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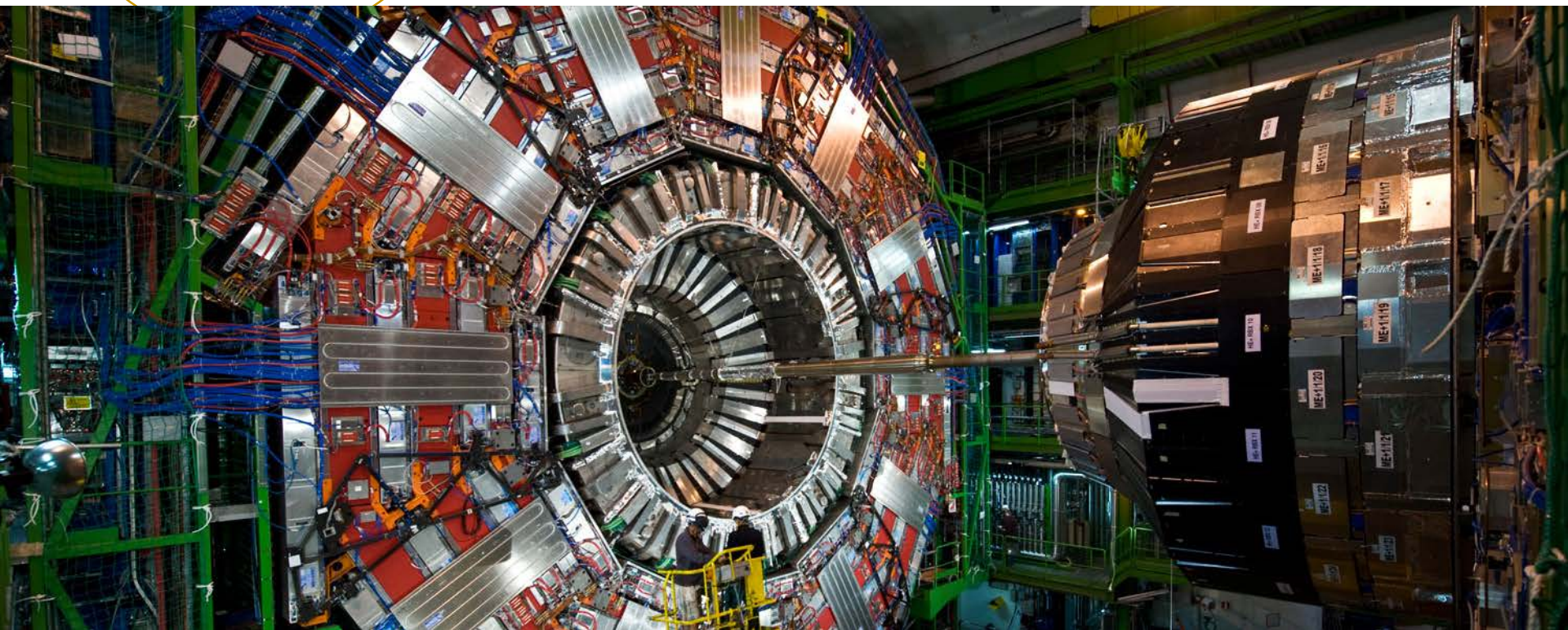
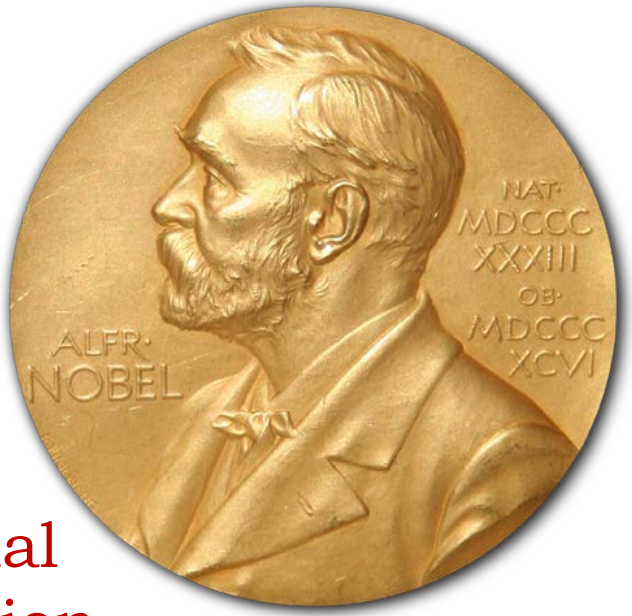
Aula Cabibbo - 1/10/2018

Particle and Astroparticle Physics Curriculum



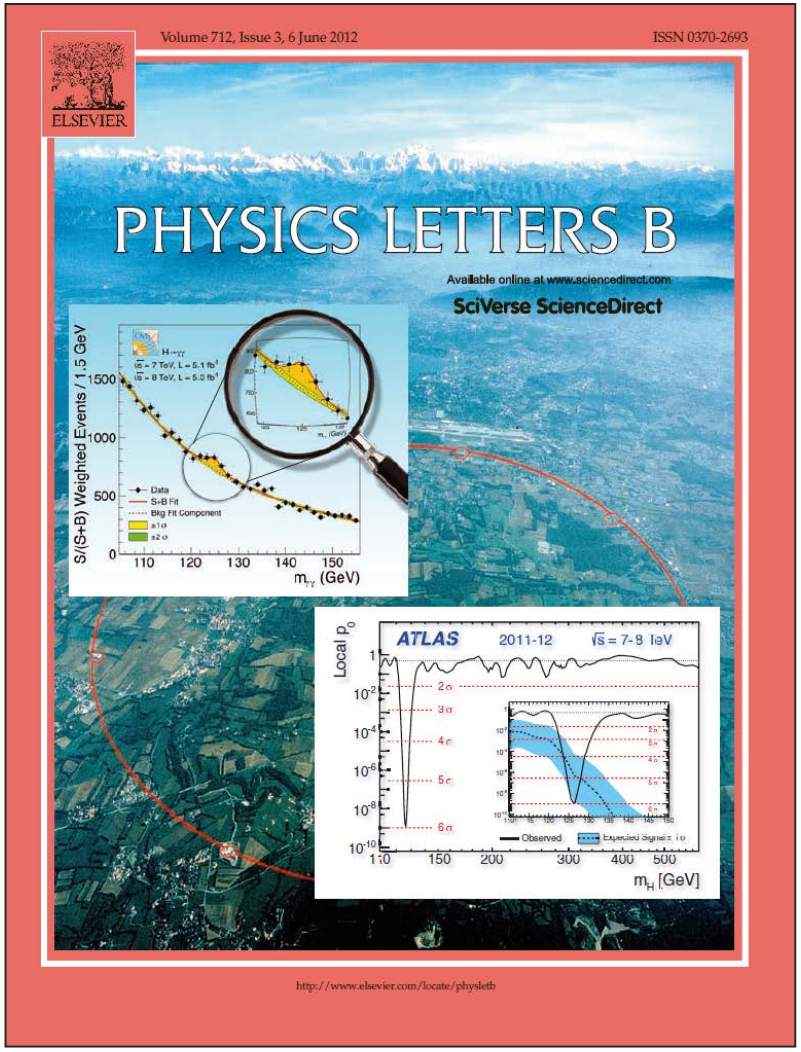
Let's start with recent Nobel Prizes in Physics

