Potential Scientific Contributions

Feb. 25, 2010

30 Standard Model Charts Available
Suitable for lamination
One per family, please

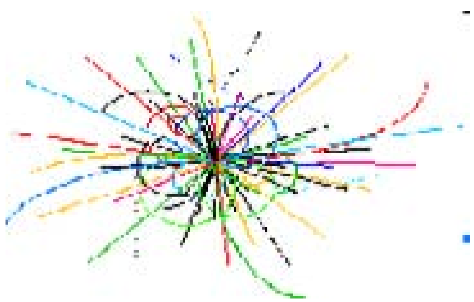
Answers to last week's questions

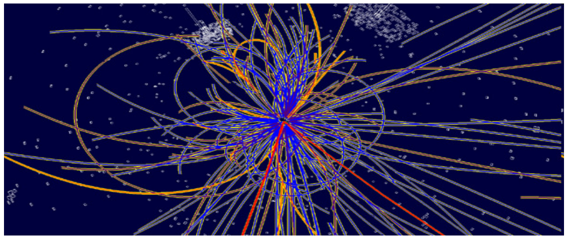
- Erratum: Proton bunch is ~16 microns (μm) (down from a mm) at collision point; human hair is 50 microns.
- The SSC was to be 20 TeV on 20 TeV;

  54 miles (90 km) in circumference;

  ~6 T magnets;

  10^{33} cm^{-2} sec^{-1} ; 10^{34} cm^{-2} sec^{-1}.

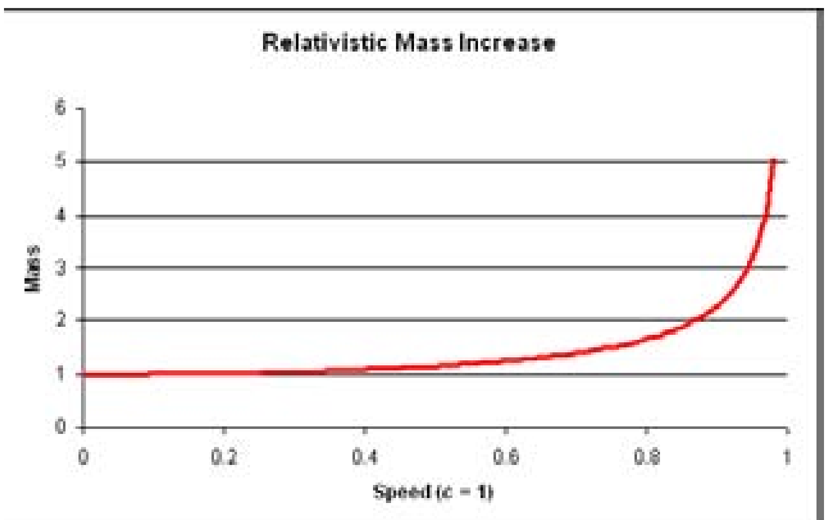




Answers to last week's questions

Rest Mass of Proton is 1.67 $\times 10^{-27}$ kg or 0.938 GeV/c^2, or

~1 GeV



Kinetic Energy of proton	Speed (% c)	Accelerator
0	0	Ion source
0.05 GeV	31.4	Linac 2
1.4 GeV	91.6	PS Booster
25 GeV	99.93	PS
450 GeV	99.9998	SPS
7,000 GeV	99.9999991	LHC

E = K.E. + rest energy

$E = mc^2 = m_0c^2/(1 - v^2/c^2)^{1/2}$

Topics

Finish up LHC detectors: CMS, ALICE (quark-gluon plasma); LHCb

Computational science: challenges of the GRID and Data handling

The Higgs Boson (source of mass)

Supersymmetry and String Theory (guest speakers)

Relation to Cosmology (guest speaker)

Importance of Basic Research

Closing Speculations

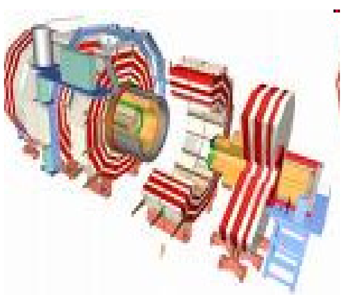
Topics

- Finish up LHC detectors: CMS, ALICE (quark-gluon plasma); LHCb
- Computational science: challenges of the GRID and Data handling
- The Higgs Boson (source of mass)
- Supersymmetry and String Theory (guest speaker)
- Relation to Cosmology (guest speaker)
- Importance of Basic Research
- Closing Speculations

