter lifetime. The distributi tracks reconstructed in the ATLAS inner detector were corrected to obtain the particle-level distributions:

$$\frac{1}{N_{\rm ev}} \cdot \frac{{\rm d}N_{\rm ch}}{{\rm d}\eta}, \quad \frac{1}{N_{\rm ev}} \cdot \frac{1}{2\pi\, p_T} \cdot \frac{{\rm d}^2 N_{\rm ch}}{{\rm d}\eta\, {\rm d}p_T}, \quad \frac{1}{N_{\rm ev}} \cdot \frac{{\rm d}N_{\rm ev}}{{\rm d}n_{\rm ch}} \quad \text{and} \quad \langle p_T \rangle \text{ vs. } n_{\rm ch},$$

where $N_{\rm ev}$ is the number of events with at least one charged particle inside the selected kinematic range, $N_{\rm ch}$ is the total num charged particles, $n_{\rm ch}$ is the number of charged particles in an event and $\langle p_T \rangle$ is the average p_T for a given number of charged par

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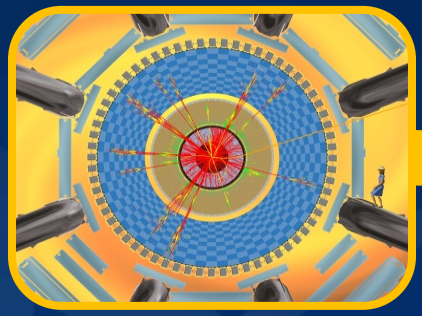
Data flow from the LHC detectors

Online triggering and filtering in detectors



Event simulation

Reconstruction

Selection and reconstruction

Raw Data (100%)

Event reprocessing

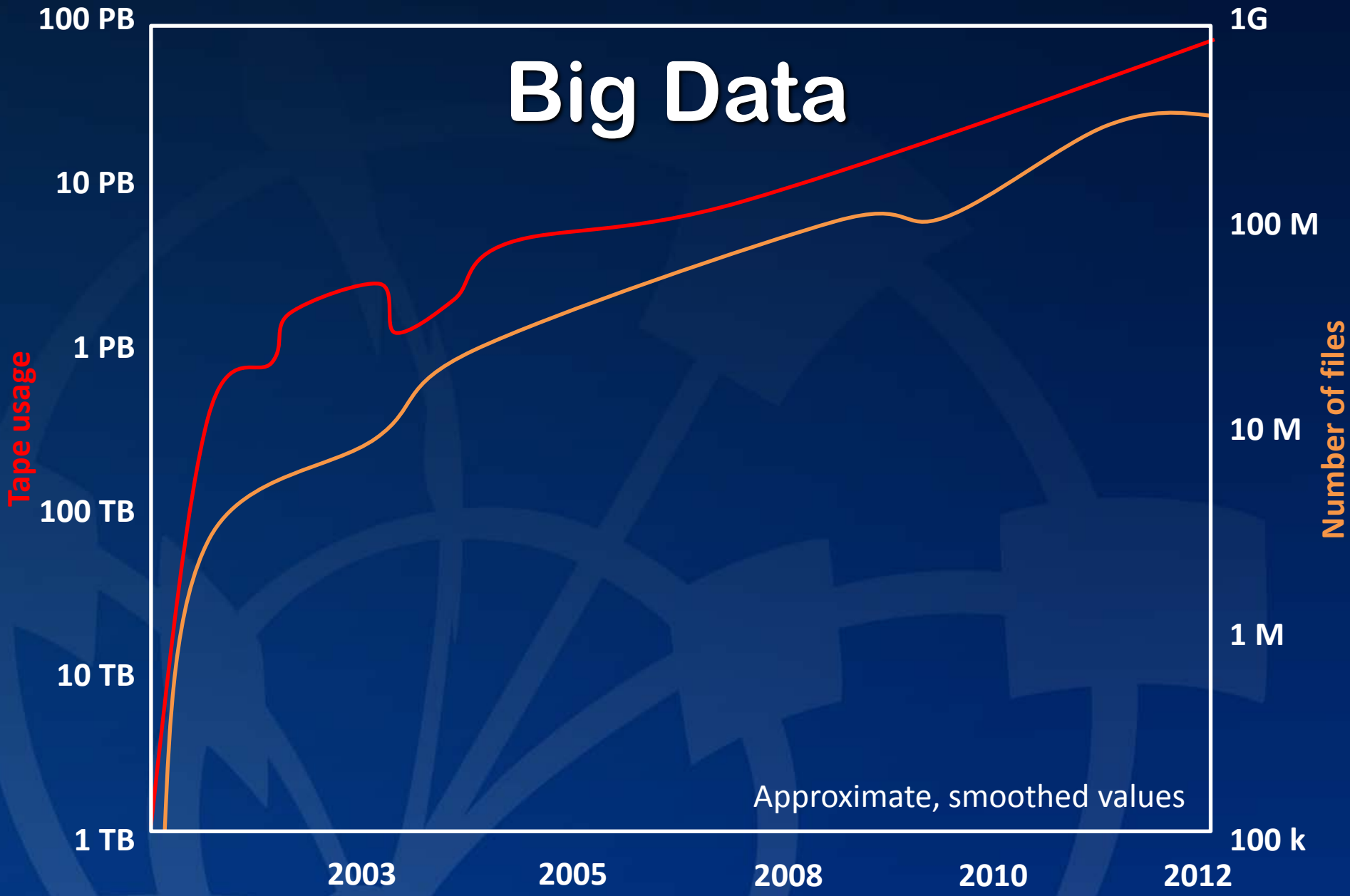
Event summary data (10%)

