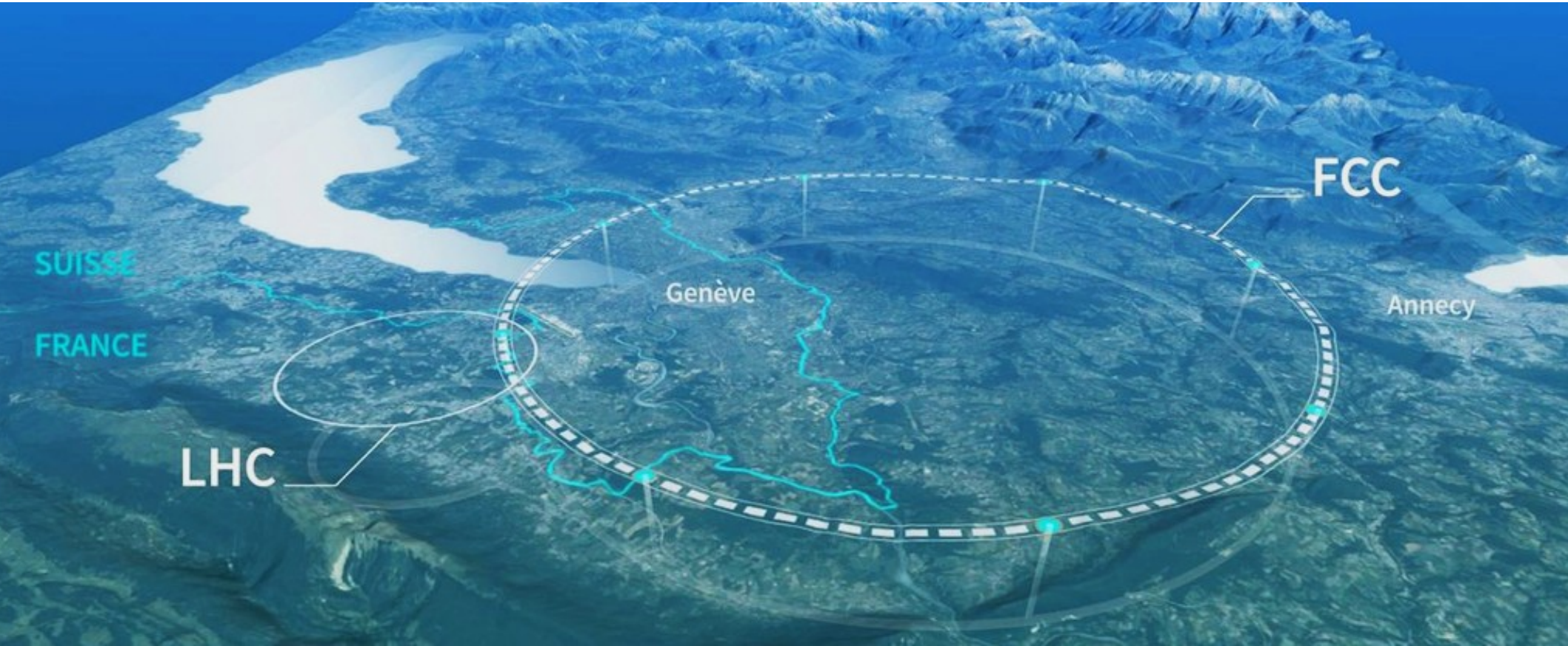
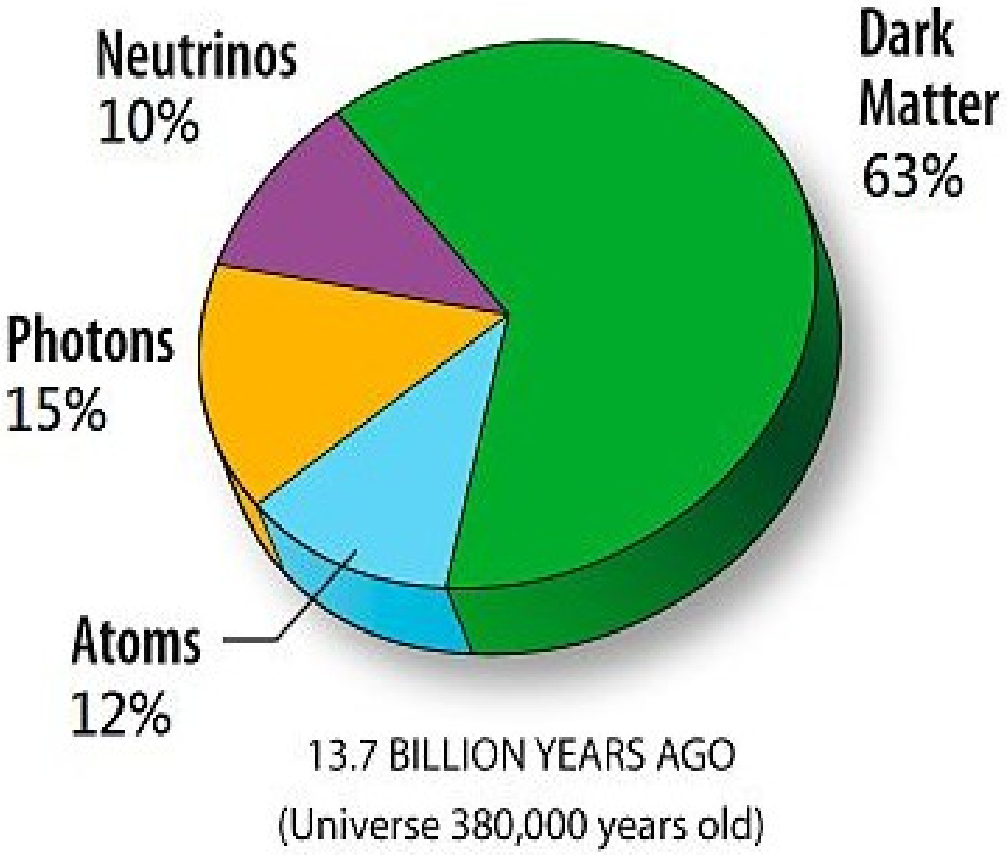
8.FCC - January Research Projects on
the Future Circular Collider (FCC-ee)

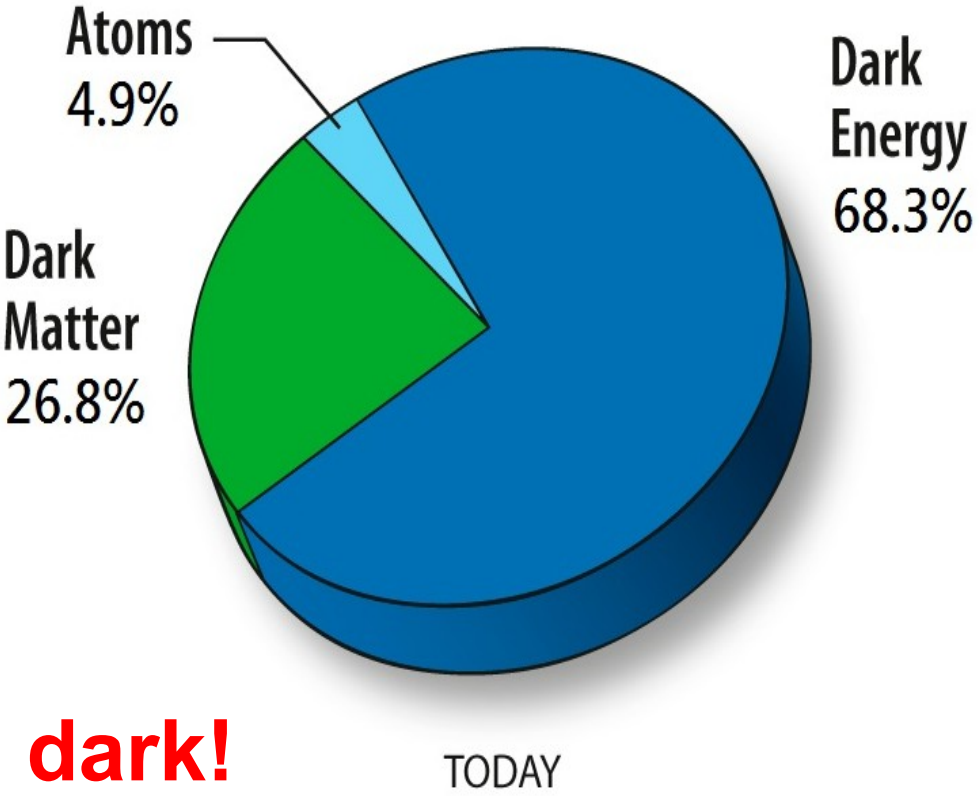
Introductory Lecture
[January 7, 2025]



What's next in Particle Physics?

