“ETTORE MAJORANA„ CENTRE FOR SCIENTIFIC CULTURE

INTERNATIONAL SCHOOL OF SUBNUCLEAR PHYSICS

XV Course: THE WHYs OF SUBNUCLEAR PHYSICS

ERICE - TRAPANI - SICILY: 23 JULY - 10 AUGUST 1977

Sponsored by the: • Italian Ministry of Public Education • Italian Ministry of Scientific and Technological Research • NATO • Sicilian Regional Government • Weizmann Institute of Science

PROGRAMME AND LECTURERS

OPENING LECTURE: A. ZICHICHI

1. DO WE UNDERSTAND ISOSPIN?

i) Why is isospin such a good symmetry? If there are four or more quarks, why does the quark mass spectrum begin with one nearly degenerate doublet (u, d) while all the remaining states are singlets with large mass separations?
ii) Why do degenerate isoscalar-isovector doublets occur frequently in the hadron mass spectrum (Λ-Σ, ϱ-ω, f-A_2)?
iii) Why are the pseudoscalar mesons so different, with no isoscalar state degenerate with the pion?

● H.J. LIPKIN, The Weizmann Institute of Science, Rehovot, Israel

2. DO WE UNDERSTAND STRANGENESS?

i) Why are total cross-sections for strange particles smaller than for non-strange particles? Strange particles are heavier than the non-strange ones. Are those two facts correlated? Also

$$\sigma_{Jp} \simeq 2\text{-}3 \text{ mb} << \sigma_{\pi p}$$
$$m_J \simeq 3.1 \text{ GeV} >> m_\pi.$$

ii) Why are the weak non-leptonic decay rates three orders of magnitude greater than the weak leptonic decay, i.e.

$$\frac{\Lambda \to \beta}{\Lambda \to \text{all}} \simeq 10^{-3}?$$

iii) Why are S- and P-waves in non-leptonic strange particle decays correlated? Strange particles behave differently from non-strange particles in ways which are still not understood. The assertion that strange and non-strange particles differ because of the strange-quark content, merely passes the buck to the quark level and explains nothing. Do we understand strangeness?
iv) What is the status of the SU(3) multiplets?

● R. BIZZARRI, University of Rome, Rome, Italy
● H.J. LIPKIN, The Weizmann Institute of Science, Rehovot, Israel

3. DO WE UNDERSTAND THE NEW PARTICLES?

i) There are four states with C = +1, between J and ψ'. Do we understand their decay rates?
ii) In the hidden charm states, why is the triplet-singlet splitting so large? Is the answer *long range spin-dependent forces?*
iii) Is the $J^{PC} = 1^{+-}$ state inside the mass-range 3.550 - 3.415 or is it pushed down by large triplet-singlet shift?
iv) Charmed mesons, $D^\pm$, D^0, D^{*0}, $D^{*\pm}$ have been observed, with the expected $\cos^2\Theta_c$ behaviour and parity violation. Is the open colour theory still alive?
v) At 4.028, analysis of the recoil mass spectrum against the detected D^0's indicates that

$$\sigma(\bar{D}^0 D^0) : \sigma(\bar{D}^0 D^{*0} + \bar{D}^{*0} D^0) : \sigma(\bar{D}^{*0} D^{*0}) \simeq 1:8:11$$

This yields the following ratios of the reduced coupling constants:

$$g^2(DD) : g^2(DD^*) : g^2(D^*D^*) \cong 1:5:100;$$

is the answer *Molecular Charmonium?*
vi) The *charm* yield at 4.415 GeV is ~ 1/3 that at 4.028 GeV. Is this due to *charm burning?*
vii) Why does $K^0_L \to \mu^+\mu^-$ not go as it should, while $\nu p \to \nu +$ anything does? Or more generally, why are weak neutral non-strange currents there, and weak neutral strange currents *not* there? Is the answer: *charm, heavy leptons,* or something else?
viii) Should we believe in the spikes observed in $\bar{p}p$ annihilations?

