Elementary Particles

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1 Overview

- From atoms to elementary particles
- An interlude on light
- "Oscillation" between particle species
- A few large experiments - LHC, SuperK, SNO, IceCube
- Dreams of an elegant description - unification, superstring theory ...

2 When are particles "elementary"?

The progression – atoms in theory and atoms in pracitce

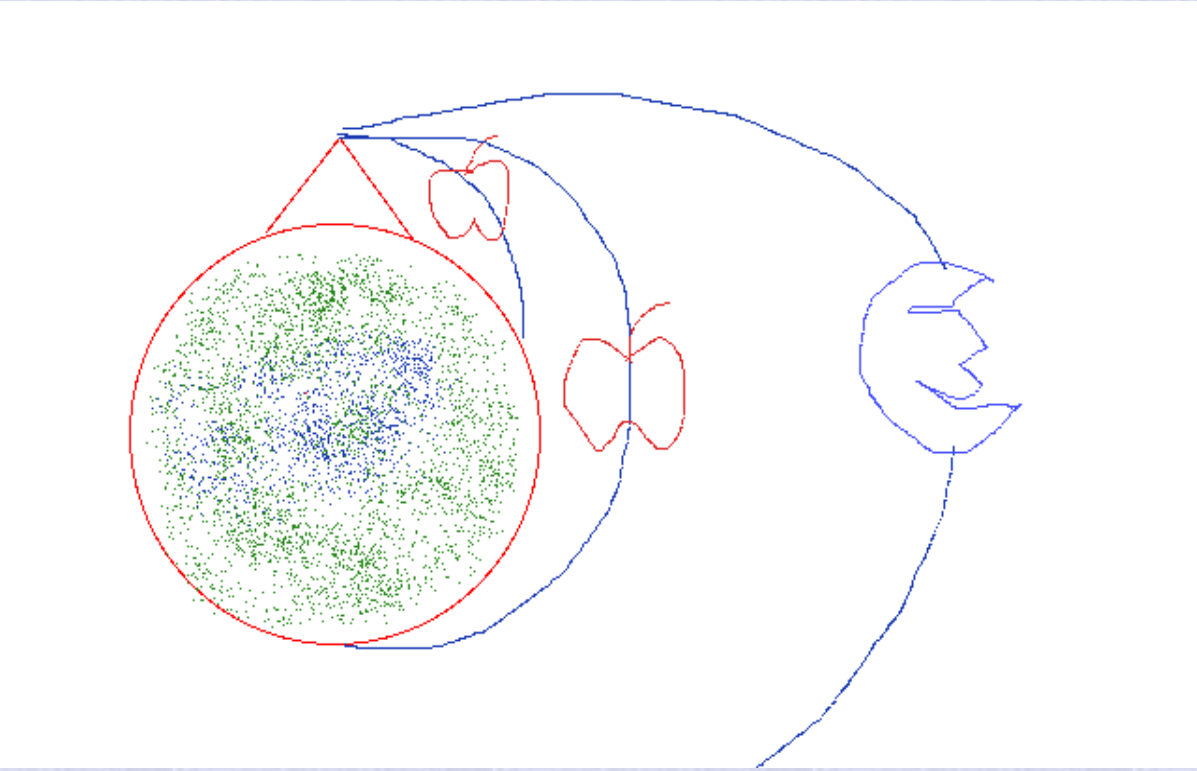
- Philosophy : Democritus "atom"; Kanada "kana"
- Evidence based science : Atoms and molecules Dalton, Avogadro, Canizzaro, Boltzmann 1810's ... to 1890's
- Becquerel discovers radioactivity 1890's
- Electron –> Thompson, MIllikan ... 1890's ; 1910's
- Rutherford shoots through the atom 1908
- Positron is discovered in cosmic rays 1931
- Chandwick establises the neutron 1932