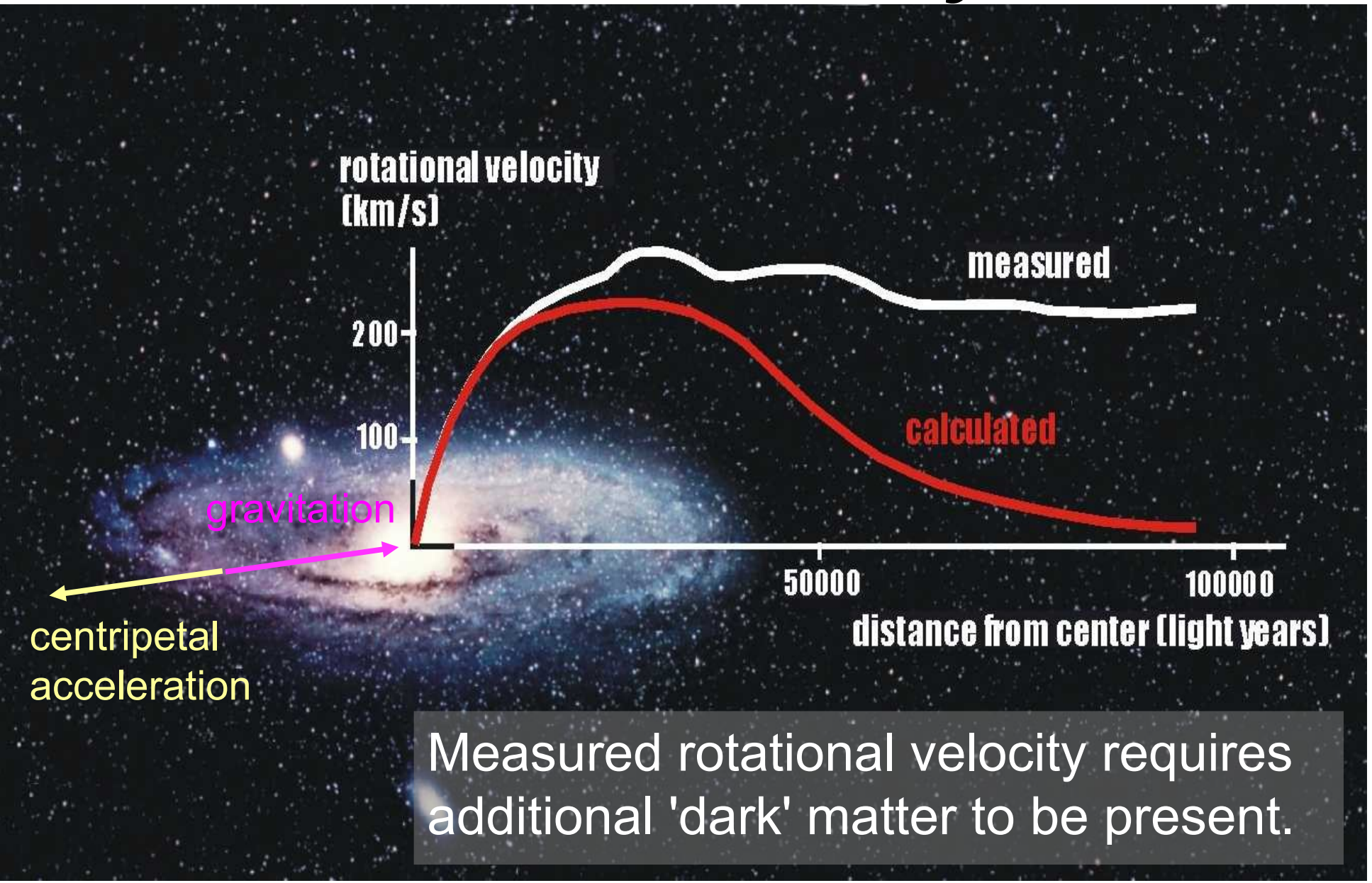
- Dark Matter





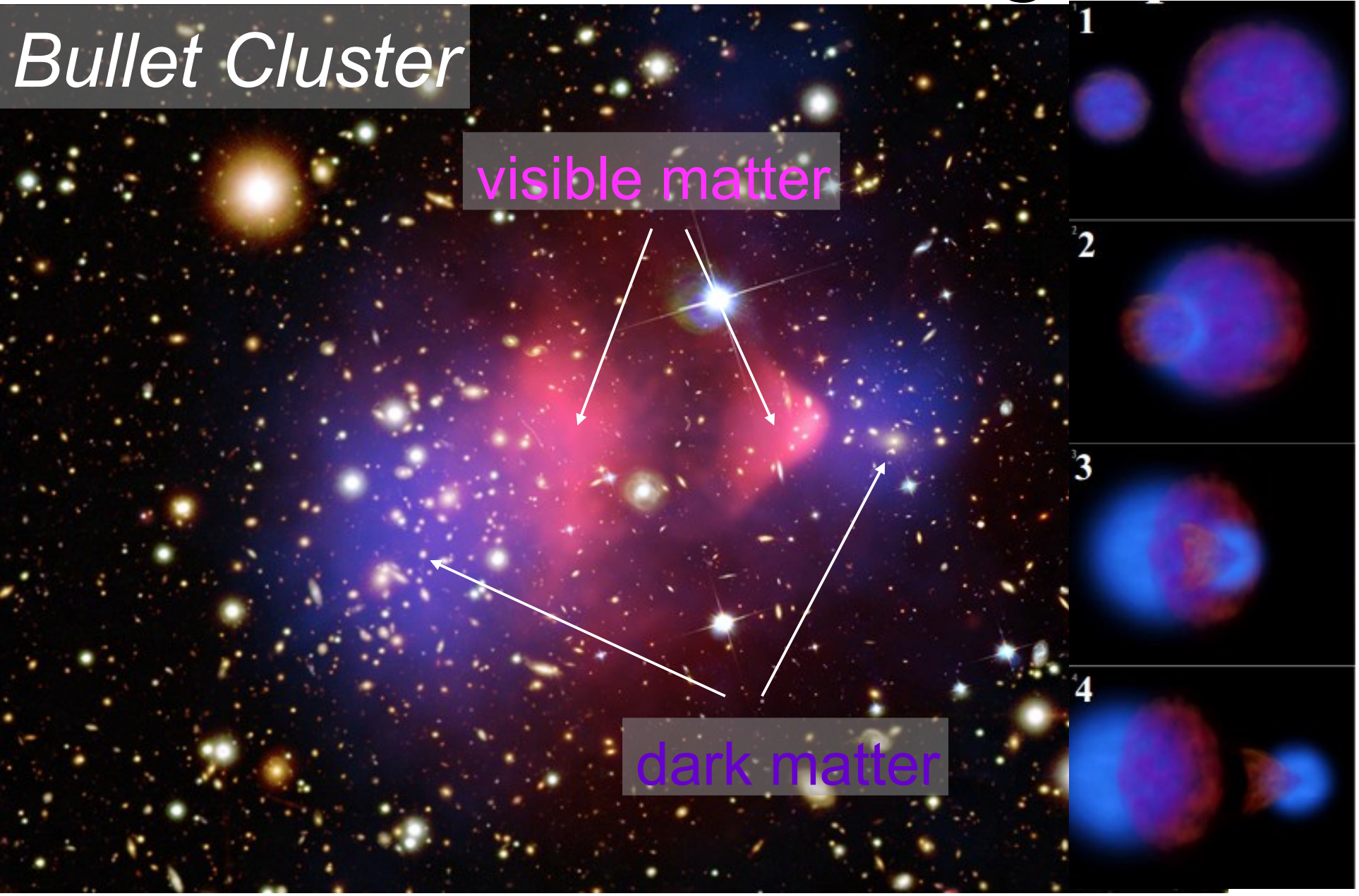
85.6% of all matter is dark!

Rotational Velocity



Measured rotational velocity requires additional 'dark' matter to be present.

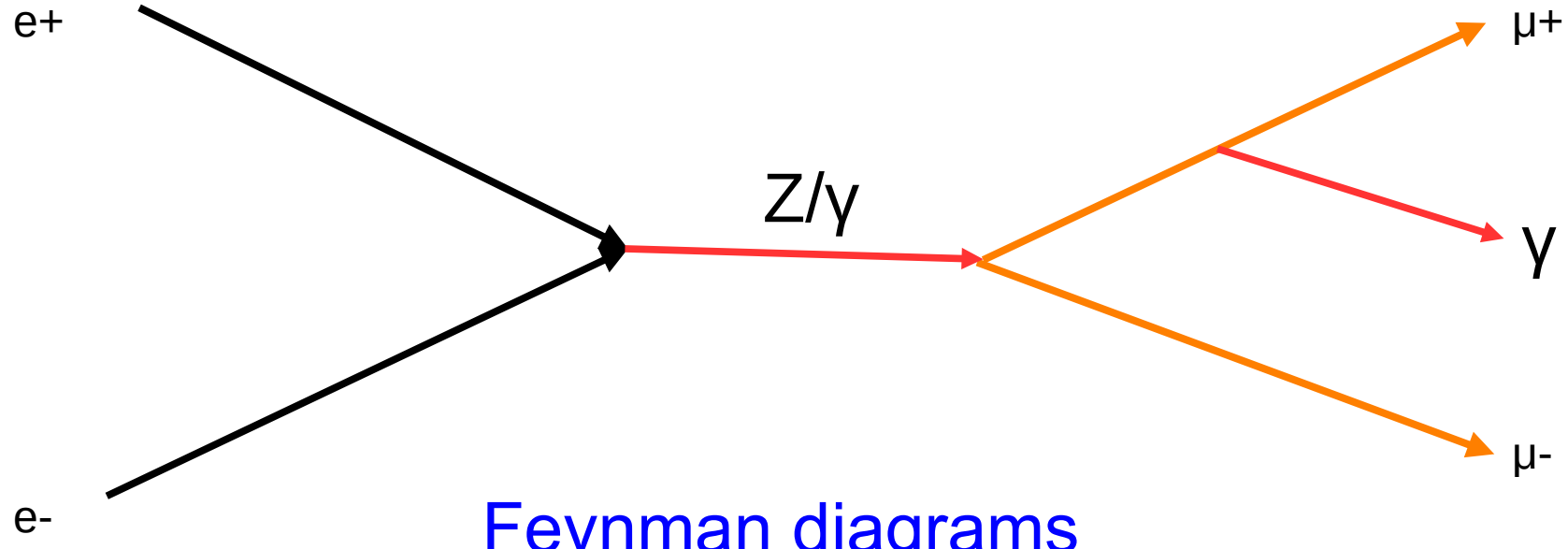
Gravitational Lensing



How to think about particle collisions

Some basic ‘rules’

- Single collision cannot be predicted: Quantum Mechanics is probabilistic
- We need to study a long, ideally infinite number of collisions
- We can draw diagrams how collisions happen
- Certain rules apply: conservation laws (ex. Charge), coupling strength
- Particles have mass and lifetimes ….
- All ‘possible diagrams’ must be considered: simple diagrams are likely



Feynman diagrams

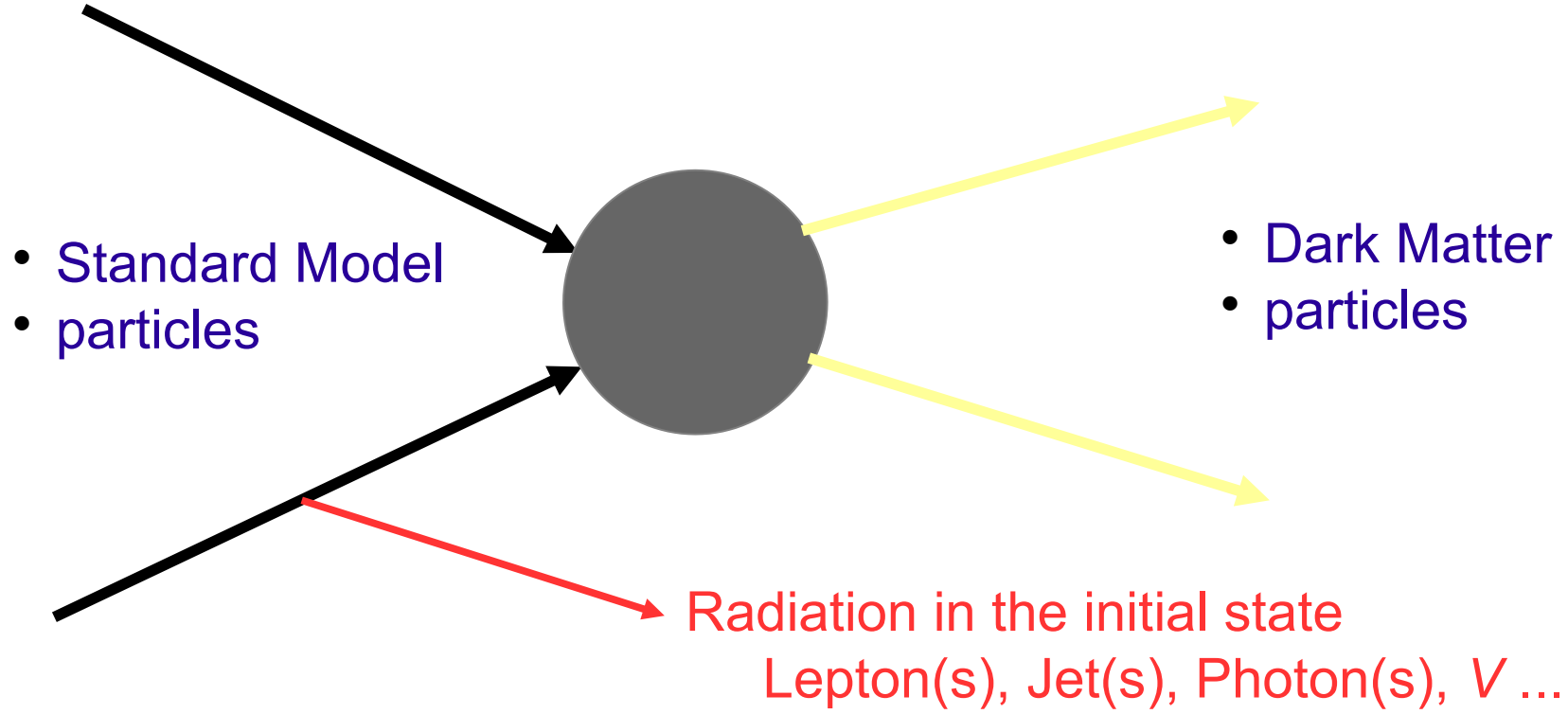
Initial state

final state

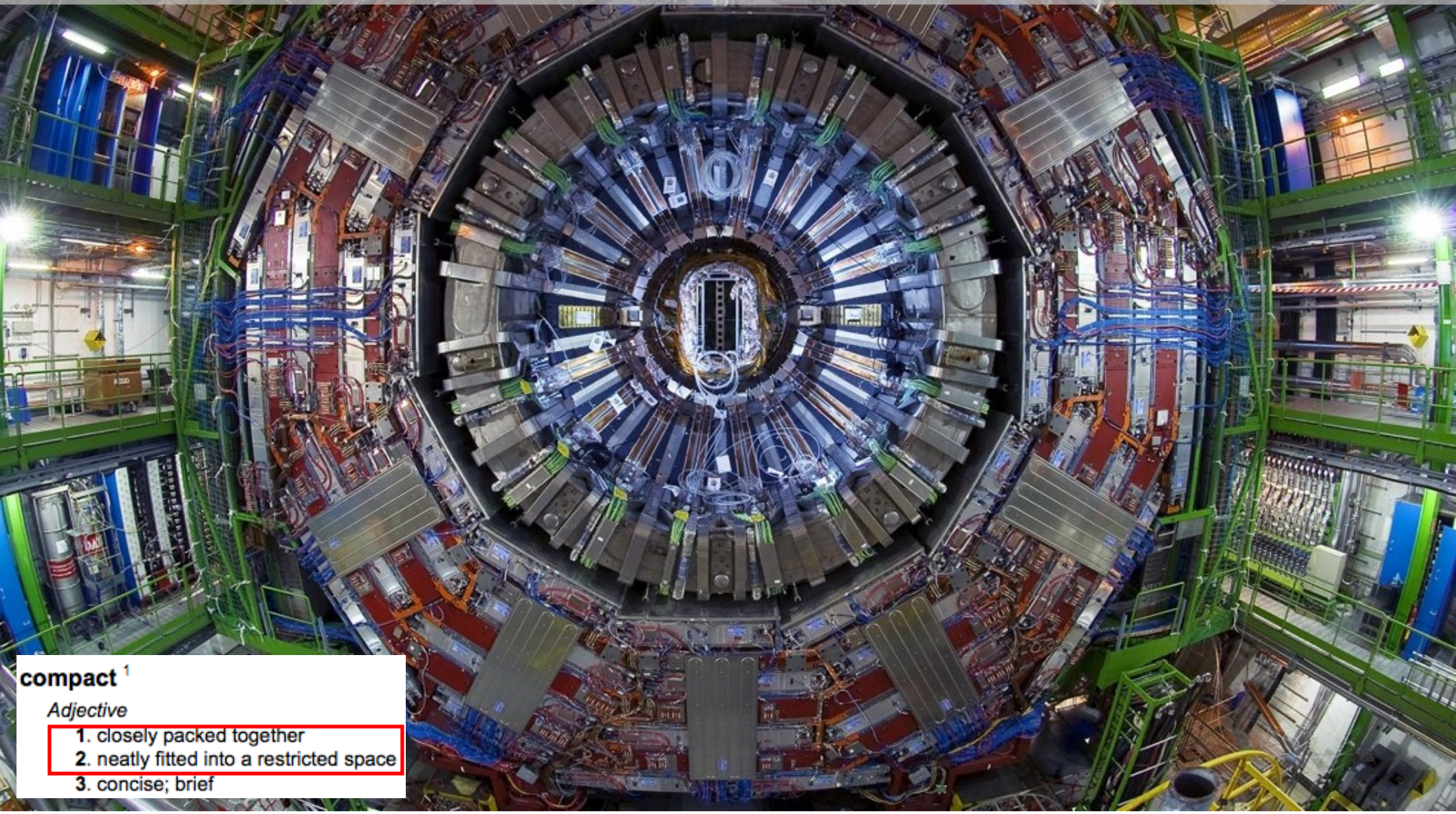
Searching Dark Matter with CMS

Signature

- Dark matter does not interact with detector
- Sooo…. the detector is empty?
- But if the initial state has radiation …. Well defined:



