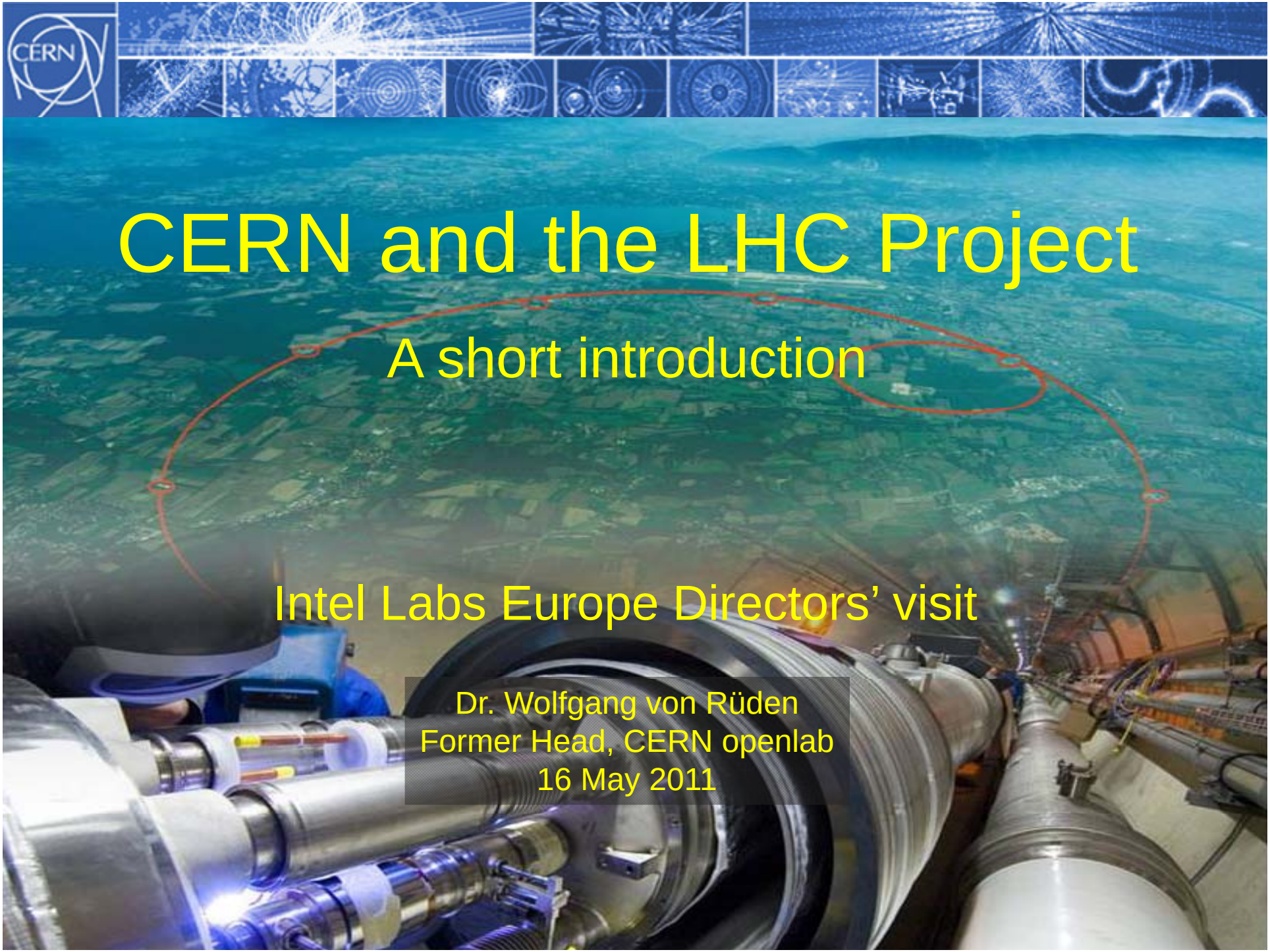

CERN and the LHC Project

A short introduction

Intel Labs Europe Directors' visit

Dr. Wolfgang von Rüden
Former Head, CERN openlab
16 May 2011

CERN openlab in brief

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

Motto: "you make it – we break it"

- Founded in 2001, phase 3 closes in 2011, phase 4 under preparation
- Evaluates state-of-the-art technologies in a very complex environment and improves them
- Test in a research environment today what will be used by industry tomorrow
- Training:
  - Young researchers
  - openlab student programme
  - Topical seminars & workshops
  - CERN School of Computing


The LHC in 10 minutes

Fundamental physics questions:

- Why do particles have mass?
  - Newton could not explain it - and neither can we…
- What is 96% of the Universe made of?
  - We only know 4% of it!
- Why is there no antimatter left in the Universe?
  - Nature should be symmetrical
- What was matter like during the first second of the Universe's life, right after the "Big Bang"?
  - A journey towards the beginning of the Universe will gives us deeper insight

CERN has built the Large Hadron Collider (LHC), allowing us to look at microscopic big bangs to gain a better understanding of the fundamental laws of nature

CERN stands for 57 years of…

- **fundamental research and discoveries**
- **technological innovation**
- **training and education**
- **bringing the world together**

1954 Rebuilding Europe
First meeting of the CERN Council

1980 East meets West
Visit of a delegation from Beijing

2008 Global Collaboration
The Large Hadron Collider involves over 100 countries

CERN Governance

Twenty Member States:

