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Technologies for Test Beam and Test Stand Data Acquisition

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Introduction

- This is a brief **survey** of DAQ technologies for **test beams** and **test stands** currently available at U.S. institutions.
  - Based on input from SLAC, BNL, and FNAL.

- The goal is to raise awareness of existing solutions and to spark discussion toward future collaborations and new developments.

SLAC

SLAC Test Beam Overview

- Input from Carsten Hast:

Facility	Purpose	Parameters
FACET-II	Accelerator R&D, Material Science, THz	Very focused and short bunches at 10GeV e+/-
ESTB	Detector R&D, LC MDI, Radiation Tests	2-16GeV primary LCLS beam or single e-
NLCTA	Accelerator R&D, Medical, Radiation Tests	60 to 160 MeV, small emittance, very versatile infrastructure
ASTA	Gun and RF Testing, RF processing, Ultrafast Electron Diffraction Beam Line	<50MeV, X- and S-Band RF power

- All supported by SLAC's Test Facilities Department

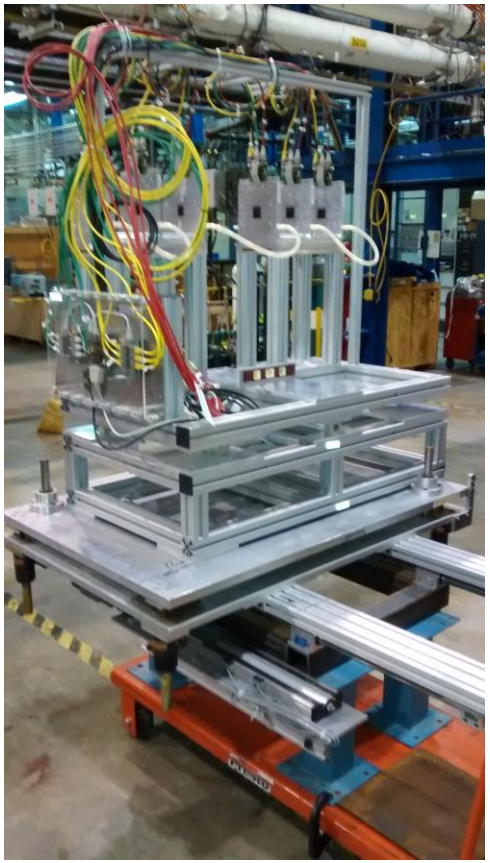

10 GeV
FACET-II
5 MeV
ASTA
2-16 GeV
& single e-
ESTB
NLCTA
60-160 MeV

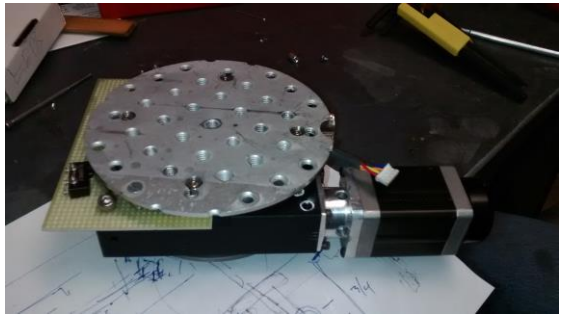
SLAC Test Beam Users and Their DAQ

- SLAC does not have a facility DAQ system.
  - Since beam is 100% electrons, particle ID is not needed.
  - Since beam energy resolution is known to 1%, energy measurement is not needed.
  - Since the trigger is predefined from the Linac timing system, no start or stop counters needed.
- So in the end, each group uses their own detector's DAQ with the facility trigger and notes the beam energy.

SLAC Caladium Silicon Telescope

- Carleton University, Ottawa, Canada loaned their telescope to SLAC.
- Motorized x-y, rotation stage, and cooling for the DUT.
- Telescope DAQ has “Rather steep learning curve.”





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SLAC Test Beam Detector & DAQ Summary

- Detectors available:
  - Scintillation counters, calorimeter modules, thin silicon pad detector, 6-layer pad tracker.
- Beam monitoring information available:
  - Beam toroid information available from EPICS.
  - Camera readout of material screens.
- Electronics available:
  - ADCs, flash ADCs, scalars
- DAQ tools available:
  - Beam information in EPICS.
  - “Camera” readout software.
- Recent DAQ needs of test beam users:
  - Ability to read information from EPICS into their DAQ.
  - Ability to read “camera” data into their DAQ or analyze it independently.
  - Ability to read facility-detector data into their DAQ.

BNL

BNL Test Beam and Test Stand DAQ - RCDAQ

- Input from Martin Purschke:
- RCDAQ (“Really Cool” DAQ) is a really lightweight DAQ system:
  - Developed by Martin!
  - Format-compatible with the (s)PHENIX DAQ
  - Has the functionality needed for all (or most) R&D efforts
  - Can easily be replicated (you can run it in your lab!)
  - Support for devices usually found in R&D setups:
    - DRS4, CAEN Modules, Struck/SIS Flash ADCs, SRS, jSEB, etc.
  - Built-in support for online monitoring
  - Built-in Elog support
  - Not monolithic, and extensible
  - Meaningful support for special events to capture and log your environment

