Physics at University of Pisa

28 April 2023

Meeting with the Intense
Early Stage Researchers

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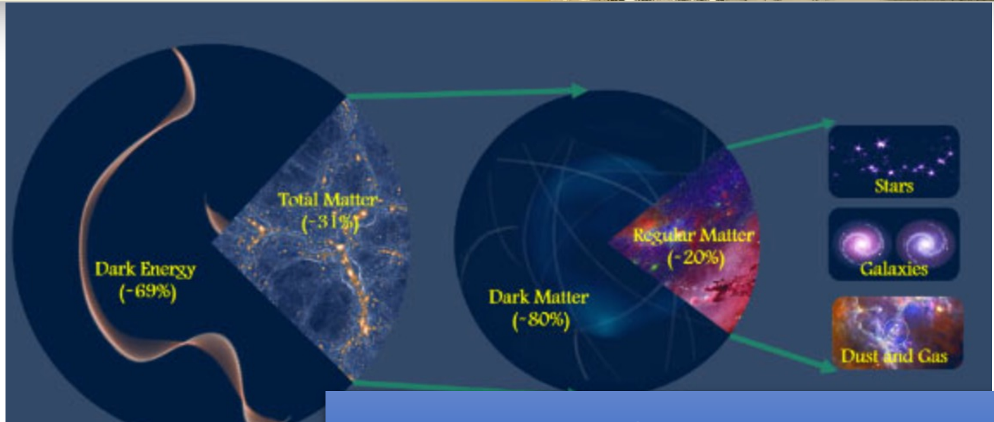
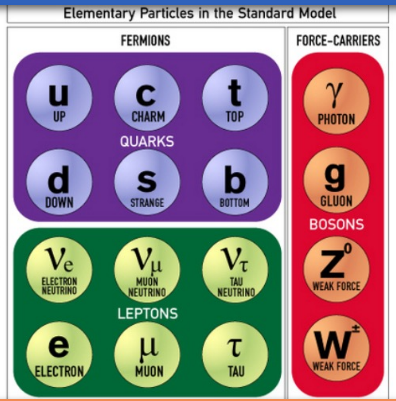
Want to know <u>how</u> and <u>why</u>? Learn Physics!

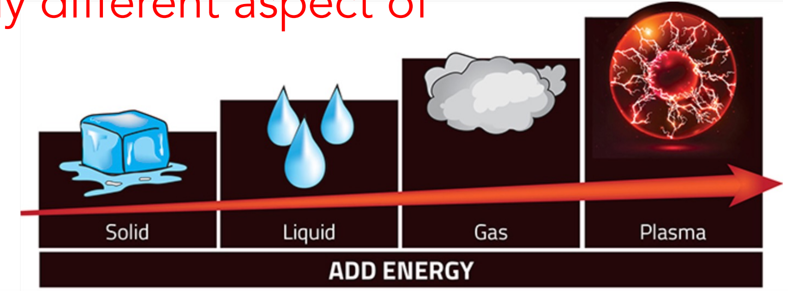
- Physics is crucial to understanding the world around us, the world inside us, and the world beyond us. It is the most basic and fundamental science.
- Physics challenges imaginations with new concepts and it leads to great discoveries! The analytical skills make physicists versatile and adaptable so they work in interesting places: **physicists are problem solvers.**
- Depending on your curriculum, you will study different aspect of the nature.



The behavior of dark matter, dark energy, galaxies and black holes.



The behavior of complex systems (the stock market, infectious disease transmission,..).



The properties of matter in standard and exotic phases (solids, liquids, plasmas, superconductors,..).

The nature of fundamental particles (protons, quarks, electrons,...).

Want a Job? People Hire Physicists

- Physics brings a broad perspective to any problem.
- A physicist learns how to consider any problem with not bound by context and with an inventive thinking!
- You can find physicists in industrial and government labs, on college campuses, in the astronaut corps, and consulting on TV shows: places where their ability to think analytically is a great asset.
  - A bachelor's degree in physics is a great foundation for many different careers…

Computer and programming design

Medicine

Physics and Astronomy Research

School science teacher

Journalism and Science writing

Defence and aerospace industry

Engineering and manufacturing

Law and government

Finance and management consulting

Did you know that?

Angela Merkel: worked as a research scientist before becoming Chancellor of Germany.

Brian May: the lead guitarist of Queen has a PhD in astrophysics from Imperial College London.

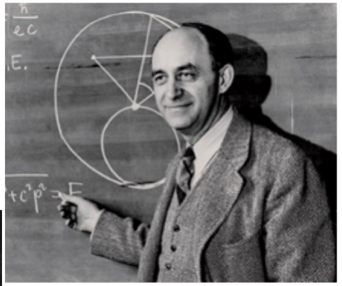
David Cohen: Writer and Executive Producer of *Futurama*. Former writer and producer for *The Simpsons*

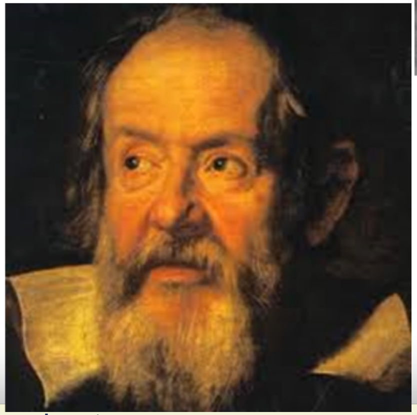
Physics @ University of Pisa

- **The University of Pisa has been founded in 1343,** it is one of the oldest universities in the world, for information please visit its website unipi.
- The school of Physics is up to 51st-100th according to the QS World Rankings by Subject.
- A legacy that starts from *Galileo Galilei* up to *Enrico Fermi* and *Carlo Rubbia*, both **Nobel Prize winners** for Physics in 1938 and 1984 respectively.

Rettorato

Physics Dept.





Pisa

- The city of Pisa has a polulation of about 100k people of which 25k are students!
- The city is also home to the University of Pisa, which has a history going back to the 12th century, the Scuola Normale Superiore di Pisa, founded by Napoleon in 1810, and its offshoot, the Sant'Anna School of Advanced Studies.

Physics Degrees

Bachelor Degree
3 Years

Monolithic Bachelor Degree, same for all students, to make sure they all have a similar background knowledge when they enter the Master studies (and make sure this is known to bachelors coming from other universities)

Master Degree
2 Years

Main focus of master studies should be to form graduated able to go into a PhD/do research -> we must offer curricula attached to our research

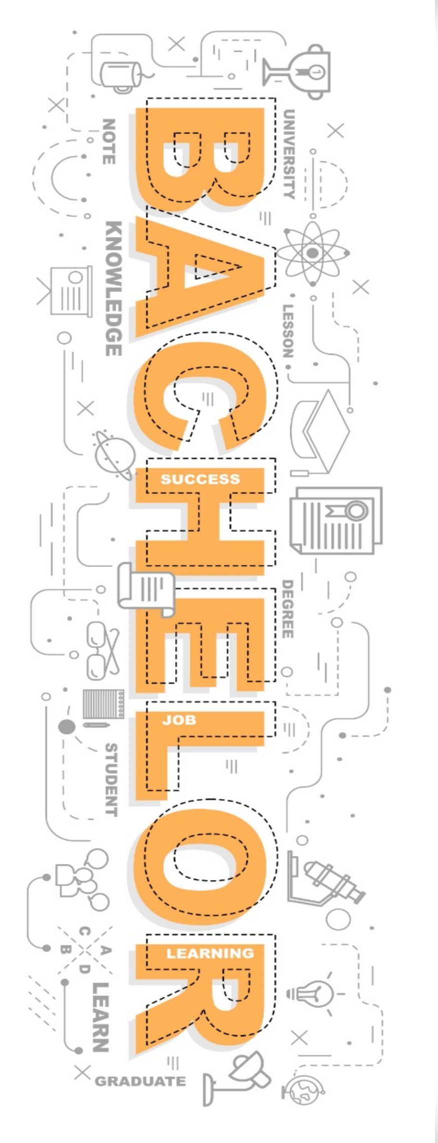
Ph.D.
3 Years

From interview of graduated master students -> 81.1 % goes into a PhD

In Italy, degree programmes are measured in terms of **University Formative Credits (CFU)**. These are equivalent to the European Credit Transfer and Accumulation System (ECTS) credits. Each CFU will require about 25 hours of lessons and study time. **Each year, a full time student should obtain 60 credits by passing exams.**

Bachelor Degree

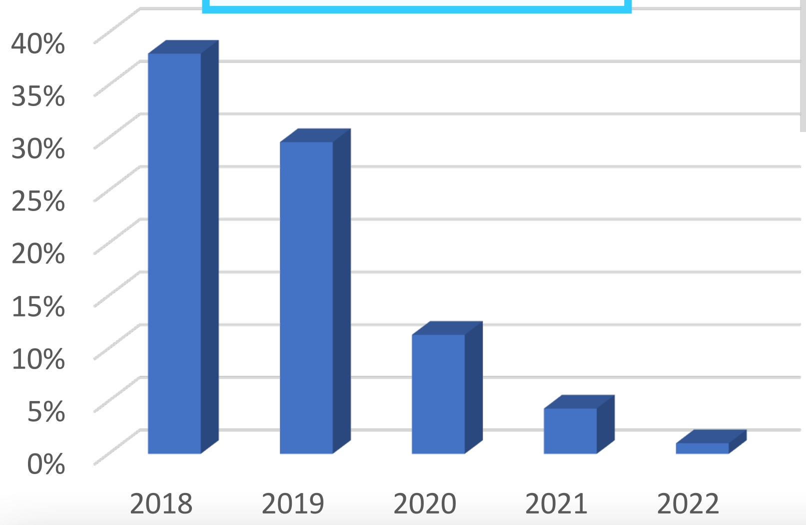
- Free enrollment (no fixed intake number, we only run an initial assessment test to tell students whether we think they might into troubles later on),
- 3 years (180 credits), on average 220 students in the first year, on average 140 get a degree (most dropout happens during the first year), median time to graduate 3 years, average time to graduate 3.6 years.
- Satisfaction: 88% of graduated are happy or very happy about their bachelor curriculum.
- After bachelor, students can carry onto a Master in Physics, but also onto a Master in Nuclear Engineering, Master in New Materials and Technologies, Master in in Exploration and Applied Geophysics

