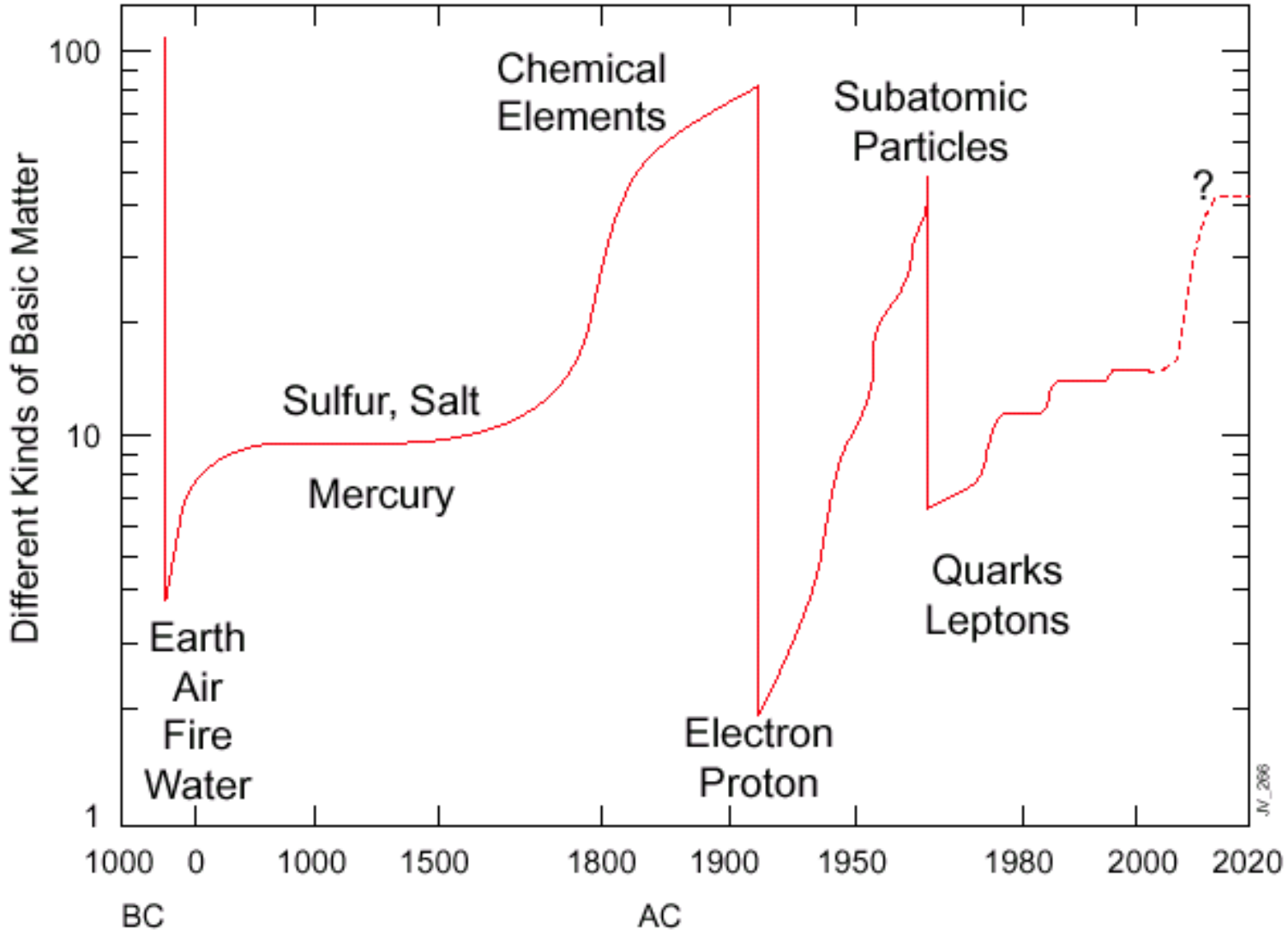
The joy and challenge of doing experimental particle physics

Satyanarayana Bheesette

Department of High Energy Physics

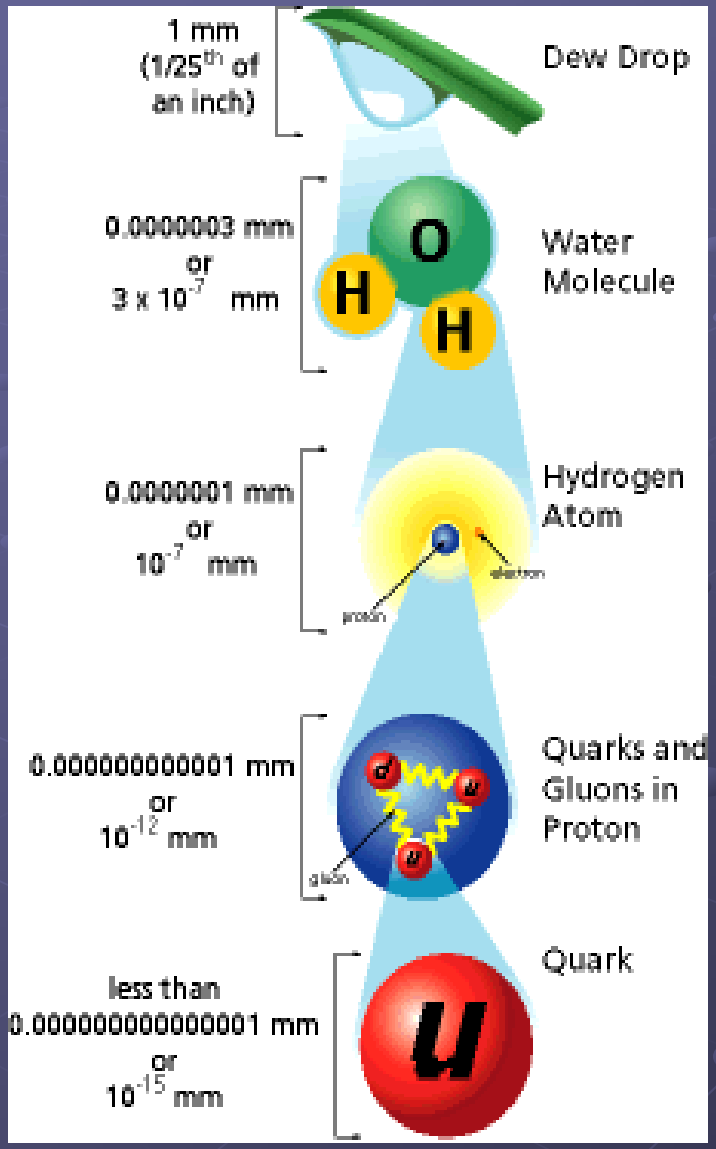
Tata Institute of Fundamental Research, Mumbai

History of constituents of matter



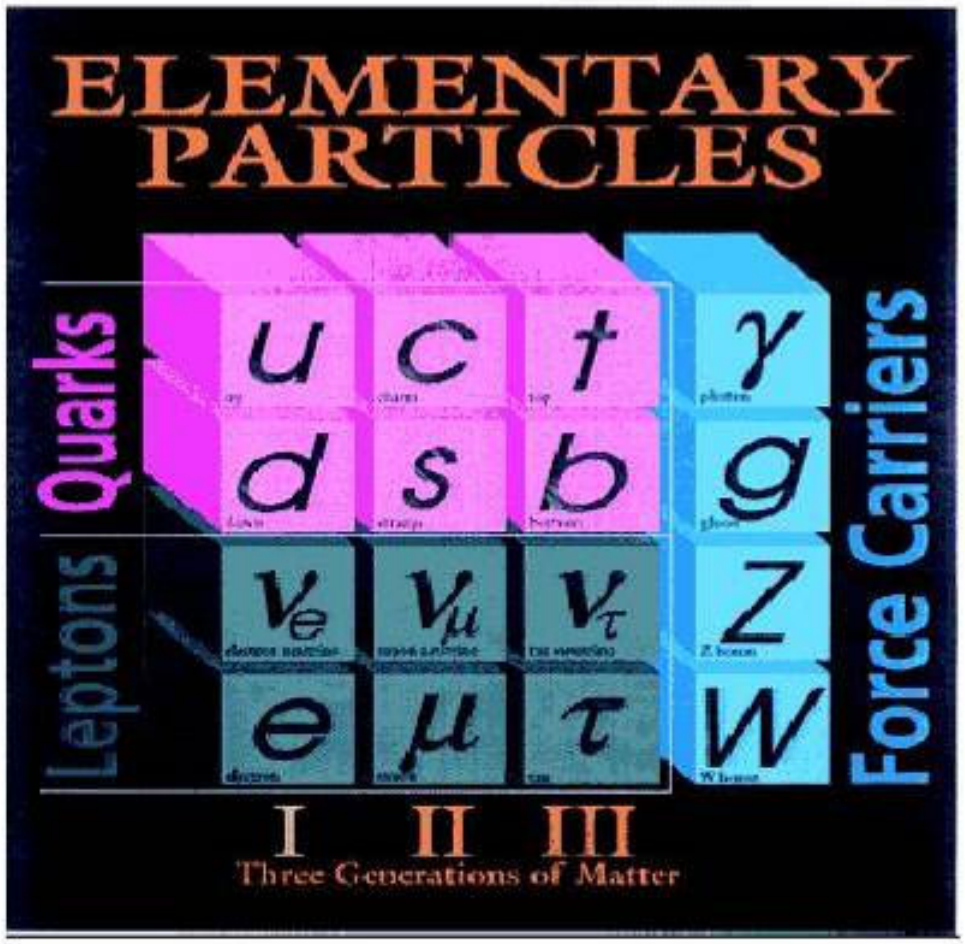
What are elementary particles?

Scientists have found that **everything** in the universe is made up from a small number of **basic building blocks** called **elementary particles**, governed by a few fundamental **forces**. High Energy Physics experiments are built typically to study these particles, their constituents and interaction among them.



A dew drop is made up of many molecules of water (1021 or a billion trillion). Each molecule is made of an oxygen atom and two hydrogen atoms (H_2O). Each atom consists of a nucleus surrounded by electrons. Electrons are leptons that are bound to the nucleus by photons, which are bosons. The nucleus of a hydrogen atom is just a single proton. Protons consist of three quarks. In the proton, gluons hold the quarks together just as photons hold the electron to the nucleus in the atom.

