Aventuras em Física Teórica

Introdução à Física de Partículas

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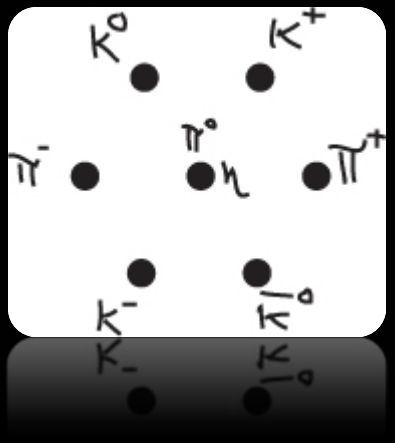
Os Hádrons e a QCD

p **PROTON** **massa:** 938 MeV spin-½ 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-½ Q = -1 S = -2 **descoberta:** 1952	Δ^{++} **DELTA DOUBLE PLUS** **massa:** 1231 MeV spin-3/2 Q = +2 S = 0 **descoberta:** 1954	Σ^{*0} **SIGMA STAR ZERO** **massa:** 1384 MeV spin-3/2 Q = 0 S = -1 **descoberta:** 1960
n **NEUTRON** **massa:** 940 MeV spin-½ 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-½ Q = +1 S = -1 **descoberta:** 1953	Δ^+ **DELTA PLUS** **massa:** 1235 MeV spin-3/2 Q = +1 S = 0 **descoberta:** 1954	Σ^{*+} **SIGMA STAR PLUS** **massa:** 1383 MeV spin-3/2 Q = +1 S = -1 **descoberta:** 1960
π^+ **PION (PI PLUS)** **massa:** 140 MeV spin-0 Q = +1 S = 0 **descoberta:** 1947	$\overline{K}^0$ **KAON (KBAR ZERO)** **massa:** 498 MeV spin-0 Q = 0 S = -1 **descoberta:** 1947	Σ^- **SIGMA MINUS** **massa:** 1197 MeV spin-½ Q = -1 S = -1 **descoberta:** 1953	Σ^0 **SIGMA ZERO** **massa:** 1193 MeV spin-½ 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-3/2 Q = -1 S = 0 **descoberta**: 1954	Ξ^0 **XI ZERO** **massa:** 1315 MeV spin-½ Q = 0 S = -2 **descoberta:** 1959	Ξ^{*-} **XI STAR MINUS** **massa:** 1535 MeV spin-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-½ Q = 0 S = -1 **descoberta:** 1951	Δ^0 **DELTA ZERO** **massa:** 1231 MeV spin-3/2 Q = 0 S = 0 **descoberta:** 1954	Σ^{*-} **SIGMA STAR MINUS** **massa:** 1387 MeV spin-3/2 Q = -1 S = -1 **descoberta:** 1960	Ξ^{*0} **XI STAR ZERO** **massa:** 1532 MeV spin-3/2 Q = 0 S = -2 **descoberta:** 1962

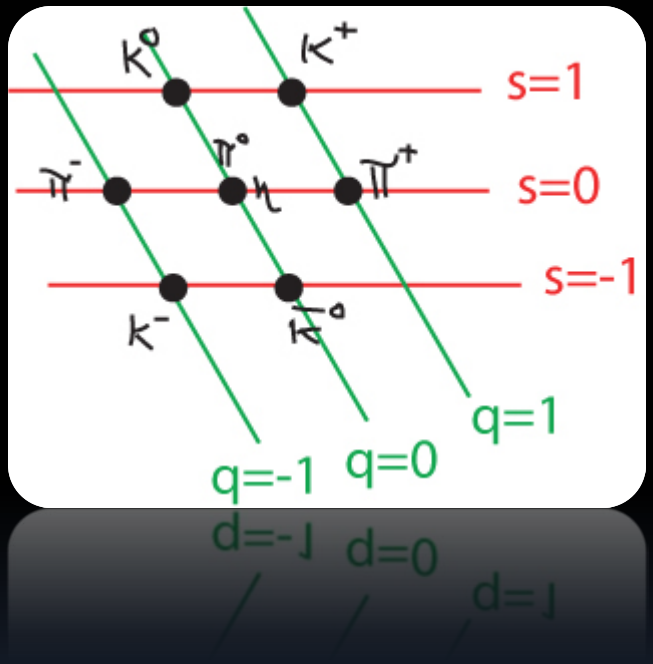
Os Hádrons e a QCD

Multipletos (octeto de mésons, spin 0):



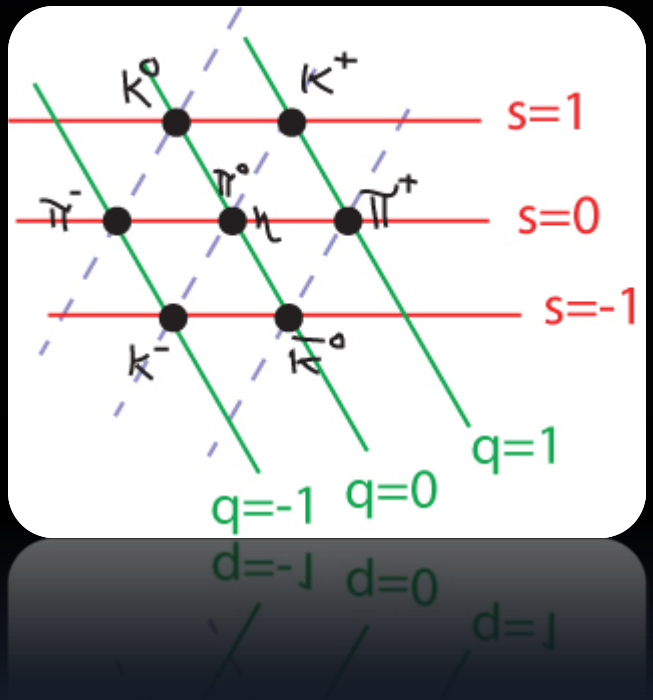
Os Hádrons e a QCD

Multipletos (octeto de mésons, spin 0):



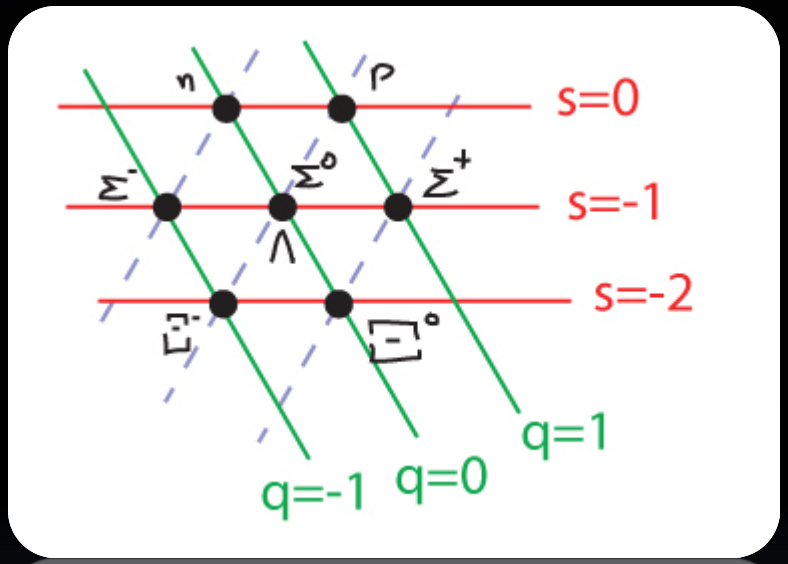
Os Hádrons e a QCD

Multipletos (octeto de mésons, spin 0):



