hCMOS Flat Fielding and Characterization

CEA-NNSA Joint Diagnostic Meeting

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LLNL - NIF Target Diagnostic

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LLNL-PRES-XXXXXX
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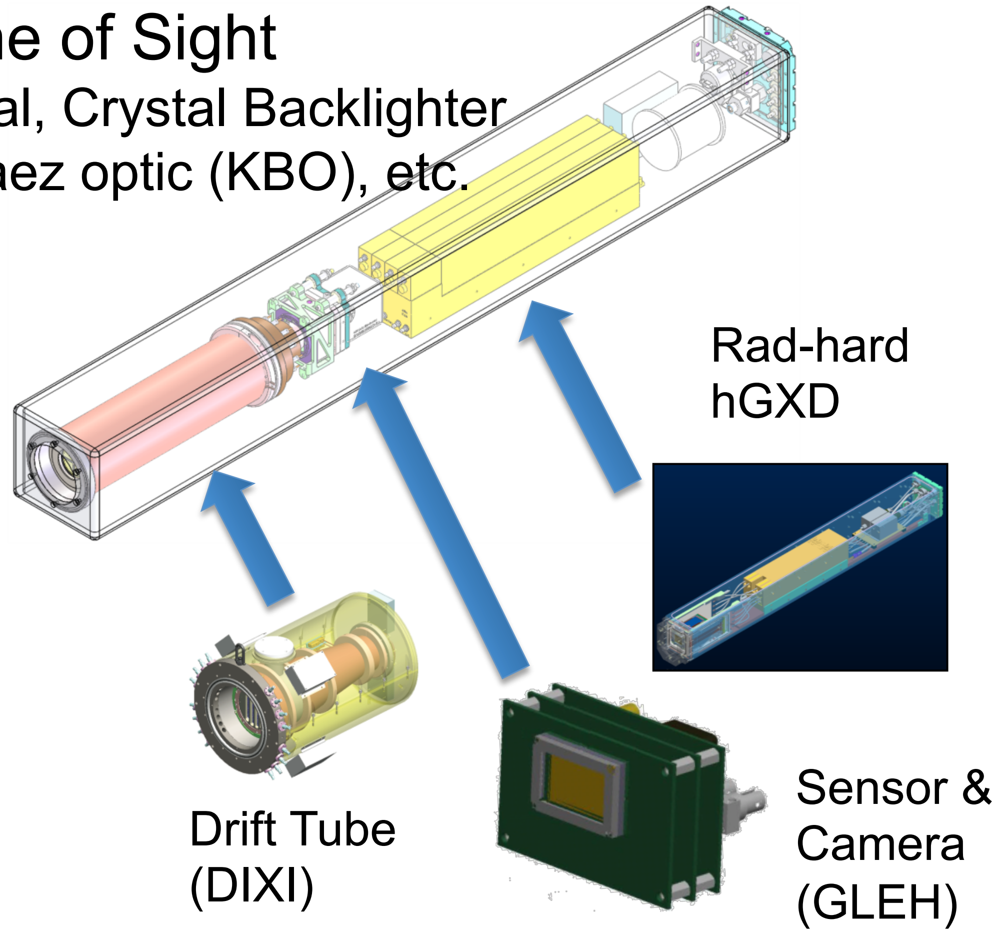
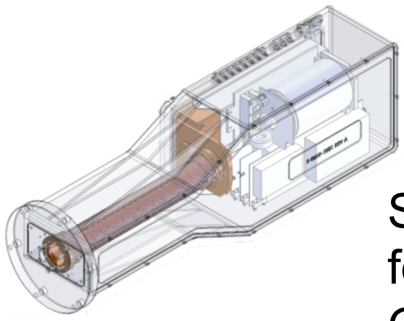
Motivation:
Develop a Single Line of Sight Diagnostic Platform

- Improved X-ray optics will require multiple images from the same Line of Sight
  - X-ray Optics: Wolter, Toroidal, Crystal Backlighter Imager (CBI), Kirkpatrick-Baez optic (KBO), etc.
- The Single Line of Sight Diagnostic (SLOS) platform combines 3 diagnostic (DIXI, GLEH, hGXD)
- Detailed understanding of image the sensor is required for successful integration



Objectives:
Understand Sensor and Integrate into NIF

- Understand the performance of the hCMOS image sensors
  - Quantify pixel level response
  - Feedback results to SNL to aid in future FPA development
  - Develop correction methods and determine performance limitations
- Step 1:Understand hCMOS Sensors
  - Build up a fully automated lab
  - Build camera boards to run sensor
- Step 2: Build NIF Rad-hard Camera
  - Evaluate Rad-hard components
  - Test Design in NIF environment
- Step 3: Integration
  - Package Diagnostic in Airbox
  - Field System in NIF



SLOS Concept for use on OMEGA

SLOS Concept for use on NIF

Outline

- Results from Furi characterization (Step 1)
  - Objectives, experimental setup and automation
  - Gate profiles, gain non-uniformity, timing skew, and linearity
- Plan for future sensor characterization (Step 1)
  - Experimental setup and facility
  - Motivation for Improved Automation
- Radiation hardened cameras for use in NIF (Step 2)
- NIF neutron radiation environment testing capabilities (Step 2)
- SLOS hCMOS integration (Step3)

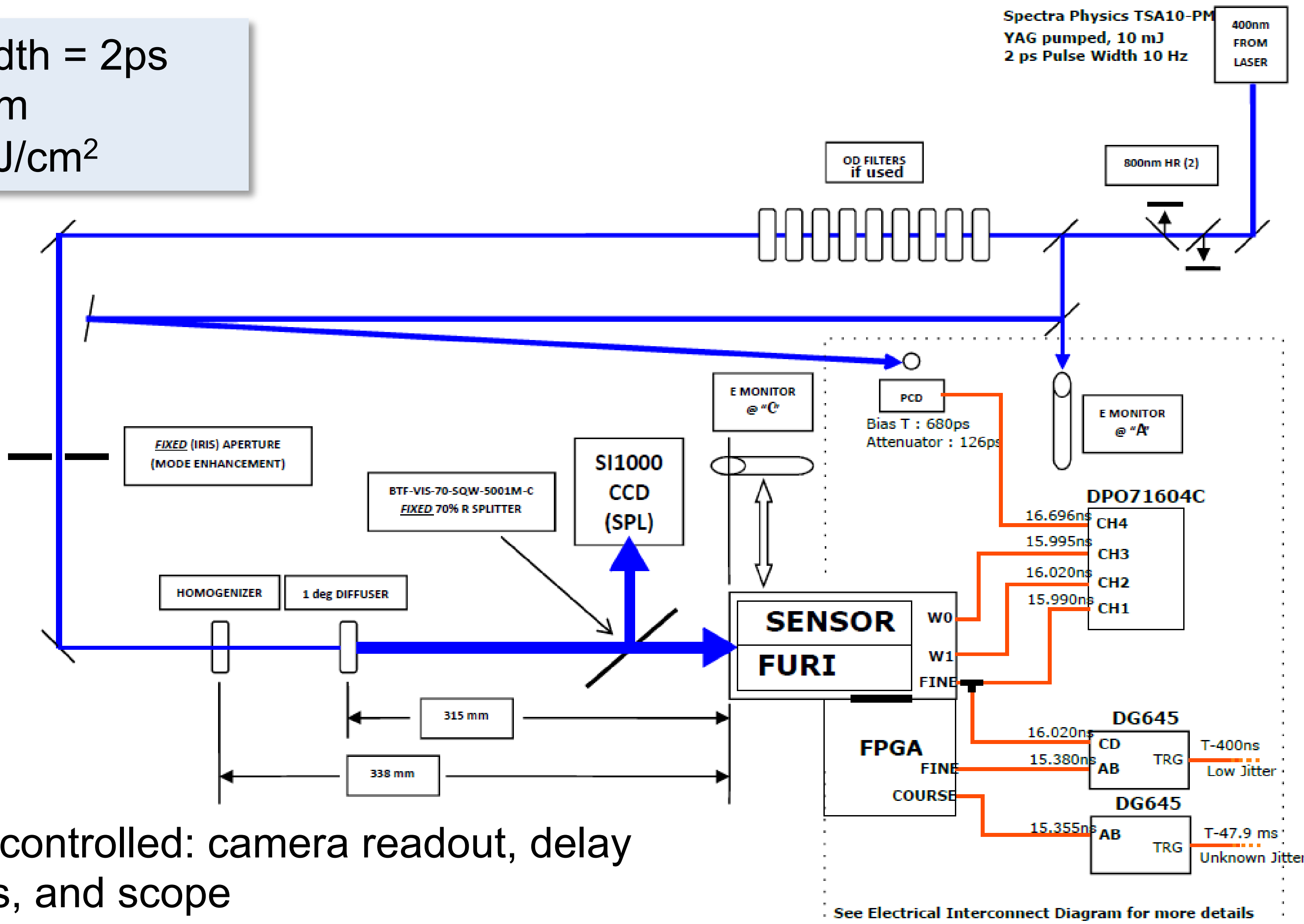
Furi Characterization

- Generate pixel level response profiles and timing delays for the Furi sensor
- Scan 2ps laser pulse in time over the gating window for the sensor
- Linearity: Hold timing constant and vary intensity of pulse using ND filters
- Analysis and Results
  - "Flat Field" pixel sensitivity at any given point in the gate profile
  - Rise time, fall time, and FWHM of each pixel's gate profile
  - Timing skew of pixels

This process will result in an amplitude response and turn on delay for every pixel in the sensor

Laser Lab Setup at NSTec Livermore

Pulse width = 2ps
λ= 400nm
E ~ 2.5uJ/cm^2

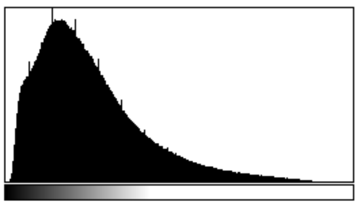


LabVIEW controlled: camera readout, delay generators, and scope

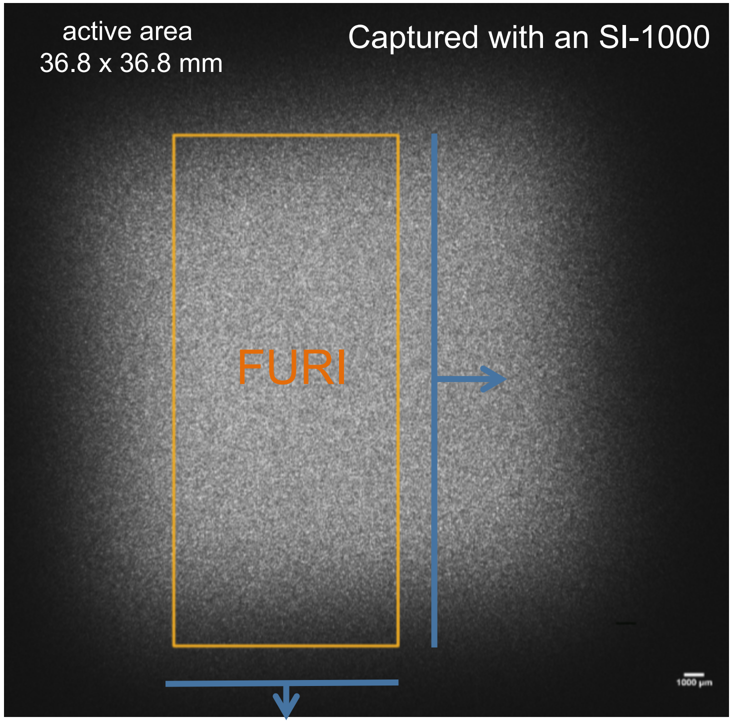
Laser Beam Uniformity:
SI1000 Beam Image

