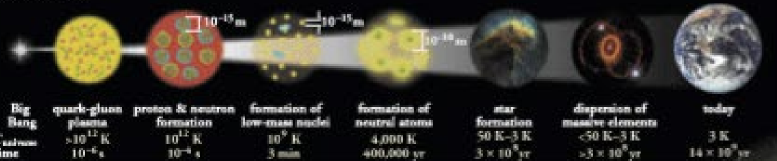
Nuclear Science

Nuclear Science is the study of the structure, properties, and interactions of the atomic nuclei. Nuclear scientists calculate and measure the masses, shapes, sizes, and decays of nuclei at rest and in collisions. They ask questions, such as: Why do nucleons stay in the nucleus? What combinations of protons and neutrons are possible? What happens when nuclei are compressed or rapidly rotated? What is the origin of the nuclei found on Earth?

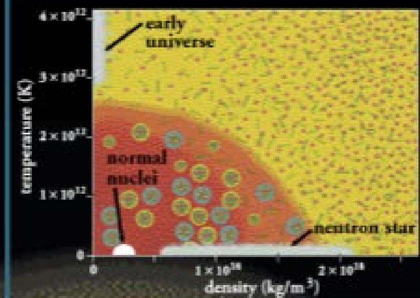
Legend: proton; neutron; electron (e^-); positron (e^+); neutrino (ν); antineutrino ($\bar{\nu}$); quark; gluon field; gluon; photon (γ); $^{14}_{6}C$ — A = mass number, Z = atomic number; N = neutron number = A − Z

Expansion of the Universe

After the Big Bang, the universe expanded and cooled. At about 10^{-6} second, the universe consisted of a soup of quarks, gluons, electrons, and neutrinos. When the temperature of the Universe, $T_{universe}$, cooled to about 10^{12} K, this soup coalesced into protons, neutrons, and electrons. As time progressed, some of the protons and neutrons formed deuterium, helium, and lithium nuclei. Still later, electrons combined with protons and these low-mass nuclei to form neutral atoms. Due to gravity, clouds of atoms contracted into stars, where hydrogen and helium fused into more massive chemical elements. Exploding stars (supernovae) form the most massive elements and disperse them into space. Our earth was formed from supernova debris.



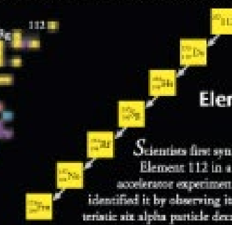
Phases of Nuclear Matter



Nuclear matter can exist in several phases. When collisions excite nuclei, individual protons and neutrons may evaporate from the nuclear fluid. At sufficiently high temperature or density, a gas of nucleons (red background) forms. At even more extreme conditions, individual nucleons may cease to have meaningful identities, merging into the quark-gluon plasma (yellow background). Current data provide hints that physicists have glimpsed the quark-gluon plasma.

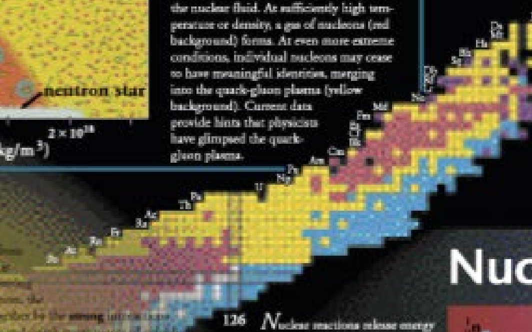
Unstable Nuclei

Stable nuclides form a narrow white band on the Chart of the Nuclides. Scientists produce unstable nuclides far from this band and study their decays, thereby learning about the extremes of nuclear conditions. In its present form, this chart contains about 2500 different nuclides. Nuclear theory predicts that there are at least 4000 more to be discovered with Z ≤ 112.

