Chris Parkes

I'm a professor at the University of Manchester. But for this period, I'm also the elected leader - in the particle physics jargon that's called the spokesperson - of the Large Hadron Collider Beauty Experiment. So LHCb - “Large Hadron Collider Beauty experiment” - is one of the four large experiments at the Large Hadron Collider. The Large Hadron Collider is the “big” accelerator at CERN and it is a 27 kilometre circumference ring and it collides protons which go round the ring at close to the speed of light, and then they collide in four places around this 27 kilometre ring. And those four places are where the big four experiments of the LHC are. One of those is LHCb, and that's the one that I'm the leader of at the moment. Now, the LHCb experiment, is a big scale experiment, covering all kinds of different areas inside particle physics. And we have 1,500 collaborators, members of the experiment, from 20 different countries contributing to the experiment.

Dave Espley

In terms of the work you do - obviously I’ve done a little bit of research and I'm not a scientist, so I apologise in advance, but if you could bear with me in terms of where the questions are pitched. There’s obviously a fundamental understanding of the model of physics. The work you're doing: would it mean that understanding would get completely rewritten, or is it a question of adding to it? In other words: there are gaps in our understanding of the fundamental model and the work we're doing will fill in those gaps?

Chris

It's a mixture of both. We've been running for basically ten years now. We started running the first runs of the LHC in 2010 and we ran through till the end of 2018. We've now put in a new version of the detector, and we’re now starting running again, in fact, as we speak (Note: July 1st 2022), it's next week that we start the run again and we'll run this version for about another ten years. And then I have ideas for a third version of the experiment, which will run throughout the 2030s. So it's a *very* long time scale project that covers really a wide range of different areas. So exactly as you're saying, some of what we're doing is really searches for new phenomena, which is beyond what we know in our current physics. If we were able to discover such a thing, that would be of course, tremendous, would be a real paradigm shift. But also a lot of things that we do are testing inside our current knowledge of physics and expanding what we know within the theoretical framework that we have, to learn more about it. Maybe to put it into numbers for a moment: So as I said, so far we've been running for about ten years and we've put out over 600 scientific papers, and a very large fraction of those contain discoveries of some type, not necessarily discoveries which break the current model of physics, but discoveries in the sense of finding out things that we did not know before that are expanding our knowledge from doing these experiments.

Dave

In terms of changing the understanding of physics - and again, I apologize, if this is out of date but in my research, I came across an article of just over a year ago in The Guardian [Note: the article can be found here: https://www.theguardian.com/science/2021/mar/23/large-hadron-collider-scientists-particle-physics] where you were talking about unstable particles called B mesons and how potentially that might change our understanding. Now, obviously it’s over a year ago, have we moved on from that or is that still the case?

Chris

Yeah, that's very much still the case. So you know we really look at a wide range of phenomena in the experiment. And one of these areas that caused quite a lot of excitement when we had a result that came out last year, was looking at particles containing the B meson and looking at them decaying into other particles. And in those other particles sometimes they decay to electrons, which I guess we're all familiar with - the particle in the atom that orbits around the nucleus - but sometimes they have decay where they decay to what's called a muon, which is the heavy version of an electron - similar to an electron, but has a heavier mass than the electron. And our basic theory predicts that we should get the same rates for the decays into electrons and muons in these particular decays of the b mesons - there’s a universality of behaviour between the electron which goes into electrons and muons. And we had some interesting hints that maybe there could be a discrepancy from this. Now, these are just hints at this point - it's not at all any kind of breakthrough - but with the new version of the detector we will be collecting far larger data samples, and this is one of the things that we will be studying to understand where this takes us in the future. More generally, a couple of the areas that my experiment really focuses on are looking at differences between matter and anti-matter, and looking for processes that are very rare - things that happen not very frequently in the proton-proton collisions. And the bit that we were just talking about is an example of some of these processes, which can be quite rare. And in both of these ideas, looking at differences between matter and antimatter, and looking at these rare decay processes, they can be things which can tell us about our current theory, but that can be ways also of searching for new physics phenomena that could be beyond what we know at the moment at all.

Dave

Just going off at a slight tangent, does it frustrate you when the work you're doing at CERN tends to get distilled down in certain parts of the media to the tabloidy “oh my God, they're going to create a black hole and kill us all” nonsense. Is that a frustration when clearly what you're working on is absolute cutting edge science that is very, very important.

