UNIVERSITÀ
DEGLI STUDI
DELL'AQUILA

DSFC
Dipartimento
di Scienze Fisiche
e Chimiche

The astroparticle physics group at University of L'Aquila

Carla Macolino
ISAPP SC meeting
Wien, 23.10.2026



L’AQUILA: VIBRANT AND CULTURAL CITY

The cultural program is based on three axes that link historical identity and technological innovation:

- **Territorial renewal through culture**
- **Multidisciplinarity and future through art, literature, new technologies and AI**
- **Social inclusion thorough education and music**



L’AQUILA 2026
Capitale italiana della Cultura







UnivAQ: UNIVERSITA DEGLI STUDI DELL'AQUILA



Renovabitur ut Aquilae juventus tua



Founded in 1596 although a "Studium" was present already in late 1400

16000 students
7 departments

Rector: Prof. Fabio Graziosi



UnivAQ: THE SCIENCE CAMPUS

The Science Campus hosts 4 departments:

-DISIM: Engineering and Information Science, Mathematics
-DISCAB: Clinical, applied and biotechnology science
-MESVA: Clinical medicine, public health and life and environment science
-DSFC:Physical and Chemical Sciences

Many laboratories and students facilities

Approved project of ~40 keuro to expand and improve infrastructure and facilities of the Science Campus







THE ASTROPARTICLE PHYSICS GROUP

Astroparticle group members

Theoreticians

- Z. Berezhiani (PO)
- Francesco Capozzi (PA)
- F. Nesti (PA)
- L. Pilo (PA)
- F.L. Villante (PO)

Experimentalists

- D. Boncioli (PA)
- A. Ferella (PA)
- N. Finetti (Ric)
- C. Macolino (PA)
- F. Salamida (PA)
- V. Rizi (PO)

With strong collaboration with GSSI, LNGS, INAF, CERN, SISSA members
Including a number of former PhD students and postdocs from Univaq

RESEARCH ACTIVITIES IN THEORY

Gravity and Cosmology

Late time cosmology

What is Dark Energy ? Cosmological constant or some medium?

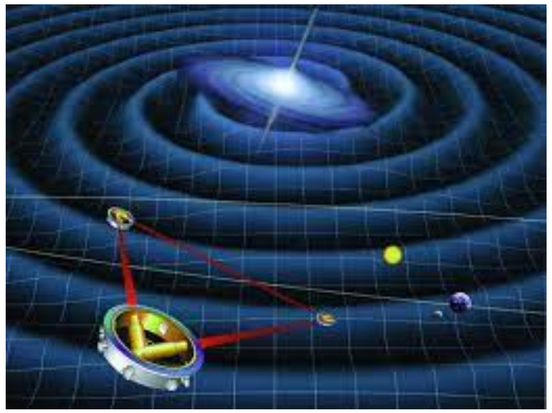
Early time cosmology

Quantum origin of initial perturbations (inflation)

Gravitational Waves physics with LISA

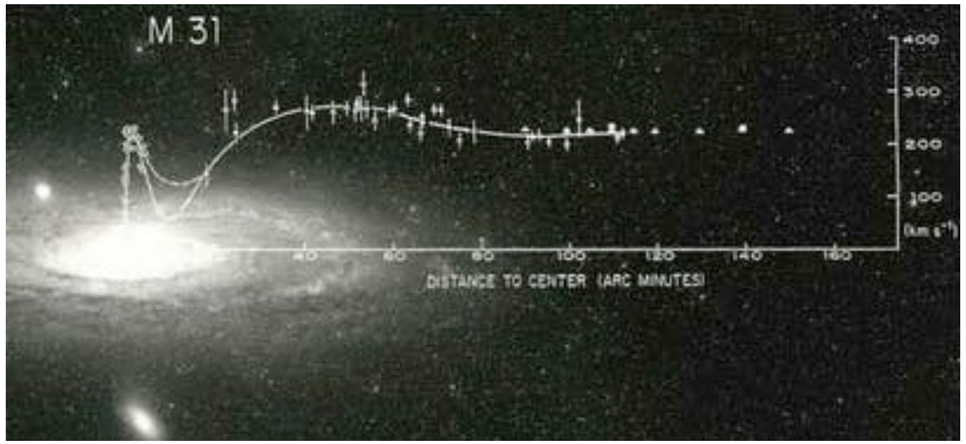
Cosmology with GWs
Testing gravity with LISA

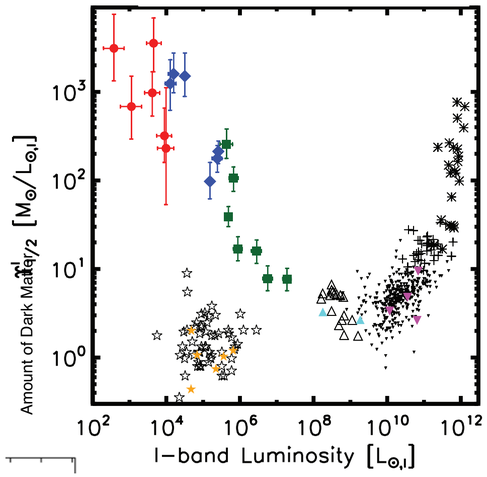
L. **Pilo**



The nature of Dark Matter

F. Nesti
Z. Berezhiani





Inputs from astrophysics - New paradigms?
Particle candidates - dark forces?

PARTICLE PHENOMENOLOGY BEYOND STANDARD MODEL

Looking for new interactions, to bring order in the SM, to account for cosmological phenomena, violation of baryon or lepton number

F. **Nesti**

Z. **Berezhiani**

Theoretical work
Phenomenology
Monte Carlo simulations

Particle phenomenology
Beyond the Standard Model

e.g. for the Large Hadron Collider @ CERN or future colliders (FCC)