Four Main Detectors

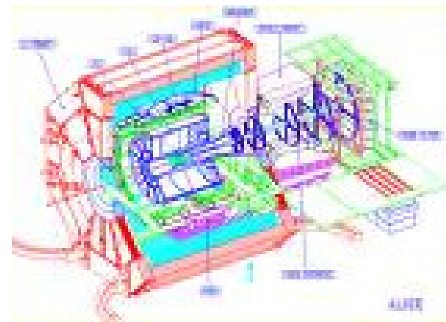
ATLAS

CMS

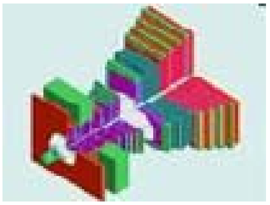


Really Big

ALICE

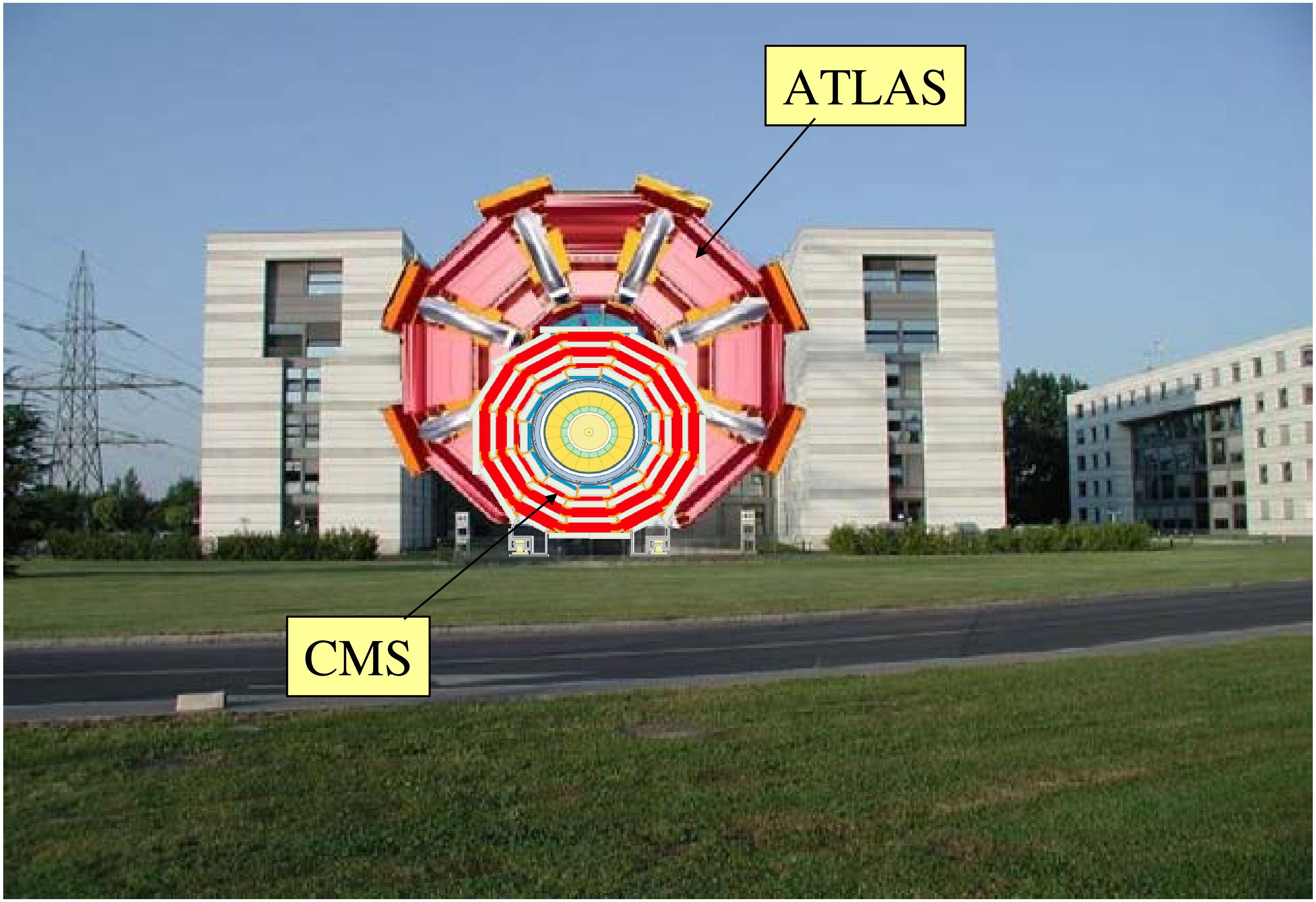


LHCb

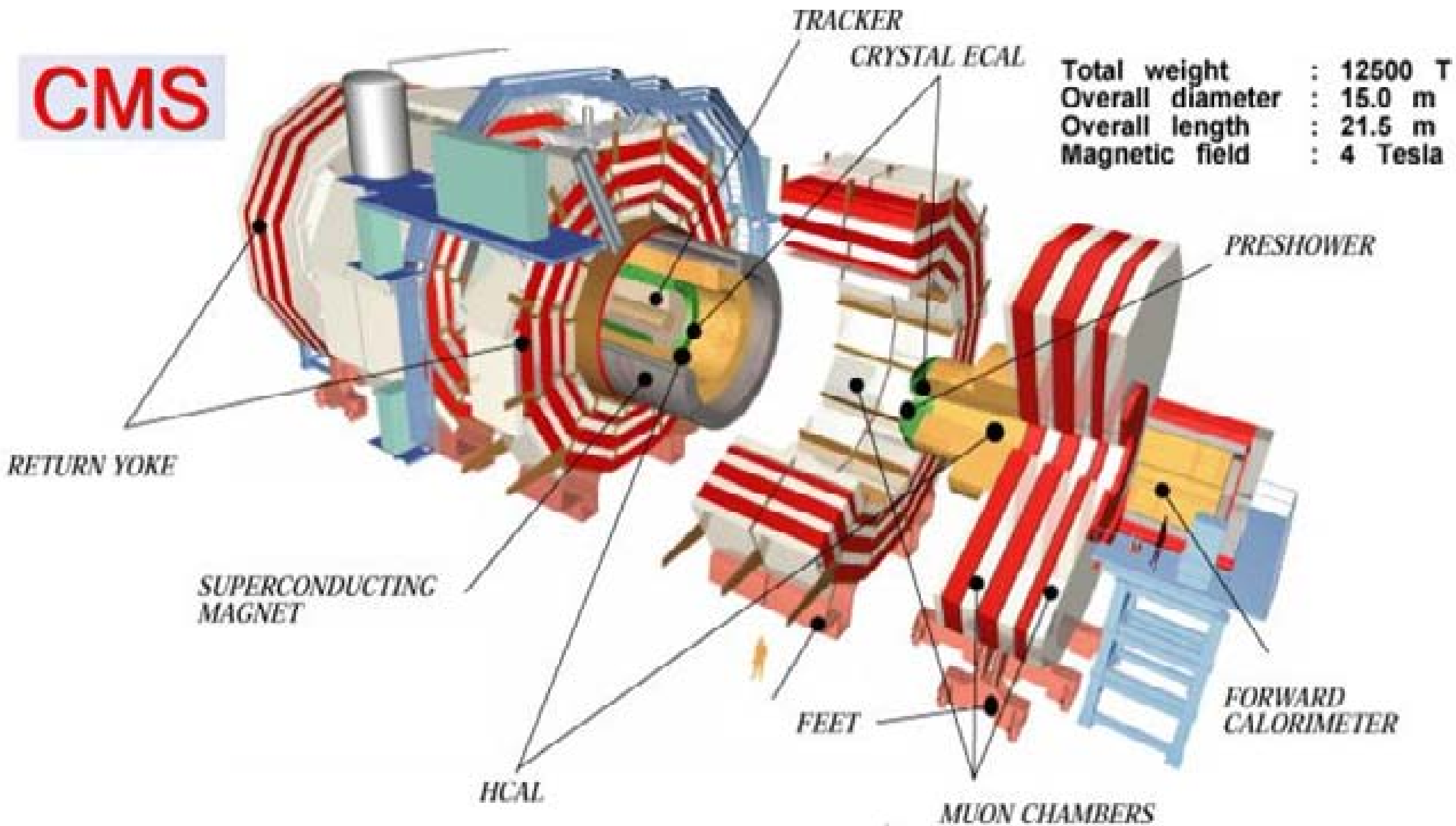


Just Big

The CMS - Compact Muon Solenoid - Detector



Compact Muon Solenoid



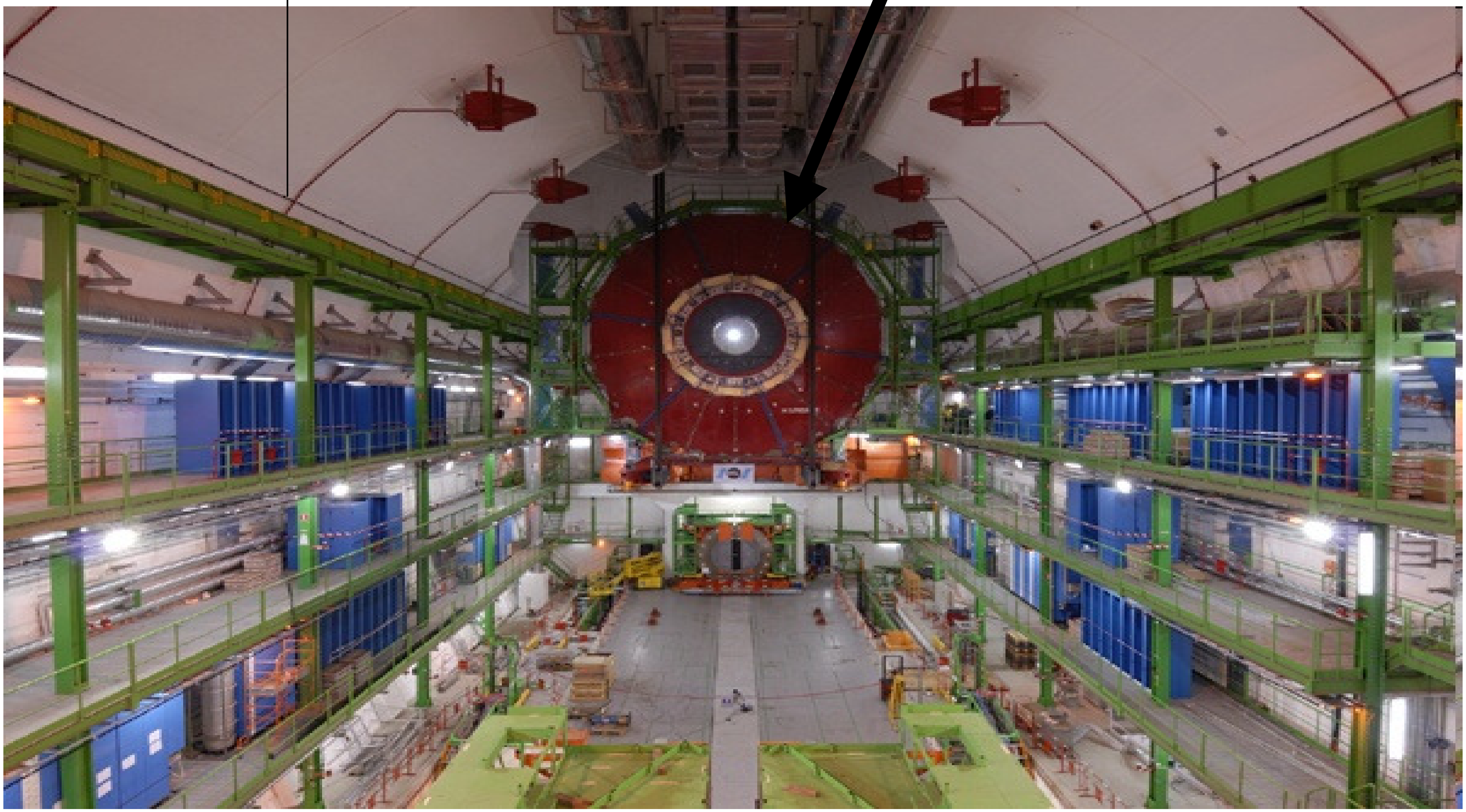
The Systems of CMS

About CMS

A CMS Disc

Earth
100 m up

400 metric tons



Cathedral size cavern

CMS – Virtually Live

Balcony-eye view

Beam pipe into CMS

Floor view

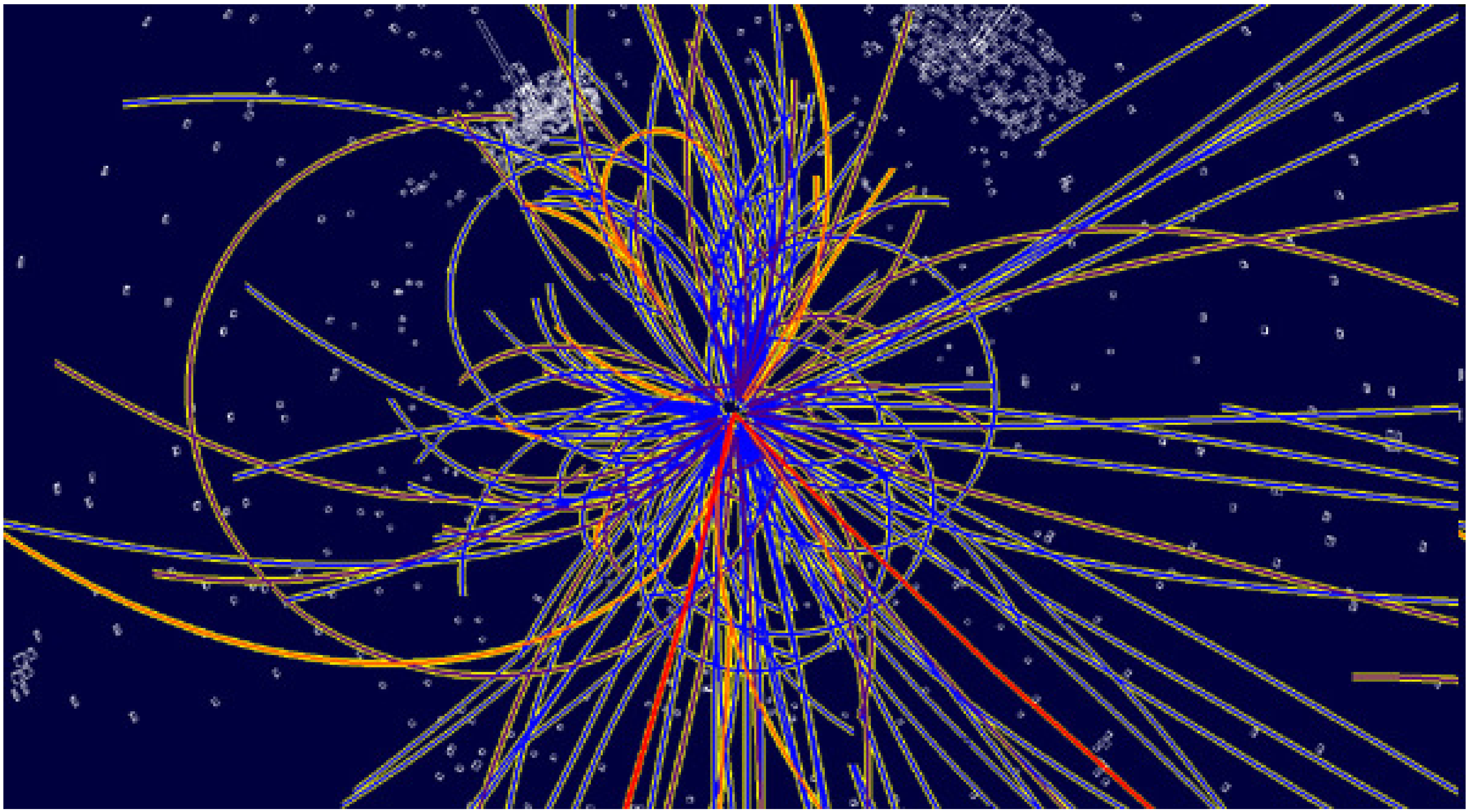
Floor view, later

Front, close to completion

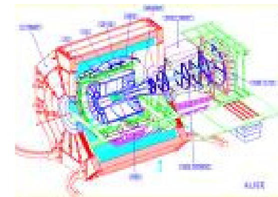
The CMS control room

Underground, near where the action is

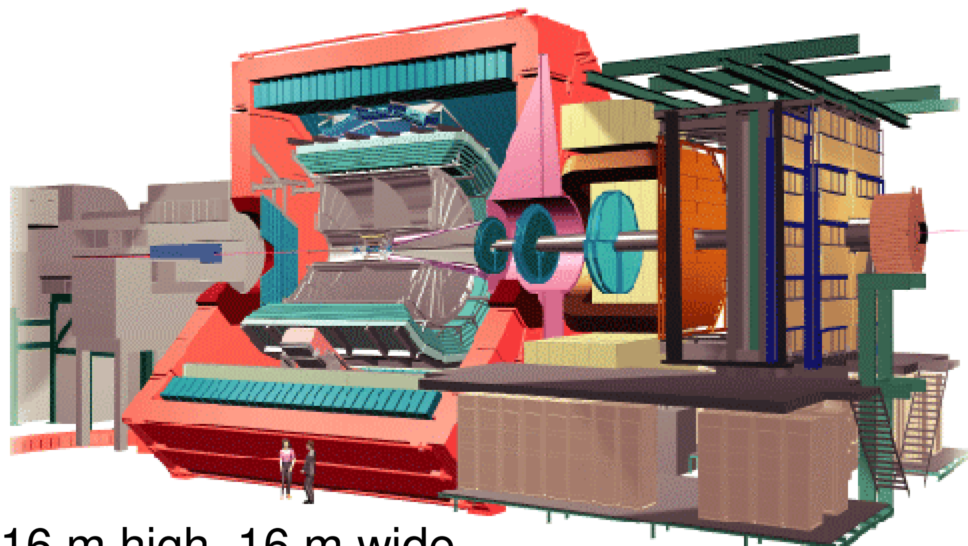
Simulated Success: What the Higgs would look like if found in CMS:



A Large Ion Collider Experiment i.e. the ALICE Detector



Virtual View



Size: 26 m long, 16 m high, 16 m wide
Weight: 10 000 tonnes
Design: central barrel plus single arm forward muon spectrometer
Location: St Genis-Pouilly, France.

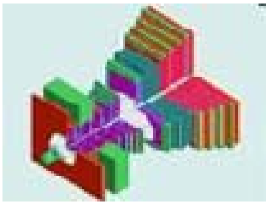
The Quark/Gluon Plasma

A simulation

~ 1 min 20 sec

A plasma is a hot, ionized gas and is the fourth state of matter (i.e solid, liquid, gas, plasma)

Large Hadron Collider beauty (LHCb) Detector



Size: 21m long, 10m high and 13m wide
Weight: 5600 tonnes
Design: forward spectrometer with planar detectors
Location: Ferney-Voltaire, France.

Topics

- Finish up LHC detectors: CMS, ALICE (quark-gluon plasma); LHCb
- Computational science: challenges of the GRID and Data handling
- The Higgs Boson (source of mass)
- Supersymmetry and String Theory (guest speaker)
- Relation to Cosmology (guest speaker)
- Importance of Basic Research
- Closing Speculations

The Third Leg of Science

Theory

Experiment

Computation

- Simulation
- GRIDS

For example,
the US Open Science Grid

A US GRID

Physics

Biology & Medicine

Chemistry

Video: intro to the GRID

The LHC GRID

~ 5 minutes

Advantages of GRID Computing

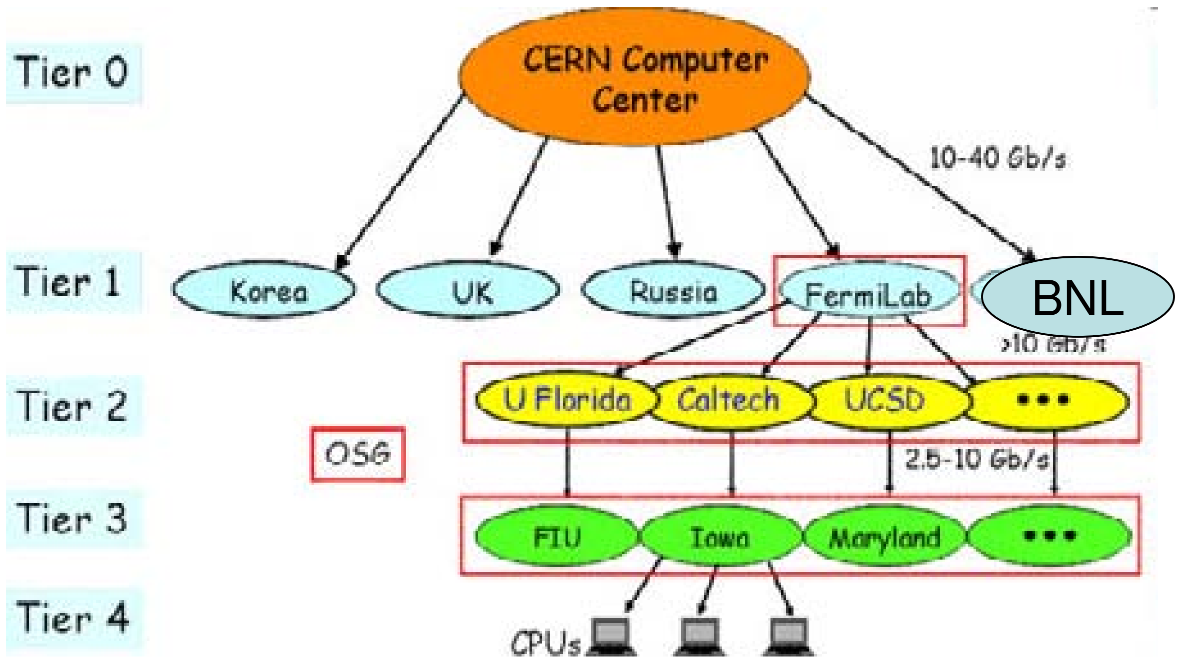
- Insurance against data loss
- Efficiencies of scale
- No single point failure
- Costs are distributed and shared
- The death of distance: innovation is local
- Inherent flexibility and adaptability

Data Handling Challenge

- *ATLAS will produce 320 MB/s*
- *CMS will produce 220 MB/s*
- *LHCb will produce 50 MB/s*
- *ALICE will produce 100 MB/s*

15 PB – PetaBytes – 1500 Trillion Bytes – 10^{15} bytes per year, or ~2 trillion CDs per year at 700MB per CD!

The US Tier 1 Centers: Fermilab



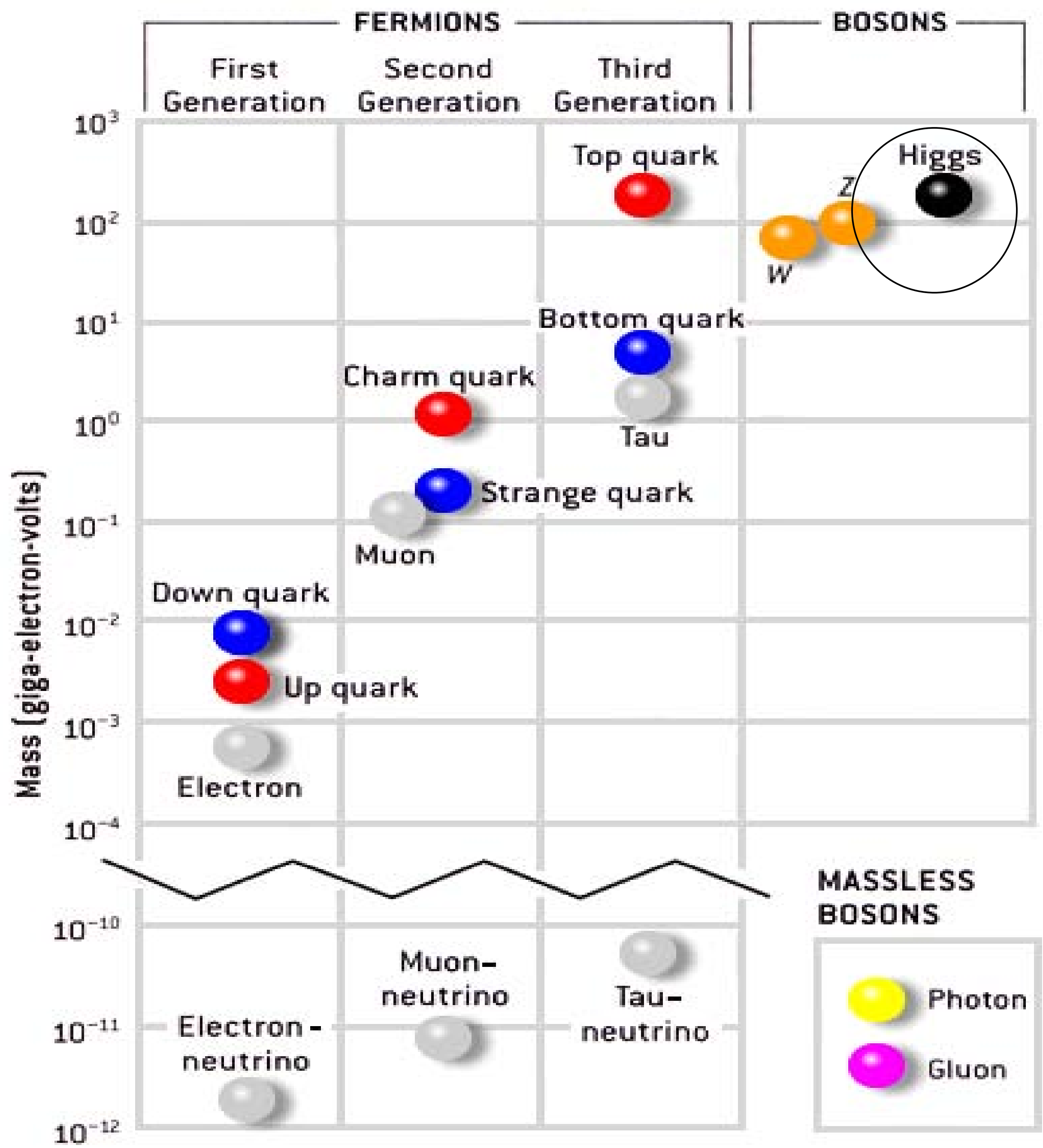
US Tier : BNL

BNL on BNL TIER 1

~ 3 min

Topics

- Finish up LHC detectors: CMS, ALICE (quark-gluon plasma); LHCb
- Computational science: challenges of the GRID and Data handling
- The Higgs Boson (source of mass)
- Supersymmetry and String Theory (guest speaker)
- Relation to Cosmology (guest speaker)
- Importance of Basic Research
- Closing Speculations


FERMIONS
First Generation
Second Generation
Third Generation
BOSONS
Mass (giga-electron-volts)
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-10}
10^{-11}
10^{-12}
Top quark
Higgs
Z
W
Bottom quark
Charm quark
Tau
Strange quark
Muon
Down quark
Up quark
Electron
Muon-neutrino
Tau-neutrino
Electron-neutrino
MASSLESS BOSONS
Photon
Gluon

