Nicola Cabibbo

and

the Rome theory group

Creta 1969

Starting point

Nicola Cabibbo graduated in February 1958 with a thesis on weak interactions done in collaboration with two other students Francesco Calogero and Paolo Guidoni.

The supervisor of the thesis was the most distinguished senior theoretical physicist in the Roman area, Bruno Toushek (1921), a brilliant Austrian transplanted to Rome, who would certainly have taken the Nobel together with Rubbia for his studies on cross-beam accelerators had he not died prematurely.

Cabibbo always considered him his mentor.

The theory group in Rome at that time

Enrico Persico (1900) was interested in the theory of synchrotron.

Marcello Cini (1923) was mainly interested in field theory, dispersion relations, and strong interactions.

Ezio Ferrari and Gianni Jona Lasinio were more or less the same age as Nicola (they started to publish more or less at the same time)

Raul Gatto (1930) was 5 years older than Nicola, graduated in 1951, had already spent three years at Berkeley, and was much more experienced than Nicola,

Some works in the years 1958-1960

- *Some rare decay modes of the K-meson*; Cabibbo, Ferrari.
- *On the radiative decay of charged π mesons*; Cabibbo.
- *Leptonic decay modes of K-mesons and hyperons*; Cabibbo, Gatto.
- *Cross sections of reactions produced by high energy neutrino beams*; Cabibbo, Gatto.
- *Pion Form Factors from Possible High-Energy Electron-Positron Experiments*; Cabibbo, Gatto.
- *Cross sections of reactions produced by high energy neutrino beams*; Cabibbo, Gatto.

First very well-known papers:

- *Quantum electrodynamics with Dirac monopoles*; Cabibbo, Ferrari, (1962).
- *Proton-antiproton annihilation into electrons, muons, and vector bosons*; Zichichi, Berman, Cabibbo, Gatto, (1962).
- *Consequences of unitary symmetry for weak and electromagnetic transitions*; Cabibbo, Gatto, (1961).

Big interest for experimental techniques

New method for producing and analyzing linearly polarized gamma-ray beams; Cabibbo, Da Prato, De Franceschi, Mosco, (1962).

The Bible

In 1960, Bruno Toushek proposed the construction of a cross-beam electron and positron accelerator in Frascati. The construction of the ADA prototype was done very quickly and the final ADONE machine went into operation in 1970.

Together with Raul Gatto, Nicola is assigned to theoretically study all the reactions that could be observed in the building electron-positron collision ring.

Thus was born a work that would be an indispensable reference for all scholars in the field, to the point that it was jokingly nicknamed the Bible.

Pion Form Factors from Possible High-Energy Electron-Positron Experiments; Cabibbo, Gatto (1960).

Electron-positron colliding beam experiments; Cabibbo, Gatto (1961).

