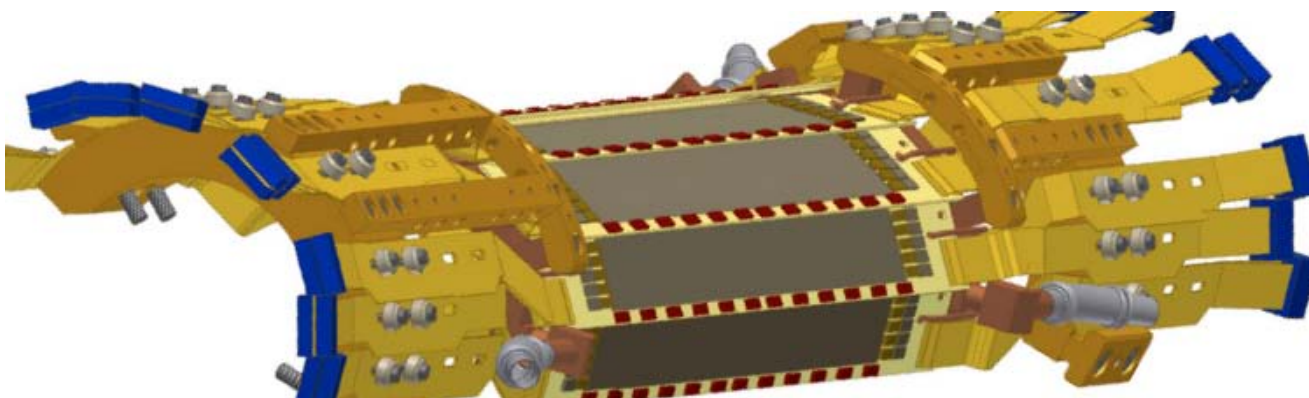


RESEARCH DIRECTOR'S REPORT

The impact of ILC detector R&D

This month's Research Director's Report was written by Marcel Demarteau, chair and convener of the ILC Detector Common Task Group

by Marcel Demarteau



Although the actual construction date of the ILC accelerator and its detectors is very uncertain, the impact of the R&D for ILC detectors is very real. Sometimes we tend to overlook the deep impact the work initiated by and carried out within the ILC detector community has already had on the whole particle physics community and beyond.

AROUND THE WORLD

Detector scientists and the chamber of GEMs

Researchers at the University of Texas at Arlington spend two weeks characterising ILC detector chamber prototypes at Fermilab's Test Beam Facility.

by Leah Hesla



Being holed up at Fermilab's Test Beam Facility for two weeks, 18 hours a day is no reason to go hungry. Researchers from the University of Texas at Arlington subsisted on instant noodles while they kept busy with their gas electron multipliers, one of the technologies being developed for the ILC detector.

DIRECTOR'S CORNER

GDE Executive Committee meeting at Caltech

by Barry Barish



The GDE Executive Committee met face-to-face at Caltech in July in order to plan the next phase of the work on the *Technical Design Report* following establishment of a new ILC baseline this past spring. The status and plans remain on track to complete the report at the end of 2012.



Summer students of science

Image: DESY

This summer 81 students of 19 different nationalities joined in the day-to-day work of research groups at the DESY Laboratory in Hamburg and Zeuthen (Berlin), participating in different activities.

An introductory talk about the ILC is included in this year's programme.

IN THE NEWS

from *physicsworld.com*

16 August 2011

China-US neutrino facility opens

The first major science project in China that has been built through a genuine international collaboration has begun operation. Once fully complete next year, the Daya Bay Reactor Neutrino Experiment – a partnership between 19 Chinese and 16 US universities – will begin searching for the final undetermined neutrino “mixing angle”, known as θ_{13} .

from *Conceivably Tech*

15 August 2011

Witnessing The Birth Of A New Particle Collider

Fermilab is scheduled to shut down its legendary Tevatron particle smasher next month, but scientists are navigating difficult political and financial waters to build the International Linear Collider (ILC) as the potential successor of the Large Hadron Collider (LHC) at CERN.

from *Xinhua News*

15 August 2011

Scientists in China detect neutrino hoping to solve antimatter mystery

Scientists in a lab with Daya Bay Nuclear Power Station in southern Guangdong Province have found neutrino through two detecting instruments, which is likely to provide clues to solving the mystery of why there is more matter than antimatter in the universe.

from *Interactions*

15 August 2011

The Daya Bay Reactor Neutrino Experiment Begins Taking Data

The experiment's first completed set of twin detectors is now recording interactions of antineutrinos (antipartners of neutrinos) as they travel away from the powerful reactors of the China Guangdong Nuclear Power Group in southern China.

