Will Bertsche

So historically when I started my graduate student career, I started in plasma physics. I was kind of interested in nonlinear dynamics, but also experimental physics. And at the time, the supervisor that I worked for, Joel Fajans, at UC Berkeley, was doing some interesting work with non-neutral plasmas and the nonlinearities associated with those plasmas, and it was interesting work because it was actually an experiment that you could run and carry out to investigate these sorts of issues, specifically in plasma dynamics and fluid dynamics. And so my graduate career was kind of spent working on sort of fundamental dynamics in plasmas. And sort of halfway through my studentship, my supervisor got contacted by the folks who were forming the Alpha collaboration at CERN and the Alpha collaboration was sort of a spin out of a collaboration called Athena, which was one of the first antihydrogen collaborations. It was the first collaboration to make antihydrogen. And they were continuing on a physics program to actually work towards making measurements on antihydrogen. And they needed to trap things. They needed to trap the atoms. And there was a lot of concern about how atom traps would play with the kinds of anti-matter plasmas that they had for forming antihydrogen. And that was really sort of in the wheelhouse of some of the work that Joel Fajans had done in the lab at Berkeley. And so we as a lab sort of agreed to work with Alpha and kind of got involved pretty early on, and built a kind of prototype experiment because for a long time, the plasma physics community had kind of said that the sorts of atom traps proposed by this anti-matter trap community would not work well with the plasmas. So we built a prototype experiment which kind of combined a non-neutral plasma trap with the kinds of magnetic fields that you use in magnetic traps and showed that in fact a conventional atom trap wouldn't work and that we really needed to consider, for trapping, making a slightly modified version of an atom trap with a higher order of multiple. I mean, this is a little technical(!), but that's what we did. So we built the experiment and demonstrated that what we were proposing to do was better than the thing that you would maybe do on the face of it, if you were just trying to build an atom trap without thinking about the plasma too much. And then we just kind of got involved in then making the full Alpha experiment. And at the end of the day, I spent basically the second half of my studentship working on this prototype experiment, and then incorporating the ideas and designs from that aspect of the prototype into the overall first version of the Alpha experiment that was that was built at CERN and started operating in about 2006. So I finished up then my studentship through the first year of commissioning in Alpha, wrote my thesis up and then had the opportunity to do a postdoc with Swansea University in the UK - they were one of the members of Alpha as well - and to continue on in that role

Dave Espley

So maybe if you could just say what your current position is at CERN and what the work involves?

Will

Well, so I'm currently the deputy spokesperson for Alpha and my focus is on our current experiment called Alpha G. So we have a couple of main apparatus at the Alpha collaboration. One apparatus is one that focuses on spectroscopy, and that's the one that we've published most of our recent results in. And in parallel, we've been developing a gravity experiment that we've just kind of been able to start running in earnest this year. And so, I mean, what that entails, of course, I'm an academic at the University of Manchester, so I have some of my students and postdocs here at CERN, but I also kind of supervise the work that's taking place on Alpha G and kind of plan both the technical and scientific programme that that we're carrying out on that apparatus at the moment. So that's kind of an exciting activity. But yeah, so I mean, this is, you know, there's a big gap between where I am now and where I was as a student. After my studentship, I continued on with a postdoc in Swansea. My, my focus at the time continued to be on the non-neutral plasma issues associated with making antihydrogen. And the big challenge there is that, you know, in order to make antihydrogen… that turns out to actually be relatively straightforward, if you get all the ingredients together in a trap. To actually make antihydrogen that you can trap is difficult because the strength of the traps we can technically make with magnets is not that strong. And what that means is that the atoms that we trap have to start out already very cold, and this is quite difficult when you have these plasmas which tend to be quite warm - they've got a lot of excess energy kicking around. To get them to recombine into a situation where they have low enough energy that they'll stay trapped - that's a lot of fancy manipulation to get there. And that was kind of the focus on what I did as a postdoc. And eventually, in fact, I used some of my experience in my graduate project at Berkeley before I started working on Alpha to actually be pretty central in making antihydrogen in the first instance that could be trapped and detected. So that was very exciting. We demonstrated that pretty definitively in about 2010, and from then on started to work towards actually doing real physics measurements with the trapped antihydrogen. And it was sort of at the tail end of that project that I continued on and was able to join the Manchester group and specifically the Accelerator Group. And my initial focus at that time was developing a big upgrade to Alpha, which would enable us to actually start doing laser spectroscopy. So the situation that we had in Alpha originally was an experiment that was really dedicated to demonstrating trapping at all and then having trapped it, then you would have a good idea about how to build the next machine that you could actually start doing measurements with. So that's what I started my kind of academic career with, and I've been sort of progressing through that sort of train of thoughts ever since. We built the spectroscopy experiment, commissioned that, and started working towards spectroscopy. And then in parallel, we had already done sort of proof of principle measurements in the original alpha device for how we might look at gravity with anti-matter. And so somewhere in sort of 2013, 2014, we started planning this gravity experiment, which we started installation in 2018 and just finished major commissioning last year. And so now hopefully this year we're able to start a physics run. So that's kind of, you know, the condensed version of the career trajectory to date.

