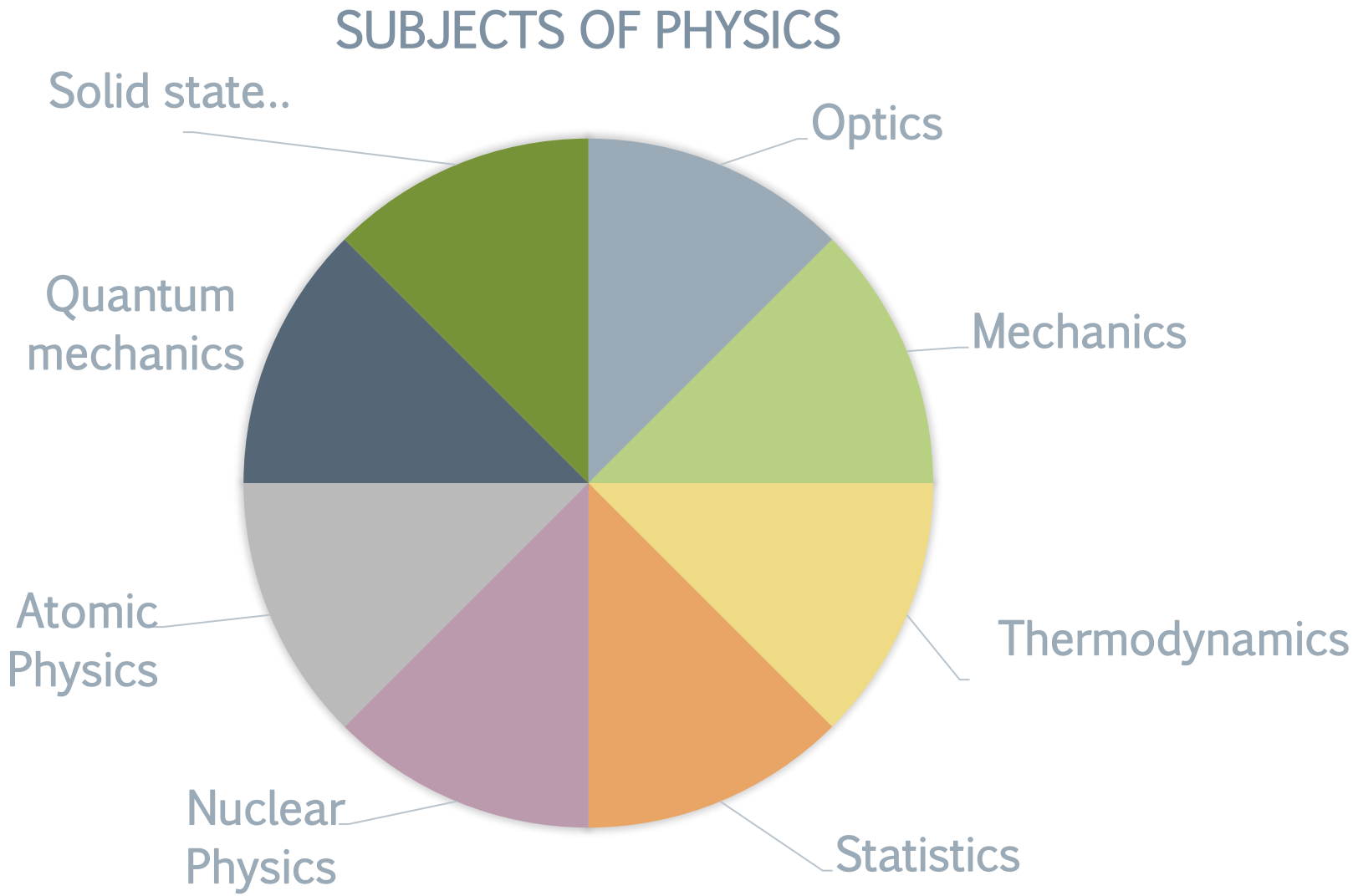
An eye to see subatomic world


SUBJECTS OF PHYSICS
Solid state..
Optics
Quantum mechanics
Mechanics
Atomic Physics
Thermodynamics
Nuclear Physics
Statistics

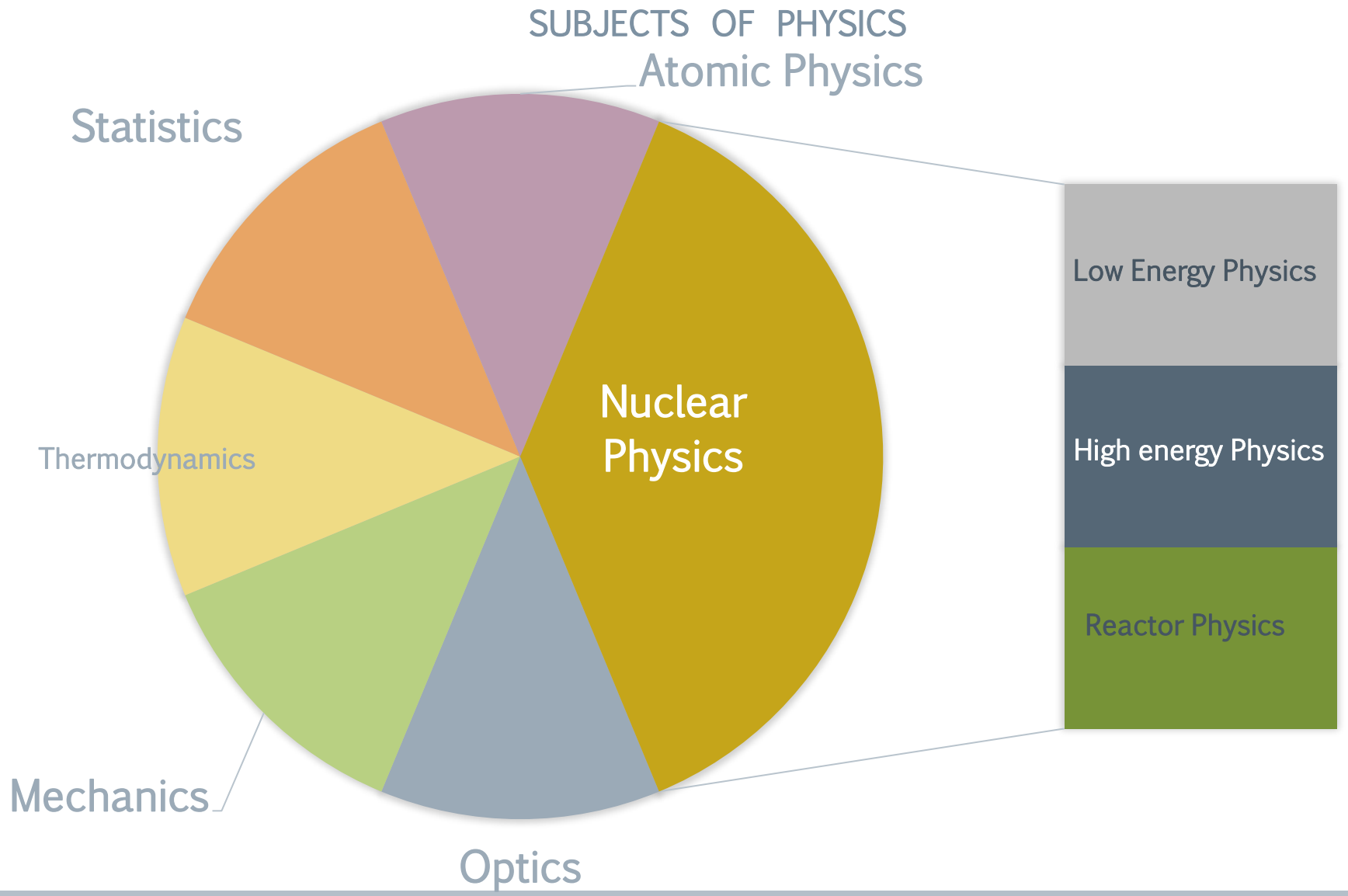

SUBJECTS OF PHYSICS
Atomic Physics
Statistics
Nuclear Physics
Thermodynamics
Mechanics
Optics
Low Energy Physics
High energy Physics
Reactor Physics

Table of Contents

Introduction to High Energy Physics

Theory

- To propose different models & check their validity
- To develop mathematical framework for the concept

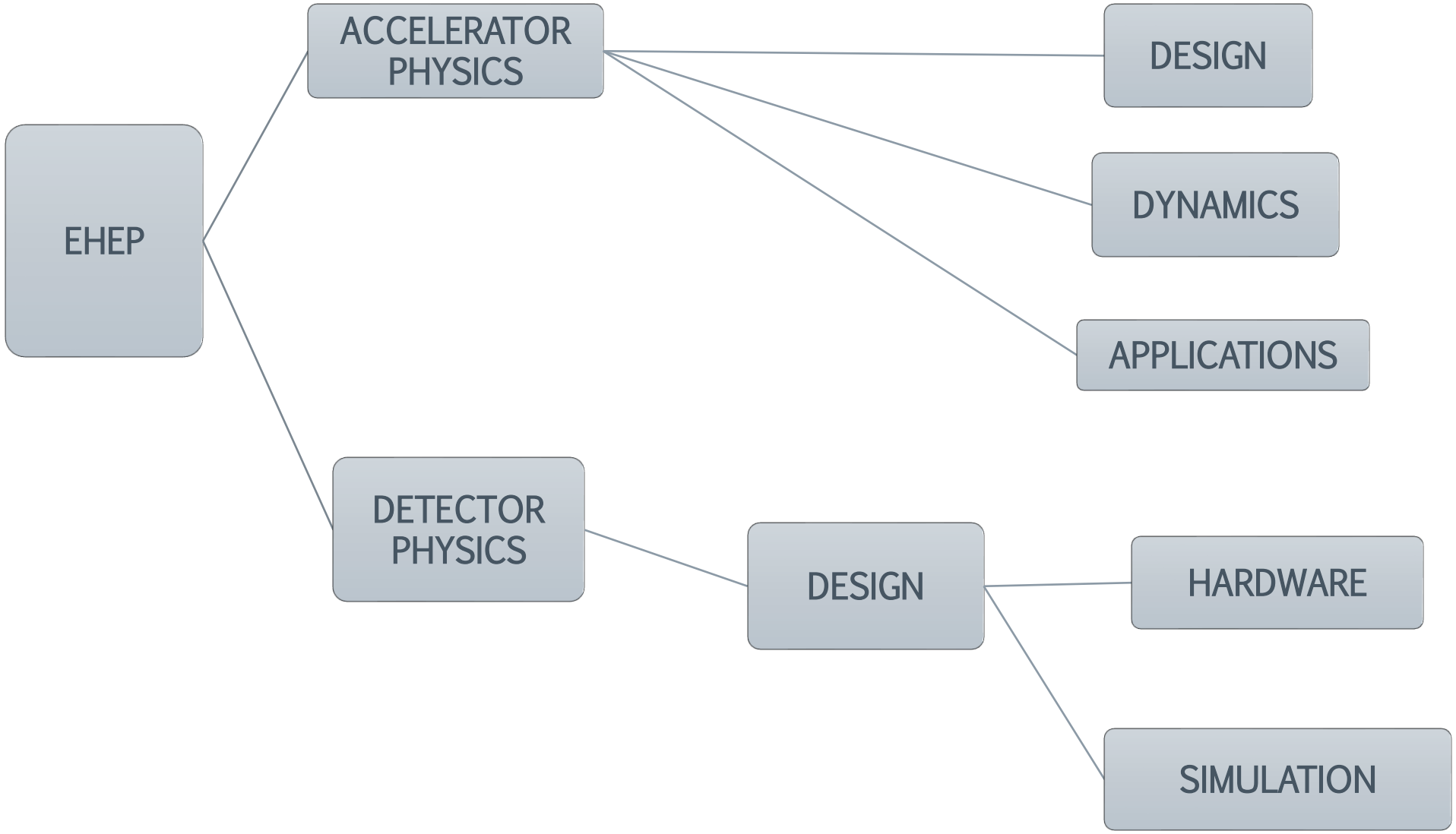
Simulations

- To use different computational tools to simulate the concept or to design complex experimental setups prior to real construction

