GXD3 at CEA, October 2015

conclusions and go forward proposals

CEA-NNSA Diagnostics workshop

29 June 2016

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On behalf of the framing camera teams

Lawrence Livermore National Laboratory

DE LA RECHERCHE À L'INDUSTRIE

cea

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The LLNL-CEA collaboration on framing camera flat fields has been very fruitful!

Applying different methods to a single camera demonstrated flat field equivalence ~25%

This may be sufficient for many experiments

Both teams have identified challenges to our methods that impact our detailed understanding of framing camera operation

We have identified remediation plans to address most of these

Going forward LLNL intends to build a lab similar to the CEA UV lab

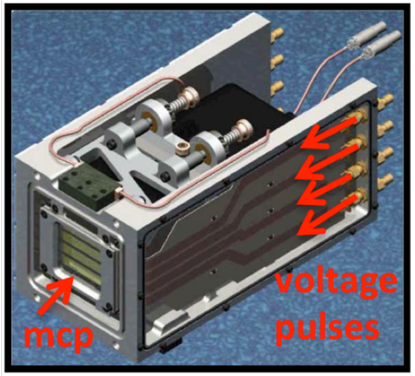
Preferably in collaboration with CEA to share best practices

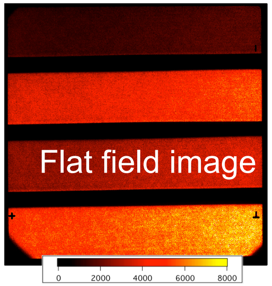
We should confirm improved equivalence between methods once mitigations are implemented

We are interested in further collaborations regarding other performance parameters such as:

camera-to-camera sensitivity; energy sensitivity; spatial resolution

Flat fielding is important because x-ray framing camera gain is very non uniform





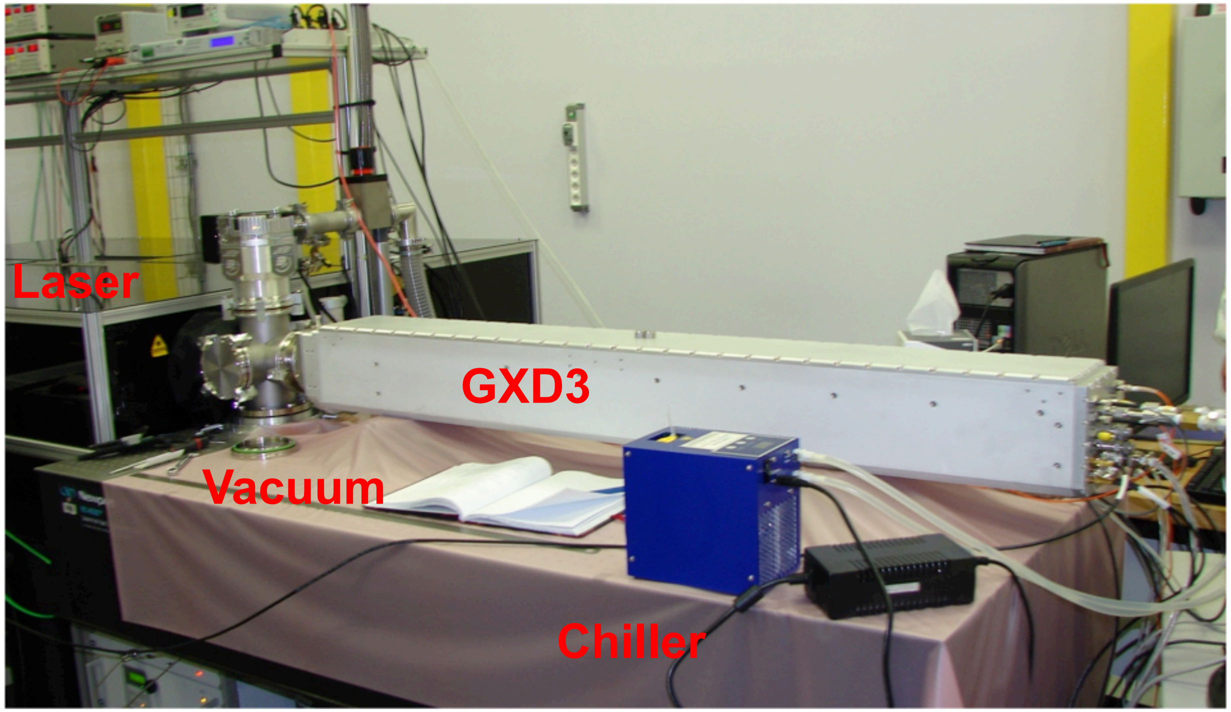
- XRFC consists of a microchannel plate (MCP) active area coated with 2-4 pulsed microstriplines for temporal gating.
- Each strip receives an independent voltage pulse that may be slightly different from the others (G~V $^{15-25}$, so small variations are significant!)
- Losses throughout strip cause "droop": gain loss from entrance to exit
- Because of cross-talk between microstrips, local gain depends on operating conditions (bias voltage and inter-strip timing)

IF framing camera data is used quantitatively, spatial variations in gain (ie "flat field") must be known!

CEA and LLNL use different techniques to create a flat field image
This collaboration is about evaluating the different techniques

We brought GXD3 to CEA-Arpajon in October, 2015

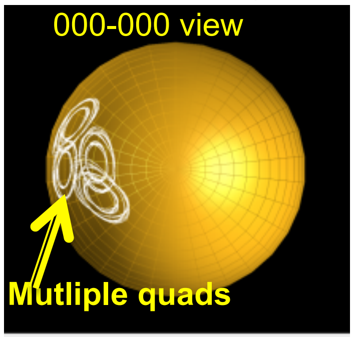
CEA and LLNL use different techniques to create a flat field image
This (portion of the) collaboration is about evaluating the different techniques *with a single camera*



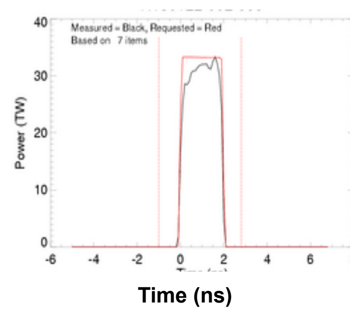
Direct X-ray Method: Single Exposure to X-rays (NIF)

- **Uniformly illuminate active area for entire measurement**
- **Signal to Framing Camera is mostly 8-9 keV x-rays**
- **Adjust observed image for time-dependent flux based on SPIDER or Dante Measurement**

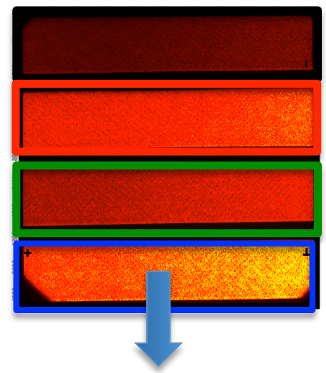
Au Sphere Target



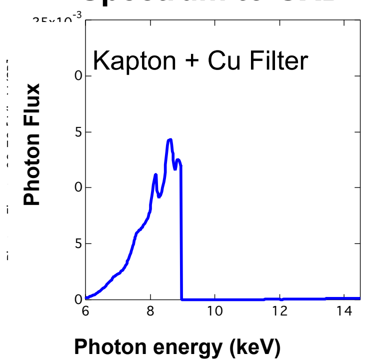
Square laser pulse



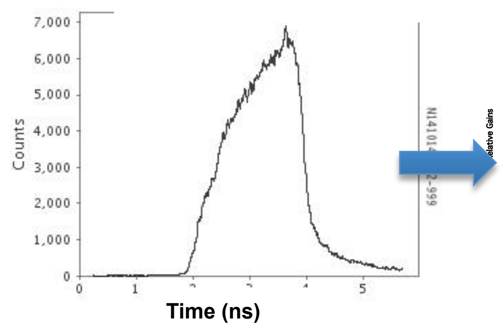
Flat Field Image



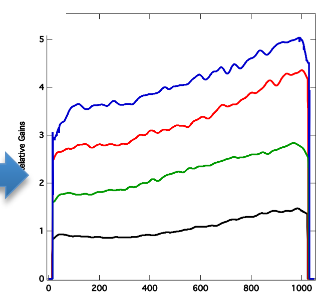
Spectrum to GXD



Streaked signal



Relative Gains

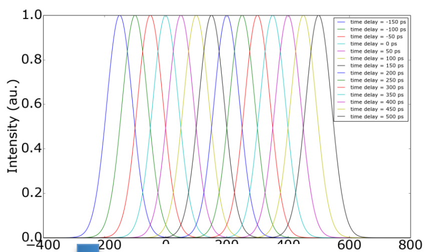


S. F. Khan, *et al.* , *Rev Sci Instrum* **83**:10, 10E118 (2012).

UV Flat-field Construction: Multiple Exposures summed to recreate a single exposure (CEA)