ANNOUNCEMENTS

Correction

In the 28 July issue of *ILC NewsLine*, mention of important contributors to the CM1 project was omitted from the article “Power to the cryomodule”. Technicians, in addition to scientists and engineers, updated the hardware and installed parts for the cryomodule. The author regrets the error.

PREPRINTS

ARXIV PREPRINTS

[1108.3220](#)

Measurement of CP asymmetries in neutralino production at the ILC

[1108.2908](#)

Forward-Backward Asymmetries of Fourth Family Fermions Through the Z' Models at Linear Colliders

CALENDAR

UPCOMING EVENTS

[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

[JSPS specially promoted research: "A global R&D program of
a state-of-the-art detector system for ILC"](#)
Sendai, Japan
12- 14 September 2011

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

[CALICE Collaboration Meeting](#)
Heidelberg, Germany
14- 16 September 2011

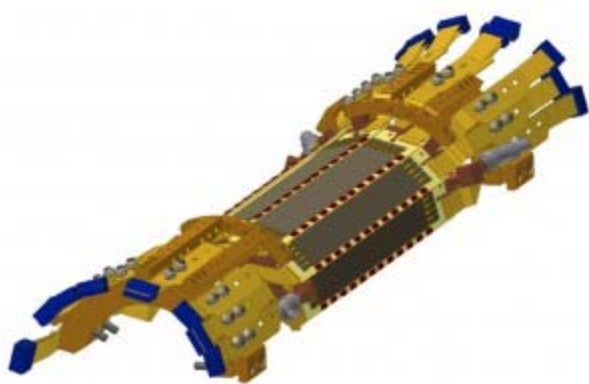
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RESEARCH DIRECTOR'S REPORT

The impact of ILC detector R&D

This month's Research Director's Report was written by Marcel Demarteau, chair and convener of the ILC Detector Common Task Group

Marcel Demarteau | 18 August 2011



Isometric view of one half of the vertex detector for the BELLE-II experiment, based on the DEPFET technology. Image: DESY



Beam telescope in the CERN and DESY test beam lines based on the MIMOSA-26 pixel sensors. Image: DESY

Although the actual construction date of the ILC accelerator and its detectors is very uncertain, the impact of the R&D for ILC detectors is very real. We are so immersed in our day-to-day activities, in the analysis of physics and test beam data, in our struggles to obtain funding, that we tend to overlook the deep impact the work initiated by and carried out within the ILC detector community has already had on the whole particle physics community and beyond. Let's take stock.

A key element to enable the ILC physics programme is the vertex detector. Primary and secondary vertex reconstruction of unprecedented accuracy is required to explore the heavy flavor and Higgs sectors. Extreme demands are put on the power consumption and mass budget of these detectors. Furthermore, detector occupancy and granularity, the readout speed and radiation hardness have to be commensurate with the experimental environment. R&D on multiple vertex detector technologies has been very active. The depleted field effect transistor (DEPFET) active pixel sensor has been studied extensively. This device is characterised by very low power consumption and the active area can be thinned to 50 micrometres (μm). Prototype detectors have been extensively beam-tested. Very good performance has been achieved to date. This development has not gone unnoticed by the BELLE-II collaboration at the KEK B-factory. Because of the extensive R&D carried out under the ILC umbrella, the BELLE-II detector had a mature technology available to be taken to the detector stage.