Dave

Thank you. Apologies if I've missed this, but does your work involve using the LHC or is it not something that you get involved with?

Will

Yeah so the Alpha as an experiment we're making antihydrogen by combining anti-matter electrons called positrons with anti-matter protons called antiprotons. Positrons are relatively easy to come by as anti-matter particles are concerned. You can get them from the radioactive decay of species you can just find naturally occurring on earth. In fact, bananas turn out to be a reasonably good source of positrons because they're a good source of potassium and some small fraction of naturally occurring potassium is a radioactive isotope that produces positrons when it decays. So a banana produces about 15 positrons a second. Okay. That's not very practical for experiments; we use salts that have been activated in a reactor to get a good flux for ourselves. But that's relatively straightforward. The connection to CERN is that antiprotons are more difficult. If you want antiprotons on earth, you need to produce them with a relatively high energy interaction. And in order to create that kind of reaction, you need accelerators. And so CERN's not the only institute in the world that can and has produced antiprotons, but they are the unique facility in the world right now that produces antiprotons that are low enough energy for experiments like Alpha to trap those antiprotons and then use them for other sorts of experiments. So in the sort of CERN accelerator complex, everybody sort of thinks about the LHC because that's the kind of big headline winner these days. But the LHC is like the fifth accelerator in a chain of accelerators that produce successively higher energy particles for use in experiments. So the LHC, at the moment, it sort of collides protons and also high energy ions. We use the protons that come from the third accelerator in CERN's accelerator chain. So somewhere halfway on the way up to the energies used at the LHC, they can produce protons that can reasonably efficiently produce antiprotons. And then those antiprotons in fact go to a very special machine at CERN called the Antiproton Decelerator, which in fact slows the antiprotons down from relatively high energies to relatively low energies. And it actually turns out that decelerators are in fact much more complicated devices to operate than accelerators in many ways. The problem of deceleration just turns out to be more difficult than acceleration, because in addition to just slowing things down, you have to actually cool the particle population. But okay, that's kind of a side technical question - but that's why the experiment takes place at CERN, because it's really a unique [place] in the world that goes down to low enough energies that we can use them in our experiments. And in fact, CERN, you know, all of the experiments that are kind of working in this low energy anti-matter field or low energy antiproton specifically, they're all in the same building. So all of our nearest competitors, we're all next to each other in one room, basically surrounded by this decelerator. And there's been, you know, a lot of interesting scientific results that have come out of that work that CERN, you know, has committed to the program. They've actually installed an additional decelerator that they just commissioned last year, that takes the antiprotons from their original decelerator and lowers them to an even lower energy, which makes life a little bit easier for all of the other experiments that are operating, and enables CERN to in fact invite more experiments to work with antiprotons. So that's been that's been a good development in the community here over the past few years.

Dave

Just talking about your work in general, does it or could it potentially impact everyday life in terms that a layman might understand? Or is it just theoretical, gaining knowledge for its own sake, which isn't a bad thing, obviously.

Will

Yeah, so the central question that we're trying to answer with this category of experiments is trying to address this issue where the universe, as we observe it today, seems to be almost entirely made of matter, which is great for all of us because we're all made of matter. And if there were a lot of antimatter around, the universe wouldn't really look the way it does today, and it would be very uncomfortable for people like us to live in it. So for us, it's fine that there's not a lot of anti-matter, but the theories that we have all sort of suggest that there should be far more anti-matter than there actually is. And we don't understand this. So there's something clearly flawed with our understanding of our theories or understanding of the universe. And the kind of work that we're doing with antihydrogen is trying to address this and trying to find the flaws in in our fundamental theories of the universe. So that doesn't have any immediate benefit in the sense that, you know, it's just obvious once you know what's wrong, that you're going to be able to make a new widget or come up with some new technology. You know, having said that, of course, you know, pushing fundamental knowledge of physics has clearly had great benefit to society in general, right? So generally trying to improve our understanding of the universe hopefully can lead to, you know, new ideas about things that you can do in the world. In addition to that, what we're doing on Alpha is fundamentally an experimental activity. We are actively engaged in sort of pushing the leading edge of certain kinds of technologies like superconducting magnets and detector electronics and these sorts of things. And, you know, those sorts of efforts can potentially lead to new technologies in those areas. And, of course, we have, you know, an active experiment. We have many PhD students and postdocs who come through, and they do, of course, interesting scientific projects, but they're also getting trained on many different technologies. And then they continue on and do different careers and benefit society in different ways that are hard to predict. So those are the sorts of impacts that that we expect that our work kind of has, generally speaking.