Example devices implemented in RCDAQ

RCDAQ

PCIe

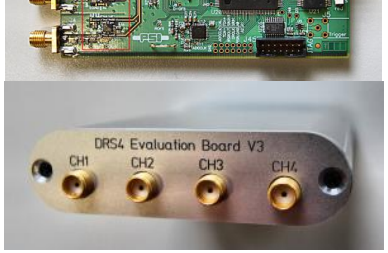
HBD Electronics Digitizer

This is used at Fermilab

PCIe

new sPHENIX digitizer prototype

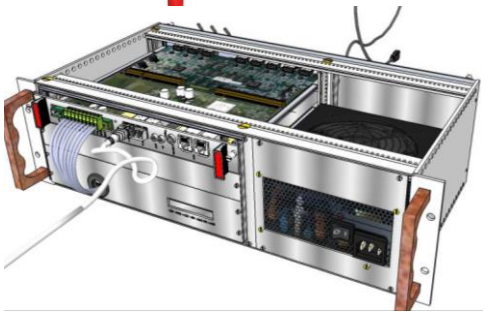
USB



DRS4 Eval board

"USB Oscilloscope"

Ethernet



The CERN RD51 SRS System

PCIe

The CAEN V1742 waveform digitizer

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RCDAQ High Points

- Each interaction with RCDAQ is a shell command or script.
- RCDAQ out of the box doesn't know about any particular hardware. All knowledge about how to readout something comes from plugins.
- Plugins make RCDAQ highly portable and also easy to distribute.

Example RCDAQ Script

The DAQ operation becomes an integral part of your shell environment

```
#! /bin/sh
STARTPOSX=0
STARTPOSY=9900
INCREMENTX=200
INCREMENTY=-200

CURRENTPOSY=$STARTPOSY
rcdaq_client daq_set_maxevents 4000

for posy in $(seq 25) ; do
    quickmove.sh $CURRENTPOSY 2
    sleep 5
    CURRENTPOSY=$( expr $CURRENTPOSY + $INCREMENTY)
    CURRENTPOSX=$STARTPOSX

    for posx in $(seq 50) ; do
     echo "moving to $CURRENTPOSX"
     quickmove.sh $CURRENTPOSX 1
     sleep 5

     rcdaq_client daq_begin
     wait_for_run_end.sh

     CURRENTPOSX=$( expr $CURRENTPOSX + $INCREMENTX)
    done
done
```

Automatic end after 4000 events

25 positions in y

move the Y motor

50 positions in x

move the x motor

start the DAQ

next x

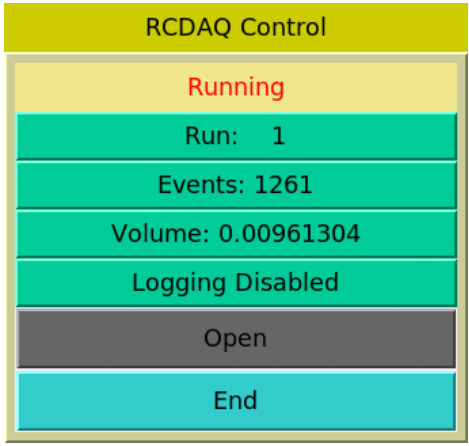
next y

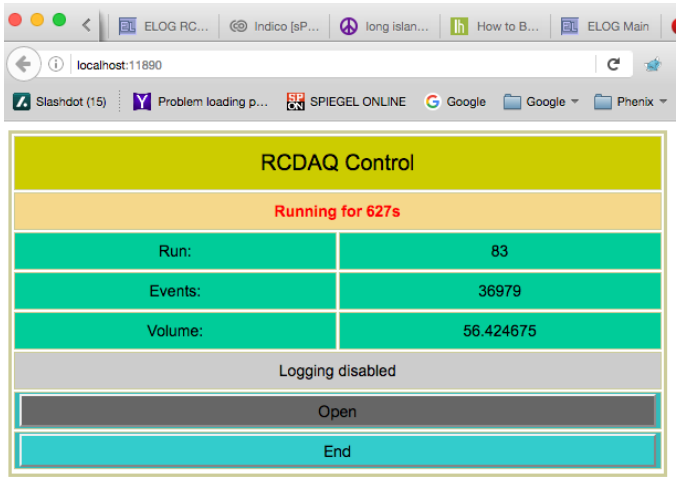
RCDAQ GUI

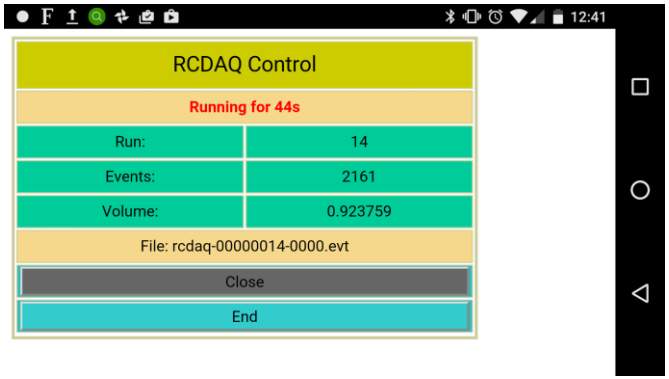
All RCDAQ GUIs are **stateless**. You can run any number of them concurrently

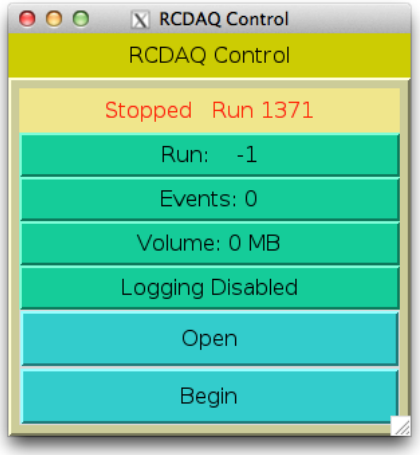
You can click “begin” in one, click “end” in the other, and mix GUIs with command line interactions.

Recently added Web controls to RCDAQ that allow you to control it from your smartphone or your tablet!