Compact Muon Solenoid



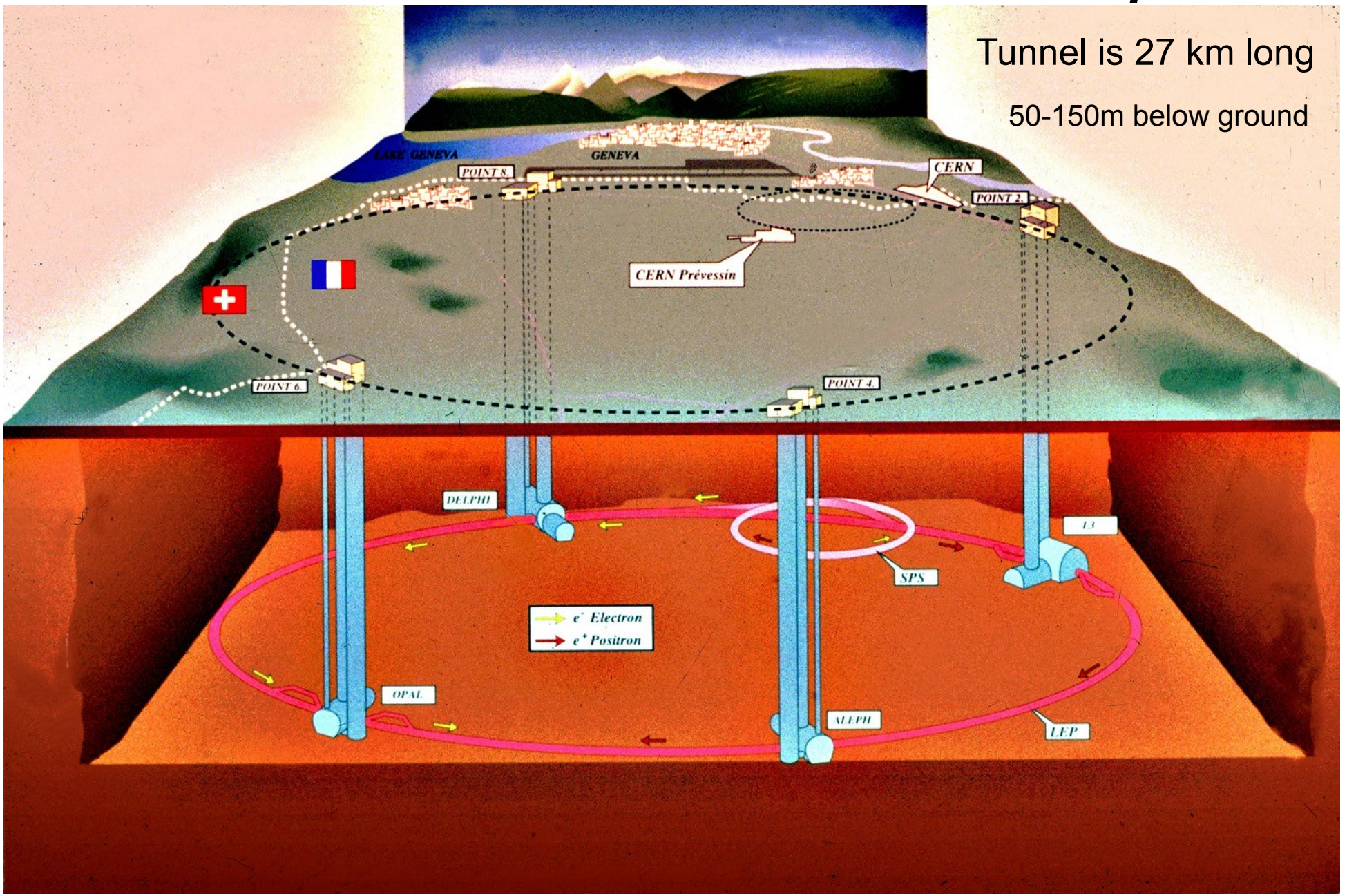
compact [1]

Adjective

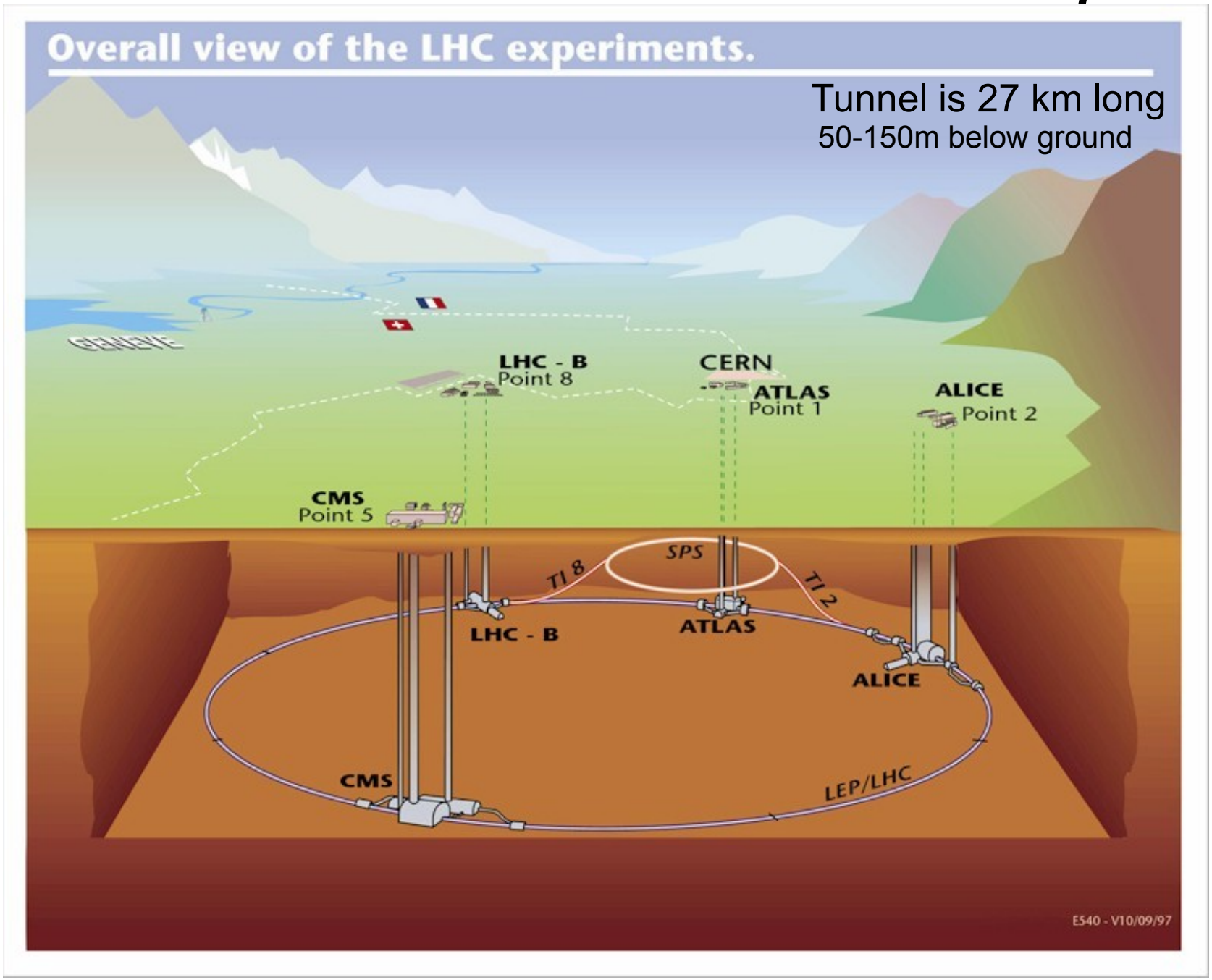
1. closely packed together
2. neatly fitted into a restricted space
3. concise; brief

Overview: CERN (Geneva, Switzerland)

