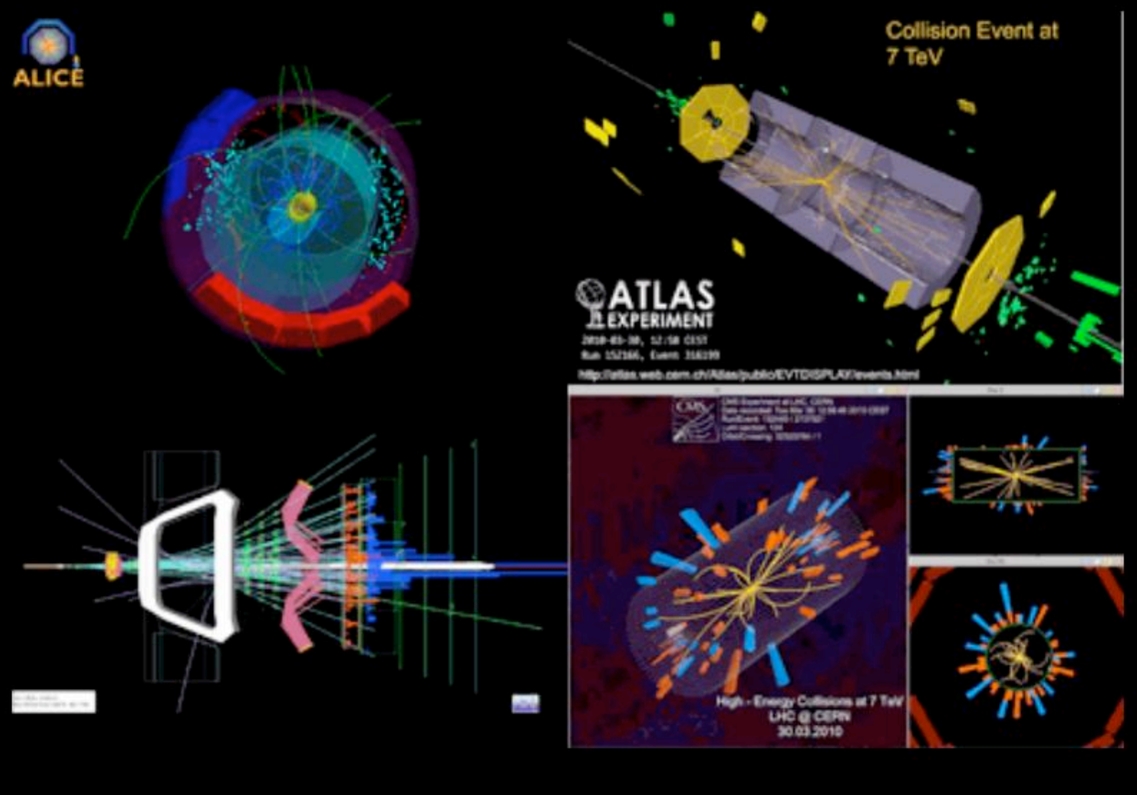


The Large Hadron Collider

Andrew Larkoski


CERN


ON AIR

Collision Event at 7 TeV

ATLAS EXPERIMENT

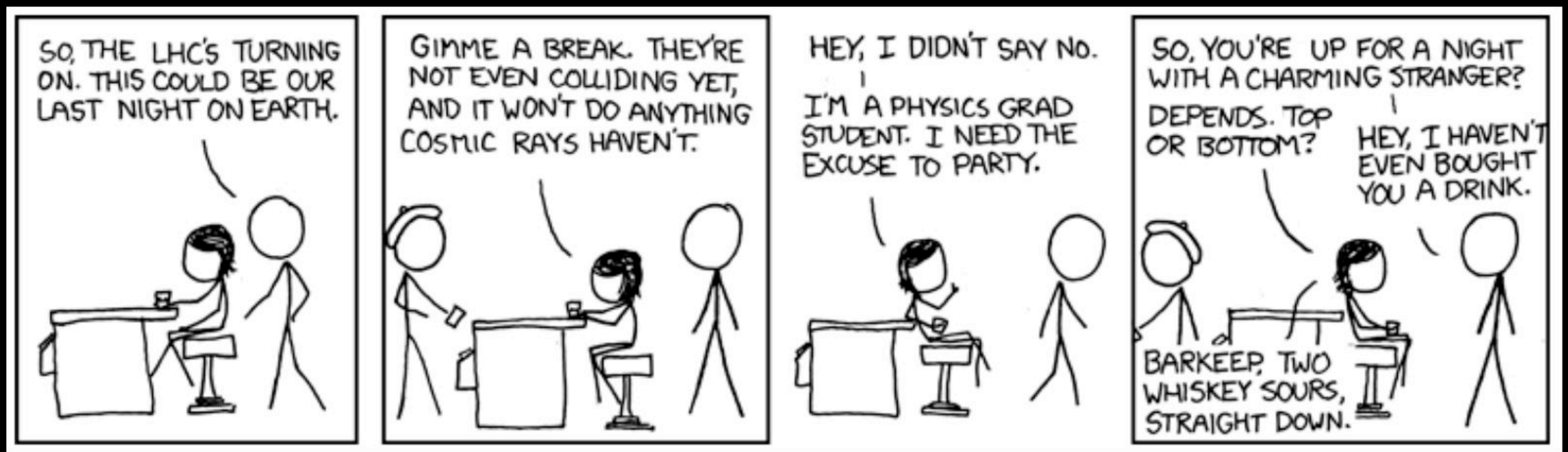
2010-03-30, 12:58 CEST

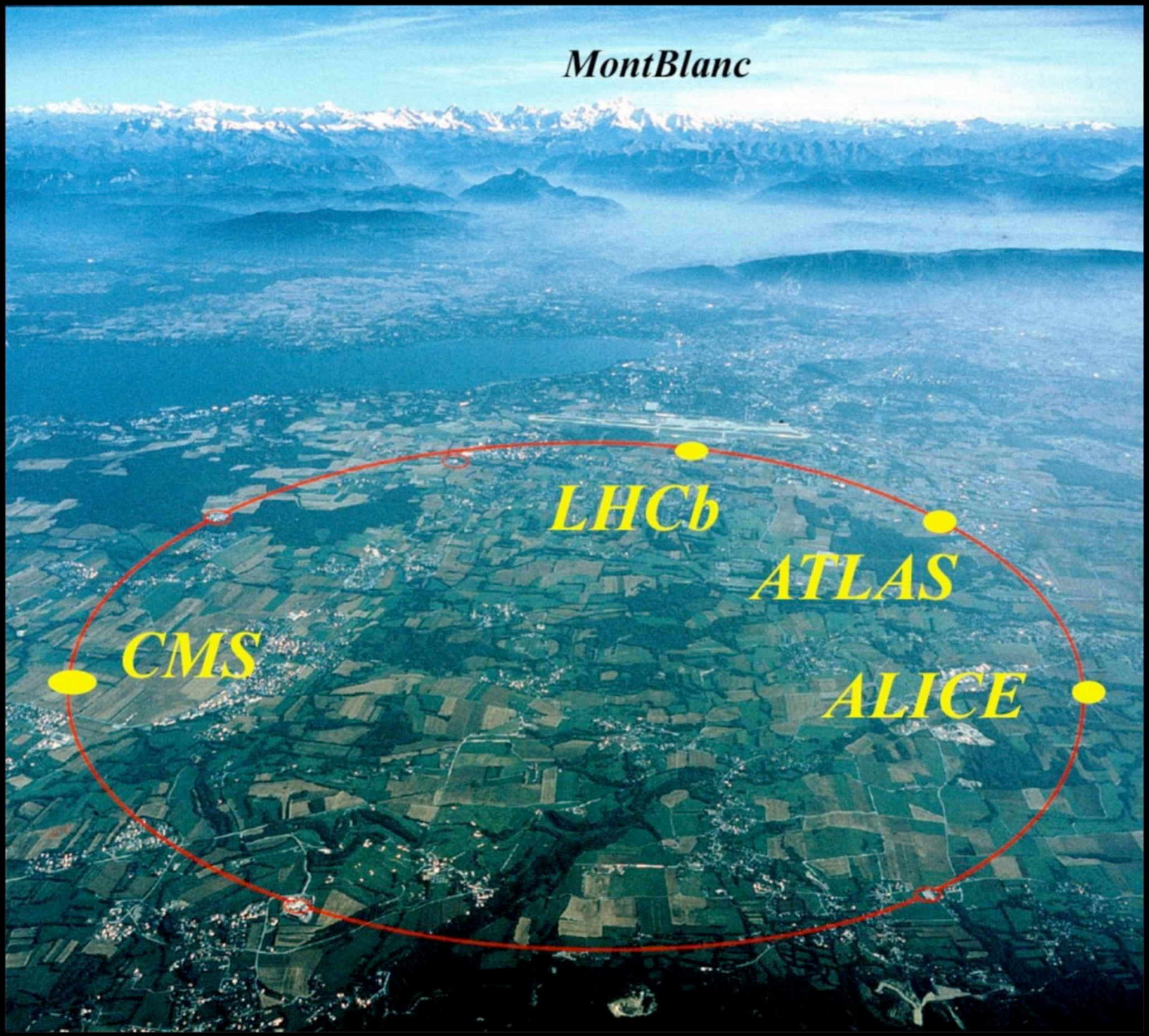
Run 152166, Event 316199

http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Outline

- Overview of the LHC
- A History of Problems
- Current Run
- Physics Goals
- Theorists' Wishlist




MontBlanc
LHCb
ATLAS
CMS
ALICE

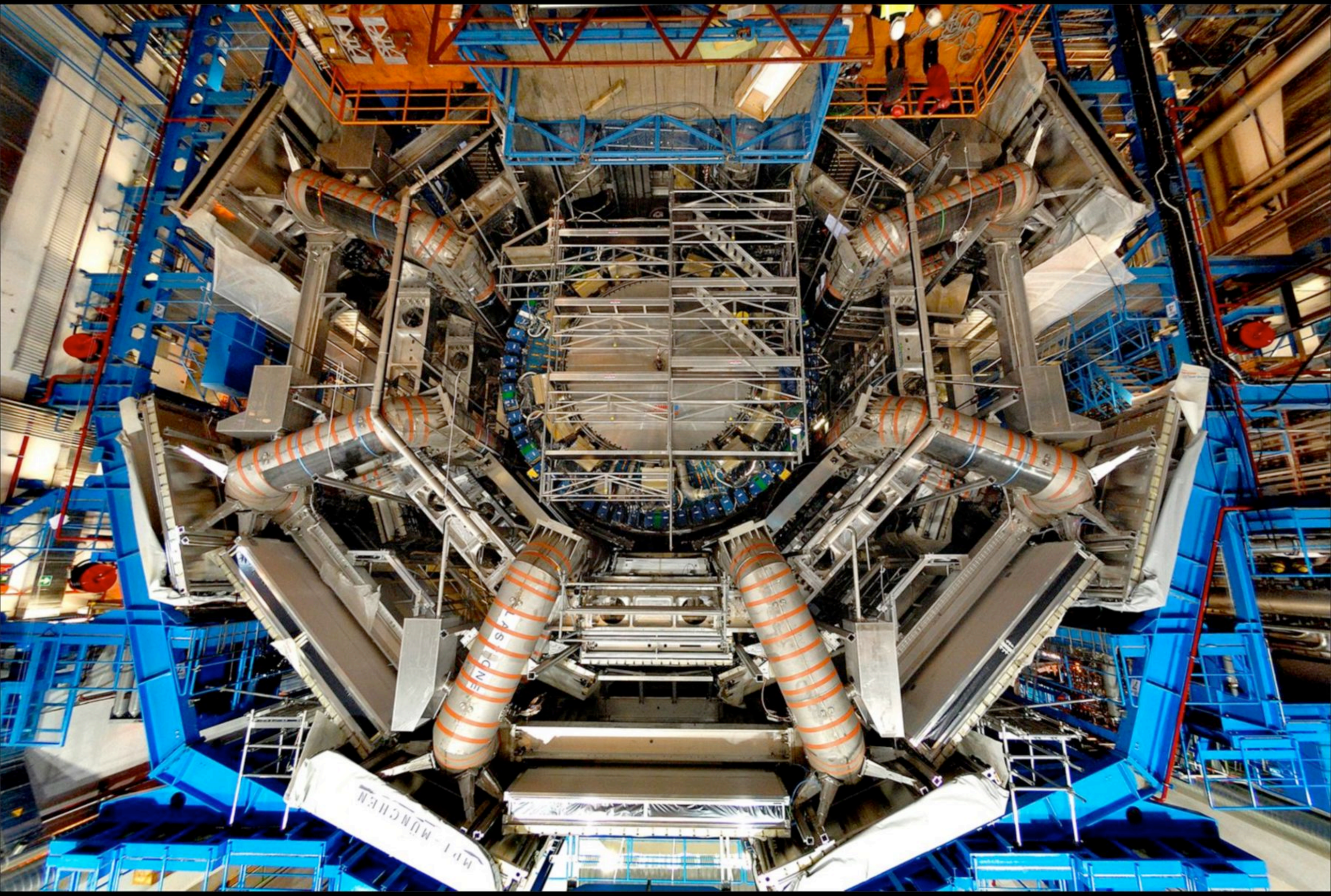
The Large Hadron Collider

- Cost: 6.3 billion Euro or 8.5 billion Dollars
- Time to Construct: 14 years
- Length: 27 km circumference
- Number of Superconducting Magnets: 9593
- Energy in a single proton: 3.5 TeV
- Energy contained in proton beam: ~700 MJ (peak)
- Energy contained in magnets: 10 GJ
- Number of experiments: 6
- Total number of physicists working on LHC: > 6000
- Data output per second: 700 Mb
- Air pressure in beamline: 10^{-11} torr
- Number of collisions per second: 600 million (peak)
- Time after the Big Bang LHC will explore: < 10^{-12} seconds
- Only Higher Energy Particle Accelerator: Chuck Norris