RCDAQ Current Use Cases

- Runs on just about any Linux machine
  - including a Raspberry Pi
- There are about 6 installations at BNL
- The DAQ of the BNL / Stony Brook / UPenn Medical Imaging Groups
- R&D efforts in the Electron-Ion Collider orbit use RCDAQ
- One of the DAQ systems available to CERN RD51 collaboration members (SRS)
- Workhorse DAQ at several Fermilab Test Beam setups
- EmCal R&D/production at UIUC
- Xiao Chün's group @GSU
- Used in ATLAS for the recent ZDC calorimeter calibration at CERN
- Used in the Arlington Medical Department, Texas

Note from Martin

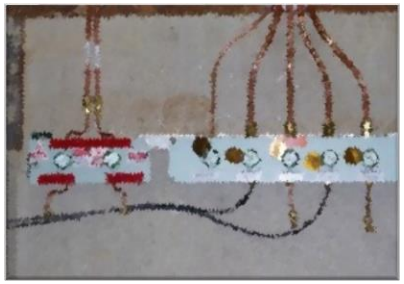
- “I will bring my portable DAQ system (aka my laptop and a DRS4) along.”
- Interested folks can get a “Really Cool” demo during the coffee break!

Fermilab Test Beam

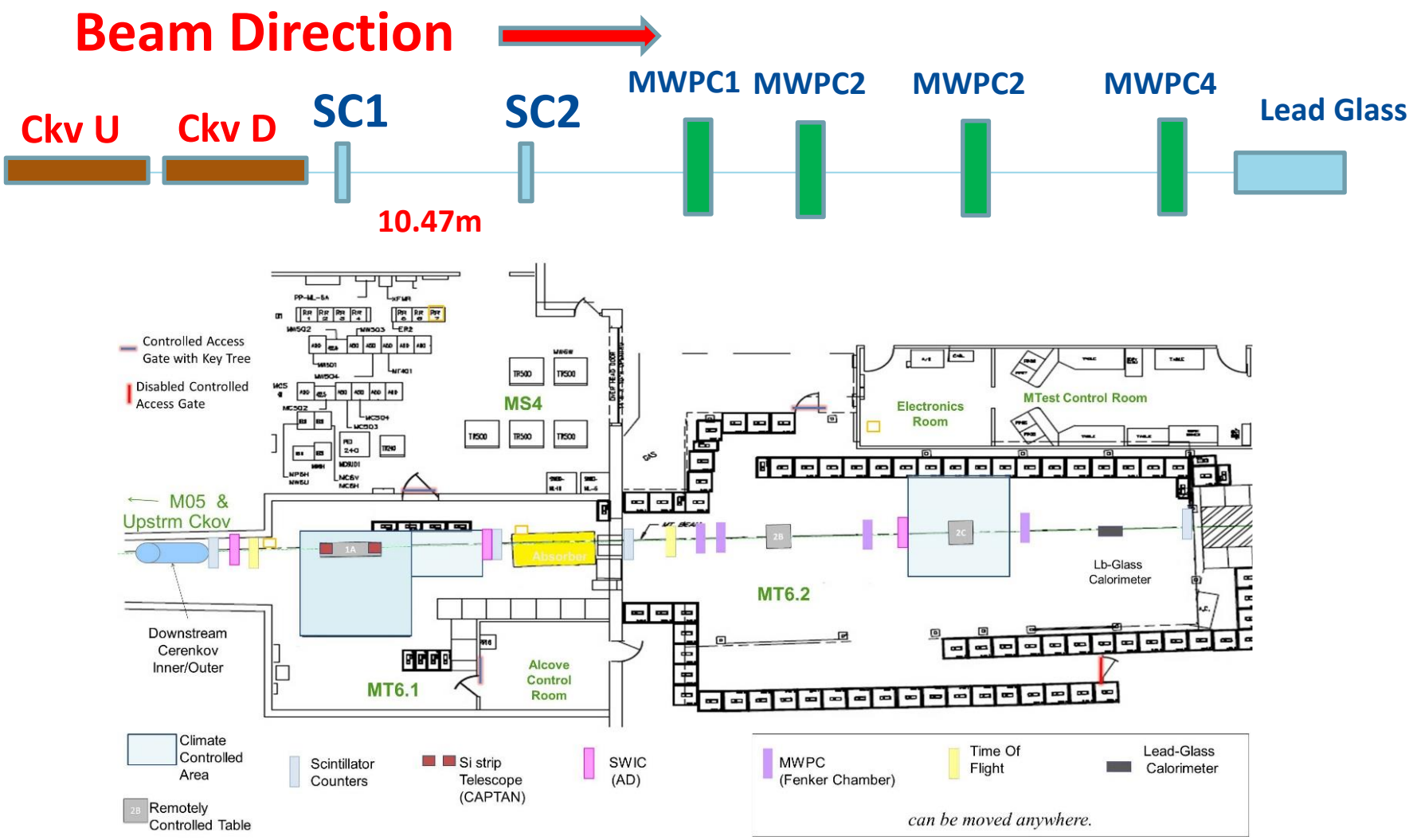
- Input from Mandy Rominsky
- Fermilab Test Beam Facility (FTBF) has been in operation since 2005
  - Over 1000 users from over 30 different countries
  - 2 Beamlines (MTest and MCenter). 200 MeV to 120 GeV.

Beam Infrastructure

- Available to users:
  - Remote controlled motion tables, Gas hookups (including flammable) cameras, signal/HV/ethernet patch panels.
  - Cables, supplies, test benches for preparation work.
  - Dedicated support staff.



