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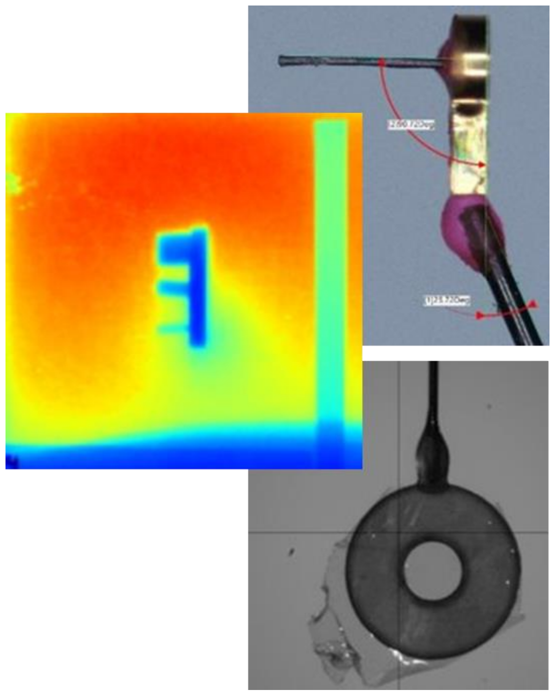
Multi-Probe 24A: Post shot Data and Analysis

Shot date: Nov. 28, 2023

David P. Broughton, Chun-Shang Wong, Steven H. Batha, Chengkun Huang, Robert Reinovsky, Thomas Schmidt, Carl Wilde, Mariana Alvarado Alvarez



Abstract

The Multi-Probe 24A experiments took place on the Omega EP laser in November 2023. The experiments consisted of shots alternating between Omega EP's two short-pulse laser beams to generate proton and deuteron ion beams from a range of film thicknesses, and x-ray sources from the established CPC+Ta wire targets. The backlighter was used for ion acceleration in the *pitcher series*, in which deuteron and proton beams characterized as a function of CD film thickness to develop a pitcher for a pitcher-catcher neutron radiographic source, while also characterizing electrons and x-rays emitted perpendicular to the target (i.e. Crosstalk for sidelighter-driven x-ray beams). The sidelighter was used for electron acceleration in the *x-ray series*, in which the electron acceleration and subsequent x-rays was characterized from the CPC+Ta wire targets and radiography was conducted with and without electro-magnetic electron defection. For the pitcher series, we found that at 500 J and 0.7 ps the 700-800 nm CD films yielded the greatest number and highest energy for both protons and deuterons. For the x-ray series, results demonstrated: a significant number of <100 keV x-rays are produced within the glue that fills the CPC cone, on-axis electron signal from the x-ray targets produce electrons resolvable up to ~10 MeV, and electron deflection (using MIFEDS) has a notable effect radiograph on noise reduction.

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Goals

The primary goals of the *x-ray series* were to:

1. Measure the on-axis and perpendicular electron source spectra (both with the CPC cone and glue, and with the CPC cone and glued Ta wire) to validate both PIC modeling of laser acceleration of electrons and subsequent MCNP modeling of electrons to x-rays conversion.
2. Measure x-ray scaling with laser energy.
3. Evaluate whether electromagnetic fields (MIFEDS) are essential to producing high quality radiographs with the CPC+Ta wire x-ray source platform, or if electron-specific filters in the filter stack may remove cross-talk.

The primary goals of the *pitcher series* were to:

1. Optimizing CD film thickness for the *pitcher* in *pitcher-catcher* neutron source, with the primary metric being proton and deuteron fluence and energy.
2. Initial assessment of neutron production and diagnostics using a LiF catcher within the near target arm (NTA) pack in front of the Thompson parabola (TPIE).
3. During these measurements electron and x-ray spectrum measurements were taken along the sidelighter axis to characterize crosstalk both with and without XBLK as an efficacy evaluation.

Results

Results for the *x-ray series* goals:

1. The CPC cone and glue produce a significant number of <100 keV x-rays and high energy electrons, the measurements with CPC cone and glued Ta wire show the same low energy x-rays with an additional high energy Bremsstrahlung contribution. The conversion of electron energy into x-rays slightly softens the electrons spectrum energy and intensity.
2. Scaling from 20 J to 80 J at 5 ps (R_{80}~16um) increased the x-ray intensity overall by about an order of magnitude, and increased endpoint energy from ~1 MeV to ~2 MeV.
3. A direct comparison of radiographs with and without electromagnetic electron deflection (MIFEDS) demonstrated that it does lead to a significant improvement in signal-to-noise.

Results for the *pitcher series* goals:

1. Initial analysis of TPIE results for CD films of 500, 600, 700, 800 nm indicates that the 800 nm film yielded the highest number and energy of protons and deuterons. Although not the parameter being optimized for, the 700 nm film yielded the highest number and energy of electrons.
2. Due to the large pitcher-catcher separation (72 cm) many of the ions interact with other components in the chamber and it was not possible to resolve the neutron production in LiF relative to production elsewhere.

3. Initial evaluation of the electron and x-ray spectrum measurements corresponding to sidelighter crosstalk resulting from the backlighter beam indicate that at max energy and best compression even with XBLK a significant fluence of particles will contribute to background signal. Successful shielding of crosstalk requires either reducing intensity (e.g. 100-250 J, 0.7 ps) or use of thicker shielding.

Summary of shot day

Shot List

Shot ID	Shot #	Beam	RID	Time	Laser Energy (J)	Spot Size (R_{80}, µm)	Pulse Length (ps)	Intensity (W/cm^2)	A_0
40082	**1**	BL	94568	10:23	227.7	16.1	16.1	1.737E+18	1.18
40083	**2**	SL	94630	11:13	19.2	18.2	18.2	1.014E+17	0.28
40084	**3**	BL	*94633*	11.53	*490.9*	*14.9*	*14.9*	*4.724E+18*	1.95
40085	**4**	SL	94631	13:02	19.1	17.6	17.6	1.115E+17	0.30
40086	**5**	BL	94644	13:35	491.5	15.3	15.3	4.368E+18	1.87
40087	**6**	SL	93537	14:47	78.8	18	18	4.301E+17	0.59
40088	**7**	BL	94645	15:50	484.4	16.5	16.5	3.432E+18	1.66
40089	**8**	SL	94632	16:55	19.2	16.9	16.9	1.266E+17	0.32
40090	**9**	BL	94646	17:37	481.6	15.2	15.2	4.365E+18	1.87
40091	**10**	SL	94011	19:05	19.2	16.9	16.9	1.266E+17	0.32
40092	**11**	BL	94647	19:49	482.5	15.8	15.8	3.894E+18	1.77

Shot notes:

Shot ID	Shot #	Comment
40082	**1**	
40083	**2**	
40084	**3**	CD foil fell off - no data for this shot.
40085	**4**	
40086	**5**	No XBLK to get direct measurement of crosstalk.
40087	**6**	XBLK-1 with 6mm Al
40088	**7**	XBLK-2 with 6mm Al. EPPS3 removed for this shot and rest of day. Within NTA held in TIM14 the radiography stack was used instead of the X-talk stack.
40089	**8**	XBLK-1 with 6mm Al.
40090	**9**	XBLK-2 with 6mm Ta.
40091	**10**	
40092	**11**	XBLK-2 with 6 mm Al + 4 mm Ta. Added 4 mm thick Mylar w/ 20um Al cover over bottom half of pack. LiF placed in top half of the pack. This swap was to reduce likelihood of clipping as mylar stuck out a little.

