Sub-Sample Time-Base Resolution in a Heterogeneous Distributed Data Acquisition Environment

What time is it Anyway ?

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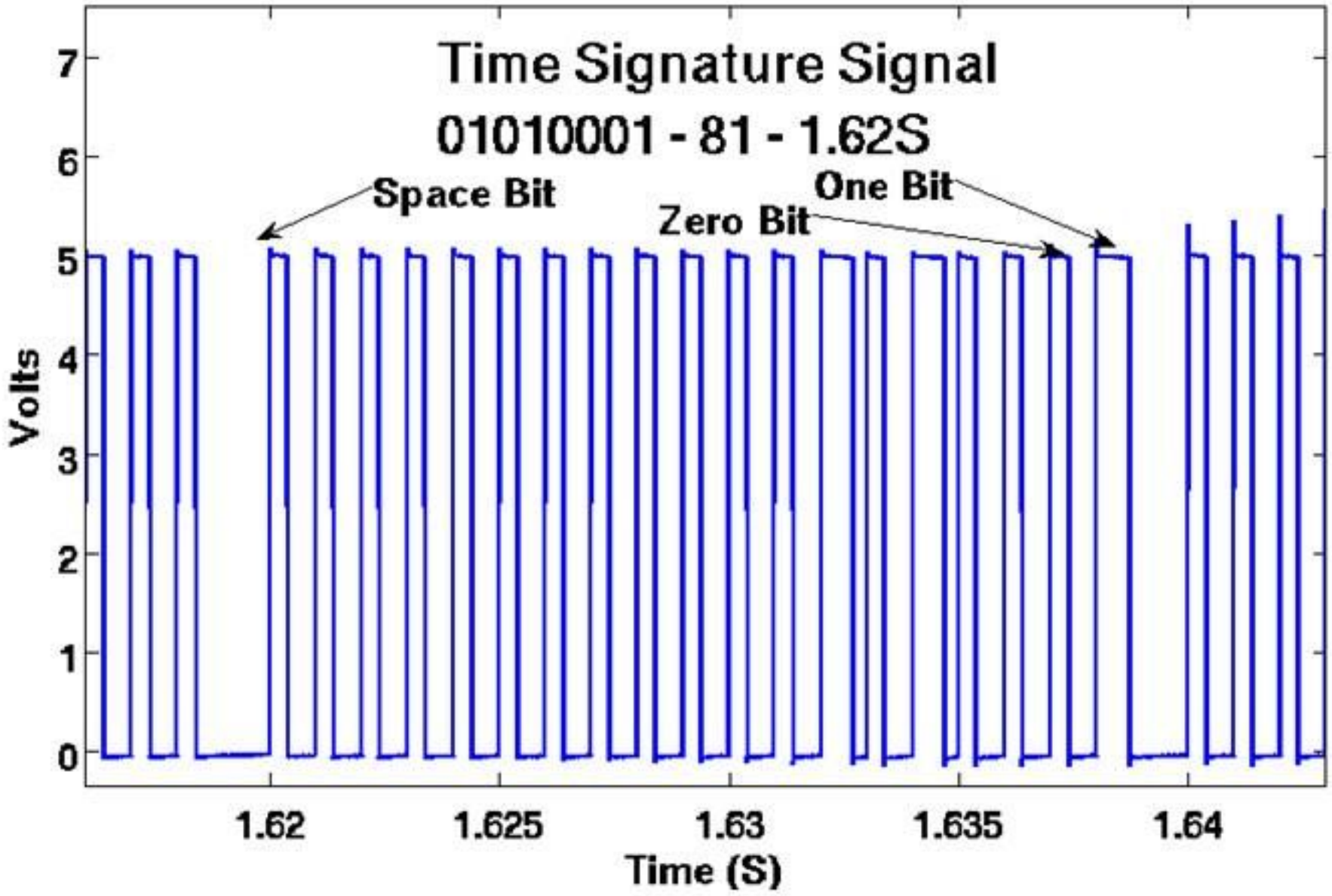
Alcator C-Mod Tokamak

- Alcator C-Mod is a high magnetic field tokamak.
- Located at MIT Plasma Science and Fusion Center in Cambridge MA, USA.
- Producing high-density, high-temperature plasmas under conditions approaching that needed for thermonuclear fusion.
- Diagnostic systems time scales range up to several minutes and resolving transient events to the sub-microsecond level.
- Plasmas last for approximately 2 seconds and are run in a 20 minute cycle.

Motivation

- 100 Hz – 100 MHz timescales
- Heterogeneous data acquisition Hardware
- Distributed data acquisition Hardware
- Centralized Timing system
  - 1 MHz
  - Optically Distributed
- **But…**
  - Hardware not always well characterized
  - Hardware not always working properly
  - Software not always configured correctly

