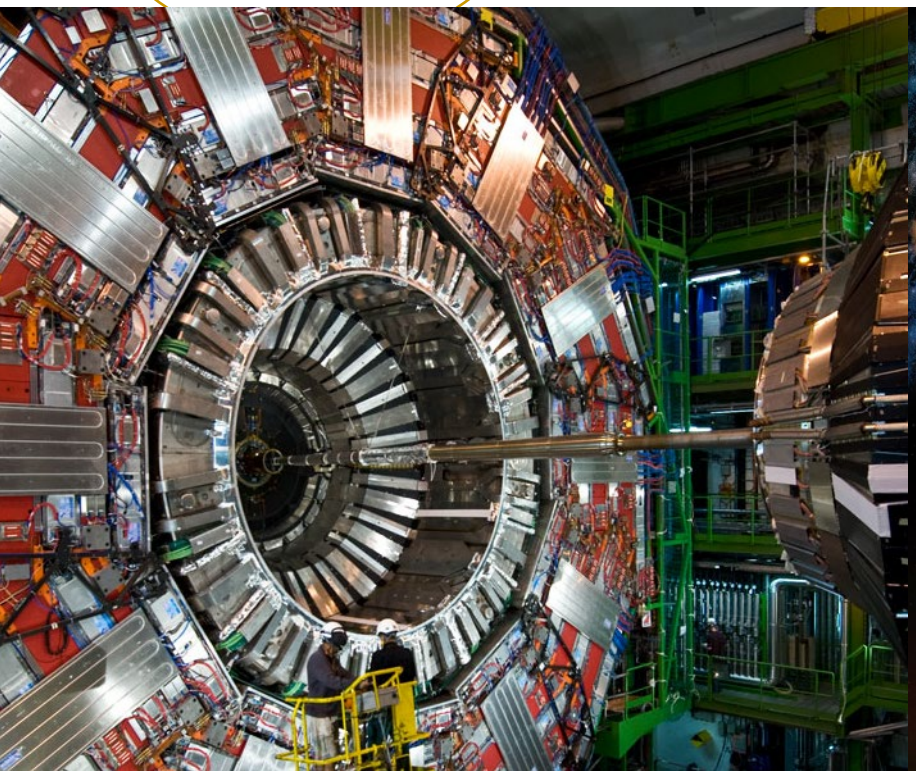
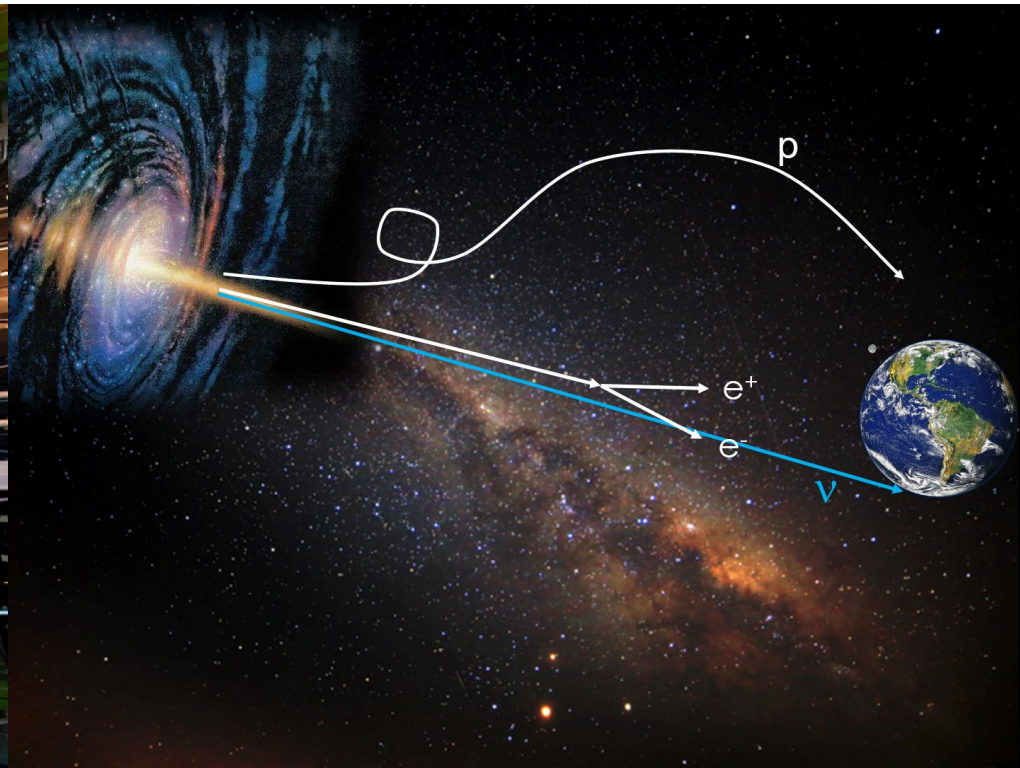
Riccardo Paramatti
Università Sapienza and INFN Roma
Aula Amaldi - 24/9/2021

Particle and Astroparticle Physics Curriculum (LM-17)