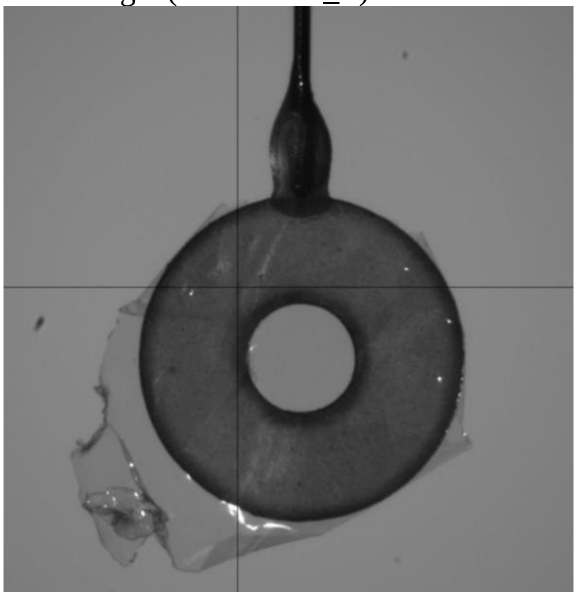
Targets and Static Objects

Targets fielded

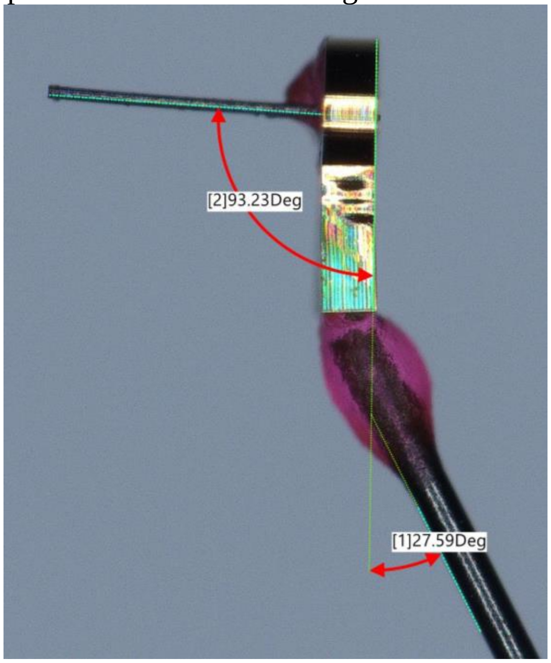
Shot ID	Shot #	Beam	Target ID	Target description	Static object ID
40082	**1**	BL	MP-24A-C_E	CD film (500nm)	–
40083	**2**	SL	MP-24A-CPC_005	CPC+wire (0.5mm × 25µm ⌀)	–
40084	**3**	BL	*MP-24A-C_F*	*CD film (500nm - foil fell off)*	–
40085	**4**	SL	MP-24A-CPC-G_001	CPC+glue (no wire)	–
40086	**5**	BL	MP-24A-A_A	CH film (500nm)	–
40087	**6**	SL	MP-24A-CPC_008	CPC+wire (0.5mm × 25µm ⌀)	–
40088	**7**	BL	MP-24A-B_I	CD film (700nm)	–
40089	**8**	SL	MP-24A-CPC_009	CPC+wire (0.5mm × 25µm ⌀)	MP-24A-SO_140
40090	**9**	BL	MP-24A-A_J	CD Film (800nm)	–
40091	**10**	SL	MP-24A-CPC_004	CPC+wire (0.5mm × 25µm ⌀)	MP-24A-SO_144
40092	**11**	BL	MP-24A-B_D	CD Film (500nm)	–

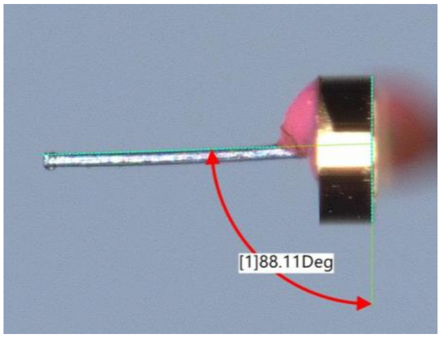
Sample Target Pictures

Example picture of CD/CH film target (MP-24A-A_E):

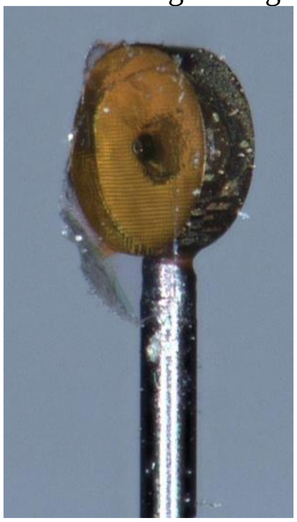


Example pictures of CPC cone and glued Ta wire target (MP-24A_CPC_004):



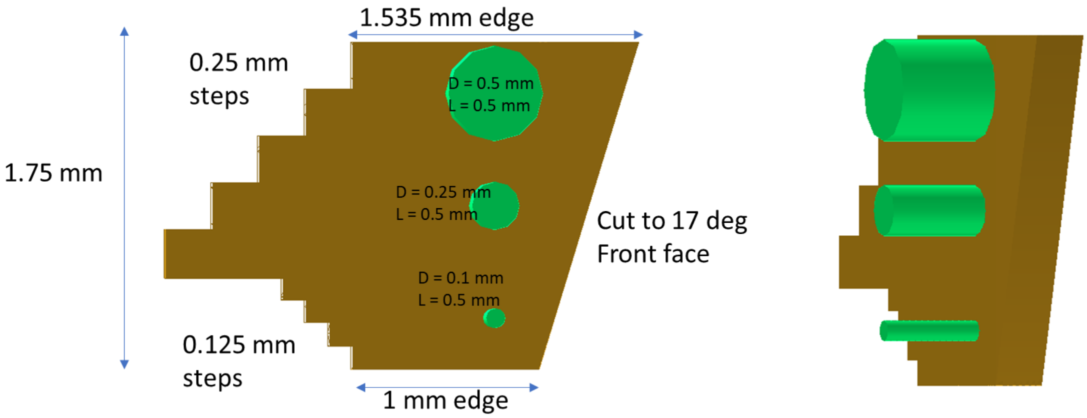


Example pictures of CPC cone and glue target (MultiProbe-EP-21A_25-600):



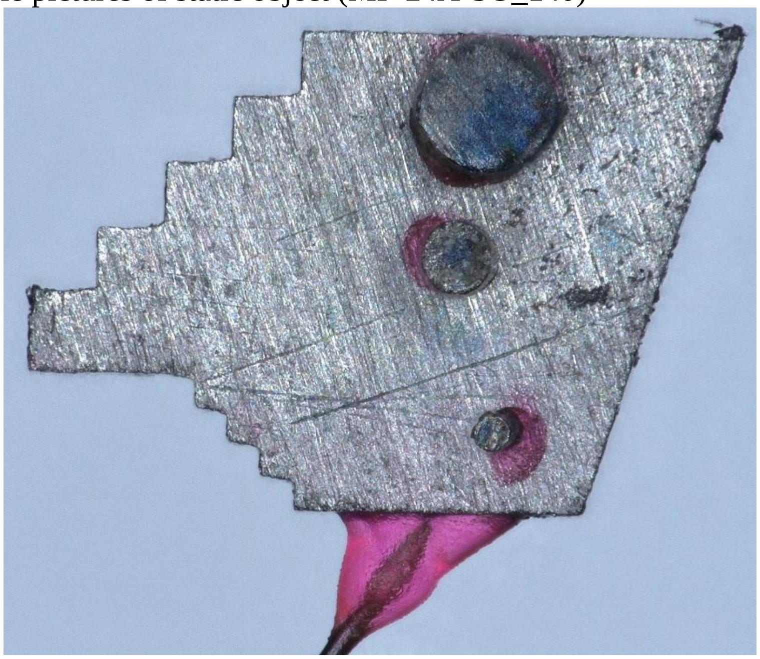
Static test object

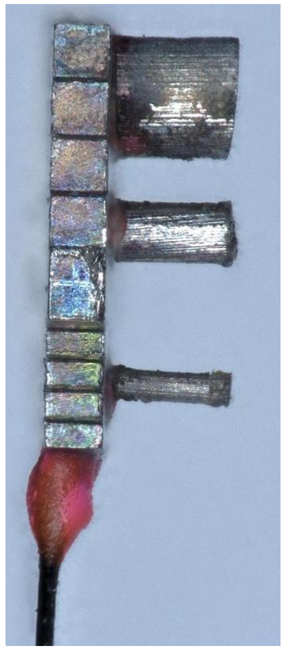
Illustration of Dimensions



Example pictures of static object

Example pictures of static object (MP-24A-SO_140)





Diagnostics

Overview by series

Configuration	X-ray series		
	xray-SL-1	**xray-SL-MIFEDS**	**xray-SL-2**
SRF RID	93537	94011	94556
Beam	SL (5ps, 20-80J)	SL (5ps, 20-80J)	SL (5ps, 20-80J)
TIM10	XBLK-1	-	-
TIM11	-	MIFEDS	-
TIM12	TPIE w/NTA (IP filter stack)	TPIE w/NTA (IP filter stack)	TPIE w/NTA (IP filter stack)
TIM13	EPPS-1	EPPS-1	EPPS-1
TIM14	EPPS-3 (IP filter stack)	NTA (IP filter stack)	NTA (IP filter stack)
Fixed diagnostics	BMXS-25	BMXS-25	BMXS-25
	RADMON-BL+SL	RADMON-BL+SL	RADMON-BL+SL

Configuration	Pitcher series	
	pitcher-catcher-BL-1	**pitcher-catcher-BL-2**
SRF RID	94568	93586
Beam	BL (0.7ps, 500J)	BL (0.7ps, 500J)
TIM10	XBLK-2	XBLK-2
TIM11	-	-
TIM12	TPIE w/NTA (LiF+NAPA)	TPIE w/NTA (LiF+NAPA)
TIM13	EPPS-1	EPPS-1
TIM14	EPPS-3 (IP filter stack)	NTA (IP filter stack)
Fixed diagnostics	RADMON-BL+SL	RADMON-BL+SL
	Visible camera	Visible camera
Neutronics	nTOF (all 4)	nTOF (all 4)

- The set of configurations were fielded such that the day began with EPPS-3 in place (configurations: xray-SL-1 and pitcher-catcher-BL-1).
- Following shot 6 EPPS-3 was removed (configurations xray-SL-2 or xray-SL-MIFEDS and pitcher-catcher-BL-2).
- The configuration with MIFEDS was only used on shot 10.

