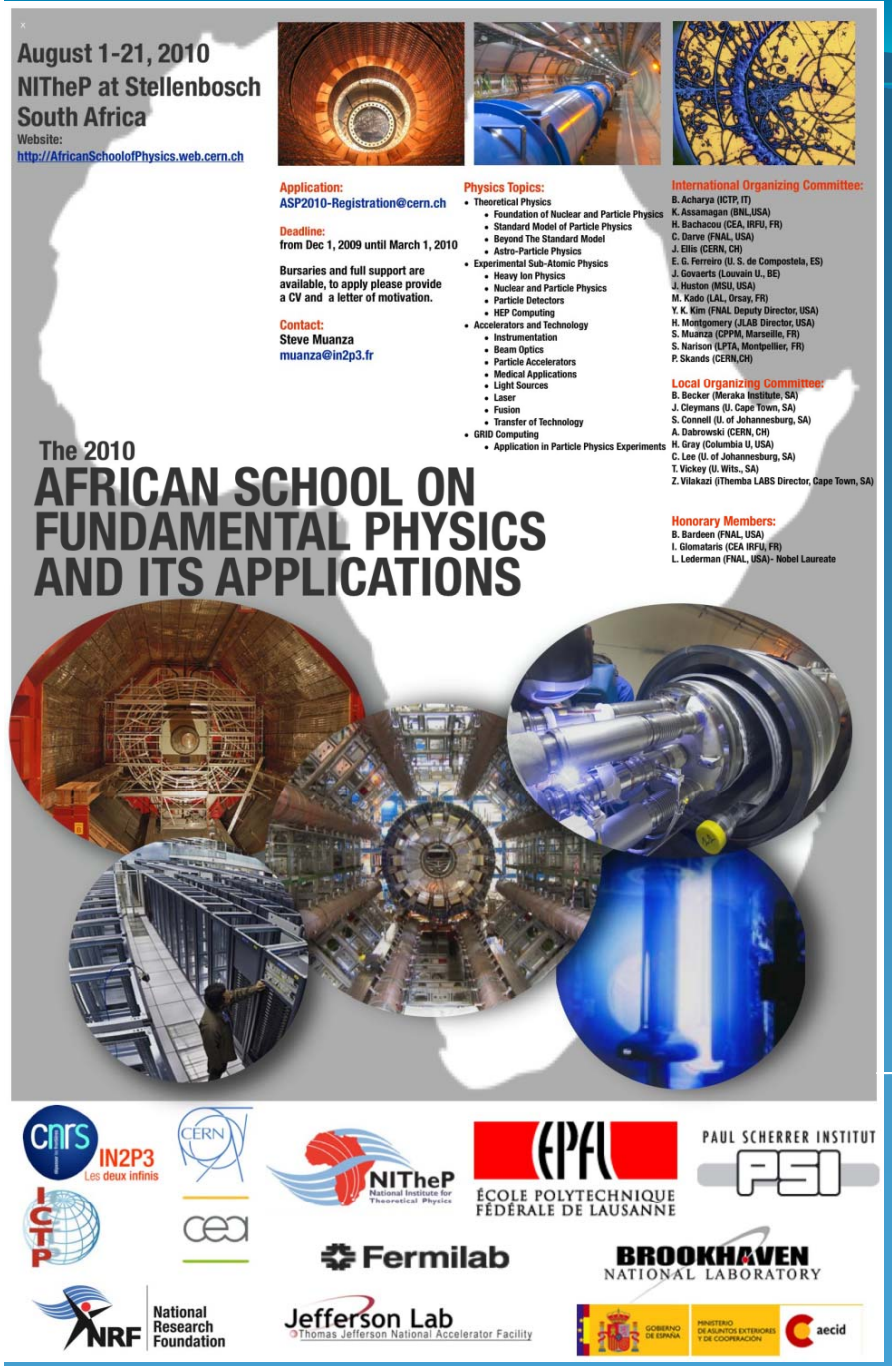


How to answer Gauguin's question in Physics...

Christine Darve / FNAL
Steve Muanza / IN2P3

MTN Science Center - August 6th, 2010

A Joint Collaboration formed of:

- France: CNRS-IN2P3, CEA , Institut des Grilles,
- Italy: ICTP,
- USA: FNAL, Jlab, BNL,
- Spain: Univ. S. de Compostela,
- Switzerland: CERN, PSI, EPFL,
- SA: NITheP, NRF.

Another Physics world without Frontiers:

➔ The first biennial African School of Fundamental Physics and its Applications

- The aim of the school is to build capacity to harvest, interpret, and exploit the results of current and future physics experiments with particle accelerators, and to increase proficiency in related applications and technologies.

- Unify … not only Forces but..
  - Theoretical Subatomic Physics.
  - Experimental Subatomic Physics.
  - Accelerators and Technology.
  - Information Technology and GRID.

Student origin:	#
Algeria	1
Cameroon	2
DR Congo	6
Egypt	3
Ethiopia	5
Ghana	1
Kenya	2
Madagascar	5
Morocco	1
Nigeria	8
Rwanda	1
South Africa	12
Senegal	1
Sudan	5
Tunisia	1
Zambia	4
Zimbabwe	2
Canada	1
Germany	1
India	1
Switzerland	1
USA	1
Total ===>	65

Courtesy of Prof. Young-Kee Kim

What is the world made of?
What holds the world together?
Where did we come from?

Primitive Thinker

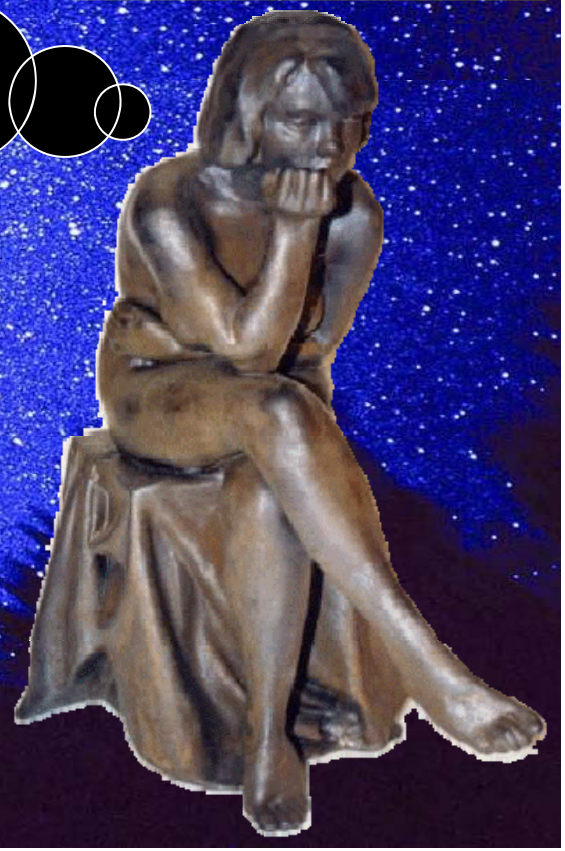
In 1872 : Gauguin still wondered:
"*Where Do We Come From*? What Are We? Where Are We Going?"

21st Century Questions in Particle Physics

Courtesy of Prof. Young-Kee Kim

- What is the origin of mass for fundamental particles?
- Why are there so many kinds of particles?
- Do all the forces become one?
- Are there extra dimensions of space?
- What are neutrinos telling us?
- Do charged leptons change from one kind to another?
- Are there undiscovered principles of nature:
  new symmetries, new physical laws?
- What happened to the antimatter?
- What is dark matter? dark energy?
- How did the universe come to be?

Evolved Thinker



"Think, think, think"

Now we accelerate... and detect...

