WEBVTT

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00:00:04.470 --> 00:00:12.570
Richard Partridge: Please to read it is Roxanne for her third lecture. Second time to trio oscillations Roxanne

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00:00:13.889 --> 00:00:27.720
Roxanne Guenette: Yes, thank you very much. Yeah. Welcome back everyone. This is gonna be a break in between the gravitational waves that we are having before and after me. This is the last lecture on the translations, as you've seen,

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00:00:28.920 --> 00:00:41.070
Roxanne Guenette: From under. You got the Theory of neutrino installations. Then I walked you through the experimental experimental his view of weapons for new installations are what is the important concept that you should remember.

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00:00:41.610 --> 00:00:46.950
Roxanne Guenette: And then we went on too long baseline, you know, experiments and how in the past those experiments have allowed us

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00:00:47.250 --> 00:00:53.640
Roxanne Guenette: In combination with other types of experiments like the reactor neutrino experiments to give us a very good landscape of what is

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00:00:54.540 --> 00:00:57.720
Roxanne Guenette: The isolation parameters that we have in our field.

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00:00:58.320 --> 00:01:10.170
Roxanne Guenette: We are still missing couple of information and we went through the big questions that are field, but really if we want to answer them. I've told you that we're going to have to go to long baselines. We know that now, thanks to the previous experiments.

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00:01:10.890 --> 00:01:21.240
Roxanne Guenette: And today what I want to do is go through how do we optimize a future experiment to make sure that we have the highest probability to make great discoveries

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00:01:21.510 --> 00:01:26.820
Roxanne Guenette: And this is really important, right, because, as everybody knows, in particle physics and in even in cosmology.

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00:01:27.210 --> 00:01:39.180
Roxanne Guenette: Every time you go to next generation of experiments, the cost goes high, a lot. So we really need to make sure that, as scientists, we do our job in making sure that we are doing small experiments and I'll walk you through this

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00:01:40.800 --> 00:01:51.510
Roxanne Guenette: And then the only things that is left to talk about when we are thinking of a solution is going to be to talk about short baseline of solutions. And I'll tell you what that means, but you'll see that

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00:01:51.990 --> 00:02:06.450
Roxanne Guenette: Our beautiful picture that Andre and I have been painting for neutrino solutions which works very well for what we know is probably incomplete because we have a lot of anomalies that experiments of unraveled and I will be talking about this.

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00:02:08.940 --> 00:02:15.630
Roxanne Guenette: So we've discussed that at the last lecture. What are the ingredients that we need to make a great Long Baseline experiments.

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00:02:16.050 --> 00:02:22.050
Roxanne Guenette: We need a powerful beam. We've overview that a little bit. We need a very good near detector.

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00:02:22.650 --> 00:02:30.630
Roxanne Guenette: The ideal Long Baseline that is going to give us exactly the right parameters space coverage that I want to unravel the Delta CP and MSRP

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00:02:31.110 --> 00:02:43.800
Roxanne Guenette: And of course we need very, very large fart detector. So I'll give you a very brief overview under lackluster today, I'm going to go through them and point out what were the challenges that we were facing when we wanted to design the future experiment.

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00:02:45.240 --> 00:02:56.370
Roxanne Guenette: So remember when I described to you how a beam of neutrinos is produced using an accelerator. I started my explanation by saying you smash accelerated protons into a target.

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00:02:57.120 --> 00:03:06.870
Roxanne Guenette: But that was on the a very tiny part of how things work. Because really, you still need to accelerate your protons. And this is a whole field right accelerate or physics.

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00:03:07.740 --> 00:03:14.760
Roxanne Guenette: We have several accelerators in the world. We have the LSC that is very well known in certain we have the Fermilab accelerators.

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00:03:15.090 --> 00:03:22.080
Roxanne Guenette: In the past it was the Tevatron but now that has shut down and we are just using the substructure of that accelerates our and this is what you're seeing

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00:03:22.650 --> 00:03:30.900
Roxanne Guenette: On this picture. It's an aerial view of the formula of complex way, you have the linear accelerator is where our protons accelerate them in stages.

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00:03:31.140 --> 00:03:39.840
Roxanne Guenette: In the linear way then in a booster where they get some energy and then they are sent to the Main Injector which is a large ring that is going to accelerate them to even higher energies.

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00:03:40.140 --> 00:03:48.000
Roxanne Guenette: And then depending on what you want to do in our case we want to do neutrinos. So we're going to extract those protons and smash them into that target.

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00:03:49.170 --> 00:03:57.210
Roxanne Guenette: But if I want in the future to build better and more powerful beings, of course, I cannot just focus on the little drawings on the top here.

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00:03:57.450 --> 00:04:04.170
Roxanne Guenette: I need the whole complex to be transformed to provide me with higher energy protons and everything needs to be better.

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00:04:04.860 --> 00:04:13.050
Roxanne Guenette: And this is what is happening because basically right now we have two beams that are quite powerful, which is the new me formula being which is used for NOVA

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00:04:13.440 --> 00:04:18.840
Roxanne Guenette: And when we talk about country know beings, we refer to its power. So you means that 700 kilowatts.

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00:04:19.380 --> 00:04:27.780

Roxanne Guenette: And then at JAY PARK. The one that is used for 32 K. They go to around 550 kilowatts. So this is the state of the art right now.

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00:04:28.050 --> 00:04:37.710
Roxanne Guenette: But in the future. We really want to go much further and actually we want to go to a couple of megawatts. So you can see that it's a significant increase and we're going to have to work hard to get that

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00:04:38.820 --> 00:04:49.710
Roxanne Guenette: The it's going to be a staged approach where we are aiming to start with a 1.2 megawatt being and then go to a 2.4 million what being in the future because as you'll see, it's quite complex.

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00:04:51.120 --> 00:05:00.090
Roxanne Guenette: I don't have time to go into the details about everything that needs to be upgraded in a beam to in the accelerator complex to provide a very powerful beam.

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00:05:00.300 --> 00:05:10.170
Roxanne Guenette: But it's very interesting, actually. And you should. I hope that one day you have a talk on that, especially, but basically what the teams are doing. And this is a radio worldwide.

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00:05:10.740 --> 00:05:18.750
Roxanne Guenette: Effort where all the experts in different parts of the accelerator are coming together because you're going to need brand new technologies for all of the steps.

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00:05:19.020 --> 00:05:27.090
Roxanne Guenette: So people are working right now to get a much higher energy Linux. That's the linear accelerator part of the beginning of the whole. So if I go back here.

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00:05:27.900 --> 00:05:37.260
Roxanne Guenette: Right now that from that this is here, where you just accelerate things in line. And so now they want to go too much higher energy. So it's a beautiful

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00:05:37.740 --> 00:05:45.660
Roxanne Guenette: long linear accelerator that you have that has many different stages that will use RF cavities to accelerate your protons along the way.

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00:05:46.140 --> 00:05:56.820
Roxanne Guenette: So that gives you a better starting point when you shoot those guys into the the booster, which is going to turn them around and accelerate them even further. And then before it goes to the Main Injector

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00:05:58.020 --> 00:06:07.470
Roxanne Guenette: Yet I think we want to do is to put more protons. Each time that we accelerate them because the more protons, you have, the more intensity of the beam, you're going to produce right

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00:06:07.740 --> 00:06:17.490
Roxanne Guenette: So piling up protons in a bunch is not that easy because you're going to need to keep them together while you accelerate them around the rings, which means you're going to need better magnets.

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00:06:18.120 --> 00:06:24.840
Roxanne Guenette: To go there and hire magnetic fields. And then, in addition to increasing the number of protons in a bunch, we want to

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00:06:25.320 --> 00:06:30.990
Roxanne Guenette: Increase the number of bunches because then you have more rapids interactions from the protons on the target.

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00:06:31.410 --> 00:06:39.630
Roxanne Guenette: But this is also something that is not that easy, because you need to make sure that the benches are well separated and you need very good control of all the parts of your accelerator.

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00:06:40.470 --> 00:06:48.090
Roxanne Guenette: And then shorts or circles, which means you want to do things quicker. So you can see that this seems very reasonable. But there was a lot of technical

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00:06:48.870 --> 00:07:01.650
Roxanne Guenette: Work to be done and work has progressed really well and the Fermilab accelerators is supposed to be ready. Sometimes in like 220 26 2028 depending on how quick

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00:07:01.950 --> 00:07:06.180
Roxanne Guenette: They can manage it. But this is something that is going forward. And we're very excited about.

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00:07:06.870 --> 00:07:13.740

Roxanne Guenette: So what's going to happen is that we're going to have a brand new neutrino beam coming from all the upgrades from the accelerator complex

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00:07:14.100 --> 00:07:25.350
Roxanne Guenette: And then what are we going to do, we're not going to reuse what we currently have for you, me, because this also has reached the limit that it can do at the 700 kilowatts. So what we had to do is to design a whole new

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00:07:26.490 --> 00:07:33.540
Roxanne Guenette: Be mastered. So remember when I showed you this picture here every bit of this new detector has to be created again.

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00:07:34.350 --> 00:07:40.770
Roxanne Guenette: So we need to extract the protons that are now very high energy and very quickly coming. We need to smash them into a target.

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00:07:41.130 --> 00:07:49.800
Roxanne Guenette: The targets. A lot of people work really hard to understand what is the ideal target for exactly what we want to do, how long how dense. It has to be. And they made choice.

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00:07:50.370 --> 00:08:03.990
Roxanne Guenette: And actually, I forgot the final choice, but it's easy to find online if you're interested. And then we need to let those missiles that are going to be producing the target decay in a decay pipe and then absorb them so that only neutrinos go through

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00:08:05.160 --> 00:08:13.500
Roxanne Guenette: You may have noticed that this beam line that is going to be at Fermilab is now going up and down. And this is actually quite a clever.

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00:08:13.890 --> 00:08:23.700
Roxanne Guenette: Thing that the accelerator physicist, did we know that it costs a lot of money to build a beam and the last thing you want to do is spend money on something that is not science related

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00:08:23.970 --> 00:08:30.660
Roxanne Guenette: And what does it cost when you have to build something like this, as you have to go underground for different reasons, but

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00:08:31.650 --> 00:08:38.970

Roxanne Guenette: It also you need your beam to go angled at the right thing goal that is going to shoot to South Dakota, where we want the neutrinos to hip.

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00:08:39.330 --> 00:08:45.630
Roxanne Guenette: So to have this angle, you can imagine that you would have to go much lower on the ground. To do this, and that would cost a lot of money to excavate

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00:08:46.080 --> 00:08:50.610
Roxanne Guenette: So people talk very hard. What, how can I keep more money for the beam.

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00:08:50.850 --> 00:09:02.370
Roxanne Guenette: Is by instead of digging which cost a lot. We're going to produce this being here it is going to go a little bit above ground and then go down. So that was very good and it allows them to put more money into the design of the been itself.

