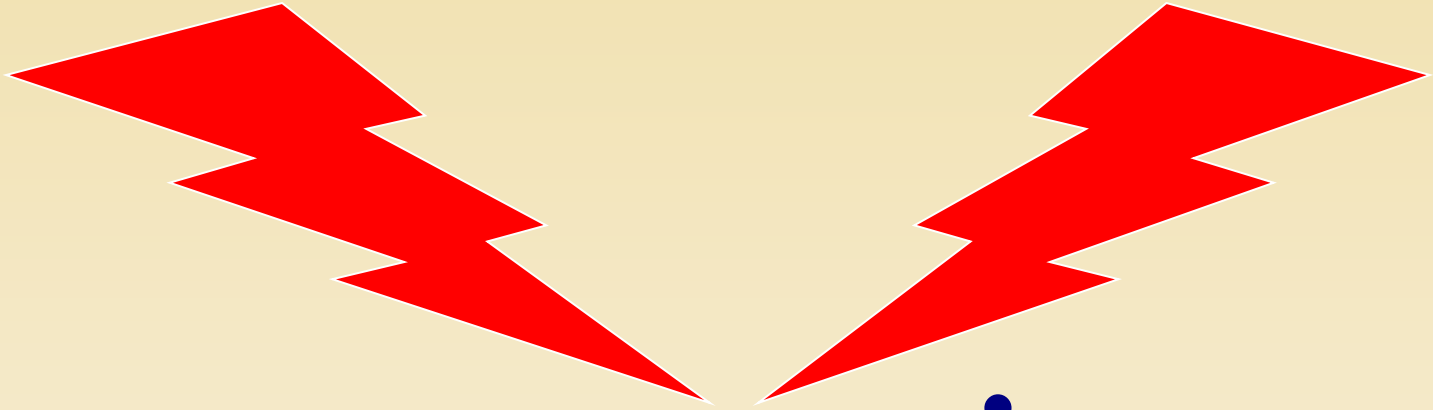
weak bosons

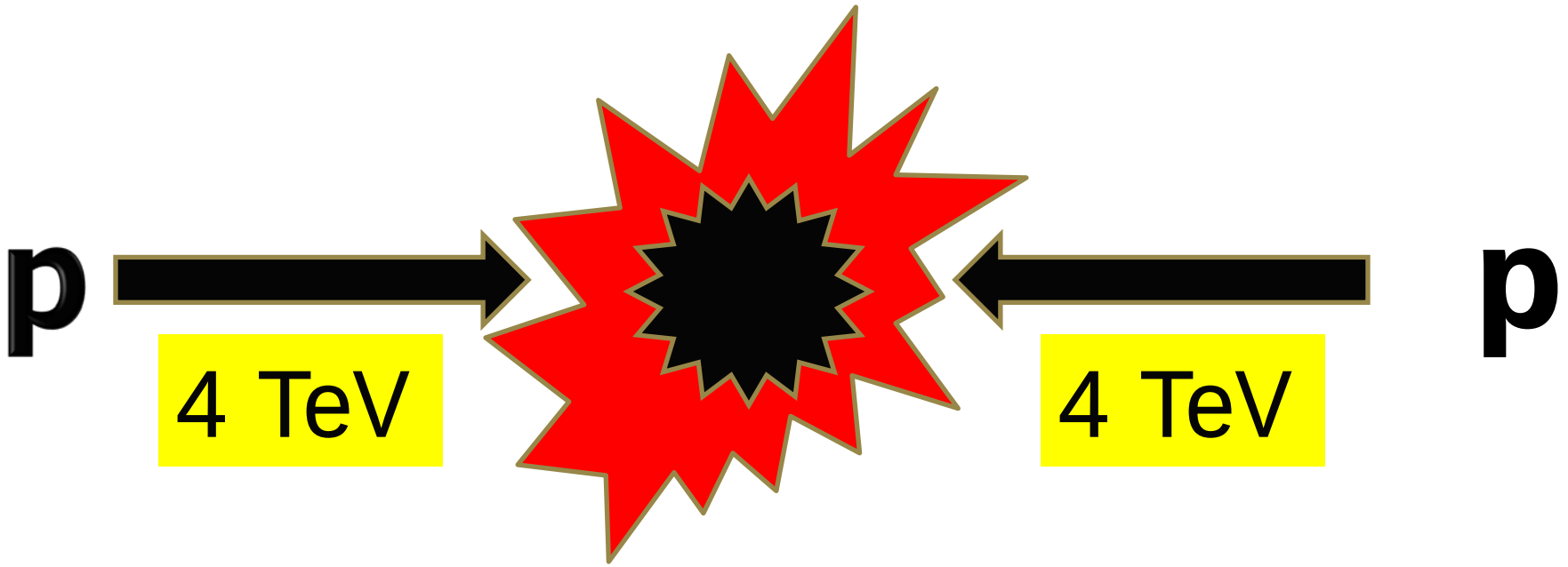


composite

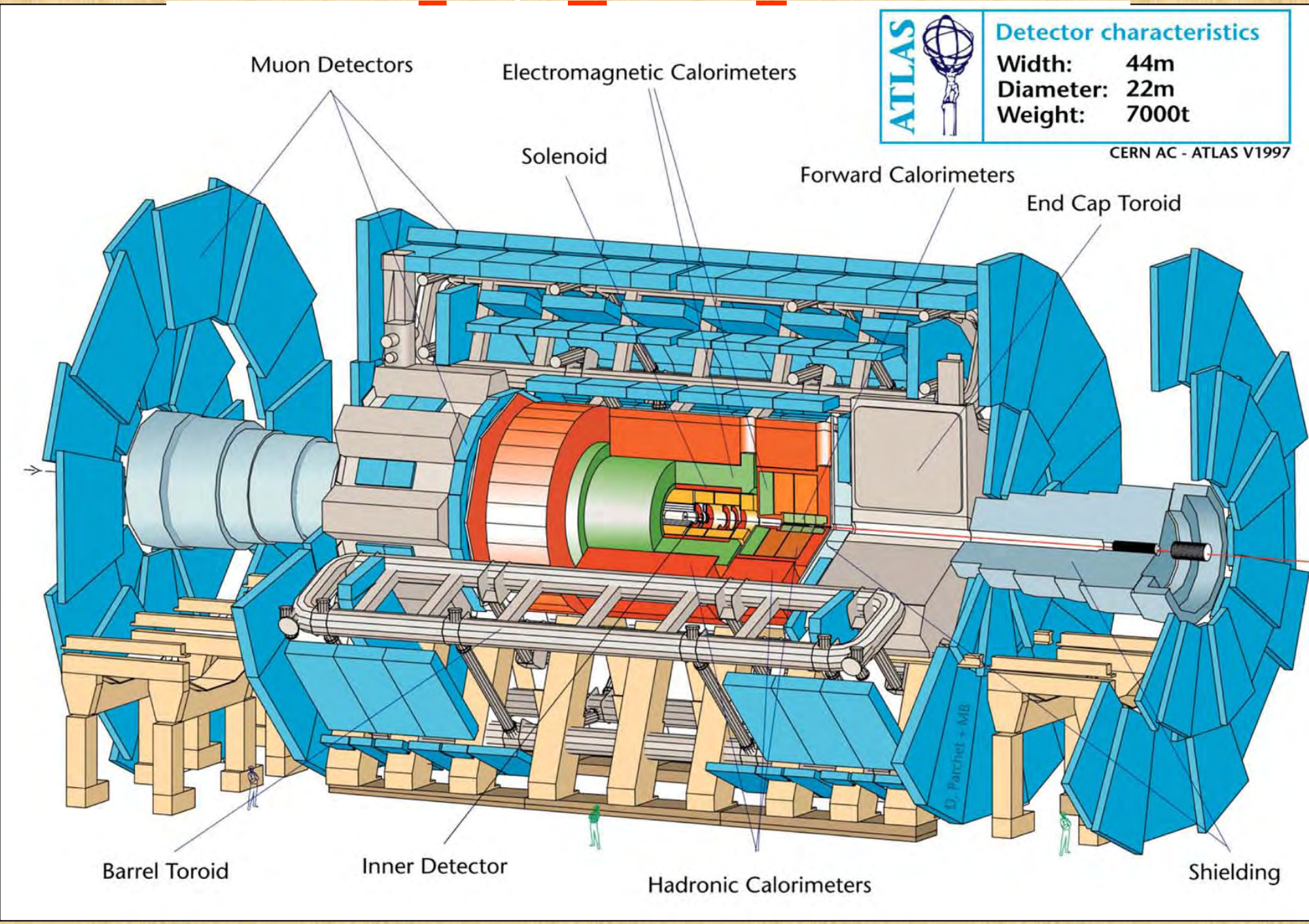
H. Fritzsch

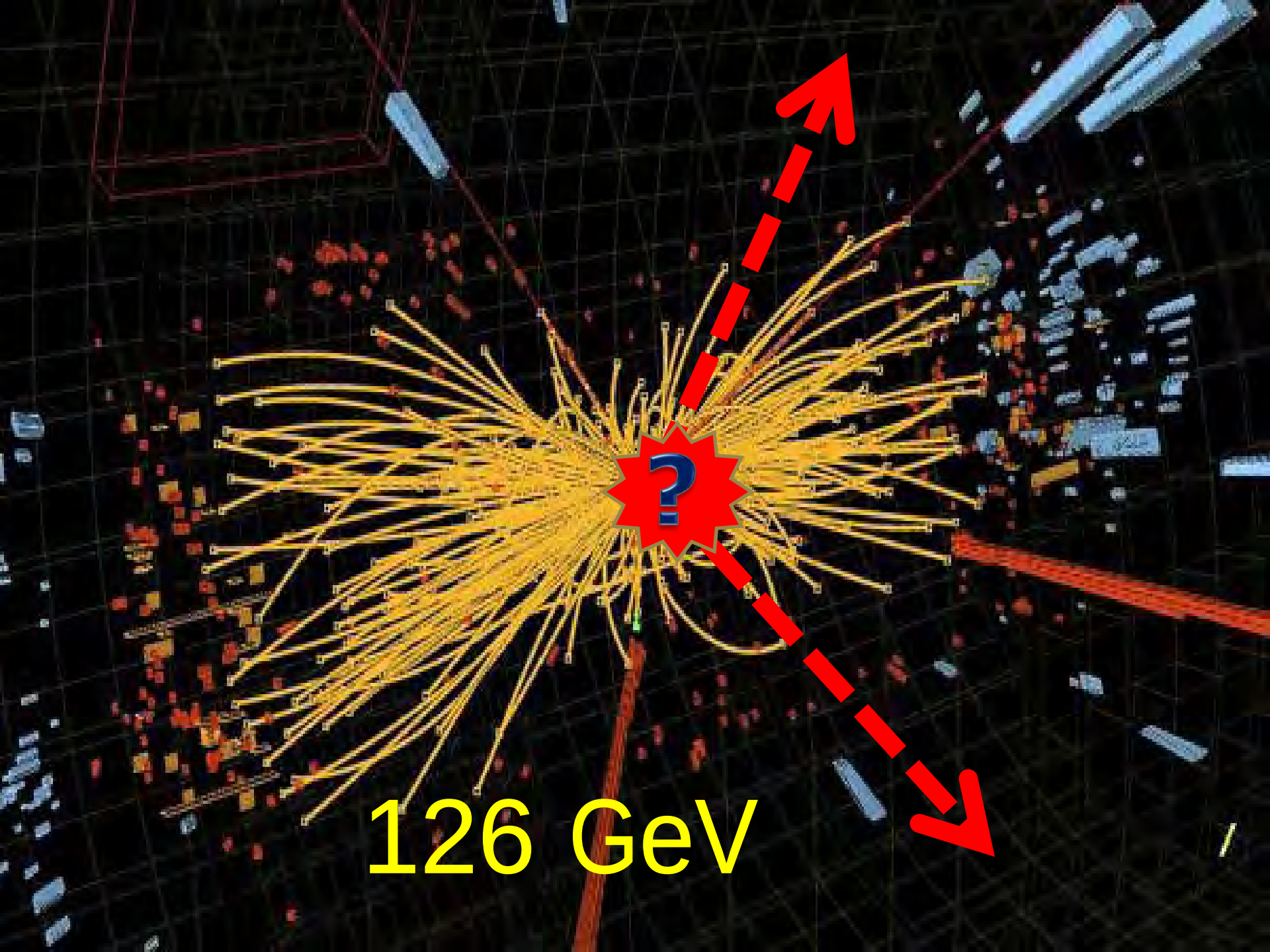
LMU Munich


LHC


p
4 TeV
4 TeV
p

ATLAS at Large Hadron Collider / CERN




?
126 GeV

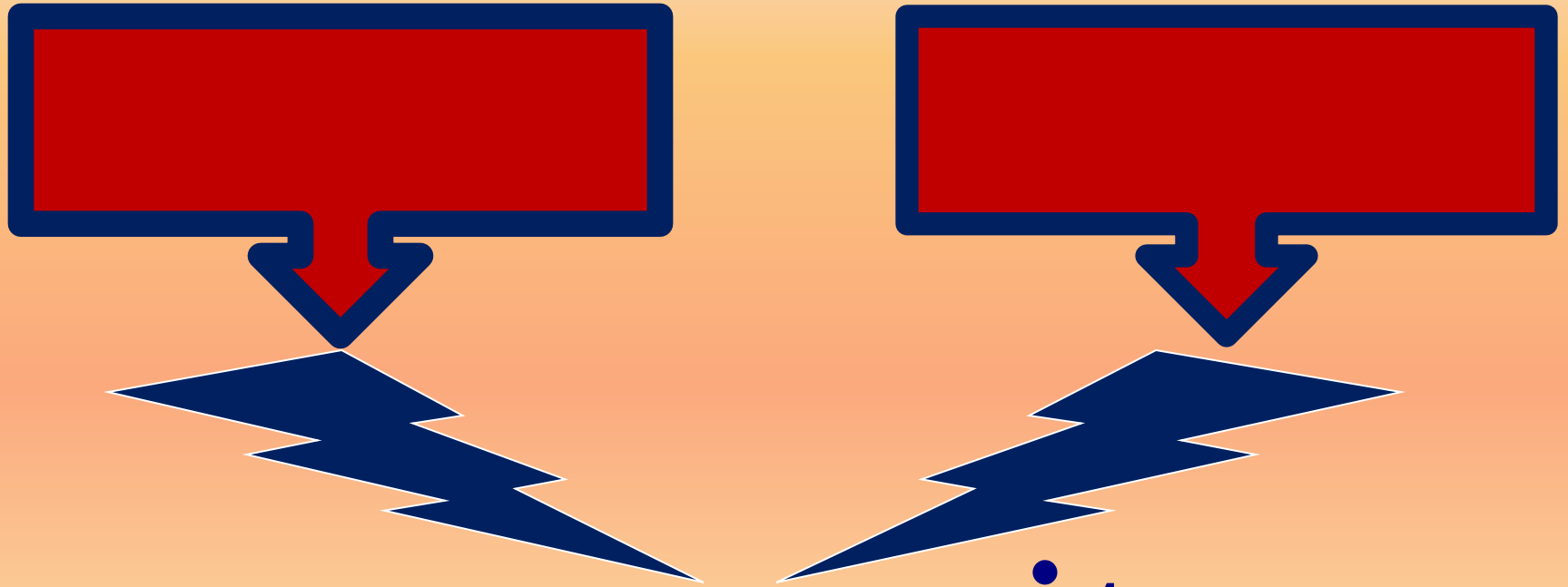
?

excited

weak boson

spin 0

weak bosons



composite

Standard Model

quarks + leptons

weak bosons

pointlike

SLAC – DESY
LEP - Tevatron

radius of electron:

radius of u/d-quark:

$$\leq 10^{-17}\, cm$$

STANDARD MODEL

! Mass of Proton !

? Mass of Weak Boson ?

proton mass

field energy of gluons and quarks

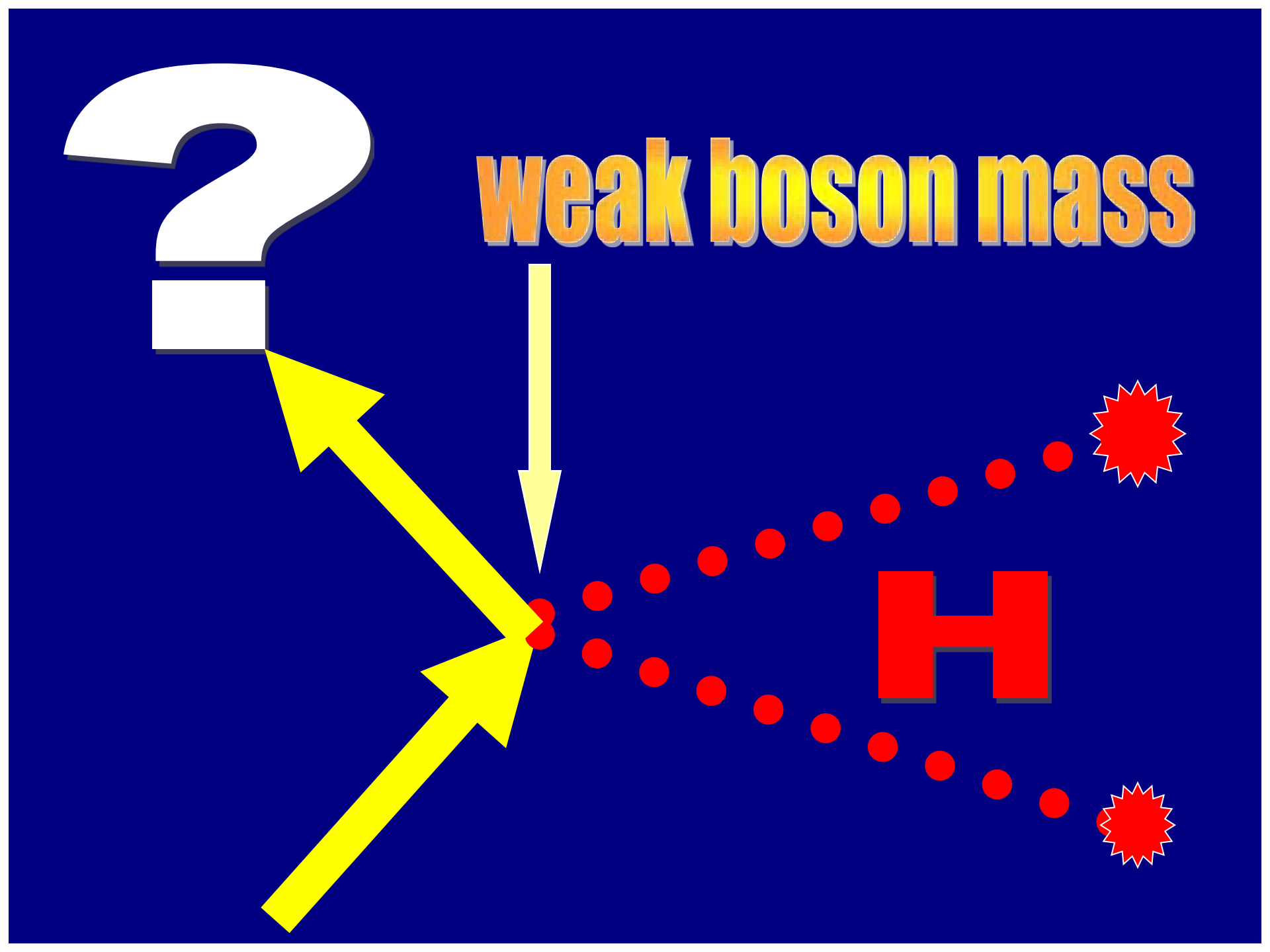
$$E(gluons) + E(quarks) = M_p c^2$$

70 % **30%**

Mass of Weak Boson ???

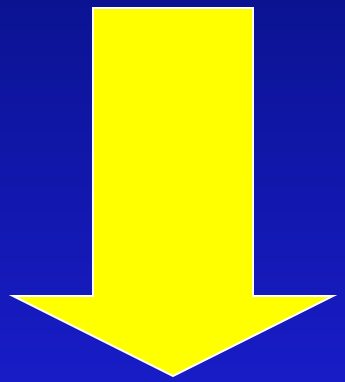
spontaneous symmetry breaking

"Higgs" - mechanism


?
weak boson mass
H

alternative:

mass generation



confinement

Example
rho – mesons

„Higgs“ mechanism

~ 1960: J. J. Sakurai

rho mesons

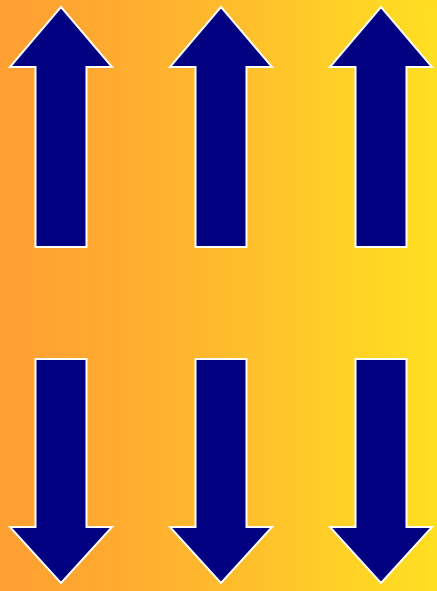
➔

elementary gauge bosons

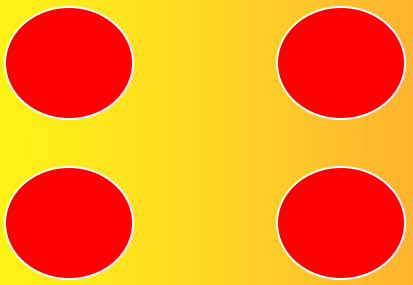
~ 1964
mass generation
for rho mesons

„Higgs“
mechanism

SU(2)



2 x 2 scalars

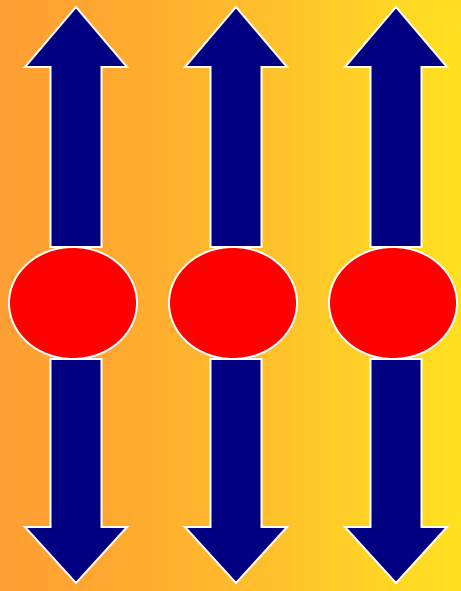


massless

mass M

rho - mesons

“Higgs“ - mechanism



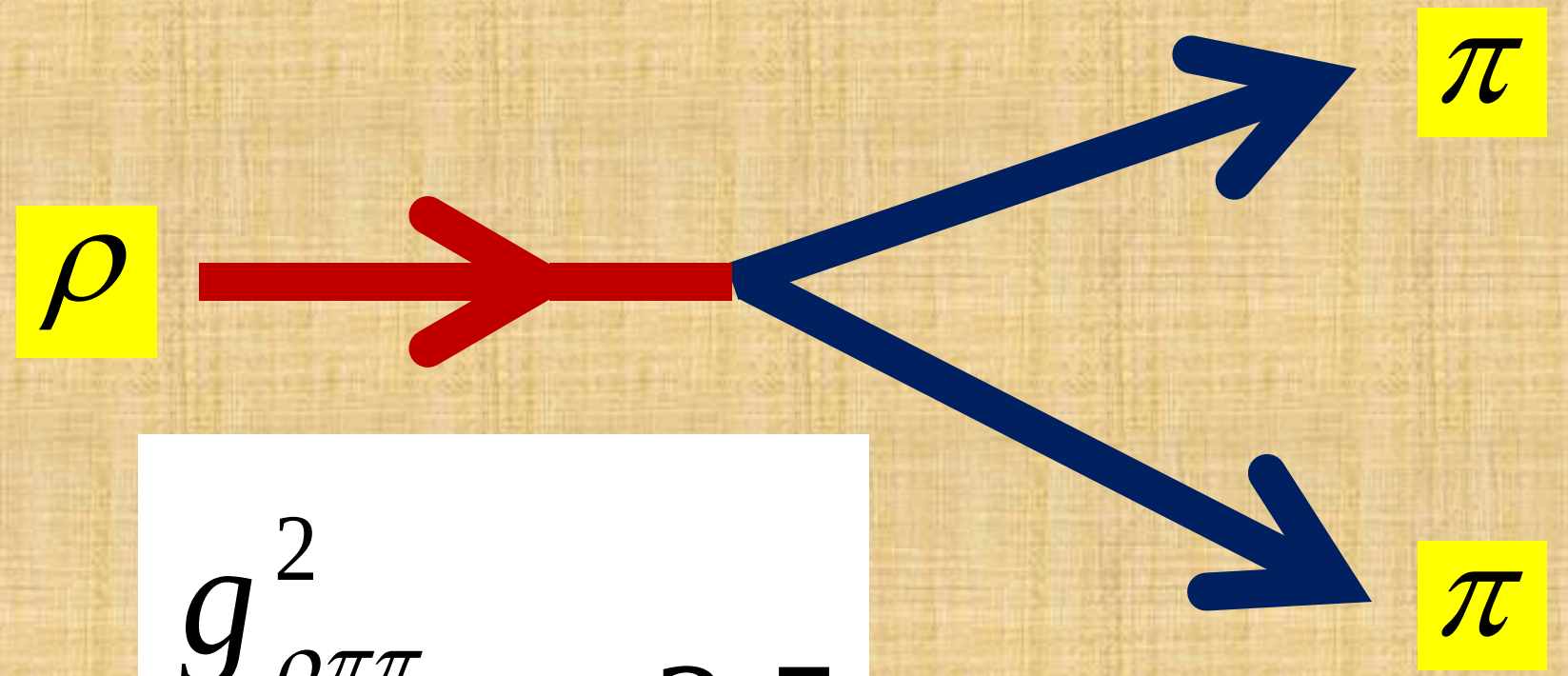
„Higgs“ - scalar

mass M

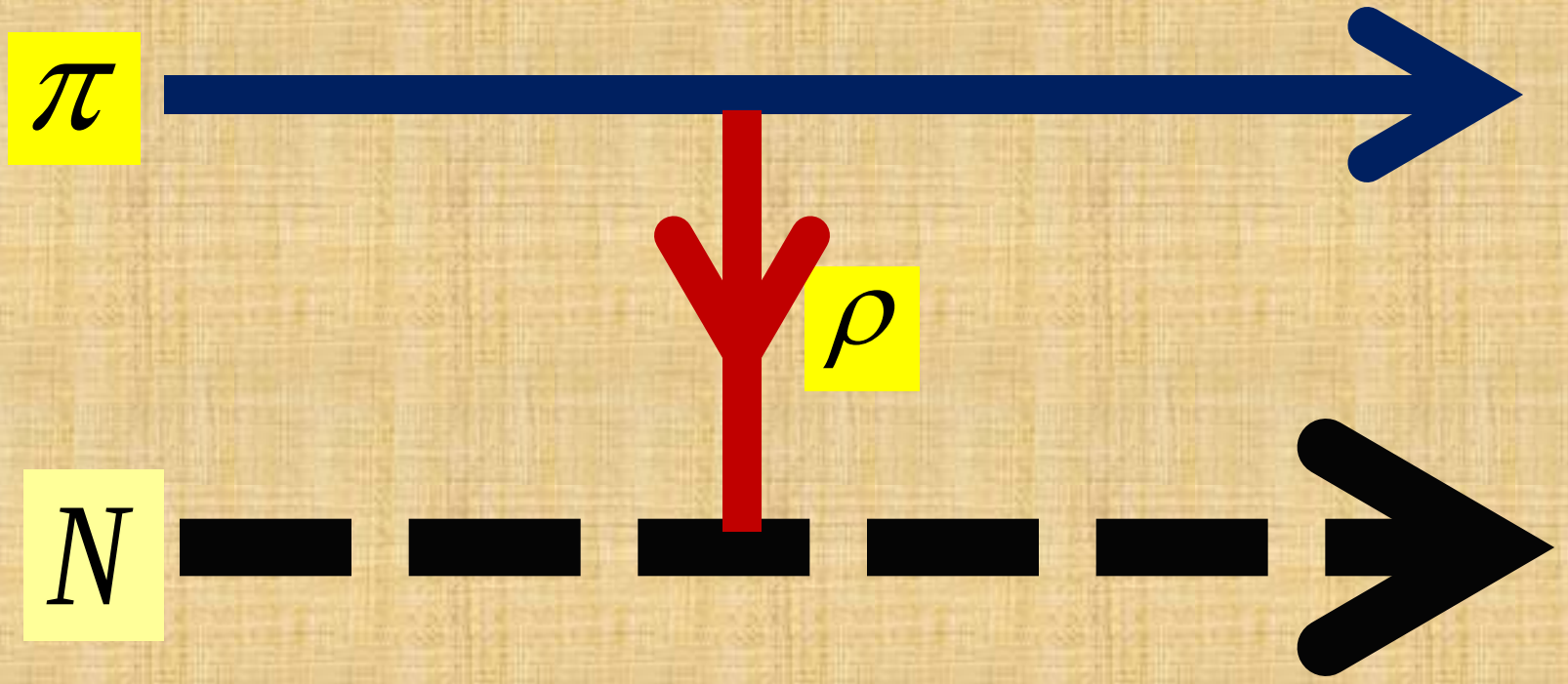
massive

rho - mesons

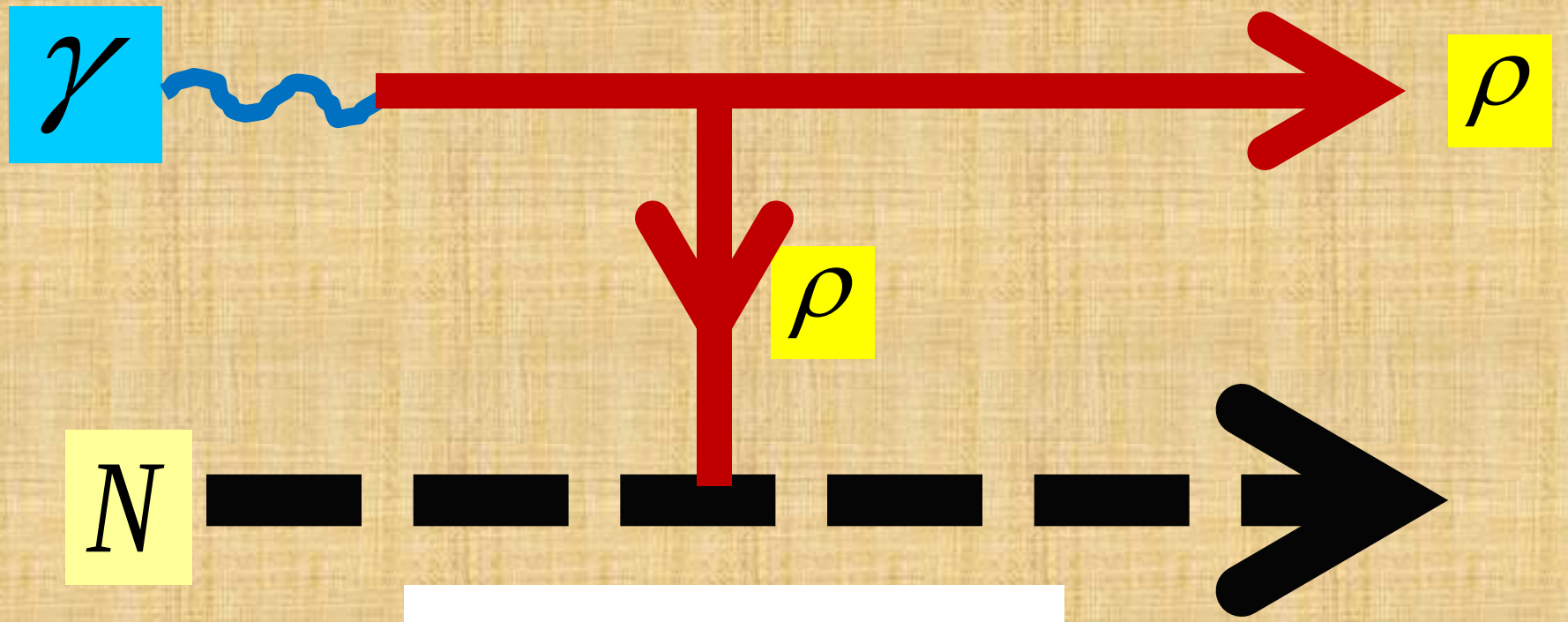
UNIVERSALITY



$$\frac{g^2_{\rho\pi\pi}}{4\pi} \approx 2.5$$

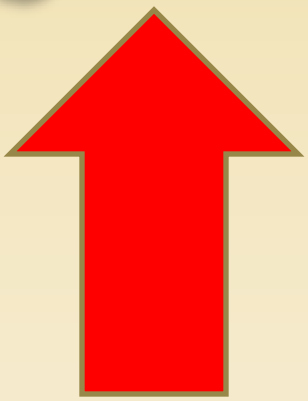


$$\frac{g^2_{\rho NN}}{4\pi} \approx 2.5$$



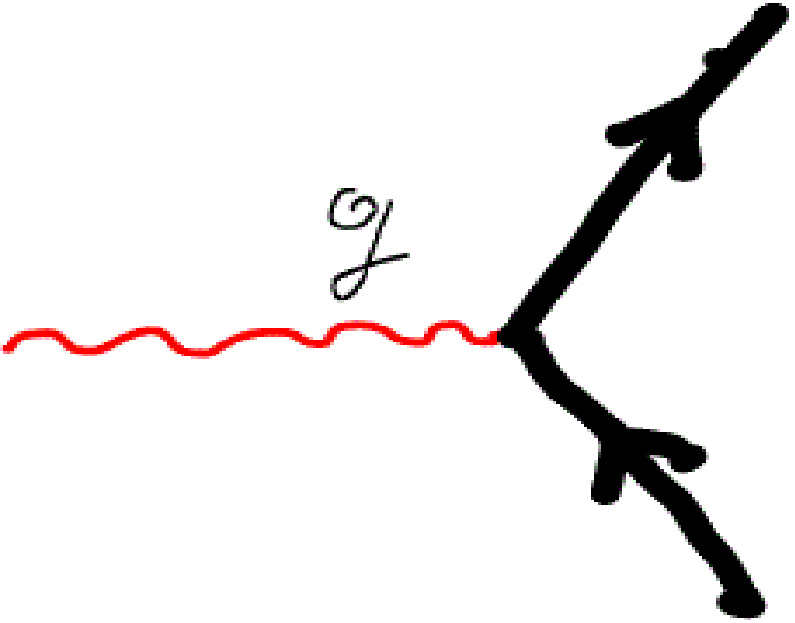
$$\frac{g^2_{\rho\rho\rho}}{4\pi} \approx 2.5$$

