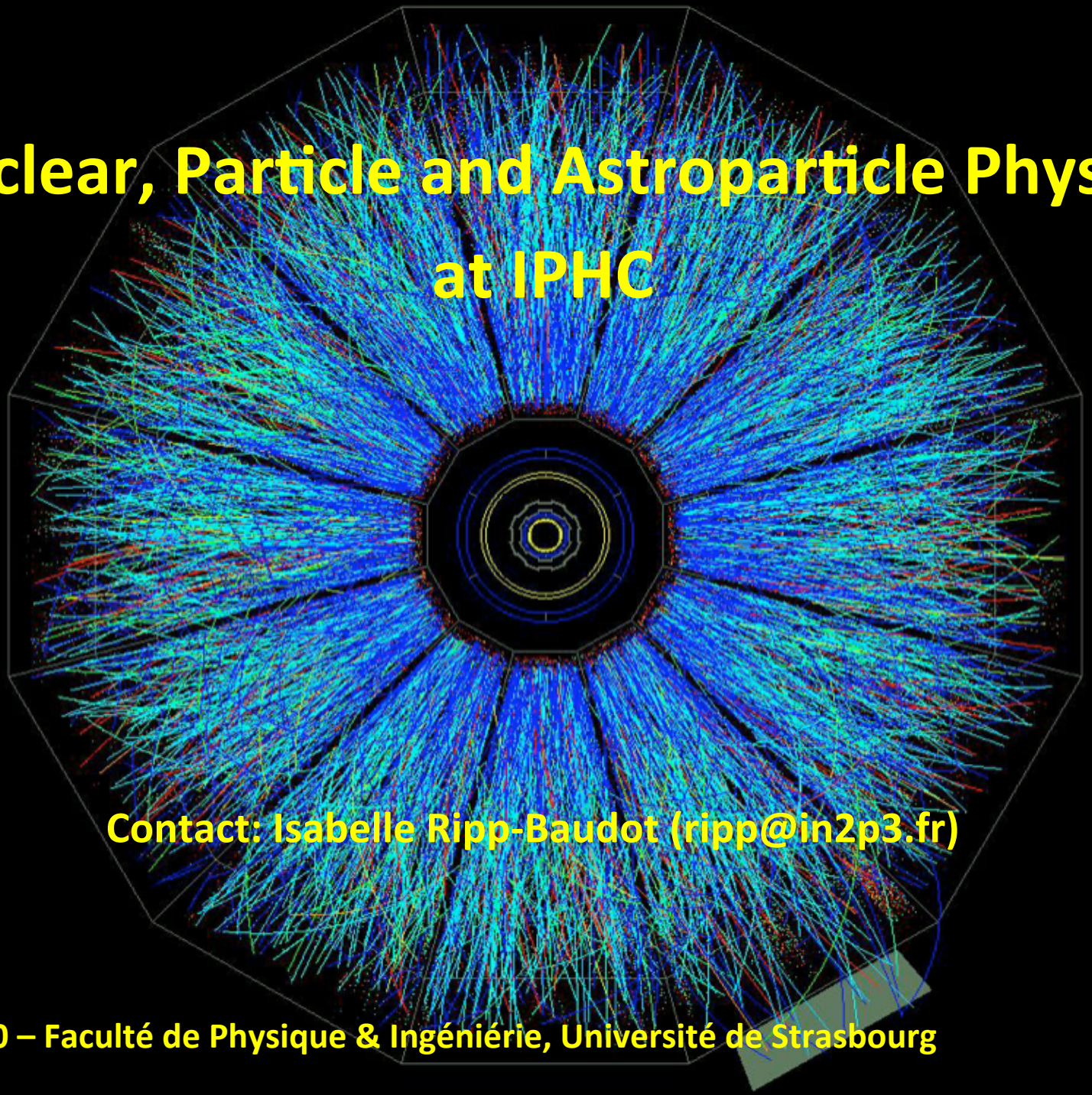
Nuclear, Particle and Astroparticle Physics at IPHC



Contact: Isabelle Ripp-Baudot (ripp@in2p3.fr)

2017/01/20 – Faculté de Physique & Ingéniérie, Université de Strasbourg

Institut Pluridisciplinaire Hubert Curien

iPHC
Institut Pluridisciplinaire
Hubert CURIEN
STRASBOURG

cnrs IN2P3 INC INEE INSB

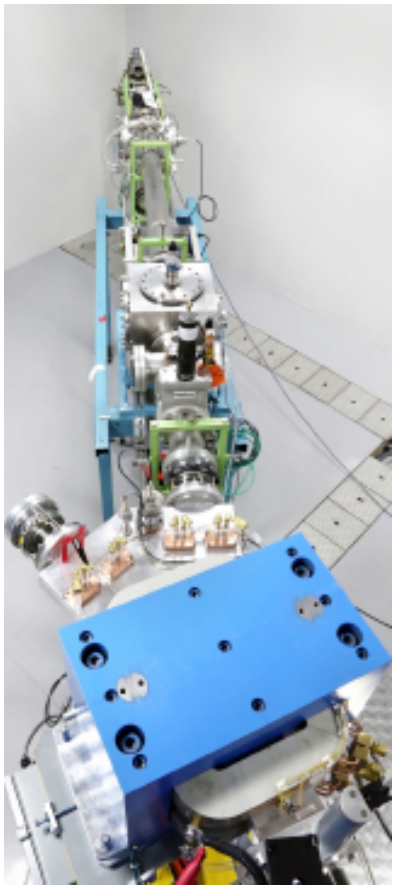
UNIVERSITÉ DE STRASBOURG

http://www.iphc.cnrs.fr/

Identity of IPHC

- Two supporting institutions:
  - CNRS : National Center for Scientific Research
    with IN2P3 = Institute of Nuclear Physics and Particle Physics
    in CNRS including nowadays also Cosmology and Astroparticles.
  - University of Strasbourg.
  - Workforce of IPHC: ~400 personnel.

- Multidisciplinary research at IPHC:
  - Present laboratory created in 2006 based on 3 former labs :
    Biology - Chemistry - Subatomic Physics.
  - Cyclotron built at IPHC in 2012: also Medical Doctors joined
    IPHC to participate to research in Molecular Imaging,
    Hadrontherapy and Radiobiology.



