THE FRONTIER OF PHYSICS AND BEYOND

Harrison B. Prosper
Florida State University

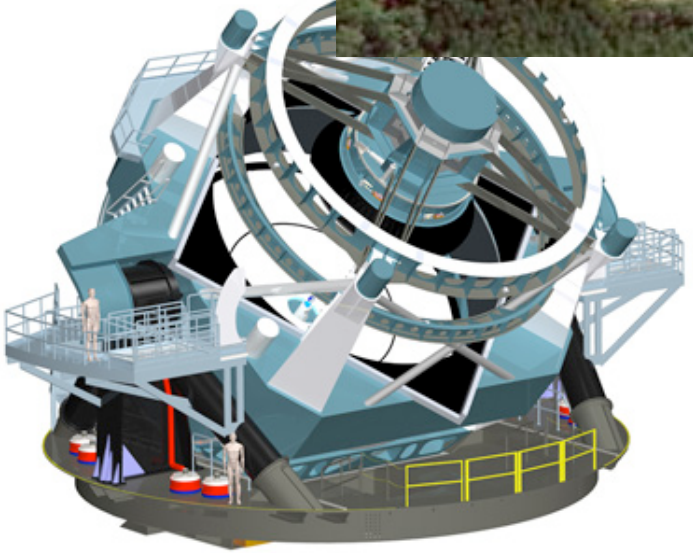
DPF Public Lecture, 12 August 2011

AdLIGO (2015)

LHC (2010)

LSST (2016)

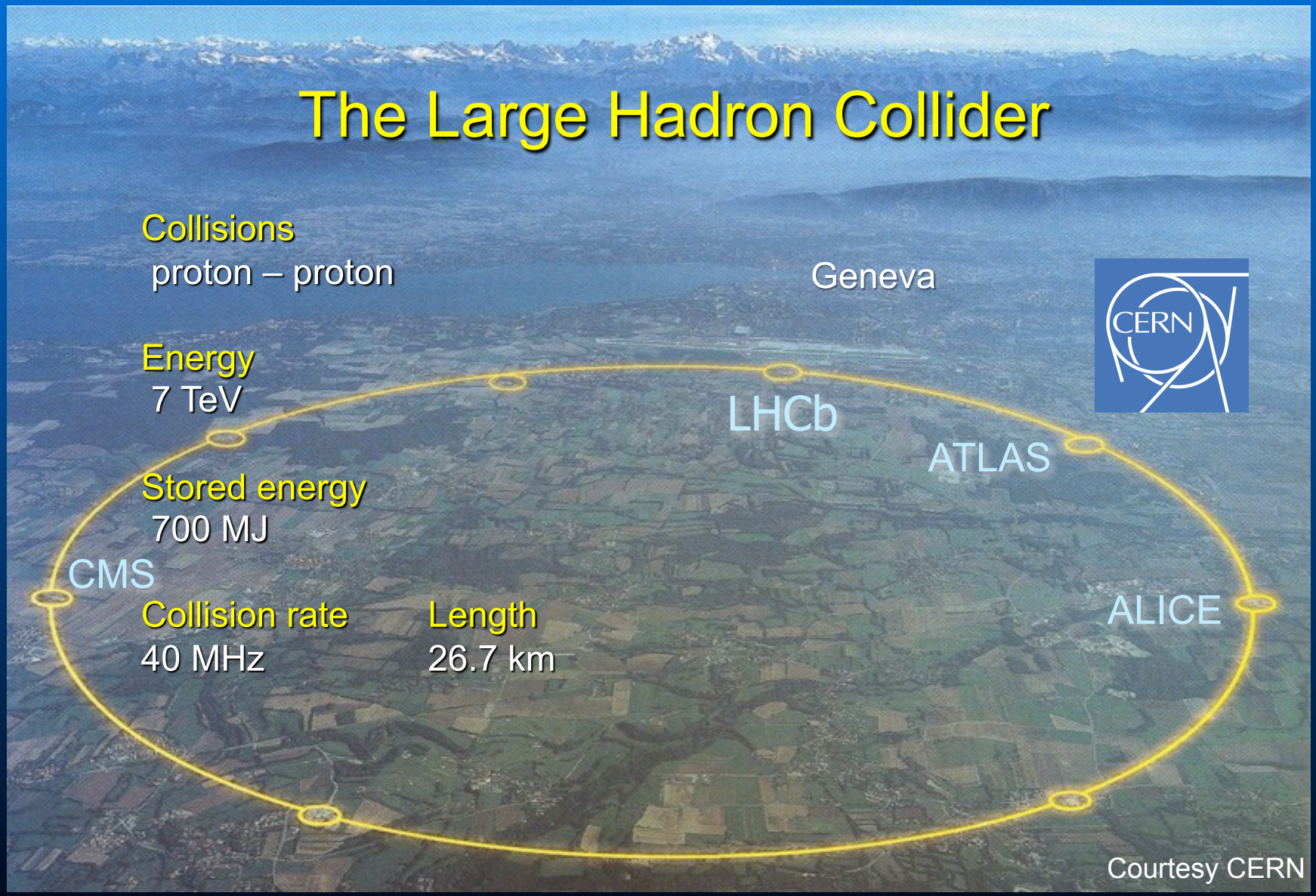
Cerro Pachon, Chile



Courtesy LSST Corp.

