European Organization for Nuclear Research
50 years of research in physics

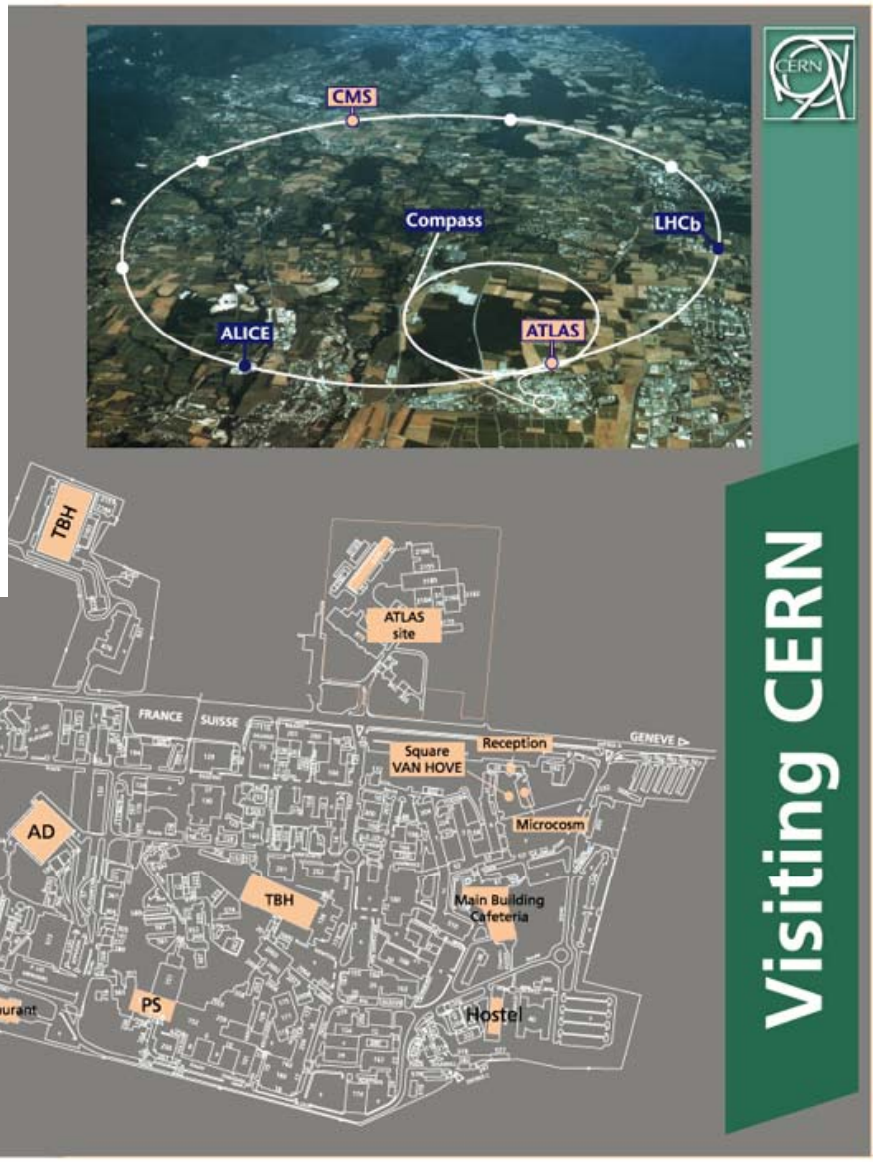
CERN

The Laboratory

Dr. Sascha Marc Schmeling
CERN PH

Introduction to CERN and High Energy Physics

- The Organization
- The Laboratory
- High Energy Physics
- The Accelerators
- The Experiments
- Spin-Offs



1949

Fi
ph

1952

Es
C
co

Oktober

Ch

1. Juli 1953

Signature of t

29. September 1954

End of the rat
member state

Belgi
Ge
Nether
Switze

La sixième session du Conseil fut organisée à Paris du 29 juin au 1er juillet 1953. C'est à cette occasion que la Convention établissant l'Organisation fut signée, sous réserve de ratification, par douze Etats membres.

For the German Federal Republic — Pour la République Fédérale d'Allemagne
subject to ratification

For the Kingdom of Belgium — Pour le Royaume de Belgique
sous réserve de ratification

For the Kingdom of Denmark — Pour le Royaume de Danemark
sous réserve de ratification

For the French Republic — Pour la République Française
sous reserve de ratification

For the Kingdom of Greece — Pour le Royaume de Grèce
sous reserve de ratification.

For Italy — Pour l'Italie
sous reserve de ratification

For the Kingdom of Norway — Pour le Royaume de Norvège
Subject to ratification
31/12 1953.

For the Kingdom of the Netherlands — Pour le Royaume des Pays-Bas
Subject to ratification

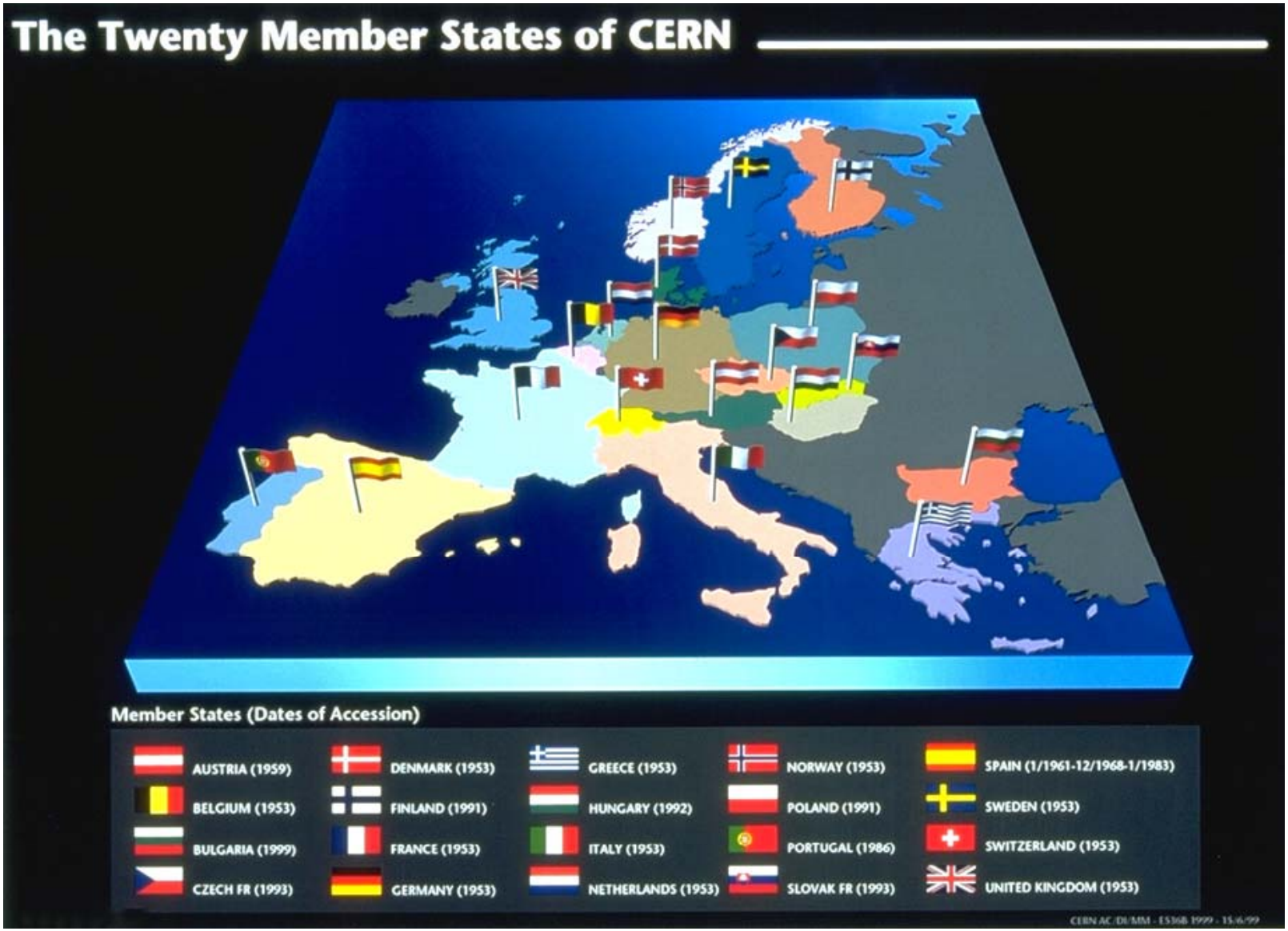
For the United Kingdom of Great Britain and Northern Ireland — Pour le Royaume-Uni de la Grande-Bretagne et de l'Irelande du Nord
Subject to ratification.

For the Kingdom of Sweden — Pour le Royaume de Suède
Subject to ratification

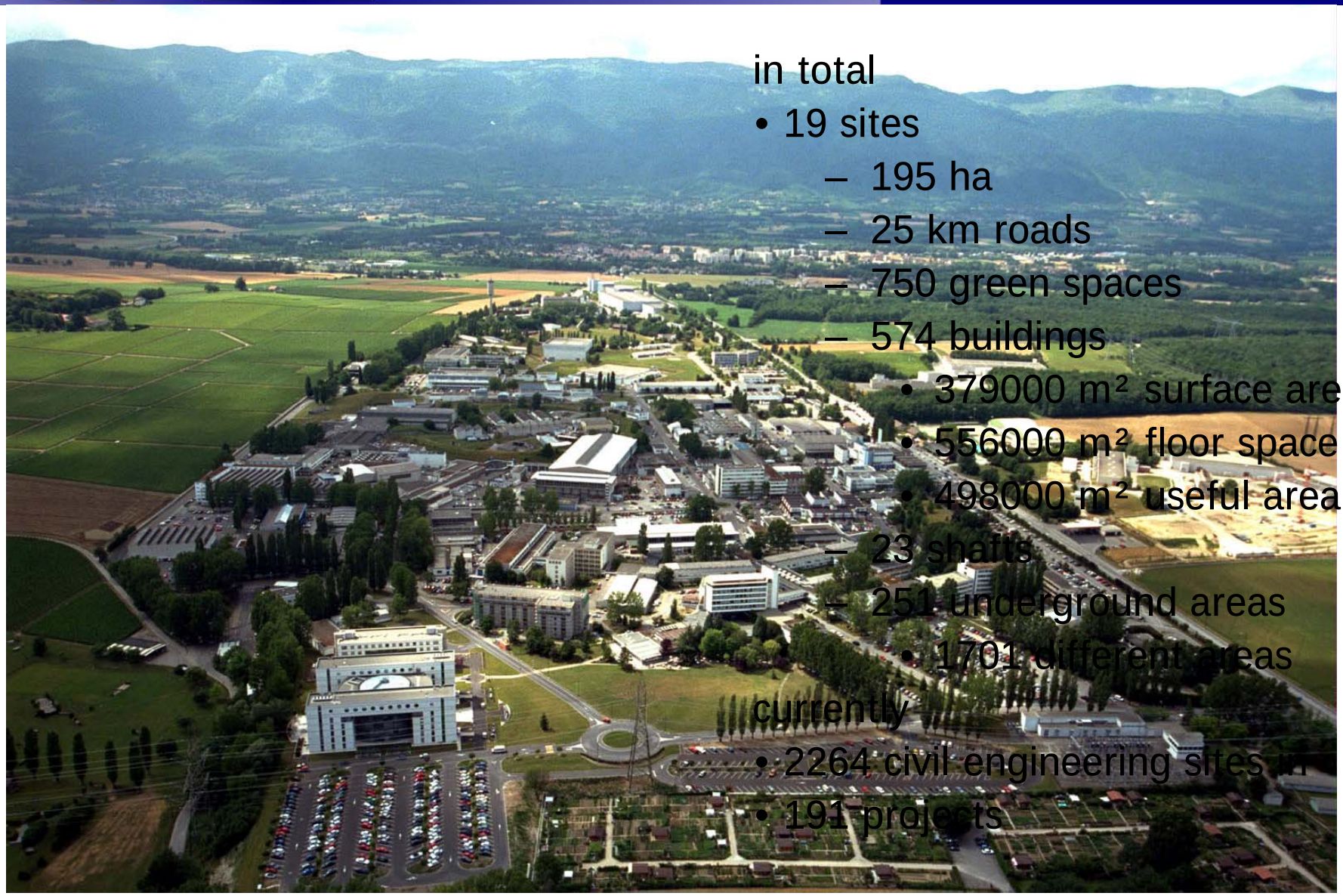
For the Confederation of Switzerland — Pour la Confédération Suisse
sous réserve de ratification.

For the Federal People's Republic of Yugoslavia — Pour la République Fédérative Populaire de Yougoslavie
sous réserve de ratification

The Sixth Session of the CERN Council took place in Paris on 29 June—1 July 1953. It was here that the Convention establishing the Organization was signed, subject to ratification, by twelve States.