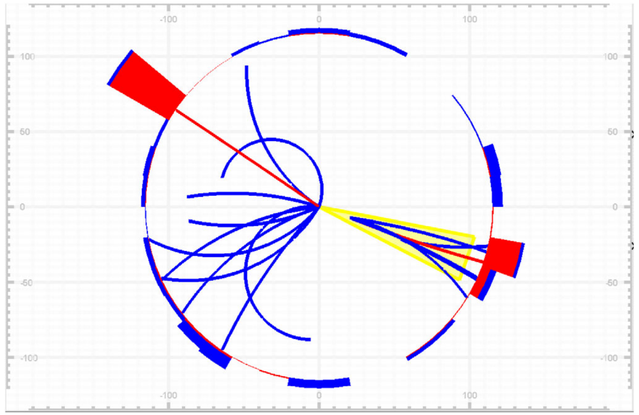
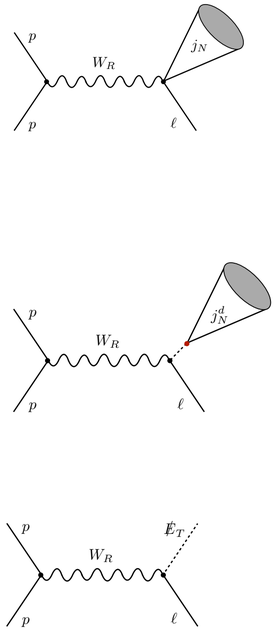
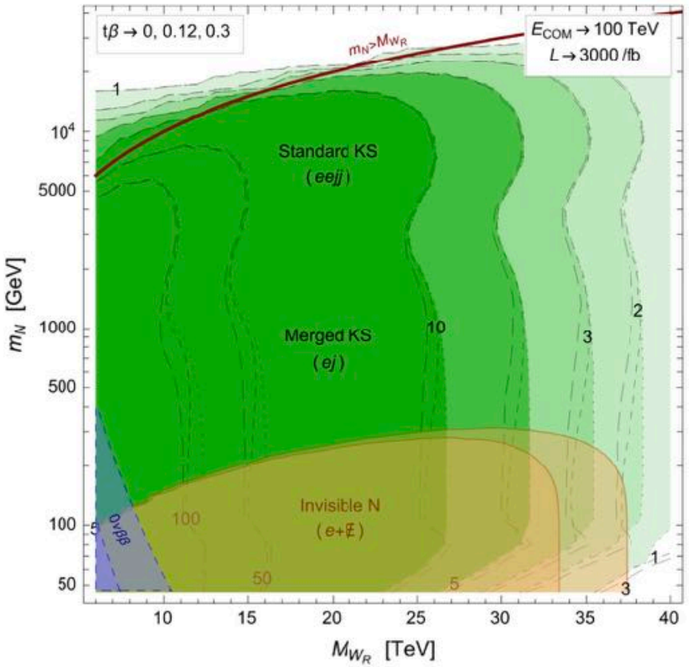


FIG. 6. A typical event featuring the prompt electron and a merged jet on the opposite side, including the secondary electron and hadronic tracks (blue) from a ∼3 cm-displaced vertex. Both,

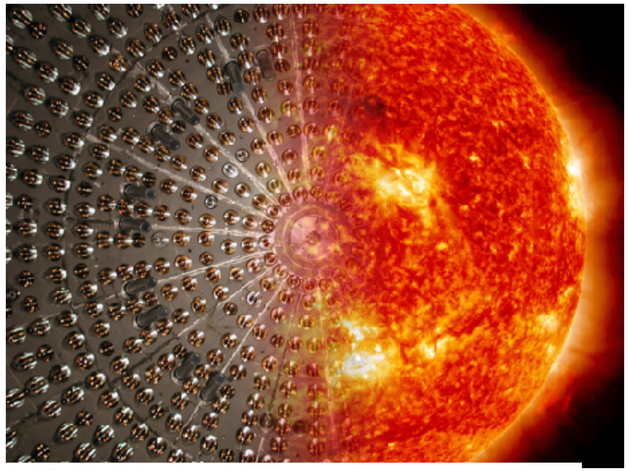


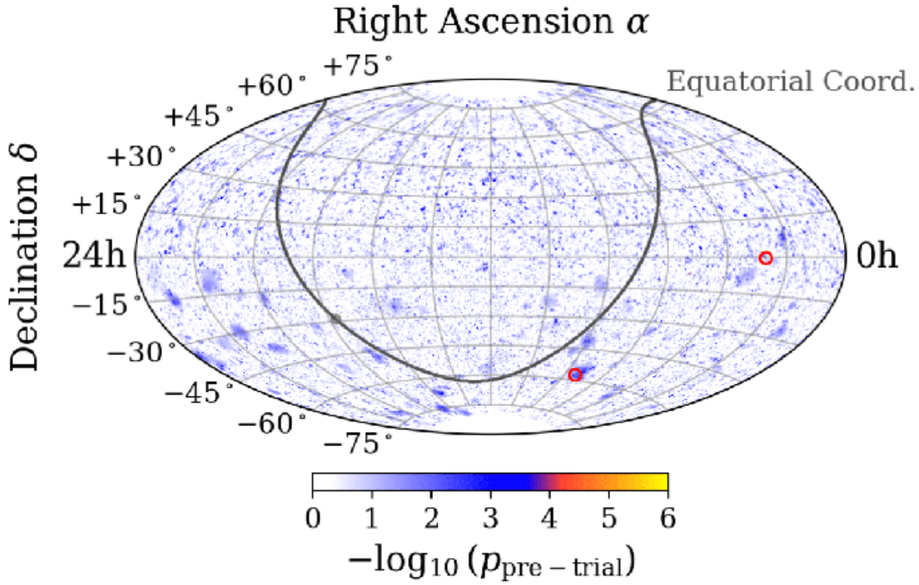


Neutrino phenomenology and astrophysics

- Solar Models
- Nuclear reactions producing neutrinos from the Sun (Borexino experimental data)
- Ultra high energy neutrinos
  Origin and propagation
  e.g. detected at Icecube
- cosmic rays interaction across the Galactic Plane, diffuse gamma-ray and hadronic neutrino production

F. L. **Villante**
F. **Capozzi**





IceCube collab. 2026

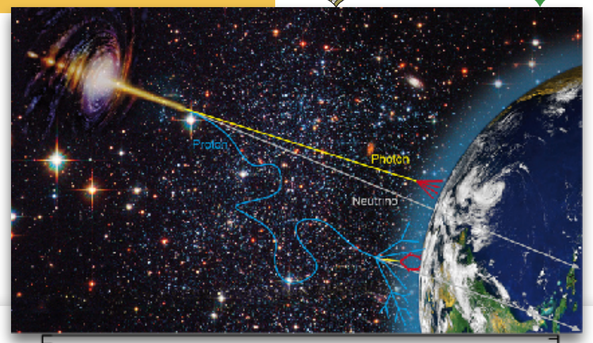
RESEARCH ACTIVITY IN

EXPERIMENTS

ASTROPARTICLE PHYSICS AT ULTRA HIGH ENERGIES

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Ultra High Energy Cosmic Rays

