ilc newsline

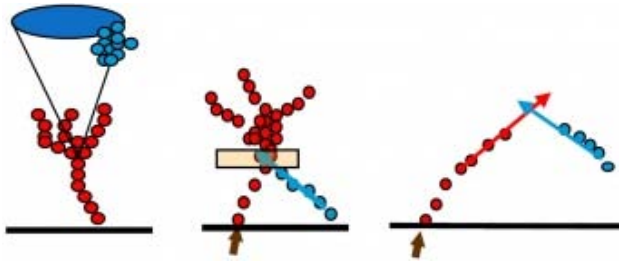
ABOUT | ARCHIVE | SUBSCRIBE | CONTACT | LINEARCOLLIDER.ORG | 15 SEPTEMBER 2011

## FEATURE

# Going with the particle flow

The particle flow algorithm joins smart programming with the high granularity of next-generation particle detectors to measure energies with unprecedented resolution

by Leah Hesla



Resolved that pictures of particle jets don't have to be fuzzy or gnarled, scientists developed the particle flow algorithm, a paradigm for effectively teasing out each particle's energy from another's. To make it work, researchers expanded the tracking capabilities of the detector model, enabling it to measure energies with higher precision.

## AROUND THE WORLD

# Light through the wall – take 2

Preparations for ALPS II are in full swing

by Gerrit Hörentrup (DESY)

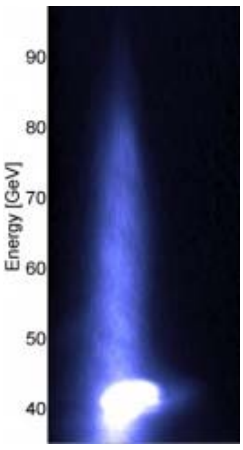


DESY's ALPS experiment aims high by searching low, looking for lightweight particles in the low-energy range. The lightweight particles could clue us into the nature of dark matter or dark energy, and ALPS is being upgraded to make more precise measurements than it could before.

## DIRECTOR'S CORNER

# Particle physics: opportunities for the future

by Barry Barish




The American Physical Society Division of Particles and Fields meeting at Brown University had a broad programme covering new results, special topics such as celebrating the Tevatron and plans for future projects. In my concluding remarks for the conference, I gave a personal view of future opportunities in particle physics.

## VIDEO OF THE WEEK



# Humboldt Professor Brian Foster

Video: Alexander von Humboldt Foundation

Brian Foster, Global Design Effort European Regional Director, recently began his tenure at DESY and the University of Hamburg as a recipient of the Alexander von Humboldt professorship. View this seven-minute video to learn about his research plans at DESY, the University and for the ILC.

## IN THE NEWS

from ***Physics World***
September 2011
Pushing the Boundaries
China's Institute for High Energy Physics is one of the world's leading particle-physics labs and has just completed the first part of a major neutrino facility at Daya Bay in the south of the country. [read page 8]

from ***Physics Today***
15 September 2011
Neutrinos from Earth's interior measure the planet's radiogenic heating
But it was not until 2005 that the KamLAND collaboration reported the first detection of geoneutrinos. Now with five times as much data in hand the international collaboration has reported its first substantive geophysics result.

from ***physicsworld.com***
12 September 2011
Particle physicist teams up with violin virtuosos
In a new collaboration the two activities are about to meet head on with the internationally renowned composer Edward Cowie teaming up with particle physicist Brian Foster and the violinist Jack Liebeck.

from ***Science News***
9 September 2011
Last Words
Tevatron's data may have more to say even after the atom smasher shuts down

## CALENDAR

### UPCOMING EVENTS

LC11: Understanding QCD at Linear Colliders in searching for new and old physics
ECT*, Trento, Italy
12- 16 September 2011

Workshop on Forward Calorimetry at Future Linear Collider (FCAL 2011)
VINCA Institute, Belgrad, Serbia
13- 15 September 2011