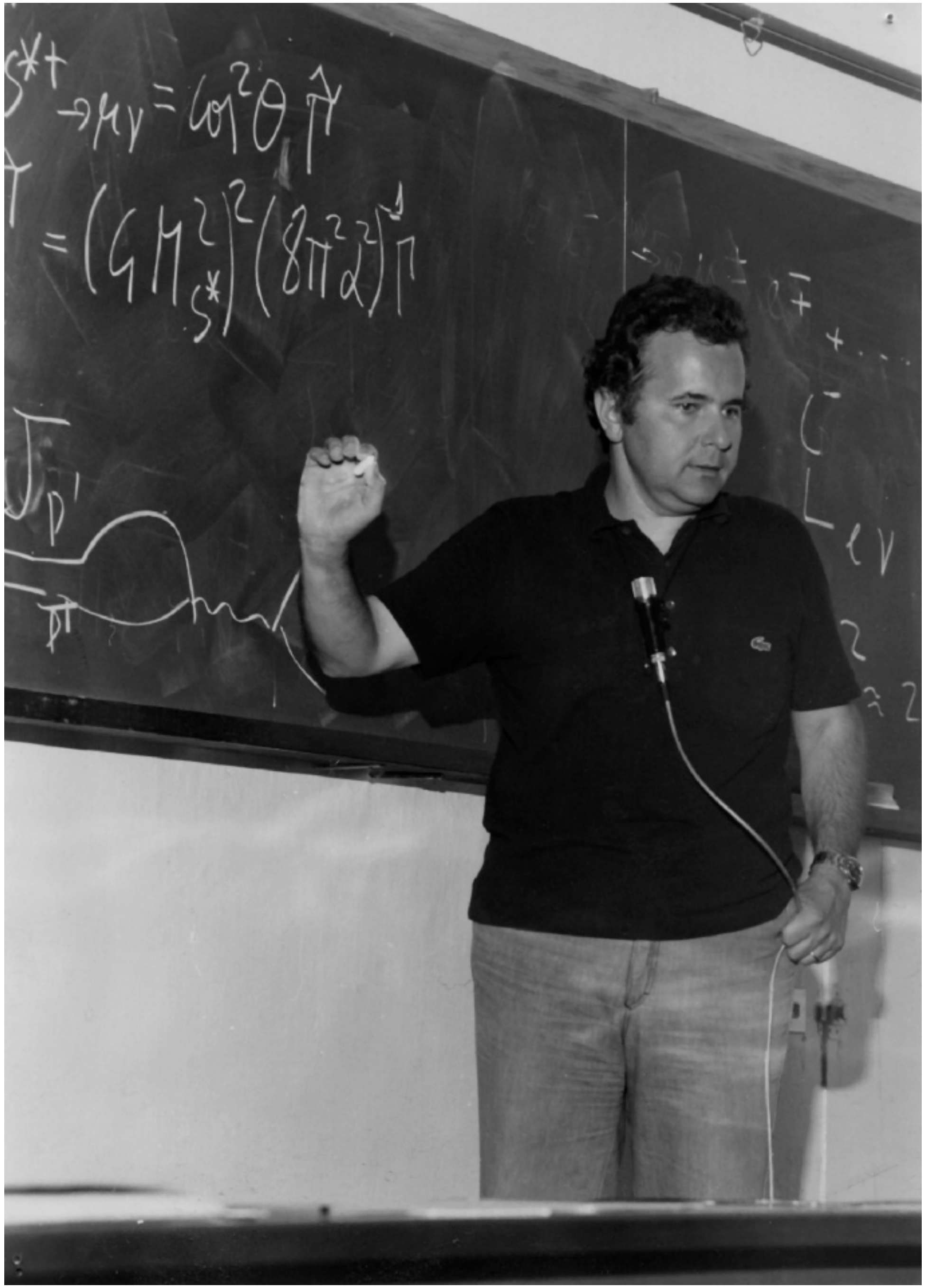
Back in Rome

In 1962 he moved to CERN. After CERN, Berkley, Harvard, and L'Aquila in 1966 came back to Rome as a full professor.

When he comes back to Rome he finds new younger people (mostly Gattini, i.e. students by Gatto) and he starts to work with them.

- *Radiative corrections and sum rules*; Cabibbo, Maiani, Preparata, (1967)
- *Dynamical interrelation of weak, electromagnetic, and strong interaction and the value of* θ; Cabibbo Maiani,(1967).
- *The* σ *term and low-energy* $\pi - N$ *scattering*; Altarelli, Cabibbo, Maiani (1970).

Some of his thesis students in Rome: Massimo Testa (1969), Giorgio Parisi (1970), Roberto Petronzio (1972), M. Rocca (1974), Roberto Benzi (1976) and Guido Martinelli (1976).



Nicola in the sixties.

Particle theory: bootstrap i.e. no local field

Around 1960 Geoffrey Chew proposed the bootstrap philosophy. There were no elementary constituents: all particles were supposed to be on the same footing. Field theory was discredited and some authors suggested that a good knowledge of quantum field theory was detrimental to the comprehension of bootstrap.

The absence of elementary point-like objects suggests that hadrons were extremely soft. This viewpoint was confirmed by the very fast decay of the proton form factor, by the exponential suppression of particle productions at large momentum transfer, and by Hagedorn theory where a maximum temperature somewhat less than 200 MeV was supposed to be present in nature.

The S matrix was the basic observable. Dispersion relations, Regge poles, and superconvergence relations were the main tools.

Particle theory: the local approach

There was also a different viewpoint: electromagnetism and the V-A theories for weak interaction were based on local currents and quantum field theory. There was some hope that the introduction of heavy vector Bosons could make the theory renormalizable.

The semi-leptonic weak interactions were mediated by a hadronic current; the local commutator of the currents and the resulting current algebra was the crucial needed for the normalization of the weak interaction vertices, which played a fundamental role in Cabibbo's theory of weak interaction.

This quantum field theory approach to physics was strongly pushed in Europe: there were strong collaborations among different scientific institutions that were later formalized in the Triangular Meetings (Paris-Rome-Utrecht, i.e. Philippe Meyer, Nicola Cabibbo, Tiny Veltman)

Partons and QCD

- *Hadron production in e^+e^- collisions*; Cabibbo, Parisi, Testa, (1970)

$$R = \frac{e^+e^- \to hadrons}{e^+e^- \to \mu^+\mu^-} = \sum_i Q_i^2 + \frac{1}{4}\sum_i B_i^2\,, \tag{1}$$

- *Deep inelastic scattering and the nature of partons*; Cabibbo, Parisi, Testa, Verganelakis, (1970).
- *Quark additivity for mass splittings in the P_∞ frame*; Cabibbo, Testa, (1974)
- *The nucleon as a bound state of three quarks and deep inelastic phenomena*; Altarelli, Cabibbo, Maiani, Petronzio, (1974)
- *Two-stage model of hadron structure: Parton distributions and their Q^2 dependence* Cabibbo, Petronzio, (1978)

Nicola's presence changed the atmosphere in Rome

Many informal discussions in his room.

