WEBVTT

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00:00:03.149 --> 00:00:14.880
mark convery: And smile and say, Oh, very pleased to have Johnny Cooley from summit about this university to give us a second lecture series on dark matter. So, Jody, go ahead and get going.

2
00:00:16.260 --> 00:00:26.580
Jodi Cooley: Thank you. So it's very nice to be back. And I'm actually excited today to be able to get out of the weeds of, you know, thinking about all the formulas and

3
00:00:27.120 --> 00:00:43.110
Jodi Cooley: Types of physics that we think about when we design experiments and to be able to give you some example of direct detection experiments that are out there that we're working on now and also give you a little flavor of what's going to maybe happen in the future.

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00:00:46.800 --> 00:01:01.260
Jodi Cooley: So let me start right away by by getting rid of, of this first concern that always comes up and that sort of addressing the question of whether or not we have already seen a dark matter signal so

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00:01:03.300 --> 00:01:12.840
Jodi Cooley: As probably everyone in the audience has heard there is a collaboration called the domino lever collaboration and they have them reporting.

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00:01:14.190 --> 00:01:18.360
Jodi Cooley: Positive results, meaning that they are seeing a dark matter signal.

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00:01:19.410 --> 00:01:21.780
Jodi Cooley: Ever since 1998

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00:01:22.980 --> 00:01:38.670
Jodi Cooley: This experiment started as the DOM experiment. It was 100 kilograms of sodium iodide crystals that were operated in the grand salsa laboratory from 1996 to 1992 2002 then they took a little break and they upgraded their experiment.

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00:01:39.990 --> 00:01:51.180
Jodi Cooley: And built the Libra experiment. So now we have the Donald Libra experiment. And that's the 250 kilograms or re that's been operating since 2003 with their first results reported in 2008

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00:01:51.780 --> 00:02:02.010
Jodi Cooley: So let me, you know, be clear that dogma first reported positive signal at greater than five sigma and then Libra has further

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00:02:03.270 --> 00:02:05.730
Jodi Cooley: Confirmed that signal for themselves.

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00:02:06.900 --> 00:02:22.890
Jodi Cooley: What they do with their crystals is they basically just measure the centralization signal for particle interactions and their detectors, so they don't discriminate against nuclear recoil and electron recoils they just have access events.

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00:02:24.120 --> 00:02:37.290
Jodi Cooley: And so here what you're going to look at is this first top slot here is showing the domino Libra phase one, which was dogma and then face to where they added Libra on

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00:02:37.950 --> 00:02:48.360
Jodi Cooley: And what you can see here is that they have observed a signal over 14 cycles at a 12.9 sigma in the two to six k Ed been

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00:02:50.220 --> 00:02:57.780
Jodi Cooley: And so as you you might know they're actually looking for the annual modulation signal which we talked about in the last lecture, period.

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00:02:58.230 --> 00:03:10.860
Jodi Cooley: And you can see that they very clearly have a signal that oscillating with a maximum in June and a minimum in December cycle after cycle after cycle, as you would expect if that was a signature you're looking for.

17
00:03:12.900 --> 00:03:23.280
Jodi Cooley: If you look, just that phase two and you ignored the first phase of the experiment, then they're reporting signal becomes a 9.5 sigma significance.

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00:03:24.510 --> 00:03:32.040
Jodi Cooley: And in phase two, they actually analyzed and even lower energy been below to kV so they went from one to six k TV.

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00:03:33.090 --> 00:03:34.920

Jodi Cooley: And that was observed over six cycles.

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00:03:36.000 --> 00:03:43.410
Jodi Cooley: You know, the issue of course. And so here's the one to six k eV then for that that second phase I was talking about.

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00:03:44.400 --> 00:03:57.210
Jodi Cooley: And so the problem that you have here is that you don't discriminate between your background and your signal. So you have to believe that you really understand all of your backgrounds and what

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00:03:57.960 --> 00:04:08.760
Jodi Cooley: And how those backgrounds behave if you have any background that could oscillate over the course of the year for variety of reasons that could fake you out.

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00:04:10.140 --> 00:04:15.990
Jodi Cooley: The other thing about the Donald Libra experiment. That is, you know, sort of problematic.

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00:04:16.440 --> 00:04:30.420
Jodi Cooley: You know, from my perspective, is that we really don't know much about the signal simply can't discriminate between electron recoils and nuclear recoils it means we don't actually know much about how the signal that they're seeing is interacting

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00:04:31.470 --> 00:04:43.980
Jodi Cooley: You know, at an atomic level in their detectors. And so in the community. There's a lot of debate over whether they are observing a background that modulates consistently or whether

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00:04:44.670 --> 00:04:56.910
Jodi Cooley: They are seeing dark matter. And part of the reason that this is such a big debate is because no other experiment has detected a signal of dark matter to be able to confirm this.

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00:04:58.020 --> 00:05:13.260
Jodi Cooley: And as a matter of fact, his intention with quite a number of experimental results in the face face at which this potentially could be a dark matter signal becomes difficult to to resolve.

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00:05:14.490 --> 00:05:24.570
Jodi Cooley: And in the community. If you were to go online look on the archive and start looking around at interpretations of dominant Libra especially background interpretations

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00:05:25.530 --> 00:05:35.700
Jodi Cooley: You'll see that there are papers written where there are disagreements on the background models for dumber Libra. So some people outside the collaboration have tried to model the background to see

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00:05:36.480 --> 00:05:52.650
Jodi Cooley: You know if they could explain it. And you know, you might ask me what is the dark matter. I mean, what is Donald lieberstein and and if I knew I would write a paper like if I knew for sure it is. I'd write a paper and maybe become very famous for, for being able to to explain it.

31
00:05:53.850 --> 00:05:56.220
Jodi Cooley: But some ideas of things that people have thought about

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00:05:57.600 --> 00:06:04.290
Jodi Cooley: There's this release of three k eV X rays and OJ electrons that are associated with a rare decayed.

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00:06:06.090 --> 00:06:19.740
Jodi Cooley: Of potassium 40 and so it's possible that the amplitude of the modulation might be able to be explained by this if it is that maybe the measurement of the crystals isn't exactly right.

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00:06:21.150 --> 00:06:25.800
Jodi Cooley: Or maybe they have a threshold that's moving on an annual cycle.

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00:06:27.120 --> 00:06:34.740
Jodi Cooley: Another paper have brought up ideas of, you know, could radioactivity from argon impurities that are in the nitrogen purge that surrounds

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00:06:35.910 --> 00:06:49.860
Jodi Cooley: The vessel. So we had talked about shielding yesterday. And a lot of times their shields are purged with pure gases to help keep the radon away. Is it possible that something, something like that could be going on.

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00:06:52.290 --> 00:06:58.950
Jodi Cooley: You know, it could be some kind of read on included neutron or gamble read flux from the cavern.

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00:07:00.060 --> 00:07:10.920
Jodi Cooley: One thing we're pretty sure it's not our view on from cosmic rays. So you want from cosmic ray would be an actual candidate because it does it is something that modulates over the course of the year in underground line.

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00:07:13.980 --> 00:07:33.480
Jodi Cooley: And so there is a worldwide effort to try to directly test with Donald Libra experiments. So essentially these are experiments that are, you know, trying to use the same techniques that Dominic Libra did with the same target in order to see if they can replicate the results.

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00:07:34.620 --> 00:07:45.540
Jodi Cooley: And it is a pretty large effort. One of the biggest challenges is getting crystal like sodium iodide crystals that are as cure and radioactivity is what Donna Libra half

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00:07:47.430 --> 00:07:55.650
Jodi Cooley: One of the most recent experiments and probably I would say the leading experiment in this field for trying to directly test. This is the cosine 100 experiment.

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00:07:56.460 --> 00:08:15.540
Jodi Cooley: This is a combination of what was formerly known as a Kim's experiment in DM ice and is located in the ganging laboratory in South Korea. They have eight copper encapsulated sodium iodide crystals are total of 106 kilograms and each crystal is looked at

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00:08:16.620 --> 00:08:22.620
Jodi Cooley: With two three entropy empties their trigger threshold is about point two photo electron

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00:08:24.240 --> 00:08:30.780
Jodi Cooley: And they do calibration of their detector using source to so it's pretty much all filled up except for those source tubes that go in

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00:08:32.100 --> 00:08:39.120
Jodi Cooley: So down here in the lower left hand corner. What you'll see is the eight crystals. Each of the crystals mass

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00:08:40.290 --> 00:08:52.410
Jodi Cooley: The powder. So the powder is basically talking about the powder that is used to grow the crystal. These are sort of like things that people develop can be trademark secret if it was a corporation.