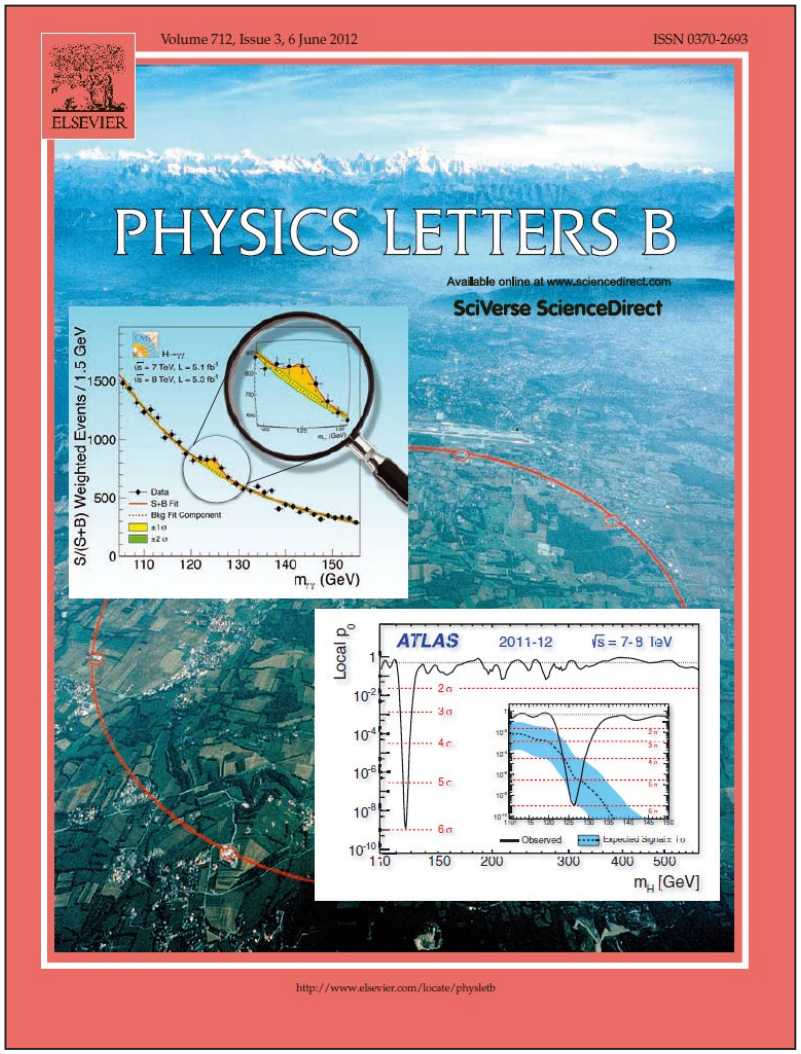


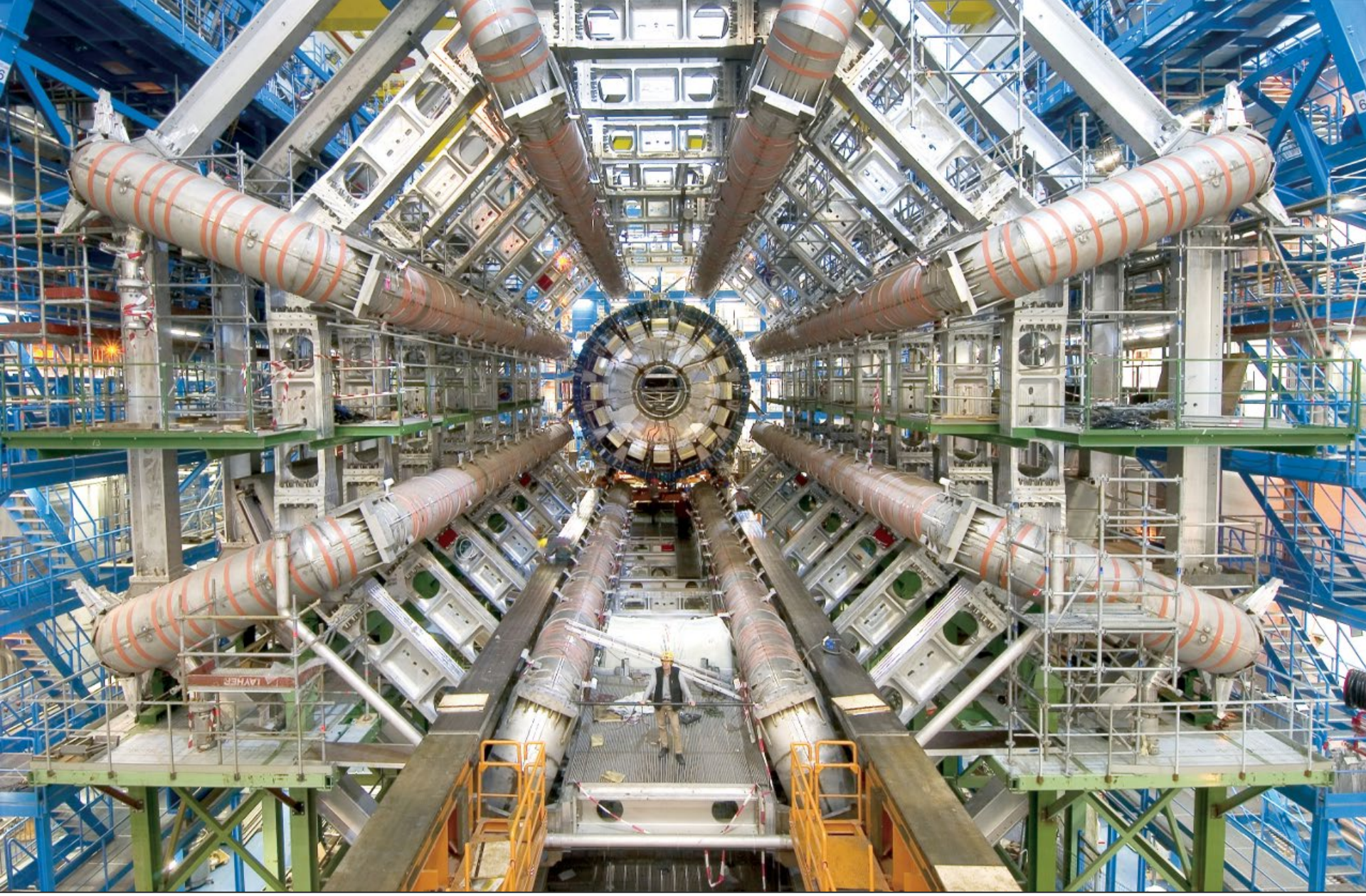
Let's start with two recent Nobel Prizes in Physics

- 2013 Nobel in Physics to P. Higgs and F. Englert after the discovery of the Higgs Boson by Atlas and CMS Collaboration.
- 2017 Nobel in Physics to R. Weiss, B.C. Barish and Kip S.Thorne after the first ever detection of gravitational waves by the LIGO/Virgo Collaboration.

Several courses of the Particle and Astroparticle Physics curriculum are given by researchers of the Sapienza Physics Department who are members of the mentioned experimental collaborations and directly contributed to these fundamental discoveries.

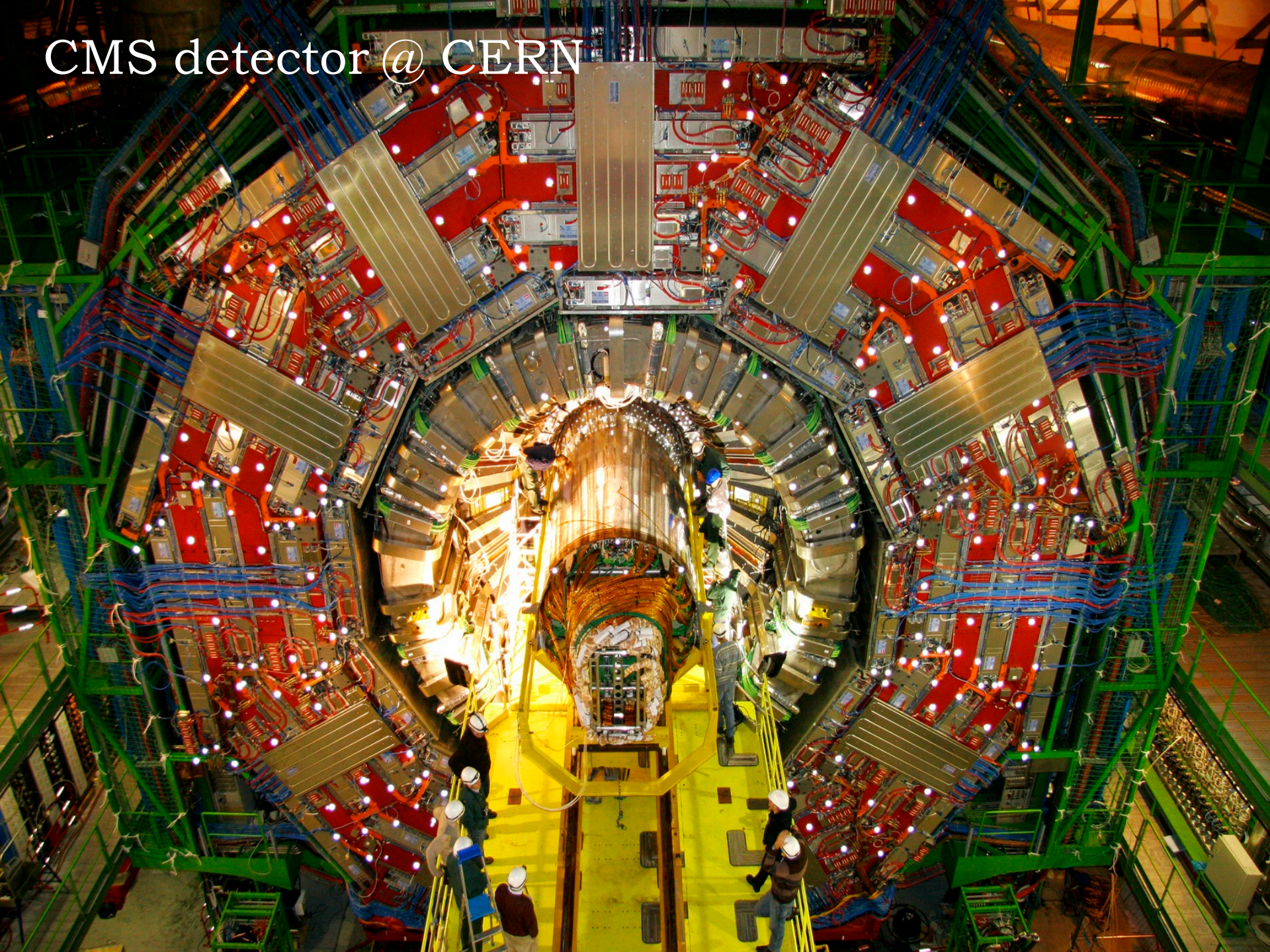
4th of July 2012: Cern announce the discovery of the Higgs Boson





