MSC IN PHYSICS: WHICH CURRICULUM

NUCLEAR AND PARTICLE PHYSICS

Giuseppe Politi
Alessia Tricomi

Struttura del piano di studi

First Year
ADVANCED QUANTUM MECHANICS
SOLID-STATE PHYSICS
NUCLEAR AND PARTICLE PHYSICS (9 CFU)
NUCLEAR AND PARTICLE PHYSICS LABORATORY
THEORY OF STRONG INTERACTIONS
NUCLEAR REACTION THEORY / *QUANTUM FIELD THEORY – I*
EXP. METHODS FOR NUCLEAR PHYSICS / *EXP. METHODS FOR PARTICLE PHYSICS*
NUCLEAR ASTROPHYSICS / *ASTROPARTICLE PHYSICS*
Elective Course (Particle sub curriculum, Application, Instrumentation)
Second Year
HEAVY IONS PHYSICS AT INTERMEDIATE AND HIGH ENERGY / *ELEMENTARY PARTICLE PHYSICS* (9 CFU)
NUCLEAR STRUCTURE / *DATA ANALYSIS TECHNIQUES FOR NUCLEAR AND PARTICLE PHYSICS*
Elective Course (Particle sub curriculum, Application, Instrumentation)

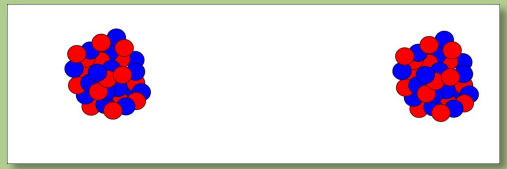
General part for fundamental physics and global aspects of curriculum

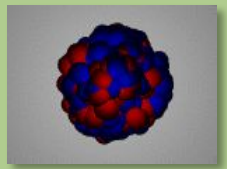
More specific part on NUCLEAR and *PARTICLE* physics, in strong connection with research activities @DFA

Elective course, for a personal characterization of study plan

Nuclear Physics main objectives

Focusing on various aspects of characteristics of Nuclear Matter and of Internal Nucleon Structure, studied with nucleus-nucleus collisions in the energy range 1 – 100 AMeV, investigated in various laboratories. thanks to top level Detection Systems and data analysis software



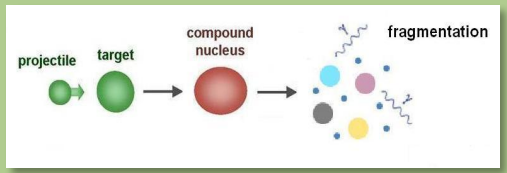


- Behaviour at different T and ρ -> equation of state - EOS of nuclear matter
- Dynamical and statistic processes; fusion, fission, fragmentation -> Phase transition
- Effects of isospin N/Z on reactions and on EOS -> nuclei far from stability
- Interaction of single nucleons with others -> nuclear structure and force
- Internal structure of nucleons -> quark-gluon plasma transition, mass, spin
- Theoretical modelling of strong interaction, nuclear structure and dynamic -> simulation of nuclear collisions
- Applications in fields such as astrophysics, medicine and environment

Nuclear Matter Characteristics

Study of Nuclear Dynamics at Intermediate Energies

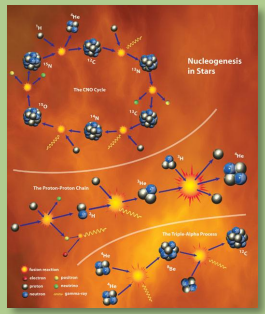
Nuclear dynamics study requires a precise detection of reaction products to achieve the event reconstruction



Use of different multidetectors to investigate several subjects of nuclear physics, with stable and radioactive beams, at low and intermediate energies

Study of Nuclear Astrophysics

Experiment studies nuclear fusion reactions at very low energies playing an important role in both stellar energy generation and in the synthesis of the elements