http://www.starlog.ro/2008/09/09/chuck-norris-lhc-facts/

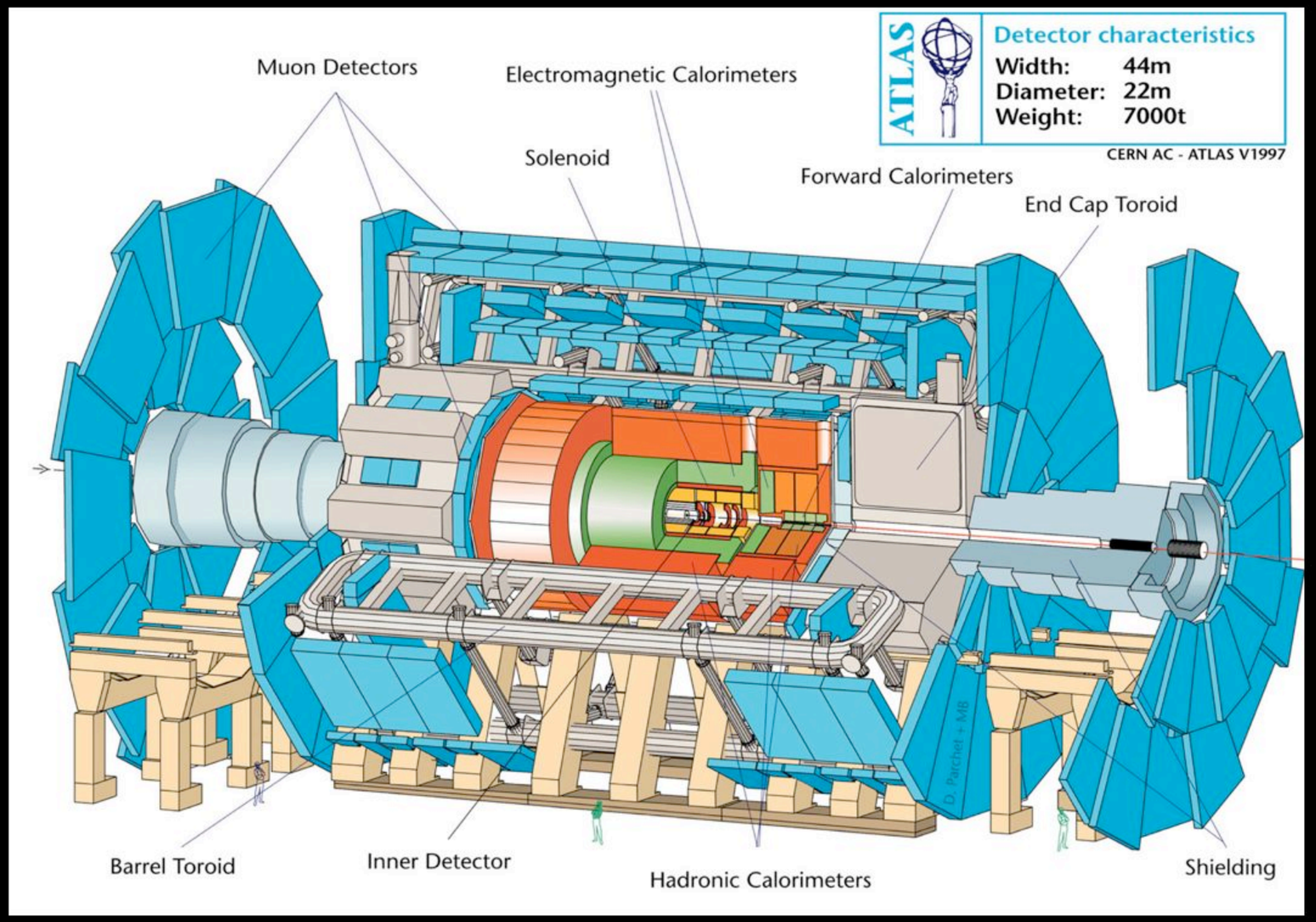
The Large Hadron Collider

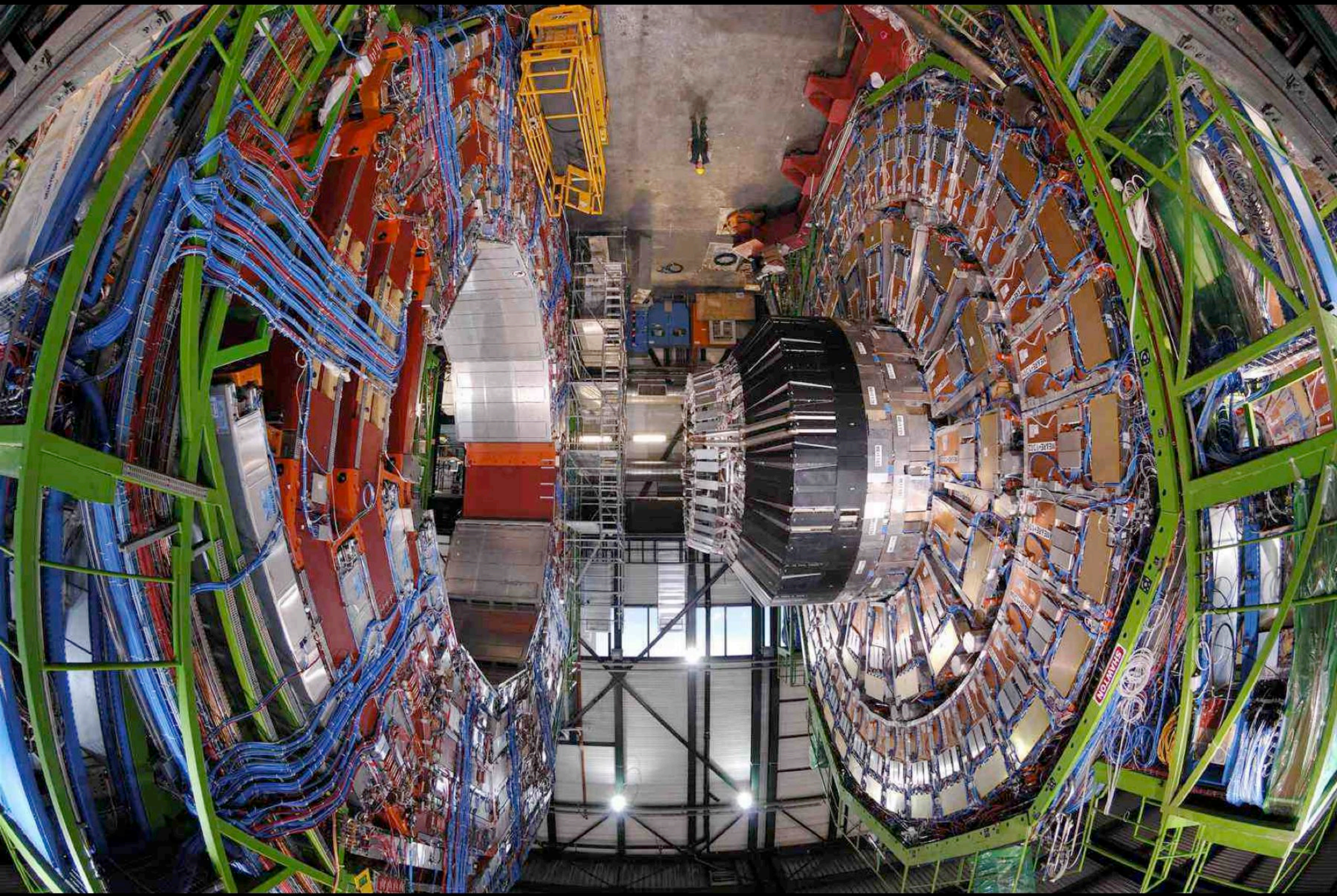
- Experiments:
  - ATLAS
  - CMS
  - ALICE
  - LHCb
  - LHCf
  - TOTEM



ATLAS

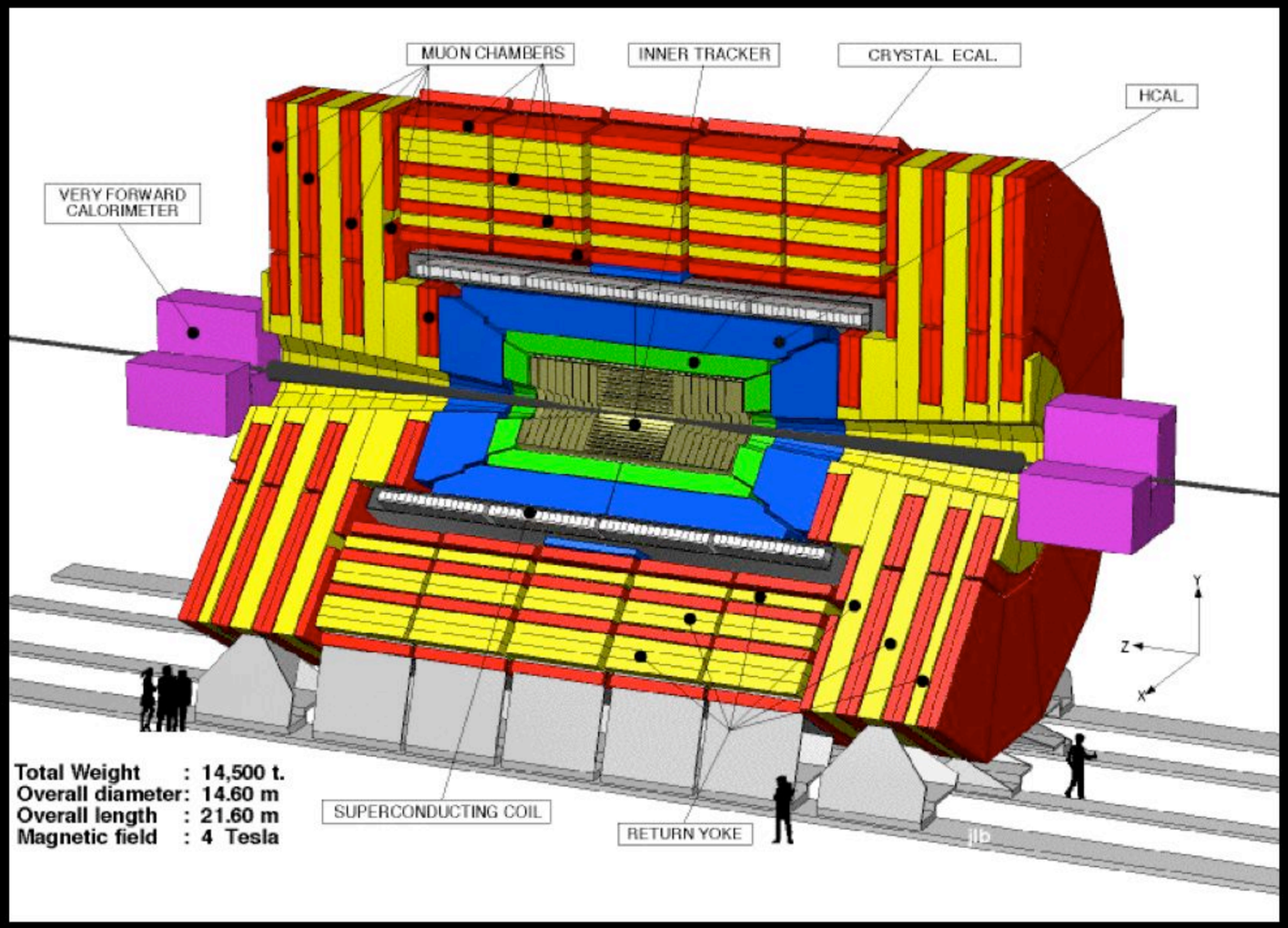
- General purpose detector
- Size: 46 x 25 x 25 m^3
- Weight: 7000 tonnes