The Twenty Member States of CERN
Member States (Dates of Accession)
AUSTRIA (1959)
BELGIUM (1953)
BULGARIA (1999)
CZECH FR (1993)
DENMARK (1953)
FINLAND (1991)
FRANCE (1953)
GERMANY (1953)
GREECE (1953)
HUNGARY (1992)
ITALY (1953)
NETHERLANDS (1953)
NORWAY (1953)
POLAND (1991)
PORTUGAL (1986)
SLOVAK FR (1993)
SPAIN (1/1961-12/1968-1/1983)
SWEDEN (1953)
SWITZERLAND (1953)
UNITED KINGDOM (1953)

CERN – The Laboratory



in total

- 19 sites
  - 195 ha
  - 25 km roads
  - 750 green spaces
  - 574 buildings
    - 379000 m² surface area
    - 556000 m² floor space
    - 498000 m² useful area
  - 23 shafts
  - 251 underground areas
    - 1701 different areas

currently

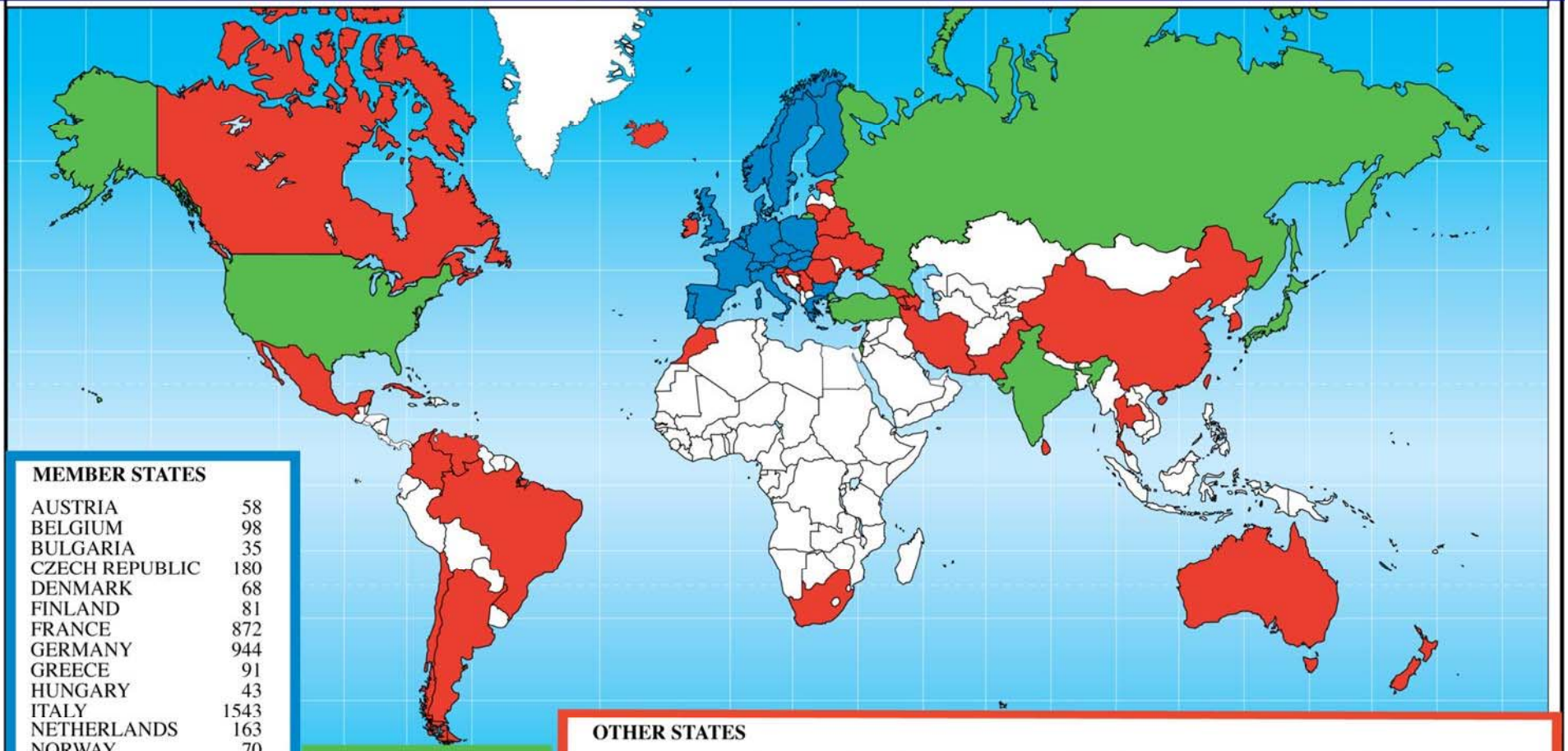
- 2264 civil engineering sites in
- 191 projects

CERN Organisation

DG
CEO

HR	FI	AB	AT	TS	IT	PH
Human Resources	Finance	Accelerators & Beams	Accelerator Technology	Technical Support	Information Technology	Physics
Enrico Chiaveri	Patrick Geeraert	Stephen Myers	Philippe Lebrun	Paolo Ciriani	Wolfgang von Rüden	Jean-Jacques Blaising

Distribution of All CERN Users by Nation of Institute on 5 February 2008



MEMBER STATES

AUSTRIA	58
BELGIUM	98
BULGARIA	35
CZECH REPUBLIC	180
DENMARK	68
FINLAND	81
FRANCE	872
GERMANY	944
GREECE	91
HUNGARY	43
ITALY	1543
NETHERLANDS	163
NORWAY	70
POLAND	175
PORTUGAL	109
SLOVAKIA	46
SPAIN	270
SWEDEN	74
SWITZERLAND	344
UNITED KINGDOM	645

5909

OBSERVER STATES

INDIA	93
ISRAEL	64
JAPAN	182
RUSSIA	940
TURKEY	35
USA	1278

2592

OTHER STATES

ARGENTINA	8	CROATIA	17	MEXICO	23	TAIWAN	40
ARMENIA	17	CUBA	3	MONTENEGRO	1	THAILAND	1
AUSTRALIA	13	CYPRUS	6	MOROCCO	6	UKRAINE	17
AZERBAIJAN	1	ESTONIA	10	NEW ZEALAND	7		
BELARUS	23	GEORGIA	9	PAKISTAN	23		
BRAZIL	68	ICELAND	1	ROMANIA	46		
CANADA	119	IRAN	6	SERBIA	16		
CHILE	4	IRELAND	14	SLOVENIA	16		
CHINA	60	KOREA	44	SOUTH AFRICA	2		
COLOMBIA	5	LITHUANIA	5	SRI LANKA	1		

632

Research to discover the principles that keep the world together.

Search for

- elementary particles
- forces
- symmetries

Physique des Particules
Physique Nucléaire
Physique du Solide
Chimie - Biologie
Mécanique
Cosmologie
Astrophysique
Astronomie
Géophysique

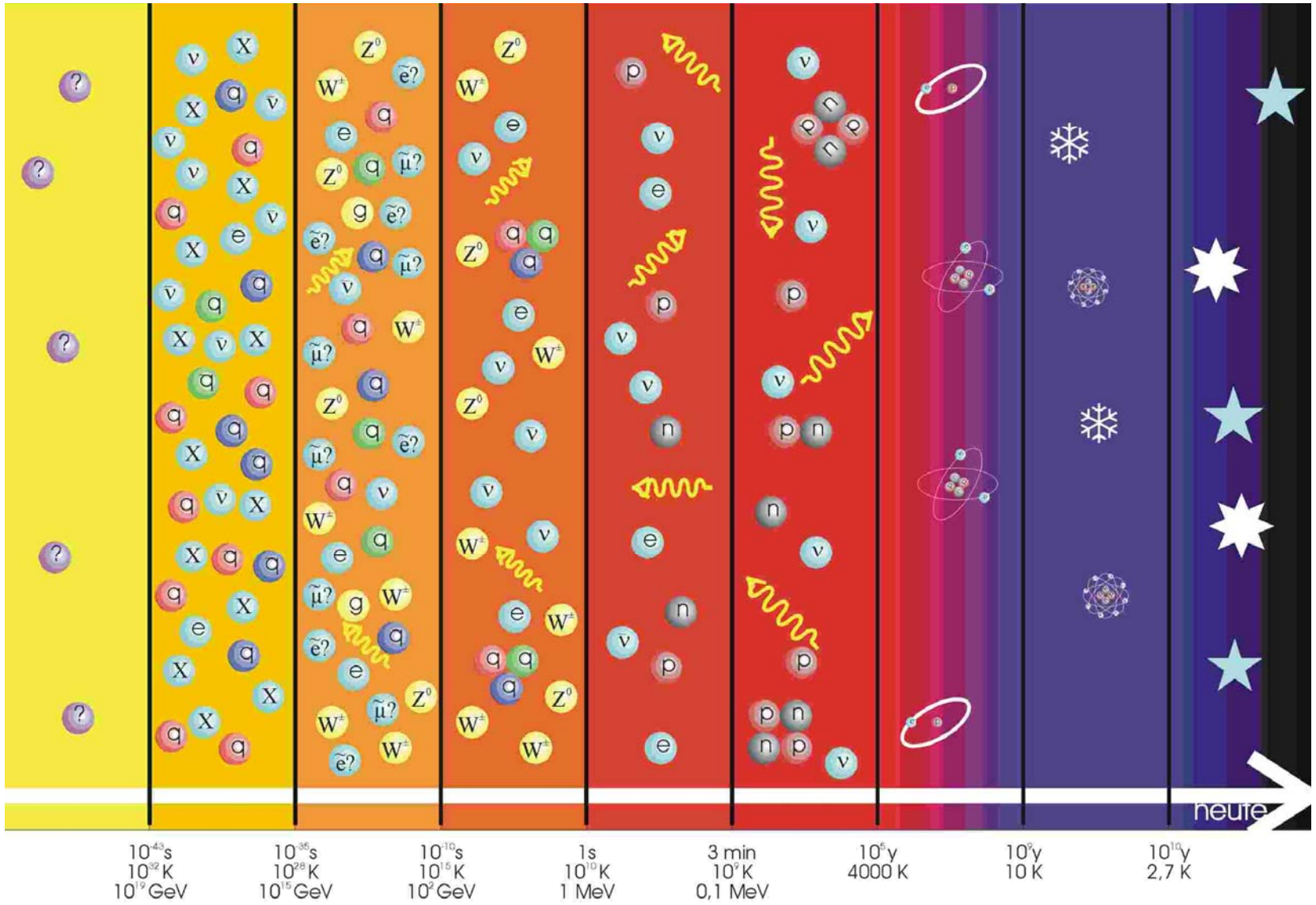
10^{-15} 10^{-12} 10^{-9} 10^{-6} 10^{-3} 1 10^{3} 10^{6} 10^{9} 10^{12} 10^{15} 10^{18} 10^{21} 10^{24}

