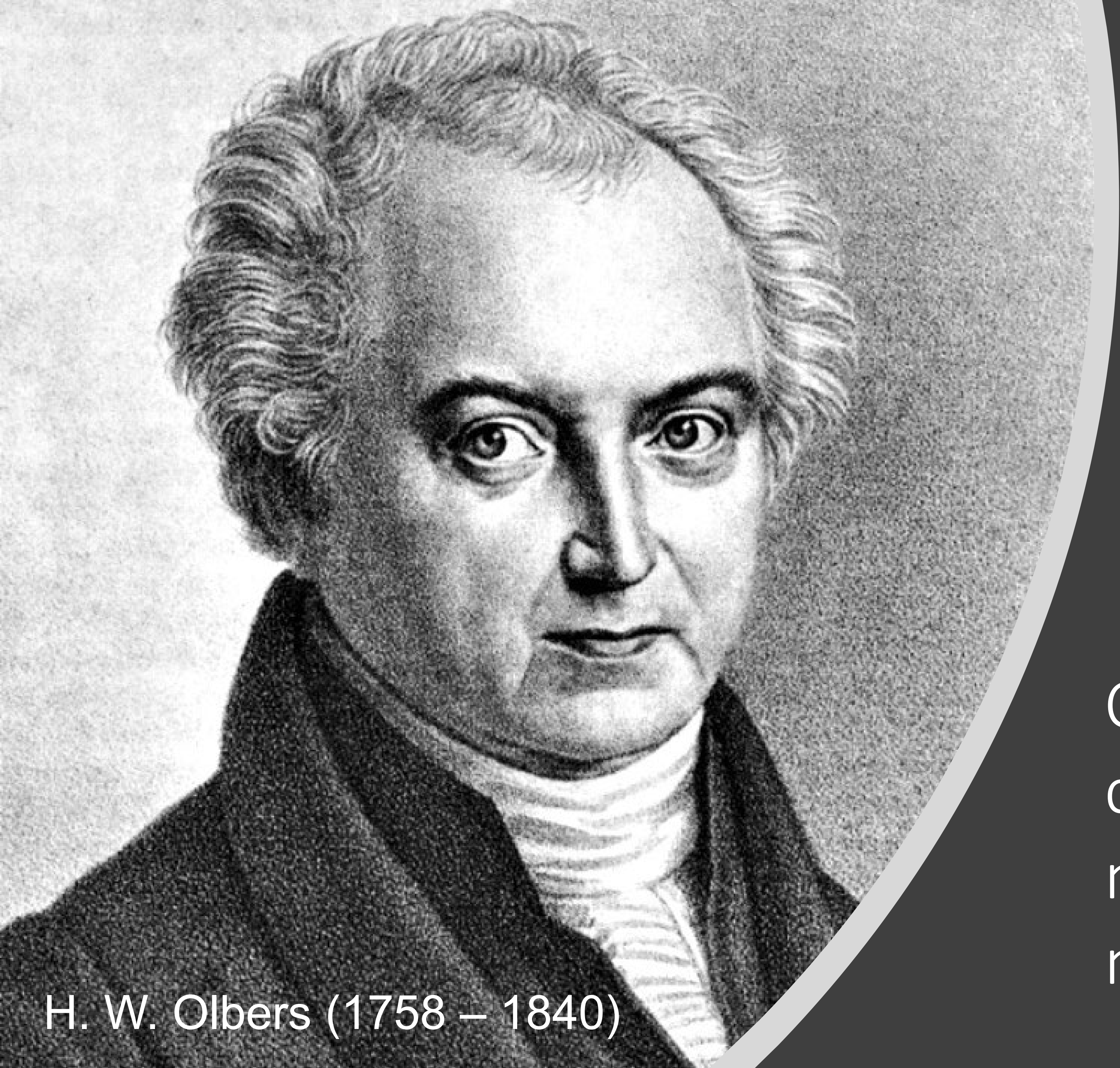
I primi istanti dell’Universo e il Quark Gluon Plasma

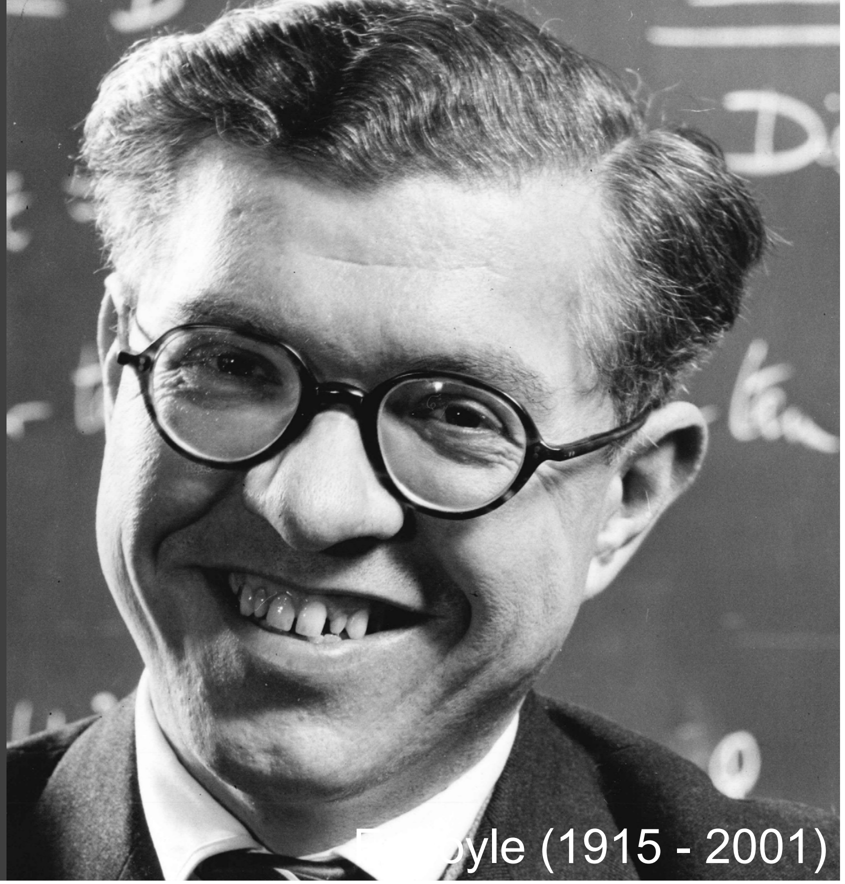
Enrico Fragiacomo
INFN – Sezione di Trieste


the BiG BANG THEORY
Spigot



Paradosso di Olbers

Com’è possibile che il cielo notturno sia buio nonostante ci sia un numero infinito di stelle?

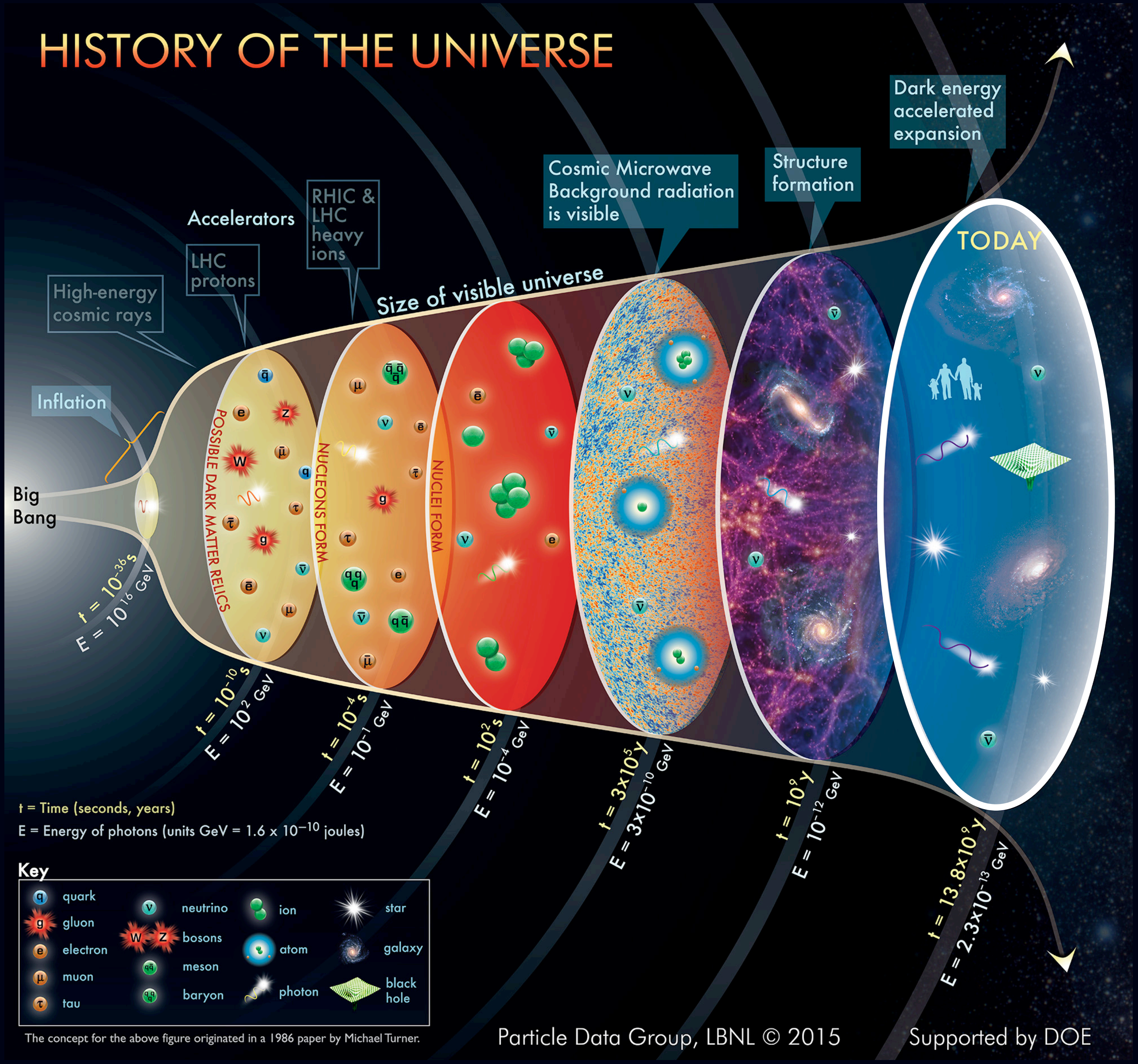


F. Hoyle (1915 - 2001)

G. E. Lemaître (1894 -1966)

E. P. Hubble (1889 – 1953)

«L'essenza della teoria del Big Bang sta nel fatto che l'Universo si sta espandendo e raffreddando. Lei noterà che non ho detto nulla riguardo a un’esplosione. La teoria del Big Bang descrive come il nostro universo evolve e non come esso iniziò», P. J. E. Peebles, 2001