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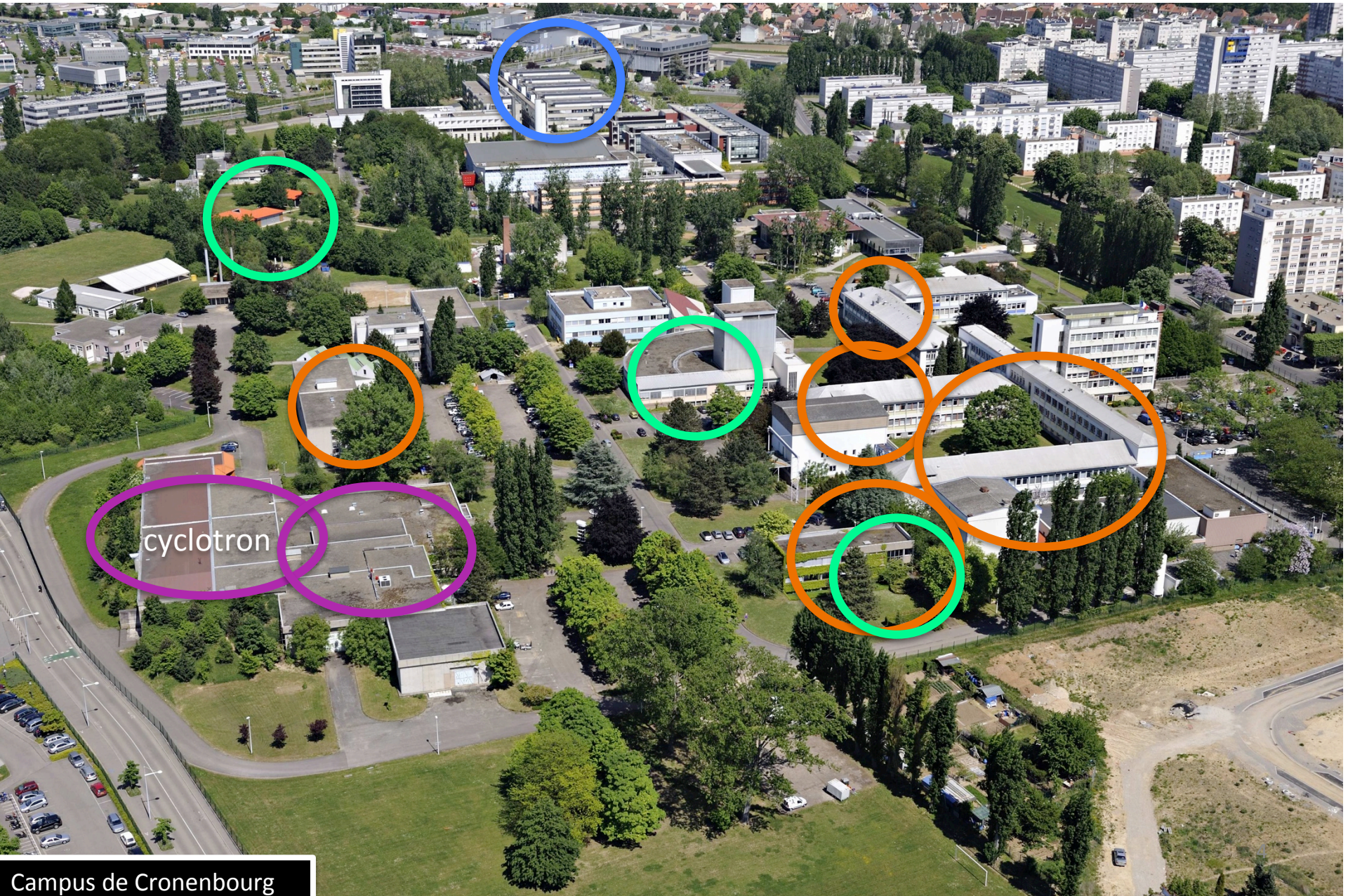
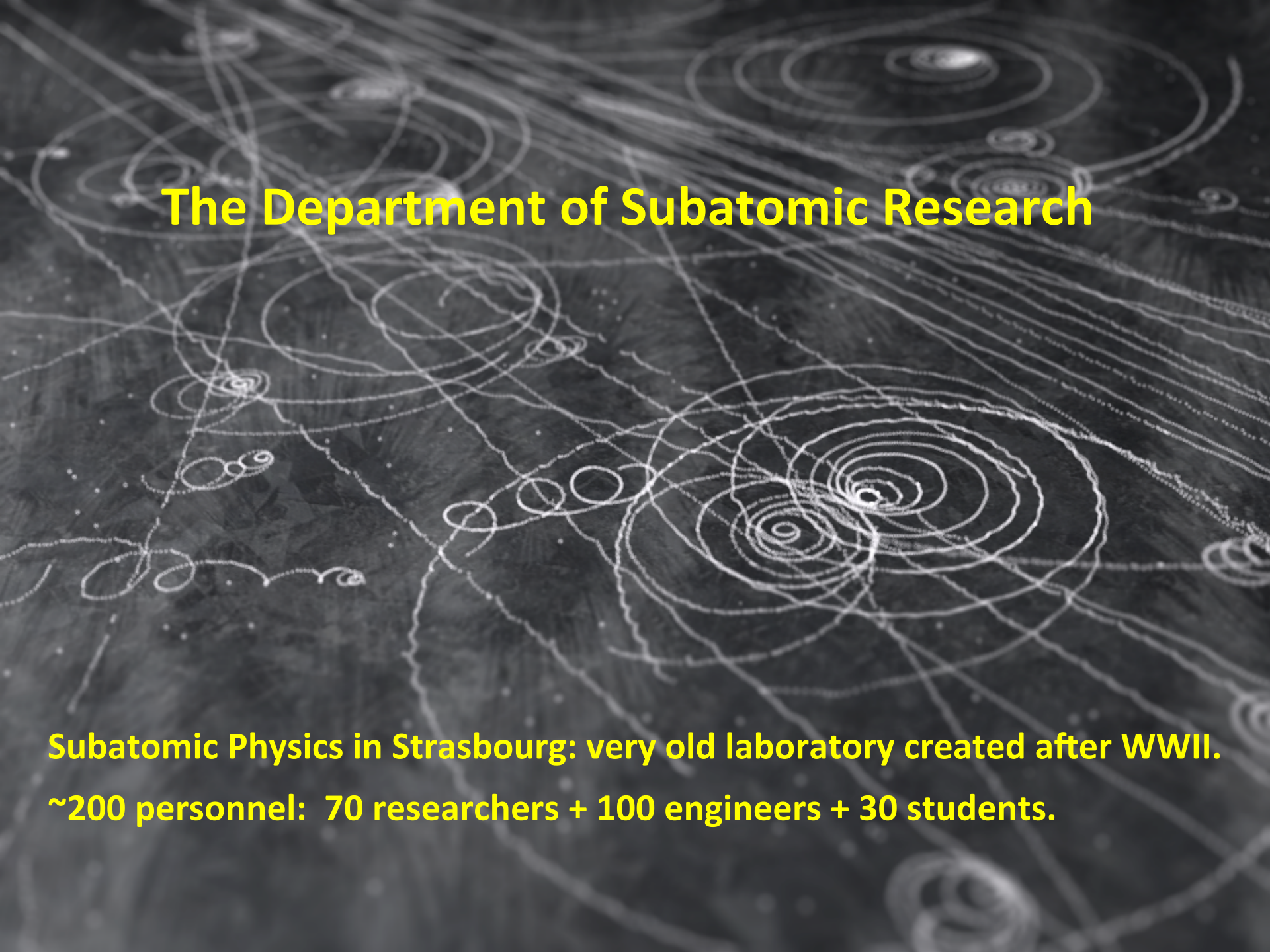


Campus de Cronenbourg

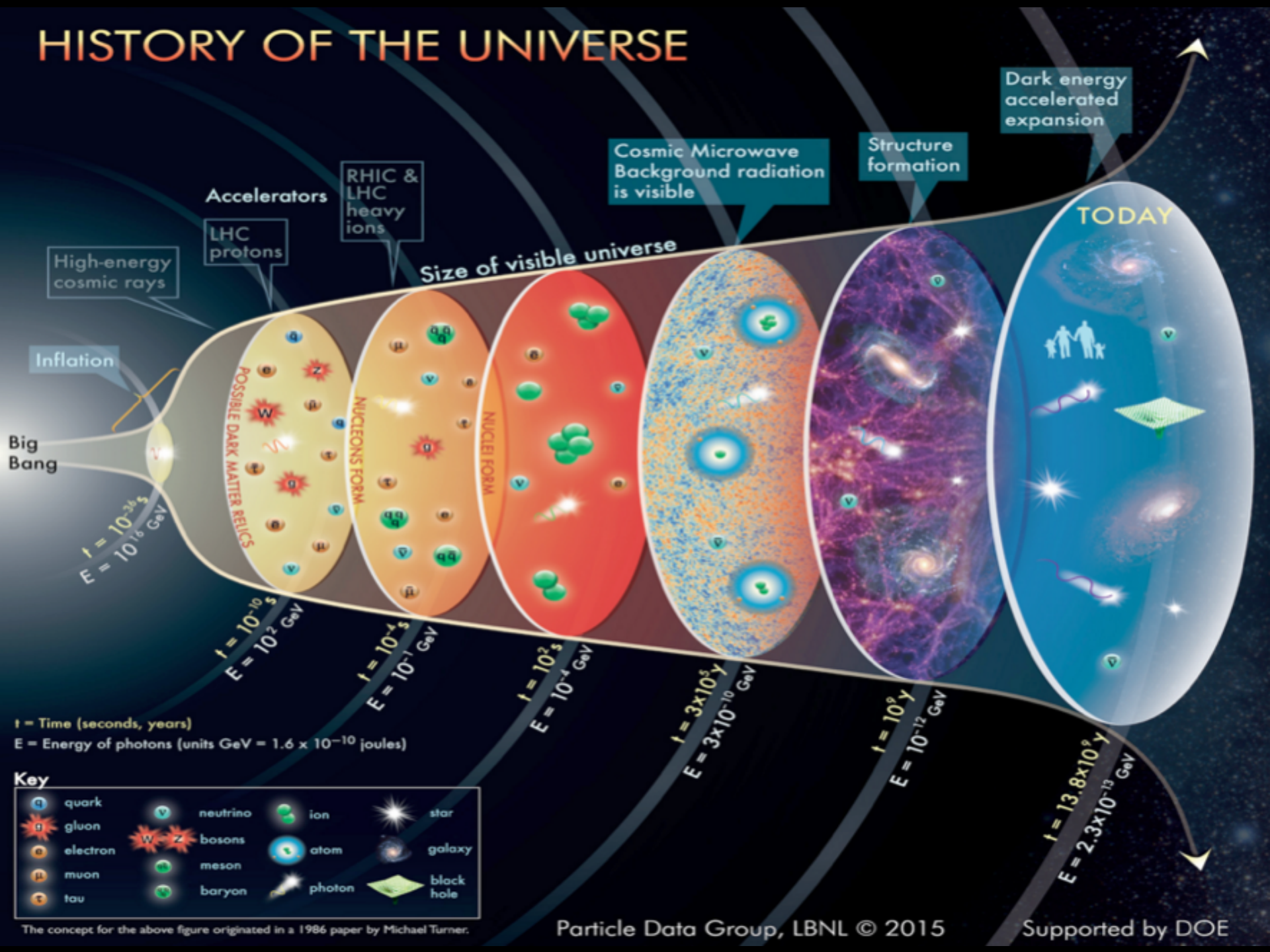


The Department of Subatomic Research

Subatomic Physics in Strasbourg: very old laboratory created after WWII.

~200 personnel: 70 researchers + 100 engineers + 30 students.