47

00:08:53.820 --> 00:09:06.930
Jodi Cooley: And then the alpha rate potassium right uranium and Dorian. So remember I kept saying these are the three things that everybody thinks about when they're making these experiments, potassium, your inventory them and then the light yield and so

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00:09:08.100 --> 00:09:15.330
Jodi Cooley: Their total background is about two to four times higher than the Donald Libra average in the region of interest.

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00:09:16.500 --> 00:09:29.160
Jodi Cooley: But they're uranium sodium and potassium are often below dogma and the polonium 210 is really close and their PMT is have very high light yield, which is which is great.

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00:09:31.290 --> 00:09:50.730
Jodi Cooley: And so cosine recently released results of a modulation search that included 1.7 years of exposure. So this is a almost 100 kilogram years of exposure, the user global fit using cosmic Janet and the sunny side all components simultaneously for the crystals.

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00:09:52.710 --> 00:09:53.130
Jodi Cooley: And

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00:09:54.180 --> 00:10:04.290
Jodi Cooley: They essentially excluded crystals one five and eight from the analysis because there were some problems with the PMT they had excessive noise and their light yield was

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00:10:06.030 --> 00:10:17.340
Jodi Cooley: was lower than they would have hoped for. And so basically their side bands outside of the region of interest to Cade as expected with the cosmic genetic components.

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00:10:18.390 --> 00:10:25.380
Jodi Cooley: And so overall the they use the good crystals and their data seem to be a good quality.

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00:10:26.640 --> 00:10:39.180
Jodi Cooley: And so what their results said was that they ended up with a best fit amplitude of point 0092 counts per kilogram per day per kV

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00:10:40.080 --> 00:11:03.210
Jodi Cooley: And the modulation happening on a cycle of like 127.2 days. And so what you can see here is looking at the amplitude modulation

versus the phase days and this plus sign here represents where the Donald Libra best fit is and the the dot here represents the cosine results.

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00:11:04.290 --> 00:11:26.040
Jodi Cooley: And so overall, basically the takeaway messages that the result was disappointing and it was consistent, both with the null hypothesis and with Donald leverages best value for a modulation. So what we can expect going forward is that it would take

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00:11:27.120 --> 00:11:33.300
Jodi Cooley: In order to get sort of a three sigma coverage of the Dharma, the raw sort of signal region.

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00:11:34.530 --> 00:11:36.960
Jodi Cooley: It would take about five years of data exposure.

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00:11:38.610 --> 00:11:49.170
Jodi Cooley: In future analyses, they're hoping to lower their threshold to at least one kV if not lower improve their events selection.

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00:11:50.220 --> 00:11:56.070
Jodi Cooley: And if they're able to do that, it wouldn't take as long to be able to do

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00:11:57.120 --> 00:12:02.580
Jodi Cooley: To to to wouldn't take five years to get to the three sigma coverage and could do it faster.

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00:12:05.400 --> 00:12:13.380
Jodi Cooley: So moving on. I'm really not going to say much about the liquid metal detectors in this talk. I'm only going to just kind of give them a cursory view.

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00:12:13.710 --> 00:12:22.620
Jodi Cooley: And that is because our Roxanne gave lectures on liquid noble TPC for dark matter searches, along with internal, external beta decay.

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00:12:23.130 --> 00:12:33.930
Jodi Cooley: And and other sorts of searches on the first day of the lectures and so I put a link here to where you can do her talk if you do want to hear some more details about these types of detectors in general.

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00:12:35.250 --> 00:12:43.020

Jodi Cooley: But for those of you who missed it. Let me give you just sort of the highlights. So dual face time projection projection chambers.

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00:12:44.010 --> 00:12:56.550
Jodi Cooley: Are sort of widely used other you there are sort of for experiments out there that are kind of leading the charge in this the xenon collaboration, the Lux I'll the collaboration. The Dark Side collaboration and Panda x

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00:12:57.720 --> 00:13:02.430
Jodi Cooley: And basically the idea is, is that you would have a particle come in and interact

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00:13:04.380 --> 00:13:14.130
Jodi Cooley: In the liquid phase of the of the detector that interaction would yield some civilization. Wait, electrons would drift off into

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00:13:14.790 --> 00:13:30.720
Jodi Cooley: The gashes region of the direct the detector. This is because there's an electric field that's applied across the whole chamber and the gas phase. The electrons are further accelerated and they produce a second centralization signal.

71
00:13:31.740 --> 00:13:47.130
Jodi Cooley: If it is that you compare the first civilization signal to the second civilizations signal. If you have a nucular recoil like you would get from a whim. You can see the ratio of these two signals would be smaller than if you had

72
00:13:48.630 --> 00:13:59.490
Jodi Cooley: An interaction from the gamma where the ratio of S one, S two. So the first civilization to the second centralization would be a larger value and then you can get

73
00:14:00.360 --> 00:14:14.820
Jodi Cooley: The z to put the pendants or where the position of the particle interaction happened in the TPC from looking at the drift time and then because the top and bottom of these detectors are instrumented with an array of

74
00:14:17.130 --> 00:14:22.770
Jodi Cooley: That both those can give you the x, y coordinates.

75
00:14:24.270 --> 00:14:36.090

Jodi Cooley: And so just to take a look at these are the three experiments that are using Xena. You can see for all three of them. What you're looking for here in the top. This is comparing going

76
00:14:37.170 --> 00:14:37.890
Jodi Cooley: Downward

77
00:14:39.090 --> 00:14:39.900
Jodi Cooley: So going

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00:14:41.340 --> 00:14:47.610
Jodi Cooley: Vertically in these thoughts are for each experiment and going horizontally. You're seeing

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00:14:48.660 --> 00:15:05.520
Jodi Cooley: calibrations on the top for electronic recoils the blue solid line is giving you the median signal in each of the three detectors and the red line is giving you what would be expected for nucular recoil, the media and the second line.

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00:15:06.540 --> 00:15:26.010
Jodi Cooley: Of plot what you're seeing is a neutron calibration. And again, the blue line here is telling you where the median would be for your electron recoil. And then the third pain is showing you dark matter searches and as you can see, you can get fairly good separation.

81
00:15:27.150 --> 00:15:31.980
Jodi Cooley: Between your electronic records and your nuclear recoils in these types of experiments.

82
00:15:33.150 --> 00:15:48.840
Jodi Cooley: So there is one piece of information I want to add that I didn't notice rocks on slides, when I was looking at them from last Monday. Monday and that is talking about how it is that we get the energy from these types of experiments. And I think this is an important thing to note

83
00:15:50.130 --> 00:15:59.250
Jodi Cooley: Because it helps you understand where research needs to be done and were errors systematic errors, perhaps could come into results.

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00:16:00.390 --> 00:16:01.080
Jodi Cooley: And so

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00:16:02.400 --> 00:16:04.260
Jodi Cooley: In a, in a TPC

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00:16:05.610 --> 00:16:15.870
Jodi Cooley: So little liquid noble your energy of your nucular recoil is going to be equal to be observed ventilation, which is measured and photo electron

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00:16:16.470 --> 00:16:30.870
Jodi Cooley: Divided by your light yield, which is in full electrons PR ke VI m times this L effective and this L effective is the simulation efficiency of a nuclear recoil.

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00:16:31.260 --> 00:16:50.670
Jodi Cooley: In liquid xenon, or if you had an Oregon experiment would be in liquid are gone. And then that is multiplied by a suppression factor se over ASR. This is the suppression of the centralization signal from the electric field for electronic recoil and new further recoil events.

89
00:16:51.870 --> 00:17:04.410
Jodi Cooley: So let's break this down a little bit further. So L effective accounts for the quenching of the centralization signal for nucular recoil and this is essentially

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00:17:05.520 --> 00:17:16.830
Jodi Cooley: What what at least is enough collaboration often use us to to get this elephant is looking at the one or making comparisons to the 122 gamma line from a cobalt 57 source.

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00:17:18.210 --> 00:17:28.770
Jodi Cooley: And then going even further. The nucular energy recoil or nucular recoil energy is also related to us to

92
00:17:29.550 --> 00:17:35.340
Jodi Cooley: And then again, that is your energy is the observed simulation and total electrons.

