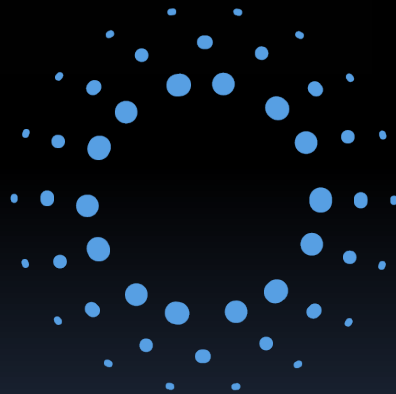


Aventuras em Física Teórica

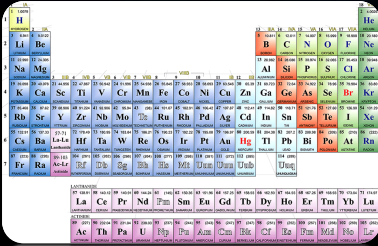
Introdução à Física de Partículas

Ricardo D'Elia Matheus



IFT - UNESP
INSTITUTO DE FÍSICA TEÓRICA

Partículas e mais partículas

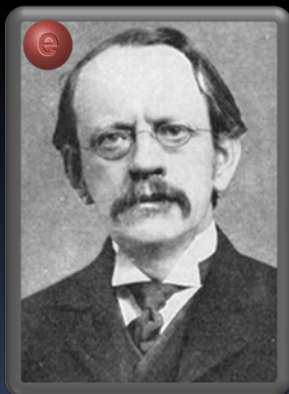


Sec XX



Exp.: 1932 a ...

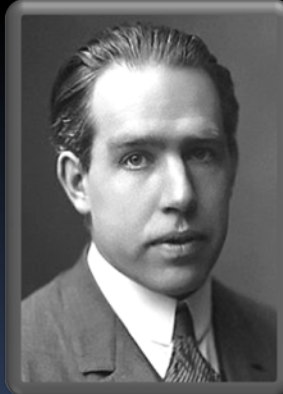
Teor.: 1920 a ...



