TP - IV

Theoretical Particle Physics Laboratory (LPTP)

Riccardo Rattazzi

Relativity

instantenous action at a distance is not possible

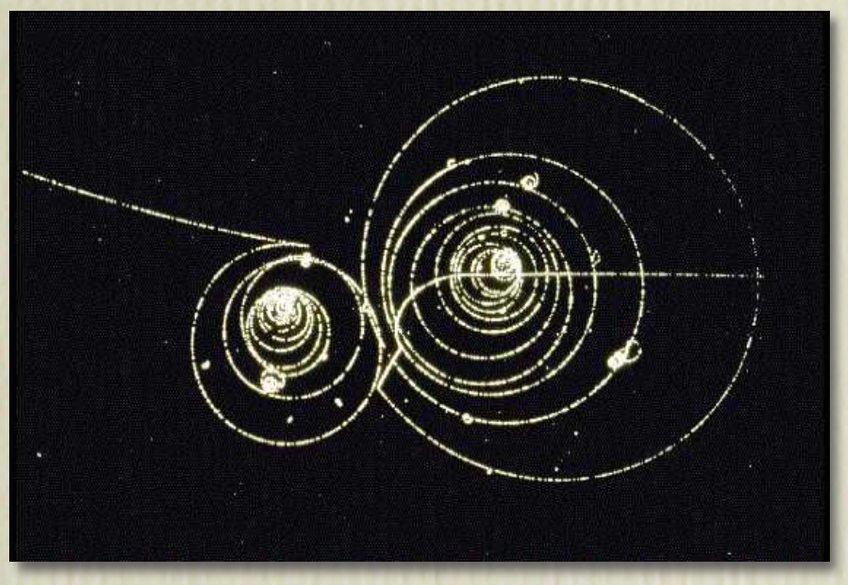
need **fields** permeating all of space

interaction carried by waves in the fields

Quantum Mechanics

Discrete nature of microworld

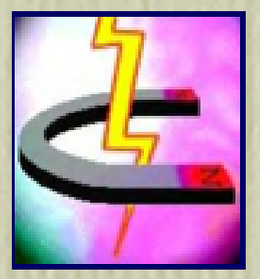
wave of smallest intensity: **particle**



Relativity → Quantum Field Theory ← Quantum Mechanics

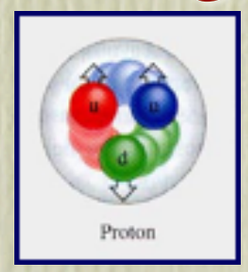
Standard Model: specific QFT describing/explaining *basically* all that we see

EM

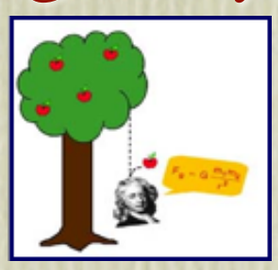


weak

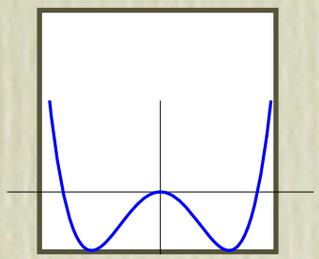
strong



gravity



Higgs



geometric — non-geometric

- Most precisely tested theory in science (electron gyromagnetic ratio, 1ppb)
- Atomic and Nuclear physics "just" complex corollaries of simple principles

...yet big mysteries persist (and deepened with Higgs discovery)

