WEBVTT

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00:00:02.760 --> 00:00:08.460
thomas rizzo: And Roxanne is good to tell us now about noble element detectors.

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00:00:10.080 --> 00:00:11.550
Roxanne Guenette: Excellent. Thank you very much.

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00:00:12.630 --> 00:00:24.750
Roxanne Guenette: Yeah so. Hi, everyone. Welcome to the last lecture of today if you attended the previous two lectures and I hope you did because they were very good and I really recommend if you were not there to go back and look at them.

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00:00:25.800 --> 00:00:35.130
Roxanne Guenette: But you're going to see that this lecture is quite different. We are going to change gear going from a more theoretical lectures to now something that is an experimental technique.

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00:00:35.970 --> 00:00:44.430
Roxanne Guenette: I'm going to talk about noble element detectors. And the reason we talked about them today on the first day is because you're going to need to understand how these detectors work.

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00:00:44.460 --> 00:00:47.700
Roxanne Guenette: For many of the next lecture is you're going to see in the next couple of days.

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00:00:48.930 --> 00:01:00.900
Roxanne Guenette: Before I start, I want to make a disclaimer. The goal of the lecture is to give you and you is either you a theorist or an experimentalists a good feel of how noble element detectors work.

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00:01:01.350 --> 00:01:11.820
Roxanne Guenette: And to do that, I'm going to start by very simple general concepts and then I'm going to pick some of them and going much more details to show you that. Also, the beauty of these detectors in their complexity.

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00:01:13.980 --> 00:01:24.660
Roxanne Guenette: Know that this lecture is not a review of all the experiments that exists using novel element detectors. I will present some of them, but I've picked them mostly to illustrate concept that I want to talk about

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00:01:25.050 --> 00:01:29.700
Roxanne Guenette: And of course I've picked them in a very subjective manner. But, you know, forgive me for that.

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00:01:31.980 --> 00:01:39.780
Roxanne Guenette: Okay. So as I kind of entered hinted, you're going to see in the next lecture that noble element detectors are pretty much everywhere.

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00:01:40.470 --> 00:01:55.740
Roxanne Guenette: So they are used to study neutrinos, such as isolation measurements which we just heard about from a theoretical side, they're also used to until the stand, how neutrinos interact and also potentially in the future us to see if supernova neutrinos, how they interact

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00:01:56.940 --> 00:02:05.340
Roxanne Guenette: They are also using dark matter or direct detections. And they are used in searches for neutral. So that will be the case, which would indicate that the neutrinos are my

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00:02:07.380 --> 00:02:16.800
Roxanne Guenette: So let me just tell you a little bit how the lecture is going to be organized. So I'm going to start by telling you what's so special about noble elements and why are they, great for particle detection.

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00:02:17.730 --> 00:02:20.640
Roxanne Guenette: We're going to see how the detectors work in a simple way.

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00:02:21.060 --> 00:02:28.230
Roxanne Guenette: And then I need to go into application to the different science that you want to do, because you're going to see that they are very different, and the details are

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00:02:28.620 --> 00:02:36.690
Roxanne Guenette: Very different from these different topics. So we're going to talk about how they're using Newtonian physics in dark matter and also in neutral as double data decay searches.

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00:02:37.470 --> 00:02:49.050
Roxanne Guenette: And if I have time at the end. I want to tell you a bit of more about how people I've been thinking to use noble elements in

novel ways and how future R amp D because there was a lot of fun to have in future endings with these detectors.

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00:02:51.270 --> 00:03:05.220
Roxanne Guenette: Okay, so what's so beautiful about noble elements. Well, when we think about particle interactions in noble elements. There are two processes that are important here. The first one is centralization and the second one is ionization

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00:03:07.350 --> 00:03:14.160
Roxanne Guenette: The beauty about simulation and noble elements is that once the sensation light is emitted and I'm going to explain to you how that works.

21
00:03:14.670 --> 00:03:28.080
Roxanne Guenette: The noble elements and themselves are transparent to that translation light and this is very important because once you've admitted photons. You don't want to start exciting your medium so that you lose those photons and you can detect them before they reach your detector.

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00:03:29.640 --> 00:03:37.800
Roxanne Guenette: In the case of ionization. Well, we're going to produce a bunch of charges electrical charges or from the electrons that are being ionized.

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00:03:38.310 --> 00:03:44.670
Roxanne Guenette: And remember that the definition of a novel elements is that they don't care about electrons passing by. They are already

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00:03:45.210 --> 00:03:54.960
Roxanne Guenette: There last orbital is already full. So they will not attach those electrons, they will let them drift over very long distances, which is great for the way we're going to use these doctors

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00:03:55.440 --> 00:04:07.050
Roxanne Guenette: And the last thing is that noble elements are so good dielectric, which means you can apply very high voltages and those voltages are going to be useful to create an electric field as I'm going to explain to drift those electrons.

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00:04:08.190 --> 00:04:17.880
Roxanne Guenette: So novels are great. And here is kind of a summary of the different noble elements that we have and then different properties that we have

27
00:04:18.450 --> 00:04:20.700
Roxanne Guenette: When we want to think about the particle detection.

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00:04:21.360 --> 00:04:27.900
Roxanne Guenette: So you can see some things that we care about, for example, is the DD X which is the amount of energy that a particle will deposit

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00:04:28.230 --> 00:04:37.710
Roxanne Guenette: In the novel element where it's going through and you can see that the higher you go in the periodic table, the more energy becomes visible from the organization.

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00:04:38.580 --> 00:04:52.020
Roxanne Guenette: And then decentralization, which I've mentioned, you can see on this in this row, the number of photons that are produced for a movie for energy deposited. And you can see that there is a lot of photons that are producing sensation and this is great.

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00:04:53.790 --> 00:04:59.250
Roxanne Guenette: The last thing, but not least when you have noble elements is that you can make jokes.

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00:05:00.300 --> 00:05:11.790
Roxanne Guenette: And I want to tell you this joke, which is our GM walks into a bar and the barman replace him. Sorry, we don't serve your kind here. And then, of course, our gun doesn't react.

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00:05:14.760 --> 00:05:24.990
Roxanne Guenette: This isn't really weird to do on zoom I'm imagining you laughing. I hope you are. But really, literally. It's like being in front of many different little argon items. So I'm going to move on.

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00:05:26.910 --> 00:05:38.250
Roxanne Guenette: Okay, so four noble elements detectors. I've mentioned that briefly. We cannot talk to them, talk about them in a very general way because each science topics that they're going to address is very different.

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00:05:38.850 --> 00:05:47.640
Roxanne Guenette: So if you think about dark matter, you're gonna have to think that they need very low energy detection threshold as low as the kV

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00:05:48.120 --> 00:05:55.560

Roxanne Guenette: If we're thinking of neutrino installations. We're going to use neutrinos that are in the GV regime. So we're talking about six orders of magnitude already just here.

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00:05:56.130 --> 00:06:06.150
Roxanne Guenette: And then if you think about neutrino as the beta decay searches. These cannot afford backgrounds that much. That's true also for dark matter, but even more true for my searches searches.

38
00:06:06.630 --> 00:06:15.150
Roxanne Guenette: And finally, you need extremely good energy resolution these like little last detectors. So really, as you're going to see the devil is going to be in the details.

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00:06:16.680 --> 00:06:23.760
Roxanne Guenette: But the technologies that you use in those two different topics is kind of here for neutrinos. One of the best candidate is liquid are grumpy PCs.

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00:06:24.210 --> 00:06:33.810
Roxanne Guenette: In the case of dark matter. We use liquid xenon or liquid are going to PCs and for nutritional SWA technically searches. We use liquid and gaseous xenon the PCs.

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00:06:34.680 --> 00:06:42.630
Roxanne Guenette: So you've all noticed that I've mentioned to PCs several time. So this is going to be important for the lecture. So let's go dive into what is it BBC

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00:06:44.670 --> 00:06:51.480
Roxanne Guenette: BBC means time prediction chambers. And as I said before, it's going to use both ionization and translation.

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00:06:52.080 --> 00:06:59.460
Roxanne Guenette: So you should be familiar with ionization. This is just the fact that when a charged particle comes in near an atom. If it has enough energy

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00:06:59.820 --> 00:07:09.420
Roxanne Guenette: To combat the binding energy from the electron to the nucleus. It's going to kick out this electron outside of the orbital of the atom.

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00:07:10.170 --> 00:07:24.150

Roxanne Guenette: I've already said that in roughly when you have about a movie amount of energy deposited. You're going to produce over 40,000 electrons from this ionization process. So they're going to be a lot of charge coming from this process.

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00:07:26.040 --> 00:07:35.580
Roxanne Guenette: What about sensation. So there are two ways you can produce sensation in nobleman detectors. The first one is called self trap exits on luminescent

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00:07:36.240 --> 00:07:41.610
Roxanne Guenette: I advise you to learn this stern by heart and plug it in conversation, you're going to look very smart.

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00:07:42.180 --> 00:07:50.520
Roxanne Guenette: But how does it work. So you have an ad or one item a charged particle is going to come over and sometimes it's not going to analyze it.

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00:07:50.910 --> 00:07:54.270
Roxanne Guenette: It's going to only excite that are going to turn into an excited state.

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00:07:54.840 --> 00:08:03.630
Roxanne Guenette: And buy some chemistry process when an organism is excited, it really wants to pair up with a second organ item and it's called a dimer, or next summer.

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00:08:04.200 --> 00:08:11.940
Roxanne Guenette: And these two are going to then come down, or D excites and separate emitting a photon. So that's the first way you can produce insulation like

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00:08:12.750 --> 00:08:22.320
Roxanne Guenette: The other one come from recombination. So here is you have to normalize ionization process, the charged particles comes in and track with your gonads I'm kicks out the electron out

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00:08:22.980 --> 00:08:31.020
Roxanne Guenette: But then that electron is going to wander around and he's going to see another potentially are going item that has been ionized before. So in our GM plus

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00:08:31.320 --> 00:08:43.380

Roxanne Guenette: And this electron is going to go with inside the that's our gun exciting it and again because of the same reason those like to be together and the timers and then they're going to relax and we admit that photon again.

