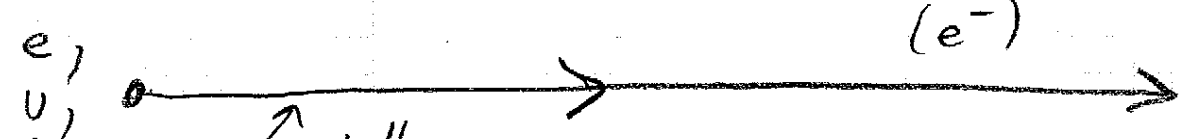


Feynman Diagrams

NO INTERACTION LIMIT

Fermions Hurtle Forward in time



$e,$
 $u,$
 $d,$
 $\nu,$

"current" in line

LOTS OF TYPES: electric, "identity", 4-momentum or higher generations!

time

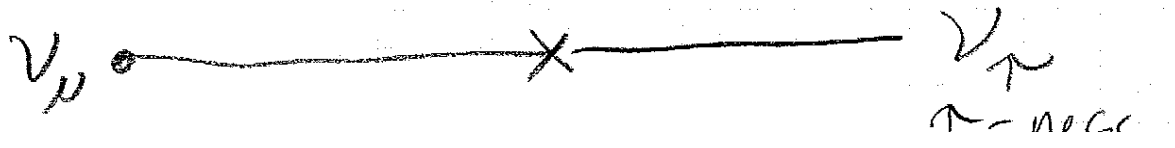
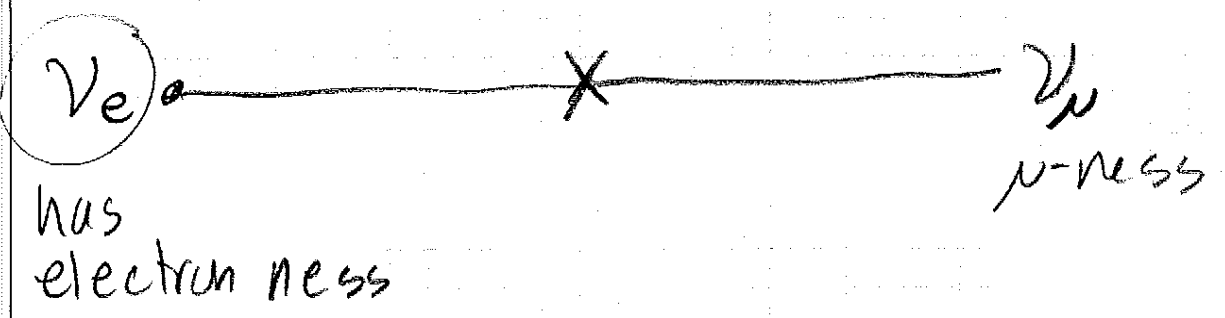
Depicts $\tilde{U}(t, t_0) | \text{state}, t_0 \rangle$

"propagator"

Complicated when $[U(t_1, t_0), U(t_2, t_0)] \neq 0$

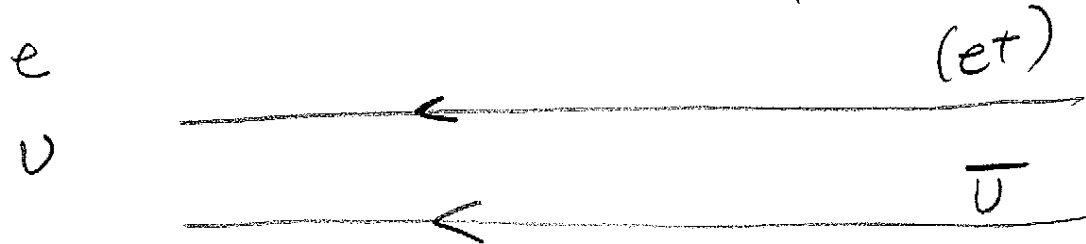
otherwise $\tilde{U}(t, t_0) \approx e^{-\frac{i}{\hbar} \int_{t_0}^t H(t') dt'}$

ONE FLY: (last 10-20 years)



ν_e, ν_μ, ν_τ not eigenstates of vacuum. - like vacuum birefringent.


ANTIPARTICLES = Particles Going Backward in Time.




(current reverses direction).