- 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.



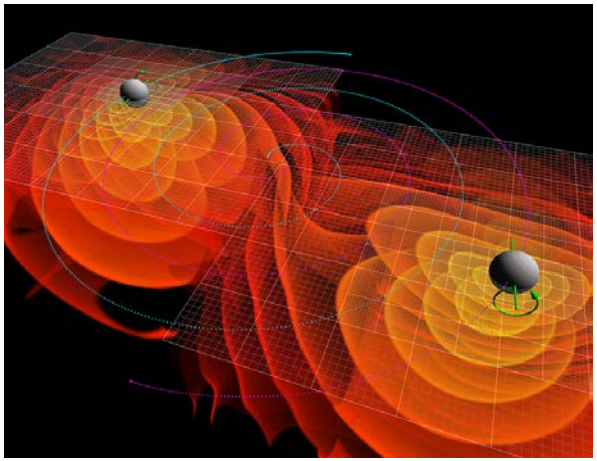
Several courses of the Particle and Astroparticle Physics curriculum are given by researchers of the Rome Physics Department who are members of the mentioned experimental collaborations and directly contributed to these fundamental discoveries.

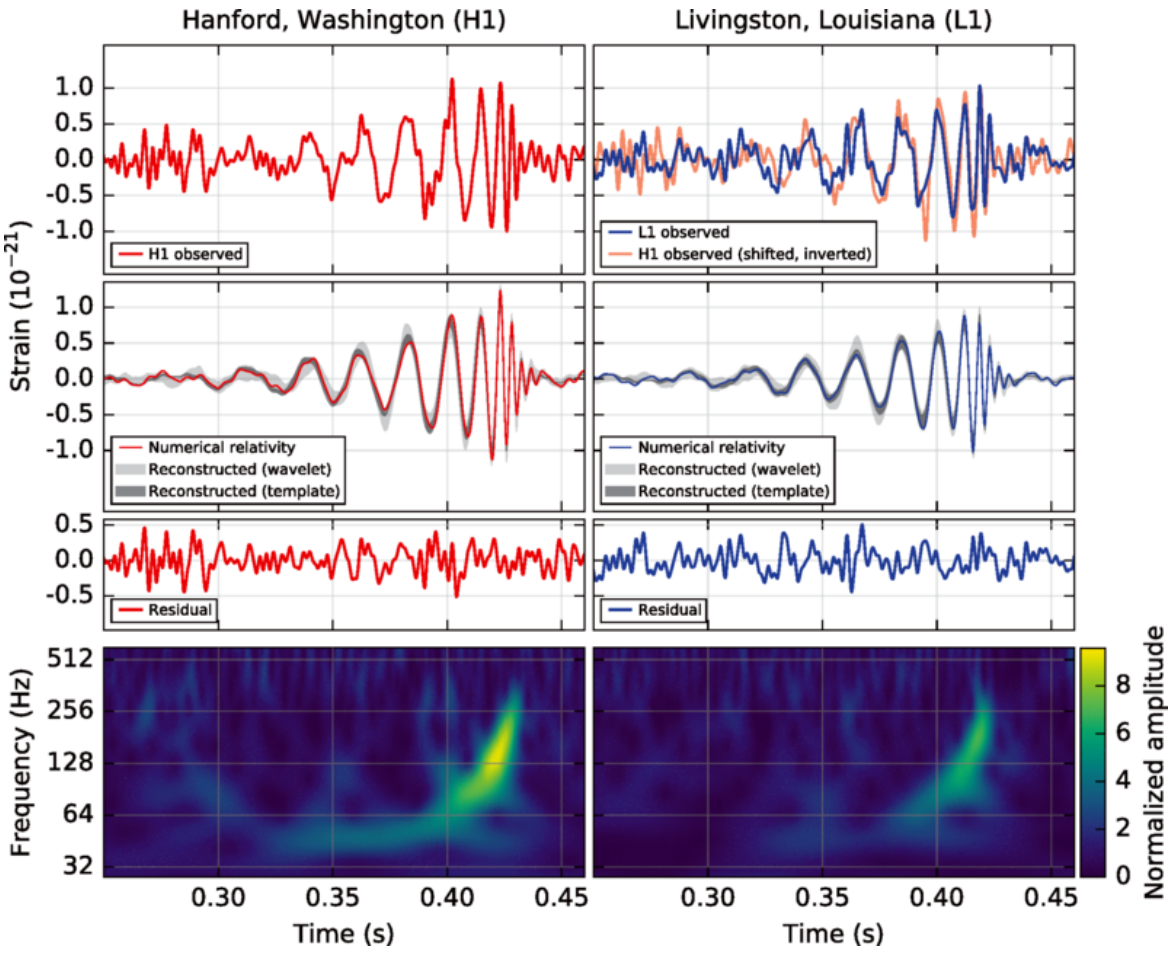
4th of July 2012: Cern announce the discovery of the Higgs Boson



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 of more than one billion light years.

