

Експерименти във физиката на елементарните частици

Експерименти във Физиката на елементарните частици

Експерименти на ускорители.

Фиксирана мишена

Колайдери

Космически лъчи

На земята

В космоса

Реактори

Други

CERN – European Centre for Nuclear Research

In one of the world's **biggest** laboratories...



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lies the world's **fastest** and most **brutal** racetrack...

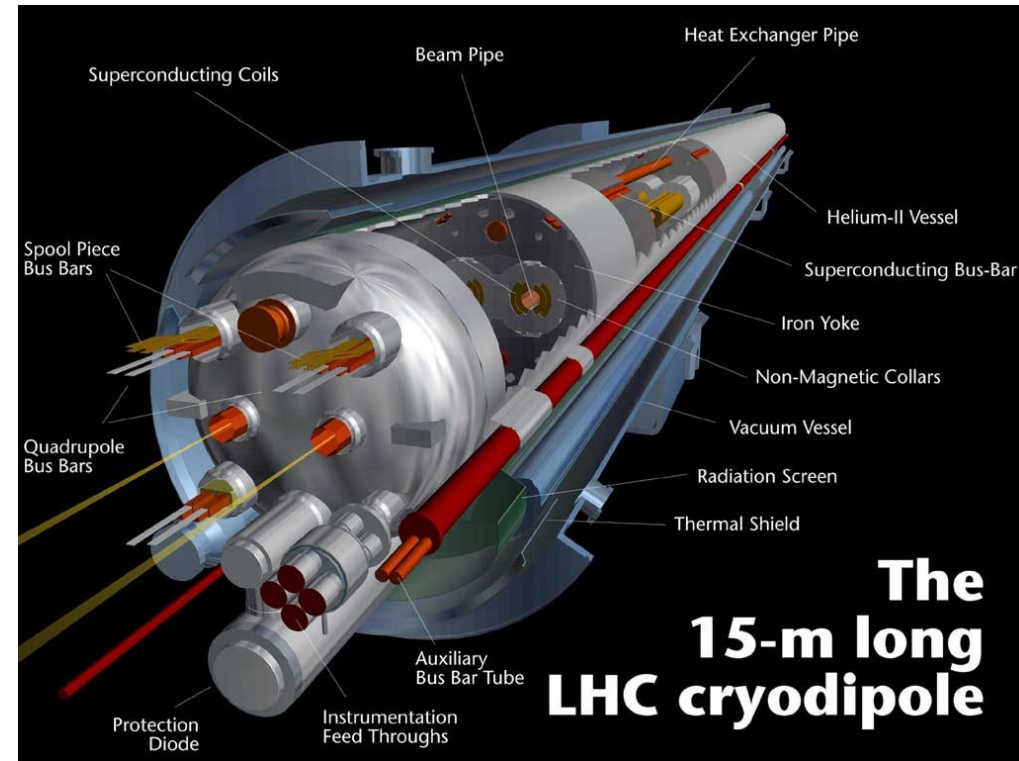
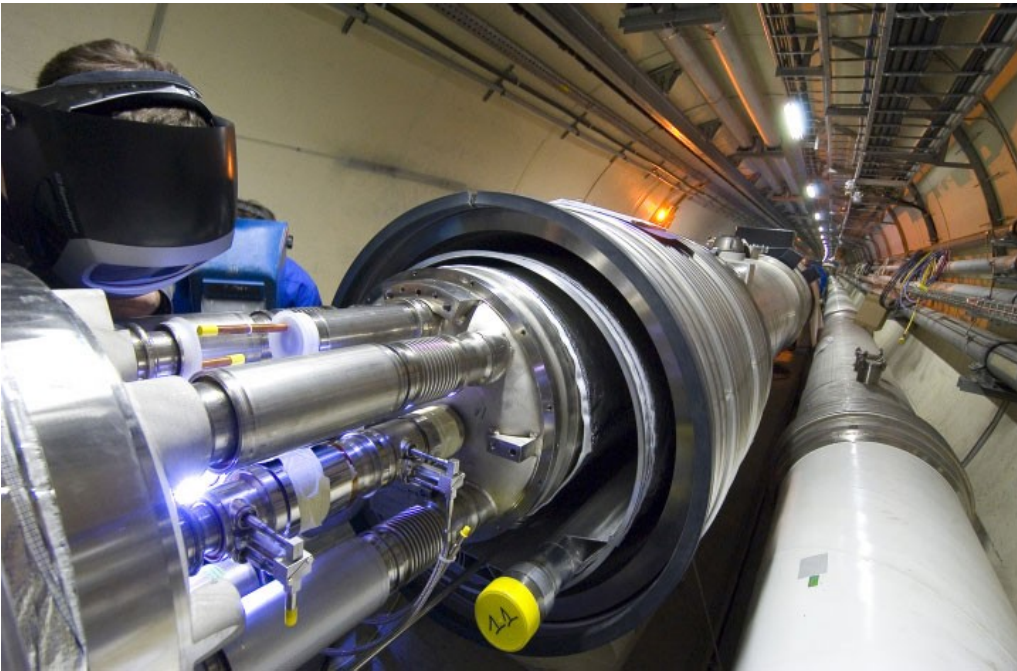


Protons race
around a 27 km
circuit at
99.999999% the
speed of light,

crashing head on
into each other
40,000,000 times
a second.

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



The beam pipe is evacuated to the same vacuum as interplanetary space
The pressure is about $1/10^{\text{th}}$ that of the surface of the moon.

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

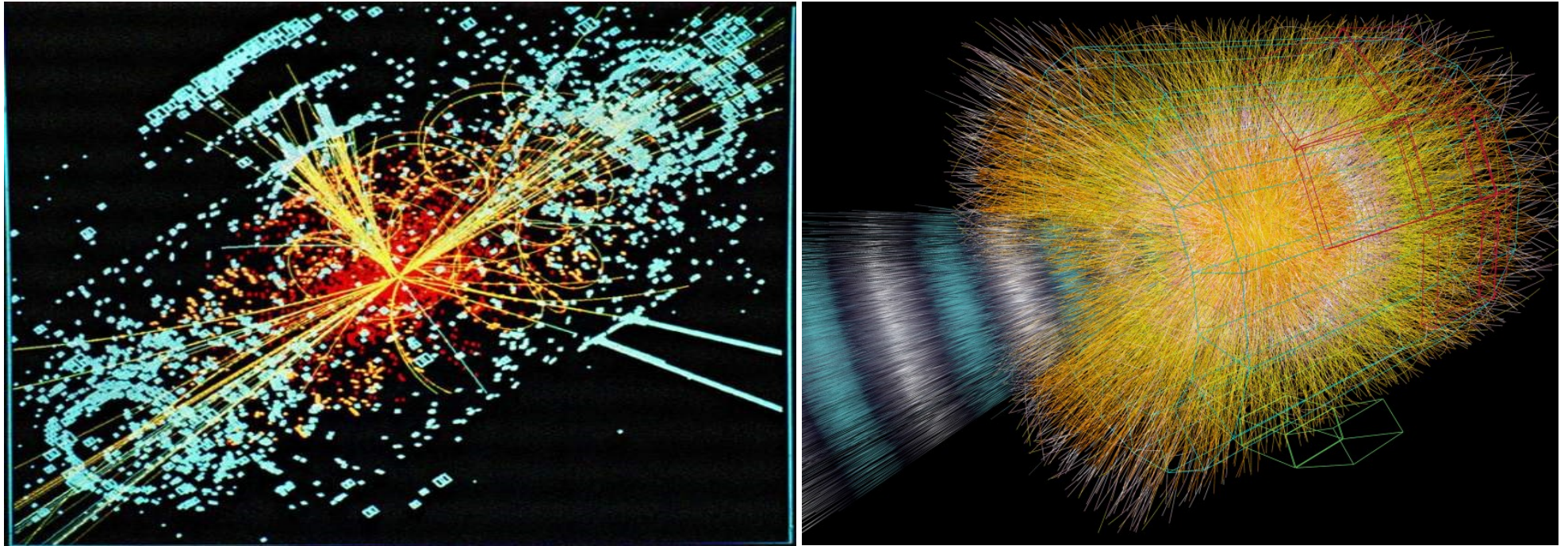


Superconducting and superfluid liquid helium is maintained at -271.3 C or 1.9 K .

That is a little colder than interstellar space.

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

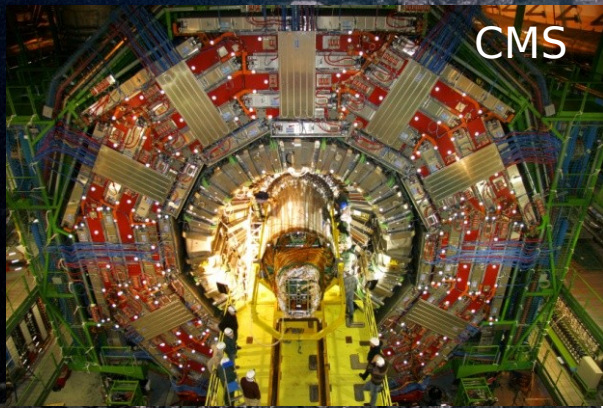


Violent collisions corresponding to temperatures a billion times higher than the core of the sun will be produced.

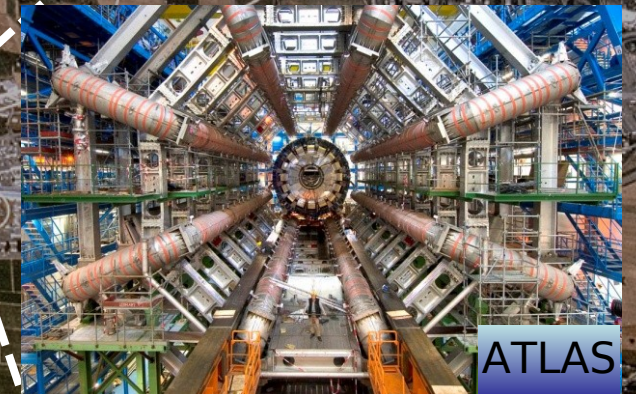
That is roughly 160,000,000,000,000,000 C

Нова ера във фундаменталната наука

Пуска на Големия Адронен Колайдер (LHC), един от най-големите и глобални научни проекти, е най-вълнуващата повратна точка във физиката на елементарните частици.

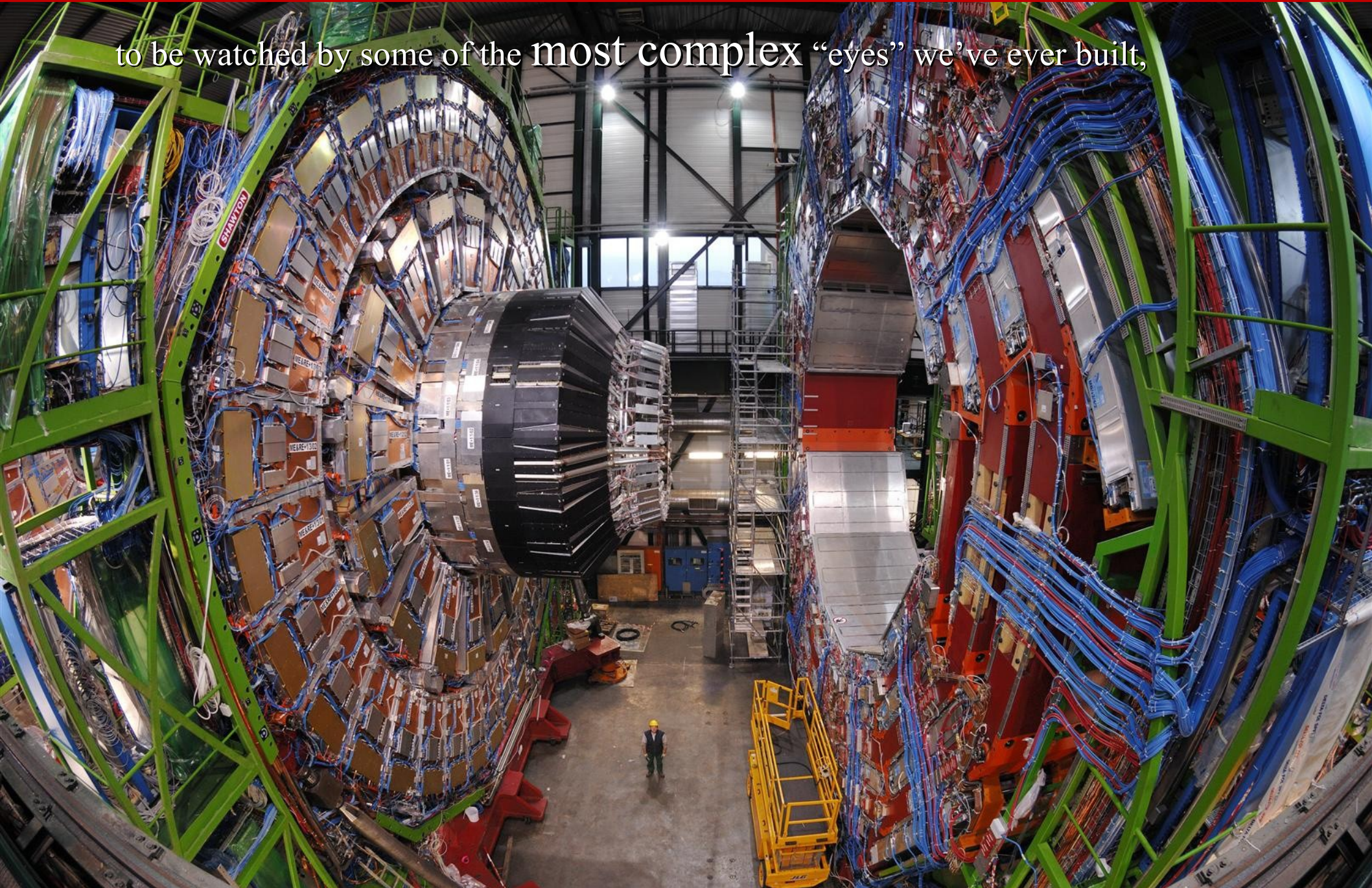


Изследване на нова енергийна граница
p-p и Pb-Pb сблъсъци



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to be watched by some of the most complex “eyes” we’ve ever built,

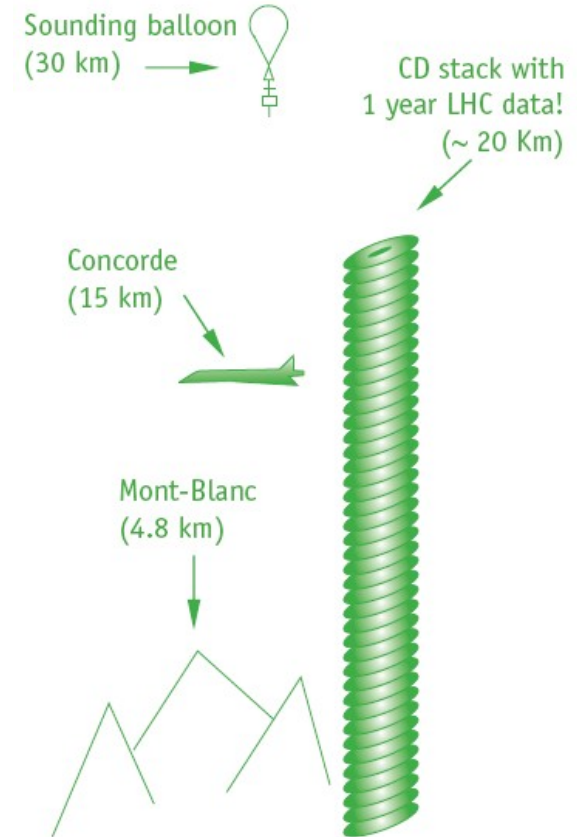
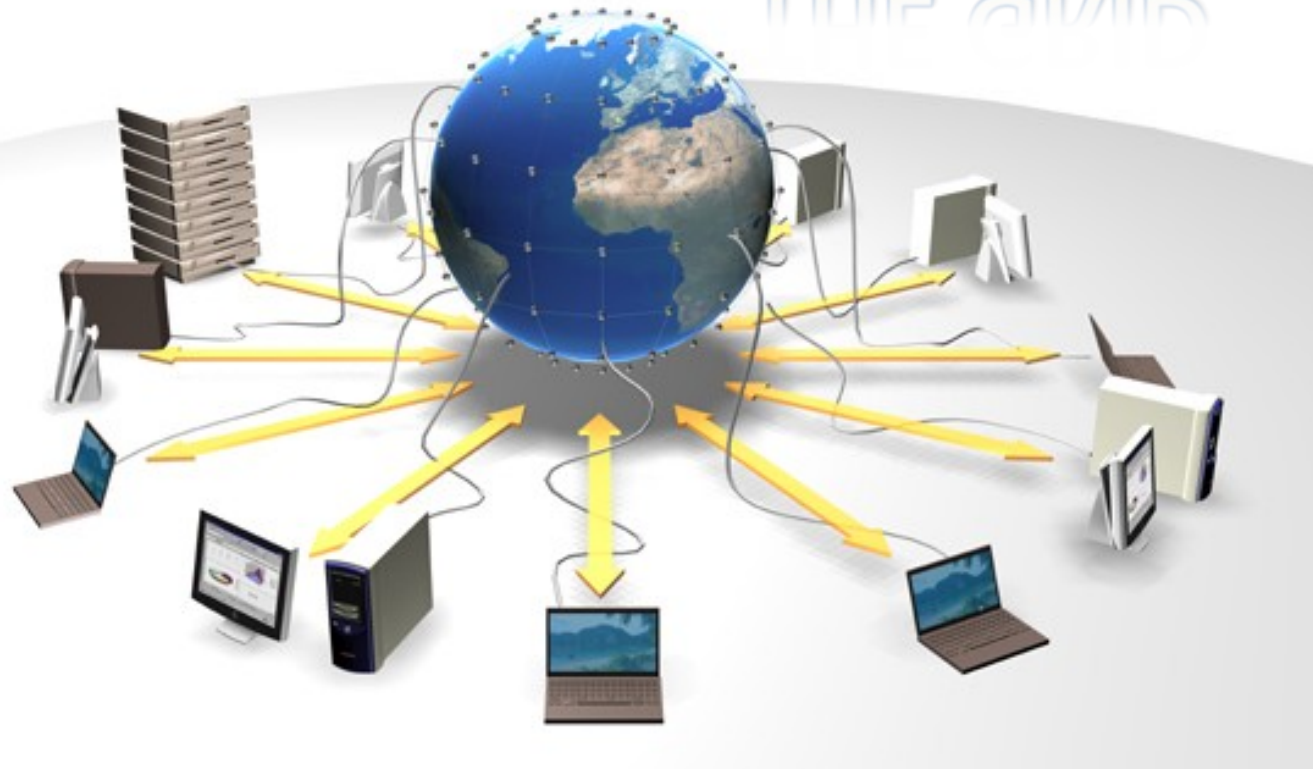


The detectors together have 140 million data channels observing at 40 million times a second.

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

THE GRID



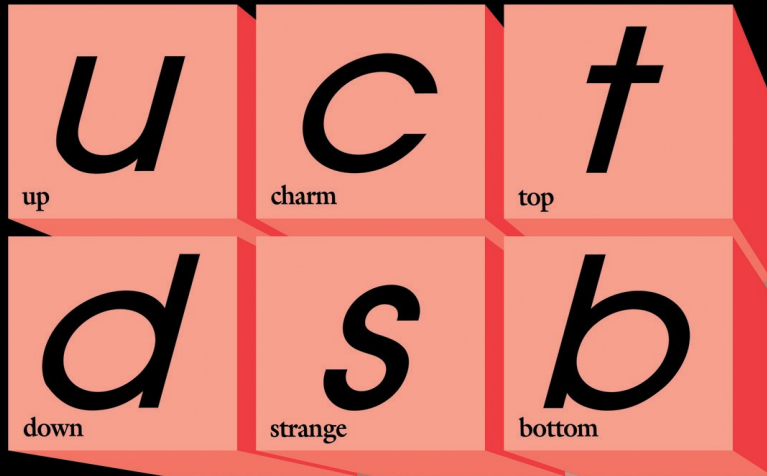
The detectors will spew out analyzed data at **700 MB/sec.**

That is ~30,000 Encyclopedia Britannicas *every second!*

That is 15,000,000 GB
(15 PB) per year

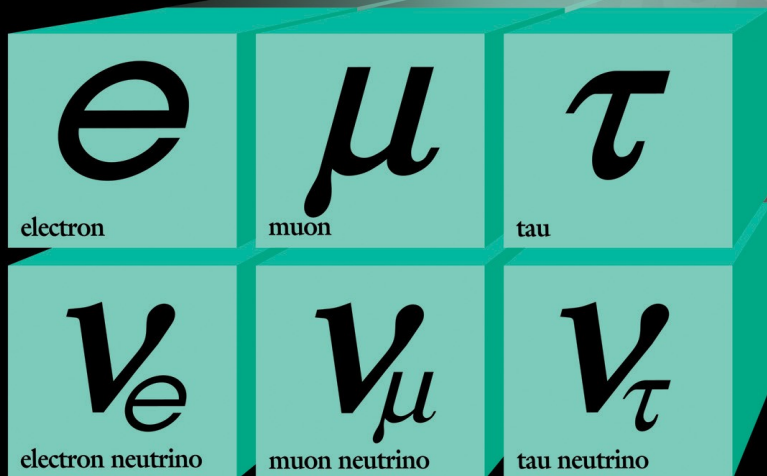
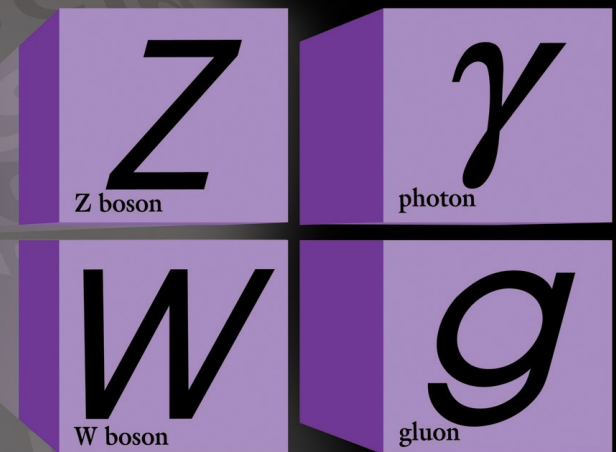
20 km stack of average CDs
per year.

Quarks



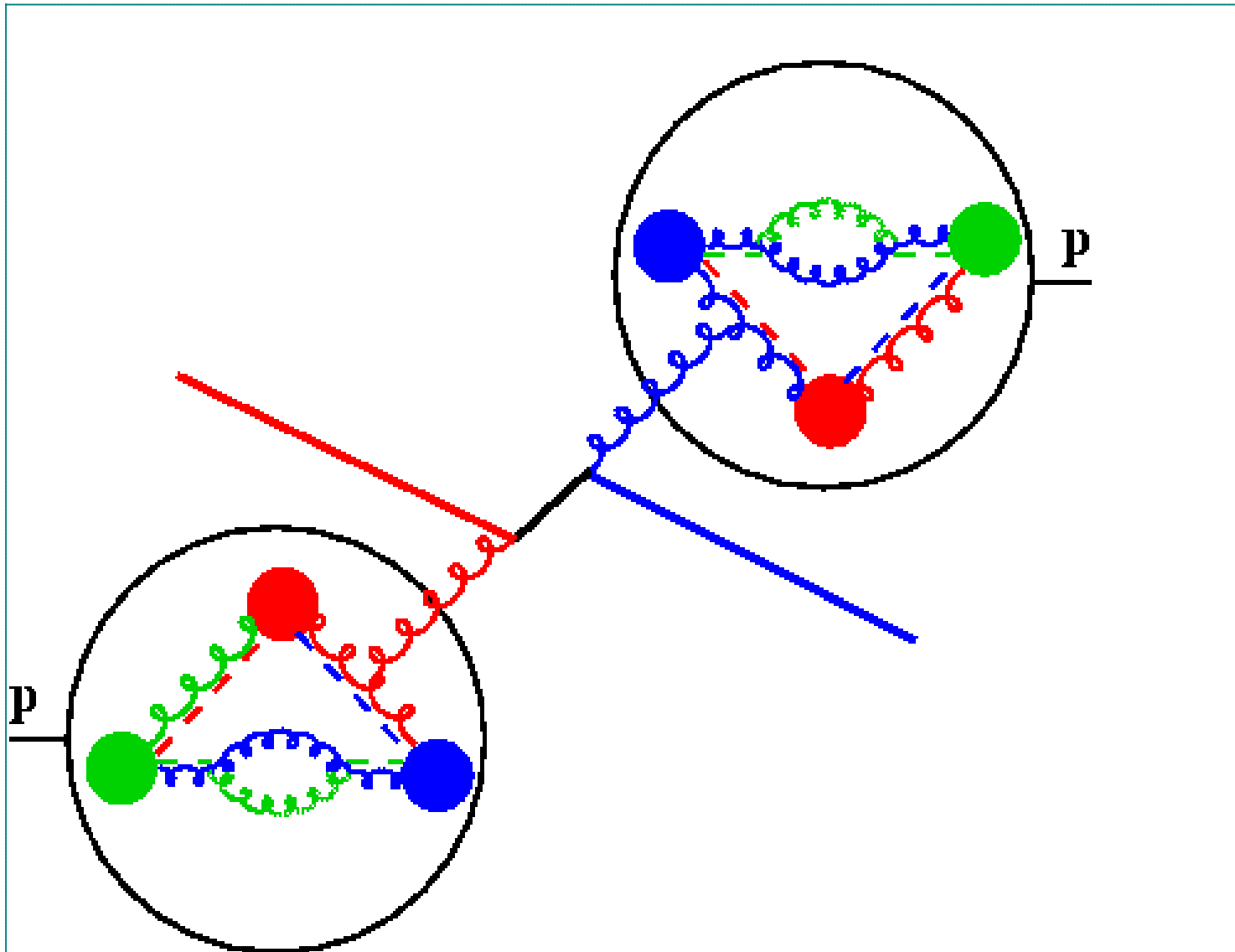
Елементарни частици

Forces




Leptons

Протон-протонни сблъсъци



Резултати от взаимодействието

Протон-протон
Оловно ядро – оловно ядро



Б-мезони, Известни частици, Хиггс бозох, суперсиметрични частици,
Екзотични частици и т.н.
Кварк-глуонна плазма

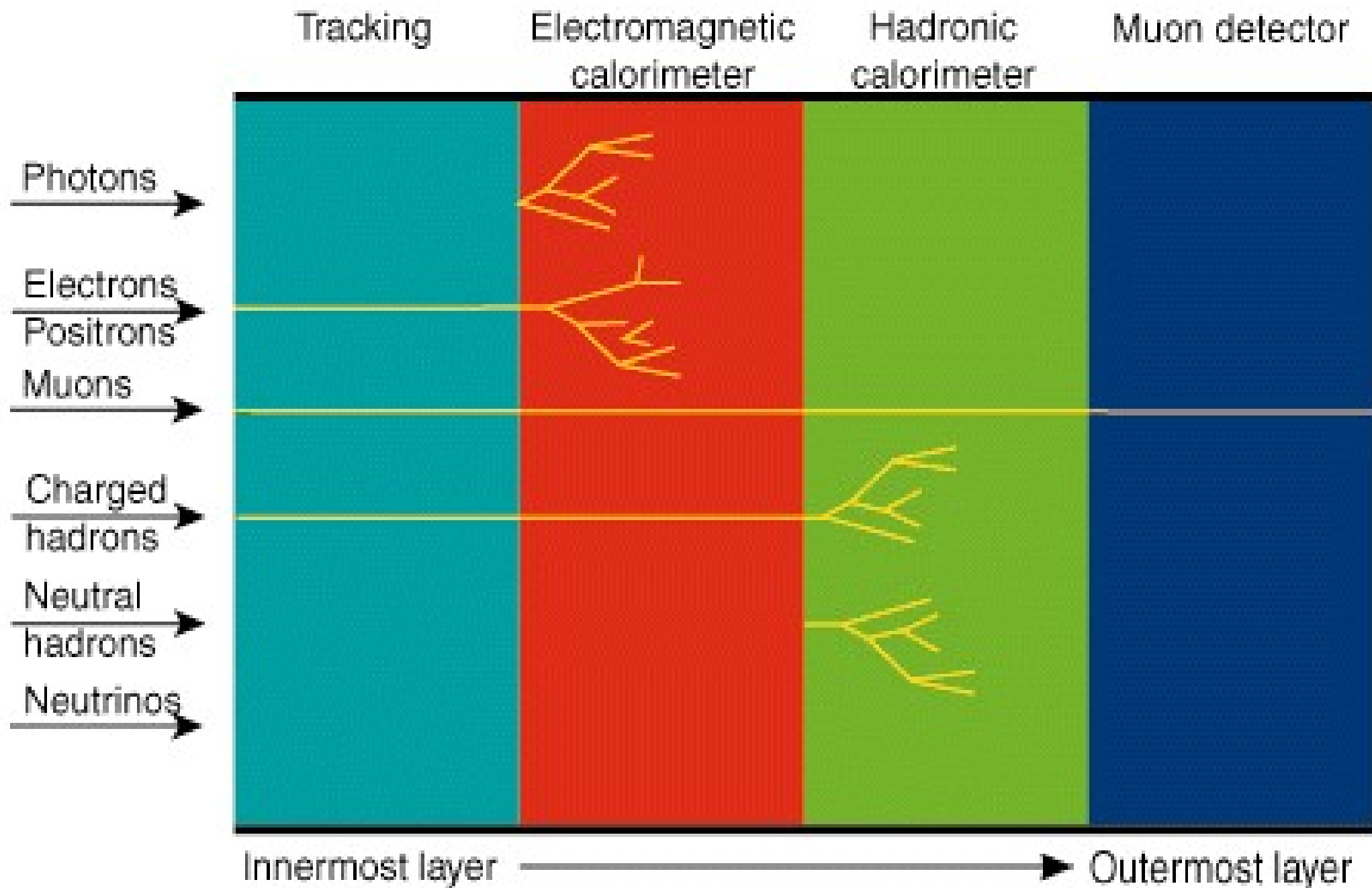


Кварки
Глуони
Адрони (бариони и мезони)
Лептони
Фотони

Регистрирани частици

- * Кварките и глюоните адронизират в струи
- * Адрони (бариони и мезони)
- * Лептони
 - * електрон, мюон, тау (разпада се и се регистрират разпадните му продукти)
 - * неутрина (не могат да се регистрират в CMS и ATLAS, Но може да се оцени каква енергия са отнесли)
- * Фотони








