concept

DECISION MAKERS, DOERS AND ADVISORS
– JOINING FORCES TO ENHANCE UTILITY OF INVESTMENTS

Concept Symposium 2010
Oscarsborg, Norway
16 – 17 September 2010

Symposium web-site: http://www.conceptsymposium.no/
Concept Research Programme: http://www.concept.ntnu.no/english/

Complexity in High Energy Physics Projects today: the LHC accelerator at CERN, Geneva

Jurgen De Jonghe

Pierre Bonnal

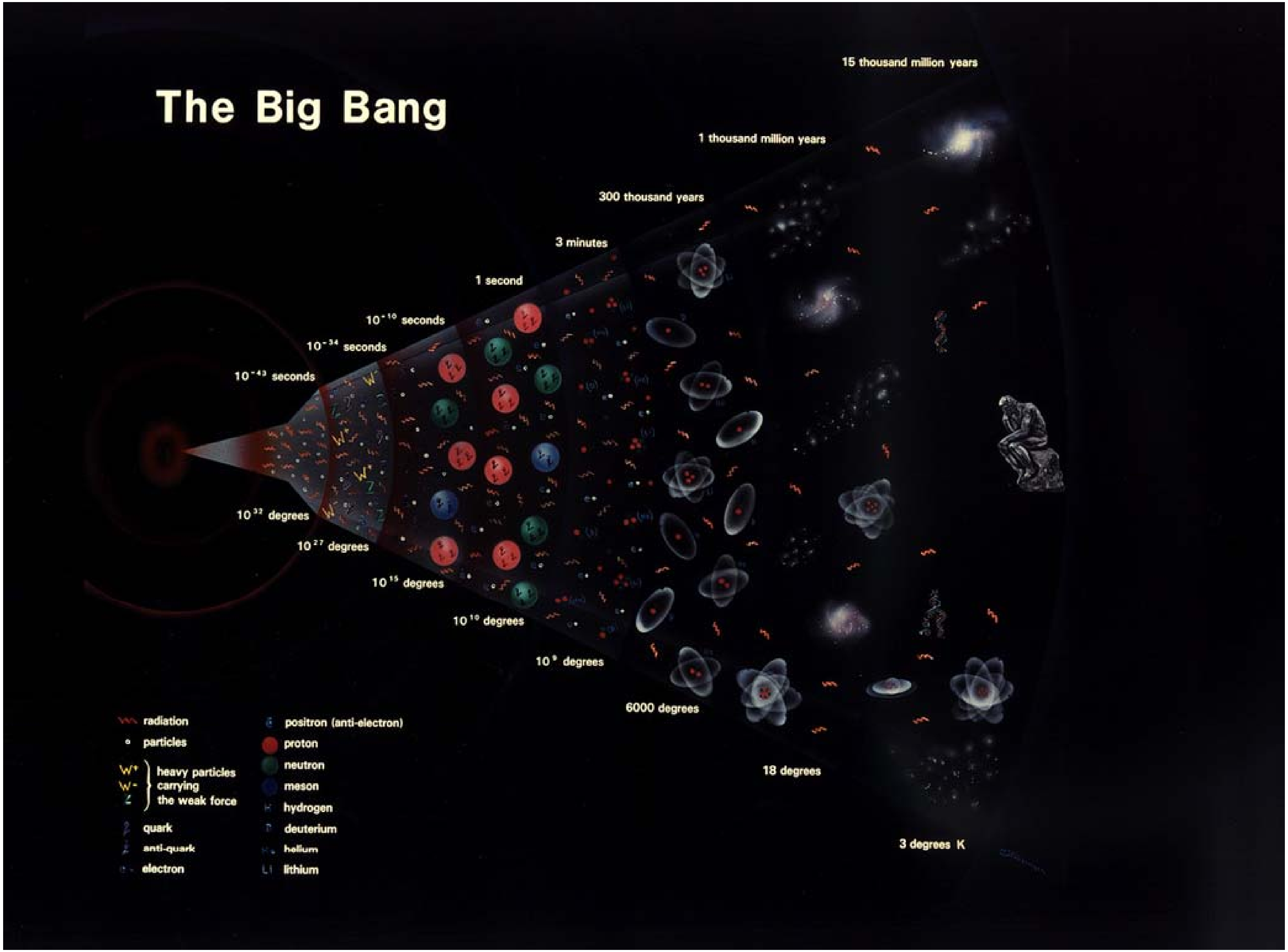
CERN, European Laboratory for Particle Physics, Geneva, Switzerland

45 minutes aiming at

- Introduction to the challenges of particle physics and CERN’s Large Hadron Collider

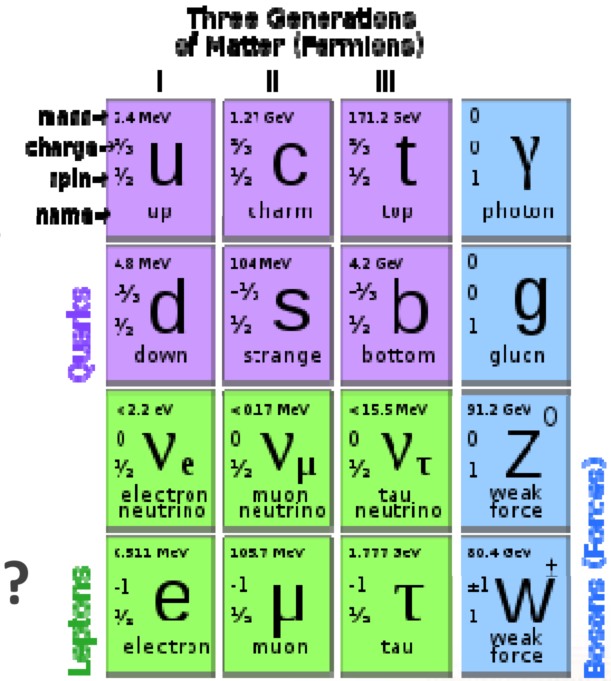
- Areas of Complexity and Constraints
  - Financial / Procurement
  - Organizational
  - Technology / Engineering
  - Aspects of PM methodology
    - o tailor-made EVM system and its specificities
    - o Linear/repetitive scheduling techniques

- LHC Detectors

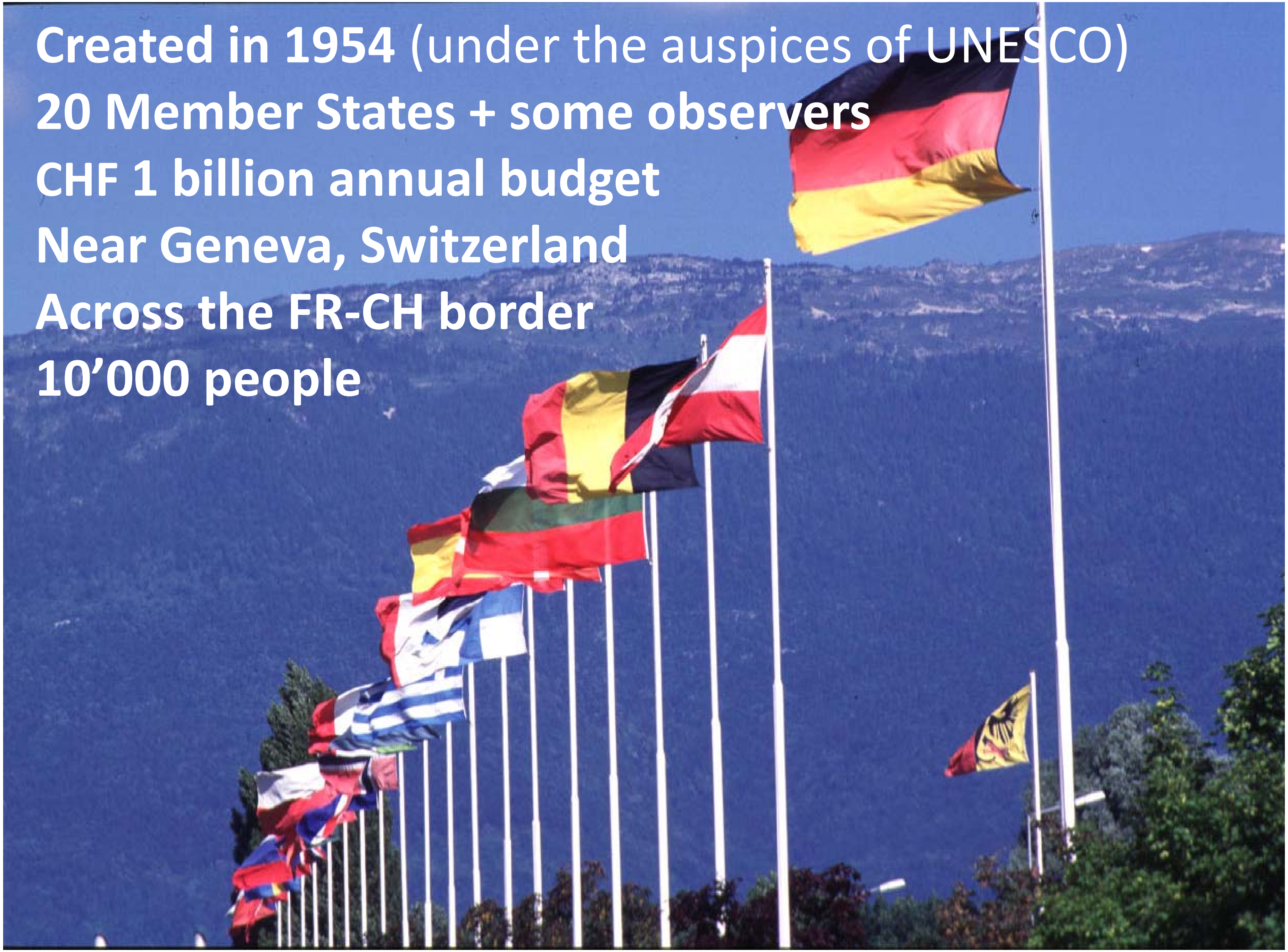

The Big Bang
10^{-43} seconds
10^{-34} seconds
10^{-10} seconds
1 second
3 minutes
300 thousand years
1 thousand million years
15 thousand million years
10^{32} degrees
10^{27} degrees
10^{15} degrees
10^{10} degrees
10^{9} degrees
6000 degrees
18 degrees
3 degrees K
radiation
particles
W^+
W^-
Z
heavy particles carrying the weak force
quark
anti-quark
electron
positron (anti-electron)
proton
neutron
meson
hydrogen
deuterium
helium
lithium

Why the LHC?

