



ITALIAN TEACHERS PROGRAMME
CERN, Ottobre 2013

Lezione II
Dal protone ai quark: l'enigma delle particelle nucleari
Luciano MAIANI . CERN e Sapienza Università di Roma
CERN. 10 Ottobre 2013.

Introduction

All varieties of matter are explained by some 100 different kinds of atoms

Mendeleev Table and Periodicity Rules brought order and PREDICTABILITY: missing elements must exist

[edit]

	10	11	12	13	14	15	16	17	18
1	H								He
2	Li	Be							
3	Na	Mg							
4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co
5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh
6	Cs	Ba	*	Hf	Ta	W	Re	Os	Ir
7	Fr	Ra	**	104	105	106	107	108	109
				Rf	Db	Sg	Bh	Hs	Mt
							Ds	Ds	Rg
								Uub	Uut
								Uuo	Uuh
									(Uus)
									118
									Uuo
* Lanthanides									
** Actinides									
57	58	59	60	61	62	63	64	65	66
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy
89	90	91	92	93	94	95	96	97	98
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf
67	68	69	70	71					
Ho	Er	Tm	Yb	Lu					
99	100	101	102	103					
Es	Fm	Md	No	Lr					

This common arrangement of the periodic table separates the lanthanides and actinides from other elements. The wide periodic table incorporates the f-block. The lanthanides are often included with the 5f and 6f elements because they form a block of 14 elements, while the theoretical g-block has only 1 element.

Many physicists doubted for long about reality of atoms

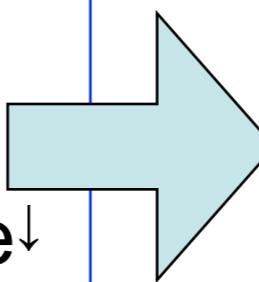
How can two hydrogen atoms be absolutely identical??

about 100 different kinds ??

Quantum Mechanics (1920-1930) is the key

Strange but simple rules:

- electrons in quantum orbits determined by integers
- two spin states for the electron: e^{\uparrow} , e^{\downarrow}
- Pauli principle: no two electrons in the same orbital-spin state



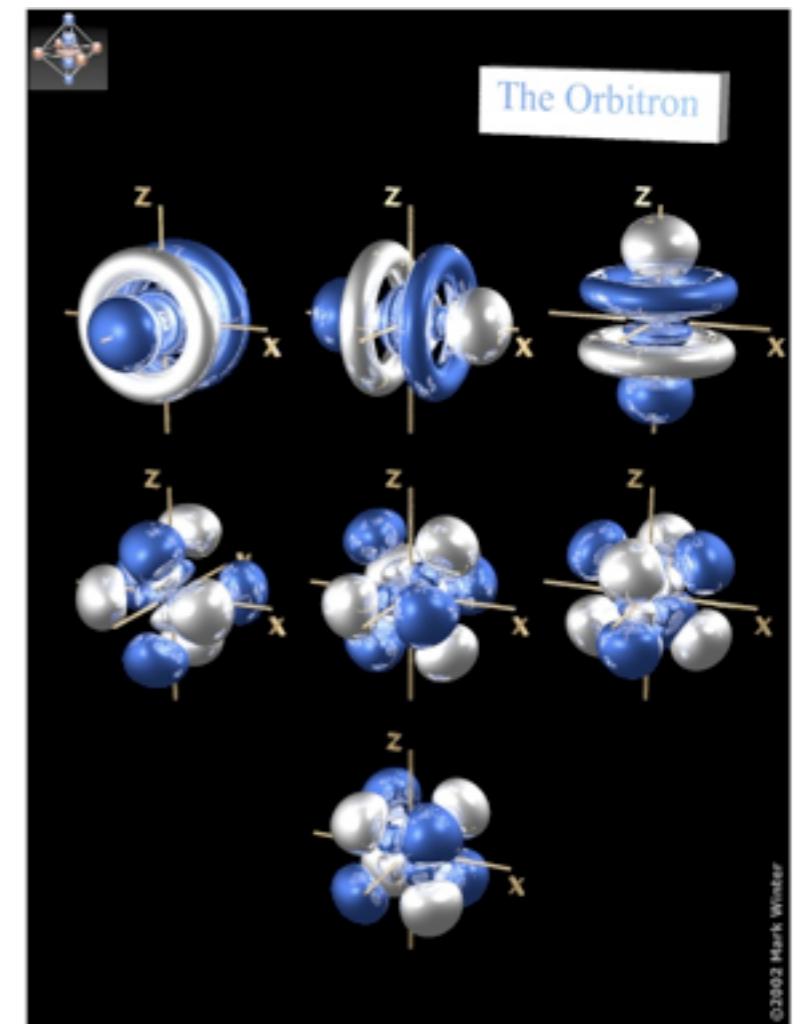
saturation of orbitals:
 $(e^{\uparrow} e^{\downarrow} e^{\uparrow})$:no, $(e^{\uparrow} e^{\downarrow}) e^{\uparrow}$: yes
periods in Mendeleev table

Mendeleev Table explained by QM assuming....

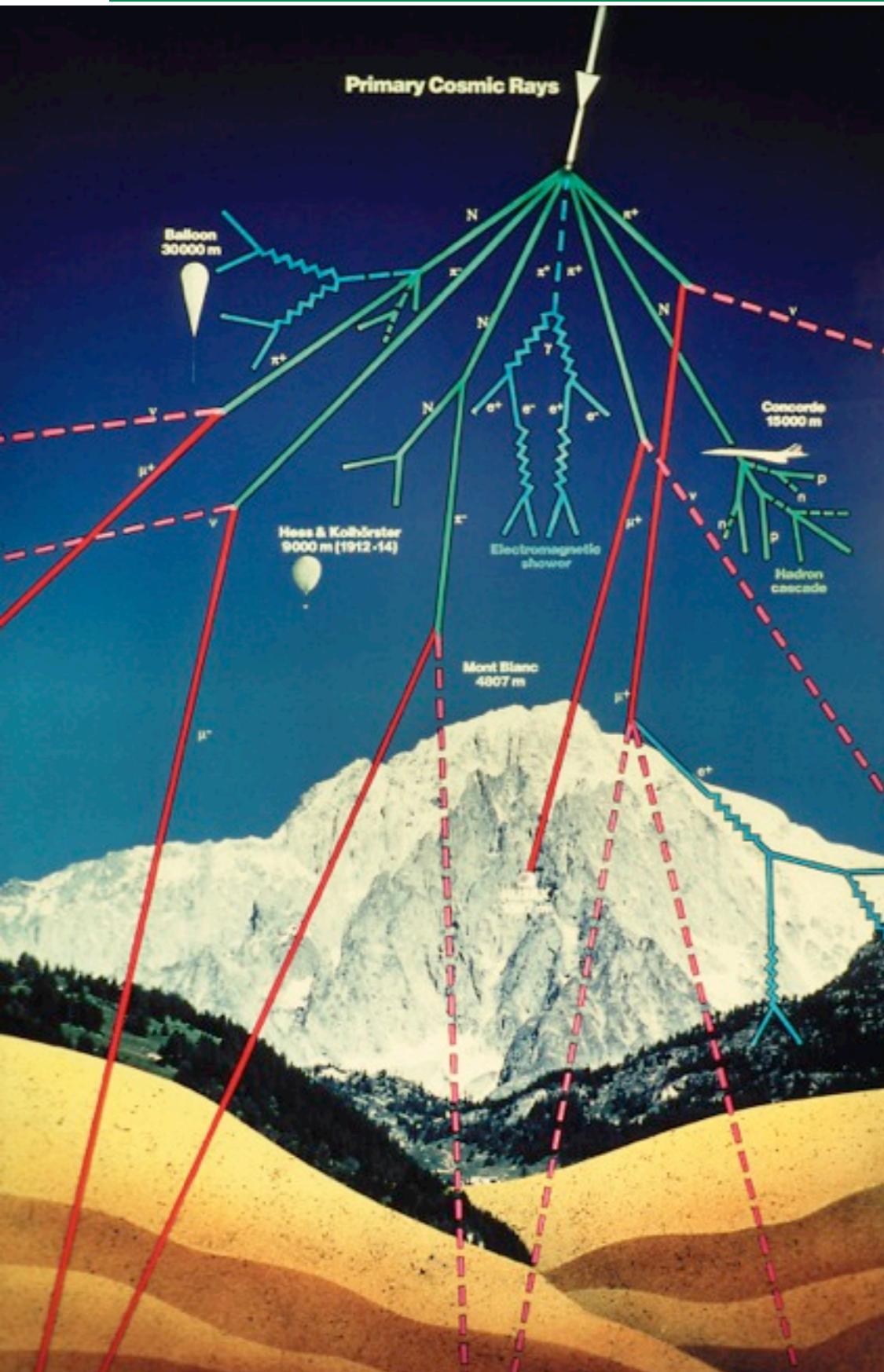
Nucleus: charge = +Z

Z orbiting electrons

are there about 100 different kinds of nuclei ???