HISTORY OF THE UNIVERSE
Dark energy accelerated expansion
Structure formation
Cosmic Microwave Background radiation is visible
RHIC & LHC heavy ions
Accelerators
LHC protons
High-energy cosmic rays
Size of visible universe
TODAY
Inflation
Big Bang
POSSIBLE DARK MATTER RELICS
NUCLEONS FORM
NUCLEI FORM
t = 10^-36 s
E = 10^16 GeV
t = 10^-10 s
E = 10^2 GeV
t = 10^-4 s
E = 10^-1 GeV
t = 10^2 s
E = 10^-4 GeV
t = 3x10^5 y
E = 3x10^-10 GeV
t = 10^9 y
E = 10^-12 GeV
t = 13.8x10^9 y
E = 2.3x10^-13 GeV
t = Time (seconds, years)
E = Energy of photons (units GeV = 1.6 x 10^-10 joules)
Key
quark
gluon
electron
muon
tau
neutrino
bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
The concept for the above figure originated in a 1986 paper by Michael Turner.
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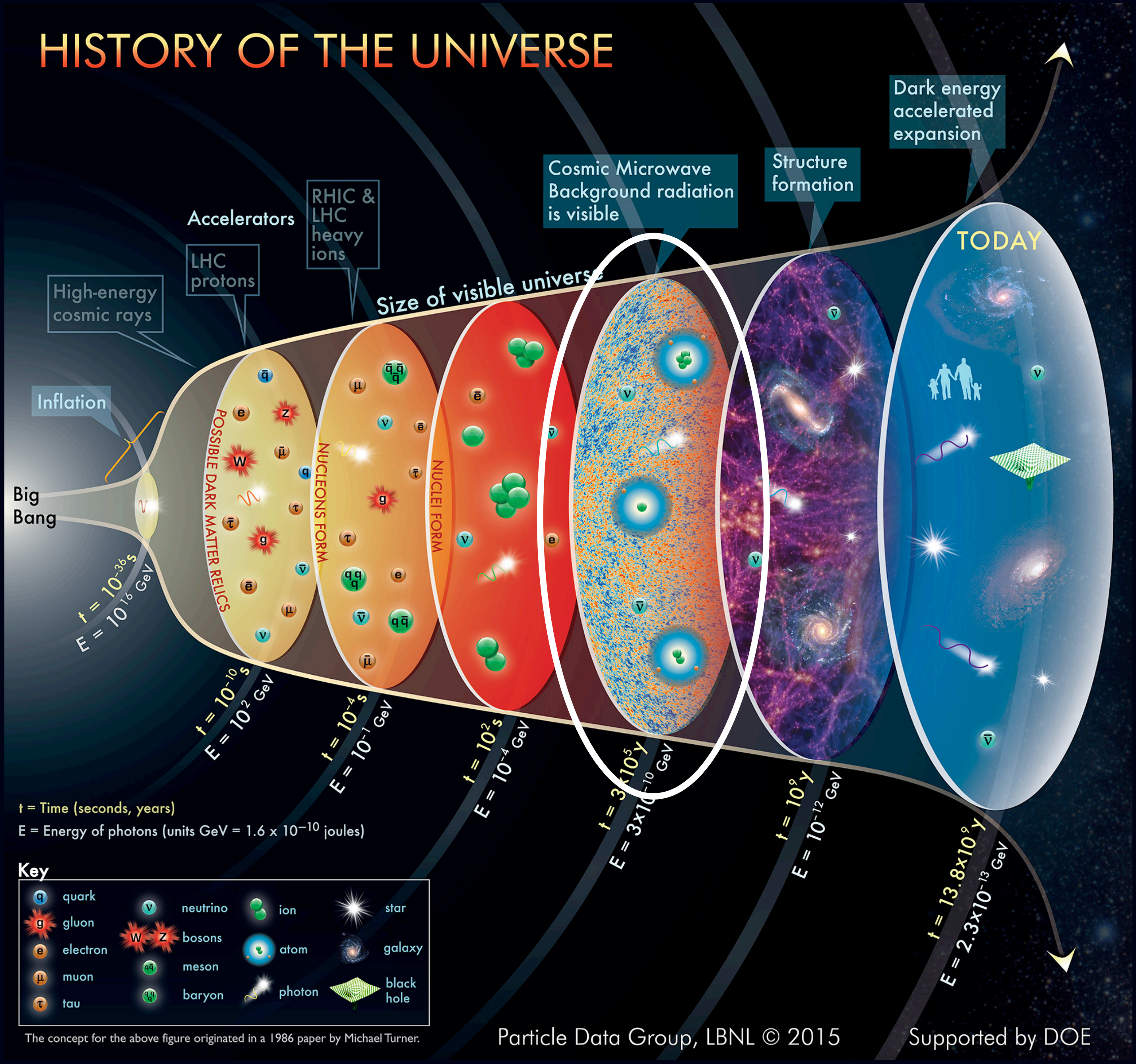
A. Penzias e R. Wilson, Bell Laboratories,1964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Big Bang Nucleosynthesis

PHYSICAL REVIEW VOLUME 73, NUMBER 7 APRIL 1, 1948

Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is five weeks prior to the date of issue. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length.

The Origin of Chemical Elements

R. A. ALPHER*
Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland
AND
H. BETHE
Cornell University, Ithaca, New York
AND
G. GAMOW
The George Washington University, Washington, D. C.
February 18, 1948

As pointed out by one of us,[1] various nuclear species must have originated not as the result of an equilibrium corresponding to a certain temperature and density, but rather as a consequence of a continuous building-up process arrested by a rapid expansion and cooling of the primordial matter. According to this picture, we must imagine the early stage of matter as a highly compressed neutron gas (overheated neutral nuclear fluid) which started decaying into protons and electrons when the gas pressure fell down as the result of universal expansion. The radiative capture of the still remaining neutrons by the newly formed protons must have led first to the formation of deuterium nuclei, and the subsequent neutron captures resulted in the building up of heavier and heavier nuclei. It must be remembered that, due to the comparatively short time allowed for this process,[1] the building up of heavier nuclei must have proceeded just above the upper fringe of the stable elements (short-lived Fermi elements), and the present frequency distribution of various atomic species was attained only somewhat later as the result of adjustment of their electric charges by β-decay.

Thus the observed slope of the abundance curve must not be related to the temperature of the original neutron gas, but rather to the time period permitted by the expansion process. Also, the individual abundances of various nuclear species must depend not so much on their intrinsic stabilities (mass defects) as on the values of their neutron capture cross sections. The equations governing such a building-up process apparently can be written in the form:

$$\frac{dn_i}{dt}=f(t)(\sigma_{i-1}n_{i-1}-\sigma_i n_i) \quad i=1,2,\cdots 238, \qquad (1)$$

where n_i and σ_i are the relative numbers and capture cross sections for the nuclei of atomic weight i, and where $f(t)$ is a factor characterizing the decrease of the density with time.

We may remark at first that the building-up process was apparently completed when the temperature of the neutron gas was still rather high, since otherwise the observed abundances would have been strongly affected by the resonances in the region of the slow neutrons. According to Hughes,[2] the neutron capture cross sections of various elements (for neutron energies of about 1 Mev) increase exponentially with atomic number halfway up the periodic system, remaining approximately constant for heavier elements.

Using these cross sections, one finds by integrating Eqs. (1) as shown in Fig. 1 that the relative abundances of various nuclear species decrease rapidly for the lighter elements and remain approximately constant for the elements heavier than silver. In order to fit the calculated curve with the observed abundances[3] it is necessary to assume the integral of $\rho_n dt$ during the building-up period is equal to 5×10^4 g sec./cm³.

On the other hand, according to the relativistic theory of the expanding universe[4] the density dependence on time is given by $\rho\cong10^6/t^2$. Since the integral of this expression diverges at $t=0$, it is necessary to assume that the building-up process began at a certain time t_0, satisfying the relation:

$$\int_{t_0}^{\infty}(10^6/t^2)dt\cong5\times10^4, \qquad (2)$$

which gives us $t_0\cong20$ sec. and $\rho_0\cong2.5\times10^5$ g sec./cm³. This result may have two meanings: (a) for the higher densities existing prior to that time the temperature of the neutron gas was so high that no aggregation was taking place, (b) the density of the universe never exceeded the value 2.5×10^5 g sec./cm³ which can possibly be understood if we

