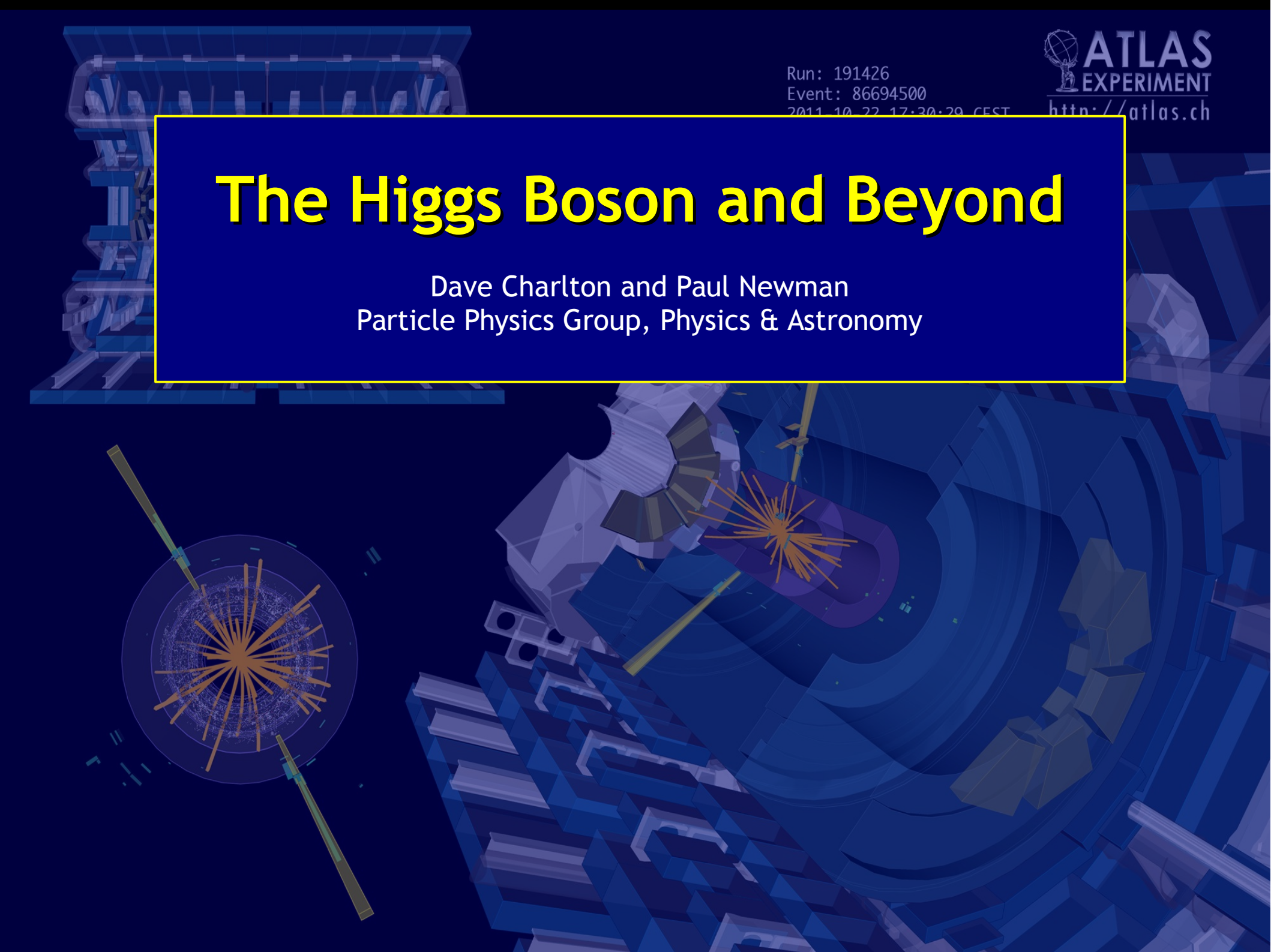
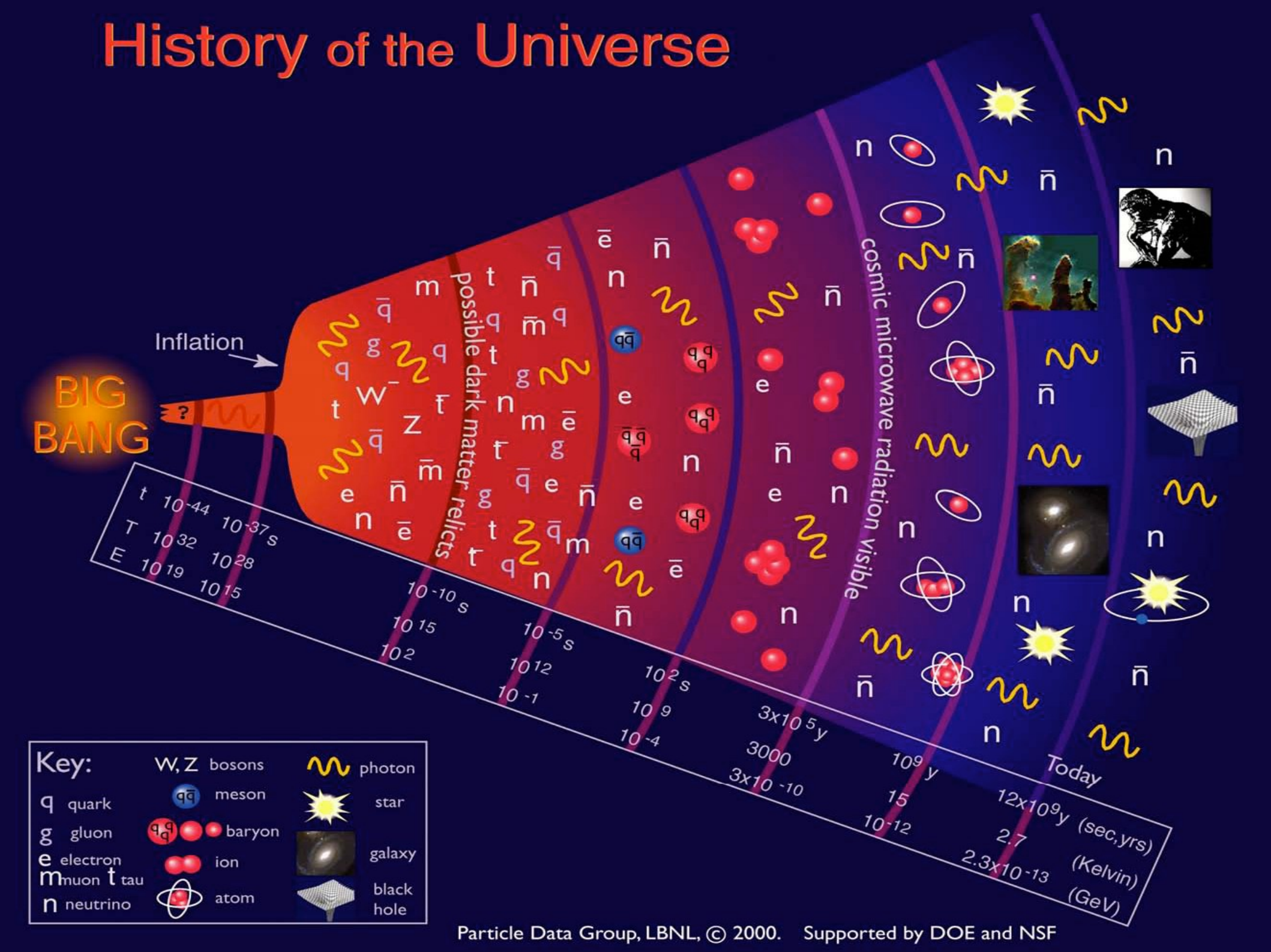


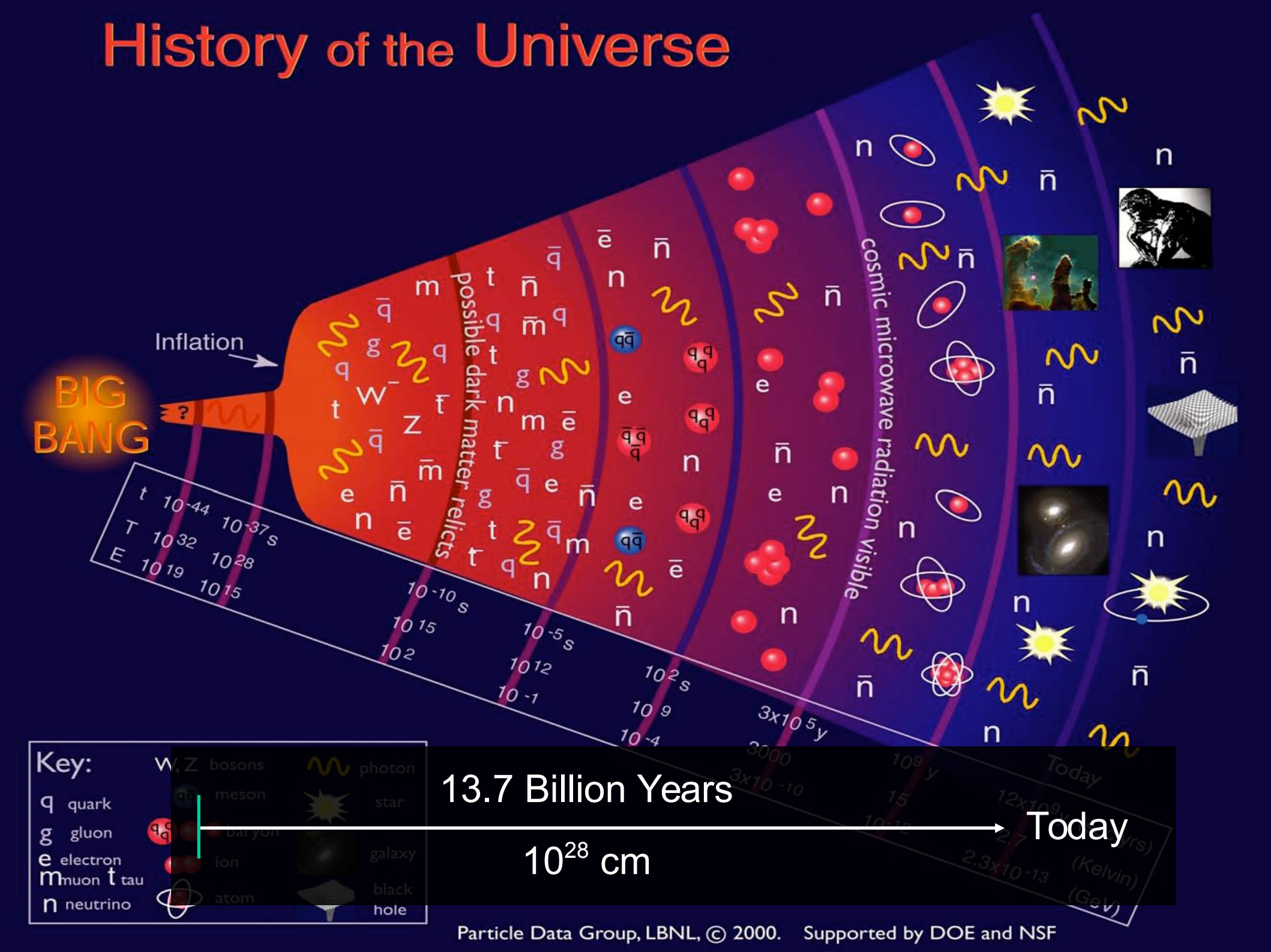
The Higgs Boson and Beyond

Dave Charlton and Paul Newman
Particle Physics Group, Physics & Astronomy

What's it all about?