Instrumentation

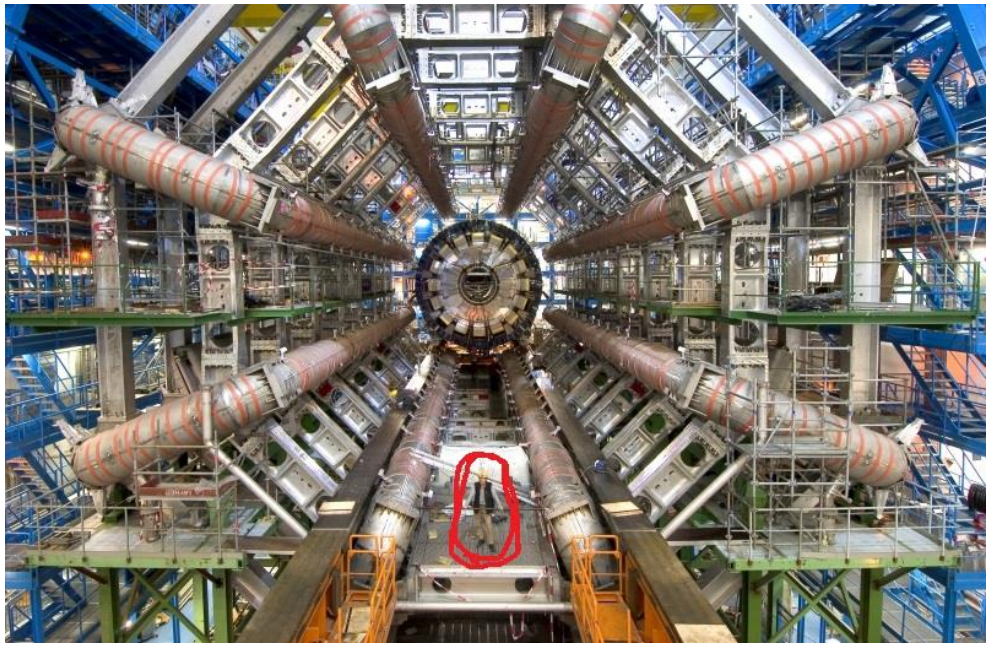
- To make necessary components for the experiments. To check and verify various factors affecting the performance of the device.

