



# Italian Physical Society

## International School of Physics “Enrico Fermi”

### 206° Course

# *New frontiers for metrology*

*From biology and chemistry to quantum and data sciences*

A. Bettini

Padova University and INFN

# *206° Course*

## *Metrology*

*From physics fundamentals to quality of life*

### **Directors**

**Martin J.T. Milton - BIPM, Paris (France)**

**Diederik S. Wiersma - LENS, Sesto Fiorentino FI and INRiM, Torino (Italy)**

**Carl J. Williams - NIST, Gaithersburg (USA)**

*This will be the 7<sup>th</sup> Course on Metrology (previous ones in 1976, 1989, 2000, 2006, 2012, 2016)*

# *The teachers*

## **Lecturers**

Marc-Olivier André - METAS, Berne-Wabern (Switzerland)

Walter Bich - INRiM, Torino (Italy)

Michael De Podesta - NPL, Teddington (UK)

Noël Dimarq - Observatoire de la Côte d'Azur, Nice (France)

Andy Henson - BIPM, Paris (France)

Steven Judge - BIPM, Paris (France)

Andrew Lewis - NPL, Teddington (UK)

Enrico Massa - INRiM, Torino (Italy)

Juris Meija - NRC, Ottawa (Canada)

Martin J.T. Milton - BIPM, Paris (France)

Gael Obein - LNE-Cnam, La Plaine Saint-Denis (France)

Ekkehard Peik - PTB, Braunschweig (Germany)

William Phillips - NIST, Gaithersburg (USA)

Karen Phinney - NIST, Gaithersburg (USA)

Michela Segà - INRiM, Torino (Italy)

Patrizia Tavella - BIPM, Paris (France)

Steven Westwood - BIPM, Paris (France)

Diederik S. Wiersma - LENS, Sesto Fiorentino and INRiM, Torino (Italy)

Carl J. Williams - NIST, Gaithersburg (USA)

Riccardo Zecchina - Università Bocconi, Milano (Italy)

## **Seminar Speakers**

Paolo Brenni - CNR and Fondazione Scienza e Tecnica, Firenze (Italy)

Massimo Inguscio - CNR, Roma (Italy) *Padova University and INFN*

# *The topics*

## *Module I: Physical metrology*

The realization of the unit of mass, the Avogadro project, measuring electricity, optical clocks with trapped ions and test of the equivalence principle with optical clocks, time scale for metrology and navigation systems, radiometry, photometry.

## *Module II: Fundamental metrology*

Measurement uncertainty, mathematical and statistical tools for time varying quantities, global traceability, big data, metrology at the international stage, the SI, temperature measurements beyond ITS-90

## *Module III: Quality of life*

Applications of metrology in chemistry and biology, radiation dosimetry, global temperature measurement, clinical chemistry, atomic weights of the elements, radioactivity metrology, reference materials in chemistry, metrological application of NMR and qNMR in organic analysis



# *Villa Monastero*

Villa Monastero, a property of the Province of Lecco, is one of the most interesting attractions of the territory thanks to its strategic location, its history, its landscape  
Since 2004 its fourteen rooms can be visited following a charming itinerary.  
The Villa offers rooms and facilities to hold meetings, conferences, etc

The Villa is surrounded by a spectacular and fascinating botanical garden which extends for two kilometres from Varenna to Fiumelatte, with several rare botanic species; it is visited yearly by about 50.000 people and offers recreation and learning opportunities thanks to the presence of many botanical species, both indigenous and exotic.



www.alamy.com - CRTYRD

# *Many thanks to* for supporting the Varenna School



# *The origins of the Varenna school*

**1953.**

President **Giovanni Polvani** creates The International School of Physics of Varenna

Polvani concluded his inaugural address of the first course, titled

Issues related to elementary particle detection, with special attention to cosmic radiation”, with the words:

*“With the hope that this ‘dress rehearsal’ – being as it is in the hands of so outstanding scientists and followed by students with so impatient inquiring mind – might proceed worthily and fruitfully grow, I have the honour to declare open the 1953 summer course of the International School of Physics of the Italian Physical Society.”*

Director: **Giampietro Puppi**

Lecturers includes: **Patrick Blackett, Cecil Powell, Beppo Occhialini, Hannes Halfvén**

# *The mythical 1954*



# 1954. 2° course

The contribution from existing and planned accelerators to elementary particles physics

Director: Giampietro Puppi: *“For the time being let us content ourselves with elementary particles and more properly let us follow them in high-energy phenomena, in that fantastic world where everything happens in tiny volumes of space incredibly small and in time intervals extraordinarily short, involving however energies which, if macroscopically scaled, would appear as frightening”*



# The “fantastic world

## INTRODUZIONE

G. POLVANI - Discorso inaugurale . . . . .	pag. 4
G. PUPPI - Prolusione . . . . .	» 8

## PARTE PRIMA - Fisica delle particelle elementari.

### SEZIONE I: Questioni relative alla Fisica dei pioni e nucleoni . . . . . pag. 17

E. FERMI - Lectures on Pions and Nucleons . . . . .	» 17
W. HEISENBERG - The production of Mesons in very High Energy Collisions . . . . .	» 96

### SEZIONE II: Questioni relative alla fotoproduzione e fenomeni connessi pag. 104

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B. T. FELD - Photomeson Production from Hydrogen . . . . .	» 139
B. T. FELD - The Photodisintegration of the Deuteron at High Energies and Associated Phenomena . . . . .	» 145
S. LOKANATHAN and J. STEINBERGER - Search for the $\beta$ -Decay of the Pion . . . . .	» 151

### SEZIONE III: Questioni riguardanti i mesoni pesanti prodotti dai raggi cosmici o dal cosmotrone. . . . . pag. 163

B. ROSSI - Lectures on Fundamental Particles . . . . .	» 163
M. CECCARELLI - Results on Heavy Mesons . . . . .	» 227
A. BONETTI - On the Identification of Charged Hyperons and the Establishment of Their Decay Schemes in Nuclear Emulsions . . . . .	» 231
C. DILWORTH and B. ROSSI - Comparison of Results on K-Particles Disintegrating at Rest in Cloud Chambers and Photoemulsions . . . . .	» 239
N. DALLAPORTA - Statistical Evidence Concerning the $\gamma$ -Meson Decay . . . . .	» 247
A. DE BENEDETTI, C. M. GARELLI, L. TALLONE and M. VIGONE - Two Examples of a Star Emitting Two Heavy Unstable Particles . . . . .	» 249
E. AMALDI - On the Measurement of the Mean Life-Time of Strange Particles . . . . .	pag. 253
R. LEVI SETTI - Unstable Fragments . . . . .	» 263

### SEZIONE IV: Questioni relative all'origine dei raggi cosmici . . . . . pag. 275

B. ROSSI - Lectures on the Origin of Cosmic Rays . . . . .	» 275
U. HABER-SCHAIM - The Energy Spectrum of the Primary Cosmic Radiation . . . . .	» 336

## PARTE SECONDA - Progetti di macchine acceleratrici.

### SEZIONE I: Progetto di macchina acceleratrice per il Centro Europeo di Ricerche Nucleari . . . . . pag. 339

E. AMALDI - CERN, the European Council for Nuclear Research . . . . .	» 339
J. B. ADAMS - The Alternating Gradient Proton Synchrotron . . . . .	» 355
A. CITRON and M. G. HINE - Experimental Facilities of the CERN Proton Synchrotron . . . . .	» 375
G. LÜDERS - Theory of Particle Orbits in the Alternating Gradient Synchrotron . . . . .	» 392
T. G. PICKAVANCE - Synchrocyclotrons and the CERN 600 MeV Machine . . . . .	» 403