93
00:17:36.240 --> 00:17:50.910
Jodi Cooley: Divided by why we're this why is a secondary application factor and it's given in terms of total electrons per electron and then one over to why we're this to why is the number of free electrons per unit energy

94
00:17:52.080 --> 00:18:06.900

Jodi Cooley: So this might be more detail than you ever thought you would get in a talk like this. But I think it's important, sometimes to just, just take a look at these these things and realize it. And there are some really great papers out there that talk about how these calibrations are done.

95
00:18:07.980 --> 00:18:12.780
Jodi Cooley: In xenon and in are gone and where the measurements on could be improved.

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00:18:13.890 --> 00:18:23.670
Jodi Cooley: So the status of current TPC experiments in the world, the xenon and 10 experiment which is in grants also is under construction.

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00:18:24.750 --> 00:18:36.240
Jodi Cooley: And basically that's expected to be around under construction from 2019 TAKING SCIENCE through 2025 and this is going to be eight tons of liquids in on

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00:18:37.260 --> 00:18:54.270
Jodi Cooley: The LD experiment is under construction right now. And I know that they are working as hard as they can to get their science data, taking up going very soon. These two experiments one neck and neck and they are always sort of leapfrogging each other in who has the best results.

99
00:18:56.040 --> 00:19:02.610
Jodi Cooley: Panda x is a Chinese experiment, they have a four ton liquid xenon experiment that is currently under construction.

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00:19:04.080 --> 00:19:07.410
Jodi Cooley: And so they are also trying to get the results out soon.

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00:19:08.430 --> 00:19:14.910
Jodi Cooley: And then the dark side 20 K experiment. This is sort of 20 or 50 tons of liquid are gone.

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00:19:16.080 --> 00:19:26.400
Jodi Cooley: As far as I know, it's still sort of under design. There's another dark side experiment that's that's running and and that you will have seen results from

103
00:19:28.590 --> 00:19:33.960
Jodi Cooley: Alright, so now I want to work on. Look, look at another technology. And this is all chambers.

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00:19:34.260 --> 00:19:41.910
Jodi Cooley: So bubble chambers where these instruments that were used for particle physics, a long time ago. You probably think of your grandparents as

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00:19:42.300 --> 00:19:50.400
Jodi Cooley: Being the type of people who would have done bubble chamber experiments and particle accelerators, but they have made a comeback in dark matter surges.

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00:19:51.270 --> 00:20:01.740
Jodi Cooley: And so let me tell you a little bit about how a bubble chamber works. So the idea is that you're trying to create a bubble in unknown in a superfood super heated liquid

107
00:20:03.360 --> 00:20:05.250
Jodi Cooley: And so the idea is that

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00:20:06.450 --> 00:20:15.960
Jodi Cooley: Let's say that you have some liquid with a bubble in it. So we're going to start with a bubble in a liquid that's in thermal and chemical equilibrium

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00:20:16.560 --> 00:20:27.540
Jodi Cooley: And so if the pressure of the bubble is greater than the pressure of the liquid. And at this point, we're just going to ignore surface tension. The bubble is going to expand.

110
00:20:29.490 --> 00:20:39.630
Jodi Cooley: If we include surface tension which can be represented by P equals to sing over are the bubble will grow when the pressure

111
00:20:40.830 --> 00:20:47.370
Jodi Cooley: Of the bubble is greater than the pressure of the liquid plus the pressure the circuit surface tension.

112
00:20:48.510 --> 00:20:56.250
Jodi Cooley: And if the radius of the bubble is greater than the critical radius, essentially, you get

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00:20:58.350 --> 00:21:02.940
Jodi Cooley: That sort of the other criteria that you need the radius of a bubble has to be bigger than

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00:21:03.480 --> 00:21:10.770
Jodi Cooley: This critical radius and the critical radius depends on the surface tension and then the pressure of the bubble and the pressure of the liquid

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00:21:11.220 --> 00:21:21.900
Jodi Cooley: And bubbles that don't meet the criteria being bigger than the critical radius and the pressure of the bubble exceeding liquid plus surface tension those bubbles will collapse.

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00:21:23.100 --> 00:21:35.670
Jodi Cooley: Okay. And so essentially you need some kind of process to start the nuclear option of a bubble. And so that has to happen.

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00:21:36.360 --> 00:21:49.680
Jodi Cooley: With some sort of threshold energy and not threshold energy is given by this fairly long formula which essentially has three components is essentially the surface energy plus the bulk energy minus the reversible work.

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00:21:51.210 --> 00:21:57.000
Jodi Cooley: Okay, so why is this important, and why is it so great. So if you take a look at this.

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00:21:58.800 --> 00:21:59.760
Jodi Cooley: This plot here.

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00:22:00.870 --> 00:22:16.590
Jodi Cooley: This is the detector response or a bubble chamber versus a threshold energy. And so what you can see is that here we have any gamma rays. What a 50 GB dark matter particle would look like neutrons alpha particles in new for the required

121
00:22:17.970 --> 00:22:25.020
Jodi Cooley: So notice that the heavier the particle becomes the higher the threshold that is needed in order to form a bubble

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00:22:27.060 --> 00:22:43.200
Jodi Cooley: So essentially what this means is that the biggest background that you have in these dark matter experiments are electron required, and that would be essentially these gamma rays would represent that in the spot. And so you can tune your bubble chambers threshold.

123

00:22:45.930 --> 00:22:50.790
Jodi Cooley: To be insensitive to these electron recoils which is your biggest background.

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00:22:52.140 --> 00:23:04.140
Jodi Cooley: And then you might worry about the neutron. And so using shielding and going to an underground location. You can moderate your neutrons to a very small or minimal level.

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00:23:05.670 --> 00:23:11.460
Jodi Cooley: So then the only thing you're left with are these alpha particles, what do you do about your alpha particles.

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00:23:13.050 --> 00:23:31.050
Jodi Cooley: Well, it turns out that you can by listening essentially to these bubbles. You can discriminate against us and whip particles. So essentially the idea being that alphas will deposit their energy over 10s of microns.

127
00:23:32.220 --> 00:23:37.080
Jodi Cooley: Where a nucular recoil like you would get from a wimp.

128
00:23:38.700 --> 00:23:58.200
Jodi Cooley: With deposit their energy over 10 nanometers. And then in addition, the alpha particles or four times louder. As you can see here, then your neutron and so the sound or this formation sound of these bubbles can be measured using P zero electric sensors.

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00:23:59.760 --> 00:24:10.140
Jodi Cooley: And so this has worked out really well. So the people program people originally started as two different experiments caso and COO, and then they merged.

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00:24:10.800 --> 00:24:26.250
Jodi Cooley: And they have done runs using several different types of technologies they had a two liter experiment they realized that at some point that they could get better sensitivity by turning their bubble chamber essentially upside down.

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00:24:27.900 --> 00:24:30.180
Jodi Cooley: So they have the the 40 leader experiment.

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00:24:31.620 --> 00:24:41.310

Jodi Cooley: And Pico 60 is in its second run and essentially going into the future that we're looking at people 500 people have some leading results.

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00:24:41.880 --> 00:24:53.550
Jodi Cooley: Looking at independence WENT NUCLEAR on cross sections. And one of the things that's really nice about these bubble chamber experiments is that you can fairly easily swap out the target.

134
00:24:56.010 --> 00:25:08.640
Jodi Cooley: And so, if ever there's a dark matter discovery. This could be really important for trying to figure out things like the dark matter. The exact mass of the dark matter, figuring out different

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00:25:11.250 --> 00:25:22.320
Jodi Cooley: Properties of the interactions, like at the nuclear scale. So that's what makes these chambers kind of exciting. What makes them difficult is building them large enough

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00:25:24.450 --> 00:25:35.850
Jodi Cooley: And so now, at this point, I'd like to move on to cryogenic detectors and by cryogenic detectors are kind of mean I need a chapter that is measuring a phone on which is like the vibrational energy inside

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00:25:36.450 --> 00:25:42.810
Jodi Cooley: The detector and that can be done by either directly measuring photons or by measuring heat signals.

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00:25:44.070 --> 00:25:51.480
Jodi Cooley: So essentially, there are two families of sensors for phone on signal of the thermal and a thermal

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00:25:53.760 --> 00:25:56.550
Jodi Cooley: The idea is that you would have

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00:25:57.810 --> 00:26:07.530
Jodi Cooley: You know, some kind of refrigerated medium with a week thermal link to an absorber, and you would measure the temperature of that absorber.