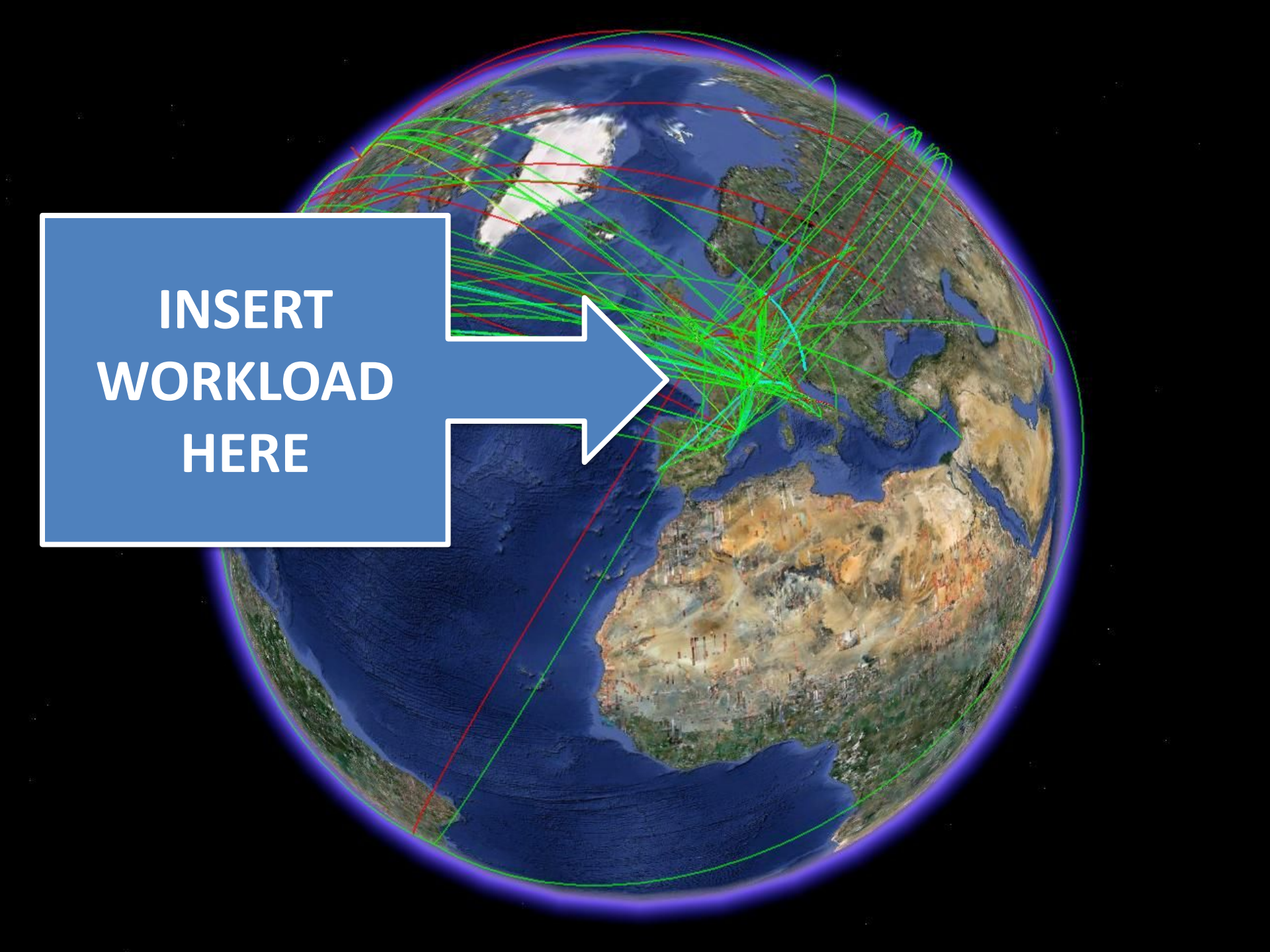
Analysis

Analysis objects (1%)

Batch physics analysis

Processed data


Big Data
100 PB
10 PB
1 PB
100 TB
10 TB
1 TB
Tape usage
1G
100 M
10 M
1 M
100 k
Number of files
2003
2005
2008
2010
2012
Approximate, smoothed values