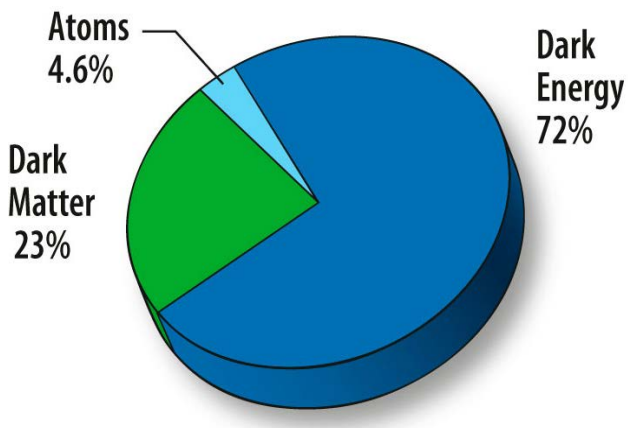




There are still many unanswered questions…

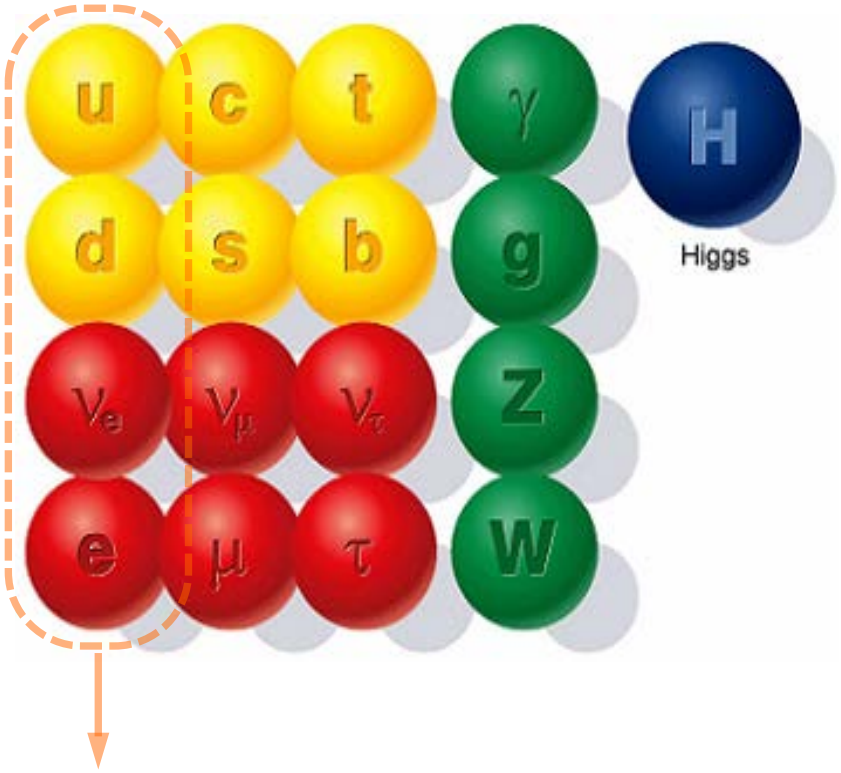
… (and many future Nobel prizes) in the study of basic costituents of matter and their interactions.

- Why just three families of leptons and quarks ?
- Why in the universe matter is strongly dominant on anti-matter ?
- How gravity is 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 ?



