CERN

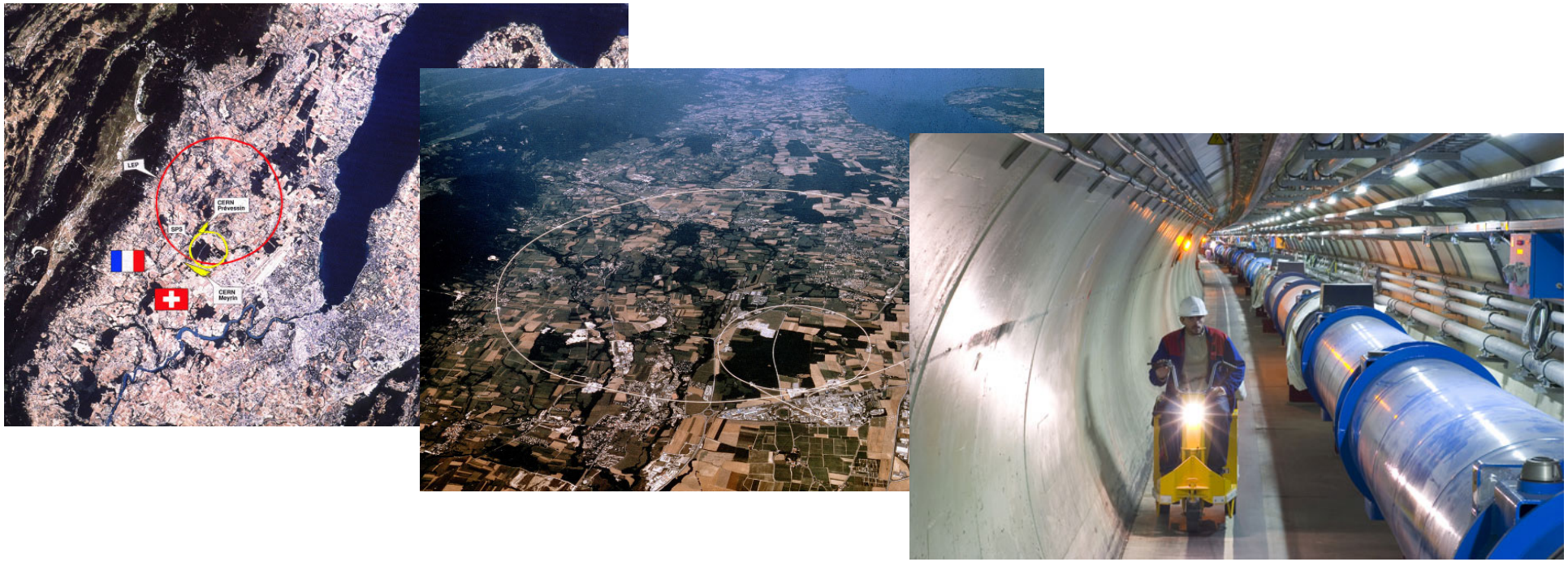
European Organization for Nuclear Research
Organisation Européenne pour la Recherche Nucléaire

The Large Hadron Collider

the world's most complex machine

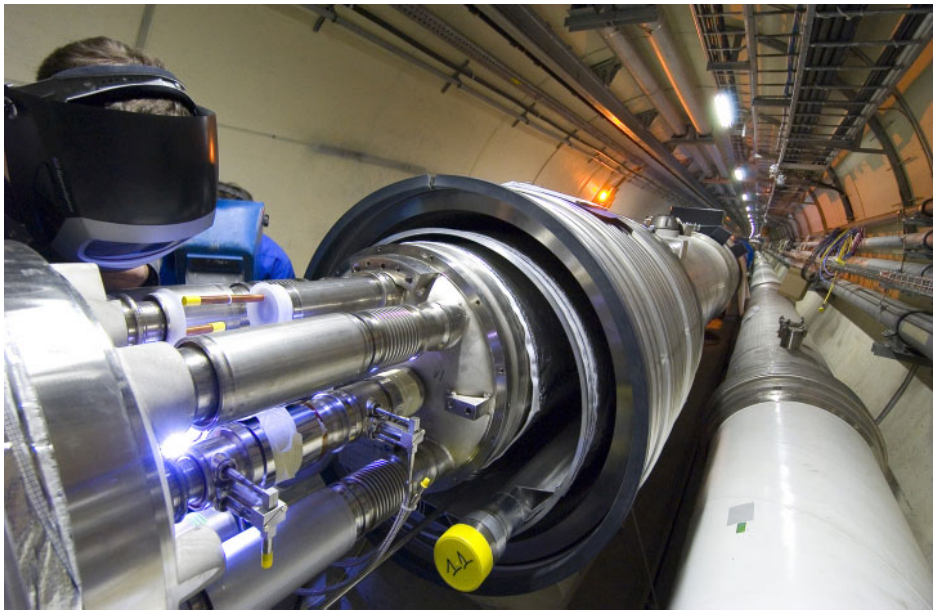
Dr James Gillies, Head of communication, CERN

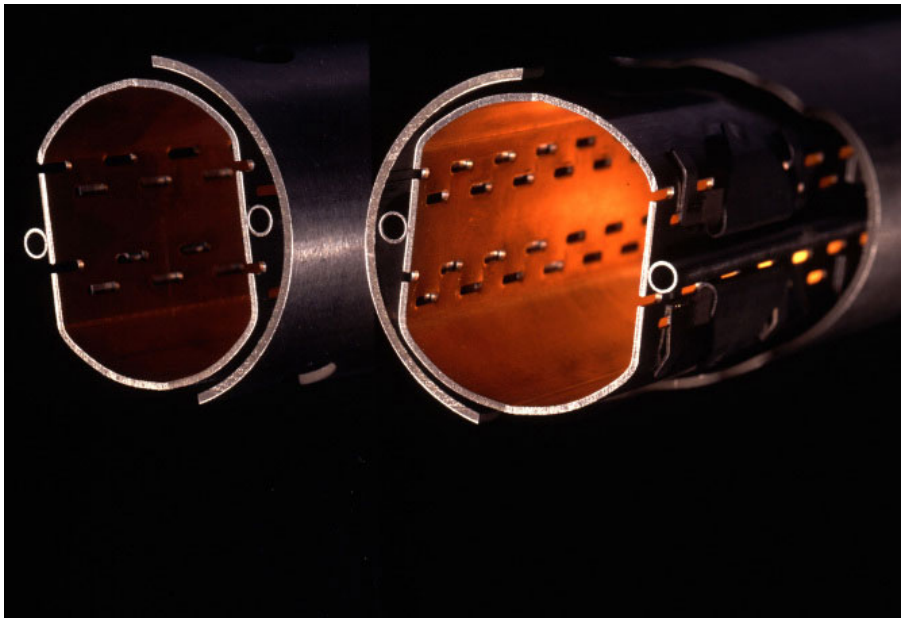
The fastest racetrack on the planet…



Trillions of protons will race around the 27km ring in opposite directions over 11,000 times a second, travelling at 99.9999991 per cent the speed of light.

The emptiest space in the solar system…

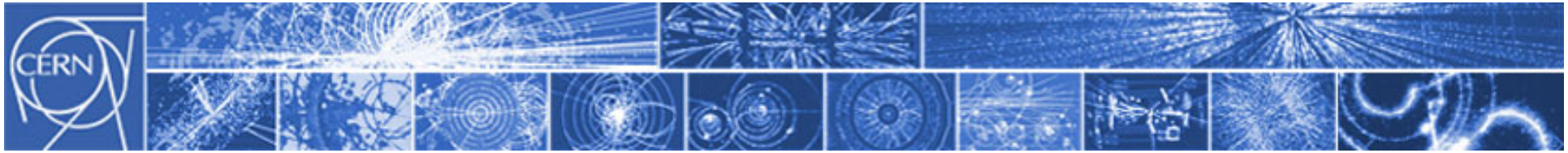




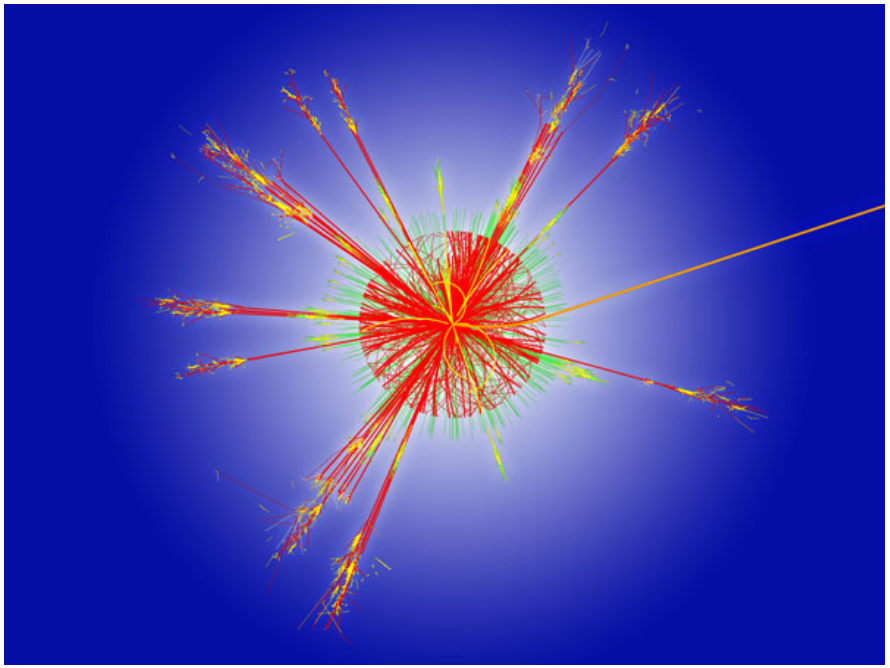
To accelerate protons to almost the speed of light requires a vacuum as empty as interplanetary space. There is 10 times more atmosphere on the moon than there will be in the LHC.

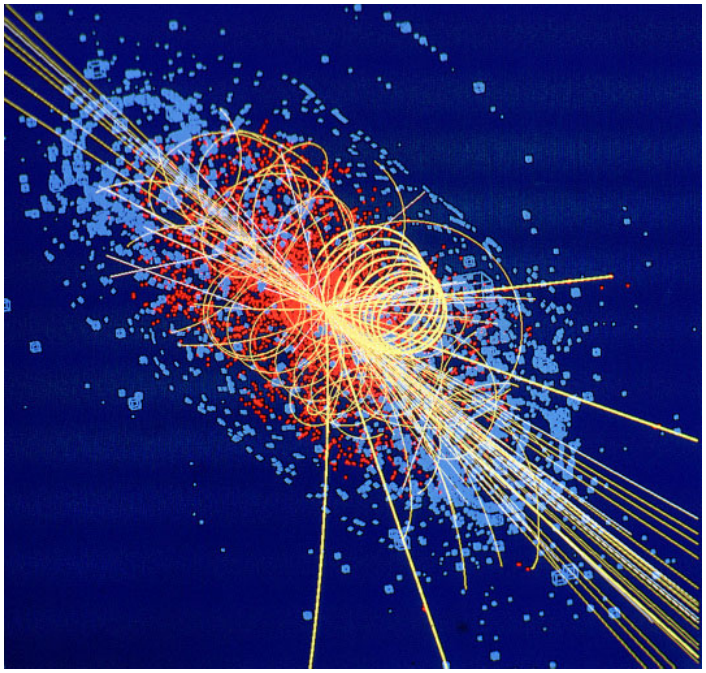
One of the coldest places in the universe…

With an operating temperature of about -271 degrees Celsius, just 1.9 degrees above absolute zero, the LHC is colder than outer space.



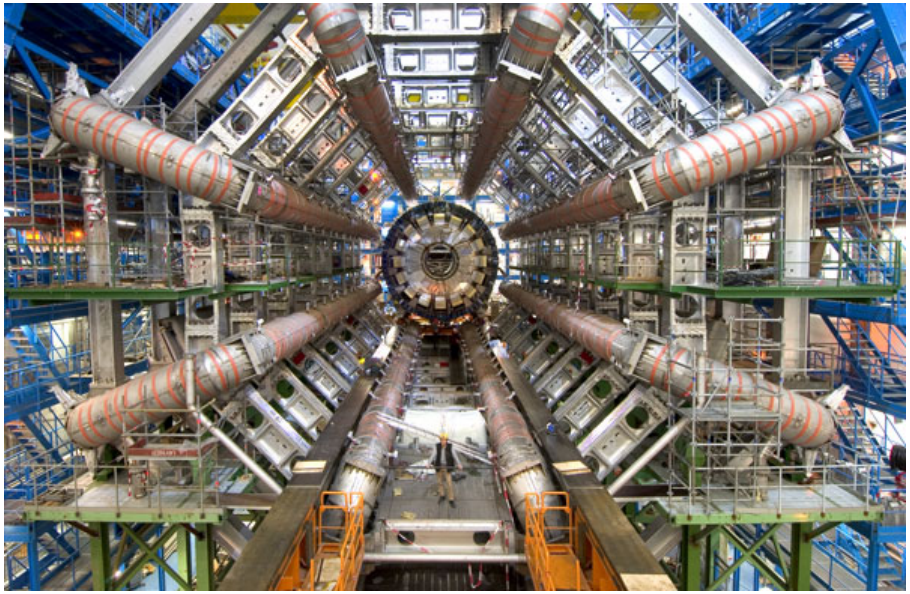
The hottest spots in the galaxy…





When two beams of protons collide, they will generate temperatures 1000 million times hotter than the heart of the sun, but in a minuscule space.

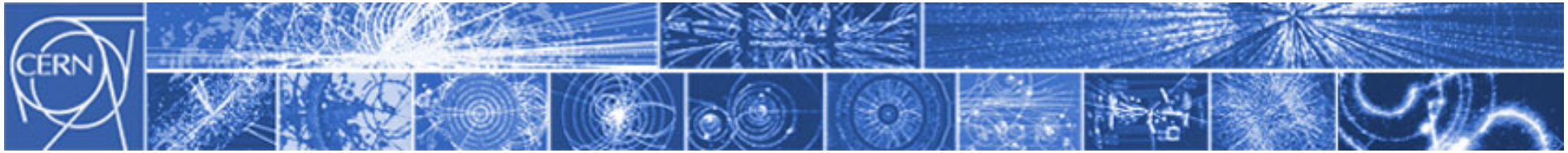
The biggest most sophisticated detectors ever built…



To sample and record the debris from up to 600 million proton collisions per second, scientists are building gargantuan devices that measure particles with micron precision.