Os Hádrons e a QCD

Multipletos (octeto de bárions, spin ½):



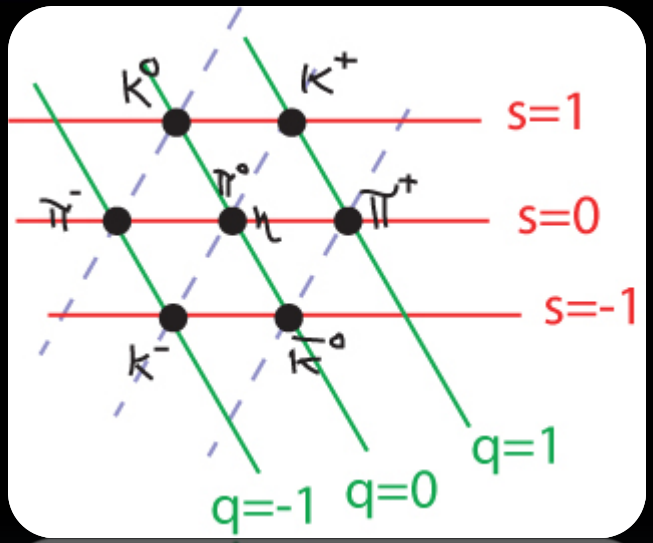
~ 940 MeV

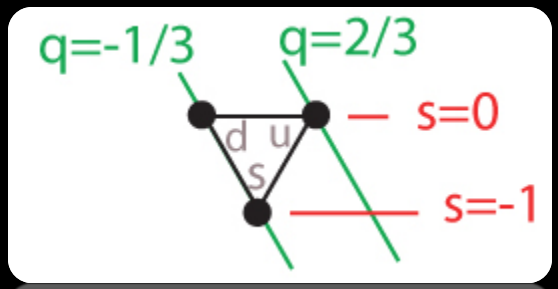
~ 1200 MeV

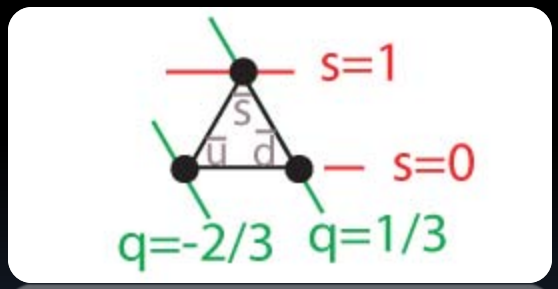
~ 1320 MeV

Os Hádrons e a QCD

Multipletos (octeto de mésons, spin 0):







Os Hádrons e a QCD

Multipletos (octeto de mésons, spin 0):

$q\bar{q}$	$u\bar{u}$	$u\bar{d}$	$u\bar{s}$	$d\bar{u}$	$d\bar{d}$	$d\bar{s}$	$s\bar{u}$	$s\bar{d}$	$s\bar{s}$
Q	0	+1	+1	-1	0	0	-1	0	0
S	0	0	+1	0	0	+1	-1	-1	0
Sím-bolo da partícula	η, π^0	π^+	K^+	π^-	η, π^0	K^0	K^-	$\bar{K}^0$	η

Os Hádrons e a QCD

Multipletos (octeto de mésons, spin 0):

$q\bar{q}$	$u\bar{u}$	$u\bar{d}$	$u\bar{s}$	$d\bar{u}$	$d\bar{d}$	$d\bar{s}$	$s\bar{u}$	$s\bar{d}$	$s\bar{s}$
Q	0	+1	+1	-1	0	0	-1	0	0
S	0	0	+1	0	0	+1	-1	-1	0
Sím-bolo da partícula	η, π^0	π^+	K^+	π^-	η, π^0	K^0	K^-	$\bar{K}^0$	η

Combinação de $u\bar{u}$ e $d\bar{d}$

Os Hádrons e a QCD

Multipletos (octeto de mésons, spin 0):

$q\bar{q}$	$u\bar{u}$	$u\bar{d}$	$u\bar{s}$	$d\bar{u}$	$d\bar{d}$	$d\bar{s}$	$s\bar{u}$	$s\bar{d}$	$s\bar{s}$
Q	0	+1	+1	-1	0	0	-1	0	0
S	0	0	+1	0	0	+1	-1	-1	0
Símbolo da partícula	η, π^0	π^+	K^+	π^-	η, π^0	K^0	K^-	$\bar{K}^0$	η

Combinação de $u\bar{u}$ e $d\bar{d}$

Combinação de $u\bar{u}$, $d\bar{d}$ e $s\bar{s}$

η' é outra combinação!

Os Hádrons e a QCD

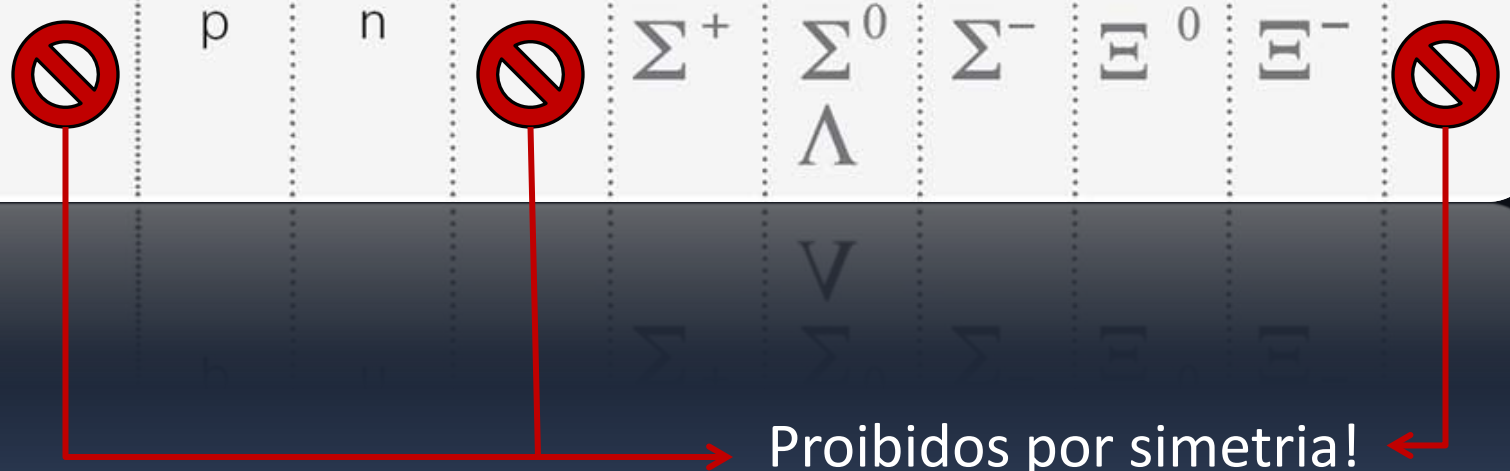
Multipletos (octeto de bárions, spin ½):

qqq	uuu	uud	udd	ddd	uus	uds	dds	uss	dss	sss
Q	+2	+1	0	-1	+1	0	-1	0	-1	-1
S	0	0	0	0	-1	-1	-1	-2	-2	-3
Bárions de spin-1/2		p	n		Σ^+	Σ^0 Λ	Σ^-	Ξ^0	Ξ^-	