The LEP/LHC Tunnel Setup



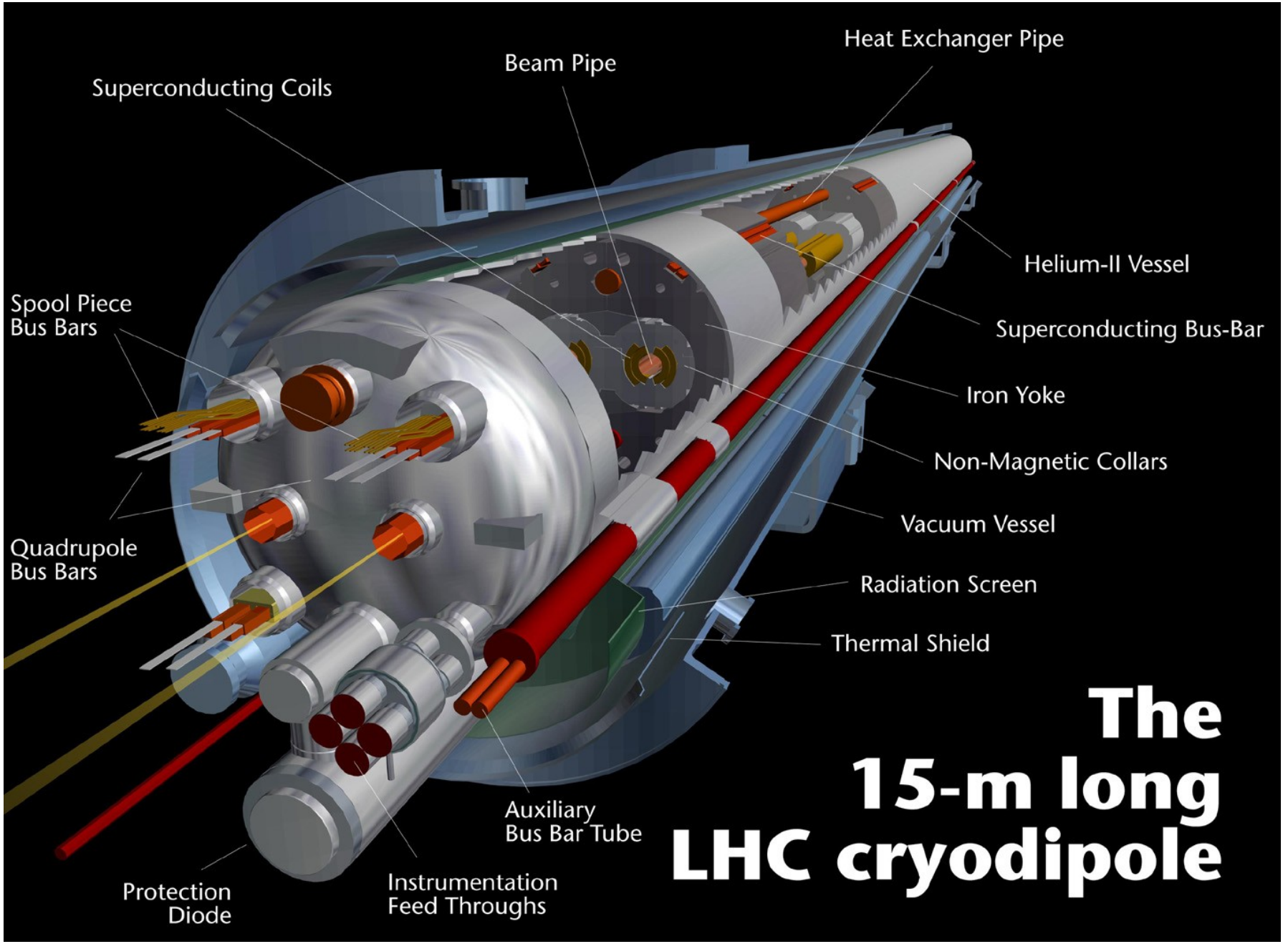
The LEP/LHC Tunnel Setup



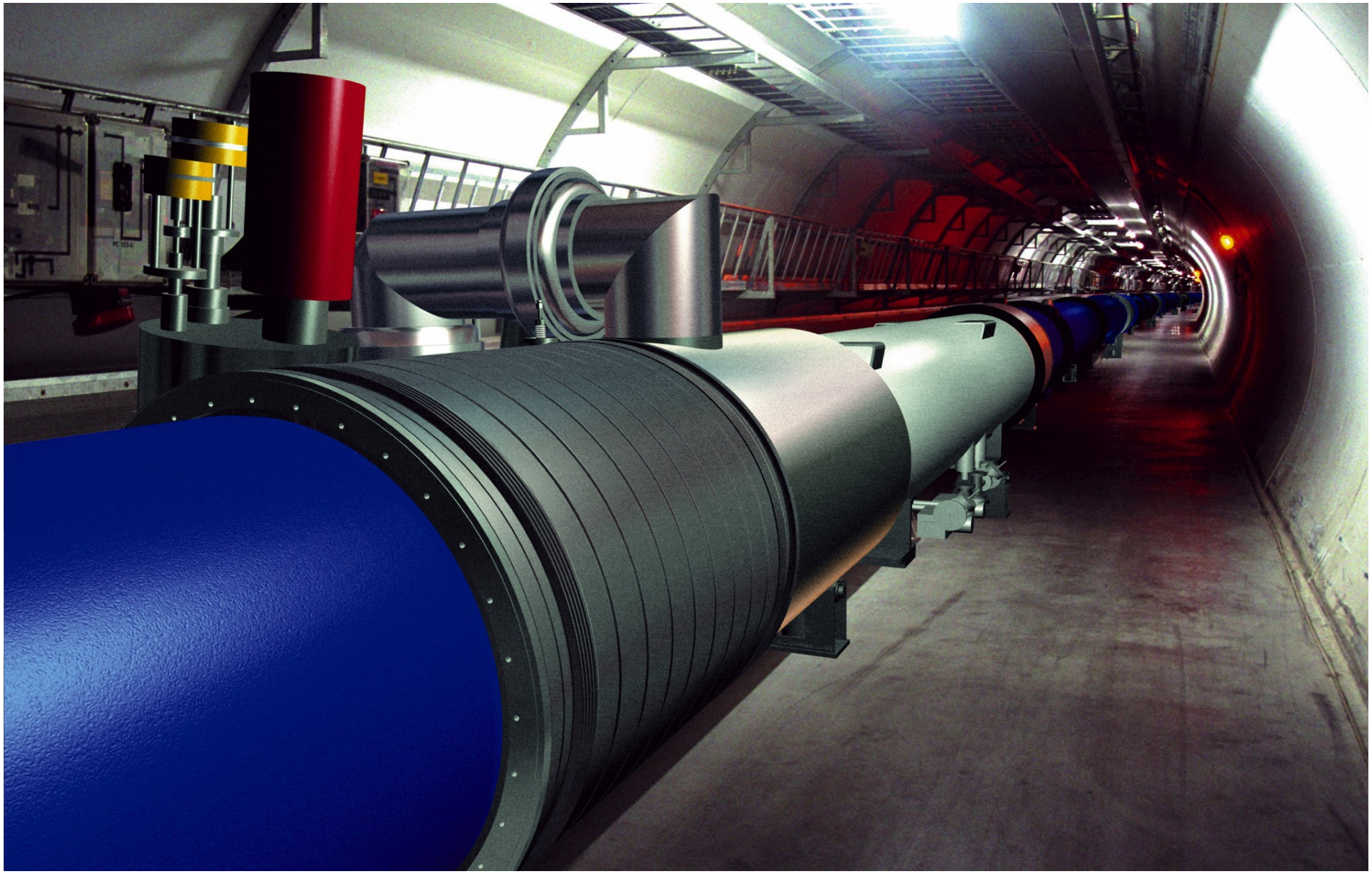
LEP Tunnel before LHC

Empty Tunnel: LEP Disassembled

The LHC Dipoles



LHC Pictures: Simulation



LHC Pictures: Real Dipoles

LHC Pictures: Tunnel with Beamlines

LHC Experiments

Two omnipurpose* detectors

- Atlas
- CMS (C.P. experiment)

One dedicated *B* physics experiment

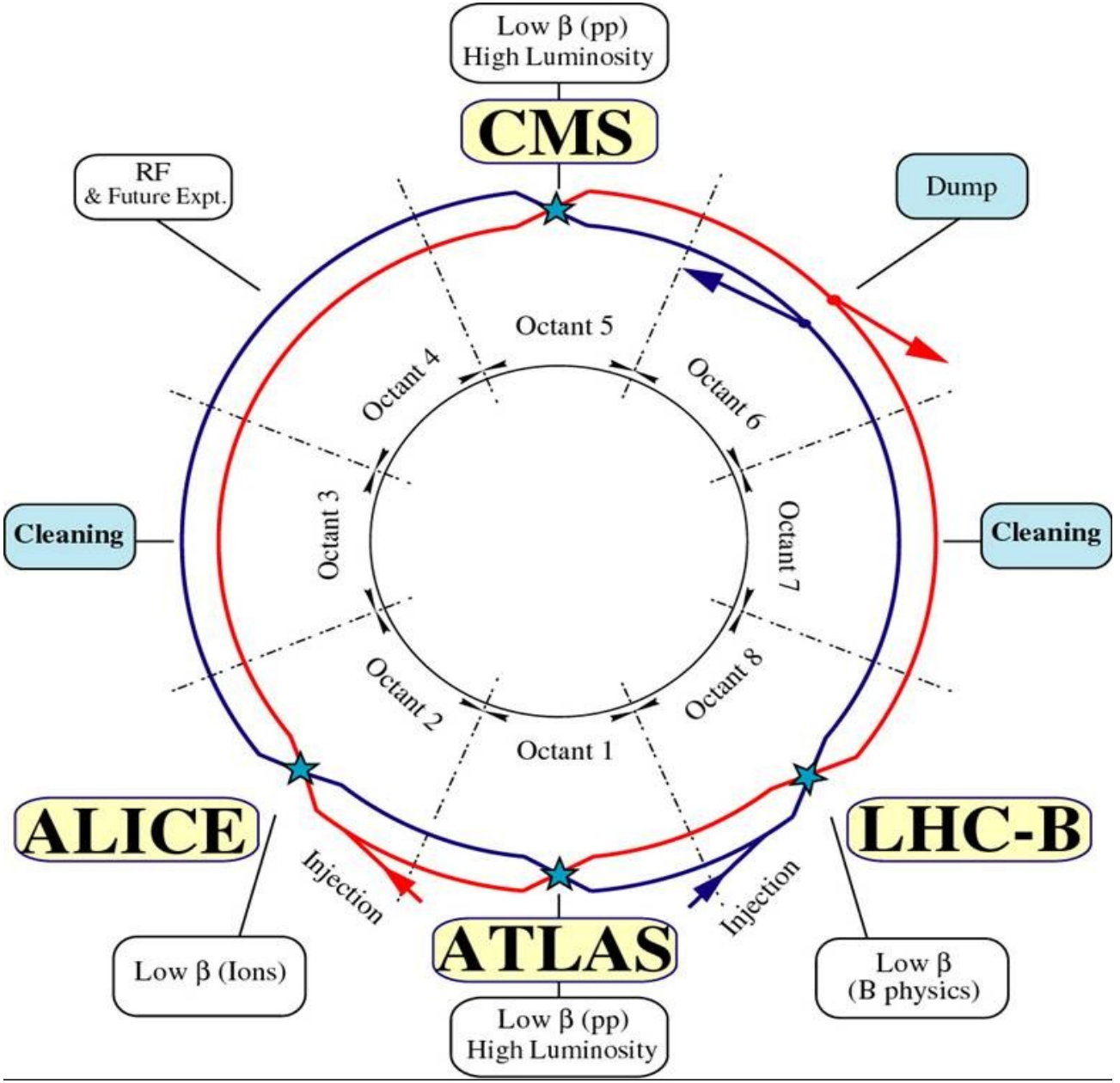
- LHCb (Eluned Smith experiment)