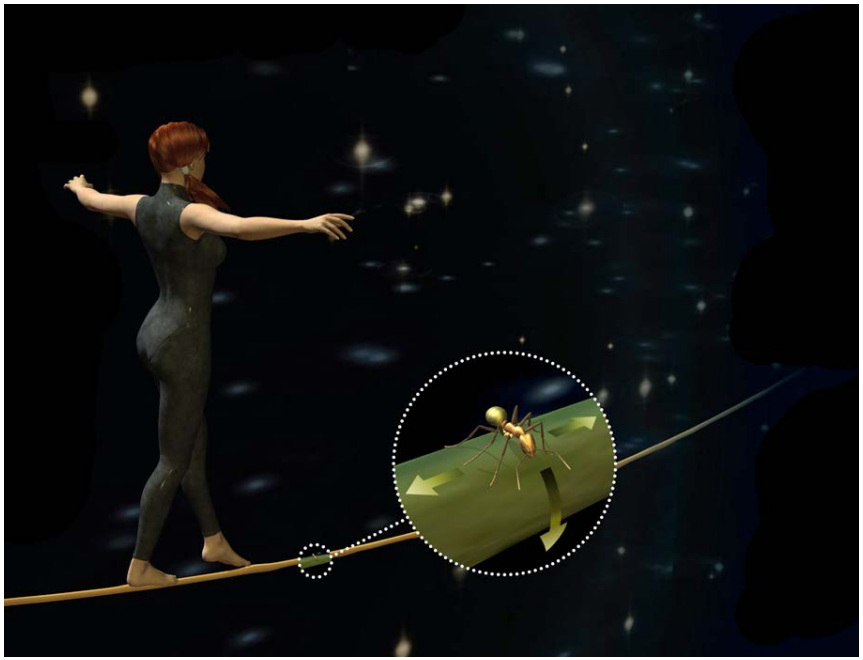
The Standard Model

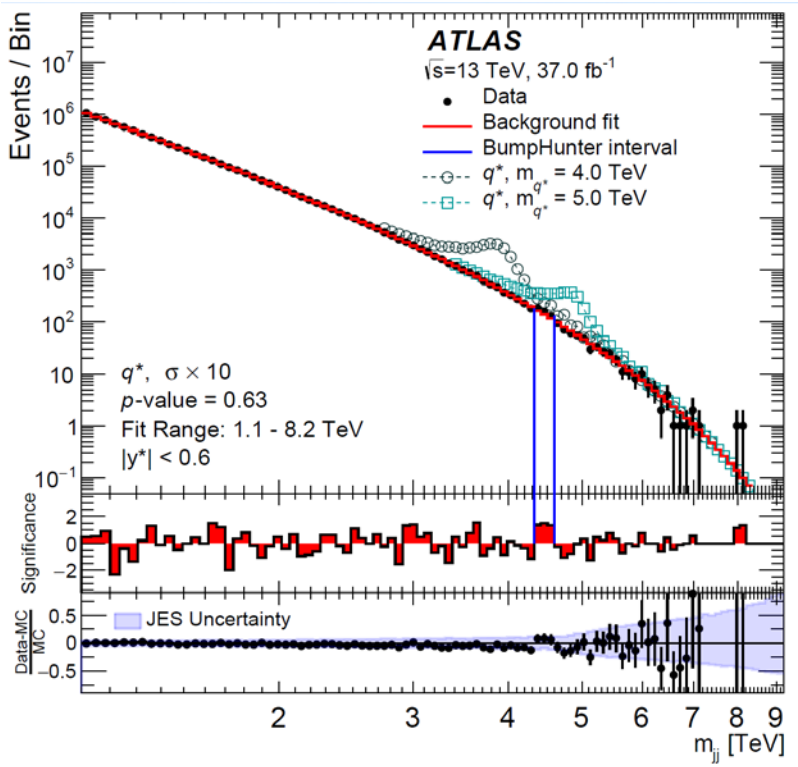
- All the (known) elementary particles and interactions are described in a beautiful theory called the Standard Model.
- Particles of matter exist in three different families.
- For any particle of matter there is a corresponding anti-matter particle.
- The Standard Model is not the full history.
  -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

Search of physics beyond the Standard Model



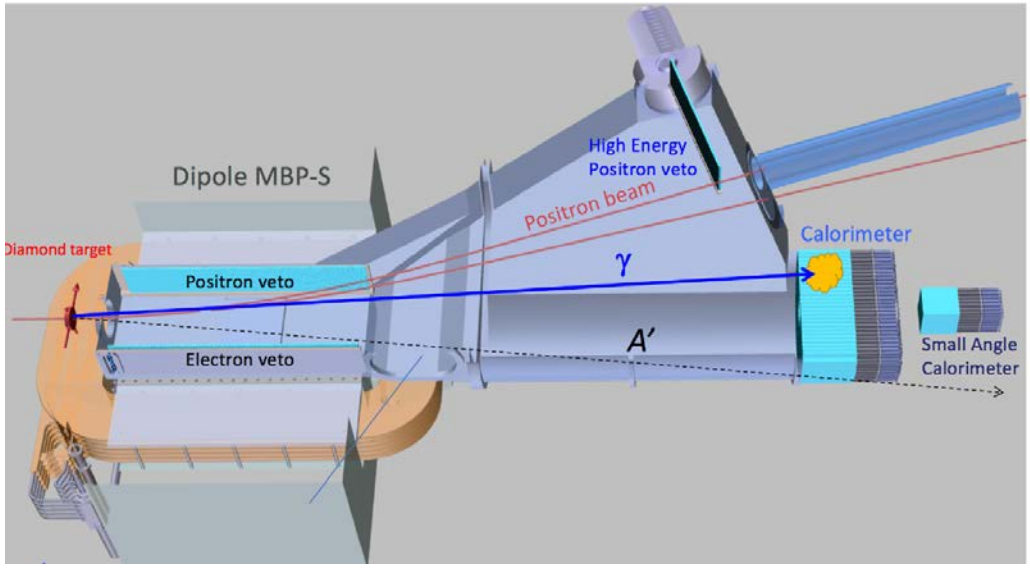


Many extensions of the Standard Model predict the existence of Extra-Dimensions. Unlike the 3+1 familiar dimensions, the ED are compactified and not directly accessible.

New resonances with very high masses (TeV scale) or excess of missing energy in the detector, e.g. Supersymmetry particles.

Search of physics beyond the Standard Model

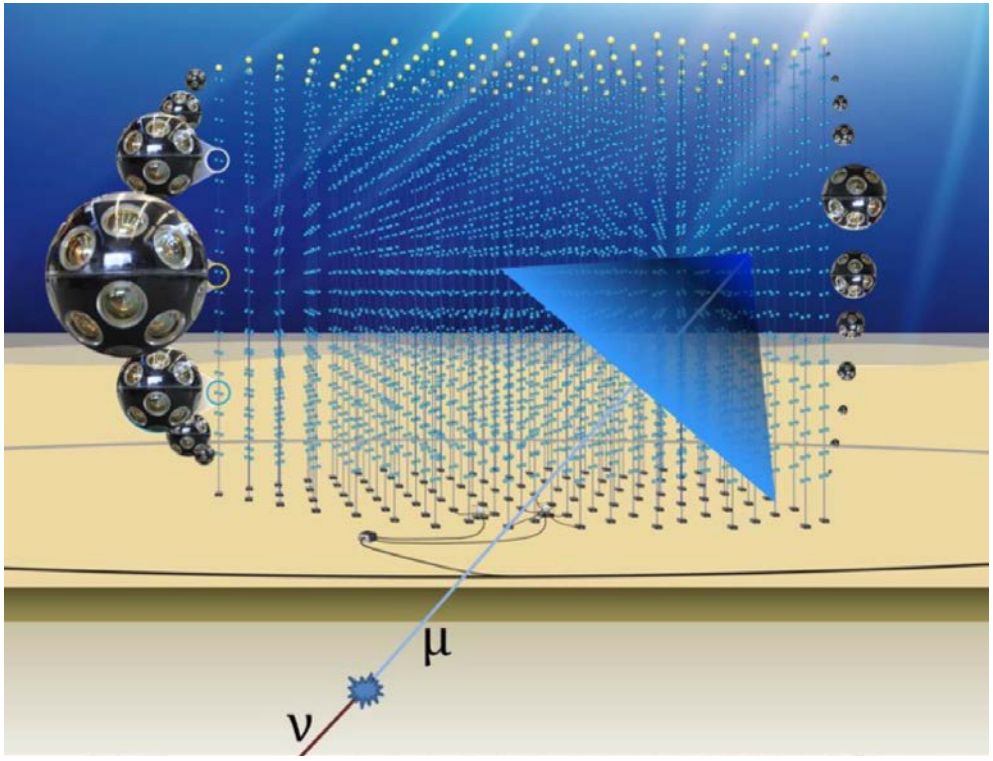
- PADME (Positron Annihilation into Dark Matter Experiment) at the INFN LNF just started the data taking.
- Search of "dark photon", a new particle connecting the Standard Model with the dark matter sector, with the process e+e- →γA'.