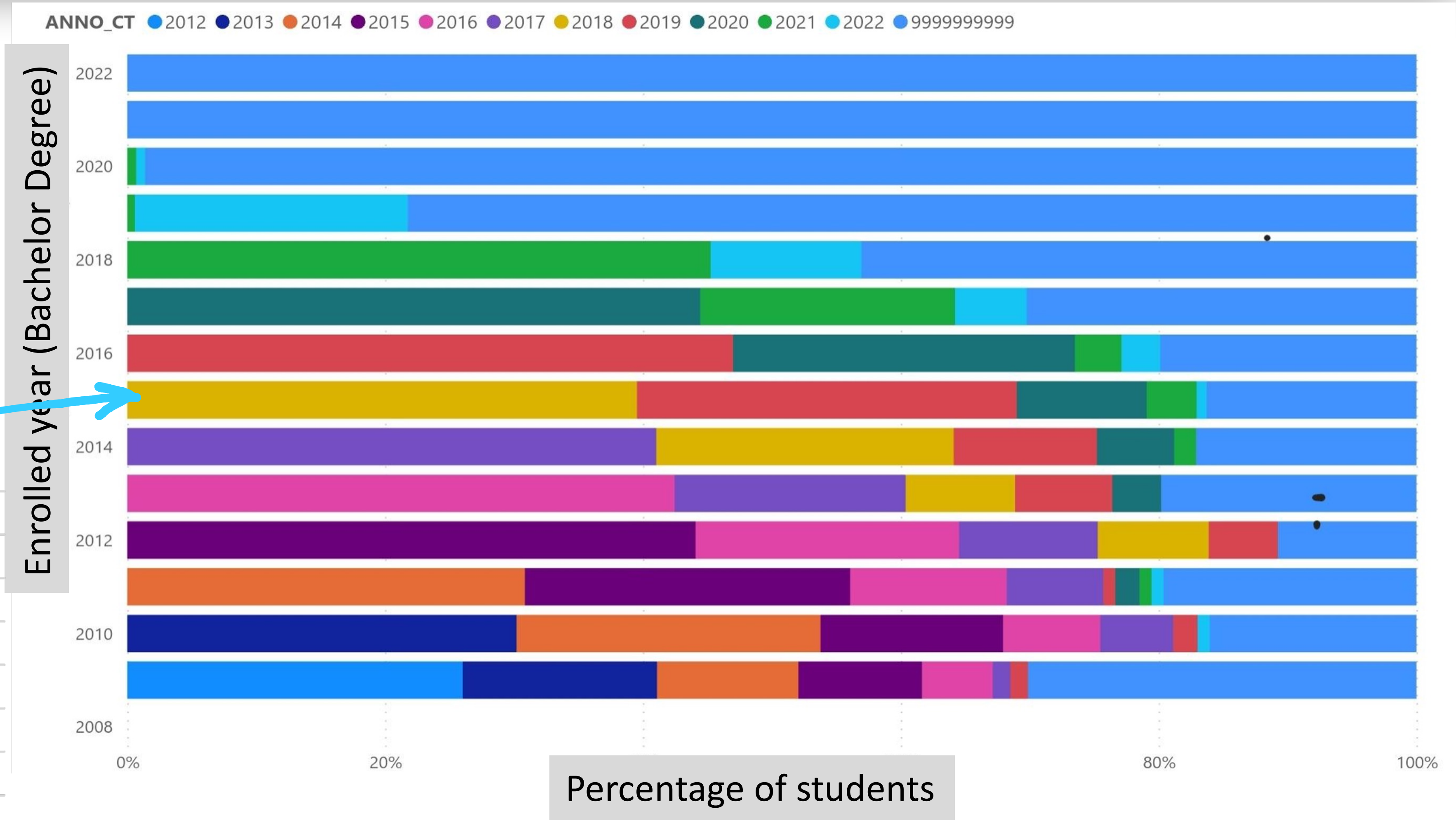


Monitoring Tools

Delay in getting a degree

Enrolled in 2015

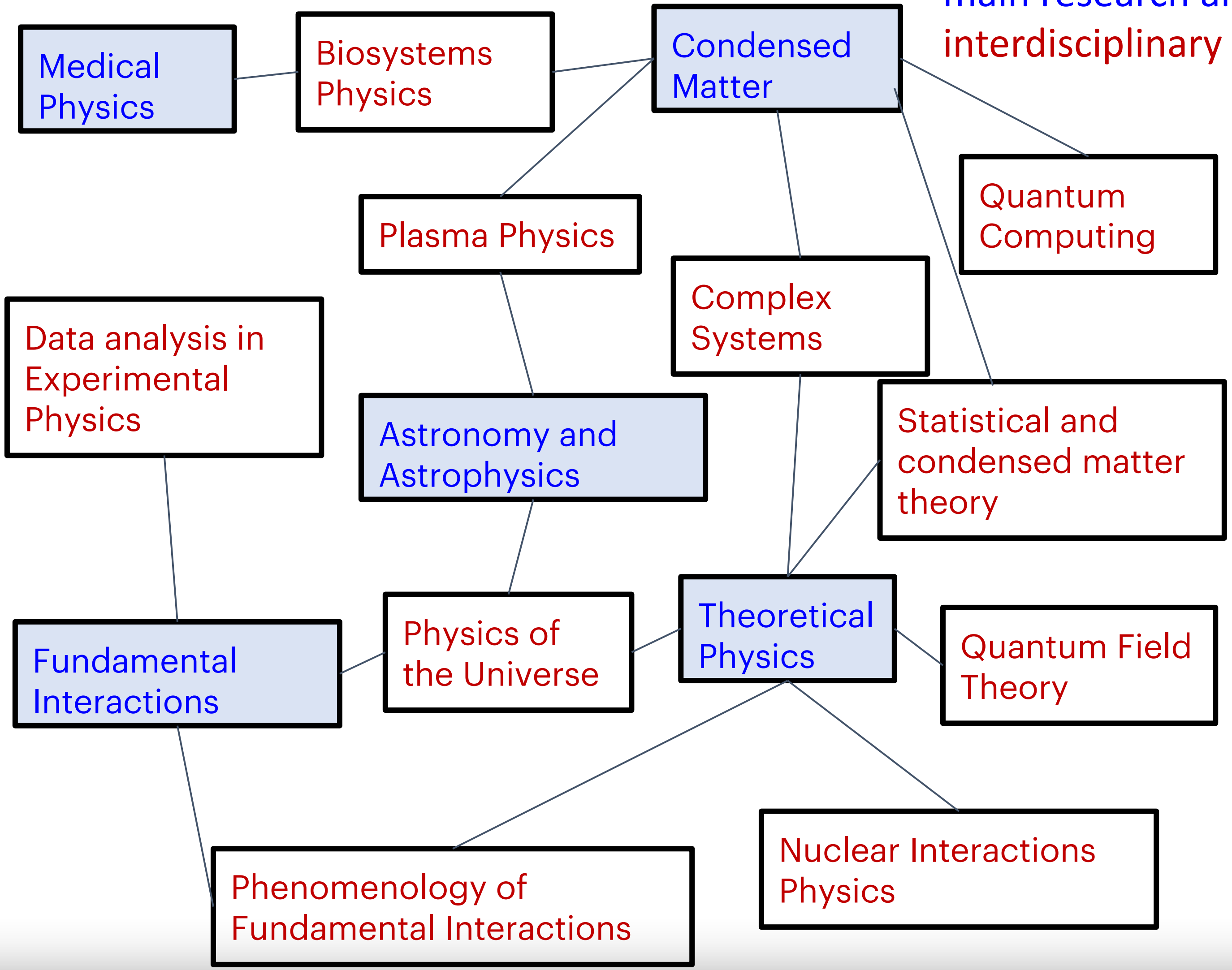




Master Degree

- Free enrollment,
- 2 years (120 credits), on average 120 students in the first year, virtually all graduate, median time to graduate (in recent years) 2 years, average time to graduate 3 years.
  - Master thesis: 45 ECTS out of 120
- Satisfaction: 91% of graduated are happy or very happy about their curriculum.
- One year after graduation, less than 9% have not yet found a job (note: PhD with a grant counts as a "job")

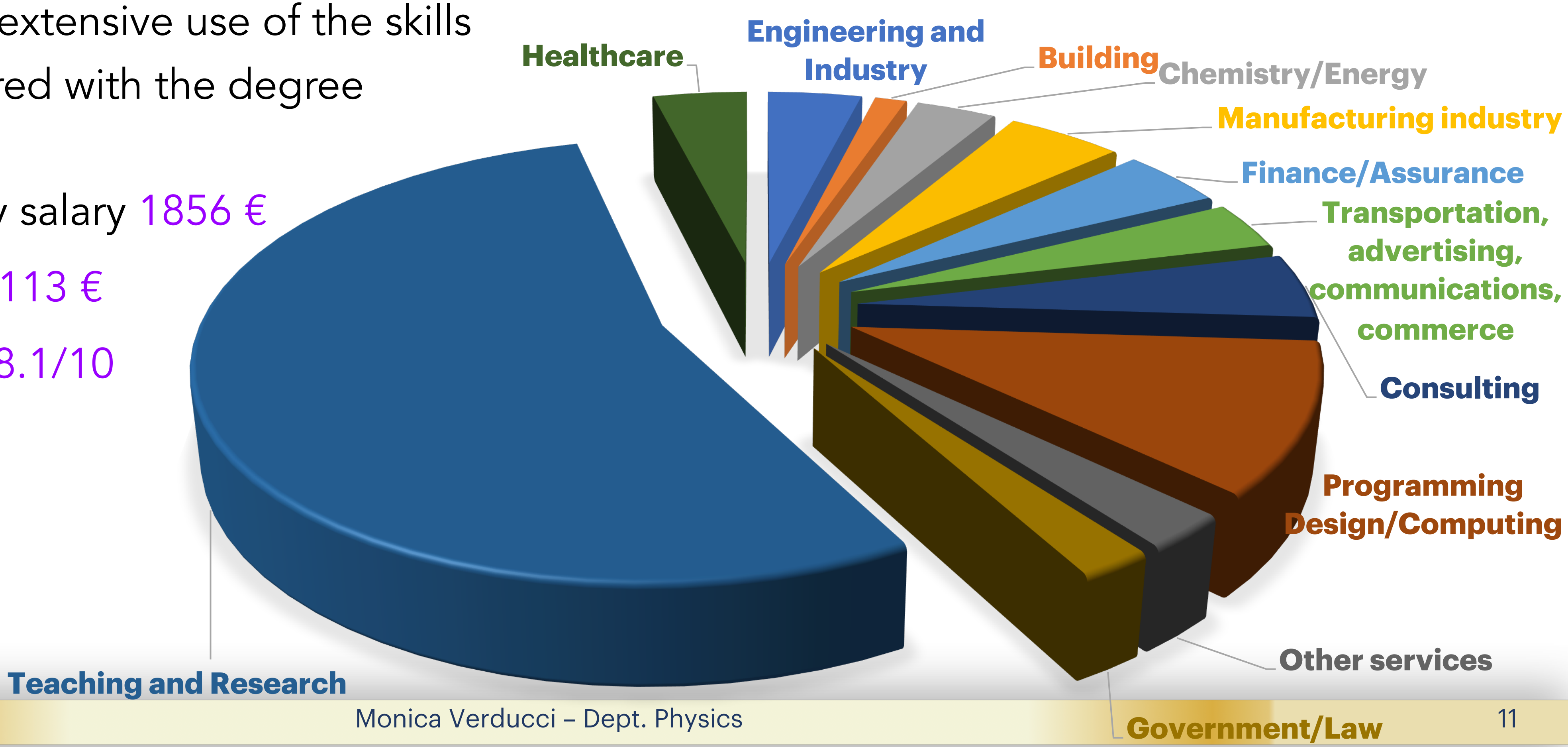
main research areas
interdisciplinary



Master's Degree in Numbers

- On average, a master's graduate in Italy works after 7 months from the master.
- After 5 years master's degree:
  - 95.3% works where the degree is required
  - 69.1% makes extensive use of the skills acquired with the degree

- Average net monthly salary 1856 €
- LM Physics@Unipi 2113 €
- Overall satisfaction 8.1/10

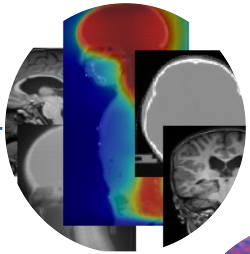


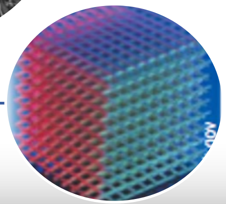
Physics Research @ Pisa


Theoretical Physics


Fundamental Interaction


Astrophysics


Medical Physics


Physics of Matter

Theoretical Physics

Fundamental Physics

- Effective field Theories
- Flavour Physics
- High-energy physics phenomenology
- Lattice QCD

Astrophysics

- Astroparticle physics
- General relativity & cosmology
- Gravitational wave astrophysics
- Quantum gravity

Statistical Physics and Condensed Matter

- Conformal field theory
- Critical phenomena
- Entanglement
- Quantum many-body physics

Nuclear Physics

- Compact stars
- Few-nucleon systems
- Nuclear & hadronic interactions
- Nuclear many-body theory

Supersymmetries

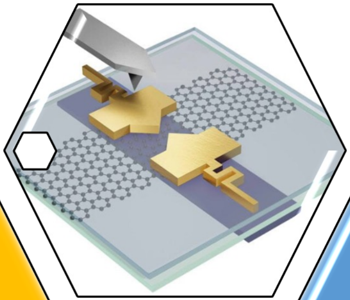
- Beyond Standard Model physics
- String theory
- Supersymmetric quantum field theories

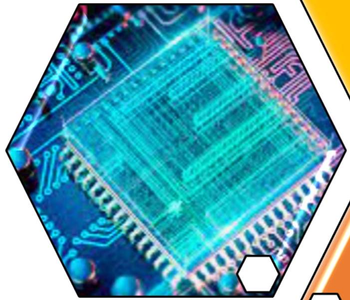
Physics of Matter

Nano-electronics: single-electron, 1D transport, quantum Hall, strongly correlated systems, conducting polymers, etc. (Nano-)materials: 2D, piezoelectrics, metamaterials, optical crystals, scaffolds…

Neural networks, chaos, econo-physics, nonlinear systems

Plasma physics: astronomy, fusion, turbulence, plasmonics, high-fields, etc.