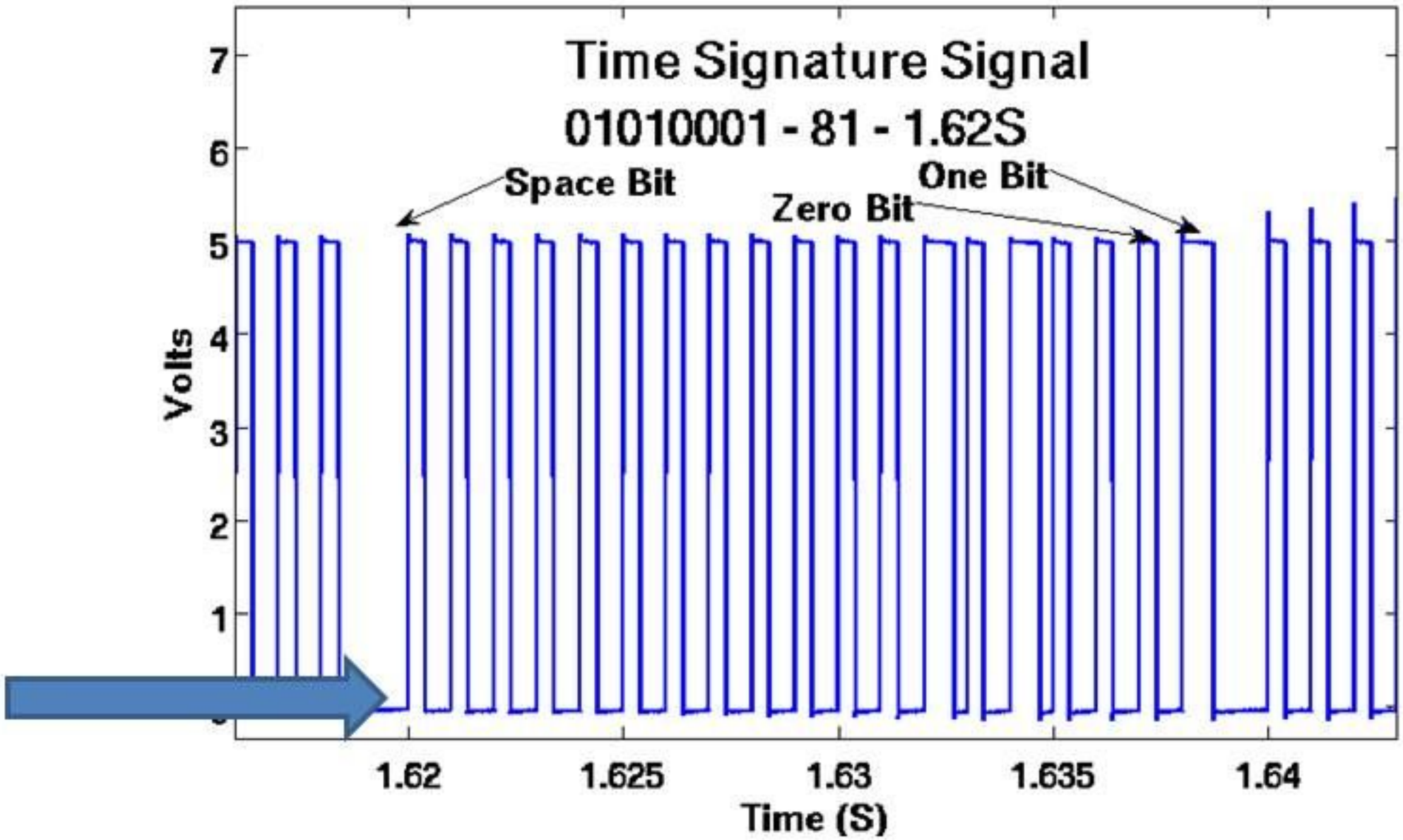
Timing Signature Signal



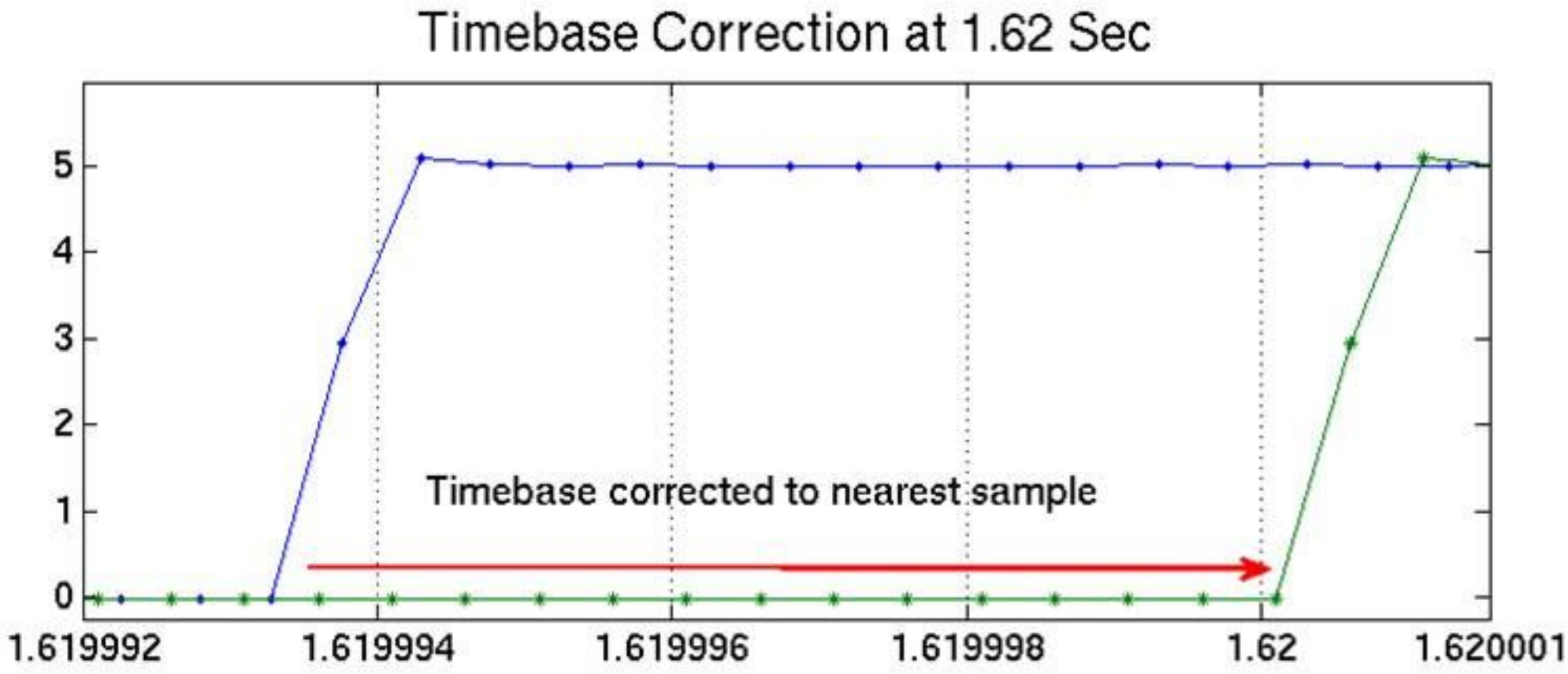
Solution

- Timing Signature Signal
  - Optically Distributed
  - Uniquely recognizable
  - Gate signal in and out when free channels not available