3 The leading light was light

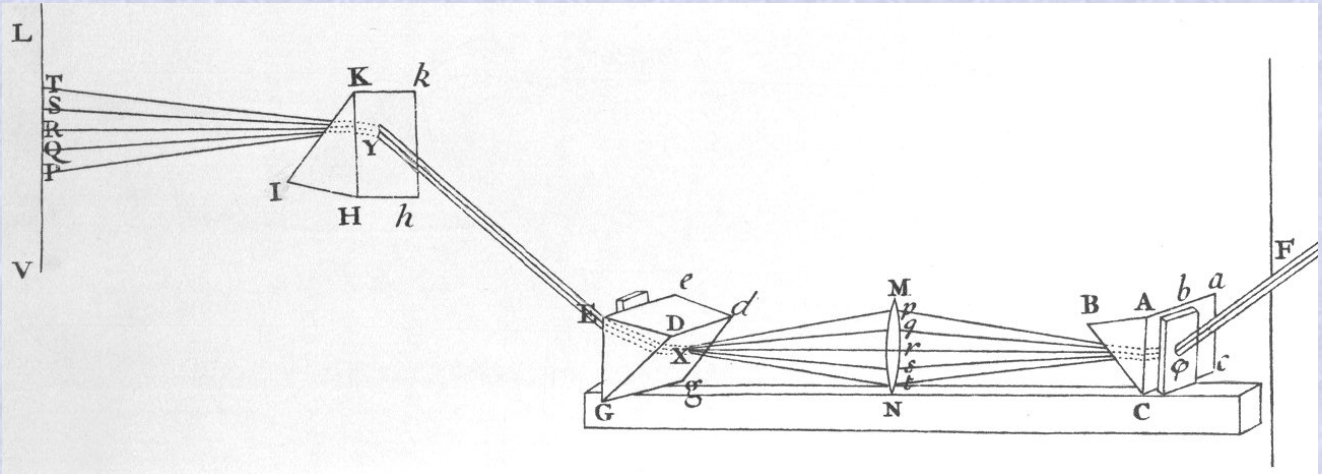
3.1 Newton creates Dynamics

The Laws of motion; the concepts of force and work

and Theory of Universal Gravitation as a force of nature



3.2 Optics from Newton to Maxwell

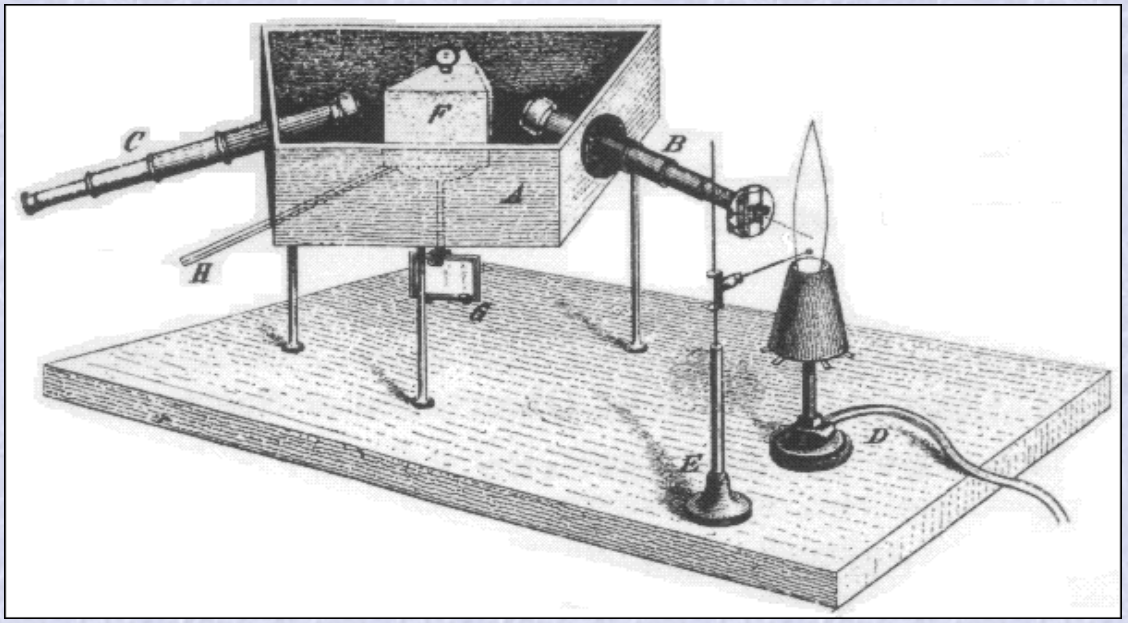


- Newton, Huygens, Young, ... theories of light
- Faraday, Ampère, Biot-Savart ... Electricity - magnetism relationship
- Maxwell –> Mathematical theory of "Electromagnetism"

Light as electromagnetic waves

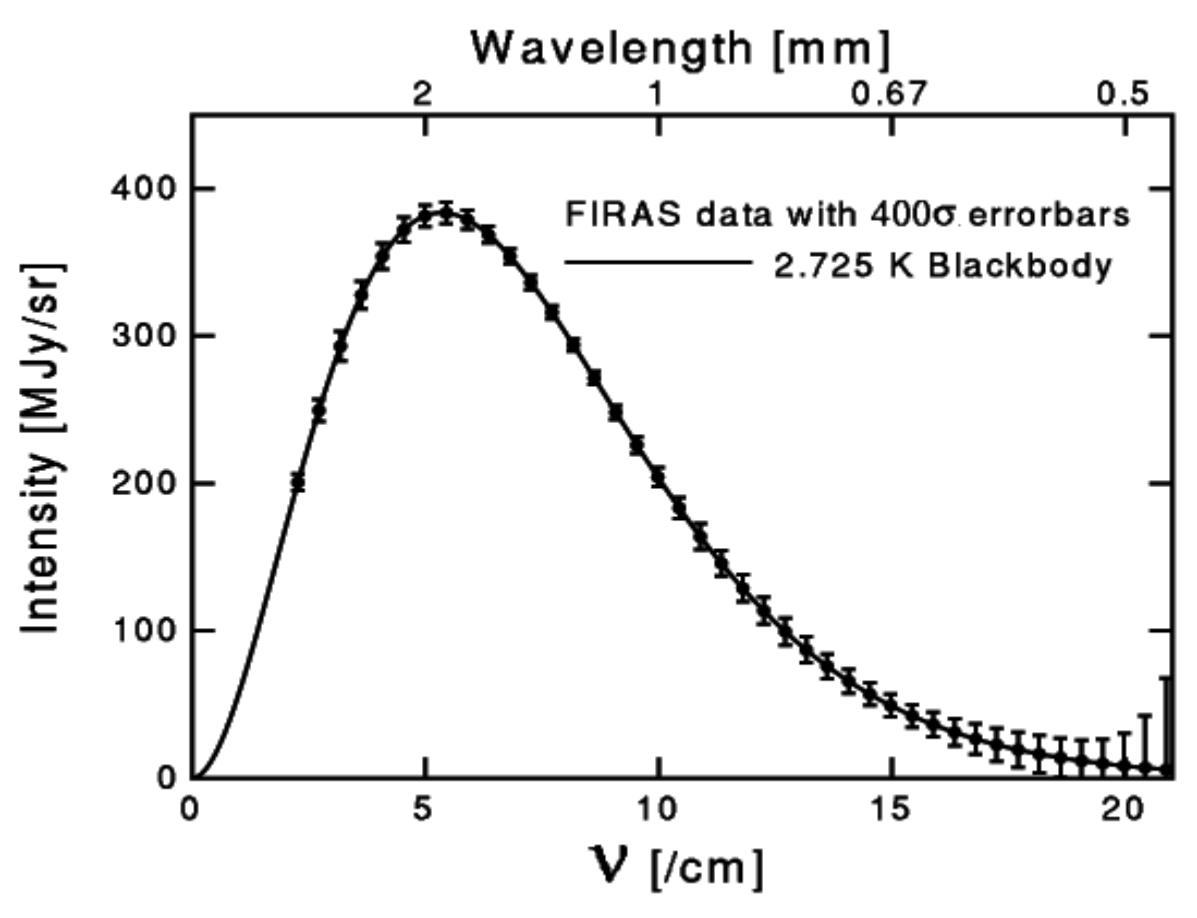
3.3 Light unites heaven and earth

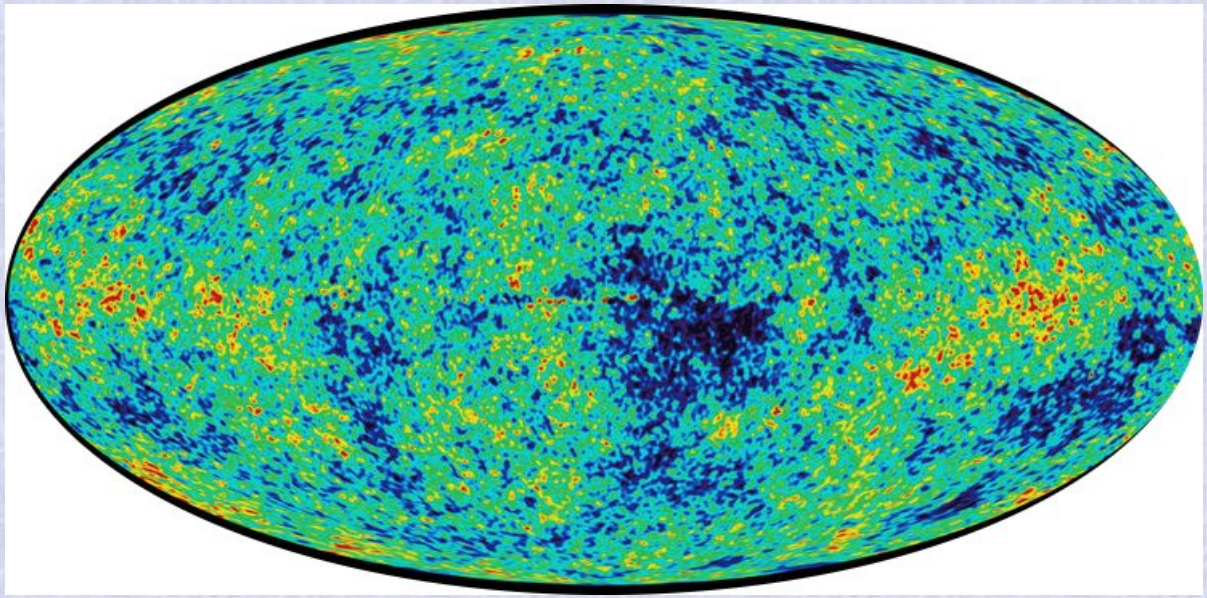
Kirchhoff and Bunsen (1860's)