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00:09:03.930 --> 00:09:10.170
Roxanne Guenette: Okay, so that's going to be the most powerful neutrino beam that we have in the world, which is going to come in the next decade.

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00:09:11.190 --> 00:09:16.710
Roxanne Guenette: What about the near detector. So what does it need mean to have a capable near detect arm.

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00:09:17.850 --> 00:09:26.490
Roxanne Guenette: So one thing I've pointed out, and I want to show it here, even in clots. Is that currently in the in the long based on experiments that we have

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00:09:26.790 --> 00:09:37.230
Roxanne Guenette: The neutrino interactions. I already told you a little bit about that and also a word just have to do this, but the uncertainties on the neutral interactions is one of the dominant systematics

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00:09:37.470 --> 00:09:42.150
Roxanne Guenette: And this is what you see on a plot that I've taken from a presentation very recently at note from the Nova.

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00:09:44.070 --> 00:09:51.480

Roxanne Guenette: Nova experiments. And here I don't want to go into details, but the width of the Aero bars tells you how big those uncertainties are.

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00:09:51.720 --> 00:09:59.580
Roxanne Guenette: And you can see I've highlighted for you for the different configurations. So in neutrino or until neutrino and for electron neutrinos and Mila neutrinos.

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00:09:59.880 --> 00:10:08.310
Roxanne Guenette: You can see that the neutrino cross section or dimensional interactions are leading systematics so we need to make sure that we understand the trends direction. Very well.

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00:10:08.550 --> 00:10:19.140
Roxanne Guenette: And for that we need to have near the factors that are going to be able to tell us exactly how neutrinos interact, because our models to simulate interactions aren't that good as we see here.

68
00:10:20.670 --> 00:10:25.230
Roxanne Guenette: I've showed you one pictures last time, but I just wanted to, it's right there are different.

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00:10:25.710 --> 00:10:29.580
Roxanne Guenette: Ways of studying interaction and it depends on the energy of the neutrinos.

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00:10:29.820 --> 00:10:39.960
Roxanne Guenette: So when neutrinos are not too high energy just below when GV roughly the dominant and traction is a charge current. We've talked about that last time is the exchange of the W, both on the charge w goes on.

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00:10:40.440 --> 00:10:51.810
Roxanne Guenette: And quasi elastic here. What it means is really is just going to be a knock on effect where the neutrino is going to come in and track with the neutron of your target producing a new on neutrino and a proton.

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00:10:53.010 --> 00:11:00.840
Roxanne Guenette: The problem, even with the security, which is the most simple interactions that we have is that in large nuclear sometimes the

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00:11:01.470 --> 00:11:14.760

Roxanne Guenette: nuclear arms are paired together. So you could imagine having a neutron paired with a proton. And what's going to happen is that correlation, because these guys are kind of tied together when the new ones comes in. It's going to break that

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00:11:15.810 --> 00:11:19.860
Roxanne Guenette: That link that they work together and that's going to make it a more complicated interactions.

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00:11:20.040 --> 00:11:27.780
Roxanne Guenette: Sometimes, you could have the production of a pile that is going to be reabsorbed. You'll never see it. So that means you're going to miss energy and your final things

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00:11:28.050 --> 00:11:40.110
Roxanne Guenette: And sometimes multiple protons are being kicked out of the nucleus. So here you can see in drawing two examples of this same exact simple interaction and you can easily imagine that if you go to more complicated.

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00:11:41.340 --> 00:11:49.950
Roxanne Guenette: Interaction, such as the charge current resonance here resonant means you have enough energy and your interaction to produce a read you read the active

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00:11:50.760 --> 00:12:02.280
Roxanne Guenette: Delta in this case. So what's going to happen is the neutrino comes in produce the normal new on neutrinos. But then, as I said, the energy was high enough that you produce the radioactive, read, read the active delta

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00:12:02.730 --> 00:12:14.370
Roxanne Guenette: Which is going to decay immediately to, let's say, a pie on an approach on in this case. Sometimes the pie is going to get out. Sometimes the pilot is going to get reabsorbed maybe kicking out even more interactions.

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00:12:15.060 --> 00:12:27.270
Roxanne Guenette: So do you see how complicated these things can be you need the factors that are going to be able to go in identified each of these individual final state particles and then you're going to be able to reconstruct piece of the puzzle.

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00:12:28.770 --> 00:12:35.460
Roxanne Guenette: How is future detectors going about this. So today I've decided to pick only the example of the do an experiment.

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00:12:35.760 --> 00:12:41.820
Roxanne Guenette: Of course, this is totally biased because I'm a doom collaborator, but you're going to see that a lot of the choices that were made by doing

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00:12:42.090 --> 00:12:47.580
Roxanne Guenette: And are quite similar to what the hyper K which is the other experiments that are mentioned later but

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00:12:48.300 --> 00:13:03.750
Roxanne Guenette: The decisions are made in a very similar way. So since this is a lecture about how we do things. I decided to pick only one. And I'll just go back and forth between the two. So what is doing going to do for the capable new detector that took a long time and people took a lot of

85
00:13:04.980 --> 00:13:09.630
Roxanne Guenette: Thought about this because they wanted to make sure that when we build, do we know exactly

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00:13:10.410 --> 00:13:21.720
Roxanne Guenette: How to control all those systematics and this led to a quite complicated system. So what you see here is going to be a tree detector system where we're going to have a small, highly

87
00:13:22.410 --> 00:13:32.910
Roxanne Guenette: Fine grained detector which is the system for on access neutral detector, the beam is that red line here. I don't know if you can see if it's quite faint. But that means that the

88
00:13:33.450 --> 00:13:38.400
Roxanne Guenette: Yeah, the neutrino members coming in straight into further types are which is called a system for on access being

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00:13:38.940 --> 00:13:52.020
Roxanne Guenette: The second one is going to be a multipurpose detector which is going to be a high pressure does are gone TPC so if you've seen my lecture on Monday, you now know why are a gaseous is good because you can go to lower energy more

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00:13:52.470 --> 00:13:58.770
Roxanne Guenette: Fine grained details into lower energy part, but this is going to be the high pressure guess the PCs that we're going to have

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00:13:59.430 --> 00:14:03.930
Roxanne Guenette: And then the last one is liquid are gone because you may have remembered when I talked about this.

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00:14:04.500 --> 00:14:11.130
Roxanne Guenette: Yesterday, it's important to have the same exact targets and you're new to factor in your fire detector, because those

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00:14:11.790 --> 00:14:22.530
Roxanne Guenette: Nuclear effects that happen are particular to each of the targets that you're using. So are gone, will have different facilities than carbon, for example, so it is important to have at least one liquid Oregon detector.

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00:14:23.070 --> 00:14:27.240
Roxanne Guenette: And here it's going to be a highly modular detectors of liquid our guns.

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00:14:27.570 --> 00:14:35.460
Roxanne Guenette: And hear what people have done is the instead of having the wires, which is what we have, usually in factors and we will have photo farted factor in doing

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00:14:35.820 --> 00:14:44.580
Roxanne Guenette: They decided to go for pixels. You can see an image here. That was a lot of our end that culminated to recent development. So this is really cutting edge technology.

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00:14:44.910 --> 00:14:54.810
Roxanne Guenette: And the pixels. The reason they are good is that the give you a 3D image instead of a 2D projection that you have to reconstruct into 3D and by having the 3D projection

98
00:14:55.260 --> 00:15:06.180
Roxanne Guenette: It's going to allow us to see more clearly without ambiguity is the events because remember we are very close to the most powerful neutral being in the world. So there'll be a lot of interactions in these new detector.

99
00:15:07.350 --> 00:15:12.660
Roxanne Guenette: So we have those three things. And in order to even make sure that we can control things very well.

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00:15:12.990 --> 00:15:18.720

Roxanne Guenette: We decided to go with a movable platform for the high pressure guests PPC and for the liquid argon detectors.

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00:15:18.990 --> 00:15:26.430
Roxanne Guenette: So you can see here, we said the beam is coming in like this for the annex this one, but the two others are going to be able to move

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00:15:26.640 --> 00:15:42.090
Roxanne Guenette: Along the classroom because remember when I showed you the effects this, what happens is that the more affects you go the narrower in energy you're being becomes so now you're going to know more precise and your energy which is going to allow you to go in more and more precision about

103
00:15:43.650 --> 00:15:47.280
Roxanne Guenette: How things are going to be designed are going to be understood.

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00:15:48.960 --> 00:15:59.190
Roxanne Guenette: Okay, so now we have to have the ingredients. This new detector should give us a lot of information and hopefully it's going to bring down the systematic error to something very small

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00:16:00.660 --> 00:16:06.750
Roxanne Guenette: But something that I promised I would talk about this. How did we choose the small baseline for experiments.

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00:16:07.770 --> 00:16:14.850
Roxanne Guenette: So of course, usually you would go immediately into the science and look at the equations and figure it out. But that's not exactly how real life works.

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00:16:15.240 --> 00:16:26.850
Roxanne Guenette: The first thing we have to think of is where can we have neutral newbies we're not going to be able to afford a brand new completely accelerator. We have couple in the world right now. So people started to existing

108
00:16:28.050 --> 00:16:39.450
Roxanne Guenette: accelerators. So we have the formula we have discerned. We have the JAY PARK. But remember that when we started these effort people even took any accelerators that could be upgraded slack, for example.

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00:16:39.720 --> 00:16:45.090
Roxanne Guenette: Brookhaven has one accelerator that could be used and they are others as well in the world that people looked at

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00:16:45.390 --> 00:16:59.430
Roxanne Guenette: Just to make sure that they did due diligence, because if you could find something that was amazing. Then we could convince people to upgrade their beam for the future, but you're going to see that these three remained still the most powerful. So they were the best choice IBM

111
00:17:01.200 --> 00:17:09.180
Roxanne Guenette: Then the second thing you need to do is you're going to need to shoot these neutrinos to somewhere that is on the ground because we really don't want too much background coming from cosmic rays.

112
00:17:09.480 --> 00:17:17.730
Roxanne Guenette: So again, you have to look at mines or underground labs that could be accessed to put your detectors, the surf. One was

113
00:17:18.390 --> 00:17:26.550
Roxanne Guenette: told about this is where the home state of mind where Davis. Did his experiment and a pass snow lab is one of the deepest labs that we have

114
00:17:26.940 --> 00:17:36.210
Roxanne Guenette: To do experiments. They also looked at the mind in Finland, I can't pronounce it. If there was finished people maybe they can help later but

115
00:17:36.720 --> 00:17:44.970
Roxanne Guenette: It's something I sell me. Sorry for missing. Missing data. But yeah, so that was a deep mine in Finland, there was Carioca, of course, were

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00:17:45.240 --> 00:17:59.430
Roxanne Guenette: Super Canada. Canada is it's not super deep, but it's quite as deep enough for what we want. We have grown so and here again, people look at many other examples that with mine where the exit factors or and other possibilities to make sure

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00:18:00.930 --> 00:18:07.320
Roxanne Guenette: And then with those constraints we started to look at the science behind the isolation.

