Currentx Current theory and the Strange Particle decay puzzle

$$\mathcal{L}_W = \frac{G}{\sqrt{2}} J^+_\mu \cdot J^\mu$$

natural from one assumption. That is that the Fermi couplings are of the nature of the interaction of a kind of current with itself:

$$J \longleftrightarrow J \qquad (12\text{-}4)$$

and the problem is to find the composition of the current J, the sum of several parts. The couplings (6-4), (6-5), and (6-6) described previously result if J is written

$$J = (\bar{\nu}e) + (\bar{\nu}\mu) + (\bar{p}n) + X \qquad (12\text{-}5)$$

Experimentally the coefficient of all first three terms are equal. All our three new couplings will result if we add to J just one term, say X, which changes strangeness. Above we have suggested solely as an example what X might be but we shall now have to consider more seriously what properties the term X might have.

An immediate consequence of this idea is that the coefficients of X to each of the three currents $(\bar{\nu}e)$, $(\bar{\nu}\mu)$, and $(\bar{p}n)$ are equal. That is, the couplings (12-1), (12-2), and (12-3) must all have the same coefficient [although it need not equal the coefficient of (6-4), (6-5), and

electron-muon universality well obeyed in Strange Particle decays

What is the strenght of X ?

4. *Leptic decays with change of strangeness are relatively much slower than those without change of strangeness* (although the $K^+ \to \mu^+ + \nu$ is a possible violation).

But if the coefficients in X are of the order of 0.1 for lepton coupling, we should expect them to be exactly the same for the ($\bar{p}n$) coupling. This is uncomfortable because the nonleptic decays seem too fast for this. They seem to require coefficients of order unity, but we cannot be sure, for we cannot really calculate these processes because of the virtual states of strongly interacting particles that are involved.

In the JxJ theory, the ***suppression of leptonic strange particle decays*** got mixed with the so called ***I=1/2 enhancement*** of non-leptonic decays.

A real mess !!

Enters Cabibbo

In his 1963 paper, Nicola made few decisive steps.

- he decided to ignore the evidence for a ΔS= -ΔQ component, which indeed was later disconfirmed (P. Franzini had a role on this).
- he ignored also the problem of the normalization of non-leptonic processes and of the I=1/2 enhancement (see later)
- he formulated a notion of universality between the *leptonic current* and *one, full hadronic current*, a combination of the SU(3) currents with ΔS=0 and ΔS=1, such as to be *equally normalized* to the lepton current. Axial currents are inserted via the V-A hypothesis. In formulae:

$$V_\lambda^{(hadron)} = a\left[V_\lambda^{(1)} + iV_\lambda^{(2)}\right] + b\left[V_\lambda^{(5)} + iV_\lambda^{(6)}\right]$$

$$a^2 + b^2 = 1$$

$$J_\lambda^{lept} = \bar{\nu}_\mu \gamma_\lambda (1-\gamma_5)\mu + \bar{\nu}_e \gamma_\lambda (1-\gamma_5) e;$$

$$J_\lambda^{(hadron)} = \cos\theta\left[J_\lambda^{(1)} + iJ_\lambda^{(2)}\right] + \sin\theta\left[J_\lambda^{(5)} + iJ_\lambda^{(6)}\right];$$

$$J_\lambda^{(i)} = V_\lambda^{(i)} - A_\lambda^{(i)}$$

The angle θ is a new constant of Nature, since known as *the Cabibbo angle*.

•A few results of these wonderful years:

•parton-model description of e^+e^- annihilation into hadrons

N. Cabibbo, G. Parisi and M. Testa, *Hadron Production In e^+ e^- Collisions*, Lett. Nuovo Cim. **4S1**, 35 (1970).

•electroweak contribution to the muon anomaly

G. Altarelli, N. Cabibbo and L. Maiani, *The Drell-Hearn sum rule and the lepton magnetic moment in the Weinberg model of weak and electromagnetic interactions*, Phys. Lett. **B40**, 415 (1972).

•parton densities in hadrons

G. Altarelli, N. Cabibbo, L. Maiani, R. Petronzio, *The Nucleon as a bound state of three quarks and deep inelastic phenomena*. Nucl.Phys. **B69**, 531 (1974).

•parton analysis of the heavy quark beta decay spectrum (affording one of the most precise determinations of the CKM mixing parameters)

G. Altarelli, N. Cabibbo and L. Maiani, *Weak Nonleptonic Decays Of Charmed Hadrons*, Phys. Lett., **B57**, 277 (1975); G. Altarelli, N. Cabibbo, G. Corbo, L. Maiani and G. Martinelli, *Leptonic Decay Of Heavy Flavors: A Theoretical Update*, Nucl. Phys., **B208**, 365 (1982).

•QCD prediction of a phase transition from hadrons into deconfined quarks and gluons starting from the limiting temperature introduced by R. Hagedorn

N. Cabibbo and G. Parisi, *Exponential Hadronic Spectrum And Quark Liberation*, Phys. Lett. **B59**, 67 (1975).

•lattice QCD calculation of weak parameters with lattice QCD,

N. Cabibbo, G. Martinelli and R. Petronzio, *Weak Interactions on the Lattice*, Nuclear Physics, **244B**, 381 381 (1984).

•upper and lower bounds to the Higgs boson and heavy fermion masses in grand unified theories.

N. Cabibbo, L. Maiani, G. Parisi, R. Petronzio, *Bounds on the Fermions and Higgs Boson Masses in Grand Unified Theories*, Nucl.Phys. **B158**, 295 (1979).

•With G. Parisi, Cabibbo proposed and realised a parallel supercomputer for lattice QCD calculations. The APE supercomputers and their subsequent evolutions have played an important role in elucidating basic QCD in the non-perturbative regime

P. Bacilieri *et al.*, *The Ape Project: A Computer For Lattice QCD*, IFUP-TH84/40, Dec. 1984; M. Albanese *et al.* [APE Collaboration], *THE APE COMPUTER: AN ARRAY PROCESSOR OPTIMIZED FOR LATTICE GAUGE THEORY SIMULATIONS*, Comput. Phys. Commun. **45**, 345 (1987).

Science Manager, teacher and friend

Nicola played an overall important role in the Italian scientific life of the turn of the century, as:

- Member of Academia Nazionale dei Lincei and of the American Academy of Science
- President of Istituto Nazionale di Fisica Nucleare: 1983-1992
- President of Ente Nazionale Energie Alternative: 1993 -1998
- President of the Pontifical Academy of Science: from 1993

He held these important positions with vision, managerial skill and universally appreciated integrity.

Nicola liked to teach and he continued to do so until his very last months.
Like all great minds, he could find simple arguments to explain the most difficult concepts.
His students were fascinated by his simplicity, gentle modes and sense of humour.
So we did, all of us we who had the privilege to be his collaborators and friends.

Nicola Cabibbo and his class of Fisica Teorica (2009)