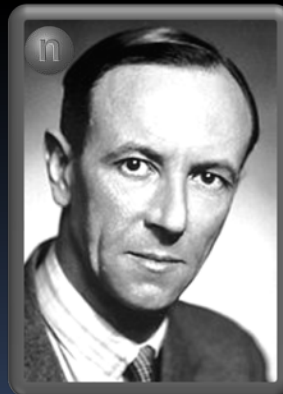
Thompson - 1898



Rutherford

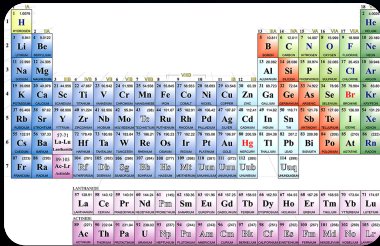


Bohr

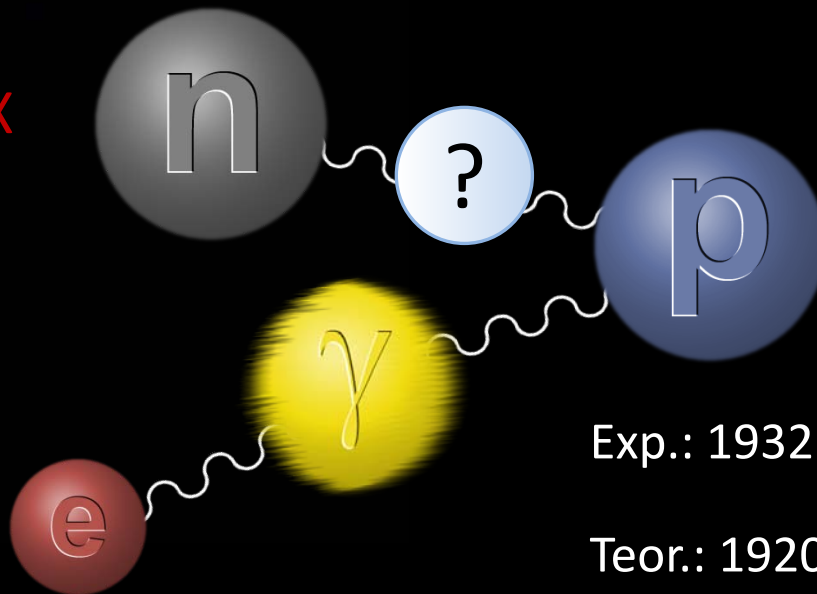


Chadwick - 1932

Partículas e mais partículas

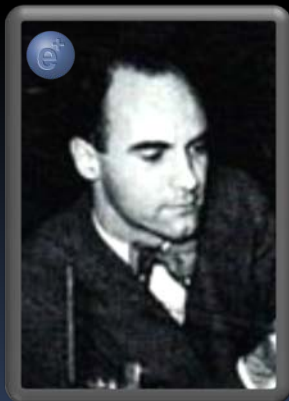


Sec XX



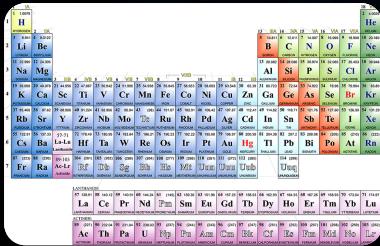
Exp.: 1932 a ...

Teor.: 1920 a ...

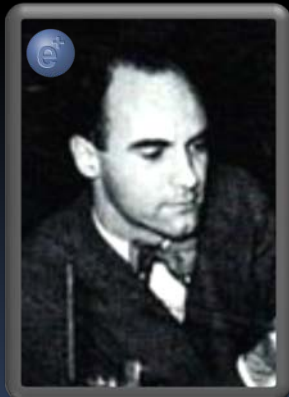
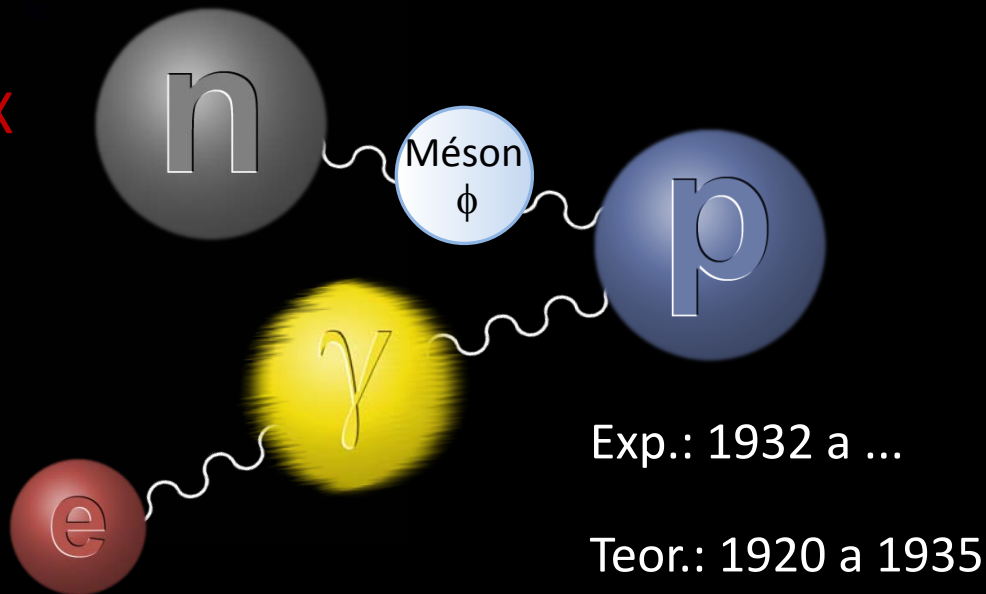