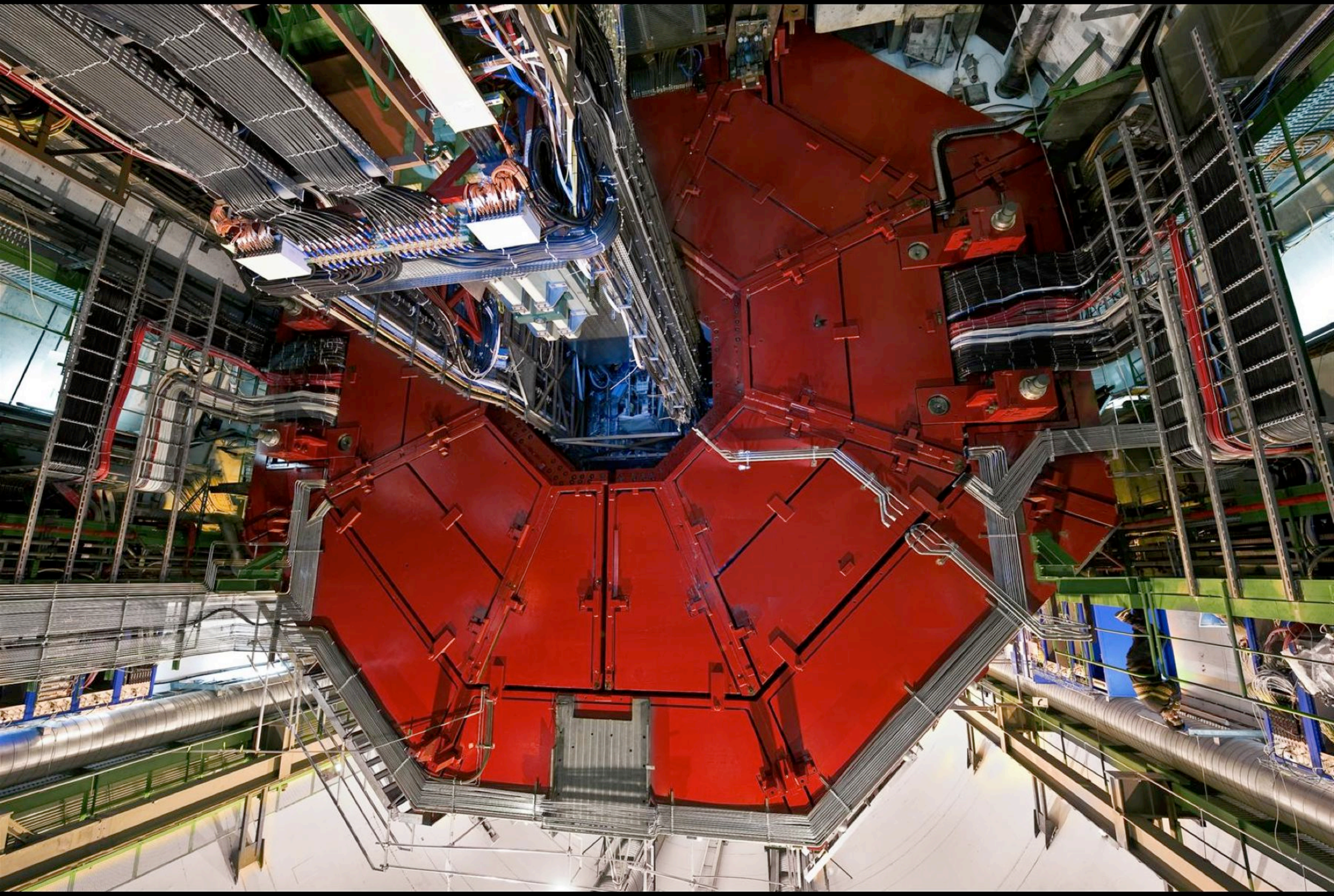




CMS

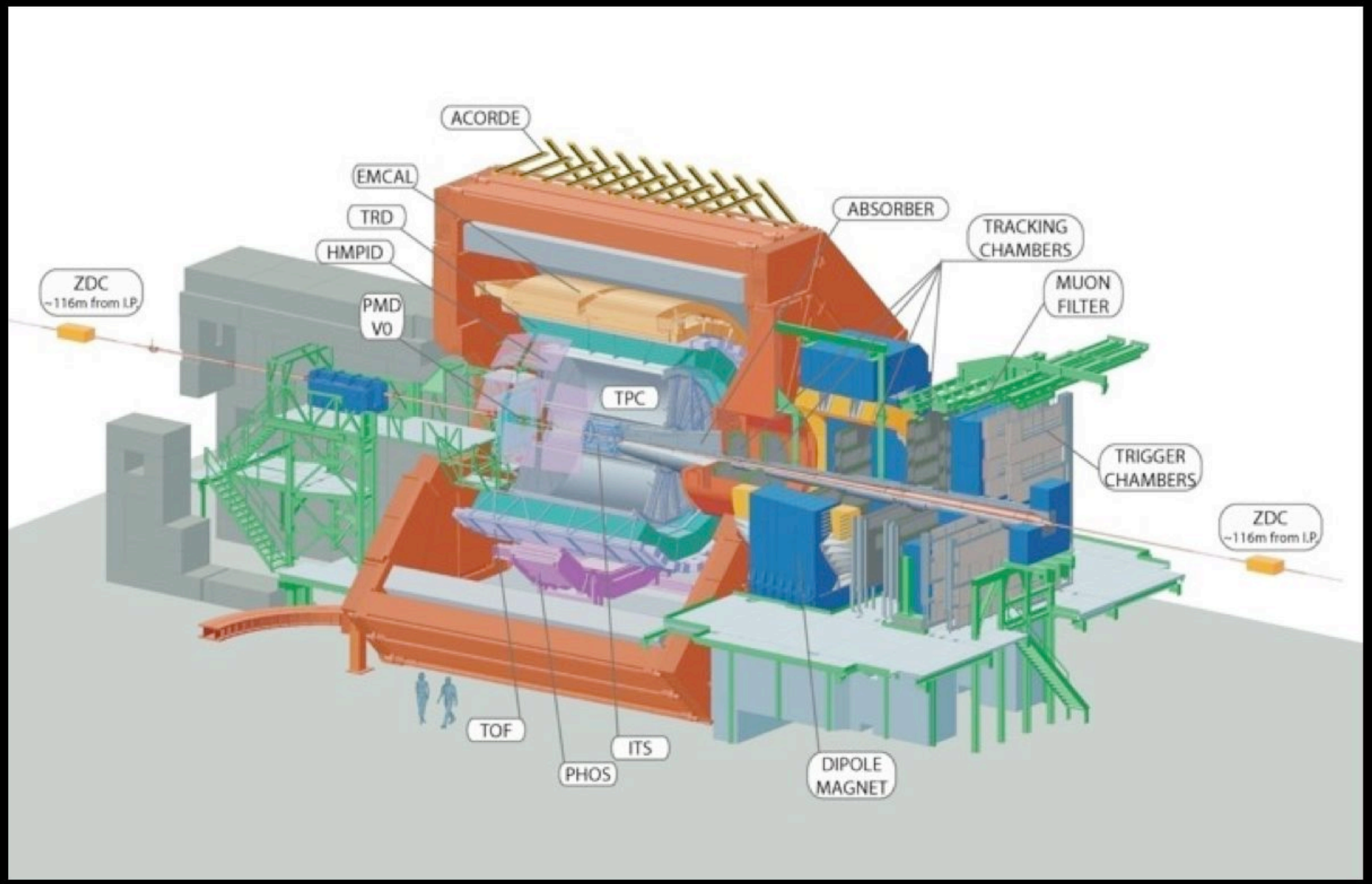
- General purpose detector
- Essentially solid iron
- Size: 21 x 15 x 15 m^3
- Weight: 12500 tonnes





