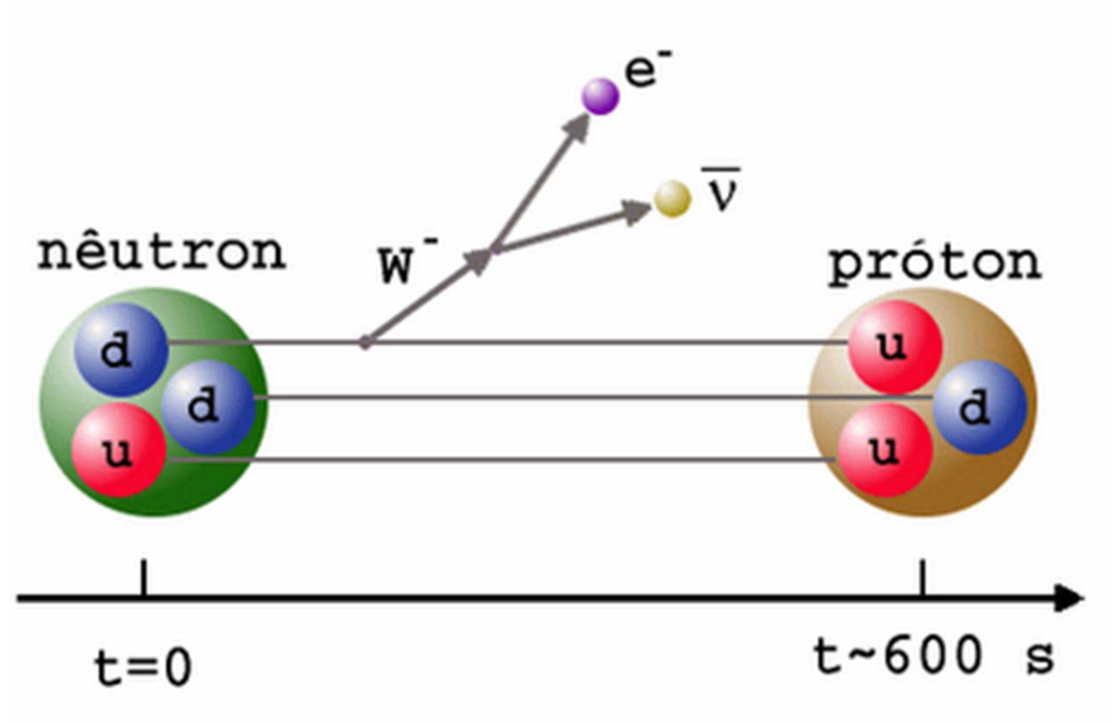


Syracuse Summer Institute
Finale on Weak Decays

Oh, so many decays, and so little time

- I've shown you one possible weak decay last time.
- A B^- meson has 100's of ways it can decay! Huh, why?
  - Because it can! (Remember, tenet of Quantum Physics)

