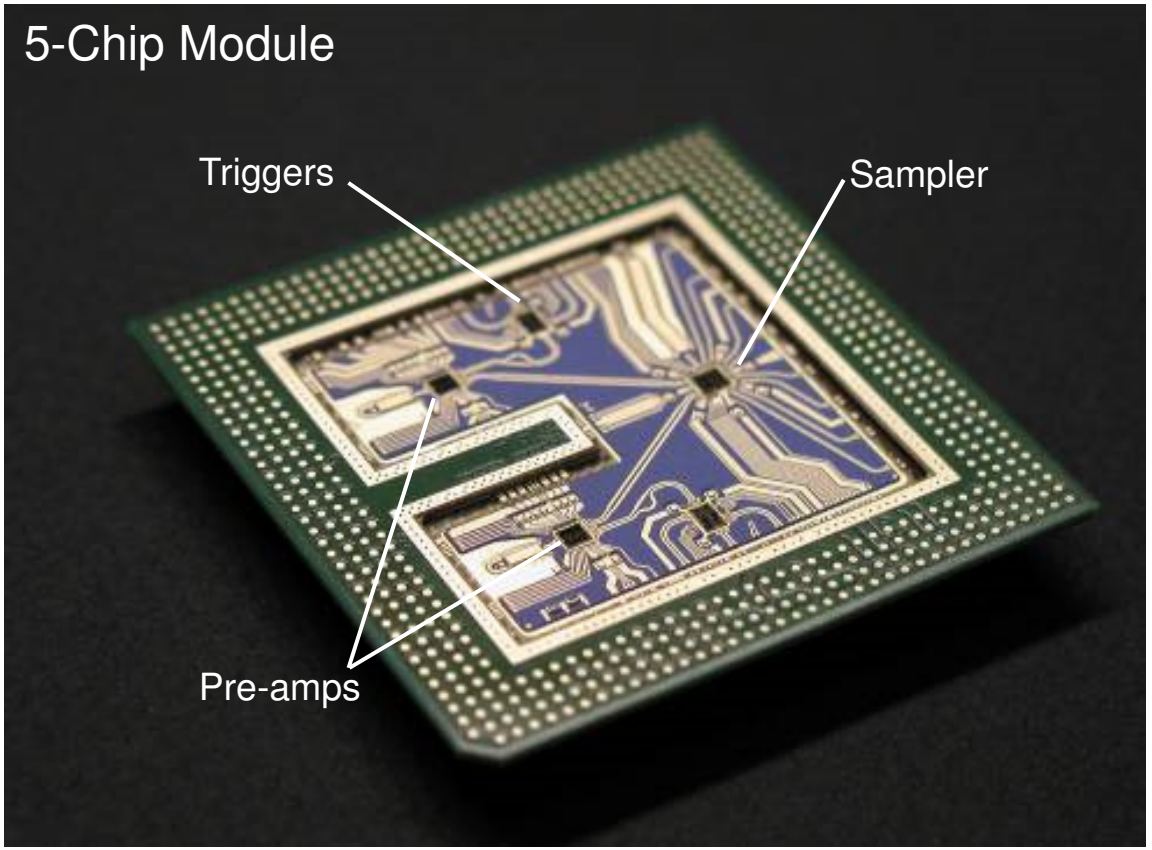
# Data Acquisition and Signal Processing for Advanced Physics Research through state of the art Oscilloscope and Digitizer Technologies

Sanchit Bhatia
Applications Expert
High Speed Digital

KEYSIGHT TECHNOLOGIES

# Advanced InP DHBT Chipsets in High Bandwidth Oscilloscopes

- Scope front end
  - Pre-amp
  - Triggers
  - Sampler
- High bandwidth probe amps