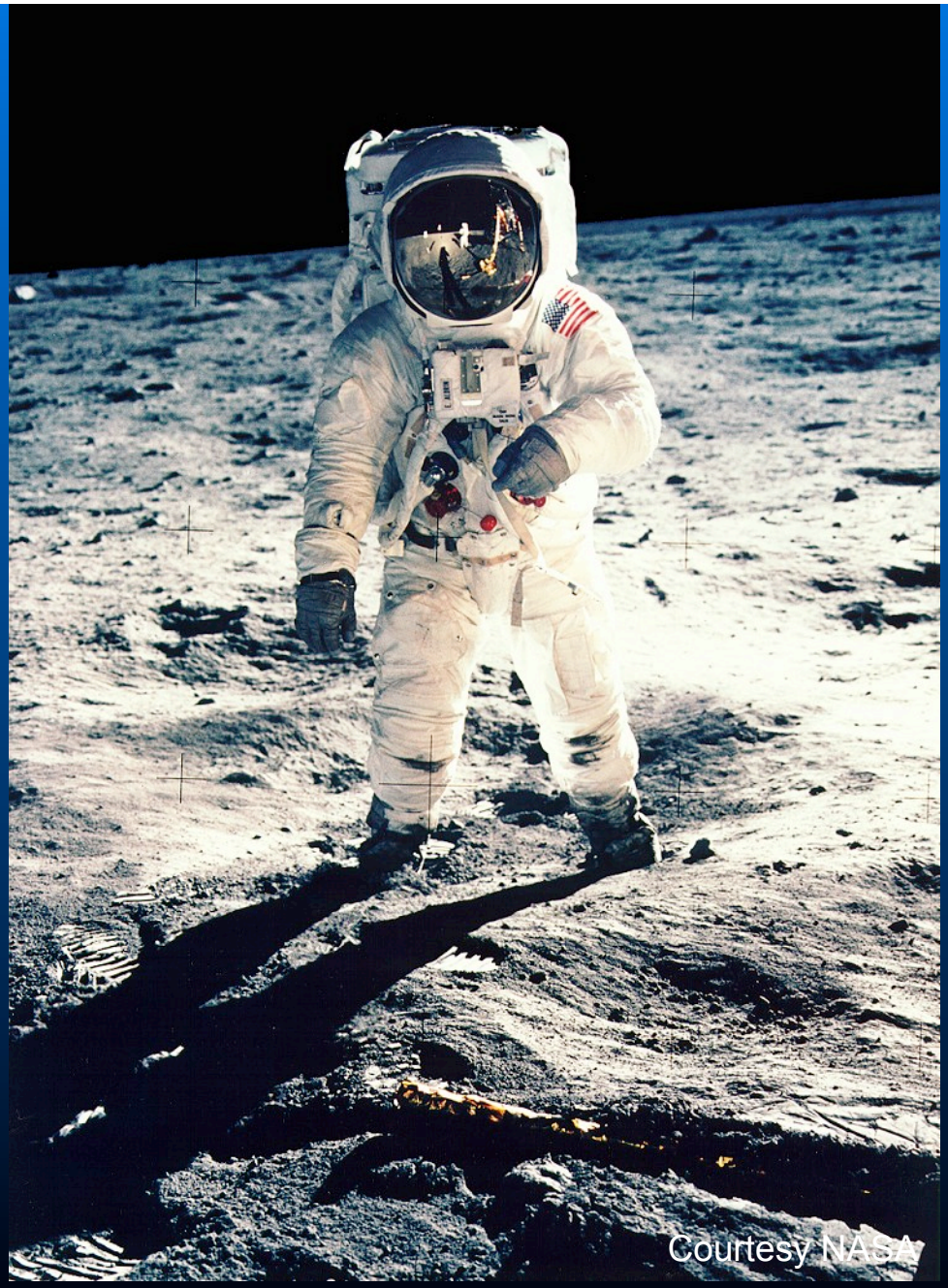
Courtesy CERN

The Large Hadron Collider

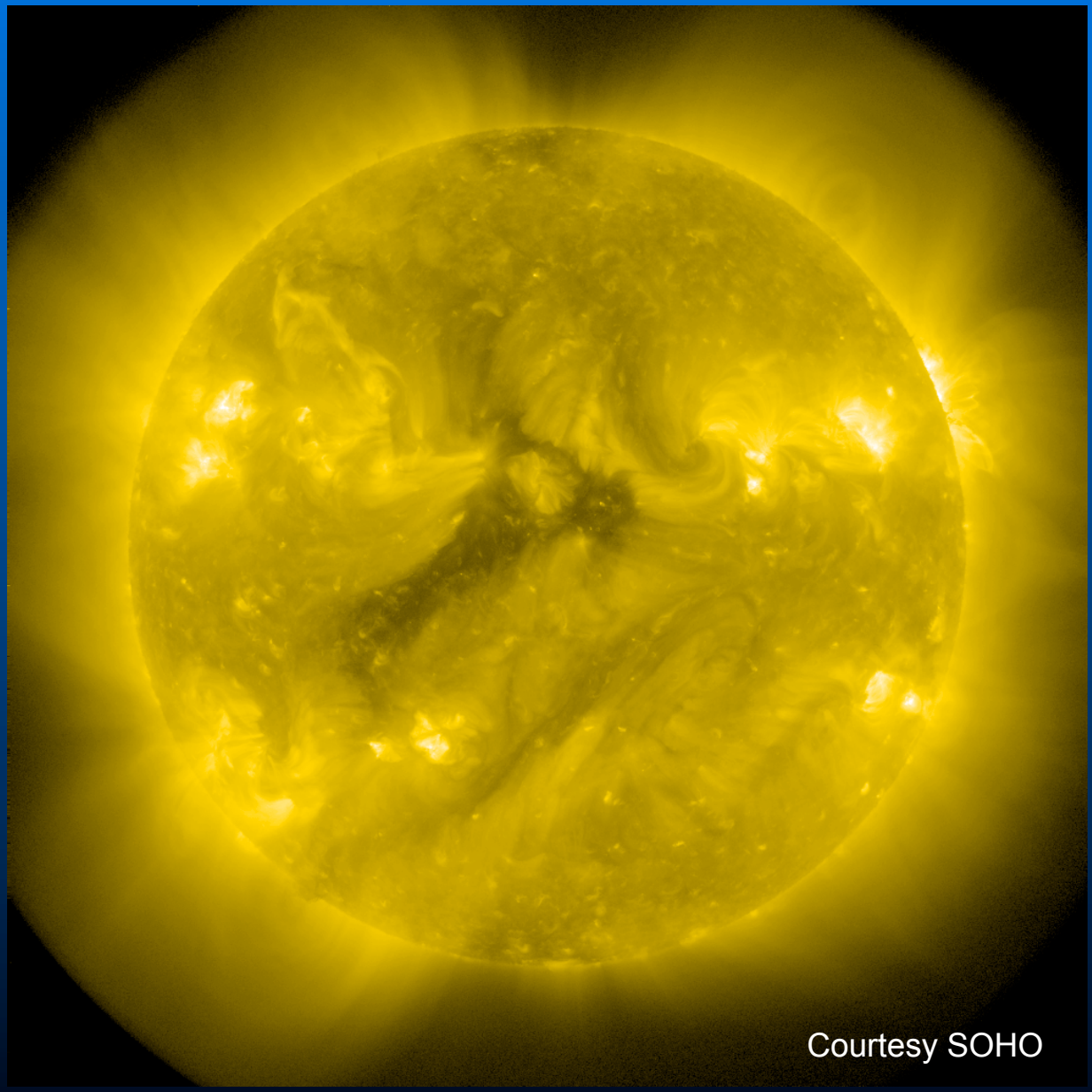



components
colder than
outer space
Courtesy CERN

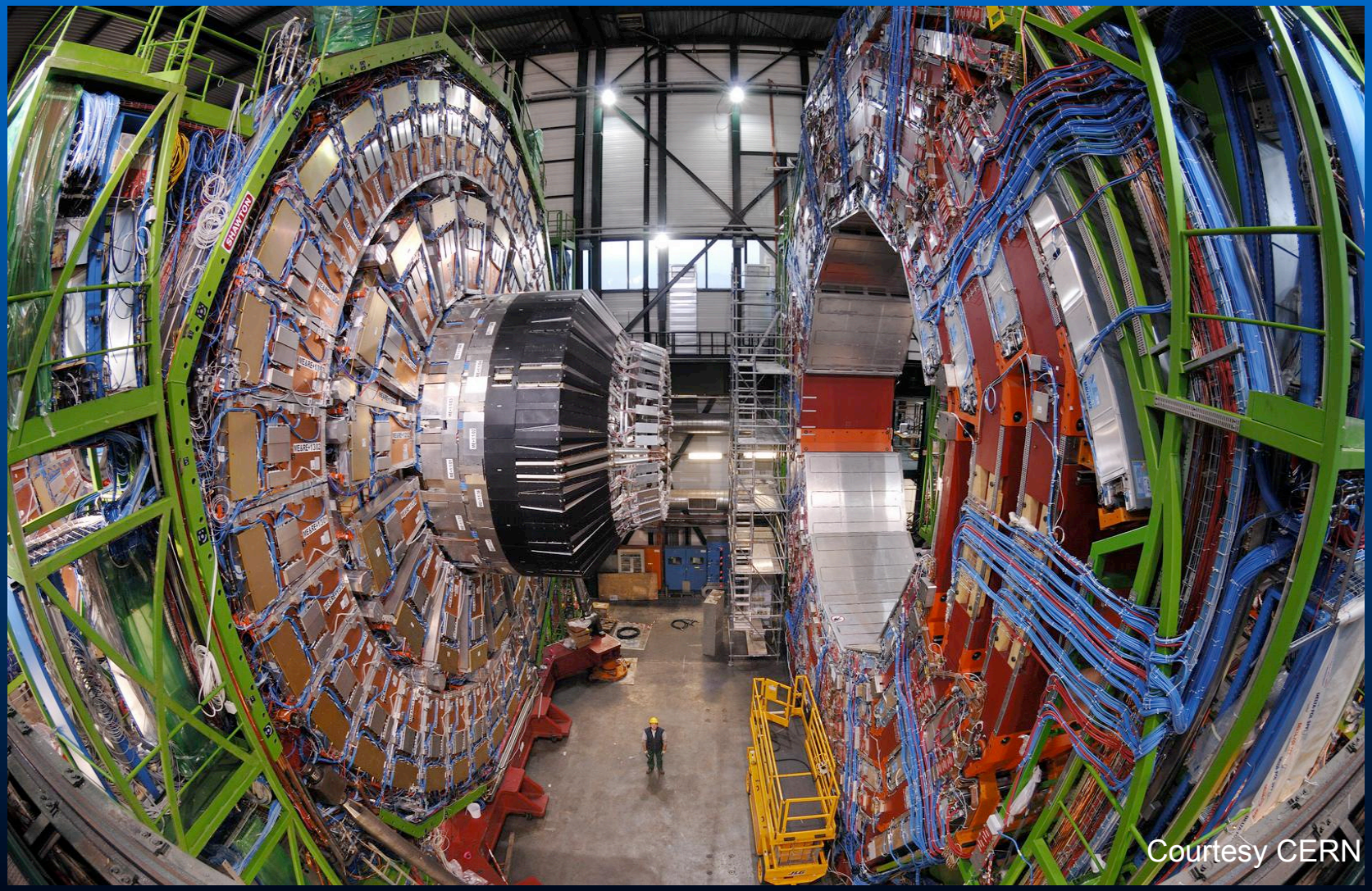
Pressure in the two, 27 km, vacuum pipes **lower** than on the Moon