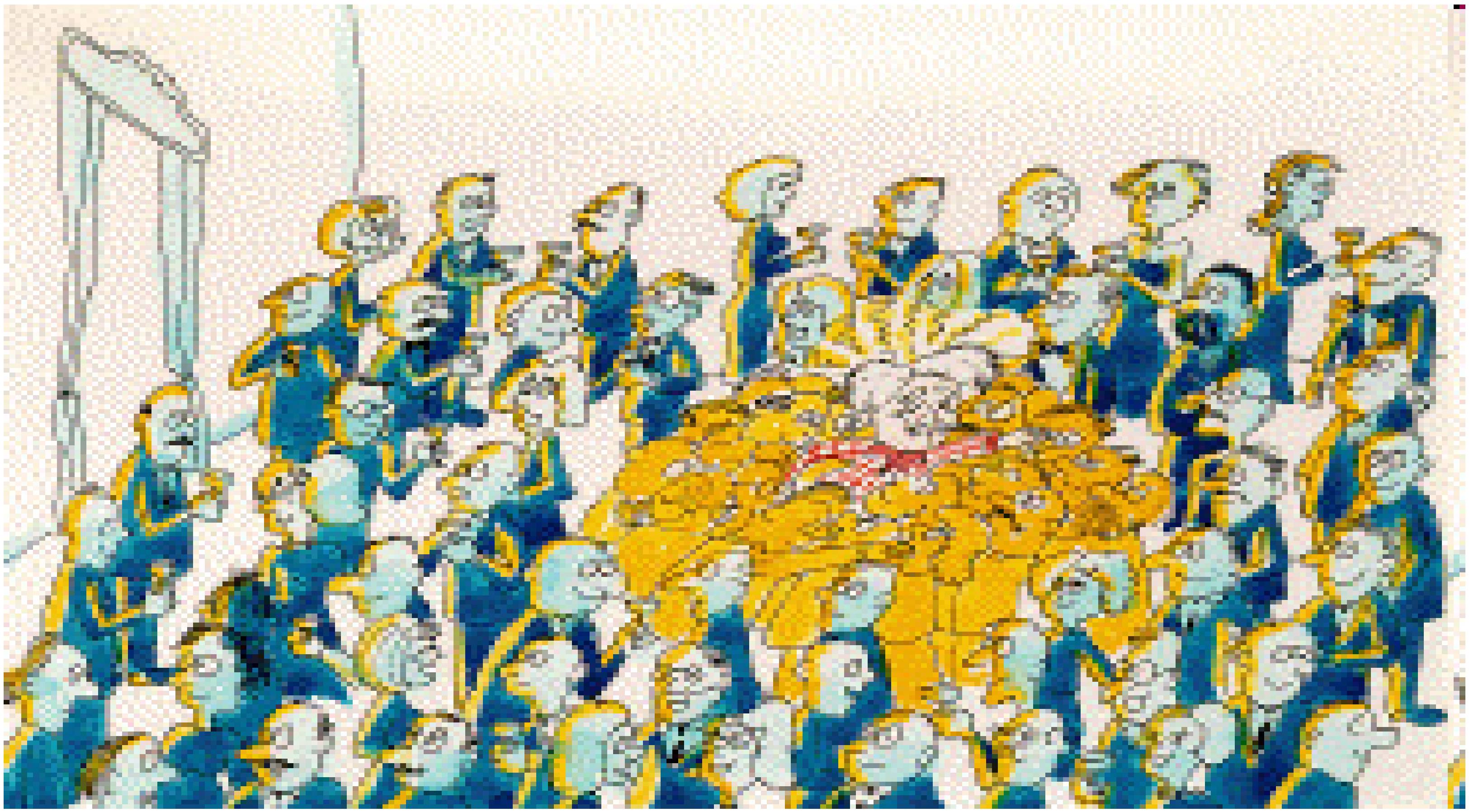
Higgs Mechanism

- How Mass is acquired
  – Higgs Field – the Mechanism
  – Higgs Boson – a force carrying particle

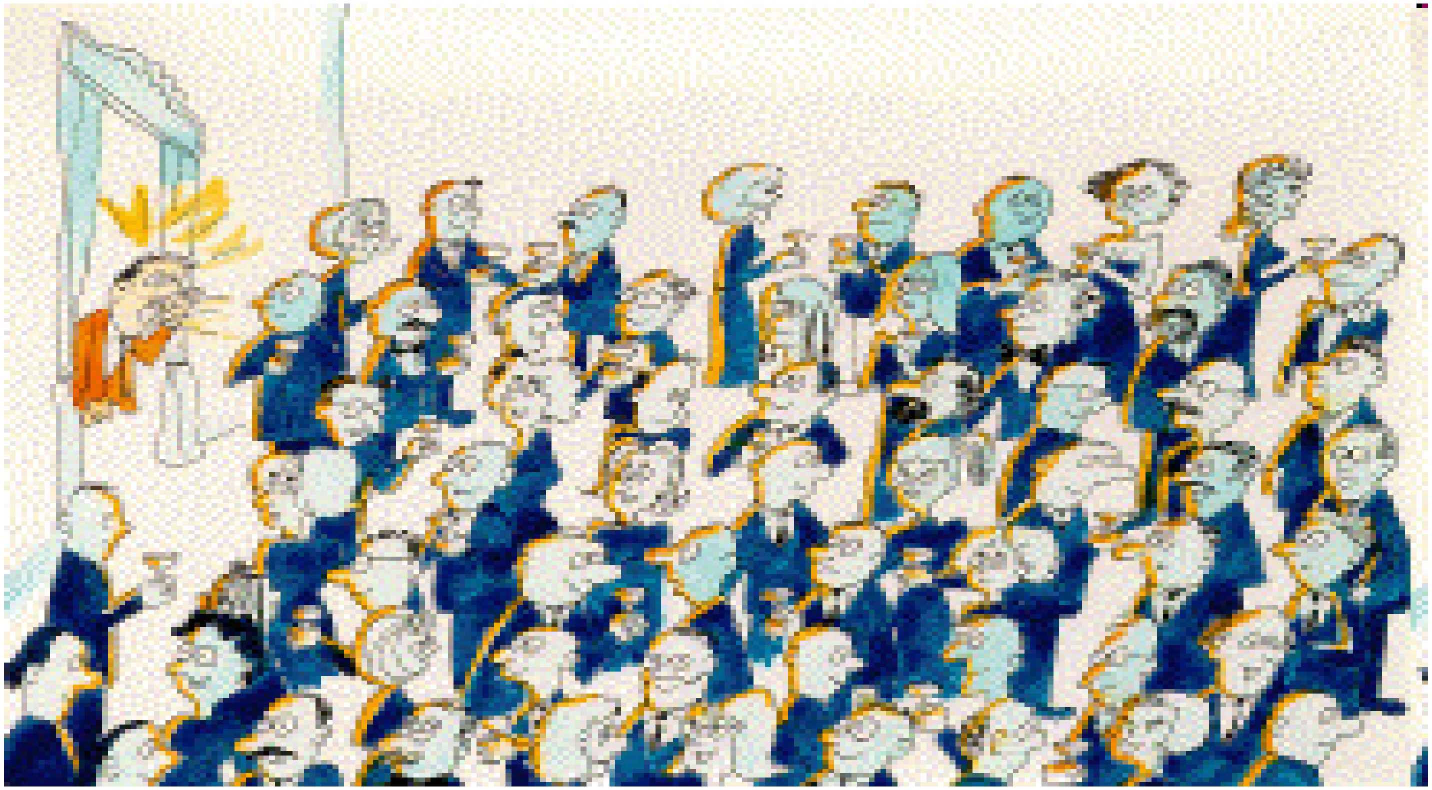
Higgs Mechanism

HiggsMechanism

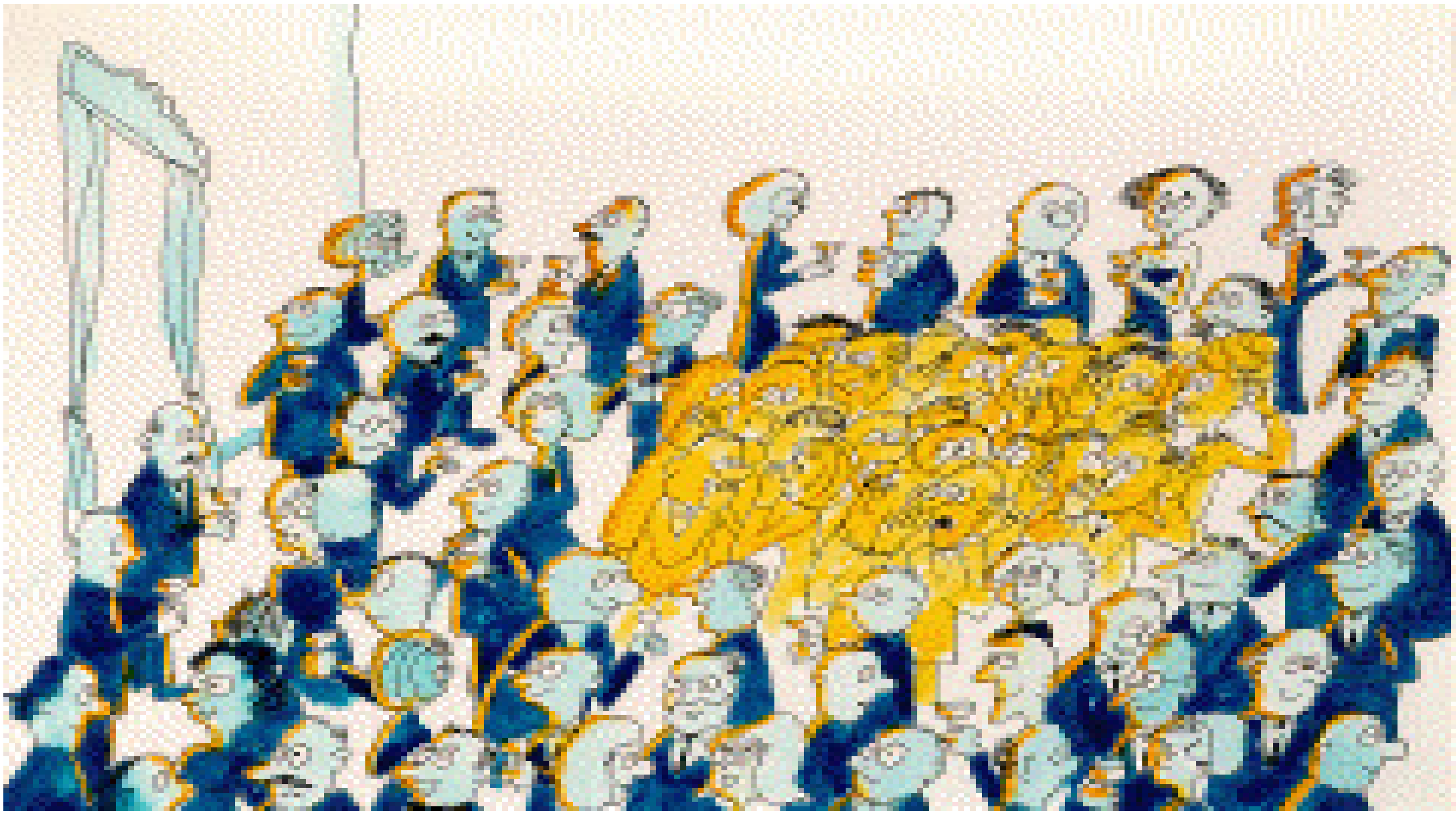
Higgs Mechanism



Higgs Boson



Higgs Boson



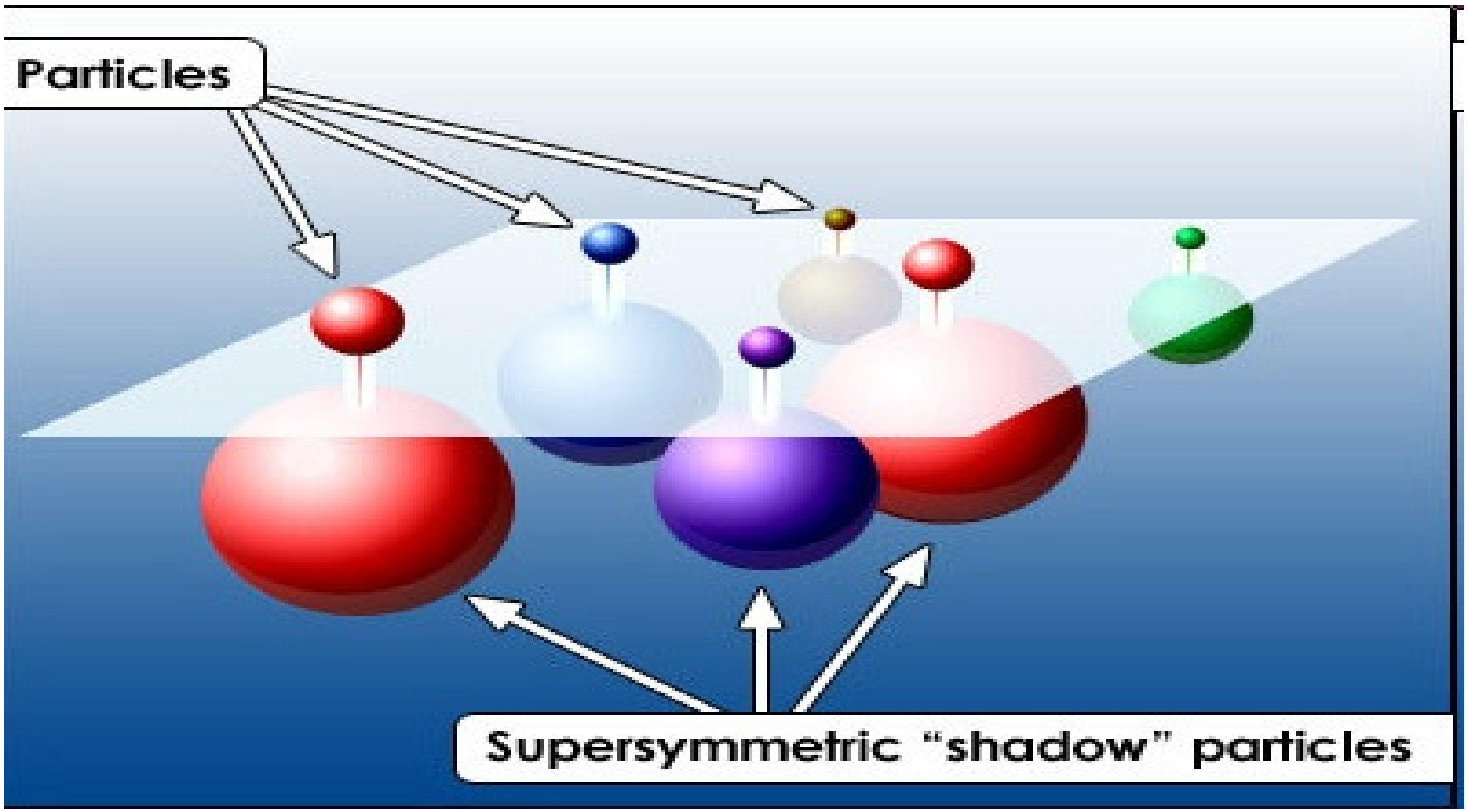
Higgs Video

Just when you think the Higgs couldn't be explained better . . .

