

# COMPOSANTS ÉLÉMENTAIRES

David Calvet



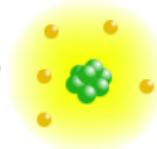
MasterClass@Clermont 2019

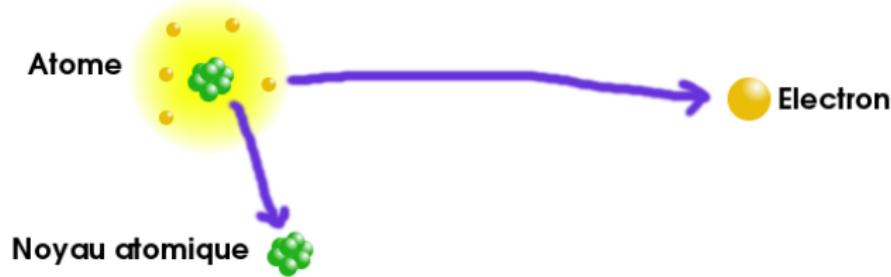
Que trouvons-nous dans cette pièce ?

The diagram illustrates the periodic table with the following features:

- Periodic Table Structure:** The main body of the table is shown with elements arranged by atomic number (Z) from left to right across horizontal rows (periods) and down vertical groups (groups).
- Lanthanide and Actinide Series:** The lanthanide series (Ce-Lu) and actinide series (Th-Pu) are depicted as separate vertical columns positioned below the main body of the table.
- Elements:** The table includes elements with Z > 18, such as K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe, Cs, Ba, La, Hf, Ta, W, Re, Os, Ir, Pt, Au, Hg, Tl, Pb, Bi, Po, At, Rn, Fr, Ra, Ac, Th, Pa, U, Np, and Pu.
- Numbering:** Elements are numbered with their atomic numbers: H (1), He (2), Li (3), Be (4), Na (11), Mg (12), K (19), Ca (20), Sc (21), Ti (22), V (23), Cr (24), Mn (25), Fe (26), Co (27), Ni (28), Cu (29), Zn (30), Ga (31), Ge (32), As (33), Se (34), Br (35), Kr (36), Rb (37), Sr (38), Y (39), Zr (40), Nb (41), Mo (42), Tc (43), Ru (44), Rh (45), Pd (46), Ag (47), Cd (48), In (49), Sn (50), Sb (51), Te (52), I (53), Xe (54), Cs (55), Ba (56), La (57), Hf (58), Ta (59), W (60), Re (61), Os (62), Ir (63), Pt (64), Au (65), Hg (66), Tl (67), Pb (68), Bi (69), Po (70), At (71), Rn (72), Fr (73), Ra (74), Ac (75), Th (76), Pa (77), U (78), Np (79), and Pu (80).

Atome





Noyau atomique



Electron



Noyau atomique



Electron



Inktober #6



Do ya think Darth  
Vader ever used his  
force powers to take  
care of those pesky  
space gnats?

omggghhink.blogspot.com

D. Calvet

**Noyau atomique**



**Electron**



Noyau atomique



Electron



Noyau atomique



Electron



Photon



Noyau atomique



Electron



Noyau atomique



Electron



Noyau atomique



Electron



Noyau atomique



Electron



Noyau atomique



Electron



Noyau atomique



Electron



Noyau atomique



Electron



Noyau atomique



Electron



## Noyau atomique



## Electron



## Noyau atomique



## Electron



D. Calvet



Atome



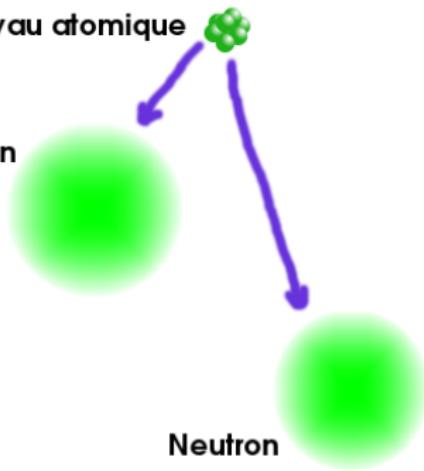
Photon

Electron

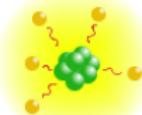
Noyau atomique

Proton

Neutron



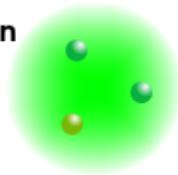
Atome



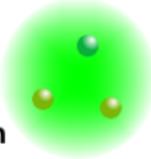
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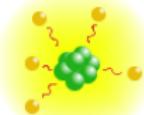
Proton



Neutron



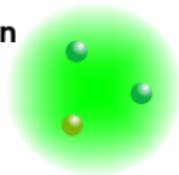
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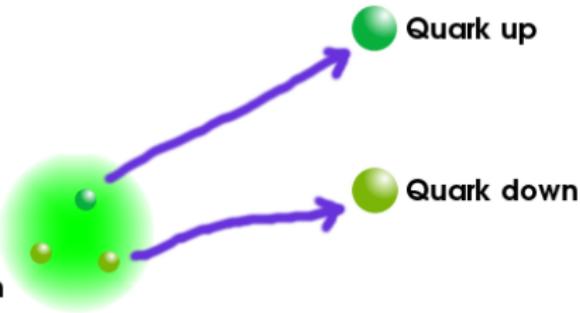
Photon

Electron

Proton



Neutron



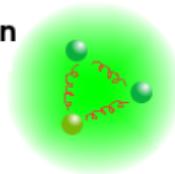
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Photon

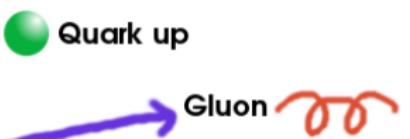


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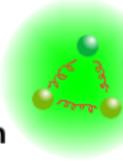


Quark up

Gluon

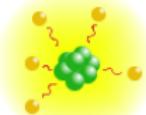


Neutron



Quark down

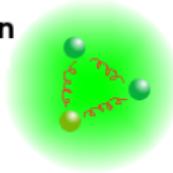
Atome



Photon

Electron

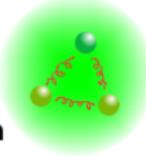
Proton



Quark up

Gluon

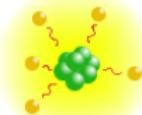
Neutron



Quark down



Atome



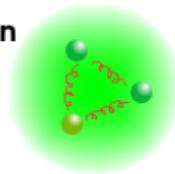
Photon



Electron



Proton



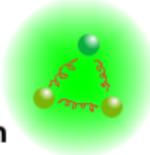
Quark up



Gluon



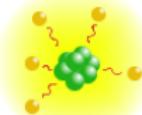
Neutron



Quark down



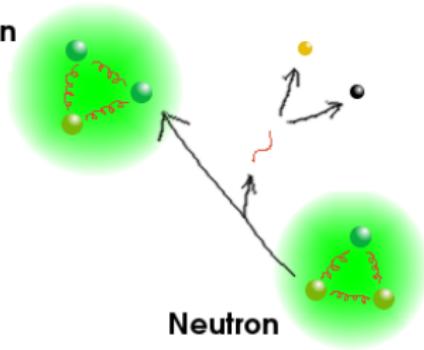
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Photon 

Electron 

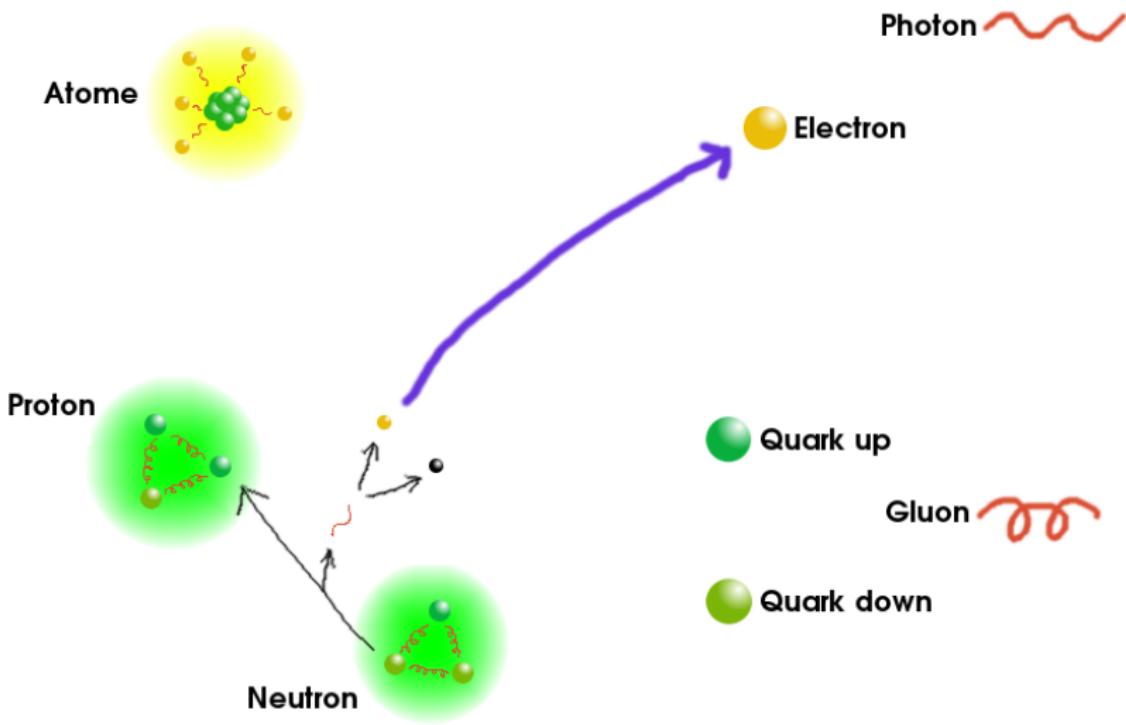
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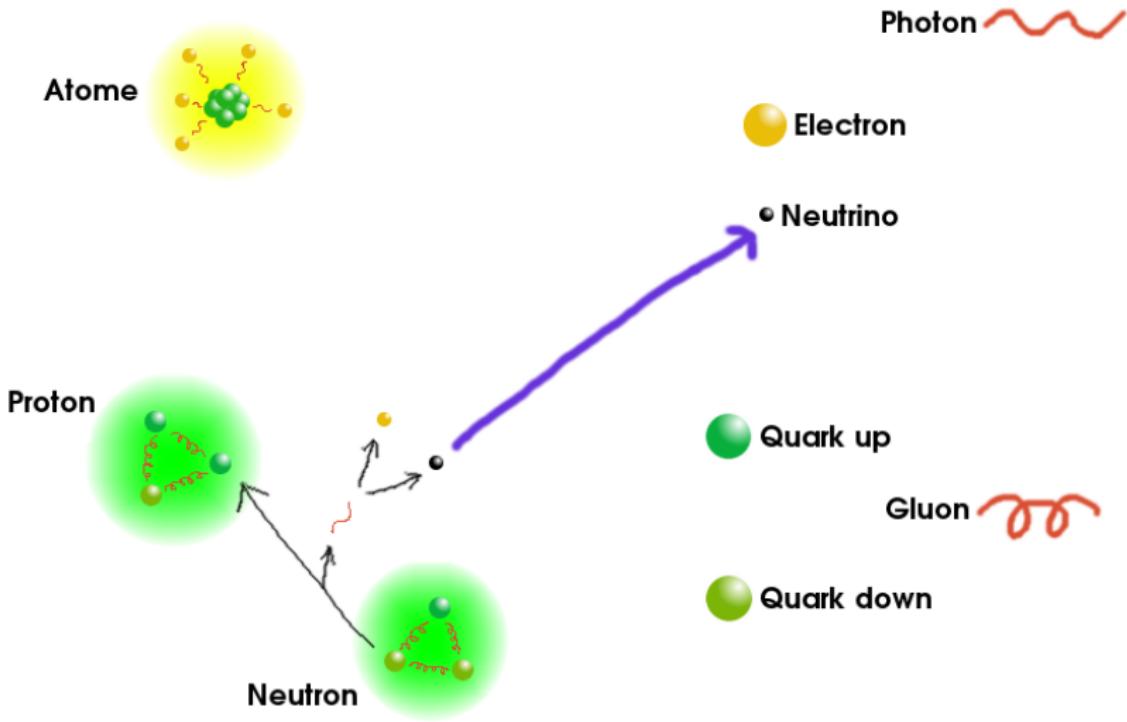