HISTORY OF THE UNIVERSE



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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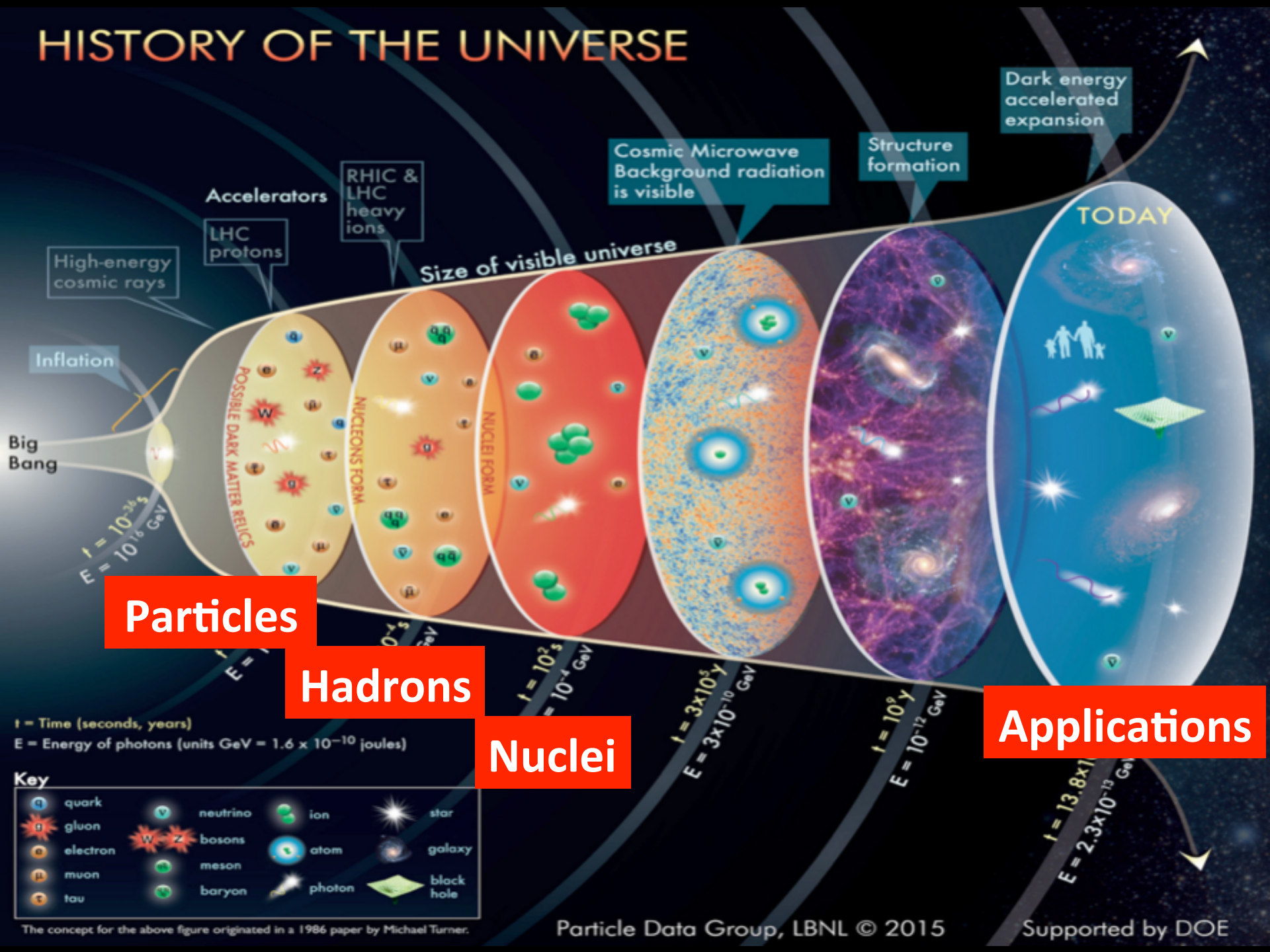
HISTORY OF THE UNIVERSE
Dark energy accelerated expansion
Cosmic Microwave Background radiation is visible
Structure formation
Accelerators
RHIC & LHC heavy ions
LHC protons
High-energy cosmic rays
Size of visible universe
TODAY
Inflation
Big Bang
POSSIBLE DARK MATTER RELICS
NUCLEONS FORM
NUCLEI FORM
Particles
Hadrons
Nuclei
Applications
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
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The concept for the above figure originated in a 1986 paper by Michael Turner.
Particle Data Group, LBNL © 2015
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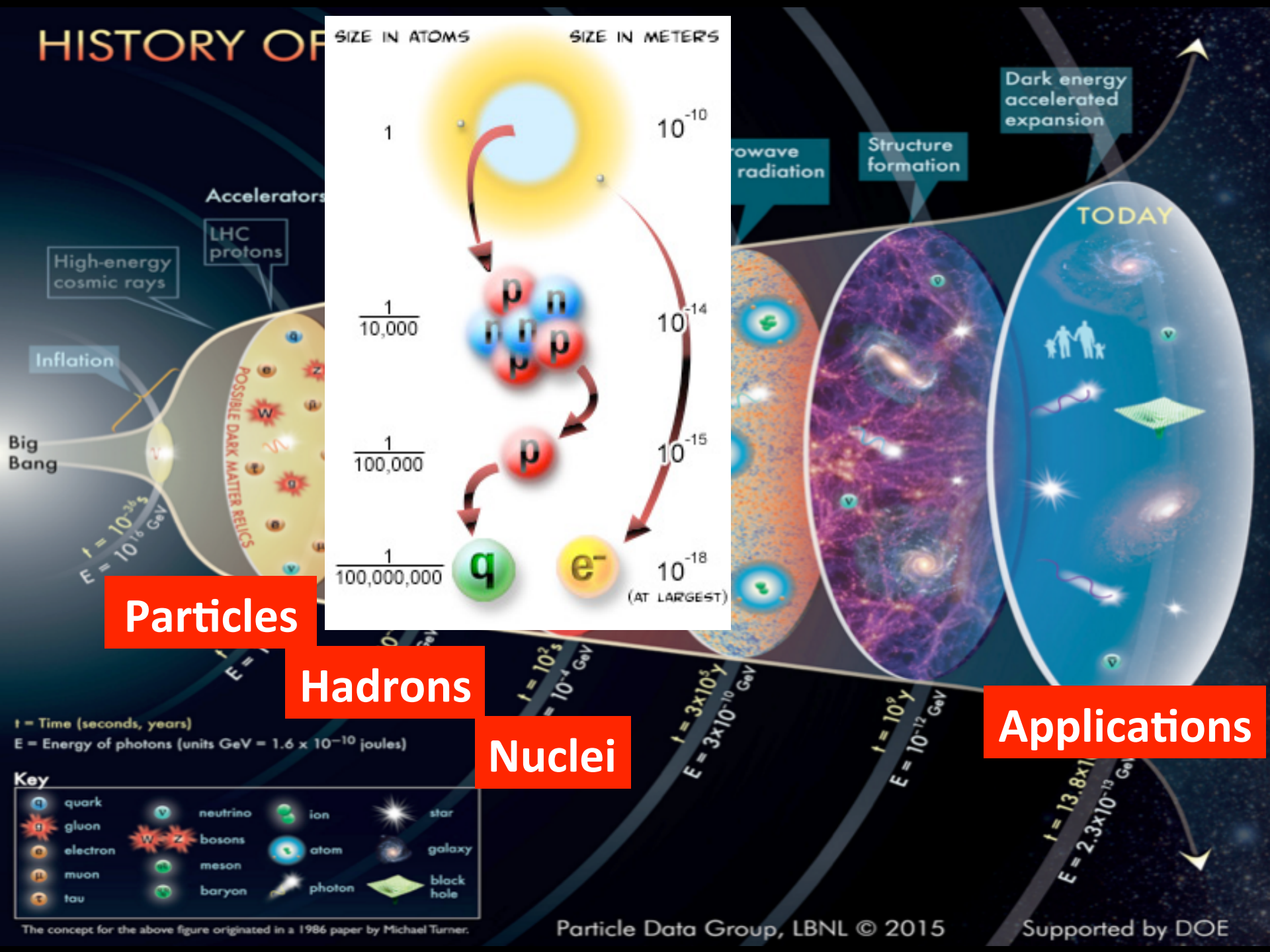
HISTORY OF
SIZE IN ATOMS
SIZE IN METERS
1
10^-10
1/10,000
10^-14
1/100,000
10^-15
1/100,000,000
10^-18
(AT LARGEST)
Accelerators
LHC protons
High-energy cosmic rays
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POSSIBLE DARK MATTER RELICS
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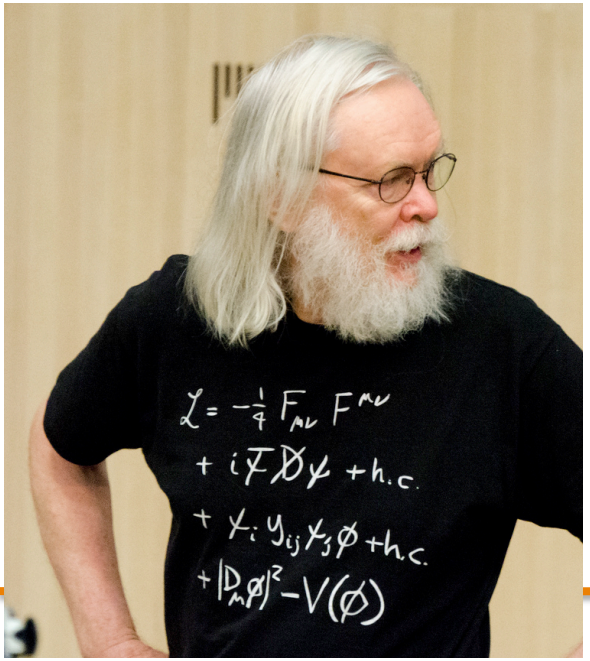
Particle physics (1)

- Goal: understand the content (particles) and the fundamental symmetries of the early universe.

- Very precise description achieved with a field theory based on special relativity and quantum mechanics.



" who ordered that?"
(by I. Rabi according to [Phys.Rept. 532 (2013) 27-64])

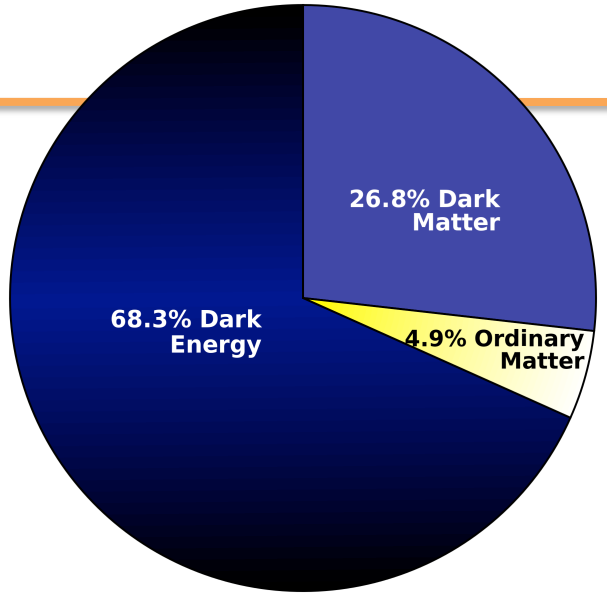
- Important concept: effective theory, valid in a given range (energy, distance, time).

