symmetry
dimensions of particle physics

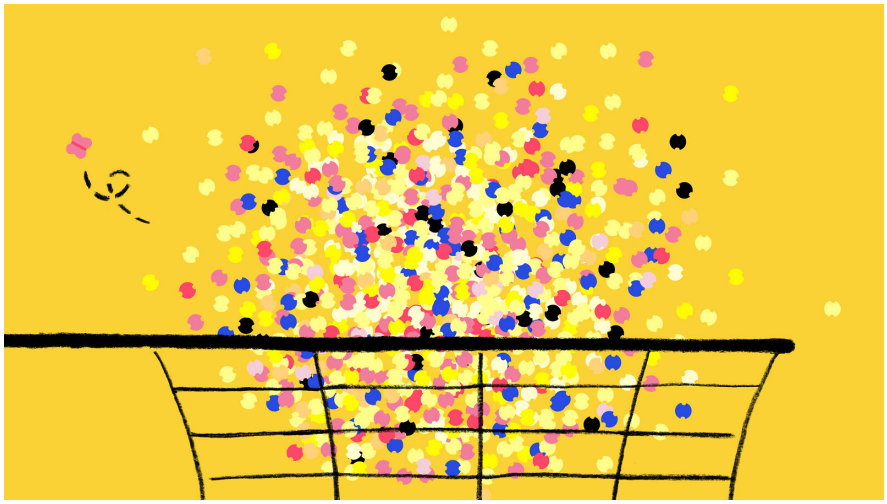


Illustration by Sandbox Studio, Chicago

Casting a wide net

05/14/19 | By Jim Daley

In their quest to discover physics beyond the Standard Model, physicists weigh the pros and cons of different search strategies.

On October 30, 1975, theorists John Ellis, Mary K. Gaillard and D.V. Nanopoulos published a paper titled "A Phenomenological Profile of the Higgs Boson." They ended their paper with a note to their fellow scientists.

"We should perhaps finish with an apology and a caution," it said. "We apologize to experimentalists for having no idea what is the mass of the Higgs boson… and for not being sure of its couplings to other particles, except that they are probably all very small.

"For these reasons, we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up."

What the theorists were cautioning against was a model-dependent search, a search for a particle predicted by a certain model—in this case, the Standard Model of particle physics.

It shouldn't have been too much of a worry. Around then, most particle physicists' experiments were general searches, not based on predictions from a particular model, says Jonathan

Feng, a theoretical particle physicist at the University of California, Irvine.

Using early particle colliders, physicists smashed electrons and protons together at high energies and looked to see what came out. Samuel Ting and Burton Richter, who shared the 1976 Nobel Prize in physics for the discovery of the charm quark, for example, were not looking for the particle with any theoretical prejudice, Feng says.

That began to change in the 1980s and '90s. That's when physicists began exploring elegant new theories such as supersymmetry, which could tie up many of the Standard Model's theoretical loose ends—and which predict the existence of a whole slew of new particles for scientists to try to find.

Of course, there was also the Higgs boson. Even though scientists didn't have a good prediction of its mass, they had good motivations for thinking it was out there waiting to be discovered.

And it was. Almost 40 years after the theorists' tongue-in-cheek warning about searching for the Higgs, Ellis found himself sitting in the main auditorium at CERN next to experimentalist Fabiola Gianotti, the spokesperson of the ATLAS experiment at the Large Hadron Collider who, along with CMS spokesperson Joseph Incandela, had just co-announced the discovery of the particle he had once so pessimistically described.

Model-dependent vs model-independent

Scientists' searches for particles predicted by certain models continue, but in recent years, searches for new physics independent of those models have begun to enjoy a resurgence as well.

"A model-independent search is supposed to distill the essence from a whole bunch of specific models and look for something that's independent of the details," Feng says. The goal is to find an interesting common feature of those models, he explains. "And then I'm going to just look for that phenomenon, irrespective of the details."

Particle physicist Sara Alderweireldt uses model-independent searches in her work on the ATLAS experiment at the Large Hadron Collider. Alderweireldt says that while many high-energy particle physics experiments are designed to make very precise measurements of a specific aspect of the Standard Model, a model-independent search allows physicists to take a wider

view and search more generally for new particles or interactions. "Instead of zooming in, we try to look in as many places as possible in a consistent way."

Such a search makes room for the unexpected, she says. "You're not dependent on the prior interpretation of something you would be looking for."

Theorist Patrick Fox and experimentalist Anadi Canepa, both at Fermilab, collaborate on searches for new physics. In Canepa's work on the CMS experiment, the other general-purpose particle detector at the LHC, many of the searches are model-independent.

While the nature of these searches allows them to "cast a wider net," Fox says, "they are in some sense shallower, because they don't manage to strongly constrain any one particular model."

At the same time, "by combining the results from many independent searches, we are getting closer to one dedicated search," Canepa says. "Developing both model-dependent and model-independent searches is the approach adopted by the CMS and ATLAS experiments to fully exploit the unprecedented potential of the LHC."

Driven by data and powered by machine learning

Model-dependent searches focus on a single assumption or look for evidence of a specific final state following an experimental particle collision. Model-independent searches are far broader—and how broad is largely driven by the speed at which data can be processed.

"We have better particle detectors, and more advanced algorithms and statistical tools that are enabling us to understand searches in broader terms," Canepa says.

One reason model-independent searches are gaining prominence is because now there is enough data to support them. Particle detectors are recording vast quantities of information, and modern computers can run simulations faster than ever before, she says. "We are able to do model-independent searches because we are able to better understand much larger amounts of data and extreme regions of parameter and phase space."

Machine-learning is a key part of this processing power, Canepa says. "That's really a change of paradigm, because it really made us make a major leap forward in terms of sensitivity [to new

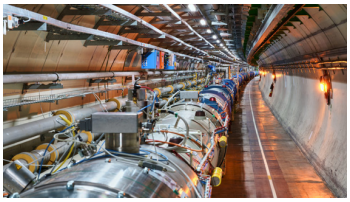
signals]. It really allows us to benefit from understanding the correlations that we didn't capture in a more classical approach."

These broader searches are an important part of modern particle physics research, Fox says.

"At a very basic level, our job is to bequeath to our descendants a better understanding of nature than we got from our ancestors," he says. "One way to do that is to produce lots of information that will stand the test of time, and one way of doing that is with model-independent searches."

Models go in and out of fashion, he adds. "But model-independent searches don't feel like they will."

popular on symmetry



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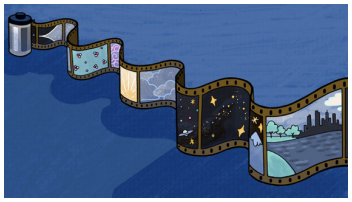

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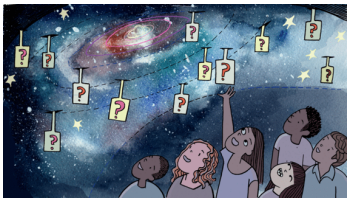

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