One dedicated heavy ion experiment

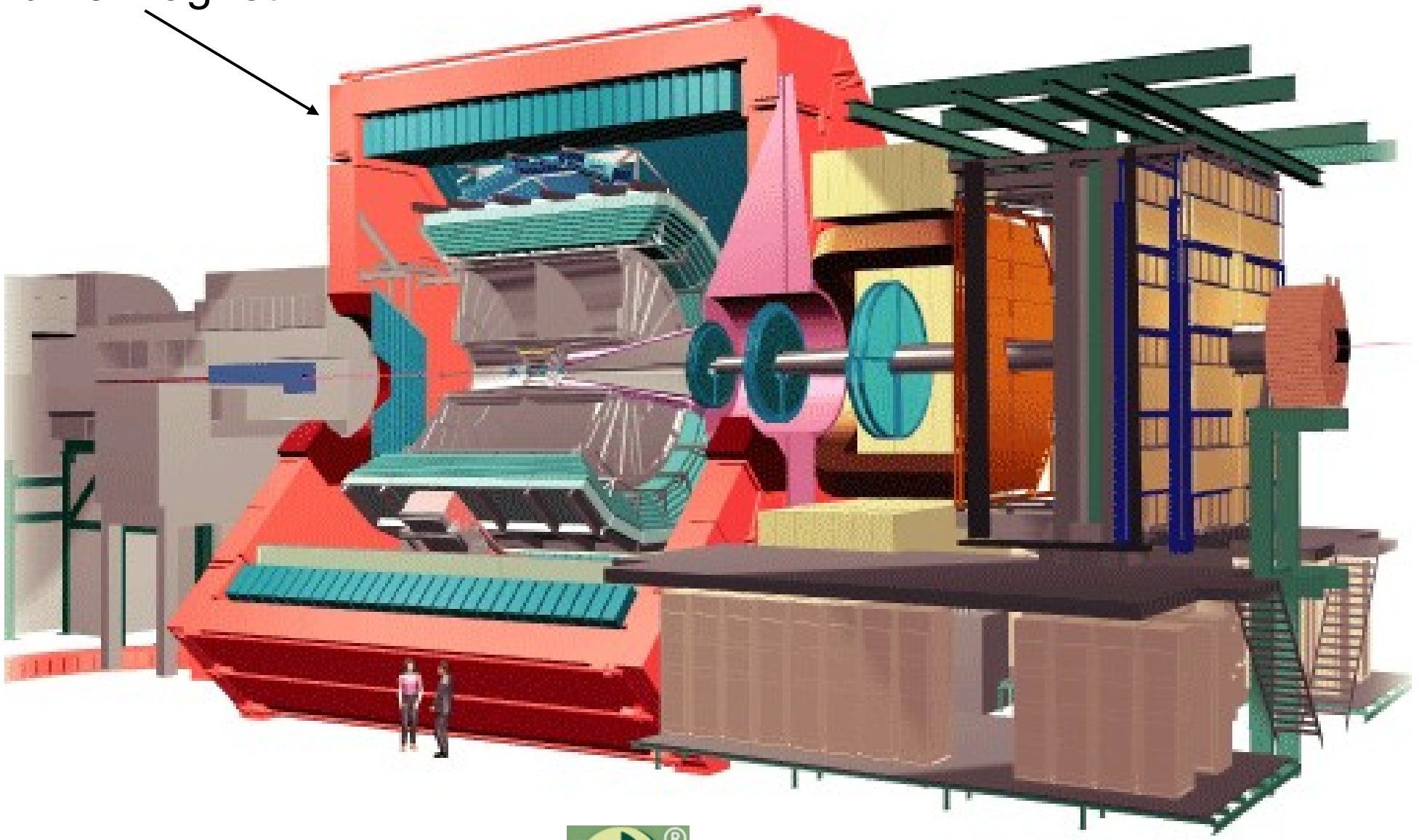
- Alice

* multipurpose = do heavy ion and *B* physics as well

The LHC Experiments

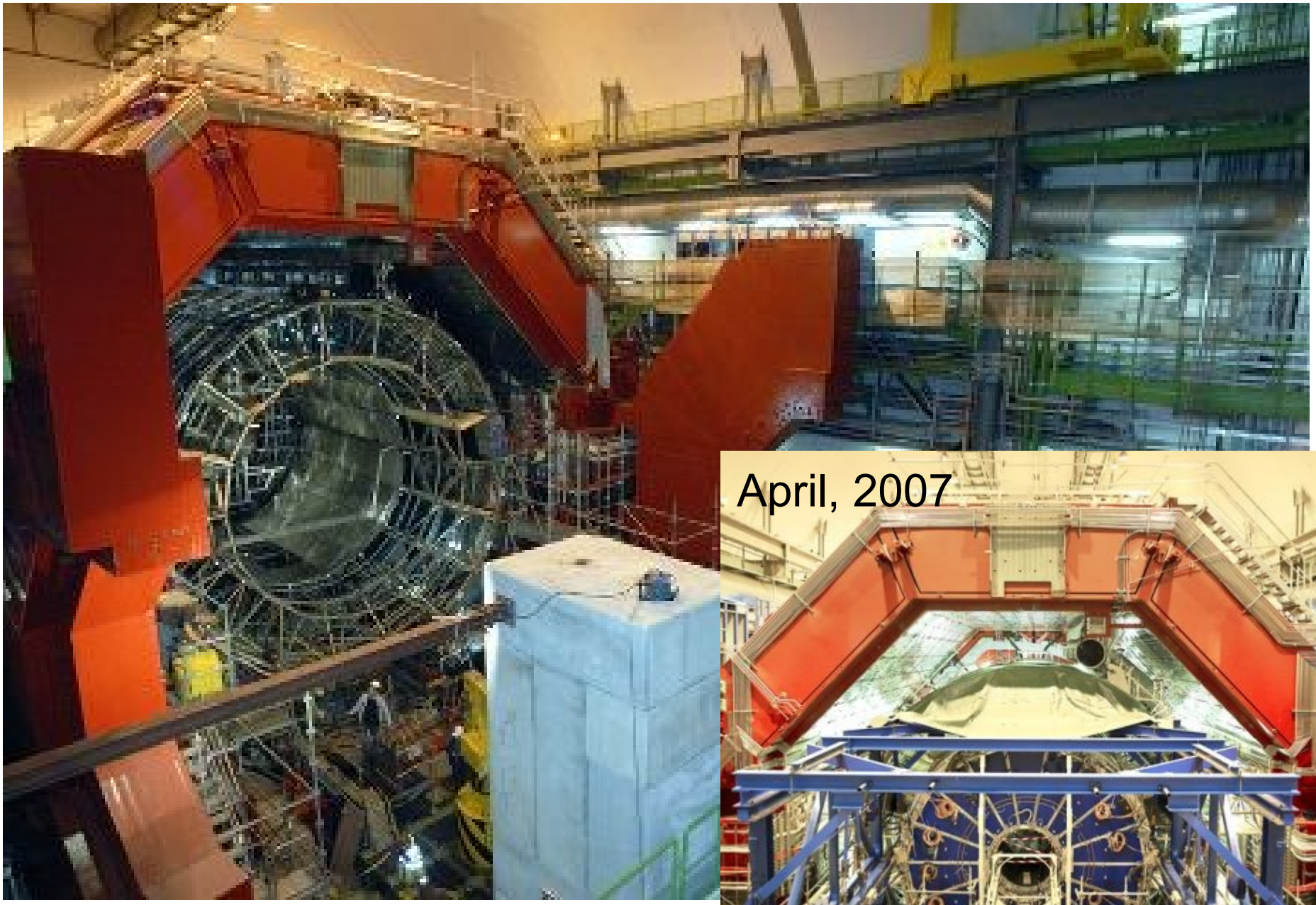


Alice: Detector Sketch



particle physicists do recycle

Alice: December 2006



Atlas/CMS Motivation

LHC is a new energy regime: uncharted territory

The guaranteed mission (seek and destroy)

- find the Standard Model Higgs: completes SM, for now
- do not find the SM Higgs: falsify the model because machine fully covers available phase space

The case for beyond the Standard Model

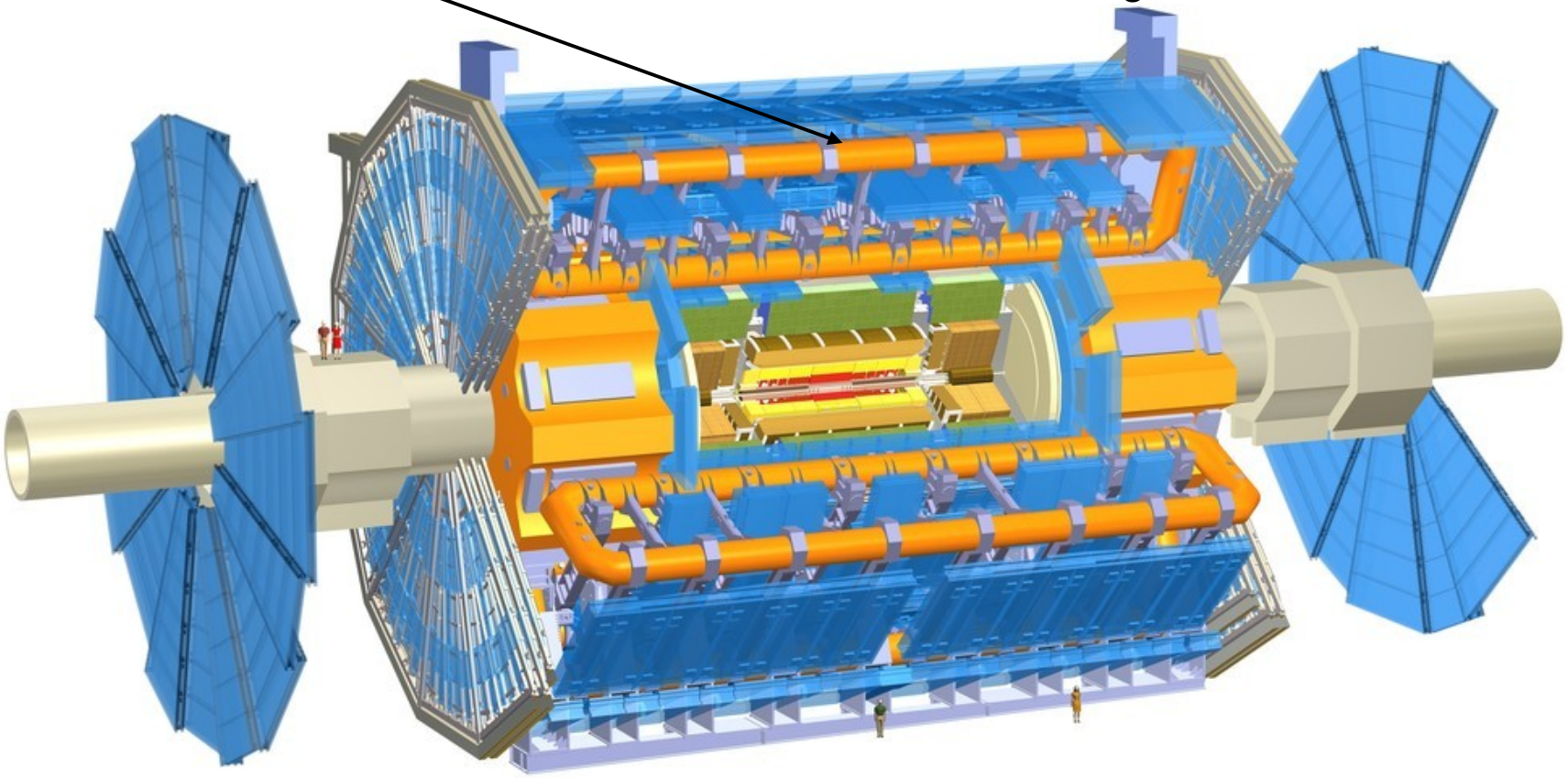
- new energy regime opens new doors
- anything beyond the Standard Model is a sensation
- be it SUSY, extra dimensions, leptoquarks, Z', ... or even better: the completely unexpected

Atlas: Detector Sketch

the biggest collider detector ever, by far

eye catcher: central air core toroid magnet

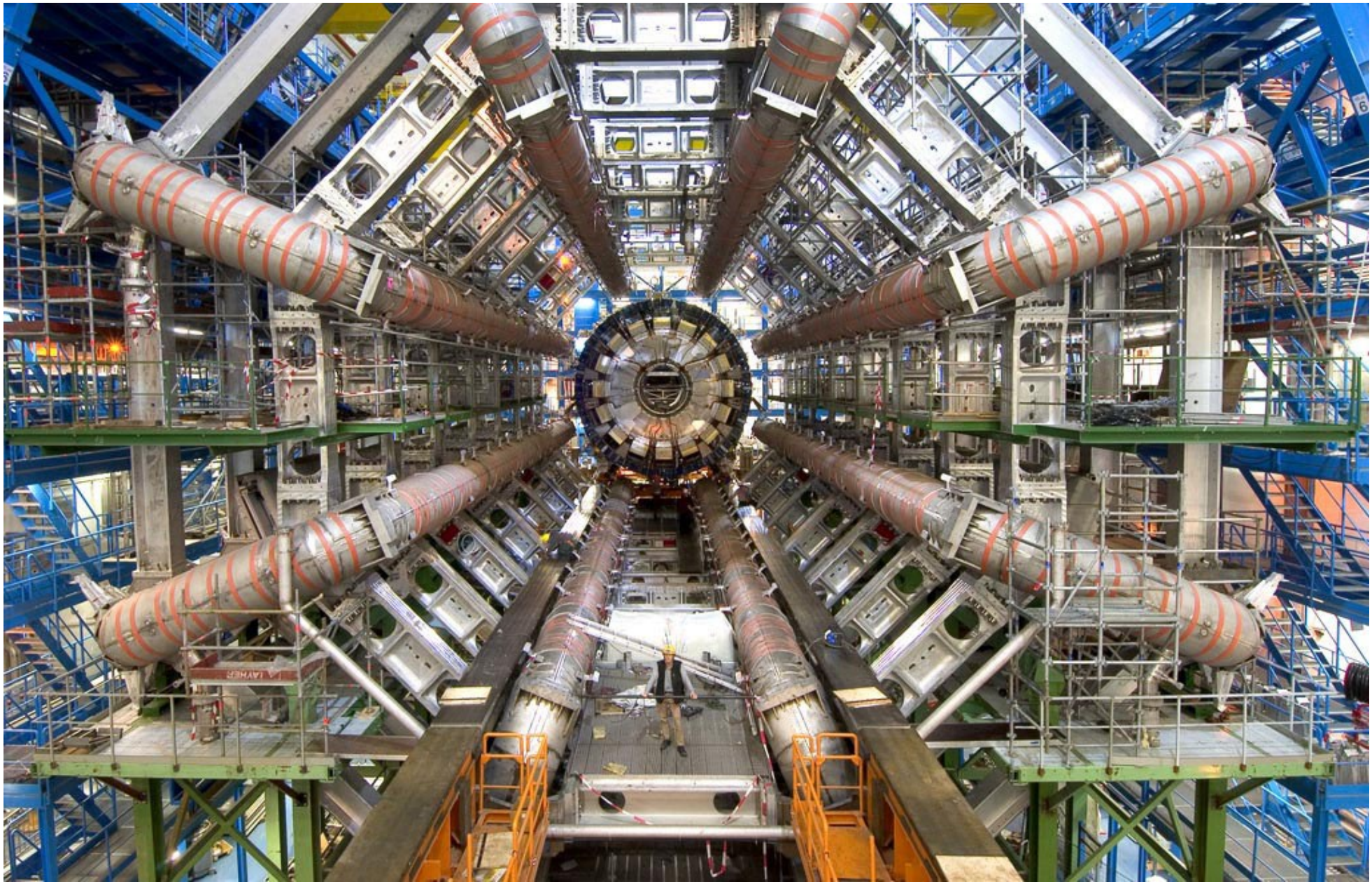
7,000 ton weight, 25 m diameter, 45 m long



light weight construction: if wrapped in plastic it floats on water (22,000 m^3)