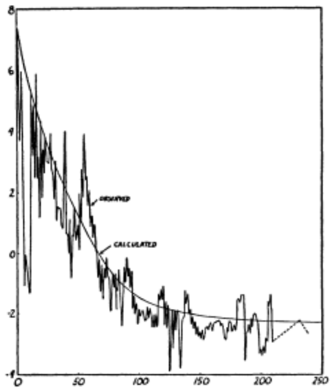


FIG. 1.
Log of relative abundance
Atomic weight

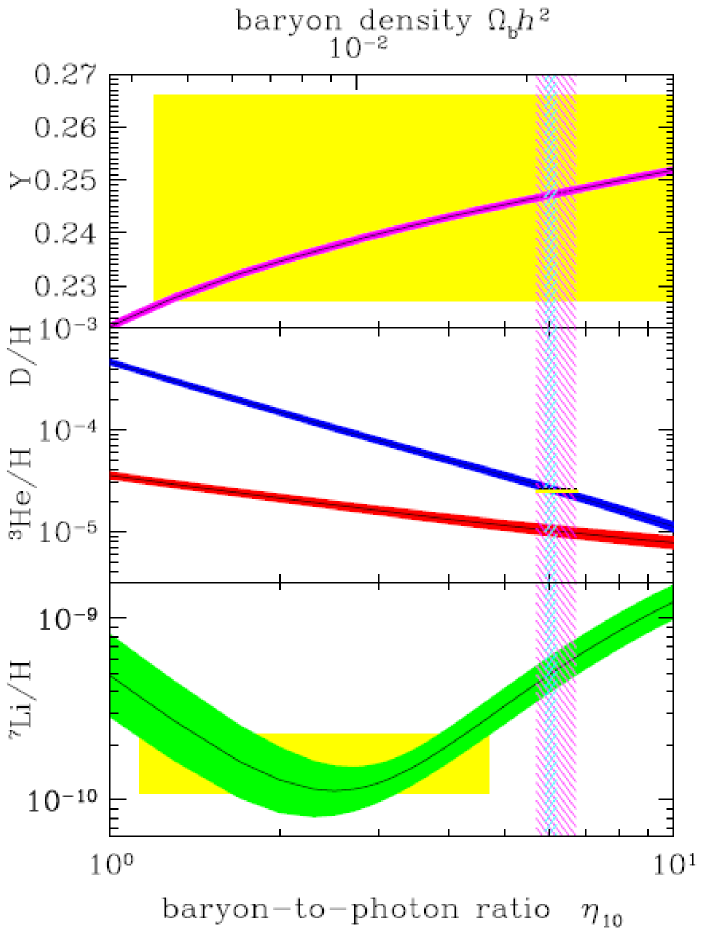
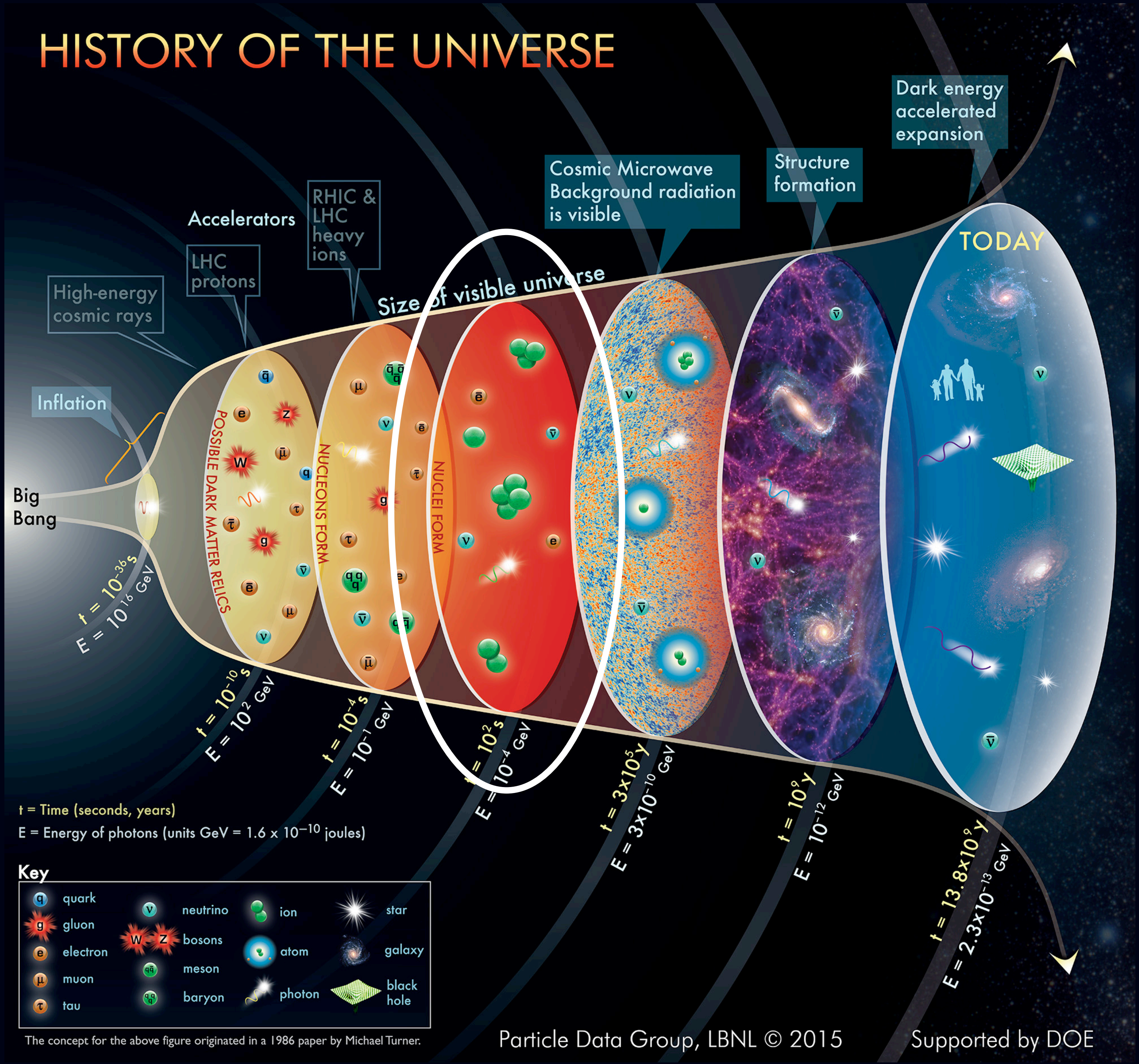


Figure 23.1: The abundances of ^{4}He, D, ^{3}He, and ^{7}Li as predicted by the standard model of Big-Bang nucleosynthesis — the bands show the 95% CL range. Boxes indicate the observed light element abundances. The narrow vertical band indicates the CMB measure of the cosmic baryon density, while the wider band indicates the BBN concordance range (both at 95% CL).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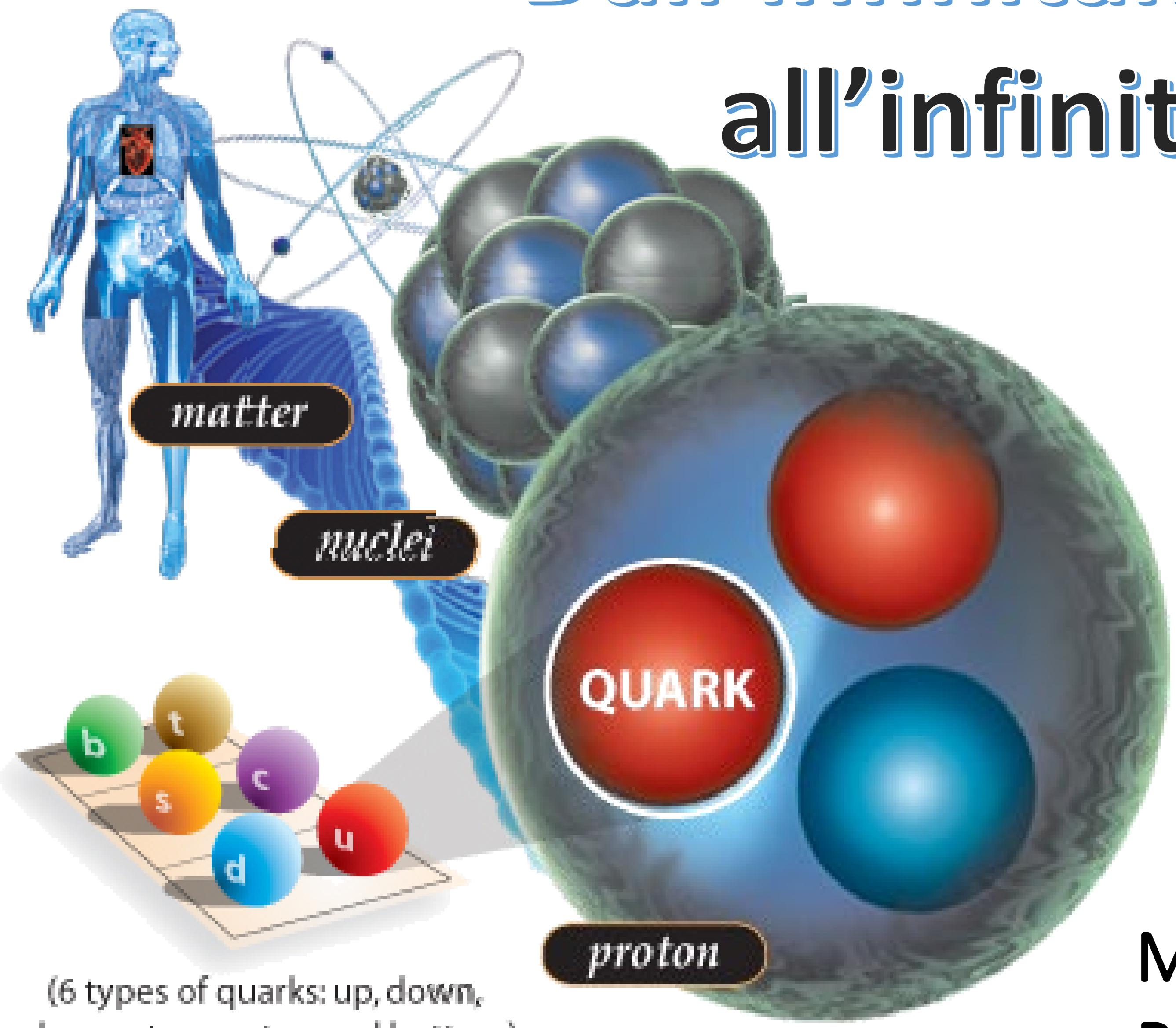
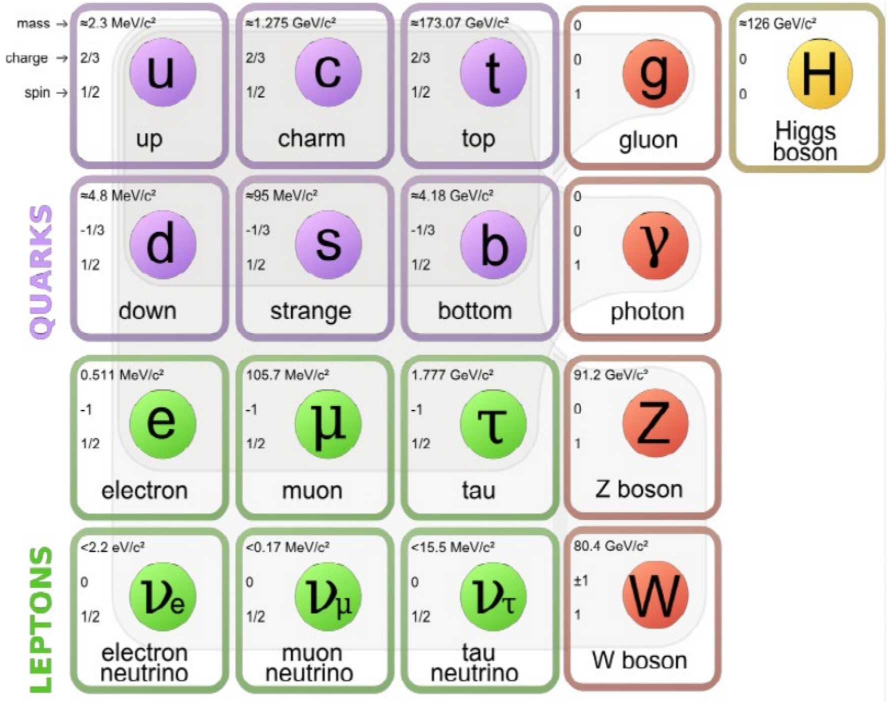
QUARK-GLUON PLASMA
PIU' DI 1000 MILIARDI DI GRADI
PER CONFRONTO TEMPERATURA DEL SOLE: 15 MILIONI DI GRADI