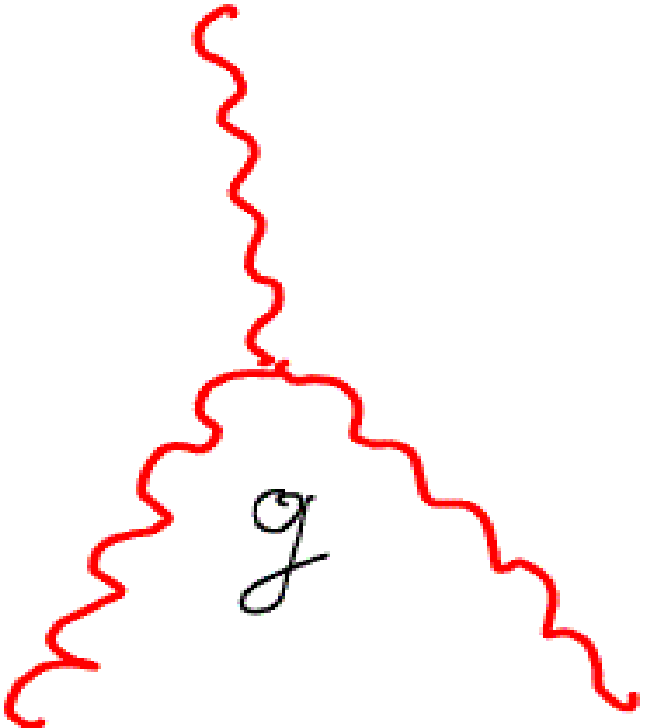
universality
of
coupling constants

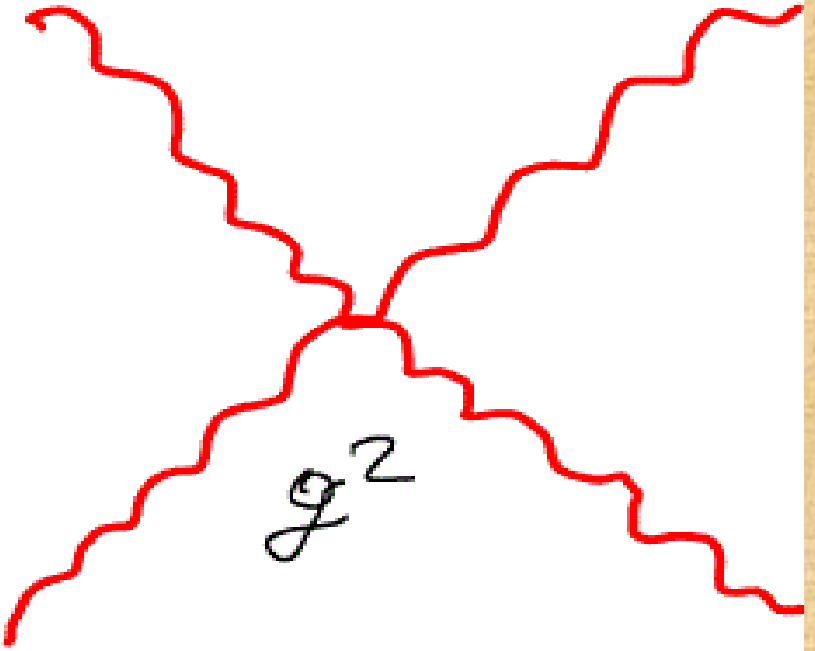


non-Abelean
gauge invariance

gauge theory

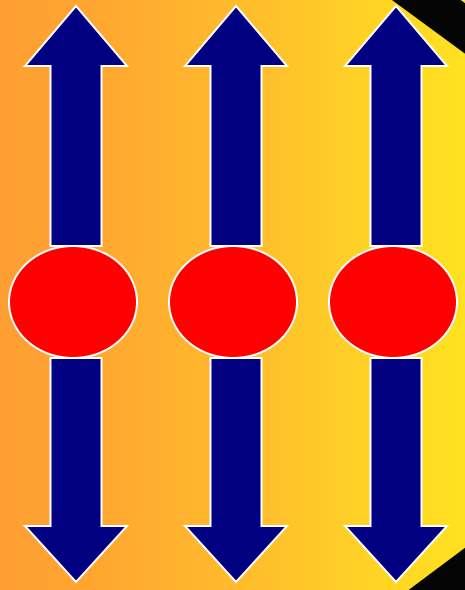







rho mesons
elementary
gauge bosons

"Higgs" - mechanism



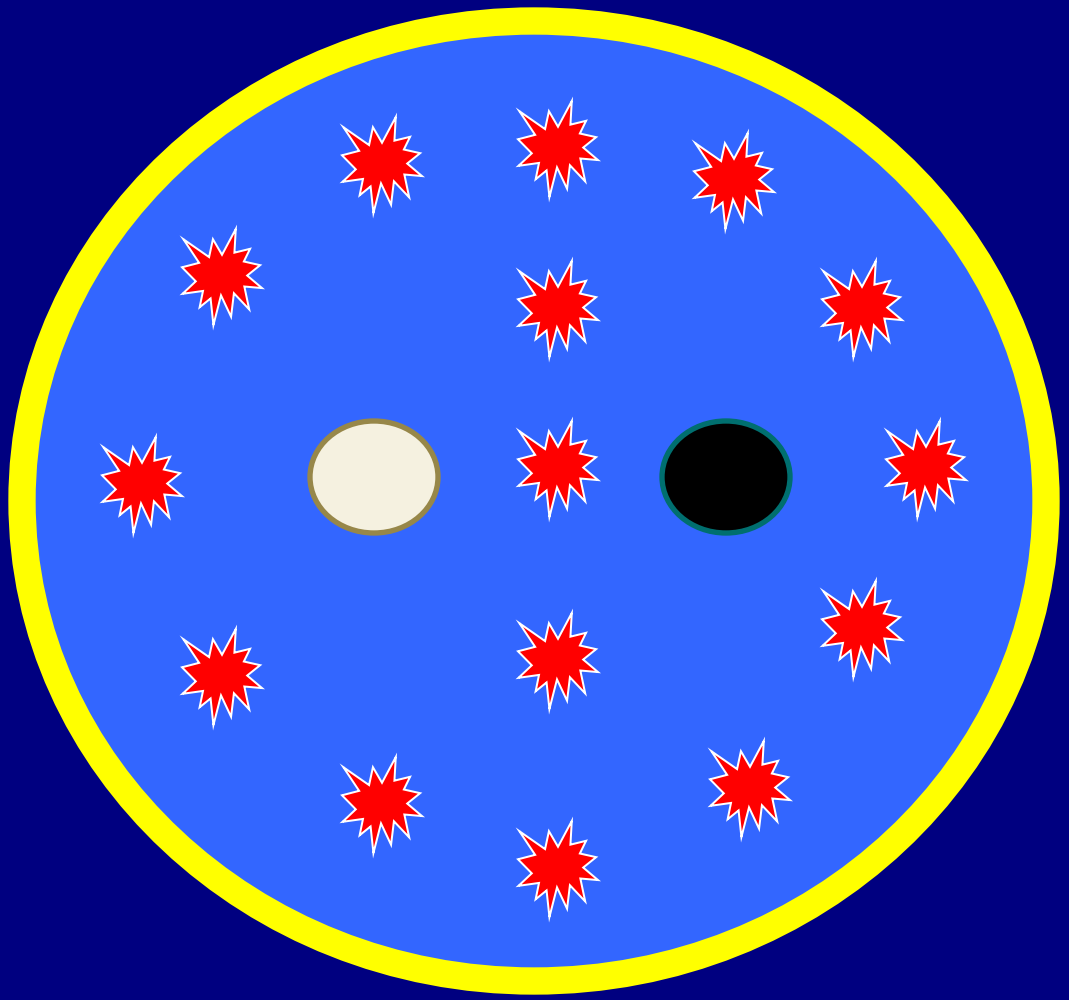
„Higgs" - scalar

mass M

massive

rho - mesons

ρ - meson in QCD :



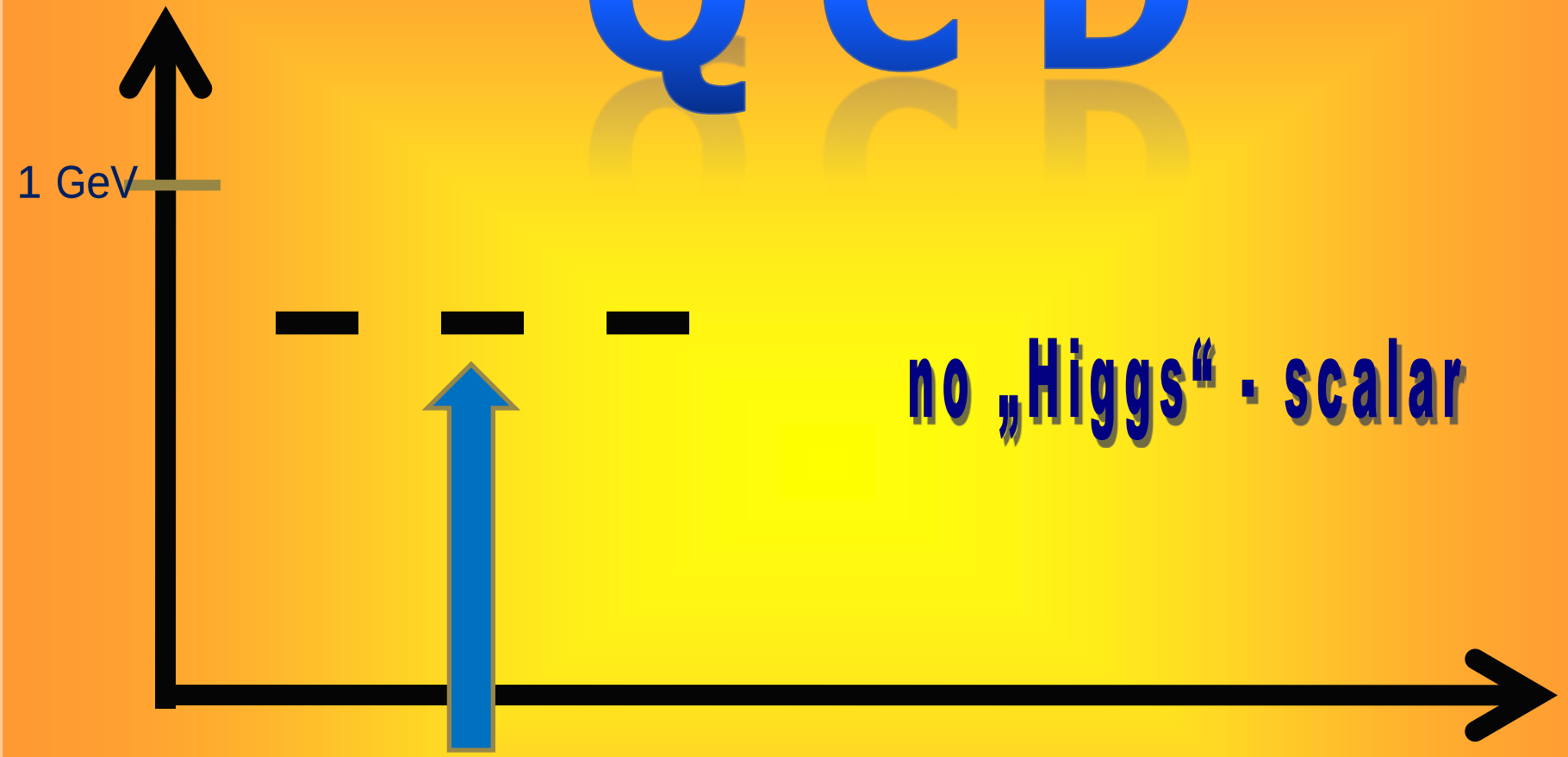
quark - antiquark - gluons

$$\rho = (\bar{q}q)$$

$$M_{\rho} \approx 760 \quad MeV$$

$$= const. \bullet \Lambda_{c}$$

Q C D

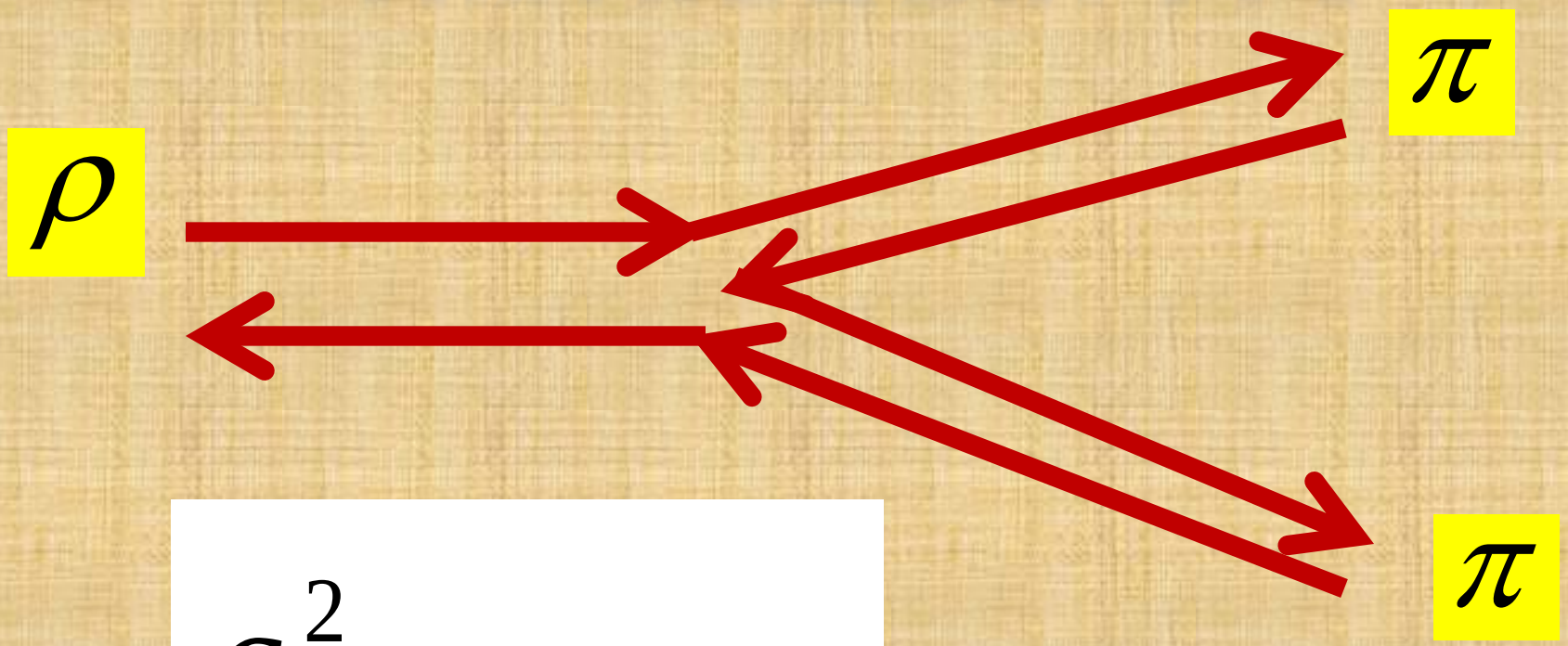


no „Higgs“ - scalar

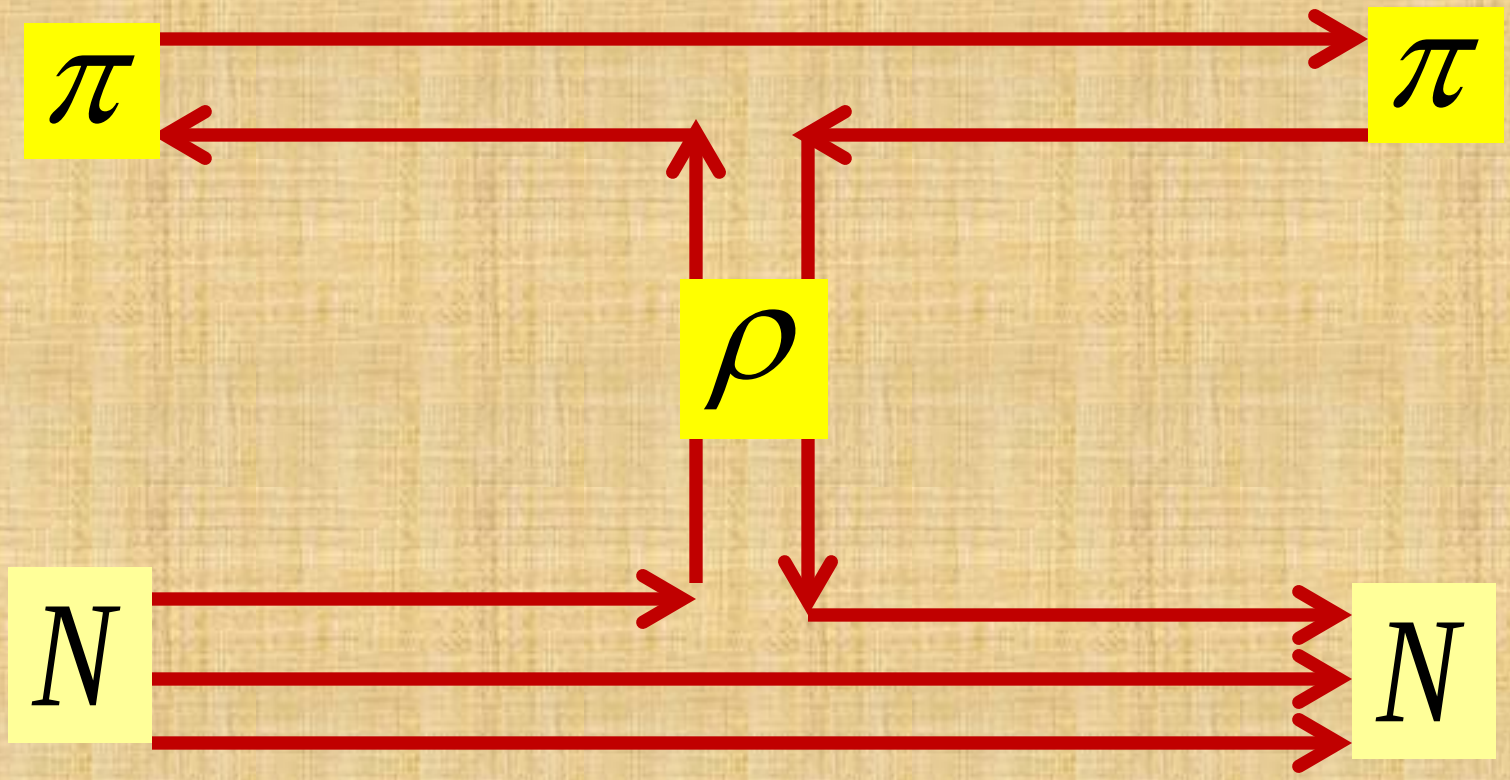
3 massive

rho - mesons

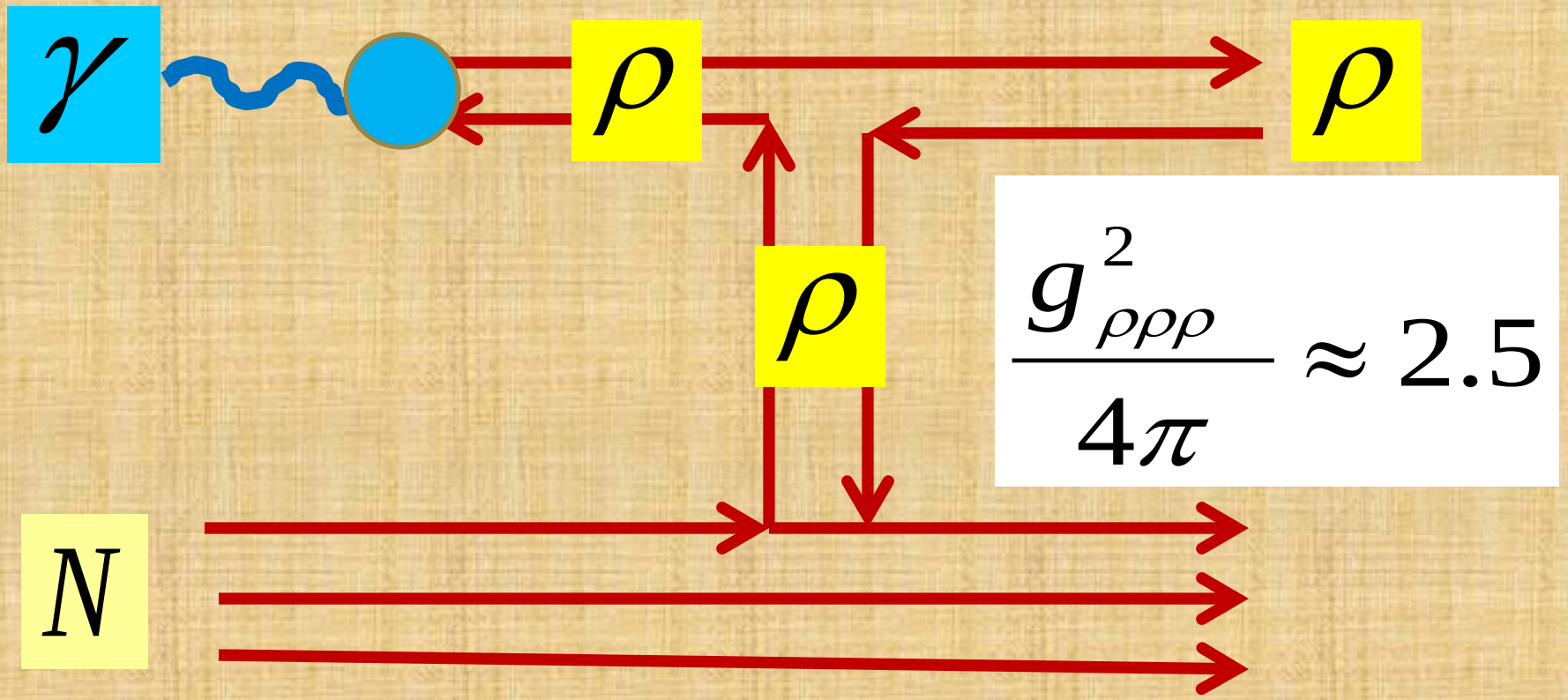
UNIVERSALITY



$$\frac{g^2_{\rho\pi\pi}}{4\pi} \approx 2.5$$

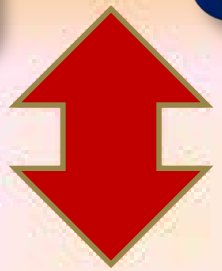


$$\frac{g^2_{\rho NN}}{4\pi} \approx 2.5$$


γ
ρ
ρ
ρ
N
$\frac{g^2_{\rho\rho\rho}}{4\pi} \approx 2.5$

universality

coupling constants



quarks

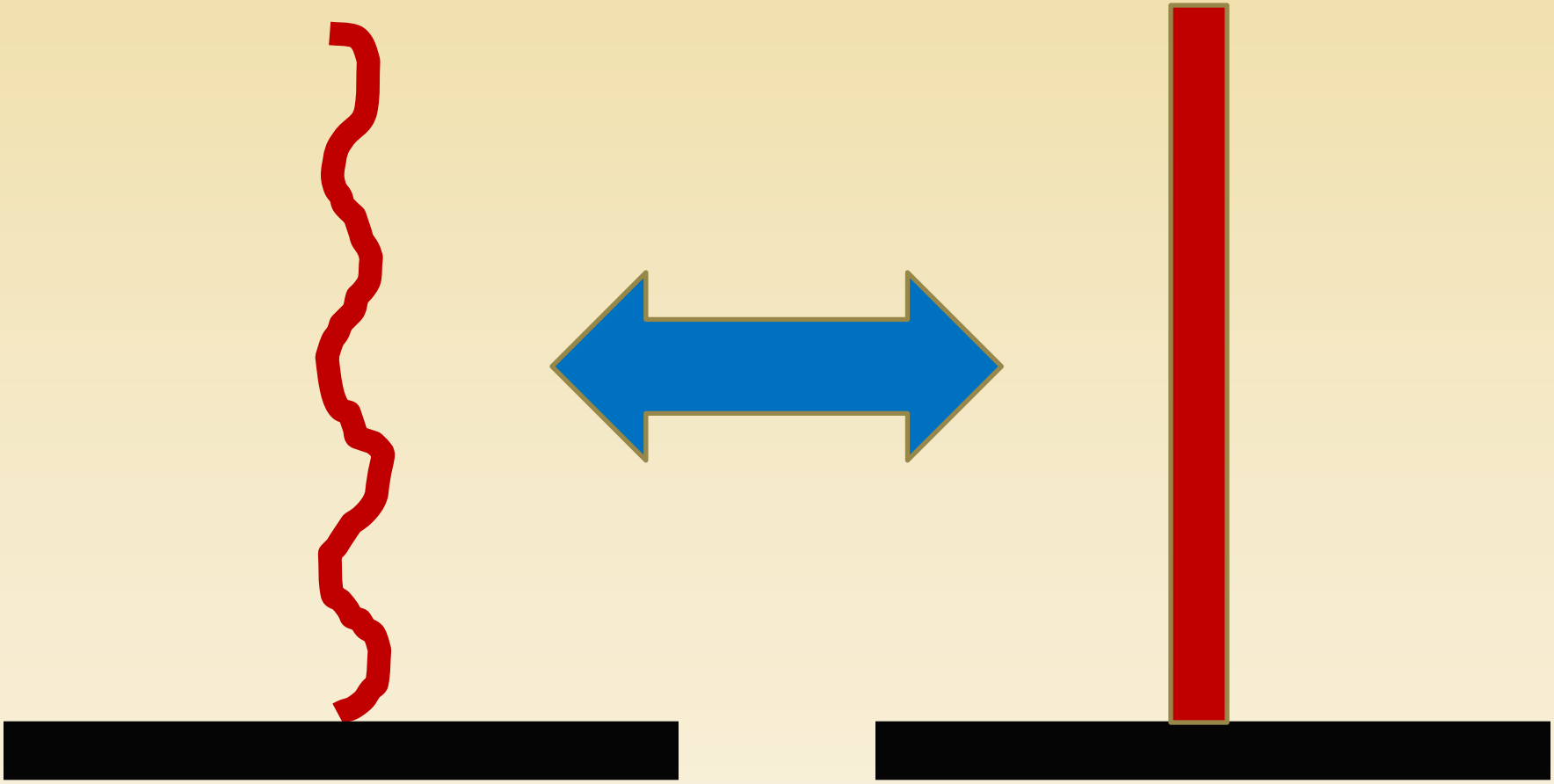
duality diagrams

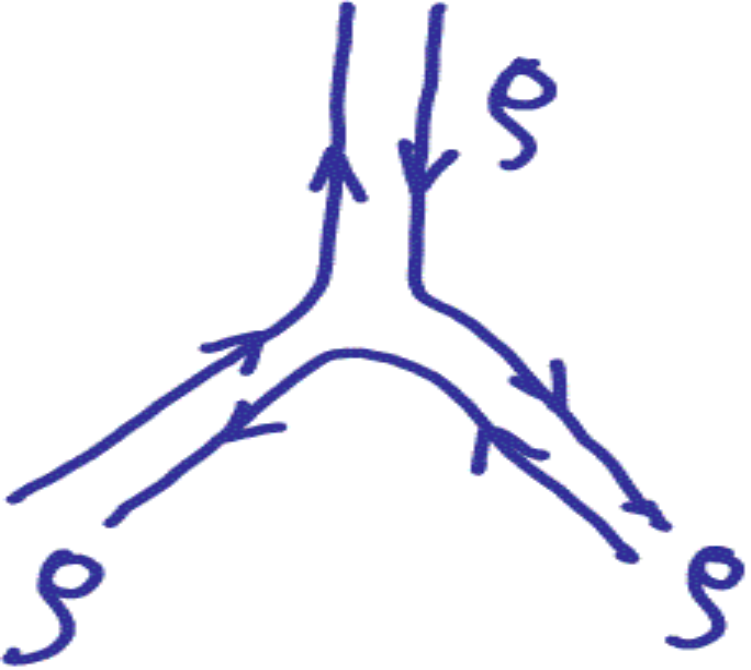
current algebra

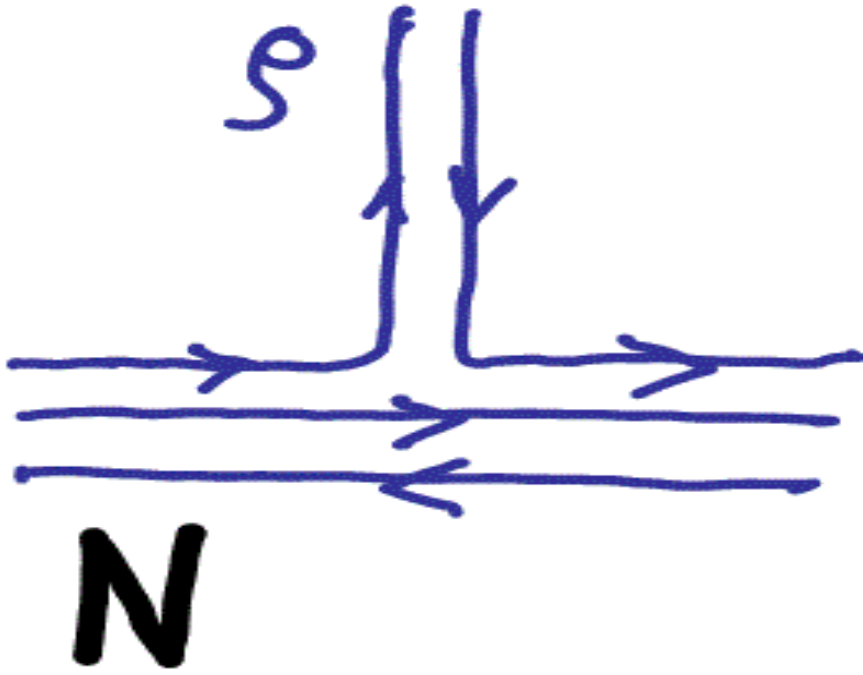
vector meson dominance

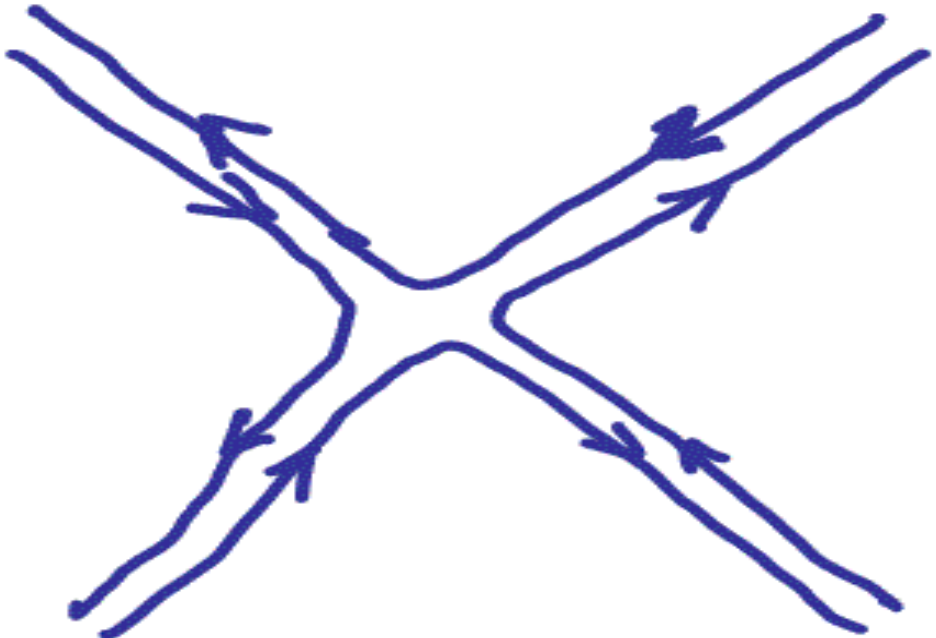
current

rho - meson

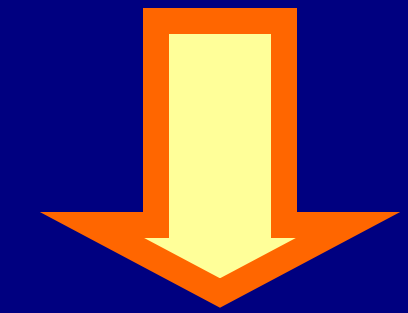



s
s
s


s
N



weak bosons



composite

old references:

Bjorken (1977)

Fritzsch and Mandelbaum (1981)

Abbott and Farhi (1981)

Barbieri and Mohapatra (1981)

Fritzsch, Kogerler and Schildknecht (1982)

Lüst (1985)

Calmet and Fritzsch (2000)

new:

H. Fritzsch

2010 - arXiv: 1010.1428

2011 - arXiv: 1105.3354

2012 - arXiv: 1203.5600

masses of composite weak bosons ?

