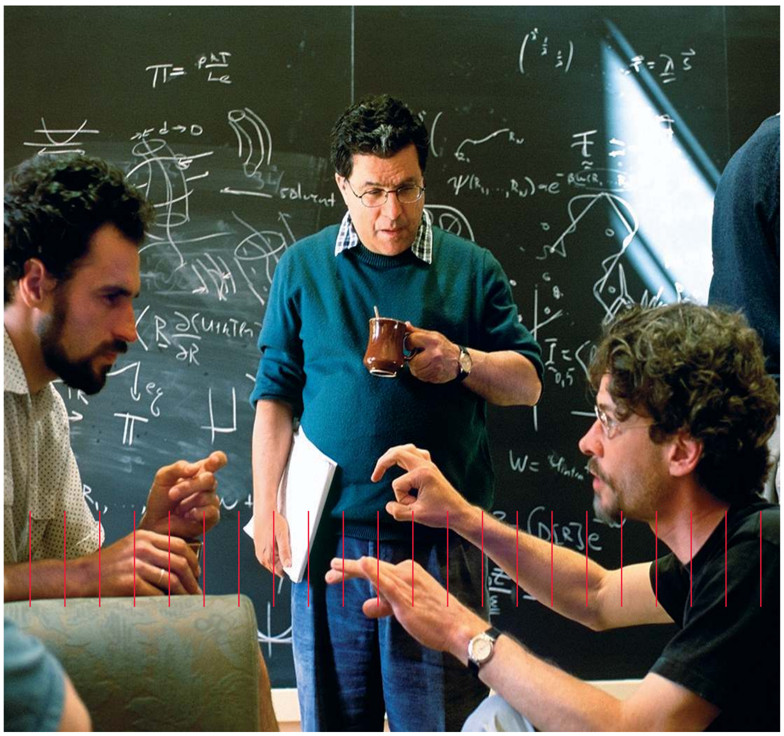
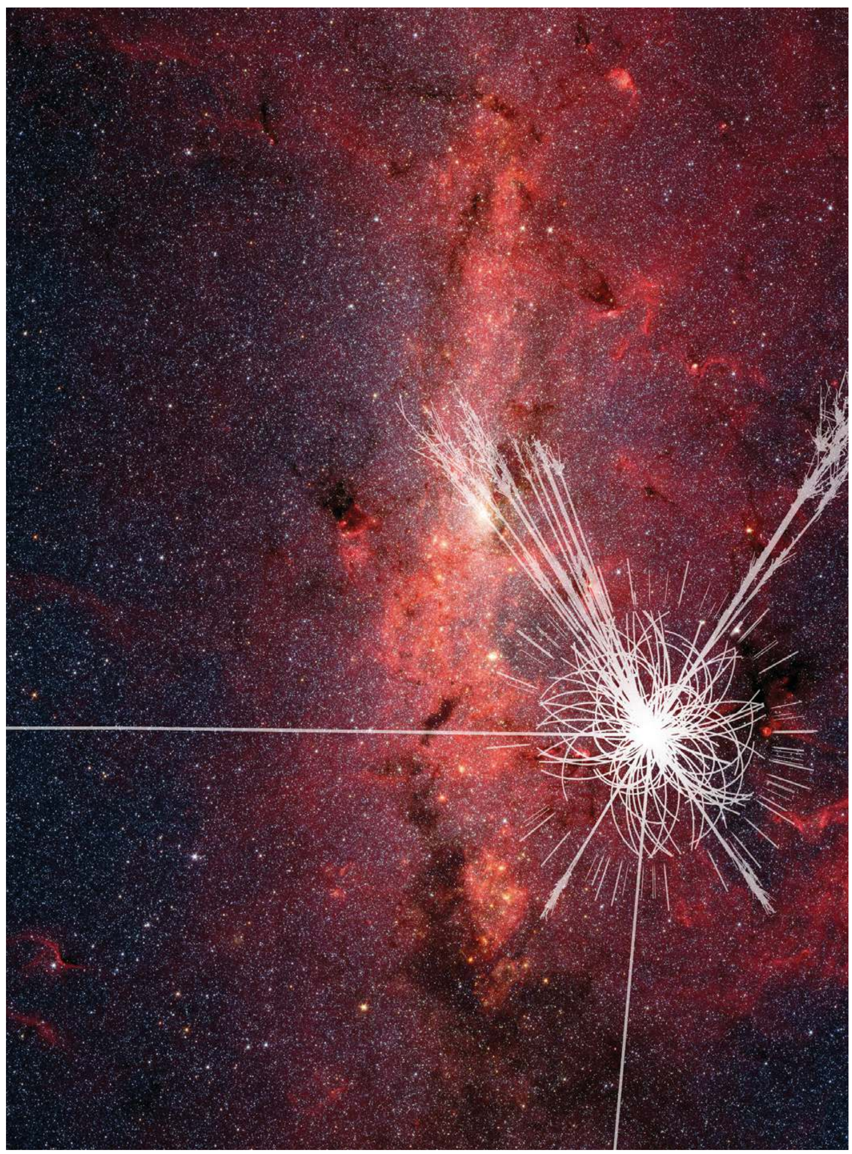
Keysight Technologies
Enhancing Measurements at the Extremes of Science