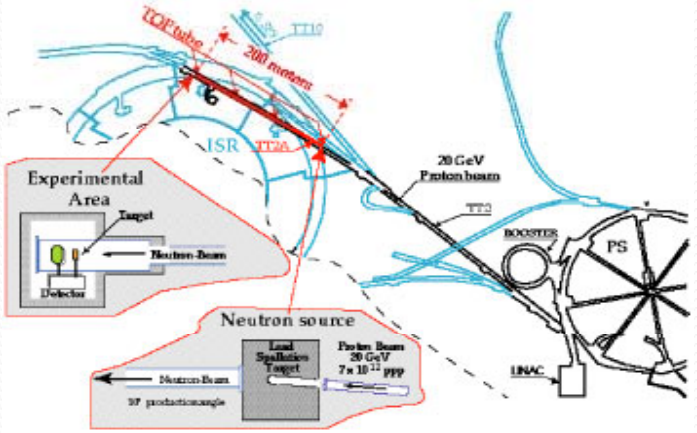
What are accelerators used for?

Today, 30,000 accelerators are in operation around world

- Discovery science: e.g. High Energy Physics

- Materials research / manufacturing: e.g. light source
- National security

- Energy and the environment
- Medical sciences: e.g. Neutron Therapy, imaging



Many generations of particle accelerators:

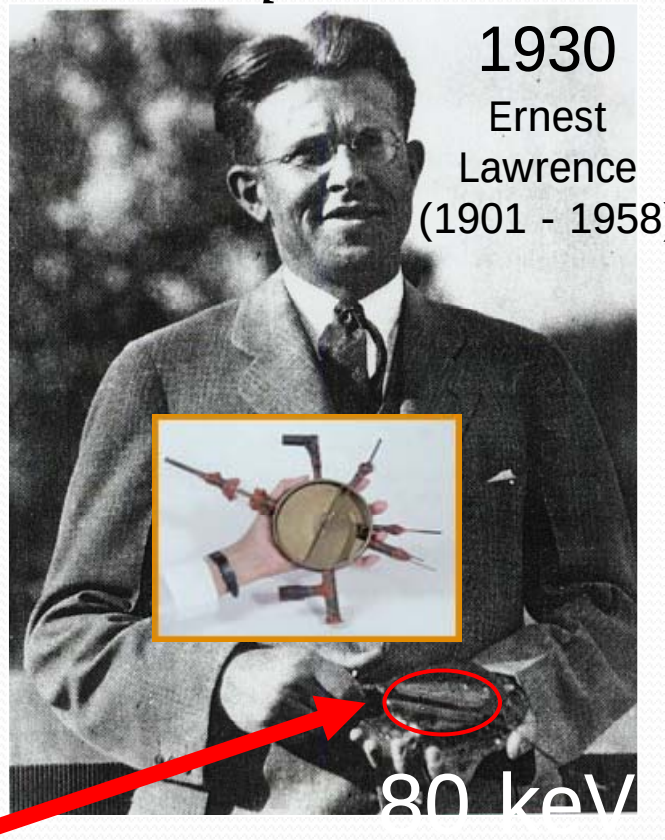
each generation built on the accomplishments of the previous ones
raising the level of technology ever higher

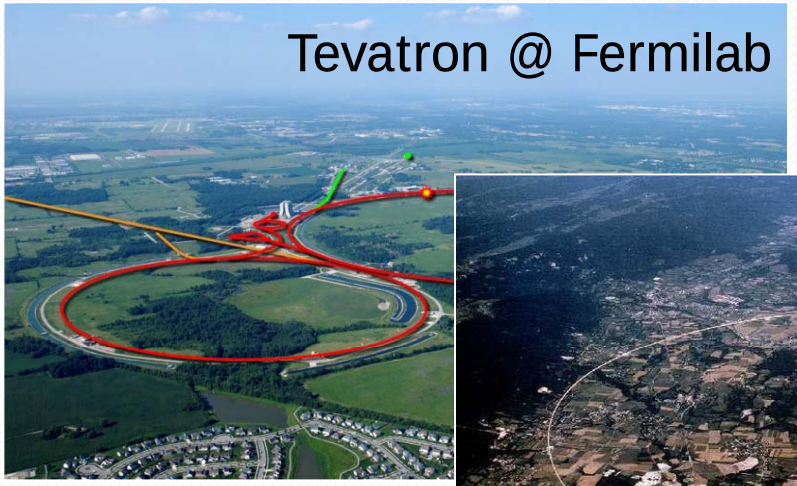
Lorentz Magnetic Force:

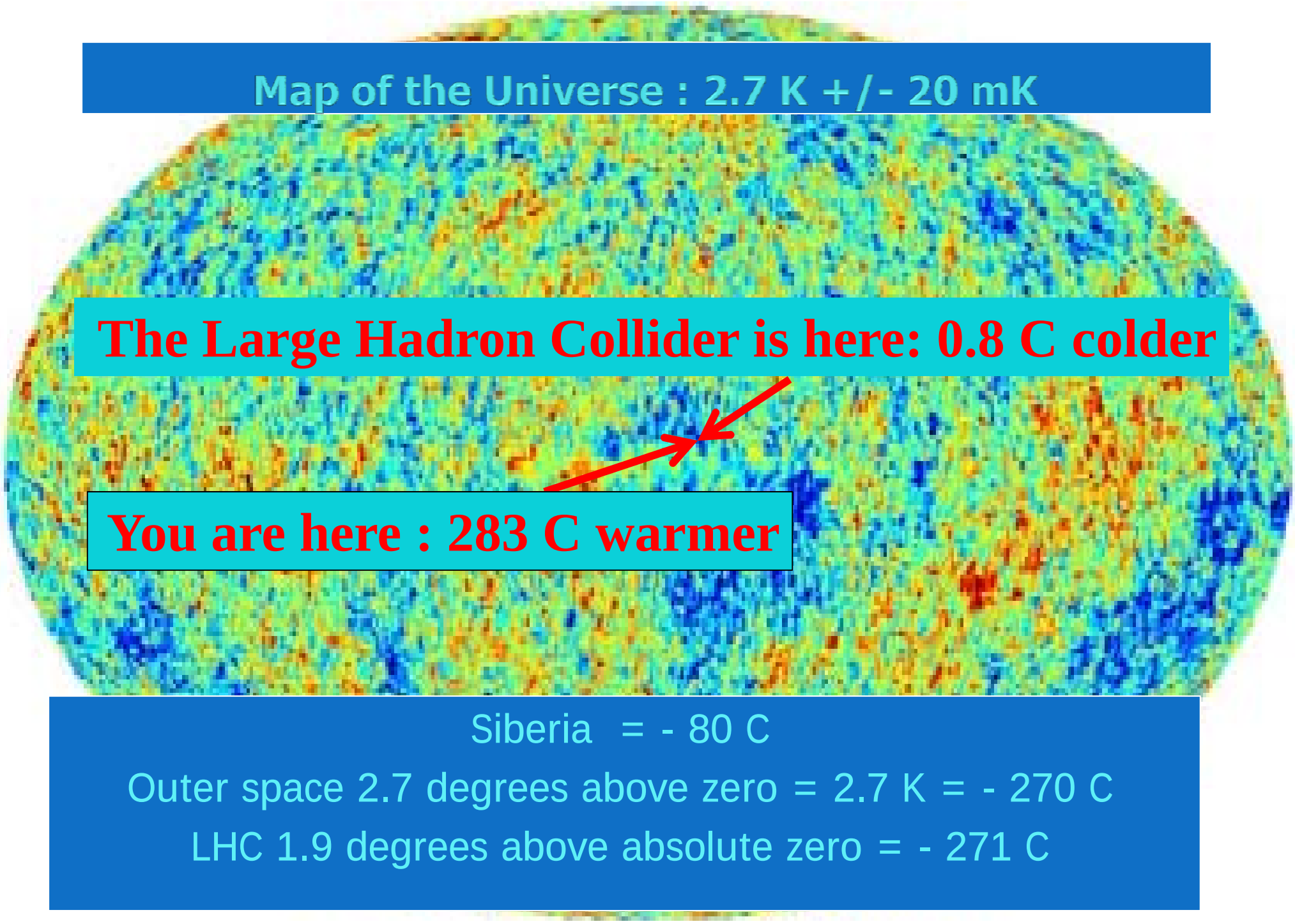
→ Bends the trajectory of a charged particle

