Good afternoon, my name is Burt Bargerstock and I am co-director of the National Collaborative for the Study of University Engagement, a division of the office of University Outreach and Engagement at Michigan State University. I welcome you to the engaged scholar speaker series and I am delighted to see so many folks this afternoon, thank you for attending. The office of University Outreach and Engagement fosters MSU's land grant mission by connecting university knowledge with community knowledge in mutually beneficial ways. UOE supports the university's academic units and MSU extension on priority issues of concern to society by collaborating with faculty and academic staff to generate, apply, transmit and preserve knowledge. UOE also conducts research designed to explore and demonstrate disciplinary and interdisciplinary impacts of the UOE scholarship in university community partnerships. In all its work UOE emphasizes university community partnerships that are collaborative, participatory, empowering, systemic, transformative, and above all anchored in scholarship. Within in UOE the National Collaborative for the Study of University Engagement plays a national leadership role with respect to conversations about the scholarship of engagement. The collaborative seeks to advance greater understanding of the nature and role of community engaged scholarship through original research and publications, institutional studies, reflection and professional development programs, advocacy and national collaborations. The collaborative thanks its co-sponsors for today's event, and it's a long list including the Department of Physics and Astronomy, the College of Natural Science, the National Superconducting Cyclotron Laboratory, the Facility for Rare Isotope Beings, the Institute for Research on Mathematics and Science Education, Abram's Planetarium, Graduate Women in Science, the Creativity Initiative at MSU, the MSU Community School of Music, Lyman Briggs College, the Residential College in the Arts and Humanities, the Honors College, the Bailey's Scholars Program, and the Graduate School. We've missed very little of the university with this list. Today's speaker is Lily Asquith. Lily Asquith received her Ph. D from the University of College London in June 2010, her research focused on the search for the elusive low mass Higgs boson, the subatomic particle believed to endow everything in the universe with mass. Proving the existence of the Higgs boson is one of the main goals of large Large Hadron Collider (LHC), located deep beneath the border between France and Switzerland. Dr. Asquith is one of the originators of the LHC Sound Project. Through this project a group of particle physicists, composers, software developers, and artists convert data from both real and simulated particle collisions at the LHC into sound. The aims of the project are to attract people to the results of the LHC experiments in a way that is novel, exciting, and accessible; to establish mutually beneficial communication between the often disparate fields of music and science and provide composers with access to LHC data; and to introduce particle physicists to the possibility of using sonification as an analytic technique and to begin to establish methods available for doing this. The LHC Sound Project won an award from Science and Technology Facilities Council for public outreach. Dr. Asquith's innovative approach to making particle physics data available to the public has also been featured on National Public Radio. In August 2010 Dr. Asquith accepted a position as a post-doctoral research scholar at the Argonne National Laboratory in Chicago where she works today. On behalf of my colleagues with the National Collaborative for the Study of University Engagement, and of course our many, many cosponsors, please join me in welcoming today's distinguished speaker [applause].

Thank you Burt, thank you. Thank you very much for having me. As I was explaining to Mark, who's doing the sound, I'm a bit of a wanderer when I speak, possibly to do with being a bit nervous so I may be moving away from the microphone like this, and if you can't hear me just do that with your head and I might see you and go back. Um okay, okay so I'm going to be talking about LHC sound, which I think is why everyone's here. But I'm also going to sneak in as much as I can about my favorite thing which is ATLAS, the detector that I'm working on, the detector that we use to collect the data that the sounds are made from and the detector that's going to find the Higgs boson, perhaps in the next year or so and give us the answers that we're hoping to get from this experiment. So these are the things I'm going to talk about today. Why I love particle physics is the first thing, and I'm not going to make it boring. The Large Hadron Collider, which Burt just mentioned, is the machine which we're using to collide particles which is based in Geneva, in Switzerland but which has a huge number of U.S. scientists working on it. I am going to talk about how I make sounds out of data and then a few words about what's ever next. This picture here is something that was drawn by my colleague Toya Walker who's an illustrator and artist and it is supposed to be the ATLAS detector as a music box, which is a nice idea that she has which was inspired by this. And this golden snitch is a reference to Harry Potter, so the thing that we're seeking is the Higgs boson. Perhaps we won't find it with sound but it might help, it might at least encourage people to enter physics who are smart enough to do things that will find it. So first, what is LHC sound? So a bit of a silly slide—a lot of my slides are—it began in south London which is where I'm from, which is why I have this accent which I'm trying to play down so that people can actually understand me. I was writing up my Ph. D thesis in the winter before I finished and this is what this pile of paper represents and the sad face because I was actually at that point in my life that many of