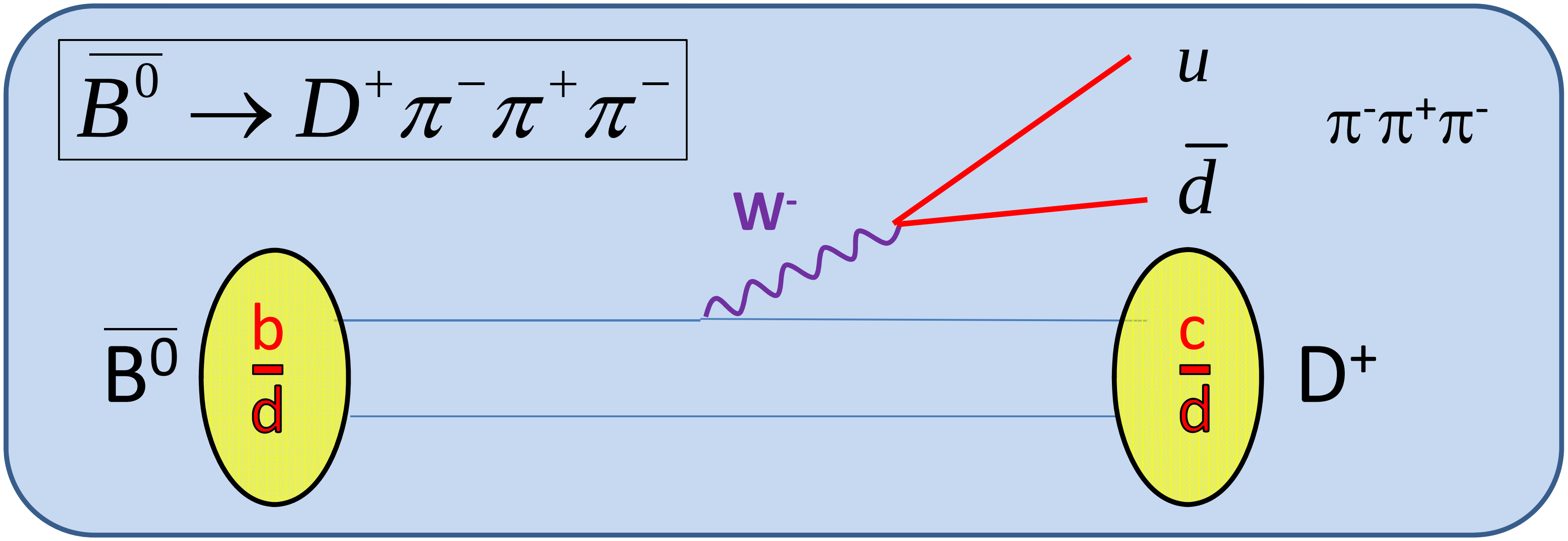
$D^-\pi^+$	$(2.68 \pm 0.13) \times 10^{-3}$	
$D^-\rho^+$	$(7.8 \pm 1.3) \times 10^{-3}$	
$D^-K^0\pi^+$	$(4.9 \pm 0.9) \times 10^{-4}$	
$D^-K^*(892)^+$	$(4.5 \pm 0.7) \times 10^{-4}$	
$D^-\omega\pi^+$	$(2.8 \pm 0.6) \times 10^{-3}$	
D^-K^+	$(2.0 \pm 0.6) \times 10^{-4}$	
$D^-K^+\overline{K}^0$	$< 3.1 \times 10^{-4}$	CL=90%
$D^-K^+\overline{K}^*(892)^0$	$(8.8 \pm 1.9) \times 10^{-4}$	
$\overline{D}^0\pi^+\pi^-$	$(8.4 \pm 0.9) \times 10^{-4}$	
$D^*(2010)^-\pi^+$	$(2.76 \pm 0.13) \times 10^{-3}$	
$D^-\pi^+\pi^+\pi^-$	$(8.0 \pm 2.5) \times 10^{-3}$	
$(D^-\pi^+\pi^+\pi^-)$ nonresonant	$(3.9 \pm 1.9) \times 10^{-3}$	
$D^-\pi^+\rho^0$	$(1.1 \pm 1.0) \times 10^{-3}$	
$D^-a_1(1260)^+$	$(6.0 \pm 3.3) \times 10^{-3}$	
$D^*(2010)^-\pi^+\pi^0$	(1.5 ± 0.5) %	
$D^*(2010)^-\rho^+$	$(6.8 \pm 0.9) \times 10^{-3}$	
$D^*(2010)^-K^+$	$(2.14 \pm 0.16) \times 10^{-4}$	
$D^*(2010)^-K^0\pi^+$	$(3.0 \pm 0.8) \times 10^{-4}$	
$D^*(2010)^-K^*(892)^+$	$(3.3 \pm 0.6) \times 10^{-4}$	
$D^*(2010)^-K^+\overline{K}^0$	$< 4.7 \times 10^{-4}$	CL=90%
$D^*(2010)^-K^+\overline{K}^*(892)^0$	$(1.29 \pm 0.33) \times 10^{-3}$	
$D^*(2010)^-\pi^+\pi^+\pi^-$	$(7.0 \pm 0.8) \times 10^{-3}$	S=1.3
$(D^*(2010)^-\pi^+\pi^+\pi^-)$ non-resonant	$(0.0 \pm 2.5) \times 10^{-3}$	
$D^*(2010)^-\pi^+\rho^0$	$(5.7 \pm 3.2) \times 10^{-3}$	
$D^*(2010)^-a_1(1260)^+$	(1.30 ± 0.27) %	
$D^*(2010)^-\pi^+\pi^+\pi^-\pi^0$	(1.76 ± 0.27) %	
$D^{*-}3\pi^+2\pi^-$	$(4.7 \pm 0.9) \times 10^{-3}$	