Temperatures a billion times **greater** than in the solar core

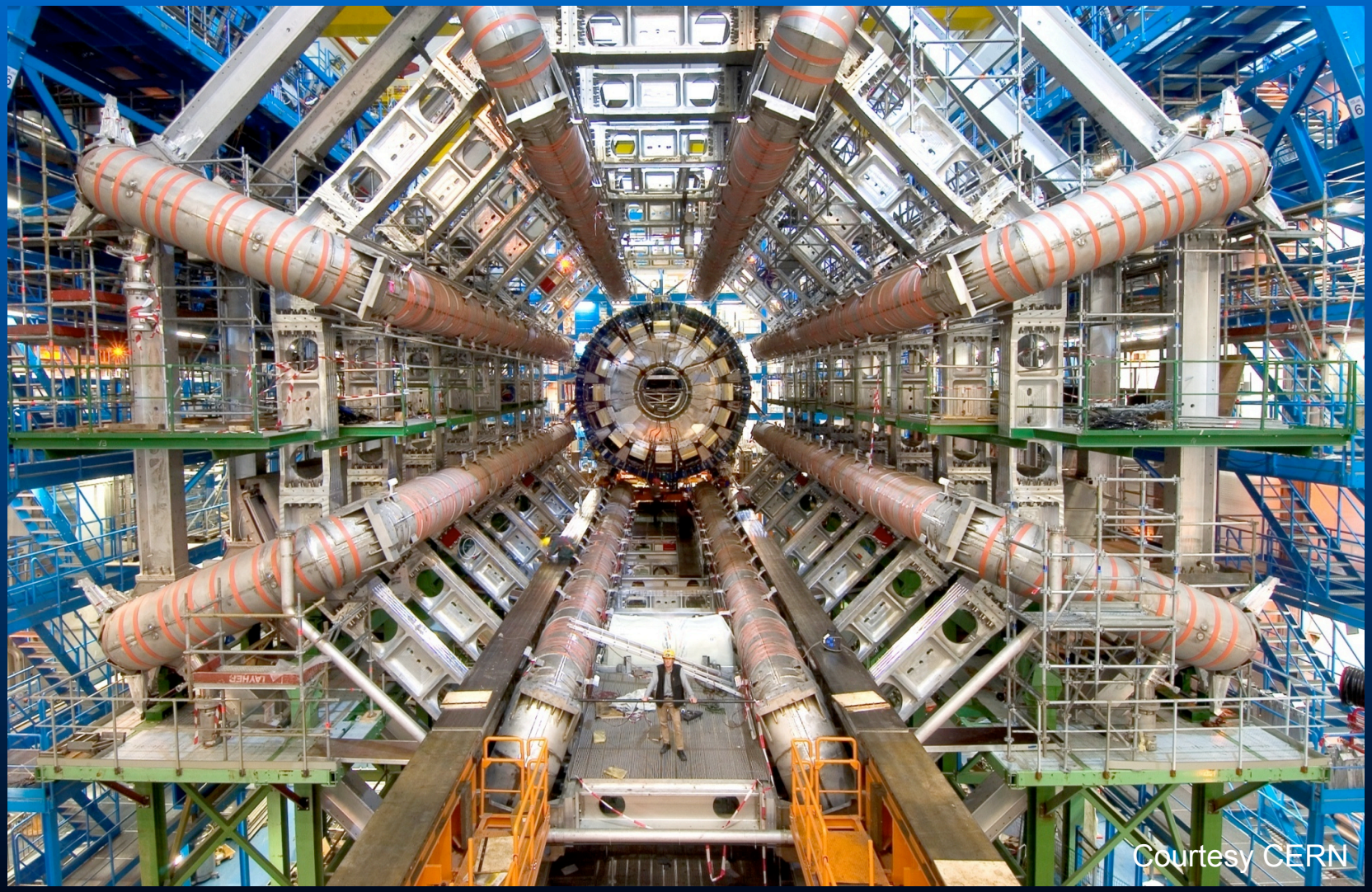


Most complex instruments ever built…



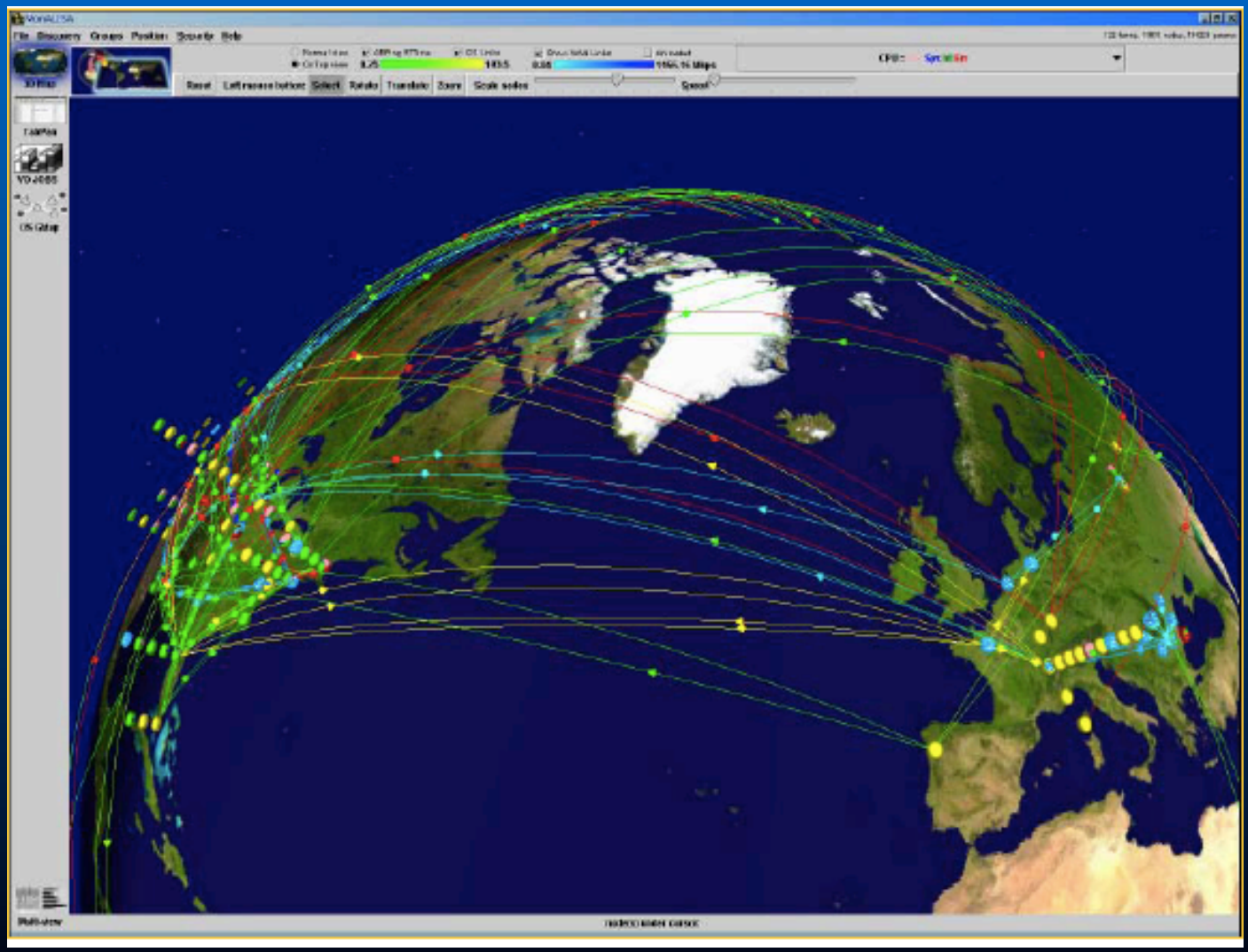
CMS

…and the **largest**



ATLAS

Biggest scientific computing project



Largest collaborative scientific project

> 7000 scientists

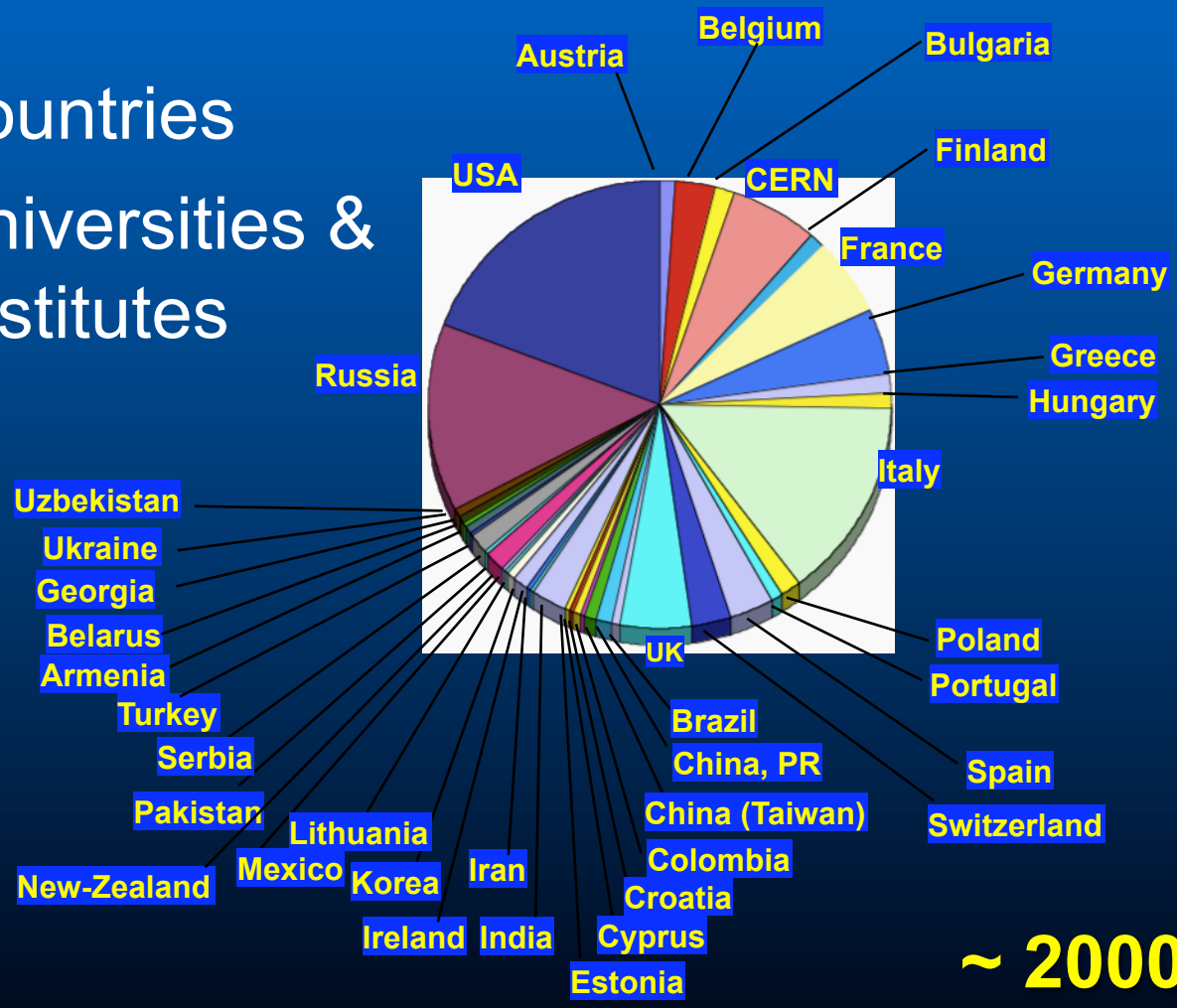
85 countries

Total project cost
$9 Billion

…And A Sociological Marvel