- Heat metals to 1200 °C; find the laws for emission and absorption spectra; relate them to absorption lines in the Sun.
- Margaret and William Huggins obtain similar spectral lines in nebulas and stars!!

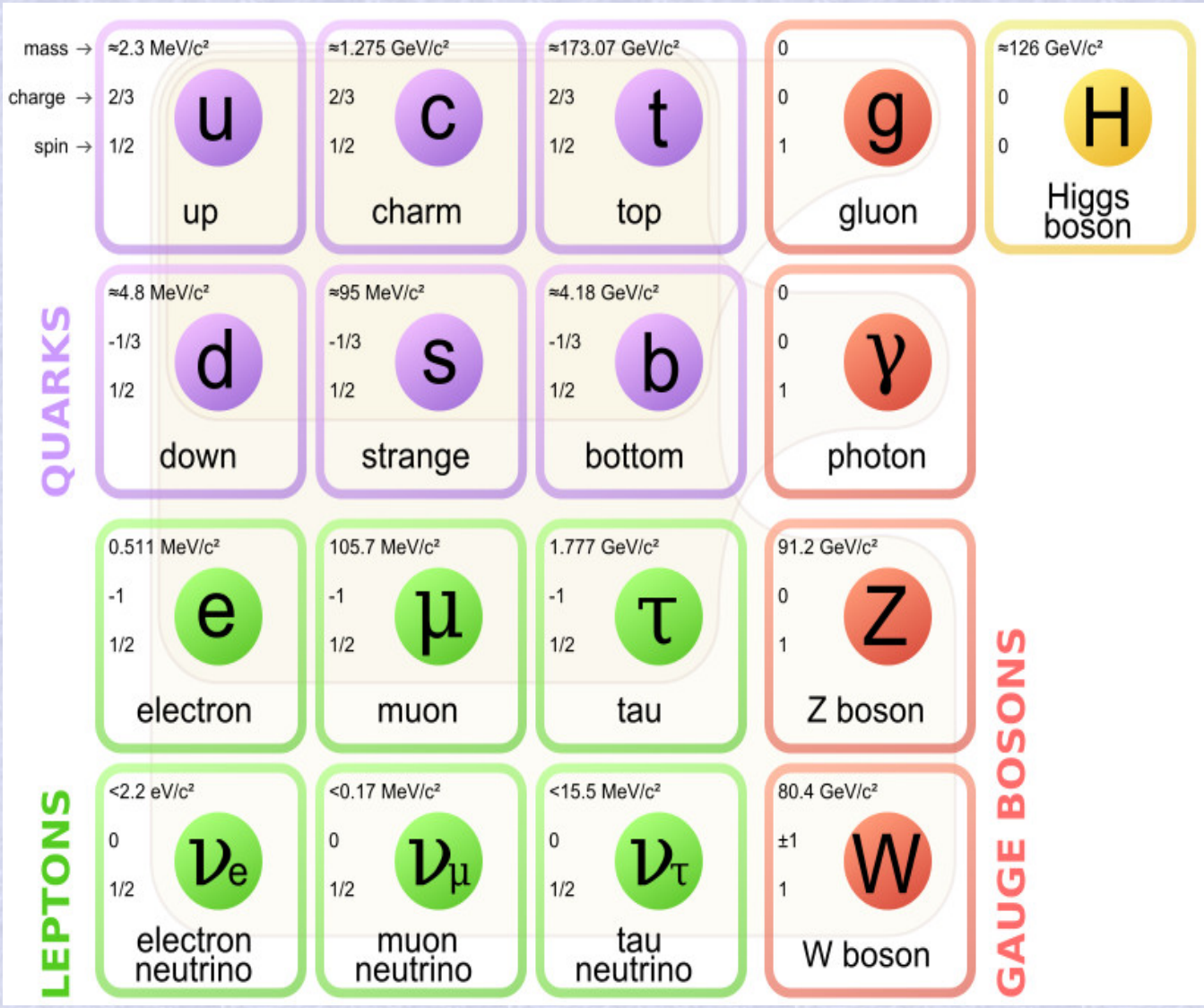
3.4 Cosmic Microwave background (Nobel 2006)





- The Universe as a whole a single glowing ball 13 billion years ago!!
- Its light today is "red shifted" into microwaves and is found to have almost exactly the same temperature 2.73 K in every direction in the sky.

4 Particle "species"



4.1 What defines the species?

- Mass zero or non-zero
- Intrinsic spin integer or half integer in $\hbar$ units
  - Integer spin-1 Bosons are force carriers
  - Graviton is integer spin-2 boson (not in the table)
  - Half integer spin-1/2 fermions are "matter"
  - Higgs boson, the only particle with spin zero … assists the spin 1 force carriers
- Gauge charges
  i. Strong force charge "color"
  ii. Weak force charge "Weak isospin"

iii. Electromagnetic charge

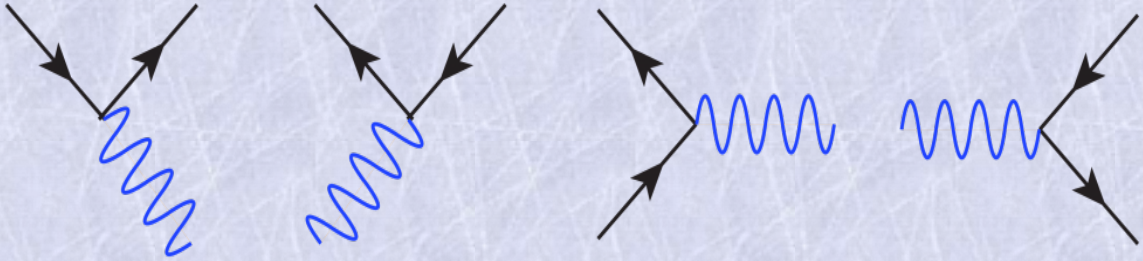
- Global "charge" (i) Baryon (ii) Lepton

  i. Flavour of B or L : All charges identical, only mass values differ. 3 families for baryons, 3 families for leptons, each family in both cases has 2 members, totally 6 generations

Declaration : Typeset using TEXMACS ...