CALICE Collaboration Meeting
Heidelberg, Germany
14- 16 September 2011

Linear Collider Workshop 2011 (LCWS11)
Granada, Spain
26- 30 September 2011

## PREPRINTS

### ARXIV PREPRINTS

1109.2811
Chronopixel Vertex Detectors for Future Linear Colliders

1109.2582
Frequency Scanned Interferometry for ILC Tracker Alignment

1109.1982
Imaging Pion Showers with the CALICE Analogue Hadron Calorimeter

ICFA Beam Dynamics Mini Workshop on Low Emittance Rings 2011
Heraklion, Greece
03- 05 October 2011

## UPCOMING SCHOOLS

CERN Accelerator School: Course on Accelerator Physics
University of Chios, Chios, Greece
18- 30 September 2011

View complete calendar

Copyright © 2011 ILC-GDE

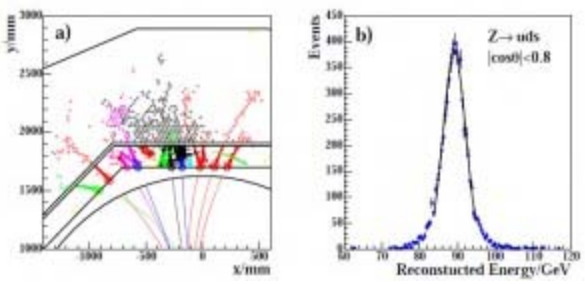
ilc newsline

FEATURE

# Going with the particle flow

The particle flow algorithm joins smart programming with the high granularity of next-generation particle detectors to measure energies with unprecedented resolution

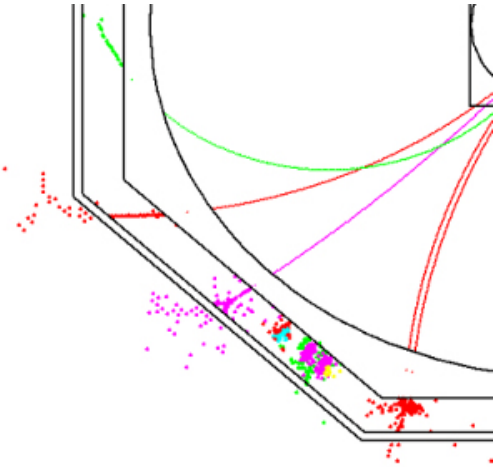
Leah Hesla | 15 September 2011




*a) An example of particle flow reconstruction of a 100-GeV jet using the PandoraPFA algorithm. b) Distribution of the total reconstructed jet energy in the decay of Z to light quarks (up, down, strange) at a centre-of-mass energy of 91.2 GeV. Image courtesy of Mark Thomson*

The familiar image of a collision event in a particle detector is a beautiful mess: Gossamer lines shoot and spiral every which way from a common point, revealing the paths of the post-collision projectiles. Unfortunately for particle tagging, the tracks almost always end in knotty energy clusters, leading physicists down trails that stop abruptly, unresolved, with a splat.

Matching each track to the right splat in the detector is the aim of the particle flow algorithm paradigm, or PFA, which is being developed for linear collider-type detectors. PFA helps scientists disentangle a collision's energy deposits by dialing up the detector's spatial resolution, bringing particle tracks into clearer focus. Simulations show that the method can resolve particle energies two to three times better than can current procedures.

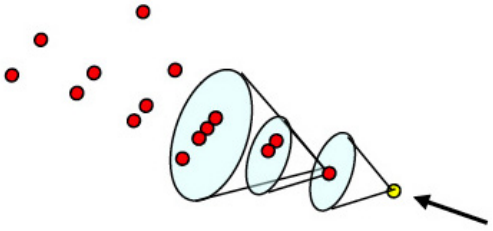


*Particle tracks inside a detector. Image courtesy of John Marshall*

"It's a real *tour de force* to be able to measure an event with that kind of precision," said SLAC's Norman Graf, who leads the American Linear Collider Physics and Detector Simulations Working Group.