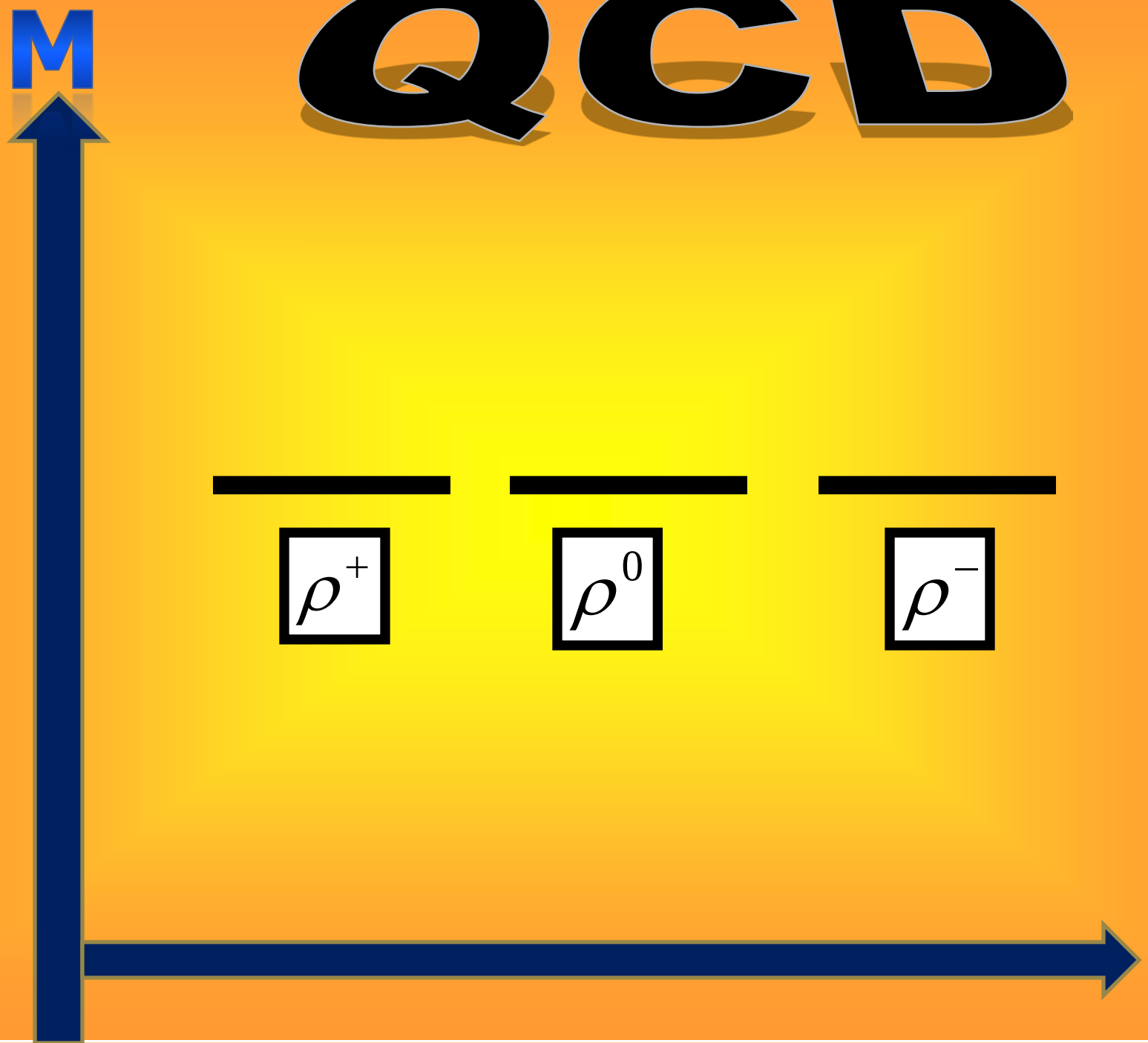
a n a l o g y

$$\rho^{+} \Leftrightarrow W^{+}$$

$$\rho^{0} \Leftrightarrow W^{0}$$

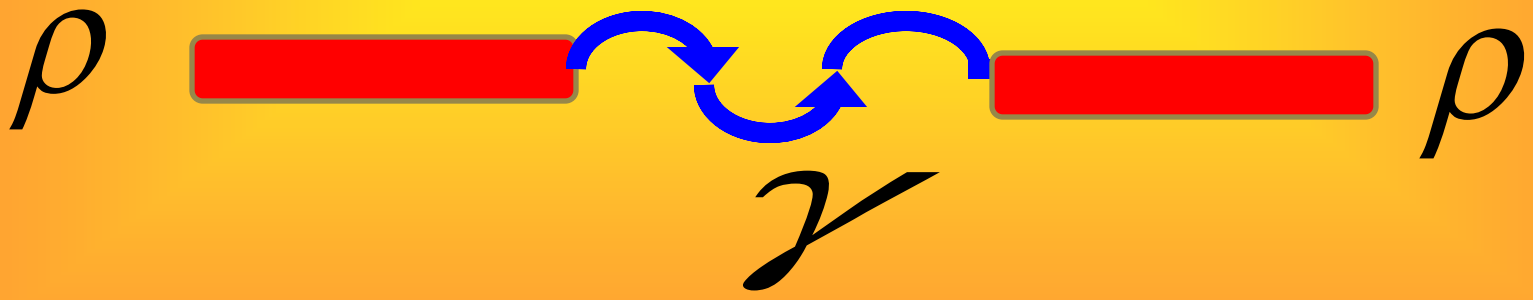
$$\rho^{-} \Leftrightarrow W^{-}$$

QCD

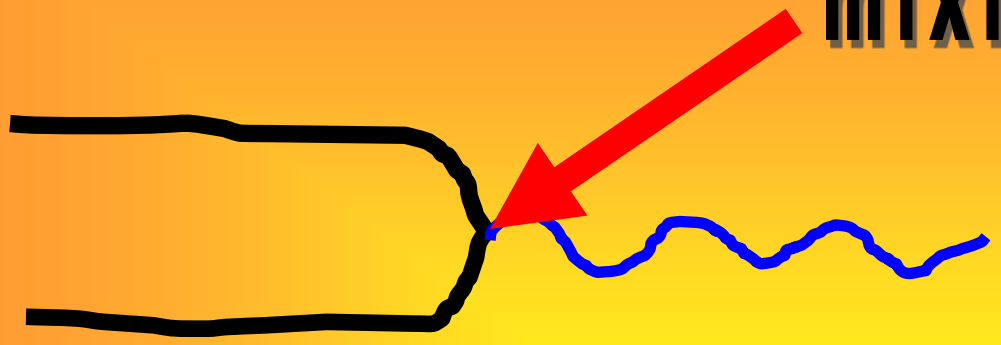


QCD + QED

Dynamical mixing of rho meson and photon:



mixing parameter m



$$m = e\frac{F_\rho}{M_\rho}$$

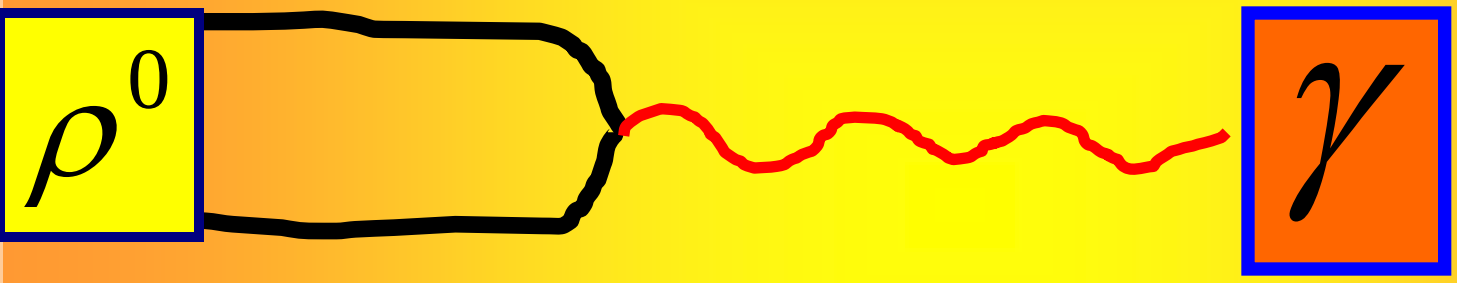
$$\langle 0|\frac{1}{2}(\bar{u}\gamma_\mu u - \bar{d}\gamma_\mu d)|\rho_0\rangle = \varepsilon_\mu M_\rho F_\rho$$

F_ρ : decay constant

$$F_\rho \approx 220 \quad MeV$$

$$F_\rho \approx \Lambda_c$$

mixing with photon



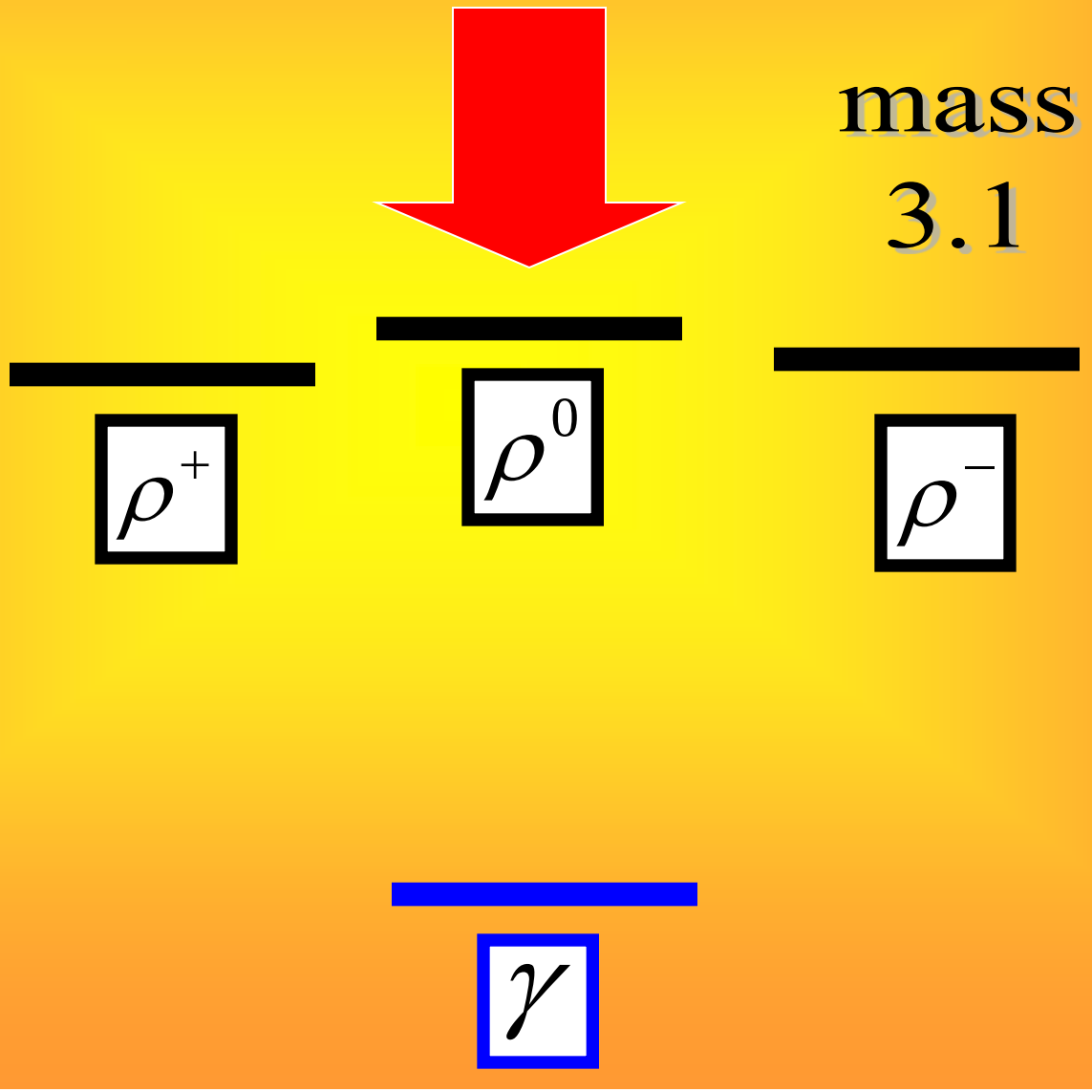
m: mixing parameter

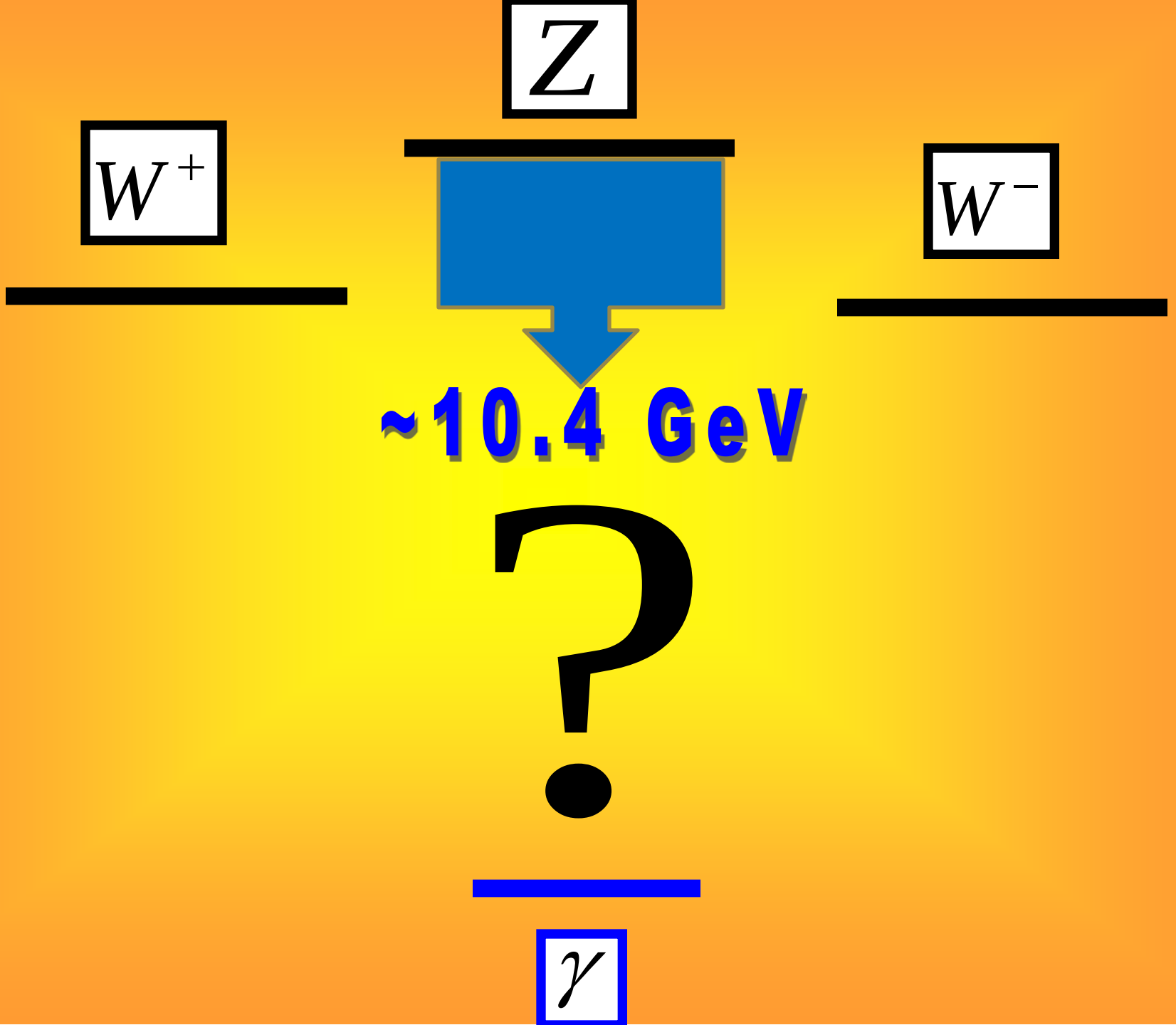
$$M_{\rho^0}^{\ 2} = \frac{M_{\rho^+}^{\ 2}}{1-m^2}$$

~ 3.1 MeV

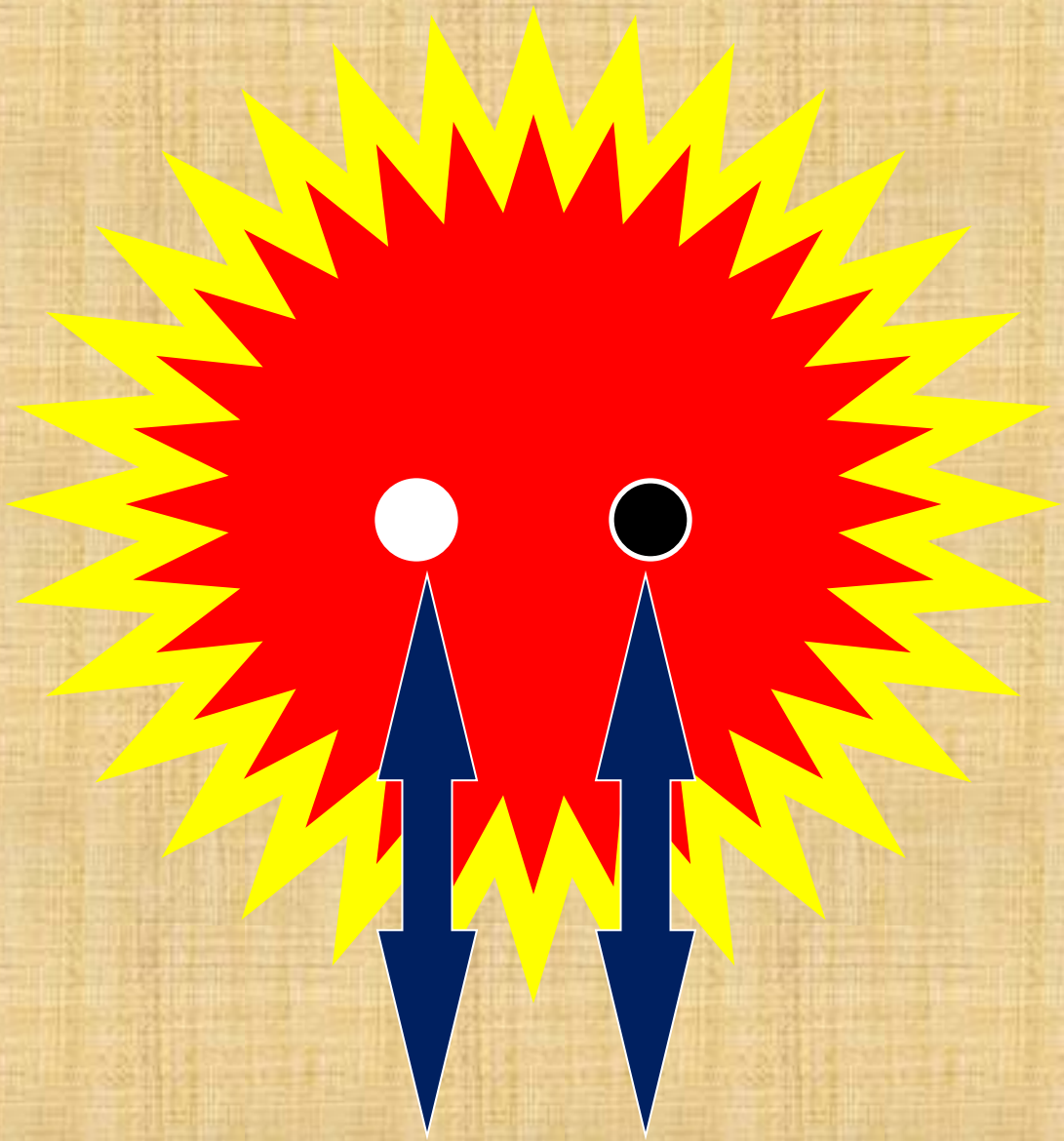
m = 0.09

QCD +QED



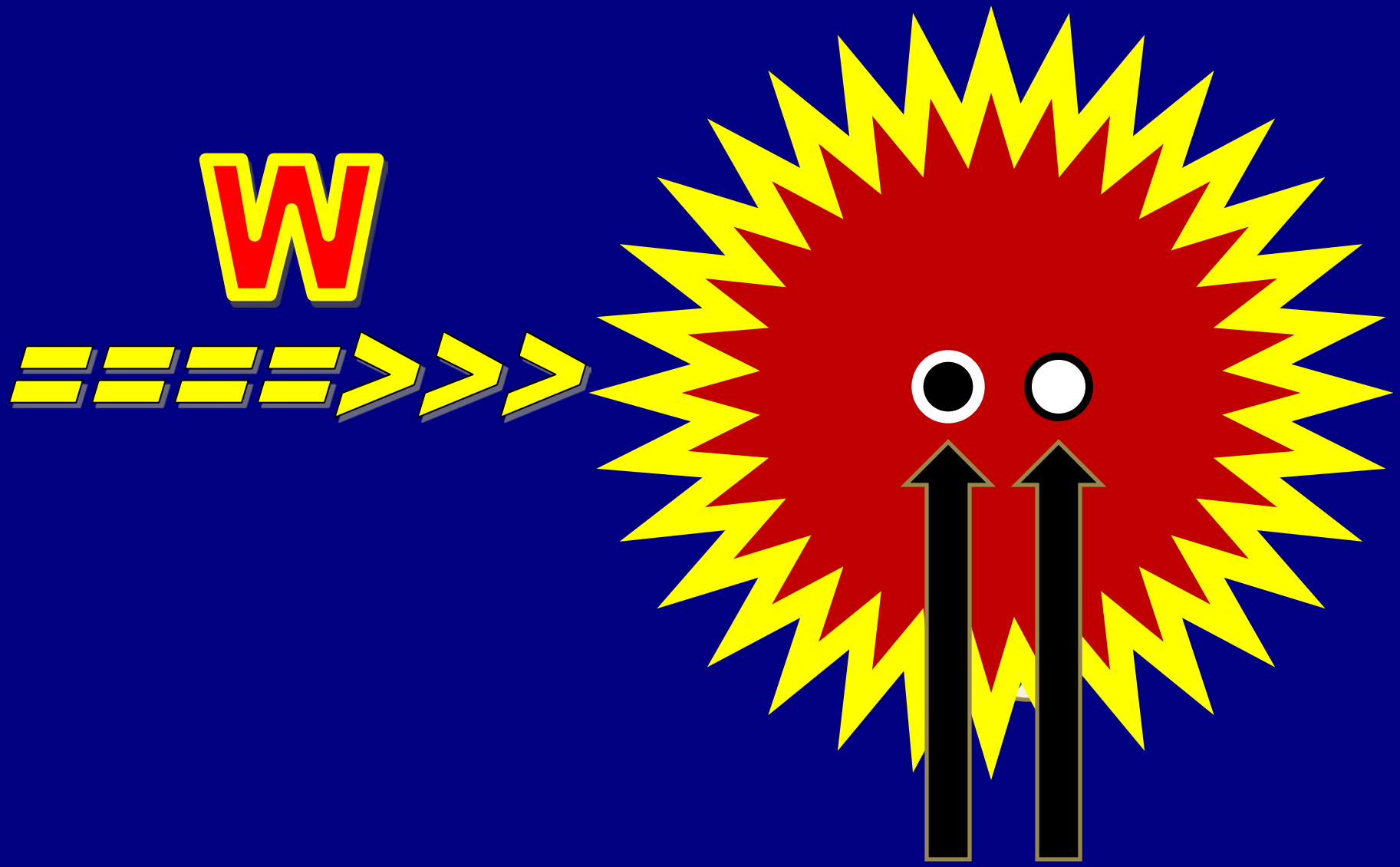

Z
W^+
W^-
~10.4 GeV
?
γ

ρ

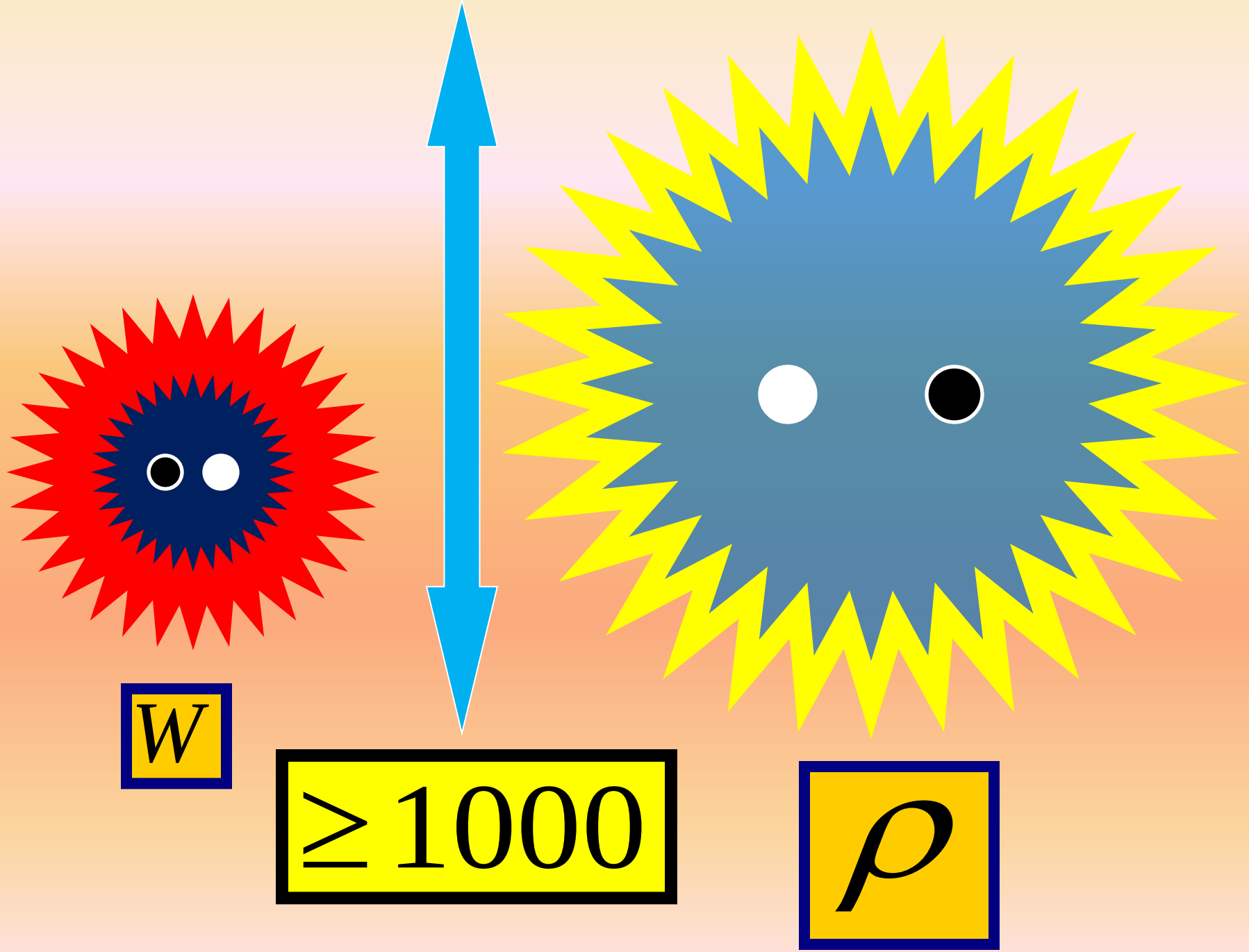


quarks

W



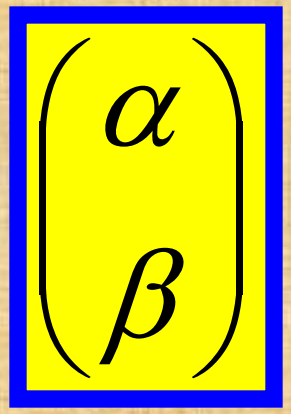
constituents

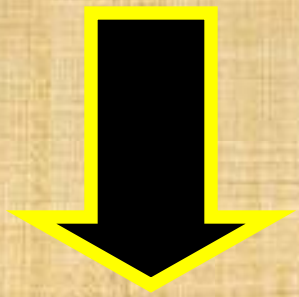

w
≥ 1000
ρ

Constituents of W-bosons

$$\begin{pmatrix} \alpha \\ \beta \end{pmatrix}$$

lefthanded fermions





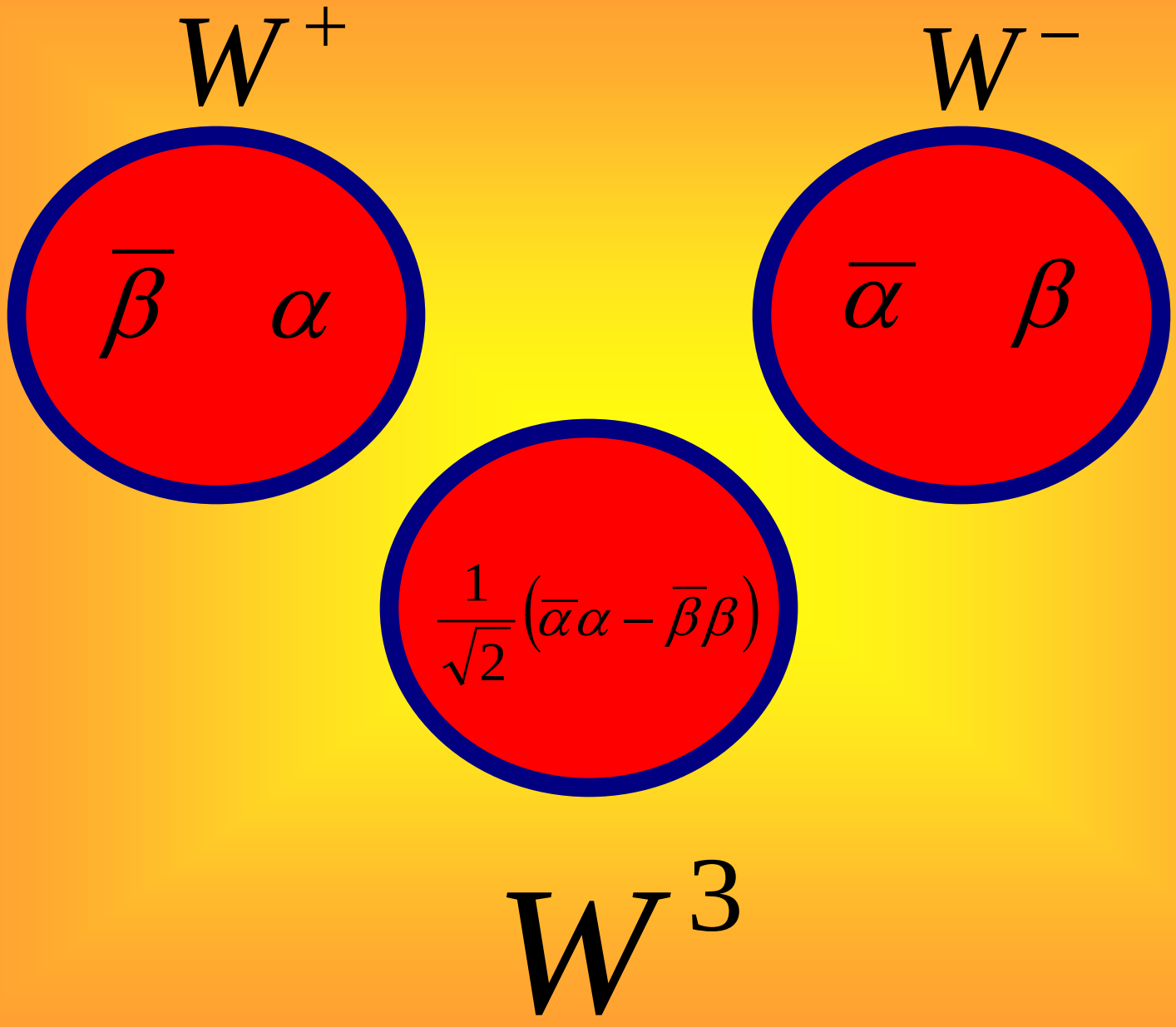
haplons

haplos ⇔ simple

electric charges

$$\alpha \Rightarrow +1/2$$

$$\beta \Rightarrow -1/2$$


W^+
W^-
$\overline{\beta}\quad\alpha$
$\overline{\alpha}\quad\beta$
$\frac{1}{\sqrt{2}}\left(\overline{\alpha}\alpha-\overline{\beta}\beta\right)$
W^3

haplons confined by gauge force

QHD

chiral gauge theory

glue ➔ gluten

gauge bosons

gluons

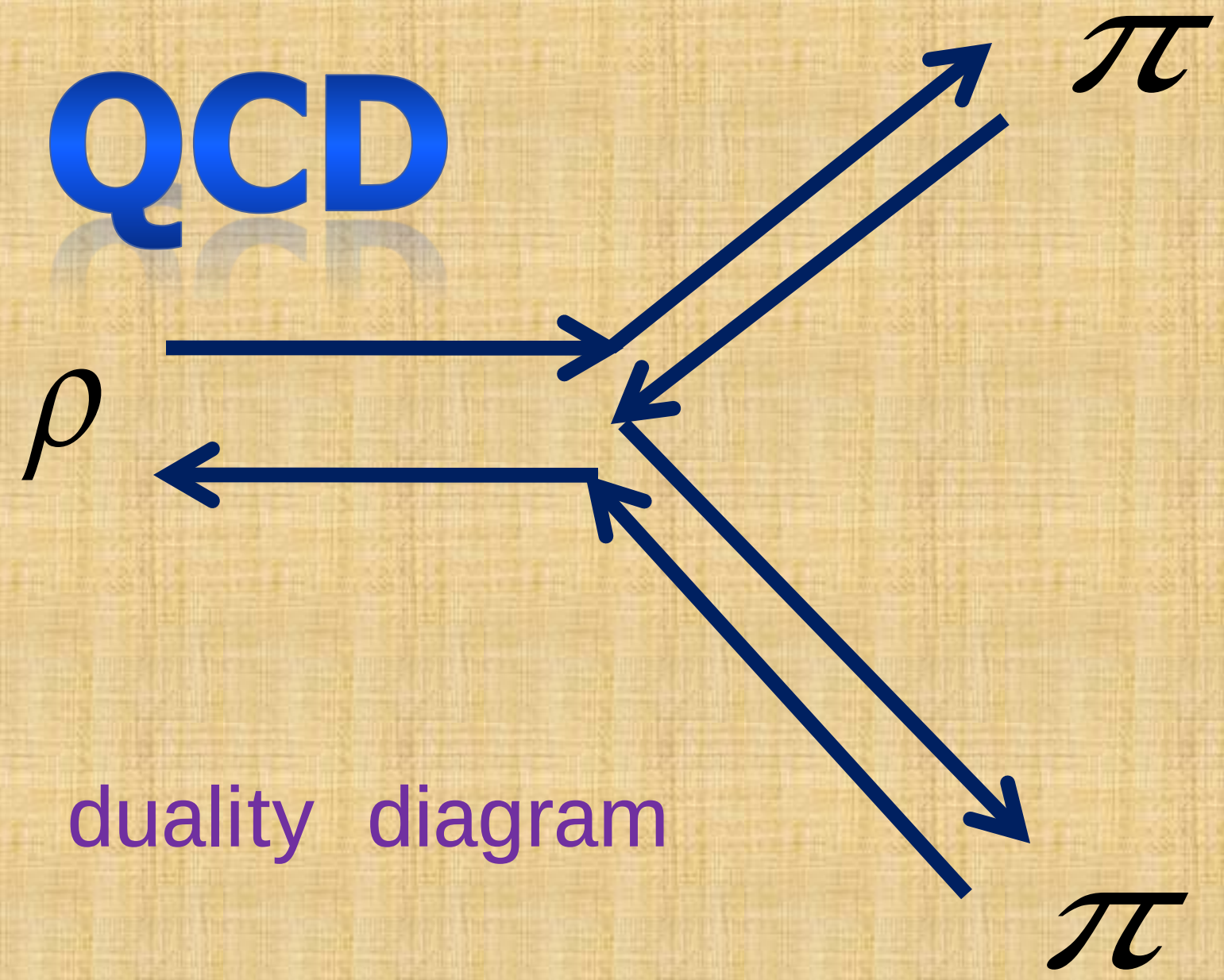
Gauge group of QHD

SU(n)