Short pulse UV laser (25ps; 213 nm)
Multiple exposures span entire framing camera window
Images Summed

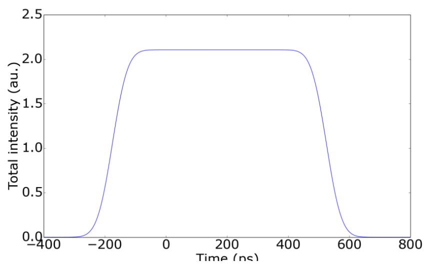
Individual Beam Profiles



Sum

Time (ps)

Equivalent source

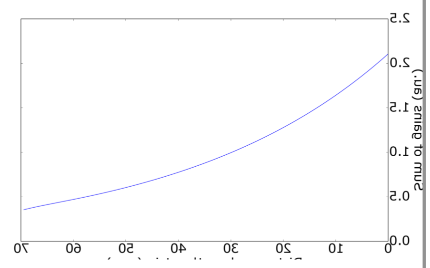


Time (ps)

Observed intensity

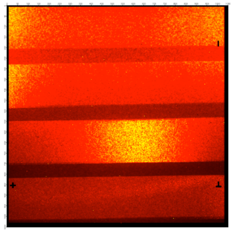
Distance at Detector

Equivalent response

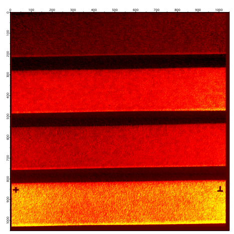


Distance at Detector

Single image



Flat Field Image

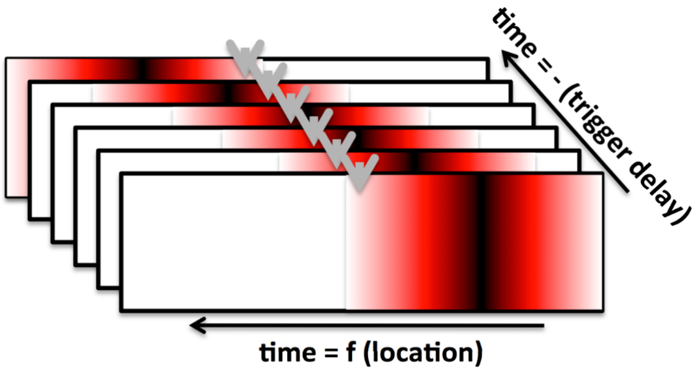


C. Trosseille, *et al.* , *Rev Sci Instrum* **85**:11, 11D620 (2014).

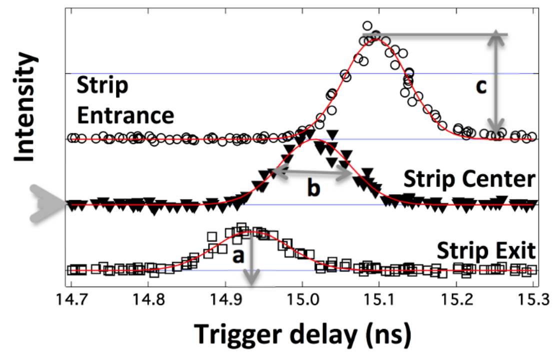
UV Gate Profile: Multiple Exposures to short UV laser analyzed in temporal space (NSTEC (and CEA))

Very short pulse UV laser (t<1ps; 200 nm)
Multiple exposures span entire framing camera window
Data analyzed for gain(time) at each location

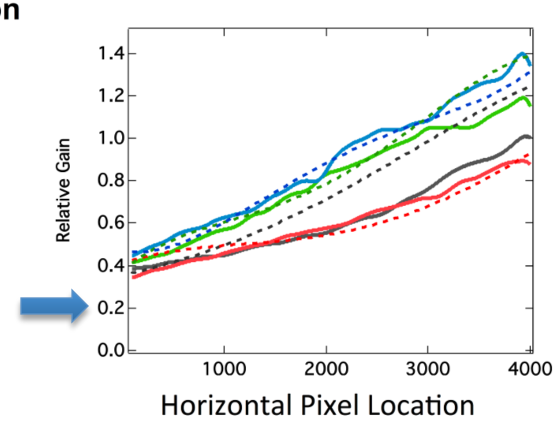
Gate Profile Data Set: intensity (location, delay)



Fit intensity to model for each location



Relative Gains



Pulse velocity and Gate width are also measured

L. R. Benedetti, *et al.*, *Rev Sci Instrum.* **87**:2, 023511 (2016).

UV flatfields were collected / constructed at four operating conditions to compare to available data

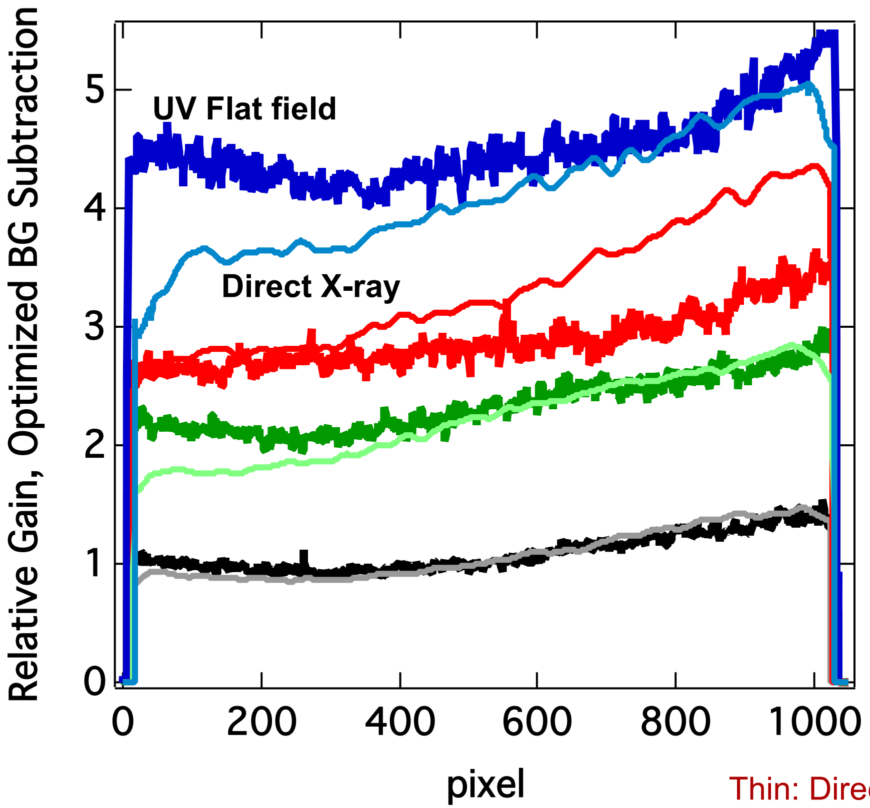
Experimental Configurations

Inter-strip Timing	Bias V	X-Ray	UV FF	UV GP	Witness
0 ps	50 V		X	X	
200 ps	100 V	X	X	(low quality)	X (150V)
350 ps	60 V	X	X		
0 ps 4000 ps 4000 ps 0 ps	60 V 100 V 100 V 60 V		X		X

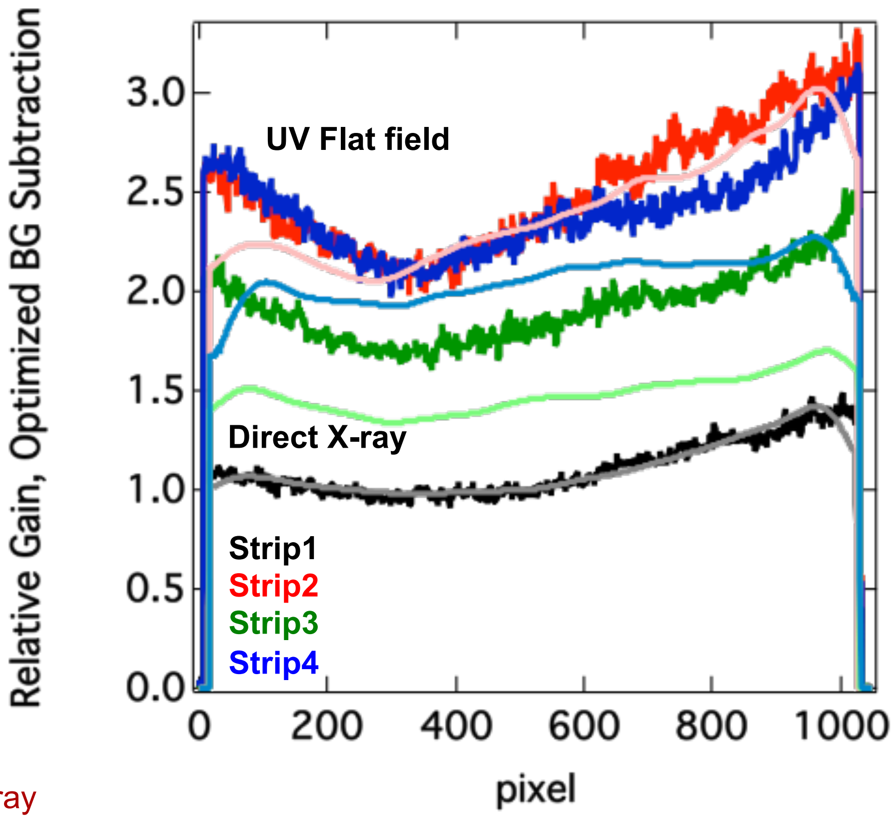
Direct X-ray
UV Flat Field Construction
UV Gate Profile
Additional witness plate experiments