Beam Instrumentation Layout – MTest



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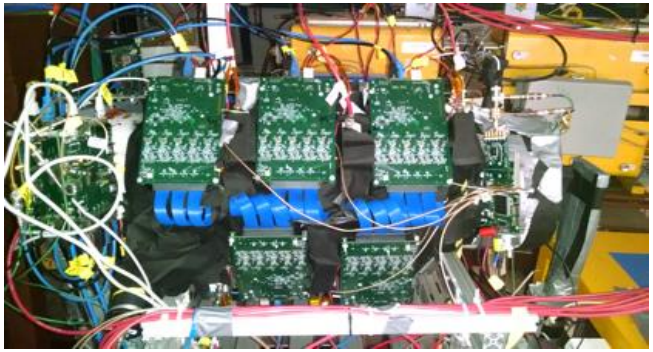
Wire Chambers and Cerenkov at FTBF

- Facility detectors readout with MIDAS.
- Commissioning readout solution with otsdaq this Fall.



Example DRS4 User at FTBF

Paul Rubinov @ FNAL modified DRS4 module firmware to improve synchronization and recompiled software for Windows.

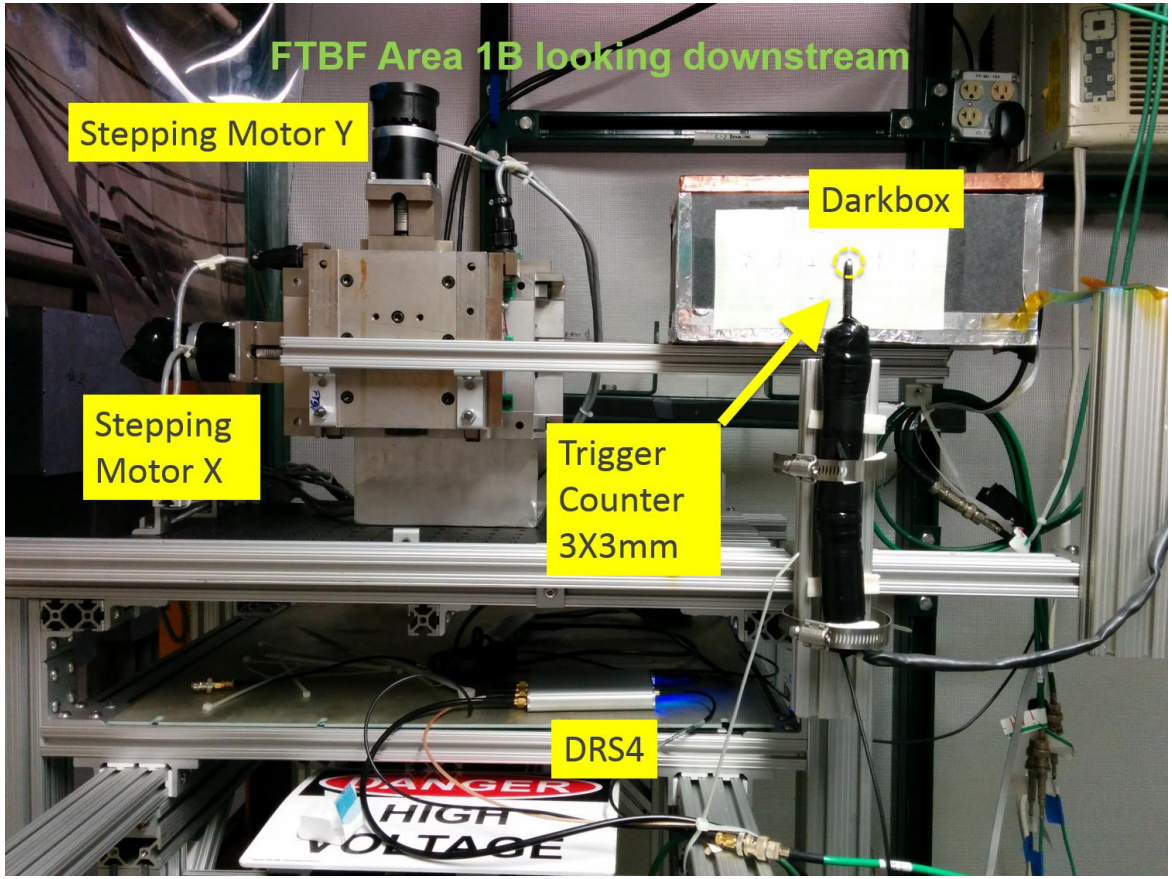


Image from Jim Freeman @ FNAL