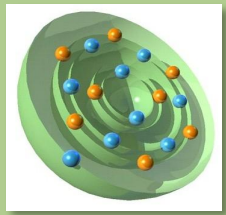


Study of Nuclear Structure

Nuclear shell model, with not well known nuclear force

Given energetic levels depend on nuclear interaction and shape

Energy Transitions -> information on nuclear structure and force



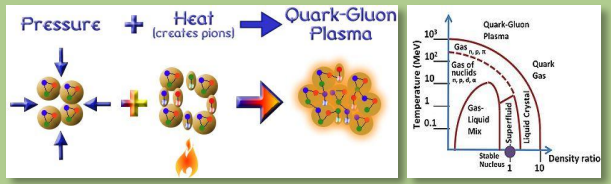
Internal Structure of Nucleons

Study of Nucleon Internal Structure with Ion Beams

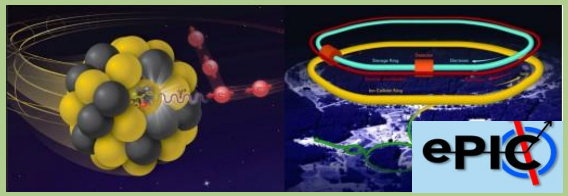
In nuclear collision at ultrarelativistic energy a large amount of energy is released in small volume -> $T = 10^{12}$ K -> universe 10 ms after Big Bang

Quark Deconfinement

-> Quark-Gluon Plasma transition



New Development of EIC, a particle accelerator that collides polarized electrons with protons and nuclei to reveal the arrangement of the quarks and gluons that make up the protons and neutrons of nuclei



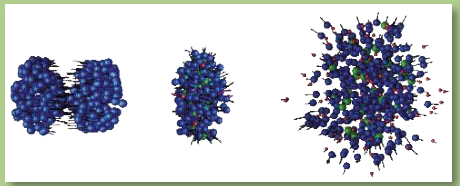
Theoretical Modelling

Study of Nuclear Reactions and Strong Interactions

Theoretical study of nuclear reaction is needed for a deeper understanding
-> models of nuclear matter behaviour and strong interaction

Dynamical and statistical models following system evolution according to Its characteristics

Comparison with data provides information on nuclear matter parameters:
nuclear potential and single particle interaction
nuclear matter characteristics -> compressibility



Applications of Nuclear Physics

Non invasive analysis techniques PIXE/XRF to measure sample composition based on nuclear / atomic interactions and on nuclear instrumentation

Ion beams to kill tumoral cells with maximum of energy released on tumour

Use of nuclear instrumentation to study contamination of various matrix and Radon presence

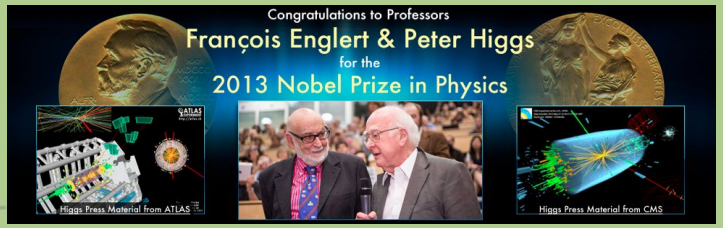
PARTICLE PHYSICS: a long PATH to discover the UNIVERSE

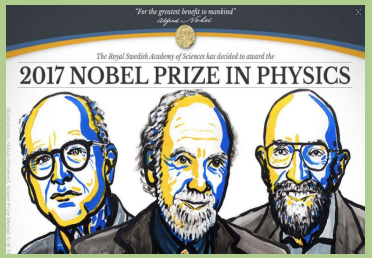
A journey that began more than 2000 years ago

- What is the world made of?
- What holds it together?
- What is the origin of the Universe?

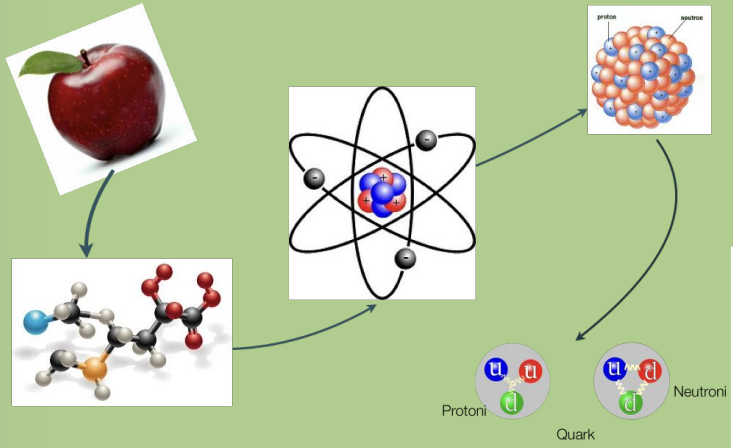
More than 150 years of exciting discoveries…

