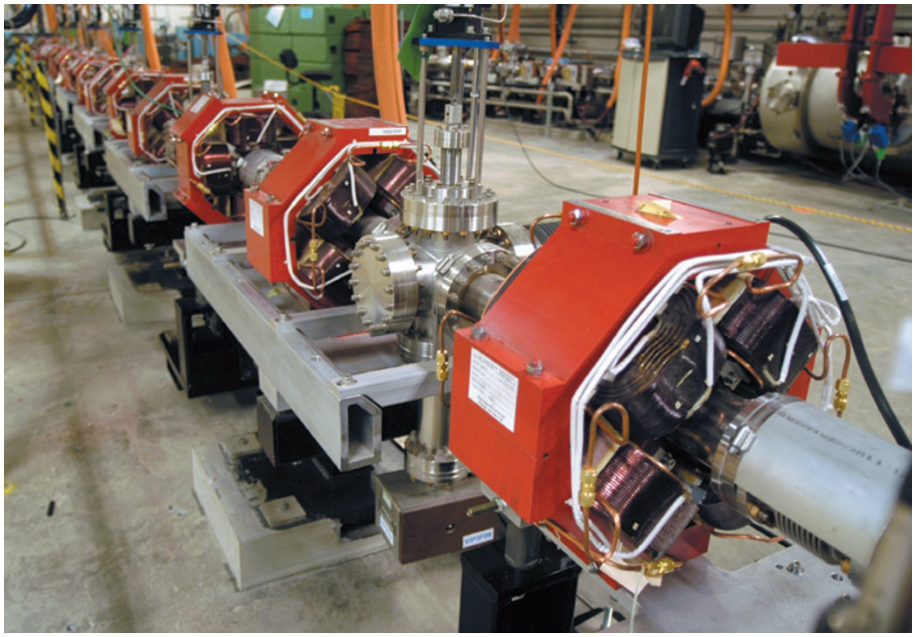
NEWS IN FOCUS

JEFFERSON LAB



The Jefferson Lab's Free-Electron Laser is a low-cost option in the bid to discover dark-sector forces.

PARTICLE PHYSICS

Physicists hunt for dark forces

Cheap colliders probe debris for hint of 'heavy' photon.

BY ERIC HAND

In tunnels beneath the Thomas Jefferson National Accelerator Facility in Newport News, Virginia, an accelerator whips a beam of electrons around a racetrack. Their energies are modest, but the beam is tightly packed with them — for it takes a very bright beam to detect a photon that doesn't shine.

In a three-week experiment due to start on 24 April, the electrons will crash into a thin tungsten target at 500 million times a second, creating a cascade of short-lived particles. Amid the debris, physicists with the Heavy Photon Search (HPS) are hoping that they will find signs of something exceedingly rare: a 'heavy' or 'dark' photon. The discovery would open the door to an unseen world of dark forces and dark atoms that theorists have long speculated about — and could help to pin down the dark matter that is thought to comprise 85% of the matter in the Universe.

The HPS researchers at the Jefferson Lab are quick to concede that the experiment, like two others at the lab probing this dark sector, is a long shot that is likely to achieve little more than null results. But the reasonable price tags for such projects — about US$3 million to build and run the HPS detector — have prompted more physicists to try. "It's always a great question in physics to go around wondering if there are more fundamental forces," says physicist John Jaros, co-spokesman for the HPS experiment.

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The dark photon, unlike conventional photons, would have mass and would be detectable only indirectly — after the dark photons have decayed into electrons and positrons (the antimatter counterparts of electrons). Yet, like the familiar photon, which carries the electromagnetic force, the dark photon would carry a force — a new fundamental force in addition to the four that we already know about. It would be the first sign of a hidden sector, which could include entire zoos of new particles, including dark matter. "It would be like when Galileo saw moons orbiting Jupiter," says Nima Arkani-Hamed, a theorist at the Institute for Advanced Study in Princeton, New Jersey.

Theorists had hoped that the Large Hadron Collider — the world's highest-energy (and most expensive) particle accelerator at CERN, Europe's high-energy physics lab near Geneva, Switzerland — would open the door to new concepts such as supersymmetry, a set of theories that would resolve some of the problems in the standard model of particle physics. But, so far, it has yielded no clues, such as the dark-matter particles predicted by some supersymmetry models. "The null results are not making people happy," says Philip Schuster, a theorist at Canada's Perimeter Institute for Theoretical Physics in Waterloo, Ontario. "People are wondering what other possibilities are out there."

Instead, some physicists are turning to the 'intensity frontier' — creating many collisions and teasing rare events from the wreckage. The electron beams at the Jefferson Lab are not the most powerful, but they are extremely intense.

The idea for a dark sector was first proposed in 1986 (B. Holdom *Phys. Lett. B* **166,** 196–198; 1986), but remained largely unexplored until a group of theorists, including Arkani-Hamed, resurrected the theory a few years ago (N. Arkani-Hamed *et al. Phys. Rev. D* **79,** 015014; 2009). The group embellished the idea in light of results from a 2006 satellite mission called PAMELA (Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics), which had observed a puzzling excess of positrons in space. Theorists suggested that they might be spawned by dark-matter particles annihilating each other. But the heavy particles most often suggested (WIMPs, weakly interacting massive particles) would have also decayed into ▶

protons and antiprotons, which weren't seen by PAMELA. A dark-matter particle from the dark sector — "even darker matter", quips Arkani-Hamed — would be seen only through a decay involving the force-carrying dark photon, which would make positrons but not antiprotons.