Обща структура

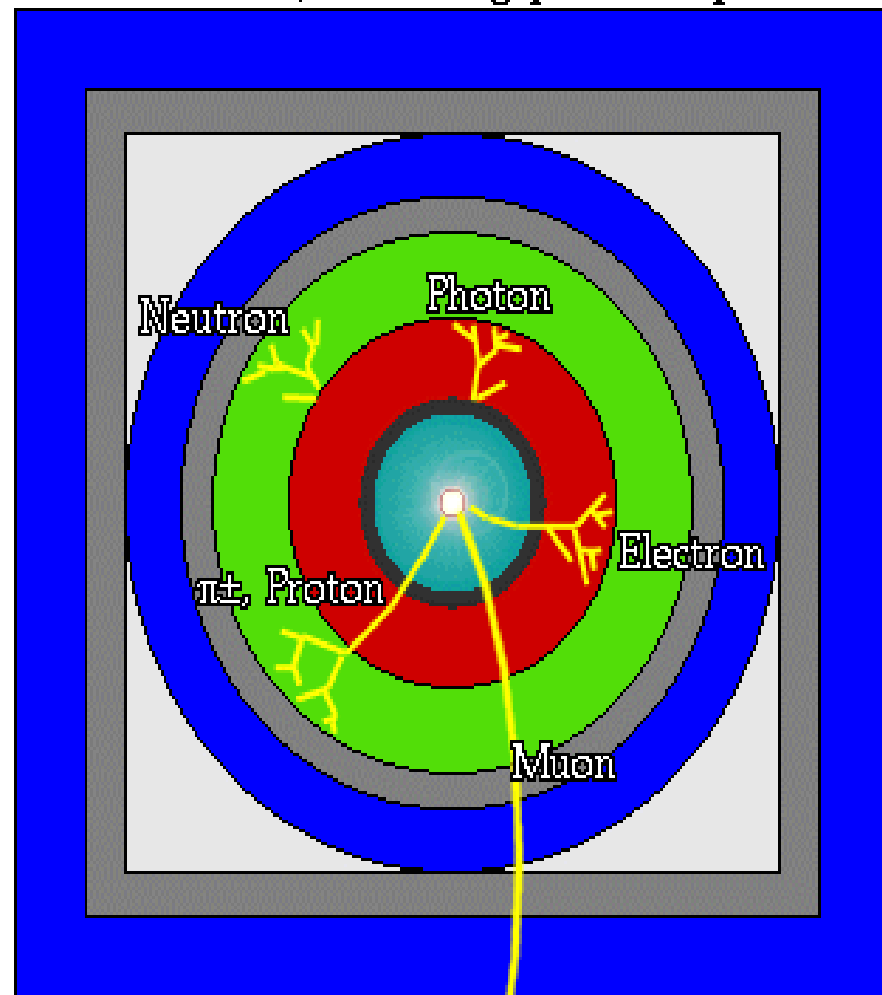


Обща структура

A detector cross-section, showing particle paths



-  Beam Pipe (center)
-  Tracking Chamber
-  Magnet Coil
-  E-M Calorimeter
-  Hadron Calorimeter
-  Magnetized Iron
-  Muon Chambers



ОСНОВНИ СИСТЕМИ

Треков детектор

Електромагнитен калориметър (ЕСАL)

Адронен калориметър (НСАL)

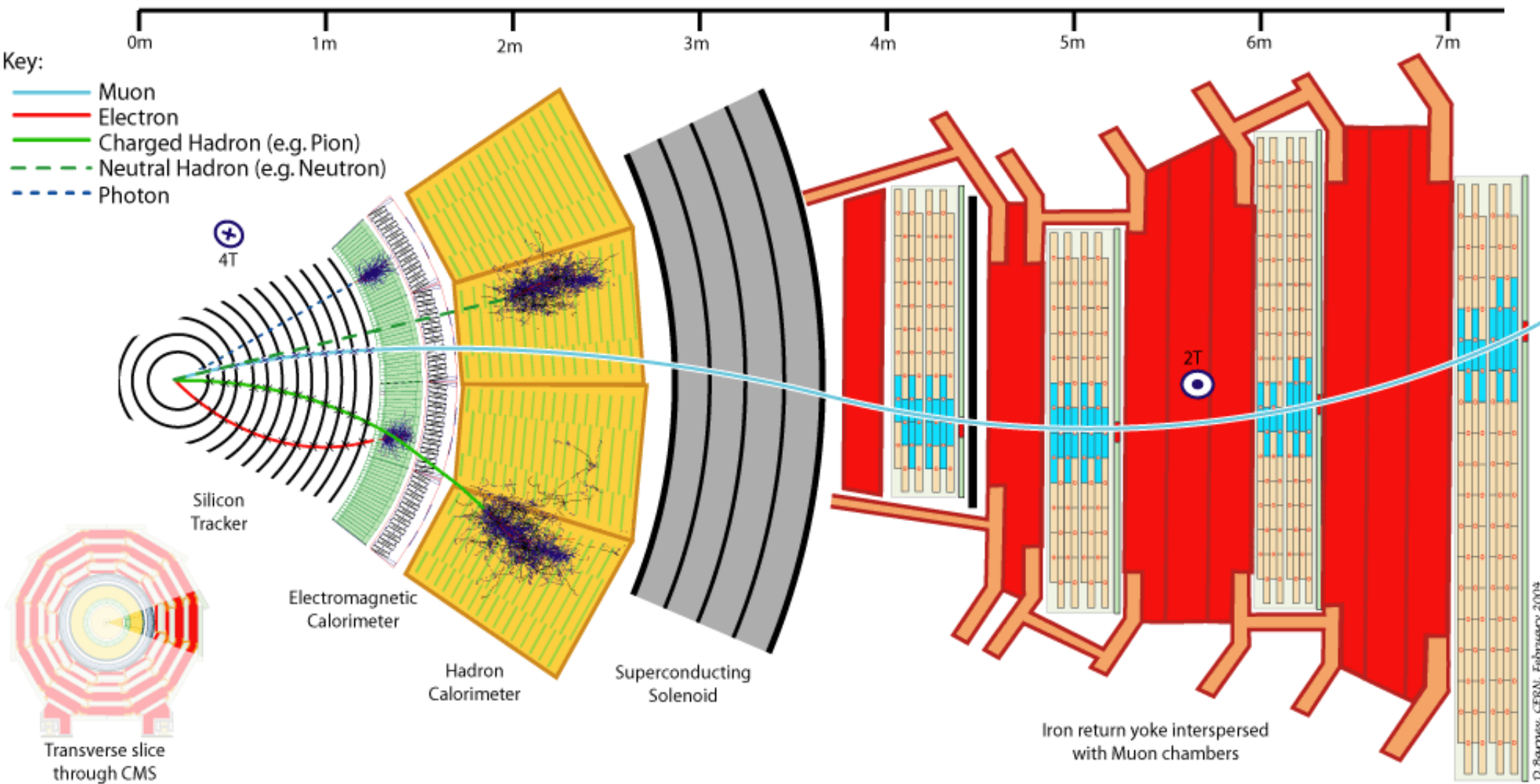
Предни калориметри (FH)

Магнит

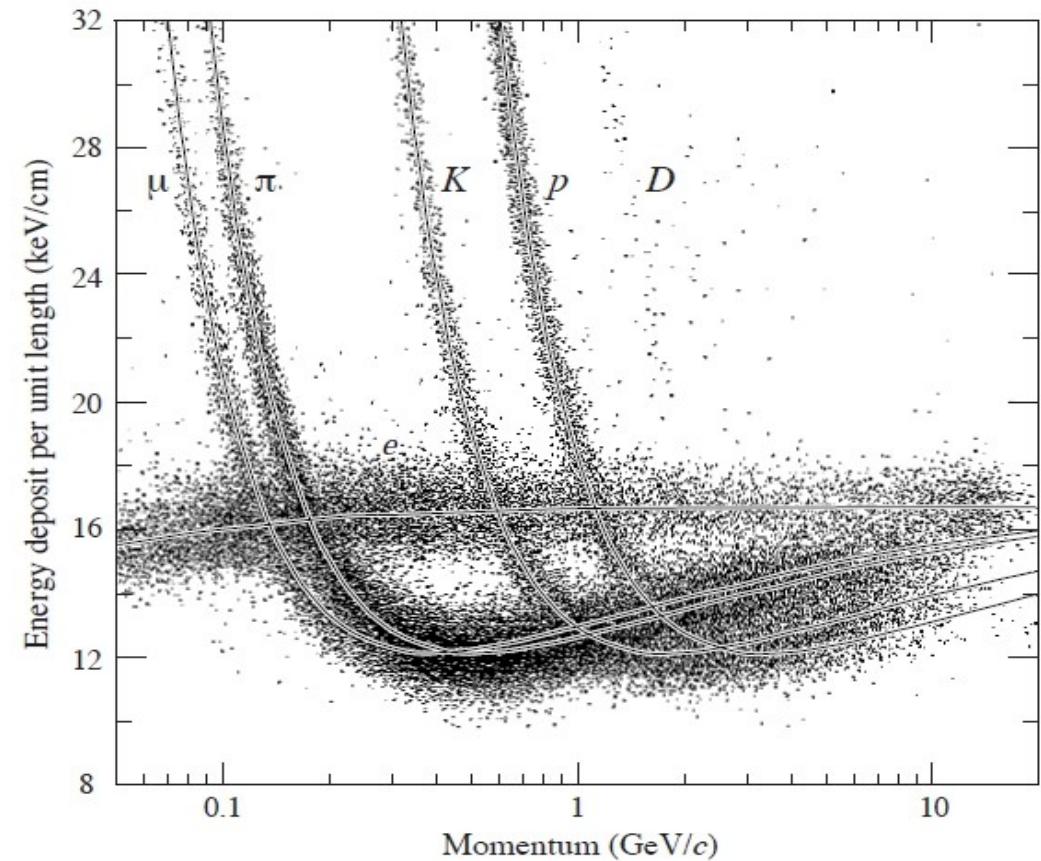
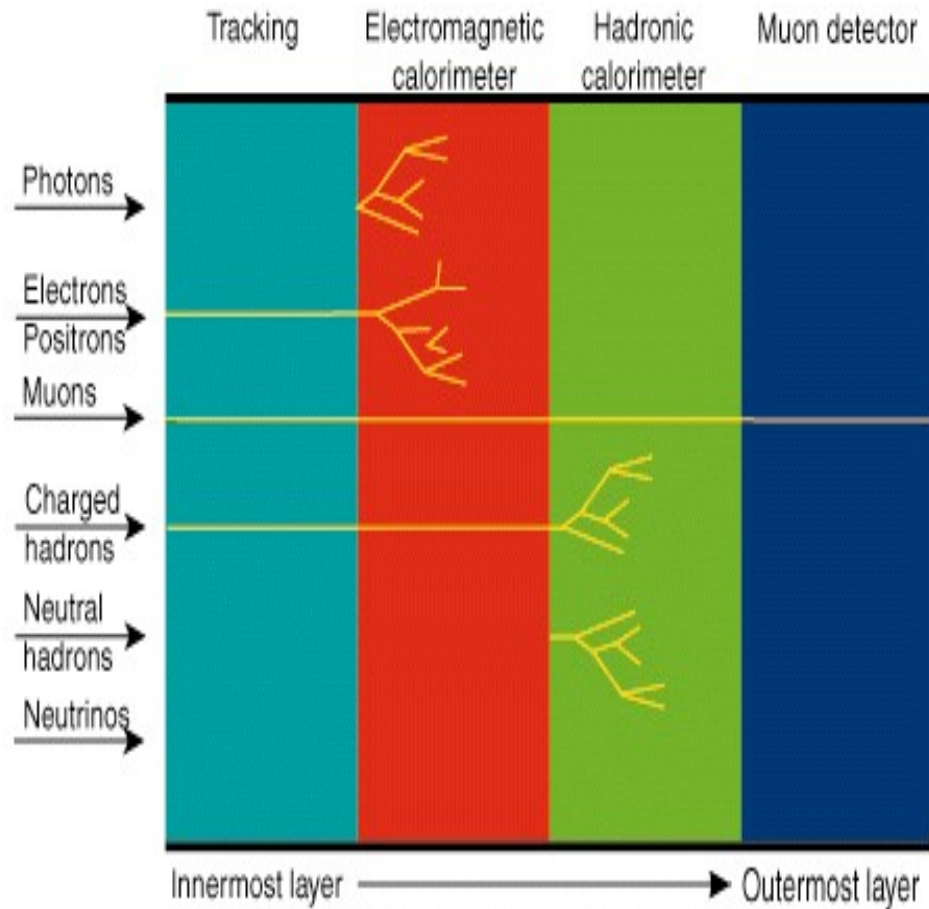
Мюонна система

Тригерна и много други системи

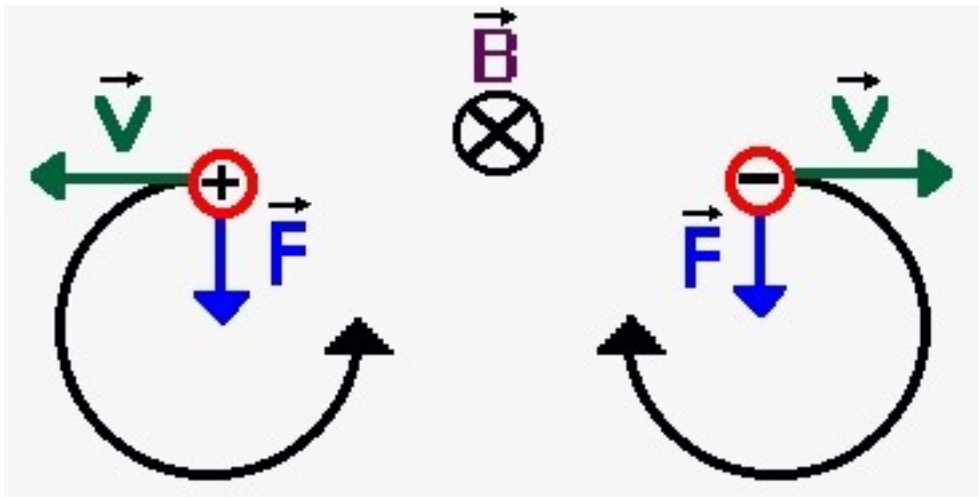
Регистриране на частици в CMS



Идентификация на частици



Измерване на импулс



$$\mathbf{P} = M\mathbf{V}$$

$$\mathbf{F}_L = Q\mathbf{V} \times \mathbf{B}$$

$$\mathbf{F}_C = MV^2/R$$

$$MV^2/R = QVB$$

$$\Rightarrow |\mathbf{P}|/Q = BR$$

$$Q = \pm e$$

$$\Rightarrow |\mathbf{P}| = eBR$$

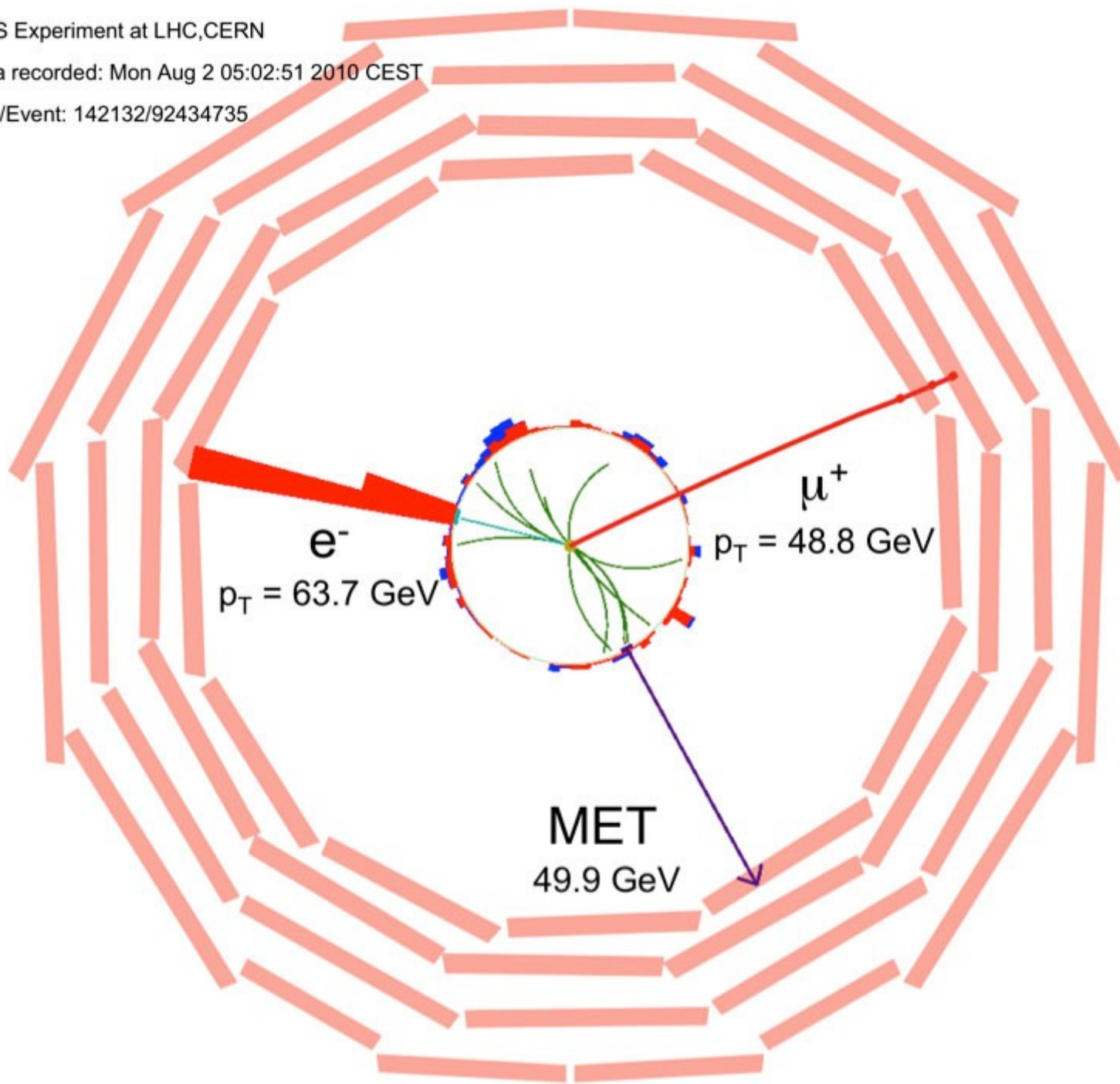
ATLAS & CMS

Система	АТЛАС	CMS
Трекер	Пикселни Силициеви стрипови Дрейфови тръбички (straw drift tubes)	Пикселни Силициеви стрипови
ECAL	Олово/Течен аргон	Кристален сцинтилационен
HCAL	Желязо/пластмасови сцинтилатори Мед/течен аргон	Месинг/пластмасови сцинтилатори
Магнит	Един соленоид (около трекера) и три тороида	САМО един соленоид, разположен ИЗВЪН калориметрите
Мюонен спектрометър	Дрейфови камери Катодни стрипови камери Камери със съпротивителна плоскост Тънкопроцепни камери	Дрейфови камери Катодни стрипови камери Камери със съпротивителна плоскост

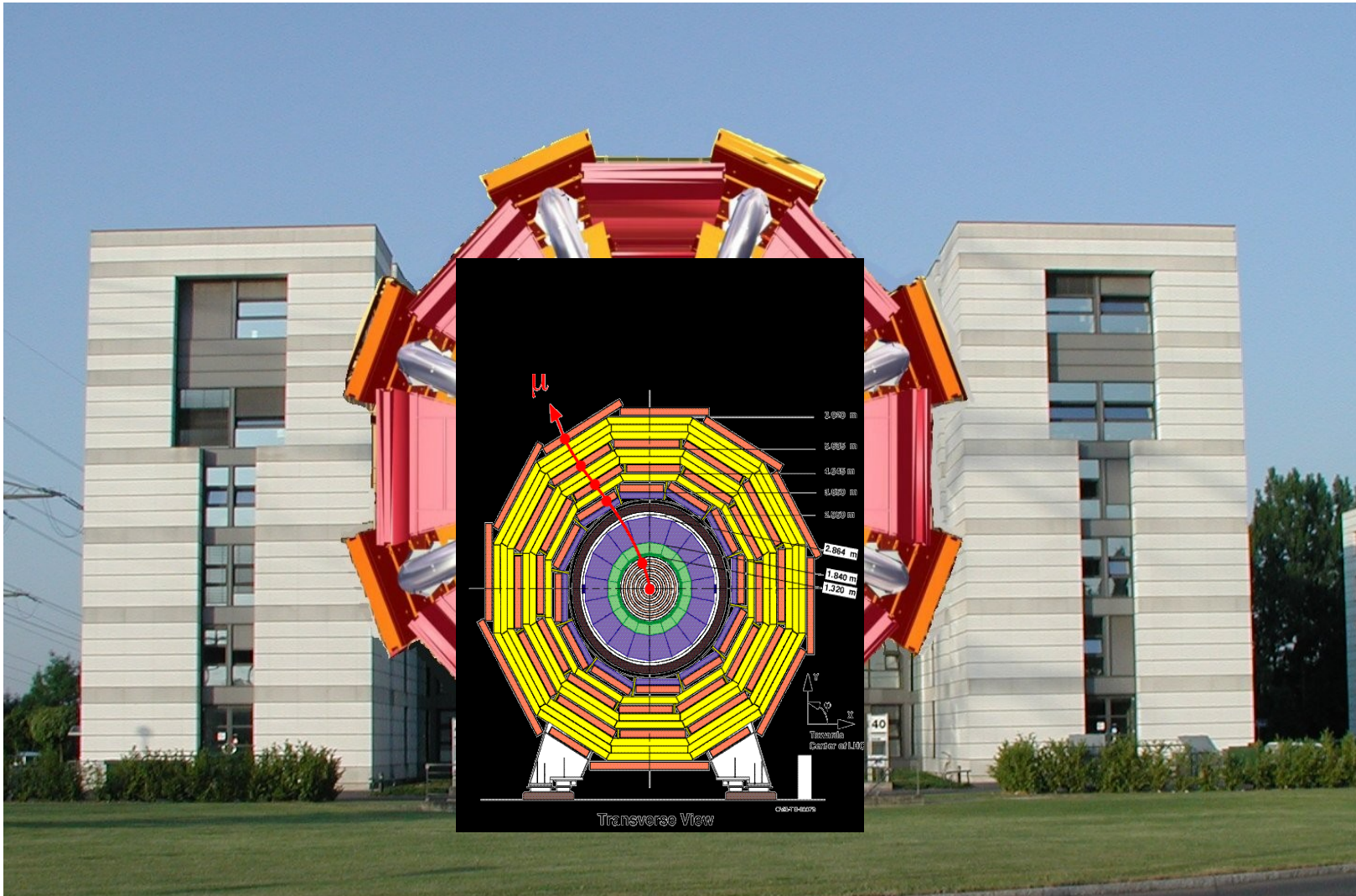
CMS Experiment at LHC,CERN

Data recorded: Mon Aug 2 05:02:51 2010 CEST

Run/Event: 142132/92434735



Building 40 at CERN



SUPERCONDUCTING COIL

CALORIMETERS

ECAL

Scintillating PbWO4 crystals

HCAL

Plastic scintillator/brass sandwich

IRON YOKE

TRACKER

Silicon Microstrips
Pixels

MUON BARREL

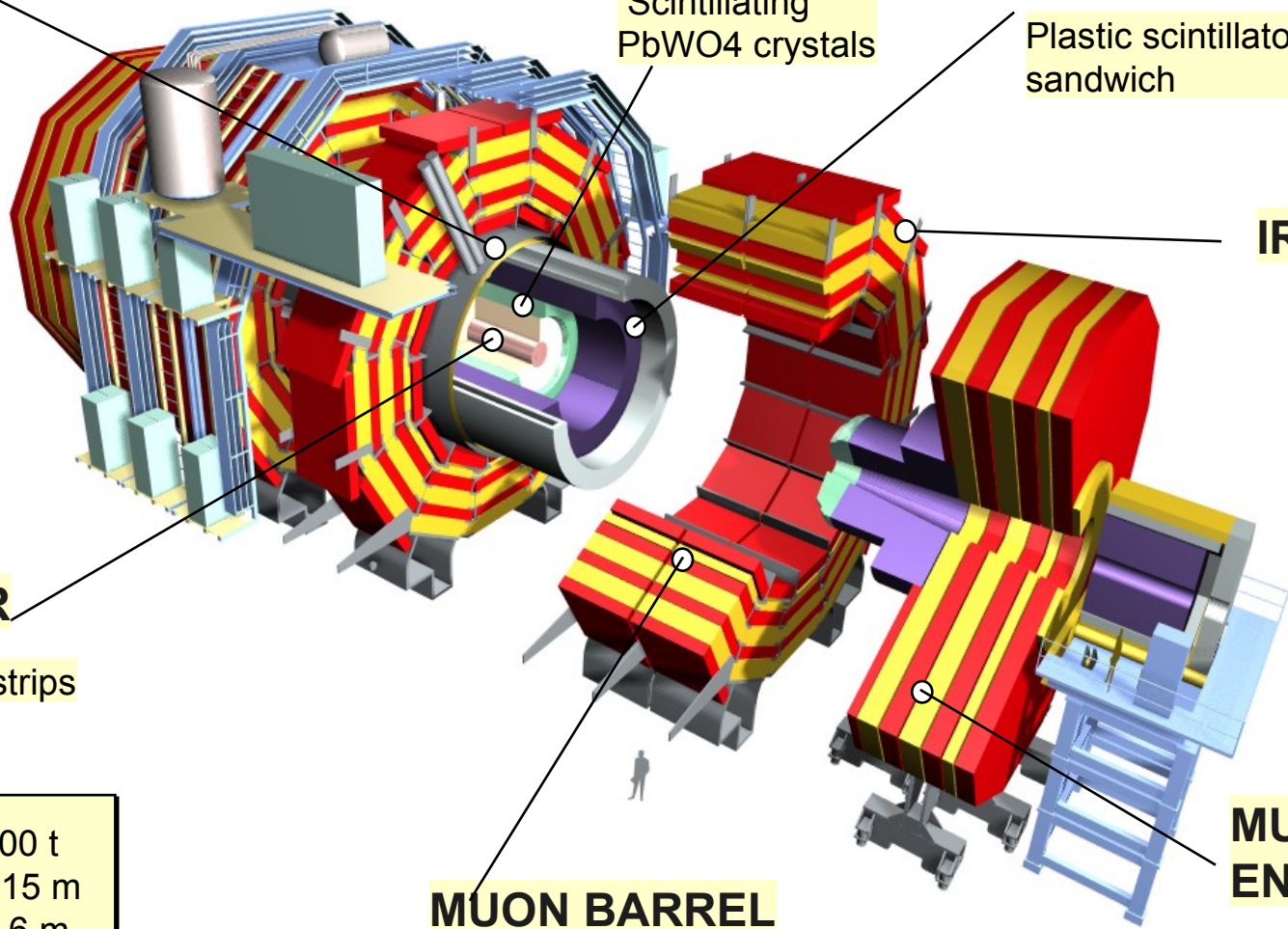
MUON ENDCAPS

Drift Tube
Chambers (DT)

Resistive Plate
Chambers (RPC)

Cathode Strip Chambers (CSC)
Resistive Plate Chambers (RPC)

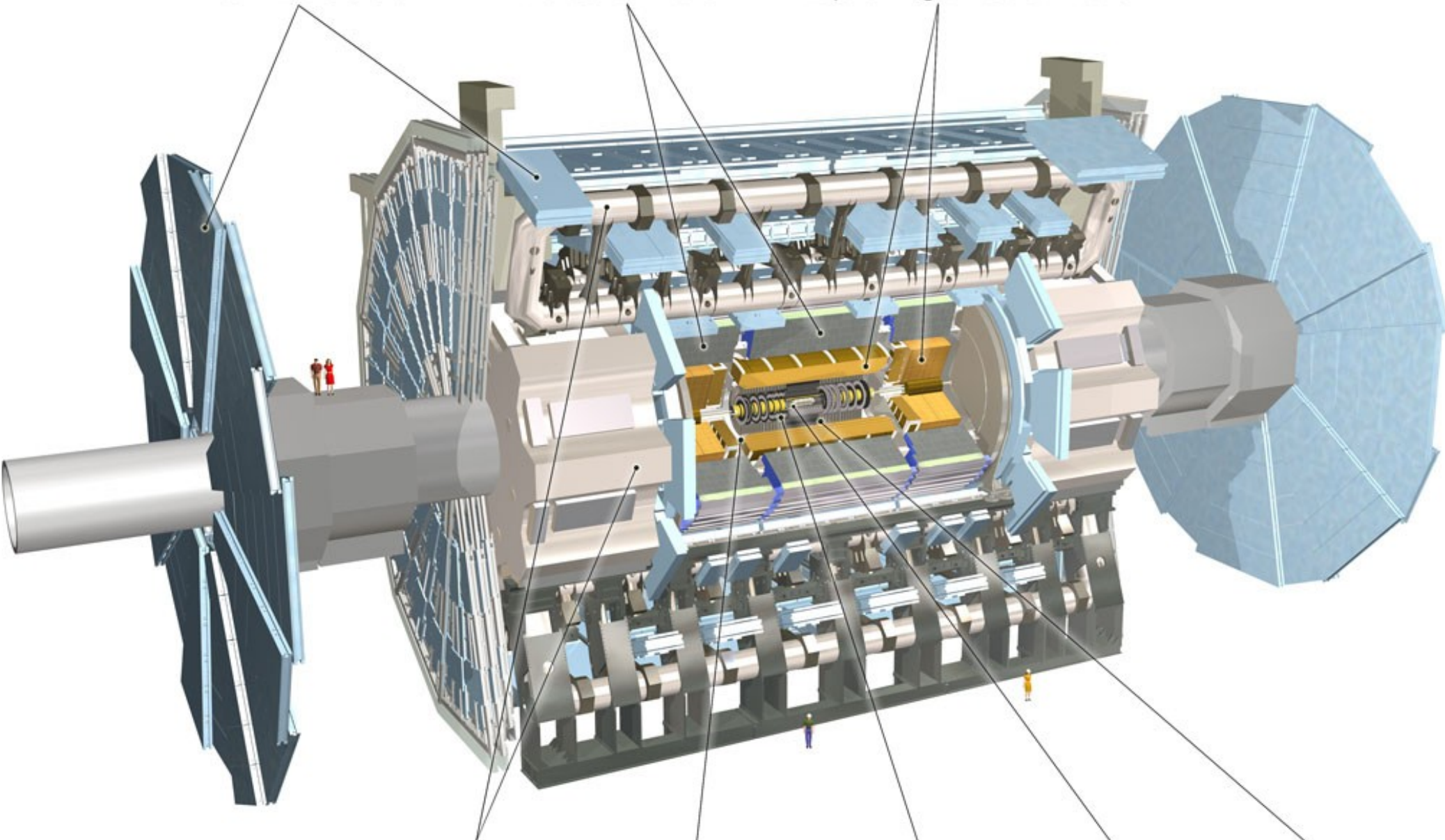
Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla



Muon Detectors

Tile Calorimeter

Liquid Argon Calorimeter



Toroid Magnets

Solenoid Magnet

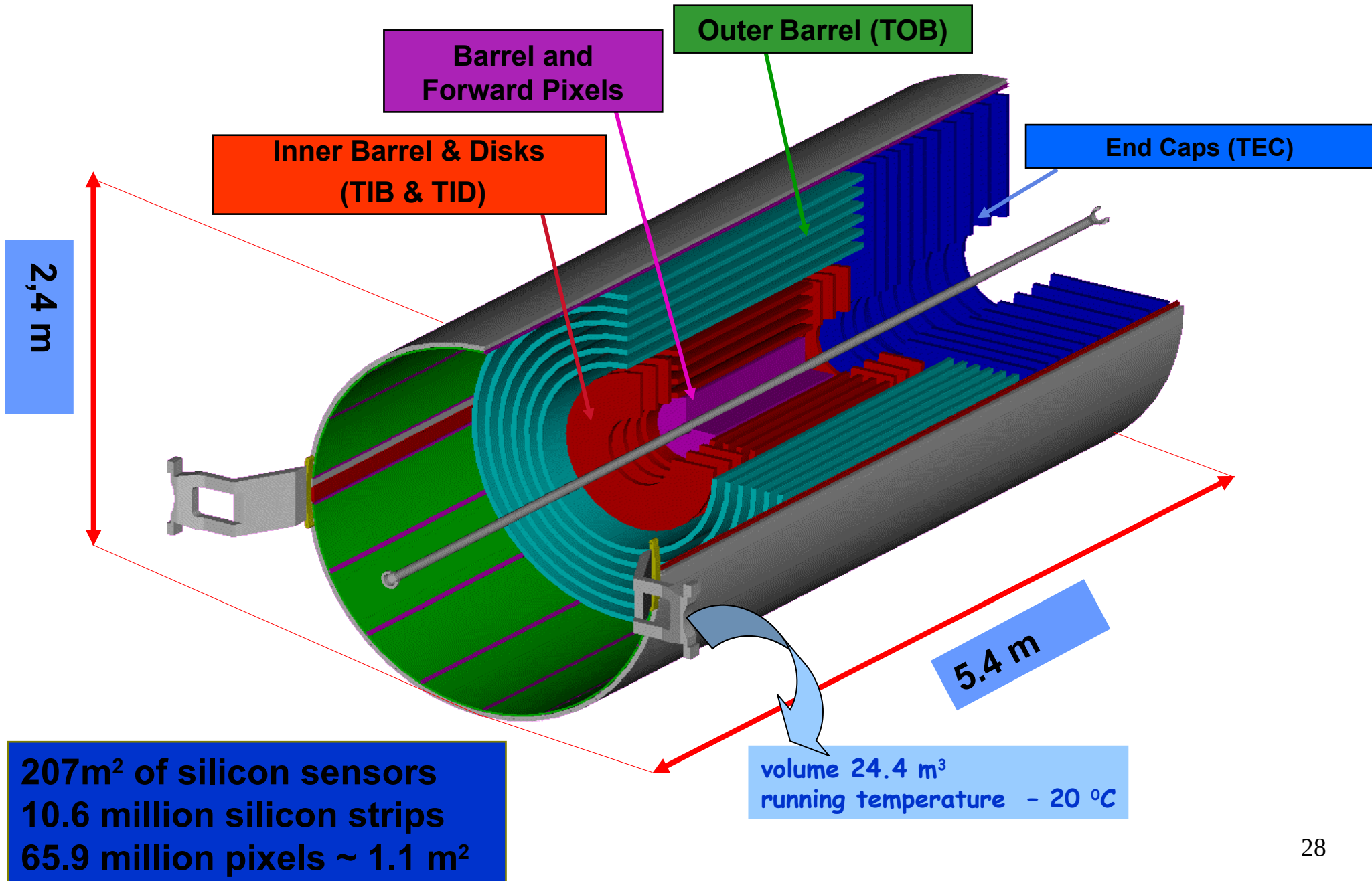
SCT Tracker

Pixel Detector

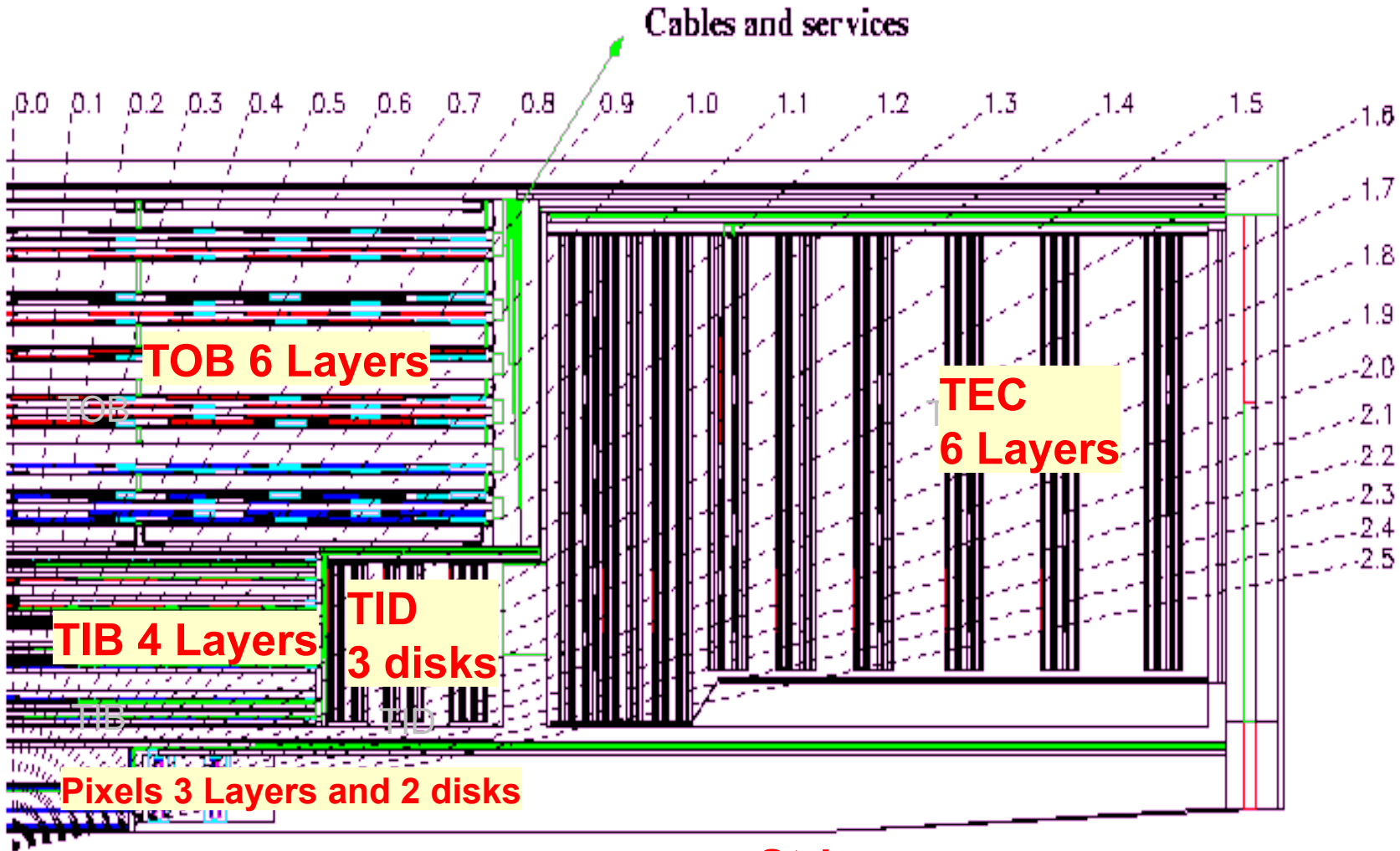
TRT Tracker

CMS

All Silicon Tracker



Inner Tracker



Pixels:

100 μm x 150 μm

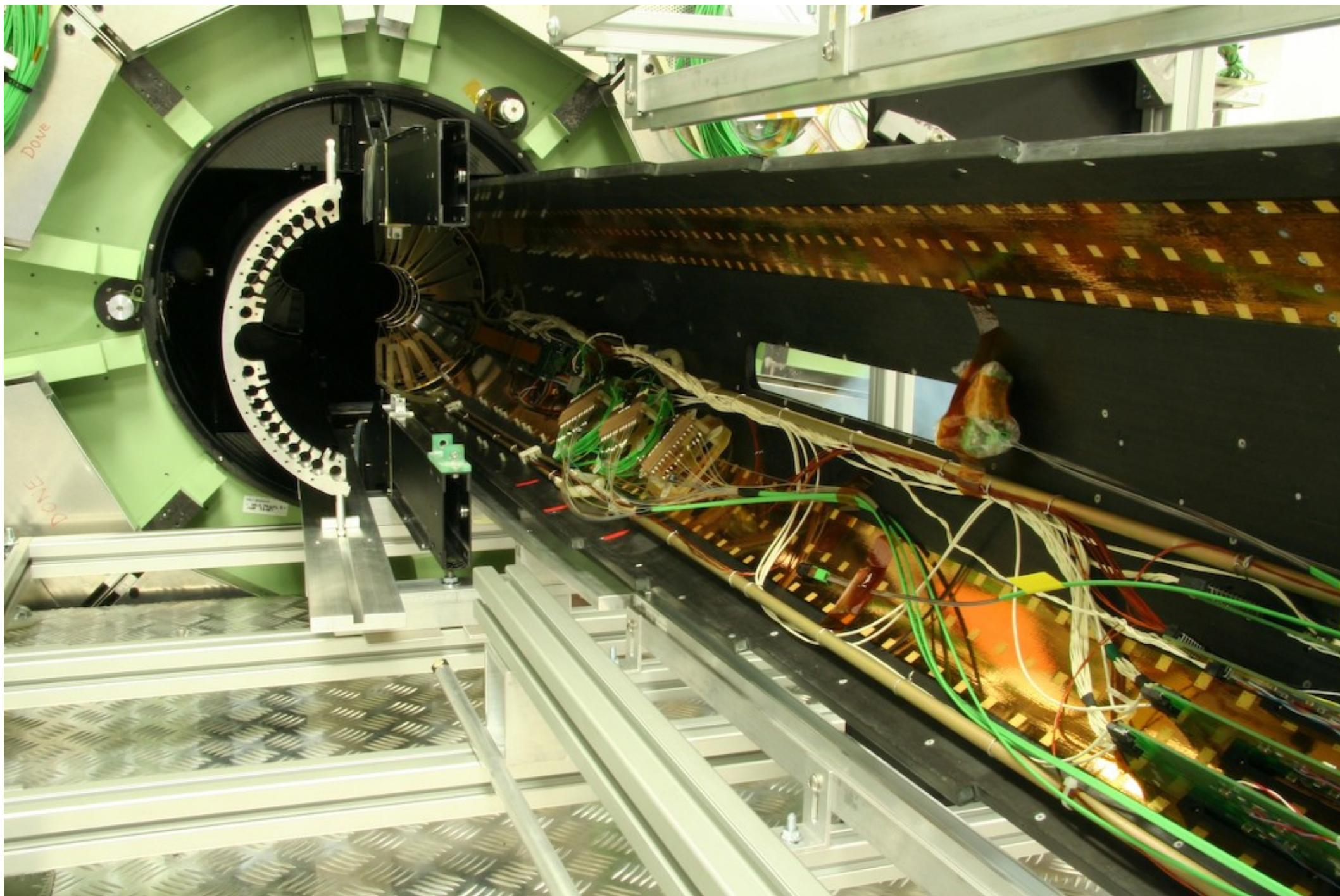
ϕ and z resolution: 15-20 μm

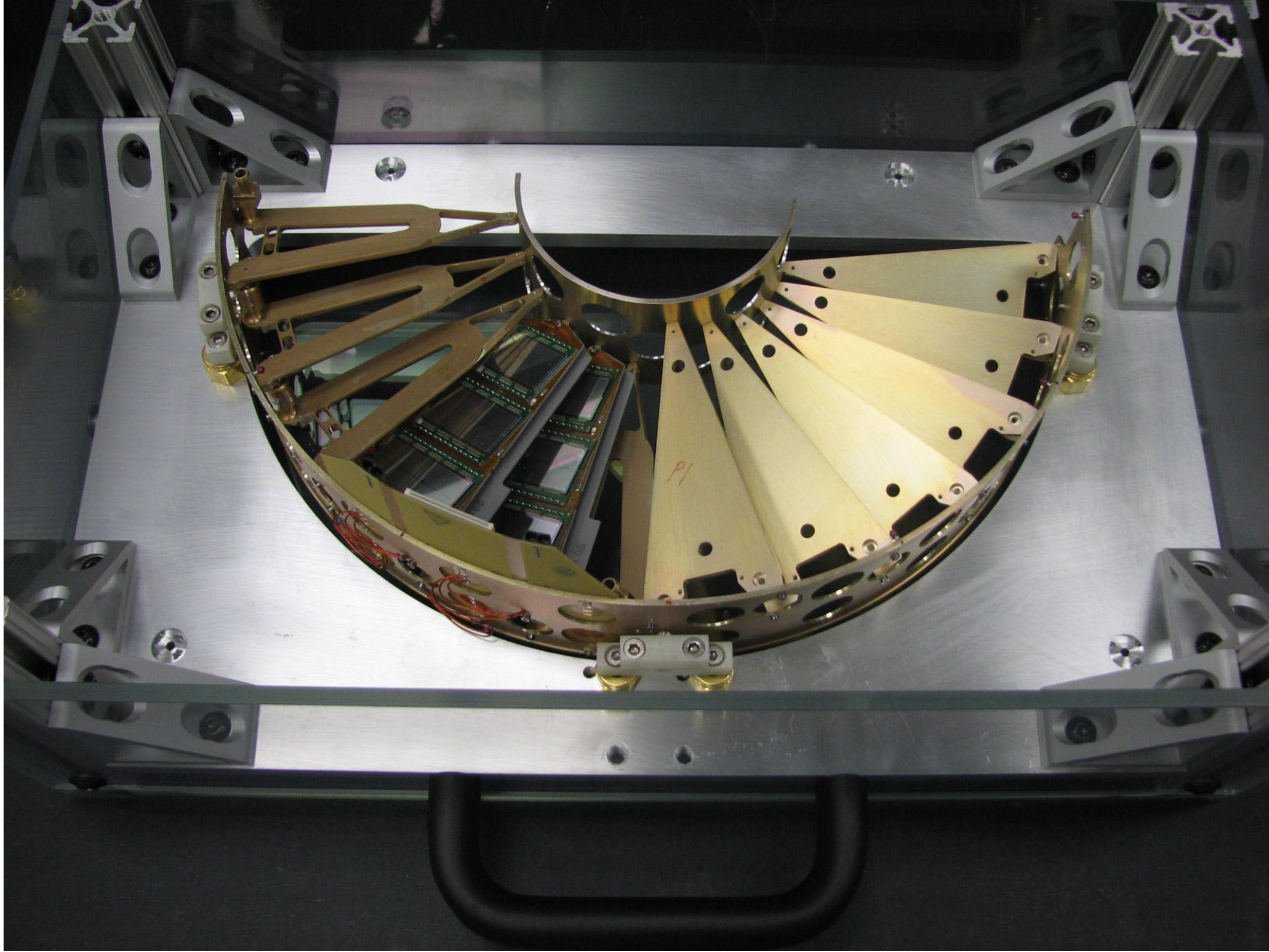
Strips:

Pitch: 80 μm to 180 μm

Hit Resolution: 20 μm to 50 μm

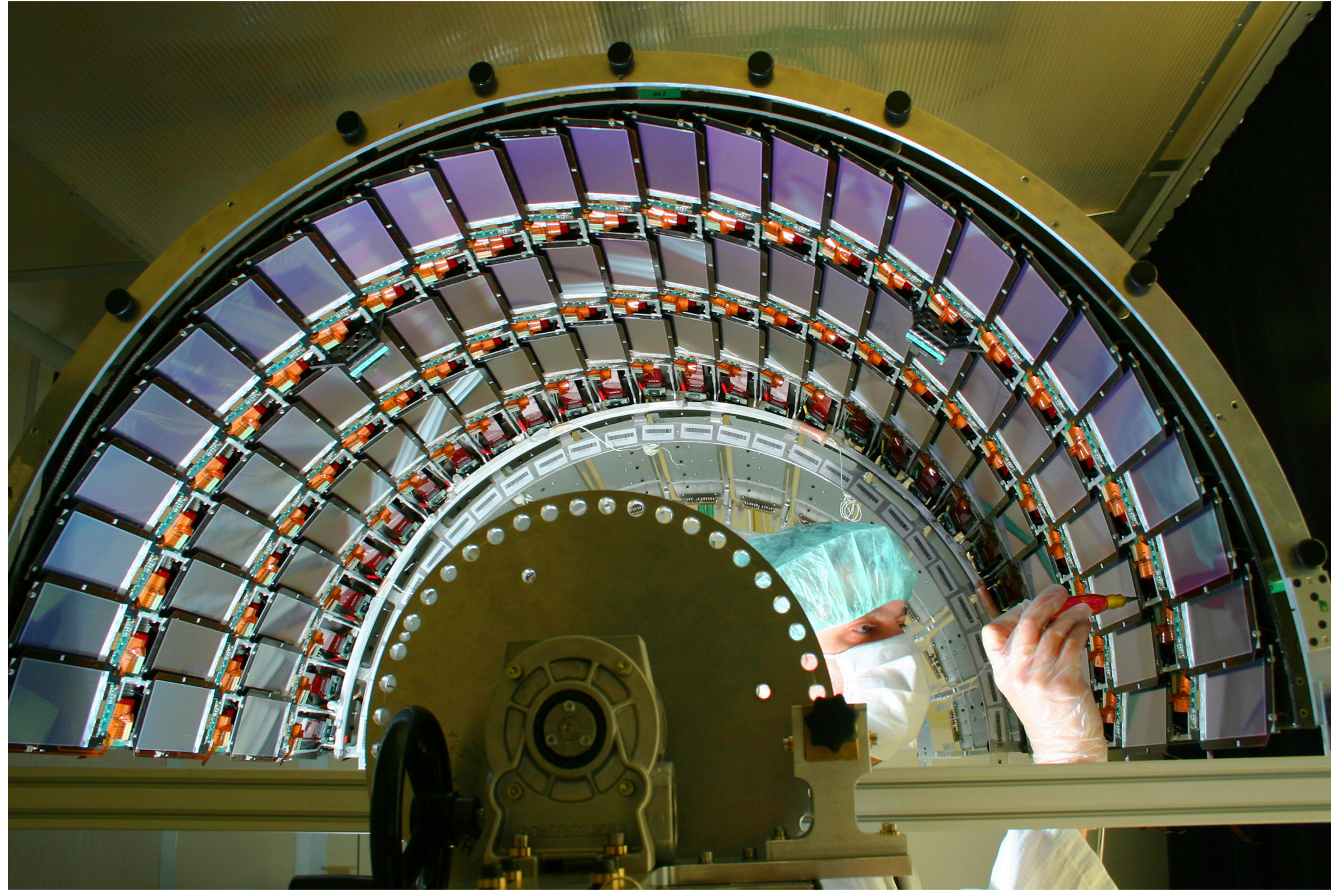
PIXEL





P1

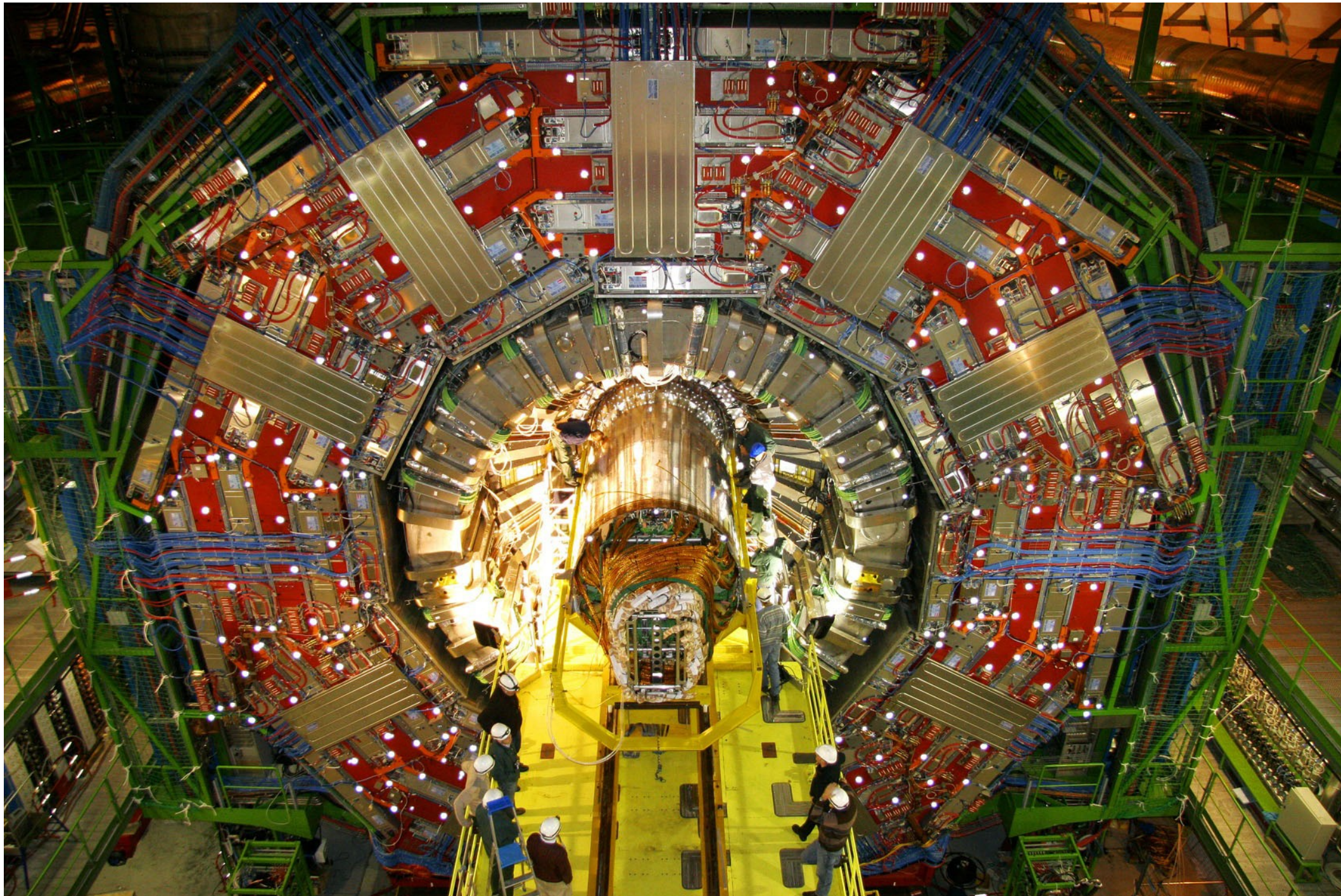
Si Strip

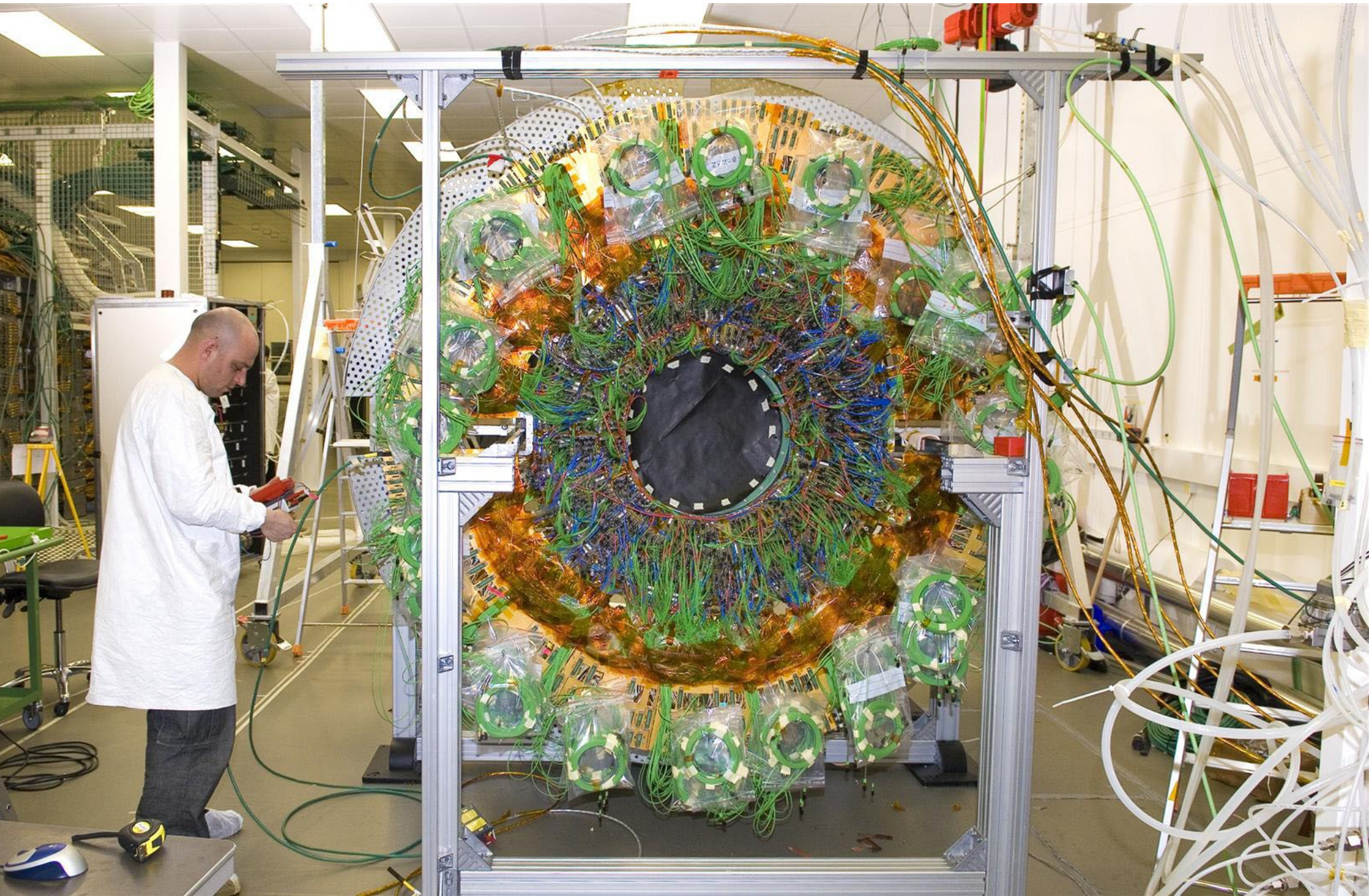


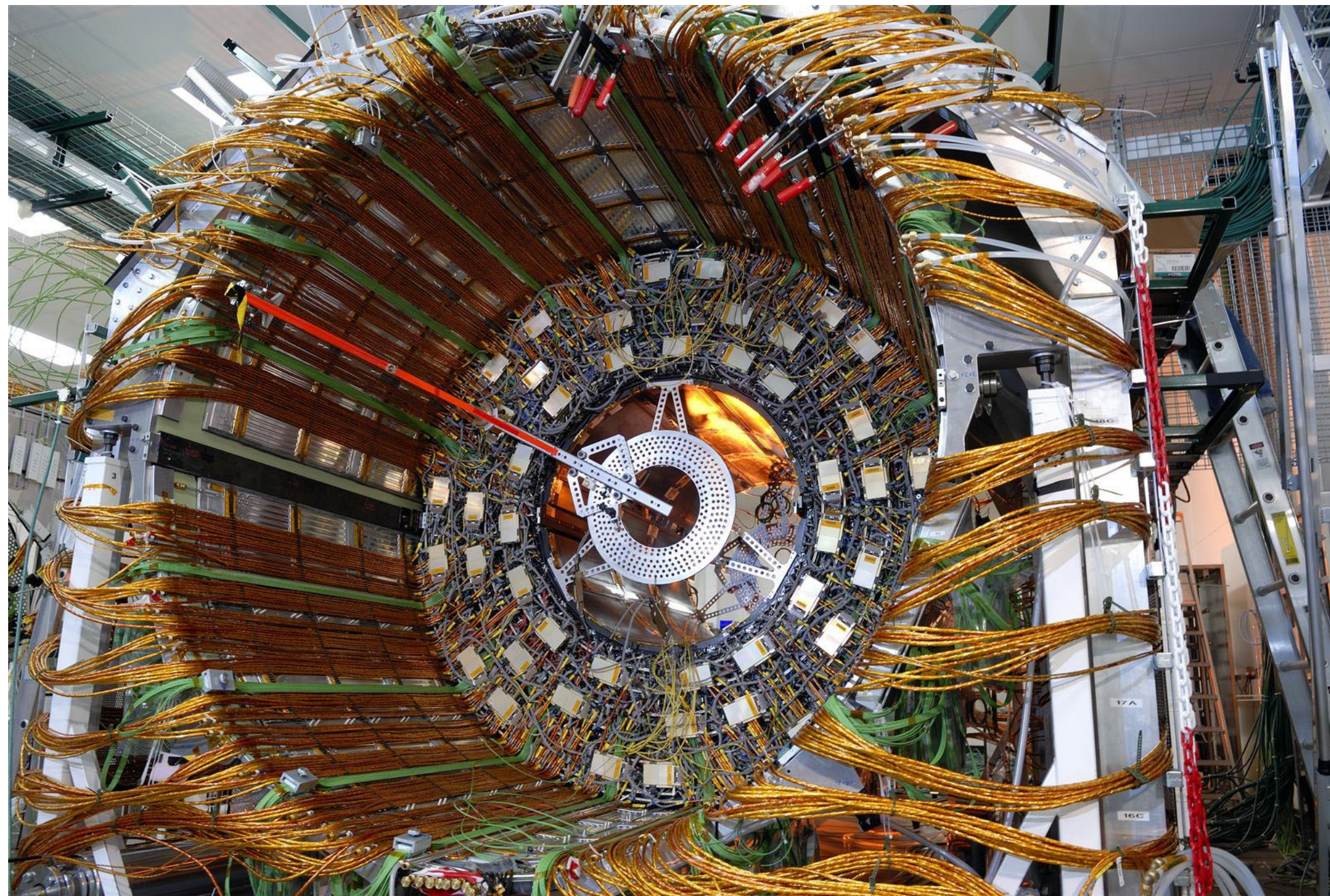


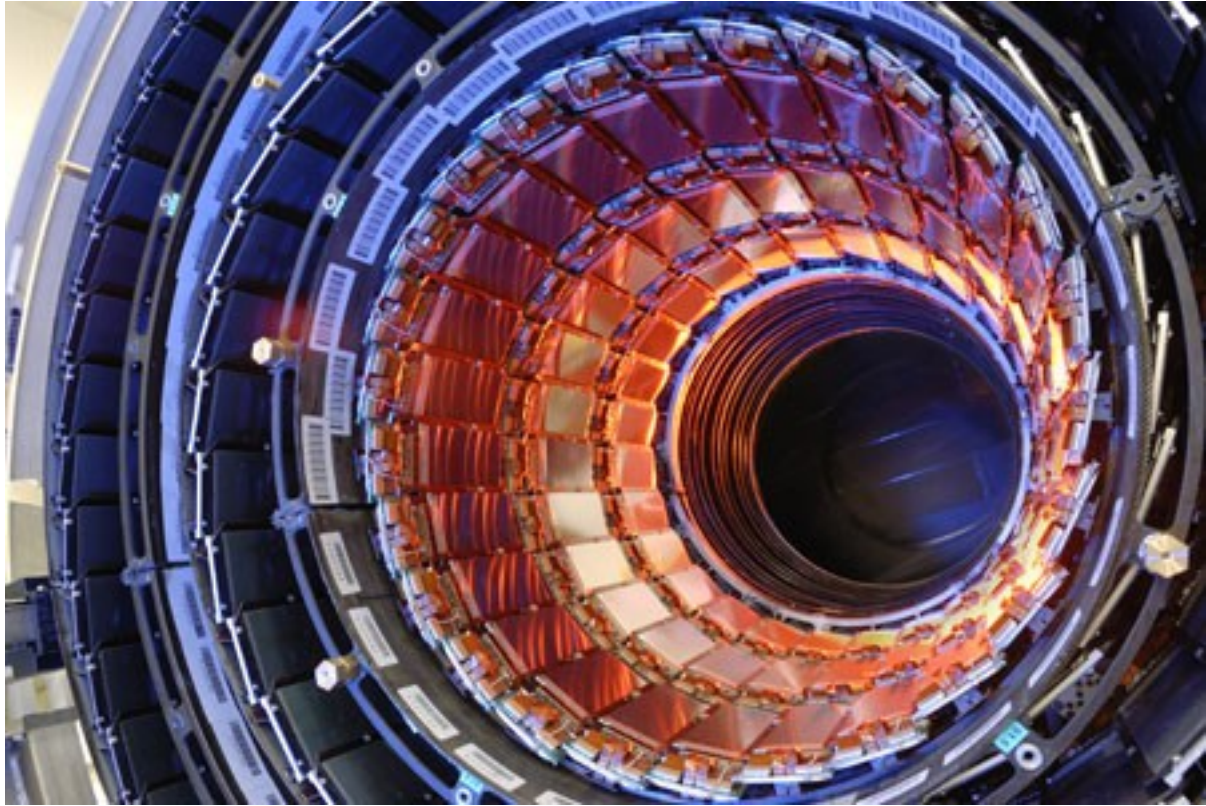


Инсталиране на тракера

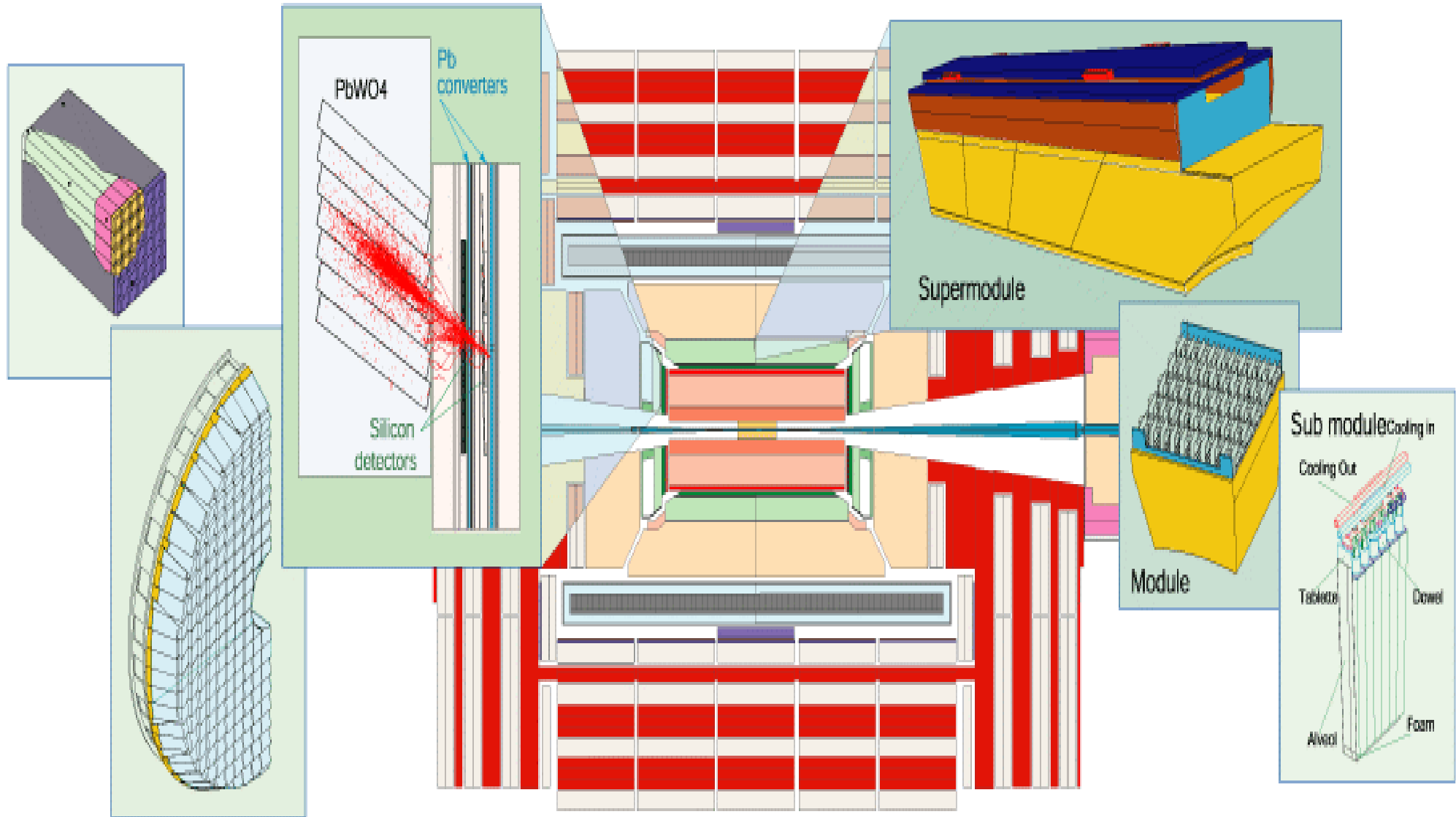






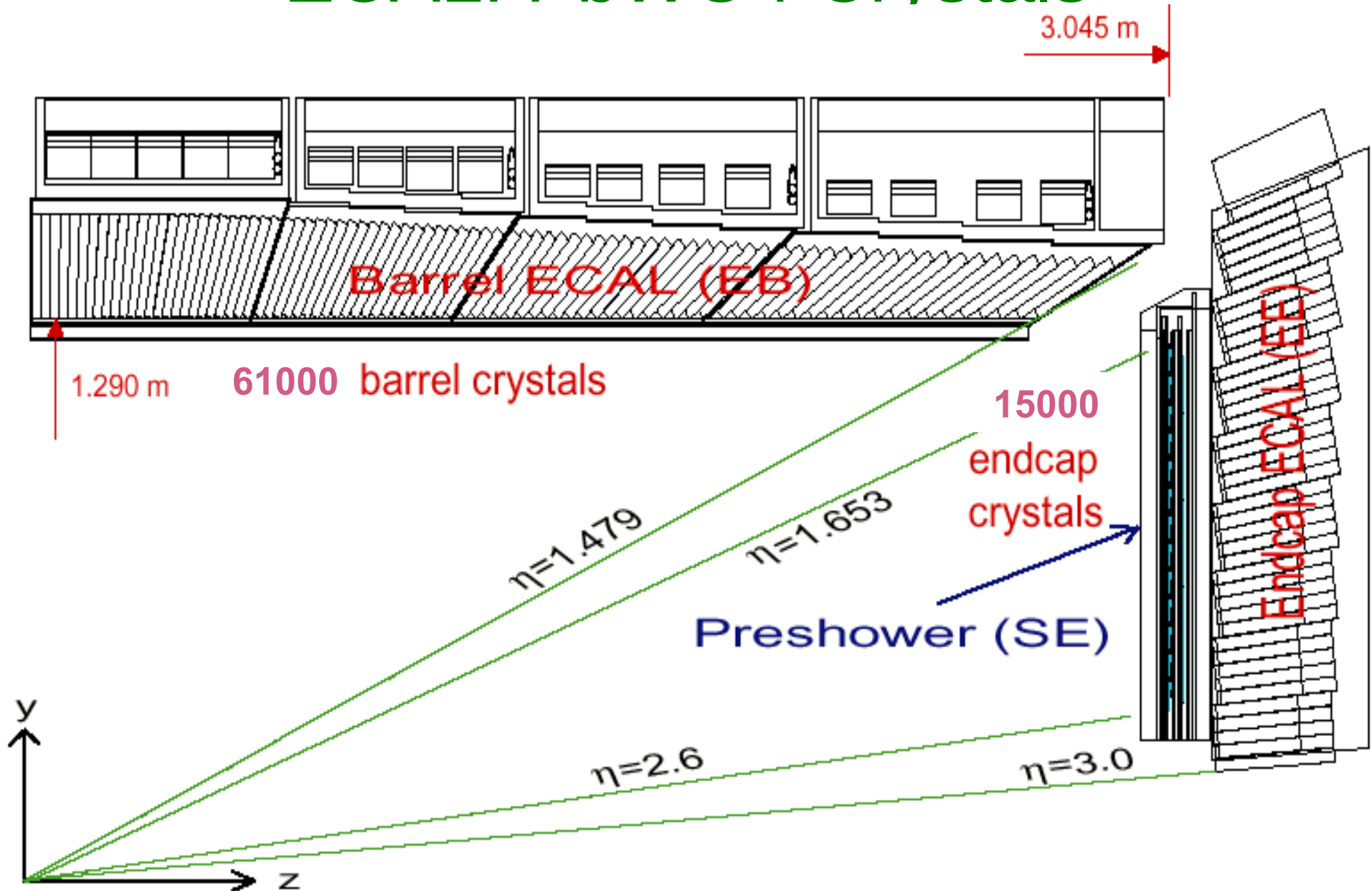


ECAL Overview

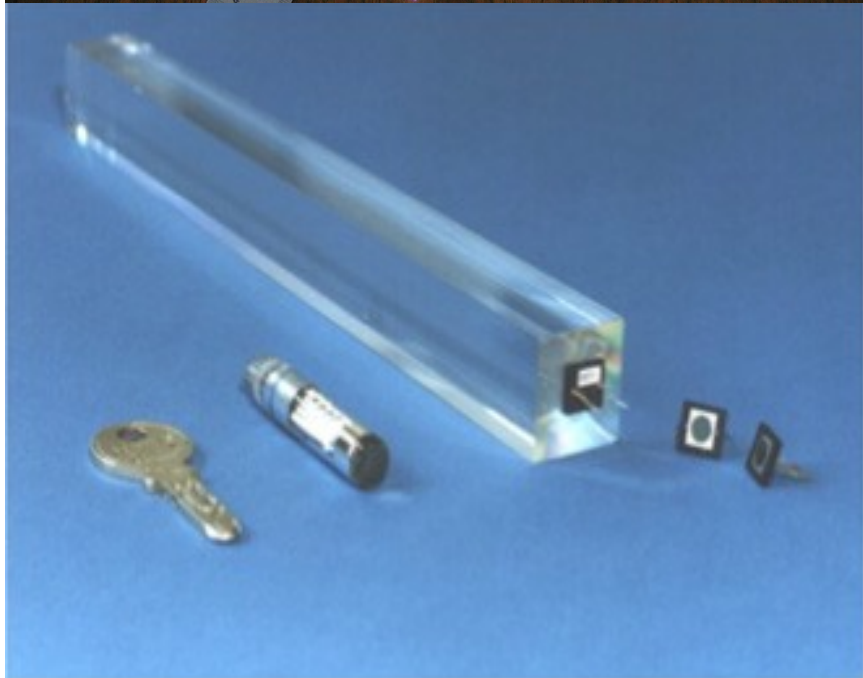
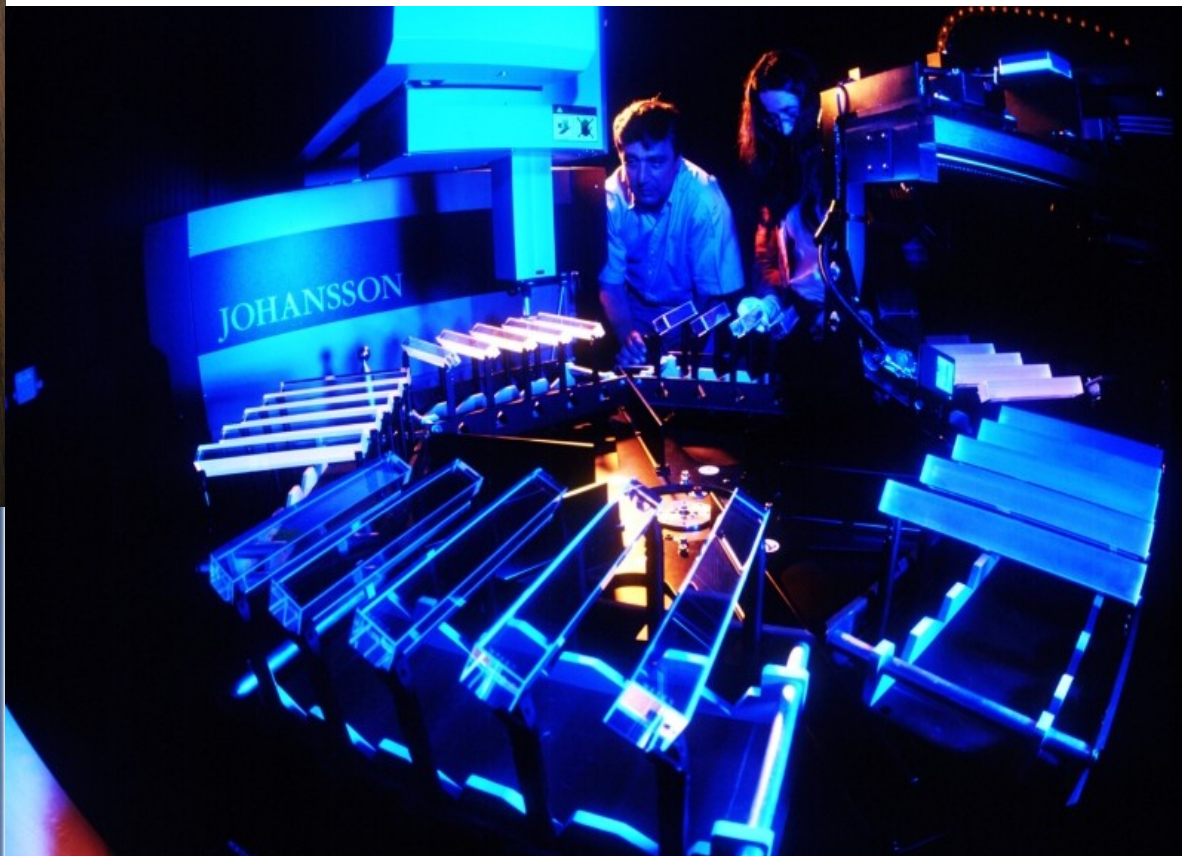




