

FEATURE

Light as a feather

The PLUME project sets a new milestone for vertex detectors

by Perrine Royole-Degieux



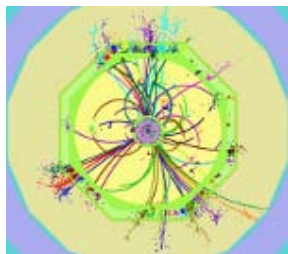
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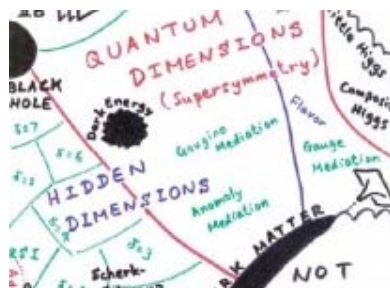
A new version of linear collider data storage software was released this past autumn to accommodate detector scientists' increasing sophistication in simulating particle events. LCIO (the name comes from 'linear collider input/output') continues to

facilitate agreement among the world's linear collider groups with a common event data model and file format for data exchange.

DIRECTOR'S CORNER

Pondering the future of particle physics

by Barry Barish



- We really don't know what is going on at TeV
- stupid theorists!
- Can we zoom in onto a point on this map?
- Expect the unexpected

The International Committee for Future Accelerators (ICFA) sponsors a meeting every three years on "Future Perspectives in High Energy Physics." This year the ICFA seminar was held at CERN and it broadly covered plans and ideas for future facilities for our field. This meeting was particularly timely, as it coincided both with the completion of the impressive first year of running of the LHC and with the kickoff of the update of the European Strategy for Particle Physics to be completed in 2013.

IMAGE OF THE WEEK



Japanese delegation explores European labs

Image: DESY

A delegation from the prefectures Fukuoka and Saga on the Japanese island Kyushu visited two European labs, CERN and DESY, last week to learn about existing research infrastructures and the labs' experiences with management, administration, local communication and a whole lot more. The region is one of two possible Japanese sites for the ILC, and the delegation, consisting of four members of the Fukuoka/Saga ILC planning committee, wanted to establish a dialogue with the European labs to exchange ideas and information. At DESY, they heard about DESY regional cooperation, socioeconomic impacts, innovation and technology transfer, outreach with local communities and of course DESY and the ILC. They also visited some facilities on campus, including the new accelerator module test hall for the European X-Ray Free-Electron laser XFEL, pictured here.

IN THE NEWS

from **Fermilab Today**

7 December 2011

[SRF advances and future accelerators at Fermilab](#)

Superconducting radio frequency (SRF) advances at Fermilab depend not only on the melting pot of Fermilab employees old and new, but also fundamentally on both national and international collaborators.

from **Discover**

6 December 2011

[Guest Post: Matt Strassler on Hunting for the Higgs](#)

After this year's very successful run of the Large Hadron Collider (LHC), the world's most powerful particle accelerator, a sense of great excitement is beginning to pervade the high-energy particle physics community. The search for the Higgs particle... or particles... or whatever appears in its place... has entered a crucial stage.

from **Physics World**

6 December 2011

[String-theory calculations describe 'birth of the universe'](#)

Researchers in Japan have developed what may be the first string-theory model with a natural mechanism for explaining why our universe would seem to exist in three spatial dimensions if it actually has six more.

from **The Guardian**

6 December 2011

[Is the Higgs boson real?](#)

Rumours abound that Cern scientists have finally glimpsed the long-sought Higgs boson. We asked physicists to share their thoughts on the elusive entity

from **symmetry breaking**

5 December 2011

[DOE's Intensity Frontier Workshop packed with ideas and people](#)

The Fundamental Physics at the Intensity Frontier Workshop was set up to survey existing research and future scientific possibilities in this area, and to gauge the level of interest from the physics community.