Austria Belgium Bulgaria Czech Republic

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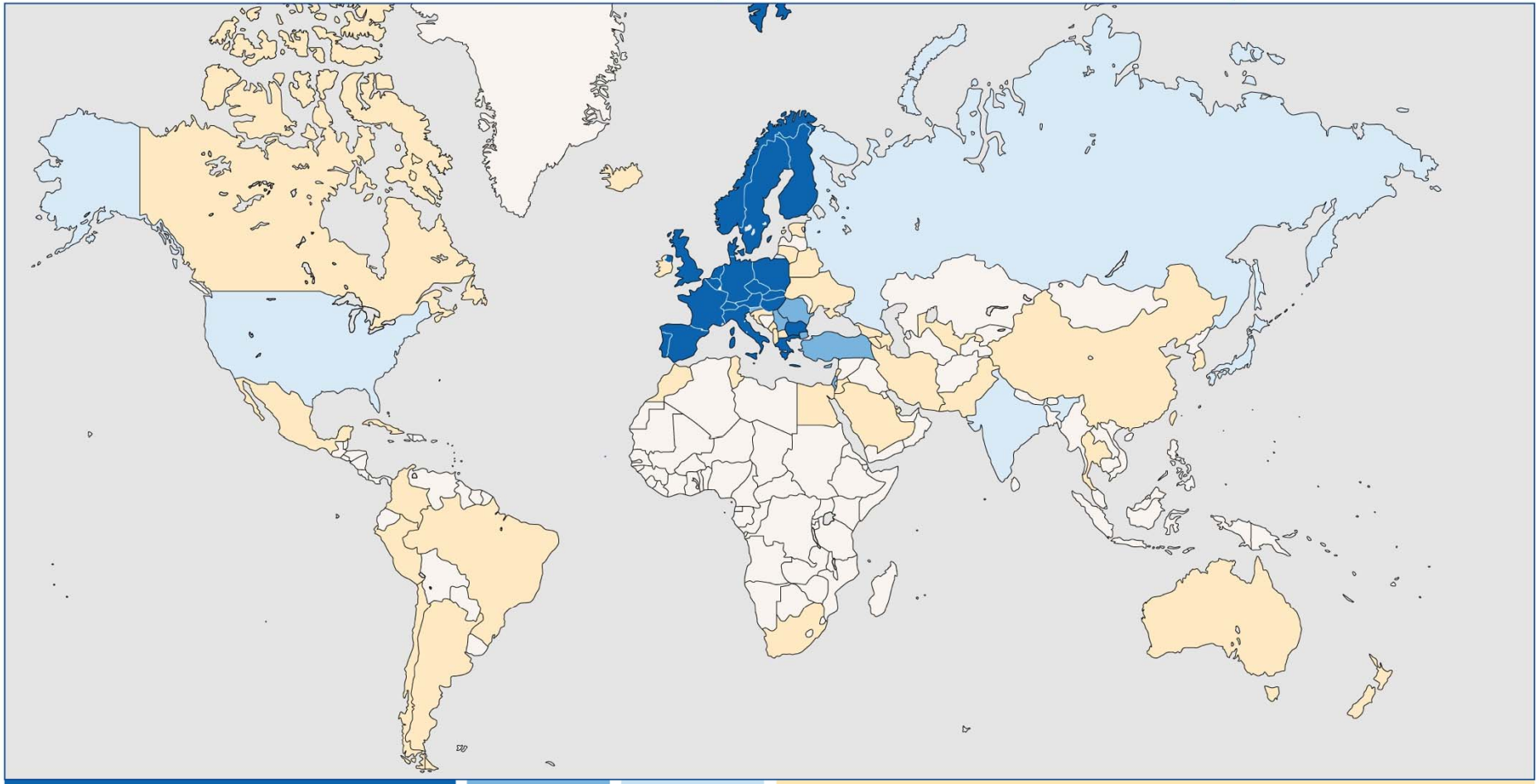
Personnel: 2250 Staff, 700 Fellows and Associates, >10'000 Users

Recent Development:

CERN Council decided in June 2010
to allow membership applications
by countries outside of Europe

Distribution of all CERN Users by Nation of Institute on 6 January 2011



Member states 6361

Austria 79	Hungary 55	Switzerland 351	
Belgium 130	Italy 1428	United Kingdom 701	
Bulgaria 47	Netherlands 171		
Czech Republic. 187	Norway. 82		
Denmark. 73	Poland 193		
Finland 84	Portugal 134		
France 854	Slovak Republic 61		
Germany. 1221	Spain 329		
Greece 109	Sweden. 72		

Prospective Members

Candidate for Accession
Romania

Membership applicants
Cyprus, Israel, Serbia, Slovenia, Turkey

Observer states 2935

India. 91	
Israel 60	
Japan 204	
Russian Federation . . 829	
Turkey 67	
USA 1684	

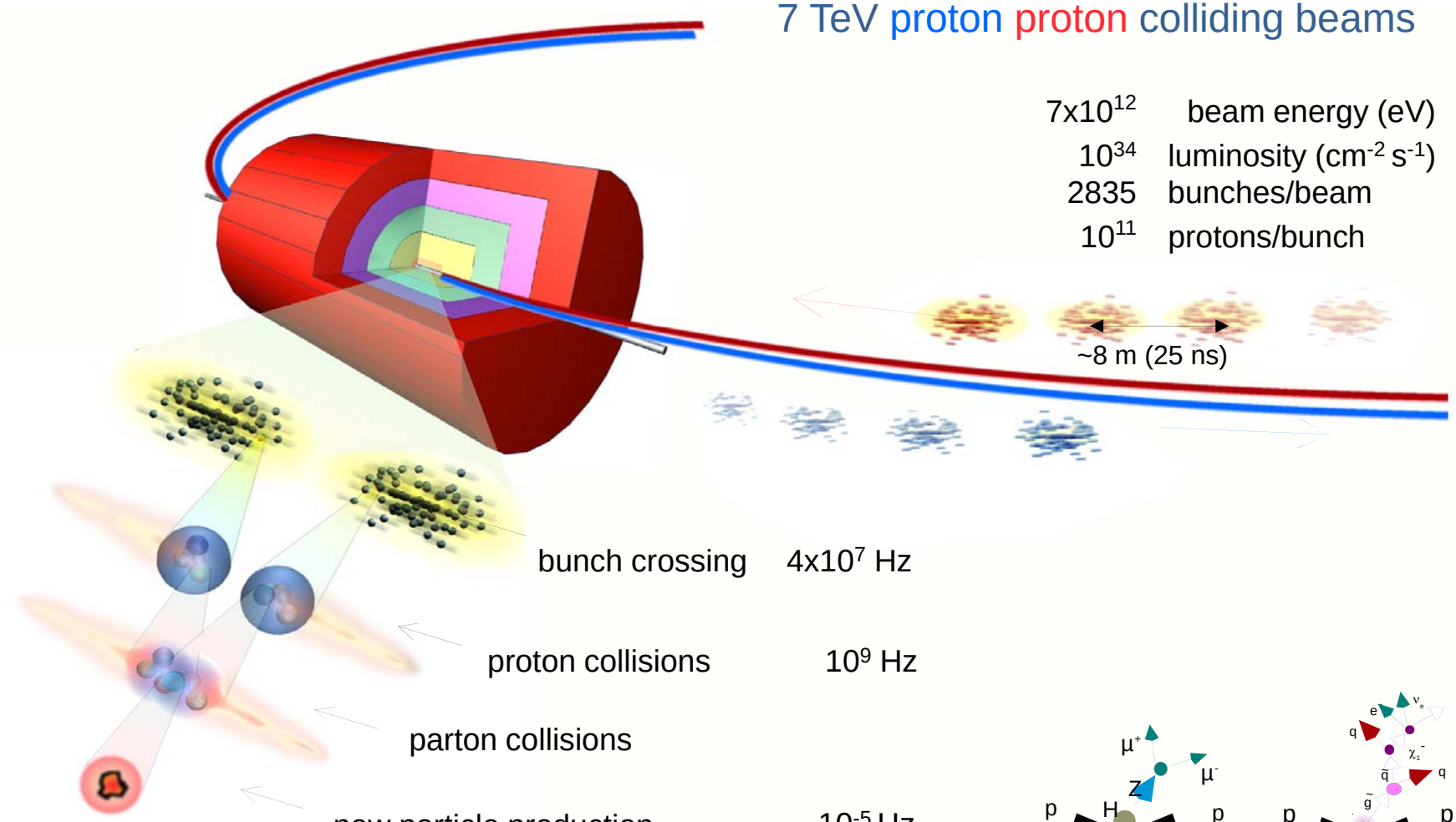
Other states 828

Albania 2	China 84	Iceland 3	Morocco 5	South Africa 11
Argentina 11	China (Taipei) 50	Iran 17	New Zealand 8	Thailand 1
Armenia 12	Colombia 9	Ireland 14	Pakistan 16	The F.Y.R.O.M 2
Australia 19	Croatia 16	Korea (Rep of) 74	Peru. 2	Tunisia 1
Azerbaijan. 1	Cuba 4	Lebanon 1	Qatar 1	Ukraine. 18
Belarus 20	Cyprus 8	Lithuania. 12	Romania 62	Uzbekistan 1
Brazil 79	Egypt 5	Malta 1	Saudi Arabia. 2	
Canada 150	Estonia 11	Mexico 32	Serbia. 22	
Chile. 3	Georgia. 8	Montenegro. 1	Slovenia 29	