38 countries

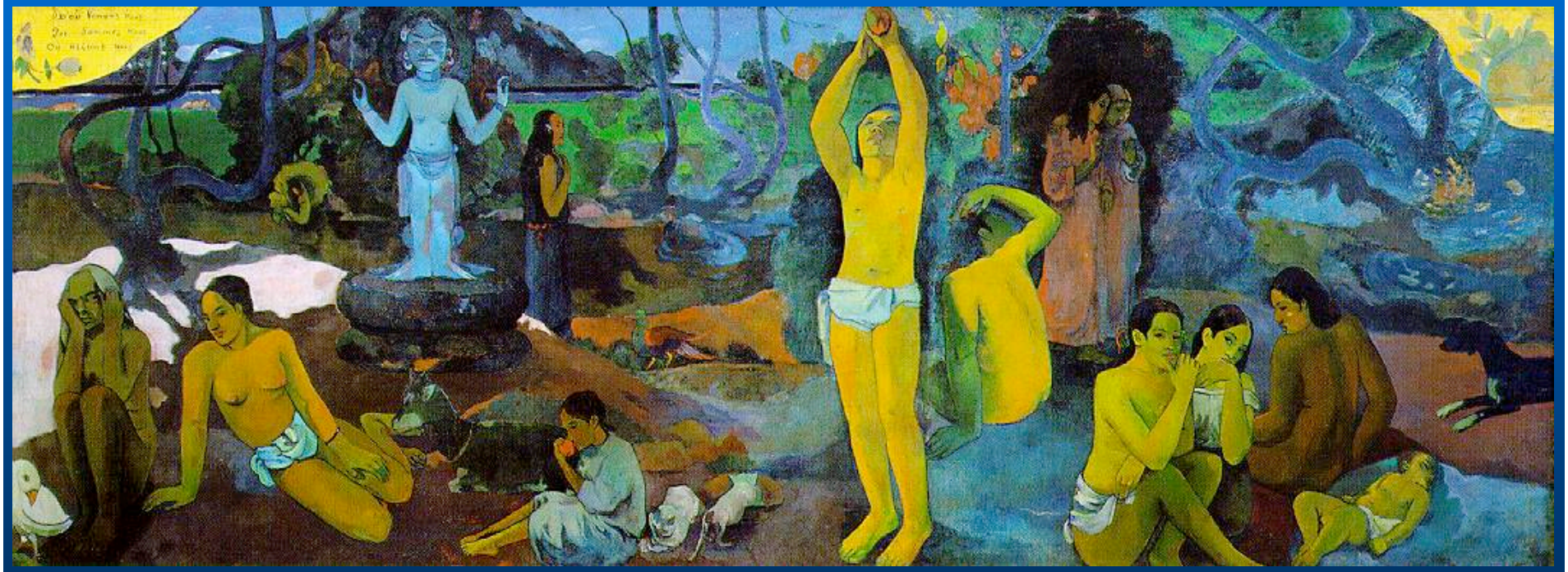
134 universities & institutes



CMS

~ 2000 physicists

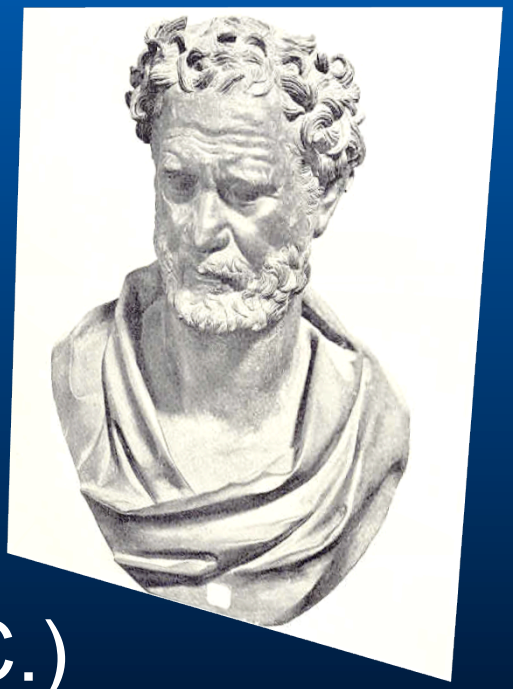
WHY ?



Where Do We Come From?
What Are We?
Where Are We Going?
Paul Gauguin (1897)
Museum of Fine Arts, Boston

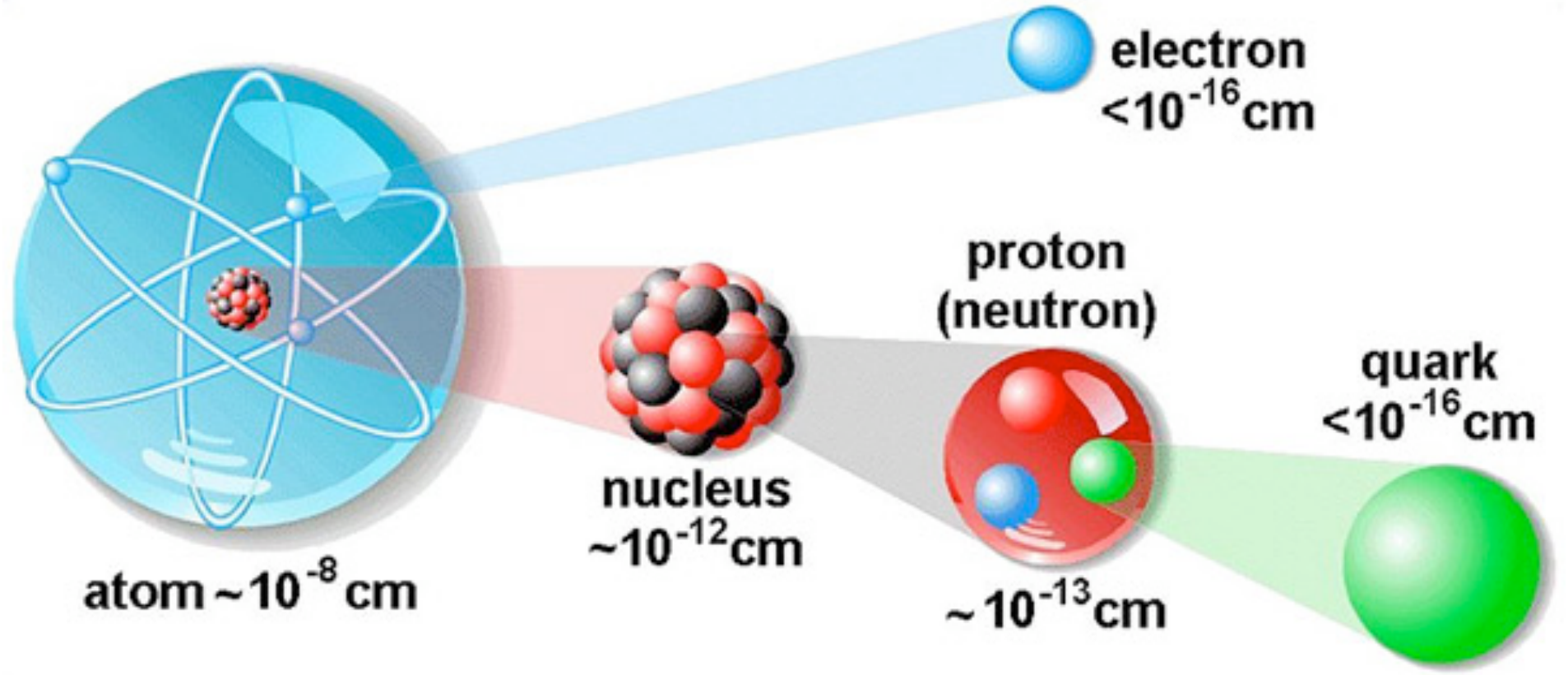
The Atomic Hypothesis

By convention there is color,
By convention sweetness,
By convention bitterness,
But in reality there are
atoms and space