### SEZIONE II: Progetto inglese di macchina acceleratrice . . . . . pag. 413

T. G. PICKAVANCE - Proton Linear Accelerators for Nuclear Research and the A.E.R.E. 600 MeV Project . . . . .	» 413
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### SEZIONE III: Progetto francese di macchina acceleratrice . . . . . pag. 423

H. BRUCK et R. LÉVI-MANDEL - Sur le projet du Synchrotron à protons de Saclay . . . . .	» 423
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### SEZIONE IV: Progetto italiano di macchina acceleratrice . . . . . pag. 442

G. SALVINI - The Italian Design of a 1000 MeV Electronsynchrotron. A Comparisons between the Strong and the Weak Focusing . . . . .	» 442
E. PERSICO - A Theory of the Capture in a High Energy Injected Synchrotron . . . . .	» 459

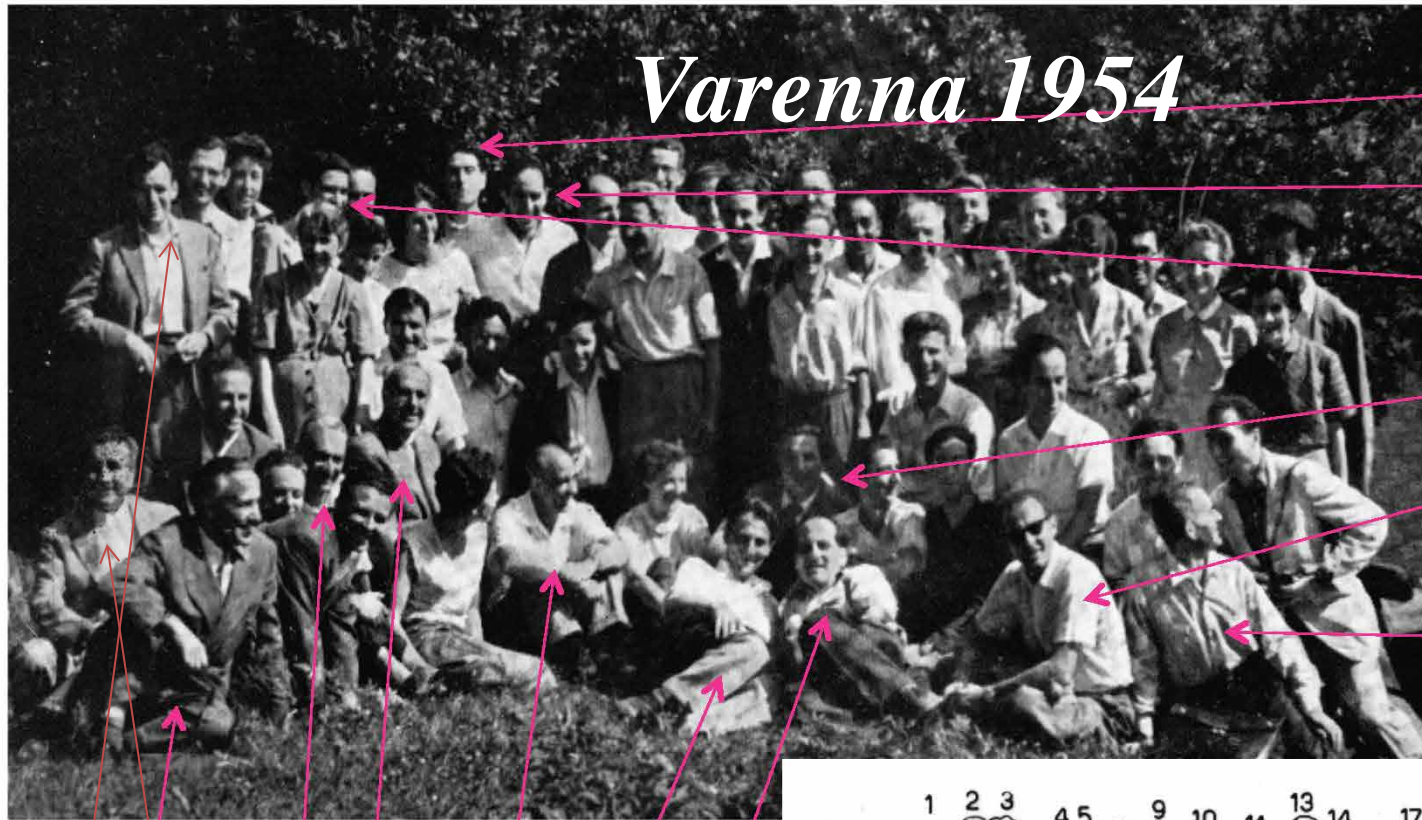
Enrico Fermi and Werner Heisenberg gave the first two lectures of a series on the physics of pions and nucleons

