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1 MARCH 2012

DIRECTOR'S CORNER

GDE Executive Committee visits Washington DC

by Barry Barish

During a face-to-face working meeting of the Global Design Effort Executive Committee, held in Washington DC last month, invited guests discussed with us how science is supported in the US system, including new project approval, the yearly budget process and the formulation of science policy.

FEATURE

The incredible shrinking pixel sensor

by Leah Hesla

We don't usually notice all three dimensions of a semiconductor chip. We note the intricate, maze-like circuitry imprinted onto one side or its reflective sensor surface. Rarely is attention paid to its depth, mostly because chips have so little of it. In the last five to ten years, the particle detector community has been working with the semiconductor industry to develop sensors' minuscule depths to create technology with integrated functionalities that could be used in fields outside particle physics.

AROUND THE WORLD

Japanese civil engineers dig deep in Europe

A contribution from the Global Design Effort's civil engineering team

by Wilhelm Bialowons (DESY), John Osborne (CERN), and Masanobu Miyahara (KEK)

Ten members from the Japanese Society for Civil Engineering's committee for civil works for future ILC facilities came to Europe in February to look at current civil engineering projects like CERN's LINAC4 and the European XFEL in Hamburg and to discuss administrative challenges. By the end of March next year, the committee will publish draft guidelines on civil solutions for a potential ILC in Japan.

IMAGE OF THE WEEK

Quantum Beam Project being readied for launch

Image: Nobu Toge

The Quantum Beam Project at KEK's Superconducting Test Facility is being prepared for start-up. On 27 February, scientists successfully produce and extract the beam from the RF-gun.

IN THE NEWS

from ***Science***
27 February
ITER Dodges Trouble With Superconducting Cables
A potential stumbling block that threatened to delay construction of the huge ITER fusion reactor—an international project based at Cadarache in France—looks like it has been resolved.

from ***Nature***
27 February 2012
Quest for quirky quantum particles may have struck gold
Evidence for elusive Majorana fermions raises possibilities for quantum computers.

from ***Brookhaven National Laboratory***
27 February 2012
Brookhaven Physicists Team Up with Medical Industry to Build Advanced Cancer Therapy Accelerator
Synchrotrons, devices that accelerate particles along a circular path by synchronizing magnetic and electric fields, have proven useful in hospitals for their efficiency and ability to generate high quantities of finely-tuned particle beams. These energetic beams are used to bombard and destroy cancerous tumors.

from ***The Economist***
24 February
Testing times
Ever since scientists in Italy announced in September that they appear to be seeing particles called neutrinos travelling faster than light people have been trying to poke holes in their findings. Perhaps none more so than the boffins from the OPERA collaboration responsible for the furore.

from ***Fermilab Today***
23 February 2012
World’s best measurement of W boson mass tests Standard Model, Higgs boson limits
Scientists from the CDF collaboration have unveiled the world’s most precise measurement of the W boson mass, based on data gathered at the Tevatron accelerator.

from ***CERN Courier***
23 February 2012
A new chair and new initiatives at ECFA
During the meeting, a decision was also taken to create a European committee to review the R&D effort for future projects. High-energy physics relies heavily on detector R&D developments: every significant improvement in detection techniques opens a new area for fundamental-physics research. Considerable amounts of labour and financial resources are committed to this field across Europe and around the world.

CALENDAR

UPCOMING EVENTS

CALICE collaboration meeting
Shinshu University, Matsumoto, Japan
5-7 March 2012

ILC Mechanical & Electrical Review and CFS Baseline Technical Review
CERN
21-23 March 2012

AIDA - Academia meets Industry: Solid-State Position Sensitive Detectors
DESY, Hamburg, Germany
26-27 March 2012

AIDA 1st Annual Meeting
DESY, Hamburg, Germany
28-30 March 2012

Joint ACFA Physics and Detector Workshop and GDE meeting on Linear Collider (KILC12)
Daegu, Korea
23-26 April 2012