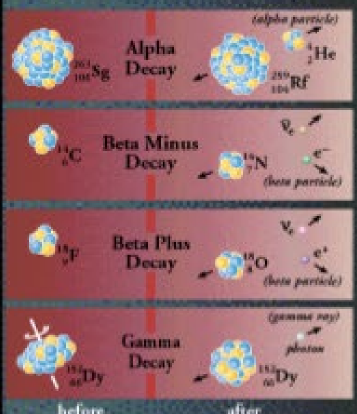


Element 112

Scientists first synthesized Element 112 in a particle accelerator experiment. They identified it by observing its characteristic six alpha particle decay chain.



Radioactivity

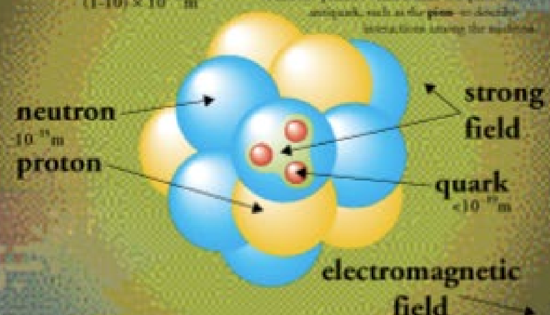


Radioactive decay transforms a nucleus by emitting different particles. In **alpha** decay, the nucleus releases a $^4_2$He nucleus—an alpha particle. In **beta** decay, the nucleus either emits an electron and antineutrino (or a positron and neutrino) or captures an atomic electron and emits a neutrino. A positron is the name for the antiparticle of the electron. Antimatter is composed of antiparticles. Both alpha and beta decays change the original nucleus into a nucleus of a different chemical element. In **gamma** decay, the nucleus lowers its internal energy by emitting a photon–a gamma ray. This decay does not modify the chemical properties of the atom.

The Nucleus

(1–10) × 10^{-15} m

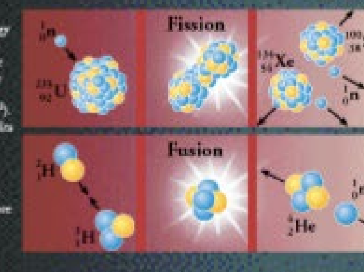
At the center of the atom's nucleus formed from **nucleons**—protons and neutrons. Each nucleon is made from three **quarks** held together by their strong interactions, which are mediated by gluons. In turn, the nucleus is held together by the **strong** interactions between the gluon and quark constituents of neighboring nucleons. Nuclear physicists often use the exchange of mesons—particles which consist of a quark and an antiquark, such as the **pion**—to describe interactions among the nucleons.



In an atom, **electrons** range around the nucleus at distances typically up to 10^5 times the nuclear diameter. If the electron cloud were drawn to scale, this chart would cover a small town.

Nuclear Energy

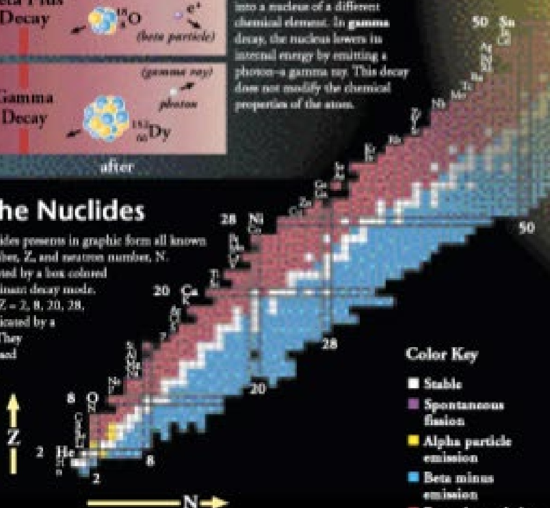
Nuclear reactions release energy when the total mass of the products is less than the sum of the masses of the initial nuclei. The "lost mass" appears as kinetic energy of the products ($E = mc^2$). In fission, a massive nucleus splits into two major fragments that usually eject one or more neutrons. In fusion, low mass nuclei combine to form a more massive nucleus plus one or more ejected particles—neutrons, protons, photons, or alpha particles.