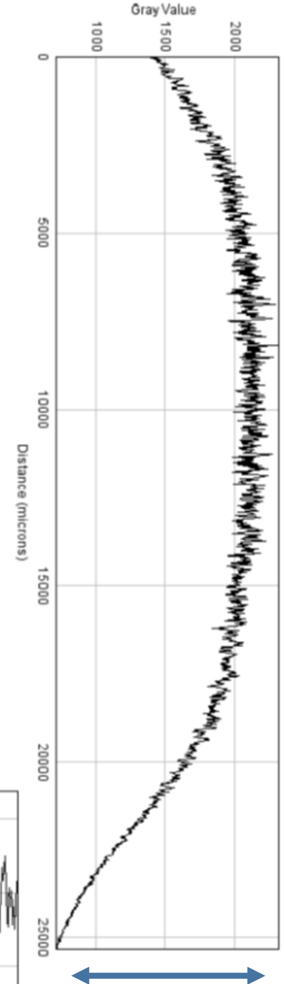
Intensity speckling didn't move from shot to shot

Pixel Distribution



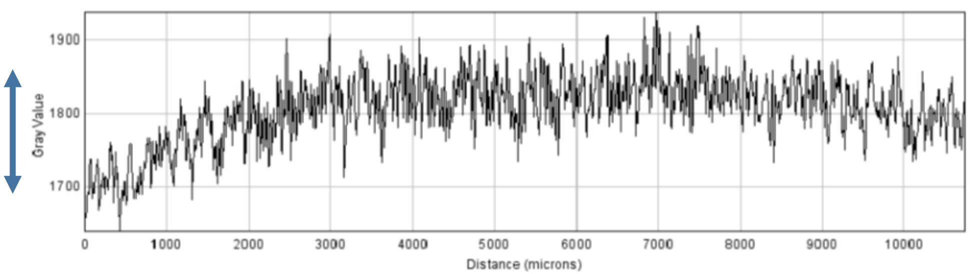
Count: 3536999
Mean: 1739.872
StdDev: 818.067
Bins: 512
Min: 512
Max: 19576
Mode: 1296 (24042)
Bin Width: 10.029



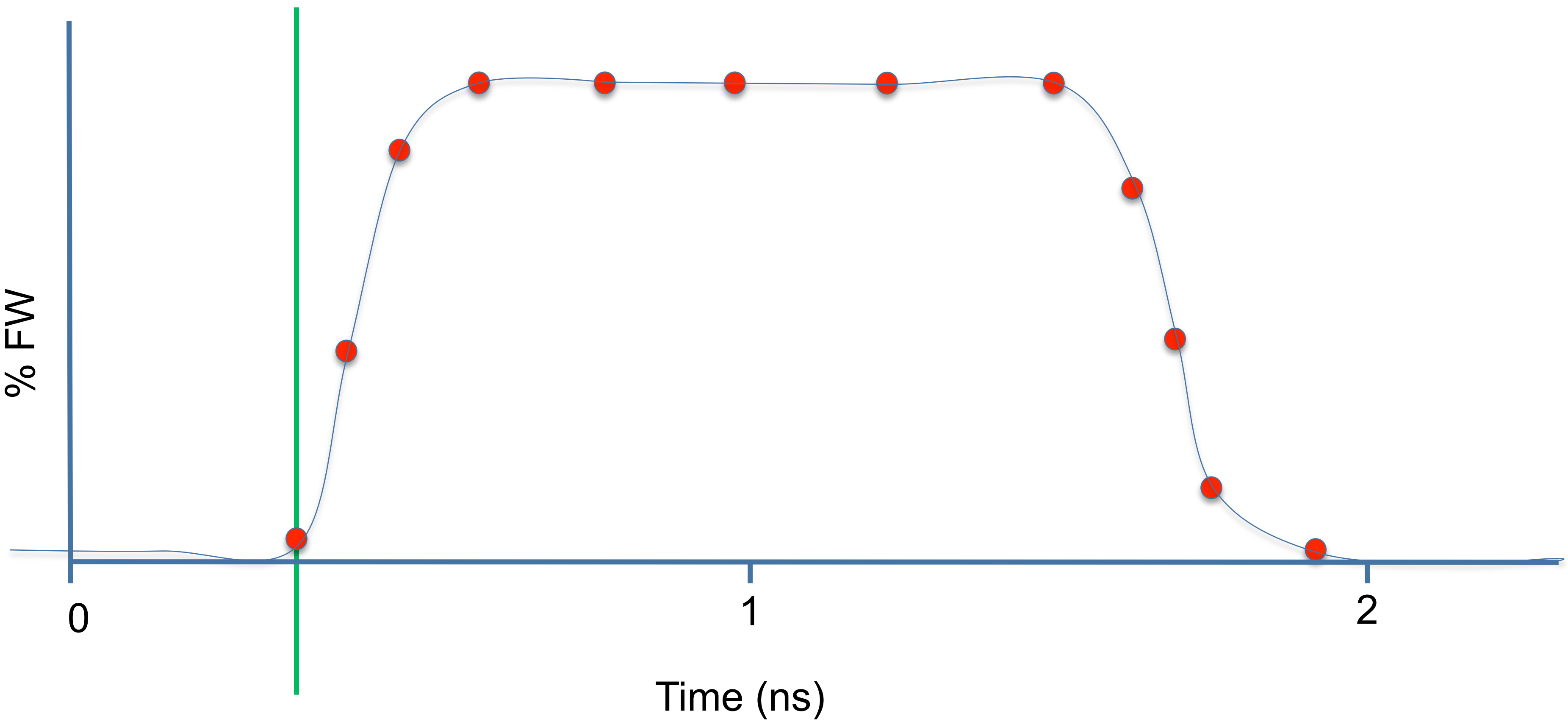


36%

9%

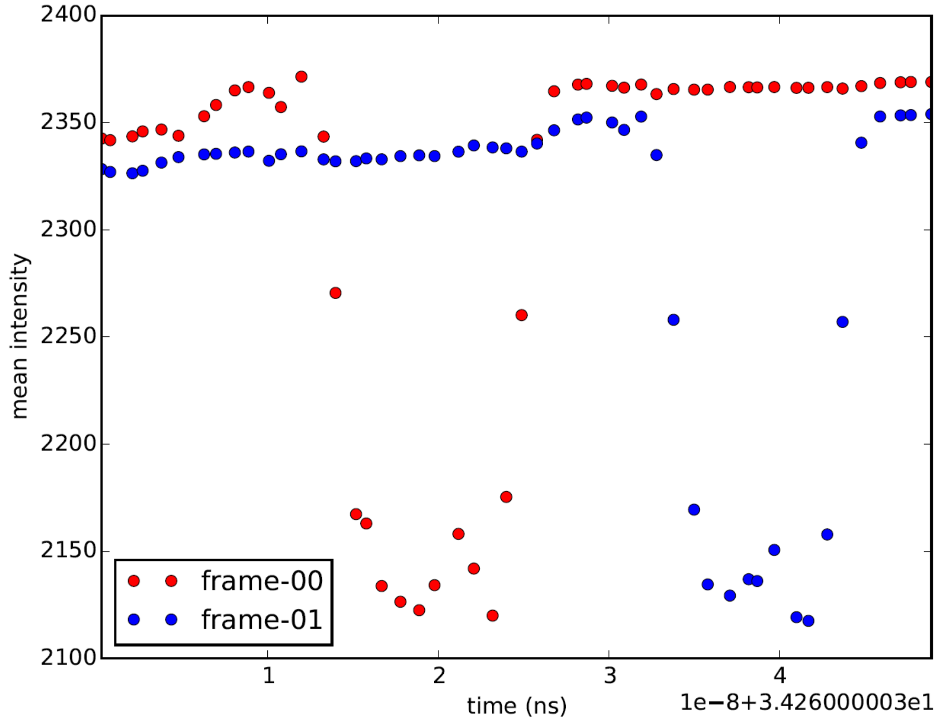


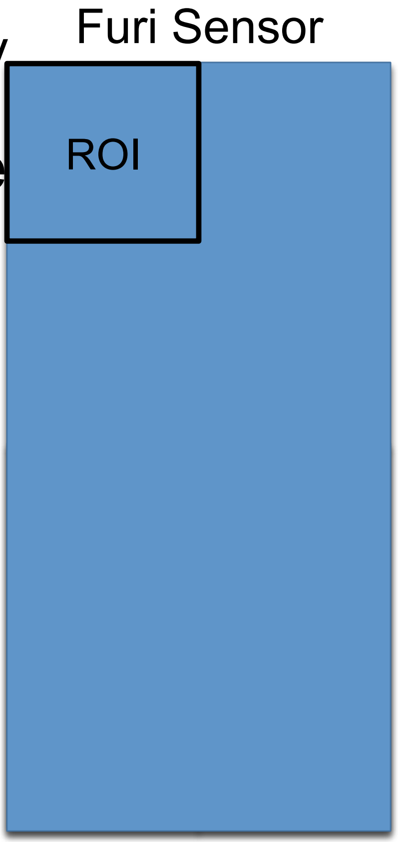
A gate profile is generated by walking laser pulse over gate window



Real Time Gate Profiles:
10-10 Data for ROI: 224-224

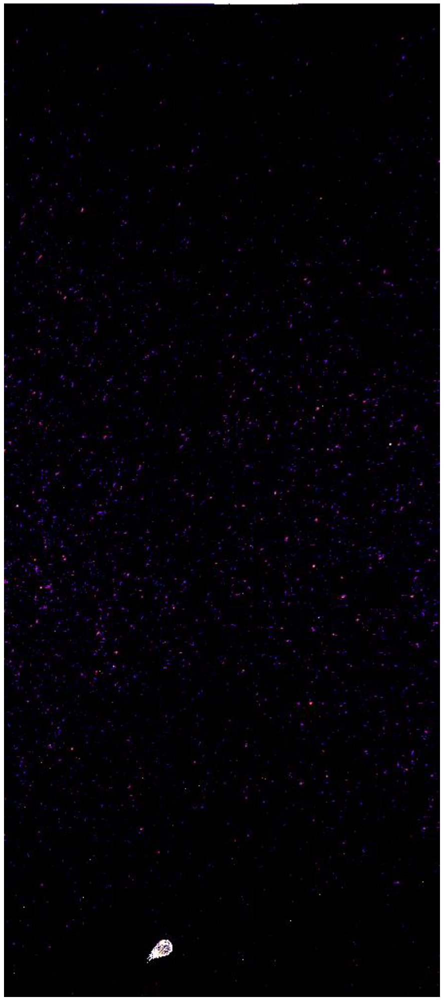
- Averaged pixel response is plotted
  - Region of Interest (ROI) size is arbitrarily
- Python Script displays data real time