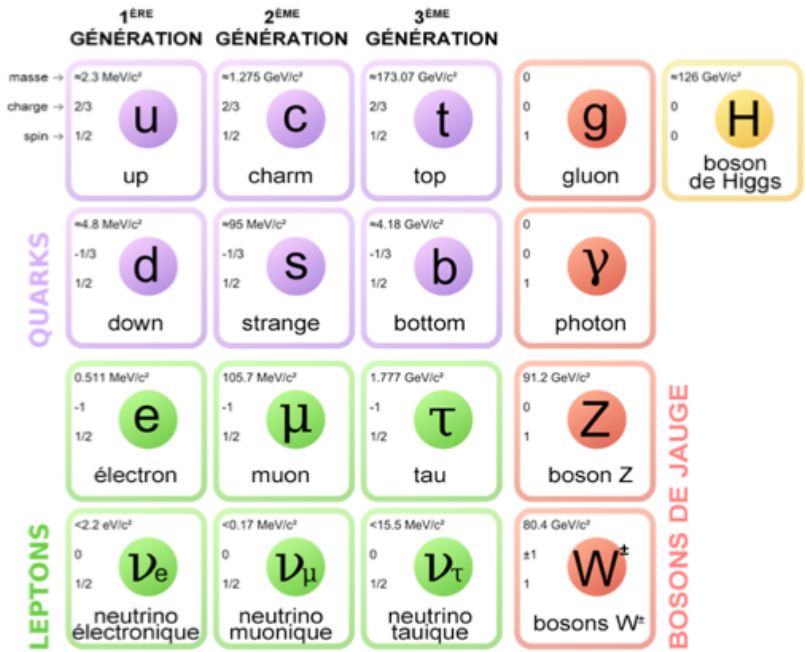
Particle physics (2)

- What theory describes nature at higher energies (younger universe)?

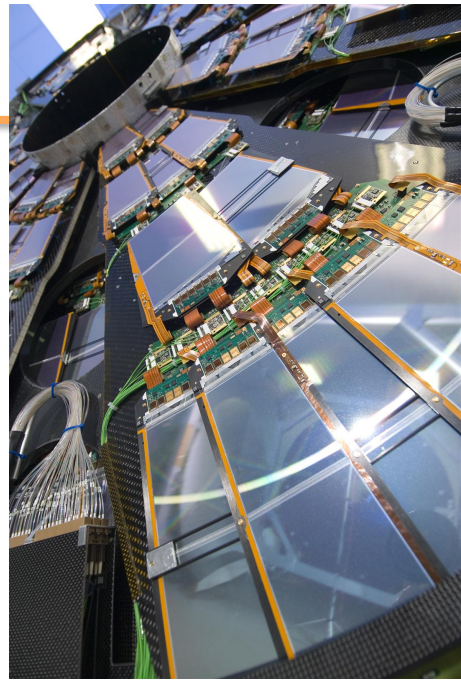
  Still many questions, e.g.:

  - Why did antimatter disappear?
  - Nature of Dark Energy?
  - Nature of Dark Matter?
  - Particles of matter: why 3 families?
  - How to include Gravitation in the theory?
  - …

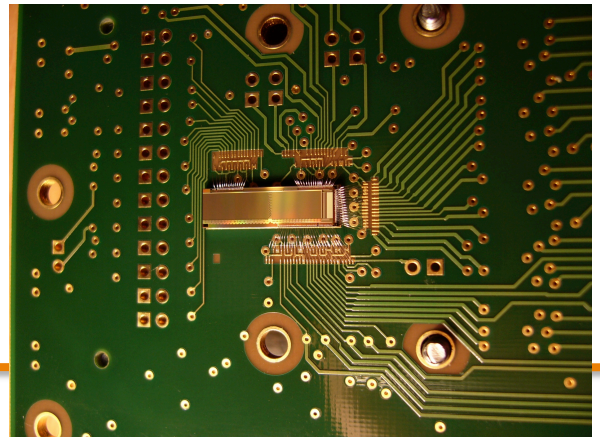




Particle physics (3)

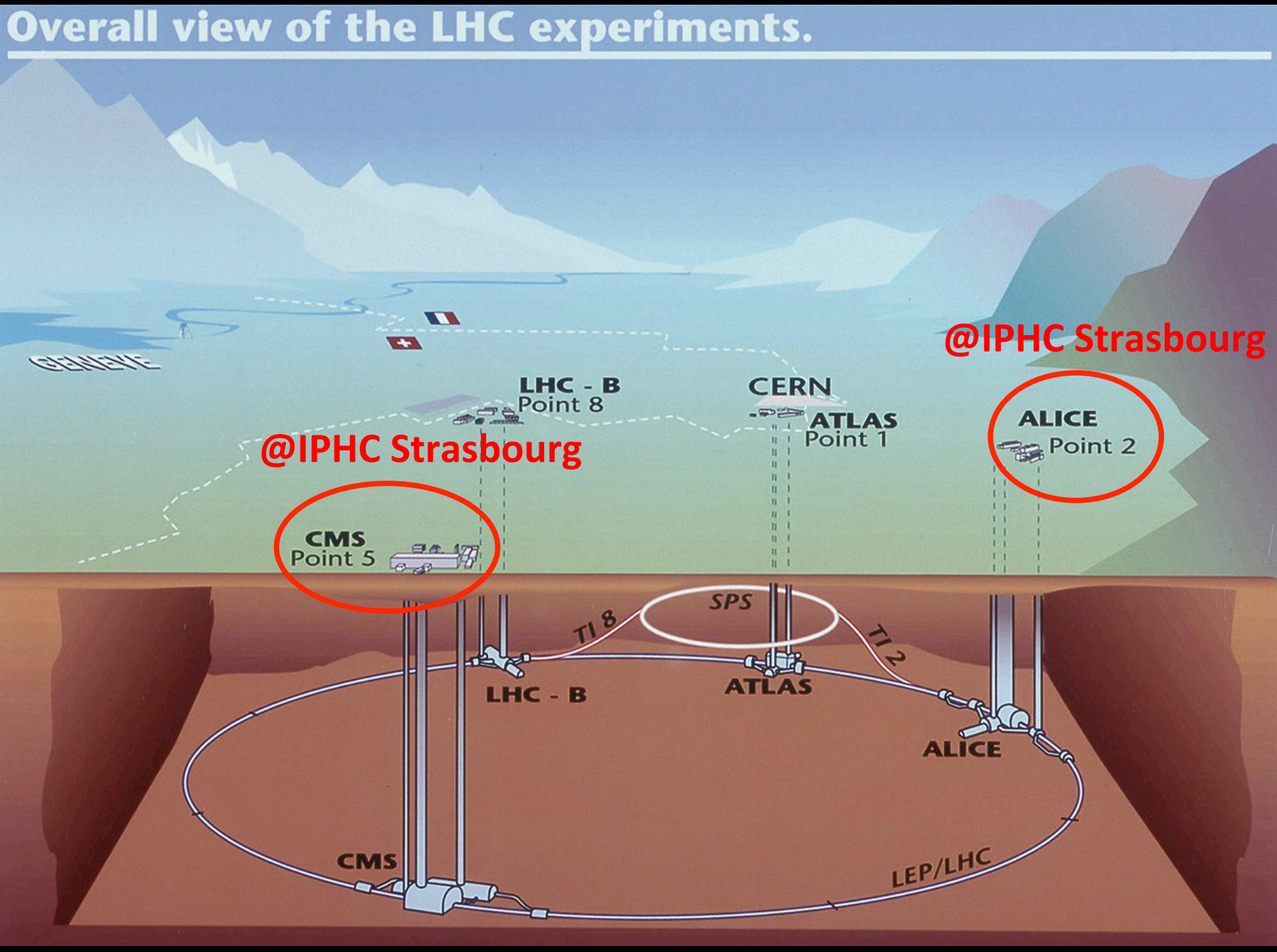


- Different approaches at IPHC to answer these questions:
  - Collisions at the energy frontier (LHC pp collisions at CERN): relativistic production of unknown particles.
  - Collisions at the intensity frontier (SuperKEKB e^+e^- collisions in Japan): sensitive to quantum manifestations of unknown particles.
  - Neutrino physics: very elusive particle, also used as a messenger of the universe.
  - Study of the Quark and Gluon Plasma with Heavy Ion collisions at LHC: new state of matter resulting from Quantum Chromodynamics (strong interaction).