- Darkside and Dama experiments at the INFN LNGS
- MEG experiment at PSI
- AMS experiment on the ISS
- And many others.

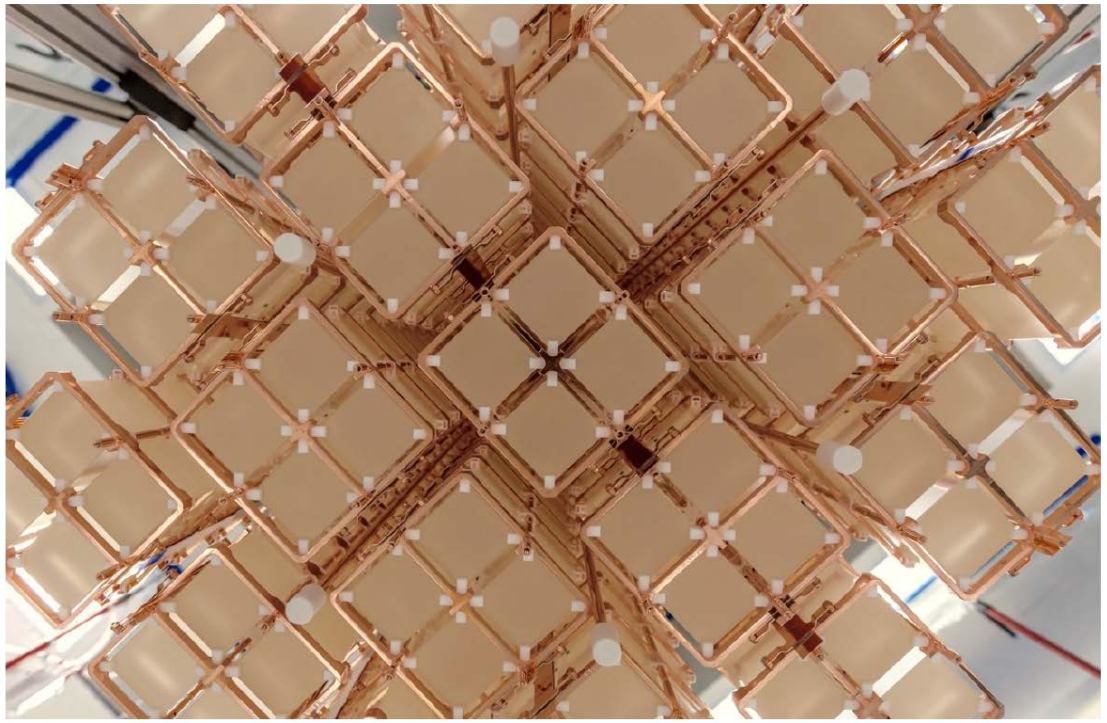
Neutrino physics

- KM3NeT: neutrino telescope of 1 km^3 to detect Cherenkov light from neutrino interaction in the deep sea.
- Goal: observation of high energy neutrino sources in the Universe and the determination of the mass hierarchy of neutrinos.



Neutrino physics

- CUORE: Cryogenic Underground Observatory for Rare Events (at the INFN – LNGS)
- Search for Neutrinoless Double Beta Decay (NDBD) to establish the nature of neutrinos: Dirac or Majorana particles ?
- T < 10 mK !!



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
  - use of multivariate analysis in radiological imaging for tumor.

All of this and much more in the Courses of Particle and Astroparticle Physics curriculum

Corso di laurea in Fisica (LM-17) - Curriculum Particle and Astroparticle Physics							
N.	Insegnamenti	CFU	year	sem.	SSD	eng	ambito
1	Relativistic Quantum Mechanics	6	1	1	FIS/02	Y	caratt.
2	Electroweak interactions	6	1	1	FIS/02	Y	caratt.
3	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
4	Elective (within group A)	6	1 / 2	1 / 2		Y	aff.-int.
5	Physics Laboratory I (propedeutic teaching to Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
6	Particle Physics	12	1	2	FIS/04	Y	caratt.
7	Mathematical Physics	6	1	2	MAT/07	Y	aff.-int.
8	Elective (free choice)	6	1	2		Y	
9	Physics Laboratory II	9	1	2	FIS/01	Y	caratt.
10	Elective (within group B)	6	2	1	FIS/01	Y	aff.-int.
11	Elective (free choice)	6	2	1		Y	
12	Internship	3	2	1		Y	AAF
13	Thesis Project	39	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

The student must choose at least 12 CFU (2 courses) labelled INF (Computer science), MAT, CHIM (Chemistry), BIO (Biology)

Courses of Particle and Astroparticle Physics curriculum

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1	Relativistic Quantum Mechanics	6	1	1	FIS/02	Y	caratt.
2	Electroweak interactions	6	1	1	FIS/02	Y	caratt.
3	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
4	Elective (within group A)	6	1 / 2	1 / 2		Y	aff.-int.
5	Physics Laboratory I (propedeutic teaching to Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
6	Particle Physics	12	1	2	FIS/04	Y	caratt.
7	Mathematical Physics	6	1	2	MAT/07	Y	aff.-int.
8	Elective (free choice)	6	1	2		Y	
9	Physics Laboratory II	9	1	2	FIS/01	Y	caratt.
10	Elective (within group B)	6	2	1	FIS/01	Y	aff.-int.
11	Elective (free choice)	6	2	1		Y	
12	Internship	3	2	1		Y	AAF
13	Thesis Project	39	2	2		Y	AAF