us have probably been at where I didn't think I wanted to do physics anymore. I hated physics, I hated my thesis, I hated my life and it was all miserable and so I got in a bus—and this is a 37 bus from Clapham Common to Brixton—and I went to see some musician friends who lived in Brixton South London who happened to have bought a new drum machine. We were playing with this and making some sounds and I had the idea that some of these sounds sounded a bit like particles whizzing around. So this is a silly story which is really how the idea came to be. I think people think it was a really sort of clever, wonderful strange idea, but it wasn't, it was just having fun with things that I liked doing that were in fact making me miserable before. Okay so why I love particle physics, um [long pause] so particle physics has many questions in it that we can answer and some that we have already and some that we haven't. And I am going to play you a little video which is by a politician in fact telling us some things which I think sums up particle physics. [VIDEO: The message is that there are known knowns, there are things we know that we know. There are known unknowns, that is to say there are things that we now know, we don't know. But there are also unknown unknowns, there are things we do not know we don't know. So when we do the best we can and we pull all this information together and we then say, ‘That's basically what we see as the situation", that is really only the known knowns and the known unknowns. VIDEO ENDS]. I couldn't actually embed this in my talk because for some reason whenever I did so the talk would just get corrupted and crash and so I had to put it separately. But I think that he was suffering a bit there because it became clear that he was kind of not making himself clear, but I thought that was wonderful, what he said. This is exactly what I'm trying to say here, there are known knowns, there are known unknowns and there unknown unknowns. That makes perfect sense to me in physics because that's exactly where we are in particle physics and we have to admit—and we're quite ready to admit—that we don't really know anything, most of it is unknown unknowns. But we have to start somewhere, so start with the known knowns and they're pretty amazing, although very few and far between. So this picture here, I am wondering and I am speaking loudly so you can still hear me, this picture here is of all of the fundamental particles that we know of and that we've worked out from experiment. The only one here that we haven't discovered is this Higgs boson which we're looking for now. Only three of these are really relevant to us actually, so this is the up and down quark on the electron. Those three particles and those three particles alone make up everything in this room including you, your heart, your lungs, your blood the air you're breathing, the ground you're standing on and the sun, the stars, everything in the solar system. The others are all unstable which means they can exist for very short amounts of time and then they turn into the ones we know. All atoms are made out of just those three things put together in different ways. So to me this is quite amazing [long pause]. We don't see quarks on their own, we infer their existence. This history of the universe picture shows where we are now on the right, where we have people thinking about philosophy and going to talks with engaged scholars. And on the left we have the Big Bang which was the moment of the creation of the universe. And just after that we have a whole bunch of free particles, but after not very long they, they got tied up into matter. They made nucleons, they made bigger particles, they were bound inside them and then they stayed like that forever, which is why we're here. So in order to look at these particles that were free at the beginning of time we have to try and go back to the conditions that we had at the beginning of time. And as you go more and more red on this diagram, it gets hotter and hotter and it gets more and more energetic and the universe gets smaller and smaller until eventually of course we reach a point of no size and infinite heat. We're not going to try to recreate that with the LHC but we're going to try to get as close as we can safely. Okay so this is just another way of trying to state that, this is the universe is about 14 billion years old. It was the first millionth of a second that we're interested in of this 14 billion years because after that it was all done, it was all finished, all the atoms were made that ever will be made. Okay. So the known unknowns and now it just gets more interesting. So why do particles have mass? So let's go through this equation, actually let's not [laughter], that's just my best joke ever because we're not obviously going to go through that, it's horrible, it's called the lagrangian. It's not very nice so let's leave that and just think instead. Why do particles have mass, or why do we care would be my first question if I hadn't talked about it already. We care because we don't know why, well first of all we don't know why particles have the masses they have. This picture on this side shows all the particles with the mass along the Y, along the upwards axis. So as you get higher up, you're higher in mass and you can see right over on this side, you can see that black dot is the Higgs, the one we haven't found. All these other ones have been found and they've been measured. And as I said, these there are the ones we're all made of and all these other ones are just things that decay. But they exist just briefly. Why do they follow this weird zig zaggy line in mass? It's something that physicists don't really like, we like things to have meaning, reason or at least to find a relationship between one thing and another and with mass this just doesn't come out at us. The other really, really vital thing about mass of course is that things have to have exactly the mass they do in order for us to be here. So if you change the