Definitive information on fielded: IP packs, LiF converter and NAPA, TPIE, EPPS

X-ray Image Plate Packs

X-ray diagnostics consisted of a combination of IP stacks on TIM-14 NTA, TPIE-NTA, behind EPPS-3 and on BMXS-25.

For the **sidelighter shots** (x-ray series), IP stacks were fielded in:

- TPIE-NTA (*LANL_X_Talk_stack*) for measurements at ~90 degrees.
- BMXS-25 (*MeV Pack*)
- Either behind EPPS-3 (*LANL_radiography_stack*) or in TIM-14 NTA (*LANL_radiography_stack*) for on-axis measurements.

For the **backlighter shots** (pitcher series), IP stacks were fielded:

- Either behind EPPS-3 (*LANL_EPPS_Rad_stack*) or in TIM-14 NTA (*LANL_X_Talk_stack*) for measurements at ~90 degrees.

Each of the fielded image plate stacks are described below.

The fixed **BMXS-25** used the LLE Standard MeV Pack. Note, BMXS does have a set of magnets included (two magnets, 2″x1″x0.5″, with surface fields of 3723 G separated by about 0.5″ to 1″).

BMXS IP Cartridge MeV Filter List		
Layer	Filter Thickness (mm)	Filter Material
1	5	Teflon
2	5	Teflon
3	0.1	Al
4	0.5	IP-1
5	0.1	Ti
6	0.5	IP-2
7	0.1	Fe
8	0.5	IP-3
9	0.1	Cu
10	0.5	IP-4
11	0.1	Mo
12	0.5	IP-5
13	0.15	Ag
14	0.5	IP-6
15	0.5	Sn
16	0.5	IP-7
17	0.5	Ta
18	0.5	IP-8
19	1.56	Au
20	0.5	IP-9
21	1	Pb
22	0.5	IP-10
23	2	Pb
24	0.5	IP-11
25	3	Pb
26	0.5	IP-12
27	4	Pb
28	0.5	IP-13
29	6.4	Pb
30	0.5	IP-14

On **Sidelighter** shots both behind **EPPS-3** and in **TIM-14 NTA** the *LANL_radiography_stack* was fielded (note that this differs from description in pre-shot report due to the limited space in the EPPS-3 IP pack holder):

Layer	IP #	Material	Thickness (mm)	Total Thickness (mm)
1		Al	0.025	0.1
2	1	MS-IP	0.5	0.525
3		Cu	0.5	1.025
4	2	MS-IP	0.5	1.525
5		Cu	1	2.525
6	3	MS-IP	0.5	3.025
7		Ta	0.5	3.525
8	4	MS-IP	0.5	4.025
9		Ta	1	5.025
10	5	MS-IP	0.5	5.525
11		Ta	2	7.525

On **backlighter** shots behind **EPPS-3** the *LANL_EPPS_rad_stack* was fielded:

Layer	IP #	Material	Thickness (mm)	Total Thickness (mm)
1		Al	0.1	0.1
2	1	MS-IP	0.5	0.6
3		Al	1	1.6
4	2	MS-IP	0.5	2.1
5		Al	2	4.1
6	3	MS-IP	0.5	4.6
7		Cu	0.5	5.1
8	4	MS-IP	0.5	5.6
9		Cu	1	6.6
10	5	MS-IP	0.5	7.1
11		Ta	0.5	7.6
12	6	MS-IP	0.5	8.1
13		Ta	1	9.1
14	7	MS-IP	0.5	9.6
15		Ta	2	11.6
16	8	MS-IP	0.5	12.1
17		Cu	0.5	12.6

On **backlighter** shots in **TIM-14 NTA** the *LANL_X_Talk_stack* was fielded:

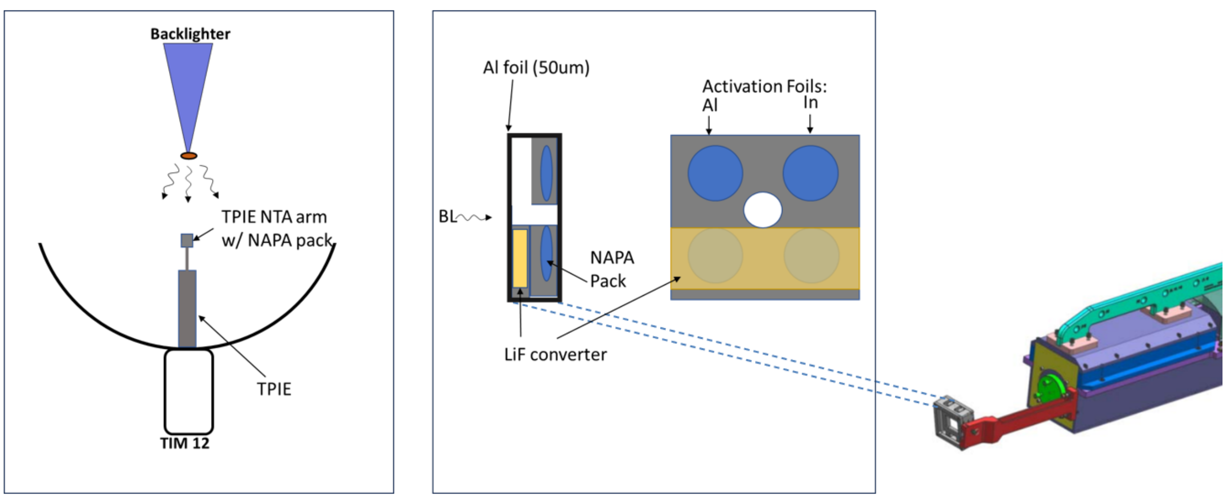
Layer	IP #	Material	Thickness (mm)	Total Thickness (mm)	Notes
1		Al	0.1	0.1	
2		Mylar	4	4.1	Mylar cut in half laterally (or vertically)
3	1	MS-IP	0.5	4.6	
4		Al	1	5.6	
5	2	MS-IP	0.5	6.1	
6		Al	2	8.1	
7	3	MS-IP	0.5	8.6	
8		Cu	0.25	8.85	
9	4	MS-IP	0.5	9.35	
10		Cu	1	10.35	
11	5	MS-IP	0.5	10.85	
12		Cu	2	12.85	
13	6	MS-IP	0.5	13.35	
14		Ta	1	14.35	
15	7	MS-IP	0.5	14.85	
16		Ta	2	16.85	
17	8	MS-IP	0.5	17.35	
18		Cu	0.5	17.85	Wrap sides in 0.5 mm Cu too

LiF converter and NAPA within TPIE NTA

The TPIE NTA arm was used to hold a pack containing a LiF converter and four activation foils. The purpose of this is to generate neutrons and measure the difference between the signal immediately beside the LiF source and the signal at a slightly increased distance (to gauge that we have some localized production above background). This pack was considered a secondary diagnostic, with a line-of-sight hole for ions to reach TPIE for reliable quantitative spectrometry.

Note that on shot 11 a change was made. An addition of 4 mm thick Mylar with 20 µm Al cover was placed over the bottom half of the front of the pack (this attenuates the bulk of the ions prior to the activation foils and the surrounding Al casing). The LiF was shifted to the top half of the pack during this to reduce likelihood of clipping the beam prior to TPIE as the mylar protruded slightly (TPIE results do suggest the ion beam was clipped).

