STRUCTURE OF MATTER

Discoveries and Mysteries

Part 2

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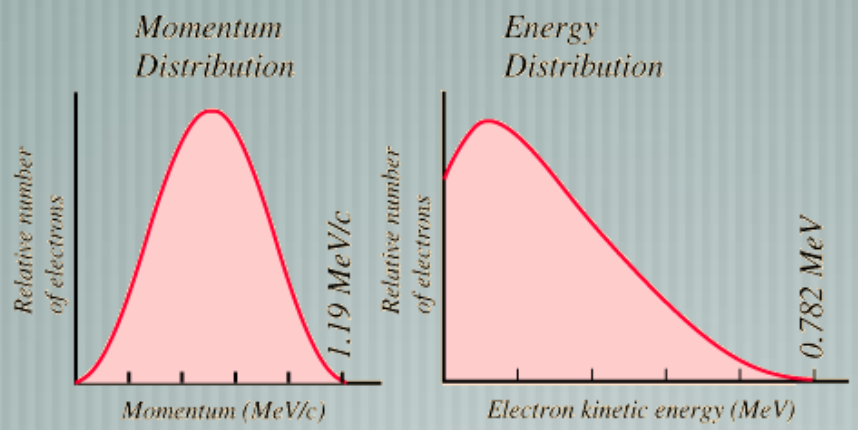
CERN

(Presenter and marginal contributions :Giacinto de Cataldo INFN Bari, Italy)

The "Weak Interaction" - What is Radioactivity ?

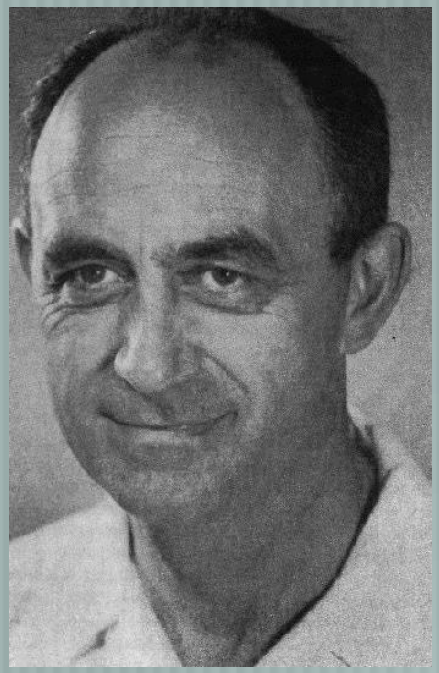
1911: Continuous (?) energy spectrum of 'beta' -rays (electrons) - energy conservation?

Z --> (Z+1) + e ?

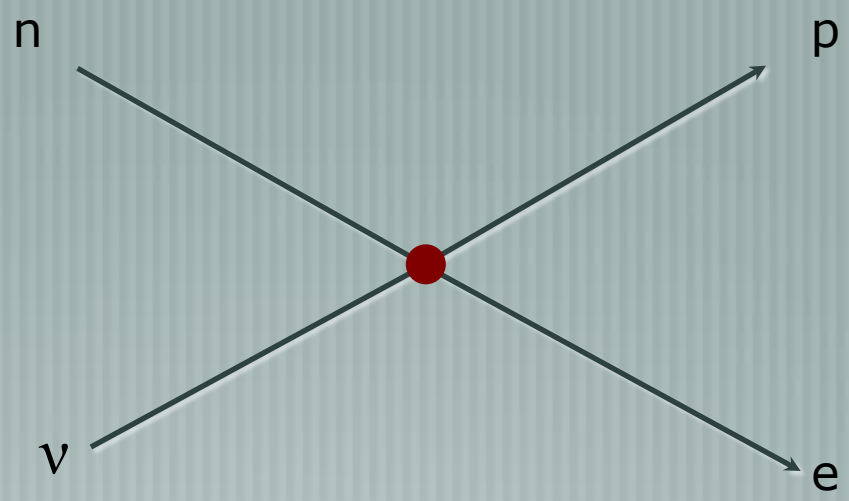


1930: Wolfgang Pauli postulates existence of 'neutrino' : **n --> p + e + ν**

The model of Enrico Fermi : “pointlike interaction”



Enrico Fermi
(1934)

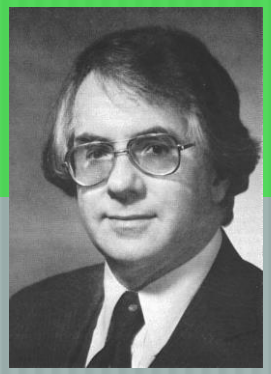


Proposed a **phenomenological** model of weak interaction

Point-like coupling with strength $G_F \sim 10^{-5}$ of e.m. interaction

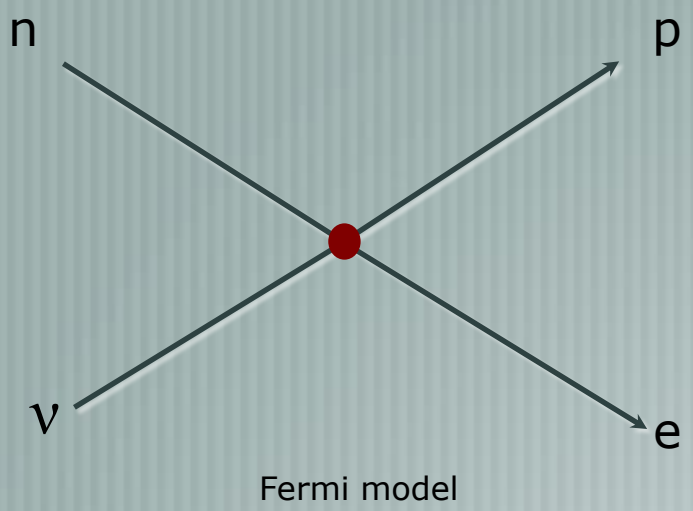
Coupling of two ‘currents’ (proton-neutron / electron-neutrino)

Fermi's model turned out to be inconsistent at E > 300 GeV



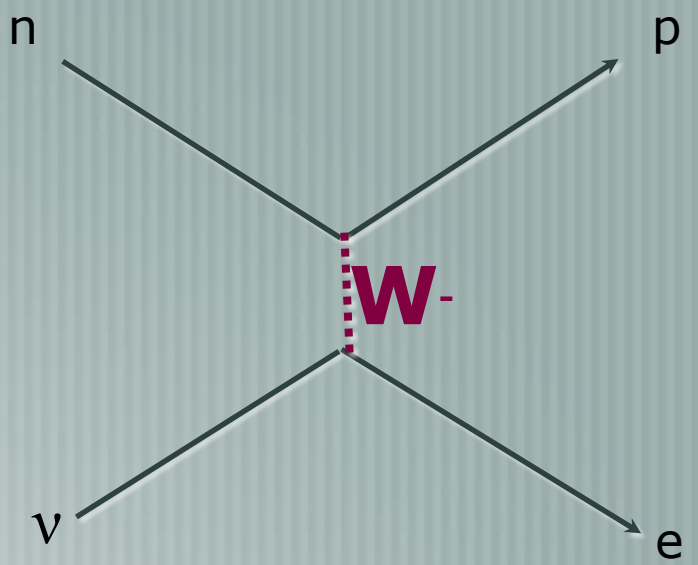
S. Glashow

probability of this reaction > 100% (E > 300 GeV)