Os Hádrons e a QCD

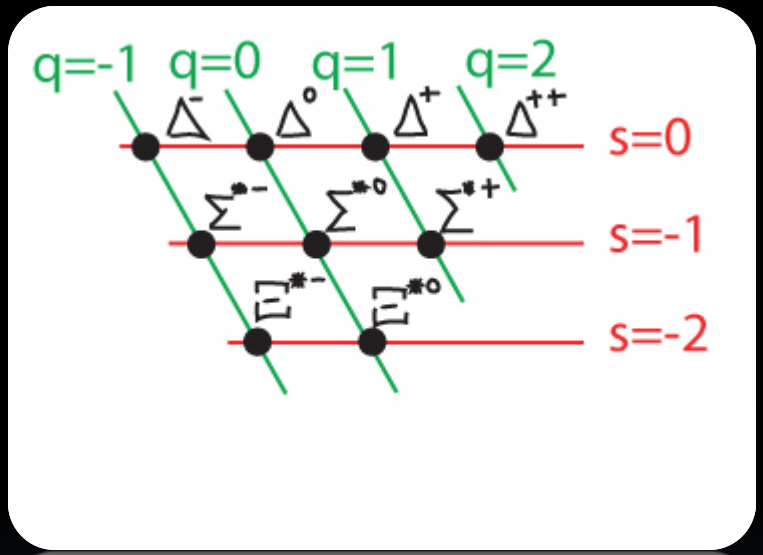
Multipletos (octeto de bárions, spin ½):

qqq	uuu	uud	udd	ddd	uus	uds	dds	uss	dss	sss
Q	+2	+1	0	-1	+1	0	-1	0	-1	-1
S	0	0	0	0	-1	-1	-1	-2	-2	-3
Bárions de spin-1/2		p	n		Σ^+	Σ^0 Λ	Σ^-	Ξ^0	Ξ^-	



Os Hádrons e a QCD

Multipletos (“quanto-pleto”? de bárions, spin 3/2):



~ 1230 MeV

~ 1380 MeV

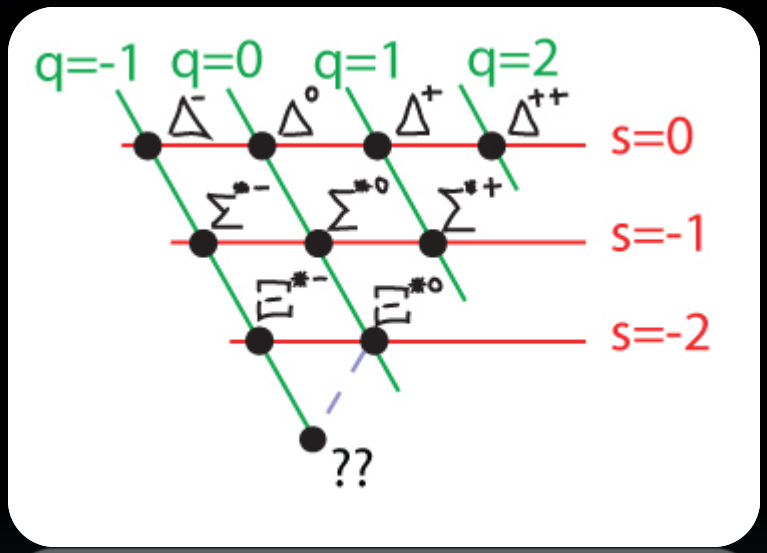
150 MeV

~ 1530 MeV

150 MeV

Os Hádrons e a QCD

Multipletos (“quanto-pleto”? de bárions, spin 3/2):