TPIE with NTA arm for LiF and neutron activation foils

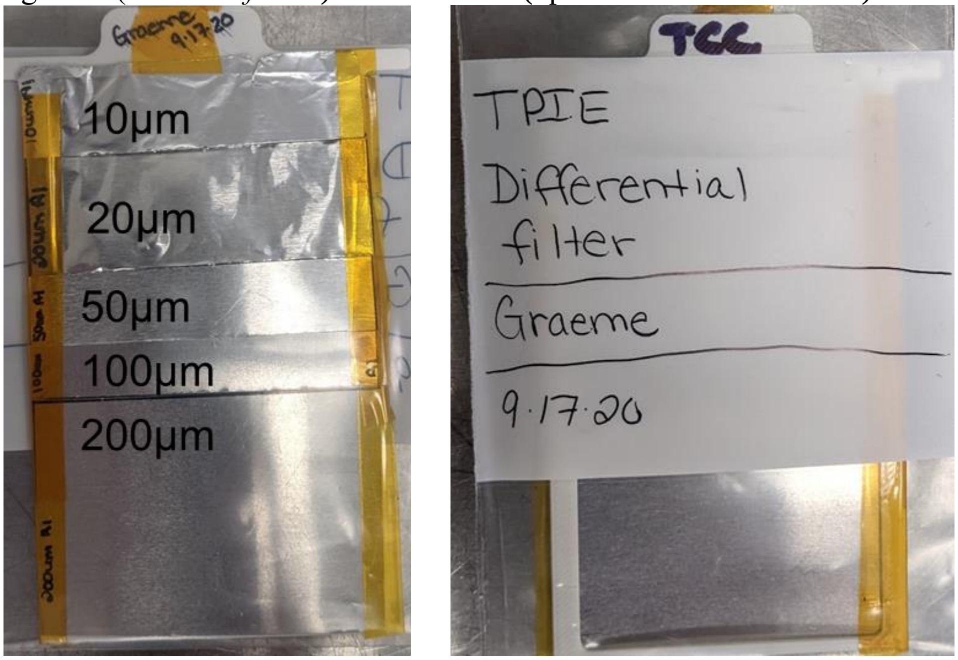


- **23mm diameter by 3mm thick foils**.
- Centered 10mm diam aperture
- Pack designed to infer neutron distribution with a thru-hole for joint use with TPIE

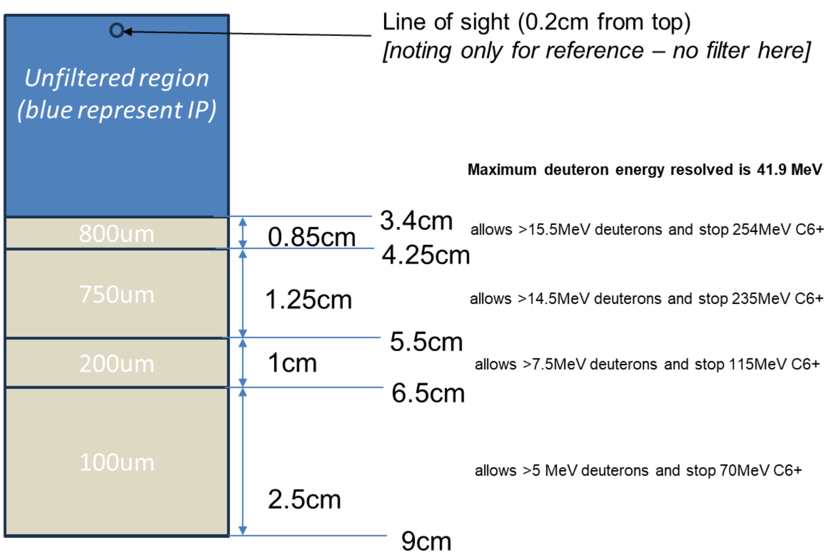
TPIE differential filtering

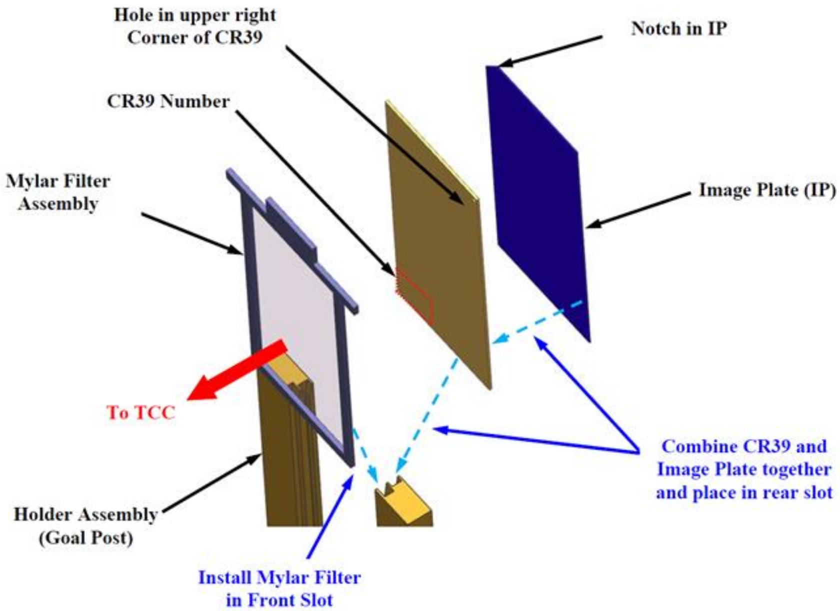
For TPIE, we will use the differential step filter below to stop C^{6+} but allow D^{+} to go through. We will have a TR image plate in back to detect the ions.

The following filter (‘*Graeme filter*’) is used for P1 (up to ~20 MeV deuterons).



The following filter (‘*LANL2023*’) was designed and built for use in P2 to measure high energy deuterons, up to ~42 MeV. This filter was not fielded and remains at LLE.





The **TPIE** parameters are as follows:

- Pinhole (Ø) 250 um
- IP in P1 (10 cm)*
- 5.6 kG magnet
- 10 kV/cm electric field (electrodes set to -5 kV and +5 kV)
- Pixel size: 50 microns
- Differential filter for CD films**

* Shot 5 (500nm CH film) used P2 without differential filter to measure maximum proton energy
** Shots 1,7,9,11 (CD film thickness scan) used P1 with Graeme’s differential filter (shown above) to measure low energy D^+ spectra

EPPS

Examples of the EPPS-1 and EPPS-3 setup are shown in the following images. For future fielding it may be useful to include a positron/proton image plate, even if that signal is not of interest, as the consistent signal between the two can give an indication of the background signal (although we were advised that there may be a need to account for the distinct curvature on the positron/electron image plates as this impacts the position dependence).

Electron Positron Proton Spectrometer 1 (EPPS) / TIM 13 EEAF Operating Procedures Users Guide

Setup - Main Housing

Magnetic Field	LLE-EPPS-1-H (0.8 Tesla)	
Standoff Dist.	47.63	cm
Minimum standoff distance = 47.63 cm (18.75") (pointer deployed distance at maximum inertion)		

Image Plates

	E	P
Image Plate	BAS-MS	
Image Plate Filter	None	None

IP1 Scanning Parameters

Scan Time		Min.
Sensitivity	10,000	
Pixel Size	25	µm

Setup - Front End

◉ Blast Shield Only
○ Image Plate Assembly

	Front Filter	Image Plate #1 (Towards TCC)	Image Plate #2
Image Plate			

IP2 Scanning Parameters

Scan Time		Min.
Sensitivity		
Pixel Size		µm

Steering

Make selections in one row only						
◉	**Target Chamber Center**					
○	**Radius**		um	**Theta**		**Phi**
○	**Distance**		um toward **Port**			

Comments/Requirements

Electron Positron Proton Spectrometer 3 rad (EPPS) / TIM 14 EEAF

Setup - Main Housing

Magnetic Field	LLE-EPPS-3-R (0.8 Tesla)	
Standoff Dist.	other	76.85 cm
Minimum standoff distance = 47.63 cm (18.75") (pointer deployed distance at maximum inertion)		

Image Plates

	E	**P**
Image Plate	BAS-MS	
Image Plate Filter	None	None

IP1 Scanning Parameters

Scan Time		Min.
Sensitivity	10,000	
Pixel Size	25	µm

Setup - Back End

IP/Filtration Stack	See Comments
Ross Pair Filter	

Rad IP Scanning Parameters

Rad IP Scan Time	ASAP	Min.
Rad IP Sensitivity	10,000	
Rad IP Pixel Size	200	µm

Steering

Make selections in one row only						
◉	**Target Chamber Center**					
○	**Radius**	um	**Theta**		**Phi**	
○	**Distance**	um toward **Port**				