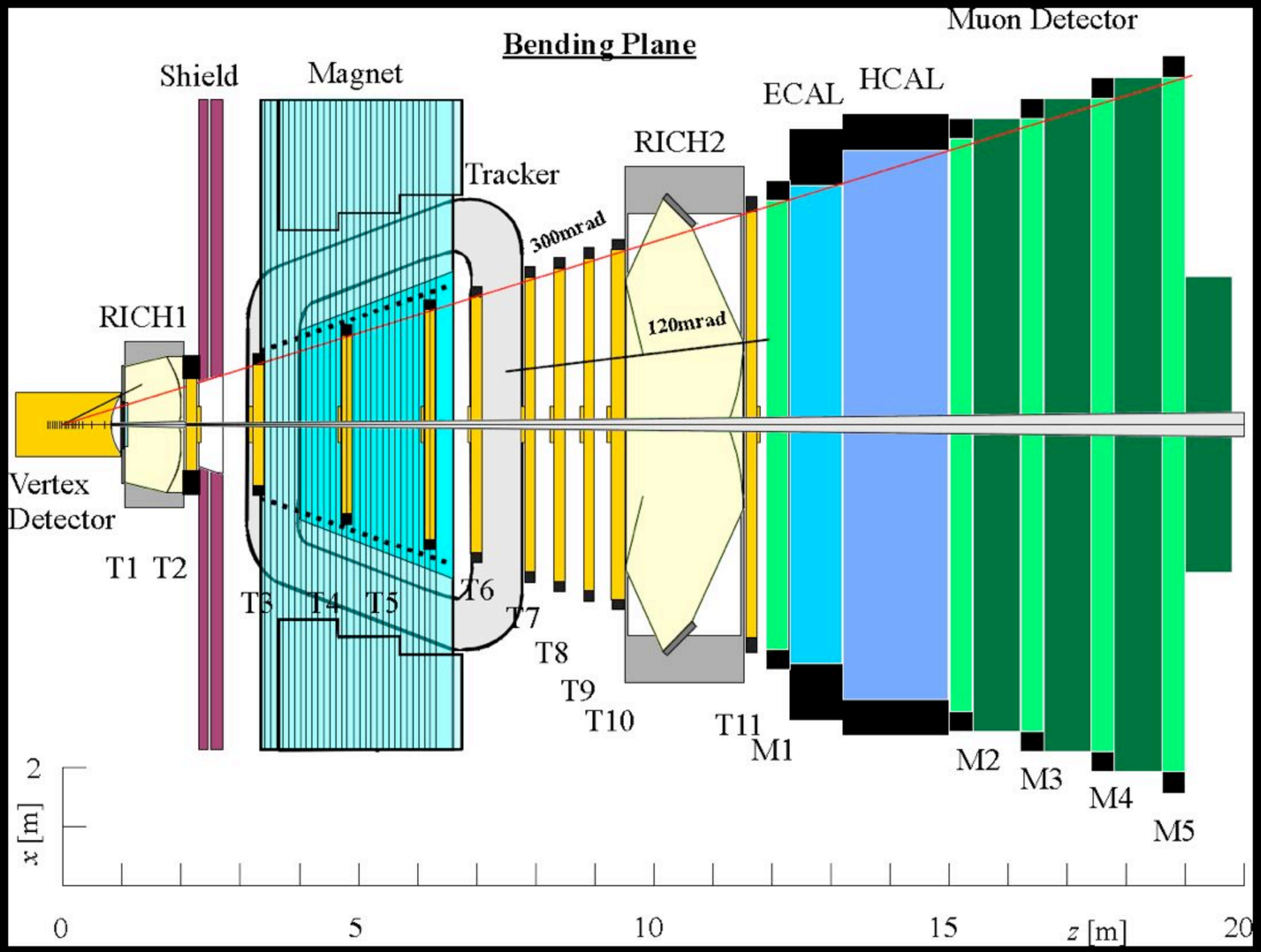
ALICE

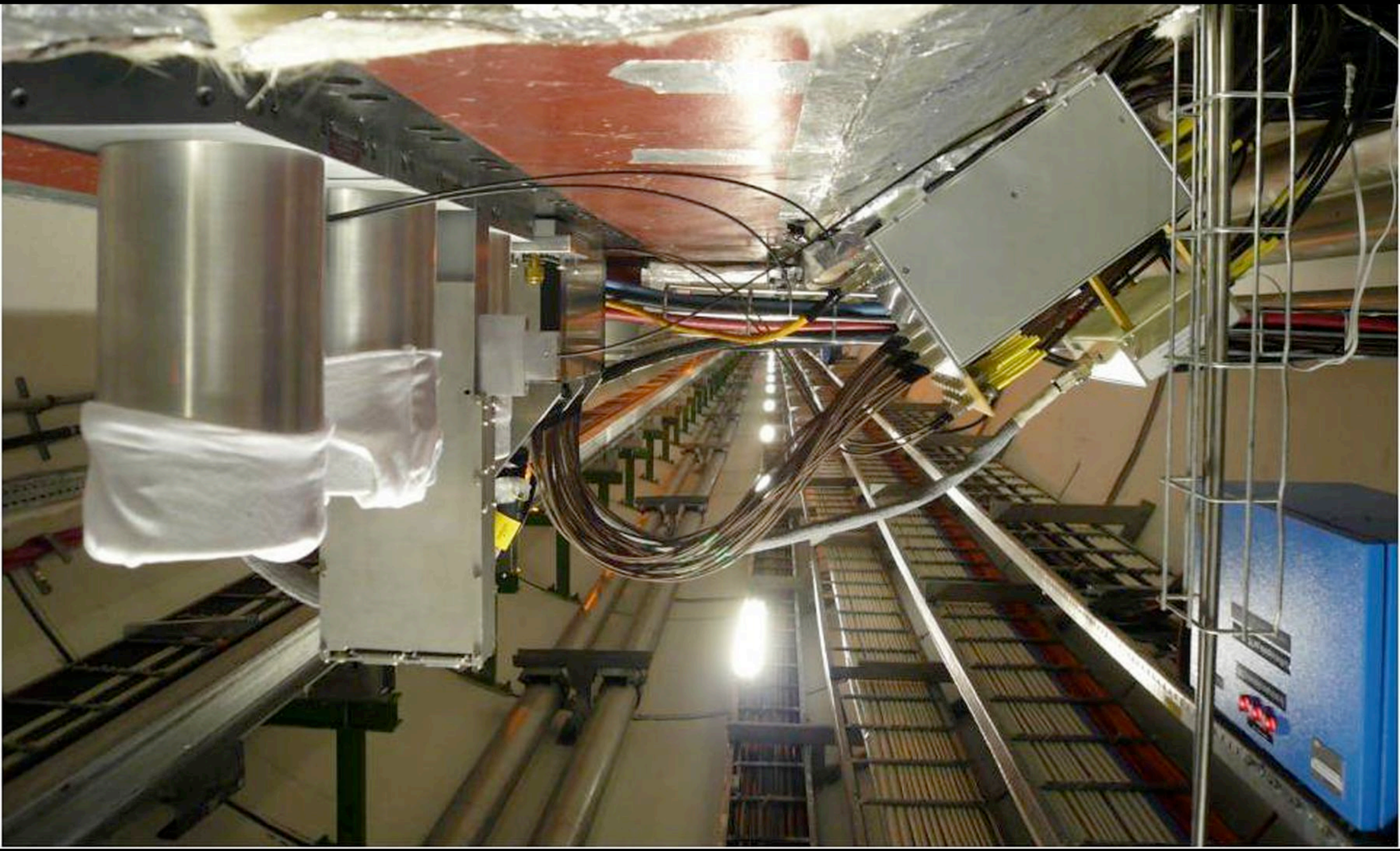
- Designed to analyze lead ion collisions
- Size: 26 x 16 x 16 m^3
- Weight: 10000 tonnes