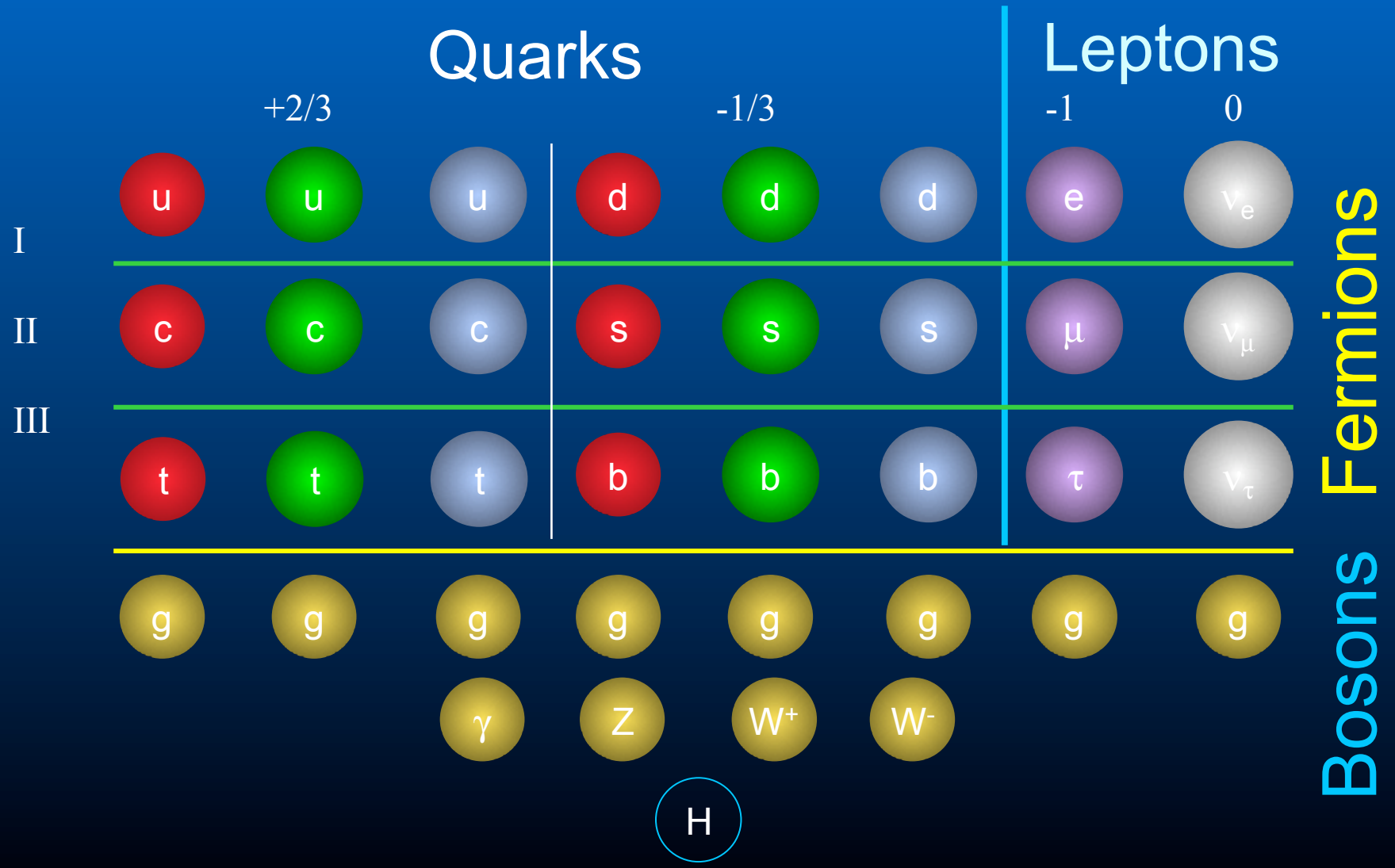


Democritus (400 B.C.)

The Atomic Hypothesis…



The Atomic Hypothesis, circa 2011



Bosons manifested as forces

Strong Force **1** (Gluons)

Binds quarks to form protons, neutrons, and nuclei

Electromagnetic Force **10^{-2}** (Photon)

Binds electrons and nuclei to form atoms

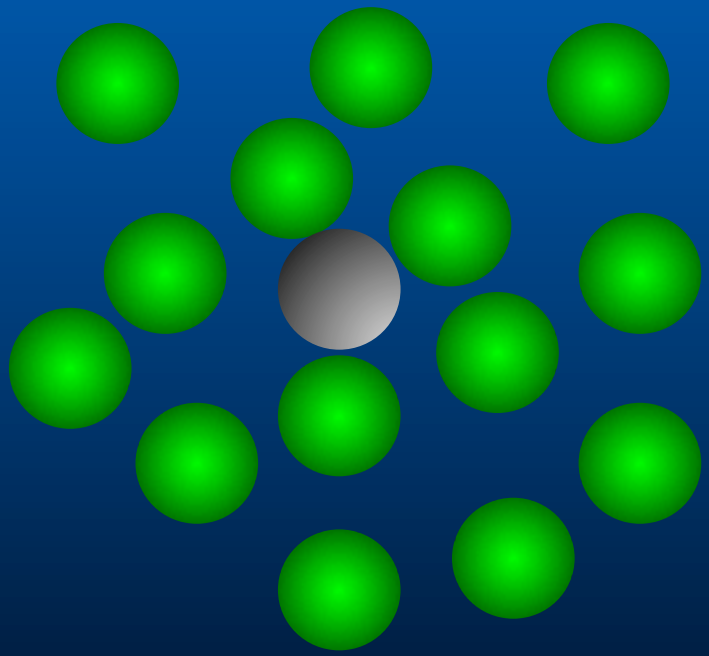
Weak Force **10^{-5}** (W & Z Bosons)

Causes radioactivity

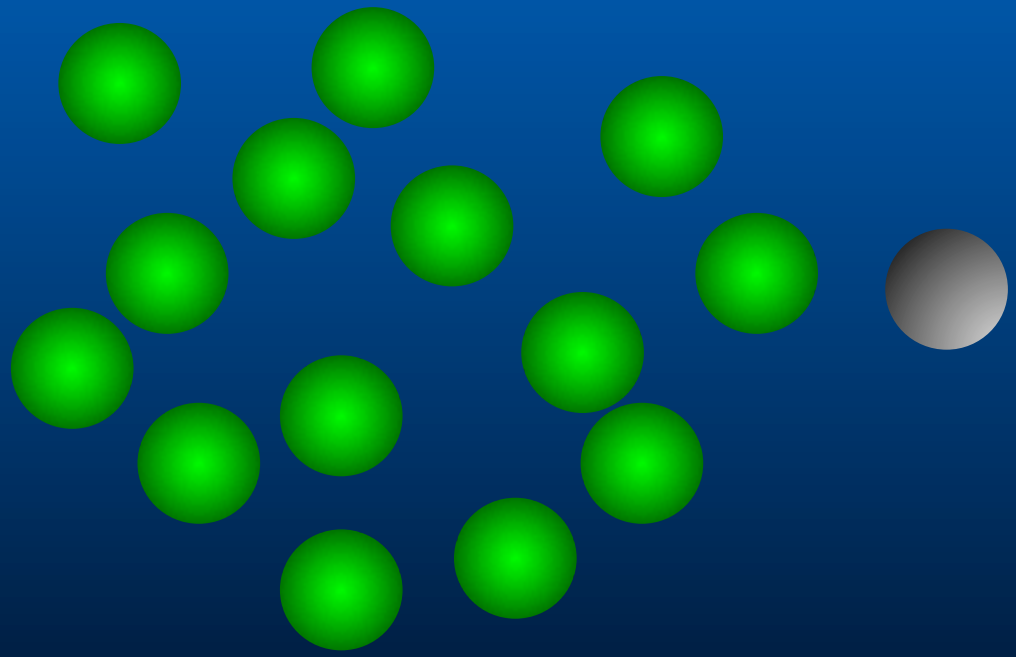
Gravitational Force **10^{-39}** (Graviton)

Binds matter on large scales

Prediction: A quark is surrounded by a cloud of color charge

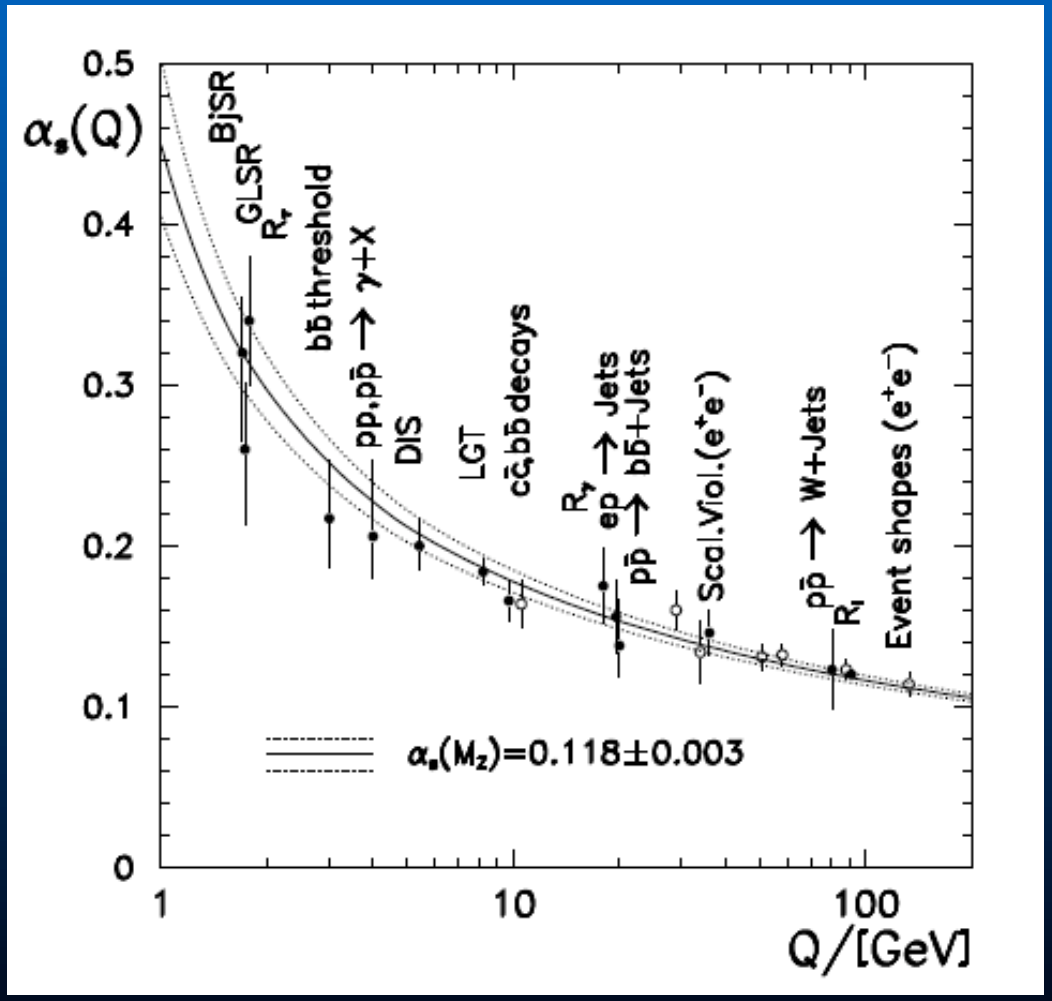


A sufficiently violent impact can dislodge the quark from its cloud, and thus temporarily