1. Il mesotrone

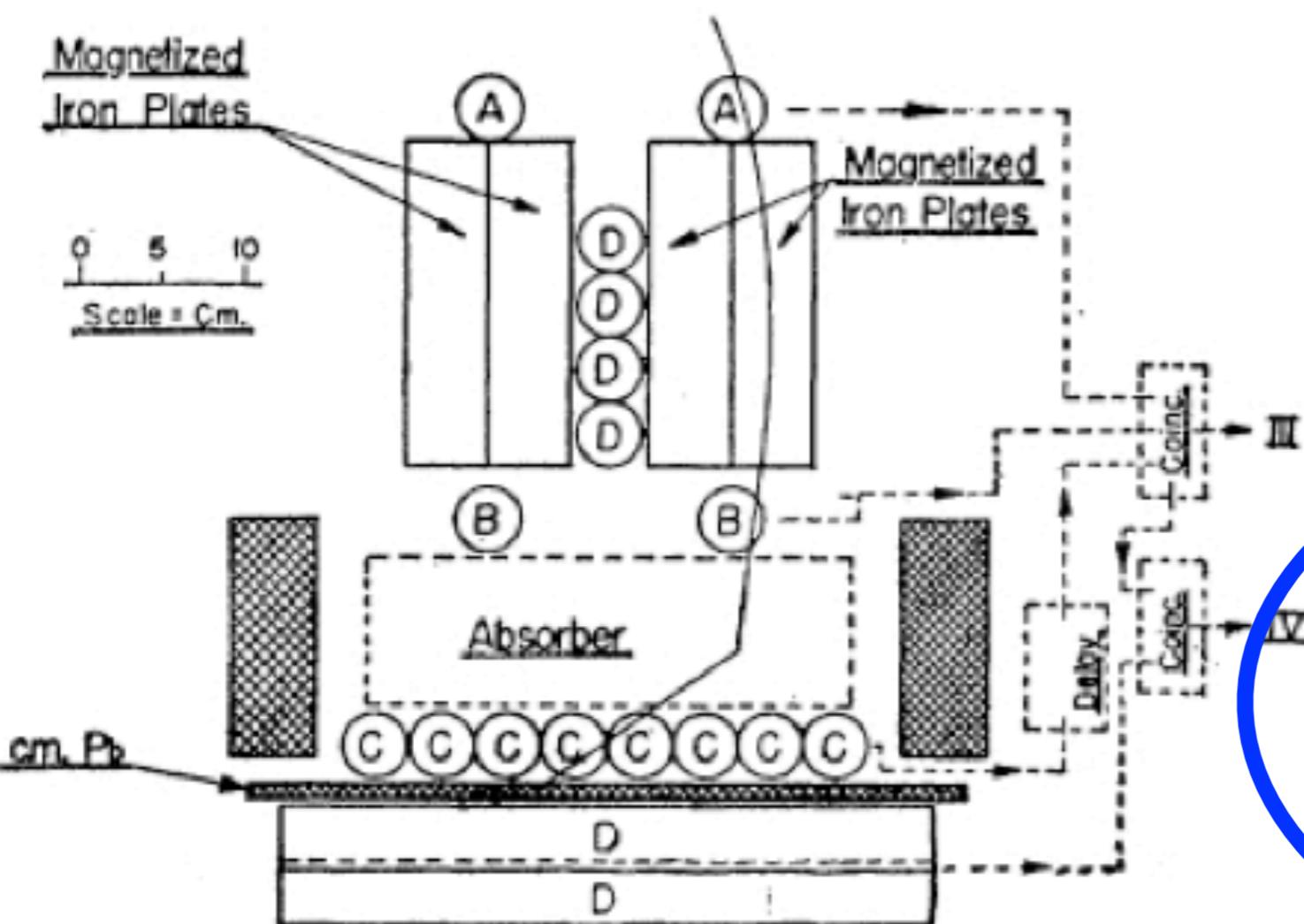


Nel 1937, C. Anderson e S. Neddermeyer scoprono una nuova particella prodotta nelle collisioni dei raggi cosmici con gli atomi dell'atmosfera.

- Ha una massa intermedia tra l'elettrone e il protone, per questo viene chiamata “mesotrone”.

La massa è prossima alla massa predetta da Yukawa per il mesone π , tanto da far pensare: “mesotrone”= mesone π : l’ultimo bosone!
Ne erano tutti convinti...

The Mesotron

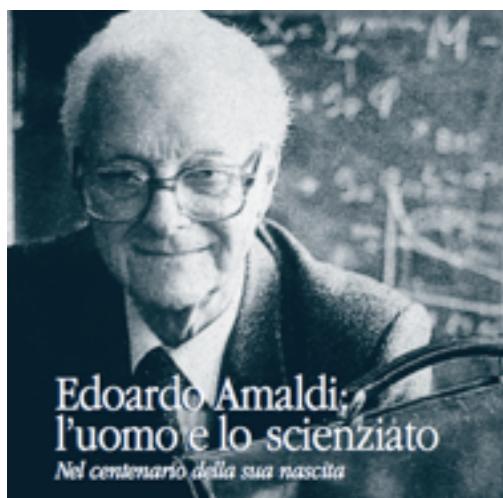


**Layout of the experiment
by Conversi, Pancini and Piccioni
Phys. Rev. 71 (1947) 209**

Quoting Louis Alvarez (Nobel lecture, 1968).
As a personal opinion, I would suggest that modern particle physics started in the last days of World War II, when a group of young Italians, Conversi, Pancini, and Piccioni, who were hiding from the German occupying forces, initiated a remarkable experiment.

3. Dai Raggi Cosmici al CERN

- 1946 (Roma): M. Conversi, E. Pancini e O. Piccioni, scoprono che il mesotrone (oggi “particella μ ”) non è associato alle forze nucleari;
- 1947 B. Pontecorvo mostra che il mesotrone è una “copia pesante” dell’elettrone: ?????
- 1940-1950: un nuovo zoo di particelle emerge dallo studio dei raggi cosmici;
- le “nuove particelle” non sono presenti nella suddivisione della materia: atomo, nucleo, nucleoni,
- ma devono avere un ruolo nell’ architettura delle forze fondamentali
- ...e possono essere studiate compiutamente solo nelle collisioni di alta energia alle macchine acceleratrici.



Fondato nel 1954, il CERN è oggi il Laboratorio base per la Fisica delle Particelle Elementari in Europa.

THE PHYSICAL REVIEW

A journal of experimental and theoretical physics established by E. L. Nichols in 1893

SECOND SERIES, VOL. 76, No. 12

DECEMBER 15, 1949

Are Mesons Elementary Particles?