In the early stages of stellar evolution of our sun and other stars, hydrogen fuses to form helium, releasing energy in the form of photons (light) and neutrinos. During the later stages of stellar evolution, more massive nuclei up to and beyond uranium are synthesized by fusion. By measuring the number of neutrinos that come from the Sun, scientists recently have demonstrated that neutrinos must have a mass greater than zero.

Chart of the Nuclides

The Chart of the Nuclides presents in graphic form all known nuclei with atomic number, Z, and neutron number, N. Each nuclide is represented by a box colored according to its predominant decay mode. **Magic numbers** (N or Z = 2, 8, 20, 28, 50, 82 and 126) are indicated by a rectangle on the chart. They correspond to major closed shells and show regions of greater nuclear binding energy.



Color Key

- Stable
- Spontaneous fission
- Alpha particle emission
- Beta minus emission
- Beta plus emission or electron capture

Applications

Radioactive Dating

Naturally occurring radioactive isotopes such as $^{14}_{6}C$ are used to date objects that were once living, such as wood. For example, from a study of artifacts found at the site, scientists determined that Stonehenge was built nearly 4,000 years ago.

Space Exploration

Sojourner used alpha particles to identify chemical elements present in Martian rocks. On Earth, nuclear reactions are used in many areas from criminal investigations to art authentication.

Nuclear Reactors

Nuclear reactors use the fission of $^{235}_{92}U$ or $^{239}_{94}Pu$ nuclei to produce electric power. Reactors and most other nuclear applications generate radioactive waste; disposal of this waste is a subject of current research.

Smoke Detectors

Many smoke detectors use a small amount of the alpha emitter $^{241}_{95}Am$ to ionize the air. Smoke entering the detector reduces the current and sets off the alarm.

Nuclear Medicine

Radioactive isotopes, such as $^{99m}_{43}Tc$, $^{60}_{27}Co$ and $^{131}_{53}I$, are commonly used in the diagnosis and treatment of disease. Positron emitters such as $^{18}_{9}F$ are used in Positron Emission Tomography (PET) to generate images of brain activity.

Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) makes use of atomic transitions involving the magnetic field of a nucleus to study the local chemical environment. This technique accurately maps the density of hydrogen to produce three-dimensional images of the human body.

www.CPEPweb.org

Astrophysical pictures courtesy NASA/JPL/Caltech and AURA/STScI.

Support from U.S. Department of Energy, Ernest Orlando Lawrence Berkeley National Laboratory – Nuclear Science Division, American Physical Society – Division of Nuclear Physics, J.M. Nitschke Fund, U.S. National Science Foundation

PREGUNTES QUE ENS FEM

- Com sorgeix la **força forta entre nucleons** a partir de l'estructura subjacent de quarks i gluons?

- Com sorgeix la complexitat de **l'estructura nuclea**r a partir de la interacció entre nucleons?

- Quins són els límits de l'**estabilitat nuclear**?

- *On de l'univers i com es* ***sintetitzen els elements*** *químics?*

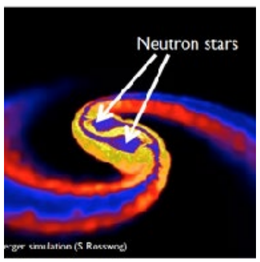
- Com es comporta la **matèria en condicions extremes** de temperatura (univers llunyà) i de densitat (estrelles de neutrons)?

The Nuclear Physics European Collaboration Committee (NuPECC) (2017 Long-Range Plan)

