One Page Summary: the Heavy Photon Search Experiment at JLAB

Just what the Dark Matter is, is one of the greatest questions in Physics today. The astronomical evidence for the existence of dark matter is indisputable, but we don't know what the Dark Matter actually is. Many physicists think it is a new sort of elementary particle. Satellite experiments are looking for tell tale signs that these particles annihilate in the cosmos; sensitive detectors on earth are searching for signs that these particles have passed through the detector and occasionally scattered, leaving a little detectable energy behind; and fixed target and collider experiments are looking for their direct production at accelerators. So far, however, the jury is out. No clear signs of dark matter have yet been discovered, making some wonder if the favorite model for Dark Matter particles, that they are so-called Weakly Interacting Massive Particles (WIMPS), is just wrong. It is certainly getting to be unlikely. One exciting alternative model posits that the Dark Matter particles are denizens of a so-called "hidden sector", a part of the universe that doesn't interact directly with *our* part, so the omnipresent Dark Matter is almost perfectly unseen. In these models hidden sector dark matter doesn't interact with the familiar forces, but has its own hidden sector force(s). The **Heavy Photon Search (HPS)** experiment at JLAB is a search for a hidden sector force particle. Instead of looking directly for the Dark Matter itself, HPS looks for the force particle associated with it. In our unhidden sector, it's like looking for the photon, the force carrying particle, instead of the electron, a particle of matter. If HPS finds a hidden sector photon (aka heavy photon), a fifth force in nature will have been discovered, the first signs of the existence of a hidden sector uncovered, and the discovery of dark matter itself could be imminent. To find the dark matter, look for the dark force.

How does HPS look for hidden sector photons? It relies on the theoretical expectation that hidden sector photons will mix very weakly with regular photons. When a high energy electron beam collides with a thin Tungsten target, it can radiate a high energy photon. It will also radiate what's called a virtual photon, a photon-like particle, but one with enough mass to decay almost instantaneously into an electron-positron pair. Massive virtual photons will mix weakly with heavy photons, albeit at a very low rate. So at least some of the time, the incident electron can create a hidden sector photon, which will in time decay back into an electron-positron pair. Virtual photon production is well known; lots of electron-positron pairs result which have a predictable broad spectrum of masses. If a heavy photon is also produced, HPS will see a sharp excess of events above the virtual photon background at the particular mass of the heavy photon. HPS will see a "bump" in the mass distribution. That's one way HPS looks for heavy photons. We don't know the mass of the heavy photon, nor do we know how strongly heavy photons are coupled to virtual photons, but we can still look for the tell tale bump. The mass of the bump tells us the mass of the heavy photon, and the height of the bump above the background tells us the heavy photon-virtual photon coupling.

Since the coupling to virtual photons is weak, heavy photon production is highly suppressed compared to that of virtual photons. The heavy photon search is thus a bit of a needle in a haystack search. But another consequence of the weak coupling helps us distinguish heavy photons from the huge virtual photon background. The weak coupling of the heavy photon to virtual photons means it takes a long time for the heavy photon to decay back into electron-positron pairs. So long a time, in fact, that the point where the heavy photon decays can be well outside the target where the heavy photon was created. Consequently, HPS measures just where the electron and positron originate. If it's well downstream of the target, we have found a heavy photon candidate.

HPS measures the momenta and trajectories of high energy electrons and positrons, calculates the mass of the electron-positron pair and measures their precise decay point. It uses a silicon microstrip tracking detector triggered by a crystal electromagnetic calorimeter and located within a strong magnetic field to do so. If HPS observes a bump in the mass spectrum or decays well downstream of the target, there is evidence for a heavy photon. If not, the experiment will exclude the range of couplings and masses that the experiment is sensitive to, and learn that heavy photons with those masses and couplings do not exist in nature.

HPS is big gamble/high payoff experiment. HPS has some guidance from theory about where to look, but certainly no sharp predictions and lots of territory to look in, not all of which can be explored. So maybe HPS won't find its quarry. But if it does, you will hear about it. It will be the discovery of a new force in nature, and maybe the first evidence for a whole new sector of the universe that has until now avoided detection.