● B.H. WIIK, DESY, Hamburg, Germany (FRG)
● M. CHEN, MIT, Cambridge, MA, USA
● G. GOLDHABER, Lawrence Berkeley Lab, Berkeley, CA, USA
● J. PEREZ-Y-JORBA, Laboratoire de l'Accélérateur Linéaire, Orsay, France
● H.J. LIPKIN, The Weizmann Institute of Science, Rehovot, Israel
● A. MARTIN, CERN, Geneva, Switzerland
● S. NILSSON, University of Stockholm, Stockholm, Sweden
● H. F. SCHOPPER, DESY, Hamburg, Germany (FRG)

4. DO WE UNDERSTAND SYMMETRY BREAKING?

i) Why is the Cabibbo angle $\sim 20°$? Can the answer be found via spontaneous symmetry breaking?
ii) Why is the rate of $K_S \to \pi\pi$ two orders of magnitude higher than $K^+ \to 2\pi$? Do we understand octet dominance?
iii) Why do $m(\omega_8)$ and $m(\omega_1)$ not coincide with the observed masses of vector mesons? Is this because of SU(3) breaking?
iv) Is there any link between the various symmetry breaking observed in nature:

$$(1+\varepsilon_3),\quad (1+\lambda_3),\quad (1+\gamma_5)?$$

Why is the world not as symmetric as expected if it were simple? Is the reason *spontaneous symmetry breaking?*

● S. COLEMAN, Harvard University, Cambridge, MA, USA

5. DO WE UNDERSTAND LEPTONS?

i) Why are the electromagnetic properties of electrons and muons identical? Is the muon a heavy electron? If so why is the only difference between "e" and "μ" in their leptonic numbers? i.e. in the domain of weak interactions, where nobody knows how to construct mass differences of the order of 10^2 MeV?
ii) Another heavy lepton — of the standard type with its own neutrino — seems to show up, with standard electromagnetic properties, at SPEAR. Why another lepton, and so heavy,

$$m \simeq 1.9 \text{ GeV}/c^2?$$

iii Is the role of the leptons to be a spy of the elementary number of quarks

$$\begin{pmatrix}\nu_e\\ e^-\end{pmatrix} \quad \begin{pmatrix}u\\ d\end{pmatrix}$$
$$\begin{pmatrix}\nu_\mu\\ \mu^-\end{pmatrix} \quad \begin{pmatrix}s\\ c\end{pmatrix}$$
$$\begin{pmatrix}\nu_\tau\\ \tau^-\end{pmatrix} \quad \begin{pmatrix}t\\ b\end{pmatrix}$$

needed to build hadrons?

● N. CABIBBO, University of Rome, Rome, Italy
● A. ZICHICHI, CERN, Geneva, Switzerland

6. DO WE UNDERSTAND THE INCLUSIVE LEPTON PRODUCTION IN HADRONIC INTERACTIONS?

i) According to the most recent results, the single lepton yield produced in hadronic interactions seems to be consistent with pair production. The only place for the contribution from leptonic decays of the *charmed* particles is the very low p_T range, still open to investigation. Do we really understand the inclusive lepton/pion ratio, all over the energy range investigated?

● A.J.S. SMITH, Princeton University, Princeton, NJ, USA

7. DO WE UNDERSTAND HIGH-ENERGY NEUTRINO REACTIONS?

i) The ratio of antineutrino to neutrino cross-sections, is $\sim \frac{1}{3}$ at low energies, but seems to be rising at energies above 50 GeV. What is the origin of this rising? Still another quantum number?
ii) And what about the y-anomaly?
iii) What is the origin of the dileptons observed in high-energy neutrino reactions?
iv) What is the origin of positron plus strange particles? Is it *charm?* Are all these phenomena correlated?
v) Is it true that *charm* is not produced in neutral current events?