Direct X-ray (NIF) is compared to UV Flat Field construction (CEA) at two conditions

100V bias, 200 ps inter strip



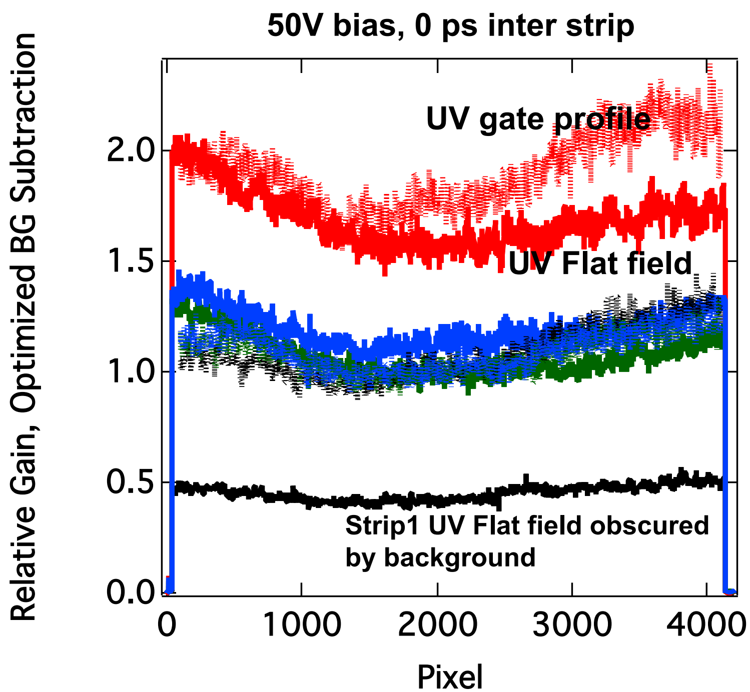
60V bias, 350 ps inter strip



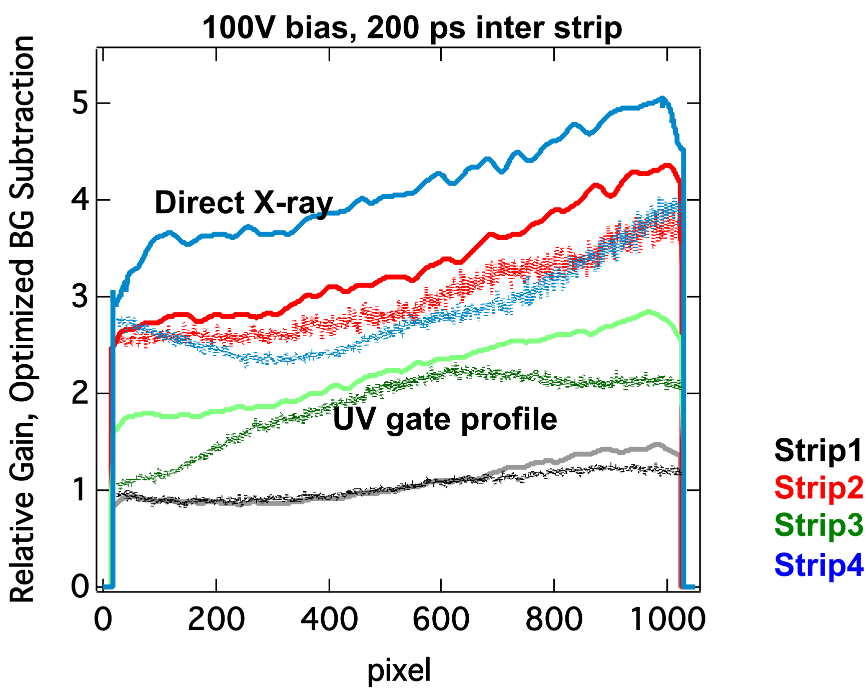
Thin: Direct X-ray
Thick: UV Flat Field Construction
Normalized to 1 at strip 1 center

The two UV methods are in the best agreement

UV Flat field construction vs UV Gate Profile

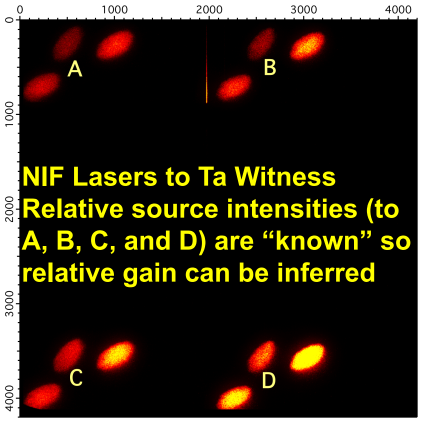


Direct X-ray method vs UV Gate Profile



Thin: Direct X-ray
Thick: UV Flat Field Construction
Dotted: UV Gate Profile

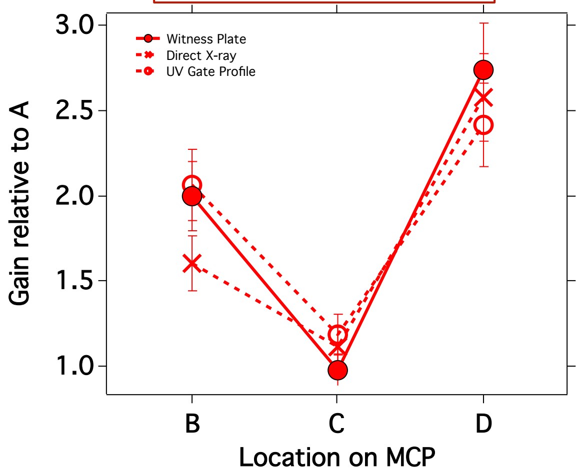
"Witness Plate" Experiments Infer Relative Gains



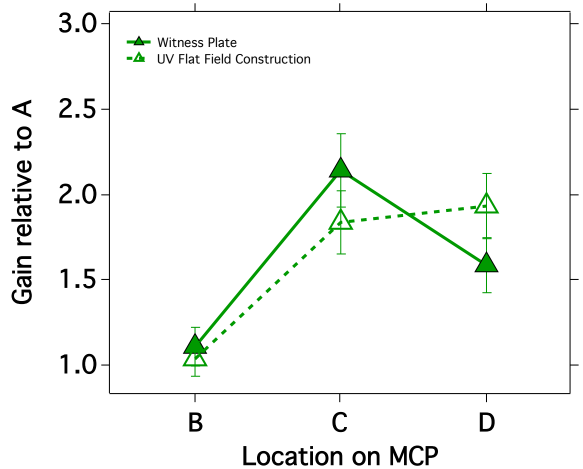
We compare the the relative gain at four locations (labeled A, B, C, D) from these experiments (closed symbols) to the relative gains at the same locations determined by our flat field measurements (open symbols)

- **Same source, imaged by pinholes to four locations at nearly the same time**
- **NIF laser, 10^{14} W/cm^2 to Ta plate, M = 2; 1-3 keV photons to MCP**
- **Analysis depends on calculated spectrum of emission**
- **Experiment was done to *three different cameras* in different configurations**