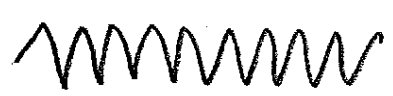
TURN ON INTERACTIONS

Bosons are "Interactors"

γ  (no arrow!)
no additive QN
other than $-\vec{p}, E$

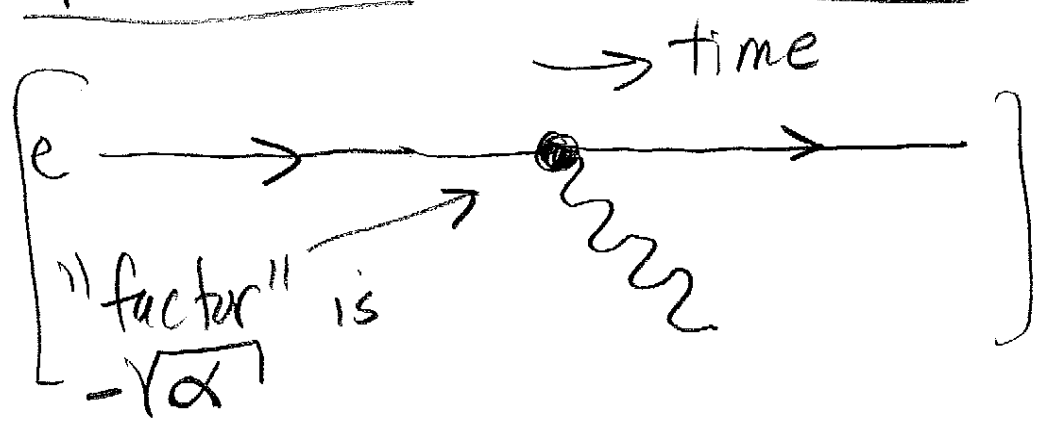
g  (!)
color \rightarrow
 \leftarrow anticolor

Z^0  (different than Grif)

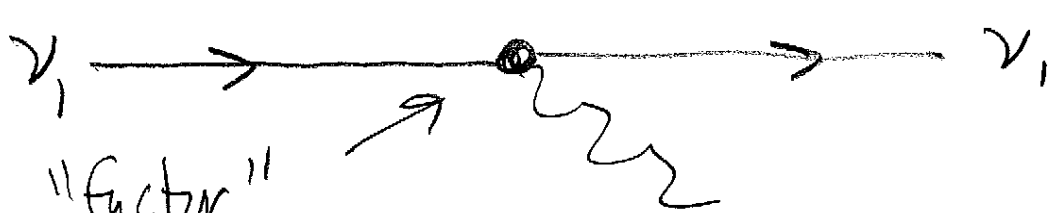
W^\pm  (THESE SPOIL STABILITY OF FERMION TABLE)

VERTEX (building block)