Però també…

Què és la **matèria fosca?**

- La **matèria fosca** interactua amb els **nuclis**



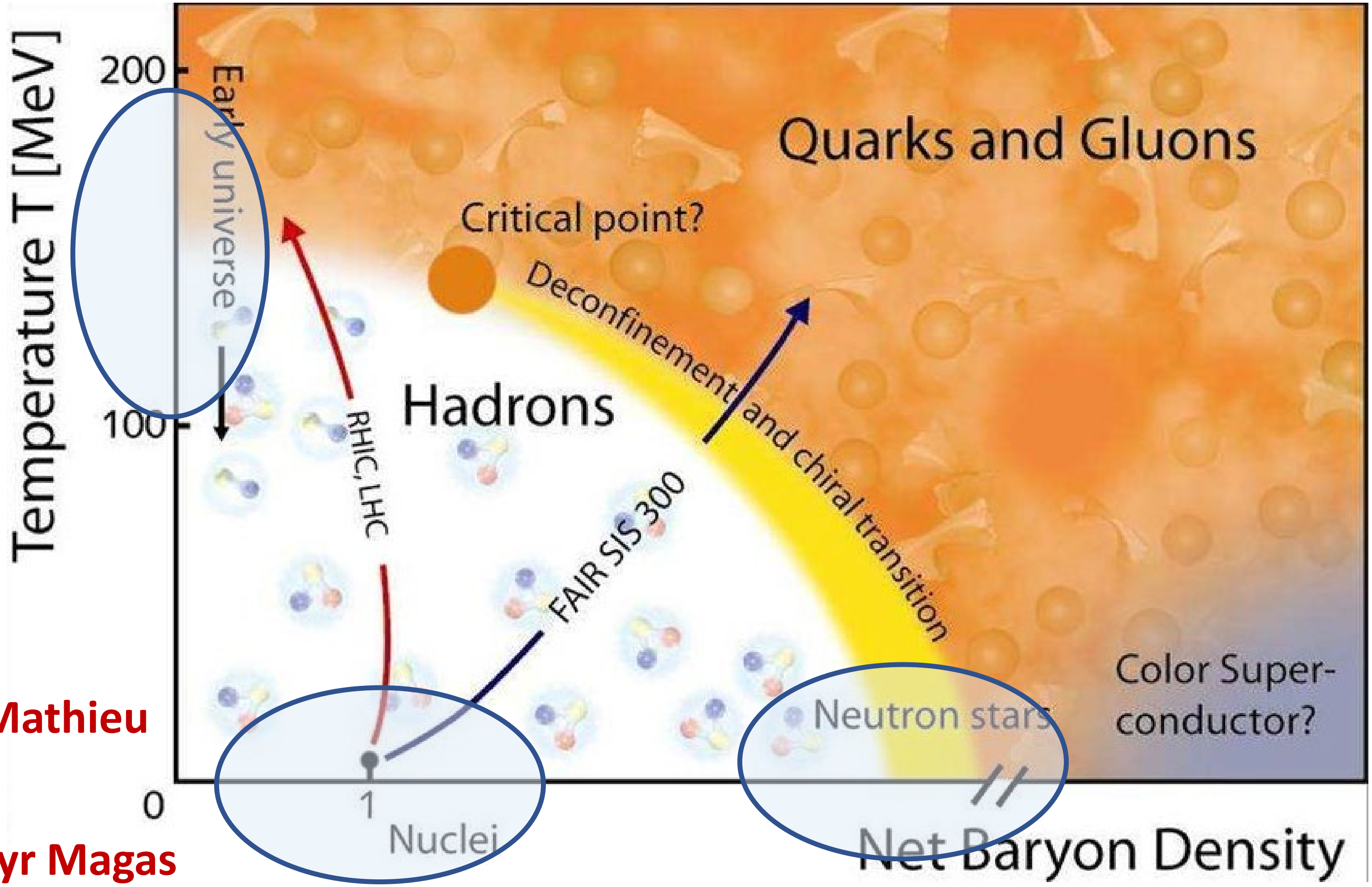
D'on sorgeixen les **ones gravitacionals?**

- Entre altres, de binaries **d'estrelles de neutrons**!