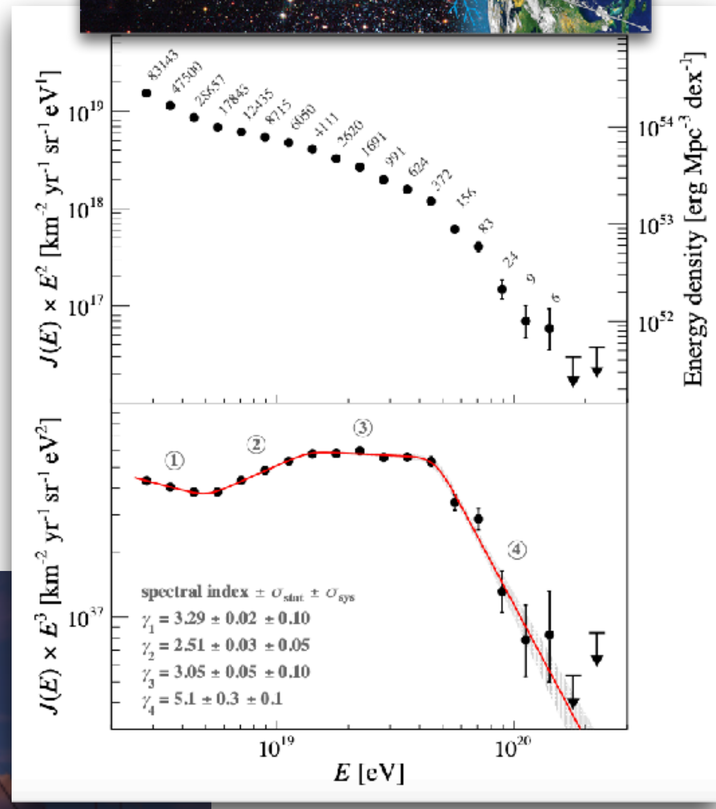
- Origin (production and interactions)
- Connections with other messengers (neutrinos, gamma, gravitational waves)
- Fundamental Physics ? (nuclear cross sections; space-time structure)

Main local expertise:

- Hardware/software for the **Pierre Auger Observatory** and **Cherenkov Telescope Array**

RESEARCH ACTIVITY IN EXPERIMENTS

D. **Boncioli** (Science Coordinator, Auger),
V. **Rizi,** F. **Salamida** (Detector Coordinator, Auger)







DARK MATTER AND NEUTRINO PHYSICS

XENON experiment

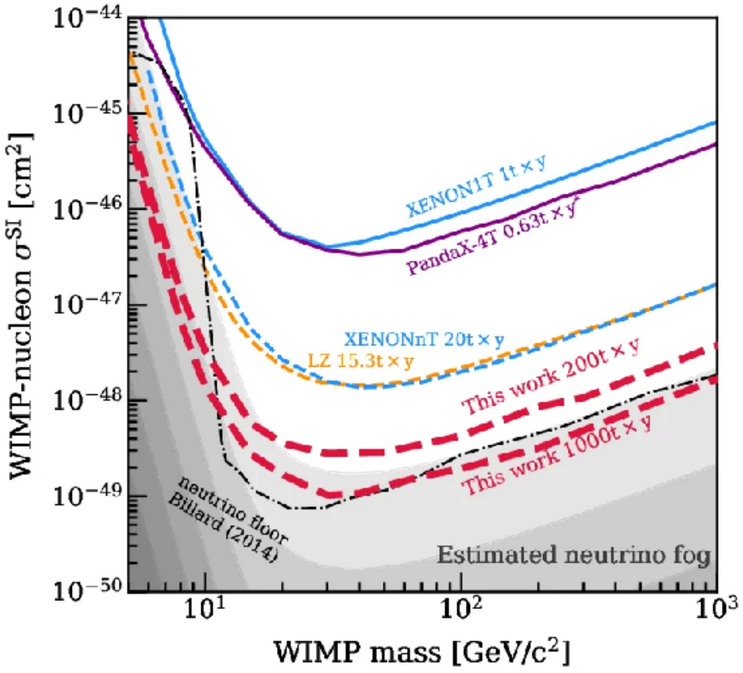
- WIMP search (large mass and sub-GeV)
- Solar neutrinos (via elastic-scattering or CEvNS)
- Supernova neutrinos
- Neutrinoless double-beta decay and other BSM channels

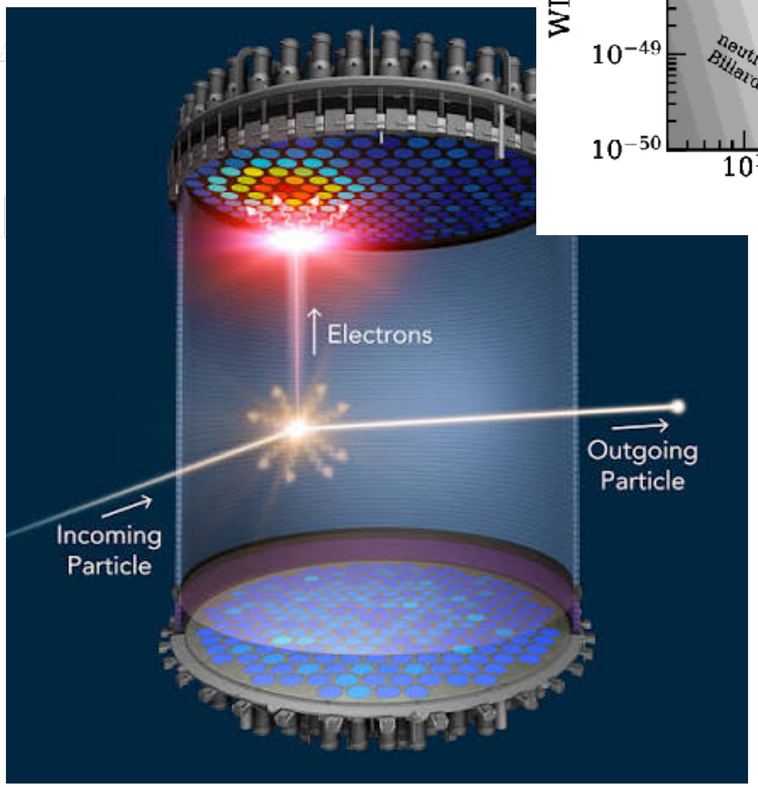
Main local expertise:

- Xe purification
- Electrodes and HV
- Photosensors
- Data analysis: high energy ER, WIMP channels, solar nu

A**. Ferella** (Purification, PR team responsible)

C**. Macolino** (Electrodes responsible, Speaker Bureau chair)

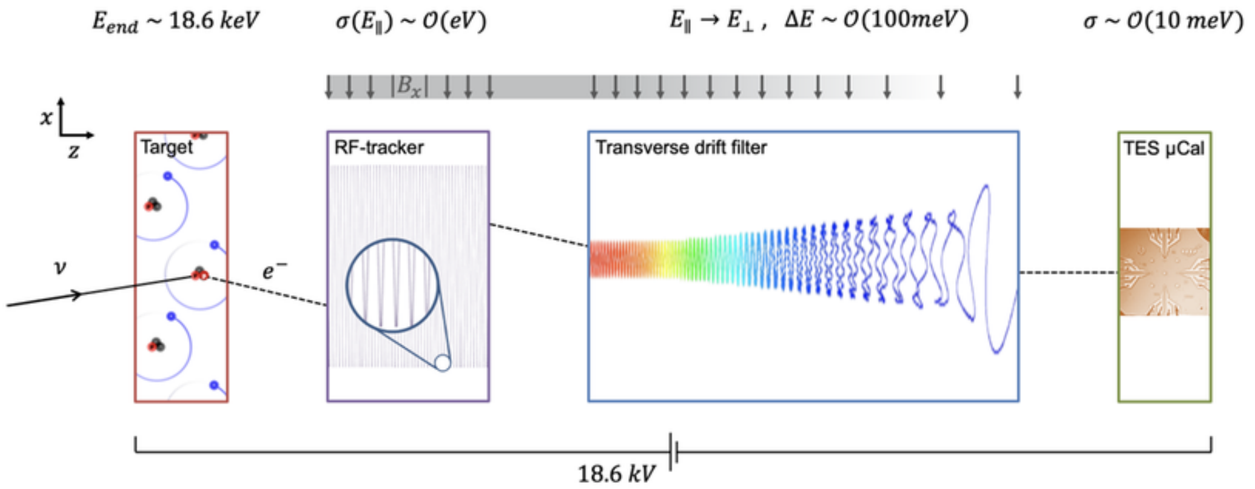




PTOLEMY experiment

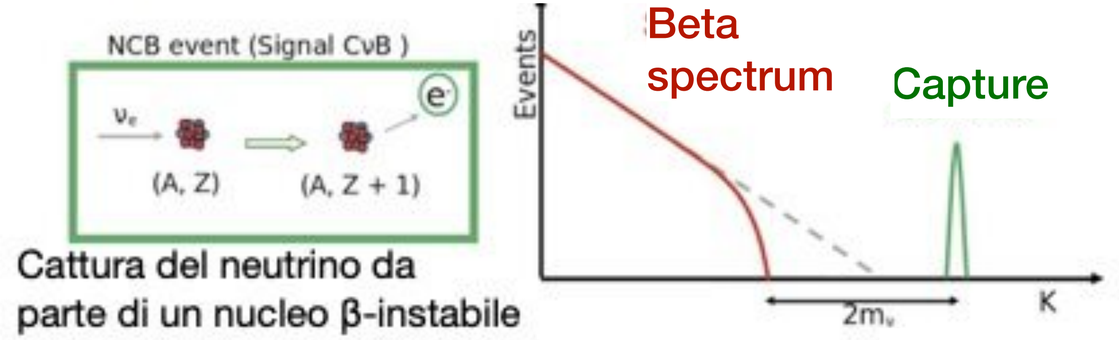
- Search for cosmic neutrino background
- Neutrino mass measurement
- Dirac/Majorana neutrino nature

Neutrino capture from a beta-decaying unstable nucleus





A. **Ferella**



$E_{total} = q(V_{TES} - V_{target}) + E_{RF} + E_{cal}$



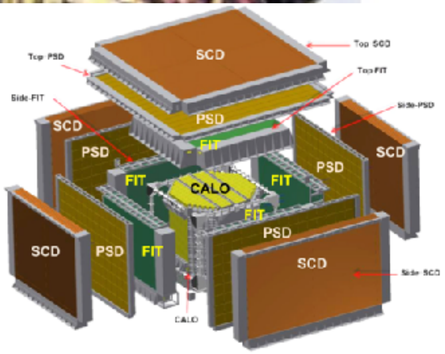
HERD experiment

N. **Finetti (INFN-Florence)**

- Space-based mission for to be installed at the China space station in 2027 (3D calorimeter)
- Galactic CRs (up to the knee), indirect DM, gamma rays



(a)

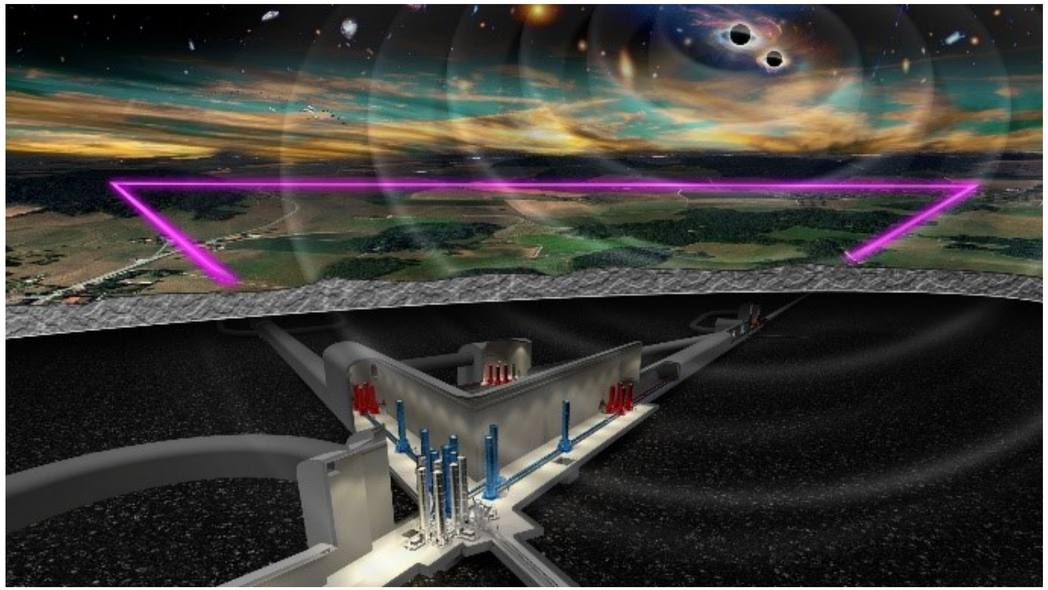


(b)