Gilberto Bernardini, Bernard T. Feld gave a second group of lectures on photoproduction

Bruno Rossi lectured on fundamental particles and on the origin of cosmic rays

Particle accelerator projects at CERN, in the UK, in France and in Italy were illustrated by world experts

# Varennna 1954



Salvini

Castagnoli

J. Steinberger

Puppi

Conversi

Leprince-Ringuet

Rossi

Fermi

G. Bernardini

Occhialini

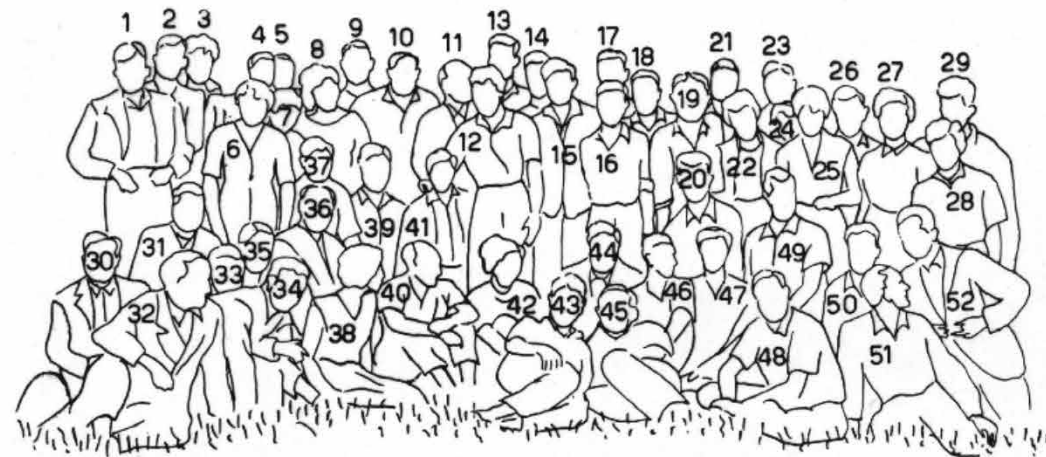
Borsellino

Polvani

**A celebrated  
group photo  
1954**

Cresti

Rostagni



1. M. CRESTI - 2. M. DEUTSCHMANN - 3. B. PUPPI - 4. J. STEINBERGER - 5. N. DALLAPORTA - 6. I. POLVANI - 7. S. C. NABBAR - 8. A. ORKIN-LE-COURTOIS - 9. G. SALVINI - 10. C. CASTAGNOLI - 11. G. FOIANI - 12. A. ROGOZINSKY - 13. J. BREZOT - 14. J. TREMBLEY - 15. M. CECCARELLI - 16. M. PORTER - 17. P. GIACOMETTI - 18. K. KANDIAH - 19. G. WATAGHIN - 20. U. HABER-SCHAIM - 21. J. G. RÖDERER - 22. B. LOCATELLI - 23. K. GOTTSTEIN - 24. C. M. GARELLI - 25. C. DILWORTH-OCCHIALINI - 26. Y. FUJIMOTO - 27. L. TALLONE - 28. G. TOMASINI - 29. R. LEVI-SETTI - 30. A. ROSTAGNI - 31. B. BRUNELLI - 32. A. BORSellino - 33. G. FIDECARO - 34. P. CALDIROLA - 35. B. ROSSI - 36. G. POLVANI - 37. H. KEEFE - 38. G. CHI - 39. M. G. K. MENON - 40. E. FERMI - 41. Y. GOLDSCHMIDT-CLERMONT - 42. M. BRUN - 43. G. BERNARDINI - 44. G. PUPPI - 45. G. OCCHIALINI - 46. L. SCARSI - 47. B. VITALE - 48. M. CONVERSI - 49. G. QUARENTI - A. BONETTI - 51. L. LEPRINCE-RINGUET - 52. B. T. FELD

