MARKUS KLUTE: Let's come back to 8.701. So in the previous video, we talked about higher-order diagrams and we looked at how we can classify those contributions to the total matrix element. We didn't do any of the calculations, or we didn't calculate the Feynman diagram itself. And I'm not actually planning to do this in the lecture. What we want to do here is investigate one of the features, a very important features of having those higher-order corrections.

So if we look at this higher-order diagram here, one of the specific ones where we have a self correction, self energy correction to the propagator C here. We find this loop here in the middle. And if you were to-- and we have all the tools at hand to actually do the calculation-- if you were to calculate the amplitude, we find this term here.

So very good. So let's investigate. The first part is this finite element here, which we can rewrite as q cubed times a finite element dq times all the angles which we have to integrate around. So we find this q cubed.

If you look at under in this fraction here, we find a q squared times q squared. And if you go to just very large values of q, that's the only thing which remains. So we have an integral, 1 over q to the fourth power, times q to the third power. And then we have to integrate this from 0 to infinity.

So if you do this, you know that this results in a logarithmic term. And if you have this evaluated at infinite, we find that it diverges. So the result of the integral is infinity.

That is a real problem. If you calculate the scattering process, the result is better not infinite. The cross-section shouldn't be infinite. The lifetime shouldn't be 0. So that is a real problem. And that actually caused this entire theory to not really make much progress for quite some time, because you were not actually able to calculate anything.

The solution is to introduce a cutoff. So what happens now if we don't just [? jump ?] to the integration [INAUDIBLE], but to some scale. And so you introduce this additional factor here in the integral. And you just calculate the integral up to a cutoff scale m.

And then you have an additional term you have to in principle evaluate from m to infinite. And you find that that additional element is still infinite. You can evaluate all the other parts.

And it turns out if you are smart and introduce the cutoff, the theory, the calculation still remain sensible, meaning that they perform fine under Lorentz transformation. All the physics intuition we have is fine. You just have the issue that still there is a contribution to this integral, which is infinite.

It turns out now by miracle that you can redefine, re-scale, or re-normalize the physical objects in your calculation such that it appears that there is a correction to your masses or a correction to your couplings. So what you find then is that there is a component which is your physical value, which is a bare mass and the bare coupling, your coupling constant, plus some correction.

There's still a problem that those corrections at infinite scale are infinite. However, when we do experiments, we are performing them at a specific scale. And so this problem of if you go to really high scales, things get out of hand, is actually not a real problem when you compare the theoretical prediction with the experiment.

There's an interesting feature here. When you actually look in the running or the evolution of your coupling, which is shown here, the function of energy that shows this as a logarithm of the energy, you can do this for the electromagnetic, for the weak, and for strong interactions. And note here that this is an inverse of the coupling.

They all run. They all are dependent and have to be evaluated at a specific scale. But unfortunately at very high mass scale, they don't all appear to converge in the same spot.

It is interesting to know that if I introduce new particles along the scale here, note that this is 10 to 10 GeV, this new particle will change the behavior of the running of the couplings. The energy behavior of the coupling changes if I introduce new couplings. And you can already understand this because I would introduce new diagrams which contribute in this way. And then those result in a change in the running behavior of the [? plot. ?]

So one of the ideas for new physics, which we might discuss in the very last lecture of this class, is that by introducing new particles along the way, you are actually able to combine all of the couplings involved-- here, electromagnetic, weak, and strong-- at a specific and specific scale, and then have a combined, unified theory describing all of the physics we discuss in nuclear and particle physics.

So that would be great. That is new physics, and we don't know if this is realized. However, what is realized in our calculations is that the physical masses and couplings we observe, they are evaluated at a specific scale. And they do run as function of a scale as shown in this plot here.

We will look at this very specifically at the running of those three interactions-- the electromagnetic, the weak, and the strong. And we can also observe this when we study the masses involved. They're have to be evaluated or are evaluated in experiments at a specific scale.