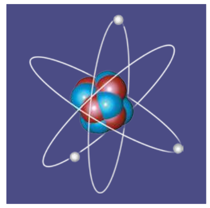


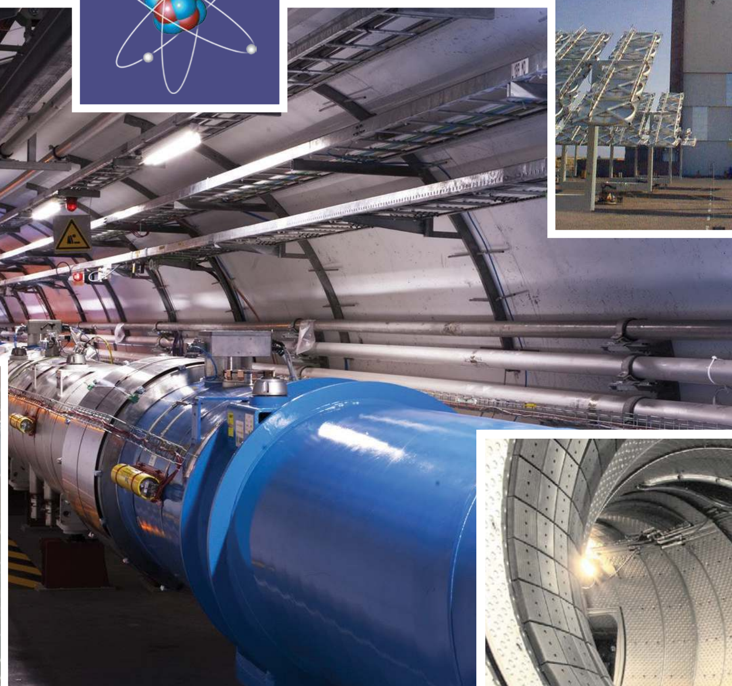
Enhancing Measurements at the Extremes of Science

At the extremes of science, research often goes beyond "scientific discovery" to become the discovery of new sciences. As you seek to expand the world's knowledge about phenomena at galactic or nanometer scales—or somewhere in between—confidence in results is strengthened by dependable measurement solutions that provide exceptional speed and data fidelity.

In laboratories around the world, Keysight Technologies instrumentation has become an integral part of advanced experimental systems. Our instruments are used in two major areas that require high-speed measurements: real-time applications and single-shot or event-based applications. We provide the extreme speed and precision needed for system monitoring and control, and for capturing data from the interactions and events in the experiments themselves.







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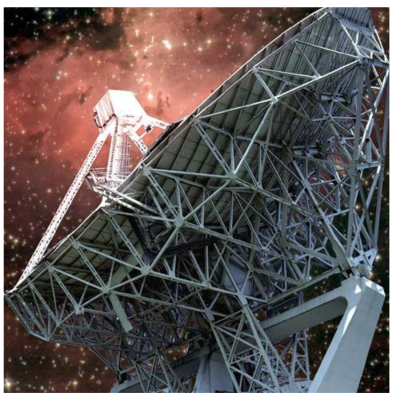


Addressing your most challenging research

Keysight's measurement solutions for advanced research can integrate directly into your experiment. Our range of instruments includes oscilloscopes, power supplies and high-speed data converters. Keysight digitizers offer distinct advantages when you need a large number of synchronized acquisition channels: high speed, low-power operation, high channel density and excellent accuracy.

The remainder of this brochure presents six cutting-edge applications in two categories: real-time applications and single-shot measurements. These range from monitoring and control of the world's most powerful synchrotron to measurements of rare gamma-ray events in the atmosphere. This is just a small sample of what's possible with Keysight instrumentation. We've worked closely with research teams around the world—and we're ready to help you create the right solution for your most challenging projects.

www.keysight.com/find/advanced-research

Setting the pace in real-time monitoring and control

Dynamic real-time measurements can enable and enhance a variety of experimental processes. Examples include setting system parameters, monitoring high-speed processes until ideal conditions are reached, and recording experimental data for seconds, minutes or hours.

