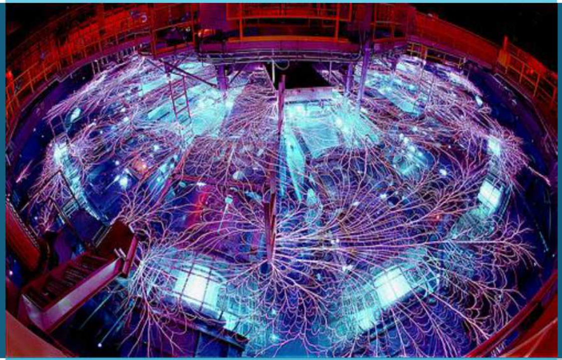
SAND2019-5780PE

TiGHER PHC Update



Tim Webb, SNL Department 1676

Z Diagnostic Workshop, April 17-18, 2019

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- Engineers: Chris Ball, Andy Maurer, and Paul Gard
- Technologists: Mike Sullivan and Chris Kirtley (both have moved on); Antoinette Maestas and Brian Ritter; Center Section Team
- MCP team: Radu Presura, Eric Georgeson, Tung Trinh, Evan Misak, and Ming Wu
- Dave Ampleford and Matt Gomez from whom I have borrowed some processed data and had many useful discussions.
- Management support: Chris Bourdon, Michael Jones, and Clark Highstrete

The work was heavily motivated by the ICF/Pulsed Power ICF FY 2018 level-2 milestone MRT 6234 which was completed.

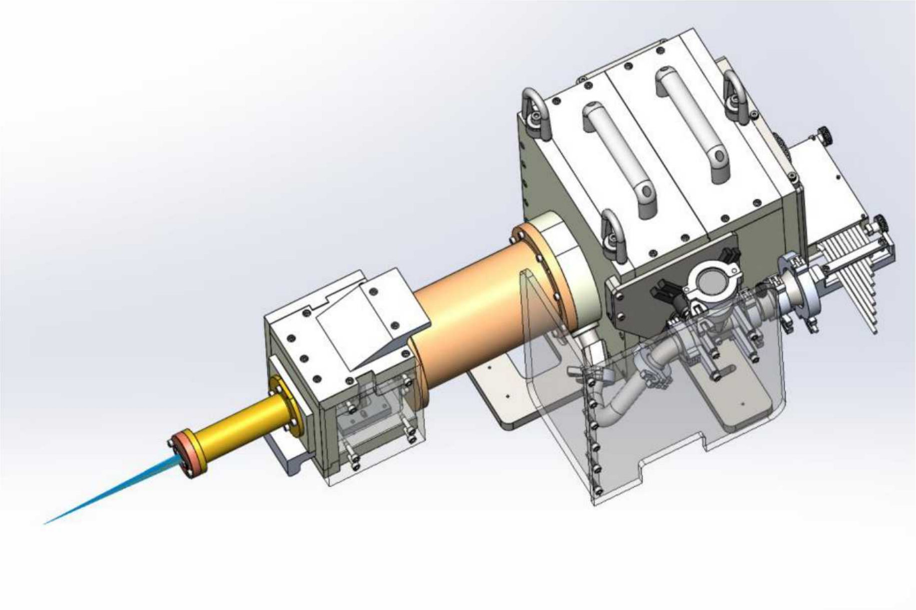
Introduction

A few years ago (mid 2015?) an effort was begun to apply the basic design of the original TiGHER (Time Gated High Energy Spectrometer) to a new diagnostics. This was called TiGHER Gen 2 originally. When I came onboard, it seemed a little late to jettison the name, so I just stuck on a modifier resulting in "TiGHER PHC." So we have two diagnostics, the Gen 1 version we refer to now as "TiGHER Spectrometer" (or "Spect") which have many similarities in design, fielding, and some hardware.

The main goal is to have multi-time-frame, two-dimensional, high-sensivitity x-ray imaging diagnostics. This was to be accomplished with:

- A multi-pin hole camera
- MCP camera for time resolution
- Located in-chamber to maximize signal flux.

The primary "customer" was MagLIF but other loads may be applicable. Hence a number of configurations were included to make the diagnostic flexible.



Some Science and Other Requirements

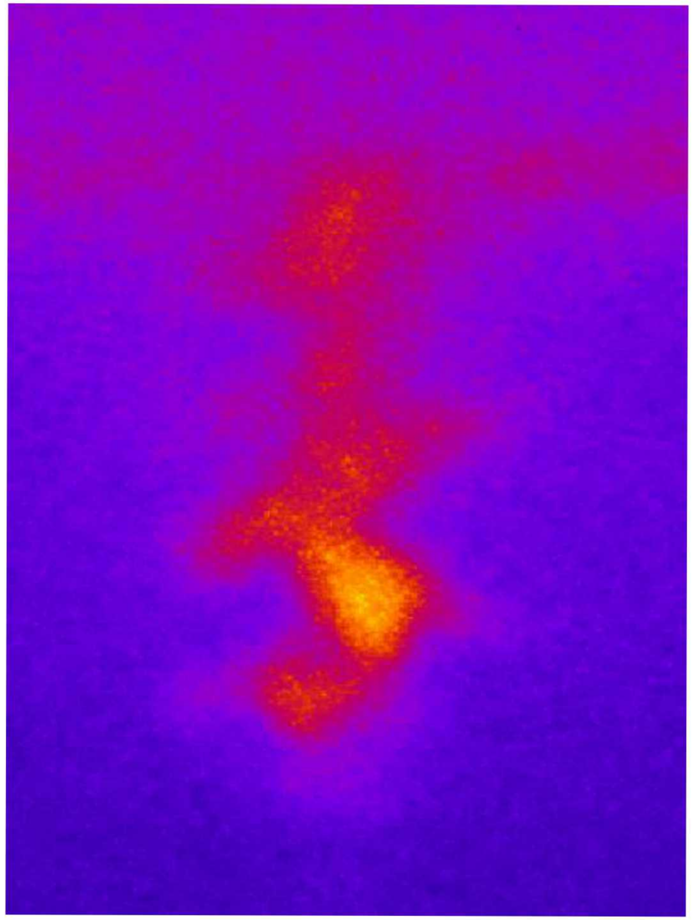
Science requirements (MagLIF-centric): What do they want to measure?

- Resolution < 50 μm
- Desire: Eight frames of 0.25 ns gate and 0.5 ns interframe.
- Signal strength on par with MLMc

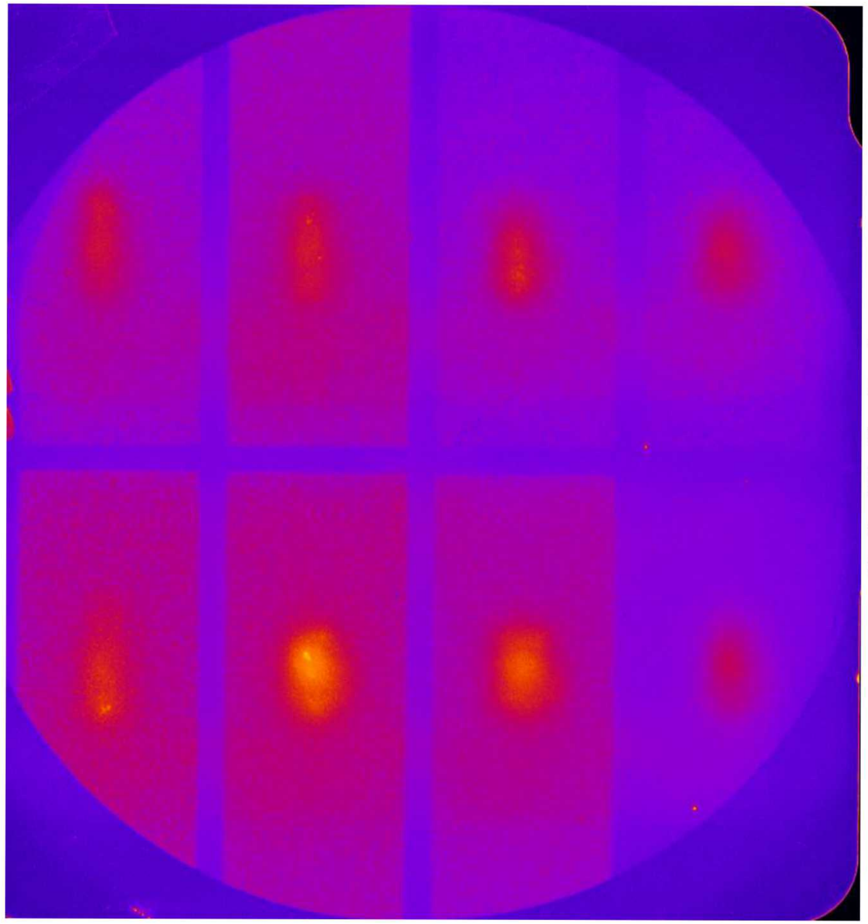
- At least one inch thick tungsten shielding to the MCP from general Z x-ray environment
- Internal pump down > 3 hours for MCP with operating vacuum in the low E-5 Torr.
- Alignment: 0.5 mm at the target.

