Recall: $j_0 = \rho = 2|N|^2 E$

but $E = \pm\sqrt{|p|^2 + m^2}$ $\Rightarrow$ ρ could be ≤ 0 !

THIS IS A PROBLEM.

Once again about Feynman's interpretation:

from $m\frac{d^2x^\mu}{d\tilde{\tau}^2} = q F^\mu_\nu \frac{dx^\nu}{d\tau}$

we learned that $\tau \to -\tilde{\tau}$ is the same as $q \to -q$

Now consider the phase factor:

$Et - \bar{p}\cdot\bar{x}$ if $t \to -t$ we must $E \to -E$

but of course since $p = m\frac{\partial r}{\partial t} \Rightarrow$ $t \to -t = \vec{p} \to -\vec{p}$

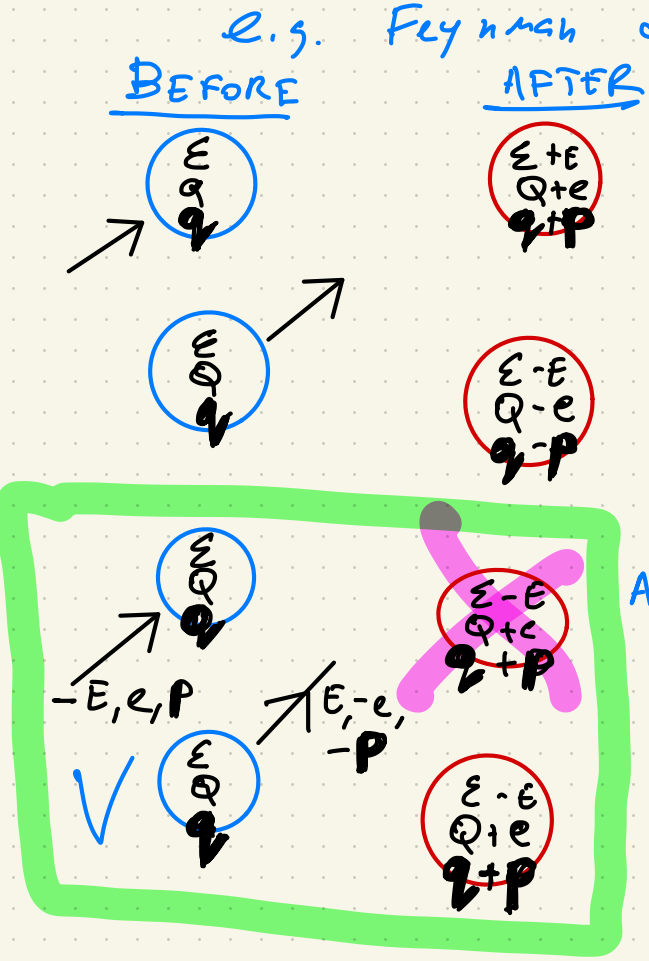
For a KG particle:

$j^\mu_{em} = q \cdot j^\mu$ for $q = +$ we have

$j^\mu_{em} = (+q)\cdot 2\cdot|N|^2(E, \vec{p})$ for $E > 0$

but for $E < 0$ we want to replace $(-)$ from $E<0$ by adding $(-)$ in front of q $\quad j^\mu_{em} = (+q)\,2|N|^2(E, \not{+}p)$ (now positive) OK!

What about interactions in general
e.g. Feynman diagrams?



SUMMARY

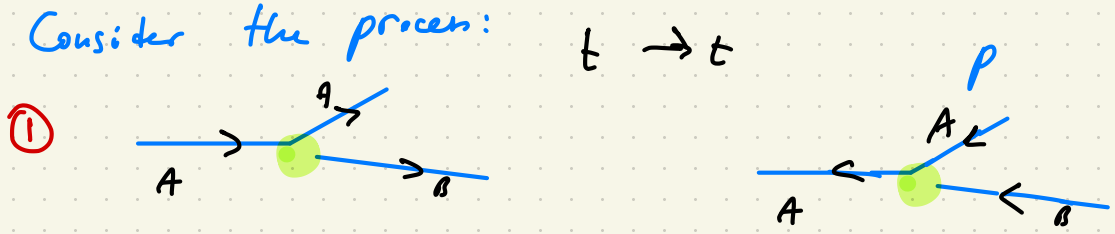
For $E = \pm\sqrt{|p|^2 + m^2}$ only positive $E>0$ are physical

The $E<0$ state are RE-INTERRETED AS positive E ANTIPARTICLES WITH MOMENTUM OPPOSITE TO THE PARTICLE

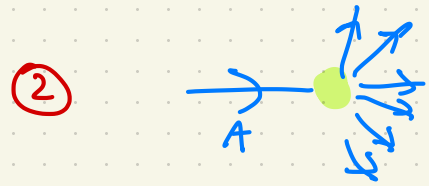
The solution of KG is the SUPERPOSITION of those 2 states $\psi =$ incoming $E>0$ particle + outgoing $E>0$ antipartic

THE ARROW OF TIME AND ANTIPARTICLES INTERPRETATION.

Consider the process:



However consider this process



What about this

Compiuli balls come to a complete standstill

The process ① vs. ②?

② is very unlikely!

even without any quantum mechanics.

The main reason is the # of ways

the process ① can go vs. ②

In the ② there are many possibilities since the balls in ② can go in many different directions

Rule of the universe 1: When we demand a lot of restrictions the chance for this event to happen is small.

If you allow all variations of the process to happen one of them likely to happen.

"Think of a number of lottery tickets vs. probality to win".

Rule of the universe 2:

Any system is likely to move from a state that has low chance to happen to the state that has a high state to happen $\Longrightarrow$ the ARROW OF TIME

Q: Why is time going in one direction?
A: if matters moves in one direction and anti matter in other direction b/c of the amount of matter is colossally larger than anti-matter

We are only finding matter around and anti-matter gets annihilated
The arrow of time agrees with the direction of matter.

Imagine the universe is made of anti-matter and we would see the entropy amongst anti-matter develop in that direction.

you would see eggs coming together shattered glass restarted into a glass and so on

But for anti-..... the world would be exactly like this Universe full of matter.

Finally: the direction of time is that of prevailing matter.

and because we cannot directly turn matter into antimatter we end up with this kind of perception.