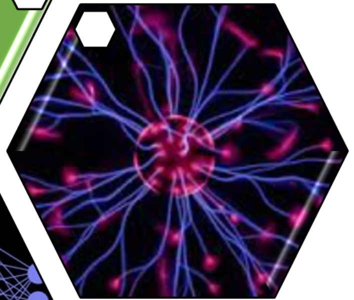


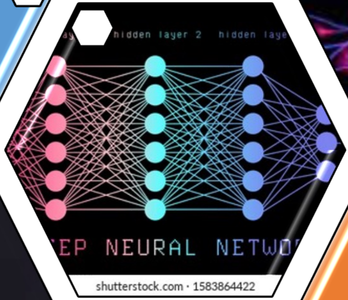
Nano-electronics and nano-materials

Photonics

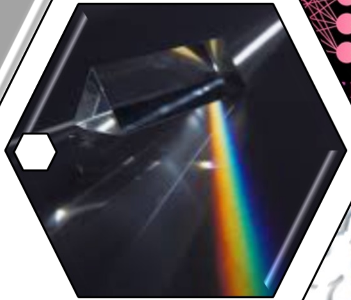
Complexity

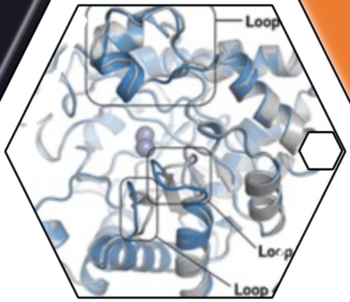
Plasma Physics





Quantum Technologies





Soft-matter and bio-system

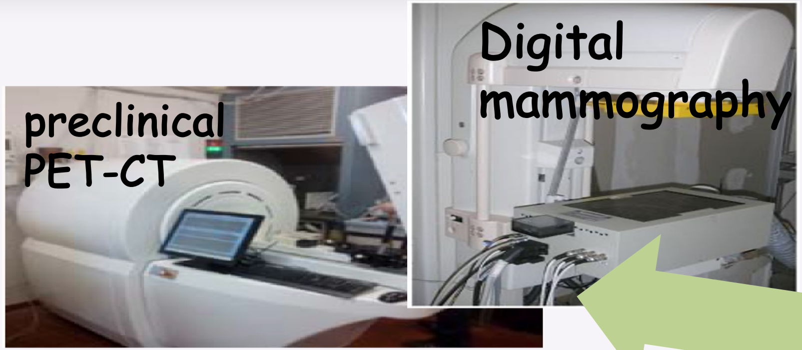
Quantum simulation, ultracold atoms, quantum batteries, quantum sensing/chemistry, metrology, quantum phase transitions, spin systems, etc.

Laser cooling, THz, polaritonics, opto-mechanics, NSOM, sensors, fibre/ organic lasers, etc.

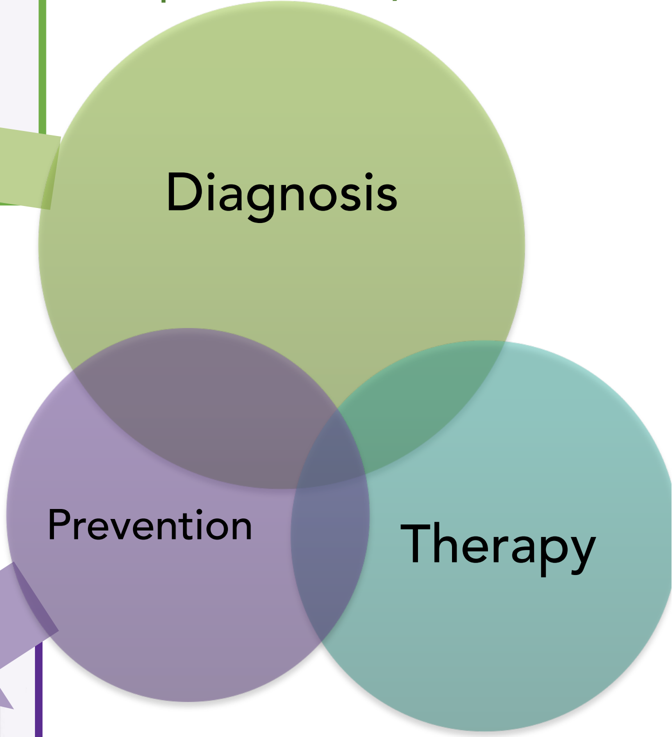
Micro/nanofluidics, aging, polymers, hydrogel, glass transition, protein dynamics, microscopy/super resolution

Medical Physics

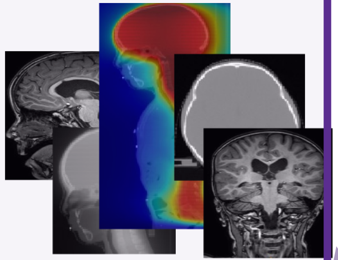
- Medical Physics is the application of physics to healthcare.
  - The Medical Physics group in Pisa develops hardware and software tools for imaging, measurement and treatment.
- The Physics Department hosts the Specialization School in Medical Physics (SSMP)
  - **SSMP** is a three-year postgraduate course that allows physicists to get the required qualification to work in the National Health System



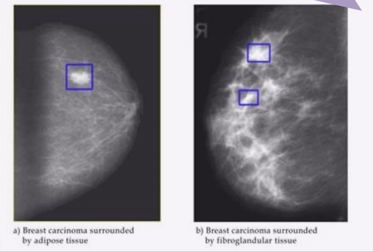
Radiological imaging
Nuclear Imaging (clinical and preclinical)…



Machine learning based predictive model through the analysis of imaging from CT, MR etc.



CAD systems for automatic detections of tumor masses and microcalcifications in mammography

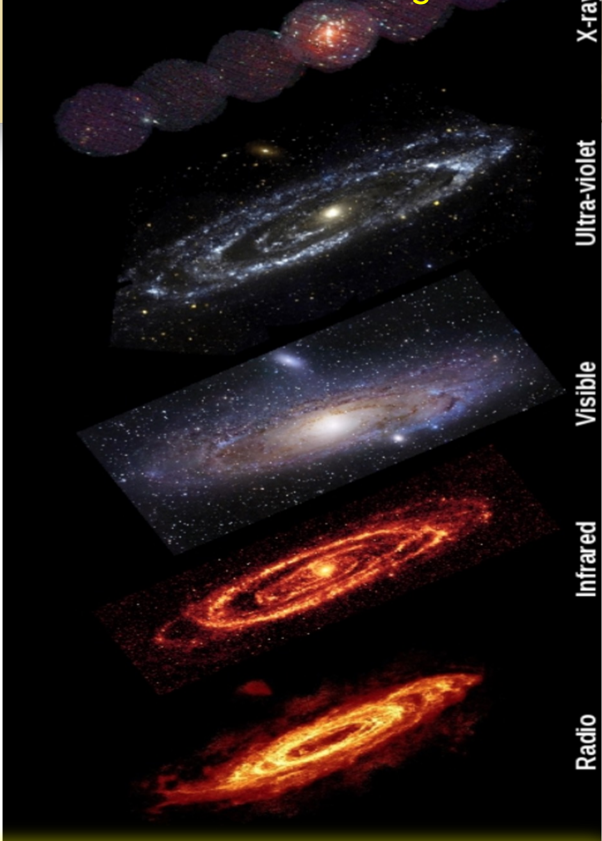


Monitoring and follow-up in hadron therapy

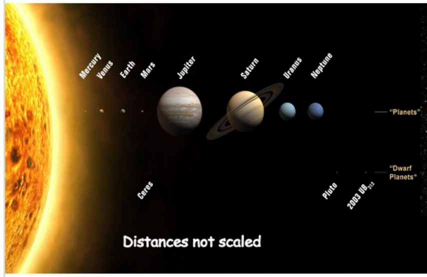
Astrophysics

- Non-reproducible phenomena about which one has a limited information
- Observational data: electromagnetic waves at different wavelengths, neutrinos, gravitational waves, cosmic rays...
- Interpretation of observations based on theoretical physics models
- Interdisciplinary topic: based on the knowledges of quantum mechanics, nuclear physics, electromagnetism, general relativity, plasma physics, statistical mechanics…..

The Andromeda galaxy observed at different wavelengths

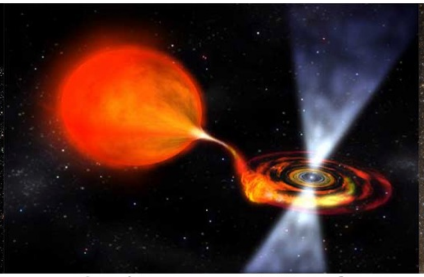


from near — to far — to very far



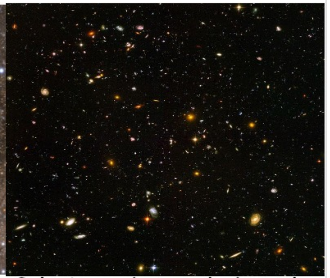
Scheme of major bodies of our solar system (from wikipedia)

Stellar cluster in the Milky Way (Hubble Space Telescope)



Graphic representation of an accretion disk in a binary system (NASA website)

Simulation of a binary black hole (from wikipedia)



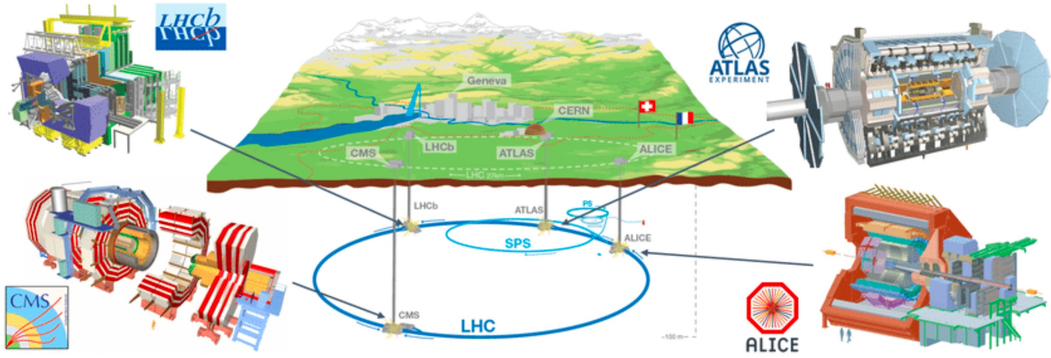
Galaxies observed by the Hubble Space Telescope up to a distance of about 13 billions of light years

My Picture of Andromeda with my telescope and with much patience!

Fundamental Interaction

- Experimental and phenomenological characterization of forces between elementary particles in nature. Research in strong connection with INFN (National Institute for Nuclear Physics).
  - Research based on particle accelerators, with experiments focused on the test of the Standard Model, the measurement of its free parameters and the search for new physics phenomena
    - **CERN**: ATLAS, CMS, LHCb, NA62, TOTEM
    - **KEK**: BELLE-II; **Fermilab**: muon g-2, Mu2e; **PSI**: MEG
  - Research based on cosmic radiation in underground laboratories, high atmosphere or space, focused on the search for new astrophysical phenomena or issues related to cosmological-scale processes
    - **Cosmics Radiation**: CALET, MAGIC, AMS-02, CTA, FERMI, IXPE, e-XTP, Km3NET, LiteBIRD, LSPE
    - **Dark matter, exotic particles**: Darkside, QUAX, STAX, AXIOMA
    - **Gravitational research**: VIRGO, Einstein telescope, MAGIA, GG, GINGER
  - Cross-field research and development activities

CERN - Geneva



Virgo - Pisa

European Gravitational Observatory (EGO)

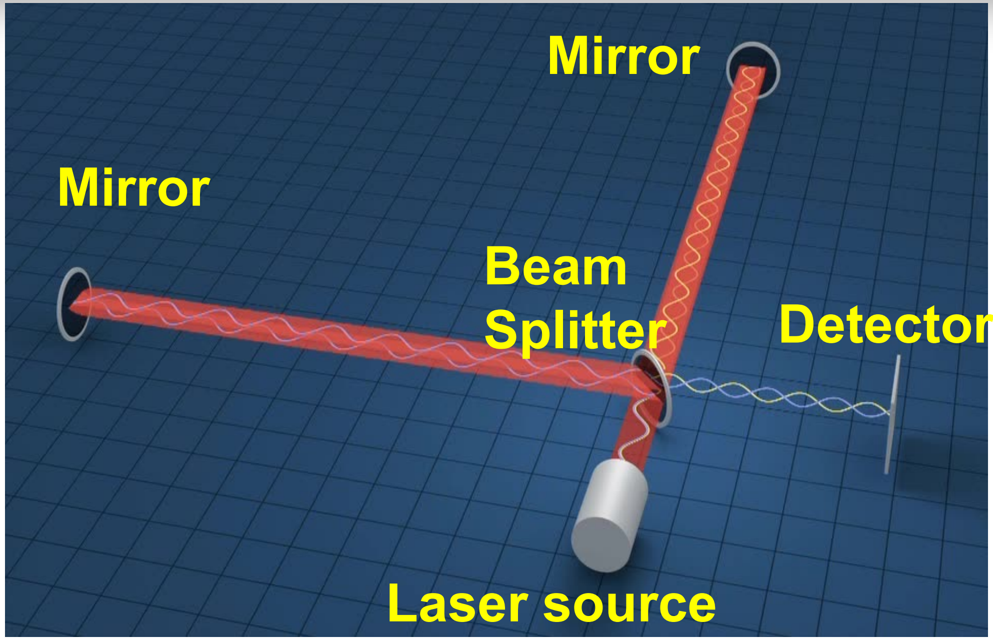
Aerial view of Virgo at EGO, near Pisa (Italy), showing also the 3km-long blue North and West Arms tubes, within which the laser beam propagates under vacuum.