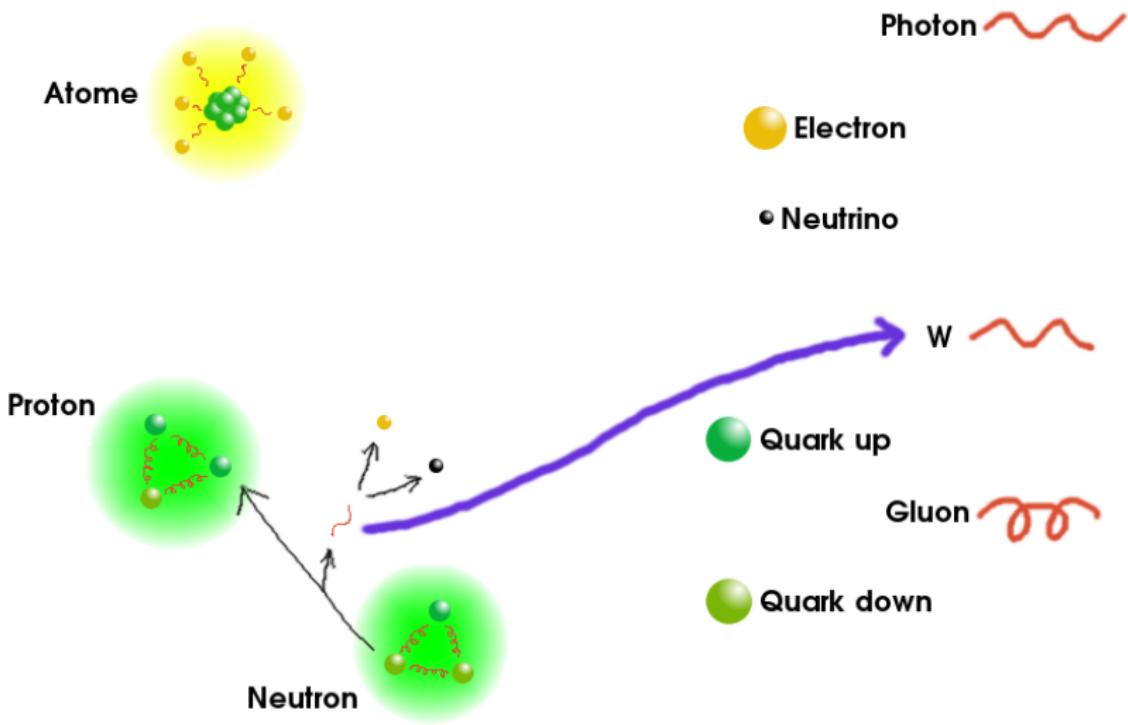
Quark up 

Gluon 

Quark down 







Photon

Electron

• Neutrino

W

Quark up

Gluon

Quark down

## Fermions



• Neutrino



## Bosons





Credit: <http://www.thelivingmoon.com>

Photon

Electron

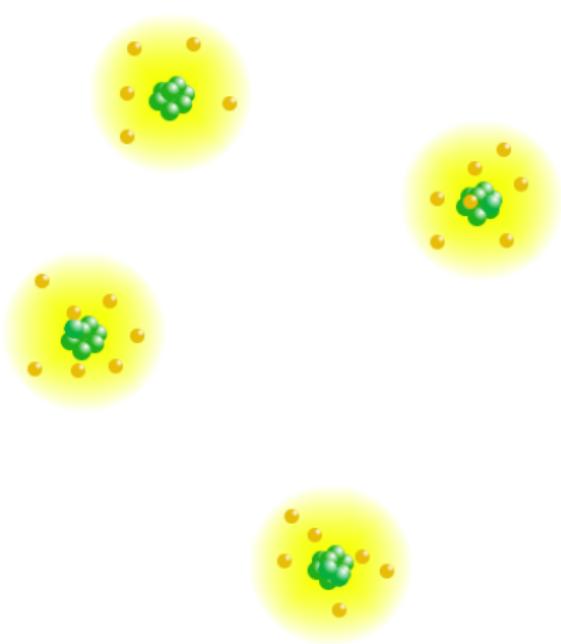
• Neutrino

W

Quark up

Gluon

Quark down



Photon

Electron

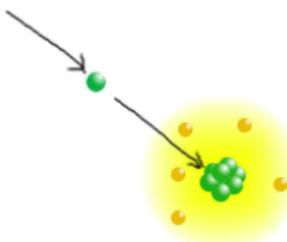
• Neutrino

W

Quark up

Gluon

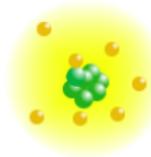
Quark down



Photon

Electron

• Neutrino



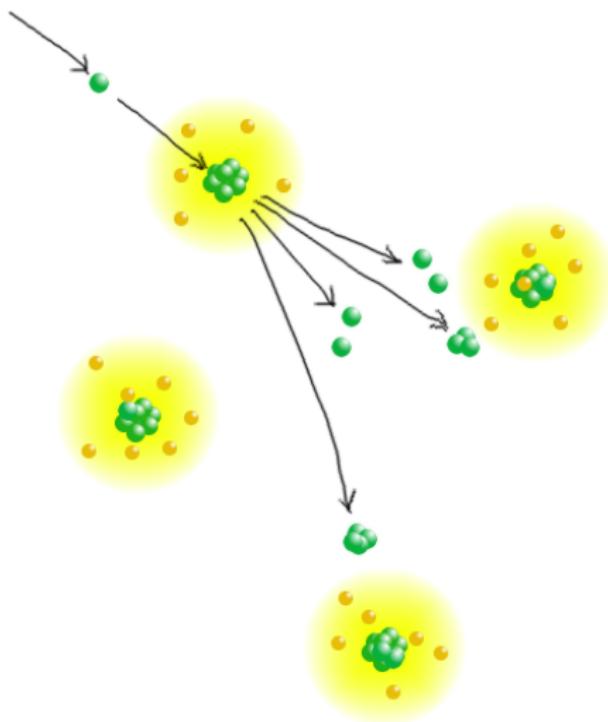
W

Quark up



Gluon

Quark down



Photon

Electron

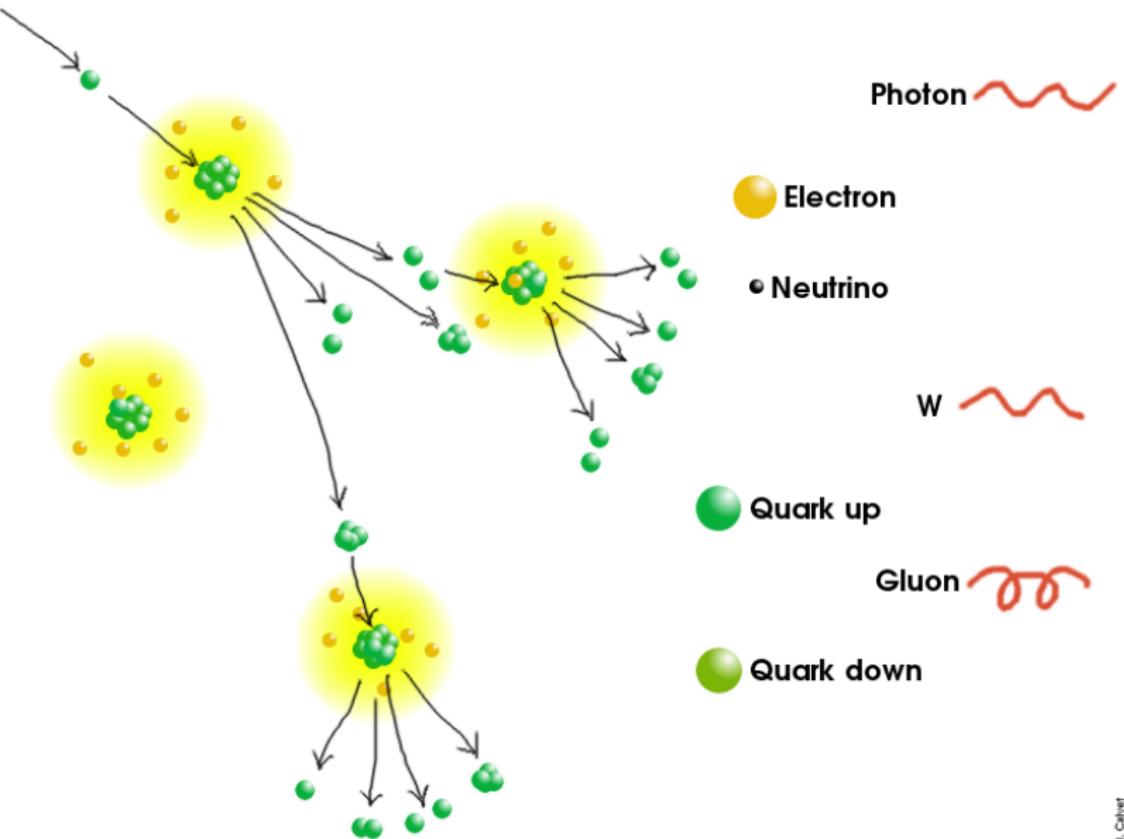
• Neutrino

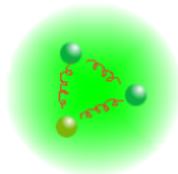
W

Quark up

Gluon

Quark down





Photon

Electron

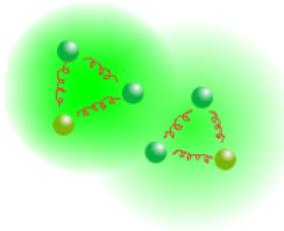