E. FERMI AND C. N. YANG*

Institute for Nuclear Studies, University of Chicago, Chicago, Illinois

(Received August 24, 1949)

We propose to discuss the hypothesis that the π -meson may not be elementary, but may be a composite particle formed by the association of a nucleon and an anti-nucleon. The first assumption will be, therefore, that both an anti-proton and an anti-neutron exist, having the same relationship to the proton and the neutron, as the electron to the positron. Although this is an assumption that goes beyond what is known experimentally, we do not view it as a very revolutionary one. We must assume, further, that between a nucleon and an anti-nucleon strong attractive forces exist, capable of binding the two particles together.

$$\pi^+ = P\bar{N} \quad (?)$$

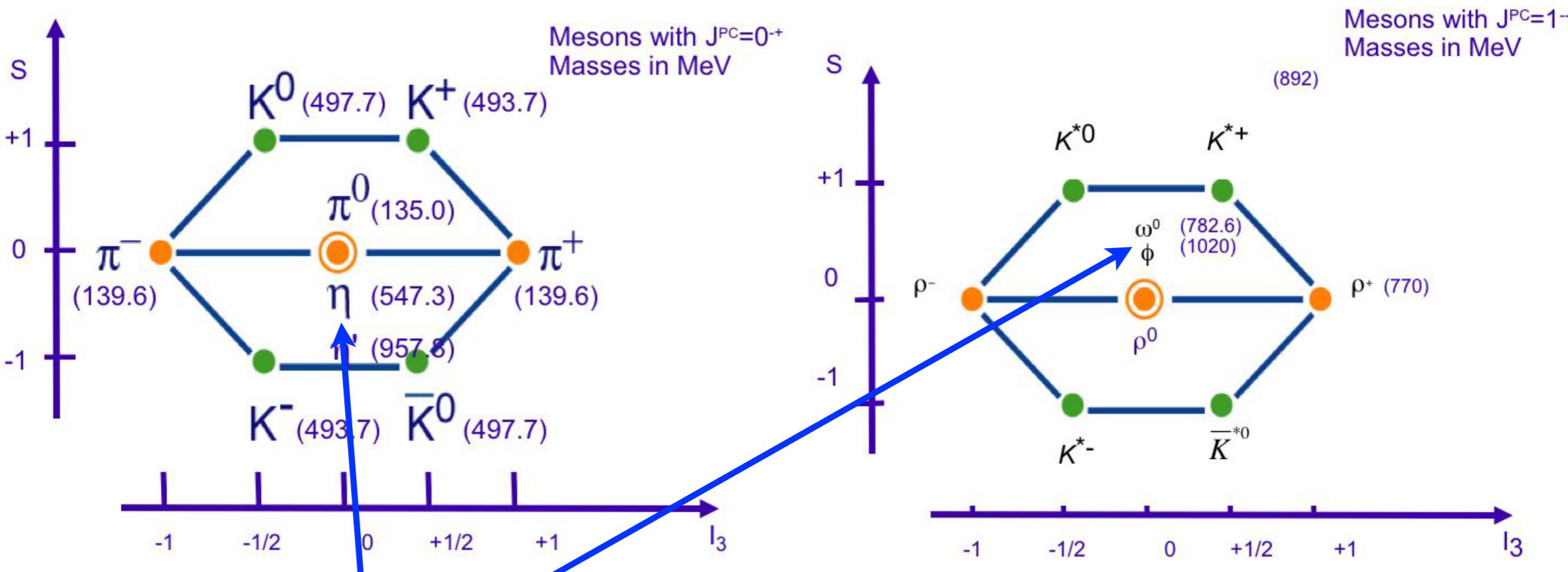
can we explain all
mesons with elementary
proton and neutron ?

further progress by
Sakata: elem. P, N, Λ

3. Symmetry

- Particles carry INPRINTED the symmetry of the underlying forces;
- The correct symmetry of subnuclear particles was identified by M. Gell-Mann and Y. Ne’eman in 1961, as SU_3 , the unitary transformations of complex 3-dimensional vectors;
- Particles should fall into typical complexes of:
 - octets and singlets (mesons)
 - octets and decuplets (baryons)
- Like Mandeleev Table, the request of *symmetry* leads to *predictability*

Meson patterns

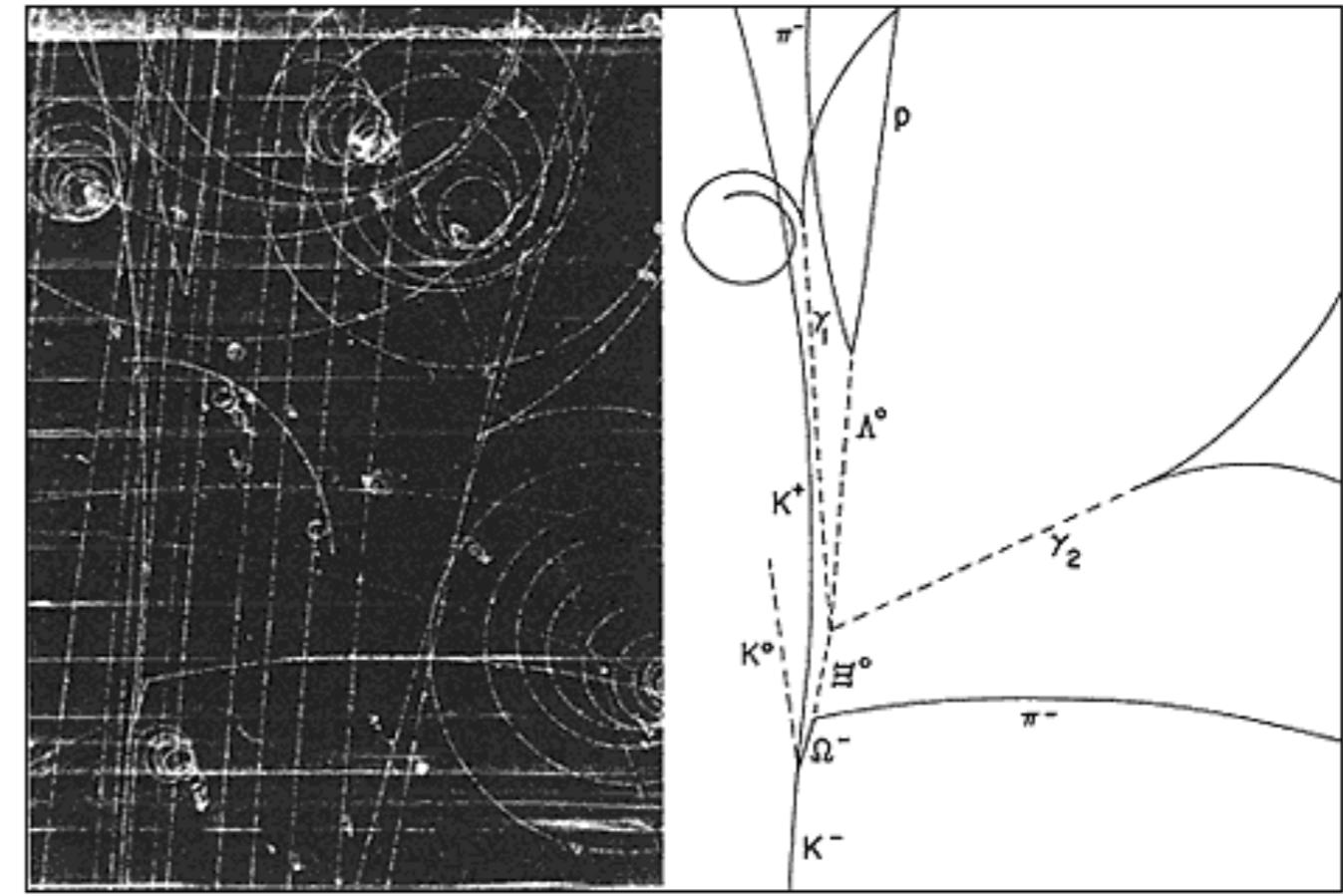
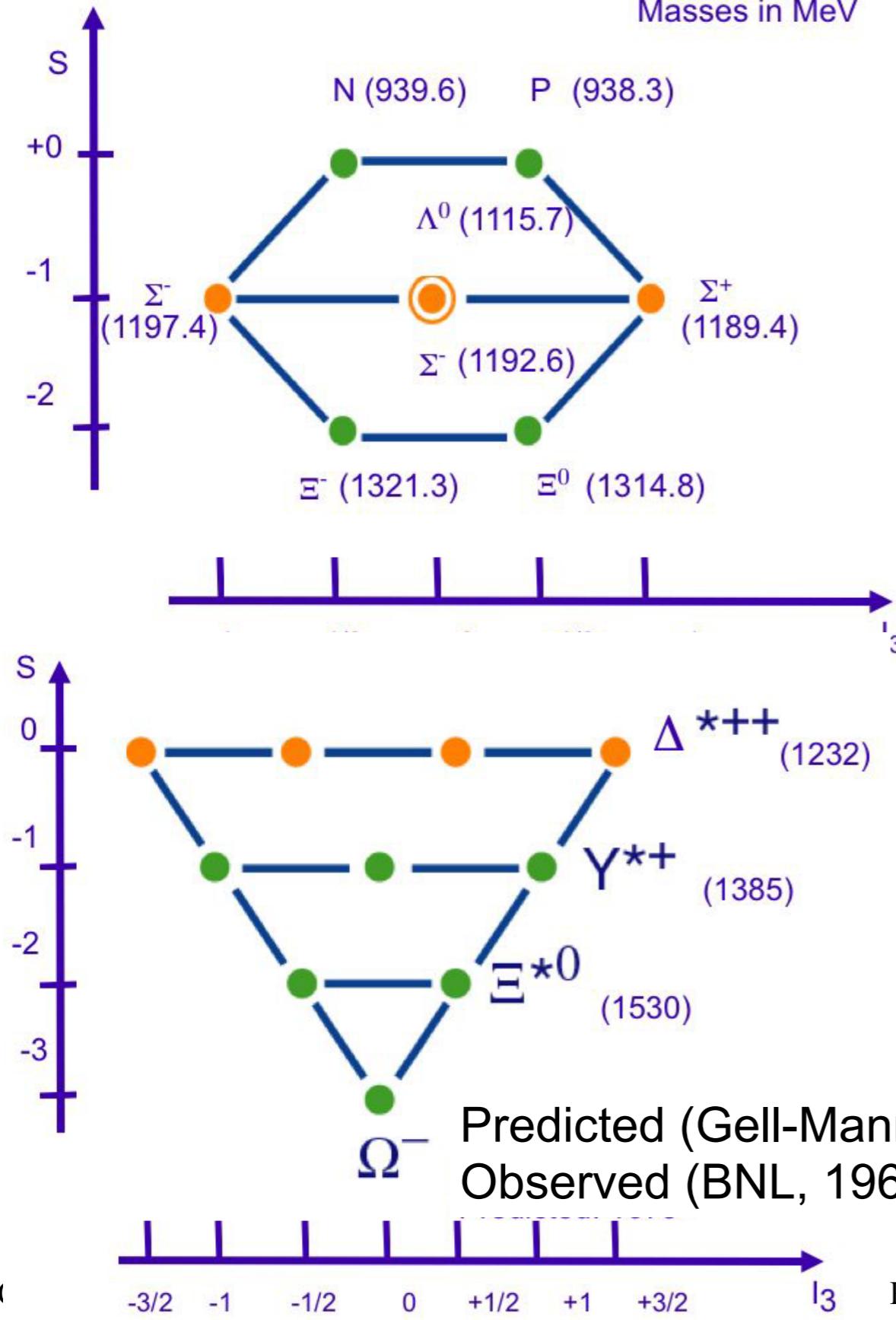