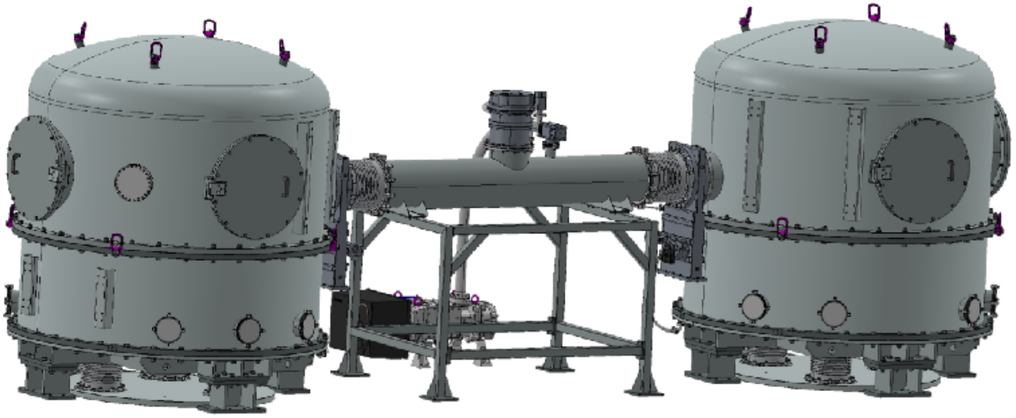
GRAVITATIONAL WAVES

EINSTEIN TELESCOPE

C. **Macolino**



- 3rd-generation, gravitational-wave observatory
- Explore the Universe through gravitational waves
- Physics near black-hole horizons, help understanding the nature of dark matter and the nature of dark energy and possible modifications of GR



GEMINI project at Laboratori del Gran Sasso (LNGS)

- ✓Development of vibration control and inter-platform control systems for ET
- ✓Test platform for novel inertial sensors (room&cryo-temperature);
- ✓Emulator of a cold lunar permanently shadowed region - GW detection on the Moon
- ✓Data analysis and evaluation of the science capacity of the ET detector configuration

COURSES

Bachelor in Physics: 3 years

Master in Particle and Astroparticle Physics: 2 years (in English)

PhD programme in Physics: 3 years

Theory courses

- Quantum Field Theory
- Gauge Theory
- Relativity & Cosmology

Phenomenology

- Particle Physics

Experimental courses

- Nuclear Physics & Methods
- Advanced Laboratory

Additional choices :

- Advanced Gravitation and Cosmology
- Standard Model and Beyond
- Dark matter and neutrino physics
- Cosmic rays and multimessenger astrophysics
- Astrophysics

Specialized courses devoted to PhD students on advanced statistical data analysis, radioactivity, cosmology, astrophysics,…

A number of complements on specific activities/subjects

SYNERGIES

LNGS ⟷ **GSSI** ⟷ **INAF**







- Scientific Collaborations
- "Chasing Science" fellowships for master students
- Summer Schools
- Projects with schools
- SHARPER/Street Science
- Housing
- Sport facilities







SISSA, ICTP, CERN: collaborations, schools Organization, conferences, joint programs (DRD2, …)

INTERNATIONAL

EULIST alliance

A bold alliance of eleven universities across Europe bridging the gap between society and technology

Cross-campus collaborative research, joint curricula, and virtual/physical mobility.



- **Erasmus+ Study**
- **Erasmus+ Traineeship**
- **Erasmus Italian**
- **Staff Mobility**

Robust Erasmus+ frameworks

Dedicated International Office

On-campus Language Centre

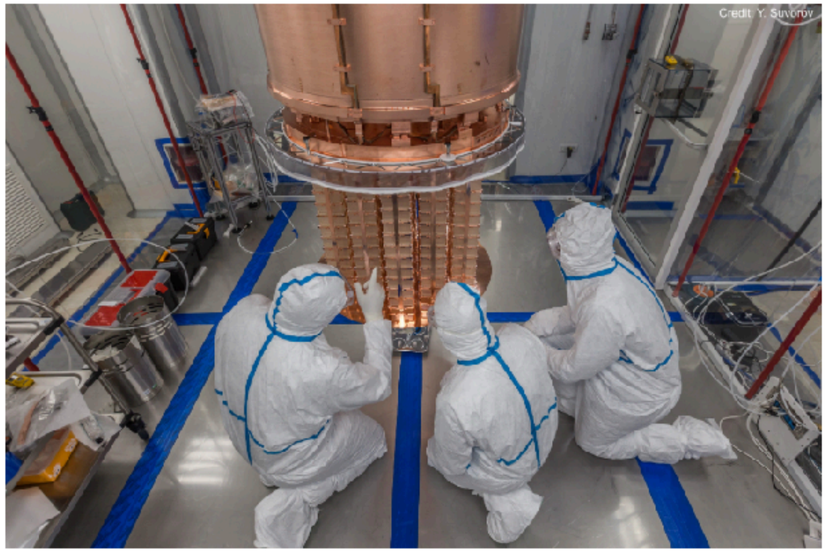


Extra-UE strategic plan

- Multiple international tracks fully taught in English (Engineering, Physics, Math, ICT).
- Core programs like InterMaths, RealMaths, and MathMods Joint Master Degrees.
- Strategic double degrees
- UNICORE - University Corridors for Refugees
- contributions to student travel and installation cost

HANDS-ON ASTROPARTICLE PHYSICS SUMMER SCHOOL

GRAN SASSO
hands-on 2025
PhD school on experimental astroparticle physics
September 8th - 18th, 2025