Gauge group of QHD:

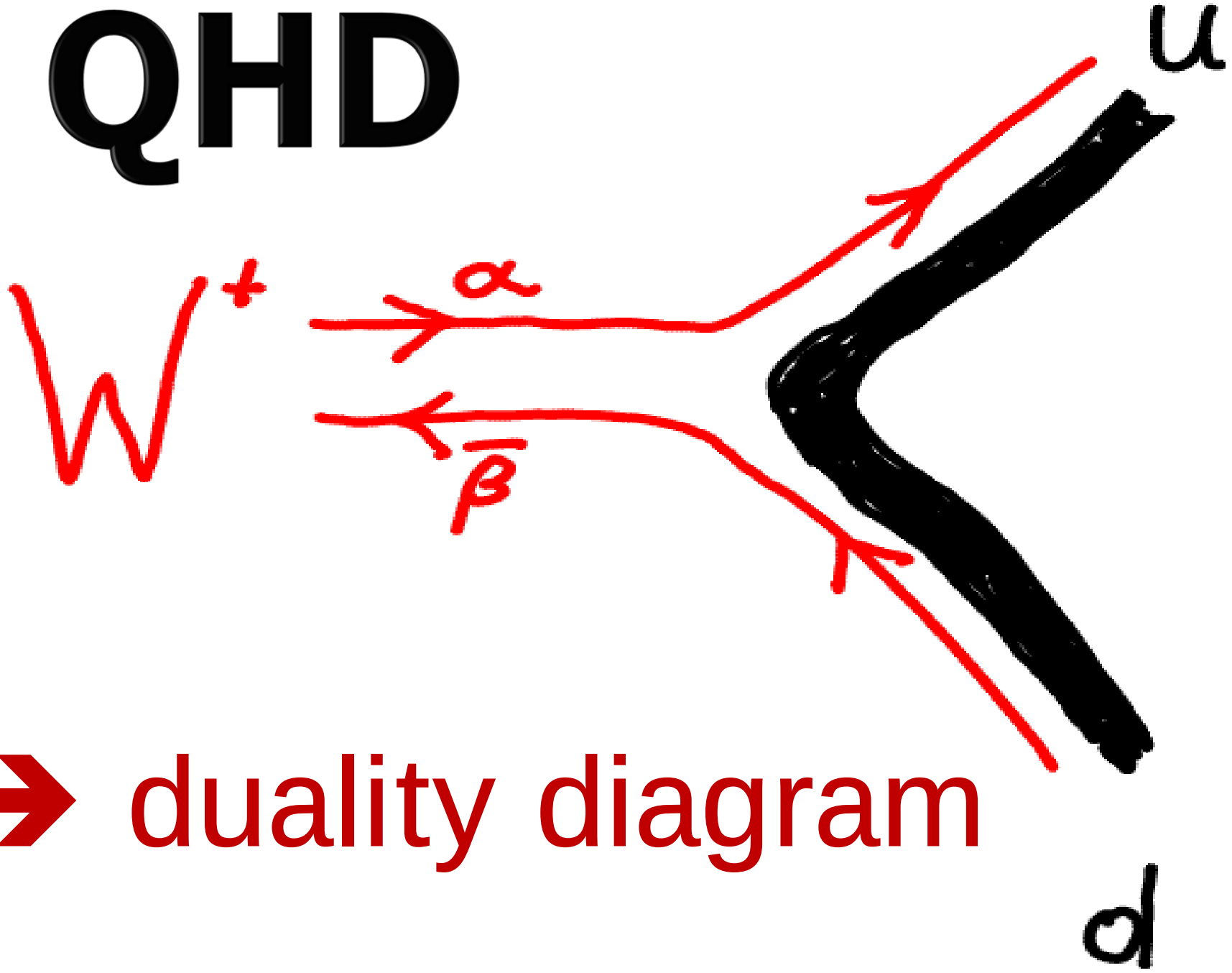
? SU(3) ?

QCD



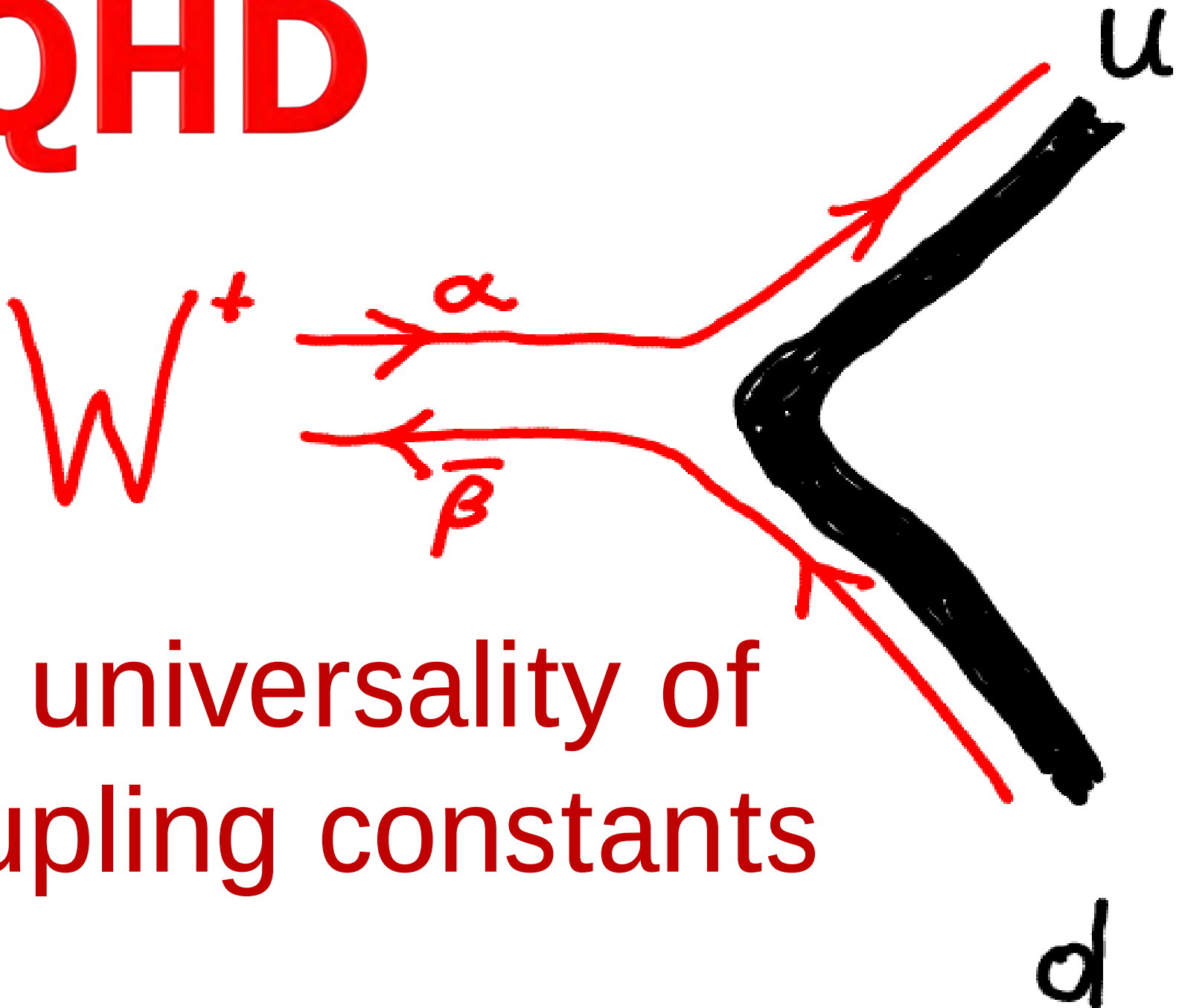
duality diagram

QHD



➔ duality diagram

QHD



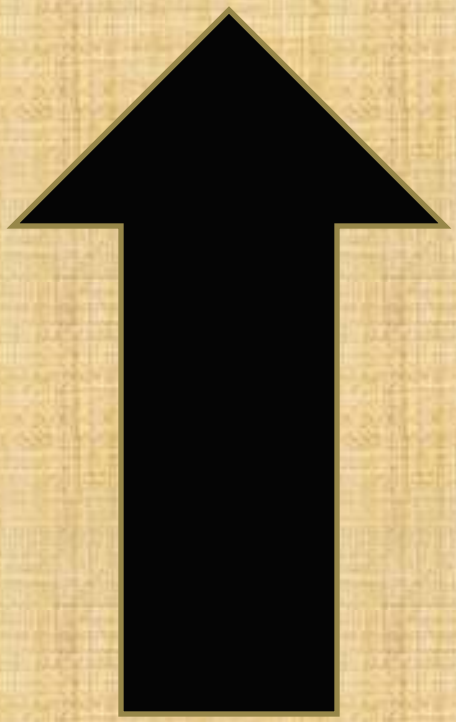
➔ universality of coupling constants

maximal parity violation

$$SU(2)_L \otimes U(1)$$

$$SU(2)_L \otimes SU(2)_R \otimes U(1)$$

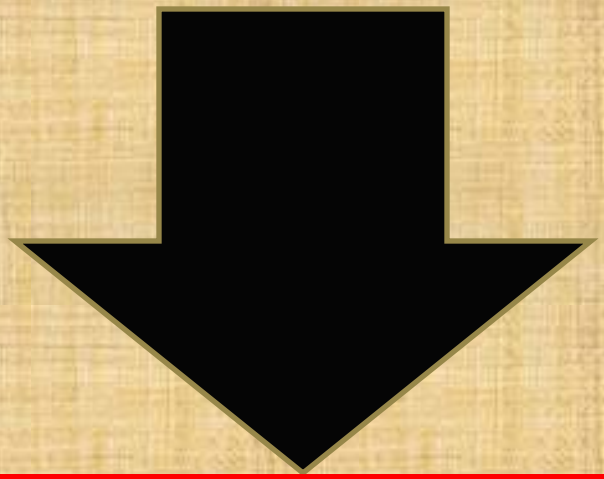
$$SU(2)_L \otimes SU(2)_R \otimes U(1)$$



$$mass \quad of \quad W_R : \quad > 1 \quad TeV$$

Standard Model

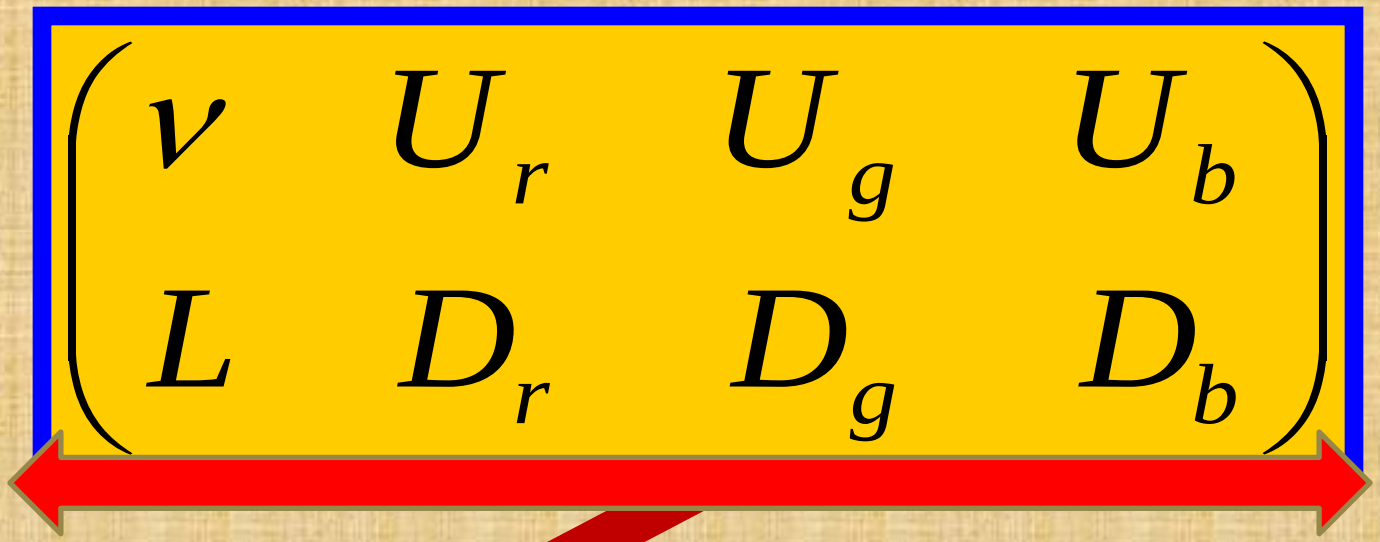
$$SU(3)_c \otimes SU(2)_L \otimes U(1)$$



$$\left(SU(3)_c \otimes U(1)\right) \otimes SU(2)_L \otimes SU(2)_R$$

$$\left(SU(3)_c \otimes U(1)\right) \otimes SU(2)_L \otimes SU(2)_R$$

$$SU(4)_{c,l} \otimes SU(2)_L \otimes SU(2)_R$$



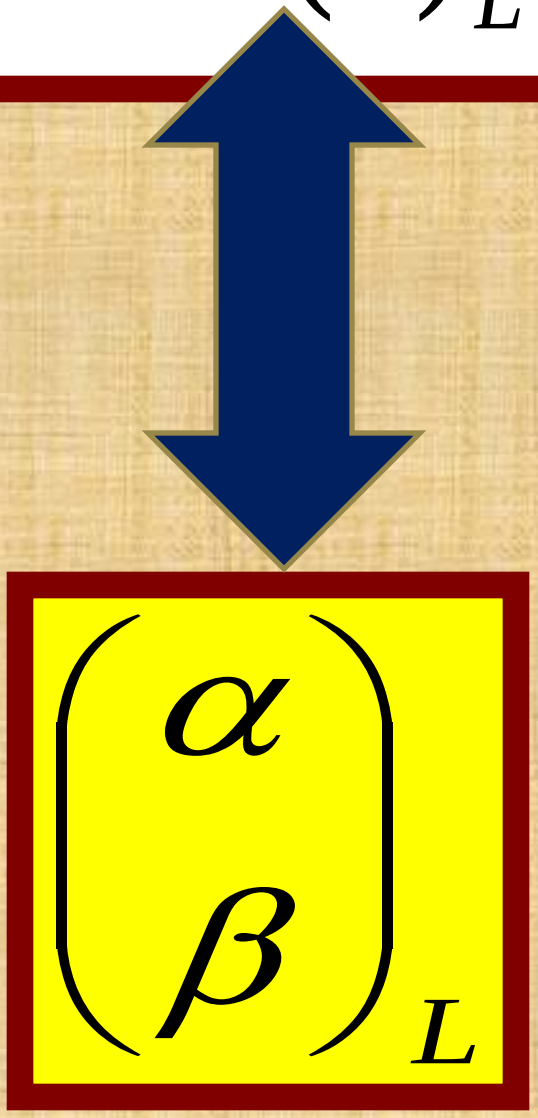
$$SU(4)_{c,l} \succ SU(3)_c \otimes U(1)$$

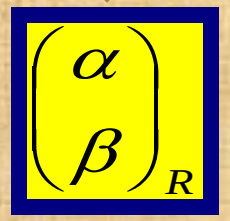
$$\begin{pmatrix} \nu & U_r & U_g & U_b \\ L & D_r & D_g & D_b \end{pmatrix}$$

4th color

J. Pati – A. Salam

$$SU(4)_{c,l} \otimes SU(2)_L \otimes SU(2)_R$$

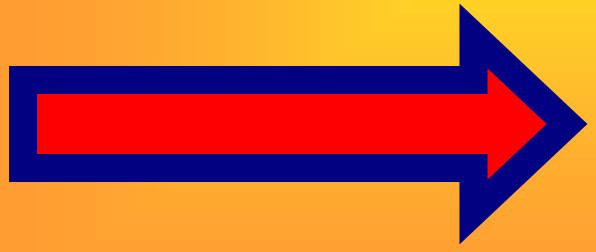




gauge group of QHD

$$SU(n)_L \otimes SU(n)_R$$

mass scale of QHD

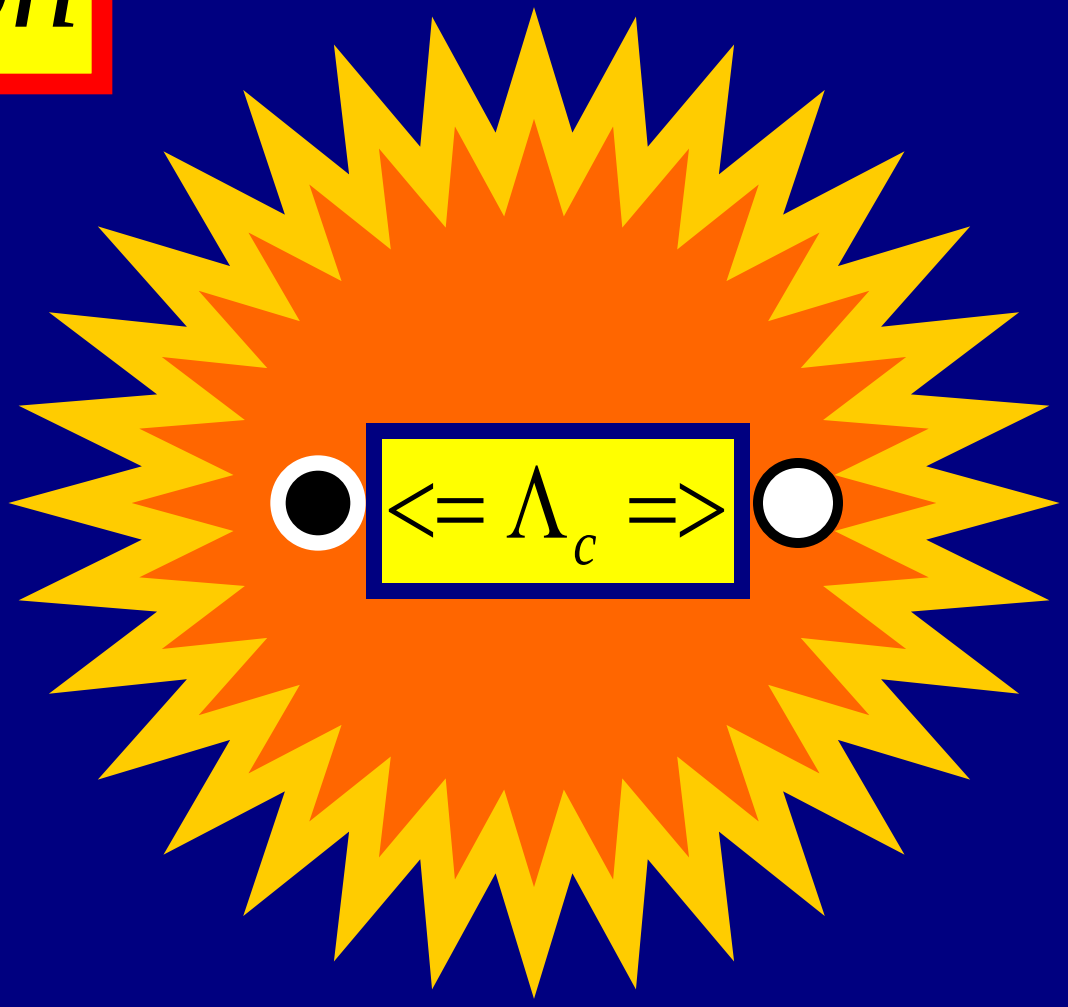


$$[\Lambda_L \quad * \quad \Lambda_R]$$

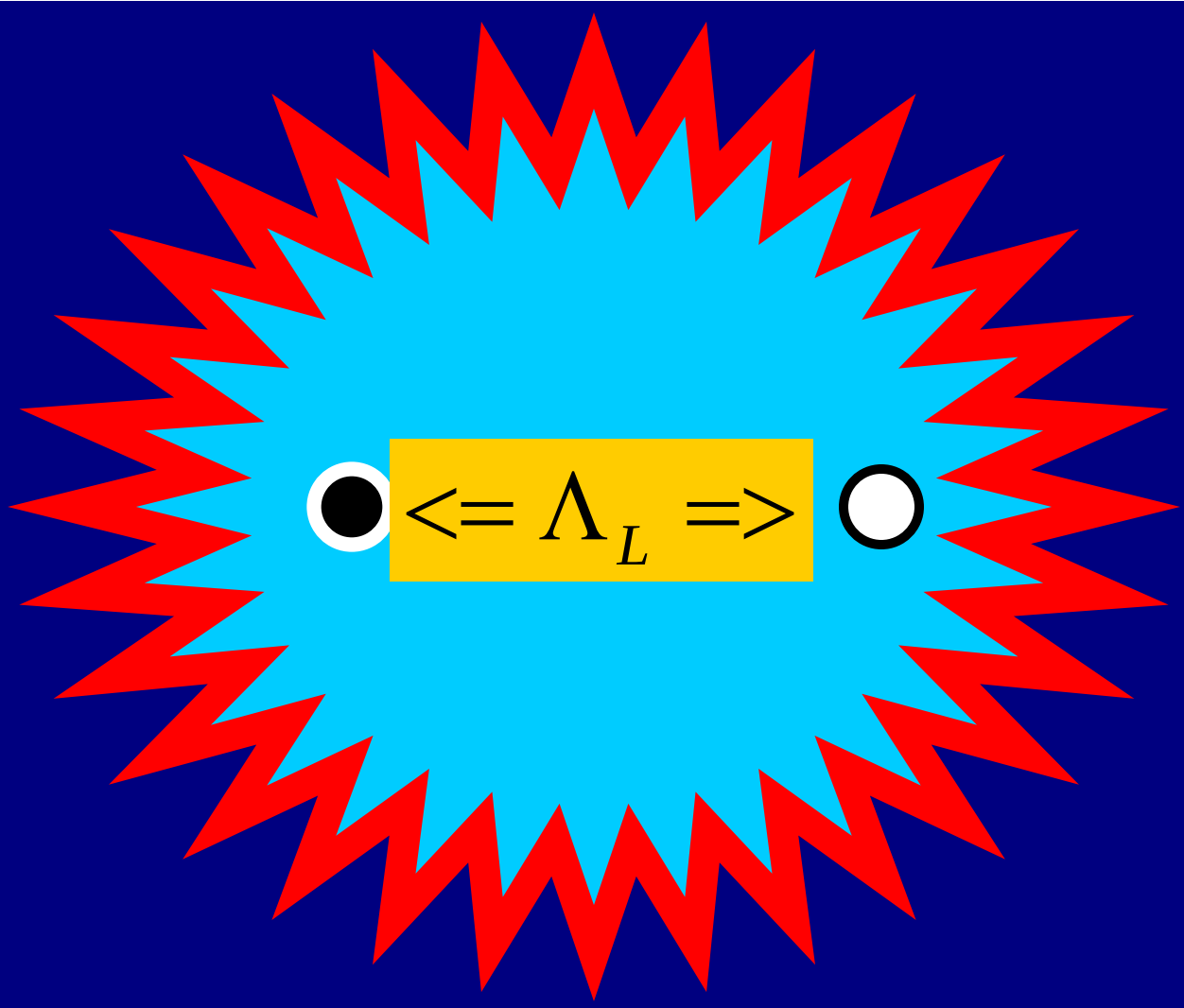
$$\Lambda_L < \Lambda_R$$

➔ parity violation

$\rho - meson$



$\Lambda_c : QCD - scale$

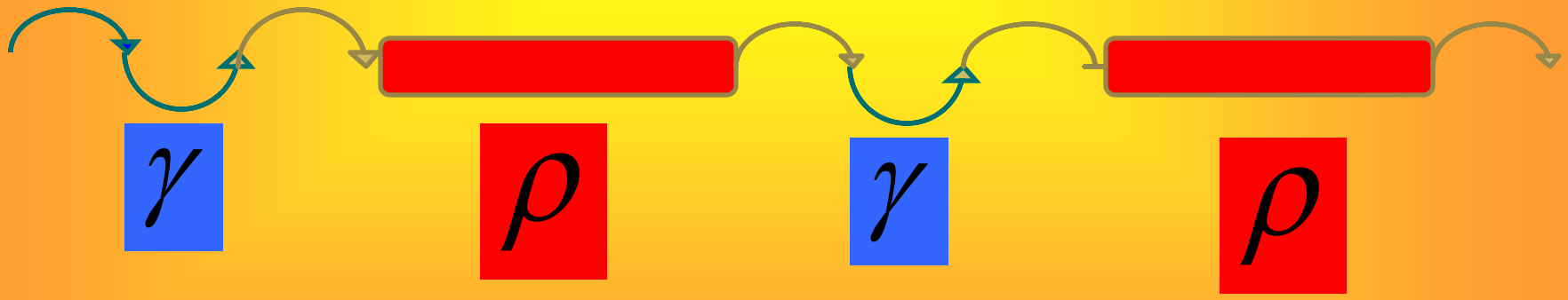


$W-boson$

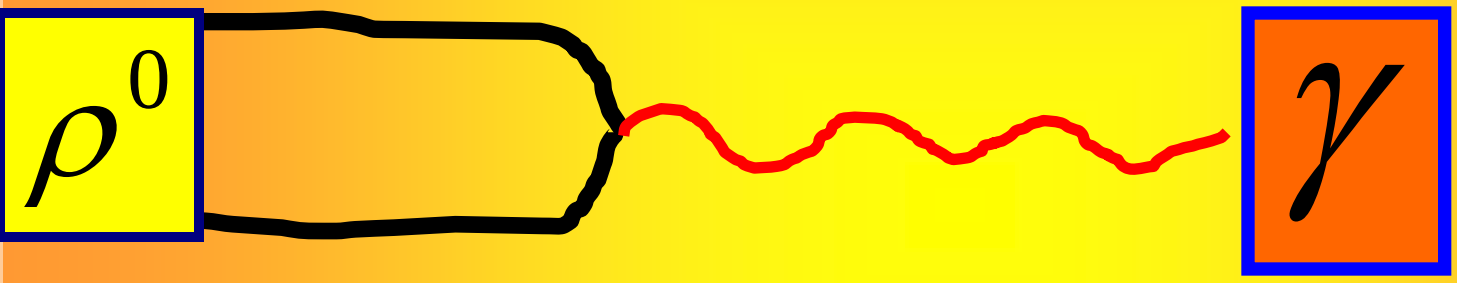
Λ_L?