fm pm nm μm mm m km Mm Gm Tm Pm Em

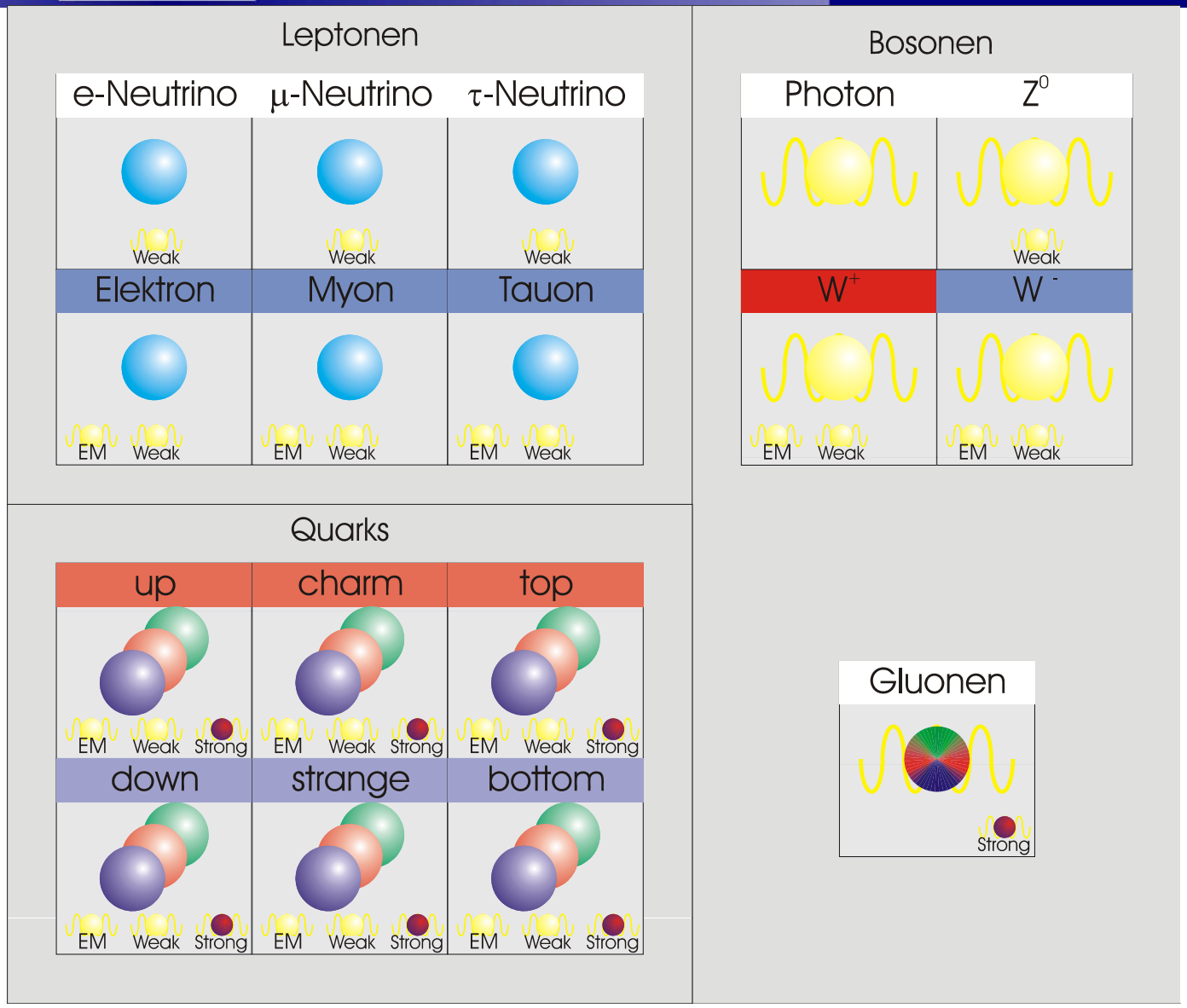
10^{-15} m = 0,000 000 000 000 001 m

D.Bertola/CERN

History of the Universe



Standard Model

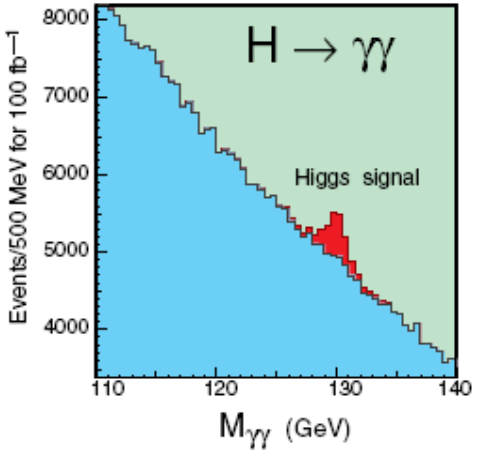


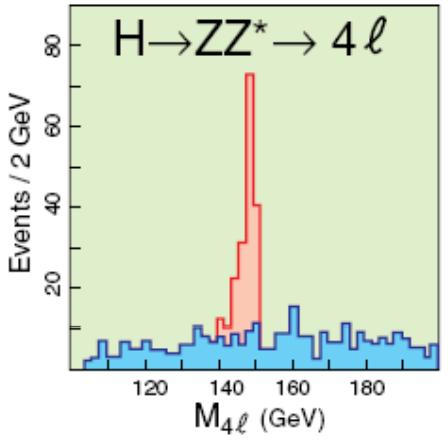
Higgs the mystery of mass

What causes particles to have mass? Why do the masses of fundamental particles differ so enormously - the top quark is more than 200,000 times heavier than the electron?

A solution has been developed by several physicists and takes the name of Peter Higgs. According to this, the whole of space is permeated by a field, similar in some ways to the electromagnetic field. As particles move through space they travel through this field. The interaction between the particles and the field is similar to the action of a viscous force felt by a particle moving through a thick liquid. The stronger the interaction of the particles with the Higgs field, the more mass they appear to have.

We know from quantum theory that fields have particles associated with them, so if the Higgs idea is right, there must be a Higgs particle. Finding it is the key to verifying whether our best hypothesis for the origin of mass is indeed correct.





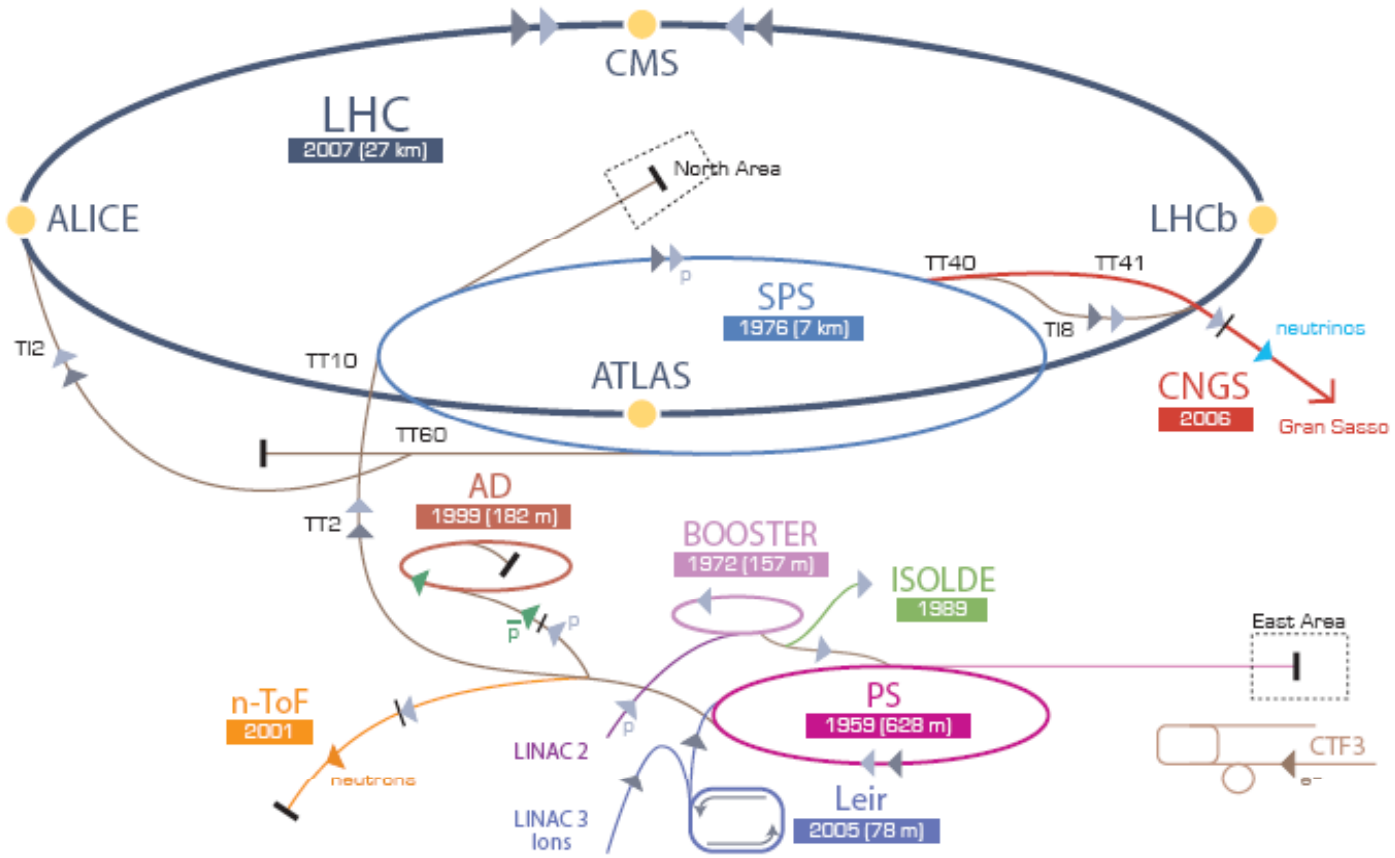
Reach high energies with accelerators

- natural accelerators
  - Astroparticle Physics
- artificial accelerators
  - Particle Physics

Probing of interactions of matter and antimatter with detectors

Accelerators at CERN

CERN Accelerator Complex

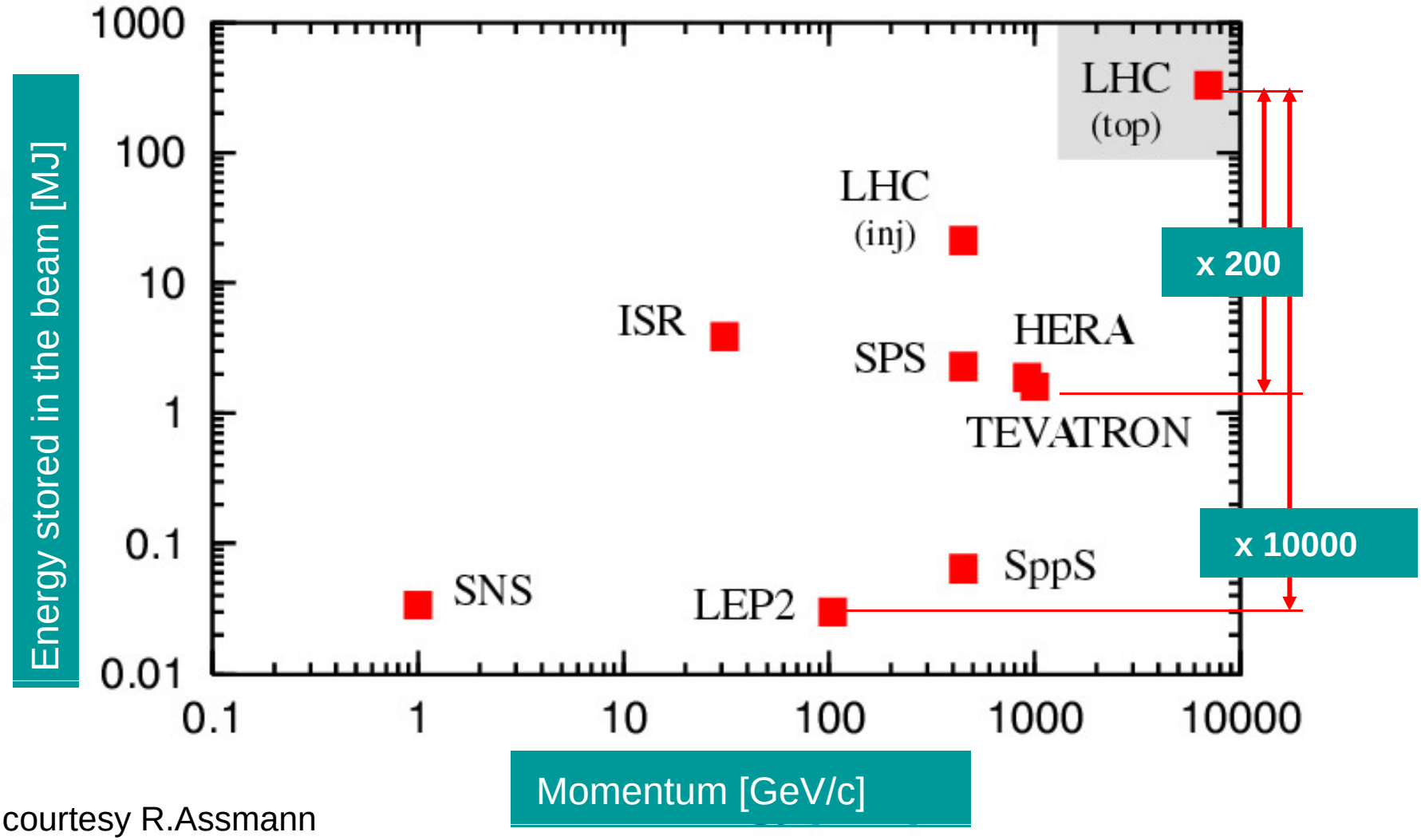


LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron

AD Antiproton Decelerator CTF3 Clic Test Facility CNGS Cern Neutrinos to Gran Sasso ISOLDE Isotope Separator OnLine DEvice

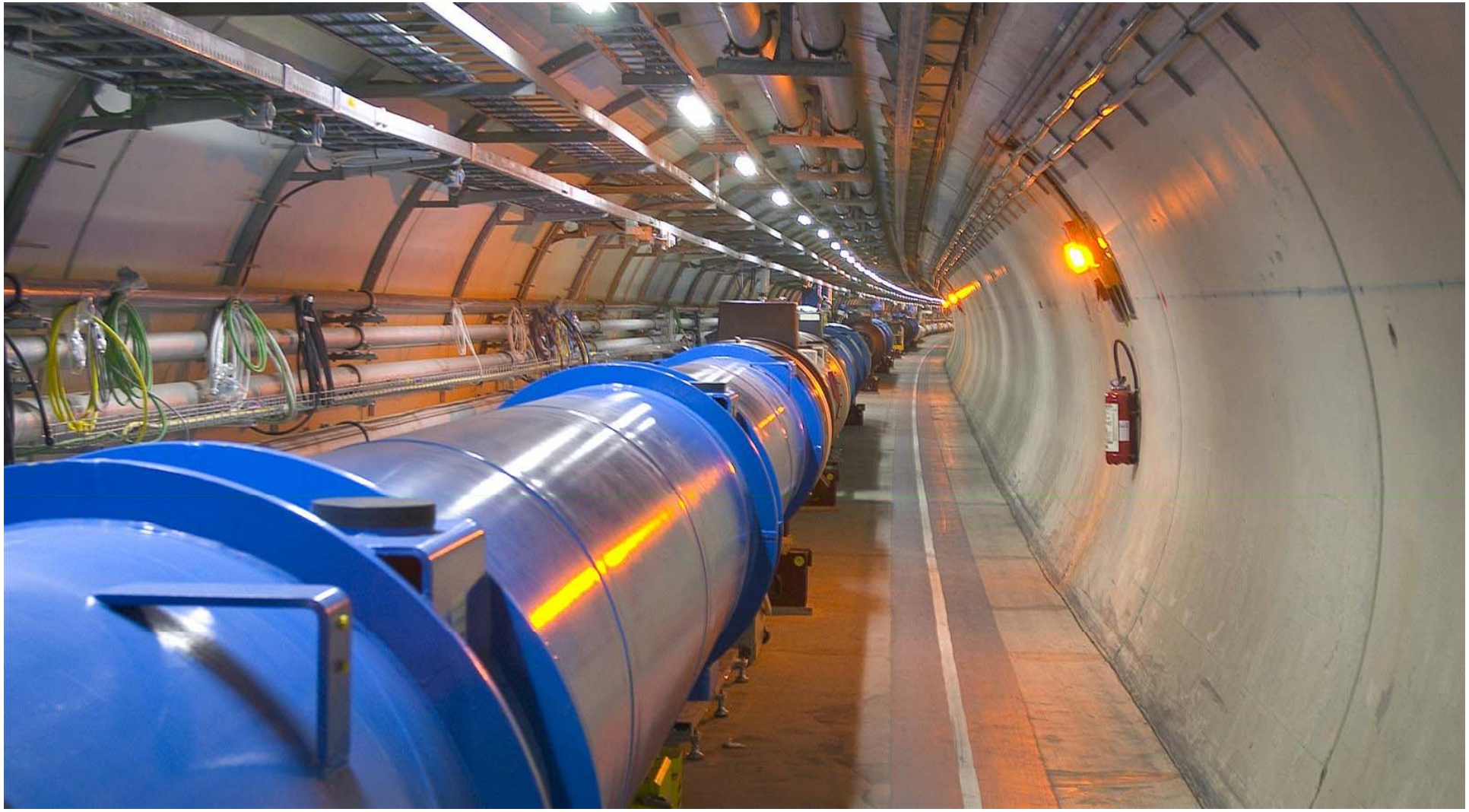
LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight

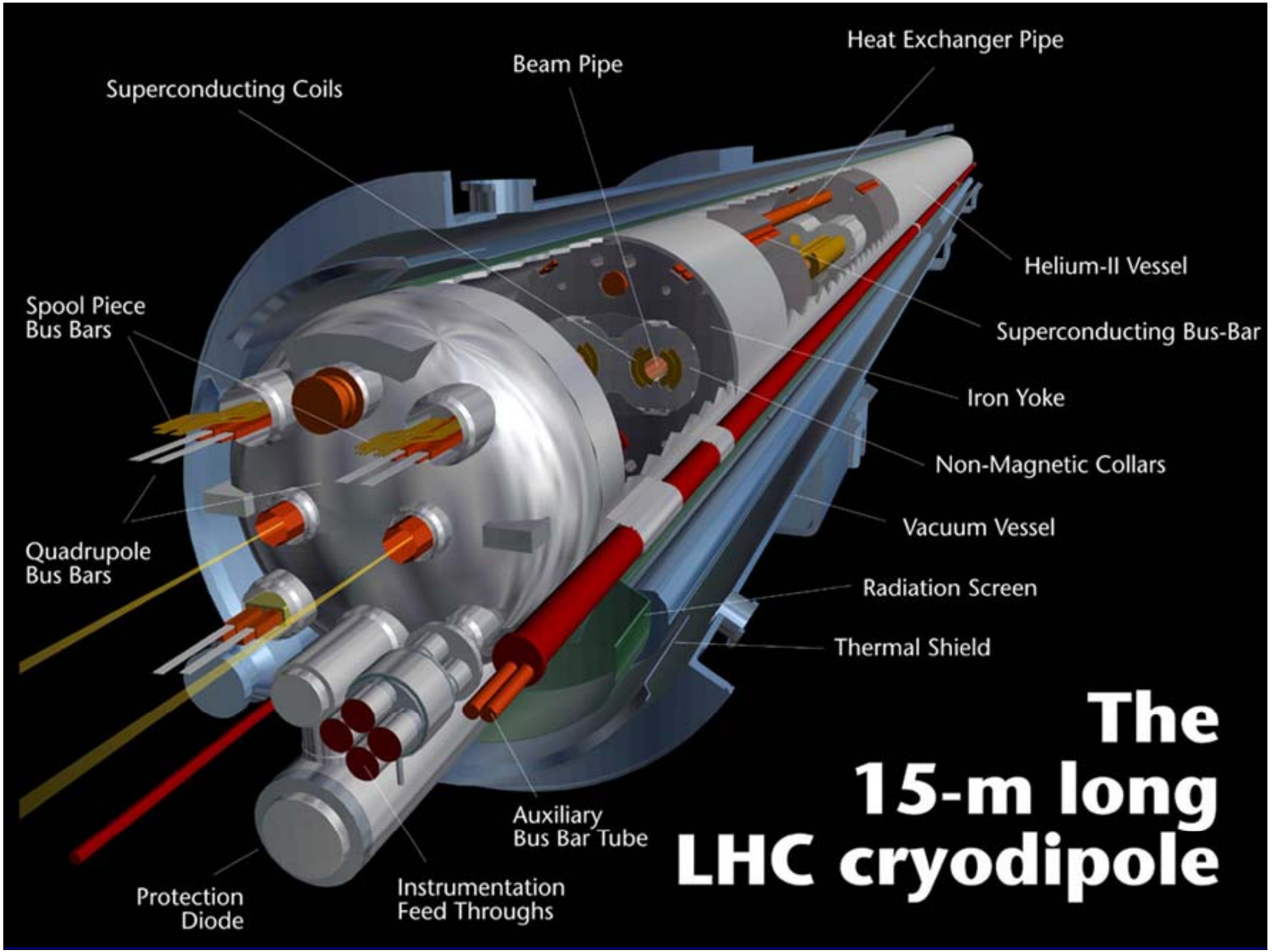
Challenges: Energy stored in the beam



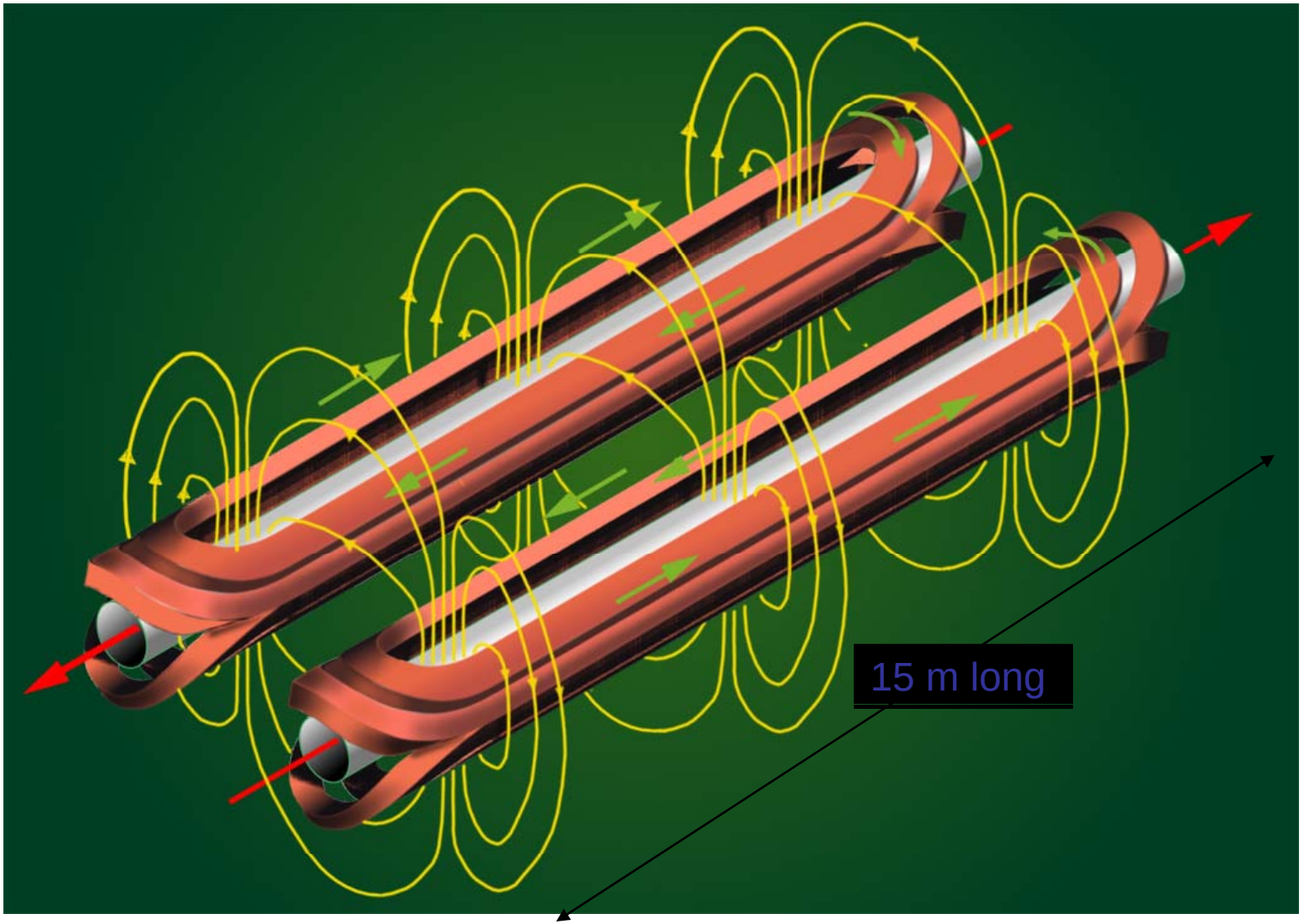
courtesy R.Assmann

LHC Tunnel

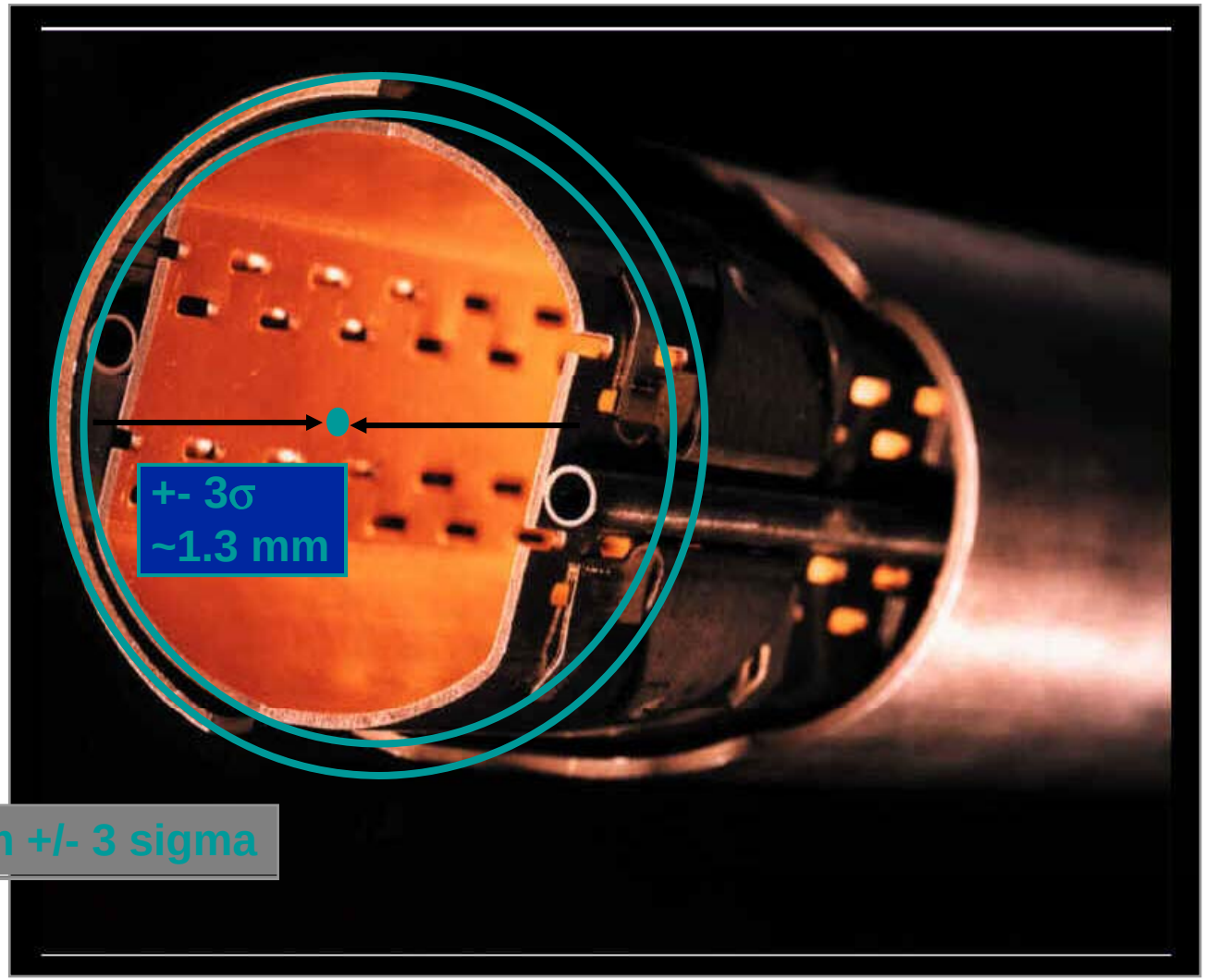



Heat Exchanger Pipe
Beam Pipe
Superconducting Coils
Helium-II Vessel
Spool Piece
Bus Bars
Superconducting Bus-Bar
Iron Yoke
Non-Magnetic Collars
Quadrupole
Bus Bars
Vacuum Vessel
Radiation Screen
Thermal Shield
The
15-m long
LHC cryodipole
Auxiliary
Bus Bar Tube
Protection
Diode
Instrumentation
Feed Throughs