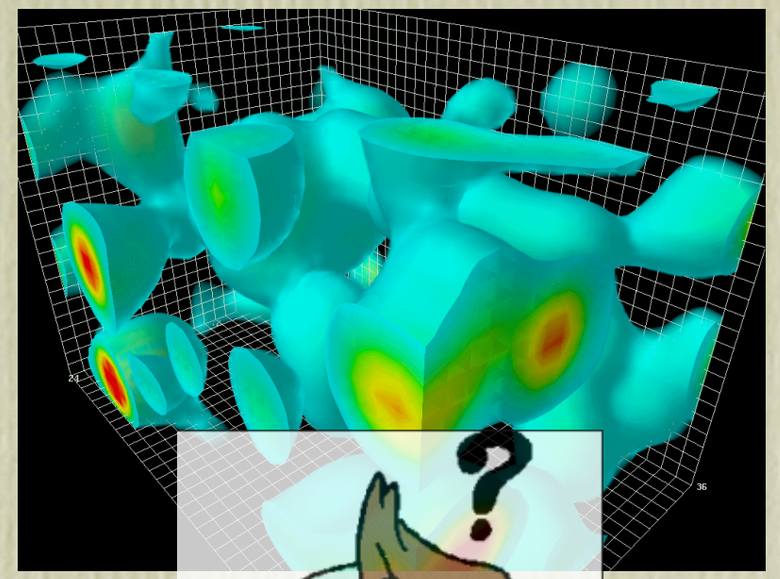
The mysteries (some of them)

- Why the Standard Model?
- What is Dark Matter made up of?
- ....
- The incredible properties of the vacuum

Quantum mechanically the vacuum is very active

Higgs force range less than 10^{-30} cm

(Hierarchy puzzle)



Universe's "size" less than 10^{-4} cm

(Dark Energy puzzle)

...well, unless some fundamental parameters are tuned to an insane accuracy

What are we missing?

Partial answers may come from the explorations of the Fermi scale at the LHC and future machines and from cosmological observations

A deeper answer will probably only come from a radical reformulation of basic principles

There is still a lot to learn on Quantum Field Theory

BSM for Millenials, lectures at the Galileo Galilei Institute, 2021

see also the articles on http://inspirehep.net//

arXiv:2412.10344 arXiv:1204.5221

arXiv:2011.00037 arXiv:1909.01269 arXiv:1902.05936

arXiv:0811.2197 arXiv:1501.03845 arXiv:0807.0004

hep-ph/0703164 hep-th/0602178 hep-th/0512260

M-I

- ✦ Symmetry in QM & Particle Physics

  Lie Groups, selection rules, spacetime symmetries...

- ✦ A little "project" at the end

  Ex.: Grand Unification, Quark Model, Supersymmetry, ...

M-II

- ✦ Quantum Field Theory at work

  S-matrix and Feynman diagrams, Fundamental processes, ...

- ✦ A less little "project" at the end

  Ex:. Standard Model and open problems

M-III

- ✦ Courses
  - *Gauge Theories and the Standard Model*
  - *Advanced Quantum Field Theory*
  - *Conformal Field Theory and Gravity*
- ✦ Preparation to Master Project

Prerequisites

Necessary

- Quantum Field Theory I & II
- Relativity and Cosmology I & II
- Quantum Mechanics III and IV

Suggested

- Statistical Physics III
- Solid State III

The group next fall

- Riccardo Rattazzi, professor, Scuola Normale Superiore, Pisa, 1990
- Marc Riembau, CERN/EPFL staff scientist, PhD UA Barcelona, 2018
- Andrew Gomes, postdoc, PhD Cornell University, 2023
- Andrea Luzio, postdoc, PhD Scuola Normale Superiore, Pisa, 2024
- Michael Stadlbauer, postdoc, Technical University Munich, 2025
- Filippo Nardi (PhD 2026)
- Javier Reig Navarro (PhD 2028)
- New PhD student

Recent PhD students

- Jan Mrazek, thesis 2011: high school teacher, Lausanne
- Alessandro Vichi, thesis 2011: Berkeley U., CERN, Pisa University (professor)
- Duccio Pappadopulo, thesis 2012: Berkeley U., New York U., Bloomberg LP NY
- Andrea Thamm, thesis 2014: Mainz U., CERN, U. Massachusetts at Amherst (professor)
- Lorenzo Vitale, thesis 2016: Boston University, G-research London
- Davide Greco, thesis 2017: UBS, Zurich
- Kin Mimouni, thesis 2019: TeSa, Aeronautics & Space, Toulouse
- Gabriel Cuomo, thesis 2020: U. Stony Brook, NYU/Princeton University, SISSA (professor)
- Alfredo Glioti thesis 2022: CEA Saclay, Università la Sapienza, Roma
- Gil Badel thesis 2022: Argusa Consulting, Suisse
- Eren Firat thesis 2025: Cambridge University