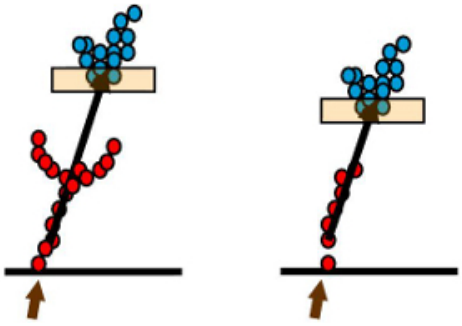
To achieve the kind of precision that would make PFA viable, scientists pushed at the traditional functional limits of the detector's calorimeter.

"The idea of particle flow is to do something completely different," said University of Cambridge's Mark Thomson, convener of the ILD Detector Concept Analysis Working Group. "Effectively the idea is to measure as little energy as possible in the calorimeter and measure as much as possible and very precisely from the tracking chambers." Tracking chambers, or trackers, show the initial path of a post-collision particle; calorimeters measure energy.



*PandoraPFA cone-based forward projective clustering. Image courtesy of John Marshall*

But in the PFA paradigm, the calorimeter gives an account, not of how much particle energy was deposited in a broad volume, as is typical, but of where the energy was deposited as a precise three-dimensional picture. This means developing a calorimeter with high granularity using many millions of small, centimetre-scale readout pads. With boosted spatial resolution, scientists could use the calorimeter like a map, zooming in close to pinpoint the location of energy splats, easing the separation of overlapping, messy clusters.



*PandoraPFA topological reconstruction based on proximity (left) and direction of track segment (right). Image courtesy of John Marshall*

Calorimeter energy measurements tend to be relatively coarse, so the PFA paradigm shifts the responsibility for measuring charged-hadron energies inward to the core of the detector, the tracker. Trackers have much better resolution than calorimeters, and linear-collider types accurately measure particle momenta to one part in 10,000. The momenta measurements are then used to calculate the particles' energies.

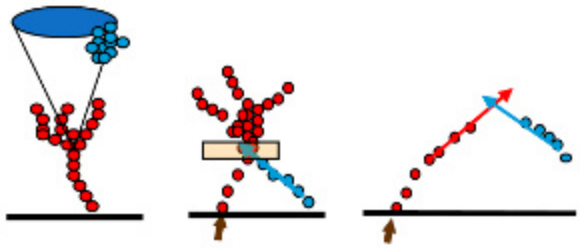
Now equipped with the resolution needed to sort clusters, scientists can follow each ultrafine track to its true terminus in the detector, reconstructing the particle path from initial collision to final demise. "We now know the energy of the particles that leave tracks perfectly, and are only left with those that don't to measure in the calorimeters," Thomson said.

Previously at the detectors at CERN's LHC in Switzerland or Fermilab's Tevatron in the US, on the rare occasion that a particle track led clearly to a specific energy cluster, scientists would take advantage of the association by using the track's high-precision momentum measurement rather than the calorimeter's much less precise energy deposit measurement. A protocol called energy flow was developed for CERN's Large Electron-Positron collider ALEPH experiment in the 1980s and '90s. CERN's ATLAS and CMS detectors and Fermilab's CDF and D0 detectors at the Tevatron also developed versions of the approach.

"Now we're taking that approach and designing a better calorimeter so that we can do this all the time and not just every once in a while," Graf said.

Scientists are working on a number of approaches to PFA for individual particle reconstruction. Thomson and John Marshall at the University of Cambridge have been developing PandoraPFA. A group at the University of Iowa is also developing the Iowa PFA to reconstruct particle paths.

Reconstructions, of course, are never simple. Even with pixilated energy clusters, one still has to make judgment calls on which pixel to associate with which track. PFA contains more than 10,000 lines of C++ to recognise patterns and make sense of gaps, kinks, breaks, backscatters, showers, and loops in particle paths. It attempts to uniquely account for every piece of the clusters – no omissions, no over-counting – with a battery of techniques.