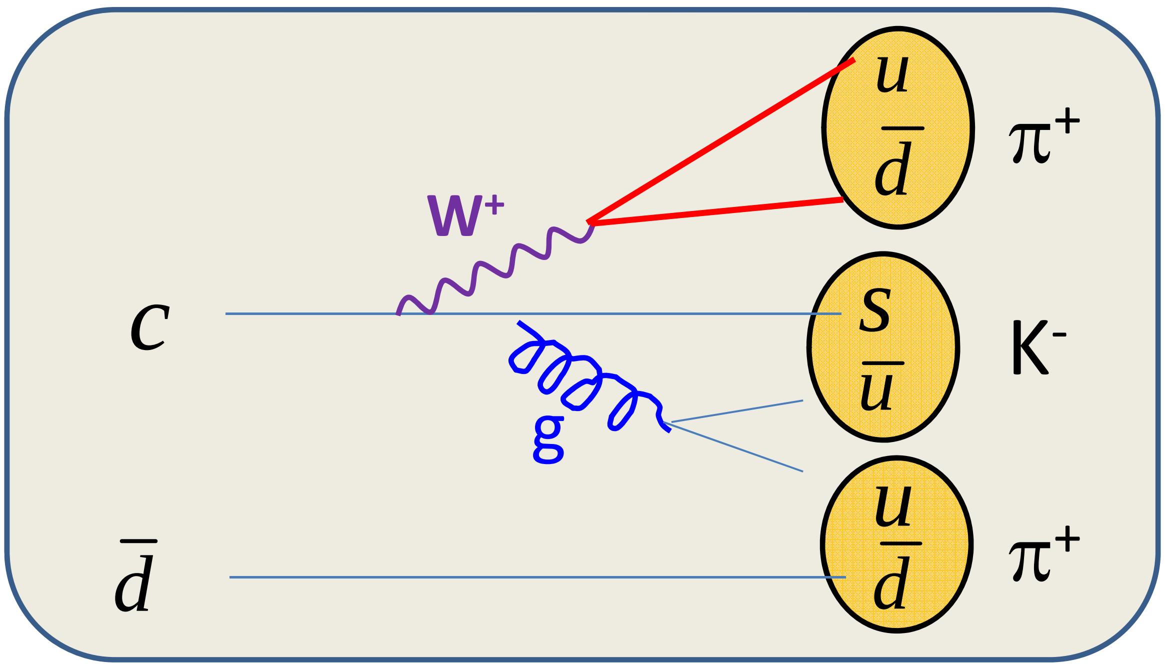
This is a small fraction of the decays known for the B^0 meson ($\bar{b}d$)

The number on the right is the fraction of time the B^0 meson undergoes that decay.

For every one of these decays, one should be able to draw a Feynman diagram to represent it!