Comments/Requirements

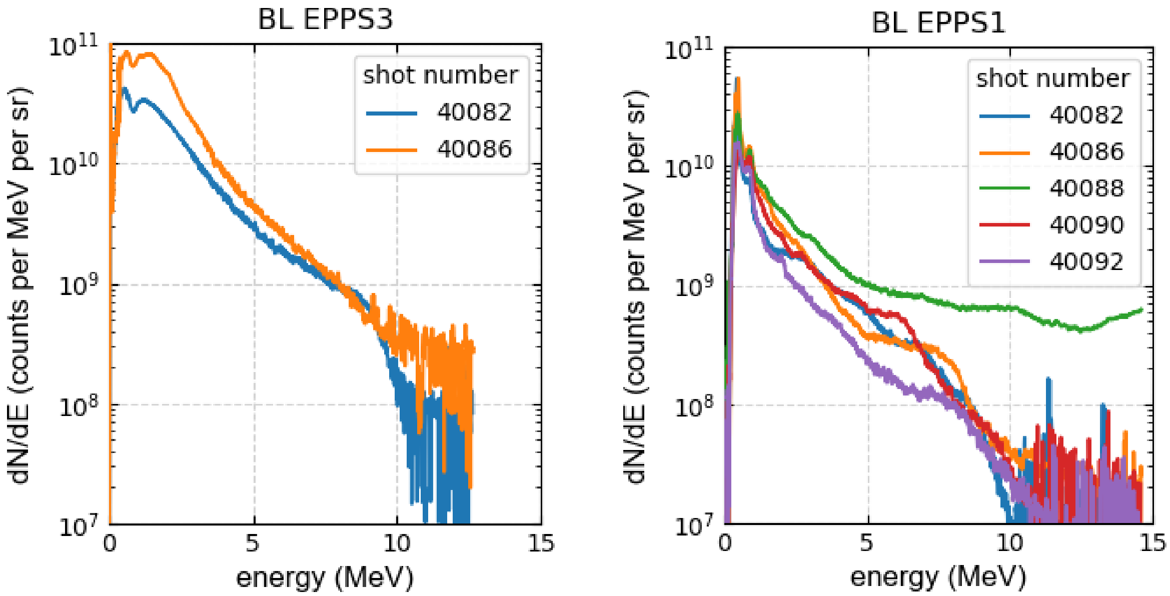
```
LANL_EPPS_Rad_stack MS-IP/0.5 mm Cu/
MS-IP/1 mm Cu/MS-IP/0.5mm Ta/MS-IP/1
mm Ta/MS-IP/2 mm Ta/MS_IP. <br>IP
SCANNING: resolution:200um,
sensitivity:10,000
```

Diagnostic Measurements

EPPS-based Electron Spectroscopy

For the *backlighter* EPPS results all electron beams were measured at roughly 90° from laser-axis, and the signal becomes challenging to resolve above background at ~10-15 MeV. The exception to this is shot 40088, which was a 700 nm CD foil, where the signal is resolved up to ~30 MeV and shows a significantly greater yield. With shots 40086-40092 all being at roughly equivalent laser energy the increase in yield using the 700 nm CD foil may result from target optimization as this target also was found to have a high yield of D^+ ions in the maximum resolvable energy region (just below 17 MeV). Further analysis comparing the 700 nm (40088) and 800 nm (40090) foil electron and ion spectra will be evaluated to conclusively determine the optimal thickness, however more experimental data may be needed.

The direct measurement of crosstalk at full energy without XBLK (EPPS3 on 40086) corresponds to the background source perpendicular for our typical proton radiography configurations (note that there is also an x-ray component to this background).

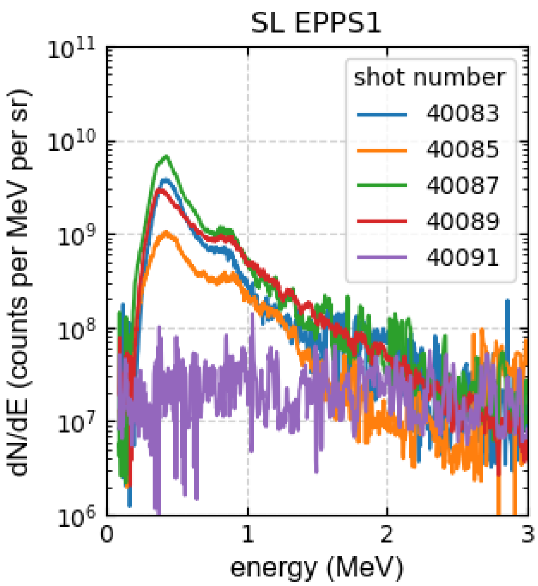


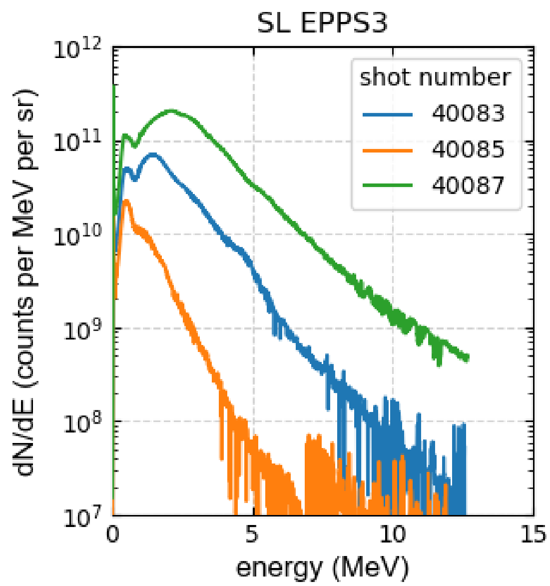
Shot ID	Shot #	Beam	Laser Energy (J)	Target
40082	**1**	BL	227.7	CD film (500nm)
40086	**5**	BL	491.5	CH film (500nm)
40088	**7**	BL	484.4	CD film (700nm)
40090	**9**	BL	481.6	CD Film (800nm)
40092	**11**	BL	482.5	CD Film (500nm)

Initial analysis of the *sidelighter* EPPS results shows that the on-axis (EPPS-3) electron emissions are significantly higher as they are resolved up to ~10 MeV. The lower energy and electron yield for the CPC+glue shot (40085) relative to the CPC+wire shot (40083), at equivalent laser energy are informative. They suggest that:

1. Without the wire a considerable fraction of laser energy may be transmitted through the preplasma and glue.
2. Transmission of electrons through the Ta wire does not appear to account for a significant amount of energy absorption (i.e. the electron spectrum with the wire is not softened at higher energies to the degree we might expect).

The increase in laser energy from 20 J (40083) to 78.8 J (40087) increases both the temperature and total number of electrons.