some particles (η , ω , ϕ) were not established when symmetry was proposed
their confirmation reinforced the picture.

Earliest studies of η were done with the Italian Sincrotrone, just built in Frascati.

The Ω^- missing link

Baryons with $J^P=1/2^+$
Masses in MeV



The bubble chamber picture of the first Omega-minus (N. Samios and coworkers)

4. QUARKS !!

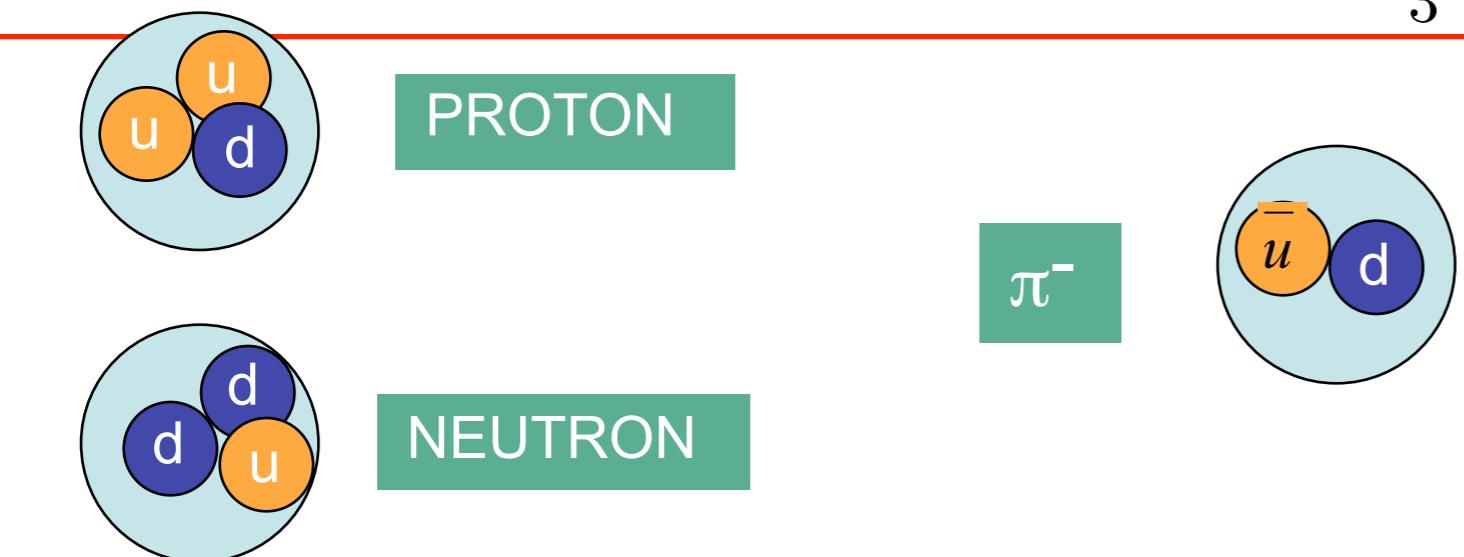
- Protons, neutrons, mesons, “strange particles” ... are composite states of *quarks and antiquarks*.
- Quarks and their masses *explain* the properties of the observed particles;
- A new « Table of Mendeleev » .

“Three quarks for Master Mark!” (M. Gell-Mann quoting J. Joyce)

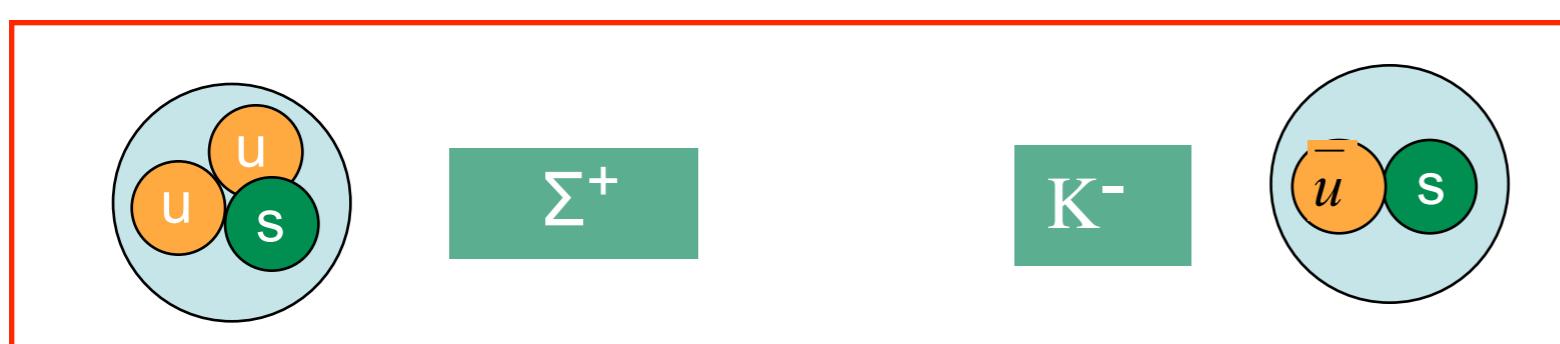
Three kinds (flavors) of quarks and their antiparticles make up old and new (strange) particles

$$q_u = \frac{2}{3}, \quad q_d = q_s = -\frac{1}{3}$$

$$q_P = \frac{2}{3} + \frac{2}{3} - \frac{1}{3} = +1, \quad q_N = \frac{2}{3} - \frac{1}{3} - \frac{1}{3} = 0, \text{ etc.}$$



π meson structure vindicates the intuition of Fermi & Yang, with quarks u, d replacing Proton and Neutron



2003- 2005: New hadrons are discovered which could indicate that more complex configurations do exists: Quantum Hadron Chemistry !!