Compare to other imaging diagnostics

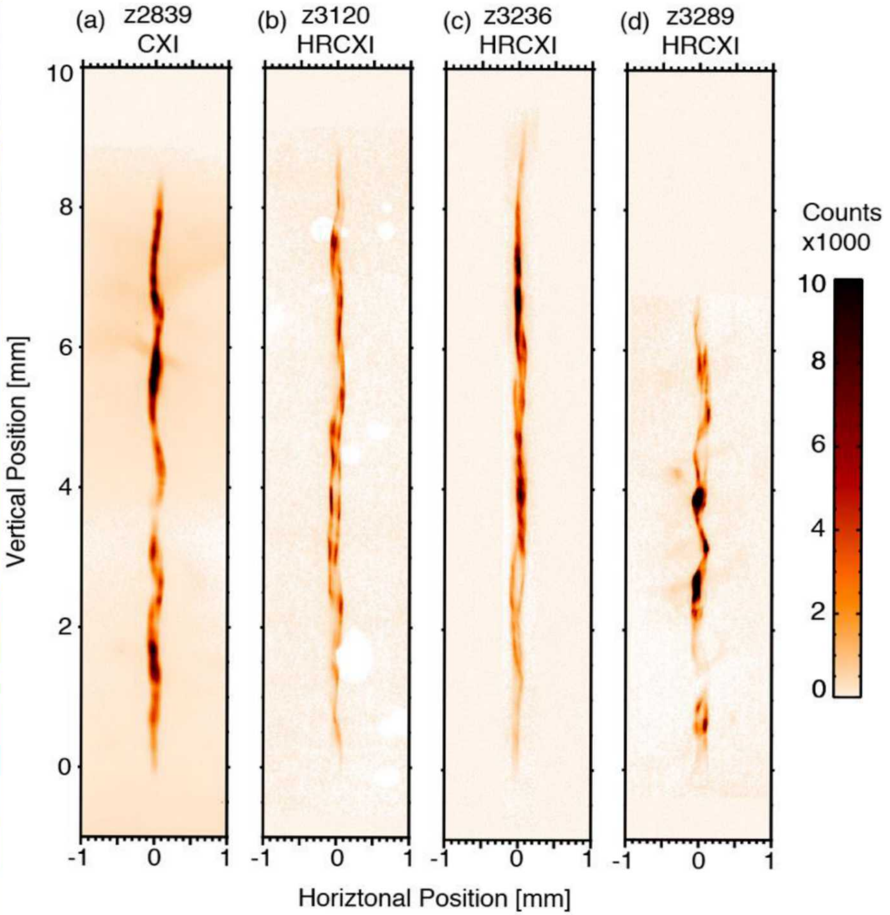
Low Resolution,
Time-Integrated: TIPC



Low Resolution,
Time-Resolved: MLM

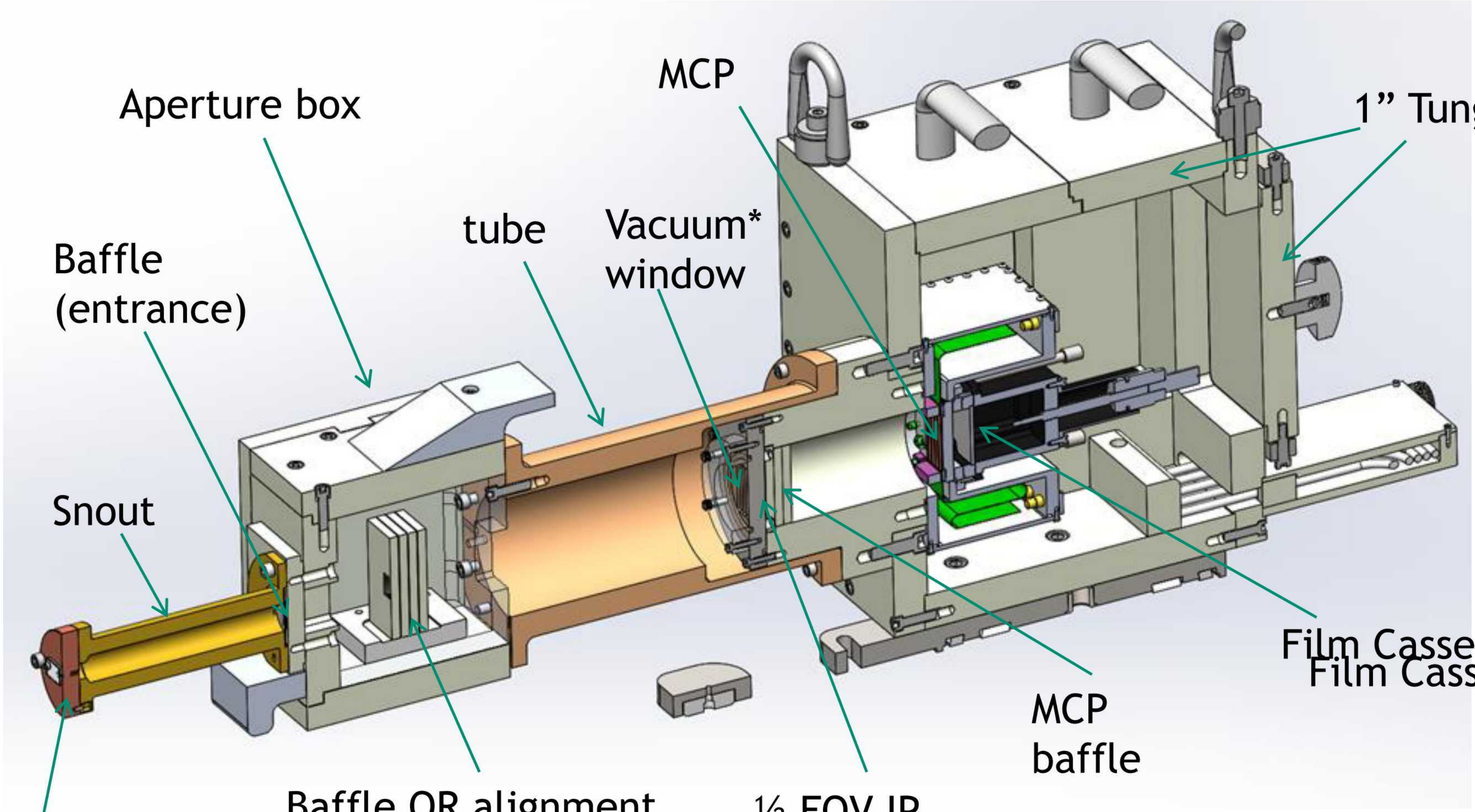


High Resolution,