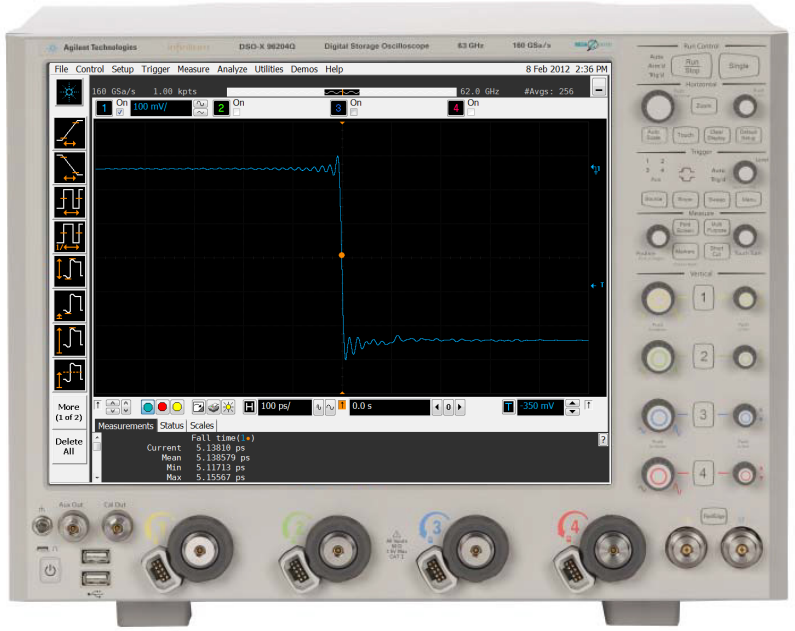



KEYSIGHT TECHNOLOGIES

# High Bandwidth Measurements upto 63 GHz Bandwidth and 5 ps pulse transition time

– *Benefit: Capture extremely fast signals*

- ✓ Capture rise times as fast as 5 ps and data rates as fast as 120 Gbit/s
- ✓ Ensures you do not miss valuable harmonic content




KEYSIGHT TECHNOLOGIES

# Multichannel High Bandwidth Measurements

- High Channel Density
  - *Benefit: Acquire time-synchronized data on more than four channels simultaneously*

- ✓ Keysight 90000Q Series oscilloscopes tied together for multichannel measurement upto 40 channels
- ✓ SubPicosecond Inter-scope skew

KEYSIGHT TECHNOLOGIES

# 8 channel Oscilloscopes – upto 13 GHz

- *Benefit: Minimize rack space by having eight channels housed within one oscilloscope frame*