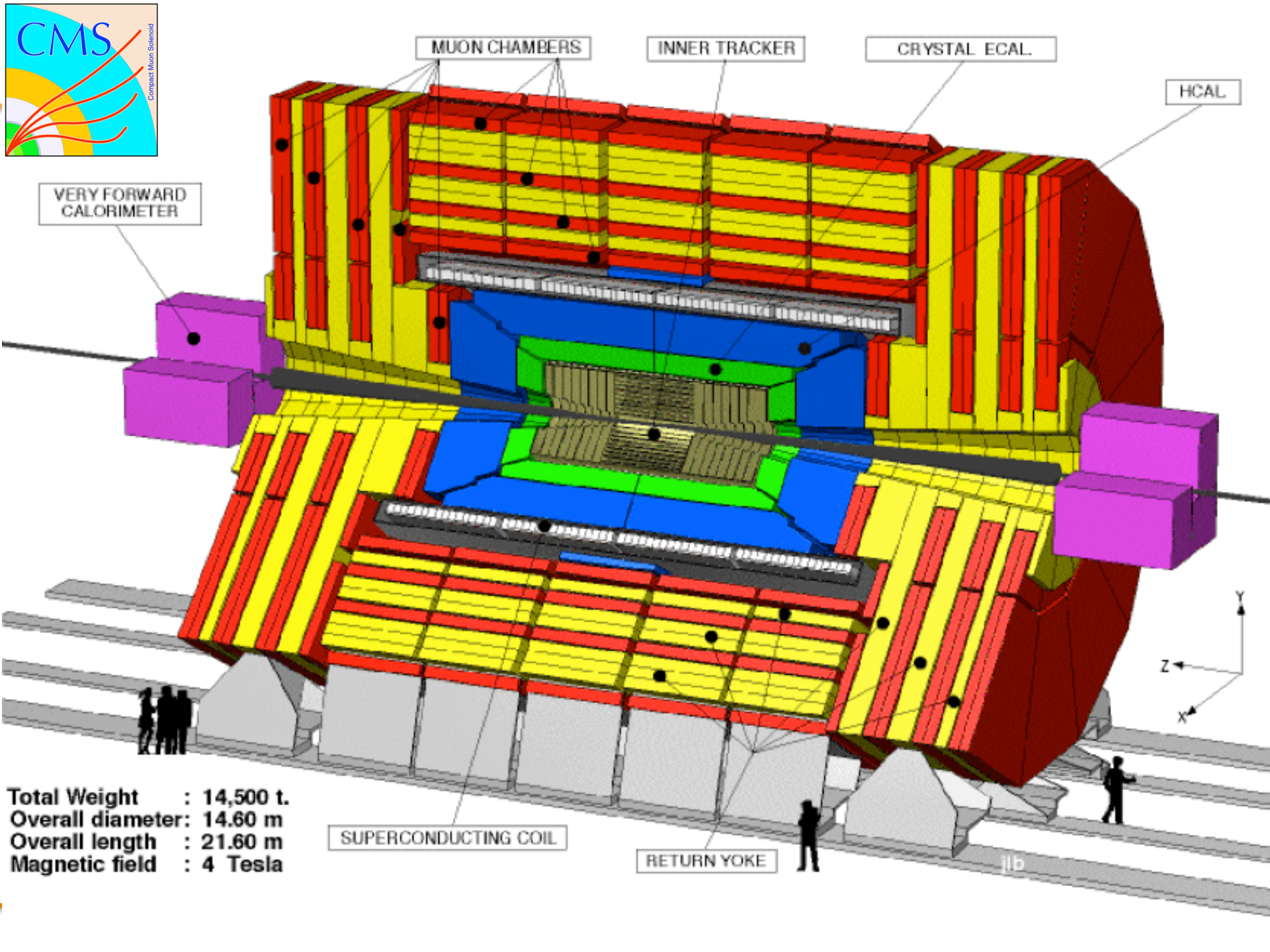


  - R&D of new instruments to improve sensitivity to very rare processes and spatial and time precision.

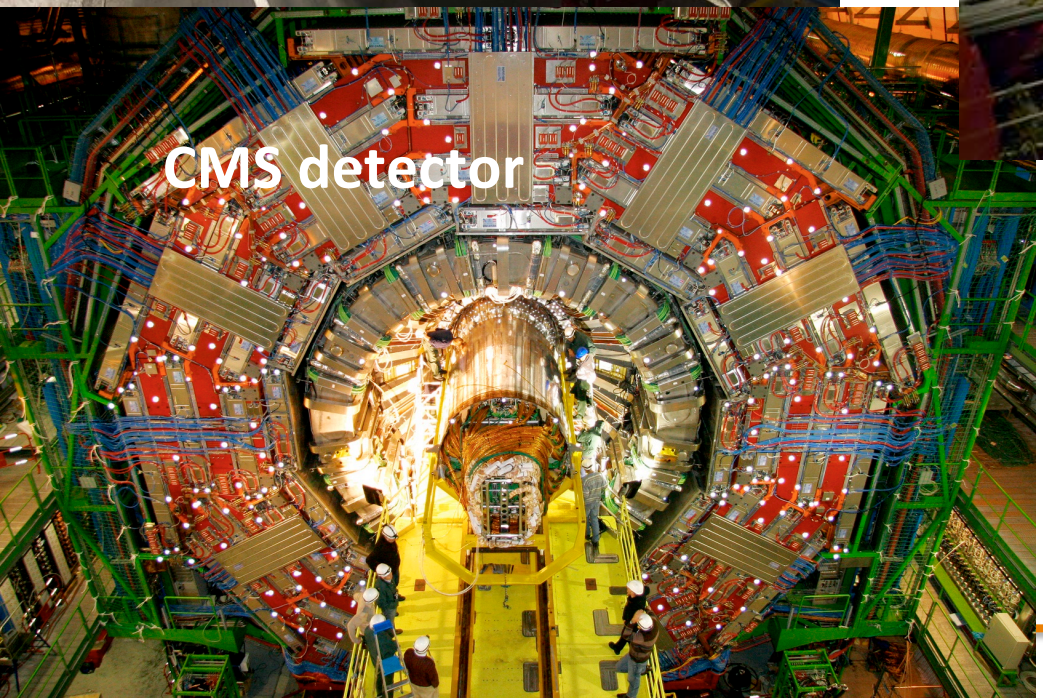
Overall view of the LHC experiments.

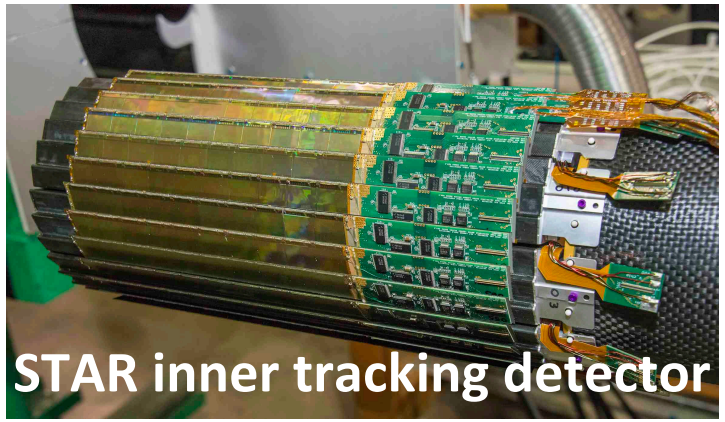



CERN
CMS
PA 5
PA 4
PA 6
PZ 3.3
LHC
Large Hadron Collider
PM 3.2
PM 7.6
ALICE
PA 2
ALICE
BA 3 - SPS3
BA 2 - SPS2
BA 4 - SPS4
SPS
BA 1 - SPS1
BA 5 - SPS5
ATLAS
LHC 1.8
LHC 1
PA 8

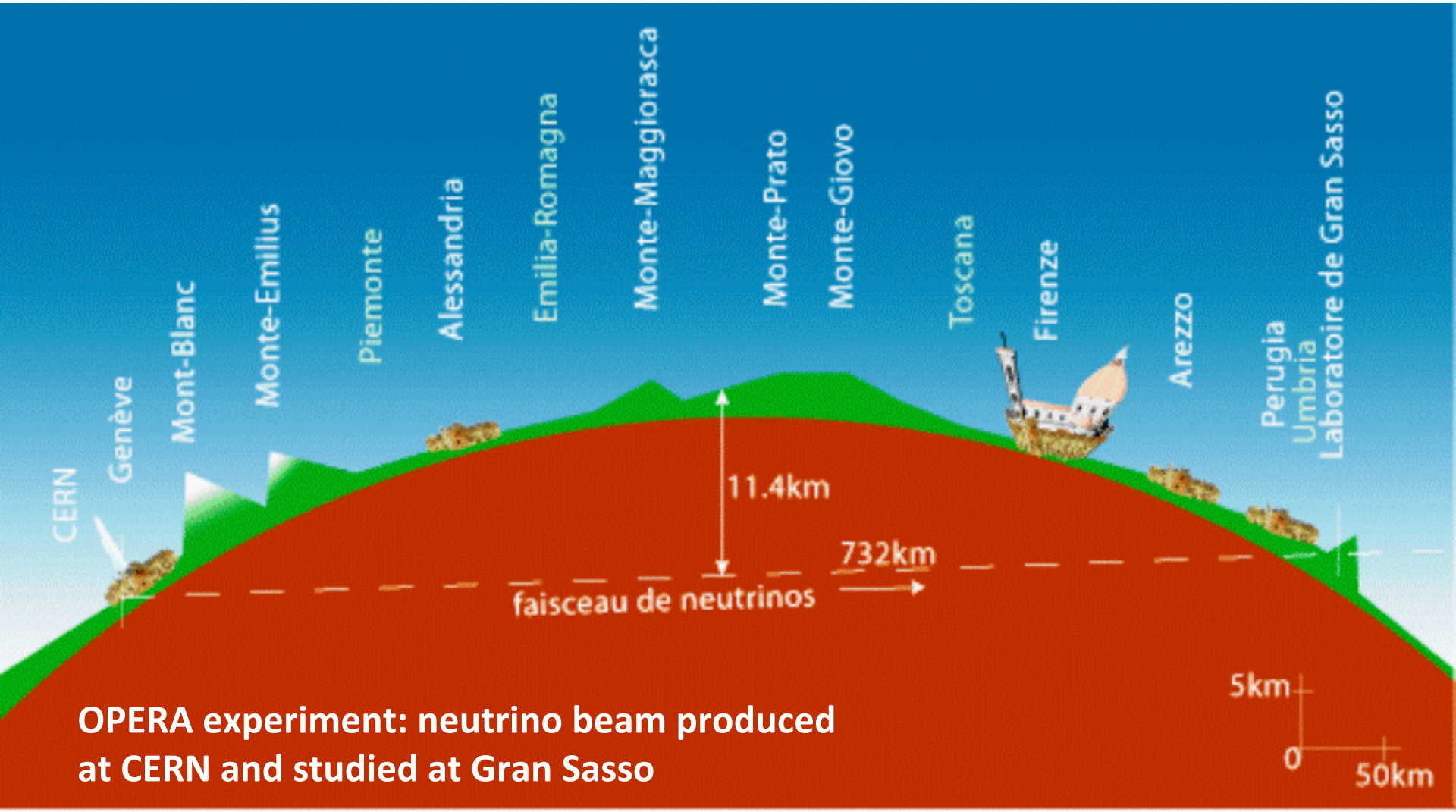

CMS
Compact Muon Solenoid
MUON CHAMBERS
INNER TRACKER
CRYSTAL ECAL
HCAL
VERY FORWARD CALORIMETER
Y
Z
X
Total Weight : 14,500 t.
Overall diameter: 14.60 m
Overall length : 21.60 m
Magnetic field : 4 Tesla
SUPERCONDUCTING COIL
RETURN YOKE
jlb