Time-Integrated: Crystal Imagers



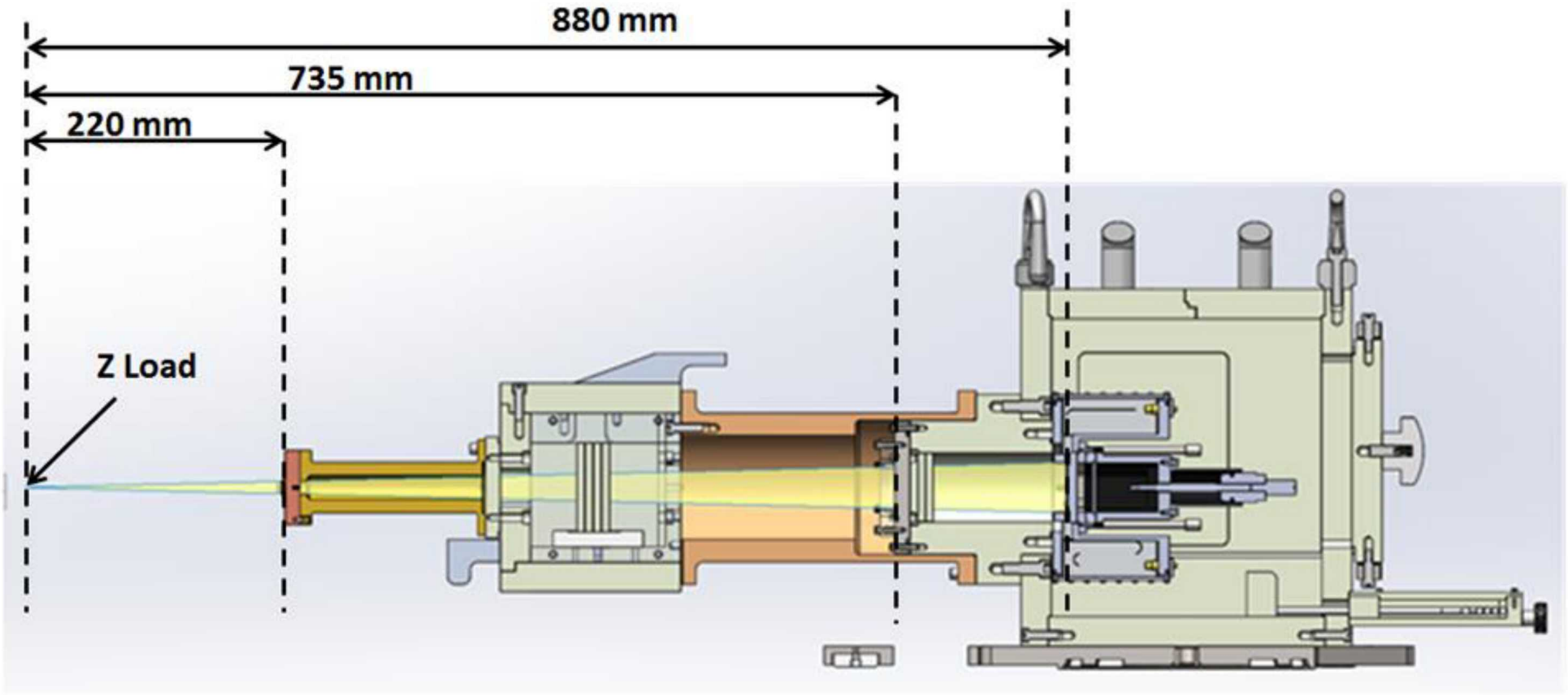
Z3293

hown here is the *Mag 3*
eometry.

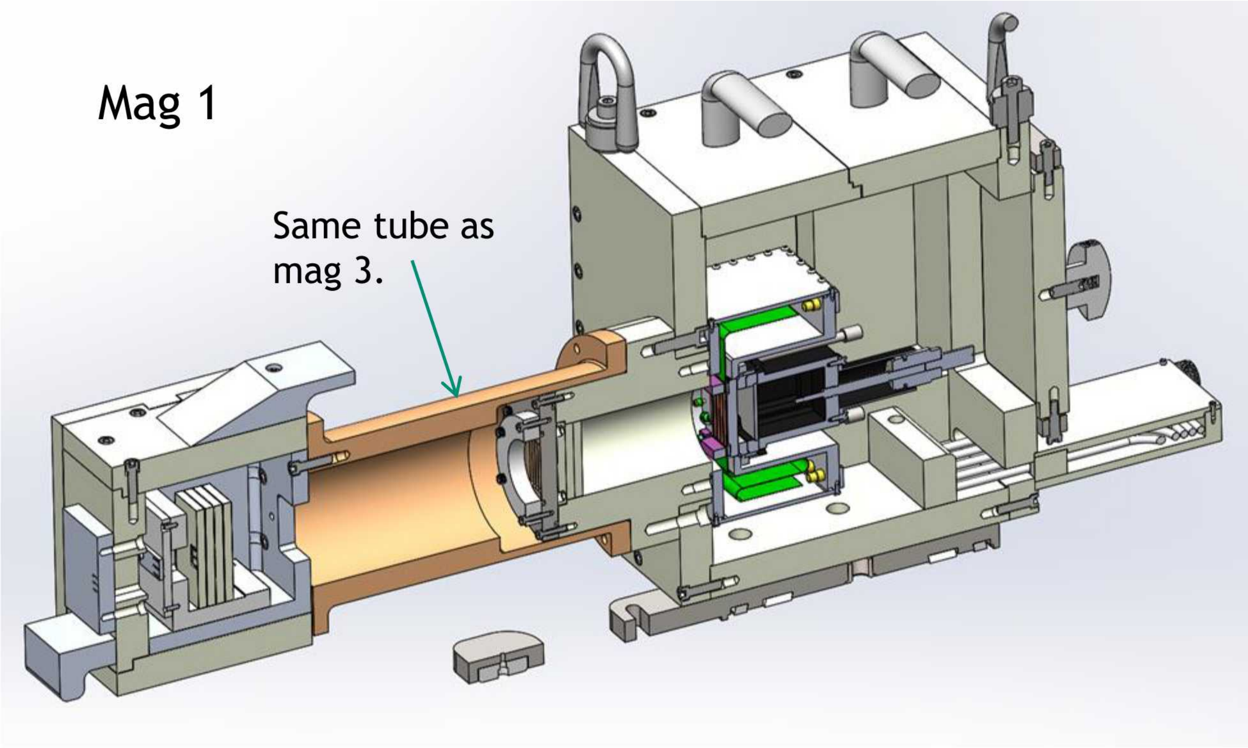


* The MCP has a
independent va
system.