  - 1 KHz bitrate
  - 19 bit signal → 2.9 Hours
- Digitize this signal with each diagnostic that requires precise time allignment

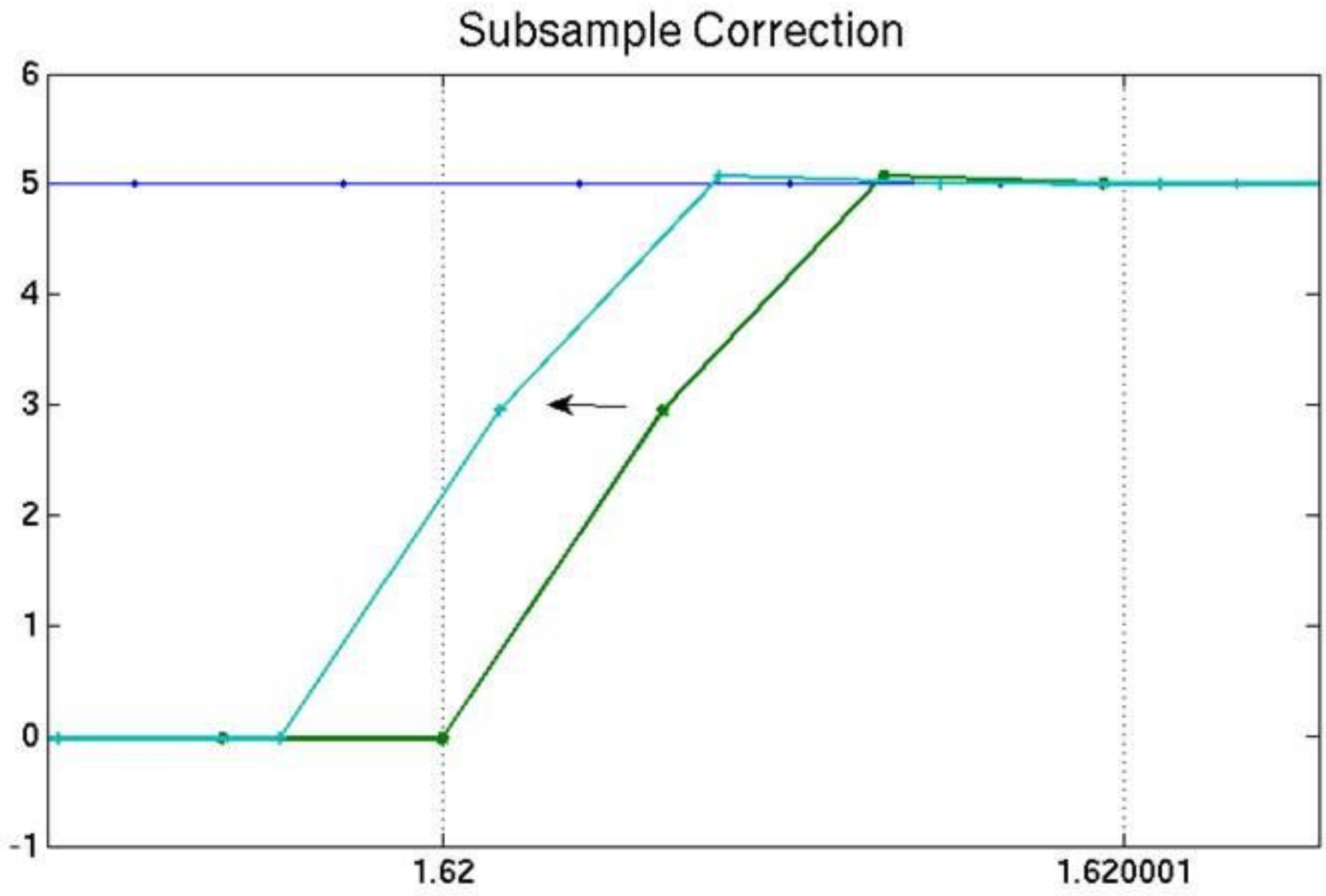
Timing Signature Signal



Timebase Correction (nearest Sample)