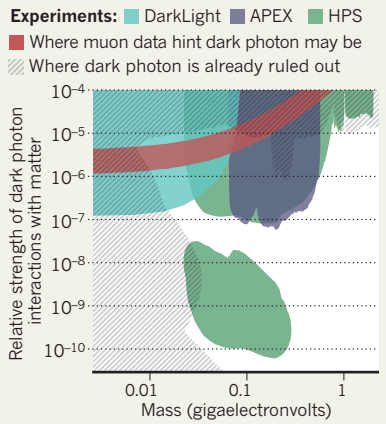
Another motivation came from an intriguing result reported in 2004 by physicists at Brookhaven National Laboratory in Upton, New York. They found that the magnetic moment created by the spin and charge of the muon, a short-lived particle similar to an electron, did not match the predictions of the standard model. This anomaly, called the muon g-2, could also be rectified by a dark-sector force, says Arkani-Hamed. He adds that the idea is not as crazy as it sounds. "The whole set-up is totally vanilla and conservative from a theorist's point of view," he says.

The predictions can be tested cheaply and relatively quickly. The main 6-giga-electronvolt electron beam at Jefferson Lab has the right energy to probe the most likely mass range for a heavy photon. After the HPS's three-week test run, the beam will be shut down for an upgrade that will double its energy. This will allow the HPS and another project, the A Prime EXperiment (APEX), to explore other parts of the dark sector in 2015. A third proposal, called DarkLight, would use the beam that drives the lab's free-electron laser to look for heavy photons at lower energies (see 'Feeling in the dark').

Arkani-Hamed says that he won't be surprised if the future path of particle physics emerges from modest experiments such as those at the Jefferson Lab, rather than from work at CERN. "It could be that these much smaller, faster, cheaper, upstart, high-intensity, low-energy experiments might actually dig up evidence for new physics before the big monsters." ■

FEELING IN THE DARK

Three experiments will search unexplored mass regions for a dark photon, which could explain why muons flout the standard model.



SOURCE: R. ESSIG, STONYBROOK UNIV.

FUNDING

Cyprus Institute loses money and support

Budget withheld as audit raises concerns.

BY ALISON ABBOTT

Once billed as the MIT of the Middle East, the Cyprus Institute in Nicosia is now so deep in crisis that it has not been able to pay last month's salaries. The Cypriot parliament is withholding the institute's 2012 budget amid a storm of criticism — from an audit exposing poor financial management to complaints about the management style of the institute's president, nuclear physicist Costas Papanicolas.

Last week, parliamentarians called for an independent analysis of the institute's activities to help to decide whether to continue financial support. The institute employs nearly 100 staff, but others have left for more secure environments. "If nothing constructive happens soon, the institute will collapse," says atmospheric chemist Jos Lelieveld of the Max Planck Institute for Chemistry in Mainz, Germany, who holds a joint position at the Cyprus Institute.

The multidisciplinary institute was conceived eight years ago by Hubert Curien, a former president of the CERN council, and John Joannides, then chief executive of the Cyprus Development Bank. Their aim was to create a high-quality research university that could bridge science communities in Europe and the Middle East, and build local research capacity. To sidestep public-sector bureaucracy, it was organized as a private, non-profit foundation.

The government provided seed money in 2005. The plan was for the institute to have six research centres and 2,500 graduate and undergraduate students by the end of 2009, and for it to be self-financing through fund-raising, grants and student fees by 2010.

Three research centres — in energy and environment, high-performance computing and archaeology — were launched in 2007. The institute formed ties with international institutions such as the Massachusetts Institute of Technology (MIT) in Cambridge and the University of Illinois at Urbana Champaign to help to plan research and offer training programmes. It also signed an agreement worth more than €3 million (US$4 million) with MIT to design a solar-energy pilot plant able to generate electricity and desalinate seawater.

But in 2010, politicians, aware that the vice-presidents for research and for operations had resigned, began to question why the institute was still receiving public money. The institute had not expanded the number of research centres and the proposed student population had not emerged to provide the anticipated US$62.5 million annual income. Moreover, no private donors had come forward.

"Naturally, we were concerned that an institute intended to be self-supporting was absorbing around €8 million of public money a year without the checks and balances that a public organization would have," says parliamentarian Nicholas Papadopoulos, one of the institute's most aggressive critics. Cyprus invests too little in research, he says, but "its small investments still need to be efficient".

In March 2011, parliament called in the auditor general. The audit report, delivered on 17 February this year, describes the business plan of the Cyprus Institute as unrealistic and over-ambitious, and criticizes a lack of transparency in its financial accounting, and in the hiring and paying of staff. It also notes that one-fifth of the staff left during 2011.

A number of scientists associated with the institute told *Nature* that they found Papanicolas' micro-management style intimidating. They say it hindered their work and is holding the institute back, although most asked not to be identified. Andrea Pozzer, who left last year for a post at the International Centre for Theoretical Physics in Trieste, Italy, says "the interdisciplinary approach of the institute was exciting. But the general atmosphere was often unhappy and there were constant rumours about poor management that were not motivating".

"If nothing constructive happens soon, the institute will collapse."

Papanicolas denies that he interfered in day-to-day scientific activities.

"I agree it may not be easy to work with Costas Papanicolas if you don't gain his trust or live up to his high expectation," says theoretical physicist Edouard Brézin at the École Normale Supérieure in Paris, and chairman of the Cyprus Institute's board of trustees. But he adds that the institute should be more transparent.

The parliament's public-accounting committee endorsed the auditor's report last week and asked the finance committee to release the first quarter of the institute's 2012 budget. But Papadopoulos, who chairs the finance committee, is postponing discussions about this. ■