QCD

Dynamical mixing of meson and photon



mixing with photon



m: mixing parameter

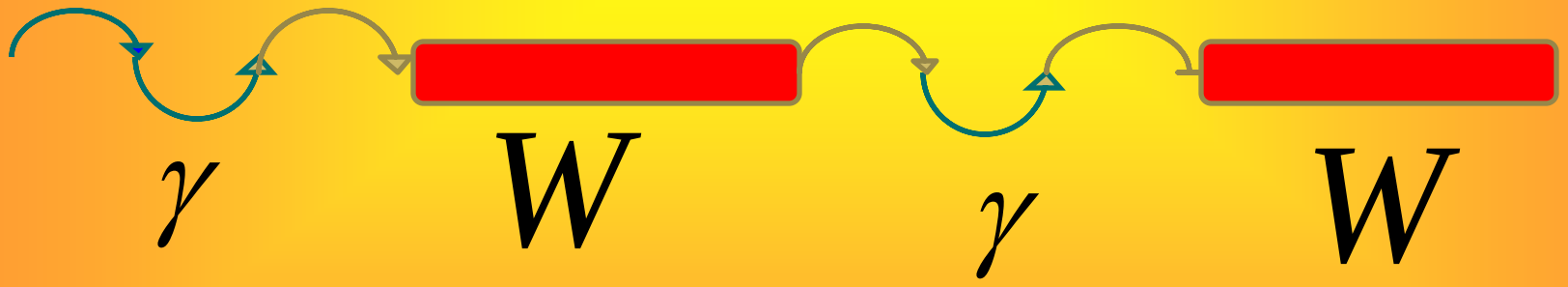
$$M_{\rho^0}^{\ 2} = \frac{M_{\rho^+}^{\ 2}}{1-m^2}$$

~ 3.1 MeV

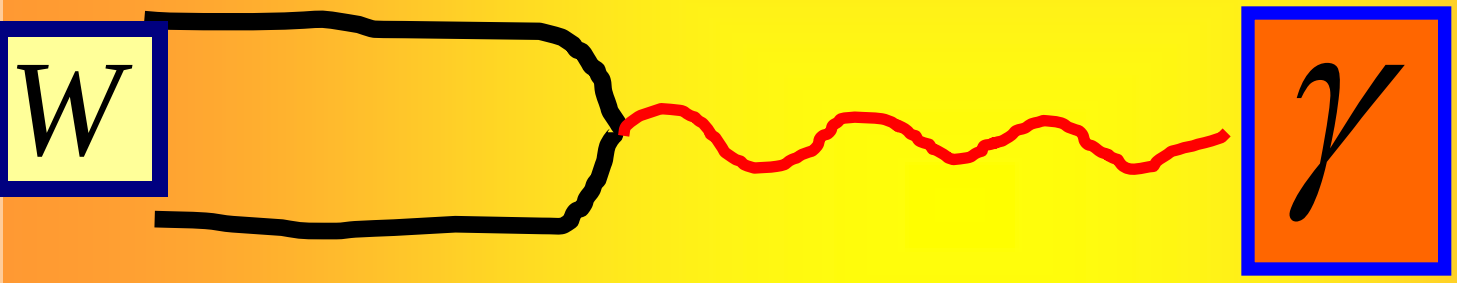
m = 0.09

QHD

Dynamical mixing of W-boson and photon



mixing of W with photon



m: mixing parameter

$$M_Z{}^2 = \frac{M_W{}^2}{1-m^2}$$

Standard Model

$$M_Z^{\,2} = \frac{M_W^{\,2}}{1 - \sin^2 \theta_w}$$

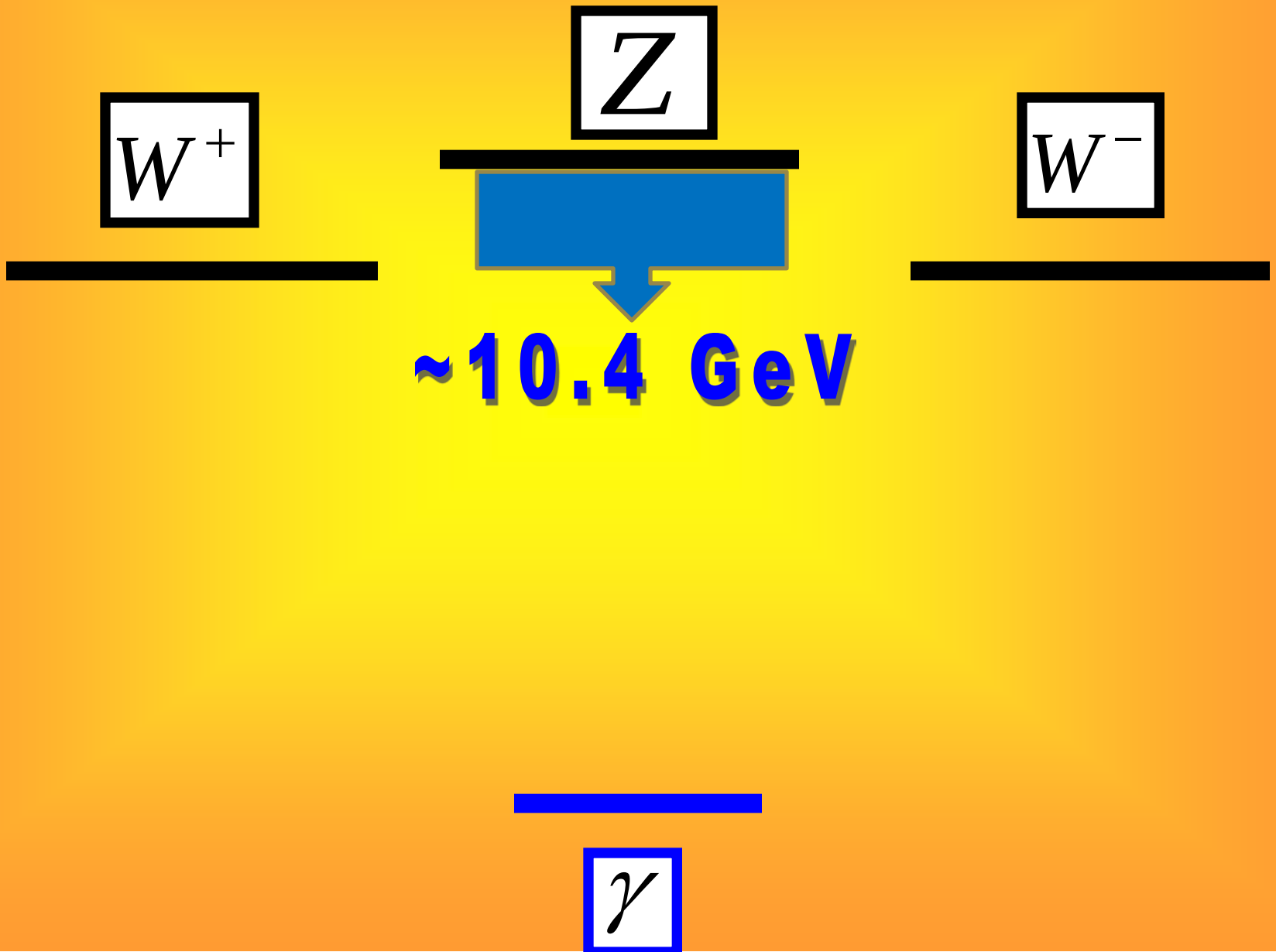
$$M_Z^{\,2} = \frac{M_W^{\,2}}{1 - m^2}$$

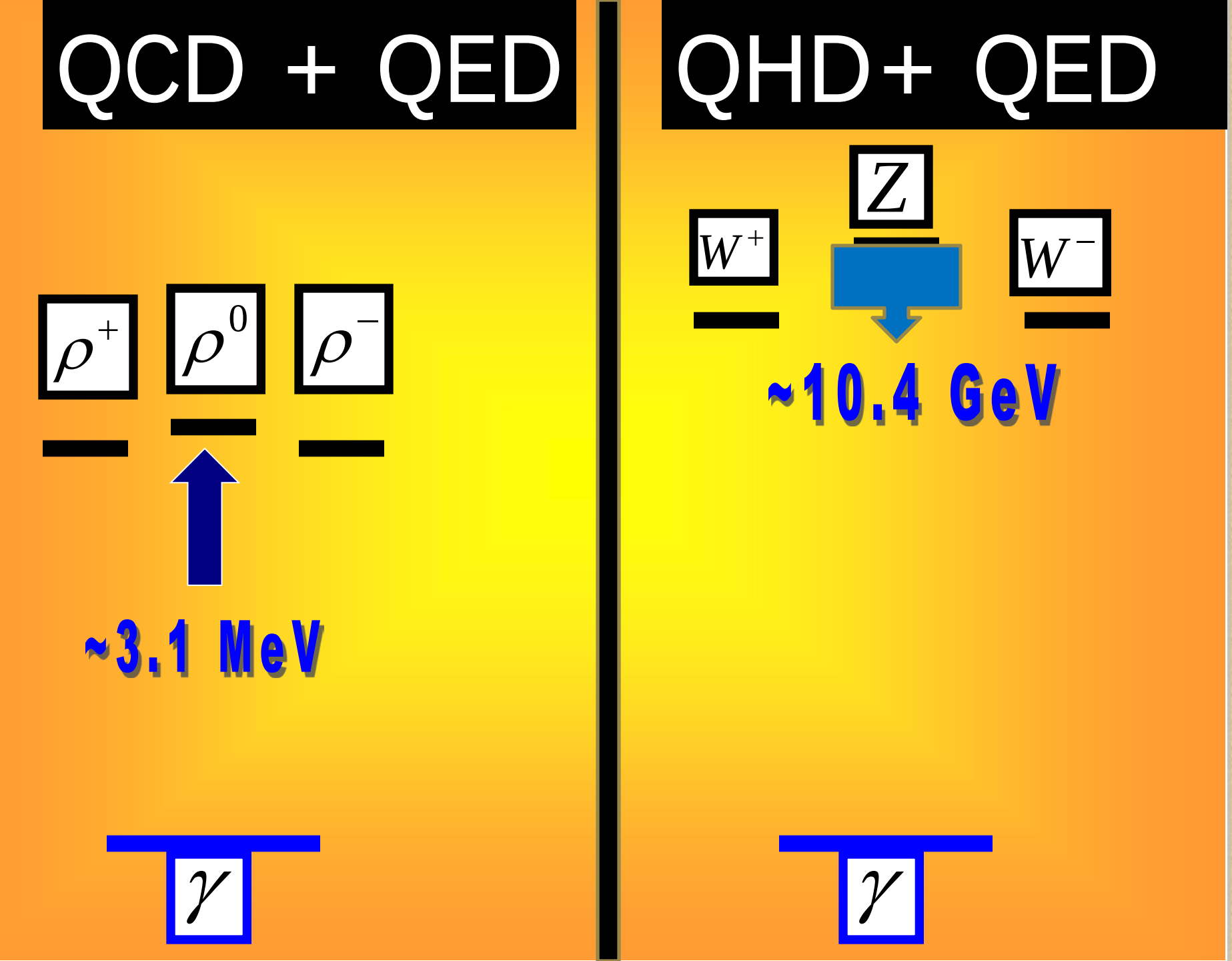
Standard Model

$$M_Z^{\,2} = \frac{M_W^{\,2}}{1 - \sin^2\theta_w}$$

$$\sin\theta_w = m \approx 0.485$$

Standard Model




QCD + QED
ρ^+
ρ^0
ρ^-
~3.1 MeV
γ
QHD+ QED
Z
W^+
W^-
~10.4 GeV
γ

W decay constant

$$\langle 0 | \frac{1}{2}(\bar{\alpha}\gamma_{\mu L}\alpha - \bar{\beta}\gamma_{\mu L}\beta) | Z \rangle = \varepsilon_{\mu} M_W F_W$$

$$m = e\frac{F_W}{M_W}$$

$$m \approx 0.485$$

$$\Rightarrow F_W \approx 125 \quad GeV$$

experimental data:

$$M_W = 80.4...GeV$$

$$M_Z = 91.19...GeV$$

$$F_W = 124.6...GeV$$

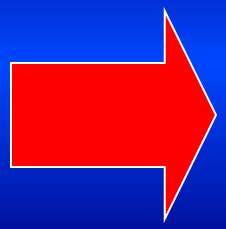
$$\sin^2 \theta_W = 0.2315$$

$$\alpha = \frac{e^2}{4\pi} \cong \frac{1}{128.9}$$

$$e \cong 0.3122$$

$$F_\rho \approx \Lambda_c \approx 220 \quad MeV$$

$$F_W \approx 0.125\_TeV$$



$$\Lambda_L$$

$$F_W \approx 0.130\_TeV$$

$$\Lambda_L \approx 0.13 \Leftrightarrow 1.0\_TeV$$

uncertainty: gauge group of QHD

$$F_W \approx 0.125\_TeV$$

$$0.12 \prec \Lambda_L \prec 1.0 \quad TeV$$

??? QHD gauge group ???

$$SU(n) \Rightarrow SU(3)$$

$$F_W \approx 0.13 \quad TeV$$

$$\Lambda_{h,L} \approx 0.13 \quad TeV$$

$$0.12 \prec \Lambda_{h,L} \prec 1.0 \quad TeV$$

$$\Lambda_{h,R} \succ\succ 1 \quad TeV$$

NEW BOSONS

New:
isoscalar

$$\frac{1}{\sqrt{2}}\left(\bar{\alpha}\alpha - \bar{\beta}\beta\right)$$

$$\frac{1}{\sqrt{2}}\left(\bar{\alpha}\alpha + \bar{\beta}\beta\right)$$

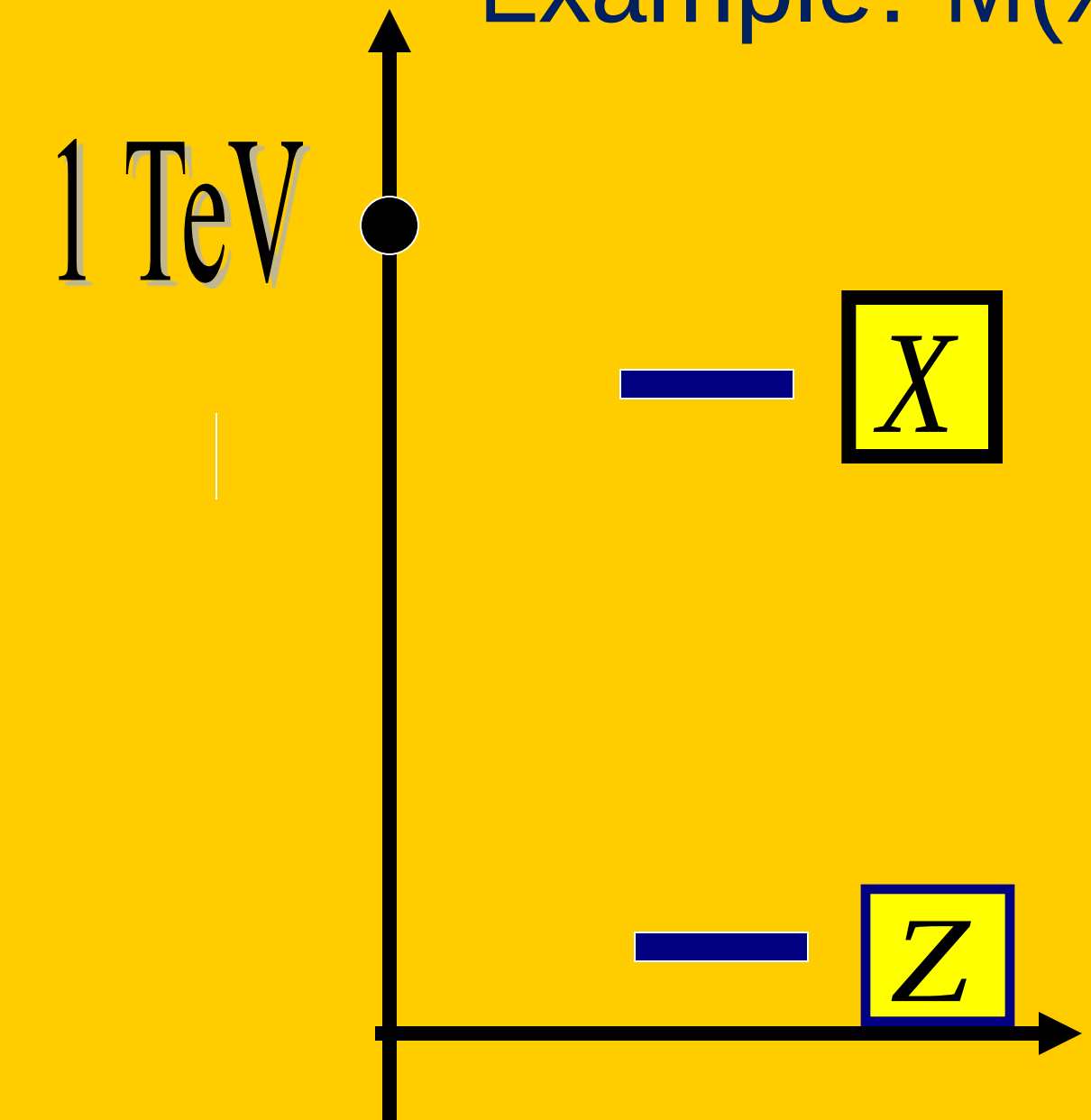
Z

X

Present lower limit on X-mass:

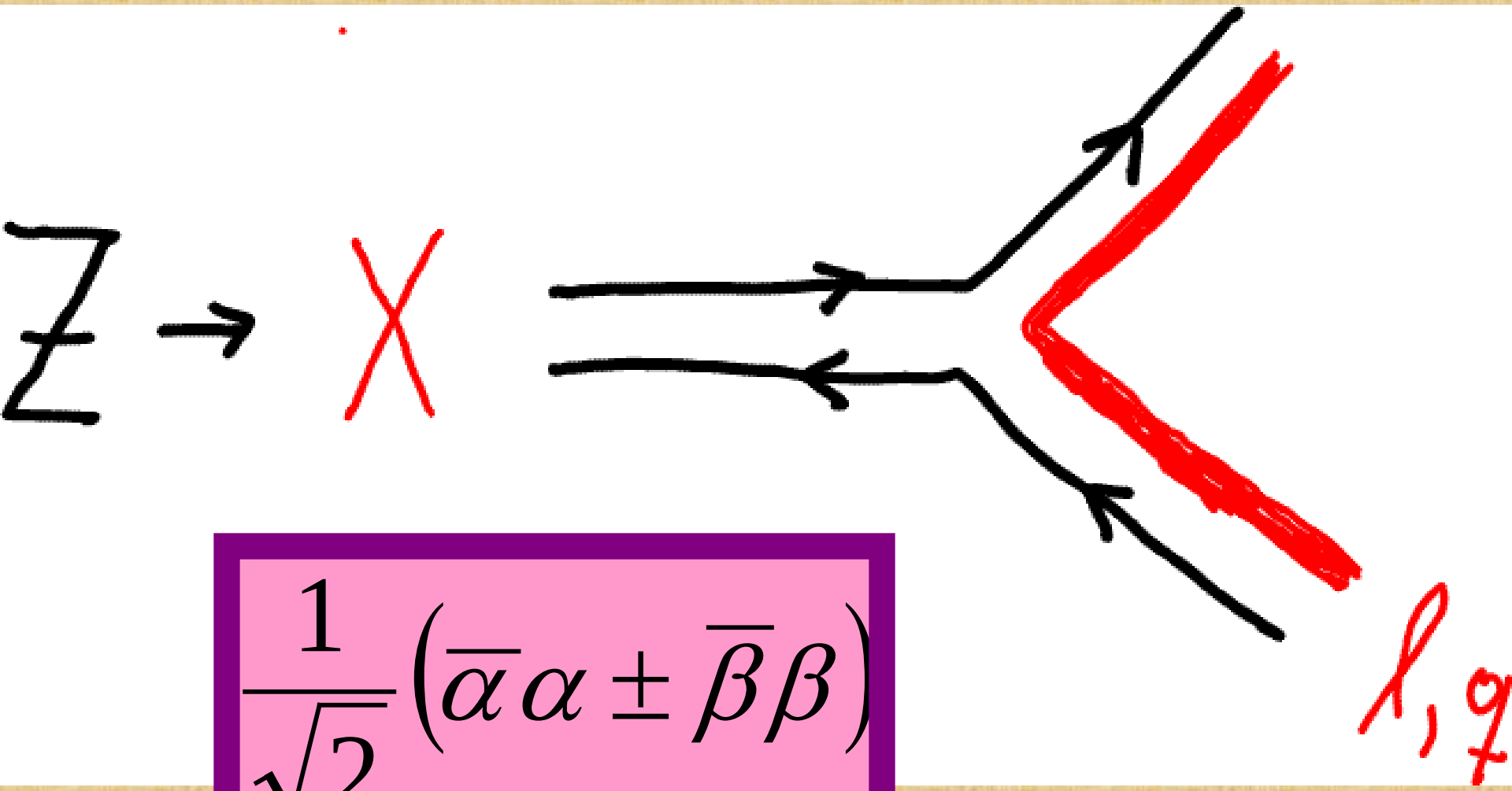
~400 GeV

Example: M(X)=0.8 TeV



Coupling of X to leptons and quarks:

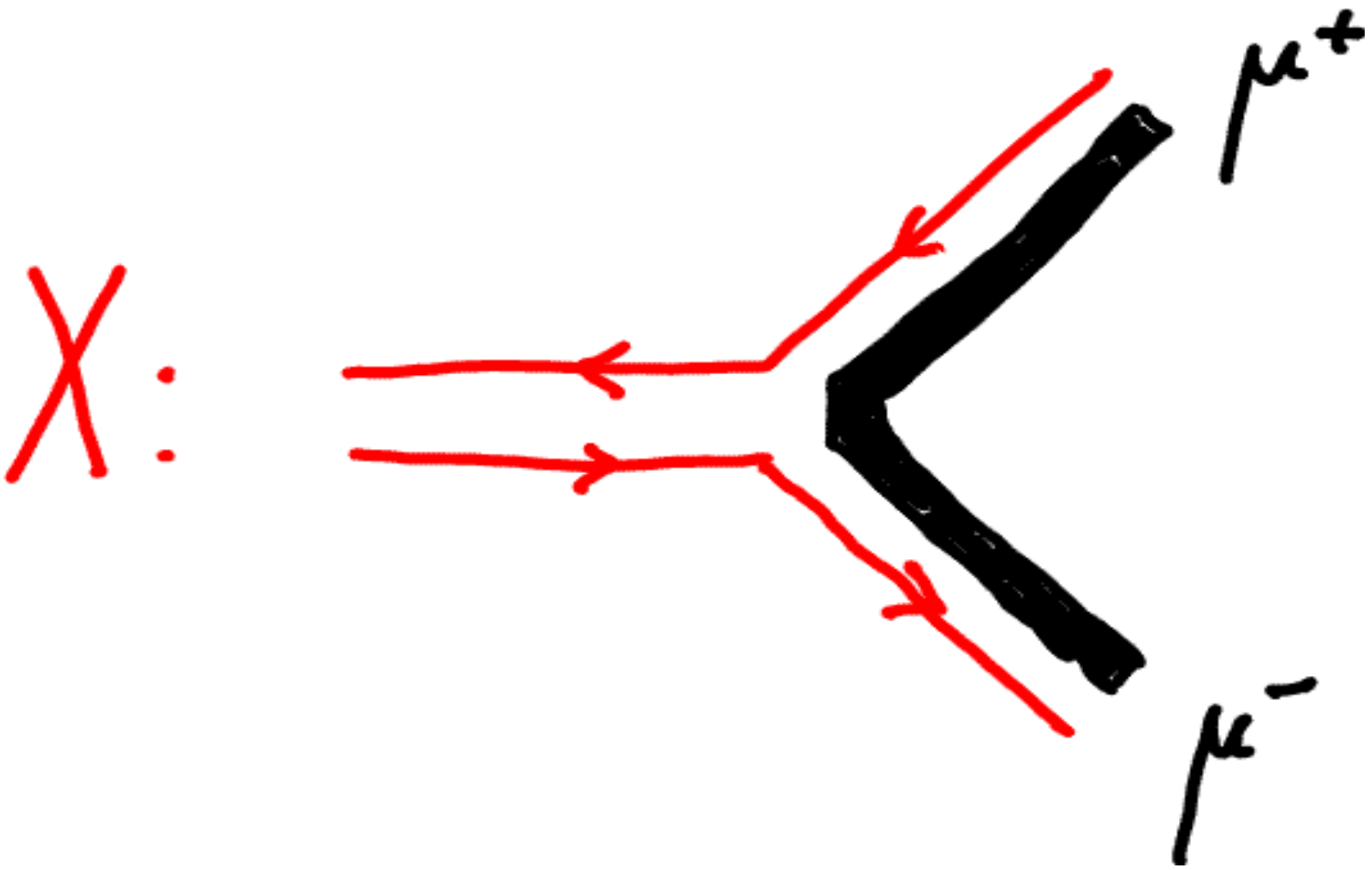
➔coupling of Z - boson



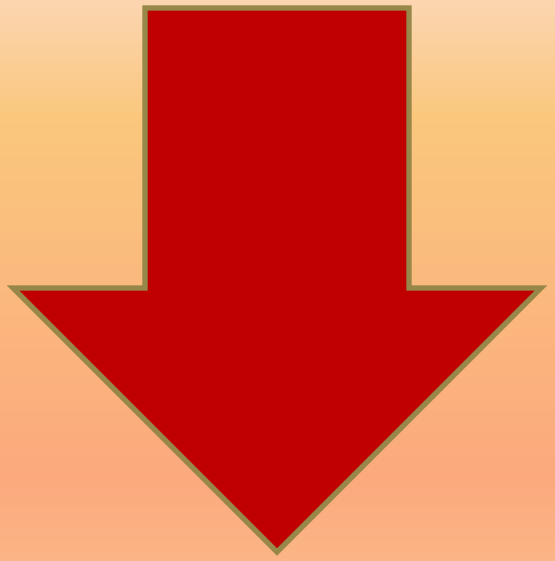
$$\frac{1}{\sqrt{2}}\left(\overline{\alpha}\alpha \pm \overline{\beta}\beta\right)$$

X – decay into muons

➔ Z – decay into muons:



$$\Gamma(Z \Rightarrow \mu^+\mu^-) \cong 84 \quad MeV$$



$$\Gamma(X \Rightarrow \mu^+\mu^-) \cong 3.6 \quad GeV$$

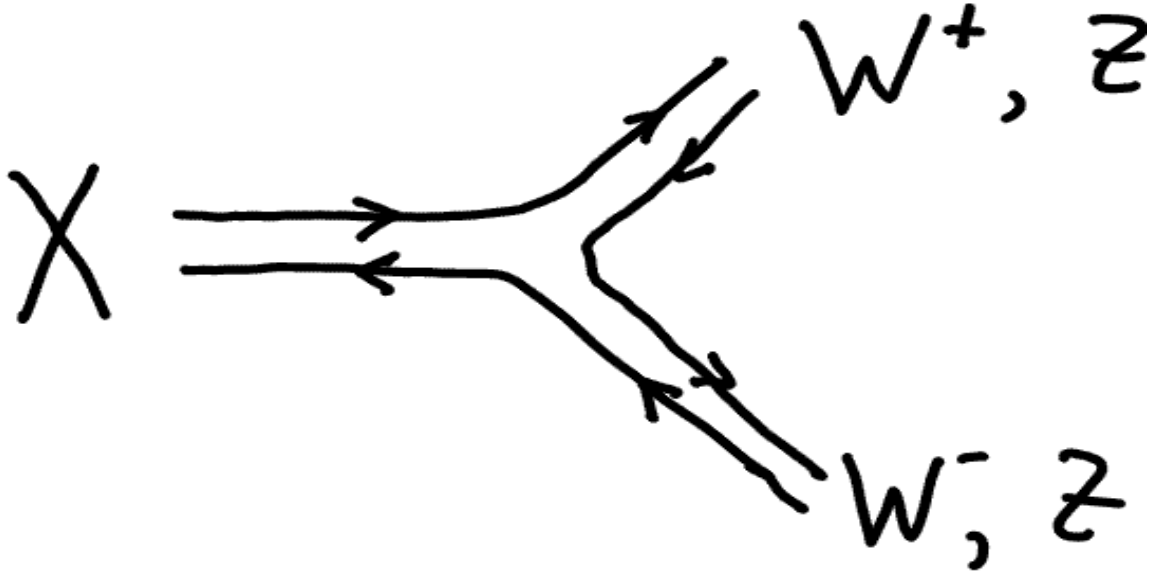
X - decays → leptons, quarks

$$\Gamma(X \to \mu^+\mu^-) \cong \Gamma(X \to e^+e^-)$$

$$\cong \Gamma(X \to \bar{\nu}_e \nu_e)$$

$$\Gamma(X \to \bar{u}u) \cong \Gamma(X \to \bar{d}d)$$

$$\cong 3 \times \Gamma(X \to \mu^+\mu^-)$$



Expected:

$$\Gamma(X \to W^+W^-) \geq \Gamma(X \to ZZ)$$

$$\Gamma(X \to \mu^+\mu^-)$$

Summation

Total width of X:

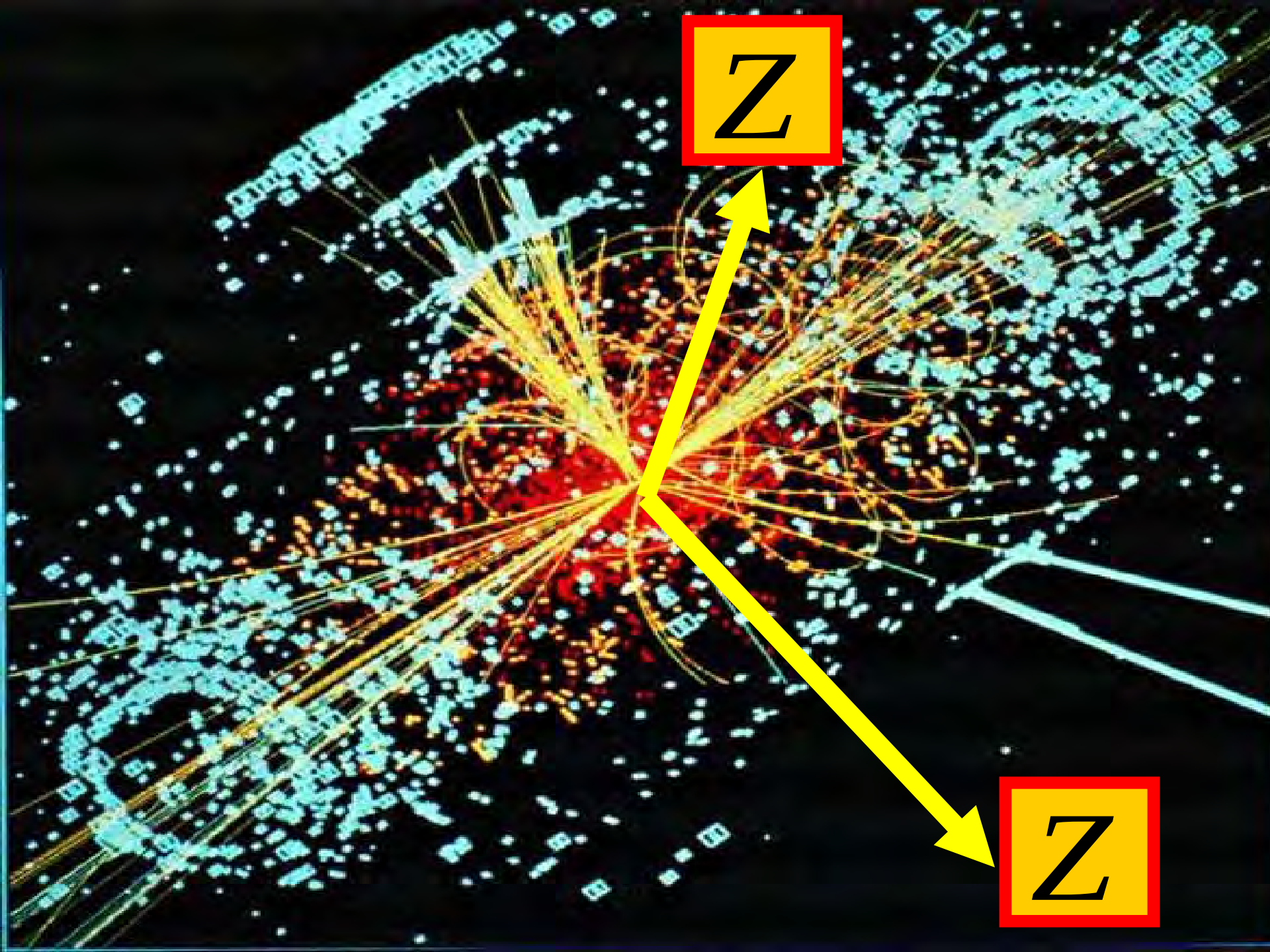
$\geq$ 200 GeV

Total width of Z:
2.5 GeV

Discovery of X-boson:

search for decay into weak bosons

$$X \Rightarrow Z + Z$$


Z
Z

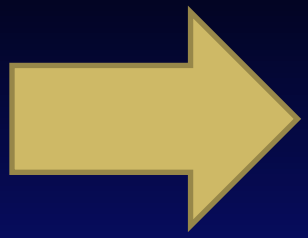
$$\Lambda_c \approx 0.3...GeV$$

complexities

of

strong interactions

~ 1 GeV



$$\Lambda_h \propto 0.3\_TeV$$
$$= 1000 \cdot \Lambda_c$$

complexities

of

QHD interactions

~ 1 TeV

EXCITED WEAK BOSONS

$I(J)$

$I : SU(2)$

$J :$ *angular momentum*

p-wave bosons

three SU(2) singlets

$$S = \frac{1}{\sqrt{2}}\left(\overline{\alpha}\alpha + \overline{\beta}\beta\right)$$

S(0) = 0 (0)

S(1) = 0 (1)

S(2) = 0 (2)

p-wave bosons

three SU(2) triplets

$$T^{+} = \overline{\beta}\alpha \qquad T^{-} = \overline{\alpha}\beta \qquad T^{0} = \frac{1}{\sqrt{2}}\left(\overline{\alpha}\alpha - \overline{\beta}\beta\right)$$

T(0) = 1 (0)

T(1) = 1 (1)