• Neutrino

W

Quark up

Gluon

Quark down



Photon

Electron

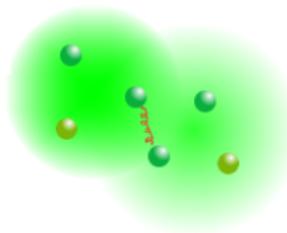
• Neutrino

W

Quark up

Gluon

Quark down



Photon

Electron

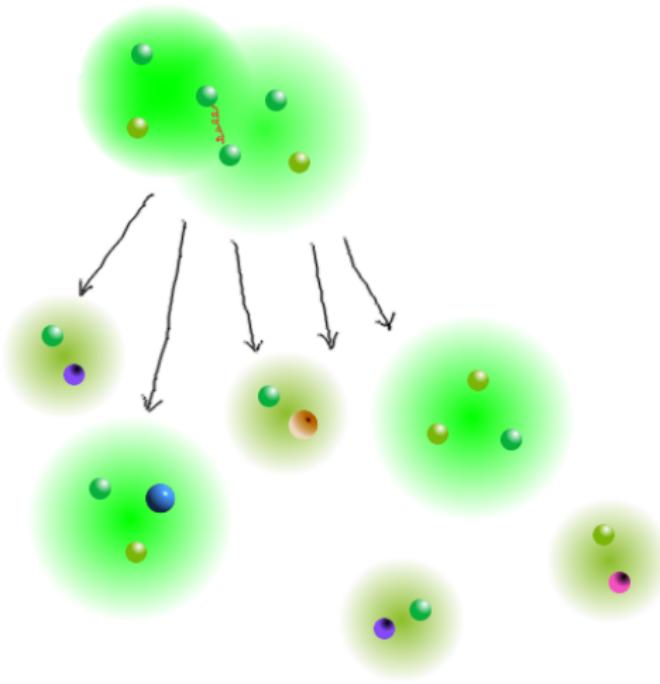
Neutrino

W

Quark up

Gluon

Quark down



Photon

Electron

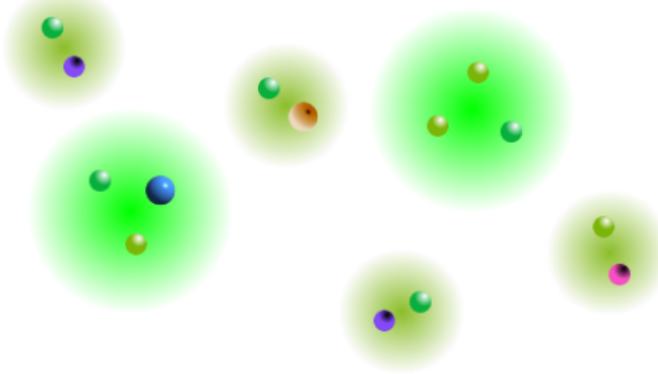
• Neutrino

W

Quark up

Gluon

Quark down



Photon

Electron

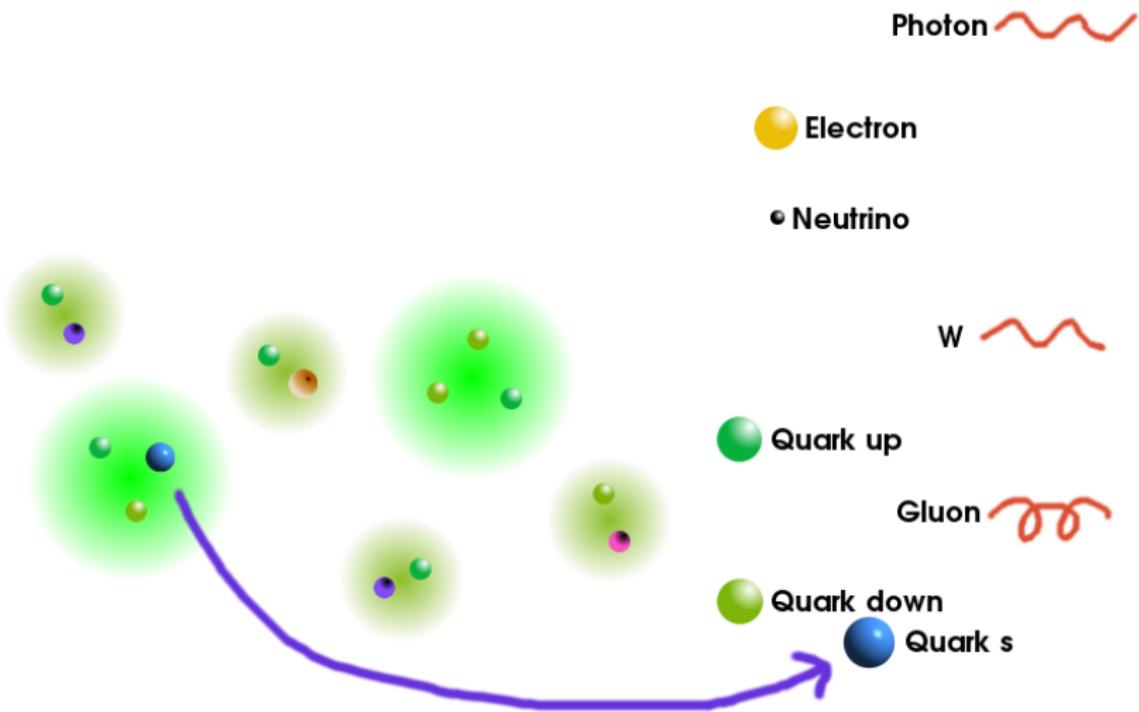
• Neutrino

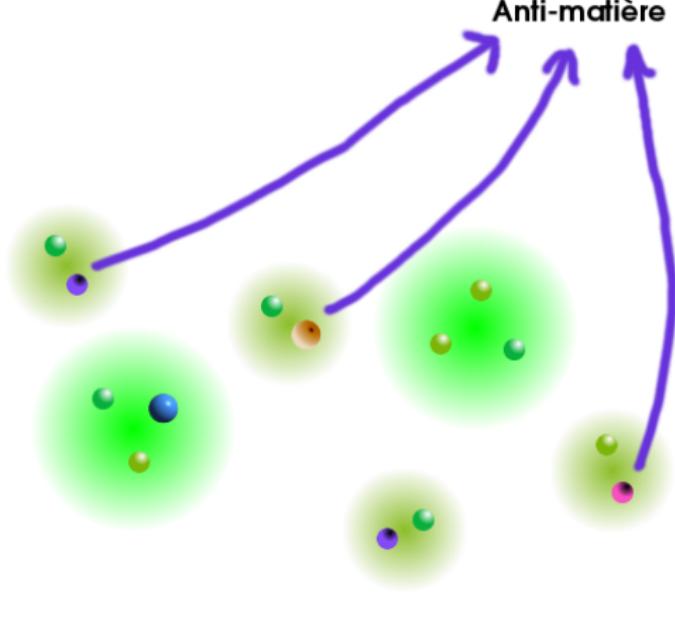
W

Quark up

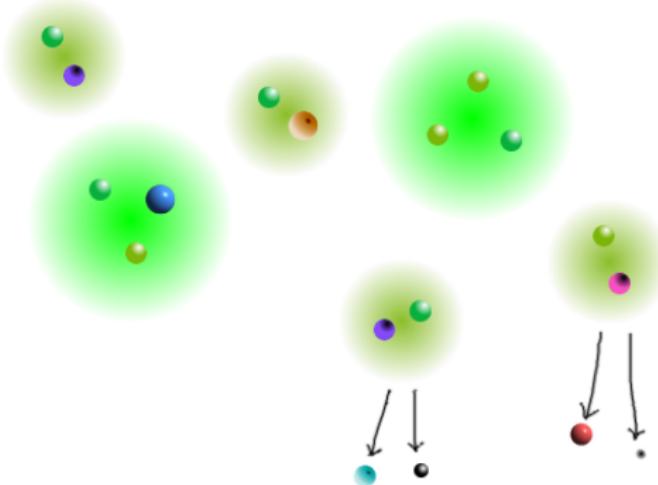
Gluon

Quark down





- Photon
- Electron
- Neutrino
- Quark up
- Gluon
- Quark down
- Quark s



Photon

Electron

• Neutrino

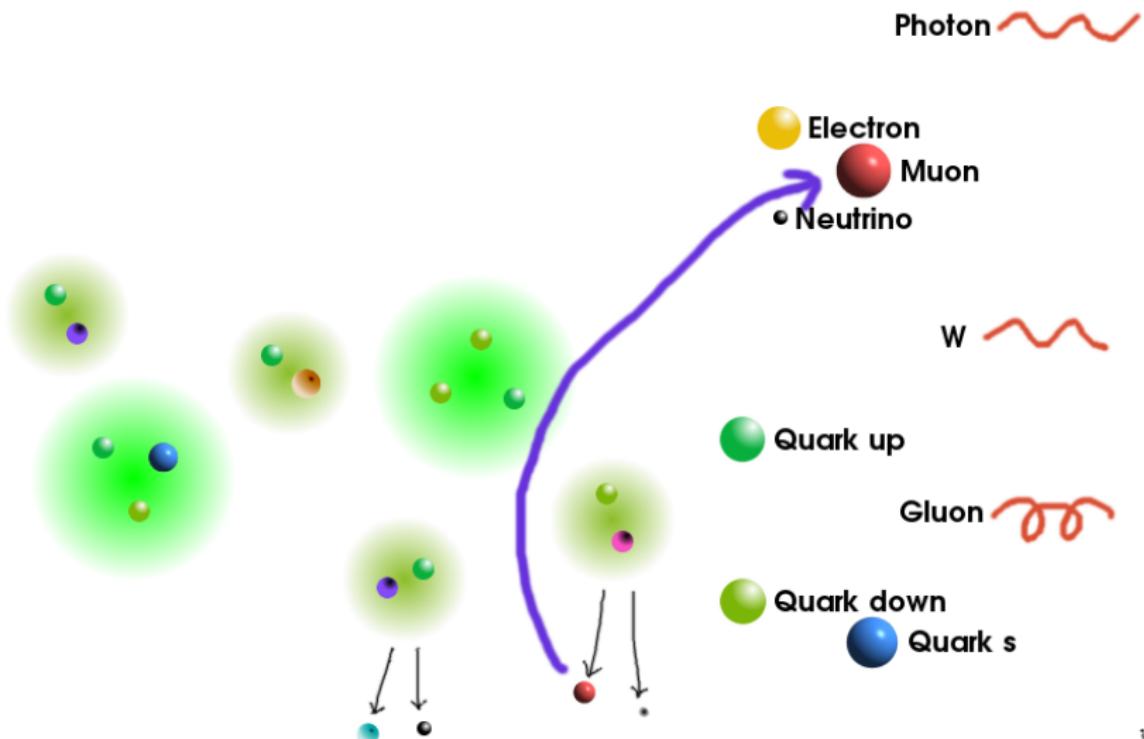
W

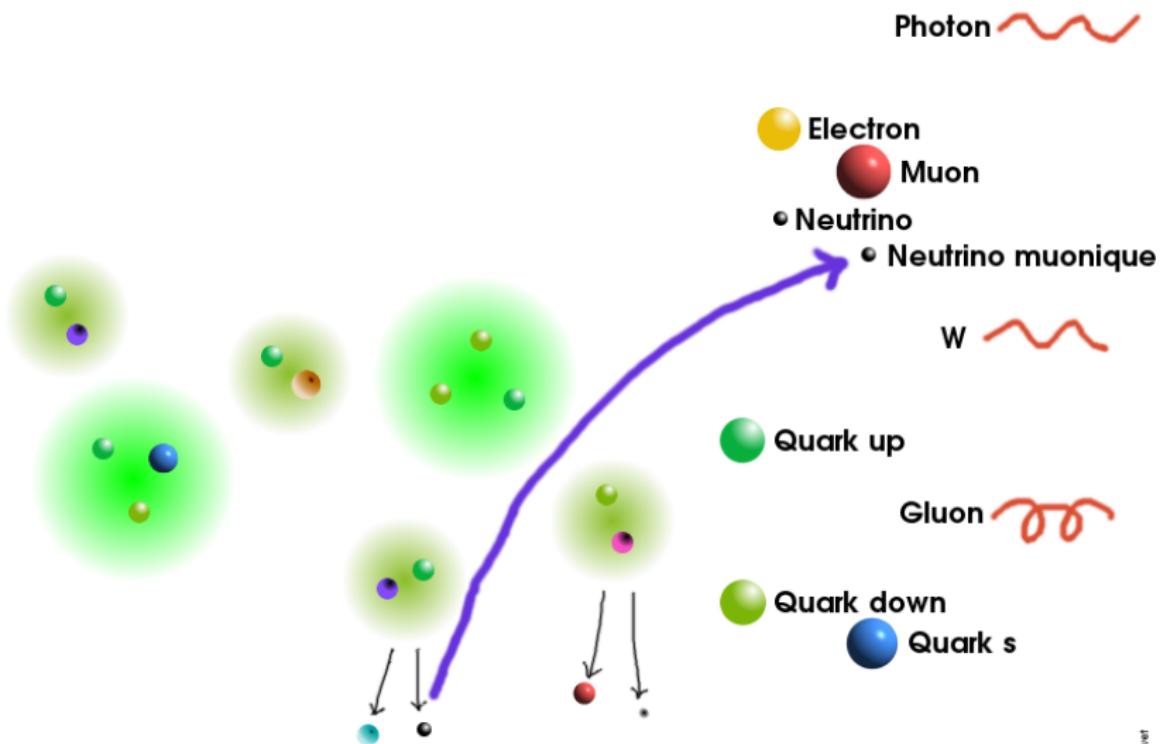
Quark up

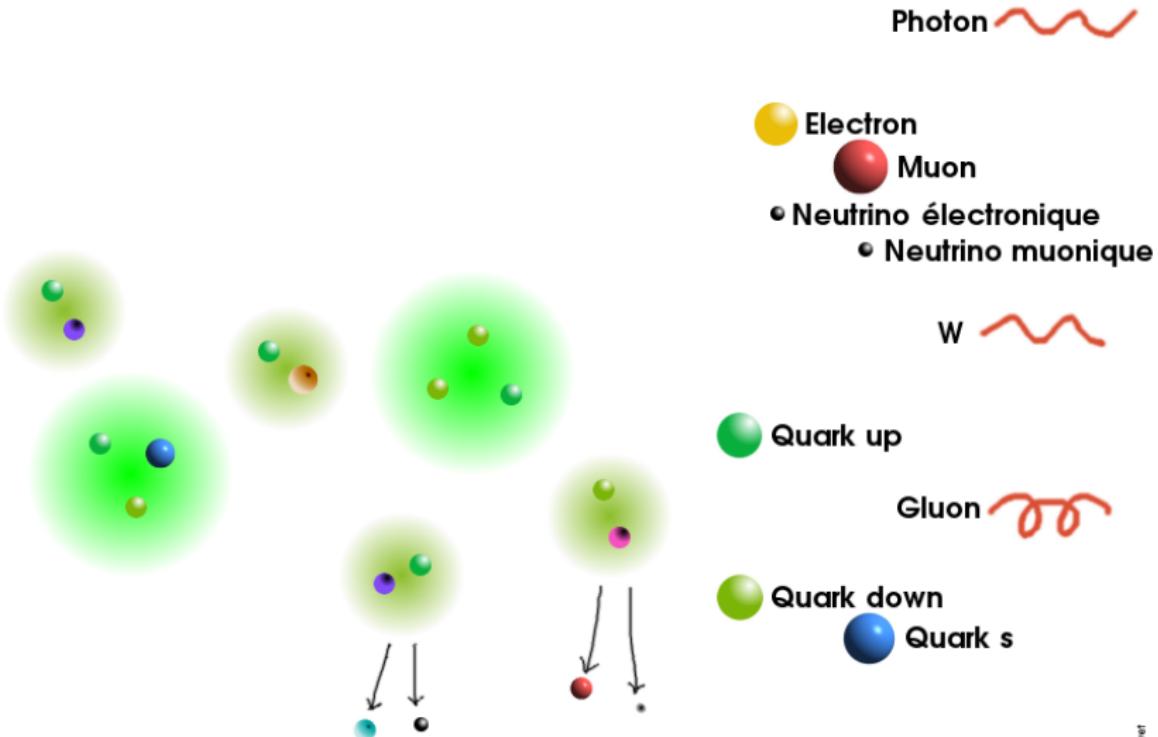
Gluon