# Fermi

Fermi gave 16 lectures in Varenna on “**PIONS and NUCLEONS**” from 16th of July to 6th of August 1954

Fermi passed away on 28 November 1954

On the 6th of August 1955 President Polvani in an official commemorative ceremony in Varenna and Como in the presence of Fermi's wife, Mrs. Laura Fermi, and Fermi's sister, Mrs Maria Sacchetti, announced that the School would be named after Enrico Fermi



A bronze medallion with his low-relief effigy was unveiled in memory and in honour of Enrico Fermi at Villa Monastero

# *The porphy plaque*

*— 1954 - 53rd of his life —*

*“Here with quiet spirit among so many natural beauties, I revealed for the last time, to a rank of men of science, the ultimate and most remote elements in motion inside the atoms, with which I had already made my name immortal”*



# *The Italian Physical Society Fermi Prize and Medal*



The prestigious prize "Enrico Fermi" has been awarded starting from 2001, to commemorate the great scientist on the occasion of the centenary of his birth

# *The courses*

**206 courses**  
**> 12000 participants**  
**60 Nobel Prize winners**



3-4 advanced courses hold every summer and directed by eminent scientists in all topical fields of contemporary physics.

The proceedings have been published since the foundation of the school.

The electronic version of the Proceedings starting from 1995 is offered in open access to the individual SIF Members through the [Members Area](#).



# Nobel Prize Winners in Varenna

Along the years several Nobel Prize Winners participated in the International School of Physics "Enrico Fermi" in Varenna as lecturers or directors.

Here is the list:

Name (prize awarded in year) in Varenna

Serge Haroche (2012)	1992 - 2001 - 2008
David J. Wineland (2012)	1991 - 2001
Roy J. Glauber (2005)	1967 (director) - 1991
John L. Hall (2005)	1991 - 1992
Th. W. Hänsch (2005)	1975 - 1992 (director) - 1995 - 1998 - 2000 - 2006 (director)
A. J. Leggett (2003)	1987
Riccardo Giacconi (2002)	1965 - 1975 (director)
Eric A. Cornell (2001)	1991 - 1998 - 2001
Wolfgang Ketterle (2001)	1991 - 1998 - 2006 (director) 1991 - 1998 - 2006 (director)
Carl E. Wieman (2001)	1991 - 1992 - 1998 (director)
Robert B. Laughlin (1998)	2002
Steven Chu (1997)	1991 - 1992
C. Cohen-Tannoudj (1997)	1960 - 1991
William D. Phillips (1997)	1991 (director)-1995-1998-2000
Georges Charpak (1992)	1984
P.-Gilles de Gennes (1991)	1973 - 1996 - 2003
Norman F. Ramsey (1989)	1991 - 2005
Wolfgang Paul (1989)	1965
Leon M. Lederman (1988)	1959 - 1964
Melvin Schwartz (1988)	1964
Jack Steinberger (1988)	1954 - 1964 - 1967 (director)
K. A. Müller (1987)	1956 - 1973 (director) - 2003
Klaus von Klitzing (1985)	2012
Carlo Rubbia (1984)	1987 - 1990
S. Chandrasekhar (1983)	1975
William A. Fowler (1983)	1965