2025 Chairs: P. Agnes (GSSI), C. Macolino (UnivAQ), N. Rossi (LNGS)

Gran Sasso Hands-on 2025 is a summer school offering PhD students the **unique opportunity** of being directly involved in the research project activities at the Gran Sasso National Laboratory of INFN (LNGS), the world-leading laboratory for underground physics, astroparticle physics, and nuclear astrophysics



- Gravitational waves
- Dark matter searches
- Neutrino physics
- Cosmic-ray physics
- Nuclear astrophysics
- Multi-messenger astrophysics
- Space-based detectors
- Quantum technologies

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Applicants

INFN Milano-Bicocca
Astrocent, Warsaw Poland

INFN Milano-Bicocca
Austrian Academy of Sciences (ÖAW)

University of Mainz

Radboud University Nijmegen

University of Windsor

INFN Cagliari

INFN Cagliari

Technical University of Munich (TUM)

University of L'Aquila

National Institute for Astrophysics (INAF)

University of Zurich

University of Milano-Bicocca

IP2I Lyon (IN2P3/CNRS)

University of Mainz

University of Houston

Meriem Arabi — University of Algiers (Algeria)

Max Planck Institute for Physics

Max Planck Institute for Physics

INFN Padua

University of L'Aquila

INFN Ferrara

Nikhef

INFN Rome Tor Vergata

University of Zurich

Queen's University

INFN Milan

University of Washington

INFN Rome Tor Vergata

F. Nardis — Not specified

E. Cipelli — Max Planck Institute for Physics

Lorenzo Ascenzo — Not specified

C. Seoane — University of Zaragoza

Francesco Rossi — Not specified

Filippo Camilli — Not specified

Fudan University

Fudan University

Max Planck Institute for Physics

University of Padua

INFN Rome Sapienza

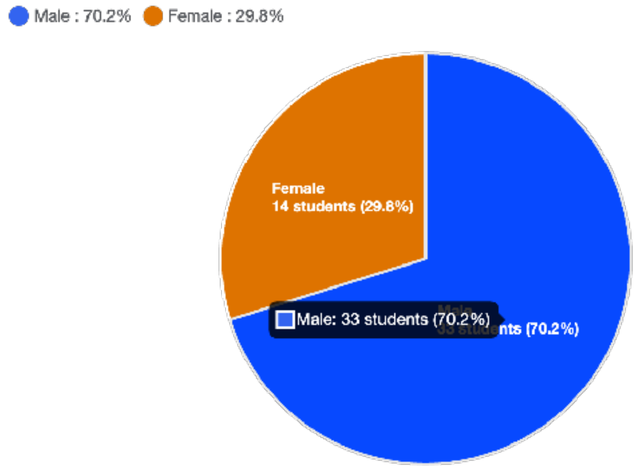
Gran Sasso National Laboratory (INFN)

University of Trento

Stockholm University

University of Hamburg

University of Berkeley



Lecturers

Pierre-André Amaudruz, TRIUMF (Electronics, DAQ and signal processing techniques)

Tomasz Bulik, NCAC (Gravitational waves)

Marco Cirelli, LPTHE (Dark matter theory)

Glen Cowan, RHUL (Statistics for rare event searches)

Rosanna Depalo, UniMI (Nuclear astrophysics)

Martin Lemoine, APC (Cosmic rays theory)

Kimberly Palladino, Oxford (Dark matter experiments)

Marco Pallavicini, INFN-Ge (Neutrino experiments)

Lorenzo Perrone, INFN-Le (Cosmic ray experiments)

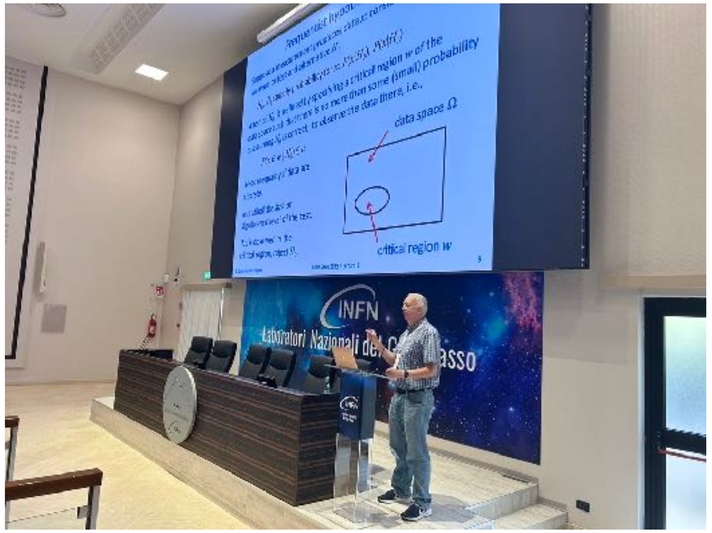
Francesco Vissani, INFN-LNGS (Neutrino theory)

HANDS-ON ASTROPARTICLE PHYSICS SUMMER SCHOOL

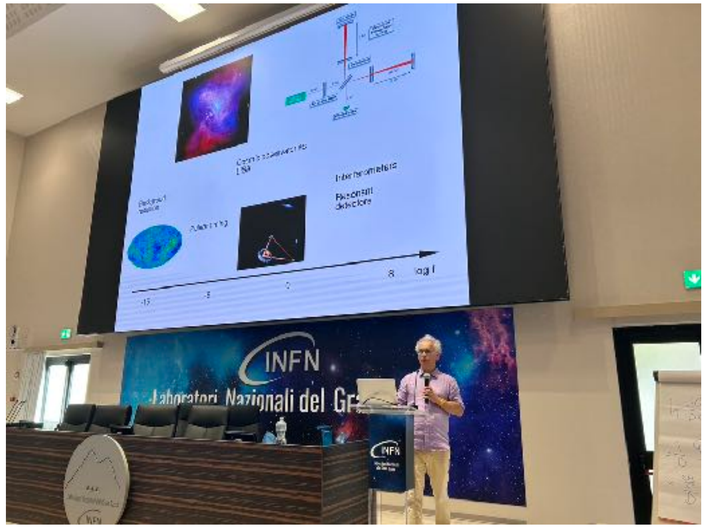
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G. Cowan