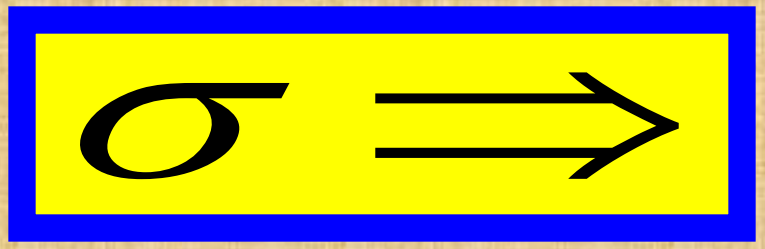
T(2) = 1 (2)

p-wave mesons (QCD)

scalar : $\sigma(\sim 700)$

vector : $h_1(1170)$

tensor : $f_2(1270)$

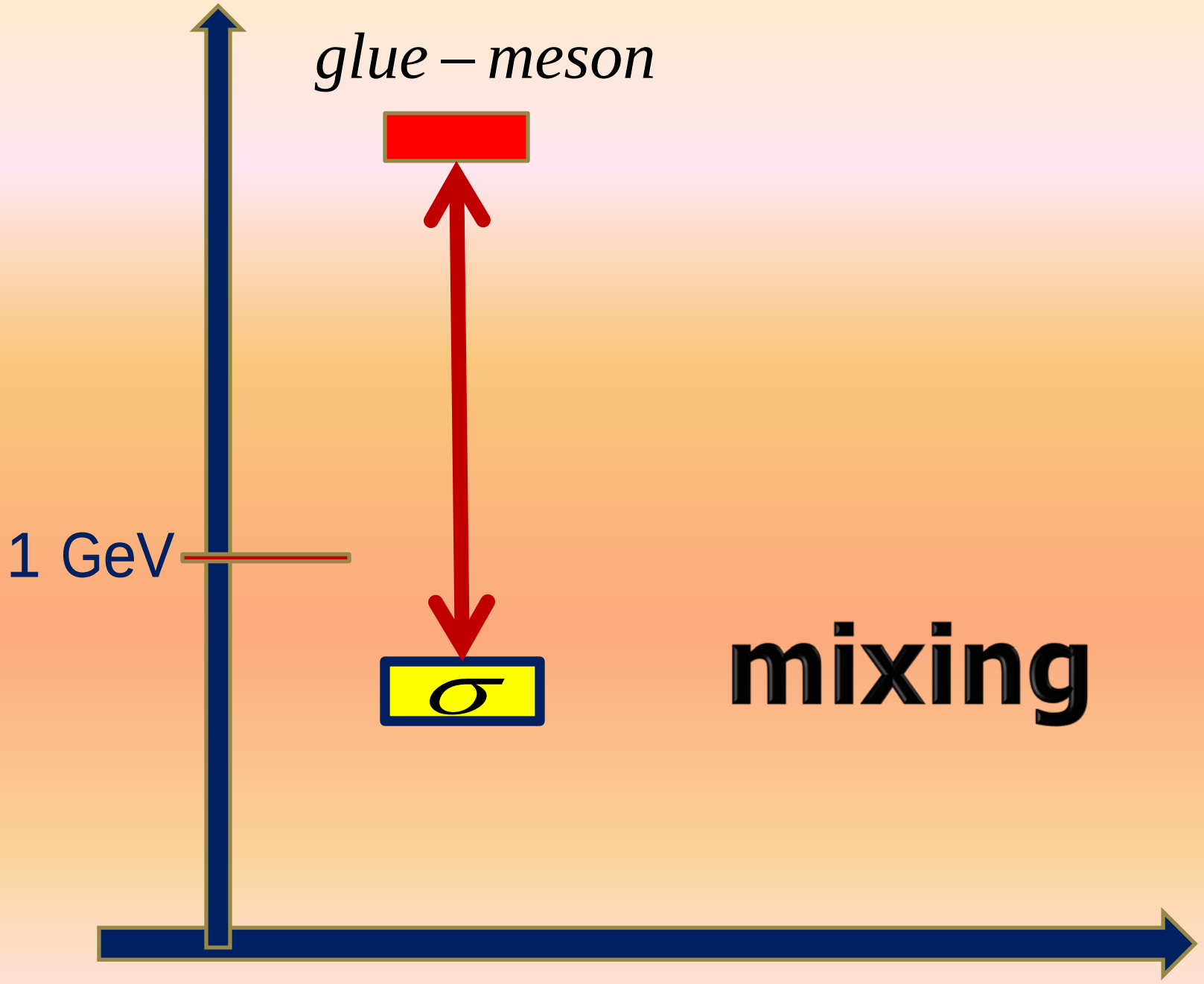


strong mixing

with

glue mesons

=> low mass

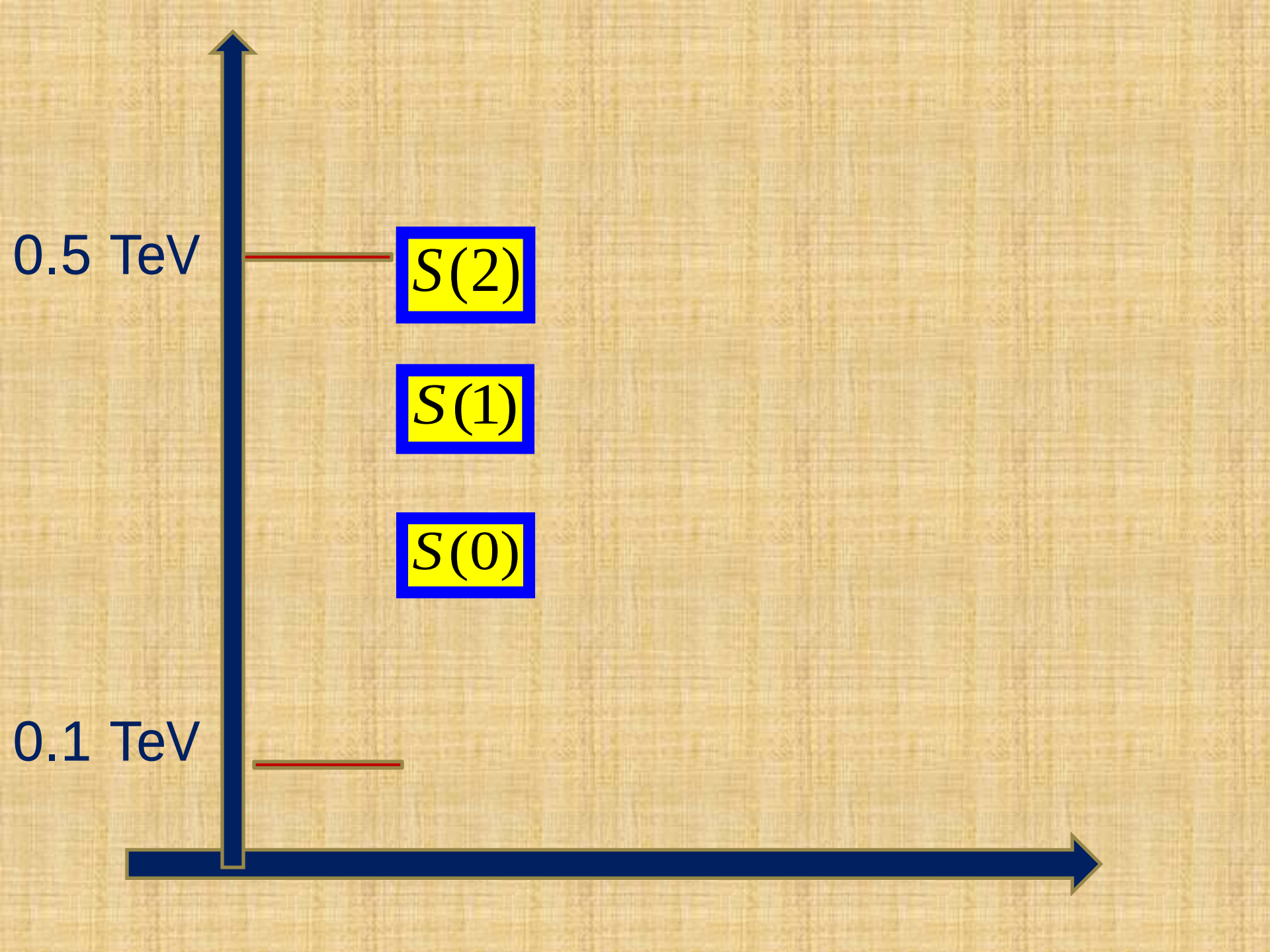

glue – meson
1 GeV
σ
mixing

analogy

$$\sigma(\sim 700) \quad \Rightarrow \quad S(0)$$

$$h_1(1170) \quad \Rightarrow \quad S(1)$$

$$f_2(1270) \quad \Rightarrow \quad S(2)$$


0.5 TeV
$S(2)$
$S(1)$
$S(0)$
0.1 TeV

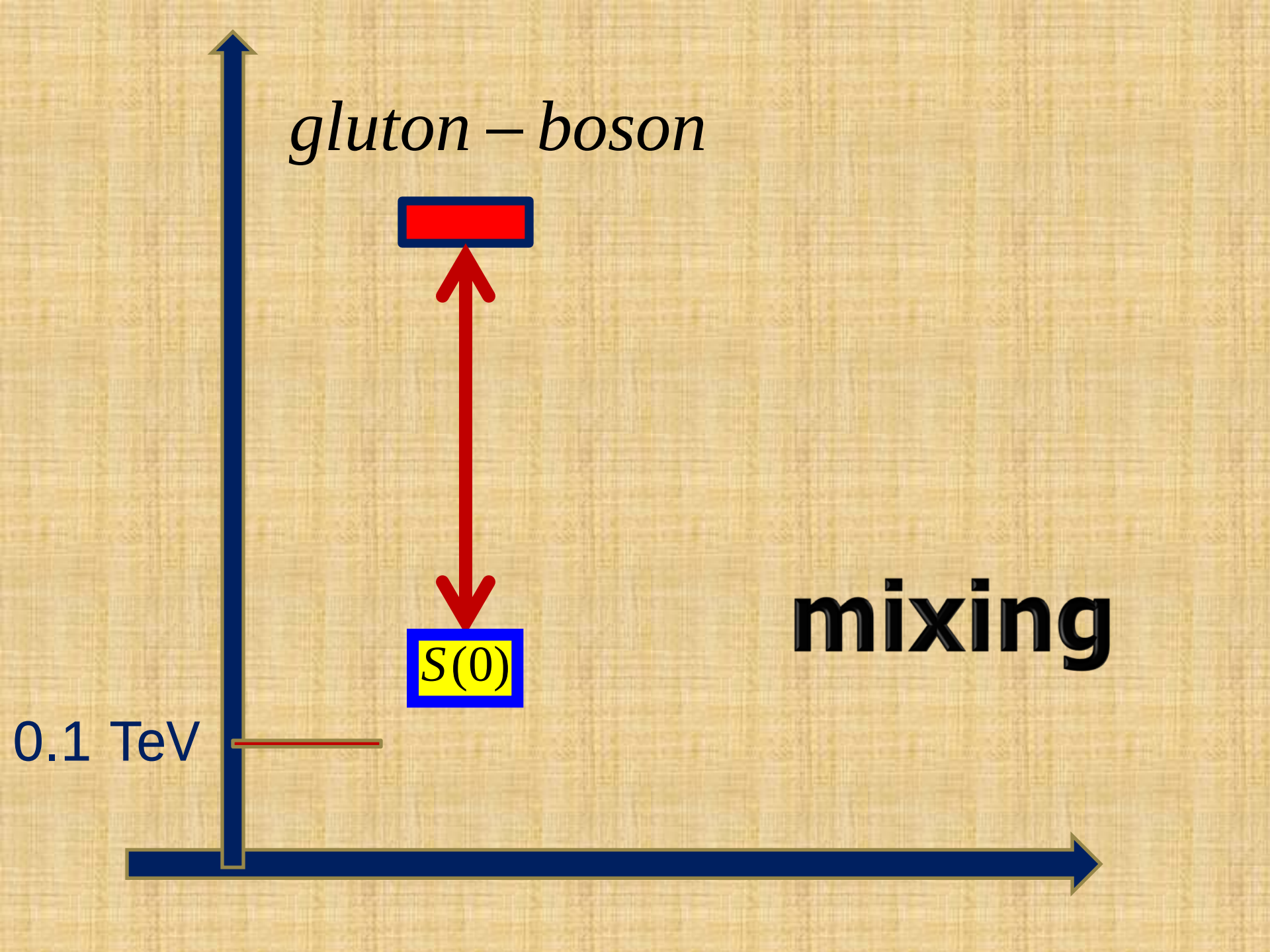
S(0)

strong mixing

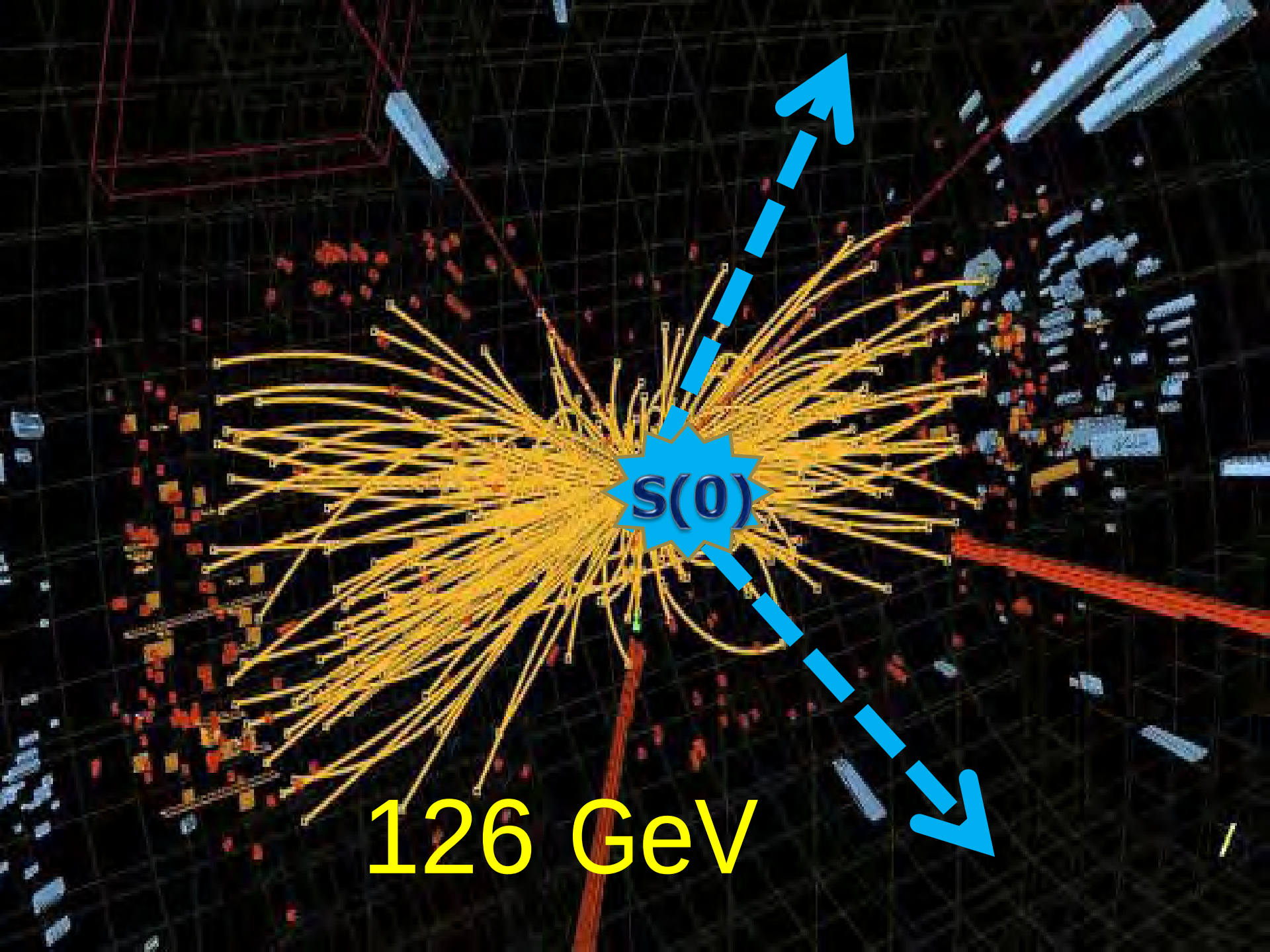
with

gluton bosons

=> low mass


gluton – boson
S(0)
mixing
0.1 TeV


S(0)
LHC
? 126 GeV ?


S(0)
126 GeV

isospin triplets in QCD

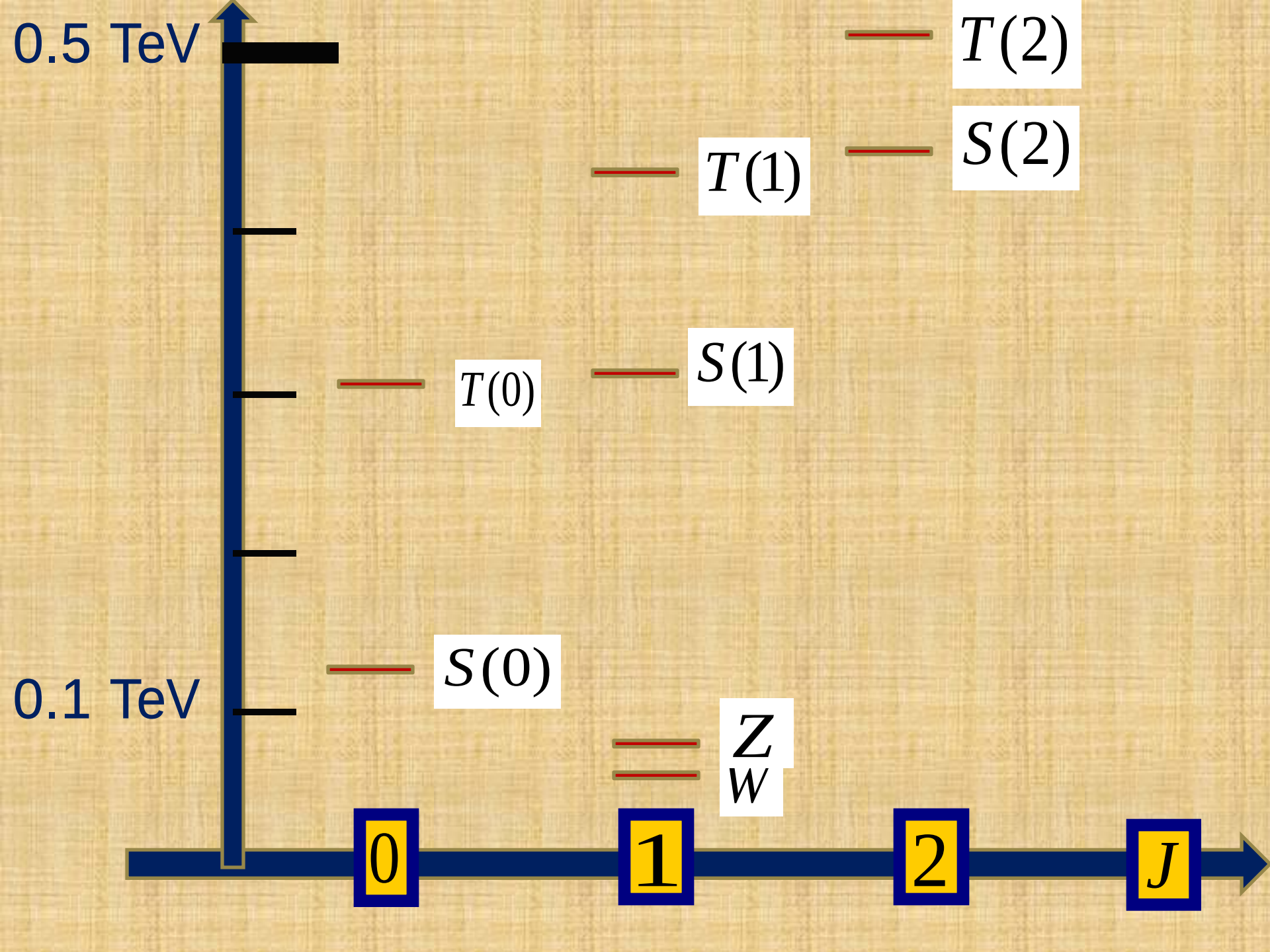
scalar :	$a_0(980)$
vector :	$b_1(1235)$
tensor :	$f_2(1270)$

analogy

$$a_0(980) \quad \Rightarrow \quad T(0)$$

$$b_1(1235) \quad \Rightarrow \quad T(1)$$

$$f_2(1270 \quad \Rightarrow \quad T(2)$$


0.5 TeV
0.1 TeV
$T(2)$
$S(2)$
$T(1)$
$S(1)$
$T(0)$
$S(0)$
Z
W
0
1
2
J

$$W^3 \Rightarrow 0.77..Z + 0.23..\gamma$$

$$S(0) \Rightarrow W^+ + W^- \quad 100\%$$

$$S(0) \Rightarrow Z + Z \quad 59\%$$

$$S(0) \Rightarrow Z + \gamma \quad 36\%$$

$$S(0) \Rightarrow \gamma + \gamma \quad 5\%$$

S(0) = decays

$$S(0) \Rightarrow "W^+"+W^-$$

$$S(0) \Rightarrow W^+ + "W^-"$$

$$S(0) \Rightarrow "Z"+Z$$

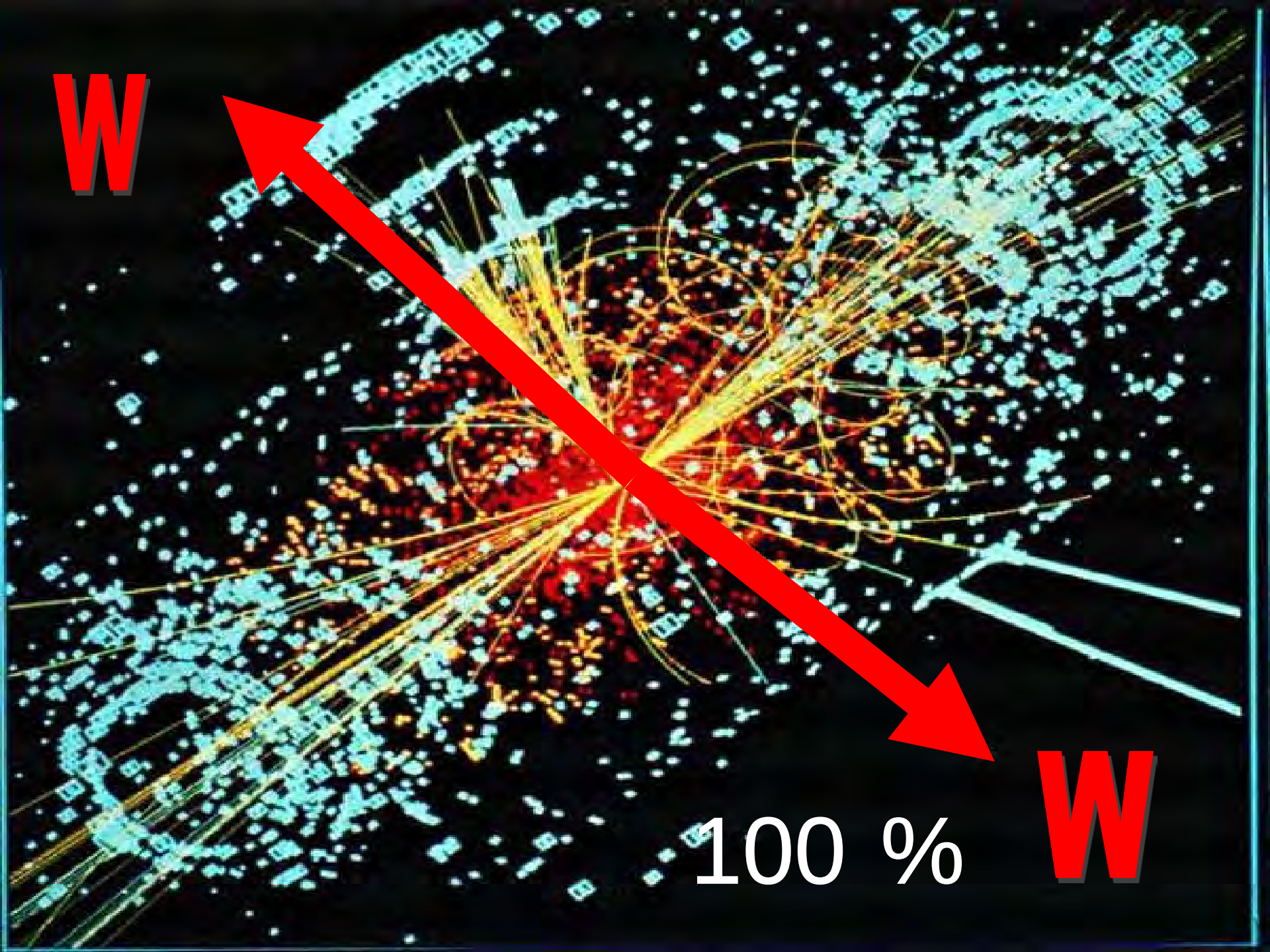
$"Z" \Rightarrow$ *virtual* Z

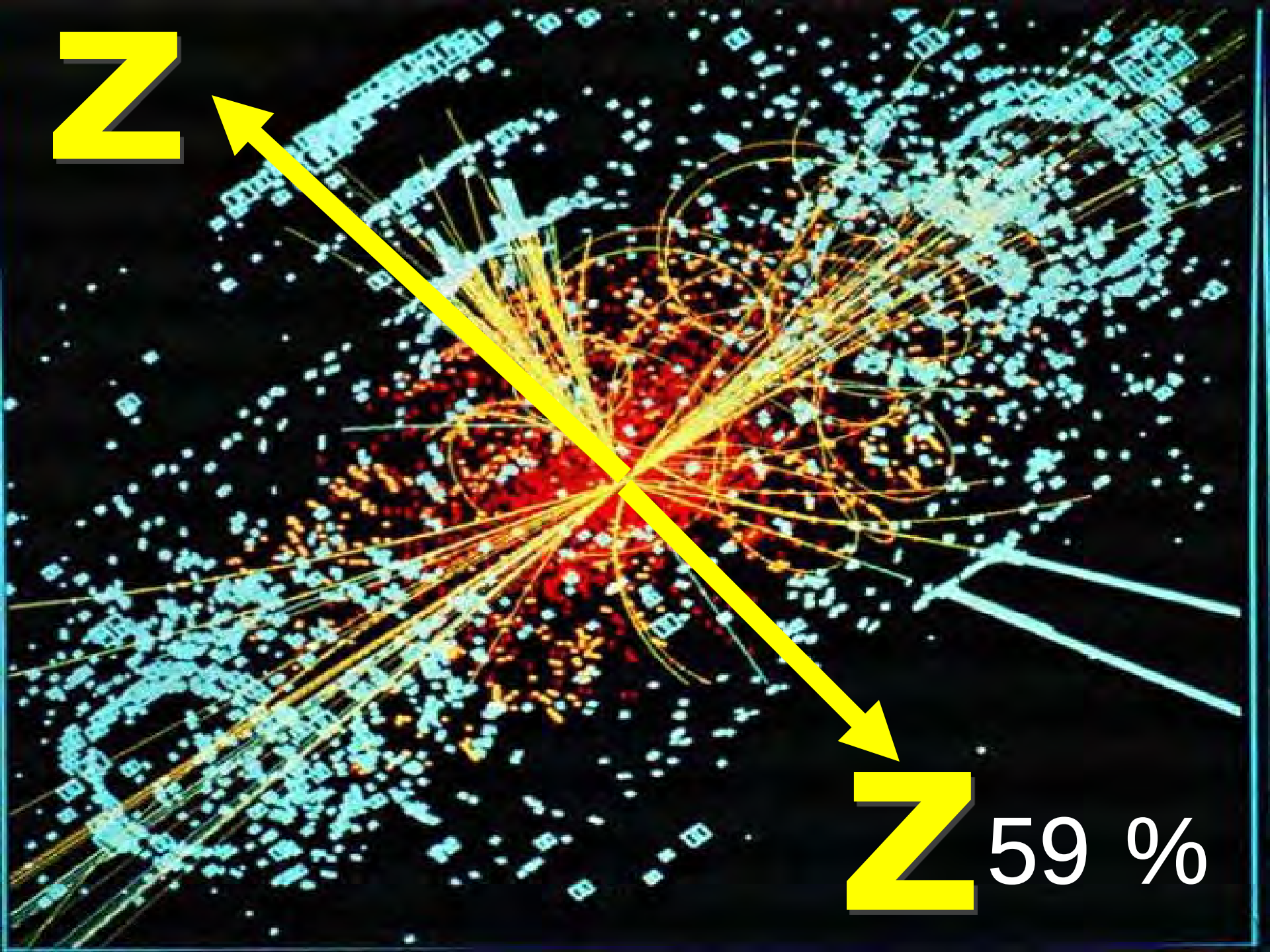
$$S(0) \Rightarrow W^{+} + W^{-}$$

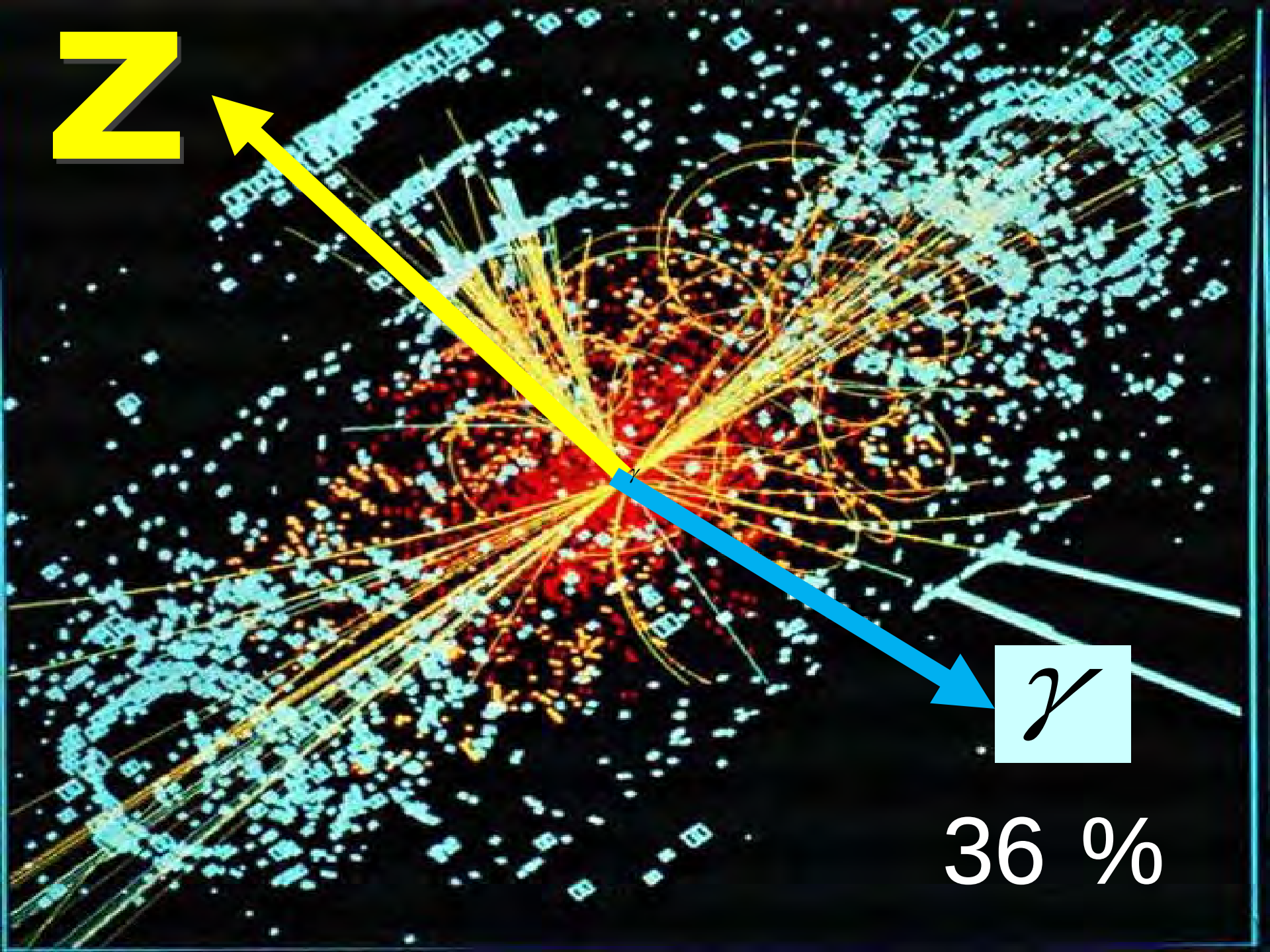
$$S(0) \Rightarrow W^{-} + W^{+}$$

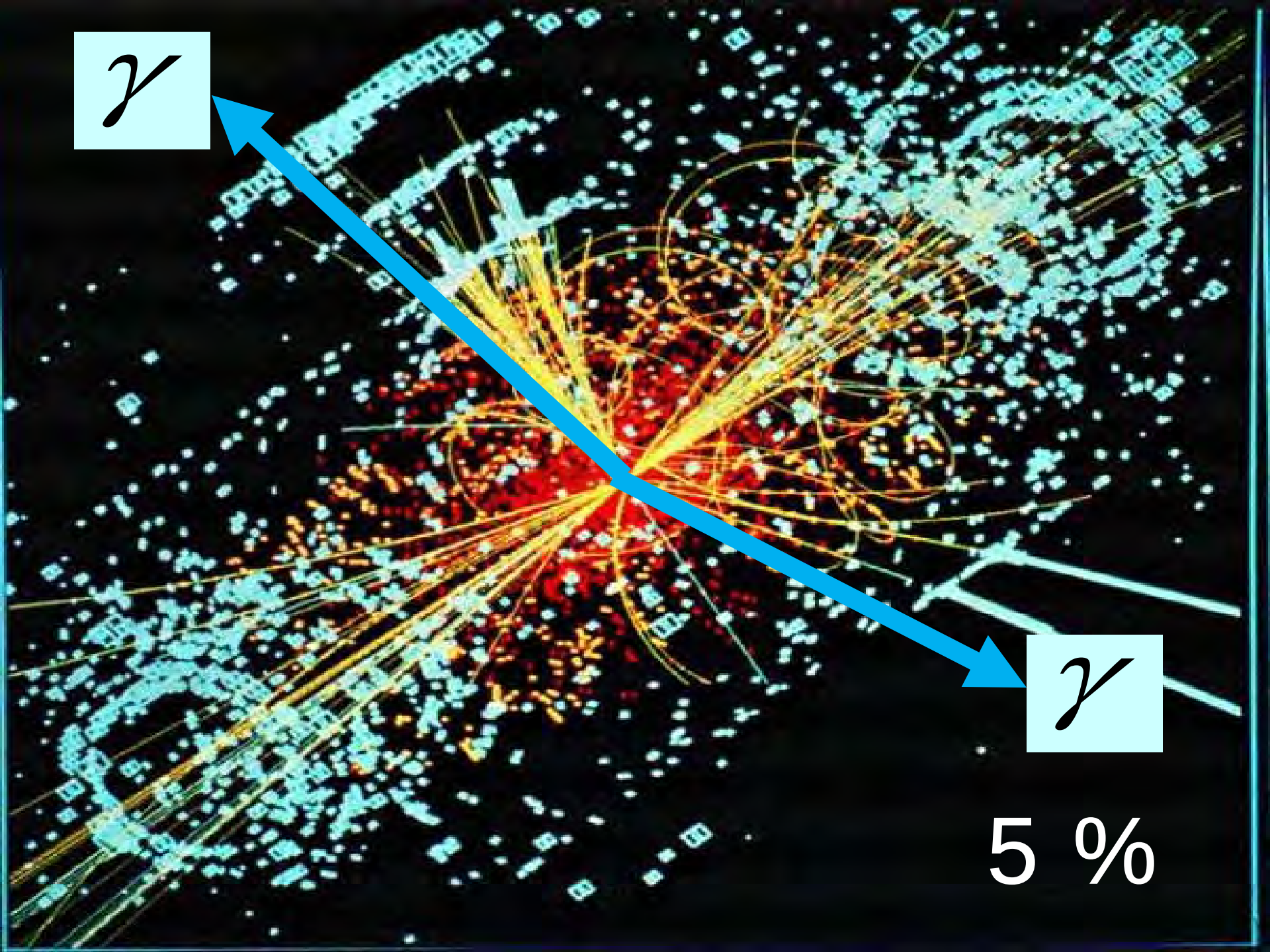
$$S(0) \Rightarrow W^{3} + W^{3}$$

$$W^{3} = \cos\theta_{w} Z + \sin\theta_{w} \gamma$$


W
100 %
W


Z
Z
59 %


Z
γ
36 %


γ
γ
5 %

Experiment

$$\frac{S(0) \Rightarrow \gamma + \gamma}{S(0) \Rightarrow W^{+} + W^{-}} \approx 0.04 \pm 0.015$$

Expected < S(0): 0.05

„Higgs“ -boson

$$\frac{H \Rightarrow \gamma + \gamma}{H \Rightarrow W^{+} + W^{-}} \approx 0.015$$