first semester, first year

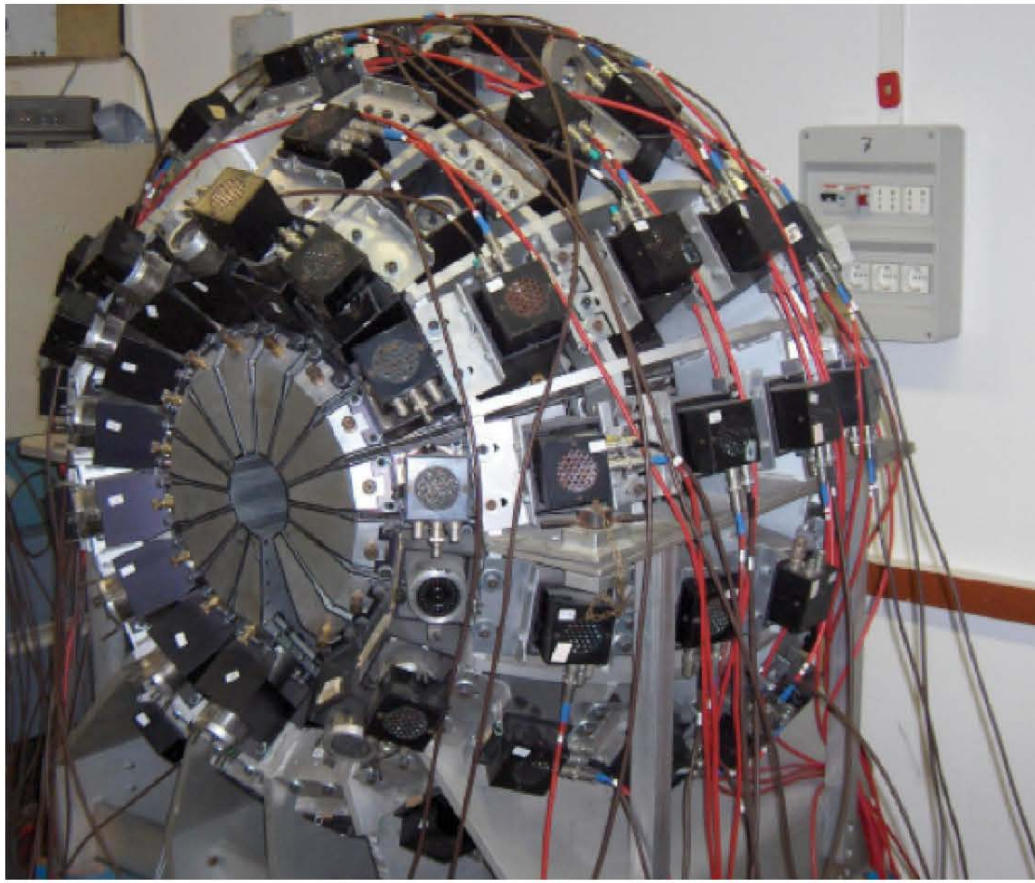
Mandatory courses:

- Relativistic Quantum Mechanics: prof. Omar Benhar (compressed course ending at the beginning of November)
- Electroweak interactions: prof. Guido Martinelli (starting just after end of RQM)
- Condensed Matter Physics
- Physics Laboratory I: prof. Gianluca Cavoto

Elective course: Computing Methods for Physics (INF/01), prof. Shahram Rahatlou

Physics Laboratory (Cavoto)

- Physics Lab. I is preparatory to Physics Lab. II. Both mandatories.
- web 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.



Courses of Particle and Astroparticle Physics curriculum

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2	Electroweak interactions	6	1	1	FIS/02	Y	caratt.
3	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
4	Elective (within group A)	6	1 / 2	1 / 2		Y	aff.-int.
5	Physics Laboratory I (propedeutic teaching to Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
6	Particle Physics	12	1	2	FIS/04	Y	caratt.
7	Mathematical Physics	6	1	2	MAT/07	Y	aff.-int.
8	Elective (free choice)	6	1	2		Y	
9	Physics Laboratory II	9	1	2	FIS/01	Y	caratt.
10	Elective (within group B)	6	2	1	FIS/01	Y	aff.-int.
11	Elective (free choice)	6	2	1		Y	
12	Internship	3	2	1		Y	AAF
13	Thesis Project		2	2		Y	AAF

second semester, first year

Mandatory courses:

- Particle Physics: prof. Paolo Bagnaia
- Mathematical Physics (MAT/07)
- Physics Laboratory II: prof. Gianluca Cavoto

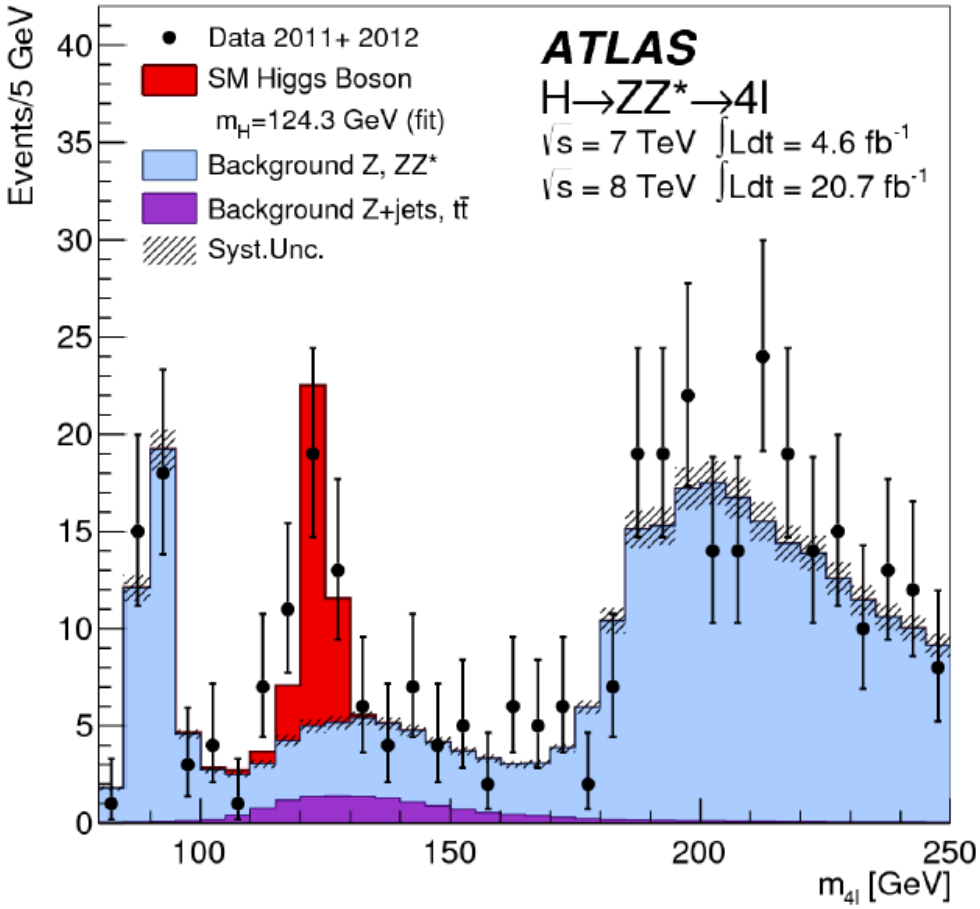
An elective course chosen among:

- Methods in Experimental Particle Physics: prof. Antonio Di Domenico
- Nuclear Physics: prof. Giovanni Salmè
- Quantum Electrodynamics (FIS/02)
- … (free choice)

Particle Physics (Bagnaia)

- It is a mandatory course.
- web page
- Program of the course:

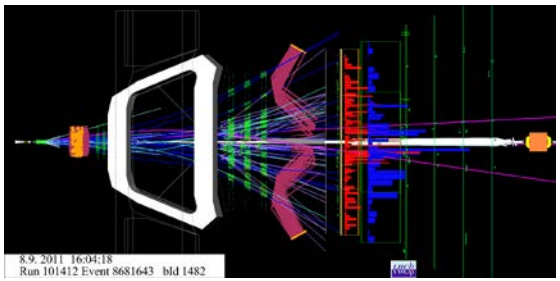
1 - The static quark model
2 - The hadron structure
3 - Heavy flavors
4 - Weak interactions
5 - The K^0 meson
6 - The Standard Model
7 - High energy neutrino interactions
8 - Hadron Colliders
9 - The CERN $Sp\bar{p}S$: W and Z discovery
10 - The CERN LEP : precision e^+e^- physics
11 - Searches and limits
12 - The CERN LHC : a) machine and detectors - b) the Higgs discovery



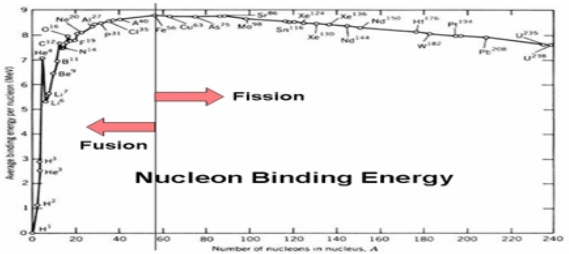
Elective course of first year

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

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



- Nuclear physics (Salmè)
  - Nuclear models, nuclear reactions, fission and fusion, nuclear astrophysics
  - web page



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2	Electroweak interactions	6	1	1	FIS/02	Y	caratt.
3	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
4	Elective (within group A)	6	1 / 2	1 / 2		Y	aff.-int.
5	Physics Laboratory I (propedeutic teaching to Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
6	Particle Physics	12	1	2	FIS/04	Y	caratt.
7	Mathematical Physics	6	1	2	MAT/07	Y	aff.-int.
8	Elective (free choice)	6	1	2		Y	
9	Physics Laboratory II	9	1	2	FIS/01	Y	caratt.
10	Elective (within group B)	6	2	1	FIS/01	Y	aff.-int.
11	Elective (free choice)	6	2	1		Y	
12	Internship	3	2	1		Y	AAF
13	Thesis Project	3	2	2		Y	AAF

first semester, second year

Gruppo B (aff.-int.)

1	Digital electronics	6	2	1	FIS/01	Y	
2	Medical Applications of Physics	6	2	1	FIS/01	Y	
3	Current Topics in Particle Physics	6	2	1	FIS/01	Y	
4	Detectors for particle physics	6	2	1	FIS/01	Y	
5	Particle and astroparticle Physics (mutuato da LM-58)	6	2	1	FIS/01	Y	
6	Experimental Gravitation (mutuato da LM-58)	6	2	1	FIS/01	Y	

Courses of Particle and Astroparticle Physics curriculum

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N.	Insegnamenti	CFU	year	sem.	SSD	eng	ambito
1	Relativistic Quantum Mechanics	6	1	1	FIS/02	Y	caratt.
2	Electroweak interactions	6	1	1	FIS/02	Y	caratt.
3	Condensed Matter Physics	6	1	1	FIS/03	Y	caratt.
4	Elective (within group A)	6	1 / 2	1 / 2		Y	aff.-int.
5	Physics Laboratory I (propedeutic teaching to Physics Laboratory II)	6	1	1	FIS/01	Y	caratt.
6	Particle Physics	12	1	2	FIS/04	Y	caratt.
7	Mathematical Physics	6	1	2	MAT/07	Y	aff.-int.
8	Elective (free choice)	6	1	2		Y	
9	Physics Laboratory II	9	1	2	FIS/01	Y	caratt.
10	Elective (within group B)	6	2	1	FIS/01	Y	aff.-int.
11	Elective (free choice)	6	2	1		Y	
12	Internship	3	2	1		Y	AAF
13	Thesis Project		2	2		Y	AAF

first semester, second year

Computer Architecture for Physics	6	2	1	INF/01
Surface Physics and Nanostructures	6	2	1	FIS/03
Quantum Field Theory	6	2	1	FIS/02

or a second one from group B (see previous slide)
or … (free choice)