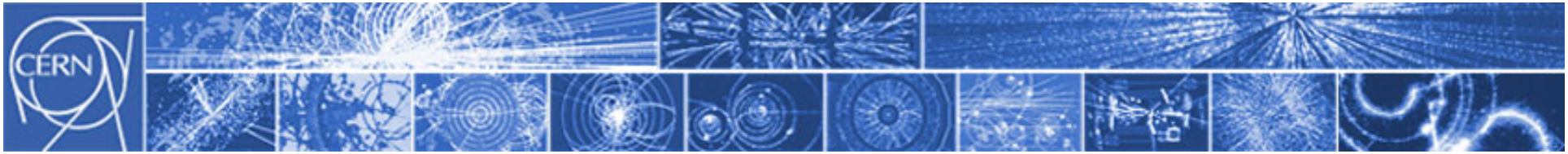
The Challenge: selection of 1 event in 10,000,000,000,000

7 TeV proton proton colliding beams

7×10^{12}	beam energy (eV)
10^{34}	luminosity ($cm^{-2}\ s^{-1}$)
2835	bunches/beam
10^{11}	protons/bunch



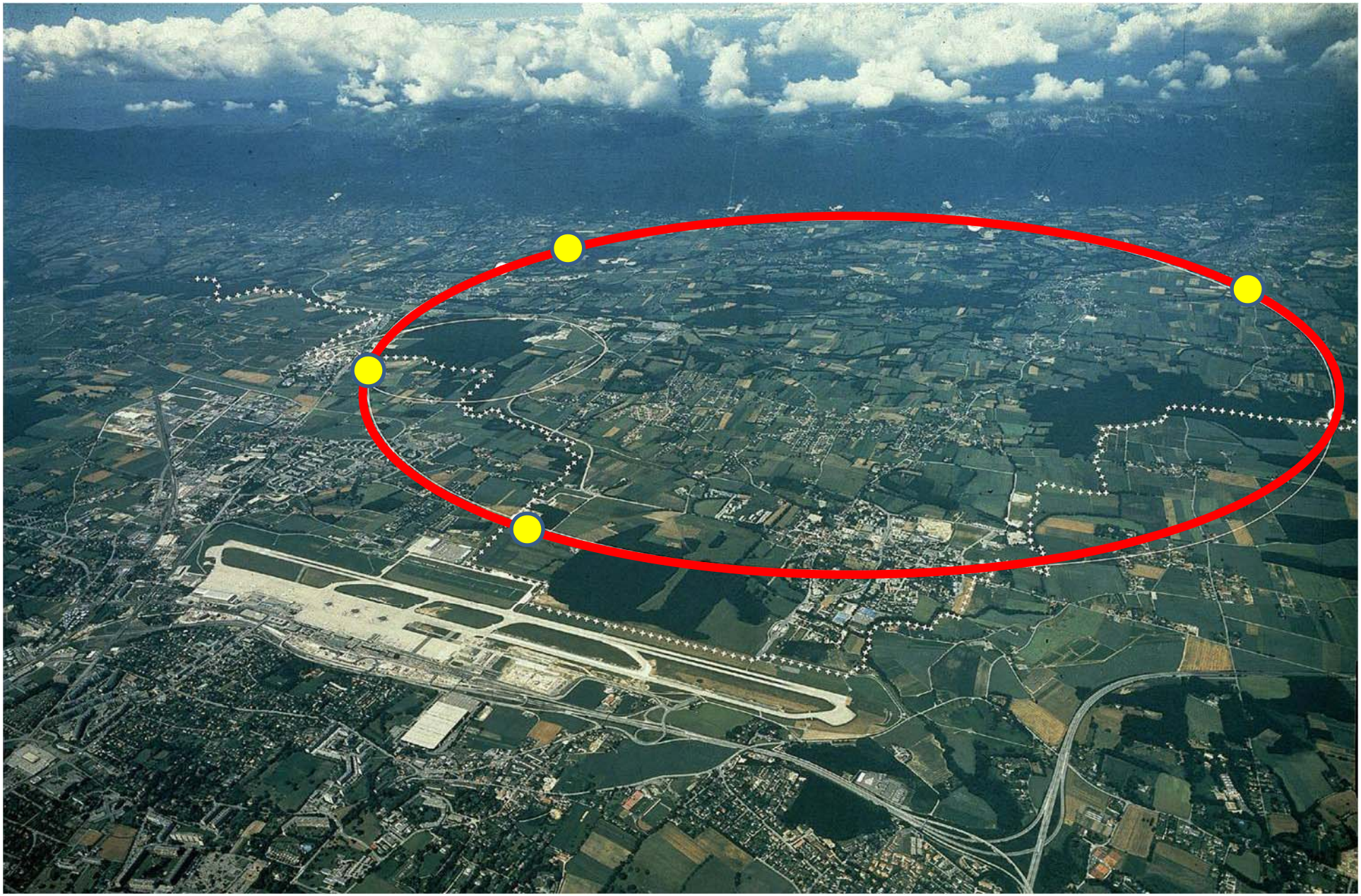
bunch crossing	4×10^7 Hz
proton collisions	10^9 Hz
parton collisions	
new particle production (Higgs, SUSY, ...)	10^{-5} Hz (1/day)