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00:08:44.400 --> 00:09:01.740
Roxanne Guenette: So this last one is important because we're going to come back to it. You can see that the ionization and the sensation are kind of going to be competing because that electron that I produce which I wanted potentially to detect as a charge it might recombine and give me a full on instead

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00:09:03.840 --> 00:09:12.360
Roxanne Guenette: One thing that is important to mention is that each of these noble elements have their own sensation wavelength. So if you see here I'm

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00:09:12.750 --> 00:09:19.680
Roxanne Guenette: Going to talk about mostly the Argonne and xenon, so here are going is at 128 nanometers and xenon is at 175

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00:09:20.370 --> 00:09:32.730
Roxanne Guenette: These wavelengths are in the far right in the vacuum ultraviolet when the vv. So this is not ideal for particle physicist, because the photon detectors that we have usually are most efficient.

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00:09:33.180 --> 00:09:45.210
Roxanne Guenette: In the visible around 400 nanometers. So we're going to need to shift this light the sensation light into a range that is visible so that we can detect them with typical either

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00:09:46.290 --> 00:09:53.040
Roxanne Guenette: Photo inspire tubes or silicon photo multipliers. But then what we're going to do is we're going to use wavelength shifters which can be

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00:09:53.610 --> 00:10:02.190
Roxanne Guenette: One traditional one is a an organic compound called CPB and we just deposit that in front of the Fulton detectors, like you can see on this picture here.

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00:10:02.490 --> 00:10:09.600
Roxanne Guenette: And then when the sensation light is going to hit this interview v. It's going to shift to visible light. So this complicates a little bit

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00:10:10.230 --> 00:10:17.130
Roxanne Guenette: The way we're going to detect the lights, because you add an extra layer literally between a destination and the detection.

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00:10:17.430 --> 00:10:30.510
Roxanne Guenette: But there are a lot of our Indian people i think you know better ways of doing that in the future. And when you think of xenon the 175. This can almost be detected by some new photon detectors directly in the future.

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00:10:32.550 --> 00:10:43.080
Roxanne Guenette: So I've mentioned this already, but the charge and the light is very complimentary in noble adamant detectors and on this club, this is kind of what you see it shows the charge

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00:10:44.160 --> 00:10:49.950
Roxanne Guenette: Which is going to be the one going up and the lights which is going to be the one going down in function of electric field.

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00:10:50.400 --> 00:10:56.940
Roxanne Guenette: And the reason this blood like works like this is you remember two slides ago, and I talked about the recombination that produces light.

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00:10:57.390 --> 00:11:06.960
Roxanne Guenette: So when I produce ionization electrons. If I have a very intense electric field. It means that this electron is going to be dragged very quickly away from the

69
00:11:07.350 --> 00:11:12.810
Roxanne Guenette: region where I musician is happening. So this guy is going to have less chances to meet an ionized.

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00:11:13.470 --> 00:11:27.000
Roxanne Guenette: Are going item to recombining so this is why you see in function of the field strength. The charge increases significantly. When you go to higher field and by opposition, the light is going to drop

71
00:11:27.660 --> 00:11:36.960
Roxanne Guenette: So when you build that effect or what you have to do is decide which one you care more about isn't the charge or the light and pick which electric fields, you would like to do for your experiment.

72
00:11:38.850 --> 00:11:45.270

Roxanne Guenette: Okay, but I haven't told you how it typically works. I only gave you the ingredients for this. So let's see. Now, how that works.

73
00:11:46.080 --> 00:11:53.160
Roxanne Guenette: So in a plane protection chamber. I have a big reservoir of noble elements. So it's either are gone or xenon

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00:11:53.790 --> 00:12:04.290
Roxanne Guenette: It charged particle which is the dotted line here is going to come in and eyes all the noble of them and atoms as I just explained, leaving cloud and cloud and clouds of ionization electron

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00:12:04.920 --> 00:12:13.110
Roxanne Guenette: But also at the same time I said there is also sensation, like that is produced. So a lot of photons are going to be emitted along the trajectory of that charged particle

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00:12:14.520 --> 00:12:21.450
Roxanne Guenette: decentralization light is very fast. It's actually the primary simulation like is the order of nano seconds so very quick.

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00:12:22.050 --> 00:12:30.420
Roxanne Guenette: Which means that if I have photon detectors which I may have had to cover with wavelength shifters to see the wavelength at 128 or 175 nanometers.

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00:12:31.170 --> 00:12:48.990
Roxanne Guenette: This these detectors are going to detect immediately the ventilation light as I said nano seconds so I can know very precisely what was the time of interaction of my particle and this can be used either for trigger or for, for, as I said, for knowing the precise time of the interaction.

79
00:12:51.810 --> 00:13:03.030
Roxanne Guenette: For the ionization I've mentioned that we use electric fields. So this is what I have here, so I will have a high voltage difference between the bottom and the top and then it means I create a high

80
00:13:04.380 --> 00:13:19.380
Roxanne Guenette: Electric field, which means that those ionization electrons are going to get to recharge are going to start moving in that electric fields, but this is quite slow. It takes roughly milliseconds for the electrons going from the interaction to go all the way at the bottom.

81
00:13:20.790 --> 00:13:34.140
Roxanne Guenette: The way you're going to read out these ionization electrons is going to be very specific to the type of experiment that you have. So we're going to come back to that. But you can easily imagine right now that we're going to collect this charge and read it out.

82
00:13:36.090 --> 00:13:44.700
Roxanne Guenette: But the fact that I had that t zero provided by disinflation lights and the drift time that it took to detect the charge. This is what we mean.

83
00:13:45.030 --> 00:13:56.820
Roxanne Guenette: By time projection, because by the time I detected. My ionization charge. I can project back to the t zero that I had from this installation and I know exactly where in my detector, the interaction took place.

84
00:13:58.710 --> 00:14:10.830
Roxanne Guenette: So this is kind of all you need to understand roughly novel eliminated actors and I hope that in the future when you're going to be thinking of those experiments because you're going to hear about them a lot. Your you will remember these processes.

85
00:14:11.460 --> 00:14:18.180
Roxanne Guenette: But as I said there was a lot of things that are much more complicated than this and actually much more beautiful. So I want to go into more details.

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00:14:19.620 --> 00:14:29.250
Roxanne Guenette: The first thing we're going to talk about is noble man detectors for Neutrino Physics, so you're going to have much more details on the physics of

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00:14:29.730 --> 00:14:43.590
Roxanne Guenette: Neutrinos you already heard from Andrew nutrient theory which you're gonna have another lecture tomorrow, but I will also be giving two lectures on the translations experiments which are going to be complementary to what Andrea explained to us today.

88
00:14:45.030 --> 00:14:58.740
Roxanne Guenette: But you can see here on this picture. This is an event display of a real interaction from the microphone liquid are gone to PCs and you can see how beautiful those images are and how very detailed the information coming from these detectors is

89
00:15:00.180 --> 00:15:03.420
Roxanne Guenette: But let's see how we use the, the doctors and internal physics.

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00:15:04.650 --> 00:15:16.800
Roxanne Guenette: So we're going to see in more details in my lectures on a solution that to do the future experiments we really want to use accelerator neutrinos, which have energies for neutrinos about jeebies

91
00:15:18.210 --> 00:15:22.350
Roxanne Guenette: We need detectors that are going to have a high neutrino detection efficiencies.

92
00:15:22.890 --> 00:15:33.420
Roxanne Guenette: You know, just by famously that neutrinos our weekly interacting. They don't interact a lot. So when they do interact and you detector. You want to make sure to catch it. Otherwise, you're wasting

93
00:15:33.840 --> 00:15:44.250
Roxanne Guenette: Time with your detector. So we need high efficiencies, of course, like any particle experiments, we need to reject background to make sure we we identify the neutrino that we are looking for.

94
00:15:45.330 --> 00:15:58.050
Roxanne Guenette: And for the future, we are thinking that we need extremely large detectors and here I'm talking about kiloton skills so kilo kilo. Remember it's 1000 ton of detectors. This is huge.

95
00:15:59.160 --> 00:16:07.410
Roxanne Guenette: So we're going to use liquid are gone to PCs for that because they are quite an ideal choice. This is an example again of the microphone inside

96
00:16:08.880 --> 00:16:16.680
Roxanne Guenette: In virtual reality mode, which is something that the venue app, if you ever come across. It is quite fun to look at. But this is the inside of a

97
00:16:17.460 --> 00:16:34.200
Roxanne Guenette: Liquid are going to PCs and it's pretty much like I was saying, you have a volume of our bond particles and track producing ionization and you have on the right, the photo multiplier tubes which have that cover of wavelength shift or to shift from 128 to 420 roughly

98

00:16:36.450 --> 00:16:45.780
Roxanne Guenette: Okay, so in the case of liquid are going to PCs for this new physics we have our neutrino interaction neutrinos don't do anything in the detector themselves. They are neutral particles.

99
00:16:46.200 --> 00:16:54.900
Roxanne Guenette: But they will interact. Luckily, with some low price action with some are going item and produce the ionization that I've mentioned just before

100
00:16:55.650 --> 00:17:03.660
Roxanne Guenette: These clouds of ionization electrons are going to be drifted towards the wire plane in this case. Remember I said each detector had its own result.

101
00:17:04.050 --> 00:17:16.320
Roxanne Guenette: So in Neutrino Physics. The simplest way of doing that is using wires. So if you have very long wires. You can imagine that when the electrons drift and they reach the wires, they're just going to produce occurrence.

102
00:17:17.010 --> 00:17:32.940
Roxanne Guenette: Just like principle of electricity, really. So you can see here on the top left these pulses that come from a bunch of electrons coming on to the wire making a signal. And then if you have several wires. You can see that those signals are going to be on all of these different wires.

103
00:17:34.290 --> 00:17:44.490
Roxanne Guenette: Remember, that's because I have the t zero which comes from the sensation lights I can project back to where the interaction happen. So I'm going to be able to do

104
00:17:45.660 --> 00:18:00.930
Roxanne Guenette: Events displays and function of time on one axis and wire number on the other axis. So really what you're going to get is a like for example here, you're going to see kind of the top views and also that time is going to give you the depth of that events which is shown here.

105
00:18:02.460 --> 00:18:11.850
Roxanne Guenette: Usually we want to have more than one plane because if you have two planes. It gives you two different views because you're going to have your wires at different angles.