Side-View Geometry



TiGHER PHC Configurations



Fielding Options

Magnifications:
3X, 1X, 0.5X

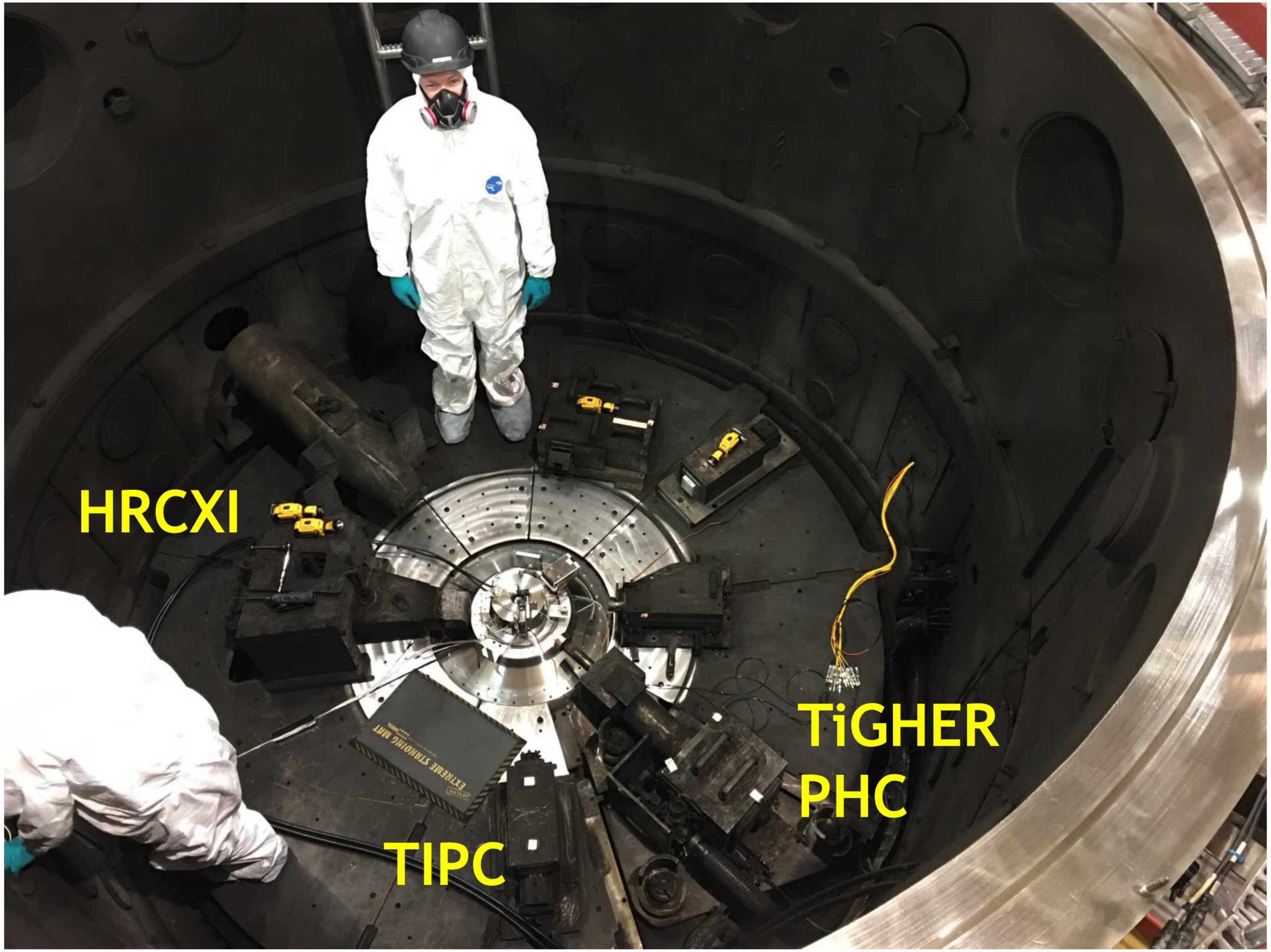
Pin Holes, MLM-style (μm):
15, 20, 30, 50, 75, 100, 150, 200, 250, 500

Number of optical paths (see Fig. 2):
Mag 3X: eight pin holes, one per MCP strip
Mag 1X, 0.5X: 24 pin holes, three per MCP strip

MCP gating, Gen II:
0.15, 0.25, 0.8 ns gates, independent gating in four sets of two.

For all magnifications, detector remains at the same distance from the source, the pin hole positions are changed. Mag 0.5 is achieved with a shorter tube.

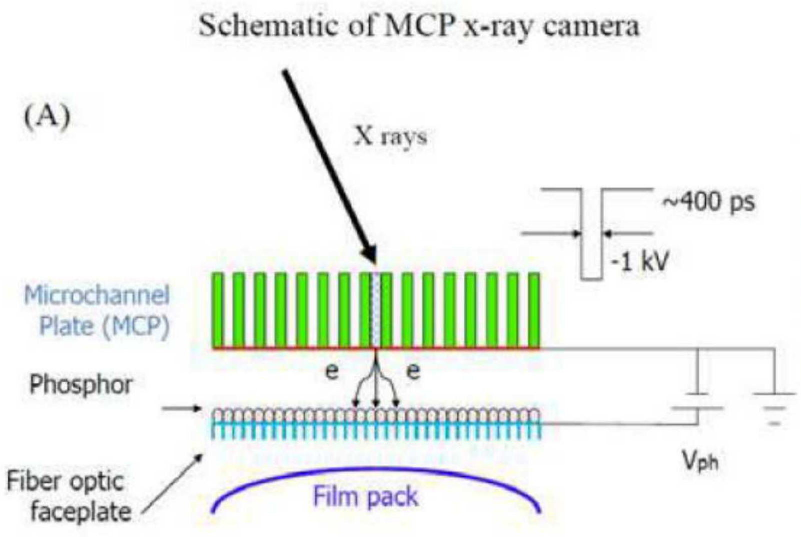
In-Chamber Installation

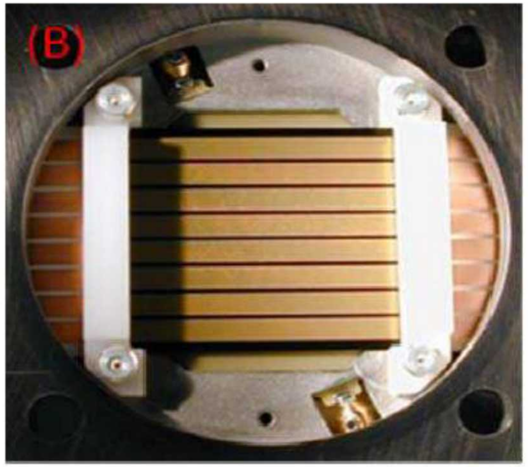


Some things that are special about TiGHER that often includes additional installation steps compared to other diagnostics.

- Special MITL deck plate with custom alignment legs.
- Vacuum pipe connection (the pumps are located outside the chamber)
- MCP cables must be connected at the chamber wall one-by-one in coordination with MCP team.
- One of the heaviest diagnostics

MCP Summary





Gen II MCPs:
8 Frames, 4 mm x 40 mm

Gate widths:
250 ps, 800 ps,

Interframe time: 1, 2, 3, ns
(custom values available)

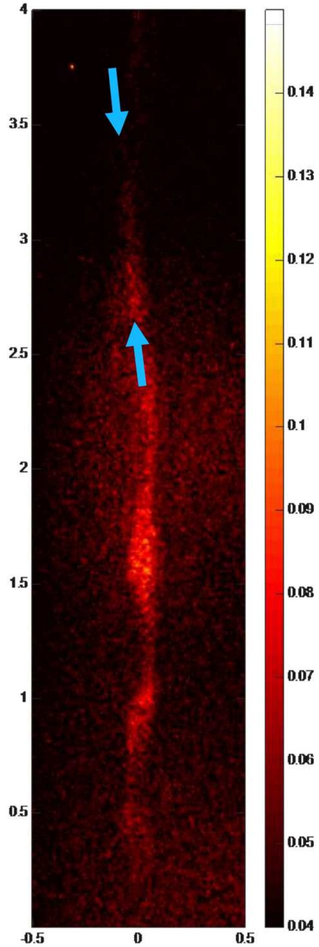
X-ray sensitivity:
< 0.25 kV to ≈ 25 kV

Gain: $G \propto V^n$, n ≈ 11 for E ≤ 3 keV, n ≈ 9 for E ≥ 20 keV
adjustable ±100 V relative to nominal -900 V

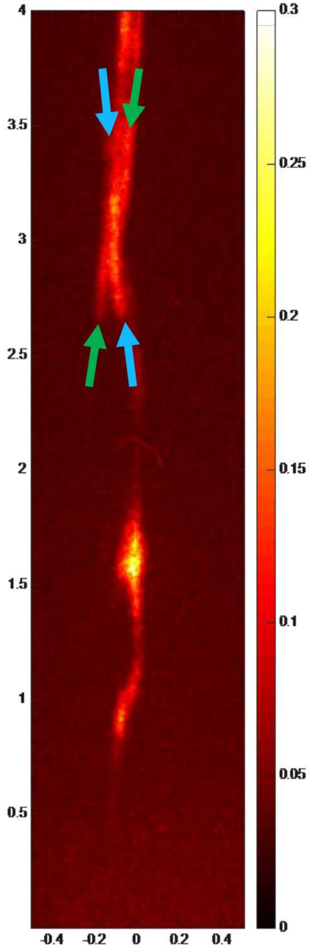
Resolution: < 50 μm @ 15 keV, normal incidence, 2.5 kV phosphor voltage