➔ Determination of the electric charge and measurement of the particle momentum

$$\vec{F} = q\,\vec{v} \times \vec{B}$$







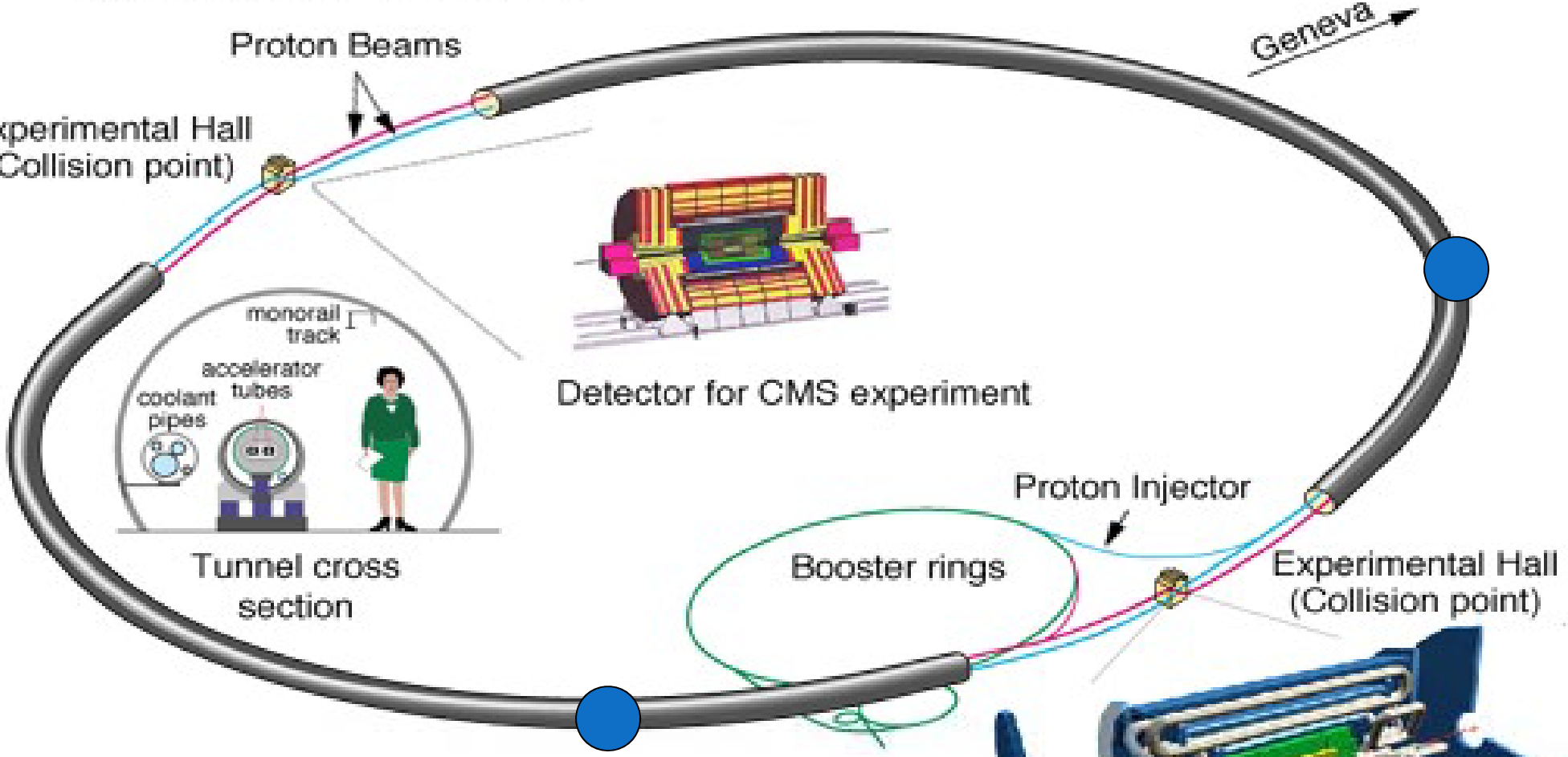
Siberia = - 80 C

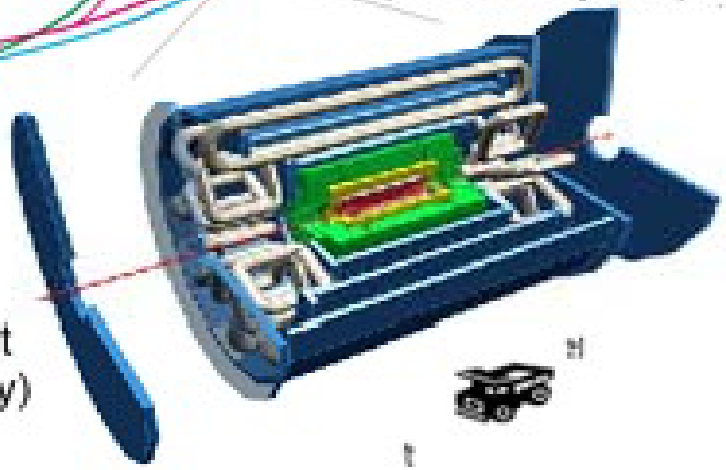
Outer space 2.7 degrees above zero = 2.7 K = - 270 C

LHC 1.9 degrees above absolute zero = - 271 C

Large Hadron Collider at CERN

Circumference 26.7 km (16.6 miles)





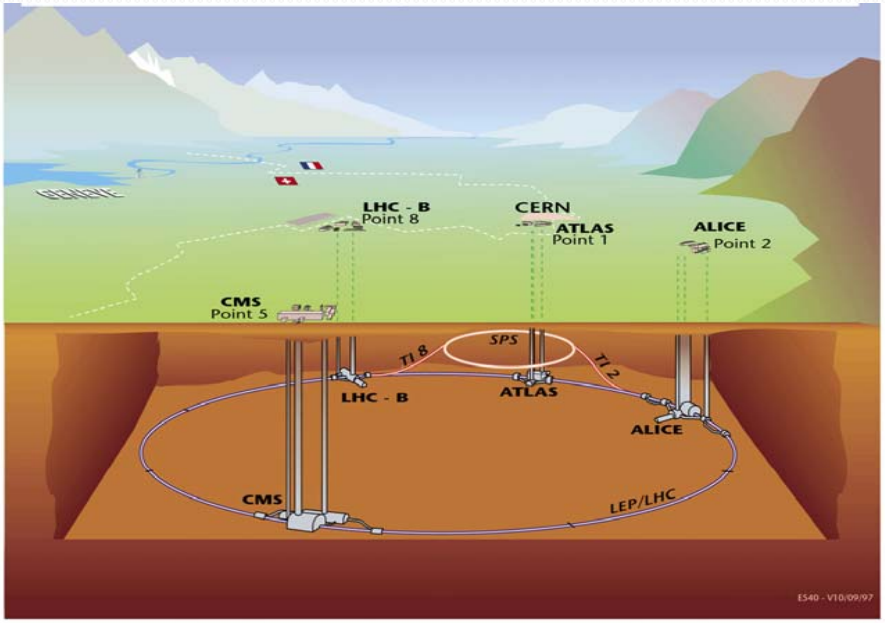
Detector for ATLAS experiment (displaced for clarity)