Què són els **neutrins?**

- Els **neutrins** interactuen amb els **nuclis**
- **Neutrins** astofísics es creen a les **estrelles de neutrons**

PHASE DIAGRAM OF THE STRONG INTERACTION



Vincent Mathieu

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Àngels Ramos

Juan Torres-Rincón

Mario Centelles

Assumpta Parreño

Arnau Ríos

APLICACIONS DE LA FÍSICA NUCLEAR

Medicine

Isotope production
Imaging
Cancer therapy
PETs & Scans

Art/Archaeology

Radioactive Dating
Ion Beam Analysis

Energy

Nuclear Power
Transmutation
New reactor design

Basic Nuclear Physics

Environment

Radiation Detection
Waste Cleanup
Climate Change
Radon

Space

Radiation Damage
Radiation Detection

Technology

Material Characterisation
Radiation Damage
Wear Testing
Accelerators

MÁSTER INTERUNIVERSITARIO EN FÍSICA NUCLEAR

https://master.us.es/fisicanuclear/

Destinado a:

- Futuros investigadores
- Profesionales (física médica, radioactividad ambiental, técnicas nucleares de análisis, centrales nucleares)

Universidades participantes:

U. de Sevilla (COORDINADORA)

U. de Barcelona

U. de Salamanca

U. Complutense Madrid

U. Autónoma de Madrid

Instituto de Estructura de la Materia (CSIC)

U. de Granada

Instituto de Física Corpuscular, Valencia (CSIC)

CIEMAT

Objetivos (I):

- Proporcionar una formación sólida en los aspectos fundamentales de la Física Nuclear, desde el punto de vista **teórico**, **experimental** y **aplicado**. Para responder a preguntas tales como

  ¿Cómo son los núcleos y cómo se miden sus propiedades?

  ¿Cómo interaccionan los núcleos?
  (con otros núcleos, con neutrinos, con materia oscura…)

  ¿Para qué sirven los núcleos atómicos?
  (aplicaciones médicas, datación, energía,…)
  (aplicaciones astrofísicas: estrellas de neutrones, ondas GW)

  ¿Qué hay más allá de los núcleos atómicos?
  (quarks, quark-gluon-plasma,….)

Objetivos (II):

- Preparar para una futura una labor investigadora en cualquier subdisciplina del campo.
- Poder desarrollar una actividad profesional en física médica, radiología, radiactividad ambiental, técnicas nucleares de análisis, técnicas de fechado por isótopos radiactivos o centrales nucleares.
- Promover el conocimiento y el intercambio científico entre los estudiantes de todo el estado.
- Fomentar la colaboración entre los grupos de investigación españoles.
- Optimizar los recursos humanos y materiales del estado español para conseguir un Máster en Física Nuclear de máximo nivel.

Estructura del máster

60 créditos ECTS (1 año):

- 6 cursos (6 créditos/curso) → **36 créditos** ECTS

  (3 cursos obligatorios, 3 cursos optativos)

Cada uno de los cursos se imparte de manera intensiva en una sede de las universidades participantes (1 semana online + 1 semana presencial).

- 1 trabajo fin de máster → **24 créditos** ECTS

Coste matrícula: 821 €

Becas: Beca movilidad de la U de Sevilla
Beca de matrícula del ICCUB (por méritos)
https://icc.ub.edu/education

Asignaturas Obligatorias:

- **ESTRUCTURA NUCLEAR: PROPIEDADES Y MODELOS (Granada)**
- **INTRODUCCIÓN A LAS REACCIONES NUCLEARES (Sevilla)**
- **FÍSICA NUCLEAR EXPERIMENTAL (Madrid o Sevilla)**

Asignaturas Optativas:

- FÍSICA NUCLEAR APLICADA I (→ Sevilla) (medioambiente y materiales)
- FÍSICA NUCLEAR APLICADA II (→ Madrid) (energía y aplicaciones bio-médicas)
- ASTROFÍSICA NUCLEAR (→ Barcelona)
- FÍSICA HADRÓNICA (→ Barcelona)
- TEORÍA CUANTICA RELATIVISTA (→ Sevilla)
- TÉCNICAS EXP. AVANZADAS EN F.N. (→ Valencia)
- TEORÍAS DE MUCHOS CUERPOS EN F.N. (→ Madrid)
- INTERACCIONES DÉBILES (→ Granada)

Els alumnes UB es matriculen a la Universitat de Sevilla !

El plazo y los procedimientos de preinscripción y matricula, variarán según la universidad de origen.