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00:18:08.310 --> 00:18:19.650
Roxanne Guenette: So remember that what we have left to do, and this was kind of very nice to know that we only had to map parameters to measure the Delta CP and the mass ordering. Everything else is quite a well known.

119
00:18:20.430 --> 00:18:33.510
Roxanne Guenette: So if I look at the probability of isolation and here I kind of have no choice to start with the new news, because this is how I produce my beans and if I want to access the CP and the mass ordering. I'm going to have to do a new E appearance study

120
00:18:34.530 --> 00:18:42.540
Roxanne Guenette: This is the full probability of escalation for three neutrinos, which now I need to pay attention to, to the neutrinos, because I'm going to go to precision measurements.

121
00:18:43.020 --> 00:18:59.790
Roxanne Guenette: You can see what it looks like, you know, it's quite long. It depends on many, many different different parameters. But as I'm an experimental is I really like to visualize these things. So let's take a look of what is the impact of baseline. It's on different different parameters.

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00:19:01.440 --> 00:19:08.220
Roxanne Guenette: The first thing I want to think of is what is the impact of the CP violation phase on a solutions.

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00:19:08.820 --> 00:19:16.200
Roxanne Guenette: Here I'm going to start with vacuum only because otherwise I'm going to mix other effects. We've already seen that. But let's take only the CP phase.

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00:19:16.620 --> 00:19:29.580
Roxanne Guenette: The y axis is the probability of isolation from Eugene UI. It has that US literary behavior, of course, and this is in function of l o v e, which is that term in my oscillation

125
00:19:30.240 --> 00:19:35.220
Roxanne Guenette: Probability, which kind of if you have the fixed baseline is then in function of energy.

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00:19:35.880 --> 00:19:43.560
Roxanne Guenette: So what do we see here the black line is the vacuum isolation, when you have no CP violation. Okay, this is what you would expect.

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00:19:44.280 --> 00:19:49.620
Roxanne Guenette: Them. Let's put maximum CP violation, which is this gray BAM here.

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00:19:50.430 --> 00:20:03.240
Roxanne Guenette: And then, which is the positive maximum one and then the negative Mexico one. Do you see how the distortion of the spectrums happens. So there was a very clear distinction between plus minus pi over to n minus pi over to

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00:20:03.690 --> 00:20:11.070
Roxanne Guenette: And then if the CP violation is pi, then you can see also how that goes with this very dashed line here.

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00:20:12.150 --> 00:20:20.910
Roxanne Guenette: So what the name of the game is going to be force an experiment, looking at this, it's going to look at it isolation spectrum and try to see where the peak.

131
00:20:21.150 --> 00:20:34.020
Roxanne Guenette: Of this isolation is so basically the Lord the energy of the peak, you're going to be able to tell where which value of CP, it is, and also by the amplitude, you're going to be able to filter and extract the CP violation.

132
00:20:35.010 --> 00:20:41.070
Roxanne Guenette: And that would be really nice if it was the end of the story, but it's not because matter effects is another thing that is very important.

133
00:20:41.460 --> 00:20:48.690
Roxanne Guenette: So now I'm going to look on this planet only matter effect here. I don't put any CP violation. So there's a CP is zero.

134
00:20:49.530 --> 00:21:00.000
Roxanne Guenette: So what is the probability of isolation looking like. Again, the black curve is what you have. If you're in vacuum adult Sep equals zero. So that's the same one I showed you in the past in the previous slide.

135
00:21:00.690 --> 00:21:11.520
Roxanne Guenette: Now let's look at the different matter effects in function of baseline because the more you go through math or the more

you're going to feel its effect. So that's quite intuitive. And this is kind of what you see, I go from

136
00:21:12.660 --> 00:21:18.150
Roxanne Guenette: Zero from vacuum isolation to 1000 kilometers 2003 thousand

137
00:21:18.780 --> 00:21:34.800
Roxanne Guenette: So immediately what you can think is that the longer the baseline, the more intense the matter effect is going to be in the easier it's going to be to separate these different curves. So that would be important. So you want to go to higher baseline. If you want to detect the matter effect.

138
00:21:36.480 --> 00:21:46.200
Roxanne Guenette: But now I'm going to have to convert those two effects because we don't know exactly what the mass hierarchy is. And this is something that I forgot to mention

139
00:21:46.680 --> 00:21:56.580
Roxanne Guenette: Is that these three curves that I've showed you were for normal hierarchy. Of course, if I now go to the inverted hierarchy and I go back to my solution probability

140
00:21:56.970 --> 00:22:09.990
Roxanne Guenette: Every sign which has a delta three to every, every parameter is that has built a treaty with now have a minus sign, which is going to change that whole probability. And do you see now I have very

141
00:22:10.950 --> 00:22:19.620
Roxanne Guenette: Even a tree thousand kilometers. This is what the math horrific does it really dumps the spectrum. So I have to involve all of these different

142
00:22:20.430 --> 00:22:36.300
Roxanne Guenette: Effects to see what happens. Let's look at another important thing here I'm showing the probability of installation for three different baselines, which is the tree hundred which is roughly 32 K 800 which is the Nova and 1300 which is doing.

143
00:22:37.380 --> 00:22:44.040
Roxanne Guenette: You can see that the further the baseline. I go, the more way goals. I'm starting to see

144
00:22:44.580 --> 00:22:55.380

Roxanne Guenette: In my estimation spectrum but also what's important is that because technically those solutions also continues here, but your detector starts also to have

145
00:22:56.250 --> 00:22:59.940
Roxanne Guenette: An energy resolution. Let me just go back here to make my point more clear.

146
00:23:00.510 --> 00:23:03.630
Roxanne Guenette: This is kind of in function of your energy. Remember I said that

147
00:23:03.840 --> 00:23:16.680
Roxanne Guenette: So you can imagine that when I go to very low energy, those wiggles starts to be so close to each other that is starting to be impossible to distinguish those solutions anymore. It just becomes like a pileup of events which is not helpful.

148
00:23:17.550 --> 00:23:22.650
Roxanne Guenette: So here, this is kind of what you're seeing in the regions are kind of the energy resolution limits.

149
00:23:22.890 --> 00:23:31.560
Roxanne Guenette: That these detectors are and this is generous right is the limit possible. In reality, we also have uncertainty. So you should think that these things go a bit higher up.

150
00:23:32.250 --> 00:23:42.600
Roxanne Guenette: In reality, so what do you gain from this is that the longer baseline, you're going to go the clearer your different a solution maximum, maximum are going to be

151
00:23:42.990 --> 00:23:51.180
Roxanne Guenette: And there was a question about that in in the previous lecture where we were seeing the disappearance spectrum of doing that had that clear double bumps.

152
00:23:51.390 --> 00:23:58.320
Roxanne Guenette: Which is not present in most of the other experiment for this exact reason, you can see that the UK only has access to the first isolation.

153
00:23:58.890 --> 00:24:11.130
Roxanne Guenette: Nova could have access to the second that because of detector effects and stuff. They don't really, they kind of go somewhere

here and then doom is going to have access to two of them. The third one is going to be matched up in the energy resolution.

154
00:24:12.570 --> 00:24:19.350
Roxanne Guenette: But OK so this gives you a feel of why we have to go too long baseline. And the last thing I want to show about this.

155
00:24:19.800 --> 00:24:30.330
Roxanne Guenette: Is that even if you had great detectors that were able to see those a solution maximum for all the different baselines. There is another thing that is useful to look at

156
00:24:31.320 --> 00:24:45.570
Roxanne Guenette: These parts are a bit complicated, but let me walk you through them. So, here what I want to show you is how big and effect can be between matter and CP violation on my probability of solution. So, to enhance that.

157
00:24:46.230 --> 00:24:52.290
Roxanne Guenette: Difference. What I'm gonna do is, we're really snuck me it's Mary be shy you plotted that but what we're going to do is

158
00:24:52.770 --> 00:25:03.540
Roxanne Guenette: You take the probability of escalation of neutrinos minus the one that you absorbing anti-neutrinos because remember to measure CP violation. We want to see how different neutrinos and instant renewals behave

159
00:25:04.080 --> 00:25:15.540
Roxanne Guenette: So by doing the symmetry between the difference over the some of those two probabilities. I start to enhance differences. What are those differences that I want to point out

160
00:25:16.560 --> 00:25:26.040
Roxanne Guenette: The black curves on these plots are coming from the first isolation maximum. This is what we had here the first big bump that is clear for every experiment.

161
00:25:26.820 --> 00:25:31.200
Roxanne Guenette: Then we have the second isolation maximums which is the red curves that are shown.

162
00:25:31.710 --> 00:25:42.000

Roxanne Guenette: Here only focus on the full curves. Those are all for a normal hierarchy. If you want later you can go back and look at the inverted hierarchy, which is the dotted lines here.

163
00:25:42.600 --> 00:25:53.940
Roxanne Guenette: But basically what is the, the higher the difference between the first isolation and the second isolation maximum is the better. I'm going to be able to measure that as symmetry.

164
00:25:54.660 --> 00:26:05.040
Roxanne Guenette: So, because basically what it's going to mean is that you're really going to be able to identify the first destination clearly and the second isolation, clearly, so you're going to have very good handle on the full spectrum.

165
00:26:05.760 --> 00:26:19.860
Roxanne Guenette: And you can see here that if you go at zero, for example, and the difference between the black and red curve is very small at short baseline, it starts to grow at longer baseline and then for doing. It's that it's biggest

166
00:26:20.550 --> 00:26:32.520
Roxanne Guenette: And then if CP is very large, like in the plus or minus pi over to you can see the difference between the black and red also start making a bigger and bigger difference

167
00:26:32.880 --> 00:26:44.460
Roxanne Guenette: And doing here can clearly tell you that, overall, this is really the best baseline to go if we want to identify the matter effect, which is going to be relevant to the mass murdering NCP phase at the same time.

168
00:26:45.900 --> 00:26:53.220
Roxanne Guenette: So I hope you kind of get a feel of why we need long baseline. And I really encourage you to go back to these plus later and think about it.

169
00:26:54.180 --> 00:27:01.920
Roxanne Guenette: Things are not super intuitive all the time because you have the metal effect, you have the neutrinos and dance neutrinos. They change signs in your probability of

170
00:27:02.370 --> 00:27:09.600
Roxanne Guenette: A solution, but I hope that you get a feel of how why we need long baselines, and why 1300 kilometers is quite ideal.