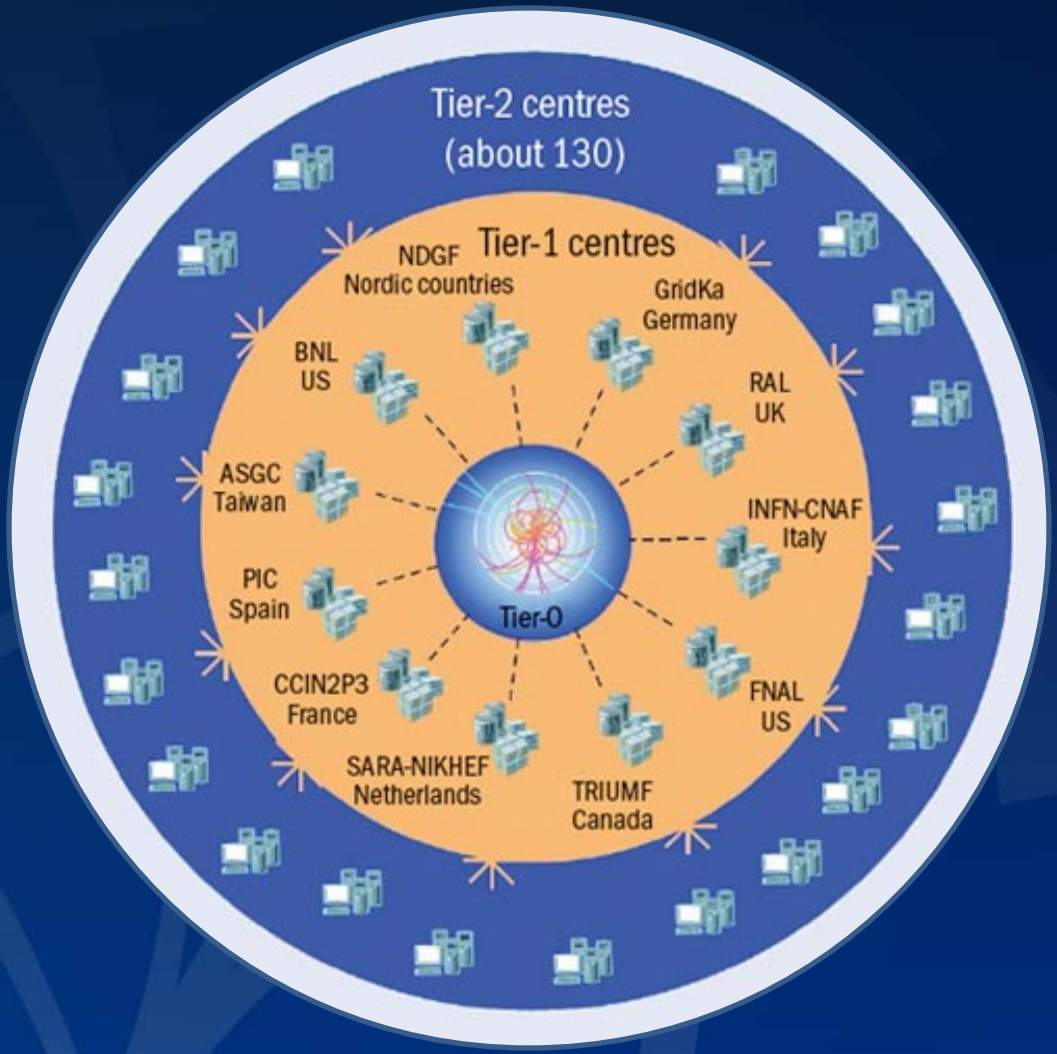

INSERT
WORKLOAD
HERE

Collaboration on big data and computing
The Worldwide LHC Computing Grid

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

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

Tier-2: Simulation, end-user analysis

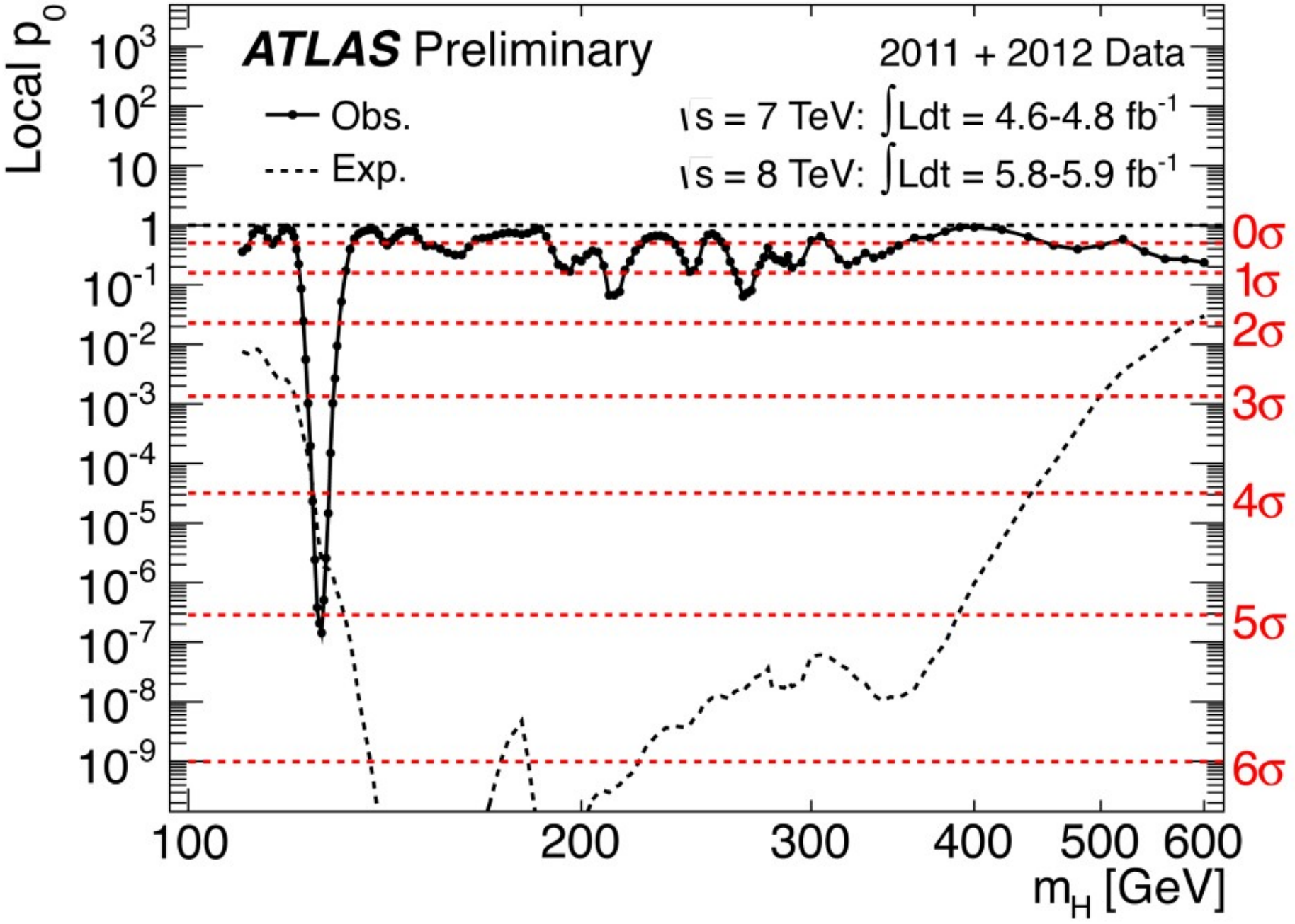


nearly 160 sites

~250'000 cores

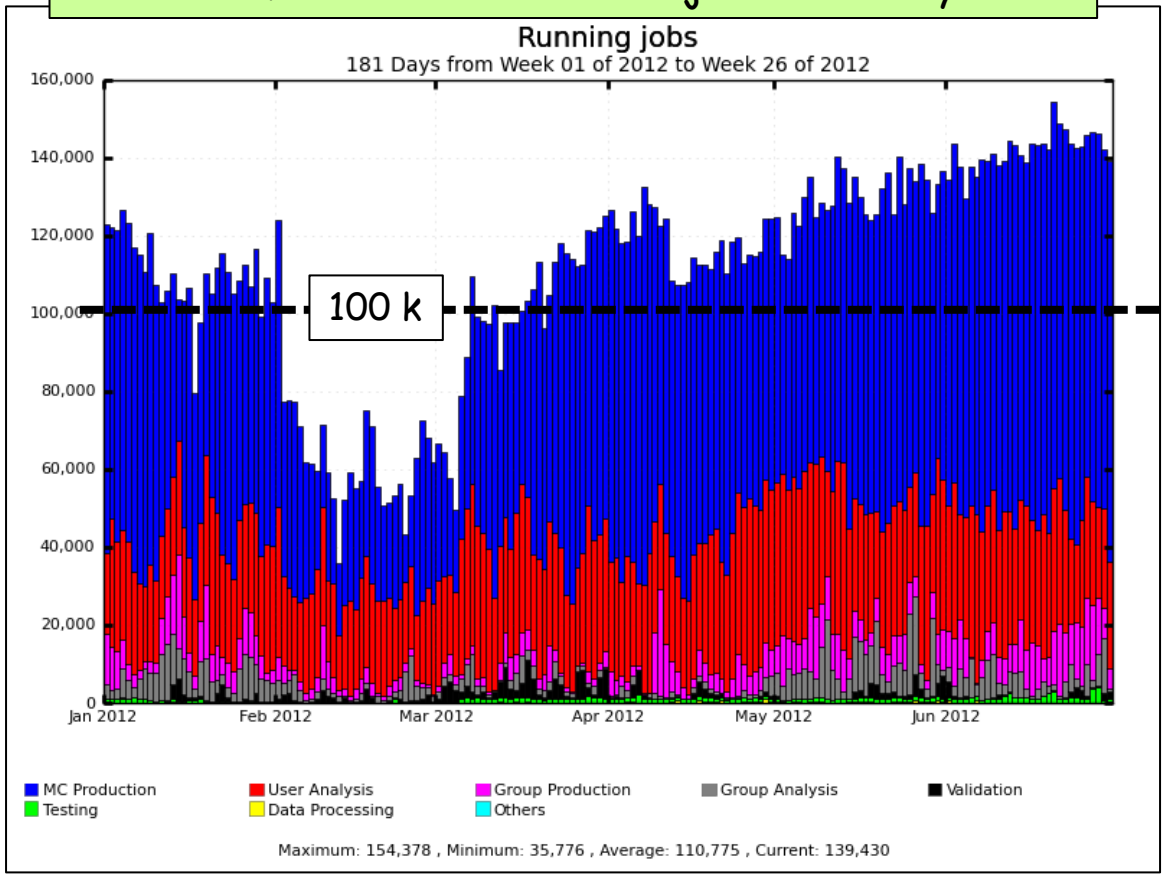
173 PB of storage

> 2 million jobs/day


ATLAS Preliminary
2011 + 2012 Data
Obs.
Exp.