Dall’infinitamente grande…..
all’infinitamente piccolo



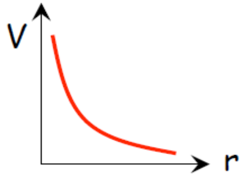
(6 types of quarks: up, down, charm, strange, top and bottom)

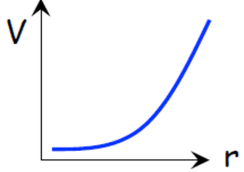


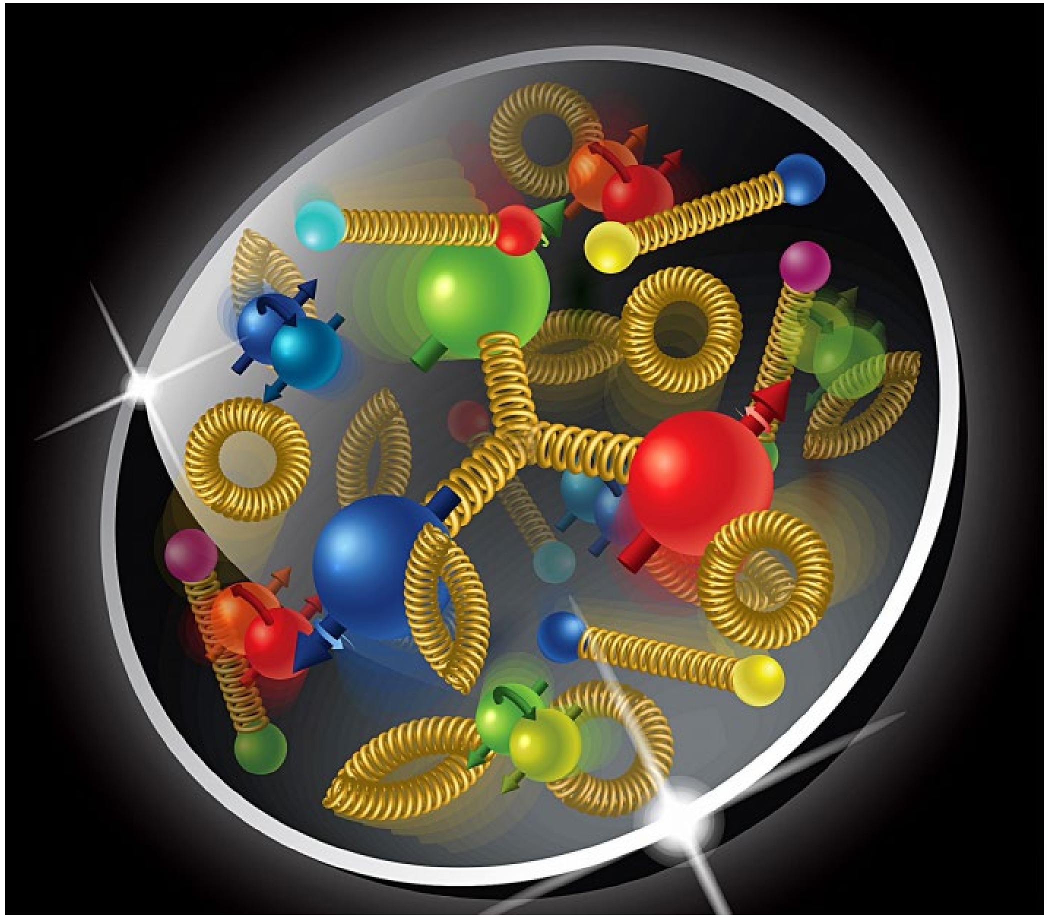
Modello Standard delle Particelle elementari

Quark confinement

$$V_{Coulomb} \propto \frac{q_1 q_2}{r} \;\Rightarrow\; V_{QCD} \propto e^{k\cdot r}$$







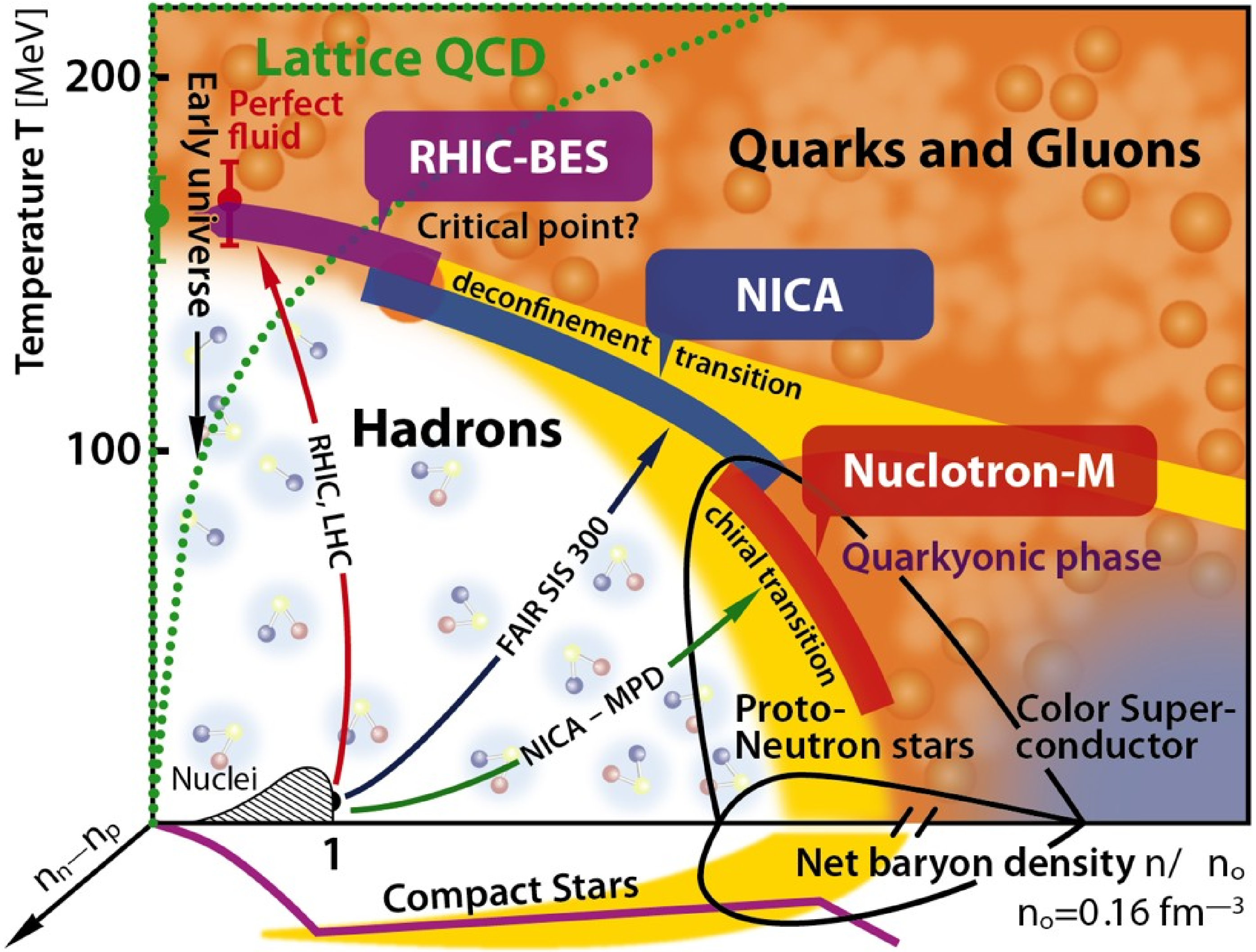
I quark, confinati nei barioni, sono come delle palline chiuse all’interno di un palloncino (MIT Bag Model). Come possiamo liberarli?

