WEBVTT

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00:00:03.090 --> 00:00:14.250
mark convery: And we're very pleased to have rectangle net from Harvard to give her second lecture first lecture on the translation experiment. Roxanne, I'll ask you to share

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00:00:15.599 --> 00:00:16.770
Roxanne Guenette: You should see that now.

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00:00:17.369 --> 00:00:20.760
mark convery: Yes. Very good, thank you. So take it away. Excellent.

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00:00:21.540 --> 00:00:23.340
Roxanne Guenette: Okay. Yeah, hi everyone again.

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00:00:23.550 --> 00:00:37.470
Roxanne Guenette: I'm back. So I think following Andres lecture is a very good timing because you got the view from an from a theorist of what nutrient solution is. And now you're going to get the view of the experimentalists

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00:00:37.920 --> 00:00:44.370
Roxanne Guenette: And I think it's interesting to get both views, you're going to see that we use different language and we care about different things.

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00:00:44.730 --> 00:00:54.570
Roxanne Guenette: But I think it's important to talk to each other and re pointed that out that if we want to make the feel advance you really need to understand both sides of the coin so that you can talk to each other.

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00:00:55.230 --> 00:01:04.950
Roxanne Guenette: So hopefully after these lectures, you're going to get a better feel of how experiments are going after neutrino installation and what happened in the past. And what's going to happen in the future.

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00:01:08.220 --> 00:01:11.850
Roxanne Guenette: Okay, so let me just tell you how I'm going to organize the lecture.

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00:01:12.990 --> 00:01:23.220

Roxanne Guenette: So the first thing I want to do is I want to give you an overview of the history of new translation. The reason I want to do that is Andrew mentioned that his lectures as well. The

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00:01:24.300 --> 00:01:39.540
Roxanne Guenette: How far we came to understand how neutrino installation work has been very chaotic and I think it's unfair to just present the field that we have today, because what happened in the past is incredibly interesting and also I love history. So, you know, you have to keep up with me here.

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00:01:40.590 --> 00:01:48.090
Roxanne Guenette: And then I'm going to go on. What is the experimental view of a neutron oscillations. We're going to go on over this briefly because you've got a very good introduction already

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00:01:48.450 --> 00:01:54.060
Roxanne Guenette: And what are the key ingredients that we need, when we are making an experiment for a new translation.

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00:01:54.600 --> 00:02:03.810
Roxanne Guenette: And then I'll finish with Long Baseline neutrino installations, because you'll see that those are going to be the one playing the most important role for the remaining questions and discussing how

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00:02:04.530 --> 00:02:12.090
Roxanne Guenette: We need to take the experimental steps, but also what are the current experiments where, where are we today regarding Long Baseline experiments.

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00:02:14.040 --> 00:02:19.200
Roxanne Guenette: So as I said, the history of neutrinos is really not straightforward and it's quite chaotic.

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00:02:19.980 --> 00:02:31.890
Roxanne Guenette: It was several decades, like over 30 years of total confusion that culminated to, when we understood that finally neutrinos do isolate, which explained the whole confusion that we had the 30

18
00:02:32.430 --> 00:02:45.960
Roxanne Guenette: Years before doubt and I'm not sure if anybody on the call is can understand what this little guy here is doing. But this is what I think of when I think about history. So if you don't know. Too bad you missed the whole

19
00:02:46.860 --> 00:02:50.070
Roxanne Guenette: Pedagogical way of learning about history. But if you do good for you.

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00:02:51.510 --> 00:03:00.960
Roxanne Guenette: So after the discovery of the neutrinos and this we're talking about discovery of electronic neutrinos was in 56 and this is the Reggio grams sense by poly

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00:03:01.440 --> 00:03:05.490
Roxanne Guenette: Bye bye rains and Cohen's to poly to say that they had discovered the neutrino.

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00:03:06.060 --> 00:03:13.050
Roxanne Guenette: And the discovery of the new on neutrinos and 62 which were two big things because now we knew we had more than one neutrinos and that they were different articles.

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00:03:13.680 --> 00:03:22.590
Roxanne Guenette: People started to show an increased interest in studying these particles, although he was fundamentally known that it's hard to studies neutrino. So you needed quite

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00:03:23.310 --> 00:03:27.810
Roxanne Guenette: A lot of motivations to go after them, but the obvious source was the sun.

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00:03:28.470 --> 00:03:38.160
Roxanne Guenette: And in the 60s. So just have to neutrals were discovered physicist had kind of a good understanding on how the sun works and how the fusion inside the sun work.

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00:03:38.550 --> 00:03:46.860
Roxanne Guenette: So there are people that had started to predict what you would see in neutrinos and one of these person that played a big role was john McCall

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00:03:47.430 --> 00:03:57.870
Roxanne Guenette: And by knowing how the fusion works into the sun how protons and helium and hydrogen interact. They could predict exactly how many neutrinos, you should expect

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00:03:58.380 --> 00:04:08.640

Roxanne Guenette: But of course they needed somebody to confirm that. So one of the friend of John's call who was called Ray Davis decided in 64 to go for the tech thing neutrinos from the sun.

29
00:04:09.240 --> 00:04:22.620
Roxanne Guenette: And that was not a small feat. So to do it. He built a tree hundred 80,000 liter of cleaning fluid in that huge was awarded. You can see here on the right, where you have the Ray Davis on top of it.

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00:04:23.160 --> 00:04:36.150
Roxanne Guenette: And you already knew that he had to go on the ground. To do that, then you went to the home stake mine, which you're going to hear from in the future because that's the same mind where we're going to go for doom and some dark model experiments. Also, like if they're like Lux and healthy.

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00:04:37.380 --> 00:04:45.780
Roxanne Guenette: But yeah, so he knew he had to go on the grounds and his idea he was actually a chemist. So, you know, good for him to go after neutrinos in those years.

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00:04:46.410 --> 00:05:02.040
Roxanne Guenette: But what he did is with this big reservoir of cleaning fluid which had actually the atom chloride 37 in you that from the reaction of an electron neutrino coming from the sun interacting with the chlorine, it would produce an argon 37 and then electron

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00:05:03.240 --> 00:05:11.910
Roxanne Guenette: So what he said is, OK, in this huge reservoir that had like a forgettable times numbers of atoms, times the 380,000 liters.

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00:05:12.420 --> 00:05:23.010
Roxanne Guenette: Is going to circulates the fluid and extract the single our GM atom that I've been produced from this solar interactions and remember those interactions are very rare.

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00:05:23.610 --> 00:05:36.690
Roxanne Guenette: So really, he was about to count single atoms in those years of war so seriously. I hope that you realize how crazy that was even today. It's a crazy thing to do to go up after single atoms.

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00:05:37.290 --> 00:05:48.240
Roxanne Guenette: But that didn't deter him and he had a very good solution for how to do this. I don't have time to go into details, but I wish that in times you're going to go in more details about this experiment because it's extremely beautiful

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00:05:49.620 --> 00:05:55.200
Roxanne Guenette: So what happened is, he was able to recirculate an extract individually. Those are going atom are 137

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00:05:55.650 --> 00:06:04.320
Roxanne Guenette: Which are resurrected that's do a myth. Some that producer reaction that emits gamma. So if you have a counter, you can detect that are going atom decay.

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00:06:05.040 --> 00:06:13.110
Roxanne Guenette: And basically you know immediately that that number of our gun that you detect is directly proportional to the number of neutrinos that came in from this reaction.

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00:06:14.670 --> 00:06:24.030
Roxanne Guenette: The results that came out is that he got roughly about 10 items single atoms of our goal every month. So this is tiny, tiny, tiny

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00:06:24.930 --> 00:06:38.190
Roxanne Guenette: And then when you calculated the flux that you have to get to get those 10 items coming in. He showed that you actually had only one third of the prediction from john Michael from the, from the sun.

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00:06:39.630 --> 00:06:44.310
Roxanne Guenette: At the beginning, people were like, yeah, right. You're going after a single atoms in debt huge factors.

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00:06:44.880 --> 00:06:48.990
Roxanne Guenette: Even if you made, you know, very small mistakes and you have a factor of two or three

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00:06:49.350 --> 00:07:02.220
Roxanne Guenette: You would recover the problem of the sun, but this experiment around for very long for actually 24 years and every year after year after year, things become more and more understood and the things stayed as one third.

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00:07:02.910 --> 00:07:11.880
Roxanne Guenette: So that started to be the Solar Neutrino problem. And there was a lot of reaction that happened. Also on the theory side because again, predicting this the whole flux of solar neutrinos.

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00:07:12.540 --> 00:07:21.120
Roxanne Guenette: From the theory in the 60s and getting it off by a factor of three is not that big deal. And it's actually interesting to talk to people who did research in these years.

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00:07:21.900 --> 00:07:32.340
Roxanne Guenette: Because they went after a lot of different ways of modifying the sun to get less neutrinos produce. And I think in those years, the there was a lot of active research and this

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00:07:33.630 --> 00:07:37.290
Roxanne Guenette: And as I said, this was known as the solar on internal problems which lasted for 30 years

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00:07:38.790 --> 00:07:47.130
Roxanne Guenette: But even if people got more and more trust in Davis experiments. There are other people that decided to go after it with follow up experiments. And there are two of them that

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00:07:47.580 --> 00:07:56.250
Roxanne Guenette: Are notable. The first one is, candy, candy, who started in 85 which was the precursor of super calm, you can do, which we'll talk about in a solution later.

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00:07:56.910 --> 00:08:09.780
Roxanne Guenette: But keep in mind the cameo can day was not built to look at solar neutrinos. It was built to search for proton decay, which was another high interest thing topic and in the 60 in the 60s until the 80s, but

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00:08:10.590 --> 00:08:19.320
Roxanne Guenette: Yeah, keep in mind that again people at the time. We're not obsessed with the solid material problem completely so they decided to use this detector as a

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00:08:19.650 --> 00:08:25.230
Roxanne Guenette: As a side project to cross check the sovereign neutrinos. And then, there wasn't one other that was called galaxies.

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00:08:25.590 --> 00:08:34.350
Roxanne Guenette: Who was sent grunts. So there was a large detector and this one was very similar to Davis instead of chlorine. It was gallium, but it was doing the same exact

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00:08:35.070 --> 00:08:42.210

Roxanne Guenette: Reaction check where a new he comes in and check with the gallery and producing a German you excited states which will decay that you can detect

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00:08:43.410 --> 00:08:52.920
Roxanne Guenette: And what happened with these is that you can see on these plots that shows the ratio from their prediction in the theory side compared to what you would expect in the experimental

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00:08:53.130 --> 00:08:57.000
Roxanne Guenette: And you would have wanted everything to be at one where the to reproduce predicts

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00:08:57.240 --> 00:09:09.120
Roxanne Guenette: But all these experiments. That's include the Galaxy one. The chlorine one from Davis and the camera candy and in the future. Super K to confirm the same results. You can see that they were all way lower than your prediction.