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00:18:12.270 --> 00:18:22.230

Roxanne Guenette: And you're gonna have two different views of the same event, which means you're going to be able to do a treaty reconstruction of your event. And this is going to be very useful to reconstruct the energy deposited by these particles.

107
00:18:23.910 --> 00:18:33.540
Roxanne Guenette: So one word about the simulation light. I said that it gives us the t zero and allows us to reconstruct so that's great but technically when you have an accelerator that produce neutrinos.

108
00:18:33.960 --> 00:18:38.820
Roxanne Guenette: The timing of an accelerator is very well known person very well known.

109
00:18:39.210 --> 00:18:49.440
Roxanne Guenette: So you can get a signal from the accelerator itself that says, Okay, get ready. I'm going to fire neutrinos. So you can read out your detector. So technically, we would not need this insulation light.

110
00:18:50.130 --> 00:18:56.760
Roxanne Guenette: But it's very useful because since neutrinos don't interact much sometimes they will go to the doctor without doing nothing.

111
00:18:57.180 --> 00:19:11.670
Roxanne Guenette: So if you have sensation lights in coincidence, with the signal that you got from the accelerator you then know that there was a real event in your detector coming from a neutrino. So you're going to be much more efficient as acquiring data from your detector.

112
00:19:13.380 --> 00:19:22.320
Roxanne Guenette: And other thing I want to mention is the wire spacing. So this is going to give you the tix on the x axis on these event displays here.

113
00:19:22.740 --> 00:19:27.690
Roxanne Guenette: So you can imagine that the closer. Those words are together, the more high resolution, you're going to get

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00:19:27.960 --> 00:19:36.300
Roxanne Guenette: So people basically look at what is the physics, they want to achieve and then optimize that wire spacing to be as good as it can be.

115
00:19:36.690 --> 00:19:45.780

Roxanne Guenette: to counterbalance other constraint that you have, which is mainly cost. Usually, but as long as you can do your physics with the word spacing that you have. You're good to go.

116
00:19:48.540 --> 00:19:57.780
Roxanne Guenette: Actually, it's like Oregon detectors usually have more than two wire planes and the reason there are two reasons for death. The first one is

117
00:19:58.800 --> 00:20:02.130
Roxanne Guenette: What happened if one of the wires is broken in one of the

118
00:20:02.700 --> 00:20:12.960
Roxanne Guenette: One of the views and one of the planes, then you're going to have a second one that sees exactly the same thing and will give you still your to the reconstruction. So we say that we have that for redundancy.

119
00:20:13.410 --> 00:20:23.640
Roxanne Guenette: But even more than that. What's important is that you can imagine if you're unlucky and your particle travels exactly along

120
00:20:24.030 --> 00:20:30.780
Roxanne Guenette: One wire, for example. So the angle and and and looking at the red wire here. So imagine you have a particle going through this

121
00:20:31.140 --> 00:20:38.100
Roxanne Guenette: When the charge is going to be drifting towards that wire. It's all going to be collected by a single wire. So when I'm going to be

122
00:20:39.060 --> 00:20:52.770
Roxanne Guenette: Doing my event display time and function of wire. I'm going to have a big blob in one wire and that's not going to be useful at all to reconstruct so that's where you appreciate having to other views that are not aligned at all with these with these particles.

123
00:20:53.850 --> 00:20:58.980
Roxanne Guenette: You may have noticed that some of them are called induction plane and some of them are called collection planes.

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00:20:59.760 --> 00:21:07.170

Roxanne Guenette: So here I don't want to go into details, but the only thing that I want you to remember is that if you have three planes, one after the other.

125
00:21:07.500 --> 00:21:13.350
Roxanne Guenette: And you have a big bunch of electrons that are coming in to be collected if you collect them on the first plane.

126
00:21:13.770 --> 00:21:20.640
Roxanne Guenette: You've lost them. You're not going to be able to see them on the next two planes. So what we do is we adjust the electric field into

127
00:21:20.880 --> 00:21:29.070
Roxanne Guenette: Into three different planes, so that when the electrons are coming in, they're going to accelerate just before they hit the first plane in a way that they're not going to be able to stop.

128
00:21:29.460 --> 00:21:44.550
Roxanne Guenette: At the first plane and then they go to re accelerate again in the next plane and then being collected on the last one. So the last one is always the collection plane and the two others are just called induction, because the electrons when they pass. They don't produce

129
00:21:45.840 --> 00:21:52.980
Roxanne Guenette: The producing deuce signal because they are going near it by producing some field around the wires. They're going to produce some

130
00:21:54.210 --> 00:22:04.860
Roxanne Guenette: Some pulses. So you can also detect them, but that yeah so I don't want to go in more details because the rest is nuts. It's to details for what I want. But yeah, you have induction and collections length.

131
00:22:06.120 --> 00:22:10.170
Roxanne Guenette: On the right you have an example of a real event coming from the microbiome, the doctor again.

132
00:22:10.500 --> 00:22:22.170
Roxanne Guenette: Where you have the same event seen in the two different planes. The top one is the collection plan. You can see these ones are very clear because remember I told you they are collected so very high resolution and the collection planes.

133
00:22:22.590 --> 00:22:28.830
Roxanne Guenette: For the induce the induction planes, the two bottom ones. You can see that the signal is a little bit less sharp

134
00:22:29.430 --> 00:22:35.160
Roxanne Guenette: But do you see how different those views are so those two little particles that are shown here, which are

135
00:22:36.030 --> 00:22:43.290
Roxanne Guenette: One of them is probably a proton. The other one is not clear, you would need to do the particle identification to make sure, but you can see when you look at them.

136
00:22:44.100 --> 00:22:53.460
Roxanne Guenette: From the other views. They are very different angles. So by having these three. I'm going to be able to do a 3D reconstruction and extract the information, as I said, to do particle identification.

137
00:22:55.590 --> 00:23:08.340
Roxanne Guenette: Today, I don't have time to go into details on how we reconstruct these particle and certifications. I could do a full lecture on how do you reconstruct events in liquid are going to PCs, but I just want to brief you give you

138
00:23:09.000 --> 00:23:17.220
Roxanne Guenette: An overview. So what happens if you have a detector that is on the surface, which, in addition to having interactions from the neutrinos will have cosmic or interactions.

139
00:23:17.820 --> 00:23:27.570
Roxanne Guenette: The first thing you do is you take a snapshot of all the charge that was recorded in your wires and then you assemble them into tracks or showers depending what you're looking at.

140
00:23:28.500 --> 00:23:39.180
Roxanne Guenette: And then you're going to try to identify these saying okay these are most likely cosmic rays because they entered from the top and from the bottom of my diversity went straight true. So those are going to be a cosmic rays.

141
00:23:39.900 --> 00:23:48.600
Roxanne Guenette: And then I'm going to use the light information from this installation to see which of these events seems to be exactly in time with the beam.

142
00:23:49.080 --> 00:23:59.430
Roxanne Guenette: Trigger that I got from the accelerator and then I can say this one seems most consistent with this. So I'm going to look at this and think that this is my material interaction that I wanted to identify

143
00:24:00.870 --> 00:24:11.970
Roxanne Guenette: In real life, as I said, what we want to do is take those to the events and here I'm showing an example of the Panda reconstruction software. There are many others that exist. People use machine learning to do these because

144
00:24:12.330 --> 00:24:27.960
Roxanne Guenette: Images or something that machine learning is very good at targeting and people are using also a demographic reconstruction. It's very clever, but we don't have time to go into details, but here in the Pandora one, you can see the different particles, which is an event coming from the podium.

145
00:24:29.070 --> 00:24:33.720
Roxanne Guenette: Test beam. So, this we know exactly what we shot at this at this detector.

146
00:24:34.350 --> 00:24:43.710
Roxanne Guenette: The different colors. So the different particles that fundamental things are in the interaction. But you can see how crazy this is when you're on the surface where you have a lot of cosmic rays.

147
00:24:44.160 --> 00:24:57.960
Roxanne Guenette: These are full 3D reconstruction of all the events that happen in the same time window that we were looking at. So, of course, you're going to need to be very good at removing cosmic rays, so that you can identify this little event that is in the middle.

148
00:24:59.400 --> 00:25:10.290
Roxanne Guenette: And then you're going to want to compare that to simulations and here at the bottom you have true example of a test beam simulations, where you have tracks and showers and then you can reconstruct those events and compare

149
00:25:12.720 --> 00:25:25.680
Roxanne Guenette: Okay, so this is how liquid are gone to PCs work but I promise you that I would go into more details about some of the topics, because I really want you to understand how complex these detectors really can be

150
00:25:26.730 --> 00:25:38.280
Roxanne Guenette: So the problem with reconstructing our events and then comparing to our simulation and extracting to physics that we want is that there is a lot of micro physics that happens into these detectors.

151
00:25:38.670 --> 00:25:53.220
Roxanne Guenette: This by the way is a picture of liquid Oregon in a large reservoir that they had a formula. So if you've never seen what liquid argon looks like that's what it looks like it's pretty cool when you think that this is that 87 Kelvin ready

152
00:25:55.350 --> 00:26:11.520
Roxanne Guenette: OK, so now I'm going to go through three things. That's the ionization charge is going to undergo while before it gets detected to show you how complicated, it's going to be to exactly bring back the interaction to it's T zero like the time production chamber wants to do.

153
00:26:12.780 --> 00:26:19.470
Roxanne Guenette: So the first thing that as I explained, you have you ionization charged particles comes in a bunch of electron ionization is produced.

154
00:26:19.890 --> 00:26:23.280
Roxanne Guenette: The number of electron ionization that is produced depends

155
00:26:23.880 --> 00:26:31.170
Roxanne Guenette: On the energy that you deposit. You can imagine that if you have a lot of energy that is deposited in the are gone, you're going to produce way more

156
00:26:31.590 --> 00:26:45.030
Roxanne Guenette: Electrons, for sure. And this is what you can see here on this formula, the number of electrons that is produced in ionization for our gun is the order of 40,000 per me be deposited and then you will split up by the energy that the particle is going to deposit

157
00:26:46.470 --> 00:26:53.550
Roxanne Guenette: Remember that the energy that is so this is W here, the energy that is given for the ionization

158
00:26:54.150 --> 00:27:07.860
Roxanne Guenette: Is going to be divided into what is available to extract the electrons from the atoms, which has, I said, has to be bigger

than the biting energy in our bonus 23.6 EV so very low. It's very easy to get electrons out of these

159
00:27:08.730 --> 00:27:22.920
Roxanne Guenette: And it's going to be also proportional to how much of these guys the electron are going to read combine and excites instead of is because remember sensation, like can be produced by two things. Either excavations or recombination.