Since decades, physicists describe fundamental particles and their interactions via the ***Standard Model****. But some questions remain…*



- **What is mass?**
  → Higgs boson
- **Matter is only 4% …dark matter & energy?**
  → Supersymmetric particles
- **Matter –Antimatter imbalance?**
  → Symmetry breaking
- **Conditions in first second of Universe's life?**
  → Quark-Gluon plasma
- **Do extra dimensions of space really exist?**
  → String theory particles



Created in 1954 (under the auspices of UNESCO)

20 Member States + some observers

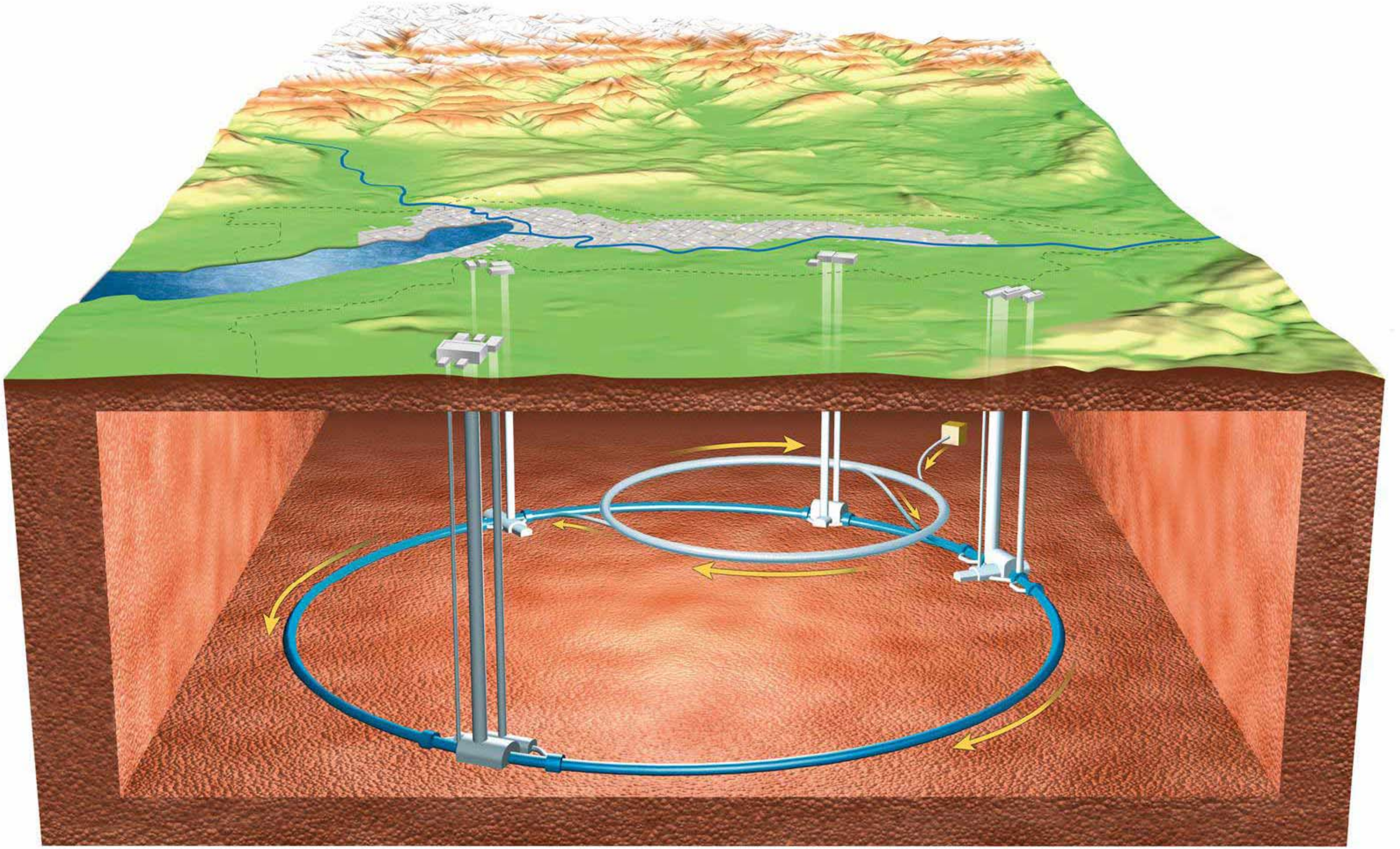
CHF 1 billion annual budget

Near Geneva, Switzerland

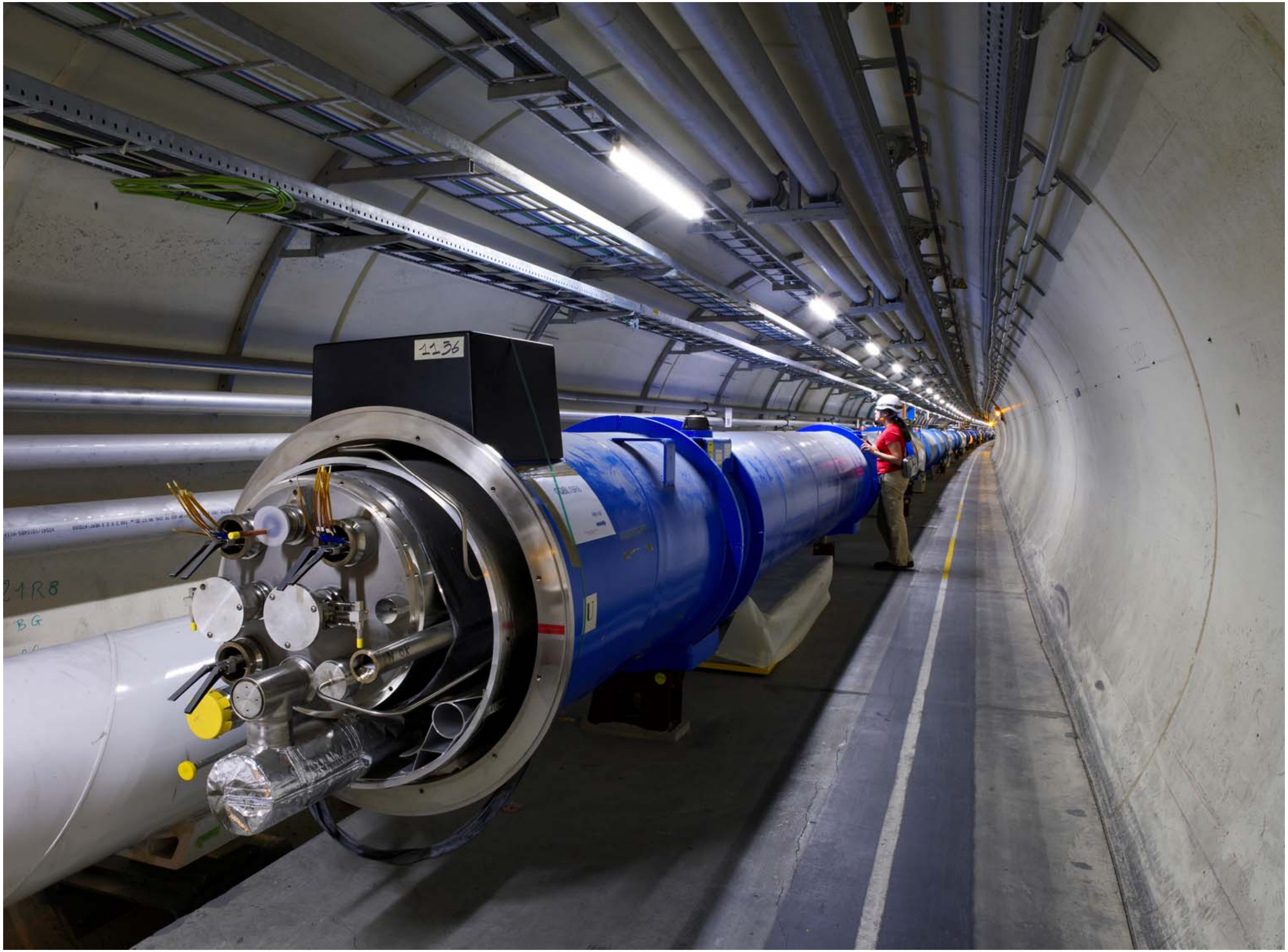
Across the FR-CH border

10’000 people

LHC Accelerator and experiments



LHC: a 27km particle collider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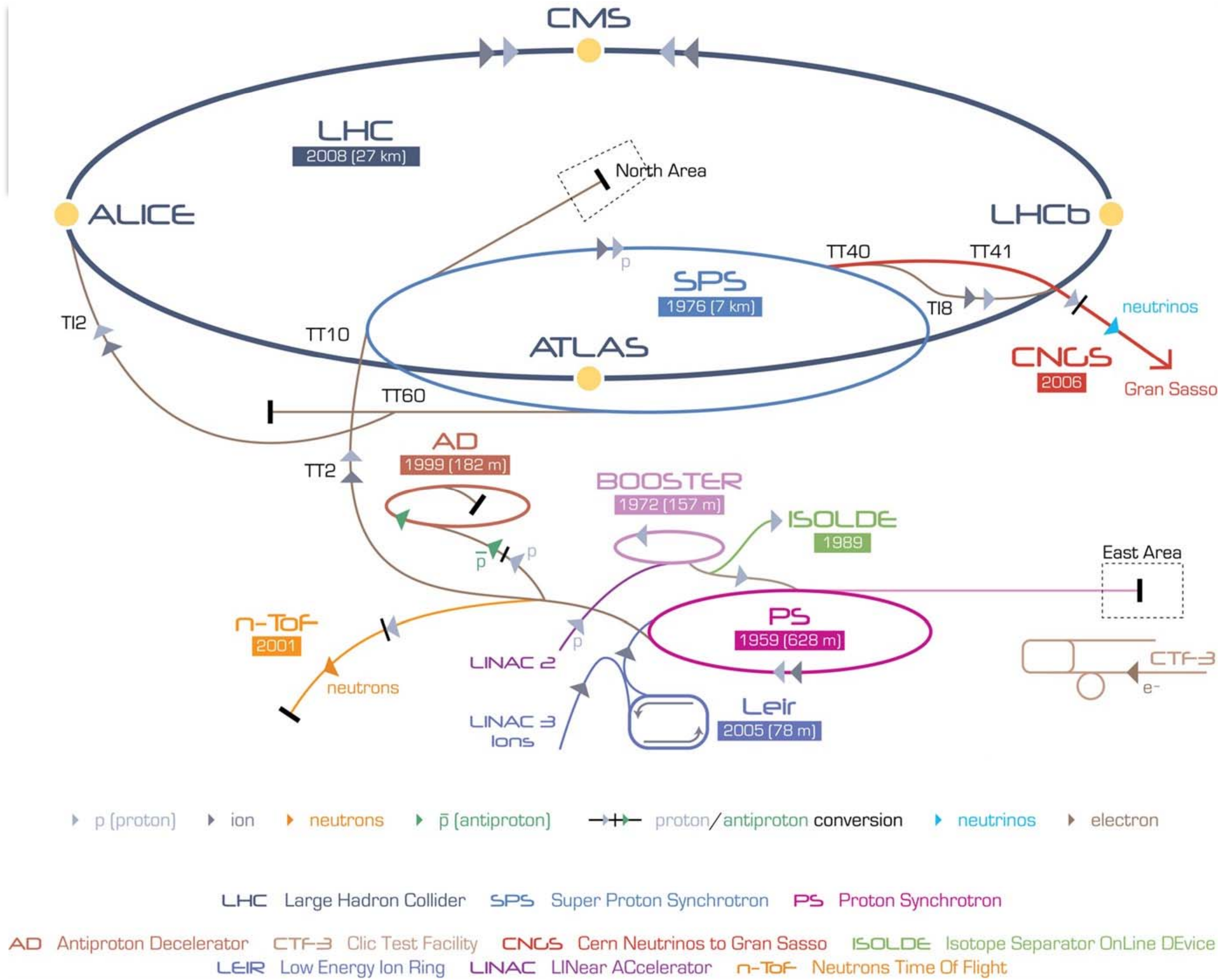
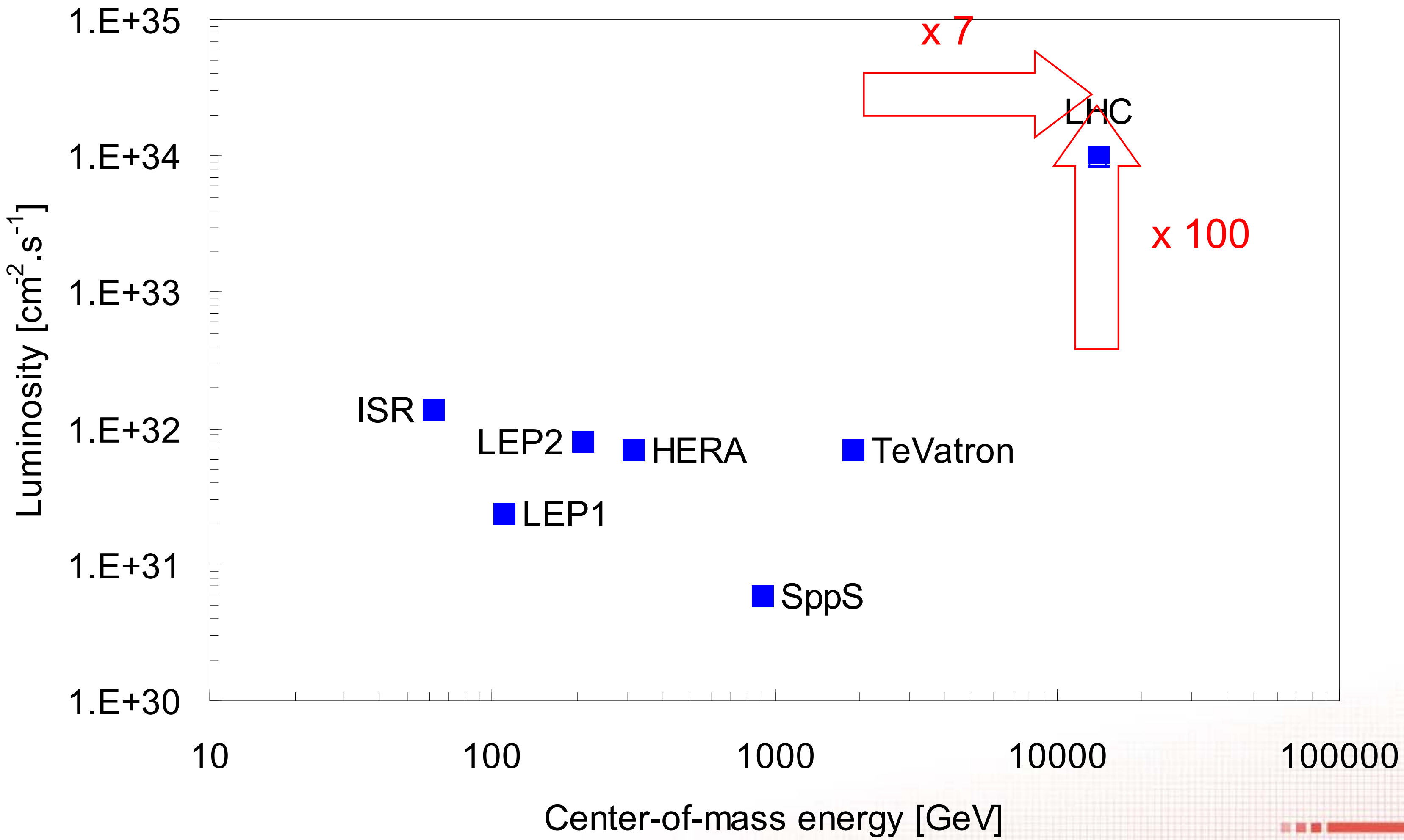
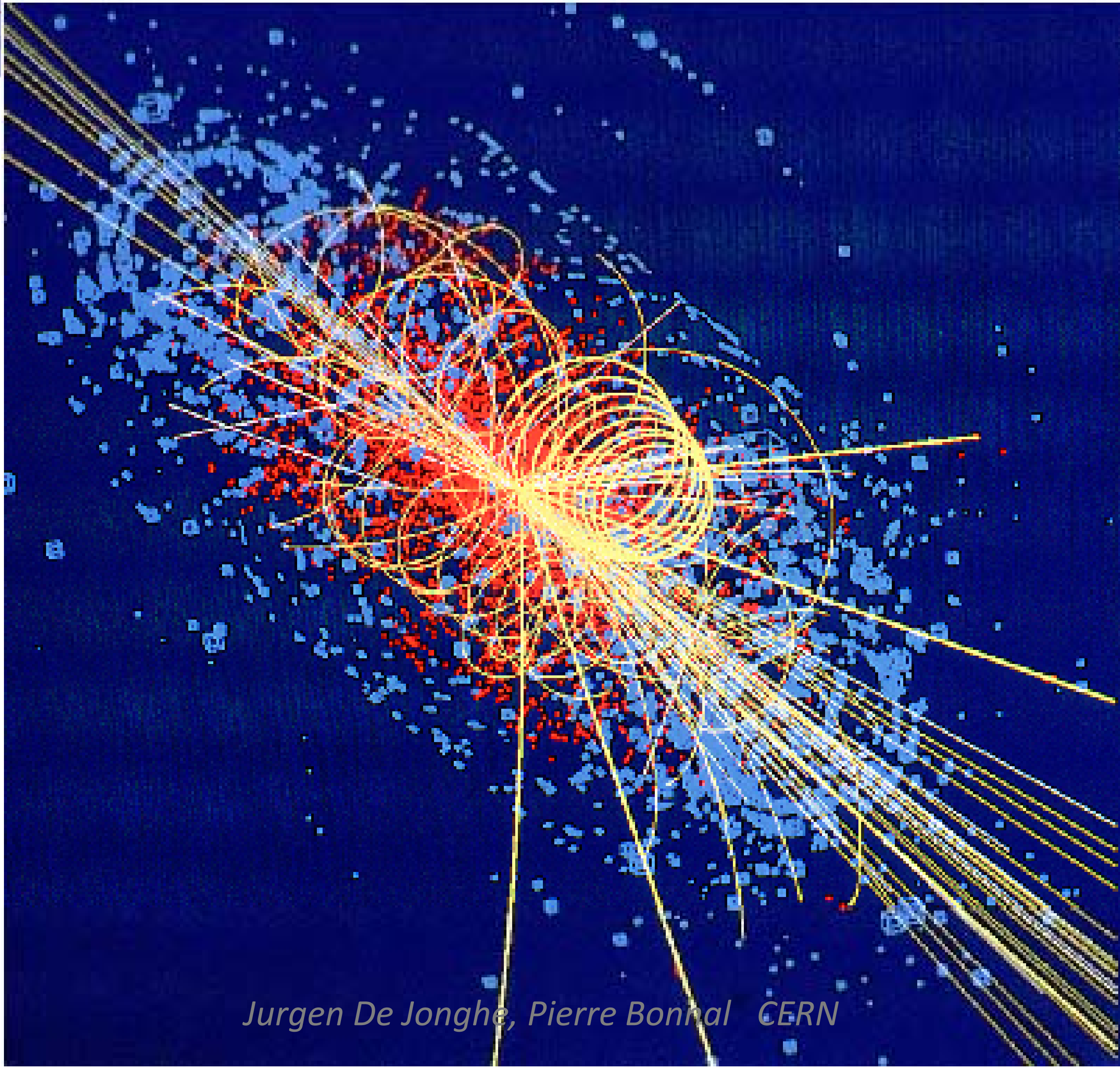