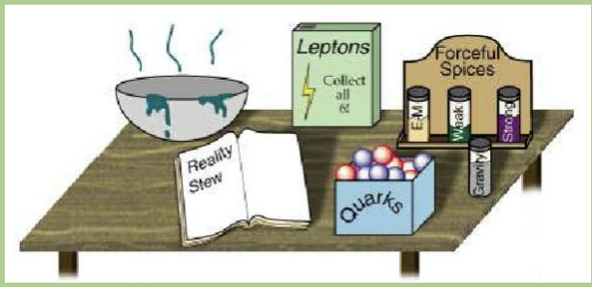
- And… Nobel Prizes





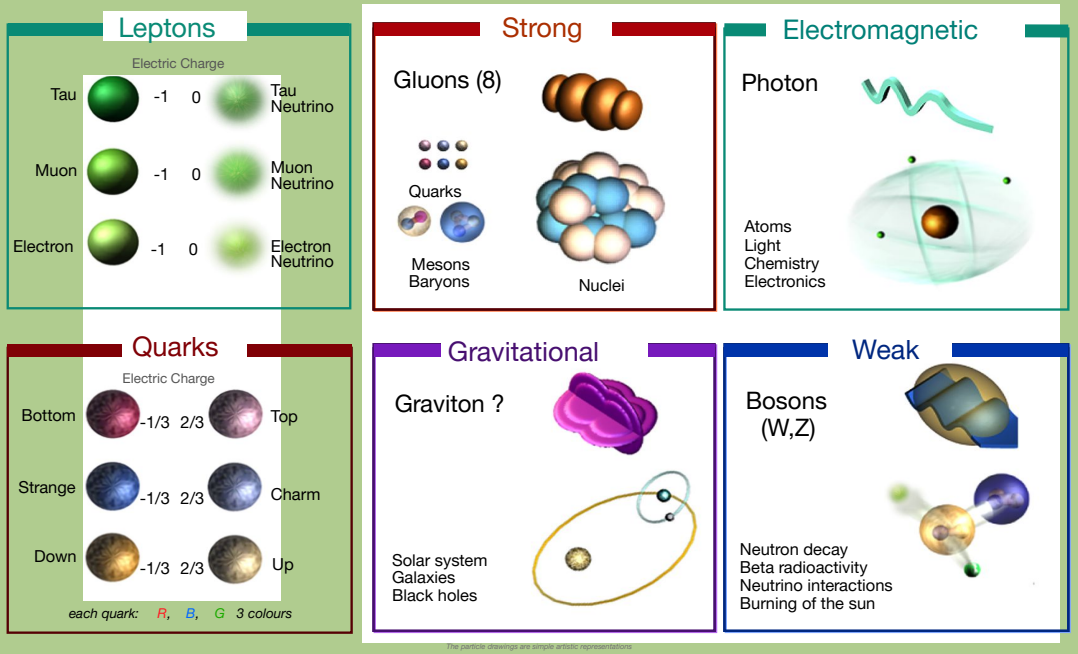
Where we are…





THE STANDARD MODEL

The standard model: particles and interactions



RESEARCH IN Particle PHYSICS

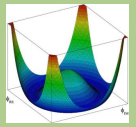
What we know is much less than the open questions

- Standard Model and Beyond…
  - Why particles have different masses ?
  - Why neutrinos are so light (or even why they have masses?)
  - Is the Higgs boson really the way to give mass to the particles?
  - Why we see matter/antimmater asymmetry in our Universe?
  - Are the Standard Model particles the only elementary particles?
  - Are they really elementary?
  - Does a Grand Unification of the interaction exhist?

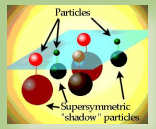
WHAT WE ARE LOOKING FOR?

The unknown

Higgs Boson



Supersimmetry



Extra Dimensions

Matter/antimatter

How – Particle Physics sub-curriculum

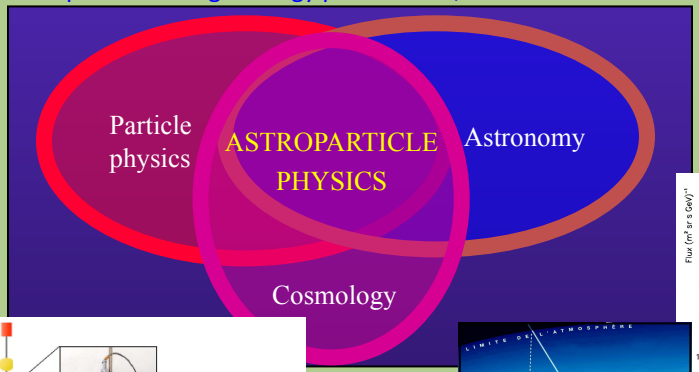
- **Study Particle Physics today: what we know and open problems?**
  - Which are the costituents of matter and interactions?
  - Standard Model and Beyond…
  - The origin of mass
  - Flavour issue
  - Grand Unification
  - Matter/Antimatter asymmetry
  - Dark Matter and Dark Energy
  - Origin of the Universe?