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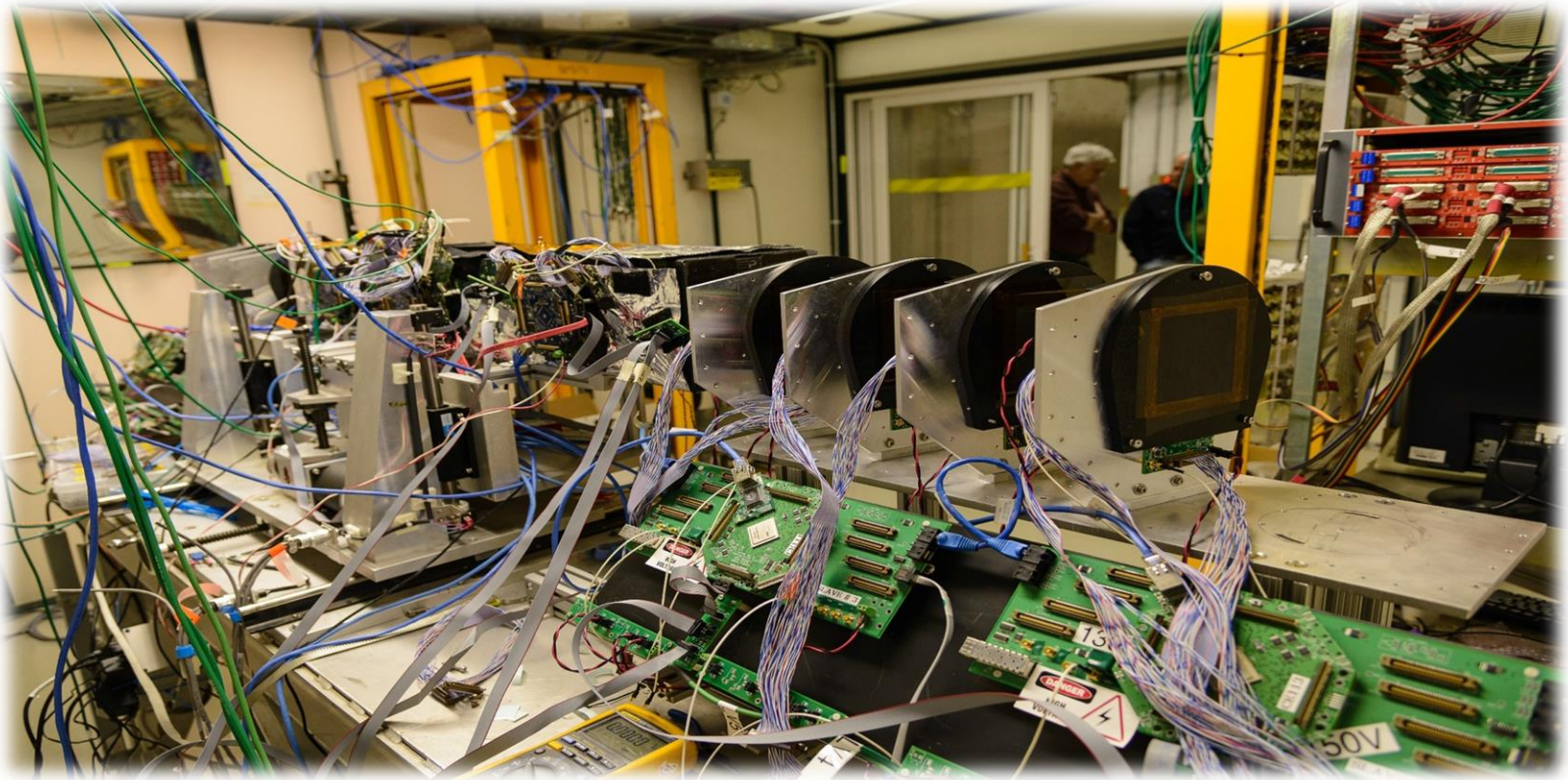
Silicon Tracking Telescopes at FTBF

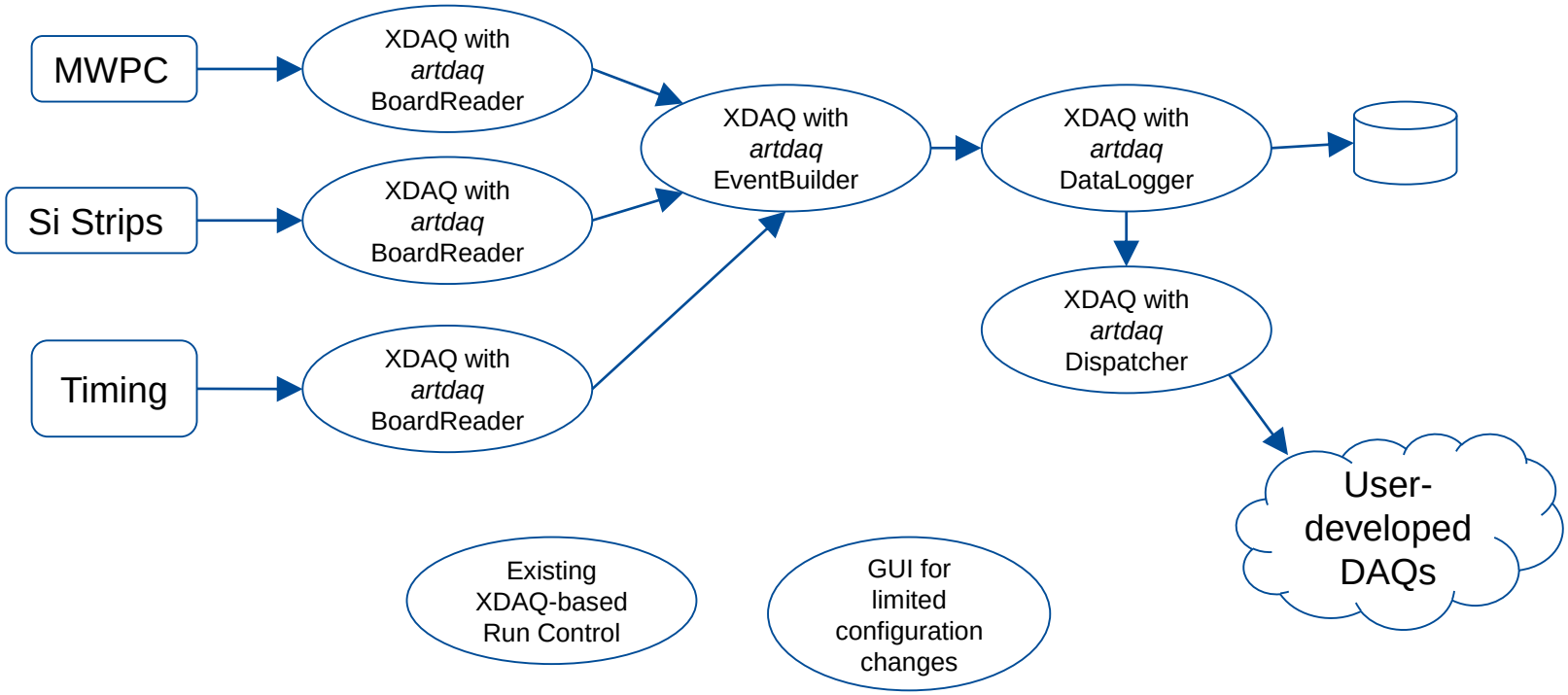
- Old pixel telescope DAQ is based on CAPTAN and Windows software suite:
  - Triggered, 2.5cm2 coverage, and 8µm track resolution
- New strip telescope DAQ is based on CAPTAN and otsdaq:
  - Dead-timeless, 16cm2 coverage, and 5µm track resolution
  - CAPTAN supported test beam and test stand of all versions of the CMS pixel chip