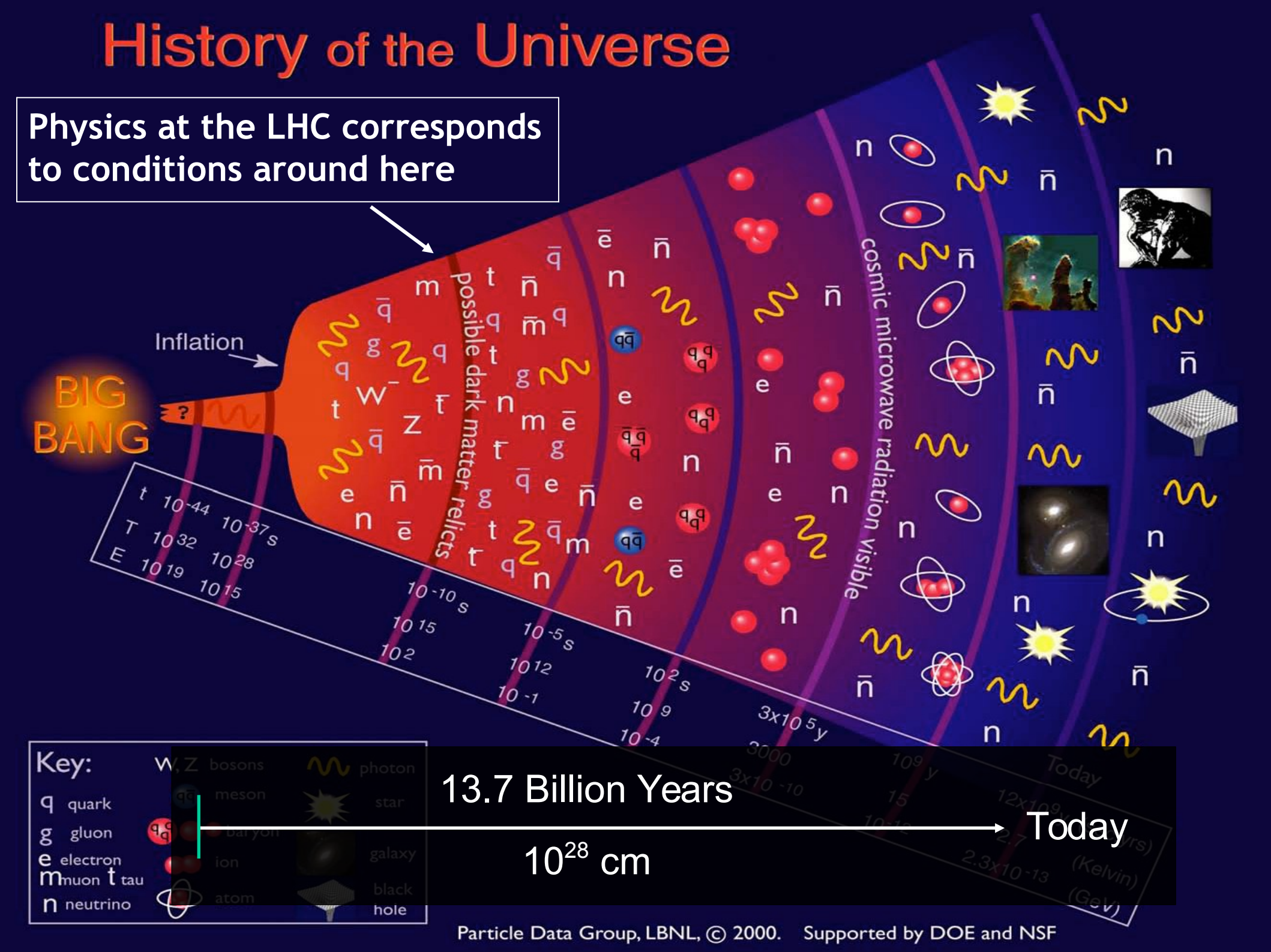
History of the Universe



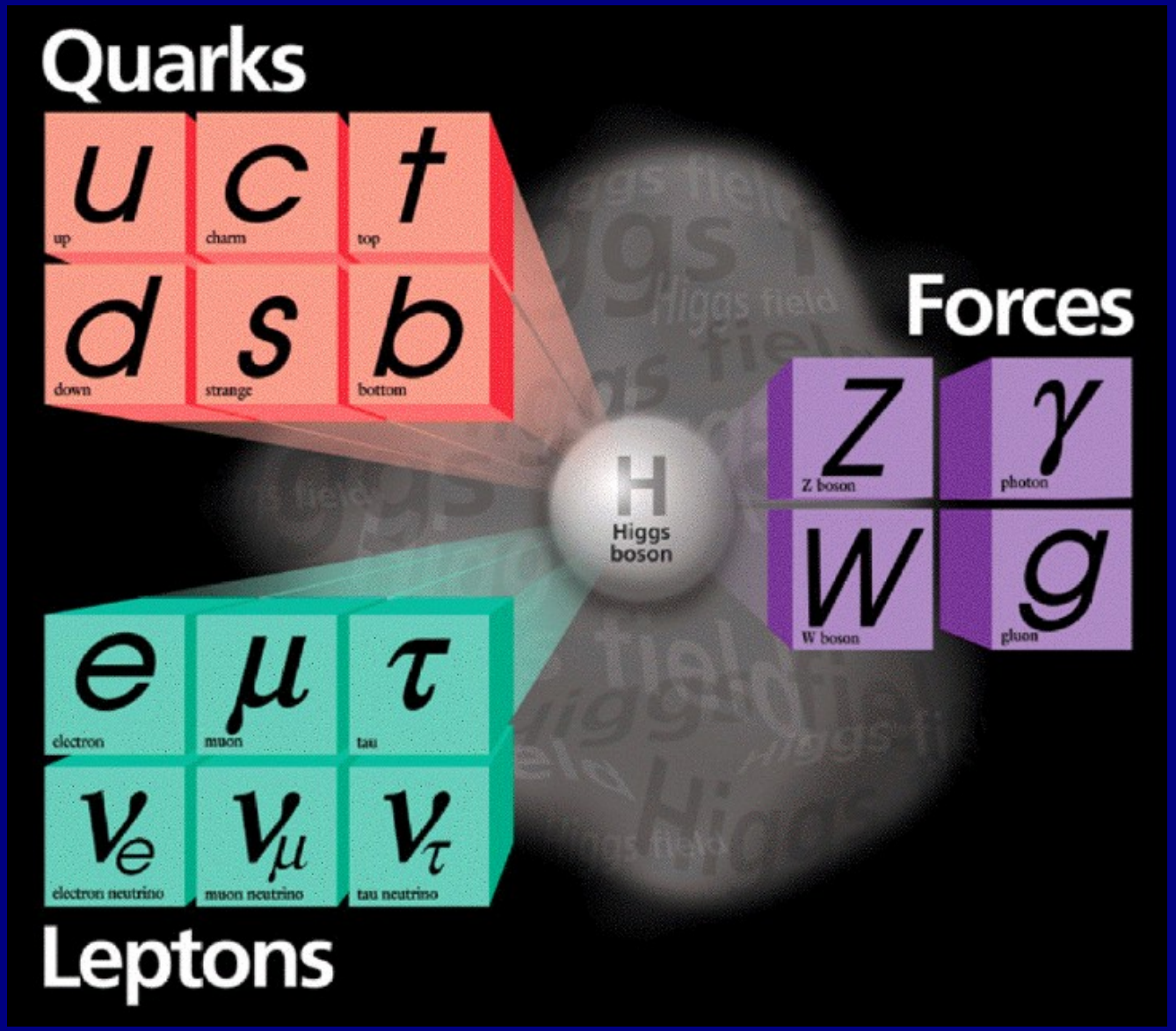

History of the Universe
BIG BANG
Inflation
?
possible dark matter relicts
cosmic microwave radiation visible
t 10-44 10-37 s
T 1032 1028
E 1019 1015
10-10 s
10 15
10 2
10-5 s
10 12
10 -1
102 s
10 9
10 -4
3x10 5 y
3000
3x10 -10
109 y
15
Today
12x10
2.7
2.3x10 -13
(Kelvin)
(GeV)
Key:
q quark
g gluon
e electron
m muon t tau
n neutrino
W, Z bosons
meson
baryon
ion
atom
photon
star
galaxy
black hole
13.7 Billion Years
Today
10^28 cm
Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