171
00:27:09.930 --> 00:27:24.990
Roxanne Guenette: And again remember that the 1300 was picked also because it's a constraint physical on the world where Fermilab to a homestay is 1300 so after doing a lot of studies physicists came out to two of us choices.

172
00:27:25.470 --> 00:27:30.600
Roxanne Guenette: That could lead to great experiment for the future. The first one is doing. I've already mentioned that

173
00:27:30.900 --> 00:27:42.390
Roxanne Guenette: This is going to be from Fermilab to a home steak mine, which is not a Stanford underground rush Research Laboratory a baseline of 1300 kilometers using liquid argon detectors.

174
00:27:42.960 --> 00:27:52.230
Roxanne Guenette: And the hyper k, which by the name of course it's a better version yet again of the cameo can do. Super. Can you can do in Hyper, can you can do

175
00:27:52.800 --> 00:28:10.230
Roxanne Guenette: Here is going to be a much larger detector of water drink of it. So a brand new detector with much better PMT and everything upgraded also the accelerator complex is going to be upgraded the little bits and then they're going to shoot. Again, they have the same baseline as before.

176
00:28:11.760 --> 00:28:21.660
Roxanne Guenette: If you are live. I would ask you on the first touch what is going to be the disadvantage of hyper K when you compare the baseline here.

177
00:28:22.710 --> 00:28:33.420
Roxanne Guenette: And you, I would imagine you all raising your hand and hopefully somebody would think that a short baseline means that the matter effect is not going to be very large in Hyper K

178
00:28:34.320 --> 00:28:42.960
Roxanne Guenette: If you know exactly what your mass our key is mass ordering it doesn't matter because now you fix it. And now you can really go back to your

179
00:28:43.530 --> 00:28:50.250

Roxanne Guenette: Measurements of Cp and that's fine because you know what your mess ordering is if you don't know where you're going to be in trouble.

180
00:28:50.520 --> 00:29:00.720
Roxanne Guenette: So hyper K made the gamble that by the time that they are there. We're going to know the mass ordering and it's kind of a safe gamble to glucose doing will be able to measure it. And there are other experiments as well.

181
00:29:01.260 --> 00:29:09.450
Roxanne Guenette: But since then, even to make sure that nobody would panic, they decided to also look at what happens when you use other sources of neutrinos like atmospheric neutrinos.

182
00:29:09.750 --> 00:29:21.300
Roxanne Guenette: And by combining all of this, they finally can get a handle on the mass ordering. So even if everybody else we're not able to say it hyper K is not too much trouble, they'll be able to do that even at this short baseline.

183
00:29:23.100 --> 00:29:32.820
Roxanne Guenette: So now what I want to do is I want to focus on a dune because again the what I want to teach you here. It doesn't matter which experiment you pick

184
00:29:34.440 --> 00:29:47.760
Roxanne Guenette: So what we're going to do as I explained, we're going to have a very powerful neutrino beam. Oh yeah, and I wanted to say something about the true beings got. I got a very good question from the previous lecture, which was why are beings.

185
00:29:48.720 --> 00:29:54.090
Roxanne Guenette: Going like one over r squared. And why are we using this technology, then, to do this.

186
00:29:54.480 --> 00:30:04.470
Roxanne Guenette: I replied that right now. The only way that we have to produce neutrino beings is the way that I've described where you smash bros on a target. And unfortunately, it does produce a wide

187
00:30:05.160 --> 00:30:18.300
Roxanne Guenette: Beam, which goes like one over r squared. But in the future. What we would like to do is have better an eternal being even then the one that I described to you and what people are thinking of is called neutrino factories.

188
00:30:18.750 --> 00:30:25.170
Roxanne Guenette: And in neutral factories. What you do is instead of accelerating protons that are going to smash in a target that is going to produce that. Why did

189
00:30:25.500 --> 00:30:35.460
Roxanne Guenette: A bunch of marathons. You could imagine accelerating new ones in a very high energy and those new ones. We know that the decay into electrons and

190
00:30:36.300 --> 00:30:46.320
Roxanne Guenette: electron neutrinos and because it's a single particle that the case immediately, then you would have a very good control of the direction so that could be like mostly like a tensile beam.

191
00:30:46.530 --> 00:30:54.480
Roxanne Guenette: But also have the energy of this neutrino. So those would be amazing. The problem is, it's not that easy to accelerate nuance in those

192
00:30:54.960 --> 00:31:06.420
Roxanne Guenette: Were cold storage rings, where you can do that a lot of people are working on this Fermilab has also a plan to try to do a new new on storage rings in the future. But if you're more interested in this.

193
00:31:06.660 --> 00:31:22.590
Roxanne Guenette: Look up the mice experiments which has done a lot of demonstration for the technology and just look up neutrino factories and you'll see that for the far future once the technological hurdles are passed, and I trust that we will go there, we will have great neutrino beans.

194
00:31:24.060 --> 00:31:33.600
Roxanne Guenette: Okay, finished the interlude dimensional beings. But yeah, so do 1.2 megawatt upgradeable to 2.4 megawatts in the future 1300 kilometers.

195
00:31:34.470 --> 00:31:43.920
Roxanne Guenette: Of baseline going to 40 kiloton of liquid argon detectors 40 kiloton is really big. So it needs a whole new cavern.

196
00:31:44.400 --> 00:31:56.910

Roxanne Guenette: The started digging up that last summer, I believe, and you can see a picture of what the lab is going to look like we're going to have four cavities, where we're going to put the 410 kiloton of liquid argon detectors.

197
00:31:57.540 --> 00:32:07.500
Roxanne Guenette: You can see how big, complex is so that's going to take a while to get it up and running, but it's going to be amazing lab when we have that we've decided to go for single phase.

198
00:32:08.610 --> 00:32:15.090
Roxanne Guenette: liquid argon detectors which are going to have wire planes to read them out, just in case you're wondering right now.

199
00:32:15.600 --> 00:32:22.500
Roxanne Guenette: I told you about the pixels that are going to be using the near detector. But here we are talking about number of cycles are so big.

200
00:32:22.890 --> 00:32:34.920
Roxanne Guenette: Right now, one detector of doom. I think a lot on module has 384,000 result wires. If you replace that by pixels. You then go up to several millions

201
00:32:35.820 --> 00:32:45.270
Roxanne Guenette: Of pixels. So the number of channels goes like crazy but Challenge accepted. We are going to look at pixel for different effects are in the future, but that's another topic.

202
00:32:46.320 --> 00:32:59.070
Roxanne Guenette: Okay, so we have these detectors and you're going to be Majoris because it's such a large detector, now that I don't want to have to drift over 20 meters, because then a lot of things can happen. Remember to electrons drifting through illiquid are gone.

203
00:32:59.430 --> 00:33:03.870
Roxanne Guenette: So we are putting all the chance on our side and we have modular approach where we have

204
00:33:04.500 --> 00:33:17.490
Roxanne Guenette: You can sum this drawing an old cathode and anode. So that means that the electrons are going to drift each side of the cathode towards the anode and these drift lengths are going to be only like two points. Something meter.

205

00:33:18.240 --> 00:33:28.260
Roxanne Guenette: And then the same thing on the other side. So we have four volumes of drift, that is available to us. So that's going to allow us to have more control on what's happening in the detector.

206
00:33:29.400 --> 00:33:35.280
Roxanne Guenette: And if you're curious default detector is going to measure 58 meter long by

207
00:33:36.360 --> 00:33:48.300
Roxanne Guenette: Wide by 12 meters high. And that's the inside detector and the whole crowd stabbed and goes through several or meters long. But that gives you that little robot person here shows you how big that detector is going to be

208
00:33:50.520 --> 00:33:57.570
Roxanne Guenette: Okay, so how is the association probably going to look for different CP violation in reality. So here I'm floating the full

209
00:33:58.830 --> 00:34:09.060
Roxanne Guenette: A solution probability taking all the parameters into account, assuming and all Malarkey those bullets exist, of course, for the inverted hierarchy. Remember I told you we have to duplicate everything

210
00:34:09.570 --> 00:34:20.760
Roxanne Guenette: Because we don't know the majority. So here the black line is not important, but it just shows you what would have happened if take 213 was zero, it means that would have happened. Nothing we could not have measured any

211
00:34:21.240 --> 00:34:33.210
Roxanne Guenette: Wiggles in that CP phase. So, that would have been very boring. So what are we going to try to do is we're going to try to distinguish between the green or red and the blue, which shows you three different values of the built Sep

212
00:34:34.560 --> 00:34:42.810
Roxanne Guenette: On the left, it's for neutrinos. And on the right, it's for answering neutrinos, because that's how when I'm going to measure this and that together. I'm going to have very good handle

213
00:34:45.540 --> 00:34:54.240
Roxanne Guenette: What is the event rates going to look like. And the fart effect on here at the top. I'm showing you the appearance signal which are new me and Anthony reappearance

214
00:34:54.480 --> 00:35:02.160
Roxanne Guenette: New we on the left, Anthony on the right and the bottom is the new new disappearance. So you want neutrinos and handsome you and Israel's on the right.

215
00:35:02.760 --> 00:35:11.010
Roxanne Guenette: You can see that clearly for the appearance. The black line is what you would expect if you there is no CP violation and see how

216
00:35:11.430 --> 00:35:21.690
Roxanne Guenette: Very different. The two values of delta CPS are shown here. So we have enough resolution and does that factor to really make sure that we're going to be able to tell these up gets us apart.

217
00:35:22.290 --> 00:35:32.100
Roxanne Guenette: And another point is we wanted to make sure that the energy resolution of this detector is good enough that you see how the peak of these guys is shifting toward the left

218
00:35:32.430 --> 00:35:41.730
Roxanne Guenette: Depending on the value. So by identifying the exact position of the peak and the amplitude of that big will be able to extract this delta CP violation.

219
00:35:42.540 --> 00:35:47.280
Roxanne Guenette: And here again is going to help us because we're going to be able to nail down the delta

220
00:35:47.880 --> 00:35:56.160
Roxanne Guenette: Squad the delta m squared, because that tells you the. Where did it is and how deep that dip is the sine square to data to tree.

221
00:35:56.790 --> 00:36:06.060
Roxanne Guenette: So with this picture. If you go back and you look at your probability of escalation, you should start to feel get a good feel of what are the different parameters playing a role here.

222
00:36:06.390 --> 00:36:11.730
Roxanne Guenette: And what we're going to do, of course, is we're going to fit all of this simultaneously to extract the parameters.

223
00:36:13.380 --> 00:36:22.110

Roxanne Guenette: What are we expecting to see for the mass or during so doing. So these pilots. I'm going to show you a lot of them for the next three slides.

224
00:36:22.740 --> 00:36:26.070
Roxanne Guenette: They are always representing the significance of the discovery.