Quark down

Quark s







Photon

Electron

Muon

• Neutrino électronique

• Neutrino muonique

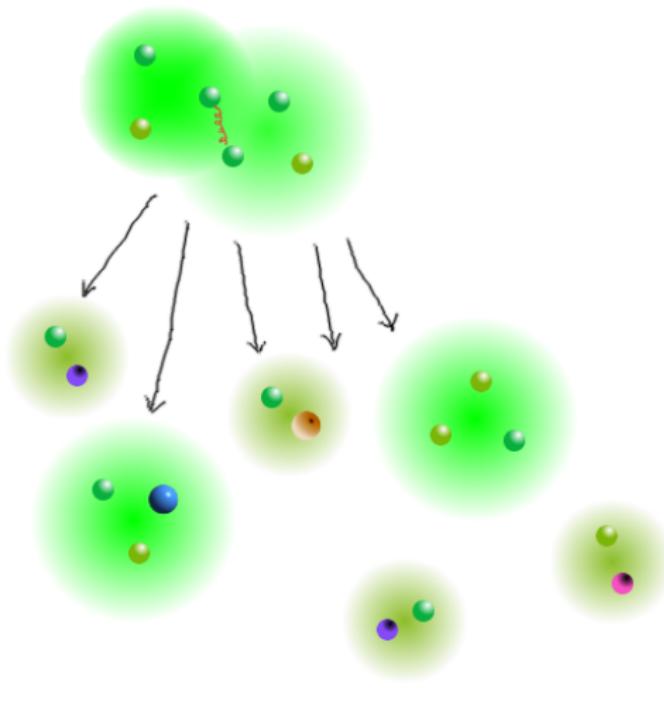
W

Quark up

Gluon

Quark down

Quark s



Photon

Electron

Muon

• Neutrino électronique

• Neutrino muonique

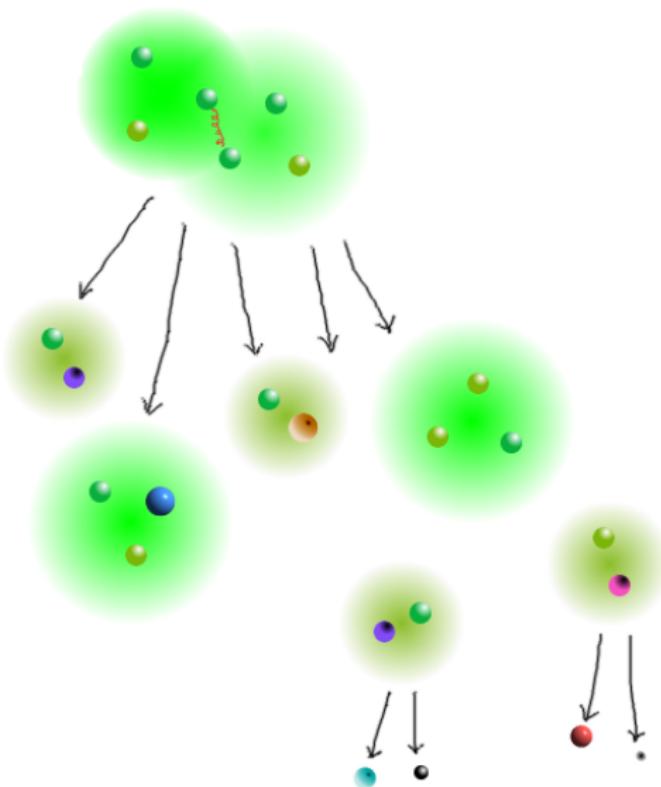
W

Quark up

Gluon

Quark down

Quark s



Photon

Electron

Muon

• Neutrino électronique

• Neutrino muonique

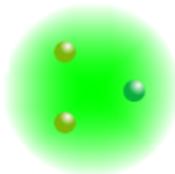
W

Quark up

Gluon

Quark down

Quark s



Photon

Electron

Muon

• Neutrino électronique

• Neutrino muonique

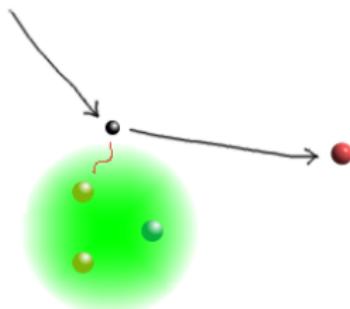
W

Quark up

Gluon

Quark down

Quark s



Photon

Electron

Muon

• Neutrino électronique

• Neutrino muonique

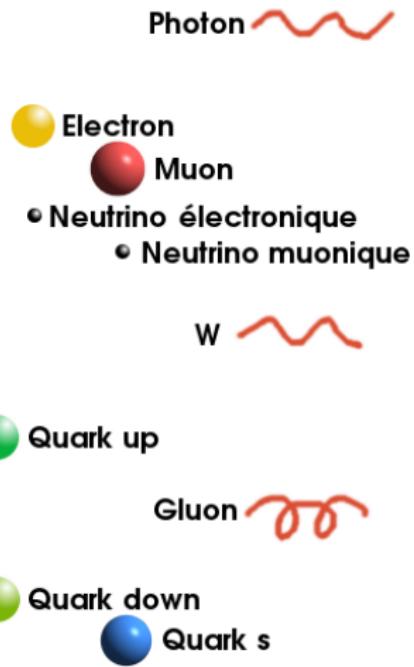
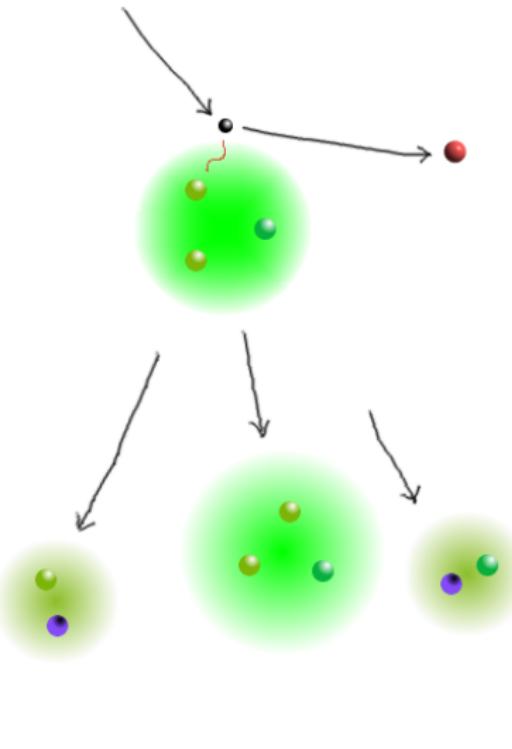
W