CMS
LHC
2008 (27 km)
North Area
ALICE
LHCb
TT40
TT41
p
SPS
1976 (7 km)
TI8
neutrinos
TI2
TT10
ATLAS
CNGS
2006
Gran Sasso
TT60
AD
1999 (182 m)
TT2
BOOSTER
1972 (157 m)
ISOLDE
1989
p̄
p
East Area
n-ToF
2001
PS
1959 (628 m)
LINAC 2
p
CTF3
e-
neutrons
LINAC 3
Ions
LEIR
2005 (78 m)
p (proton)
ion
neutrons
p̄ (antiproton)
proton/antiproton conversion
neutrinos
electron
LHC Large Hadron Collider
SPS Super Proton Synchrotron
PS Proton Synchrotron
AD Antiproton Decelerator
CTF3 Clic Test Facility
CNGS Cern Neutrinos to Gran Sasso
ISOLDE Isotope Separator OnLine DEvice
LEIR Low Energy Ion Ring
LINAC LINear ACcelerator
n-ToF Neutrons Time Of Flight

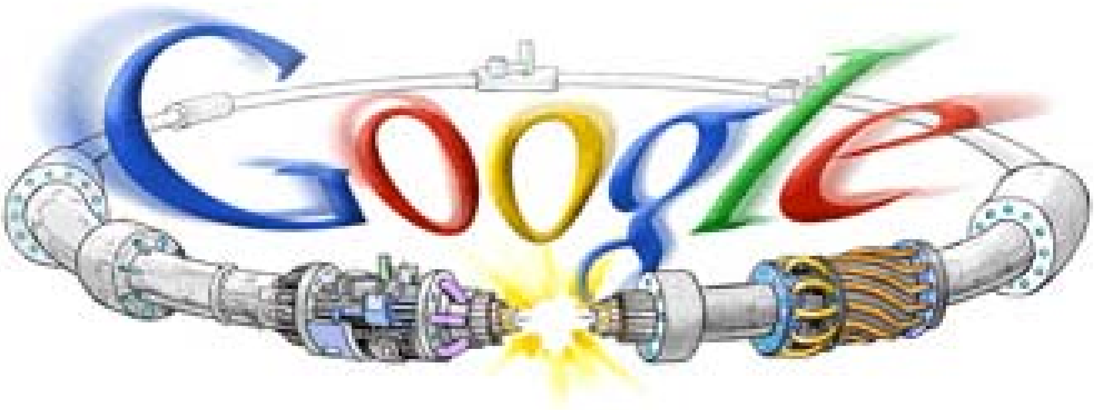
LHC compared to existing accelerators



Our Objective…



Sept. 10th, 2008



I guess you understand why…

Google Search | I'm Feeling Lucky

Birth of the LHC

- The LHC Adventure started 25 years ago.
- After 10 years of preparation, CERN Council approved the project on 16th December 1994. However, without increasing the CERN budget
  - ➢ <u>two stage</u> LHC
- External financial contributions:
  - Japan: 1995 + 1996 + 1998
  - India + Russia + Canada: 1996
  - US: 1997
- Simultaneously Germany (to ease burden of reunification) reduces subscription (by almost 9%). Other member states immediately joined (Maastricht). CERN takes out loans.
- Council approves the construction of the machine in a <u>single stage</u> in December 1996, basically with all contingency removed....

Financial/Procurement

- Reduced budget, financed over long duration (gov't changes, budget cycles)
- Take national interest into account and ensure fair industrial return to Member States
- Procurement constraints:
  - Deal with risks of lowest-bidder economics
  - Balance innovation/creativity with quality control
  - If "unfeasable" ⇨ prototype at CERN and industrialize
  - Tight budget/schedule versus long lead times of essential components and tooling, business failure
  - Material: more than 3 GCHF*95* (3.75GCHF);
  - Over 6000 different suppliers and contractors

Organizational

- Size & Duration of construction project
  - 20-year life span (including pre-project activities):
    - o Work-force changes: physicists, engineers and technicians retire
    - o Flair & knowledge is lost (even with the best effort of documentation)
  - Some 500 staff × 12 years (1995–2007)

- Interface with Experiment Collaborations:
  - o CERN is Host laboratory: provides infrastructure and services to run detectors
  - o Experiments: loose management structure
  - o ATLAS: 2500 scientists/engineers from 180 institutes in 35 countries

- Human aspect: bringing world experts together: “herding cats” (german cats, italian cats...)

Design: use existing infrastructure

- Existing tunnel
  - Max energy ~ bending radius x maximum field strength
  - Small for two independent rings (3.8m)
  - Parts of the tunnel under Jura mountains (large static water pressure)
- Re-use existing injector chain
- Detector caverns: largest ever excavated in such ground conditions
- Straddling the Swiss-French border