Dave

And sort of taking that on a step, do you have any particular or specific hopes in the way your work will develop in future, any discoveries that you think you would…

Will

Well, I mean, what we're doing is making measurements to test things that everybody basically assumes are true about anti-matter, but no one has actually been able to test directly. So it's very likely that the experiments that we're doing, certainly in the short term, will largely agree with the kinds of experiments you would do with the matter equivalent - hydrogen in this case. Of course, it would be very exciting to actually find a difference, right? So that would be that would definitely be interesting. But if nothing else, we're able to kind of, you know, constrain the sorts of theories that can help understand what's going on in the world with matter and anti-matter. So that's a useful activity. I mean, for my part, I do think that the gravity experiment is quite exciting. And, you know, so we're kind of in our first generation of gravity experiments. I think there's some interesting things down the road, once we've kind of got this level of precision going, to make anti-matter interferometry

[Bad connection]

That would be a challenging, kind of an interesting long term goal to help with both gravity precision, but also with other kinds of spectroscopy measurements we might be interested in making.

Dave

A question out of left field slightly, I think, but: do you get frustrated when you see science reduced to this tabloidy "Oh my God, they might create a black hole and kill us all!" nonsense. Or does that not really bother you at all? Do you just get on with it?

Will

I mean, it's tricky, right? Like that this is what gets headlined in the tabloids. And I think, you know, when people have legitimate questions about the kinds of issues raised like this, for example, the black holes question, you know, I think the community takes that sort of thing pretty seriously. And, you know, in the black hole case specifically, I think there was a really compelling scientific response to, you know, whether we should be concerned with micro black holes or something like that being produced at the LHC. And I think that's an appropriate scientific response, so when, you know, the public raises those sorts of issues they can be addressed. I think there are more challenging kinds of things that that we do receive that don't really have easy rational answers, shall we say, right? There are definitely people who, you know, sometimes they don't understand what CERN is and the way we work as scientists. And they're concerned that we're somehow developing secret technologies, which we definitely aren't. I mean, Alpha as an experiment is entirely funded by public money. All of our results are fully accessible by the public. So that's kind of how we operate, we don't have some hidden agenda that that we're working towards. So, you know, those sorts of things can be - I don't know if they're challenging, exactly - it's definitely a thing. And the only thing you can do is try and educate the public about it. I do have a funny story about this, where we were upgrading part of our spectroscopy experiment. We were in the process of improving our clocks; one of the limitations of our experimental results at the moment is how well we can tell time at our experiments, because we're basically comparing time according to anti-hydrogen with time according to the rest of the matter universe on some level. And so we're improving our clocks. And you know, these clocks are pretty complicated devices. They involve all sorts of technologies and microwaves and lasers and electronics. And so we're trying to integrate this in an experiment. And then you just have to buy parts from companies, right, to do things. You buy components, you plug them in, you know, you get things operating to do what you want to do. And we had a contact with... it was just like a company that that produces, you know, has a good reputation of producing certain kinds of equipment that are useful on this on this chain. And so we got in touch and we wanted to get a quote to buy this equipment from them. And the salesperson just flat out refused to give us a quote because they thought that the work CERN was doing was evil.

Dave

Oh, my God.

Will

So, I mean, that's certainly the first time I've seen that kind of negative press, you know, cycle back in a way that has impacted our work. I mean, it means that we just have to find a different manufacturer for what we were trying to do. But, you know, that was that was definitely an unusual outcome, I guess.

Dave

Yeah. I think that was the basis of the question really because you can think, what, 20, 30 years ago when, you know, those kind of views were really on the fringes. But one of the negatives of the rise of the Internet - and there are lots of positives, obviously - one of the negatives is it amplifies those people and it amplifies those views. I mean, when it gets to the stage where a salesman will presumably lose commission, lose money for his company and turn down a sale simply because of these bizarre views that he's picked up about what you guys do. It does have a real world impact then, doesn't it?

Will

It was very strange. I mean, the company, it's a US company and we were working through the European distributor and basically the European distributor was like... I mean, we went back and forth and we, you know, we even wrote the company and asked them if this was, you know, some kind of a joke. And they were like, no, this really isn't a joke. And the European distributor affirmed to us that the people at the head of the company really believed this. This wasn't just some kind of one off view by some random salesperson. So anyway, that was strange. We're not even in the category of experiments that get accused of doing things like making black holes! So that was kind of a one off.