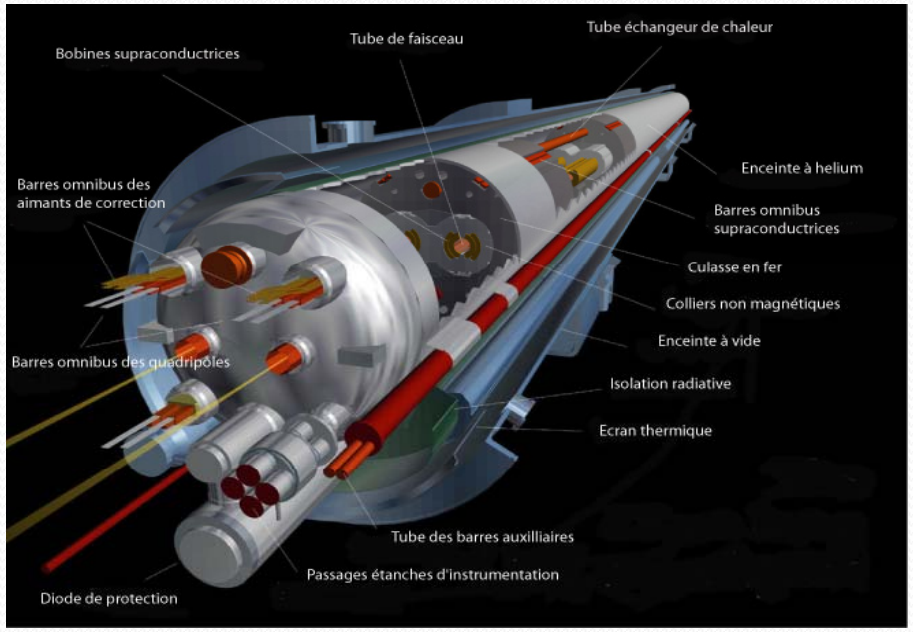
- 24 km of magnets colder than the outer space
- 9600 magnets
- 2808 bunches of 100 * billions protons
- data : 20 km of CDs stacked per year

Key technologies of the LHC

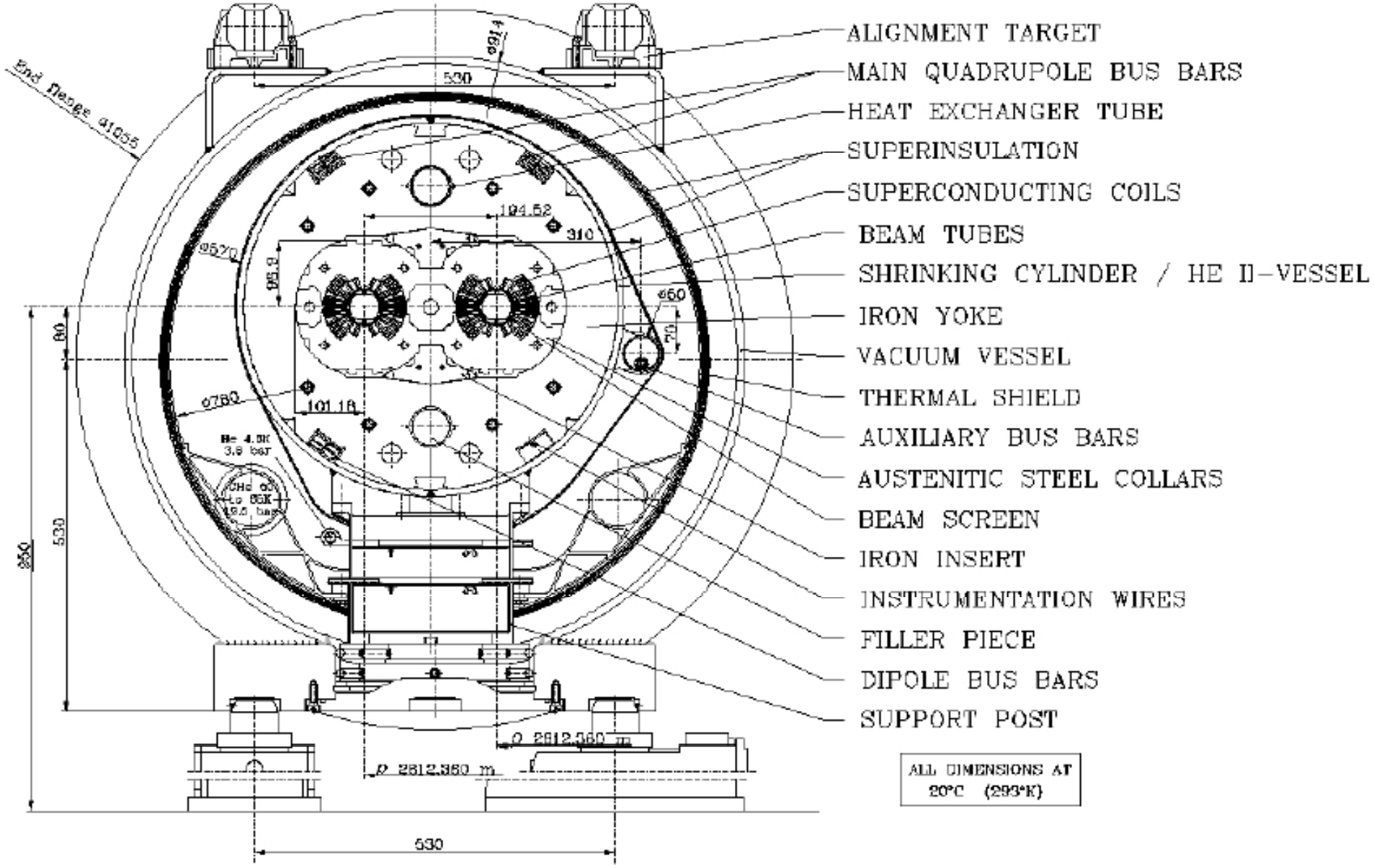
- <u>High field superconducting magnets</u>
  - 1250 t of Nb-Ti superconducting materials
  - 7600 km of superconducting “Rutherford” cables

- <u>Superfluid helium cryogenics (< 2 K) and Vacuum techniques</u>
  - Pressurized and saturated superfluid helium, in two-phase flow
  - Cryostats and thermal insulation
  - Efficient and large capacity helium refrigerators
  - Cryogen storage and management (100 t He)



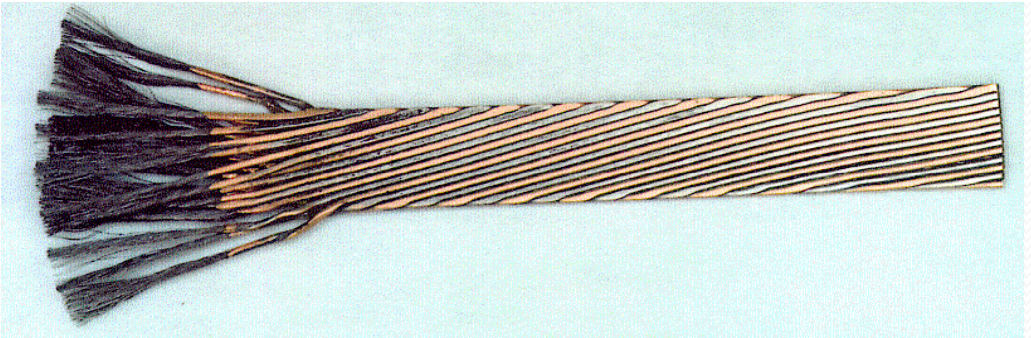


LHC Project Report – Main Dipole cross-section

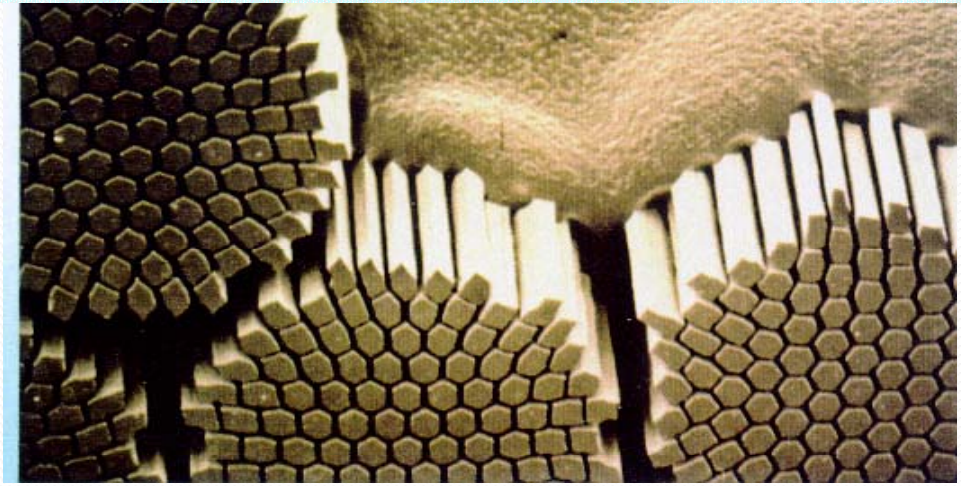


7600 km of cable made of 270 000 km of strand (6 earth circumferences)