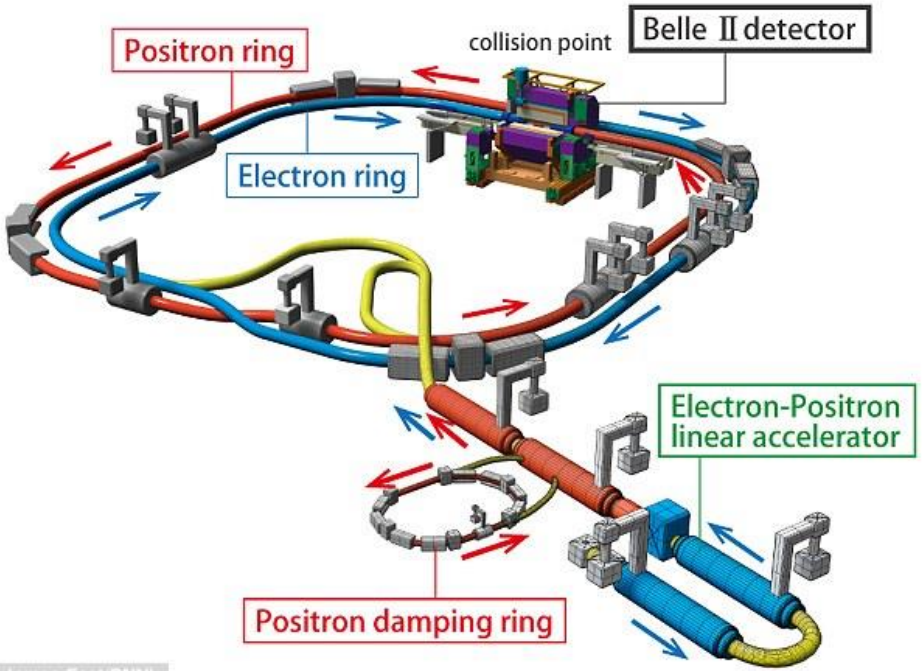
High Energy Physics Instrumentation

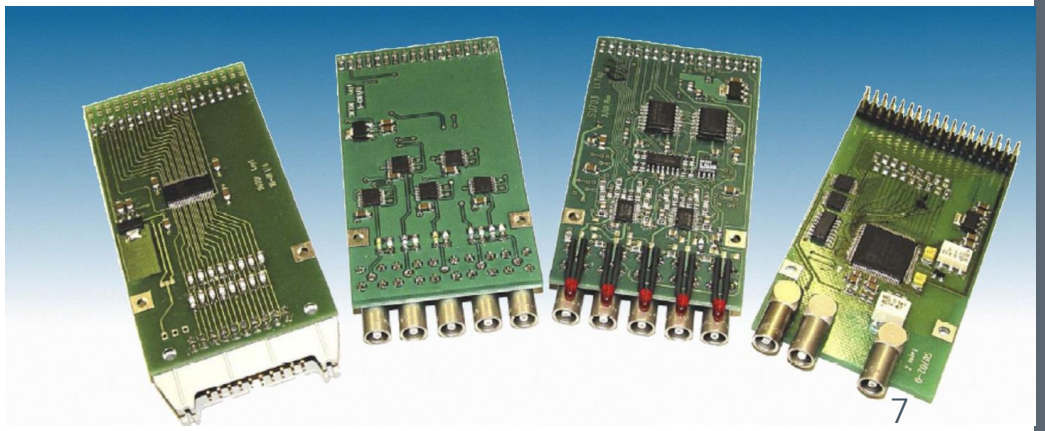


Experimental requirements for HEP

- A Particle Accelerator
- A Detector
- Fast and Special Electronics



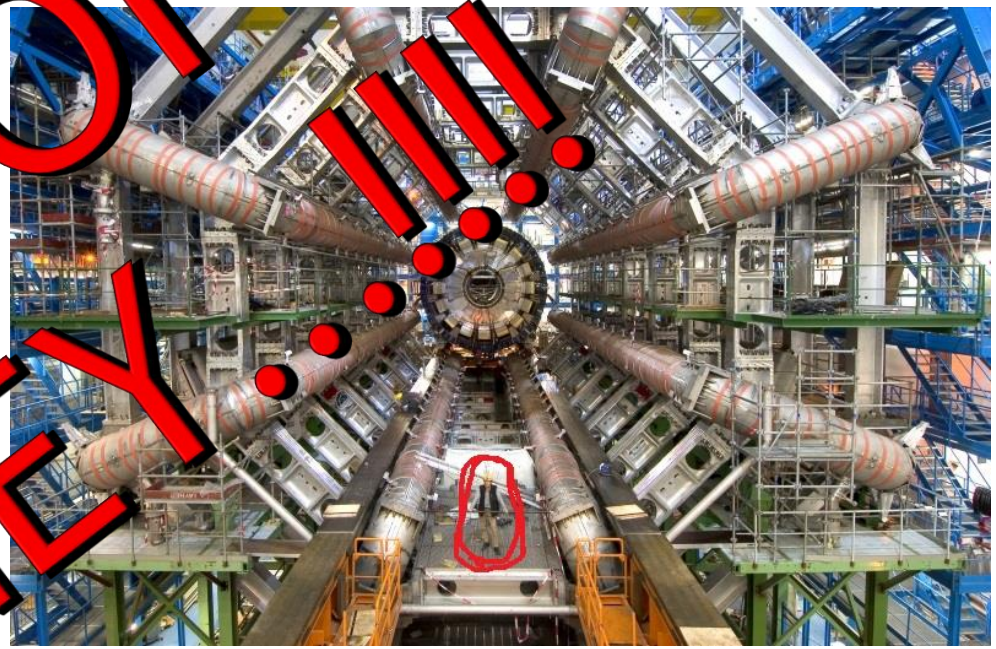


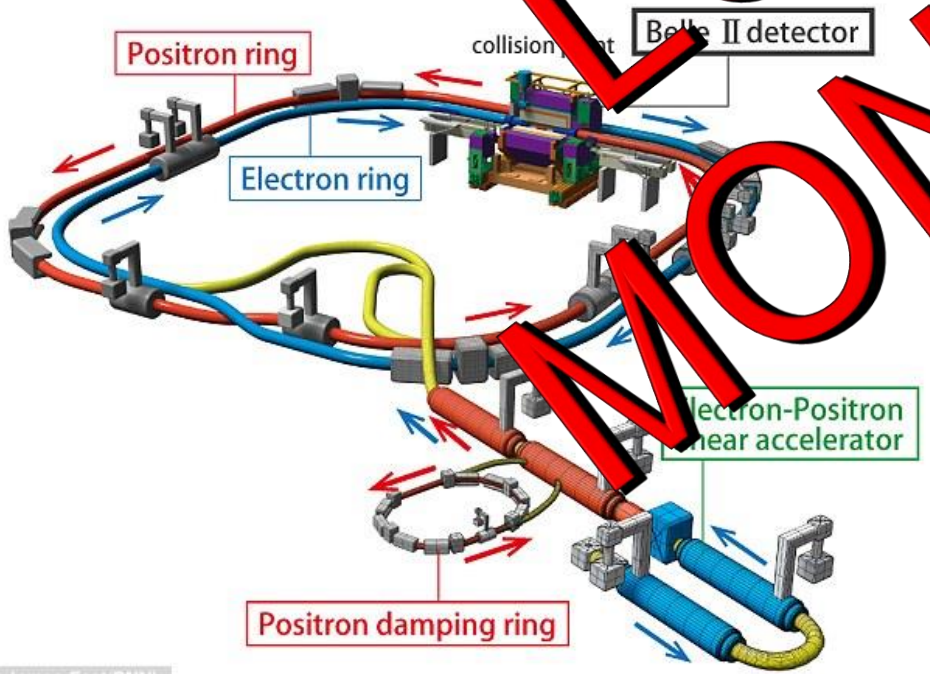


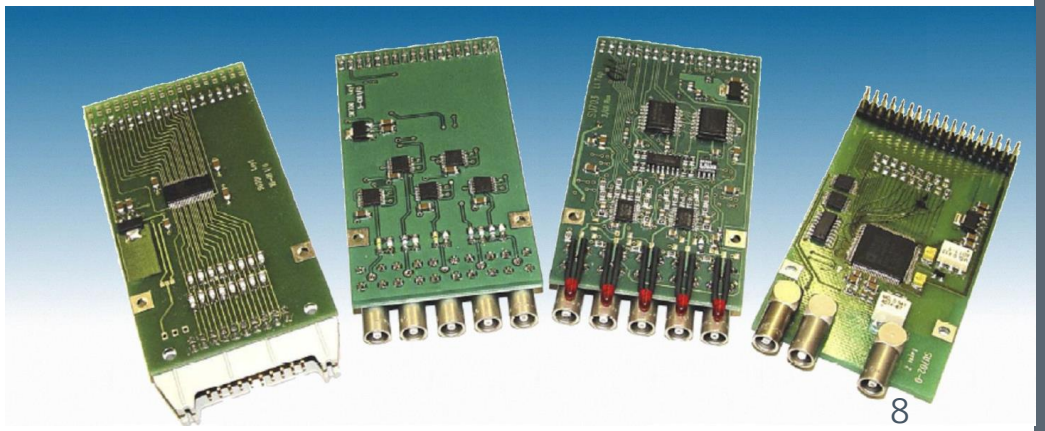
Experimental requirements for HEP

- A Particle Accelerator
- A Detector
- Fast and Special Electronics

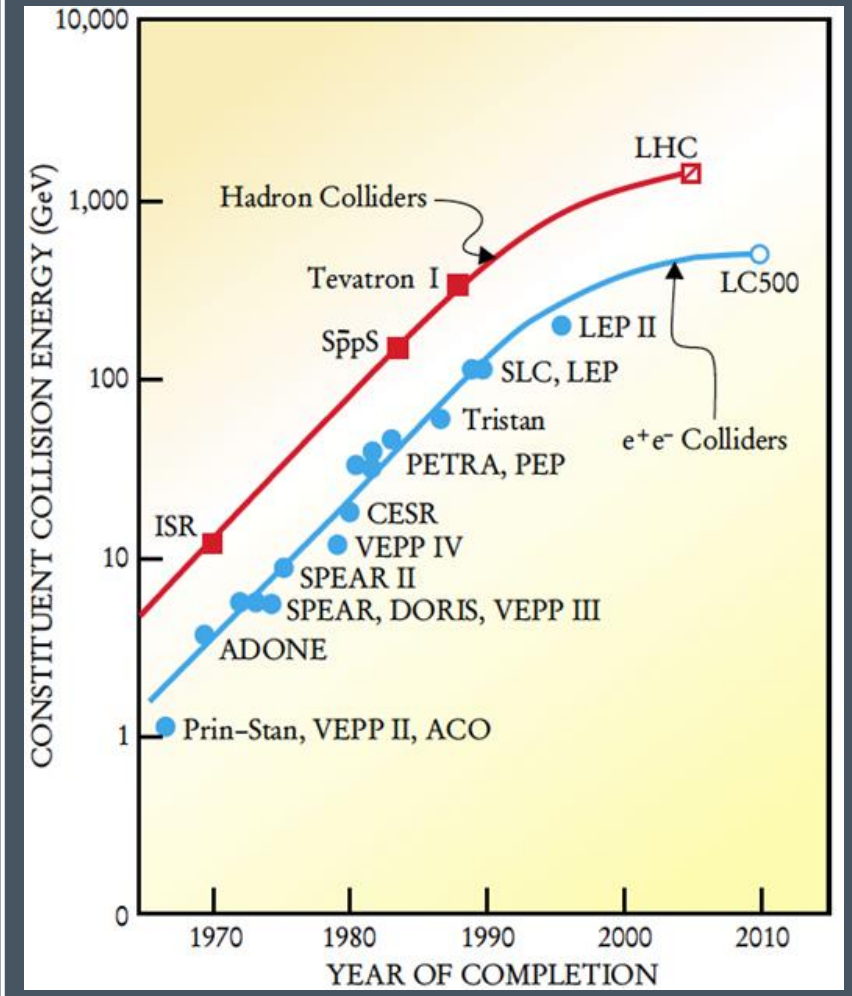
A LOT OF MONEY…!!!!