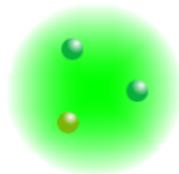
Quark up

Gluon

Quark down

Quark s





Photon

Electron

Muon

• Neutrino électronique

• Neutrino muonique

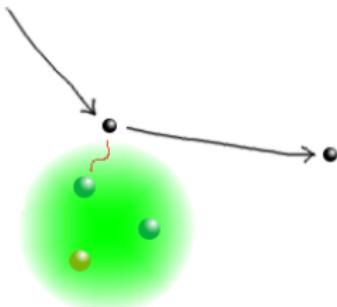
W

Quark up

Gluon

Quark down

Quark s



Photon

Electron

Muon

• Neutrino électronique

• Neutrino muonique

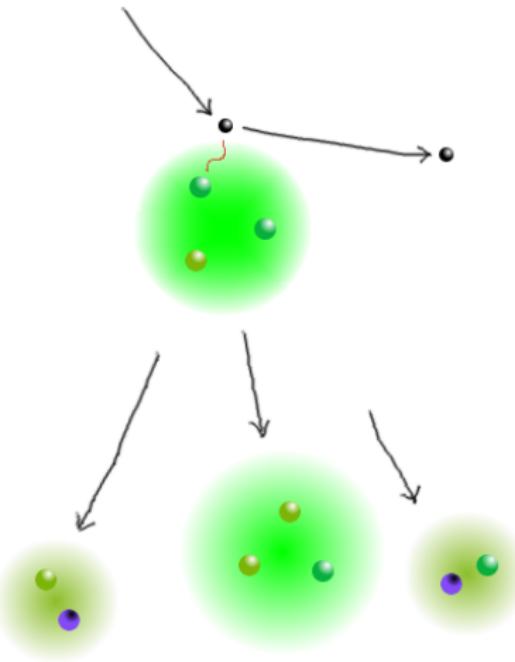
W

Quark up

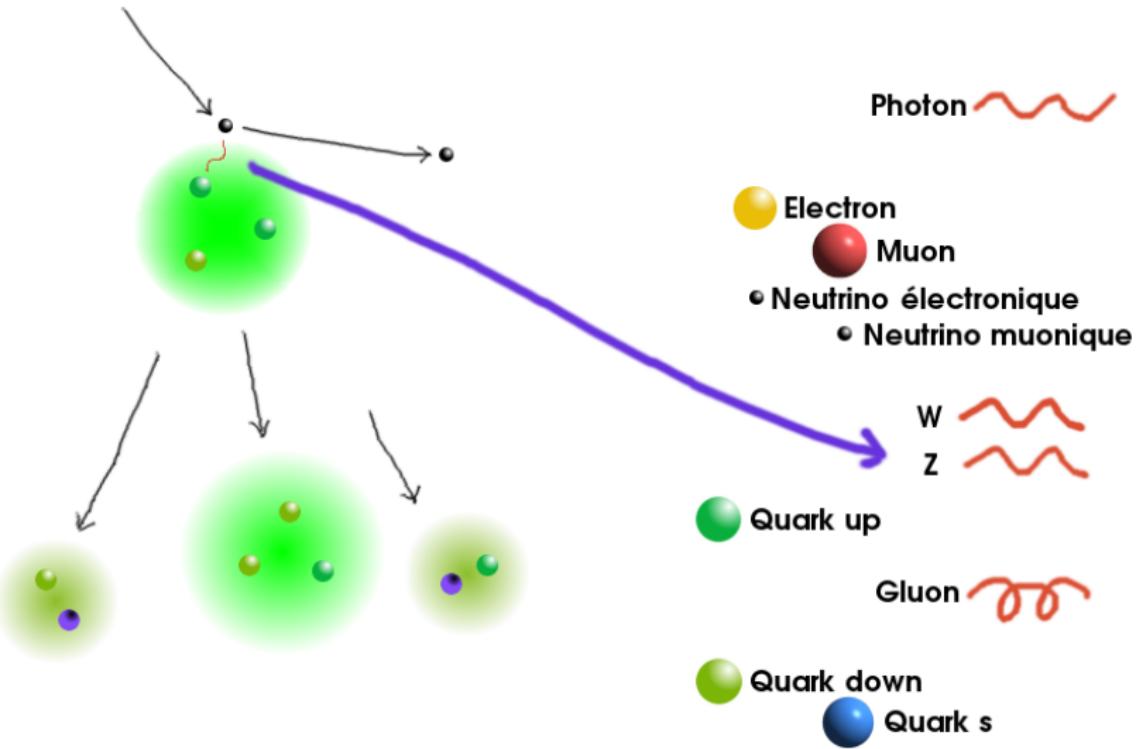
Gluon

Quark down

Quark s



- Photon
- Electron
- Muon
- Neutrino électronique
- Neutrino muonique
- 
- W
- 
- Quark up
- Gluon
- 
- Quark down
- Quark s