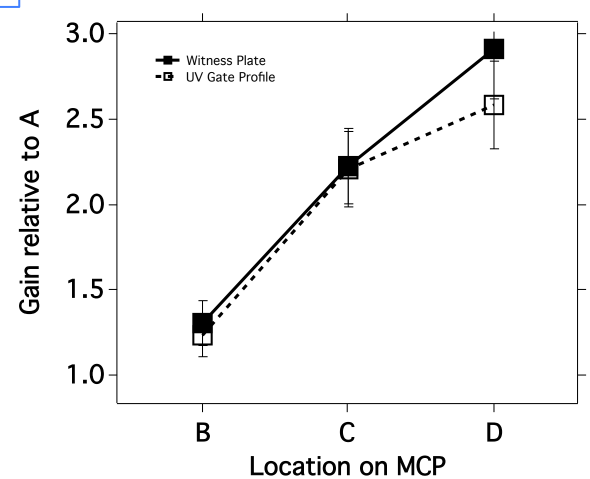
GXD1, Direct x-ray



GXD3, UV Flat field construction



HGXD1, UV Gate Profile



Error bars 10%

Solid: Witness plate
Open: Flat field

All methods agree with witness plate within 25%.
None agree within 10%

Pickworth, in preparation

All methods agree to about 25%

Internal Consistency Summary

- **When compared at identical operating conditions, all methods agree on gain order (which strip is brighter) and approximate droop.**
- **No methods agree within 10% at all locations.**
- **The two UV methods are most internally consistent**
- **There are significant differences between x-ray and UV methods in degree of reflection at strip exit**

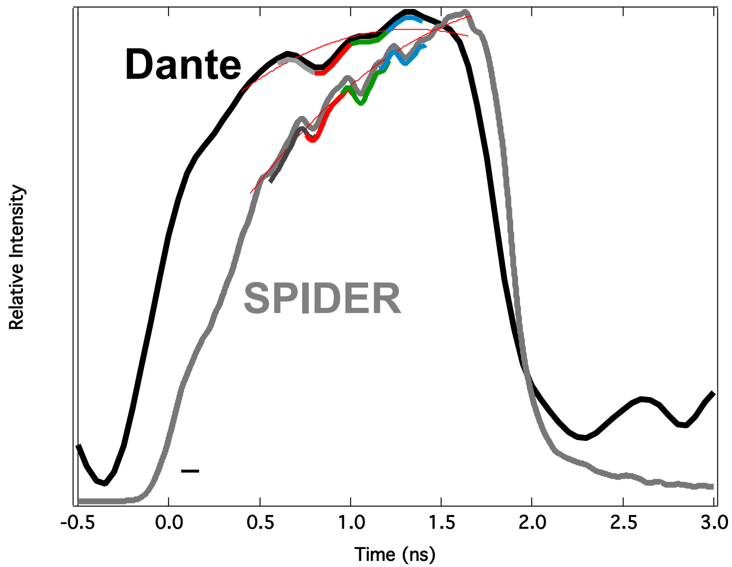
Differences between UV and x-ray response

- **Artifact effect** is much stronger for UV sources because photons interact at top of MCP and are held there until voltage pulse arrives
- **Reflection effect** is enhanced for UV sources

Uncertainty in Direct X-ray Method (NIF shot) is primarily related to determination of flux to GXD

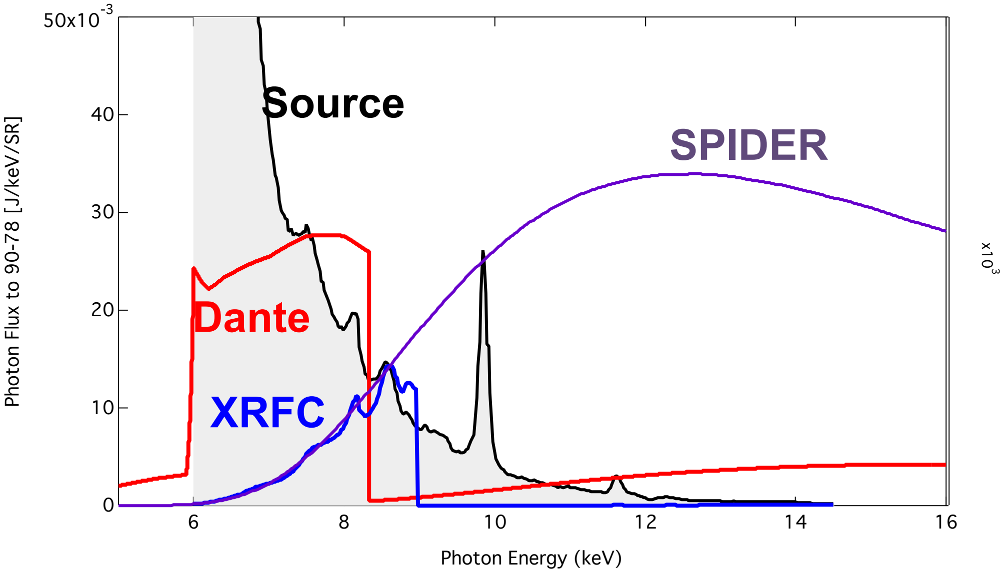
A reference instrument is required to normalize flat field by flux to mcp vs time

- **Relative timing is uncertain**
- **Emission oscillation not always distinguishable from noise**
- **Reference instrument signal levels are often LOW**
- **Spectral response is not equivalent**



N50916 – GXD3, 200 ps interstrip

Spider sees slower rise
Dante sees faster



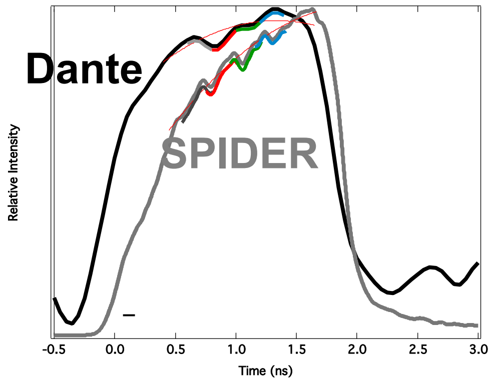
Spider sees harder x-rays;
Dante sees softer x-rays

Determination of flux to GXD can be improved by adjusting reference instrument setup for spectral-temporal equivalence

Dante and SPIDER references have been seen simplistically and were used in configurations convenient to the facility

Dante: build up a diode with identical filtering to GXD (Cu +kapton)
- **+ increase aperture/solid angle for signal levels**
- **+ add timing pulse after x-ray pulse to account for poor cross timing accuracy**
- **+ (account for Dante temporal response)**

SPIDER: add Cu filter to achieve 9keV cutoff **Source**
- **+ reduce CH if necessary for signal level**

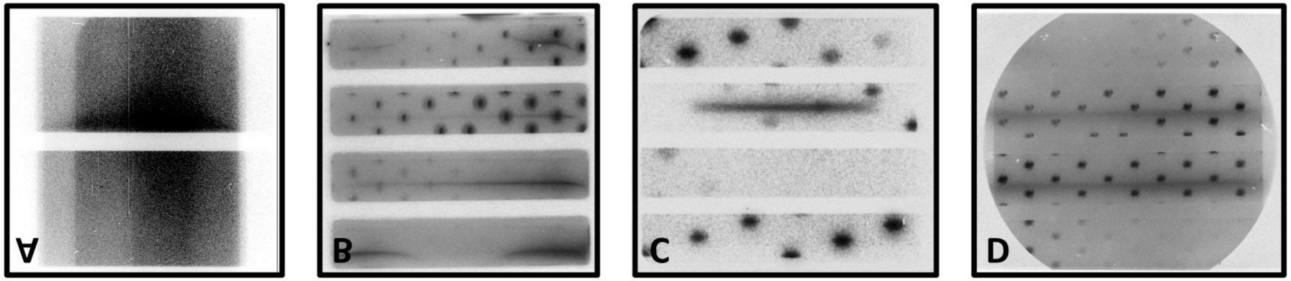


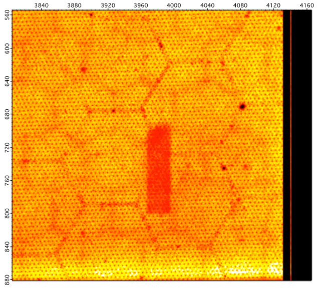
When filtered equivalently, we hope that Dante and SPIDER will see equivalent flux histories

Additional uncertainty sources in direct X-ray method

Early-light artifacts may alias results (GXD)

X-rays on NIF 1 ns before trigger





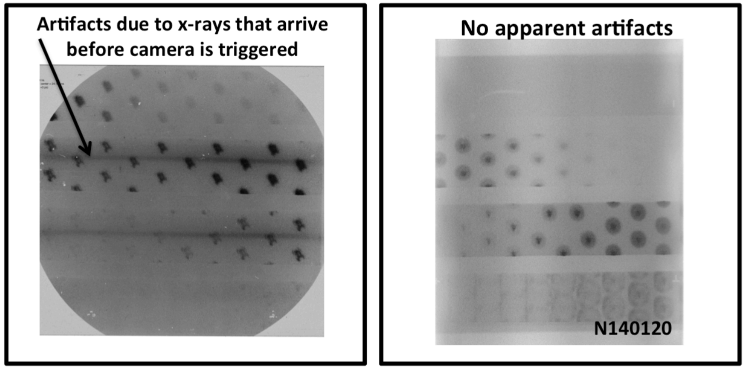
Statistics are poor

- Statistical repeatability not yet demonstrated
- Signal needed to distinguish fixed pattern details is 10x greater than linear range