Adjust for Known Rise-Time of Waveform



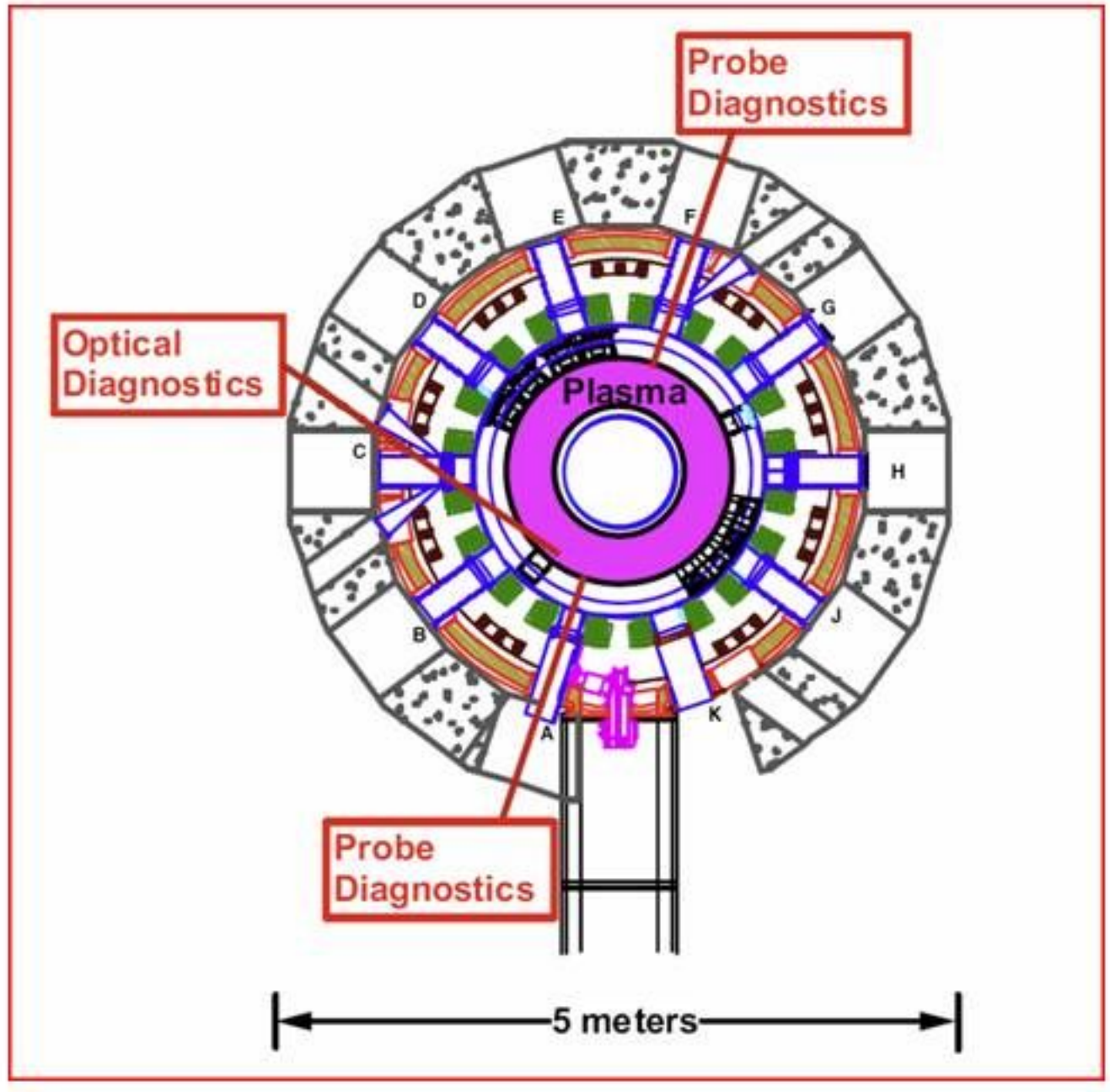
Initial Deployment

- An optical fluctuation diagnostic that images local plasma emission in two dimensions and measures changes in light emission at frequencies up to 1 MHz. The diagnostic is used to study the turbulence as the edge of the plasma with spatial structure from ~0.3-6 cm and at frequencies </~ 1 MHz.