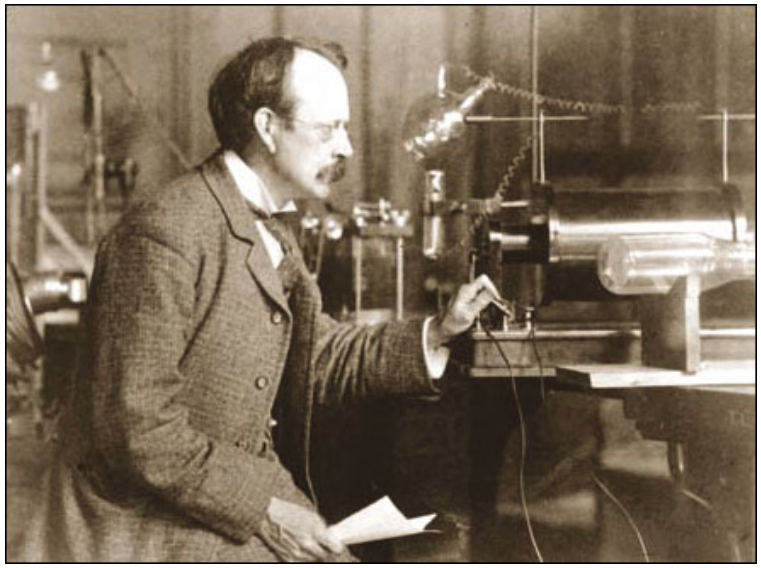
The most extensive computer system in the world…

To analyse the data, tens of thousands of computers around the world are being harnessed in the Grid. The laboratory that gave the world the web, is now taking distributed computing a big step further.



The accelerator

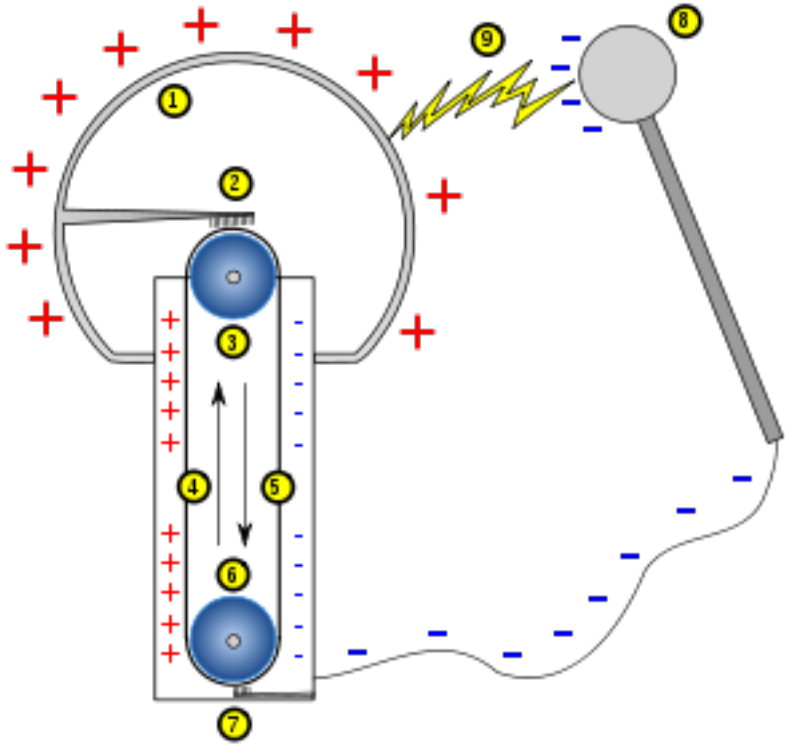
Early accelerators…



J. J. Thomson
Cathode ray tube
Discovered electrons in 1897

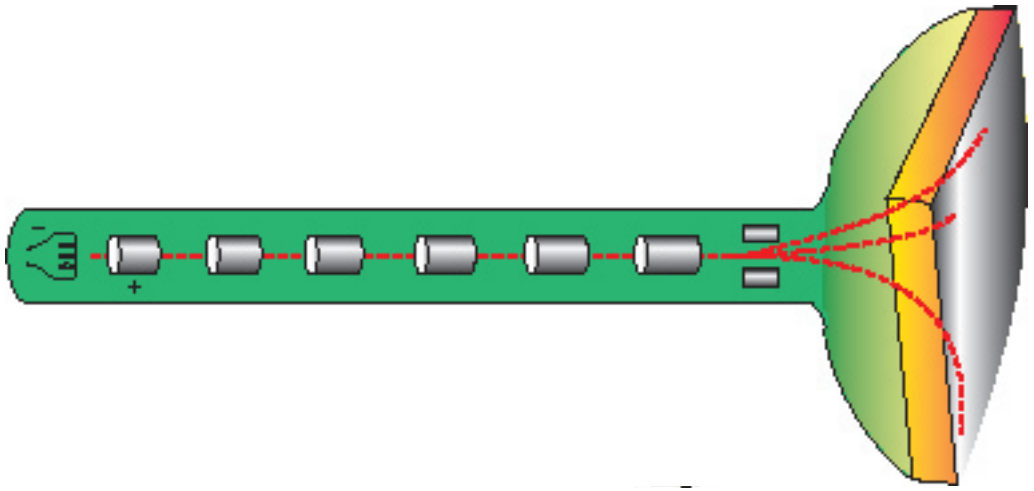
Van de Graaf generator
Invented in 1929

Early accelerators…

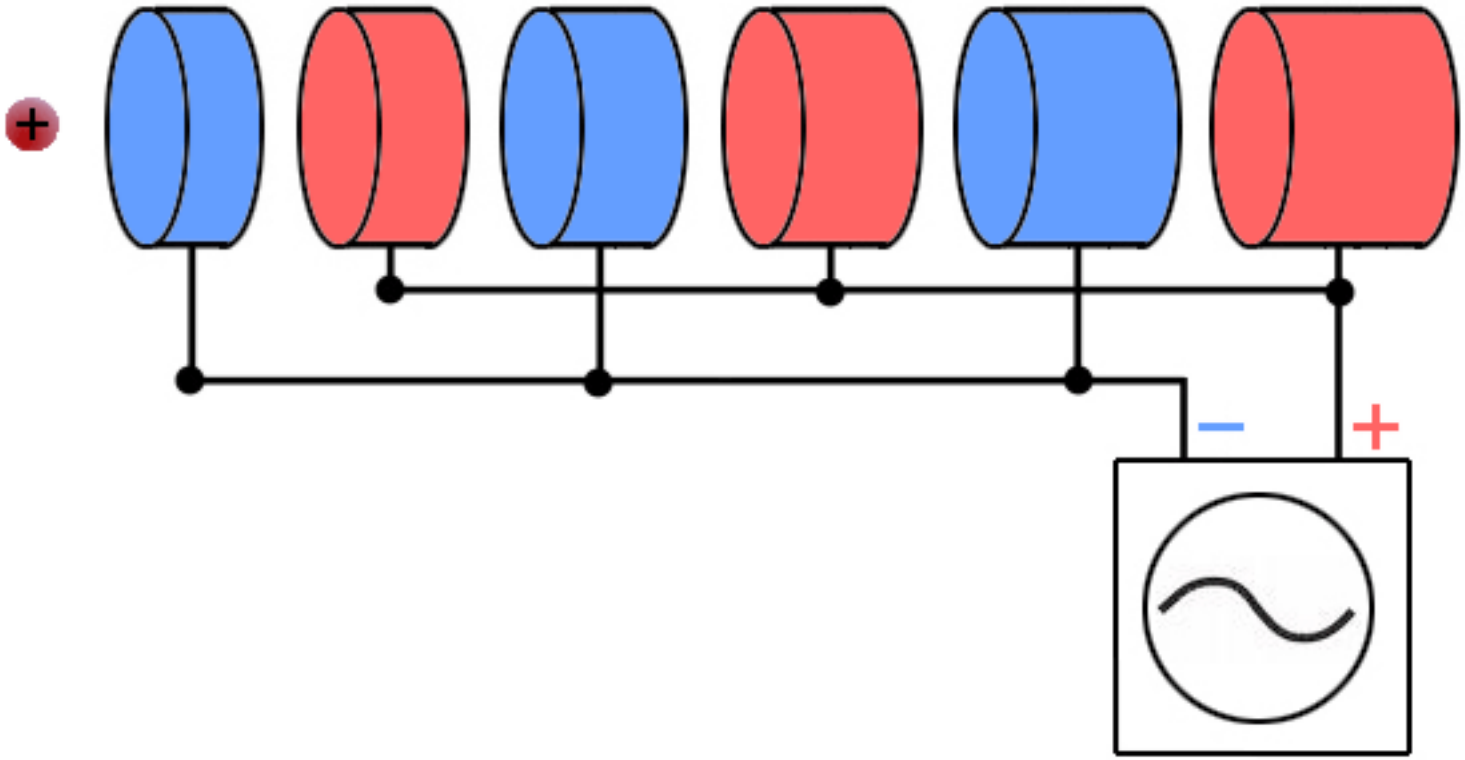


Cockcroft Walton
Nuclear transmutation
Nobel Prize 1951

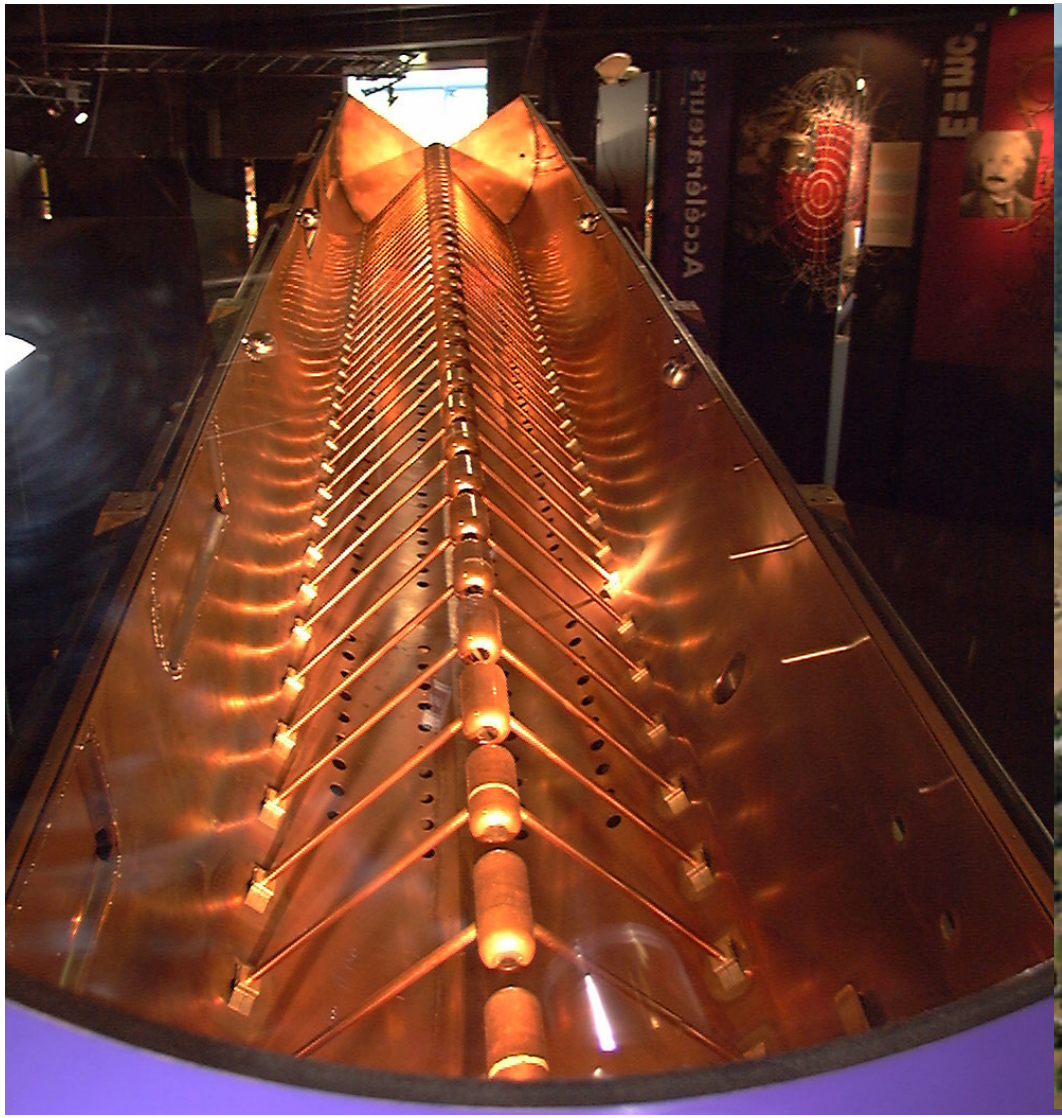
The accelerator (that used to be) in your living room



