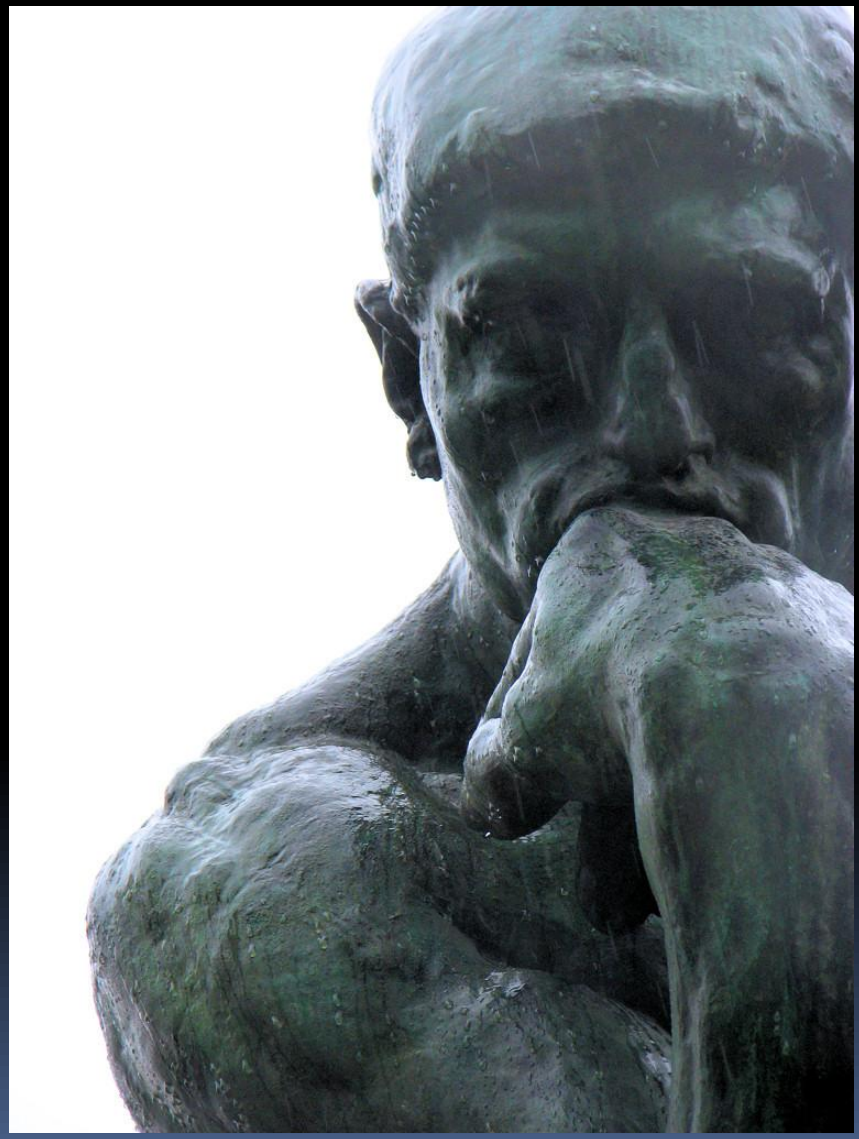
Dr. B.Satyanarayana
Scientific Officer (G)
Department of High Energy Physics
Tata Institute of Fundamental Research, Mumbai

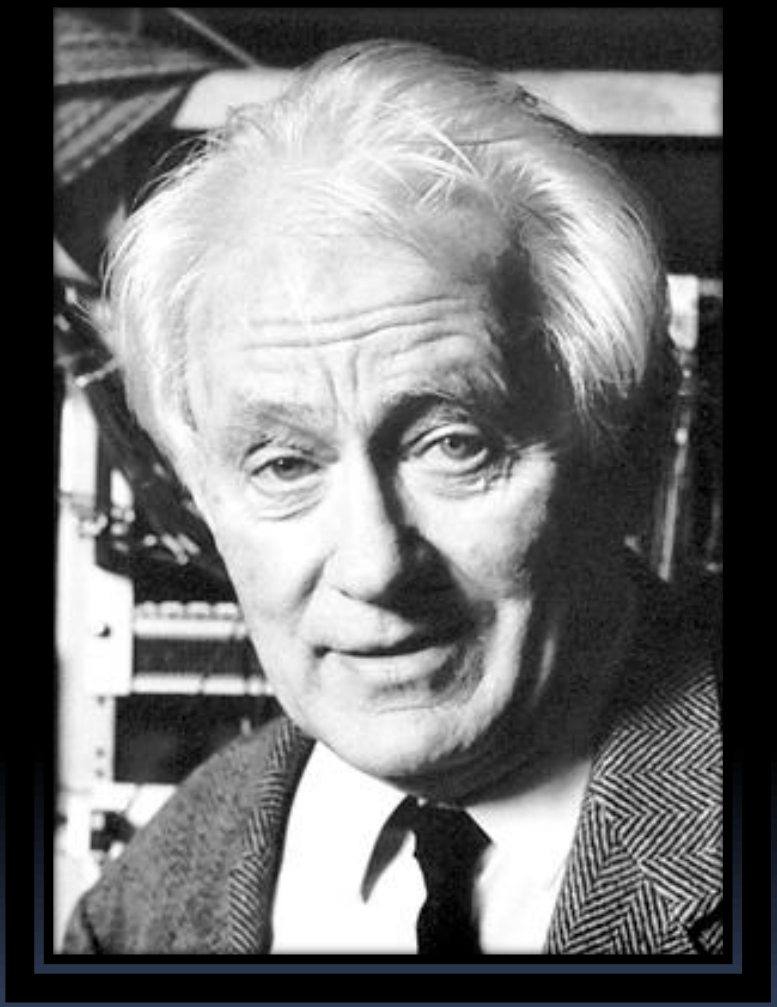
INNOVATION AND PRODUCTIVITY: ENABLERS *EVEN* FOR EMERGING PHYSICS EXPERIMENTS

Aims of particle physics

- What is the origin of mass?
- What holds it all together?
- How many space-time dimensions do we live in?
- Are the particles fundamental or do they possess structure?
- 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?



Science and Instrumentation



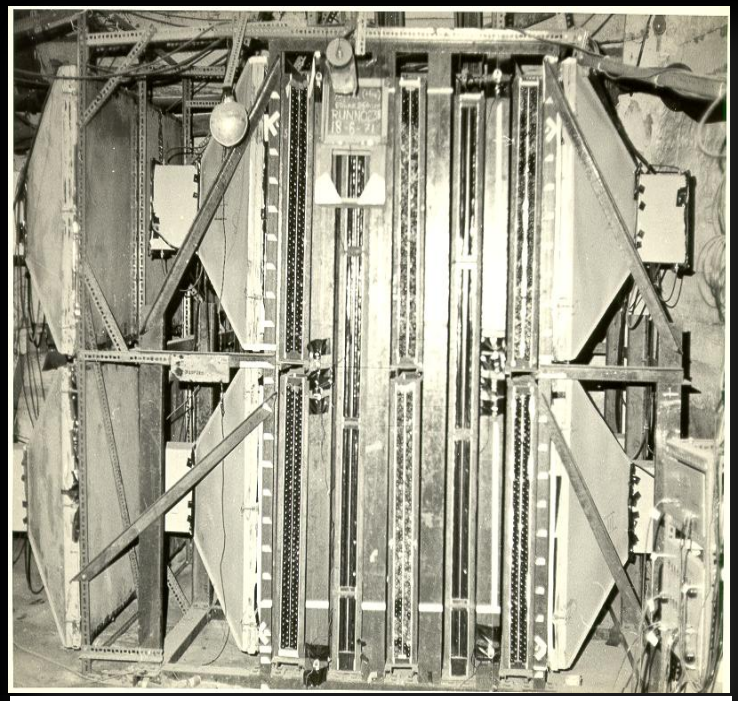
Georges Charpak (1924–2010)

The Nobel Prize in Physics 1992 was awarded to Georges Charpak "for his invention and development of particle detectors, in particular the multi-wire proportional chamber".

"The discoveries of the W and Z bosons at CERN, the charm quark at SLAC and Brookhaven and the top quark at Fermilab would not have been possible without this type of detector, and current research in high energy physics continues to depend on these devices".