Technology/Engineering

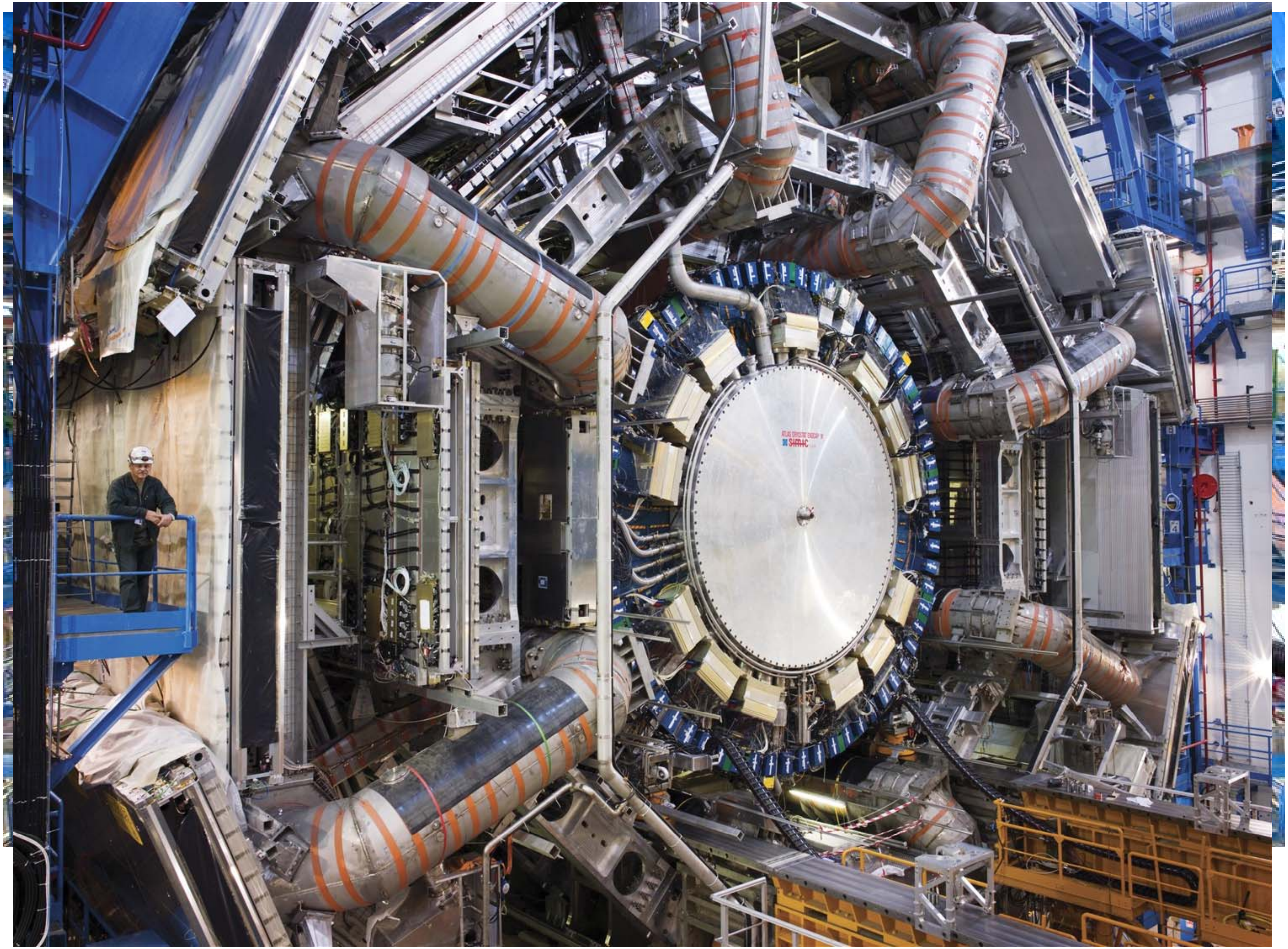
- Significant technologies, production methods and instruments did not yet exist at the start of the project
  - Superconducting magnets (+ Alignment)
  - Cryogenics
  - Vacuum, RF, Collimation, Instrumentation, Transfer Lines, Power Convertors
  - IT…
  - Civil Engineering…

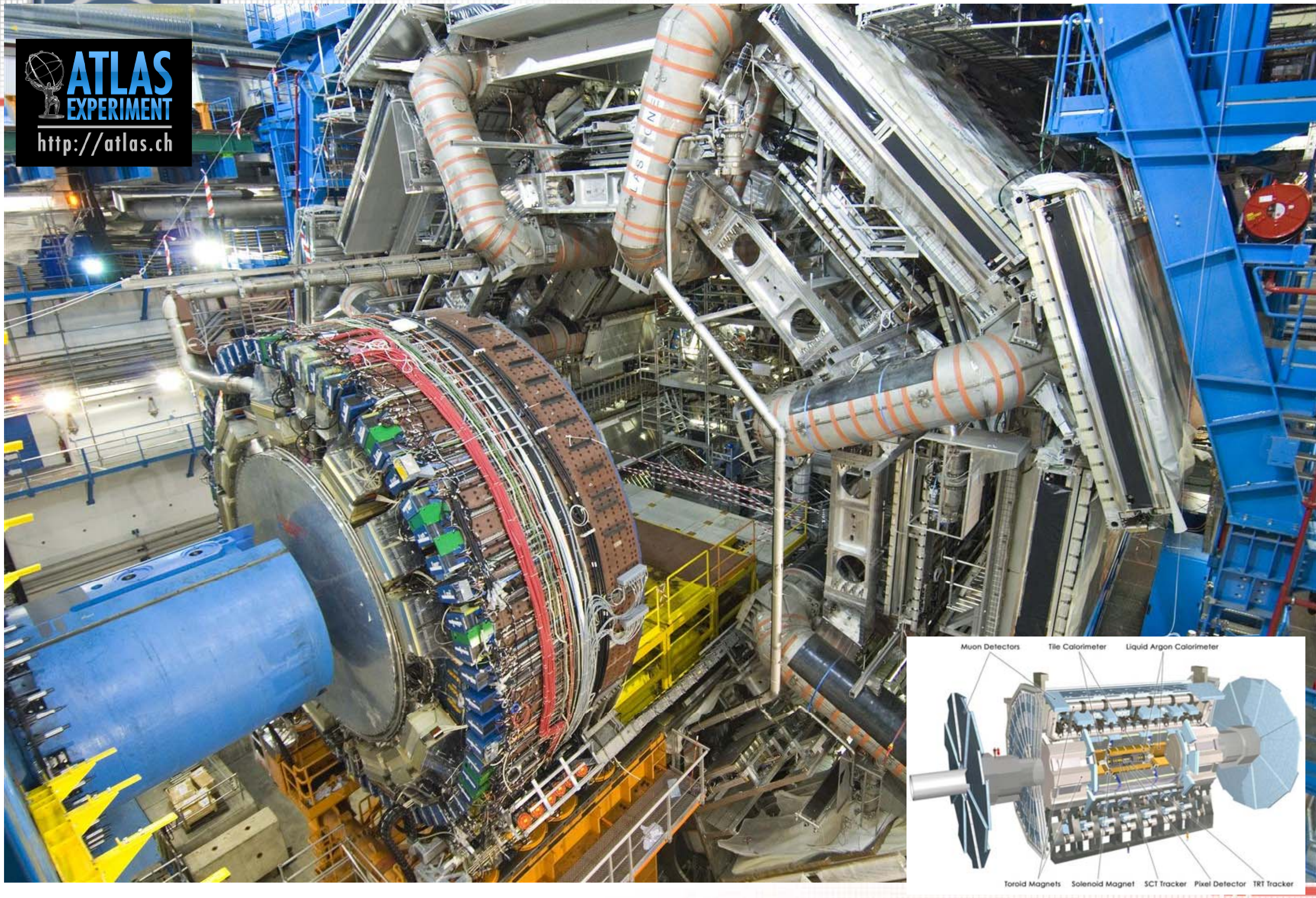
15 Pbytes

a pile of DVD's that is 30% higher than Mount Everest!

3.75 million DVDs / year

Point 1 - UX15 cavern - Concreting of vault panel n°2 - April 10, 2001 - CERN ST-CE

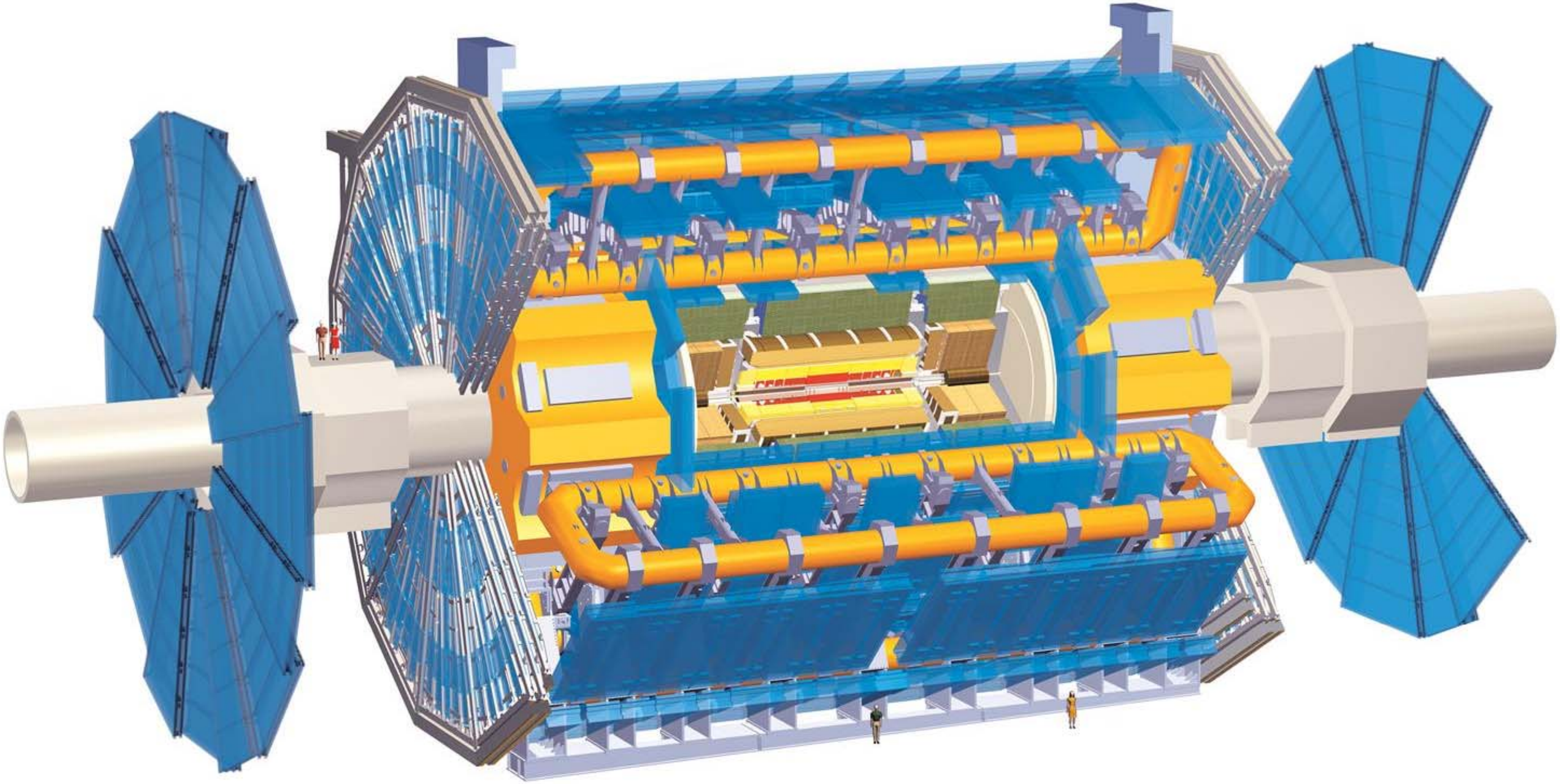



ATLAS
EXPERIMENT
http://atlas.ch
Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

April, 2007

Technology/Engineering (Detectors)

- 1 billion pairs of protons interacting per second
  - 100’s of billions of particles produced every second
  - equipment challenge, radiation hardness



CERN's EVMS | *Project audit of 2001*

- 18% overspend announcement … only

- Technical Coordinator → "the project is behind schedule"
- Project Administrator → "the project is under-running"
- Ad hoc link between cost control and scheduling system

- The LHC Project Management Team was not in position to demonstrate that the project could be completed within allocated budget.