Another B meson decay

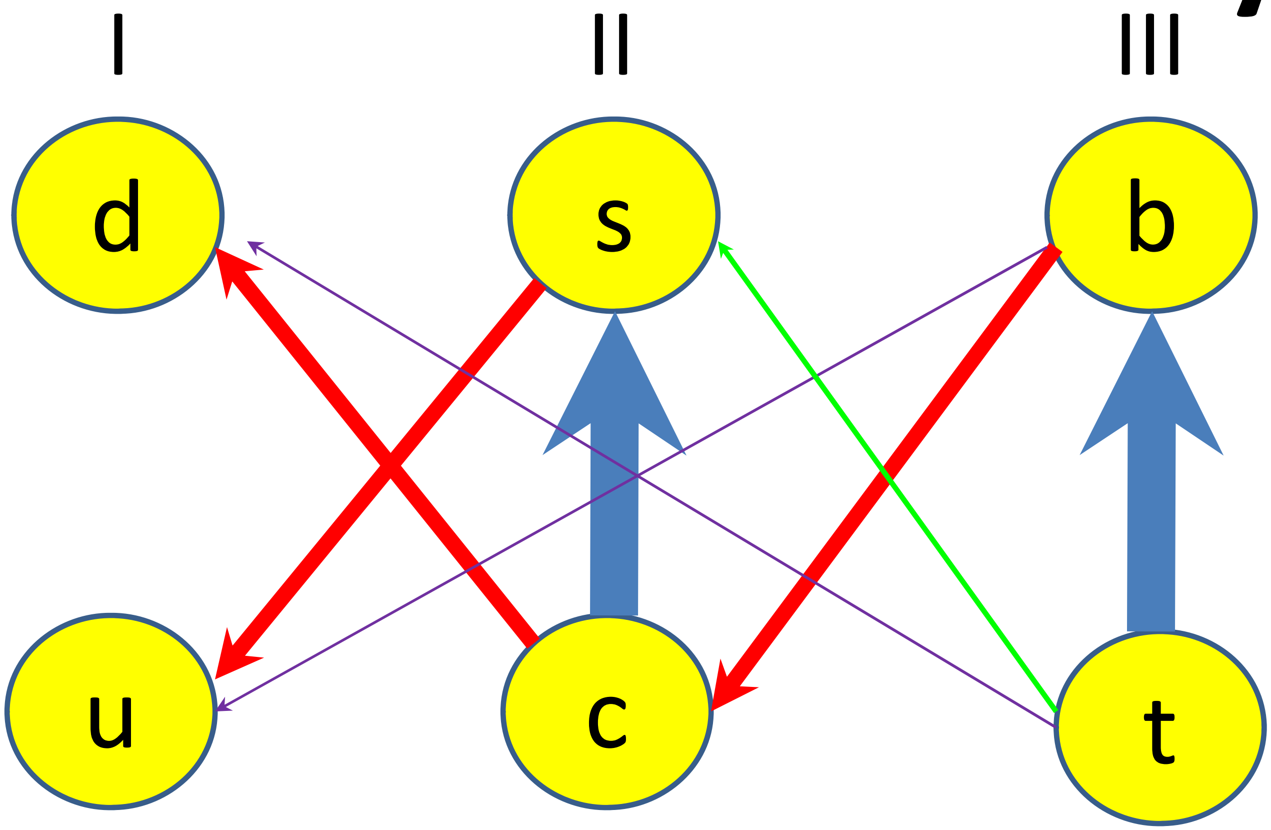




$D^+ \rightarrow K^-\pi^+\pi^+$

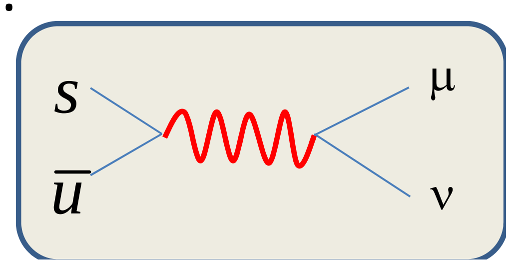
Happens ~9% of the time

Weak Decays



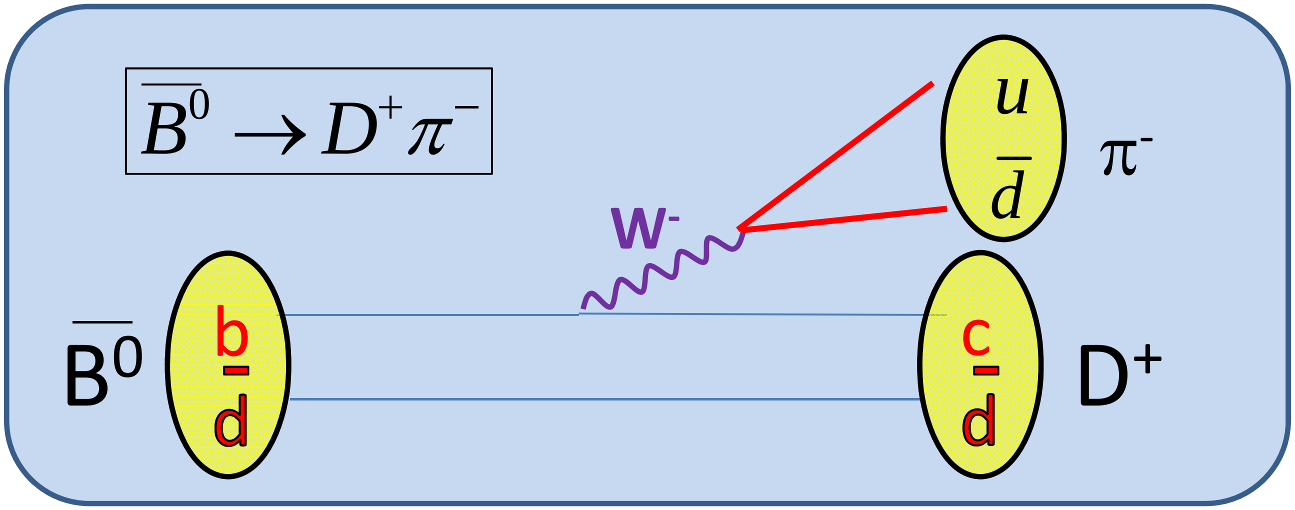
Width of arrows give a qualitative feel for the decay rate.

- Top: t→b >>> t→s or t→d.
- Bottom: b→c >> b→u .
