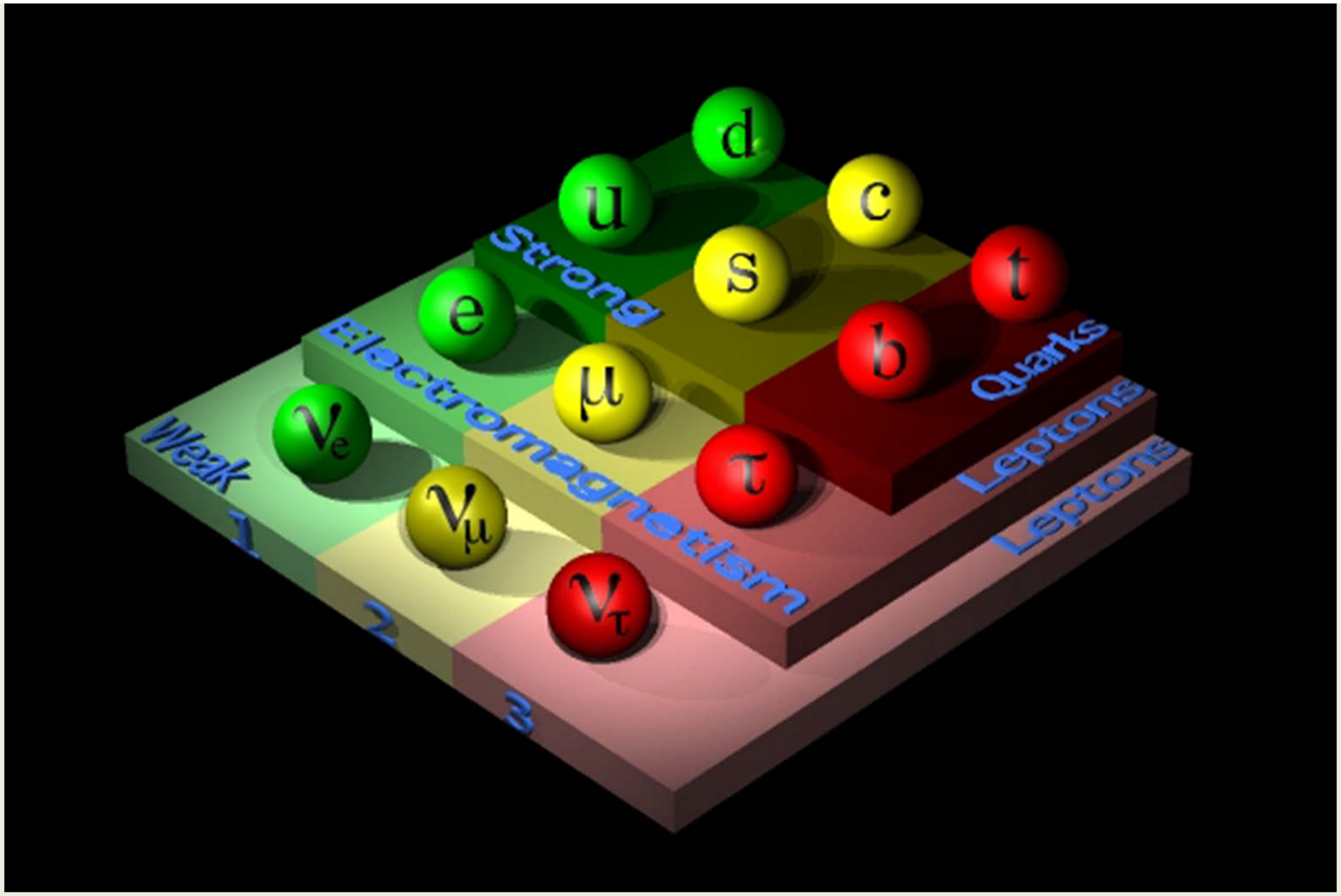


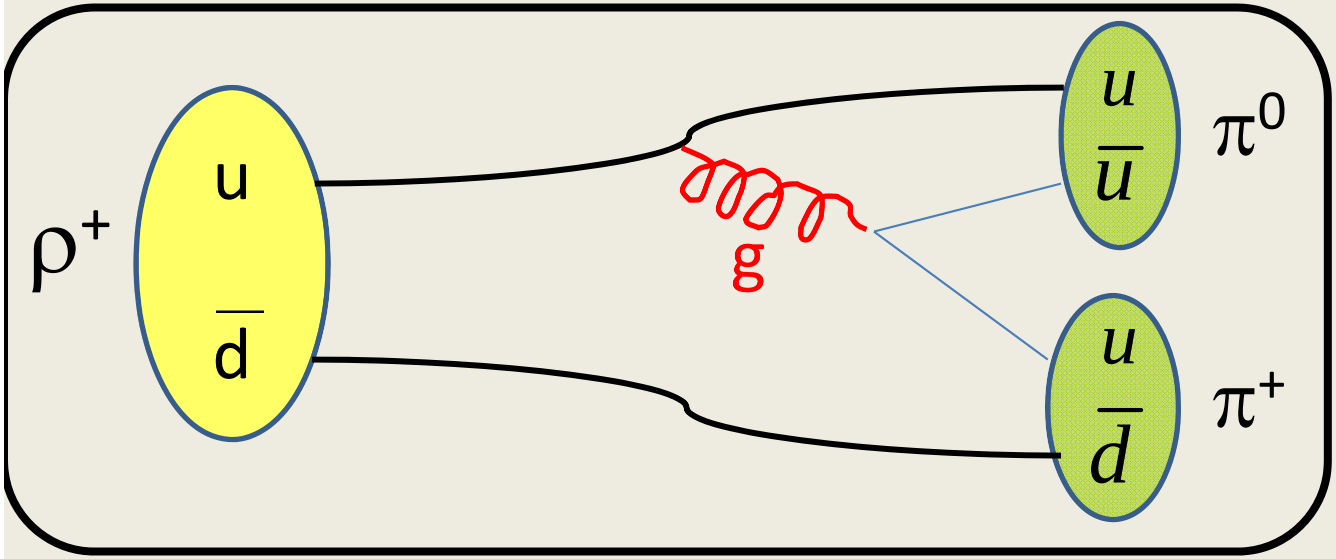
Quarknet
Syracuse Summer Institute
Strong Forces, finale

Last time – Key points

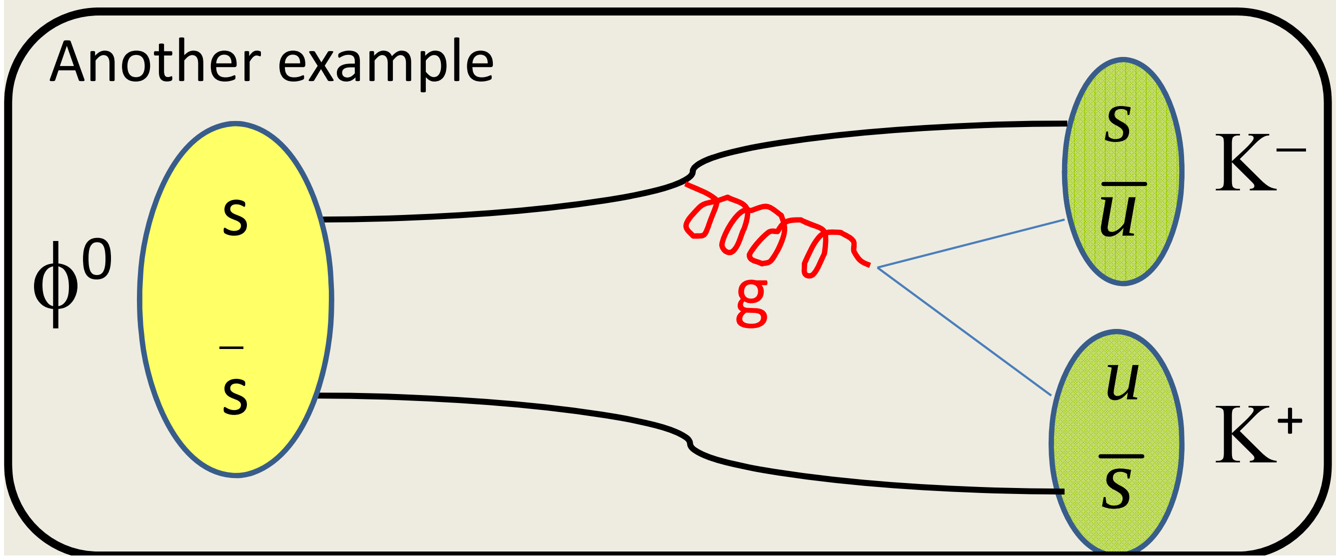
- Feynman diagrams: pictorial representation of interaction between fundamental particles and force carriers.
  - Both “scattering” and decays
- Energy and momentum conservation applies at each “vertex”
- The mass of an object is a measure of it’s “self-energy”.
- Strong & EM force can only add or remove $q\bar{q}$ pairs, they CANNOT change the quark not the lepton type.

