

DIRECTOR'S CORNER

The mass production of SRF linac cavities

Today's issue features a Director's Corner from Marc Ross, Project Manager for the Global Design Effort.

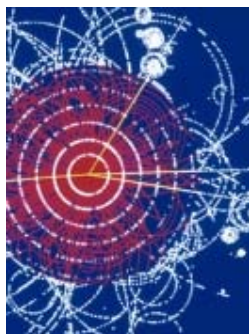
by Marc Ross



Niobium's superconducting ability recommends it as a metal of choice for ILC accelerating cavities, but it brings challenges to the R&D table. Laboratories and industry alike work to set down the best possible, most cost-effective process for forming niobium into high-performing structures.

FEATURE

From symmetry breaking: Higgs buzz at summer physics conference



Physicists could be on their way to discovering the Higgs boson, if it exists, by next year. Scientists in two experiments at the Large Hadron Collider pleasantly surprised attendees at the European Physical Society conference this afternoon by both showing small hints of what could be the prized particle in the same area.

AROUND THE WORLD

Power to the cryomodule

by Leah Hesla



Cryomodule 1 at Fermilab is now being powered as a complete, multi-cavity instrument. Scientists will subject it to superconducting radiofrequency tests over the coming weeks.



International Europhysics Conference on High-Energy Physics

Images: LPSC/Tomas Jezo

During the 2011 Europhysics Conference on High-Energy Physics (HEP 2011) press conference, CERN Director General Rolf Heuer ad libbed for the journalists an explanation of the role of the Higgs boson in the standard model of subatomic particles...with his two hands. "We know everything about the Higgs boson except whether it exists," he concluded. [View more photos](#)

[View videos](#) from the conference.

IN THE NEWS

from **Der Spiegel**

27 July

[Jagd nach dem Higgs-Boson: Teilchenphysiker stehen kurz vor dem Zieleinlauf](#)

Denn gleich zwei Experimente der Physiker liefern Hinweise auf die Existenz des Higgs Bosons: Die LHC-Detektoren "Atlas" und "CMS" registrierten eine ungewöhnliche Häufigkeit von leichteren Teilen im Massebereich von 130 bis 145 Giga-Elektronenvolt (GeV).

from **Fermilab Today**

27 July 2011

[Tevatron experiments close in on Higgs particle](#)

Scientists of the CDF and DZero collaborations at Fermilab continue to increase the sensitivity of their Tevatron experiments to the Higgs particle and narrow the range in which the particle seems to be hiding.

from **Le Figaro**

26 July 2011

[Les premières traces du boson de Higgs](#)

«Je sais que c'est difficile, mais il faut être patient», assure Rolf Heuer, le directeur général du Cern. Il refuse, comme ses collègues, de sauter le pas et de confirmer la découverte du boson de Higgs, mais son petit sourire en coin trahit tout de même son excitation.

from **Deutschlandradio**

26 July 2011

[Und es hat CLIC gemacht](#)

Der Nachfolger des 27 Kilometer großen Beschleunigerrings könnte den Namen "CLIC" tragen. Das Konzept dazu wurde auf der Europäischen Teilchenphysik-Konferenz in Grenoble vorgestellt.

from **Fermilab Today**

25 July 2011

[DZero announces top quark asymmetry result, questions theory](#)

A new result from Fermilab's DZero experiment was announced Saturday at the European Physical Society conference in Grenoble, France, studying the production of the top quark and its antimatter counterpart, the antitop quark, in proton-antiproton collisions.

from **Nature News**

25 July 2011

[Hint of Higgs, but little more](#)

When its experiments started in earnest earlier this year, many scientists hoped that the world's most powerful collider would

turn up new particles, additional dimensions and perhaps even a small black hole or two. But beyond a handful of unusual events, the latest data from the Large Hadron Collider (LHC) are frustratingly ordinary.

from **New Scientist**

25 July 2011

[Should we worry about what the LHC is not finding?](#)

The Higgs boson is still missing – but perhaps we should be more worried about what else the Large Hadron Collider hasn't found yet.

from **Nature News**

23 July 2011

[Asymmetric quarks defy standard model of physics](#)