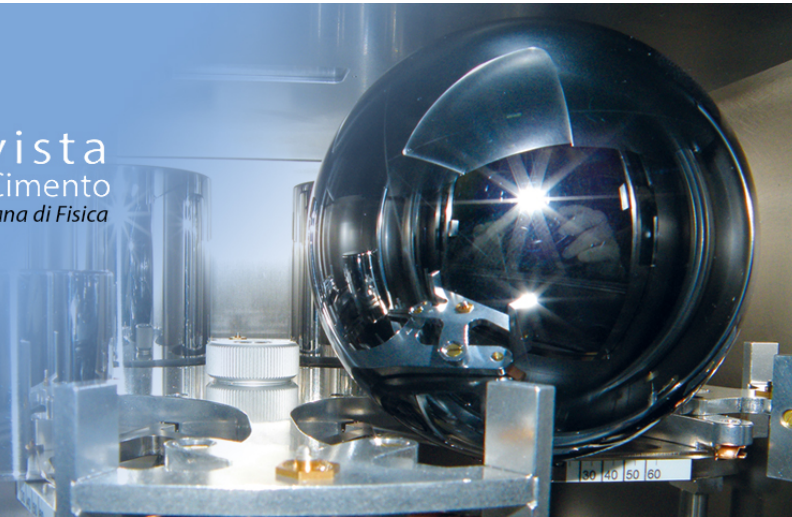
Nicolaas Bloembergen (1981)	1963 - 1975 (director)
Arthur L. Schawlow (1981)	1963 - 1992
Sheldon Lee Glashow (1979)	1964
Abdus Salam (1979)	1971
Arno Allan Penzias (1978)	2004
Philip W. Anderson (1977)	1966 - 1983 - 1987
Sir Nevill F. Mott (1977)	1957
John H. van Vleck (1977)	1956
Aage Niels Bohr (1975)	1976 (director) - 1955
Ben Roy Mottelson (1975)	1960 - 1976 - 1992
Leo Esaki (1973)	1991
Leon Neil Cooper (1972)	1955
John R. Schrieffer (1972)	1957 - 1973 - 1983 - 1987 (director) - 1992 - 1997
Dennis Gabor (1971)	1958
Hannes O. G. Alfvén (1970)	1959 (director)
Louis E. F. Néel (1970)	1956
Luis Walter Alvarez (1968)	1964 (director)
Hans Albrecht Bethe (1967)	1984
Alfred Kastler (1966)	1956 - 1960
Charles Hard Townes (1964)	1955 - 1960 - 1963 (director)
Eugene Paul Wigner (1963)	1963 (director)
Donald Arthur Glaser (1960)	1953
Tsung-Dao (T.D.) Lee (1957)	1964 (director)
John Bardeen (1956)	1983
Willis Eugene Lamb (1955)	1963
Edwards Mills Purcell (1952)	1956
Cecil Frank Powell (1950)	1953
Patrick M. S. Blackett (1948)	1953
Wolfgang Pauli (1945)	1958
Isidor Isaac Rabi (1944)	1955
Enrico Fermi (1938)	1954
Paul A. M. Dirac (1933)	1972
Werner K. Heisenberg (1932)	1954
L.-V.P.R. de Broglie (1929)	1970