~ 1230 MeV

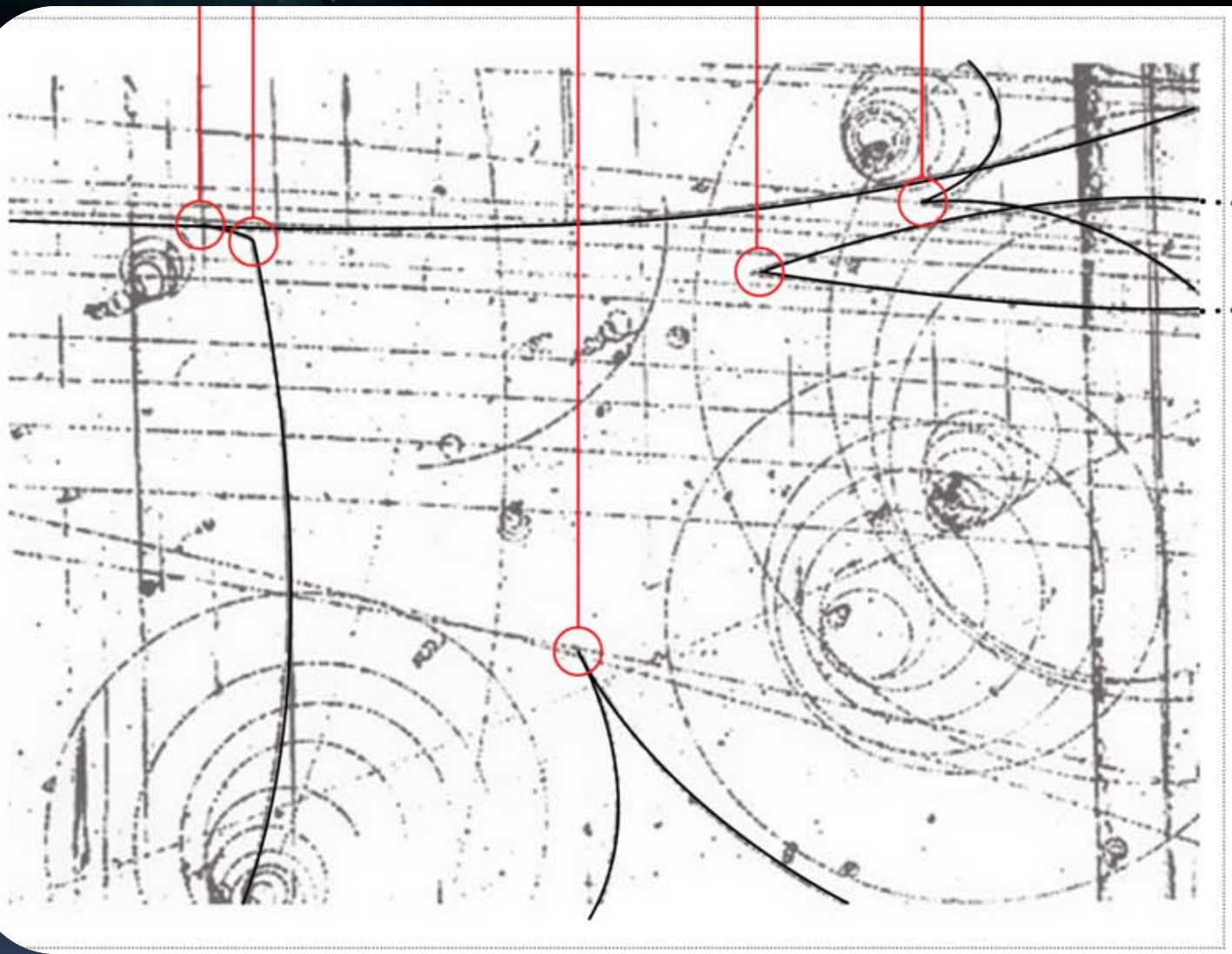
~ 1380 MeV

150 MeV

~ 1530 MeV

150 MeV

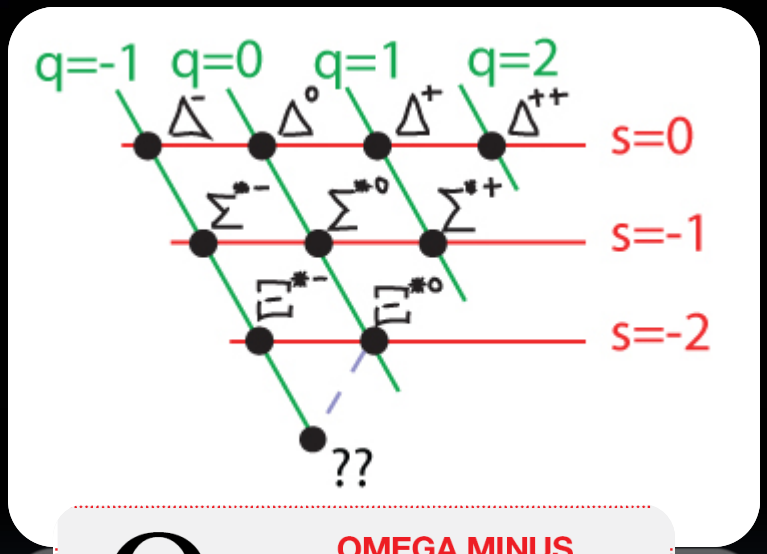
Os Hádrons e a QCD



Exercício:
ache o Ω

Os Hádrons e a QCD

Multipletos (decupleto de bárions, spin 3/2):



~ 1230 MeV

~ 1380 MeV — 150 MeV

~ 1530 MeV — 150 MeV

Ω^-

OMEGA MINUS

massa: 1672 MeV

spin-3/2

Q = -1

S = -3

descoberta: 1964

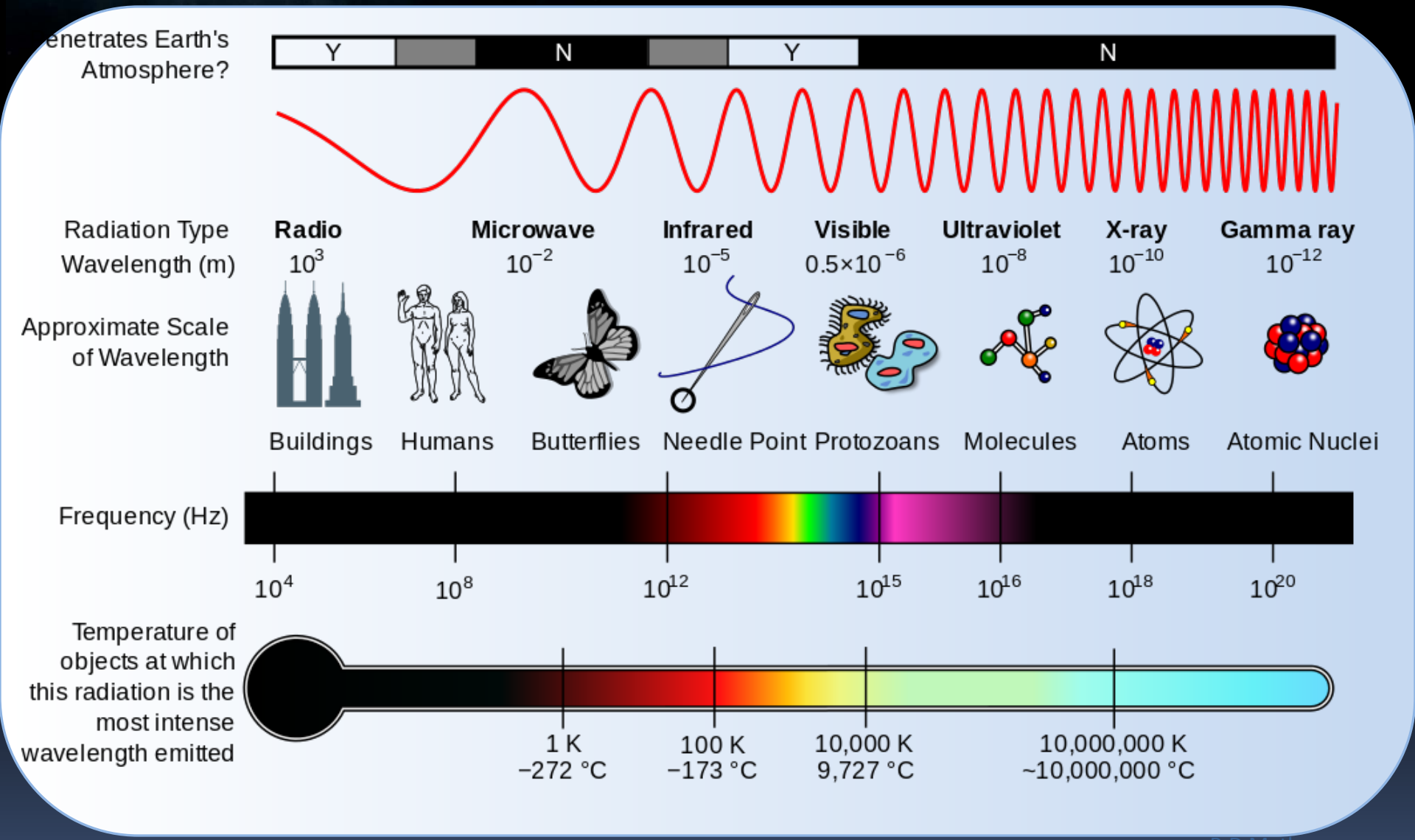
Murray Gell-Mann

Os Hádrons e a QCD

Multipletos (decupleto de bárions, spin 3/2):

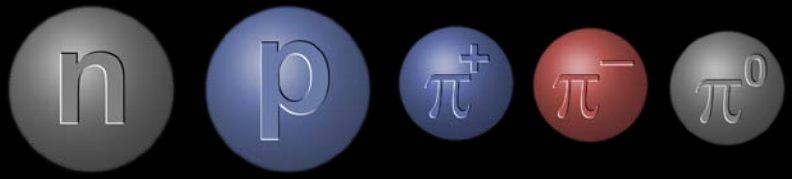
qqq	uuu	uud	udd	ddd	uus	uds	dds	uss	dss	sss
Q	+2	+1	0	-1	+1	0	-1	0	-1	-1
S	0	0	0	0	-1	-1	-1	-2	-2	-3
Bárions de spin-3/2	Δ^{++}	Δ^{+}	Δ^{0}	Δ^{-}	Σ^{*+}	Σ^{*0}	Σ^{*-}	Ξ^{*0}	Ξ^{*-}	Ω^{-}
Bárions de spin-1/2		p	n		Σ^{+}	Σ^{0} Λ	Σ^{-}	Ξ^{0}	Ξ^{-}	

Os Hádrons e a QCD



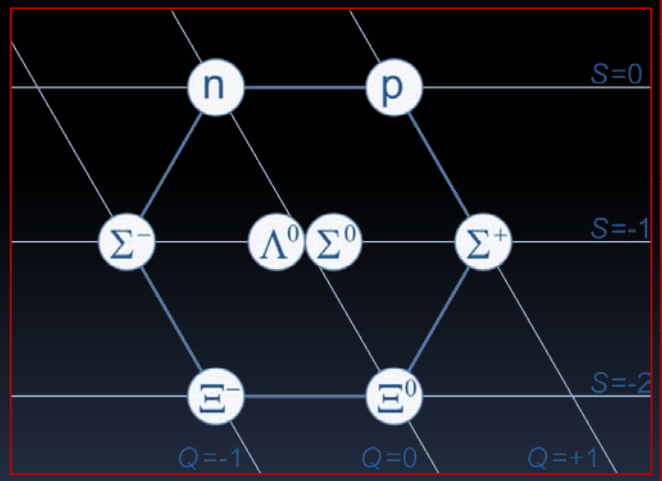
Os Hádrons e a QCD

A situação era bem complicada no setor dos hadrons: as partículas que interagiam fortemente:



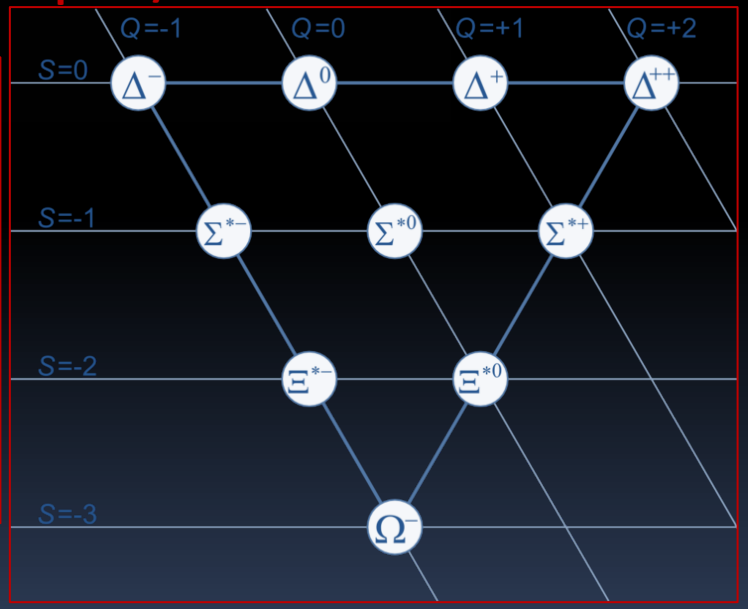
Um padrão foi lentamente emergindo:

Spin ½



Estranheza S

Spin 3/2

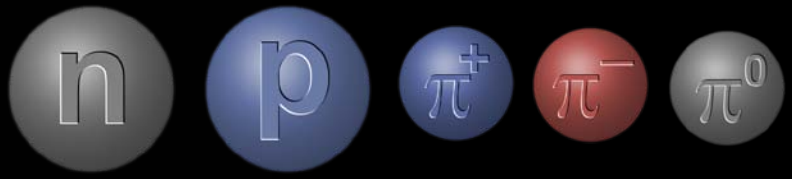


Nishijima

Gell-Mann

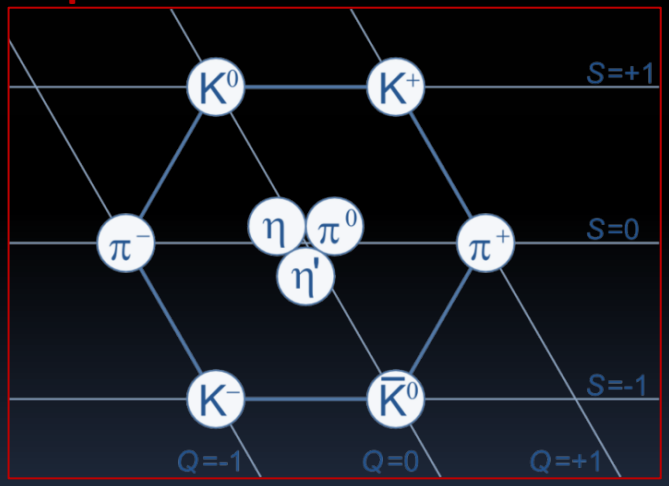
Os Hádrons e a QCD

A situação era bem complicada no setor dos hadrons: as partículas que interagiam fortemente:

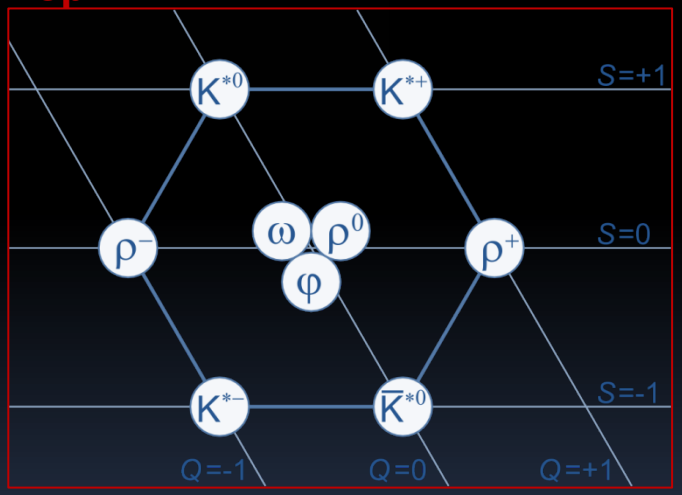


Um padrão foi lentamente emergindo:

Spin 0



Spin 1



Estranheza S

Nishijima

Gell-Mann

Os Hádrons e a QCD

"Three quarks for Muster Mark!"

Q = 2/3 **u** up

Q = -1/3 **d** down **s** strange

Zweig

Os Hádrons e a QCD

"*Three* quarks for Muster Mark!"

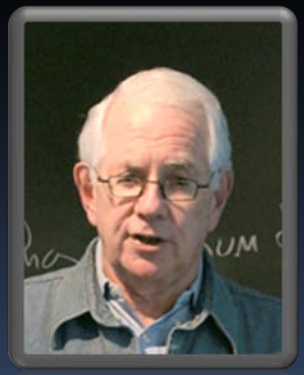
Q = 2/3	u up	c charm
Q = -1/3	d down	s strange

Zweig

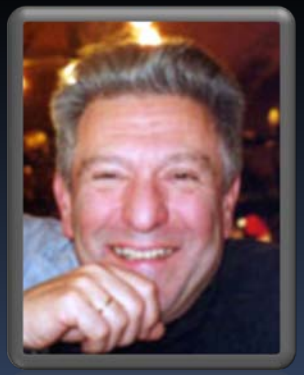
Mecanismo GIM

u,d,s,c - Sabores

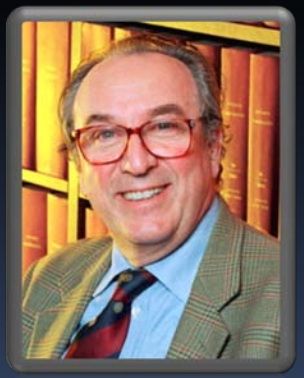
Glashow



Iliopoulos



Maiani



Os Hádrons e a QCD

Spin 3/2

S = 0

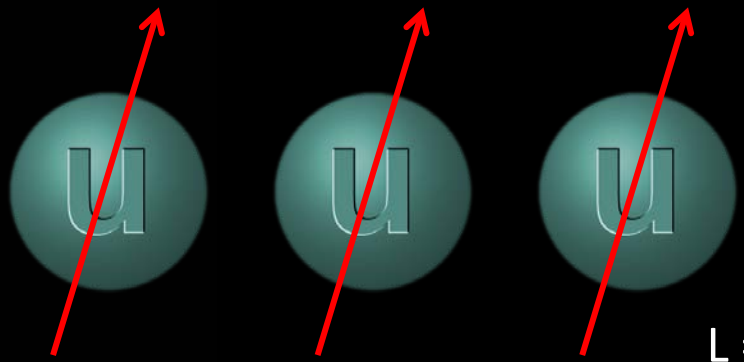
Q = 2

Os Hádrons e a QCD

Spin 3/2

S = 0

Q = 2



1/2 1/2 1/2

L = 0
(estado fundamental)