In such situations, high-speed data acquisition requires maximum throughput. Keysight Acqiris digitizers implement innovative techniques that maximize data bandwidth and ensure rapid measurements. Today, these capabilities are providing superior throughput in applications such as the control and monitoring of particle and electron beams, and in real-time processing for microwave spectrometry.

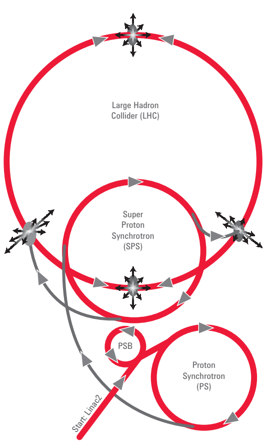
"Our beam-monitoring measurements are made possible by Keysight Acqiris digitizers: They provide the speed and bandwidth needed to capture and analyze our signals of interest."

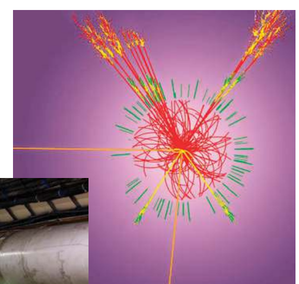
Stéphane Deghaye Engineer (Computing) Controls Group, Beam Department CERN – European Organization for Nuclear Research

Controlling particle beams

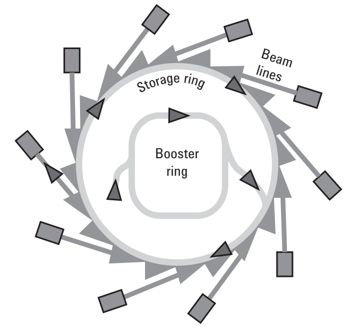
The Large Hadron Collider (LHC) at CERN is the world's most powerful particle accelerator, capable of producing 7 TeV. The CERN Control Centre (CCC) manages the LHC and the chain of accelerators that feed it. Along the injector chain, the Open Analogue Signal Information System (OASIS) can acquire and display more than 2,000 individual analog signals.

With proton bunches traveling near the speed of light, measurement speed is critical and digitizers must have very short dead time between measurements. This is one of the key reasons CERN is using Keysight Acqiris digitizers in all of its accelerators. More than 70 are currently installed, ranging from 500 MSa/s to 8 GSa/s with 8- or 10-bit resolution on one, two or four channels. They are being used to perform wideband beam monitoring and to monitor forward and reverse RF signals in the accelerator cavities.





Photos courtesy of CERN.



Generating high-intensity light

Synchrotron light sources accelerate electrons to produce photon beams that are more than one million times brighter than the sun. This intense light is used for imaging experiments in materials science, biology and medicine down to sub-nano-meter scales.

To create a high-quality beam, the Australian Synchrotron (AS) uses a technique called fill-pattern monitoring (FPM) to measure real-time intensity distribution of electron bunches in the storage ring. Its approach to FPM uses an ultra-fast optical diode and a high-performance digitizer to detect and measure optical synchrotron radiation.

Working with Keysight, the AS team developed a diode/digitizer detector that provides bunch-by-bunch resolution. This enables computer-controlled injection of additional electrons into the storage ring to compensate for losses, or to create custom fill patterns for specific experiments. The Keysight-based approach is now an integral part of the control system software at the Australian Synchrotron.

Performing real-time FFT spectrometry

In atmospheric research, substances such as ozone and carbon dioxide are quantified using microwave radiometry, which measures the weak radiation emitted by the rotational transitions of molecules. Those emissions produce spectral lines with shapes that are a function of pressure, enabling the creation of altitude profiles for substances under investigation.

The frequency resolution of the measurement apparatus determines the maximum altitude at which volume mixing ratio profiles can be obtained. Overall measurement bandwidth determines the lower altitude limit.

Real-time fast Fourier transform (FFT) spectrometry is an alternative to the acousto-optical spectrometers (AOS) commonly carried aloft in observation aircraft. In comparative testing, a real-time system config-ured with Keysight Acqiris digitizers provided comparable results and offered operational advantages: larger vertical range and better vertical resolution; equal or better dynamic range; and greater stability versus temperature and vibration.