160
00:27:24.030 --> 00:27:32.730
Roxanne Guenette: And then here on this plot, I showed the DD X. So the amount of energy deposited in functional of the path of a particle and function of the

161
00:27:32.970 --> 00:27:48.030
Roxanne Guenette: Kinetic energy of that particle. And you can see that for different particles here, the top one to read this protons and neutrons and blue. You can get a feel of who is going to extract more electrons and the others. So protons are highly ionizing and will produce a lot of

162
00:27:49.500 --> 00:27:59.280
Roxanne Guenette: Ionization electrons. And this is where why the appear read in our event displays because a lot of them have been produced at the same time, just because of this equation here.

163
00:28:01.080 --> 00:28:20.250
Roxanne Guenette: Okay, so I've produced a button a bunch of ionization electron. Now I need to transport them. So I told you that I going to use an electric field, but how fast the electrons are going to go in that electric field is actually something that we have known empirically, so there is no

164
00:28:21.420 --> 00:28:25.890
Roxanne Guenette: The Physics of this is so complex that we don't have a formula, just that we calculate analytically.

165
00:28:26.400 --> 00:28:37.380
Roxanne Guenette: So what people have done is they've taken measurements of how long it takes for electrons to go from one point to another in function of electric fields. And you can see here, these

166
00:28:38.220 --> 00:28:54.030
Roxanne Guenette: Data points are from the Icarus experiment which took data in the like 2000 roughly 2000 and you can see that you can compare

that, because of course the velocity is going to depend on the temperature, you can imagine that the hotter it is, the more

167
00:28:55.080 --> 00:29:00.870
Roxanne Guenette: Loose or crazy those electrons are so they are going to be less quick at going through

168
00:29:01.320 --> 00:29:11.400
Roxanne Guenette: And basically, what we do is we take those data and then we flip them with this empirical formula has a lot of fire meters and then we get the feel of how quick, you're going to be

169
00:29:11.910 --> 00:29:24.750
Roxanne Guenette: And this we're going to need, right, because when I'm going to compare the to the t zero, I need to know how long these guys have been how quick they have come to me because, of course, the quicker you go, the less further away. You started

170
00:29:26.640 --> 00:29:31.260
Roxanne Guenette: And then the. Another thing that happens to those bunch of electrons is that they are going to diffuse

171
00:29:31.680 --> 00:29:42.810
Roxanne Guenette: So they are not sticking altogether sharply like they were at the production at my trace of the particles and this is annoying because the more that they're going to defuse

172
00:29:43.080 --> 00:29:52.140
Roxanne Guenette: The left precision. I'm gonna have to reconstruct the trajectory that they started from here, I just wanted to put the formula of that.

173
00:29:53.550 --> 00:30:01.770
Roxanne Guenette: Diffusion factor. So the sigma is how much the fusion happens and you can have that diffusion transverse Lee, but also launched internally.

174
00:30:02.130 --> 00:30:07.860
Roxanne Guenette: Happening and it depends on the coefficients that I'm going to have to measure because we don't know that analytically.

175
00:30:08.220 --> 00:30:14.070
Roxanne Guenette: Of course, it's going to depend on how far you're going to go just further you're going to go the more time, you're going to have to diffuse

176
00:30:14.490 --> 00:30:21.360
Roxanne Guenette: And then it's going to be inversely proportional to that trick fields because the faster you go, the less time you're going to spend diffusing

177
00:30:22.320 --> 00:30:30.660
Roxanne Guenette: And what people have done, as I said, we had to measure it. So we just take many different values at different electric fields. And then we tried to assume

178
00:30:31.020 --> 00:30:42.840
Roxanne Guenette: How much diffusion, the war and we'd get. And you can see here how actually we're not very good at muddling that super precisely so it's going to be a systematic errors in our in the way that we're going to try to understand things

179
00:30:44.670 --> 00:30:57.240
Roxanne Guenette: And the last thing that happened is recombination. So I've mentioned that already. That will happen your organization electrons will meet other organizations that were already ionized and they will recombine.

180
00:30:59.100 --> 00:31:07.830
Roxanne Guenette: The weight of the happens is also not completely known. We have two models which are both empirical that people have tried to feel try to understand this.

181
00:31:08.790 --> 00:31:15.600
Roxanne Guenette: So we have some from Icarus, we have some from our notes, but what you see on the right is that the

182
00:31:16.140 --> 00:31:22.140
Roxanne Guenette: Amount of charge and the amount of like that I already explained, which are mutually complimentary

183
00:31:22.770 --> 00:31:28.470
Roxanne Guenette: Is going to depend on the electric field because I said that already, the faster you go, the less chance you're going to have to

184
00:31:29.070 --> 00:31:41.040
Roxanne Guenette: Recombine but it also depends on how much energy you have deposited at the beginning. If you've was just a little bit of energy and you have just a little bit of accusation electrons, the recombination is going to be more

185
00:31:42.060 --> 00:31:56.790
Roxanne Guenette: affecting you. Then if you had a lot of them, shown here, and this is why those curves which are 413 10 and 30 amount of MIT Energy. So the amount of energy that poses when you have them minimizing ionizing particle

186
00:31:57.510 --> 00:32:01.890
Roxanne Guenette: You can see that the impact is bigger for for low energy then for high energy

187
00:32:03.300 --> 00:32:12.510
Roxanne Guenette: Of course, you don't have to understand this, right, the what what I want you to get out of this is that it is complicated to understand how the electrons. I've been traveling

188
00:32:13.050 --> 00:32:27.690
Roxanne Guenette: And the last thing that happened in addition of this normal ionization and normal recommendation is that you might have impurities in your detector. I told you that novels were great, because they will not attach any of the

189
00:32:29.100 --> 00:32:38.430
Roxanne Guenette: Charge coming true because they're noble, but if you have impurities like water, oxygen, nitrogen, these guys are not noble at all, and they are going to attach

190
00:32:38.700 --> 00:32:44.670
Roxanne Guenette: And actually the way that that works is very complicated and it depends on the chemistry of these different molecules.

191
00:32:45.060 --> 00:32:52.860
Roxanne Guenette: Because one would have expected that in function of electric fields which means the quicker that you go, the less

192
00:32:53.550 --> 00:32:58.590
Roxanne Guenette: Border you're going to be by the impurities. So all the curves here should go that the

193
00:32:59.580 --> 00:33:06.420
Roxanne Guenette: Attachment goes down for everybody, but you can see that it does go down for some, but for some it goes up. And this is because of complicated

194

00:33:07.290 --> 00:33:18.270
Roxanne Guenette: Chemistry where sometimes the electrons that are traveling fast have just the amount of energy necessary necessary to excite those molecules in the right state and stuff. So it's quite interesting.

195
00:33:19.200 --> 00:33:23.280
Roxanne Guenette: But what we have to do is for each charge that we're going to collect

196
00:33:23.550 --> 00:33:33.720
Roxanne Guenette: We need to correct to know how much charge. Did I had at the beginning when the whole thing started. And this is going to dictate exponentially with the number of impurities that you have. And these are going to be

197
00:33:34.110 --> 00:33:39.090
Roxanne Guenette: extracted by to knowing the concentration that you have of these impurities and then fitting them.

198
00:33:40.800 --> 00:33:45.750
Roxanne Guenette: And the last thing I want to mention, in case you are you're not convinced yet that things are complicated

199
00:33:47.220 --> 00:33:54.870
Roxanne Guenette: You know that the two PCs rely on electric fields. Right. I mentioned electric fields at almost all of my slides from the, from the past.

200
00:33:55.200 --> 00:34:02.880
Roxanne Guenette: So we rely on the fact that the electric field is very uniform in the detector, because if you don't have a uniform field, then you electrons are going to

201
00:34:03.300 --> 00:34:09.930
Roxanne Guenette: Going to do crazy things and we don't want up. Unfortunately, they are the factors that are located on the surface, which are

202
00:34:10.830 --> 00:34:19.770
Roxanne Guenette: Constantly received constant cosmic rewrites and we know that there are a lot of cosmic rays. Right. And what's going to happen is they're going to come in, into detector.

203
00:34:20.130 --> 00:34:32.550

Roxanne Guenette: ionizing like crazy. The are going atoms. The electrons are going to be drifted like normal, but the heavy ions that are left behind the argon ions, they are going to drift really slowly because they're very heavy

204
00:34:33.180 --> 00:34:39.990
Roxanne Guenette: And then because you have a constant flux. Those are going to start piling up near the end point near the cathode.

205
00:34:40.470 --> 00:34:46.110
Roxanne Guenette: Which means that the electric field near the cathode is going to be highly distorted compared to near

206
00:34:46.620 --> 00:34:51.360
Roxanne Guenette: Where they are being collected at the anode and this is exactly what you see from the microbiome experiments.

207
00:34:51.660 --> 00:35:04.230
Roxanne Guenette: Where the Amtrak. So those cosmic rays go through the detector, they should bring a beautiful square because they go through to hold it, that are all the time. And you can see that towards the cathode. We are losing the

208
00:35:05.400 --> 00:35:08.160
Roxanne Guenette: The nice uniform electric field.

209
00:35:09.630 --> 00:35:18.900
Roxanne Guenette: In addition, if that's not complicated enough in these detectors. We also have flow right because we do recirculate the whole detector to get the purity.

210
00:35:19.260 --> 00:35:29.700
Roxanne Guenette: As good as possible. We don't want the attachment coming from the impurities mentioned the previous slide. So we recirculate and we rip your fine recirculate which is going to create flows into detector.

211
00:35:30.240 --> 00:35:36.090
Roxanne Guenette: Here on this blog, I have an example of the flow that is predicted into production, which is a detector.