# *La Rivista del Nuovo Cimento*

## *recent issues on metrology*

2 42 2019

La Rivista  
del Nuovo Cimento  
della Società Italiana di Fisica



*Walter Bich*

**The third-millennium  
International System of Units**  
*In your folder*

6 42 2019

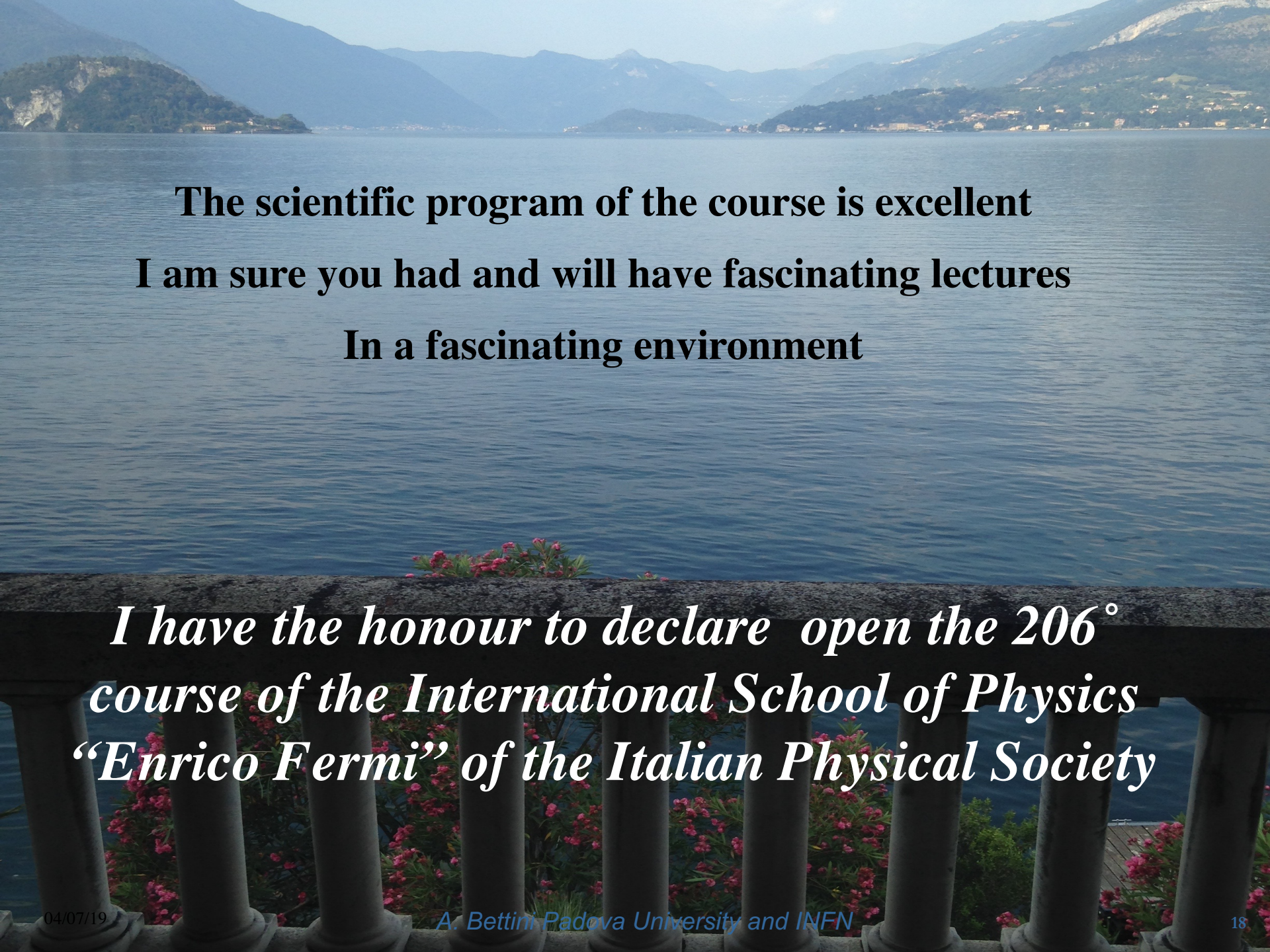
La Rivista  
del Nuovo Cimento  
della Società Italiana di Fisica



*Terry Quinn*

**The Metre Convention of  
1875: A Commentary and  
new English edition**

*Open access this month at  
<https://www.sif.it/riviste/sif/ncr/contents/2019/042/06>*



**The scientific program of the course is excellent**  
**I am sure you had and will have fascinating lectures**  
**In a fascinating environment**

*I have the honour to declare open the 206<sup>o</sup>  
course of the International School of Physics  
“Enrico Fermi” of the Italian Physical Society*