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00:09:09.960 --> 00:09:15.780
Roxanne Guenette: So what was wrong experiments or theory, of course, depending on who us you have different answers.

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00:09:16.110 --> 00:09:24.180
Roxanne Guenette: But the point here is that it was getting harder and harder to say that experiments were wrong, because all of them were pointing towards the same thing.

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00:09:25.140 --> 00:09:37.920
Roxanne Guenette: Well, we had to wait until 98 for the Super camera camera, which was an expanded upgraded version of the candy, candy detector much more photo multiplier tubes and much more precise of the factor in a bigger one.

62
00:09:38.940 --> 00:09:44.190
Roxanne Guenette: Where they use water to drink of I don't want to go into details on these factors here because it's not a detector.

63
00:09:44.370 --> 00:09:56.520
Roxanne Guenette: Lecture, but they're pretty cool the way they work. And the you can see on the right. This is an image of a new one nutrient interaction that produce turning off lights in a very precise ring that can be identified quite easily.

64
00:09:58.110 --> 00:10:07.410

Roxanne Guenette: So what happened with super K. They were looking at cosmic rays. We know that when cosmic protons or cosmic particles interact in the atmosphere. They produce those cascade.

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00:10:07.620 --> 00:10:15.210
Roxanne Guenette: Of particles, which then some of them with the k into neutrinos. So there was a high influx of neutrinos coming from the atmosphere. If you think the earth.

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00:10:15.690 --> 00:10:22.350
Roxanne Guenette: Depending on where you are on Earth. You're going to always have the flux that comes from the top in the atmosphere, but also the same flux that went through the

67
00:10:22.650 --> 00:10:29.490
Roxanne Guenette: Earth and because neutrinos don't interact much, a lot of them will go all the way from the bottom of the Earth towards your detector.

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00:10:30.030 --> 00:10:37.290
Roxanne Guenette: So super K was located in Japan. And what they did is they compared the flux coming from the top, which shouldn't escalate because they don't have a lot of

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00:10:37.680 --> 00:10:49.050
Roxanne Guenette: Length to go through and then you compare that with the flux coming from the button, which would go through the all her earth which has more probability of escalation. If that's the case, and then they would compare the ratio

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00:10:49.770 --> 00:10:58.050
Roxanne Guenette: And this is what you see on the right book where you see the red points are the data. So this is the number of interaction that detected the red points is that data.

71
00:10:58.410 --> 00:11:04.170
Roxanne Guenette: And you can see that from coming from the bottom, which is this arrow here on the right on the left, sorry.

72
00:11:04.770 --> 00:11:14.790
Roxanne Guenette: There is way less events that you would expect coming from the top, hinting at a solution. And actually when you start fitting. You can see that the blue line is what you would expect if there was no

73
00:11:15.630 --> 00:11:20.130

Roxanne Guenette: Solution, which you see the rates would be very similar from the top and the bottom

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00:11:20.430 --> 00:11:29.820
Roxanne Guenette: And then the dash green lines is what you would expect if you did have a solution and that fitted very well. And actually in 98 they had enough data to claim a five sigma discovery.

75
00:11:30.360 --> 00:11:40.770
Roxanne Guenette: So that was huge. But what does have to do with the solar neutrino problems. These are atmospheric neutrinos. So, okay, maybe neutrino. It's like, but is that really what was happening with the sun.

76
00:11:41.310 --> 00:11:49.140
Roxanne Guenette: For this, we had to wait for the snow experiments. And you can see snow started just the year after super K discovery. So very good timing.

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00:11:50.100 --> 00:12:01.830
Roxanne Guenette: Snow is located in Canada in one of the deepest underground laboratories in snow lab in Sudbury, and what they did here is they were very opportunistic because in Canada in those years.

78
00:12:02.580 --> 00:12:08.430
Roxanne Guenette: The nuclear program. Wasn't going super well kind of decided that that was not one of its strength.

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00:12:08.760 --> 00:12:19.800
Roxanne Guenette: But in the way to go to the nuclear program they had built that they had made a lot of heavy water which is when you have a water atom with the hydrogen, where you included that another

80
00:12:20.190 --> 00:12:33.600
Roxanne Guenette: Neutron you forced on neutron in the hydrogen. So you have a proton and neutron instead of just the normal proton. So that heavy water is great for neutrinos because it gives you more targets for the neutrino to interact. So you have more ability of interaction.

81
00:12:34.620 --> 00:12:41.460
Roxanne Guenette: So what they did is they started. Okay. One sec, I lost my notes.

82
00:12:47.790 --> 00:12:50.070
Just one second, guys. Sorry about that.

83
00:13:09.150 --> 00:13:10.650
Roxanne Guenette: Of course I didn't have my

84
00:13:33.960 --> 00:13:36.870
Roxanne Guenette: Okay, so you should see that now.

85
00:13:38.640 --> 00:13:40.290
mark convery: Yeah, looks good. Excellent. Okay.

86
00:13:40.320 --> 00:13:40.920
Roxanne Guenette: Sorry about that.

87
00:13:41.430 --> 00:13:50.460
Roxanne Guenette: So yeah, so the first thing that they did is they just use the heavy water and the way they were doing is they were looking for the solar neutrinos, which are electron neutrinos that was

88
00:13:52.020 --> 00:13:53.970
Okay, one sec. I'm gonna use the

89
00:13:59.340 --> 00:14:00.540
PDF instead

90
00:14:10.950 --> 00:14:15.420
Roxanne Guenette: Okay, yeah, I think this fall was too big for for for keynote.

91
00:14:16.440 --> 00:14:18.720
Roxanne Guenette: So now let me in that center right

92
00:14:29.010 --> 00:14:31.200
Roxanne Guenette: Okay, we're talking about this today.

93
00:14:40.230 --> 00:14:50.340
Roxanne Guenette: Okay, so we're back to this no experiments. So they're looking for electron neutrinos, which come in and interact with the heavy water which is, as I said, the neutrons and protons and then

94
00:14:56.250 --> 00:14:58.410
Once again, guys, I'm so sorry about this.

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00:15:18.720 --> 00:15:21.870
Roxanne Guenette: Okay. Hopefully it's not gonna play by itself.

96
00:15:39.630 --> 00:15:51.090
Roxanne Guenette: Okay, back at this no experiments. So yeah, so they were looking at electron neutrinos coming in doing a charge current interaction and then producing an electron that will do that shrink of radiation that I mentioned for super K

97
00:15:51.960 --> 00:16:02.190
Roxanne Guenette: So what happens when you look at for this reaction is that you are sensitive only to electron neutrinos, which is kind of what they wanted, right, because they were looking for electric materials coming from the sun.

98
00:16:03.720 --> 00:16:14.280
Roxanne Guenette: But then what they did. Later on, is they said okay, because we are thinking that their neutrino solution from what super K said let's add salt to the water which is

99
00:16:15.240 --> 00:16:21.450
Roxanne Guenette: Yeah, which is a CLS, you know, and what does that do is that when you include the chlorine.

100
00:16:21.810 --> 00:16:30.270
Roxanne Guenette: The interaction that will happen where you neutrino comes in and here it can be any neutrino. It doesn't need to be an electron one you want, and how it feels can do that as well.

101
00:16:30.870 --> 00:16:39.780
Roxanne Guenette: They will enter and produce a reaction where a neutron from the deuterium from the heavy water is kicked out and then will be captured in the chlorine.

102
00:16:40.050 --> 00:16:46.410
Roxanne Guenette: And then exciting exciting up and really sings gamma that can be detected by the photo multiplier tubes of the detector.

103
00:16:47.190 --> 00:16:58.050
Roxanne Guenette: What does that mean is that here. Dr sense they are sensitive to neutral current interaction which are which are basically any type of neutrinos new these new music new towers can interact here.

104
00:16:58.560 --> 00:17:08.430

Roxanne Guenette: And what was the big results. So this is the same plot that I showed you before, but now there are more experiments because we're for during time. You can see the typical experiment that had lower results.

105
00:17:08.700 --> 00:17:15.720
Roxanne Guenette: And the first results from snow, the charge current one also had a third of the expected flux seeing

106
00:17:16.140 --> 00:17:26.850
Roxanne Guenette: Which was kind of surprising because it was the same as the others. But then when they looked at all the different flavors of neutrinos. The recovered the full flux that was predicted by john backhaul

107
00:17:27.390 --> 00:17:40.620
Roxanne Guenette: So this really was the key to understand the solar neutrino problems because now when you that neutrino isolated and snow proved that actually the sun had exactly the same flux, as we were expecting. So that was a great result.

108
00:17:41.940 --> 00:17:52.860
Roxanne Guenette: Since then, many other experiments. I've confirmed that so Cameron was a big player in this what they were doing is they were using reactor neutrinos nuclear reactors are big sources of anti electron neutrinos.

109
00:17:53.190 --> 00:18:09.240
Roxanne Guenette: And the big result from Kremlin. Is that the way that their experiment was designed it, they were able to look at the probability of a solution over as a different LL very alcohol come back to that later. But this shape here that shows the US military

110
00:18:11.580 --> 00:18:18.270
Roxanne Guenette: Thing, the US military behavior was really what proved that neutrinos really isolate and it's not another weird phenomena.

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00:18:19.260 --> 00:18:26.850
Roxanne Guenette: And after that people have been able to produce their own neutrinos with accelerator will come back to that. But here you really control the energy and the baseline.

112
00:18:27.090 --> 00:18:38.340
Roxanne Guenette: And you can see on this report that shows the event spectrum, the data, which is always the black points are always

completely different than the understated spectrum that you would see for those three and we'll come back to that.

113
00:18:39.660 --> 00:18:52.200
Roxanne Guenette: So the point of this little history thing is that it's as clear now that neutral escalates, and we know that they do, and I hope that you kind of get a feel that things went crazy. And it took a long time to be where we are at today.

114
00:18:54.540 --> 00:19:05.370
Roxanne Guenette: But we understand now how neutrino escalates, and you had a very good introduction from from Andre on this, but now let me give you the experimental point of view of neutrino solutions.