Linacs…



Linacs…

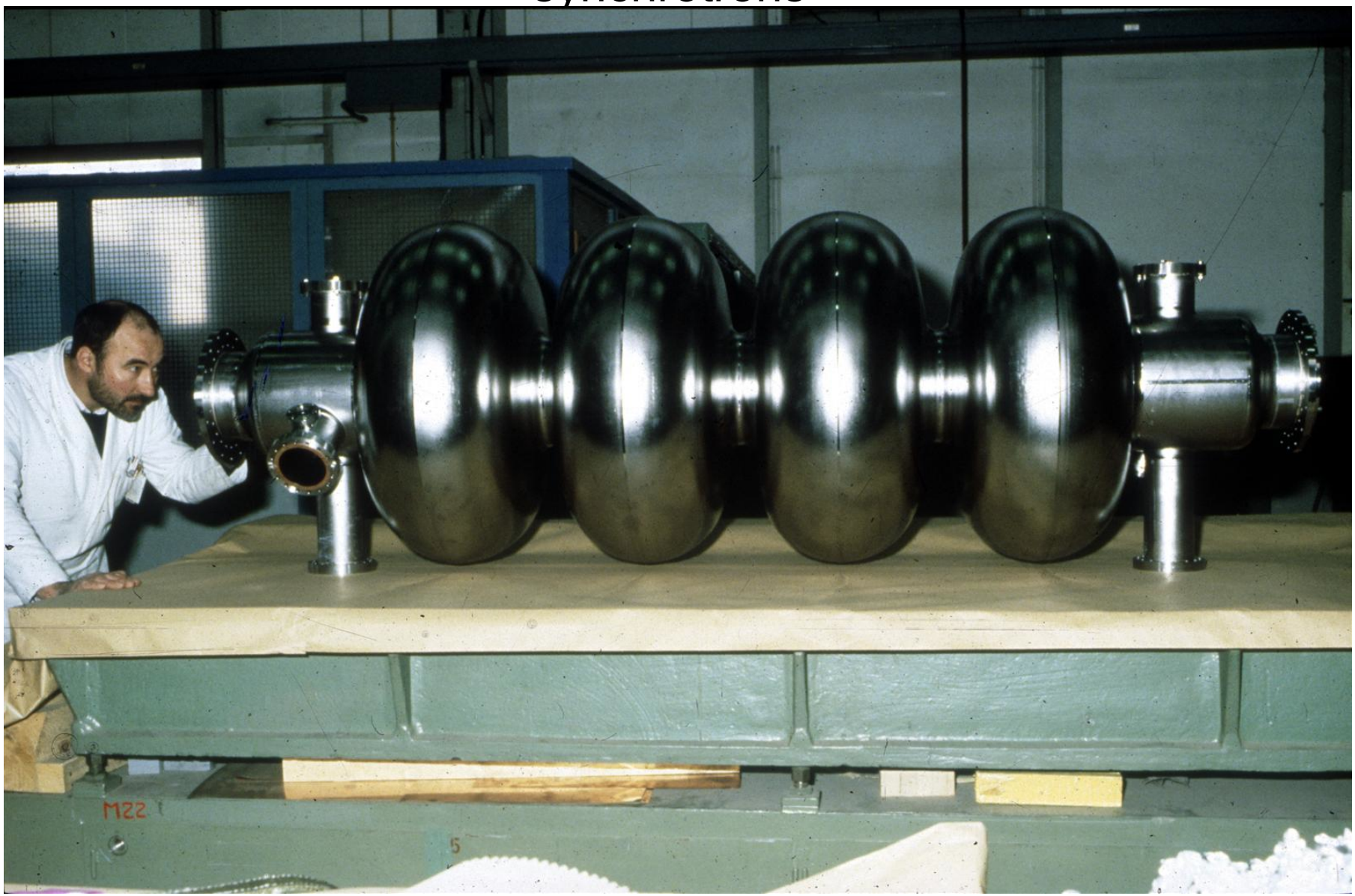


The motion of particles in a magnetic field

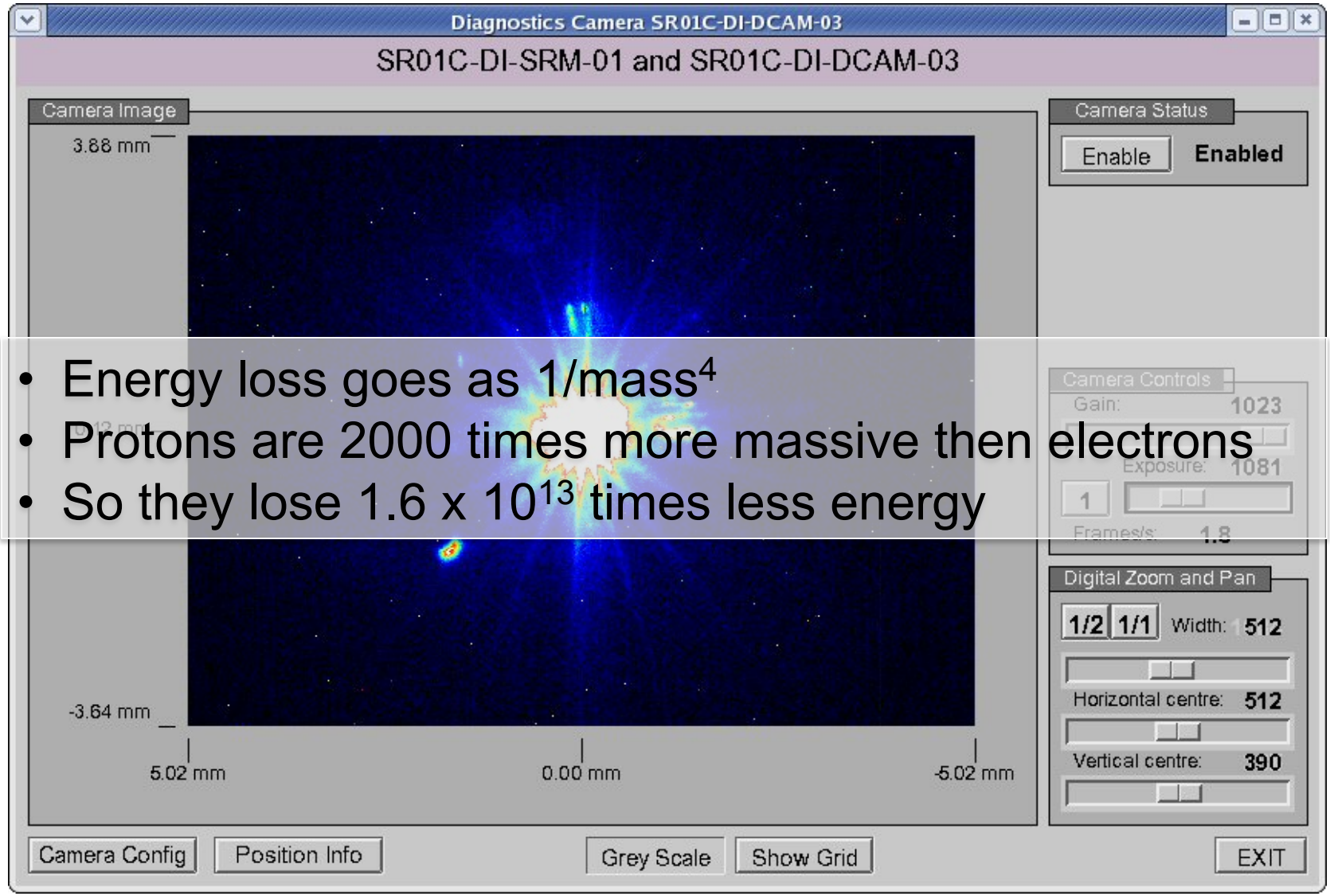
Basic principles: electric and magnetic fields

The cyclotron

synchrotrons



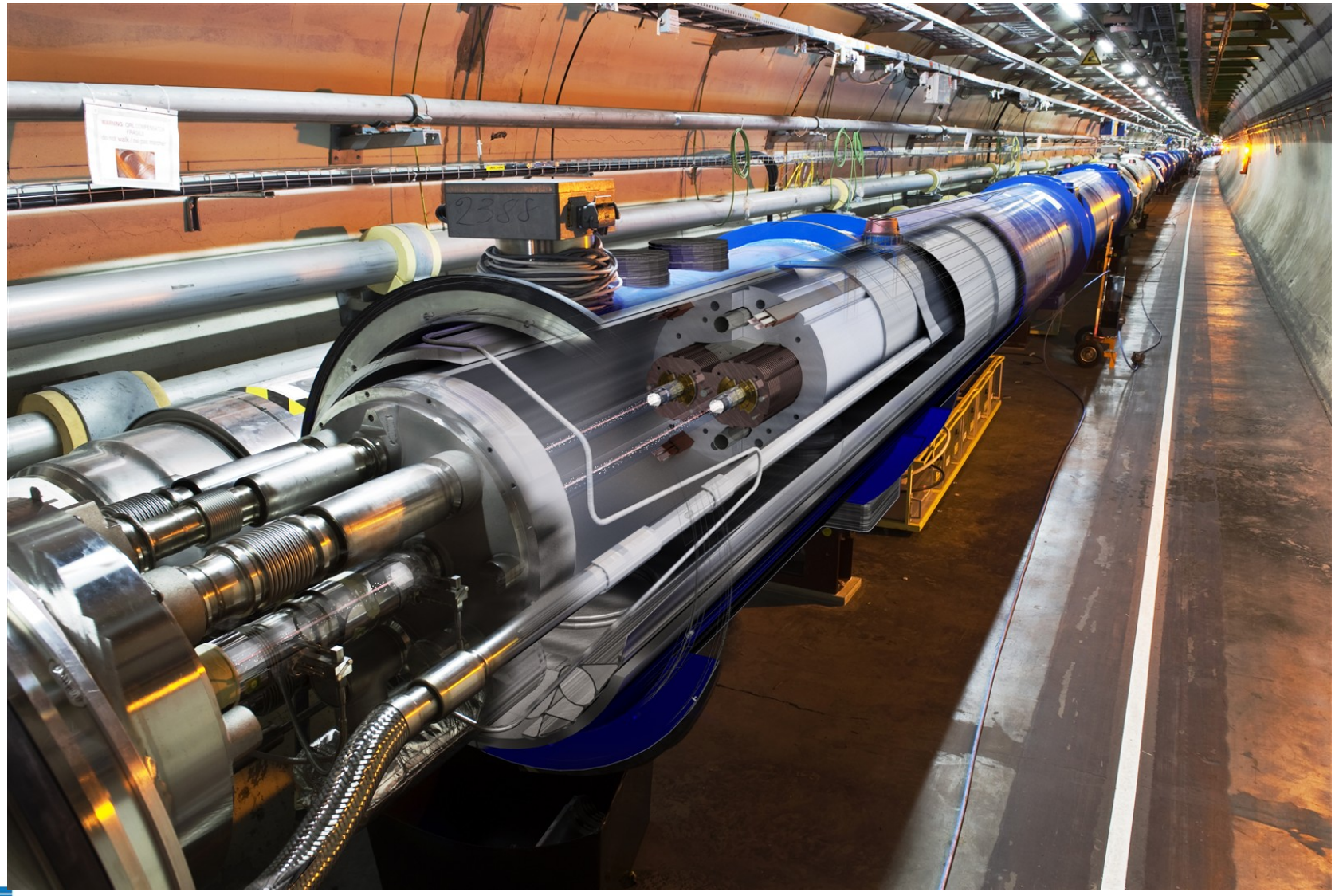
Leptons or hadrons?

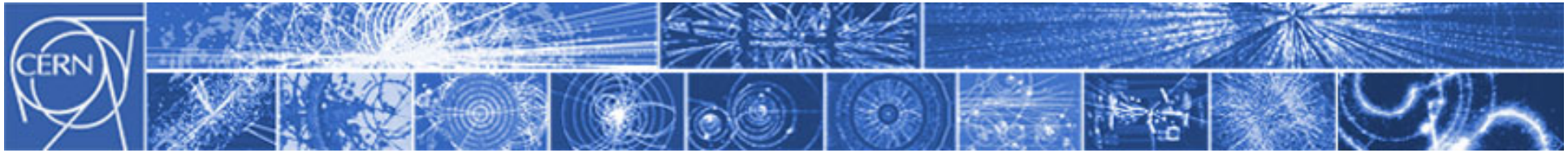


- Energy loss goes as $1/\text{mass}^4$
- Protons are 2000 times more massive then electrons
- So they lose 1.6×10^{13} times less energy

Leptons or hadrons?

CERN's accelerator complex





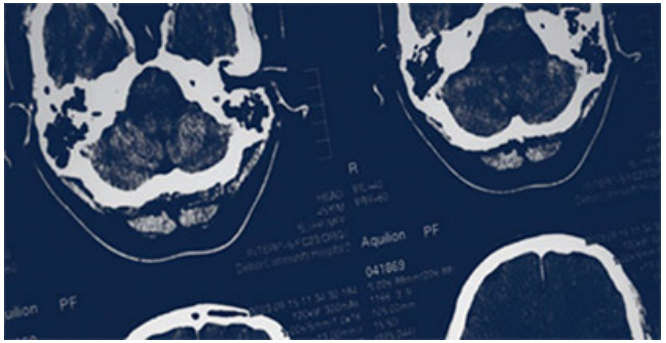
The LHC facts and figures

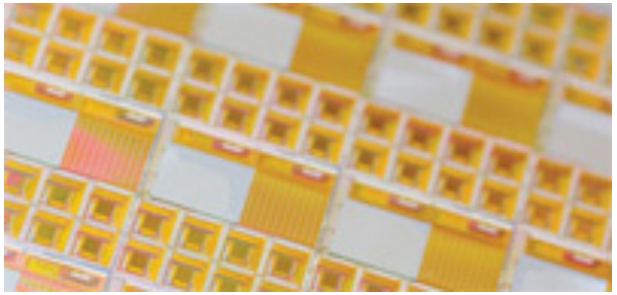
Quantity	number
Circumference	26 659 m
Dipole operating temperature	1.9 K (-271.3°C)
Number of magnets	9593
Number of main dipoles	1232
Number of main quadrupoles	392
Number of RF cavities	8 per beam
Nominal energy, protons	7 TeV
Nominal energy, ions	2.76 TeV/u (*)
Peak magnetic dipole field	8.33 T
Min. distance between bunches	~7 m
Design luminosity	10^{34} cm^{-2} s^{-1}
No. of bunches per proton beam	2808
No. of protons per bunch (at start)	1.1×10^{11}
Number of turns per second	11 245
Number of collisions per second	600 million

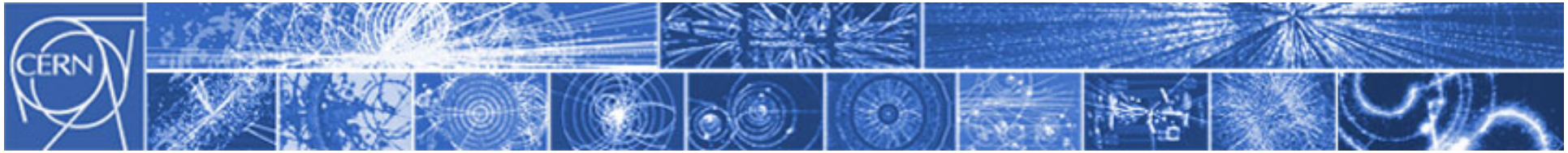
(*) Energy per nucleon

Applications of accelerators

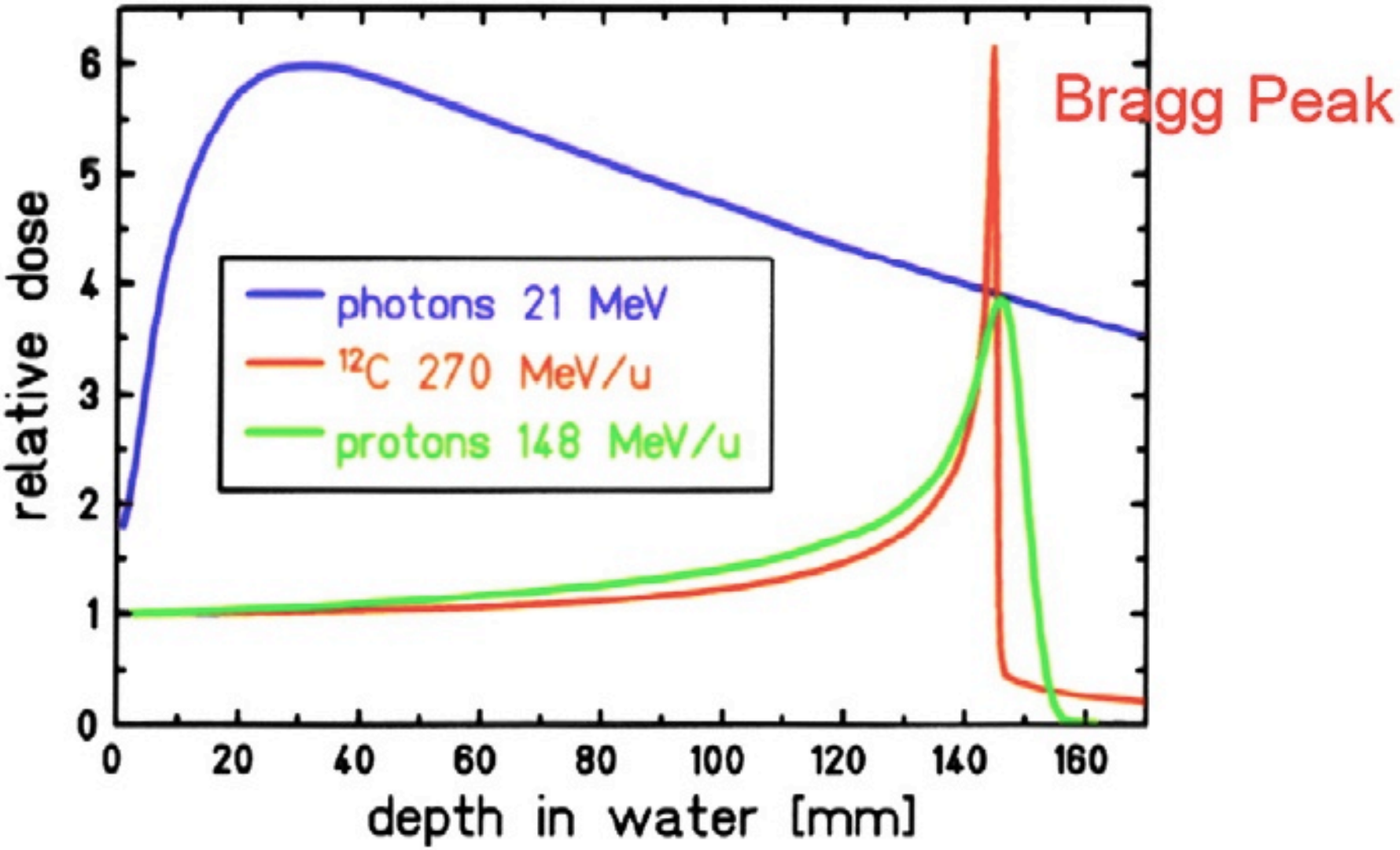
Materials
Shrink wrap
Medical imaging
Ion implantation
Energy
Cancer therapy…