Photon

Electron

Muon

• Neutrino électronique

• Neutrino muonique

W   
Z

Quark up

Gluon

Quark down

Quark s



Electron



- Neutrino électronique
- Neutrino muonique



Photon



Muon



Electron

- Neutrino électronique
- Neutrino muonique

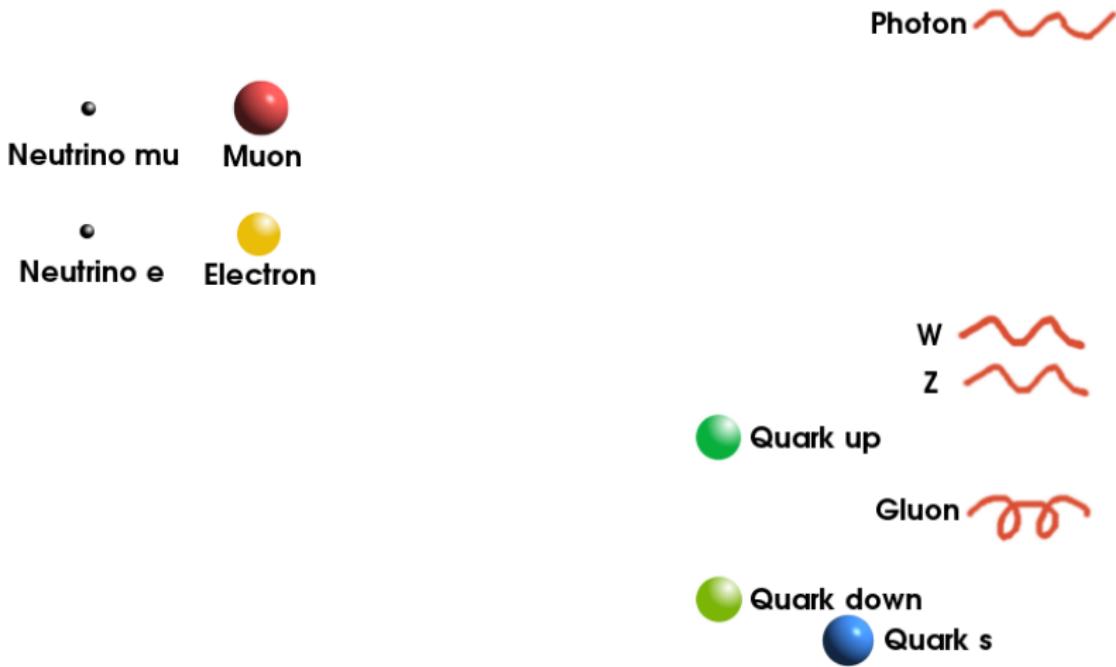
W   
Z

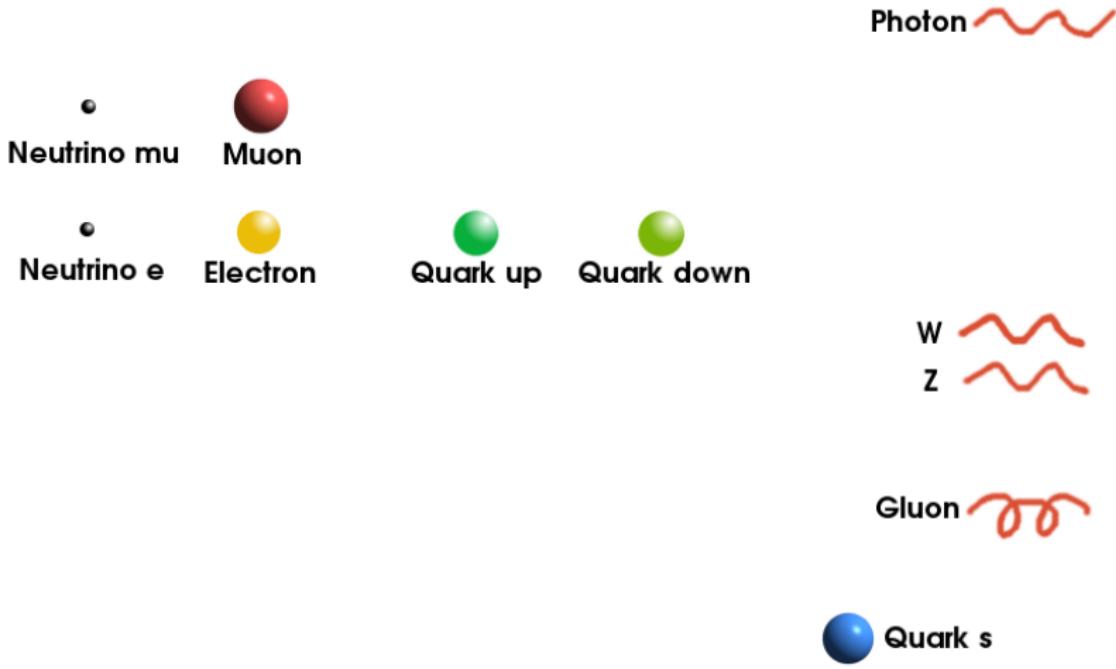
Quark up

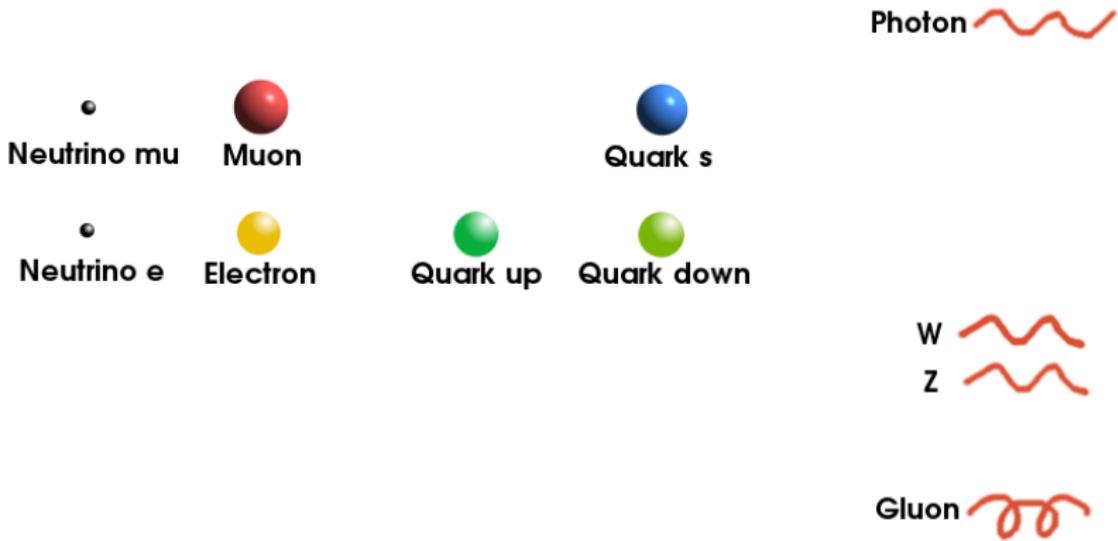
Gluon

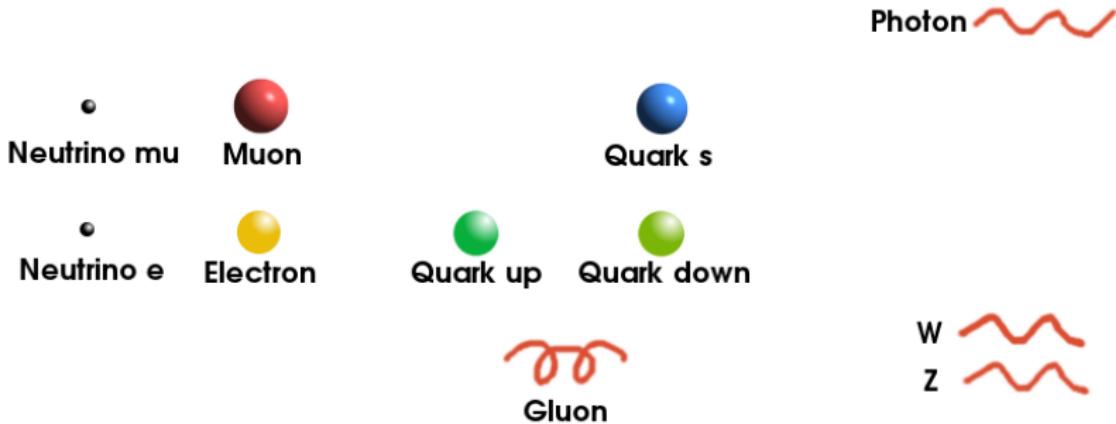
Quark down

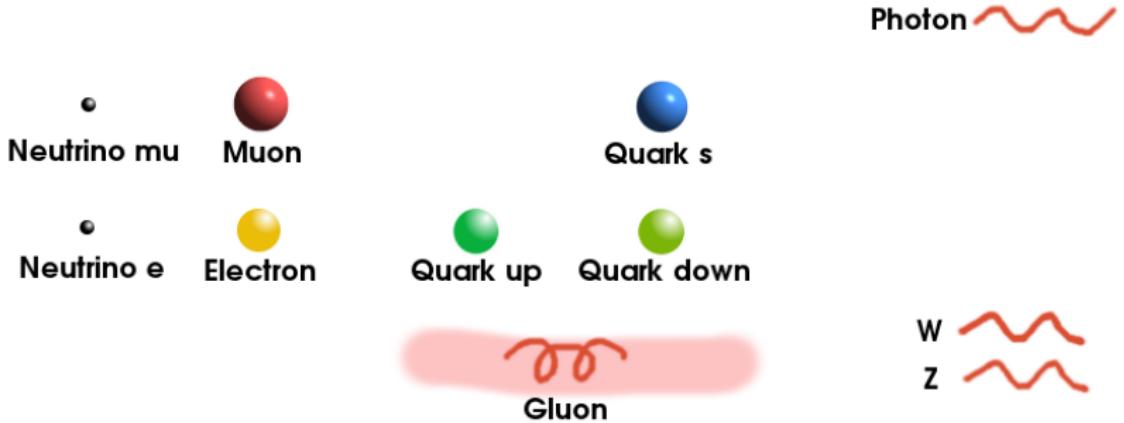
Quark s

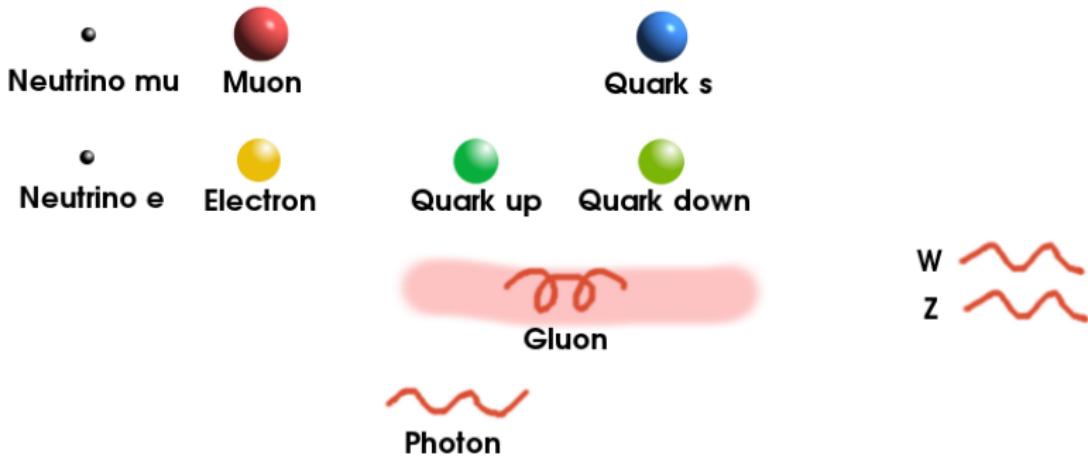