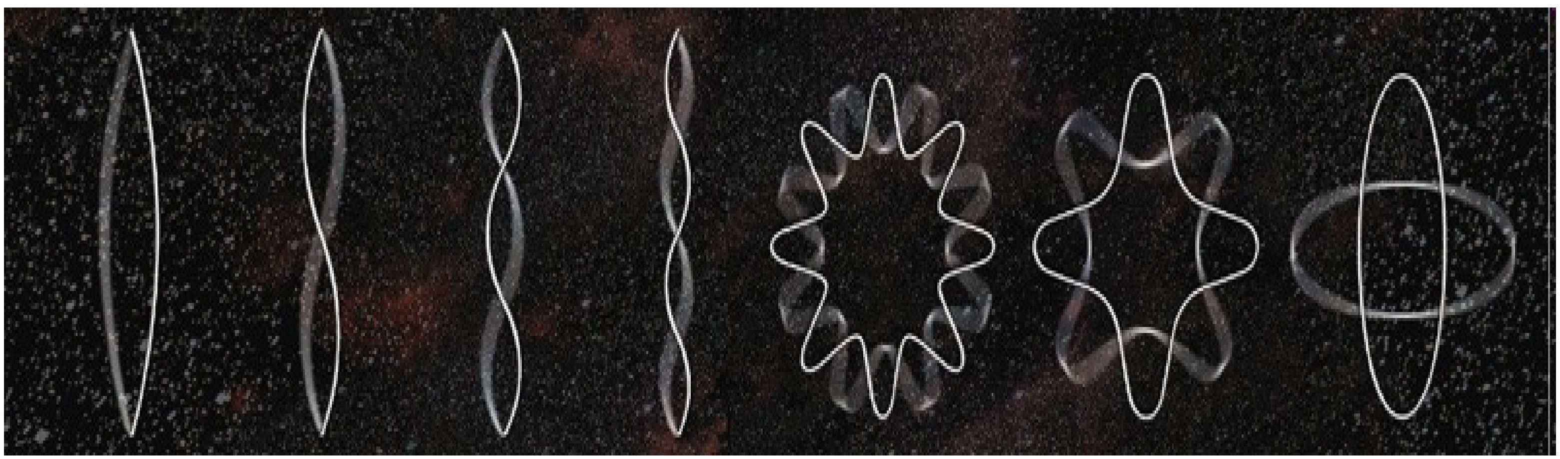
Topics

- Finish up LHC detectors: CMS, ALICE (quark-gluon plasma); LHCb
- Computational science: challenges of the GRID and Data handling
- The Higgs Boson (source of mass)
- Supersymmetry and String Theory (guest speaker)
- Relation to Cosmology (guest speaker)
- Importance of Basic Research
- Closing Speculations

Supersymmetry



String Theory



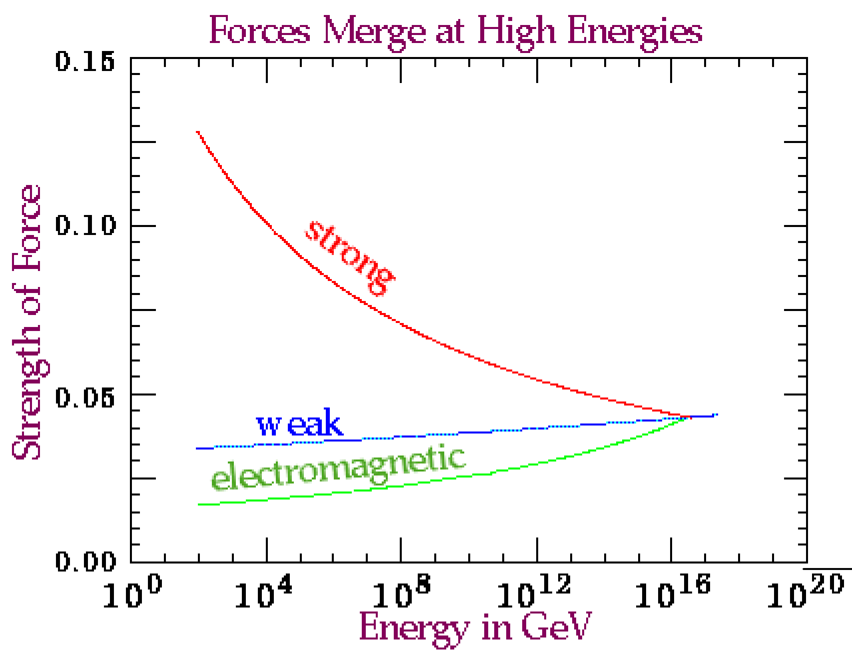
String Theory in 2 x (2 Minutes)

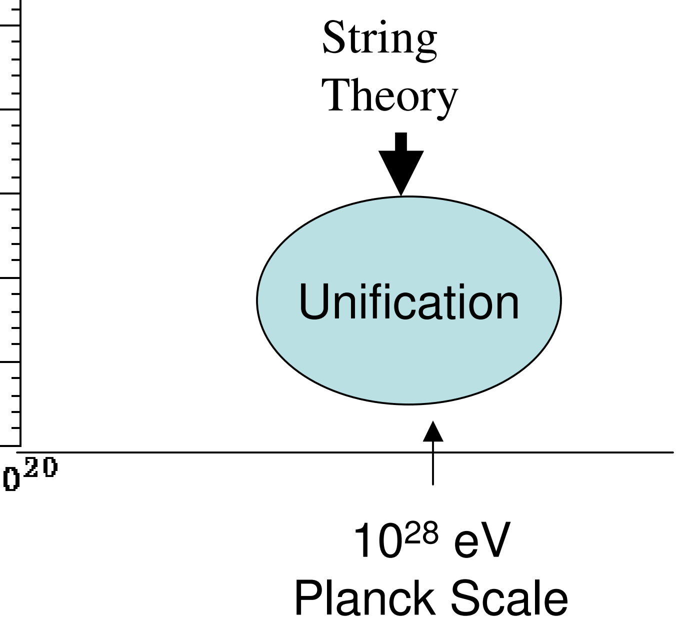
- String theory is simple
- Another, more scientific view

String Theory in 9 Minutes

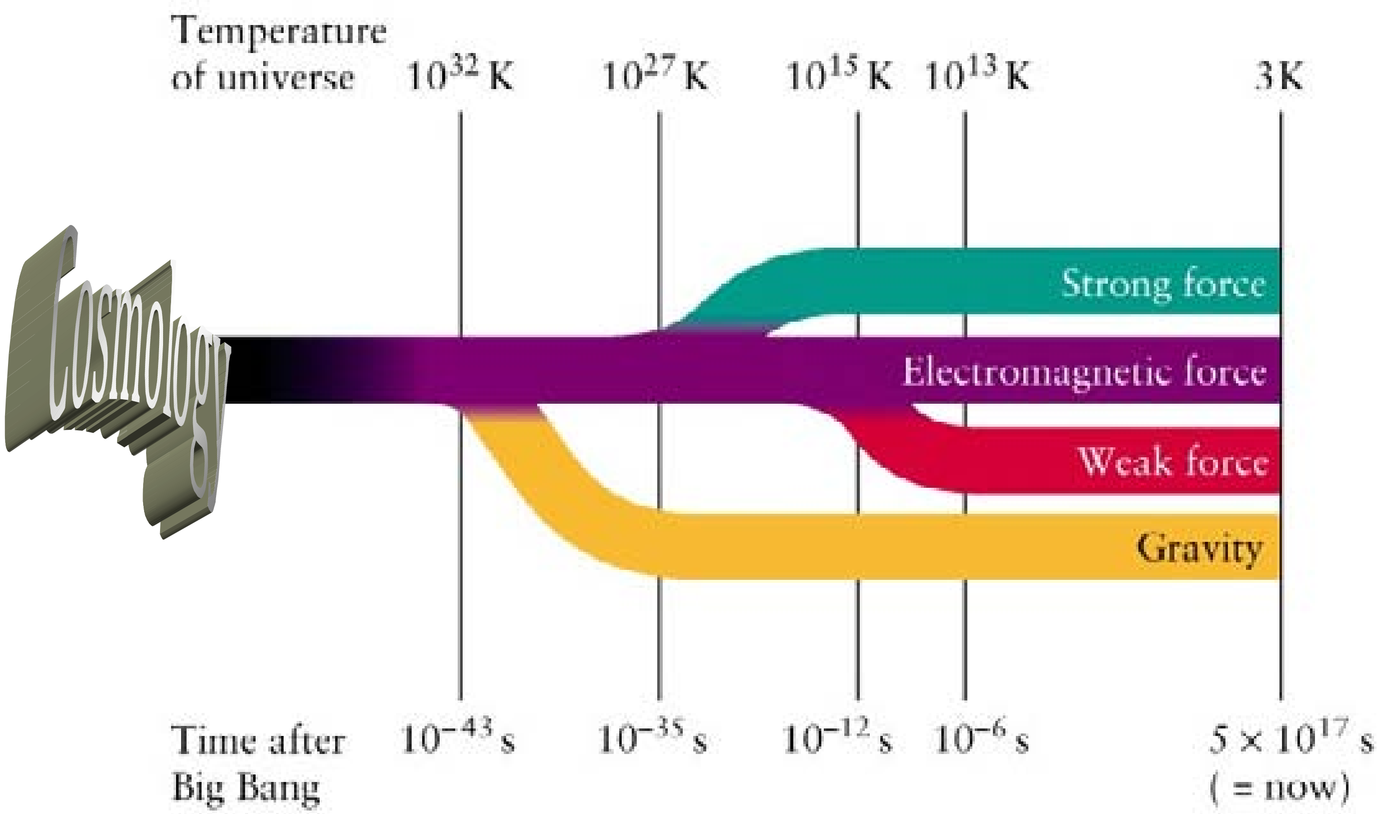
Guest Interviewee

Unification of Forces





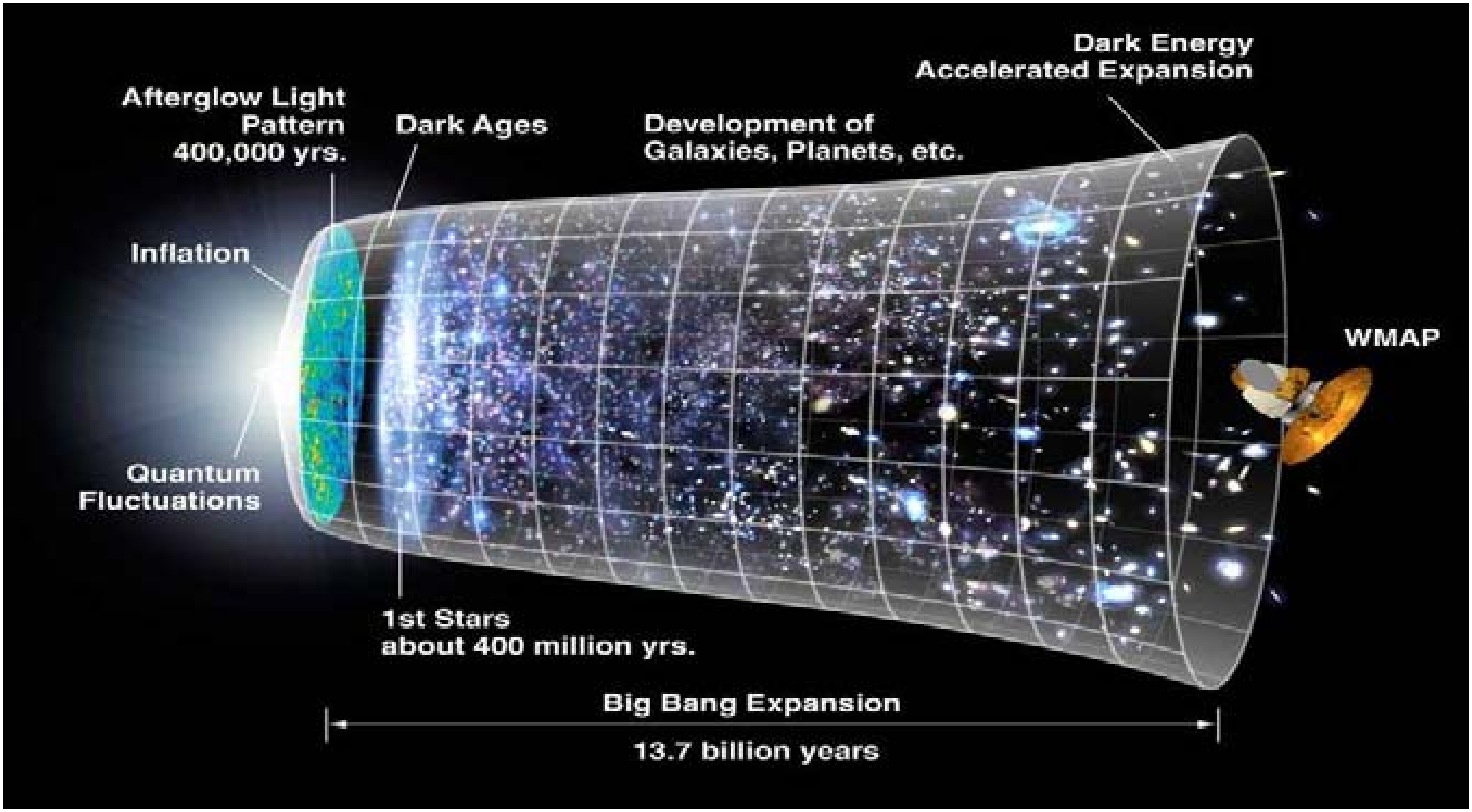
Unification of Forces



Topics

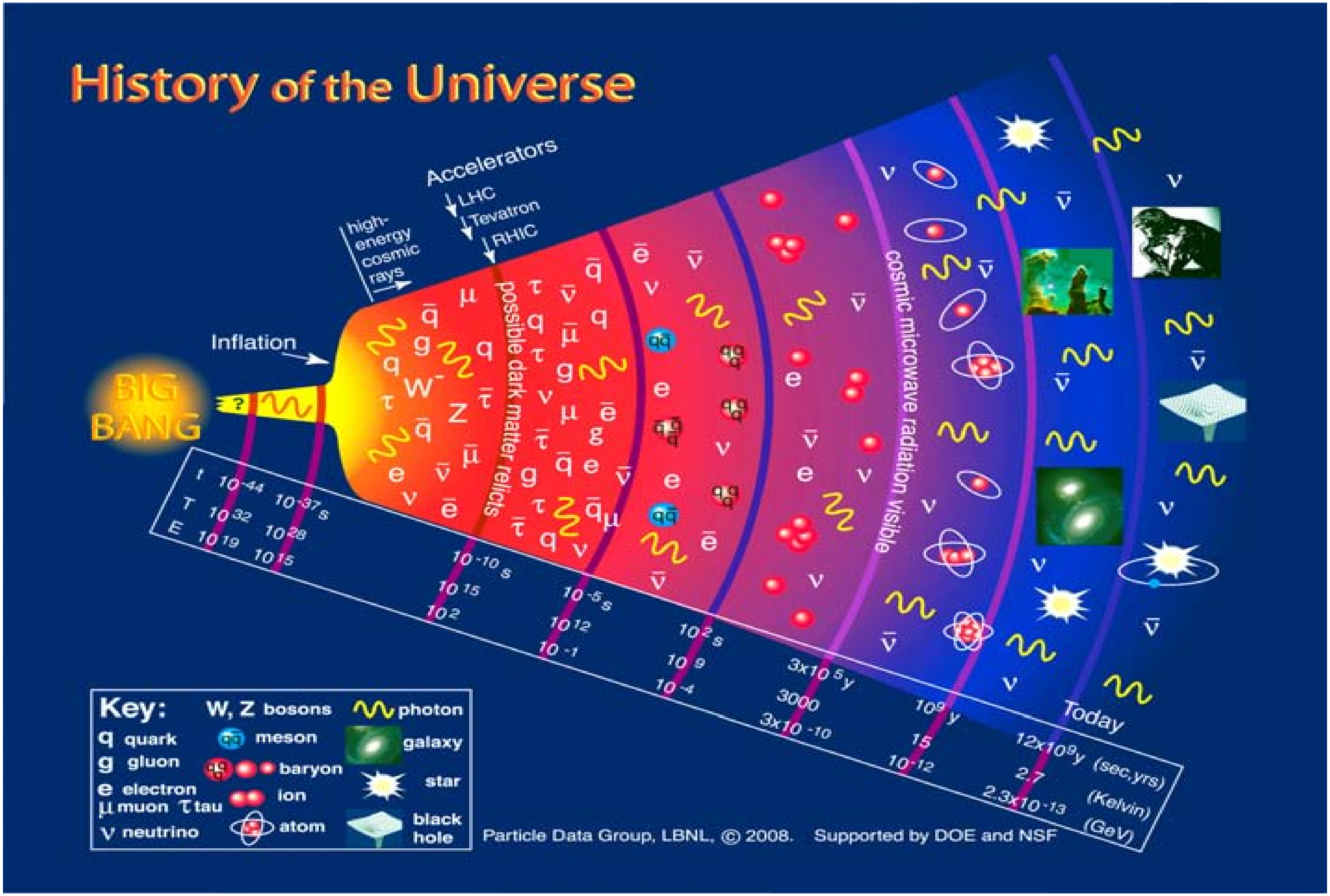
- Finish up LHC detectors: CMS, ALICE (quark-gluon plasma); LHCb
- Computational science: the challenges of the GRID and Data handling
- The Higgs Boson (source of mass)
- Supersymmetry and String Theory (guest speaker)
- Relation to Cosmology (guest speaker)
- Importance of Basic Research
- Closing Speculations