212
00:35:37.350 --> 00:35:43.290
Roxanne Guenette: Running at CERN and you can see the rather he is our where there was kind of a little vertices

213
00:35:43.680 --> 00:35:56.160
Roxanne Guenette: So if you have ions that are being produced all the time by cosmic rays. These guys are going to be cut into those vertices for longer and they are going to distort the start even further, the electric field.

214
00:35:57.540 --> 00:36:10.860
Roxanne Guenette: So you can see that if I'm going to want to reconstruct all my particles and understand exactly what happened at the t zero. I'm going to have to understand all the micro physics. I just talked about and calibrate very well. All of these detectors.

215
00:36:11.790 --> 00:36:26.430
Roxanne Guenette: But you know as an experimental is this is a lot of fun because it means you're going to have a lot of work to do to understand your detector and that's fine, but I hope that I gave you a feel of how complicated the physics is really even if the principle is very simple.

216
00:36:28.020 --> 00:36:41.220
Roxanne Guenette: Now I want to change gear and talk about noble elements factors for dark model, you're going to have to lectures in the future about direct dark matter searches and you're going to see that a nobleman detectors are quite useful.

217
00:36:43.230 --> 00:36:44.730
Roxanne Guenette: If I'm thinking about document or

218
00:36:45.180 --> 00:36:59.220
Roxanne Guenette: I'm going to need very large detectors here to write because we know that dark matter hasn't interacted yet with our detector. So if it's out there. It's really, really wiki interacting. So I'm going to need larger and larger detector to see if they're if they're there.

219
00:36:59.670 --> 00:37:05.730
Roxanne Guenette: And here we're talking about multi timescales 10s or to 100 ton of detectors.

220
00:37:07.110 --> 00:37:15.210
Roxanne Guenette: I've mentioned this before you need very low energy threshold and the reason you want. This is a plug that illustrates this where you have the

221
00:37:15.840 --> 00:37:28.170
Roxanne Guenette: Number of events that you would expect from the 100 GV neutralino which is one of the you're going to see all of that in the

next in future lectures. But if you imagine that you have a particle that is a dark matter of that mass

222
00:37:29.310 --> 00:37:34.410
Roxanne Guenette: The number of count that you're going to see a new detector per kilogram. So remember we have done.

223
00:37:34.980 --> 00:37:45.390
Roxanne Guenette: Per year is shown here. And you can see that, depending on what is your energy threshold, you're going to see less and less and less of those events because basically, they are not

224
00:37:46.380 --> 00:38:01.530
Roxanne Guenette: heavy enough to make the detectors react to large amount of energy deposited. So what you want here is to lower as much as possible, your threshold to give you a better chance to see as high as possible detection rates.

225
00:38:03.270 --> 00:38:13.800
Roxanne Guenette: The last thing you're going to need is low, backgrounds, of course, because you don't want these detectors to be saturated with neutrons and electrons. What you want is them to be as clean as possible because when you're going to see that.

226
00:38:14.370 --> 00:38:20.700
Roxanne Guenette: Dark Matter particle interacting in that year. You don't want to miss it and think that it was a fake interaction.

227
00:38:22.530 --> 00:38:33.510
Roxanne Guenette: Okay, so when I look at this here I've shown it the green curve is green on blue is germanium. That's not an oval, so forget it. For now, but it's just for comparison, and are going to the red one.

228
00:38:34.200 --> 00:38:43.230
Roxanne Guenette: So one could think if you're not able to go to low recoil threshold, you better go for are going right because you're going to have a higher amount of the

229
00:38:43.950 --> 00:38:57.510
Roxanne Guenette: Chance to see the dark metal particles. But then if you know that you're going to go to low threshold go for xenon because it's much higher. And this is simply because the genome is bigger. So the interaction rates is more probable in a big atom than in a smaller item.

230
00:38:59.280 --> 00:39:10.500

Roxanne Guenette: But the problem with our goal is that when we get it from the atmosphere which is actually quite simple to do that. And that's why our gun is so cheap and I didn't mention that when when I talked about liquid are going to PCs.

231
00:39:10.800 --> 00:39:18.330
Roxanne Guenette: But if I wanted to go to kill it on. It's better to be quite cheap. Otherwise, I'm not going to be able to buy it with all the money that we have for science.

232
00:39:18.750 --> 00:39:36.030
Roxanne Guenette: So are going. This is very cheap because we have it in the atmosphere and people extracted all the time. But the problem with that are gone, is that it has an isotope called are gone 39 that is highly radioactive and the case at below at the end point is 565 kV

233
00:39:37.590 --> 00:39:49.530
Roxanne Guenette: If you're doing GV physics. You really don't care about this, but if you're doing kV physics you really care about that. And on this plot at the bottom. This is what the deep collaboration season in their

234
00:39:50.310 --> 00:40:00.540
Roxanne Guenette: Liquid county PCs here. I don't want to go into details. The only thing I want to point out is you see that at low energy at recoil. The gray line that is shown here.

235
00:40:01.080 --> 00:40:07.260
Roxanne Guenette: Is the are gone 39 so that's going to really mess up your lower energy detectors.

236
00:40:07.860 --> 00:40:20.190
Roxanne Guenette: So after this. People are like, okay, are going is too crazy, we cannot use that for dark matter. We're going to go for xenon, even if we know that we're going to have to push the threshold until we found on the Underground are gone. And I'll come back to that.

237
00:40:21.720 --> 00:40:31.020
Roxanne Guenette: Okay, liquid xenon to PCs. So this is what was for a while to to be the only solution as noble element to go for the future.

238
00:40:31.740 --> 00:40:46.110
Roxanne Guenette: These are factors work exactly the same as all the others, you have a particle come in. Hopefully a dark model is going to interact producing sensation light as I explained also ionization electrons that are going to be drifted towards

239
00:40:47.220 --> 00:40:48.240
Roxanne Guenette: A readout system.

240
00:40:49.290 --> 00:40:59.790
Roxanne Guenette: Indicates case of dark matter because I want such a small energy threshold. It means I'm going to have very few of these ionization charge to detect

241
00:41:00.270 --> 00:41:10.320
Roxanne Guenette: So what I'm going to want to do is amplify the signal. One way of doing of doing that is using electroluminescent where you have a very high electric field.

242
00:41:10.770 --> 00:41:21.900
Roxanne Guenette: Here at the top. And when these electric ionization electrons, enter, enter that very high electric field, they're going to start exciting the xenon atoms.

243
00:41:22.140 --> 00:41:30.990
Roxanne Guenette: Producing a lot of photons which are actually proportional to the electrons that came in. So for example, if I had one electron coming in, depending on the

244
00:41:32.520 --> 00:41:49.140
Roxanne Guenette: Gap that you have the extra field that you have in that gap, you can get something like 30 photons per single electron. So that's an amplification, which is great. We refer to the signal as the St. Because it's the second light signal that we get into those detectors.

245
00:41:50.280 --> 00:41:56.400
Roxanne Guenette: And the last one is the sensation one ended nano seconds timescale that I've mentioned before.

246
00:41:57.000 --> 00:42:10.530
Roxanne Guenette: So in dark metal detectors. When you're going to see is, you're going to have the S one, which is a small signal of disinformation light and then after milliseconds of drift, you're going to have the signal which is an amplified signal that you see here.

247
00:42:12.180 --> 00:42:19.170
Roxanne Guenette: And other nice things about liquid xenon is that itself shielding when you have very large detectors, the

248

00:42:19.620 --> 00:42:25.500
Roxanne Guenette: particles coming from outside like a photons or or an electron, producing a photons will

249
00:42:25.950 --> 00:42:37.170
Roxanne Guenette: Not be able to go far inside the xenon because they get stuck. The activation length for the length before photons cups is going to be roughly below 10 centimeters.

250
00:42:37.620 --> 00:42:47.970
Roxanne Guenette: Depending on the energy, but roughly. So it means that if you have a detectors that is several meters. When you look at the center of your you're going to have very pure no background early. So this is great.

251
00:42:49.500 --> 00:42:56.610
Roxanne Guenette: By comparing s one s to by looking at the time that it took for things to go. You can reconstruct the position.

252
00:42:57.660 --> 00:43:02.970
Roxanne Guenette: Of the interaction and also by looking where your light is being emitted in the SU

253
00:43:03.390 --> 00:43:17.280
Roxanne Guenette: So you can get positions that are millimeter or level, which is great as well to especially to reject background. If an event happened very near the surface of the detector, you need, you know that it was probably a background. Right. You want events in uniform inside

254
00:43:18.660 --> 00:43:32.250
Roxanne Guenette: And then one very powerful thing that the dark matter. People have discovered is that when you compare the S one and the S to coming from different particles you get very powerful ways of rejecting background.

255
00:43:33.060 --> 00:43:43.260
Roxanne Guenette: There are two things that happen when we have interaction and and detector at those very low energy recall. The first one is that you're charged particle hits and the electron

256
00:43:43.710 --> 00:43:54.210
Roxanne Guenette: And that electron that is recoiling. Even if it's very low energy, you can see that the new detector. But what we care about is more heavy particles like neutrons or wimps.

257

00:43:54.660 --> 00:44:00.510
Roxanne Guenette: dark matter particles that are coming in and out, or go to do electron recoils and nuclear Rico, sorry.

258
00:44:00.990 --> 00:44:08.610
Roxanne Guenette: So those nuclear recalls. I'm going to leave different trace and this is exactly what you see the gamma rays, which are electron Rico's produce a smallest one.

259
00:44:08.940 --> 00:44:12.720
Roxanne Guenette: And a largest to and then the heavier particle like the WIMPs or the neutrons.

260
00:44:12.990 --> 00:44:26.880
Roxanne Guenette: The producer largest one signal and also a large as to signal, but the ratio of those two, which is what you see on this blood on the right, the ratio of as to over s one is very different for the electrons which are in blue and for the

261
00:44:27.360 --> 00:44:32.940
Roxanne Guenette: Nuclear recoil, which are in red. So this is going to give you an extra power to reject background.

262
00:44:34.980 --> 00:44:42.390
Roxanne Guenette: Let me say one last word before I move on to other type of the type of science about the liquid are going to PCs.