UPCOMING SCHOOLS

Physics and Technology of Particle Accelerators (JUAS 2012)
Geneva, Switzerland
9 January-16 March 2012

USPAS sponsored by Michigan State University
Grand Rapids, Michigan, US
18-29 March 2012

AIDA Student Tutorial - Solid State Detectors
DESY, Hamburg, Germany
27 March 2012

View complete calendar

PREPRINTS

ARXIV PREPRINTS

1202.6336
Thrust distribution resummation in e^{+}e^{-} collisions

1202.6324
Measurement of radiative neutralino production

1202.6295
Pair-production and Three-body Decay of the Lighter Stop at the ILC in One-loop Order in the MSSM

1202.6284
Chargino Production at a future LC in the MSSM with complex Parameters: NLO Corrections

1202.6239
Air cooling for Vertex Detectors

1202.6231
Higgs at ILC in Universal Extra Dimensions in Light of Recent LHC Data

1202.6080
Construction of the Digital Hadron Calorimeter

1202.6013
Top Higgs Yukawa Coupling Analysis from e+e- -> ttH -> bW bW bb

1202.5987
Heat Load and Stress Studies for an Design of the Photon Collimator for the ILC Positron Source

1202.5860
News from CERN, LHC Status and Strategy for Linear Colliders

1202.5832
R&D Status of FPCCD Vertex Detector for ILD

1202.5781
Status of MadLoop/aMC@NLO

1202.5661
Single Production of Fourth Family Sneutrino via RPV Couplings at Linear Colliders

1202.5652
Test of Little Higgs Mechanism at Future Colliders

1202.5644
QCD at work: from lepton to hadron colliders and back

1202.5567
The 1m3 Semidigital Hadronic Prototype

1202.5152
Progress for Higgs Bosons Physics at the LC

1202.4955
Higgs Branching Fraction Study in ILC

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DIRECTOR'S CORNER

GDE Executive Committee visits Washington DC

Barry Barish | 1 March 2012

Francis Slakey, Associate Director for Public Affairs at the American Physical Society

The Global Design Effort (GDE) Executive Committee met for a face-to-face meeting in the Washington DC offices of the American Physical Society from 8-9 February. At that meeting, we invited some guests to inform us about how science policy and funding work in the US government. Our mandate for the GDE is soon approaching its final milestone, the delivery of a *Technical Design Report* (TDR). In fact, the US President's FY2013 budget submission to Congress, the starting point for the yearly US budget process, contains no ILC follow-on funding beyond the TDR! The budget language recognises the accomplishments of the GDE and the anticipated successful completion of the ILC TDR at the end of this year. Nevertheless, it is clear that a new approach will be required to obtain continued funding towards an ILC project.

We had a very interesting session with Francis Slakey, the American Physical Society (APS) Associate Director for Public Affairs. He explained the role the APS plays in affecting US science policy and in advocating for science funding. Francis used a recent example of a study carried out by the APS Panel on Public Affairs in collaboration with the Material Research Society titled ***Energy Critical Elements***. The study illustrates how the APS addresses important science policy issues, calling on experts in their membership (and beyond) to carry out targeted studies. He explained how specific recommendations from such a study can be used to influence government science policy. This particular study, which focussed on energy-critical elements used in emerging technologies, analysed the needs for critical elements and how to ensure their availability. Such critical elements include, for example, tellurium used in solar panels, lithium used in wind turbines and batteries in hybrid cars, terbium used in compact fluorescent bulbs to provide colour balance, and other such new technologies. Slakey pointed out that based on the recommendations from this study, there is now new legislation pending in Congress.

In addition to the APS work on science policy issues, Slakey described the various steps involved in the US budget cycle and how the process works. He also traced the history of last year's science budgets, identifying areas where APS and other science advocacy groups were able to gather support to restore science budget cuts, even in a year where the overall US budget was under severe pressure.