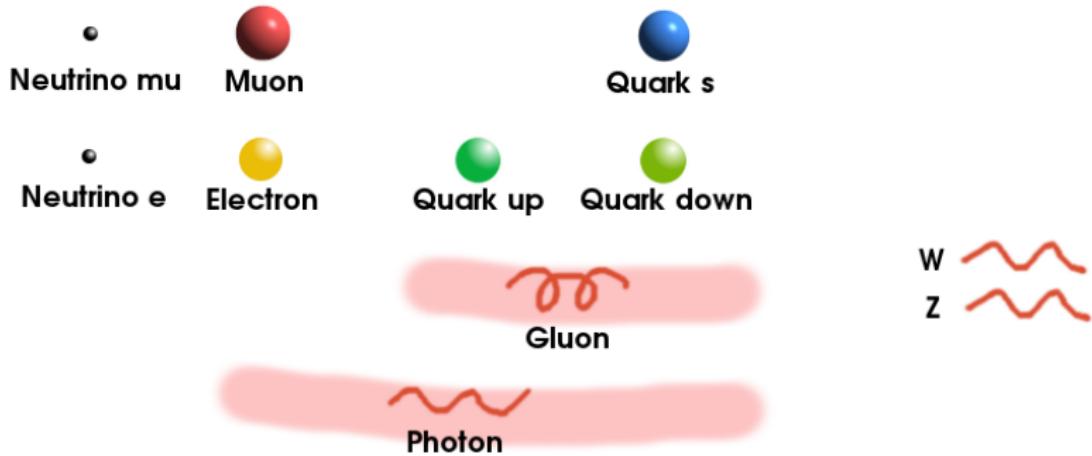


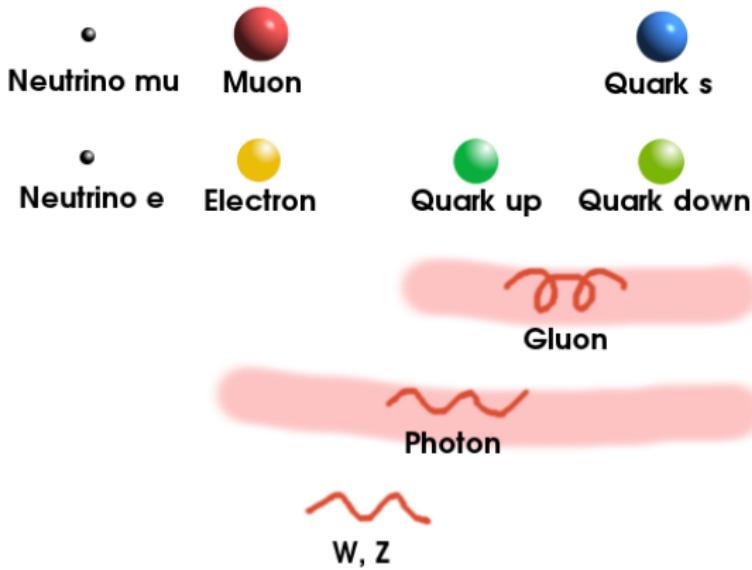


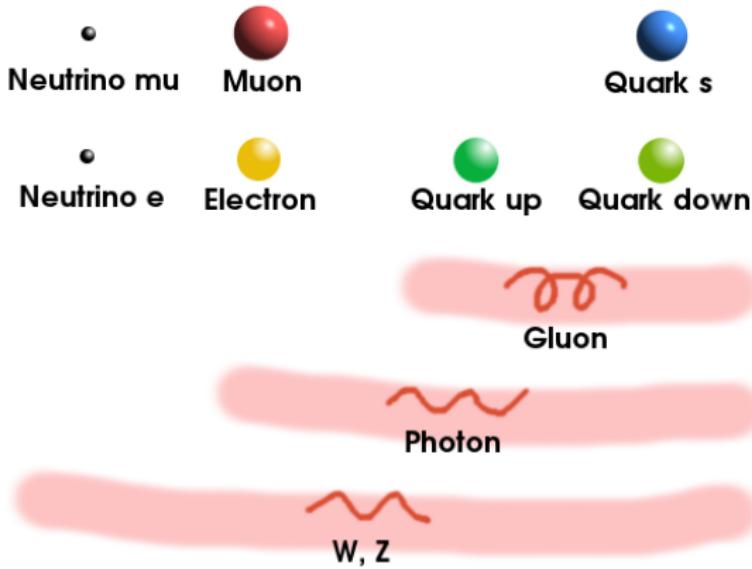


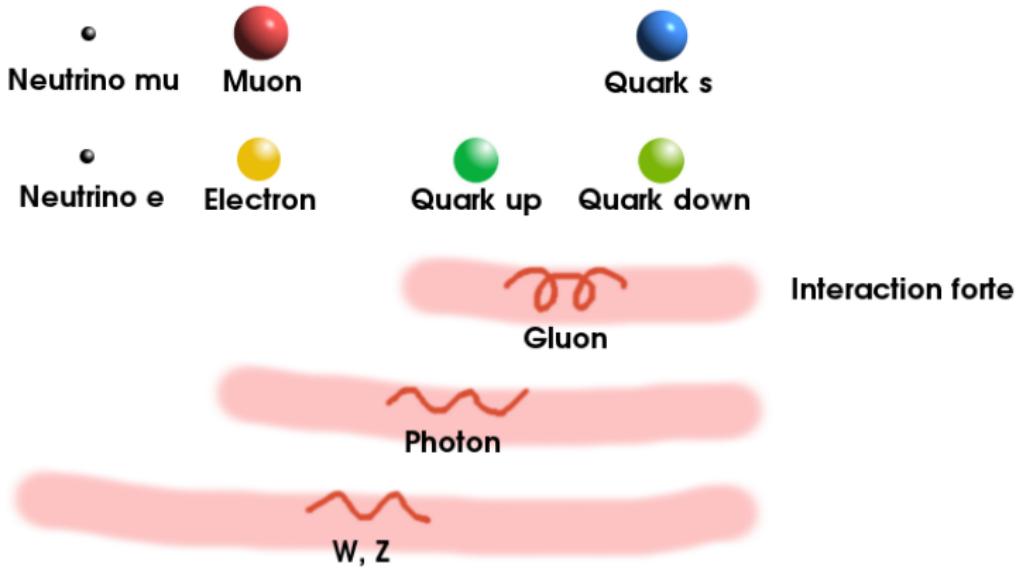












Neutrino mu



Muon



Quark s



Neutrino e



Electron



Quark up



Quark down



Gluon



Interaction forte

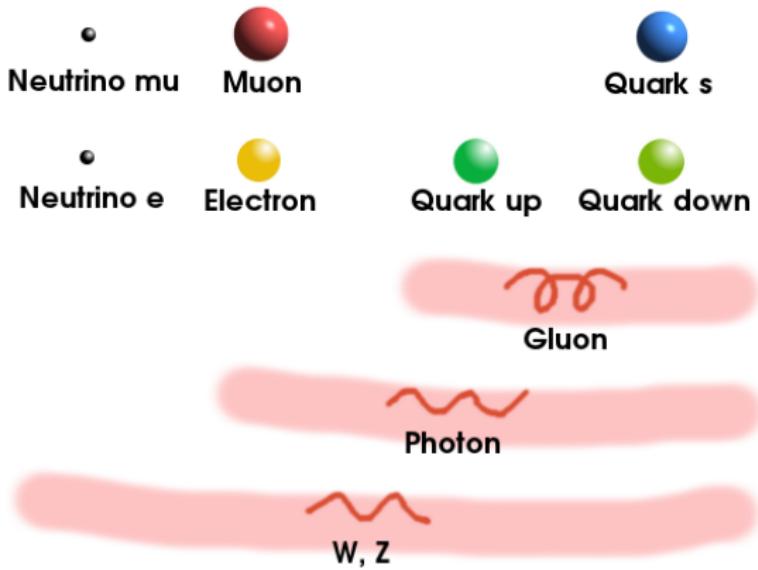
Photon

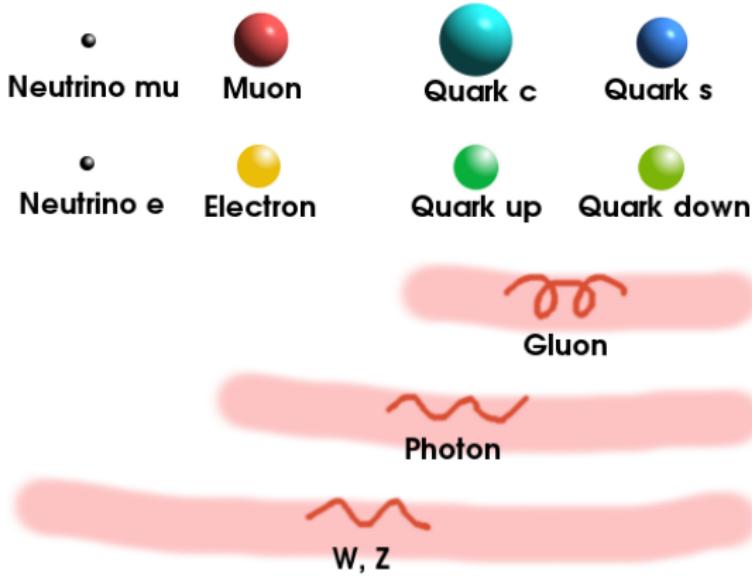


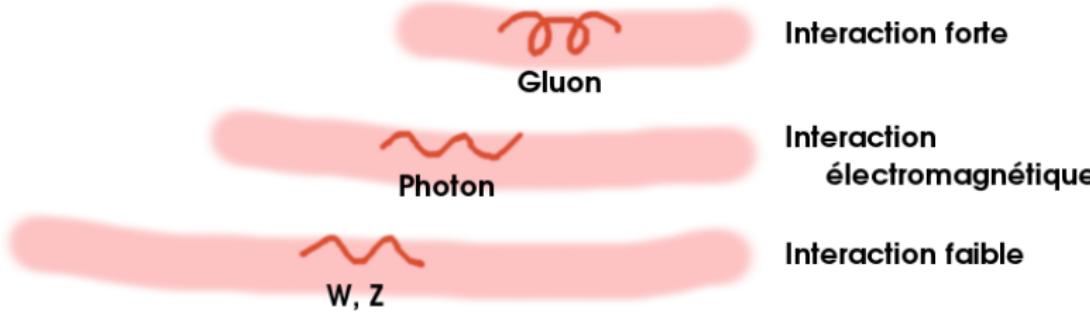
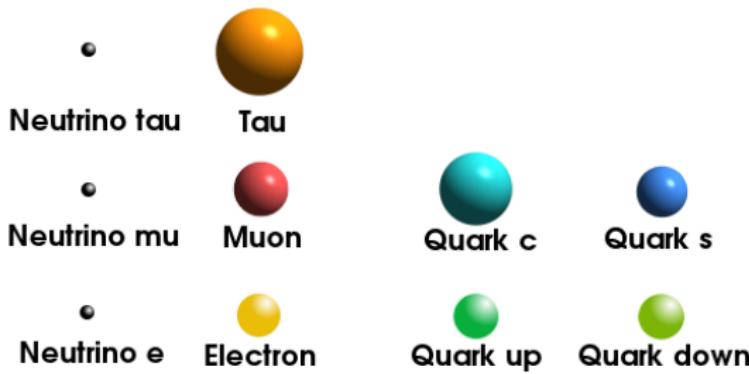
Interaction  
électromagnétique