225
00:36:26.610 --> 00:36:36.240
Roxanne Guenette: So think in terms of sigma here five is a five sigma discovery and remember to sigma as an evidence. So it's good but not there yet. So what do you see immediately from this

226
00:36:36.990 --> 00:36:48.510
Roxanne Guenette: These curves show for seven years of running and 10 years of running, you can see that very quickly, we're going to be able to tell at five sigma for sure what the mass ordering is and that

227
00:36:49.140 --> 00:36:56.670
Roxanne Guenette: With of these curves is all the uncertainties that we have been doing people have done a total jobs are trying to understand everything that can go wrong in the system ethics.

228
00:36:57.480 --> 00:37:05.400
Roxanne Guenette: So this is the range of of significance that we're going to observe. If you want to know how long it's going to take us. This is the

229
00:37:05.760 --> 00:37:17.010
Roxanne Guenette: Sensitivity again in function of the time that we're going to be running and here it's time of because doing is going to be a staged approach. We're going to build the first detector. Then the second and the third and the fourth

230
00:37:17.220 --> 00:37:35.460
Roxanne Guenette: The beam is going to come online. And then I can make data. So this is what stage me but you can see here that depending on the value of CP, of course, because we can be lucky or unlucky. We're going to start being able to tell the mass ordering as five sigma, at least at

231
00:37:36.480 --> 00:37:45.030
Roxanne Guenette: Least anyway at the minimum in two years time so that's great news. So mass ordering check. We're going to, we're going to be able to do that.

232

00:37:46.650 --> 00:37:57.060
Roxanne Guenette: What about CP violation. This, of course, it gets a bit more complicated, right, because if the just smaller that effect is the harder it's going to be, it's going to be detected

233
00:37:57.420 --> 00:38:03.030
Roxanne Guenette: So what do we see here is again the sensitivity of the function of the different values of Cp and this is what I was telling you

234
00:38:03.390 --> 00:38:14.940
Roxanne Guenette: If we say that CP is maximal plus or minus pi over to then you have the highest chance to detect it. And actually, you can see we would get a five sigma discovery of this up violation of its maximum

235
00:38:15.540 --> 00:38:23.670
Roxanne Guenette: If it's not maximum then of course the sensitivity started decreasing and we can get the tree sigma coverage of over off of these parameters space.

236
00:38:24.000 --> 00:38:31.170
Roxanne Guenette: And then maybe if it's really zero, then we're just going to be able to exclude everything else and never know exactly what the value is, unfortunately, but

237
00:38:31.920 --> 00:38:44.160
Roxanne Guenette: You know, I have faith in nature so we'll see. And also, the reason I have faith in nature is because you took a nova seems very promising in the fact that maybe CP is quite large. So fingers crossed.

238
00:38:44.730 --> 00:38:48.690
Roxanne Guenette: If you wanted to know and function of years here. It's starting to be a bit more scary.

239
00:38:49.350 --> 00:39:00.780
Roxanne Guenette: So I told you the master during his in two years. If you want to five sigma discovery at the minimum, you're gonna have to wait seven years and that is if you're lucky, because then you can go to easily 14 years

240
00:39:01.800 --> 00:39:11.250
Roxanne Guenette: So that's a kind of a long time. But hey, I'm still going to be doing physics and 14 years so it's okay with the worst weight, the weight. It's worth the wait.

241

00:39:12.540 --> 00:39:30.480
Roxanne Guenette: And finally, if you care about. How good are we going to be able to measure delta Sep because let's imagine that it isn't the maximum how precise, are we going to know this value. So this is the resolution in the greens that we're going to be able to make depending on its value.

242
00:39:32.130 --> 00:39:32.730
Roxanne Guenette: Yeah.

243
00:39:33.960 --> 00:39:37.770
Roxanne Guenette: Way explain it. No, I don't want to explain it yet. So here, the only thing

244
00:39:38.310 --> 00:39:46.530
Roxanne Guenette: That is important is, of course, the more time you pass the more precise your measurement is going to become and that's exactly what you see the precision gets much better.

245
00:39:46.800 --> 00:39:54.930
Roxanne Guenette: And then the width of this band is because of the other parameters that you're going to constrain better and better. So the uncertainty becomes smaller in depth resolution.

246
00:39:55.680 --> 00:40:04.650
Roxanne Guenette: So yeah, here you have. It's basically the remaining questions that we have, we're going to be able to answer most of them if we are patient enough

247
00:40:05.010 --> 00:40:19.380
Roxanne Guenette: And we may have great surprises. What if we learned that delta CP is maximum. What if we learned that the same square data to tree is maximum. Those are two things that could underlie new symmetries. And that would be very exciting.

248
00:40:20.400 --> 00:40:30.000
Roxanne Guenette: The next generation of experiments such as doing in a hyper k at very good prospects to answer all of these remaining questions. So I think it's going to be quite an exciting time in the future.

249
00:40:30.510 --> 00:40:37.080
Roxanne Guenette: And yes, you have to be patient. But remember that there was a lot of fun to have. In the meantime, and if you're a theorist.

250
00:40:37.290 --> 00:40:43.980
Roxanne Guenette: Is the perfect time right now to predict a lot of things that dune and hyper cake and check because then if you were right, you're going to be famous.

251
00:40:44.190 --> 00:40:54.000
Roxanne Guenette: If you're an experimental is can you try to make these detector better you have time, because we're going to build these detectors in the future. So if you have great ideas in the experimental side.

252
00:40:54.300 --> 00:40:58.680
Roxanne Guenette: Go forth and implement them in future modules of noon and the experiment is going to be even better.

253
00:40:59.730 --> 00:41:05.610
Roxanne Guenette: But what is our dream. And this is true for experimentalists and theorist, you may be aware

254
00:41:06.060 --> 00:41:14.940
Roxanne Guenette: If you are a friends with the quark sector that with all the time and all the experiments that they've done with time in the court sector.

255
00:41:15.240 --> 00:41:24.210
Roxanne Guenette: They've been able to understand the scam matrix which explained the association between the quarks to such a precise level that you can see here on this, but all the difference.

256
00:41:26.670 --> 00:41:34.830
Roxanne Guenette: Measurements and all the parameters space allowed and this is the triangle that when you prioritize them. The, the scam matrix, you can extract those parameters.

257
00:41:35.160 --> 00:41:43.950
Roxanne Guenette: But do you see how constrained this triangle is like the precision of this is beautiful. I think this is one of the most beautiful plots that we have in particle physics.

258
00:41:44.280 --> 00:41:53.100
Roxanne Guenette: So my dream is to see exactly the same thing for the PMs matrix. So hopefully that dream happens before I retire, but if not you guys will go for it. So,

259

00:41:54.960 --> 00:42:09.360
Roxanne Guenette: That's it for long baseline. That's it for the traditional traditional more three neutrino a solution. Now, as I promised you I need to talk about short baseline neutrino isolation.

260
00:42:10.560 --> 00:42:21.750
Roxanne Guenette: So before I go there. I want to remind you that we know for sure that we have on the tree neutrinos, which we call active neutrinos. This is redundant tree neutrinos.

261
00:42:22.710 --> 00:42:29.070
Roxanne Guenette: Because there was a lot of experiments in the past that we're looking at the case of Zappos ons into neutrino nuns neutrinos.

262
00:42:29.430 --> 00:42:43.350
Roxanne Guenette: And they've measured that with many different factors with incredible precision these points here that I shown from the different experiments, the Aero bars had been inflated by a factor of 10 so that you can just see them. And then when you feel the difference

263
00:42:44.580 --> 00:42:57.330
Roxanne Guenette: A hypothesis of two, three or four neutrinos. You can see that there is no way that the data is allowing you to divert from the tree neutrino. So we know that tree neutrinos and track with matters. And that's for sure.

264
00:42:58.650 --> 00:43:05.820
Roxanne Guenette: And I've given you one and a half lecture and under they gave you one and a half lectures on the isolation of the tree neutrino paradigm

265
00:43:06.090 --> 00:43:19.290
Roxanne Guenette: How amazingly well. Now we can measure all of these different parameters by using the public, you have isolation and this is again the summary of all the primary throws we've measured and remember I said we were in the order of percent level precision now.

266
00:43:20.160 --> 00:43:24.780
Roxanne Guenette: So there is no point anymore to discuss about

267
00:43:26.460 --> 00:43:31.230
Roxanne Guenette: So, so they are all we know that the Trina Trina paradigm is great and works really well.

268
00:43:32.670 --> 00:43:39.570

Roxanne Guenette: The reason we talked about long baseline is kind of redundant in a sense because like now when I want to measure that.

269
00:43:40.320 --> 00:43:49.200
Roxanne Guenette: To delta x squared that I have from my true neutrinos, which is seven minus trim Fenton minus five. Then I need ovaries. Whoops. There was a mistake here. It should be plus

270
00:43:49.920 --> 00:44:00.840
Roxanne Guenette: The elevator. He needs to be done to the three times to the five and then I know that I have to go to bass lines that are thousands to millions of kilometers. If I'm thinking of the sun, for example.

271
00:44:01.770 --> 00:44:13.950
Roxanne Guenette: So they are all long baseline. So as I said, it would be redundant to specify every time. Long Baseline isolation, because a solution of our tree neutrinos is always that long baseline for the future.

272
00:44:14.850 --> 00:44:23.460
Roxanne Guenette: But let's take a look at the full view of all the different experiments that I've ever done neutrino sedation ever

273
00:44:23.910 --> 00:44:34.260
Roxanne Guenette: So in this plot is the famous delta x squared, that we always blood and here it's the time of the data instead of the sign that I usually show in my previous lecture, but you can, you know, it's the same thing.

274
00:44:34.920 --> 00:44:44.160
Roxanne Guenette: So what do we see here, of course, many experiments have different sensitivities. Right. So when the extract department or space, depending on how precise. They are sometimes, there was large area.

275
00:44:44.370 --> 00:44:51.570
Roxanne Guenette: Of depth parameter space that is allowed, but that's fine because what we do is we combine all of the experiments that are sensitive to different parameters.

276
00:44:51.810 --> 00:44:57.960
Roxanne Guenette: And where the intersection of all of this is that's where your final precise answer is, and this is what you see here.

277

00:44:58.350 --> 00:45:08.370
Roxanne Guenette: The 12 delta x squared, that we have from our genome neutrinos attempt to minus treat them to minus five are shown here in this band and there. And you can see that where everything

278
00:45:09.180 --> 00:45:15.750
Roxanne Guenette: Meets that that's where your value is. So you can see that we have very good uncertainties on these different values.

279
00:45:16.980 --> 00:45:22.350
Roxanne Guenette: But immediately your ideas should be caused by all of this here what is happening there.

280
00:45:23.820 --> 00:45:32.850
Roxanne Guenette: So there, there was a bunch of experiment that looked at different parameters space. As you can see, because it's access the different times square which is very large.