A modo de orientación el calendario de matriculación en **Andalucía** para el curso 2021-2022 lo puedes ver en:

http://www.juntadeandalucia.es/economiayconocimiento/sguit/?q=masteres&d=mo_calendario.php

El precio en el curso 2020-2021 ha sido 13,68 euros/crédito.

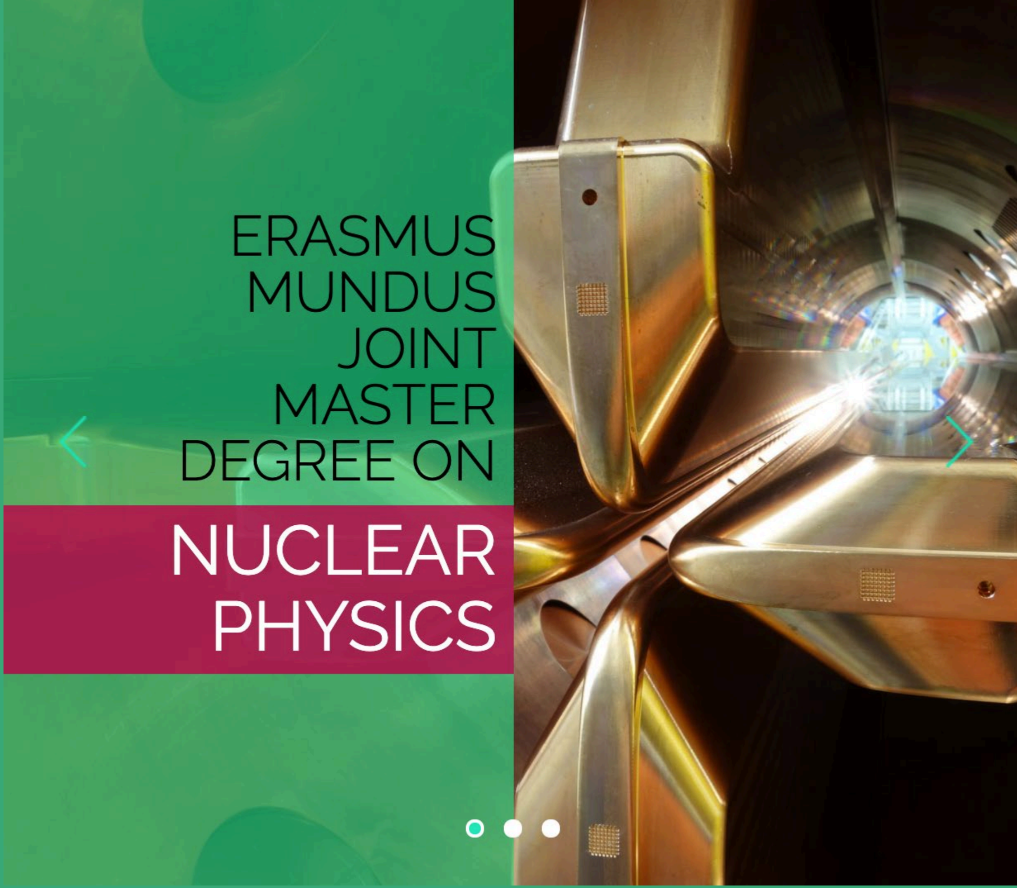
SEGUNDA FASE (Estudiantes españoles y extranjeros)	
Plazo de entrega de solicitudes	Del 24 de junio al 6 de julio
Fecha límite para haber abonado los derechos de expedición del título:	6 de septiembre
Proceso de evaluación de las solicitudes	Hasta el 22 de julio
Publicación de la primera lista de adjudicación.	26 de julio (a lo largo del día)
Plazo de alegaciones, revisión o reclamaciones	del 26 al 29 de julio
Primer plazo de matrícula, reserva de plaza y/o confirmación de lista de espera	Del 27 al 29 de julio
Publicación de la segunda y última lista de adjudicación	12 de septiembre (a lo largo del día)
Plazo de alegaciones, revisión o reclamaciones	del 12 al 15 de septiembre
Segundo plazo de matricula y/o confirmación de lista de espera	del 13 al 15 de septiembre