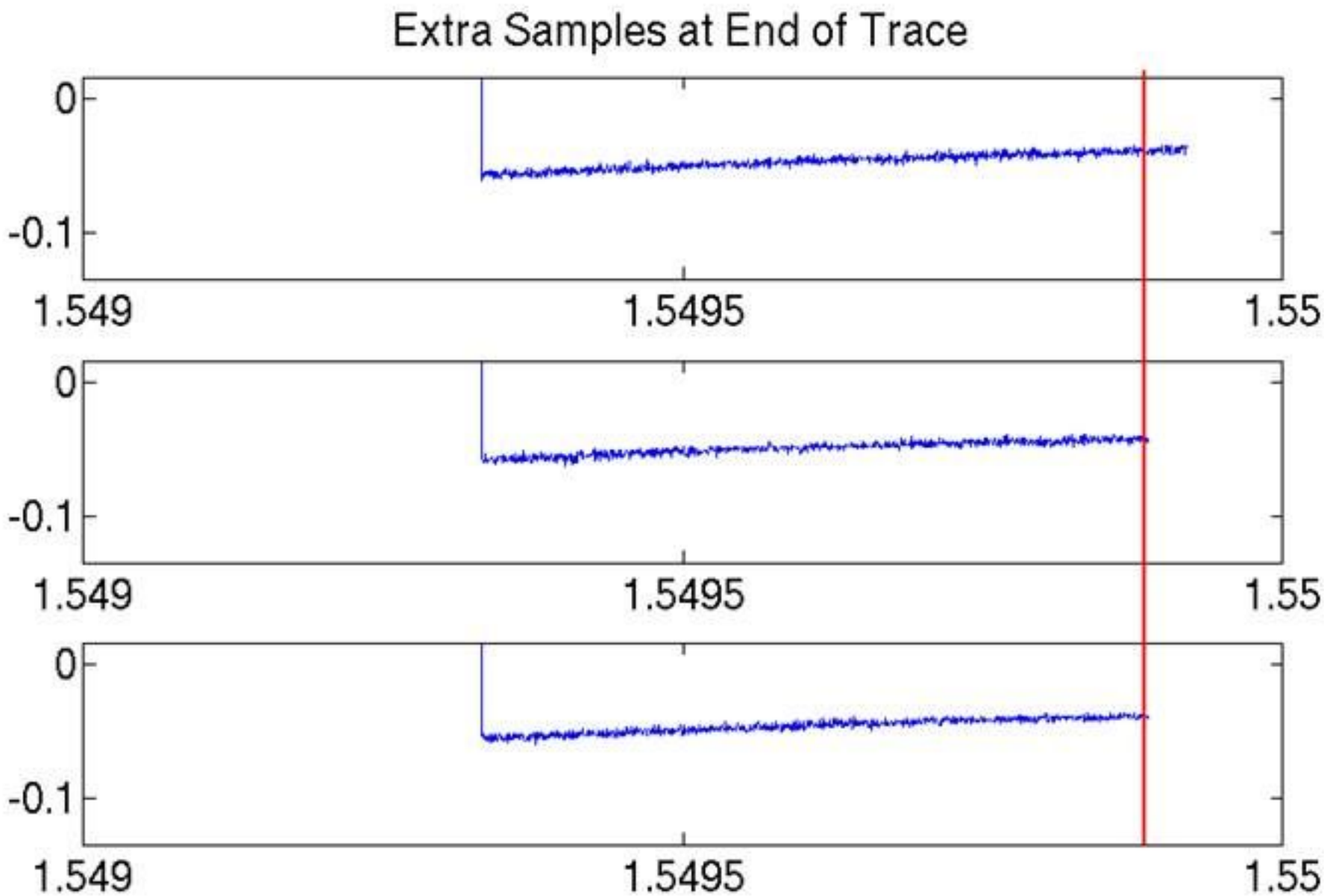
- An array of plasma-sensing probe diagnostics, including fixed and spatially-scanning Langmuir probes, wall surface temperature thermocouples and calorimeter probes. Sampling frequencies of 0.1, 0.5 and 5 MHz are simultaneously employed. This cluster of diagnostics is located in a bay that is +90° around the torus from the optical diagnostics.

- A second array of plasma-sensing probe diagnostics, similar to above, but located -90° from the optical diagnostics.