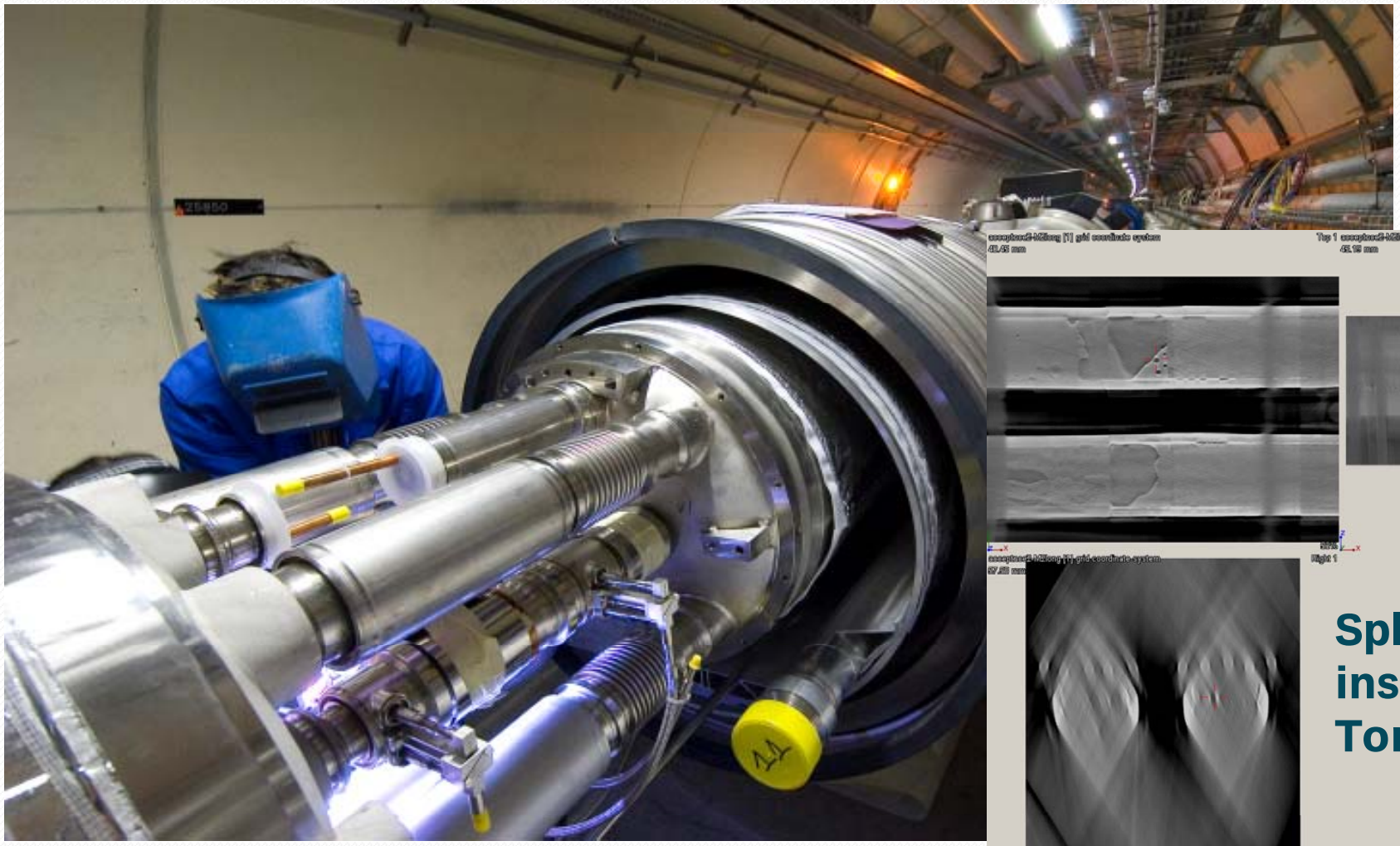
→ filaments : 6 times back and forth to the Sun + 150 trips to the moon



	Inner Cable	Outer Cable
Number of strands	28	36
Strand diameter	1.065 mm	0.825 mm
Filament diameter	7 µm	6 µm
Number of filaments	~ 8900	~ 6520
Cable width	15.1 mm	15.1 mm
Mid-thickness	1.900 mm	1.480 mm
Keystone angle	1.25 °	0.90 °
Transposition length	115 mm	100 mm
Ratio Cu/Sc	≥ 1.6	≥ 1.9

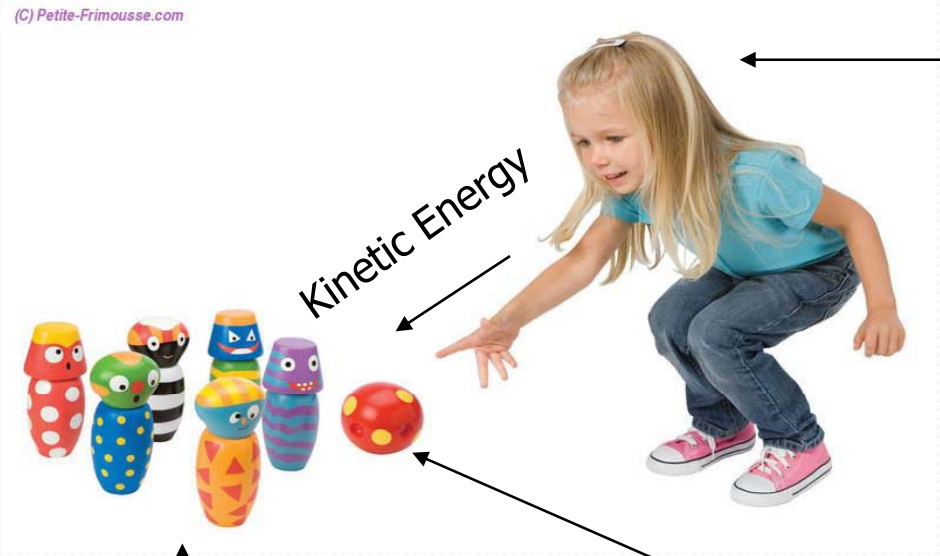


Interconnection of cryo-magnets in the LHC tunnel



Splice inspection by Tomography

Detection: Introductory Analogy



Research Procedure:

1. Throw the ball w/ a certain E in a given direction
2. Ball scatters through the skittles
3. Measure the scattering angles, the E losses,...
4. Infer the skittles arrangement and properties

Introductory Analogy

Particle Physics:

- now imagine we don't see the skittles
- we don't even know what they are
- they lay on the top of a high cupboard