Profesores UB:

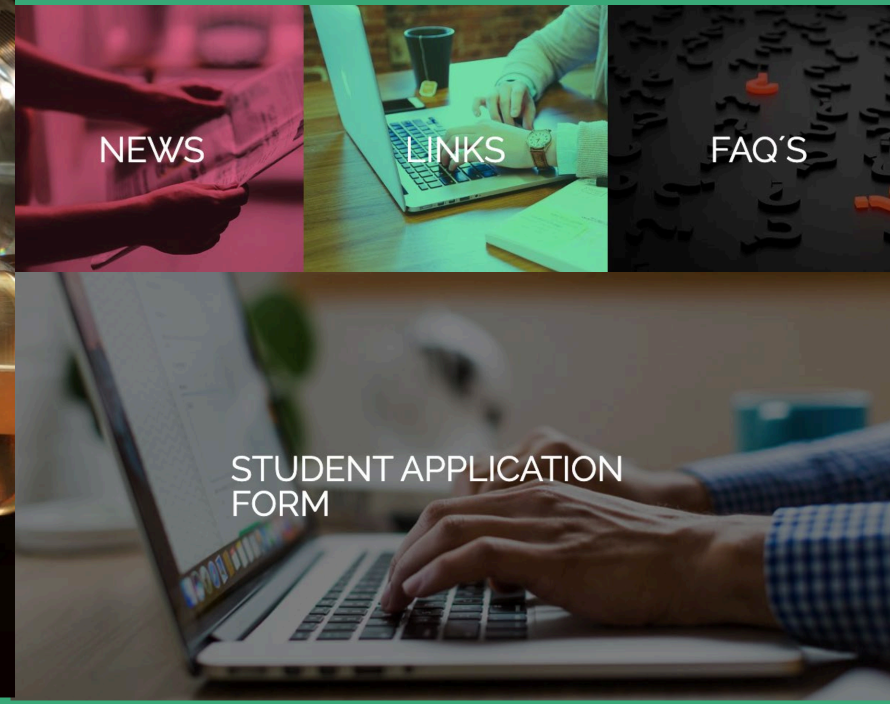
Mario Centelles
Volodymyr Magas
Vincent Mathieu
Javier Menéndez
Assumpta Parreño
Àngels Ramos
Arnau Ríos
Juan Torres-Rincón
Laura Tolós (IEC-CSIC)

Coordinador: Manuel García León (U. Sevilla), manugar@us.es

Coordinadora UB: Àngels Ramos, angels.ramos@ub.edu



http://www.emm-nucphys.eu/



The applications period for the NUCPHYS 6.0 generation is open from November 15th, 2021 until January 15th, 2022!

CLOSED

But a new deadline might be opened for self-funded students ...
(we will know in a couple of weeks)