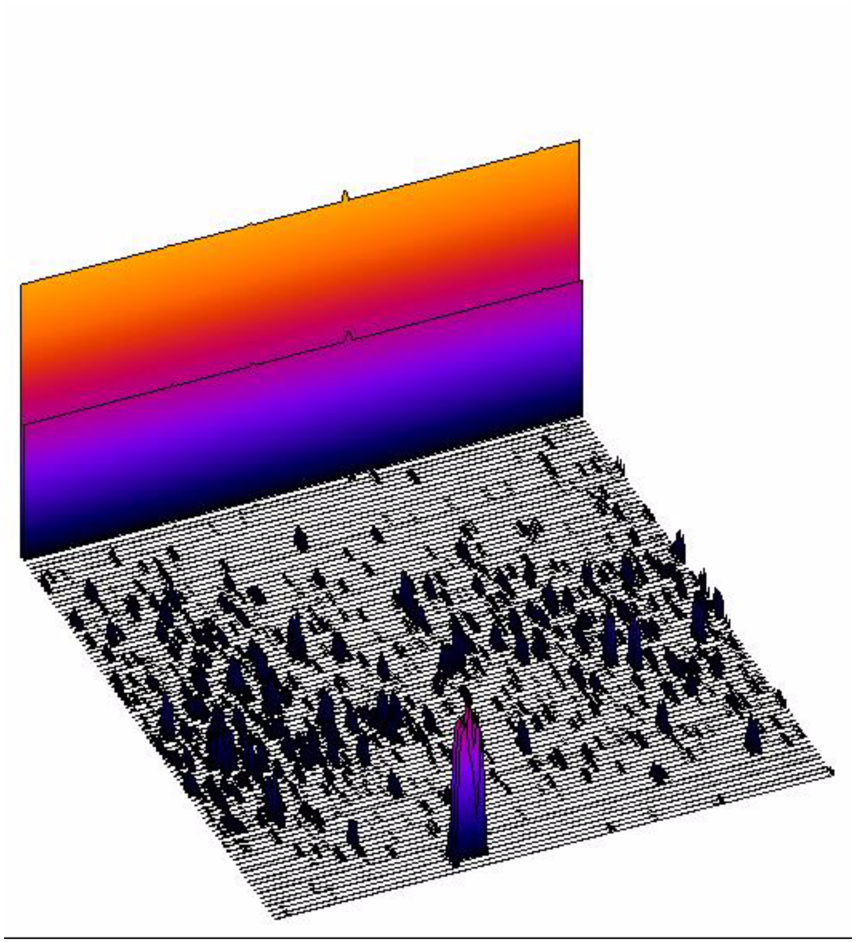




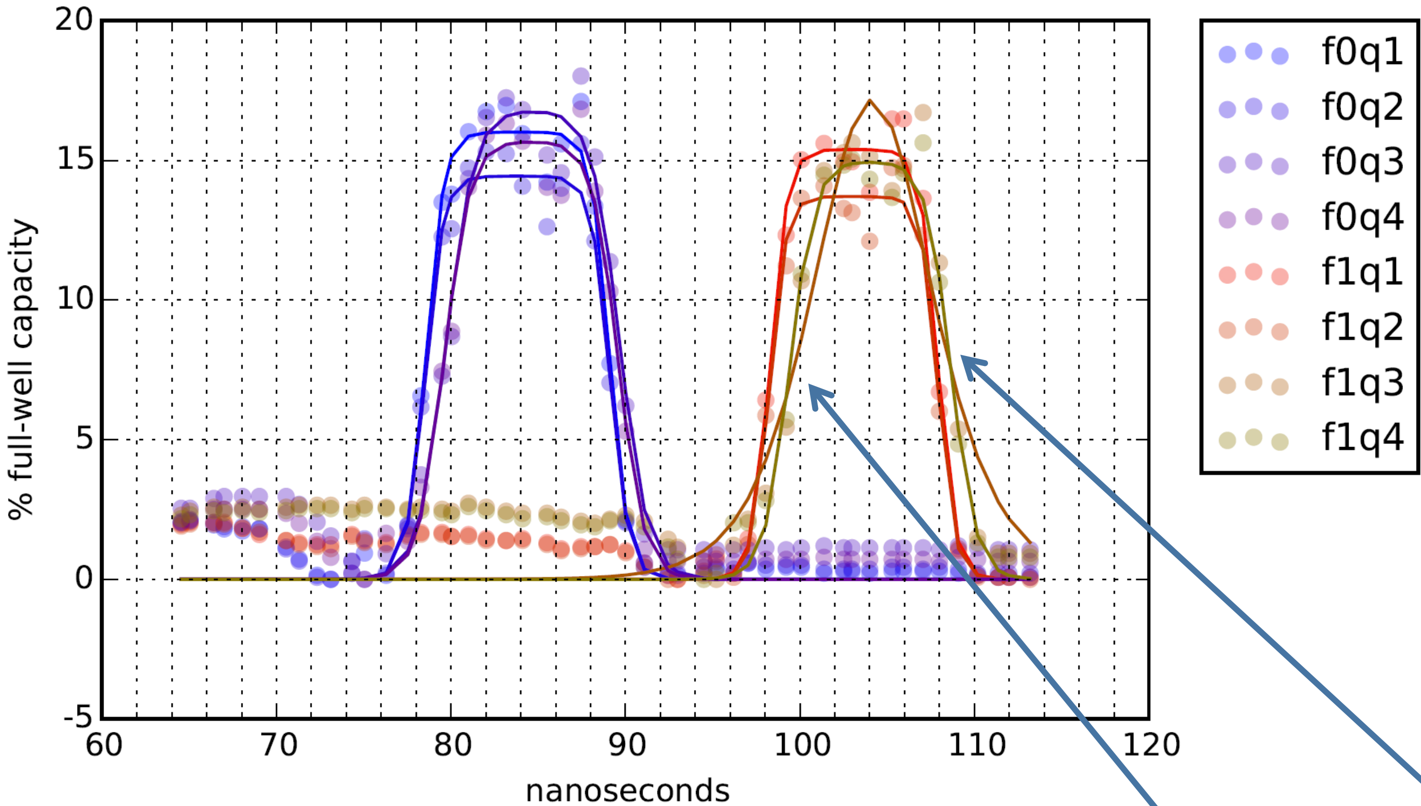
Timing Modes Tested
2-1
2-2
2-3
2-8
8-2
9-1
10-10
19-1

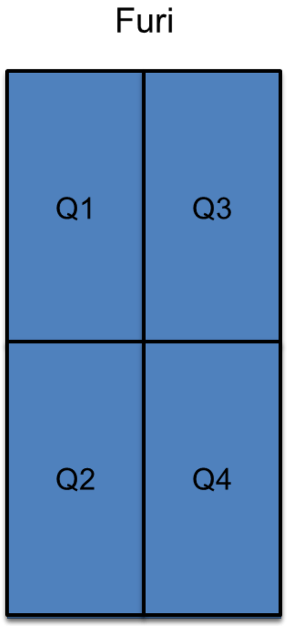
Rising Edge Movie:
20ps steps 2-2 Timing Mode