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00:19:06.000 --> 00:19:10.470
Roxanne Guenette: So we know that we have the flavor against states that are mixing with the mass, like in space.

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00:19:11.070 --> 00:19:18.810
Roxanne Guenette: And we know that it's actually much easier to look at these in a two by two neutrino case because that's actually an approximation that holds for many things.

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00:19:19.320 --> 00:19:26.910
Roxanne Guenette: And when we do this, we can extract the probability of a solution that Andre showed us before. So for a neutrino have a certain flavor of going to another one.

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00:19:27.120 --> 00:19:34.110
Roxanne Guenette: It's going to depend on the takes up our meters, which is the amount of mixing you have from the two neutrinos, which comes from this matrix here.

119
00:19:34.590 --> 00:19:44.970
Roxanne Guenette: The difference of the masses square of the tutorials. You're looking at and the l&d which are the baseline how long you've gone through before you escalate and also the energy

120
00:19:46.500 --> 00:19:58.530
Roxanne Guenette: So let me look at this probability of isolation, because this is about a solution experiments. So when we look at this, I already mentioned the theta and the delta x squared are the physics parameters that we want to measure.

121
00:19:58.950 --> 00:20:09.750

Roxanne Guenette: As an experimental is what I'm gonna do is I'm going to select an element. He that is going to be up small or sometimes I'll have no choice. As you'll see, but that I can then extract those two parameters.

122
00:20:10.170 --> 00:20:13.920
Roxanne Guenette: And this is why every time you look for experiments.

123
00:20:14.520 --> 00:20:24.390
Roxanne Guenette: That are talking about the solution, you will see these plots, we show the delta x squared in function of science square to tighter because you can see that those two parameters actually convert together.

124
00:20:24.660 --> 00:20:36.060
Roxanne Guenette: And what we're gonna do is we're going to say what is the area allowed from my results when I fit this probability in the Delta underscore science core to data parameter space.

125
00:20:37.470 --> 00:20:44.610
Roxanne Guenette: Okay, so what if people done well. There was a lot of places where we had free neutrinos cosmic rays are free.

126
00:20:45.120 --> 00:20:56.160
Roxanne Guenette: Here the baseline goes like crazy, right, because we go from 10 kilometers, which is in the atmosphere to all the way to the other side of the earth, which is 12,000 kilometers and the energy of the

127
00:20:57.180 --> 00:21:03.360
Roxanne Guenette: Cosmic neutrinos is very wide. It goes from point one to 1000 GV actually it can go higher as well.

128
00:21:03.630 --> 00:21:10.980
Roxanne Guenette: But this means that for atmospheric neutrinos, you have a wide coverage of the delivery, which means of wide coverage of the delta square that is shown here.

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00:21:11.790 --> 00:21:19.590
Roxanne Guenette: If you produce your own neutrinos, you're going to have baselines, of the order of 100 to 1000 kilometers and usually accelerators produce GV neutrinos.

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00:21:19.860 --> 00:21:29.190

Roxanne Guenette: So here we have access to a delta square the order of pencil minus tooth instantly history. And then if you look at the sun than the distance from some to Earth is really huge 10

131
00:21:29.610 --> 00:21:43.050
Roxanne Guenette: Times the eight kilometers and the energy of those guys are in the order of MTV. So here you get very, very small delta x squared coverage. So you can see with this that we can cover a wide range of delta x squared.

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00:21:43.530 --> 00:21:49.170
Roxanne Guenette: And it turns. Also, it turns out also that when we have this matrix, the escalation matrix.

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00:21:49.710 --> 00:21:59.550
Roxanne Guenette: We can permit rise it into three different ones that will only talk to to neutrinos at the time. And this is great, right, because I just told you that we like to look at

134
00:21:59.880 --> 00:22:07.860
Roxanne Guenette: To one to one association in a just a two by two matrix, instead of having the full one. So here's what you see, each of these

135
00:22:08.550 --> 00:22:17.430
Roxanne Guenette: Mixing and goals data to tree data one tree and data. One, two, are going to be probed with apartment or space different depending on the experiment that you have

136
00:22:17.850 --> 00:22:31.500
Roxanne Guenette: So you can see here I've shown you accelerator in atmospherics are great for two tree accelerator and short baselines are great for one tree and then Solar's are are great for the theta one, two, and this is at the bottom of the

137
00:22:33.000 --> 00:22:46.680
Roxanne Guenette: Table that is shown from the PG code that exactly says that if you're looking at social experiment, the dominant parameters, you're going to be looking at is data. One, two, which is very good for us because we can then pick exactly the experiments we want for what we want to do.

138
00:22:48.930 --> 00:22:55.710
Roxanne Guenette: I want to say a word about data one three here and this, this is for people in the audience that are more cynical about science that I am

139
00:22:56.310 --> 00:23:01.140
Roxanne Guenette: But I remember when I joined the trio physics, which was just before 2011

140
00:23:01.710 --> 00:23:10.950
Roxanne Guenette: The reactor experiments that had and remember here. If I go back reactor experiments actually can prob take a one tree right there was one called show

141
00:23:11.550 --> 00:23:19.860
Roxanne Guenette: Who had been trying to detect data one tree and hadn't seen anything so they had put a limit of the science square to data one tree of smaller than point 19

142
00:23:20.760 --> 00:23:28.320
Roxanne Guenette: And people were worried in those years because we didn't know how small this ain't with this guy was and if this guy was very, very, very small.

143
00:23:28.710 --> 00:23:35.820
Roxanne Guenette: You can see in the matrix that it's actually tied to the Delta CP, which is a very important point that we want to measure it has Andre said

144
00:23:36.450 --> 00:23:42.480
Roxanne Guenette: So if science. If the data entry is very small. It means that will never be able to look at

145
00:23:42.960 --> 00:23:48.450
Roxanne Guenette: Delta CP ever so people were very nervous because without that we couldn't go forward.

146
00:23:48.840 --> 00:23:57.750
Roxanne Guenette: So we built a lot of a bunch of experiments, three of them to make sure that we would not miss the airport, since he had diabetes in China Reno and South Korea and double showing friends.

147
00:23:58.140 --> 00:24:04.320
Roxanne Guenette: And they all turned on and it took very little time actually less than a year before they were able to measure.

148
00:24:04.560 --> 00:24:11.100

Roxanne Guenette: The sine theta one tree, which was point away and you see how close we were we were effect or two away from getting it.

149
00:24:11.400 --> 00:24:23.610
Roxanne Guenette: So for people that will say in the future. Like, what's the point to build a future HC we've already looked at it and you know there is not that much in the future. Same thing with dark metal detectors. Is that really worth it to go. Just for the next generation that is

150
00:24:24.180 --> 00:24:39.540
Roxanne Guenette: Going to give you on the effects of town better. Yes, it is because the history has shown that actually you can have luck and make certain be kind to you. So data entry was that, and we were super happy because now we knew that we could measure delta CP if it's big enough.

151
00:24:41.520 --> 00:24:46.230
Roxanne Guenette: Okay, where are we now, so we have measured all the

152
00:24:46.620 --> 00:24:55.200
Roxanne Guenette: Mixing angles data one to one tree and to tree. And this is a table of the PG code that shows you all the values I don't want you to focus on this, but it's just the point I want to make

153
00:24:55.410 --> 00:25:02.820
Roxanne Guenette: Is that the three angles. I've been measured and the to delta x squared. I've been measured and at the bottom. I've shown the precision of these different measurements.

154
00:25:03.000 --> 00:25:11.130
Roxanne Guenette: And we are now at the level of like few percent precision measurements and this is really great for the future, because we're kind of entering of precision measurement error.

155
00:25:11.520 --> 00:25:16.950
Roxanne Guenette: If you talk to the card Gary's Neil going to tell you that this is not precision but you know we're getting there. It's good news.

156
00:25:18.720 --> 00:25:21.750
Roxanne Guenette: So where do we go then we've measured kind of all of them.

157
00:25:22.650 --> 00:25:35.940

Roxanne Guenette: But it's not finished. And actually, the remaining questions that we have in the field are very important. I've listed them here was the absolute maximum engineers. We don't know what is the nature of the neutrino director marijuana. We don't know.

158
00:25:36.240 --> 00:25:46.110
Roxanne Guenette: What is the mass ordering is the data to tree really maximal Andre mentioned that, that if you have a maximal angle it usually shows that maybe you have a

159
00:25:46.410 --> 00:25:52.620
Roxanne Guenette: Underlying symmetry and we are looking for underlying cemeteries for a long time now. So that would be great to know if this is maximum.

160
00:25:53.070 --> 00:25:58.980
Roxanne Guenette: Is there CP violation and energy sector and if yes, how big is it. And then are there certain tree nose.

161
00:25:59.460 --> 00:26:15.150
Roxanne Guenette: And a good thing for my talk is that all of these for bottom questions are actually accessible by using neutrino solution. So I'm going to focus on the first three of those for because the sterile neutrinos are a slightly different topic, and I'll cover them in my next lecture.

162
00:26:17.520 --> 00:26:27.000
Roxanne Guenette: I also wanted to give you my take on why should you care about these questions, and I hope that you're already convinced because I'm going to give very good arguments, but let me give you my side.

163
00:26:27.750 --> 00:26:38.430
Roxanne Guenette: So we don't know which of the mass hierarchy or the mass ordering is the right one. Why do we want to know. Well, the first thing is we simplified a lot the predictions that we are making when we are

164
00:26:38.910 --> 00:26:49.740
Roxanne Guenette: Doing our calculations, because right now we are obligated to consider both cases we are obligated to show you, plus that have the normal order invited cases and the duplicates all the efforts that we're doing.

165
00:26:50.430 --> 00:27:02.790

Roxanne Guenette: The other thing is great unification theories would like the quark and electrons to follow the same ordering because it's much more natural for those theories to do that, but not all of them.

166
00:27:03.450 --> 00:27:09.690
Roxanne Guenette: actually predict this so by knowing which one is correct. We are going to be able to constraints from of those grunting unification theory.

167
00:27:10.080 --> 00:27:14.010
Roxanne Guenette: And then the last point that I'm not going to go in detail because literally in our lecture will talk about this.

168
00:27:14.340 --> 00:27:22.320
Roxanne Guenette: When we are looking at the parameters space allowed for a national level beta decay searches, which would tell us that there's those are my Ohana. This is what you see

169
00:27:22.650 --> 00:27:26.640
Roxanne Guenette: And again, I don't want to explain it, but you can see that the inverted our key region.