otsdaq and *artdaq* for Test Beam and Test Stand DAQs

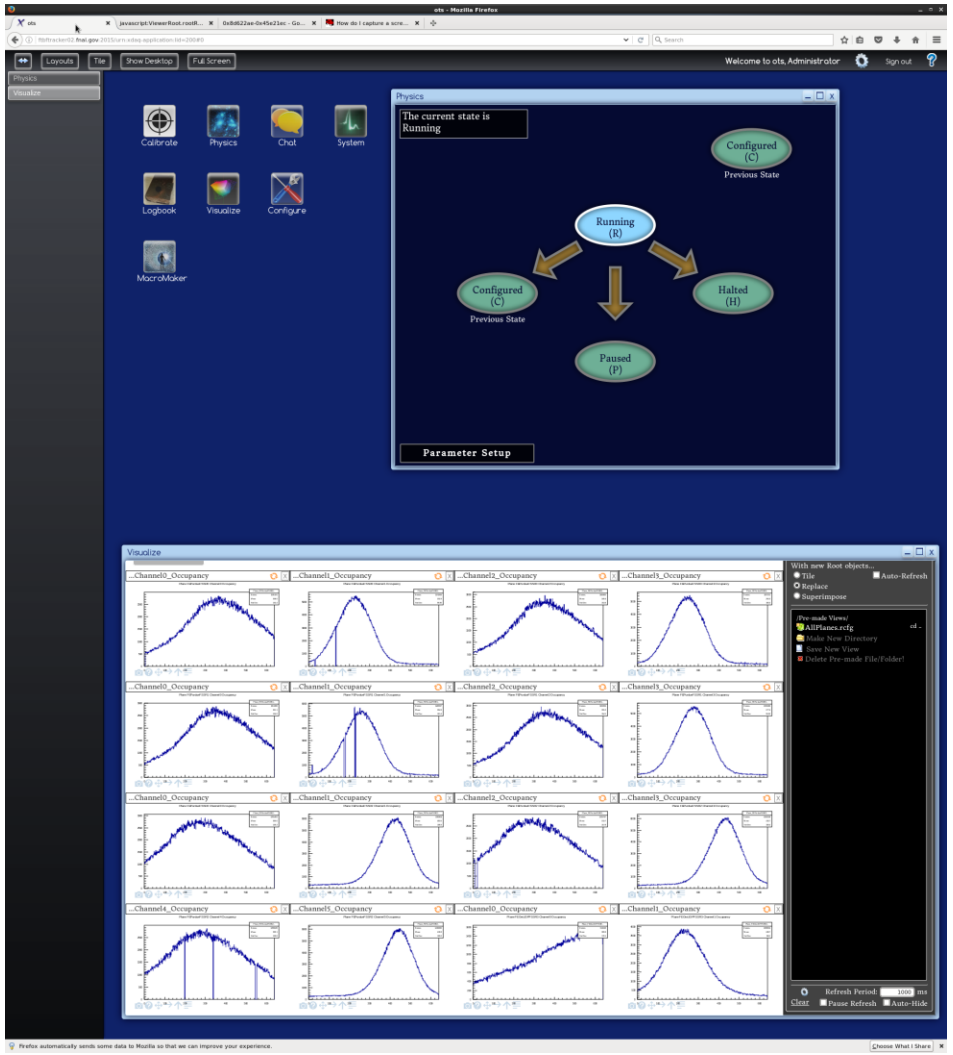
- otsdaq is a Ready-to-Use DAQ solution aimed at test beams, test stands, and other rapid-deployment scenarios.
  - otsdaq uses the artdaq framework under-the-hood, providing flexibility and scalability to meet evolving DAQ needs.
  - Existing library of supported front-end boards and firmware modules implementing a simple UDP protocol.
  - Provides run control and readout software that works with otsdaq firmware. Extensible via plug-ins.
- artdaq is a plugin-based DAQ framework, used by several Fermilab experiments such as DUNE and mu2e.
  - Flexible design allows for different detector technologies and event selection.
  - Allows for data to be analyzed mid-stream for software triggers.
  - Configurable asynchronous readout.
  - artdaq filtering modules are compatible with the art analysis suite.