Elementary constituents of matter, 1963



Elementary constituents of matter, today

Quarks

$$\begin{pmatrix} u \\ d \end{pmatrix}, \begin{pmatrix} c \\ s \end{pmatrix}, \begin{pmatrix} t \\ b \end{pmatrix}$$

Filling the vacant places has been an exciting adventure:

c

predicted 1970 (Glashow, Iliopoulos, Maiani)
observed 1974 (Ting, Richter) and 1976
(SLAC)

$$\begin{pmatrix} \nu_e \\ e \end{pmatrix}, \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}, \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}$$

τ
not predicted

observed 1976 (Perl et al.)

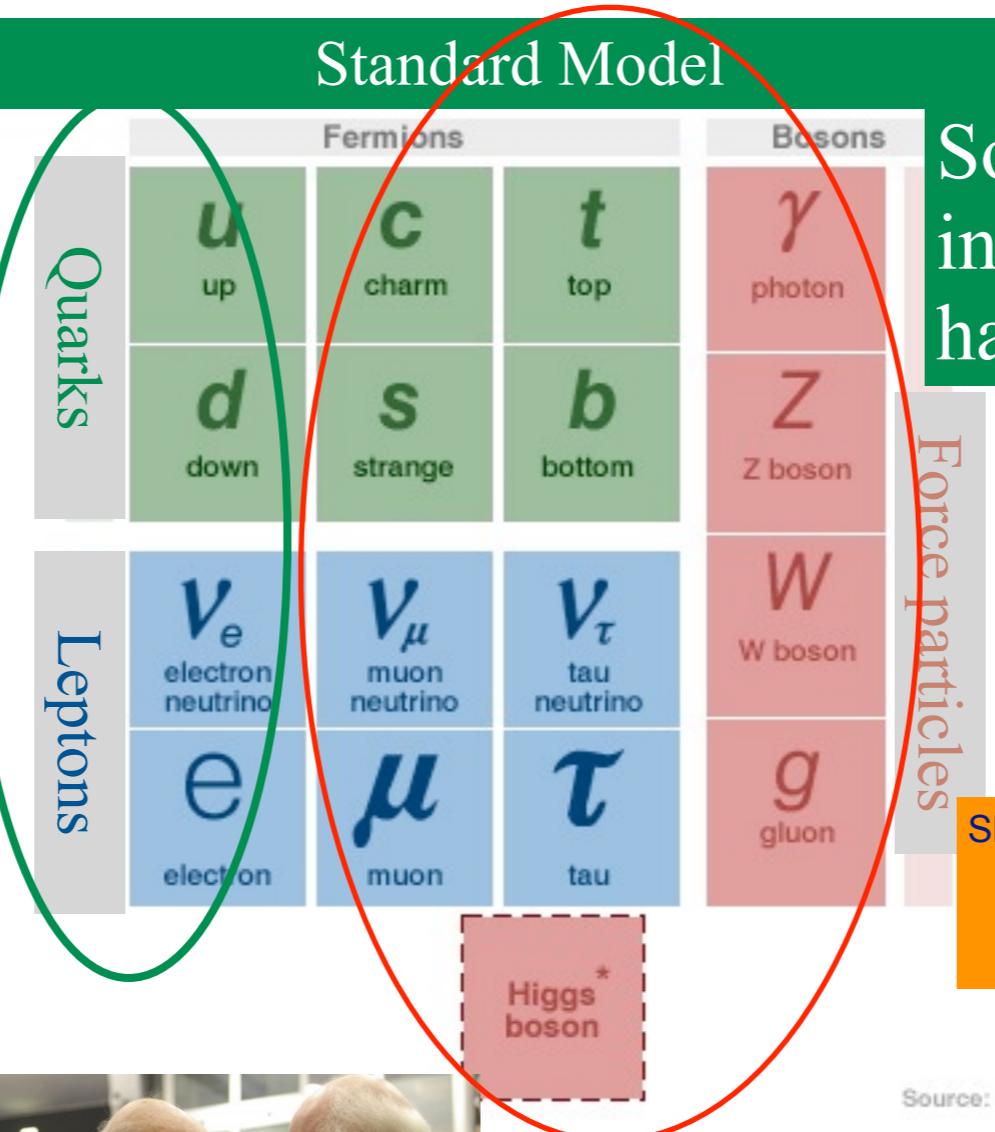
t, b

predicted 1973 (Kobayashi, Maskawa)
observed 1976 (b, Lederman et al.) and 1994
(t, CDF Collab. at Fermilab).

4. Costituenti della materia e Forze Fondamentali, 2013



Murray Gell-Mann

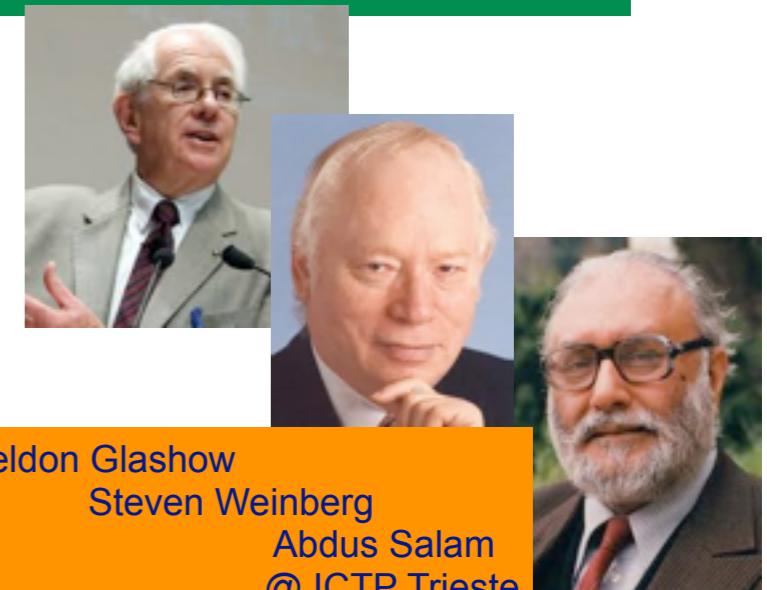


I quark e i leptoni più leggeri sono i costituenti della materia ordinaria



Robert Englert e Peter Higgs

Sono tutte particelle instabili: che ruolo hanno nell'Universo?



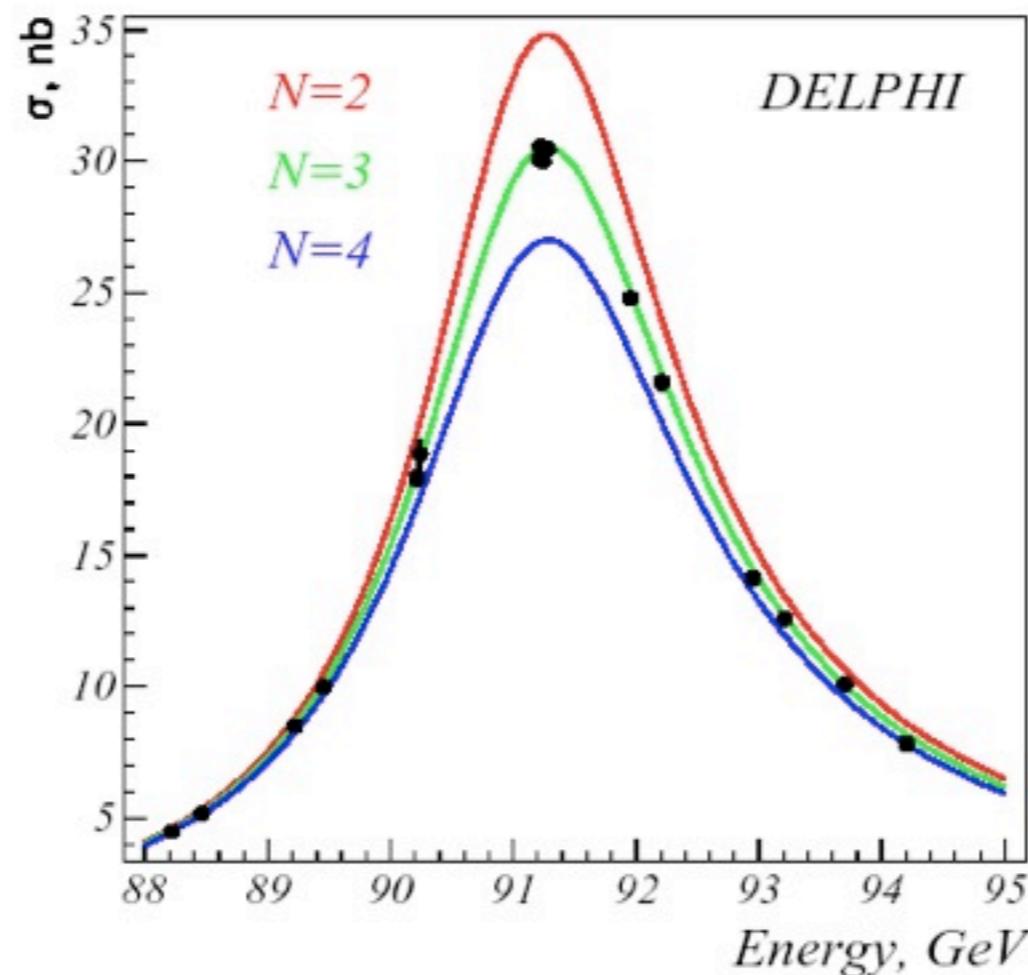
Carlo Rubbia

Three generations only ?