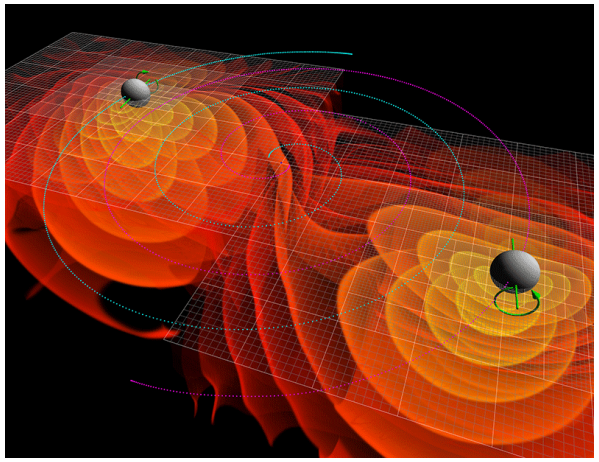
ATLAS detector @ CERN

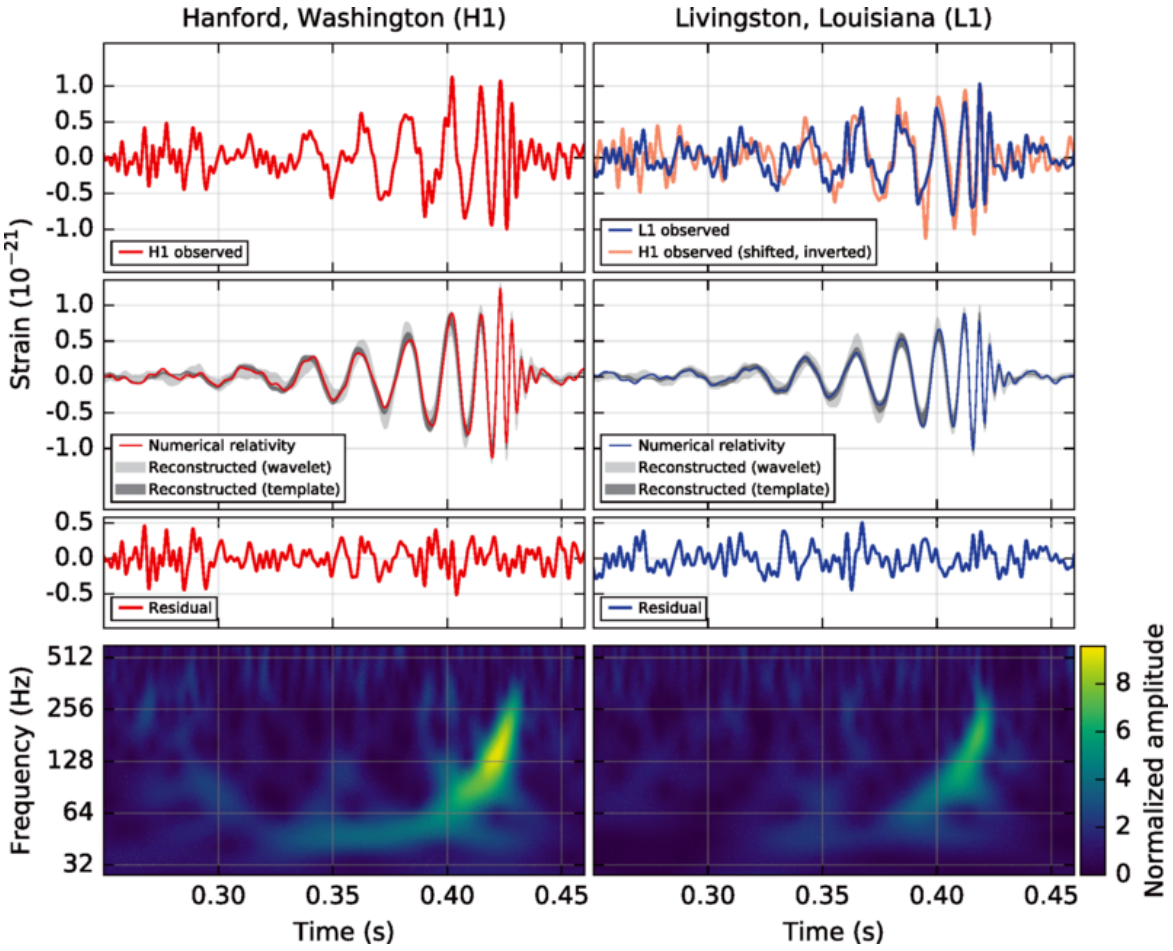
CMS detector @ CERN



14th September 2015: first direct detection of gravitational wave.

The event GW150914 is the merging of two black holes, about 30 solar masses each, at a distance greater than one billion light years.