History of the Universe

Physics at the LHC corresponds to conditions around here



Particles and Forces: The Standard Model

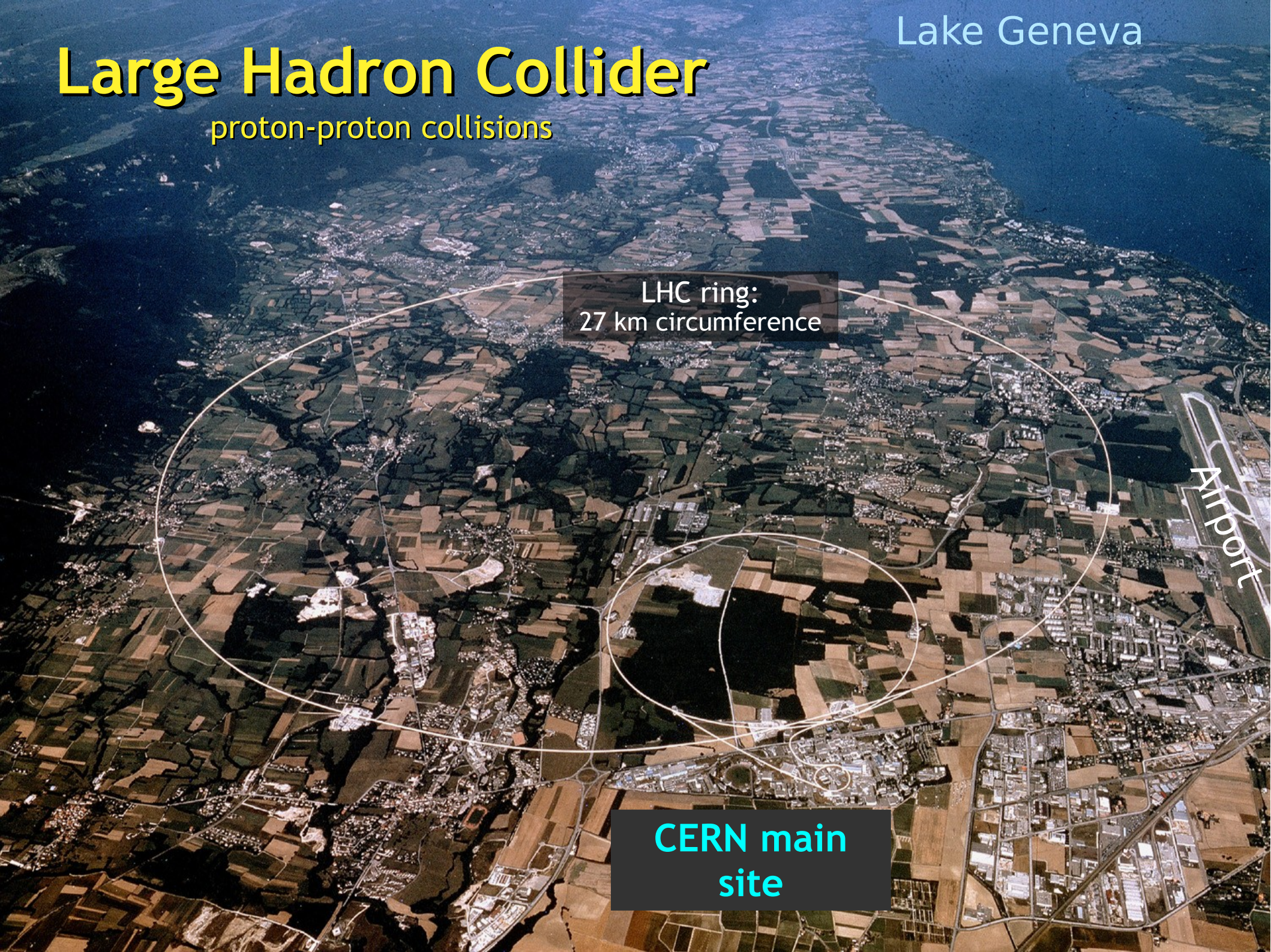


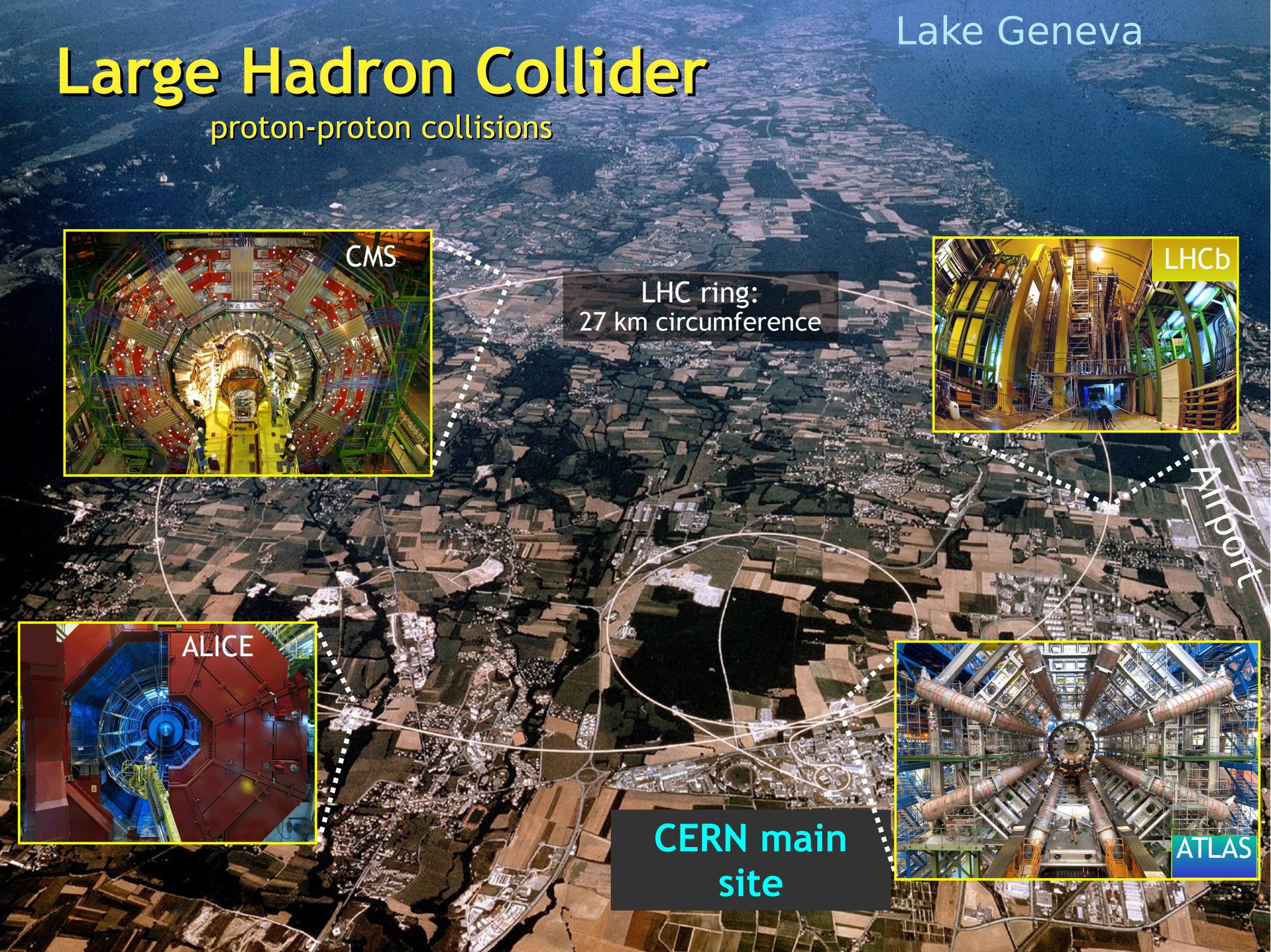
Matter Particles

Force-carriers

Fermions

Bosons

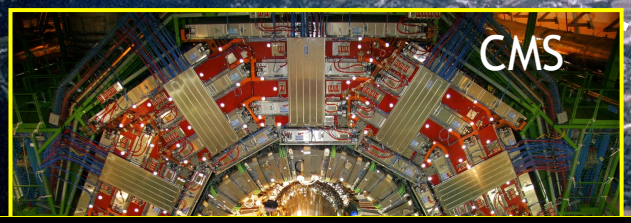

Large Hadron Collider
proton-proton collisions
Lake Geneva
LHC ring:
27 km circumference
Airport
CERN main site


Lake Geneva
Large Hadron Collider
proton-proton collisions
CMS
LHC ring:
27 km circumference
LHCb
Airport
ALICE
CERN main site
ATLAS

Large Hadron Collider

proton-proton collisions

Lake Geneva

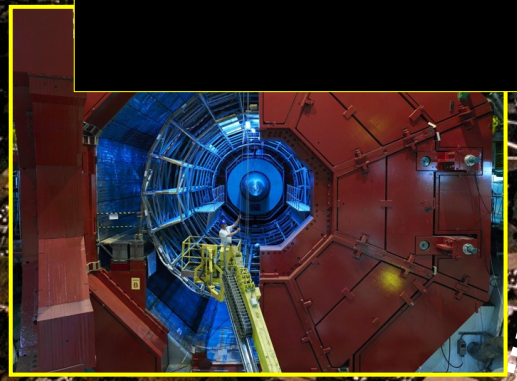


LHC ring:
27 km circumference

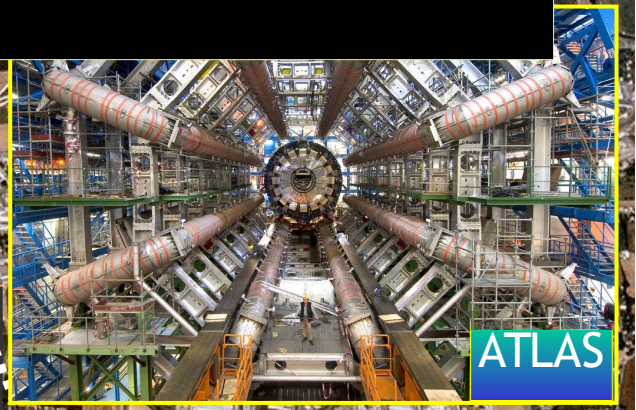
ATLAS and CMS are the two "discovery experiments"