Indian tradition of high energy physics

Atmospheric neutrino detector at Kolar Gold Fields –1965



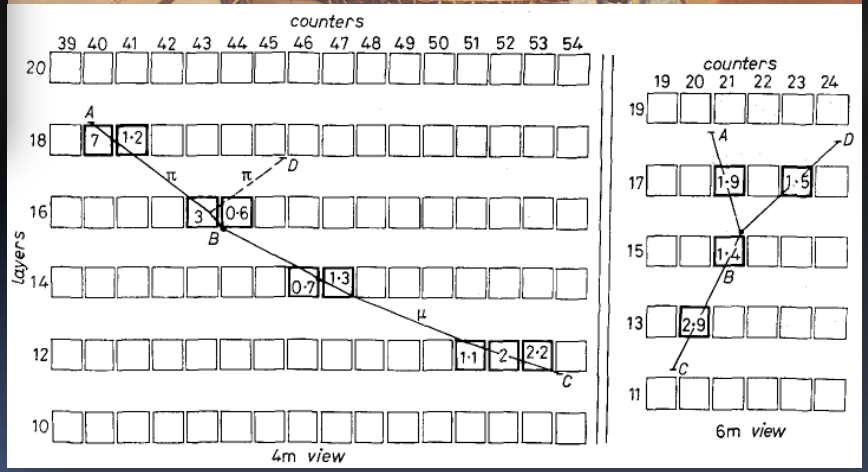
DETECTION OF MUONS PRODUCED BY COSMIC RAY NEUTRINO DEEP UNDERGROUND

C. V. ACHAR, M. G. K. MENON, V. S. NARASIMHAM, P. V. RAMANA MURTHY and B. V. SREEKANTAN,
Tata Institute of Fundamental Research, Colaba, Bombay

K. HINOTANI and S. MIYAKE,
Osaka City University, Osaka, Japan

D. R. CREED, J. L. OSBORNE, J. B. M. PATTISON and A. W. WOLFENDALE
University of Durham, Durham, U.K.

Received 12 July 1965



Proton decay experiments

Fermilab, where TOP was discovered

Numbers...

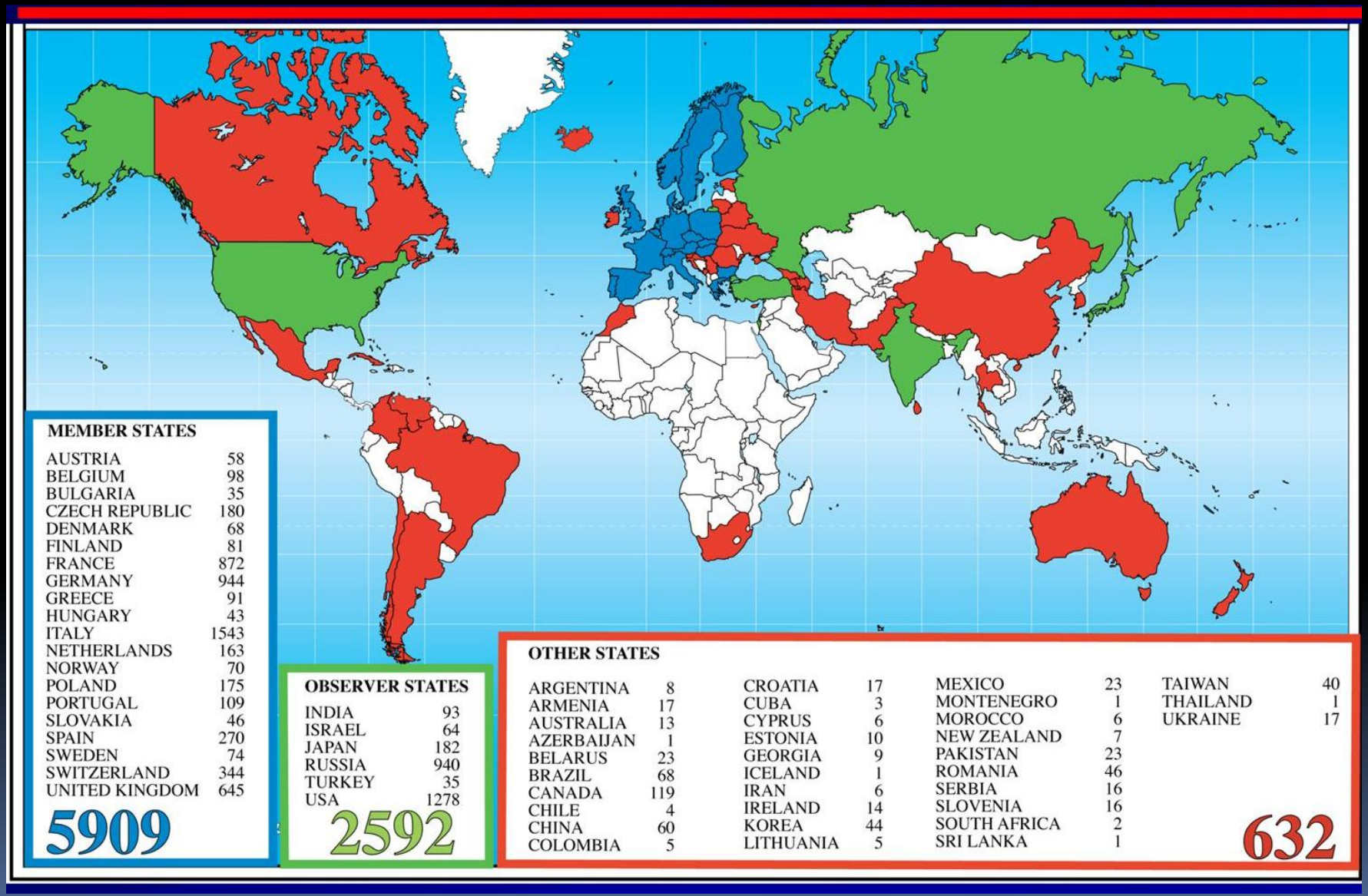
TOTAL USERS

U.S.	Physicists	Students	Subtotal	Institutions
University	761	445	1206	93
Industry	0	0	0	0
National Lab.	402	20	422	6
Subtotal	1163	465	1628	99

Non-U.S.	Physicists	Students	Subtotal	Institutions
University	459	195	654	91
Industry	0	0	0	0
National Lab.	294	39	333	23
Subtotal	753	234	987	114

TOTAL	1916	699	2615	213

CERN: A world laboratory



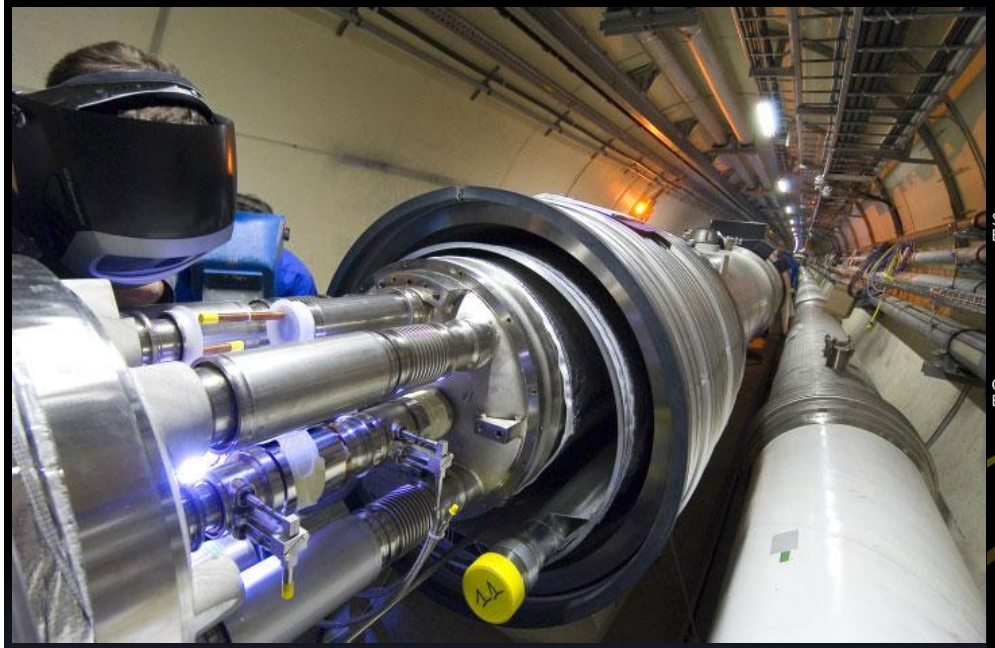
World's most powerful particle accelerator

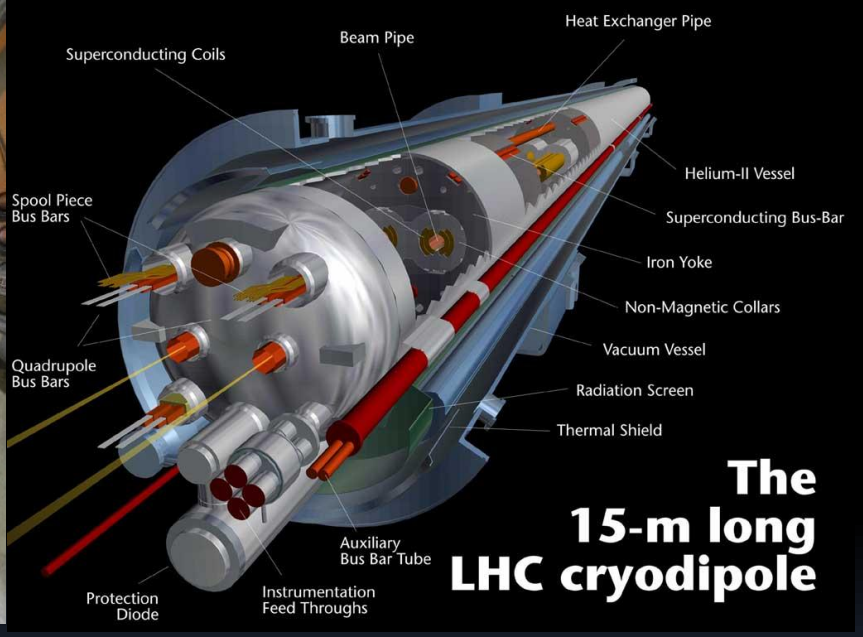
Startling facts about LHC accelerator

Protons race around a 27 km circuit at **99.999999%** the speed of light, crashing head on into each other **40,000,000** times a second.