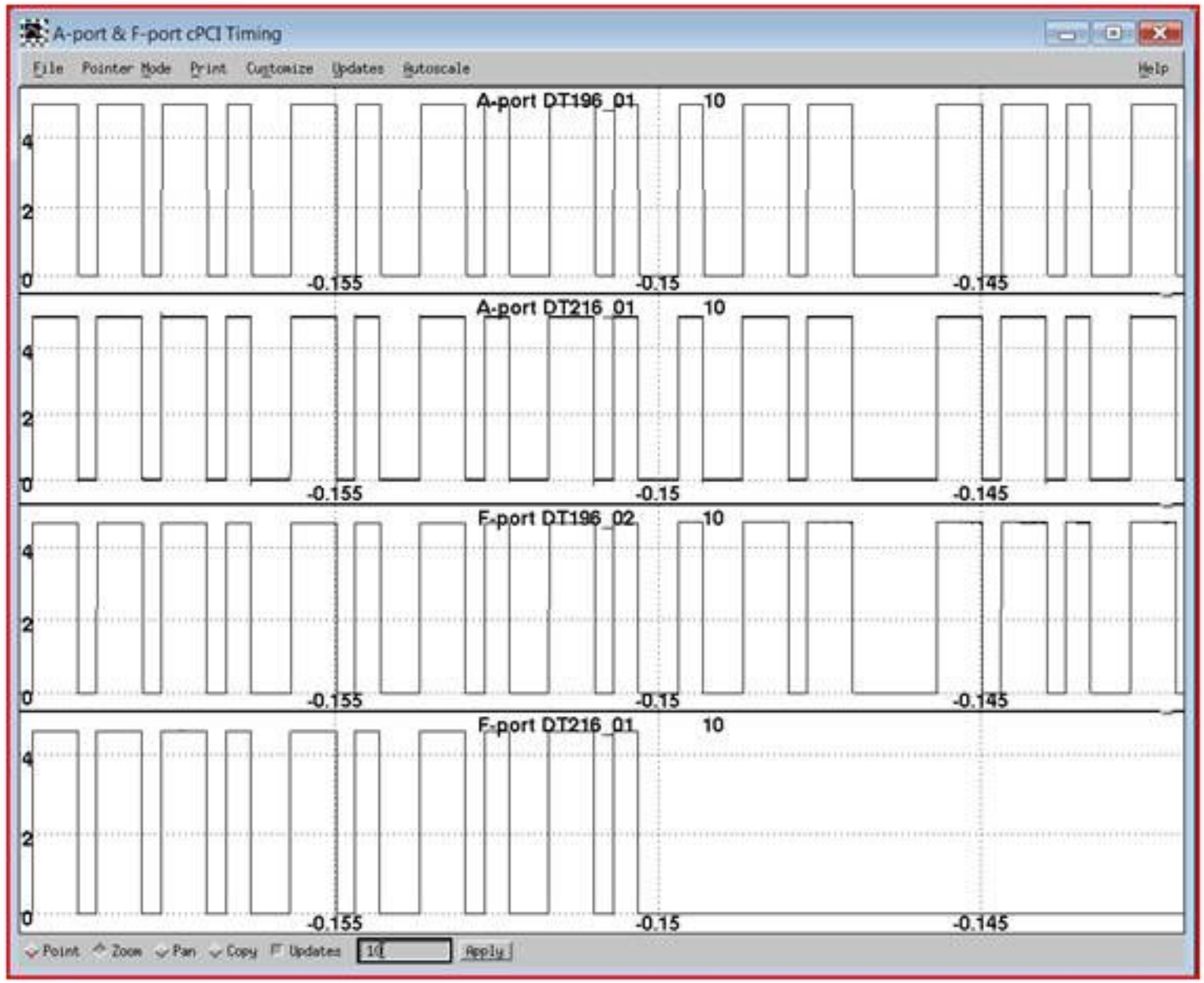
Plan View of C-mod Experiment



Identify extra samples

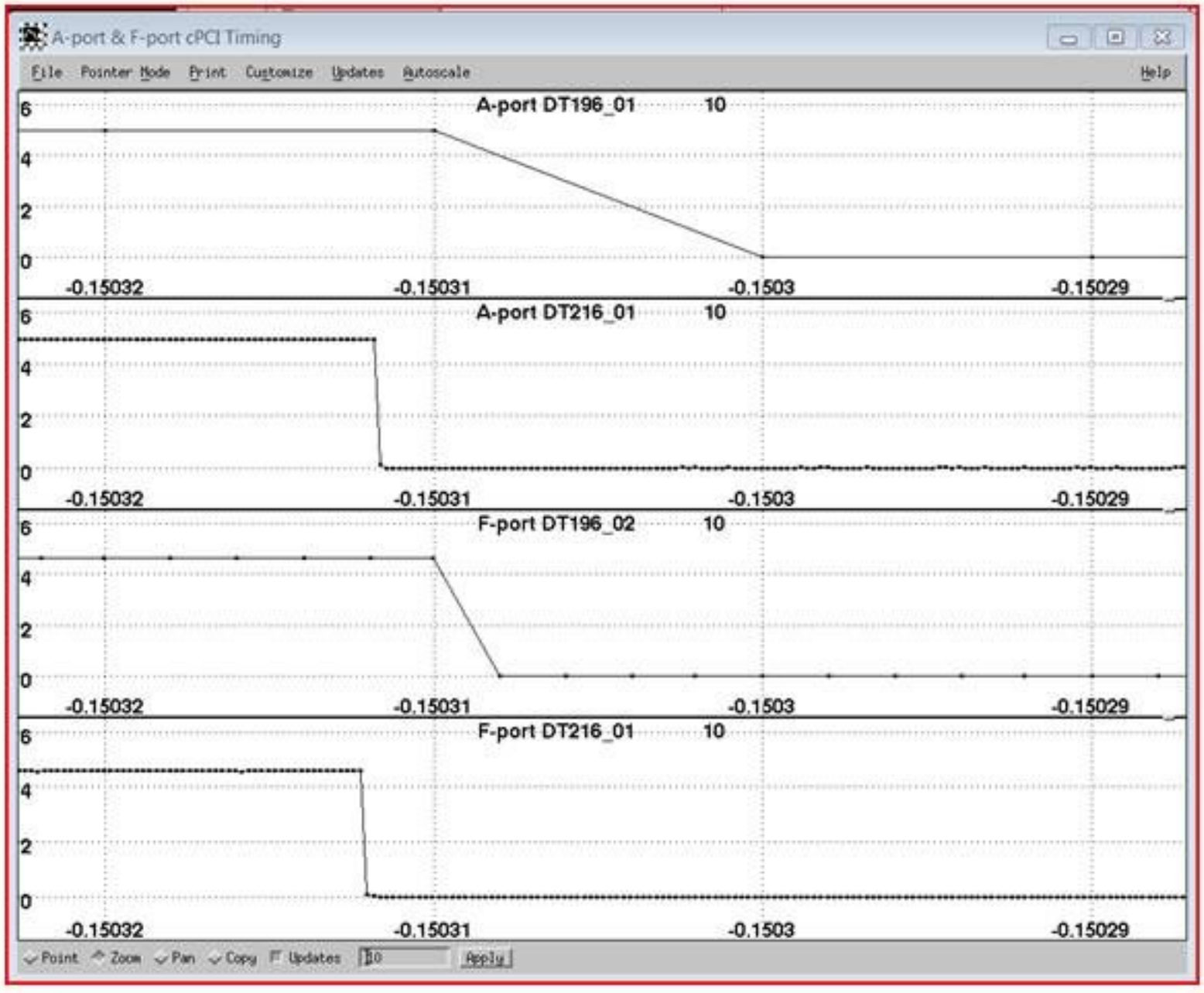


Probes (early) gross alignment



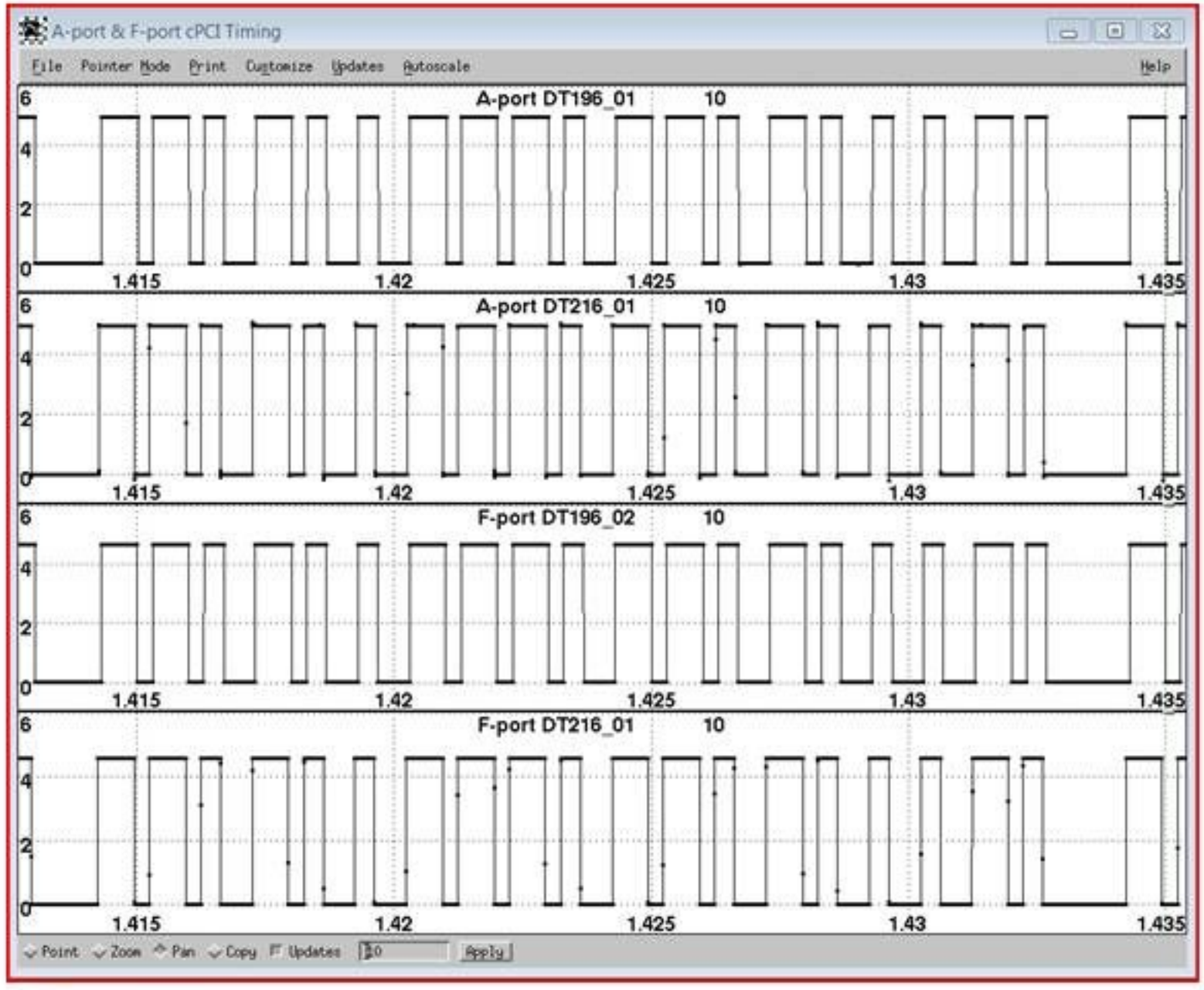
- The probe diagnostics located 180° apart on the machine.
- They are aquired on three separate timescales.
- The fast digitizers are acquired using Internal, unsynchronized clocks.
- The time signature signal can be gated in and out with an acquired data signal.