Schematic from: C.A. Kruschwitz and M. Wu. "Monte Carlo Simulations of Microchannel Plate-Based, Time-Gated Imagers." http://www.intechopen.com/books/applications-of-montecarlo-method-in-science-and-engineering/monte-carlo-simulations-of-microchannel-plate-based-time-gated-xray-imagers . (2011)

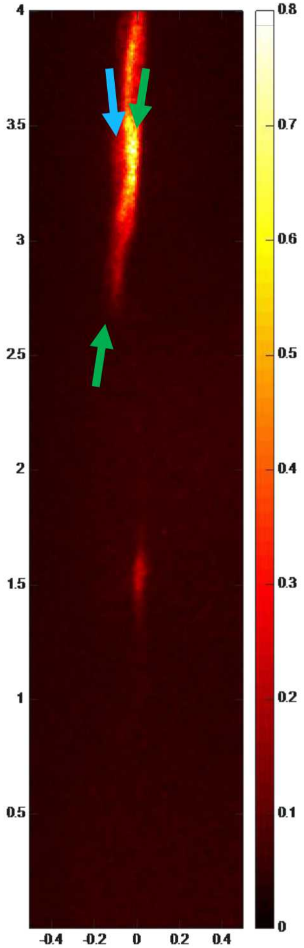
Processed Data on Z3292



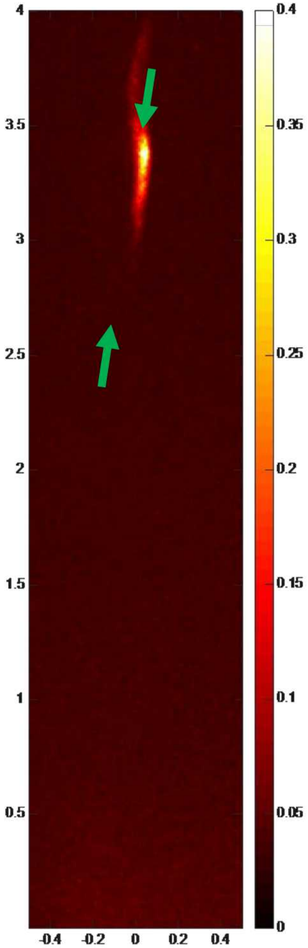
Frame 3



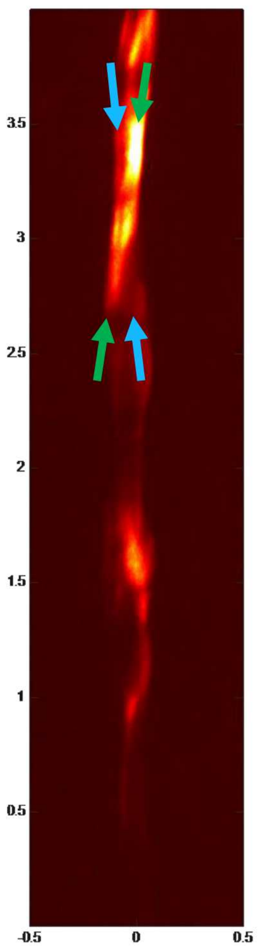
Frame 4



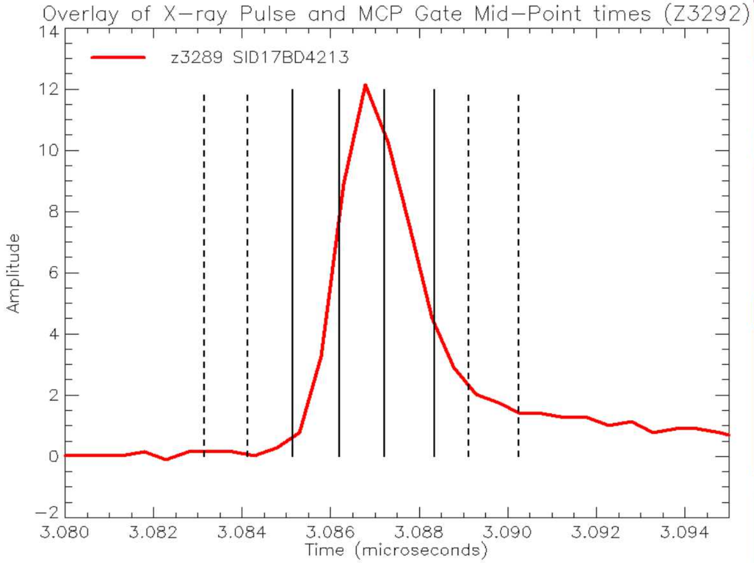
Frame 5



Frame 6

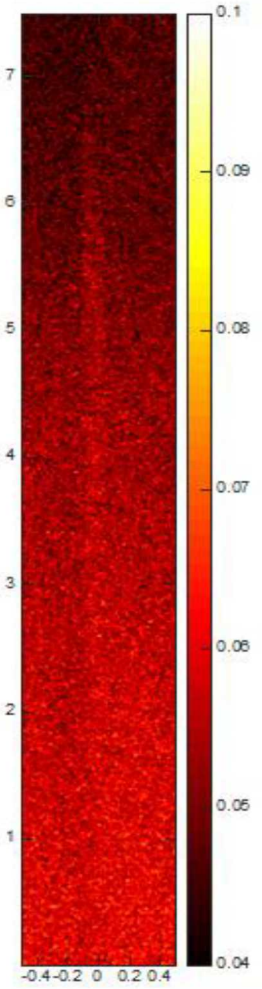


HRCXI

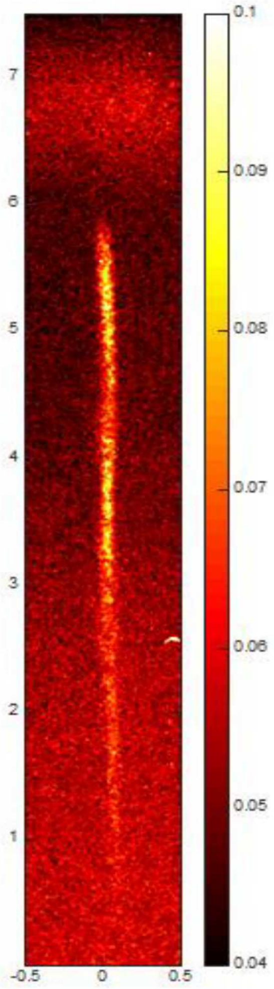


Note: X-ray pulse data from a different shot where timing appeared to be similar.

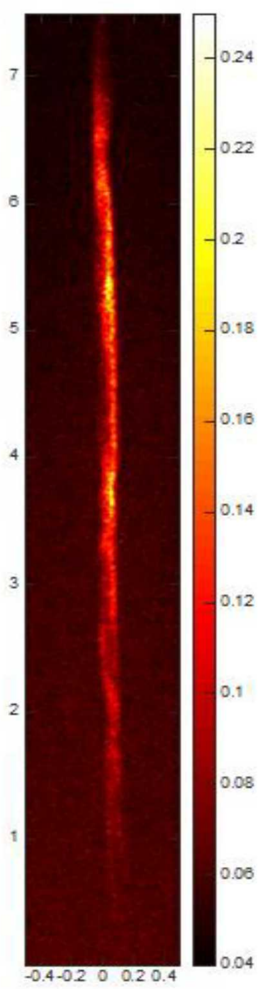
Another shot, Z3296, with lower yield and different images.