5 Doodling the diagrams – Feynman

Building blocks – "basic vertices"



These are not physical processes.

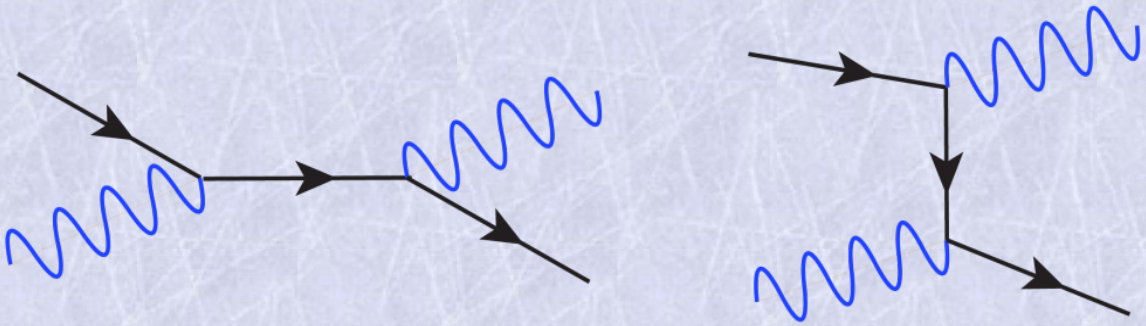
Note that energy momentum are not conserved in such pictures .

These are simple methods for putting together the calculation.

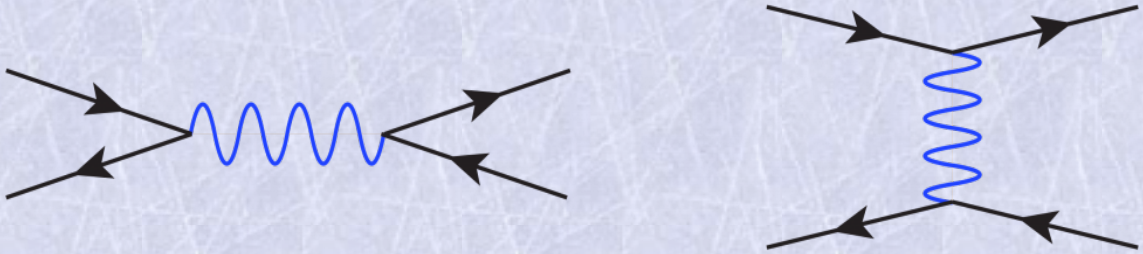
A mathematical expression attaches to each line and vertex.

The "particles" flowing in such diagrams are called "virtual particles".

Electron - photon scatterning (Compton scattering)



Electron - positron (Bhabha scattering)



5.1 Electroweak Theory Nobel (1979)

Sheldon Glashow, Abdus Salam and Steven Weinberg

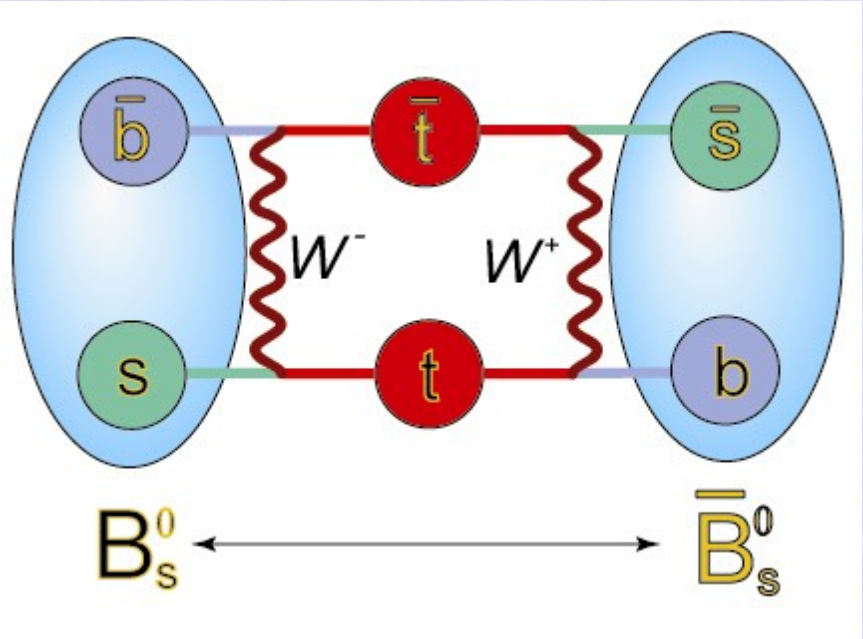
5.2 Strong Force Nobel (2004)

David Politzer, David Gross, and Frank Wilczek

6 An identity crisis?

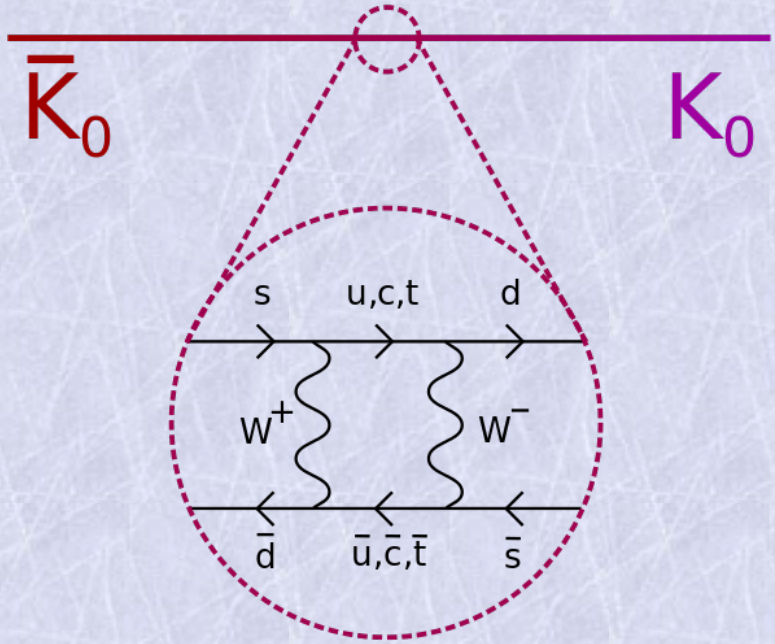
"To be or not to be, that is the question ..."
- Shakepeare's Hamlet

To B or B-bar is a routine occurrence for B mesons :-)



But much before B mesons were …

the K mesons and their anti-particles $\bar{K}$ (K-bar) mesons $d\bar{s}$ and $\bar{d}s$.