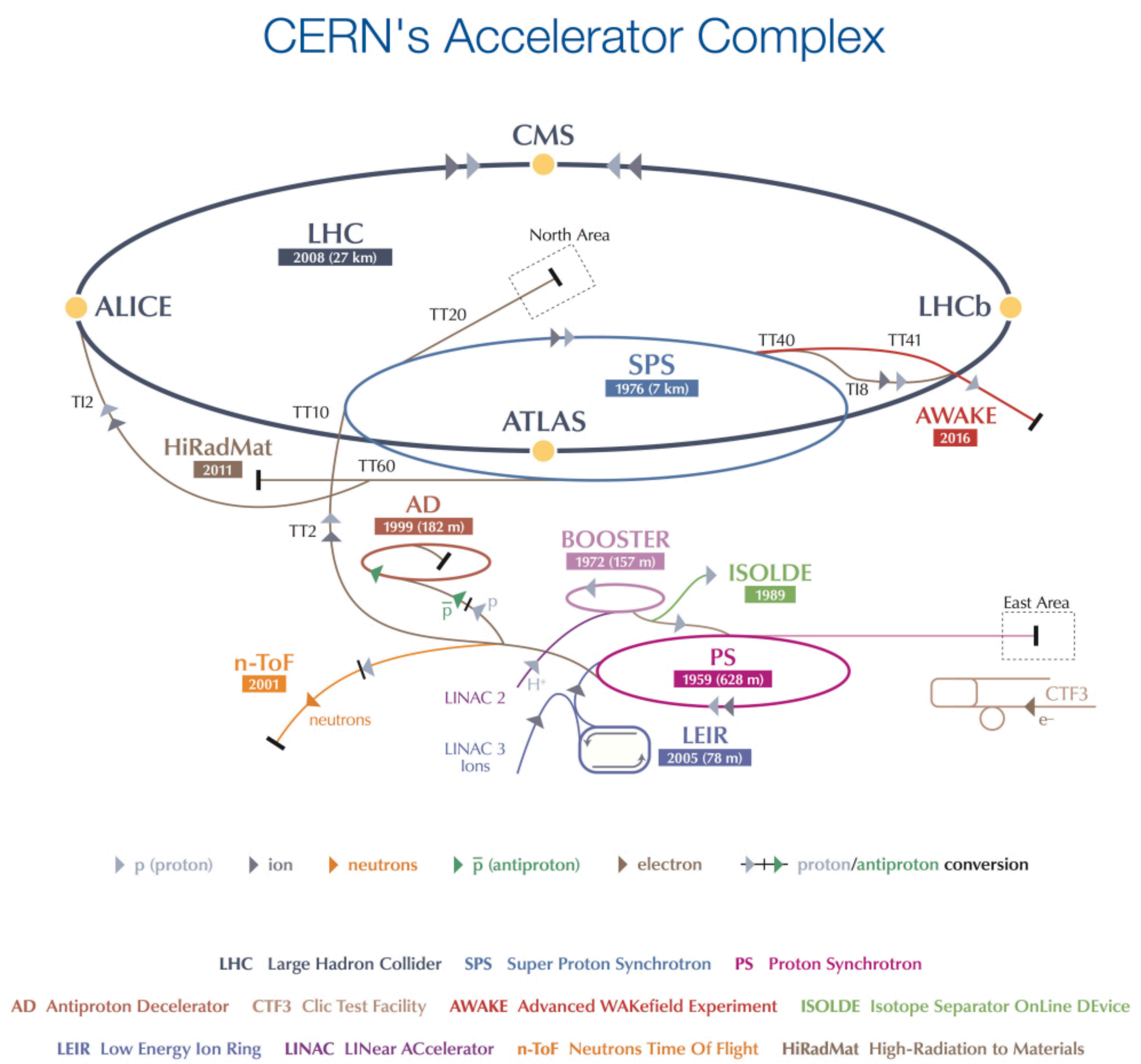
1) **Schiacciando i barioni uno contro l’altro (aumentando la densità)**