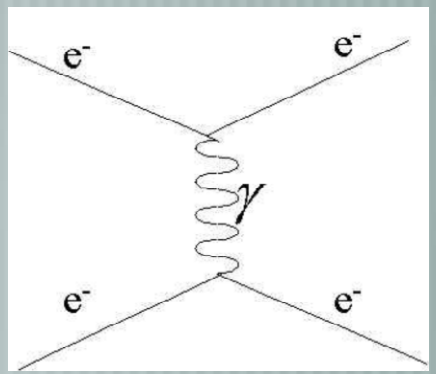
Fermi model

New Idea (1958)

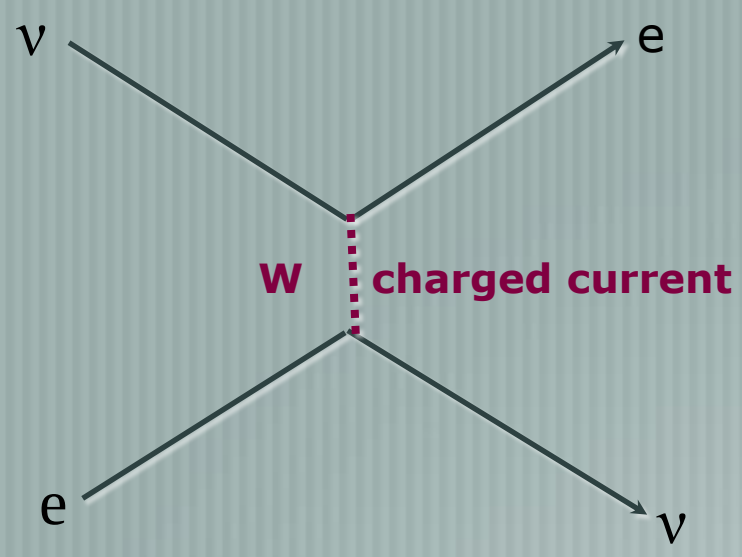


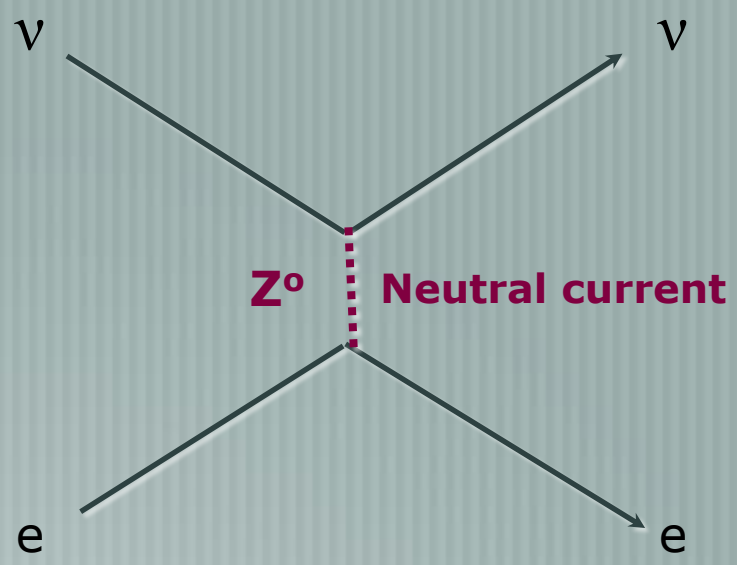
Weak interaction transmitted by massive vector bosons (in analogy to photon exchange!)

Large mass (80 GeV) explains short range ($2 \cdot 10^{-18}$ m) and small cross-sections



Unification of electromagnetic and weak interaction



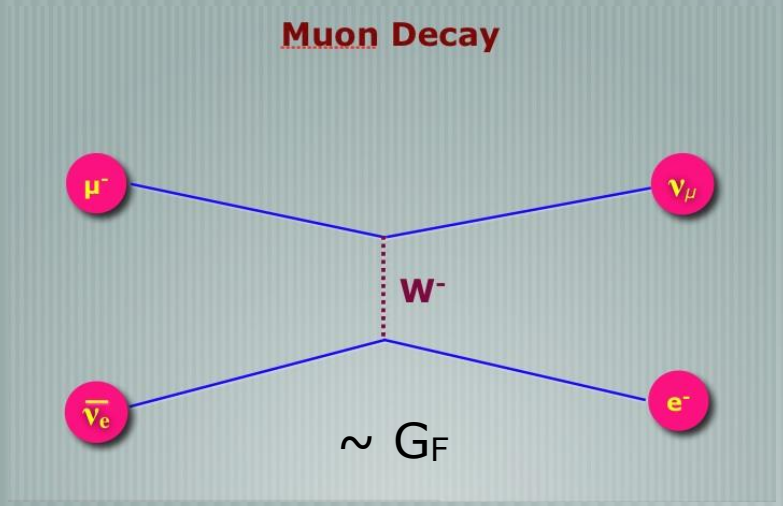


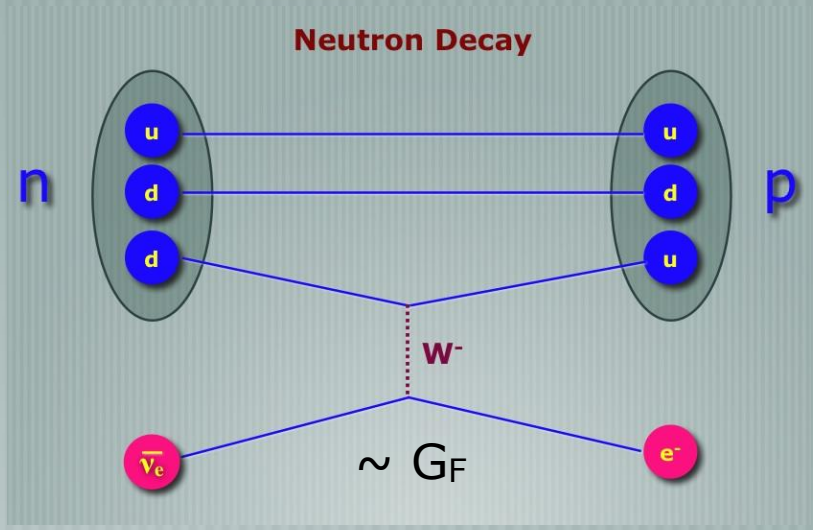
Glashow, Salam, Weinberg (1968) - Electroweak Force