√s = 7 TeV: ∫Ldt = 4.6-4.8 fb-1
√s = 8 TeV: ∫Ldt = 5.8-5.9 fb-1
Local p0
10^3
10^2
10
1
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
0σ
1σ
2σ
3σ
4σ
5σ
6σ
100
200
300
400
500
600
mH [GeV]

It would have been impossible to release physics results so quickly without the outstanding performance of the Grid (including the CERN Tier-0)

Number of concurrent ATLAS jobs Jan-July 2012



Includes MC production, user and group analysis at CERN, 10 Tier1-s, ~ 70 Tier-2 federations → > 80 sites

> 1500 distinct ATLAS users do analysis on the GRID

- Available resources fully used/stressed (beyond pledges in some cases)
- Massive production of 8 TeV Monte Carlo samples
- Very effective and flexible Computing Model and Operation team → accommodate high trigger rates and pile-up, intense MC simulation, analysis demands from worldwide users (through e.g. dynamic data placement)

A wealth of knowledge

- Academic Training program
- Summer Student program
- Physics and computing schools
- Technical Training program
- CERN Teacher schools
- Outreach programs
- EU FP7 programs

Innovation in science

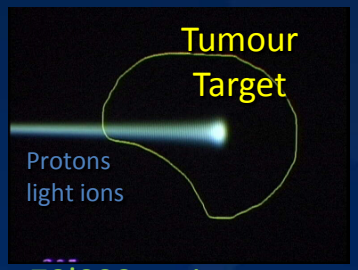
Medical Applications as an Example of Particle Physics Spin-off

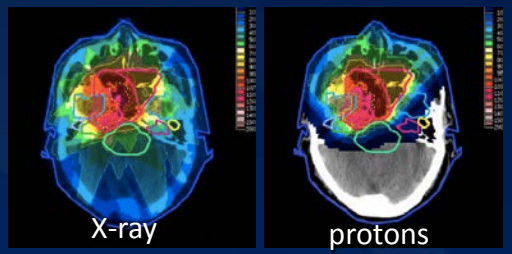
Accelerating particle beams

~30’000 accelerators worldwide

~17’000 used for medicine

⟺ Hadron Therapy

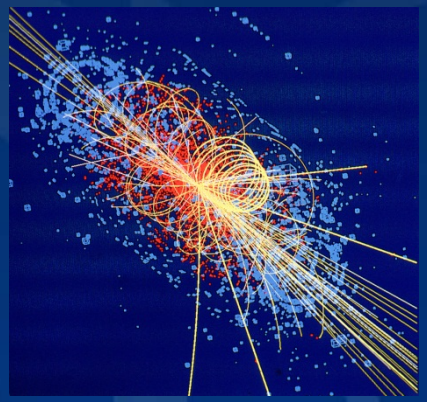




Leadership in Ion Beam Therapy now in Europe and Japan

>70’000 patients treated worldwide (30 facilities)