Anderson - 1932

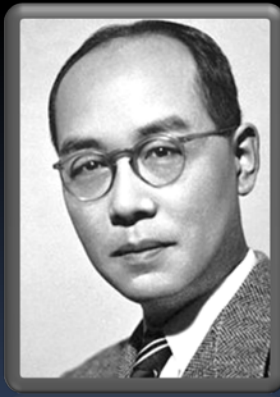
Partículas e mais partículas



Sec XX



Anderson - 1932

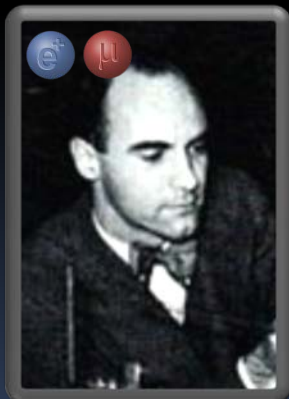
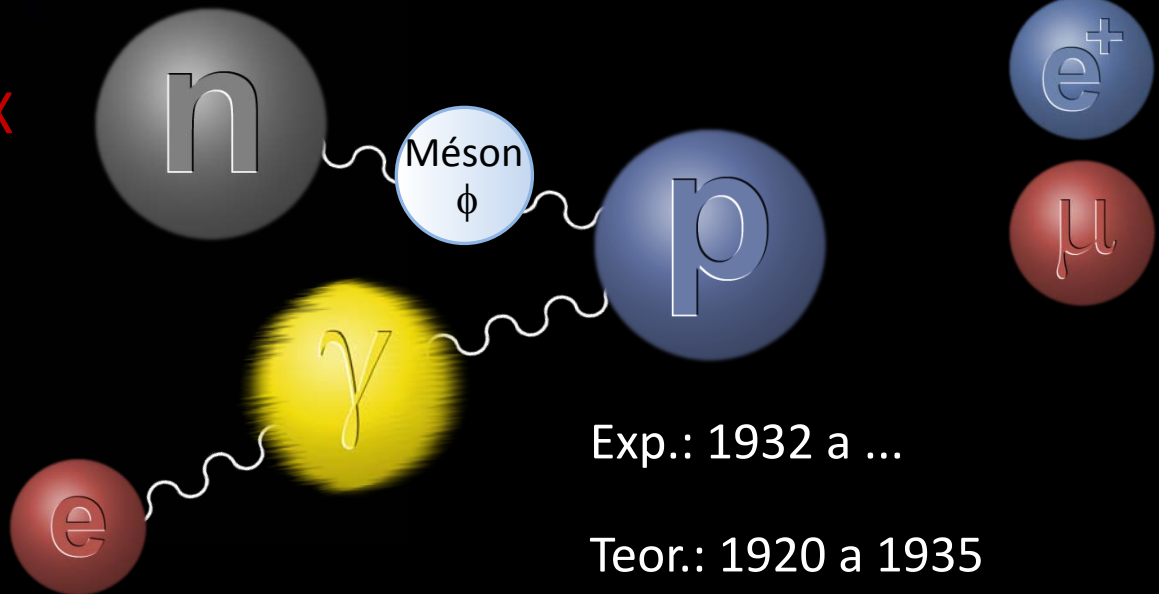


Yukawa - 1935

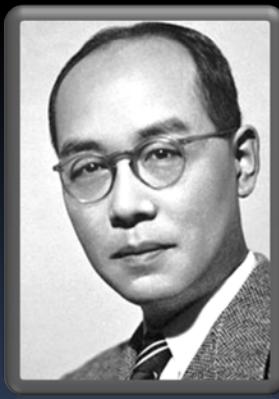