● C. RUBBIA, CERN, Geneva, Switzerland
● N. SAMIOS, Brookhaven National Lab., Upton, NY, USA

8. DO WE UNDERSTAND TOTAL, ELASTIC AND DIFFERENTIAL CROSS-SECTIONS?

i) Why is the elastic scattering imaginary at high energy? Or, in Regge-language, why do *even* signatures dominate and *odd* signatures become negligible? Is this because diffraction is shadow scattering? Do we understand diffraction scattering?
ii) Why is the Pomeron slope so small?
iii) Why is

$$\frac{\sigma(pp)_{\text{elastic}}}{\sigma(pp)_{\text{total}}} \simeq \frac{1}{5}$$

and already energy-independent?
iv) Why are meson cross-sections smaller than baryon cross-sections? More precisely, do we understand the inequalities of the total cross-sections:

$$\sigma_{\bar{p}p} > \sigma_{pp} > \sigma_{\pi^-p} > \sigma_{\pi^+p} > \sigma_{K^-p} > \sigma_{K^+p} > \sigma_{\varrho p} > \sigma_{Jp}?$$

and the identical forward slopes inequalities

$$b_{\bar{p}p} > b_{pp} > b_{\pi^-p} > b_{\pi^+p} > b_{K^-p} > b_{K^+p} > b_{\varrho p} > b_{Jp};$$

in particular, do we understand why the (J p) slope is so small?
v) Why do total cross-sections rise with energy as much as they do?

● F.E. LOW, MIT, Cambridge, MA, USA
● H.I. MIETTINEN, SLAC, Stanford, CA, USA

9. DO WE UNDERSTAND THE HIGH-ENERGY PHENOMENA OBSERVED IN NUCLEI?

i) Why is the exponent of the A-dependence for high p_T events so high? Can this be explained in terms of coherent nuclear effects?
ii) What about the multipion diffractive production and its A-dependence?

● J.W. CRONIN, University of Chicago, Chicago, IL, USA

10. DO WE UNDERSTAND THE INCLUSIVE ELECTROMAGNETIC COUPLING OF THE HADRONS?

i) At relatively low energy we observe that the inclusive electromagnetic coupling of the hadrons is point-like. Is it because the hadrons are made of superelementary constituents? And if so, why do they not show up? Is the answer: *confinement?*
ii) Departures from scaling have been observed in high-energy μ-induced deep inelastic processes. Are these departures understood in terms of new quantum numbers being excited within the nucleon constituents? Or are they within standard field theory expectation?
iii) Are the deuteron corrections really understood in the ratio of the proton to neutron structure functions? What is the value of

$$\frac{\nu W_2^n}{\nu W_2^p} \text{ when } \omega \to 1?$$

● G. PREPARATA, CERN, Geneva, Switzerland

11. SHOULD WE BELIEVE IN QUARKS?

i) Why is SU(3) there? Is this because the so-called elementary particles are made of quarks?
ii) Why is 3/2 the maximum value of isospin found in the baryon spectrum and 3 the maximum value of strangeness? Is this because baryons are made of three quarks?
iii) Why is

$$\frac{\sigma(\pi p)}{\sigma(pp)} \simeq \frac{2}{3}?$$

Is this because mesons are made of two quarks and baryons of three quarks?
iv) Do the electromagnetic form factors of pions and nucleons have different q^2-dependence? Do we understand the elastic electromagnetic form factors of elementary particles?
v) Why do single quark transitions dominate? i.e. Why is it so easy to have spectator quarks?
vi) Why have quarks so far not been found? Is it because quarks are geometrical entities deprived of physical meaning or because the confinement theories predict the truth, or because the production process has not been correctly investigated in past experiments?

● H. J. LIPKIN, The Weizmann Institute of Science, Rehovot, Israel
● G. PREPARATA, CERN, Geneva, Switzerland
● A. ZICHICHI, CERN, Geneva, Switzerland

12. SHOULD WE REALLY BELIEVE IN ANOTHER FUNDAMENTAL INTERACTION?

i) Why does

$$K_L \to 2\pi$$

go? Or more generally, why is CP violated? Is this because a new interaction — superweak — is at work?

● L.B. OKUN, Academy of Sciences of the USSR, Moscow, USSR
● L. WOLFENSTEIN, Carnegie-Mellon University, Pittsburgh, PA, USA

13. DO WE UNDERSTAND THE UNIVERSALITY FEATURES OBSERVED IN NATURE?

i) Why is the weak charge universal?
ii) Why is the electric charge universal?
iii) Why are the proton, the neutron, the Λ^0, as examples of baryonic states, and the e^-, μ^-, ν_e, as examples of leptonic states, all left handed when they interact weakly? Is this due to the fact that they sometimes transform from one to the other? Is this related to the fact that the bare electric charges of the electron and proton (i.e. of the two best measured so far) are equal?