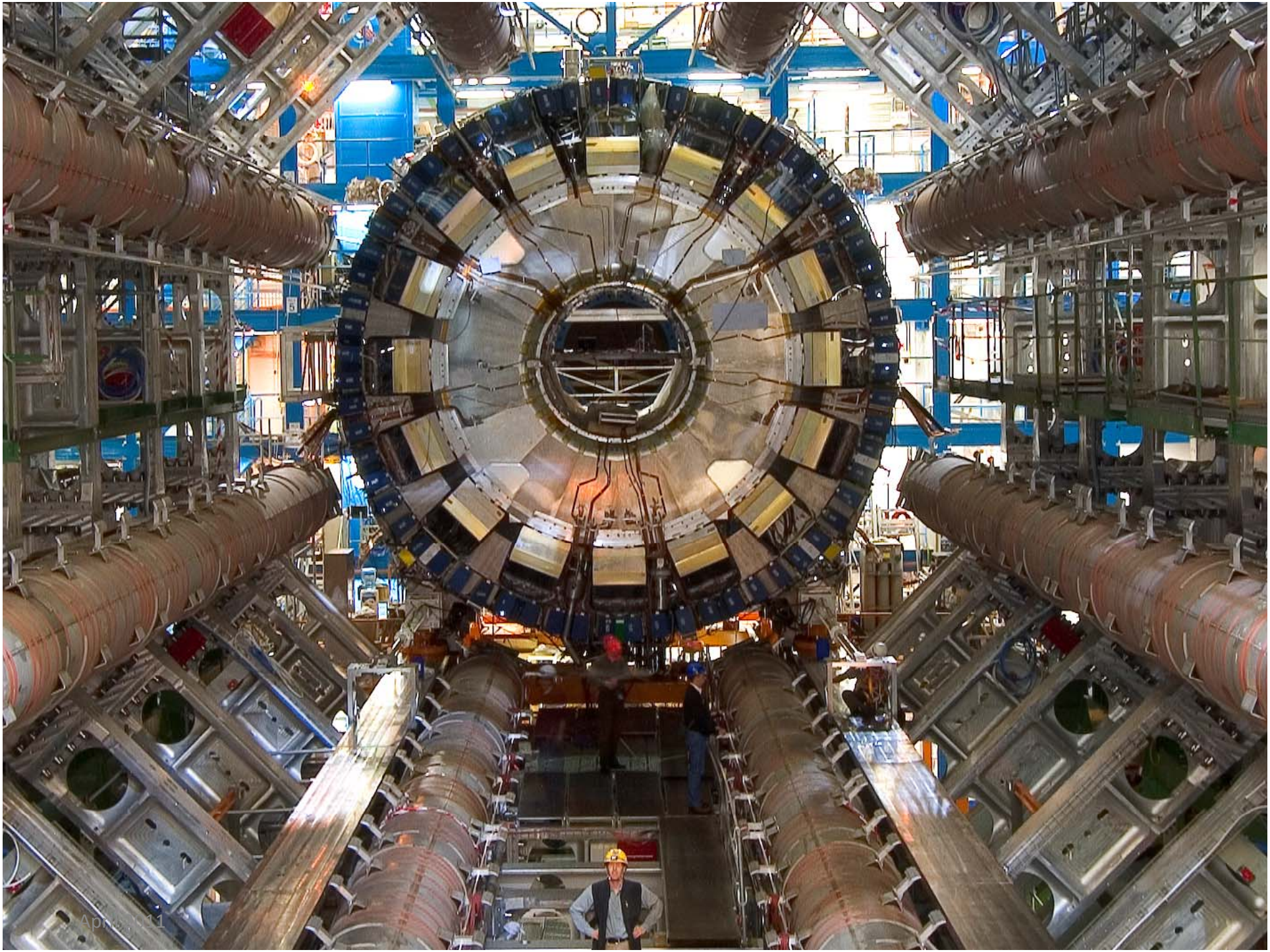
CERN's tools

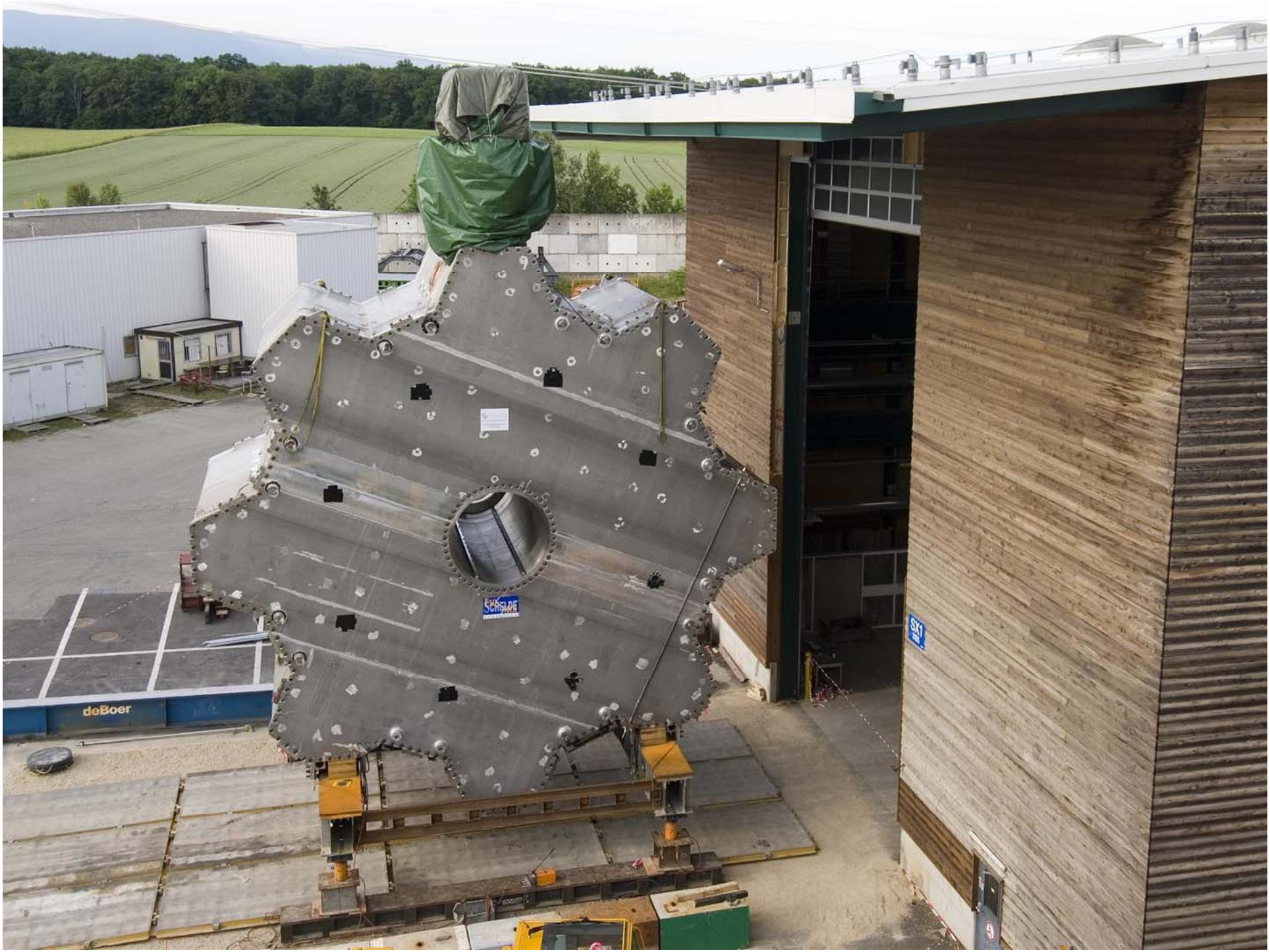
- The world's most powerful accelerator: LHC
  - A 27 km long tunnel filled with high-tech instruments
  - Equipped with thousands of superconducting magnets
  - Accelerates particles to energies never obtained before
  - Produces particle collisions creating microscopic "big bangs"
- Very large sophisticated detectors
  - Four experiments each the size of a cathedral
  - Hundred million measurement channels each
  - Data acquisition systems treating Petabytes per second
- Top level computing to distribute and analyse the data
  - A Computing Grid linking ~140 computer centres around the globe
  - Sufficient computing power, storage and networking to handle 15 Petabytes per year, making them available to thousands of physicists for analysis