Standard model of particle physics



$M_e \sim 0.5$ MeV

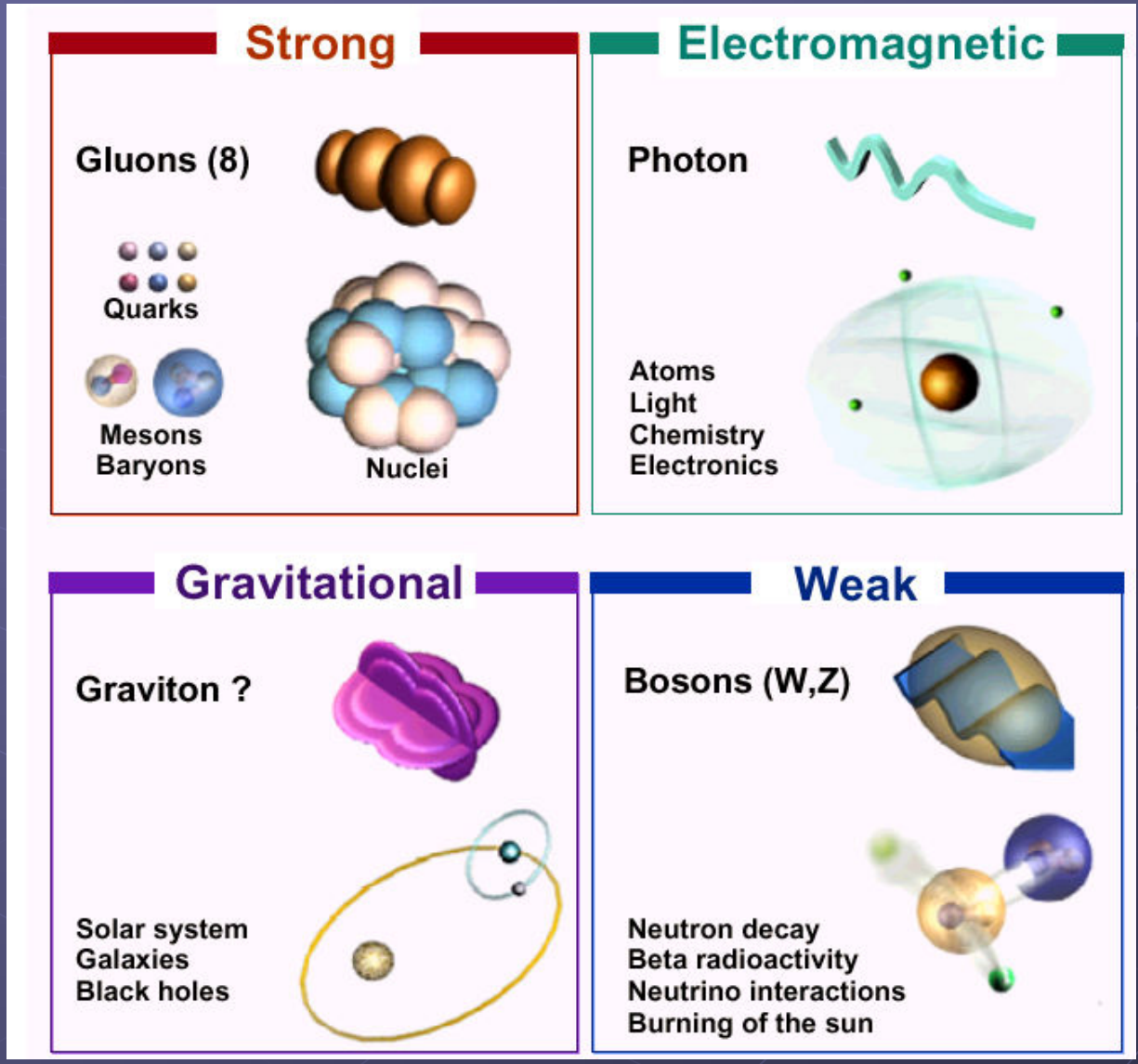
$M_\nu \sim 0$

$M_t \sim 175{,}000$ MeV!

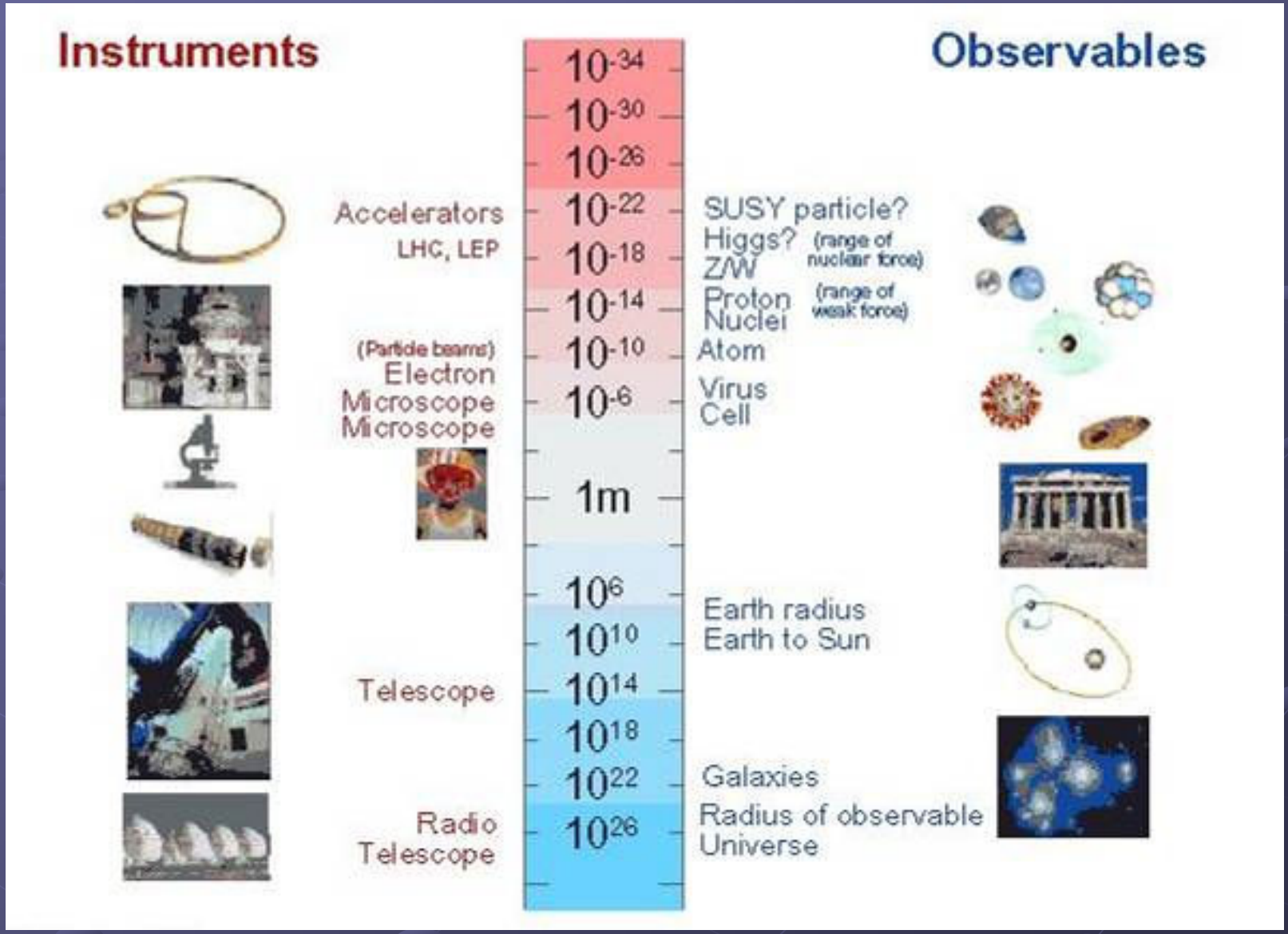
$M_\gamma = 0$

$M_Z \sim 100{,}000$ MeV

Fundamental forces in nature



Size of things



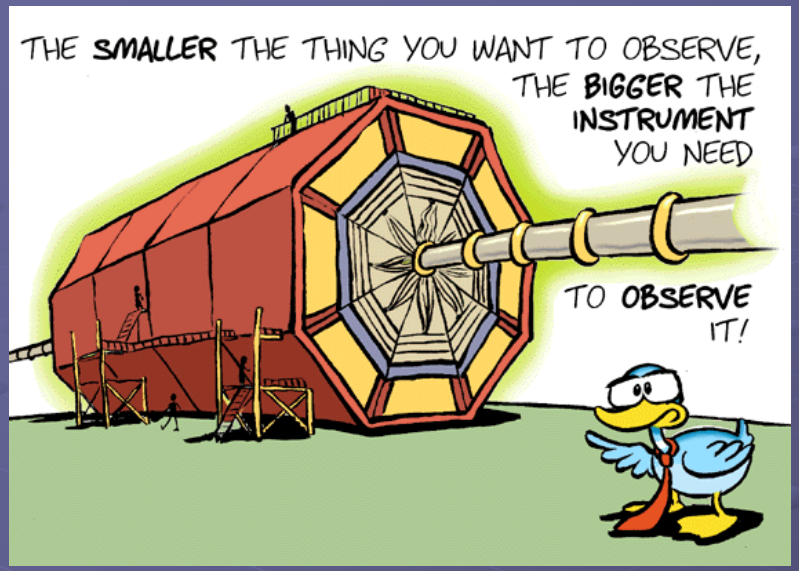
Energy scales

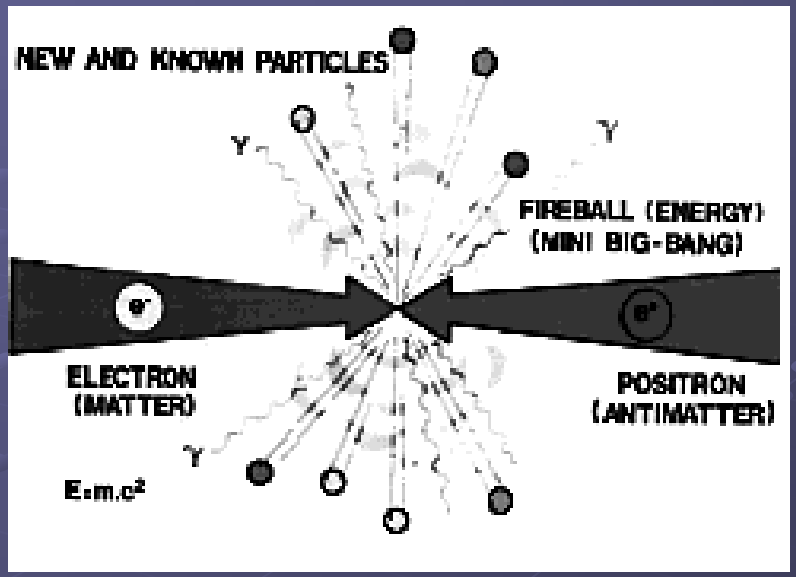
- Mass, energy, distance, temperature and time are related quantities.
- Unit of energy is the *electron Volt.* Energy gained by an electron in passing through a voltage difference of one volt.
- Some examples:
  - Mass of atom : 0.01MeV
  - Mass of Nucleus : 10MeV
  - Mass of electron : 0.5MeV
  - Mass of proton : 1GeV
  - Mass of Top quark: 173GeV
  - Accelerators : 2-14TeV
  - Astrophysics : PeV
- Wavelength of the probe radiation should be smaller than the object to be resolved.