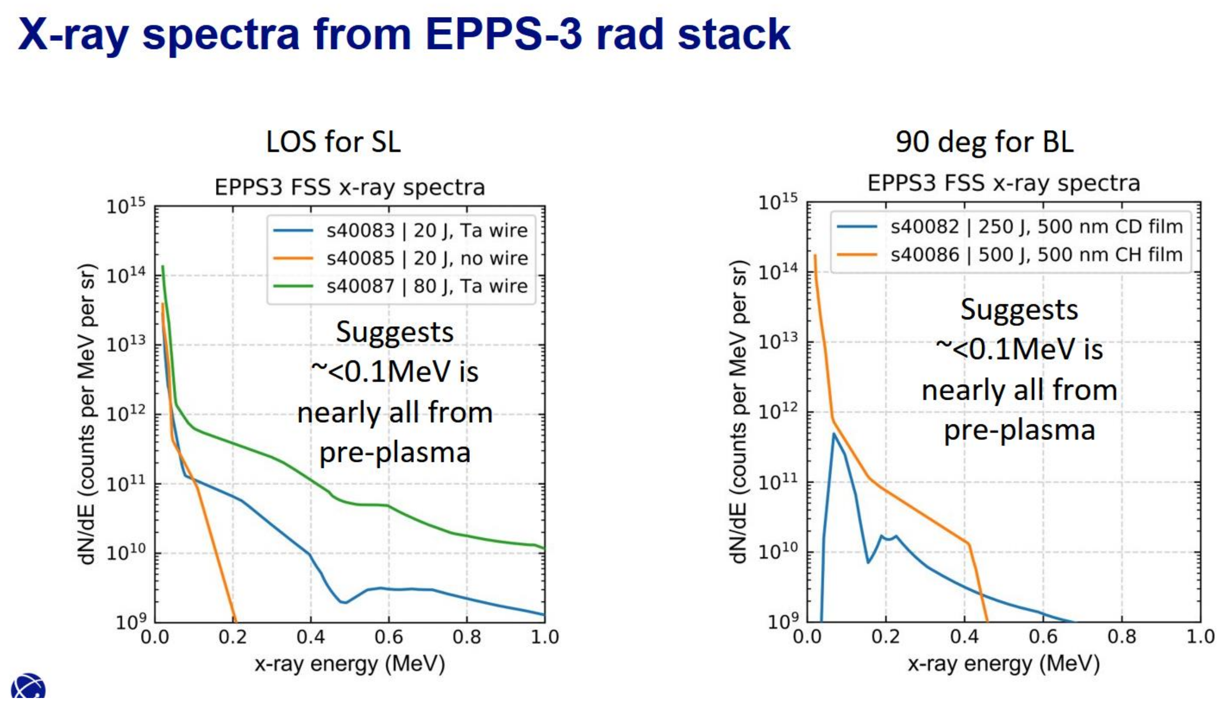




Shot ID	Shot #	Beam	Laser Energy (J)	Target
40083	**2**	SL	19.2	CPC+wire (0.5mm × 25µm ⌀)
40085	**4**	SL	19.1	CPC+glue (no wire)
40087	**6**	SL	78.8	CPC+wire (0.5mm × 25µm ⌀)
40089	**8**	SL	19.2	CPC+wire (0.5mm × 25µm ⌀)
40091	**10**	SL	19.2	CPC+wire (0.5mm × 25µm ⌀)

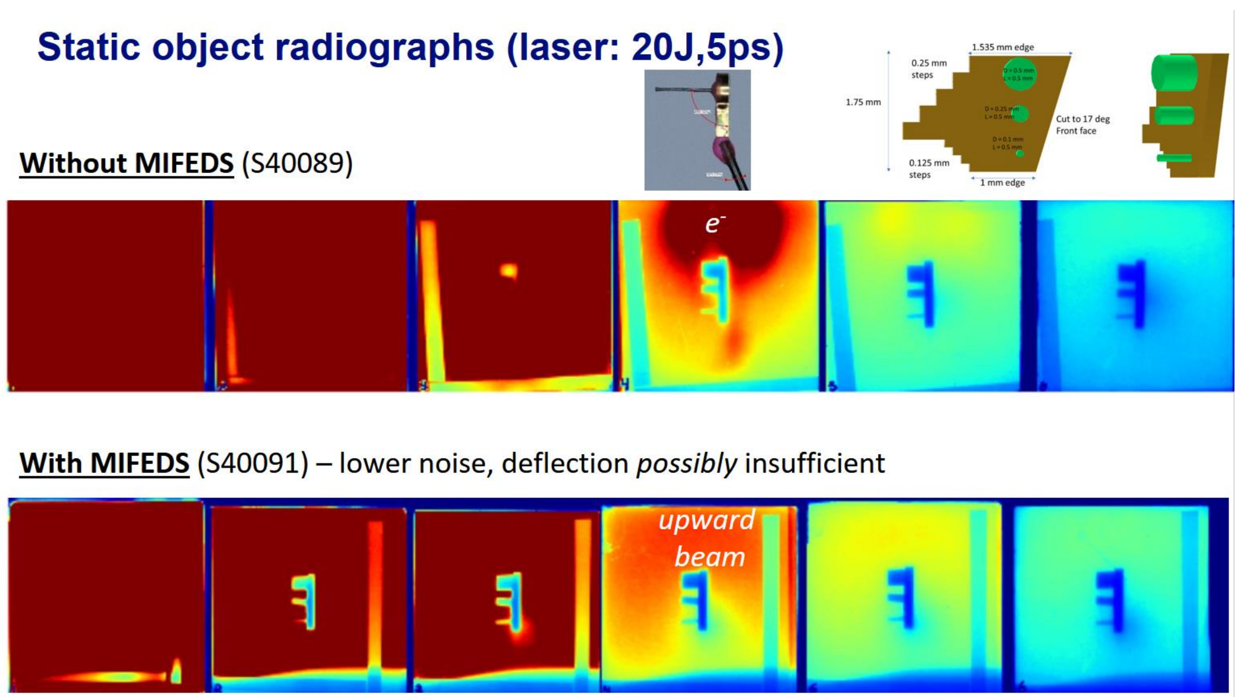
Image Plate Filter Stack-based X-ray Spectroscopy

Analysis of the EPPS-3 rad stack for the sidelighter (along laser-axis) found nearly all the x-rays <100 keV originate from the pre-plasma filling the CPC cone (i.e. glue) rather than from bremsstrahlung interactions in Ta. For the backlighter (perpendicular to laser-axis) with CD and CH films the x-ray intensity and signal decrease significantly when laser energy is reduced from 500 J to 250 J (with constant 0.7 ps pulse length). Reducing laser intensity may be key to reducing the crosstalk.



X-ray Radiography

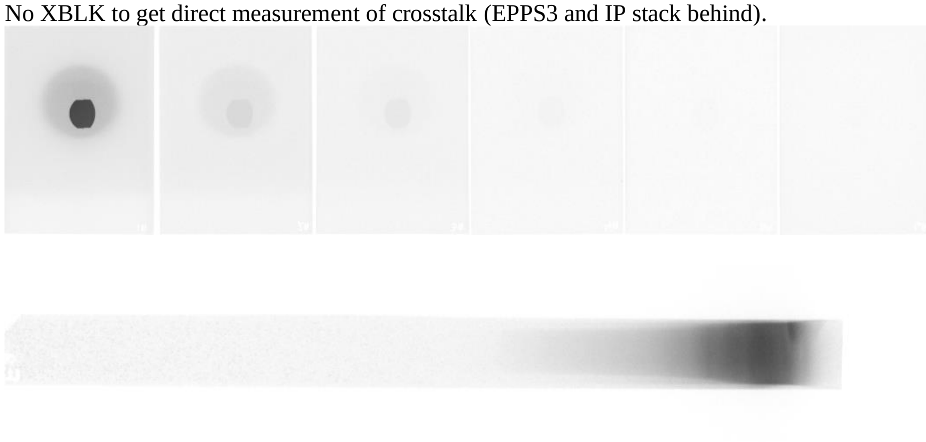
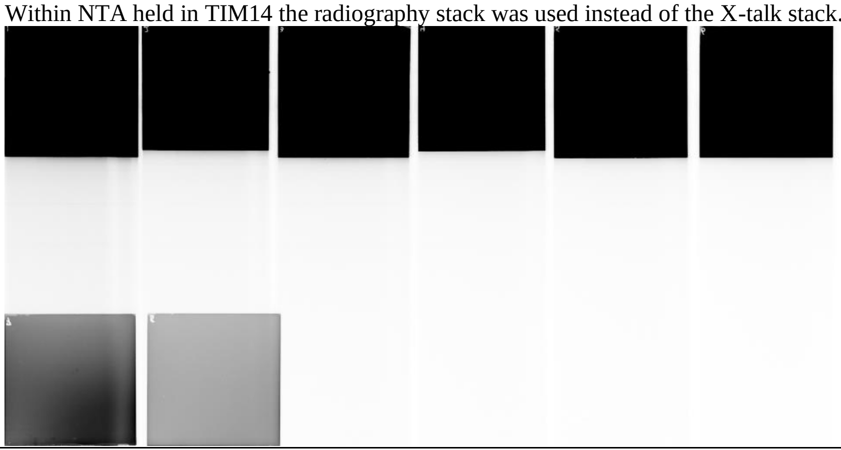
Detailed analysis of image quality is ongoing, but qualitative assessment of the radiographs indicates that the noise is notable reduced using MIFEDS to deflect electrons. In both cases it is possible to resolve even the smallest 125um diameter wire.