Virgo: a Gravitational Wave detector, based at the European Gravitational Observatory (EGO), near Pisa (Italy)

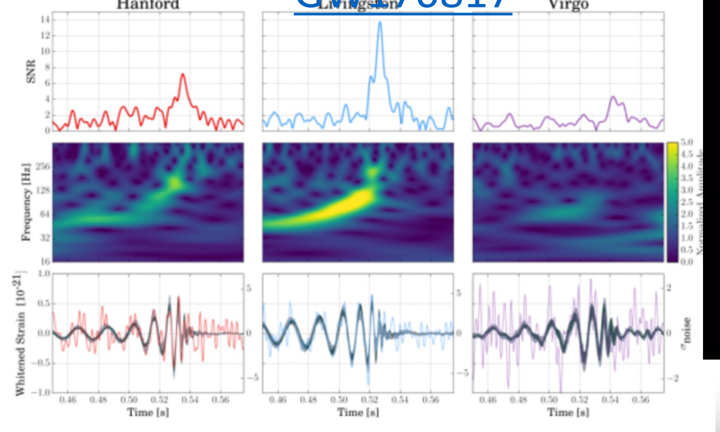
- The **Virgo interferometer** is a large Michelson interferometer designed to detect gravitational waves predicted by the general theory of relativity.
- Other interferometers similar to Virgo have the same goal of detecting gravitational waves, including the two LIGO interferometers in the United States (at the Hanford Site and in Livingston, Louisiana) and the Japanese interferometer KAGRA.

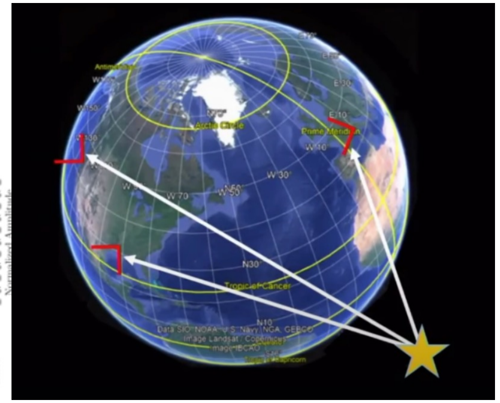
How do we see Gravitational Waves?

- The decrease over time of this binary pulsar's orbital period is in excellent probe of the hypothesis that the system is losing energy by emitting gravitational waves.
- Direct Probe: An incoming gravitational wave changes the optical path of the laser beams in the arms, which then changes the interference pattern.
  - In 2016, Virgo joined the two LIGO detectors ("aLIGO). On 14 August 2017, LIGO and Virgo detected a signal, GW170814. It was the first binary black hole merger detected by both LIGO and Virgo (and the first one for Virgo).
  - Just few days later, GW170817 was detected by the LIGO and Virgo on 17 August 2017. The signal was produced by the last minutes of two neutron stars spiralling closer to each other and finally merging.



GW170817

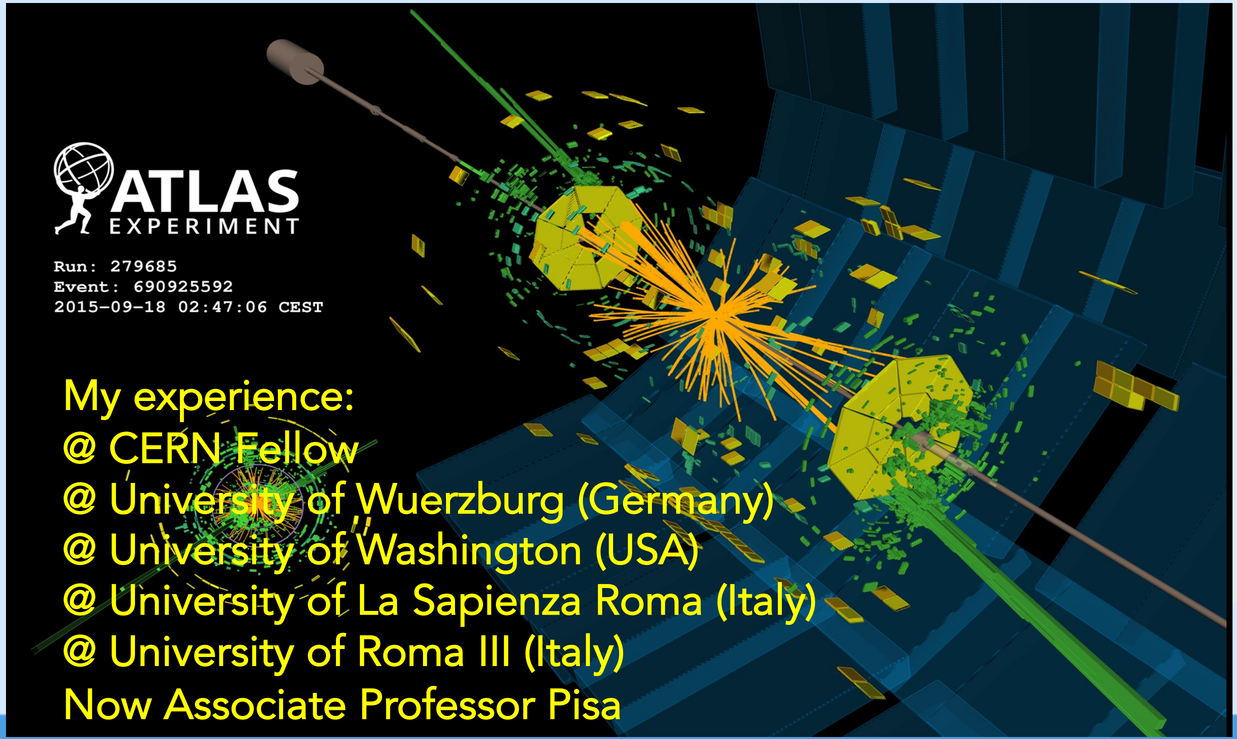




My Experience in Particle Physics

REPUBBLICA ITALIANA
MINISTERO DELL'INTERNO
CARTA DI IDENTITÀ / *IDENTITY CARD*
COMUNE / *MUNICIPALITY*

CA00000XX



- Experimental particle physicist on the ATLAS experiment at the LHC since 2001. My research focuses on the physics of fundamental particles and their interactions.
- Experience on
  - **Detector construction** and commissioning of the ATLAS Muon (assembly and quality control of the muon system, **software infrastructure** and **data management** (DB development).
  - **Physics Analysis**: Higgs into 4 leptons, non Standard Model particles, Dark matter candidates and long-lived searches.

NON VALIDA PER L'ESPATRIO

Connection with the World

- Schools
- Dual Degrees
- Student Mobility
- Collaboration and Projects

EU Projects

Horizon2020 Project :

1. NEWS (H2020-MSCA-RISE-2016) New WindowS on the universe and technological advancements from trilateral EU-US-Japan collaboration
2. POLKA (H2020-MSCA-ITN-2018) POLlution Know-how and Abatement
3. INTENSE (H2020.MSCA-RISE-2018) Particle physics experiments at the intensity frontier, from new physics to spin-offs. A cooperative Europe-United States-Japan effort
4. INTENSE (H2020.MSCA-ITN-2019) Particle physics experiments at the intensity frontier. A cooperative Europe-United States effort
5. TAULEPGAMMA (H2020.MSCA-IF-2020) Search for Lepton Flavour Violating Decay Tau to Lepton + Gamma at the Belle II experiment
6. REINFORCE (H2020-SwafS-2019-1) Research Infrastructures FOR Citizens in Europe
7. Tips in SCQFT (H2020.MSCA-IF-2017) Lattice gauge theories studies of timely theoretical and phenomenological questions in strongly couple quantum field theories
8. PROBES (H2020.MSCA-RISE-2020) Probes of new physics and technological advancements from particle and gravitational wave physics experiments
9. MIR-BOSE (H2020-FETOPEN-1-2016-2017) Mid- and far-IR optoelectronic devices based on Bose-Einstein condensation
10. ASPIRE (H2020-SPACE-2018-2020) Advanced Space Propulsion for Innovative Realization of space Exploration
11. SENSE (HORIZON-MSCA-2021-SE-01) Search for new physics and technological advancements from neutrino experiments at the high intensity frontier

ERC Project :

1. NEO-NAT (ERC-2014-ADG) Understanding the mass scales in nature
2. SouLMan-MAP (ERC-2012-ADG) Sound-Light Manipulation in the Teraherz
3. CFT-MAP (ERC-2017-STG) Charting the space of Conformal Field Theories: a combined numerical and Analytical aPproach
4. ASYMOV (ERC-2020-COG) Power to LHC data; an ASYmptotically Model-independent measurement of the W boson mass
5. UTOFTP (ERA-NET COFUND) Ultra-Time-Of-Flight Positron Emission Tomography with multi-channel Silicon photomultipliers and photonic crystals

+ many more initiatives at National (PRIN) and regional (Regione Toscana) level

Dual Master Program

- **Dual Master Diploma in Physics with ECOLE POLYTECHNIQUE**
  - Since September 2016 we started the double diploma in Physics between the UNIPI Physics Department and the l'Ecole Polytechnique nearby Paris. For UNIPI students, the agreement is based on an admission exam (foreign students). The study plan will last 6 years in total (3.5 in Pisa, 2.5 a X). At the end the student will be awarded the Laurea Triennale and Magistrale (UNIPI) and the Diploma D'Ingénier – Ingénieur Polytechnicien and Diplome de l'Ecole Polytechnique (Ecole Polytechnique).
- **Dual Master Diploma in Physics with SORBONNE UNIVERSITE'**
  - At the moment, it is mostly dedicated to Fundamental Interactions, Plasma Physics, Space and Laboratory. For UNIPI students:
    - Year I (UNIPI): basic formative courses (mandatory) + optional courses within the Study Plan indications.
    - Year II (SORBONNE): specific courses + French exams + Master Thesis
    - At the end the student will be awarded the Laurea Triennale and Magistrale (UNIPI) and Master Degree (SORBONNE).

- **Dual Master Diploma in Physics with Johannes Gutenberg Universität Mainz**
  - Brand new agreement stipulated in 2023. Similar agreement of the one with Sorbonne University.

Schools and Mobility

Summer student program with different options depending on the level of the students.
Long (>4 weeks) and Short (1 week) opportunity. This year:

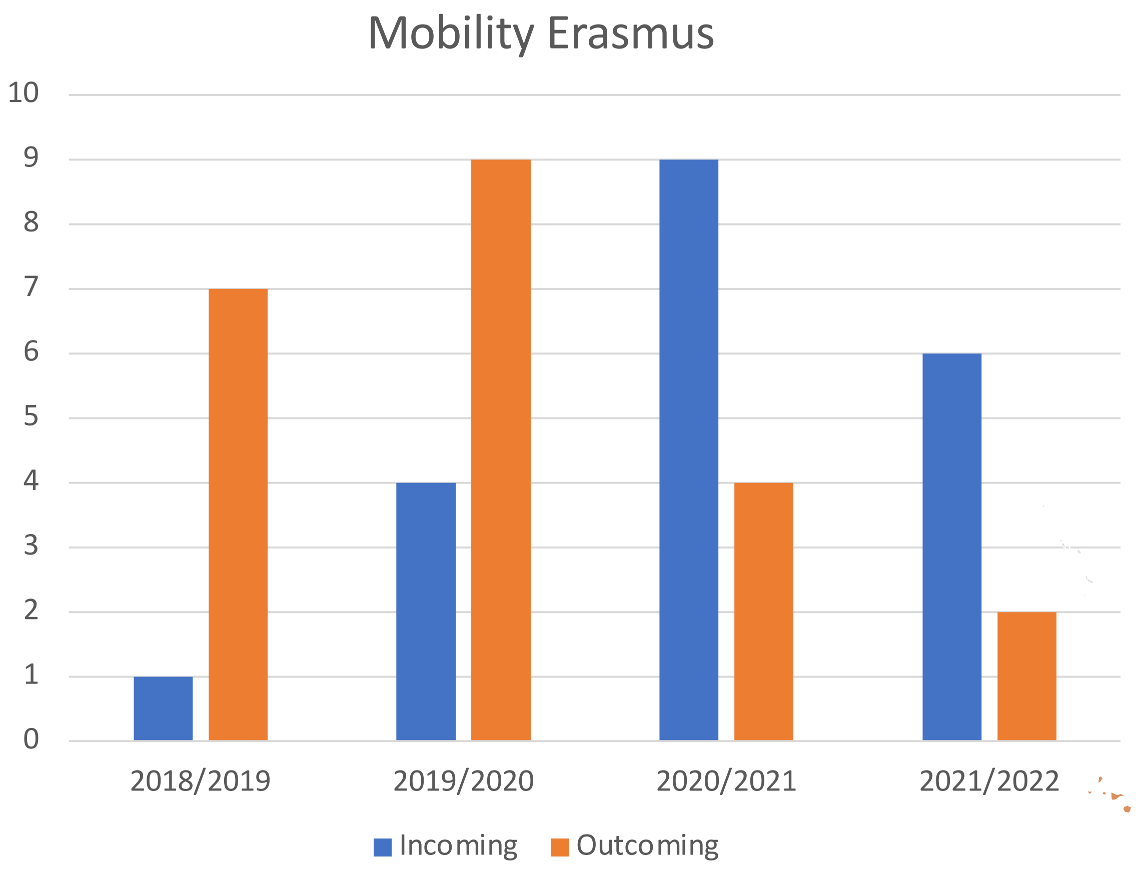
- 2D Quantum Matter (July 10 – 13, 2023)
- Summer Students at Fermilab and other International Laboratories (July 24–Sept 22, 2023)
- CERN OPENLab summer student program (July–Sept, 2023)