Example of strong decay

- The ρ^+ meson is an excite state of a $(u\bar{d})$.
- How does it decay?



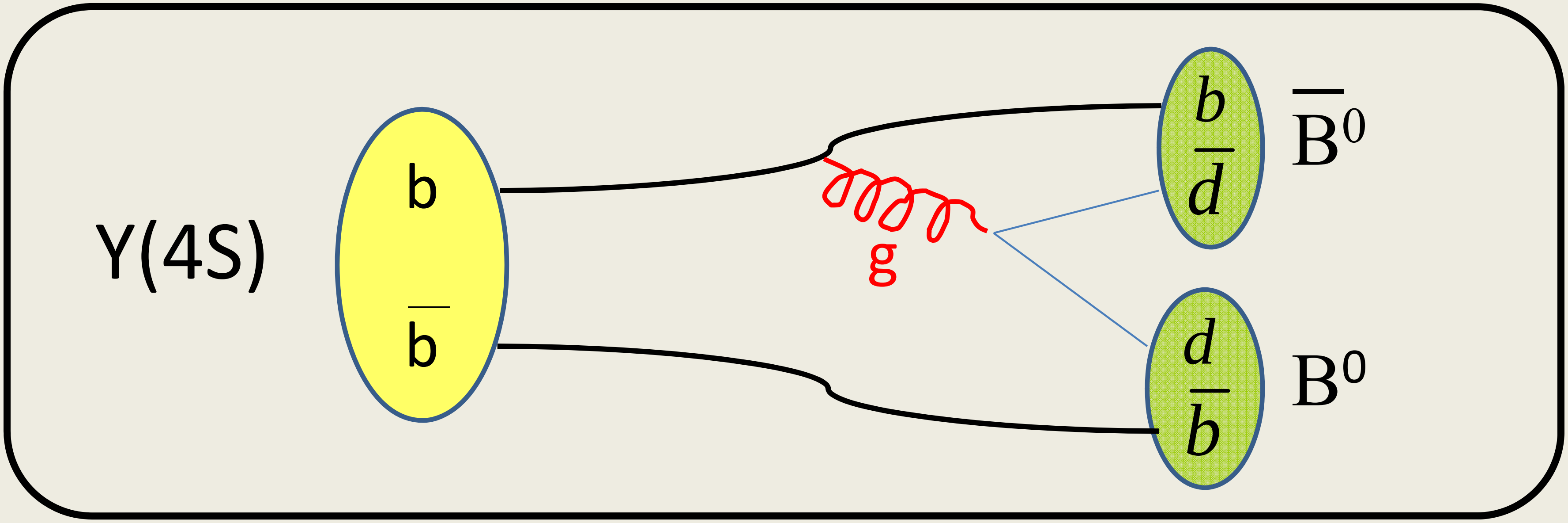
- ❑ Strong decay.
- ❑ Note the gluon produces a $q\bar{q}$ pair.
- ❑ The original quarks are still there!
- ❑ Could also get $g \rightarrow d\bar{d}$, which would still yield $\pi^+\pi^0$.



- ❑ Could also get $g \rightarrow d\bar{d}$, which would then yield K^0 and K^0.