mass of the proton which is what is inside the hydrogen atom by just 10% you don't have any life in the universe. You have no stars forming, you have no atoms at all and the reason why that is is because the proton becomes unstable and decays. And if you adjust the mass of the electron by just .2% you get a similar result: no life. So none of us, no stars, nothing. So mass is kind of quite crucial, and we have no idea what causes it, why things have the masses they do until this guy Higgs came along and gave us quite a good theory that we haven't proved yet which says that particles get mass because of the Higgs field. I'm not going to go into that today though. So all these other questions, these known unknowns, these things that have absolutely huge questions that we just have no idea how to answer. What happened to all the anti-matter? Because when the universe was created we know, if we know anything, we know that matter and anti-matter were created in equal amounts. They have to have been because that's how it works, we see this happen all the time. If you create a particle, you create an anti-particle too, there's no other way to do it unless all the laws of physics are wrong. So where is it? It's just not there. Are there anti-matter galaxies out there somewhere? Maybe there are, but I don't think that even answers this question completely. Why are galaxies rotating so quickly when in fact, why are the edges rotating so quickly? We are on the edge of a galaxy, we are in one of the arms of a spiral galaxy, where we are now. And we're moving too quickly around so we should be moving according to a certain [inaudible] called inverse square, and it doesn't matter if you don't know what that is, but we should be moving at a certain speed and we're moving too quickly. And this suggests that there's more mass out there than we can see. This is something that people may have heard of as dark matter. The third point here, why is the universe expanding at an accelerating rate? It's not growing but slowing down, it's speeding up. What's causing that? What's causing the universe to blow apart at faster and faster rates? This bizarre thing that we call dark energy but know nothing about what so ever, it's guesswork. Um are there extra spatial dimensions? So just to throw this in because it's a possible theory. We think of space being something that we can imagine and visualize in our head as having this, this and this dimension, what if there are others that we just can't conceive of? It would explain certain things according to some theorists. So these are the known unknowns. And this is just a diagram that shows what I just said really, but it's trying to tell you how much of what there is. So just five percent of these top four boxes of the universe is made of matter that we have any understanding of, all the rest we have absolutely no idea what is going on. We divide it into dark energy and dark matter but that really doesn't mean anything. We don't know what it is, we can't observe it, we can't measure it, we can't do anything with it. We could just come up with crazy ideas and no one could stop us. Okay so the unknown unknowns, well just a question mark of course, I can't say what they are [laughter]. But maybe one of you has an idea, you know, or maybe one of your kids does or maybe some kid is about to die of starvation somewhere, I don't know, it's really sad to think of that but someone should be born at some point who's going to come up with an answer, or at least a question that makes us think because we are really really lost. We know that, we are aware of it. So we're struggling around in the dark but we have the LHC now, so we're going to do some good things with it. So I am going to tell you how much I love it and how amazing it is. It's large and it collides hadrons, so that's where it gets its name from. Um you know what the large and the collide are, but the hadron is just a weird word and I think in America you pronounce it "hay-dron" although you didn't, so I don't know. I say hadron, this is a hadron. It's a kind of hadron, a proton is a hadron, so is a neutron and there's several different kinds of them. In the Large Hadron Collider we generally collide these things: protons. It's not called the large proton collider because sometimes we collide other things. So I guess the people who work on the experiments that collide others things were just like, "No we're not calling it proton" but we should do because it's just confusing. This is what a proton is, it comes from the nucleus inside the middle of an atom. We make them to collide by getting a bottle of hydrogen gas. And hydrogen is just a proton and an electron whizzing around it, we just strip off the electrons and then we pump the protons into a big long pipe and then we turn them around with a magnet so we make them faster and faster and faster until they're nearly at the speed of light and we keep accelerating them even then. And when there are going that close to the speed of light that they can't go any quicker they start to actually get bigger because that's what happens in particle physics, they get really really big and they grow in a cross section we call it. And then when they collide you get an almighty mess of debris. So they're not fundamental particles, protons, because they've got other bits inside them. So to be a fundamental particle you can't be made of anything else, you just have to be made of yourself, and that's what these things are, quarks. They are fundamental. So you think, if you collide something that only contains quarks with something that only contains quarks, how do you get other stuff? And you get other stuff by releasing energy. So the two protons collide and release energy and that energy is just available for anything, any of these little creatures that lie in the vacuum all the time to just jump up and become real just for a little moment. And that's really what happens. So this is why we built it, we want to work out what's inside protons, what