- **Study Particle Physics today: experiments at accelerators**
  - **LEP, TeVatron, B-Factories**
  - LHC – Large Hadron Collider
  - What about the future?

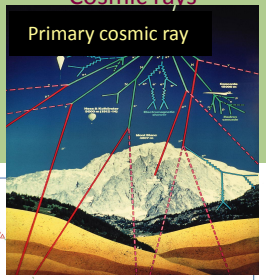
- Study Particle Physics today: Astroparticle Physics
  - Particle Physics without accelerators. How? Cosmic Rays, Neutrinos,…
  - Neutrino Physics
  - Cosmic Rays Physics
  - Dark Matter and Dark Energy

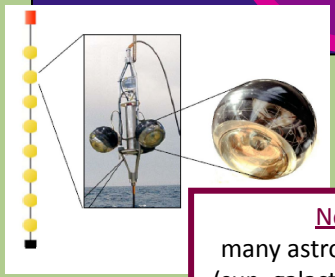
Astroparticle PHYSICS

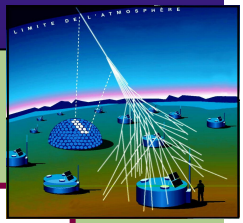
Astroparticle → high energy phenomena, cosmic accelerators

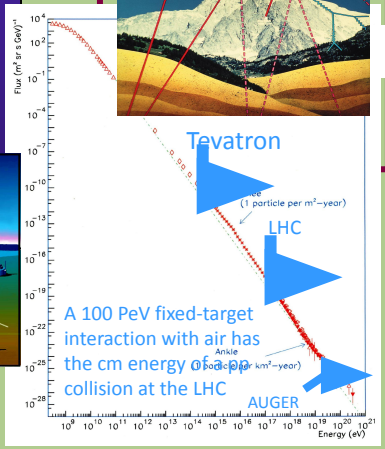


Cosmic rays





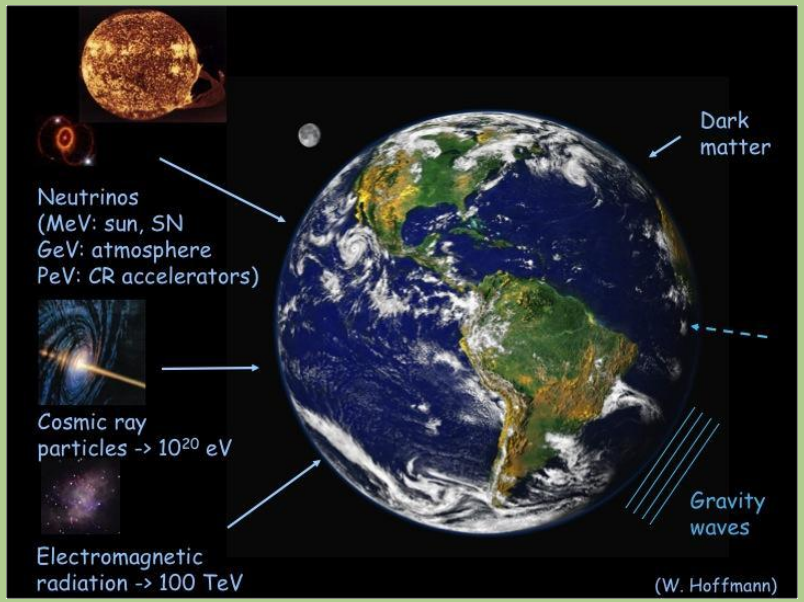




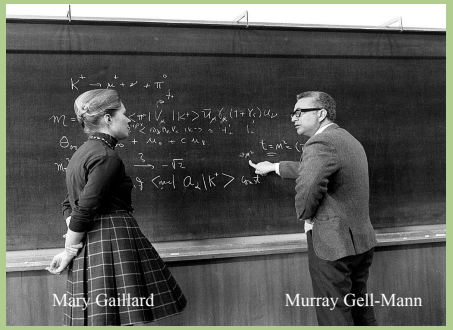
Neutrinos

many astrophysical sources (sun, galactic center, AGN…)