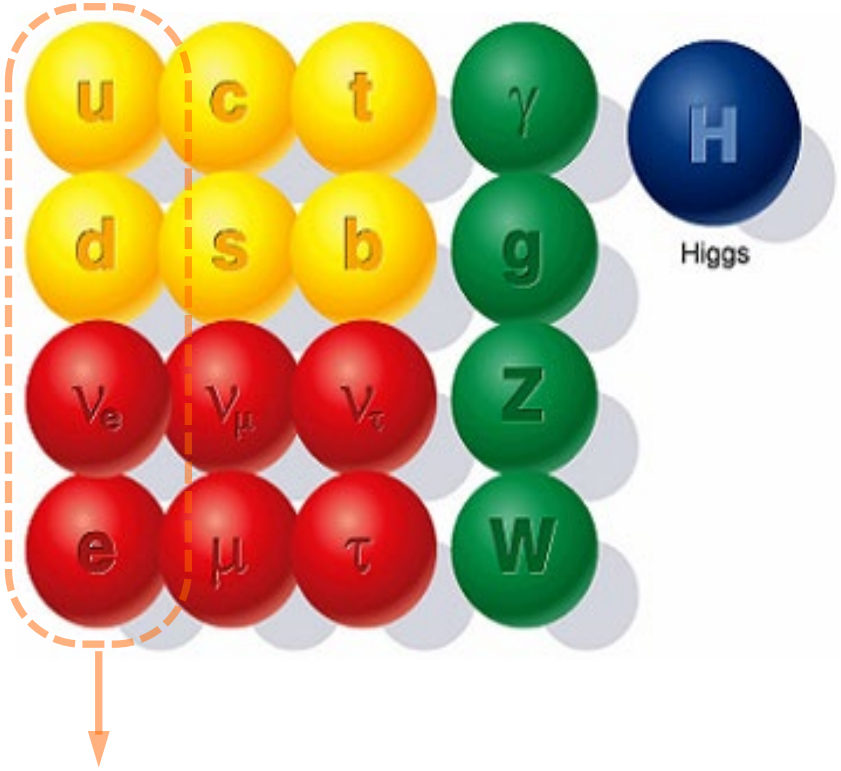




Virgo Interferometer

The Standard Model

- All the (known) elementary particles and interactions are described in a beautiful theory called the Standard Model.
- Particles of matter exist in three different families.
- For any particle of matter there is a corresponding anti-matter particle.
- The Standard Model is not the full history.
  - For instance, what about the gravitational interaction and its mediator ?

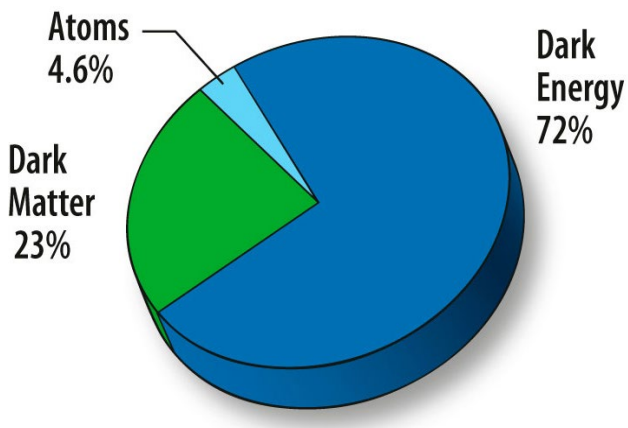


All the matter around us (atoms, molecules, planets, stars,..) is made of first family particles.

There are still many unanswered questions…

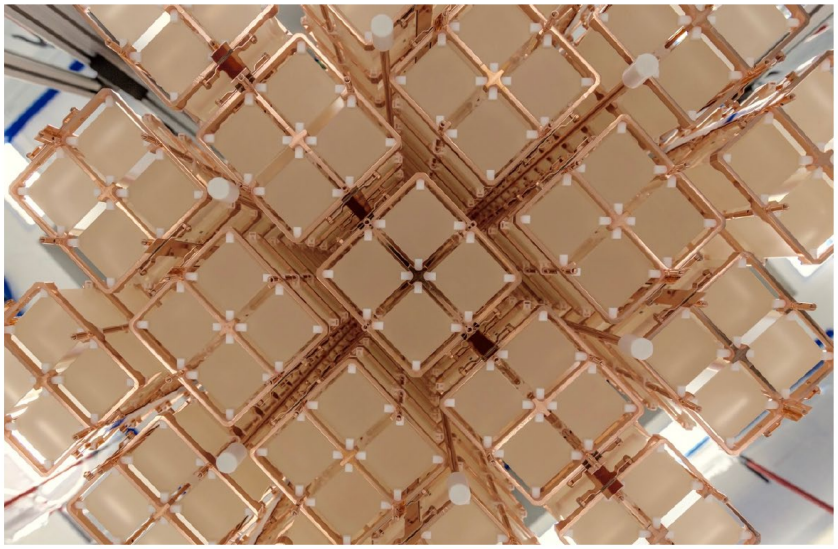
… (and many future Nobel prizes) in the study of basic constituents of matter and their interactions.

- Why just three families of leptons and quarks ?
- Why, in the universe, matter is strongly dominant on anti-matter ?
- How is gravity connected to the other forces ?
- Is the neutrino a Majorana or a Dirac particle ? Which is its mass ?
- What is the dark matter ? And the dark energy ?



You will learn about the instruments to answer all these questions!

- Particle accelerators
- Particle and heavy ions detectors
- Neutrino detectors
- Neutrino telescopes
- Cosmic ray experiments
- Gravitational wave detectors

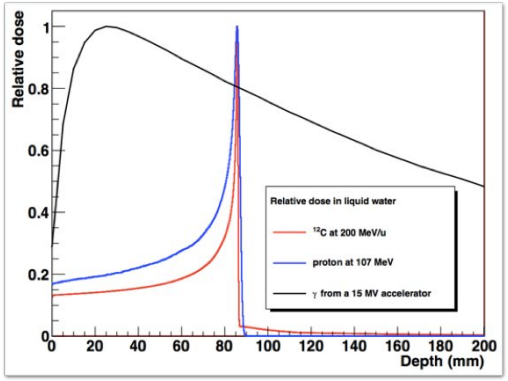


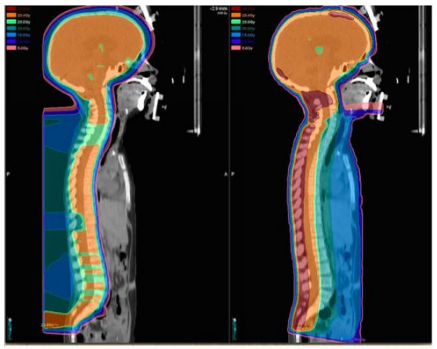
CUORE at Gran Sasso INFN Lab.
Neutrinoless Double Beta Decay

Intense use of advanced statistics tools, multivariate analysis and machine learning techniques

Applied research: medical application of physics

- The competences acquired in detector design and construction, in statistical analysis and the knowledge of particle and nuclear physics are exploited for several applications, mostly medical.
- Applied Radiation Physics Group (Physics and SBAI departments) is active on:
  - estimation of the dose delivery in Hadron Therapy
  - development of a novel technique of Radio-guided Surgery
  - and much more…





Particle and Astroparticle curriculum in Physics (LM-17)

- The Particle and Astroparticle (PAP) curriculum of LM-17 is taught in English.
  The aim is twofold:
  - facilitate the entry in the research field
  - allow foreign student attendance
- Excellent opportunity to complete the master degree with a thesis project in an international laboratory in the world.