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00:26:08.520 --> 00:26:21.120
Jodi Cooley: I'm the thermal sensors that wait for the civilization of finance within the bulk of the sensor within the bulk of the material in the center itself and then the temperature increases equal

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00:26:21.840 --> 00:26:29.940
Jodi Cooley: To the deposited energy over the heat capacity of the system. And so there are essentially two technologies that are widely used.

143
00:26:30.630 --> 00:26:42.150
Jodi Cooley: For trying to measure this type of signal. One of them is a neutron dope germanium sensor or an MTV. And then the other one is a transition edge sensor or T. S.

144
00:26:43.620 --> 00:26:50.310
Jodi Cooley: So let me just briefly describe which what each of the six sensors are or how they work.

145
00:26:51.420 --> 00:27:04.350
Jodi Cooley: So entities are small germanium semiconductor crystals that have been exposed to a neutron flux in order to make a large but yet control density of impure

146
00:27:07.260 --> 00:27:17.670
Jodi Cooley: So the MTD measures the temperature variations relative to a base temperature T not and that Tina is set to be on the transition from superconducting

147
00:27:19.980 --> 00:27:24.390
Jodi Cooley: With a temperature dependence of the resistance.

148
00:27:25.560 --> 00:27:28.050
Jodi Cooley: Yeah, that temperature dependence on the resistance.

149
00:27:29.400 --> 00:27:30.780
Jodi Cooley: So in MTD

150
00:27:31.980 --> 00:27:41.160
Jodi Cooley: The resistance is continuously measured by flowing current through it and then measuring the results of the voltage and the sensors are essentially that include

151
00:27:41.790 --> 00:28:00.990
Jodi Cooley: To your crystal or two, which is your substrate, the medium that target with you are using dark matter antibodies essentially our thermal sensors, meaning that the detector, essentially you're waiting for an equilibrium condition before you're making that measurement

152
00:28:03.360 --> 00:28:06.210
Jodi Cooley: Transition of sensor isn't a thermal

153
00:28:07.380 --> 00:28:09.720
Jodi Cooley: Sort of sense or meaning that it can pick up

154
00:28:11.070 --> 00:28:22.650
Jodi Cooley: It doesn't need to wait for the phone audio system to come to people remembered his start making the measurements. It's a thing conducting super film film that also operate in the near

155
00:28:23.550 --> 00:28:30.690
Jodi Cooley: Its TC. The idea is that, again, you need refrigeration, you need to be very low temperatures to make this work.

156
00:28:31.320 --> 00:28:50.880
Jodi Cooley: So your particle will come in to your detector like your absorber create the phone on the phone on our a thermal, meaning they haven't finalized yet they start traveling into essentially a collection fin, which is also superconducting and so when those bonuses enter that

157
00:28:52.020 --> 00:29:03.450
Jodi Cooley: Finn essentially kind of heat it up a little bit. So because it was superconducting your electrons were in cooper pairs. When you add that extra energy you break the Cooper pairs.

158
00:29:04.200 --> 00:29:17.880
Jodi Cooley: And then you start having quality particles that are transported into the transit transition of sensor again that transition edge sensor is set to be superconducting so when you don't energy into it essentially you're dumping heat into it.

159
00:29:19.200 --> 00:29:24.120
Jodi Cooley: And that all can be read out with a series of squishy.

160
00:29:26.610 --> 00:29:27.210
Jodi Cooley: So,

161
00:29:29.010 --> 00:29:34.680
Jodi Cooley: superseding MS is one of the experiments that uses this type of technology.

162
00:29:36.660 --> 00:30:00.030

Jodi Cooley: Right now the superseding MS snow lab experiment is in the process of fabrication and construction at 11 Canada is imagine that there will be or the plan. I shouldn't say imagined is going to be an initial payload of the four towers each of those towers will have six attackers.

163
00:30:03.060 --> 00:30:08.400
Jodi Cooley: Basically there are two different types of detectors and I will talk a little bit about each of these detectors and why

164
00:30:09.000 --> 00:30:19.740
Jodi Cooley: They could be important. Two of them are called high voltage detectors and two of them are called Isaac detectors. The eyes of detector is based on sort of the original CMS technology.

165
00:30:20.670 --> 00:30:34.230
Jodi Cooley: The eyes of detectors on each side have eight phone on channels and to charge sensors and the age the detectors have just the phone on sensors. So the phone on channels on each side.

166
00:30:35.700 --> 00:30:42.810
Jodi Cooley: So taking a look at one of these detectors and I want to apologize because I didn't have a mask.

167
00:30:43.230 --> 00:30:55.980
Jodi Cooley: Of the current supersede EMF detectors are going to smell out. So for those of you who are really sharp out there, you will realize that this mask is for a superseding MS Sudan detector. I apologize.

168
00:30:56.940 --> 00:31:11.550
Jodi Cooley: But the layout is essentially the same. It's just how these sensors are arranged on the crystal that sort of changes, but the basic idea of having interleaved phone on sensors that are grounded and represented here in blue.

169
00:31:12.450 --> 00:31:34.020
Jodi Cooley: And charge read outlines that are bias is the same. Now if I zoom in on these charged sensors. What you will see here in gray or the aluminum fence and in green here is your transition as sensor. So that's essentially the thermometer that's reading out your phone on signal.

170
00:31:36.540 --> 00:31:47.910
Jodi Cooley: I said superseding most has these two different types of detectors. One of them is this standard Isaac, and the idea was that is that you can measure these prompt

171
00:31:48.510 --> 00:32:09.720
Jodi Cooley: Phone on these primary phone and you measure ionization signals and by taking by measuring this and taking the ratio of the ionization signal to the phone signal and plotting it versus energy you get very good discrimination of electron recoils and

172
00:32:11.280 --> 00:32:24.870
Jodi Cooley: I'm sorry, the electron recall of up here. And in this green line would be where your nucular requires a line. Now you'll notice this is done with a calibration source to really, you know, get a good sense for what your background reduction would be

173
00:32:26.100 --> 00:32:40.650
Jodi Cooley: All of these events that are rad our surface events and these are rejected by enforcing that the charge collection on both faces of the sensor be symmetric.

174
00:32:44.340 --> 00:32:48.630
Jodi Cooley: The Super CMS high voltage detectors work a little bit different so

175
00:32:49.170 --> 00:32:59.310
Jodi Cooley: What you do is you ramp up the field to make it very hot. And the reason that you do this is that if you have a wimp interacting your detector. Sorry, wrong direction.

176
00:33:00.000 --> 00:33:07.170
Jodi Cooley: If you have a when interacting in your chapter immediately you get these prompt finance I talked about so phone on that were generated

177
00:33:08.220 --> 00:33:16.260
Jodi Cooley: By just the initial interaction of your dark matter or CANDIDATES SAY with your nucleus or with your electron or what, whatever it may be.

178
00:33:17.700 --> 00:33:27.270
Jodi Cooley: As those finance are drifted through the electric field they create more phone which we call LTE phone ons, or for short. I call them.

179
00:33:28.740 --> 00:33:30.180
Jodi Cooley: And you get a large number of these

180
00:33:31.500 --> 00:33:48.900

Jodi Cooley: And so essentially your total phone on energy is a combination of these prompt primary phone on and the loop phones, the loop phone on depend upon the number of electron whole pairs that are generated and your bias voltage

181
00:33:51.540 --> 00:34:03.660
Jodi Cooley: And basically by wrapping this up and and generating all these loops phone on what you can do is you can get an ultra high resolution indirect measurement of the charge

182
00:34:04.710 --> 00:34:18.810
Jodi Cooley: And we've demonstrated a threshold as low as 56 EV E in our detectors, the trade off is is that there's there's no yield measurement, so you don't get that.

183
00:34:20.280 --> 00:34:29.610
Jodi Cooley: discrimination between electron recoils a nuclear recoils and you don't get the face discrimination. So in this mode, it's important to have a handle on your backgrounds.

184
00:34:31.560 --> 00:34:33.990
Jodi Cooley: Okay, so let me make a little aside here because

185
00:34:35.400 --> 00:34:47.100
Jodi Cooley: I know that we often talk about this in our community without thinking about it because, you know, why doesn't everybody know what a ke VI Vi is Kate easy E. Sorry, or ke VI n are

186
00:34:48.240 --> 00:35:02.100
Jodi Cooley: So let me, let me show you a few definitions here so that you can come up to speed. So remember I had had the total phone on energy is sort of that initial recoil energy plus your look for

187
00:35:03.810 --> 00:35:16.620
Jodi Cooley: Okay, so if you assume that the event is an electron recoil event. And then I'm just going to take the case in CMS we bias or voltage or bias or detectors of three volts.