- Charm: (c→s) ~ 25 x (c→d); smaller total decay rate.
- Strange: s→u dominates in many cases, but not all.. e.g. $K^+ \rightarrow \mu\nu$ dominant (no "u" quark in final state)

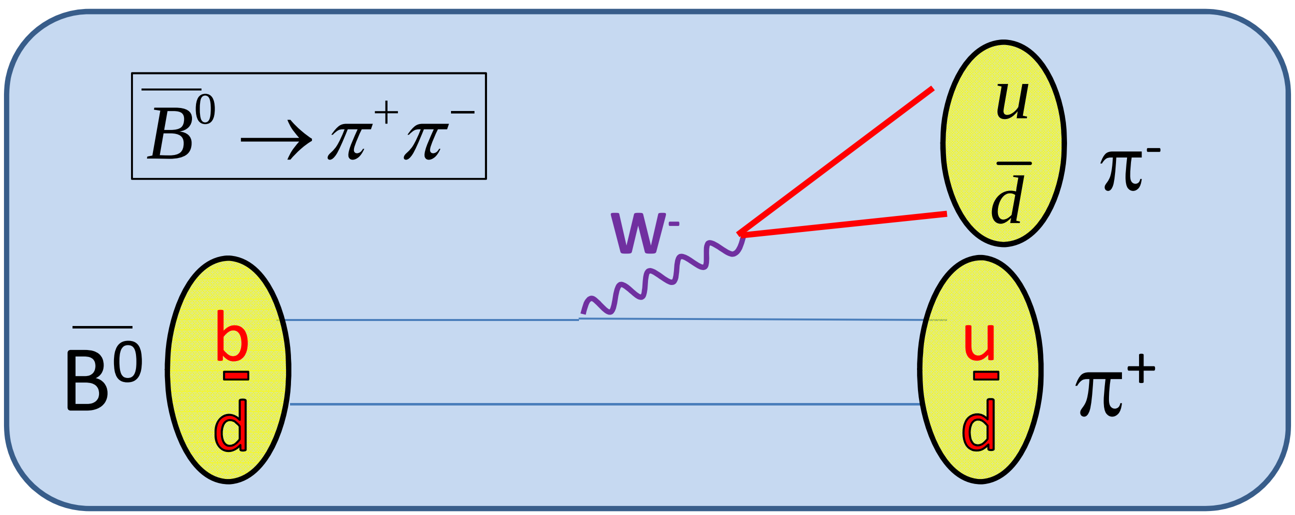


Comparison of "Branching Fractions"

"Branching fraction" is just a fancy name that tells how often a particle decays to some particular final state.