170
00:27:26.970 --> 00:27:35.580
Roxanne Guenette: Is much more accessible than the normal inverted our key region, depending on the mass of course because here they are exactly identical, but here you can see that

171
00:27:35.910 --> 00:27:44.100
Roxanne Guenette: You would kind of prefer to be inverted. If you're looking for a depth why decay. So it's important that we understand which of the scenario. It is

172
00:27:45.300 --> 00:27:55.980
Roxanne Guenette: What about CP violation. Why do we care and they specifically said that he wouldn't go into details to why this is important, but I'll give you a 220 seconds version of this.

173
00:27:56.820 --> 00:28:02.280
Roxanne Guenette: From Dec cosmologists and if you want to know more about that. You can ask about the cosmologists that are going to give you lectures in this

174
00:28:02.760 --> 00:28:15.240

Roxanne Guenette: Series. But we know that at the early universe we produced exactly the same amount of matter and antimatter and then the universe evolved and today we know that our universe is matter dominated

175
00:28:15.750 --> 00:28:28.200
Roxanne Guenette: So, something happened from the Big Bang to today that converted the anti matter into MATTER HOW DID THAT HAPPEN. WE DON'T KNOW, BUT WE HAVE A GREAT ingredient which is called CP violation CP means charge

176
00:28:29.490 --> 00:28:34.530
Roxanne Guenette: Which converts a particle into its infancy particle and parity P is the change of velocity

177
00:28:35.070 --> 00:28:42.570
Roxanne Guenette: Going from LSD normal ones to reversed when you combine those two. This is really how you go from an empty particle to a particle

178
00:28:43.380 --> 00:28:55.170
Roxanne Guenette: So how I neutrinos coming into this. If I have an answer neutrino which is right, then did, which is, I know that we have in our world. If I see be transformed that I'm going to get a left handed neutrino.

179
00:28:55.800 --> 00:29:06.390
Roxanne Guenette: So what I'm going to do is, I know that our solution is very powerful. And if I study the isolation of once neutrinos and I compare it to the isolation advanced neutrinos. And it turns out that those two things are different.

180
00:29:06.720 --> 00:29:20.460
Roxanne Guenette: I'm going to know that CP wasn't preserved and this is going to be able to measure by doing a solution which is this matrix again the escalation matrix that is going to give me this value of the Delta CP power meter which tells me how much CP there is

181
00:29:21.810 --> 00:29:25.200
Roxanne Guenette: And then they are more. This picture was shown almost at the end of

182
00:29:26.220 --> 00:29:35.850
Roxanne Guenette: His talk and it's one of his fingers when you look at this, you should feel uncomfortable because you can see here, all the all the other particles of the standard model are at the top.

183

00:29:36.120 --> 00:29:41.310
Roxanne Guenette: And even if this looks complex the order they are kind of clustered together and then you have the neutrinos that are at the bottom.

184
00:29:41.580 --> 00:29:49.320
Roxanne Guenette: Orders of magnitude lower than the others. This is weird. Maybe nature is weird, but maybe not. Maybe there was something behind that tells us why this is happening.

185
00:29:49.800 --> 00:30:00.210
Roxanne Guenette: If you look at them mixing matrix because we know mixing happened in the QUOTE CARD sector as well. This matrix is beautifully diagonal why we don't know, but then the left on is completely different.

186
00:30:00.630 --> 00:30:07.620
Roxanne Guenette: Why is this so different. Maybe we're missing something much bigger. And this is really why we're going after understanding neutrinos way better.

187
00:30:10.680 --> 00:30:18.840
Roxanne Guenette: So how do a solution experiments work. We want to go after all of these parameters and go with very high precision. So we need to build experiments.

188
00:30:19.770 --> 00:30:24.060
Roxanne Guenette: The first thing you're going to need to do is to decide which is your nutritional source.

189
00:30:24.450 --> 00:30:34.470
Roxanne Guenette: And this is important because it's going to set the type of neutrino. Remember I said that the sun was an example of a source of electron neutrinos, because that's a fusion producing them.

190
00:30:35.130 --> 00:30:42.600
Roxanne Guenette: But there are a lot of others, the reactors Busan to neutrinos cosmic rays produced mainly me on neutrinos, but a bunch of all the others as well.

191
00:30:42.930 --> 00:30:56.880
Roxanne Guenette: As supernova produce that Ektron neutrinos as well. And then if you have a beam. You can decide which one and this also will set up your energy, because remember, we're going to care about the baseline and the energy of the neutrinos. In our experiment. So you choose your source.

192
00:30:58.110 --> 00:31:06.000
Roxanne Guenette: You choose your detector technology and here again, there are beautiful different detectors that he can have super K full of

193
00:31:07.530 --> 00:31:19.020
Roxanne Guenette: Fulfillment suppliers, you have nice sense later detectors. Some people even go crazy because you needed very large detect are in the US, the whole ocean or the

194
00:31:19.470 --> 00:31:29.340
Roxanne Guenette: Ice in Antarctica to be part of their detector so that it can be much bigger. And of course, you've seen from yesterday's lecture noble elements liquid are going to pieces are really good for this as well.

195
00:31:31.170 --> 00:31:46.860
Roxanne Guenette: Then you're going to need to choose a baseline. That was the last thing that was missing compared to the energy here. So the L amp D, which is going to set department or space that I'm going to be studying we have examples of doing that 1300 kilometers TK a 300 and Nova at 800 kilometers.

196
00:31:49.440 --> 00:31:52.080
Roxanne Guenette: You're going to need to pick a channel that you want to study.

197
00:31:52.500 --> 00:32:02.250
Roxanne Guenette: You can either study appearance. In this case, what does that mean is that you produce a certain type of neutrinos and you look for the appearance of a different type of neutrinos and this is the well.

198
00:32:02.610 --> 00:32:08.010
Roxanne Guenette: Known now probably tennis probability of oscillation equation that you've seen before.

199
00:32:08.340 --> 00:32:21.690
Roxanne Guenette: But you can also look for disappearance, where you look at how many neutrinos you produce and how many were left at the end. And this those two probabilities of course are complimentary totaling to one. So you're going to pick one of those two channels or hopefully both of them.

200
00:32:22.710 --> 00:32:28.890

Roxanne Guenette: And then you're going to compare the events that you're observing at your detector and function of energy. So the

201
00:32:29.670 --> 00:32:36.900
Roxanne Guenette: Electron do neutrino spectrum events spectrum and you're going to compare your data points which are shown here in black.

202
00:32:37.380 --> 00:32:41.580
Roxanne Guenette: To the honestly the spectrum. So what would you expect if you had no isolation.

203
00:32:42.000 --> 00:32:47.100
Roxanne Guenette: And then you, you're going to see like oh my god I have way less than I was expecting. So I'm going to fit.

204
00:32:47.370 --> 00:32:55.320
Roxanne Guenette: The oscillation probability formula that I had before. Now I'm looking at this appearance. So if I go back. I'm going to fit this disappearance probability

205
00:32:55.800 --> 00:33:02.910
Roxanne Guenette: And with this filter. I'm going to be able to extract the parameters that are allowed delta x squared. Science Core to data and I'm going to plug them giving my answer.

206
00:33:05.400 --> 00:33:14.640
Roxanne Guenette: But okay, this that I just told you is kind of in a nutshell. So I hope that this is very clear for you. And in the future, you'll be able to understand that very easily.

207
00:33:14.910 --> 00:33:21.330
Roxanne Guenette: But once more. I really like to go into what are the big challenges of all of these things. And the story is a bit more complicated.

208
00:33:21.750 --> 00:33:32.610
Roxanne Guenette: I told you, you only had to pick a source because you need to type in the energy. But the problem is it's extremely hard to know precisely what is the exact flux of neutrino you're producing

209
00:33:33.060 --> 00:33:41.700
Roxanne Guenette: So in the sun, we are getting quite good actually. But there's still some issues with the CMO, for example, flux that is still unknown.

210
00:33:42.150 --> 00:33:47.670
Roxanne Guenette: When we produce them. You would think that since you are producing him in an accelerator you know exactly what you produce

211
00:33:48.030 --> 00:33:57.660
Roxanne Guenette: But that the case of the Muslims and I'll come back to how you produce a beam of neutrinos, but it's very hard to predict everything that's happening in the case of those may zones.

212
00:33:58.110 --> 00:34:05.310
Roxanne Guenette: And then even in reactors are. It's quite hard to understand all that happened in the fusions of those different isotopes that produce the neutrinos.

213
00:34:05.670 --> 00:34:17.880
Roxanne Guenette: So we don't know the flux with super high precision and that's annoying, because remember, I'm going to compare my isolated events to what I would have expected without a solution and if you don't know exactly what's happening. That's a systematic errors.

214
00:34:19.050 --> 00:34:24.660
Roxanne Guenette: In addition, when we use our detectors to study neutrino interaction. There is a lot of complication.

215
00:34:25.020 --> 00:34:35.940
Roxanne Guenette: You may think, and actually I do think like that when I think I was charged currents neutral interaction where I am. You on neutrinos, for example, is coming and exchanging a charge W Bo zone. That's what it charged current interaction.

216
00:34:36.240 --> 00:34:43.500
Roxanne Guenette: With a neutron of my detector, it's producing and you want to charge me one, which tells me that I had a new new coming in and a proton.

217
00:34:43.950 --> 00:34:53.280
Roxanne Guenette: super clean signature charge currents are two golden channels for us to look. But when you have a large nucleus like are gone or carbon or abduction.

218
00:34:54.210 --> 00:35:05.820
Roxanne Guenette: There are things in the nucleus that happen that will mess up this beautiful Fineman diagram. So you have a neutrino coming in from this little arrow interacting with a neutron. Exactly. Like I said, and getting out the charge

219
00:35:07.050 --> 00:35:23.070
Roxanne Guenette: New ones. But then what happens after this is complicated, the neutrons will recall the protons will be produced. They may be correlated. So they will move together. Do you may produce pions that will then be absorbed. So basically, if you look at this plot.

220
00:35:23.580 --> 00:35:40.020
Roxanne Guenette: It's a mess. When you come out of the nucleus. And we don't understand that very precisely. And again, it's a problem, because remember, I want to know exactly what I'm observing in my isolated events to compare that to the flux that is not completely known. So that's another big systematics

221
00:35:41.700 --> 00:35:44.460
Roxanne Guenette: And then for the baseline, you heard from

222
00:35:44.700 --> 00:35:57.510
Roxanne Guenette: What Andre said in in his thought that there was many different effects that the neutrinos will undergo when they're traveling in matter you have matter effects you have mass ordering because those two things are going to compete, depending on which

223
00:35:57.780 --> 00:36:05.370
Roxanne Guenette: Mass ordering is right and then delta CP, which gives you that neutrinos and antimalarials behave differently is also going to compete with network effects.