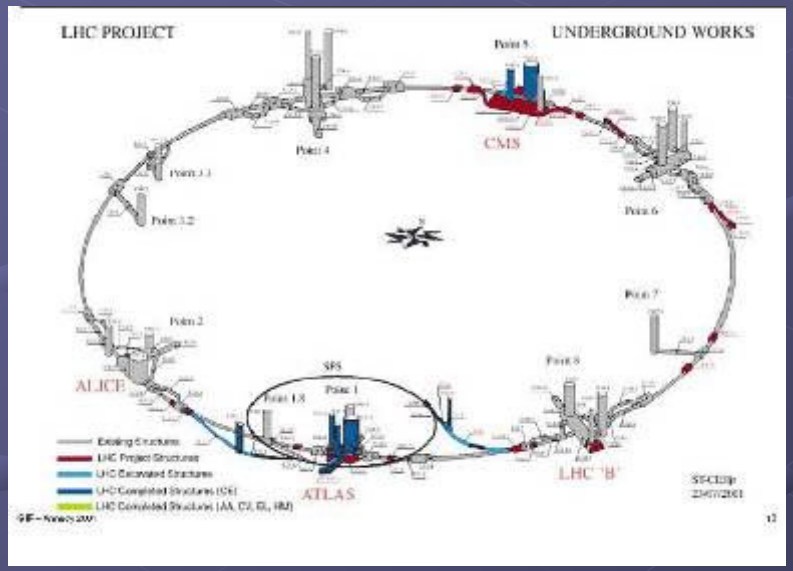
Goals of experimental particle physics

- What is the origin of mass?
- How many space-time dimensions do we live in?
- Are the particles fundamental or do they possess structure?
- What are the forces that control the behaviour of fundamental particles at the most basic level?
- Why there is overwhelmingly more matter than the anti-matter in the universe?
- What is the nature of the dark matter that pervades our galaxy?
- Experimentally measure the energy, direction and identity of the products of hard interactions as precisely as possible.

Particle accelerators







Physics processes of measurements

- Energy loss by the particle
- Cherenkov radiation
- Bremsstrahlung
- Photoelectric effect
- Compton scattering
- Pair production

Measurements

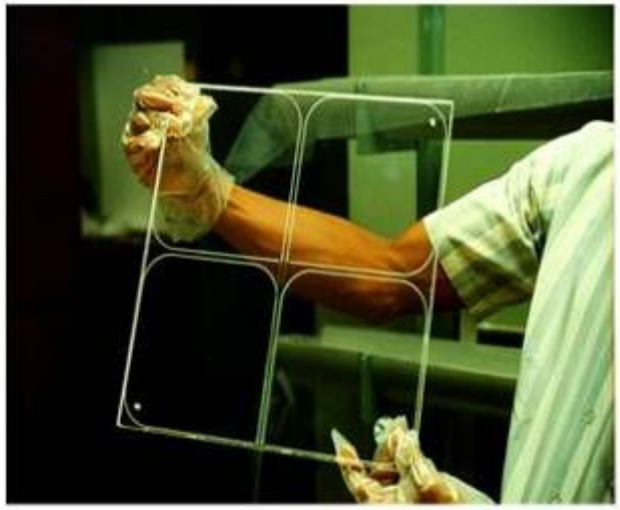
- Some primary and some derived
- Light
- Energy
- Charge/Current
- Pulse height/Voltage
- Relative timing
- Position/Particle track

High energy physics detectors

- Glass mirrors
- Scintillators
- Optical fibers
- Crystals
- Photo Multiplier Tubes
- Photo Diodes
- Gas proportional chambers
- Drift chambers
- Calorimeters
- Glass Spark Chambers
- Silicon strip detectors
- Hybrid detectors

Optical mirrors

Scintillator and optical fiber assemblies



Crystals

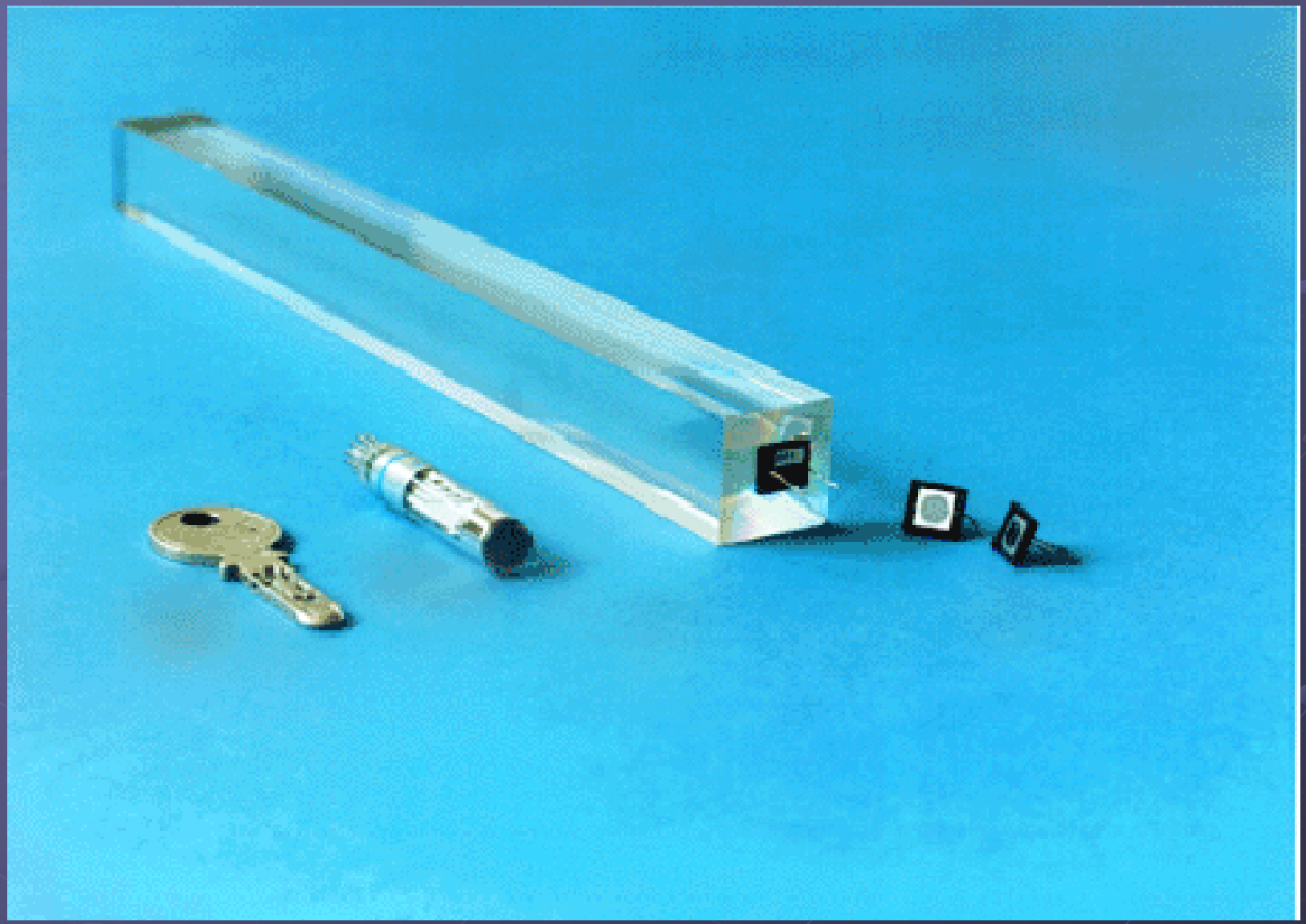
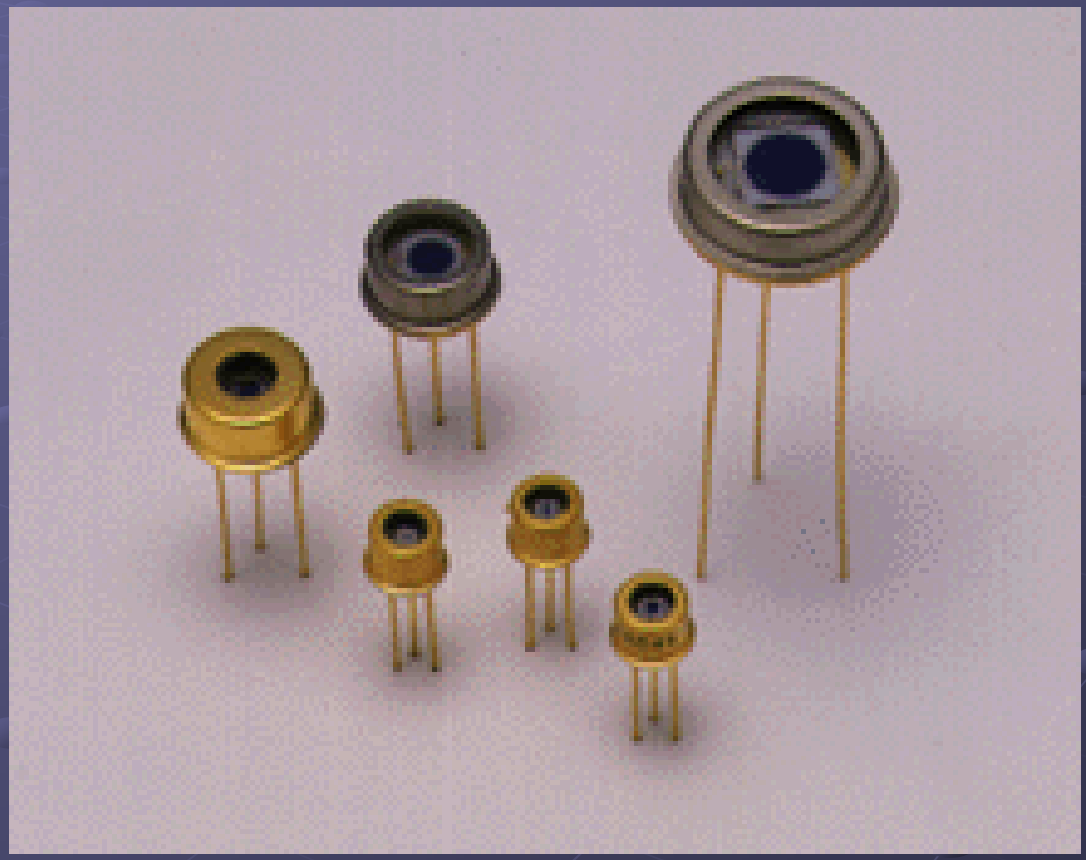
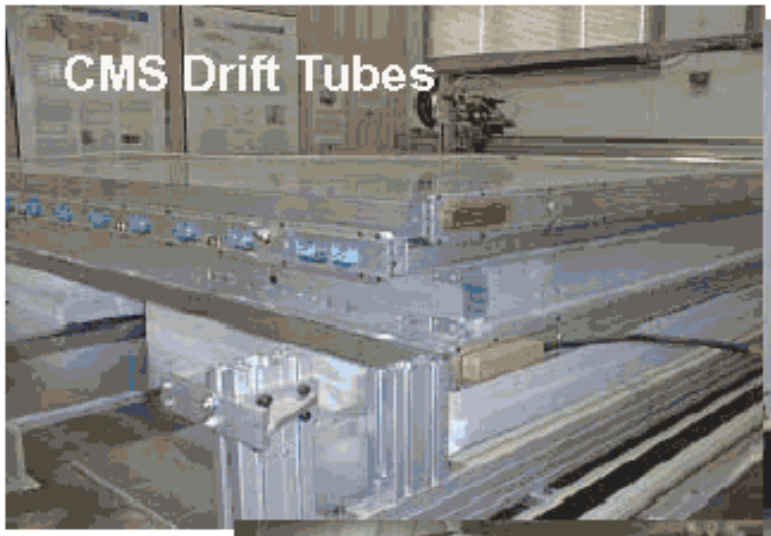