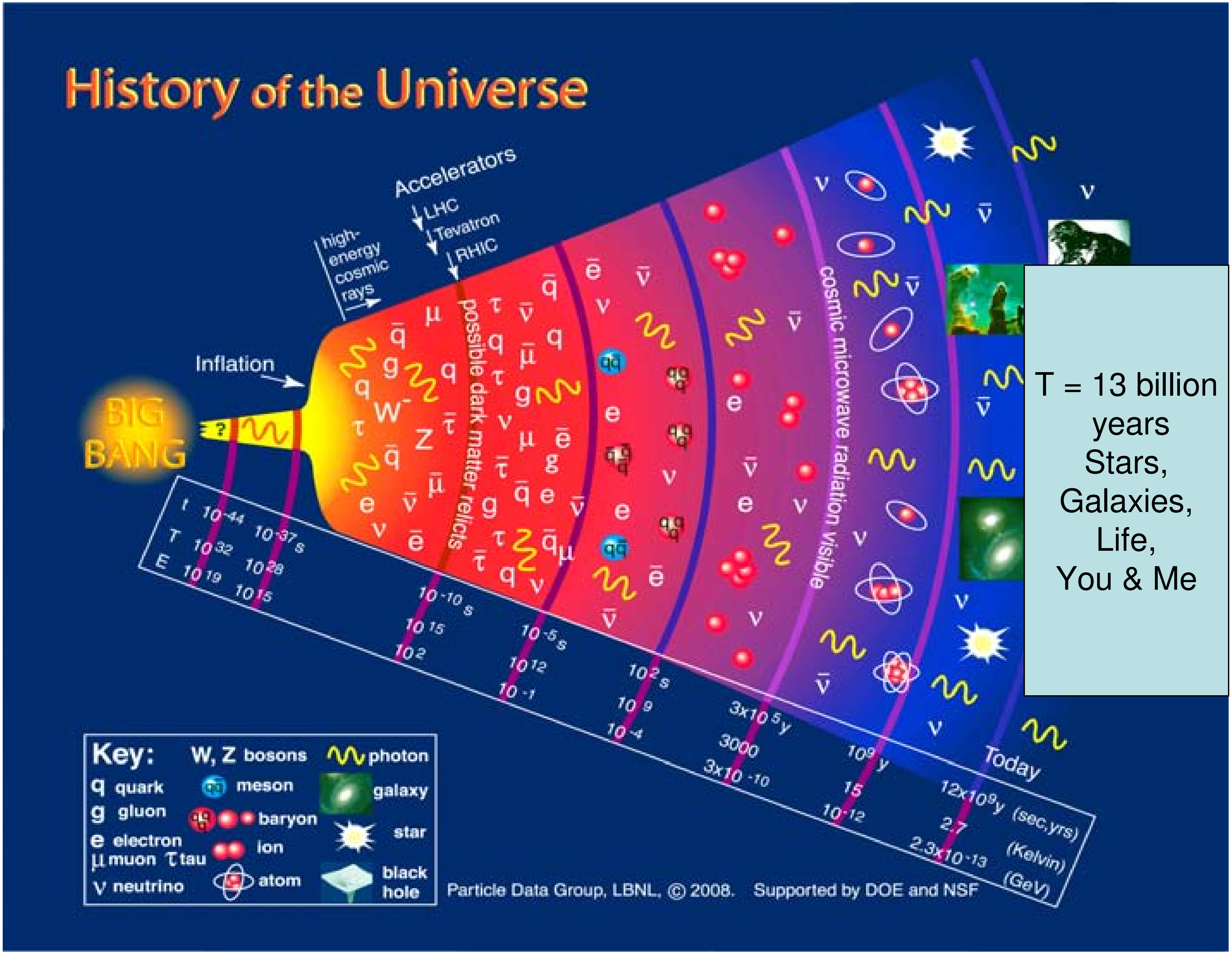
History of the Universe
(as seen by an Astronomer)



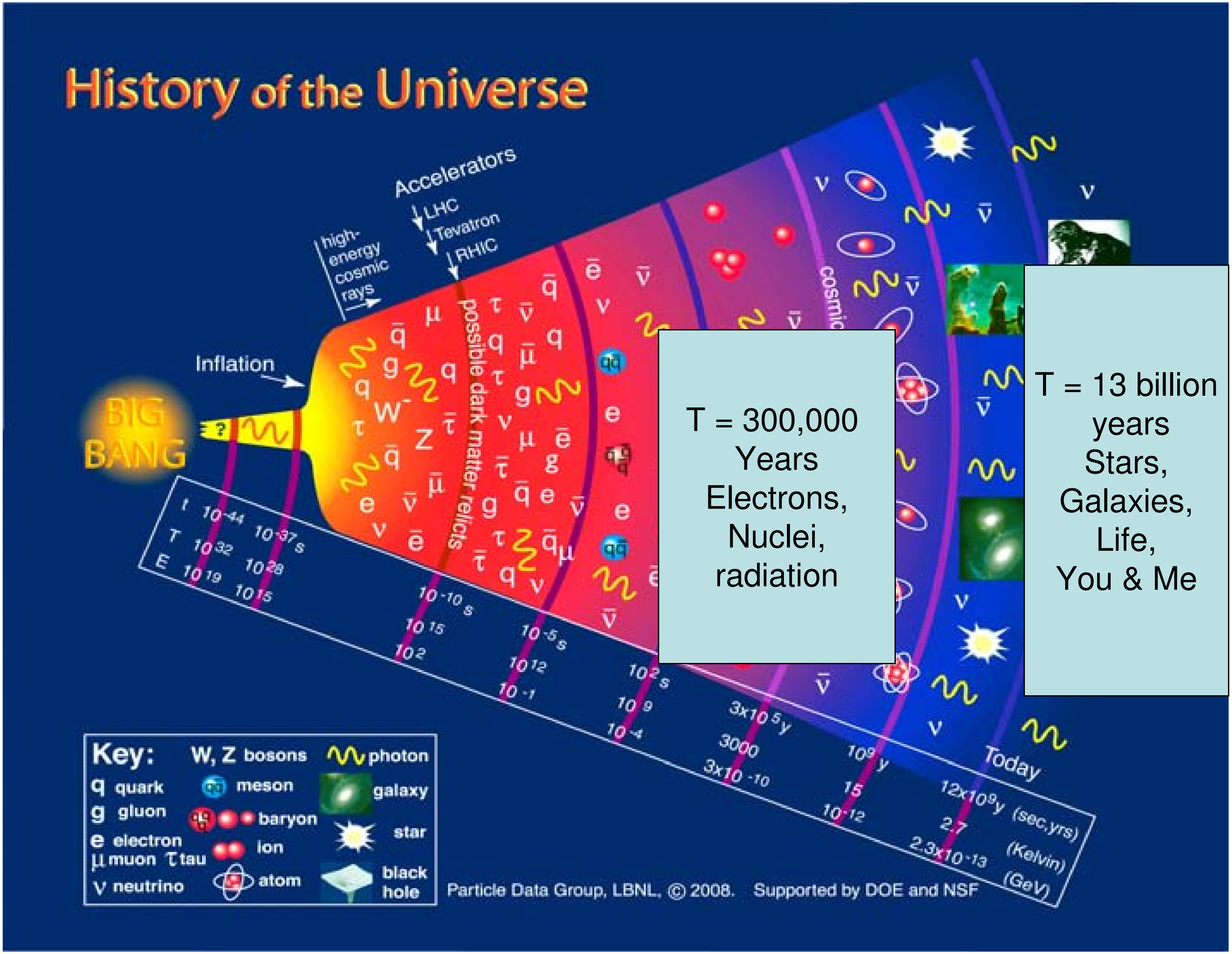
History of the Universe

(as seen by a particle physicist)



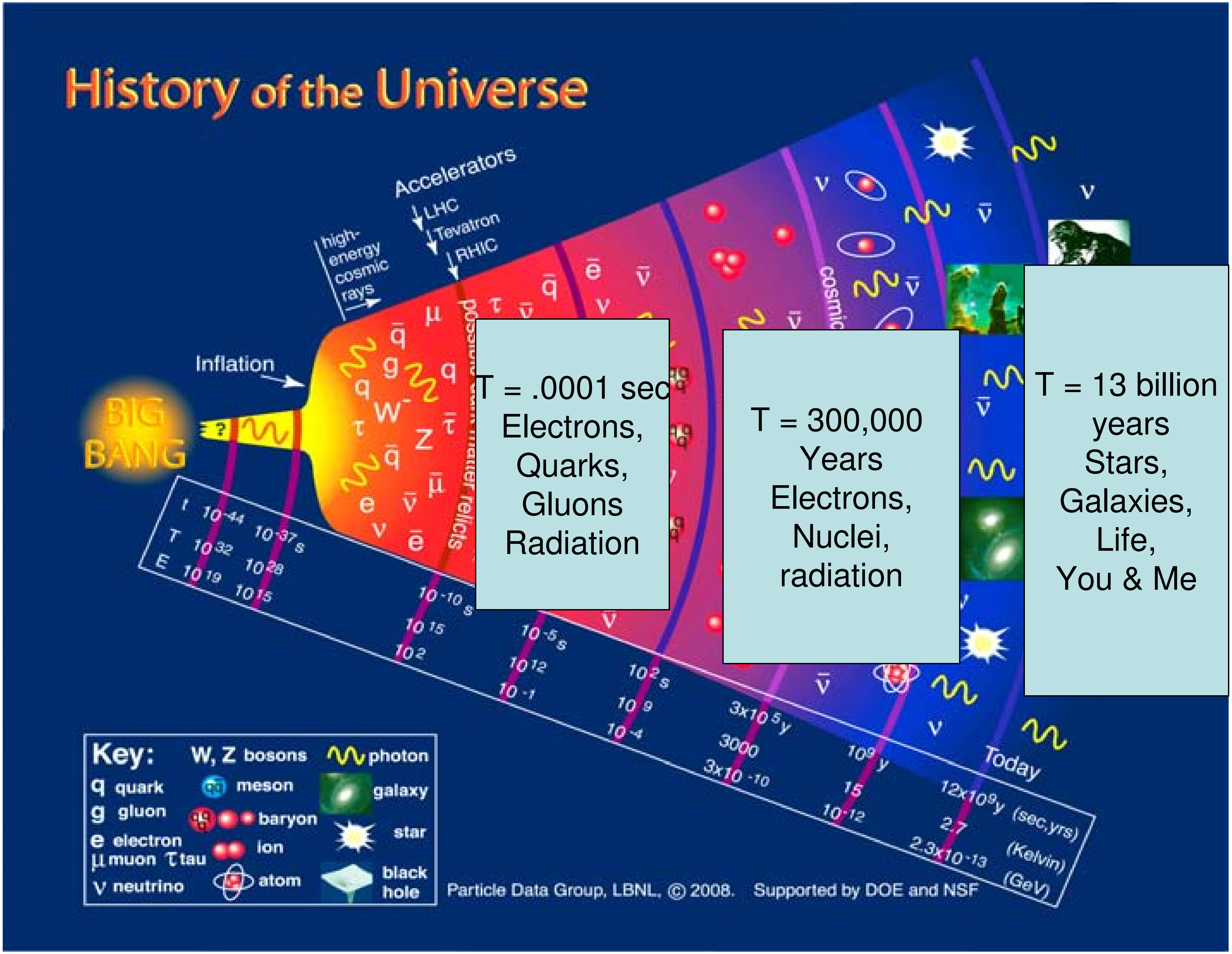


T = 13 billion years
Stars,
Galaxies,
Life,
You & Me



T = 300,000 Years
Electrons,
Nuclei,
radiation

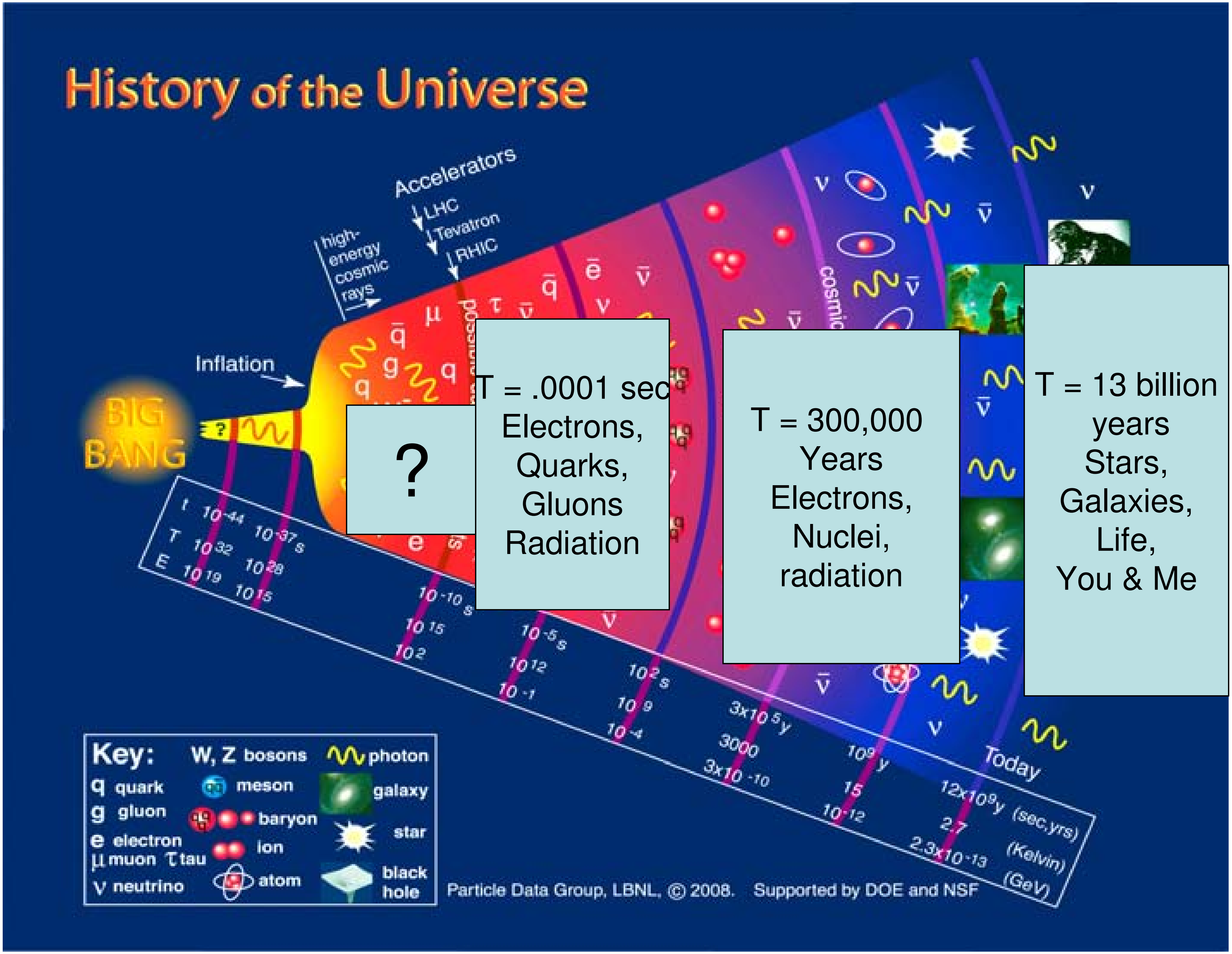
T = 13 billion years
Stars,
Galaxies,
Life,
You & Me