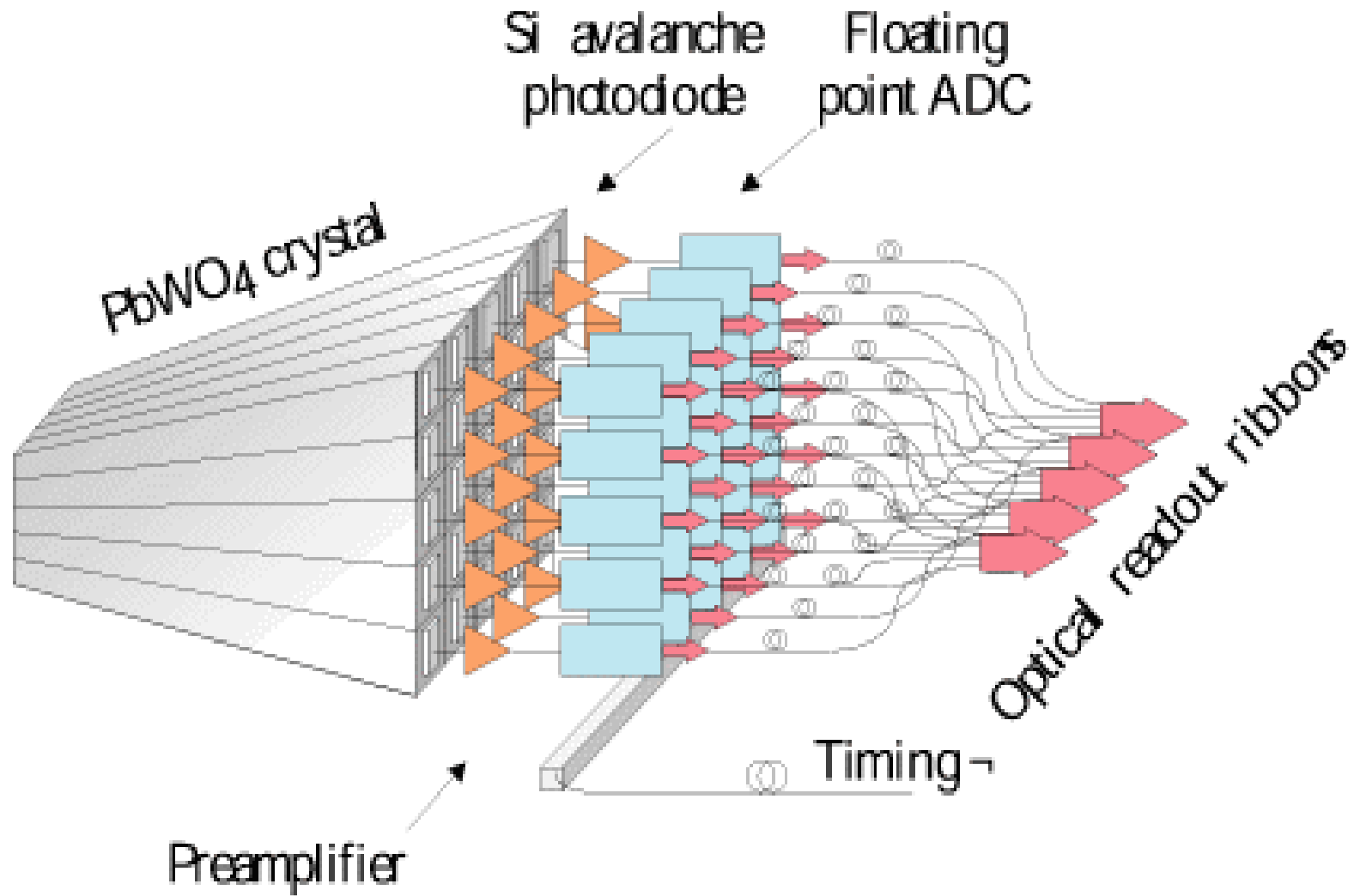
ECAL: PbWO4 Crystals



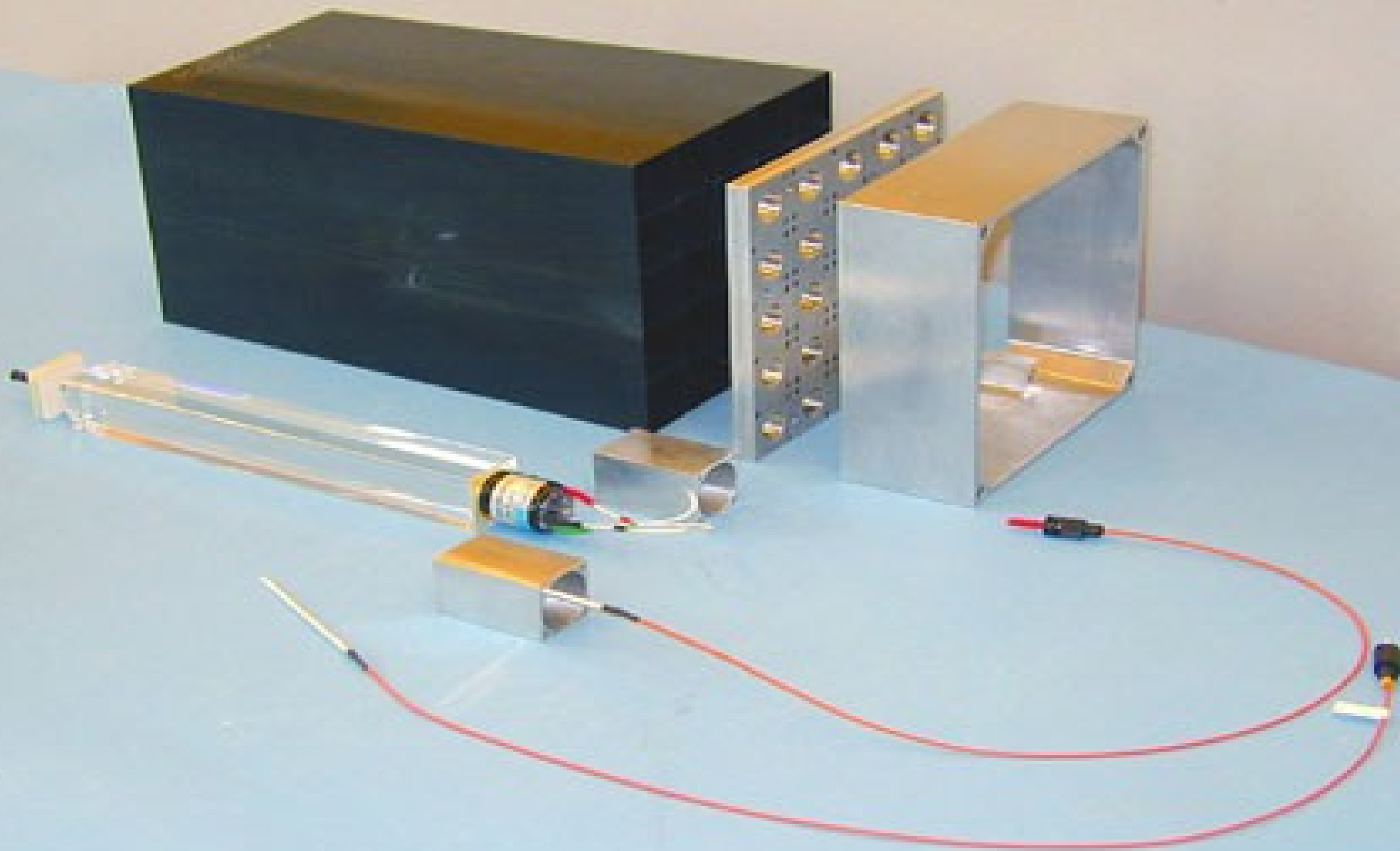
PbWO₄ crystals



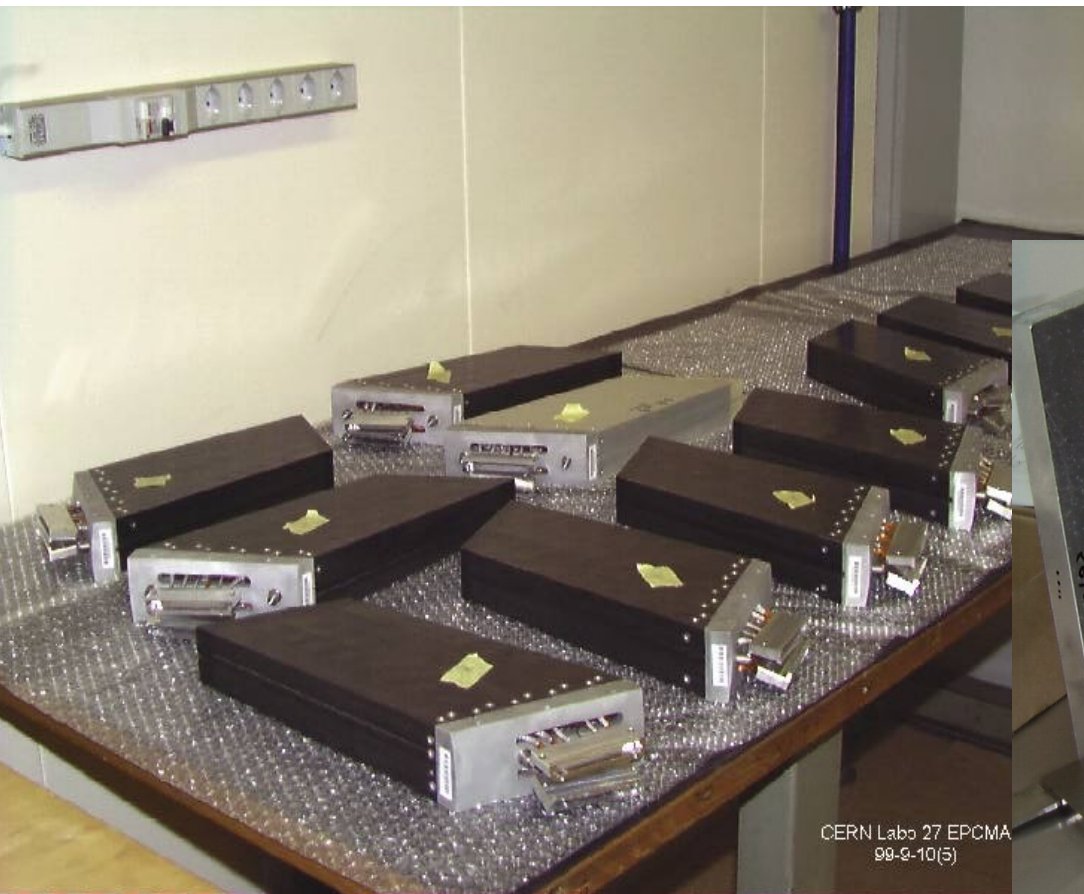
ECAL

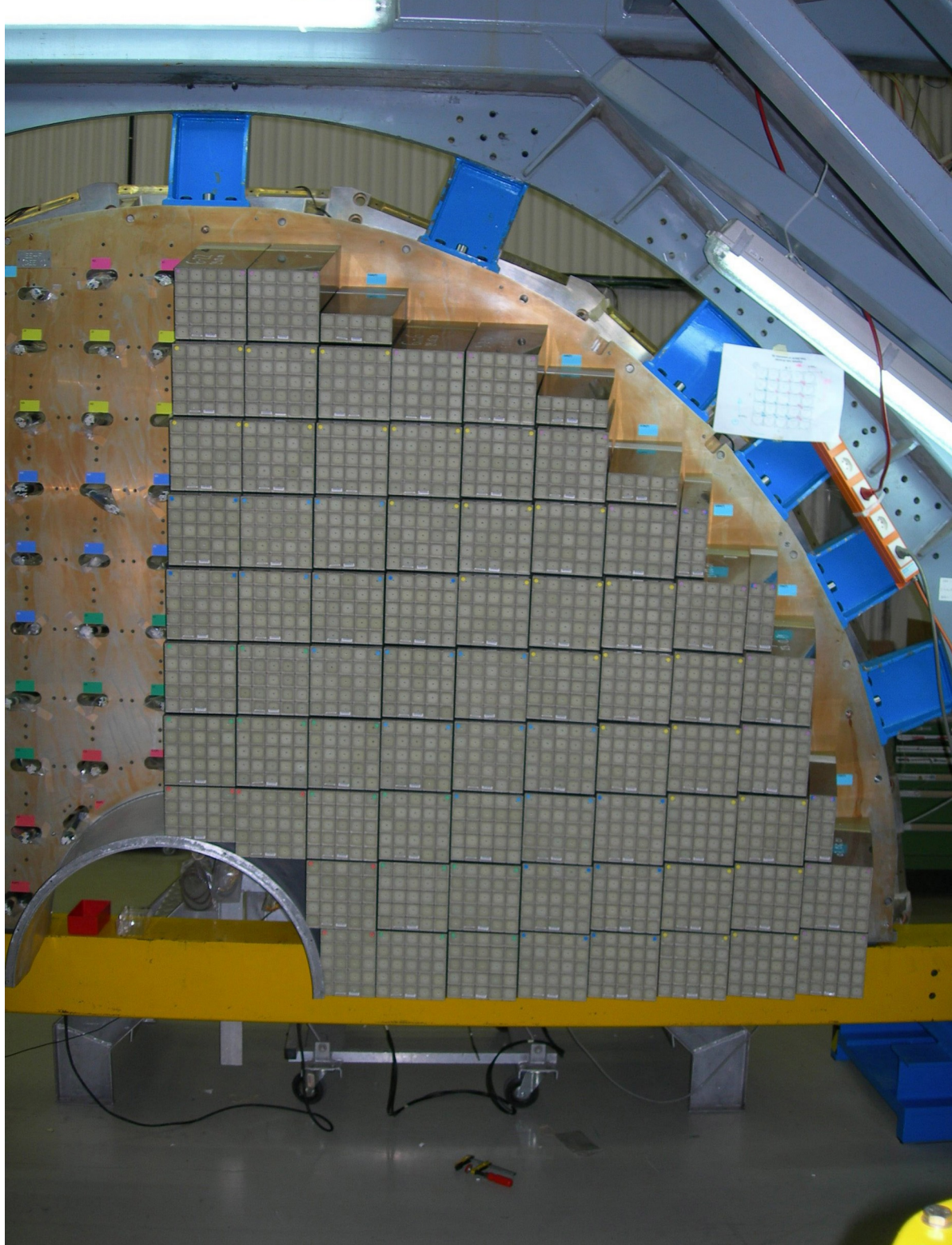


Електромагнитен калориметър

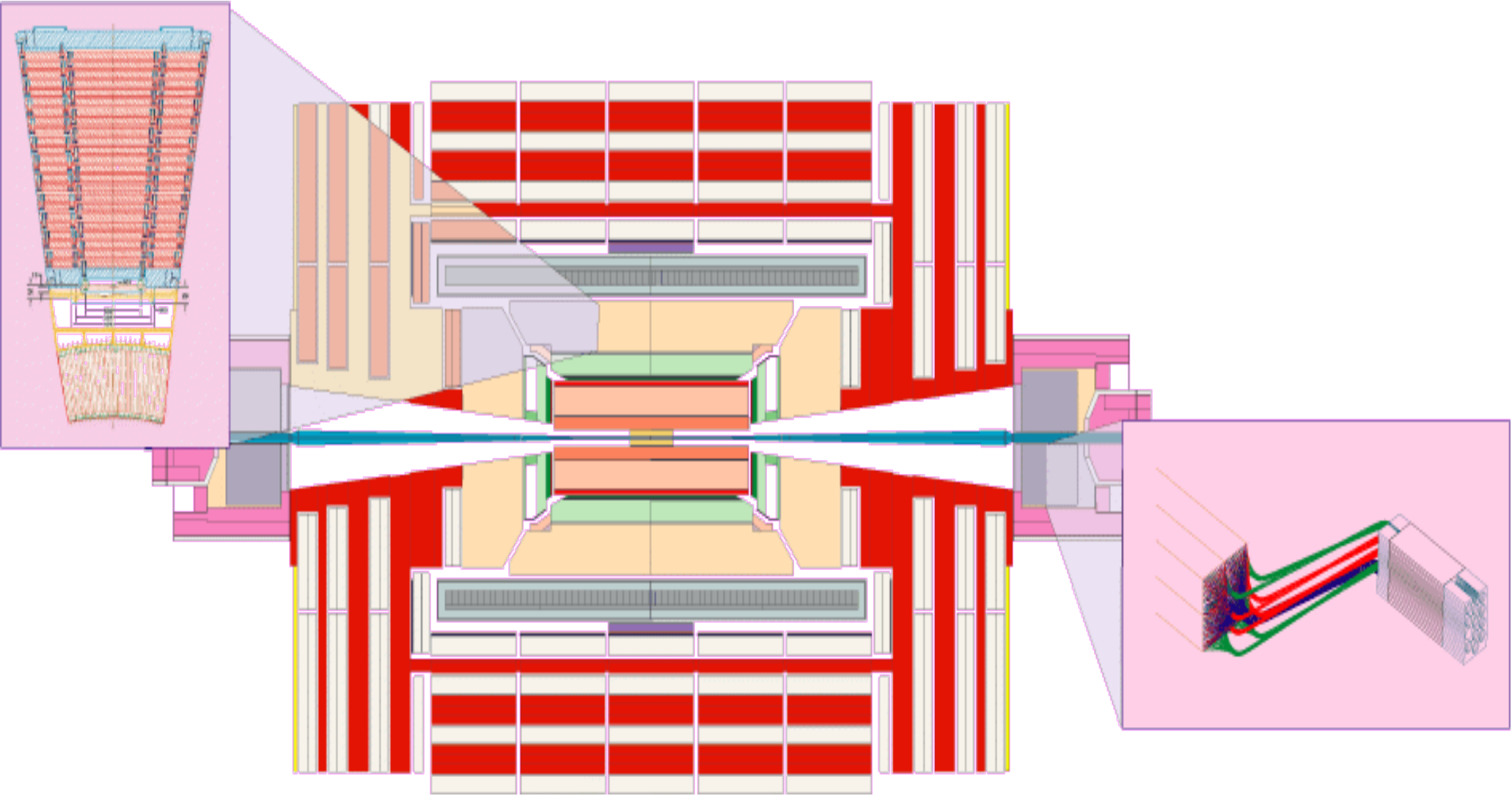


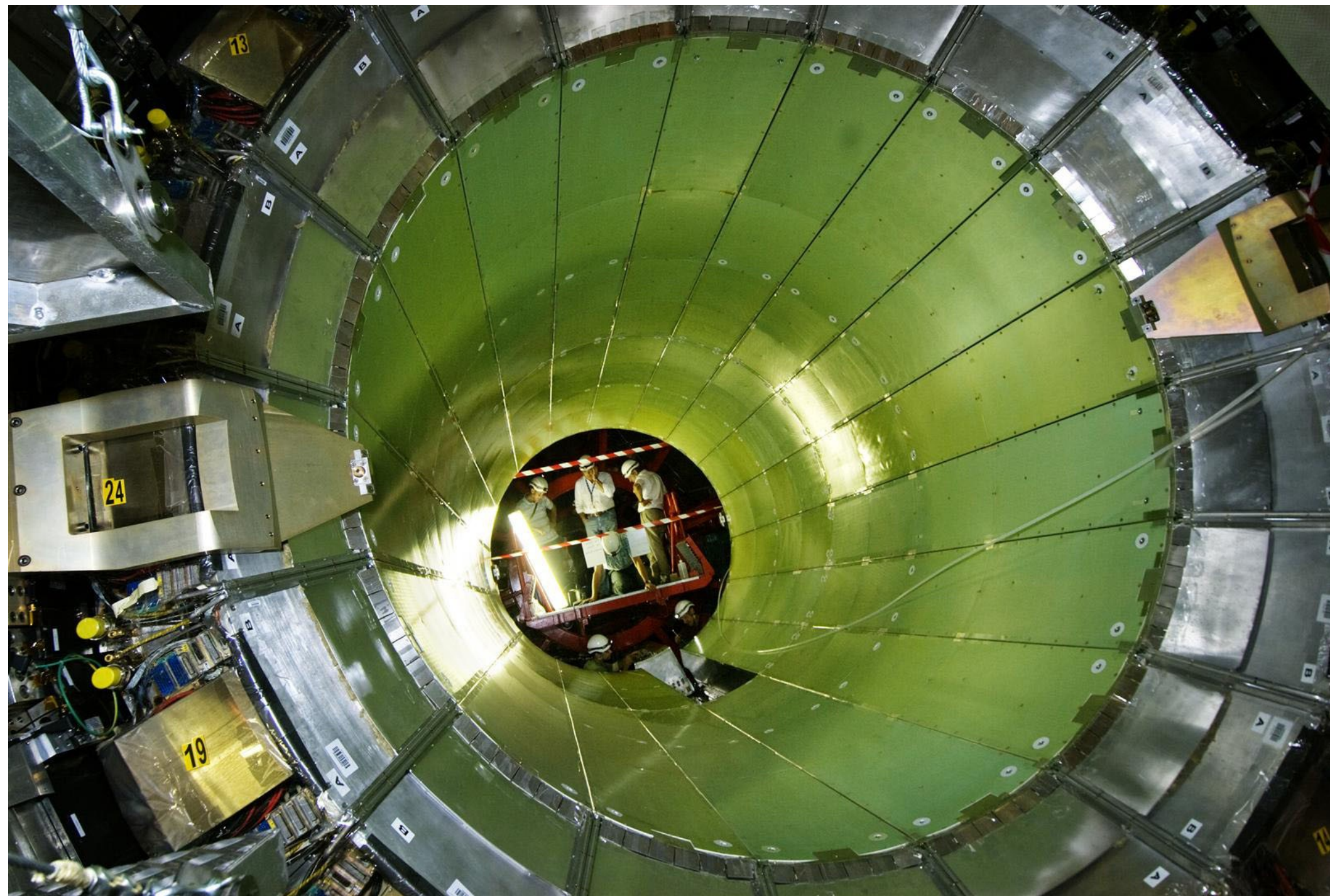
ECAL module





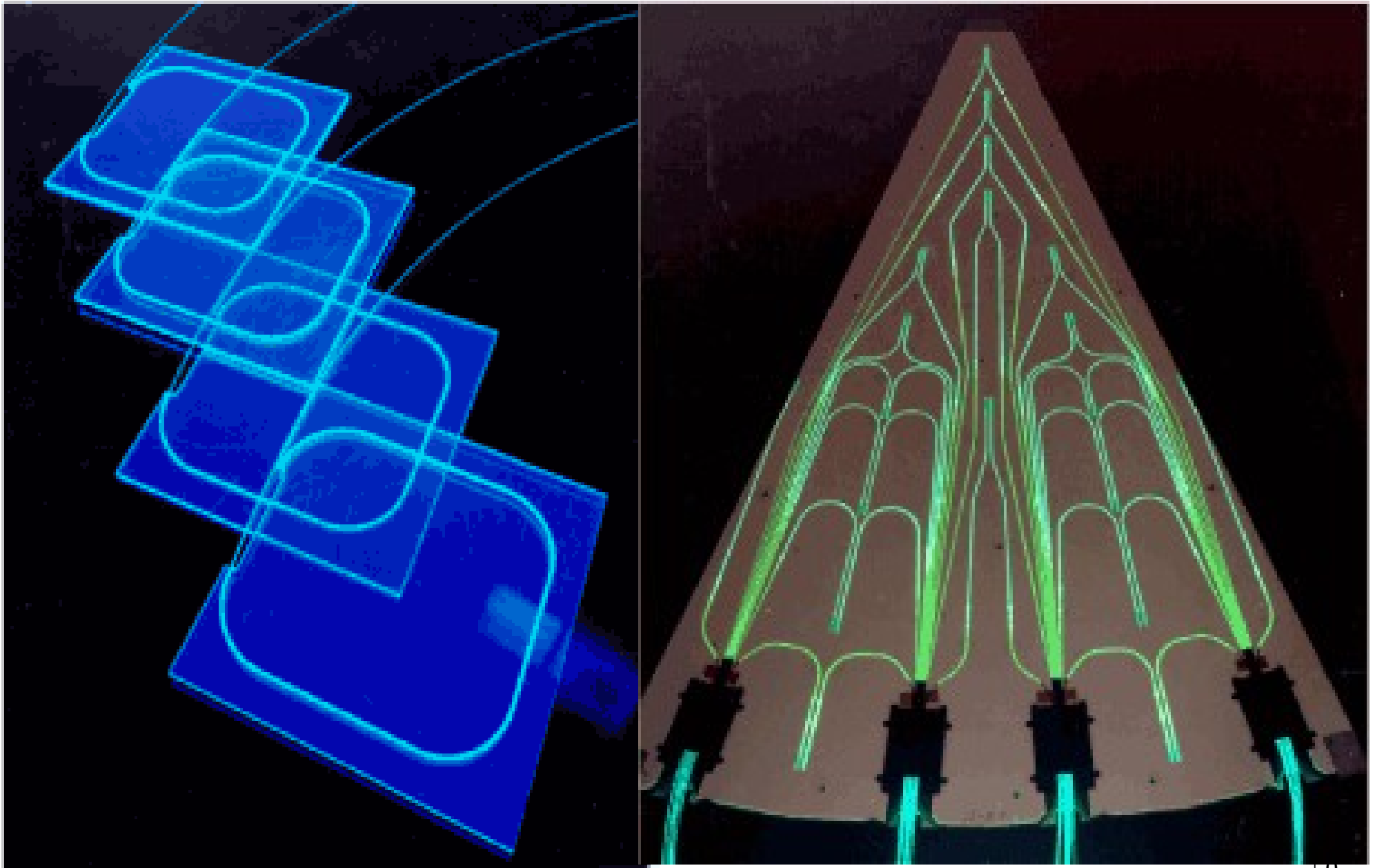
HCAL overview

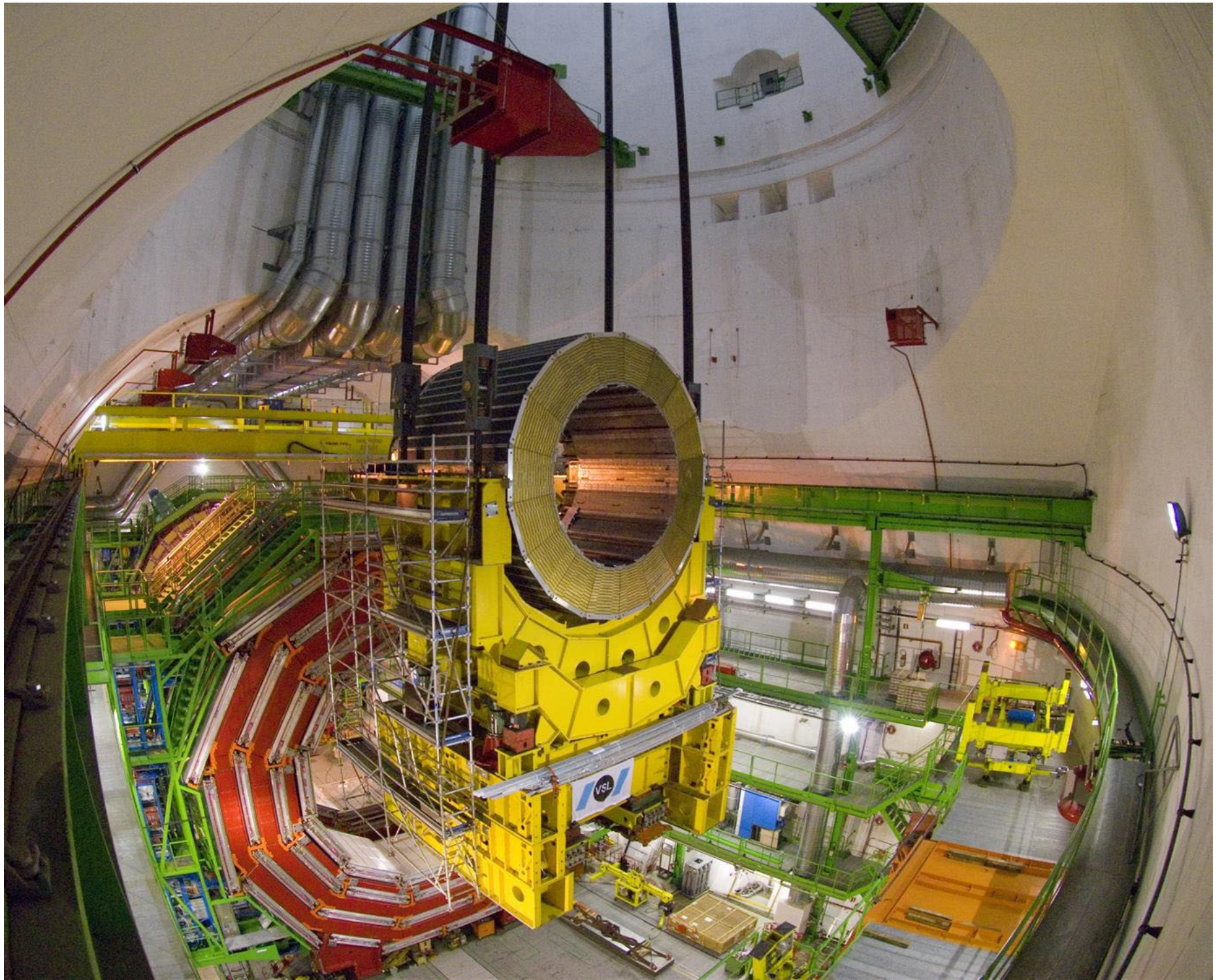






HCAL Scintillators



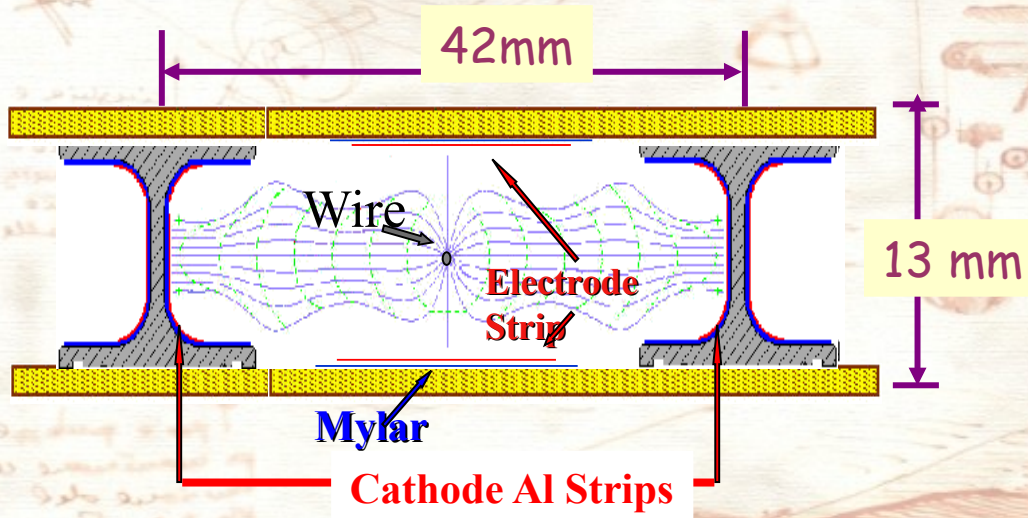




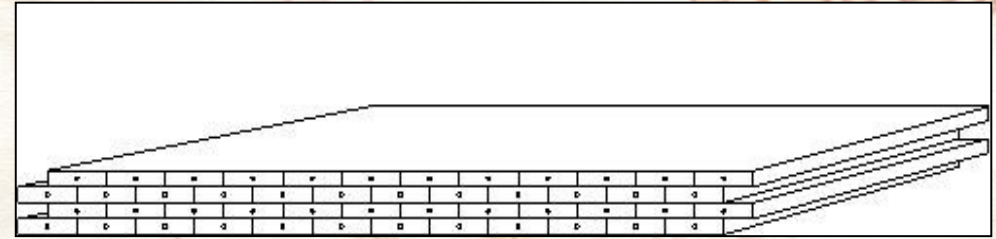
Forward Hadron CAL



Drift Tube Chambers



4 Layers = 1 Superlayer (SL)

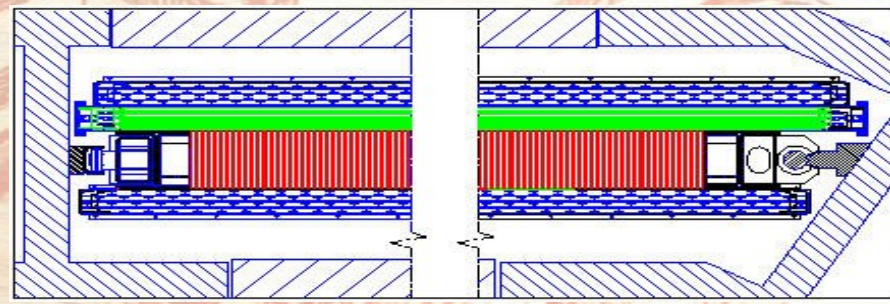


Independent Subunit

(Gas tightness, HV, Front End)

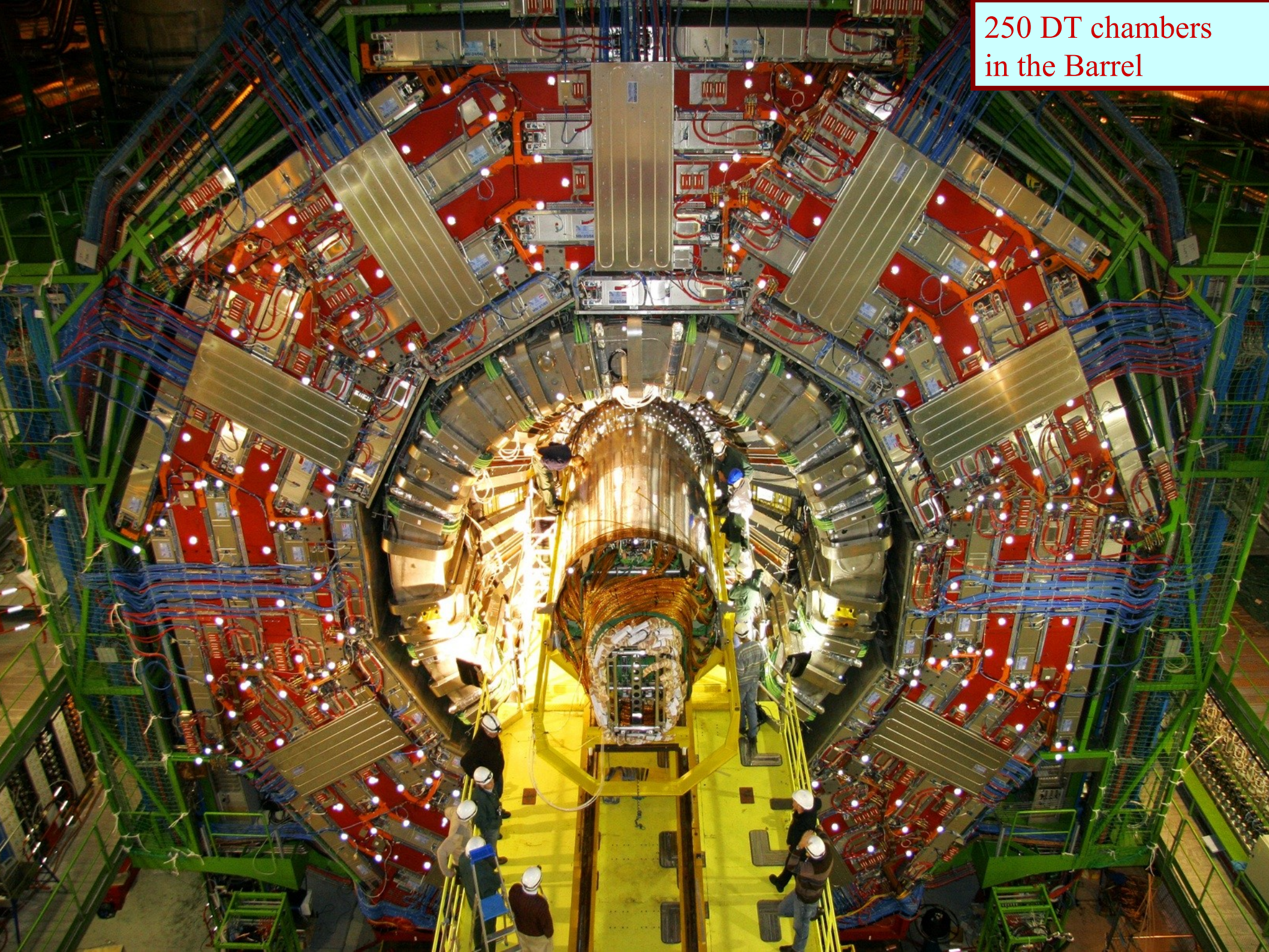
GAS:	Ar/CO ₂	(85/15)
HV:	Wires	3600 V
	Strips	1800 V
	I-beams	-1200 V

Φ SL
θ SL
Honeycomb
Φ SL

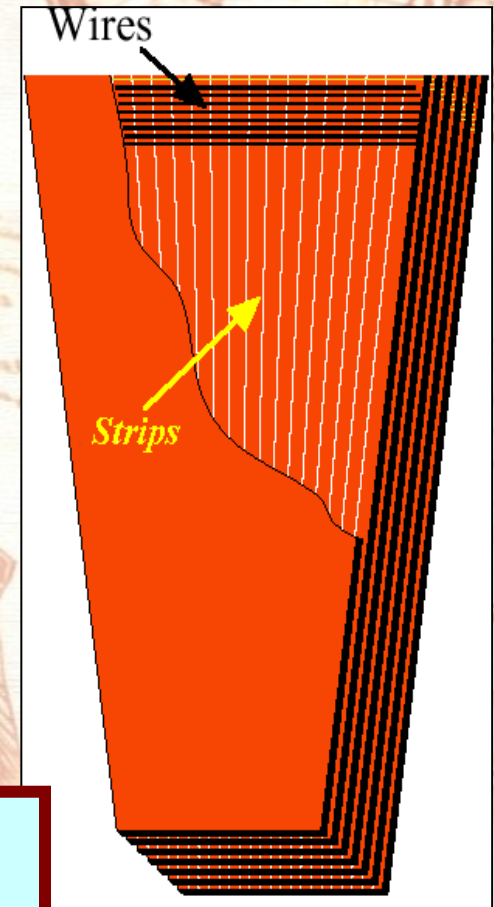
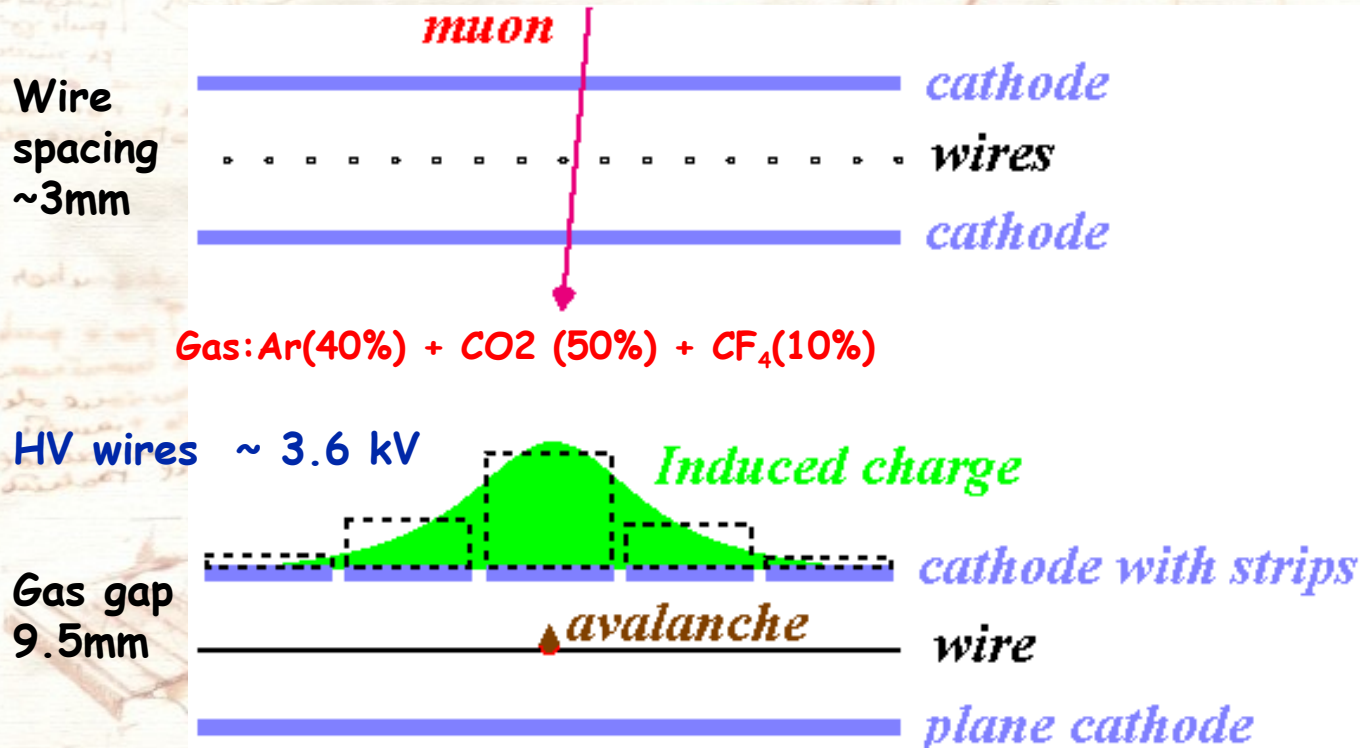


Tmax:	380 ns	Single Wire	→	100μm Φ
Drift Velocity :	~ 55μm/ns	Resolution :	< 300 μm	150μm θ

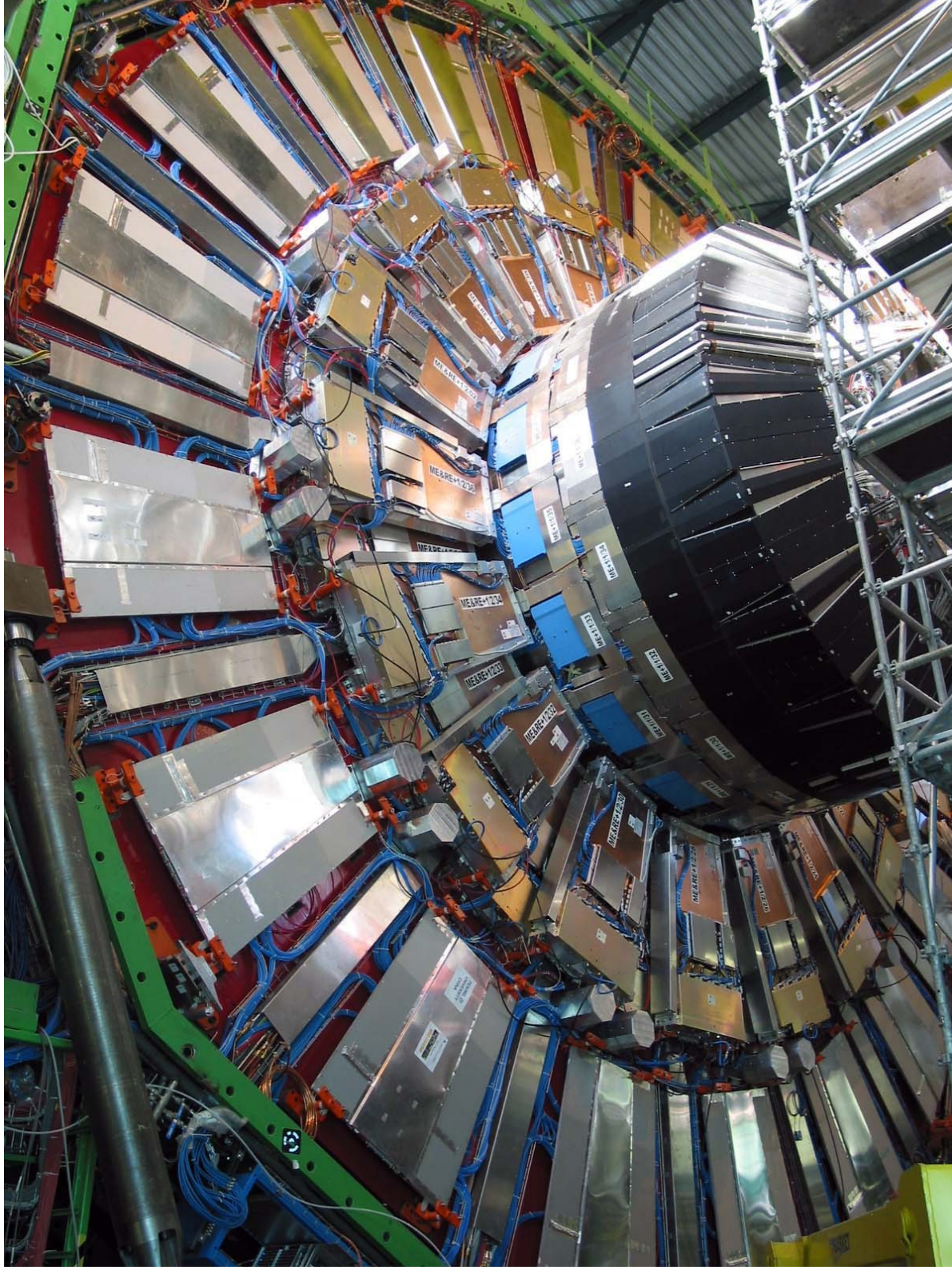
250 DT chambers
in the Barrel



Cathode Strip Chambers (CSC)