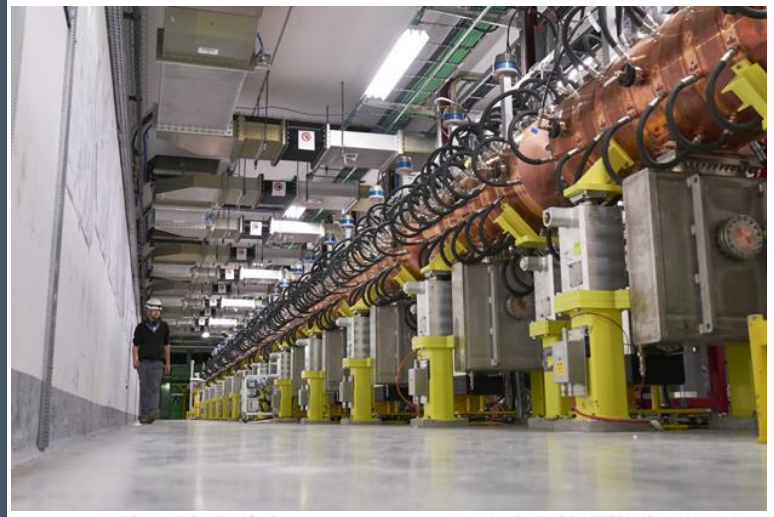


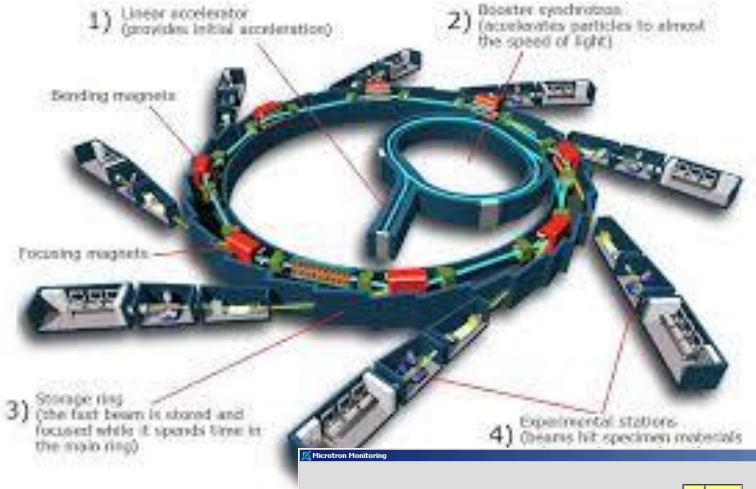


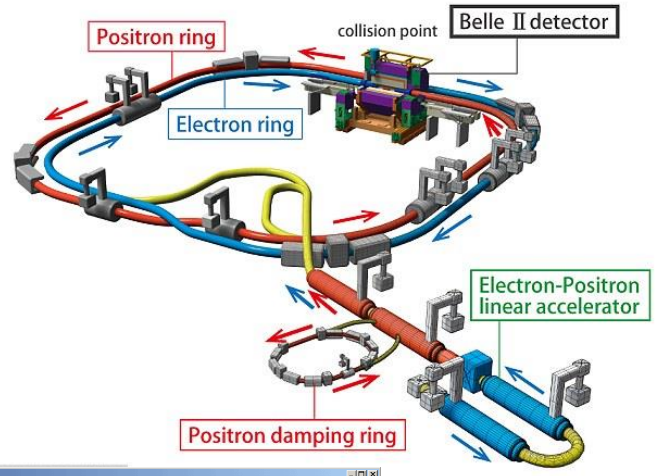


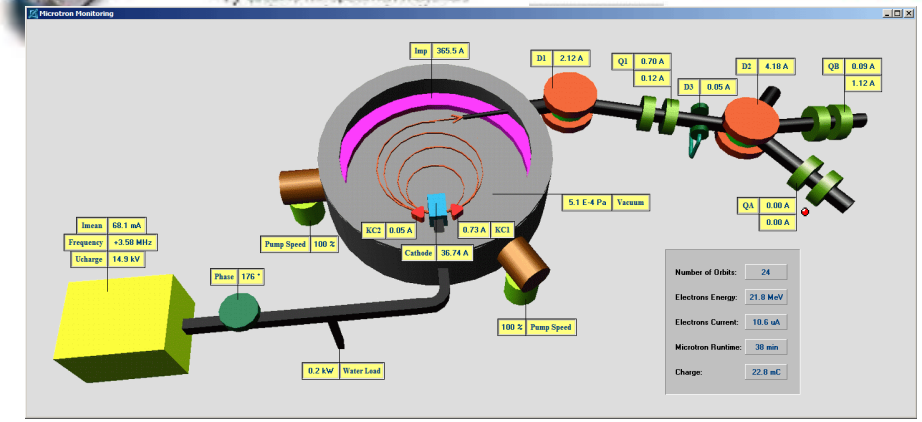
TYPES OF ACCELERATORS



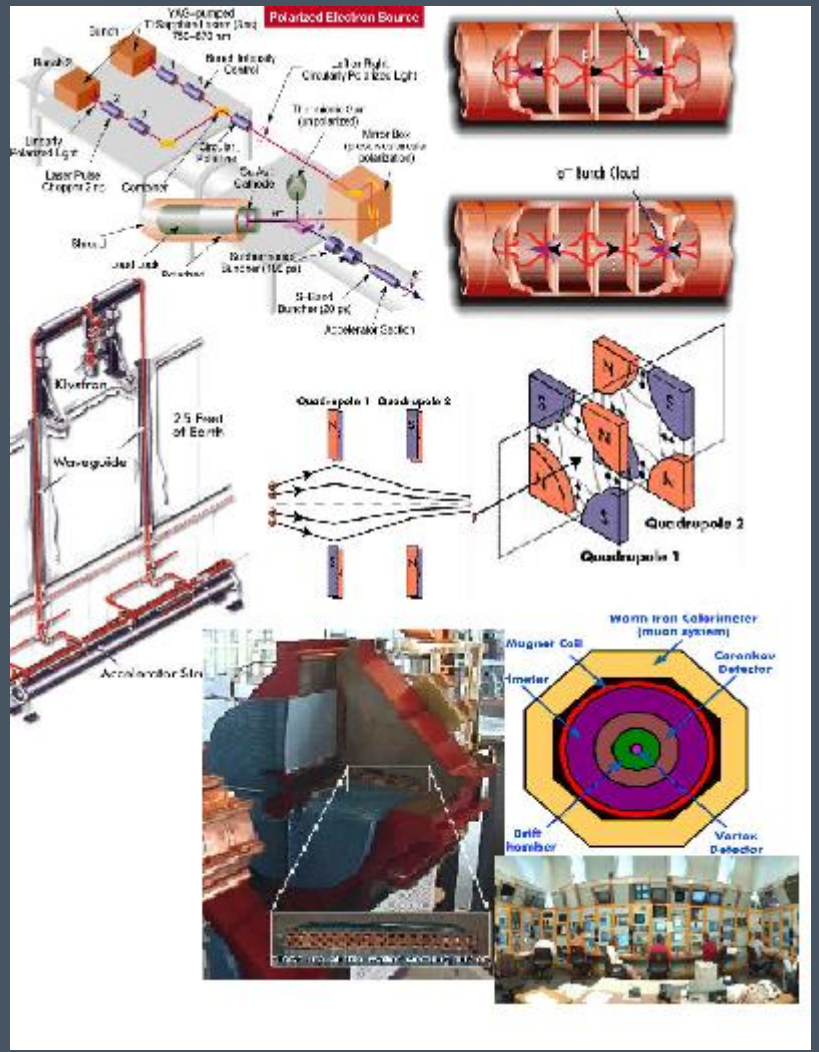








COMPONENTS OF A TYPICAL ACCELERATOR

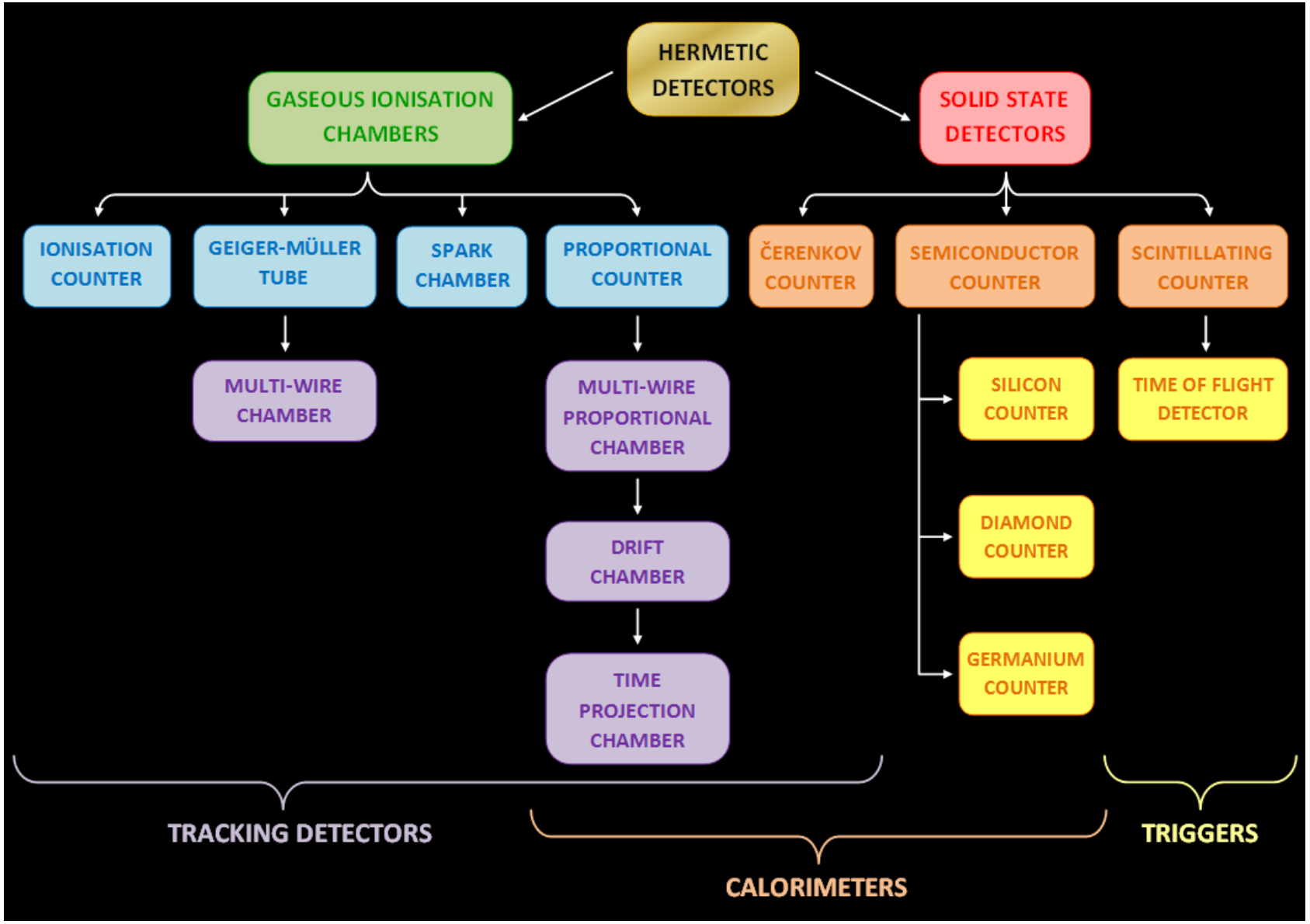


- All particle accelerators, whether linacs or circular, have the following basic parts:
- **Particle source** - provides the particles that will be accelerated
- **Copper tube** - the particle beam travels in a vacuum inside this tube
- **Klystrons** - microwave generators that make the waves on which the particles ride
- **Electromagnets** (conventional, superconducting) - keep the particles confined to a narrow beam while they are travelling in the vacuum, and also steer the beam when necessary
- **Targets** - what the accelerated particles collide with
- **Detectors** - devices that look at the pieces and radiation thrown out from the collision
- **Vacuum systems** - remove air and dust from the tube of the accelerator
- **Cooling systems** - remove the heat generated by the magnets
- **Computer/electronic systems** - control the operation of the accelerator and analyze the data from the experiments
- **Shielding** - protects the operators, technicians and public from the radiation generated by the experiments
- **Monitoring systems** - closed-circuit television and radiation detectors to see what happens inside the accelerator (for safety purposes)
- **Electrical power system** - provides electricity for the entire device
- **Storage rings** - store particle beams temporarily when not in use

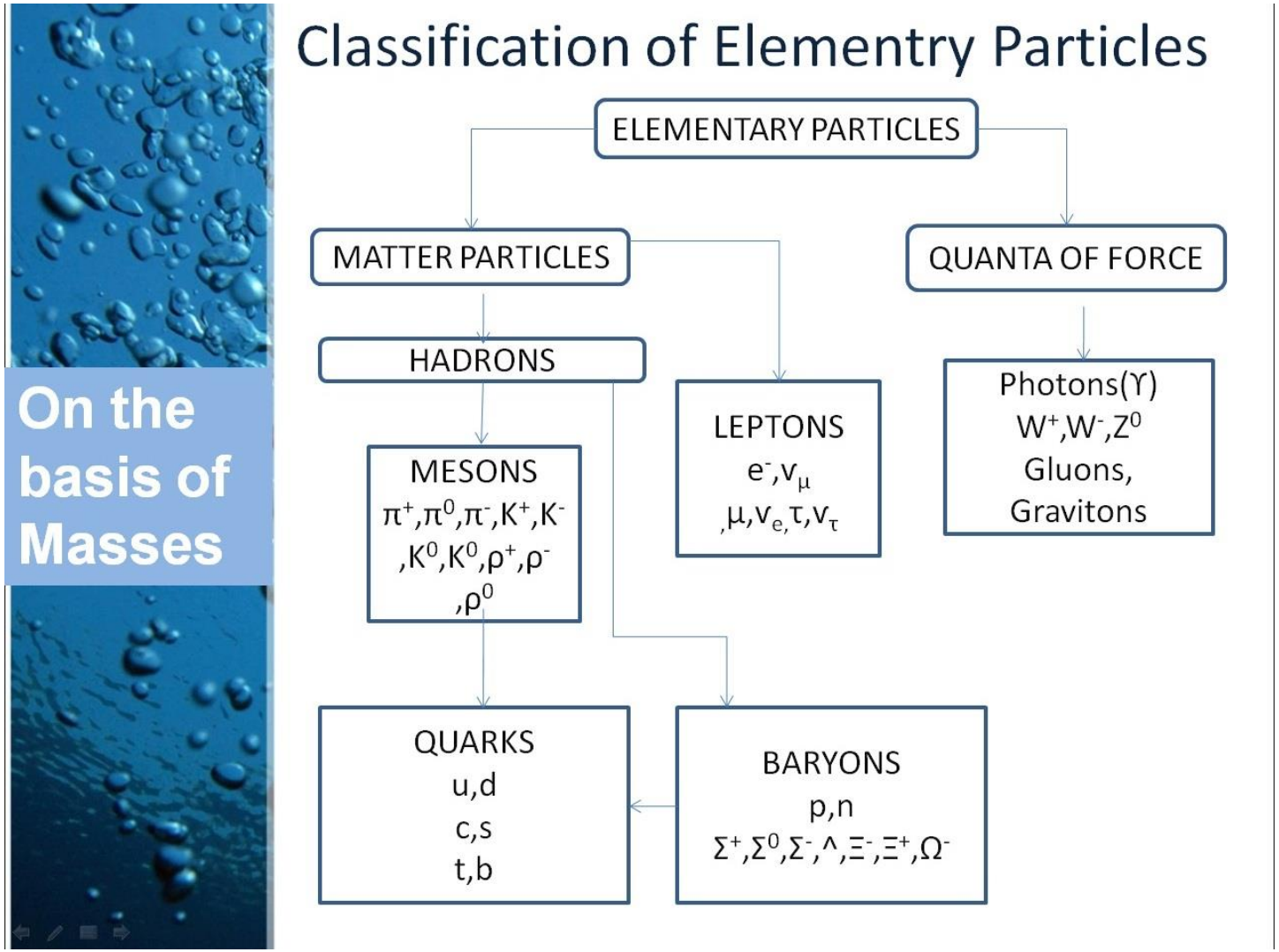
Lets See What are Detectors…

- Detectors are Device which detects particle or its property (velocity, charge etc) by exploiting one(or more) of the physical property of Detector material.
- For example Gas detector exploits the fact that charge particle when pass through a gas, ionizes the gas in to electron and ion pairs.
- In HEP we don’t have one detector but detector system with many sub detectors.