FTBF “facility DAQ” *otsdaq* instance (short-term plan)



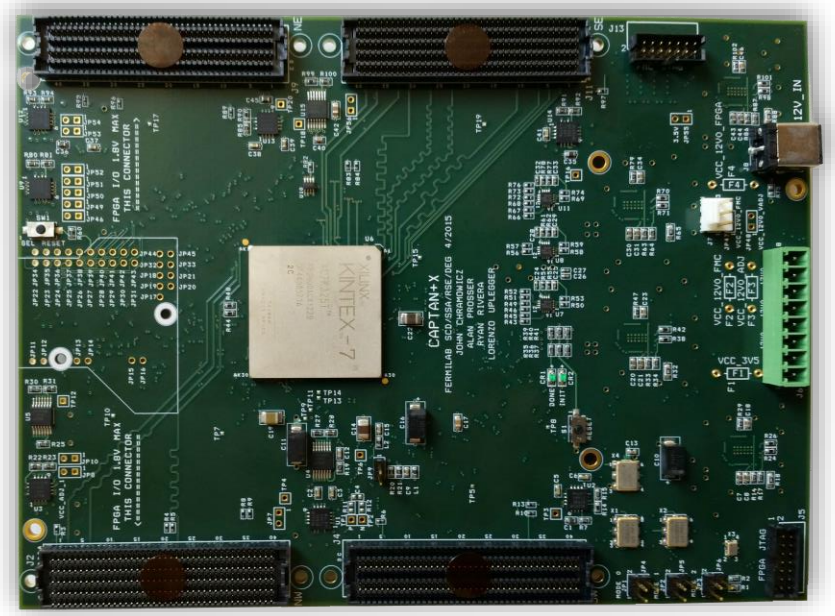
otsdaq GUI Through Web Browser

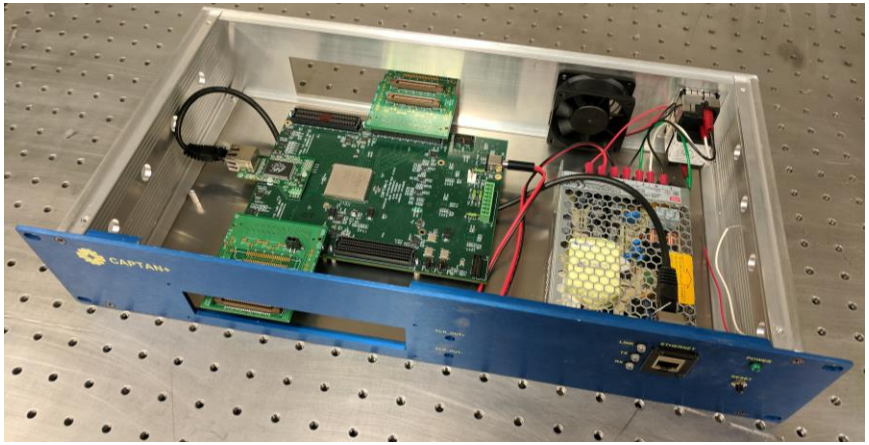
- Accessible through any device with Chrome or Firefox.
- A lot of development effort in web GUI framework.
- Goal is for users to never have to touch a console while running.
- Web GUI API for user development of their own compatible web apps.



Test Stand Hardware - CAPTAN+

- CAPTAN+ (“CAPTAN plus”) is the next generation CAPTAN card.
  - A leap from Xilinx 4 series to 7 series.
  - Two versions based on Artix-7 and Kintext-7
    - The ‘X’ stands for “eXtreme” for its support of 10G links.
- **Features:**
  - Gigabit Ethernet
  - 4 FMC connectors, 16 Links
  - 400 GPIO
  - otsdaq plug-n-play capable
  - Rack-mount enclosure