>21’000 patients treated in Europe (9 facilities)

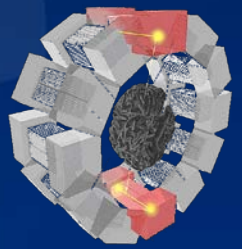


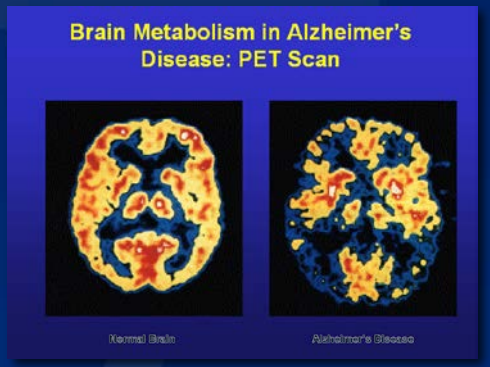
Detecting particles

⟺ Imaging

Clinical trial in Portugal for new breast imaging system (ClearPEM)

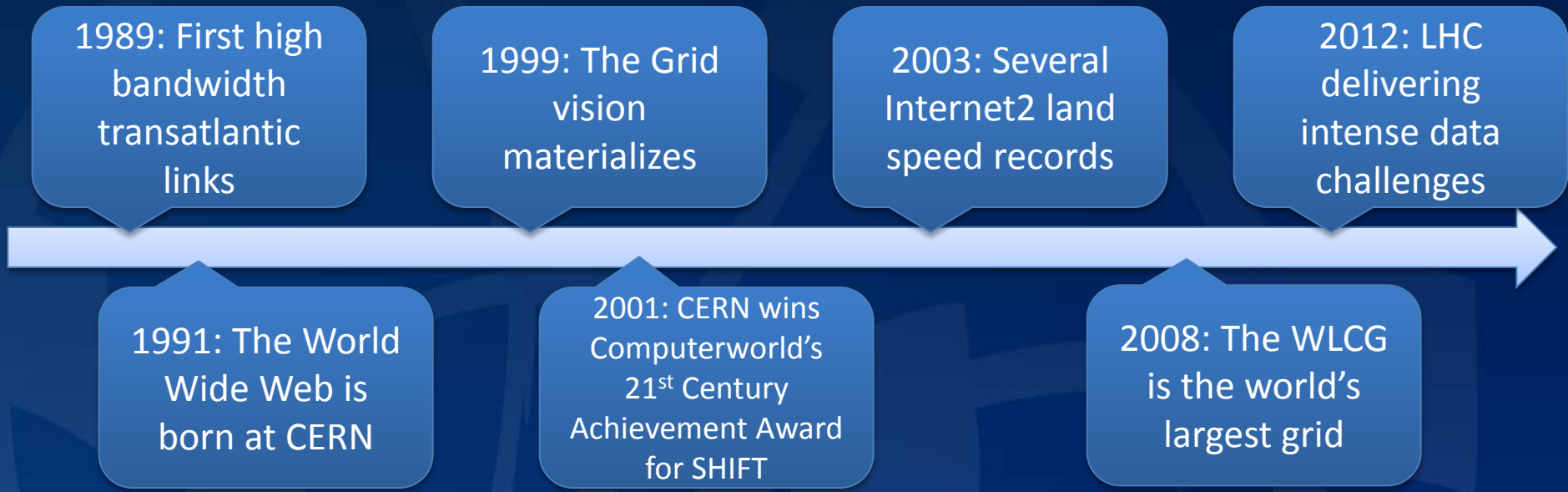
PET Scanner





From F.Hemmer

Innovation in computing



The CERN openlab

A unique research partnership of CERN and the industry
Objective: The advancement of cutting-edge computing solutions to be used by the worldwide LHC community