Coils for Dipolemagnets



56.0 mm



Beam +/- 3 sigma

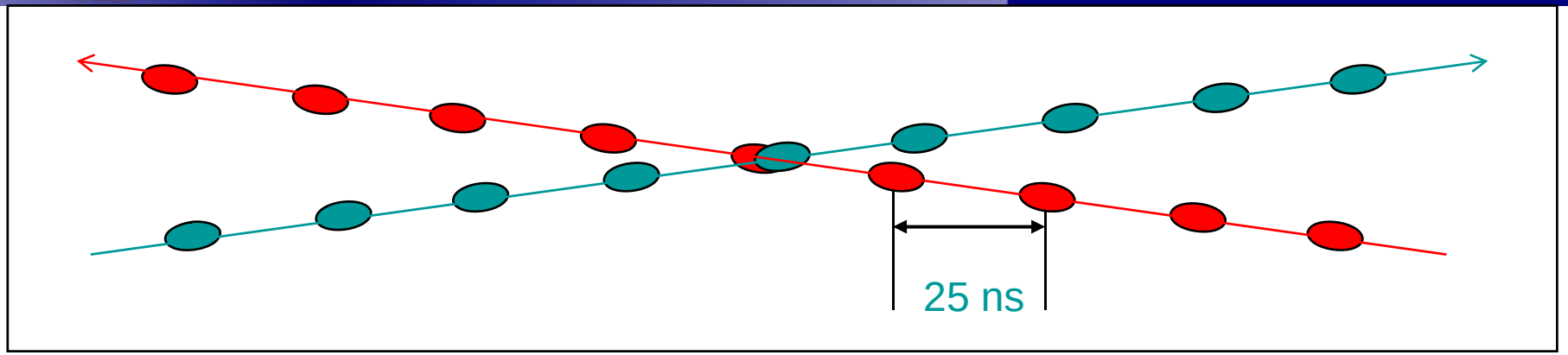
Energy stored in LHC magnets

$$E_{dipole} = 0.5 \bullet L_{dipole} \bullet I^2_{dipole}$$

Energy stored in one dipole is 7.6 MJoule

For all 1232 dipoles in the LHC: 9.4 GJ

Energy stored in the beams



Beam energy: Proton Energy • Number of Bunches • Number of protons per bunch

Proton Energy: 7 TeV

In order to achieve very high luminosity:

Number of bunches per beam: 2808

Number of protons per bunch: $1.05 \bullet 10^{11}$

Energy per beam: 346 MJoule

What does this mean?

10 GJoule……

corresponds to the energy of 1900 kg TNT

corresponds to the energy of 400 kg Chocolate

corresponds to the energy for heating and melting
12000 kg of copper

corresponds to the energy produced by of one nuclear power plant during about 10 seconds

Could this damage equipment?

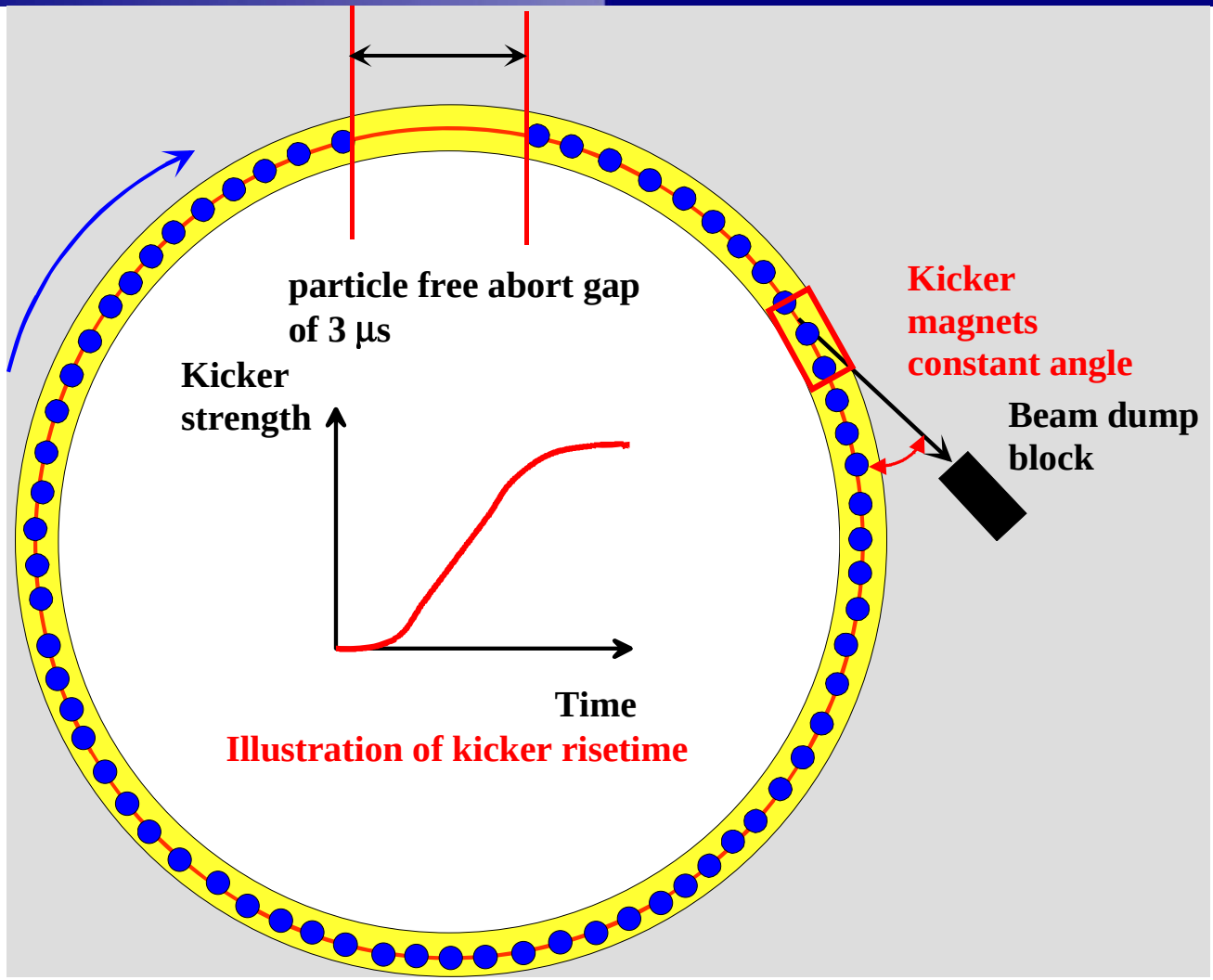
How fast can this energy be released?

Requirement for clean beam dump

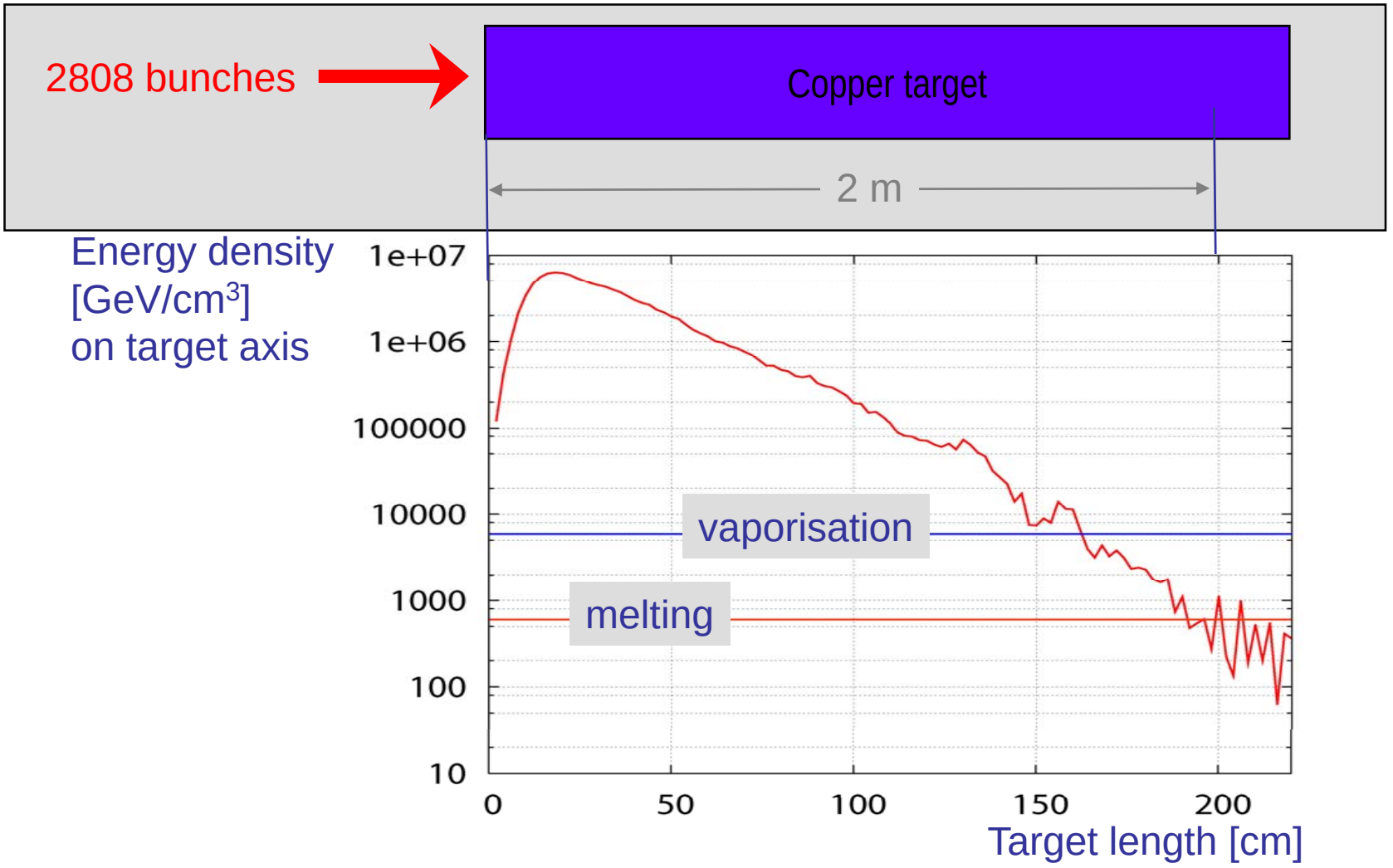
Beam dump must be synchronised with particle free gap

