

# Drawing Feynman Diagrams

Reminder: leptons  $\begin{pmatrix} e^- \\ \nu_e \end{pmatrix} \begin{pmatrix} \mu^- \\ \nu_\mu \end{pmatrix} \begin{pmatrix} \tau^- \\ \nu_\tau \end{pmatrix}$

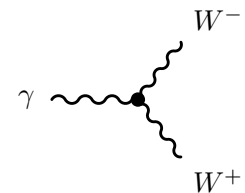
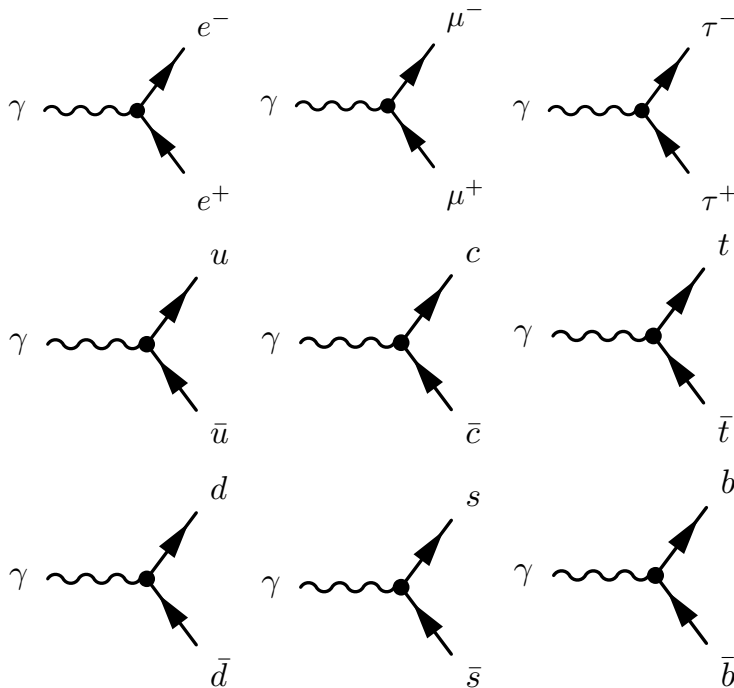
quarks  $\begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix} \quad \begin{pmatrix} Q = +\frac{2}{3} \\ Q = -\frac{1}{3} \end{pmatrix}$

	EM( $\gamma$ )	Weak ( $W^\pm, Z$ )	Strong ( $g$ )
$q$	✓	✓	✓
$\ell^\pm$	✓	✓	
$\nu$	✓		

## Allowed Vertices

### EM Interaction

- must involve a photon  $\gamma$ , and **charged** particles
- coupling strength  $Q\sqrt{\alpha}$   $Q$ =charge