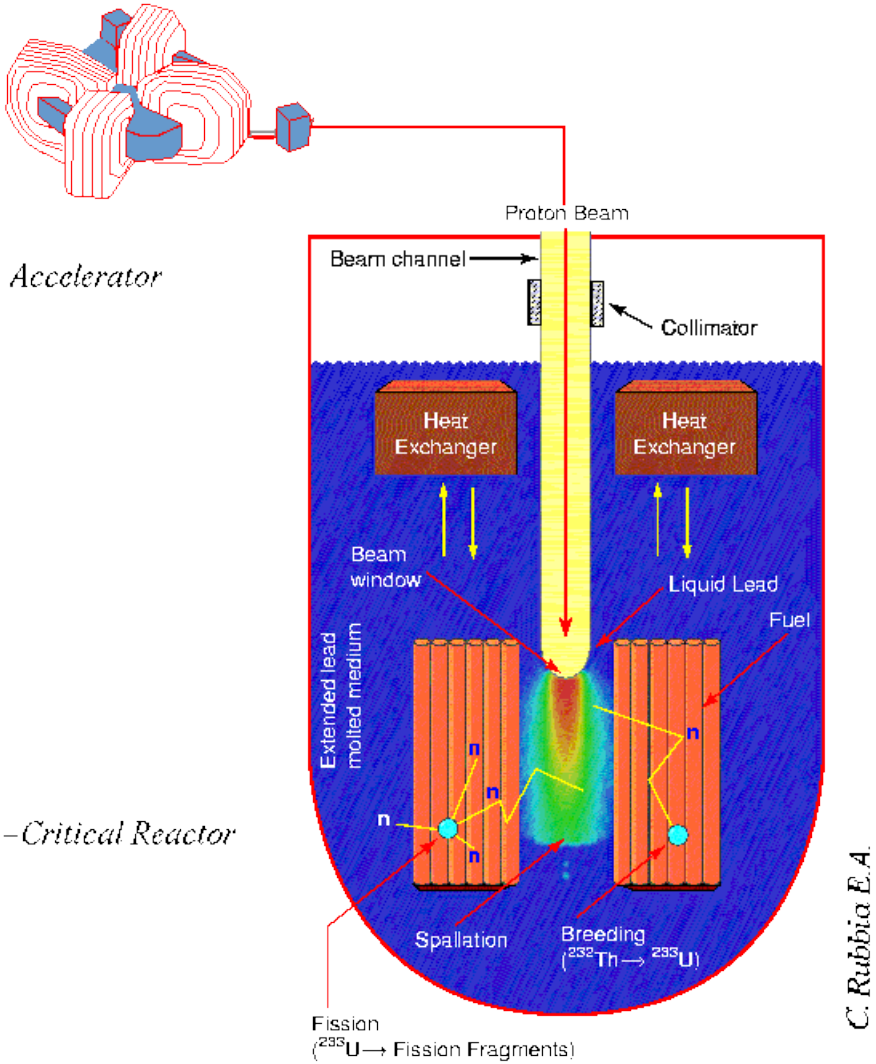




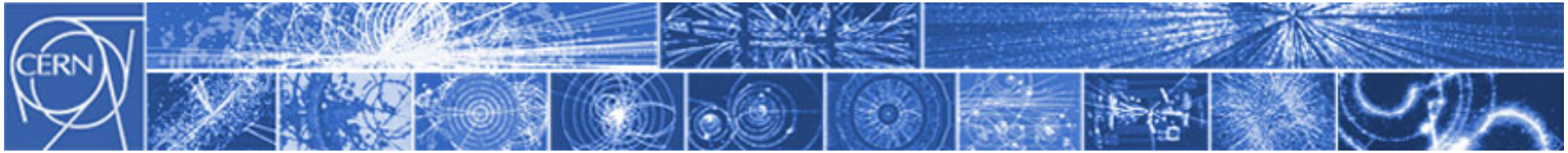
Hadron therapy



Accelerator Driven Systems

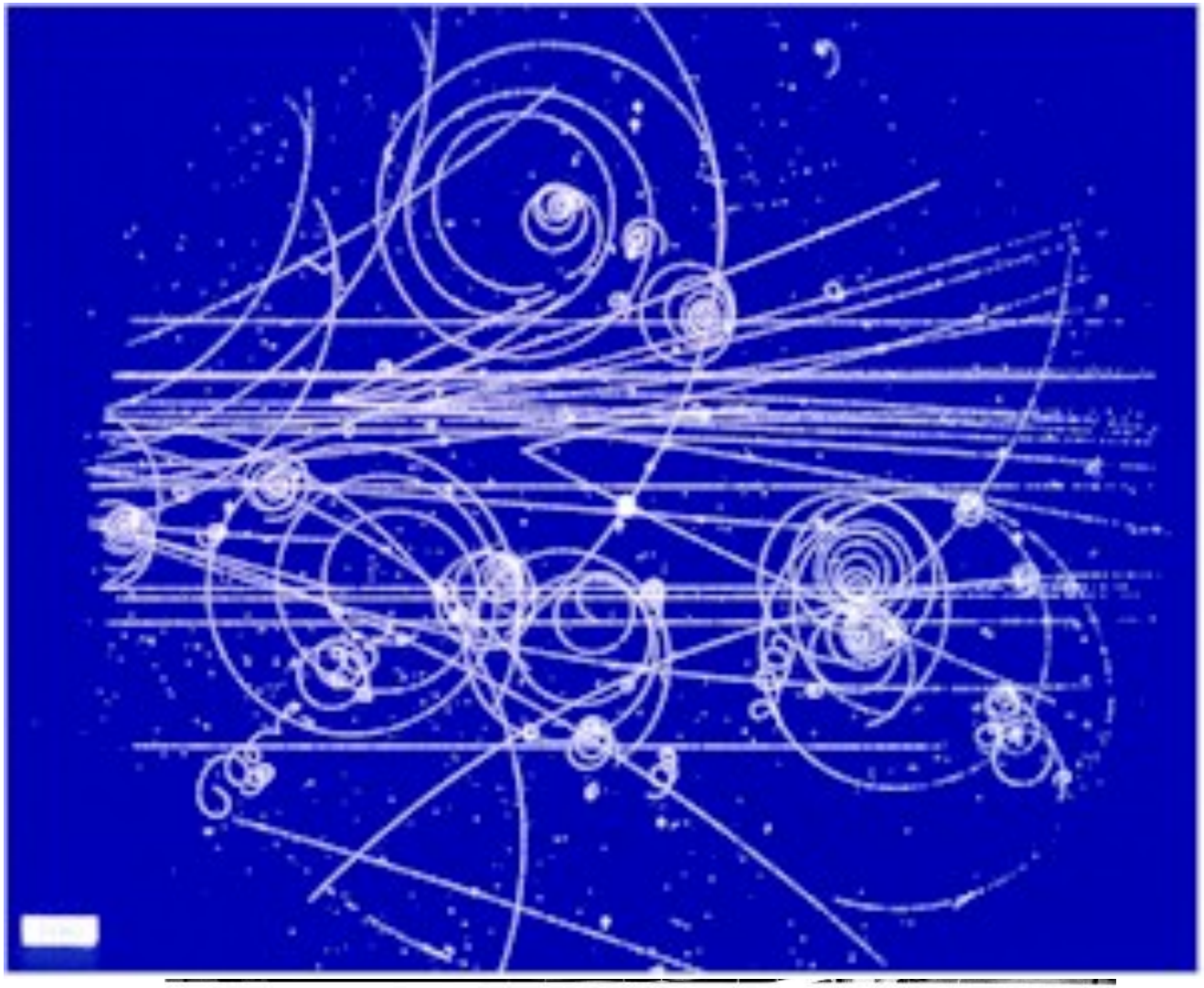


C. Rubbia E.A.



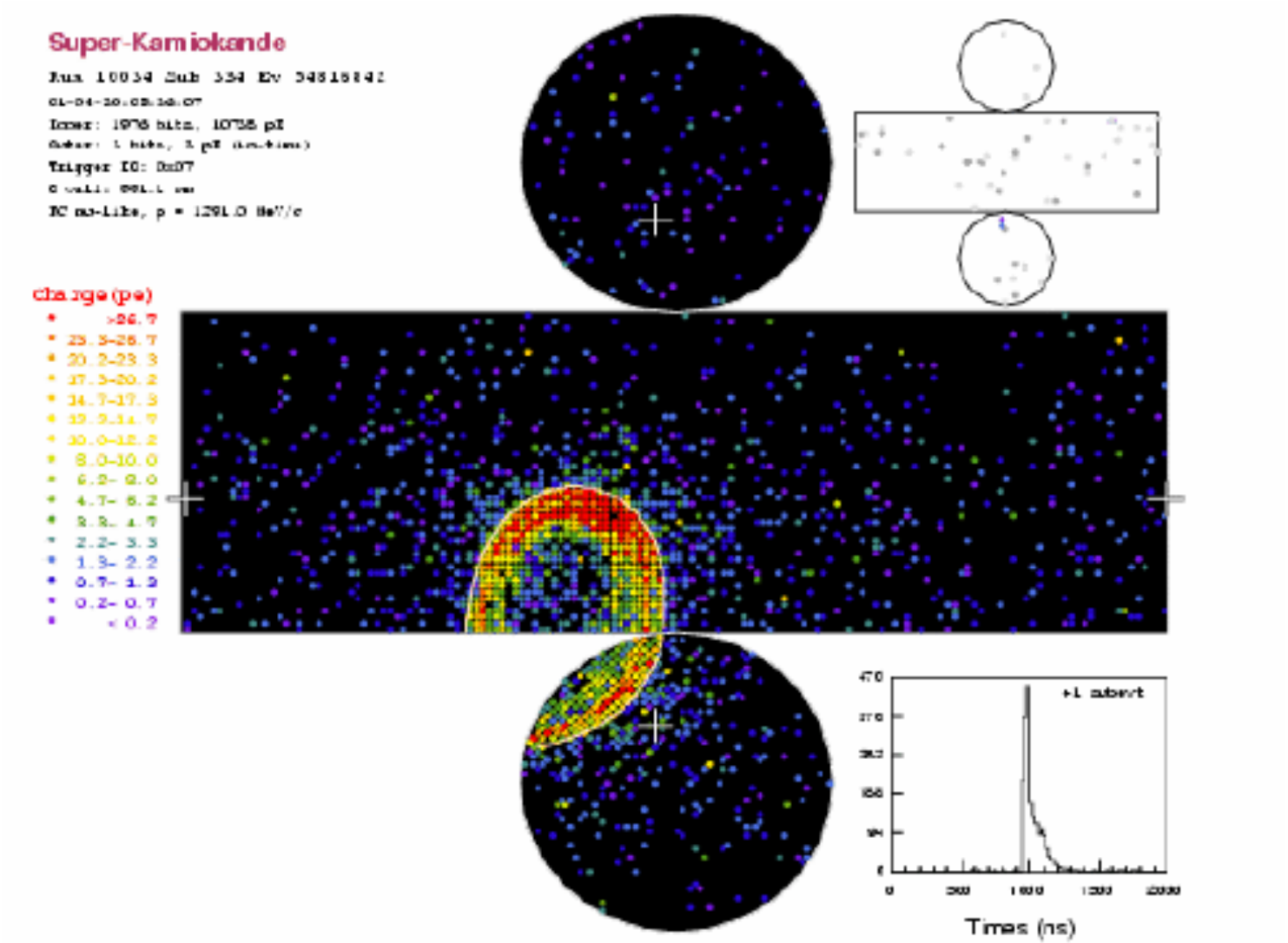
The detectors

The basics - ionisation



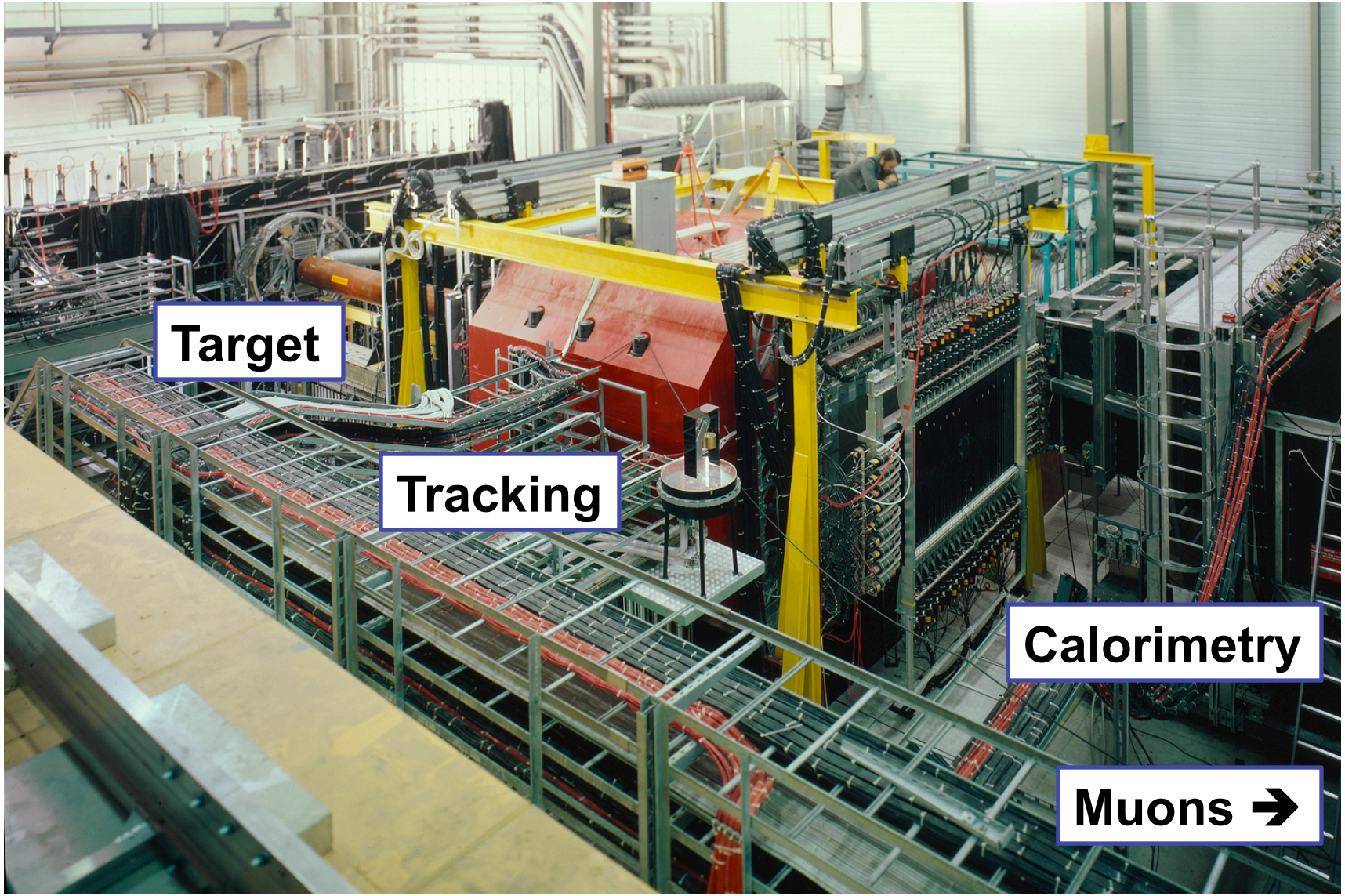
The basics - scintillation

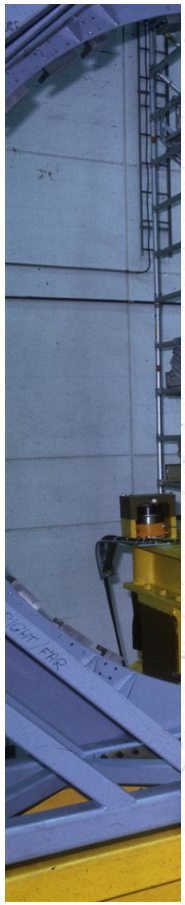
The basics – Cerenkov light

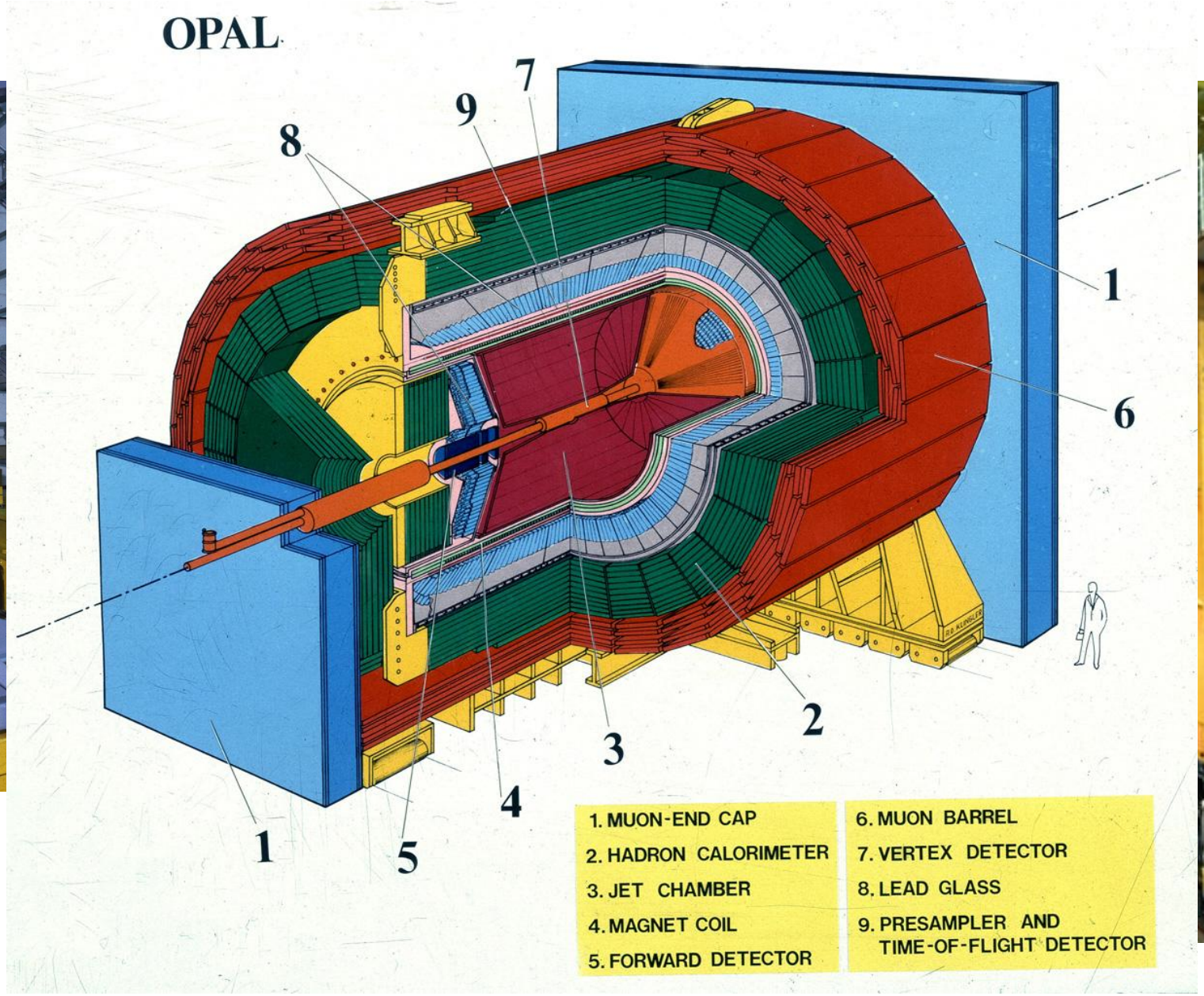


Georges Charpak 1924-2010

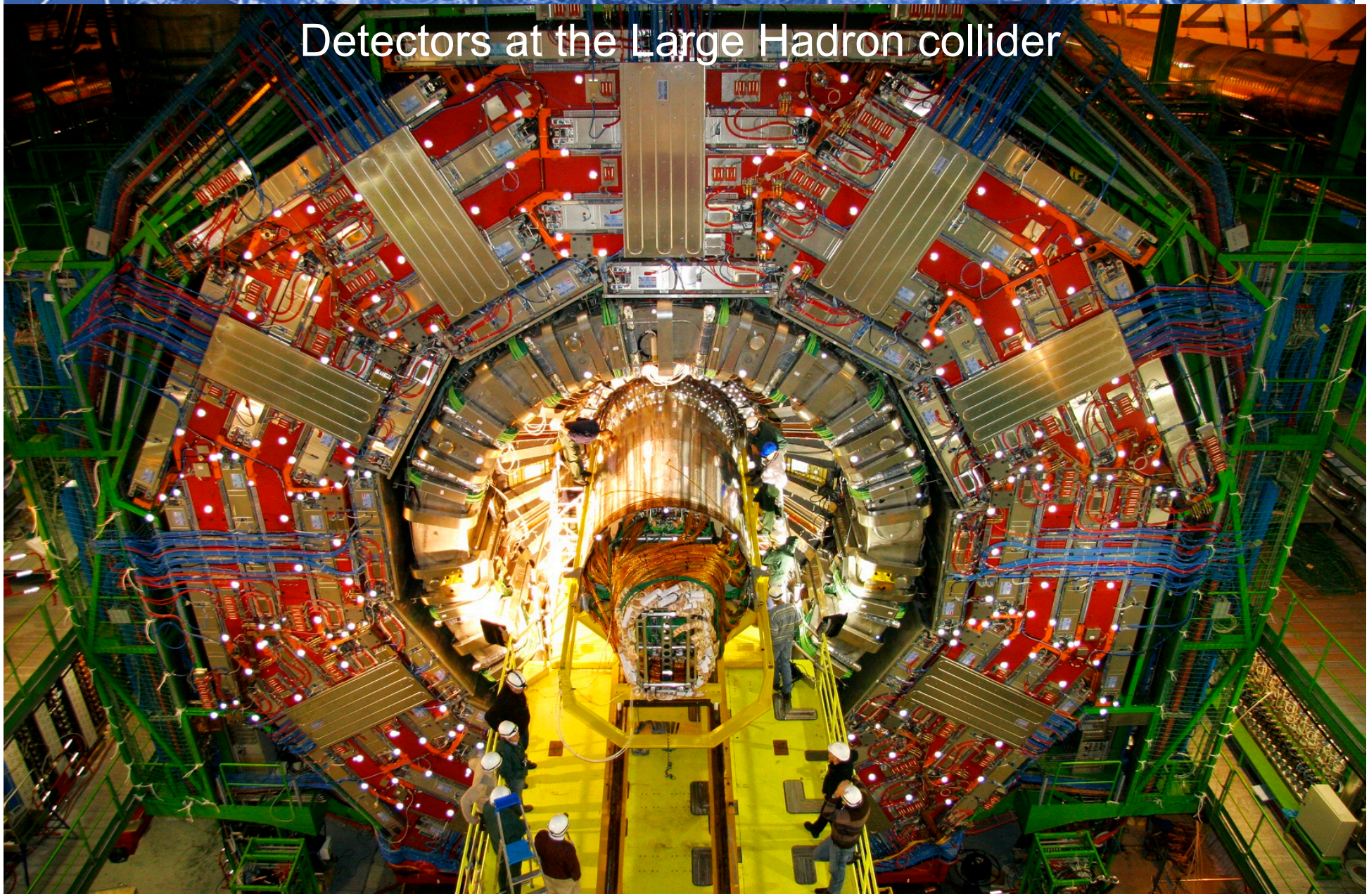
A layered approach

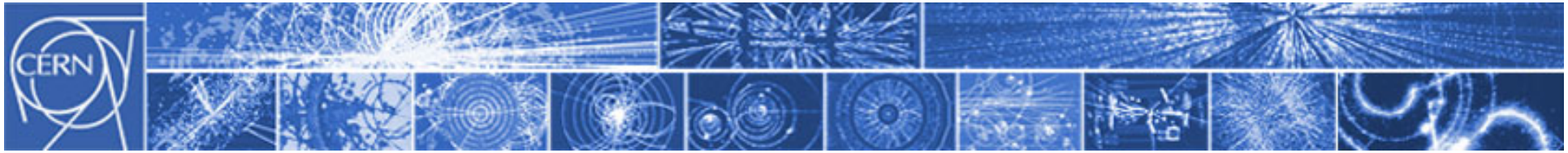