Strength of kicker and septum magnets must match energy of the beam

« Particle free gap » must be free of particles

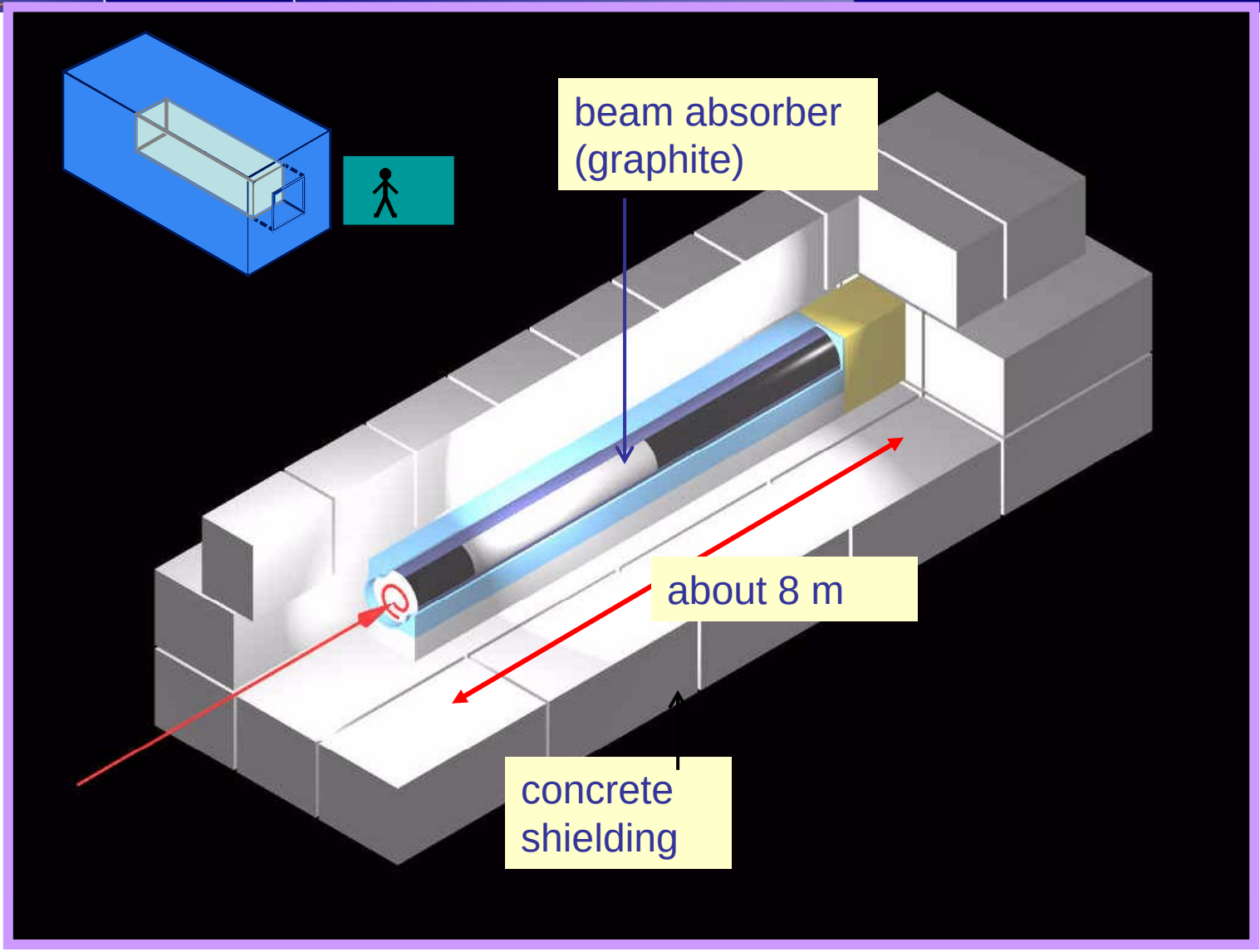


Full LHC beam deflected into copper target

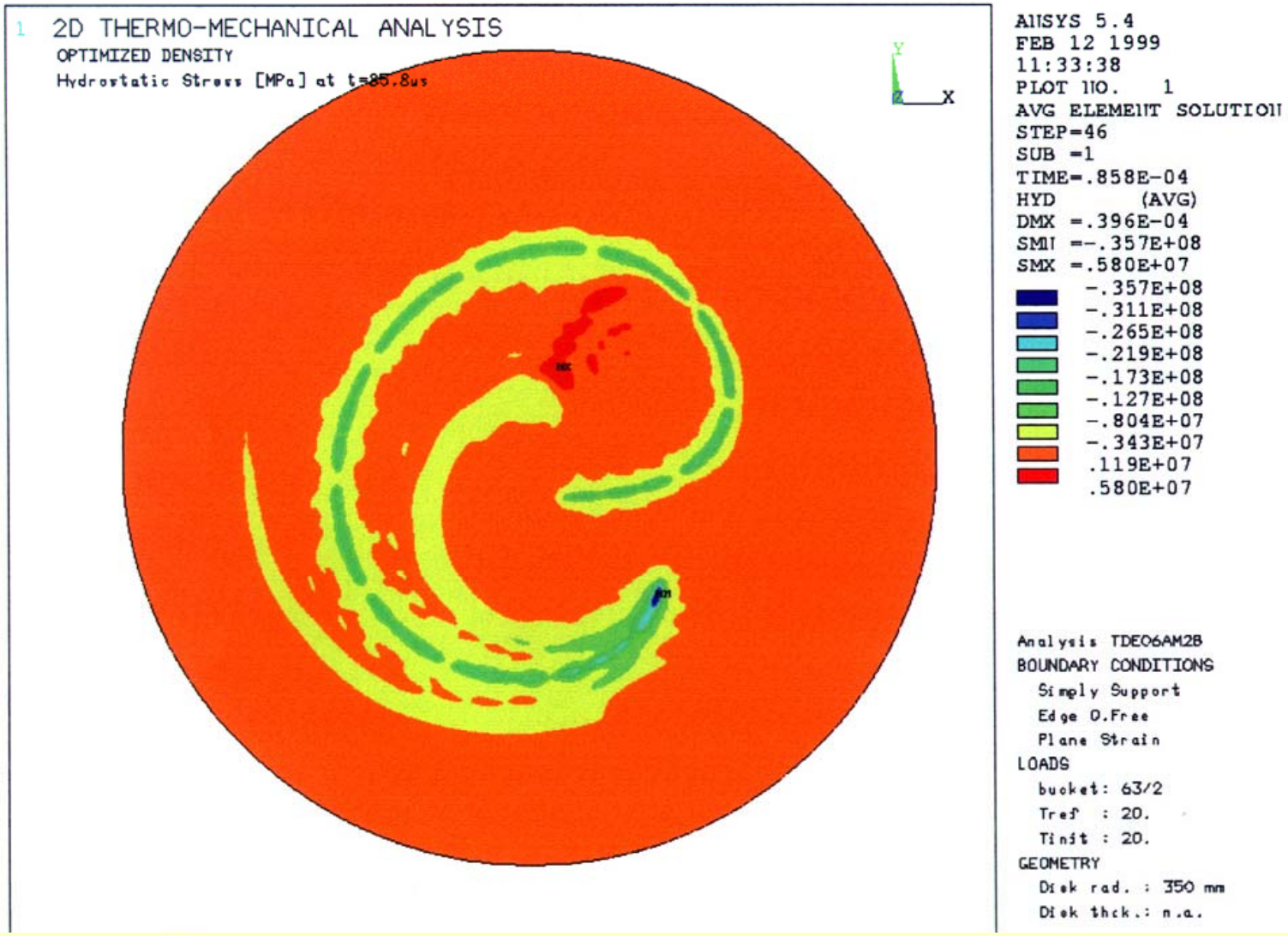


N.Tahir (GSI) et al.

Beam Dump Block - Layout



Hydrostatic stress after beam deposition



L.Bruno: Thermo-Mechanical Analysis with ANSYS

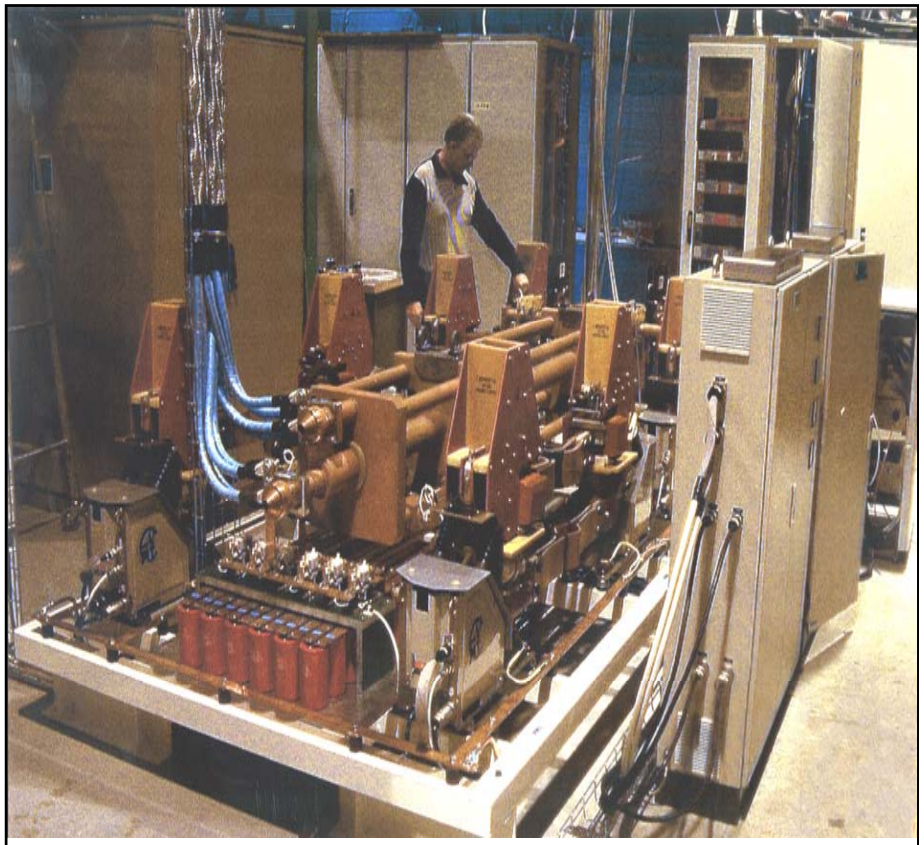
Machine protection: Magnet energy

Energy in dipole magnets: 10 GJoule

… per sector reduced to 1.3 GJoule

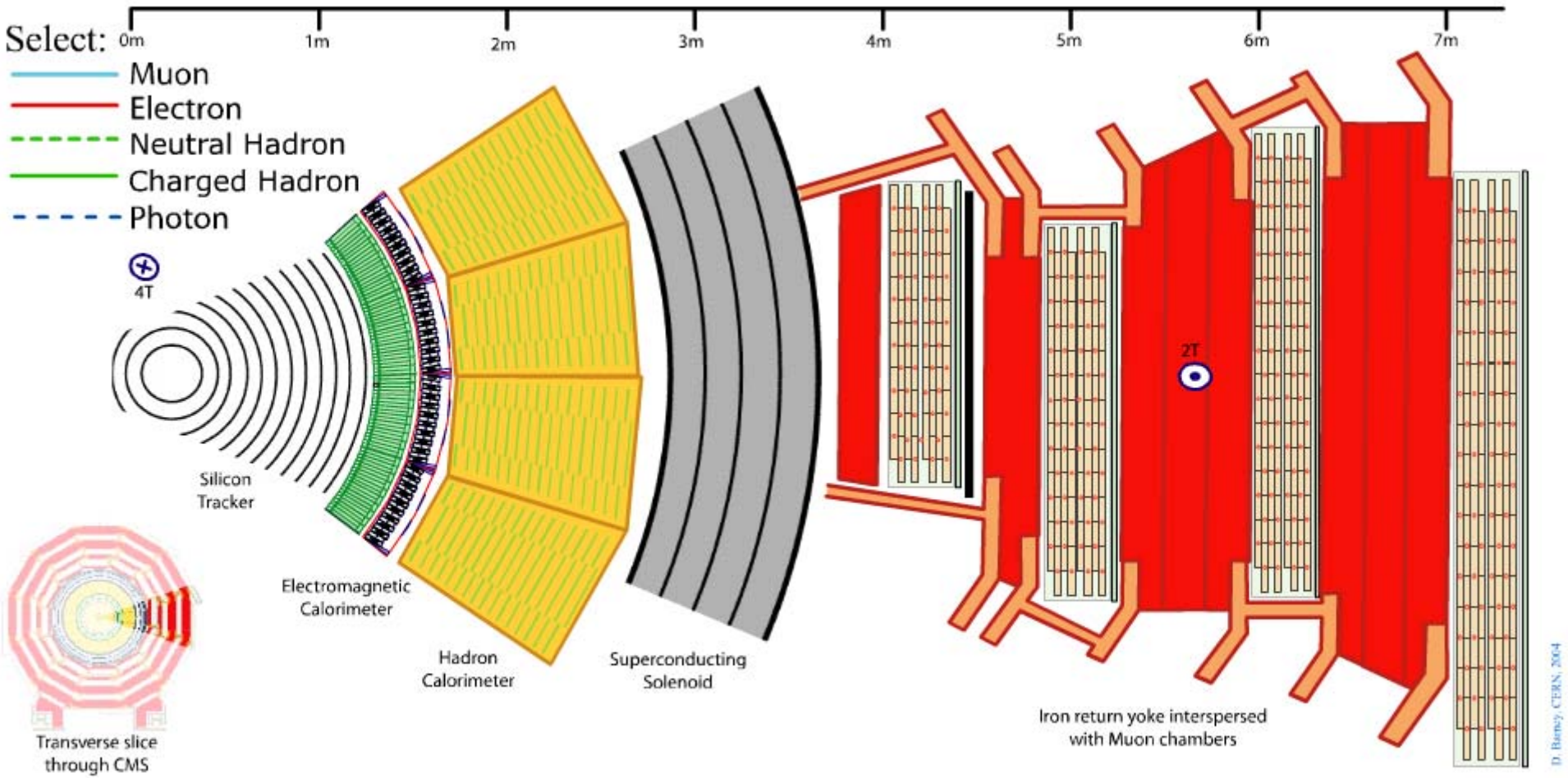
Uncontrolled release of energy is prevented:

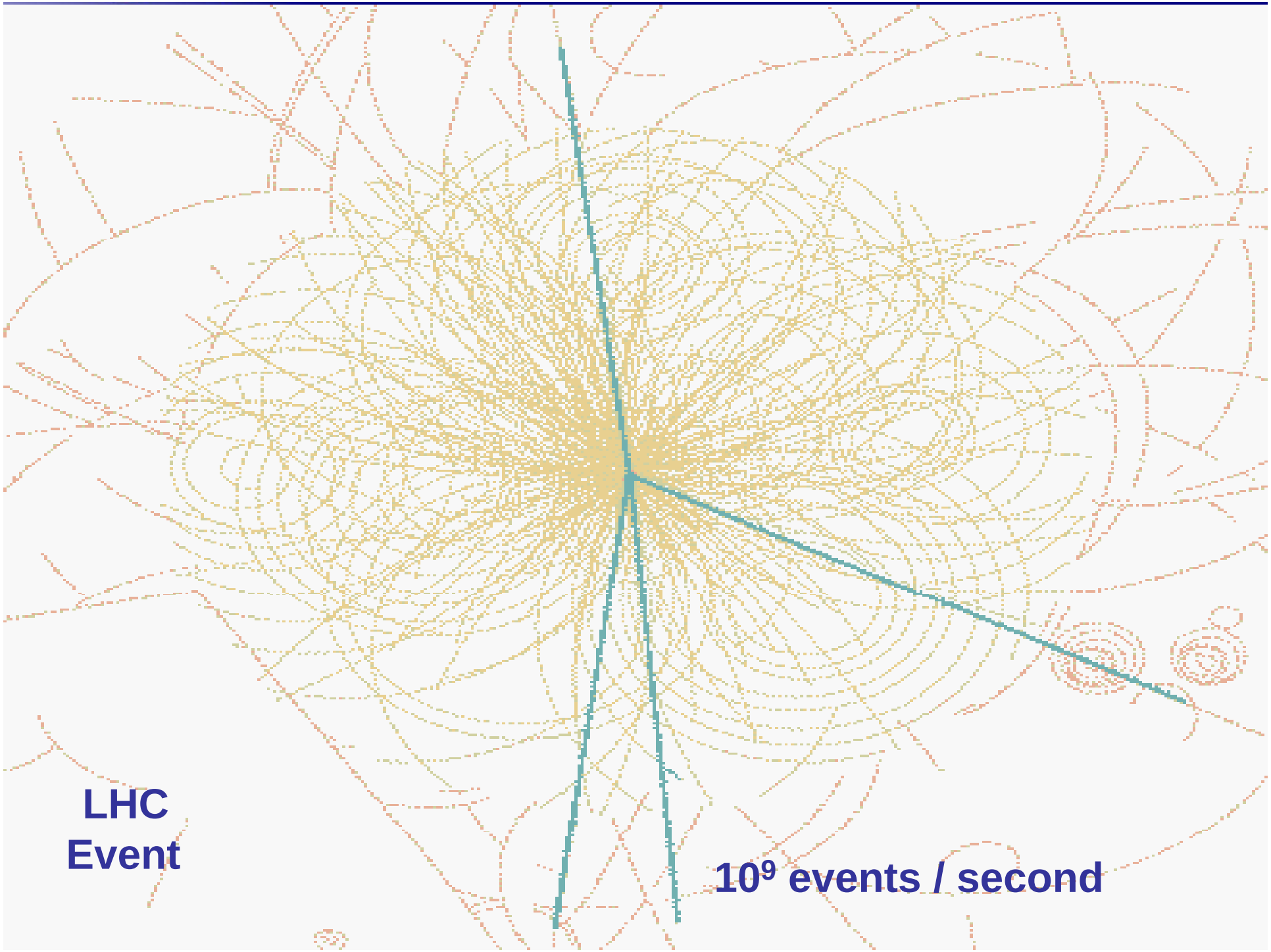
- **Fire quench heaters**
- **Current by-passes magnet via power diode**
- **Extract energy by switching a resistor into the circuit - the resistor with a mass of eight tons is heated to 300 °C**

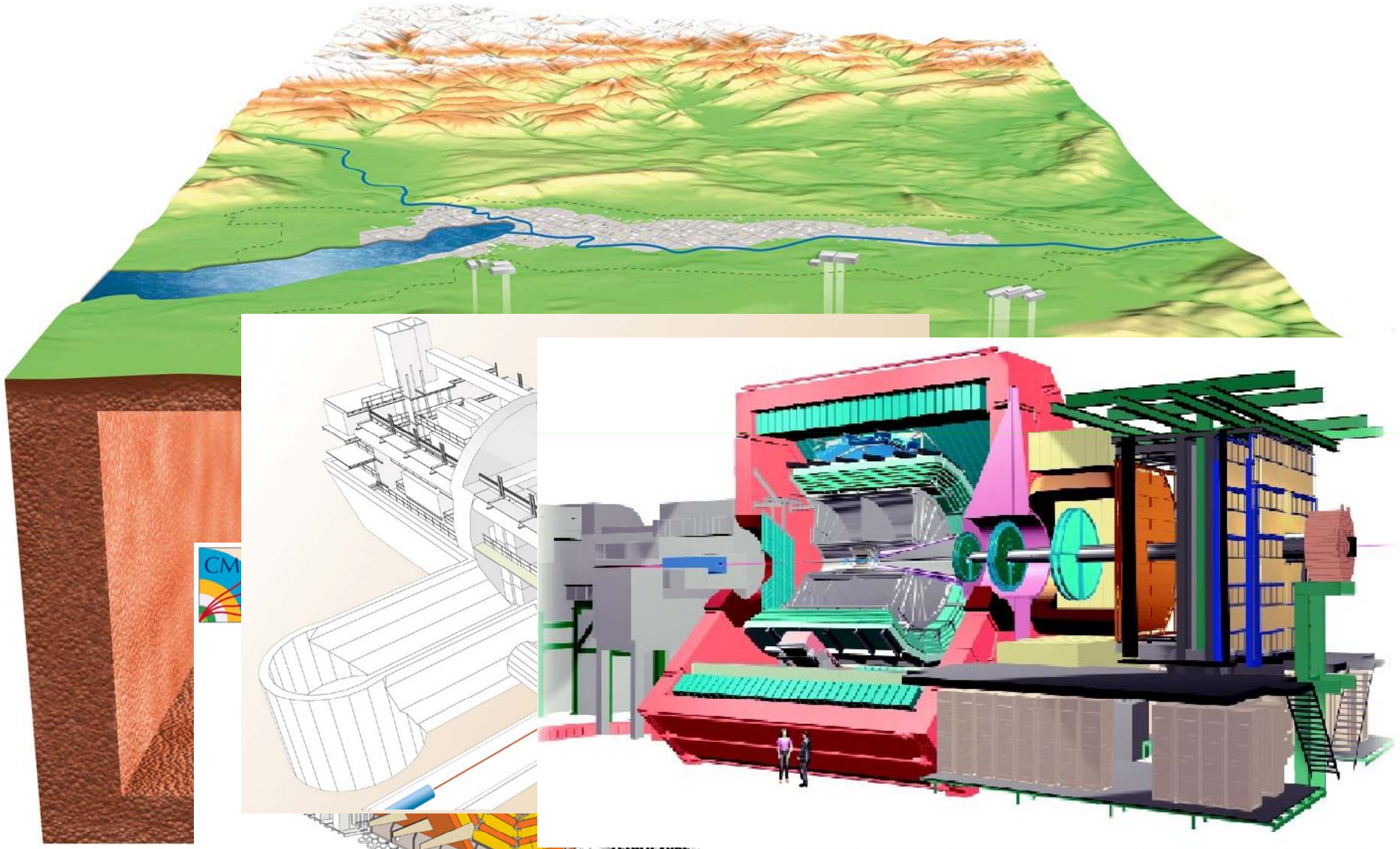


13 kA switches from Protvino Russia

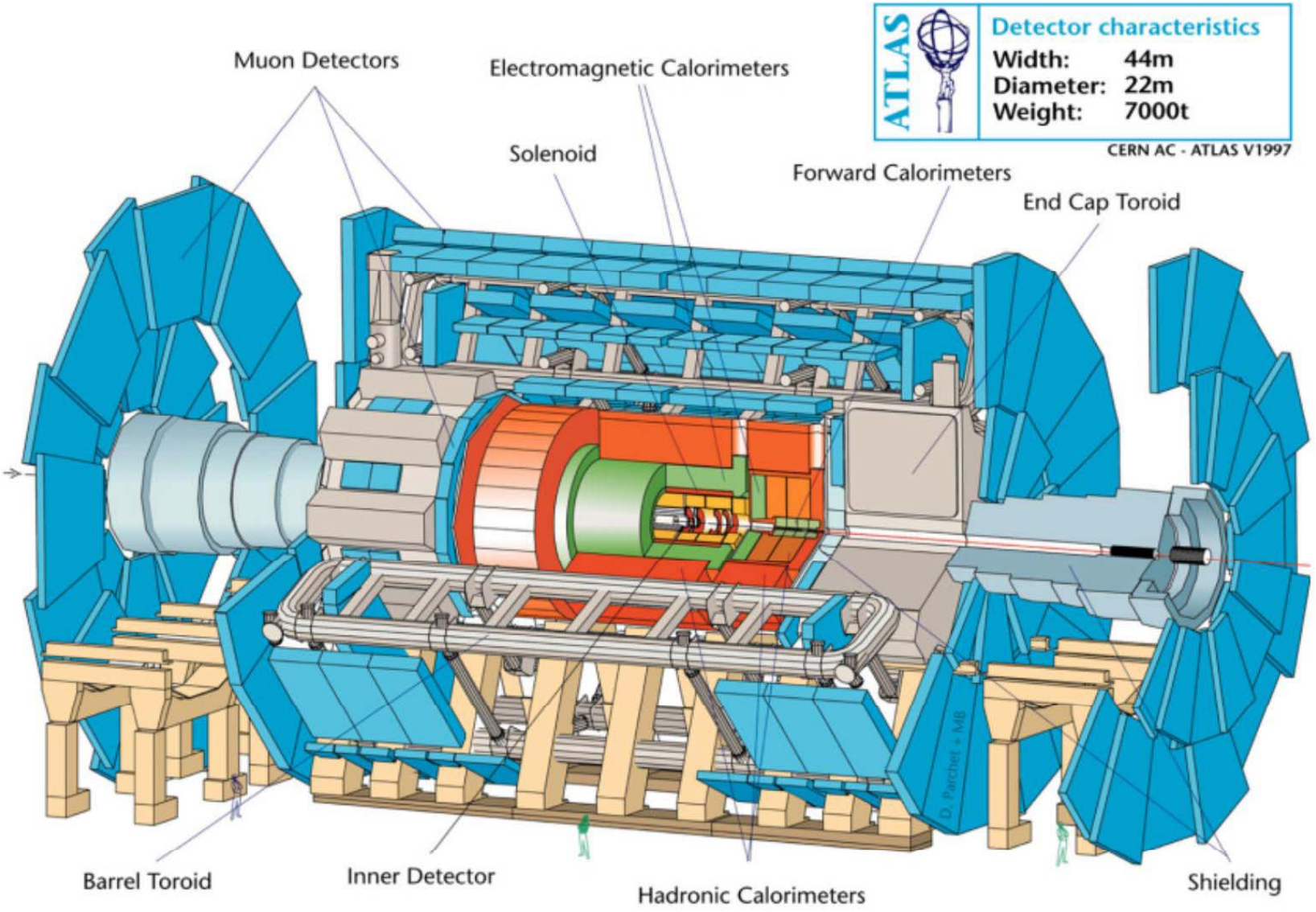
CMS Event

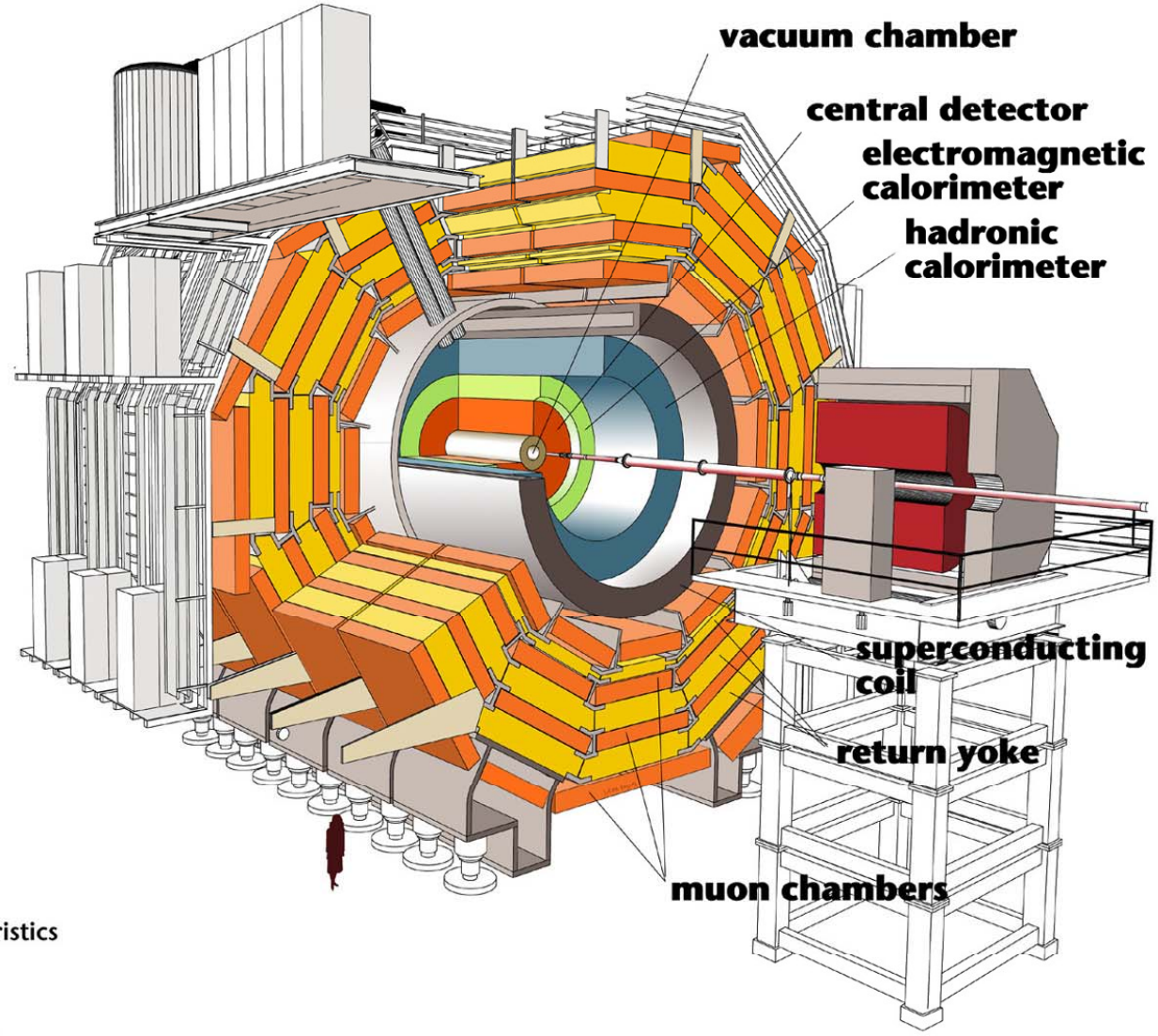

Select:
Muon
Electron
Neutral Hadron
Charged Hadron
Photon
0m
1m
2m
3m
4m
5m
6m
7m
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS
D. Barney, CERN, 2004