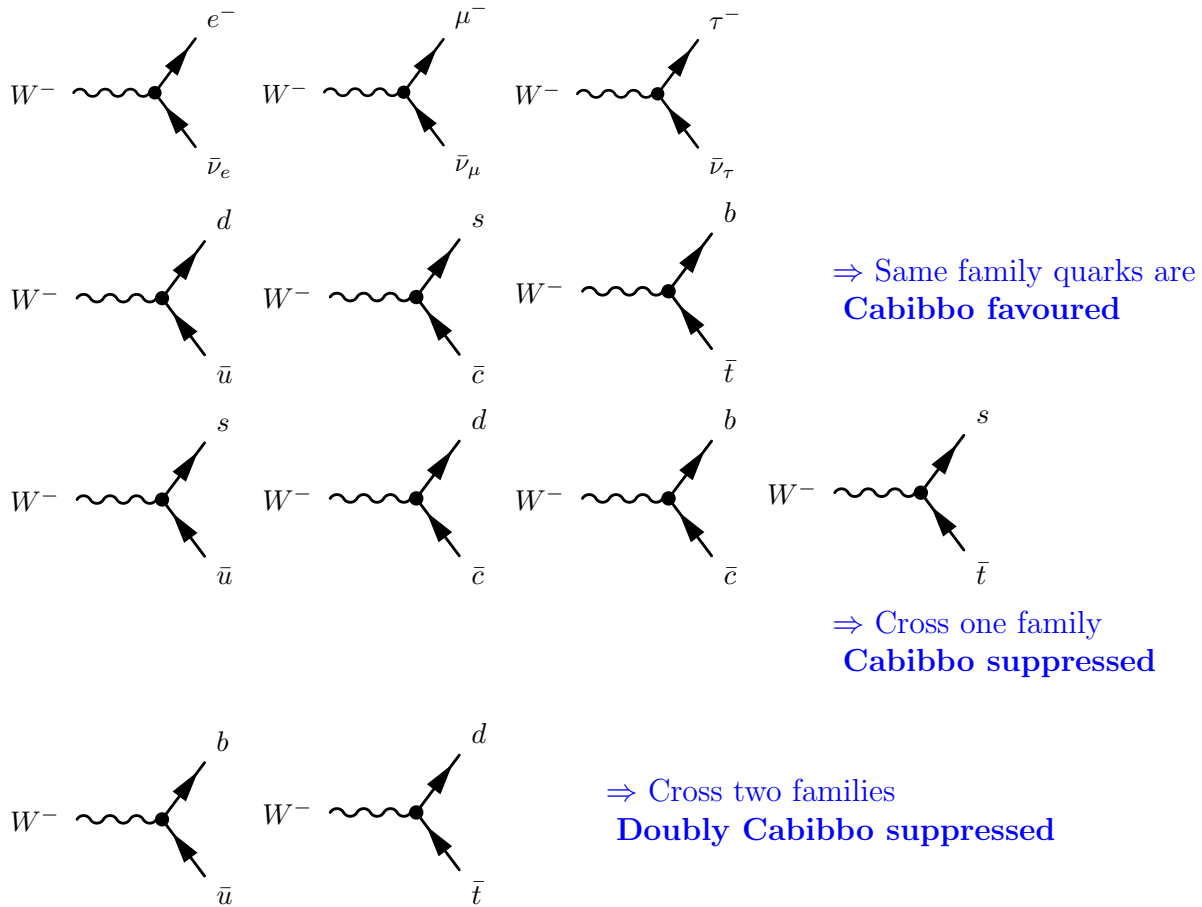


Triple Gauge Vertex

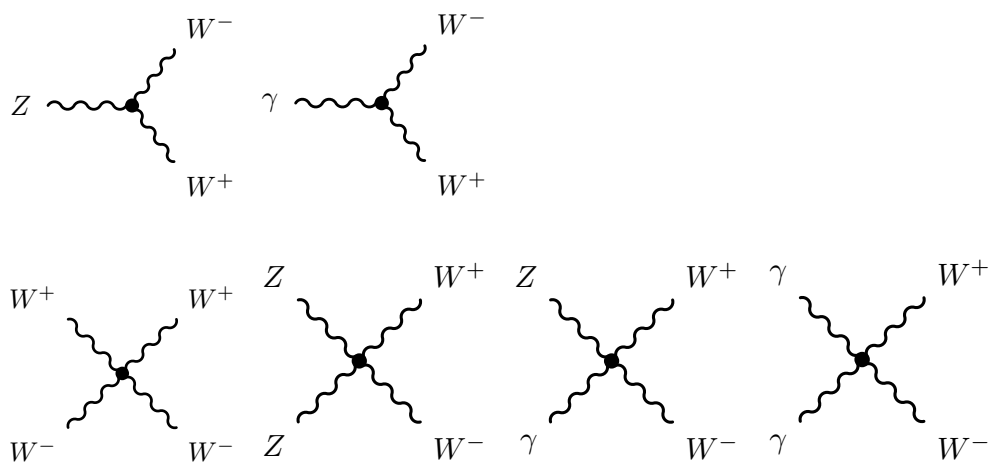
## Weak Interaction

- must involve a gauge vector boson  $Z$  or  $W^\pm$
- coupling strength  $g_w$
- tip: if you see a  $\nu$  or  $\bar{\nu}$ , it must be a weak interaction