Get the details

For more information about Keysight solutions in real-time monitoring and control, please visit **www.keysight.com/find/advanced-research**

Enhancing real-time monitoring and control

U1065A cPCI high-speed digitizer
Provides 10-bit resolution on one to four channels at 2-8 GSa/s; up to 400 MB/s via PCI interface; 1 GSa acquisition memory; and simultaneous acquisition and readout for applications with high trigger rates.

U1080A ePCI high-speed digitizer with onboard FPGA
Offers 8-bit resolution on two channels at 2-4 GSa/s; onboard FPGA for signal processing; and optional firmware for real-time 32 Kpt free-running FFT at full ADC speed.

U1084A PCIe high-speed digitizer with onboard FPGA
Offers 8-bit resolution on two channels at 2-4 GSa/s; onboard FPGA for signal procession; up to 500 MB/s with 4x PCIe interface; and firmware options for onboard data reduction.

Capturing the details from single-shot events

In one-shot experiments, the ability to capture an entire event makes it possible to perform detailed post-processing and analysis from multiple perspectives. This is crucial when identifying rare events, capturing explosive events, and optimizing atomic-level processes.

For these applications, data acquisition requires high speed, excellent measurement fidelity and deep memory. Keysight has implemented a variety of innovative techniques that ensure complete and detailed data capture: trigger delay, data streaming and multi-channel synchronization.

"Keysight digitizers allowed the n_TOF research team to carry out our neutron-capture experiments exactly as envisaged. With long internal memory, high clock accuracies and useful data-reduction procedures, the digitizers were exactly what we needed."

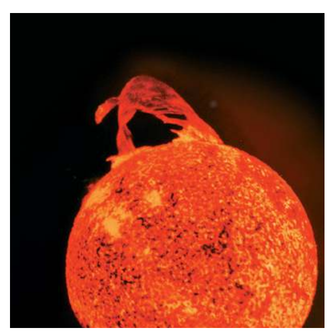
Paolo Cennini
n_TOF Technical Coordinator
CERN – European Organization for Nuclear Research

Extending radio astronomy

Astronomers use advanced techniques to identify events that visible observations may hint at, or miss entirely. One example is gamma rays, which are the latest frontier in radio astronomy. These rays are produced by processes such as super-massive black holes at the centers of active galaxies, or by pulsars left over from supernova explosions.

Although gamma rays are absorbed high in Earth's atmosphere, the absorption process creates bursts of Cherenkov radiation that last a few nanoseconds. Those bursts can be measured using ground-based detectors, but this is challenging because cosmic rays (abundant) and gamma rays (rare) both produce Cherenkov radiation. Keysight Acqiris digitizers make it possible to distinguish the two, increasing the probability of capturing true gamma ray events through capabilities such as trigger delay and nanosecond resolution.

Enhancing optical velocimetry



Many types of shock and non-shock experiments use optical velocimetry as a diagnostic tool. A technique called photon Doppler velocimetry (PDV) is a simple and relatively inexpensive way to measure surface velocities. One example system uses optical fiber, a continuous-wave (CW) fiber laser, a fiber optic circulator, an optical probe, a detector and a high-performance digitizer. Velocity information is embedded as a frequency within a time-domain signal and digital signal processing (DSP) methods can extract even very weak signals with high accuracy.

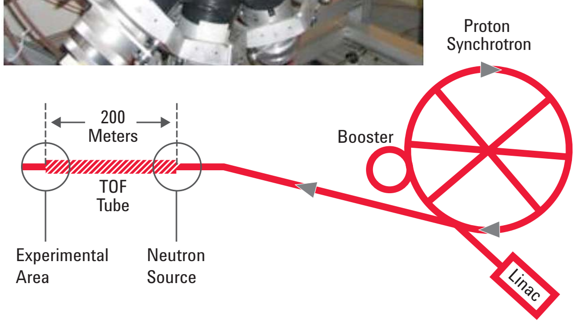
The upper limit of velocity measurements depends on the analog bandwidth of the digitizer: the wider the bandwidth the higher the apparent velocities. The absolute accuracy of PDV depends on the accuracy of the digitizer's time base and the wavelength of the laser. Keysight instruments are well-suited to these experiments: researchers are measuring surface velocities up to 2.325 km/s with Keysight Acqiris digitizers and up to 10 km/s with Keysight digitizing scopes.

Optimizing the transmutation of nuclear waste

Nuclear power generation produces radioactive waste material that must be managed. For decades, researchers have sought ways to reduce the volume of that waste and reduce its toxicity to the environment. Today, transmutation is an emerging technique that changes radioactive elements into shorter-lived or stable substances.