188
00:35:17.760 --> 00:35:28.980
Jodi Cooley: The recoil energy in ke VI can then be expressed as the total energy minus this component. So I've just rearranged this equation. That's all I've done

189
00:35:30.780 --> 00:35:41.460

Jodi Cooley: All right, so I can rewrite the number of charges that I have, as the total energy divided by

190
00:35:43.110 --> 00:35:49.320
Jodi Cooley: The amount of energy that's required to create one electron pair and in germanium. This is three, Ed.

191
00:35:50.850 --> 00:35:53.670
Jodi Cooley: So you can see why I picked up will devise a revolt.

192
00:35:55.140 --> 00:35:57.810
Jodi Cooley: So that means this case that are

193
00:35:59.880 --> 00:36:05.910
Jodi Cooley: Recoil energy and he is equal to the total energy minus the charge energy

194
00:36:07.170 --> 00:36:16.230
Jodi Cooley: Now if I go the other direction. And I assume that the event was a nuclear recoil. There's a smaller correction for the loop finance that needs to be applied.

195
00:36:16.800 --> 00:36:27.060
Jodi Cooley: And what that correction is the mean ionization energy for nucular recoil and it's determined by using calibration data, we use a 252 California source.

196
00:36:27.990 --> 00:36:40.530
Jodi Cooley: And so essentially here you have the total phone on energy minus look energy which is this function here, which is a constant times the energy to another constant

197
00:36:42.810 --> 00:36:43.740
Jodi Cooley: Okay, so

198
00:36:44.940 --> 00:36:50.940
Jodi Cooley: How does, how does, what does this look like. And I just want to say if you're confused by this or you want to see this explained out a really good

199
00:36:51.960 --> 00:37:08.430
Jodi Cooley: Reference for these energy skills is David Morris thesis chapters three and four, in particular, and I have a link here. So in

this plot, you're looking at ionization energy. Mia measured in ke VI E versus recoil energy in ke VI and our

200
00:37:10.110 --> 00:37:19.500
Jodi Cooley: And essentially here. The red is showing you sort of lines of constant energy between the two scales.

201
00:37:20.190 --> 00:37:38.820
Jodi Cooley: And in green would be the mean energy of nuclear recoil. And so this is determined by California. I'm sorry, the little green dots here are those data points and then the blue, here's the main energy of the electron recoil band for a Varian 133 source. So right here.

202
00:37:39.930 --> 00:37:42.300
Jodi Cooley: At about 10.4 ke VI.

203
00:37:44.280 --> 00:37:53.610
Jodi Cooley: Unknown line energy line from this calibration appears. And you can see that that's that 10.4 ke VI.

204
00:37:54.900 --> 00:38:00.930
Jodi Cooley: And electron recoil and it appears to be at about 16 K TV on the new Phila recoil Specter.

205
00:38:02.160 --> 00:38:07.860
Jodi Cooley: So a little aside in case you're ever read this in the literature and you wonder what it means.

206
00:38:09.870 --> 00:38:14.850
Jodi Cooley: Right so superseding us know lab is a generation to experiment that's under construction and snow lab.

207
00:38:15.510 --> 00:38:27.120
Jodi Cooley: Snow lab at about 6900 meters water equivalent. So that will reduce the factor by about 100 of them you on flocks from cosmic rays compared to when they experiment with that Sudan.

208
00:38:28.080 --> 00:38:39.150
Jodi Cooley: There's a class 2000 clean room underground across that is being built that can accommodate up to seven towers and I already mentioned the initial payload.

209
00:38:40.920 --> 00:39:00.300

Jodi Cooley: The cool thing about these detectors, is that there is a wide range of sensitivity by having two different detector types, you have a sensitivity to your traditional nucular recoils although at these high energies, the liquid nobles are clearly the dominant player in the game.

210
00:39:01.710 --> 00:39:07.230
Jodi Cooley: But you can still do nuclear recoils at lower energies in a low threshold.

211
00:39:08.460 --> 00:39:09.360
Jodi Cooley: Sort of regime.

212
00:39:10.620 --> 00:39:13.230
Jodi Cooley: There are the high voltage detectors which have

213
00:39:14.790 --> 00:39:22.110
Jodi Cooley: Sort of energy range here. And then if we start doing electron only or absorption analyses, you can start to get to lower and lower.

214
00:39:23.310 --> 00:39:26.730
Jodi Cooley: Or you're able to access lower and lower master.

215
00:39:28.470 --> 00:39:36.570
Jodi Cooley: So another experiment that uses these the same type of thermal technology is the crust experiment.

216
00:39:37.590 --> 00:39:43.440
Jodi Cooley: So crest searches for dark matter interaction in a

217
00:39:45.900 --> 00:39:48.690
Jodi Cooley: In a CA W for crystal.

218
00:39:49.710 --> 00:39:57.900
Jodi Cooley: They operate a $15 Calvin. So again, you see that cryogenic temperature. Essentially, they have cryogenic

219
00:39:59.610 --> 00:40:06.510
Jodi Cooley: TSS that read out their vibrational energy and then they also read out centralization. So these crystals.

220
00:40:07.650 --> 00:40:17.190

Jodi Cooley: They simulate. And so you can see here essentially they if you take a light yield. So this would be the amount of centralization energy that they met her divided by

221
00:40:17.760 --> 00:40:30.810
Jodi Cooley: Their own on energy applauded versus energy. You can see that their backgrounds have a much higher value of you then nucular recoils that would happen off the oxygen or the tungsten

222
00:40:32.970 --> 00:40:39.210
Jodi Cooley: And so they also have put our recent results where they have very impressive reach to low energies.

223
00:40:41.550 --> 00:40:43.980
Jodi Cooley: It was more than a magnitude of improvement.

224
00:40:45.030 --> 00:40:51.240
Jodi Cooley: At point five GB and they extended their reach all the way down 2.1 60

225
00:40:53.160 --> 00:41:12.060
Jodi Cooley: The problem, of course, is that they were sensitivity limited below about 200 EV, and you can kind of see that here in this spot you know they have these these access events here on that they needed to that they need to be able to beat down in order to access for energies.

226
00:41:13.170 --> 00:41:30.180
Jodi Cooley: So their future plan is that they just in July started a second round or a second round of measurements using modified detectors. They had a successful cool down, but they had to stop due to the coronavirus

227
00:41:31.200 --> 00:41:41.970
Jodi Cooley: But they are running now and then they're planning for an upgrade in 2020 and 21 in order to accommodate more readout channels and more modules.

228
00:41:42.930 --> 00:41:56.160
Jodi Cooley: They also have a new crowd staff design and they're further developing their sensors to push their detectors to lower and lower threshold and then they also are continuing studies using alternate crystals.

229
00:41:59.220 --> 00:42:12.060

Jodi Cooley: So, you know, as we're looking at this, we are essentially continuing to march down and energy. And so ultimately what these detectors could do would be able to detect single electron whole pairs.

230
00:42:13.740 --> 00:42:32.580
Jodi Cooley: That's the best we can do. And so basically, the idea here is that we want to take a look at the energy scale in semiconductors. So, electron excitation momentum and energy skills in semiconductors. They can be used.

231
00:42:33.930 --> 00:42:35.820
Jodi Cooley: To search for really like master matter.

232
00:42:36.900 --> 00:42:43.170
Jodi Cooley: And so as an example, let's take a look at silicon, silicon, have the band gap energy of about 1.2 EV

233
00:42:44.250 --> 00:42:51.900
Jodi Cooley: This is an indirect band gap. So it requires a phone on in order for the transition to happen and it's temperature dependent

234
00:42:53.490 --> 00:43:02.190
Jodi Cooley: So the energy required to create an electronic whole pair on average in silicon is 3.6 ed and again this is temperature dependent

235
00:43:04.320 --> 00:43:17.010
Jodi Cooley: And so what this means, if you take a look at this is that, you know, we can be sensitive to Energy Department posits that are on order EV for electron scattering to something like order 20 before on nucular scattering

236
00:43:18.690 --> 00:43:24.900
Jodi Cooley: But you know when we start to make detectors like this and we start to think about them were kind of leaving the realm of particles.