281
00:45:33.360 --> 00:45:41.850
Roxanne Guenette: And some of them so anomalies. But if I'm talking about a delta x squared that is much higher than the others. I'm talking the order of one

282
00:45:42.450 --> 00:45:50.280
Roxanne Guenette: Then I'm obligated to add another neutrino because to delta and square comes from to neutrinos and treat them telling square come from for neutrinos.

283
00:45:50.790 --> 00:45:58.650
Roxanne Guenette: And this is exactly what you would have. So you would add a new a new neutrino. That is a mix of all the others, but mostly stairwell.

284
00:45:59.040 --> 00:46:01.860
Roxanne Guenette: And the Delta would be around one squared.

285
00:46:02.190 --> 00:46:11.280
Roxanne Guenette: Here, it doesn't matter where you put that arrow, because these guys are tend to minus three times one minus five. And this is one so treat to five orders of magnitude smaller these different so

286
00:46:11.520 --> 00:46:15.450
Roxanne Guenette: You know, it doesn't matter if you say that this is one of the B squared or that is one of you squared.

287
00:46:17.070 --> 00:46:25.110
Roxanne Guenette: But if I look at this in order to get one of you squared in my probability of isolation. I need an allegory. That is the order of one

288
00:46:25.620 --> 00:46:32.670
Roxanne Guenette: Which means that the depending on what energy. I'm going to look out for the neutrinos. The baseline now becomes the order of meters two kilometers.

289
00:46:33.030 --> 00:46:37.770
Roxanne Guenette: So this is why we talked about short baseline oscillation. When we talk about stay around neutrinos.

290
00:46:38.430 --> 00:46:46.020
Roxanne Guenette: And why did I say style is because if I want to add another neutrino in my tree neutrino paradigm that I know for sure that

291
00:46:46.440 --> 00:46:56.490
Roxanne Guenette: Lap has proven that is only reactive neutrinos. This guy needs to be sterile. It needs to not interact normally with math or because other at particle physics experiment would have seen it before.

292
00:46:58.230 --> 00:47:09.060
Roxanne Guenette: Okay, so, Arthur on a tree knows a thing, do they exist. Well, they've been a lot of experiments that have seen things that are weird that could maybe explain based around neutrinos.

293
00:47:09.420 --> 00:47:15.480
Roxanne Guenette: So in this table, you have different experiments. And I'm going to go through them quite quickly because I have 10 minutes left.

294
00:47:16.200 --> 00:47:22.350
Roxanne Guenette: And you can see that, depending on how they did their experiments they had different type of

295
00:47:22.980 --> 00:47:26.490
Roxanne Guenette: Neutrinos produce and also different type of channels that they were looking for.

296
00:47:26.940 --> 00:47:39.810

Roxanne Guenette: And all of them have excesses that we're seeing or deficit. So, depends on how they were looking at it. But look at the significance of these things. We are going from 3.8 sigma to 2.8 sigma

297
00:47:40.320 --> 00:47:48.390
Roxanne Guenette: These are only evidence and in neutral physics. We know that weird things happen all the time. So that's why people never

298
00:47:49.170 --> 00:47:56.460
Roxanne Guenette: were never able to prove anything yet, because those significance are not high enough, but what are those experiments. That's

299
00:47:57.120 --> 00:48:13.500
Roxanne Guenette: We have the first one, and I still one of the most convincing today. Although many Buddhists competing with that, I'll come back to with is the lesson the experiment that was in Los Alamos taking data in the late 1990s at Los Alamos, they had a proton beam.

300
00:48:14.550 --> 00:48:24.930
Roxanne Guenette: That was shooting again protons on a target producing clients, but here they were the energies of all of these things allowed them to stop.

301
00:48:25.260 --> 00:48:34.170
Roxanne Guenette: The part the clients so that they would decay at rest and when did you get for us. The great thing is that you know exactly the energy because it's related to the mass of the pie and

302
00:48:35.310 --> 00:48:41.640
Roxanne Guenette: This is not completely true. Because, of course, there was a mess of particles and there that will also dictate to others. But really, their main

303
00:48:42.960 --> 00:48:59.850
Roxanne Guenette: Signal their main source was answering us and then they had the detector that was waiting there to see anti new he appearance to see if that would happen. And remember, we are in the 2000s. Right, so we don't know things very well. So at the time it was a good idea to check different baseline.

304
00:49:01.620 --> 00:49:11.400
Roxanne Guenette: So they had a large detector which was 167 ton of mineral or with liquid sense later and they were looking for. And verse beta decay.

305

00:49:12.270 --> 00:49:16.380
Roxanne Guenette: Reactions where you have the unseen.

306
00:49:16.920 --> 00:49:24.810
Roxanne Guenette: electron neutrinos coming in and tracking with a proton, producing a neutrons that wanders around and get captured in the liquid circulating emitting light.

307
00:49:25.080 --> 00:49:35.220
Roxanne Guenette: And then you have the elect the positron that wonders that he likes very quickly to her like signal. So those two coincidental signal tells you that you had an

308
00:49:35.940 --> 00:49:55.050
Roxanne Guenette: Electron nutri anti new electronic neutrino ochre occurring. This is a technique that is done in all director experiments. By the way, this reaction. So what did they see you can see this is this spectrum and function of a livery, but really, because the he is quite the alias quite

309
00:49:56.160 --> 00:49:59.040
Roxanne Guenette: Narrow basically you can think of just as functional energy

310
00:49:59.670 --> 00:50:06.930
Roxanne Guenette: You can see their data points which is shown in black, the red and the black is two grams were what they were expecting as background.

311
00:50:07.260 --> 00:50:20.070
Roxanne Guenette: So you can see a clear access. Actually it's a 3.8 sigma access over the background and when you feel the probability of isolation of a neutrino of something like one a, b squared. This is what you get in blue.

312
00:50:20.610 --> 00:50:34.290
Roxanne Guenette: Do you see how nicely that fits. And actually, if you go to the delta is going to function of time square to theta plot the blue areas is what would be allowed by Ellison B and C. Again, this is the one e squared that I was referring to in the past.

313
00:50:35.940 --> 00:50:36.540
Richard Partridge: I don't have

314
00:50:36.990 --> 00:50:37.350

Richard Partridge: Lips.

315
00:50:37.380 --> 00:50:38.820
Roxanne Guenette: Go ahead, five minutes.

316
00:50:41.790 --> 00:50:42.210
Roxanne Guenette: Yes.

317
00:50:42.270 --> 00:50:43.980
Roxanne Guenette: Right, Richard. You wanted to tell me five minutes.

318
00:50:44.190 --> 00:50:45.780
Richard Partridge: Five minutes. Cool.

319
00:50:45.840 --> 00:50:46.260
Thank you.

320
00:50:47.400 --> 00:50:48.570
Roxanne Guenette: Okay, so I have to skip

321
00:50:50.190 --> 00:50:57.570
Roxanne Guenette: And you'll see, now I'm going to go a bit quicker and you're going to get kind of confused and that's okay because they're strong internal story is indeed confusing.

322
00:50:57.960 --> 00:51:06.870
Roxanne Guenette: So what happened after I listened. He was there sarong neutrinos there. If yes, that would be incredible. So they did the mini moon experiments which was a Fermilab now using a different been

323
00:51:07.200 --> 00:51:12.720
Roxanne Guenette: Using a different effect are but still probing the elver you just as sensitive to around one

324
00:51:13.350 --> 00:51:23.040
Roxanne Guenette: A, b squared. So they did this experiment. And one thing that happened is that the first result they put out where they were looking at you on neutrinos. The

325
00:51:23.340 --> 00:51:32.370
Roxanne Guenette: Oscillating into electron neutrinos. Remember at us and he was anti new news to Anthony's the new muting you eat results from any boom certain nothing

326
00:51:33.390 --> 00:51:38.370
Roxanne Guenette: That was consistent with the lesson D. So people thought, okay, fine, it's finished. Most around neutrinos.

327
00:51:38.730 --> 00:51:51.060
Roxanne Guenette: But no, no, no, it wasn't finished because even if many Boone didn't see anything coincidence with LSD, they still had an excess at low energy, and this is what is shown on this plot of the event spectrum and function of the energy

328
00:51:51.450 --> 00:52:04.380
Roxanne Guenette: The LSAT signal was expected to be here. The sword. No access but that lower energy. So one and again if you feel the access of this, you were able to start seeing something, but that was different than an SMB so confusion.

329
00:52:04.920 --> 00:52:19.530
Roxanne Guenette: Then they said let's switch to answer neutrinos, because we really want to compare to SMB, they did that Anthony mutual funds new we and then in 2011 surprise they did see an access that was not consistent with the lesson, be they took more data.

330
00:52:20.730 --> 00:52:28.860
Roxanne Guenette: And just before I go there if you're curious about what is the parameter space and Dell times square sine square to data allowed by the mini Boone result. This is what you have here.

331
00:52:29.340 --> 00:52:41.700
Roxanne Guenette: So you can see that in the neutral mode. There was quite a lot of tension between the two. But then in anti-neutrinos things fit much nicer be continued to take more and more and more data and in

332
00:52:44.340 --> 00:52:53.700
Roxanne Guenette: I'll show you a lot later the show that actually now all the results make sounds within mini Boone and they do see an excess of events that is consistent with the lesson.

333
00:52:55.290 --> 00:53:06.120
Roxanne Guenette: But if that was not complicated enough other experiments. Remember galaxy. I told you that was the experiment that tried to confirm the Davis and experiment and solar neutral problems.

334
00:53:06.690 --> 00:53:16.020

Roxanne Guenette: What they were doing in there in those years is they were calibrating there detector with very powerful new resources, the decay of chromium, for example, or our GM sources.

335
00:53:16.410 --> 00:53:23.520
Roxanne Guenette: And there they could predict this analysis was done much later. By the way, but it's easy to predict how many

336
00:53:24.060 --> 00:53:33.060
Roxanne Guenette: New ease you're expecting. And when somebody looks at the previous data from the galaxy. They actually showed that the amount of new easy. We're expecting from the source.

337
00:53:33.480 --> 00:53:48.390
Roxanne Guenette: was not what was detected. We were actually detecting less events with the detector that were predicted and this was about the tree sigma access deficit, actually, in this case, which was also consistent with an one easy

338
00:53:49.500 --> 00:53:50.340
Roxanne Guenette: One. A B squared.

339
00:53:51.690 --> 00:53:59.370
Roxanne Guenette: And the other thing that I want to briefly go over is the reactor and Emily. So remember right now. Everything I'm telling you is happening in 2011

340
00:54:00.180 --> 00:54:07.140
Roxanne Guenette: Damn the reactor experiments that were going after beta one three wanted to get a better estimate of the flux

341
00:54:07.650 --> 00:54:13.260
Roxanne Guenette: To make sure that they could predict what they would see of the fart detector before they could build their new detector.