- The electromagnetic and weak interaction are different aspects of the same 'electroweak' force
- All quarks and leptons have a 'weak' charge
- There should be a 'heavy photon' (Z^o) and two charged vector boson ($W^{\pm}$) of mass ~ 50-100 GeV
- **The W,Z bosons acquire their mass by interacting with the "Higgs field" (1964)**

Fields

Electroweak interaction is the SAME for leptons and quarks





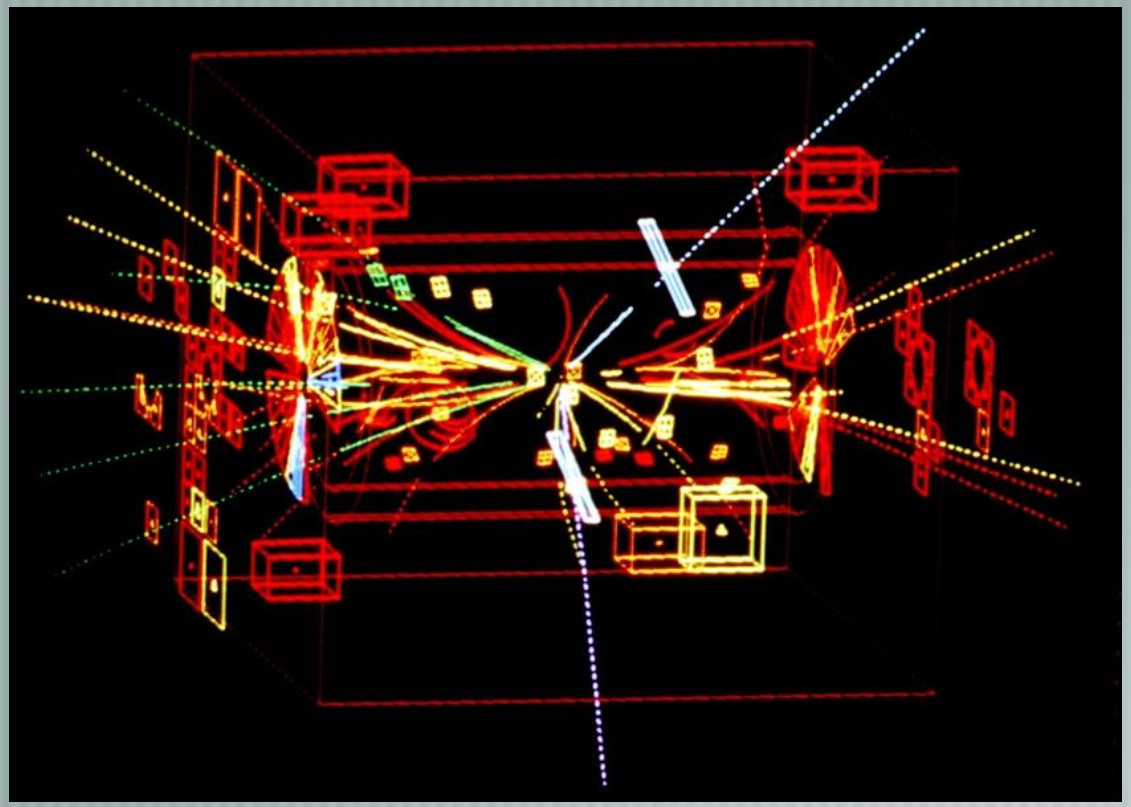
"Universality*" - transmitted by W, Z bosons, same strength!

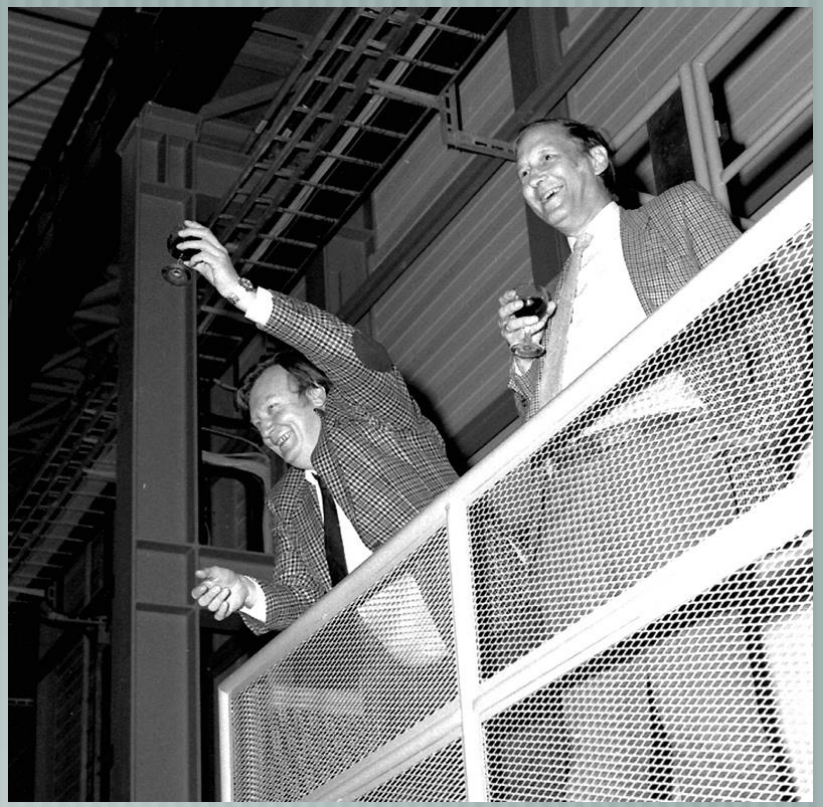
*Assuming a little bit of 'quark' mixing

$$d' = d \cos\theta_c + s \sin\theta_c$$
$$s' = -d \sin\theta_c + s \cos\theta_c$$

θ_c = Cabbibo angle ~ 20^o

Discovery of the W, Z bosons at CERN (1983)





(C. Rubbia, S. van der Meer)

Approaching the 'Standard Model' of today

A legendary paper, predicting a new quark (Glashow, Iliopoulos, Maiani)

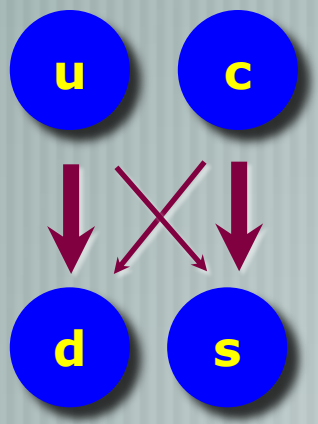
PHYSICAL REVIEW D VOLUME 2, NUMBER 7 1 OCTOBER 1970

Weak Interactions with Lepton-Hadron Symmetry*

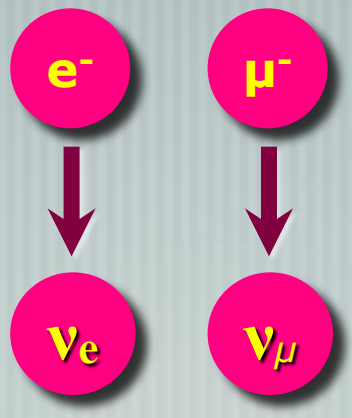
S. L. GLASHOW, J. ILIOPOULOS, AND L. MAIANI†
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 02139
(Received 5 March 1970)

We propose a model of weak interactions in which the currents are constructed out of four basic quark fields and interact with a charged massive vector boson. We show, to all orders in perturbation theory, that the leading divergences do not violate any strong-interaction symmetry and the next to the leading divergences respect all observed weak-interaction selection rules. The model features a remarkable symmetry between leptons and quarks. The extension of our model to a complete Yang-Milis theory is discussed.