holds them together, why we're here you know just all that kind of stuff. So we built this enormous, gigantic machine so that we can take apart the protons so that we can look at the very, very basic bits that make up matter and this is our machine. So um you can see these things here are the detectors, the four main detectors, there are another couple of small ones. The top half of this picture is France and the bottom half is Switzerland. Me and my daughter used to live just here and Geneva airport is just here. So it's a very very big machine and it's kind of international, it's owned by everyone. And here's some quick facts on it: so the whole circumference of it is 27 kilometers, so these protons go a very long way around. The magnets that keep the protons bending—because they don't really want to bend naturally—they have to be super conducting to be strong enough to do that, so to be superconducting they have to be extremely cold. In fact they're the coldest thing in our solar system, they're colder than the space just outside our atmosphere, they're just close to absolute zero, which is -270 centigrade which in American is something like -460 Fahrenheit so very very very cold. A proton, and these beams does ten thousand laps, 27 kilometer thing every second, so they are really going very close to the speed of light. Um and the detectors are recording an enormous amount of data, so we can't record everything that happens in these conditions, but we do our best to record the interesting stuff. We do record, we can record 15 million gigabytes of data per year, so that's, so the amount of printed information in all books in the word times by a thousand is what we'll be recording. The black hole thing, I've just put this as another tease at the bottom there, when we first started running the experiment lots of people said, "You're going to make a black hole and we're going to die" and they didn't say anything when we didn't, they didn't say, "Oh sorry we were wrong". So I just bring it up at every possible occasion just to rub it in that we didn't make a black hole [laughter]. So we can't say that we definitely won't, but we can't say that we definitely won't make dragons either, and it's about the same probability [laughter]. Okay so this is the ATLAS detector which is the biggest one on the LHC and it's my one. And on the left there is before it got finished and the right is still not finished, but that's my first visit to it, it's just really exciting. And I've got a little film which probably won't work but it just shows the building of it. Aww it didn't work, I'm really sorry, but I was going to say actually that I always put videos and sounds in these talks and always something goes wrong, so hopefully some of the others won't go wrong. Oh! There it is, look. Okay let me turn the sound off. Okay so this is working now, so this is all going to be random from now on, we don't know what's going to happen with the films. This is ATLAS being built and we speed it up in one minute. So we have these webcams in the pit, which is about a hundred feet underground and it took fifteen years to build this thing. But we just speed it up here and make it a minute. So these big things, oh it's too quick here for me. We can just look at it and think, "Wow that's the best detector I've ever seen", in particular it's much better than the second biggest one at the LHC which is called CMS, which is inferior. This is the unidetector going in, this giant great thing here which is being built, that's called a [inaudible], okay so that's it. So very pleased with myself that the video worked, we'll see what goes on next. Okay so ATLAS is a huge, massive experiment. It's one of the detectors on the collider and there's three thousand of us working on it. This is the number of meetings we have a month, this says four thousand, that's what I look like most of the time, rather than that which I thought I would be looking like. It's not glamorous, it's really miserable most of the time—no it's not really, it's brilliant. Okay so here we have another film and this is just to show you what happens when the protons collide in the middle of the detector. So it's kind of hard to visualize unless you've seen it a thousand times like I have, so here's some help. There are the protons and there's them colliding, so these things, these lines that are coming out of this point, these are the particles that were made in the collision. And they are shooting out into the detector where we measure them. I'm just going to play that again, oh no I'm not, yes I am. [Long pause] Okay it doesn't look like I am, sorry. So this is something that we can take a photo of. So what I just showed you, this collision showed two little balls coming in from either side of the detector, hitting each other in the center and then a big spray of stuff coming out. So in this picture here we have the detector. Here's a couple of little people just to show you how big it is. We have a beam of protons coming in this side and one coming in this side, and they collide in the center. Now if you're looking at it like this you get a picture like this. And this is called an event display, we use these all the time, we use them for education, we use them in newspapers and things like that. We also use them in physics, I was using them just the other day to take a look at some events. This is a kind of beautiful picture, like a photograph of an event of the aftermath of a collision. And this is what it used to look like in the seventies, the same sort of thing. This is tracks in a bubble chamber which is what we used to have to look at, now we have 80,000 computers to analyze the data and we occasionally look at one of those colored or animated pictures. In the seventies they used to take real photographs, that is what they used as a detector and then they would use their eyes. So they had teams of people sort of their junior scientists just looking at these photographic plates and trying to spot new particles like that. Okay