Particle Physics – Misc Research 1

What's The Deal with Matter-Antimatter Asymmetry:

Why is it that the universe is so predominantly made of matter and hardly contains any antimatter at all? In theory the big bang should have created equal amounts of both but for some reason today almost everything is made of matter, this is known as matter-antimatter asymmetry and remains one of the largest unsolved questions in physics.

Of course, to get this out of the way, if we were instead made from antimatter and matter was the outlier we would instead consider the idea of everything being made from matter to be weird. We might even have called antimatter matter and vice versa, in theory there is no practical difference (bar from opposite charge) between matter and antimatter.

But what if there was? If there was even a slight difference in how matter and antimatter reacted to forces, or a slight change in properties, then that could easily explain the asymmetry.

Another explanation that I personally quite like but haven't seen much of (maybe its easily disproven and I'm unaware) is that of the anthropic principle (also known as the observation selection effect).

Say that in the conditions of the big bang the probability for matter and antimatter to be created is exactly 50/50, you would expect, in an average scenario, that an equal amount of matter and antimatter would be created, collide, and then turn into photons. This is clearly not the case but how does the anthropic principle support this?

Simply put the anthropic principle states that certain conditions (regardless of how unlikely) will inherently exist because if they did not then the observer noting that they exist would also not exist. In our case let's say that antimatter and matter both existed equally, could life evolve in a universe like this? No of course not* therefore we only exist to point out the improbable asymmetry between matter and antimatter because if that improbable asymmetry didn't happen then we wouldn't exist to point it out.

One more explanation for asymmetry is that far away galaxies exist made from antimatter, these antimatter galaxies would have to be far away in intergalactic space or else we would have detected the gamma rays detected by the annihilation of particles in intergalactic space as they collided with the antigalaxy. Due to no such gamma rays being detected even at the low luminosity expected from an antimatter galaxy this theory is considered unlikely.

The final explanation that I feel like mentioning (though not the last one ever) is that of the mirror anti-universe. Imagine that at the big bang two universes are created, one with more matter, the anti-universe with more antimatter. The anti-universe flows backwards in time while the universe flows forwards. This theory even results in an explanation for dark matter in the form of superheavy neutrinos formed from the production of the universe

* Certainly not with physics the way that we know it.

anti-universe pair. This is an interesting theory to say the least but hasn't been able to show that it can reproduce observations about the expansion of the universe.

How the F**k Do We Detect Neutrinos:

So, neutrinos are tiny with almost no mass and no charge, hundreds of billions pass through each of us every second and yet no effect is measurable. So how then are detectors able to work?

Neutrinos only interact with other particles through the weak interaction (which, as the name implies, isn't particularly strong) and gravity (which due to the neutrino's mass is even less strong). This results in detectors being massive in order to detect a reasonable number of neutrinos but how do they do it?

The first neutrinos were detected through the Cowan–Reines neutrino experiment in 1956 which involved two targets of cadmium chloride solution and scintillator detectors (effectively radiation detectors). As antineutrinos pass through the solution, they occasionally result in inverse beta decay [(Figure 1)]. The resulting positrons annihilate with the electrons in the solution allowing for detectable gamma rays.

Chlorine detectors are another type and work through allowing neutrinos to pass through a tank of chlorine containing fluid. The neutrinos will occasionally convert a common isotope of chlorine (chlorine 37) into argon 37 through beta decay. The fluid is then purged with helium gas, and the argon content is measured. Some other designs use a similar idea but with gallium 71 instead of chlorine 37.

Cherenkov detectors are one of the more beautiful ways of detecting neutrinos. This method is due to Cherenkov radiation which is effectively a lightspeed version of a sonic boom shockwave [(Figure 2 and 3)]. When a charged lepton such as a positron or electron is produced through inverse beta decay the charged particle travels through a vat of water or ice (or other clear material) it produces a blue glow due to Cherenkov radiation [(Figure 4)]. Due to their use of water or ice Cherenkov detectors can be submerged in the ocean and use the surrounding water as the medium. Examples of Cherenkov detectors include those giant water-filled things with golden balls that you might've seen in three body problem (the show on Netflix) [(Figure 5)].

Tracking calorimeters are another type and work by using absorbers and detectors that work similar to the Cowan–Reines neutrino experiment but by usually using steel as opposed to a solution however these are only useful for high energy neutrinos as they require the production of muons in order to detect the neutrinos.