In Birmingham we work on ATLAS

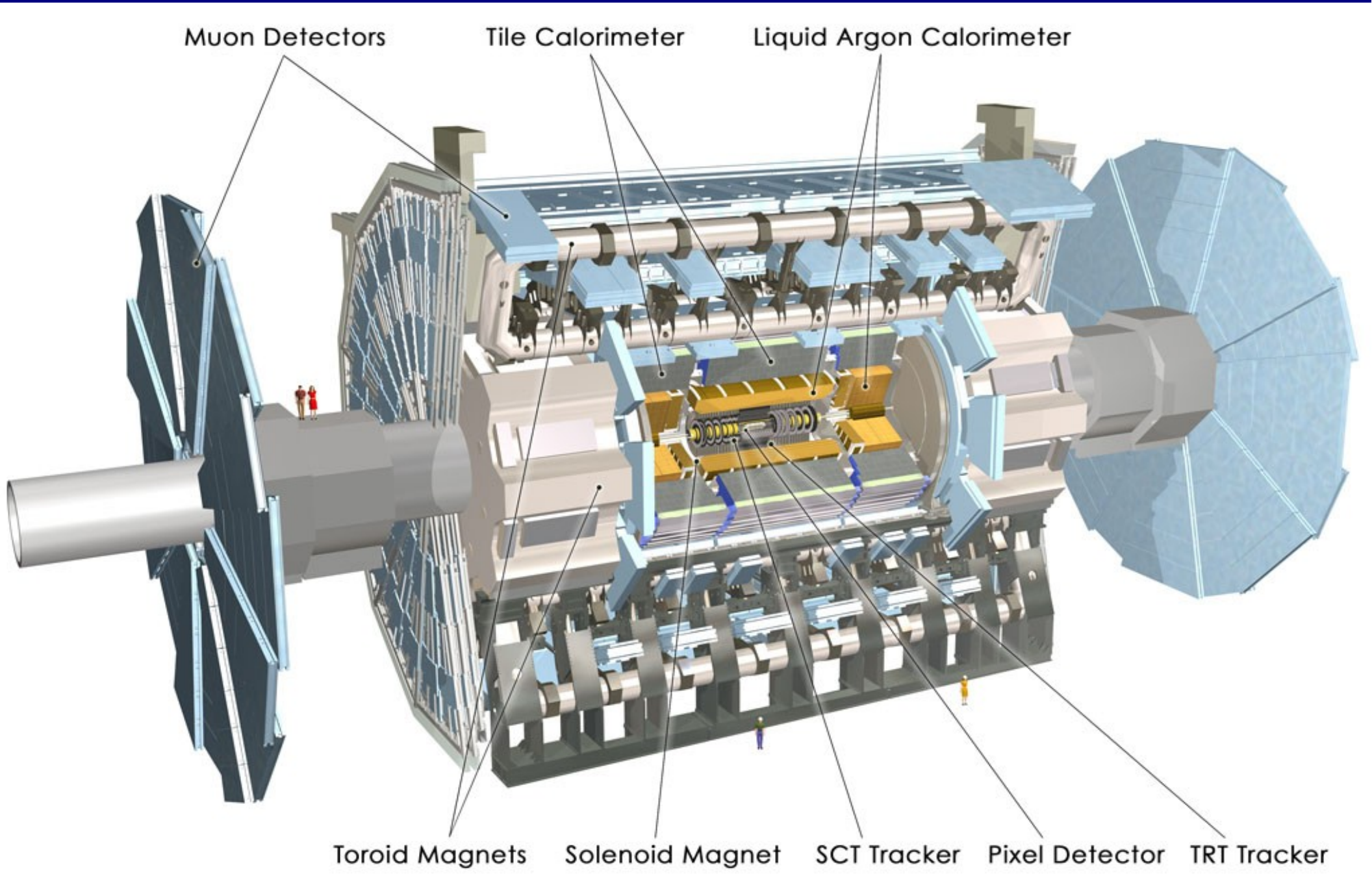
also ALICE and LHCb



CERN main site



ATLAS Detector



A global collaboration

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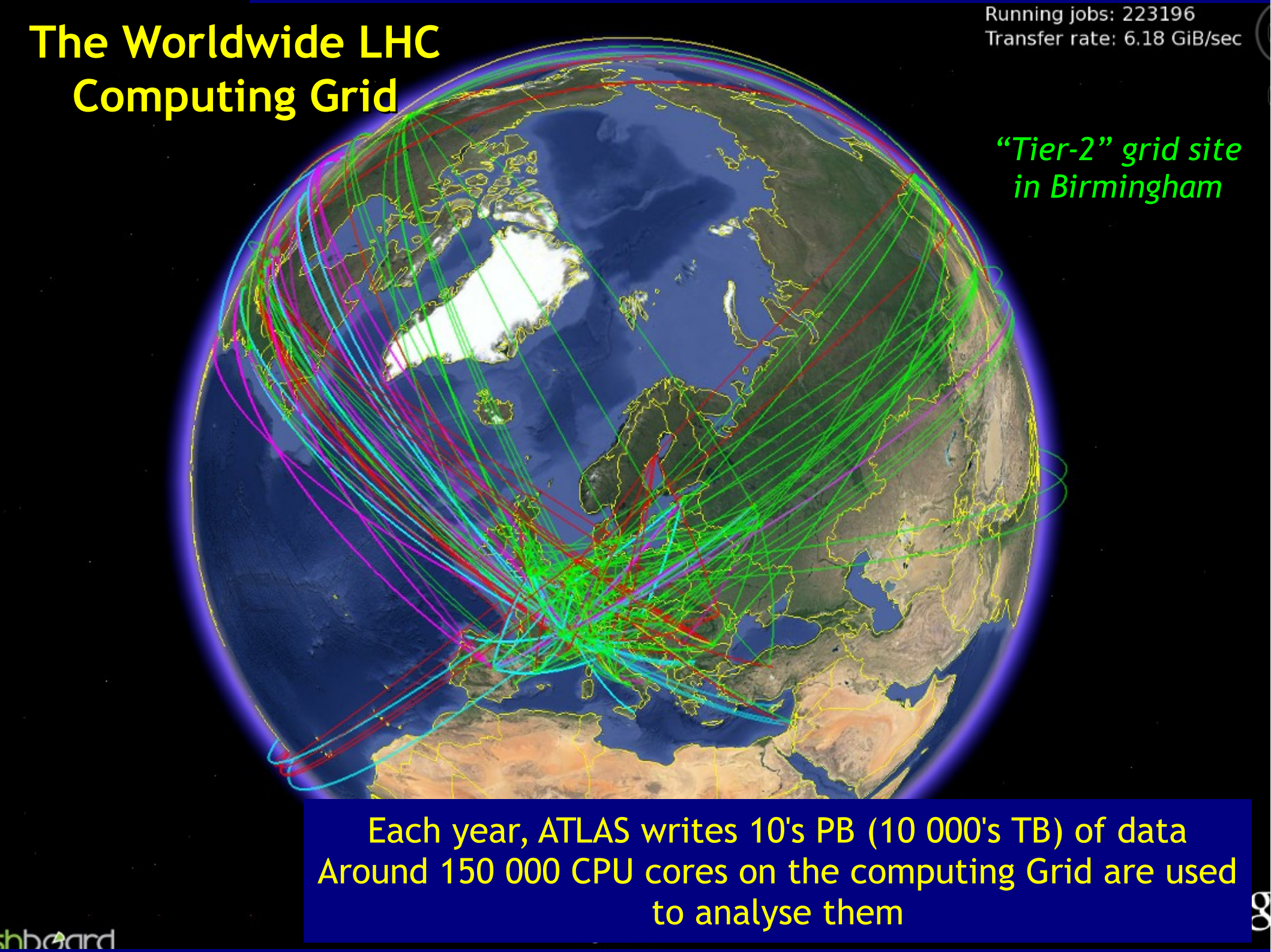
2900 scientific authors, including 1000 students

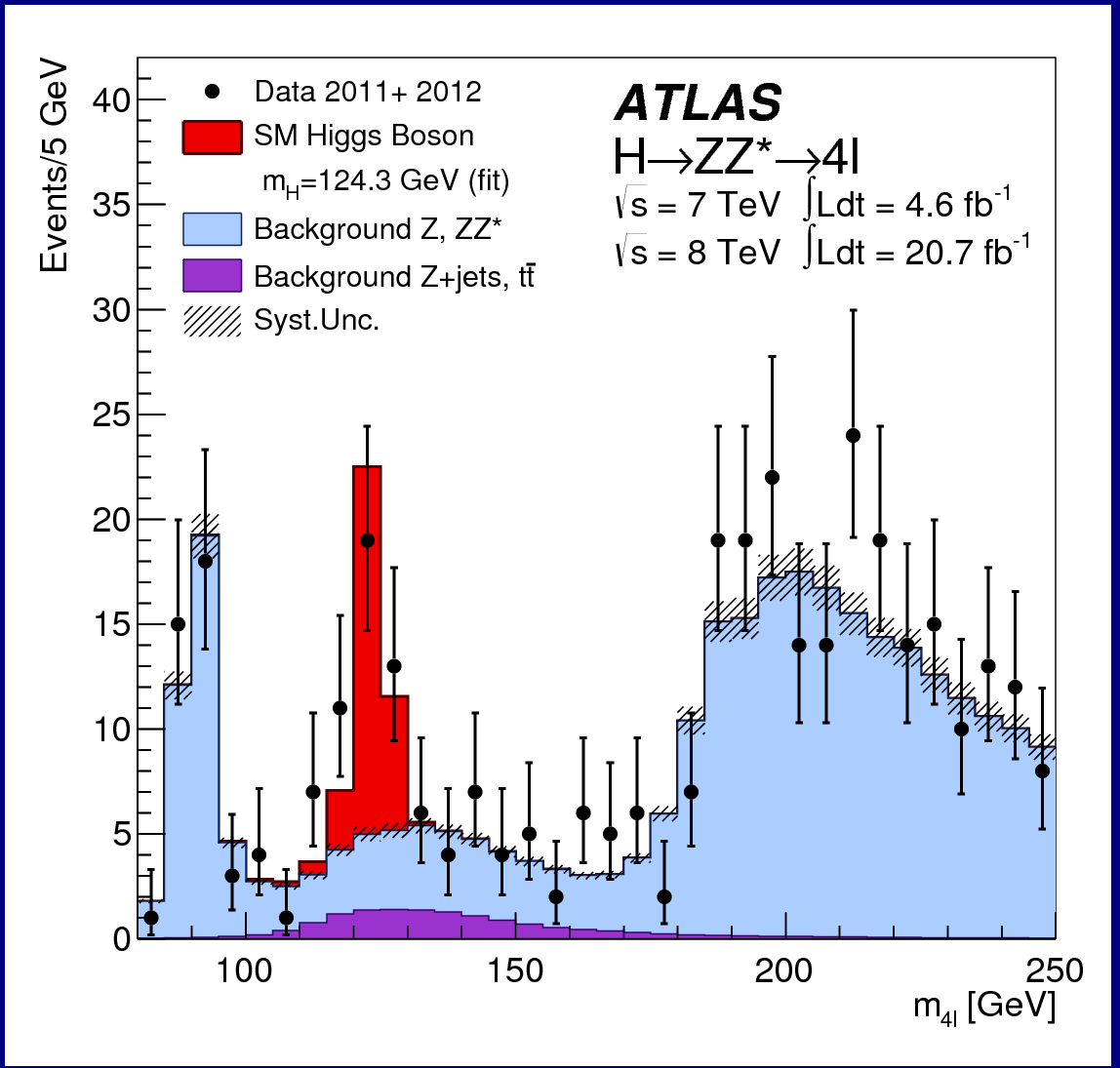
Adelaide, Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, HU Berlin, Bern, **Birmingham**, UAN Bogota, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brazil Cluster, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, CERN, Chinese Cluster, Chicago, Chile, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, SMU Dallas, UT Dallas, DESY, Dortmund, TU Dresden, JINR Dubna, Duke, Edinburgh, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, Göttingen, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Iowa, UC Irvine, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Kyushu, Lancaster, UN La Plata, Lecce, Lisbon LIP, Liverpool, Ljubljana, QM London, RH London, UC London, Louisiana Tech, Lund, UA Madrid, Mainz, Manchester, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, RUPHE Morocco, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Nagoya, Naples, New Mexico, New York, Nijmegen, Northern Illinois University, BINP Novosibirsk, NPI Petersburg, Ohio SU, Okayama, Oklahoma, Oklahoma SU, Olomouc, Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Rome I, Rome II, Rome III, RAL-STFC, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC, South Africa Cluster, Stockholm, KTH Stockholm, Stony Brook, Sydney, Sussex, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Tokyo Tech, Toronto, TRIUMF, Tsukuba, Tufts, Udine/ICTP, Uppsala, UI Urbana, Valencia, UBC Vancouver, Victoria, Warwick, Waseda, Washington, Weizmann Rehovot, FH Wiener Neustadt, Wisconsin, Wuppertal, Würzburg, Yale, Yerevan