342
00:54:13.950 --> 00:54:23.490
Roxanne Guenette: And here again, to cut a long story short, what they said is by their new better calculations made by many people. The so that the previous flux was

343
00:54:24.000 --> 00:54:30.600
Roxanne Guenette: Underestimated so now when you think of all director experiments that have happened in the past, you now have a higher flux

344

00:54:30.900 --> 00:54:37.620
Roxanne Guenette: But all of these guys. So less neutrinos than the higher flux was predicting and that was giving a tree signal anomaly.

345
00:54:38.160 --> 00:54:45.720
Roxanne Guenette: So people got very excited. But then the reactor no money is now being even more complex because neutrinos never get us

346
00:54:46.380 --> 00:54:53.520
Roxanne Guenette: Easy on interpreting the results. But here I just want to point out, and you can ask me questions in the future or read about it but

347
00:54:53.940 --> 00:55:08.640
Roxanne Guenette: We, it turns out that the reactor flux, even when we have high very much better predictions, it's still not very well understood, and this is what you see here we have a ratio between the near and far detector in double show, for example.

348
00:55:09.000 --> 00:55:11.730
Roxanne Guenette: And here, everything should cancel, and we should have a flat.

349
00:55:13.110 --> 00:55:24.360
Roxanne Guenette: A flat ratio, but there is a bump at five, a movie that comes from the fact that actually we don't understand the flux at all coming from these reactors and I, we could talk about that more.

350
00:55:25.830 --> 00:55:40.140
Roxanne Guenette: This is the new mini moon results that I wanted to show, and now the access in both is is consistent and the access is a total of almost five sigma. So, this is going to be real. Is it as derogatory note, we have to check

351
00:55:42.180 --> 00:55:47.640
Roxanne Guenette: Okay, I'm out of time, guys. But just to wrap up the entrust him.

352
00:55:48.660 --> 00:55:51.780
Roxanne Guenette: Staring at Reno's ever I've really been something and function of time.

353
00:55:52.290 --> 00:56:00.540

Roxanne Guenette: In the beginning, we get excited, then nothing happened mini Boone said no we said okay, fine then 2011 a lot of things a lot of things happened.

354
00:56:00.810 --> 00:56:06.240
Roxanne Guenette: And now we are today where we don't know exactly what's happening with surround neutrinos and why we don't know.

355
00:56:06.720 --> 00:56:19.920
Roxanne Guenette: I don't have time to go into details. I'll leave this slide there for you to go back. But when we try to make a coherent picture of all the results that we have, we are not able to explain what's happening in the appearance

356
00:56:20.730 --> 00:56:26.070
Roxanne Guenette: Results and in the disappearance results. Those are in complete tension so

357
00:56:26.580 --> 00:56:32.760
Roxanne Guenette: Read that slide on your own later. This is a beautiful summary of me. Kelly mazzone that they're at the Attorney General Conference.

358
00:56:33.150 --> 00:56:44.790
Roxanne Guenette: But right now we know that there are anomalies. These things are not going away. We cannot explain them very nicely. But if we want to explain them. We need new physics and potentially surround neutrinos.

359
00:56:46.080 --> 00:56:49.830
Roxanne Guenette: So for the future. We don't know exactly.

360
00:56:51.120 --> 00:57:02.670
Roxanne Guenette: So, so to go forward. How do we do that. I know I'm out of time. So I just want to flash your the short baseline neutrino program as firming up is going to x is going to look for certain neutrinos.

361
00:57:03.000 --> 00:57:08.730
Roxanne Guenette: And this is what it's going to be like, Do remember that bill times square sine square to data that I showed you

362
00:57:09.570 --> 00:57:18.840
Roxanne Guenette: For LSD. This is the five sigma contours that the short baseline program is going to go. So we really are hoping that we're going to have an answer for you.

363
00:57:19.770 --> 00:57:29.970
Roxanne Guenette: And if you want to be entertained. There is a new anomaly that came from the neutrino for reactors and I've just put three papers you that show you how interesting science can be

364
00:57:30.330 --> 00:57:40.740
Roxanne Guenette: Those are three papers that came out within days of each other. The National for experiments showed their results that has a clear oscillation signal and declined at the sea oscillation as your baseline.

365
00:57:41.130 --> 00:57:49.800
Roxanne Guenette: And then the prospect collaboration replied to them to say, I don't think you did the analysis properly and then the new journal for collaboration reply and said, yes, we think so.

366
00:57:49.950 --> 00:57:52.770
Roxanne Guenette: I recommend those two to read for you if you're interested.

367
00:57:53.520 --> 00:58:01.800
Roxanne Guenette: But yeah, I am out of time. And the last thing I want to say before I finish is that imagine that if you have to run neutrinos and you don't know it.

368
00:58:02.160 --> 00:58:08.580
Roxanne Guenette: And you're going to do future a sedation experiments, you're going to mess up your isolation experiments, for sure.

369
00:58:08.820 --> 00:58:19.680
Roxanne Guenette: Because a solutions is becoming so precise that if you mix a sterile neutrino in there and you don't know that is that you can enter press your final results in the wrong way.

370
00:58:21.120 --> 00:58:24.840
Roxanne Guenette: So I'll let you read that. But I hope that you don't understand

371
00:58:25.110 --> 00:58:39.060
Roxanne Guenette: That isolation physics is extremely interesting. We will have some answers surround neutrino is a mess, a little bit, but we are going after it because the reward of finding a new particle which is what every particle physics is going after these incredibly important.

372
00:58:40.290 --> 00:58:41.970
Richard Partridge: Thank you. And sorry for going over time.

373
00:58:42.450 --> 00:58:51.720
Richard Partridge: Thank you, Sam for just absolutely beautiful set of lectures and Neutrino Physics, Charlie, you know, some questions.

374
00:58:52.380 --> 00:59:03.990
charlie young: Yeah, thank you. Roxanne for wonderful three sets of three lectures, we have a number of questions. We'll see how many we can get through the rest will be handled in offline and post it to the agenda page.

375
00:59:04.980 --> 00:59:19.800
charlie young: So the first question, why are we so concerned about reducing systematic uncertainty wins statistical uncertainties are so large, should we be focusing on reducing the statistical uncertainties instead

376
00:59:20.850 --> 00:59:29.730
Roxanne Guenette: That's a very good point. So the first thing you want to do, indeed, is to go for the statistics. If you look at the dune. I don't know if I can go back quickly.

377
00:59:31.290 --> 00:59:32.850
Here, you should see that still

378
00:59:34.440 --> 00:59:36.570
Roxanne Guenette: If I go to the event spectrum.

379
00:59:44.580 --> 00:59:57.270
Roxanne Guenette: Here. So you can see in there that despite the fact that some of them will have quite low stats like the news. For example, the others have decent statistics.

380
00:59:57.480 --> 01:00:10.080
Roxanne Guenette: So good, and especially in the disappearance. So with all of these statistics errors we are kind of okay to do what we want to do, but the systematics what they're gonna do is they're going to affect many things among the

381
01:00:10.740 --> 01:00:21.180
Roxanne Guenette: Energy reconstruction, for example. So by not knowing exactly where the peak is that's going to be bad. And that's going to be

bad. Even if you have great statistics in your new media, new media appearance, for example.

382
01:00:22.020 --> 01:00:31.620
Roxanne Guenette: So we want to do both the statistics, we're going to have to wait. A lot of time and hopefully in the future. We're going to have better experiments, but

383
01:00:31.980 --> 01:00:44.670
Roxanne Guenette: With the current systematic statistics. We're going to be okay if we control the systematics good enough to show what I have shown you here. So, and if you look at the dune 3dr you're going to see there, there is a clear

384
01:00:45.090 --> 01:00:53.100
Roxanne Guenette: Comparison between know systematics and with systematics and you can study the airplane still a big role. So we need to go after them no choice.

385
01:00:55.200 --> 01:00:59.700
charlie young: Okay, so there's a question about slide 22

386
01:01:01.800 --> 01:01:07.380
charlie young: Someone noticed that there are many more events for neutrinos than there are four empty neutrinos.

387
01:01:07.860 --> 01:01:09.930
charlie young: Yeah. Why is that

388
01:01:10.650 --> 01:01:19.860
Roxanne Guenette: So this comes from the fact that when I explained at the last lecture how we make nutritional beans, it's much more difficult to produce anti-neutrinos

389
01:01:20.130 --> 01:01:30.240
Roxanne Guenette: And they're kind of two reasons. But the first one is, we're shooting protons positively charged particles on the target, which will produce mostly positively charged may zones.

390
01:01:30.570 --> 01:01:41.610
Roxanne Guenette: So when we're going to reverse the current to focus the negatively charged Masons. We're going to start with less of them and also depending on the energy of these different ones. The decay to Anthony

391
01:01:43.470 --> 01:01:54.660
Roxanne Guenette: And neutrinos are going to be less intense than in the neutrino ones. So basically, yeah, we, we are less good at producing them. So that's why the and we are less good at having them.

392
01:01:56.850 --> 01:02:02.880
charlie young: So this is probably a related question how does high power protons help

393
01:02:06.300 --> 01:02:08.700
Roxanne Guenette: Okay, I'm not sure exactly a

394
01:02:08.850 --> 01:02:13.410
charlie young: Slide for where we talk about starting with a high power proton

395
01:02:15.390 --> 01:02:23.370
Roxanne Guenette: So that the power of the Pro. So, it depends. I'm going to interpret this question as, how does it help to have more protons.

396
01:02:23.940 --> 01:02:44.250
Roxanne Guenette: Or higher energies. So there are two things here that we care about. You want to control your energy of the protons in in your final beam. So we did the optimization of what is the best being energy beam that we would like to have to do the studies for doing so when I look at these

397
01:02:45.390 --> 01:02:47.940
Roxanne Guenette: Plots, for example, which is the isolation and function of

398
01:02:49.260 --> 01:03:05.940
Roxanne Guenette: Of baseline, remember that it was a part of the energy here. So we know that having like a GV beam is going to be a very good idea and the higher in our J want the more energetic those protons need to be the second part is I want to have as many

399
01:03:07.050 --> 01:03:22.530
Roxanne Guenette: Neutrinos as possible. So by shooting more protons on the target. I'm going to produce more Masons, which would indicate into two neutrinos. So I care about both the energy and the power and the amount of protons that I'm producing

400
01:03:24.660 --> 01:03:27.660

charlie young: OK, the next question is about slide 14

401
01:03:30.000 --> 01:03:40.680
charlie young: When we talk about the neutrino energy here. Does that include a spectrum of the beam energies in it or is it a unique energy

402
01:03:41.190 --> 01:03:45.210
Roxanne Guenette: So in this one. This is a good point because

403
01:03:45.780 --> 01:03:58.740
Roxanne Guenette: I told you, right, that is not super intuitive to extract all the different interplay of the different parameters. So the reason we put these probability in function of neutrino energy over baseline is to get rid of that.