- Partners support manpower and equipment in dedicated competence centers
- openlab delivers published research and evaluations based on partners' solutions – in a very challenging setting
- Created robust hands-on training program in various computing topics, including international computing schools; Summer Student program
- Past involvement: Enterasys Networks, IBM, Voltaire, F-secure, Stonesoft, EDS; Future involvement: Huawei
- Now in phase IV: 2012-2014

http://cern.ch/openlab

A European Cloud Computing Partnership: big science teams up with big business

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

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

DLR cnes

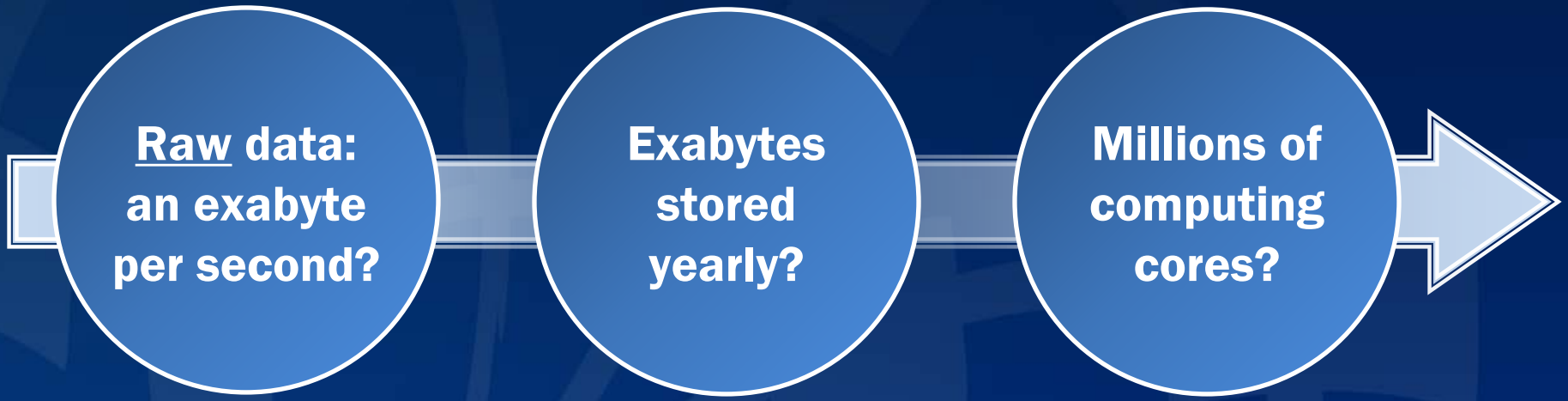
To create an Earth Observation platform, focusing on earthquake and volcano research

Atos · Capgemini CONSULTING.TECHNOLOGY.OUTSOURCING · CloudSigma · CSA cloud security alliance · egi · interoute from the ground to the cloud · logica be brilliant together · OpenNebula.org The Open Source Toolkit for Cloud Computing · orange Business Services · SAP · the SERVER LABS the IT architects · sixsq · Telefónica · terradue 2.0 · THALES · Trust IT · T-Systems

From B.Jones

Big(ger) data

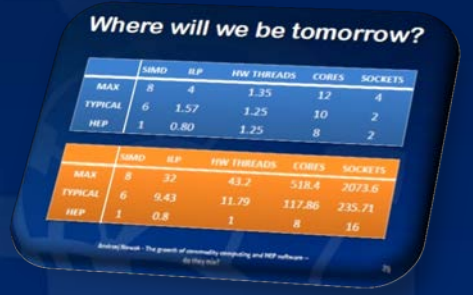
Data rates at the LHC to increase by ~100x



"Sustainable computing"

Future directions in computing

- **Software replacing hardware**
  - Programmability replaces rigid structures
- **Intensive compute**
  - Local farms must have much higher processing capacity
- **Accelerators**
  - Experiments with Intel MIC and GPUs
- **Silicon photonics**



Accelerating Science and Innovation

Continued support of the worldwide physics community and the European population

Great science and engineering + great partners = great innovation