- A.A. 2021/22: renovated curriculum.

Particle and Astroparticle curriculum in one slide

Corso di laurea in Fisica (LM-17) - Curriculum Particle and Astroparticle Physics							
N.	**Insegnamenti**	**CFU**	**anno**	**sem.**	**SSD**	**eng**	**ambito**
1	**Introduction to Quantum Field Theory**	6	1	1	FIS/02	Y	caratt.
2	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
3	Physics Laboratory I (propedeutic teaching to Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
4	Electroweak Interactions	6	**1**	**2**	FIS/02	Y	caratt.
5	**Group Theory in Mathematical Physics**	6	1	2	MAT/07	Y	aff.-int.
6	Particle Physics	6	1	2	FIS/04	Y	caratt.
7	Physics Laboratory II	9	1	2	FIS/01	Y	caratt.
8	English language	4	1	2		Y	AAF
9	Elective (within group A)	6	**1 / 2**	**1 / 2**	FIS/01	Y	caratt.
10	Elective (within group B)	6	**1 / 2**	**1 / 2**		Y	aff.-int.
11	Elective (within group B)	6	**1 / 2**	**1 / 2**		Y	aff.-int.
12	Elective (free choice)	6	**1 / 2**	**1 / 2**		Y	
13	Elective (free choice)	6	**1 / 2**	**1 / 2**		Y	
14	Internship	3	2	1		Y	AAF
15	Thesis Project	38	2	2		Y	AAF

CFU = number of credits

SSD: Settore Scientifico Disciplinare

- FIS: Physics course
  - FIS/01: experimental physics
  - FIS/02: theoretical physics
  - FIS/03: condensed matter physics
  - FIS/04: nuclear and subnuclear physics
- MAT: Mathematics course

Three semesters.
Seven compulsory courses
+ five optional courses.

Courses of Particle and Astroparticle Physics curriculum

first semester, first year

N.	Insegnamenti	CFU	anno	sem.	SSD
1	**Introduction to Quantum Field Theory**	6	1	1	FIS/02
2	Condensed Matter Physics	6	1	1	FIS/03
3	Physics Laboratory I (propedeutic teaching to Physics Laboratory II)	6	1	1	FIS/01

Mandatory courses:

- Introduction to Quantum Field Theory (was Relativistic Quantum Mechanics): *prof. Antonio Davide Polosa (A-J) and prof. Roberto Bonciani (K-Z)*
- Condensed Matter Physics: *prof. Antonio Polimeni (A-J) and prof. Sergio Caprara (K-Z)*
- Physics Laboratory I: *prof. Gianluca Cavoto*

Suggested elective course: Computing Methods for Physics (INF/01), *prof. Francesco Pannarale*

Courses of Particle and Astroparticle Physics curriculum

second semester, first year

4	Electroweak Interactions	6	**1**	**2**	FIS/02
5	**Group Theory in Mathematical Physics**	6	1	2	MAT/07
6	Particle Physics	6	1	2	FIS/04
7	Physics Laboratory II	9	1	2	FIS/01
8	English language	4	1	2	

Mandatory courses:

- Electroweak Interactions (was in the first semester): *prof. Roberto Contino*
- Particle Physics: *prof. Paolo Bagnaia*
- Group Theory in Mathematical Physics (was Mathematical Physics): *prof. Gianluca Panati*
- Physics Laboratory II: *prof. Gianluca Cavoto*

Courses of Particle and Astroparticle Physics curriculum

9	Elective (within group A)	6	**1 / 2**	**1 / 2**	FIS/01
10	Elective (within group B)	6	**1 / 2**	**1 / 2**	
11	Elective (within group B)	6	**1 / 2**	**1 / 2**	
12	Elective (free choice)	6	**1 / 2**	**1 / 2**	
13	Elective (free choice)	6	**1 / 2**	**1 / 2**	

- Five elective courses; (almost) no constraints on the year/semester allocation
- The student plan must include at least 12 CFUs not labelled as FIS; for instance, INF (Computer science), MAT, CHIM (Chemistry), BIO (Biology).
  The 6 CFUs of Group Theory in Mathematical Physics are counted.
- Although it is suggested to plan two exams in the second year, moving one exam from first to second year (or viceversa) is allowed.
- The two free choices should preserve the consistency of the course plan; courses in Italian can be selected as free choice.