The LHC between the airport and the Jura mountains



Inside the Large Hadron Collider

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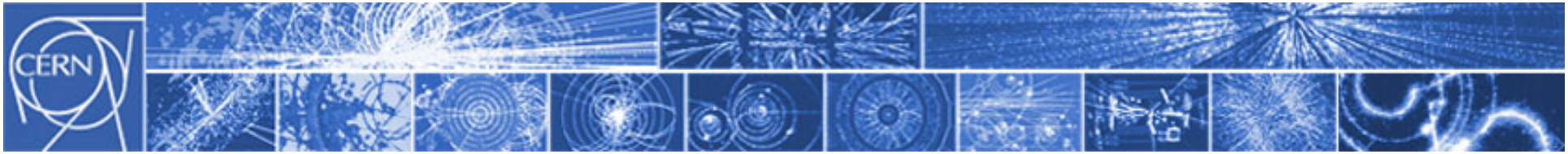
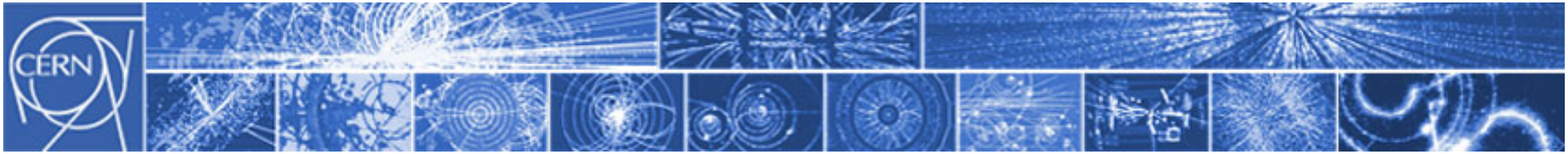


The Computing Challenge

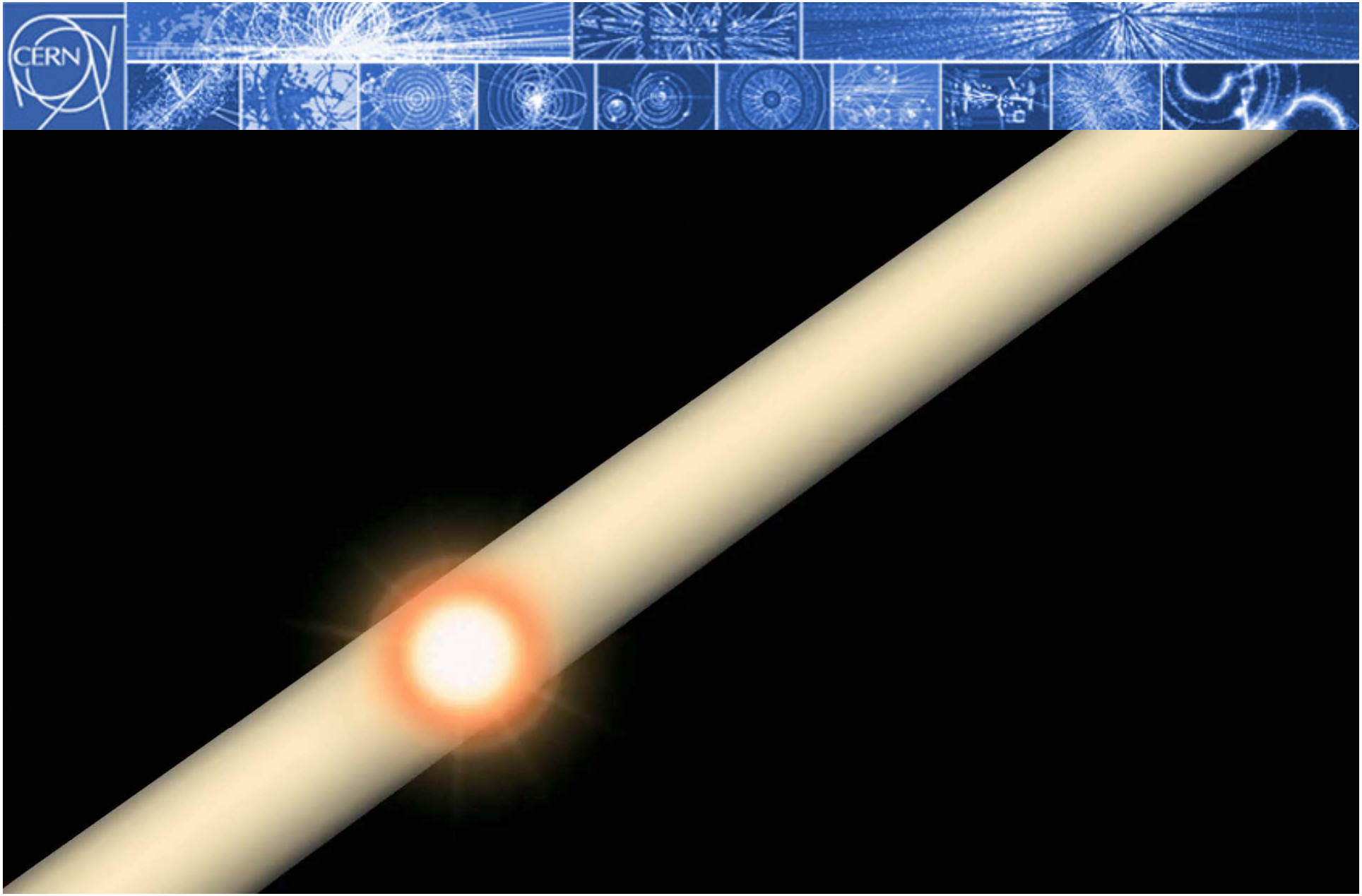
- Search for extremely rare events – a needle in huge hay stack
- Very high initial data rates – up to 1 Petabyte per second
- Massive data reduction directly at the detectors
- After filtering, still 1-2 GB/second leading to over 15 PB/year, to be stored, distributed and analyzed
- Users are distributed all over the Globe
- Many institutes/universities/teams contribute with compute power and disk storage, but all do their own way