Superconducting magnets: A great spinoff

in the **emptiest** space in our solar system…





The beam pipe is evacuated to the same vacuum as interplanetary space
The pressure is about 1/10th that of the surface of the moon.

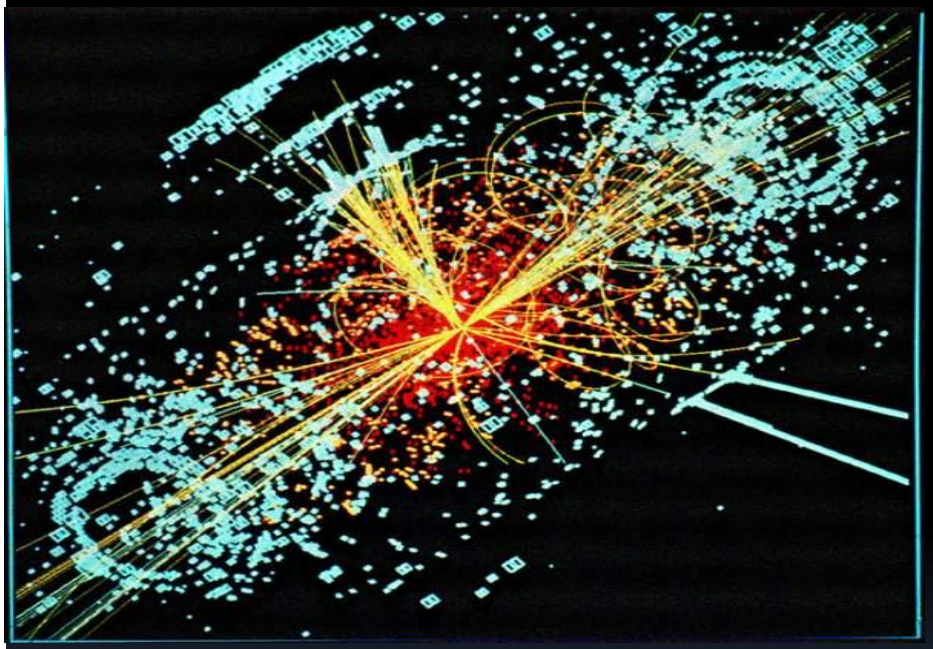
Cold facts about the LHC machine

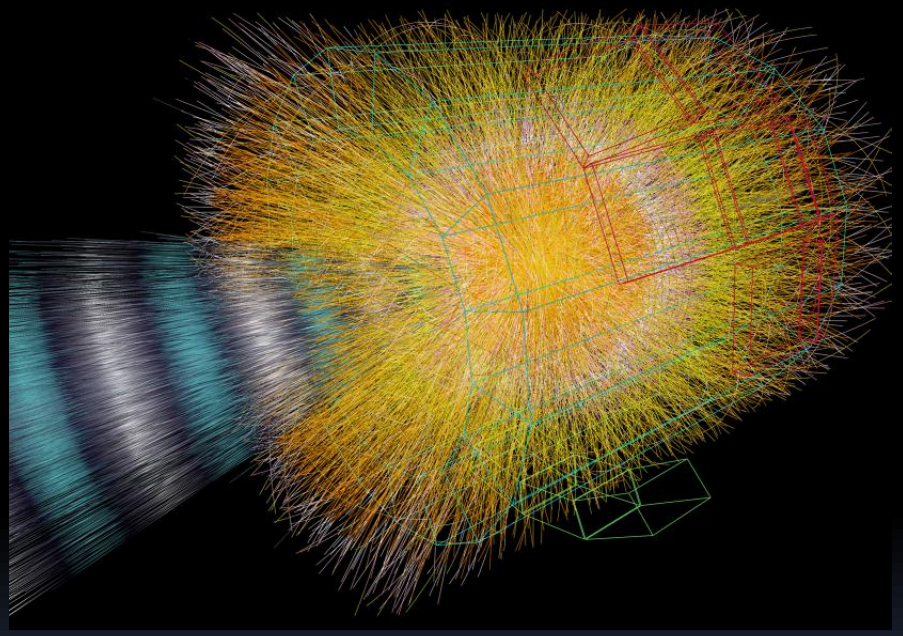
in one of the **coldest** regions in the universe…

Superconducting and superfluid liquid helium is maintained at -271.3 °C or 1.9 °K.
That is a little colder than interstellar space.

Particle interactions inside LHC

will occur some of the **hottest** reactions in our galaxy…



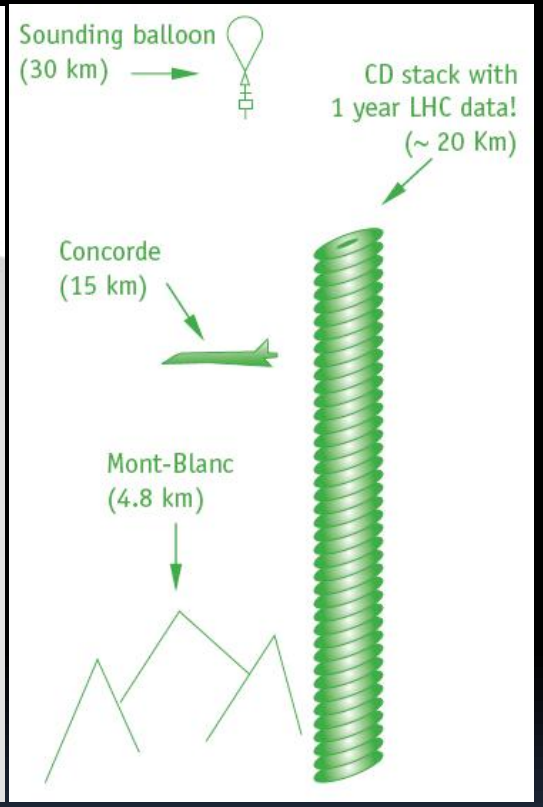


Violent collisions corresponding to temperatures a billion times higher than the core of the sun will be produced. That is roughly 160,000,000,000,000,000 C

One of the experiments looking for Higgs

World Wide Web was invented at CERN

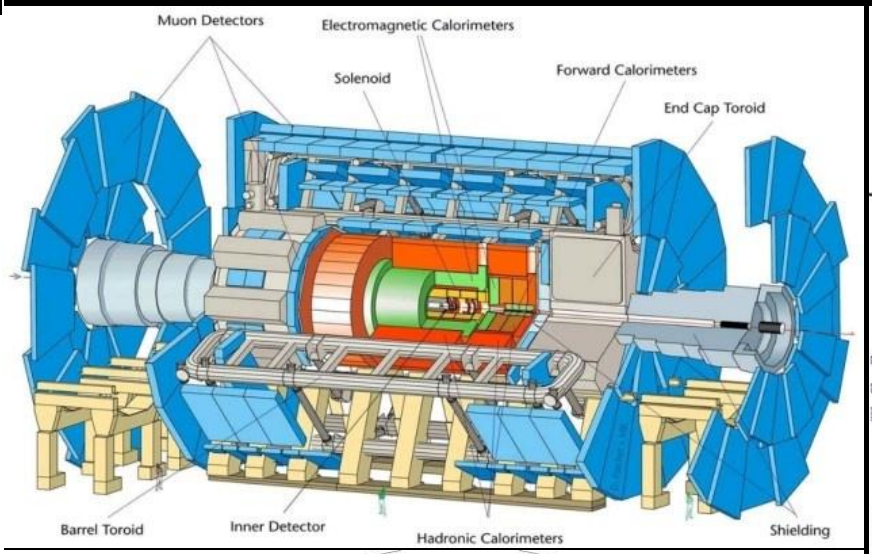
and analyzed by the most **powerful** computing system in the world.