Chris

Well, when I was working as a Ph.D. student, you know, 30 years ago, there was much less coverage of the kinds of physics that we're doing. So, the first thing I'd say is I'm quite pleased with the fact that the kinds of fundamental physics that we're doing now is much better known in the general public now than it used to be. There's been a lot more media coverage over the last ten years with the LHC, with some of the breakthroughs that we've made. And I think people are much more educated about what we do. You know, if I go back to before the LHC and I told people that I worked at CERN, you know, you spoke to your average taxi driver, he wouldn't have a clue what was what it was about. Whereas now people have some knowledge of what CERN is about and what the LHC is about. So I think, you know, the fact that you get these tabloidy stories is to some extent a corollary of that. You know, it comes with the fact that there is a much higher profile for what we're doing. I mean, you're right that the actual “we're going to destroy everybody in a black hole” is clearly something which, you know, you need to reassure people, you need to explain the science behind what we're doing. You need to explain that the experiments that we're doing, while we've never done them on earth before, what we're really doing is creating the same kind of conditions that would have existed in the early universe. And by doing these experiments, you're trying to find out about this fundamental physics, but that what we're doing is, that it's not dangerous. We make a big program in the local area around CERN to ensure that the population in the local area know what we're doing as well, to ensure that there's good support and that people feel on board with what’s happening here.

Dave

And sort of in an, in a similar vein, one of the other things that does seep into the mainstream coverage over here is the potential to have a new collider, sort of many degrees of magnitude bigger than the LHC. Is that going to happen?

Chris

There's a five year design study ongoing at the moment. Every half a dozen years or so we have what's called the European Strategy for Particle Physics, where we scope out where we would like to go in the future, for the field, and these projects as we're explaining are extremely large scale and therefore they also have large time horizons for them. I was explaining with the LHC experiment alone, we're already plotting out what we want to do into the 2040s. And this is for exploiting this fantastic machine, the LHC, that we have at the moment. But we're also starting to look at, indeed, what could come after the LHC. So this is a five year design study for what's called the FCC at the moment, the Future Circular Collider, which would be a collider with an energy about seven times that of the current LHC located in the same sort of area as CERN – we're on the French Swiss border near Geneva - and there's a whole set of different aspects of that. You know, clearly one thinks first about the physics and what we could deliver for that, but it's actually much broader than that. You know, you have to think about the civil engineering for it, the local area, the political support, and all these elements are going together at the moment into this design study that's going to report in, I think 2026 to see whether this is a project that could potentially go ahead. I mean, personally, I think it's extremely exciting and I think if it turns out that there is a possibility for this, I think it could really be the next big machine for our field.

Dave

And is there any limit to how big you can go? Are there gains to be got from going bigger and bigger - do they tail off or is it proportionally, you know - even 500 miles circumference?

Chris

I mean, so far, honestly, if you look back at the history of the subject, every time we've increased the energy of the colliders that we've been able to produce, we've discovered new phenomena. So as of yet, we don't see any end in sight. You know, with the LHC, we had this major discovery, the Higgs boson, that you've probably heard about. And a whole range of things that we might come on to later, that the LHC's discovered. And yeah, the hope would, of course, be that the FCC would do something similar. Now, beyond that? Wow, we're really into territory that is beyond both of our lifespans, I think, because these projects are extremely long time periods. I mean, the FCC, we're talking about running the LHC until the 2040s. The FCC would probably start maybe 7 to 10 years after that. So already that you can see the time horizons for these projects are huge. So yeah, where humanity's going to go in the future, I don't know. But I think what we can do right now is try to push the boundaries inside the technology that we have available.

Dave

We were talking in July 2022, around the time that the LHCb team at CERN announced the discovery of three new exotic particles. Chris gave more detail.