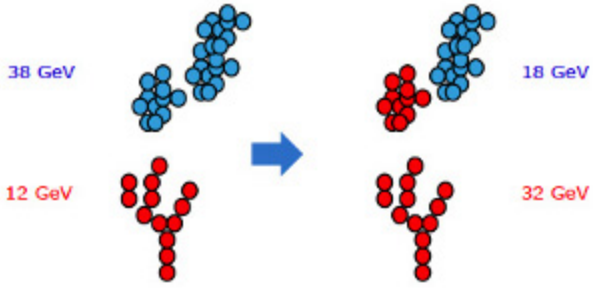


*PandoraPFA topological reconstruction based on projected cone (left), backscatter patterns (middle) and looping tracks (right). Image courtesy of John Marshall*

The techniques involve, for example, removing isolated hits or erring on the side of splitting up clusters that belong to a single track rather than aggregating clusters that may belong to more than one track. PFA puts various reconstructions through their paces until it hits on the right fit for a track-cluster association.

Extensive simulations have borne out PFA's effectiveness: In the last few years the potential of PFA at the ILC has been conclusively demonstrated using the PandoraPFA approach.

"You can unambiguously associate a cluster in the calorimeter with a shower from a particle," Graf said. Not only that, but you can also make the association with every single particle jet, yielding 100 percent efficiency in particle energy bookkeeping.




*PandoraPFA 30-GeV track. Image courtesy of John Marshall*

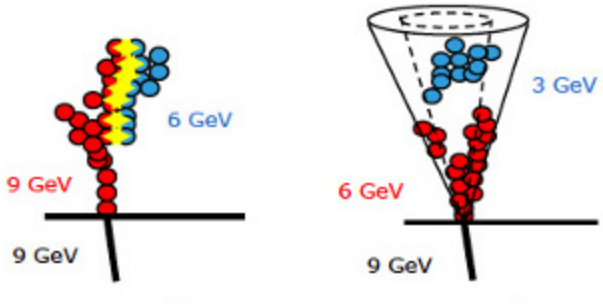
On the hardware side, the CALICE collaboration (Calorimeter for Linear Collider Experiment) develops high-granularity calorimeters for use with a particle flow algorithm, exposing the calorimeters to test beam to characterise their performance, data from which is used in simulations.

Though the PFA approach was developed for the ILC detectors, its application reaches further.

“It is definitely applicable to any collider environment,” Graf said. That includes the higher-collision-energy CLIC, for which PFA is also being developed.

“Initially I wasn’t convinced it would work at CLIC energies, because the particle densities seemed too high, but in the last year or so we have demonstrated it works rather well,” Thomson said.

“The possibility of designing a detector with this as its driving motivation appealed to me from early on,” Graf said. “Why wouldn’t you go with such a superb detector to do the best possible physics you can do in a precision environment?”




*PandoraPFA fragment removal: layers in close contact (left), fraction of energy in cone (right). Image courtesy of John Marshall*

CALICE | CALORIMETRY R&D | DETECTOR R&D | PARTICLE FLOW ALGORITHM

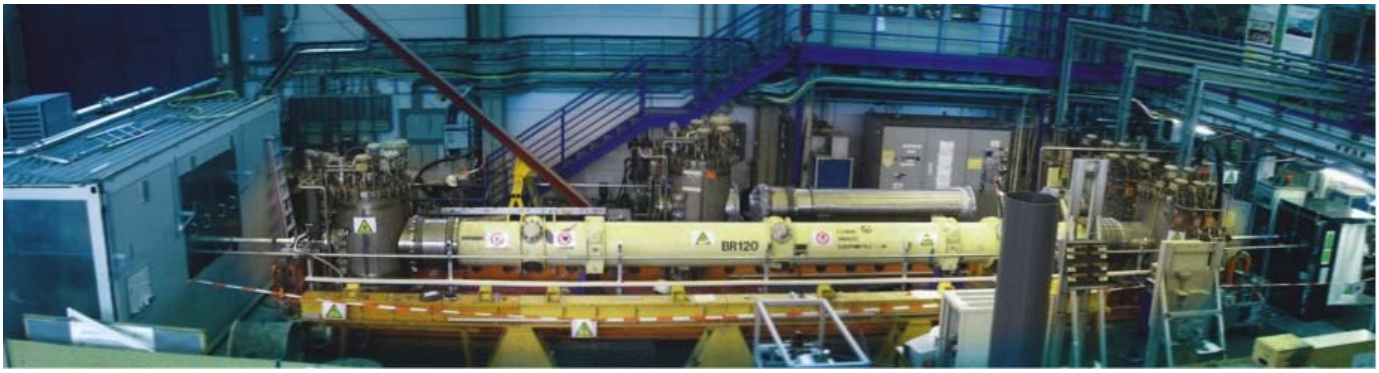
Copyright © 2011 ILC GDE
Printed from http://newsline.linearcollider.org