✓ Houses eight 40 GSa/s ADCs and two CPUs in a 7U high package

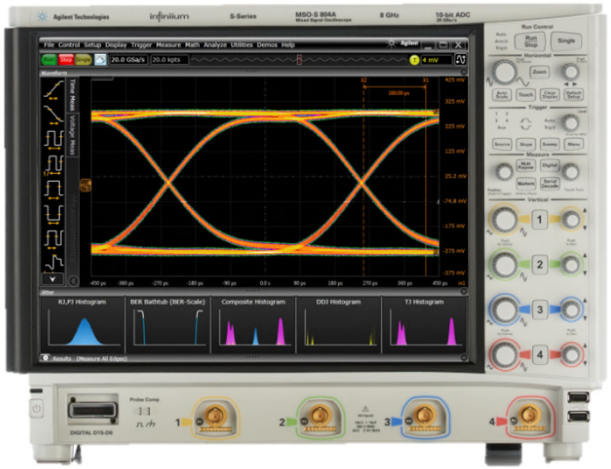
✓ Available in 8, 12, or 13 GHz models

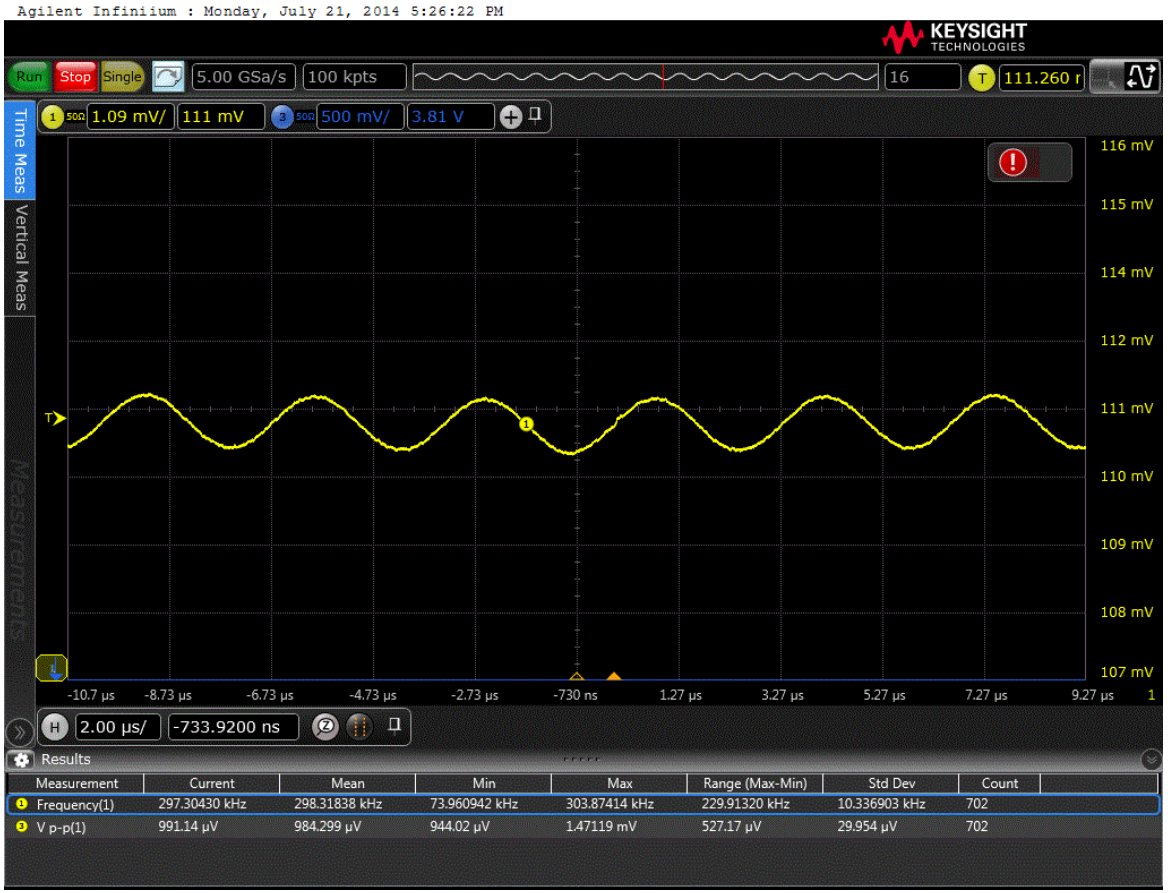
KEYSIGHT TECHNOLOGIES

# High Resolution High Bandwidth Measurements

## 1mVpp Sine Wave

20GS/s, 8 GHz
10-bit ADC



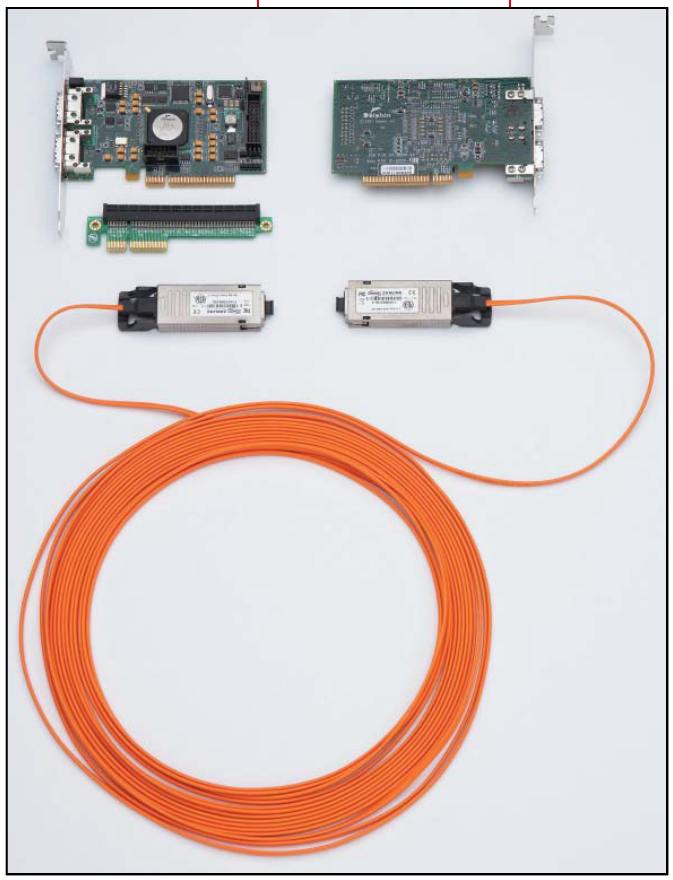



KEYSIGHT TECHNOLOGIES

# Fast Data Offload

*PCIe High Speed Interconnect and USB3*

- ✓ Fast transfer rate
- ✓ Fiber optic cabling up to 10 meters
- ✓ Setup: 20 GSa/s, 1 kpts of memory, 4 channels simultaneously coming from a photodiode of an optical reciever. SSD installed and new data offload optimization program used.