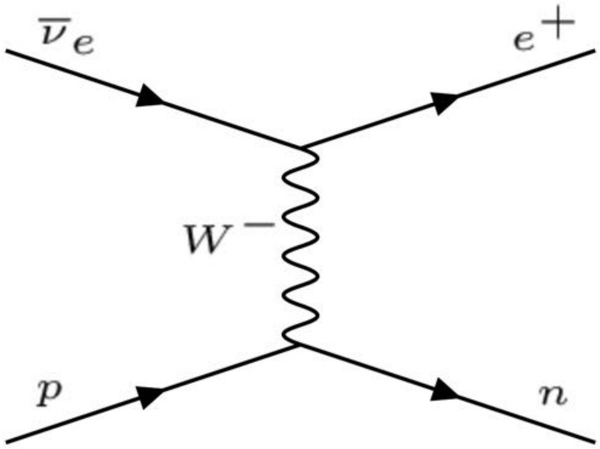

Figure 1: Feynman diagram of inverse beta decay, an anti-neutrino interacts (through a W^- boson) with a proton to form a neutron and a positron, same works with neutrinos and neutrons (through a W^+) producing a proton and an electron (Credit: ResearchGate)

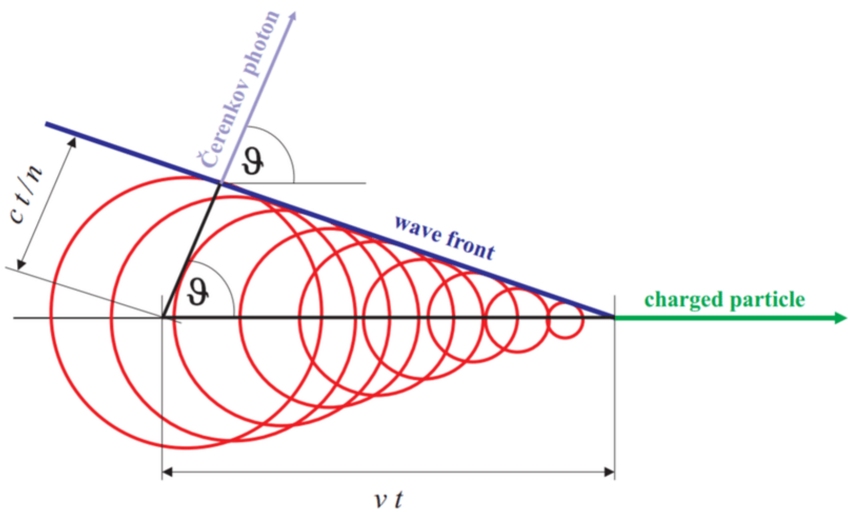

Figure 2: A Cherenkov Radiation diagram, the particle travels faster than the speed of light *in the material* (not in a vacuum) and so creates a shockwave (Credit: ResearchGate)

Figure 3: An F-35A Lighting II shows off its vapour cone, while not entirely due to breaking the sound barrier it works in a similar way (Credit: Wikimedia Commons User: Hnapel)