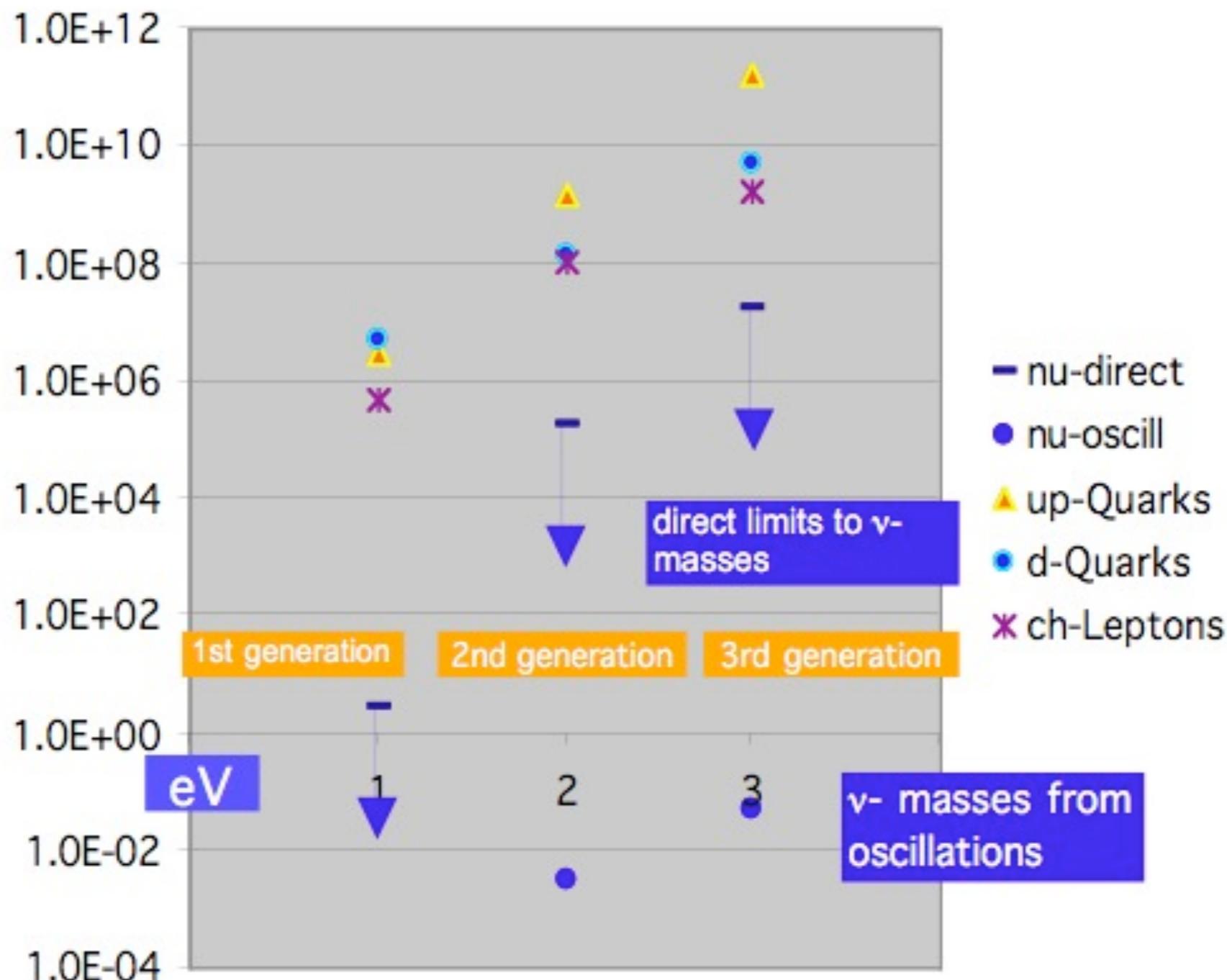
A VERY EARLY AND CLEAR ANSWER FROM LEP:

Only Three Light Neutrinos

INTRODUCED IN THE BIG BANG MODEL THIS RESULT LEADS TO PREDICT 24 PERCENT OF PRIMORDIAL HELIUM IN THE UNIVERSE, WHICH IS THE OBSERVED VALUE.



Matter is made by elementary fermions: quarks and leptons



heaviest neutrino mass: $4 \cdot 10^{-2}$ eV; top quark mass: $1.7 \cdot 10^{11}$ eV
about 13 orders of magnitude !!!

COLOR and QCD

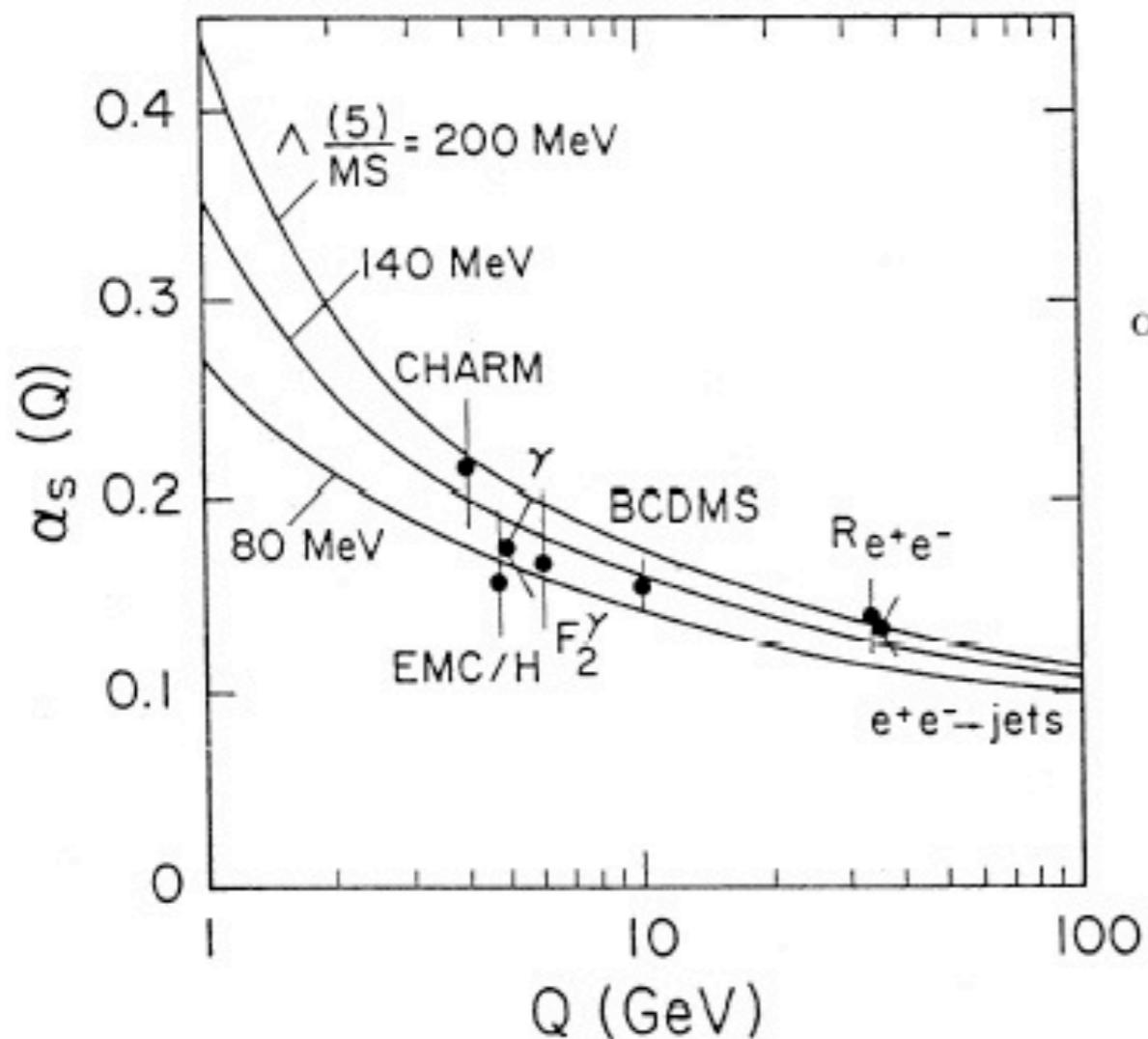
- $\Delta^{++} = (u\uparrow u\uparrow u\uparrow)$?
- ***is impossible*** by Pauli exclusion principle
- quarks have an additional “quality” called color, with three values (conventionally: red, green, blue);
- $\Delta^{++} = u_r\uparrow u_g\uparrow u_b\uparrow$ ***is possible***, and is unique (color singlet) Han&Nambu
- if being color singlet is the rule...
- the lowest state of six quarks will collapse into two color singlet baryons: THIS IS HOW NUCLEI ARE MADE, hence atoms
- ...reconstructing Mendeleev from below (we have only qualitative control, at the moment)
- Quantum Chromo Dynamics: gives a dynamical meaning to color (like electric charge in electrodynamics)