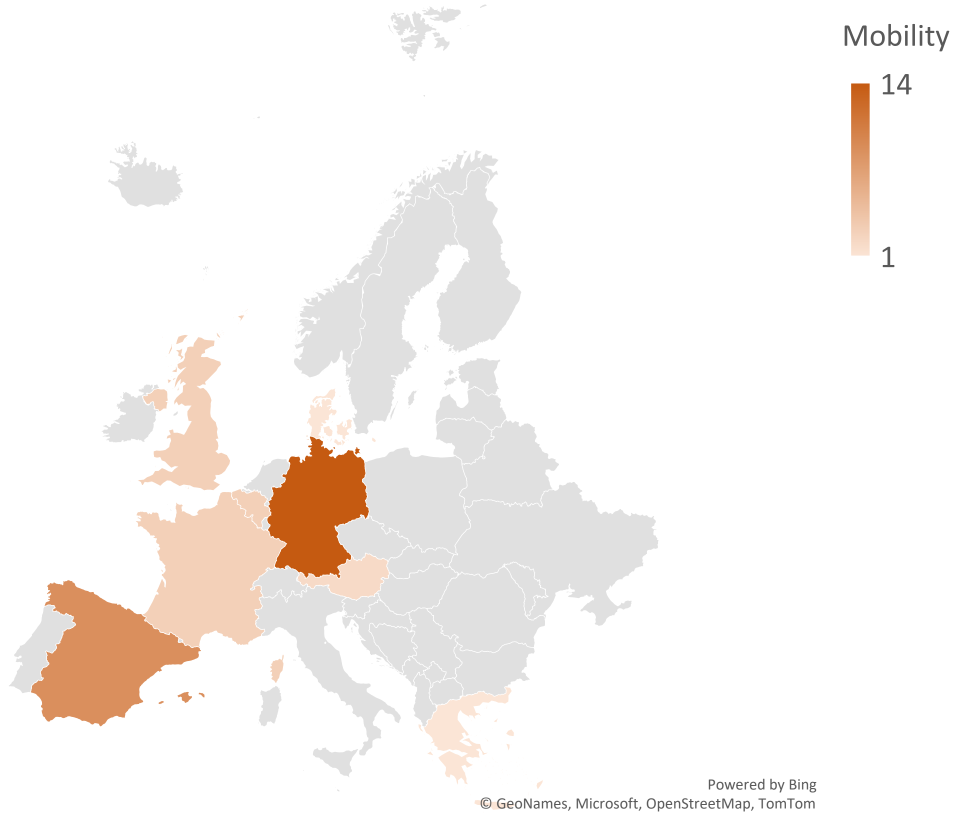
More information here

Physics Department strongly support the **Erasmus+** mobility program

Erasmus+

Erasmus in 2018-2022





Further Information

General Information on the Curriculum of the Master/Bachelor:
Teaching Coordinator: Dott.ssa Antonella Spinosa
Teaching Secretary: Roberta Giusti, Rossella Gargani
Coordinator of Physics Degrees: Prof.ssa Chiara Roda
(email: name.surname@unipi.it -> chiara.roda@unipi.it)

Help and support:
Teachers and assistants
Tutor Students

My mail: monica.verducci@unipi.it

THANKS!

MORE INFORMATION

Summer Schools (2022-2023)

2D Quantum Matter **(July 10 – 13, 2023)**

TOPIC: study of 2D materials such as graphene, transition metal dichalcogenides, and other graphene-related materials (state-of-the-art theory, synthesis, nanofabraction, and electronic/optoelectronic applications of 2D crystals)

TARGET: PhD and late-stage master students in Physics, Material Science and Engineering

AIM: to give an opportunity to interact with leading-edge scientists in the context of 2D materials and learn about subjects that are usually hardly touched during standard educational programs

Summer Students at Fermilab and other International Laboratories **(July 24–Sept 22, 2023)**

TOPIC: Train students in the Fermilab research groups (muon experiments Muon (g-2) and Mu2e, neutrino experiments, MicroBooNE, Icarus, SBND, DUNE, CMS, MuonCollider), Fermilab Accelerator Division and Scientific Computing Division and Superconducting Quantum Materials and Systems Center, and Space Science Laboratories in the United States

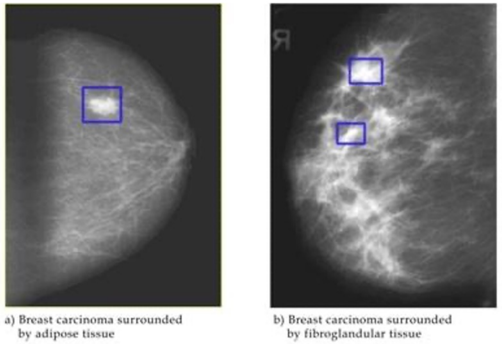
TARGET: Late-stage master students in Physics, Material Science and Engineering

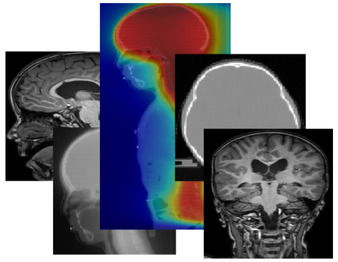
AIM: provide a 9-week hands-on training at International Particle Physics and Space Science laboratories in the United States

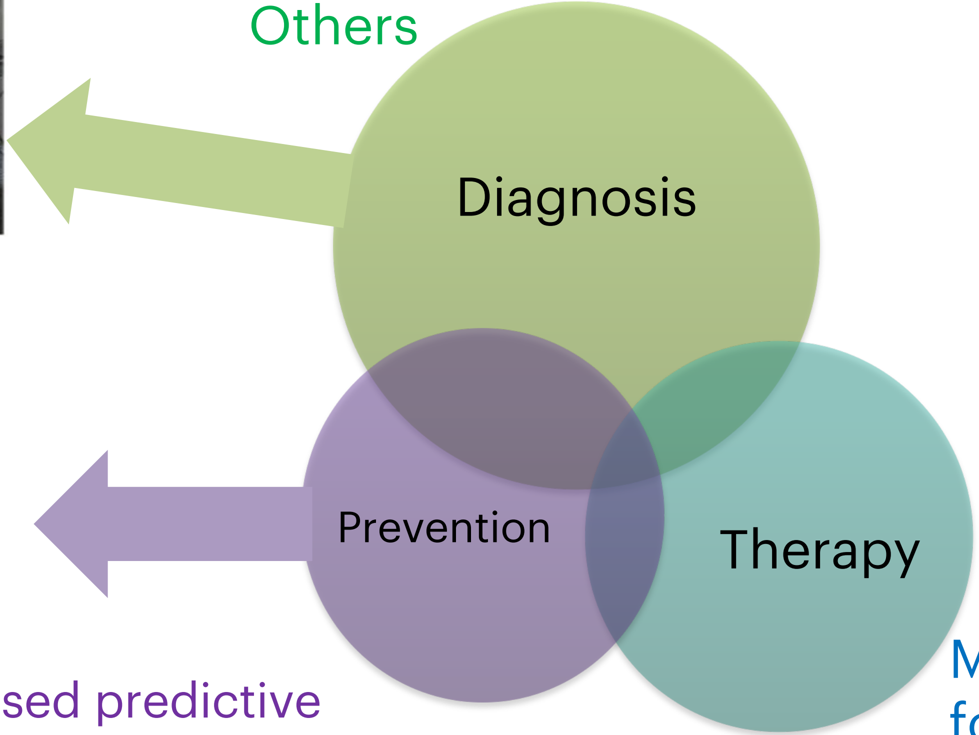
Medical Physics

Medical Physics is the application of physics to healthcare. The Medical Physics group in Pisa develops hardware and software tools for imaging, measurement and treatment.

Radiological imaging
Nuclear Imaging (clinical and preclinical)
Others







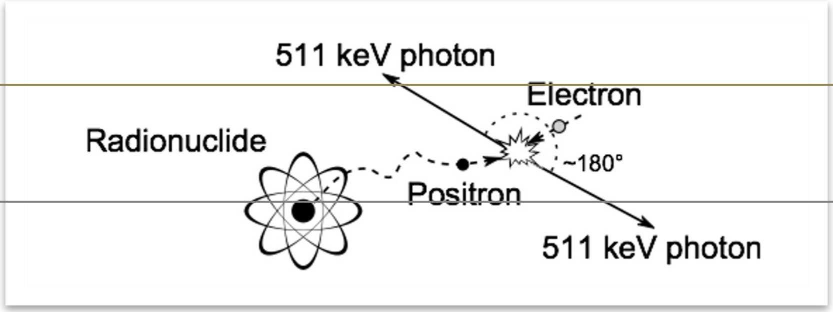
CAD systems for automatic detections of tumor masses and microcalcifications in mammography

Machine learning based predictive model through the analysis of imaging from CT, MR etc.

Monitoring and follow-up in hadrontherapy

UTOFPET: Ultra-Time-Of-Flight Positron Emission Tomography

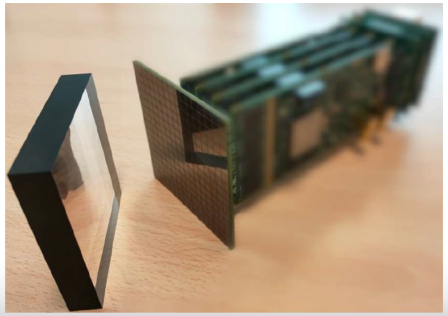
Positron emission tomography (PET) measures the activity distribution A(x,y,z) due to β+ emitters



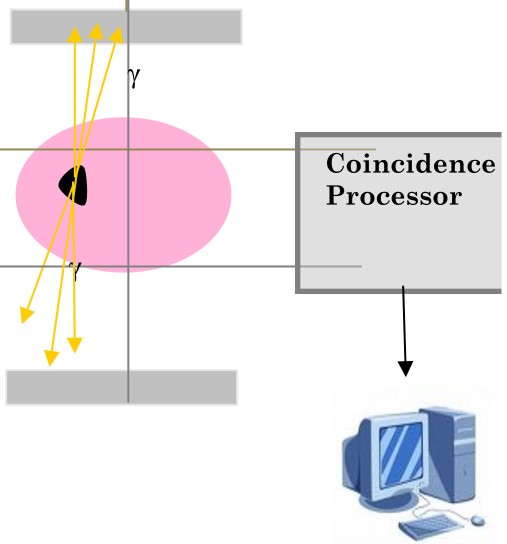
UTOFPET is a European project for the development of time-of-flight PET detectors with **ultra high time resolution**, thanks to the use of photonic crystals and artificial intelligence algorithms

UTOFPET

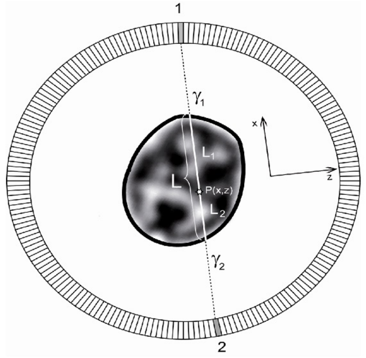
SEVENTH FRAMEWORK PROGRAMME



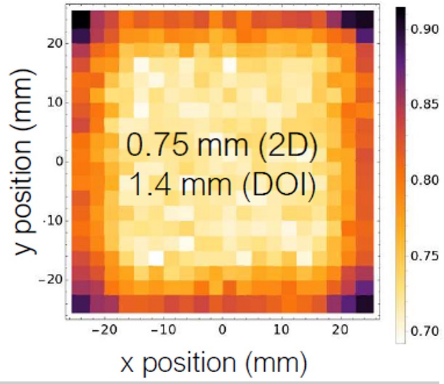
PET detector



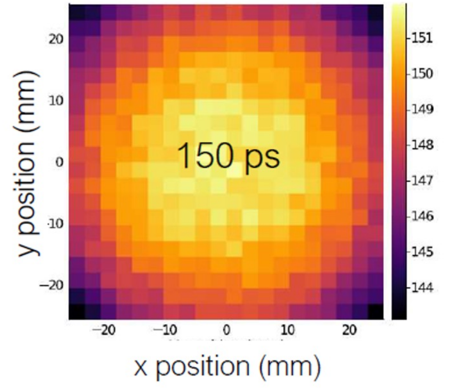
PET scanner



Spatial resolution (FWHM)