Quarks



Leptons

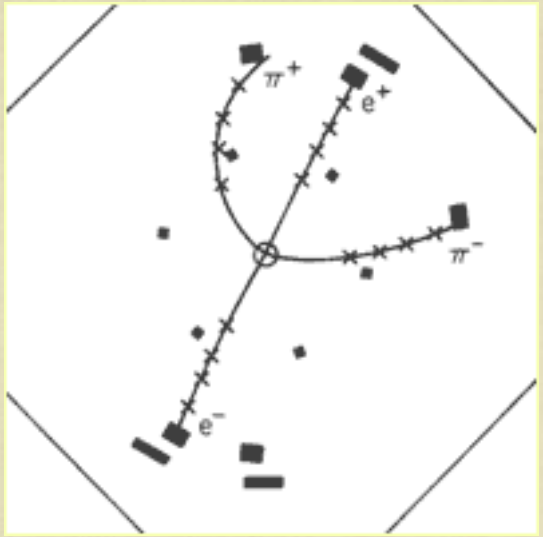


The "Standard Model" of 1970

Discovery of the 'charm' quark in 1974

NOVEMBER REVOLUTION (11 November 1974)

'Psi' at SLAC (Burt Richter)
'**J**' at Brookhaven (Sam Ting)
Compromise: J/Psi



"Extremely" long lifetime (~10^{-20} sec)
Decay only possible through electroweak interaction

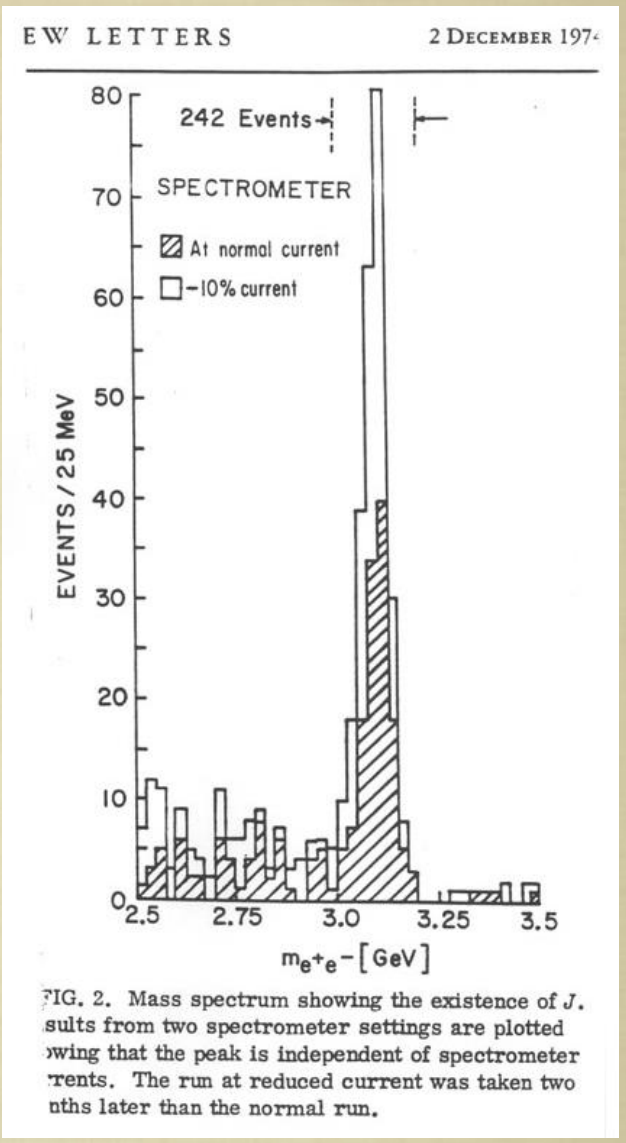
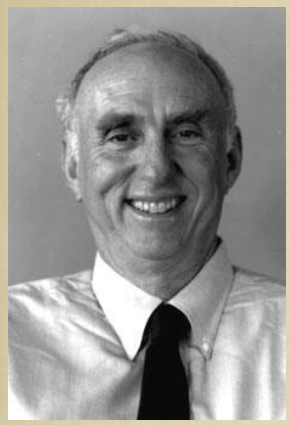


FIG. 2. Mass spectrum showing the existence of J. sults from two spectrometer settings are plotted owing that the peak is independent of spectrometer rents. The run at reduced current was taken two nths later than the normal run.

PARTICLE SPECTRUM

But a third family of particles was going to be discovered



Martin Perl

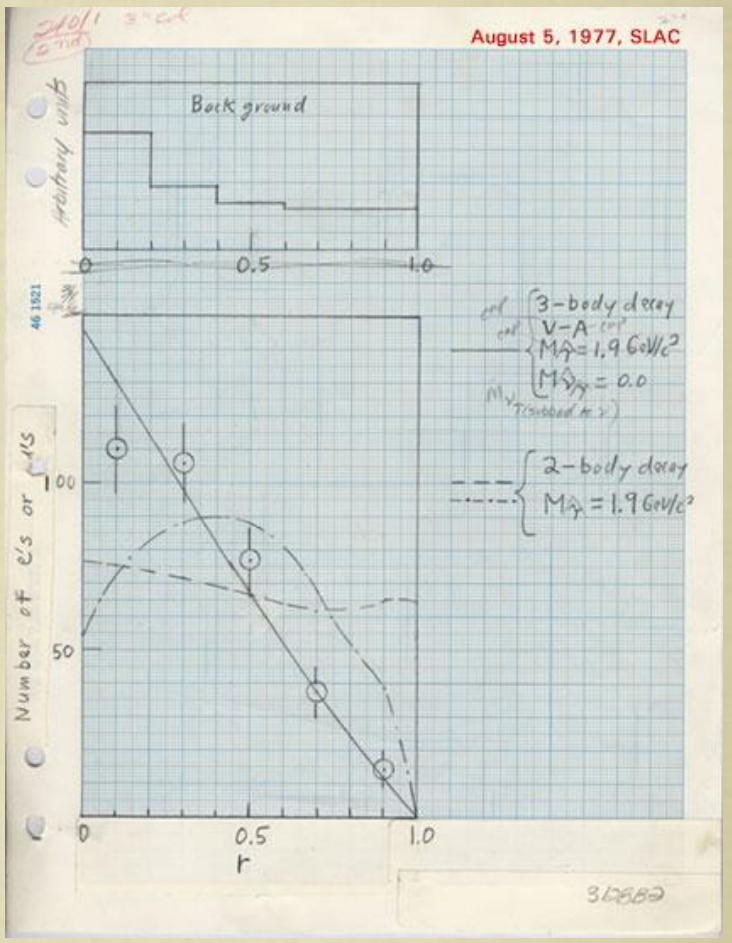
A new 'heavy electron' with 3500 x m_e

(τ lepton)

... who ordered that?