● A. SALAM, Imperial College, London, UK

14. SHOULD WE BELIEVE IN GAUGE THEORIES?

i) We do not observe any of the processes predicted by theory to have infinite rates, such as all higher order weak interaction processes and electromagnetic mass differences. Are we sure that something physically very relevant is not missing which causes all attempts to have a renormalizable theory of weak interactions to fail? Can the way out be gauge theory?
ii) All phenomena so far observed can be described in terms of six interactions. How many fundamental interactions are there? Are they all orthogonal to each other, or have they a common origin?
iii) What about *Instantons?*

● S. COLEMAN, Harvard University, Cambridge, MA, USA
● B. ZUMINO, CERN, Geneva, Switzerland

15. CAN INTERNAL AND LORENTZ GROUP SYMMETRIES BE UNIFIED?

We observe regularities which go beyond SU(3); for example SU(6):
— explains the empirical agreement between the coefficients of the Gell-Mann-Okubo mass formula for baryon octet and decuplet, by the merging of these two SU(3) multiplets in a 56 multiplet of SU(6). Furthermore, the ratio of magnetic moments μ_n/μ_p is predicted to be -2/3 (exp. -0.68); transition magnetic moments are in qualitative agreement as well;
— explains the initial degeneracy of ϱ and ω;
— gives the correct amount of (ω-ϱ) mixing;
— predicts the equality

$$m_K^2 - m_\pi^2 = m_{K^*}^2 - m_\varrho^2$$

which is checked by experiment, as well as the Johnson-Treiman relations for (πp) and (Kp) total cross-sections, and the relations between decay amplitudes in non-leptonic strange particle decays.
i) Is all this because unitary spin and Dirac spins are correlated?

● F. GURSEY, Yale University, New Haven, CT, USA
● B. ZUMINO, CERN, Geneva, Switzerland

16. SHOULD WE BELIEVE IN QUANTUM FIELD THEORY?

Most of our understanding in subnuclear physics is based on quantum field theory (QFT). The only working example of QFT is quantum electrodynamics: everybody has failed to detect its breaking, even at the highest colliding (e^+e^-) energies.
i) Is QFT viable as a mathematical structure?
ii) At a more fundamental level, is quantum mechanics credible?

● K. HEPP, ETH, Zurich, Switzerland
● R. HOFSTADTER, Stanford University, Stanford, CA, USA
● A.S. WIGHTMAN, Princeton University, Princeton, NJ, USA
● E.P. WIGNER, Princeton University, Princeton, NJ, USA

17. BEYOND PRESENT KNOWLEDGE

i) Quantum mechanics is based on complex numbers; can an extension to quaternions and octonions lead to a deeper understanding of particle physics?
ii) At a very fundamental level, what do we know about space? Why is it nearly flat?
iii) The proton lifetime is $\tau_p \sim 10^{30}\,\tau_{\text{universe}}$ at least. Why is the proton so stable?

● I. I. RABI, Columbia University, New York, NY, USA
● S.C.C. TING, MIT, Cambridge, MA, USA
● V.F. WEISSKOPF, MIT, Cambridge, MA, USA
● J.A. WHEELER, Princeton University, Princeton, NJ, USA
● E.P. WIGNER, Princeton University, Princeton, NJ, USA
● C.N. YANG, SUNY, Stony Brook, NY, USA

CLOSING LECTURE: E.P. WIGNER

THE FUTURE OF HIGH ENERGY PHYSICS IN THE WORLD

A special session chaired by: I.I. RABI - New York

The ($\bar{p}p$) project	— C. RUBBIA, Geneva, CH
The (ep) project	— B. H. WIIK, Hamburg, FRG
The (e^+e^-) project	— A. ZICHICHI, Geneva, CH
The PETRA project	— G. A. VOSS, Hamburg, FRG
The PEP project	— B. RICHTER, Stanford, USA
The LISR project	— K. JOHNSEN, Geneva, CH
The ISABELLE project	— R. RAU, New York, USA
The World machine	— R. R. WILSON, Batavia, USA
Thinking at CERN about the future	— L. VAN HOVE, Geneva, CH

PURPOSE OF THE SCHOOL

In spite of the spectacular results obtained in recent times, Subnuclear Physics is far from reaching the asymptotic limit of a field without a future. This is testified by the large number of problems which open up at a rate at least comparable with that of new results.