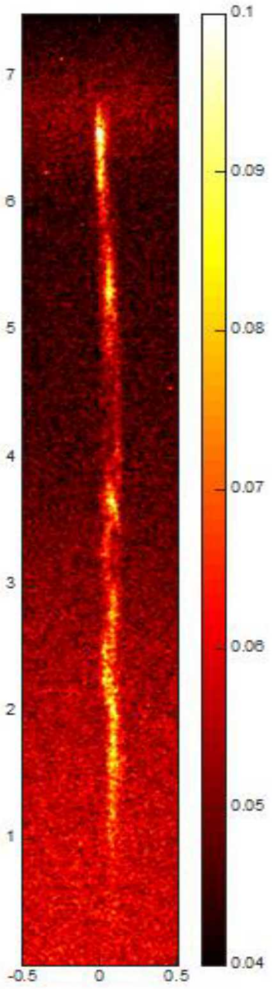
Frame 4



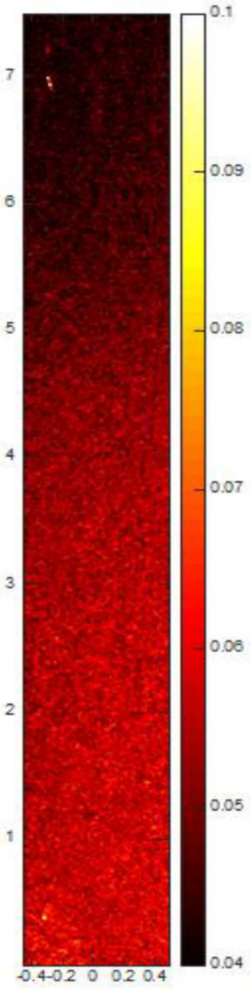
Frame 5



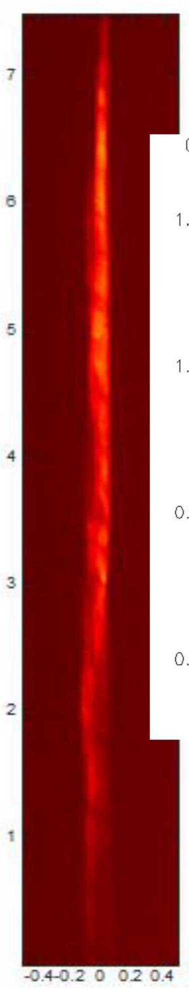
Frame 6



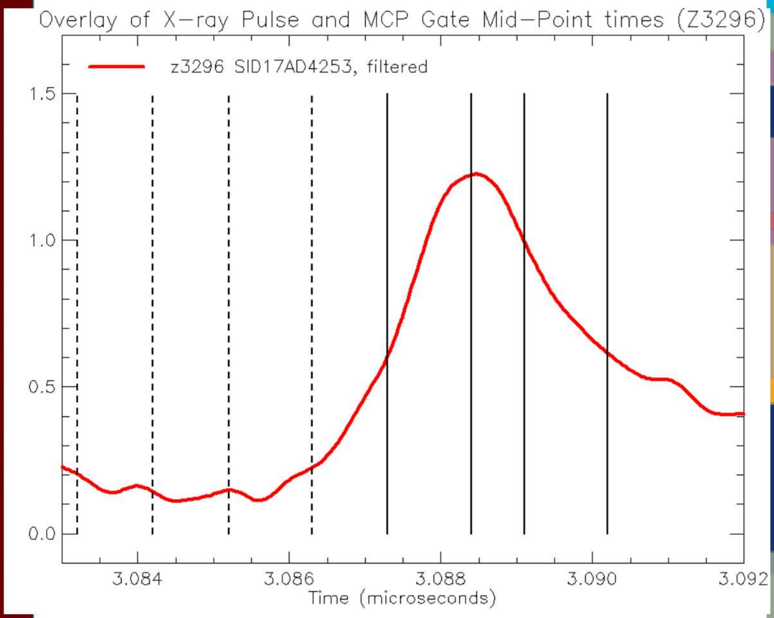
Frame 7



Frame 8



HRCXI



Note: this *is* the x-ray pulse from this shot.

Notes on resolution and sensitivity

As configured on the shots just shown, the magnification was three and 30 micron pin holes were used. The spatial resolution at the source plane is a convolution of the projected pin hole size and the scaled detector (MCP) resolution and is approximated by the formula at right.

$$Res^2 = \left[ph\left(\frac{M+1}{M}\right)\right]^2 + \left[\frac{mcp}{M}\right]^2$$

I have seen differing MCP resolution values and it depends on several factors, but I will use 65 μm here (at the detector plane). Note that the films are digitized at 22 microns. This results in an expected resolution of 45 μm. Use at a mag 1.0 configuration results in a resolution approximately doubling to 88 μm.

It is worth noting that other available configurations have trade-off with sensitive and resolution.

- 15 or 20 μm pin holes – this drops signal in favor of higher resolution.
- Shorter MCP gates, such as 250 ps.
- Increasing MCP gain and phosphor voltage (latter will improve resolution as well).

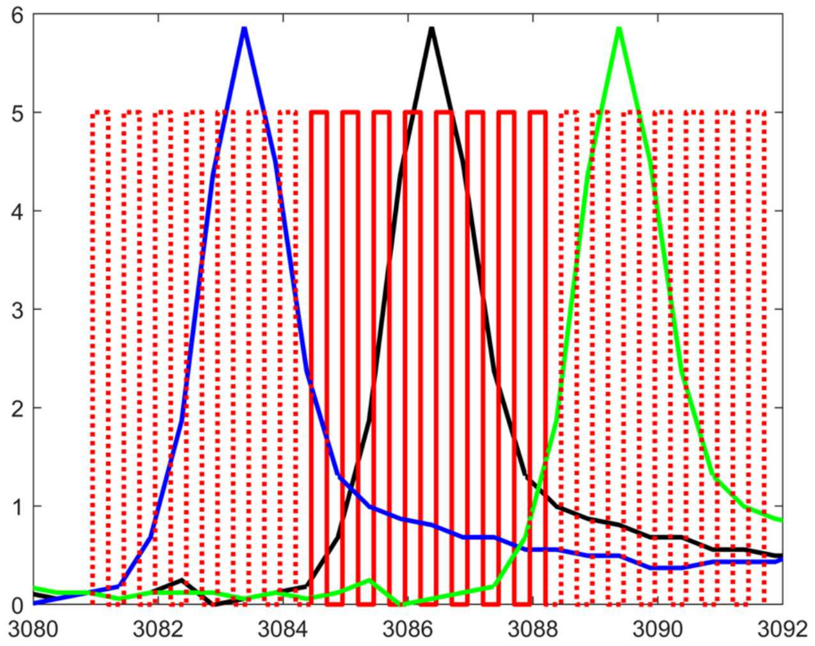
Conclusions and Future Work

We have shown that time-resolved stagnation images with decent signal-to-background ratios are readily achievable. Here are some near-term considerations for improvement.