BF=2.68x10^{-3}



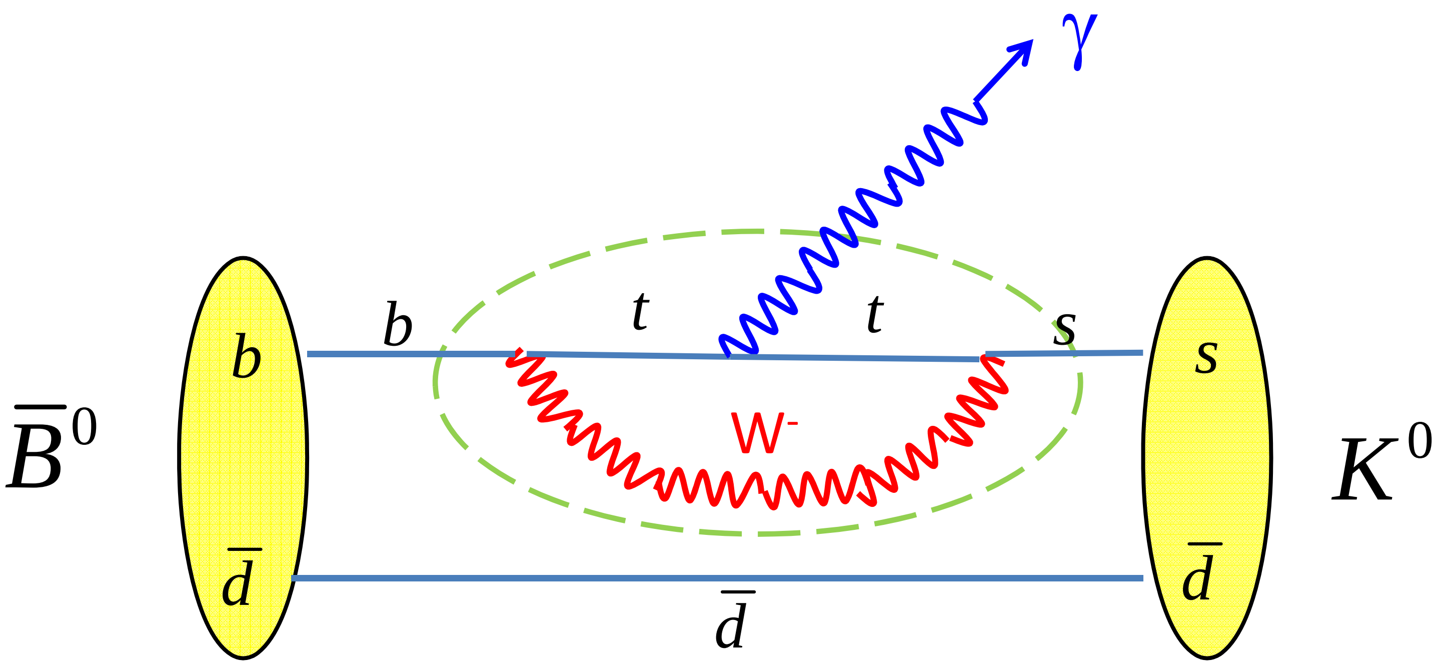
BF=5.15x10^{-6}

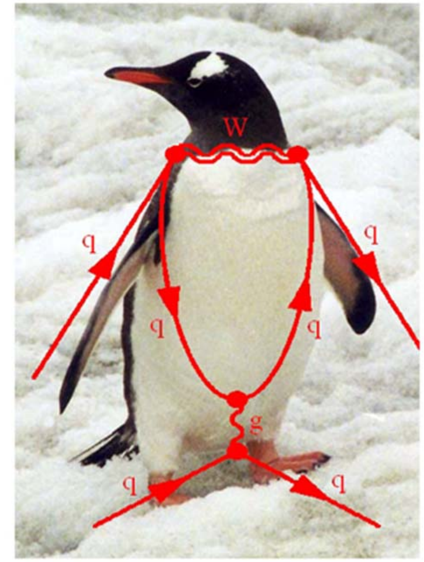
New Physics in B decays

- If in the decay of a particle, there is a virtual particle "loop", there is the potential for a new particle to contribute to the decay.
  - Since it's emitted and re-absorbed, it needn't conserve energy, as long as $\Delta E \Delta t \sim \hbar$
  - Example coming on next slide.