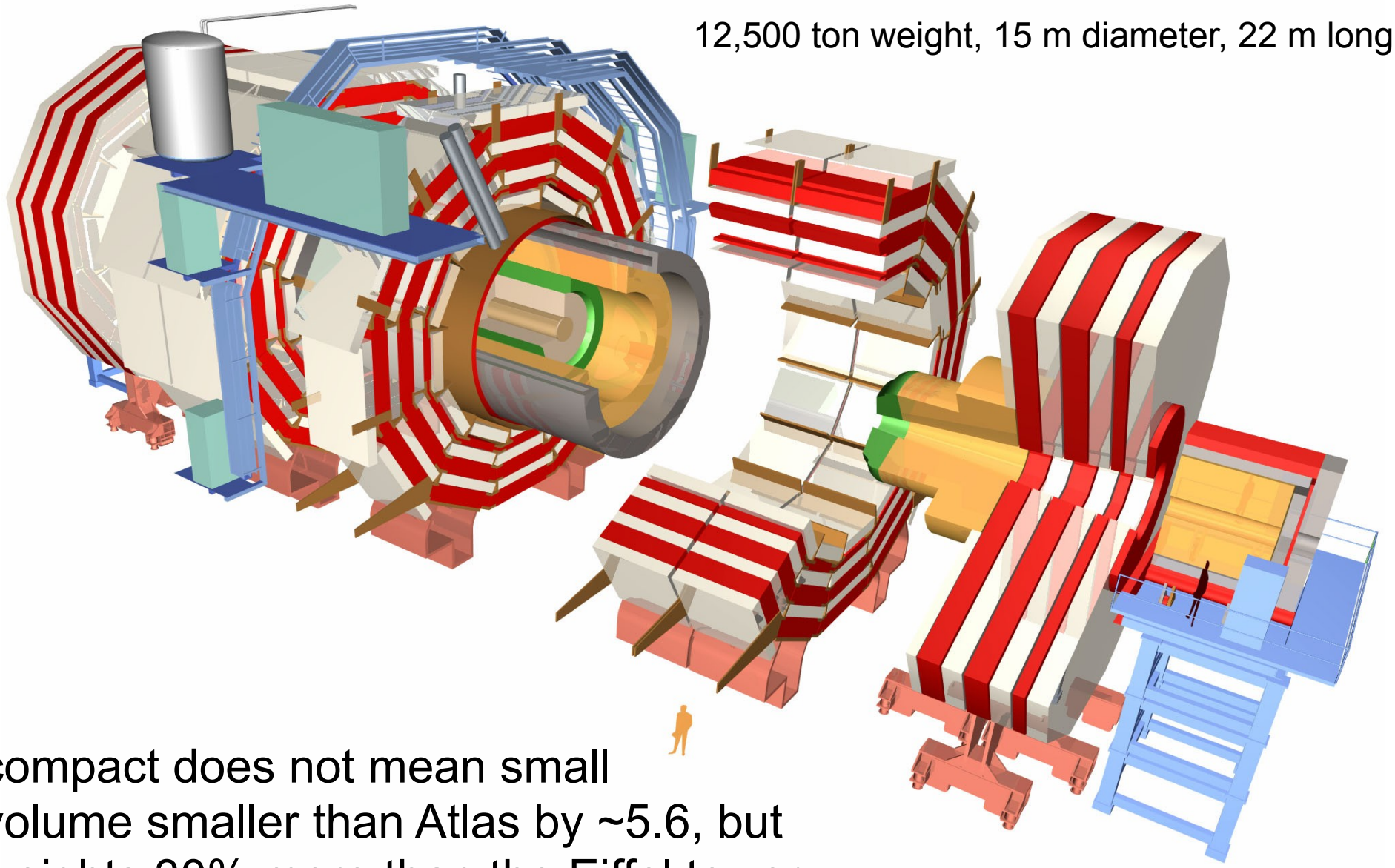
still, weights more than half the Eiffel tower

Atlas: Real Installation



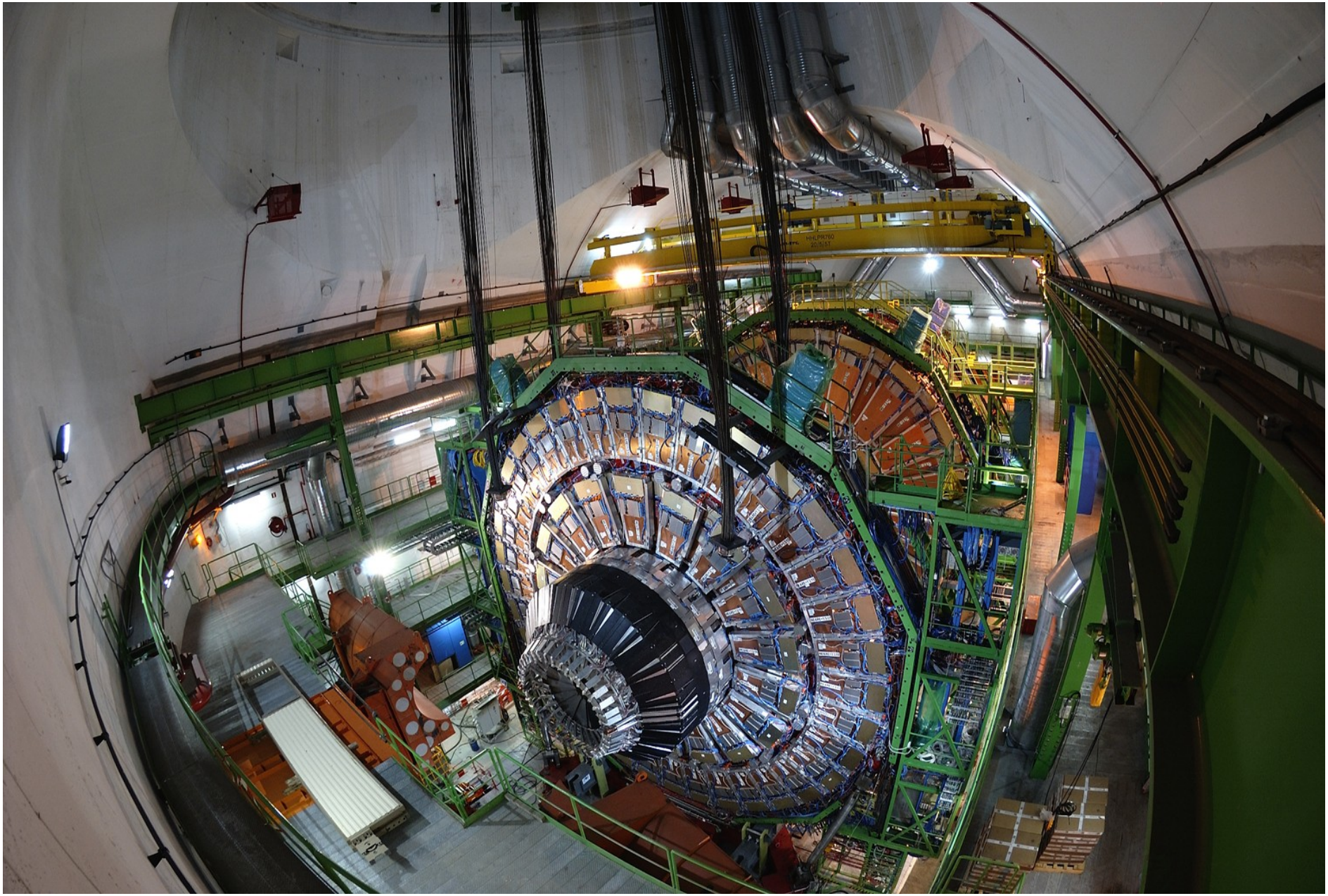
CMS – Compact Muon Solenoid

12,500 ton weight, 15 m diameter, 22 m long



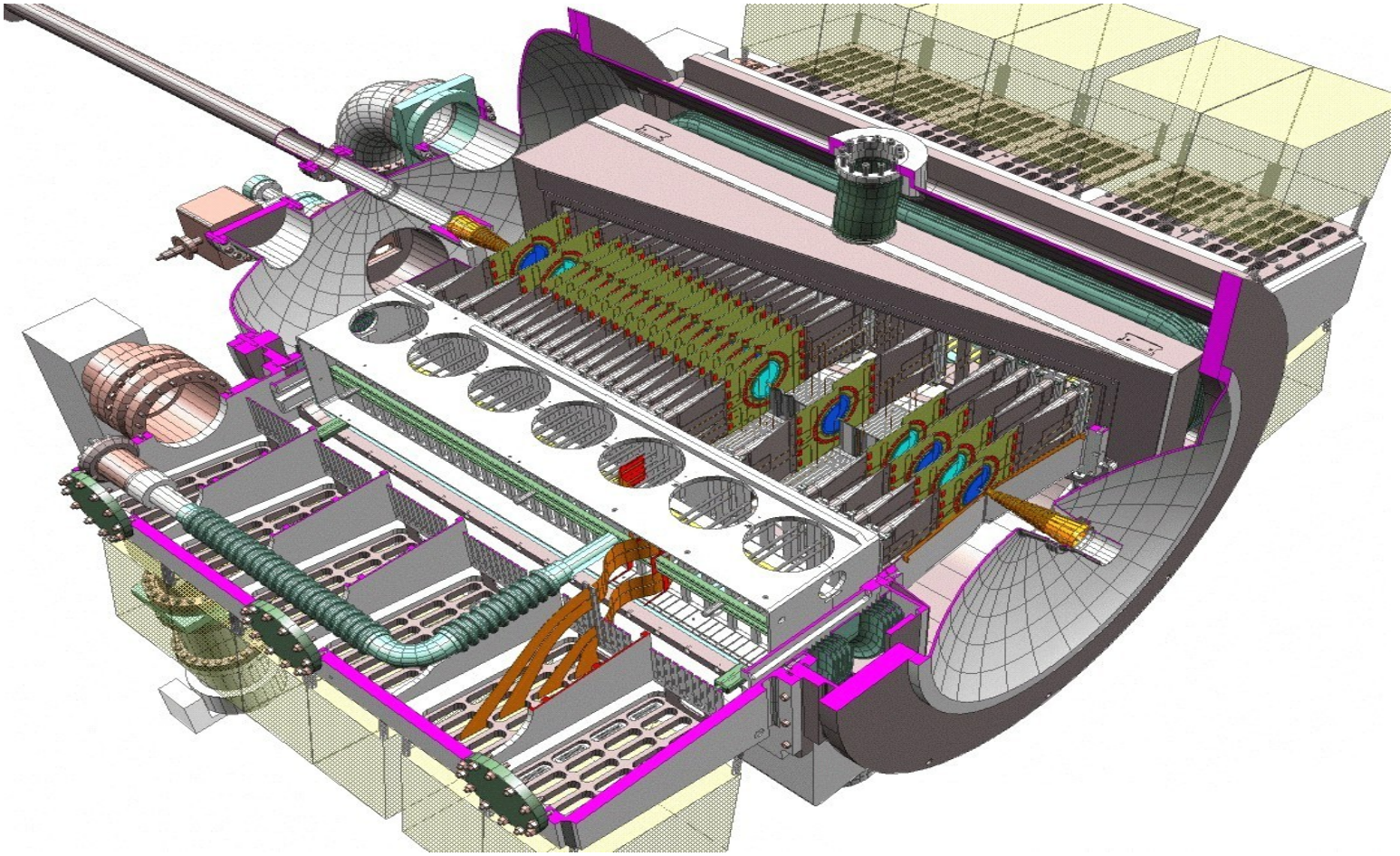
compact does not mean small
volume smaller than Atlas by ~5.6, but
weights 30% more than the Eiffel tower
eye catcher: brilliant design in separately removable slices