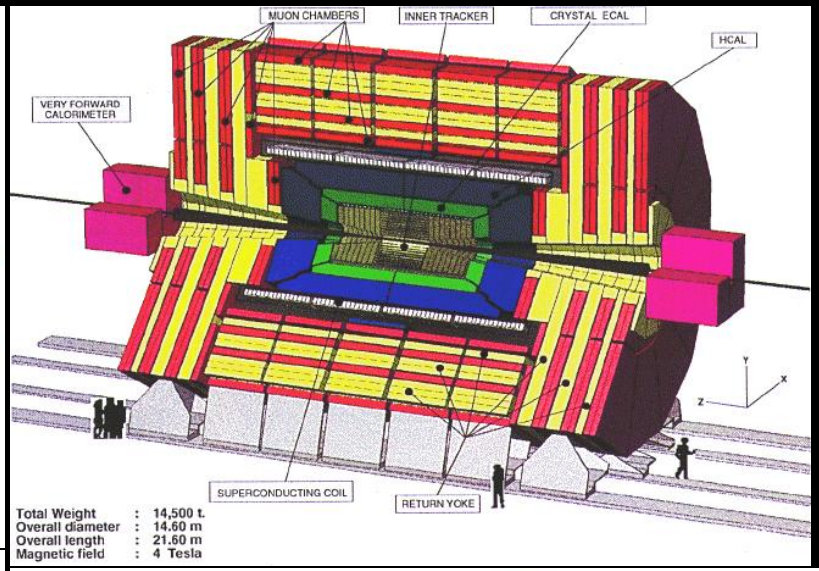


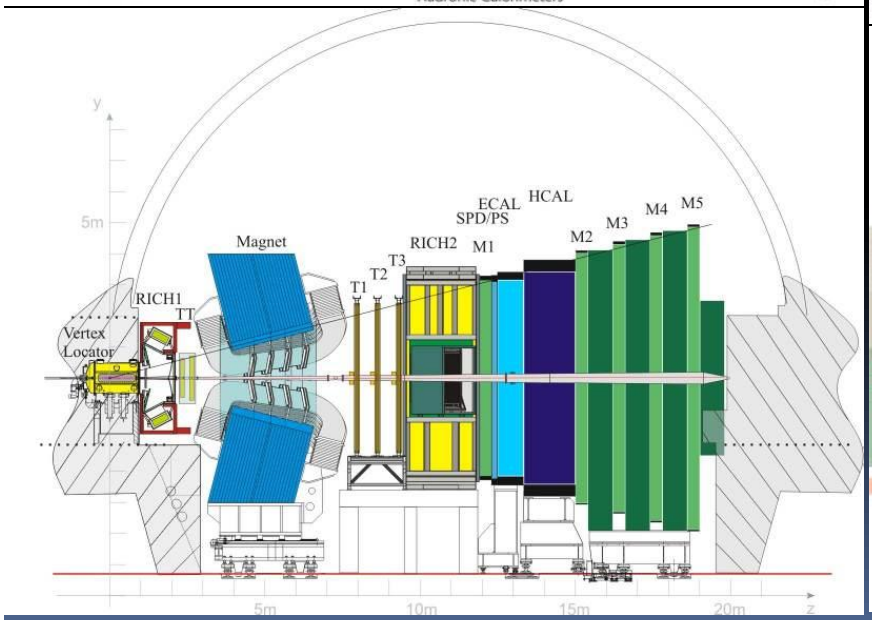
The detectors will spew out analyzed data at **700 MB/sec.**
That is ~30,000 Encyclopedia Britannicas *every second*!

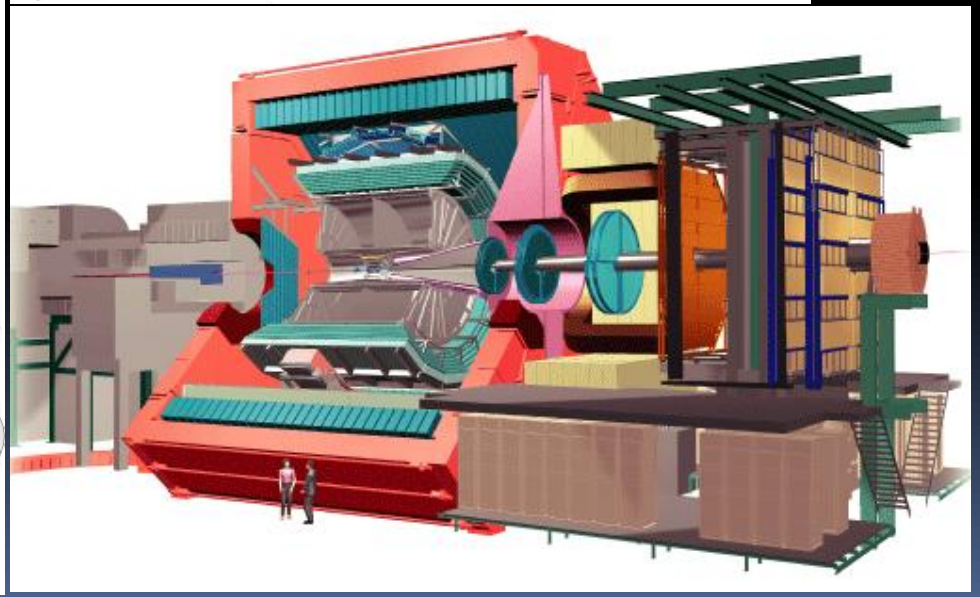
15,000,000 GB (or 20 km stack of CDs) per year