so onto making sounds out of data. Apologies to those who find it boring, the very long introduction, but I think you need to understand that stuff in order to really know what I'm talking about. So this is how we do it. So first of all you can actually make sound out of any data, it doesn't have to be exciting ATLAS data, it can be an insect walking along a table data. So this is my example for today, this is a millipede and her name is Maude. And I am going to record her movements in a table because I want to tell you something about Maude without showing you this boring numbers, I want to show you, I want to play you a sound instead. So I've recorded three things about her, she has forty seven legs; hopefully I mean that's a mad number of legs. No biologists here to tell me off? Maybe she lost a leg in a fight or something. She's got 12 centimeters long, and she walks at 10 millimeters a second. So I can tell you that those things about her by showing you this table, or I couldn't I could do something better, I could map these things that I've measured to audible properties. So I'm mapping physical properties that we're used to, to audible ones that we can hear. So in this example I am going to say that the number of legs Maude has is going to be mapped to volume, that the length of her body is going to be the duration, so the duration of the sound, and the speed she is going at is going to be mapped to the pitch. So a slow Maude would have a low pitch [hums] and a fast Maude would be like [makes higher hum noise]. In case anyone didn't know what pitch is, maybe my daughter. Okay so um, how can I use this data? I can tell Maude from a different millipede with fewer legs, obviously just by listening to the sound because the sound that the millipede with thirty legs is making is going to be different; Maude's going to be louder because she has more legs. If she has a baby and it's only small then I know that it's smaller than Maude because the sound is a shorter duration. And if Maude was running very quickly I could tell just by listening to this sound, this single note because the pitch would be higher than what I was used to. This is, nearly all the sounds that we made in this project, this is just all we did. It's parameter mapping, it's taking something that we can measure and it's turning it, it's mapping it to an audible property, something we can hear in a sound. So these are the things that we are particularly good at hearing, we're really really good if we close our eyes, at knowing where a sound is coming from, even with our eyes open. But you can just play the game easier if you close your eyes. So I think we're better like this in this sort plane around than we are above our heads just because where our ears are, right? You can't use them so well when you're thinking about up here. But we're really really good at this plane of saying exactly where a sound is coming from. I think it's about three degrees that we can pinpoint a sound to. And a similar thing with a spatial absence of sound; if a whole room is full of sound but there's a little bit where someone's not making a noise, I'm also really good at hearing that, hearing that silence. So you can play at home doing this. Um we can recognize tiny, tiny differences in rhythm and in tempo and in pitch over time and we also, strangely I think, we agree very clearly as human beings on what sounds good and what doesn't. This is very interesting to me and I'm sure to lots of people, but I don't, I haven't heard an argument for why this is that's really convinced me, why do we agree on what sounds good? Not me and my daughter personally [laughs], that's not a good example right, but generally we know what sounds in tune and what doesn't. Why don't we use our ears if we're so good, if they're so good, why do we always use our eyes when we analyze data? We don't use our ears, really, for any kind of work. Okay so just as I mentioned before event displays, these photos of events where an event is the aftermath of a collision in the detector. These are used all the time and I think I mentioned before as well is I used these just last week I was using them. I had some very very odd results that I was looking at and I thought, well there's about two hundred events here that the first thing every young post-doc thinks is I've definitely found a new particle, and then you have to go and tell someone and they just go, "You're mad, go and look at event displays" and then you realize that you're mad. So this is what I did and I saw immediately that I was mad because there were huge dumps of energy along this region in the detector which aren't physics, they're the beam getting spilled. I never thought of that because it just wasn't obvious to me until I looked at the picture. So they're really useful these things, they're not just good for putting in your magazines or websites, we do actually use them all the time. I thought maybe we could do something with our ears that was similar to these useful event displays that we use our eyes with. So my initial thought was, what do these particles sound like? And I instantly knew, I knew exactly what every particle sounded like, just as I could always assign a color to the moon in my mind when I was an undergraduate. This is something that people, people personify these things that they love and I love particles so I know that electrons are blue and sound like xylophones. And I think a lot of other physicists that I spoke to had the same kind of idea and some of [inaudible] that are up here, they knew as well but they didn't agree with me, unfortunately. So um the thing that came out of this really is that they thought that; so these things that they're talking about at the top here are hadrons. They tended to all agree that hadrons hitting the detector sounded really complex, kind of ugly. What have they said? Like a man carrying twelve pints on a tray falling down a long flight of stairs. And that, I can imagine that that would be what this kind of thing