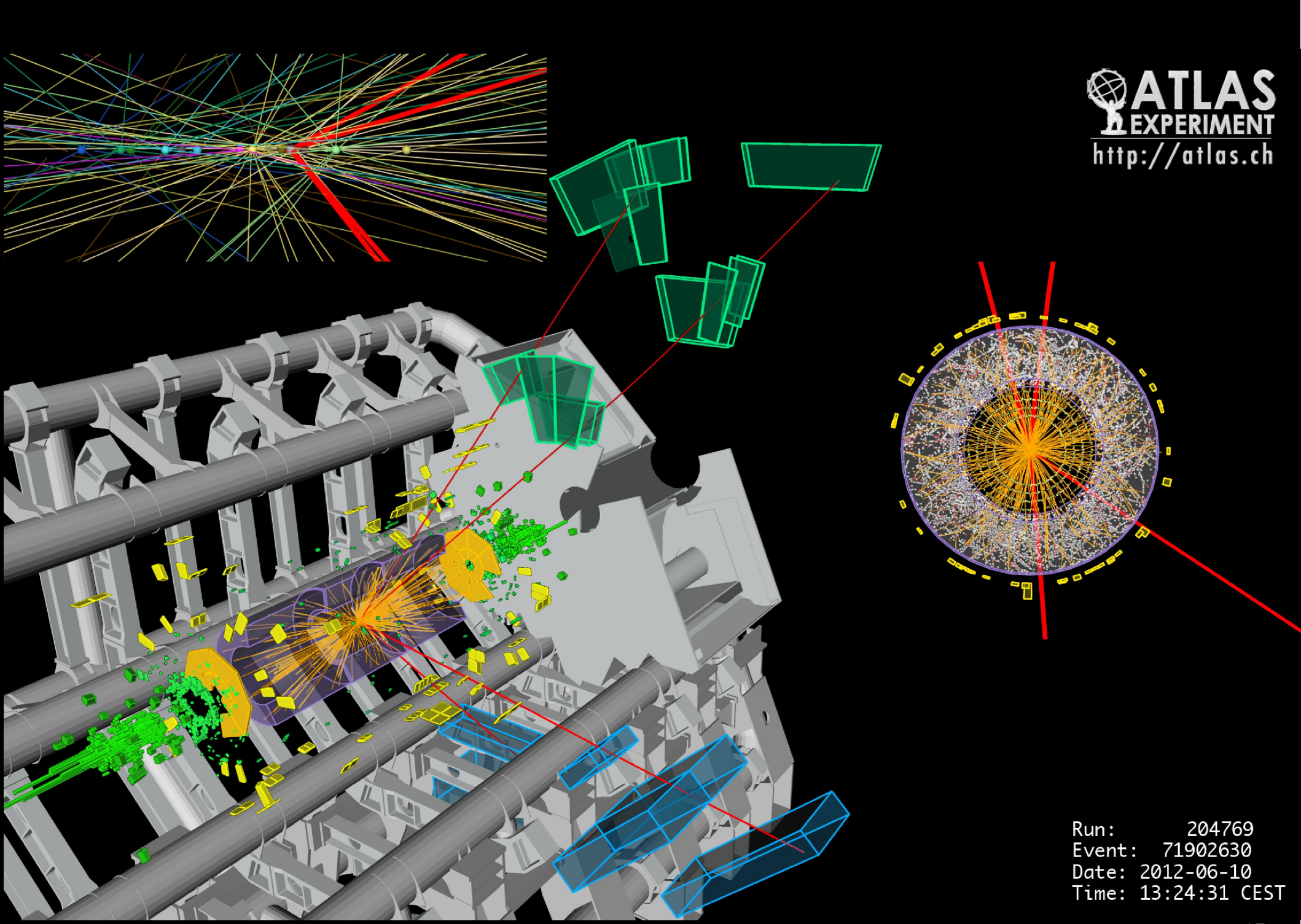
The Worldwide LHC Computing Grid



Each year, ATLAS writes 10's PB (10 000's TB) of data
Around 150 000 CPU cores on the computing Grid are used to analyse them

The Higgs Boson Discovery




ATLAS
EXPERIMENT
http://atlas.ch
Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

What's Next?

LHC Roadmap

Run 1: energy 7-8 TeV, 25 fb^{-1} of data

Shutdown 1: phase 0 upgrade

Run 2: energy 13 TeV, 120 fb^{-1} of data

Shutdown 2: phase 1 upgrade

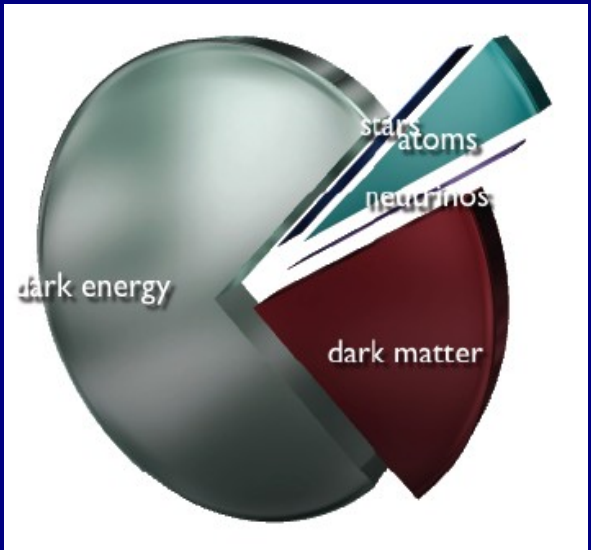
Run 3: energy 14 TeV, 350 fb^{-1} of data

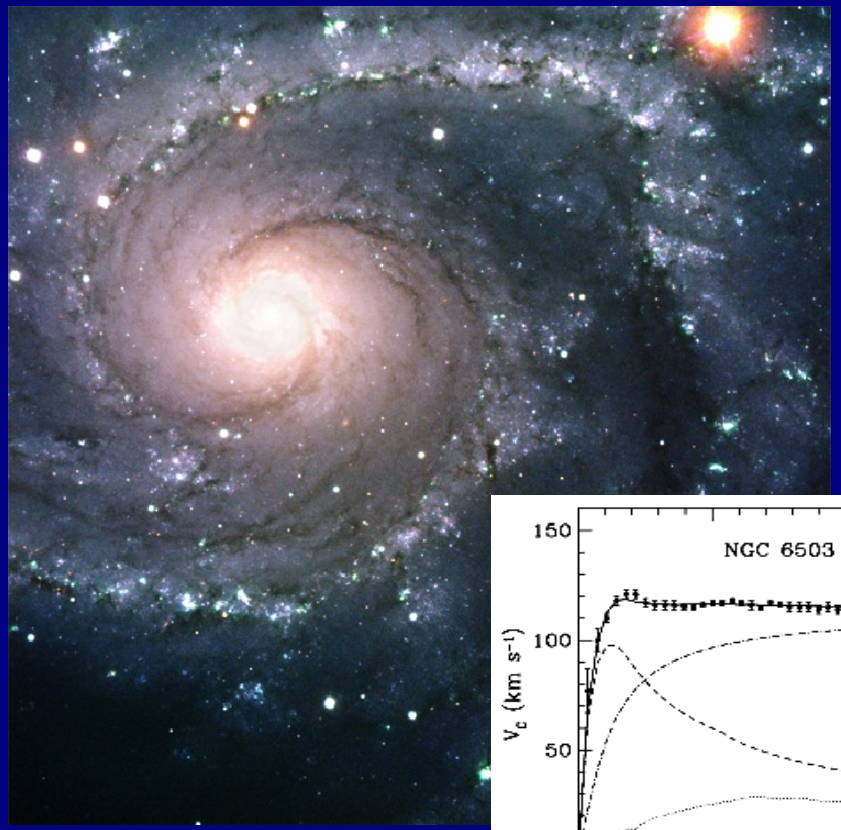
Shutdown 3: phase 2 upgrade

HL-LHC: energy 14 TeV, 3000 fb^{-1} of data

Dark Matter

Most of our universe is missing...





Astrophysical measurements indicate that the Universe is made of:

- 5% of known matter
- 25 % of "dark matter"
- 70% of "dark energy"

The LHC may produce dark matter particles directly

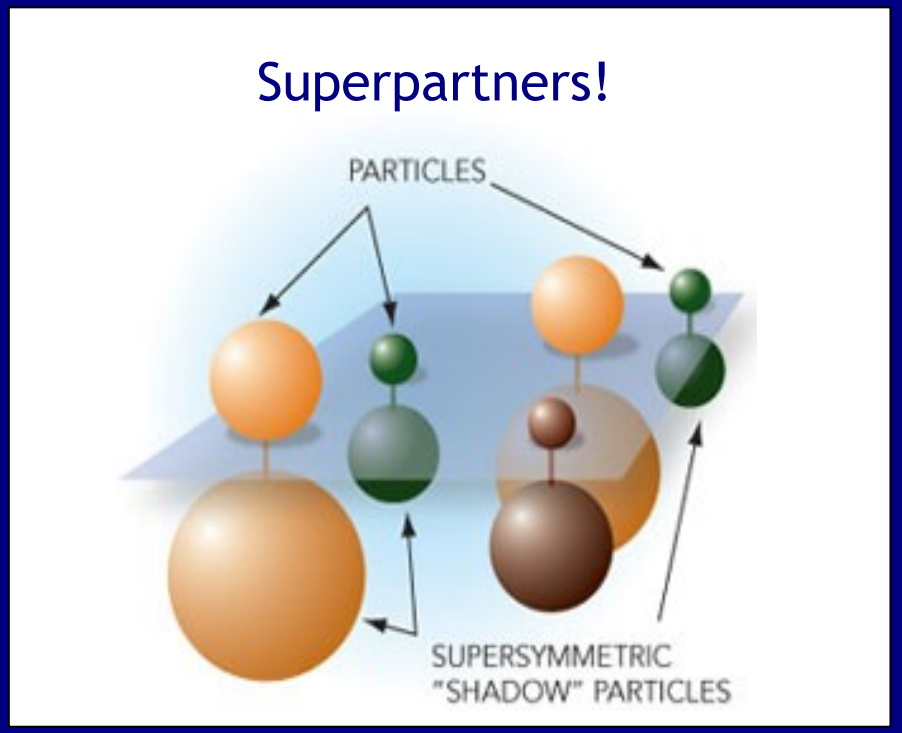
Supersymmetry

A new symmetry between fermions and bosons

Predicts many new particles, including at least four more Higgs bosons
Squarks (stop, sbottom…), sleptons, winos, binos, gauginos…