Types of Particle Detectors



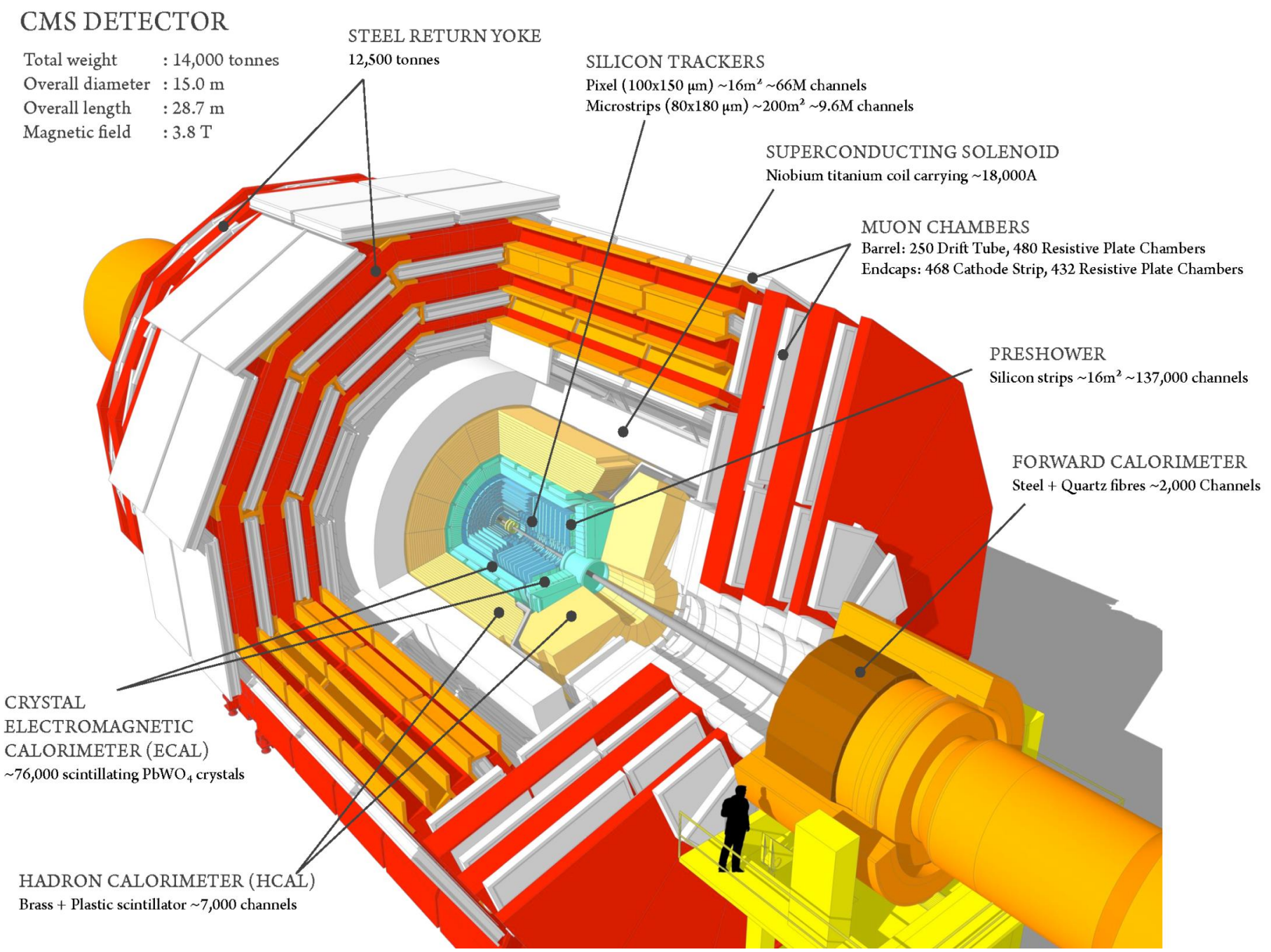
Types of Elemantary Particles

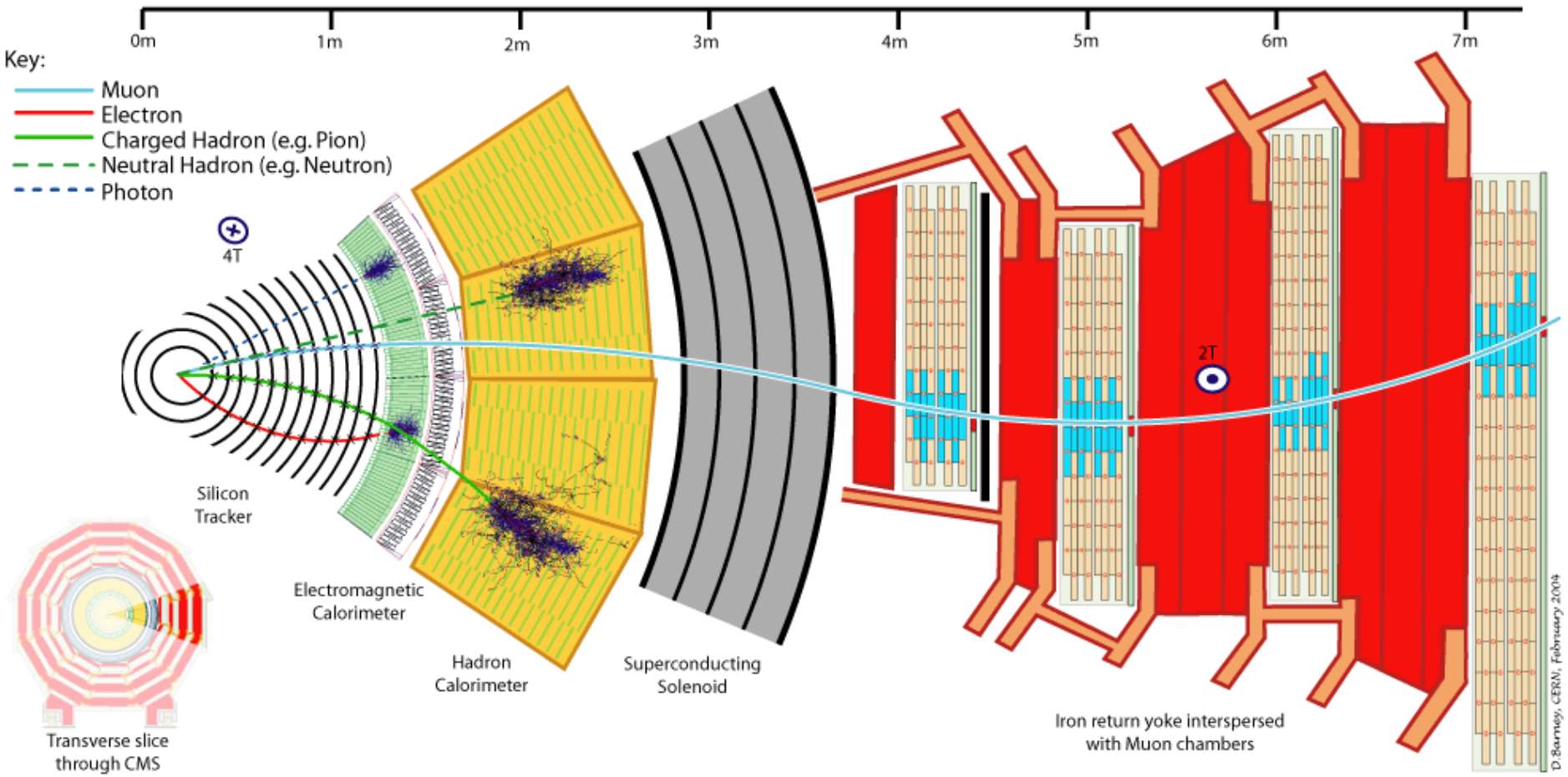


HOW ARE THE PARTICLE DETECTED

- A detector system has many layers of different sub-detectors.
- Each Layer has its own role in an experiment.
- The choice of sub detector is based on where that sub-detector is placed and what it will detect.

- The main equation of HEP is Einstein's relativistic equation.
- $E=p^2c^2+m^2c^4$
- A detector detects only one property at time ie, Energy or momentum or velocity.
- For complete information about whole event one also needs position of detector where particle hit the detector.
- Thus there are three main roles of detector.
- Tracking, Caloriemetry, Pid.


CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm) ~16m² ~66M channels
Microstrips (80x180 μm) ~200m² ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16m² ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels



Reference: https://commons.wikimedia.org/wiki/File:Schema_transverse_cms.png

Why to have multi-layered detector system

- Each detector can perform only one task at a time.
- Any detector system is designed to operate at particular energy only. It will not give desired results if operated below or over the range at which it was designed.
- Since we need many other information other than physical properties of particle, we need many different detectors in whole system.
- The data from each of sub system has to be combined and analysed which requires lots of computational power.
- Electronics required to read detector signals have limited response time.