Another strong decay

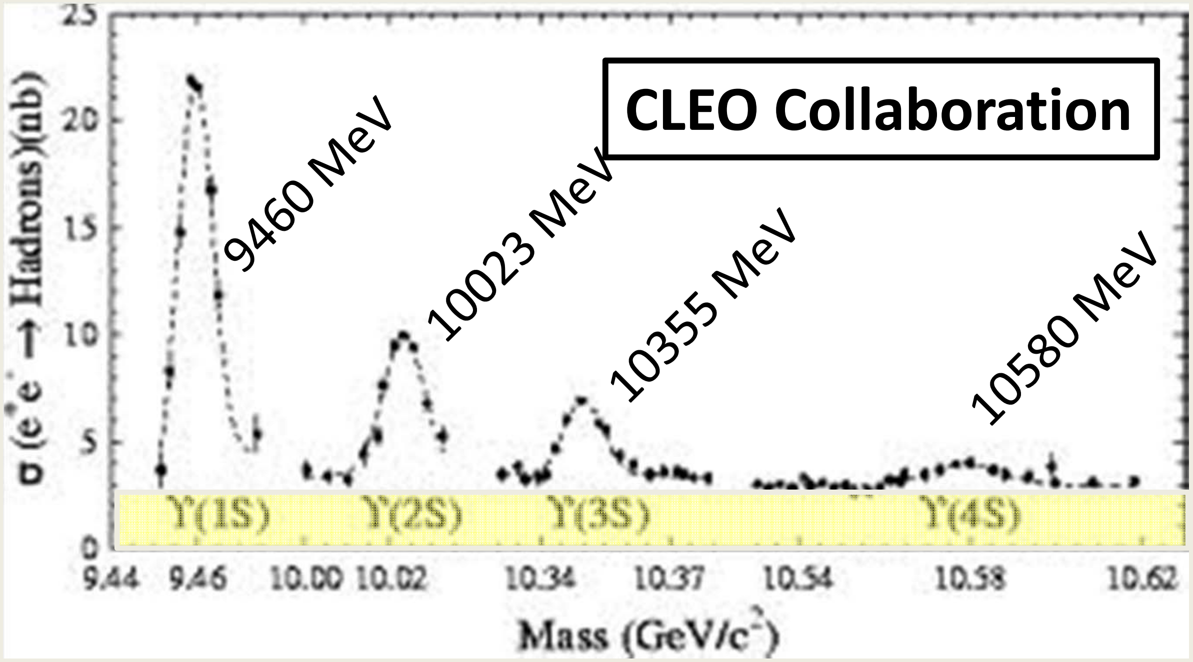
- The Υ(4S) is the bound state of a (b $\bar{b}$)
- The "4S" is the same spectroscopic notation as in "4s" in H-atom!
  - That is, principal quantum number n = 4 & ℓ = 0 for the b$\bar{b}$ system



The Υ(4S) has been the "work-horse" for studying B meson decays over the last 20 years!
What if the g→u$\bar{u}$?

The $b\bar{b}$ atoms!

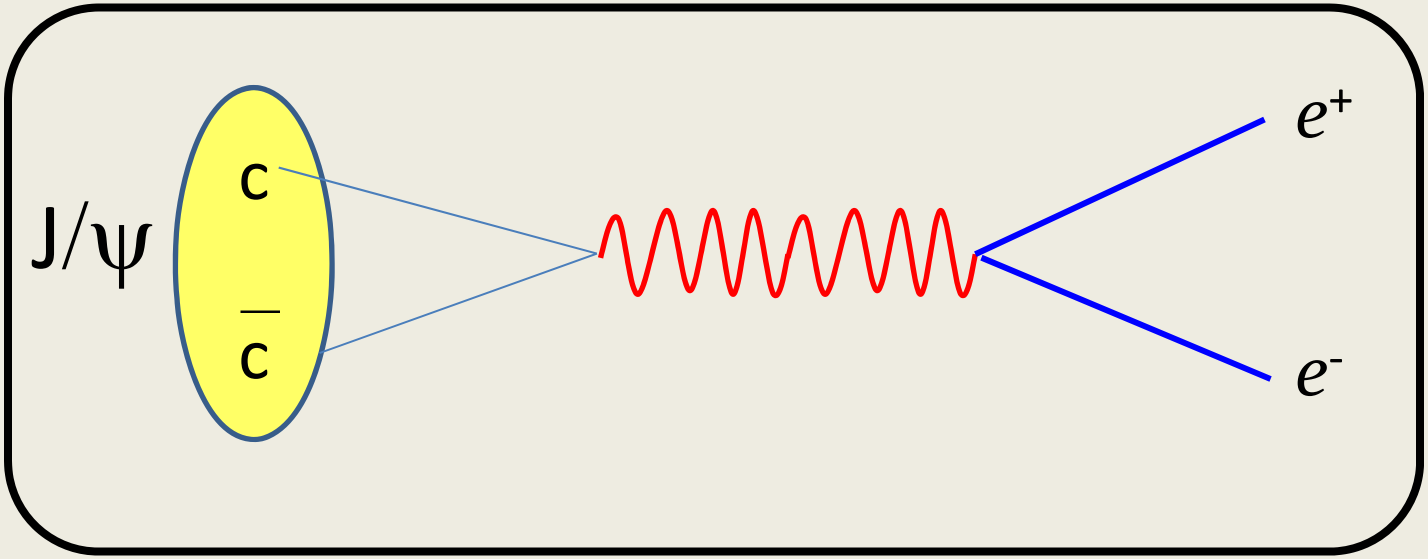
To get these data, CLEO collided e^- and e^+, varying the beam energy from 4.725 GeV to 5.81 GeV. Simply count the #events that produce hadrons.