CMS: Installation

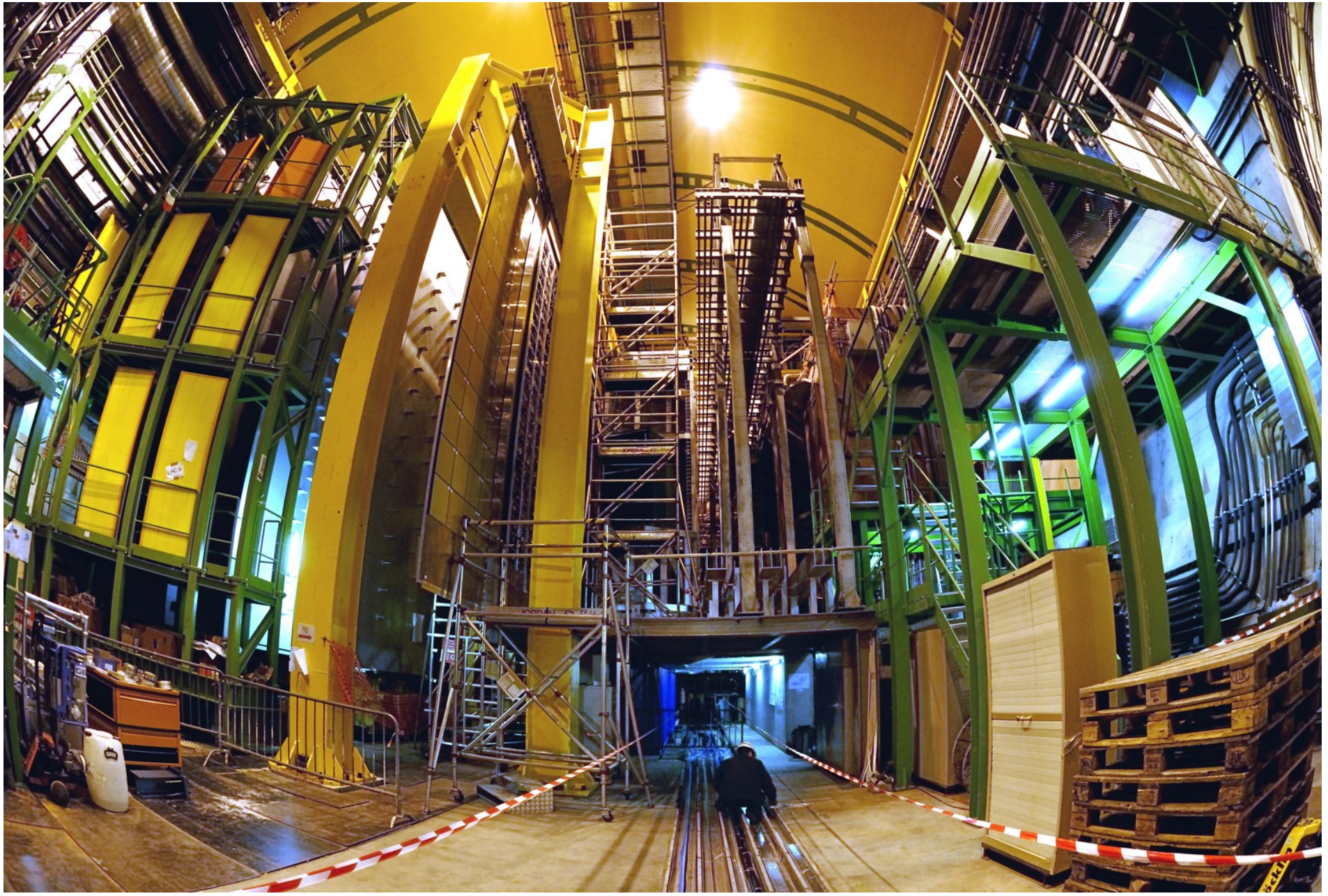


LHCb: Mission and Sketch

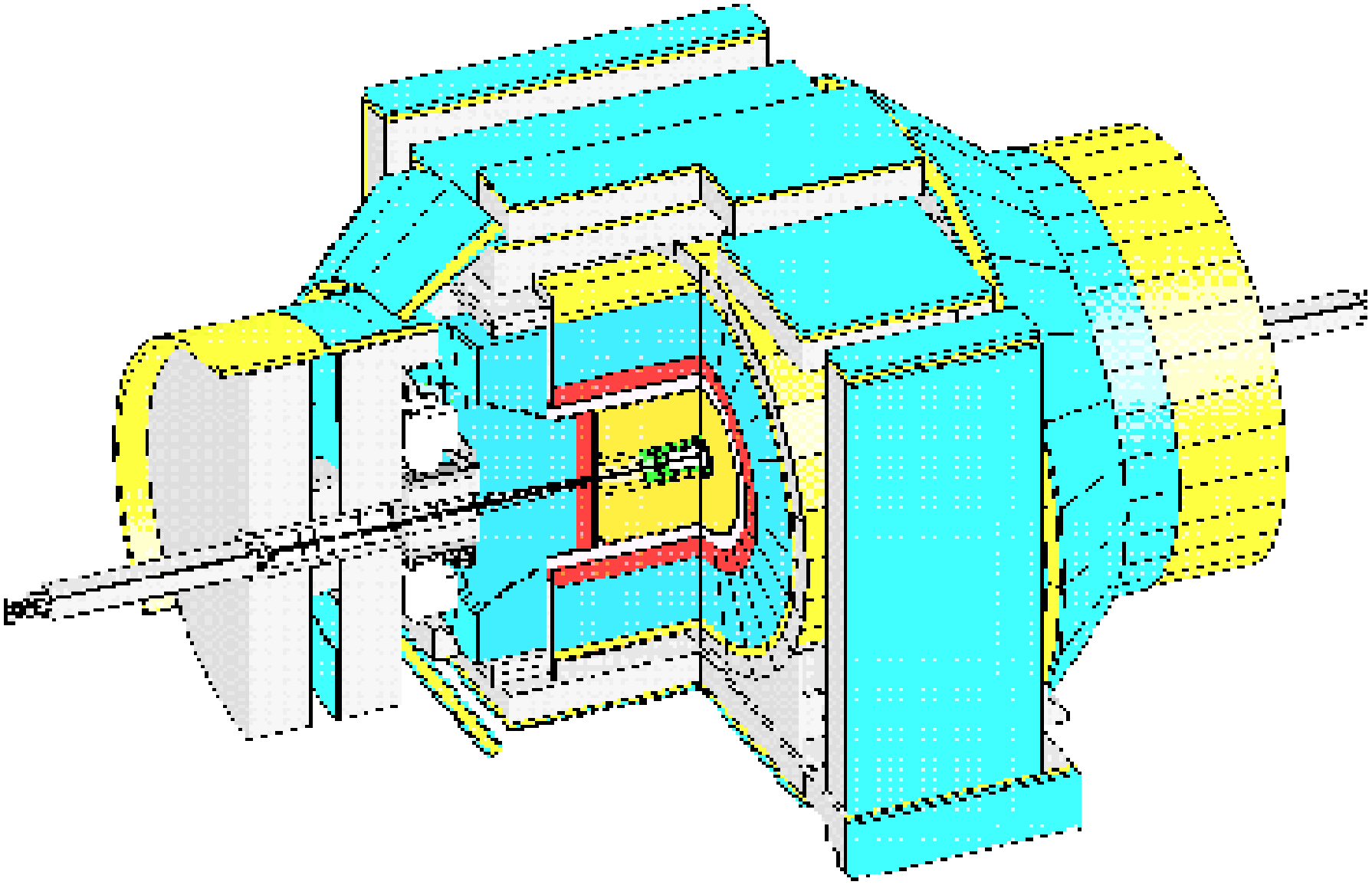
- The Large Hadron Collider beauty experiment
- for precise measurements of *CP* violation and rare decays