Probes Early fine alignment



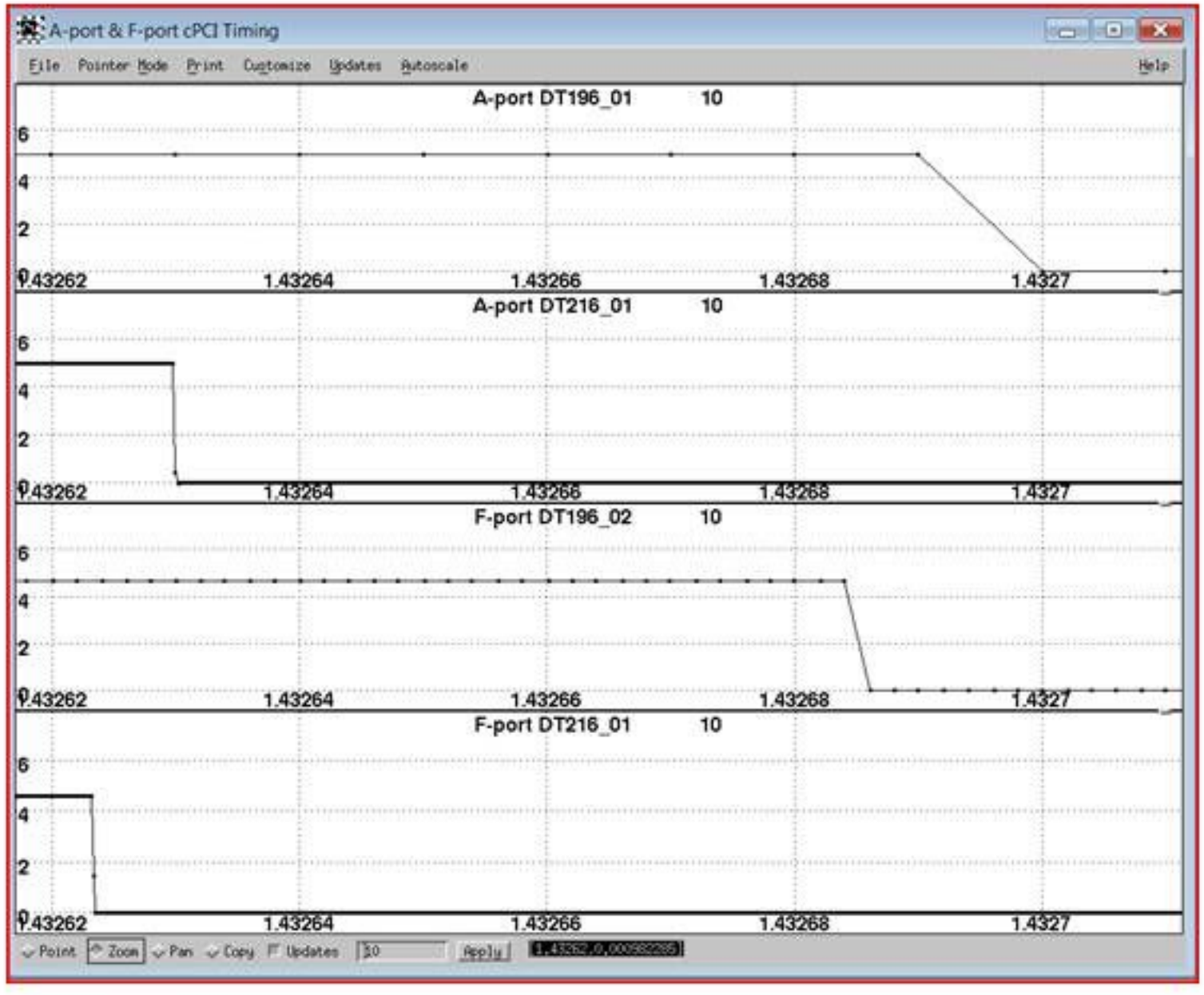
- Alignment good for early samples.

Probes (late) gross alignment



- Course alignment good after 1.4 seconds
- But...

Probes (late) details



- The differences between fast digitizer's internal clocks are clear.
- The one sample discrepancy between slow digitizer channels, can be accounted for by indeterminate phase of the sampling clock.

Aligning Real measurements

- Hot plasma ejection event can be seen at the mid-plane and in the diverter at the bottom of the machine.
- The timing signature signals for the digitizers align, so the measurement time-bases are believable.
- The 45 microsecond propagation delay from mid-plane to the diverter is real and significant.

Conclusions

- The System provides a simple effective tool to resolve timing issues.
- It does not rely on correctness of recorded time stamps.
- If required, it can provide sub-sampling frequency time accuracy.
- Some possible extensions are:
  - To base the time stamps on an external time source (GPS).
  - To provide multiple time signature signals at varying frequency and numbers of bits.
  - In cases where we know that the times need to be corrected, the time-base reconstruction can be fully automated.

Alcator C-Mod

Thank you for your attention.

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