CALENDAR

UPCOMING EVENTS

[TESLA Technology Collaboration \(TTC\) Meeting](#)
IHEP, Beijing, China
05- 08 December 2011

[5th Annual Workshop of the Helmholtz Alliance "Physics at the Terascale"](#)
Bonn, Germany
07- 09 December 2011

[2nd International Workshop on Accelerator-Driven Sub-Critical Systems & Thorium Utilization](#)
Bhabha Atomic Research Centre, Mumbai, India
11- 14 December 2011

[SiD Workshop](#)
SLAC
14- 16 December 2011

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PREPRINTS

ARXIV PREPRINTS

[1112.0943](#)
Laboratory frame analysis of $e^+ e^- \rightarrow \mu^+ \mu^-$ scattering in the Noncommutative Standard Model

[1112.0908](#)
Top quark polarization at a polarized linear $e^+ e^-$ collider

[1112.0760](#)
Chargino Decays in the Complex MSSM: A Full One-Loop Analysis

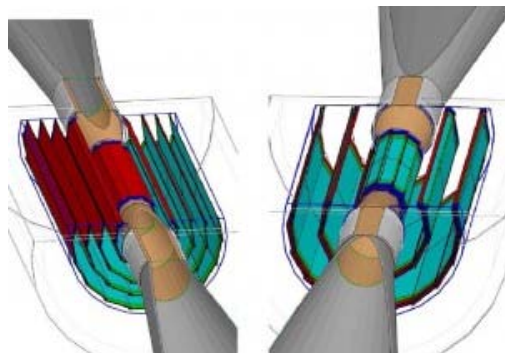
[1111.7289](#)
Heavy Scalar Top Quark Decays in the Complex MSSM: A Full One-Loop Analysis

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The PLUME project sets a new milestone for vertex detectors

Perrine Royole-Degieux | 8 December 2011



Possible geometries for the ILC International Large Detector. Shown on the left is a design based on five single-sided layers; on the right, a design based on three double-sided layers. Image: ILD

A group of European physicists, the PLUME collaboration, aims to prototype an ultra-light device intended to equip one of the thinnest and lightest elements at the inner heart of the ILC detectors: the vertex detector. At CERN one month ago, a full-scale prototype equipped with CMOS pixel sensors was successfully tested in beam.

At the ILC, physicists will take advantage of the well defined interaction parameters and of moderately demanding running conditions (compared with those of the Large Hadron Collider at CERN, for example) to scrutinise phenomena involving very short-lived particles such as tau leptons or charm particles. This implies challenging specifications for the ILC detectors in terms of precision, especially for the sub-detector closest to the interaction region, the vertex detector.

Compared to an LHC detector, an ILC vertex detector will need to be significantly lighter and more precise. On the other hand, its sensitivity to radiation damage will not be a major concern for most of the detection technologies available today, but the hit occupancy and the power consumption remain driving parameters. ILC physicists thus have to find a new, linear-collider-specific trade-off between these competing parameters and look for novel sensor technologies suited to this peculiar combination of specifications.

CMOS pixel sensors are one of the pixel technologies (besides CCDs, DEPFETs, and others) potentially complying with the requested performances. They are under development in several countries around the world, including France, the UK and the USA.

For more than ten years now, the Institut pluridisciplinaire Hubert Curien (IPHC), a CNRS / University of Strasbourg lab in France, is developing CMOS pixel sensors for various applications. For many years, most of the ILC-related developments have been pursued in collaboration with CEA/Irfu in Saclay, France. The sensors have the peculiarity of being monolithic, which means that they integrate in the same chip the charge sensing part and the signal processing micro-circuits. Their 10- to 20- micrometre-thin sensing layer and their highly integrated read-out circuitry allow them to be made very thin. One of the most recent versions, called MIMOSA-26, thinned to 50 micrometres, is already equipping beam telescopes on test beam lines at both DESY in Germany and CERN. Adapted versions are also getting used in subatomic physics experiments.

The vertex detector will of course be made of a large number of sensors. And though MIMOSA-26 has already shown very promising performances as a single sensor, one may ask what happens when the full vertex detector is paved with them. Will these properties stay the same after integration?