I remember the Massimo Testa and I were ofter going in his room to see what was happening.

There were open discussions on new results, on computations that could be done...

Sometimes we were going just to tell him what we were doing and getting his advise.

I remember a seminar in November 1974 that Nicola was supposed do to in Frascati suggesting to change the energy of the colliding beam of e^+e^- in a continuous way, in order to scan fo a charmed-anticharmed resonance.

The ρ bremsstrahlung; Cabibbo, Rocca, (1974)

Let me start with the $e^+ + e^- \to 2e^+ + 2e^-$ drama (or comedy), around 1970-1971.

There was a wrong computation (by a factor $E^2/m_e^2 \approx 10^6$. Nicola derived the correct result by generalizing the Weizsäcker–Williams method. Nicola's predictions were tested at Frascati, thanks to a technique developed by Guido Barbiellini Amidei.

I was also impressed by the P_∞ frame. He derived some fast way to compute radiative corrections introducing the probability of finding a photon in the electron and a photon in an electron.

These equations were a well-known toolbox in Rome and they were at the basis of the Altarelli-Parisi equations.

photon materializes as an e^+e^- pair. Finally, the e^- of the pair annihilates with the incoming e^+ to give a ρ. The W-W approximation consists in assuming that a physical electron of high momentum has a certain probability of appearing as an $e^- + \gamma$ state. This probability, integrated over transverse momenta, can be computed by non-covariant perturbation theory to be :

$$\frac{dP_{e\to e\gamma}(\eta)}{d\eta} = \frac{\alpha}{\pi}\,\frac{1+(1-\eta)^2}{\eta}\left[\log\frac{E}{m_e}+\dots\right] \tag{2.2}$$

where η is the fraction of longitudinal momentum carried by the photon and non-leading terms have been neglected. In our case we will define a probability for an electron to appear as an electron plus a pair. This probability will be taken to be the product of that in Eq. (2.2) and the probability for a photon to appear as an e^+e^- pair, for which we obtain (ε being the fraction of longitudinal momentum carried by the e^-) :

$$\frac{dP_{\gamma\to e^+e^-}(\varepsilon)}{d\varepsilon} \simeq \frac{\alpha}{2\pi}\left[1+(1-2\varepsilon)^2\right]\left[\log\frac{E_\gamma}{m_e}+\dots\right] \tag{2.3}$$

Finally, we note that the invariant mass of the hadronic state produced in the collision between the incoming positron and the electron of momentum $\varepsilon\eta\vec{p}_1$ is : $s = 4E^2\varepsilon\eta$. So that we will write :

$$\sigma_{\rho\,\mathrm{brems.}}(4E^2) = 2\int d\varepsilon\, d\eta\, \frac{dP_{\gamma\to e^+e^-}}{d\varepsilon}\,\frac{dP_{e^-\to e^-\gamma}}{d\eta}\,\sigma_{e^+e^-\to h}(4E^2\varepsilon\eta)$$

The weak interactions goes on

- *Enhancement of non-leptonic decays of charmed particles*; G Altarelli, N Cabibbo, L Maiani (1974).
- *The Drell-Hearn sum rule and the Lepton magnetic moment in the Weinberg model of weak and electromagnetic interactions*; G Altarelli, N Cabibbo, L Maiani (1974).
- *The lifetime of charmed particles and Two-body decays of charmed mesons*; N Cabibbo, L Maiani (1978).
- *Leptonic decay of heavy flavors: A theoretical update*; G Altarelli, N Cabibbo, G Corbo, L Maiani, G Martinelli (1982).

Exponential hadronic spectrum and quark liberation; Cabibbo, Parisi (1975).

The exponentially increasing spectrum proposed by Hagedorn is not necessarily connected with a limiting temperature, but it is present in any system that undergoes a second-order phase transition. We suggest that the “observed” exponential spectrum is connected to the existence of a different phase of the vacuum in which quarks are not confined.

Bounds on the fermions and Higgs boson masses in grand unified theories; Cabibbo, Maiani, Parisi, Petronzio (1979).

In the framework of grand unifying theories, the requirement that no interaction becomes strong and no vacuum instability develops up to the unification energy is shown to imply upper bounds to the fermion masses as well as upper and lower bounds to the Higgs boson mass.

The results were in wonderful agreement with the value found 25 years later, dangerously near to the lower bound.

His scientific influence was overwhelming.

Thanks to his international achievements, Cabibbo became an exemplar whom both younger physicists and those his age wanted to imitate. He showed that it was possible to have an excellent school of theoretical physics in Italy, as demonstrated by the accomplishments of his students and younger collaborators.

Cabibbo had an infectious enthusiasm for physics. He was a born problem solver; to him, physics was a kind of play, like putting together the pieces of a puzzle to form a meaningful pattern from an incoherent data set. I will always remember him saying, “Why should we study this problem if we do not amuse ourselves in solving it?”