LHCb

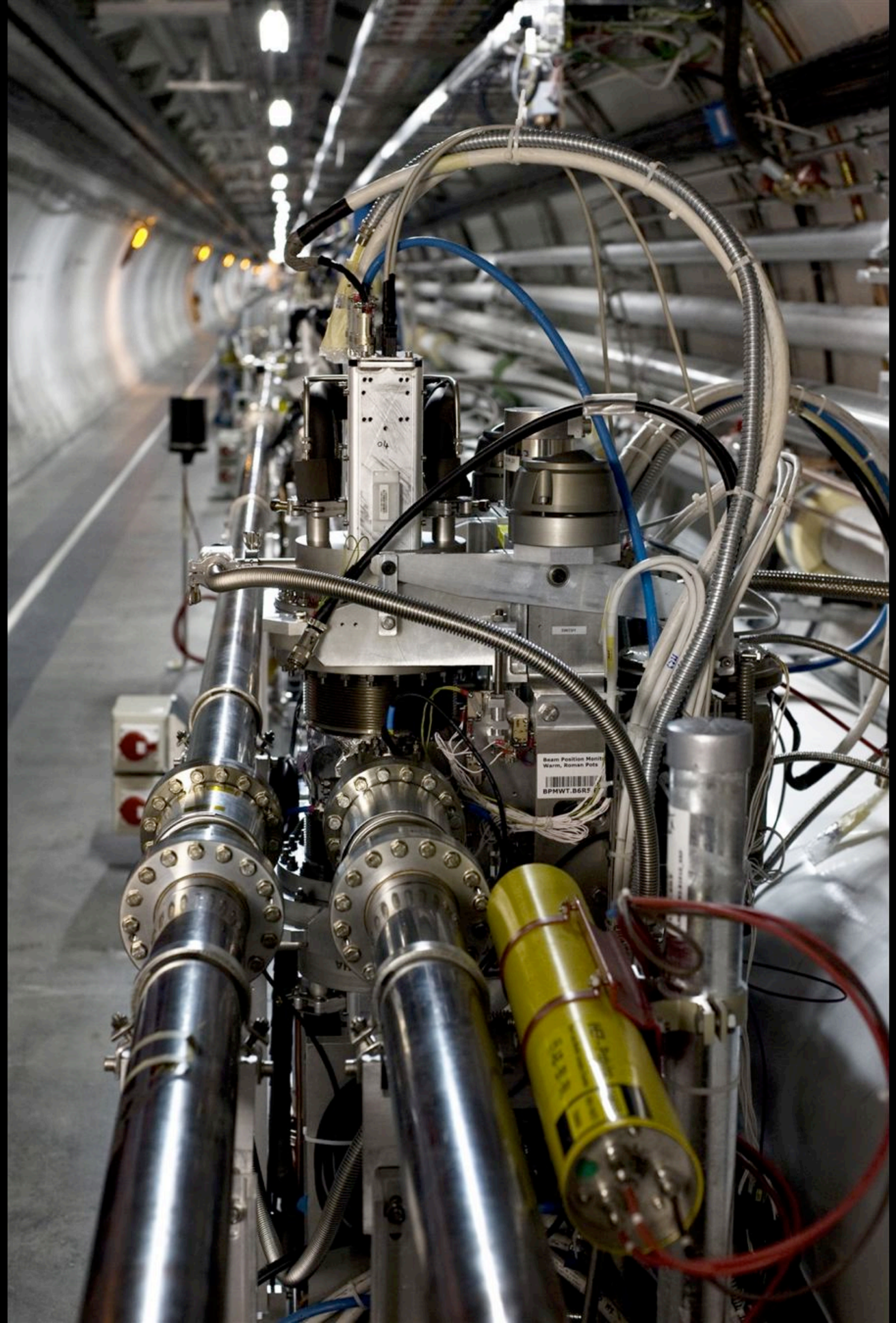
- Designed to study CP violation in b-quark systems
- Size: 21 x 10 x 13 m^3
- Weight: 5600 tonnes





LHCf

- Positioned 140 m from ATLAS collision point
- Designed to measure particles very close to beamline
- Size: 30 x 10 x 10 cm^3
- Weight: 40 kg


Beam Position Monit
Warm, Roman Pots
BPMWT.86R5

TOTEM

- Designed to measure cross section of protons
- Near CMS collision point
- Uses vacuum chambers called “Roman Pots”
- Size: 4 Roman pots separated by ~100 m
    - 5 x 5 m^2 cross section
- Weight: 20 tonnes

Bumps in the Road

- September 10, 2008

Bumps in the Road

- September 19, 2008

Current Run

- March 30, 2010
- 18 Months or 1 fb^{-1}
  - ~11,000 Higgs bosons produced
  - ~130,000 Top quarks produced
- Goal: Find the Standard Model and calibrate the machine
  - Some: New physics can be discovered!
- Shut down for 2012 to repair
  - (World will end anyway . . .)

Future Schedule of LHC

- After 2012 shutdown:
  - Ramp up to 7 TeV on 7 TeV
  - After ~10 years, upgrade to SLHC
- Future of Particle Physics: Linear Collider?

Card game restriction in LHC can only be successful!

Holger B. Nielsen, Masao Ninomiya

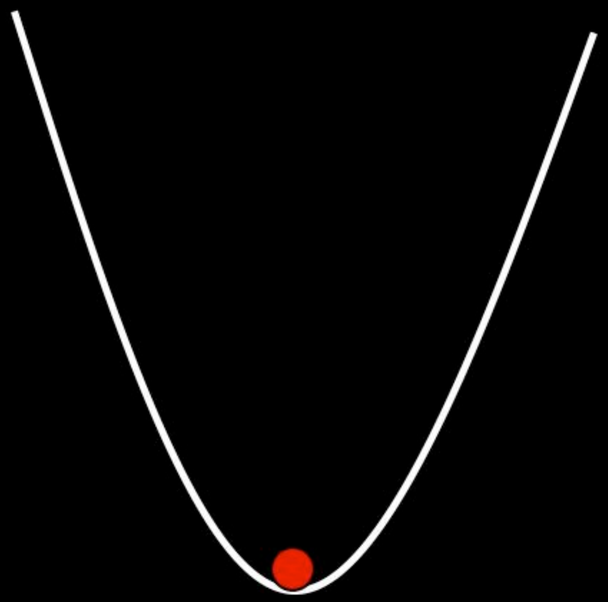
(Submitted on 2 Oct 2009 (v1), last revised 23 Oct 2009 (this version, v3))

We argue that a restriction determined by a drawn card or quantum random numbers, on the running of LHC (Large Hadron Collider), which was proposed in earlier articles by us, can only result in an, at first, apparent success whatever the outcome. This previous work was concerned with looking for backward causation and/or influence from the future, which, in our previous model, was assumed to have the effect of arranging bad luck for large Higgs producing machines, such as LHC and the never finished SSC (Superconducting Super Collider) stopped by Congress because of such bad luck, so as not to allow them to work.