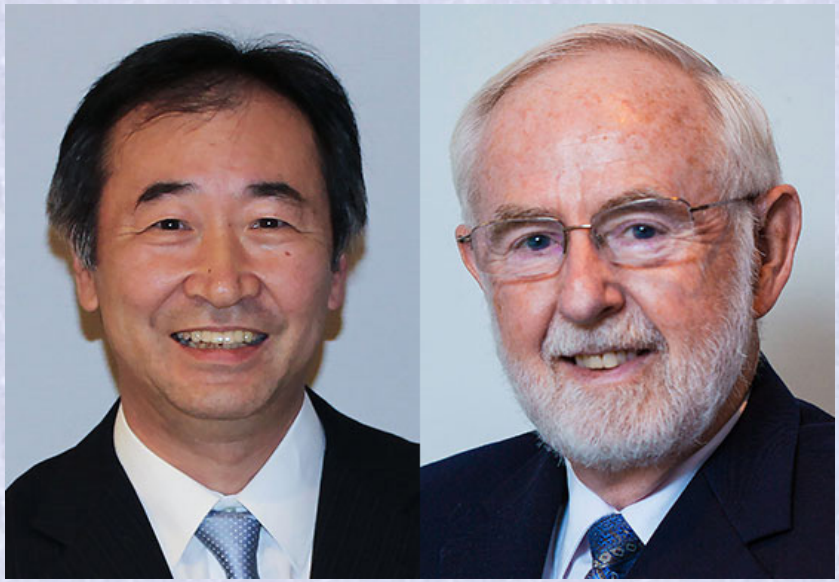


and the same is true of neutrinos …

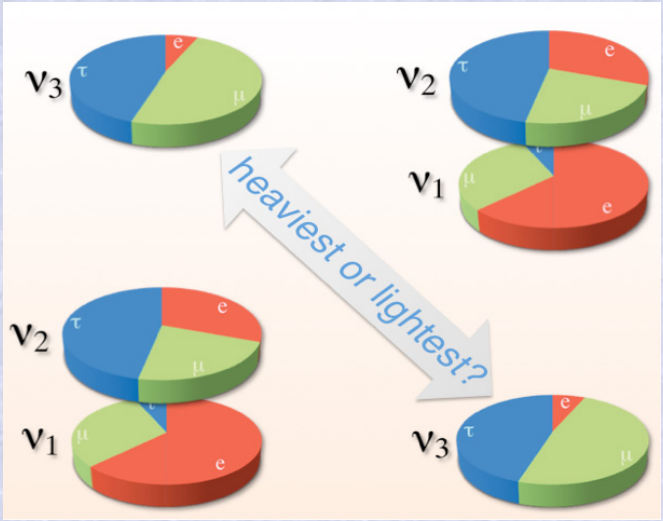
6.1 Neutrino Oscillation Nobel (2015)

K. Kajita of super-Kamokande Laboratory Japan

and John McDonald of SNO Lab Canada



6.1.1 Will the right Ms. Neutrino come forward?



Free flying avatar – mass or inertia identity ν_1, ν_2 and ν_3

vs.

Weak ineraction avatar – ν_e, ν_μ, and ν_τ.

(Note Greek symbol ν="nu" is used here for neutrino)

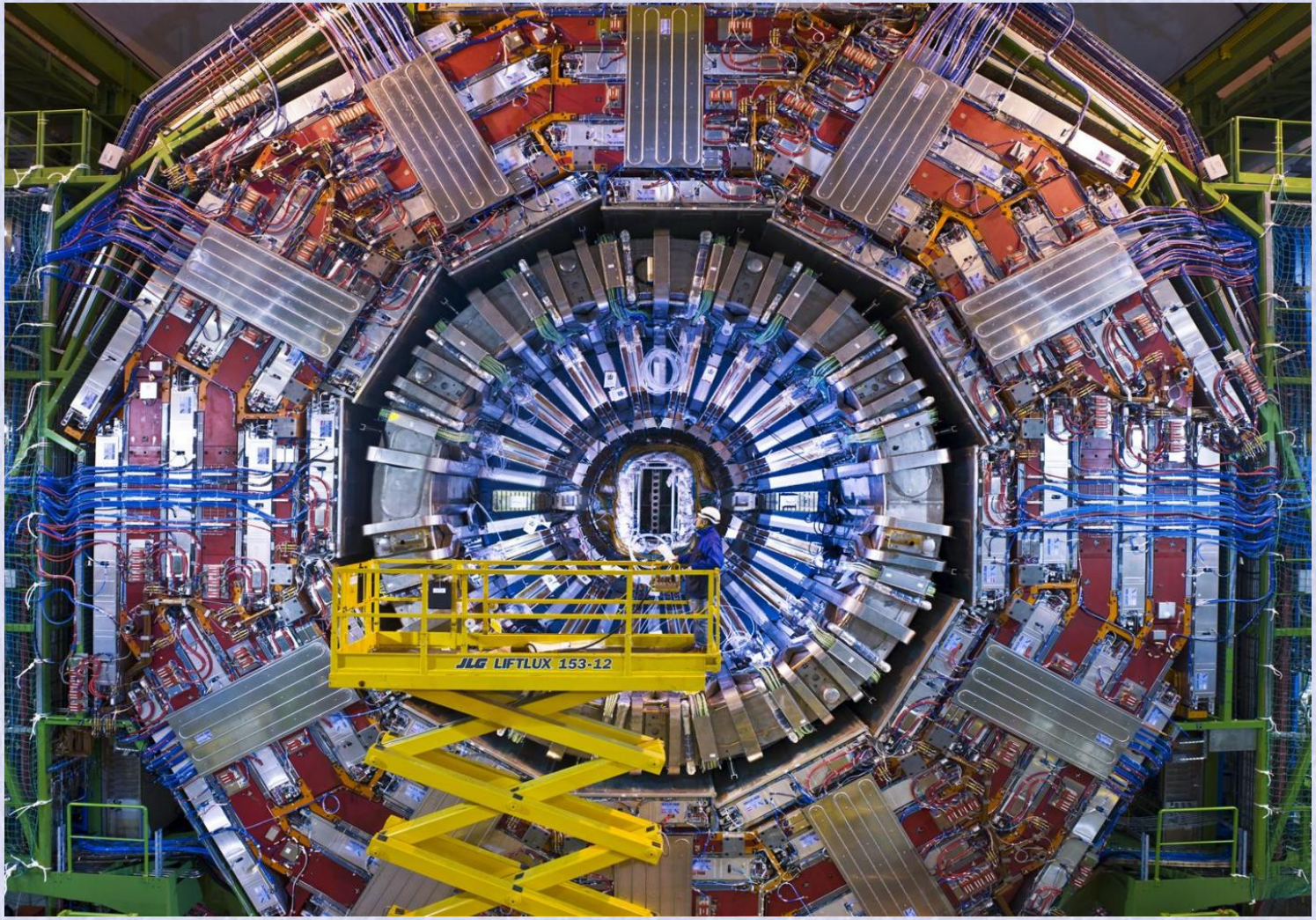
6.2 What is at stake?