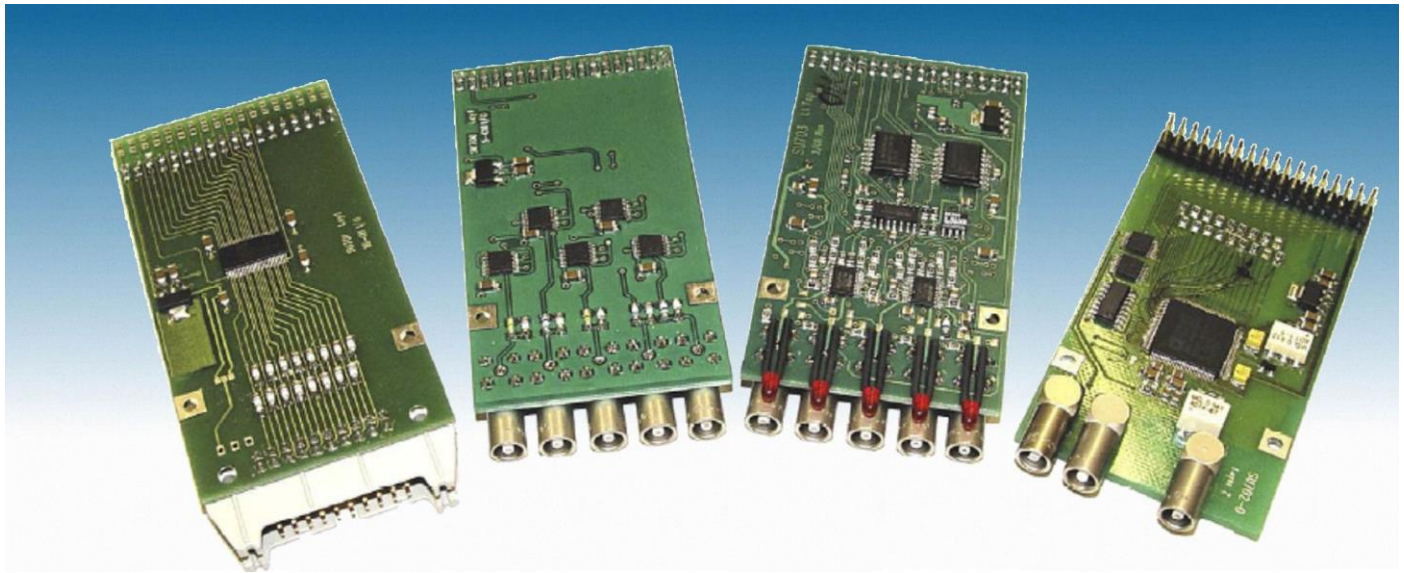
Electronics for Detectors

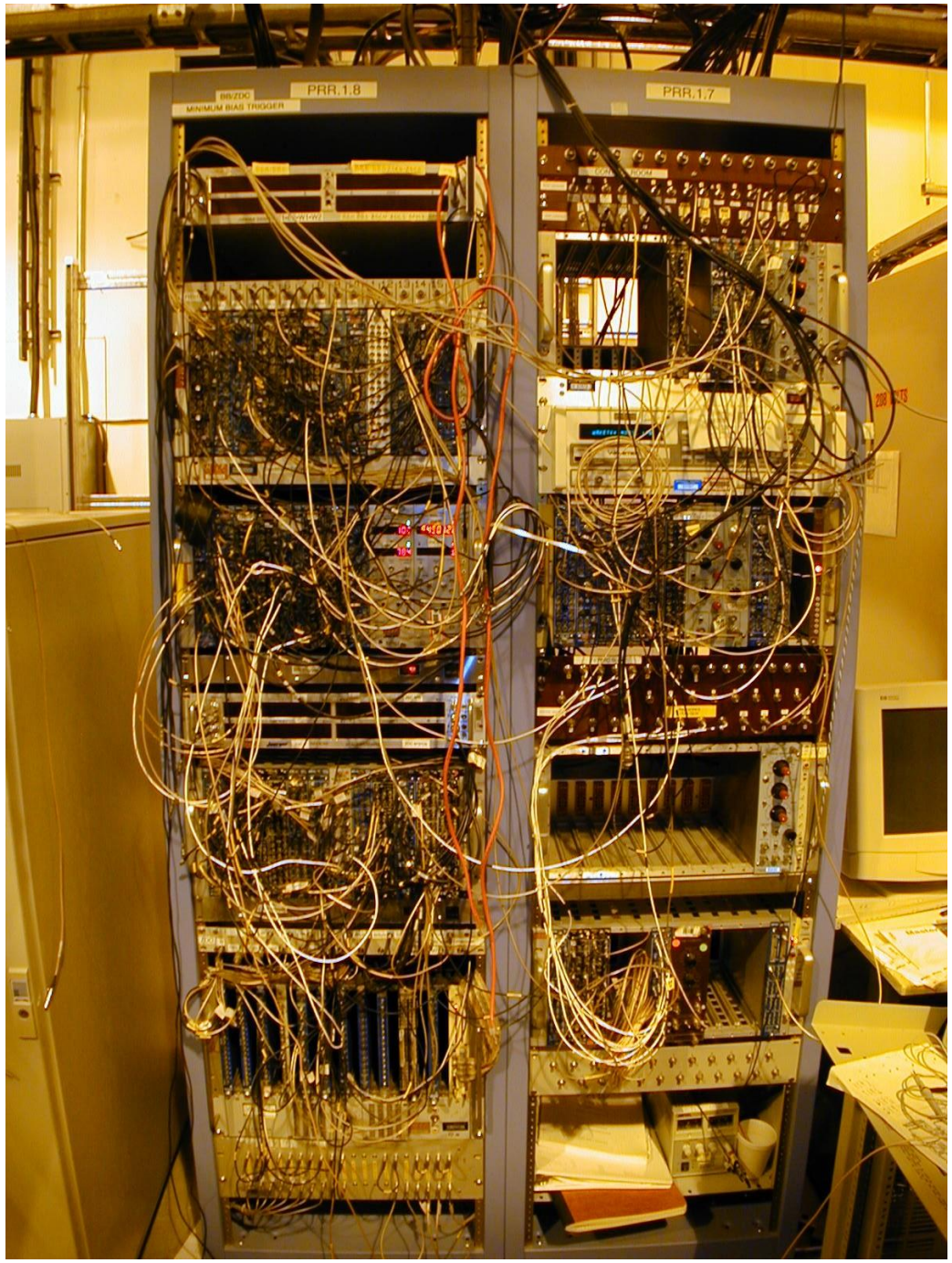
- Nuclear electronics is a subfield of electronics concerned with the design and use of high-speed electronic systems for nuclear physics and elementary particle physics research, and for industrial and medical use.
- Some of the essential components that make up the elements of a nuclear electronic analysis system include:
- Detectors
- Preamplifiers
- Discriminators
- Coincidence and veto logic gates.
- Counters
- Pulse height analysers

- The Nuclear Instrumentation Module(NIM) standard defines the mechanical and electrical specification of electronic modules used in particle and nuclear physics.
- NIM standard was first developed by U.S Atomic Energy Commision in 1968-69. It was recently revised in 1990.
- It provides common foot print for all electronic modules in a larger chasis often called as NIM crate.

NIM crate without modules(Left) and with Modules(Right)

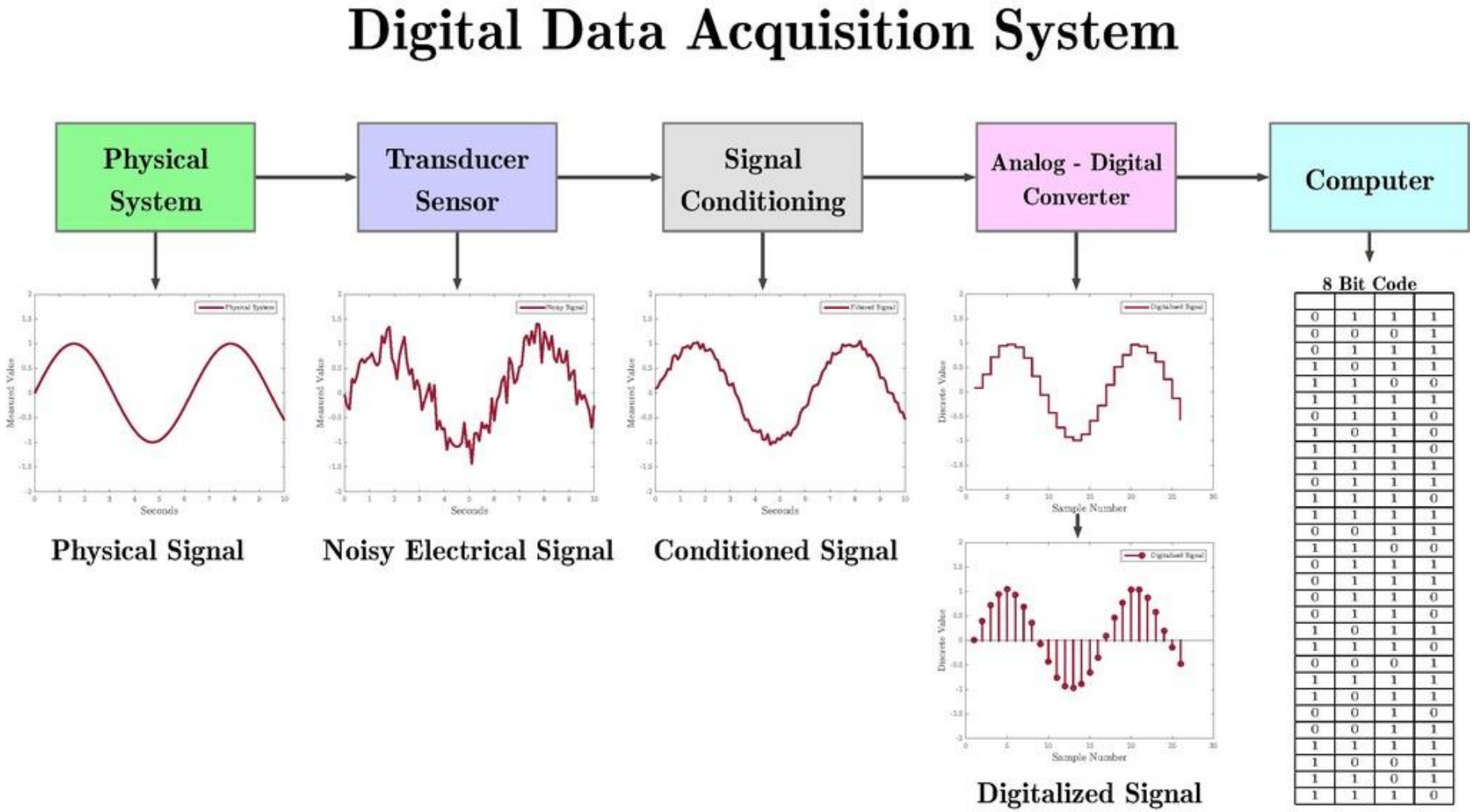
NIM Modules and lemo cables





NIM crate(s) with very simple and easy connection scheme…!!

Analysing Signals

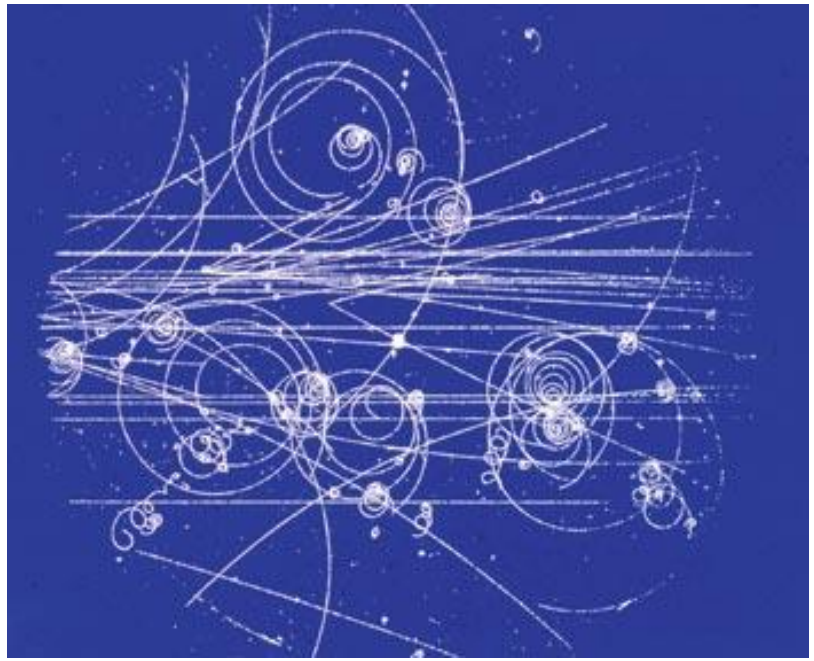


Analysing Signals

- It is important to convert signals from detectors in electronic form as its easy to handle.
- Electronic signals are converted to digital information so that we can store or manipulate as we desired.
- It is also easy to transmit digital information for long distance via internet and hence one can work remotely also from very far distance.