Jerry Blazey, Assistant Director for Physical Sciences at the Office of Science and Technology Policy

Jerry Blazey, who is very familiar to those of us in the ILC GDE (he previously served at the DOE Office of High Energy Physics with responsibility for the ILC R&D programme), is now Assistant Director for Physical Sciences in the Office of Science and Technology Policy (OSTP). OSTP advises the President on science and technology issues, both domestic and international. Jerry explained the administration's stated views regarding international collaboration, emphasising the desire of the Obama administration to develop international partnerships. He also pointed out some of the priorities of the administration, and noted how a project like the ILC might fit into such overall priorities.

The perspectives given to us by Drs. Blazey and Slakey were very informative, especially as we consider how our long-term programme can continue on a path towards an ILC project, following submission of the TDR. Although the immediate goal of the GDE is focussed on producing a solid and viable technical design, we all recognise that mapping out the next steps towards a real ILC project must be addressed and will be a major challenge. The problem is simply how to approach the very likely interim period of several years before a linear collider can be proposed and funded with a programme that will advance the ILC technically, while at the same time be intrinsically justifiable.

APS | DOE | OSTP | TDR | US BUDGET

FEATURE

The incredible shrinking pixel sensor

Leah Hesla | 1 March 2012

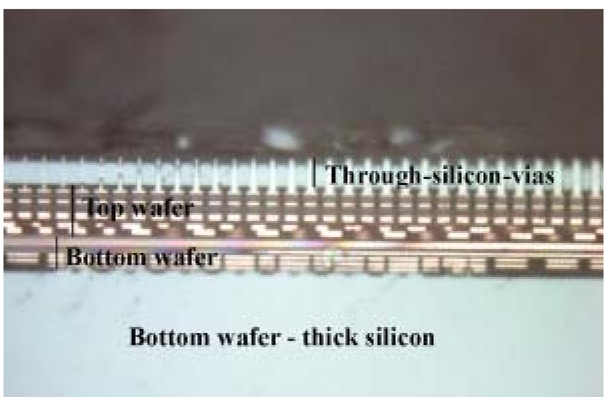
Inside your pocket-sized mobile device, there likely sits a Lego-brick-sized camera inside of which lies a thumbnail-sized sensor. The sensor, sliver though it is, is on its way to being smaller.

ILC researchers have been developing more compact pixel sensors, similar to those in cell-phone cameras, for detecting particle showers. The sensor's diminished size is thanks to a semiconductor innovation called vertical integration, more familiarly known as 3-D sensor technology.

"The 3-D technique lets you build the sensor up rather than across," said Fermilab's Ron Lipton, who works on detector R&D for the ILC. Like skyscrapers, these newer sensors create and make use of vertically available real estate, enabling tighter connections between components and freeing up the horizontal space for still more sensors.

Or as Lipton put it, "It makes a horizontal sandwich."

Standard chip components are arranged roughly side-by-side on a single plane. The central processing unit is situated next to the memory, and signals from millions of memory cells travel along horizontal paths to get to the processor.



Cross-section of an early prototype of a vertically integrated sensor. The spacing of the through-silicon-vias is 4 microns. One of the challenges of constructing vertically integrated chips is aligning the layers. The bond between wafers is aligned to be about 2 microns. Recent runs have improved this to the sub-micron accuracy. Image: Donna Hicks, Fermilab

By layering the device's components on top of each other rather than laying them next to each other, researchers are able to reduce the chip's overall size.

What the sensor loses in size, it gains in data quality and transmission. Shorter, more direct circuitry between pixel and processor allows for higher bandwidths, enabling information to move faster. It also saves power that would otherwise be wasted on longer-than-necessary electrical pathways and resistive elements. The layering technique makes room for more pixels and memory, yielding higher-quality and higher-resolution data.

"It allows you to save on a number of levels," Lipton said.

Around 2006 ILC scientists learned about 3-D technology and consulted with MIT-Lincoln Labs in Lexington, Massachusetts, US, to develop lean, efficient and high-quality 3-D pixel sensor prototypes for the ILC's detectors.