ATLAS,CMS,ALICE & LHCb detectors

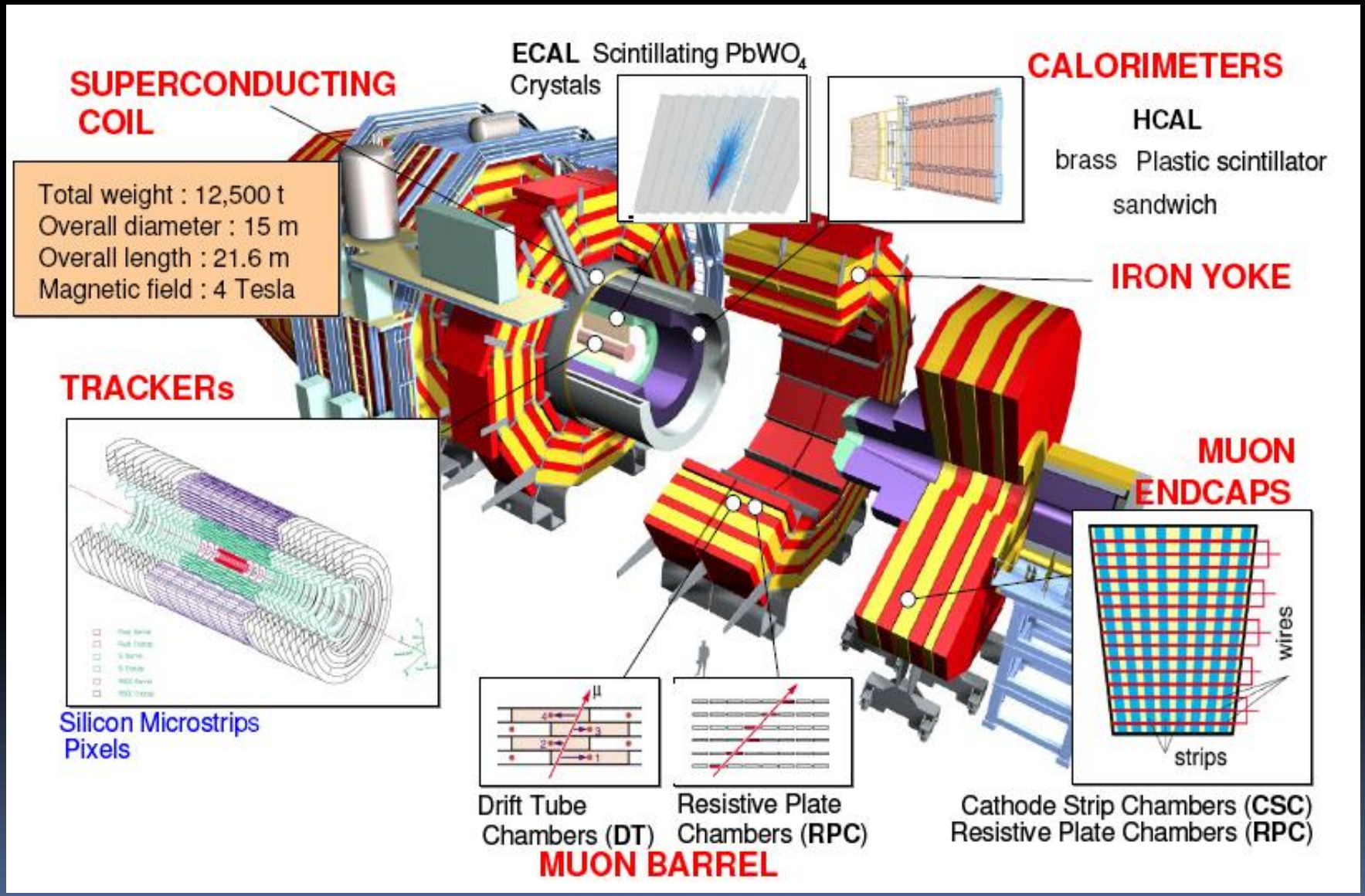






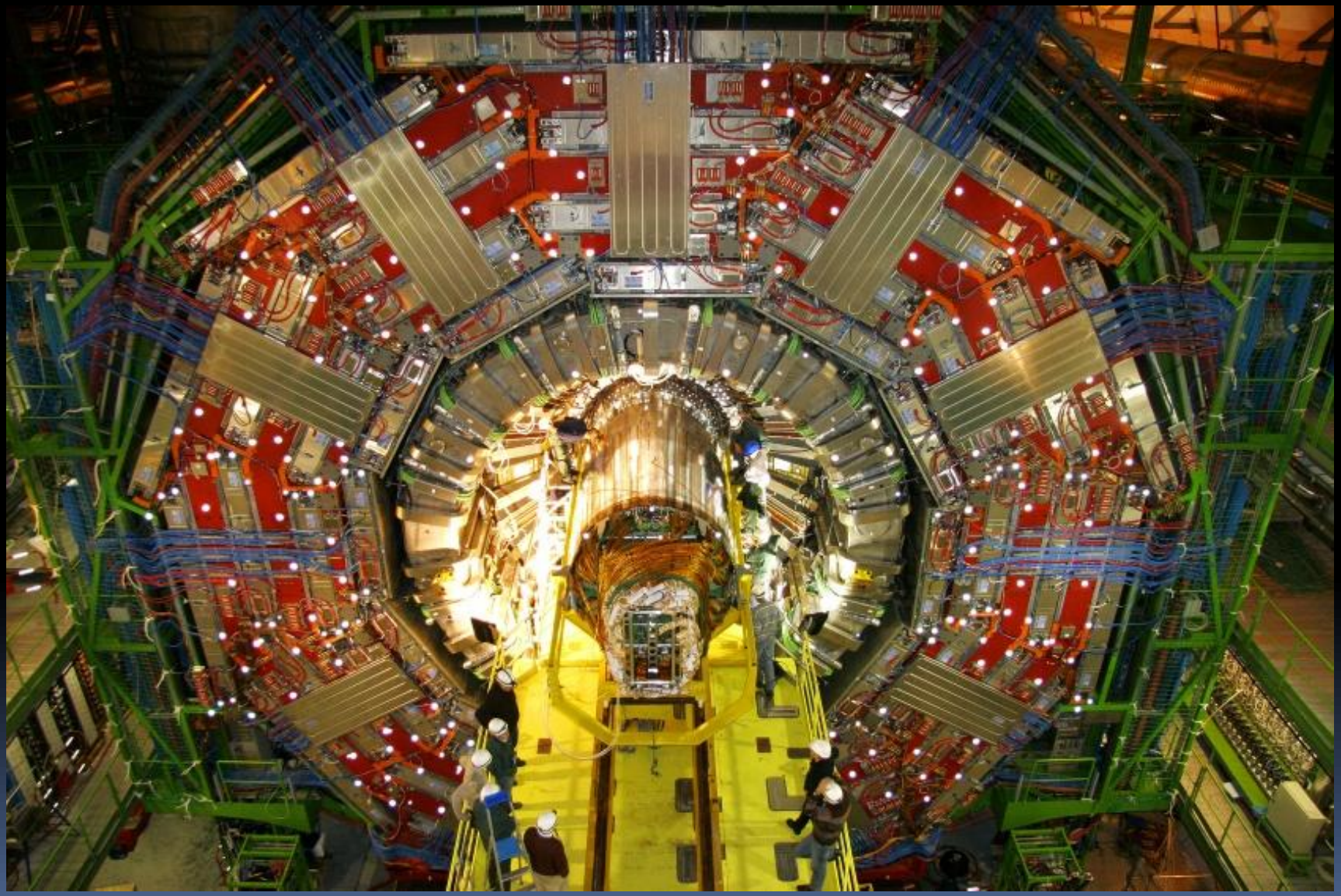


CMS Experiment



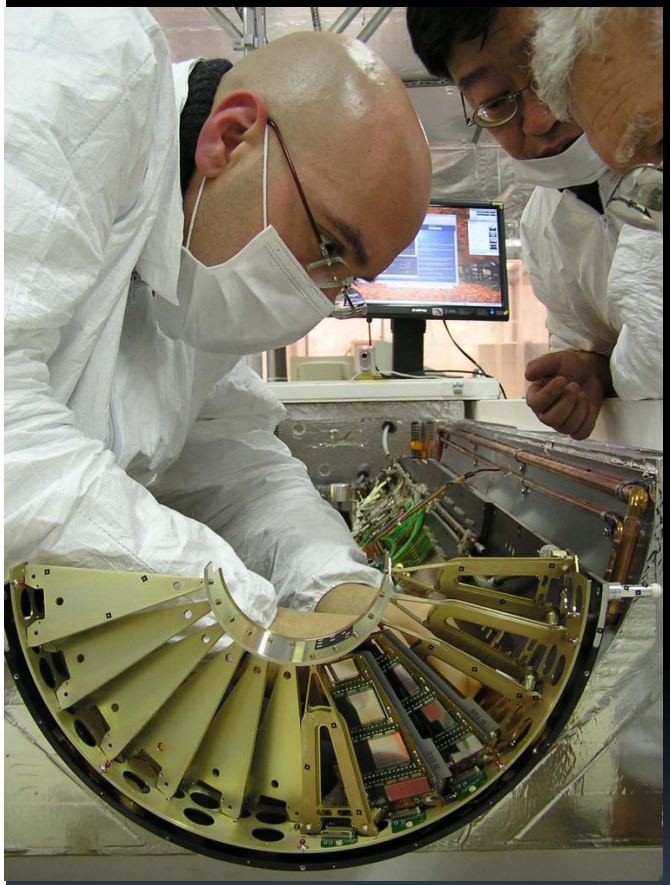
Home for a modern physics experiment

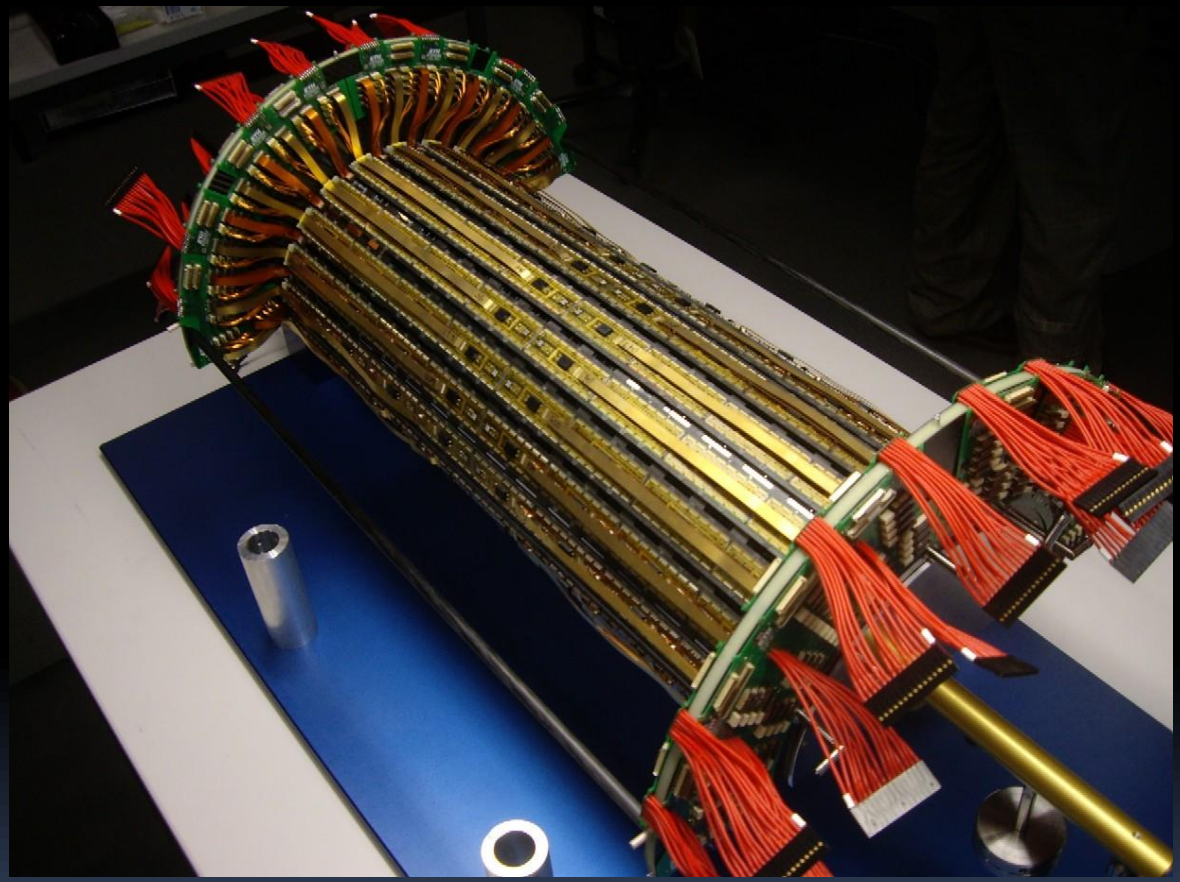
Gigantic detectors for modern experiments