- ✓ Results: Achieved average of 1000 acquisitions in 4-5 seconds with peak at 450-500 Hz



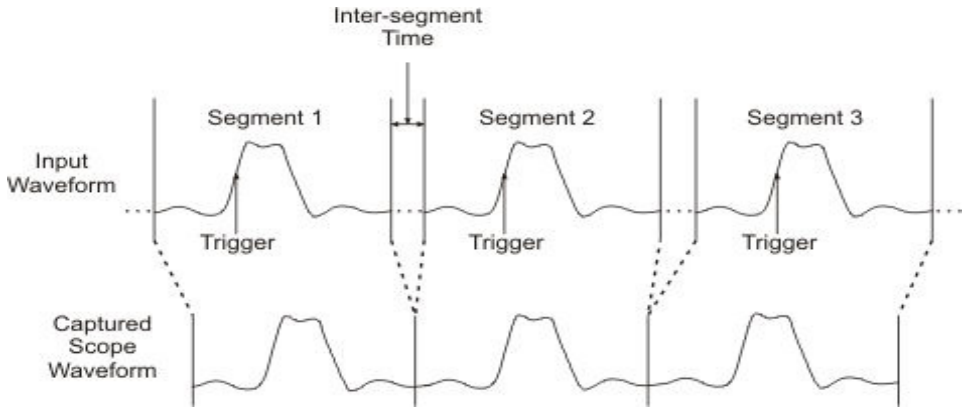
KEYSIGHT TECHNOLOGIES

# Pulsed Measurements in Advanced Physics

- Segmented Memory
  - *Benefit: Useful acquisition mode for bursts/pulses that have events of interest separated by long periods of dead time.*

✓ Scope's memory is divided into segments. When trigger event occurs, the scope captures the data for the first segment and stops once the first segment's memory is filled. Then the scope waits for the next trigger event and repeats for subsequent segments.