224
00:36:05.550 --> 00:36:11.370
Roxanne Guenette: So you have to disentangle all of these different things very well if you want to claim that you have precision measurements.

225
00:36:12.180 --> 00:36:20.940
Roxanne Guenette: So what people are going to do, of course, is not fit the simple to neutrino probability because we know there are true neutrinos and they all play some heroes, even if it's quite small.

226
00:36:21.540 --> 00:36:30.180
Roxanne Guenette: When you read the high probability you need to have more precision. So we're going to fit our spectrums, hopefully, in many different channels.

227
00:36:30.480 --> 00:36:44.010

Roxanne Guenette: With the Trina Trina probability and we're going to fit them all simultaneously to extract as much information as possible. This is not really complicated people know how to do that. But it's more complex than just a simple fifth I shown, I have some on the earlier slides.

228
00:36:46.680 --> 00:37:03.210
Roxanne Guenette: Okay, so what do we plan for the future them I've shown you how do we make those experiments and we've made some of them. So what do we do now we know that the big questions are remaining which is the, is there a CP violation, what is the mass ordering is tater to tree maximally

229
00:37:04.350 --> 00:37:11.490
Roxanne Guenette: Maximal angle we need Long Baseline oscillation experiments. To do this, we now know that thanks to all the previous experiments.

230
00:37:12.000 --> 00:37:21.000
Roxanne Guenette: So what we're gonna do is we're going to pick a neutral new being that we're going to produce ourselves because we're going to control as much as possible. The energy of our neutrinos.

231
00:37:21.540 --> 00:37:28.950
Roxanne Guenette: We're going to pick a detector technology for the future, as I said, liquid are going to PCs are going to be one of the choice that we're going to use for the future experiments.

232
00:37:29.370 --> 00:37:40.860
Roxanne Guenette: And then the baseline, the way we chose it is quite complicated. And actually, I want to take sometimes in the next lecture to walk you through what happened to for us to pick baselines that we have today.

233
00:37:43.080 --> 00:37:52.770
Roxanne Guenette: So a typical Long Baseline neutral experiments is going to look like this. This is a picture from the dune experiments where you're going to have a neutrino beam as I just said that produce new on neutrinos.

234
00:37:53.130 --> 00:37:57.600
Roxanne Guenette: That's going to shoot them to a near detector. I'll tell you what the needs are as important in a second.

235
00:37:57.900 --> 00:38:05.700

Roxanne Guenette: You're going to let the neutrinos travel long time long baseline for them to a slate and then you're going to have very large fire detectors.

236
00:38:06.000 --> 00:38:13.800
Roxanne Guenette: To see what you compare from the spectrum that you see a default detector compared to what you observe and the near detector. The uninsulated spectrum.

237
00:38:14.400 --> 00:38:20.640
Roxanne Guenette: So let's go through these things neutrino being I promised you I would explain to you a bit more how we produce these guys.

238
00:38:21.330 --> 00:38:30.210
Roxanne Guenette: So here it's in a nutshell again. So what we do is we accelerate protons. We know that many accelerators around the world know how to accelerate protons.

239
00:38:30.570 --> 00:38:37.950
Roxanne Guenette: We shoot them into a target this target is going to produce a bunch of may zones like pions Keanu some new ones.

240
00:38:38.550 --> 00:38:46.650
Roxanne Guenette: Then you're going to apply a very strong magnetic field so that you're going to focus only the positively charged may zones that you've produced

241
00:38:47.280 --> 00:38:56.100
Roxanne Guenette: Because if you have the right magnetic field, you're going to be able to focus one charge, in particular, do you focus that the charge London negates the ones go away.

242
00:38:56.460 --> 00:39:06.090
Roxanne Guenette: In theory, some of them will still you'll see, and then these Muslims are going to decay into particles. So the pioneers is going to decay to a new ones and and Anthony and

243
00:39:06.510 --> 00:39:12.390
Roxanne Guenette: Your neutrinos and then other particles also will take a photo like the moon can also became to an electron

244
00:39:13.230 --> 00:39:17.940
Roxanne Guenette: Neutrinos. So what is going to happen is that at the end, you're going to have a beam.

245
00:39:18.300 --> 00:39:25.710
Roxanne Guenette: Of neutrinos that is produced mainly new on neutrinos because of the way I've constructed this the lion's mane indicate to neutrinos.

246
00:39:26.010 --> 00:39:40.080
Roxanne Guenette: But you will have some small contamination of electron neutrinos and you've been also anti neutrinos, not just the new one neutrinos. So it's not perfect, but the main product of this beam is going to be you want neutrinos.

247
00:39:41.400 --> 00:39:54.600
Roxanne Guenette: The beauty of this is you can reverse the horn currents that I just mentioned to you that focus that positive charge. If you reverse the current you're going to focus now the negatively charged particles, which would then became mostly into anti

248
00:39:55.080 --> 00:40:05.730
Roxanne Guenette: You on the tree knows which would then give you an answer you neutrino been when that's important, right, because we're going to want to compare neutrino installation to entrepreneur solution. So now we have a beam for both

249
00:40:06.390 --> 00:40:12.330
Roxanne Guenette: I want to mention here since I'm talking about this, that it is much harder and you have way less

250
00:40:13.260 --> 00:40:21.330
Roxanne Guenette: negates the future charged Hadron that are being made zones are being produce into target because we're hitting positively charged protons to this.

251
00:40:21.570 --> 00:40:32.100
Roxanne Guenette: So we are less efficient at producing neutrino beings then neutrino beams and you're going to see that in in many pilots in the future that when we go to answer neutrinos, the number of events dropped considerably.

252
00:40:33.510 --> 00:40:44.790
Roxanne Guenette: But still, so we have our beam we know how to do this, we're going to need a new detector. And usually what we would like to do is to have the new detector that is completely identical to the fart detector.

253
00:40:45.390 --> 00:40:51.780

Roxanne Guenette: But here, remember the new detector is very close to the flux. So, that means we're going to see a lot of events coming from

254
00:40:52.170 --> 00:40:58.530
Roxanne Guenette: The from the beam. So we don't need very large detector which is not true at one over r squared distance

255
00:40:58.920 --> 00:41:07.770
Roxanne Guenette: So we're going to have the factors are going to be much smaller in the new detector case. So they cannot be identical also to save money. We don't want to build two huge detectors.

256
00:41:08.460 --> 00:41:20.610
Roxanne Guenette: But sometimes it's also not possible to have exactly the same technology. So what people do is they make sure that at least they have similar targets in the new detector compared to the fire detector to understand the interaction of neutrinos in those crazy interviews.

257
00:41:22.050 --> 00:41:33.390
Roxanne Guenette: So the first goal of the new detector is going to be to provide the honest slated spectrum because as I said, we don't know the flux completely well. So, and this is what these floods show this is for Dominus

258
00:41:33.870 --> 00:41:44.880
Roxanne Guenette: New me detector is that was running in the past. This is the flux that is observe and the new detectors, the black points in three different configuration of the being low energy medium energy and a high energy

259
00:41:45.330 --> 00:41:55.050
Roxanne Guenette: And you can see that the black points, which is what you see underneath the doctor never perfectly fits the predictions that we have from our simulations. Here we have two different summation of blue and the red

260
00:41:55.500 --> 00:42:00.630
Roxanne Guenette: So this is why it's important to get a new director, because otherwise we would have errors coming from our simulations.

261
00:42:01.350 --> 00:42:06.030
Roxanne Guenette: And then the second goal is that by having the near end the fart detector which are almost as

262

00:42:06.630 --> 00:42:13.590
Roxanne Guenette: Good as possible, we're going to be able to cancel. Some of those uncertainties coming from the flux and also from the nutrient directions.

263
00:42:13.860 --> 00:42:28.050
Roxanne Guenette: Because the whatever happened in the new detector will also happen in the fire detector and this will cancel, mostly, there is still some details that I am not going to go into details, but there are some errors that do not cancel completely

264
00:42:29.880 --> 00:42:36.540
Roxanne Guenette: The details of the baseline. I already told you, I want to discuss that next lecture because it takes a while to go through and there's many different things we want to talk about

265
00:42:37.050 --> 00:42:45.030
Roxanne Guenette: And then a final point is the fire detectors. I've told you that we are 1300 kilometres away. For example, using the

266
00:42:45.420 --> 00:42:56.790
Roxanne Guenette: Doom detectors. This is far away from the source and the decrease over one over r squared. So we're going to have a very, very low flux of neutrinos at that baseline.

267
00:42:57.240 --> 00:43:08.130
Roxanne Guenette: And in addition, neutrinos do not interact a lot. They have very, very small cross section. So the only way to do a proper experiment is to have very, very large detectors, we are talking about kilotons scales here.

268
00:43:08.970 --> 00:43:22.170
Roxanne Guenette: In addition here on the bottom. What you're seeing is the event spectrum. So the number of events and function of energy. We're going to detect for electron neutrinos anti electron neutrinos. See here the difference. We're talking about 120 at the maximum and

269
00:43:22.650 --> 00:43:29.670
Roxanne Guenette: 27th and a maximum for answer neutrinos. I've told you why that happens mostly and then this at the bottom you have the new moon the anthem, you

270
00:43:30.330 --> 00:43:44.310
Roxanne Guenette: Remember what we're going to do is we're going to fit all of the spectrum together to understand the probability and to extract

the parameters. So you want the energy of the spectrum to be very well known because the dip here is going to tell you

271
00:43:45.030 --> 00:43:58.200
Roxanne Guenette: Where the the Dell time square meters is exactly so you want high precision and you want to measure the amplitude very well as well to extract the power meter. So you're going to need high precision measurements in the fire detector.

272
00:44:01.740 --> 00:44:17.130
Roxanne Guenette: So the reason that we are allowed to build future experiment is because we are building on many different paths experiment that I've contributed to our field. And I want to take the remaining time that I have, which should be just under 10 minutes I think I've lost track of time.

273
00:44:18.390 --> 00:44:28.050
Roxanne Guenette: But I will. I want to go quickly here because each experiment can be a full lecture. Right. They all have incredible specificities but I want to give you an overview here. What happened in the past.