Quadrant Gate Profiles:
10-10 timing mode

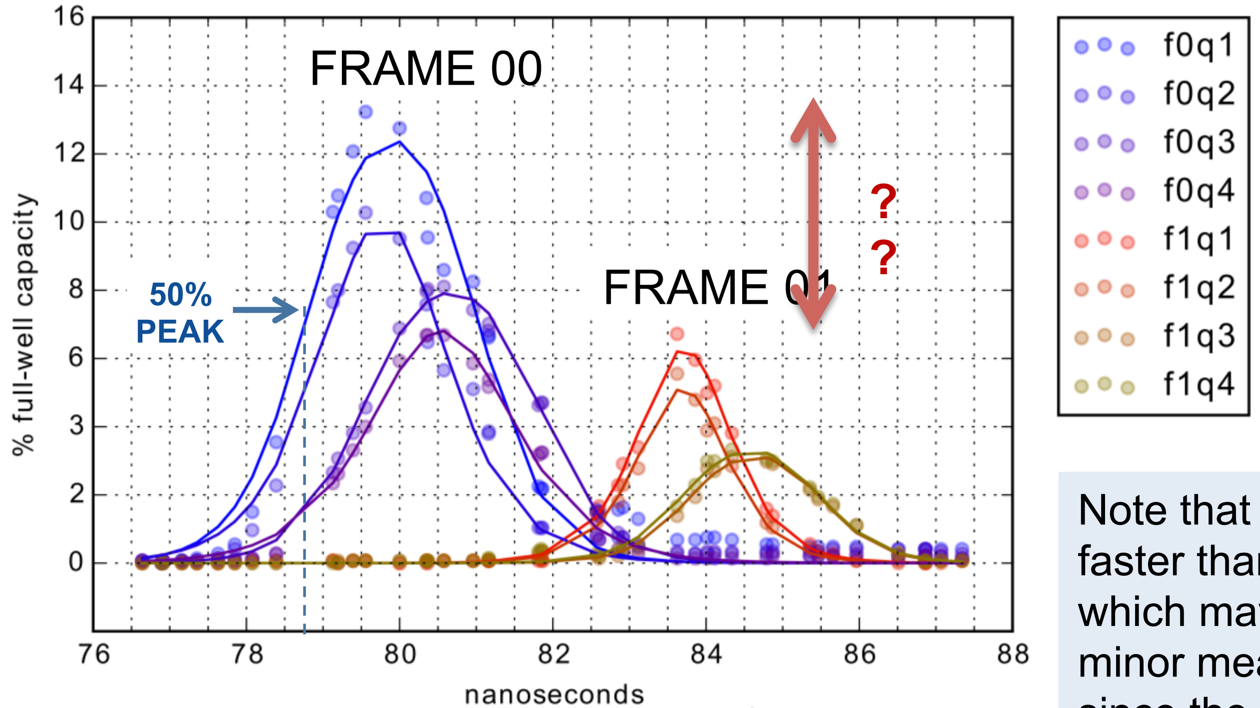


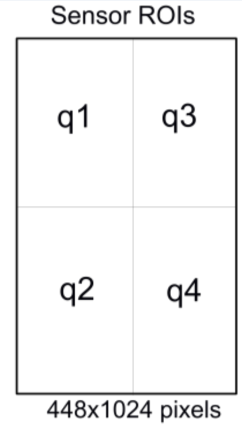


Each gate profiles fit with two sigmoids

$f(t) = A/1 + exp(-t - t1/\tau) - A/1 + exp(-t - t2/\tau)$

Quadrant Gate Profiles:
2-2 Timing Mode

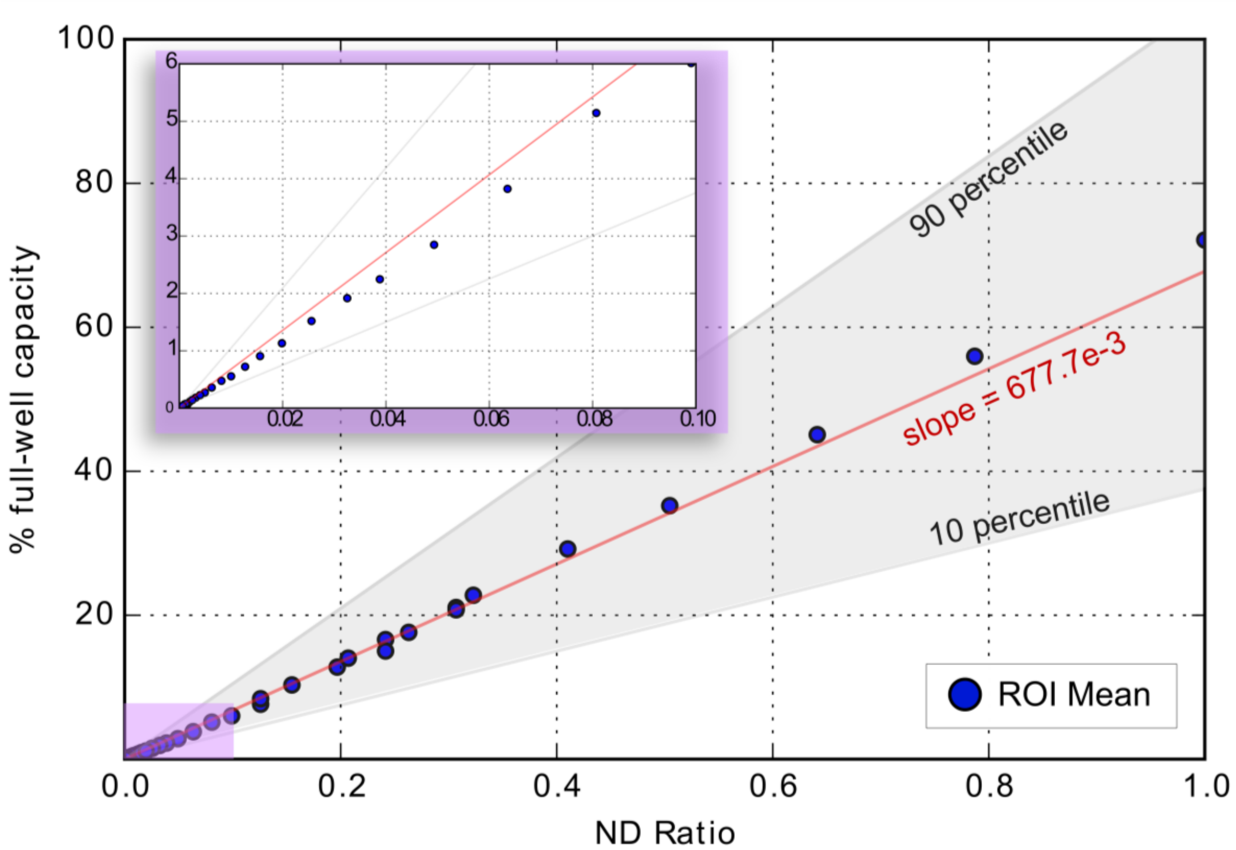


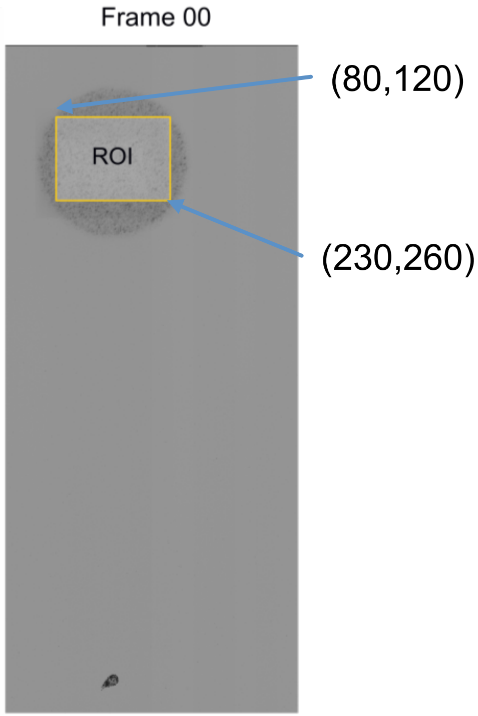


		Frame 00		Frame 01		
		50%Peak (ns)	FWHM (ns)	50%Peak (ns)	FWHM (ns)	
LHS	q1	78.7	2.5	83.0	1.4	q1 LHS
LHS	q2	78.8	2.0	83.0	1.4	q2 LHS
RHS	q3	79.4	2.4	82.9	2.0	q3 RHS
RHS	q4	79.4	2.1	82.7	2.1	q4 RHS

Note that the rising edge was faster than the falling edge which may have led some to minor measurement errors since the fit function assumed symmetry

Linearity Check:
A ROI representative of typical shot data was used





1. Test was done in Timing Mode 8-2
2. Taken at in the middle of the gate profile for all frame quadrants, T= 82.6ns

Due to beam speckle, some pixels exceeded the full-well capacity before others which likely skewed the response. The test mimicked a use scenario with a small active area and wide ranging intensities.

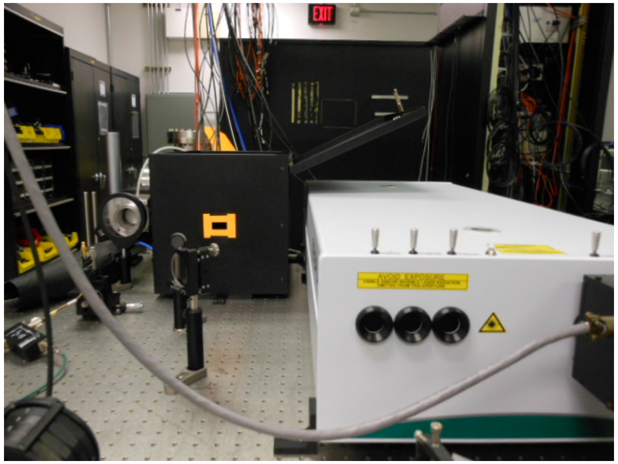
Furi Testing at NSTec vs. Icarus Testing at LLNL

- Furi testing at NSTec:
  - 8 gate profiles (of ~170)
  - ~500+ data points
  - Camera board readout: ~2.5min per point
  - Duration: ~4 weeks
- Icarus vs Furi:
  - 4 vs. 2 frames
  - 32 vs. 14 readout channels
  - Two 40-bit vs. One 20-bit frame patter registers
  - 512 vs. 448 columns
- Icarus Testing at LLNL
  - Up to 780 gate profiles
  - 100 points per profile
  - **3250!** hours at 2.5min per point
  - **130** hours at 10s per point
- Sandia's new RevC Camera Board is Faster!

Sensor characterization requires fast, automated, data collection

LLNL Framing Camera Laser Lab:
Fully Automated Characterization Facility

- Use Framing Camera Laser EKSPLA PL2230 ND:YAG
  - 532nm and 213nm output
- Similar setup used at General Atomics for characterizing pulse dilation photocathode and drift tube
- Python Control Scripts Automate
  - Camera Readoff
  - 3 Delay Generators
  - 12GHz Scope
  - Low Voltage Power Supply
  - Energy meter
  - Any new equipment as needed



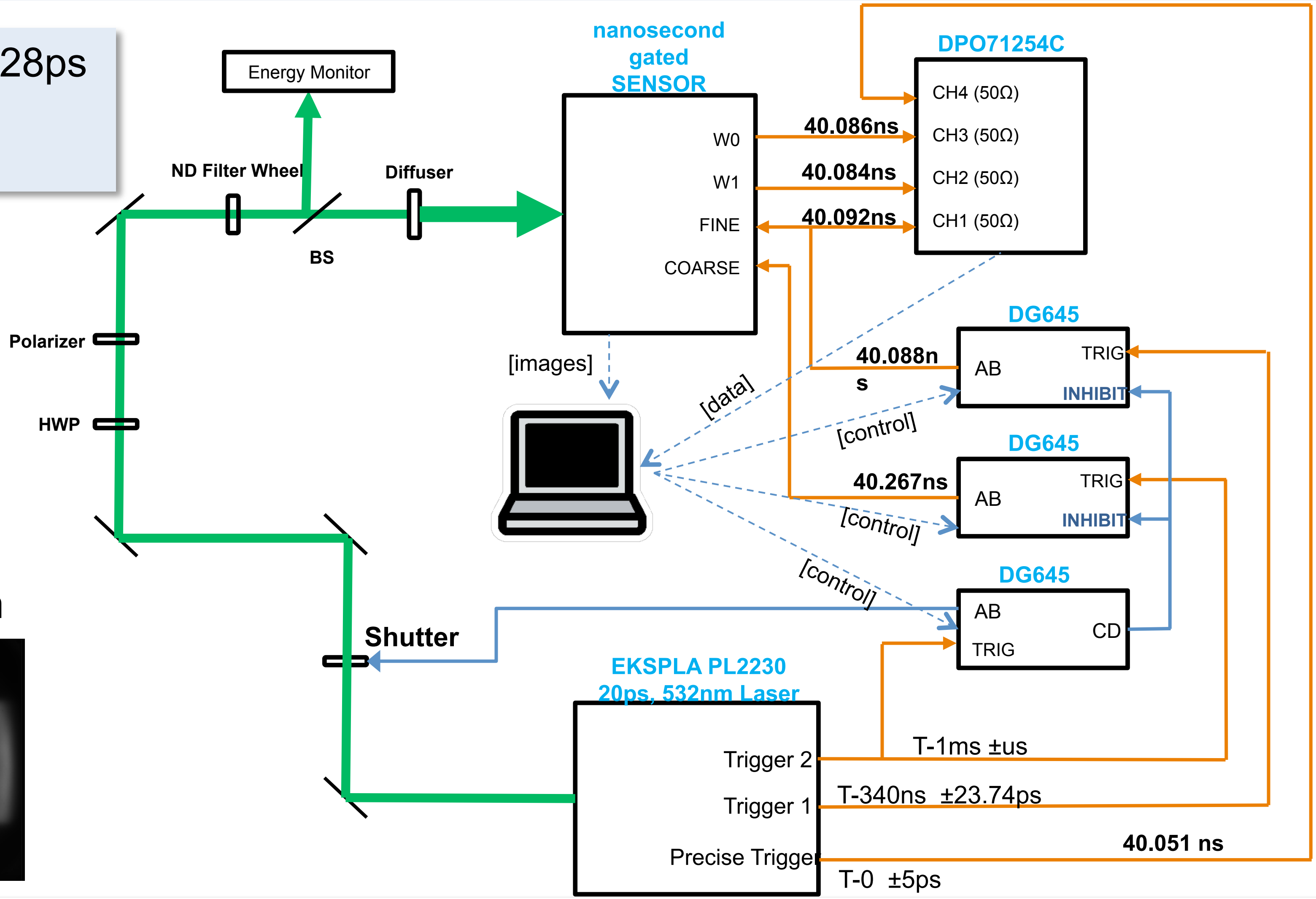
EKSPLA PL2230 ND:YAG Laser

Parameter	Value
Pulse energy at 1053nm	>40mJ
Pulse energy at 532nm	18mJ
Pulse energy at 355nm	12mJ
Pulse energy at 266nm	5mJ
Pulse energy at 213nm	2mJ
Pulse duration (FWHM)	**28ps**
Pre-pulse contrast	> 200:1
Triggering mode	internal/external
Beam diameter	~6 mm

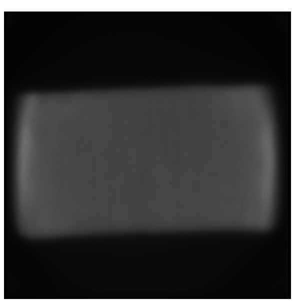
LLNL Framing Camera Laser Lab:

Laser and Controls Setup for hCMOS Sensor Characterization

Pulse width = 28ps
λ= 532nm
E ~ 1uJ/cm^2

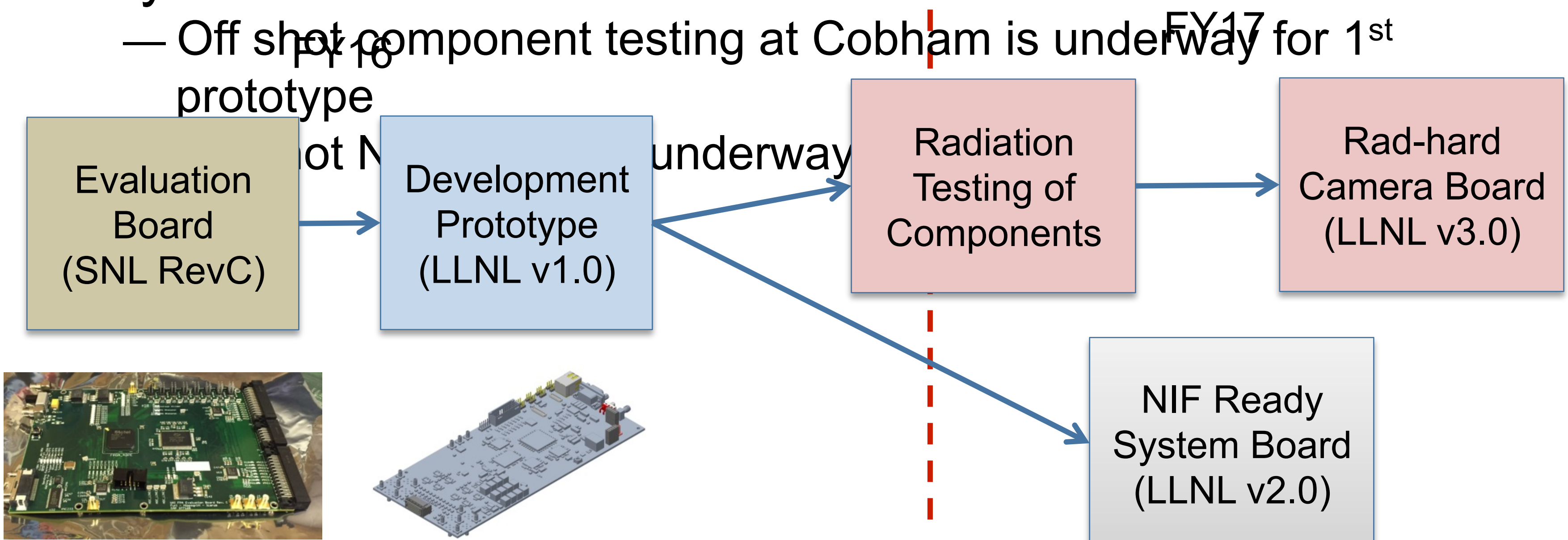


Laser Beam



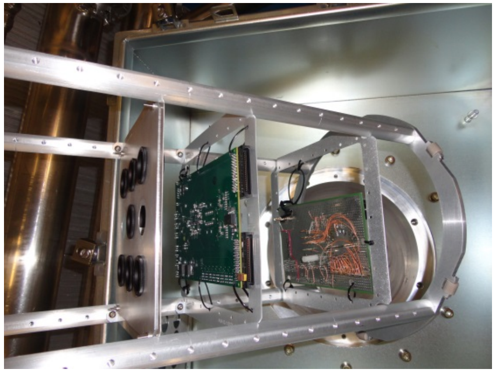
Rad-hard Cameras for use in NIF

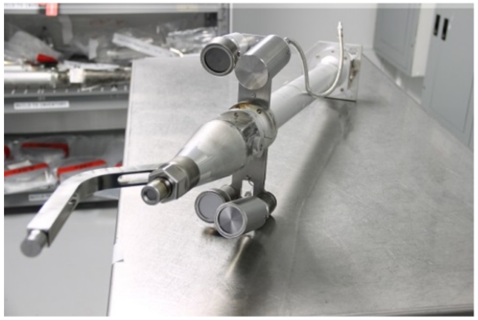
- Camera electronics must operate in >5e10 n/cm^2 environments
  - Commercial electronics to fail at a fluence >5e9 n/cm^2
- LLNL is building and testing neutron hardened camera systems
  - Off shot component testing at Cobham is underway for 1st prototype
  - ot N underway

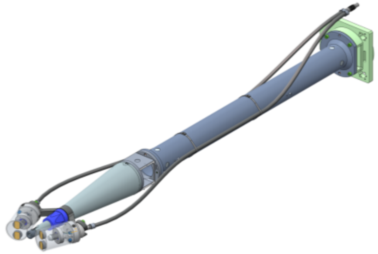


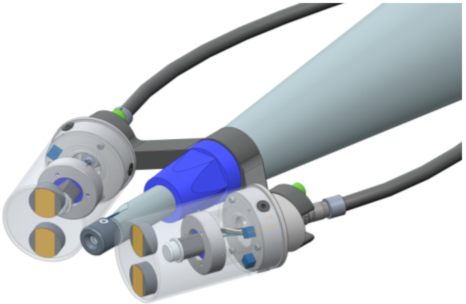
NIF On Shot Radiation Test Facilities

- Neutron Test Well (4.5m)
  - — Twisted pair and coax cables
- DIM Based Camera Test Box (1.5m)
  - — Twisted pair, MM fibers, and cooling water
- Neutron Effects Diagnostic (0.1m)
  - — Twisted pair



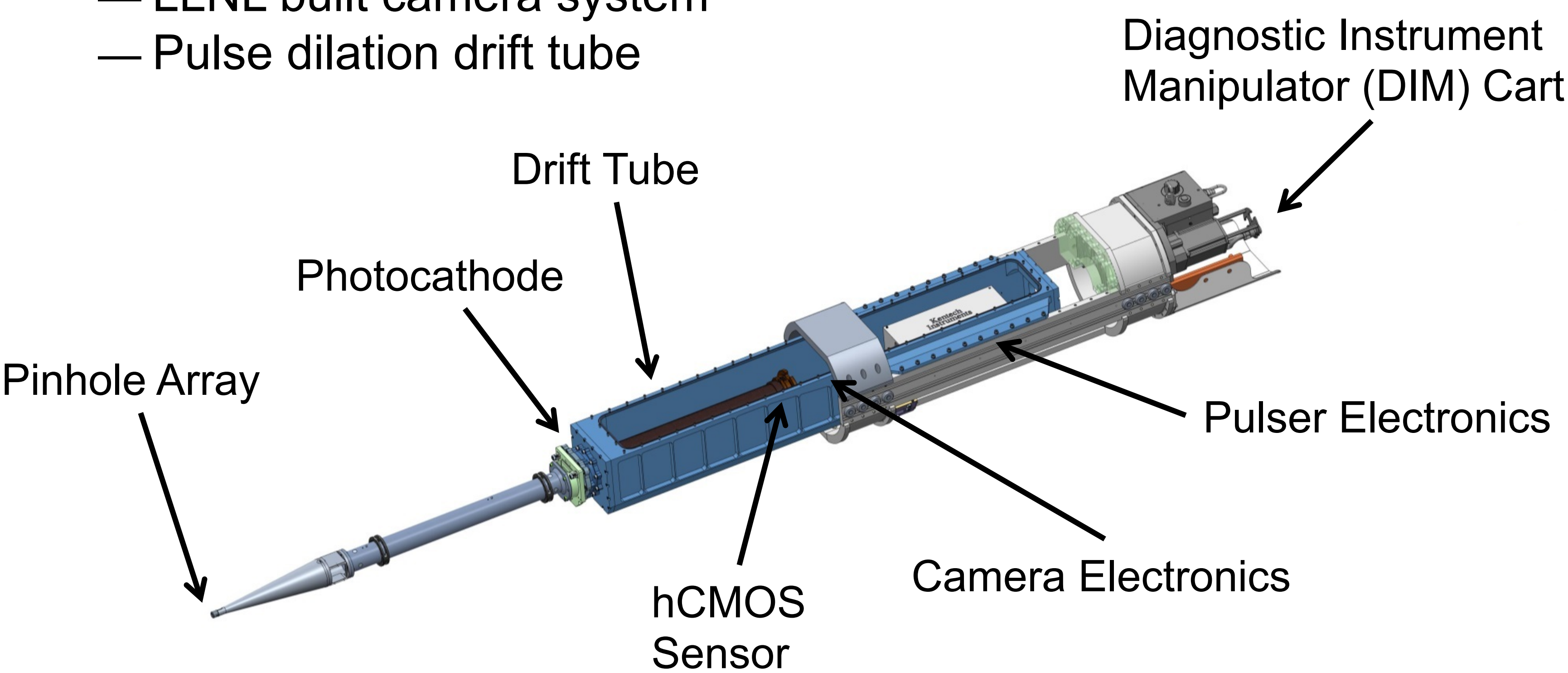




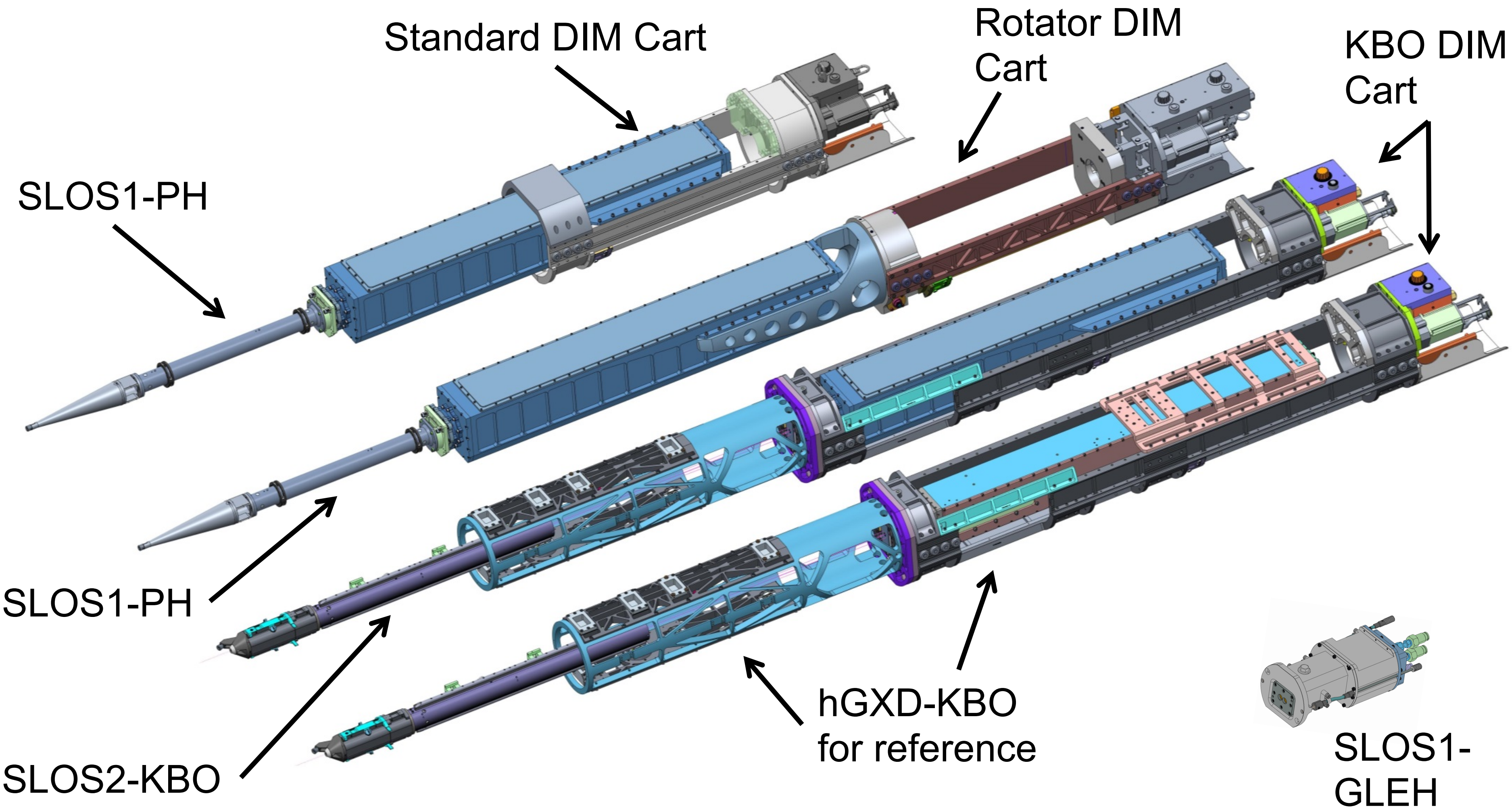


Integrate Camera System into SLOS1 Diagnostic

- SLOS1 Integrates:
  - — Pinhole Array or a Crystal Backlighter Imager (CBI) X-ray Optic
  - — The Icarus sensor in the chamber vacuum
  - — LLNL built camera system
  - — Pulse dilation drift tube