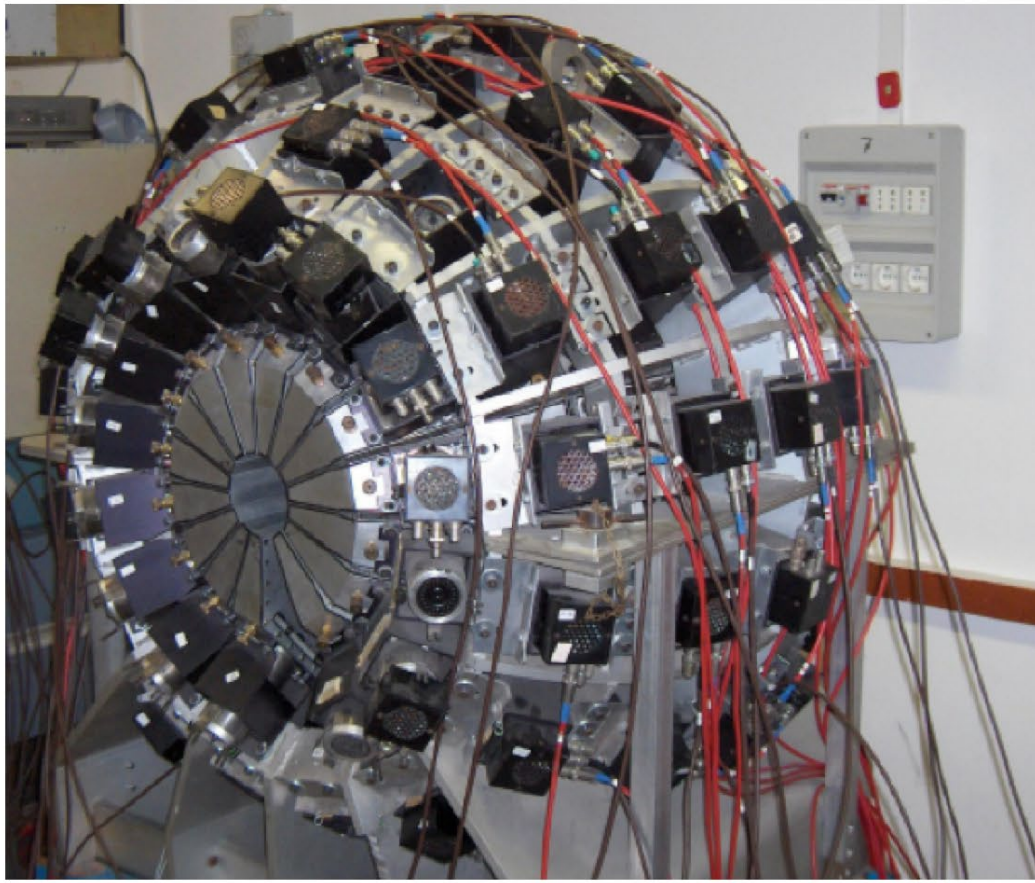
Groups A & B

1	Computing Methods for Physics	6	1	1	INF/01
2	**Advanced Machine Learning Methods for Physics**	6	1	2	INF/01
3	Computer Architecture for Physics	6	1	2	INF/01
4	Detectors and Accelerators in Particle Physics	6	1	2	FIS/01
5	Methods in Experimental Particle Physics	6	1	2	FIS/01
6	Nuclear Physics	6	1	2	FIS/04
7	**Plasma Physics and Nuclear Fusion (mutuato da LM-30)**	6	1	2	FIS/01
8	Quantum Electrodynamics	6	1	2	FIS/02
9	**Symmetries and Fundamental Interactions**	6	1	2	FIS/02
10	Collider Particle Physics	6	2	1	FIS/01
11	Experimental Gravitation (mutuato da LM-58)	6	2	1	FIS/01
12	Medical Applications of Physics	6	2	1	FIS/01
13	**Neutrinos and Dark Matter**	6	2	1	FIS/01
14	Particle and Astroparticle Physics (mutuato da LM-58)	6	2	1	FIS/01
15	Quantum Field Theory	6	2	1	FIS/02
16	Solid State Sensors	6	2	1	FIS/01
17	Weak Interactions in the Standard Model and Beyond	6	2	1	FIS/02

New course or new in the table

Physics Laboratory (Cavoto)

- Physics Lab. I is propedeutic to Physics Lab. II. Both mandatories.
- gomp page
- facebook page
- Content of the course:
  - Interaction of radiation with matter
  - Gas, semiconductor, scintillation detectors
  - Spectrometers, calorimeters, Cherenkov counters
  - Signal formation & electronics
  - Statistics for data analysis
- In Physics Lab. II:
  - Realization of a small scale experiment in groups of few students.



Particle Physics and Collider Particle Physics (Bagnaia)

- Particle Physics is a first year mandatory course. (web page)

1 - The static quark model

2 - The hadron structure

3 - Heavy flavors

4 - Weak interactions

5 - The K^0 meson

6 - The Standard Model

7 - High energy neutrino interactions

- Collider Particle Physics is a second year elective course. (web page)

1 - Hadron Colliders

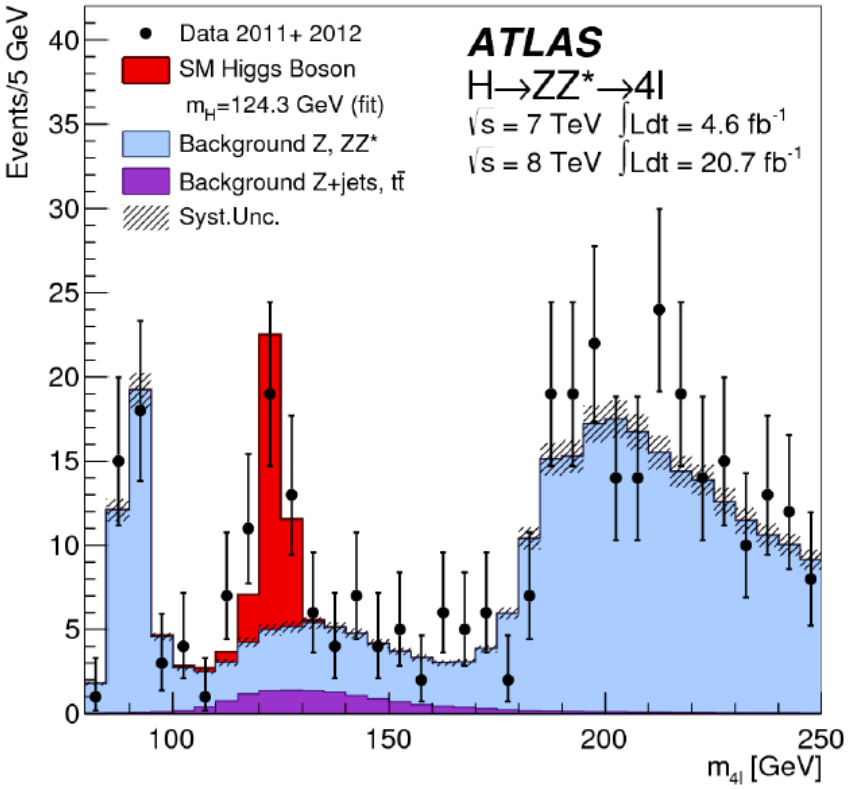
2 - The CERN $Sp\bar{p}S$: W and Z discovery

3 - The CERN LEP : precision e^+e^- physics

4 - Searches and limits

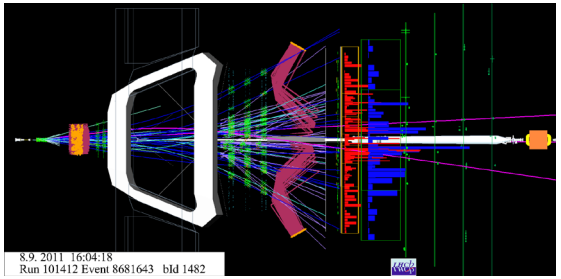
5 - The CERN LHC : a) machine and detectors - b) the Higgs discovery

6 - Physics bSM



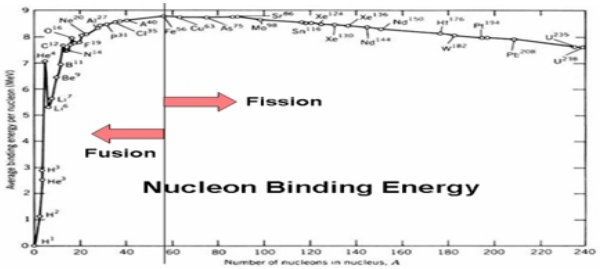
Elective courses

- Methods in Experimental Particle Physics (prof. A. Di Domenico)
  - How experiments are designed & how data are analyzed: logic and design of the experiment, quantities to measure, advanced statistics
  - web page



- Detectors and Accelerators for Particle Physics (prof. S. Giagu)
  - Advanced course on detectors: HEP & neutrino detectors, Medical Physics & neutron detectors, Basics of accelerator technique
  - web page

- Nuclear physics (prof. S. de Cecco)
  - Nuclear models, nuclear reactions, fission and fusion, nuclear astrophysics
  - elearning page