Coincidence time resolution (FWHM)

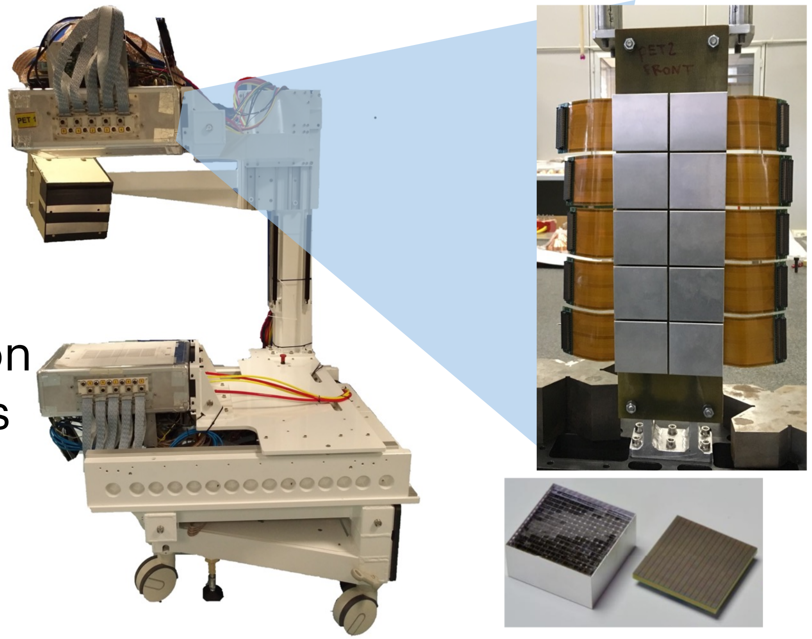


INSIDE: Innovative solutions for In-beam monitoring in Hadrontherapy

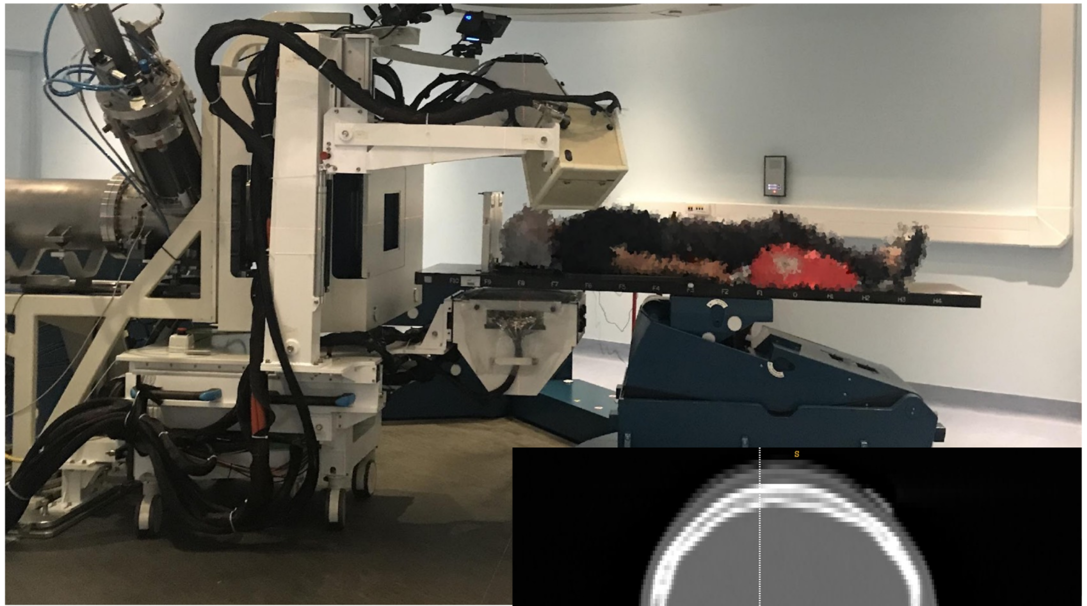
Hadrontherapy generates β+ emitters in the patients, eg.: $^{16}O\,(p,n)\,^{15}O$, $^{12}C\,(p,n)\,^{11}C$

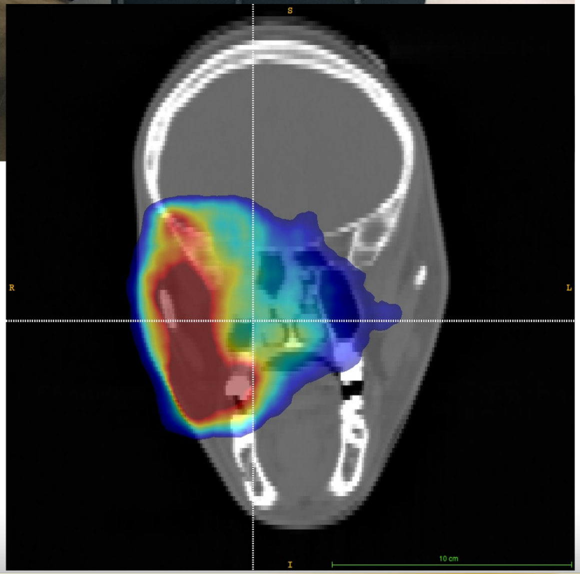
The compliance of the released treatment with the clinical prescription is performed measuring the induced activity using a PET scanner

2 × 5 array of detection modules (10 × 25 cm^2)



The PET scanner is mounted on a mobile support. The clinical feasibility and effectiveness of the method is under study in a clinical trial at **CNAO**



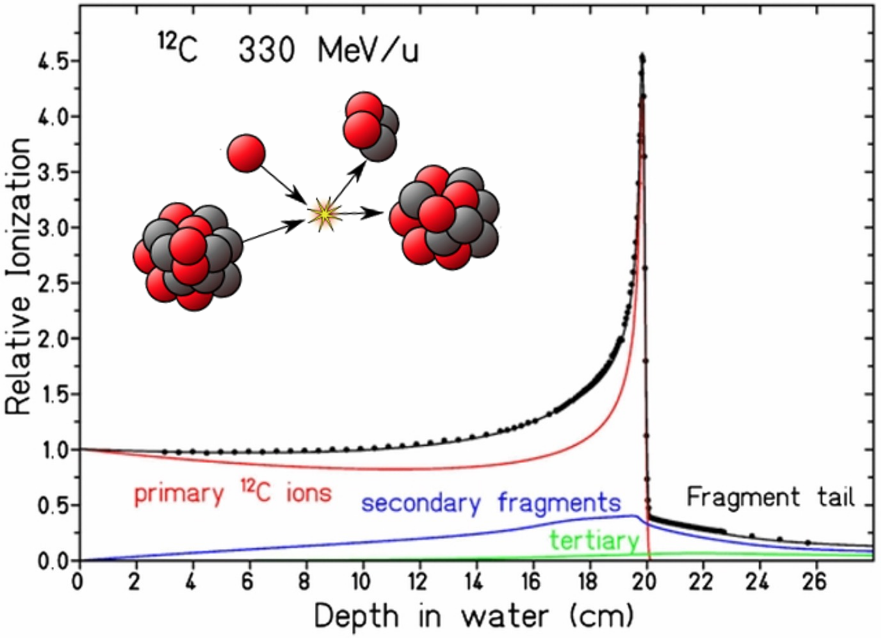


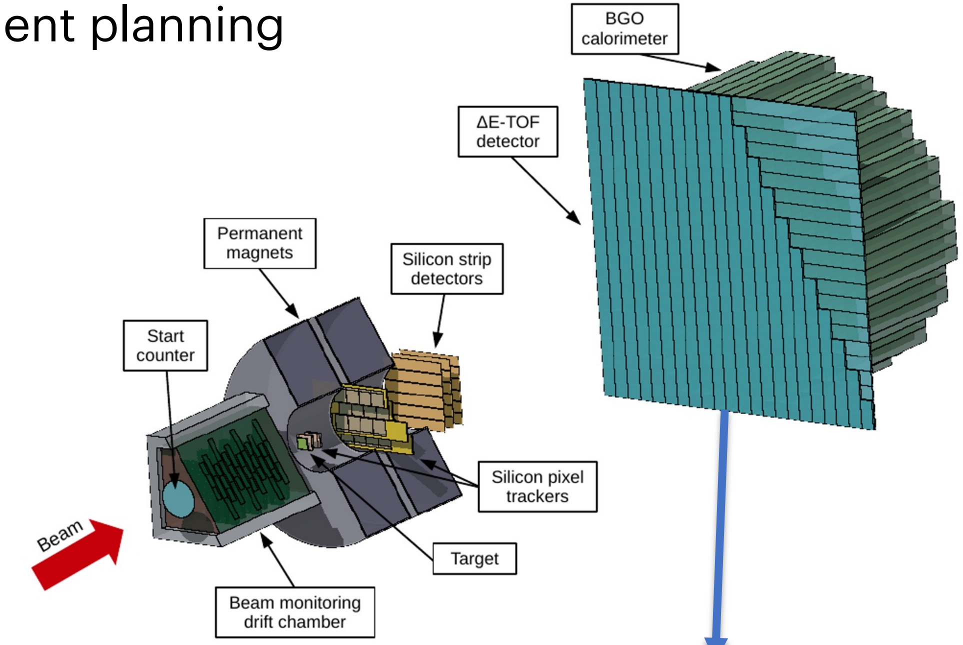
Measured induced activity distribution superimposed to the patient CT used for dose planning

Info: giuseppina.bisogni@pi.infn.it,

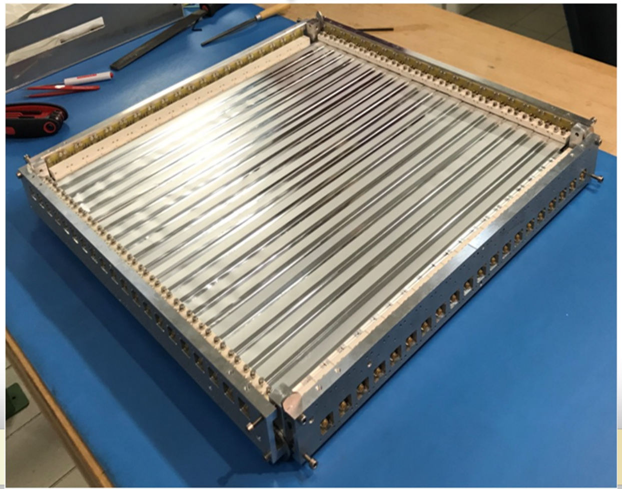
FOOT: FragmentatiOn Of Target

FOOT aims at measuring the double-differential fragmentation cross-section for therapeutic beams and ions composing the human body, to improve treatment planning





The INFN section of Pisa has developed the TOF-Wall detector, which measures the fragment time-of-flight and energy deposit to identify its charge Z.



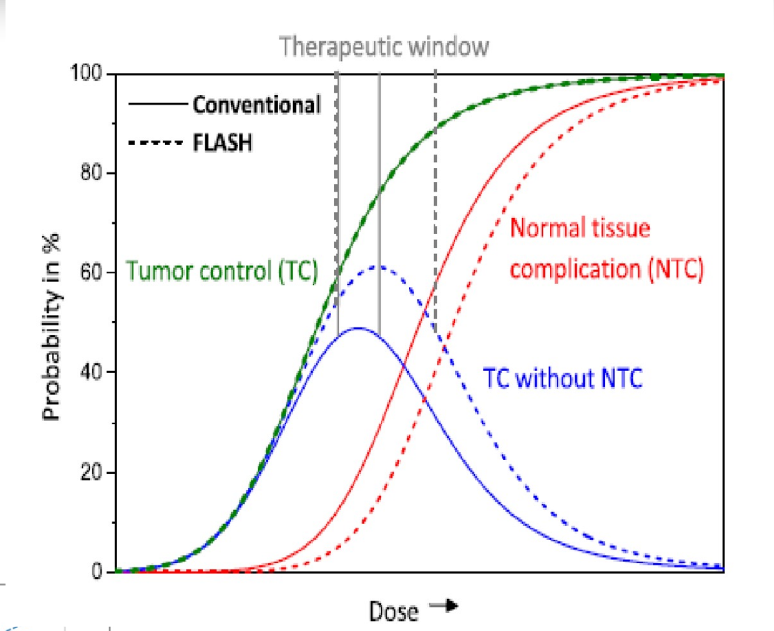
The current energy resolution σ_E / μ_E is 4%-6% and the TOF-Wall contribution to the TOF system time resolution is 20-25 ps (σ) for carbon ions and 80-100 ps for protons.