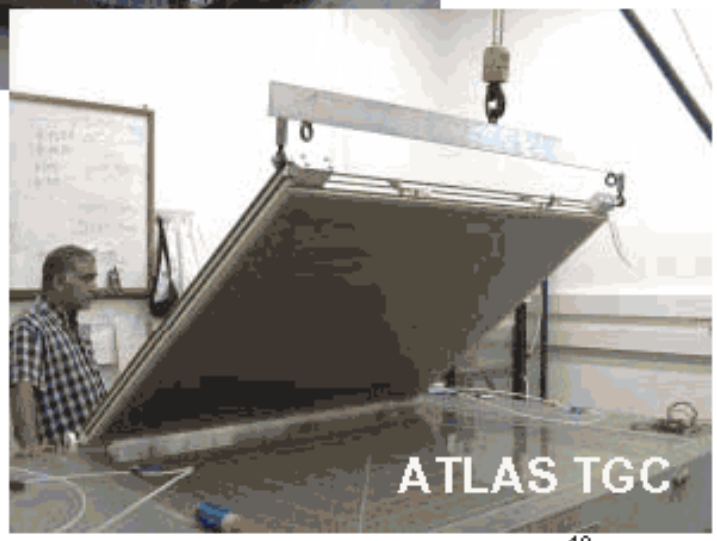
Photo multipliers and diodes



Used for measuring the light generated by other detectors

Gas proportional chambers





GIF – Annecy 2001

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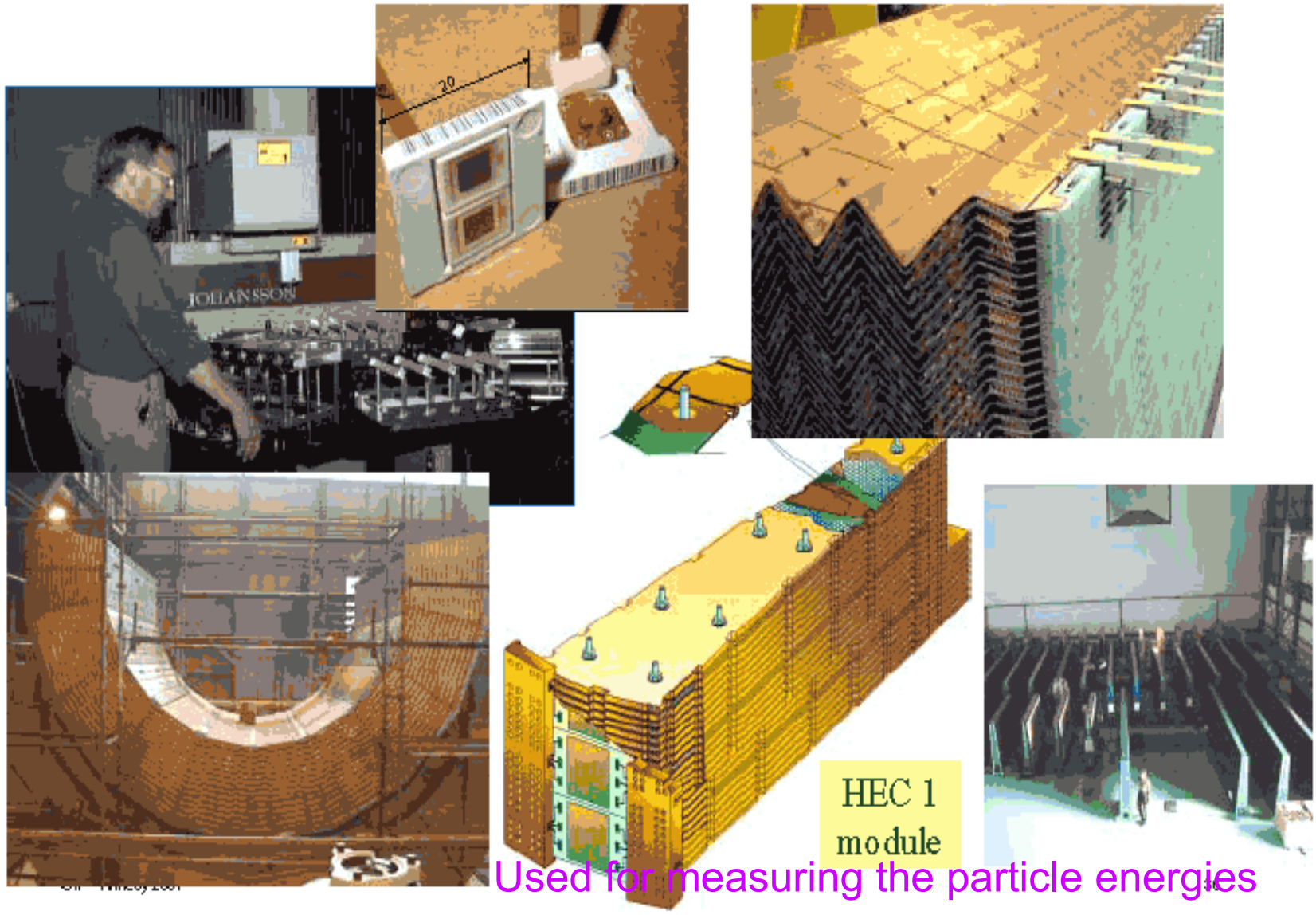
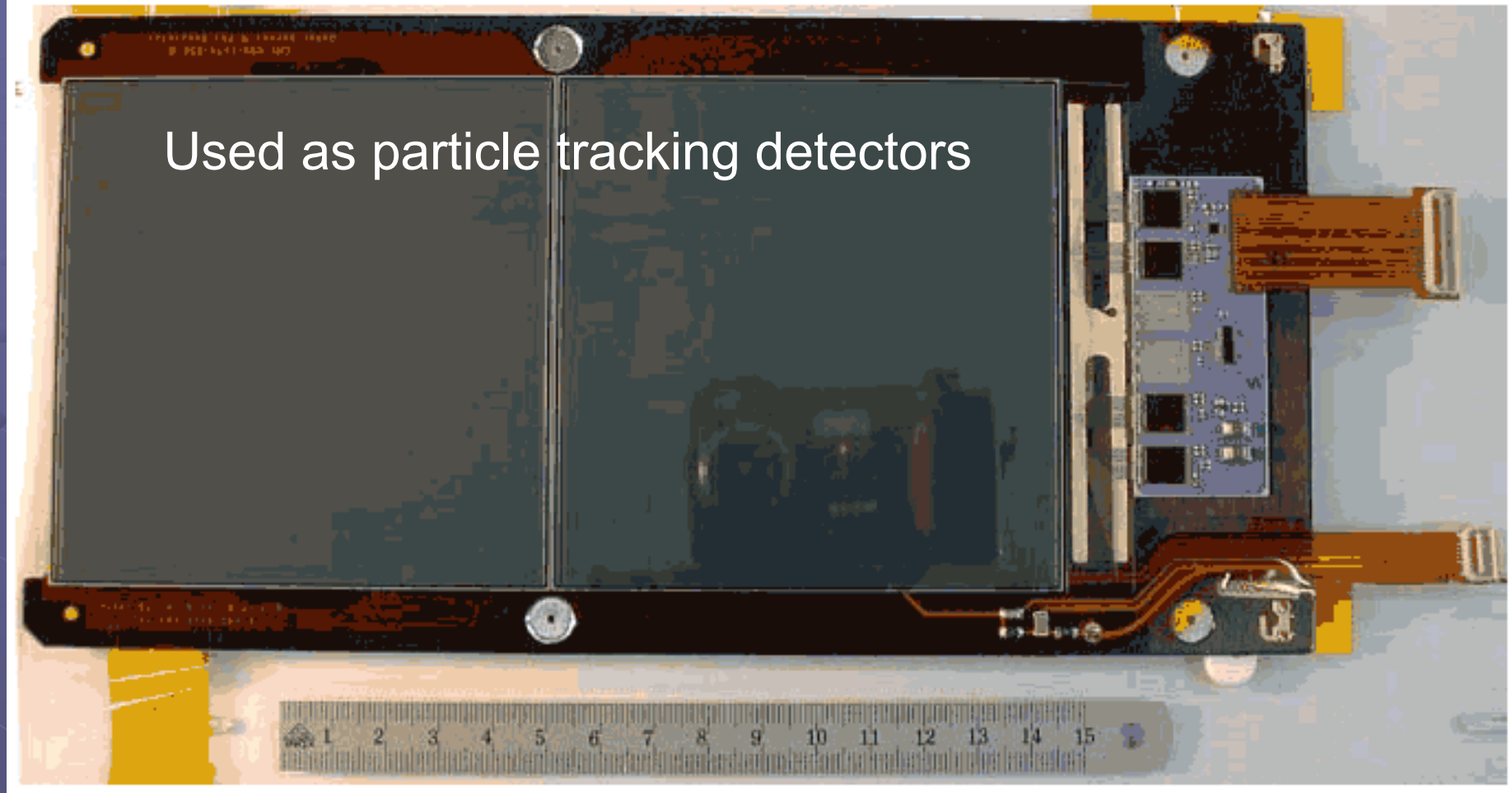
Calorimeters