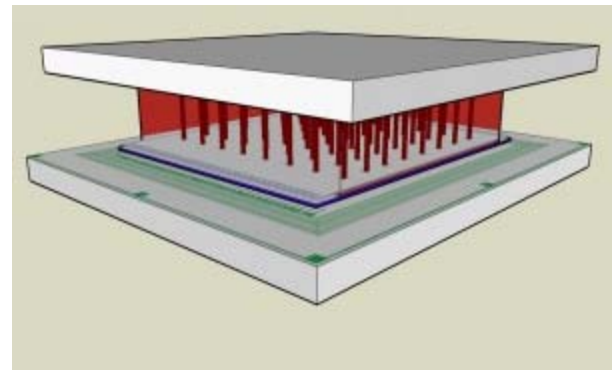
Another approach is the CMOS pixel sensor technology, which has the intrinsic advantages of the ability to implement very high granularity, very thin sensors and integrated processing circuitry in a commercial process. Driven by the ILC physics needs, more than 30 sensor prototypes have been produced in the MIMOSA series. A recent incarnation, the MIMOSA-26, is a matrix of 1152×576 pixels with a pitch of $18.4 \mu\text{m}$. Beam telescopes in the test beam lines at both DESY and CERN, available to the whole user

community, are currently equipped with this sensor. It is also the sensor of choice for the heavy flavor tracker of the STAR experiment at RHIC at Brookhaven in the US, expected to see data around 2013. An adapted version of this sensor also

provides the baseline architecture for the micro-vertex detector for the Compressed Baryonic Matter experiment at FAIR at GSI in Germany. Also here, the long and extensive ILC R&D programme has brought this technology to a maturity level that it can be readily applied in these experiments.

Another type of sensor, the vertically integrated silicon, or 3-D technology for short, consists of layers of extremely thin silicon stacked on top of each other with interconnections between the layers. Each layer can be as thin as $7\text{ }\mu\text{m}$ and could be optimised for its function. This relatively new technology was unambiguously motivated by the requirements for ILC vertex detectors and is currently a serious candidate technology for the upgrades of trackers for the LHC experiments. The silicon-on-insulator (SOI) technology, another vertex detector technology actively being developed by the ILC community, has already been applied as an X-ray imager.

One of the hallmarks of an ILC detector is a fine-grained calorimeter enabling jet energy reconstruction through the particle flow concept. These calorimeters provide an image of the evolution of the interaction of the particles in the calorimeter that was not imaginable a decade ago. It is in large part made possible through the advent of silicon photo-diodes operated in Geiger mode, or SiPM, the ability to embed modern readout electronics inside the detector and for the associated data acquisition systems to handle large channel counts. The field of medical imaging has already recognised the potential of these calorimeters for proton computed tomography (pCT). pCT is very much like a fixed target experiment: a proton beam is measured before it hits a target, in this case part of the human body, and its direction and energy is measured when it exits the target. The new pCT detector concepts use miniature ILC calorimeters with SiPM readout as range detectors for the protons. This allows for cheaper experimental setups with faster readout providing more accurate images.



*Conceptual view of a 3-D silicon assembly for a track trigger for an LHC upgrade showing a silicon sensor at the top and bottom interconnected through an interposer.
Image: Ron Lipton*

An important element of the ILC physics programme is to uniquely map the Higgs sector. The most accurate determination of the Higgs mass is achieved through the recoil mass determination, which requires excellent charged particle momentum resolution. The time projection chamber (TPC) is the technology of choice for the ILD (International Large Detector) detector concept, the R&D for which is being carried out by the LC-TPC horizontal detector R&D collaboration. Different technologies are being studied in great detail in a large parameter space by the LC-TPC collaboration. In 2009 three large micro-pattern gas detector TPCs were installed in the near detector of the Tokai-to-Kamioka (T2K) experiment in Japan. The group readily states that without the ILC TPC R&D programme, there would have been no T2K TPCs. The T2K collaboration recently announced the observation of electron neutrino appearance events using the neutrino beam from J-PARC to the Super Kamiokande detector. This indication that muon neutrinos oscillate to electron neutrinos could imply that the last unknown neutrino mixing angle is relatively large. This is a nice example of the intricately interwoven matrix of detector development. The unconventional and unexpected marriage of a magnet used in the discovery of the W and Z bosons, combined with the groundbreaking R&D on a tracking detector for the proposed ILC project, has led to shedding light on a key parameter of the neutrino mixing matrix. Remarkable indeed!