Info: matteo.morrocchi@pi.infn.it, https://web.infn.it/foot/en/home/

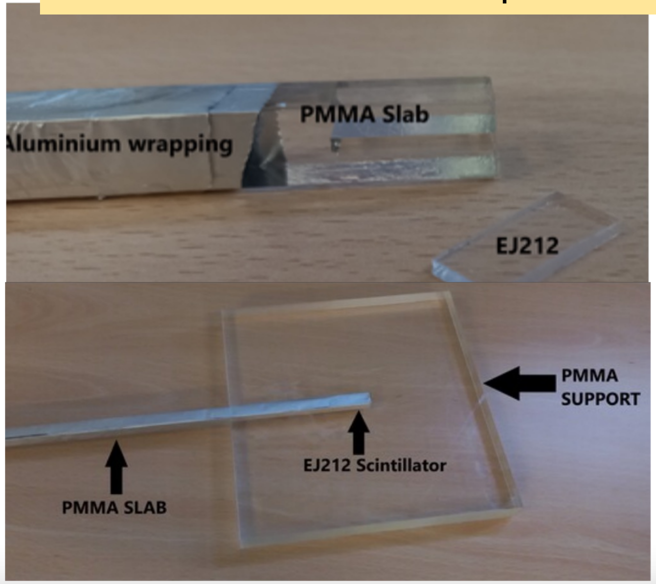
FRIDA: Flash Radiotherapy with hIgh Dose-rate particle beAms

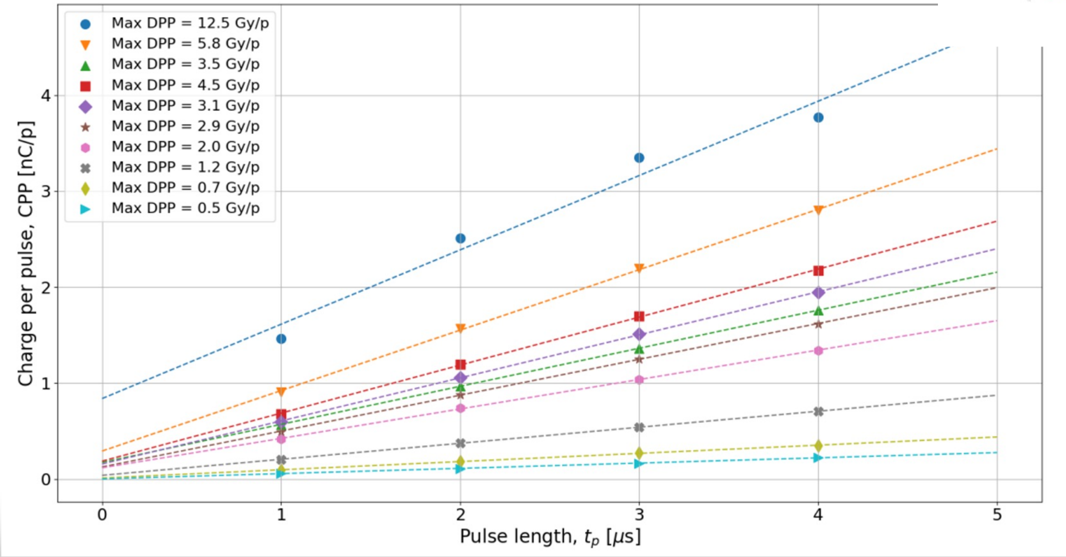
FRIDA studies all aspects of the **FLASH effect** in radiotherapy: delivering dose in less than 200 ms at a rate higher than 40 Gy/s, the **effect on the tumor** is **unchanged** while the **damage** to the tissue is **reduced** with respect to conventional radiotherapy

The INFN Pisa is developing 1D, 2D, and 3D FLASH dosimeters using plastic scintillators coupled to optical fibers. Tests are ongoing at **CPFR** in Pisa (Centro Pisano Flash RadioTherapy)



Plastic scintillator response to different dose-per-pulse levels





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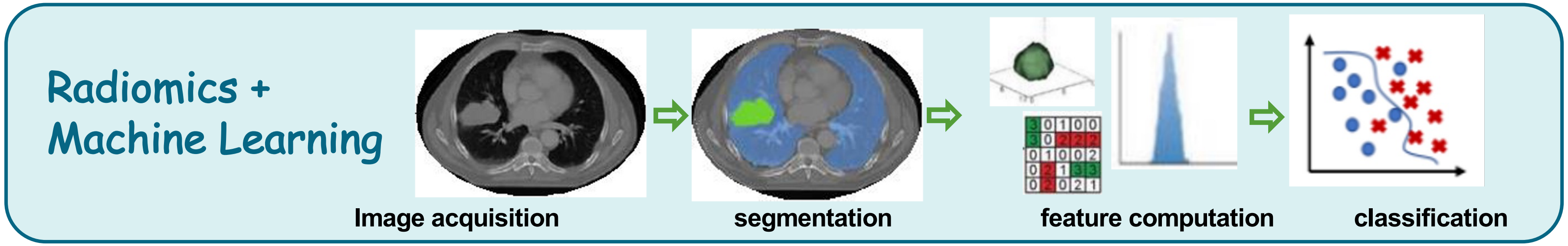
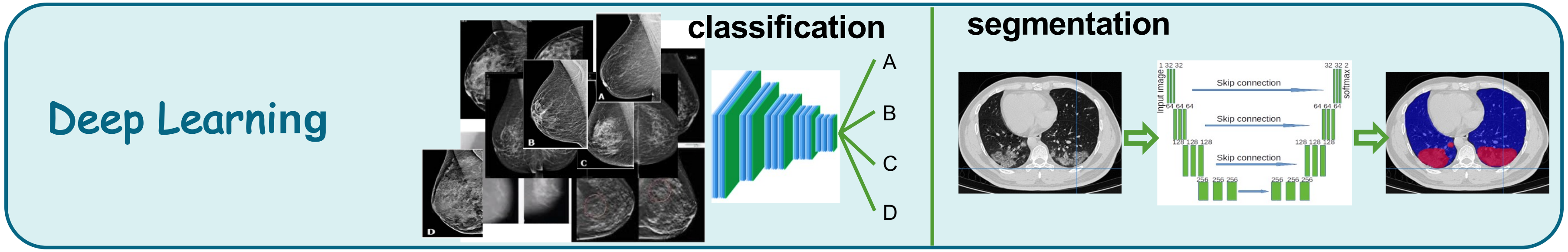
AIM: Artificial Intelligence in Medicine

Artificial Intelligence is to become the next revolution in **medical diagnostics** and **therapy**.

- New image processing and data analysis strategies need to be developed and extensively validated.
- They include Radiomics + Machine learning approaches, or direct image analysis via Deep Learning





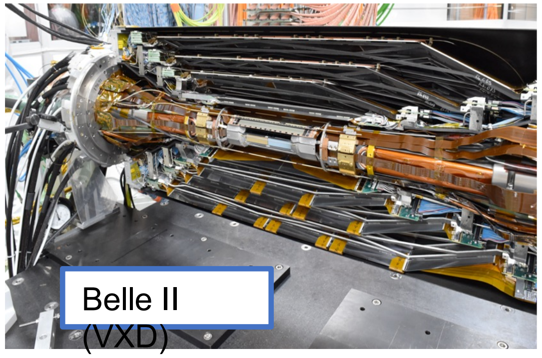
Info: alessandra.retico@pi.infn.it, https://www.pi.infn.it/aim

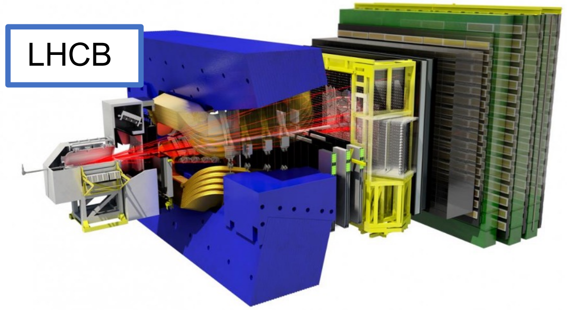
Fundamental Interactions

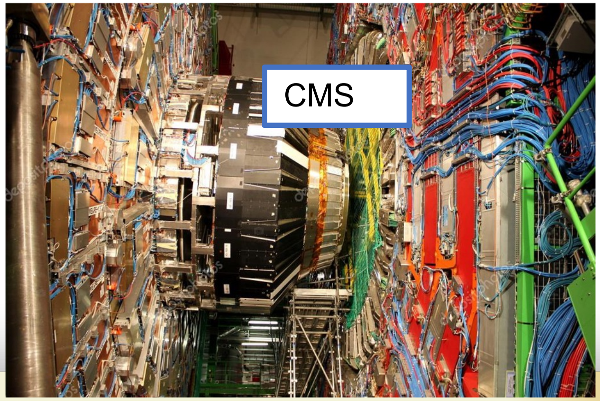
A. Research based on particle accelerators, with experiments focused on the test of the Standard Model, the measurement of its free parameters and the search for new physics phenomena:

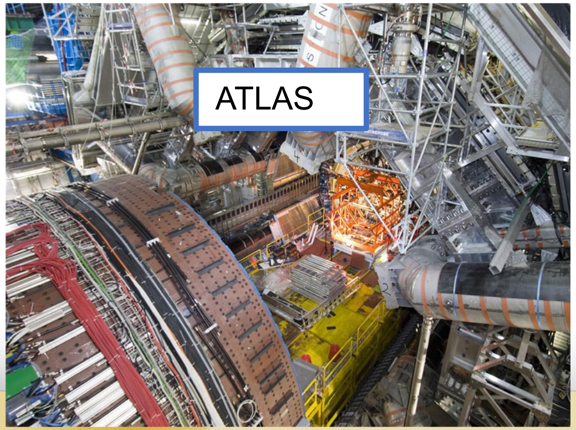
- research at energy frontier, both through direct production of new particles, and indirectly through precision measurements (ATLAS, CMS, TOTEM at CERN);
- research at the intensity frontier in processes changing the hadronic flavor at hadron or lepton colliders (LHCb at CERN, BELLE-II at KEK) and in fixed-target reactions (NA62 at CERN);
- research at the intensity frontier in lepton-flavour violating processes (MEG at PSI, Mu2e at Fermilab), and precision measurements of static properties of the muon (muon g-2 at Fermilab)

Experimental and phenomenological characterization of forces between elementary particles in nature. Research in strong connection with INFN (National Institute for Nuclear Physics).









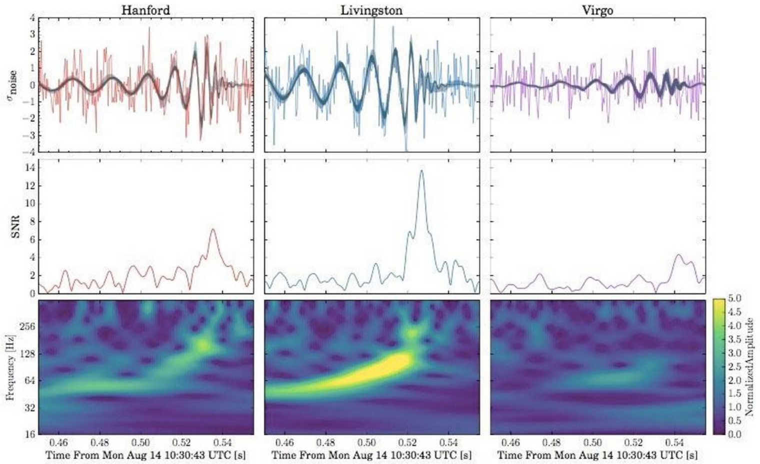
Fundamental Interactions

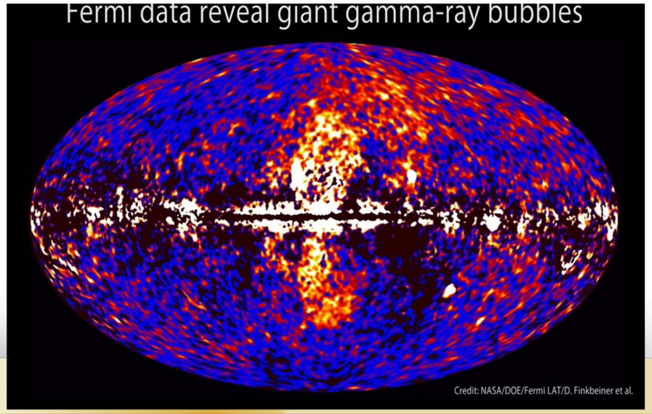
B. Research based on cosmic radiation in underground laboratories, high atmosphere or space, focused on the search for new astrophysical phenomena or issues related to cosmological-scale processes:

- experiments on charged cosmic radiation (CALET, MAGIC, AMS-02), electromagnetic radiation (CTA, FERMI), including polarization studies (IXPE, e-XTP and neutrinos of astrophysical origin (Km3NET);
- measurement of the properties of the cosmic background radiation (LiteBIRI LSPE);
- direct search of dark matter (Darkside) and of exotic particles of cosmic relevanc such as axions (QUAX, STAX, AXIOMA);
- Gravitation physics research, through direct detection of gravitational wave (VIRGO, Einstein telescope) and tests of general relativity (GG, GINGER, MAGIA).