Newly released observations of the top quark — the heaviest of all known fundamental particles — could topple the standard model of particle physics. Data from collisions at the Tevatron particle accelerator at Fermilab in Batavia, Illinois, hint that some of the top quark's interactions are governed by an as-yet unknown force, communicated by a hypothetical particle called the top gluon.

from **symmetry breaking**

22 July 2011

[How to find the Higgs particle; first Higgs search results from LHC and Tevatron](#)

...Finding the tell-tale sign of a Higgs boson among all other particle signatures is like searching for a drop of ink in an ocean. Only if the accelerators produce more and more collisions do scientists stand a chance of finding enough evidence for the Higgs particle.

from **Nature News**

22 July 2011

[Collider sees tantalizing hint of Higgs](#)

For now, physicists are only willing to call them 'excess events', but fresh data from two experiments at the Large Hadron Collider (LHC) are hinting at something unusual — and it could be the most sought-after particle in all of physics.

from **Science Now**

22 July 2011

[Particle Physicists Report Possible Hints of Long-Sought Higgs Boson](#)

Physicists working with the world's largest atom smasher may have spotted evidence of the long-sought Higgs boson. At least that's the unofficial result that has the 800 physicists here for the biannual Europhysics Conference on High-Energy Physics abuzz.

from **The Guardian**

22 July 2011

[Cern scientists suspect glimpse of Higgs boson](#)

Scientists may have caught their first glimpse of the elusive Higgs boson, which is thought to give mass to the basic building blocks of nature.

from **physicsworld.com**

22 July 2011

[Higgs cornered in Grenoble](#)

The latest data from experiments at the Large Hadron Collider (LHC) leave significantly less room for the Higgs boson to hide — that is the take-home message from the Europhysics Conference of High-Energy Physics in Grenoble, France.

from **Fermilab**

20 July 2011

[Fermilab experiment discovers a heavy relative of the neutron](#)

Scientists of the CDF collaboration at the Department of Energy's Fermi National Accelerator Laboratory announced the observation of a new particle, the neutral Xi-sub-b.

CALENDAR

UPCOMING EVENTS

[15th International Conference on RF Superconductivity \(SRF2011\)](#)

Sheraton Chicago Hotel & Towers, Chicago, IL
25- 29 July 2011

[Meeting of the Division of Particles and Fields of the American Physical Society \(DPF 2011\)](#)
Brown University, Providence, Rhode Island, USA
09- 13 August 2011

[Lepton Photon 2011 XXV International Symposium on Lepton Photon Interactions at High Energies](#)
Tata Institute of Fundamental Research, Mumbai, India
22- 27 August 2011

[ILC positron collaboration meeting](#)
IHEP, Beijing, China
27 August 2011

[POSIPOL 2011](#)
IHEP, Beijing, China
28- 30 August 2011

[Supersymmetry 2011 \(SUSY 2011\)](#)
Fermilab, Batavia, IL
28 August- 02 September 2011

[XXXI Physics in Collision \(PIC 2011\)](#)
Simon Fraser University, Vancouver, Canada
28 August- 01 September 2011

[The 2nd International Particle Accelerator Conference \(IPAC'11\)](#)
San Sebastian, Spain
04- 09 September 2011

[View complete calendar](#)

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Marc Ross | 28 July 2011



Impure niobium feedstock is being melted by high-power electron beams. The molten niobium drops into a crucible. This is one of the many steps involved in removing impurities from the metal. Image: Waldemar Singer

A significant fraction of ILC R&D has focused on the production of accelerating cavities, which requires a thorough understanding of the behaviour and properties of niobium, the metal of choice for ILC cavities.

The 2007 ILC *Reference Design Report* showed that the better part of the construction project effort will be taken up by comparatively low-technology standard accelerator components and civil construction. The remaining roughly 40 percent of the effort is to be devoted to advanced-technology linac parts, especially the cryogenic linac and its central component, the pure niobium sheet metal cavities. The Global Design Effort's upcoming *Technical Design Report* will include one or more models of how the project would be commissioned and built.

Both ILC researchers and industrial companies have invested a prodigious amount of time and energy in understanding niobium from its extraction at the mine to its formation into accelerating cavities to the cavity's vertical dewar qualification test. In its multiple-step treatment, niobium is reduced, purified, rolled, formed, welded and chemically polished. Most of these steps are done by our industrial partners; they have the specialised equipment and have proven their expertise during the ongoing Technical Design Phase (TDP) of ILC R&D. The final step of testing and qualifying cavity performance is best done by an institutional partner.