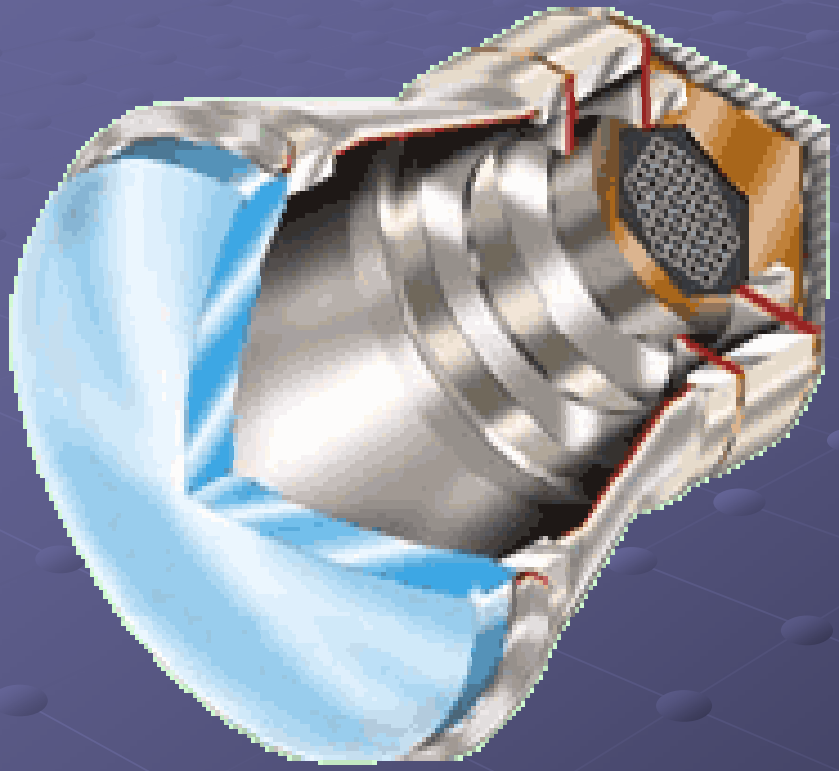


Used for measuring the particle energies

Silicon strip detector

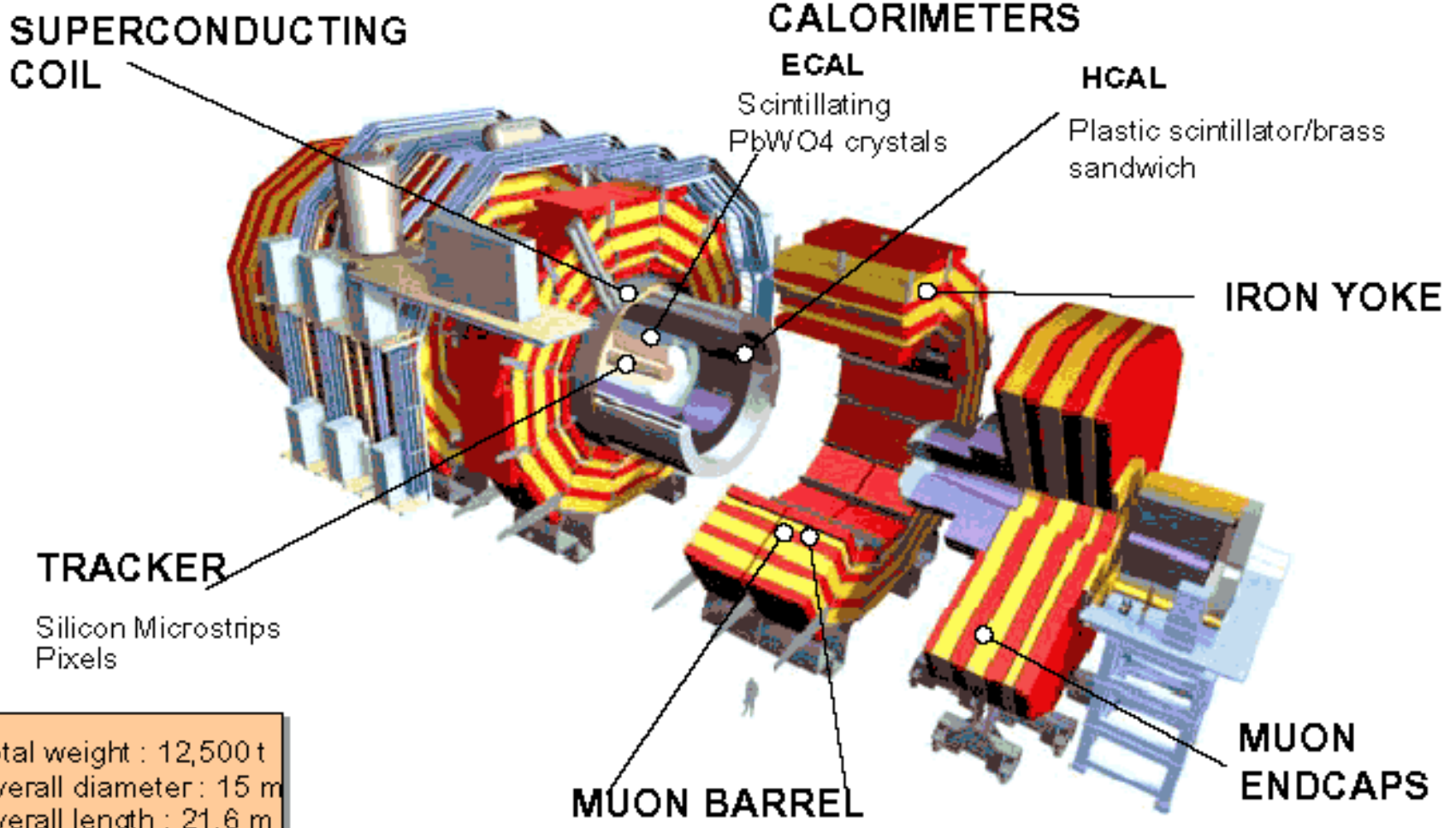


Hybrid detectors



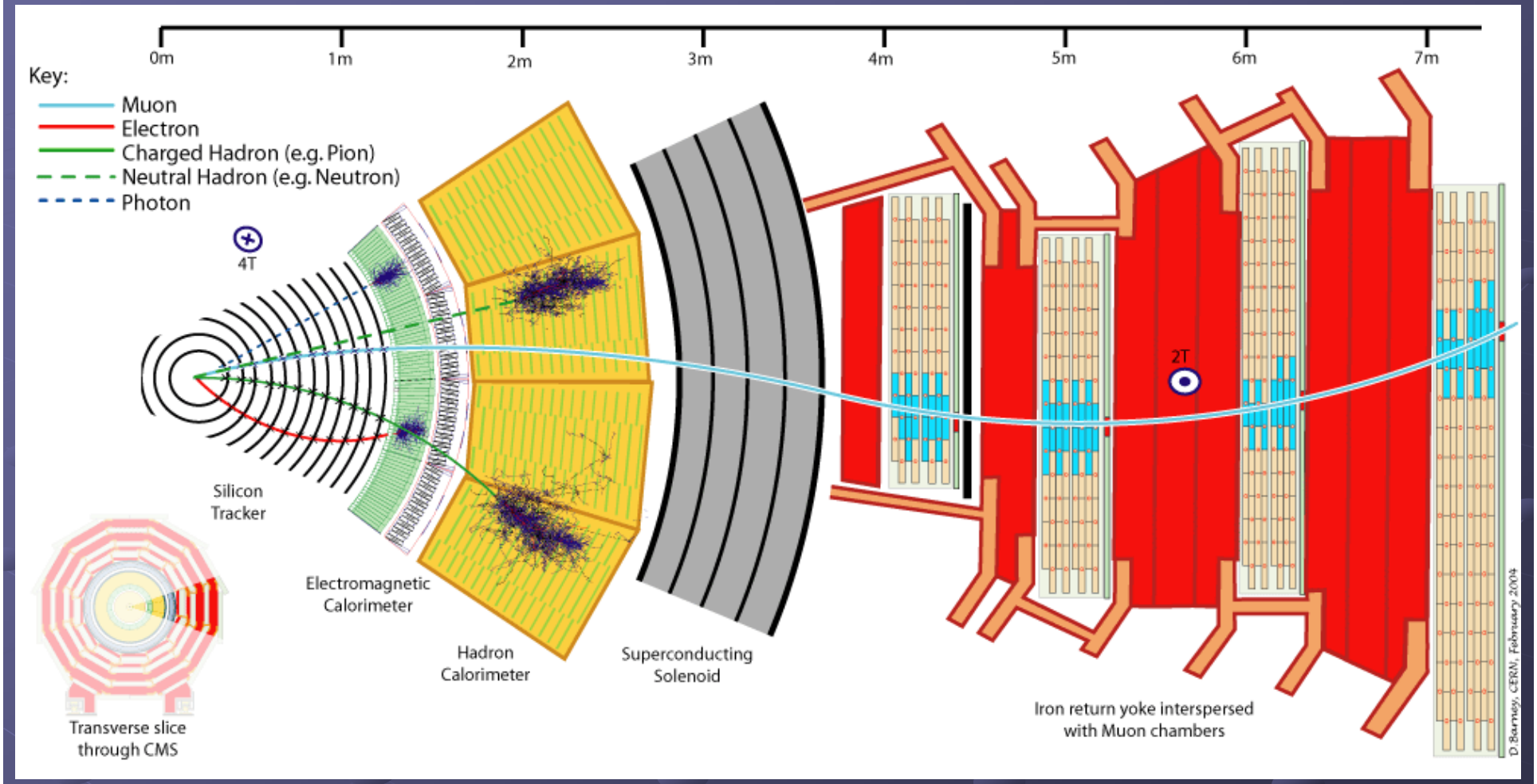
- Makes use of advantages of photomultiplier and silicon detectors
- New device: Silicon Photo Multiplier (SiPM)