Trapezoidal Chambers (10° or 20° in Φ), 6 layers
 Radial cathode strips – measure Φ (75-150 μm)
 Wires orthogonal to strips
 Precise timing measurement (BX) - ~ 4.5 ns
 Coarse measurement of the radial position (16-54 mm)



CSC

Resistive Plate Chambers

Resistive Plates – bakelite with bulk resistivity $(2 \pm 1) \cdot 10^{10} \Omega \text{cm}$

Gas gap ($2 \text{mm} \pm 20 \mu\text{m}$ wide)

Gas mixture, containing

96% $\text{C}_2\text{H}_2\text{F}_4$ (Freon),

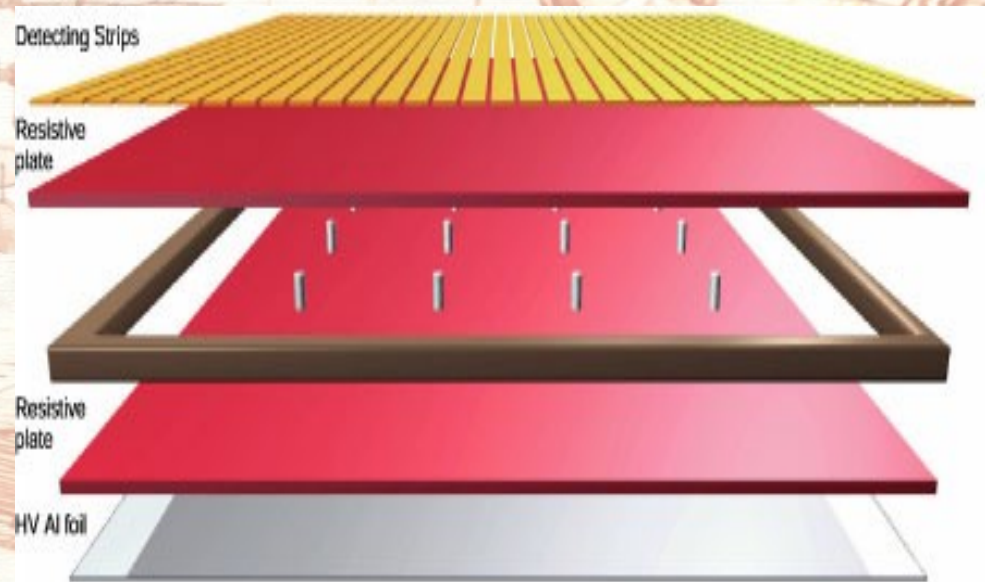
3,5 % isobutan, SF_6 – 0,5 %

Graphite electrodes with resistivity $300 \text{ k}\Omega / \text{cm}$

Insulating PET film (0.3 mm thick)

Detecting copper strips

$40 \mu\text{m}$ thick, 2–4 cm wide and 1250 mm long

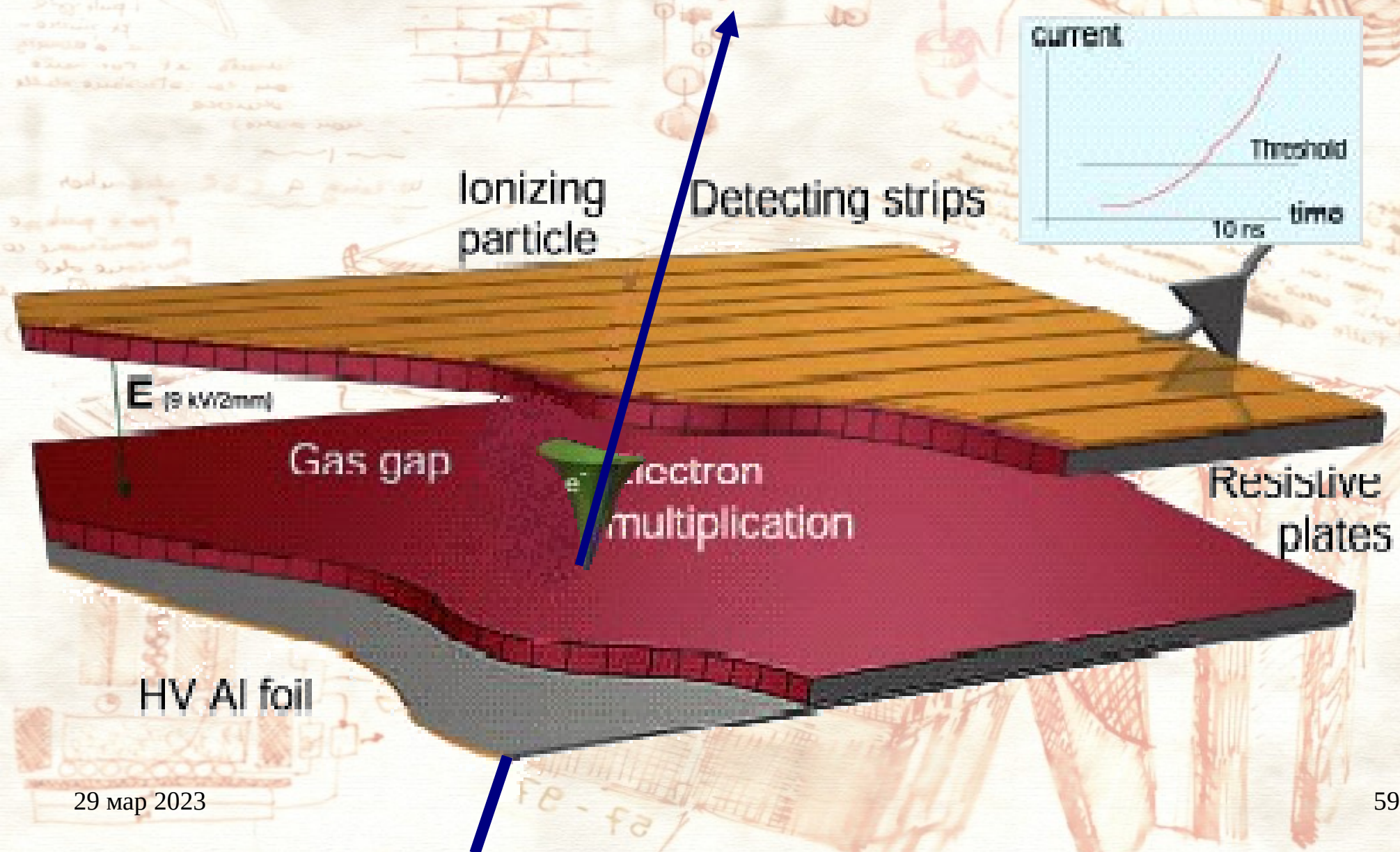


Spacers (cylinders with diameter 10 mm and height 2mm)