The SLOS diagnostic system can be fielded in many configurations



Acknowledgements

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  - Matthew Dayton, Chris Macaraeg, Brad Funsten, Pat Gardner, Sabrina Nagel, Brian Pepmeier, Bill Thompson, John Celeste, Jeremy Hill, Ken Charron, Perry Bell
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  - Terrance Hilsabeck
- National Security Technologies, Livermore Operations
  - Andrew Mead

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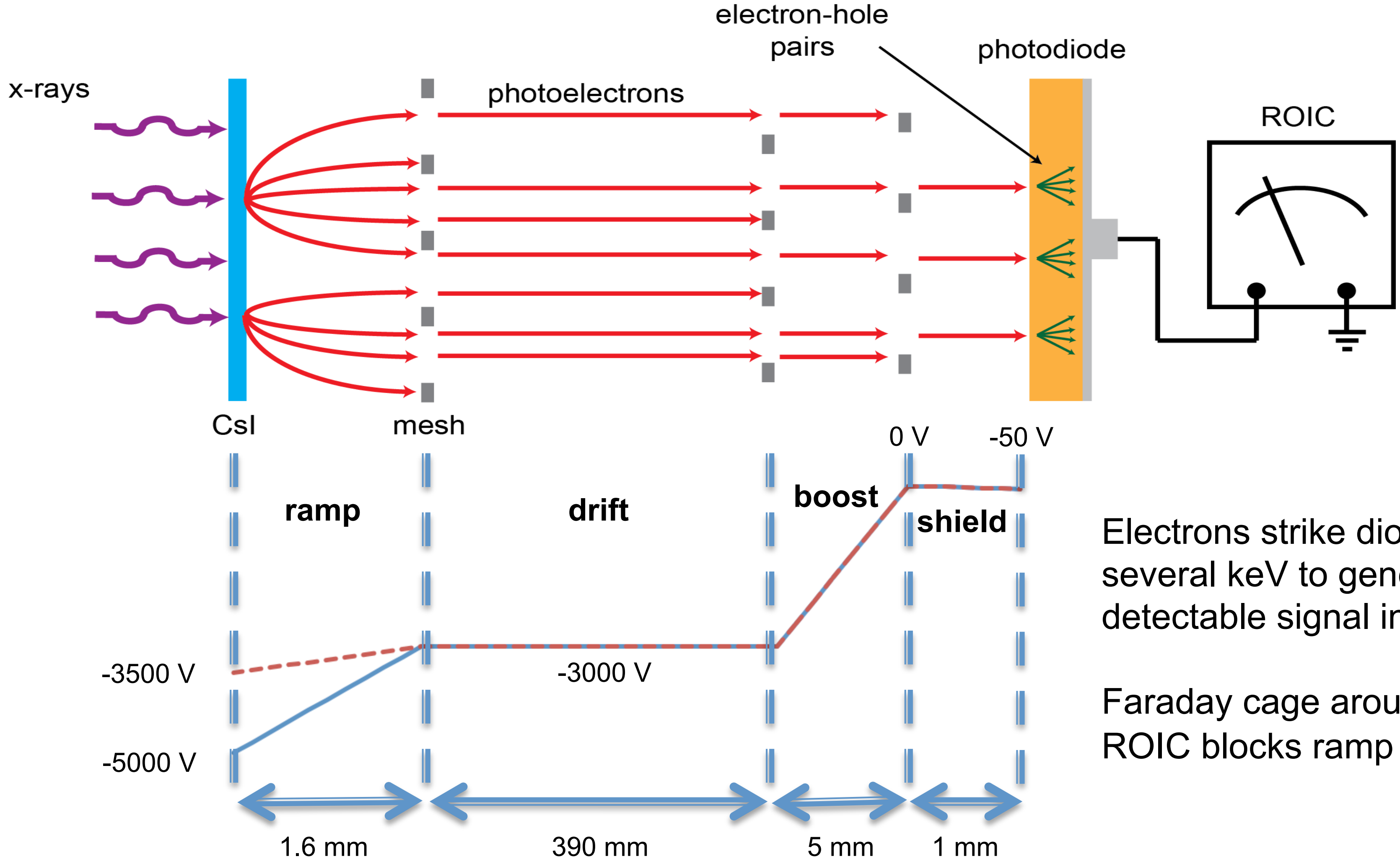
Backup Slides

- SLOS Drift Tube Concept
- Peak Response Ratio from 8 timing modes
- Furi Photon Transfer Curve
- Gate Profile for 10-10 timing mode in quadrants
- Gate Profile Fitting Equation
- Furi Movie and Raw points for Rising Edge of Gate
- Furi Colum Timing Skew
- Detailed Icarus Test Plan