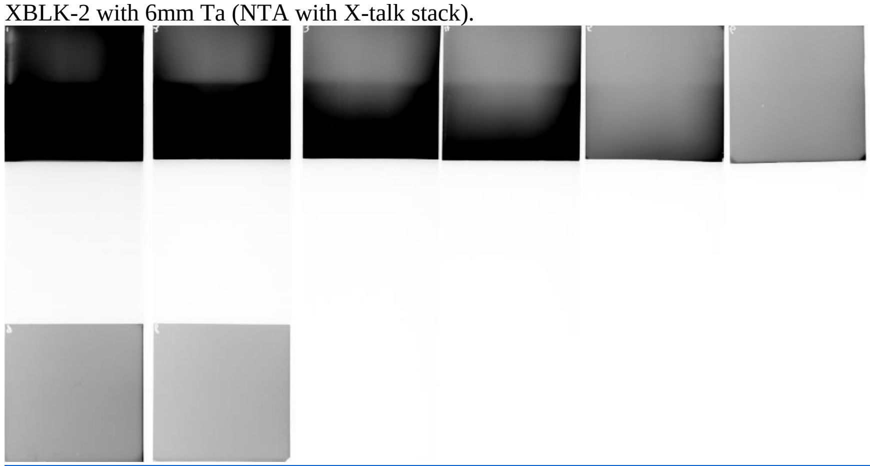
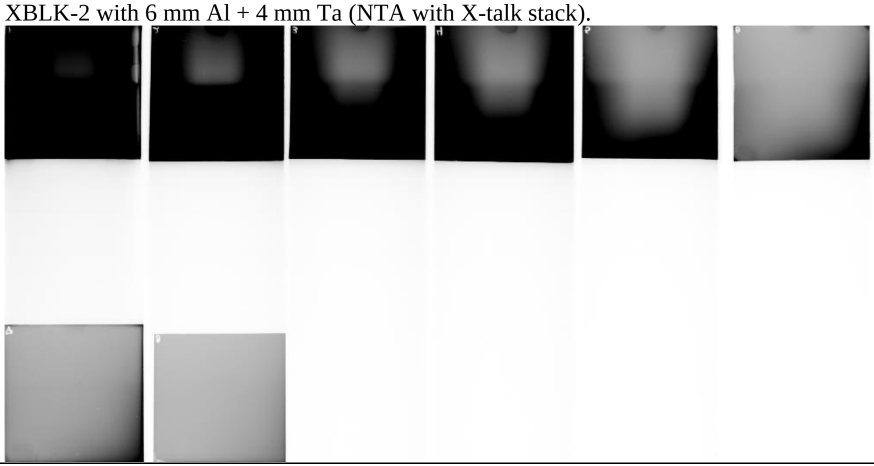


XBLK results

The table below lists the XBLK filter and shows the corresponding raw IP scans perpendicular to the beam (i.e. behind XBLK shielding except for 40086 where crosstalk was measured directly). In each case the first scan is shown.

Qualitatively the filter stacks show that the mylar filtering on the upper portion of the 40090/40092 scans had a significant impact on signal reduction, indicating the large contribution of electrons to the signal. This stems from high electron fluence and the high sensitivity of IP to electrons (sensitivity to x-rays is typically indirect, requiring generation of electrons which then deposit energy in the IP).

40086	**5 /BL** **500nm CH film** **491.5J,0.7ps**	No XBLK to get direct measurement of crosstalk (EPPS3 and IP stack behind). 
40087	**6 / SL** **CPC+wire** **78.8J,5ps**	XBLK-1 with 6mm Al (EPPS1) 
40088	**7 / BL** **700nm CD film** **484.4J, 0.7ps**	XBLK-2 with 6mm Al. EPPS3 removed for this shot and rest of day. Within NTA held in TIM14 the radiography stack was used instead of the X-talk stack. 

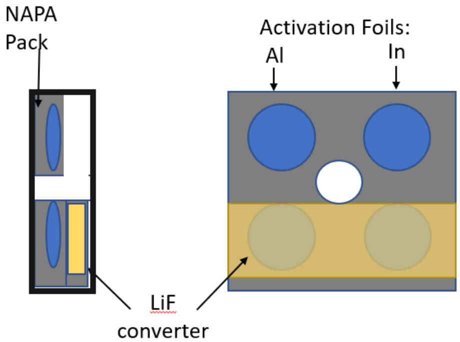
40089	**8 / SL** **CPC+wire** **19.2J, 5ps**	XBLK-1 with 6mm Al (EPPS1).
40090	**9 / BL** **800nm CD film** **481.6J, 0.7ps**	XBLK-2 with 6mm Ta (NTA with X-talk stack). 
40092	**11 / BL** **500nm CD film** **482.5J, 0.7ps**	XBLK-2 with 6 mm Al + 4 mm Ta (NTA with X-talk stack). 

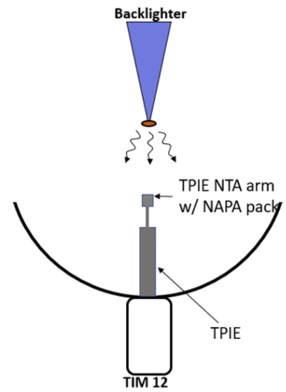
NAPA results

The following slides were provided by Ben Stanley from LLE who led the design, fielding, and analysis of the activation results.

The main outcome of these results was that in this configuration, with the converter very far away (72 cm), the activation signal appears to be dominated by noise. This suggests that the ion beam divergence leads to neutron production in components other than just the LiF foil, such as Al of the EP chamber and NTA components. Improvements could likely be seen by placing the converter within ~mm of the ion source or by shielding ions emitted at higher angles to collimate the beam and ensure neutron production is limited to the LiF converter.

LANL Goal: Optimizing CD film thickness for pitcher in pitcher-catcher neutron source. Primary metric of pitcher performance is TPIE spectra, neutron activation and nTOF are secondary





- LiF was wrapped with 20 um of Al foil per facility requirement (PI requirement was no more than 100um Al)
- Pack standoff distance was 8 cm

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First use of NAPA pack with TPIE

- Was warned that previous experiments using NTA packs and TPIE do not always work due to clipping
- Investigation showed drawing for packs are wrong which give ~1/4'' play within the pack
- New NAPA packs were machined with appropriate dimensions to ensure a centered thru hole for ions to reach TPIE

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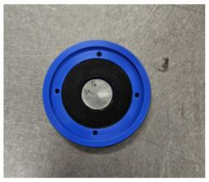
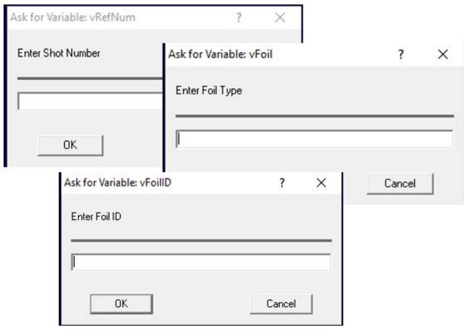
Activation

Each foil was placed in one of our spare 50mm foil holders and centered with a 3d printed spacer



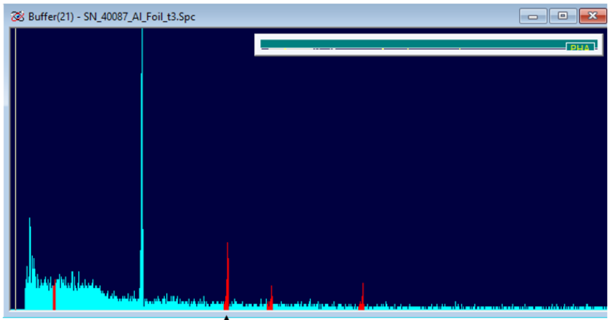
Each foil was measured individually with the HPGe detector

A custom acquire program was run with the Ortec software
- Acquire time was adjusted manually before beginning
- Program asked for shot number, foil type and foil location via pop-up
- Based on foil type entered, pre-defined ROIs were loaded. ROI files created from previous measurements of these foil types on OMEGA
- Program saved spectrums and generated reports based with file names based on user inputs



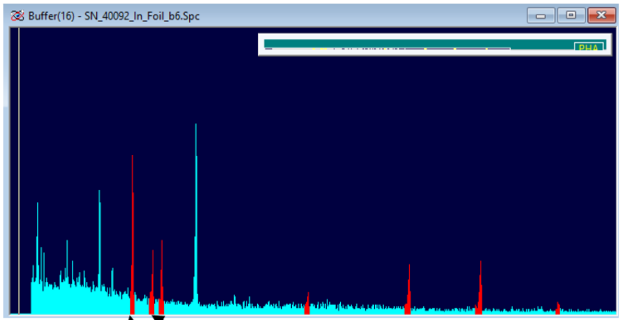
Example spectrums

Aluminum



27Al(n,p)27Mg reaction used for foil activity comparison (843 keV)