Copper shielding

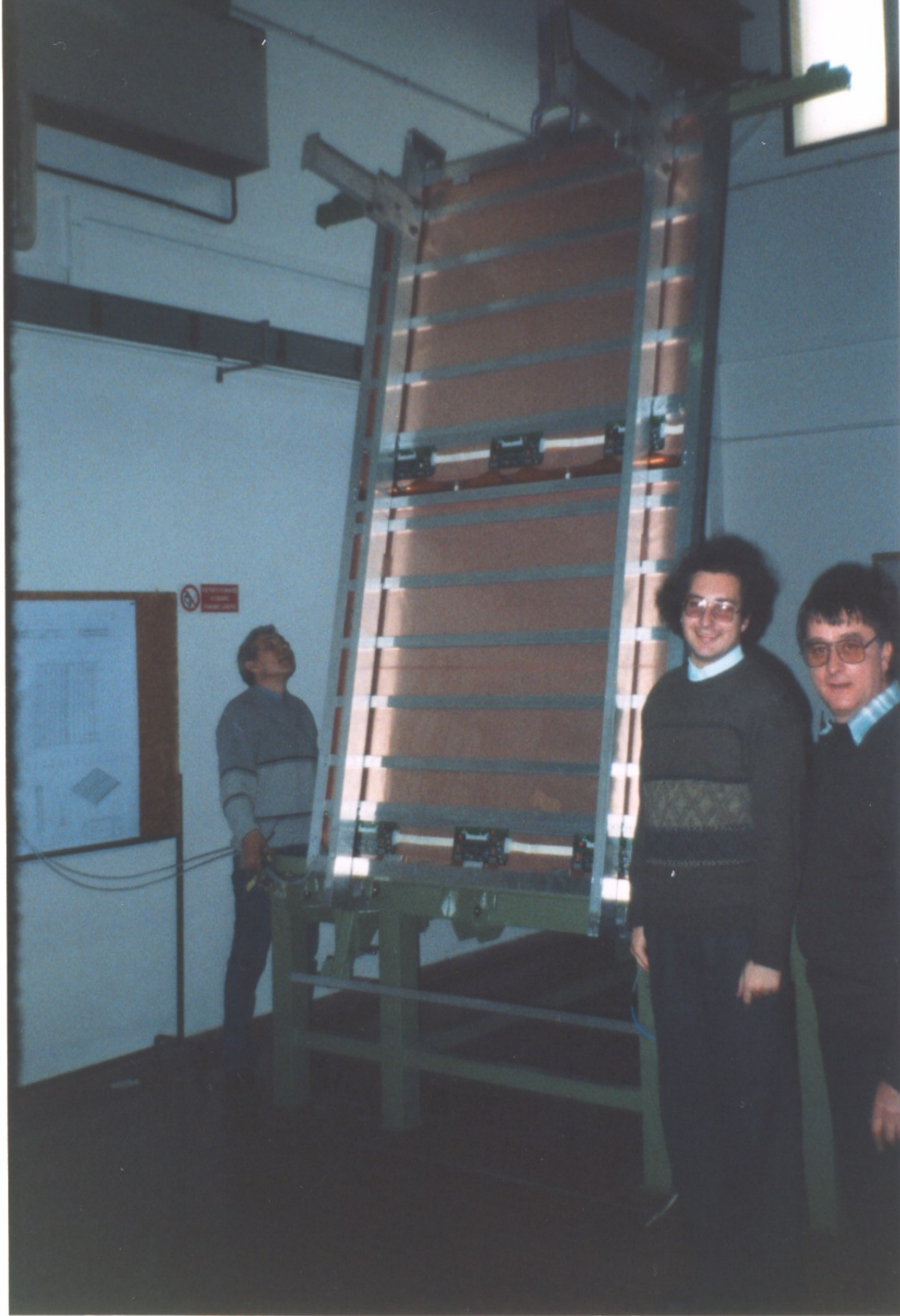
Linseed oil treatment

RPC - Principle of Action

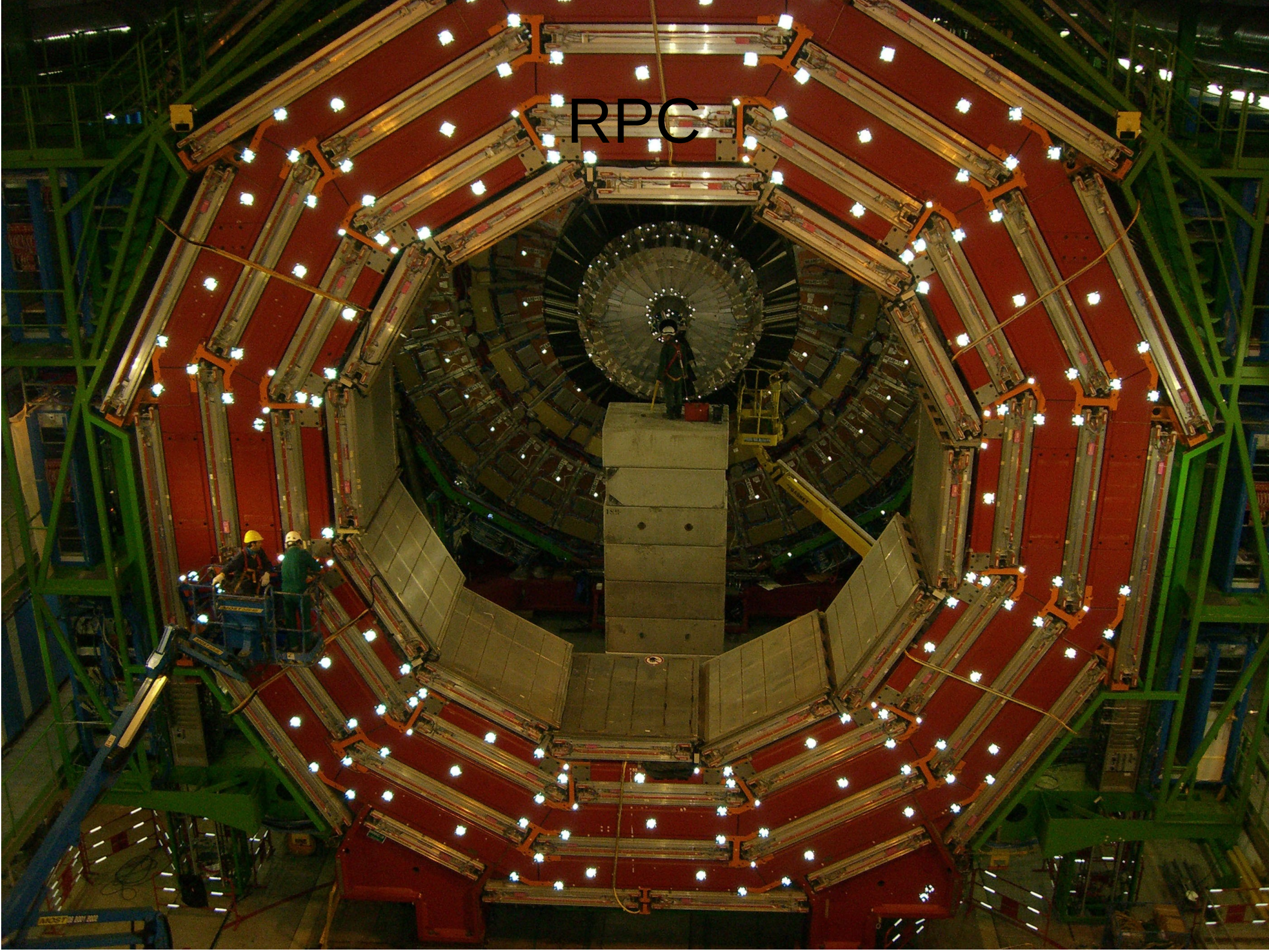


**Първата RPC
камера за CMS
14 февруари 2002 г.**

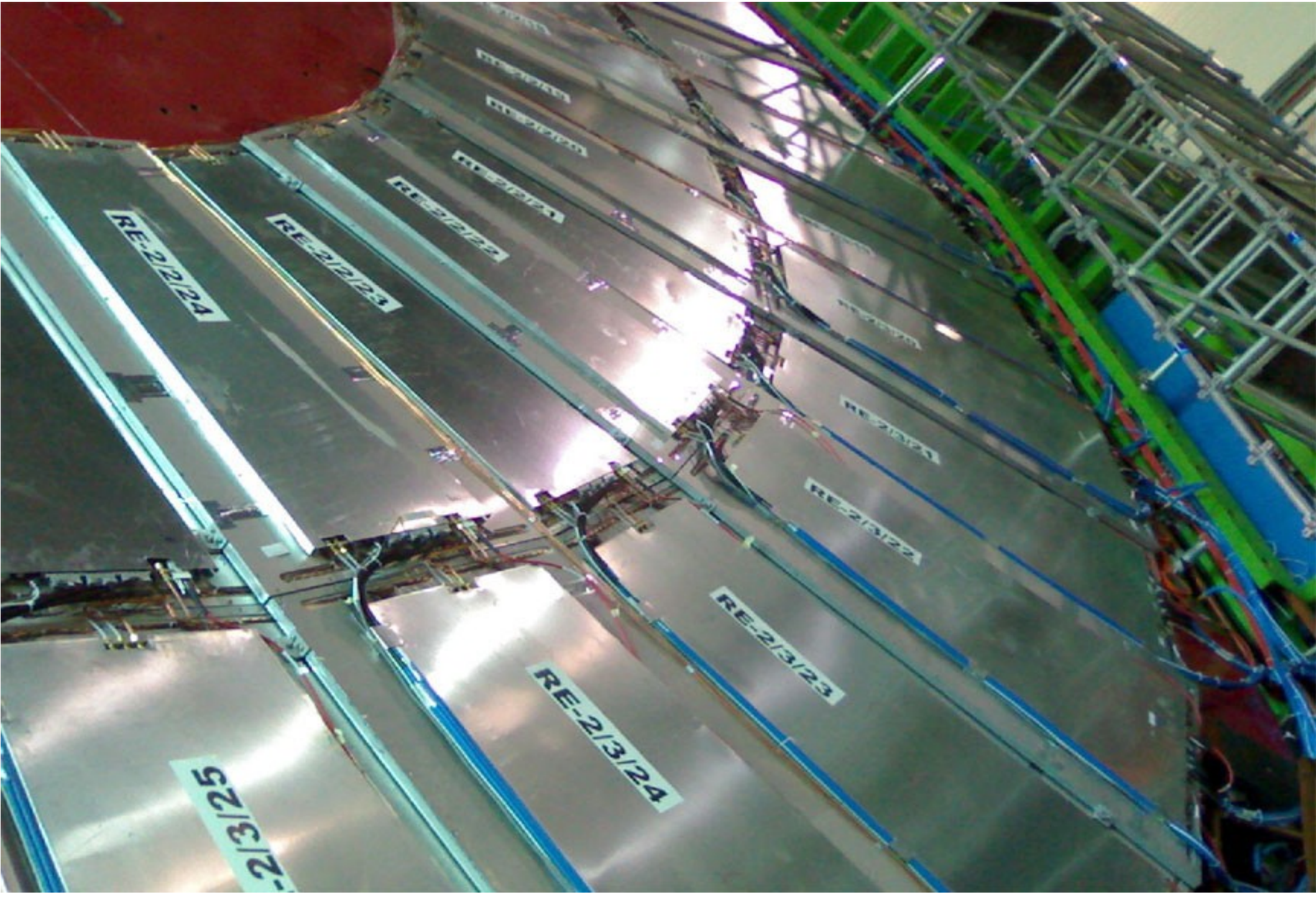
29 мар 2023



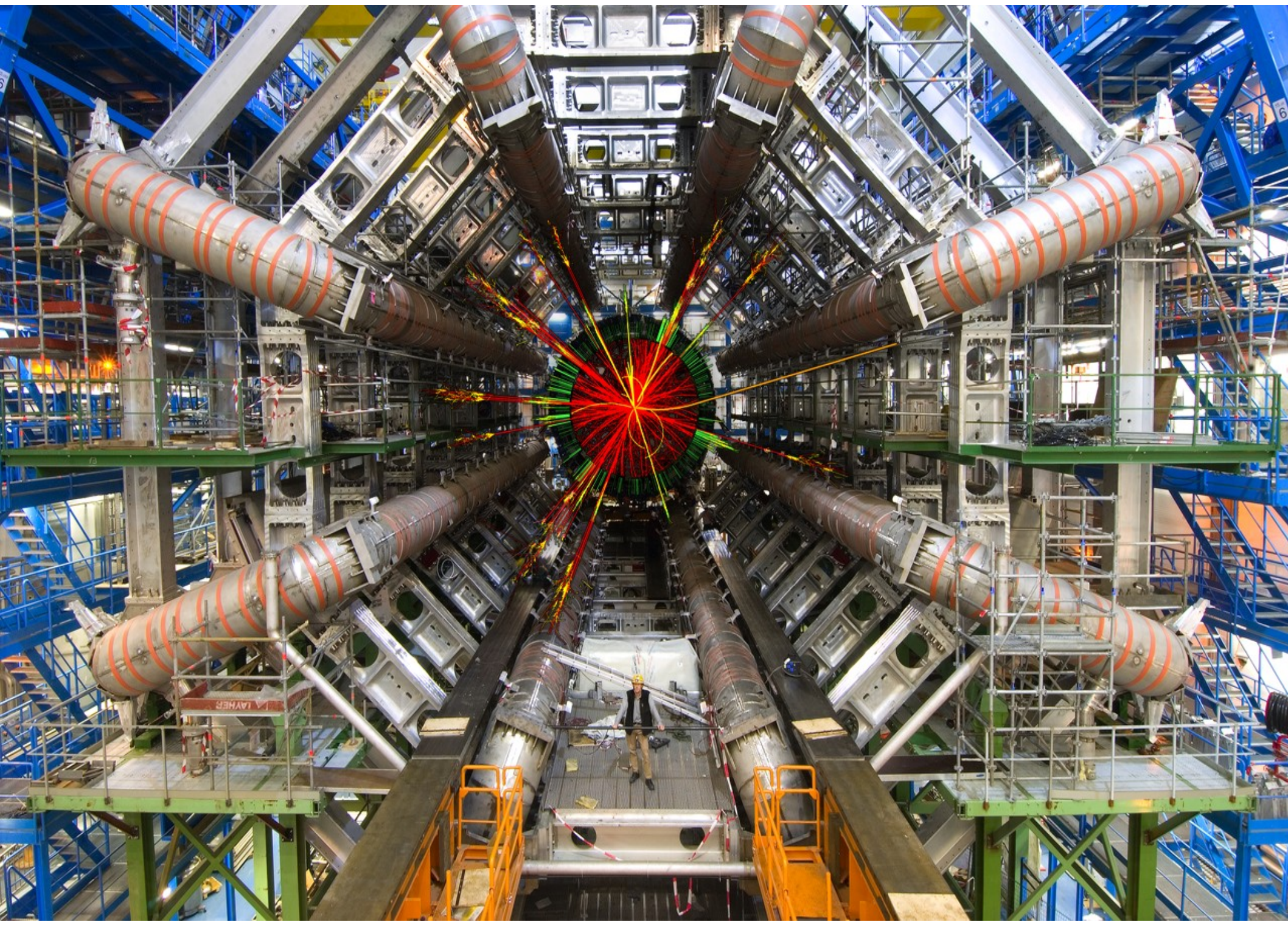
RPC



RPC



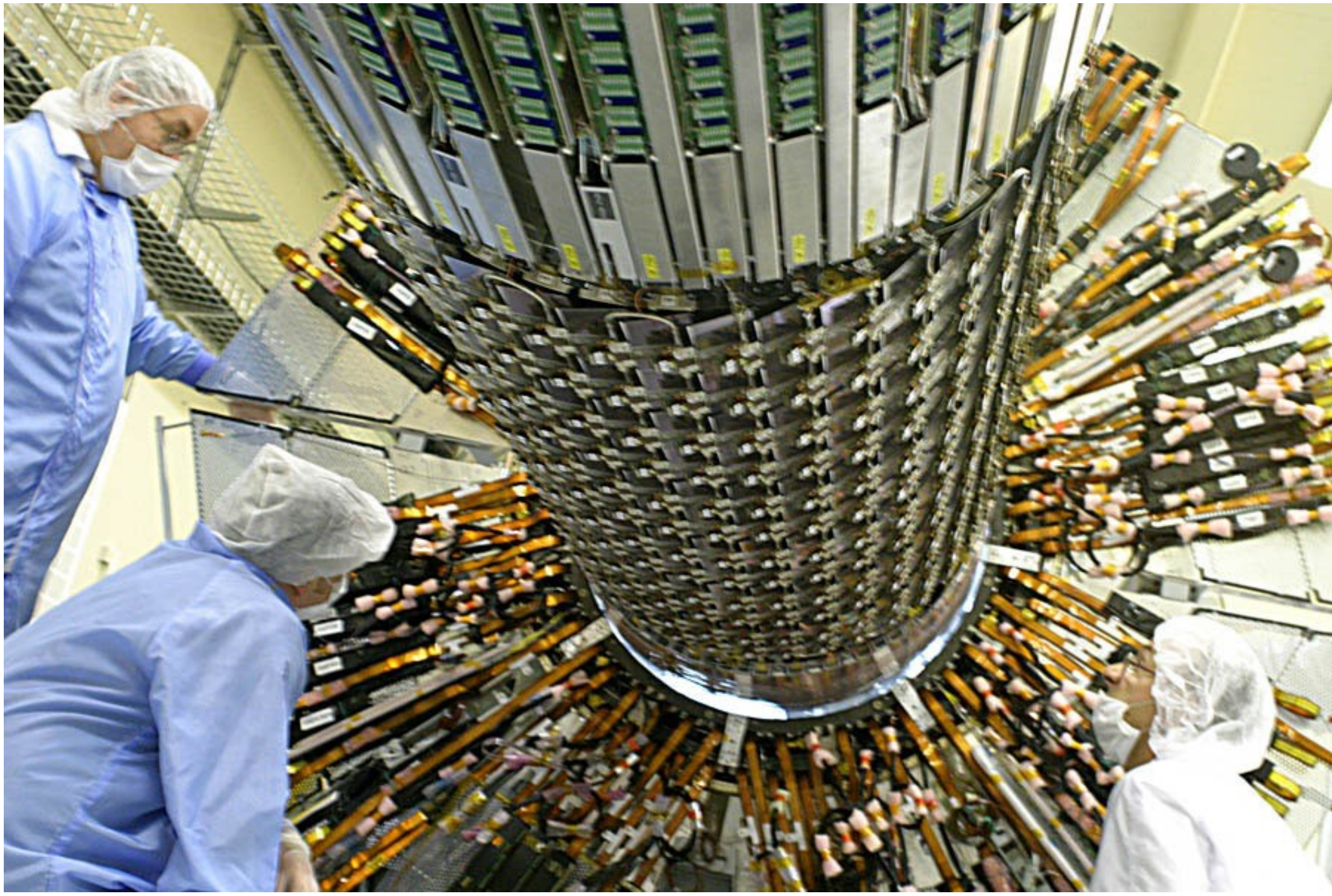
ATLAS



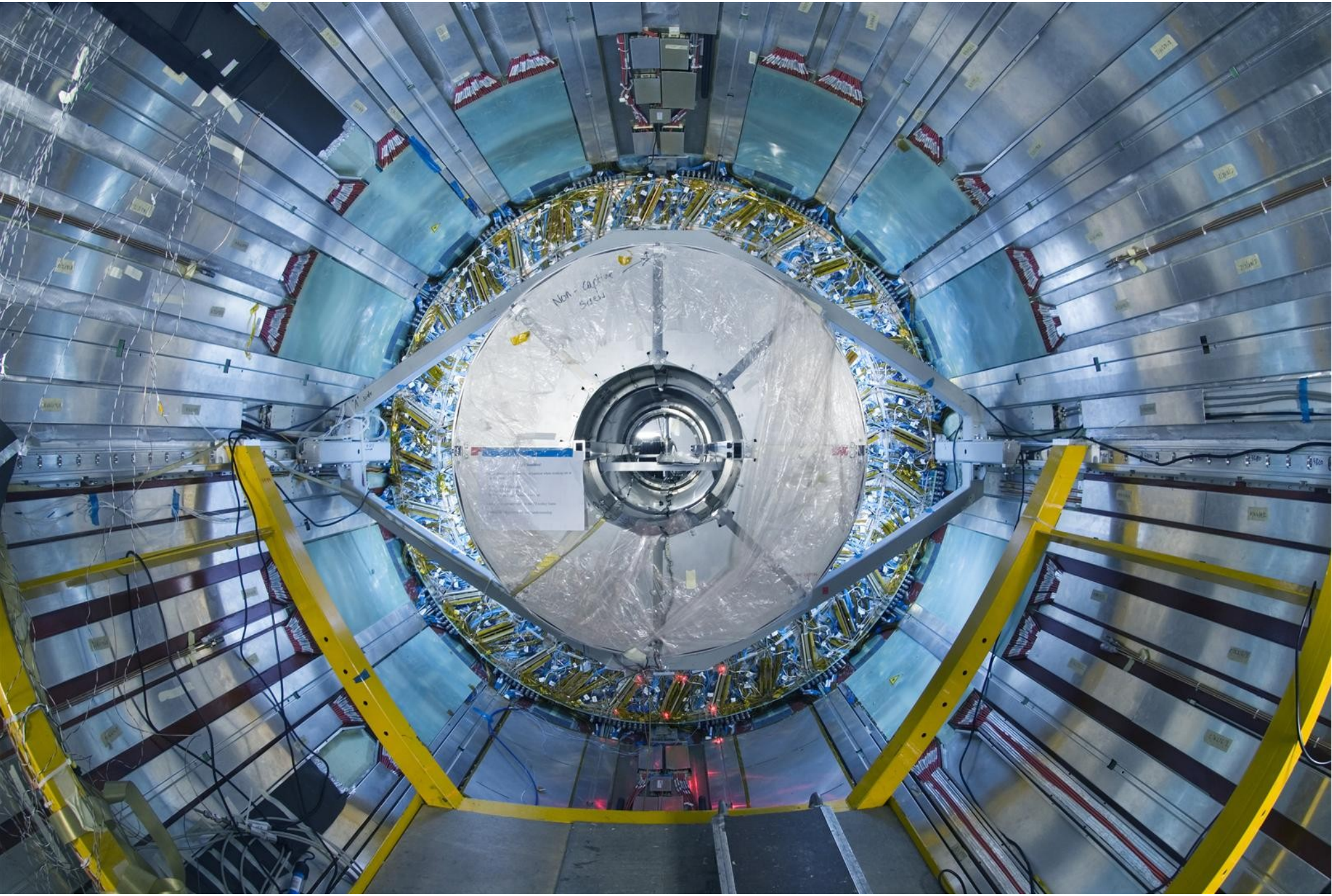
PIXEL



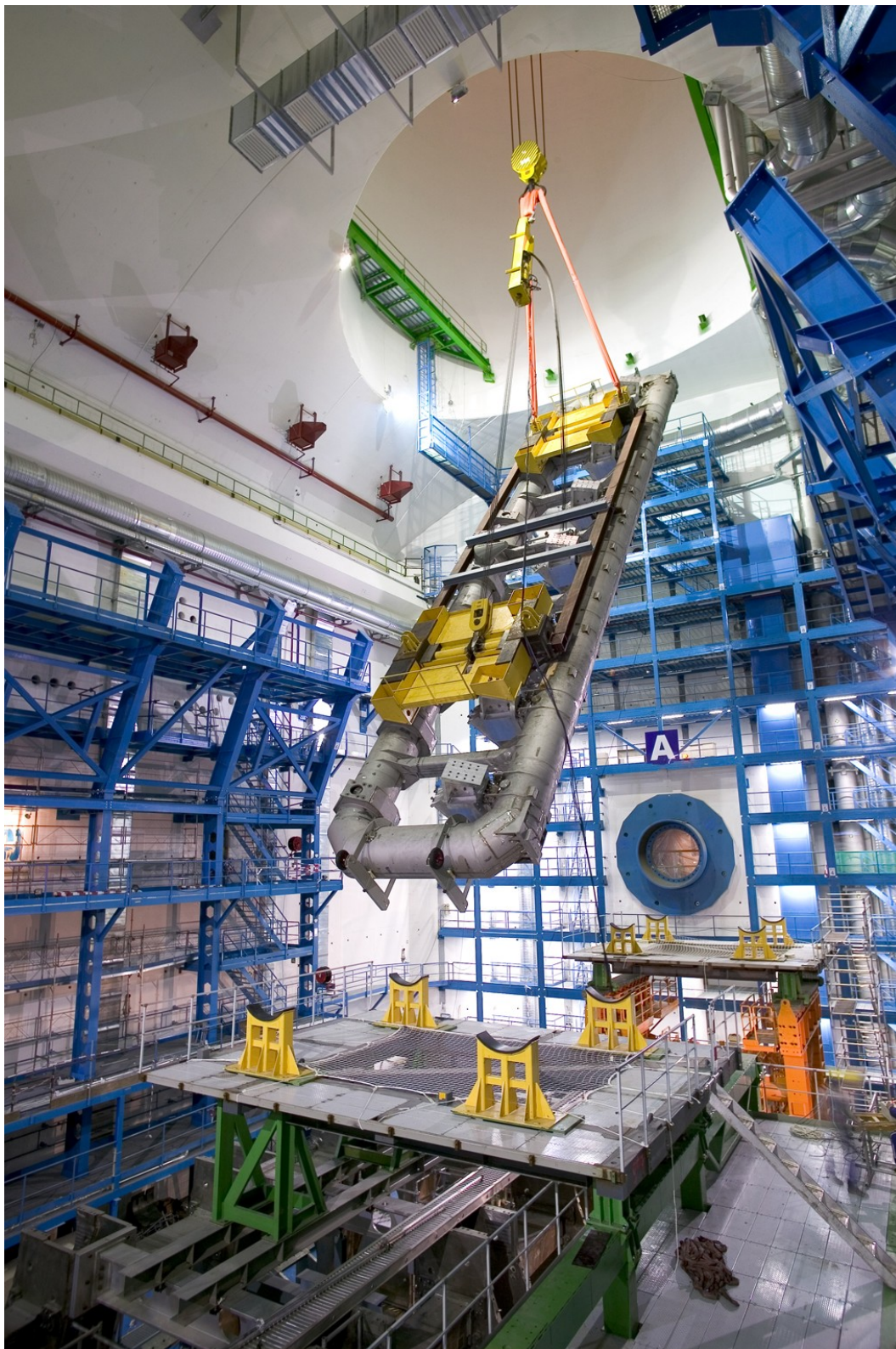
Si strips

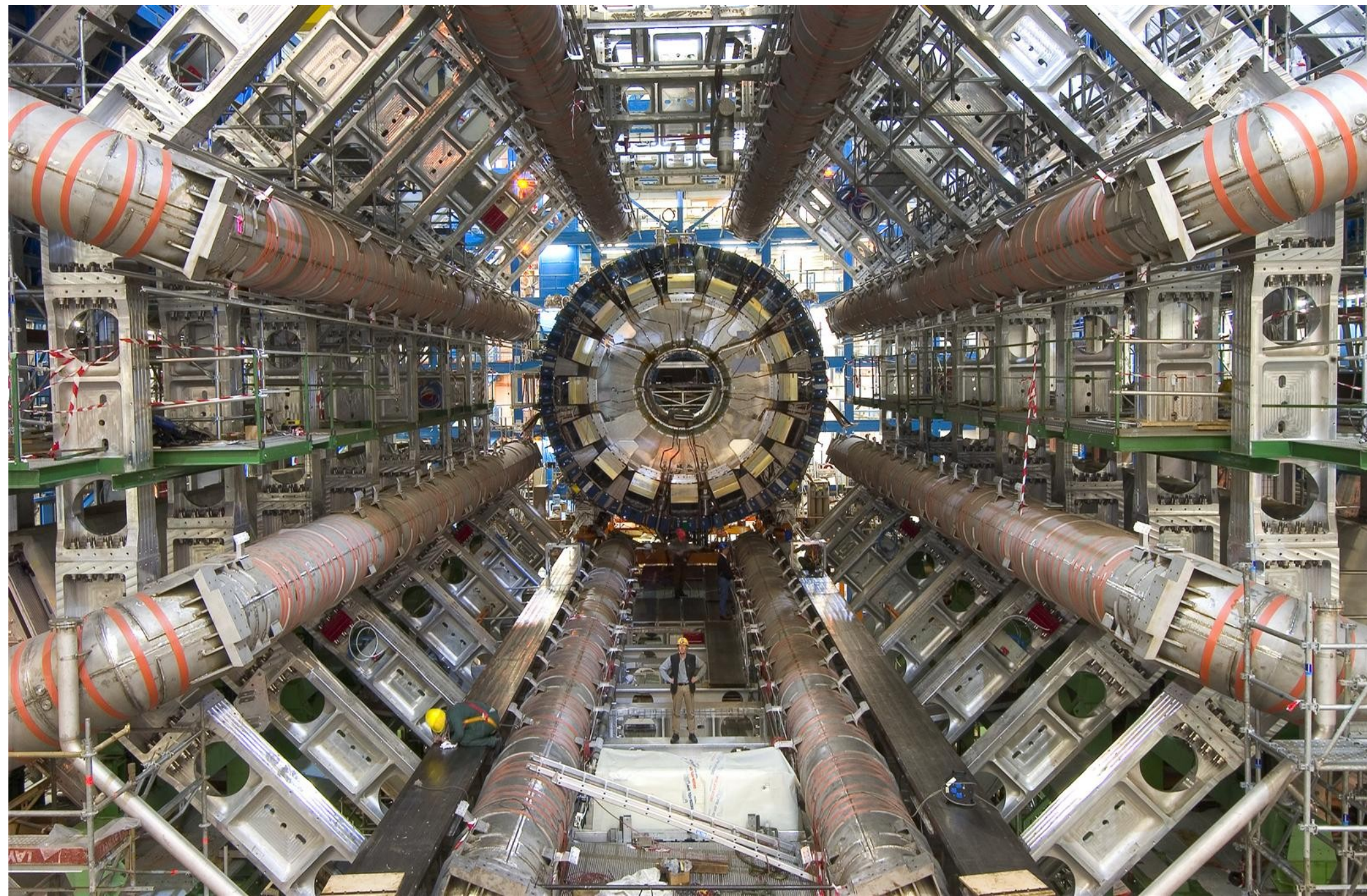


TRD



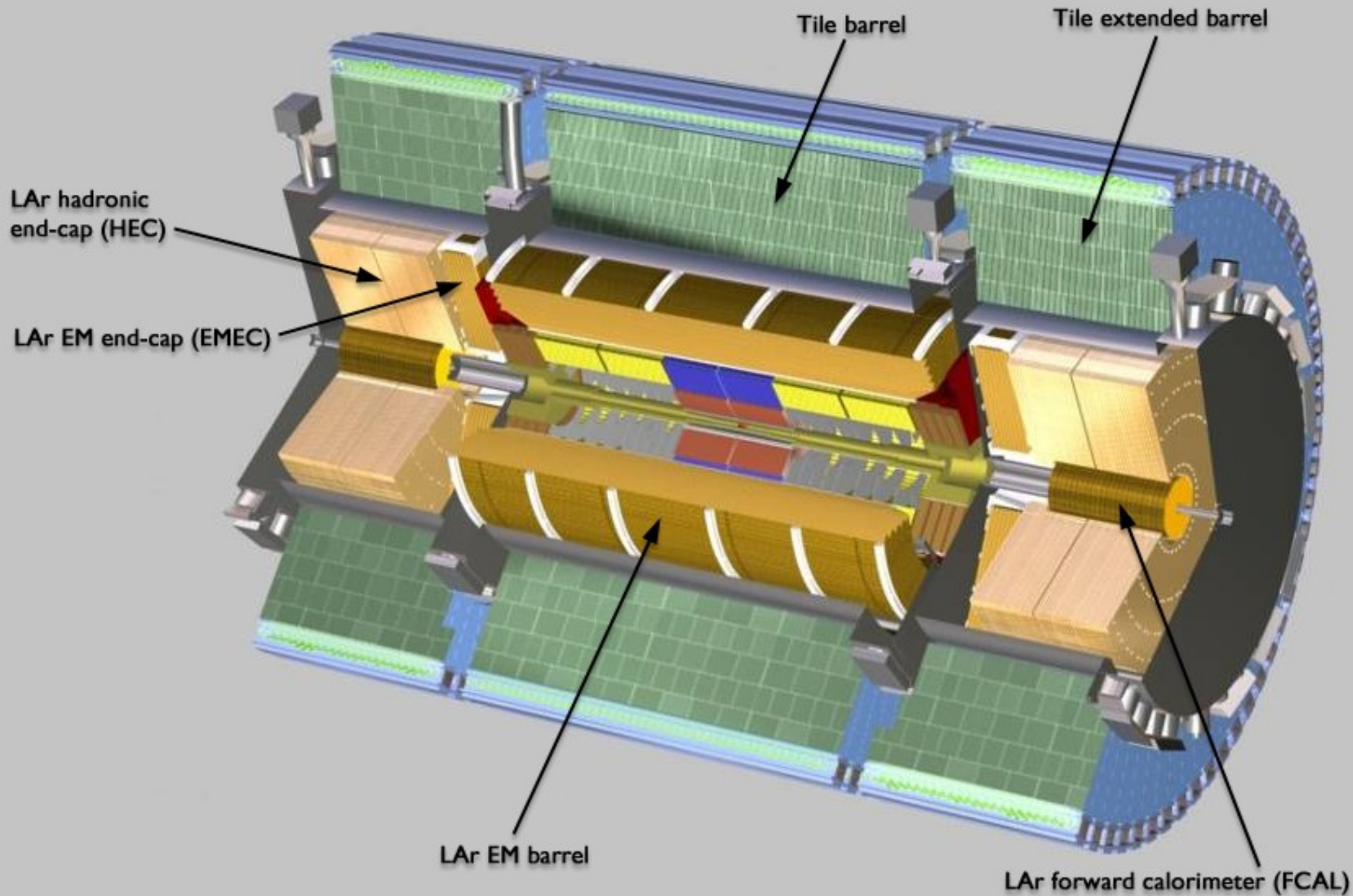






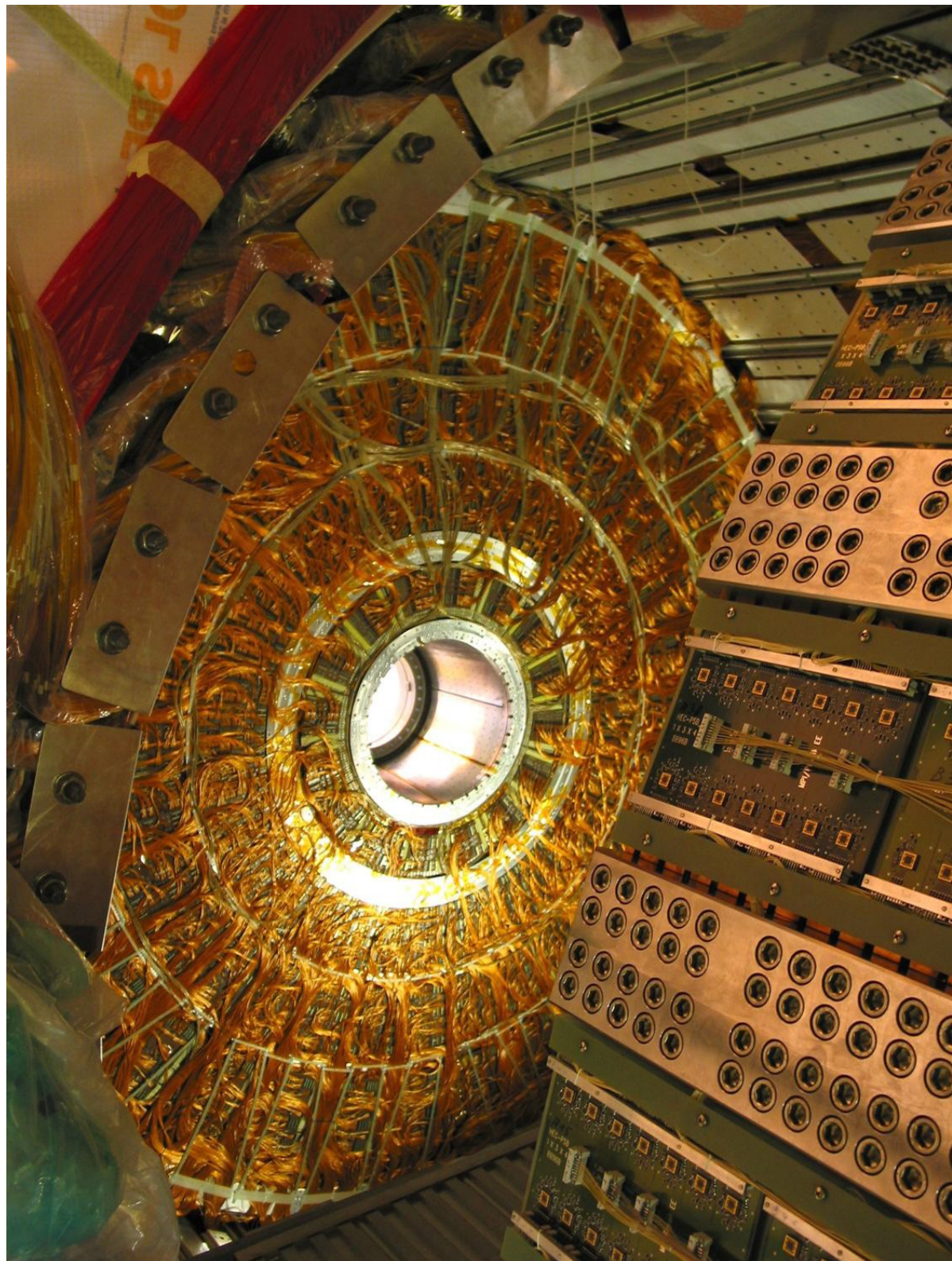




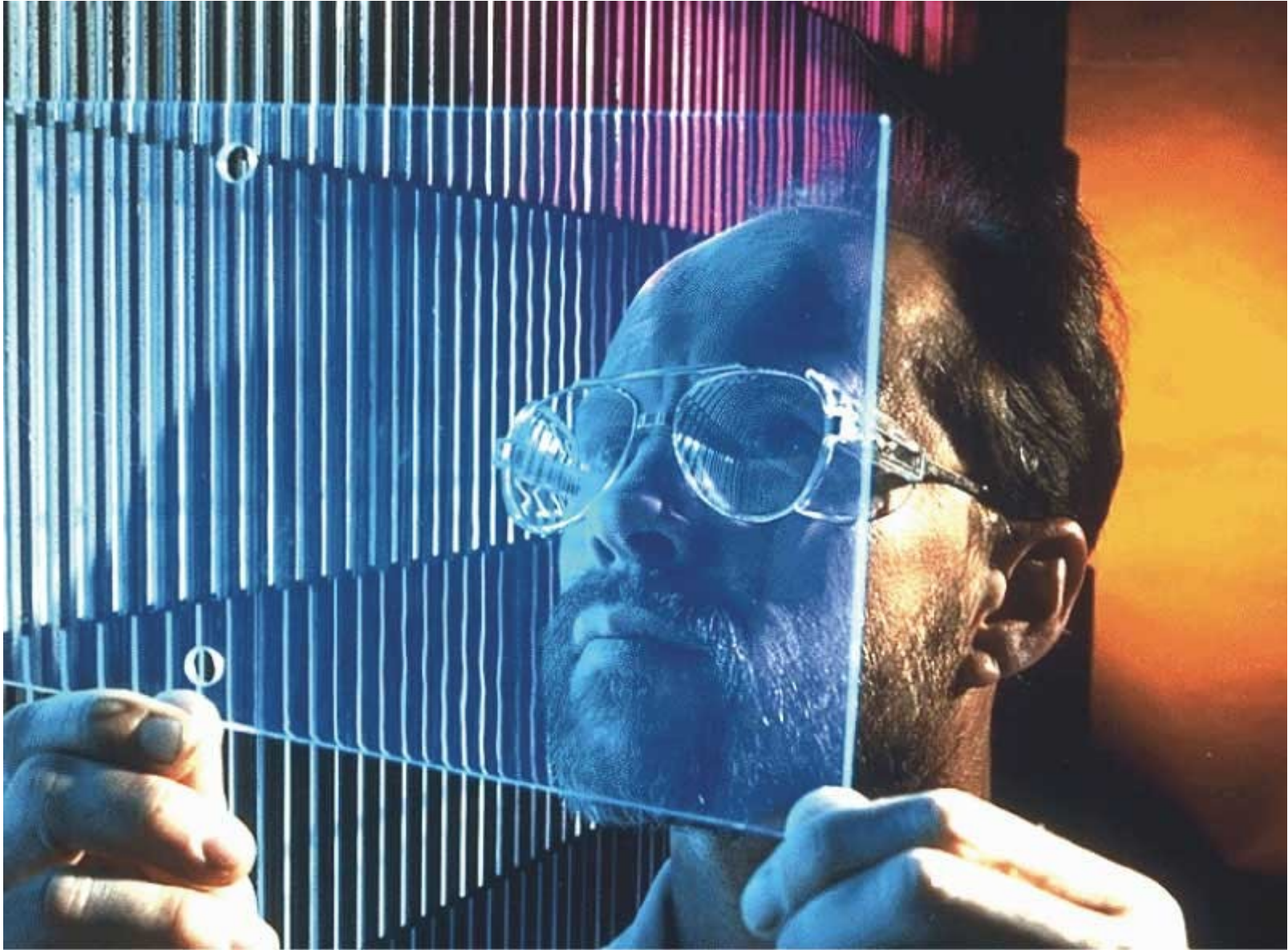


LAr

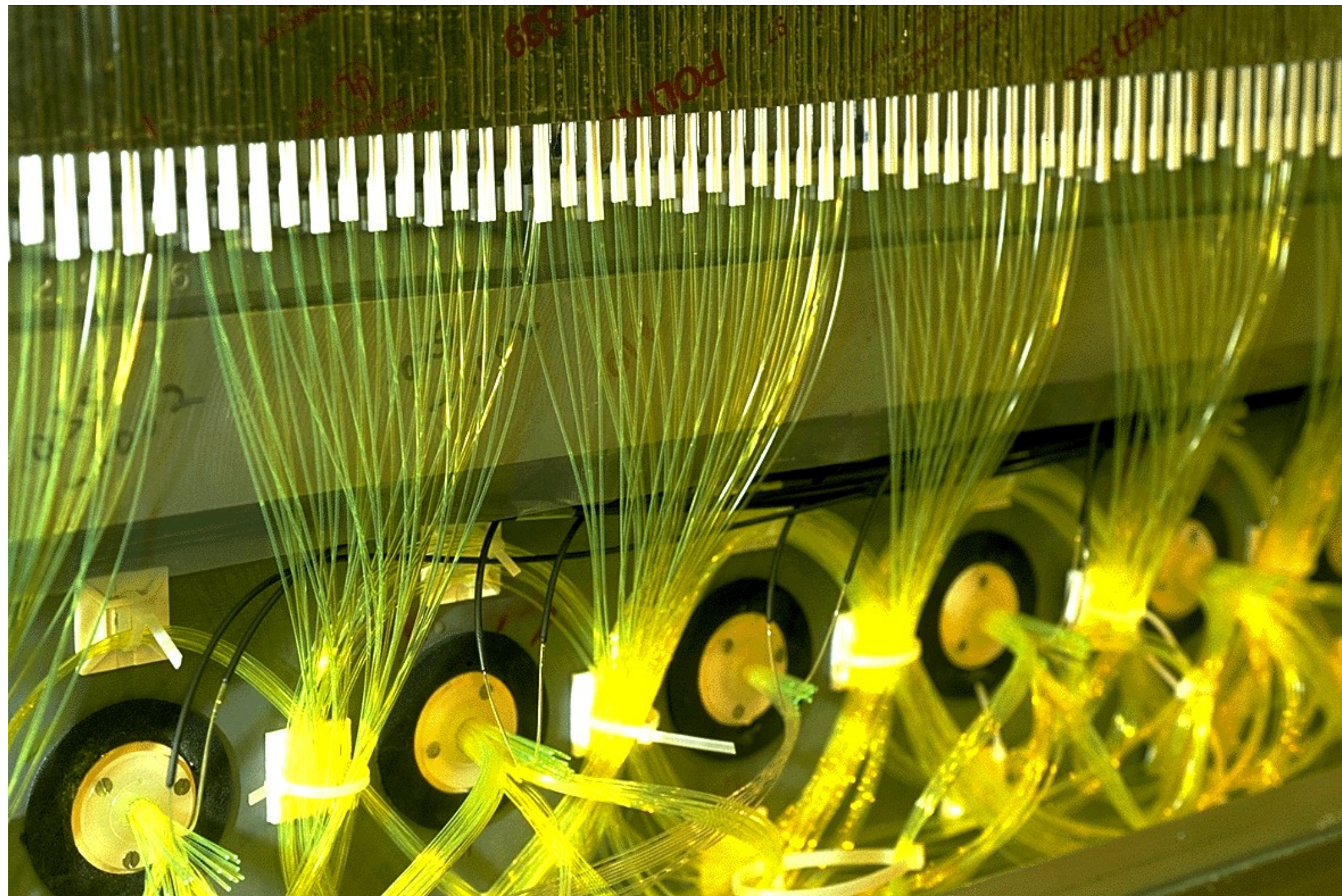


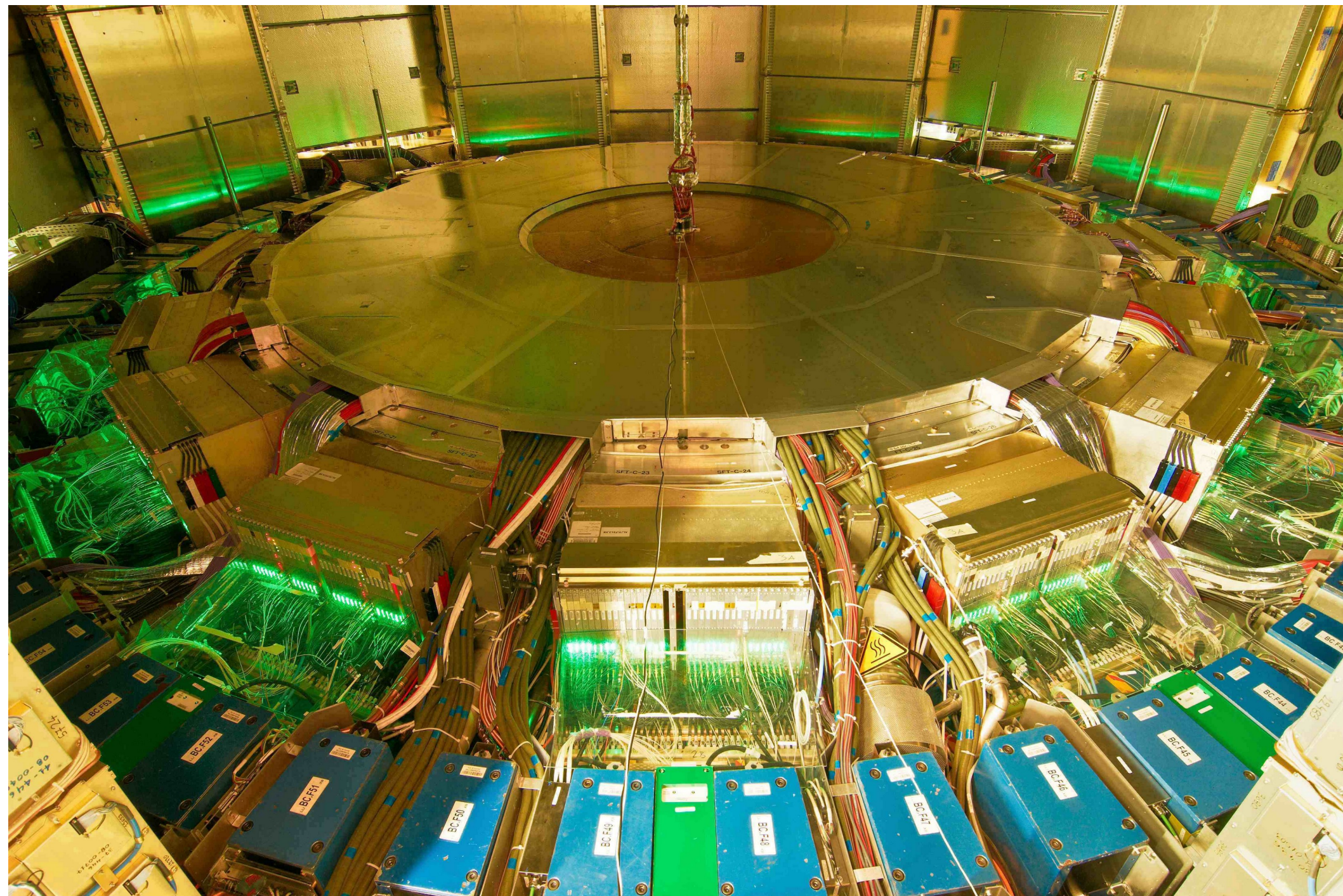


HCAL





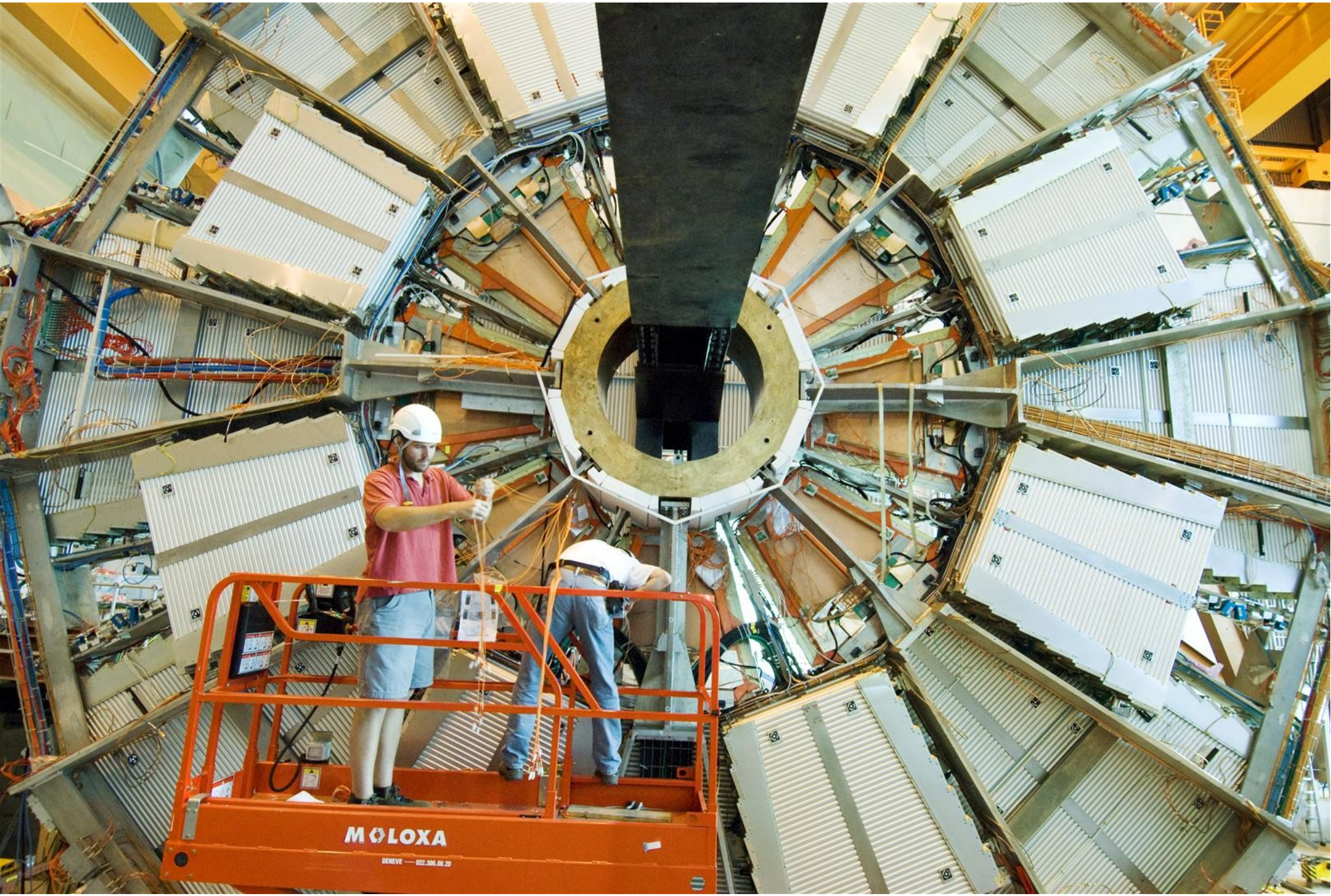




RPC



CSC

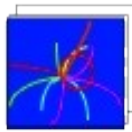


DT



EA-01-03011

Trigger and DAQ



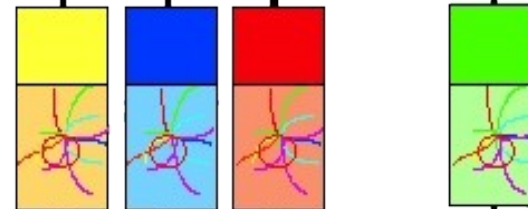
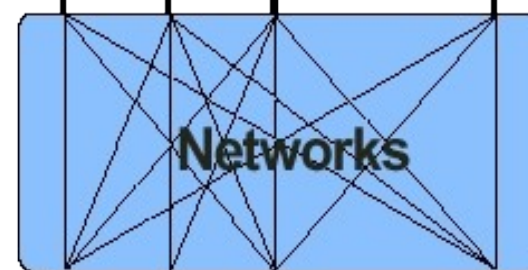
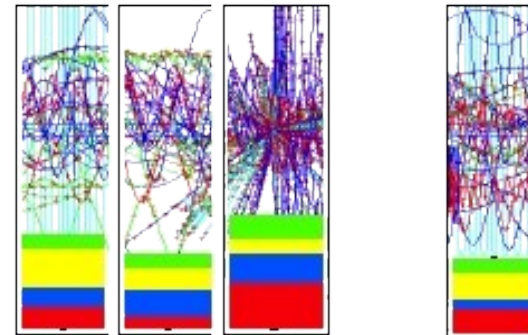
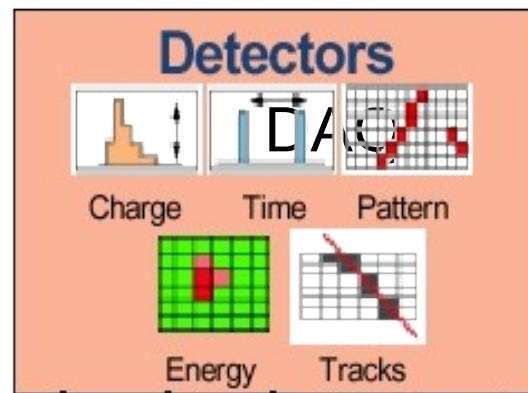
40 MHz
COLLISION RATE