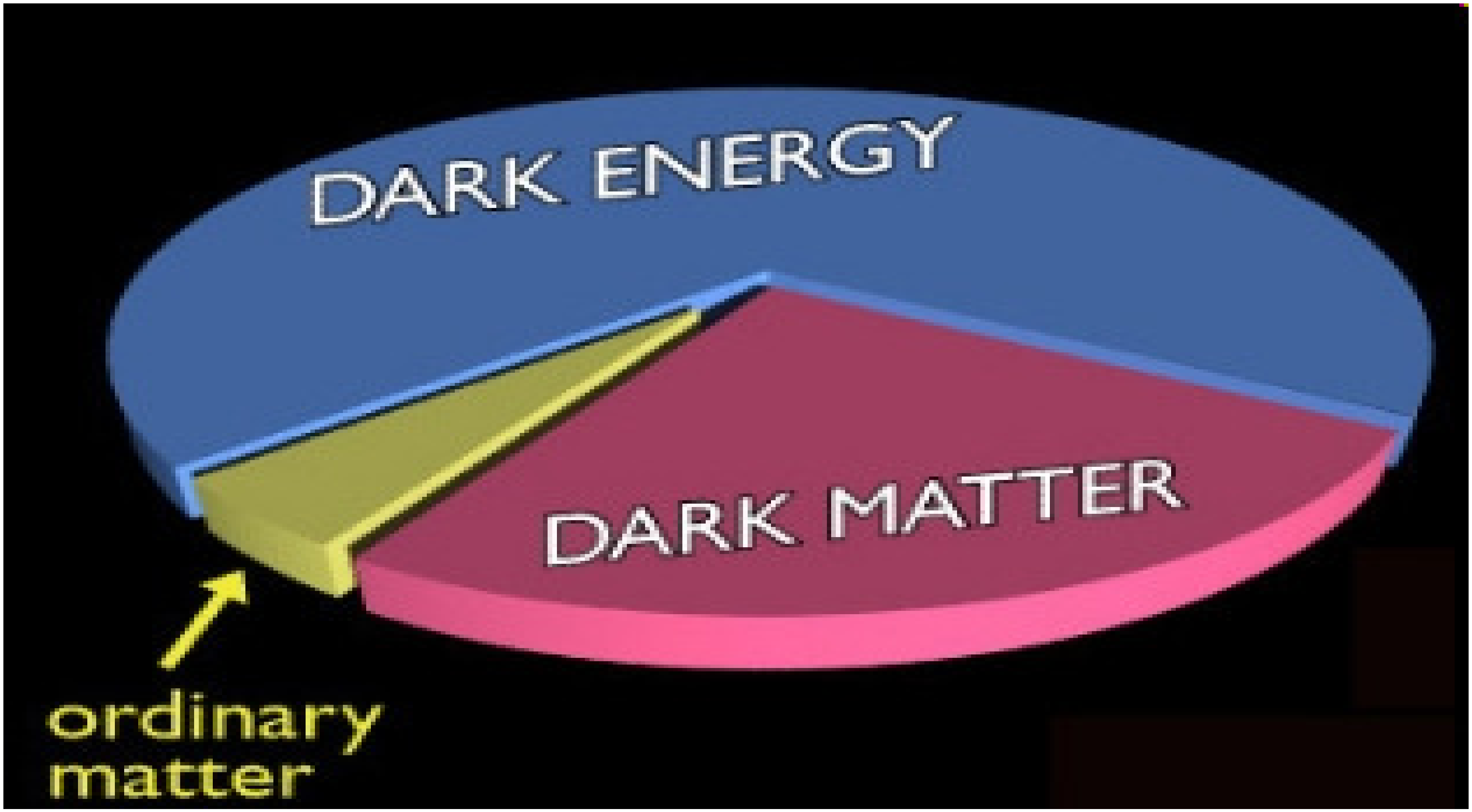
T = .0001 sec
Electrons,
Quarks,
Gluons
Radiation

T = 300,000
Years
Electrons,
Nuclei,
radiation

T = 13 billion
years
Stars,
Galaxies,
Life,
You & Me


History of the Universe
Accelerators
LHC
Tevatron
RHIC
high-energy cosmic rays
Inflation
BIG BANG
?
T = .0001 sec
Electrons,
Quarks,
Gluons
Radiation
T = 300,000
Years
Electrons,
Nuclei,
radiation
T = 13 billion
years
Stars,
Galaxies,
Life,
You & Me
Today
Key:
q quark
g gluon
e electron
μ muon τ tau
ν neutrino
W, Z bosons
meson
baryon
ion
atom
photon
galaxy
star
black hole
Particle Data Group, LBNL, © 2008. Supported by DOE and NSF

Need for Light on the Dark. . .



An Expert's Explanation:

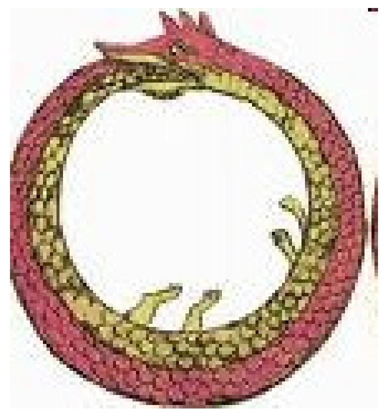
[Special guest and virtual presenter]

~ 16 minutes

“. . . And the “size scale” continues to collapse, as the study of the largest things of which we know is found to have more and more in common with the study of the smaller things of which we know.”

-- NAS Report, a Space Program Worthy of a Great Nation, 2009

Oroborus



The Most Important Product of Knowledge is Ignorance (of what we don't know), Informed & Intelligent -- David Gross

Topics

- Finish up LHC detectors: CMS, ALICE (quark-gluon plasma); LHCb
- Computational science: the challenges of the GRID and Data handling
- The Higgs Boson (source of mass)
- Supersymmetry and String Theory (guest speaker)
- Relation to Cosmology (guest speaker)
- Importance of Basic Research
- Closing Speculations

What's the Use of Basic Research?

➔Basic Science [i.e. knowledge]– motivated by curiosity; responsibility of governments

Strategic – directed, both government & industry

Applied – designed to answer specific questions; industry

"What's the Use of Basic Science?", Sir C.H. Llewellyn Smith, DG of CERN, 1994-1998

Spin-offs and Stimulation of industries

- Accelerators
  ➔Cancer therapy; medicine

  – Semiconductor industry
  – Sterilization of food, medical, sewage
  – Radiation processing
  – Non-destructive testing
  – Incineration of nuclear wastes
  – Synchrotron radiation – biology, materials,
  – Neutron sources – biology, materials

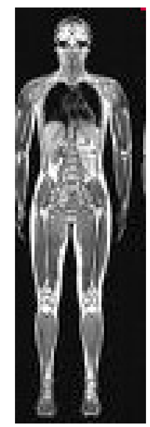
Spin-offs and Stimulation of industries

- Particle detectors
  - Crystal detectors
    - Medical imaging
    - ➔Security
    - Non-destructive testing
    - Research
  - Multi-wire proportional chambers
    - Container inspection
  - Semiconductor detectors
    - Pixels in cameras, flat panel TVs, etc

Spin-offs and Stimulation of industries

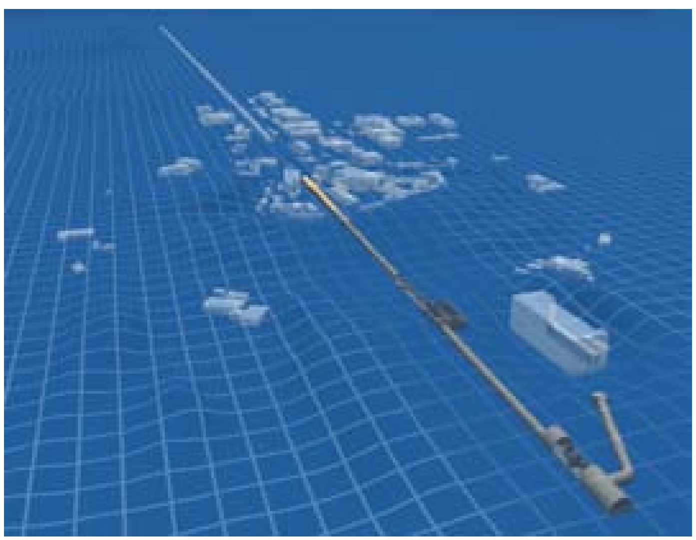
- Informatics
  - World Wide Web
  - Simulation programs
  - Fault diagnosis
  - Control systems
  - Simulation by parallel computing
  - Data base mining
- Superconductivity

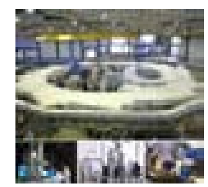
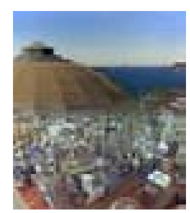
  ➔Magnets for MRI scanners (a.k.a. NMR)



Spin-offs and Stimulation of industries

- Nano-revolution comes from synchrotron radiation, formerly a waste product
- What is synchrotron radiation, what it can do at LCLS ~ 6 min



Basic Research: What's the Use?

- Education:
  - Problem solving skills, learn by doing
  - Networking, real and virtual
  - Transfer to other fields, e.g. finance

What’s the use of Basic Research?

- Culture
  - Congress; “What will your lab [Fermilab] contribute to the defesne of the US?”; Bob Wilson: “Nothing, but it will make it worth defending.”
  - Silicon Valley ➔ MIT + Entrepreneur; Stanford + Entrepreneurs
- Economists:
  - As an investment: Mansfield, 1991: ROR = 28%
  - Robert Solow, 1987 Nobel Address: “technology remains the dominant engine of growth, with human capital investment in second place.”
- A Certainty: not possible to exploit new laws & facts of nature if remain undiscovered.

Topics

- Finish up LHC detectors: CMS, ALICE (quark-gluon plasma); LHCb
- Computational science: GRID and the Data handling and computational challenges
- The Higgs Boson (source of mass)
- Supersymmetry and String Theory (guest speakers)
- Relation to Cosmology (guest speaker)
- Importance of Basic Research
- Closing Speculations

Closing Speculation

History as a guide

- Gladstone: “What use is electricity?”

  Faraday: “One day Sir you may tax it.”
- Lord Kelvin: “There is nothing new to be discovered in physics now. All that remains is more and more precise measurement.”
- Rutherford: “Anyone who expects a source of power from the transformation of atoms is talking moonshine.”
- DNA -- Atomic Energy Commission, then DOE: radiation effects on biology
- Climate change – AEC & DOE: atmospheric fallout

Closing Speculation

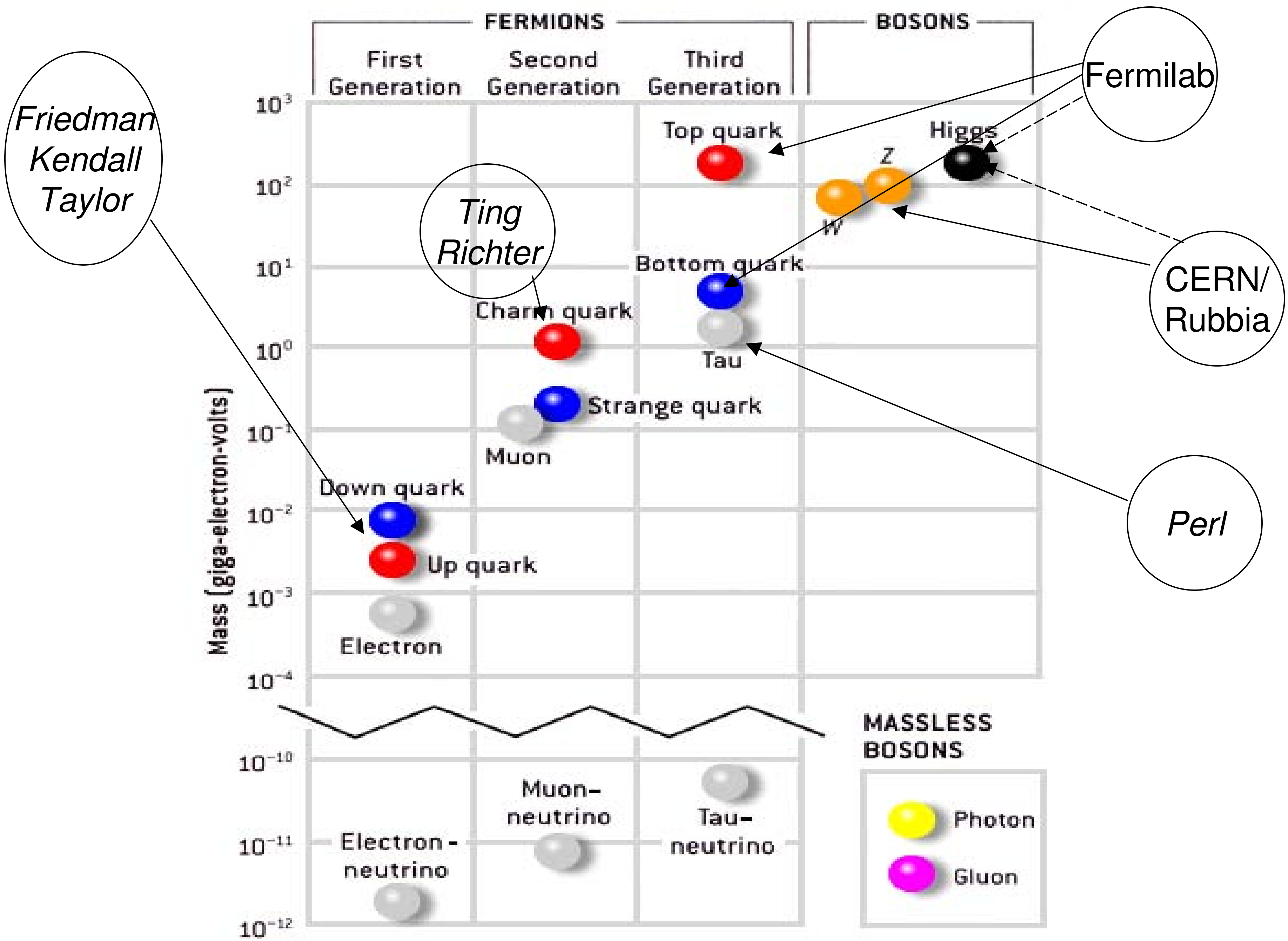
Organizational Vanguard?

- CERN is a unique, truly international Laboratory
- Adventures in the sociology of large science: ATLAS, CMS, LHCb, etc
- Future of Science: inevitably international?

Closing Speculation

Financing (2009 budget)

MC	Contribution %	MCHF	MEuros
Germany	19.88	218.6	144
France	15.34	168.7	111.2
UK	14.7	161.6	106.5
Italy	11.51	126.5	83.4
Spain	8.52	93.7	61.8
NL	4.79	52.7	34.7
CH	3.01	33.1	21.8
Poland	2.85	31.4	20.7
Total	100	1096.6	724


FERMIONS
BOSONS
First Generation
Second Generation
Third Generation
Mass (giga-electron-volts)
Top quark
Higgs
Z
W
Bottom quark
Charm quark
Tau
Strange quark
Muon
Down quark
Up quark
Electron
Muon-neutrino
Tau-neutrino
Electron-neutrino
MASSLESS BOSONS
Photon
Gluon
Friedman Kendall Taylor
Ting Richter
Fermilab
CERN/ Rubbia
Perl

Closing Speculation

On the side of history?