- **Key point:** Even though you may not see it directly, it will leave its fingerprints.
  - Deviations from SM expected rates or other observable quantities.

“Penguin” decays

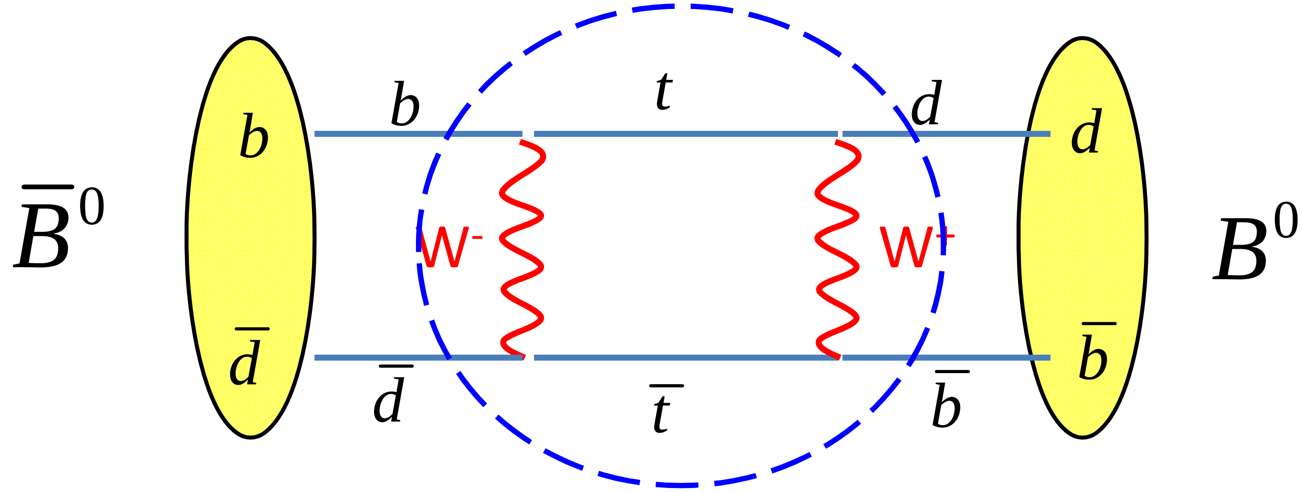




- Involves a virtual W boson loop – suppressed in the SM.
  - **Potential for new, high mass particles to contribute in these kinds of “loop diagrams”.**
  - **Just replace W and top quark with some new physics particles!**