would sound like if it had a sound, it summons up that kind of thought in your mind. It's messy, it's difficult, it's a big dangerous, it's got a strong noise whereas these less complicated particles, they seem to invoke feelings in people that people thought they were more musical. So for example, here we go Jay Size, this particles has two names because it was discovered by two people at the same time. They're tings on a high triangle. Electrons go "twang" like a very high note on an acoustic guitar, neurons are a much deeper twang. So these are just some of the comments I got when I first started out here. So the idea itself was quite gradual and very confused at the beginning. It was a small project which began with myself and one musician and then this one musician who's called Ed Chocolate introduced me to these two other composers. This is Richard and this is Archer and between myself, Richard and Archer we are LHC Sound, so we are really the entire project other than lots and lots of people who have collaborated a little bit and supplied sounds or supplied pictures or supplied some kind of input. So we talked together over a long period of time, particularly myself and Richard and we turned ATLAS data into sounds by this process which is this wonderfully interesting picture of code. The data comes in this format when I see it, it comes in code basically and I turn it into numbers and I then send it into this program that Richard wrote that turns the numbers into sounds. Um let's just hope this works. So this is the first sound that we made, unfortunately there is a huge black square over the picture, but I don't think it matters too much. Did you see a little glimpse of it then? Let me just do that once more, there. Once more. Anyway, it's showing you the picture that I showed before which is this looking head on at the detector so that what you see is a circle. So the first idea that we had was to do a kind of sweep of the detector like you imagine um the radar on a battleship or submarine, you know that it goes round itself and it goes boop boop and the beep is when it hits something. So we thought what happens if you stand in the middle of the detector and you do that? There's a lot going on, right? So you're going to get [long beeping noise]. So we get this sound using real data. Okay it works [audio plays, sounds like chimes], so this is real ATLAS data using tracks from the detector. So the tracks are the particles, every time we hit one we have a note. And the pitch of the note is mapped to how, how much momentum it carries, or how much energy, how energetic it is. Energy is kind of proportional to speed, so you could relate that somehow to how fast that particle was moving. I will play it again while I tell you what it is. The very short distances between the notes are because the whole detector is full of these things and that's how noisy it is in there. This is what we have to deal with and the loudness is I think mapped to the distance out, I'm sorry, yes the loudness is mapped to the distance outwards from the collision point where the detector is. So this was a first really simple example that we made, we were quite pleased with that. We tried it with a few different instruments; I think that's a marimba that Richard chose for that one. But then we moved on. We actually played with a lot of things and I'm actually just going to show you a few examples today. This is an example of jets which is my new favorite topic in physics and it's what I've been working on for the last year. And a jet is a spray of particles that is created in a collision. A single particle will decay and then those particles will decay and then those will decay, so you've got like a shower where the number of particles increases and increases and increases out into this cone shape. This is what we've tried to draw here. So in this example we've again chosen three things to map to sound, we've decided that when you go—I'm sorry I've lost the sound. So we decided that as you go outwards from the interaction point which is kind of like time moving on, this is time moving on into sound. When you go outwards from the axis there's a jet, so when you get further away from the path along which you're moving, this is the pitch, so in green there this is the pitch and that is higher if you're further off the beaten path as it were. The energy is um is mapped to volume, so a lot of energy deposited, it is splurges of energy we're talking about is where the particles stops, it dumps all its energy, you've got a splurge. And we took in a cone full of splurges. So if the splurge has a lot of energy, it's loud. [audio of particle sounds]. And this peters out and goes on for quite a while now, but the point is I think that if you were, if you were at the center of the detector when a collision happened and the particles that were created were going out towards the outside of the detector and you were moving along the center of their path with them, this is what you would hear around you [makes noises], all around you as you moved along. Now you've got to the very outskirts of the detector, hardly anything is happening out here but there's a little beep. I am going to cut the rest off. Okay so another example which is kind of different is we thought, well forget about the physics, I think it was actually when we had some trouble getting a hold of some data, we thought let's just listen to the inner detector. What does the actual detector itself sound like if you just fire simulated particles? So when we say simulated we're not talking about real data, we don't even need collisions to be going on in the detector, we just use software. So we use a software detector and we use software events. What happens? What does it sound like when you just fire particles through this bit of the detector? And so this bit of the detector is probably, about up to here and is probably about about as tall as me. And these are just layers and layers of silicon and there's a layer in here as well. I