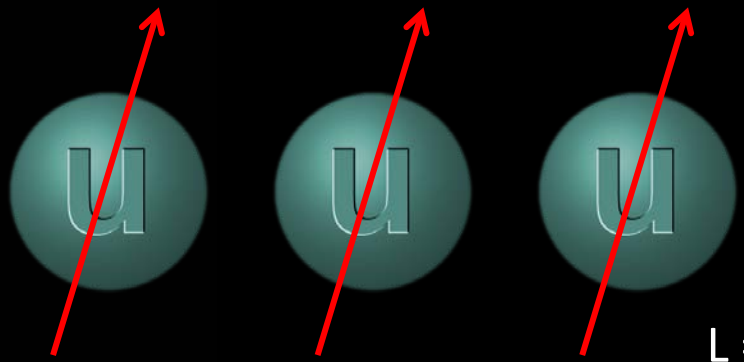
Problema de estatística

Os Hádrons e a QCD

Spin 3/2

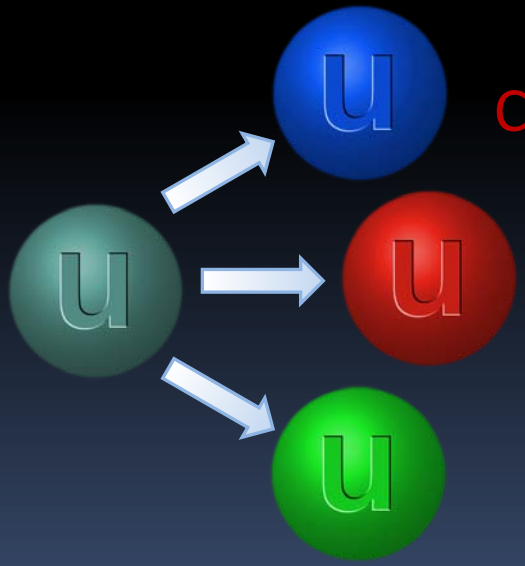
S = 0

Q = 2



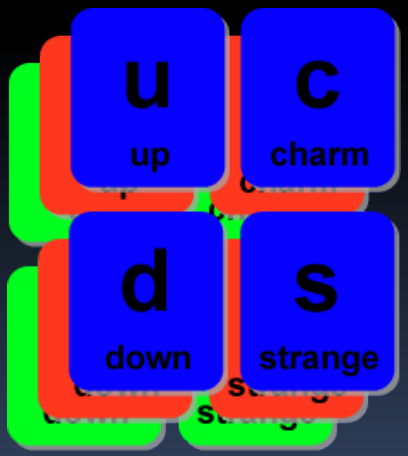
L = 0
(estado fundamental)