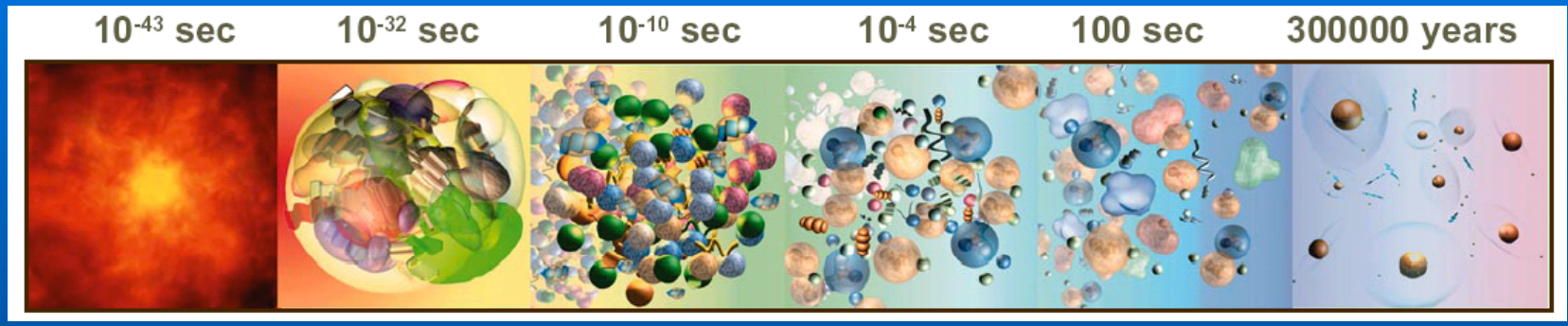
lower the quark's effective charge

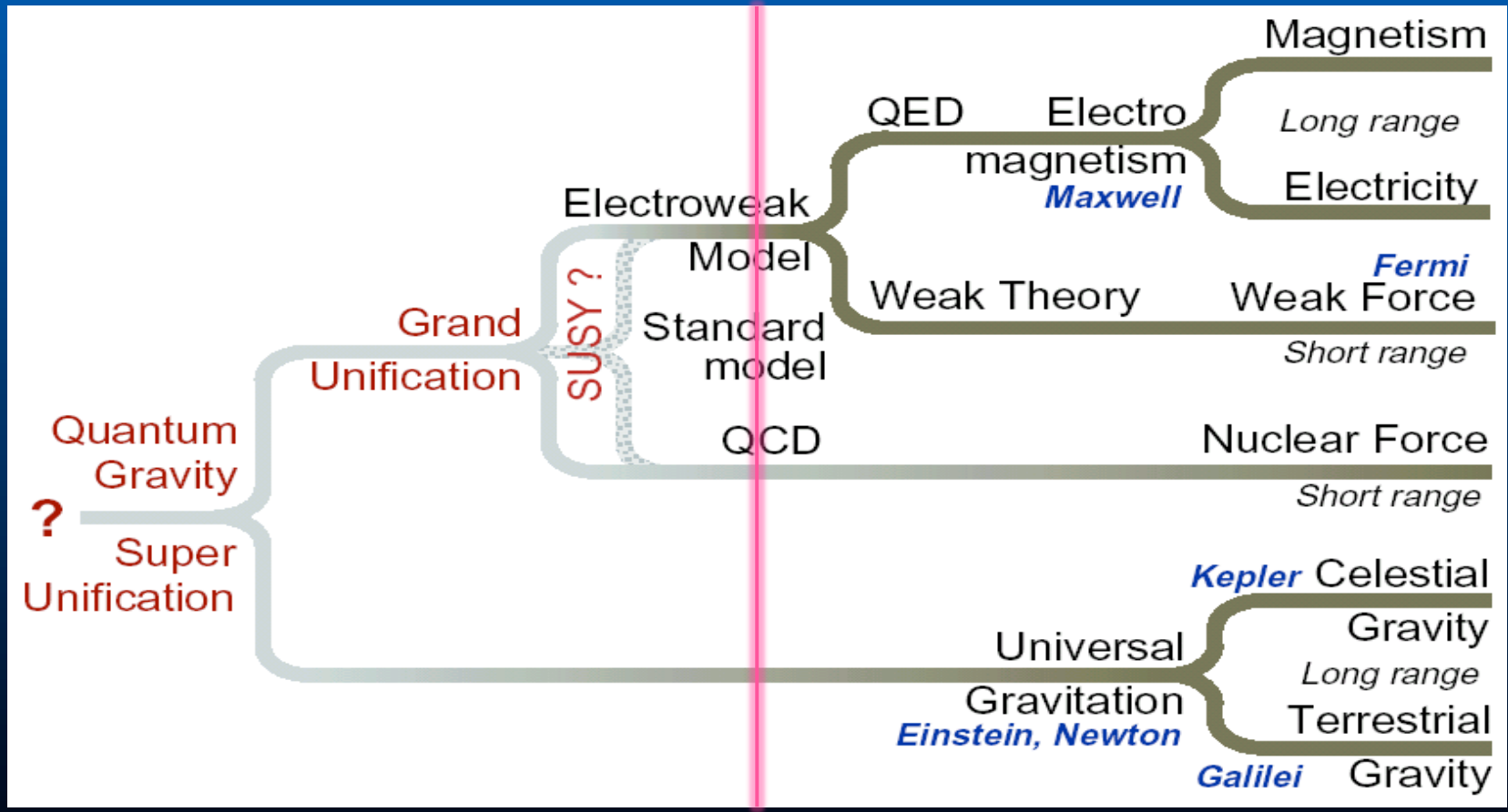
Experimental verification



Quarks become quasi-free when struck hard enough

(**asymptotic freedom**)


10^{-43} sec
10^{-32} sec
10^{-10} sec
10^{-4} sec
100 sec
300000 years


Magnetism
QED
Electro
magnetism
Maxwell
Long range
Electricity
Electroweak
Model
Fermi
Weak Theory
Weak Force
Short range
Grand
Unification
SUSY ?
Standard
model
QCD
Nuclear Force
Short range
Quantum
Gravity
?
Super
Unification
Kepler
Celestial
Gravity
Universal
Gravitation
Einstein, Newton
Long range
Terrestrial
Gravity
Galilei

…but, we must venture Beyond

…BECAUSE…

…of the things we don't understand

The Mass Puzzle

Why do quarks and leptons have mass?

The Identity Puzzle

What makes an electron an electron, a top quark a top quark, etc.?

The Matter Puzzle

Why is there overwhelmingly more matter than antimatter?

…more things we don't understand

The Just-So Puzzle

Do we need to explain the Standard Model parameters, e.g., the quark masses?

The Dark Matter Puzzle

What is dark matter?

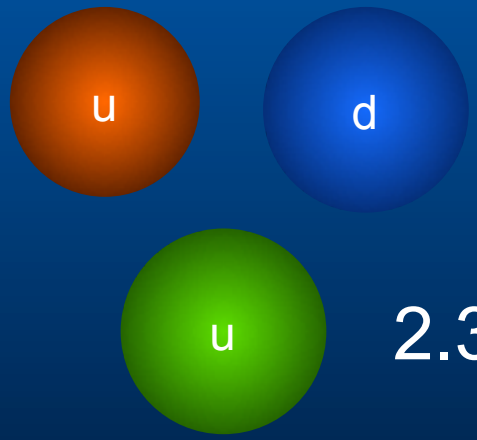
The Dark Energy Puzzle

What is dark energy?

The Mass Puzzle

The Higgs hypothesis: particle masses arise from the interaction of (massless) particles with the Higgs field

$$m = \frac{E}{c^2}$$



Total mass 9.6 MeV

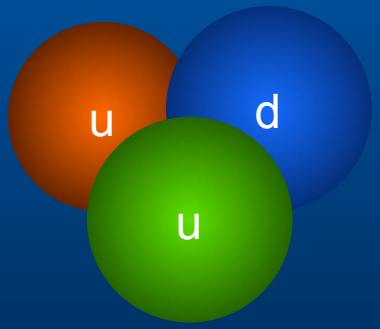
But, proton mass is **938** MeV !

The Just-So Puzzle

2.3 MeV
2.3 MeV
5.0 MeV

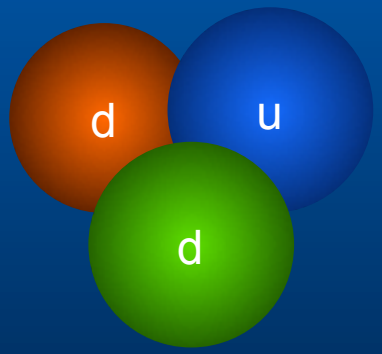
9.6 MeV

Proton



938.3 MeV
– 9.6 MeV
928.7 MeV

Neutron



939.6 MeV
–12.3 MeV
927.3 MeV

5.0 MeV
5.0 MeV
2.3 MeV

12.3 MeV

Do we need to explain this?