The asymptotic freedom revolution

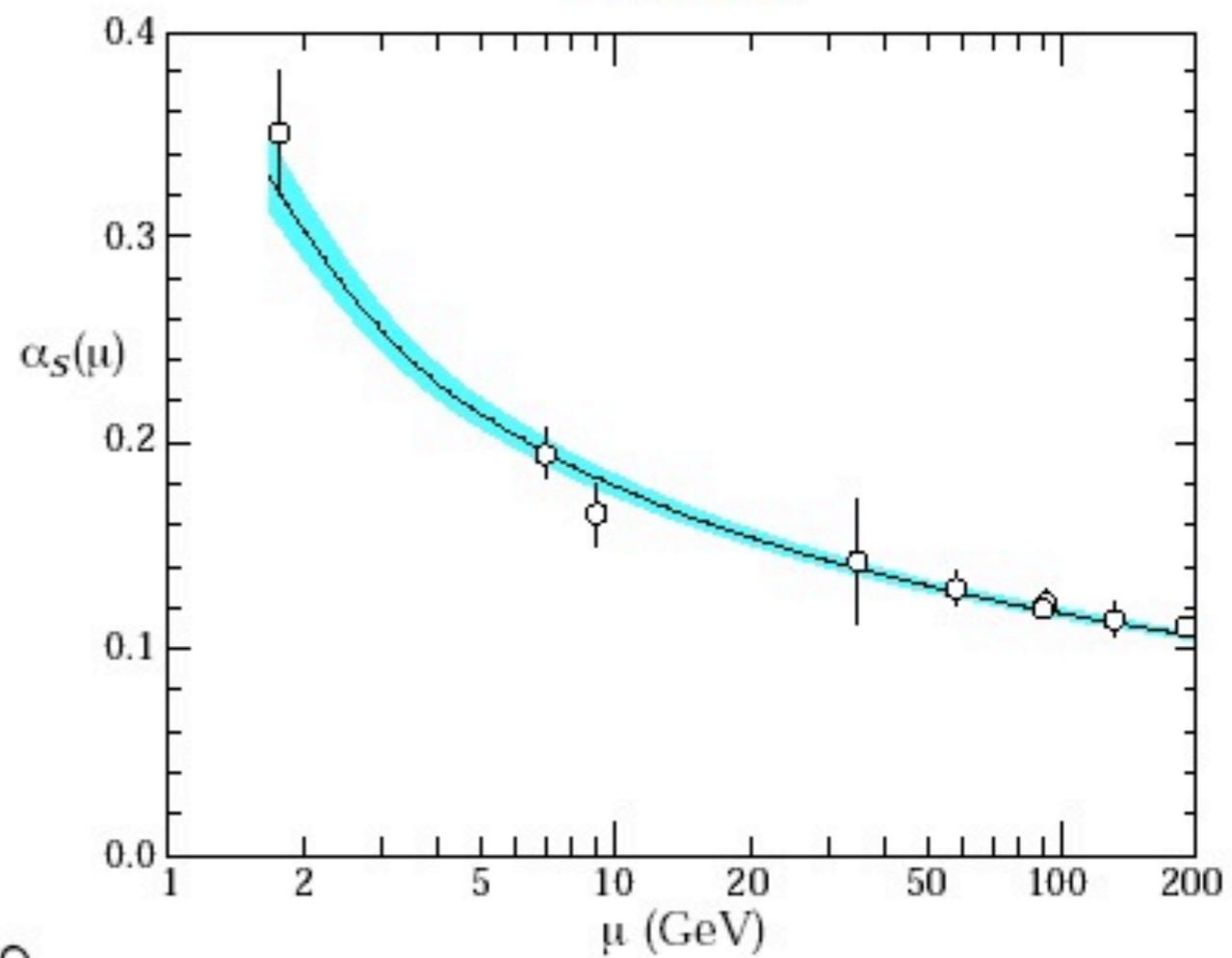
Gross, Wilczek and Politzer (1973)

The QCD coupling decreases at high

1989



2000



$$\alpha_s(M_Z) = 0.11 \pm 0.01$$

Physics at LEPI (after Altarelli)

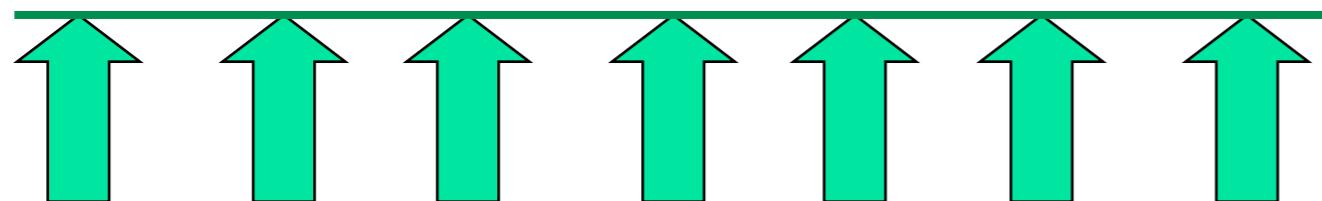
$$\alpha_s(M_Z) = 0.118 \pm 0.002$$

Particle Data Group 2000

5. Il Bosone di Higgs

L'origine delle masse

- Un campo pervade lo spazio ed influenza il moto delle particelle
- Il campo “distingue” tra le particelle collegate dalla simmetria .. W, Z acquistano una massa, il fotone resta a massa zero etc.



- Il VUOTO è come la superficie di un lago perfettamente calmo

- Nelle collisioni si producono delle onde...



... che corrispondono ad una nuova particella: il **BOSONE di HIGGS**

- Il bosone di Higgs è necessario per l' accordo tra teoria e Natura...
- Ma dà una nuova visione del VUOTO, che puo spiegare nuovi fenomeni: (inflazione, universo caotico, ...)
- per trovarlo, è stata costruita una macchina mondiale: LHC al CERN di Ginevra.