with  $W^\pm$

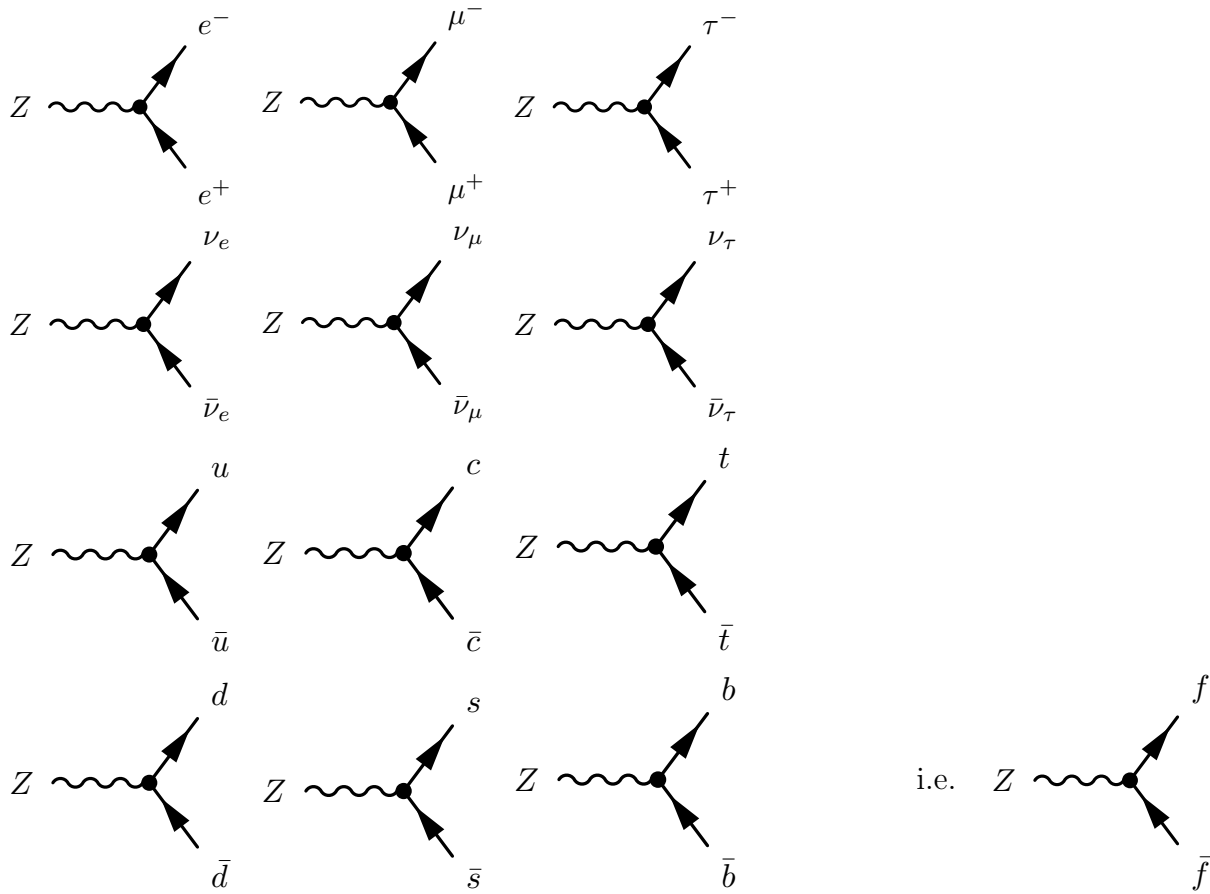


Also, Triple/Four Gauge Vertex

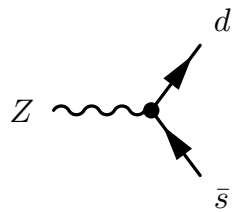


with  $Z$

Same as  $\gamma$  diagrams, but + vertices with  $\nu$

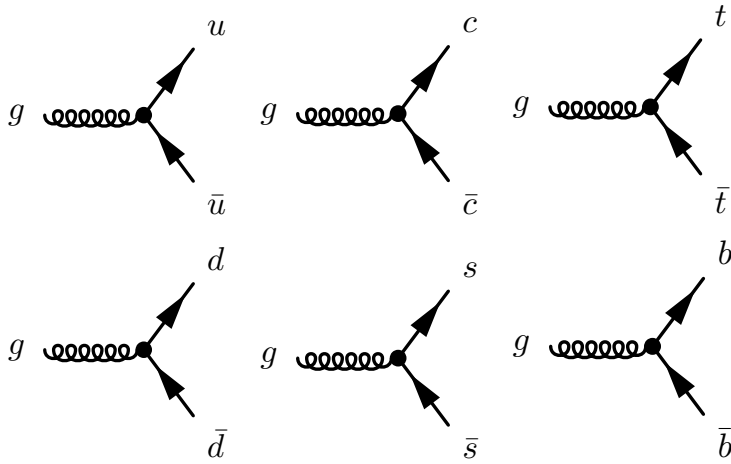


Not Allowed: Flavour Changing Neutral Currents (FCNC)

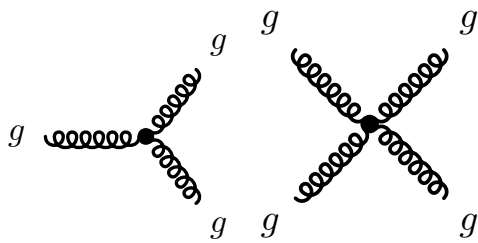


## Strong Interaction

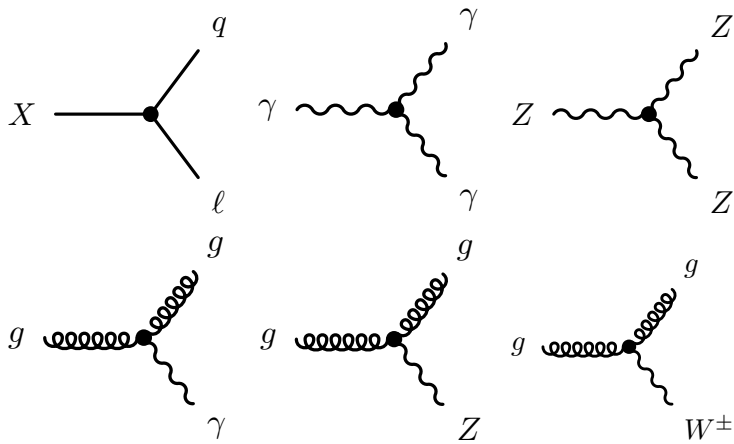
- must involve a gluon  $g$  and/or quark  $q$
- coupling strength  $\sqrt{\alpha_s}$
- conserve strangeness, charm etc



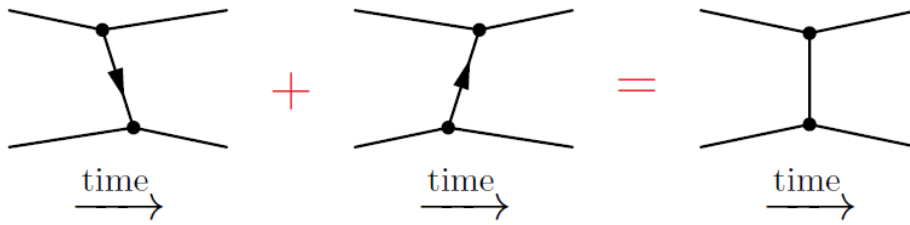
Also, Triple Gauge Vertex



## Forbidden vertices



### All time ordering



### Summary

1. Draw the lines, vertices and arrows
2. Label all particles
3. Check charge, lepton number, baryon number etc is conserved at each vertex
4. Label all vertices with the coupling constant (EM:  $Q\sqrt{\alpha}$ , Weak:  $g_W$ , Strong:  $\sqrt{\alpha_s}$ )
5. Indicate you know  $\sigma \propto |M|^2 \propto \text{coupling constant}^2$
6. Every physical process has at least 2 vertices

### Common pitfalls

- Time Order (n.b. time: left→right)
- No 4-junction vertices - always 3-junction (except  $gg \rightarrow gg$ )