MicoMegas-based time projection chamber for the T2K experiment in Japan, based on ILC detector R&D. Image: T2K

Our record of forecasting science and technology research impacts is very poor. Sometimes, often in these economically challenging times, the impact of basic fundamental research is being questioned. The community, however, consistently demonstrates the widespread benefits resulting from inquiry-based research for the field of particle physics and beyond. Detector development for the ILC has penetrated already many areas of science as will be outlined in more detail in a forthcoming report. It is a testimony of the caliber of the work being carried out. The community can rightfully take pride in its already many accomplishments.

[3-D SILICON TECHNOLOGY](#) | [CALORIMETER](#) | [CMOS](#) | [DETECTOR R&D](#) | [DETECTORS](#) | [ILD](#) | [SENSOR](#) | [SOI TECHNOLOGY](#) | [TECHNOLOGY TRANSFER](#) | [TIME PROJECTION CHAMBER](#) | [TPC](#) | [VERTEX DETECTOR](#)

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AROUND THE WORLD

Detector scientists and the chamber of GEMs

Researchers at the University of Texas at Arlington spend two weeks characterising ILC detector chamber prototypes at Fermilab's Test Beam Facility.

Leah Hesla | 18 August 2011

Three researchers working on a detector for the ILC recently drove their components 1,500 kilometres from Arlington, Texas to Batavia, Illinois to get to know their detectors a bit better.

For approximately two weeks, researchers from the University of Texas at Arlington (UTA) sent muon, proton and pion beams through their chamber prototypes at the Fermilab Test Beam Facility, gathering data to see how they respond under different conditions. The chambers are made of gas electron multipliers, or GEMs. As part of the efforts of the CALICE collaboration, these detectors are being developed for the digital hadron calorimeter (DHCAL) to be used in future accelerators such as the ILC.



University of Texas at Arlington researchers Danrae Pray, Jaehoon Yu and Seongtae Park visited the Fermilab Test Beam Facility this month to characterise their GEM calorimeter chambers. Image: Jaehoon Yu



The UTA team's four GEM chambers set up in the Fermilab Test Beam Facility. Three of these chambers are read out through 1-bit DCAL chip and one is read out through 13-bit KPIX chip. Image: Jaehoon Yu

The GEMs and electronics work together to recreate pictures of particle showers as they shoot through the calorimeter.

The UTA team chamber prototype is about the size of a slim stack of vinyl record albums – 30 centimetres each in length and width, a few millimetres thick. In their test setup, four chambers are stood on end, one close behind the other, facing the beam.

At one point during their tests at Fermilab, the UTA team got an unexpectedly large surge of protons.

"It didn't kill our detectors – they were able to function as if nothing happened," said University of Texas at Arlington's Jaehoon Yu, who is co-leading the effort to develop GEM technology for DHCAL. "We can pulse it with very high-intensity protons, at least, 'very high' in our sense. These operators would laugh if I said 20,000 protons qualified as high intensity."

GEMs use micrometres-thin copper-cladded plastic foils to amplify the electric signal when a charged particle such as a proton passes through the chamber. Two square GEMs foils, spaced 1 millimetre apart, are placed in the middle of the chamber. The rest of the chamber is filled with argon-carbon dioxide gas. When particles are sent through the chamber, they ionise the gas inside it. Thanks to the voltage that's applied across the chamber, the electrons from the gaseous molecules head for the back of the chamber through the GEM foils. The electrons pass through the first foil, ejecting more electrons from the gas molecules that occupy holes in the foil. Those new electrons head towards the second foil, releasing an even greater avalanche of electrons. The newly multiplied electron population – about 10,000 times greater than the electrons released initially from the gas – is large enough to be read as a signal by electronic sensors in

the very back of the chamber. That signal tells scientists when and where (and whether or not) a particle passed through.

The nice thing about GEM technology is the relatively small voltage applied across each foil – only a few hundred volts. That means it doesn't take a lot of time for the detector to get ready to take on the next wave of electrons.