AROUND THE WORLD

# Light through the wall – take 2

## Preparations for ALPS II are in full swing

Gerrit Hörentrup (DESY) | 15 September 2011




*ALPS: a still-small version. The huge one is yet to come. Image: DESY*

Bending a HERA magnet straight may sound bizarre, but it is an important prerequisite for ALPS II. Last year, the "light shining through a wall" experiment ALPS at DESY in Germany did not find the lightweight particles it was looking for, but it did obtain the best - exclusion limits worldwide for hidden light particles . Thus, for the ALPS collaboration, there is no doubt that "ALPS must become larger and more precise."

ALPS stands for "any light particle search". Since 2007, it has searched for very light particles such as axions. To find them, laser light is sent through a HERA dipole with a wall in its centre. The general assumption is obvious: light shining through a wall – no way! However, where axions do exist, the light's behaviour would be completely different. The laser light could transform into an axion in the magnetic field, traverse the wall and transform back into a photon again behind the wall. The result is light shining through the wall.

"A whole series of axion-like particles just tumble out of string theory," explains ALPS spokesperson Axel Lindner. These extremely light particles – should they exist – could give answers to some open questions of particle physics. Extremely light particles could make up dark matter or explain dark energy – 95 percent of our universe that is so far unknown to us. Moreover, the longer that high-energy - experiments as the LHC run without detecting particles that might explain such phenomena, the ever more fascinating the low-energy range becomes.

The final location for the installation of ALPS II, planned for the period after the completion of the European XFEL, will be in the HERA tunnel. A giant version of ALPS is to increase the current experiment's measuring precision: twelve superconducting magnets in front and twelve behind the wall – instead of one magnet in total – form the basic structure. Yet this presents the ALPS collaboration – and the participating scientists from the Albert Einstein Institute Hannover, the Sternwarte Bergedorf Observatory and the University of Hamburg – with challenges, because the beam pipe of the HERA dipoles is bent. In order to send light through all magnets, some of them will have to be straightened! In addition to the magnets, ALPS II includes a new superconducting detector, a stronger laser and a much more complex optical structure. In this final stage, ALPS would be able to search for axions and other super-light particles with more precision than the current astrophysical experiments in this field.

Until then, many further steps are required. First, the scientists have to find out whether a straightened magnet works as well as a bent one. Parallel to this, the laser technology will be tested – initially on a smaller scale, at 20 instead of 200 metres, in a new laser laboratory in the HERA hall west, and without magnets. This, however, is not only an ordinary test run; at this stage ALPS will also search for so-called hidden photons. These are other particles that might exist in the low-energy range and that, in contrast to axion-like particles, might also appear without a magnetic field. "As soon as it becomes clear that the optics work on this small scale, we will expand the whole structure to 200 metres in the HERA tunnel – again without magnets at first," Lindner says about the later-stage procedure. Only when everything is running well there will the DESY directorate be asked to decide on the construction of ALPS II with a total of 24 magnets.

ALPS is not the only experiment searching for light particles in Hamburg. DESY is also collaborating in the Solar Hidden Photon Search experiment – SHIPS for short – at the Sternwarte Bergedorf Observatory. Possible cooperation with CERN scientists is also in the air. “The axion research field becomes more and more exciting,” says Lindner. “DESY’s outstanding infrastructure and know-how provide the chance to continue to be in the front line of this new particle physics research field.”