C. Cross-field research and development activities:

- innovative detection techniques,
- instruments for data selection and acquisition in extreme conditions in terms of environment or performance,
- advanced techniques for data analysis
- instruments focused on technological applications





Teaching Activity in Medical Physics

- **Medical Physics I** (Physical foundations of the diagnostics and therapy methods, detectors, electronics, software, radiography, positron emission tomography, nuclear magnetic resonance, radiotherapy)
- **Medical Physics II** (nuclear and molecular imaging, optical imaging, tomographic images reconstruction, radiotherapy with charged particles)
- **Medical Physics Laboratory** (use and characterization of basic detection systems used in medical physics)
- **Dosimetry** (dosimetry of ionizing radiation, dosimetry in radiotherapy, radiodiagnostic and in radioprotection)
- **Nuclear Magnetic Resonance** (classical and quantum nuclear magnetic resonance, 3D tomography with magnetic resonance for "in-vivo" imaging)
- **Computing methods for experimental physics and data analysis** (programming tools for experimental physics for particle physics and medical physics)
- **Physiology, physiopathology and diagnostics** (biomedic diagnostics, clinical applications, bioelectric signals, nuclear medicine, magnetic resonance imaging)
- **Biophysics** (cell biophysics, spectroscopic, microscopic and molecular dynamics techniques)
- **Biorobotics and complex systems** (smart materials, simulation of biological systems)

Several courses for the SSFM

Specialization **S**chool in **M**edical **P**hysics is a three-year postgraduate course that allows physicists to get the required qualification to work in the National Health System

The Physics Department hosts the SSFM

Teaching Activity in Astrophysics

- **Astrophysical processes** (radiative transfer and spectral formation, hydrodynamics applied to astrophysics, accretion and outflow phenomena)
- **Stellar Physics** (stellar structure and evolution, theoretical procedures for the analysis of stars in Galactic and extragalactic clusters and field stars)
- **Observational astrophysics** (laboratory experiences and theoretical lessons for the observational analysis of astrophysical processes, e.g. photon detection and calibration, photometry, polarimetry and spectro-polarimetry, analyses of space based and ground based archival data)
- **Black holes** (Schwarzschild and Kerr metrics, quasi normal modes, gravitational waves from binary black holes, accretion physics)
- **Physics of the cosmic diffuse medium** (physics of the interstellar and intergalactic medium taking into account the ionized, atomic and molecular phases)
- **Introduction to Bayesian probability theory** (derivation of the Bayes theorem, parameter evaluations and hypothesis testing)
- **Extragalactic astrophysics and cosmology** (cosmology, galaxy evolution, galactic structure, galactic dynamics, chemical evolution of galaxies, star formation history of stellar populations)
- **Planetary systems** (planetary dynamics, atmospheres of exoplanets (spectra, magnetosphere, stellar winds etc..), internal structure of rocky and Jovian planets, formation of planets, comparative planetology of the solar system)
- **Physics of the atmosphere** (atmospheric structure and variability, barotropic and baroclinic atmospheric dynamics, cyclic climate variability, applications to climate change, applications to non-terrestrial and exoplanet atmospheres)
- **General Astrophysics** (general introduction to the interstellar medium, stars and stellar evolution, compact objects, the Milky Way and external galaxies; the course is aimed at non-astrophysics students)

Teaching Activity in Fundamental Interactions

- **Fundamental Interactions** (provide a quantitative Introduction to particle physics and their interactions; Particle classification; Symmetries and conservation laws; Weak interactions and hadronic processes; Measurement techniques)
- **Fundamental Interactions Laboratory** (Observation of cosmic rays, measurement of the flux and angular distribution; Measurement of the Rutherford and Compton differential cross section; Observation of electron-positron annihilation; Measurement of the muon lifetime; Observation of parity violation in weak interactions)
- **Elementary Particle Physics** (Electromagnetic interactions; Hadronic interactions, quark model, chiral symmetry and QCD; Electroweak unification, Higgs mechanism, Standard Model; Flavour physics for qurks and leptons, neutrino oscillations, CP violation; W, Z and Higgs boson phenomenology; Axions, Grand Unification, Supersymmetri, Dark Matter)
- **Astroparticle Physics** (Phenomenology of Cosmic rays; Sources of acceleration of cosmic rays; Stellar fusion reactions; Neutrino emission from ordinary stars; Solar neutrinos detection; Supernovae; Atmospheric neutrinos and their detection; Introduction to cosmology; Candidates for dark matter; Experimental detection of dark matter with direct and indirect methods)
- **Gravitational Wave Physics** (Theory and characteristics of Gravitational Waves; Sources; Interferometric detectors; Data analysis)
- **Particle Accelerators** (physical mechanism that determine the particle motion; basic components of an accelerator)
- **Instrumentation for Fundamental Interaction Physics** (Advanced instrumentation for ionizing radiation) Application in nuclear and particle physics; Modern sensor technologies and detector systems)
- **Statistical Analysis of Data** (Theory and applications)

Teaching Activity in Fundamental Interactions

- **Computing methods for Experimental Physics and Data Analysis** (python programming; parallel computing, GPU; Deep learning; computing in HEP; Image processing in Medical Physics)
- **Discrete Symmetries** (Violation of the P, C, T, CP, CPT symmetries and conservation of the leptonic and barionic number)
- **Hadron Collider Physics** (Recent developments in particle physics though the study of proton-antiproton and proton-proton collisions at CERN and Fermilab)
- **Recent Highlights in Fundamental Interactions** (Monographic course: Dark Matter searches; astronomic evidence; Galactic rotation curves; Baryonic Dark Matter; Modified gravity; Particles and Dark Matter, Dark matter and cosmology; Dark matter searches)
- **Introduction to Neutrino Physics** (neutrinos from beta decays; experimental evidence for three neutrino types; Neutrino helicity; cross sections of charged and neutral current neutrino interactions; Neutrino oscillations; Experiments with neutrinos with accelerators, nuclear reactors and atmospheric and solar neutrinos; Direct mass measurements; Neutrinos in astrophysics and cosmology)
- **Experimental Methods for Astroparticle Physics** (Experimental techniques for astrophysics observations with a Multi-messenger approach; Measurements of fluxes, spectra and position of astrophysics sources)
- **Monte Carlo Methods for Experimental Physics** (Mathematical foundations and statistical methods for Monte Carlo simulations; hands-on training on High Energy Physics problems)

Teaching Activities In Physics Matter

- **Solid State Physics**: quantitative crystal geometry, direct/reciprocal lattices, particles scattering by crystals; Sommerfeld theory of metals, electron gas in magnetic field; Band theory and k-space methods; Interacting electronic-nuclear systems and the adiabatic principle; Optical properties of metals; transport in intrinsic and homogeneously doped semiconductors.
- **Fundamentals of radiation-matter interaction**: Semi-classical theory of interaction; Quantum theory of the EM field (vacuum, non classical states, "dressed states", photon statistics, interactions); Coherence and correlations; detection, photon counting, fluctuations; Collective phenomena; Lasers; Nonlinear optics.
- **Laboratory Experiments**: Static holography, Dynamic holography, Optical fibers, Microlithography, Microfluidics.
- **Condensed Matter Physics**: Theoretical Physics relevant for studying condensed matter systems: linear-response theory, diagrammatic perturbation theory, and Landau theory of normal Fermi liquids; semiclassical Boltzmann transport theory and Landauer-Büttiker theory; Physics of the fractional quantum Hall effect; Sachdev-Ye-Kitaev model
- **Complex systems**: Brownian motion, stochastic differential equations (theory and simulations); Stable distributions (fat tails); Caos (deterministic systems and dissipative systems), turbulence, fractals; Clusters analysis, random matrices; Applications to econophysics, liquid states, plasmas, climatology.
- **Disordered systems**: Description and interpretation of disorder in liquids, glasses and polymers; Dynamics and thermodynamics of non equilibrium states in passive and active matter; Experimental techniques for the study of disordered systems.
- **Quantum computing and technologies**: Quantum circuits. EPR entangled states. Bell inequality. Classical Turing machines and physical implementation of quantum computers: optical photons, ion traps, entangled photons, nuclear magnetic resonance. Analysis of Bell states. Dense coding. Notions of Quantum Teleportation and Cryptography
- **Plasma physics**: Description Space and Laboratory plasmas; Dynamics of a complex systems (Space plasmas, turbulence in fluids, astrophysics, thermonuclear fusion).
- **Numerical methods**: Markov chain Monte Carlo and applications to statistical mechanics; Renormalization group of the density matrix; Tensorial networks; PDE (parabolic, hyperbolic); DFT (ab initio) calculations; Molecular dynamics.
- **Biorobotics and Complex Systems**: Smart materials, simulation of biological systems.

+many more…

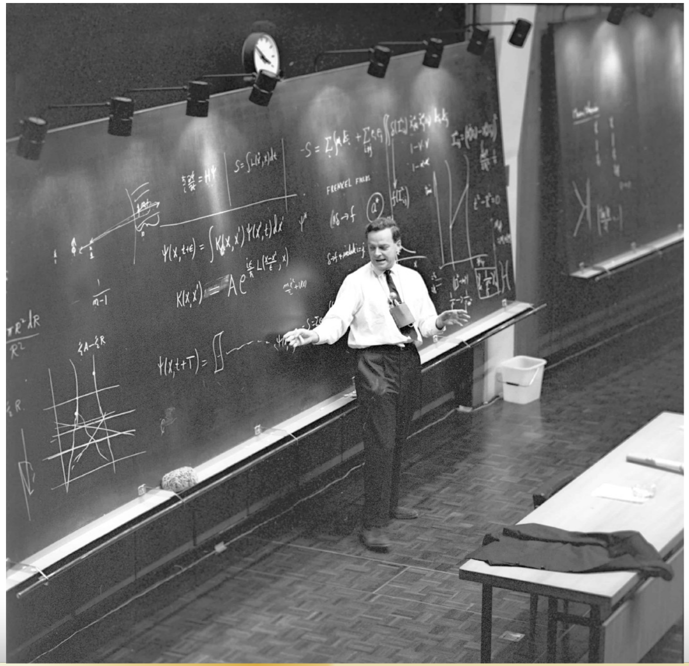
Teaching activity in Theoretical Physics

Basic courses in theoretical physics

- Theoretical physics I-II (scattering, quantum field theory, path integral, gauge theories, …)
- General relativity (geometry of space-time, gravitational waves & cosmology, …)
- Statistical Physics (classical & quantum phase transitions, critical phenomena, …)
- Numerical methods for physics (Monte Carlo, exact diagonalization, DMRG, …)

More specialized courses

- Quantum chromodynamics (QCD)
- Cosmology of the first universe
- Gravity theories
- Nuclear physics
- Compact stars
- Quantum fields and topologies
- Nonperturbative aspects of quantum mechanics



Bachelor Degree UniPi

First Year(60 CFU)

Fisica 1 (15 CFU)

Lab 1 con elementi di computazione (15 CFU)

Analisi matematica (15 CFU)
Geometria e algebra lineare (12 CFU)

Prova di Lingua inglese B2 (3 CFU)

Second Year (57 CFU)

Fisica 2 (15 CFU)
Meccanica Classica (12 CFU)

Lab 2 (12 CFU)

Complementi di Analisi (6 CFU)
Metodi Matematici (6 CFU)

Chimica Generale (6 CFU)

Third Year (63 CFU)

Meccanica Quantistica (15 CFU)
Struttura della Materia (6 CFU)
Fisica 3 (9 CFU)

Corso di Laboratorio a scelta (12 CFU)

Metodi Matematici 2 o in alternativa Informatica (6 CFU)

Free Credits (12 CFU)
Final Exam (3 CFU)

In the third year the student can choose some exams depending on the CFU [CFU: credito formativo universitario]