Massa do Méson: cerca de 100 MeV

Partículas e mais partículas

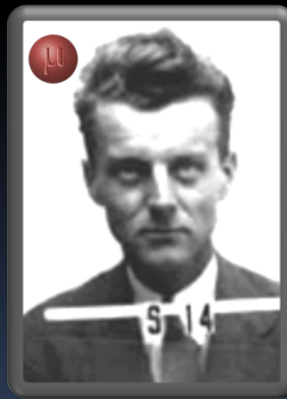
Sec XX



Anderson - 1932,
1936



Yukawa - 1935



Neddermeyer - 1936

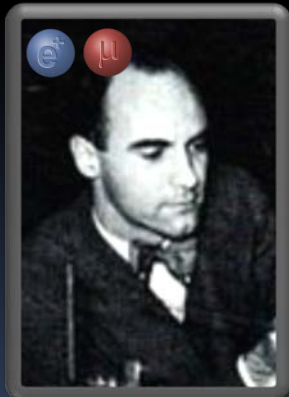
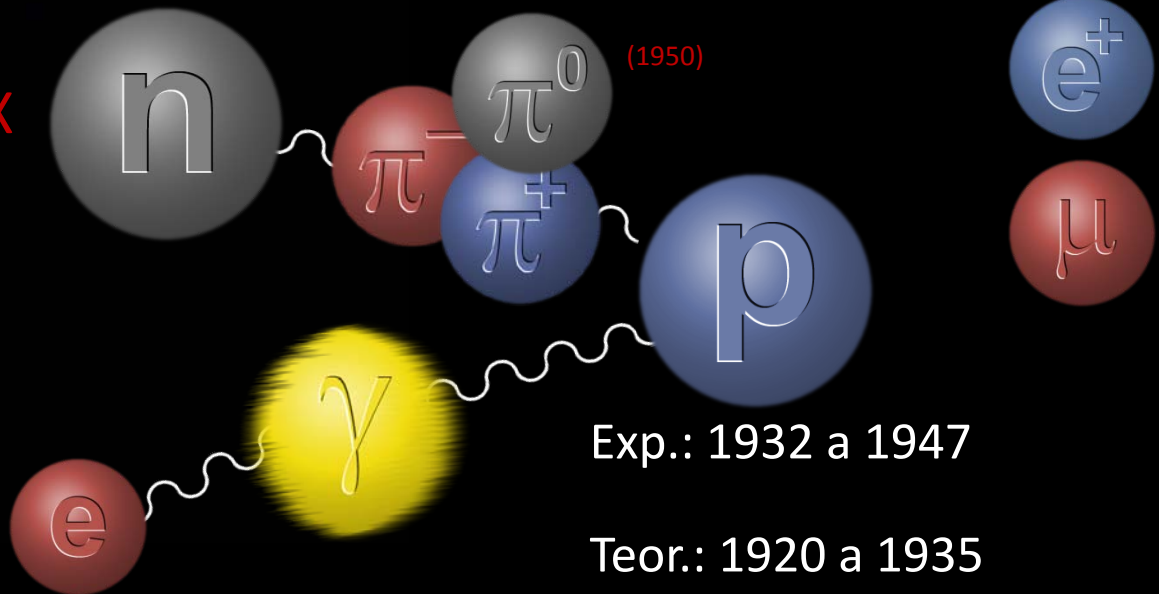
$$m_{\mu} = 105 \text{ MeV}$$