2) **Riscaldandoli a 10^{12} K**

Hagedorn’s Absolute hot

Diagramma di fase della materia nucleare





Facts and figures about the LHC

Circumference: 26659 m

Dipole 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

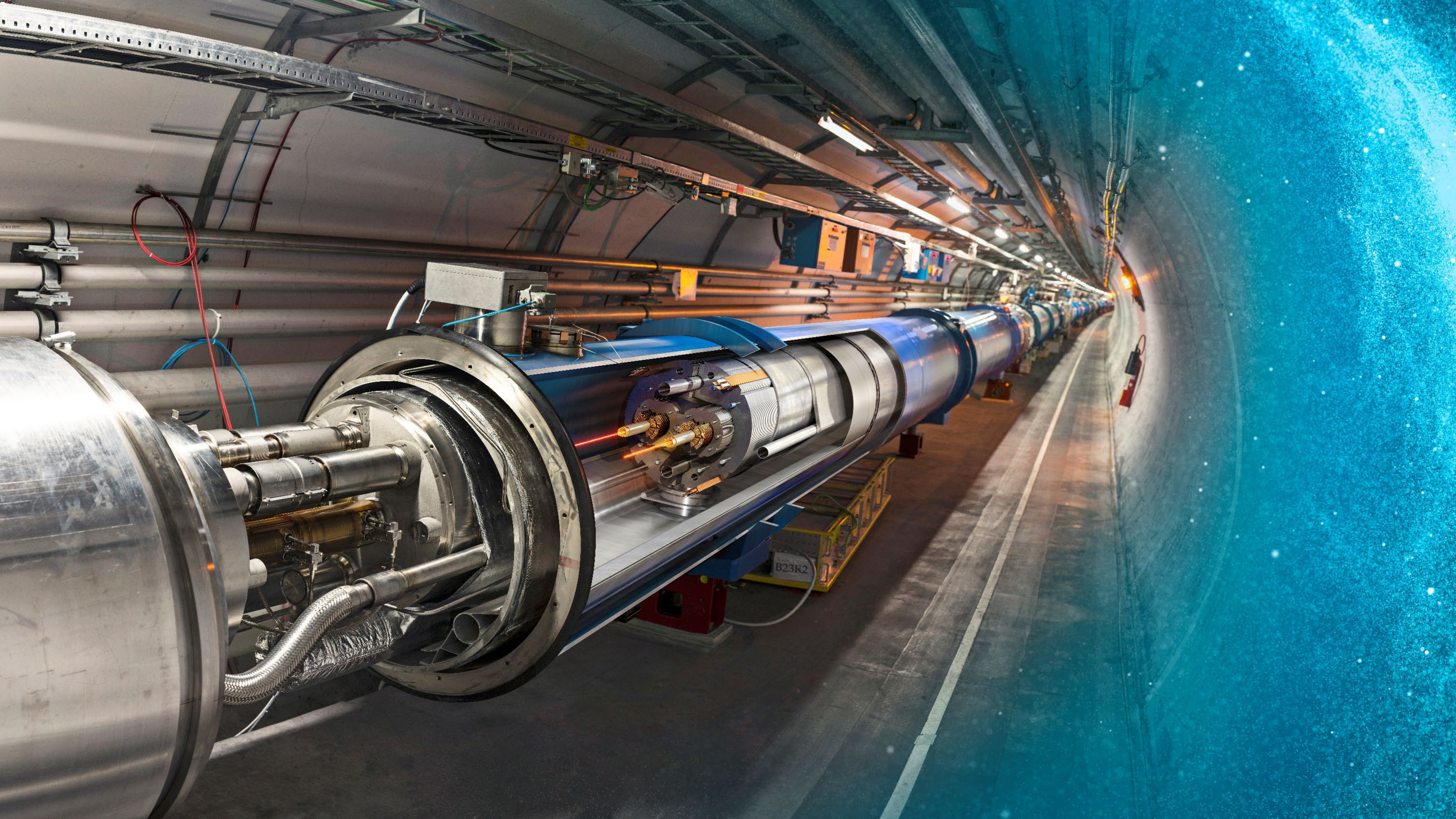
No. of bunches per proton beam: 2808

No. of protons per bunch: 1.2 x 10^{11}

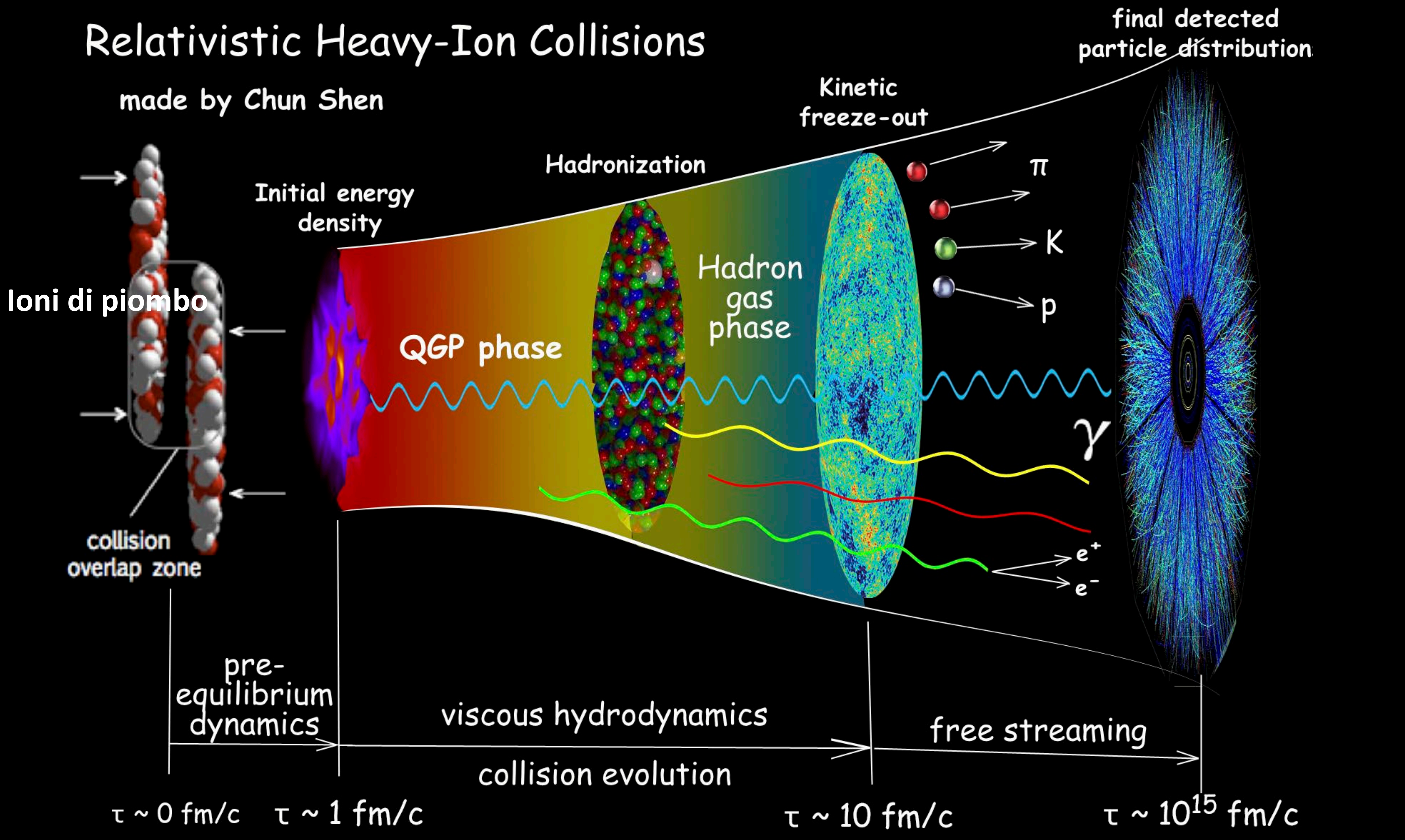
Number of turns per second: 11245

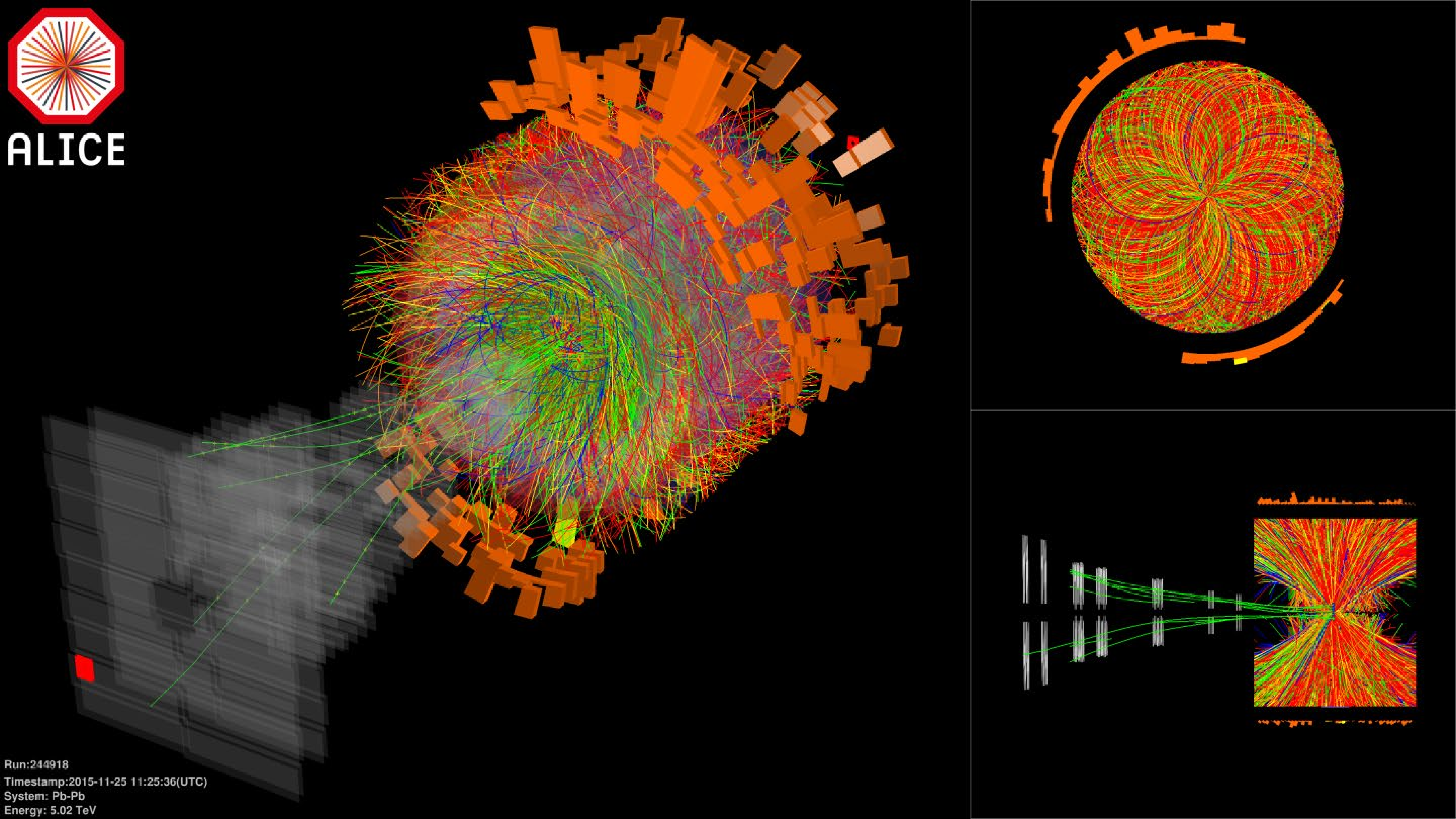
Number of collisions per second: 1 billion

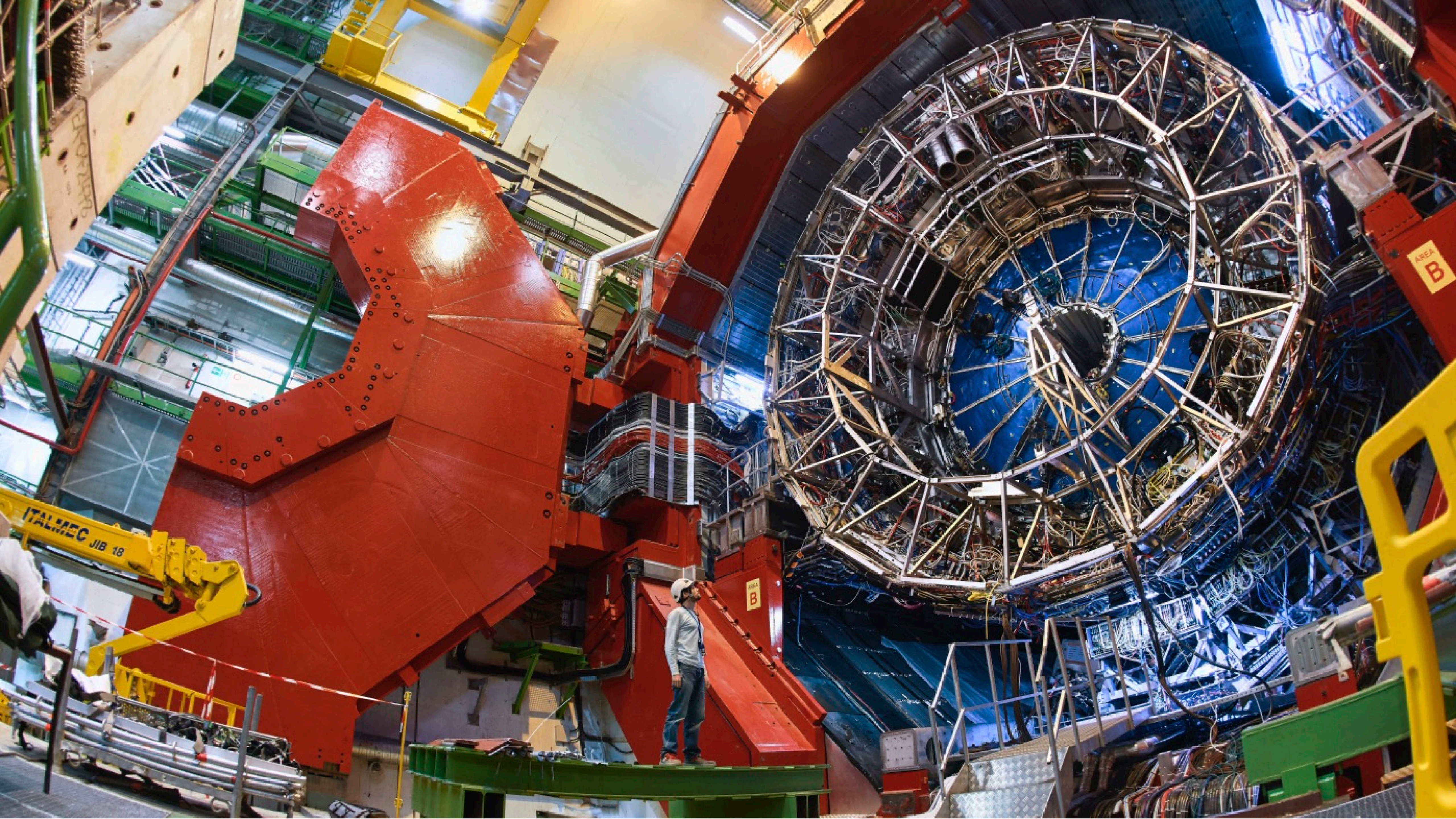
At full energy, each of the two proton beams in the LHC have a total energy equivalent to a 400 t train (like the French TGV) travelling at 150 km/h. This is enough energy to melt 500 kg of copper