Additional uncertainty sources in direct X-ray method

Add ERASER to GXDs to prevent early light artifacts

HGXI1 without ERASER | HGXD2F with ERASER



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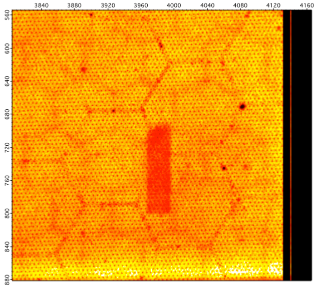
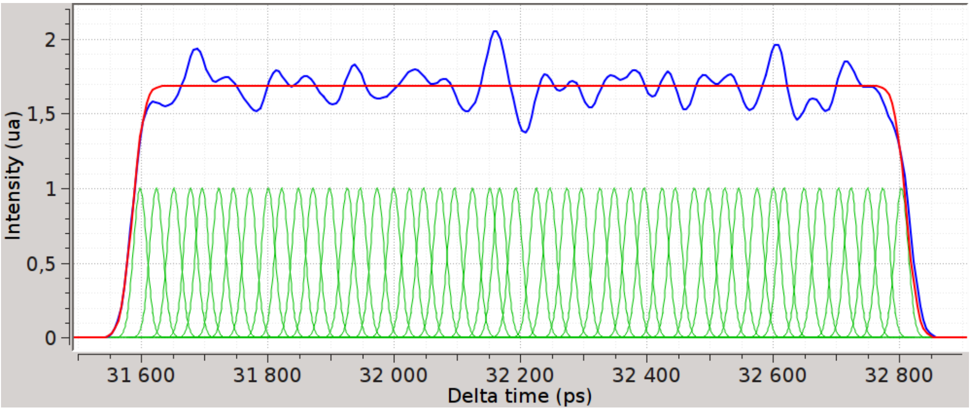


Statistics are poor

- Statistical repeatability could be demonstrated with multiple identical NIF shots
- Fixed pattern noise is unlikely to be correctable with this method

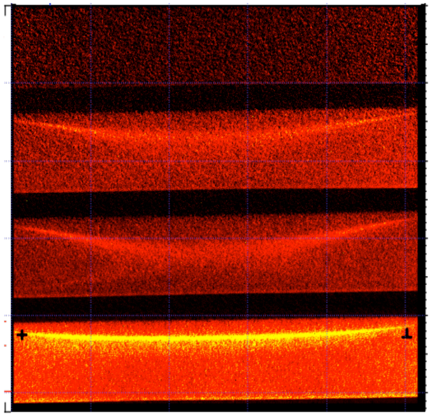
There are "issues" with UV source reconstruction

Uniformly-spaced Gaussians can make a flat source, but jitter prevents us from achieving perfect uniform spacing



Sum of jittered Gaussians is not flat

Early-light artifact is prominent in naively summed image



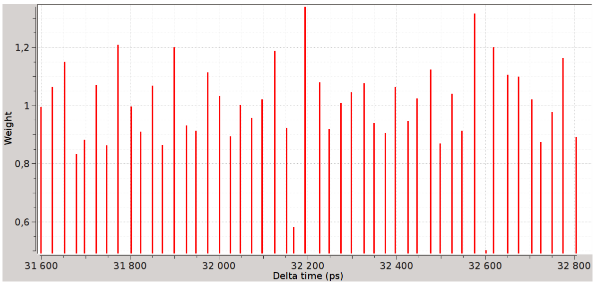
Artifact effect is much stronger for UV sources because photons interact at top of MCP and are held there until voltage pulse arrives

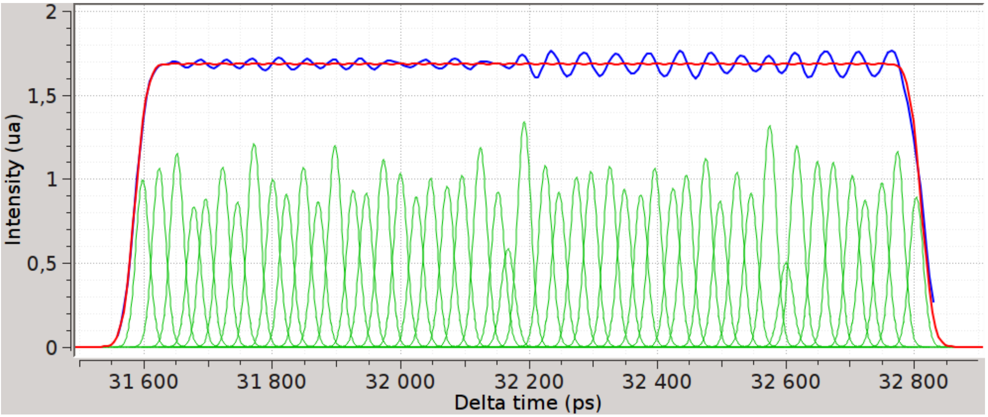
Weighted, summed source

Weighted, summed flat field

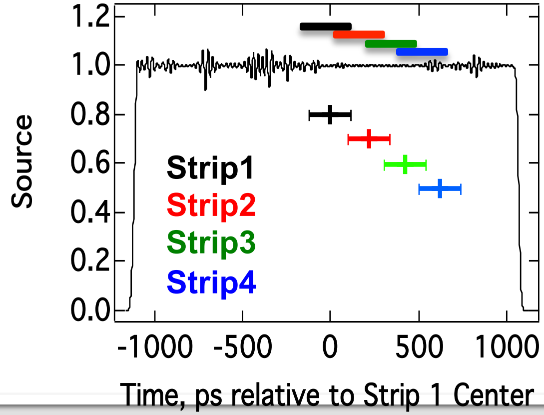
Source reconstruction is a solvable problem

Non-uniformly spaced Gaussians can be weighted to optimize flatness of source



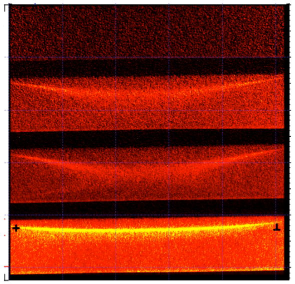


UV "source" can be re-interpreted as an individual source for each strip to prevent artifacts

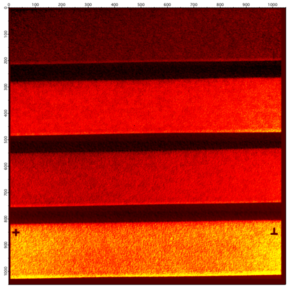


Weighted, summed source

Weighted, summed flat field



Using entire source

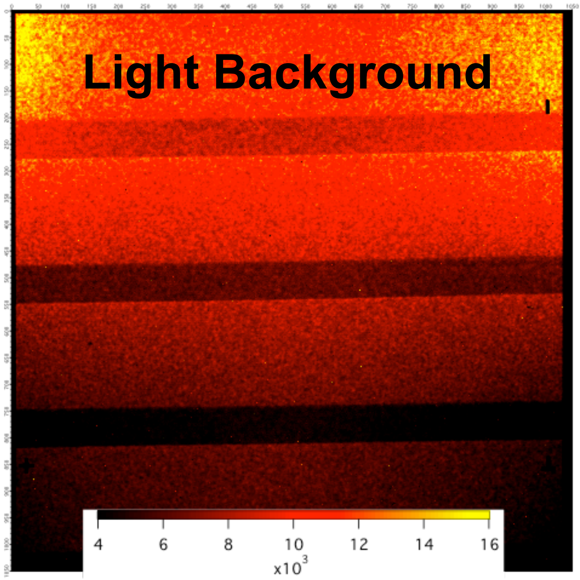


Using limited-time sources (bars)

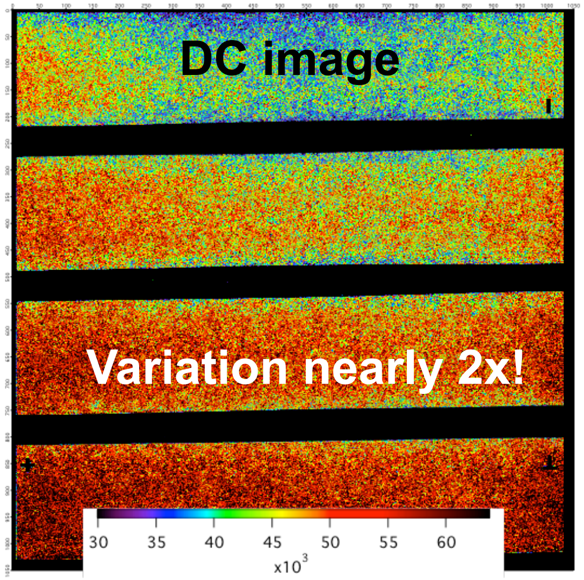
Non uniformity of background and DC images is very detrimental to UV flat field construction