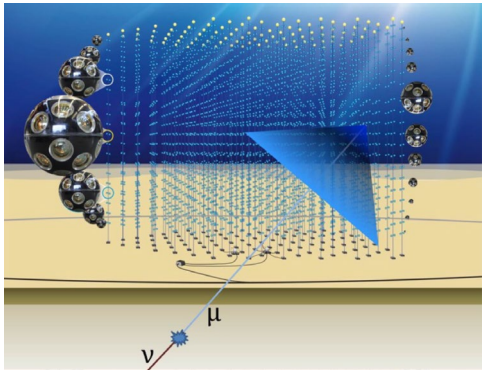


Elective courses

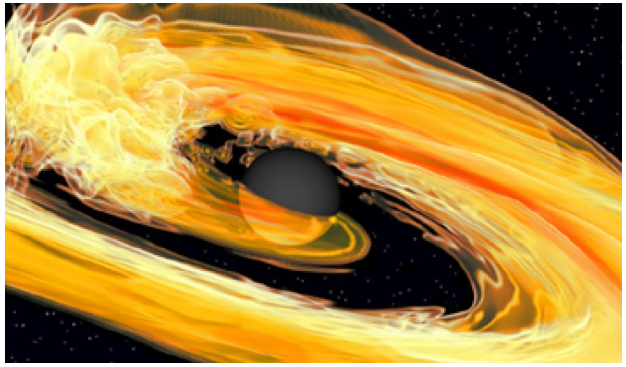
- Neutrinos and Dark Matter (prof. M. Vignati)
  - Neutrino interactions, masses and oscillations. Neutrino sources. Dark matter. WIMP and axions.
  - web page (Current Topics)
- Medical application of Physics (proff. Saini and Pani)
  - Imaging techniques and instrumentation, nuclear magnetic resonance (MRI), PET, radio-guided surgery, hadronteraphy.
  - web page
- Solid state sensors (proff. Polimeni and Bocci)
  - Fundamentals of semiconductor materials. Operational function of basic optoelectronics devices. Working principles of photon detectors. Readout circuit of semiconductor devices. Digital conversion of signals.
  - web page

Elective courses (LM58)

- Particle and Astroparticle Physics (prof. A. Capone)
  - Problematics in High Energy Cosmic Rays (HECR) physics, study of experiments acting, or under construction, in the HECR field, open problems: antimatter, dark matter, neutrino properties.
  - web page

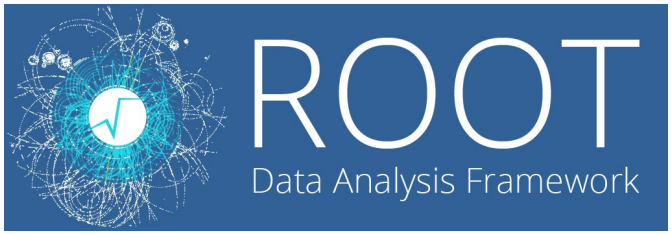


- Experimental Gravitation (prof. F. Ricci)
  - Current status of the experimental search for Gravitational Waves(GW), experimental bases of Gravitation, effects of GW on matter, GW detectors and source of noise in detectors.
  - web page



Elective courses (INF)

- Computing Methods for Physics (prof. F. Pannarale)
  - C++, machine leaning, Python with examples taken from LHC data analysis.
  - (preliminary) web page



- Computer Architecture for Physics (proff. A. Lonardo and A. Biagioni)
  - Introduction to hardware, logic design; processor architecture.
  - web page

- Advanced Machine Learning for Physics (prof. S. Giagu)
  - Deep learning e deep neural network; convolutional neural networks. Models for analysis of sequences (RNN, LSTM/GRU, Transformers). AutoEncoders, GANs. Quantum Neural Network
  - web page

New web site:

https://web.infn.it/area-particelle-roma/

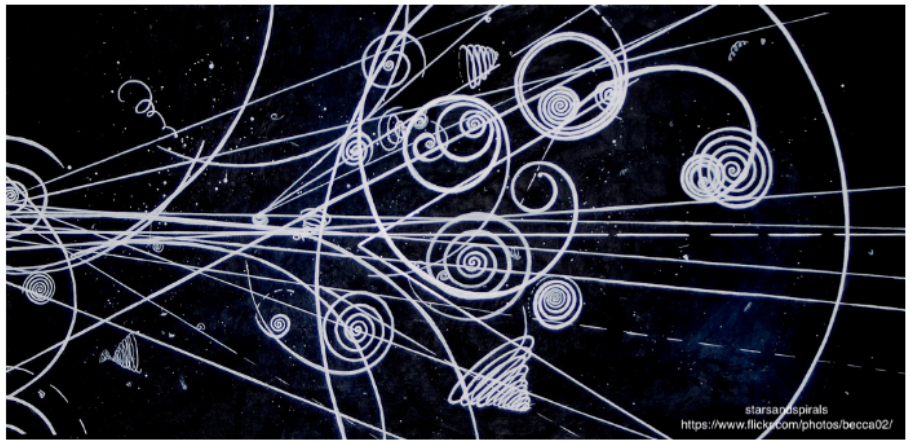
Particle and Astroparticle Physics

Dipartimento di Fisica - Sapienza Università di Roma

This page collects information on the Particle and Astroparticle Physics group of the Sapienza University of Rome.

The Particle and Astroparticle Physics group comprises various reasearch teams involved in many experiments in the **Particle physic, Astroparticle physics and Gravitational waves** areas.

Information on programs and courses for master students and opportunities for master theses are available **here**.



- The site collects recommended courses for different specializations of the master student program.

Suggested specializations.

EXPERIMENTAL PARTICLE PHYSICS

- 1st year, 1st semester: Computing Methods for Physics
- 1st year, 2nd semester: Detectors and Accelerators in Particle Physics
- 1st year, 2nd semester: Methods in Experimental Particle Physics
- 2nd year, 1st semester: Collider Particle Physics
- 2nd year, 1st semester: one course among Current Topics in Particle Physics and Solid State Sensors

ASTROPARTICLE AND GRAVITATIONAL WAVES

- 1st year, 1st semester: Computing Methods for Physics
- 1st year, 2nd semester: Detectors and Accelerators in Particle Physics
- 1st year, 2nd semester: one course chosen among Methods in Experimental Particle Physics and Nuclear Physics
- 2nd year, 1st semester: Particle and Astroparticle Physics
- 2nd year, 1st semester: Experimental Gravitation

Suggested specializations.

PHENOMENOLOGY

- 1st year, 1st semester: Computing Methods for Physics
- 1st year, 2nd semester: one course chosen among Methods in Experimental Particle Physics and Nuclear Physics
- 1st year, 2nd semester: Quantum Electrodynamics
- 2nd year, 1st semester: Quantum Field Theory
- 2nd year, 1st semester: Weak Interactions in the Standard Model and beyond

APPLIED PHYSICS

- 1st year, 1st semester: Computing Methods for Physics
- 1st year, 2nd semester: one course chosen among Detectors and Accelerators in Particle Physics, Methods in Experimental Particle Physics, and Nuclear Physics
- 1st year, 2nd semester: Computer Architecture for Physics
- 2nd year, 1st semester: Medical Applications of Physics
- 2nd year, 1st semester: Solid State Sensors

Thesis proposals

- https://www.phys.uniroma1.it/fisica/sites/default/files/showcase/showcase.html

DIPARTIMENTO DI FISICA

SAPIENZA UNIVERSITÀ DI ROMA

Elenco delle tesi disponibili

Selezionare l'Area Tematica di Ricerca.