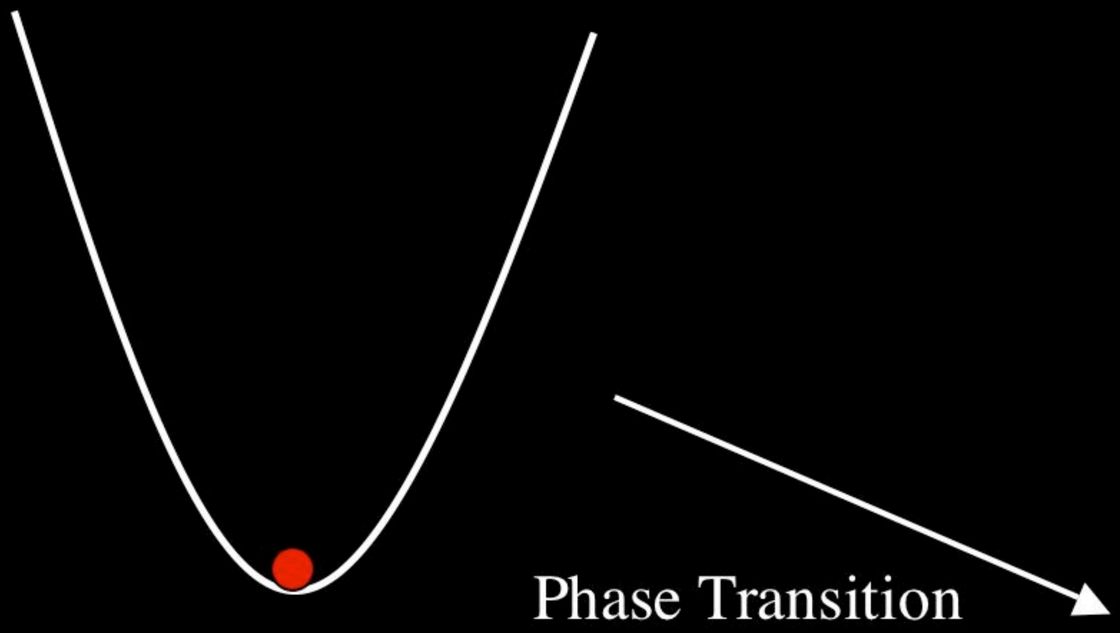
Physics Goals

- Three Main Physics Goals:
  - Find the Standard Model!
  - Electroweak Symmetry Breaking
  - Dark Matter
- Searching for models to explain issues:
  - Supersymmetry
  - Extra Dimensions
  - Technicolor, others

