



INTERNATIONAL SCHOOL OF SUBNUCLEAR PHYSICS

GRAVITY AND MATTER IN THE SUBNUCLEAR WORLD

58th Course – ERICE-SICILY: 15 – 24 JUNE 2022

Sponsored by the: • Italian Ministry of Education, University and Scientific Research • Sicilian Regional Government • Academies of Sciences of Estonia, Georgia, Lithuania, Russia and Ukraine • Chinese Academy of Sciences • Commission of the European Communities • European Physical Society • Italian National Institute for Nuclear Physics • Weizmann Institute of Science • World Federation of Scientists • World Laboratory

PROGRAMME AND LECTURERS

OPENING LECTURE

Fundamental quantum mechanics, quantum gravity and black holes, how our understanding is improving
 • G. 't HOOFT, Utrecht University, Utrecht, NL

THEORY, PHENOMENOLOGY & EXPERIMENTS

Observing the universe through gravitational waves: What are we learning?
 • G. CELLA, INFN, Pisa, IT

Status and perspectives of direct detection of dark matter
 • M. LINDNER, Max Planck Institute for Nuclear Physics, Heidelberg, DE

Axions in particle physics and cosmology
"Invisible" axion search methods
 • P. SIKIVIE, University of Florida, Gainesville, FL, US

What does cosmology tell us about neutrinos?
 • L. VERDE, Instituto de Ciencias del Cosmos (ICC), UB-IEEC, Facultad de Física, Barcelona, ES; ICREA, Universitat de Barcelona, Barcelona, ES

Status of neutrino masses, oscillations and mixing
 • M.C. GONZÁLEZ-GARCÍA, C.N. Yang Institute for Theoretical Physics, Stony Brook University, Stony Brook, NY, US; ICREA, Universitat de Barcelona, Barcelona, ES

Are neutrino and antineutrino the same particle?
 • A. BETTINI, INFN & Padua University, Padua, IT

What is the origin of the extreme high energy cosmic rays?
 • G. MORLINO, INAF, Florence, IT

The challenge of g minus 2

• L. LELLOUCH, Centre de Physique Théorique, CNRS–Luminy, Marseille, FR

High T QCD plasma and QCD Phase diagram

• M. STEPHANOV, University of Illinois, Chicago, IL, US

Probing dense matter with neutron star mergers

• M.G. ALFORD, Washington University, Saint Louis, MO, US

LHC and perturbative QCD

• E. LAENEN, NIKHEF, Amsterdam, NL

The present status of the Standard Model with some focus on Steven Weinberg's contributions

• J.R. ELLIS, CERN, Geneva, CH

HIGHLIGHTS

ATLAS and CMS

• M. COBAL, Udine University, Udine, IT

LHCb

• M. PEPE ALTARELLI, CERN, Geneva, CH

ALICE

• L. MUSA, CERN, Geneva, CH

BNL and RHIC

• L. RUAN, Brookhaven National Laboratory, Upton, NY, US

GRAN SASSO

• A. ZOCCOLI, INFN, Rome, IT

ICCR

• Y. KOSHIO, Okayama University, Okayama, JP

Ice Cube

• F. HALZEN, University of Wisconsin-Madison, WI, US

FAIR

• P. GIUBELLINO, GSI and FAIR, Institute für Theoretische Physik, Darmstadt, DE

CLOSING LECTURE

The New Manhattan Project

• A. ZICHICHI, CERN, Geneva, CH; University of Bologna & INFN, IT

FIFTEEN PROBLEMS OPEN FOR COMPETITION

THE FIRST GROUP: MIXINGS

- 1) Is there an explanation for the flavour mixing mechanisms in the Weak Interactions?
- 2) Why do these mechanisms produce results that differ substantially in the quark and in the lepton sectors?
- 3) The Higgs mechanism causes states to mix in the electroweak sector, Instantons cause mixing in the strong interactions. Can all these mixings have a unique origin?

THE SECOND GROUP: ELEMENTARY AND COMPOSITE STATES

- 4) What is the role of instantons in the spectrum of hadrons in QCD? Where are the scalar hadronic states in QCD? Are there scalar states in the leptonic system?
- 5) Why are there only fundamental particles with the minimum quark or lepton quantum numbers? Do elementary particles with higher, composite quantum numbers exist?
- 6) Is there a fundamental reason why elementary fermions exist (quarks and leptons) but not elementary scalars in the same mass range? What elementary physical principle is responsible for the curious mass value of the Higgs particle?
- 7) Do we really need sterile neutrinos? If yes, why? If not, why?

THE THIRD GROUP: SYMMETRY BREAKINGS

- 8) Why are the global discrete symmetries (C, P, CP, T) explicitly and not spontaneously broken, as it seems to be the case today? We say "it seems" because being discreet, if spontaneously broken they would not generate a Goldstone boson.
- 9) To what extent can we be confident that the Supersymmetry breaking threshold is not at the Planck Scale? (If this were the case it would be impossible to find at LHC any evidence for Supersymmetry).