→ a simple, elegant candidate for dark matter

SUSY also helps explain how the Higgs boson can be so light



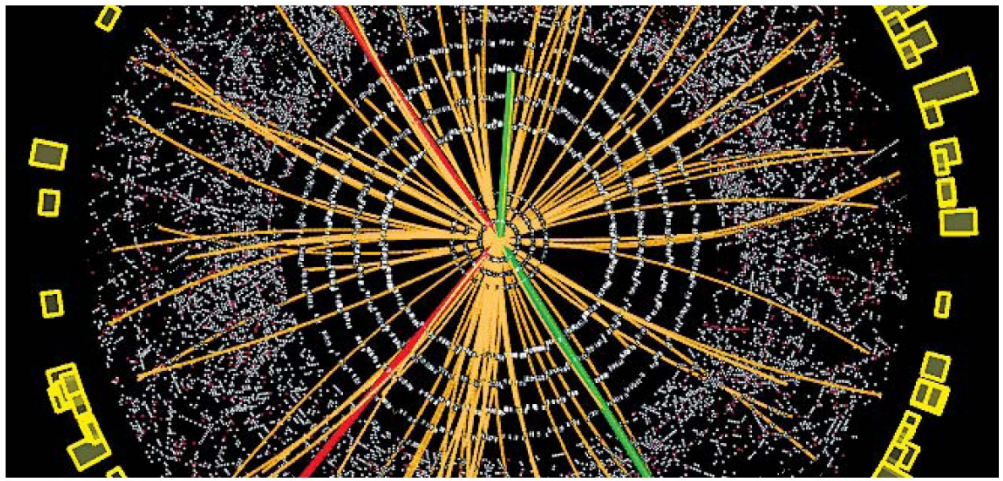
"hierarchy problem"

Supersymmetry may well show up when the LHC turns on again in 2015 with new, higher energy, collisions

Higgs Discovery

July 4th 2012 (CERN and Melbourne)

Higgs was right Picture that changes the way we see the universe for ever



Ian Sample Geneva

Higgs Discovery

I was there too!

Why is the Higgs Boson so Special?

It’s like looking for a needle in a haystack

Why is the Higgs Boson so Special?

~~It's like looking for a needle in a haystack~~

It's like looking for a needle in 10000 haystacks

Why is the Higgs Boson so Special?

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It's like looking for a piece of hay in 10000 haystacks

Why is the Higgs Boson so Special?

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It's like looking for a piece of hay in 10000 haystacks

- A third fundamentally new type of "stuff", quite distinct from matter particles and force-exchanging particles

Why is the Higgs Boson so Special?

~~It's like looking for a needle in a haystack~~

~~It's like looking for a needle in 10000 haystacks~~

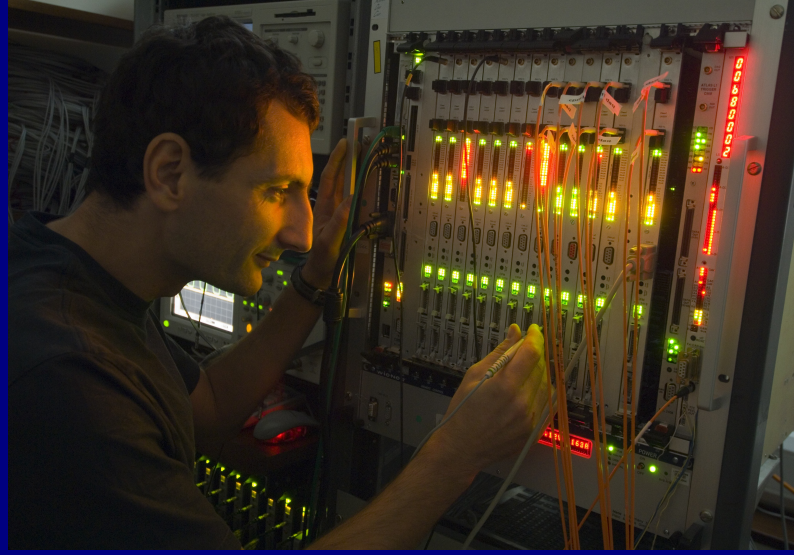
It's like looking for a piece of hay in 10000 haystacks

- A third fundamentally new type of "stuff", quite distinct from matter particles and force-exchanging particles

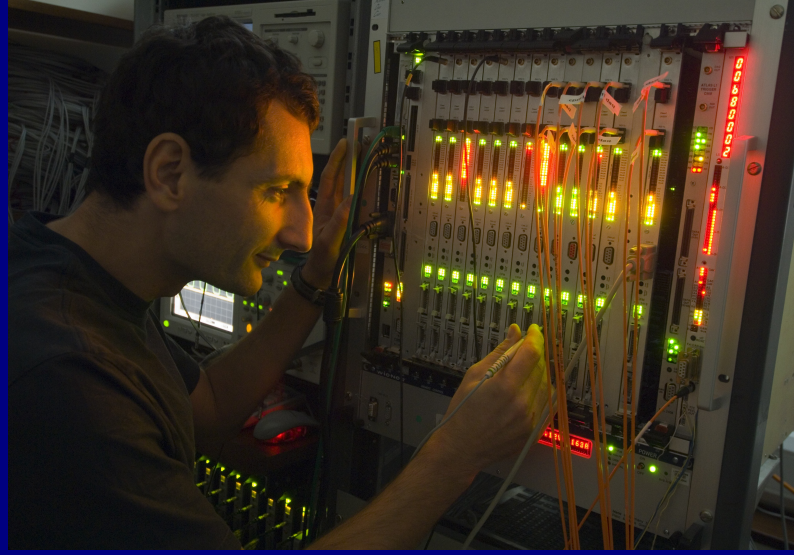
- The Higgs field is strange. Unlike e.g. gravitational fields:
    - it doesn't have a direction
    - it doesn't require a source (even in inter-galactic space)

Birmingham in ATLAS

Online event selection (“trigger”)
Decides within 2 millionths of a second which “one in a thousand” collision events to keep
Major design and testing in Birmingham



Birmingham in ATLAS



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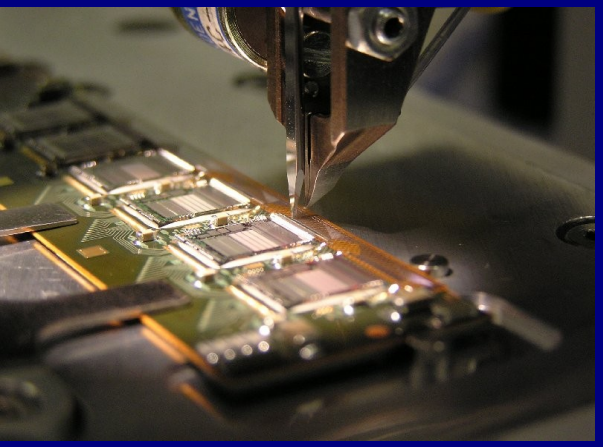
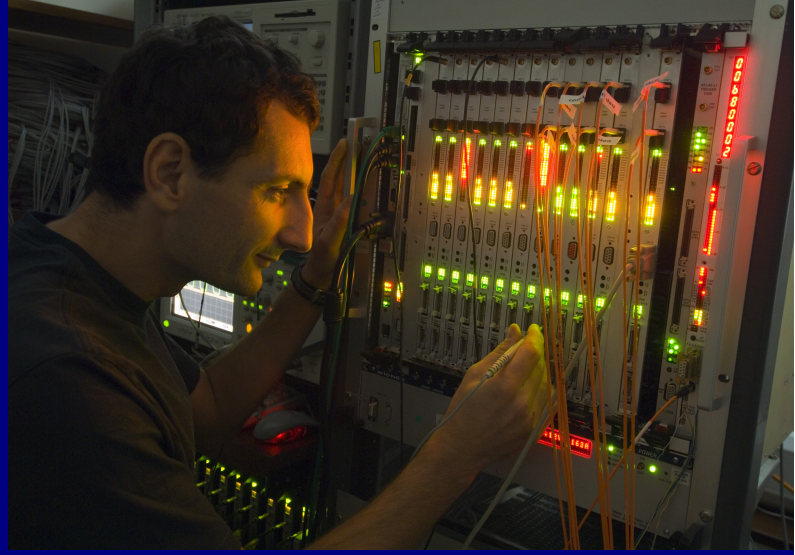


Particle tracker
Measures particle paths to within 20 μm
>600 readout hybrids assembled & tested in Birmingham

Birmingham in ATLAS



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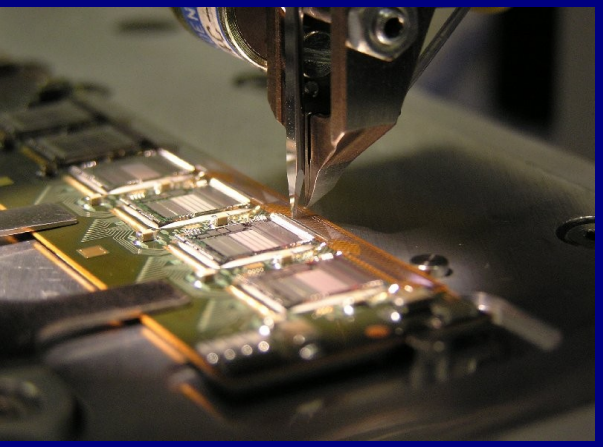

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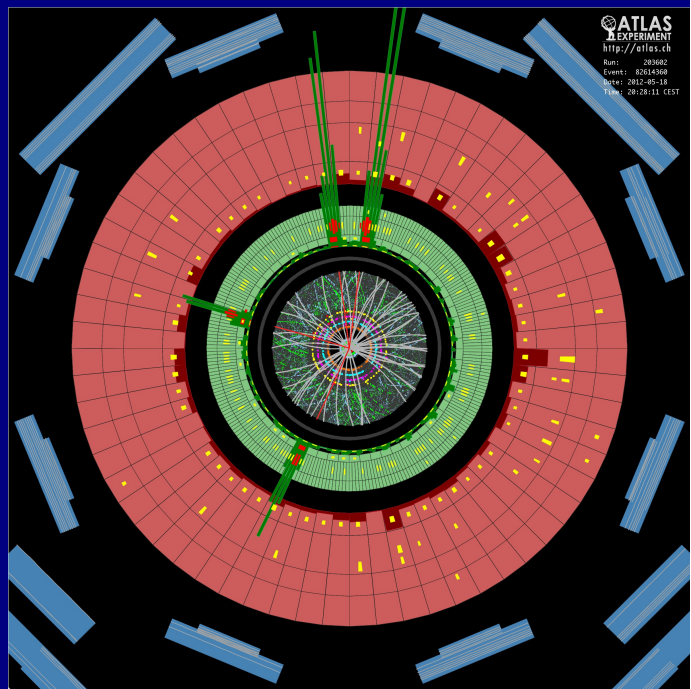
Physics analysis
Leading role in data analysis leading to Higgs discovery as well as several other physics topics