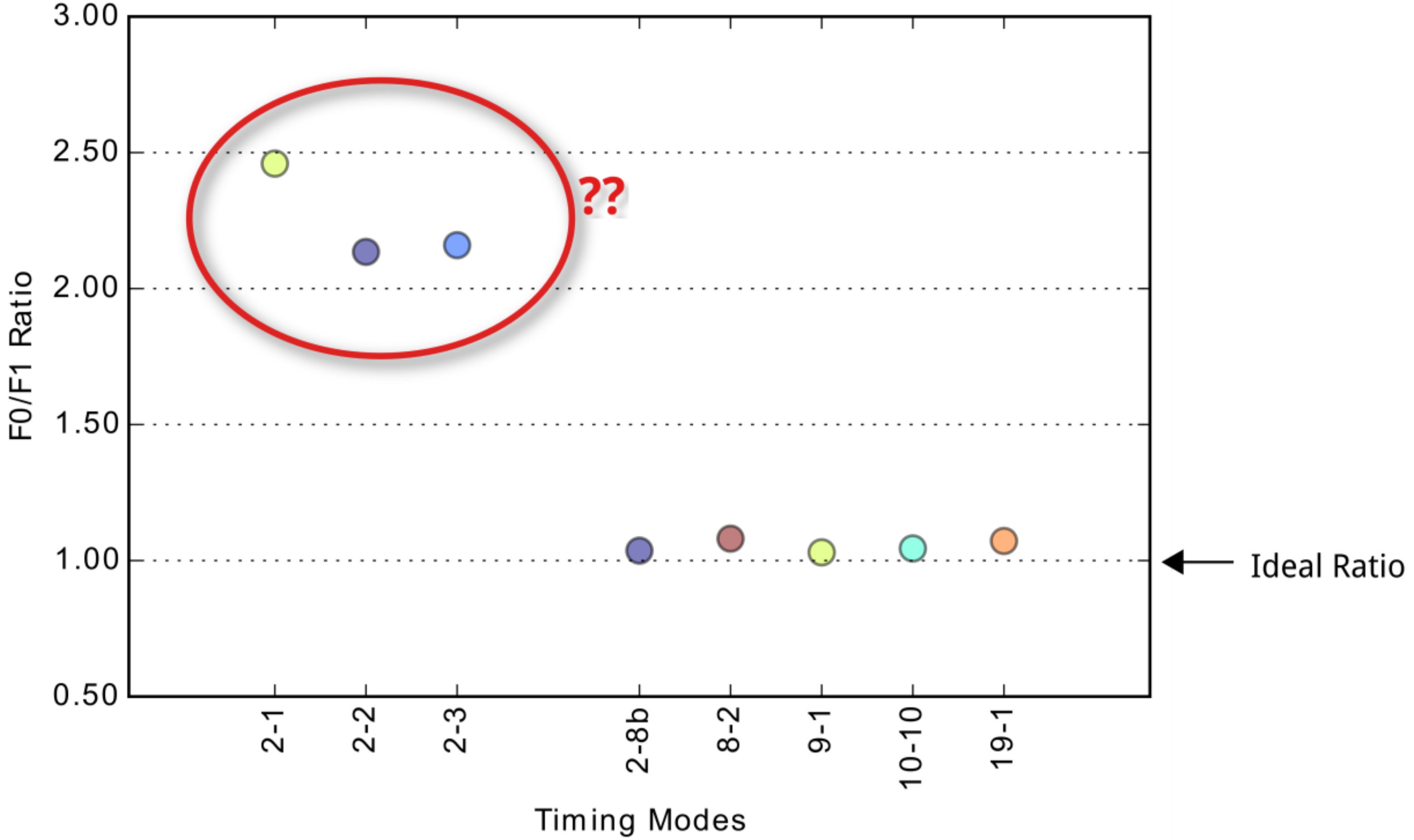
SLOS Drift Tube Concept of Operation



Electrons strike diode with several keV to generate detectable signal in ROIC

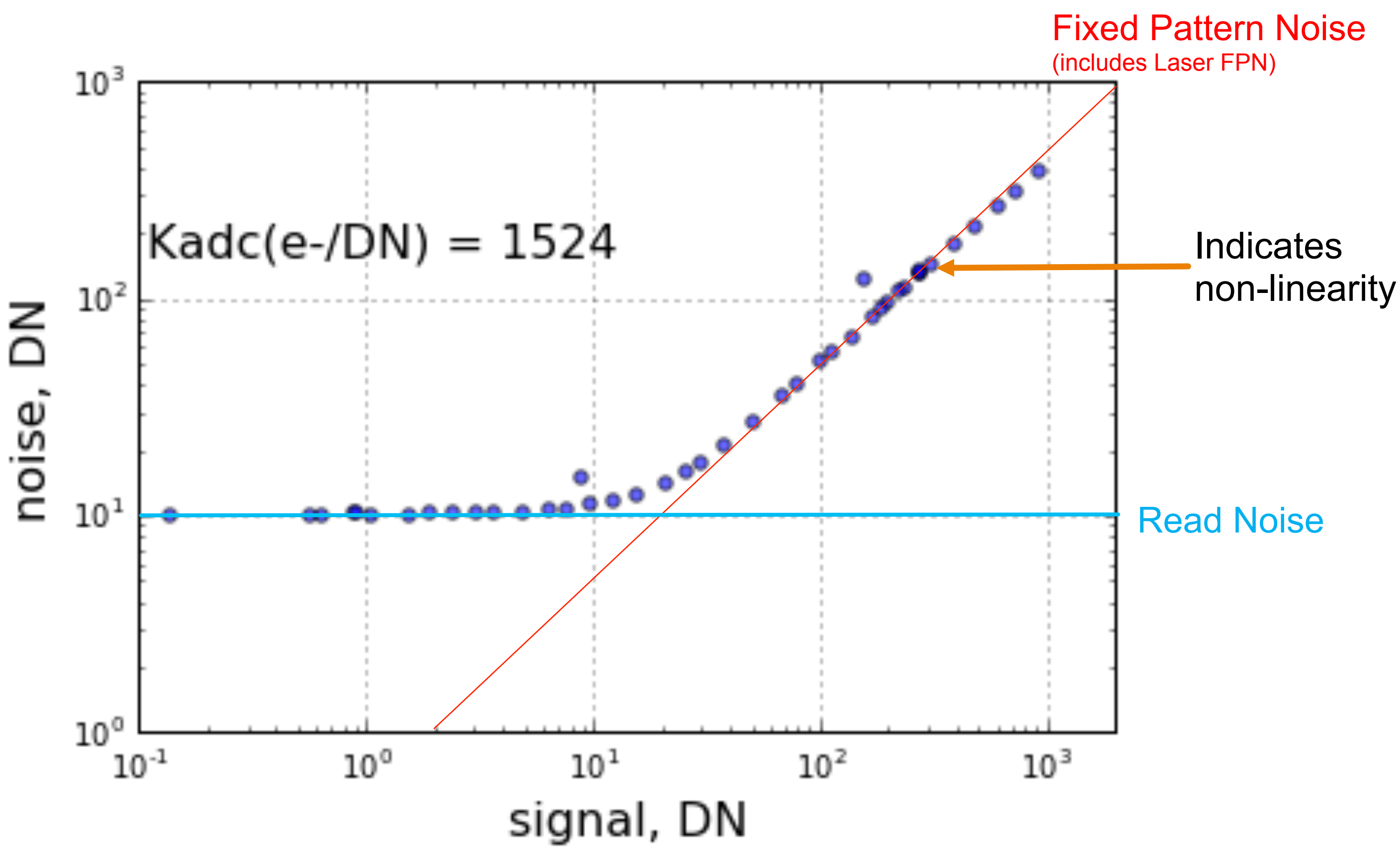
Faraday cage around ROIC blocks ramp noise

Ratio of peak response from Frame0 to Frame1 varies with timing mode



Every timing mode must be characterized

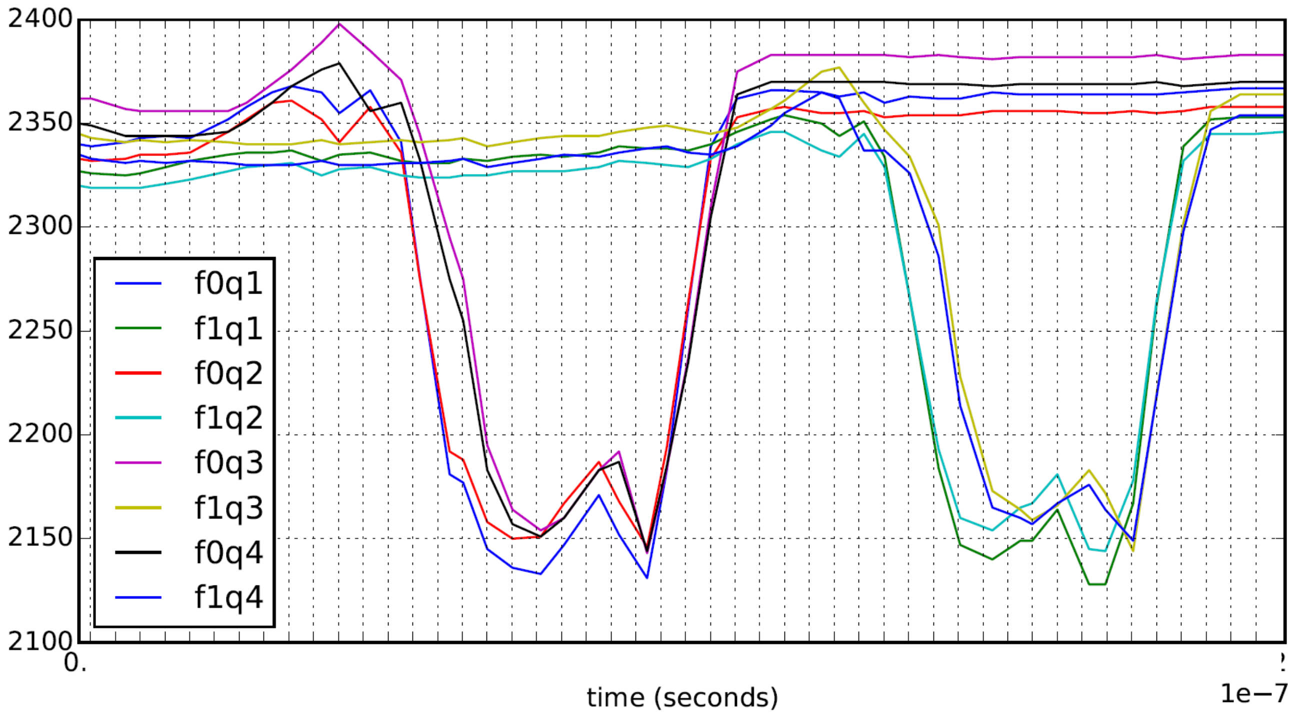
Furi Photon Transfer Curve

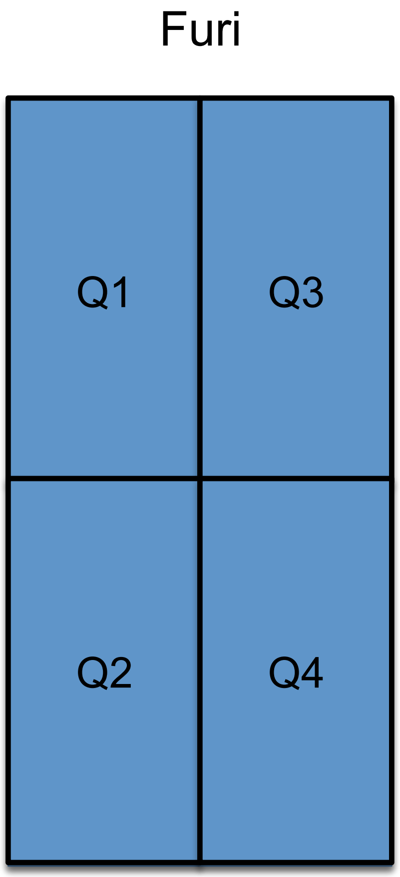


The ADC gain cannot be derived graphically since the system is not shot noise limited at any point.

Gate Profiles for any number of ROIs can be generated (10-10 timing mode shown)

- Minimum recommended ROI size is 2x2
  - At the individual pixel level beam speck movement causes errors in analysis





Gate Profile Fitting Equation

- Fit method: Two Sigmoids
  - — Allows for flat tops needed for longer timing modes
  - — Tau was equal for both sigmoids to reduce processing time
  - — Different rising and falling edge rates could be used in the future

$$f(t)=A/1+exp(-t-t1/\tau)-A/1+exp(-t-t2/\tau)$$

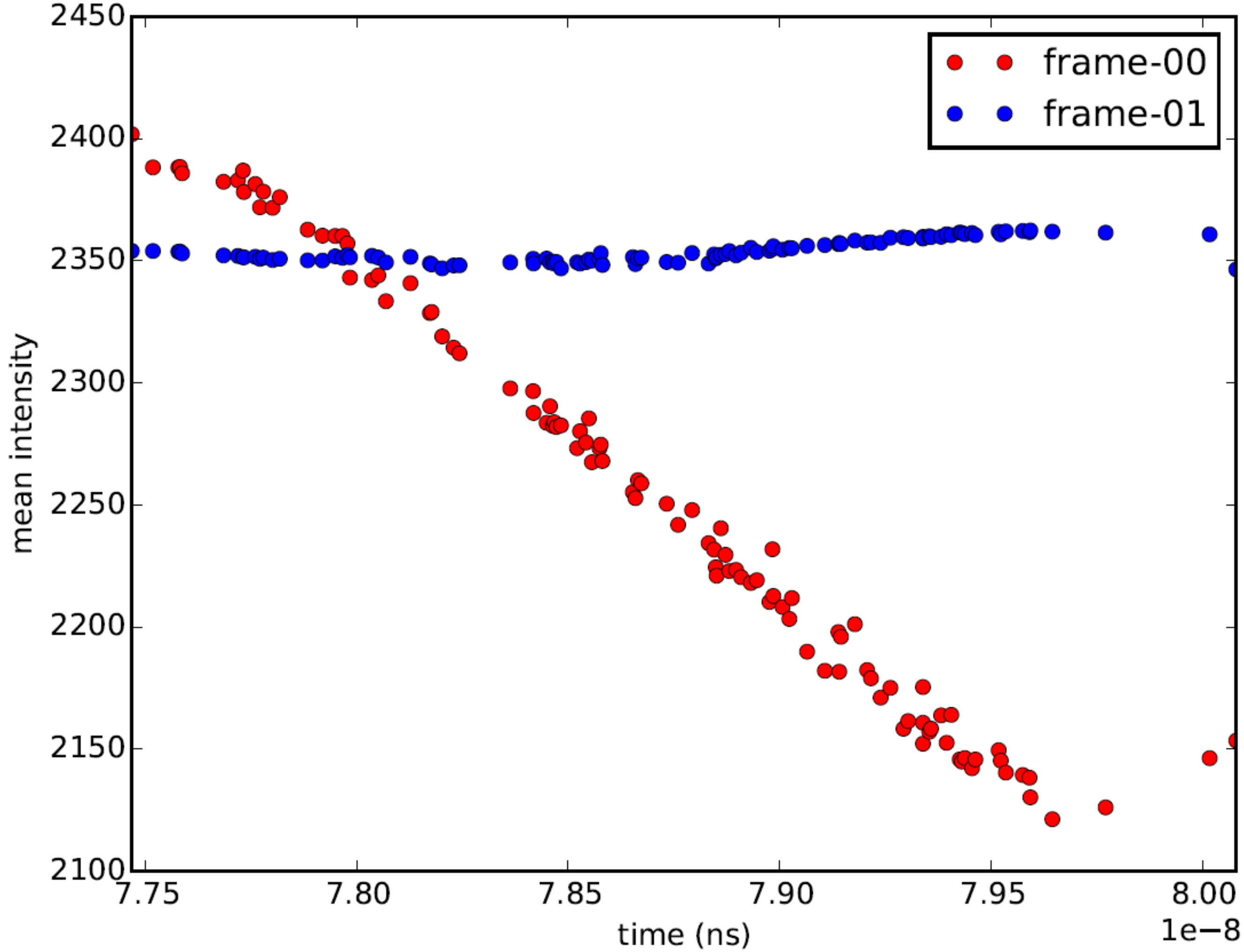
Example Fitting Parameters

	A	t1	t2	tau
f0q1	0.160178	7.85E-08	8.91E-08	5.30E-10
f1q1	0.153915	9.83E-08	1.08E-07	4.99E-10
f0q2	0.144384	7.85E-08	8.91E-08	5.28E-10
f1q2	0.13709	9.82E-08	1.08E-07	4.76E-10
f0q3	0.16814	7.97E-08	8.97E-08	7.99E-10
f1q3	48.82261	1.04E-07	1.04E-07	2.31E-09
f0q4	0.156966	7.96E-08	8.96E-08	7.33E-10
f1q4	0.149829	9.94E-08	1.09E-07	7.06E-10