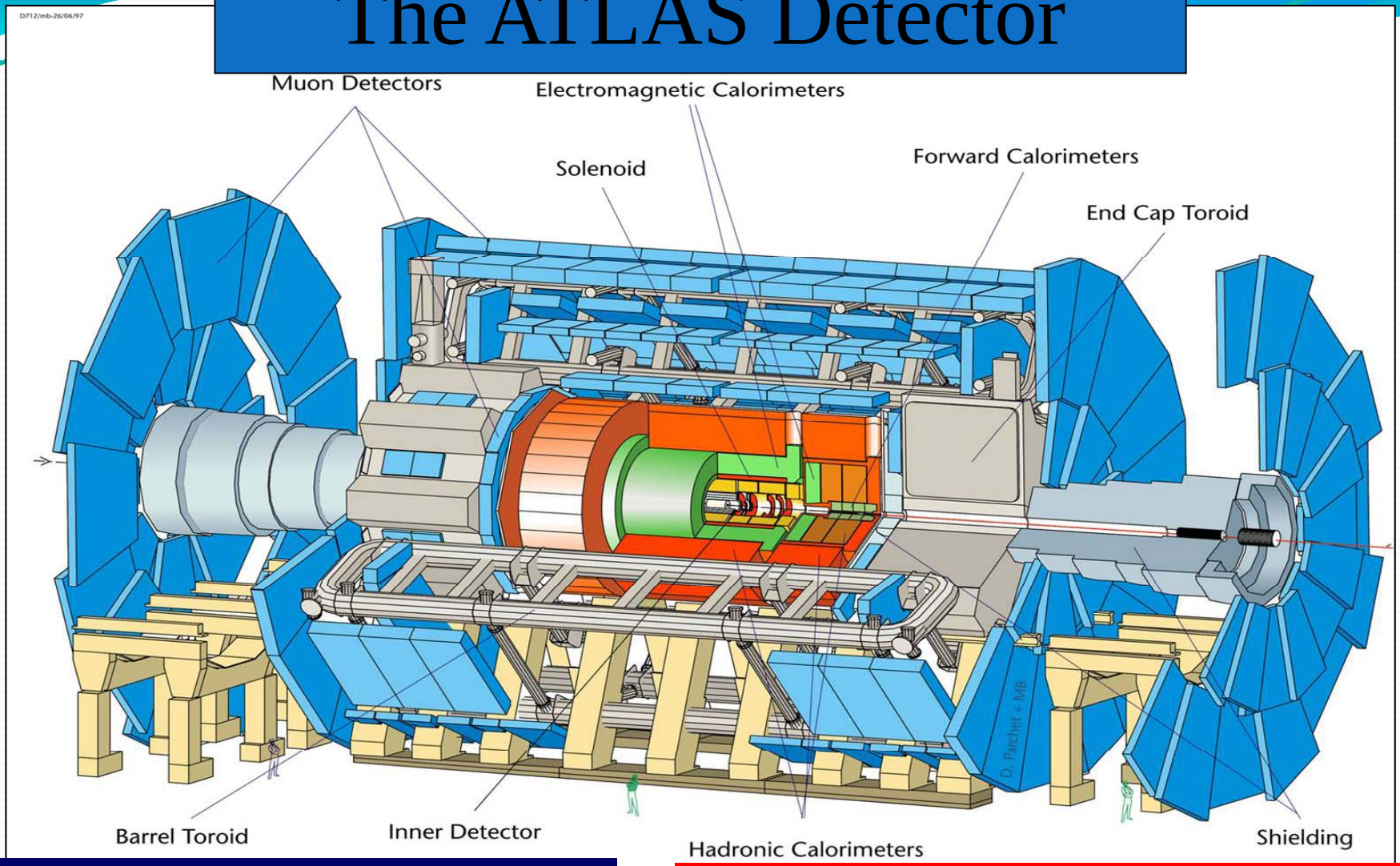
Research Procedure:

1. Strongly throw the ball up the cupboard (E,α,θ)
2. Ask a friend to catch the ball on the other side
3. To register the sound of the collisions
3. To measure outcoming (E',α',θ')
4. Ask another friend on the side to infer the skittels arrangement and properties

Casting:

- Ball thrower: accelerator physicist, accelerates particle to probe matter
- Ball catcher: detector physicist, measures the produced particles
- Interpreter: theoretical physicist, imagines the result ahead of time or try to infer a posteriori

The ATLAS Detector

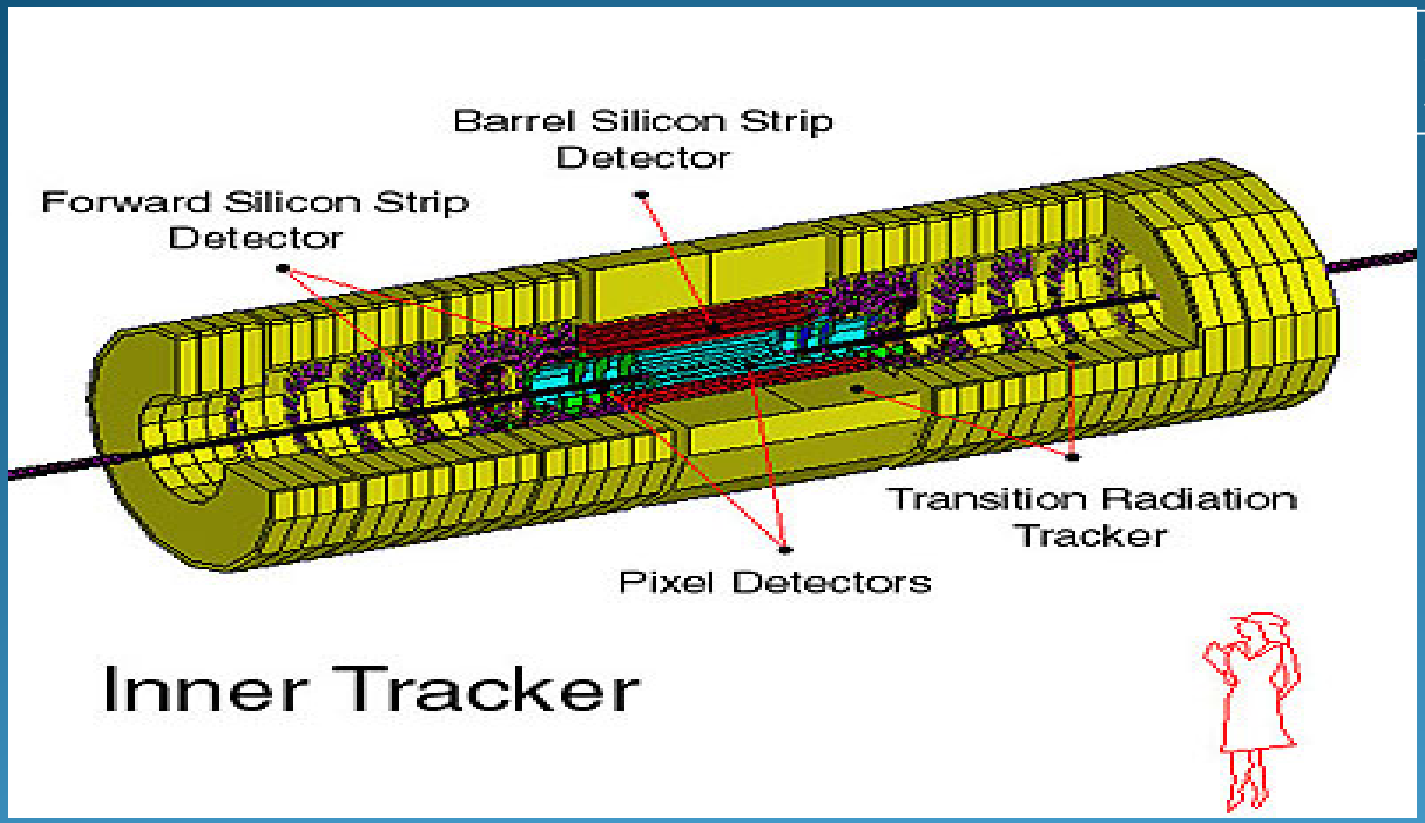


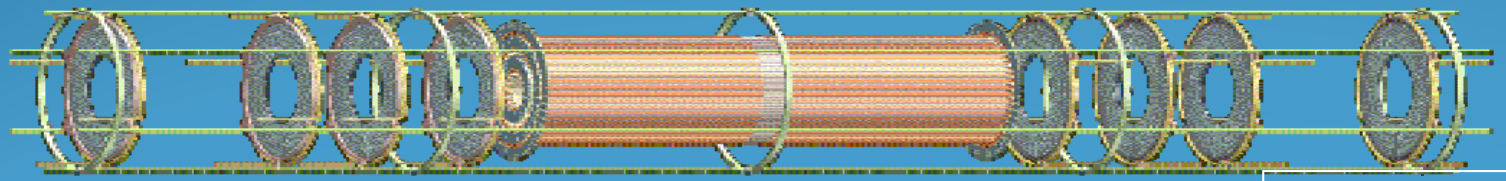
Diameter	25 m
Total length	46 m
Overall weight	7000 tons