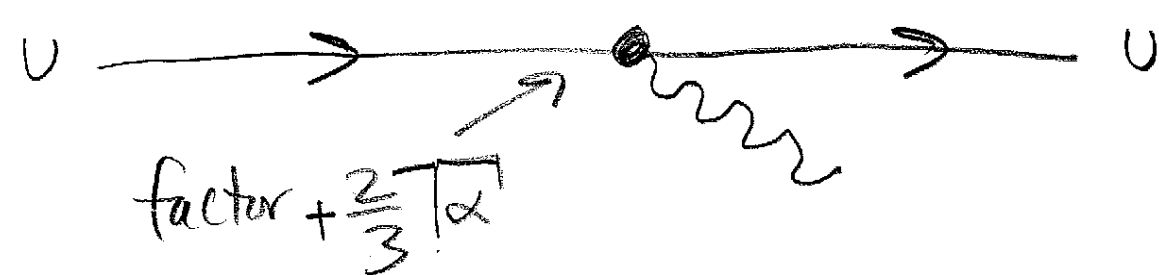
net charge = -1



net electric charge = -1



Neutrino Electrically Neutral



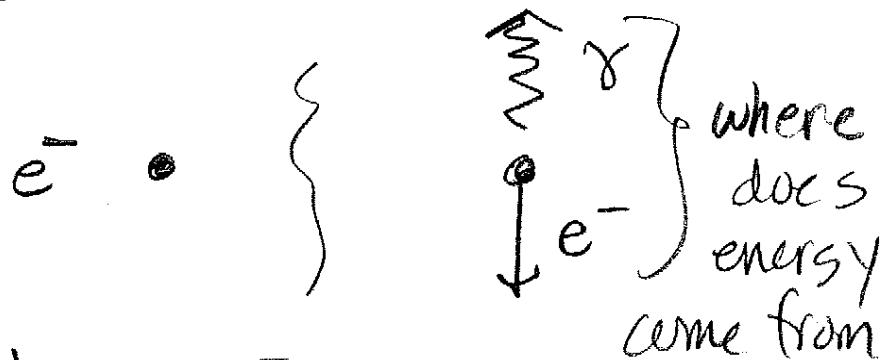
Processes: $e^- \rightarrow e^- \gamma$

Diagram looks fine!

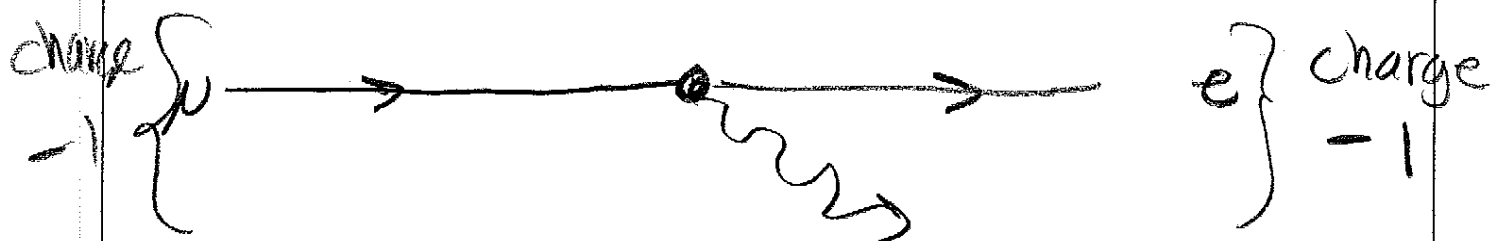
Still can't go...

ENERGY MOMENTUM NOT CONSERVED

Why: jump into initial rest frame of e^-



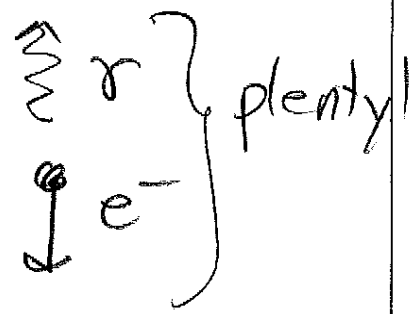
What about --- $\mu^- \rightarrow e^- \gamma$



Rest frame:

$$m_\mu c^2 = 106 \text{ MeV}$$

μ^-

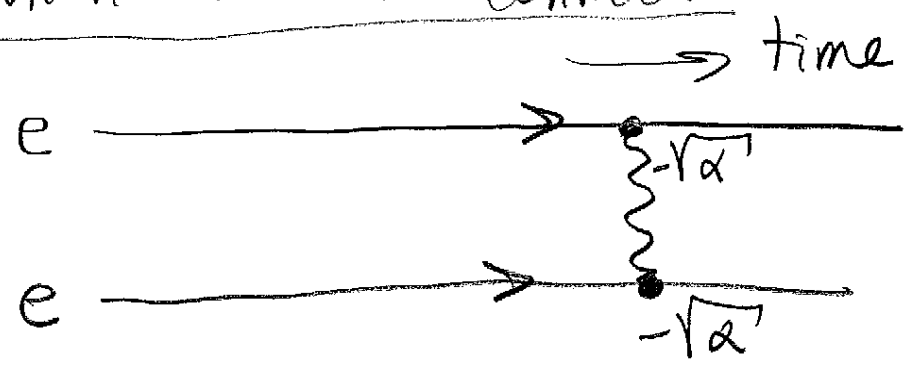


NO: muon-ness not conserved

(allways true at "LOWEST ORDER"
for electr charged fermions
emitting NEUTRAL BOSONS)

BIG MYSTERY, But Accept It
Real Strength of Feynman Technique

When Bosons Connect



e^-e^- interaction

(A) Energy in a state

$$\langle \underbrace{e^- e^-}_{\text{same}} | H | \underbrace{e^- e^-}_{\text{same}} \rangle$$

= "expectation value"