OPAL
7
9
8
1
6
2
3
4
1
5
1. MUON-END CAP
2. HADRON CALORIMETER
3. JET CHAMBER
4. MAGNET COIL
5. FORWARD DETECTOR
6. MUON BARREL
7. VERTEX DETECTOR
8. LEAD GLASS
9. PRESAMPLER AND TIME-OF-FLIGHT DETECTOR

Detectors at the Large Hadron collider

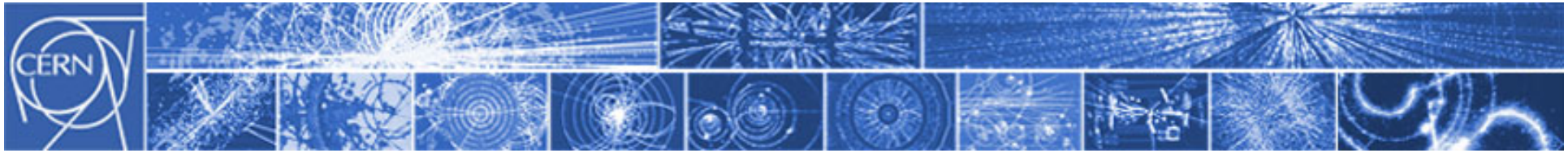




The anatomy of the Compact Muon Solenoid

Largest silicon-sensor system ever made

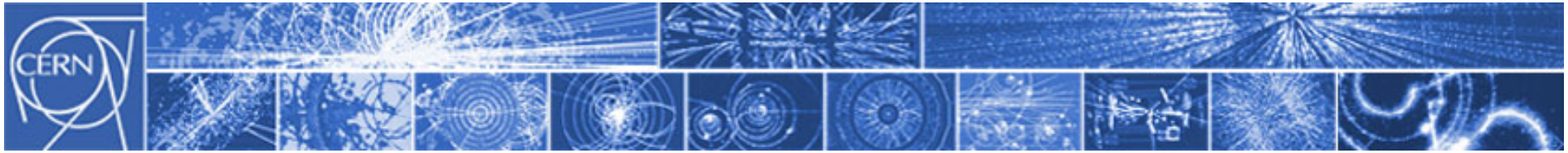
- More than 220m^2 of sensors
- More than 60 million electronics channels (pixels and microstrips)
- 6m long, ~2.2m diameter, operates at -15^oC