LHC
Event
10⁹ events / second


muon chambers
Detector characteristics
Width: 22m
Diameter: 15m
Weight: 14'500t

ATLAS Experiment

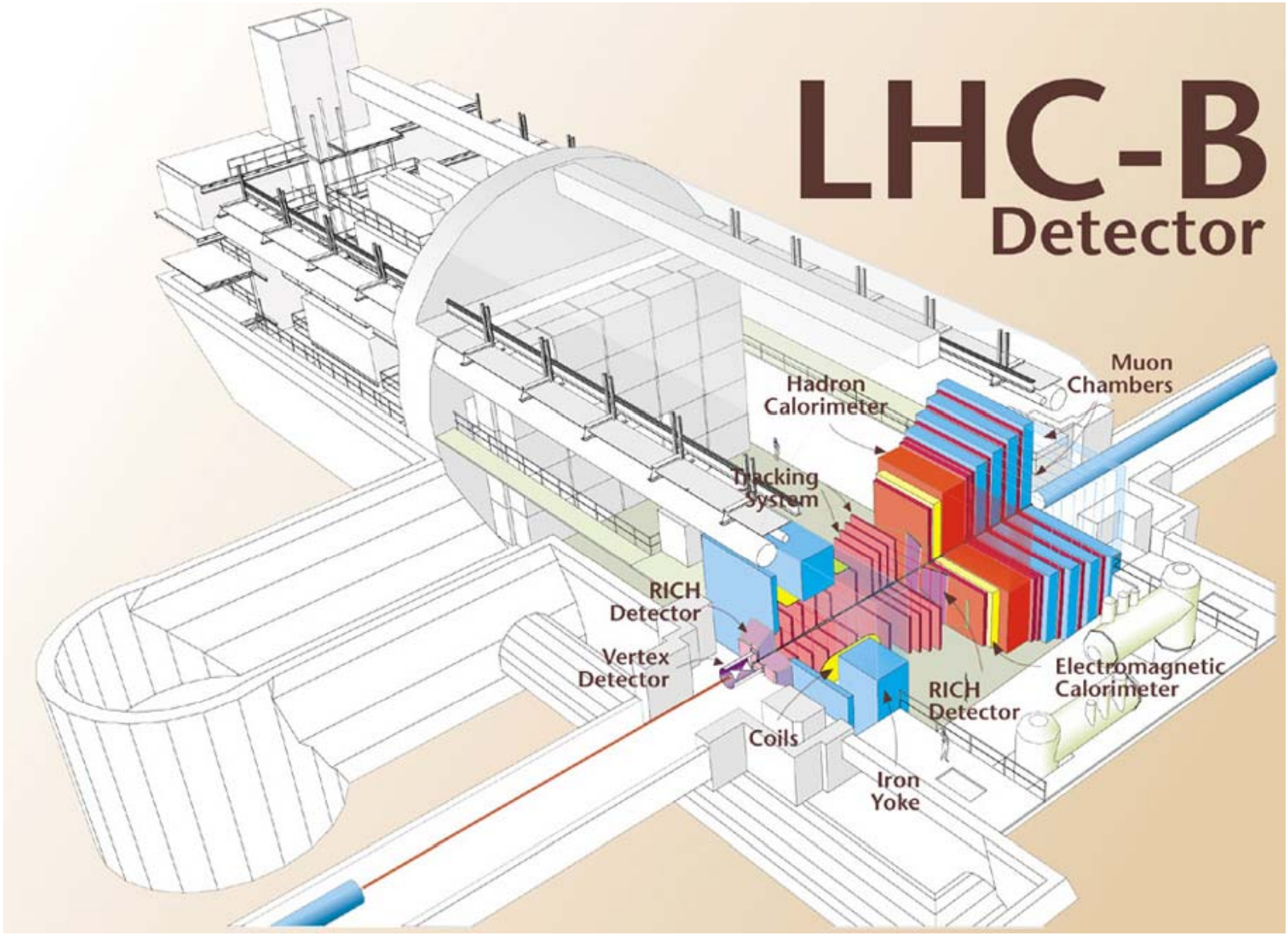




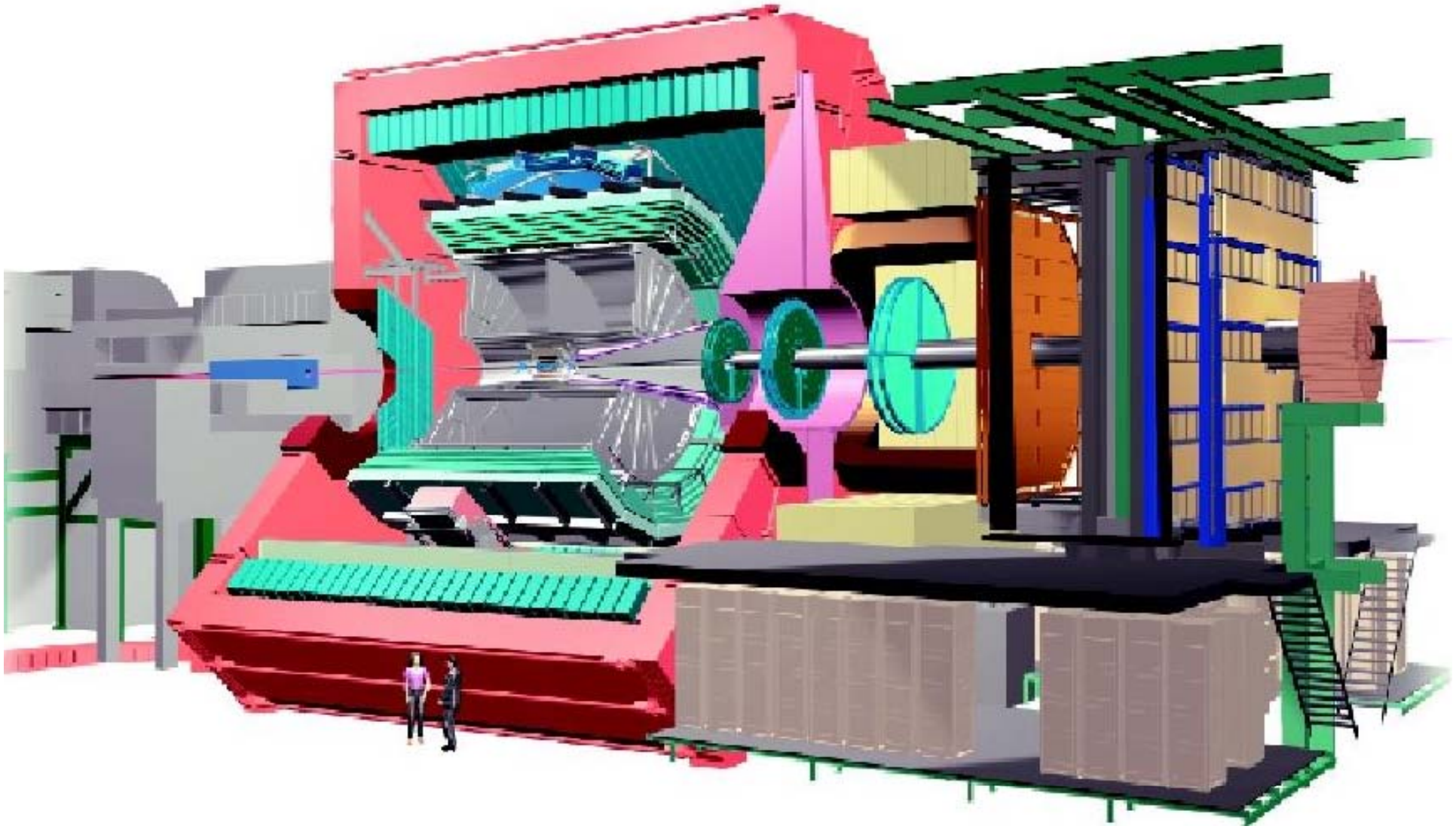
Detector characteristics

Width: 22m
Diameter: 15m
Weight: 14'500t

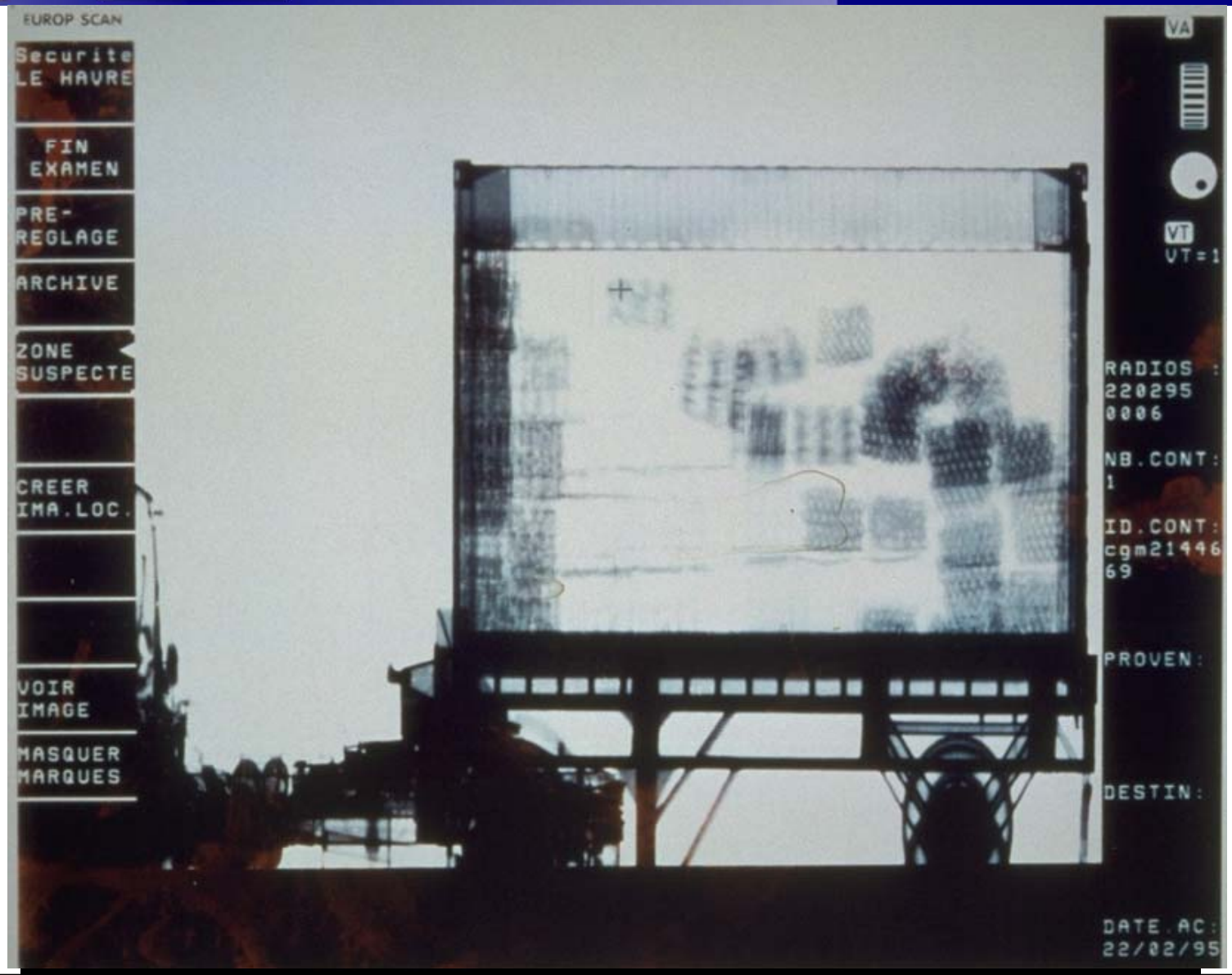
LHCb Experiment



ALICE Experiment



Spin-Offs


EUROP SCAN
Securite
LE HAVRE
FIN
EXAMEN
PRE-
REGLAGE
ARCHIVE
ZONE
SUSPECTE
CREER
IMA.LOC.
VOIR
IMAGE
MASQUER
MARQUES
VA
VT
VT=1
RADIOS :
220295
0006
NB.CONT:
1
ID.CONT:
cgm21446
69
PROVEN:
DESTIN:
DATE AC:
22/02/95

Your Questions ?