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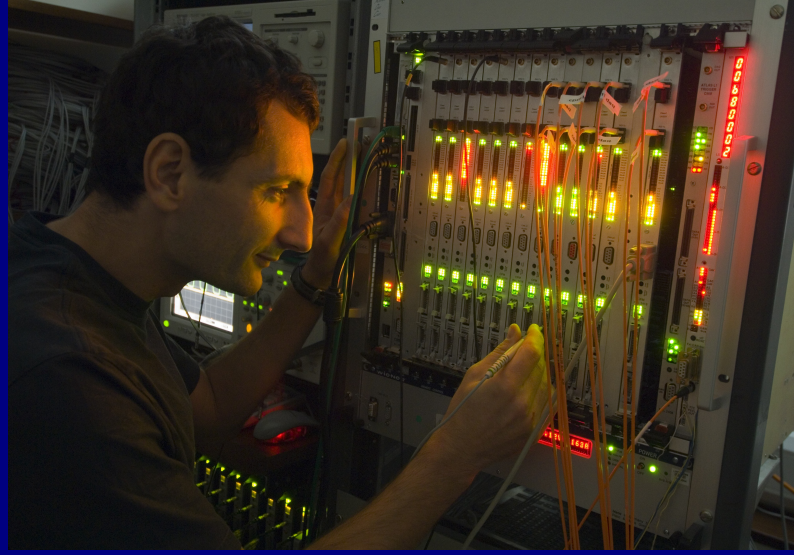

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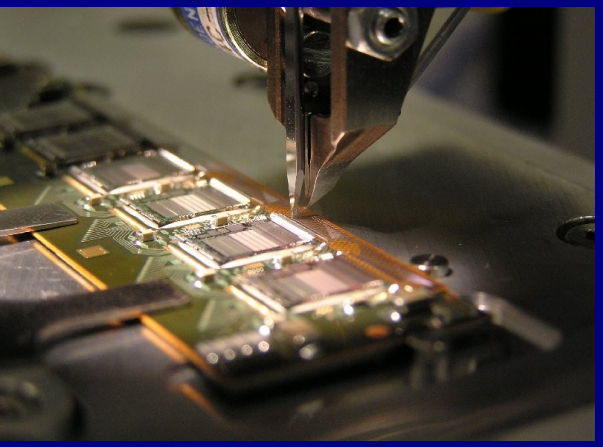

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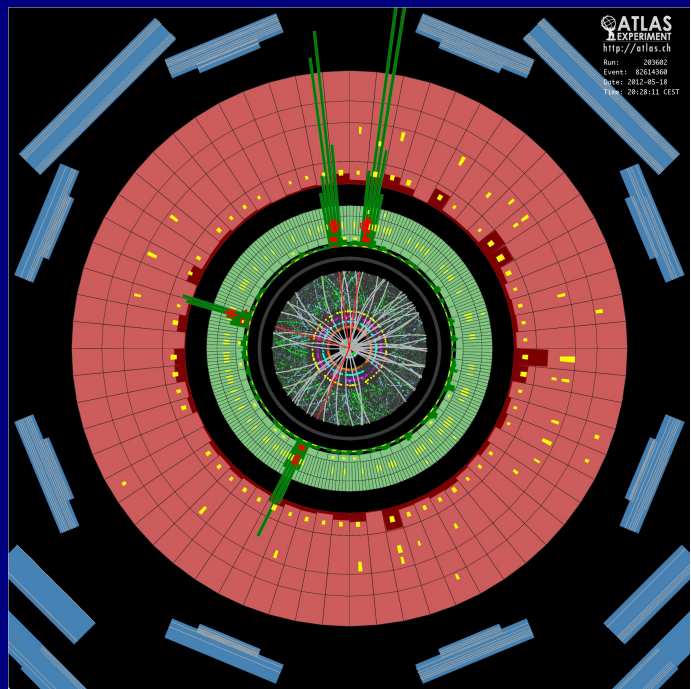
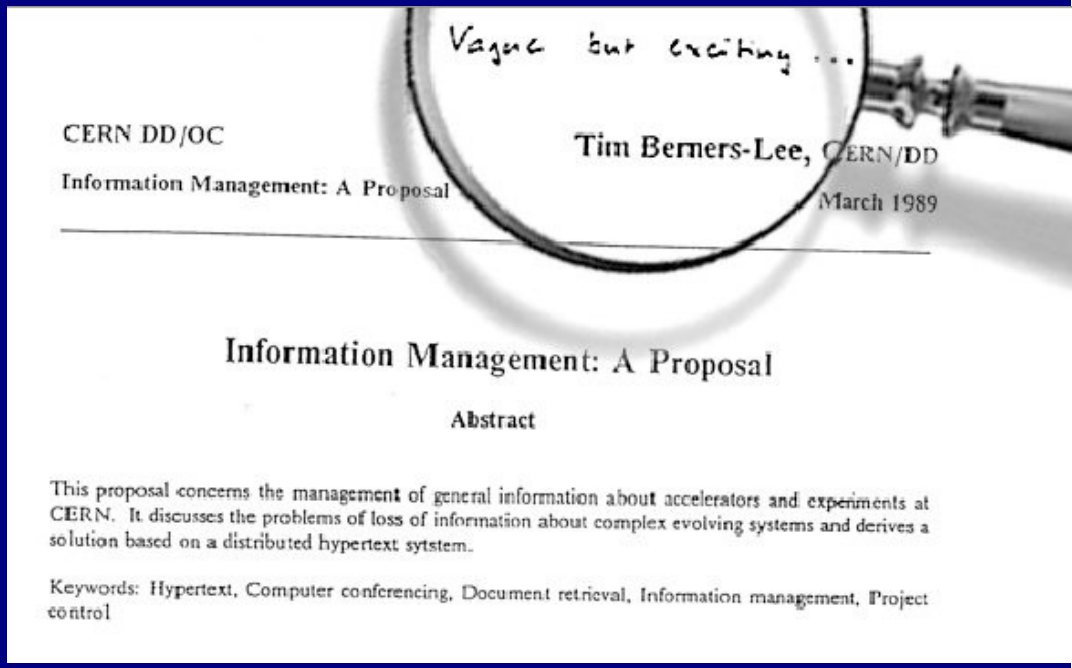


… and many more, including event visualisation …

What has the Higgs ever Done for me?

Spin-offs

Medical applications, national security, touch-screen technology, www …



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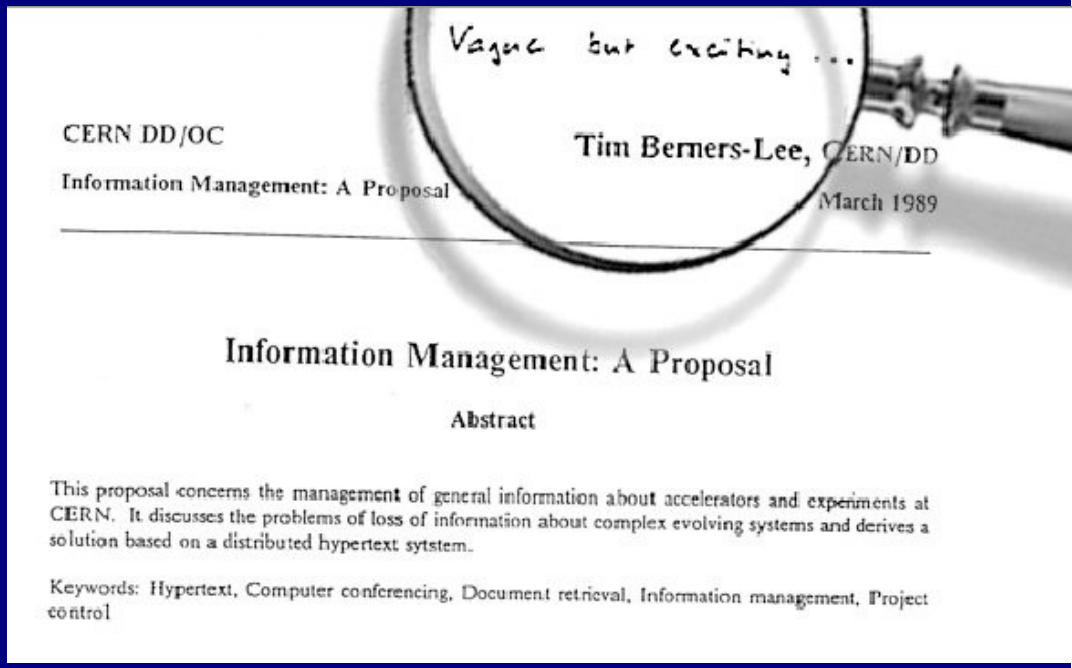
Attracting Young Talent to STEM

- 8.3% increase in applications to physics degree courses
- 72% of 1st year students cite particle physics as a reason for degree choice



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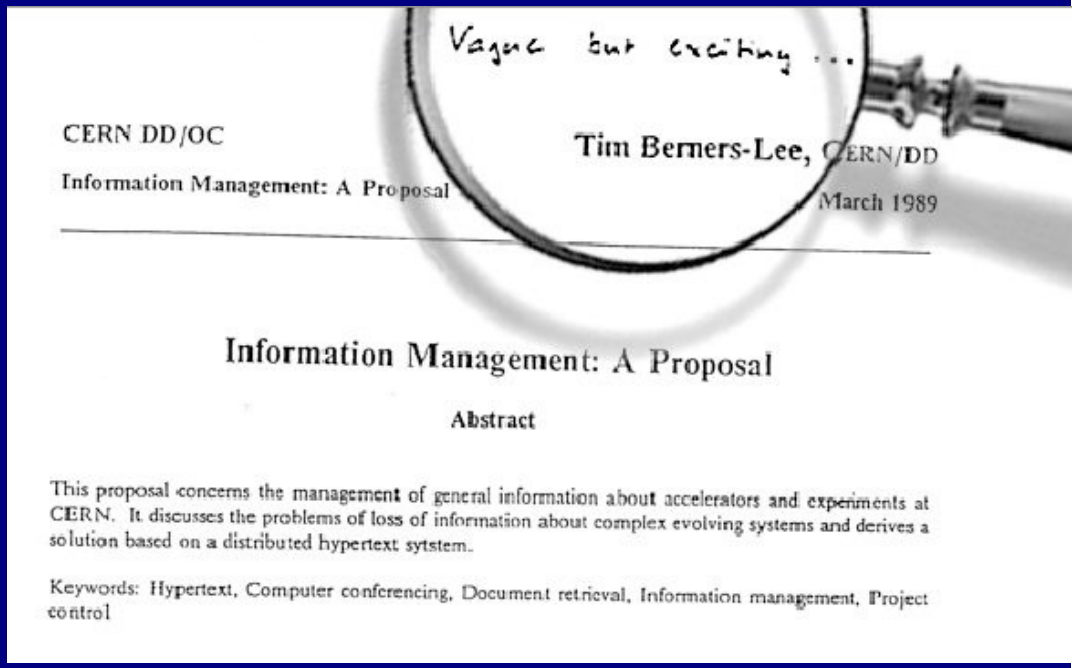
Unknown Future Technologies?