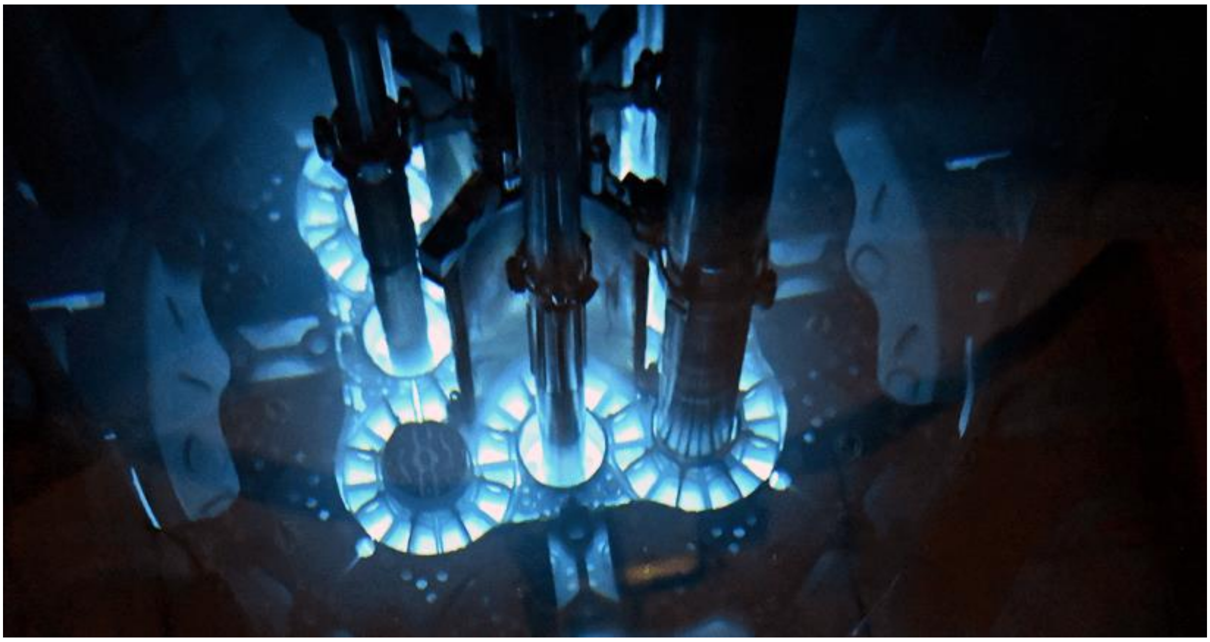

Figure 4: Cherenkov Radiation, the radiation produces a blue glow a bit like Tony Stark's arc reactor from the marvel comics and films (Credit: US Department of Energy)

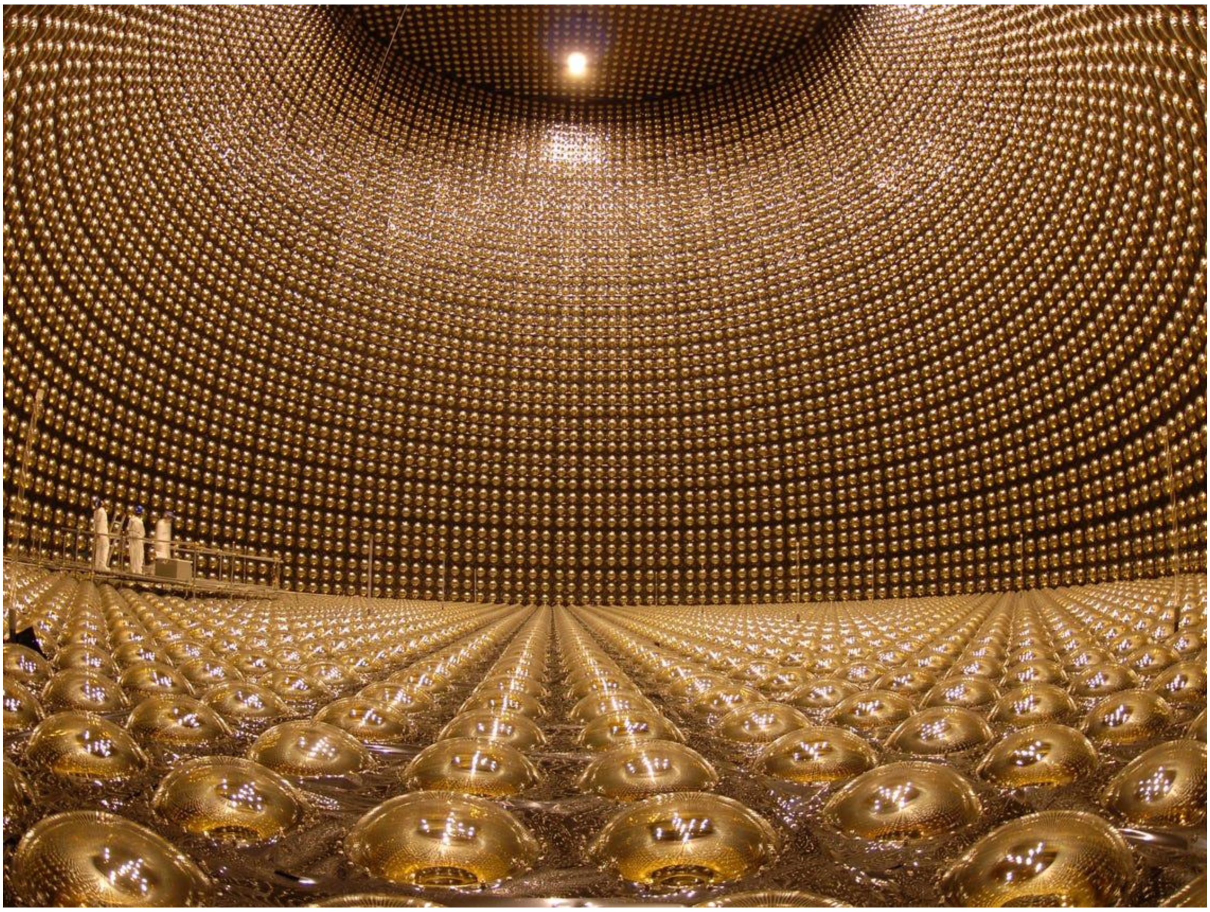

Figure 5: The Super-Kamiokande neutrino detector in Japan (Source: Business Insider)