call that the first layer, this green bit's the second layer, these blue bits are the third layer and that great big yellow it's called a drift chamber, it's a kind of different kind of detector, that's the fourth layer. So you have four possibilities for sound in this example. [Sound plays] So when you hear that fourth sound is different, it's higher in this case. And that last one was actually absent which we signify with a clap. The reason why this sounds the way it does it because we map the pitch to the number of hits in here. If you get a lot of hits, which you do in layer four, then you get a high sound. This is kind of a funny example but I actually, sound wise I really like it so I thought I'd play it for you. Okay and so nearly to the end but really a very different example, something that Archer whose, as I said before Richard and Archer are the composers I was working with, most of the sounds I've just played were things that, very simple things that Richard new that my very limited knowledge of music could understand and we could work together with. But Archer kind of went off on a crazy mission on his own a bit and did some really interesting stuff. So this example is something he did where he used an existing sound, in this case running water, and then he took the data that we gave him—we have him the same data that Richard had to play with—and he turned it, he turned this running water sound into a different sound by shaping it using the data. So he stretched it out and he took it apart, this existing sound, using the data. So it's just a different method of sonification. And I need to turn it up, it's a bit quiet this one, sorry. [audio plays]. So you can hear that this is a very weird sound, and a lot of the very weird ones that we've got are from Archer and they've made some of the most beautiful impact on some of the compositions people have been doing. They are also the hardest to understand, for me to understand and therefore for anyone because I do the explaining. They also have nothing to do with the crab nebula, which I put up here. I just love the picture [laughter], and I don't want to use the picture of Archer's face, I don't want to embarrass him by using it again and big. So that's the crab nebula. Okay that's enough out of you, stream. Okay so this is the end of my talk and I just wanted to say a few words about what's ever next. Normally at this point in a talk I think that I would say, "Next I plan to do this that and the other, we're doing this" and I'm not going to do that here because I don't have any plans, it's kind of an open book now. For the last few months I've done very little work on any of this, I've been separated by the Atlantic Ocean from my colleagues and I don't have any time because I work 15 hours a day banging my head against the desk. But it doesn't mean that I don't want to, so I do want to collaborate with people in the future and to do stuff. But really where I would normally say, "These are my plans", I would say here I want to hear from people if they have plans. Um and I've just said how happy I am, really, to have been involved in this so far and in the future. And I think my favorite thing that I've got from it, apart from having experiences like I've had all day today with meeting people who have these amazing and weird and crazy ideas, is just the amount of creativity that people have. And you know you can give them a little noise, like a squeaking thing, a table of numbers and they come up with something that just blows my mind and makes me feel really happy to be involved. So I am going to leave you with a composition which is not a noise but is actually, I think music which is made purely from the sounds that we've created and put on the website. It's by someone called Carla Scaletti who was working with us a lot towards the more recent months of the project and her invention. And so I am leaving you this, thank you for having me [audio plays]. It's quite long [laughs]. Sorry Carla, oh that's really disappointing, I've got backup. There we go. Okay this is much less problematic than I normally get, so bare with me. We will play a piece from here. So actually it's four minutes long, so if you want to, if people want to get up and go to the loo and have a drink of water [laughter]. Thank you. [Applause]. Do you want me to turn it down? [Burt Bargerstock: Does anyone have any questions for Lily? This would be a good time to ask those]. You want it on? Okay, okay so I will come and have questions. [Inaudible audience question]. So this is something that, in particular in the beginning I was really excited about. Slowly as time has gone on, the more physicists I've talked to and had cold water poured upon me, I've just lost momentum with it. I think that there's obvious ways which we could use our ears to analyze data because why not? We use our eyes; our ears are great at other things. I mean our eyes can see one octave in frequency where our ears can hear many is one example. But our ears are also better than eyes in many other ways and to put them together actually seems like a sensible thing. But to actually implement this in the ATLAS collaboration in which everyone like me is working 68 hour weeks on physics and getting the man power, even though there are three thousand of us, is proven quite soul destroying. I mean like for example this project has been running for two years and I am the only physicist working on it. That's what I have to contend with. [Audience member question: What strikes me about this project, because I know there are lots of artists out there that kind of generate interest in their work by allowing others to remix it. So basically allowing, saying "Okay this part of the copyright allows you to do certain things with my work" and so what you have here is essentially the same thing, only instead art per se, it's data. And being allowed to make a composition like this also reminds me of things like [inaudible]]. Which was wonderful. [Audience member continues: And there was another, there was a dance company who does this thing, I can't remember what it's called, but they basically cover the history of the universe and the physical issues arising from that in an hour or so. And so this just seems like another opportunity to do that sort of thing. I'm getting to a question. I, you have obviously a lot of collaborators, I am just wondering what is sort of the public response in other people approaching you about?]