Biofisica, Fisica Medica, e Fisica dei Beni Culturali	Fisica delle Particelle e delle Interazioni Fondamentali	Generale	Struttura della Materia e Fisica dei Biosistemi

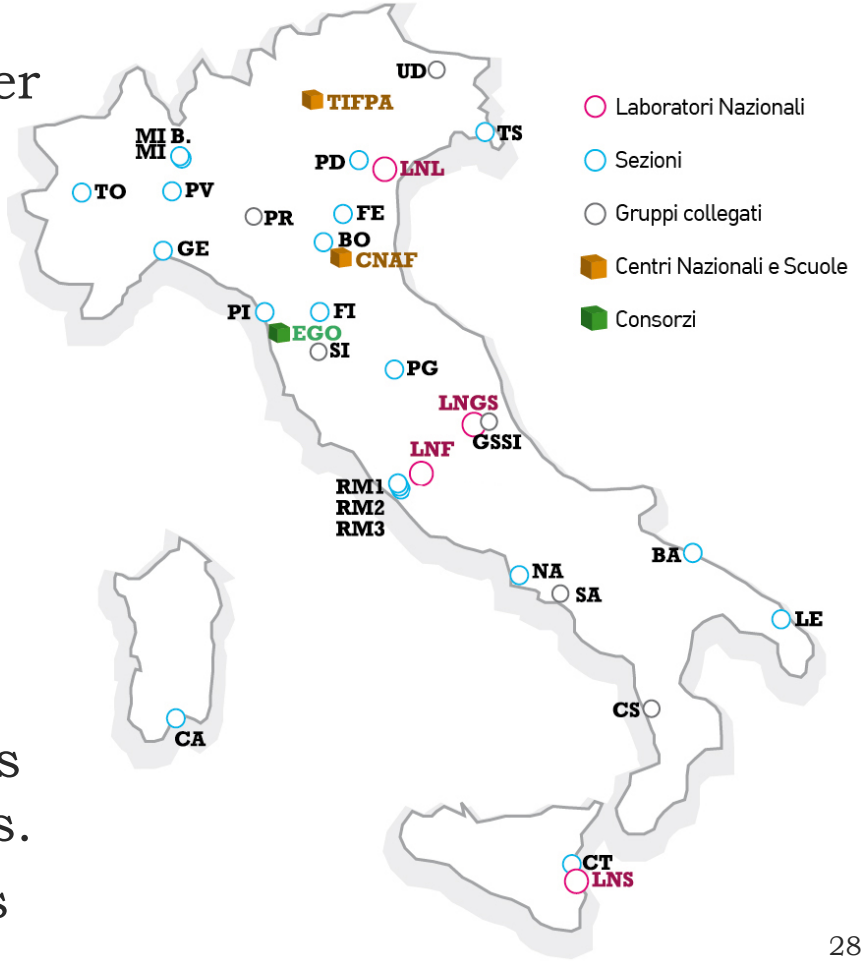
Selezionare il settore di Ricerca.

E' ammessa la selezione multipla, tuttavia, per conoscere le tesi presenti in un settore di ricerca e' necessario deselezionare le eventuali ricerche effettuate negli altri settori.

Acceleratori e rivelatori di particelle elementari	Fisica Astroparticellare	Rivelatori di Onde Gravitazionali

Istituto Nazionale di Fisica Nucleare (INFN)

- INFN is the Italian research agency dedicated to the study of the fundamental constituents of matter and their interactions.
- The research activities presented here are mainly founded by INFN. Research groups include both University and INFN staff.
- INFN divisions are located in the Physics Departments (web site of Rome division).
- Availability of master thesis in national/international laboratories and in international collaborations.
- PhD school on Accelerator Physics



INFN Scolarship

Istituto Nazionale di Fisica Nucleare

CONCORSO PER IL CONFERIMENTO

DI N. 5 BORSE DI STUDIO PER ATTIVITA' DI FORMAZIONE SCIENTIFICA

PER STUDENTI UNIVERSITARI

È indetto un concorso per titoli ed esame colloquio per n. 5 borse di studio a sostegno della formazione scientifica di studenti universitari nel campo della fisica sperimentale dell'INFN durante lo svolgimento della tesi magistrale, su uno dei temi riportati nell'allegato A del bando. Ciascun tema verrà assegnato ad un solo vincitore secondo l'ordine della graduatoria di merito.

Ciascuna borsa avrà la durata di sei mesi con decorrenza **1° febbraio 2021** e non potrà proseguire oltre la data di conseguimento del titolo di laurea magistrale.

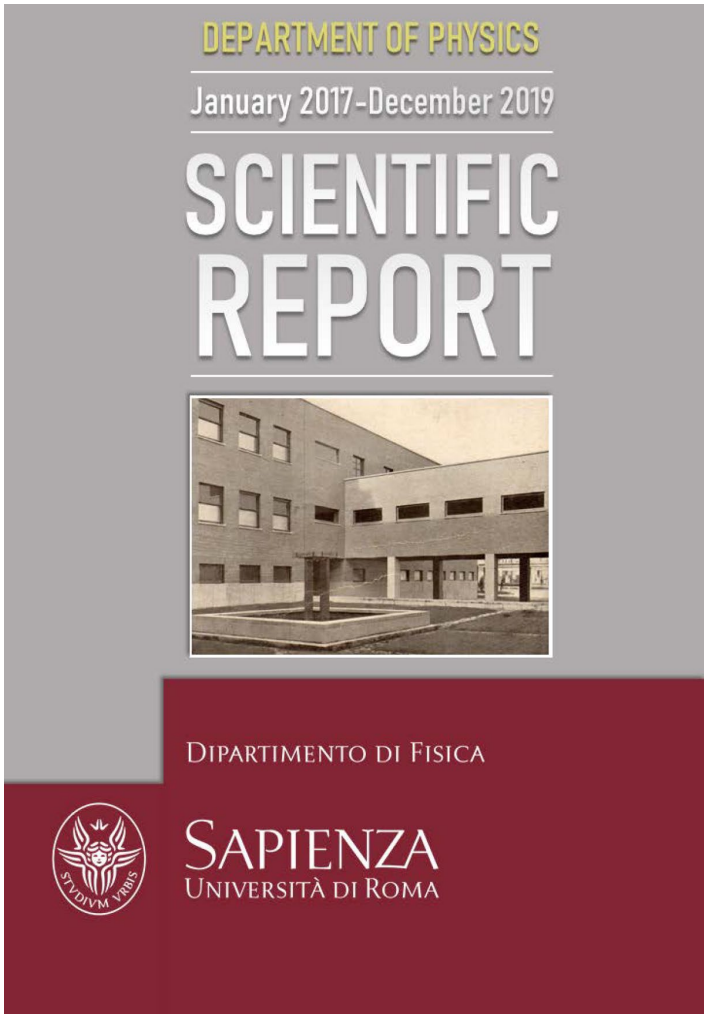
- conseguimento della laurea triennale nel 2019;

- iscrizione al curriculum di Fisica Nucleare e Subnucleare del I° anno della laurea magistrale nell'anno accademico 2019-2020 con una media voti esame non inferiore a 27/30.

Few final remarks…

- More information about ongoing researches in the Scientific Report of Department of Physics (link).
  Pages 97-159 dedicated to particle and astroparticle physics.

- Practical infos about courses:
  https://corsidilaurea.uniroma1.it/it/corso/2021/30055/programmazione



Questions on PAP curriculum:
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tel 0649694250
office 202F, Marconi building