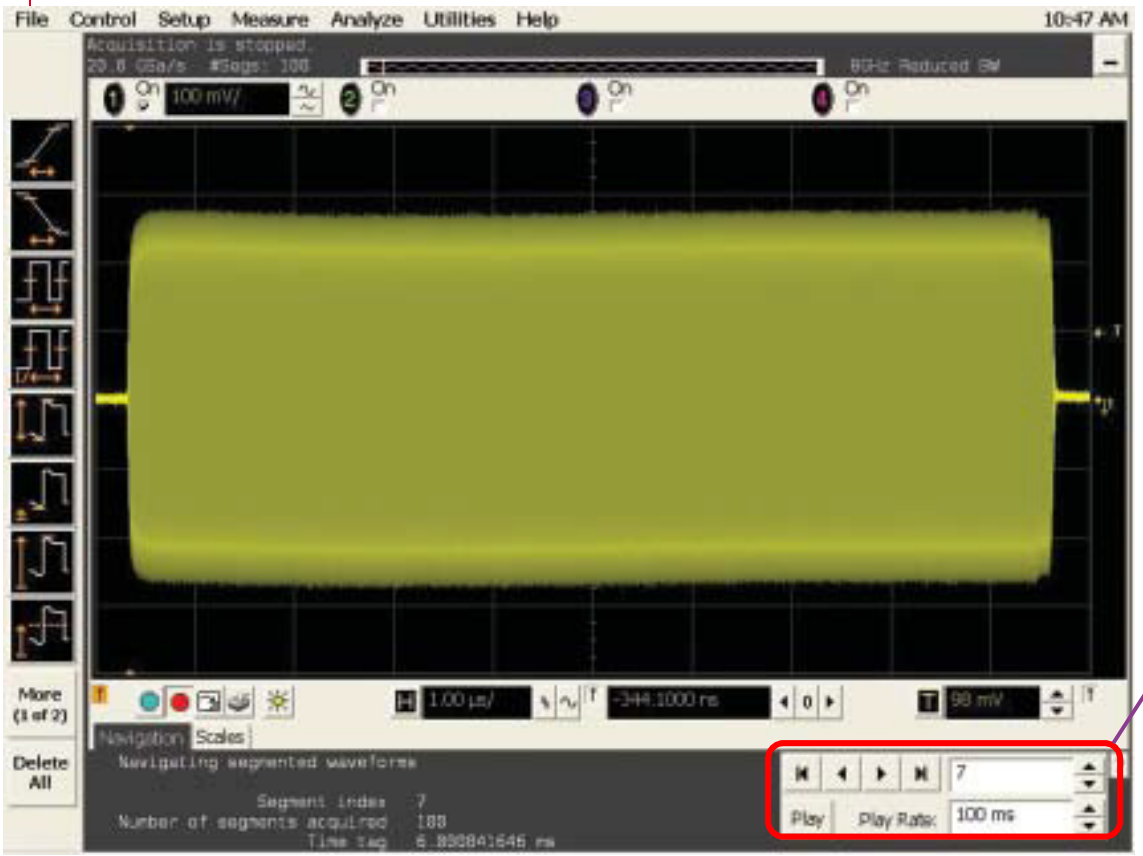
✓ Capture only the portion of the waveform that is of interest. Sample at a very high sample rate.




KEYSIGHT TECHNOLOGIES

# Pulsed Measurements in Advanced Physics

- Segmented Memory (continued...)




Navigation controls to step through each segment after acquisition

KEYSIGHT TECHNOLOGIES

# Measurement System Calibration

## Oscilloscope with Pulse Generator to Calibrate and Align Measurement

- ✓ Extend oscilloscope calibration out to the end of cables and fixtures to measure your critical signals at their source
- ✓ Remove loss and phase distortions in your measurement system
- ✓ Perform high bandwidth single ended or differential step response measurements
- ✓ De-skew multiple signal paths for accurately time-aligned measurements