An accelerator experiment

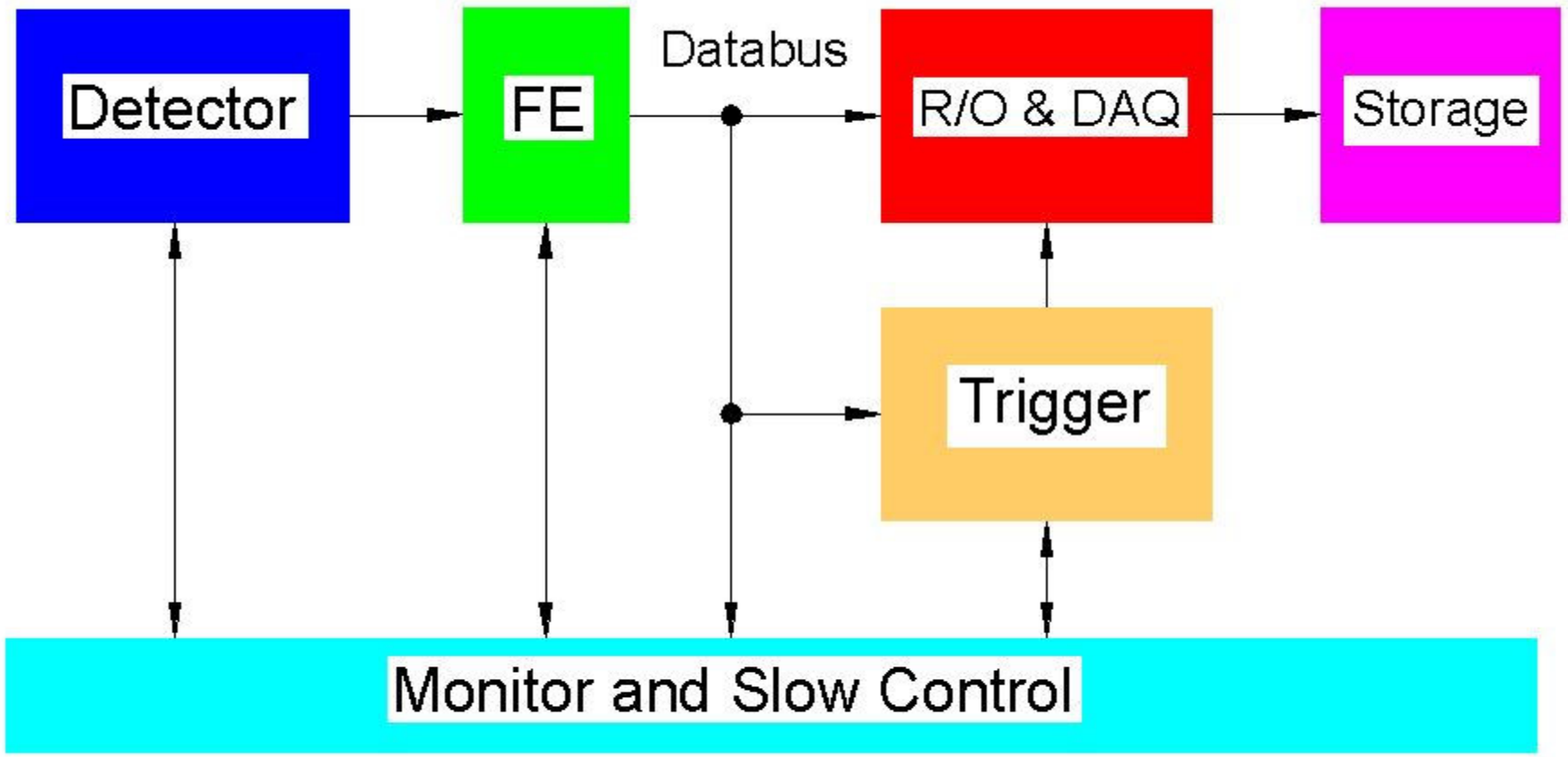


Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla

Slice of an accelerator physics experiment



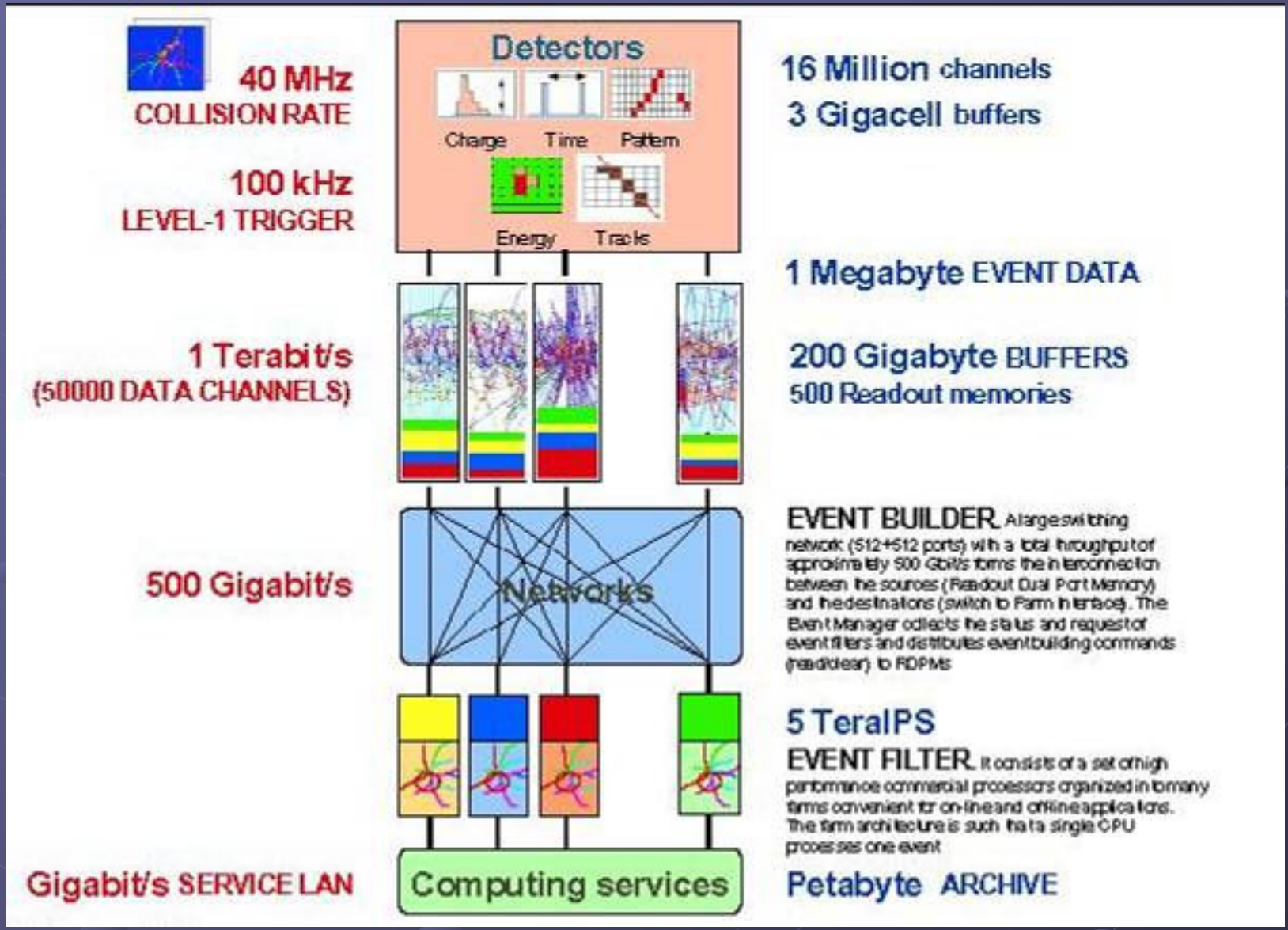
Concept of HEP instrumentation



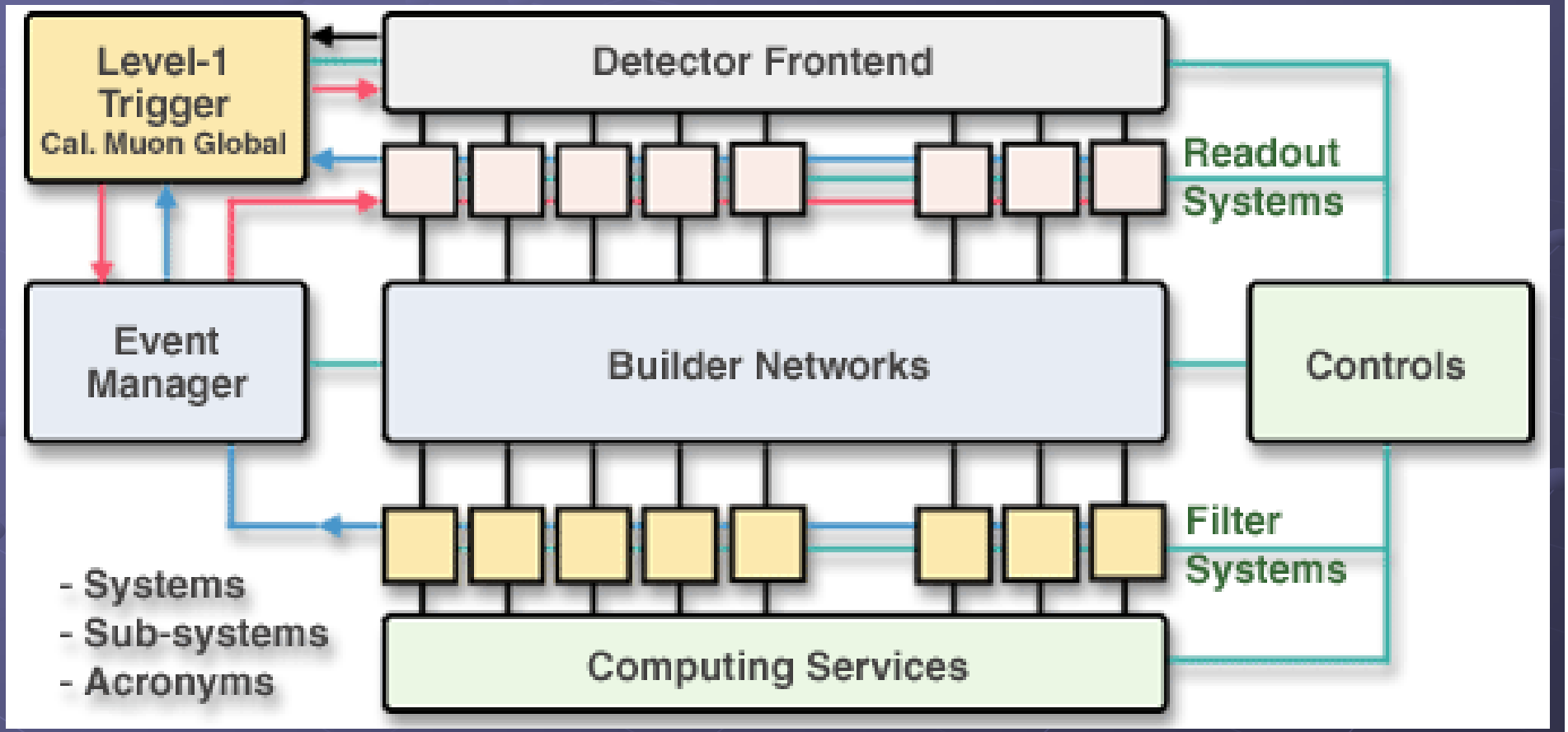
Measuring tools

- Amplifiers and Comparators
- Analog to Digital Converters
- Charge to Digital Converters
- Time to Digital Converters
- Latches and Registers
- Memories
- *Logic systems*
- Hybrids