THE FOURTH GROUP: DEEP FUNDAMENTAL QUESTIONS AND THE PLANCKIAN DOMAIN

- 10) Can we identify new physical principles that would allow us to calculate any of the coupling parameters of the Standard Theory that are still freely adjustable today?
- 11) What is the nature of the non-baryonic matter in and between Galaxies that betrays its presence only by its gravitational force?
- 12) Does a natural explanation exist for the extremely tiny but non-vanishing observed value of the cosmological coupling constant?
- 13) How can we obtain more information concerning the laws of nature in the domain of the Planck units?
- 14) Is the Planckian domain the place where we can make models?
- 15) Is gravitation a more fundamental force than the other forces? Can therefore QED, QFD and QCD, and perhaps also a GUT theory be considered to be emergent forces?

INVITED SCIENTISTS

- C.M. BECCHI, University of Genova, Genova, IT
- L. CIFARELLI, University of Bologna; INFN, Bologna, IT
- P.H. DAMGAARD, Theoretical Particle Physics and Cosmology, Niels Bohr Institute, Copenhagen, DK
- C. GALBIATI, Princeton University, Princeton, NJ, US; Gran Sasso Science Institute, L'Aquila, IT
- D. HAITDT, DESY, Hamburg, DE
- C.P. KORTHALS-ALTES, CNRS-Luminy, Marseille, FR
- A. MASIERO, University of Padua, Padua, IT

ONE OF THE AIMS OF THE SCHOOL is to encourage and promote young physicists to achieve recognition at an international level. A worldwide competition is open to select **New Talents**. Young fellows who think they have the ability to compete are invited to apply. At the end of the School the Diplomas to the **Best New Talents** will be awarded by a Committee composed by the Lecturers and the Invited Scientists.

SPECIAL SESSIONS FOR NEW TALENTS. Each student may propose a contribution for open presentation. The Board of Lecturers and Invited Scientists will select the best proposals. The selection will be based solely on "scientific excellence", without favour to geographical distribution, the Laboratory or the University of origin. Priority will be given to the new material of either experimental or theoretical nature, especially if the candidate has made an important contribution to the results to be presented. A review paper has lower priority and, as before, will only be selected if the candidate can point out some new features in the field reviewed. There will be poster sessions whereby each student will have the privilege of presenting the results of current studies and interacting with other participants to their mutual benefit.

BOARD OF LECTURERS AND INVITED SCIENTISTS. In addition to the Lecturers, a group of distinguished physicists is invited to contribute to the lively intellectual atmosphere of the School by participating in the discussions following the Lectures. Lecturers and Invited Scientists will take part in the selection of the **New Talents** and in the award of the various scholarships and grants open for competition.

DIPLOMAS FOR THE BEST NEW TALENTS

The following Diplomas have been established in honour of distinguished physicists who have participated in the activities of our School:

GUIDO ALTARELLI
 RICHARD ARNOWITT
 JOHN S. BELL
 PATRICK M.S. BLACKETT
 NICOLA CABIBBO
 JAMES CHADWICK
 SIDNEY COLEMAN
 RICHARD H. DALITZ
 AMOS DE-SHALIT
 PAUL A.M. DIRAC
 SIDNEY D. DRELL
 BRUNO FERRETTI
 RICHARD P. FEYNMAN

VLADIMIR N. GRIBOV
 ROBERT HOFSTADTER
 GUNNAR KÄLLEN
 SEYMOUR J. LINDENBAUM
 LEV N. LIPATOV
 TOM MASSAM
 YOICHIRO NAMBU
 YUVAL NE'EMAN
 GIUSEPPE P.S. OCCHIALINI
 ORESTE PICCIONI
 BRUNO PONTECORVO
 GIAMPIETRO PUPPI
 ISIDOR I. RABI

GIULIO RACAH
 NORMAN F. RAMSEY
 BRUNO ROSSI
 GIORGIO SALVINI
 JULIAN S. SCHWINGER
 VICTOR F. WEISSKOPF
 EUGENE P. WIGNER
 ARTHUR S. WIGHTMAN
 BJORN H. WIJK
 KENNETH G. WILSON
 CHIEN SHIUNG WU
 BRUNO ZUMINO

These Diplomas will be awarded at the end of the Course by the Board of Lecturers and Invited Scientists.

VICTOR WEISSKOPF COMMEMORATIVE FUND. The *WORLD FEDERATION OF SCIENTISTS* (WFS) has established this fund to support needy students. At the time of the application to the School, students who need financial support should apply for this fund, specifying their needs (i.e. fee only, or full board and lodging, or low-cost travel expenses).