(foi confundido com o “méson” de Yukawa por algum tempo)

“Who ordered that?” – I.I. Rabi

Partículas e mais partículas

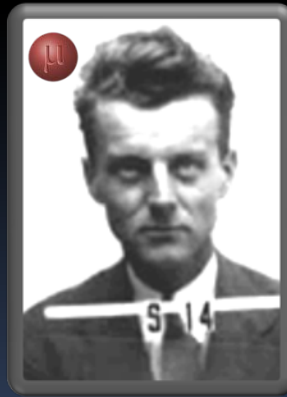
Sec XX



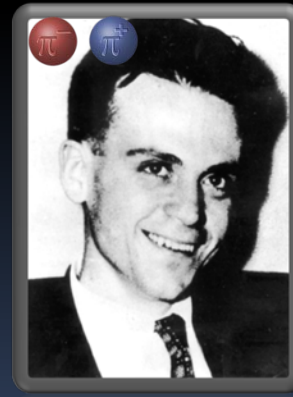
Anderson - 1932, 1936



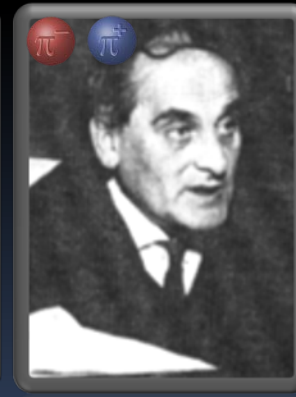
Yukawa - 1935



Neddermeyer - 1936



Lattes - 1947

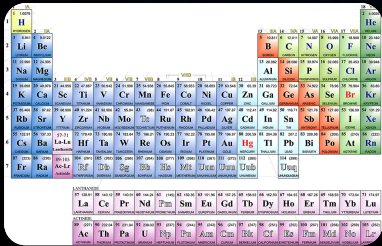


Occhialini - 1947

$$m_{\pi^+} = 140 \text{ MeV}$$

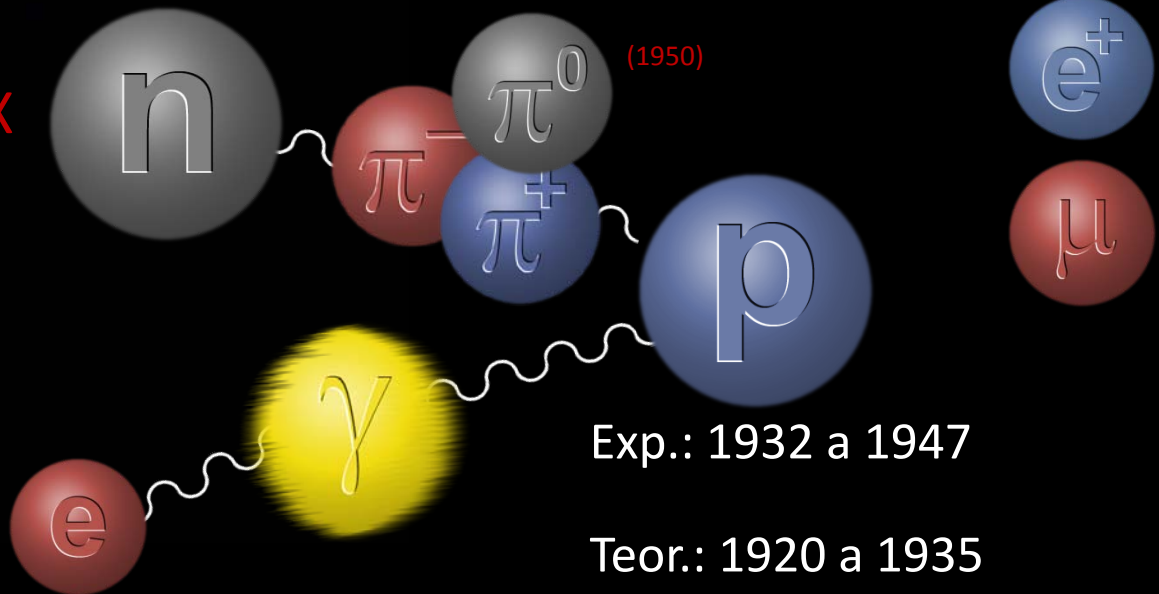
$$m_{\pi^0} = 135 \text{ MeV}$$

Partículas e mais partículas



A small image of the periodic table of elements, showing the standard layout with element symbols and names.

Sec XX



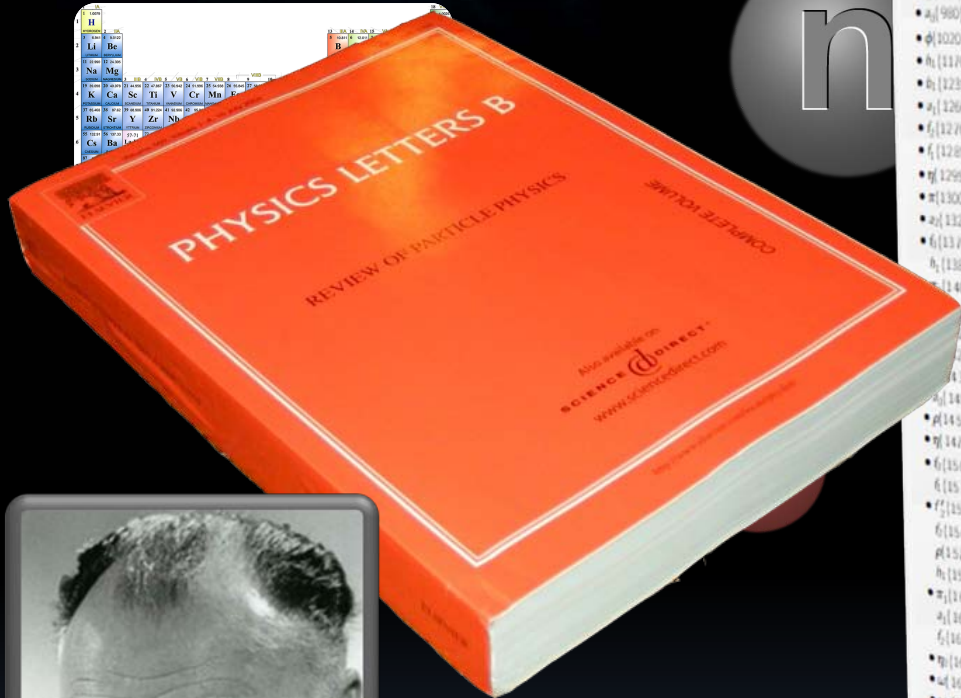
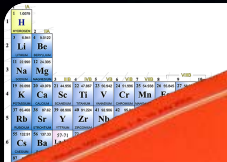
A simplicidade não durou...

1947: Kaon (~500 MeV)

1947: Λ^0 (~1.1 GeV)

> 90 partículas nos próximos 30 anos!