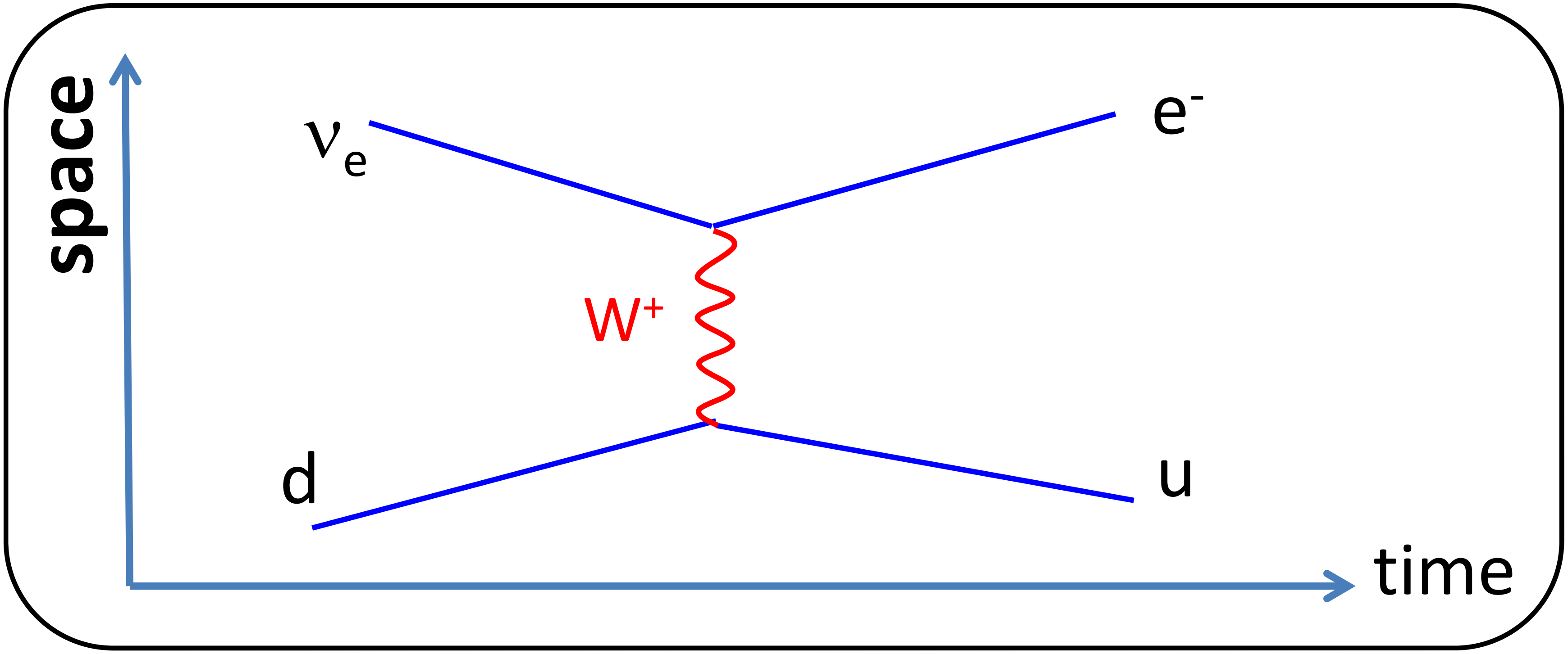
Particle-antiparticle mixing

- Oddly enough, the weak interaction allows certain particles to transform into their antiparticles.



- The B←→$\overline{\text{B}}$ oscillation occurs ~200 billion times per second.
- Alternately said, the B←→$\overline{\text{B}}$ oscillate back & forth with a period of ~5 pico-seconds.
- Recall, that the decay time is ~ 1.5 ps.
- So, about 20% of produced B^0 mesons will decay as $\overline{\text{B}}^0$!
- Involves 2 W bosons – suppressed in the SM.
- Involves a "loop" with 2 virtual top quarks and 2 W's.
  - **Potential for new, high mass particles to contribute**

Neutrino Interactions



- Here, a neutrino interacts with a d-quark. The neutrino emits a W^+ and turns into an e-.

- The d-quark absorbs the W^+ and turns into a u-quark.

The force carriers and what they couple to

Force	Carrier	Mass	Quarks u c t d s b	Charged Leptons e μ τ	Neutral Leptons ν_e ν_μ ν_τ
EM	Photon	0	Yes	Yes	No
Strong	Gluon	0	Yes	No	No
Weak	$W^{\pm}$, Z^0	~100X proton mass	Yes	Yes	Yes