- Why are there 3 families of matter particles?
- why are there exactly 3 in Leptonic and in Baryonic sector?
- Why does Weak force not respect what strong force defines?
- Why does Weak force not respect what inertia defines?
    - ... or vice versa, both above points.
- Finally, what is the origin of mass of each species?

7 Some important experiments

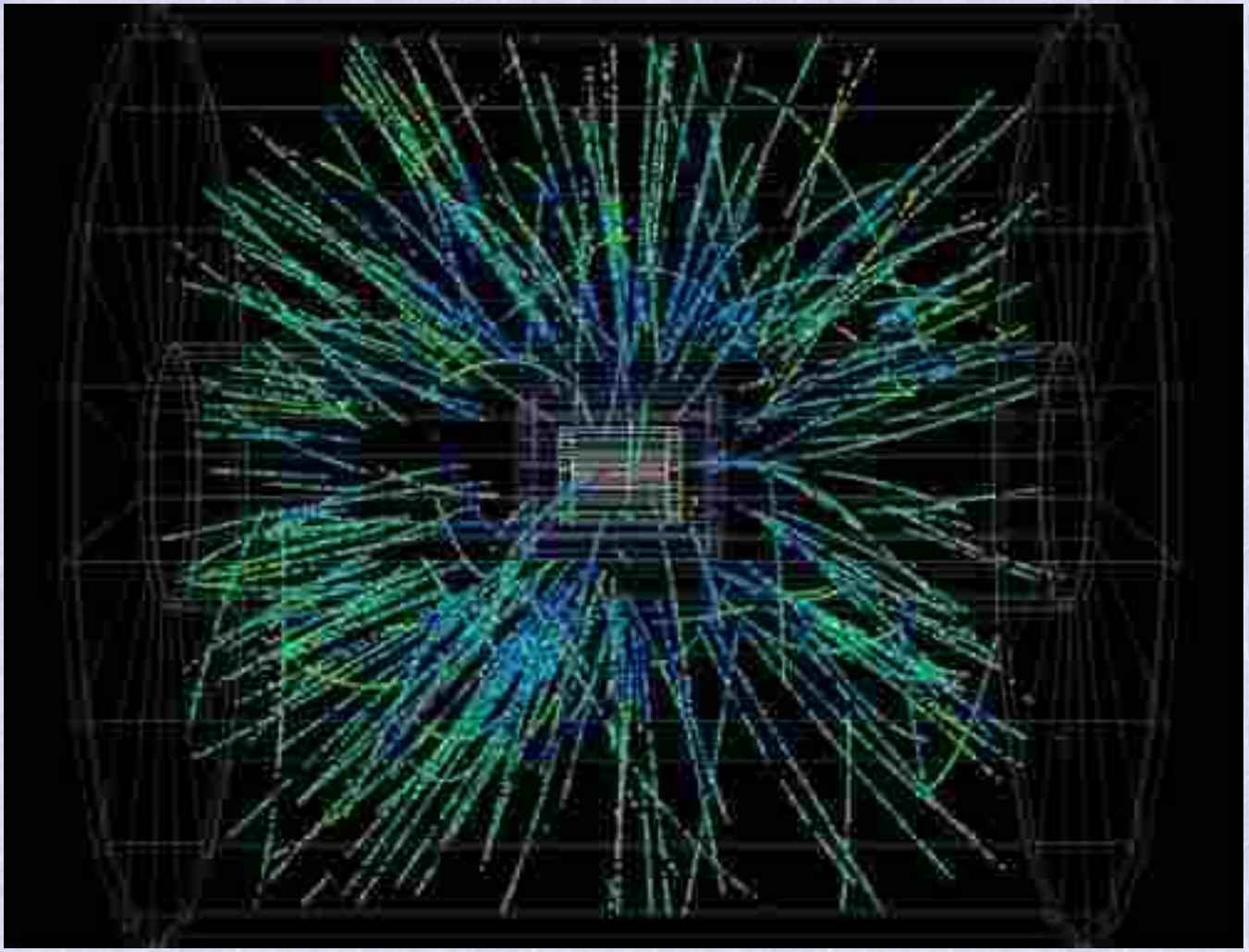
7.1 The Large Hadronic Collider (LHC)