237
00:43:26.100 --> 00:43:28.980
Jodi Cooley: in particle physics, you're usually thinking about energies that are greater than

238
00:43:29.880 --> 00:43:36.540
Jodi Cooley: A KB. But in solid state physics, you're looking at energies and considering them they're lower than say roughly 30 dB.

239
00:43:37.320 --> 00:43:45.030

Jodi Cooley: So solid state physics, you have to consider and think about into physics, a multi body systems were in particle physics.

240
00:43:45.660 --> 00:43:57.090
Jodi Cooley: You know we just think of single free particles when we're doing our calculations off the time. And so in that case, you know, our energies are just the momentum squared divided by two tenths of math.

241
00:43:58.860 --> 00:44:00.210
Jodi Cooley: But in solid state because

242
00:44:01.380 --> 00:44:19.560
Jodi Cooley: The allowed energies and momentum are given by dispersion relations and so we have to we have to break out the statistical mechanics of it. And so, you know, in that regime, then we're part of how effective masses, rather than well defined methods.

243
00:44:21.780 --> 00:44:24.120
Jodi Cooley: So there are some challenges and

244
00:44:25.590 --> 00:44:36.030
Jodi Cooley: Essentially the detector responses. One of the biggest challenges you need to know details about the band structure, they may become increasingly important when you're working this regime.

245
00:44:37.290 --> 00:44:43.680
Jodi Cooley: You need a PDF in order to get the number of electron whole pairs at any given energy deposition

246
00:44:44.730 --> 00:45:00.060
Jodi Cooley: You have to consider final statistics. Remember I said that dispersion probability start to become important. And for nucular recoils the quenching starts to become something that that you could consider

247
00:45:01.380 --> 00:45:16.230
Jodi Cooley: So here you're seeing the Leonhardt theory, which is the theory for coaching that has been used traditionally in our field versus some empirical data that came from the dominant collaboration for silicon

248
00:45:18.150 --> 00:45:18.780
Jodi Cooley: So,

249
00:45:20.550 --> 00:45:32.760

Jodi Cooley: In addition to that impurities in your crystal can lead to partial energy deposits. And so what this means is, is in order to get the single electron whole

250
00:45:33.960 --> 00:45:45.090
Jodi Cooley: Sensitivity what you're trying to do is your quantization your phone arms around one electron whole pair to electron whole pairs three electron whole pair. So you're trying to quantify your signal.

251
00:45:45.900 --> 00:46:04.770
Jodi Cooley: But if you have crystal impurities, then you start to get, you know, a signal sort of in between those peaks that should be happening around each of your integer pairs. And if that's too big, it becomes really difficult to tease out of that quantization that you're looking for.

252
00:46:07.410 --> 00:46:17.430
Jodi Cooley: Backgrounds also are something that you have to consider. So spectral information about radioactive decays at the end scale can be required.

253
00:46:19.590 --> 00:46:34.170
Jodi Cooley: I aren't optical phone has become significant backgrounds that low energy. So you have to come up with strategies to try to be back those backgrounds. And finally, your dark or your leakage current can become significant

254
00:46:36.120 --> 00:46:45.750
Jodi Cooley: So just to take a look. I want you to walk away with the idea that this is really promising, even though it is difficult. There have been several collaborations. Now that

255
00:46:46.410 --> 00:46:56.910
Jodi Cooley: Have looked into this and my collaborators and supersede DMS collaboration have demonstrated with HIV EV detectors, a high voltage TV.

256
00:46:57.870 --> 00:47:08.970
Jodi Cooley: The ability to see a single whole pairs. And so you can see this quantization that I was talking about this has one electron whole pair, two, three, and so forth. And here are several papers that you can

257
00:47:09.540 --> 00:47:16.860
Jodi Cooley: Further read if you're interested more in this topic of essentially what's really cool about these chapters, is that

258

00:47:18.570 --> 00:47:23.580
Jodi Cooley: You know with really small detectors and small

259
00:47:25.710 --> 00:47:31.050
Jodi Cooley: Expect exposures, you can actually make significant contributions.

260
00:47:32.280 --> 00:47:37.290
Jodi Cooley: To to the sensitivity and parameter space that that has never been explored for dark matter.

261
00:47:41.070 --> 00:47:53.220
Jodi Cooley: So there's another collaboration that also uses these phone on signals and it's very similar to supersede the math on the major difference between the two collaboration is is that

262
00:47:53.880 --> 00:48:03.630
Jodi Cooley: For the most part, the Edelweiss collaboration uses these MTV sensors and the super CMS collaboration uses the TS sensors to read out their phones and so

263
00:48:04.680 --> 00:48:10.230
Jodi Cooley: They also have them working on sort of this high voltage operation.

264
00:48:13.320 --> 00:48:18.990
Jodi Cooley: Whoops, sorry runway and here's, here's a picture of sort of their results.

265
00:48:20.070 --> 00:48:29.190
Jodi Cooley: And so you can see that for them the backgrounds are really a bit more problematic and they have them for superseding months and

266
00:48:29.790 --> 00:48:34.830
Jodi Cooley: They have been studying the hypothesis of what types of backgrounds could be contributing

267
00:48:35.310 --> 00:48:49.350
Jodi Cooley: And the unfortunate thing is that there's not a single smoking gun. There's not just one background that could be that that is causing them troubles. It really seems like it's going to be some combination of multiple backgrounds that they have explored.

268
00:48:52.620 --> 00:49:05.820

Jodi Cooley: So kind of moving on to another technology, but a technology that's still able to do this single electron whole pair discrimination is looking at detectors that take advantage of CDs.

269
00:49:07.140 --> 00:49:16.950
Jodi Cooley: So since I and Dominic are the two collaboration, sort of in this field since he has put out results recently using the skipper on CDs.

270
00:49:17.940 --> 00:49:35.190
Jodi Cooley: Essentially, this is a solid electronic noise CCD that had a skipper readout. So the idea is you're kind of her powerful comes in, you know, kick some electronic auto conduction band and that sort of like your signal and so CCD

271
00:49:36.750 --> 00:49:53.250
Jodi Cooley: Sensors, traditionally, you know, kind of have to wipe their technology that one snapshot of the energy measurement and then you have to kind of follow us. It was a reset it. The skipper CCD allows you to take multiple pictures and this allows them to get to this sort of very low.

272
00:49:55.470 --> 00:49:57.000
Jodi Cooley: Resolution that you're seeing in care.

273
00:49:58.650 --> 00:50:13.260
Jodi Cooley: And so just talking about plans for the skipper see cds in the future. I'm sensing has moved to snow out for their Phase one is operational the complete experiment eventually will contain 100 grams.

274
00:50:14.520 --> 00:50:22.650
Jodi Cooley: After that comes Dominic em at Madame, and this would be basically one kilogram of the CCD

275
00:50:23.970 --> 00:50:34.050
Jodi Cooley: And Dominic originally did not use the skipper CCD read out but they had really low dark noise, which is great, but when they go to Madame

276
00:50:34.080 --> 00:50:43.740
Jodi Cooley: They're going to also use the skipper CCD and then going way into the future, you have a skirt, which would be like 10 kilograms of these center. The skipper CCD

277
00:50:46.110 --> 00:50:47.610

Jodi Cooley: So about five minutes left.

278
00:50:48.030 --> 00:50:53.790
Jodi Cooley: Yeah, I say I am actually wrapping it up. And so now I'm going to start to get into more

279
00:50:54.420 --> 00:51:06.990
Jodi Cooley: I don't want to say speculative. But this, this is really more of the R amp D that's going on in this little maps range. And there's a lot of it and because I have five minutes. I can't tell you all about it. I really like a whole nother lecture would be great but

280
00:51:08.580 --> 00:51:25.170
Jodi Cooley: Let me talk about spice, this is something that one of my colleagues net pile has been working on. So these are some Evie polar interactions and color genetic crystal experiments. And so in an ionic crystal, the photo the photons are oscillating

281
00:51:27.390 --> 00:51:28.500
Jodi Cooley: As electric dipole

282
00:51:29.520 --> 00:51:30.300
Jodi Cooley: And so

283
00:51:32.880 --> 00:51:33.840
Jodi Cooley: Basically

284
00:51:35.220 --> 00:51:42.030
Jodi Cooley: Very large couple instill phone on your very large coupling to the finance and very large couplings and dark photon.