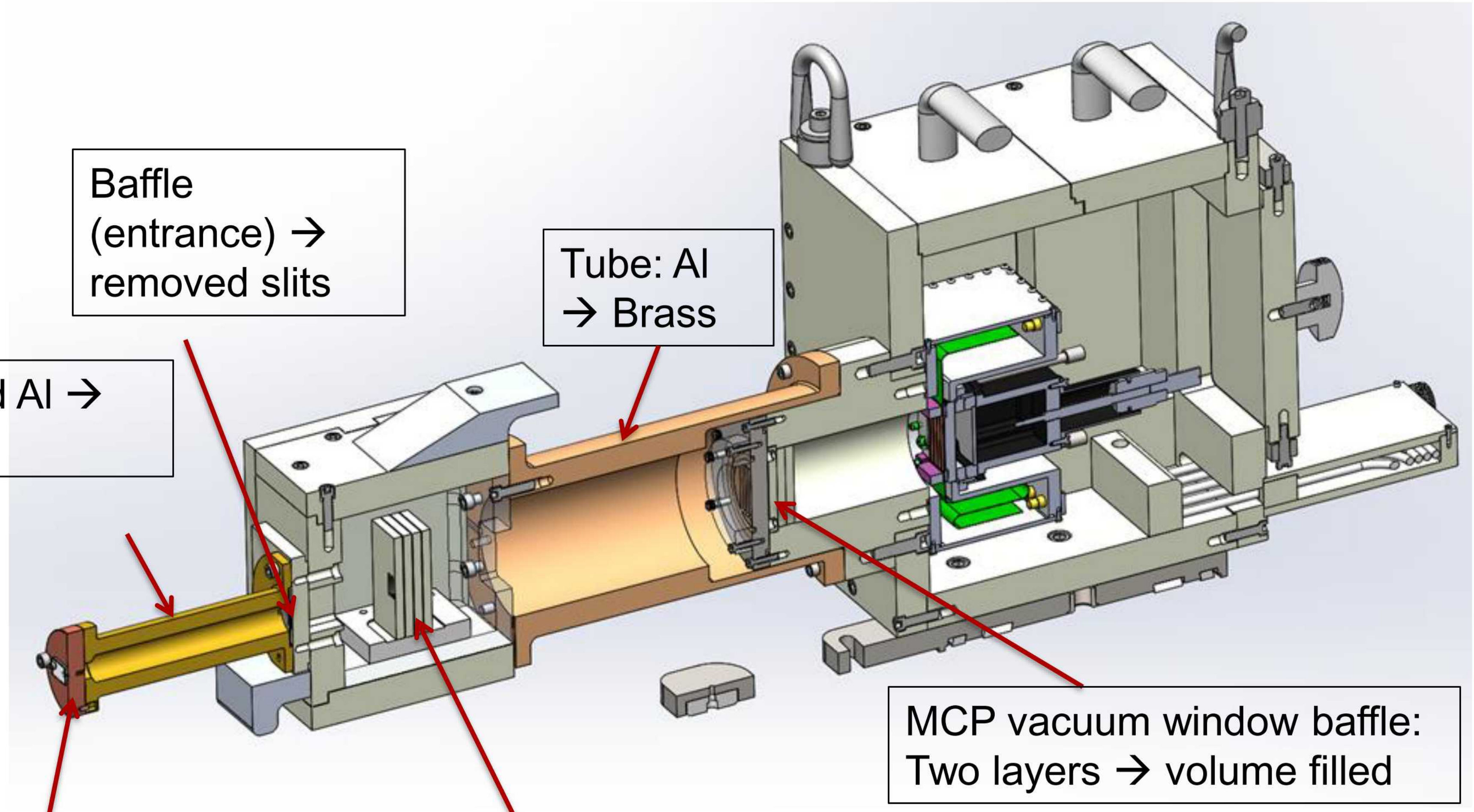
- Matt Gomez has proposed introducing *multi-pulsing the MCP* in order to increase temporal resolution while simultaneously increasing the likelihood that the MagLIF pulse will still be captured given the inherent jitter which is mostly Z and load dependent. (See figure below which is borrowed from one of M. Gomez's presentations.)

- Improving the internal vacuum quality in the vicinity of the MCP is a high priority since performance and lifetime is highly dependent on this condition. Methods include shortening vacuum lines and even including in-chamber pumping methods such as getters.

- Some performance parameters such as number of frames and magnification are limited by the MCP geometry. Could we consider a new MCP design?



Changes to TiGHER Shielding



Baffle (entrance) → removed slits

Tube: Al → Brass

Snout: slotted Al → brass

MCP vacuum window baffle: Two layers → volume filled

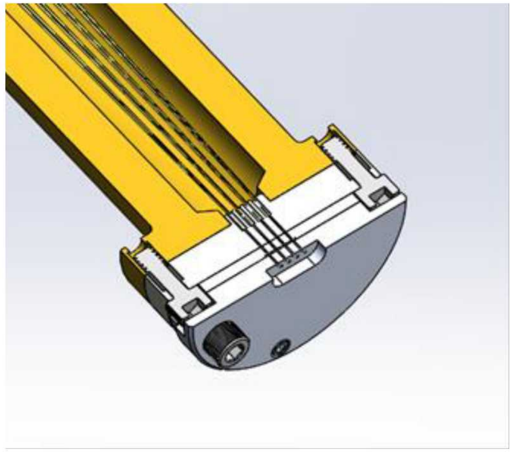
Pin hole plate: Al → Cu → W

Aperture box baffle → removed

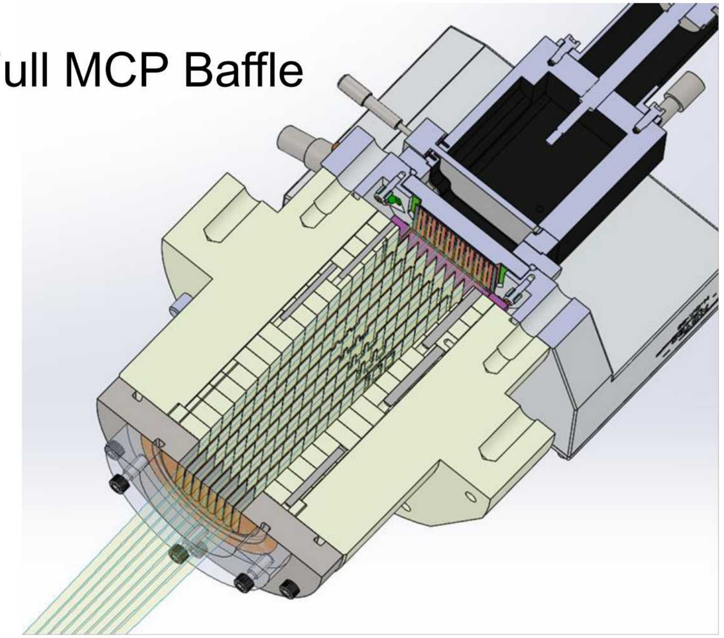
Observations

- It is difficult to prove what changes introduced what effect. Backgrounds can be caused by different sources.
- Image plates fielded at several places inside the instrument indicated that high energy background originates from the “general direction” of the source (i.e. not outer MITLs or general chamber scatter).
- My opinion: tungsten pin hole plate is the most beneficial change.
- Baffles at intermediate position (e.g. Aperture Box) may actually introduce problems due to extended sources.
- It is not definitive whether changes to “Tube” or “Snout” had much effect (though it is not harmful).
- Could not utilize full MCP baffle because it was too dirty or trapped too much gas for sufficient MCP vacuum.