100 kHz
LEVEL-1 TRIGGER

1 Terabit/s
(50000 DATA CHANNELS)

500 Gigabit/s

290 Gigabit/s SERVICE LAN



16 Million channels
3 Gigacell buffers

1 Megabyte EVENT DATA

200 Gigabyte BUFFERS
500 Readout memories

EVENT BUILDER. A large switching network (512+512 ports) with a total throughput of approximately 500 Gbit/s forms the interconnection between the sources (Readout Dual Port Memory) and the destinations (switch to Farm Interface). The Event Manager collects the status and request of event filters and distributes event building commands (read/clear) to RDPMs

5 TeraIPS

EVENT FILTER. It consists of a set of high performance commercial processors organized into many farms convenient for on-line and off-line applications. The farm architecture is such that a single CPU processes one event

Petabyte ARCHIVE

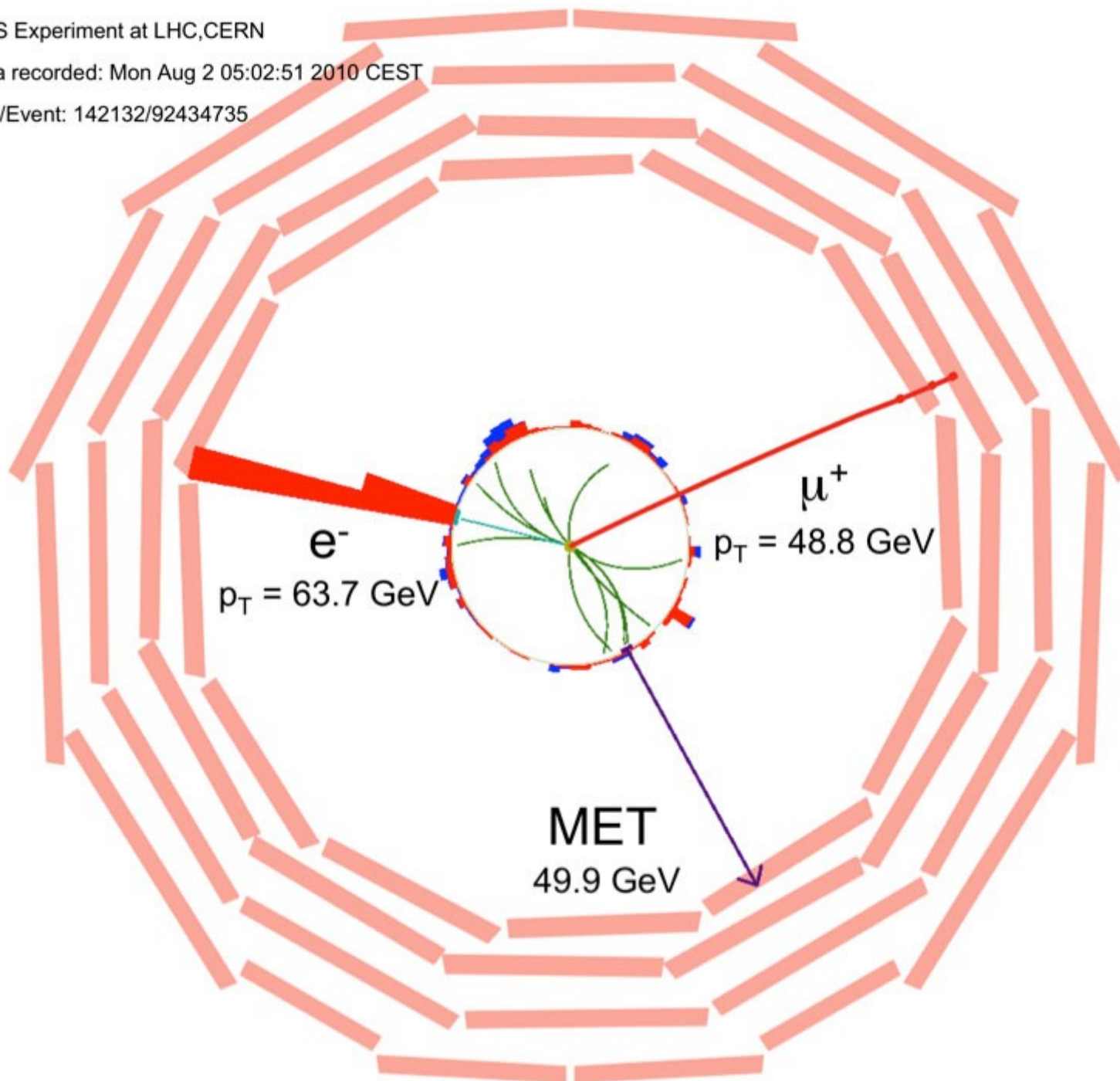
DAQ



CMS Experiment at LHC,CERN

Data recorded: Mon Aug 2 05:02:51 2010 CEST

Run/Event: 142132/92434735



Data processing

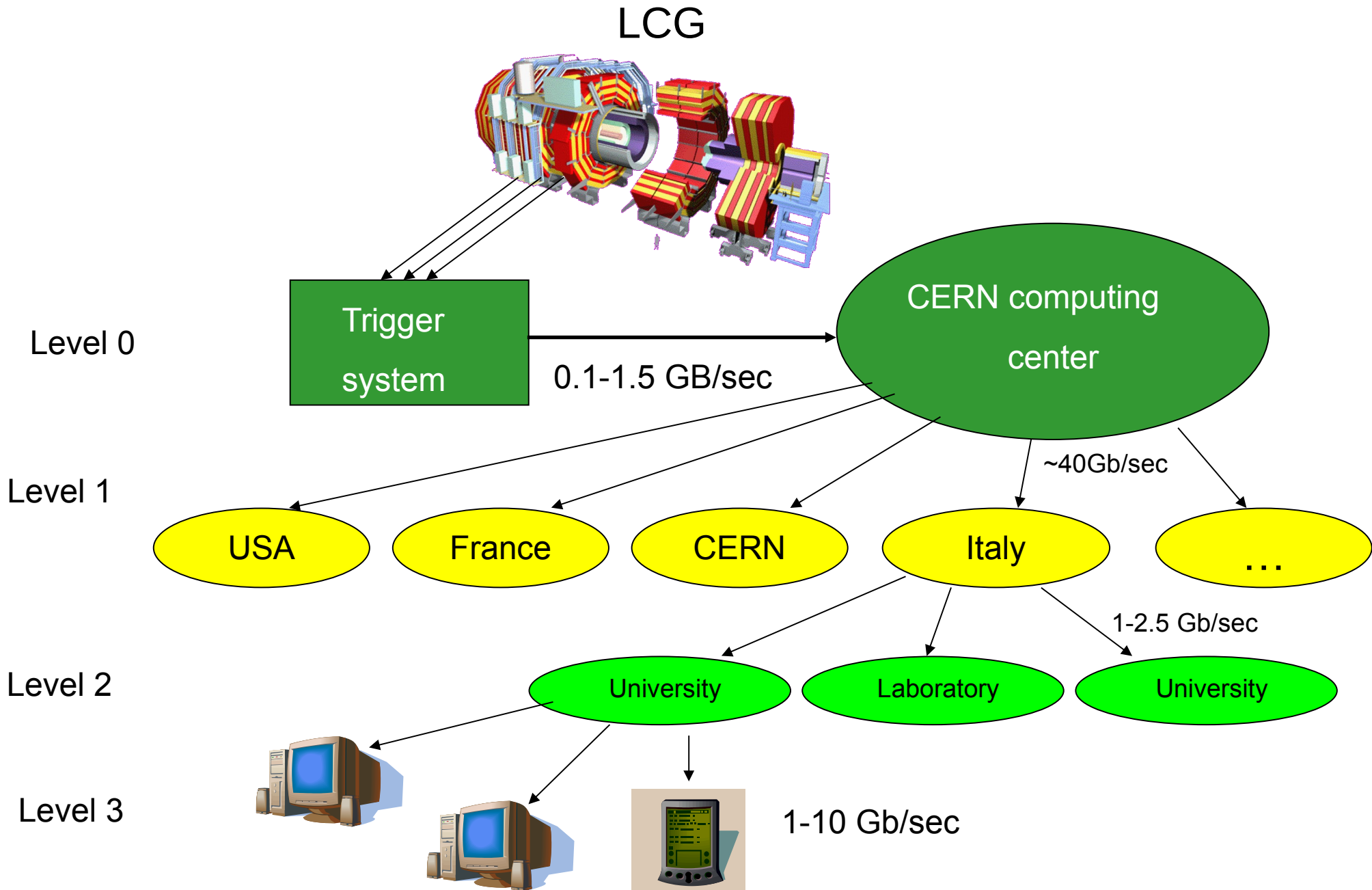


1 PB/sec

Filtering in real time:

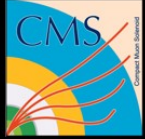
1 PB per year

Selection of interesting events and data compression



	ATLAS	CMS
MAGNET (S)	Air-core toroids + solenoid in inner cavity Calorimeters outside field 4 magnets	Solenoid Calorimeters inside field 1 magnet
TRACKER	Si pixels + strips TRD → particle identification B= 2T $\sigma/p_T \sim 5 \times 10^{-4} p_T(\text{GeV}) \oplus 0.01$	Si pixels + strips No particle identification B= 4T $\sigma/p_T \sim 1.5 \times 10^{-4} p_T(\text{GeV}) \oplus 0.005$
EM CALO	Pb-liquid argon $\sigma/E \sim 10\%/\sqrt{E}$ uniform longitudinal segmentation	PbWO ₄ crystals $\sigma/E \sim 3\%/\sqrt{E}$ no longitudinal segmentation
HAD CALO	Fe-scint. + Cu-liquid argon (10 λ) $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$	Brass-scint. (> 5.8 λ +catcher) $\sigma/E \sim 100\%/\sqrt{E} \oplus 0.05$
MUON	Air → $\sigma/p_T \sim 7\%$ at 1 TeV standalone	Fe → $\sigma/p_T \sim 5\%$ at 1 TeV combining with tracker

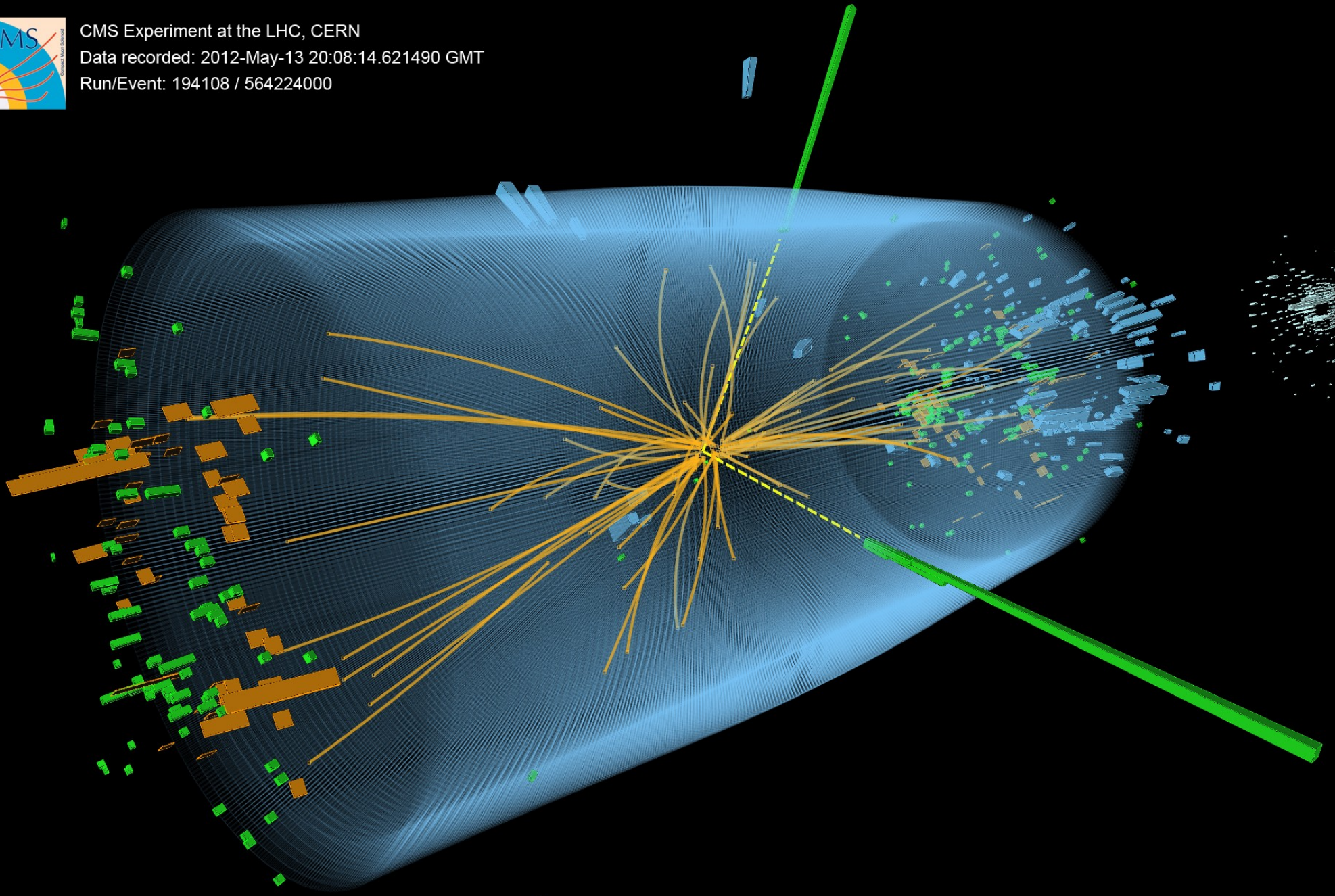
Хиггс бозон

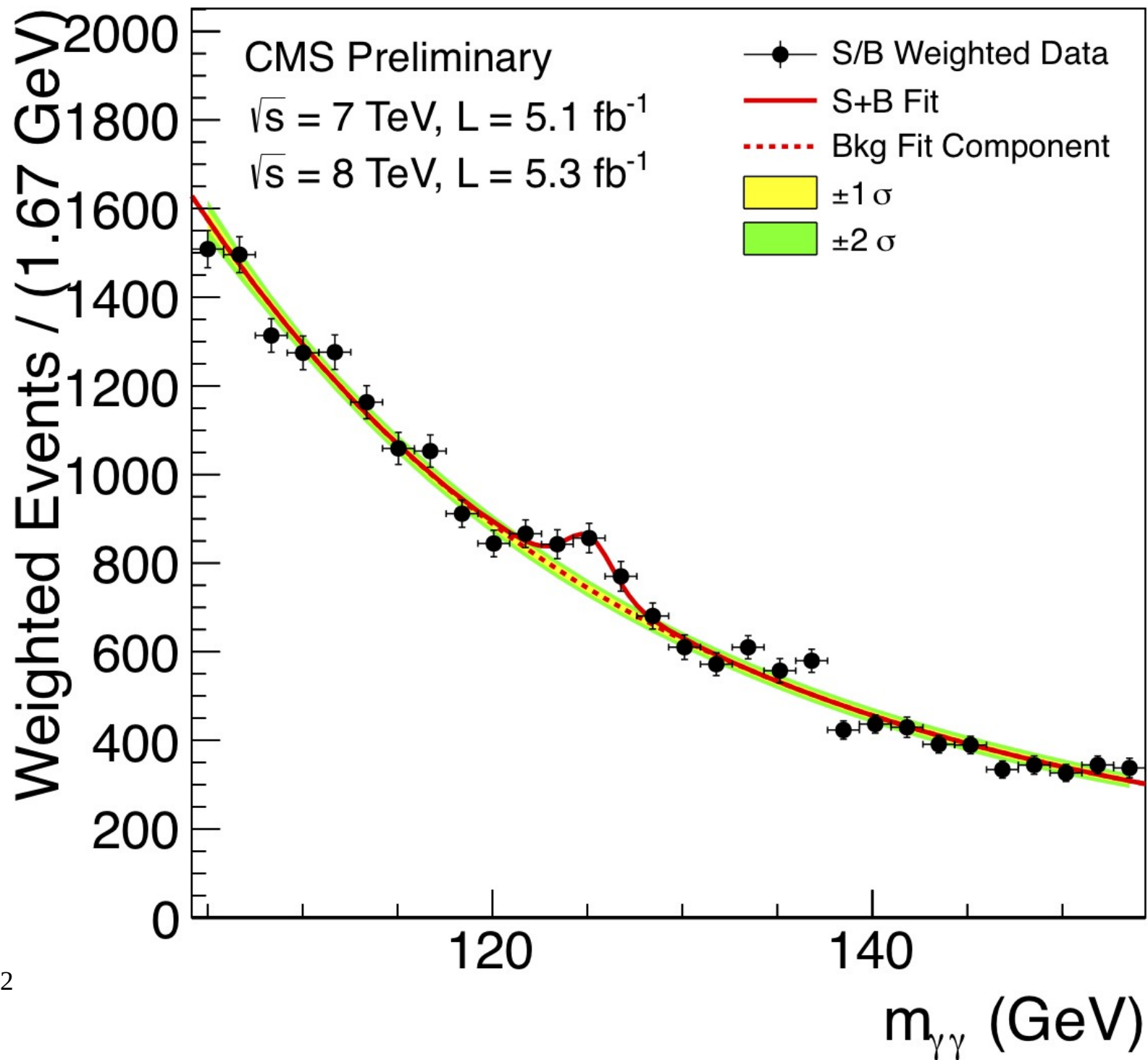


CMS Experiment at the LHC, CERN

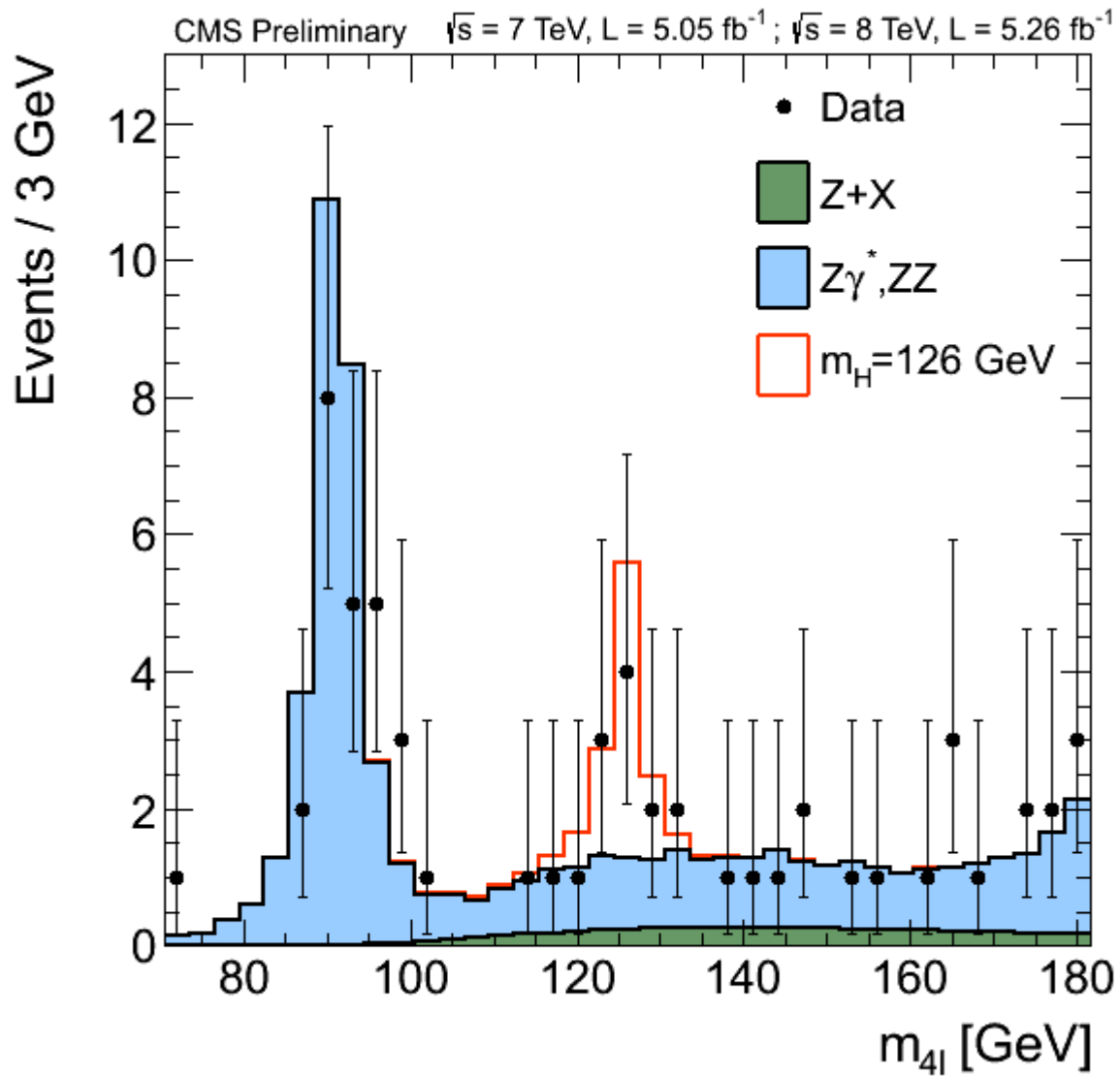
Data recorded: 2012-May-13 20:08:14.621490 GMT

Run/Event: 194108 / 564224000

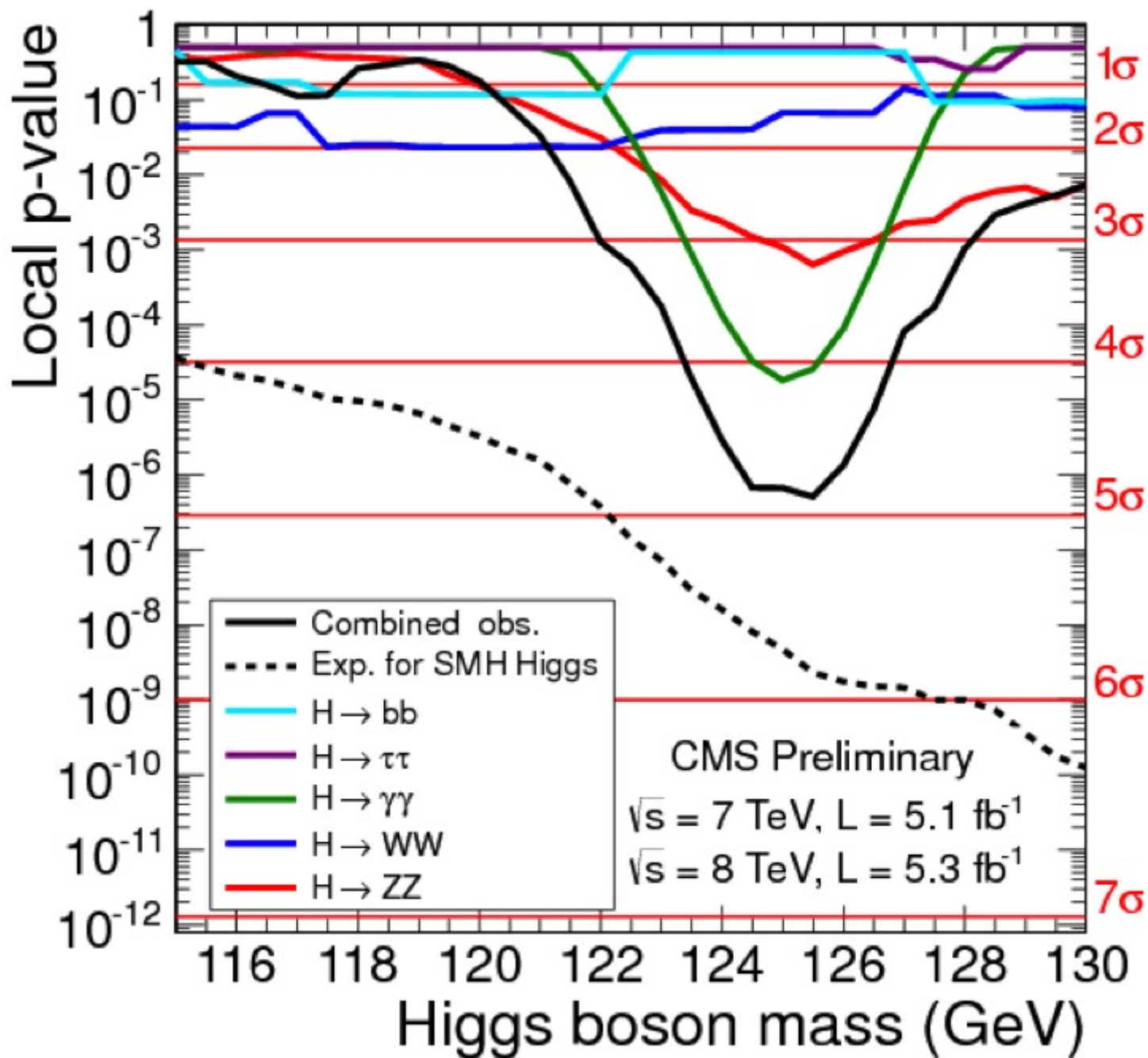




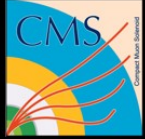
Хиггс бозон



Хиггс бозон



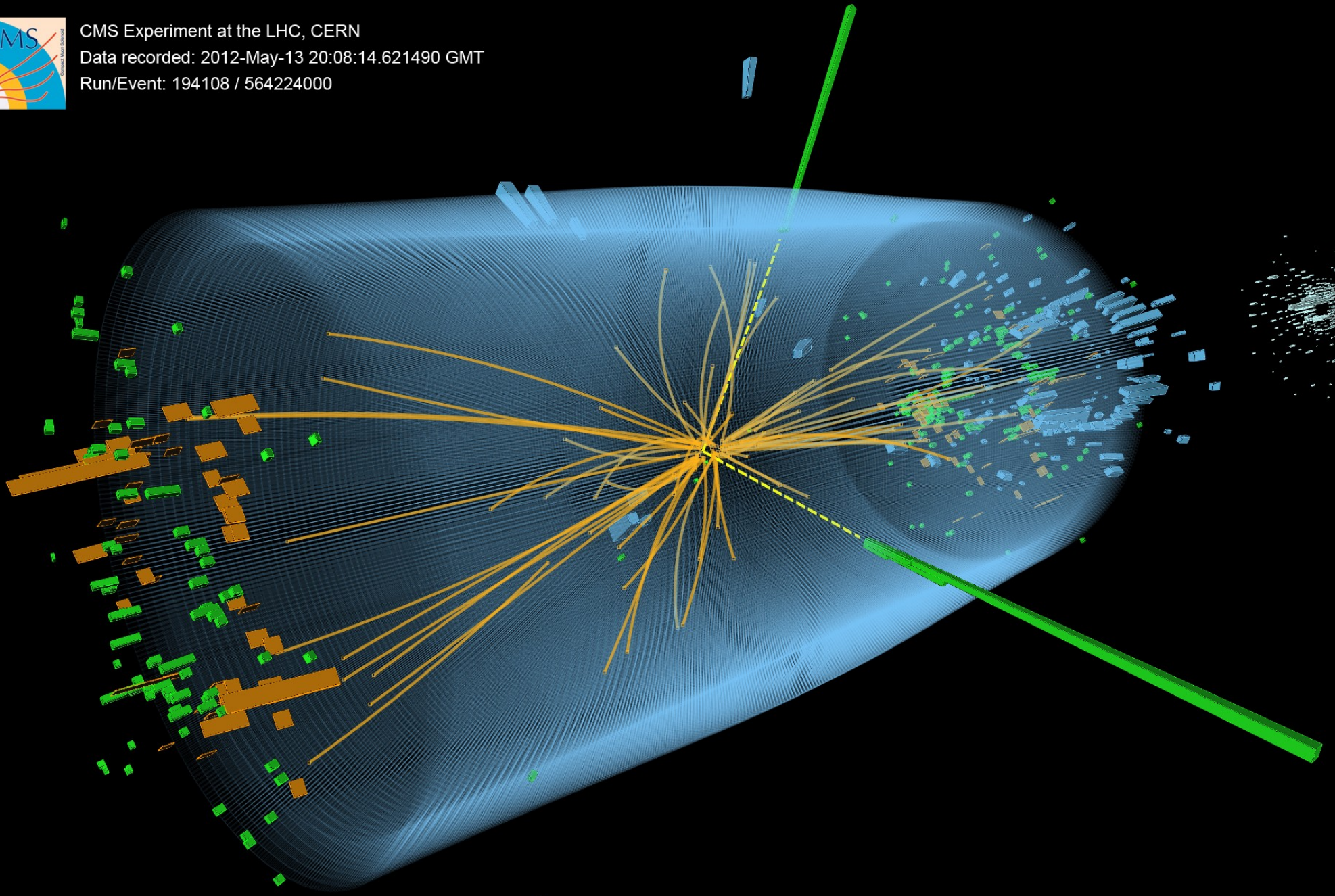
Хиггс бозон



CMS Experiment at the LHC, CERN

Data recorded: 2012-May-13 20:08:14.621490 GMT

Run/Event: 194108 / 564224000



Back up

Backup slides