KEYSIGHT TECHNOLOGIES

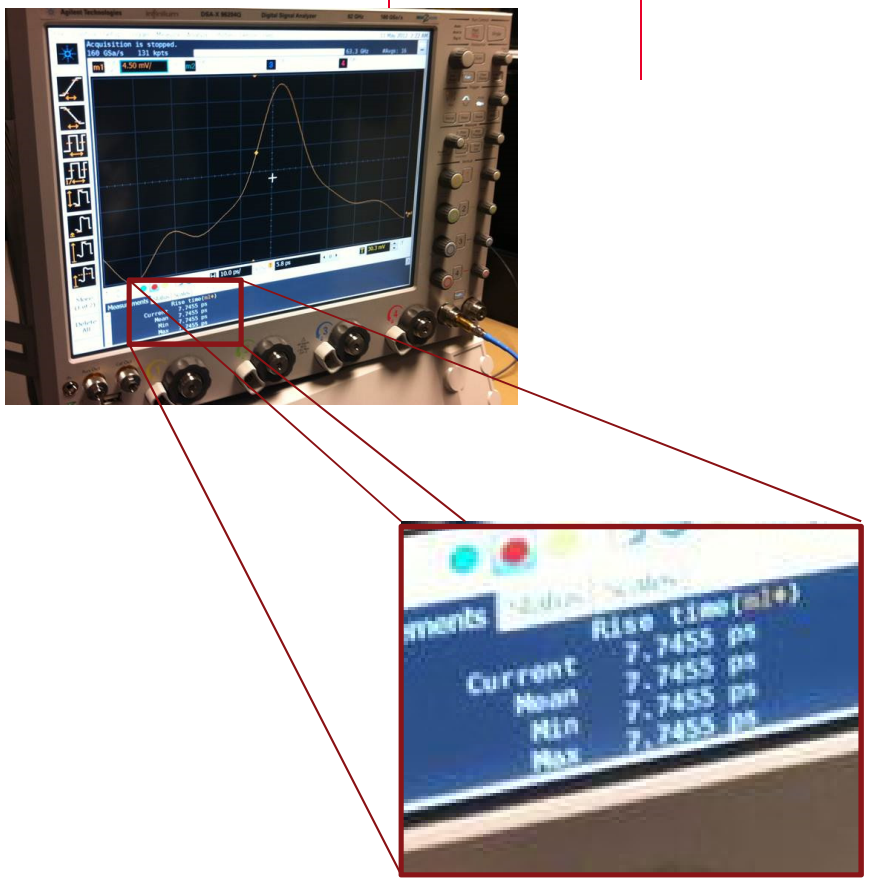
# Case Studies

KEYSIGHT TECHNOLOGIES

# Karlsruhe Institute of Technology (Germany)

## Capturing Pulses Inside an Accelerator Ring

- ✓ Wanted to capture pulses inside their accelerator ring in order to improve detectors
- ✓ Had been searching for a solution for a while. Finally, with the 63 GHz Q-Series, they were able to accomplish their goal – capture the ~7.7 ps edge.
- ✓ Peer-Reviewed Article on Results: “Real-time Measurement of Picosecond THz Pulses by an Ultra-Fast $YBa_2Cu_3O_7$-d Detection System” P. Thoma, A. Scheuring, M Hofherr, W. Wunsch, K. Il’in; *Appl. Phys. Lett.* **101**, 142601 (2012).




KEYSIGHT TECHNOLOGIES

# Photon Doppler Velocimetry (PDV)

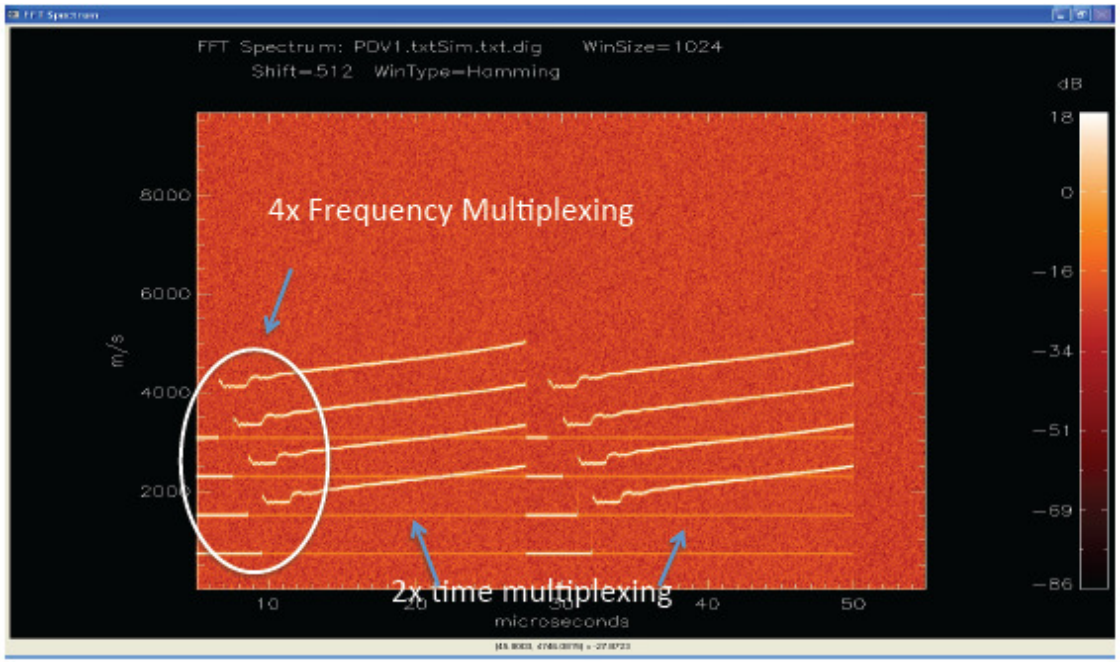
- **Precise high velocity measurements using doppler shifted light**