THERE MUST BE A WHOLE NEW FAMILY

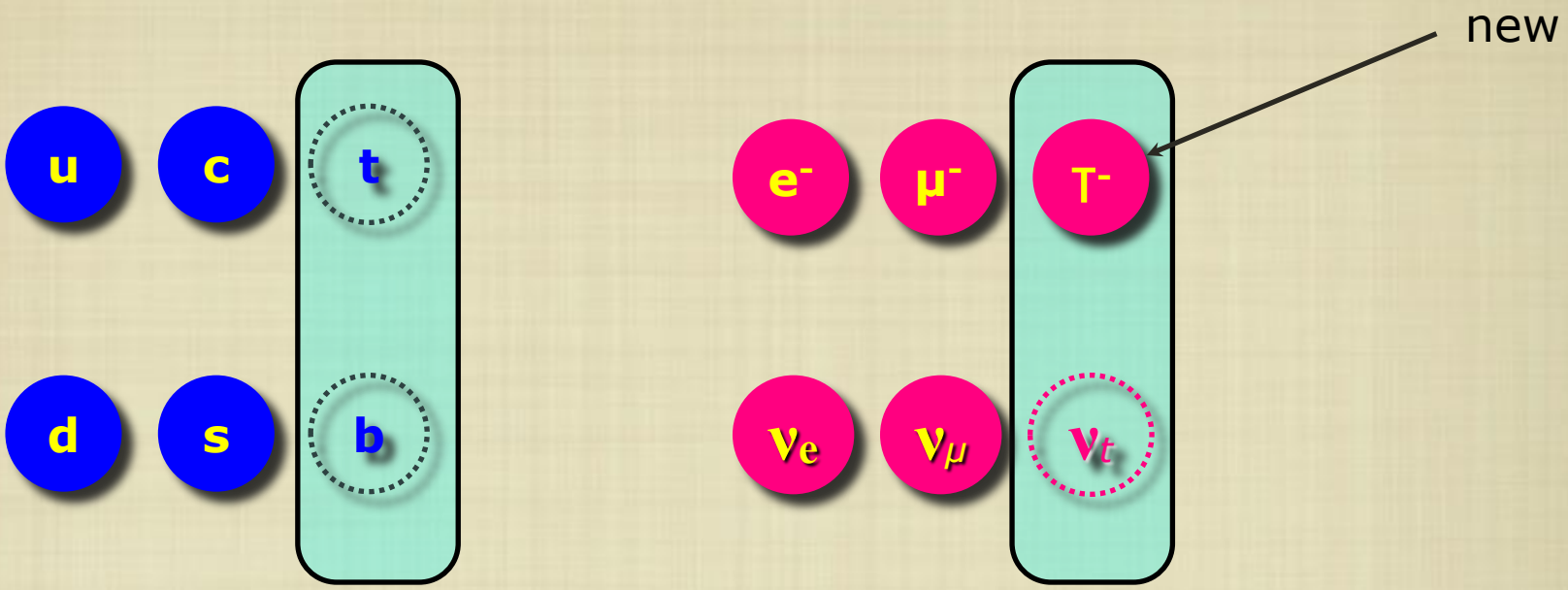
another neutrino (the 'tau neutrino'),
and two more quarks ('top' and 'bottom')



Marty Perl's logbook page

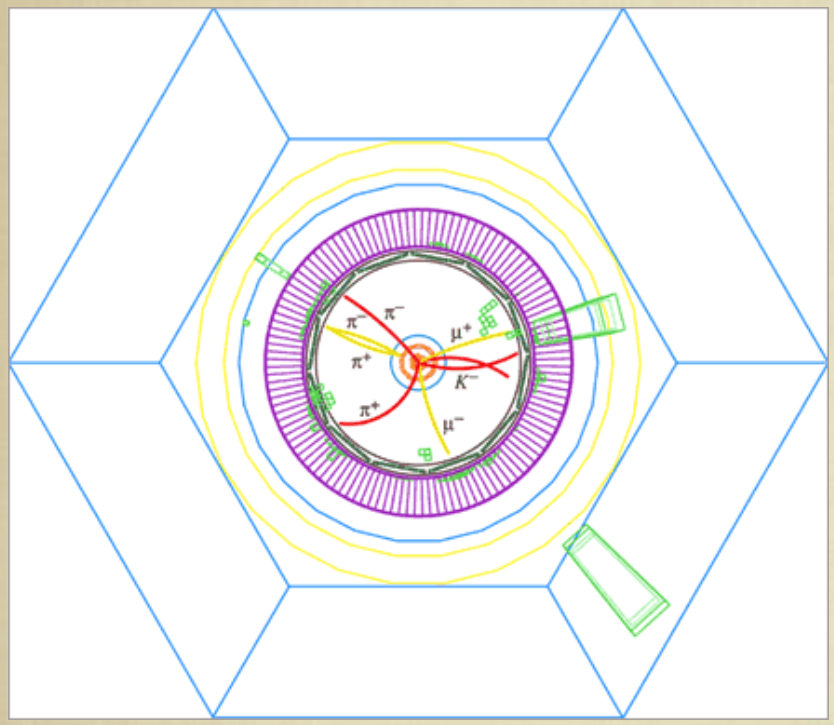
PARTICLE SPECTRUM

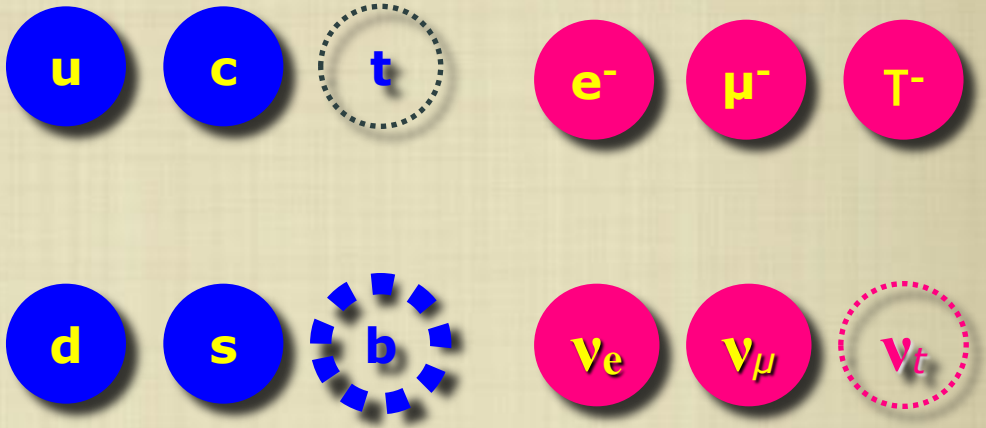
The search for the other family members started