Collider physics





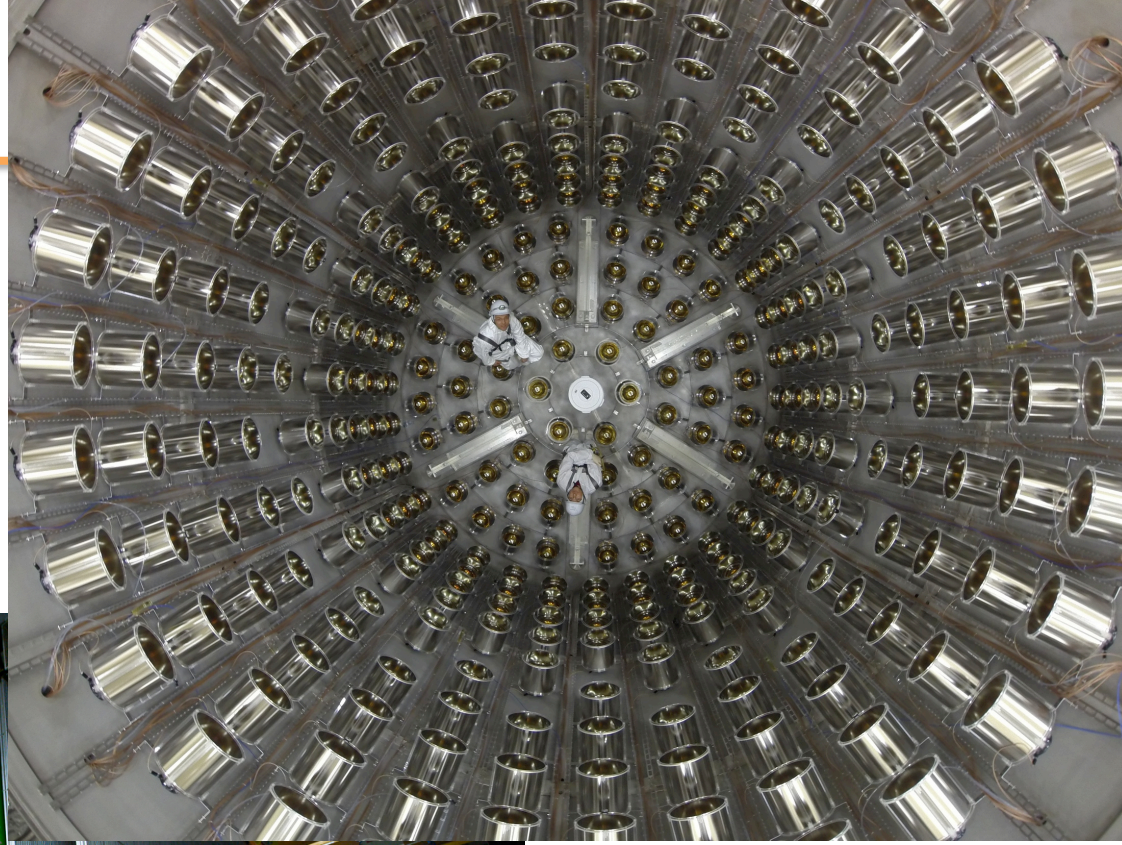
Neutrino physics



OPERA experiment: neutrino beam produced at CERN and studied at Gran Sasso

Neutrino physics

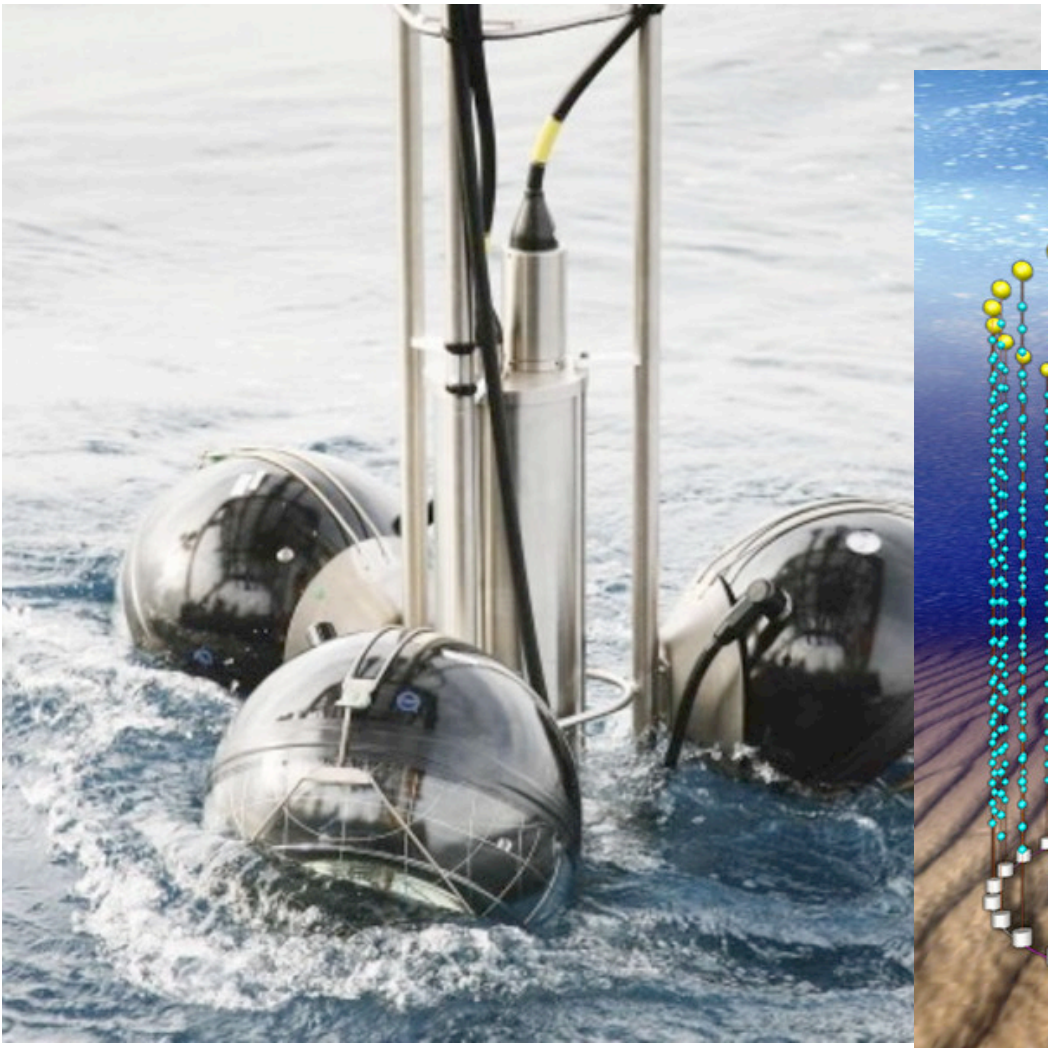
Double-Chooz detector of neutrinos produced by the Chooz nuclear plant. ➔