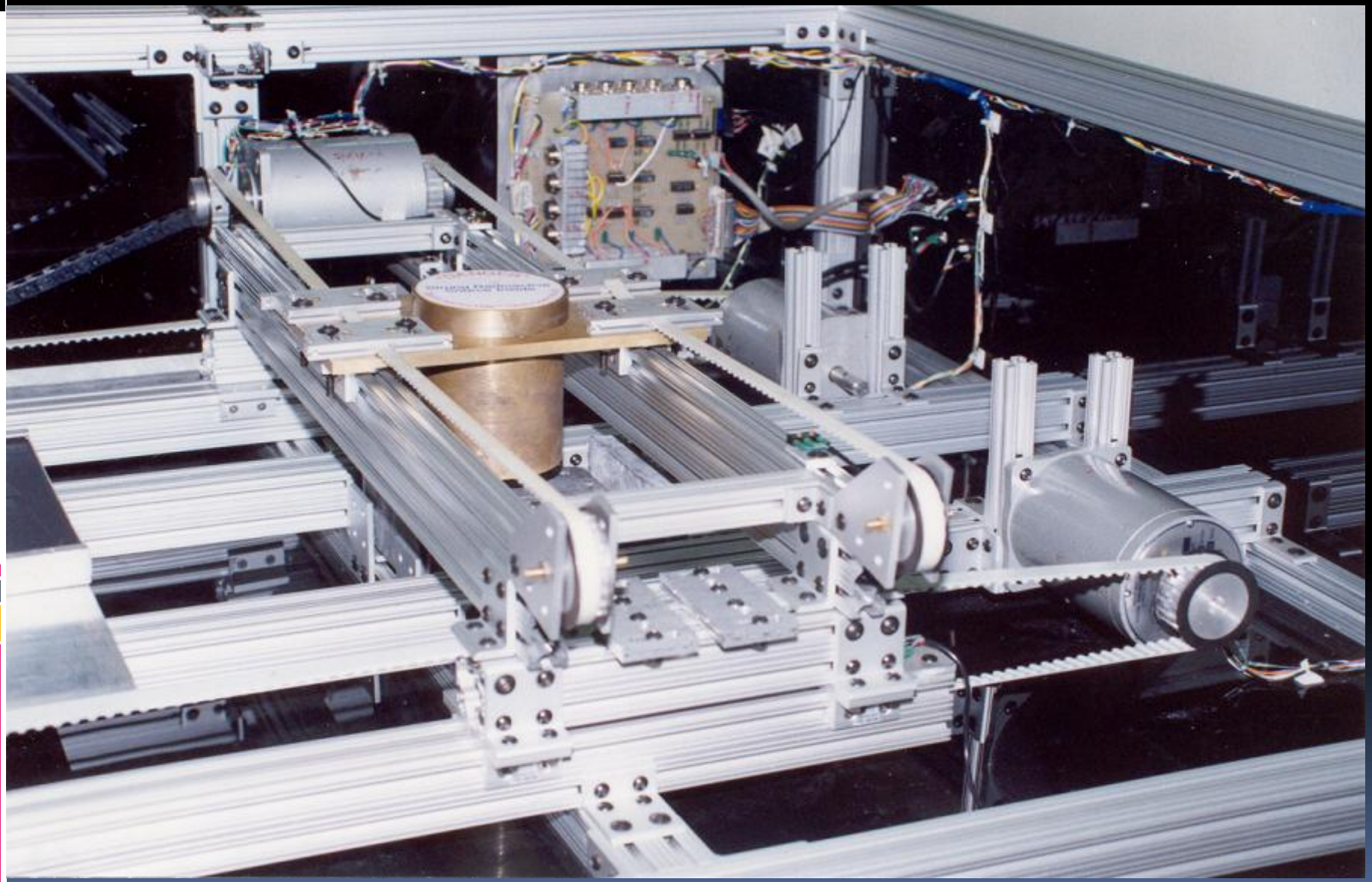
Electromagnetic Calorimeter crystals

Silicon pixel detectors



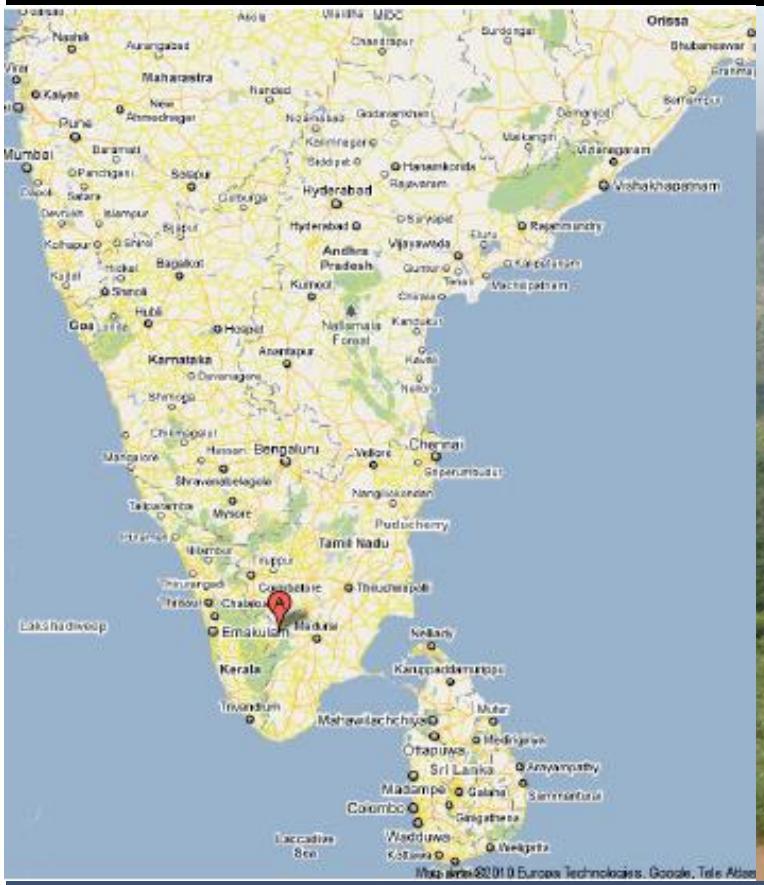


Radioactive scanner for detector QC

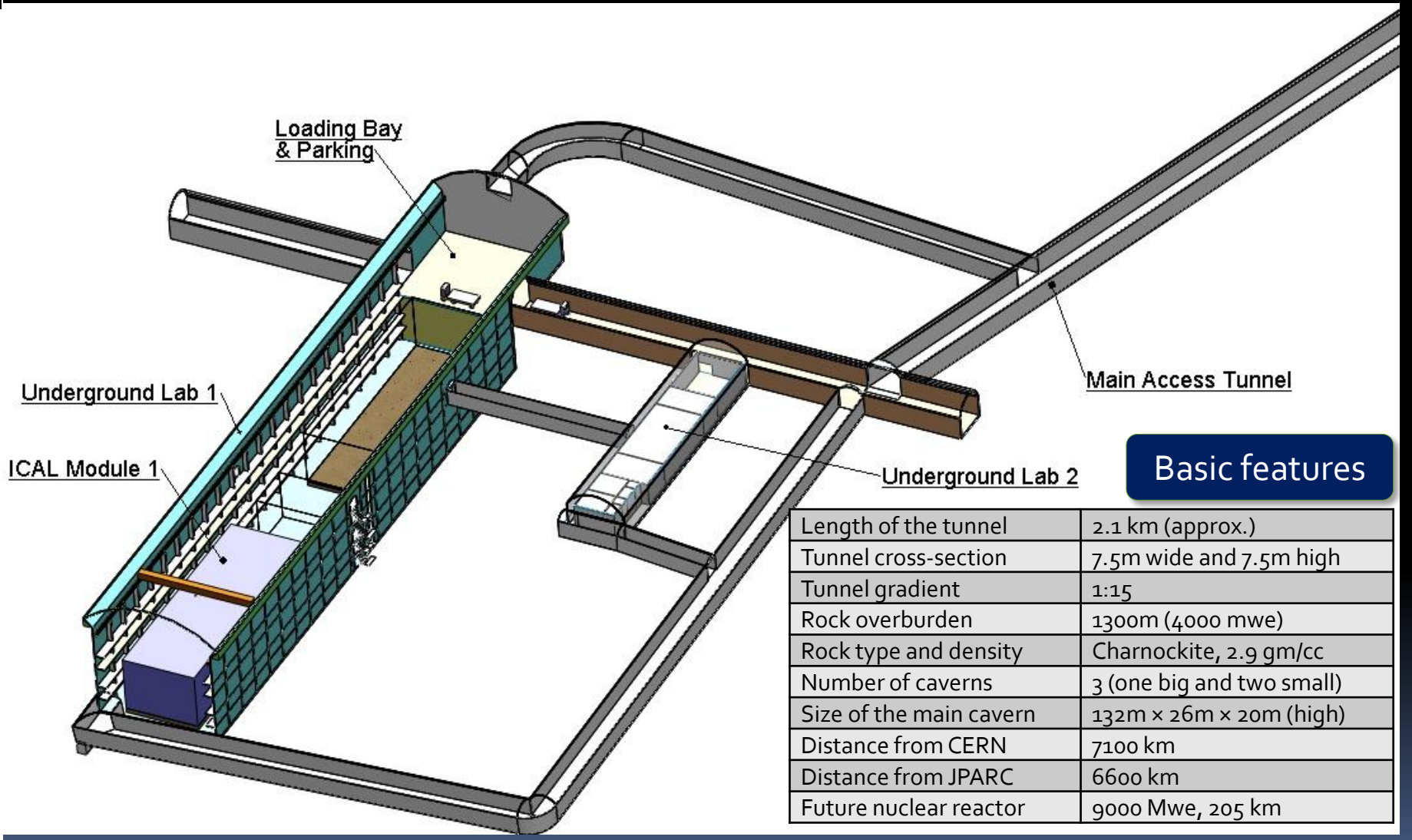


India-based Neutrino Observatory (INO)