PARTICLE SPECTRUM

Discovery of the **'Bottom' Quark (Fermilab)**





Quarks Leptons

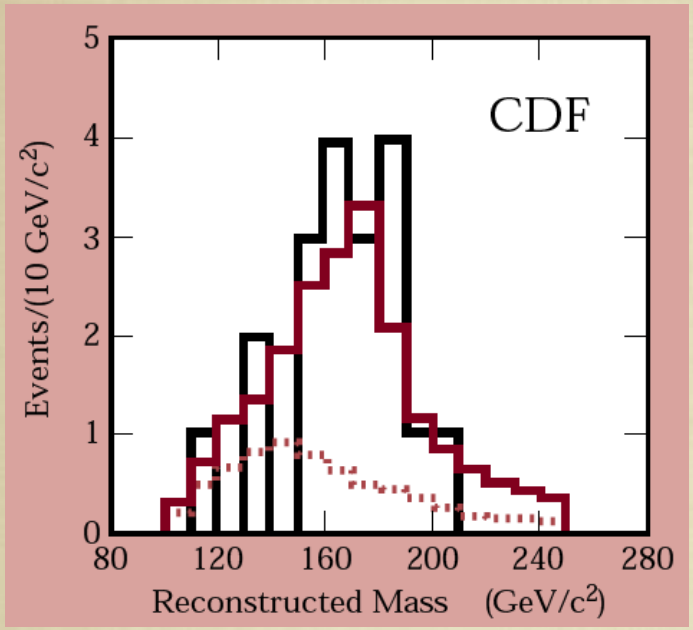
In 1977 physicists discovered a new meson called the Upsilon at the Fermi National Accelerator Laboratory.

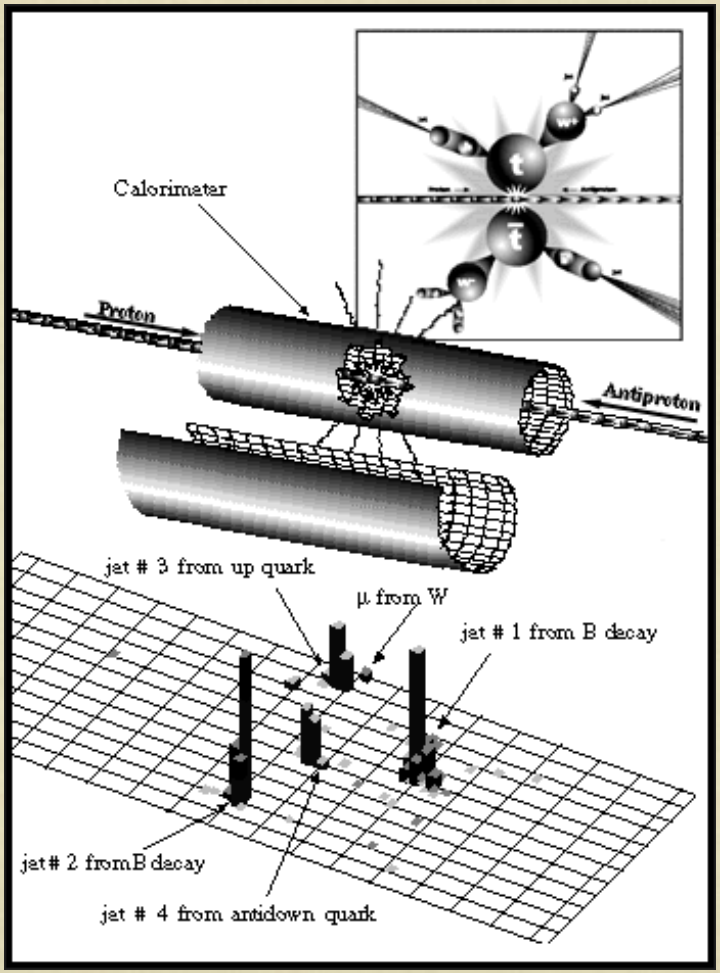
This meson was immediately recognized as being composed of a bottom/anti-bottom quark pair.

The bottom quark had charge -1/3 and a mass of roughly 5 GeV.

PARTICLE SPECTRUM

Discovery of the **'Top' Quark (Fermilab)**





u c t

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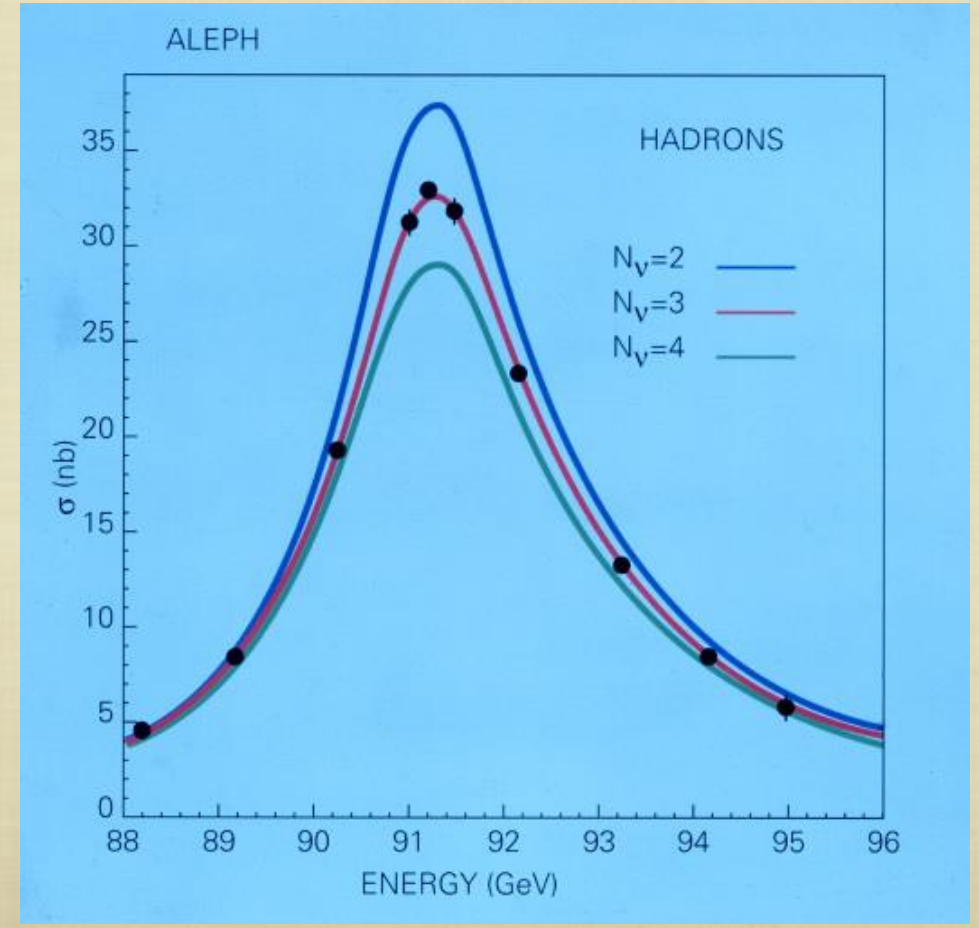
Quarks