- Member States asked CERN Management and the LHC Project Management to set up a formal Project Control System

CERN's EVMS | *Main characteristics*

- an **EVM**-based project control system (ANSI standard 748)
- **deliverable-oriented**
- interfaced to CERN's corporate systems (accounting, contract management, human resource)
- manages in-kind contributions
- **collaborative**
  - lean project management team
  - upfront prediction and *ad hoc* alerting
  - **transparency** is promoted: discover overlapping or incomplete areas
  - web based…

Outcome of EVM experience…

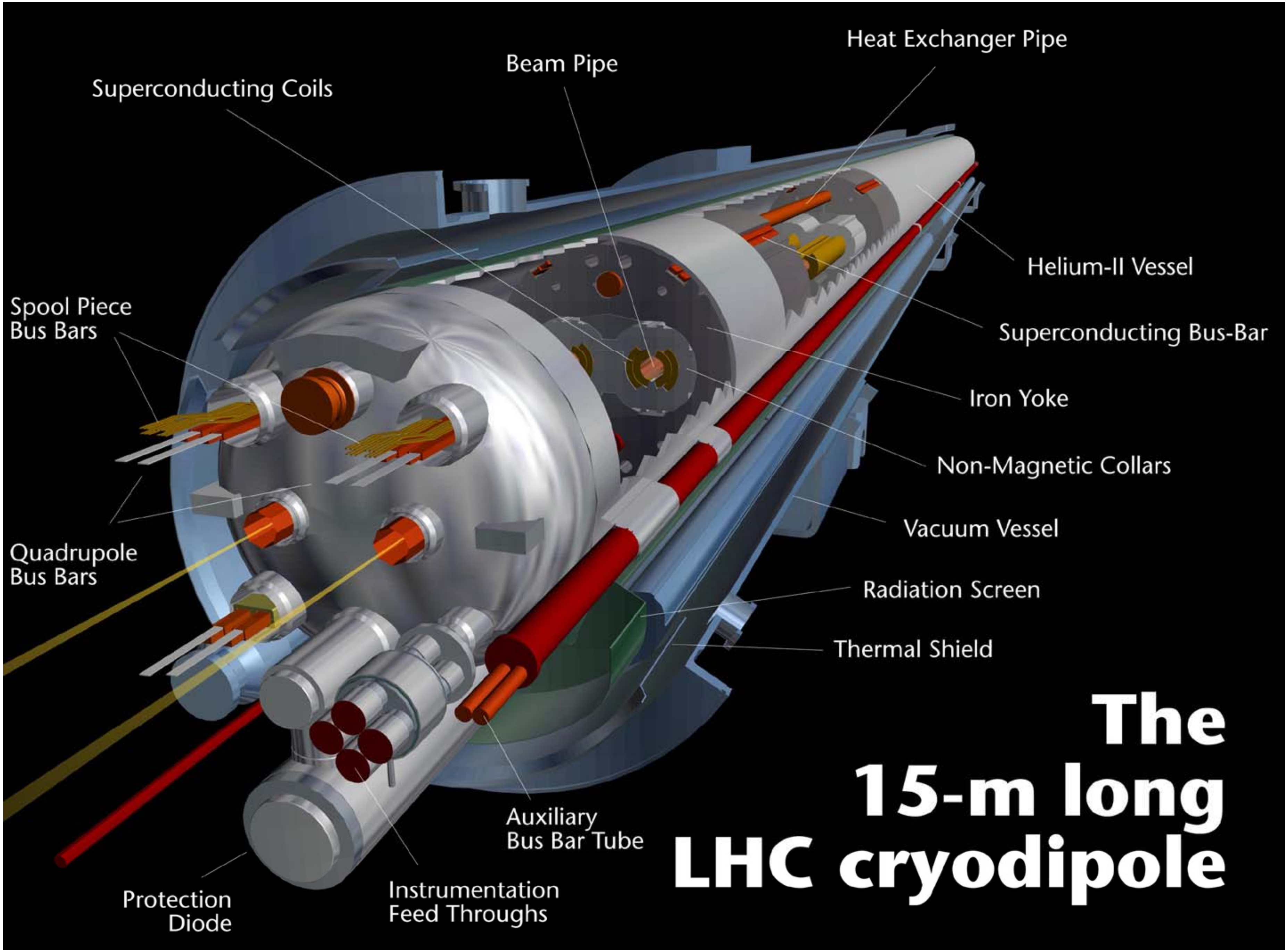
Introduction of EVM half-way through the project:

- ***Re-established trust with Member States***
  - ✓ *Further overruns were discussed in the context of proven project control.*

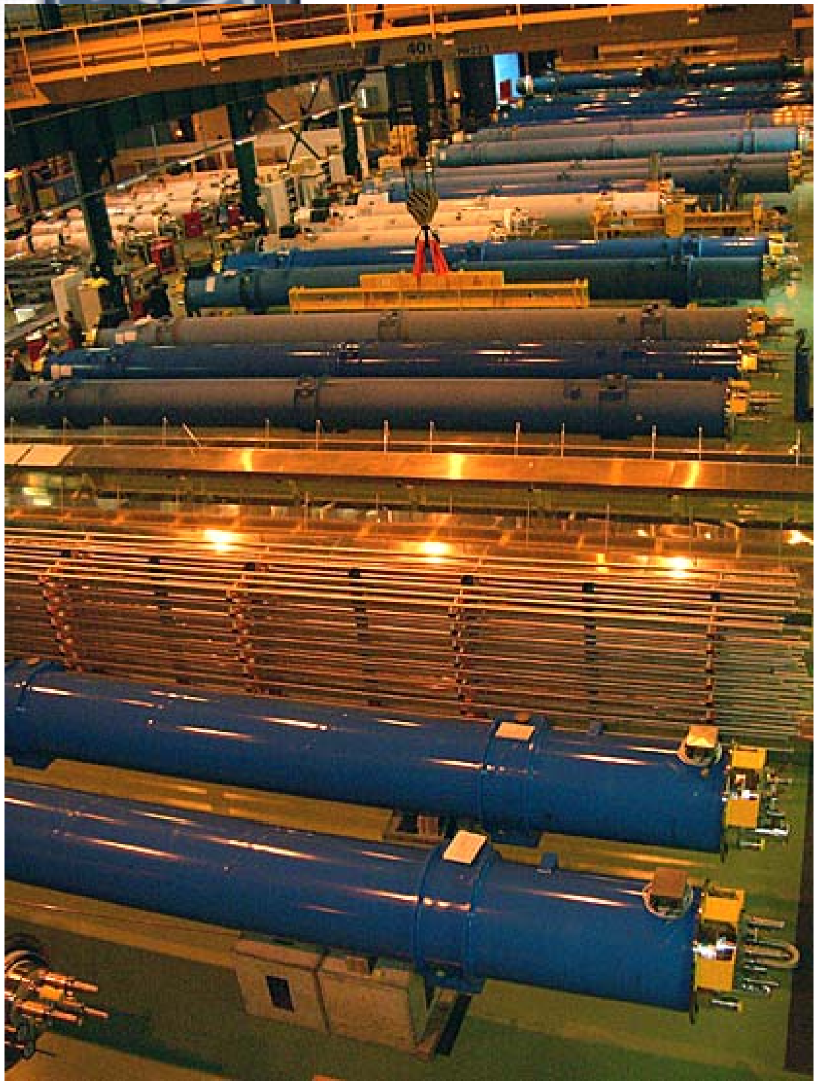
- *Project culture and cost awareness of project engineers improved*

Scheduling

- CPM (Critical Path) / PDM (Precedence Diagramming)
  - Excellent companions to EVM, a critical task is not necessarily expensive…
  - Fragile for large sets of tasks