The first thing the chip needed was a good slimming down.

Circuitry only occupies the seven-or-so topmost microns of the sensor's processing chip. The rest of the chip's mass simply gives you a way to handle it. It's nonessential.

“The top few microns is where all the action is, where all the brain power is,” said Argonne National Laboratory’s Marcel Demarteau, chair and convener of the ILC Common Task Group. “For us, the rest is just redundant. If you can get rid of that mass, it’s better.”

For 3-D sensor technology, the bulk of the processing chip is sanded down to close the roughly seven-micron-thick silicon wafer housing the circuit.

In the 3-D integrated configuration, the sensor, comprising millions of pixels arranged in a grid, lies squarely beneath the processing chip. Between them are the electrical connections, which go from pixel (in the bottom layer) to processor (the top layer), and an agent to keep them aligned.

In its bulkier form, the processing chip is soldered to the sensor. Though solder bumps get the job done, serving as both glue and electrical connections between each pixel and the processor, they tend to be expensive to apply and, at roughly 100 microns, make the chip size larger than what ILC researchers wanted.

Faced with a now razor-thin processing chip that had lost its bulk, researchers needed a new way to connect the two slivery layers. They turned to oxide bonding, a technique that has been under development for about a decade, to glue them together. And rather than rely on solder bumps, the electrical connection between each pixel and the processor would be forged through microscopic tungsten pillars, called through-silicon-vias (TSVs). These pillars, which can be anywhere from 1.5 to 20 microns thick, would replace the solder bumps, boulders by comparison. The TSV emerges as a slender stem from each of the millions of pixels in the sensor and shoots up towards the processor ceiling. The base of the TSV is necessarily much smaller than the pixel from which it emerges, leaving as much of the pixel space as possible available for data collection.

The net effect of cutting mass and switching out larger parts is a sensor that is 10 times smaller in depth and in area – a useful improvement when you’re designing a detector.

“A lot of the pain in designing these detectors is finding out how you can fit the sensor with all its functionality in the geometry that’s available,” Lipton said. The sensors are designed for the innermost part of the detector, called the vertex detector, which immediately surrounds the particle collision site. Reduced in size, now thousands of these compact sensors could fit into their assigned space, about the size of a paper towel roll.

The semiconductor industry hasn’t yet developed 3-D technology to the state of the art. The design software infrastructure and development of industry standards need further work. Still, detector researchers believe it’s only a matter of time before vertically integrated sensors, crucial for the development of particle detection, are good enough that other fields of science may want to take advantage of them.

“There’s enormous potential for memory devices,” Demarteau said. One vertically integrated sensor could accomplish a prodigious amount of work for applications that rely on memory and pattern recognition, such as iris scans for security or biochips for medicine, by speeding up the process of mining billions of patterns. “Once you start talking about those possibilities, you open up whole new fields of science. The market is enormous for this technology,” he said.

ILC researchers are currently working with companies Tezzaron in Naperville, Illinois and Ziptronix in Morrisville, North Carolina to develop prototypes of the pixel sensor, which they expect will be ready around May.

DETECTOR ACTIVITIES | DETECTOR R&D | MONOLITHIC ACTIVE PIXEL SENSORS | PIXEL SENSORS

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AROUND THE WORLD

Japanese civil engineers dig deep in Europe

A contribution from the Global Design Effort's civil engineering team

Wilhelm Bialowons (DESY), John Osborne (CERN), and Masanobu Miyahara (KEK) | 1 March 2012

Ten members from the Japanese Society for Civil Engineering's committee for civil works for future ILC facilities came to Europe in February to look at current civil engineering projects like CERN's LINAC4 and the European XFEL in Hamburg and to discuss administrative challenges. By the end of March next year, the committee will publish draft guidelines on civil solutions for a potential ILC in Japan.