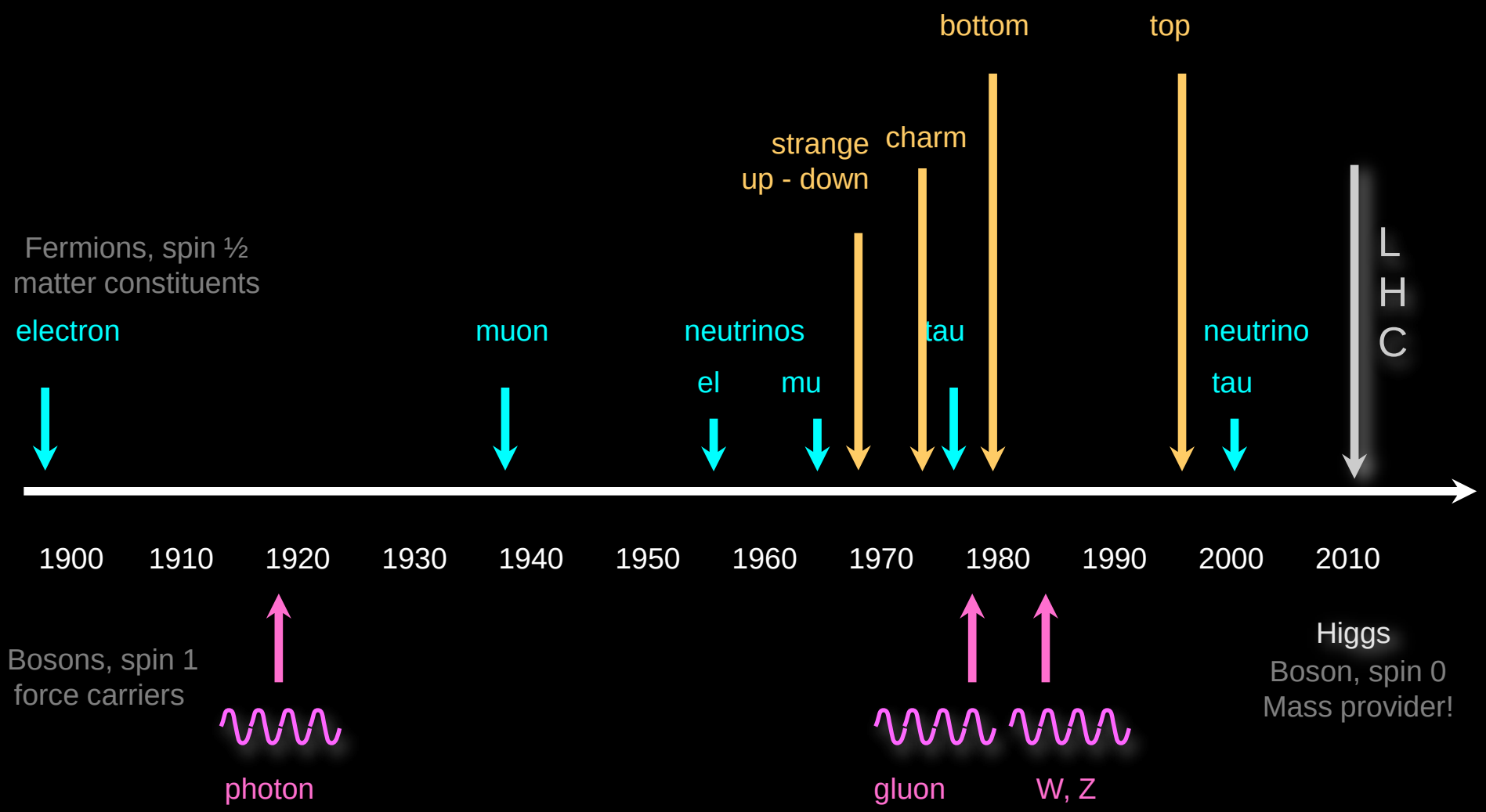
PARTICLE SPECTRUM

EXACTLY 3 families of particles

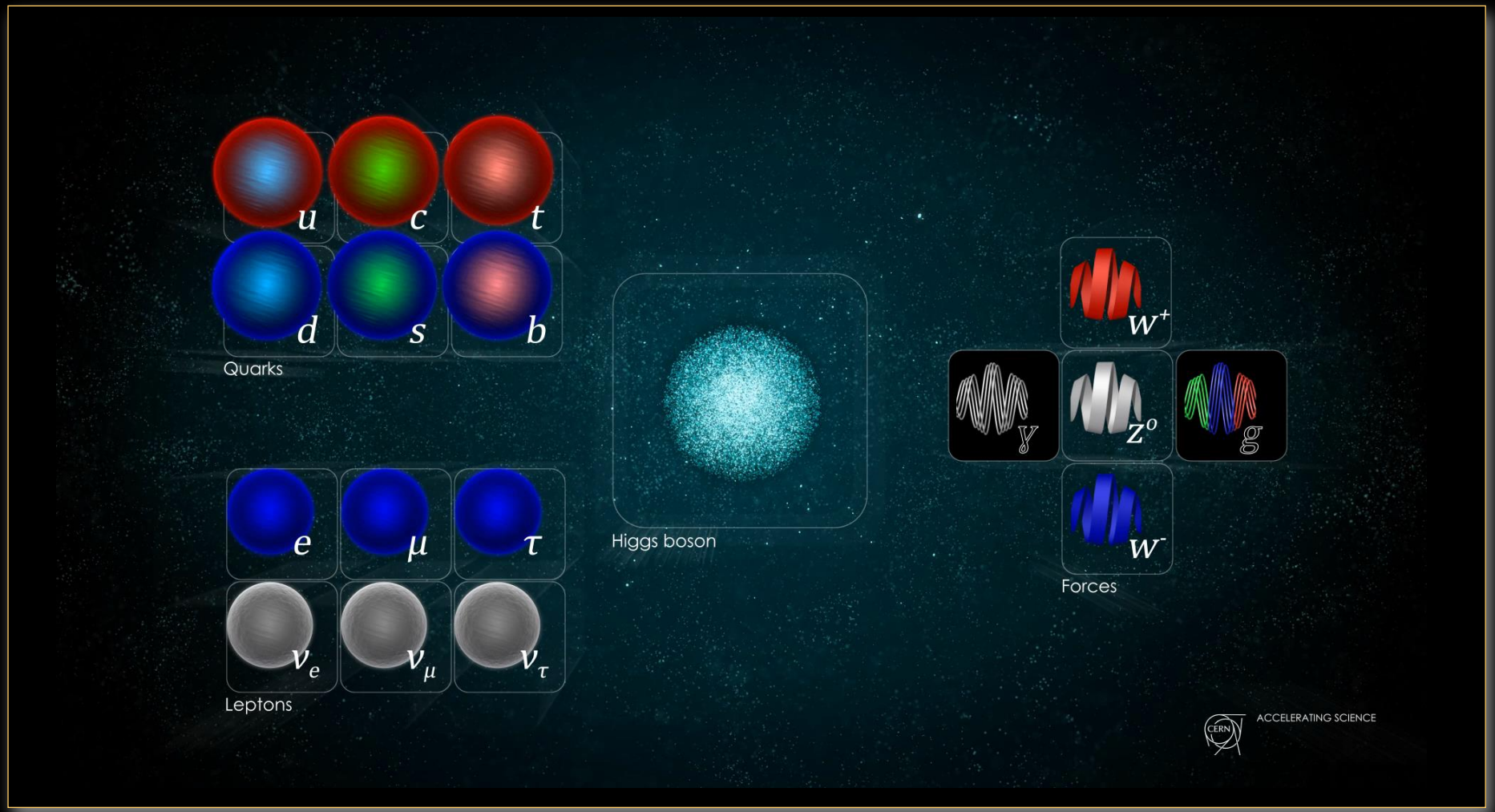
LEP measures the decay width of the Z^o particle