404
01:03:59.250 --> 01:04:04.590
Roxanne Guenette: So now I'm because also even the baseline. Think about it. When I produce my neutrinos.

405
01:04:05.370 --> 01:04:14.130
Roxanne Guenette: They will. I mean, in doing it doesn't really matter because it's it's 1300 kilometers, but just the fact that they travel in the detector which is 70 meters long.

406
01:04:14.640 --> 01:04:21.960
Roxanne Guenette: The baseline change a little bit. Again, it doesn't matter. In June, but in shorter baseline experiment. It does. So if you start

407
01:04:22.860 --> 01:04:33.000
Roxanne Guenette: Even putting the energy and the baseline convolution in those button, it becomes impossible to see the difference. But to answer your question is in these pure probability plots.

408
01:04:33.810 --> 01:04:37.140
Roxanne Guenette: I don't really care. I just care about the ratio. So it's true that

409
01:04:37.860 --> 01:04:52.290
Roxanne Guenette: I'm going to have different if I have a full spectrum of energy, these curves are going to change slightly because they're going to have a different energy. So knowing those it's a specific he over at you over L that I'm plotting. But if you go to

410

01:04:53.400 --> 01:04:56.190
Roxanne Guenette: These ones here that includes the full

411
01:04:57.420 --> 01:05:02.670
Roxanne Guenette: The full spectrum. And the same thing when you look at the beam events. Those are fully

412
01:05:04.410 --> 01:05:06.000
Roxanne Guenette: propagated through the whole energy

413
01:05:07.440 --> 01:05:22.200
charlie young: Okay, thank you. Here's a question about Long Baseline, why don't we have a 3000 kilometer baseline your train new experiment is that because we are unable to align the neutrino beam over such a long distance

414
01:05:23.400 --> 01:05:36.150
Roxanne Guenette: This is a good point because, again, if we go back to these slides, then the, the further way that you go, the more handle. You could have for matter effect. But what is the biggest

415
01:05:36.750 --> 01:05:54.870
Roxanne Guenette: Downside of doing that is the one over r squared. If I go to 3000 kilometers, go back here and look at the divide this flux by one over r squared. And you're going to go down a lot. So right now it's not a good idea to go further too much further than those

416
01:05:54.930 --> 01:06:02.580
Roxanne Guenette: Because we're going to have to wait for too long. And also, as I said, we played an optimization game at some point it's not completely clear.

417
01:06:02.970 --> 01:06:14.910
Roxanne Guenette: If you gain that much. Once you've identified the mass our key. You know what it is. And you can focus on the others for the Delta CP, and there you know you can do it that short or baseline.

418
01:06:17.010 --> 01:06:17.400
charlie young: Thank you.

419
01:06:17.520 --> 01:06:20.040
Roxanne Guenette: It was a full optimization of everything together.

420
01:06:21.450 --> 01:06:24.600

charlie young: Right. So, one more question. This is about. Slide seven

421
01:06:25.800 --> 01:06:30.780
charlie young: There are four graphs. And the question is, what's the difference between them.

422
01:06:31.860 --> 01:06:45.450
Roxanne Guenette: Yeah. So here I went super quickly. Sorry about that, because I just wanted to illustrate how cross sections were at the top of most of them, but these. This is from the Nova experiment and they are the answer. The systematics on certainty coming from there.

423
01:06:46.530 --> 01:07:00.570
Roxanne Guenette: On the left side is the neutrino events on the right side is the answer. Nutrient events and the top ones are for new one neutrinos and at the bottom is for electron neutrinos. So all of them have different systematics

424
01:07:01.110 --> 01:07:09.840
Roxanne Guenette: Because depending on how the detector works and how well we've understood cross sections in the past and the flux and stuff. So that's why you have to show them separately. Yeah.

425
01:07:11.880 --> 01:07:17.640
charlie young: Thank you. Another question. When do we expect dune to start operating

426
01:07:19.020 --> 01:07:26.850
Roxanne Guenette: So that's a very good question and we are going to start building the detector is next year in 2021

427
01:07:27.630 --> 01:07:33.990
Roxanne Guenette: We are expecting about two years to complete the first detector and go put it on the ground. So if I go back here.

428
01:07:34.230 --> 01:07:44.760
Roxanne Guenette: So the first director, which is a single phase liquid on the factors should take about two years. So now 21 in 23 we are starting to put it on the ground. It takes about a year 2024

429
01:07:45.150 --> 01:07:47.280
Roxanne Guenette: We have the first detector that is running.

430
01:07:47.610 --> 01:07:57.420

Roxanne Guenette: We don't have the most powerful being yet. It's not ready. So we're going to take cosmic rays. We're going to have to wait because there was not that many cosmic rays. But there was a lot of atmospheric neutrinos. So that's okay too.

431
01:07:58.080 --> 01:08:09.390
Roxanne Guenette: And then two years later, roughly 2026 we should get a new be take these numbers with a grain of salt. Anybody that has ever done particle physics experiments knows that delays are possible.

432
01:08:10.200 --> 01:08:14.310
Roxanne Guenette: But yeah, so the current timeline is roughly 2026 we get the beam.

433
01:08:14.850 --> 01:08:21.810
Roxanne Guenette: That was two years later and and the first module. It means you're not have time to complete the second module. So we have 20 kiloton of detectors.

434
01:08:22.260 --> 01:08:36.150
Roxanne Guenette: With the beam. Then we build a near detector and then and so on and so on. That's why all the plots and they're doing to the ours are called staged because of what I just said. Here the full that actor running should be by 2030

435
01:08:37.950 --> 01:08:41.130
Roxanne Guenette: And then we just need 14 years to find sippy violation.

436
01:08:43.170 --> 01:08:43.650
charlie young: Do

437
01:08:45.780 --> 01:08:48.030
charlie young: Here's a question about slide 25

438
01:08:50.970 --> 01:08:59.730
charlie young: So to curse, which are typically shifted relative to one another. Why are they foot shifted relative to one another, like that.

439
01:09:00.630 --> 01:09:08.040
Roxanne Guenette: So this is just because we took three snapshot in time, one for seven years, one for 10 years and one for 15 years

440
01:09:08.490 --> 01:09:16.680

Roxanne Guenette: And basically, the longer you go, the more data you have and the more precision, you start getting. So basically when you have

441
01:09:17.250 --> 01:09:31.710
Roxanne Guenette: Not a lot of time, the precision is not very good. And then the precision because remember this is the resolution in function of degrees. The smaller that delta that smaller that the degree is the better precision, you have and this is exactly what you see here where you start.

442
01:09:32.760 --> 01:09:38.550
Roxanne Guenette: Going down to 15 years. Now you precision is almost twice what you had when you started

443
01:09:40.230 --> 01:09:44.310
Roxanne Guenette: Which is mainly from statistics. Right, so

444
01:09:44.640 --> 01:09:47.610
charlie young: The next question is regard slide 18

445
01:09:49.440 --> 01:09:52.110
charlie young: And it's a little bit related to the last one.

446
01:09:54.090 --> 01:09:57.420
charlie young: Is doing gonna have a harder time measuring delta CP

447
01:09:58.590 --> 01:10:00.840
charlie young: For example, plus minus pi over to

448
01:10:03.120 --> 01:10:15.600
Roxanne Guenette: And not really so if you go back here. It does slightly less good if you compare those two here. So I guess that this person is asking because I events. This is how

449
01:10:16.050 --> 01:10:24.090
Roxanne Guenette: When you can separate those two curves. Very well. You get a better power at understanding everything and here it's smaller.

450
01:10:24.510 --> 01:10:30.330
Roxanne Guenette: And this is true. And this is why you see that those two bumps are symmetric. So when it's

451

01:10:31.140 --> 01:10:42.600
Roxanne Guenette: The other one we get a higher sensitivity than when its maximum but keep in mind that this is even if it's smaller than that, it's still big enough that we have handle. And this is actually why

452
01:10:43.290 --> 01:10:48.600
Roxanne Guenette: hypercar is also able to do that, even if they have a short baseline, even if the difference is not

453
01:10:50.010 --> 01:10:52.170
Roxanne Guenette: That big. It's big enough. Yeah.

454
01:10:54.180 --> 01:10:55.200
Richard Partridge: One more question.

455
01:10:56.490 --> 01:10:57.060
charlie young: Okay.

456
01:10:58.170 --> 01:11:03.780
charlie young: Can you explain the LSAT anomaly. And how was it related to calyx.

457
01:11:04.800 --> 01:11:09.540
Roxanne Guenette: So explaining it in physics storm icons, because we still don't know what happened.

458
01:11:10.740 --> 01:11:18.930
Roxanne Guenette: But the if we go back here. Basically what this is an excess of us of events that could come from isolation.

459
01:11:19.380 --> 01:11:23.850
Roxanne Guenette: And this is what you see on this block here where the data is much higher than what you were expecting.

460
01:11:24.270 --> 01:11:28.980
Roxanne Guenette: So if this is truly coming from a solution which this is what the blue curve suggests

461
01:11:29.310 --> 01:11:39.870
Roxanne Guenette: Then it could be around the tree. No. So what would happen is you would have an answer for you on tree know that traveled converted to a stairwell through our don't do anything reconverted to an electron

462
01:11:40.320 --> 01:11:52.200
Roxanne Guenette: anti-neutrinos and we detected it in a detector and why it does it. It does relate to all the other animals that I talked about is that this will be the same thing here. You produced electron neutrinos and your sources.

463
01:11:52.380 --> 01:11:54.510
Roxanne Guenette: You knew you were expecting X amount

464
01:11:54.810 --> 01:11:57.630
Roxanne Guenette: And you detected. Why that is much smaller than x

465
01:11:57.930 --> 01:12:10.290
Roxanne Guenette: Which tells you that you had a deficit of events. How can you explain that. Well, the new way that we're emitted in the source. They turned into several neutrinos, which we cannot detect so I detected less events, then was possible to see

466
01:12:10.800 --> 01:12:23.220
Roxanne Guenette: And this is also the same thing with the reactor and all of these guys show that maybe you could have a solution between normal neutrinos to stare out sometimes coming back to normal neutrinos that we can detect

467
01:12:25.410 --> 01:12:28.590
charlie young: Thank you very much, Richard. You want to take

468
01:12:29.880 --> 01:12:30.540
charlie young: Take it away.

469
01:12:31.590 --> 01:12:33.090
Richard Partridge: Yeah, thank you.

470
01:12:34.320 --> 01:12:36.870
Richard Partridge: And you have a

471
01:12:38.190 --> 01:12:40.110
Richard Partridge: About an eight minute break here.

472
01:12:41.400 --> 01:12:42.810
Richard Partridge: I'm stopping recording now.