Niobium, found in nature as niobium pentoxide, is one of the five refractory metal elements, so named for their resistance to wear and

their very high melting point. Very high-temperature reduction and purification processes are required to prepare it for our use. It must be free of low-mass gasses to less than roughly 30 parts per million.

The extreme chemical resistance of niobium makes it difficult to layer or to combine with common metals such as copper and aluminium (as done in the past at the Large Electron-Positron Collider at CERN) and still get the excellent cavity performance of 35 megavolts per metre. Typically these metals are not at all used as part of the ILC cavity production as it is impractical to keep the strong acid from touching them.

After removing gas and light element impurities, the forged niobium bar must be rolled into sheets and etched and ground to make what is referred to as a semi-finished product.

It is well known that the superconductivity of niobium is better when the residual resistance ratio (RRR) is high; a typical RRR for ILC prototype cavities is around 300. However, high-RRR material is so pure it lacks strength and the inherent fine-grained crystalline structure that is often seen in metals alloyed with various impurities. During the sheet rolling and deep-drawing process that shapes the sheets into cup-shaped half-cells, the highly ductile ultra-pure niobium can flow too much and can easily 'cold-weld' or stick to itself. These effects have been largely overcome in the last 20 years and with great care we can now keep voids and contaminants from being introduced at this stage. To maintain the quality of the input feedstock during this semi-finished product stage, a relatively large fraction of the feedstock, sometimes approaching 50 percent, is discarded.

The final step in cavity fabrication is the assembly of the formed, machined parts into a unit using electron beam welding (EBW). Simpler welding technology has been tried and found to be ineffective, especially for the demanding equator welds that are used to close each of the nine cells in the cavity. EBW is an automated, batch-oriented process that takes place in high vacuum. High vacuum keeps the niobium free of impurities.

Early in the Technical Design Phase the experienced DESY / TESLA team in Germany showed a cost breakdown of cavity fabrication that clearly identified EBW as a cost driver (see slide 17).

With a determined effort, the team developed a plan for an optimised set of EBW machines and associated tooling, thereby reducing production costs by a substantial factor. To prove this optimisation and to better understand the EBW process, KEK recently constructed and is now commissioning a 'pilot plant' cavity fabrication facility. The plant includes the forming, trimming, weld-prep etching and welding machines in a well-organised cleanroom environment. Even with delayed delivery due to the great 2011 Tohoku earthquake, we expect preliminary results during the current TDP.

The mass production models in preparation for the TDR were the central topic for discussion at the 2nd Workshop on SCRF Cavity Technology and Industrialization for the ILC. The models to be considered must balance technical considerations, such as those listed above, against the production process itself, component interface definitions, vendor models – often based on existing companies – and ILC project member in-kind contribution models. For the TDP, we can be pleased with our technical progress in understanding niobium cavity performance and with our practical progress in assembling a global industrial team for the task of building the ILC.

CAVITY PRODUCTION | CAVITY PRODUCTION PILOT PLANT | NIOBIUM

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Higgs buzz at summer physics conference

July 22, 2011 | 2:25 pm

Physicists could be on their way to discovering the Higgs boson, if it exists, by next year. Scientists in two experiments at the Large Hadron Collider pleasantly surprised attendees at the European Physical Society conference this afternoon by both showing small hints of what could be the prized particle in the same area.

“This is what we expect to find on the road to the Higgs,” said Gigi Rolandi, physics coordinator for the CMS experiment.

Both experiments found excesses in the 130-150 GeV mass region. But the excesses did not have enough statistical significance to count as evidence of the Higgs.

If the Higgs really is lurking in this region, it is still in reach of experiments at Fermilab’s Tevatron. Although the accelerator will shut down for good at the end of September, Fermilab’s CDF and DZero experiments will continue to collect data up until that point and to improve their analyses.

“This should give us the sensitivity to make a new statement about the 114-180 mass range,” said Rob Roser, CDF co-spokesperson. Read more about the differences between Higgs searches at the Tevatron and at the LHC [here](#).

The CDF and DZero experiments announced expanded exclusions in the search for their specialty, the low-mass Higgs, this morning. On Wednesday, the two experiments will announce their combined Higgs results.