126 GeV „Higgs“ boson

decay into leptons

electrons : muon : tauons

0.00002 : 1 : 286

126 GeV

S(0)

electrons : muon : tauons

1 : 1 : 1

decays of S(1) M= 320 Gev

$$S(1) \Rightarrow W^+ + W^-$$

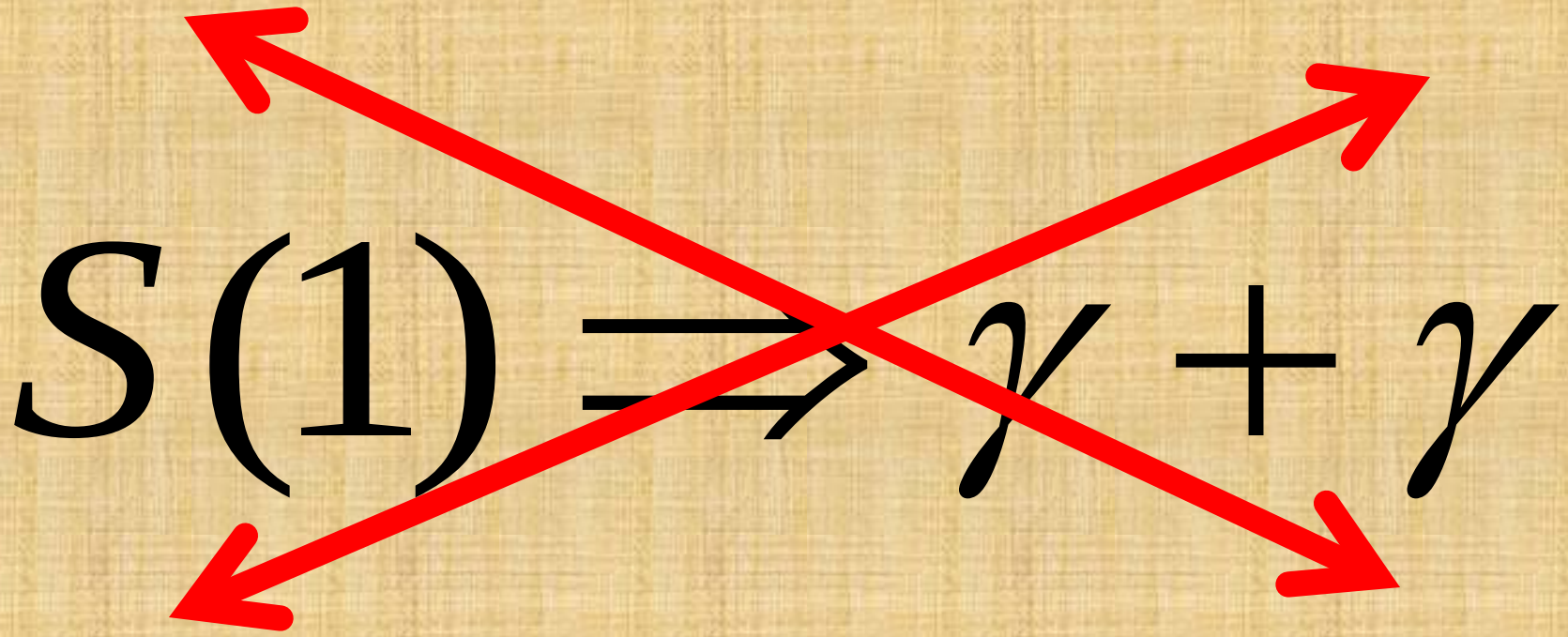
$$S(1) \Rightarrow Z + Z$$

$$S(1) \Rightarrow Z + Z + \gamma$$

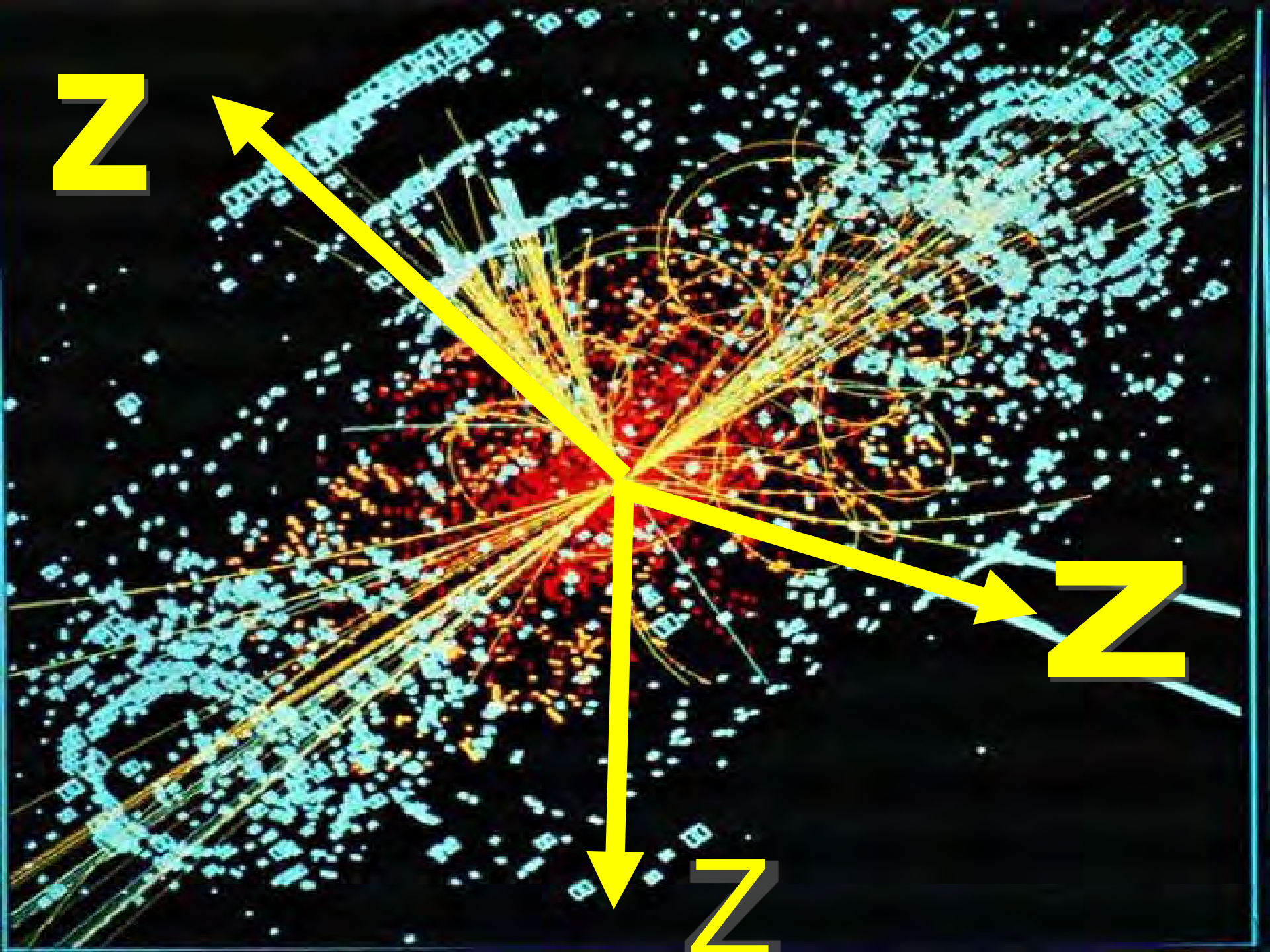
$$S(1) \Rightarrow Z + Z + Z$$

$$S(1) \Rightarrow Z + \gamma + \gamma$$

$$S(1) \Rightarrow \gamma + \gamma + \gamma$$



Landau-Yang-Theorem


Z
Z
Z

three

lepton-quark

families

$$\begin{pmatrix} \nu_e & u & u & u \\ e^- & d & d & d \end{pmatrix}$$

$$\begin{pmatrix} \nu_\mu & c & c & c \\ \mu^- & s & s & s \end{pmatrix}$$

$$\begin{pmatrix} \nu_\tau & t & t & t \\ \tau^- & b & b & b \end{pmatrix}$$

24

? fundamental ?

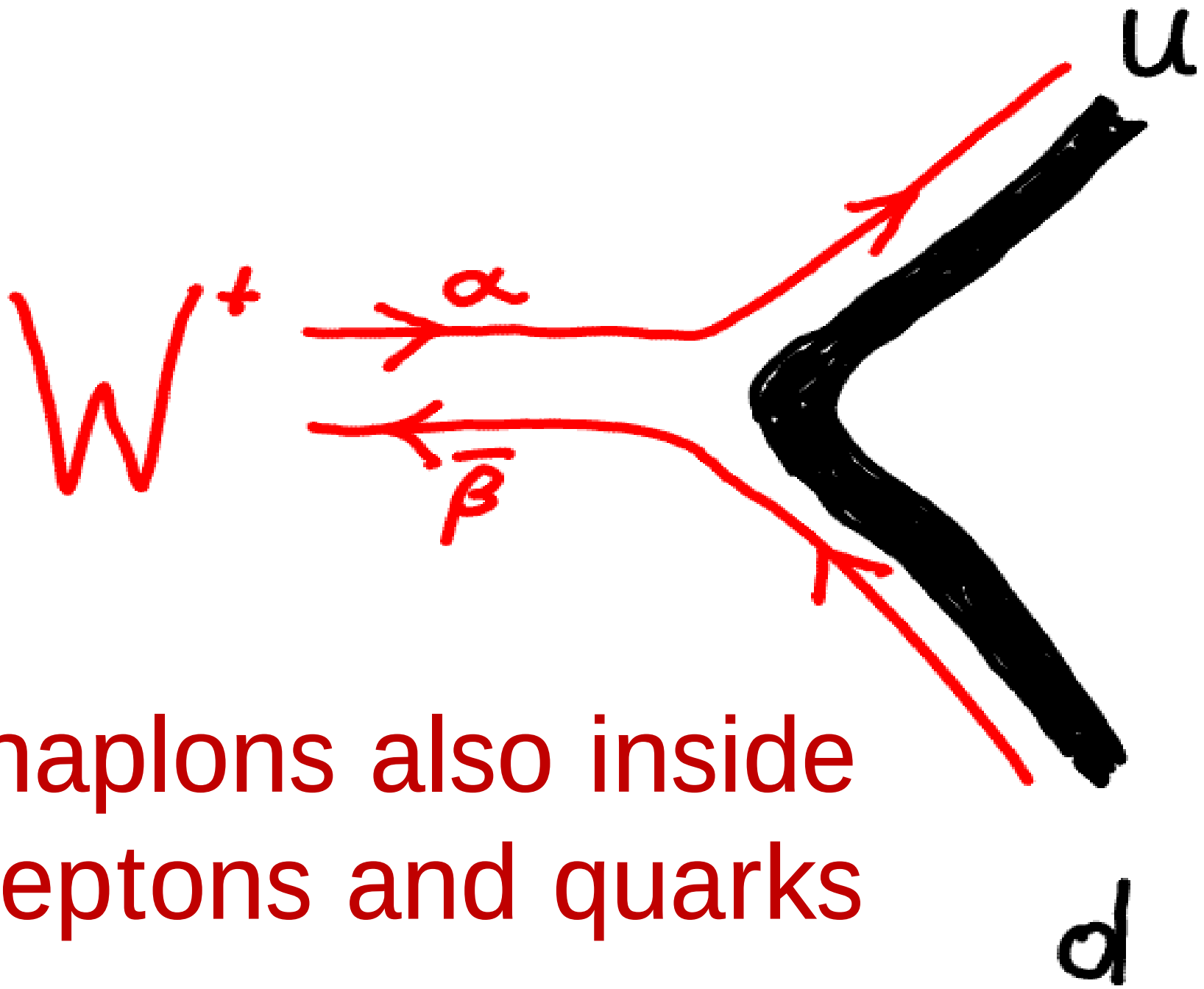
fermions

? 12 masses ?

? 10 mixing parameter ?

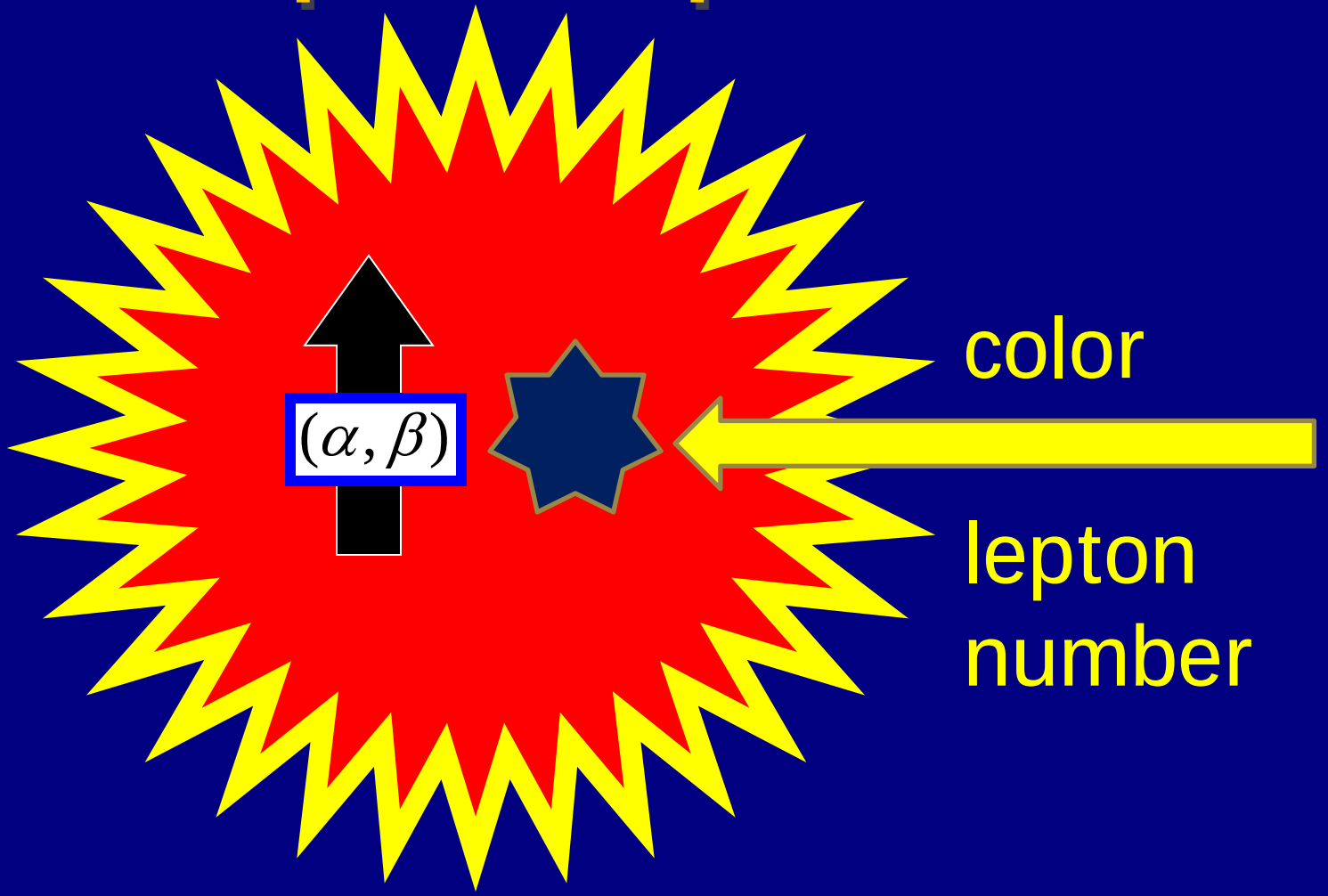
leptons and quarks

➔composite



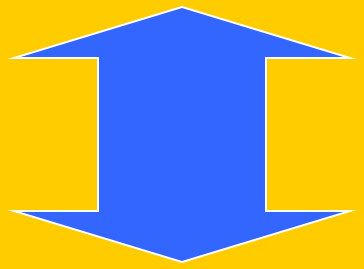
haplons also inside
leptons and quarks

leptons - quarks



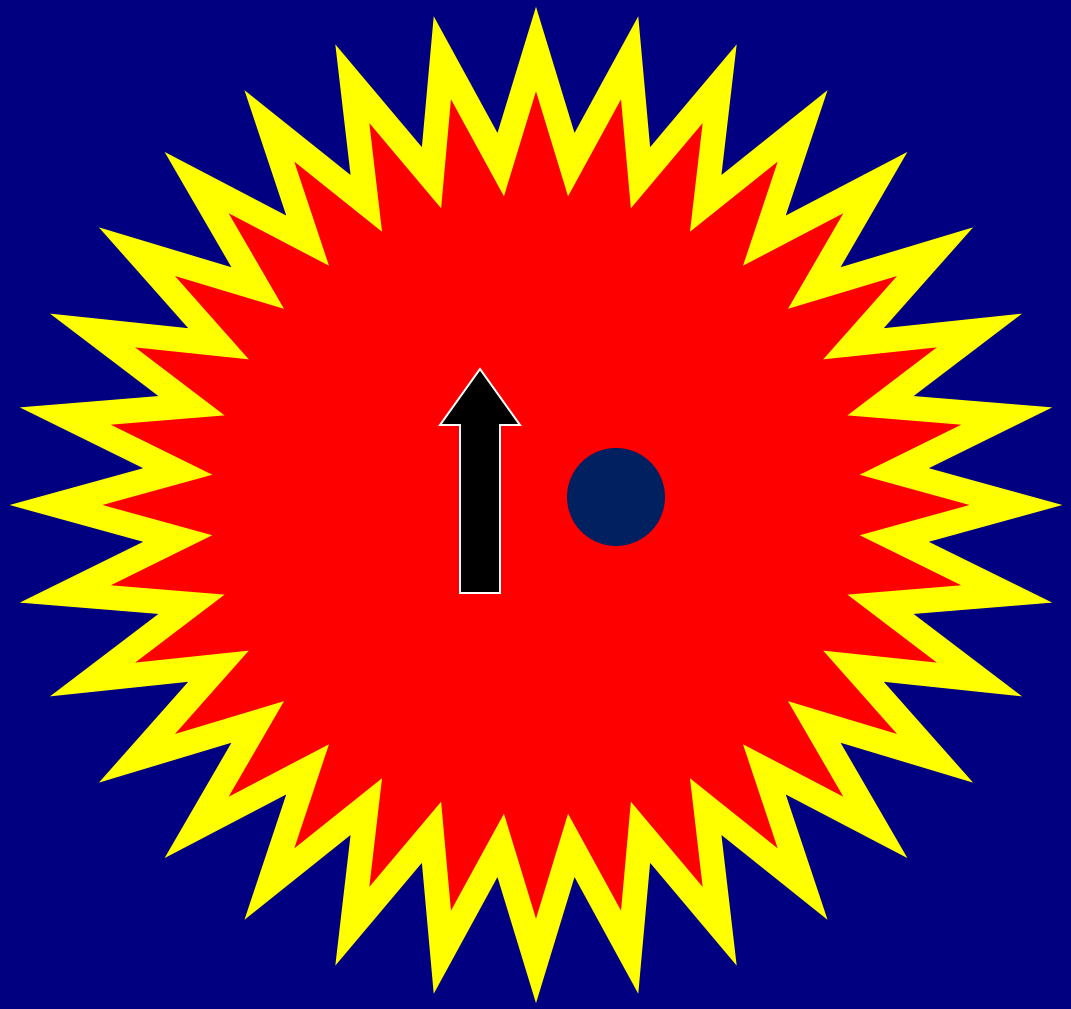
simplest theory:

leptons - quarks



(fermion + scalar)

leptons - quarks



lepton-quark-family

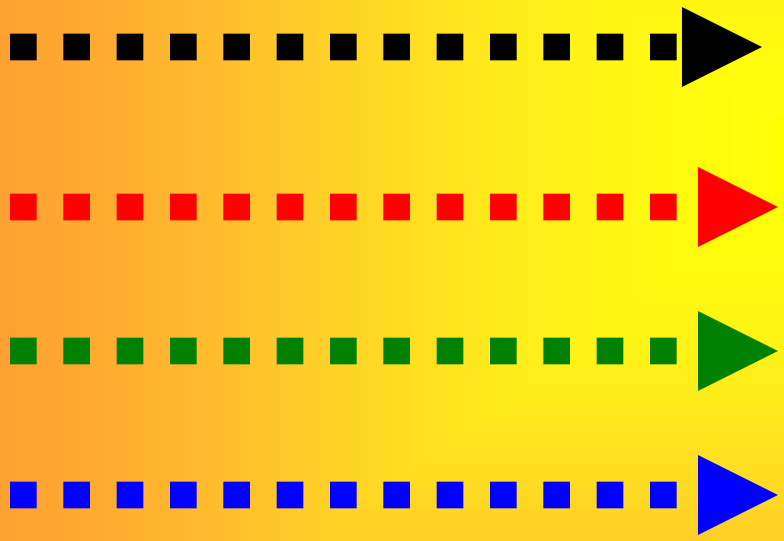
$$\begin{pmatrix} \nu & U_r & U_g & U_b \\ L & D_r & D_g & D_b \end{pmatrix} \{SU(2)$$

$$\begin{pmatrix} \nu & U_r & U_g & U_b \\ L & D_r & D_g & D_b \end{pmatrix}$$

$$\{SU(2)$$

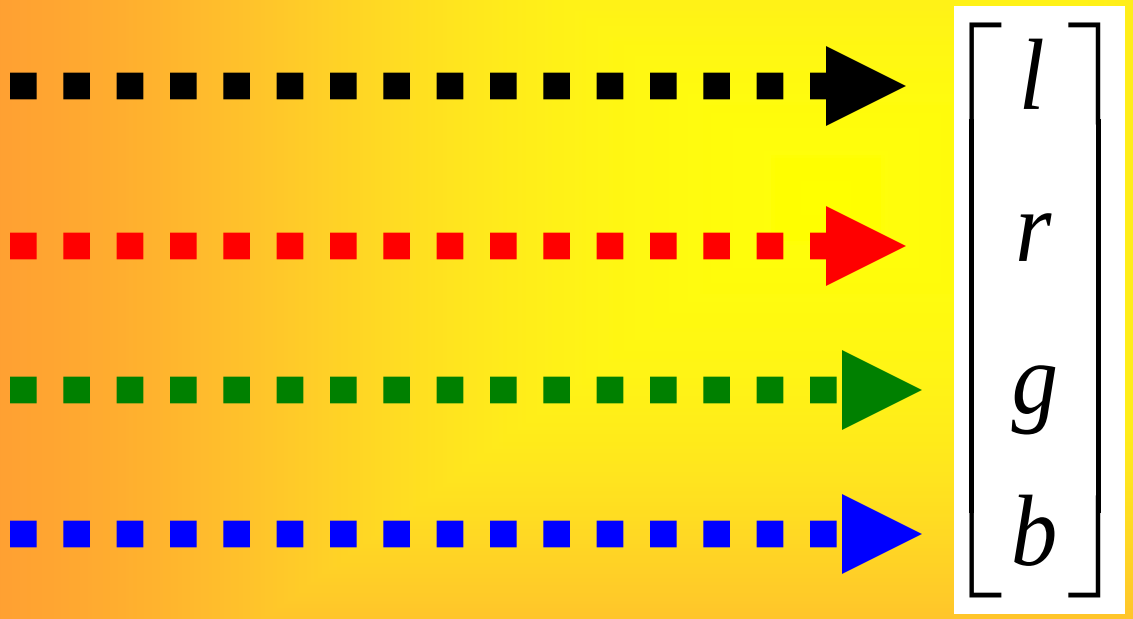
$$SU(4) \Rightarrow U(1) \otimes SU(3)_c$$

2 fermions



$SU(4)$

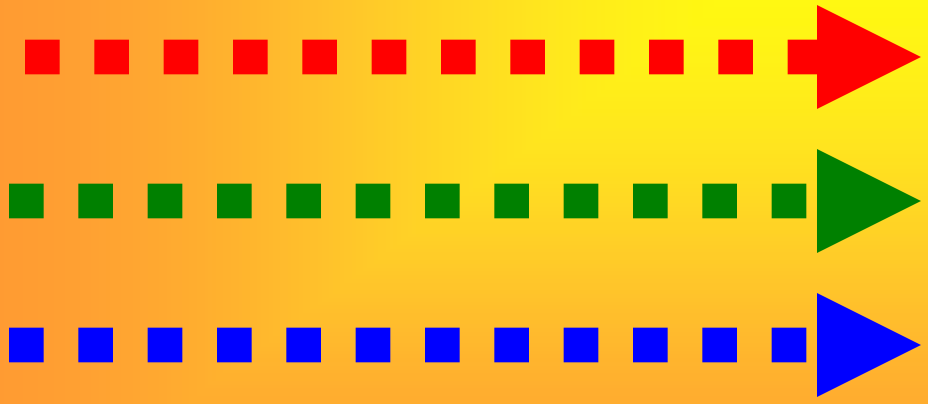
2 fermions



4 scalars

4 scalars

inside leptons



inside quarks

electric charges

$$\begin{matrix}\alpha \\ \beta\end{matrix} \Rightarrow \begin{pmatrix}1/2 \\ -1/2\end{pmatrix} \bullet e$$

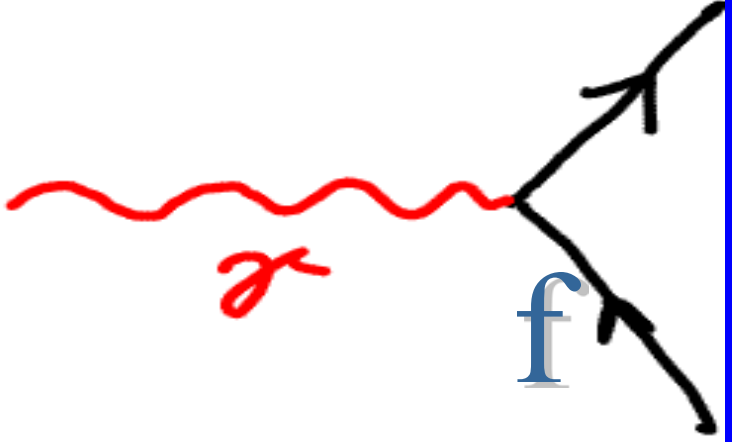
$r: \ +1/6$

$l: \ -1/2$

$g: \ +1/6$

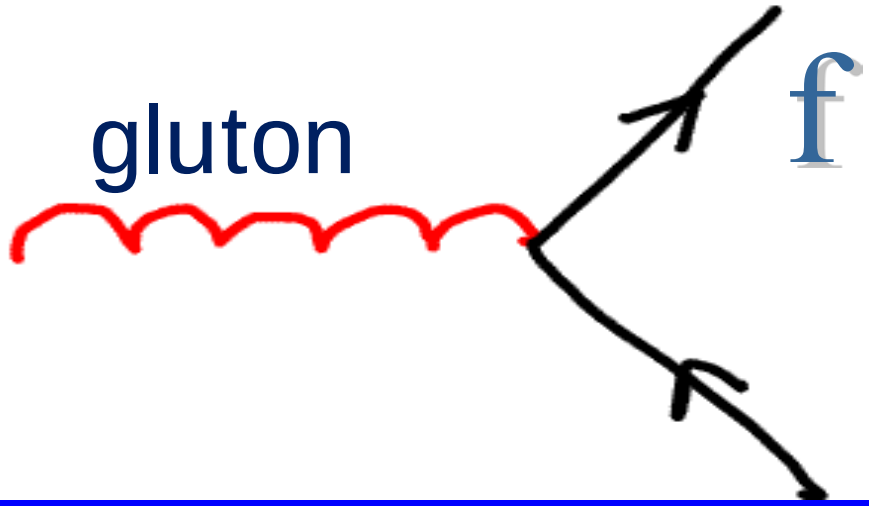
$b: \ +1/6$

charges quantized !

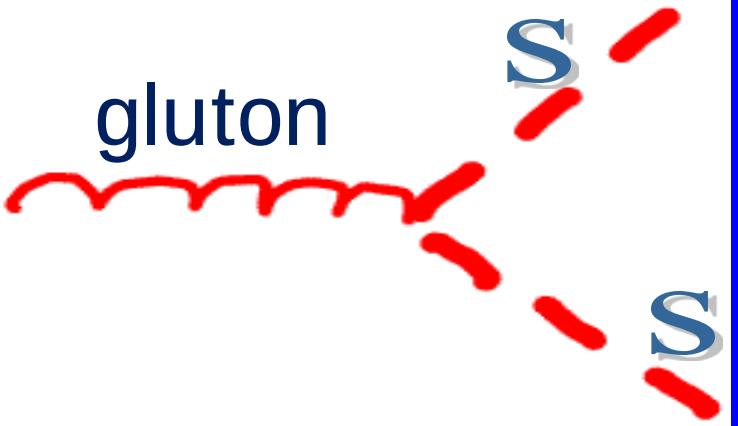


interactions

gluton



gluton



leptons

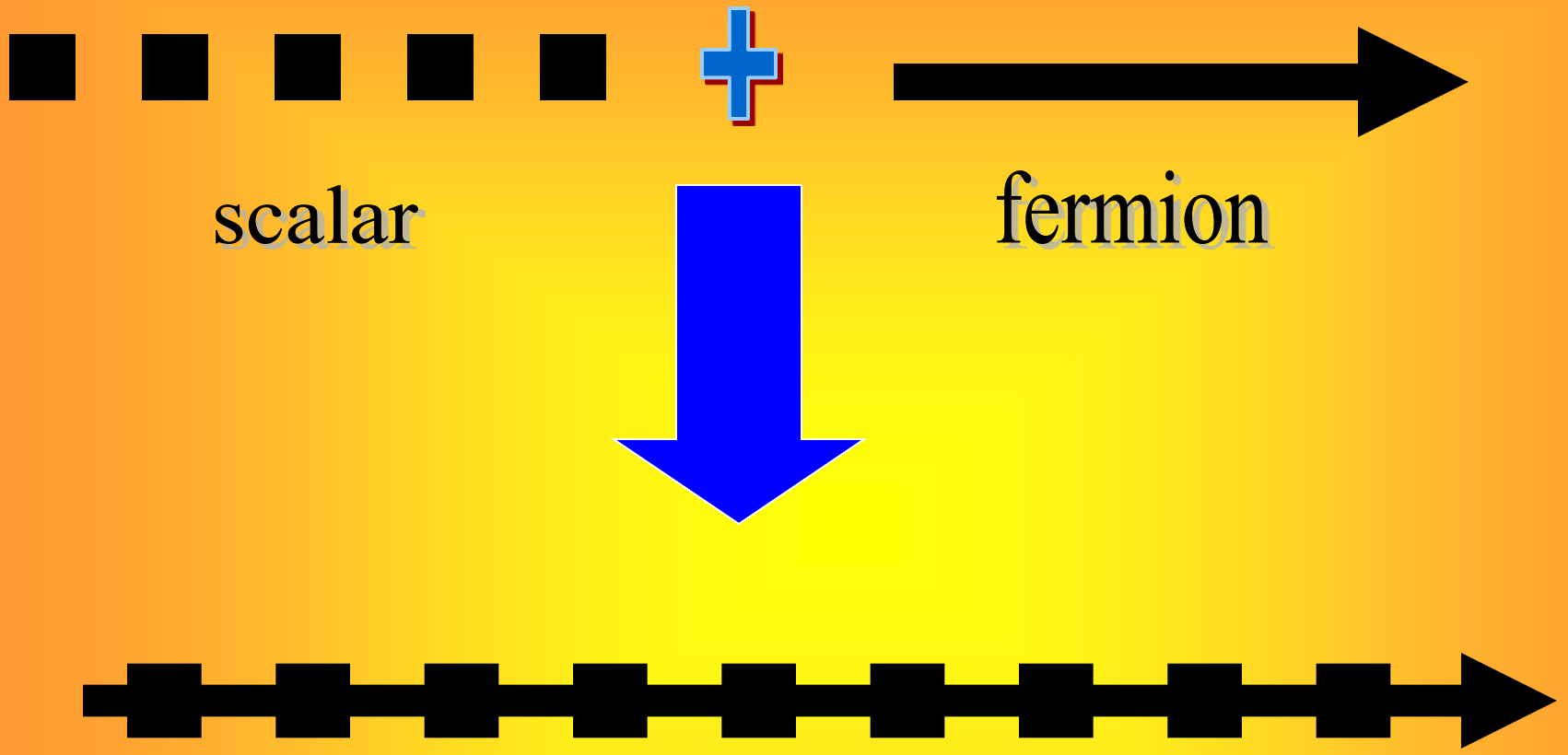
$$(\alpha l): \nu_e - \nu_\mu - \nu_\tau$$