"It can recover fast from an avalanche," Yu said. "That's why these detectors can be used close to the beamline, where there are a lot more interactions." With the detector's quick recovery time, the chamber can accept a relatively high-intensity beam of charged particles.

For the ILC project, GEM technology is a complementary technology to [resistive plate chambers](#), which use resistive glass plates rather than thin copper-clad foils to generate electron signals. It is a well-known technology, and as such was selected for initial exploratory technology for SiD (silicon detector) DHCAL. However, GEM technology is promising, and some LHC experiments are working on advancing it for their detector pieces.

While the gas electron multiplier amplifies the message that a particle has passed through, it works together with sensors to precisely describe the particle's path. The UTA group has been working with two different chips to capture this electric signal from the chamber. One is digital (1 bit); the other is analog (13 bits). These chips are affixed to the anode at the very back of the GEM detector.

The 13-bit analog chip, called KPiX, is being developed by Stanford Linear Accelerator Center National Laboratory in the US for the silicon-tungsten electromagnetic calorimeter for the ILC. KPiX was used in one of UTA's four chamber prototypes. The current version of the chip can read out 512 channels, of which 64, arranged in an eight-by-eight square, are used for GEM chamber. The signal from this chip provides charge distributions measured by the UTA prototype.

"This charge distribution is beautiful," said Yu. The high statistics data the team took with the KPiX chip agreed nicely with data from previous tests.

The digital sensor, used in the team's other three chamber prototypes, is the DCAL chip developed jointly by Argonne National Laboratory in the US and Fermilab. Each chamber's 256 active pads are read out by four of these chips (a total of 12 chips for the three chambers) for a finely grained readout of the particle's path through it.

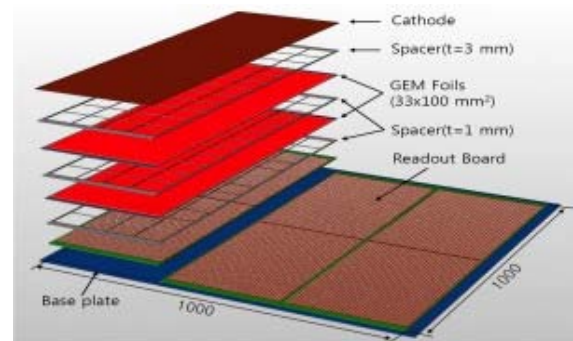
The UTA group put their chamber prototypes through a variety of conditions, varying the high voltage applied across each chamber; moving the chambers around relative to the beam to see whether their position makes a difference; determining, of the particles that actually pass through, how many are actually seen by the detectors. The multitude of tests filled their days.

"Since we want precision of about a percent or better, it requires a lot of events and therefore a lot of time," Yu said.

The team is also testing a small prototype chamber (2 centimetres by 2 centimetres) developed for medical imaging purposes in the back of the detector stack. The prototype for this GEM image amplifier, called GIA, is the result of the collaboration with the University of Texas Southwestern Medical Center.

Over the next year the team will construct larger chambers, 33 centimetres by 100 centimetres in dimension, and put three of them together to make up 1-metre-square detectors. Thanks to this and many other efforts around the world, the GEM technology could be fully developed not just for fundamental physics but for applications such as X-ray imaging for astronomy, defense and medicine.

Learn more about [DHCAL and GEMs](#).



Three of the 33-centimetre by 100-centimetre chambers, seen on the left hand side, will be put together to make up 100-cm by 100-cm square detector plane. Image: Jaehoon Yu



UTA's 2-centimetre by 2-centimetre GIA (GEM image amplifier) chamber prototype, developed for medical imaging purposes, sits at the very back of the detector stack (inside circle). Image: Jaehoon Yu

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DIRECTOR'S CORNER

GDE Executive Committee meeting at Caltech

Barry Barish | 18 August 2011



Mike Harrison, Americas Regional Director, led the discussions of ILC implementation planning. In the background is a bust of Richard Feynman, illustrious Caltech physicist. Image: GDE

The GDE Executive Committee held an important face-to-face meeting at Caltech in the US from 19 – 20 July 2011. Having established the new baseline for the ILC *Technical Design Report* (TDR) this past spring, the meeting concentrated on detailed planning for R&D, design and the actual scope and content of the report, which is planned to be completed at the end of 2012. Of particular note at this meeting were discussions of the first drafts of the TDR section on implementation planning. The meeting's discussions ranged from planning for technical baseline reviews of final subsystem accelerator designs to worldwide industrialisation of the superconducting radiofrequency components.