"This is by far not obvious," says Jérôme Baudot, University of Strasbourg researcher belonging to the PICSEL team at IPHC. "While integrating a sensor, you introduce a mechanical structure and electrical cables, which all add extra material seen by traversing particles. Moreover, the air flow needed to evacuate the dissipated heat tends to induce mechanical vibrations. All these

effects can alter the genuine spatial resolution. Despite being well known, they have not yet been demonstrated to be under control when the targeted single point resolution is better than three micrometres.”

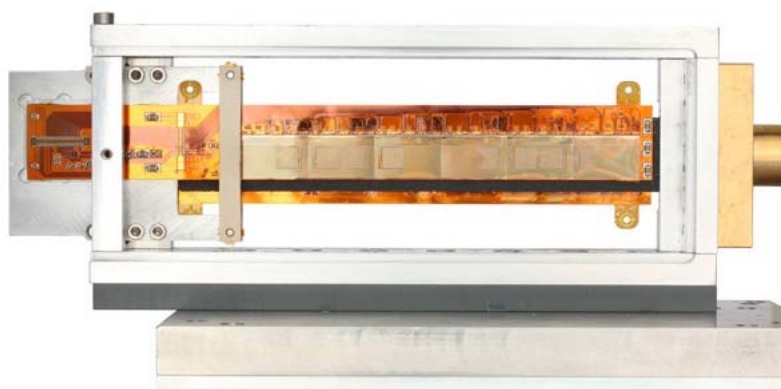
The appropriately named PLUME (Pixelated Ladder with Ultra-low Material Embedding) project (the name “plume” means “feather” in French) is developing ultra-light “ladder” prototypes that are supposed to match the specifications of an ILC vertex detector. The double-sided ladder concept consists of two layers of sensors, each connected on a micro-cable, separated by a light support structure made of foam.

So, what does this ladder look like? Six sensors are butted on each side, adding up to a total sensitive area of $12 \times 1 \text{ cm}^2$. It contains eight million pixels and is read entirely in about 100 microseconds. The present prototype weighs 10 grammes. In terms of physics, these 10 grammes stand for 0.6 percent of radiation length. The final goal of PLUME is to reduce the amount of material crossed by particles down to about 0.3 percent in 2012. For this to happen, the PLUME team expects to manage substantially reducing the foam density and the micro-cable material.

The PLUME ladder prototype was tested at the CERN-SPS from 30 October to 6 November, and its performances were assessed. “We are very enthusiastic with the preliminary results, since we measured that the spatial resolution on the track crossing point is the same for the ladder as for a single sensor in stand-alone operation.” said Baudot. “It is actually better – below three micrometres – when combining the information from both sides of the ladder. Also, having a double-sided ladder allows us to estimate the track direction with a resolution of about 1.5 milliradians from our preliminary analysis. These two features illustrate some of the benefits expected from the double-sided ladder concept.”

The precise determination of the detection efficiency of this particle tracker, among the thinnest and quickest ever built, requires more detailed analysis. “Nevertheless, the challenge is already partially won with a preliminary value in excess of 99.5 percent,” he said.

The PLUME project gathers physicists from DESY, the Universities of Oxford and Bristol in the UK and IPHC in France. With these promising results, the collaboration demonstrated that the approach followed to realise ladders adapted to an ILC vertex detector is on a good track for achieving the challenging performance level required by the ILC physics programme.



*View of the double-sided PLUME ladder, equipped with CMOS pixel sensors.
Image: IPHC*



The PLUME ladder tested at CERN in November 2011 in a beam telescope. Image: IPHC/Jérôme Baudot

[CMOS](#) | [CNRS/IN2P3](#) | [DESY](#) | [IPHC](#) | [MIMOSA-26](#) | [MONOLITHIC PIXEL DETECTOR](#) | [PLUME](#) | [UNIVERSITY OF BRISTOL](#) | [UNIVERSITY OF OXFORD](#) | [UNIVERSITY OF STRASBOURG](#) | [VERTEX DETECTOR](#)

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FEATURE

LCIO 2.0 improves simulation coordination

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Leah Hesla | 8 December 2011

The data model that transformed the linear collider detector community from a computational Tower of Babel into a group that inputs with one voice has gotten an update.