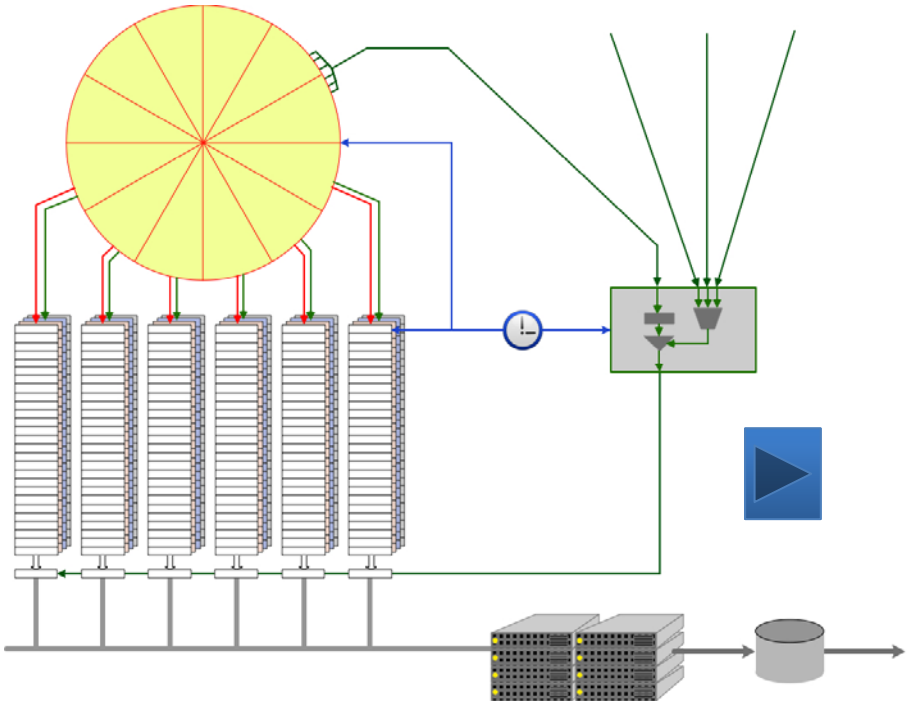
The Answer

- Nature was and is kind to us: trivial data parallelism allows us to use cheap commodity solutions, easily scalable!
- Introduced PCs to replace mainframes in the 90s
- We profited from Moore's law fully for many years
- Arrival of excellent networks allowed the creation of a global Grid infrastructure called the World-wide LHC Computing Grid (WLCG)
- Massive investment in software development from 2002-10
- World-wide Authentication & Authorization Infrastructure