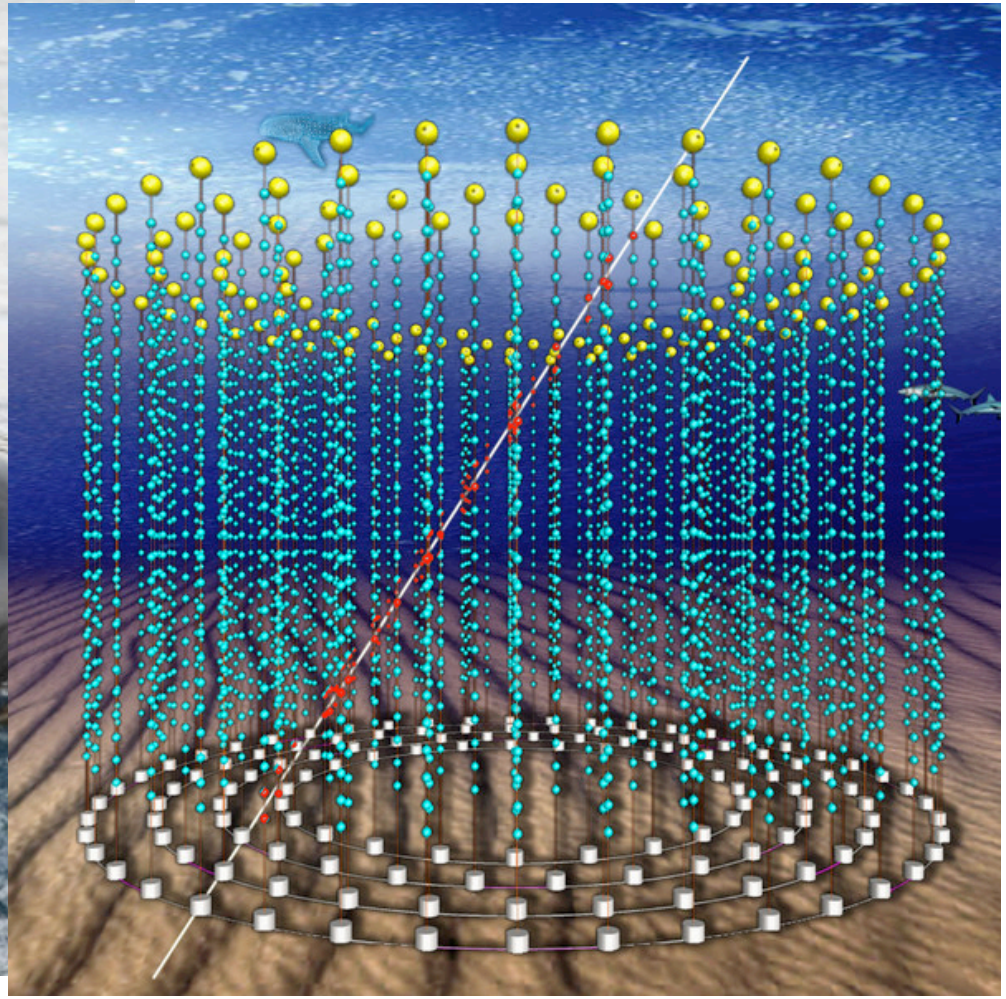


➔ OPERA detector of neutrinos produced at CERN, after a 723 km travel in earth.

Neutrino physics

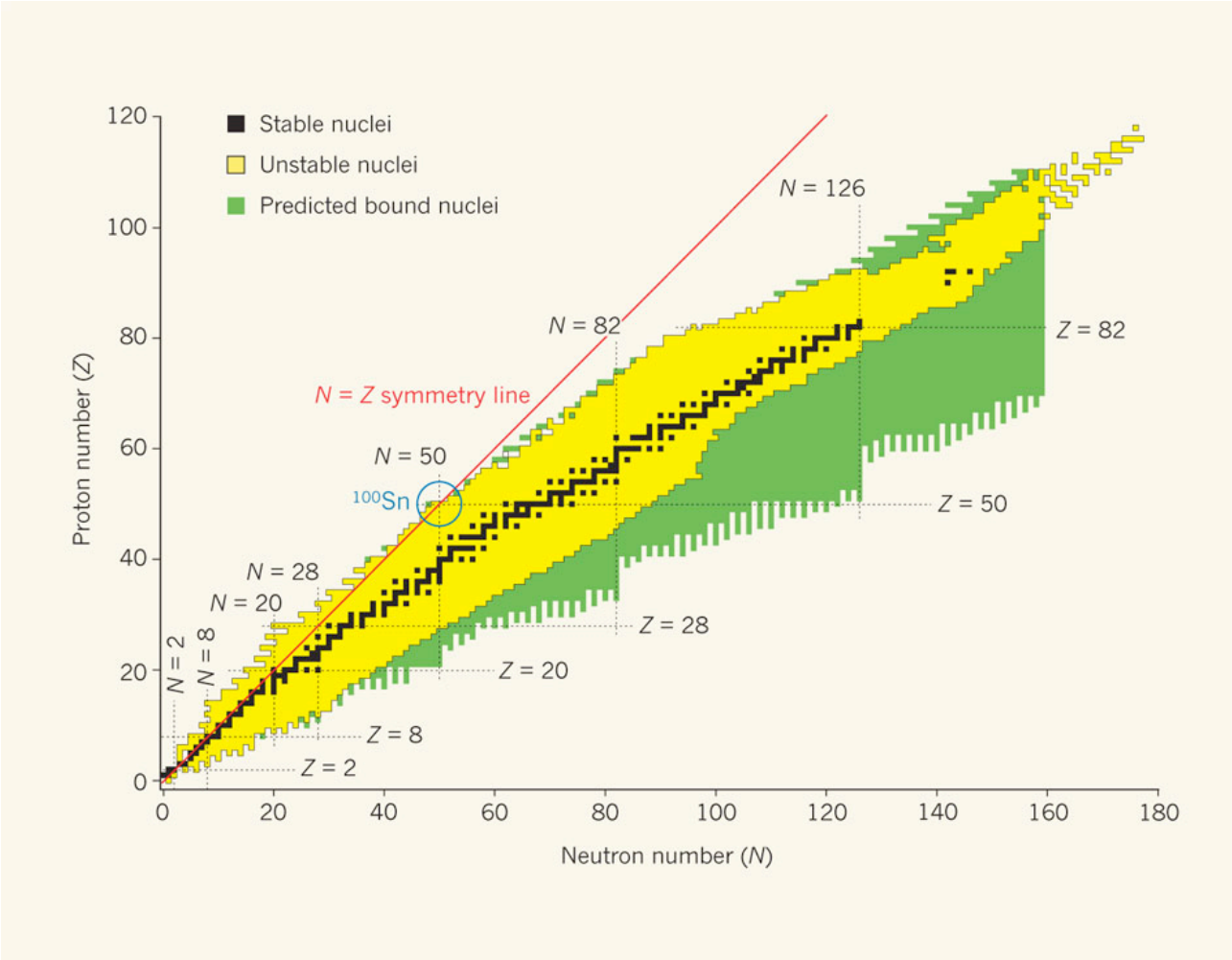
ANTARES and KM3NeT submarine telescopes to detect atmospheric neutrinos.





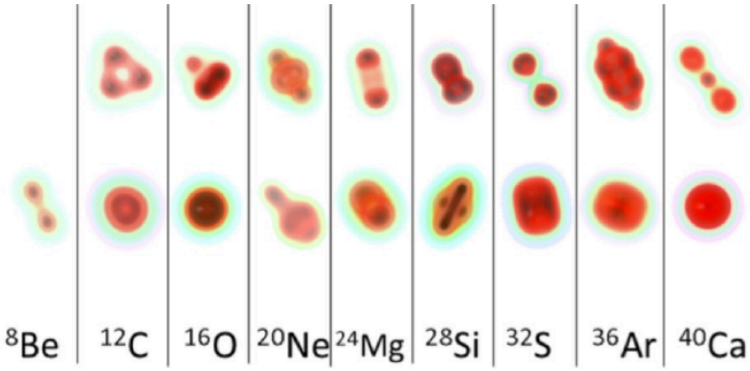
Nuclear physics (1)

- Goal: why are nuclei stable? How were they created?

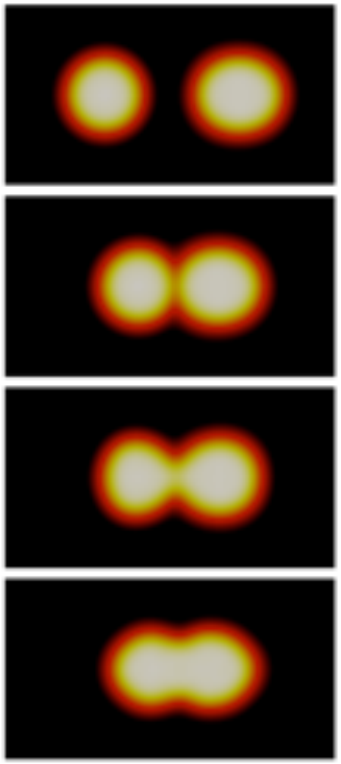


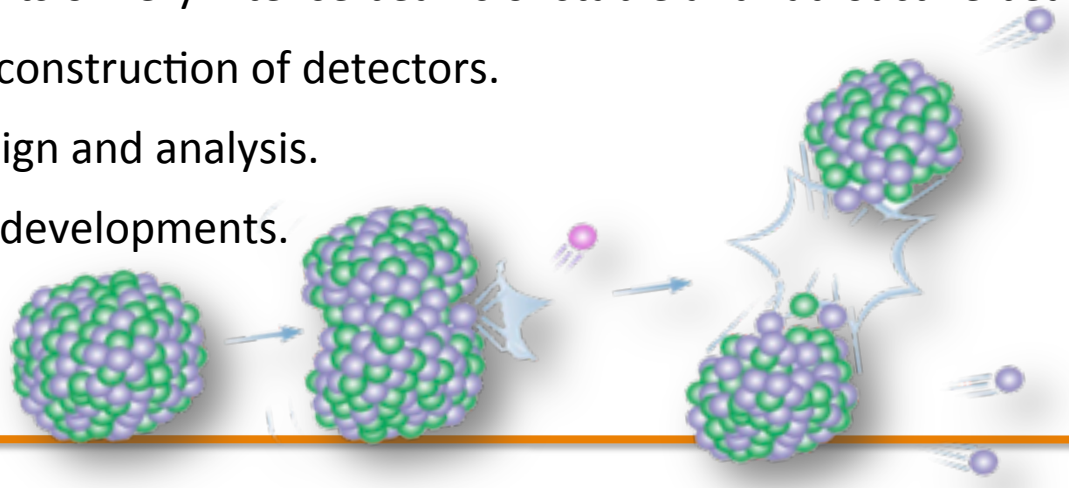
Nuclear physics (2)

- Main questions:
  - Limits of stability as a function of the nucleus shape, its mass (study of superheavy elements), the asymmetry between numbers of neutrons vs. protons.
  - How are the light nuclei produced in the early universe?
  - How are the heavy nuclei produced in stars?



