Fisica Teorica 2 / Advanced Quantum Field Theory

(the course)

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Prerequisites

This is an advanced course in quantum field theory, so it requires the knowledge of the topics discussed in the "Fisica Teorica 1 / Quantum Field Theory" course.

In several points we will come into contact with topics discussed from a different/complementary perspective in

- Meccanica Statistica / Statistical Mechanics
- Metodi Numerici per la Fisica / Computational Physics Laboratory

but these courses are not prerequisites for FT2/AQFT.

There will also likely be connections with Cromodinamica Quantistica / Quantum Chromodynamics and Condensed Matter Physics.

The approach used

In FT1/QFT the canonical quantization approach to QFT has been adopted, which emphasizes the relation with QM and makes the computation of cross sections quite natural.

$$_{\text{out}}\langle\{\boldsymbol{p}_i\}_i|\{\boldsymbol{k}_i\}\rangle_{\text{in}} = {}_{\text{in}}\langle\{\boldsymbol{p}_i\}_i|S|\{\boldsymbol{k}_i\}\rangle_{\text{in}}$$

In FT2/AQFT the functional integral approach to QFT will be (mostly) used, which makes the relation with statistical mechanics pretty transparent and simplifies some technical points when dealing with gauge theories.

$$\langle 0|T[\phi_H(x_1)\cdots\phi_H(x_n)]|0\rangle \longleftrightarrow \langle\phi(x_1)\cdots\phi(x_n)\rangle$$

Topics to be discussed (1)

- Second quantization (many body QM)
- Path-integration
  - in quantum mechanics and quantum statistical mechanics, generating functional
  - in scalar quantum field theory, perturbation theory, generating functionals, semiclassical expansion
  - with coherent states, fermionic fields, QFTs at finite T
- Spectral representation and LSZ reduction formulae
- QED: gauge fixing and perturbation theory (maybe BRST)
- Renormalization
  - the logic of renormaliztion
  - one loop examples and power counting
  - regularization methods (mainly dimensional regularization)
  - renormalization & renormalization group (mainly MS scheme)

Topics to be discussed (2)

- Symmetries
  - symmetries and spontaneous symmetry breaking
  - Ward-Takahashi identities for global symm., Goldstone theorem
  - Ward-Takahashi identities in QED
  - Abelian Higgs mechanism
- Lectures on fundamental interactions ($\approx$ 12h)
  - NonAbelian gauge theories: quantization, renormalization, and RG behavior
  - NonAbelian Higgs mechanism
  - The Standard Model, the Fermi theory and effective QFTs
- Lectures on condensed matter physics ($\approx$ 12h)
  - Correlations and susceptibilities in statistical systems
  - Critical phenomena: Landau theory, Wilson approach to RG and ϵ-expansion
  - Large N expansion: saddle point solution, critical behaviors, triviality

Practical info

The total amount of lectures is $\approx$ 64h but $\approx$ half of the last $\approx$ 24h are optional. You will have to chose between

- Lectures on fundamental interactions ($\approx$ 12h)
- Lectures on condensed matter physics ($\approx$ 12h)

For the exam you will have to solve at least one problem (suggested two) from the list on the elearning page of the course

https://elearning.df.unipi.it/course/view.php?id=262

The discussion of the **techniques and methods used** in the solution, **as well as the physical context** of the problem, will be the starting point of the oral exam.