Astroparticle PHYSICS

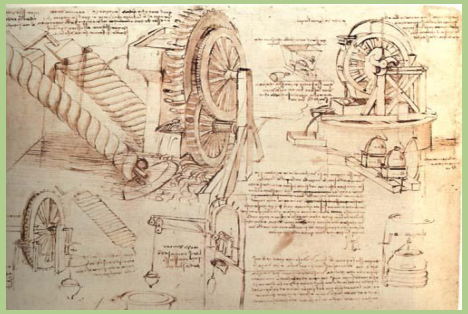


What you need in a particle PHYSICS experiment



A Theory/idea

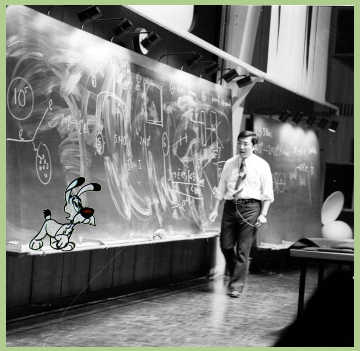
a cafetteria



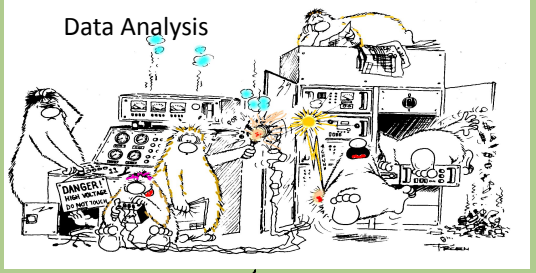
Clear Designs

What you need in a particle PHYSICS experiment

Easy access to the experiment



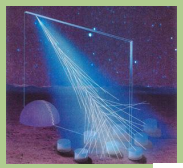
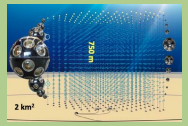
And a Nobel Prize ;-)

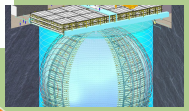


Detectors and Data Analysis

Lot of experiments and opportunities to work in international collaborations

- CMS Experiment (Higgs Boson, Supersymmetry, BSM, SLHC)
- LHCf Experiment (Astroparticle – HECR)
- RD-FA (Research & Development on future accelerator post LHC)
- Auger Experiment (HECR)
- CTA Experiment (Gamma Rays and multimessenger)
- DARKSIDE (Direct Dark Matter searches)
- Mu@FNAL (ICARUS) Experiment (Neutrino Physics)
- JUNO Experiment (Neutrino Physics)
- KM3NET(Neutrino Physics)
- SPB2 (HECR)
- Innovative detector development
- Possibility of summer stage
  - Summer student CERN, FNAL, DESY
  - INFN and CSFNSM fellowships



Summary and Perspectives

Curriculum showing fundamental basis and specific parts on Nuclear and Particle Physics, correlated to research activities at DFA, with INFN support

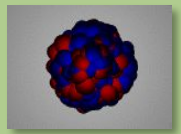
Study of nuclear matter, nucleon structure,

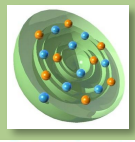
Standard Model and beyond

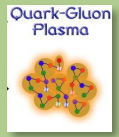
Innovative instrumentation development

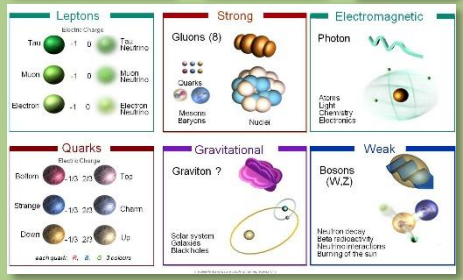
(detectors, electronics, beam production)

Application to various fields









All subjects are linked to available MSc thesis

Activities at LNS with stable and radioactive beams, within international collaborations

Activities, in collaboration with INFN, in other laboratories in Italy & abroad CERN, FERMILAB - JLAB - BNL - MSU (USA), GANIL (F), GSI - DESY (D) for data taking, analysis, stages

Grant for thesis development by INFN and CSFNSM

Summary and Perspectives

Post Master Formation

Grants after MSc by INFN and CSFNSM

PhD and Post-Doc grants (Italy/abroad)

Scuola di Specializzazione in Fisica Medica

Occupational opportunities

Universities and Research Organizations in Italy and abroad

Public Companies (ARPA, Hospital)

Private Companies into domain (Spin-Off in detectors and electronics, Medical applications)

Private Companies out of domain (computer science, data management)

MSC IN PHYSICS: WHICH CURRICULUM

GRAZIE

PER

L'ATTENZIONE

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