B23R2

The Little Bang

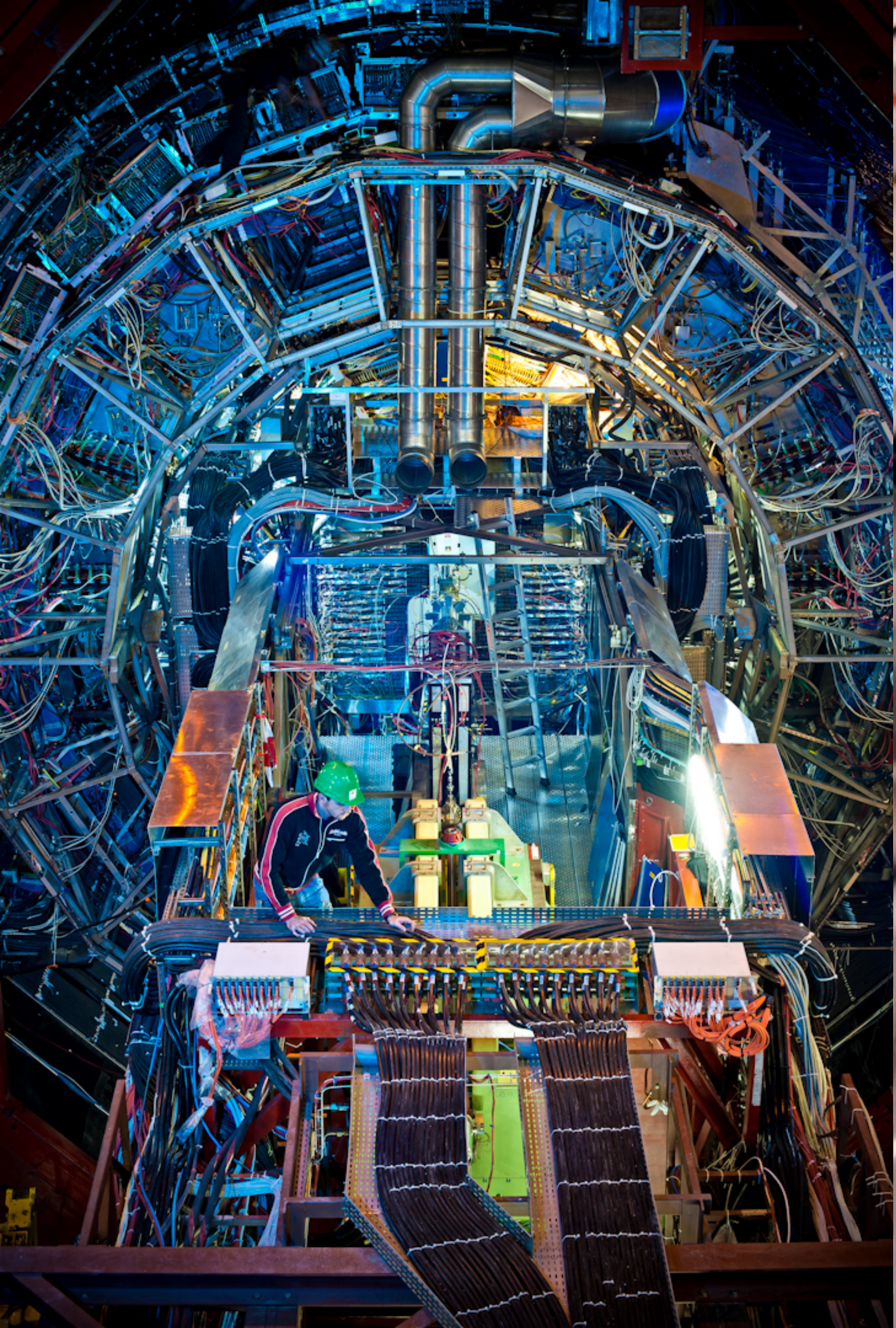


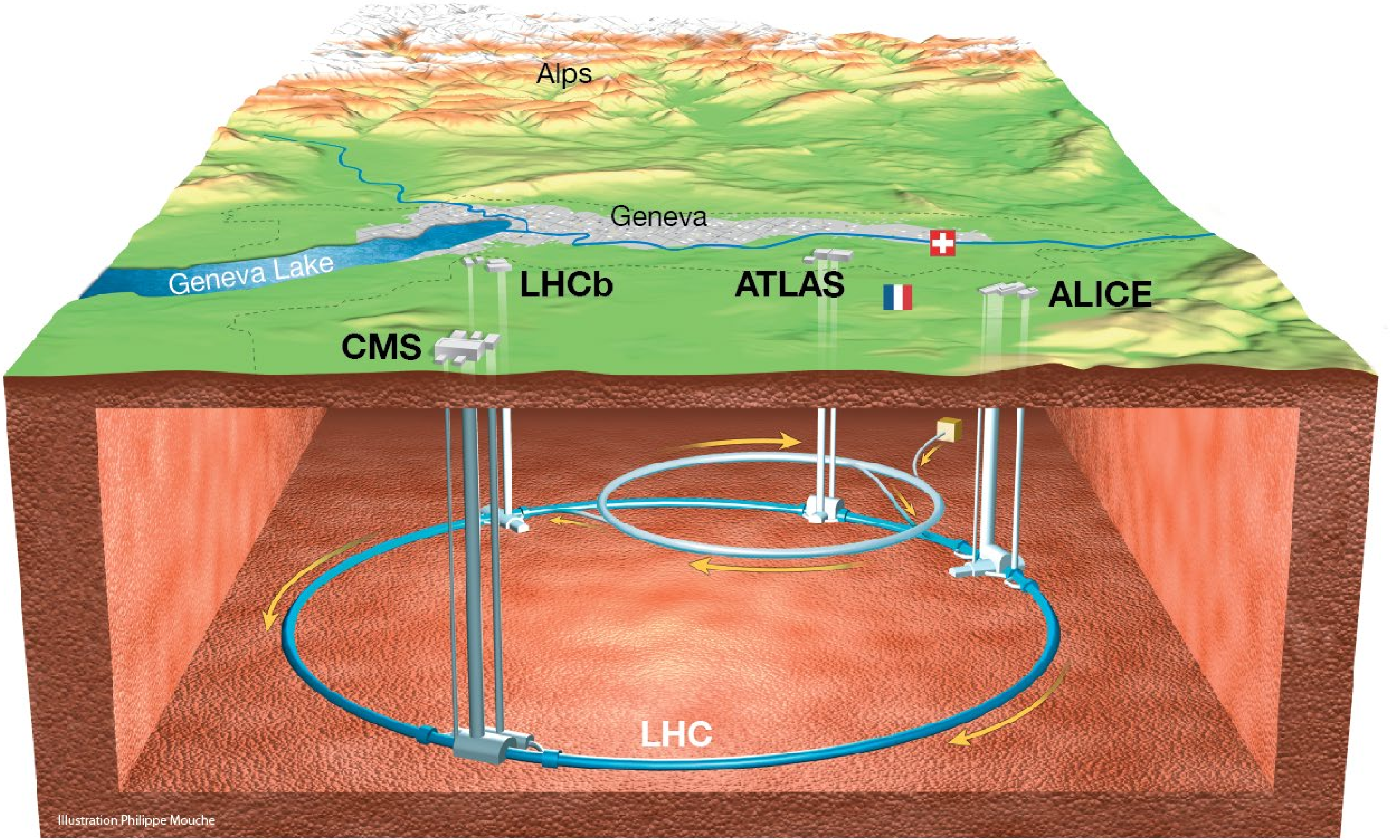

ALICE
Run:244918
Timestamp:2015-11-25 11:25:36(UTC)
System: Pb-Pb
Energy: 5.02 TeV