Partículas e m



"Had I foreseen that, I would have gone into botany" – W. Pauli

LEIGHT UNFLAVORED (S = C = B = 0)	STRANGE (S = ±1, C = B = 0)	UNFLAVORED, STRANGE (C = S = ±1)	CC $\bar{u}\bar{d}$ (J^{PC})	
π^{\pm} $1^{-}(0^{-})$ π^0 $1^{-}(0^{-})$ η $0^{+}(0^{-})$ $\rho(770)$ $1^{+}(0^{-})$ $\omega(782)$ $0^{-}(1^{-})$ $\eta(958)$ $0^{+}(0^{-})$ $\phi(1020)$ $0^{-}(1^{-})$ $\eta(1170)$ $0^{-}(1^{-})$ $\eta(1235)$ $1^{-}(1^{-})$ $\eta(1260)$ $1^{-}(1^{-})$ $\rho(1270)$ $0^{+}(2^{-})$ $\rho(1450)$ $0^{+}(1^{-})$ $\omega(1370)$ $0^{+}(0^{-})$ $\eta(1380)$ $0^{+}(1^{-})$ $\rho(1450)$ $0^{+}(1^{-})$ $\rho(1470)$ $0^{+}(1^{-})$ $\omega(1500)$ $0^{+}(0^{-})$ $\phi(1520)$ $0^{+}(1^{-})$ $\rho(1565)$ $0^{+}(2^{-})$ $\rho(1570)$ $1^{+}(1^{-})$ $\eta(1595)$ $0^{-}(1^{-})$ $\omega(1600)$ $1^{-}(1^{-})$ $\omega(1640)$ $1^{-}(1^{-})$ $\rho(1644)$ $0^{+}(2^{-})$ $\omega(1650)$ $0^{-}(1^{-})$ $\omega(1670)$ $0^{-}(1^{-})$	$\pi(1670)$ $1^{-}(2^{-})$ $\rho(1680)$ $0^{-}(1^{-})$ $\rho(1690)$ $1^{+}(3^{-})$ $\rho(1700)$ $1^{+}(1^{-})$ $\omega(1710)$ $0^{+}(0^{-})$ $\eta(1760)$ $0^{+}(0^{-})$ $\pi(1800)$ $1^{-}(0^{-})$ $\rho(1810)$ $0^{+}(2^{+})$ $X(1835)$ $?^{2}(2^{-})$ $\omega(1850)$ $0^{-}(3^{-})$ $\eta(1870)$ $0^{-}(2^{-})$ $\omega(1880)$ $1^{-}(2^{-})$ $\rho(1900)$ $1^{-}(1^{-})$ $\rho(1910)$ $0^{+}(2^{+})$ $\phi(1950)$ $0^{+}(2^{+})$ $\rho(1990)$ $1^{-}(1^{-})$ $\rho(2010)$ $0^{+}(2^{+})$ $\rho(2020)$ $0^{+}(0^{+})$ $\omega(2040)$ $1^{-}(4^{+})$ $\phi(2050)$ $0^{+}(4^{+})$ $\omega(2100)$ $1^{-}(2^{-})$ $\rho(2100)$ $0^{+}(0^{+})$ $\rho(2150)$ $0^{+}(2^{+})$ $\rho(2150)$ $1^{-}(1^{-})$ $\phi(2170)$ $0^{-}(3^{-})$ $\rho(2200)$ $0^{+}(0^{+})$ $\phi(2220)$ $0^{+}(2^{+})$ $\eta(2225)$ $0^{+}(0^{-})$ $\rho(2250)$ $1^{+}(3^{-})$ $\phi(2300)$ $0^{+}(2^{+})$ $\phi(2300)$ $0^{+}(4^{+})$ $\phi(2330)$ $0^{+}(0^{+})$ $\phi(2340)$ $0^{+}(2^{+})$ $\rho(2350)$ $1^{+}(5^{-})$ $\omega(2450)$ $1^{-}(6^{+})$ $\phi(2510)$ $0^{+}(6^{+})$	K^{\pm} $1/2(0^{-})$ K^0 $1/2(0^{-})$ K_S^0 $1/2(0^{-})$ K_L^0 $1/2(0^{-})$ $K_S^0(800)$ $1/2(0^{+})$ $K^*(892)$ $1/2(1^{-})$ $K_1(1270)$ $1/2(1^{+})$ $K_1(1400)$ $1/2(1^{+})$ $K^*(1410)$ $1/2(1^{-})$ $K_1^*(1430)$ $1/2(0^{+})$ $K_1^*(1430)$ $1/2(2^{+})$ $K(1460)$ $1/2(0^{-})$ $K_2(1580)$ $1/2(2^{+})$ $K(1630)$ $1/2(2^{+})$ $K_1(1650)$ $1/2(1^{+})$ $K^*(1680)$ $1/2(1^{-})$ $K^*(1770)$ $1/2(2^{-})$ $K^*(1780)$ $1/2(3^{-})$ $K_2^*(1820)$ $1/2(2^{-})$ $K(1830)$ $1/2(0^{-})$ $K_1^*(1950)$ $1/2(0^{+})$ $K_2^*(1980)$ $1/2(2^{+})$ $K_2^*(2045)$ $1/2(4^{+})$ $K_2(2250)$ $1/2(2^{-})$ $K_2^*(2320)$ $1/2(3^{+})$ $K_1^*(2380)$ $1/2(1^{-})$ $K_4(2500)$ $1/2(4^{-})$ $K(3100)$ $?