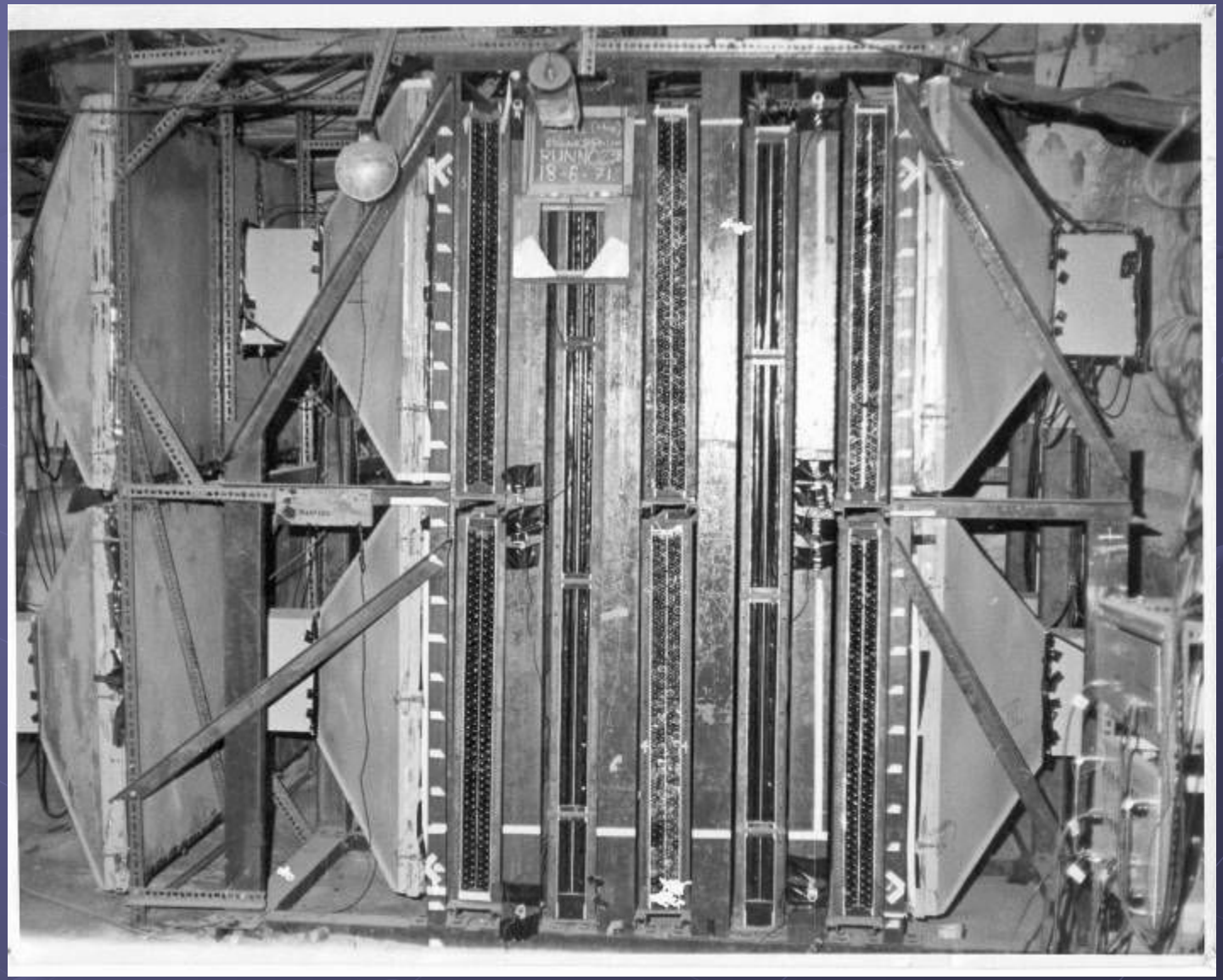
Principle of data acquisition



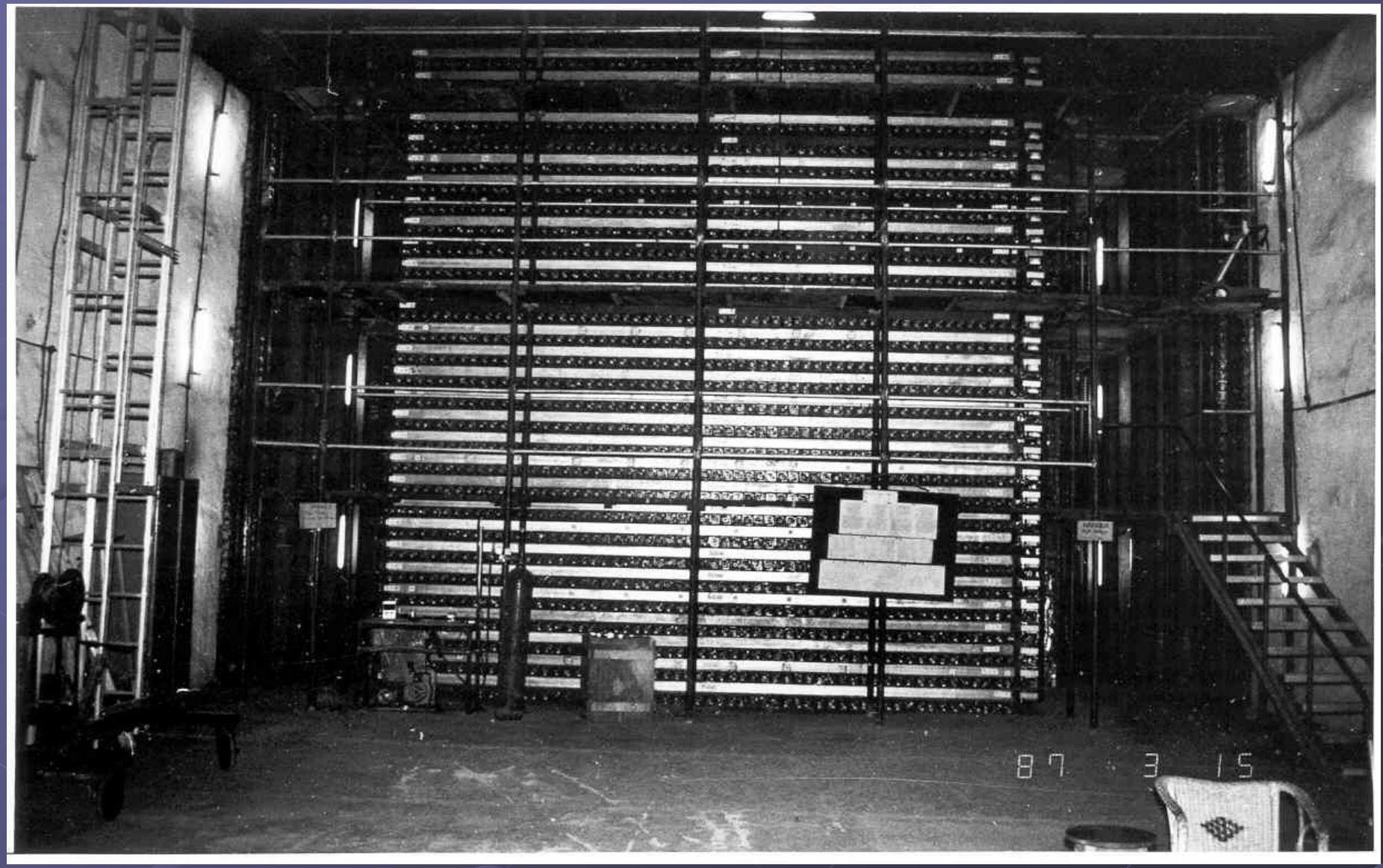
Trigger and data acquisition system



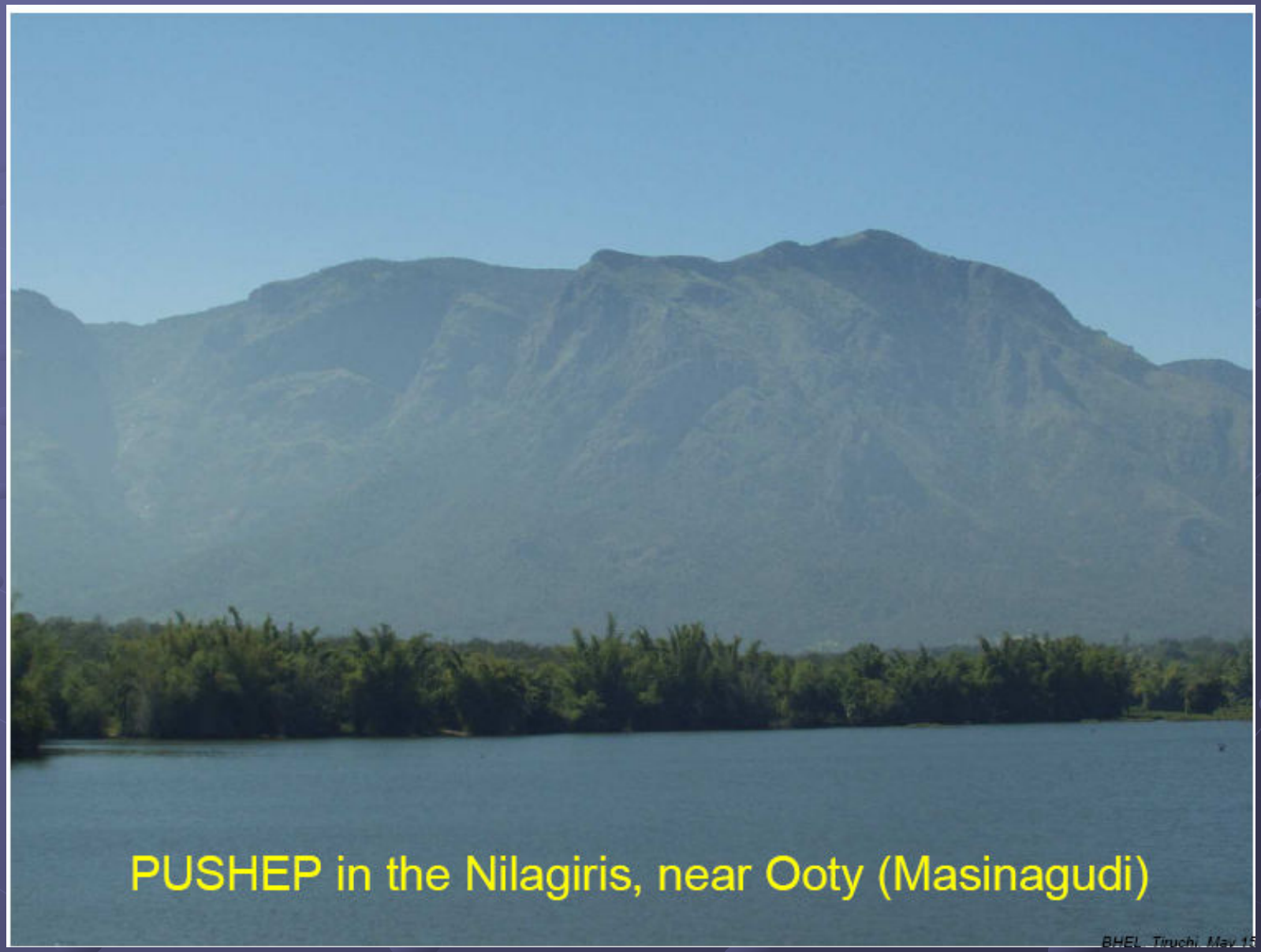
A vintage underground neutrino detector



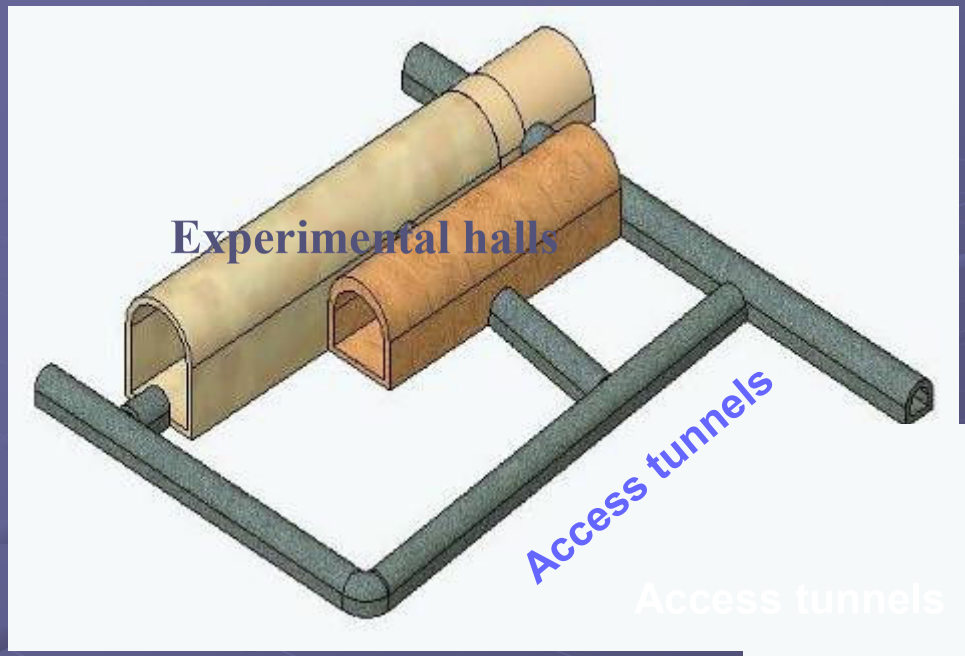
An underground proton decay experiment

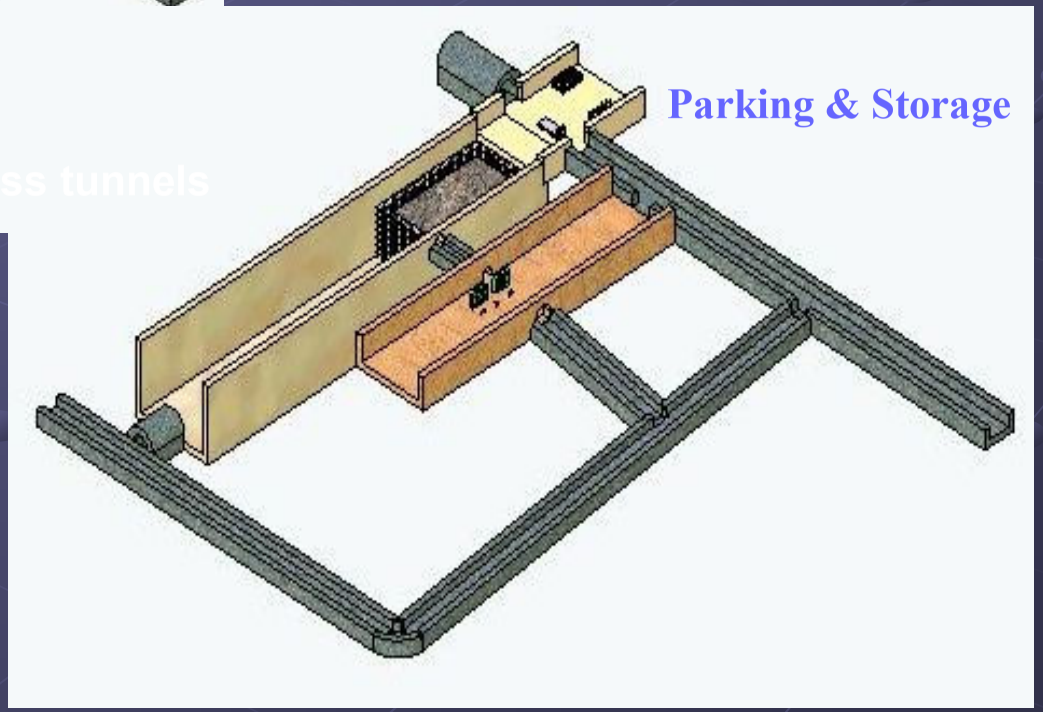


INO cavern site

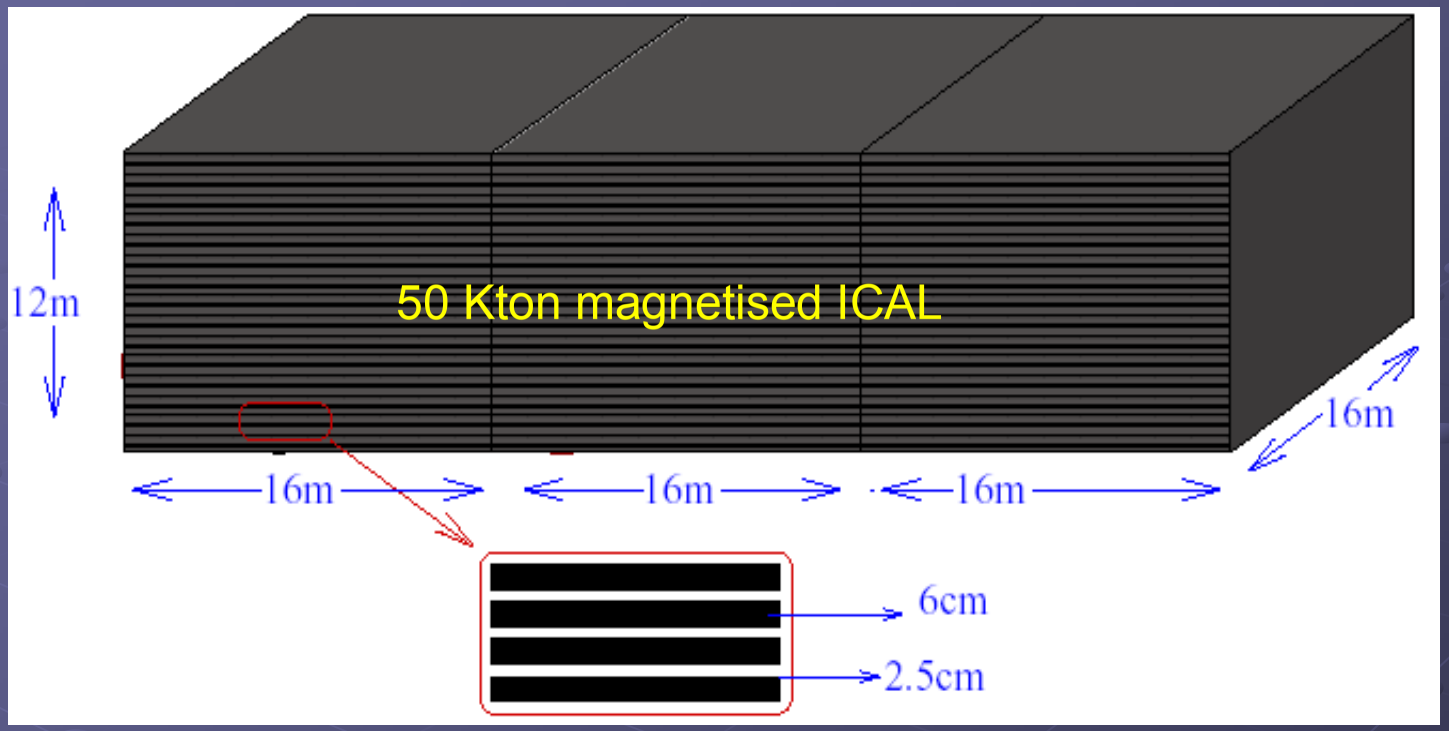


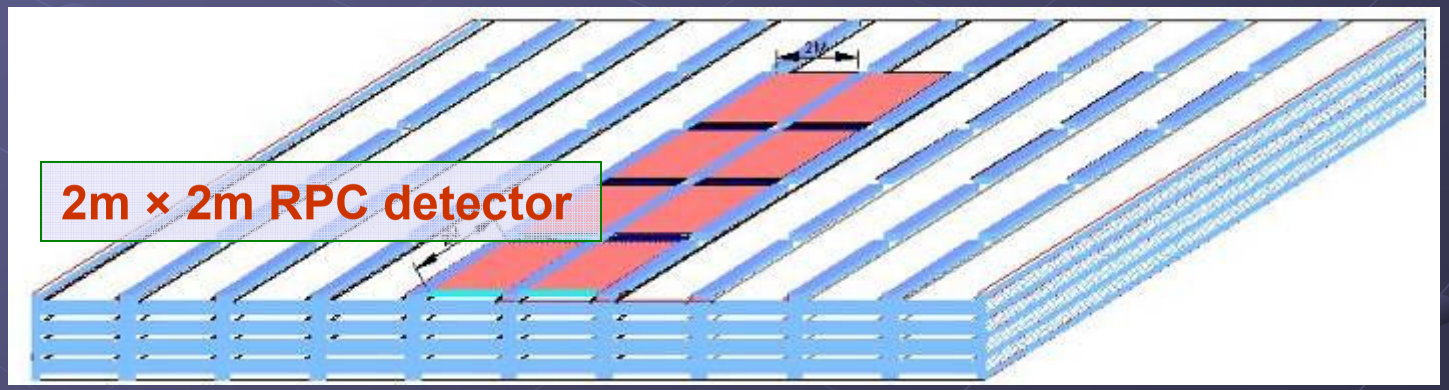
INO underground cavern design





INO Iron Calorimeter detector concept





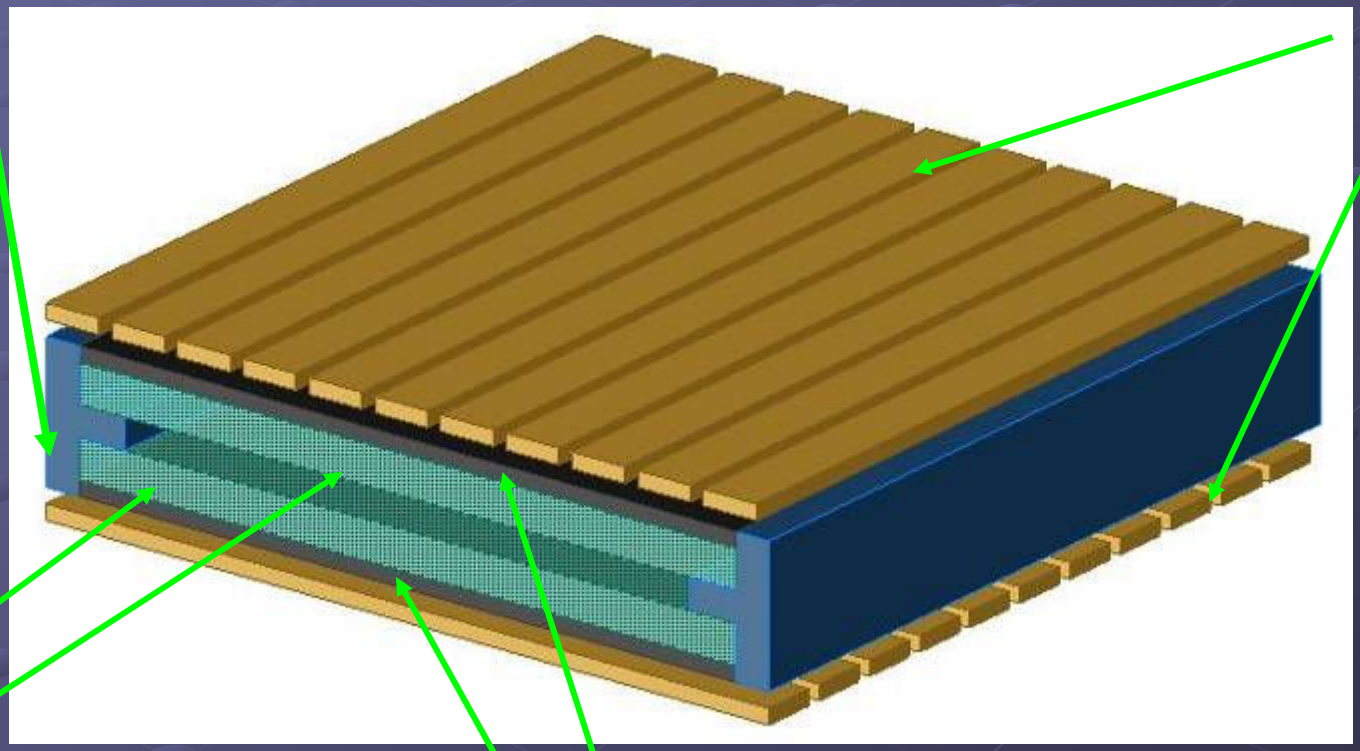
ICAL detector fact sheet

No. of modules	3
Module dimensions	16 m X 16 m X 12 m
Detector dimensions	48 m X 16 m X 12 m
No. of layers	140
Iron plate thickness	6 cm
Gap for RPC trays	2.5 cm
Magnetic field	1.3 Tesla
RPC dimensions	2 m X 2 m
Readout strip width	3 cm
No. of RPCs/Road/Layer	8
No. of Roads/Layer/Module	8
No. of RPC units/Layer	192
No. of RPC units	26880
No. of readout channels	3.6×10^6

Construction of an RPC detector

2 mm thick spacer

Two 3 mm thick float glass separated by 2 mm spacer



Pickup strips

Glass plates

Resistive coating on the outer surfaces of glass

Summary

- We are poised to answer some of the biggest questions in physics.
- Many of the answers will come from LHC experiments and a large number of non-accelerator experiments.
- The LHC at CERN opens the window on the crucial energy scale of 1 TeV.
- Many non-accelerator and astroparticle physics experiment will collect evidence of interactions at much higher energy scales.
- Our notion of space and time may be radically altered
- There may even be a revolution in physics.
- BUT, the experiments cost billions, take decades to build, demand multi-national collaborations, pose huge challenges in detector design, construction, instrumentation, electronics, data acquisition, data storage, computation and physics analysis!

References

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- CMS experiment: http://cms.cern.ch
- INO experiment: http://www.imsc.res.in/~ino