- Large Science projects are indispensable to the health and vitality of U.S. science
- LHC, ITER – Big Science gone Global – require long-term commitments
- Science Research is a de facto international enterprise
- Many of the best research facilities are now outside the U.S.

Report to the President and Congress on Large Science Projects, DOE, 1996

Take Home Messages?

- The only reliable prediction of scientific advancement seems to be that it is unpredictable,& well beyond our current imagination and perception of physical Reality.
- Science progress requires big facilities. Big facilities require cooperation to be effective.
- We are learning real time about the consequences of informatics, e.g. GRID, instant global communications, etc.
- Fundamental, forefront physics advancement today & tomorrow requires collaboration and sustained, serious investments on the part of Governments and other funding sources.
- Economic spin offs tend to be immense, but are not the proper motivation for the funding science. The Science is.

Web References

An overview of physics: David Gross, the Coming Revolutions in Theoretical Physics

http://www.youtube.com/watch?v=AM7SnUlw-DU

http://www.particleadventure.org/

http://public.web.cern.ch/public/

http://hands-on-cern.physto.se/hoc_v21en/index.html

BACK UP

Future: supersymmetry and string theory

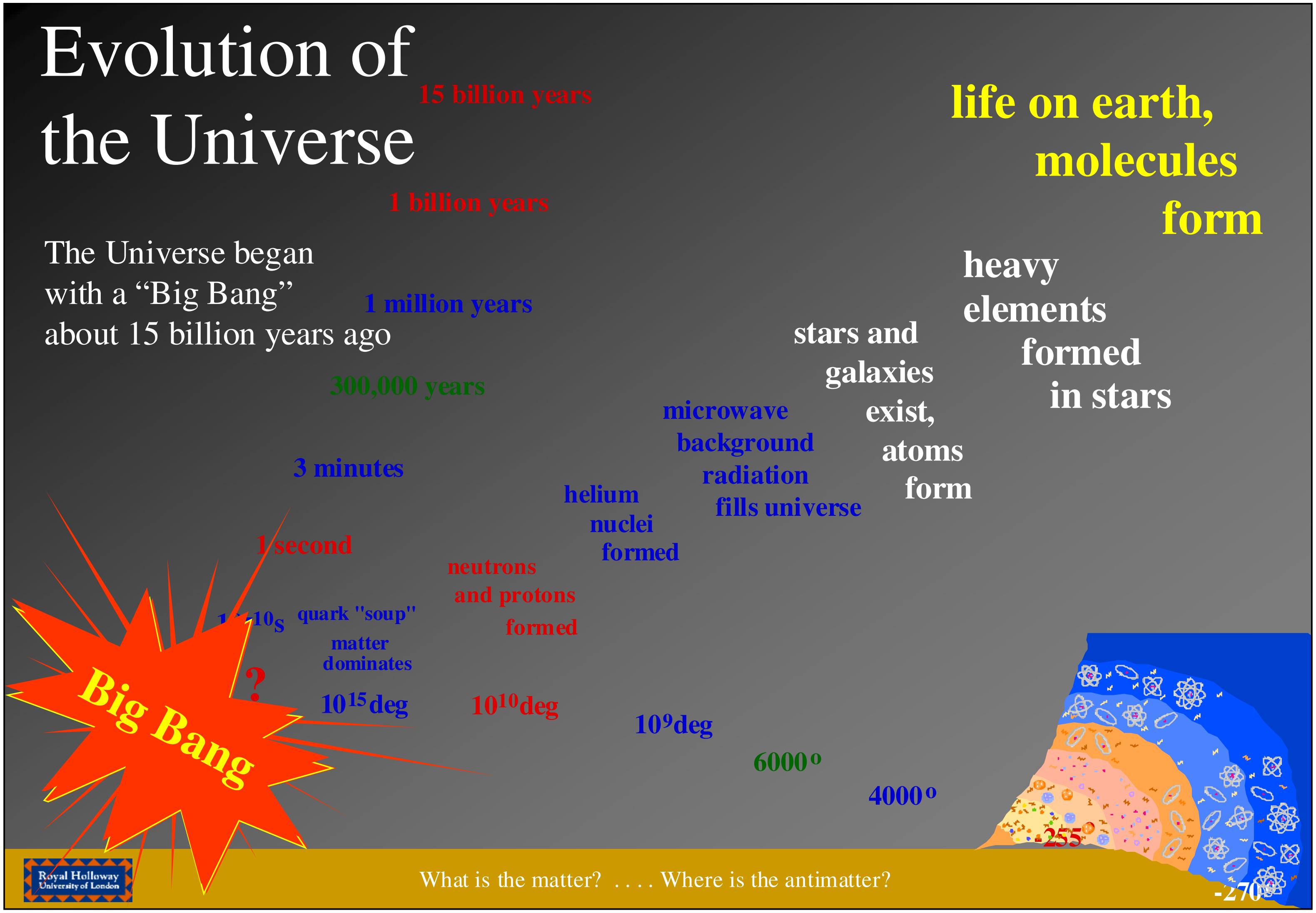
- http://www.youtube.com/watch?v=AM7SnUlw-DU

- David Gross lecture

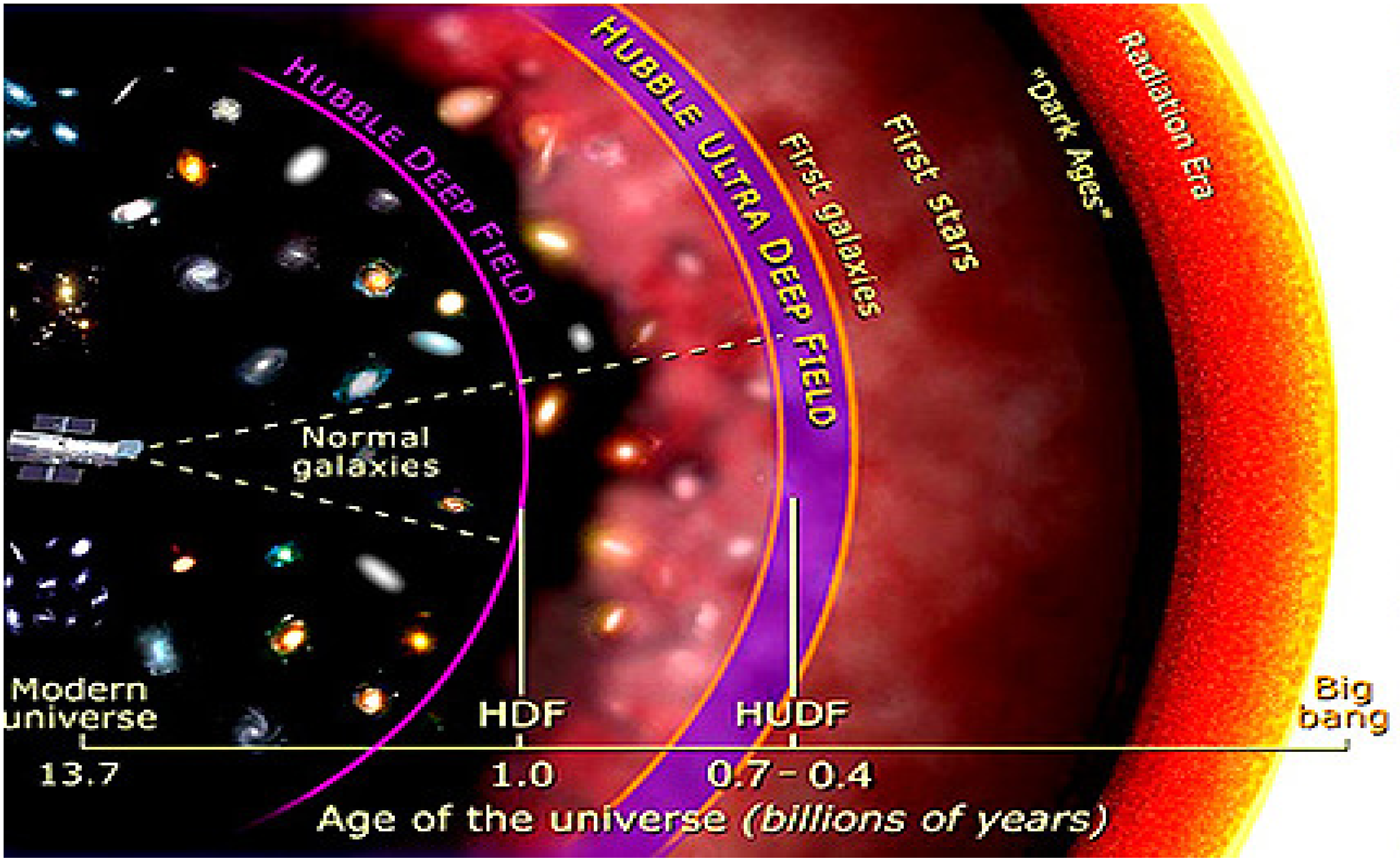
A pro explains GUTs

- http://www.fnal.gov/pub/science/questions/einsteins-dream-04.html

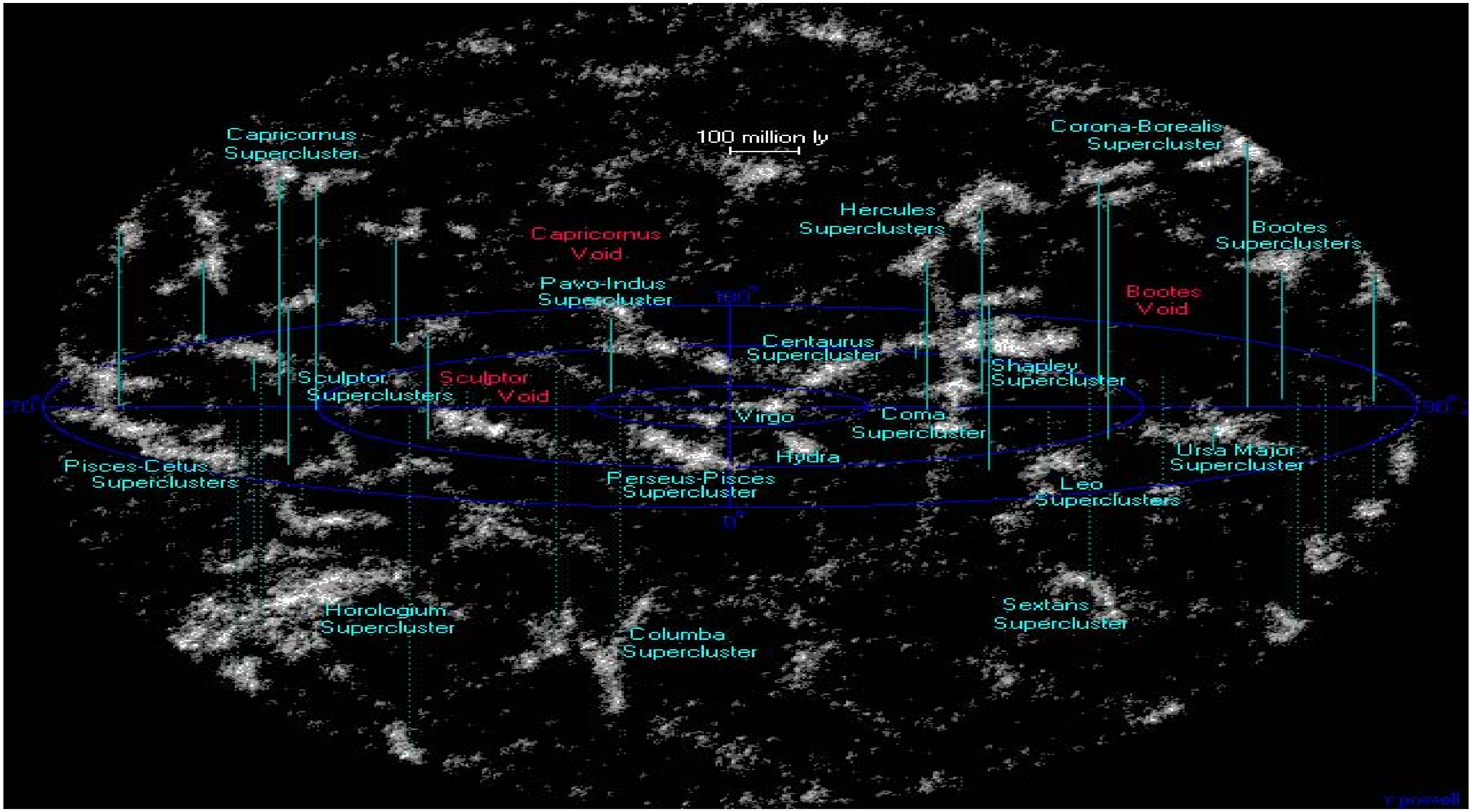
Universe


Evolution of the Universe
15 billion years
1 billion years
The Universe began with a “Big Bang” about 15 billion years ago
1 million years
300,000 years
3 minutes
1 second
quark "soup"
matter dominates
?
Big Bang
10^{15}deg
neutrons and protons formed
10^{10}deg
helium nuclei formed
10^{9}deg
microwave background radiation fills universe
6000°
stars and galaxies exist, atoms form
4000°
heavy elements formed in stars
life on earth, molecules form
-255°
-270°
Royal Holloway University of London
What is the matter? . . . . Where is the antimatter?

