What's the Matter? That's What U.Va. Physicists Are Seeking to Detect

December 3, 2010 — One of the great and fundamental questions in physics is: Why is there matter? Physicists theorize that in the instant after the Big Bang created the makings of the universe, there were nearly equal amounts of matter and anti-matter, protons and anti-protons, neutrons and anti-neutrons. They should have annihilated each other, resulting in … nothing.

Instead, for some reason, more matter was created than anti-matter, and the universe was born.

"Without this asymmetry that occurred, without this slight abundance of matter over anti-matter, there would be nothing," said Craig Dukes, a physicist in the **High Energy Physics Laboratory** in the University of Virginia's **College of Arts & Sciences**. "The universe would be a boring place. There would be no stars, no planets, no people, no books. There would be no filet mignon."

Nor physicists, for that matter. But because the universe instead is made up of atoms and molecules, elements and compounds, Dukes and his colleagues are here to try to understand how it happened.

"We just want to know why the universe is the way it is," he said.

Dukes is a member of a multi-institutional team building a $280 million, 15,000-ton detector designed to help answer the fundamental question of why matter prevailed. The detector, being built in northern Minnesota near International Falls, will complement another smaller detector recently constructed at Fermilab near Chicago.

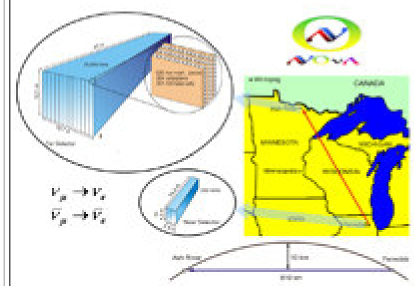
Dukes is using a $2.5 million grant from the U.S. Department of Energy to fabricate essential components to the new detectors at the national high energy physics facility.

"We're playing a key role in building detectors that will allow us to conduct a long-running series of investigations called the NOvA Neutrino Experiment, that hopefully will get to the very heart of matter," Dukes said.

Physicists will investigate matter-antimatter asymmetries in neutrinos. Among the most abundant particles in the universe, neutrinos were present at the very beginning of the universe, and those same neutrinos are present today. These relics of the infant universe may be – at least in theory until experiments get under way in 2013 – the very source for the matter/anti-matter asymmetry of the universe and a way to explain how things happened at the beginning.

"We will be looking at a process, and then looking at the anti-process, how neutrinos change from one type to another," Dukes said.

Far detector site is under construction in northern Minnesota. (click for high-res version)



The near and far detectors are separated by 503 miles. (click for high-res version)

Standing, left to right: physicist Craig Dukes; electrical engineer

To do this scientists need two neutrino detectors; one to measure how many neutrinos are produced in a particle accelerator at Fermilab, and another much larger detector, 503 miles away, to capture a high energy beam and detect how those neutrinos have changed in the span of an instant of time. The beam, which will be passing mostly underground, is harmless to humans and other life. If neutrinos and anti-neutrinos change differently from one type to another, this might explain the process that may have happened to produce a slight abundance of matter over antimatter at the beginning of the universe.

The large distance between the detectors is needed to allow time for a change to the neutrinos to occur, and physicists are betting they will, hence the $280 million gamble. The far detector must be much larger than the near detector because the neutrinos, as they travel the more than 500 miles at nearly the speed of light, spread out into a large defuse beam, requiring a large mitt, so to speak, with which to catch them. The first round of experiments will be conducted over a six-year period, and sorting out the data with high-speed computers will take several more years.

Construction of the NOvA experiment started in May 2009 and the first set of physics data is expected from the near detector early next year. The far detector is under construction and will be fully operational in 2013.

Dukes' U.Va. team of physicists, graduate students and undergraduate students has been working on building and deploying components since 2008. They have built and installed a power distribution system that provides power to the near detector electronics, and other systems that run and monitor the detector. Two of each system are needed, one for each of the two detectors. The systems for the near detector are already in place and operating.

"If we ultimately are able to see a difference between the way neutrinos behave, and the way anti-neutrinos behave, then it possibly could be a reason for why there's an asymmetry in the matter and antimatter in the universe," Dukes said. "It could be the reason we have a matter-dominated universe rather than nothing at all. We may be on the verge of a new understanding of physics."

— By Fariss Samarrai

Stephen Goadhouse; Postdoc Ralf Ehrlich; undergraduate Dale Mudd. Sitting, left to right: undergraduates Krister Lagergren and Jason Gran. (click for high-res version_

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