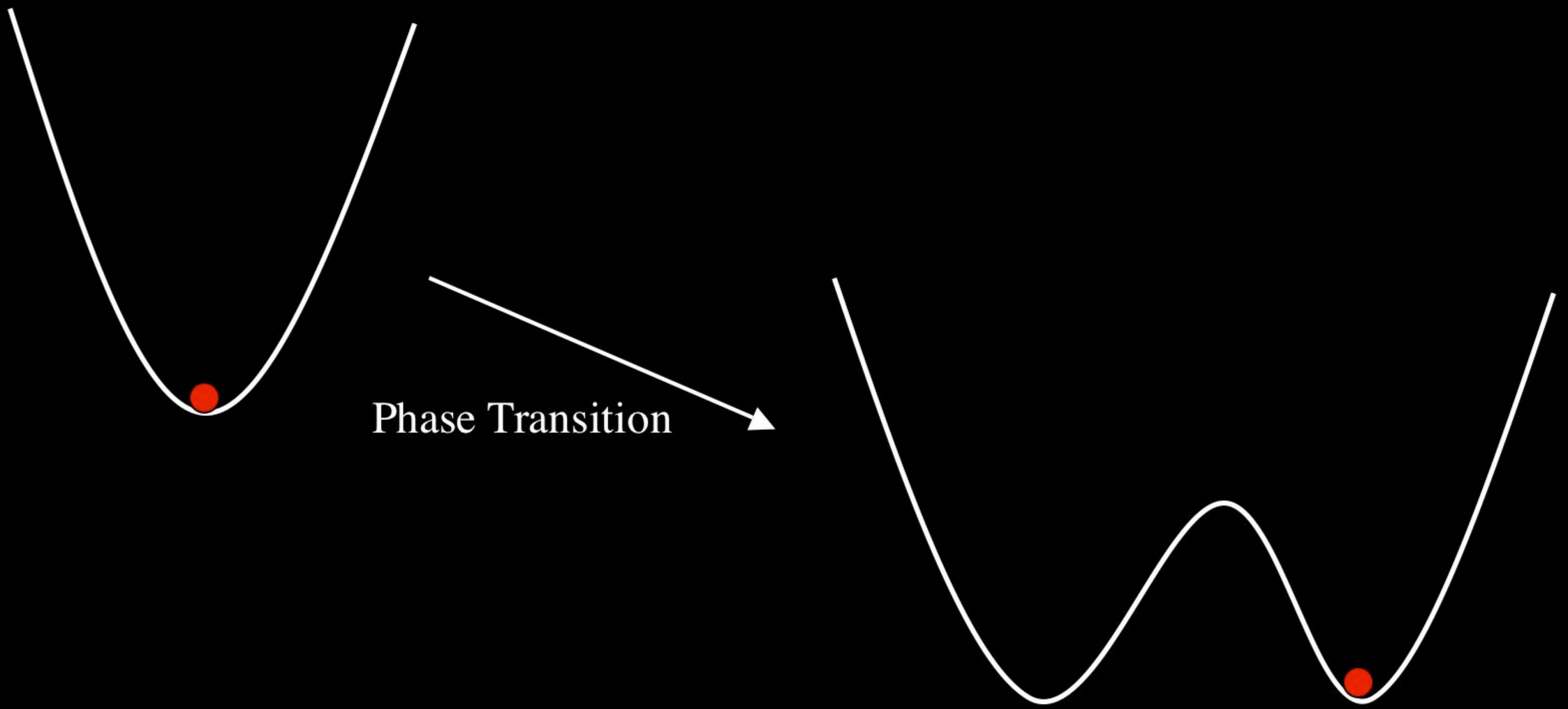
Electroweak Symmetry Breaking



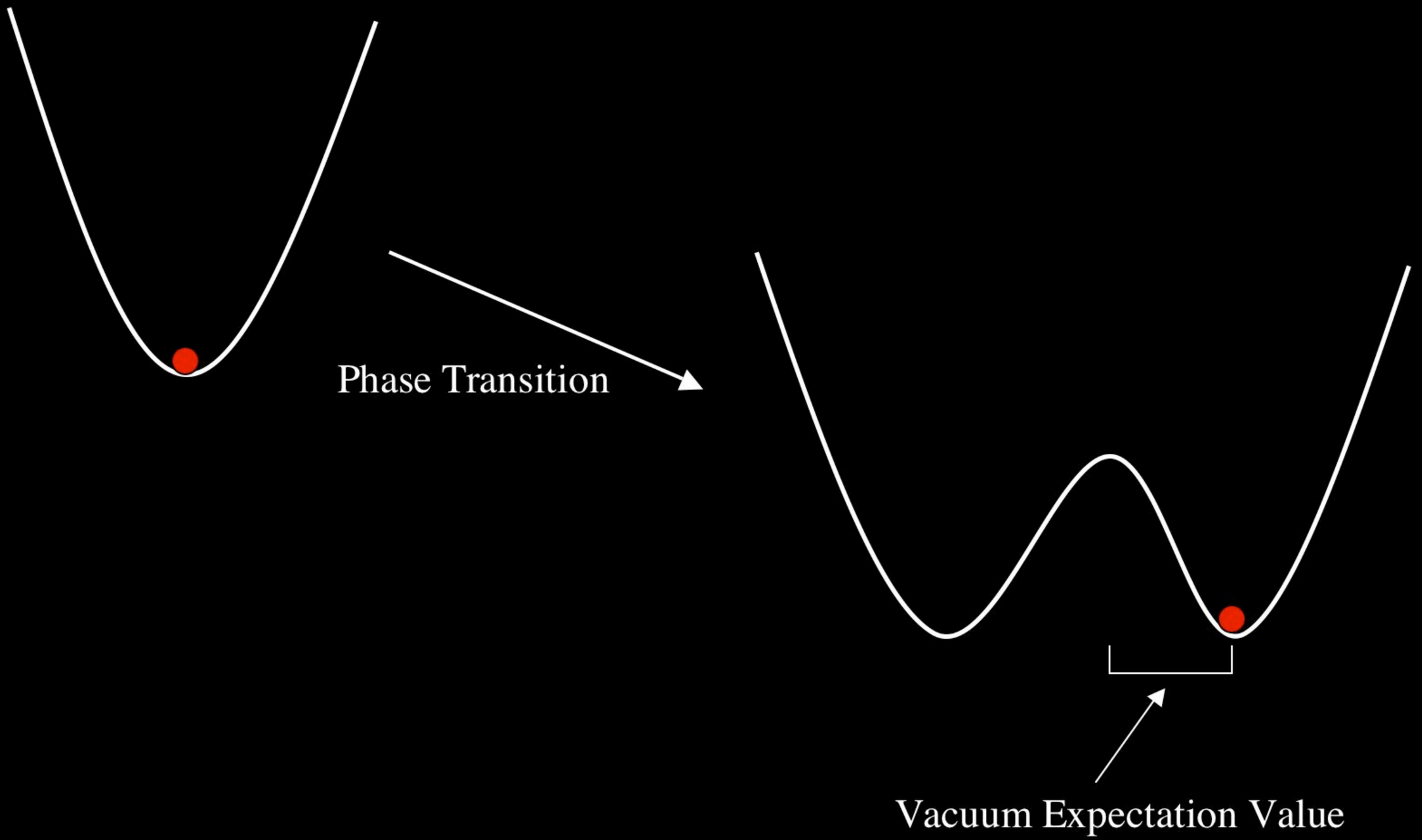
Electroweak Symmetry Breaking



Electroweak Symmetry Breaking



Electroweak Symmetry Breaking

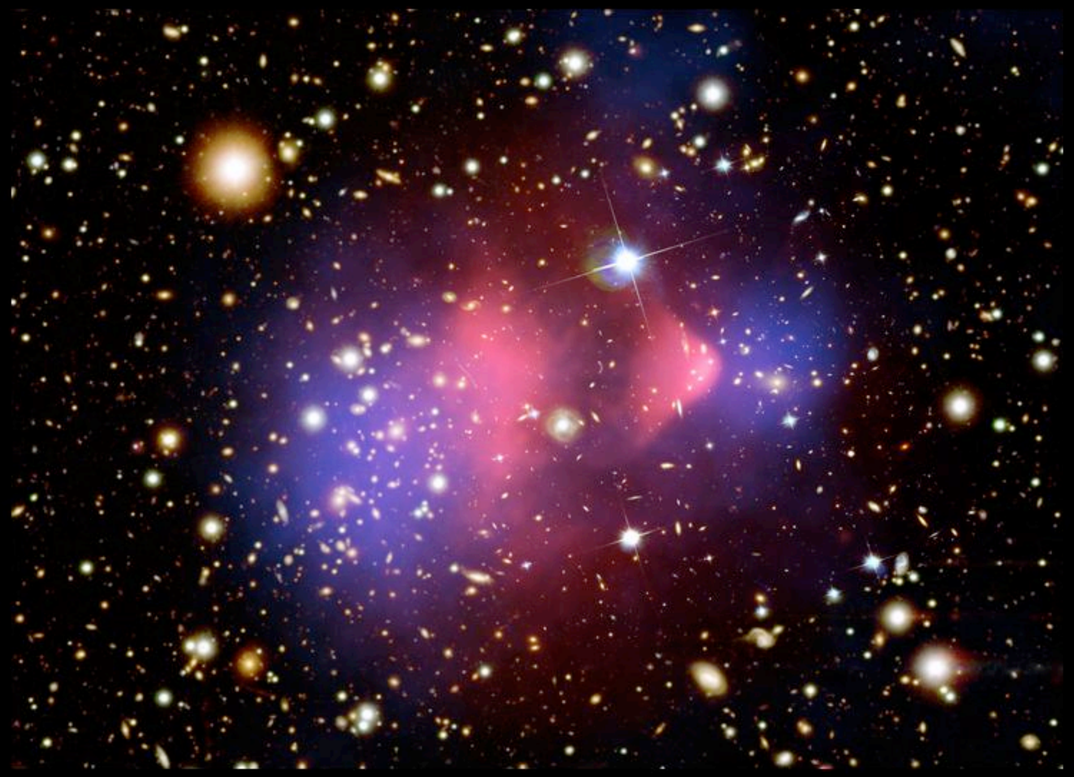


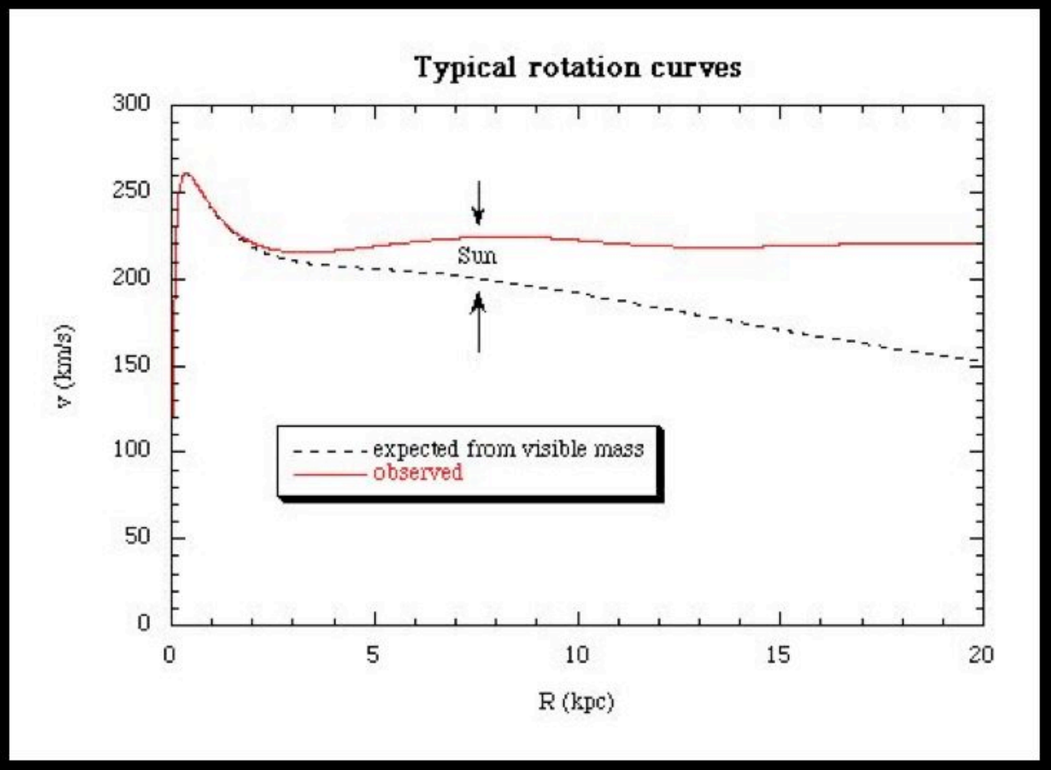
Electroweak Symmetry Breaking

- Fundamental forces are identified with some symmetry
- Particle mass is not consistent with all symmetries
- Have to break Electroweak symmetry to give mass
- In Standard Model:
    - Electroweak symmetry is broken by Higgs boson
    - Have no direct evidence for Higgs!
- Questions LHC will address:
    - Is electroweak symmetry broken by the SM Higgs?
    - Is electroweak symmetry broken by another mechanism?
    - What new physics exists above the electroweak scale?

Dark Matter

- Most of the mass of the universe seems to be of unknown origin
- Evidence:





- Explanation:
  - New particles and interactions!
  - New theory of gravity at large distances!
  - No idea!

Dark Matter

- Most popular explanation:
  - An entirely new sector of physics
  - Possibly supersymmetric particles, extra dimensional particles, even more general scenarios
- Many direct detection experiments searching
  - No conclusive evidence yet
- Questions LHC will address:
  - Is dark matter a particle?
  - If so, does it have interactions with the SM?
  - What are its properties (mass, charges, spin, etc.)?