274
00:44:29.340 --> 00:44:38.910
Roxanne Guenette: So the first longest line experiment that we had was called meanness this experiment was using a beam at Fermilab shooting it all the way to the Sudan mine in Minnesota.

275
00:44:39.360 --> 00:44:51.750
Roxanne Guenette: And the baseline was 735 kilometers. At that time, they knew that the only thing they could do was looking for a new one neutrino does appearance appearance is very small, so they couldn't do that at the time.

276
00:44:52.320 --> 00:45:00.840
Roxanne Guenette: They decided to go for we know neutrinos don't interact much so let's have as heavy detectors as possible to increase the probability of interaction.

277
00:45:01.050 --> 00:45:17.460
Roxanne Guenette: So they have those massive I run trackers, and you can see here the new detector was one kiloton of Iran that was looking at the formula and in the Sudan mine. You had 5.4 kiloton of Iran. And those were Iran plates. Enter spaced with

278
00:45:18.210 --> 00:45:22.230

Roxanne Guenette: Centimeters so that they could actually see something you don't see anything in the RM

279
00:45:22.800 --> 00:45:37.890
Roxanne Guenette: But then the so that was a tracker. They also had the magnetic field, which meant that the charged particles, if there were positively charged or negatively charged will curl at different different sides, so they could tell if it was a new on the train or in and see new one neutrino.

280
00:45:38.910 --> 00:45:48.150
Roxanne Guenette: They run from 2005 to 2012 but then the upgraded and because the beam was still there for free. They still run as a minnows plus experiment for four more years.

281
00:45:48.930 --> 00:45:53.160
Roxanne Guenette: What did they do for us. Oh no, just before that. This is an example of what the

282
00:45:53.730 --> 00:46:01.860
Roxanne Guenette: ninos event displays looks like. This is what I was telling you I run sense later Iran sense later Iran sense later and you can track the new ones.

283
00:46:02.130 --> 00:46:09.270
Roxanne Guenette: And because you have a magnetic field. You can see on these different event displays the curvature of the mutual and and this is a reconstructed

284
00:46:10.140 --> 00:46:16.110
Roxanne Guenette: New one neutrino here. So that's how the events look in these with actors and what did they do for us.

285
00:46:16.410 --> 00:46:26.940
Roxanne Guenette: The study new Moody's appearance. So remember from the probability of a solution that gives us to delta x squared tree to and find square to data to tree. Actually, you can convert them if you want

286
00:46:27.420 --> 00:46:33.810
Roxanne Guenette: But this is the famous blood that I'm talking about delta square on one sons sang a square to data and the other one.

287
00:46:34.110 --> 00:46:42.390

Roxanne Guenette: And you can see the parameters that are allowed from the beam in gray and also from atmospheric neutrinos. Those are always there for free. So they did both at the same time.

288
00:46:43.650 --> 00:46:50.400
Roxanne Guenette: And yes, it does look like a face. So I think this is the closest that we can come from nature trying to speak to us.

289
00:46:51.900 --> 00:46:57.090
Roxanne Guenette: If you think about that, if you think that nature is trying to speak to us, you can ask me knows

290
00:46:57.450 --> 00:47:03.660
Roxanne Guenette: What is the preferred hierarchy, you think when you look at this, because remember here my dealt Time Square.

291
00:47:03.990 --> 00:47:14.160
Roxanne Guenette: I didn't put any value is not positive or negative because I don't know yet. But what I'm going to do is I'm going to sit everything and see what the data tells me related to the sign of delta x squared.

292
00:47:14.520 --> 00:47:24.270
Roxanne Guenette: And this is what nature tells us. I don't know if I, you know, maybe it's normal hierarchy, but we'll see. We need more data for this, but this is a him from nature.

293
00:47:26.400 --> 00:47:32.520
Roxanne Guenette: The next experiment that played a big role is TK TK was located in Japan, using the JAY PARK being

294
00:47:33.270 --> 00:47:45.930
Roxanne Guenette: Which is sending neutrinos 295 kilometers. So this is the shortest Long Baseline that we have to the super K detectors. We know very well done superconductor discovered the association of

295
00:47:46.410 --> 00:47:51.480
Roxanne Guenette: Neutrinos. And this detector is extremely well understood has been running forever. So that's great.

296
00:47:51.900 --> 00:47:59.970
Roxanne Guenette: And of course they have a new detector and also use but this one is not water drink of its a mix of many different type of detectors.

297
00:48:00.420 --> 00:48:07.860
Roxanne Guenette: One particularities about teach. Okay. And the next one I'm going to talk about, which is Nova is that here. They're using and have access beam.

298
00:48:08.310 --> 00:48:18.600
Roxanne Guenette: I don't have much time to go into details, but when you produce that beam of Mason's that I told you about the way that the kinematics works in the decades of the reasons

299
00:48:19.110 --> 00:48:25.350
Roxanne Guenette: You notice quite quickly that if you go off axis. So if you start going at a different opening angle.

300
00:48:25.680 --> 00:48:36.330
Roxanne Guenette: The energy of the neutrinos that are produces that the case at those angles. It's much more narrow. So the black curve here is the spectrum produced from the JAY PARK beam.

301
00:48:36.900 --> 00:48:51.720
Roxanne Guenette: In on axis. So you can see it has a wide range of energies. And then if you start going affects us all the way to 2.5 you start narrowing your energy and this is great, right, because l very better control means better precision for the future.

302
00:48:53.280 --> 00:48:58.500
Roxanne Guenette: This is what the events looks like in the near detector. It's a complicated detector with many different

303
00:48:59.160 --> 00:49:09.630
Roxanne Guenette: Sub detectors which some have water because super case of water detector and you can see an interaction there. And at the bottom, as I've explained to you what a trick of detectors work with to rank of

304
00:49:10.230 --> 00:49:23.340
Roxanne Guenette: Light being emitted along the particles. So this is a view on events. We know that because also, in addition, the new one has the key to and Michelle electron at the end. And on the right, you have an electron, which comes from electron neutrinos, which is the signal. They're looking for

305
00:49:24.840 --> 00:49:35.370

Roxanne Guenette: So two games. Doesn't an elephant made the first observation of the new, new, new appearance. Remember me knows was doing disappearance studies because they didn't have enough events and why

306
00:49:35.610 --> 00:49:41.250
Roxanne Guenette: Because after a couple of years of running to the case of six events. So that's not a lot for your statistics.

307
00:49:41.790 --> 00:49:52.050
Roxanne Guenette: Did okay now has the best constraint on science go to Data and this is what you see here on the bottom plot of the Delta and square sine square to data plots the range allowed from the UK is the

308
00:49:53.280 --> 00:49:54.600
Roxanne Guenette: narrowest that we have

309
00:49:55.140 --> 00:50:10.200
Roxanne Guenette: recently took a show does indication that delta CP, which is directly correlated signed square theta one, three. Remember from the matrix and this is what you see here at the bottom. The sign square data one tree which is directly correlated to delta CP

310
00:50:10.890 --> 00:50:23.640
Roxanne Guenette: The region's allowed by TK are shown in blue, but then to can you that they are not the ideal experiment for measuring data one tree. The ideal experiment for that are reactors. Remember we saw that before.

311
00:50:24.150 --> 00:50:32.190
Roxanne Guenette: So if the US, the results from the other reactor experiments which is this green band their results become much more constraining. This is what we see here.

312
00:50:32.550 --> 00:50:45.600
Roxanne Guenette: And you can see that the preferred but this we are talking about 68% and 90% confidence level. Let's not get completely excited with this. It's a good hint. But we're not there yet. We need five sigma results here.

313
00:50:46.170 --> 00:50:59.910
Roxanne Guenette: But this hand tells us that actually CP might be very large tree by over two or minus by over two, depending on how you think about this, but you can see this as their results. And this was published in Nature recently. So you can go read it if you want.

314

00:51:01.980 --> 00:51:02.610
mark convery: Also been

315
00:51:02.760 --> 00:51:03.300
mark convery: Five minutes one

316
00:51:03.870 --> 00:51:05.160
Roxanne Guenette: Perfect. Thank you very much.

317
00:51:05.550 --> 00:51:06.780
Roxanne Guenette: And also, the last thing.

318
00:51:07.230 --> 00:51:21.240
Roxanne Guenette: Is that TK prefers the normal mass ordering again I in a very low so significance. But still, that's the preferred value and remember me knows was also thinking about normal mass ordering to

319
00:51:23.190 --> 00:51:37.080
Roxanne Guenette: The other experiment I want to mention is Nova. So, nova is also new to new experiment. The same thing SDK. It's also an effect this experiment, although much smaller angle point eight degrees instead of 2.5 compared to today.

320
00:51:37.830 --> 00:51:48.810
Roxanne Guenette: It's using a beam at Fermilab and it's shooting it to ask river also in Minnesota, I think, which is not that far from the student mine the detector that they're using is plastic.

321
00:51:49.860 --> 00:51:58.320
Roxanne Guenette: filled with liquid sense later. So you can see here to have a huge 14 kiloton fart detector and this is the plastics and the plastic

322
00:51:59.160 --> 00:52:06.660
Roxanne Guenette: It's PVC, actually, which is a something that people put in their house for for for pipes that is filled with

323
00:52:07.320 --> 00:52:17.850
Roxanne Guenette: Liquid sense later and they have a PMT is at the end of them, they have a small little tighter. That is exactly identical. So this is really good for NOVA because you're going to have a good control of the system ethics.

324
00:52:19.080 --> 00:52:35.910

Roxanne Guenette: And then what the events look like you can see that on the right here because it's all, it's a liquid sense liters that are angled at different which are stacked at different orientation. You didn't get segmented little cubes along the detector that you can reconstruct the events.

325
00:52:37.320 --> 00:52:45.750
Roxanne Guenette: And one thing that is beautiful about Nova is that by the time they reach out the the full detector which is not it's a little bit on the ground, but not much of ASH RIVER.

326
00:52:46.230 --> 00:52:56.250
Roxanne Guenette: It's full of cosmic rays, and this is one event one beam event compared to the readout. Do you see how many crazy cosmic rays. There isn't there.

327
00:52:56.580 --> 00:53:03.990
Roxanne Guenette: But do not worry because they have very good techniques of removing those cosmic rays and they can that's so efficiently that when they are done.

328
00:53:04.410 --> 00:53:14.880
Roxanne Guenette: Well, what you get is on the right is a single new on Neutrino interaction very clearly so cosmic rays is not an issue for them. And at the bottom you have an electron neutrino.