Light BG is brighter than data

Image variation likely due to pore-angle effects



MCP at 0V; phosphor at 0V

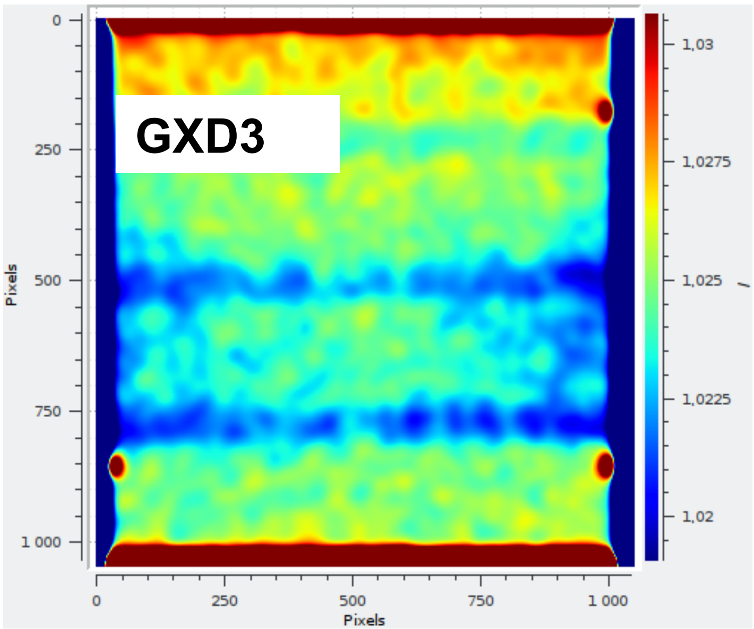


MCP at -750V; Phosphor at 3kV

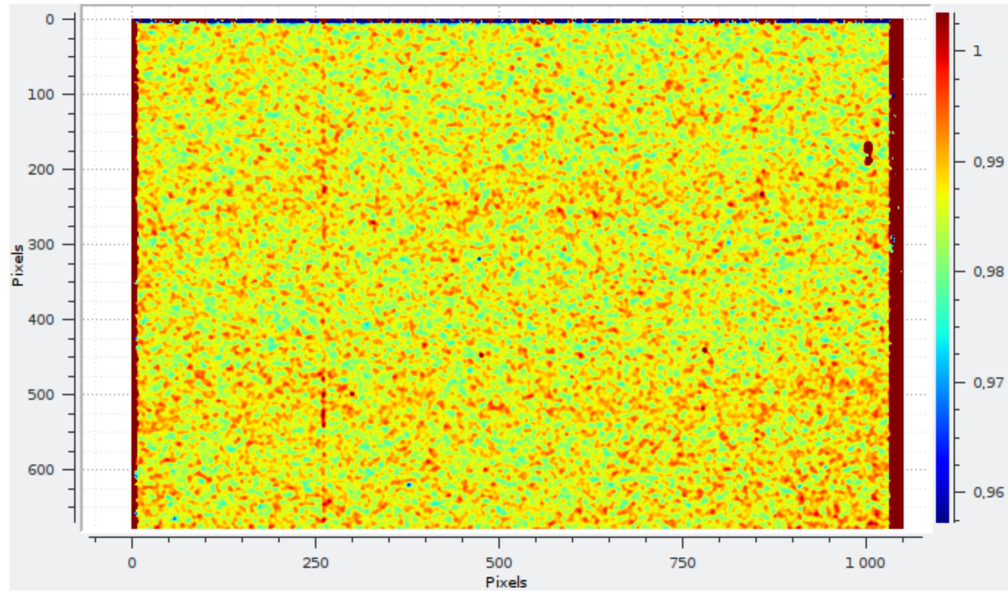
Background subtraction is critical because the flat field construction sums images that are mostly dark

ackground is not measurable *as we thought*

“Light background” : Laser on, instrument off indicates light that reaches phosphor without amplification



With/without phosphor voltage
(setup 06, using late shots)



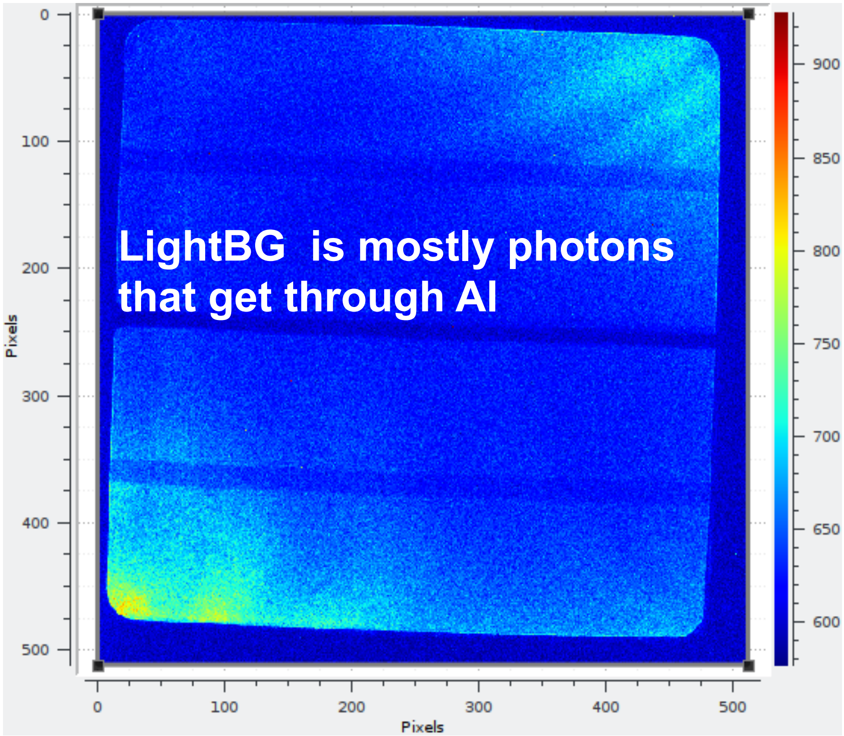
Ratio of ratios : setup 09d / setup 06

• Light background signals with and without phosphor voltage are not proportional, so we are probably not subtracting the right amount of background everywhere.

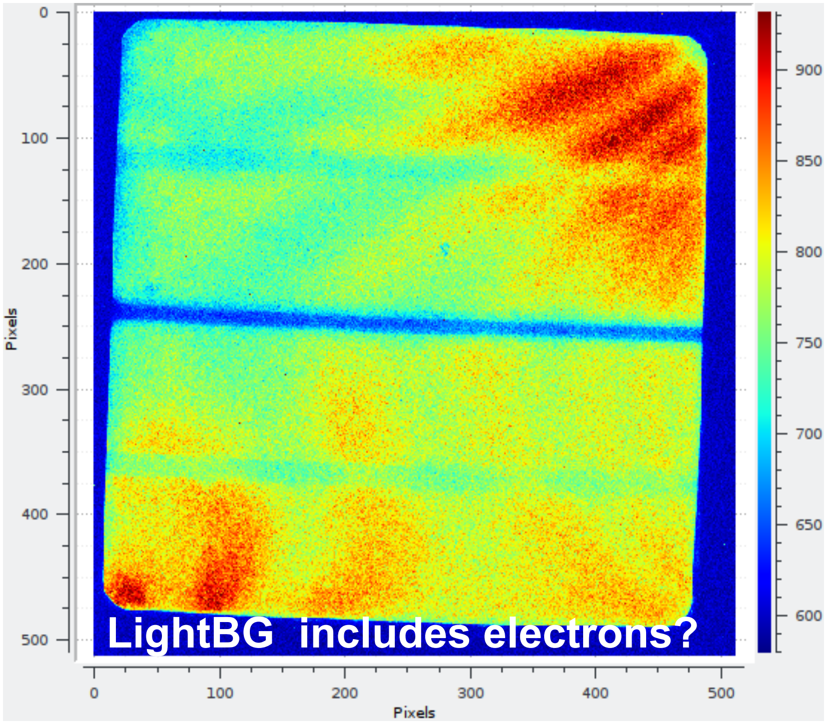
• The phosphor voltage on/ phosphor voltage off ratio seems to remain the same between configurations (multiplicative constant).