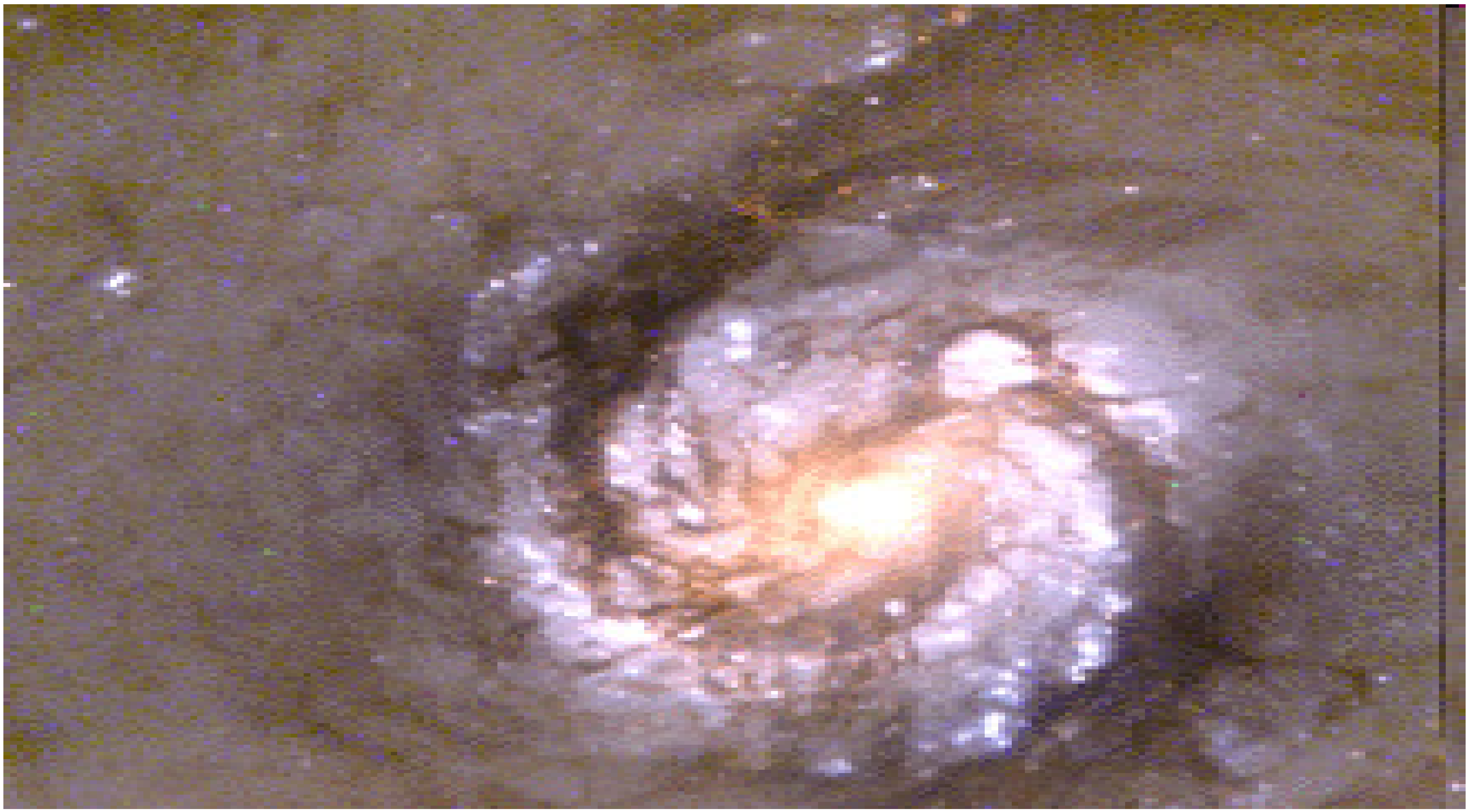
History of the Universe



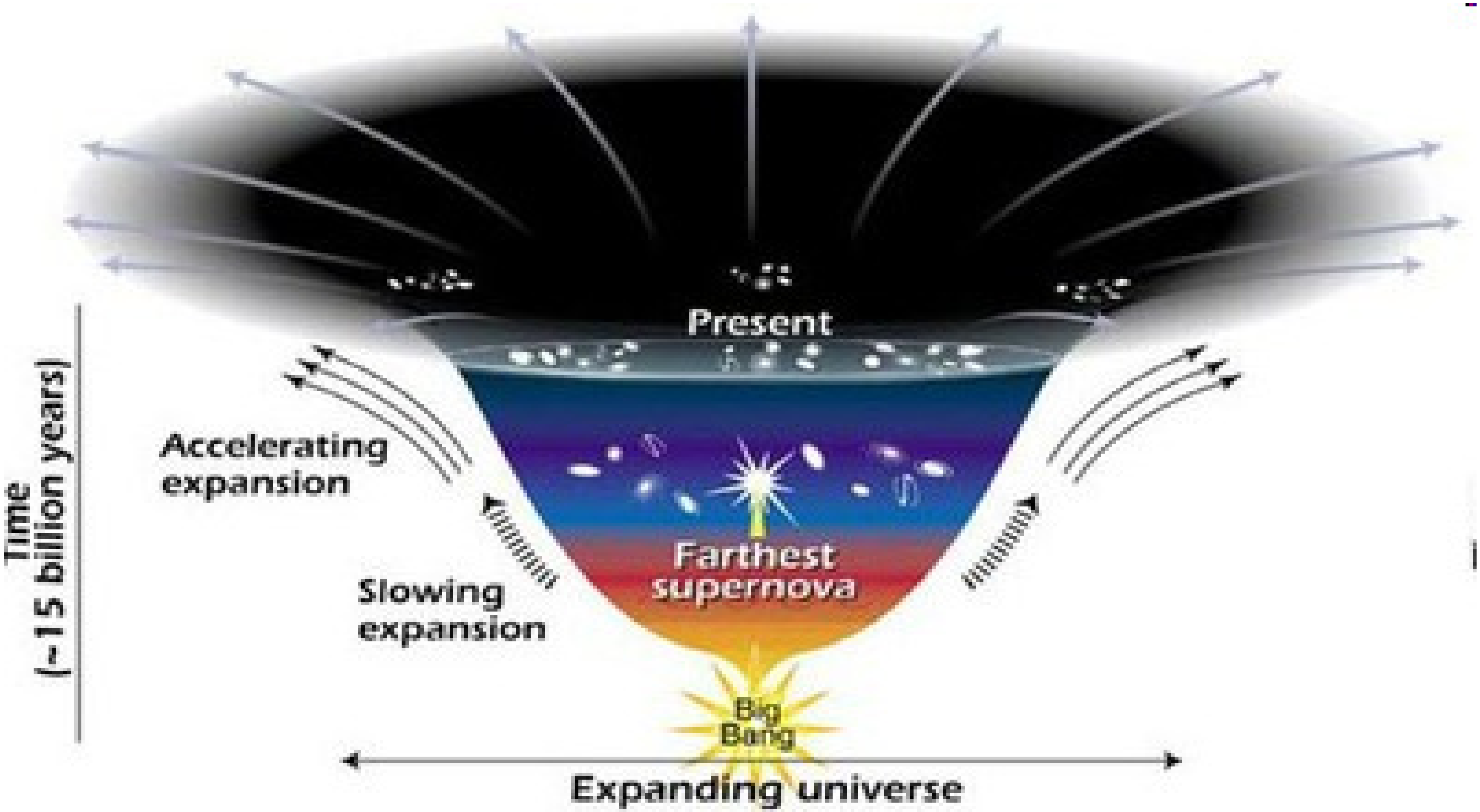
lumpiness


Capricornus Supercluster
100 million ly
Corona-Borealis Supercluster
Hercules Superclusters
Capricornus Void
Bootes Superclusters
Pavo-Indus Supercluster
Bootes Void
Centaurus Supercluster
Shapley Supercluster
Sculptor Superclusters
Sculptor Void
Virgo
Coma Supercluster
Hydra
Ursa Major Supercluster
Pisces-Cetus Superclusters
Perseus-Pisces Supercluster
Leo Superclusters
Sextans Supercluster
Horologium Supercluster
Columba Supercluster

Dark Matter



Dark Energy

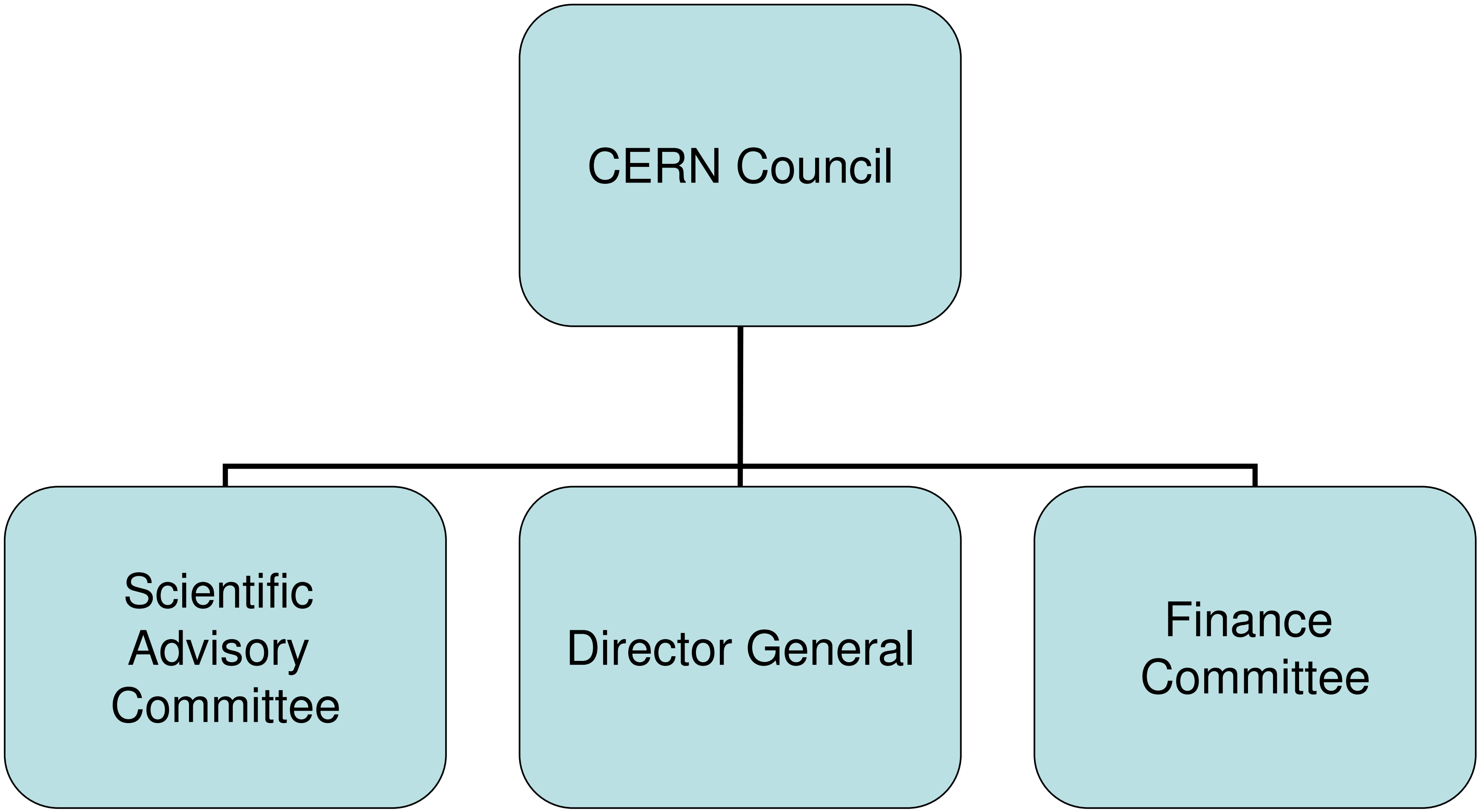


Present
Accelerating expansion
Slowing expansion
Farthest supernova
Big Bang
Time (~15 billion years)
Expanding universe

CERN –*Conseil Européen pour la Recherche Nucléaire*

From original 11 to 20

Organization



US Role in LHC

- LHC Machine -- $200M, in kind, DOE, capped
- LHC Detectors -- $250M, in kind, DOE; $81M form NSF, capped
  - Best efforts,
- Observer, not a Member

U.S. LHC Machine Contribution

U.S. Collaborating Institutions: >1700 scientists, engineers, grad students

US ATLAS

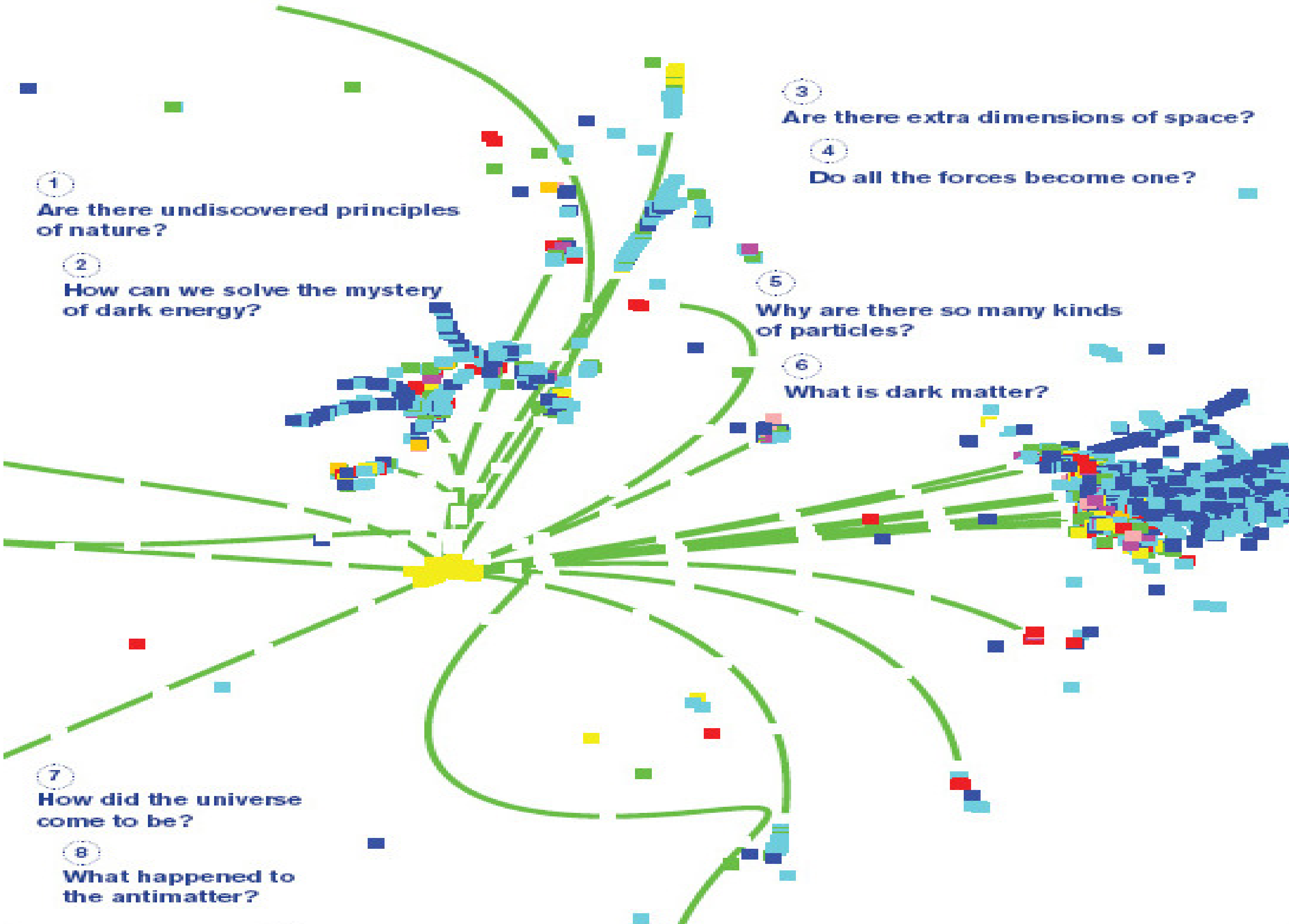
- 700 physicists, engineers, grad students
- 44 institutions (BNL host national lab, mostly universities)
- The whole ATLAS collaboration includes 2900 physicists from 37 countries and 169 institutions.
- Tracking systems (pixel, semiconductor and transition radiation tracker); Calorimeters (Liquid Argon Calorimeter, Tile Calorimeter); Muon Spectrometer
- Data Acquisition and Computing

US CMS

- 49 institutions,430 Ph.D. physicists, ~ 200 graduate students, & >300 engineers, technicians, and computer scientists
- 3000 scientists and engineers; 83 institutes in 38 countries, spanning Europe, Asia, the Americas and Australasia.
- US working on Hadron & Electromagnetic Calorimeters; Muon Detector; Silicon Strip Tracking system; Forward Silicon Pixel Tracking System; Trigger System and Data Acquisition
- Computing

Questions for the Universe

Discoveries at the Large Hadron Collider promise to revolutionize our understanding of the universe. The LHC experiments could reveal answers to many of the most profound questions of the physical world.



1. Are there undiscovered principles of nature?
2. How can we solve the mystery of dark energy?
3. Are there extra dimensions of space?
4. Do all the forces become one?
5. Why are there so many kinds of particles?
6. What is dark matter?
7. How did the universe come to be?
8. What happened to the antimatter?

US CMS

National Science Foundation

U.S. DEPARTMENT OF

Interview with Head of CERN IT

- http://cdsweb.cern.ch/record/1129134
- ~ 7 min

Grid Computing

http://www.gridcafe.org/version1/openday/Whatis.html

Tie in to Cosmology

- http://www.atlas.ch/multimedia/html-nc/feature-atlas.html

On the side of history?

- Fundamental physics is now centered at CERN
- Does computer linkages (and English) make geography irrelevant?
- Is globalization inevitable in science?
- Is the US prepared for 21st century science?
  - US has been an unreliable Big Science Partner
  - US STEM education is problematical
  - US industry “outsourcing” to other countries