Peter Higgs @ Erice, 2007
(con Verònica Riquer)

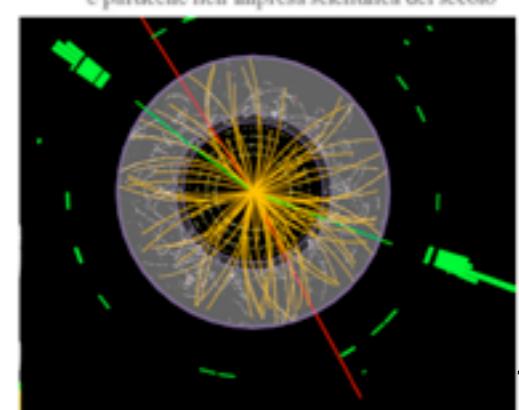


6. LHC al CERN- protagonisti



Luciano Maiani
Romeo Bassoli
**A caccia
del bosone di Higgs**

Magneti, governi, scienziati
e particelle nell'impresa scientifica del secolo



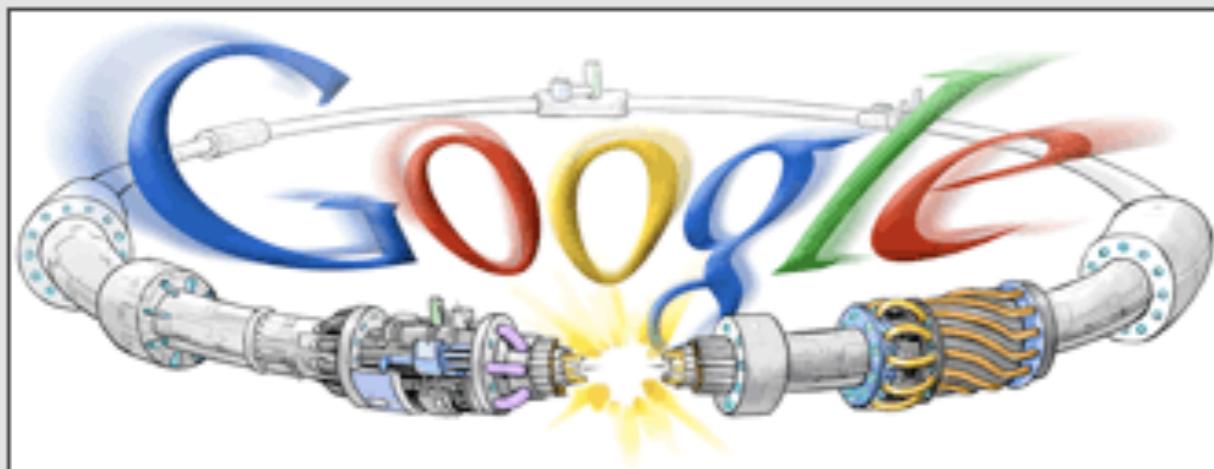
LHC: primi fasci, 10 Settembre 08



GOOGLE, lo stesso giorno

Google LHC Logo

Today, Google place a different logo for their homepage having **Large Hadron Collider (LHC)** experiment theme.



We can easily see the excitement about this LHC experiment on any face who have interest in science and scientific things specially in physics as this would be the future of physics.

Scientists at the CERN research centre in Switzerland are aiming to use this wonder machine to gain a better understanding of the birth and structure of the universe, and to fill gaps in our knowledge of

physics.

Well, it's a big topic to discuss...I am not that much intelligent...however a well known **Prof Stephen Hawking** said that "Whatever the LHC finds or fails to find, the results will tell us a lot about the structure of the universe."

Cheers!

[September 10, 2008](#) - Posted by [imstrategist](#) | [Uncategorized](#) | [Google, LHC Experiment](#) | [1 Comment](#)

1 Comment »

1. Yaaay, im still alive, no black holes 😊



Comment by ZeroZool | September 10, 2008

Gli obiettivi di LHC

- Trovare il Bosone di Higgs

!!!!

L' Origine delle masse

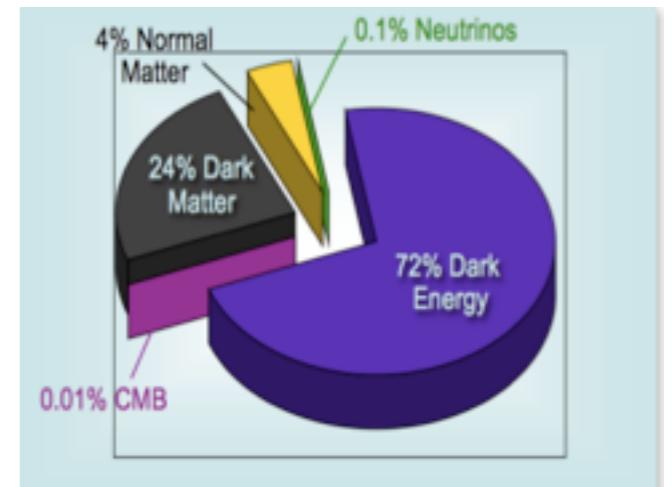
- Trovare le Particelle Supersimmetriche

L' Origine dello Spin

L'Unificazione delle Forze **richiede** una Simmetria che colleghi particelle con spin differenti: questa è la SUPERSIMMETRIA scoperta al CERN negli anni settanta da J. Wess e B. Zumino

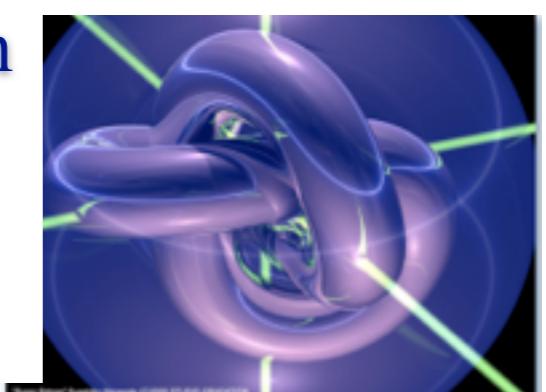
- Scoprire la natura della Materia Oscura

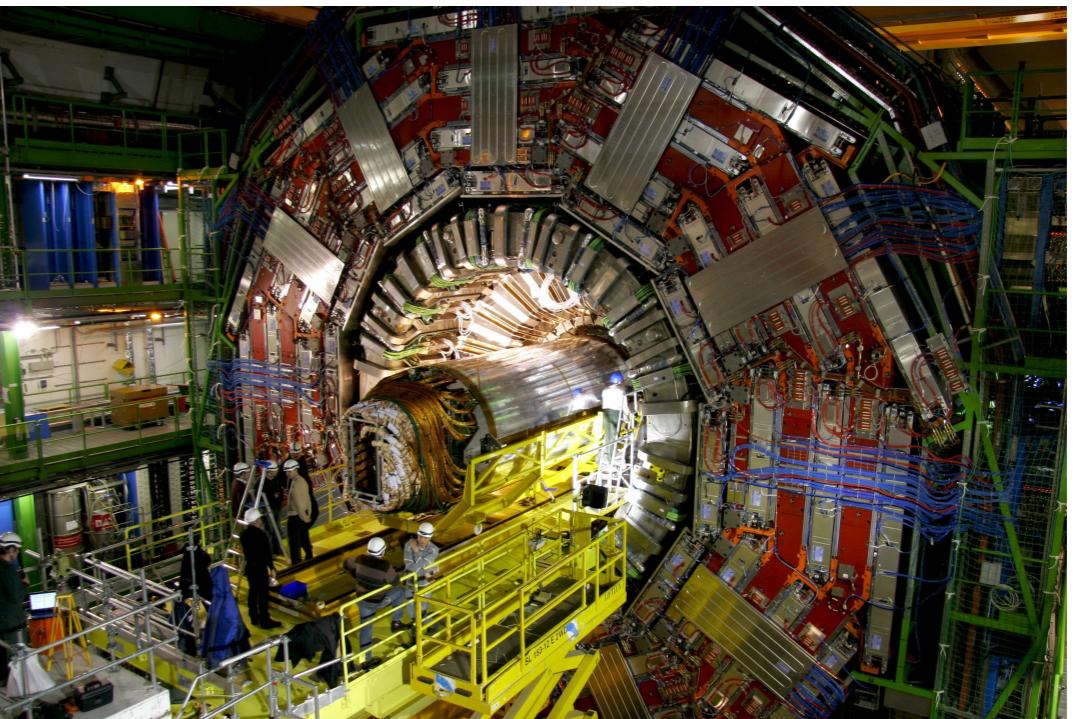
Supersimmetria Cosmica ?



- Ricercare nuove dimensioni dello spazio

- La moderna formulazione della Gravità Quantistica non è consistente in 3 dimensioni spaziali !!
- ci vogliono dimensioni extra, curve.. ma quali sono le loro dimensioni?





"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"



L'AVVENTURA CONTINUA !!