The anatomy of the Compact Muon Solenoid

Hermetic calorimeter

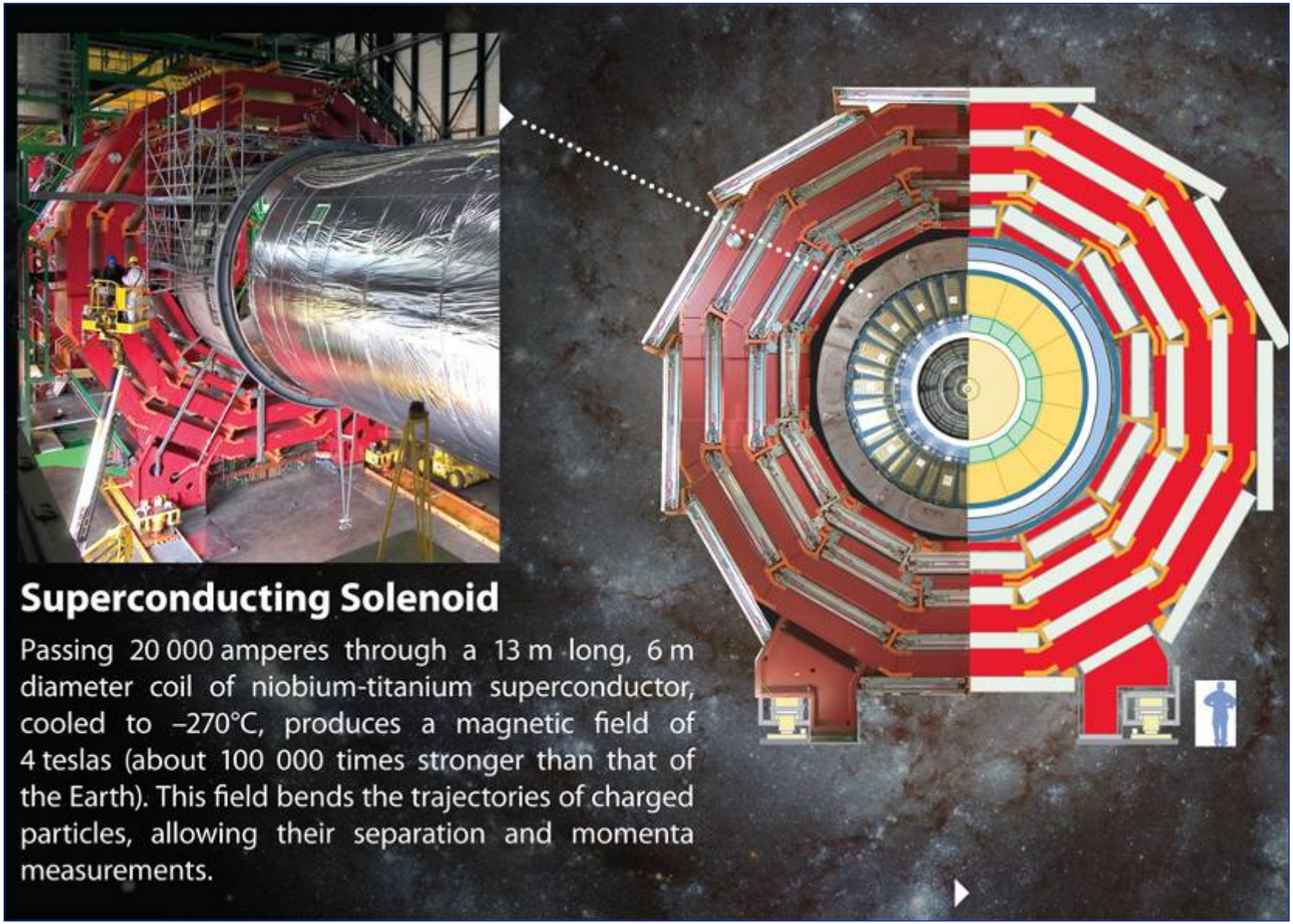
- Lead tungstate ($PbWO_4$) crystals create electromagnetic showers and produce scintillation light
- Barrel: ~64000 crystals constructed in 36 “supermodules” (1700 crystals each); light detected by avalanche photodiodes
- Endcaps: ~16000 crystals constructed as “supercrystals” – 5x5 arrays; light detected by vacuum phototriode



Three parts to the puzzle

- Barrel HCAL made of 36 brass wedges, each of which is ~35 tonnes
- Endcap HCAL made from brass recuperated from Russian military
- Forward HCAL (known as HF) made from steel embedded with quartz fibres

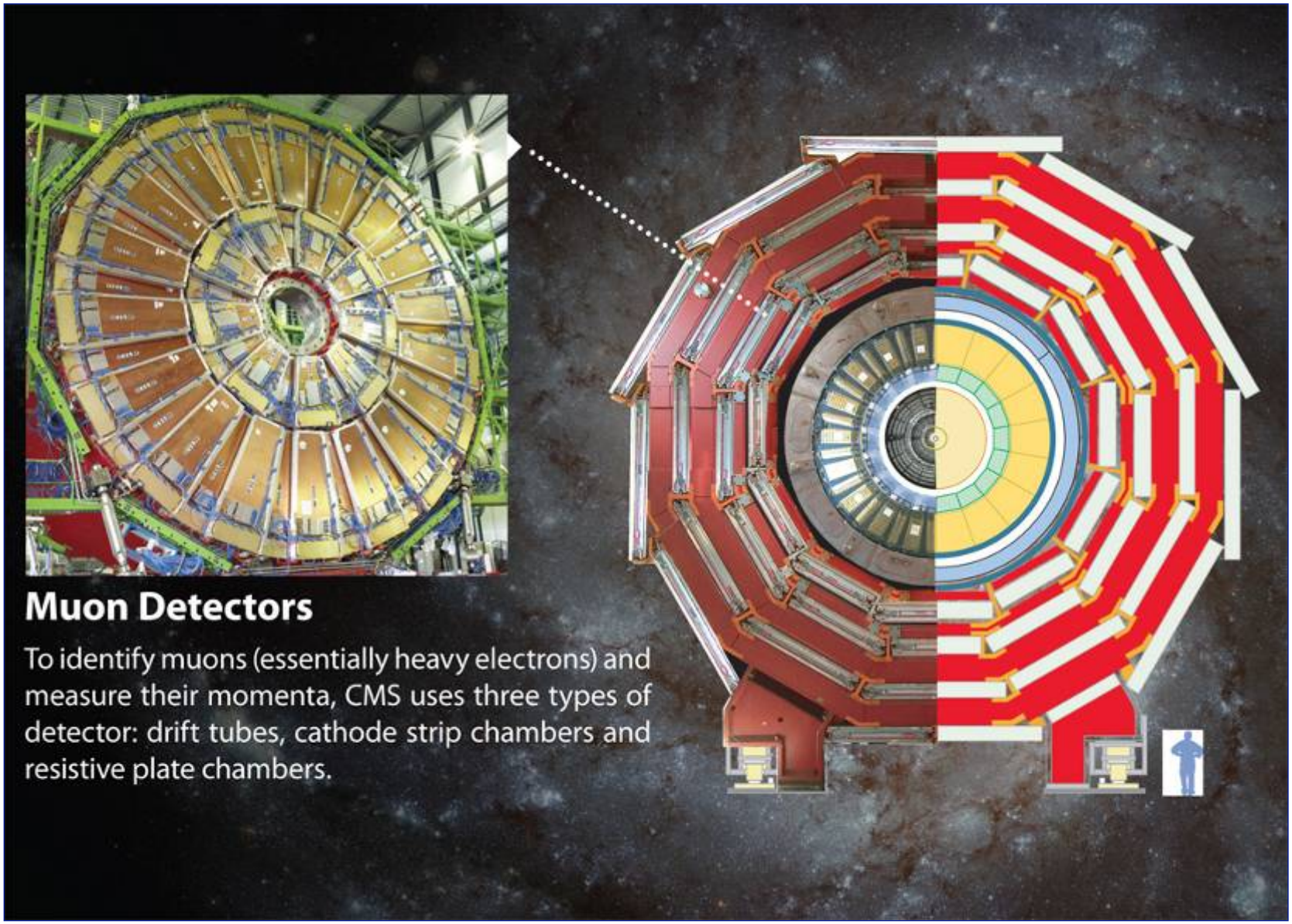
The anatomy of the Compact Muon Solenoid



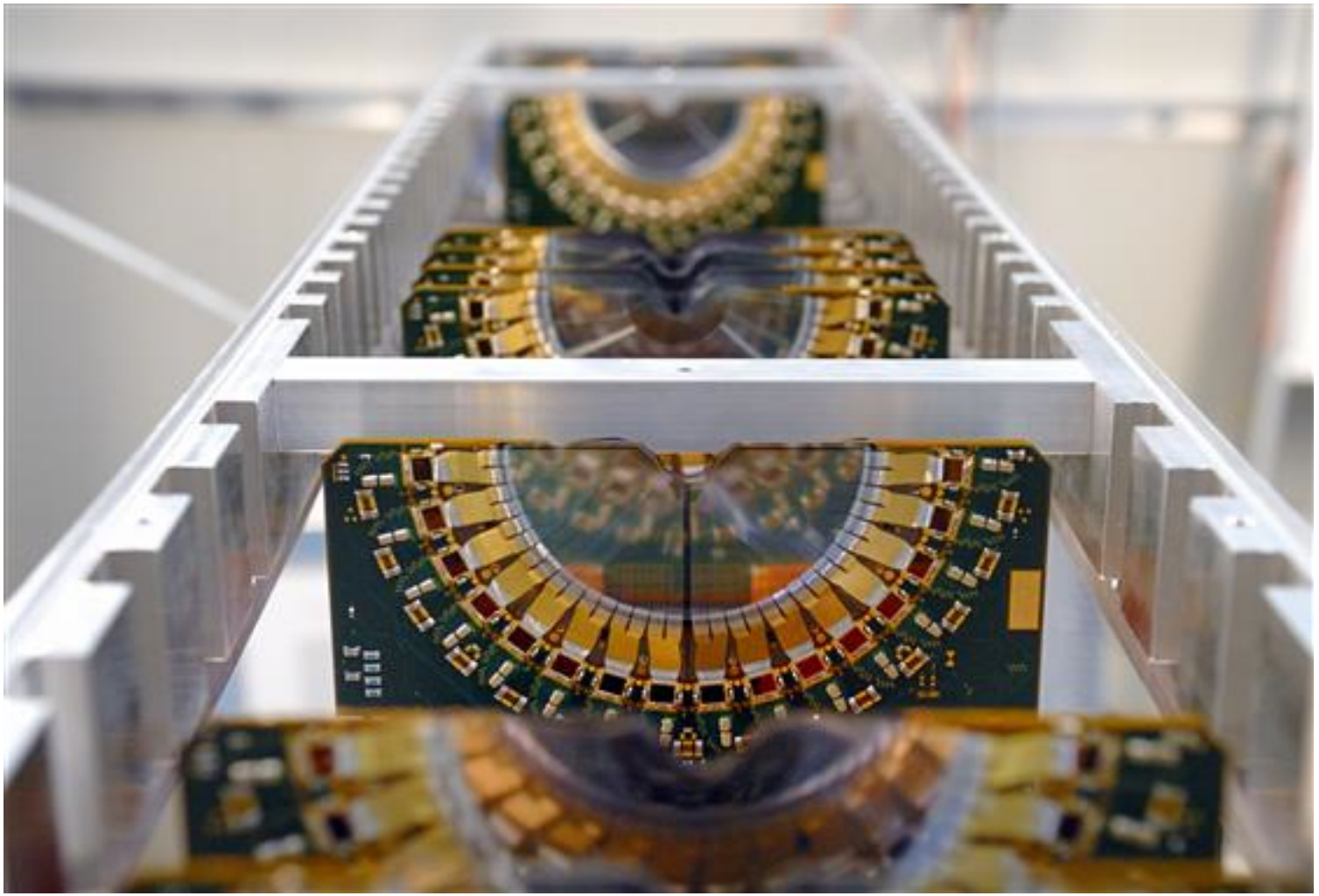
Superconducting Solenoid

Passing 20 000 amperes through a 13 m long, 6 m diameter coil of niobium-titanium superconductor, cooled to –270°C, produces a magnetic field of 4 teslas (about 100 000 times stronger than that of the Earth). This field bends the trajectories of charged particles, allowing their separation and momenta measurements.