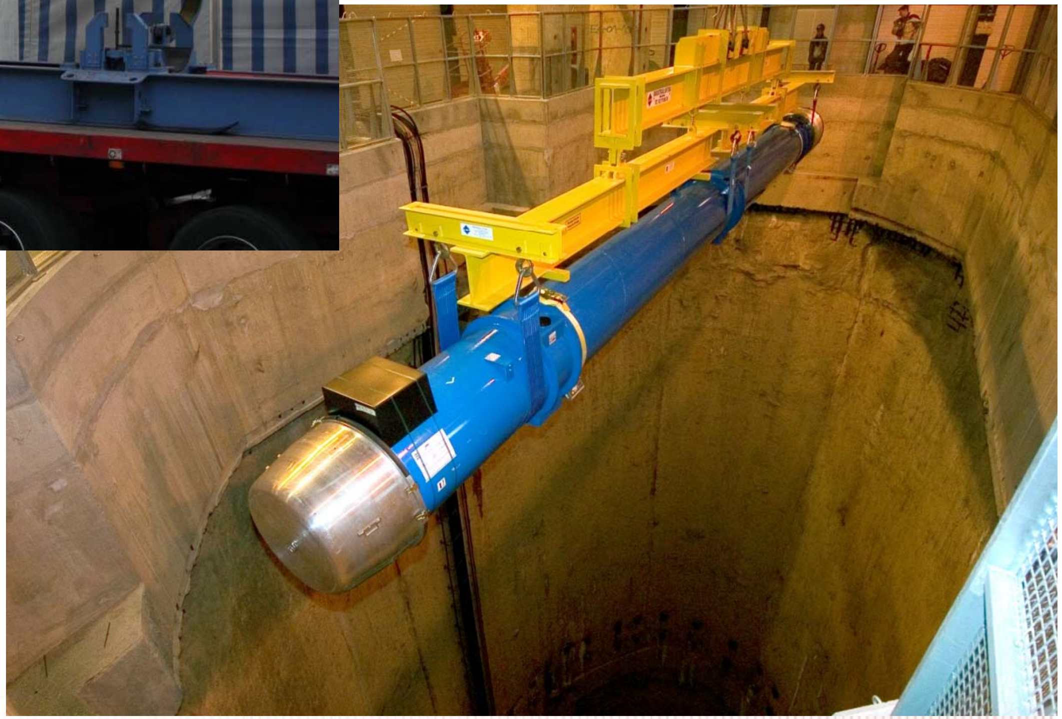

Heat Exchanger Pipe
Beam Pipe
Superconducting Coils
Helium-II Vessel
Spool Piece
Bus Bars
Superconducting Bus-Bar
Iron Yoke
Non-Magnetic Collars
Vacuum Vessel
Quadrupole
Bus Bars
Radiation Screen
Thermal Shield
The
15-m long
LHC cryodipole
Auxiliary
Bus Bar Tube
Protection
Diode
Instrumentation
Feed Throughs