Chris

So we've announced the discovery of what's called a pair of tetraquarks and a pentaquark. Now, let me explain that to you a little bit. The particles of which the atomic nucleus are made up, are the proton and the neutron. And the proton in the neutron consist of three quarks that are bound together. There are also particles that contain two quarks, that are bound together. And during the 1960s and 1970s there became this “zoo” of these particles that we found containing two particles bound together and three particles bound together. Collectively, these particles containing quarks are called hadrons, just to use a word of terminology. Now, it was speculated already from very early on when people started to understand that particles like the proton and the neutron were made out of these more fundamental particles called quarks, that there could be more exotic hadrons, which could contain four quarks or five quarks. So a particle containing four quarks is known as a tetraquark and a particle containing five quarks is known as a pentaquark. And over the last years at LHCb, we've discovered a number of these tetra quarks and pentaquarks. And what we've just announced is the discovery of four more, and I can talk about three of them in particular. So one of them is a pentaquark. We discovered our first pentaquark back in 2015. There were very few of them discovered, and this new pentaquark that we found contains one of these quarks known as the strange quark. And it’s the first pentaquark that we've found that contains this strange quark. Now, in nature, there were six types of quark and one of those quarks is this one called the strange quark. And this is the first pentaquark containing the strange quark. So that's something interesting about this. The pentaquarks decay into other particles and those particles that they decay into… the previous pentaquarks decayed into one set of particular particles in that final state. And this new one decays into other particles. So it's really also only the second kind of “class” of pentaquarks that we’ve found. Okay, that’s pentaquarks. And then at the same time, we've also announced the discovery of tetraquarks. And now these tetraquarks contain four quarks joined together, bound together. And what's one of the things that’s particularly interesting about these tetra quarks is that what we’ve found is a pair of tetra quarks. Both these tetraquarks have the same mass as each other, but they have different electrical charge. One of them is neutral, like the neutron, for example - it has no electric charge. The other one has double electric charge - that is, it has twice the electric charge of the proton: this is the first tetraquark we found that has double electric charge to it. And these two, they both have the same mass as each other. They come as a pair, therefore. So what's really happening here is it looks like we have two particles that have very closely related structures in terms of which quarks are inside them. And if you exchange a couple of those quarks inside the one particle, then you get the other particle instead. So you've got a pair of them which are closely related, which is telling you something about building up a family of these tetraquarks. So these exotic hadrons, these ones that contain four or five particles - we now seem to be moving into a slightly new era of them. So for the last few years we started to discover some of these and now we're moving into understanding that actually - it looks like they come in families. It looks like they come built into structures, which one can explain out of the fundamental quarks that we know about.

Dave

That’s fascinating. It might be a silly question, really, but where do you get most satisfaction - from discovering something that you didn't expect, or from filling in a gap where you theorized something and the discovery proves the theory was right. Is that a question you can answer?

Chris

Yeah. No, I mean, really a great thing, honestly, I find, about the job that I'm doing is that it has such a broad range of things. I mean, I'll broaden out from what you were saying, even. You know, we've talked so far mostly about the physics itself and the discoveries we're making in the physics, and the things that we're learning. And of course, that's our physics output and what we do. But there's lots of elements to it, because we're also a very large collaboration with, you know, 1500 people working across 20 countries, all working together. So there's a very strong kind of international collaboration element to it. And I think one of the things that people really understand when you come out and actually visit and see what we're doing, is also the strong element of engineering and computer science in what we do. It really cuts across all areas of the so-called STEM subjects. It's not just the physics projects at all. It really goes all the way from theoretical physics through to experimental techniques to data analysis to big civil engineering, mechanical, electrical engineering projects, to the analysis of the huge data samples that we have, which really use cutting edge computer technologies. And we work very closely with industry as well to be able to produce these big objects. And in the international collaboration, these detectors are built out in all the institutes around the world, and then we bring it all together at CERN. So in Manchester, you know, we've been building a really key element of this new detector that we're that we're going to have operating from the start of the new run.

In Manchester we've built this this component, which is called the vertex locator, which is the detectors which surround the collision point. So the protons are brought into collision. And from the proton-proton collision, you get a whole spray of new particles being produced and then they go first through these silicon detectors that we've assembled in Manchester, and then they go out through the rest of the detector and each part of the detector will measure different characteristics about them. And really the bit that we've assembled in Manchester is kind of at the heart of it because it's the first elements that the particles go through. They have an extremely high precision. You can think of them as like the cameras that are in your mobile phone, but these ones have very small elements. Each element is about 55 by 55 microns - the pixels inside it. And this version is "radiation hard" and it takes pictures 40 million times a second. And from those pictures, you can then reconstruct the particles that were produced that flew through your detector using all the other parts of the detector as well. You can find out about what was produced, and that is the data that you analyse to ultimately come up with the kinds of physics results that we were discussing earlier.

Dave

Chris also mentioned that it had recently been announced that the UK government had agreed funding for the next version of the LHCb experiment, to take the team into the 2030s. He gave more detail about the importance of such funding.

Chris

As we were saying earlier that these projects are extremely long scale projects and we've been having ideas about the version of the project of the LHCb experiment that will operate in the 2030s. We organized a meeting, an international kick off meeting for this project, which I hosted in Manchester in 2016. And then for the last few years we've been starting to go through the approval process for this next big project for the 2030s. And in the last few months we issued a document which is called t he Framework Technical Design Report, and this this lays out the plans for what it is we'd like to build and what science we'd like to do with this project, in the 2030s. And this document has been approved, and we've been now starting to discuss the funding of this project, and just a few weeks ago the UK has announced that it wishes to fund this project and is giving a £50 million grant for the construction across all the UK institutes for the construction of this version of the project for the 2030s.