A committee on civil works for the ILC facilities in Japan was set up by the Rock Mechanics and Tunnel Engineering Committees of the Japan Society of Civil Engineering in 2006. In the past the committee studied four sample sites for the ILC in Japan as well as problems and solutions for the underground ILC facilities. In March 2010 the committee started to work out guidelines for the underground ILC facilities in Japan. Currently the committee consists of more than fifty engineers and scientists affiliated with universities, institutes, construction and consultancy companies concerned with major underground facilities in Japan. The leader of the committee is Professor Hiroshi Chikahisa, Director of the Geotechnical Engineering Division at the Yamaguchi University in South Japan. Masanobu Miyahara (KEK) from the GDE Conventional Facilities and Siting group is also member of this committee. A first draft guideline will be completed by March 2013 and an interim report by March of this year.

The Japanese visitors inspected the CMS cavern from a civil engineering point of view. Image: Masanobu Miyahara

In February, ten committee members visited CERN in Geneva, Switzerland and DESY in Hamburg, Germany for one day each. They wanted to find out more about the underground activities at both places and the current state of the ongoing projects.

After the visitors were welcomed by CERN Director General Rolf Heuer and Emmanuel Tsesmelis from International Relations, the morning session concentrated on lessons learnt during the recent LHC civil engineering works. John Osborne from CERN's civil engineering group explained how the LHC worksites were organised and highlighted some of the problems encountered during the works. Discussions concentrated on both technical and contractual challenges that were overcome. Plans for CLIC and ILC at CERN were also reviewed.

In the afternoon, the party first visited the recently completed LINAC4 injection complex, including the 150 metres of new tunnel that was constructed using the 'cut and cover' technique. Subsequently, and due to fact that the LHC was on a 'technical stop', the visitors were lucky enough to have access to the CMS underground complex, where many civil engineering challenges were overcome during construction, for example, water ingress and unexpected ground movements. Of particular interest was the 2000-tonne CMS concrete cover on top of the experimental shaft, which is very similar to the proposed platforms that will be used to 'push-pull' the ILC detectors.

In Hamburg the group received a short introduction and then visited the European XFEL construction area in Schenefeld. The excavation of the pit for the experimental hall made by slurry walls and an underwater concrete slab is already finished. The whole volume dives into the water table. Therefore the basement is fixed by several hundred friction anchors in the ground and the walls are stabilised by a grid of concrete beams. The group could go downstairs to the slab and get an impression of the size of the hall. Final construction is on the way and the tunnel boring of the last of five photon beam line tunnels could be observed. The tunnel is bored by a tunnel boring machine (TBM) and lined with precast watertight concrete segments. The TBM cutting head rotates in a compartment filled with a pressured liquid called bentonite. The bentonite suspension resists the soil and hydraulic pressure to avoid displacements at the surface. The liquid also transports the soil to be separated above ground in centrifuges. Within the steel cylinder behind the head (called the shield) a complete tunnel ring is assembled from the precast concrete segments. The group could look into the tunnel and was able to observe the supply of the machine with precast segments and liquid concrete for the filling of the ring slit between the tunnel and the soil. In the afternoon the XFEL mock-up tunnel and the HERA hall West was on the agenda. At the end of the day DESY and XFEL experts discussed dozens of questions asked by the committee.

JSC committee members in front of a photon beam line tunnel portal. Masanobu Miyahara at the right and the committee leader professor Chikahisa are beside the two DESY guides Wilhelm Bialowons and Frank Lehner. The piping for the bentonite can be seen on the right side. (By the way: just after taking this photo the snow stopped falling and the sun started shining, as it mostly does in Hamburg…). Image: Hans-Joachim Christ, DESY

The visits to CERN and DESY proved very fruitful, and many ideas and lessons learnt were taken on board for serious consideration by the JSC team developing a technical guideline for the ILC in Japan. Professor Chikahisa expressed his hope that this communication will be mutually beneficial.

CERN | CIVIL ENGINEERING | DESY | JAPAN | XFEL