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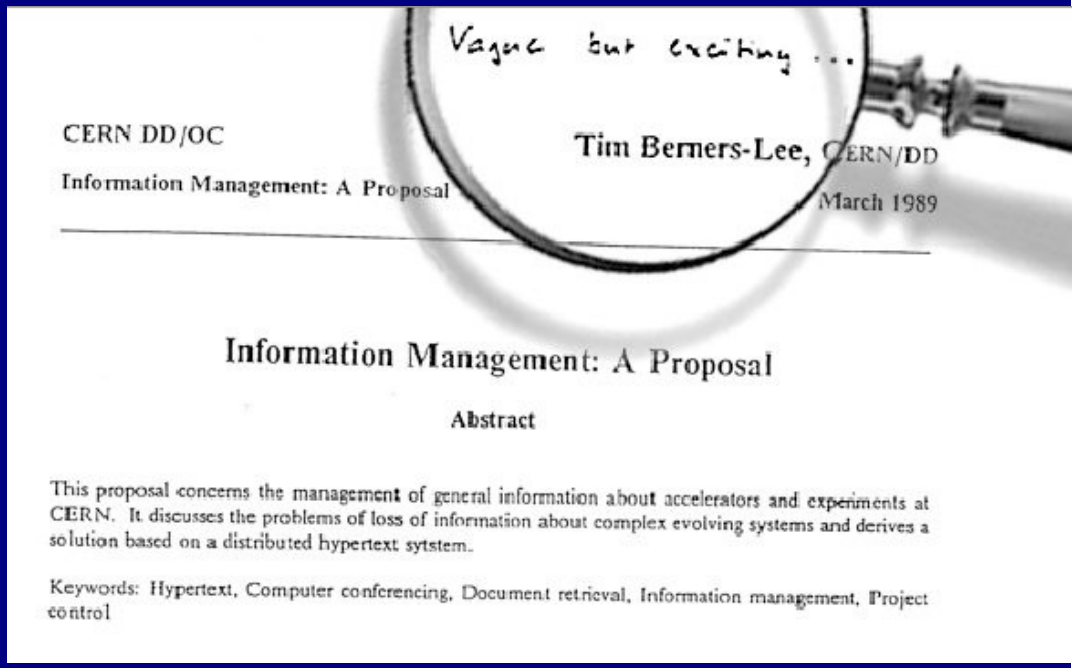
Unknown Future Technologies?

A collective deeper understanding of the mechanics of the Universe


Vague but exciting ...

CERN DD/OC

Tim Berners-Lee, CERN/DD

Information Management: A Proposal

March 1989

Information Management: A Proposal

Abstract

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext sytstem.

Keywords: Hypertext, Computer conferencing, Document retrieval, Information management, Project control

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Discovery of New Particle Could Redefine Physical World

By DENNIS OVERBYE
21 minutes ago

The discovery by physicists at CERN's Large Hadron Collider, if confirmed to be the Higgs boson particle, could lead to a new understanding of how the universe began.

• The Lede Blog: What in the

Agence France-Presse — Getty Images

OPINION »

EDITORIAL

Too Quiet, Again, on Health Care

The Obama campaign forcefully countered Republican misinforma the reform law.

MARKETS » At 7:

Britain	Germany
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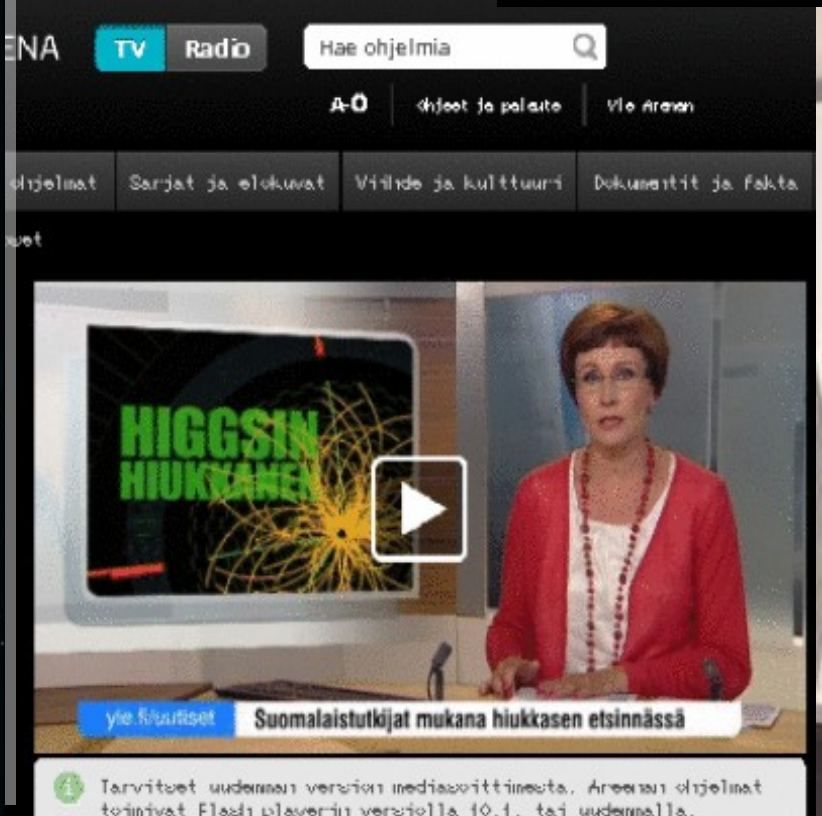
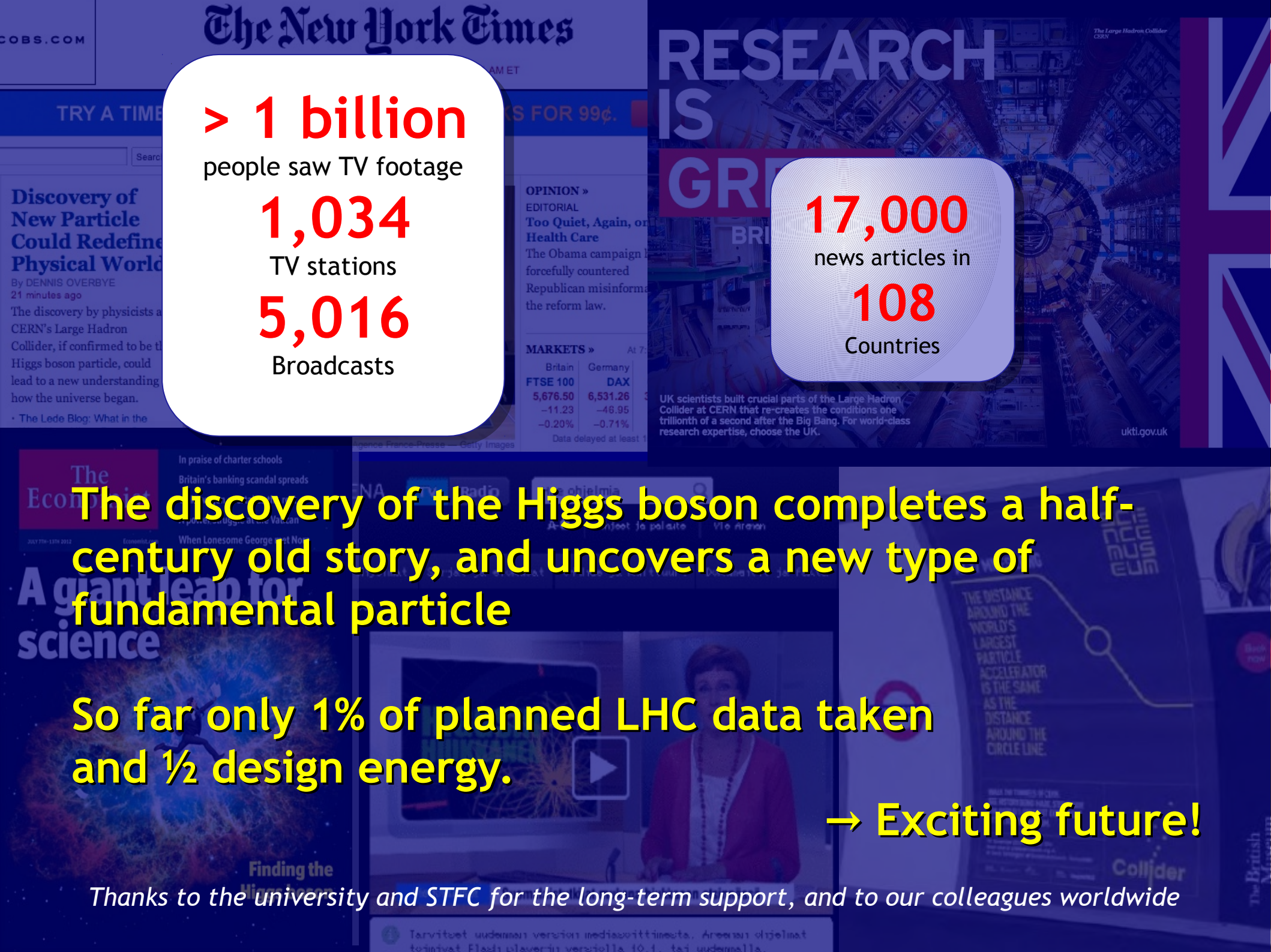
5,676.50	6,531.26
–11.23	–46.95
–0.20%	–0.71%

Data delayed at least 1




> 1 billion
people saw TV footage
1,034
TV stations
5,016
Broadcasts
17,000
news articles in
108
Countries
The New York Times
RESEARCH IS GR
UK scientists built crucial parts of the Large Hadron Collider at CERN that re-creates the conditions one trillionth of a second after the Big Bang. For world-class research expertise, choose the UK.
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A giant leap for science
Finding the Higgs boson
The Distance around the world's largest particle accelerator is the same as the distance around the circle line
Collider
The discovery of the Higgs boson completes a half-century old story, and uncovers a new type of fundamental particle
So far only 1% of planned LHC data taken and ½ design energy.
→ Exciting future!
Thanks to the university and STFC for the long-term support, and to our colleagues worldwide