Light background (CEA MCP detector, uncollimated beam)

- **ARGOS camera has aluminized phosphor so few photons should reach phosphor directly**



Phosphor voltage off

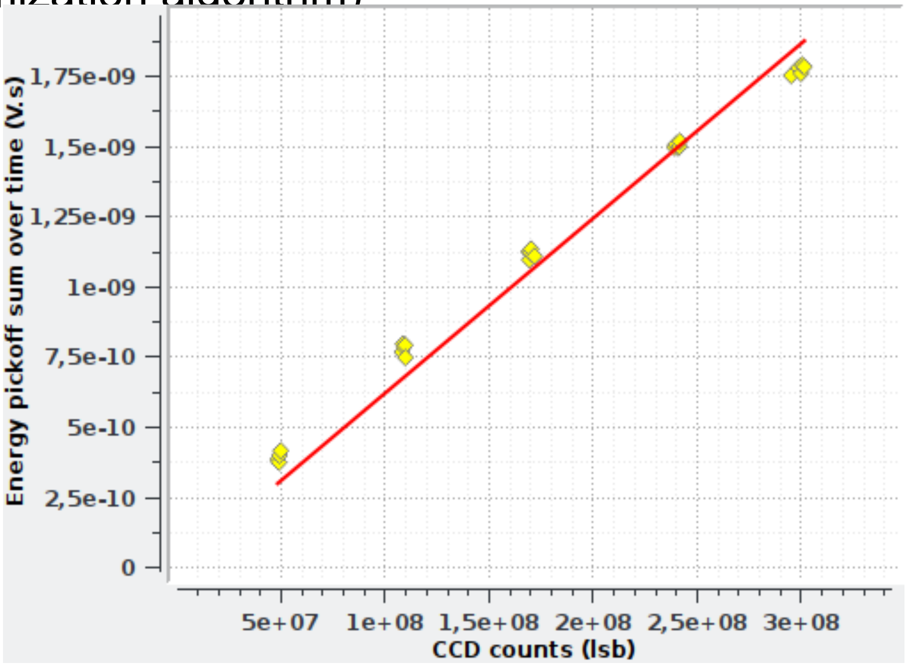


Phosphor voltage on, same color scale

- In both cases, some photons are converted into electrons late inside the MCP pores, which are then seen has an additional signal on the CCD

Light background subtraction is further complicated by changing laser energy

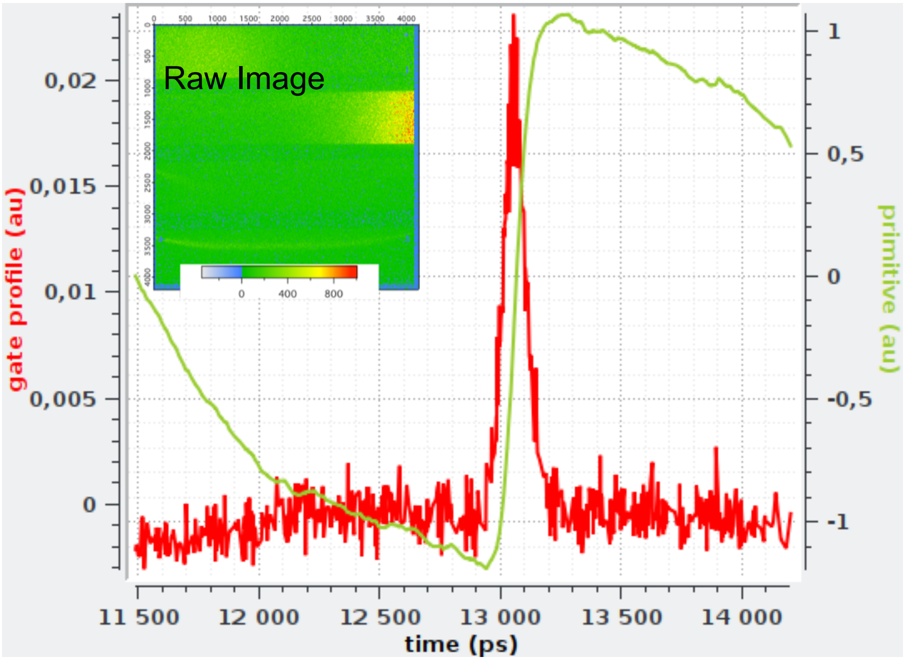
- Laser energy was dropping continuously and we took light backgrounds at the end of an experiment, so a **deviation from linearity** in the **energy monitoring pickoff** could explain the tendency to subtract too much background (before using the optimization algorithm)



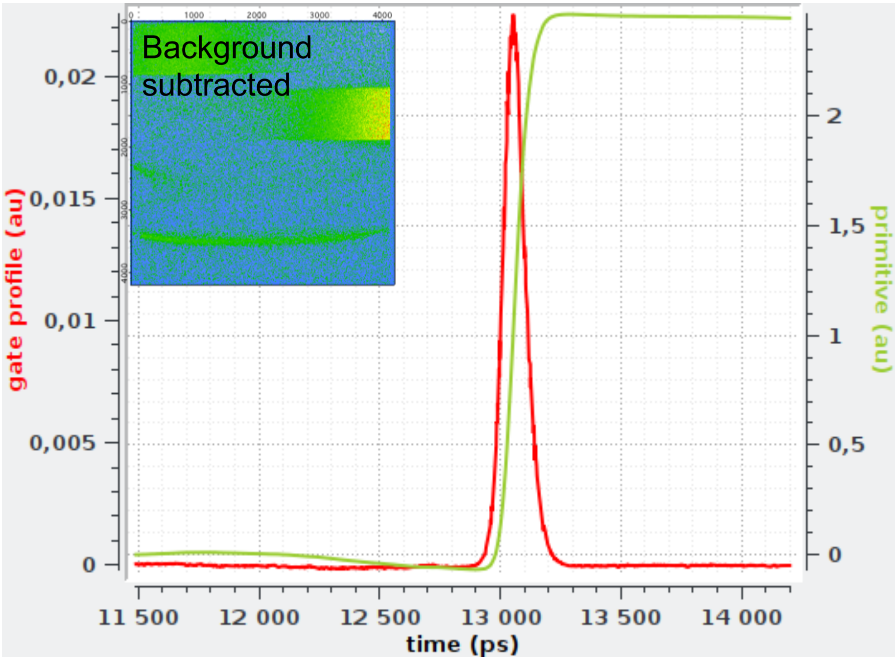
Energy pickoff linearity (diamonds = data, red = linear fit)

We developed an alogorithm to optimize background subtraction by maximizing the number of pixels near zero

Setup 07, center strip 1



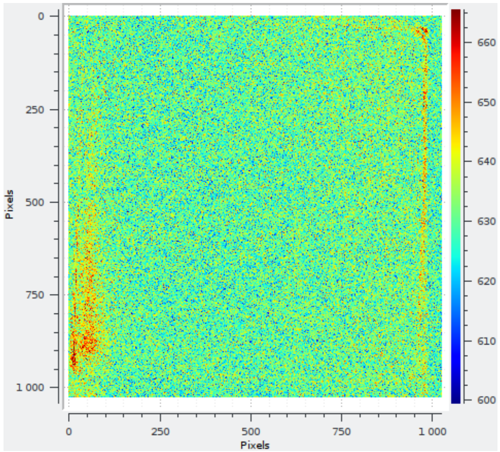
Without optimized background subtraction (OBS)



With OBS

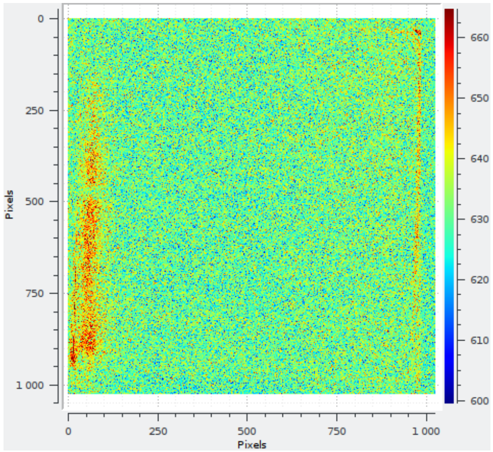
Even with OBS, there is evidence that non-zero values of the gate profile have an impact (few percents) on the flat-fielding value (ie. value of the primitive at the end of the time range)

nts at CEA confirm that light background can be nearly elimiated by changing angle of laser relative to MCP

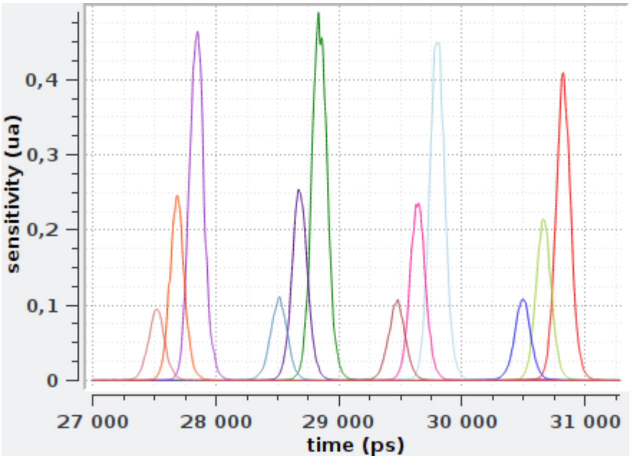


Light background (phosphor voltage off)