“There must be more matter than stars.....”

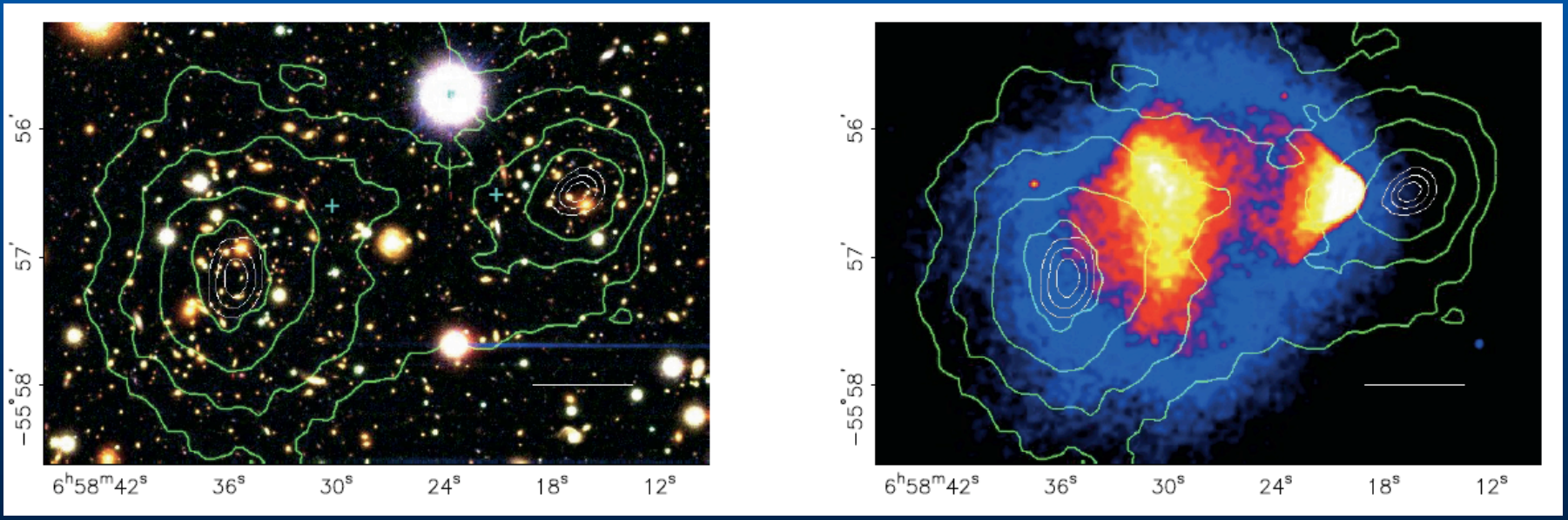
Jan H. Oort (1932)

nine-tenths of Coma Cluster is made of dark matter

Fritz Zwicky (1933)

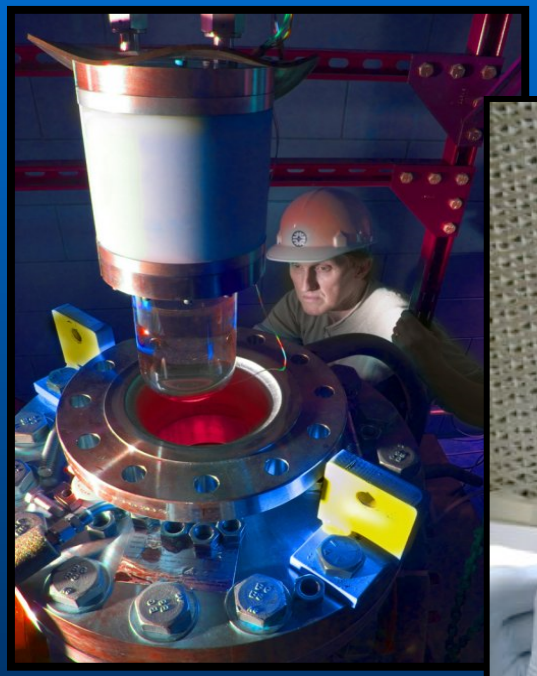
The Whirlpool Galaxy — M51 HUBBLESITE.org