285
00:51:43.590 --> 00:52:04.500
Jodi Cooley: So there's an effort underway in polar crystal Rd using a variety of substrates and again this is taking a crystal a polarized crystal, essentially. And, you know, putting some transition as sensors on it to try to to get very low very precise.

286
00:52:05.760 --> 00:52:16.920
Jodi Cooley: Experiments. And so let me just rather than trying to explain this in a very short time, let me point you to some resources in the case that you're interested in some of this already in these technologies.

287
00:52:17.280 --> 00:52:25.860

Jodi Cooley: So Matt pile gave a colloquium at slack here. I think it was just this last frame and you can access that colloquium and watch it.

288
00:52:26.610 --> 00:52:34.470
Jodi Cooley: Through this site here. He's a really terrific speaker and this talk, I think really lays things out in the same sort of

289
00:52:35.190 --> 00:52:45.150
Jodi Cooley: Spirit of the slack Summer Institute. I think it's, it's fairly easy to understand. If you don't want to take a whole hour into it and you want to go with something that's only 25 minutes long.

290
00:52:45.930 --> 00:52:58.560
Jodi Cooley: IBM had a virtual conference this year. Kevin Zurich gave the opening talk and she also talked about some of these technologies and then another technology that I won't get to talk about, but it's also pretty cool.

291
00:52:59.700 --> 00:53:11.730
Jodi Cooley: Is using super fluid helium for the dark matter target and although I could not find a really great talk to point you to this paper here really describes that technology pretty well.

292
00:53:14.310 --> 00:53:17.130
Jodi Cooley: So where is it that we're going

293
00:53:18.420 --> 00:53:24.720
Jodi Cooley: So at this point, this fun here sort of summarizes our traditional dark matter thinking

294
00:53:26.010 --> 00:53:32.100
Jodi Cooley: Where we sort of had high we had dark matter that was higher than 10 GB. And we were looking at dark matter, less than

295
00:53:33.270 --> 00:53:44.190
Jodi Cooley: 10 GB and sort of in solid lines here and a great are regions that have already been excluded and the dashed lines and then shaded and pink.

296
00:53:44.790 --> 00:53:56.190
Jodi Cooley: Are the regions that I would say in the next decade, we may be able to sweep out and then yellow here is where you have that neutrino background that we talked about in the last lecture.

297

00:53:56.940 --> 00:54:09.000
Jodi Cooley: But what's the like within the last year or two people have really started thinking about going even lighter and dark matter. And you know, I tried to give you a sense for the type of Rd that's been going on.

298
00:54:09.600 --> 00:54:19.590
Jodi Cooley: And people have been thinking about ways that you could even take like xenon technology or the argon technology and instead of looking for scattering often nuclei looking

299
00:54:20.280 --> 00:54:37.980
Jodi Cooley: For scattering off electron and looking at different ways that the dark matter might interact and so here you can see a couple of plots just kind of pointing out those new faces. And I'm sure that to imitate had talked about some of these in history lectures.

300
00:54:39.480 --> 00:54:40.740
Jodi Cooley: So in conclusion,

301
00:54:42.210 --> 00:54:54.810
Jodi Cooley: The next decade is going to be really exciting for dark better direct detection. There are various g two experiments that are coming online eminently and they're going to be covering a lot of new parameter space.

302
00:54:56.040 --> 00:55:05.850
Jodi Cooley: Although the WIMPs remain a very interesting and viable dark matter candidate. There are other scenarios that are great gaining traction in the theoretical community.

303
00:55:06.270 --> 00:55:13.620
Jodi Cooley: And there are new ideas from the experimental community on how we might be able to access those regions.

304
00:55:14.550 --> 00:55:29.700
Jodi Cooley: So given the wealth of theoretical possibilities. The diversity of experimental designs and targets. I think that that I'm hoping that that very soon we might be able to discover a signal.

305
00:55:30.930 --> 00:55:36.480
Jodi Cooley: And if not, certainly we are going to be pestering a number of models. Thank you.

306
00:55:38.850 --> 00:55:42.090

mark convery: Great, thank you very much. God for very interesting and comprehensive talk

307
00:55:43.380 --> 00:55:47.370
mark convery: And passed over now to suit on. Who's going to manage the question.

308
00:55:48.090 --> 00:55:56.520
dong su: Yeah, great. Thank God for nice tour of all these different varieties of detectors. So the question. Let's start with page 55

309
00:55:58.290 --> 00:56:00.300
dong su: Is on the Dharma liberal is

310
00:56:00.660 --> 00:56:02.010
dong su: How they get the crystal to

311
00:56:02.010 --> 00:56:02.940
dong su: Be such a purity.

312
00:56:04.110 --> 00:56:08.400
Jodi Cooley: Um, so my recollection is that

313
00:56:09.960 --> 00:56:24.120
Jodi Cooley: That it had to do with taking I think they just took the crystal they pulled it took a sample. Pull it again and they just kept doing this until it got pure enough that's, that's my understanding of the process.

314
00:56:27.210 --> 00:56:29.580
Jodi Cooley: That was kind of expensive, but it was a factor.

315
00:56:31.980 --> 00:56:32.220
Right.

316
00:56:33.390 --> 00:56:35.820
dong su: Okay. So on page 57

317
00:56:37.020 --> 00:56:38.190
dong su: I talked about

318
00:56:39.600 --> 00:56:44.160

dong su: The region of interest on site vendors, how the region interest in sight, then define

319
00:56:44.910 --> 00:56:45.270
OK.

320
00:56:46.950 --> 00:57:02.970
Jodi Cooley: So the region of interest is the the the energy region, the two to six k GV and the side bands would be, you know, sort of the, the region, you know, to the left or to the right of that thought. So lower than that and higher than that.

321
00:57:05.400 --> 00:57:12.420
Jodi Cooley: In some way so the idea is that they would take the energy region of interest and block it out and then they would look at

322
00:57:13.500 --> 00:57:18.420
Jodi Cooley: I'm not sure if they use, you know, sort of, one, two, or three sigma away from

323
00:57:18.990 --> 00:57:30.780
Jodi Cooley: You know that energy region of interest and sort of use that as the side band, but it would be essentially those regions, just outside to the right into the left, looking at the counts there and making sure that those are consistent with them.

324
00:57:32.190 --> 00:57:32.400
Jodi Cooley: Yeah.

325
00:57:32.490 --> 00:57:36.750
dong su: They may be asking why that is, is normally

326
00:57:36.810 --> 00:57:45.840
Jodi Cooley: I don't I don't recall off the top of my head how wide that was, but I do have the PRL listed here. So, you know, we can easily look at our

327
00:57:46.950 --> 00:57:56.610
dong su: Okay. Um, so the next question answered me popped up yesterday as well. So why do women interact with new target instead of the platform.

328
00:57:58.620 --> 00:58:01.440
Jodi Cooley: Oh, it's a week. It's a week interaction.

329
00:58:04.560 --> 00:58:08.100
Jodi Cooley: And so the week interaction comes out of the interaction with the nucleus.

330
00:58:09.300 --> 00:58:14.040
Jodi Cooley: It's because it's interacting with the weak force or through the weak force.

331
00:58:17.550 --> 00:58:17.850
dong su: Right.

332
00:58:21.480 --> 00:58:23.520
dong su: Electrons and the nucleus.

333
00:58:26.280 --> 00:58:29.070
Jodi Cooley: So the WIMPs when it interact with the electrons.

334
00:58:30.360 --> 00:58:31.140
Jodi Cooley: I'm confused.

335
00:58:35.340 --> 00:58:37.440
dong su: Okay, maybe let's move on to the

336
00:58:37.440 --> 00:58:41.580
Jodi Cooley: Next guy. I'm sorry. I'm confused by the question perhaps somebody else understands what

337
00:58:41.850 --> 00:58:43.470
dong su: Will be the

338
00:58:44.550 --> 00:58:45.120
Jodi Cooley: Better than me.

339
00:58:49.410 --> 00:58:57.330
dong su: Yeah, the most mostly the experiments, talking about the whimsy interacting with the nucleus. But one thing that looks awfully interact. It

340
00:58:57.750 --> 00:58:59.370
dong su: Also could have maybe

341
00:58:59.820 --> 00:59:01.500
Jodi Cooley: Week interaction with the electron

342
00:59:04.470 --> 00:59:10.770
Jodi Cooley: I don't know. I'm sorry. Somebody else would I would need a theorist to help with that or or somebody

343
00:59:15.630 --> 00:59:16.530
dong su: Okay, we go

344
00:59:18.000 --> 00:59:18.330
dong su: Oh,

345
00:59:20.700 --> 00:59:26.070
mark convery: I was gonna say neutrinos certainly interact with electrons, but usually targeted attack. Maybe, maybe.