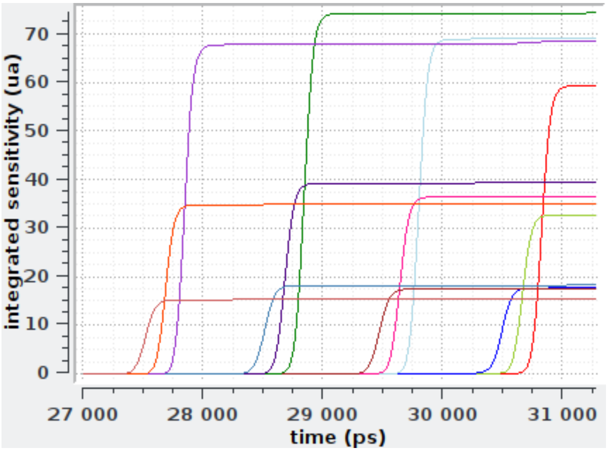
- We used a special flange to have the laser beam incidence depart 7° from normal
- Background is considerably reduced, with or without phosphor voltage
- Gate profiles look « clean » without any background subtraction tweaking (obviously)
- Needs to be confirmed with GXD



Light background (phosphor voltage on), same color scale



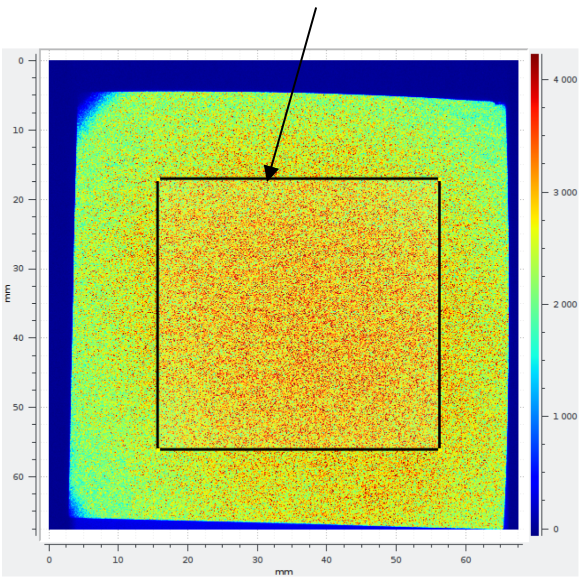
Gate profiles (strip 1-4, 3 locations)



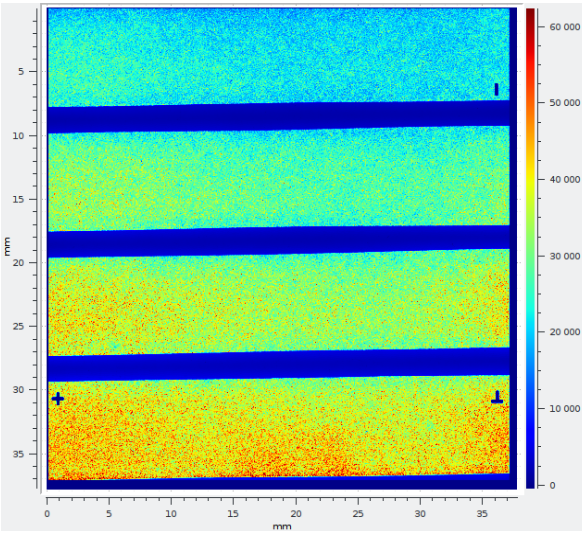
Associated primitives

Non-uniformity in DC image is not due to non-uniformity in laser source

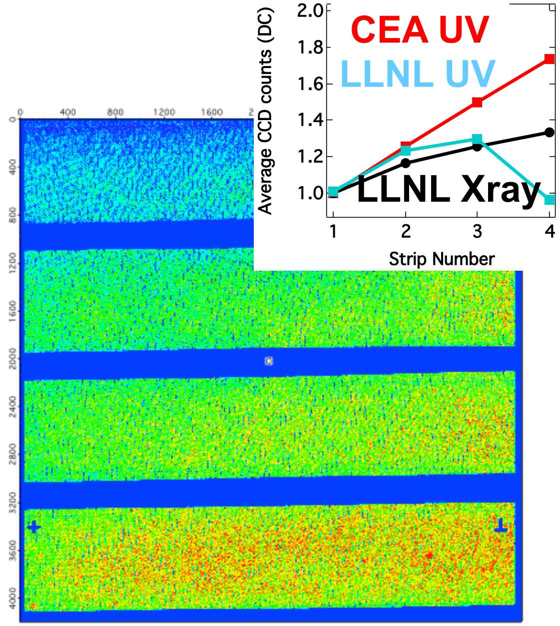
Approximate region seen by GXD3



Beam uniformity seen by P43 phosphor screen + fiber-optics taper



GXD3 DC biased MCP (UV)
DC gain exponent measured between 9.9 and 9.8 for the different strips



GXD3 DC biased MCP (X-ray)
DC gain exponent measured between 10.9 and 11.2 for the different strips

- By-construction, beam should be collimated (source in the focal plane of a 100mm diameter lens)
- Re-alignment of the laser beam did not improve the DC-image uniformity
- GXD3 does show top-to-bottom DC non-uniformity in x-ray lab, but less than observed at CEA, UV
  - Additional DC non uniformity may be related to light background

UV flat field construction seems useful for LLNL

Confirm effectiveness of flange/incident angle to remove light background and reduce DC non-uniformity with GXD

Build a UV pulsed laser lab at LLNL

Using CEA expertise; similar enough to be directly comparable
Need a "bigger laser" to calibrate flat fields at high gain

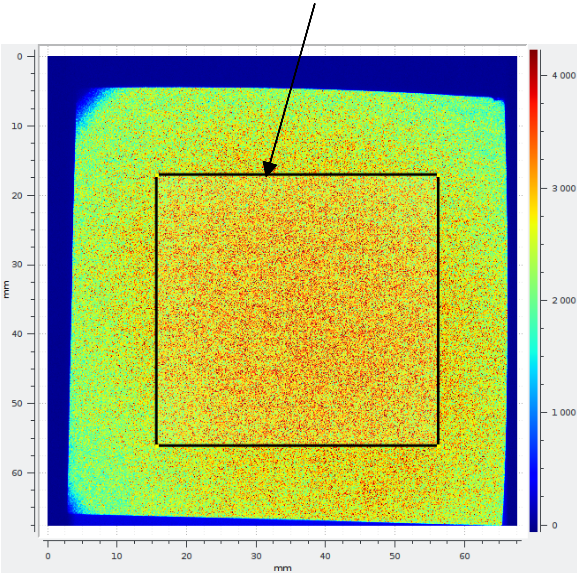
With an automated offline system we could assess statistical issues that we could never do with NIF shots alone

Reproducibility
Variation with signal level and saturation
Many configurations
Sum many flat fields to characterize fixed pattern noise

Want to confirm that X-ray and UV method converge once both are improved

How much laser do we need?

Approximate region seen by GXD3



~3mJ in 5-omega 25ps (FWHM) pulse is sufficient to illuminate GXD on high to medium gain (50 – 100 V bias) for collecting UV flat field data

Flux = 10 μJ/cm^2

Ideally we would be able to flat field up to 200 V bias at least (need x10)

Flux Goal = 100 μJ/cm^2

We are interested in continuing the collaboration to address other framing camera performance issues

Engineering/Design issues (MCP coatings; cross talk mitigation; …)

Variation in DQE (gain/sensitivity) between cameras

At NIF, x-ray flat field shots serve TWO functions :

#2 Relative Gain across MCP ("flat field")

#1 Determination of relative sensitivity to enable experiment setup

We are interested in developing more robust methods to determine camera-to-camera sensitivity

Variation in DQE (gain/sensitivity) with photon energy

There is some evidence that there is a difference between DC and pulsed

Spatial resolution

Our cameras have large tails in the MTF. Characterizing these under pulsed operations and reducing their amplitude is a challenge.

The LLNL-CEA collaboration on framing camera flat fields has been very fruitful!

Applying different methods to a single camera demonstrated flat field equivalence ~25%

This may be sufficient for many experiments

Both teams have identified challenges to our methods that impact our detailed understanding of framing camera operation

We have identified remediation plans to address most of these

Going forward LLNL intends to build a lab similar to the CEA UV lab

Preferably in collaboration with CEA to share best practices

We should confirm improved equivalence between methods once mitigations are implemented

We are interested in further collaborations regarding other performance parameters such as:

camera-to-camera sensitivity; energy sensitivity; spatial resolution

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