The anatomy of the Compact Muon Solenoid

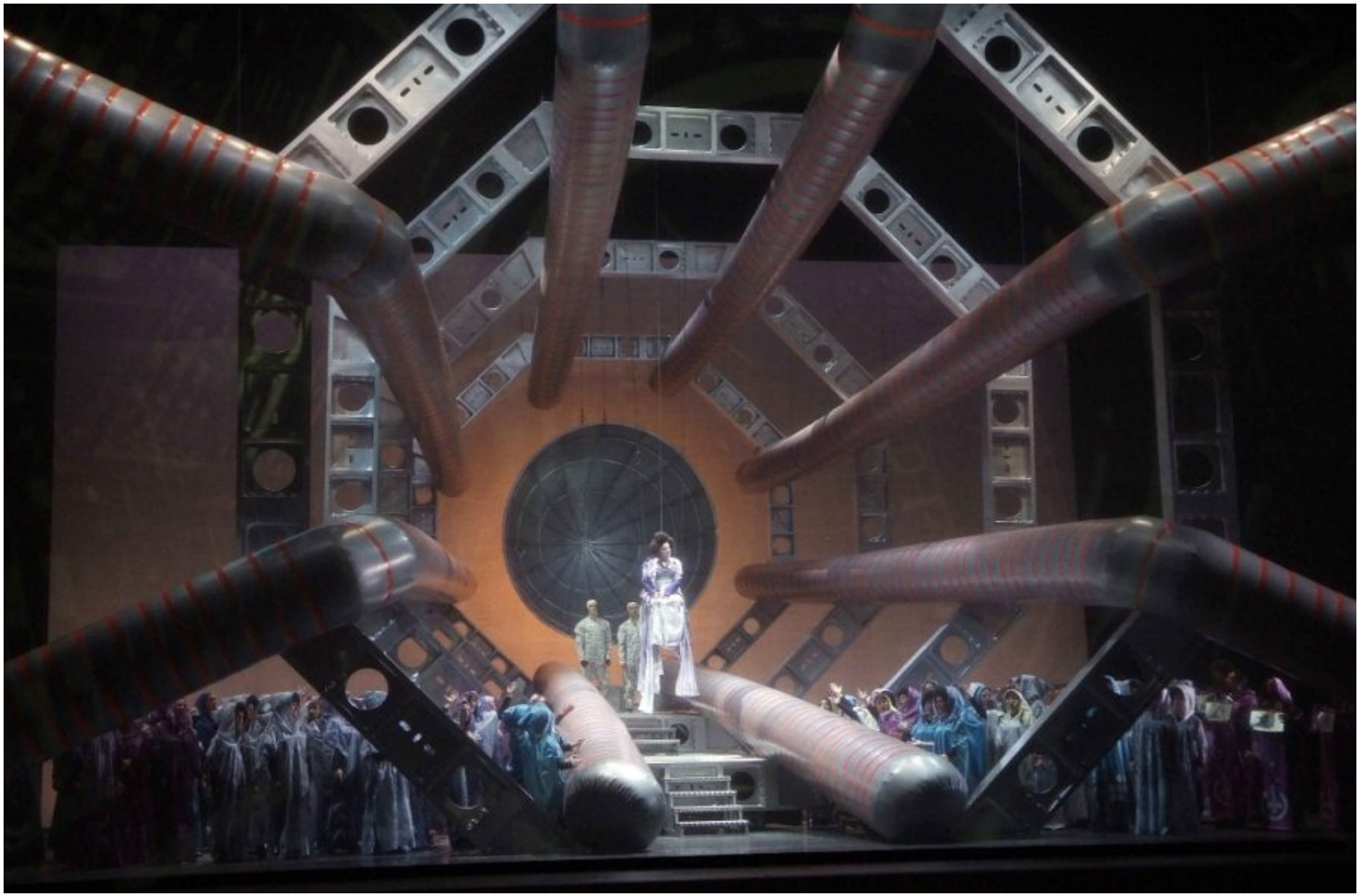


LHC examples: VELO



Approaches 5mm of the beam. Measures to 10microns

LHC examples: ATLAS muons



The world’s largest toroid magnet. Air cored so can be bigger

LHC examples: ALICE TPC

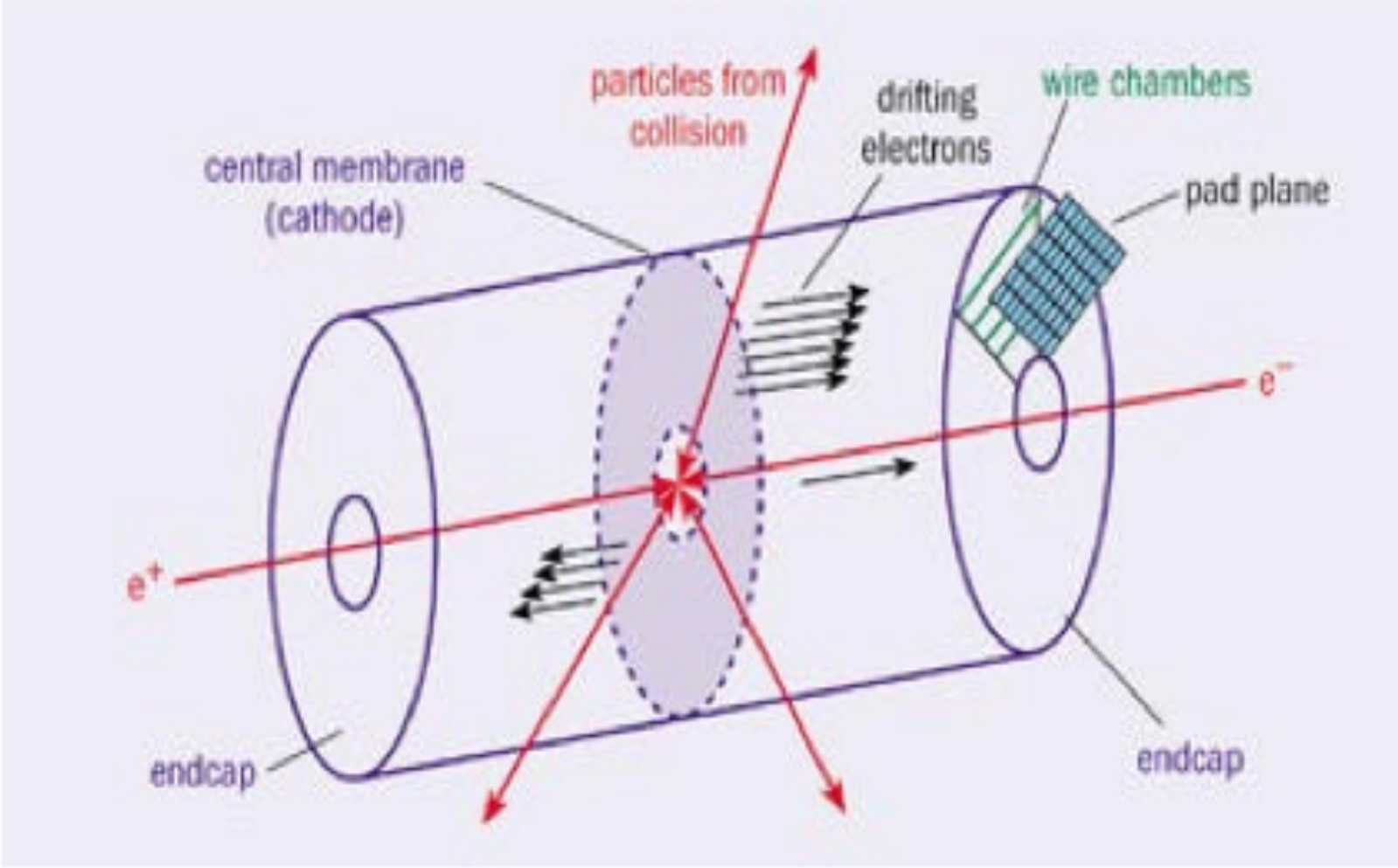
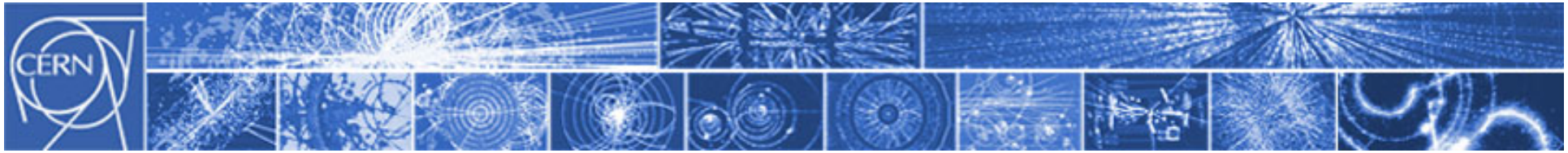


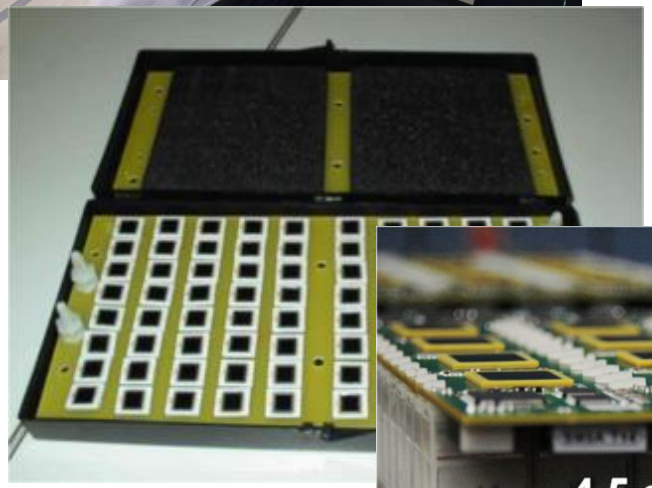
Figure 1. The TPC principle as proposed by David Nygren in 1974

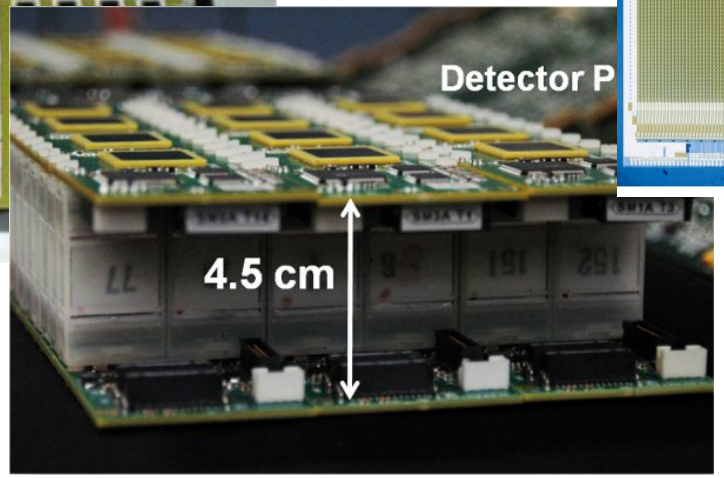


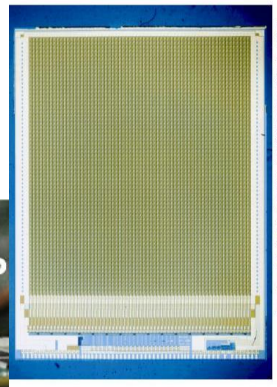
Applications of detectors

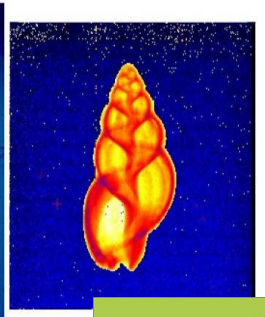
Applications of detectors

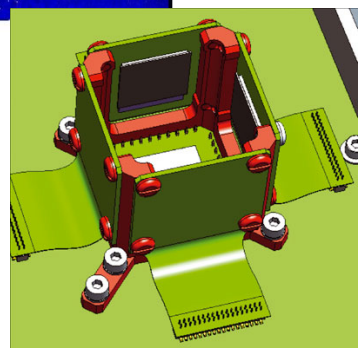
Medical imaging: PET, PET/MRI, Medipix
Electronics: APD
Education: LUCID

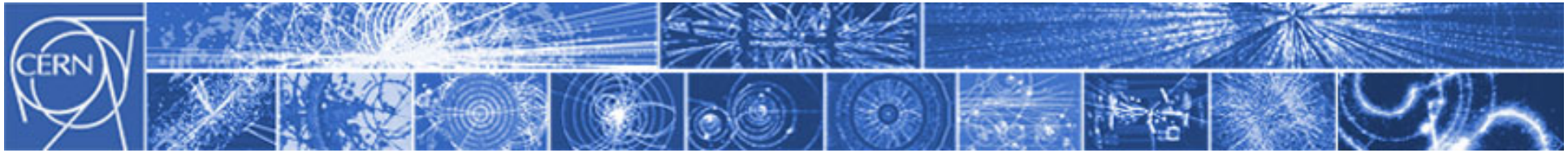






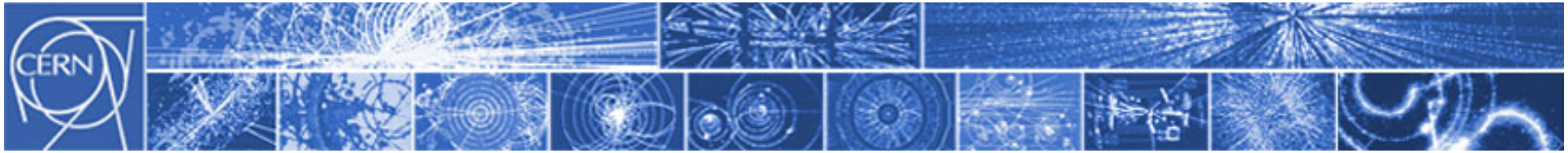






The computing

1950s: CERN's human computer



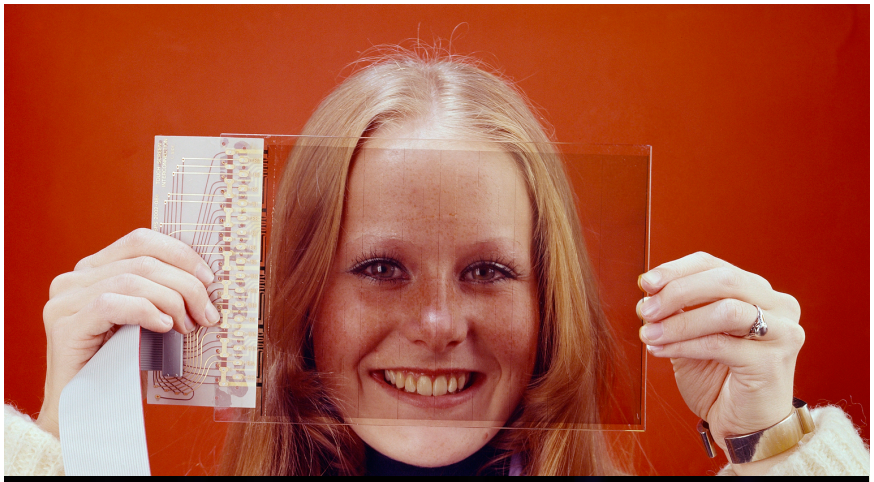
1958: Ferranti Mercury

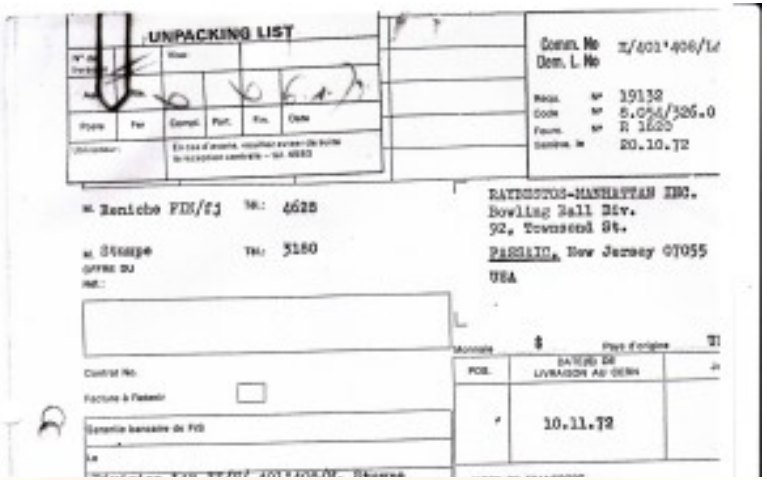
17 hours…

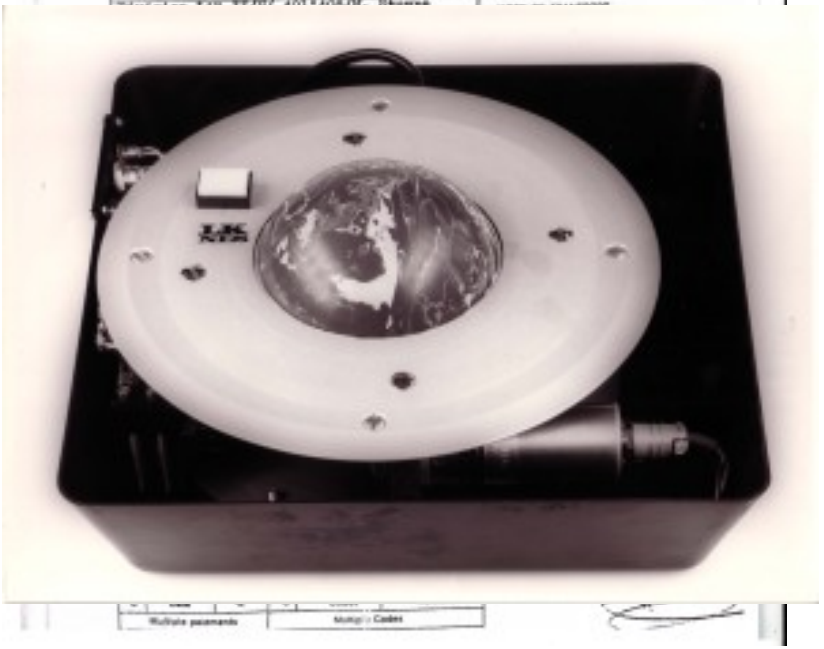
1960s-1990s: Norsk data, PDP, Vax, IBM mainframe, CRAY…