Scientists measure statistical significance in units called sigma, written as the Greek letter σ . These high-energy experiments usually require 3σ level of confidence, about 99.7 percent certainty, to claim they’ve seen evidence of something. They need 5σ to claim a discovery. The ATLAS experiment reported excesses at confidence levels between 2 and 2.8σ , and the CMS experiment found similar excesses at close to 3σ .

After the two experiments combine their results — a mathematical process much more arduous than simple addition — they could find themselves on new ground. They hope to do this in the next few months, at the latest by the winter conferences, said Kyle Cranmer, an assistant professor at New York University who presented the results for the ATLAS collaboration.

“The fact that these two experiments with different issues, different approaches and different modeling found similar results leads you to believe it might not be just a fluke,” Cranmer said. “This is what it would look like if it were real.”

If the accelerator and the detectors continue to function as impressively as they have been, ATLAS and CMS should be able to at least double their data by the end of the year, [increasing their reach](#). This could flatten the excesses if they turn out to be mere statistical fluctuations. Both experiments have seen bumps come and go as they’ve gone through their data, as have experiments before them.

“DZero has seen these kinds of effects vanish,” said Sebastien Greder of Institut Pluridisciplinaire Hubert Curien in Strasbourg, who presented DZero’s Higgs results.

The excesses could also be hints of new physics other than the Higgs. Whatever the case, scientists have made huge strides in ruling out places the Higgs could be hiding.

The ATLAS collaboration ruled out two areas, 155-190 GeV and 295-450 GeV, with a 95 percent confidence level. Similarly, the CMS collaboration excluded the ranges from 149-206 GeV and 300-440 GeV, plus three short segments in between, with the same confidence.

“We have excluded regions of mass not explored before by the Tevatron,” said Fabiola Gianotti, spokesperson for the ATLAS experiment. “The area where it can be has gotten narrower and narrower.”

The hunt continues.

Kathryn Grim

AROUND THE WORLD

Power to the cryomodule

[Leah Hesla](#) | [28 July 2011](#)



CM1 with its recently installed RF distribution system ready for testing. Image: Jerry Leibfritz

Cryomodule 1 is now firing on all eight cavities.

Cryomodule 1, Fermilab's test cryomodule for ILC-type accelerating cavities and superconducting radiofrequency (SRF) technology, was powered up as a complete, multi-cavity instrument earlier this month. Previously, researchers had delivered power only to the individual cavities inside it.

"We've operated superconducting cavities before, but this is the next step in scale," said Sergei Nagaitsev of Fermilab's Accelerator Division. "Operating a single cavity in its own cryostat is comparable, but with a full cryomodule, the complexity goes up by an order of magnitude."

Since the [cool-down of CM1](#) last November, scientists, engineers and technicians have been busy installing the plumbing for power distribution, called waveguides; upgrading the water skid, which helps

with the cooling of the high-power RF equipment; and taking data on each cavity's accelerating gradient and quality factor, or Q. Researchers completed the cavity tests in June.

"The big question now is how this module performs compared to when the cavities were at DESY," said Fermilab's Elvin Harms. The German physics lab DESY provided all eight CM1 cavities, which were tested before they came across the Atlantic. Over the coming weeks, researchers will continue to feed power into cryomodule to gather data on how cavities perform as a single unit rather than as individual elements. The hope is that their gradients and Q will be in reasonable agreement with DESY's numbers.

To make sure the data that comes through is reliable, the CM1 team will work on calibrations, test RF power operation, and work the kinks out of the system. Then comes a multi-week programme where scientists will perform stability tests and beam studies for the ILC beam current programme, which includes tests that can be conducted without the presence of beam. Researchers will also use CM1 for tests for Project X, Fermilab's proposed proton accelerator programme.

Not all sailing was smooth in the time since the November cool-down. Some cavities still have wrinkles that need to be ironed out.

"Nevertheless, the fact that the integration of it all into a single system worked is a tremendous boost for the Accelerator Division, the Technical Division and our collaborators," Nagaitsev said.

Collaborators on CM1 include researchers from DESY, INFN in Italy and KEK in Japan.

"Many people have invested a lot of time in CM1," Harms said. "They've been eagerly waiting to get this to this day."

[CM1](#) | [CRYOMODULE](#) | [FERMILAB](#)

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