Elective course of group B

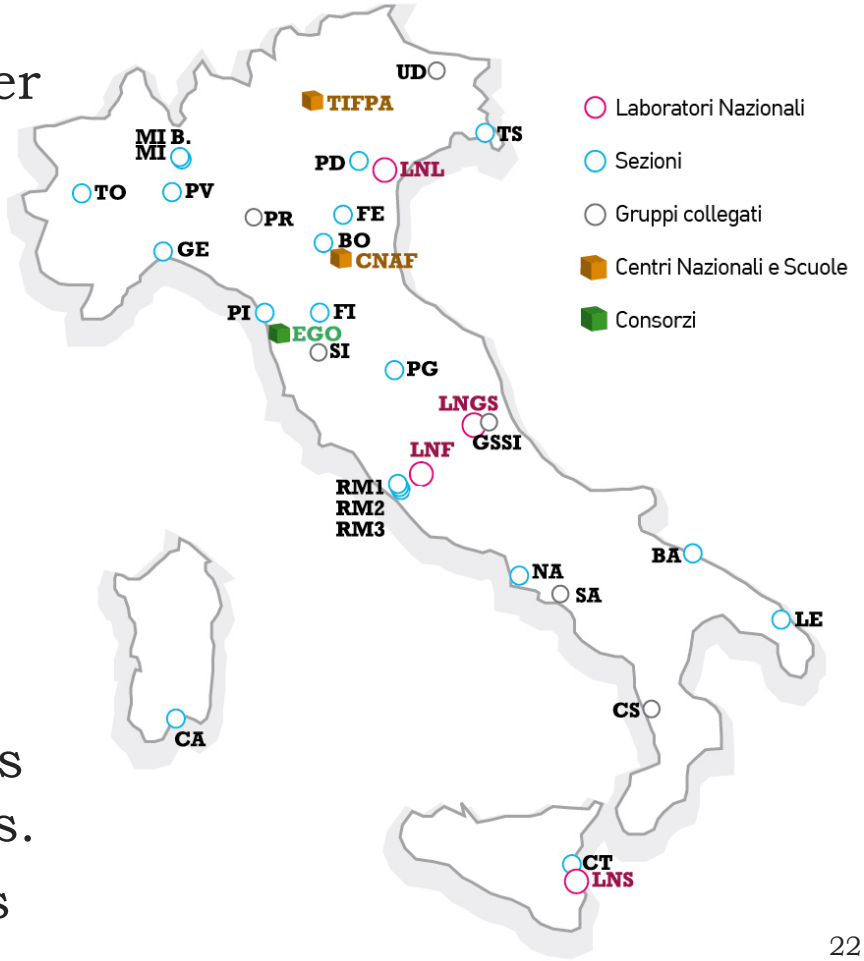
- Digital Electronics (prof. Franco Meddi)
  - Advanced course of digital electronics; multiple Output Combinational Logic Networks, timing of logical networks, miniaturization.
  - web page
- Medical application of Physics (prof. Saini and prof. Pani)
  - Imaging techniques and instrumentation, nuclear magnetic resonance (MRI), PET, radio-guided surgery, hadronteraphy.
  - web page
- Current Topics in Particle Physics (prof. Simonetta Gentile)
  - Advanced course of particle physics. Hadron colliders physics: heavy ions and pp, indirect Dark Matter search, neutrino or astroparticle physics
  - web page

Elective course of group B

- Detectors for particle physics (prof. Francesco Lacava)
  - Advanced course on detectors: HEP & neutrino detectors, Medical Physics & neutron detectors, Basics of accelerator technique
  - web page
- Particle and Astroparticle Physics (prof. Antonio 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. Fulvio 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

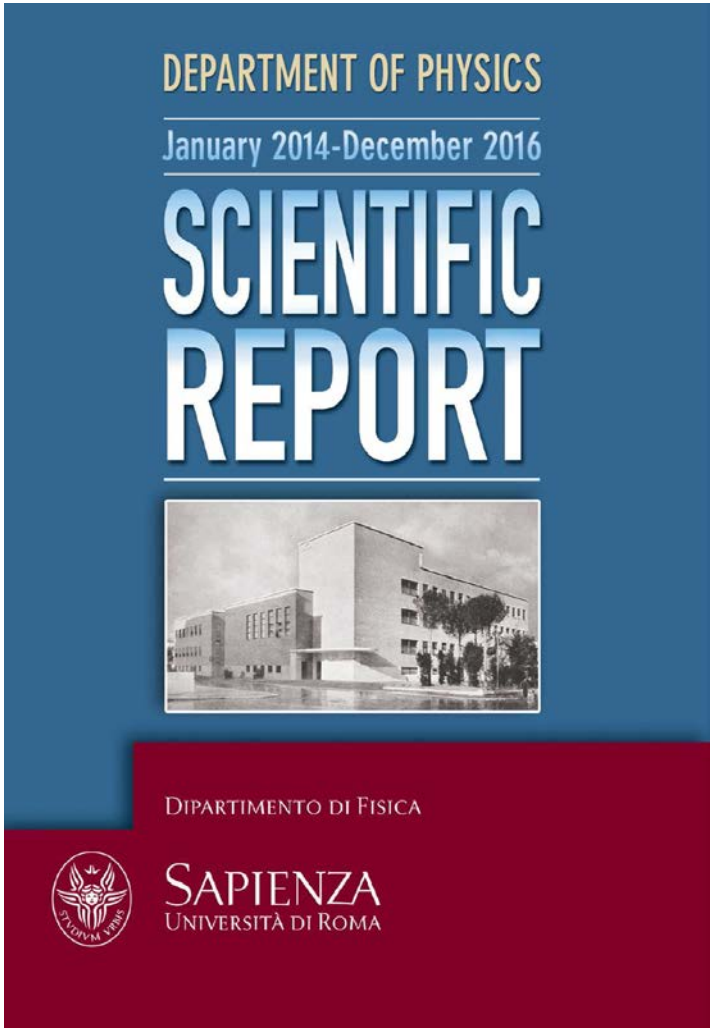
Istituto Nazionale di Fisica Nucleare (INFN)

- 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



Few final remarks…

- More information about ongoing researches in the Scientific Report of Department of Physics (link). Pages 84-126 dedicated to particle and astroparticle physics.
- Web site with master thesis propostals: http://www.roma1.infn.it/people/organtini/showcase/Showcase.html



For any other question:

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