MARKUS KLUTE: Welcome back to 8.701. So in this short video, we'll talking about the effects of renormalization and higher-order QED diagrams.

And we have already seen that when we perform the integration of a matrix element over q, that there's infinities. And those infinities can be gotten around with by introducing a cut-off scale, and then only integrating up to this cut-off scale, and in effect renormalize or redefine masses and couplings involved.

So the first of such an effect or effective higher order is the so-called vacuum polarization. So you have high-order contribution which may look like this, an additional loop, which you can think about in the photon is so energetic that it can polarize the vacuum and produce a particle-antiparticle pair. And that particle and antiparticle pair then provides kind of a screening of the charge you want to probe.

So I mentioned this particle here emits a photon and wants to probe the electric charge of this particle. The fact that there is this vacuum polarization going on screens the charge you actually want to probe. So effectively, you see a charge which is either reduced or increased, depending on the impact, on the sort of impact.

So the fine structure constant, remember, alpha, is 1/137 [INAUDIBLE] at 0. We measure that the value of alpha slightly increases as we go to higher and higher energies. And so this has been measured in many places, experimentally confirmed, for example, at lab where, at the [INAUDIBLE] of the W or the scale of the W mass, the value of alpha has been measured to 1/128.

And you can do this analytically. You can calculate what the scale of effect is and plot this. So you see here the running of alpha QED as a function of the energy scale. And you see this increase here.

There's another interesting point. As you open up new particles of higher masses, quark and antiquark pairs, you find this kind of stepping approach here-- the new particles, for example. The muon, antimuon, and the quarks and antiquarks are [INAUDIBLE].

All right. So this is the first effect, vacuum polarization. The second effect is very interesting-- probably one of the most famous higher-order processes in QED. And it has to do with the anomalous magnetic moment. The magnetic moment is defined as the factor g times e over 2m times S, the spin of the particle.

Diagrams of this form here modify the vertex. So instead of having a vertex like this, you have higher orders which modify the [INAUDIBLE]. This leads, then, to a modified magnetic moment of the fermion involved-- in this case, an electron, but it can also [INAUDIBLE] muon or tau or another form.

So this was shown by Schwinger already in 1948, and then experimentally confirmed many times after. This g minus [INAUDIBLE], which is 2, leading order, is modified to 2 plus pi over alpha in next leading order.

We can calculate this to many orders, and with mind-blowing precision. So the precision is better than 10 to the minus 12 pi now. I think it's 1.7 [INAUDIBLE] at this stage. And experiments have tried to measure this to find new effects. I mentioned you can have new particles which make modifications to the magnetic moment here. And you would have sensitivity by making experimental measurements.

So the electrons [INAUDIBLE] muon g minus 2 has been measured with very high precision. No new physics have been observed, but some differences are small differences that have caused quite some excitement about further improvements in g minus 2 measurements specifically for the muon. So they're ongoing at this point.