1 second…

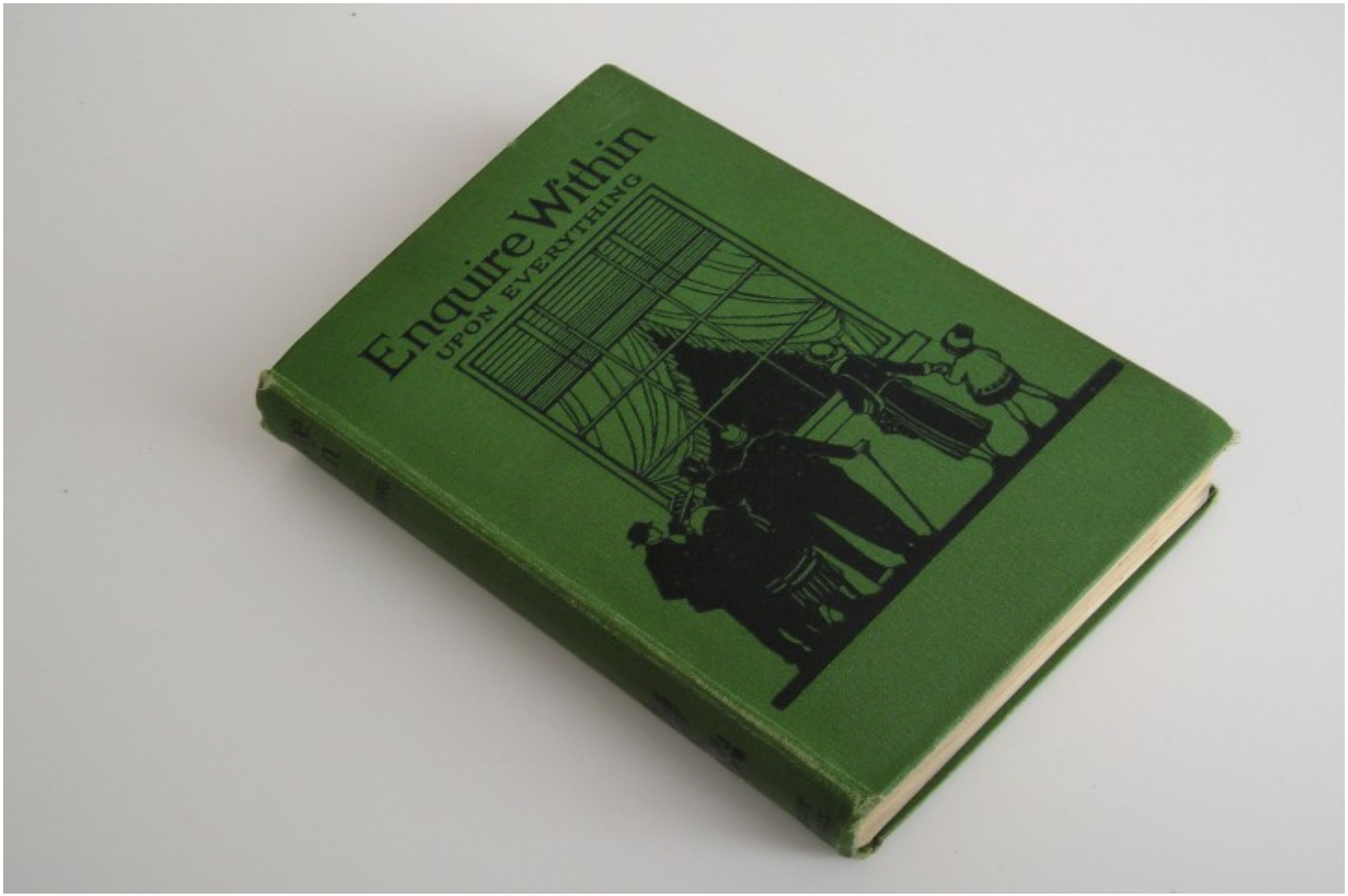
SPS Accelerator control systems







PS control system computerised 1980

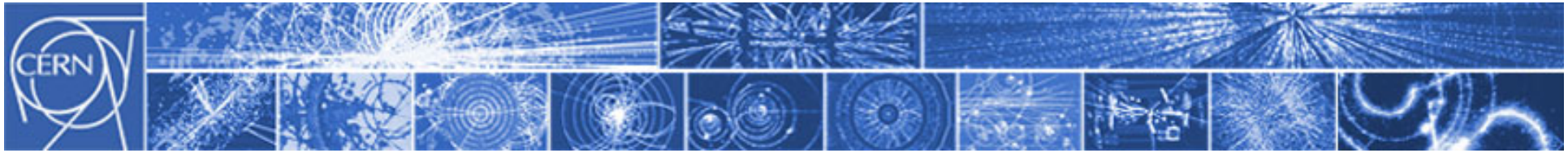


Early networking at CERN

Top priority status at computer centre:
Bicycle online

~~CERNET~~ INTERNET

The World Wide Web



The most valuable document ever?

930430

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

STATEMENT CONCERNING CERN W3 SOFTWARE RELEASE INTO PUBLIC DOMAIN

TO WHOM IT MAY CONCERN

Introduction

The World Wide Web, hereafter referred to as W3, is a global computer networked information system.

The W3 project provides a collaborative information system independent of hardware and software platform, and physical location. The project spans technical design notes, documentation, news, discussion, educational material, personal notes, publicity, bulletin boards, live status information and numerical data as a uniform continuum, seamlessly intergated with similar information in other disciplines.

The information is presented to the user as a web of interlinked documents .

Acces to information through W3 is:

- via a hypertext model;
- network based, world wide;
- information format independent;
- highly platform/operating system independent;
- scalable from local notes to distributed data bases.

Webs can be independent, subsets or supersets of each other. They can be local, regional or worldwide. The documents available on a web may reside on any computer supported by that web.

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Declaration

The following CERN software is hereby put into the public domain:

- W 3 basic ("line-mode") client
- W 3 basic server
- W 3 library of common code.

CERN's intention in this is to further compatibility, common practices, and standards in networking and computer supported collaboration. This does not constitute a precedent to be applied to any other CERN copyright software.

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Geneva, 30 April 1993

W. Hoogland
Director of Research

H. Weber
Director of Administration

opie certifiée conforme

ait à Genève le 03-05-93

ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
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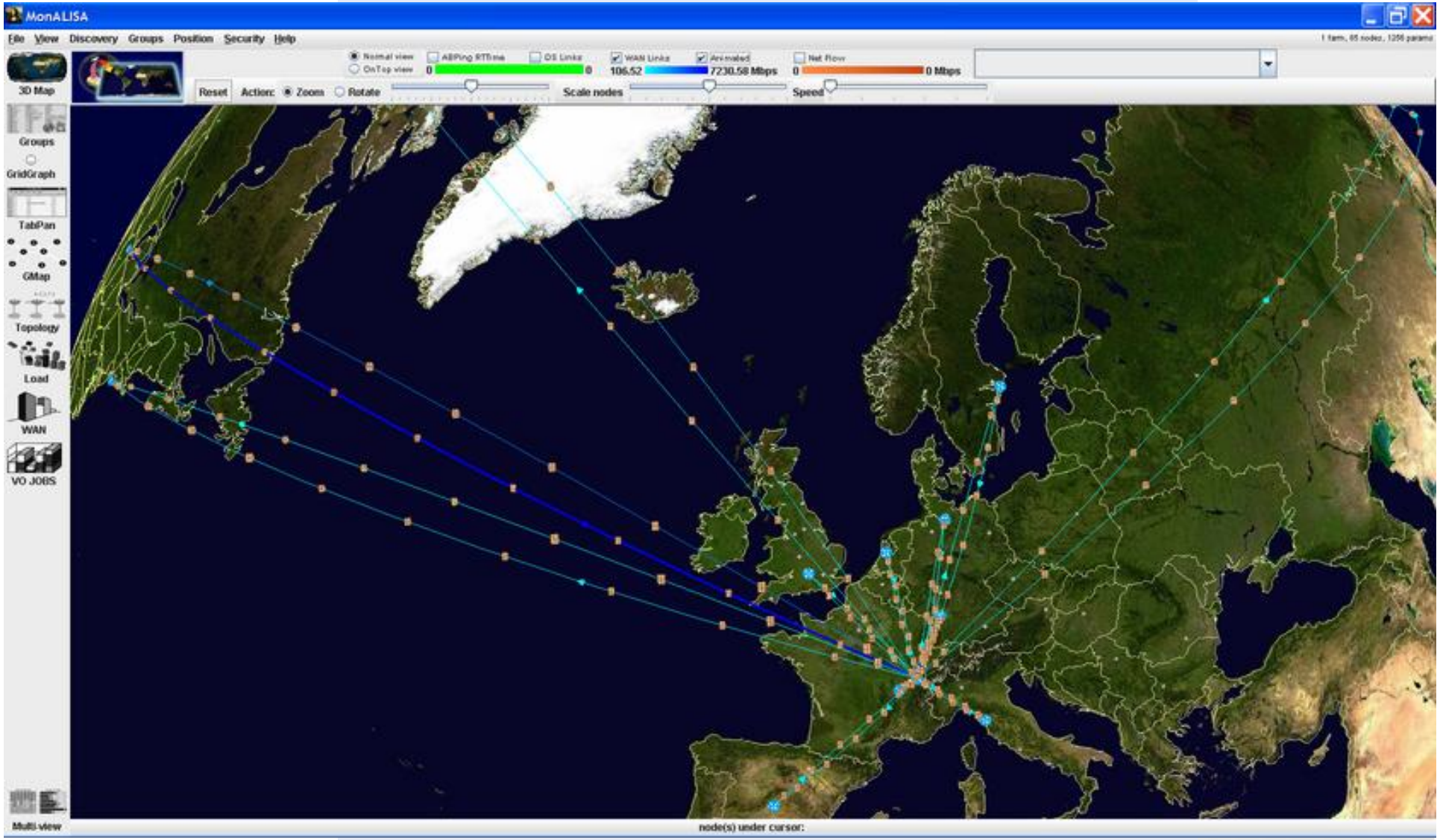
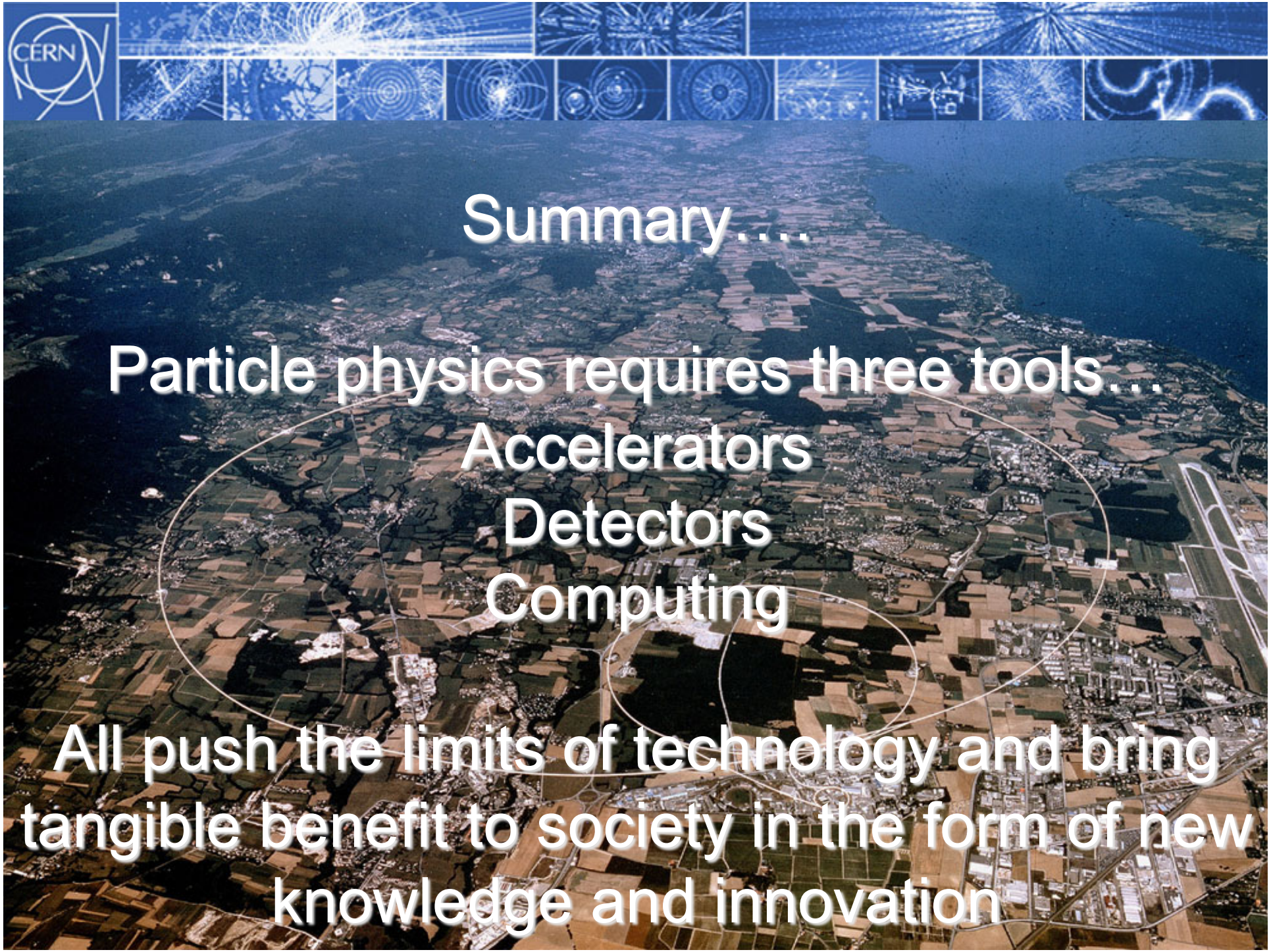
The Grid


MonALISA
File View Discovery Groups Position Security Help
Reset
Action: Zoom Rotate
Scale nodes
Speed
3D Map
Groups
GridGraph
TabPan
GMap
Topology
Load
WAN
VO JOBS
Multi-view
node(s) under cursor:


Summary….
Particle physics requires three tools…
Accelerators
Detectors
Computing
All push the limits of technology and bring tangible benefit to society in the form of new knowledge and innovation


Next time….
Angels, Demons and Black Holes
Demystifying the LHC