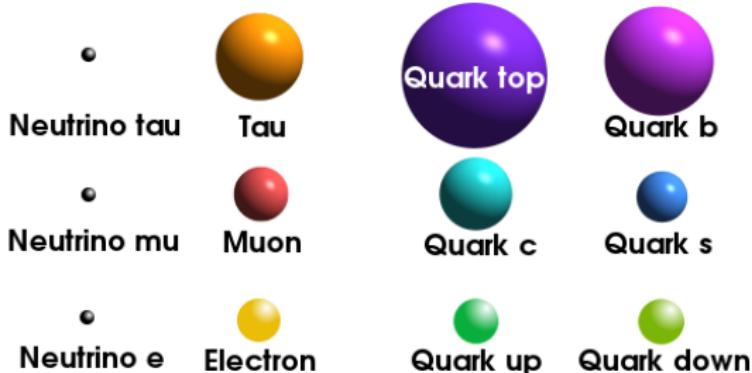
W, Z











Gluon

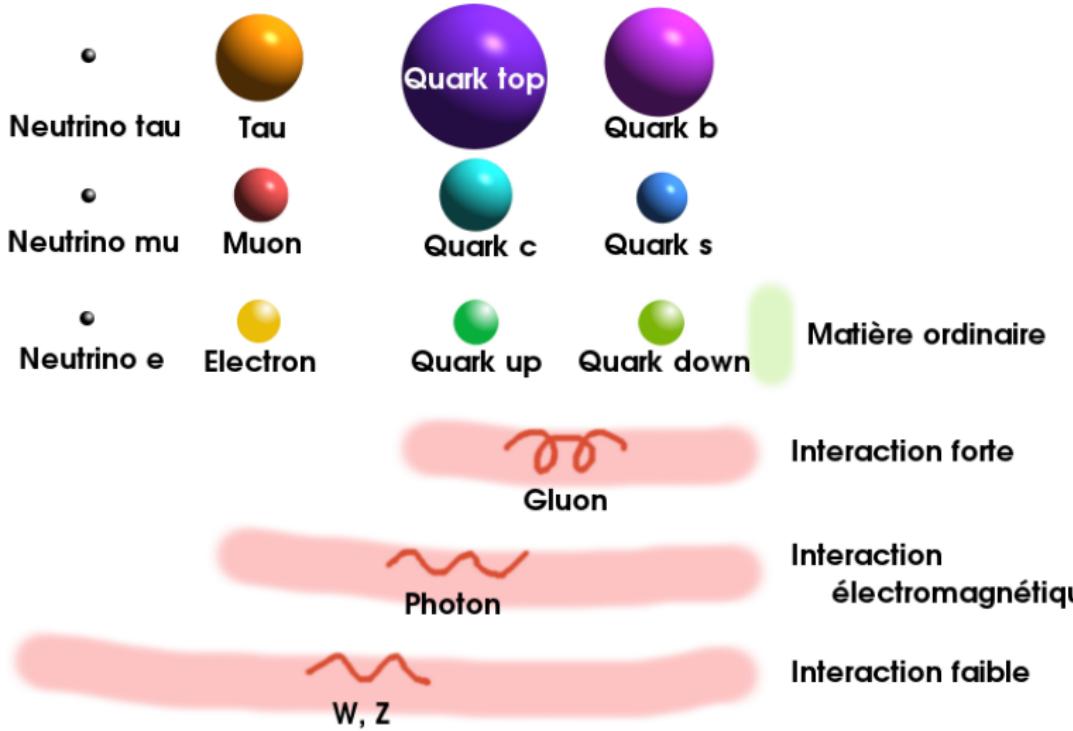
Interaction forte

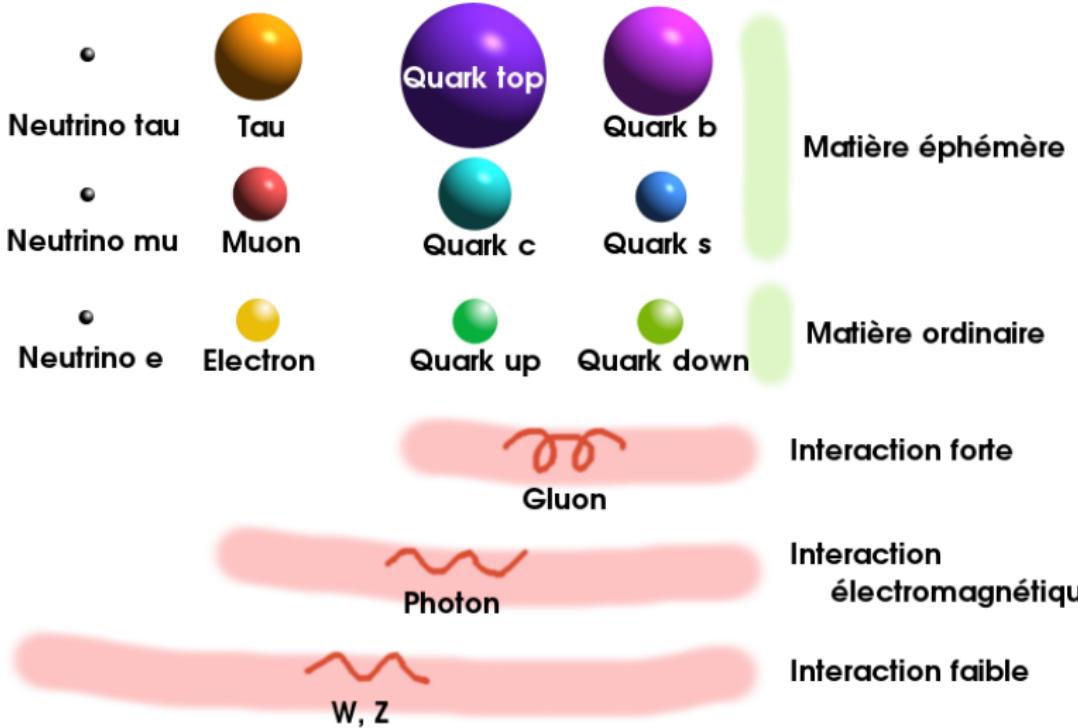
Photon

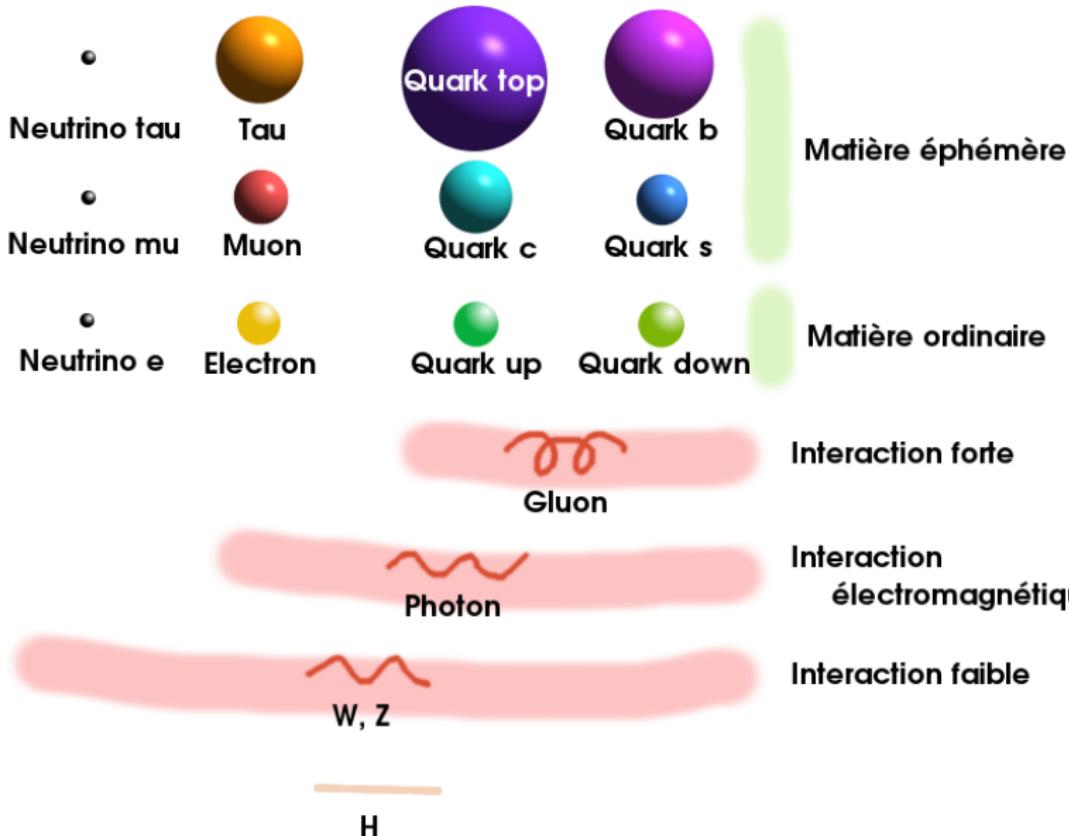
Interaction  
électromagnétique

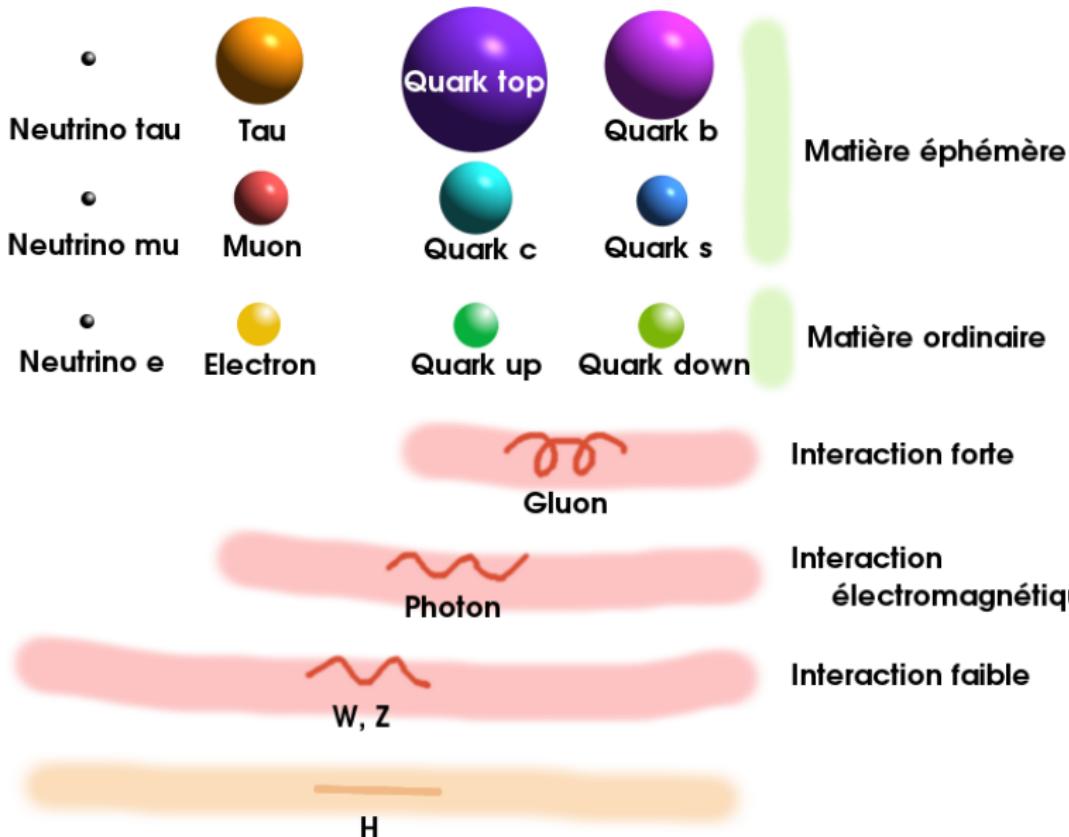
W, Z

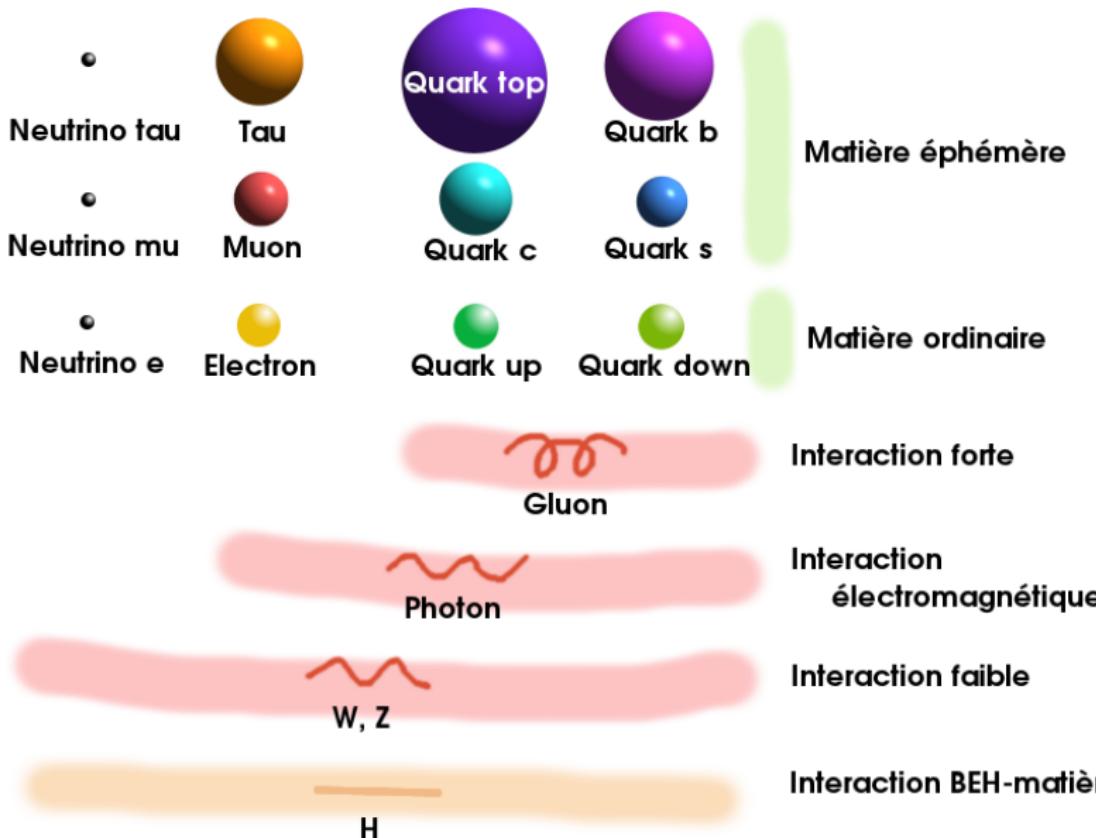
Interaction faible











# Le Modèle Standard (simplifié)

$$\begin{aligned}\mathcal{L} = & -\frac{1}{4} B_{\mu\nu} B^{\mu\nu} - \frac{1}{4} W_{\mu\nu}^a W_a^{\mu\nu} - \frac{1}{4} G_{\mu\nu}^a G_a^{\mu\nu} \\ & + \sum_{familles} \left( i(\bar{\nu}_e \bar{e})_L \gamma_\mu D_L^\mu \begin{pmatrix} \nu_e \\ e \end{pmatrix}_L + i\bar{e}_R \gamma_\mu D_R^\mu e_R + i(\bar{u} \bar{d})_L \gamma_\mu D_L^\mu \begin{pmatrix} u \\ d \end{pmatrix}_L + i \sum_{u,d} \bar{q}_R \gamma_\mu D_R^\mu q_R \right) \\ & \quad + \sum_{quarks} i(\bar{q}_R \bar{q}_V \bar{q}_B) \gamma_\mu D_C^\mu \begin{pmatrix} q_R \\ q_V \\ q_B \end{pmatrix} \\ & \quad - \sum_{familles} g_e \left( \bar{e}_R \Phi^\dagger \begin{pmatrix} \nu_e \\ e \end{pmatrix}_L + (\bar{\nu}_e \bar{e})_L \Phi e_R \right) \\ & - \sum_{familles} \left[ g_u \left( \bar{u}_R \tilde{\Phi}^\dagger \begin{pmatrix} u \\ d \end{pmatrix}_L + (\bar{u} \bar{d})_L \tilde{\Phi} u_R \right) + g_d \left( \bar{d}_R \Phi^\dagger \begin{pmatrix} u \\ d \end{pmatrix}_L + (\bar{u} \bar{d})_L \Phi d_R \right) \right] + \mathcal{L}_{mélange} \\ & \quad + (D_{L\mu} \Phi)^\dagger (D_L^\mu \Phi) - \mu^2 \Phi^\dagger \Phi - \lambda (\Phi^\dagger \Phi)^2\end{aligned}$$

$$D_R^\mu = \partial^\mu + ig_1 \frac{Y_W}{2} B^\mu, D_L^\mu = \partial^\mu + ig_2 \frac{\sigma^a}{2} W_a^\mu + ig_1 \frac{Y_W}{2} B^\mu$$

$$D_C^\mu = \partial^\mu + ig_3 \frac{\lambda^a}{2} G_a^\mu$$