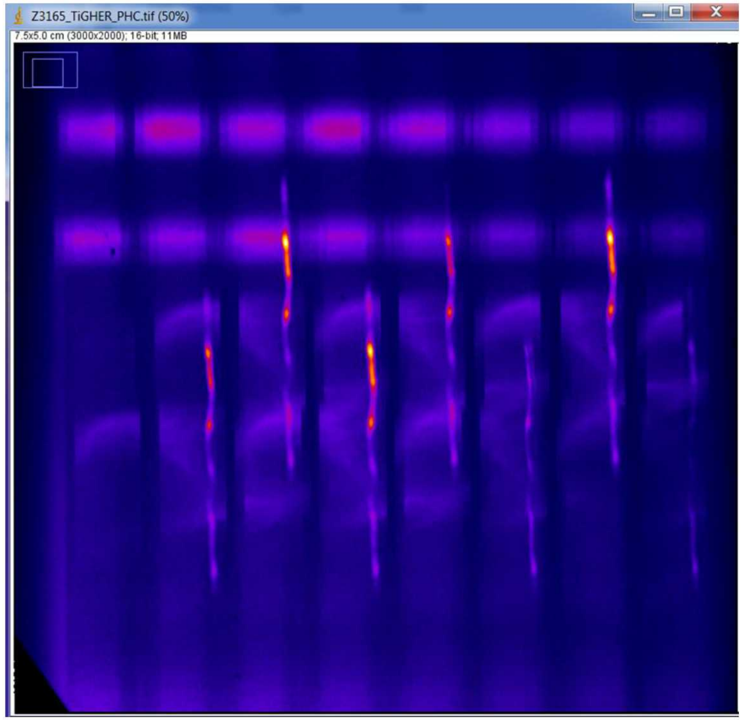
Tungsten pin hole plate



Full MCP Baffle

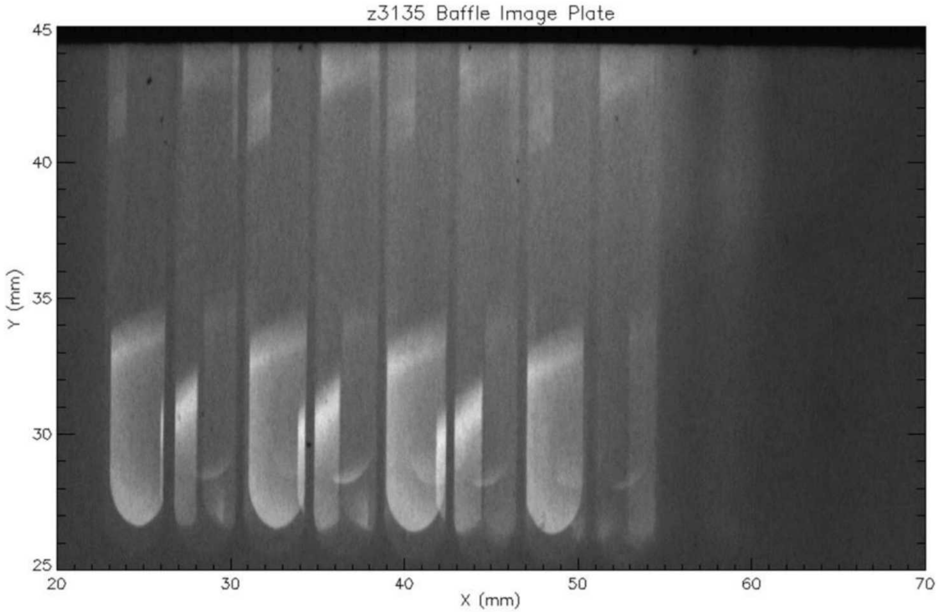


"Extended sources" impact the TiGHER PHC or Similar Diagnostics



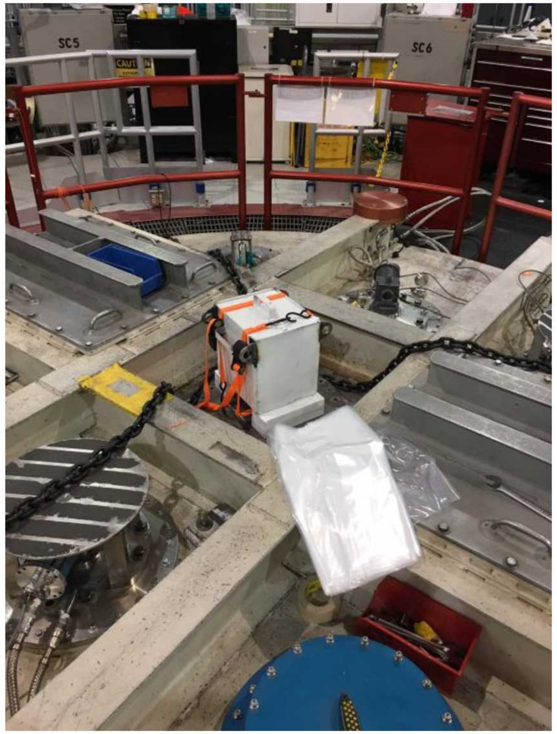
Multiple baffles extended in space *may* interfere with each other when confronting extended sources.

Care should be extended in the design and alignment of baffles.

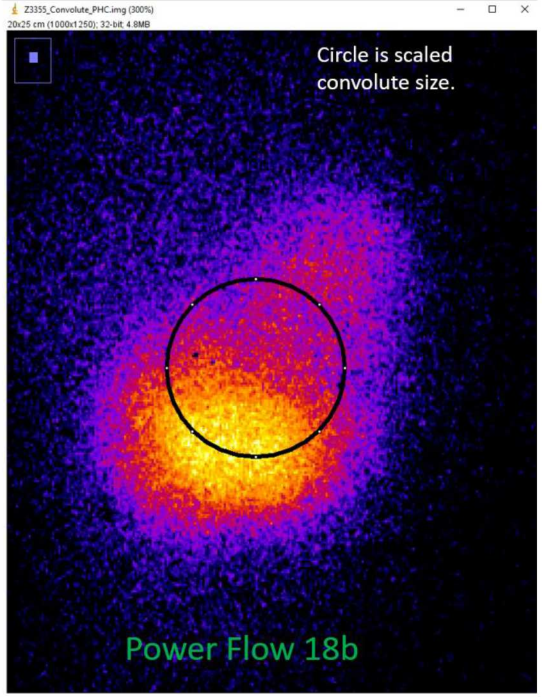


This is a time-integrated result with Image Plates. MagLIF source had ring-like structure that extended beyond a single "frame". The bands above were also caused by a large extended source. There are two of them because the pin holes were staggered in height.

“High” energy sources from around the Z load are present.

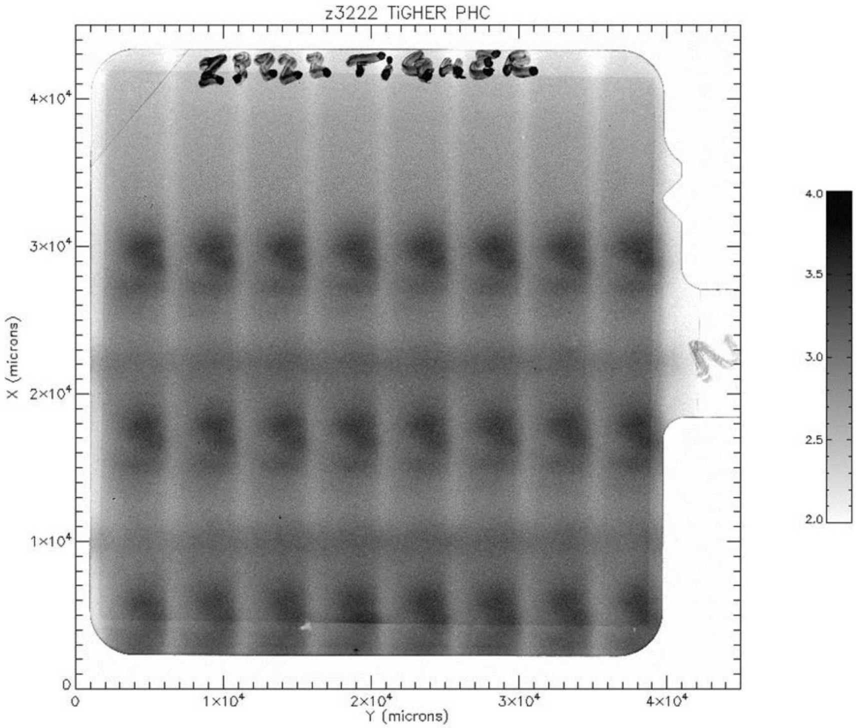


Crude PHC on top lid.



Large MITL losses on that shot still energetic enough to penetrate blast shield and lid.

TiGHER result from Mo Wire Array. MCP likely *functioned*, but image is time-integrated *anyway.*



1 MeV photon transmission through 1”:	
Tungsten: 6.3%	Aluminum: 66%
Copper: 26%	Stainless steel: 29%

We could design diagnostics to spatially measure size and spectrum of background x-ray sources.