Over 2000 scientists and engineers
Nearly 40 countries
More components than a moon rocket

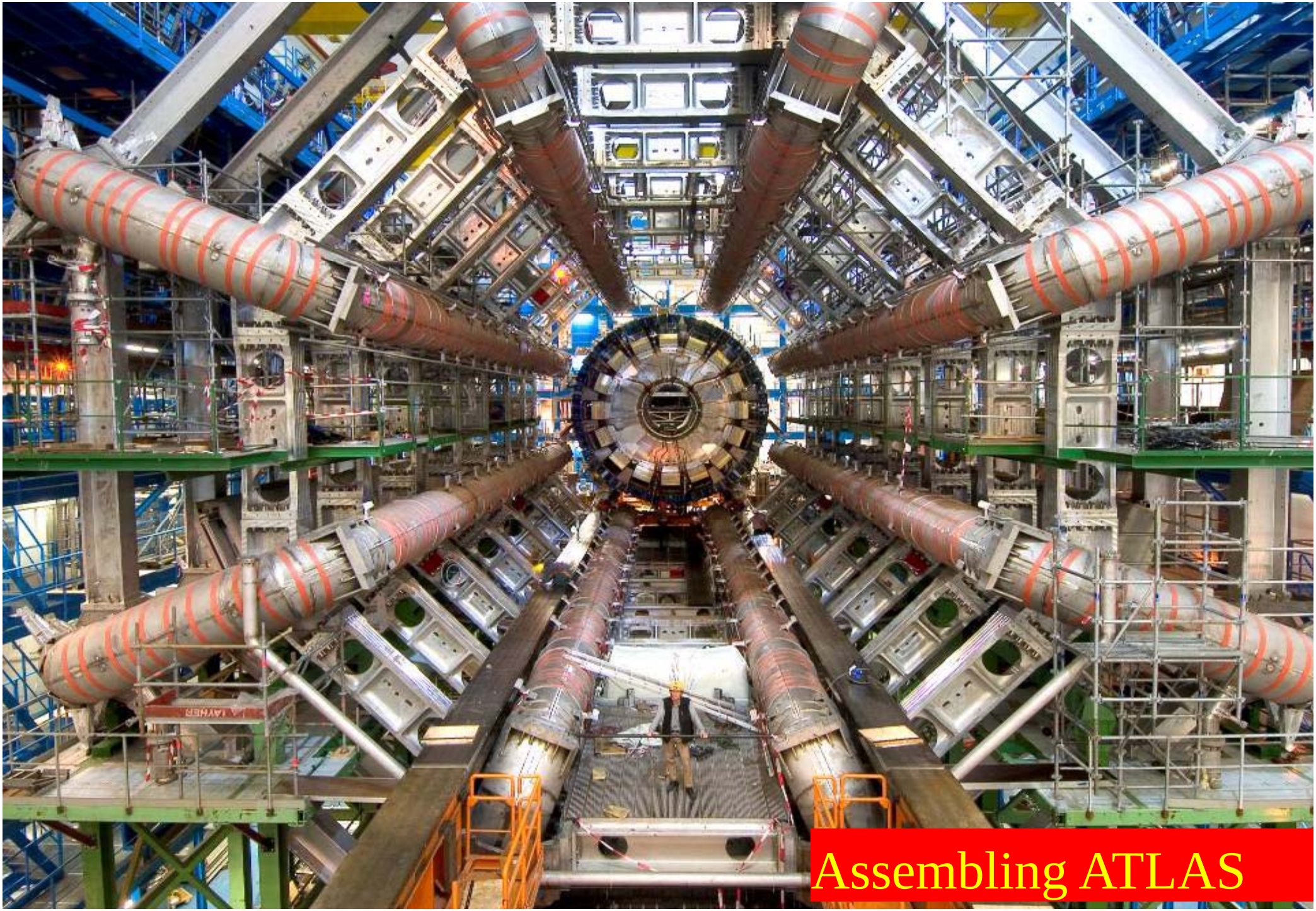
Inner Tracking Detectors

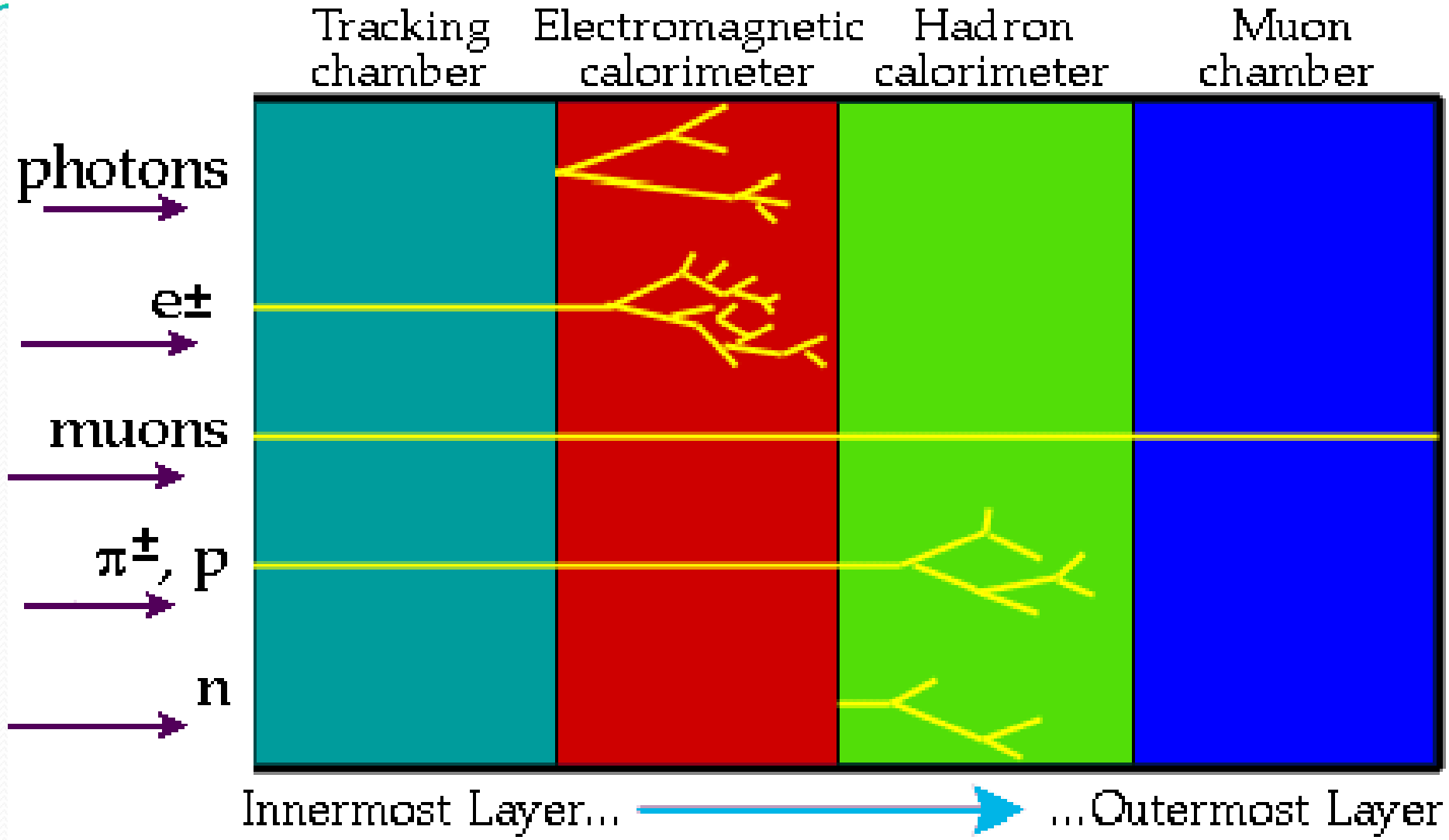
x 1.15m



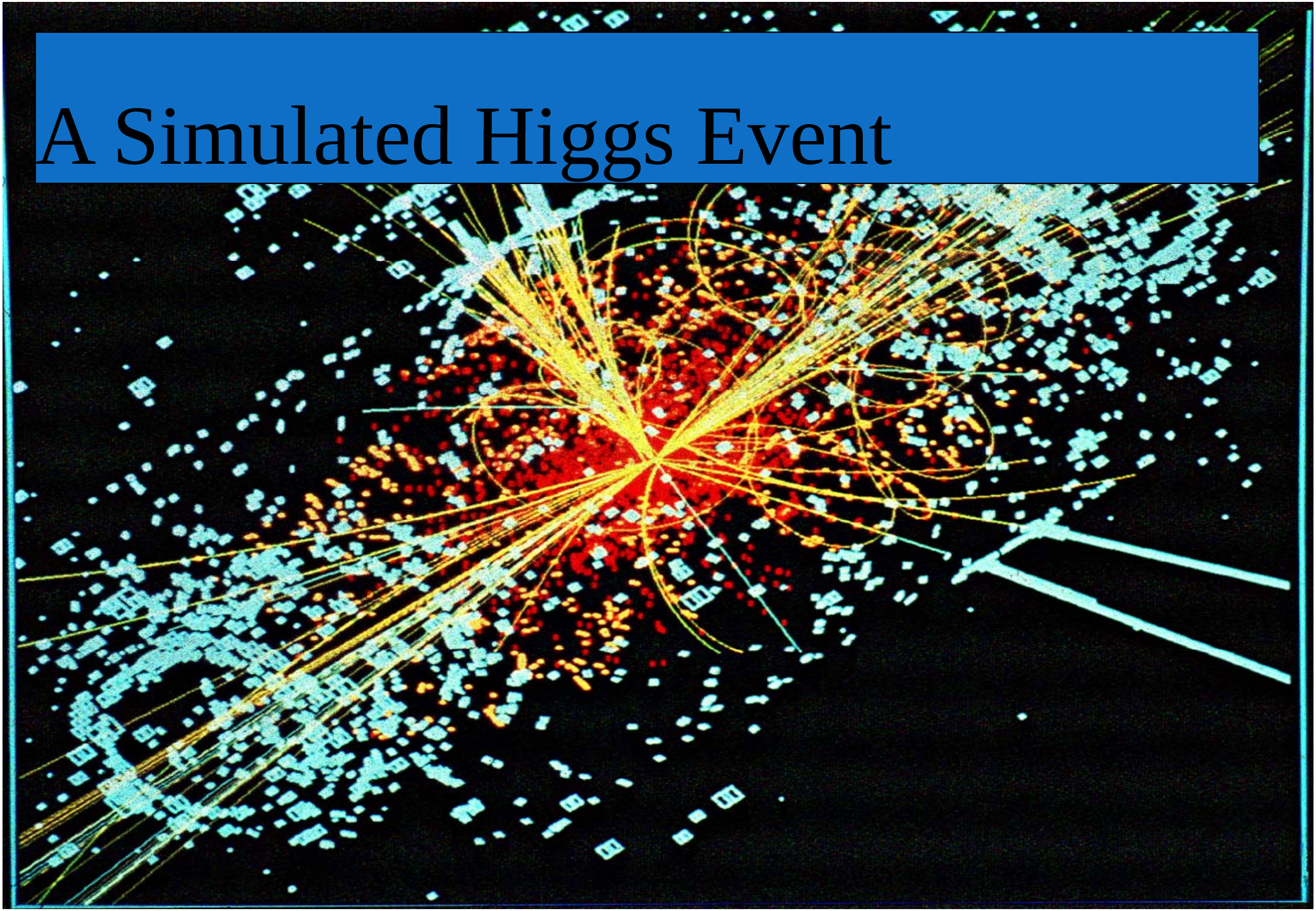


$$L \times l = 300 \times 50\ \mu m, 140\ M,$$
$$\sigma_{x,y} = 10 - 20\ \mu m$$