^{2}(?^{2})$	D_s^{\pm} $0(0^{-})$ D_s^0 $0(0^{+})$ $D_{s1}^{\pm}(2317)^{\pm}$ $0(0^{+})$ $D_{s1}^{\pm}(2460)^{\pm}$ $0(1^{+})$ $D_{s1}^{\pm}(2536)^{\pm}$ $0(1^{+})$ $D_{s1}^{\pm}(2573)$ $0(?)^?$ $D_{s1}^{\pm}(2700)^{\pm}$ $0(1^{+})$ $D_{s2}^{\pm}(2860)^{\pm}$ $0(?)^?$ $D_{s2}^{\pm}(3040)^{\pm}$ $0(?)^?$ BOTTOM (B = ±1) B^{\pm} $1/2(0^{-})$ B^0 $1/2(0^{-})$ B^{\pm}/B^0 ADMIXTURE $B_s^{\pm}/B_s^0/B_s^{\pm}/b$ baryon ADMIXTURE V_{cb} and V_{ub} CKM Matrix Elements B^* $1/2(1^{-})$ $B_1^*(5732)$ $?(?)^?$ $B_1^*(5721)^0$ $1/2(1^{+})$ $B_2^*(5747)^0$ $1/2(2^{+})$ BOTTOM, STRANGE (B = ±1, S = ∓1) B_c^+ $0(0^{-})$ B_c^0 $0(1^{-})$ $B_{c1}^+(5830)^0$ $0(1^{+})$ $B_{c1}^{*0}(5840)^0$ $0(2^{-})$ $B_{c1}^{*+}(5850)$ $?(?)^?$ CHARMED (C = ±1) D^{\pm} $1/2(0^{-})$ D^0 $1/2(0^{-})$ $D^*(2007)^0$ $1/2(1^{-})$ $D^*(2010)^{\pm}$ $1/2(1^{-})$ $D^*(2400)^{\pm}$ $1/2(0^{+})$ $D_{s1}^{\pm}(2400)^{\pm}$ $1/2(0^{+})$ $D_1(2420)^0$ $1/2(1^{+})$ $D_1(2420)^{\pm}$ $1/2(2^{+})$ $D_1(2430)^0$ $1/2(1^{+})$ $D_1^*(2460)^0$ $1/2(2^{+})$ $D_1^*(2460)^{\pm}$ $1/2(2^{+})$	$\eta_c(1S)$ $0^{+}(0^{-})$ $J/\psi(1S)$ $0^{-}(1^{-})$ $\chi_{c0}(1P)$ $0^{+}(0^{+})$ $\chi_{c1}(1P)$ $0^{+}(1^{+})$ $\eta_c(1P)$ $?^2(1^{+})$ $\chi_{c2}(1P)$ $0^{+}(2^{+})$ $\eta_c(2S)$ $0^{+}(0^{-})$ $\psi(2S)$ $0^{-}(1^{-})$ $\psi(3770)$ $0^{-}(1^{-})$ $X(3872)$ $0^2(?)^2$ $X(3915)$ $0^{+}(2^{+})$ $\chi_{c2}(2P)$ $0^{+}(2^{+})$ $X(3940)$ $?^2(?)^2$ $\psi(4040)$ $0^{-}(1^{-})$ $X(4050)^{\pm}$ $?(?)^?$ $X(4140)$ $0^{+}(?^2)$ $\psi(4160)$ $0^{-}(1^{-})$ $X(4360)$ $?^2(?)^2$ $X(4250)^{\pm}$ $?(?)^?$ $X(4260)$ $?^2(1^{-})$ $X(4350)$ $0^{+}(2^{+})$ $X(4360)$ $?^2(1^{-})$ $\psi(4415)$ $0^{-}(1^{-})$ $X(4430)^{\pm}$ $?(?)^?$ $X(4460)$ $?^2(1^{-})$ $\bar{u}\bar{d}$ $\eta(1S)$ $0^{+}(0^{-})$ $T(1S)$ $0^{-}(1^{-})$ $\chi_{b0}(1P)$ $0^{+}(0^{+})$ $\chi_{b1}(1P)$ $0^{+}(1^{+})$ $\eta_b(1P)$ $?^2(1^{+})$ $\chi_{b2}(1P)$ $0^{+}(2^{+})$ $T(2S)$ $0^{-}(1^{-})$ $T(1D)$ $0^{-}(2^{-})$ $\chi_{b0}(2P)$ $0^{+}(0^{+})$ $\chi_{b1}(2P)$ $0^{+}(1^{+})$ $\eta_b(2P)$ $?^2(1^{+})$ $\chi_{b2}(2P)$ $0^{+}(2^{+})$ $T(3S)$ $0^{-}(1^{-})$ $\chi_b(3P)$ $?^2(?)^2$ $T(4S)$ $0^{-}(1^{-})$ $X(10610)^{\pm}$ $?^2(1^{+})$ $X(10650)^{\pm}$ $?^2(1^{+})$ $T(10860)$ $0^{-}(1^{-})$ $T(11020)$ $0^{-}(1^{-})$