This is WHY we have decided to present this year's programme in a provocative format, based on a series of WHYs. Each WHY will be reviewed as follows: 1st - Statement of the problem; 2nd - Experimental status; 3rd - Outlook. In spite of the classification into many groups, some of the WHYs are obviously correlated. This is again a crucial point of investigation which will be developed at the School, where the greatest world experts will be confronted with the critical audience of young and old Erice physicists.

SPECIAL SCHOLARSHIPS

The following special Scholarships have been established in honour of, and named after, the late Physicists

PATRICK M. S. BLACKETT	JAMES CHADWICK	AMOS DE-SHALIT
GUNNAR KÄLLEN	ANDRÉ LAGARRIGUE	GIULIO RACAH

These Scholarships cover registration fees and full board and lodging in Erice.

POETIC TOUCH

According to a legend, Erice, son of Venus, founded a small town on top of a mountain (750 metres above sea level) more than three thousand years ago.

Homer (~ 1,000 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. Among the sights there, the Castle of Venus and the Cyclopean Walls can be admired. Other masterpieces of ancient Greek civilization, such as Motya, Segesta and Selinunte, are to be found in the neighbourhood. On the Aegadian Islands, which can be reached by cable car plus hydrofoil boat in about two hours, there are prehistoric murals in the famous grotto of Levanzo, the Grotte Marine of Marettimo, and the recently discovered paleolithic grottoes of Favignana. There are splendid beaches, the farthest about 40 minutes' drive from Erice, at San Vito Lo Capo, Scopello, Cornino, and wild beaches around Monte Cofano.

Please note:

● It is regretted that, owing to the limited number of places available in the lecture hall, it will not be possible to allow any person not selected by the Committee of the School to follow the course.

● NSF travel grants are restricted to USA citizens. Applications for these should be made as soon as possible through the Director of the School.

THE BEST ERICE LECTURER PRIZE

On the occasion of the 15th Anniversary of the International School of Subnuclear Physics a special Prize has been established for the « Best Erice Lecturer ». The Prize will be awarded by the Mayor of the City of Erice during the official celebration of the 15th Anniversary of the Subnuclear Physics School.

GENERAL INFORMATION

Persons wishing to attend the Course should write to the Secretary of the School:

● Miss MARIA ZAINI
International School of Subnuclear Physics
1211 Genève 23 - Switzerland

They should specify:
i) date and place of birth together with their present nationality;
ii) degree and other academic qualifications;
iii) list of publications;
iv) present position and place of work;
and include:
v) a letter of recommendation from their research group leader or from a professor of physics.

The subscription fee is 1,000 Swiss francs. Thanks to the generosity of the sponsoring Institutions, partial support can be given to some deserving students who need financial help. This must be specified and justified in the application letter.

● *PLEASE NOTE* that the special Scholarships as well as any other form of financial support will be awarded in consultation with the Board of Lecturers at the end of the Course, in order to allow a more direct judgement of all the applicants.

Closing date for application: June 20, 1977

No special application-form is required.

A letter will be sent to successful applicants by June 25. Students experiencing difficulties with travel documentation and needing to know before June 25 whether or not their applications have been accepted, may obtain an earlier special decision by submitting a justified request.

Students must be in Erice on July 23 not later than 5 p.m. Please note that the Calendar Holidays and the School Holidays are totally uncorrelated. More detailed information, including the timetable of the lectures, will be sent to successful applicants together with the letter of acceptance.

A. ZICHICHI - DIRECTOR

SPECIAL ANNOUNCEMENT

Information about the Schools and the activities of the CENTRE can be found in the official Journal of the CENTRE:

PSC Progress in Scientific Culture
CCSEM - 91016 - ERICE - Trapani - ITALY