. It's been absolutely wonderful, I mean it's been mind blowing, the response that we've had from the public and from the creative world, has been mind blowing. You know we had to move the website, it got crushed because there was so much interest and all the you know, the thousands of emails and people phoning and really great stuff. So we were surprised by how it took off, it took peoples' imaginations I think. Yeah, you did ask a question, did I answer it [laughs]? [Audience member comment: I like hearing that it is popular]. It's hugely popular. [Audience member comment: It's so accessible, people now days with the technological tools they have are very very good at remixing]. Yeah so I think one of the questions I asked earlier was, why do we use our eyes to analyze data and not our ears? And I think one of the answer I gave myself quite early on was that we've had sort of printed material and digital printed material around for quite some time, we also had computerated graphics have been progressing rapidly, but have done so from a while ago, a couple of decades on that. Um whereas digital sound is perhaps a little behind? I mean are we progressing more rapidly now than we prospered in the 80s with that? Should I just take that out? No. Sorry, can we live with that little noise, sorry. Hello? [Audience comment: I am an artist, and I am thrilled that I understood anything you said]. Oh good I am so glad. [Audience comment: My question is, I had done an art show where I had photographed people and I had the photographs introduced as touchable art so that people would be comfortable, and they chose to call the show "Facial Vision" which is another word for echo location. And echo location is the ability of individuals to experience sound, not as it's generated but as they experience it. So my question is, you know your collision sound, is the generation of the collision sound a representation of the initiation, or does it have anything to do with how the particles that are also present are receiving that?]. It is exactly about how the other particles are receiving it. So the—[Audience member interrupts: So it is actually the sound of echo location?]. Yeah kind of, it's, it's difficult to really put it in a box what it is, but I think like for the example that I was discussion with Zach earlier is someone said to me, "What is, these jets, what are they, what do they look like? Are they this big or how big are they?" and was asking me to explain more about them. And I said, "Oh they are about from here to the end of that room in the detector". They only exist really in the detector because they are particles being detected. So in fact this whole room is full of particles, you've got neutrons streaming through your body right now like you've got three hundred going through your thumbnail every second. They just don't interact with you, but there are other ones that are interacting with you. So there are photons pouring down on you reflecting off you, that's why I can see you. But the particles that are in this jet, they could also be present here but we can't see them because there's no detector. So when you say, so when you say do the particles that are also present reflect that sound, do they kind of, does their presence affect it? Absolutely, just like a stick hitting that chair would not sound the same as a stick hitting the air because that's the difference. I mean there would be no real sound whereas here you've got a detector, you're detecting the sound. Yeah? [Inaudible question]. Um we don't, we don't know anything but we believe that they don't. So for one of the differences between quarks and atoms—apart from the fact that we're much smarter now and much more likely to be right—it's that we haven't actually observed a quark on its own. They exist bound up in atoms; they are really an invention of our minds, anyway. We accept this, we acknowledge this, perhaps we don't promote it to the public very much, but we invented the idea of quarks, or a guy called Murray Gell-Mann did. He had the idea that these new particles that we were finding had certain properties that we could understand if they were all made of three little, or two, little things that he called quarks. No one listened to him and time went on and more and more particles were found and they all fit into his beautiful theory, that's how these things develop. We're now so sure that all our answer will fit into this theory that we say quarks are real, they're actual real things and they are fundamental. That's where we are now, so fifty years. Maybe quarks don't even exists, it's possible. [Inaudible question]. Right. I don't think so, I think that the neutrino is going faster than light is something that, I think they were right to publish and to talk about it because that's what they observed, but I think there is an uncertainty in their measurement that they've missed. And when they find out what it is, we will realize that the neutrinos are not going faster than light. A paper was published about seven, ten days ago by a couple of theorists showing that they can't do this. Lots of people are, I mean one of the problems with it, my main problem is that this experiment called OPERA which made this measurement, the whole experiment is based on the principal that special relativity holds. And if these things have gone faster than the speed of light, special relativity does not hold, so it just contradicts the fact that they've even done the experiment, it doesn't work on any level for me and it just can't be true [laughter]. [Applause].