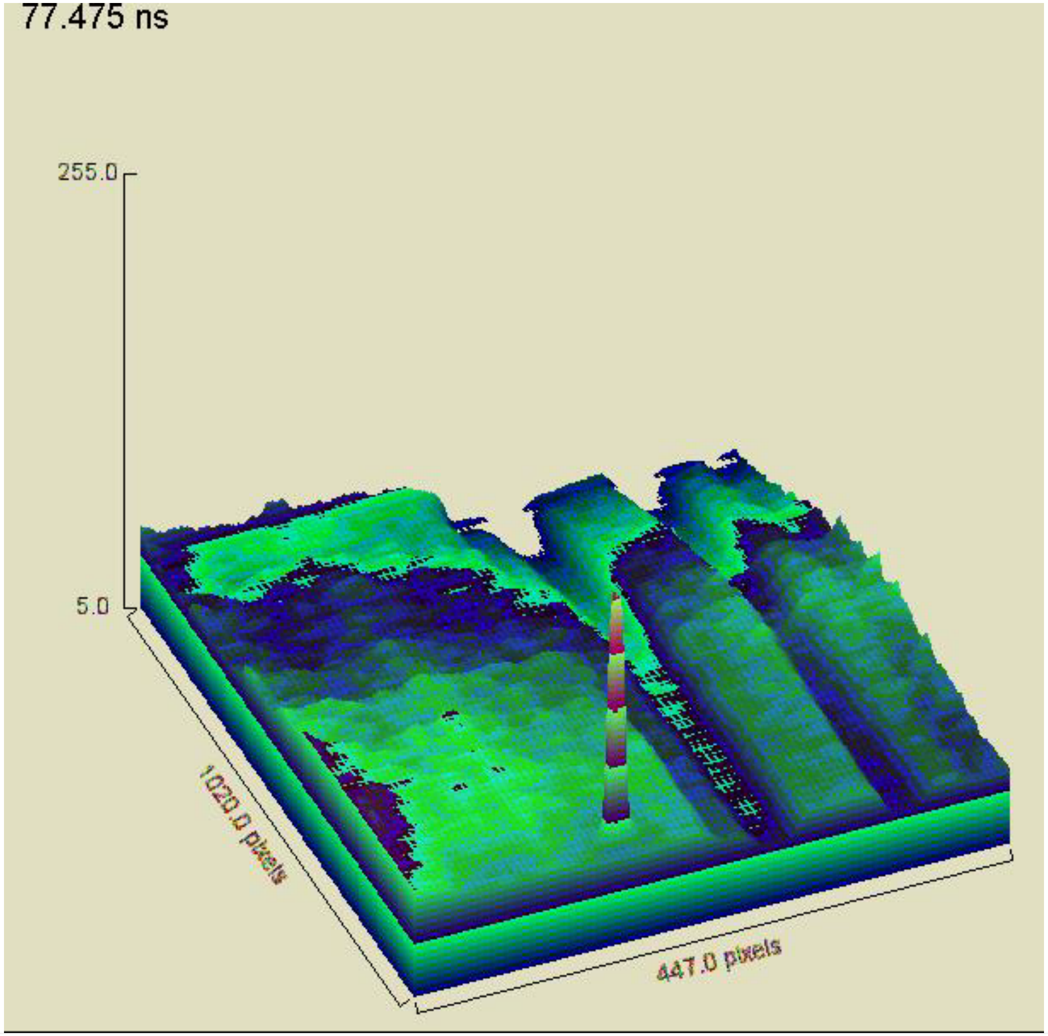
Example Results

	Peak	FWHM	RT	t1: 10%Peak	t2: 50%Peak
f0q1	0.160263	1.06E-08	2.33E-09	7.74E-08	7.85E-08
f1q1	0.153963	9.65E-09	2.18E-09	9.72E-08	9.83E-08
f0q2	0.144372	1.06E-08	2.32E-09	7.73E-08	7.85E-08
f1q2	0.13708	9.70E-09	2.10E-09	9.72E-08	9.82E-08
f0q3	0.167486	9.98E-09	3.48E-09	7.80E-08	7.97E-08
f1q3	0.154568	9.27E-09	3.14E-09	9.79E-08	9.95E-08
f0q4	0.156621	1.00E-08	3.21E-09	7.80E-08	7.96E-08
f1q4	0.149409	9.29E-09	3.09E-09	9.78E-08	9.94E-08

Edge Scan 20ps steps for Profile Movie

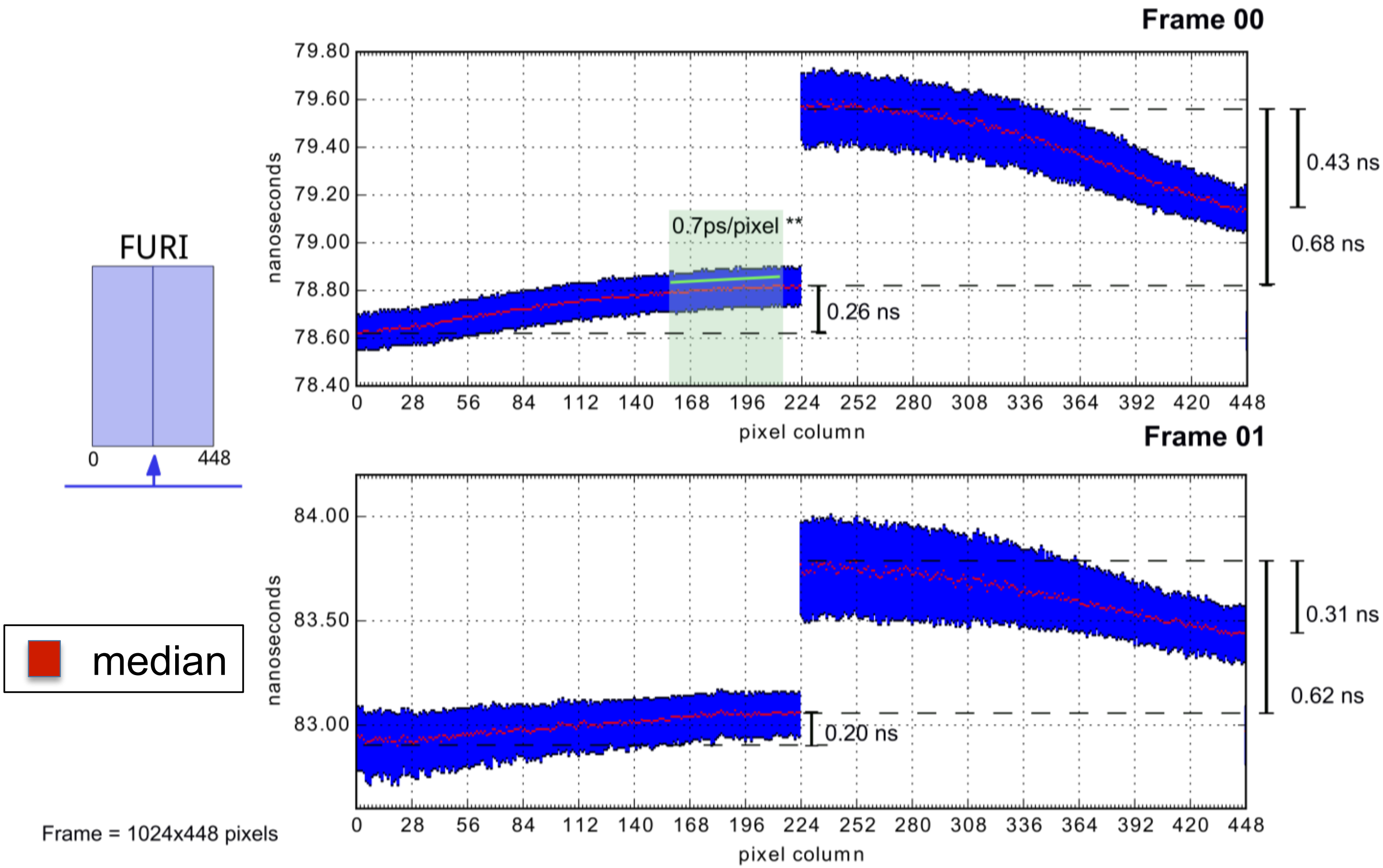


Gate Profile Movie 2-2 Timing Mode



Furi Column Timing Skew

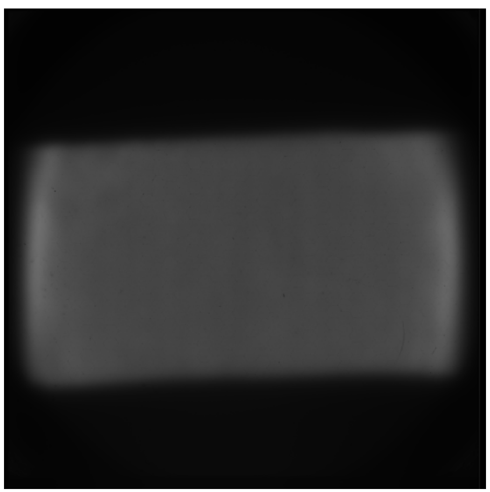
2-2 timing mode



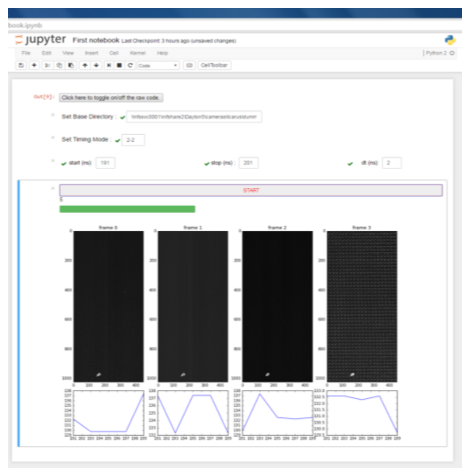
Frame = 1024x448 pixels

Detailed Icarus Test Plan

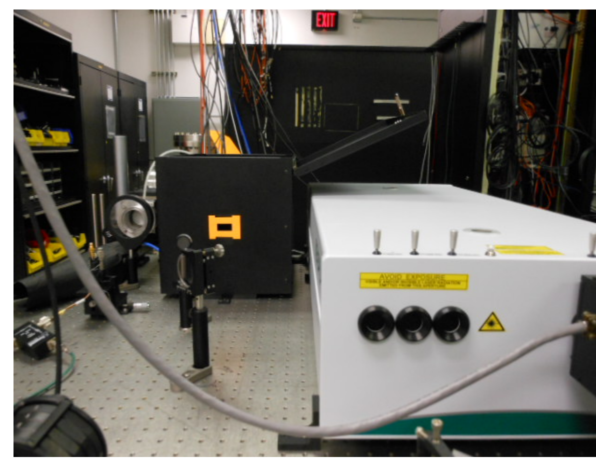
Test Type	Variables	Description
GP	Nominal OC	Gate profiles, use divA and divB for shutter monitors
GP	Hemi	Hemisphere timing gate profiles skew, with additional scope for other monitors, make sure scope interpolates
GP	Vrst	Vrst scan, profiles
GP	Vpd	Vpd 50V to 2V, profile
JIT	Nominal OC	Jitter measurement, No images needed. Could be extracted from Gate profile data, but cleaner this way
PTC	block edge loc	PTC (linearity and FW)
PTC	block edge loc	MTF (contrast edge) same software as PTC
PTC	V-ab	anti-bloom scan, PTC w/VAB



Laser Beam in Camera Box



Python GUI



LLNL X-ray Timing Lab