Os Hádrons e a QCD

A situação era bem complicada no setor dos **hadrons**: as partículas que interagem fortemente.

Hádrons



Léptons



Os Hádrons e a QCD

p

PROTON
massa: 938 MeV

spin- $\frac{1}{2}$
Q = +1
S = 0

descoberta: 1919

K^+

KAON (K PLUS)
massa: 494 MeV

spin-0
Q = +1
S = +1

descoberta: 1947

Ξ^-

XI MINUS
massa: 1322 MeV

spin- $\frac{1}{2}$
Q = -1
S = -2

descoberta: 1952

Δ^{++}

DELTA DOUBLE PLUS
massa: 1231 MeV

spin- $\frac{3}{2}$
Q = +2
S = 0

descoberta: 1954

Σ^{*0}

SIGMA STAR ZERO
massa: 1384 MeV

spin- $\frac{3}{2}$
Q = 0
S = -1

descoberta: 1960

n

NEUTRON
massa: 940 MeV

spin- $\frac{1}{2}$
Q = 0
S = 0

descoberta: 1932

π^-

PION (PI MINUS)
massa: 140 MeV

spin-0
Q = -1
S = 0

descoberta: 1947

Σ^+

SIGMA PLUS
massa: 1189 MeV

spin- $\frac{1}{2}$
Q = +1
S = -1

descoberta: 1953

Δ^+

DELTA PLUS
massa: 1235 MeV

spin- $\frac{3}{2}$
Q = +1
S = 0

descoberta: 1954

Σ^{*+}

SIGMA STAR PLUS
massa: 1383 MeV

spin- $\frac{3}{2}$
Q = +1
S = -1

descoberta: 1960

π^+

PION (PI PLUS)
massa: 140 MeV

spin-0
Q = +1
S = 0

descoberta: 1947

\bar{K}^0

KAON (KBAR ZERO)
massa: 498 MeV

spin-0
Q = 0
S = -1

descoberta: 1947

Σ^-

SIGMA MINUS
massa: 1197 MeV

spin- $\frac{1}{2}$
Q = -1
S = -1

descoberta: 1953

Σ^0

SIGMA ZERO
massa: 1193 MeV

spin- $\frac{1}{2}$
Q = 0
S = -1

descoberta: 1956

η

ETA
massa: 548 MeV

spin-0
Q = 0
S = 0

descoberta: 1961

K^-

KAON (K MINUS)
massa: 494 MeV

spin-0
Q = -1
S = -1

descoberta: 1947

π^0

PION (PI ZERO)
massa: 135 MeV

spin-0
Q = 0
S = 0

descoberta: 1949

Δ^-

DELTA MINUS
massa: 1232 MeV

spin- $\frac{3}{2}$
Q = -1
S = 0

descoberta: 1954

Ξ^0

XI ZERO
massa: 1315 MeV

spin- $\frac{1}{2}$
Q = 0
S = -2

descoberta: 1959

Ξ^{*-}

XI STAR MINUS
massa: 1535 MeV

spin- $\frac{3}{2}$
Q = -1
S = -2

descoberta: 1962

K^0

KAON (K ZERO)
massa: 498 MeV

spin-0
Q = 0
S = +1

descoberta: 1947

Λ

LAMBDA
massa: 1116 MeV

spin- $\frac{1}{2}$
Q = 0
S = -1

descoberta: 1951

Δ^0

DELTA ZERO
massa: 1231 MeV

spin- $\frac{3}{2}$
Q = 0
S = 0

descoberta: 1954

Σ^{*-}

SIGMA STAR MINUS
massa: 1387 MeV

spin- $\frac{3}{2}$
Q = -1
S = -1

descoberta: 1960

Ξ^{*0}

XI STAR ZERO
massa: 1532 MeV

spin- $\frac{3}{2}$
Q = 0
S = -2

descoberta: 1962