- => It is up and running, serving science, but … a next step is needed

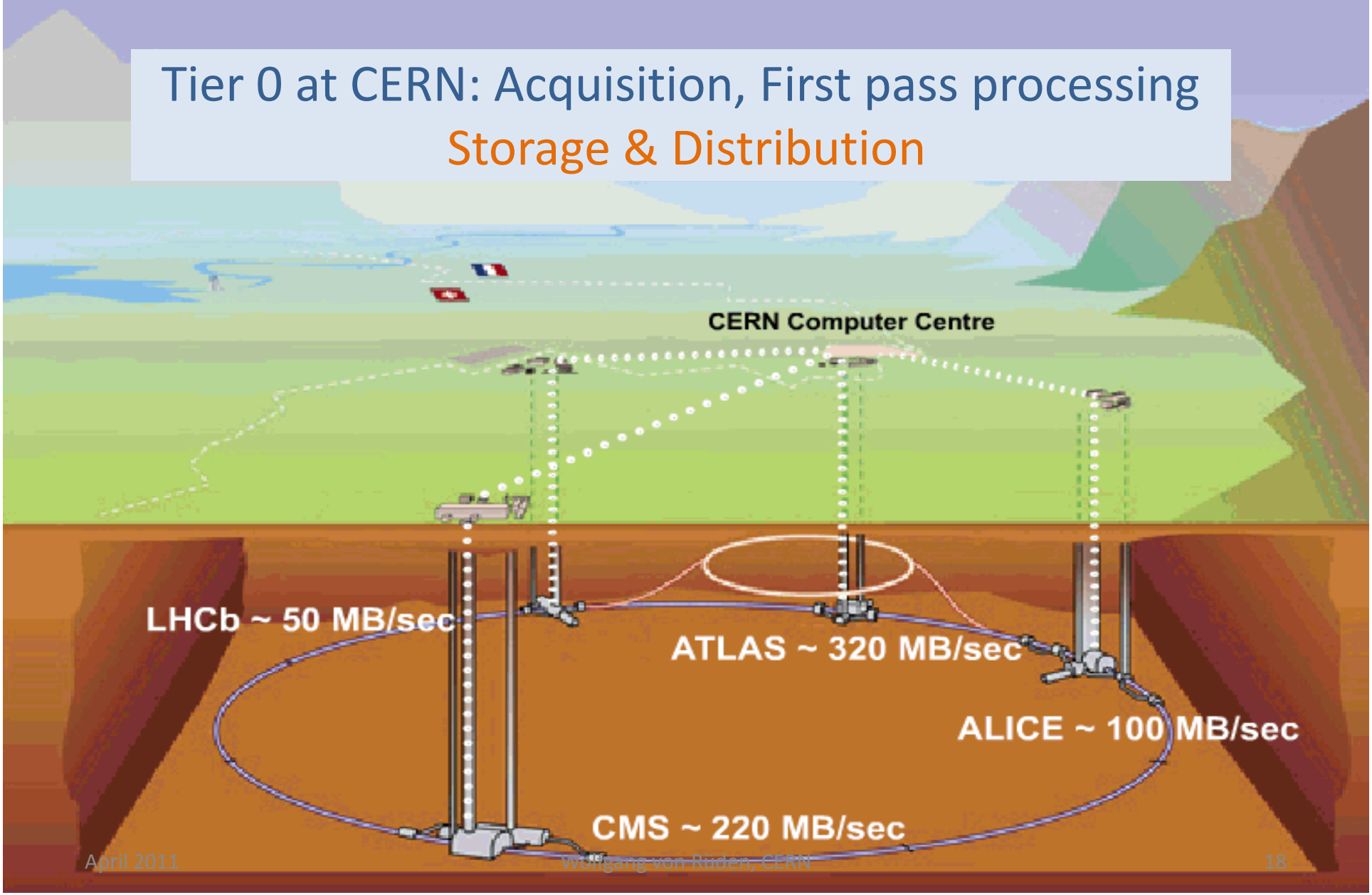


Massive on-line data reduction

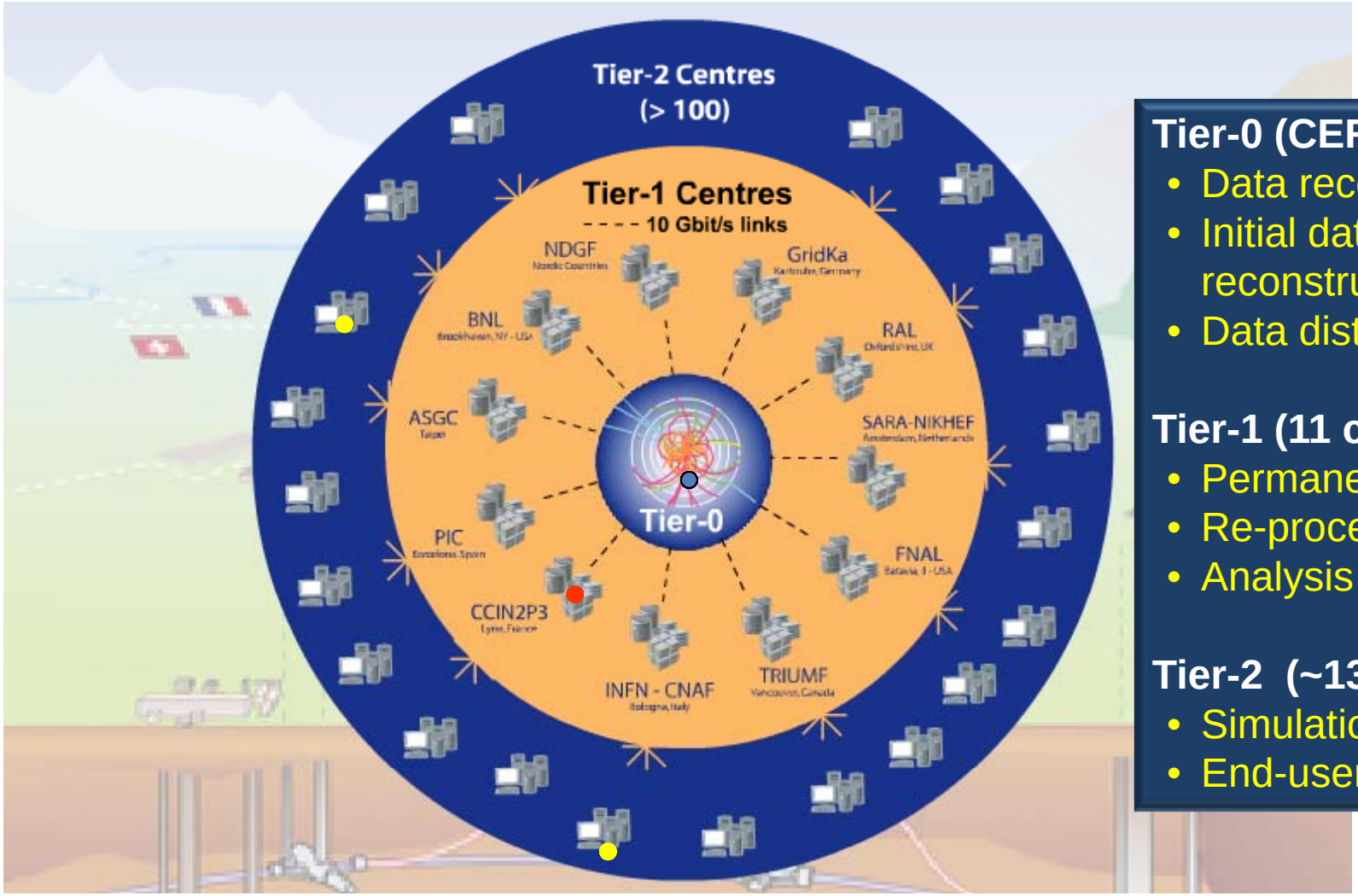


- Collision every 25 ns
- It takes 3 µs to make a selection, i.e. 40 new events arrive during this time
- Solution:
  - pipelined data
  - pipelined selection
- Dead-time-free operation

Tier 0 at CERN: Acquisition, First pass processing
Storage & Distribution



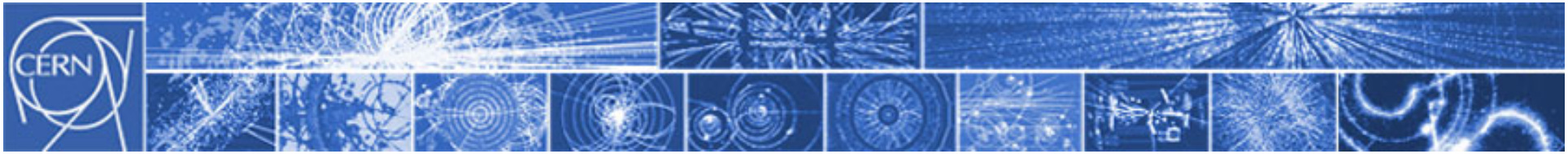
Tier 0 – Tier 1 – Tier 2



Tier-0 (CERN):
- Data recording
- Initial data reconstruction
- Data distribution

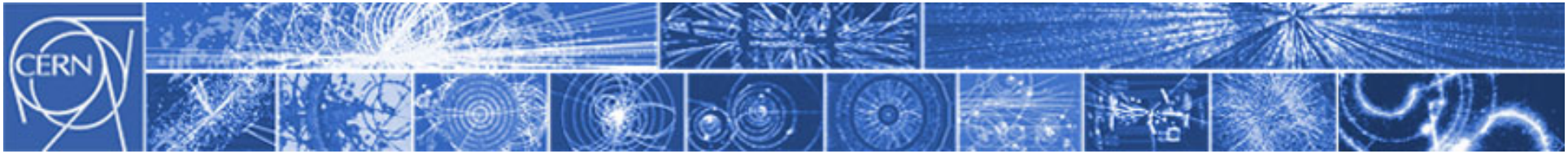
Tier-1 (11 centres):
- Permanent storage
- Re-processing
- Analysis

Tier-2 (~130 centres):
- Simulation
- End-user analysis



Computing technology used for physics

- High Throughput Computing, no High Performance Computing
- PC based commodity servers only, running Scientific Linux
- NAS disk storage & tape mass storage
- 10 Gb/s based backbone, aggregate data rate ~1 TB/s
- In-house developed computer centre management suite
- Community developed Grid software
- End-user developed physics applications and high-level data management
- Extensive use of databases to run accelerator & experiments
- Distributed operation

