■ SCIENCE

Anti-matter hunt pays off

Canadian physicists find evidence nature really is lopsided in certain processes

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REALLY WIRED: A scientist at TRIUMF, Canada's national laboratory for particle and nuclear physics in Vancouver, replaced 19 of the 29,000 wires in the Canadian-built detector used to probe the nature of anti-matter.

WHENEVER Star Trek needed a dramatic crisis, the show knew they could count on anti-matter.

Anti-matter fuelled the warp drive that propelled those starships. It was dangerous stuff. Just a small glitch in the containment field and, kaboom, goodbye Enterprise or Voyageur and all who sailed in her.

And that's what most people know about anti-matter: Its tricky but strictly science-fiction stuff.

An elite group of Canadian physicists, however, know that anti-matter is not only tricky but quite real as well. It's also confounding, exasperating and mostly missing in the universe: The Canadians are part of a massive international research effort trying to get to the bottom of one of the most fundamental mysteries: why nature is lopsided, seemingly favouring matter over anti-matter.

'It would be like having two armies on the field, one with a billion soldiers and the other with a billion and one. They slaughter each other evenly until just the one extra soldier is left'

— STEW SMITH
TEAM LEADER

"There really is a fundamental difference in how matter and anti-matter react," says Christopher Hearty, a research scientist with the Institute of Particle Physics at the University of British Columbia.

Hearty is Canada's representative on the executive board that runs BaBar, an extremely sensitive detector hooked up to a flow of fleeting subatomic particles called B mesons produced in the linear accelerator at California's Stanford University.

One of the five measuring devices at the heart of BaBar is a cat's cradle Of 29,000 ultrafine wires, called a drift chamber, which was designed and constructed under trying circumstances at TRIUMF, Canada's national laboratory for particle and nuclear physics in Vancouver.

BaBar embodies the high-stakes game of what's called New Physics. It's a collaboration among 600 scientists and engineers from 73 institutions in nine countries, including UBC, the University of Victoria, the University of Montreal and McGill University. The combined price tag for the detector and what's called the B factory is roughly $300 million.

This huge investment and two years of intense research produced new evidence earlier this month that some processes in nature really are lopsided. By recording the almost instantaneous disintegrations of 32 Million pairs of B mesons and anti-B mesons, BaBar confirmed that the matter and anti-matter versions of the particles decay at different rates.

Physicists call this difference the charge-parity violation CP violation sounds incredibly arcane but it may lie at the heart of why our universe exists.

If the universe was indeed created by a Big Bang, then that massive of energy ($E=mc^2$) should also have created equal amounts of matter and anti-matter. They would then have cancelled one another and we wouldn't be here today.

An alternate explanation much favoured by sci-fi writers is that the original matter and anti-matter divided creating a mirror universe of anti-matter somewhere.

Since any cosmic anti-matter would be annihilated by collisions with matter before reaching the Earth's surface, scientists have been looking above the planet for traces of anti-matter.

A high-energy particle detector on the space shuttle in 1998 didn't spot a single anti-nucleus among three million nuclei. A more sensitive version of the detector is planned for the space station in 2004.

But a mirror universe isn't necessary if matter and anti-matter behave differently. Even a minute difference in decay rates, for instance, could have been enough to give matter the crucial edge in the Big Bang.

"It would be like having two armies on the field, one with a billion soldiers and the other with a billion and one. They slaughter each other evenly until just the one extra soldier is left," says Stew Smith, team leader and spokesman for BaBar

Actually a difference of one in 10 billion might have been enough, according to measurements of the cosmic background radiation. But the theory at the core of modern particle physics — the so-called Standard Model — can only explain a billionth of even that minute difference. There isn't anywhere near enough lopsidedness in the Standard Model for matter to triumph as it did.

That's why at least some BaBar experimenters were hoping to find a bigger decay difference for B mesons than allowed by the Standard Model. But the actual measurement agreed closely with the model's predicted difference.

"The Standard Model wins again," says a laughing Smith.

Yet the quest to explain lopsidedness is far from over. BaBar will continue with more and more precise measurements of various characteristics of B mesons over the next several years.

And the world's most powerful accelerator — the $6 billion Large Hadron Collider — is scheduled to begin operating in 2006 at Europe's particle physics laboratory (CERN) near Geneva.

Physicists believe that this new accelerator will bash together enough protons with high enough energies to produce a never-before-seen subatomic particle known as the Higgs boson, considered the doorway to the future of physics.

If the Higgs boson exists and if its mass is relatively small then the theoretical prospects for a mirror universe brighten. If the Higgs boson is middle weight, then the Standard Model can probably be rejigged to accommodate it. But if is heavy, then entirely new models will be needed to describe the particle universe.

For physicists, matters don't get much more exciting than this. But getting in on the ground floor of BaBar in the mid1990s proved difficult for Canadians because the federal government had just slashed funding for scientific research.

Originally Canadian physicists proposed taking full responsibility for BaBar's drift chamber, which would have cost $4 million. But when the federal granting council could come up with only $500,000, the researchers had to scramble.

Eventually the chamber was built in Vancouver with more than $2 million donated by France and Italy and another $500,000 of in-kind support from TRIUMF. But the funding hassle in Canada so frustrated McGill physicist David MacFarlane that he snapped up an attractive job offer from the University of California at San Diego.

MacFarlane was part of a group of about 15 Canadian physicists who helped blaze the trail for this month's BaBar success during an international experiment called ARGUS at Germany's national accelerator facility near Hamburg between 1983 and 1993.

"We wanted to evolve Canadian participation in ARGUS into participation in one of the B factories when they got built. But the timing was unfortunate," he says.

So now MacFarlane heads the U.S. group responsible for the key analysis behind the BaBar results. And he's not the only expatriate Canadian scientist playing a key role in the BaBar effort.

Stanford University physicist Patricia Burchat, a University of Toronto graduate, has coordinated analysis from the experiment's physics results. And Stew Smith, the Princeton University researcher who is the public face of BaBar, is originally from Victoria and studied physics at UBC.

Smith got to go home temporarily when construction of the drift chamber began at TRIUMF in March, 1997.

"A year later, we put it in the truck to leave for Stanford and I cried," he says.