- The peaks correspond to the production of $b\bar{b}$ resonances.
- Only the Y(4S) has mass > 2xM_B , allowing it to decay into BB [M_B = 5279 MeV]
- The Y(1S) – Y(3S) **cannot** decay to $B\bar{B}$; they decay in other ways to hadrons, or even leptons.
- How do the splitting here compare to the H-atom? Why?
- Any idea what's the "stuff" under the peaks?

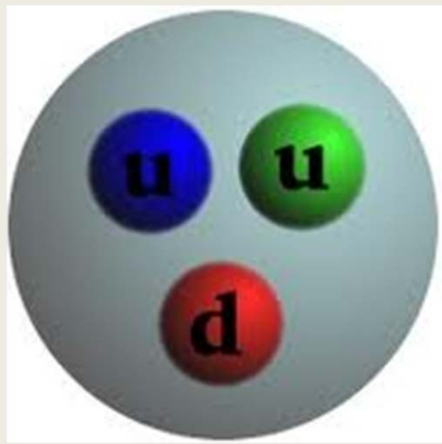
Electromagnetic decay

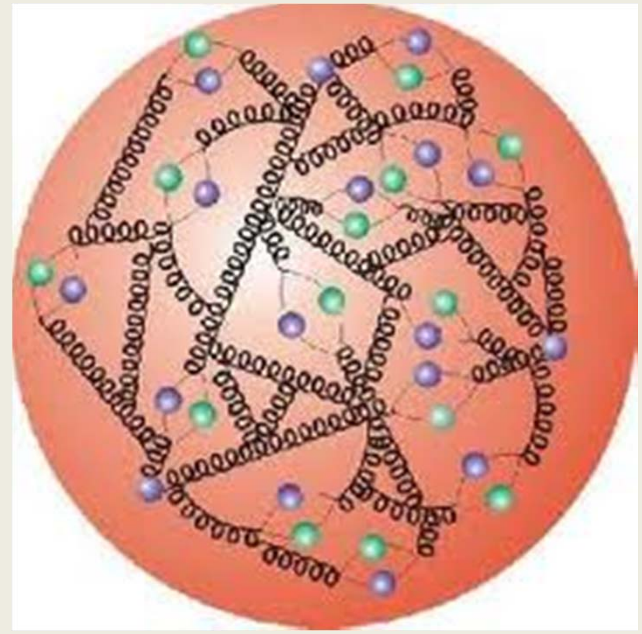
- The J/ψ meson is a (c $\bar{c}$)



- This is an example of an electromagnetic decay.
- The original c $\bar{c}$ quarks have annihilated into pure energy (a photon), which then transformed back into mass (pair of leptons).
- This J/ψ decay occurs about 6% of the time.

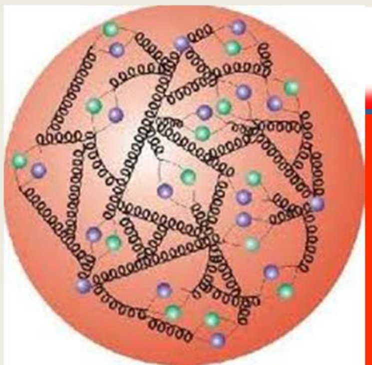
Back to the “simple” proton





- For a high school student, knowing it’s made of 3 quarks (uud) is probably sufficient.
- But, so you’re aware … it’s much more complicated!
- The quarks are continually interacting by exchanging gluons.
- The gluons can split into quark-antiquark pairs.
  - These $q\bar{q}$ pairs are “virtual”… they pop in & out of existence.

So, at the Large Hadron Collider we’re doing this



In the collisions, we are not looking at a whole proton scattering off another whole proton.
Rather we are really looking at quarks and gluons interacting with each other.