ILC software developers released LCIO 2.0 this autumn. The new version of LCIO, a particle event data model, includes features that help scientists cope with the increasingly sophisticated data being fed into particle event simulations.

"We considerably improved the data model – in particular for the description of charged particle tracks – and put in little things from users' requests or features we thought would improve physicists' lives," said DESY's Frank Gaede, one of the main developers of LCIO and coordinator of ILCSoft, one of two software packages for which LCIO is the core.

Once upon a time, ILC physicists' lives were direly in need of improvement when it came to sharing simulation data with other regions. As an ostensibly international project, ILC detector groups' simulation efforts were decidedly not global: three different regions used three different computing formats to describe a simulated particle event.

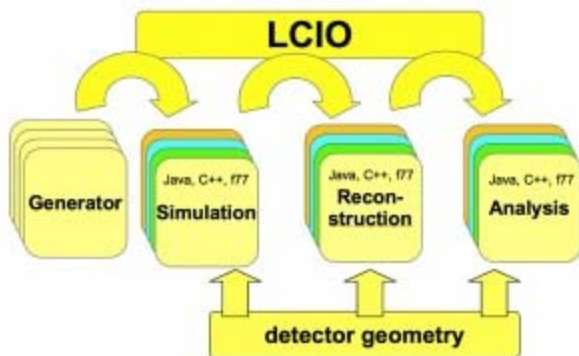


Illustration of the way LCIO works with multiple software formats. Image: DESY

To produce simulations, scientists first generate a particle event – say, a collision between a positron and electron with 250 gigaelectronvolts of energy – using a standard format. But in subsequent steps, they typically use their own programs to run the event through different scenarios. From those scenarios' outcomes, they again use their own codes to reconstruct and analyse the collision picture.

In itself, it's not startling that different detector groups accomplish their tasks using different software formats. Each of the four detectors at the Large Hadron Collider in Switzerland, for example, uses its own in-house definition for event elements such as cluster, hit, particle and track. As large, effectively competing experiments with thousands of scientists working on them, there's little incentive to develop a common

description of a particle event for all four.

"It makes sense," said SLAC's Norman Graf, who leads the American Linear Collider Physics and Detector Simulations Working Group. "Each wants to hold its reconstruction close to its chest so it can beat the other guy."

The linear collider detector community, on the other hand, is smaller and global. It makes sense for them to agree on a computational definition of a particle event.

"We're a very open collaborative, cooperative environment in the linear collider, so when someone writes an algorithm, they share it with the world community and we run it," Graf said.

But in the beginning, the multiplicity of software formats used by detector groups hamstrung exchange between them. Asian and European groups were using C++ software and some legacy Fortran. US groups were using a mix of Java and C++ to write their code.

“Physicists are real keen on standards,” Graf said. “Unfortunately, the mantra is, Standards are good, so let’s have lots of them.”

It’s a plight that all ILC researchers contend with – striving for harmony in a setting where the internationality of the work brings with it unavoidable differences. Scientists who work on accelerator physics for the ILC deal with regional differences in machinery by instituting plug-compatibility for machine components. Though a machine part made in Asia may not be identical to its European analogue, if both fulfil the same function and can be easily joined to the rest of the machine through plug-compatible couplers, the machine can run with that kind of variety.

Folks working on detectors decided they needed to be plug-compatible in their own way.

In 2003 Graf and Tony Johnson from SLAC and Ties Behnke and Gaede from DESY got together at SLAC to begin the development of a common data model that would replace the many different formats then on the market.

The result of the four scientists’ effort was LCIO – linear collider input/output. It established precise computational definitions for particle events that could be read out by any program. Soon it was adopted by most groups involved in the ILC around the world. The event element ‘track’, for example, would be defined in the same way for everyone, and subtle definitional variations would no longer be a complicating factor for event readouts.

“You save people in various groups from always having to understand what the other group’s data format is, translate it into the right code, and translate it into their own data format,” Gaede said.