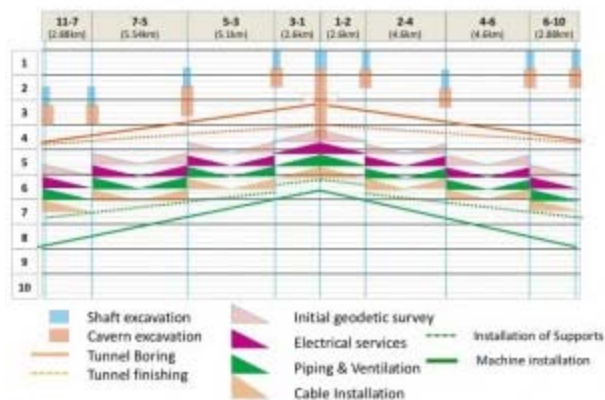
The GDE Executive Committee (EC) is a group of the senior leadership of the GDE that meets weekly by teleconference to review and plan all aspects of our activities, to make top-level decisions, to organise meetings, and is generally the engine that runs the GDE. I chair the EC meetings in which I ask for reports, promote discussion and ask advice on the wide range of activities of the GDE. The EC has been invaluable to me and very effective, even though it primarily meets via cyberspace. However, even with the advances in conducting web-based long-distance meetings, we still find it necessary to have regular face-to-face meetings. We meet together during major ILC workshops two or three times per year, and in addition we

schedule dedicated face-to-face meetings between these workshops.

The meeting in Pasadena came at a particularly crucial time, because after two years of intense concentration, we have established the baseline for the ILC technical design, our major goal as a GDE deliverable. The new baseline involves a set of four major changes from the reference design produced in 2007, plus many smaller changes. Planning for pulling this all together into a coherent design and presenting it in a TDR was the principal theme of the Caltech EC meeting.

Much of the TDR will consist of an update of material presented in our earlier *Reference Design Report*, and there will be some important additions. In particular, especially within the EC, we have been discussing a wide range of issues related to how the ILC should be successfully implemented.

An Example ILC Construction Schedule



An example of a possible schedule from the draft version of the Project Implementation Plan that could apply to many sites

In many ways, the ILC represents new challenges in how to organise and manage a very large project, because of its inherent global nature. In the design stages, we have been able to carry out a successful R&D and design programme such that we have globally set priorities, organised the work and made decisions. How to maintain this global underpinning, once the ILC evolves into a construction project, presents new challenges. Hence, we have taken on areas of implementation planning in order that our understanding of these issues can be taken into account in the technical design we present, and so that we can help document the insights we have gained as to how the global ILC project should be implemented.

The Project Implementation Planning (PIP) section of the TDR was a major subject of discussion at the Caltech EC meeting. This part of the TDR will contain sections on governance (a subject we have been working on for some time and have already [documented](#)). Other subsections will discuss: funding models; project management; host responsibilities; siting issues; in-kind contribution models; industrialisation and mass production of superconducting radiofrequency linac components; project schedule; and future technical activities. Mike Harrison is leading the PIP efforts. Although there is little precedent for including such a section in a technical proposal, we believe this section will contain valuable information on many of the issues that will confront the ILC, once it becomes a real project. Once the draft version of this section becomes more mature, we will begin to circulate it for comments.



*Steiner Stapnes, Compact Linear Collider Study Leader, reported on both the CLIC plans and CERN perspectives to the EC at Caltech.
Image: GDE*

[EXECUTIVE COMMITTEE](#) | [PROJECT IMPLEMENTATION PLANNING](#) | [TDR](#) | [TECHNICAL DESIGN REPORT](#)

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