U. de Sevilla (COORDINADORA)

U. de Barcelona

U. de Salamanca

U. Complutense Madrid

U. Autónoma de Madrid

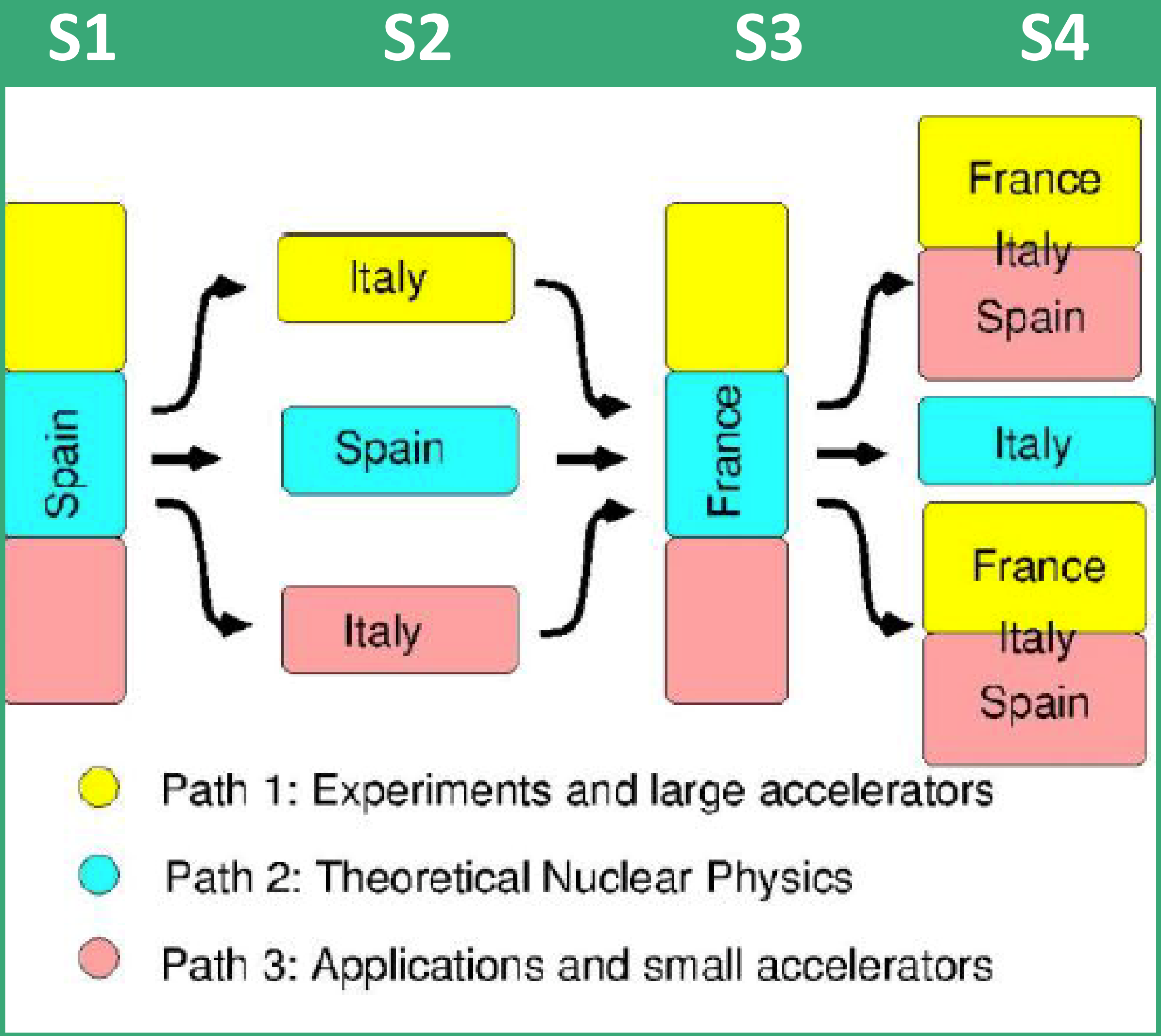
U. di Catania (Italia)

U. di Padova (Italia)

U. De Caen (Francia)

Organization of the Masters Course

The The Master is divided in four semesters (2 years)



- **ADMISSION CRITERIA:**

  Bachelor's degree in physical sciences or an equivalent degree (180 ECTS or more)

  Number of students (per intake): 25

  (selection based on academic qualifications)

- **FINAL DEGREE:**

  Joint Master Degree by the Consortium universities

Fees and funding:

Cost (2 years=120 ECTs) is 6000 €, but…

1. **16 Erasmus+ Scholarships**

   (12 for partner country students +

   4 for programme country students)

2. **Self-paying students**

- **Fee waivers** (up to 70% of the registration fee)→ Cost: **1800 €**
- **Mobility grants** (Erasmus + Learning Mobility of Individuals (LMI)) up to 6 months (to cover costs of S3 or S4)
- **Other grants** (UniCAEN, ICC-UB, …)

Remember!

The call for application for the new edition 2022/2024 is now open until 15th January 2022!

CLOSED

But a new deadline might be opened for self-funded students ...
(we will know in a couple of weeks)

http://www.emm-nucphys.eu/