Difficulties

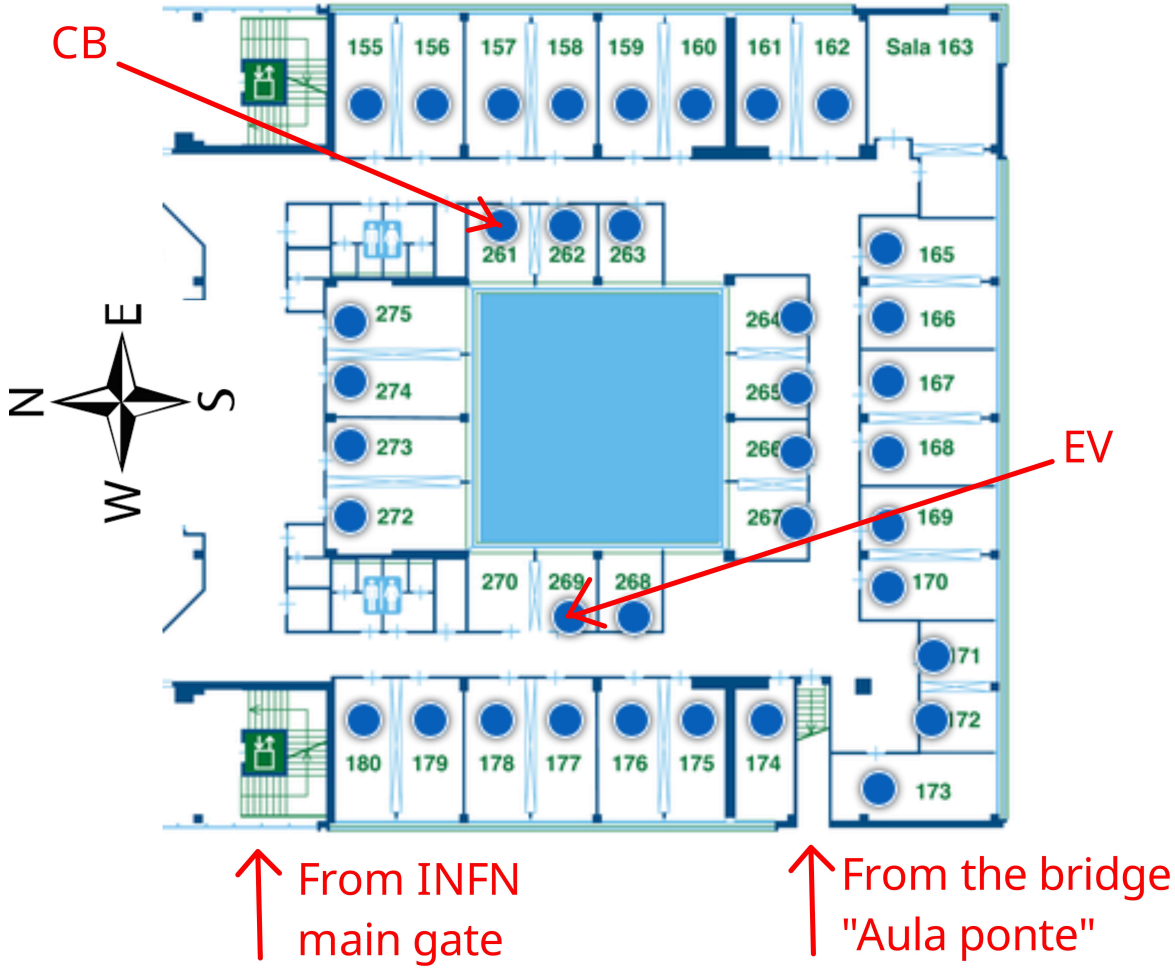
The aim of the FT2/AQFT course is quite ambitious and there are two main sources of difficulties

- technical difficulties: computations immediately become quite involved and in several places it will be impossible to carry out all the steps in detail during the lectures (hence the problems).
- conceptual difficulties: the topics discussed are very abstract and it is essential to maintain both a global view of the physics studied and an understanding of how the various pieces fit together in an actual computation.

Fundamental point (especially related to conceptual difficulties): **attend lectures actively and ask questions whenever something is not clear! DO NOT wait months...**

Where to find us

1st floor of building C



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What has been left out (incomplete list...)

- Renormalization of composite operators, OPE
- Canonical quantization of gauge theories, θ-dependence
- BRST symmetry & Slavnov-Taylor identities
- Anomalies
- Systematics of effective field theories
- Semiclassical approximation
- Large order behavior of perturbative series and resummation techniques
- Two dimensional models and CFT
- Dualities in SFT and topological phase transitions
- Disordered systems
- Out of equilibrium physics
- Lattice gauge theories