T. Bulik

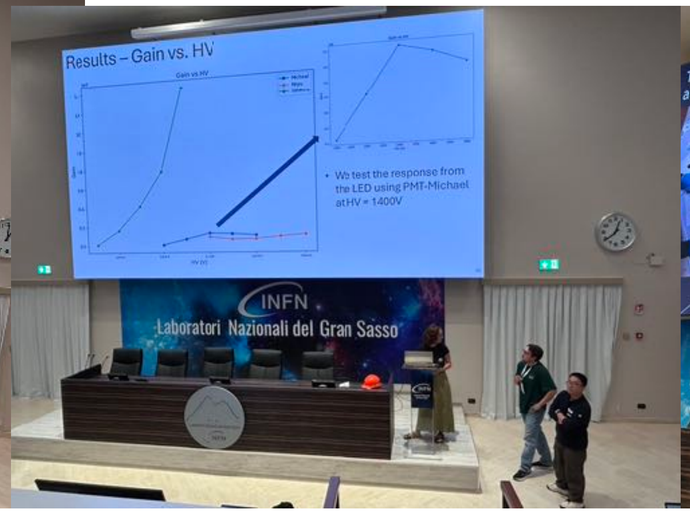


2025 HANDS-ON EDITION success

-> excellent lectures and research projects

LNGS scientific attractiveness and L'Aquila city convenience









Hands-on activities

1) Data analysis and interpretation of UHECR measurements by the Pierre Auger Observatory
2) mounting of a scintillating calorimeter with double readout and subsequent cooldown to 10 mK
3) Characterization of Transition Edge Sensors based Dark Matter Prototypes
4) Characterization of cryogenic calorimeters for 0νββ decay/characterization of thermal/mechanical performance of Pulse Tube cryocoolers
5) Characterization and optimization of an Optically readout TPC for Direct Dark Matter Search
6) Characterization and integration of large SiPM arrays in the NOA facility
7) DAQ operation and synchronization tests
8) Control of the GEMINI platforms
9) Light guide characterization/LAr purity monitoring
10) Cross section measurements at LUNA (Laboratory for Underground Nuclear Astrophysics)
11) Performance evaluation and particle detection for upcoming space missions
12) High-frequency electronics testing for the RF detector prototype of the PTOLEMY experiment.
13) Characterization and measurements with an ultra-pure sodium iodide crystal
14) Energy Reconstruction, Signals Correction, Using Machine Learning for data analysis from the XENONnT experiment
15) Characterization of GAGG-based neutron detectors

2 priorities indicated during registration

Homepage
Timetable
Important dates
Hands-On activities
Lecturers
Organizing Committee and Project Supervisors
Fee and accomodation
Venue and travel info
Accommodation
Social and special events
Application
Public Lecture "From Pythagoras to antimatter"

Contact
hands-on@lngs.infn.it

Hands-On activities

1) Data analysis and interpretation of UHECR measurements by the Pierre Auger Observatory

Experimental framework: **AUGER**

Field: **Cosmic Rays**

The activity will be focused on the use of the Monte Carlo simulation code SimProp for the propagation of UHECRs in the extragalactic space. The energy spectrum of UHECRs and cosmogenic neutrinos will be computed corresponding to variations of spectral parameters at the UHECR sources as well as to different choices for the UHECR mass composition. The expected fluxes will be compared to the Auger open dataset of measurements of the energy spectrum and composition

2) mounting of a scintillating calorimeter with double readout and subsequent cooldown to 10 mK

Experimental framework: **COSINUS**

Field: **Dark Matter, low temperature calorimeters**

This hands-on activity offers PhD students the opportunity to build and operate low-temperature calorimeters, essential tools in particle and astroparticle physics. We will assemble the calorimeter, coupling it to either an NTD (Neutron Transmutation Doped) or TES (Transition Edge Sensor) thermometer. After coupling, the system will be cooled down in a cryostat to operational temperatures, and students will monitor the process to ensure optimal performance. Once operational, we will test the calorimeter's calibration, gaining valuable experience in data acquisition and cryogenic experiments. This activity provides practical knowledge of assembling, calibrating, and operating low-temperature detectors used in advanced research.

3) Characterization of Transition Edge Sensors based Dark Matter Prototypes

Experimental framework: **CRESST**

Field: **Dark Matter**

The activity will be carried out in the CRESST test Facility (LNGS underground Lab). The activity will include the operation of cryogenic detectors and data interpretation.

Hands-on activities

- Commitment of LNGS/Univaq/GSSI researchers
- Underground facilities
- Above ground facilities: workspaces, canteen, auditorium (mainly at LNGS)

4) Characterization of cryogenic calorimeters for 0νββ decay/characterization of thermal/mechanical performance of Pulse Tube cryocoolers

Experimental framework: **CUORE-CUPID**

Field: **Cryogenic calorimeters / Cryogen-free refrigerators**

The study of the Majorana nature of the neutrino represents one of the most interesting challenges in astroparticle physics. CUORE is the first calorimetric detector searching for neutrinoless double beta decay to reach the scale of one ton at 10 mK. It has the largest milliKelvin infrastructure in the world, utilizing a cryostat equipped with 5 Pulse Tube (PT) cryocoolers that provide two stages of pre-cooling at 35 K and 3.5 K. The CUPID experiment will further enhance the sensitivity by tripling the number of detectors and developing innovative cryogenic calorimeters with dual readout (light + heat) to identify the process while rejecting the main contaminations. To enable this scaling-up, the cryostat will also undergo an upgrade of the PT cryocoolers to improve its thermal and mechanical performance.