263
00:44:43.170 --> 00:44:48.270
Roxanne Guenette: I told you that we didn't want to use them because they are very contaminated with that are going 39

264
00:44:48.570 --> 00:44:58.290
Roxanne Guenette: But when you look at this blood which is the same one I showed you here between the, the ratio of S to have as one which is here shown as fast and slow, fast as the S one and slow is the as to

265
00:44:58.860 --> 00:45:07.920
Roxanne Guenette: These are exactly the same plot. And do you see how much more separated liquid Oregon allows you between the nuclear recall and the electron recall

266
00:45:08.430 --> 00:45:19.590
Roxanne Guenette: So by having this bigger separation, you know that you're going to be better at rejecting background. So technically, we

should not give up on the poor are gone. And this is where the ingenuity of particle physicist was amazing.

267
00:45:20.370 --> 00:45:30.420
Roxanne Guenette: What did I say we couldn't use are gone from the air, because it was contaminated with underground. So, people said like fine. Where can I get are gone. That is not contaminated with

268
00:45:30.870 --> 00:45:40.800
Roxanne Guenette: Are gone through nine. And this is when you go on the ground and it started checking, how do people extract gas from underground to notice that you could actually see

269
00:45:41.370 --> 00:45:51.660
Roxanne Guenette: Our gun a byproduct of what the companies are extracting from underground, which had not been exposed to cosmic rays had not been activated into that a retroactive are going 39

270
00:45:52.260 --> 00:46:00.510
Roxanne Guenette: And they started teaming up with these companies and now we are able to get pure are gone from underground that has no argon 39

271
00:46:00.960 --> 00:46:09.540
Roxanne Guenette: And this is what you see on this, but the effect that it has on on detectors, is that you go from. So this is a number of events from backgrounds that you would get normally

272
00:46:09.960 --> 00:46:19.470
Roxanne Guenette: The black curve is what you get in a normal air are gone. And you see how crazy drop two orders of magnitude less background by using the underground are gone.

273
00:46:20.160 --> 00:46:24.240
Roxanne Guenette: So now, it means that for the future, people can go forward with like what our bone.

274
00:46:24.540 --> 00:46:33.870
Roxanne Guenette: And they are using dual phase are going to PCs, which is exactly what I told you about liquid xenon two pieces which are also jewel phase two phases, because of the liquid and the gals.

275
00:46:34.110 --> 00:46:45.000
Roxanne Guenette: And the guests face is that region where we create the electoral innocence. So the principle is exactly the same is just, you

have a different target and some experiments are going forward in the future with this.

276
00:46:47.100 --> 00:46:56.670
Roxanne Guenette: I just wanted to mention to you that they are some detractors that are actually not the PCs, so they do not drift, the electrons. The only use the ventilation life from the interaction.

277
00:46:56.910 --> 00:47:04.260
Roxanne Guenette: And this is they are called single phase. So it's a big reservoir of liquid are gone and you have PMT is all around them, because with

278
00:47:04.830 --> 00:47:18.960
Roxanne Guenette: The timing of this installation, remember, is that the order of nano seconds you're going to be able to reconstruct exactly the location of your events and the energy because of the amount of sensation. So this is an example of such a detector deep 3600 which are beautiful detectors.

279
00:47:20.250 --> 00:47:34.230
Roxanne Guenette: But yeah, so those probably are not going to be used in the future because these guys doing the 3600 are combining the efforts with a dark side with the dual phase and they're going to go forward with a dual phase, but I just wanted to know that it also does work.

280
00:47:36.630 --> 00:47:49.020
Roxanne Guenette: Okay, I gave you a lot of information. But there was one last topic that I want to bring because these detectors used for double beta decay studies are also quite different and special

281
00:47:50.370 --> 00:47:56.490
Roxanne Guenette: So you're going to see in the lecture from Lynn Linda next couple of days about nutrient dense, that will be the case that

282
00:47:56.880 --> 00:48:00.300
Roxanne Guenette: If we do observe a new terminal. So there will be time decay.

283
00:48:00.510 --> 00:48:11.700
Roxanne Guenette: It will tell us without a doubt that we've discovered that neutrinos are my have enough article which is going to be a huge deal. I'll let her the punch line to say why that's such a big deal. But it's important to look for it.

284

00:48:12.750 --> 00:48:21.840
Roxanne Guenette: And here, when we look for web dedicates you need to have isotopes or atoms that undergo that will be the case. And there are not many of them. They're actually just

285
00:48:22.440 --> 00:48:39.420
Roxanne Guenette: Roughly 30 elements in the whole periodic table isotopes that will go will do that will be the case and in novel, we're lucky enough that there was one which is xenon 136 but here we didn't have to think very long between are going to end xenon, it has to be known.

286
00:48:41.610 --> 00:48:56.430
Roxanne Guenette: For these detectors. The name of the game. And you'll see that I don't want to go too much in detail, but is that the regular web dedicates happen all the time and they emit a whole energy spectrums, because when you have two electrons being emitted out of the

287
00:48:56.970 --> 00:49:07.770
Roxanne Guenette: Interaction. You also have to neutrinos that carry with them a random amount of energy, which means that the sum of all these decades will have any allowed energy into two electrons.

288
00:49:08.460 --> 00:49:23.790
Roxanne Guenette: If you have a neutral. So that would be dedicated means the neutrinos aren't a part of the interaction, only two electrons, you know, exactly. You can calculate that analytically, the energy that is emitted in that case. So you have a very clear amount of energy for the original list.

289
00:49:25.050 --> 00:49:34.800
Roxanne Guenette: If I want to absorb this I'm going to need very large detector and here we're talking about 10 scale detectors and why are they the smallest of the two others that I talked to you before.

290
00:49:35.130 --> 00:49:40.170
Roxanne Guenette: Is because they need to be so crazy good those detectors looking for the bobby dedicate

291
00:49:40.380 --> 00:49:47.130
Roxanne Guenette: That right now. We don't even know how to go to kill it on scale with these. It would be amazing to go because you will have so much more possibility.

292
00:49:47.340 --> 00:49:56.970

Roxanne Guenette: But as I said, they need to be so good at everything else that we're not thinking that yet. So right now we are very modest and we're thinking over more tongue scale experiments.

293
00:49:58.290 --> 00:50:08.460
Roxanne Guenette: You need to have extremely good energy resolution, because I'm going to see maybe one event, potentially, and I need to make sure that this guy fail exactly in this little red peak.

294
00:50:08.730 --> 00:50:16.710
Roxanne Guenette: If I don't have a resolution that is good enough and the resolution is like this. Then I'm not going to know if that's event was really an internal S w said okay

295
00:50:17.520 --> 00:50:26.850
Roxanne Guenette: I'm going to need very low background. We're talking about the Rare. Rare. Rare, rare events that we're looking for in particle physics. So you don't want backgrounds as little as possible.

296
00:50:27.690 --> 00:50:34.650
Roxanne Guenette: And the energy of interest in case of xenon is 2.5 and maybe this is where that peak of neutrinos liberty dedicates happening.

297
00:50:36.000 --> 00:50:44.670
Roxanne Guenette: So to pursue this science. We have two choices it, as I said, it has to be xenon, but people have come up with ideas with liquids, you know, and gases xenon

298
00:50:45.570 --> 00:50:46.410
thomas rizzo: Start rocking

299
00:50:46.620 --> 00:50:47.580
thomas rizzo: Yes minutes

300
00:50:47.940 --> 00:50:48.660
Roxanne Guenette: Yeah, thank you.

301
00:50:48.840 --> 00:50:49.320
thomas rizzo: Perfect.

302
00:50:50.220 --> 00:51:01.050
Roxanne Guenette: So the first one is liquids in on the PCs. I've already told you how those things work here. They're going to be single phase. So we're not going to have that electroluminescent region. So when I have

303
00:51:01.410 --> 00:51:13.260
Roxanne Guenette: Two electrons which are charged particles, going to the detectors. They'll produce ionization, which is going to be drifted to wire planes. This is what you see the gray areas here and simulation light which is going to be detected by

304
00:51:14.010 --> 00:51:17.430
Roxanne Guenette: Here it's evidential diodes, but any would work for now.

305
00:51:18.540 --> 00:51:30.900
Roxanne Guenette: The big breakthrough of these detectors, is that we can reconstruct the energy coming from the ionization with these wires, we can reconstruct the energy coming from decentralization coming from the MTS

306
00:51:31.590 --> 00:51:39.960
Roxanne Guenette: But the beauty that people saw and this is really great is that they notice that because we know that the light and the charges complimentary

307
00:51:40.380 --> 00:51:45.690
Roxanne Guenette: If you pull up this the simulation light energy reconstructed in function of the ionization energy reconstructed

308
00:51:46.320 --> 00:51:56.610
Roxanne Guenette: And you use an axis that is rotated along this correlation. You get extremely good resolution and this is what is illustrated on the right, where you have

309
00:51:56.970 --> 00:52:06.450
Roxanne Guenette: The green shows the resolution in functional energy for the light. The blue is for the charge and the red is from that rotated combination. And do you see

310
00:52:06.690 --> 00:52:15.990
Roxanne Guenette: Here near the peak where I care about 2.5 and movie. How much narrower, the combination is so that was a breakthrough and these factors are going to be great for the future.

311
00:52:17.220 --> 00:52:25.890
Roxanne Guenette: But the last topic, and then I'm finished. So I should just have enough time is the high pressure gasoline on two PCs, which is the other way to do this.

312
00:52:26.550 --> 00:52:32.010
Roxanne Guenette: Here it's again it's a TPC charge is going to be produced sensation light is going to be produced.

313
00:52:32.430 --> 00:52:45.570
Roxanne Guenette: The charge in high pressure gets to be sees is also amplified with an electronic media since regions, I already explained that to you. So the charge is going to be converted into light with the S one and then. So here again.

314
00:52:46.110 --> 00:52:54.570
Roxanne Guenette: So here I'm going to have different ways of looking at this, the tracking plane which is going to be made a very small city council to multipliers.

315
00:52:54.810 --> 00:53:01.410
Roxanne Guenette: Is going to be used to image the same way liquid are going to be co workers, providing those great images from the trial interactions.

316
00:53:01.890 --> 00:53:13.320
Roxanne Guenette: High pressure guess the pieces can do that too, with the tracking plane and the energy is reconstructed sometimes with photo multiplier tubes which are good at knowing exactly how much energy was from the region.