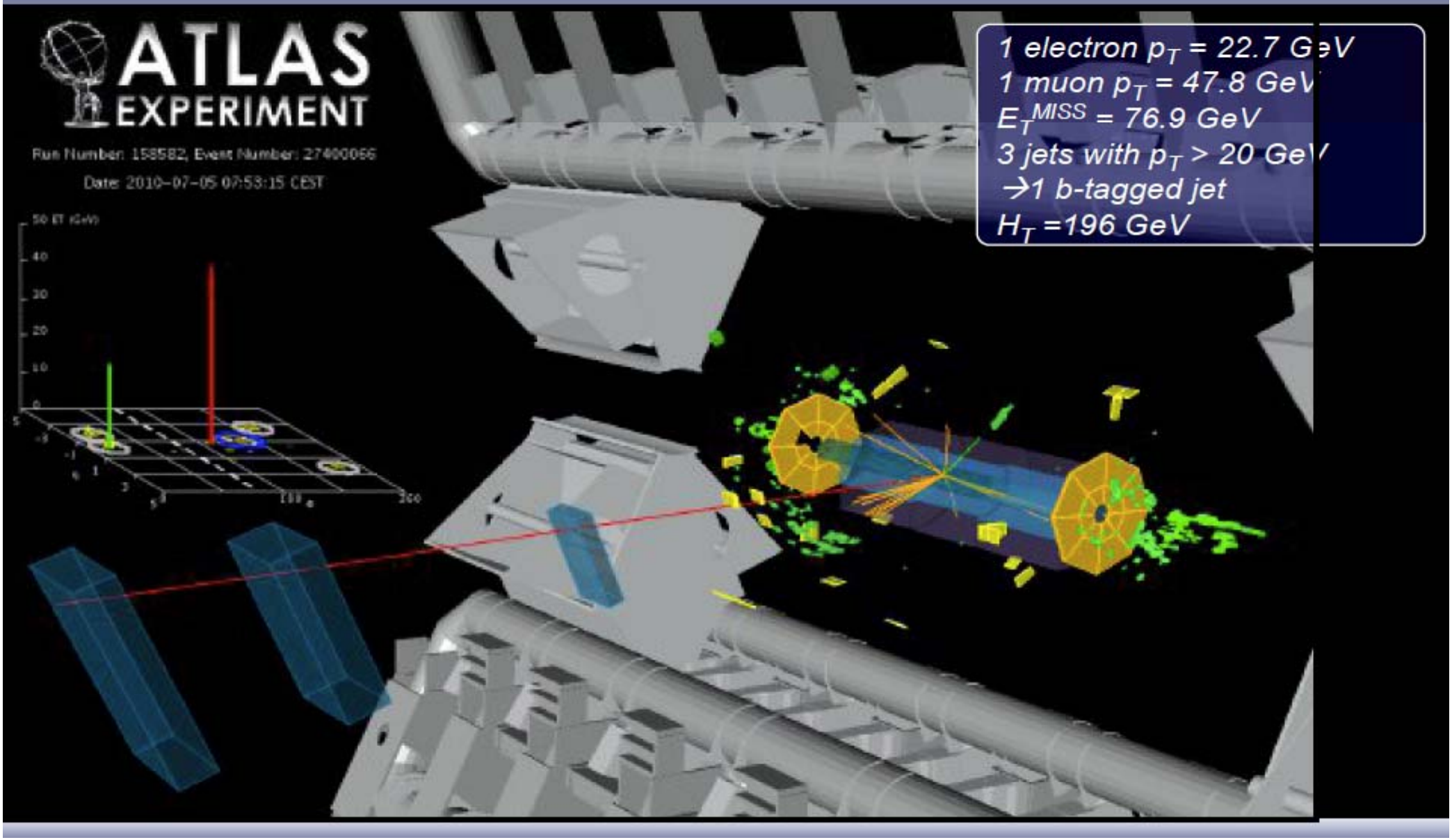

Assembling ATLAS


Tracking chamber
Electromagnetic calorimeter
Hadron calorimeter
Muon chamber
photons
e±
muons
π±, p
n
Innermost Layer...
...Outermost Layer

A Simulated Higgs Event



Top Pair Candidate in ATLAS



No Black Holes yet!

CMS 4-Jet Event @ 2.36 TeV