Students will be introduced to the basics of calorimetric detectors and techniques at Kelvin and milliKelvin temperatures, with a particular focus on the CUORE/CUPID cryostat. They will participate in the characterization of the PT cryocoolers and the thermalization with reduced vibration transmission and high thermal efficiency of the CUPID experiment, in a dedicated cryostat capable of reaching a base

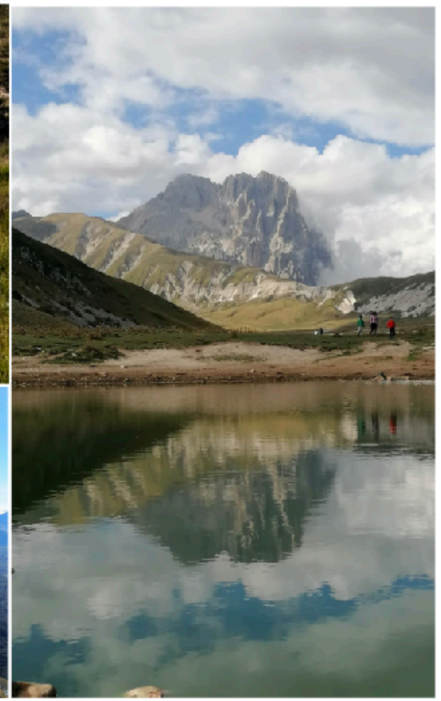
agenda.infn.it

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Gran Sasso National Park





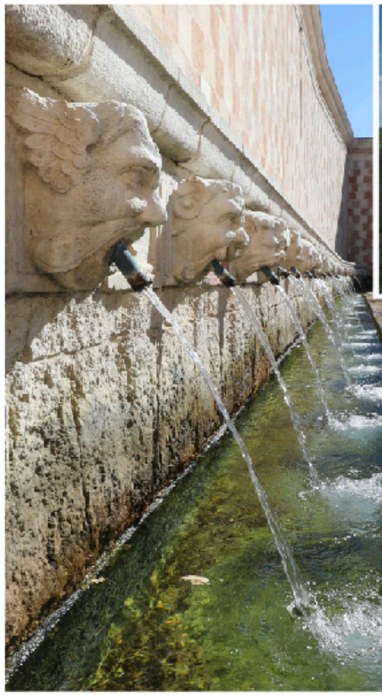








L'Aquila city tour









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Dinner

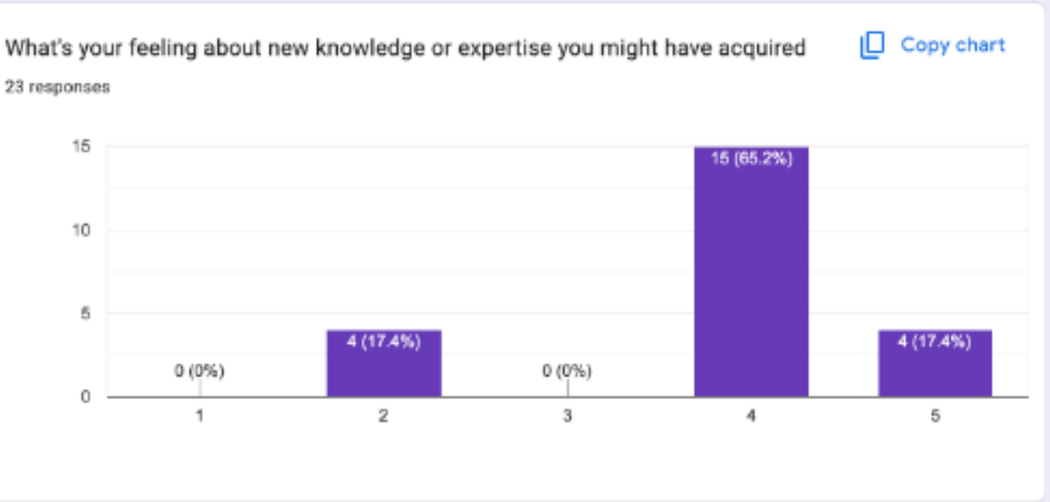


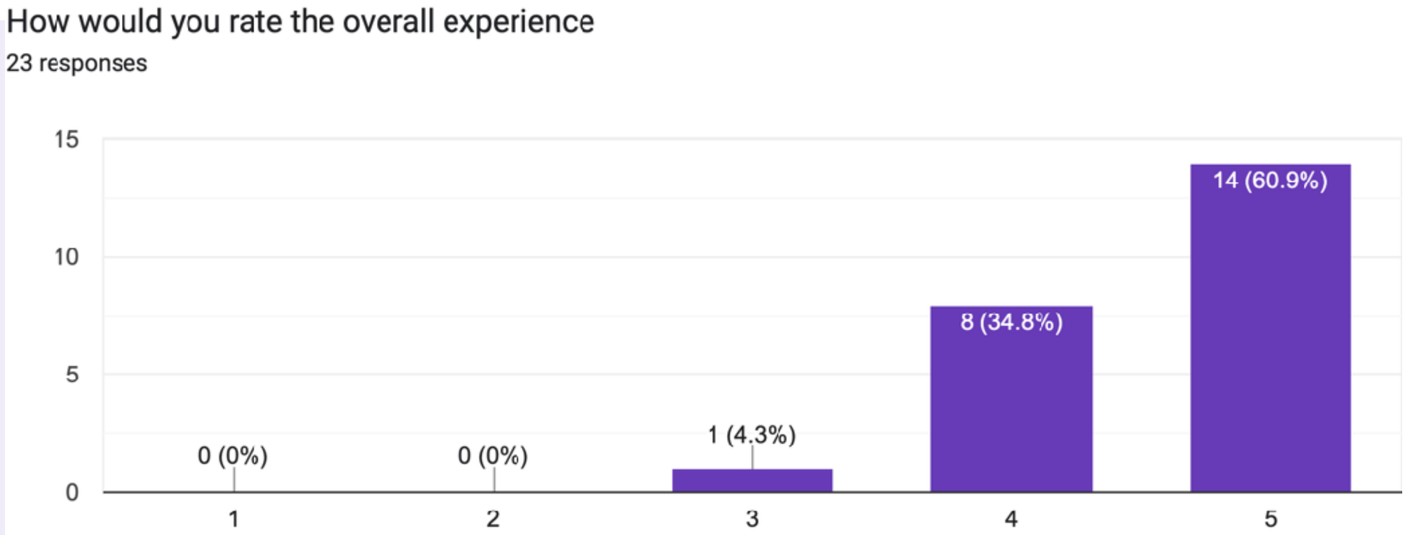




Feedback







Organisers have done a great job. Keep organising these kind of schools.

In my opinion, this school not only give a chance to students to be the part of the LNGS but also gives a ***great boost to the confidence****.*

Thank you so much for the opportunity.

All the best to the supporting staffs and tutors

CONCLUSIONS

We are looking forward to work within the ISAPP network to propose, organise and advertise advanced training in astroparticle physics, fostering global collaboration and training of the next generation of researchers in this field