Experiments at accelerators have discovered the whole set of fundamental particles



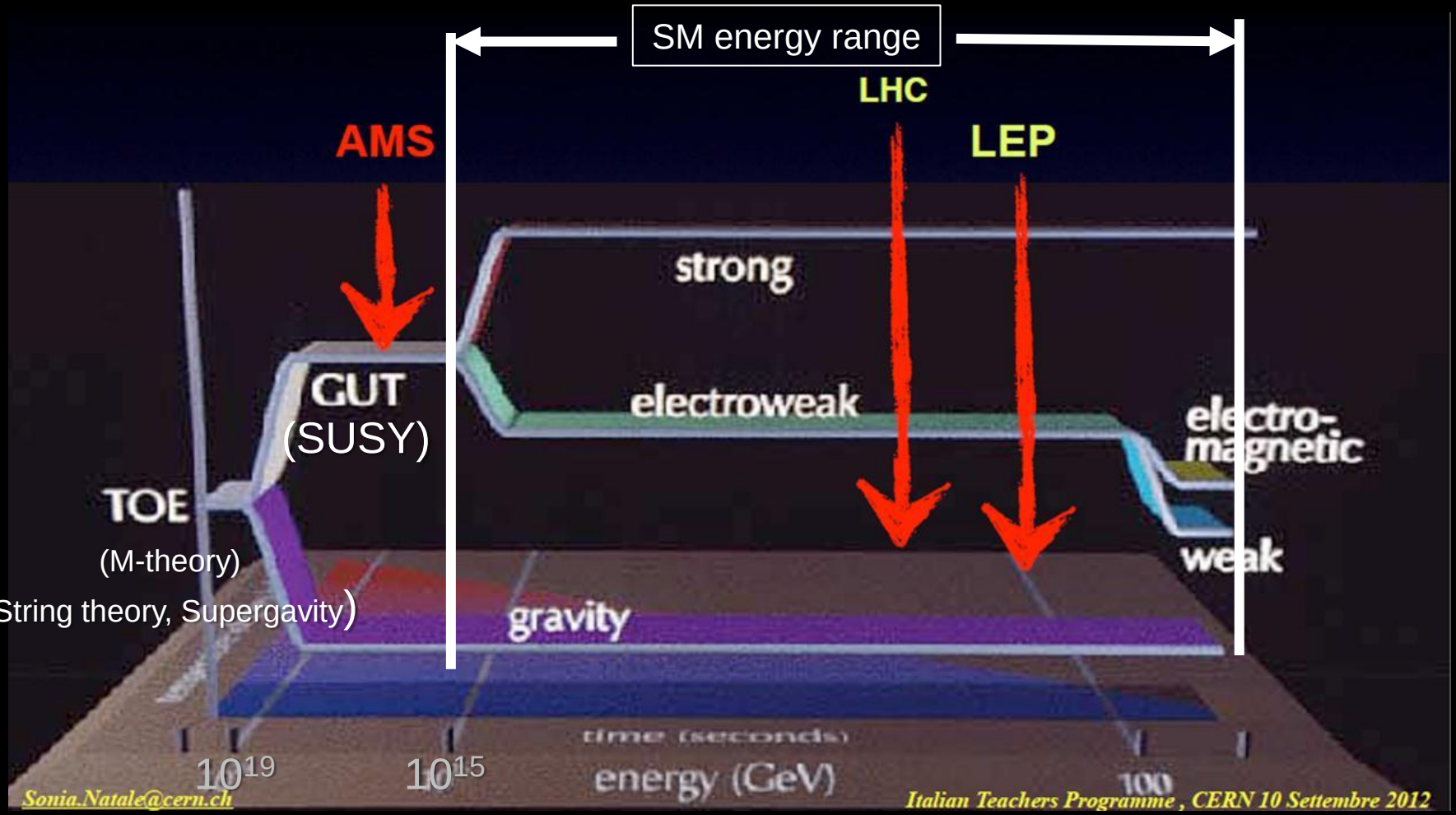
Standard model = ‘periodic system’ of elementary particles



Particles Higgs Fields

Beyond the SM towards a Theory of Everithing

(gdc)



Summary part 1 and 2

- Special relativity: c constant, space and time not constant, new 4-dimensions space-time by Minkowsky;
- Energy qunta hv, particle-wave duality λ=h/p,=> Quantum Mechanics (QM) with state (Ψ wave function) and observables (math. E, p Operators): Schrodinger eq;
- Special relativity + QM => Dirac equation => animatter and electron spin;
- QED: photon as field quanta, quantum vacuum as ground state of Maxwel EM field (virtual particles). QED: a succesful model;
- Electroweak force: unification of EM and weak interactions. Extension of the QED model to include new massive field quanta: Z°, $W^{\pm}$. (REM Higss mechanism required for masses!).
- Particle zoo=> quarks more fundamental components: u,d,s;
- Approaching the SM: Universality of EW , three lept fam => three quark families;
- QCD for the strong interaction: again following the QED model, 8 (massless, not sensitive to the Higgs fied) gluon quanta, each with 3 colours (charge of stron interaction);
- STANDARD MODEL: paceful existence of Electroweek, QCD and Higgs Mechanism.
- Waht about the unification of SM+Gravity in a Theory of Everithing (ToE) ??? (gdc)