346
00:59:26.490 --> 00:59:28.650
Jodi Cooley: Neutrinos are really light right

347
00:59:28.710 --> 00:59:29.550
mark convery: Yeah yeah

348
00:59:29.610 --> 00:59:42.570
Jodi Cooley: alder so the cross section, you know, like the corner at that level, they, they, you would expect that, but with a weekly interacting heavy particle. Thank you. You expect

349
00:59:44.850 --> 00:59:48.210
Jodi Cooley: Expect the interaction to do with the nucleus. Yeah, you're

350
00:59:48.510 --> 00:59:48.750
Right.

351
00:59:51.870 --> 00:59:56.310
dong su: Okay, so let's move on to the next one is on 68 page 68

352
01:00:00.330 --> 01:00:02.370
dong su: So there's an element MTV.

353
01:00:03.420 --> 01:00:09.900

dong su: So that really rely on to actually keep it on the critical temperature, how the keep the TV is on the critical temperature

354
01:00:10.830 --> 01:00:13.980
Jodi Cooley: They just use like some electro thermal feedback.

355
01:00:15.540 --> 01:00:19.140
Jodi Cooley: Essentially to help to to keep the temperature

356
01:00:21.480 --> 01:00:23.520
Jodi Cooley: To keep the temperature at the critical temperature

357
01:00:24.900 --> 01:00:27.030
Jodi Cooley: It's just, it's a feedback system.

358
01:00:28.740 --> 01:00:31.590
dong su: Yeah, there's there's regular will control feedback. Yeah.

359
01:00:33.180 --> 01:00:37.710
dong su: I'm on page 71. I think that's the is it

360
01:00:38.310 --> 01:00:38.640
Jodi Cooley: Yes.

361
01:00:39.150 --> 01:00:41.670
dong su: What's up, I mentioned, what's the dimensions of

362
01:00:43.530 --> 01:00:43.770
Jodi Cooley: Okay.

363
01:00:46.110 --> 01:00:52.230
Jodi Cooley: All right. So yeah, I didn't write that down. So these crystals are four inches in diameter and roughly an inch

364
01:00:53.820 --> 01:01:02.340
Jodi Cooley: And I'm sure if Richard partridge is online. He's going to get upset because I didn't give it in millimeters precisely but but that essentially gives you the size of the dimension.

365
01:01:04.350 --> 01:01:04.530
Yeah.

366
01:01:06.150 --> 01:01:07.980
dong su: Okay, so the next one.

367
01:01:09.450 --> 01:01:15.150
dong su: Is this question, who is anybody utilizing molecular vibration with the dark matter.

368
01:01:15.690 --> 01:01:21.600
Jodi Cooley: Yeah, so there is R amp D in molecular vibrations for dark matter.

369
01:01:23.190 --> 01:01:38.430
Jodi Cooley: I think that there is a group. This is what I may have to put some answers like as far as pointing to exact papers I may have to do that offline. But I think there is a group or the Weizmann Institute in Israel, that's working on that.

370
01:01:39.600 --> 01:01:43.590
Jodi Cooley: And I'm trying to remember if there's a group in the US as well, but that is certainly

371
01:01:44.790 --> 01:01:46.260
Jodi Cooley: Certainly one of the ideas.

372
01:01:47.580 --> 01:01:52.770
Jodi Cooley: You know, talking about where I said, there could be this whole third other talk that would fit really well into their

373
01:01:53.400 --> 01:02:03.570
dong su: Yeah, that sounds like a perfect place to actually put the the written authors in the in the written on. So to the Q AMP. A later on some of those pointers, though the way

374
01:02:03.750 --> 01:02:09.210
Jodi Cooley: Yeah. Yeah, no, I am certainly can, and nuts. That's my intention is to go back through and try to put some

375
01:02:10.380 --> 01:02:13.620
Jodi Cooley: References in that people can use if they're interested. Yeah.

376
01:02:13.890 --> 01:02:18.210
dong su: We'll put that into your written also later. Okay. So on page 98

377
01:02:21.450 --> 01:02:26.850
dong su: So there's this certain dump of the big gumball. The nutritional background that round 10 G.

378
01:02:27.150 --> 01:02:30.630
Jodi Cooley: Yeah, that's the boron eight neutrinos. Yeah, right.

379
01:02:31.020 --> 01:02:41.160
Jodi Cooley: Yeah, right. Yeah. So this is so this is like your, your solar and this is the boron eight and then down here you have atmospheric and the diffuse supernova background.

380
01:02:42.300 --> 01:02:43.110
Jodi Cooley: So they just

381
01:02:44.790 --> 01:02:45.990
Jodi Cooley: It's just different.

382
01:02:47.130 --> 01:02:58.140
Jodi Cooley: cross sections for the different prophecies. So if you remember back to the lecture that we had yesterday, your solar neutrino interactions were happening through electron

383
01:03:00.870 --> 01:03:02.070
Jodi Cooley: They just happened to be

384
01:03:03.420 --> 01:03:16.050
Jodi Cooley: You know, it just happens to do. So these are sort of the interactions that would be happening from neutrinos that come from the sun. And then down here you would be dominated by atmospheric and the diffuse neutrino background.

385
01:03:17.070 --> 01:03:20.820
Jodi Cooley: Or drug abuse neutrinos come to us supernovas. Right.

386
01:03:21.240 --> 01:03:23.160
dong su: Yeah, because the bar is solar and female basis.

387
01:03:24.150 --> 01:03:34.290
Jodi Cooley: Yeah, this is, this is actually a for sure signal if these detectors, get down to here and they don't see that boron eight signal which should be a new Hillary coil.

388
01:03:35.910 --> 01:03:37.020
Jodi Cooley: There's something not working right.

389
01:03:38.400 --> 01:03:44.430
dong su: Okay, so one last question is are there and experiment using both sides and compensate

390
01:03:45.150 --> 01:03:46.650
Jodi Cooley: For using both what I'm sorry.

391
01:03:47.040 --> 01:03:48.180
dong su: Oh, science and constantly

392
01:03:48.990 --> 01:03:50.310
Jodi Cooley: Was Einstein kind of thing.

393
01:03:52.140 --> 01:03:52.890
Jodi Cooley: I don't know.

394
01:03:55.470 --> 01:03:57.060
Jodi Cooley: Does anybody else on the panel. No.

395
01:03:59.160 --> 01:04:02.610
Jodi Cooley: I'm not certain. I can't think of one. But that doesn't mean it doesn't exist.

396
01:04:02.790 --> 01:04:03.690
grzegorz madejski: I haven't heard either

397
01:04:05.820 --> 01:04:09.210
mark convery: Yes. What about the largest goes, I was Einstein condensate right now.

398
01:04:10.950 --> 01:04:12.600
mark convery: Yeah, very much.

399
01:04:13.350 --> 01:04:14.040
Jodi Cooley: Yeah, probably not.

400
01:04:16.710 --> 01:04:19.890

dong su: Yeah, anyway. That's all the all the questions and thanks very much.

401
01:04:20.850 --> 01:04:22.170
Jodi Cooley: You're welcome. Also, I

402
01:04:22.530 --> 01:04:24.600
Jodi Cooley: Will put up a second lecture.

403
01:04:25.770 --> 01:04:30.180
Jodi Cooley: Like so. I have the slides up that I had before I give them today. But this morning.

404
01:04:31.200 --> 01:04:39.450
Jodi Cooley: Just think, just in case I added a couple of backups, because I thought somebody might ask me about super fluid helium. There's a great paper on it. But here's a summary and I also

405
01:04:40.050 --> 01:04:48.690
Jodi Cooley: Put a slide in about a little bit more on how the skipper CCP is worth in case someone asking the Q AMP. A so I will add those slides as well. In case anyone's interested

406
01:04:50.940 --> 01:04:51.540
Jodi Cooley: Thank you.

407
01:04:52.620 --> 01:04:54.510
mark convery: Hey, thanks so much. Appreciate it.

408
01:04:54.750 --> 01:04:56.790
mark convery: Thank you, wonderful talk much.

409
01:04:57.720 --> 01:04:59.040
mark convery: Full stop recording