317
00:53:15.120 --> 00:53:34.050
Roxanne Guenette: Because I went from liquid to gas, it means that I have way less target right liquid has a lot of targets in it. So now I have, I need very high pressure to try to pack as much possible targets in my detector. If I want to see them, but then I'm going to have

318
00:53:35.100 --> 00:53:50.850
Roxanne Guenette: Great topology selections. Because if I'm in gas, the electrons, even at the MTV level are going to be able to go around up to 10s of centimeters. And this is what you see on this track here. You can imagine a events happening.

319
00:53:51.120 --> 00:53:56.220
Roxanne Guenette: And you can see it measures roughly 20 centimeters. So that gives you great images.

320
00:53:57.420 --> 00:54:08.160

Roxanne Guenette: And this is what you see at the bottom, why we want the images is because when we have a real debate that's happening where two electrons are emitted. They're going to wander around and stuff at the brand peak.

321
00:54:08.640 --> 00:54:16.560
Roxanne Guenette: Which is shown here. Those two blurbs that you can clearly identified compared to a background event where you had only one electron, because it didn't come from Adobe vindicate

322
00:54:16.830 --> 00:54:24.660
Roxanne Guenette: And this has only one bright peak. So by comparing those two, which is what you see here, you're going to be able to show how this, this works.

323
00:54:26.490 --> 00:54:32.010
Roxanne Guenette: The energy resolution also remember double beta decay needs the best energy resolution possible

324
00:54:32.430 --> 00:54:39.660
Roxanne Guenette: When you're in jazz. You start from a better point and this is what is shown here. The energy realization and function of density of the xenon

325
00:54:39.990 --> 00:54:45.480
Roxanne Guenette: In the guest phase which is at the bottom, you can see that there is a solution starts at around point 3%

326
00:54:45.750 --> 00:54:56.100
Roxanne Guenette: So you starting from a great point of view. And then things are good micro physics is going to happen again dettori are deteriorating that's resolution, but at least you're starting from a good point.

327
00:54:56.820 --> 00:55:02.070
Roxanne Guenette: And the last thing is you're going to be able to calibrate your detector very easily because you're in a gas face.

328
00:55:02.280 --> 00:55:10.350
Roxanne Guenette: So you can imagine having something like Krypton at 3am which is a very resurrects of sources that the case in two hours. So very quickly.

329
00:55:10.650 --> 00:55:15.840

Roxanne Guenette: You should that as a gas in your detector, the flow mix way quicker than and Nick, what are gone.

330
00:55:16.230 --> 00:55:31.440
Roxanne Guenette: Or liquid xenon, so that means that you can have your detect are full of calibration sources that around kV 40 kV and you can map out the entire detector several times during your data, taking and that's going to be very useful to understand the micro physics. I was talking to you about

331
00:55:32.820 --> 00:55:46.380
Roxanne Guenette: And I'm running out of time, but what I wanted to say here is that these, the way that we use high pressure guests. If you see gives us a great energy resolution below 1% where we care about in the 2.5 inch TV. So this is very promising.

332
00:55:46.830 --> 00:55:56.370
Roxanne Guenette: And these are example of events of the tracking plane. So the imaging capabilities from the signal which has to blobs compared to backgrounds that have single clubs.

333
00:55:58.620 --> 00:56:07.920
Roxanne Guenette: So I need to wrap up, as I said, these detectors are great to do a lot of different science neutrino installation double beta decay searches dark matter searches.

334
00:56:08.040 --> 00:56:14.910
Roxanne Guenette: I didn't talk about collider physics, but remember that some of the first liquid argon detectors were actually Keller mentors for collider physics.

335
00:56:15.300 --> 00:56:20.580
Roxanne Guenette: And there are different technologies. I only presented to you the most important right now, the ones that are most

336
00:56:21.360 --> 00:56:26.040
Roxanne Guenette: Visible but all of them that I've listed here are going to be using the future.

337
00:56:26.970 --> 00:56:33.450
Roxanne Guenette: And before I finished. I want to tell you that people I've even been thinking outside of the box with these detectors.

338
00:56:33.660 --> 00:56:41.370

Roxanne Guenette: I've shown you the normal ways of using them. But people have thought, what if I combine. So I'm just going to give you the example on the right, because I'm out of time, but

339
00:56:41.790 --> 00:56:51.300
Roxanne Guenette: What if I combined the beauty of the sensations coming from xenon, or are gone with another technique that has been very successful for dark matter experiments which are called bubble chambers.

340
00:56:51.660 --> 00:56:59.940
Roxanne Guenette: So what people have done is that the inserted some xenon in some are gone in bubble chambers and when things happen which produce a bubble that you can see

341
00:57:00.150 --> 00:57:10.230
Roxanne Guenette: Now it also produced translation light. So these are called multi modal detector is because they see different they see the heat that produce a bubble and delight that produce the signal.

342
00:57:12.180 --> 00:57:22.950
Roxanne Guenette: So that's it for today guys. I hope that you understand that novel elements actors are playing a big role. And we'll play a big role in particle physics. So you kind of have to understand roughly how they

343
00:57:22.950 --> 00:57:23.340
Roxanne Guenette: Work.

344
00:57:23.910 --> 00:57:31.860
Roxanne Guenette: And you could you could see by the different topics that I covered that are very versatile and scalable. Luckily for us, because we're going to be looking for very low processes.

345
00:57:32.640 --> 00:57:43.920
Roxanne Guenette: But there is a lot of things that you need to understand before you can claim that these detectors are used to their full potential. And that's why the whole experimental communities, doing a lot of R amp D and having a lot of fun with these great directors.

346
00:57:45.060 --> 00:57:46.740
Roxanne Guenette: Thank you for questions.

347
00:57:47.910 --> 00:57:50.700
thomas rizzo: Excellent, excellent. Thank you. Roxanne for a great talk.

348
00:57:51.780 --> 00:57:54.360
thomas rizzo: Will turn this over rich will ask you some questions.

349
00:57:56.190 --> 00:58:12.570
Richard Partridge: Hi, Roxanne, we have a number of questions that have been posted and I'm going to pick out a few of them and we will try and get to the rest of them offline. The first question is,

350
00:58:13.980 --> 00:58:14.820
What

351
00:58:16.890 --> 00:58:29.520
Richard Partridge: Can you please explain again why noble elements are sort of transparent towards the minute simulation bite can just like be absorbed by the ground state or atoms to excite them.

352
00:58:30.600 --> 00:58:34.890
Roxanne Guenette: So that's a very good question because I said this is the reason why these are so good.

353
00:58:35.400 --> 00:58:46.020
Roxanne Guenette: So the reason that that works is like it's kind of by pure chemistry chance. So when you have those sensation, like that is limited as one single wavelength was 128

354
00:58:46.320 --> 00:58:54.540
Roxanne Guenette: If you remember how chemistry works. They are so different levels that you can excite in an atom. And these levels are very specific to different items.

355
00:58:55.110 --> 00:59:10.800
Roxanne Guenette: It just turns out that the 128 if I'm thinking about are gone cannot excite exactly any of these excited states. So when it's going to be going. True. I'm not going to trigger any of them. If I was a different wavelength that would have one of those.

356
00:59:11.910 --> 00:59:14.790
Roxanne Guenette: States, then that could happen. But in our case it's not

357
00:59:16.020 --> 00:59:22.170
Roxanne Guenette: So I hope I don't want to go into the chemistry details, but I think that's that gets the point across.

358
00:59:25.980 --> 00:59:36.510
Richard Partridge: Next question is since the detectors for neutrino and dark matter or similar can we use present neutrino detectors for dark matter detection and vice versa.

359
00:59:37.650 --> 00:59:45.390
Roxanne Guenette: That's also a good question, right, because you know that in the future. We're going to have a kiloton scaled effect or is the largest novel Adam and detector ever built.

360
00:59:45.930 --> 00:59:57.030
Roxanne Guenette: So it would be good if we could do everything with that single one, but I think that, from what I showed that the physics requirements are so different. Let's just take the backgrounds, for example.

361
00:59:57.510 --> 01:00:06.300
Roxanne Guenette: When I build a dark smaller experiments which is a liquid PPC I'm going to select material that is extremely clean of

362
01:00:06.900 --> 01:00:22.140
Roxanne Guenette: Radioactivity like, you know, right, the dust is very retroactive petroleum and the uranium that we have in the air can emit a lot of regulations that can be detected in every sense of the factors like dark model. So when I build a dark matter one I select material that is low.

363
01:00:22.140 --> 01:00:22.680
Richard Partridge: Purity

364
01:00:22.770 --> 01:00:29.310
Roxanne Guenette: You have to contact vendors to make sure that what they're going to sell you is going to be clean. You've tested, even before you install it.

365
01:00:29.550 --> 01:00:36.450
Roxanne Guenette: You do that in a clean room where everybody is like suited up to make sure that we're not going to put any dust in our detector and we close it up.

366
01:00:36.960 --> 01:00:49.500
Roxanne Guenette: Now imagine that you're building Dune, which is a 70 meters by 20 by 20 so imagine all the material that you have there. And I'll try to select materials that are so Reggie pure you just like

367
01:00:50.310 --> 01:01:00.570
Roxanne Guenette: Bread. The cost like crazy. So unfortunately we cannot use those. There are ways of thinking you could imagine having some

368
01:01:01.800 --> 01:01:12.690
Roxanne Guenette: Financials arena in the middle. But then you're confined to smaller detectors. So for now, we are obligated to think in the tree different science goals that I've

369
01:01:13.170 --> 01:01:26.040
Roxanne Guenette: Shown to you and people are trying really hard to think of ways to come up with solutions for everybody. We are aware that we do not want to waste any resources between the tree, but it's two different. Yeah.

370
01:01:30.180 --> 01:01:36.450
Richard Partridge: Okay. A little background noise here. But hopefully you can hear.

371
01:01:37.680 --> 01:01:47.700
Richard Partridge: How is the spatial resolution you find is a functional the distance between two parallel word. Is there a minimum distance by which the words need to be separate.

372
01:01:49.050 --> 01:01:54.000
Roxanne Guenette: That's a very good question from somebody that cares about the micro physics, which is great.

373
01:01:54.390 --> 01:01:58.230
Roxanne Guenette: So technically what you would want to do is have them as close as possible.