*This article originally appeared in the 1 September issue of DESY InForm.*

ALPS | DESY | HERA

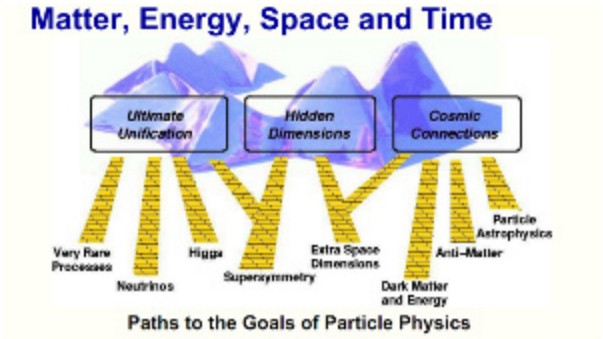
Copyright © 2011 ILC GDE
Printed from http://newsline.linearcollider.org

ilc newsline

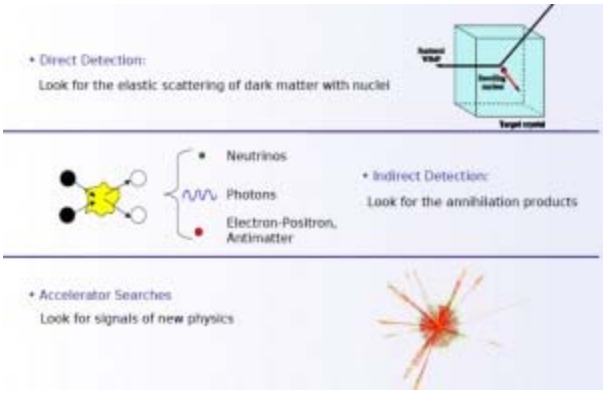
DIRECTOR'S CORNER

# Particle physics: opportunities for the future

Barry Barish | 15 September 2011




*The field of particle physics as defined in the HEPAP Long Range Plan for Particle Physics in 2000, chaired by Jon Bagger and myself*



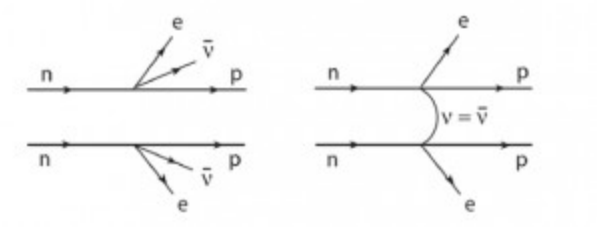

*Dark matter is being searched for underground, in space and with accelerators. This central issue in astrophysics may find its resolution in new particles discovered at LHC.*

Last week in this column I discussed a special tribute to the Tevatron made at the Division of Particles and Fields (DPF) of the American Physical Society conference at Brown University in Providence, Rhode Island from 9-13 August. This week I will share some of the key points I made in my concluding remarks for this conference. This year's DPF conference was very well attended and had a programme that broadly covered the field of particle physics and related topics of interest. The DPF plans to organise this conference every second year in the future.

What is particle physics? I began my talk by trying to define the field. There is no universal short definition, but I prefer a rather broad high-level definition of the underlying science goals. The one we used in developing the long-range plan for particle physics for the High Energy Physics Advisory Panel (HEPAP) in 2000 was the study of matter, energy, space and time. From these flow a very diverse research programme. Whatever definition you prefer, the field experimentally has broadened to include not only accelerator-based experiments, but also major experiments underground, at the South Pole and even in space.

Historically, particle physics advanced through the development of higher- and higher-energy accelerators, epitomised by that of both high-energy electron-positron and hadron-hadron colliders. In a sense, the field could have been characterised as an 'observational science,' much like astronomy, where we developed a new more powerful telescope (accelerator) from which a series of spectacular discoveries followed. In the modern era, we have evolved from an observational science to an inquiry-based science where the instruments we build are focused on specific scientific questions, often inspired by theory. Examples of such questions are: What is the dark matter? Is the neutrino its own antiparticle? Are there further symmetries in nature?