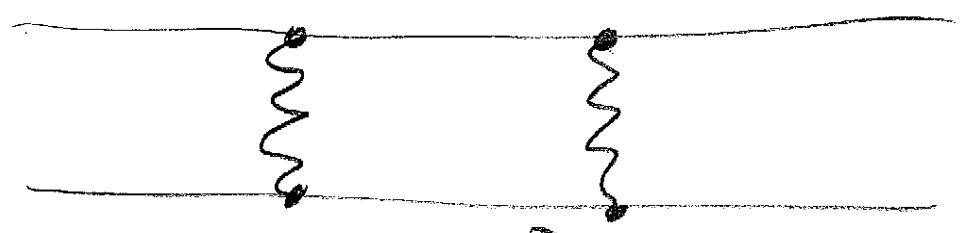
$\propto (-i\alpha') \times (-i\alpha)$ product of vertex factors

$\propto \alpha \rightarrow \left(\frac{e^2}{\hbar c}\right) \rightarrow \frac{e^2}{\hbar c} \frac{\hbar c}{r}$

Visualization of QM

Are rules to get Exp. Value.

(B) Can visualize "higher order"



$O(\alpha^2)$

$$E = a\alpha + b\alpha^2 + c\alpha^3 + \dots$$

(C) THAT IS ONE VIRTUAL PHOTON.... FIND THAT IT TRANSFERS MOMENTUM, NO ENERGY! conserved!

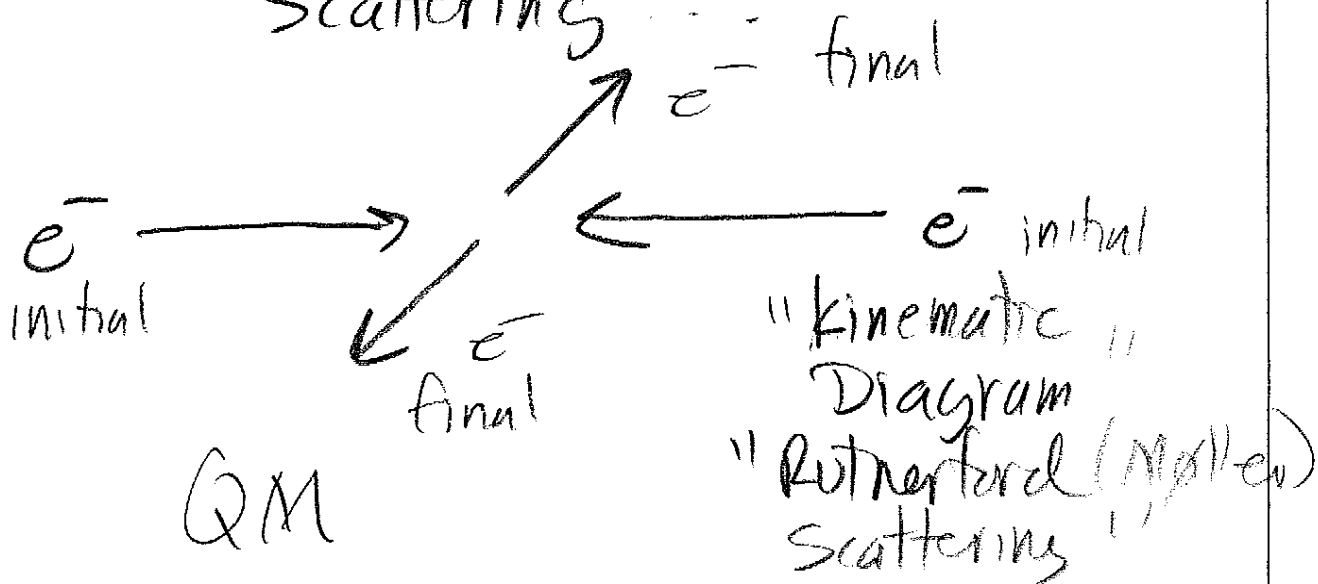
A vector : $(0, \vec{q})$

$$M^2 = (0^2 - |\vec{q}|^2) < 0 !$$

"TUNNELING"

(D) ALSO DESCRIBES Transitions....

Scattering



$$\langle e^- e^- (\text{final}) | U(\infty, -\infty) | e^- e^- (\text{initial}) \rangle$$