Magnets: preparation for installation

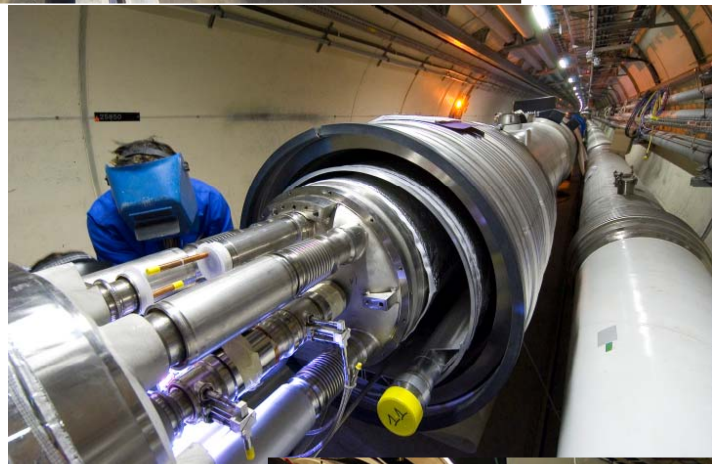


Hall SMI2

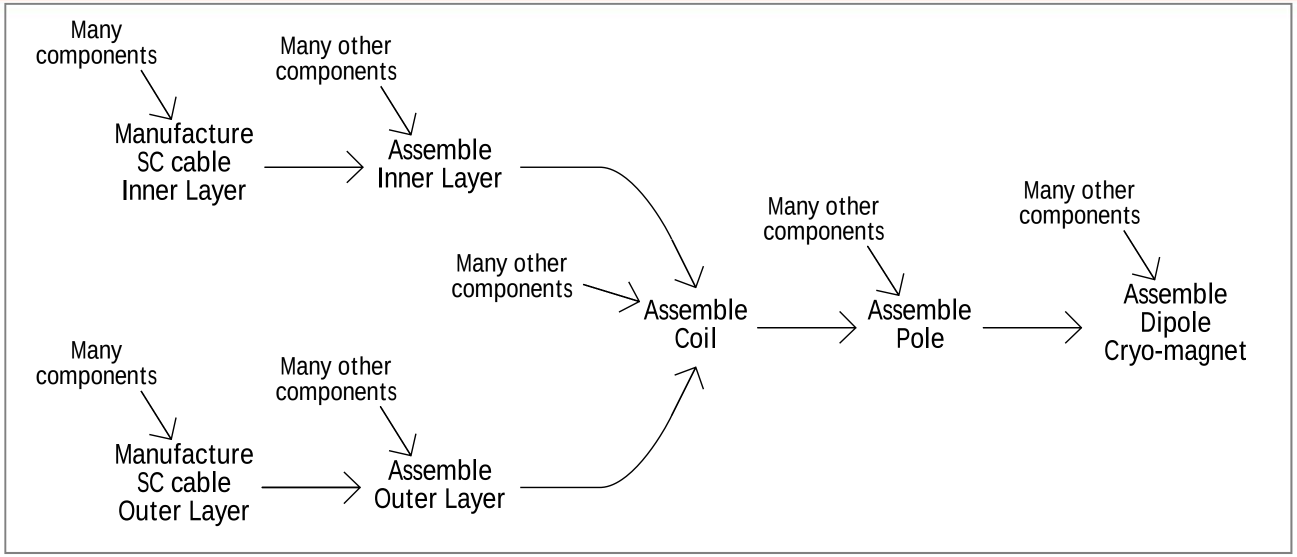
Transport

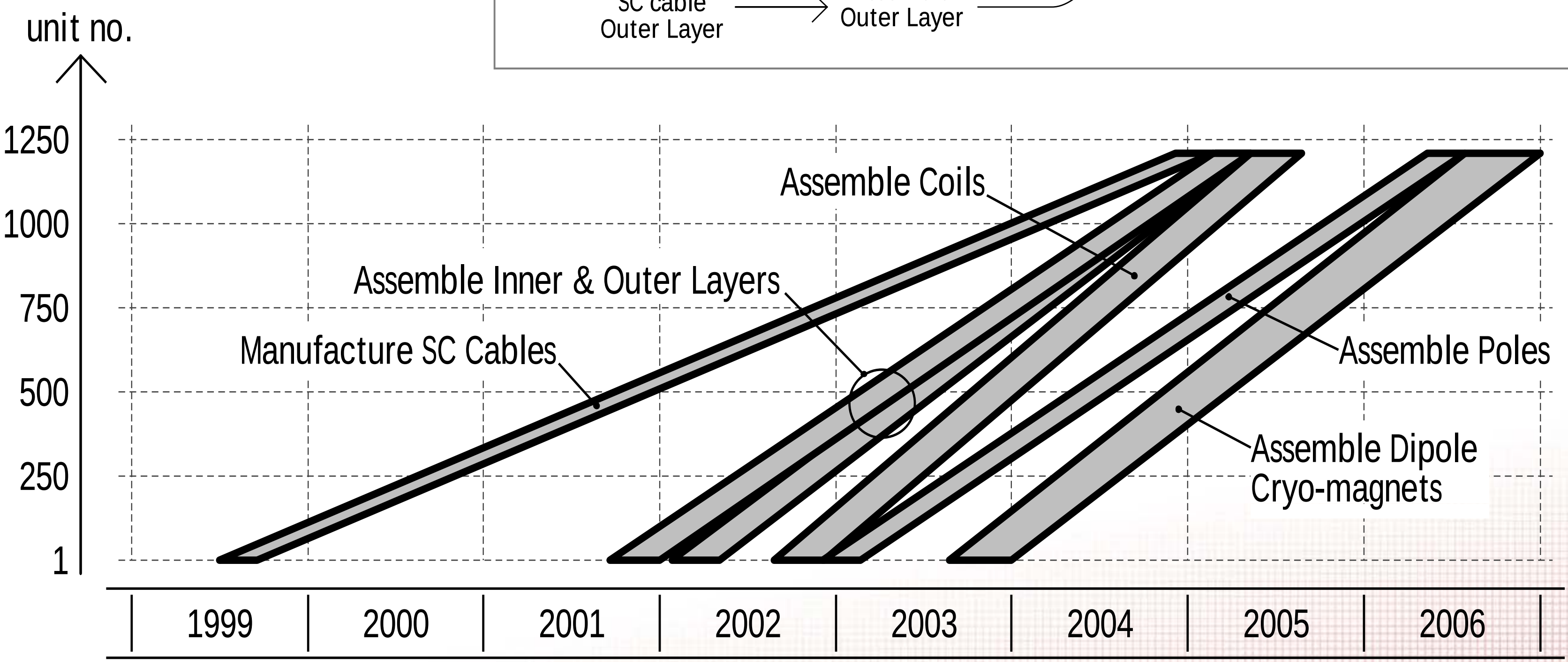


Installing dipoles…



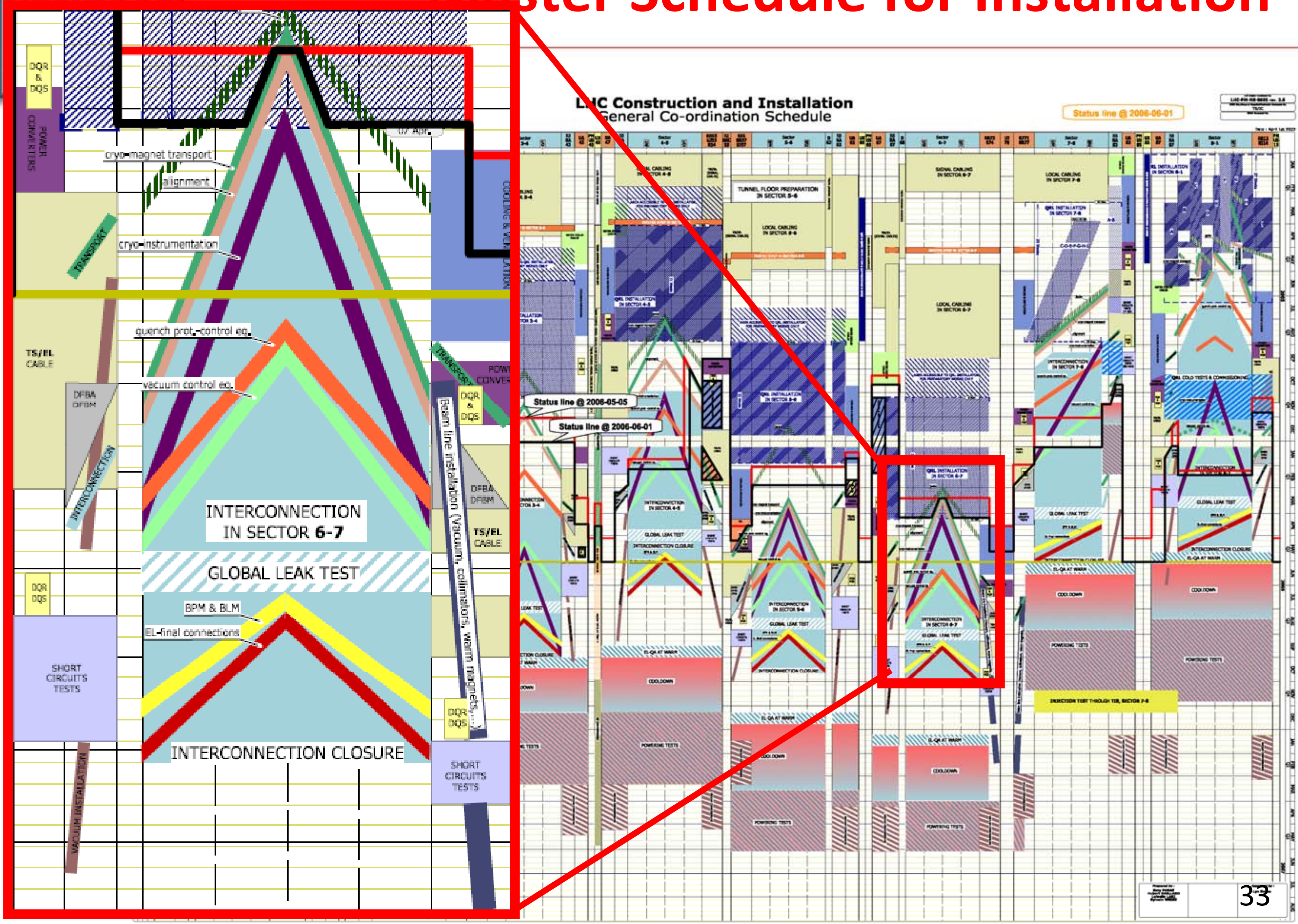
Repetitive Schedule for the Production of LHC Dipole Cryo-magnets (Coils)





Slight schedule issue …

Master Schedule for Installation



Linear/Repetitive scheduling

- repetitive activities often have different production rates.
- production rate imbalance → negatively impacting project performance
  - Work stoppages, inefficient utilization of resources
- Setting up a project activity network diagram for strict application of CPM or PDM is hard.
  Example:
  - 1800 cryo-magnets need to be manufactured and installed. Each has a complex workflow: hundreds of operations in assembly

➢ Introduction of <u>analytical</u> Linear Scheduling Method

  ➢ Much less maintenance work on the schedule!

LHC accelerator versus detectors

- Accelerator:
  - Central project management
  - Formal monitoring through EVM

- Detector
  - Leadership is Coordination & Stewardship. Authority comes out of respect from peers
  - Monitoring through milestone tracking
    - o Due to the nature of the project accounting (decentralized resources allocation), technical milestones planning was not resources-loaded
  - Financial Risk reduced: try to obtain as much in deliverables/in-kind as possible

ATLAS Foundation

- Defined in the Construction Memorandum of Understanding
  - 40 Funding Agencies from 35 countries; 164 participating institutes
  - Construction capital: 475 MCHF in 1995 ATLAS Swiss Francs, not including home institute infrastructure nor manpower (estimated at 5310 man-years)
  - Note: ATLAS is not a legal entity. Relies heavily on CERN as Host Lab

- Risks
  - Financial: try to obtain as much in deliverables/in-kind as possible (268 MCHF provided as in-kind "deliverables") ⇨ FA's to share the financial risks
  - Technology:
    - Traditionally at design: identify all future risks and look for measures to reduce/mitigate
    - "In a highly uncertain technological environment: leave the decision to the last possible moment – that way you reduce uncertainty. That is the only way. Reducing uncertainty, rather than fixing the risks. " (quote from Markus Nordberg)

ATLAS (Governance) Philosophy

- During construction, provide maximum autonomy for systems => decentralized decision making. For the installation and running of the experiment, do the opposite and bring everyone together
- **Collaboration** concept dominates all aspects and daily life:
  - Nominations by expertise rather than by demographic considerations
  - Democratic process (“1 institute, 1 vote”). Everything by consensus
  - Leadership through Coordination & Stewardship.
  - Very flat hierarchy
  - Authority comes out of respect from peers.
- Motivation of participants
  - One-in-a-lifetime opportunity, built for themselves
  - Competition

ATLAS Project Management

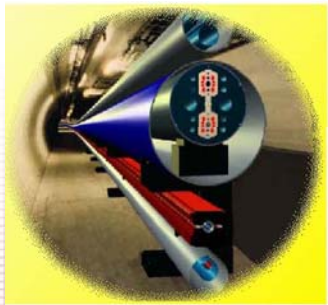
- Minimum administrative overhead
- Monitoring through milestone tracking
  - Due to the nature of the project accounting (decentralized resources allocation), technical milestone planning was not resources-loaded

Any PM professional observing the "light-weight" processes in place must conclude this cannot work at this scale*. Yet, somehow it did.

* As a tool provider supporting these processes, I admit to have had my doubts.

Future plan for operation and upgrade programme of the LHC

- **2012 - early 2013**: shutdown to repair, consolidate and improve
- **2013 – 2015**: operation towards 7 TeV/beam
- **2016**: long shutdown to connect Linac 4, complete PS Booster energy upgrade, the collimation system enhancement + detector improvements.
- **2017-2019**: operation at 7 TeV and (at least) design luminosity.
- **~2020**: HL-LHC upgrade of the accelerator itself (inner triplets, crab cavities...) + the bottlenecks of the injector chain.
- **2035???**: an HE-LHC based on 20 T magnets for a 33 TeV Collider (Nb3Sn + HTS Magnets)



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The second annual earned value analysis conference for continental Europe

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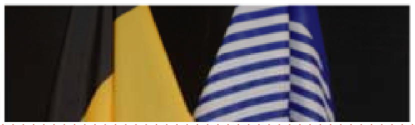
Research meets Practice

Earned Value is the gold standard method for measuring and managing achievement in projects, programmes and portfolios. It is at the heart of the best project controls systems. Earned Value is widely used on projects large and small: From buildings to battleships, opera to aircraft to zoos and even Olympic games. A full Earned Value implementation satisfies even the most stringent governance requirements.

Yet Earned Value is still not well known or understood. The EVA Europe 2010 conference will showcase Earned Value activity with a focus firmly on Europe. It is bringing practitioners, customers and suppliers together to share knowledge and discuss solutions. The aim of EVA Europe is to increase the use of Earned Value in ways that will enable Europe to prosper safely and ethically in its global role.

Keynote speaker on EVA-Europe 2010 Astronaut Frank De Winne

(Photo: European Space Agency (ESA))



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Project Program Process X4P Practitioners

Thank you!

jurgen.de.jonghe@cern.ch

Economic Risks

- Managing a Project Baseline is not a straightforward exercise: imprecise figures, unexpected events...
- The comparison of actual figures with planned ones is not straightforward either: inflation, variations of FX rates...

- Practices are, in this respect, not (so much) standardized!

- Technical problems, programmatic problems… are the responsibility of the project management teams
- But can a project management team be made responsible for economical or commercial unexpected events?

Economic Risk: Inflation