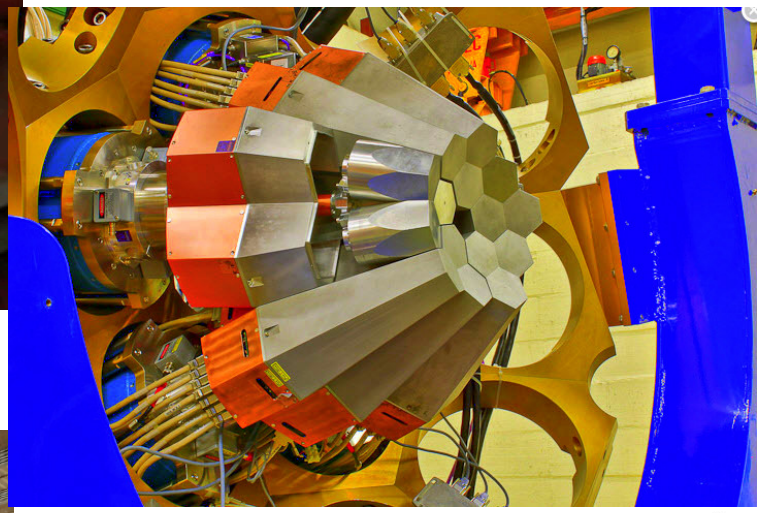
- Research activities:
  - Developments of very intense beams of stable and radioactive beams.
  - Design and construction of detectors.
  - Data campaign and analysis.
  - Theoretical developments.



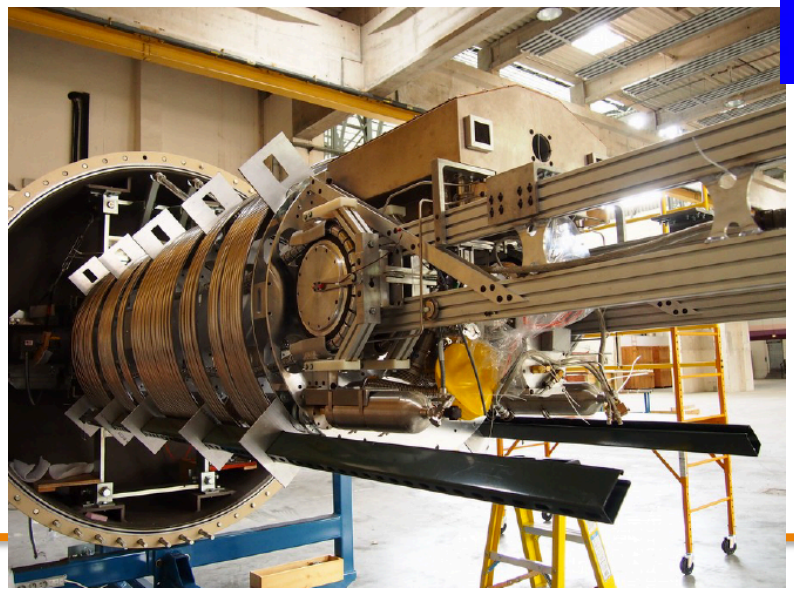


Nuclear physics (3)

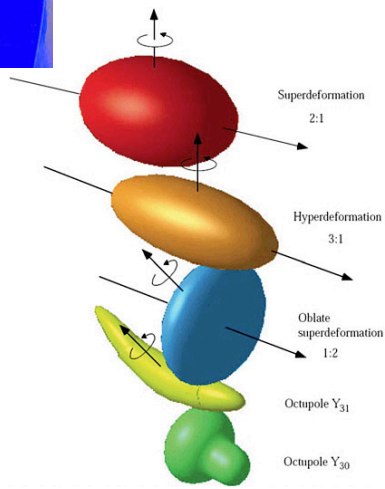
← Development of new intense beams of ^{50}Ti to produce superheavy nuclei.



↑ AGATA 4π gamma-ray spectrometer.

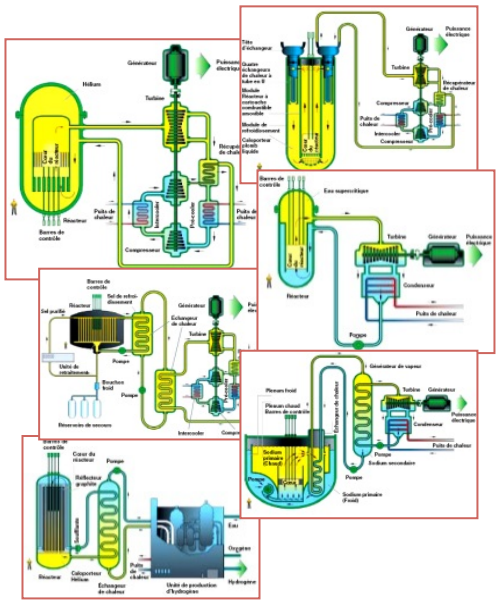


← Andromède accelerator (Orsay).

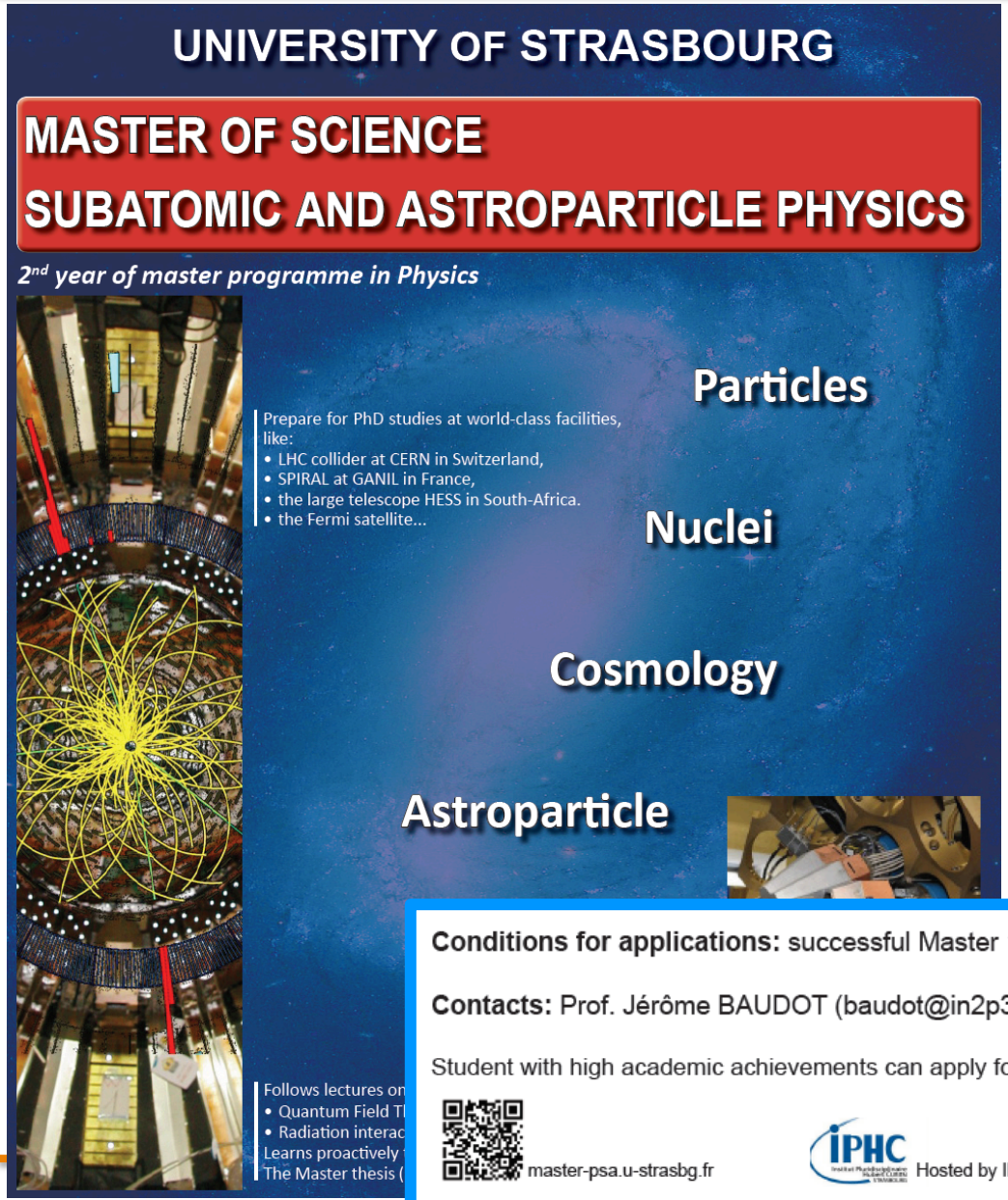


Applications to Energy, Environment and Health

- Use of fundamental knowledge in subatomic physics and radiochemistry to answer societal issues:
  - Nuclear energy: nuclear data needed to simulate and design the next generation of nuclear reactors.
  - Dosimetry and metrology of ionising radiations: radioactive pollution, radiation worker safety, ionised food, dose monitoring during hadrontherapy.
  - Radiochemistry: ground pollution, chemical modification and impact of ionising radiation on organic matter.



The Master of Subatomic and Astroparticle Physics in Strasbourg



- Hosting laboratory: IPHC / DRS.
- Content:
  - Common and chosen lectures,
  - Project in Physics: 1 month,
  - Research internship: 4 months,
  - Both theoretical and experimental points of view.
- After the Master:
  - PhD thesis (possible grants).
  - Industry: nuclear power, Big Data, nuclear metrology, simulation, …

Conditions for applications: successful Master 1 in physics or equivalent.

Contacts: Prof. Jérôme BAUDOT (baudot@in2p3.fr)

Student with high academic achievements can apply for a grant of excellence.

Faculty of physics & engineering
3 rue de l'Université
67000 Strasbourg
France

P&I Physique et Ingénierie — UNIVERSITÉ DE STRASBOURG

Thank you for your attention