PURPOSE OF THE SCHOOL

We focus our attention on the future of our Physics in all Labs the world over. The lectures will be, as usual, fully devoted to the latest and most significant achievements in theoretical and in experimental physics.

In fact during the last half century the School has been involved in all crucial steps of our Physics. Few examples: SU(3) flavour and SU(6) [with SU(2)-spin coupled with SU(3)-flavour] dismantled by the "No-Go-Theorem", the battle between S-Matrix and Field Theory, the Universality of the weak forces [started with the g-parameter and the non existence of the "flavour changing-neutral currents" solved by the existence of "charm"], the experimental search for the 3rd lepton in the early sixties before the discovery of CP breaking, the birth of the Electroweak Unification and the SSB (Spontaneous Symmetry Breaking) mechanism, the discovery of the negative sign of the beta-function and of asymptotic freedom, the triumph of non Abelian field theories (QCD and QFD) with all consequences (including Instantons), the discovery of Supersymmetry (many years – and not few days – after the "No-Go-Theorem"). Now we would like LHC to give us the first sign for the existence of the Superworld or of phenomena due to BSM Physics. Finally we should not forget that, since complexity exists at the fundamental level, a totally unexpected discovery should be given to us by LHC or by some other Lab engaged at the frontier of our knowledge.

THE BRIDGE BETWEEN UNIVERSITY TEACHING AND ADVANCED PHYSICS LABS SUCH AS CERN

The Ettore Majorana Foundation and Centre for Scientific Culture (EMFCSC) has celebrated its 50th Anniversary over the three past years 2011-2013. Why three years? The EMFCSC started in 1961 when one of us first discussed with John Bell the problem of creating a bridge between university courses and activities in advanced physics laboratories such as CERN. A year later on May 8th at CERN, Bell, Patrick Blackett, Victor Weisskopf, Isidor Rabi and Zichichi formally established in Geneva, at CERN, the existence of EMFCSC. The Centre's first activity was the School of Subnuclear Physics at Erice in 1963. This is why the celebrations have been over the years. In 2011 we have celebrated the discovery of the negative sign of the beta-function and of asymptotic freedom. In 2012 we have celebrated QCD. In 2013 the Spontaneous Symmetry Breaking (SSB) and Instantons. In 2014 the Quarks. In 2015 we have celebrated the triumph of Ettore Majorana: in Supergravity and in Solid State Physics with Superconductivity.

PLEASE NOTE

Participants must arrive in Erice on June 15, not later than 5 p.m.

POETIC TOUCH

According to legend, Erice, son of Venus and Neptune, founded a small town on top of a mountain (750 metres above sea level) more than three thousand years ago. The founder of modern history – i.e. the recording of events in a methodic and chronological sequence as they really happened without reference to mythical causes – the great Thucydides (~500 B.C.), writing about events connected with the conquest of Troy (1183 B.C.) said: *«After the fall of Troy some Trojans on their escape from the Achaei arrived in Sicily by boat and as they settled near the border with the Sicilians all together they were named Elymi: their towns were Segesta and Erice.»* This inspired Virgil to describe the arrival of the Trojan royal family in Erice and the burial of Anchise, by his son Enea, on the coast below Erice. Homer (~1000 B.C.), Theocritus (~300 B.C.), Polybius (~200 B.C.), Virgil (~50 B.C.), Horace (~20 B.C.), and others have celebrated this magnificent spot in Sicily in their poems. During seven centuries (XIII-XIX) the town of Erice was under the leadership of a local oligarchy, whose wisdom assured a long period of cultural development and economic prosperity which in turn gave rise to the many churches, monasteries and private palaces which you see today. In Erice you can admire the Castle of Venus, the Cyclopean Walls (~800 B.C.) and the Gothic Cathedral (~1300 A.D.). Erice is at present a mixture of ancient and medieval architecture. Other masterpieces of ancient civilization are to be found in the neighbourhood: at Motya (Phoenician), Segesta (Elymian), and Selinunte (Greek). On the Aegadian Islands – theatre of the decisive naval battle of the first Punic War (264-241 B.C.) – suggestive neolithic and paleolithic vestiges are still visible: the grottoes of Favignana, the carvings and murals of Levanzo.

Splendid beaches are to be found at San Vito Lo Capo, Scopello, and Cornino, and a wild and rocky coast around Monte Cofano: all at less than one hour's drive from Erice.

APPLICATIONS

Interested candidates should send a letter to the Director of the School:
 Professor Antonino ZICHICHI
 CERN, CH-1211 GENEVA 23, Switzerland

Needed: i) date of birth and present activity; ii) nationality; iii) letter of recommendation from a senior physicist.

More information about the other activities of the
 "ETTORE MAJORANA" FOUNDATION AND CENTRE FOR SCIENTIFIC CULTURE
 can be found on the WWW at the following address:
<http://www.ecscm.infn.it>