The questions we have on our lips are profound and challenging to answer. We often need to develop new instruments involving new technology and large costs. So, despite the richness of the field and the topics and questions we are asking, we must pick and choose among many opportunities. A powerful new accelerator, like the Large Hadron Collider in Switzerland, can address a number of the central questions in the field. At the DPF meeting, we saw the impressive performance of the LHC, promising a large amount of data before the machine is turned off for an extended shutdown, currently scheduled for the end 2012. That shutdown will be used to fix the problems that are currently limiting the energy of the machine to 3.5 teraelectronvolts (TeV) per beam.




*The observation of neutrinoless double beta decay, shown on the right diagram, would prove that the neutrino is its own antiparticle. The experimental prospects are promising.*

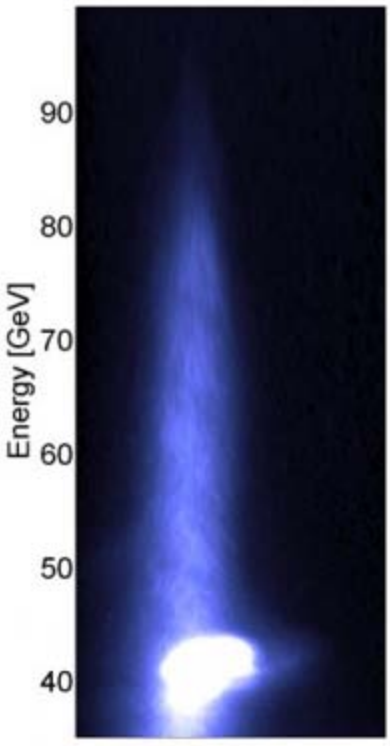
At DPF, we saw early results for the Higgs particle that could be characterised by the word 'maybe.' This is a significant use of the word, because it means there are hints that could develop into evidence for the Higgs (or go away), and there is the promise to resolve the issue perhaps by the end of the year, or certainly before the shutdown. The early searches for a new symmetry, supersymmetry, have so far come up empty and the experiments are beginning to rule out specific supersymmetric particles up to near a teraelectronvolt.

There are many attractive probes for new particle physics, including underground laboratories that will do the next generation of long baseline neutrino experiments, possibly even observing charge-parity violation for neutrinos. Other attractive experimental areas include the search for dark matter at accelerators (which relates to supersymmetry), in space and underground.

The experimental opportunity that I find particularly attractive is neutrinoless double beta decay, which probes whether the neutrino is its own antiparticle (Majorana neutrinos). One can envision large detectors capable of reaching the atmospheric neutrino mass scale or even the solar neutrino mass scale.

Lastly, one can ask what the future will be for our main experimental tool, high-energy particle accelerators. Will the LHC, or maybe a complementary lepton collider, be our last major high-energy machine? I don't think so! The main culprit that limits particle accelerators is materials, one way or another. Eliminating materials is the key to the future. Recent advances in developing plasma wakefield accelerators are especially promising.

The electron beam accelerator at SLAC uses two miles (3.22 kilometres) of conventional accelerator to reach 40 GeV and in an experiment using a beam-based plasma wakefield accelerator, electrons were boosted to about 80 GeV in only one metre of acceleration. In other R&D on laser-based plasma wakefield accelerators, advances have been made in controlling both the energy spread and divergence of the beam. Of course, many years of R&D are needed before we can anticipate a new generation of accelerators, but the promise is there, and the next generation of R&D projects is underway.




*Doubling the energy of electrons emerging from the SLAC linac using one-metre of plasma accelerator*

From my perspective, particle physics may have changed its nature and may have changed its tools, but the prospects remain bright. We have many fundamental problems to address, and are developing tools to address them.

DPF | FUTURE | FUTURE ACCELERATORS | PARTICLE PHYSICS

Copyright © 2011 ILC GDE
Printed from http://newsline.linearcollider.org