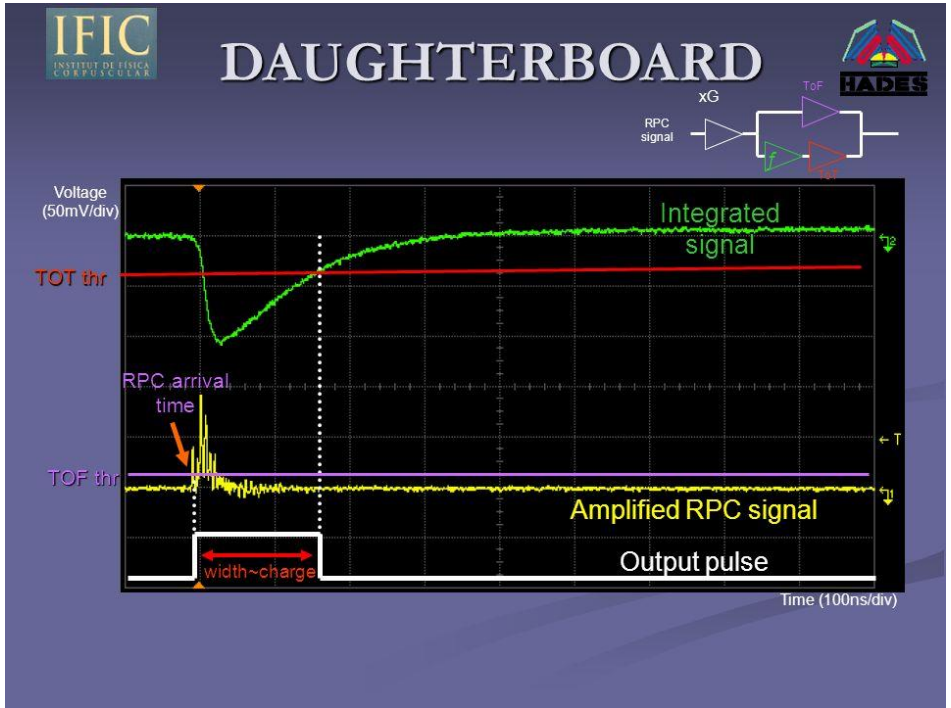
ANALYSING SIGNALS

- It is important to convert signals from detectors in electronic form as its easy to handle.
- Electronic signals are converted to digital information so that we can store or manipulate as we desired.
- It is also easy to transmit digital information for long distance via internet and hence one can work remotely also from very far distance.

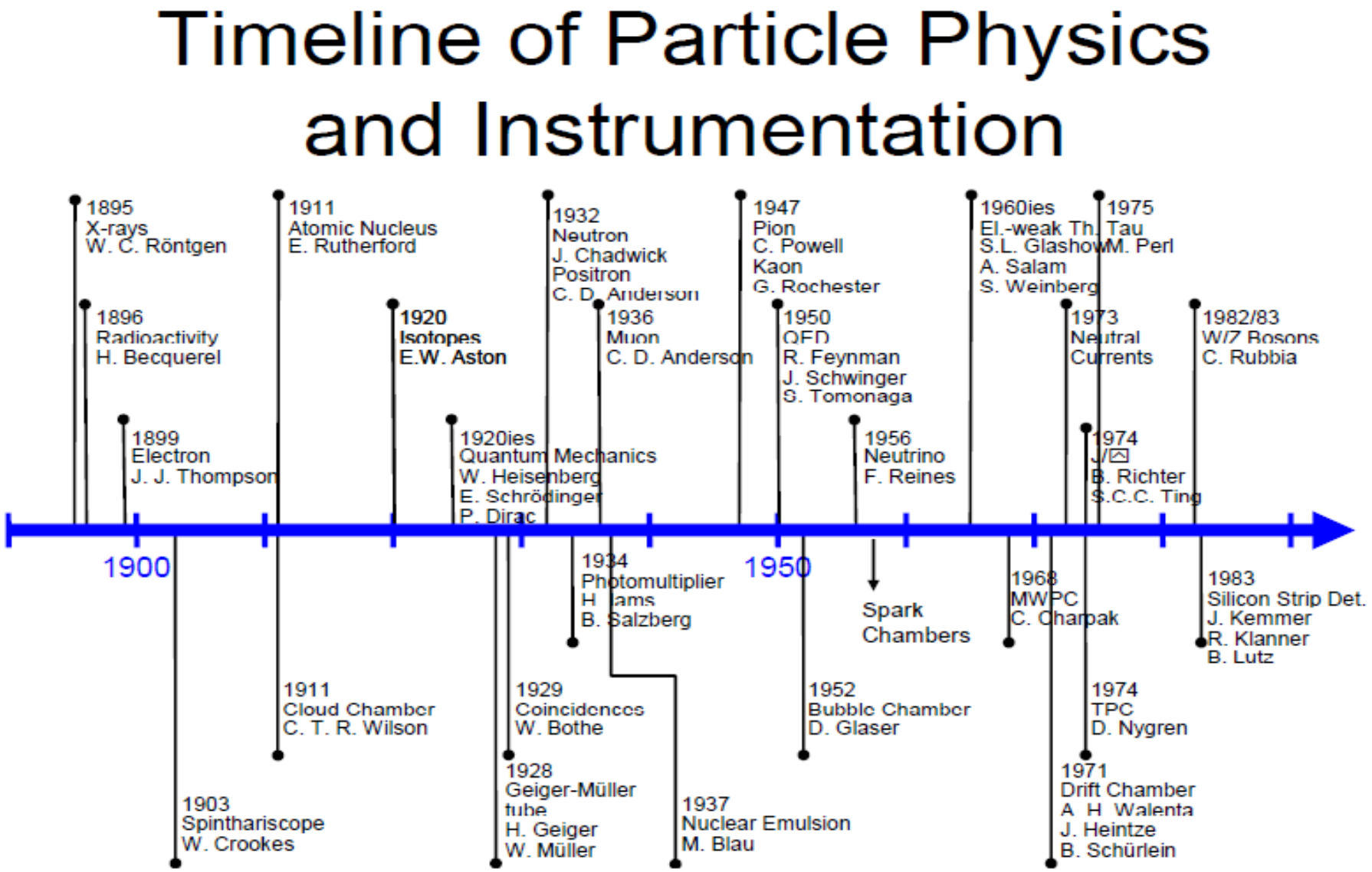


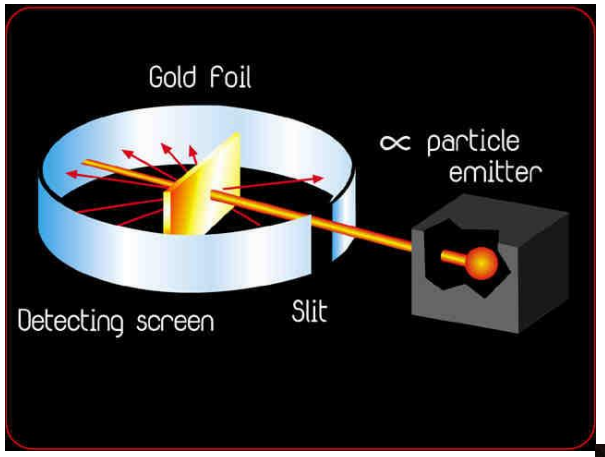
Tracks from Bubble chamber(1960s)

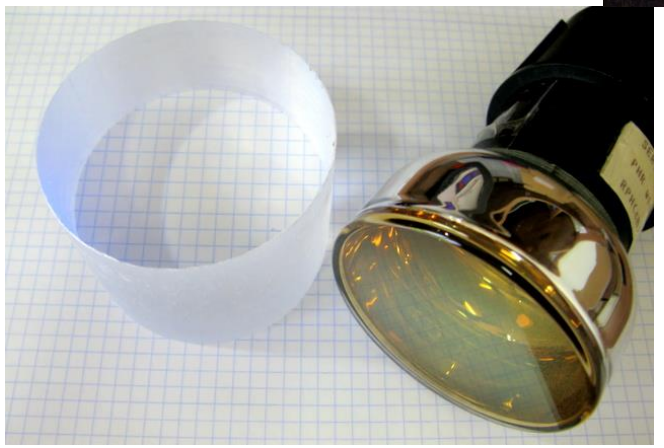
Signals from RPC (present)