Transmutation occurs naturally during radioactive decay and it can be accelerated artificially using neutron interactions at precise energy levels that correspond to the radioactive material in question. To optimize the transmutation of nuclear waste on an industrial scale requires methods that “finger print” exact interaction energies. One such method is called neutron time-of-flight (n_TOF), which directs protons at a lead target. A flux of these neutrons then impacts a nearby sample of radioactive material and the interaction is observed.

Precise control and optimization of the n_TOF process depends on the resolution of the neutron energies that can be observed. At CERN, researchers are using an experimental arrangement that includes Keysight Acqiris digitizers. This system is enabling observations of neutron interactions with more detail and greater accuracy over a wider energy range.



Get the details

For more information about Keysight solutions in single-shot applications, please visit www.keysight.com/find/advanced-research

Enhancing measurements of single-shot events

U1050A cPCI time-to-digital converter
Records time of arrival on 12 channels with timing resolution of 5 ps or 50 ps.

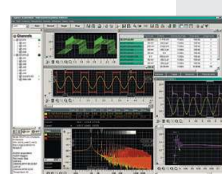
U1064A cPCI high-speed digitizer
Offers 8-bit resolution on one to four channels at 1-4 GSa/s and up to 32 MSa acquisition memory.

U1065A cPCI high-speed digitizer
Offers 10-bit resolution on one to four channels at 2-8 GSa/s and up to 1 GSa acquisition memory.

U1056B cPCI high-speed data converter systems
Combines digitizers, chassis, interfaces and accessories with AcqirisMAQS software to create a complete data acquisition system.

M9703A AXIe high-speed digitizer
Offers 12-bit resolution on four to eight channels at 1- 3.2 GSa/s and up to 4 GSa acquisition memory.

AXIe high-speed data acquisition system
Install five M9703A AXIe digitizers in the M9505A 5-slot AXIe chassis to form a 40-channel 12-bit 1.6 GS/s acquisition system.



AcqirisMAQS multi-channel acquisition software
Turnkey software designed specifically for control and monitoring of data acquisition systems.

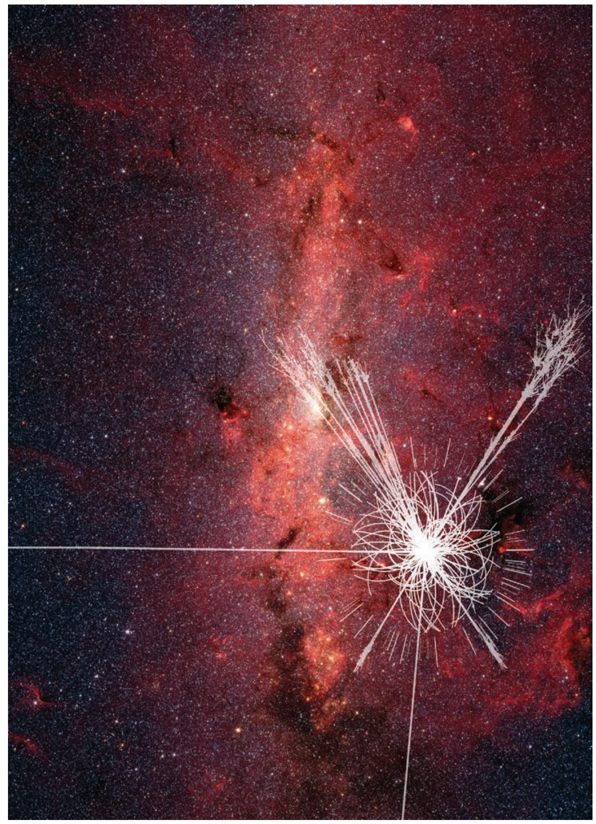
Enhancing measurements at the extremes of science

At the extremes of science, research often goes beyond "scientific discovery" to become the discovery of new sciences. Keysight is ready to help: In advanced research facilities around the world, our instrumentation has become an integral part of demanding experimental systems. Whether you're focusing on real-time applications or single-shot events, we offer the speed and precision needed for system monitoring and control, and for capturing data from the experiments themselves—even at the extremes of science.

To learn more, please visit us on the Web at www.keysight.com/find/advanced-research

"The radio astronomy receiver we designed for *Max-Plank-Institut für Radioastronomie* provides a practical demonstration of the dramatic technology advances that can be achieved through the application of Acqiris technology."

John Summers
Vice President of Sales and Business Development
RF Engines



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