$$(\beta l): e - \mu - \tau$$

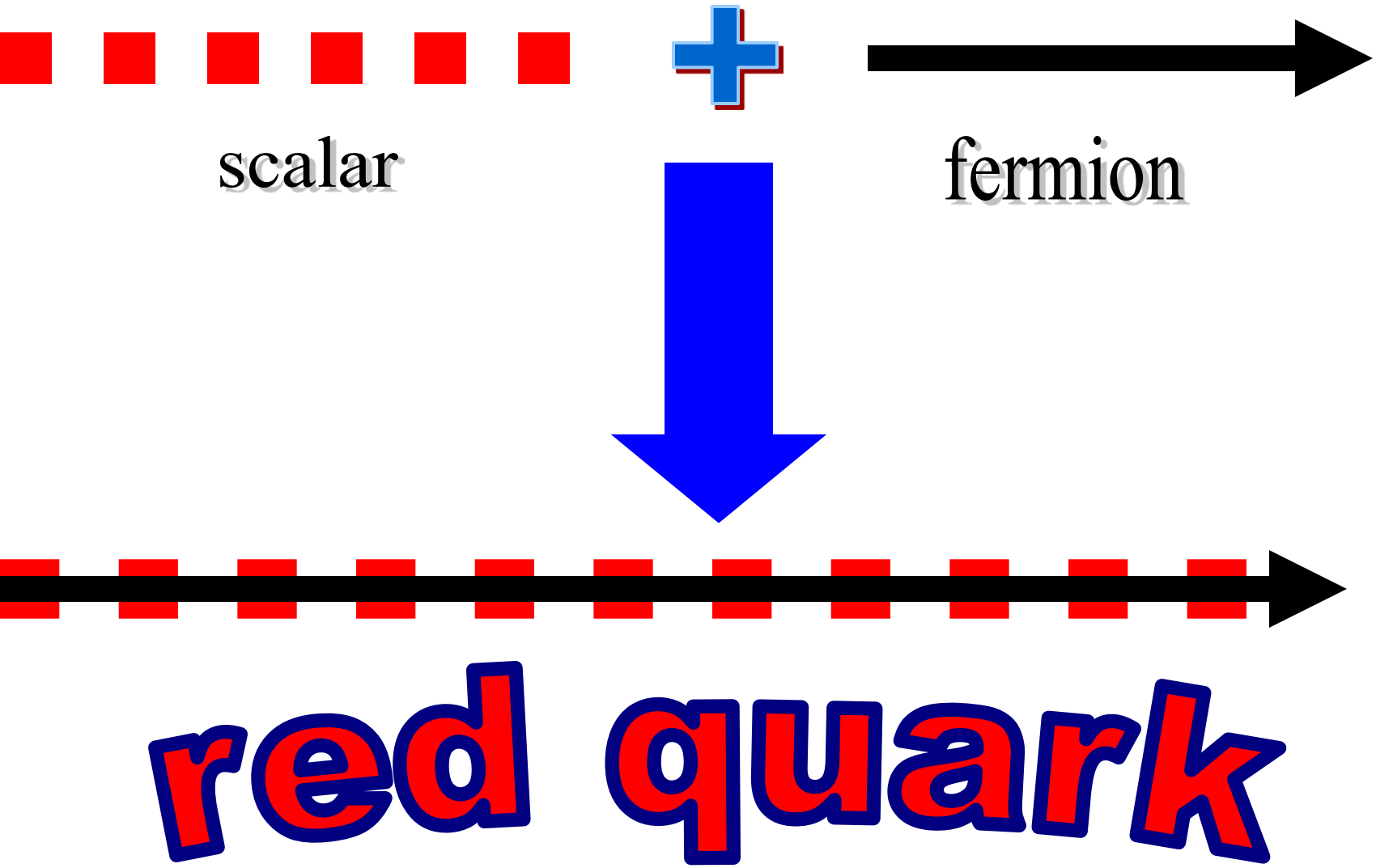
$$(\alpha r): u_r, c_r, t_r$$

$$(\beta r): d_r, s_r, b_r$$

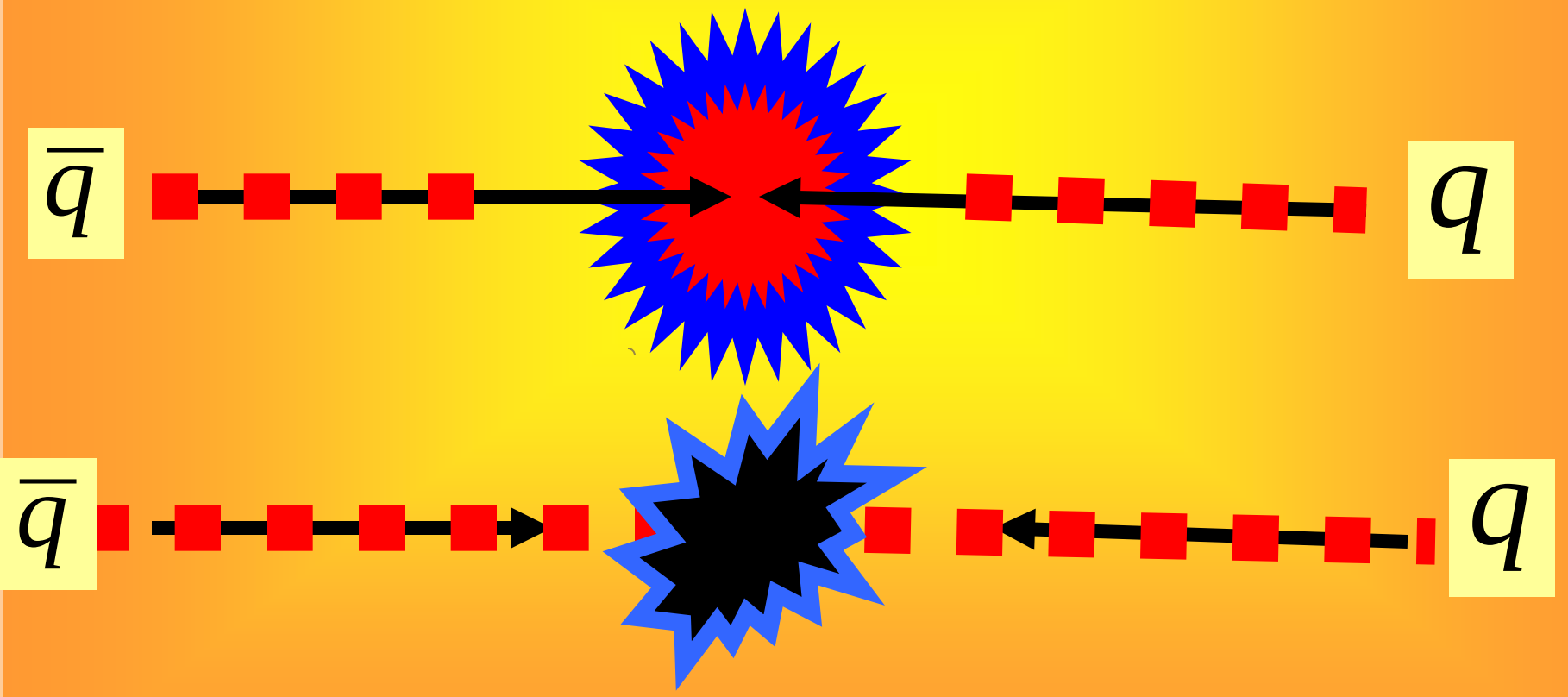
red quarks

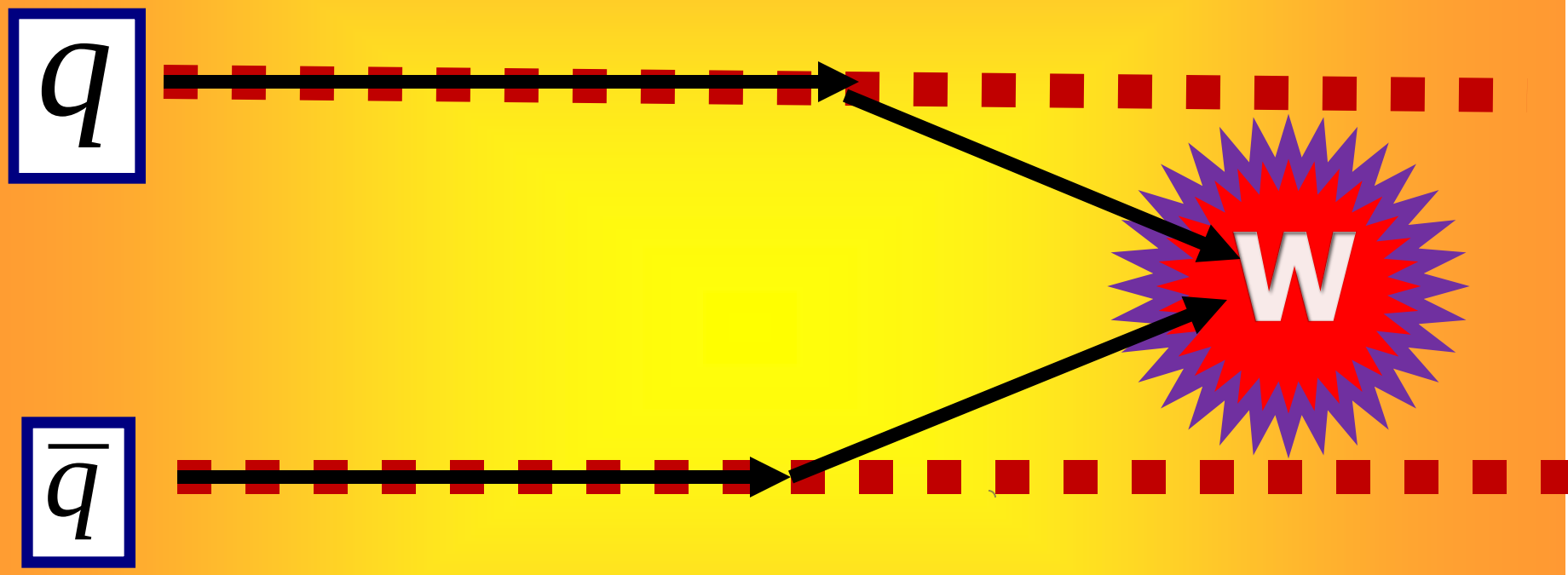


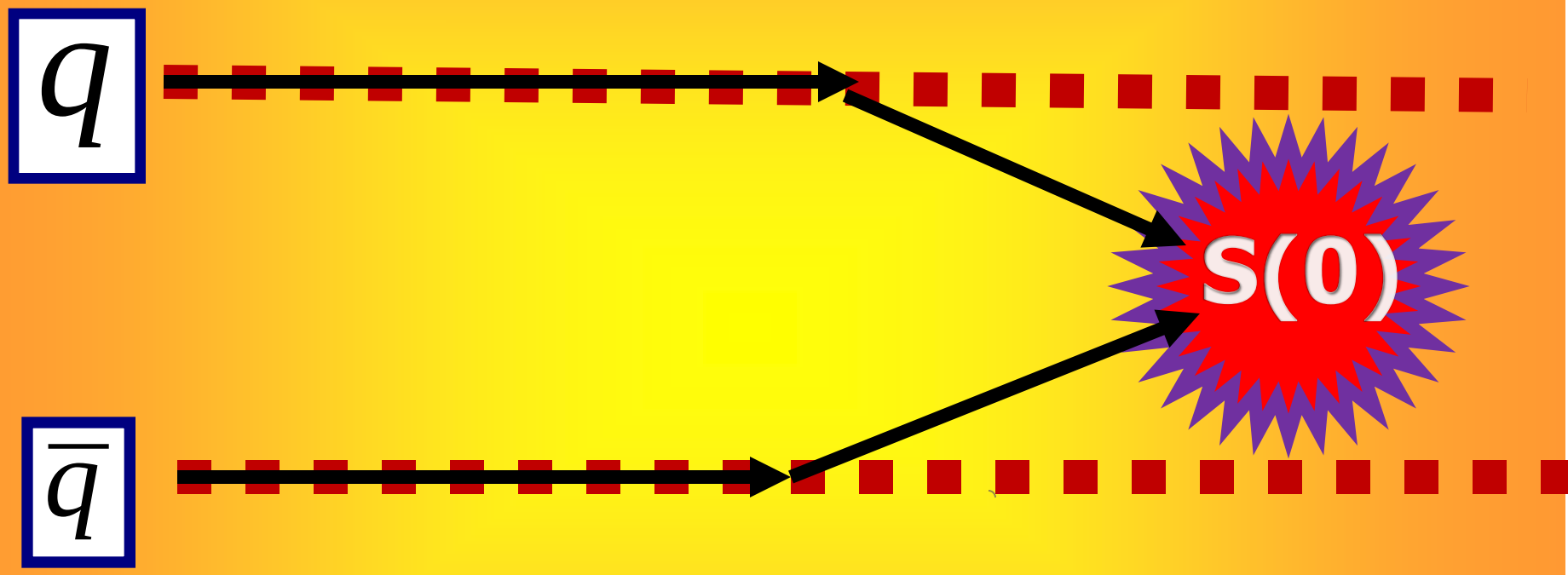
electron

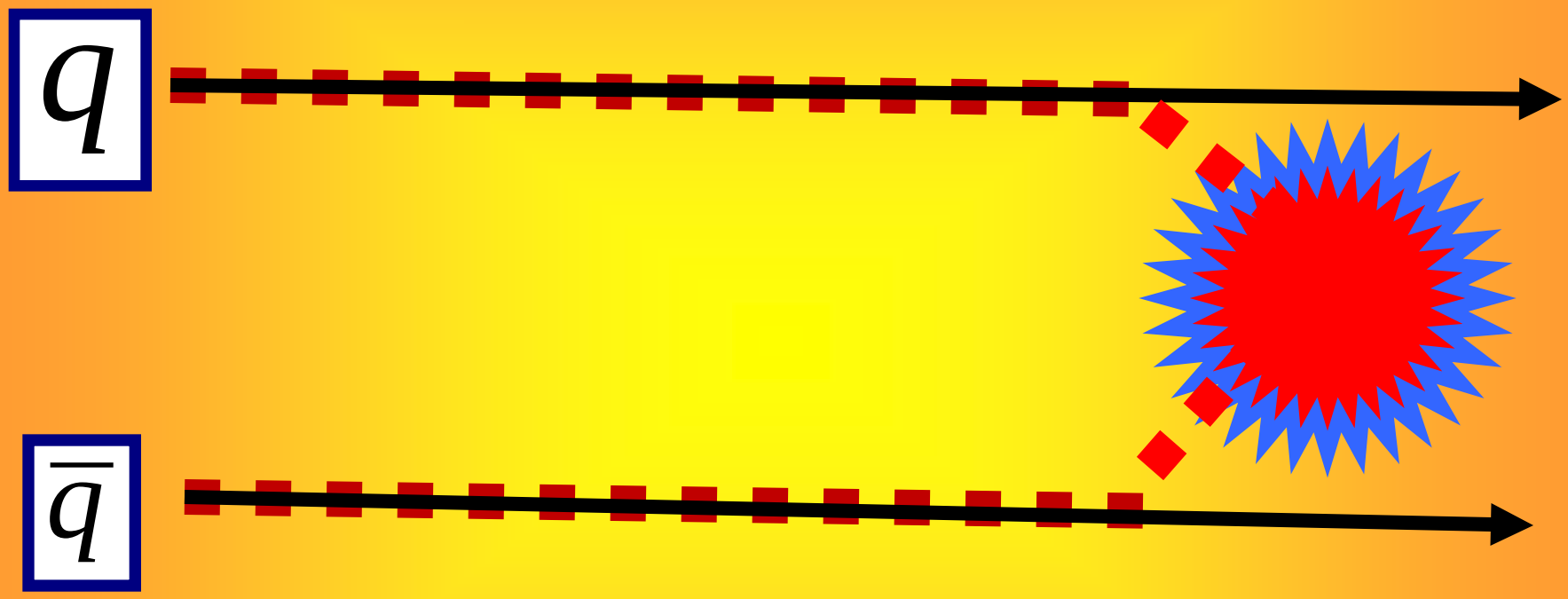

scalar
fermion
red quark

quark – antiquark scattering:

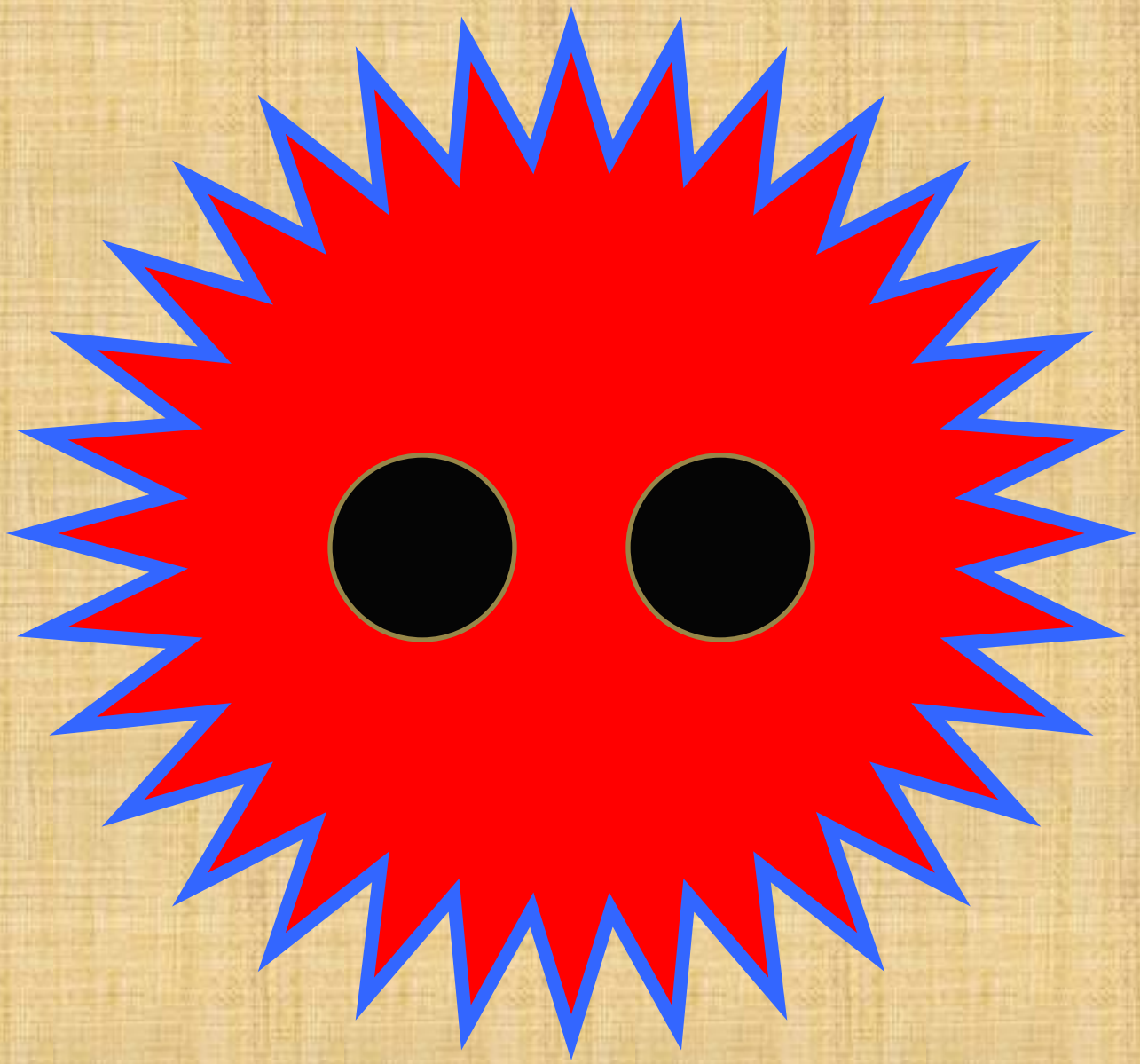



q
$\overline{q}$
W


q
$\bar{q}$
S(0)

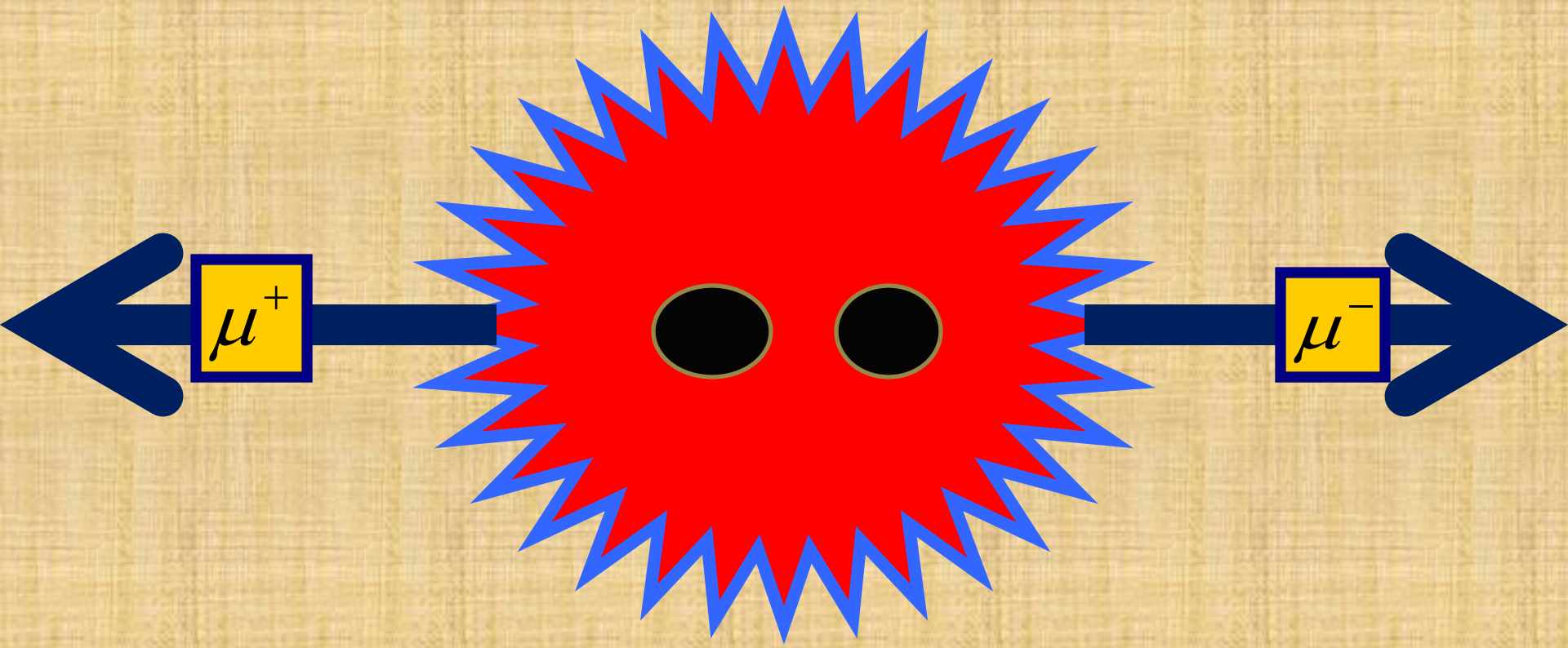


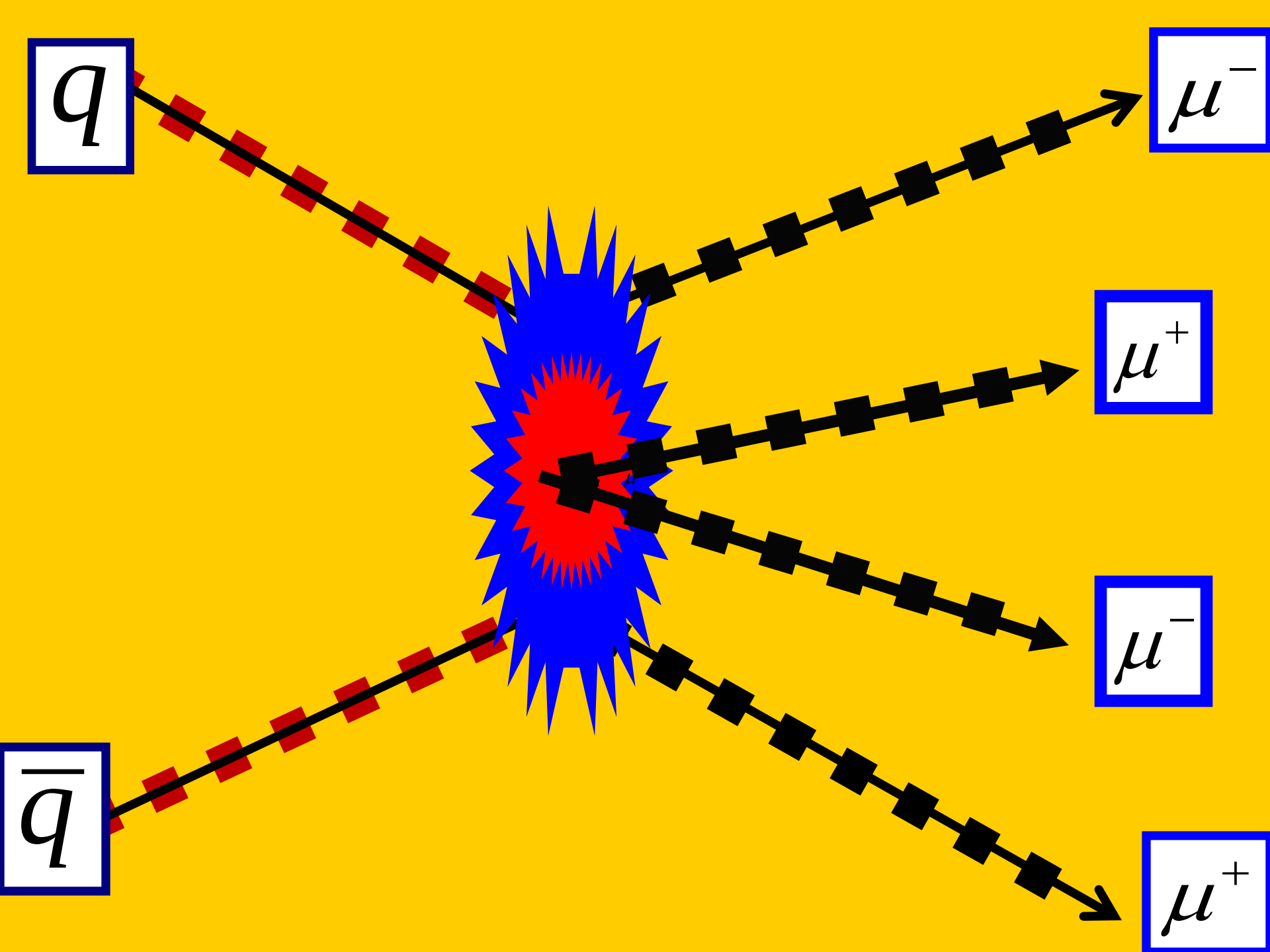
bound states of two scalars

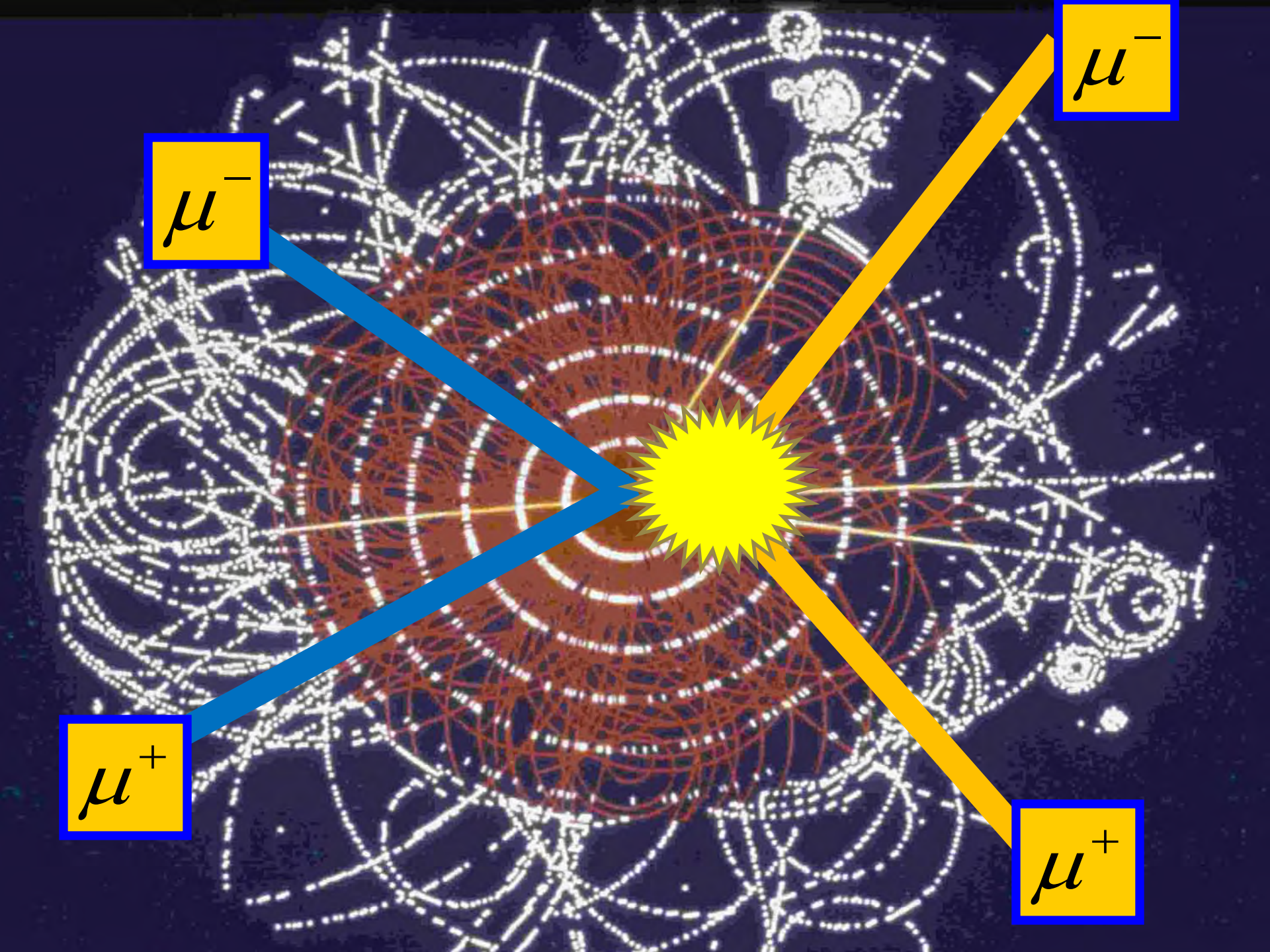


M>0.5 TeV ?

decay into leptons and quarks




q
$\bar{q}$
μ^-
μ^+
μ^-
μ^+


μ^-
μ^-
μ^+
μ^+

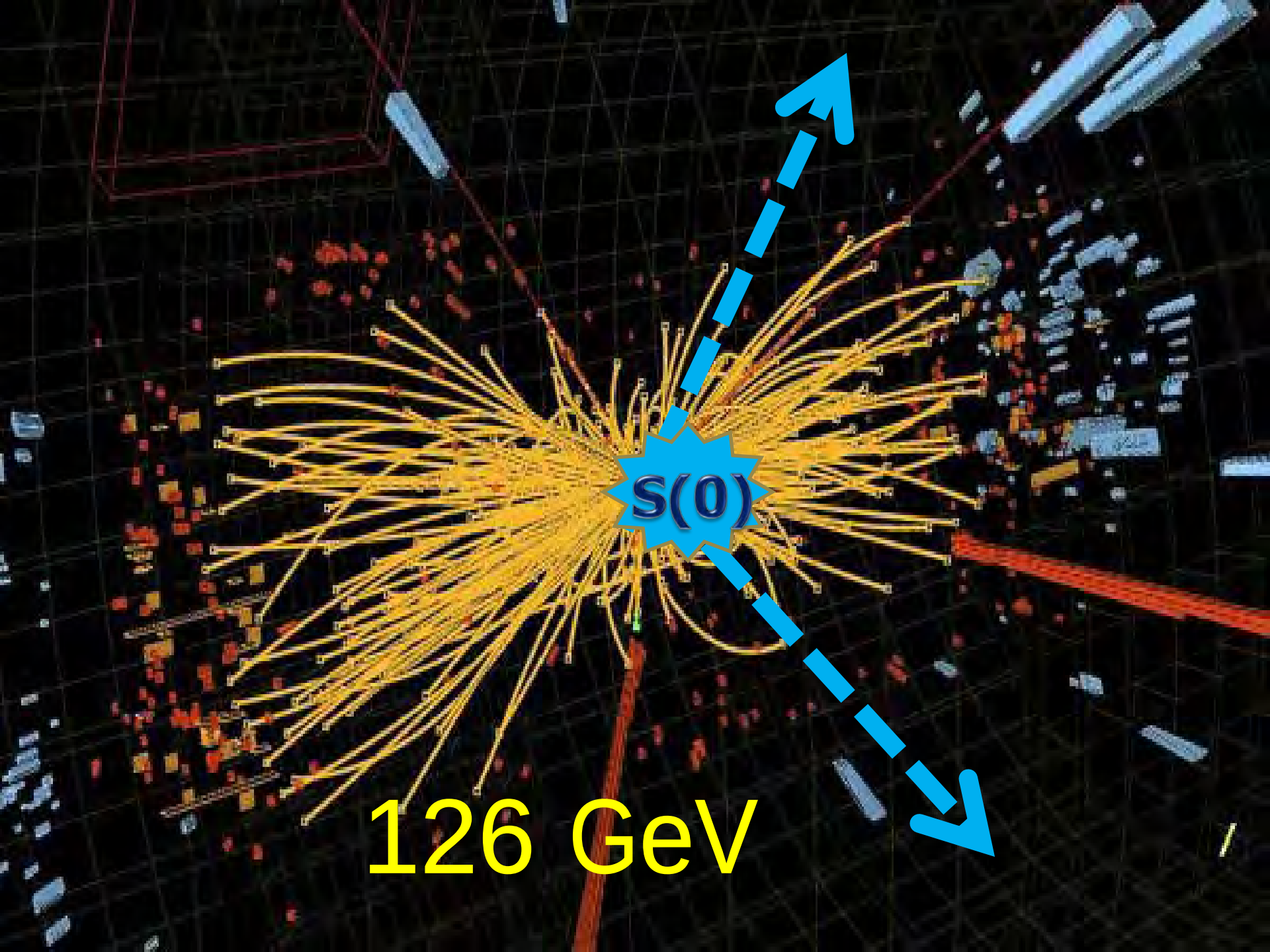
conclusions

weak bosons

leptons

quarks

$\Rightarrow$ composite


S(0)
126 GeV

S(0)
excited
weak boson
Spin 0


many QHD resonances
above
1 TeV
L H C