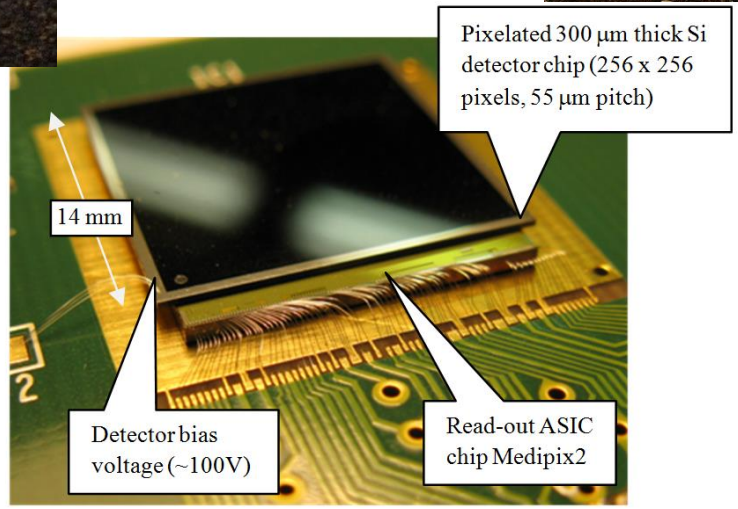


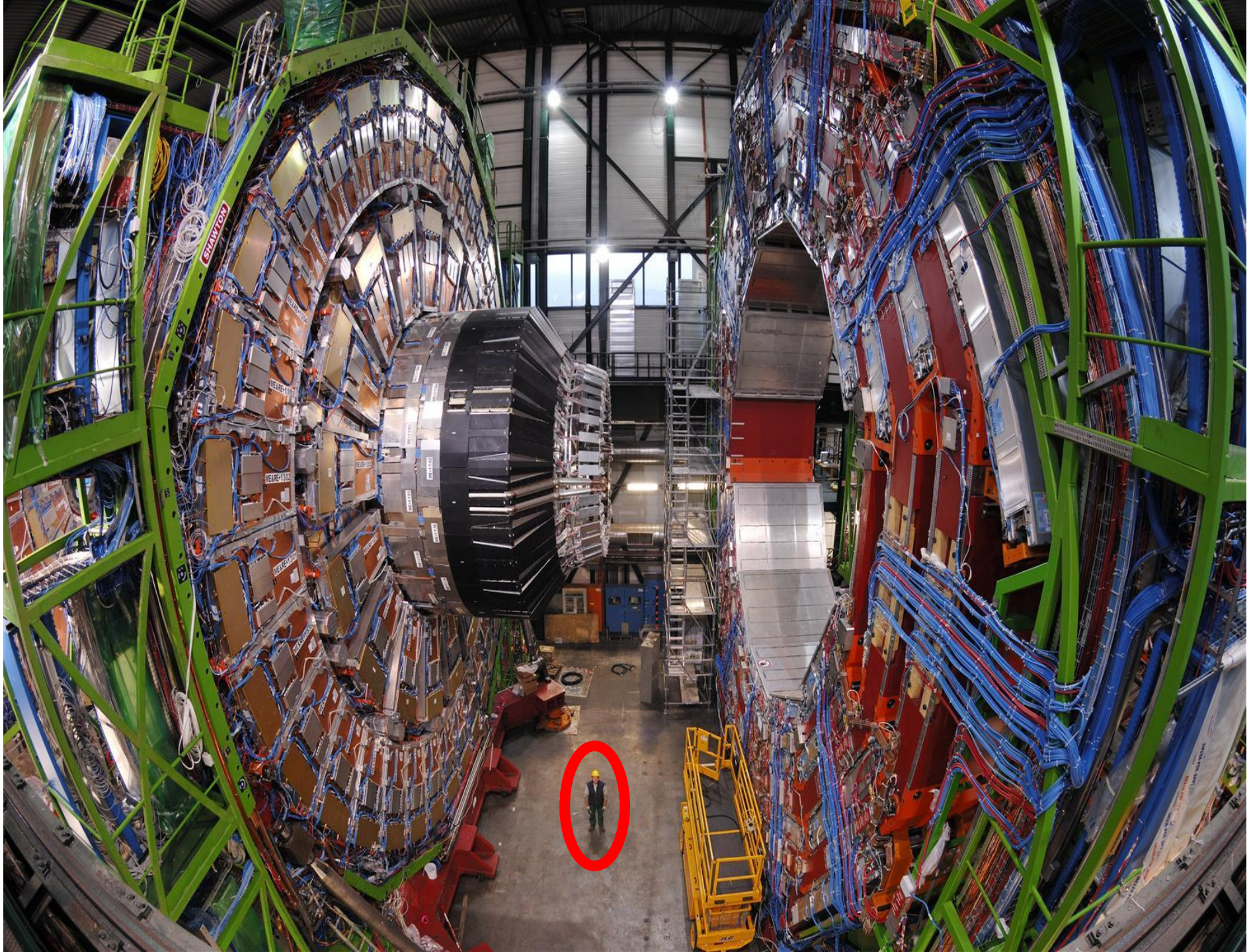
Where are we now ...!!!

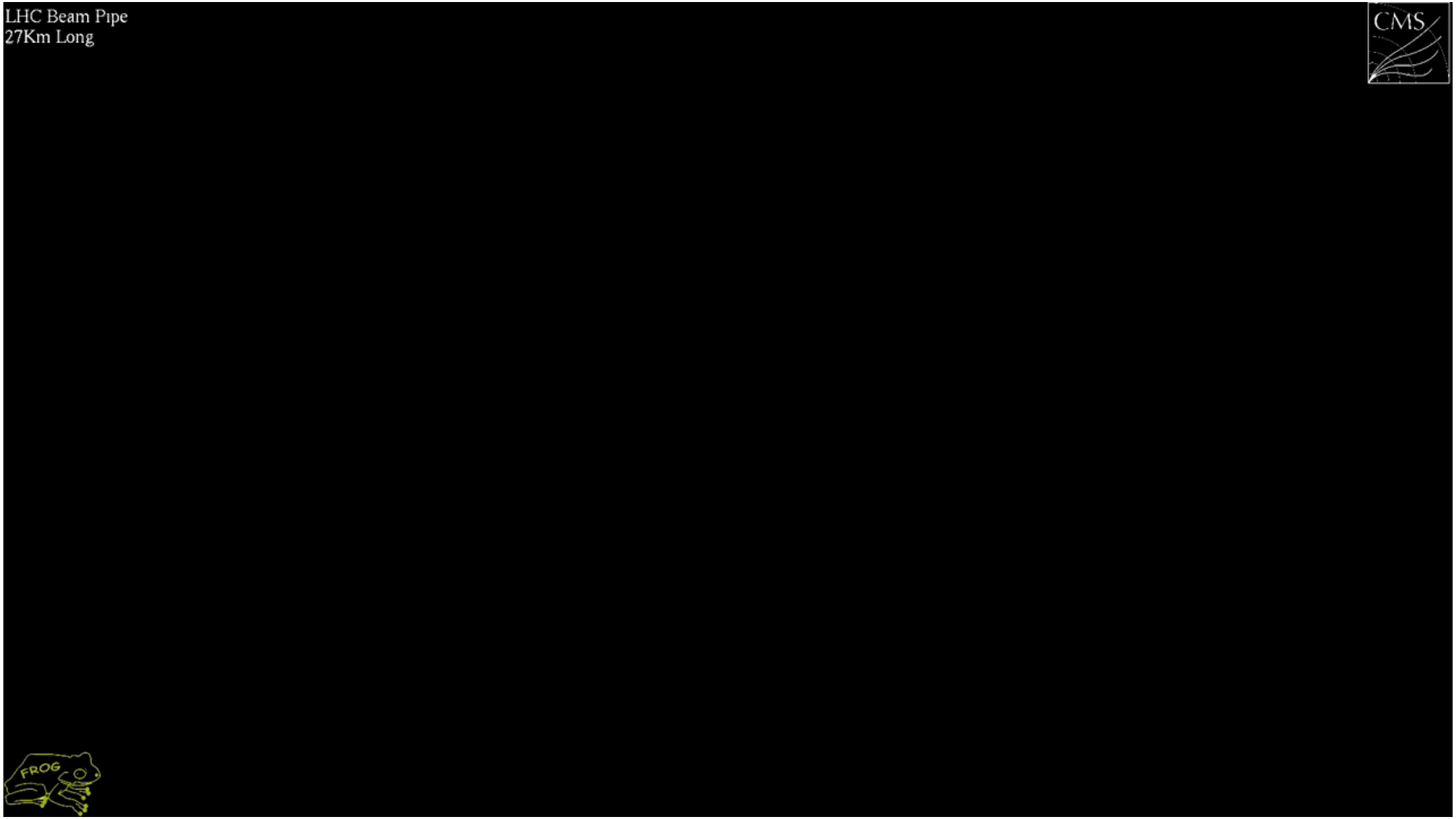



Gold Foil
∝ particle emitter
Detecting screen
Slit




Pixelated 300 µm thick Si detector chip (256 x 256 pixels, 55 µm pitch)
14 mm
Detector bias voltage (~100V)
Read-out ASIC chip Medipix2

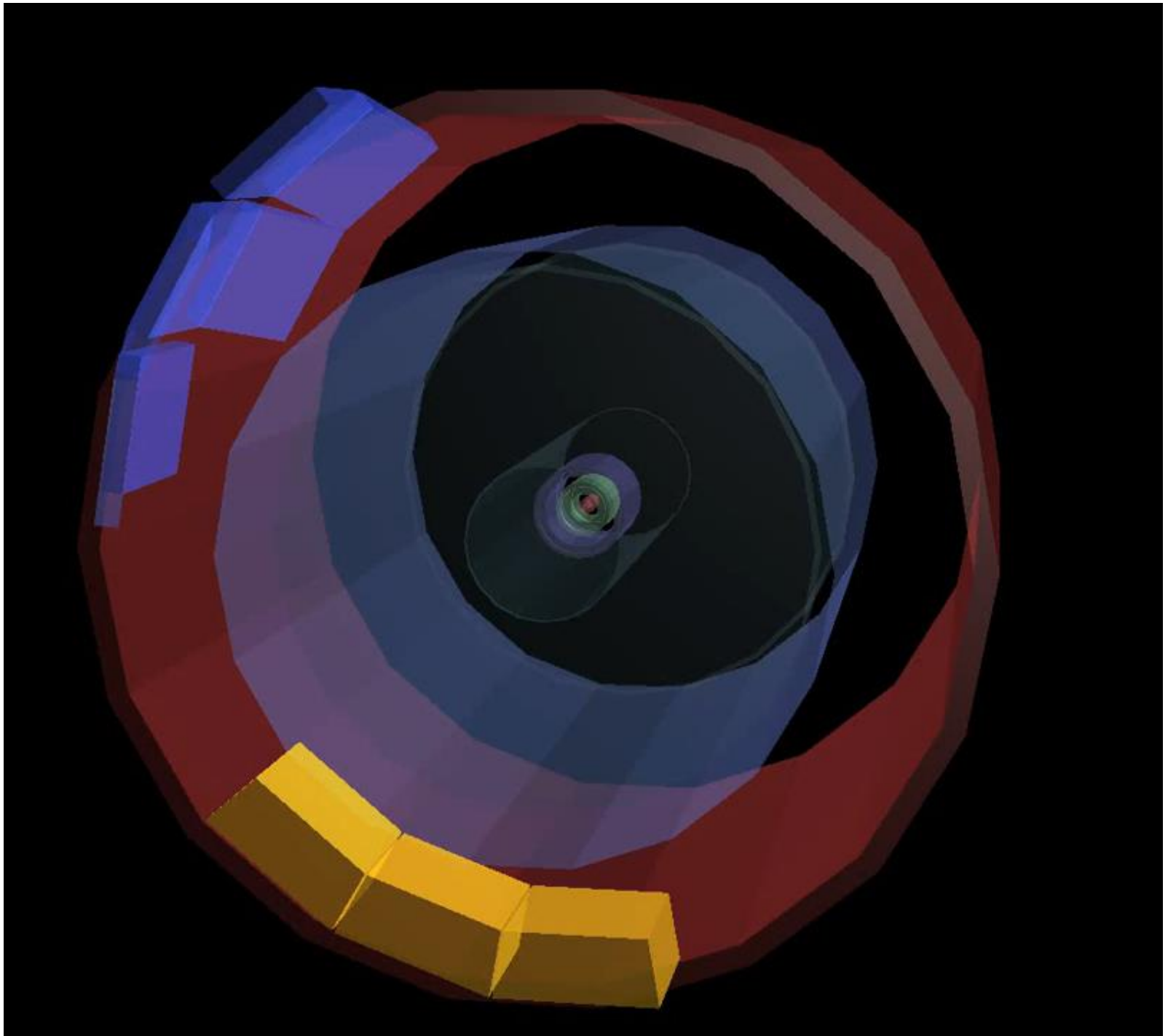



LHC Beam Pipe
27Km Long
CMS
FROG

Computer grid
of CERN

CERN’s network around the globe.

In India we have ALICE center at VECC Kolkata



References

- http://detectors.fnal.gov/EDIT2012/Lectures/2_Nygren_HistoryPP.pdf
- www.Wikipedia.org
- http://www.accelerators-for-society.org/about-accelerators/index.php?id=21
- http://science.howstuffworks.com/atom-smasher1.htm

Enough of boring lecutre...lets do something crazy....

lets try to catch some muons..some alpa ..some beta particles...

SPECIAL THANKS TO THESE PEOPLE

Top left – Akshay Jariwala

Top Right – Viresh Thakkar

Bottom left - Vipul Kheraj

Bottom Right – Pruthul Desai