✓ Use array of lasers and detectors to digitize doppler shifted light → 3D time evolution of event velocities

✓ Need oscilloscopes with enough bandwidth to measure velocities >20 km/s (~1.3GHz required per km/s)

✓ Requires deep memory, low noise, and high ENOB to enable time and frequency division multiplexing

✓ Many publications, such as: “Photonic doppler velocimetry in shock physics experiments,” P. Mercier, J. Benier, A. Azzolina, J.M. Lagrange and D. Partouche, J. Phys. IV France, vol. 134, 805-812, August 2006




KEYSIGHT TECHNOLOGIES

# Hot Plasma Temperature Measurements

## Improve measurement of spatial distribution of temperature by characterizing Thompson scattering

- ✓ A powerful diagnostic method to measure the temperature of hot plasma in applications such as Tokamak reactors is to scatter electromagnetic radiation from the plasma.

- ✓ This method is attractive because it does not disturb the process in the reactor and can also determine detailed information about the distribution function of electrons and ions in the plasma.

- ✓ Value Proposition – What do these researchers care about and how can Agilent oscilloscopes help?
  - High signal integrity / high fidelity measurements
  - High channel density
  - > 4 synchronized channels
  - Fast data transfer

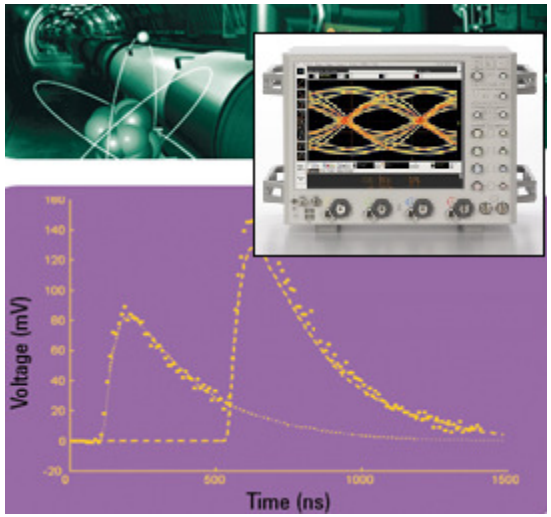
KEYSIGHT TECHNOLOGIES

# Nuclear Plasma / Particle Physics Experiments

## Example Application

- ✓ Applications in this area include:
  - Particle detection and analysis
  - Pulse height analysis
  - Half-life measurements
  - Spectroscopy and time interval analysis

- ✓ Value Proposition – What do these researchers care about and how can Agilent digitizers help?
  - Complex analysis capabilities
  - Accurate measurement results – signal integrity
  - Fast PC-based data acquisition and processing using programs such as C++, LabView, Matlab, …




KEYSIGHT TECHNOLOGIES

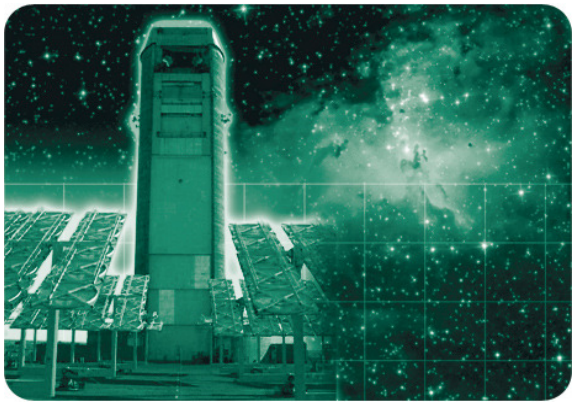
# Cherenkov Radiation

## Example Application

- ✓ The study of Cherenkov radiation (produced when gamma rays are absorbed high in the Earth's atmosphere) has allowed ground-based astronomers to open a new window in the electromagnetic observation spectrum.