Now, thanks to LCIO, a group in Hamburg, Germany can read a file written with Java in Palo Alto, US into their C++ Marlin application.

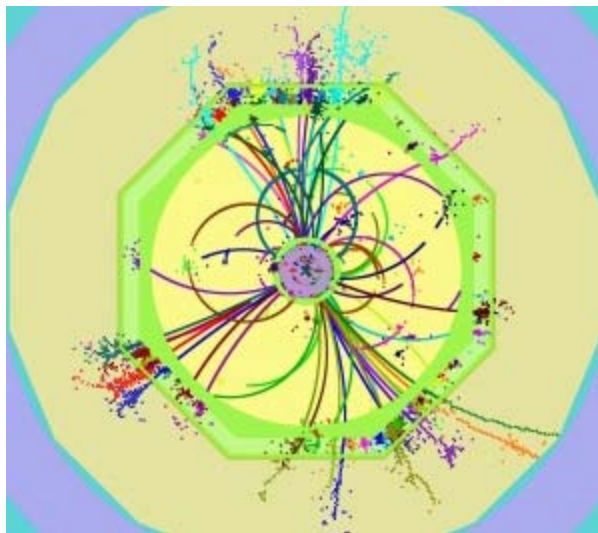
LCIO isn’t only for those who work in pure simulations. Scientists who work on test beams also use LCIO to store real particle events from brick-and-mortar prototype detectors.

Nor is its use limited to the ILC. The CLIC detector groups use LCIO, and there is talk of adopting it for another lepton collider, the proposed muon collider.

Earlier this year developers worked to extend LCIO to LCIO 2.0 to accommodate the evermore-detailed particle flow algorithms scientists are developing for event reconstructions. They also incorporated a feature called direct access. This saves users the trouble of having to wade through an entire file to find a particular event. With direct access, a user can easily locate a specific indexed event for study.

The scientists that started the LCIO effort were doggedly determined to persuade the world’s linear collider detector researchers to converge on a single data model for global use, and, said Gaede, scientists are now glad they did.

“Most people would agree that this was worth it – it’s made everyone’s lives easier.”



A $t\bar{t}$ event simulated and reconstructed using ILCSoft, one of two software programs with LCIO at its core. Image: DESY

[DETECTOR R&D](#) | [LCIO](#) | [PARTICLE SIMULATION](#) | [SOFTWARE](#)

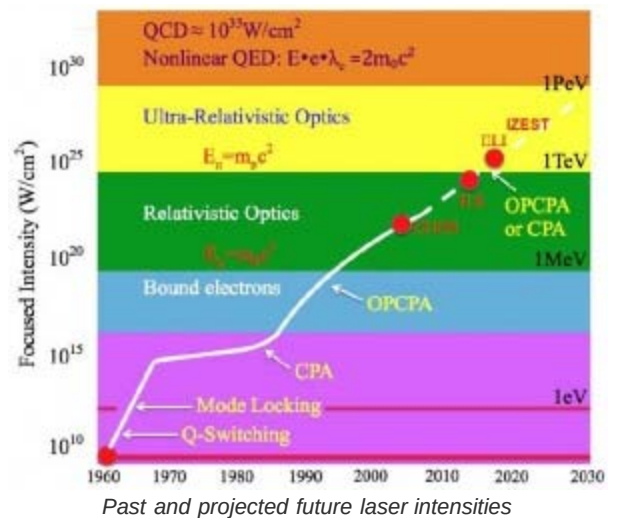
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Hitoshi Murayama of IPMU, Japan and UC Berkeley, US, gave a colourful talk on future opportunities in the field

Finally, the most forward-looking talk given at the ICFA seminar was by Toshiki Tajima, who reviewed the advanced and future projections for laser technology, and the [potential for future laser plasma accelerators](#) (view [video](#)).

The range of opportunities in the coming years for large new facilities for particle physics bodes very well for the future of the field. Clearly, we will not get everything we desire, certainly in the short term. But I am confident and the ICFA seminar illustrated that we know ways to move forward and make steady progress in developing exciting new facilities for particle physics, and well far into the future.



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