Location: 9°58′ North; 77°16′ East, 110km from Madurai (South India)



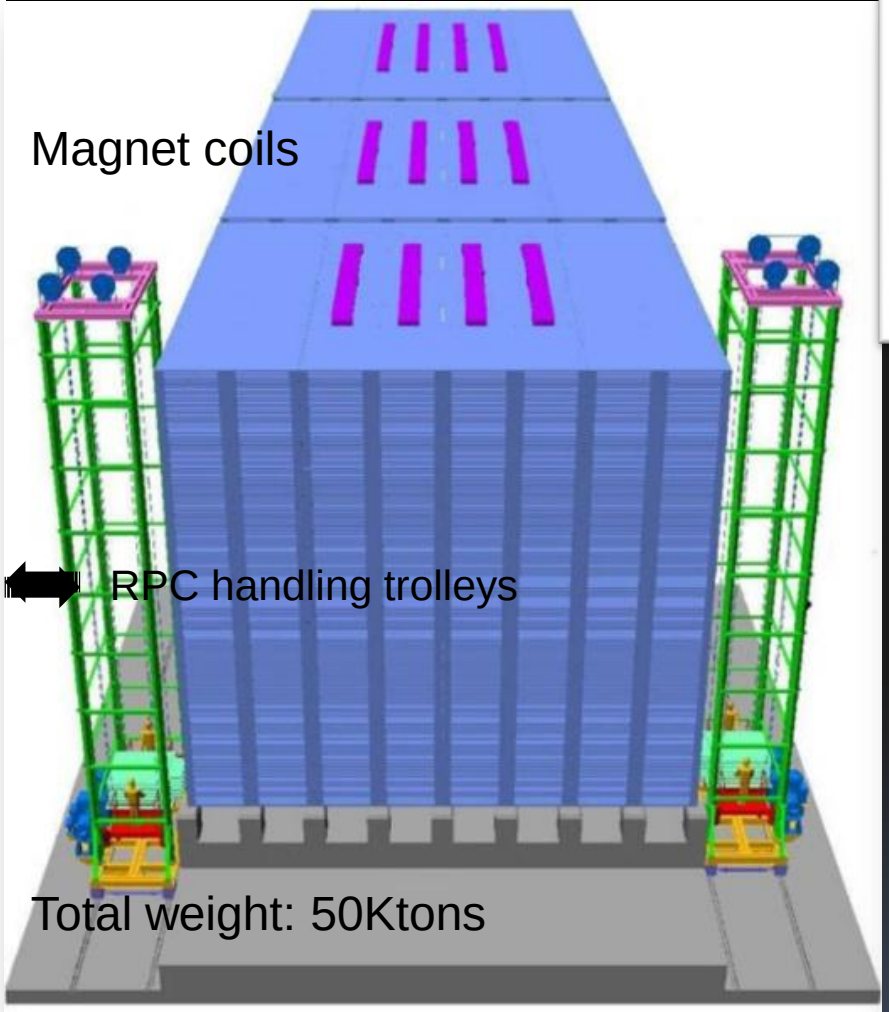
Schematic of the underground labs

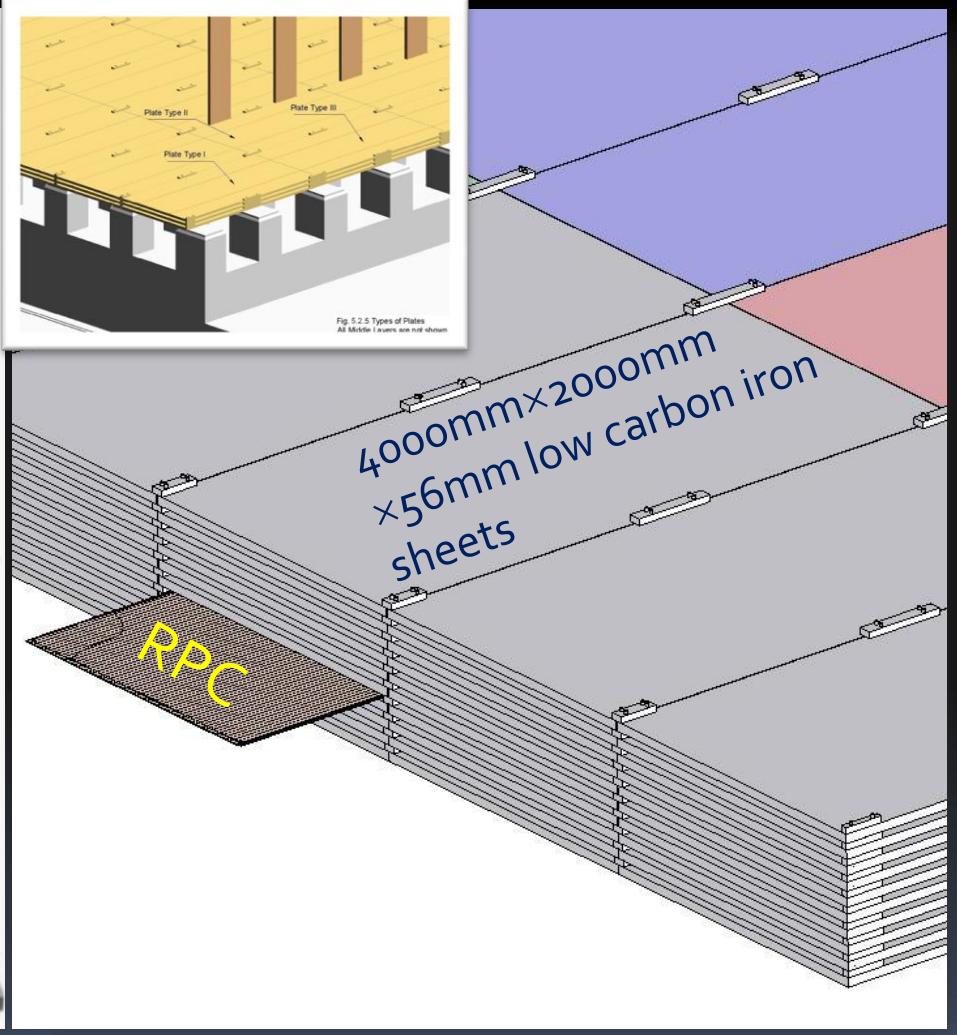


Basic features

Length of the tunnel	2.1 km (approx.)
Tunnel cross-section	7.5m wide and 7.5m high
Tunnel gradient	1:15
Rock overburden	1300m (4000 mwe)
Rock type and density	Charnockite, 2.9 gm/cc
Number of caverns	3 (one big and two small)
Size of the main cavern	132m × 26m × 20m (high)
Distance from CERN	7100 km
Distance from JPARC	6600 km
Future nuclear reactor	9000 Mwe, 205 km