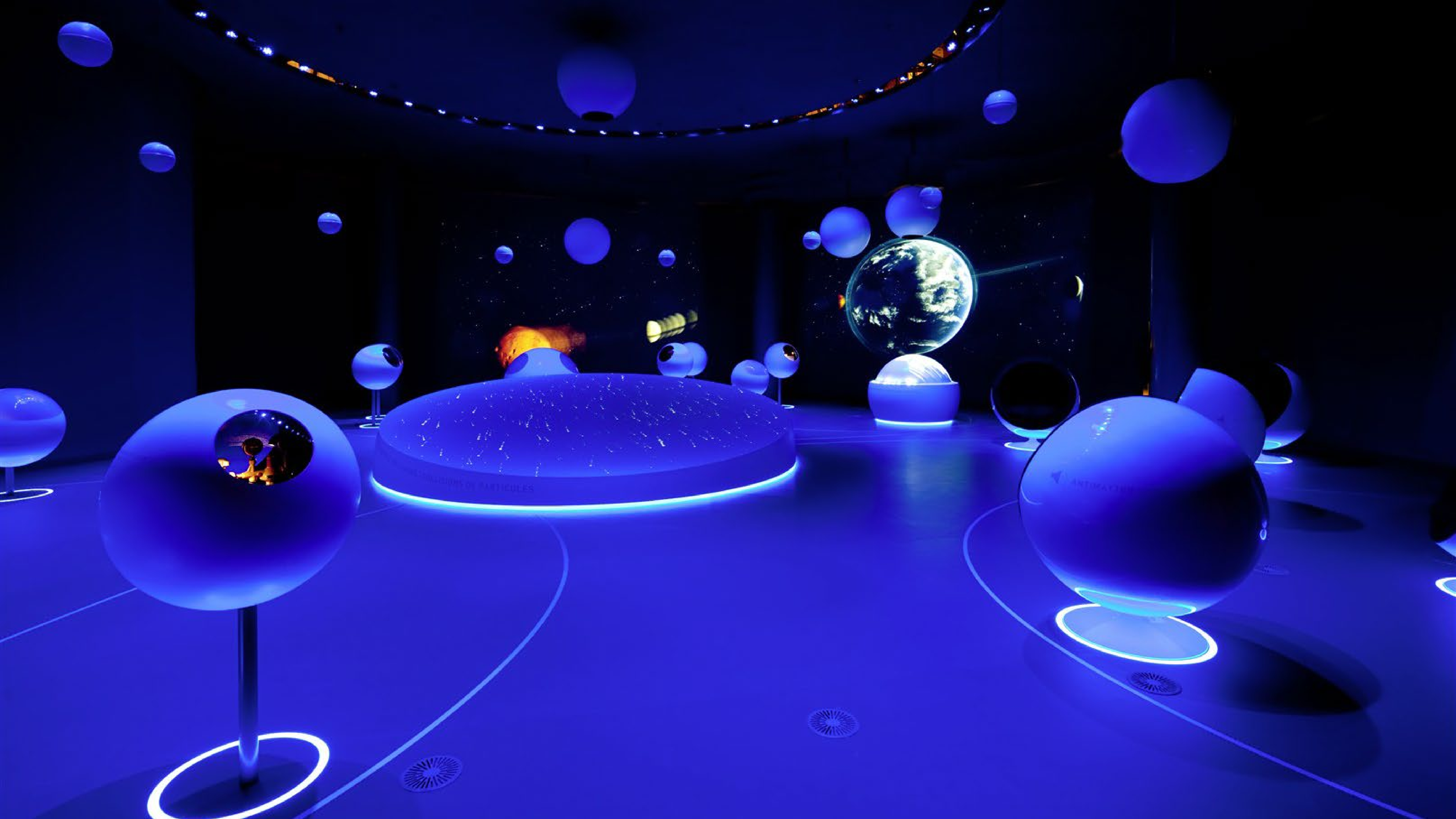


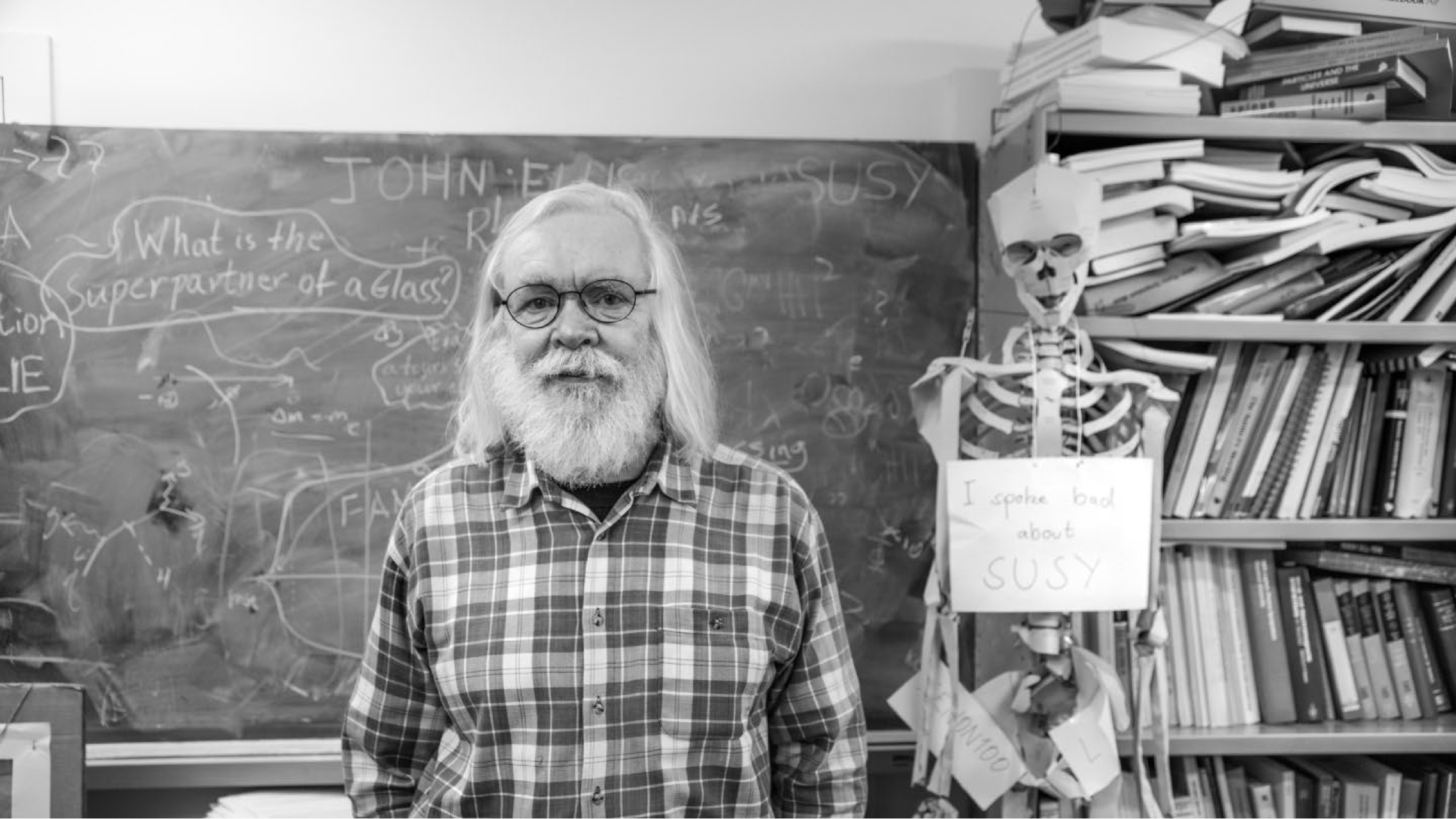
AREA
B
ITALMEC JIB 18

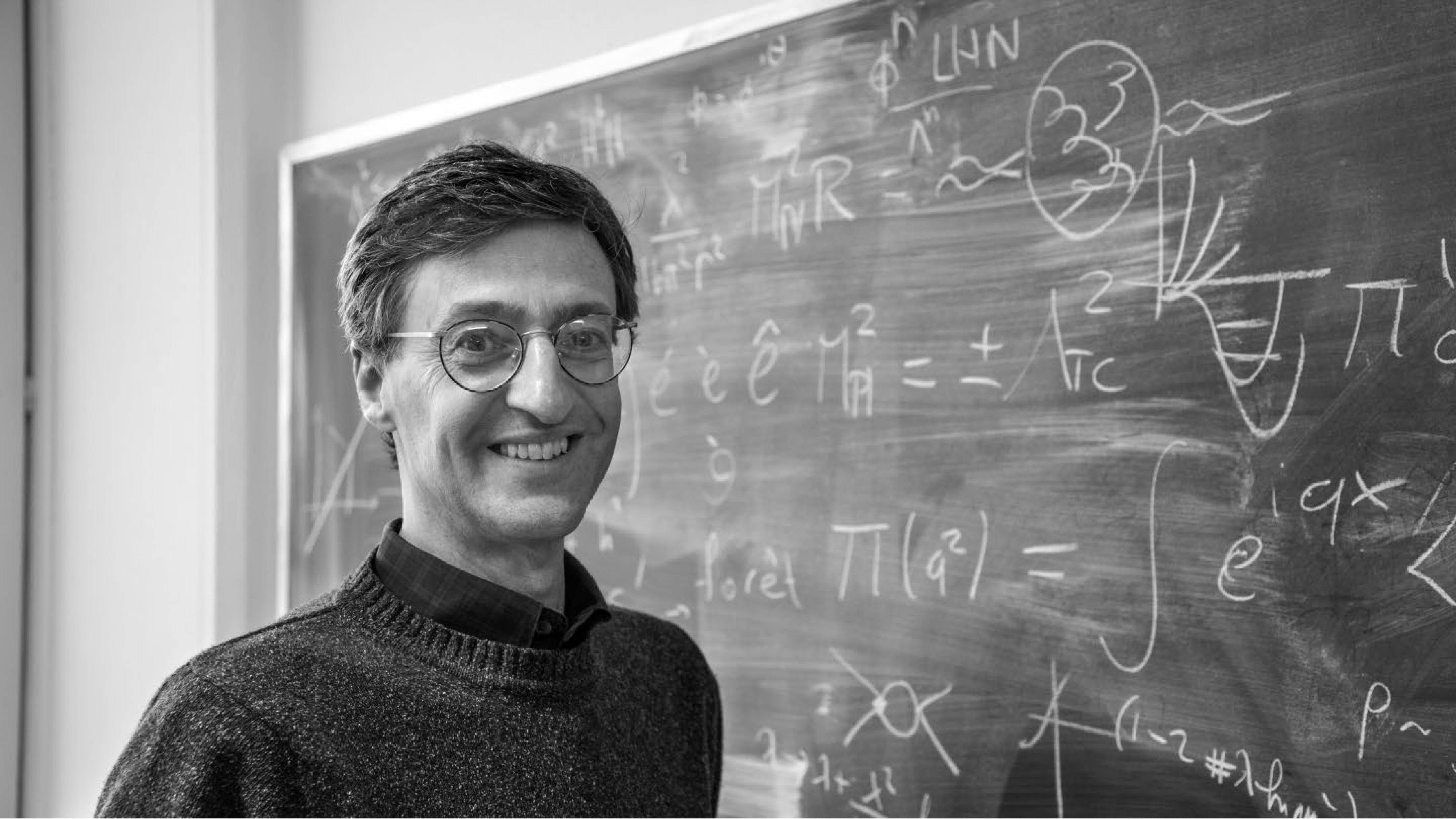
BRUNNHUBER
krantechnik
N° d'identification PR774
Charge admissible totale
40 t
ITALMEC




Alps
Geneva
Geneva Lake
LHCb
ATLAS
ALICE
CMS
LHC
Illustration Philippe Mouche

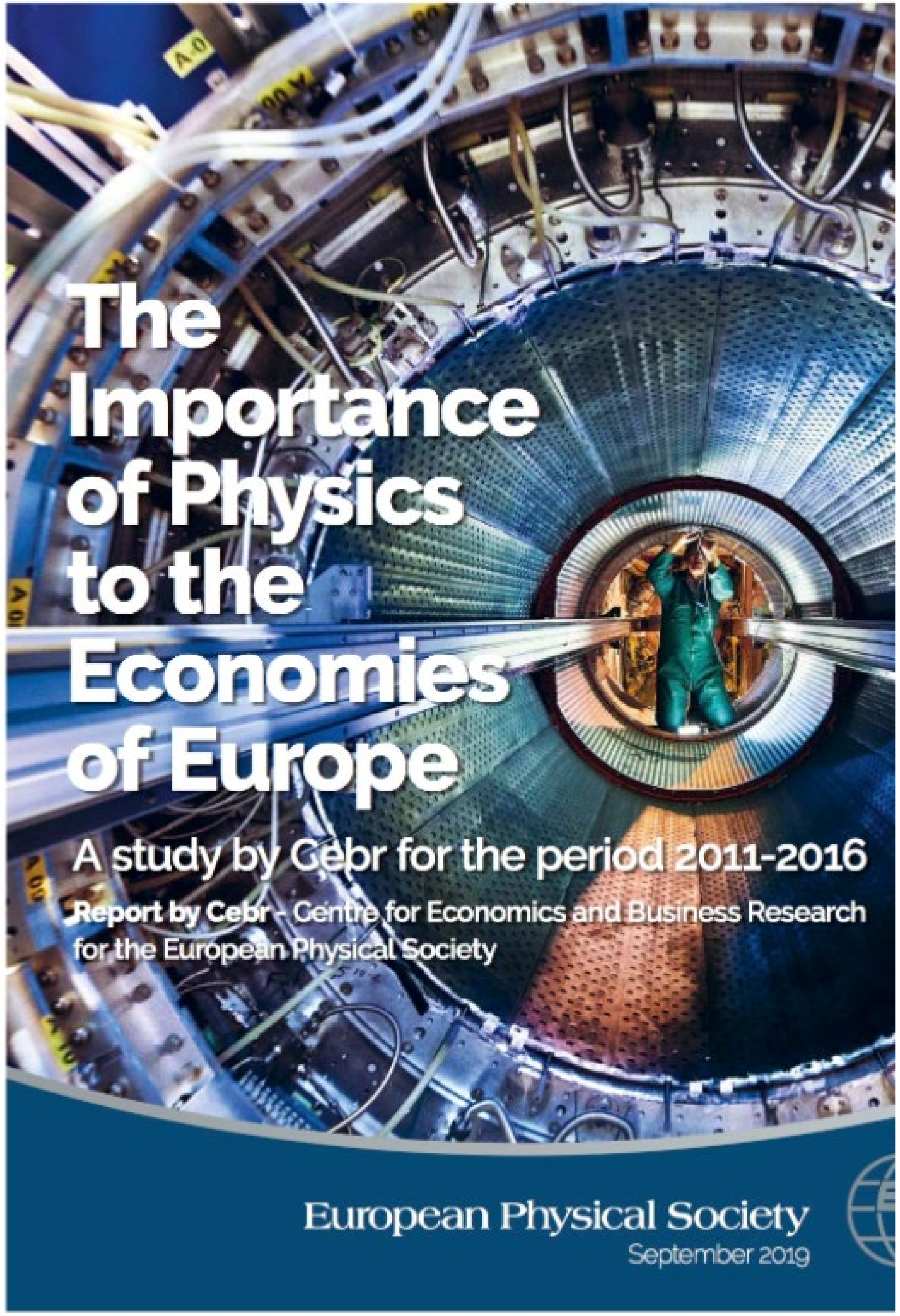



What is the Superpartner of a Glass?
I spoke bad about SUSY




LHC 2008
LHC 2008
CERN

“A price worth paying”, R. Heuer,
CERN Courier, 7 luglio 2020


The Importance of Physics to the Economies of Europe
A study by Cebr for the period 2011-2016
Report by Cebr - Centre for Economics and Business Research for the European Physical Society
European Physical Society
September 2019


Grazie dell’attenzione!