Animating AEgIS

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Introduction

My project for the Summer of 2023 at CERN was a combination of art and science that was creatively as well as academically stimulating. I was assigned to work on AEgIS, a project studying gravitational effects on antimatter. Currently, the experiment is tasked mostly with the actual creation of antimatter, a process which involves firstly the creation of positronium, which is then combined with antiprotons to make antihydrogen. Since this entire process happens on atomic scales, the physics involved is completely unseen and difficult to explain to someone not in the field. My task was to create videos running through the physics of AEgIS. These videos will be displayed to those touring CERN and to others who needed a succinct explanation of the physics happening. The videos will be projected next to the experiment itself in the Antiproton Decelerator. The overall idea is to not only display the physics occurring in the interior of AEgIS, but to join the experiment's hardware to its internal processes.

Process

I needed to firstly learn, myself, how AEgIS worked, and I had to learn it well. I had multiple different people walk me through the process, but I opted to make my animations very changeable instead of perfect, so those combing through the animations after me could edit them without much grief.

The first hurdle I had to cross was Blender. My modeling training was in 3DsMax, a professional software that, while good, is extremely expensive. So, my team and I opted to instead use Blender, an open source software for modeling and animation. The program, while not particularly difficult to start with, is very large, and a bit intimidating for someone who has never used it. My first two weeks were spent exploring the software.

Since I was mostly working with particles, I needed to manipulate a large number of objects in a relatively particular way, and Blender's particle systems were a little complicated and not very specialized. Luckily, Blender has its own Python package–so I could write Python codes that looped through the objects I wanted to move. This not only made the process faster than attempting to move the objects individually, but also achieved my goal of making the animations changeable. I created a set of generic functions that could be applied to any collection of objects and manipulate them all in a particular way. For instance, one function made a group of objects vibrate, with easily changeable parameters such as how far the objects moved with each vibration and how fast they traveled.

The second problem came in deciding what to actually show in the videos. They needed to be as accessible as I could make them, given that they would be shown to a wide variety of people who may or may not know anything about physics. However, they also had to be completely correct, since they would be an official product of AEgIS and couldn't be misleading. There was a sweet spot we needed to hit. The viewer needed to visualize what was happening without taking the representation too far. In a sense, it needed to get across the idea of what was going on but not hopelessly confuse the viewer in the process. I was the movie director for AEgIS, deciding what needed to be portrayed, how it should look, and what could be left out.

One particular struggle was how to portray the creation of positronium. The process involves a positron approaching an electron. The probability clouds of the electron and the positron overlap and create positronium. However, the idea of probability clouds is difficult to get across visually, and I had portrayed all particles as solid round balls up to this point. So, I had to transition from a solid ball particle to an object made from combined probability clouds. I went through a couple different iterations of this particular animation, which my advisor and I decided again and again were not quite right. Eventually, we created an animation where the balls deform into teardrop shapes and combine to become one solid ball–positronium.

In terms of camerawork, I opted for mostly zooms rather than straight cuts to different 'scenes'. This was in order to more accurately join AEgIS's hardware to the physics within. However, this came with a problem of scale. Even with the zooms, I had to portray particles as much larger than they really are. This was definitely the largest inaccuracy in all the animations, but it was a necessary evil. It would be near impossible to see the particles in any of the animations if they were true to size. It was suggested that I do a separate 'scale' video. This video would show how small these particles actually are, starting with some reference point and scaling down in magnitudes. This video was cut due to time constraints, but ideally there would be some added feature to demonstrate that the sizes of the portrayals are not accurate.

Results

My finished series of animations tells a story–antihydrogen from start to finish. The assumed starting point is after the delivery of antiprotons by CERN's Antiproton Decelerator and the production of positrons by AEgIS's internal radioactive source. At the end of this summer, I have created this story with twelve finished animations, summarized below.

Title	Summary	Length (seconds)	Narrative Order
1Ttrapvideo	Shows AEgIS's antiproton trap from the outside and removes infrastructure to make the essential parts of the trap easier to see. Video then zooms inside to show the silicone target.	15s	0
roughparticlesintotarget	Shows positrons moving into the silicone	19s	1

	target. Depicts the porous material of the target.		
throughsilicone	Zooms to the atomic level to show the silicone atomic lattice. Approaching positrons decay or slow down within the silicone matrix.	29s	2
zoomouttotube	Zooms out of the atomic level and shows a positron's movement into a tube within the silicone target's porous surface. The positron moves into the silicon oxide coating of the tube, where free electrons vibrate.	24s	3
makingpositronium	Shows how the electron and positron are attracted to each other, combining to make positronium.	12s	4
posoutoftube	The fully formed positronium works its way out of the tube, traveling back into the experiment.	20s	5
poswithoutexcite	Zooms back out to show the electron trap and antiproton cloud. Demonstrates how unexcited positronium decays before it reaches the cloud.	12s	6
lasertime	Shows the track of the laser around the antiproton trap, then zooms to positronium entering the laser.	16s	7
gettingexcited	Postironum crosses the laser, causing the positron and electron within to gain energy and increase orbit speed and radius.	14s	8
movingthroughlazer	Zooms out to show positronium moving through the laser and increasing in size. Video pans to show that the excited positronium is reaching the antiproton cloud.	14s	9
makingantihydrgoen	Shows the approach of positronium towards an antiproton. The positron is caught by the antiproton and the leftover electron is ejected.	10s	10

finishedantihydrogen	Shows fully formed antihydrogen traveling down the length of the trap.	13s	11

These videos accomplished the base goal of my project–take the viewer through the entire process of what is actually going on in AEgIS. A viewer with no knowledge of physics should be able to watch these videos and understand, to a certain extent, how antihydrogen is made.

Future work

These videos are far from perfect. In fact, it would be more accurate to say the *animations* are finished, but the videos are far from it. Firstly, each of these videos has something that should be fixed. These fixes are mostly aesthetic, although some fixes are scientific. For instance, my positrons in 'throughsilicone' decay into three gammas where they should decay into only two. However, these types of fixes are few.

These videos need to be resolved of these various issues, but hopefully the code I have written will allow the animations to be easily changed, as was the intent. The larger concern is labels. Text is not easy to manipulate in Blender, so the team opted to instead add labels after the fact. While the particles and objects are aesthetically consistent (keeping the same colors throughout each video), they are currently unnamed. Someone else on the AEgIS team will need to go through these videos in an editing software and decide where to place the labels. THe videos should be clear enough for a member of the project well-versed in the physics of AEgIS to know what particle is which, but explanatory captions or perhaps an auditory voiceover will be left to the discretion of whoever takes over the project after me.

There is also the question of the fall experiment. Since the project is currently concerned with the actual production of antihydrogen, that is what my videos focused on. But, the main goal of the experiment is to measure gravity's effect on antimatter. Thus, it would be fitting to follow up my last video with a video describing what the fall experiment would hypothetically look like.

Conclusion

Ultimately, my videos are a quick and easy way for the viewer to understand AEgIS. Although not the most technical project, these videos required a firm grasp on the physics and mechanics of the experiment in a way that required me to learn and learn well, and I believe it reflects in my finished project.