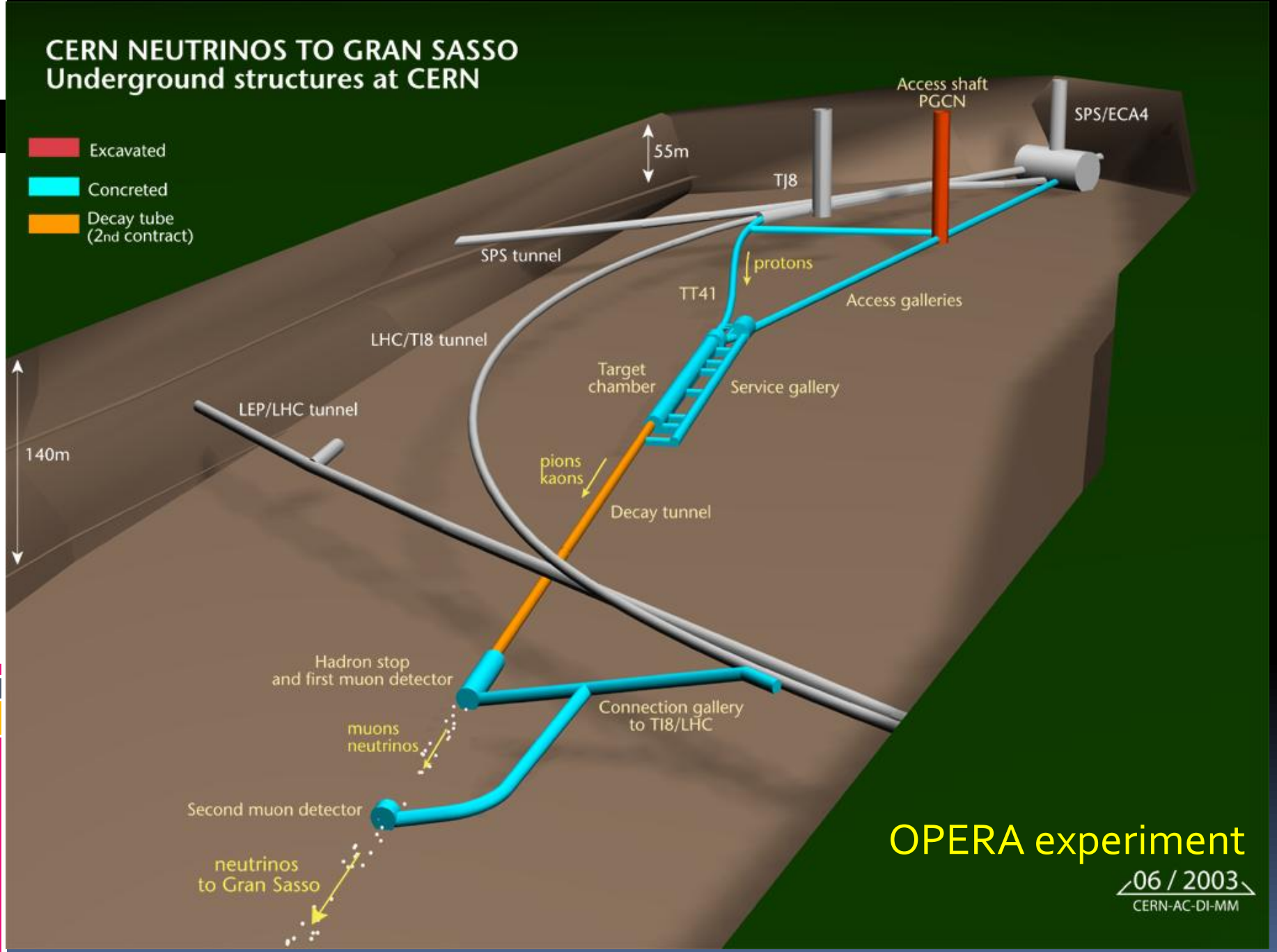
ICAL detector and construction



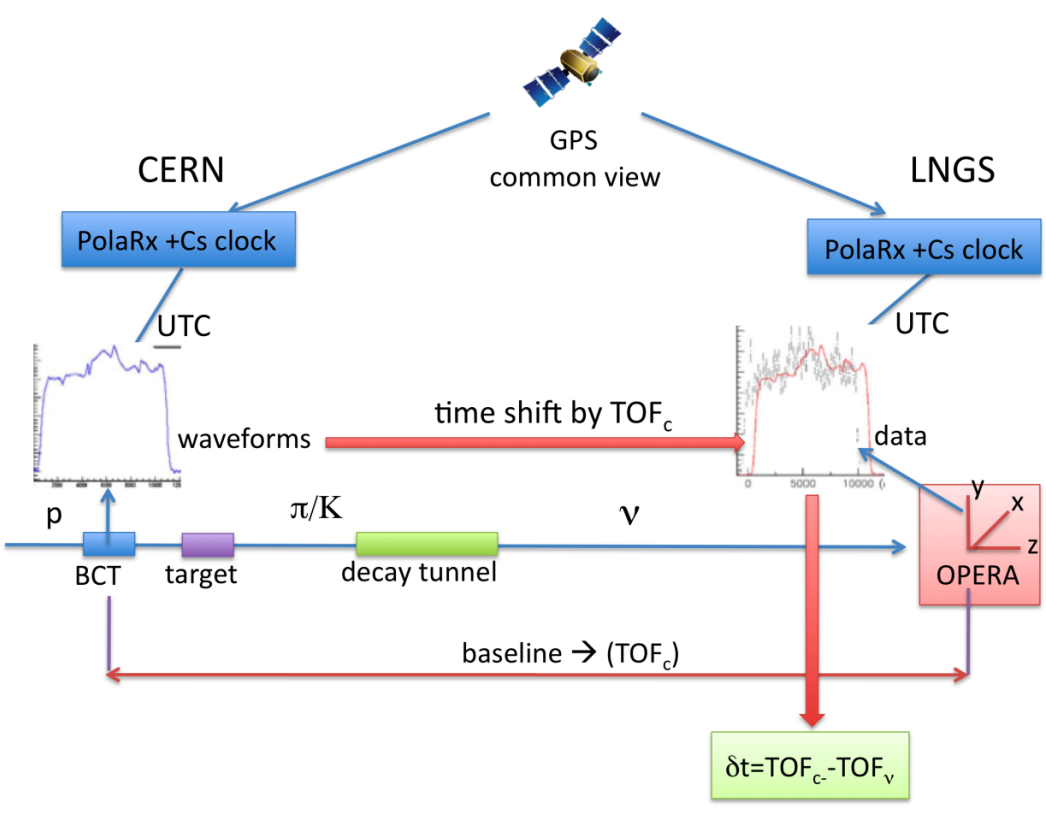


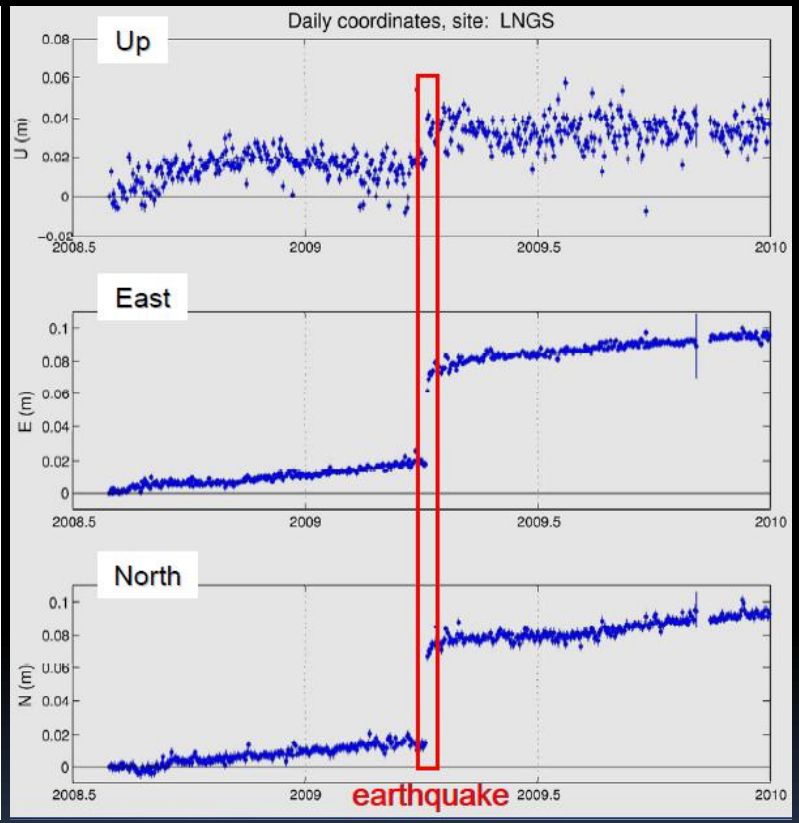
Factsheet of ICAL detector

No. of modules	3
Module dimensions	16m × 16m × 14.5m
Detector dimensions	48.4m × 16m × 14.5m
No. of layers	150
Iron plate thickness	56mm
Gap for RPC trays	40mm
Magnetic field	1.3Tesla
RPC dimensions	1,950mm × 1,840mm × 24mm
Readout strip pitch	3 0mm
No. of RPCs/Road/Layer	8
No. of Roads/Layer/Module	8
No. of RPC units/Layer	192
No. of RPC units	28,800 (97,505m^2)
No. of readout strips	3,686,400


CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN
Excavated
Concreted
Decay tube
(2nd contract)
55m
Access shaft
PGCN
SPS/ECA4
TI8
SPS tunnel
protons
TT41
Access galleries
LHC/TI8 tunnel
Target
chamber
Service gallery
LEP/LHC tunnel
140m
pions
kaons
Decay tunnel
Hadron stop
and first muon detector
Connection gallery
to TI8/LHC
muons
neutrinos
Second muon detector
neutrinos
to Gran Sasso
OPERA experiment
06 / 2003
CERN-AC-DI-MM

Precise time & distance measurement





Earthquake April 2009, displacement 7cm

Basic Science Research is a way of life!

- Innovation is what distinguishes humans from other living objects.
- Good science is also measured by its quality and productivity.
- Every new scientific discovery often opens up a new branch of science and a jungle of possible further discoveries.
- The technological spin-offs of this research are benefitting the man on the street immensely.

Acknowledgements

- KGF underground experiment s (TIFR)
- Fermilab (USA)
- CERN & CMS experiments (Geneva)
- OPERA experiment (Gran Sasso)