Compact Muon Solenoid detector with India's participation



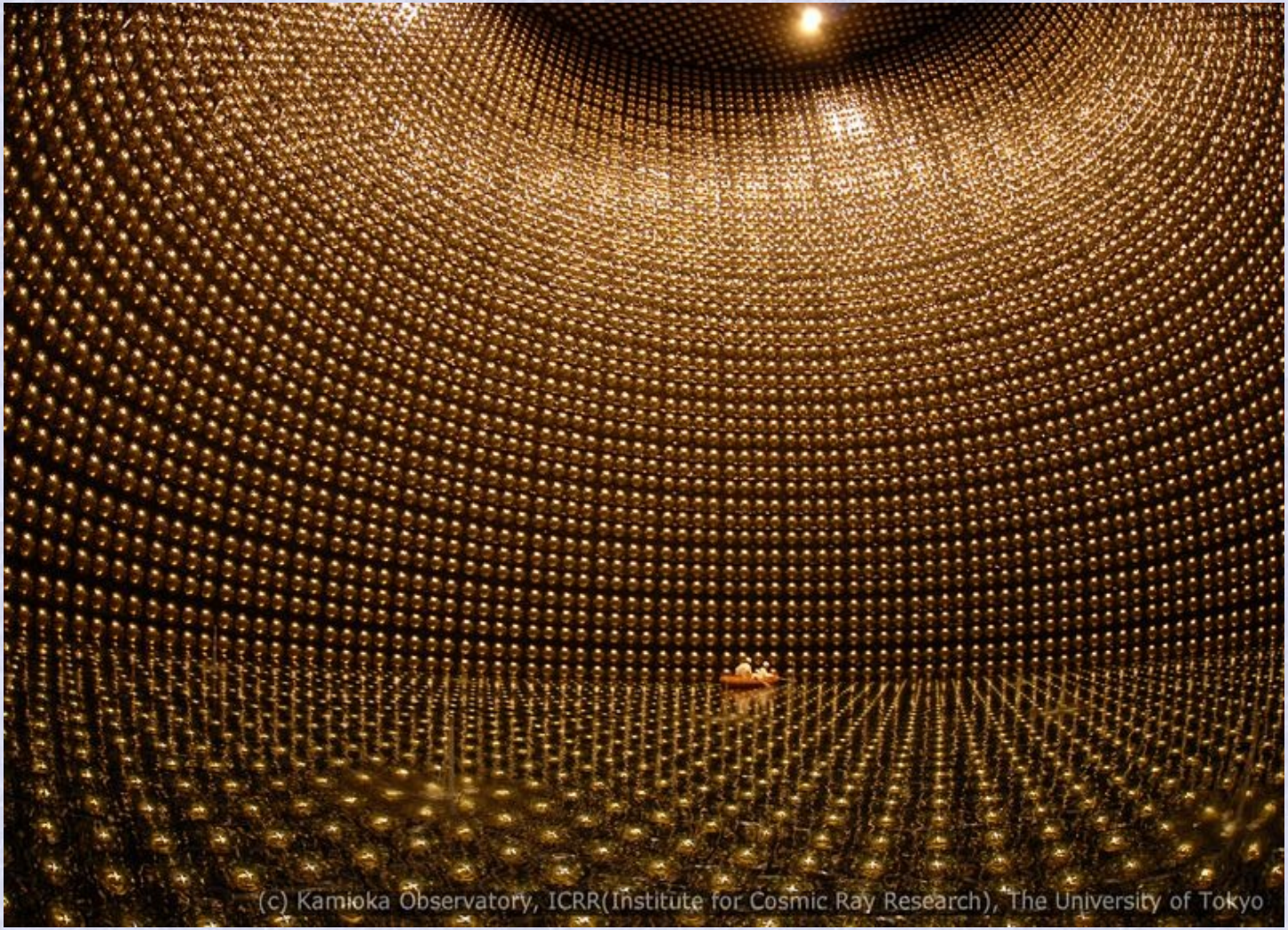
Note the man in blue

A typical event

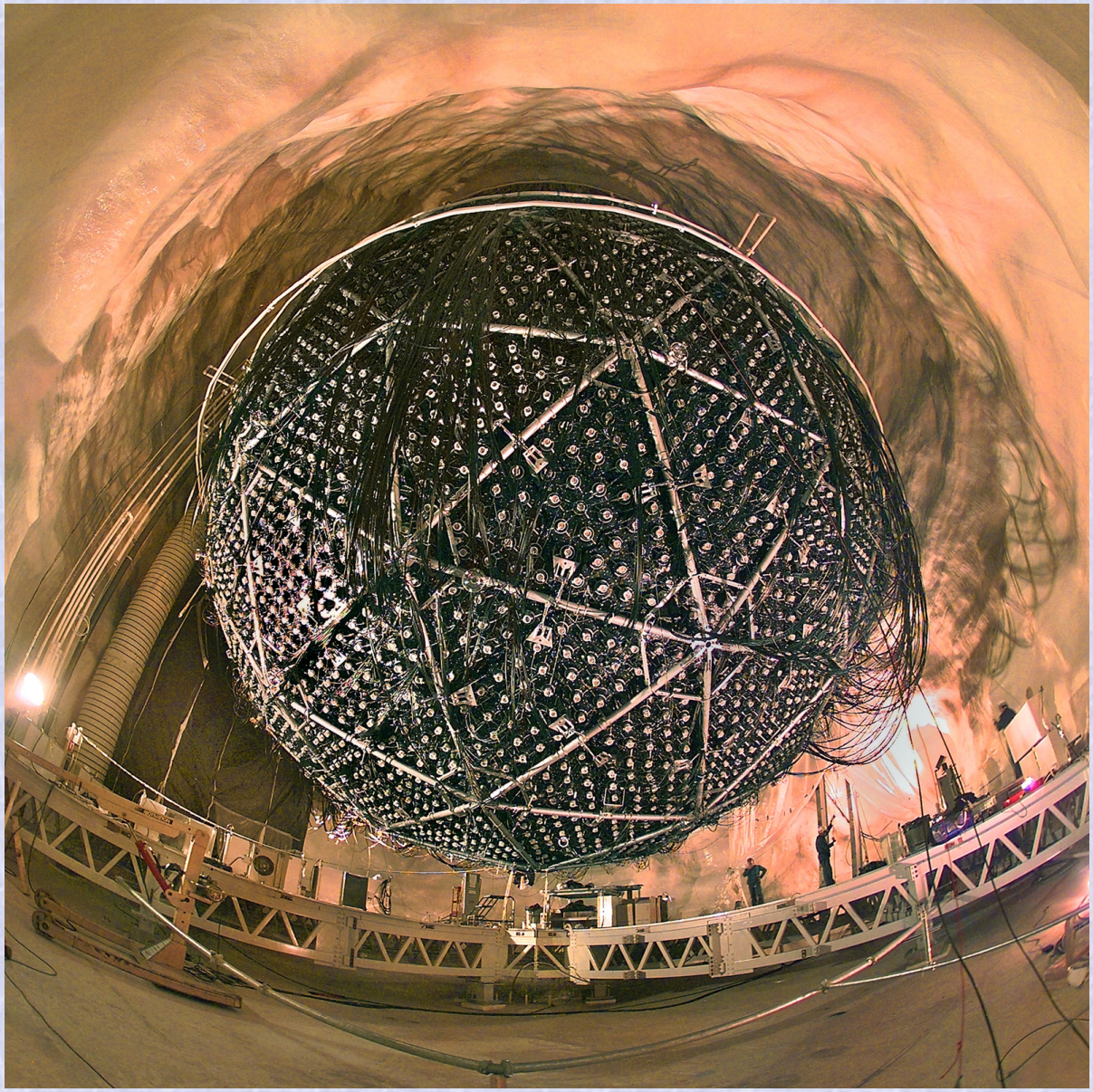


7.2 Hunting the elusive neutrinos

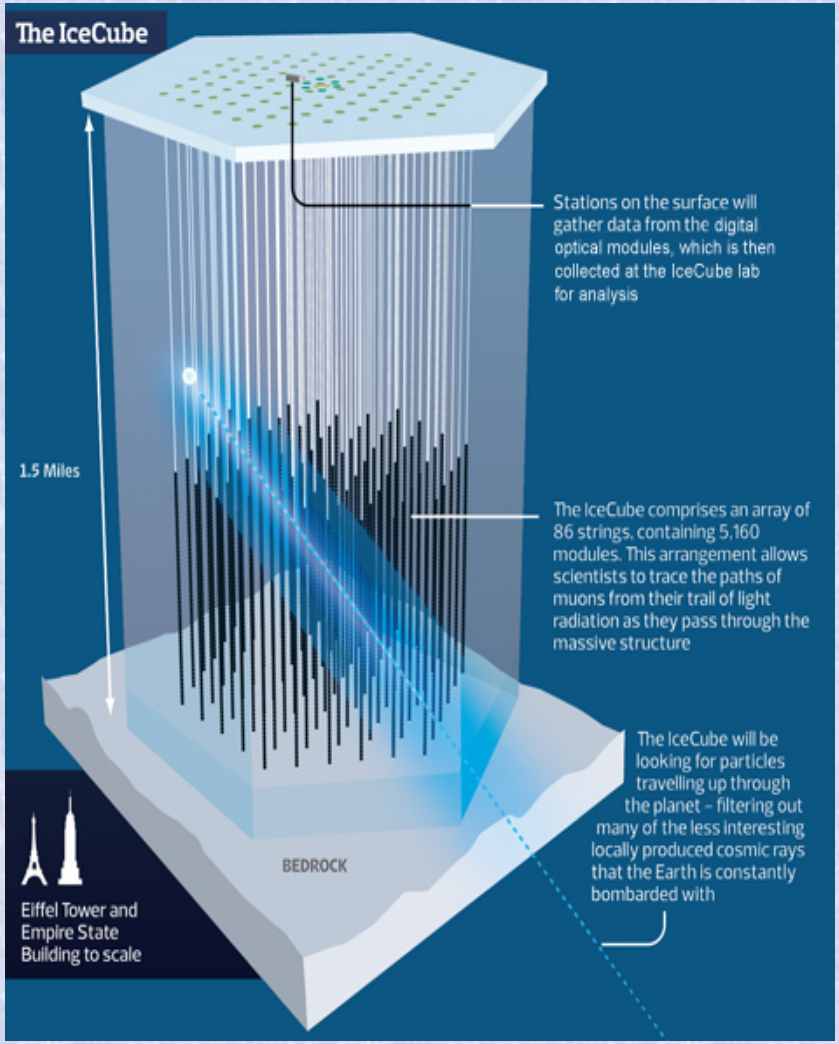
7.2.1 super-Kamiokande Japan



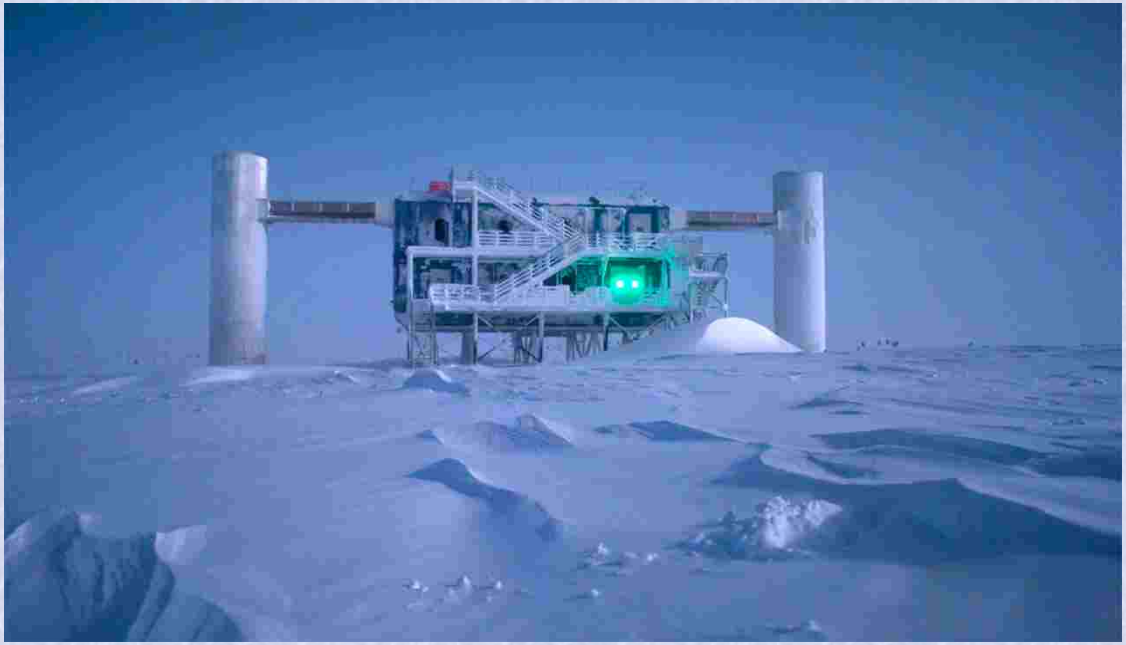
7.2.2 Sudbury Neutrino Observatory Canada



7.2.3 IceCube observatory – Antarctica

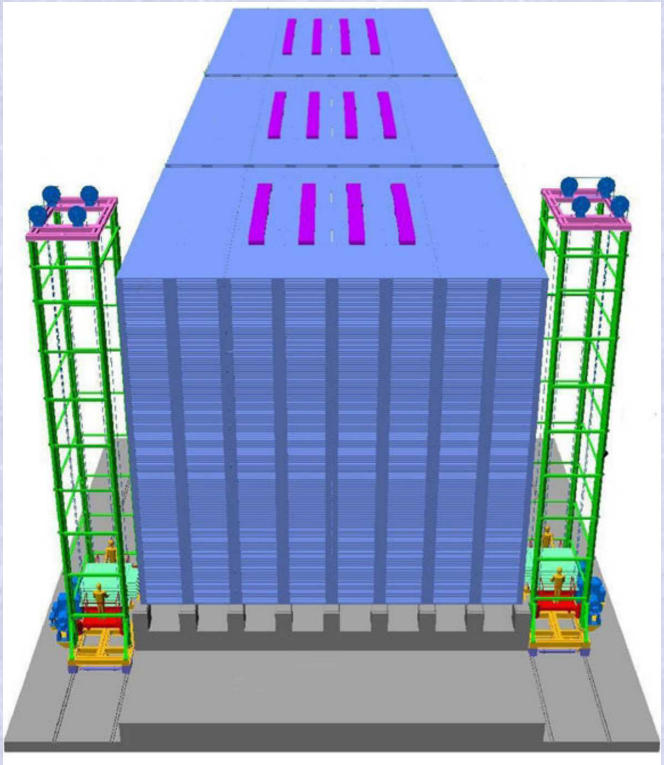


IceCube external view



7.2.4 The proposed India Based Neutrino Observatory (INO)

ICAL detector with 50 kTons iron to make the neutrino scatter and create a μ lepton (muon) track in Resistive Plate Detectors (RPC's)



To be located under Nilgiri mountains at Theni, Madurai District, TN

8 Mathematics, Technology and Physics

- Newton's "Mathematical Principles of Natural Philosophy"
- Relativistic Quantum Theory – Feynman diagrams
- Why are there three kinds of forces?
  - Grand Unified theory
- "What about Grvaity?" – Salam
  - Supersymmetry
  - Superstring Theory

Hope you enjoyed it!

Thanks to TEXMACS