Worlds in collision – the Bullet Cluster



D. Clowe et al., Astrophys. J. **648**, 109 (2006)

COUPP



CDMS

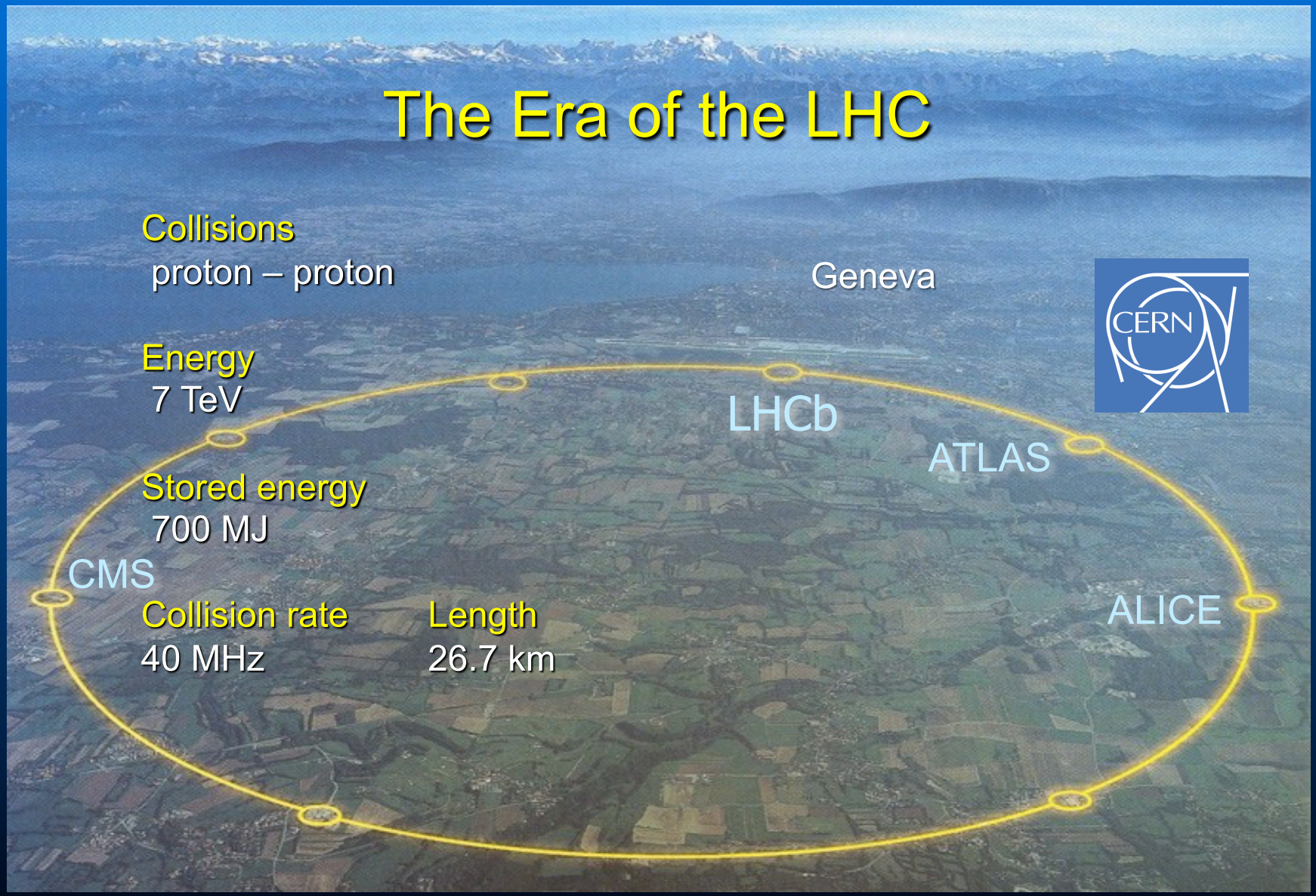
XENON

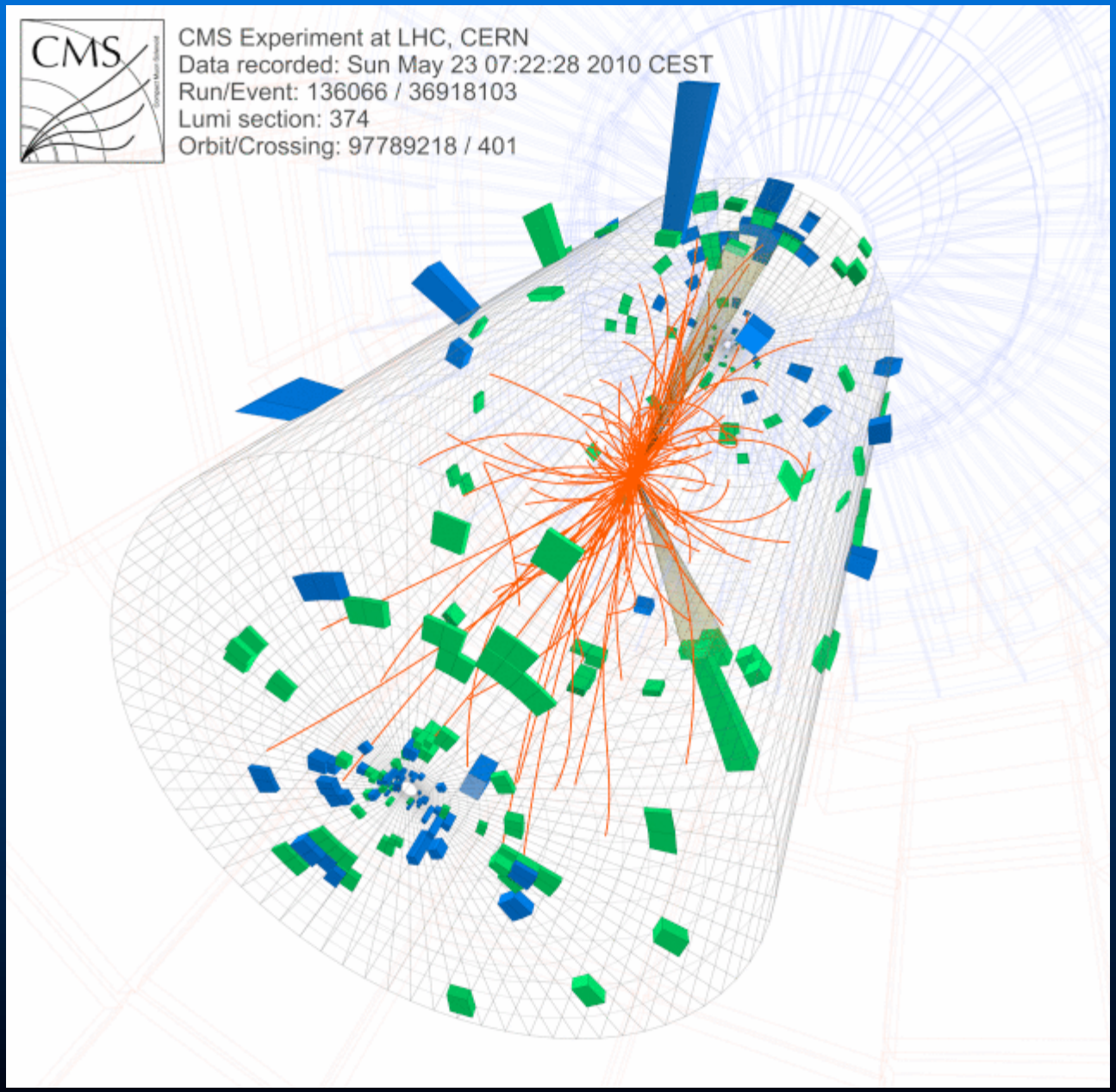
DAMA

IceCube

Fermi/GLAST

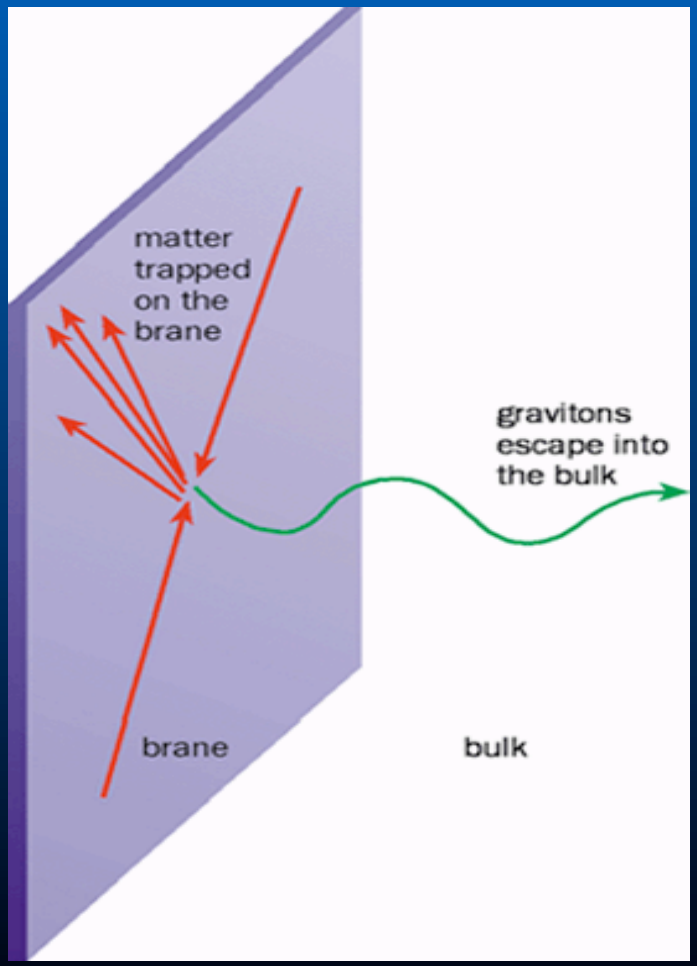
The Era of the LHC



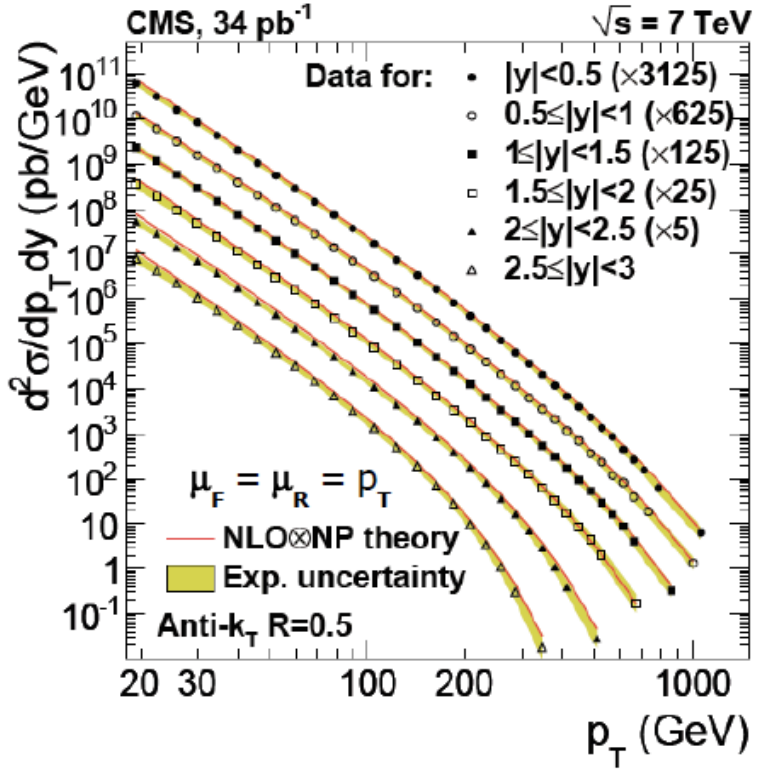

CMS
CMS Experiment at LHC, CERN
Data recorded: Sun May 23 07:22:28 2010 CEST
Run/Event: 136066 / 36918103
Lumi section: 374
Orbit/Crossing: 97789218 / 401

What might we find?

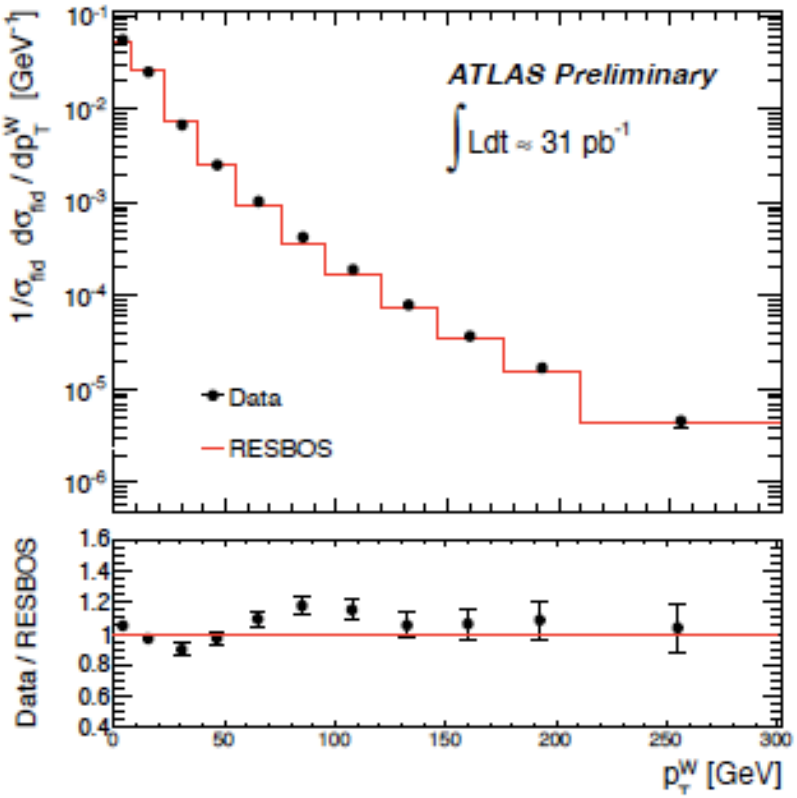
- Higgs boson *****
- Dark matter ****
- Quark and lepton substructure ***
- The unexpected **
- Black holes *
- Nothing!



Nothing new yet…but stay tuned!



CMS public result: QCD-10-011
arXiv:1106.0208v1 [hep-ex]



[8] STDM-2011-15

The End

"I do not know what I may appear to the world; but to myself I seem to have been only like a boy, playing on the seashore, and diverting myself, in now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me."

Sir Isaac Newton

Many thanks to the taxpayers of the World