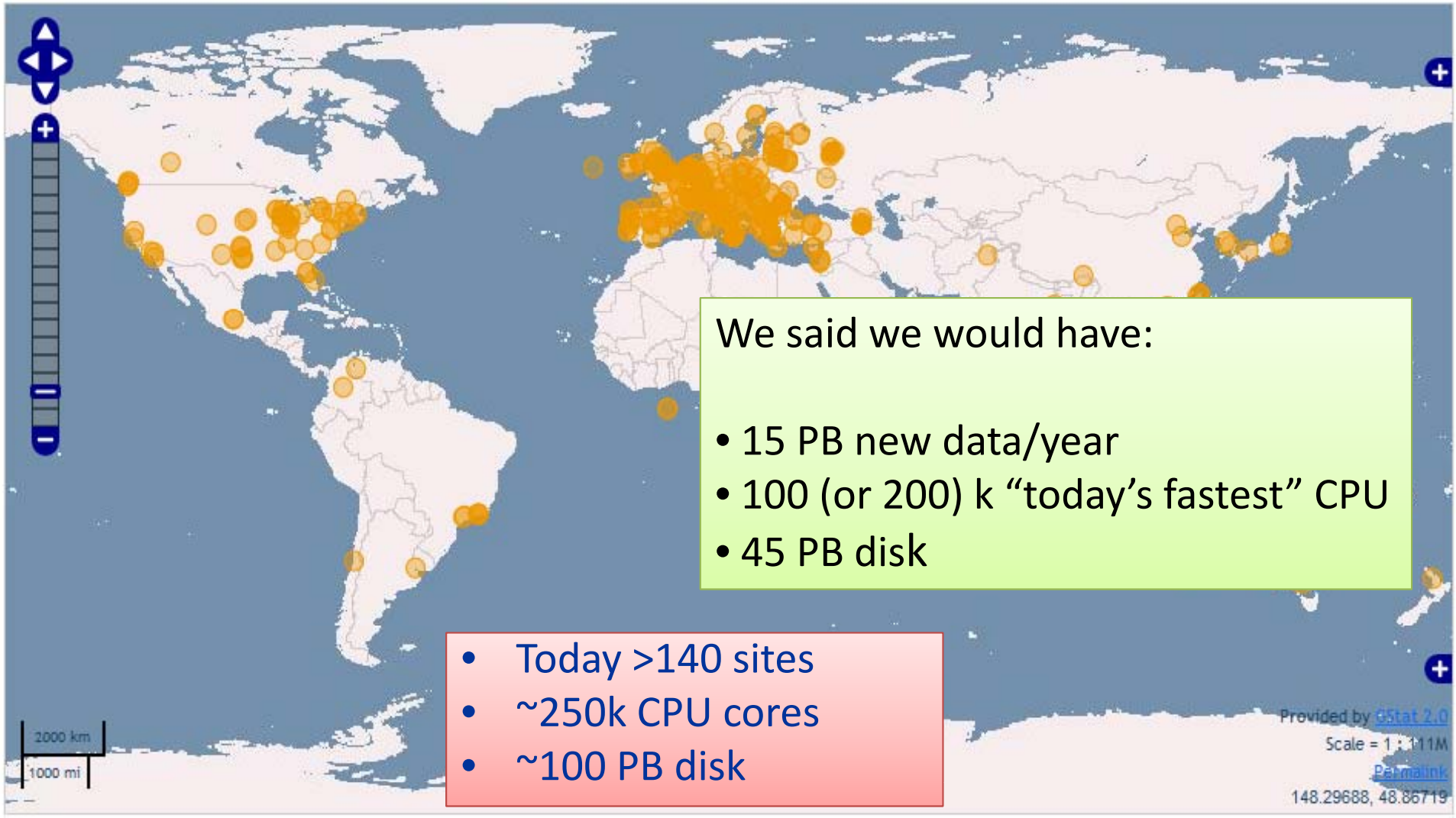


Capacity of CERN's data centre (Tier0)

- Compute Nodes:
  - 8'000 systems
  - 65'000 CPUs (cores)
- Disk storage:
  - 63 Petabyte
  - 63'000 disk drives
- Tape storage:
  - capacity: 45 Petabyte
  - in use: 37 Petabyte (added 17 PB in 2010)
  - slots: 66'000 slots in tape libraries (plus 10'000 for backups)
  - 70 drives T10'000B
  - growth: 25-30 PB/year

- Corresponds to ~15% of the total capacity in WLCG

Worldwide resources



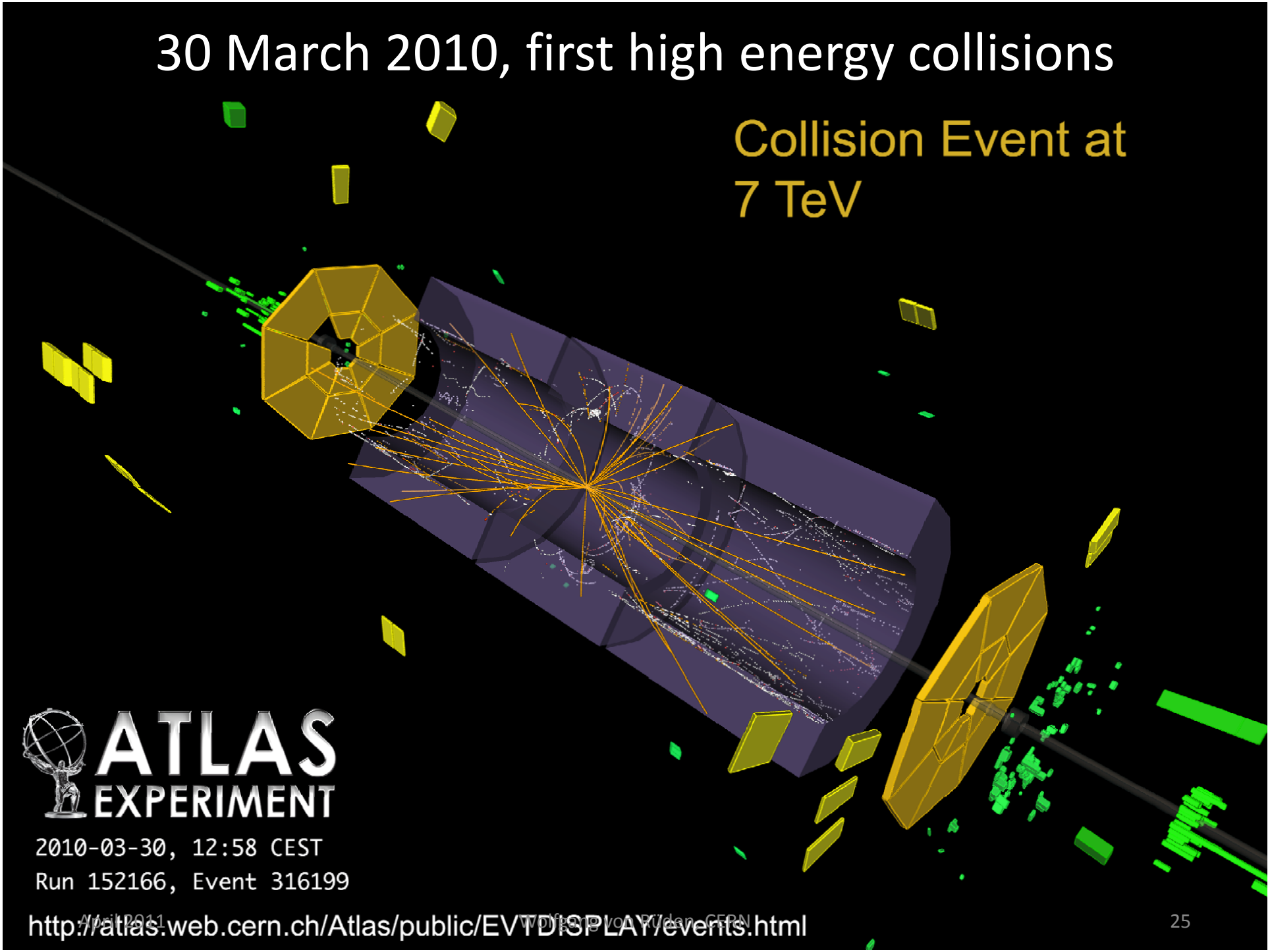
Example ATLAS experiment:

~2900 physicists, 174 universities, 34 countries

After more than 20 years of planning, development and implementation…,

... the big moment

30 March 2010, first high energy collisions

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Transfer rate: 7.44 GiB/sec
Thank you!
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CMS
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