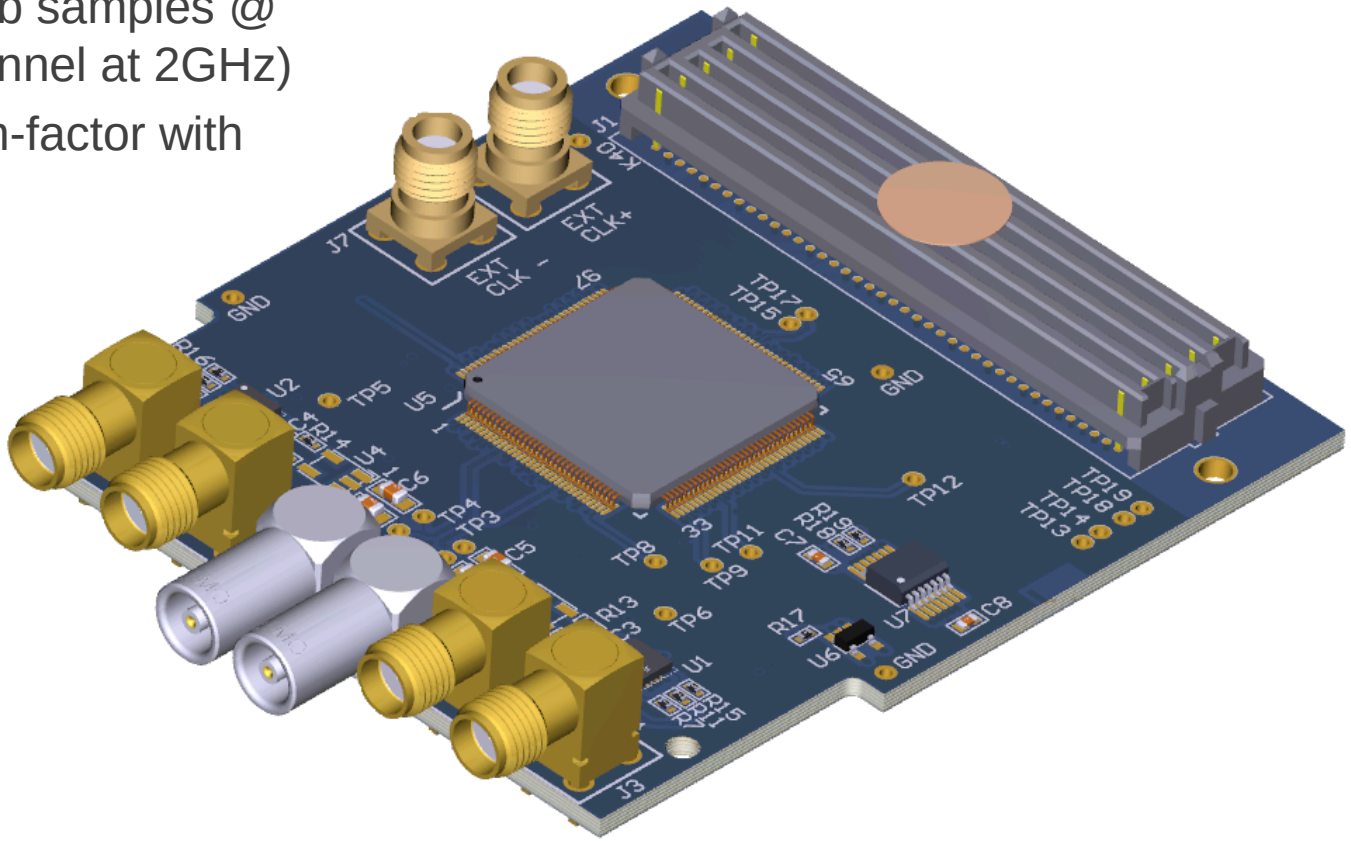


Test Stand Hardware - NIM+

- FPGA-based coincidence module.
  - Custom daughter card (FNAL/PPD) to digitize NIM signals for processing on CAPTAN+ FPGA board (FNAL/SCD).
- Firmware developed for signal processing (delay and stretch).
- Remote setting of parameters via otsdaq and data readout event-by-event supported
- Successfully used in 4 efforts at FTBF in May.
- Goal is 2 modules available from PREP in next month.

Test Stand Hardware - gADC NIM Module

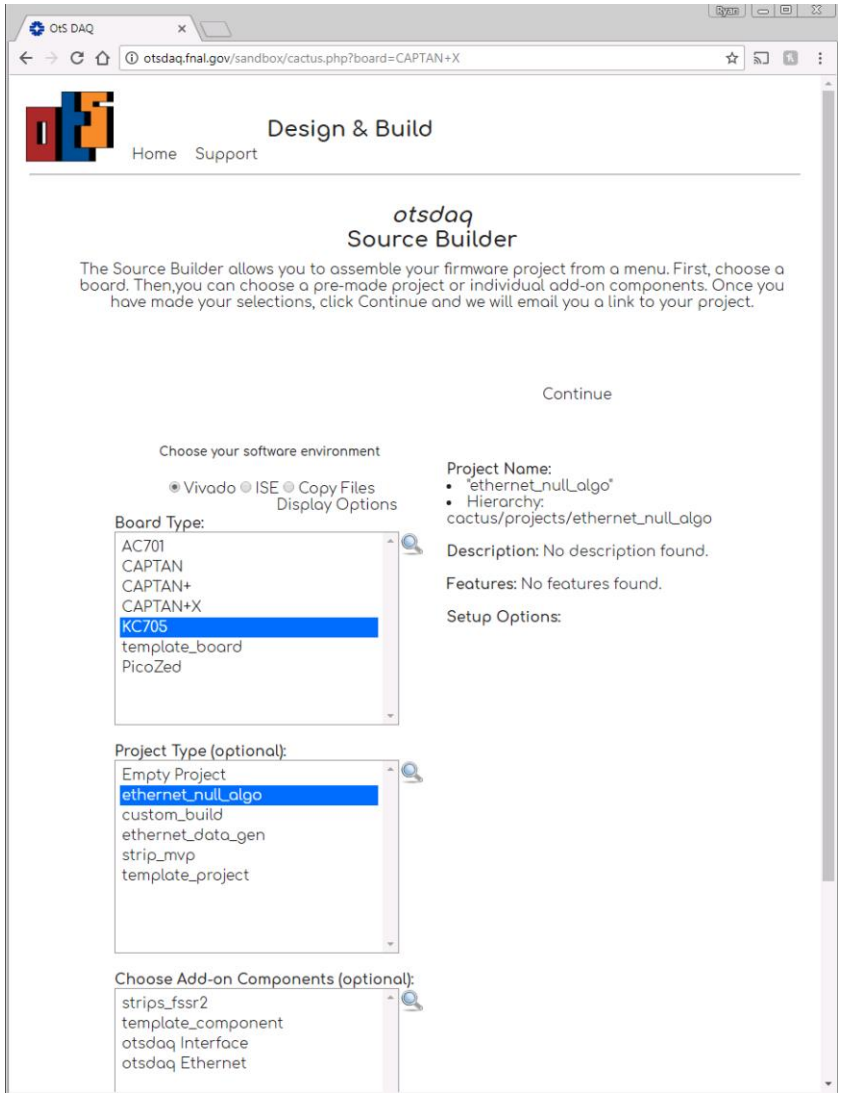
- “gigabit ADC” FMC module
- Features:
  - 2 channels of 8b samples @ 1GHz (or 1 channel at 2GHz)
  - Fits in NIM form-factor with CAPTAN+
  - Digital GPIO



First boards expected in December.

otsdaq Firmware Library Distributions

- Web GUI for generating firmware projects.
  - http://otsdaq.fnal.gov/beta/cactus.php
  - Try “custom_build” project
- Back-end built on Cactus project (CERN/Univ. of Bristol)
  - No modifications necessary
  - Added concept of “setup and install” script
- Example:
  - Choose board, choose project, choose add-ons, customize parameters.
  - Email with zip file attached!



DAQ Commonalities

- Test beams:
  - Trigger and clock distribution
  - Tracking telescopes
  - Logbook, collaborating tools
  - Scintillators, scalars
- Test stands:
  - ADCs
  - Plug-in based software/firmware
  - Lightweight software/firmware
  - Easy-to-use software/firmware
- Likely there are test beam and test stand DAQ solutions I missed?!