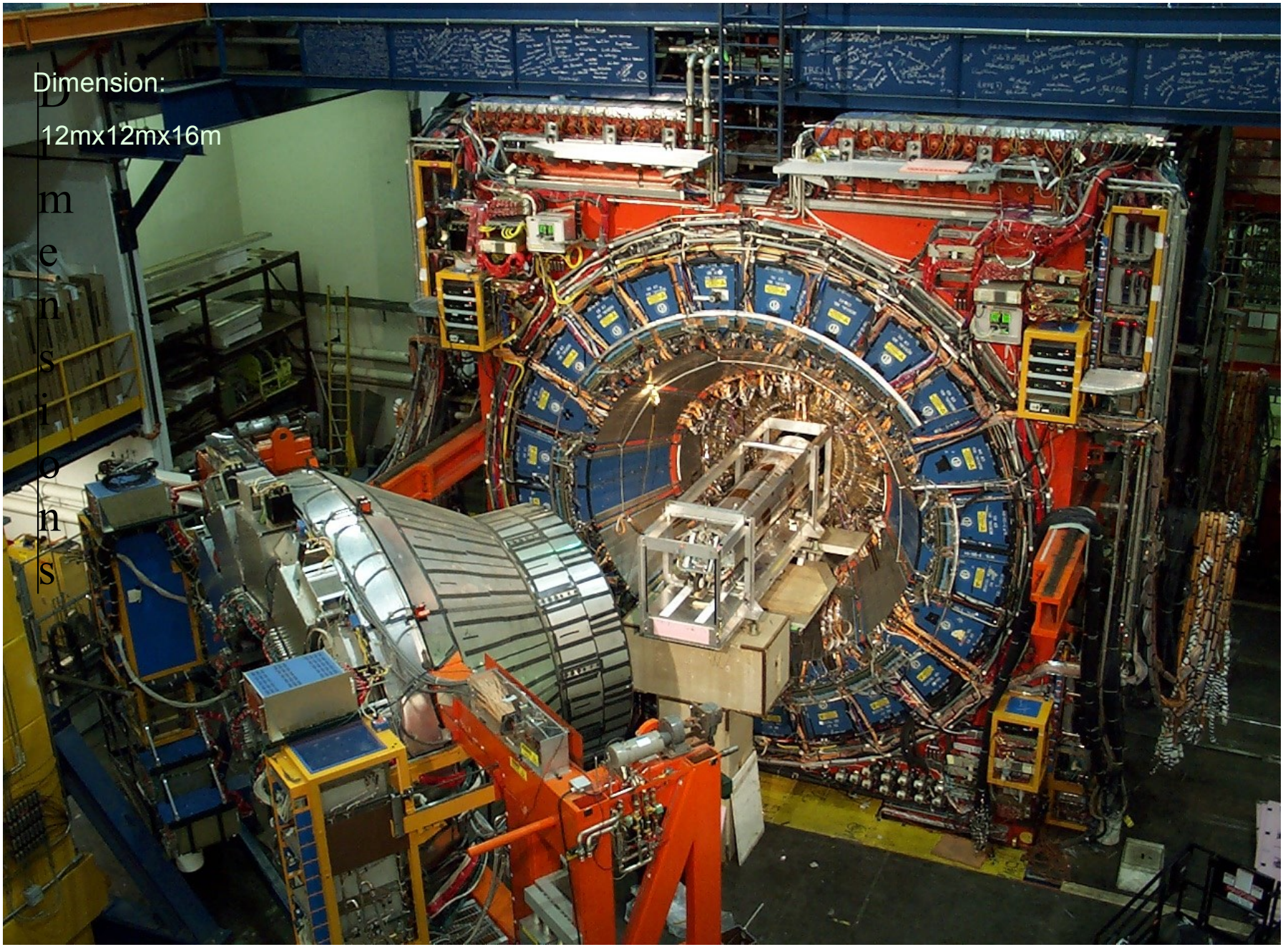
LHCb: At the Interaction Point



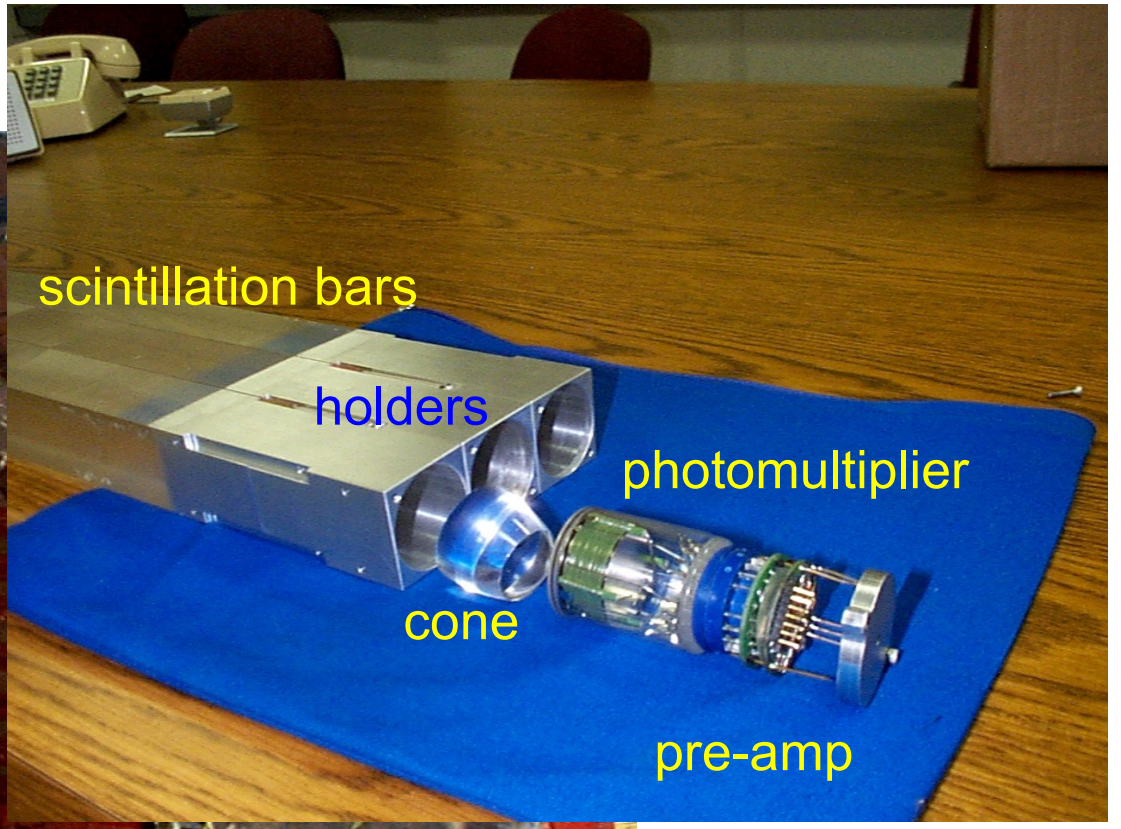
CDF: Sketch

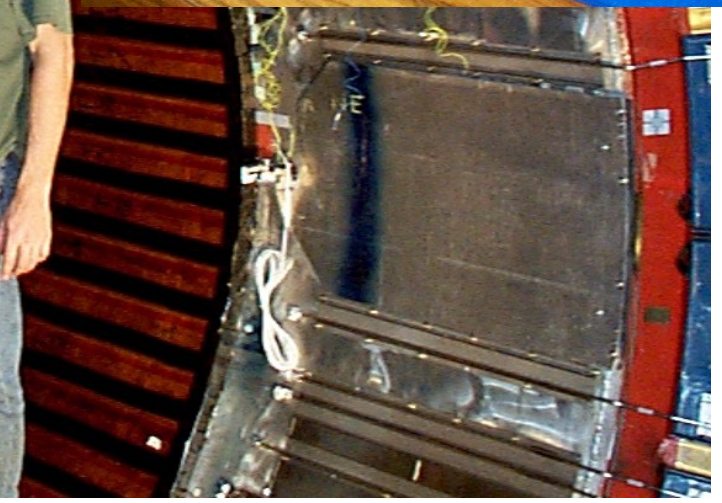


CDF Detector Pictures



CDF: Time Of Flight Detector





CDF: Central Outer Tracker

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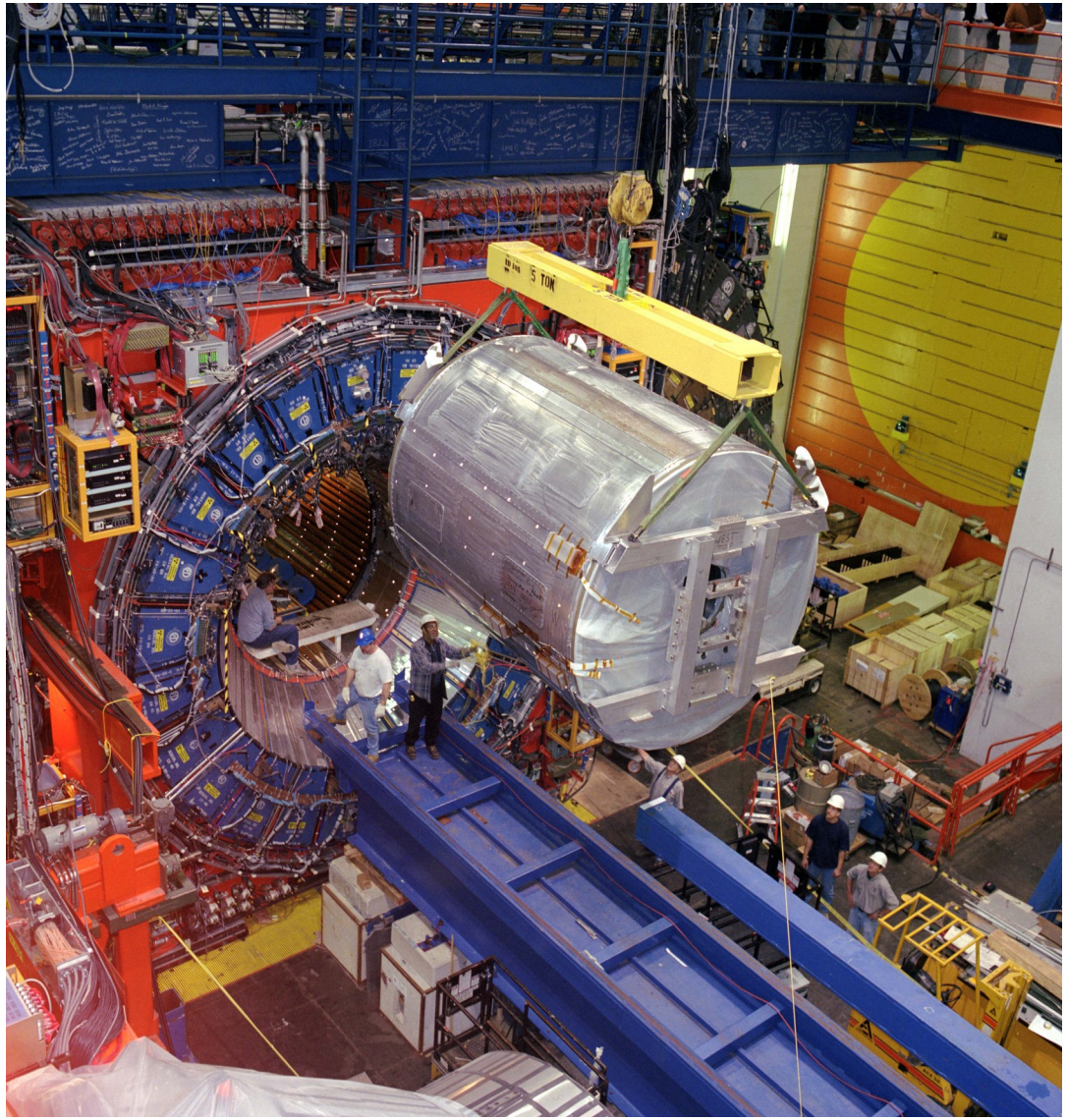
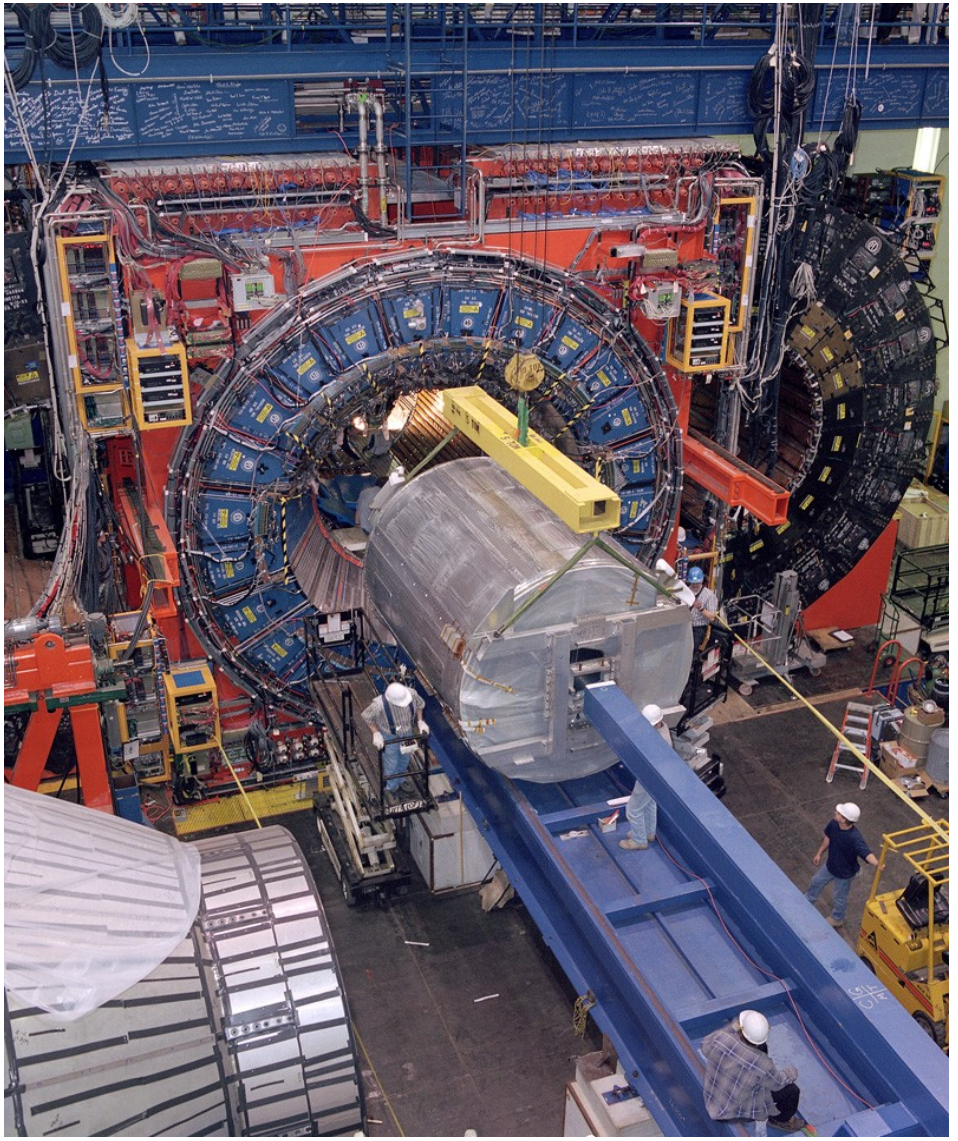
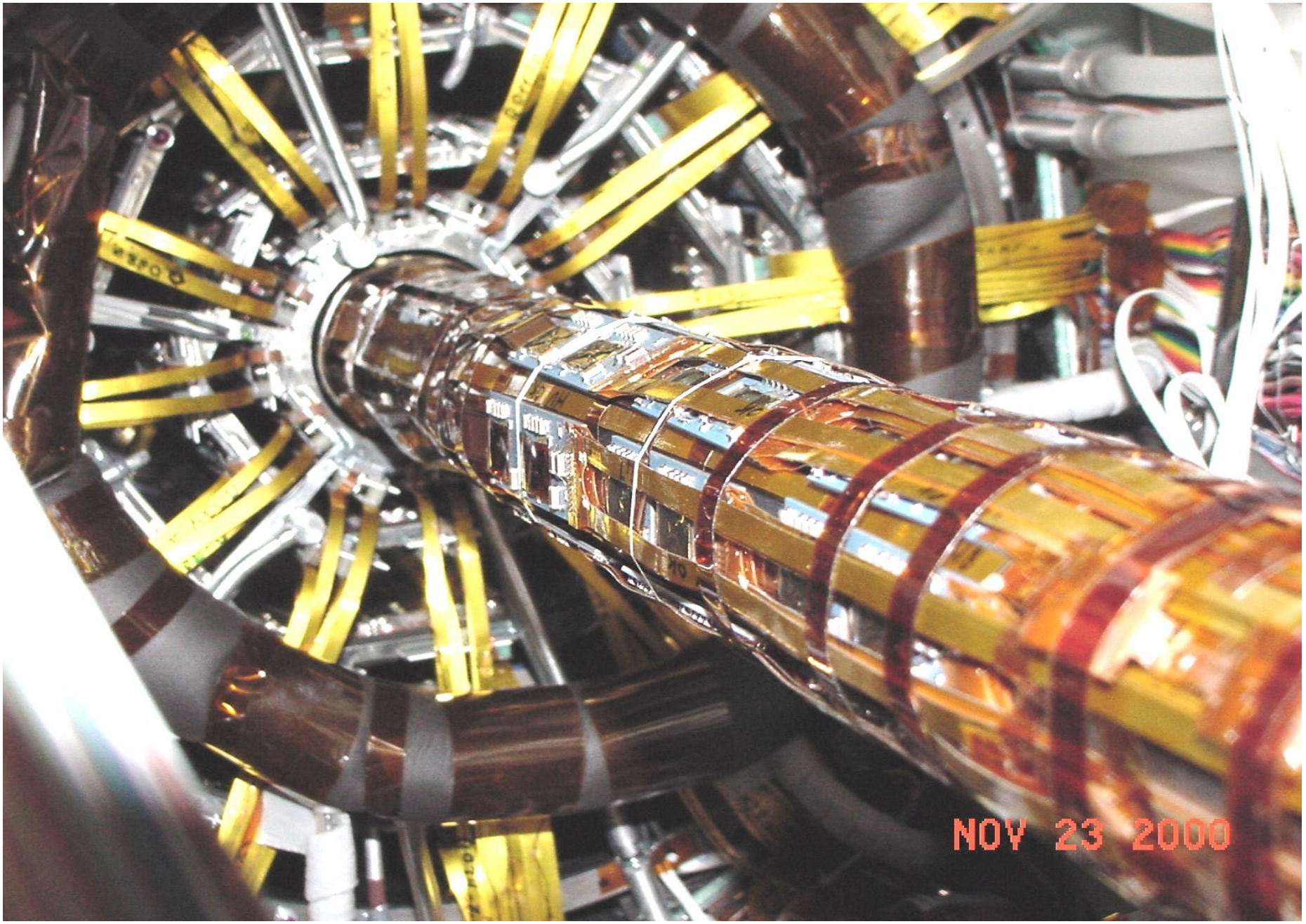




CDF: Silicon Detector

CDF: Silicon Vertex Detector



Conclusions

We have a month ahead of us

- Learn how an experimenters work
- Experimental setup
- Basic physics ideas
- Basic measurements
- Give a talk

Instructions for course

- get registered for a user account on subMIT our computing resource
- Review the projects to see which one you are most interested in