- ✓ Cherenkov radiation is faint and brief (lasting only a few nanoseconds) and sensitive electronics are needed to detect it and to determine the direction from which the gamma rays originated.

- ✓ Value Proposition – What do these researchers care about and how can Agilent digitizers help?
  - Rapid data transfer to a PC for processing
  - Ability to synchronize a large number of channels
  - High channel density



KEYSIGHT TECHNOLOGIES

# AXIe High-Speed Digitizer

## Features, Benefits and Applications

| Target Applications | Particle Physics | µW/RF Astronomy | Tokamak (Fusion) | Inertial confinement (Fusion) | Hydrodynamics X-Ray imaging |
|---|---|---|---|---|---|


### Product Features

- 12-bit resolution
- Up to 3.2 GS/s
- 8 channels in a single-slot AXIe module
- PCIe x4 Gen2 back-plane connectivity

### Your Benefits

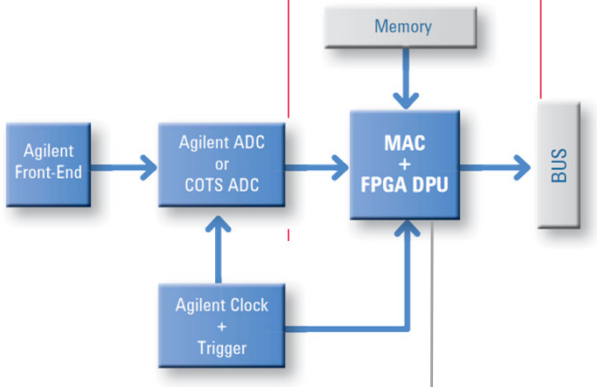
- High dynamic range for the best measurement fidelity
- Measure the fastest signals
- Highest channel density to easily build high number of synchronous acquisition channels
- Highest measurement throughput

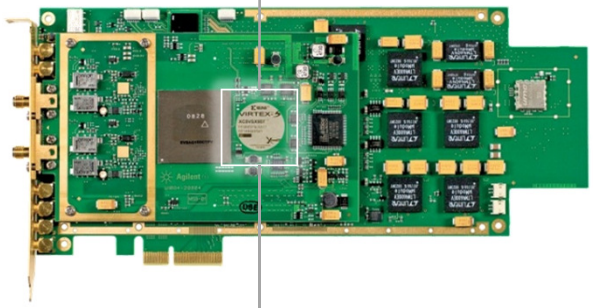
KEYSIGHT TECHNOLOGIES

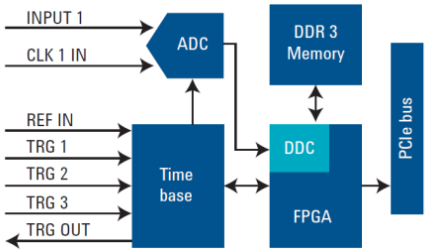
# Firmware Available

- The MAC + FPGA DPU provides capacity for real-time processing such as:

- Real-time sampling and averaging (AVG)
- Simultaneous acquisition and readout (DGS)
- Real-time signal peak detection and analysis (TDC)
- Basic high-speed digitization with long acquisition memory (DGT)
- Simultaneous multibuffer acquisition and readout (SAR)
- Sustained sequence recoding (SSR)
- Firmware development kit (FDK)
- Fast Fourier transform (FFT)
- Digital down-conversion (DDC)
- Frequency counter firmware (FC1)






KEYSIGHT TECHNOLOGIES

# Oscilloscope and Digitizer Applications

Infiniium Oscilloscopes
High Bandwidth

63 GHz 8 Bit

10 bit 8 GHz

Additional front-end flexibility

Built-in Apps
Probing

BW

Digitizers

Lower Bandwidth

Higher Resolution

Optimized for viewing
and analysis on the instrument

Optimized for
fast offload speeds

KEYSIGHT TECHNOLOGIES

# THANK YOU

sanchit_bhatia@keysight.com
info@asepl.in

KEYSIGHT TECHNOLOGIES