329
00:53:16.170 --> 00:53:21.960
Roxanne Guenette: Which is a shower, instead of a nice straight line from the new one. So this is just in case you wanted to see those

330
00:53:22.650 --> 00:53:35.340
Roxanne Guenette: What did Nova do for us. They were the first one to observe the appearance of anti electron neutrinos GK got the price for the electron neutrinos and Nova, the price for the anti new reappearance in 2018

331
00:53:35.940 --> 00:53:45.240
Roxanne Guenette: They have the best constraint on delta m squared, which is this parameter here. So that means they have the narrowest ban allowed for delta x squared.

332
00:53:46.950 --> 00:53:53.970
Roxanne Guenette: The when they look at the Delta CP. This is the plot that is on the right here, you see here, they've shown it in different

333

00:53:54.510 --> 00:54:04.350
Roxanne Guenette: Because remember that all those parameters are correlated. Right. We are a tree neutrino of isolation, so here they show the results and find square to data to tree and function of delta CT

334
00:54:04.770 --> 00:54:17.370
Roxanne Guenette: And I already told you that TK preferred the tree pi over to CP violation. And of course, like neutrinos. I've always done to us in the past Nova sees exactly the opposite of what to do. Casey's

335
00:54:17.760 --> 00:54:27.450
Roxanne Guenette: Again, we are in the 60 to 90% confidence level. It's nothing yet to be scared of. But isn't it interesting. That'd be exactly the opposite of the two

336
00:54:27.750 --> 00:54:43.350
Roxanne Guenette: So in the future, those two experiments are going to meet together and work together. This is kind of beautiful science where they're going to try to combine both results and see what they can extract from from both results Nova also prefers the normal mass ordering at a certain level.

337
00:54:44.430 --> 00:54:56.580
Roxanne Guenette: And here on this block, you can see all the different experiments that we've had from the past that has been able to measure delta x squared and sine square and the black one is Nova. That's why I was telling you that they get the narrowest range for delta him to tree.

338
00:54:57.720 --> 00:55:04.230
Roxanne Guenette: So we are getting a lot of information, but the last experiment. I want to talk about, which is another crazy

339
00:55:06.510 --> 00:55:15.090
Roxanne Guenette: Interesting experiment which is the opera one what opera was doing is they were after the isolation between you two new town.

340
00:55:15.750 --> 00:55:23.370
Roxanne Guenette: So new towns are notoriously difficult to see the reason. First is that you need very high energy to produce them.

341
00:55:24.120 --> 00:55:30.990
Roxanne Guenette: And then they're going to decay in to Tao, which are very heavy and very quickly decay into something else. So you're going to need

342
00:55:31.230 --> 00:55:41.340
Roxanne Guenette: A large factor to allow for a neutrino to interact, even if it's a new tile. There was no cross section very highly segmented because you want to see that very short track coming from

343
00:55:41.880 --> 00:55:50.880
Roxanne Guenette: The new tile before the case to two other particles and from the tower sorry that because if the case to the other particles.

344
00:55:51.540 --> 00:56:07.170
Roxanne Guenette: So upper I said fine. We're going to try to do this. They use a beam at CERN, which was the GS being which was 17 GV so very high energy neutrinos. This is, I said to allow those new muse to to go to a new town.

345
00:56:07.800 --> 00:56:18.060
Roxanne Guenette: And they had a baseline of 732 meters and this is kind of not really a choice. It's big distance between starting guns. So you definitely need to go underground. If you want to do a crazy experiment like that.

346
00:56:18.360 --> 00:56:25.230
Roxanne Guenette: And when I say crazy. It's a positive because it's very difficult. They had an experiment that was made.

347
00:56:25.680 --> 00:56:40.530
Roxanne Guenette: Of many different little cubes of about this size that had emotions layers emotion is something that we know is very good for town that that's actually how the donut experiments was also able to to see the the

348
00:56:41.640 --> 00:56:53.190
Roxanne Guenette: Discovery of the towel, the Newtown. Sorry. So what they do is they have those little bricks that are quite small and they have those emotions layers that were developed with Kodak exactly for that experiments.

349
00:56:53.640 --> 00:57:01.980
Roxanne Guenette: And then they look for a trigger in the detector. So it's a huge factor with many, many, many, many different bricks, then they see an interaction.

350
00:57:02.490 --> 00:57:05.820
Roxanne Guenette: They go in with little robots takes those bricks out

351
00:57:06.420 --> 00:57:16.650
Roxanne Guenette: Send the bricks, two labs like burn had some and then other collaborators also had where they have microscope, you take this break and you take pictures of the emotions layers.

352
00:57:16.980 --> 00:57:23.070
Roxanne Guenette: To reconstruct the interaction that happened from all the bricks. So here is an example of the different

353
00:57:24.000 --> 00:57:32.310
Roxanne Guenette: triggers that are so from all the bricks. You can put that back together like a puzzle. Luckily, you have tracer so you know exactly where the pieces go but still

354
00:57:32.700 --> 00:57:40.590
Roxanne Guenette: And then you put them back together to a single interaction. I almost want to do a minute of silence for people who did that.

355
00:57:41.250 --> 00:57:46.620
Roxanne Guenette: It's, it's so tedious, but they were able to do it and look at this on the bottom right.

356
00:57:47.010 --> 00:57:56.520
Roxanne Guenette: This is what happened while they are waiting for a towel interaction new type of interaction. So you have a lot of events, a lot of events, mostly coming from your neutrinos.

357
00:57:57.330 --> 00:58:04.410
Roxanne Guenette: And then you get them all to make sure that the vertex corresponds to something that happened in the detector, because otherwise you have no chance.

358
00:58:04.890 --> 00:58:10.650
Roxanne Guenette: And then you remove all the ones that are coming from your neutrinos and you're left with 1000 neutrino.

359
00:58:11.220 --> 00:58:21.330
Roxanne Guenette: So this is beautiful and they run for four years and they did. So the first observation of new news to Newtown with 10 events that they did in four years.

360
00:58:21.960 --> 00:58:24.900
Roxanne Guenette: So this is kind of sad and sounds because

361
00:58:25.200 --> 00:58:34.530
Roxanne Guenette: New Tao would be very important to give us the last piece of the puzzle. When we're doing a solution. If you can do new reappearance new disappearance new tower appearance.

362
00:58:34.710 --> 00:58:41.070
Roxanne Guenette: Then you really have every single part of the puzzle that you can put back together to understand very well neutral interaction.

363
00:58:41.400 --> 00:58:53.580
Roxanne Guenette: But the new tower is extremely difficult and I wanted to show you this because in the future if somebody can come up with a better way to detect new titles, they're going to be very famous because Dune, for example, would love to see new titles.

364
00:58:55.140 --> 00:58:56.010
Roxanne Guenette: But it's very hard.

365
00:58:57.060 --> 00:58:58.770
Roxanne Guenette: Okay, that's it for today.

366
00:58:59.970 --> 00:59:11.610
Roxanne Guenette: We saw that the history of new translation was not straightforward and you saw right that I went from different topics. And that was kind of plan in a sounds because I want you to get a feel that it was not that easy to come where we are.

367
00:59:11.970 --> 00:59:19.320
Roxanne Guenette: And in the future, it's also going to be like that. I already told you that no one today are telling us that delta CP is completely different.

368
00:59:19.560 --> 00:59:28.680
Roxanne Guenette: At low significance. I know, but still it's getting already puzzling. So we are looking forward to the future and maybe it's you when you're going to be more grown up like me.

369
00:59:29.250 --> 00:59:36.270
Roxanne Guenette: That you're going to be telling the next generation that actually, you know, things were not that straightforward still from now on to the future.

370

00:59:37.080 --> 00:59:50.580
Roxanne Guenette: I hope you got a good feel of how the experiments work, how we choose the different parameters, how we built our experiments to do isolation and I hope that you also understood why Long Baseline neutrino experiments are what we're going to use for the future.

371
00:59:51.690 --> 01:00:00.540
Roxanne Guenette: So in the next lecture. What we're gonna do is we're going to discuss exactly about that. How are we going forward from here we're going to build. Too Long Baseline experiment dune and hyper K

372
01:00:00.930 --> 01:00:07.140
Roxanne Guenette: How did we make sure that we are proposing the most optimal experiments. And how are we going to answer the remaining questions that we have

373
01:00:07.560 --> 01:00:17.250
Roxanne Guenette: And finally, I have to say something about short baseline isolation, which couldn't escape the presents of surrounding Reno's because if that's the case, it completely destroys

374
01:00:17.970 --> 01:00:25.230
Roxanne Guenette: The way we understand our solutions, until now, so thank you guys and I'm going to take any questions that you may have.

375
01:00:26.760 --> 01:00:34.920
mark convery: A contract fan for very interesting talk. Hearing the true history of neutrino oscillations. So if you'll pass it over to Tom for the question.

376
01:00:41.970 --> 01:00:42.240
mark convery: I'm

377
01:00:47.220 --> 01:00:48.810
thomas rizzo: Sorry, I got disconnected.

378
01:00:50.580 --> 01:00:53.100
thomas rizzo: Okay. Let's see now. Sorry.

379
01:00:54.210 --> 01:00:57.660
thomas rizzo: Okay, so the first question is on slide five

380
01:01:00.390 --> 01:01:02.160
Roxanne Guenette: What properties of the flute.

381
01:01:03.420 --> 01:01:04.050
thomas rizzo: And you hear me.

382
01:01:04.290 --> 01:01:04.950
Roxanne Guenette: Yeah, yeah. Sorry.

383
01:01:05.160 --> 01:01:14.100
thomas rizzo: Sorry. Slide five what properties of the fluid make it ideal for the director to detect detection detect isolation.

384
01:01:17.700 --> 01:01:26.790
Roxanne Guenette: Yeah, so here. So remember I said that Davis was a chemist. So basically, for him. He looked at

385
01:01:27.180 --> 01:01:31.380
Roxanne Guenette: What are the reaction. And these are just normal beta decay reaction where

386
01:01:32.370 --> 01:01:34.500
Roxanne Guenette: Khloe Ryan is just one before.

387
01:01:35.670 --> 01:01:41.850
Roxanne Guenette: Are gone. So basically, when to nutrient when industrial comes in. It interacts with the protons, which is going to convert to

388
01:01:42.480 --> 01:01:48.810
Roxanne Guenette: A neutron or vice versa. I can see it in my head, but one of one of the two is going to convert to the other one.