Problema de estatística



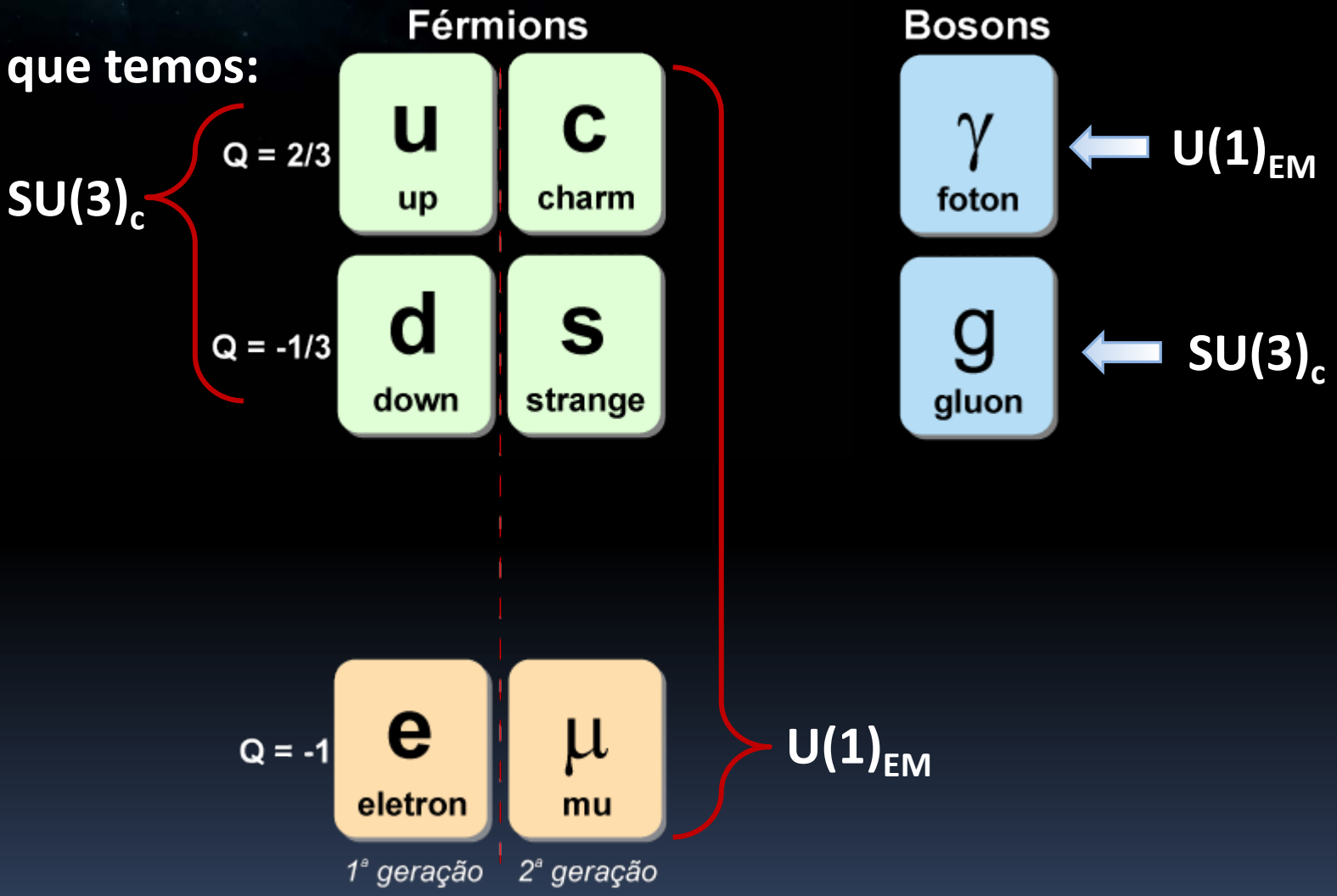
Cor

$$q = \begin{pmatrix} q_R \\ q_G \\ q_B \end{pmatrix}$$

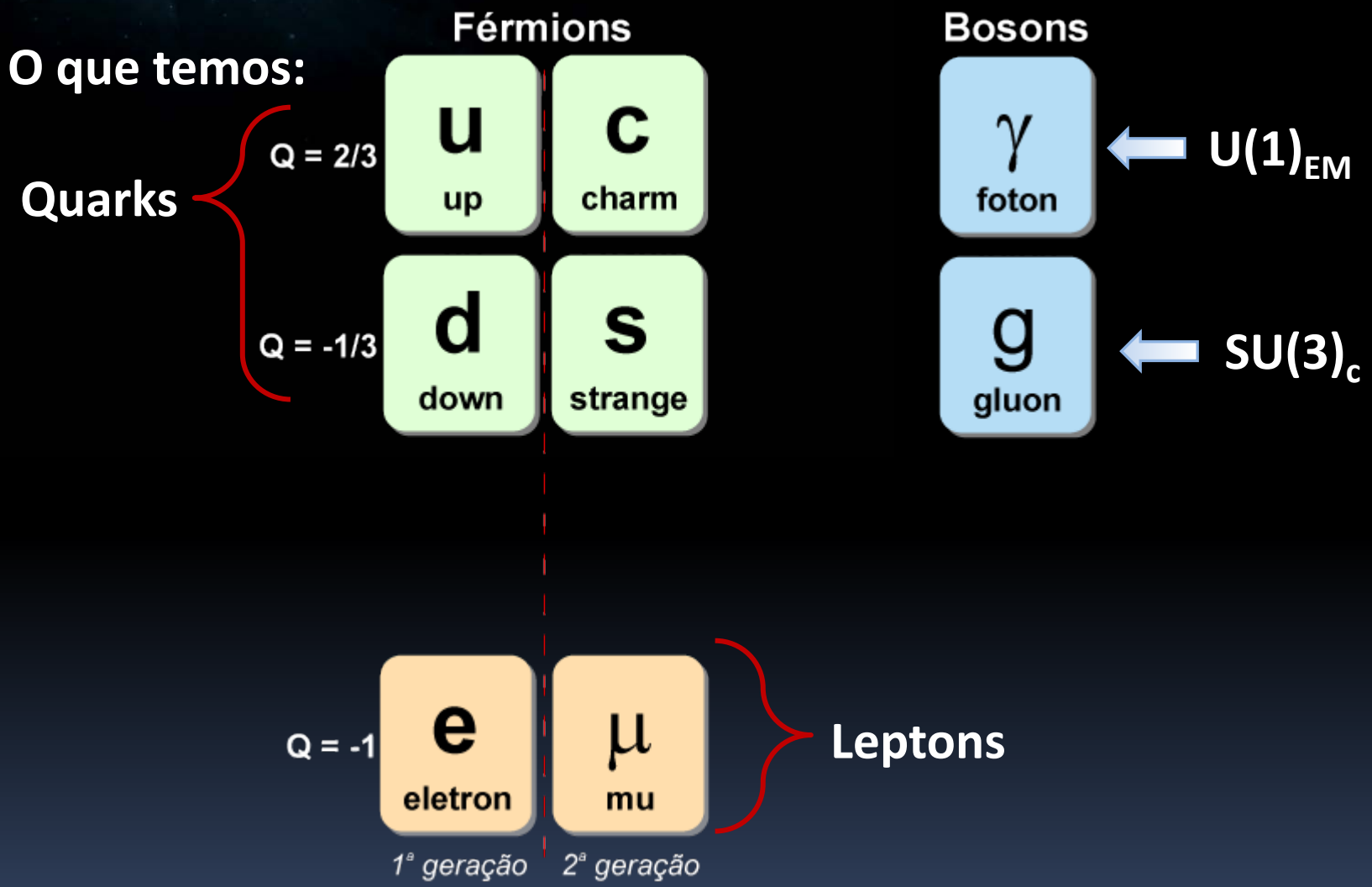


Construindo o Modelo Padrão da Física de Partículas

O que temos:

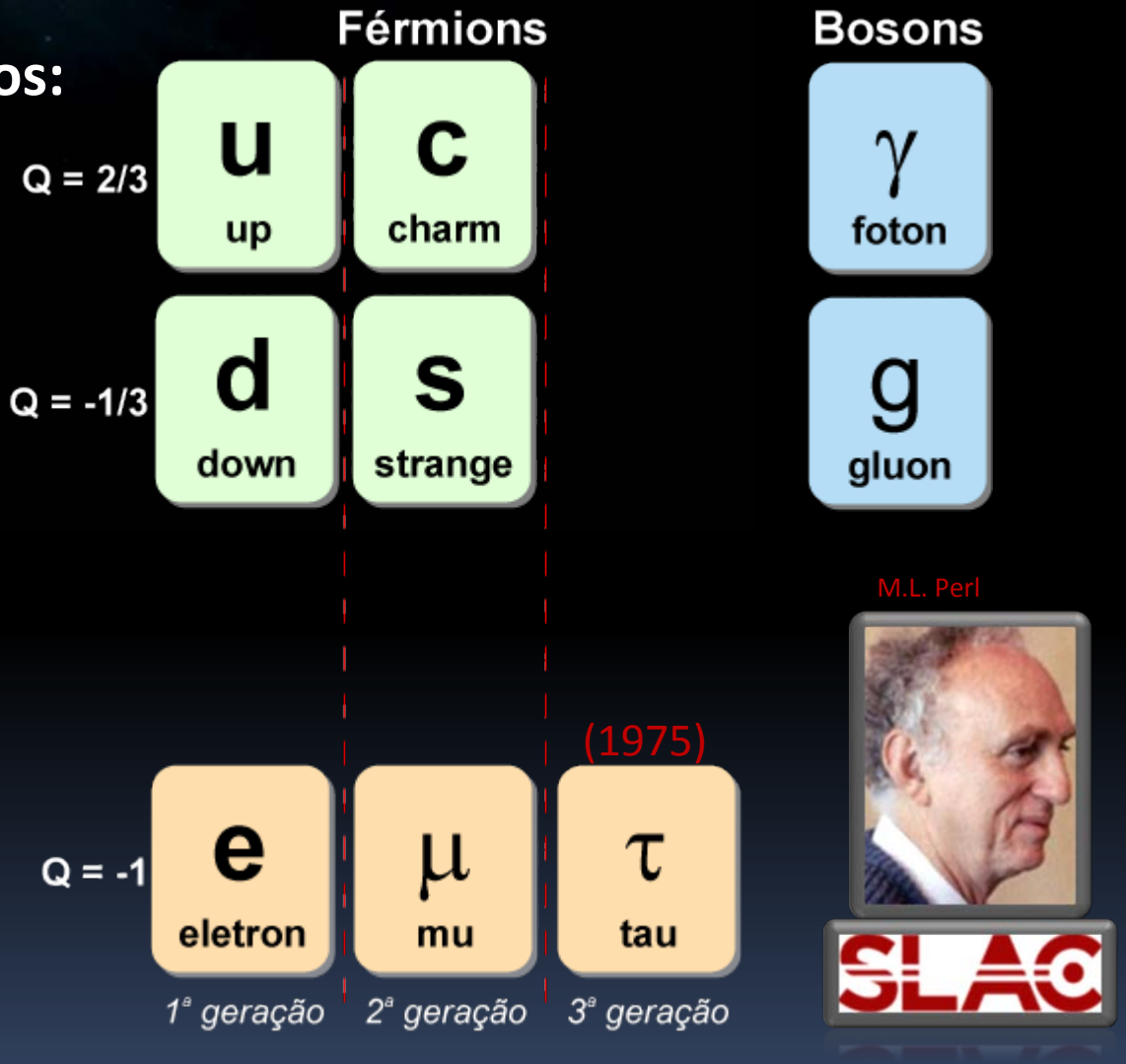


Construindo o Modelo Padrão da Física de Partículas



Construindo o Modelo Padrão da Física de Partículas

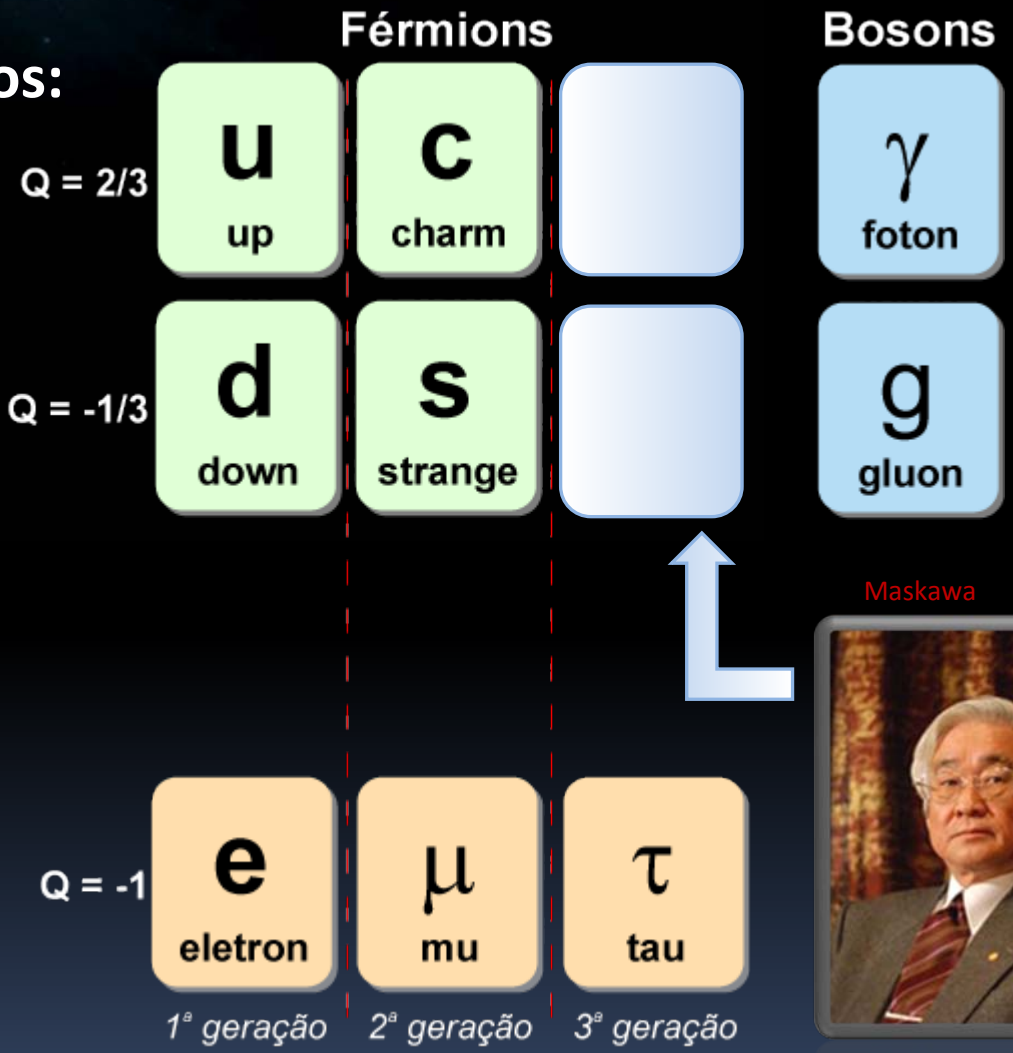
O que temos:



M.L. Perl

Construindo o Modelo Padrão da Física de Partículas

O que temos:



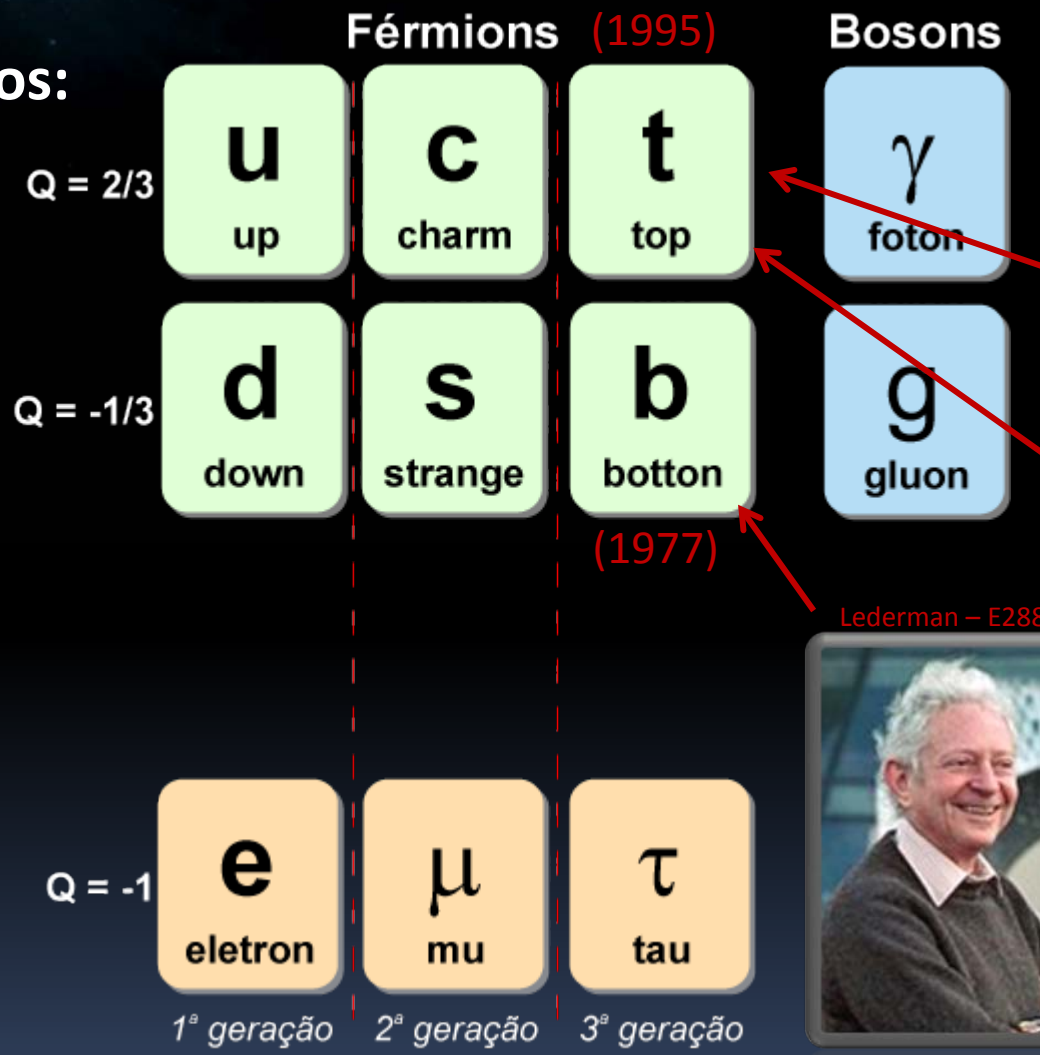
Maskawa

Kobayashi

Violação de CP

Construindo o Modelo Padrão da Física de Partículas

O que temos:



Fermilab

CDF

DØ

Lederman – E288

O (parcialmente) culpado por ouvirmos tanto "partículo de deus"

R.D.Matheus