374
01:01:58.500 --> 01:02:10.140
Roxanne Guenette: Because then you would have very good resolution. So let's imagine you go to even like those wires are usually 150 microns thick so you could just think of having three times that distance and having very fine grain.

375
01:02:10.590 --> 01:02:14.400
Roxanne Guenette: But what is the first thing that those electrons are going to do in their produce. They're going to diffuse

376
01:02:14.790 --> 01:02:18.720
Roxanne Guenette: So there was no way that you will benefit by having

377
01:02:19.020 --> 01:02:31.590
Roxanne Guenette: Wire spacing. That is below the the fusions that you have, if you think of liquid argon detectors for Neutrino Physics, the drift over 2.6 meters, because they're very large detectors. So diffusion is becoming quite big.

378
01:02:32.130 --> 01:02:39.330
Roxanne Guenette: So you have a minimum distance that comes from the micro physics that you can get. And then you're going to try to see how much it cost and how much

379
01:02:40.200 --> 01:02:44.370
Roxanne Guenette: Background selection power rejection power, you're going to have with your different

380
01:02:45.300 --> 01:02:56.070
Roxanne Guenette: Spacing people have put a lot of effort into simulating many different ones. And for example, in doing. We decided to go for five millimeter spacing, which is good enough for what we want, or don't we could go

381
01:02:56.970 --> 01:03:03.390
Roxanne Guenette: Lower the diffusion is not the limit here. But if you go back to neutral, so beta decay, for example.

382
01:03:04.320 --> 01:03:22.800
Roxanne Guenette: These also the resolution here is given by sipping not by wires. So here again you could push the resolution coming from those. So the point is, what is the ideal spacing. Well it again, it depends on your physics requirements, but you have to beat micro physics.

383
01:03:27.510 --> 01:03:28.950
Richard Partridge: Okay, thank you.

384
01:03:30.720 --> 01:03:33.810
Richard Partridge: Next question is,

385
01:03:38.070 --> 01:03:56.070
Richard Partridge: It appears that we combinations are intrinsic to the Oregon or Xena me that even if you had 100% pure and Obama who still get the same week combination probability is a very dirty detector. That's how do we tell the difference between recombination and electro negative impurities.

386
01:03:56.910 --> 01:04:06.630
Roxanne Guenette: That's a very good point. It's not easy once you have a dirty detector. So ideally what you would do is you would understand

387
01:04:07.140 --> 01:04:12.930
Roxanne Guenette: Extremely well those two processes, you would have calibrated them in different environments. And you could

388
01:04:13.410 --> 01:04:23.010
Roxanne Guenette: Extract the parameters and just fit them back into your detector and that would be perfect, but in reality we can never have a infinitely pure the

389
01:04:23.940 --> 01:04:30.780
Roxanne Guenette: Noble elements. So you will always have contamination. So these effects are always going to be involved. So the only way that we have to do.

390
01:04:31.110 --> 01:04:45.840
Roxanne Guenette: Is to make a lot of measurements like by many different techniques and then combine that into our understanding, and then at some point it will remain a limiting systematics on certain even if very small compared to other things. But yeah, that's very good point.

391
01:04:48.660 --> 01:04:57.960
Richard Partridge: The next question is how quickly is our good 39 produced from cosmic my exposure. Will this be a concern for the time scale of an experiment.

392
01:04:58.920 --> 01:05:09.810
Roxanne Guenette: That's it. So dark matter experiments. Luckily, are always located on the ground, because otherwise backgrounds is too high. So what people are doing. And that's a good question. In

393
01:05:10.260 --> 01:05:12.810
Roxanne Guenette: The sense that you have to be careful with that are gone already knowing

394
01:05:13.080 --> 01:05:18.780
Roxanne Guenette: When you extract it, you need to go, store it as soon as possible on the ground, because otherwise you're going to activate it.

395
01:05:19.230 --> 01:05:24.660

Roxanne Guenette: So if you can do that very quickly. And that's why the people in the future are thinking of having

396
01:05:25.260 --> 01:05:35.940
Roxanne Guenette: Plans of extraction of underground are gone very near where they're going to be located there detectors. So there is one in the US in Colorado, there is one in Sylvania in Italy.

397
01:05:36.420 --> 01:05:44.220
Roxanne Guenette: It's not very, it's quite near to get on muscle near is relative, I guess. And these are going to be extracted CMT music the underground and stored there.

398
01:05:44.670 --> 01:05:56.430
Roxanne Guenette: And underground, the rates of kosmix is so small that you know it's one for, I don't know. I'm saying anything because it depends where you are, but you're not gonna have a lot of our gun 39 activated on the ground.

399
01:06:00.000 --> 01:06:14.460
Richard Partridge: Thank you. Next question is, as of now we only know that dark matter interacts only gravitational how liquid noble elements produced simulation process that is predominantly electromagnetic

400
01:06:15.660 --> 01:06:18.150
Roxanne Guenette: This comes from is skeptical.

401
01:06:19.140 --> 01:06:25.860
Roxanne Guenette: We don't know if dark matter do only interact revelation live by gravitational waves.

402
01:06:27.420 --> 01:06:40.830
Roxanne Guenette: We are doing that for nothing, but we don't know that. So we need to go check to make sure that they don't interact weekly. But yeah, we were thinking a gamble here hoping that particles do interact weekly at some level.

403
01:06:42.540 --> 01:06:48.360
Roxanne Guenette: Thanks. The theorists, there was many different ways that those particles get can interact, though. So, that's okay.

404
01:06:51.660 --> 01:06:59.250
Richard Partridge: Um, what factors can be important when deciding between capturing charge or light, etc.

405
01:07:01.050 --> 01:07:09.240
Roxanne Guenette: That's a it's an optimization game, you're going to have to think of your physics that you want to do, how difficult it is

406
01:07:10.050 --> 01:07:22.020
Roxanne Guenette: To, for example, remember how I showed that has very high electric field you get very low amount of sensation. So if you were able to go to very, very high electric fields, you could

407
01:07:22.590 --> 01:07:34.380
Roxanne Guenette: Opt for having more charge, but it's not easy. Technically, to go to high voltages and here I'm talking about right now we are the order of 100 kilo volts, that we can apply to create those electric fields.

408
01:07:34.770 --> 01:07:45.750
Roxanne Guenette: So going higher than that. It's got is it technically challenging. So again, if you were telling me, can you please give me a detector that it has that high voltage, I would tell you. Well, I need to do R amp D.

409
01:07:46.200 --> 01:07:52.140
Roxanne Guenette: So that's why people have been playing at the optimization of what you want to do with the physics. What is doable.

410
01:07:52.470 --> 01:08:01.470
Roxanne Guenette: With the technology that we have, how can we push this technology in the future to get to something even more optimal. And this is why I was saying that there is a lot of R amp D happening.

411
01:08:01.740 --> 01:08:13.410
Roxanne Guenette: Because another thing that I didn't mention is you can cheat the sensation by having gas mixture. So in the liquid Oregon detectors. Remember I said 128 nanometers was too low.

412
01:08:13.980 --> 01:08:20.550
Roxanne Guenette: To detect with normal photo detection, the factors you can dope the are gone with xenon

413
01:08:21.090 --> 01:08:37.230
Roxanne Guenette: Which then will mean that the sensation light is pushed up to 175 and maybe you can detect them detected directly. So we are really thinking of everything to make use of actors Bella, and I hope that you will be too because they'll be around for a while. So any ideas is worth investigating

414
01:08:39.750 --> 01:08:41.760
thomas rizzo: Maybe time for one more short question.

415
01:08:42.330 --> 01:08:56.430
Richard Partridge: Okay, last question in a solution only detector. How do you construct the total energy as well as it is one over as to discrimination that tells you whether you sign of electronic or nuclear recoil.

416
01:08:57.570 --> 01:09:02.640
Roxanne Guenette: So in the single phase, you don't have to. So you only have the S one

417
01:09:03.120 --> 01:09:13.380
Roxanne Guenette: So what they are doing. There is they are trying to because they see all the light right. You saw how I can maybe go back to this, the really have a 100% coverage of the

418
01:09:14.250 --> 01:09:20.160
Roxanne Guenette: Of the inside of the doctor is you see how tightly packed those PMT is our and this isn't in 3D, as well.

419
01:09:20.700 --> 01:09:28.080
Roxanne Guenette: So with this, they can know exactly where the position happen so basically they know that if it happened near the surface. It's a background.

420
01:09:28.530 --> 01:09:34.050
Roxanne Guenette: They can also reconstruct all the energy because everything that goes into sensation.

421
01:09:34.500 --> 01:09:40.740
Roxanne Guenette: Is going to be detected and if they calibrate the detector very well because of course they don't see the charge. So that is lost.

422
01:09:41.010 --> 01:09:49.740
Roxanne Guenette: But if you calibrate the very well with the sources that you know the exact energy. You know, this factor difference between the charge and the

423
01:09:50.520 --> 01:10:00.930

Roxanne Guenette: End the light. So the energy is not too hard to reconstruct and then the last thing is differentiating between electric electric electronic records and

424
01:10:02.070 --> 01:10:09.870
Roxanne Guenette: Nuclear recoils so this is also done in a way that by studying the pulses that come from the amount of light that is being

425
01:10:11.430 --> 01:10:24.030
Roxanne Guenette: Recorded electric vehicles are lower energy done nuclear recall, so they can also play that game, but it's not as powerful as the poor shape discrimination on an event by event phases. So they are going just by the total energy

426
01:10:26.580 --> 01:10:27.150
Richard Partridge: Thank you.

427
01:10:28.620 --> 01:10:37.080
thomas rizzo: Okay great, thanks. Rich and thanks so much. Roxanne, for that great presentation. And of course, we're going to see you again tomorrow.

428
01:10:37.770 --> 01:10:38.100
Yes.

429
01:10:39.840 --> 01:10:54.780
thomas rizzo: Very good. Thanks again. Just one comment for everyone, before we, before we go earlier, there was some problem with finding the links for the posters on the SSI page. Hopefully that problem is resolved. Now, so you should all go

430
01:10:54.780 --> 01:10:56.910
thomas rizzo: Have a look at some of these really nice posters.

431
01:10:58.140 --> 01:11:03.750
thomas rizzo: And enjoy yourself. And we'll see you all tomorrow, or at least virtually. Okay, goodbye.