389
01:01:49.410 --> 01:01:57.990
Roxanne Guenette: Produce then an electron. So basically he knew that you needed something like this, where beta decay was quite powerful. And that you could

390
01:01:58.710 --> 01:02:11.640
Roxanne Guenette: Then have atom, which in this case here is are gone 37 that you would be able to detect so he could have picked something else, probably, I don't know why exactly decided to probably because of the price of cleaning fluid which is really cheap.

391
01:02:12.120 --> 01:02:16.680

Roxanne Guenette: But also because he knew that in his experiment he would, he would be able to recirculate

392
01:02:17.760 --> 01:02:36.330
Roxanne Guenette: The the the medium of the detector to extract the Argonne 37 because another important thing that I, as I said, I don't have time to go into details. But one way that it was extracting. Those are gone 37 atoms was by using argon gas in general to kind of

393
01:02:37.500 --> 01:02:41.130
Roxanne Guenette: bubble up in the detector to to extract the

394
01:02:42.570 --> 01:02:57.990
Roxanne Guenette: Some part of the fluids because are gone. Remember those and react so it was a good gals that could be used to transport that single are gone 37 atom. So, I think. Yeah. Basically, there was many things that came into play. And I don't know exactly.

395
01:02:59.460 --> 01:03:02.610
Roxanne Guenette: How we made the final decision, but it was definitely a good one.

396
01:03:03.300 --> 01:03:14.340
Roxanne Guenette: Because remember, I told you that a gallium from galaxy which is the experiment that happened in the future. They made a conscious decision to use gallium and not closing because gallium also have the new

397
01:03:14.820 --> 01:03:22.290
Roxanne Guenette: Neutron reaction at a different energy much lower energy. So that was different than the previous one.

398
01:03:25.140 --> 01:03:26.460
thomas rizzo: Okay. On slide 11

399
01:03:28.170 --> 01:03:34.350
thomas rizzo: Excuse me, can you explain again why neutrinos can be from the bottom were important to detect

400
01:03:35.610 --> 01:03:45.090
Roxanne Guenette: Yeah. So remember that at the time, we are not sure about neutrino isolation. So the only thing that we have a feel for is that

401

01:03:45.510 --> 01:04:00.840
Roxanne Guenette: If neutrinos a slate, the longer they travel, the more probable, which should be the de escalate and that's what super K went on to. So by looking from the atmospheric neutrinos from the top. These guys are producing the atmosphere, just above the detector.

402
01:04:00.930 --> 01:04:08.310
Roxanne Guenette: So they don't travel very far. And then by comparing that to the ones that come from the bottom. They were also producing the atmosphere in the bottom of the

403
01:04:08.370 --> 01:04:19.560
Roxanne Guenette: Earth here. But then, these guys have to go through the whole earth before they can make it to the detector. So they have a higher probability of isolation if isolation exists. And this is exactly what they saw.

404
01:04:23.250 --> 01:04:29.340
thomas rizzo: A general question is, do it, do Angular modulation appear in solar neutrino oscillation experiments.

405
01:04:36.300 --> 01:04:36.540
mark convery: Sorry.

406
01:04:36.600 --> 01:04:37.140
Roxanne Guenette: Go ahead.

407
01:04:38.400 --> 01:04:40.050
mark convery: I was gonna say I think getting annual right

408
01:04:43.260 --> 01:04:49.320
thomas rizzo: Yeah, I mean, because the earth Sun distance varies over the year is that is that baseline change observable.

409
01:04:50.430 --> 01:04:52.200
Roxanne Guenette: So that I know so

410
01:04:52.500 --> 01:04:54.780
Roxanne Guenette: I'm not completely sure if the experiments that we have

411
01:04:54.780 --> 01:05:08.340
Roxanne Guenette: Today are precise enough to do that. But I have a feel that I've seen those plots. So one thing that I'm sure is that you can

have pictures of the Sun moving in the detector. So people are able to do that and bugs, you know, was very

412
01:05:08.910 --> 01:05:14.460
Roxanne Guenette: Precise experiment that has this entangle, a lot of the matter, matter of fact. Yeah, the S.

413
01:05:16.950 --> 01:05:30.990
Roxanne Guenette: MSW effects that under they referred to. So yeah, I'm not sure about the annual modulation. If the soil. Yeah, I would have to check. I think the answer is yes, but I would double check with the solar industry experts.

414
01:05:35.310 --> 01:05:36.750
thomas rizzo: On slide 51

415
01:05:39.420 --> 01:05:42.330
thomas rizzo: Why there are two peaks in the music neutrino spectrum.

416
01:05:48.780 --> 01:05:52.140
Roxanne Guenette: Yeah, so this is actually something that we're super happy about.

417
01:05:52.740 --> 01:06:04.560
Roxanne Guenette: In doing and you don't see that in any other experiment. And this is because, and we're going to talk about that more in the next lecture. But remember, the escalation probability goes up and down and up and down.

418
01:06:05.310 --> 01:06:20.370
Roxanne Guenette: Just because it's an us literary behavior in the case of doing the baseline that we have is just right to allow us to see two of those speak and we call them the first maximum in the second isolation maximum

419
01:06:21.240 --> 01:06:26.100
Roxanne Guenette: And this is just, yeah, just the probability of the solution that you see twice in this one.

420
01:06:26.910 --> 01:06:36.270
Roxanne Guenette: You in theory you should see it in the electron neutrinos, too, but it's become it's here and we don't have, it's too low energy for this detector, but we've got next next

421

01:06:37.080 --> 01:06:43.200
Roxanne Guenette: Lecture. I'm going to go in details to show you those spectrum in this government very clear of what the probability of isolation looks like.

422
01:06:47.430 --> 01:06:48.660
thomas rizzo: On the same slide.

423
01:06:50.520 --> 01:07:01.590
thomas rizzo: Why does the flux decreases one over r squared. If we produced it in a forward momentum beam when the neutrinos move, mostly in the forward direction and conserve momentum.

424
01:07:02.670 --> 01:07:05.400
Roxanne Guenette: So ideally, that's exactly what you were doing you

425
01:07:05.400 --> 01:07:07.290
Roxanne Guenette: Do we would do a laser beam.

426
01:07:07.530 --> 01:07:13.770
Roxanne Guenette: And that would be great because then you would have all Unitarians going through. Unfortunately, that's not at all how it happens.

427
01:07:14.070 --> 01:07:23.370
Roxanne Guenette: The, the case of Mason's even if they're mostly forward because of the Lawrence boost that they get, they still decay into white being so it's really just like a

428
01:07:23.820 --> 01:07:34.830
Roxanne Guenette: The beam does do exactly that. Unfortunately, so if people have ideas on how to do cancel beings again please pursue that because that's gonna be very useful.

429
01:07:37.980 --> 01:07:39.240
thomas rizzo: On slide 60

430
01:07:40.740 --> 01:07:44.580
thomas rizzo: What is the favorite statistical methodology used in these experiments.

431
01:07:45.900 --> 01:07:53.310
Roxanne Guenette: All of the above. So statistical ways of studying low events has been something part of many

432
01:07:53.910 --> 01:08:08.940
Roxanne Guenette: Experiments and actually now most experiments to UK for sure are going to do a Bayesian approach and a frequencies approach where they're going to try those two different and see the results and often in their papers, they're going to show the results from both of these

433
01:08:09.060 --> 01:08:10.200
Roxanne Guenette: And they all

434
01:08:11.100 --> 01:08:23.910
Roxanne Guenette: points towards the same thing is just idea and the strength of the signal is slightly different. But yeah, we are. We're aware that's statistical methods are at play here. And people have been trying them many different ones.

435
01:08:25.980 --> 01:08:31.830
thomas rizzo: Same slide. Why is the reactor neutrino constraint, independent of the CP phase.

436
01:08:33.390 --> 01:08:34.920
Roxanne Guenette: So that's comes back.

437
01:08:34.980 --> 01:08:41.370
Roxanne Guenette: To the fives, that when we look at the escalation matrix. Let me just go back to it.

438
01:08:44.310 --> 01:08:59.820
Roxanne Guenette: So this escalation matrix here depending on the parameters. So destination matrix, as I said, we can go to only one three. And I guess that the person that is asking because we see the delta that is attached to the to the one, three here.

439
01:09:00.240 --> 01:09:06.930
Roxanne Guenette: But remember that that's not the only the data is not the only thing that we have access to. So we have unfortunately to look at the whole

440
01:09:07.200 --> 01:09:18.840
Roxanne Guenette: Equation of escalation and actually we do look at it in a tree neutrino isolation and when you look at reactors reactors are an energy of one to one on MTV depending

441
01:09:19.380 --> 01:09:31.200

Roxanne Guenette: Of what you're looking at. And then their baseline. You cannot go too far off from a reactor because also if you go very far. You're going to be contaminated by Old Yeller reactors in the same country, for example.

442
01:09:31.680 --> 01:09:41.100
Roxanne Guenette: So people go to maybe a kilometer maximum away from from the reactors. So when you plug that in the energy of the reactor and the

443
01:09:41.610 --> 01:09:54.450
Roxanne Guenette: Baseline that you have access to this doesn't allow you to see this parameter here it's negligible. You don't see it. You don't have access to it. So really the only guys that can look at this is really the Long Baseline

444
01:09:55.530 --> 01:09:59.850
Roxanne Guenette: Once, and we're going to talk about a little bit more about that next lecture.

445
01:10:00.930 --> 01:10:10.620
mark convery: Um, I think we better cut it off there. We're getting over time. So thank you very much. Roxanne for the great talk. There's a bunch of questions here so that I think some of them are looking forward to

446
01:10:11.310 --> 01:10:19.920
mark convery: Tomorrow's lecture. So maybe we can we can hold off until tomorrow for them. Thank you very much for this lecture, and we look forward to your lecture tomorrow and

447
01:10:20.070 --> 01:10:21.420
Roxanne Guenette: Last time you hear me tomorrow.

448
01:10:23.550 --> 01:10:26.490
mark convery: Unfortunately, and so

449
01:10:26.880 --> 01:10:37.770
mark convery: That will I guess we'll do it for today. Tomorrow resume again at nine o'clock Pacific time and in addition to Roxanne's lectures will have two lectures on gravitational waves. So switching gears a little bit, but

450
01:10:38.880 --> 01:10:45.330
mark convery: Before tomorrow as well. So thank you much. Thank you so much, everyone. And we'll see you tomorrow at nine o'clock.