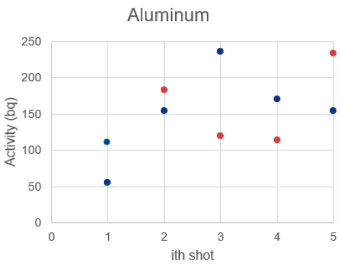
Indium

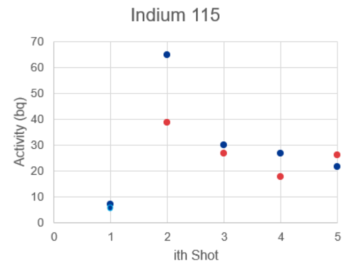


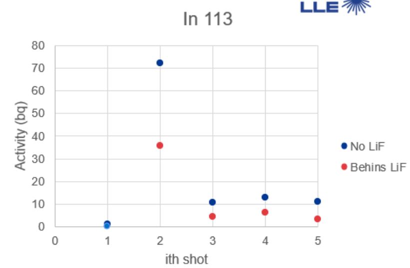
115(n,n')115mIn & 113(n,n')113mIn reaction used for foil activity comparison (336 & 392 keV)

Activity levels were lower than expected, especially for aluminum. Partially caused by the 25 - 30 min recovery time, partially due to physics

Post shot activity was calculated for each foil. Results were generally not as expected with the activity of foils behind the LiF being lower than the foils without LiF in front of them







	Shot Number	Target Type	Target Thickness	Laser Energy	Note
1	40082	CD	500nm	227.7J	No LiF (background)
2	40086	CH	500nm	491.5J	
3	40088	CD	700nm	484.4J	
4	40090	CD	800nm	481.6J	
5	40092	CD	800nm	482.5 J	See next slide

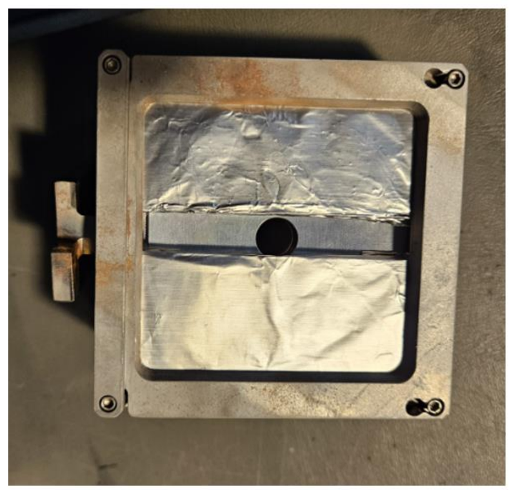
Last shot change

For the last shot a 4mm thick piece of mylar was added in front of the other set of foils which did not have the LiF in front of them

The idea behind this was to stop deuterons from directly hitting the aluminum NAPA cover plate

Here the activity of the foils behind the LiF was larger for the 27Al(n.p)27Mg and 115(n.n')115mIn reactions but not the 113(n.n')113mIn reaction

Note: a second variable was added as the PIs decided put the LiF at the top of pack though it had been running at the bottom previously

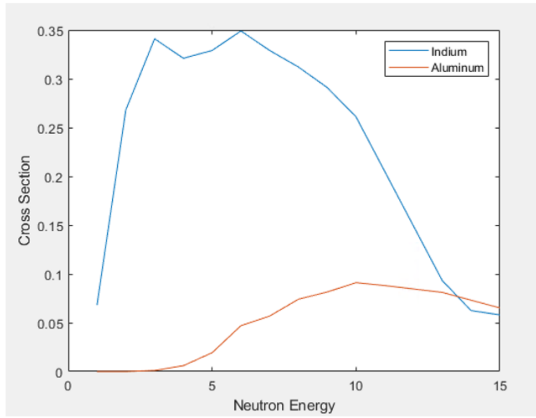


Activation cross sections and decay half lives

UR LLE

In T1/2 = 4.49 hr
In br = 45.8%

Al T1/2 = 0.16 hr
Al br = 71.8%



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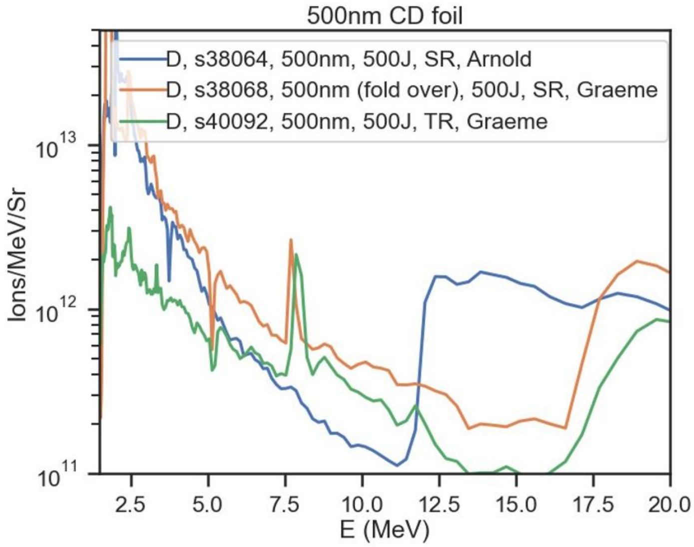
TPIE results

The following show the FY24A shots along with results from the FY23 campaign that used similar CD foil targets.

FY24A shots: 40082, 40086, 40088, 40090, 40092
FY23 shots: 38064, 38066

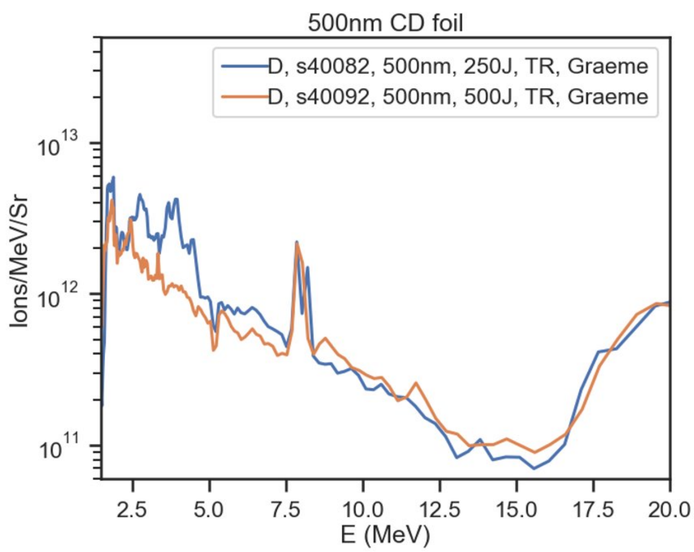
The result from 8976 (final plot in this section) is from a reanalysis of Drew Higginson's data from the nRS–11A campaign (shots taken 17 Feb. 2011) to give a contrast of a 1000 J long pulse laser optimized for the TNSA regime relative to our shot pulse transparency regime acceleration. These results will be analyzed further, but initial comparison is supportive of the short pulse approach.

For our thickness scan outlined in the following pages, results suggest the 700 nm and 800 nm thick CD targets performs best for the high intensity conditions corresponding to the relativistic transparency regime. Here best performance refers to the target yielding the highest number and energy of ions (specifically D^+). These results are encouraging and will serve as a basis for future neutron pitcher-catcher development studies.



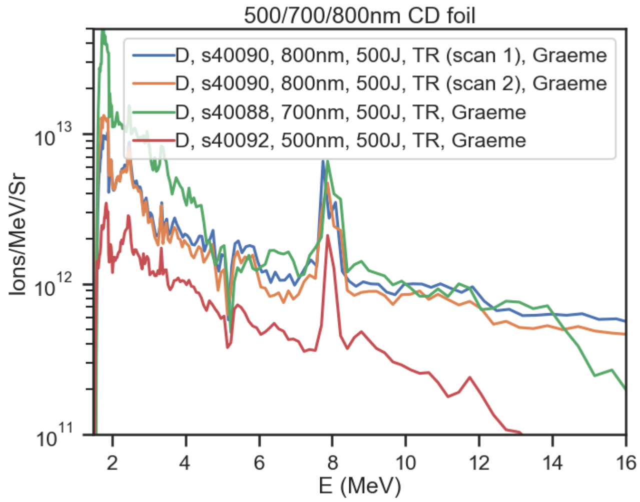
Shot	Ions/sr	Ions	Total ion energy (J)
38064 (<11MeV)	1.47e16	4.57e12	1.68
38066 (<16MeV)	1.73e16	5.37e12	2.00
40092 (<16MeV)	2.25e15	6.98e11	0.34

Comparison of 500nm CD film results in MP23 and MP24A shows that thicker film may be more optimal. A direct comparison of TR and SR IP results may not be possible due to PSL calibration, but the trend is similar.

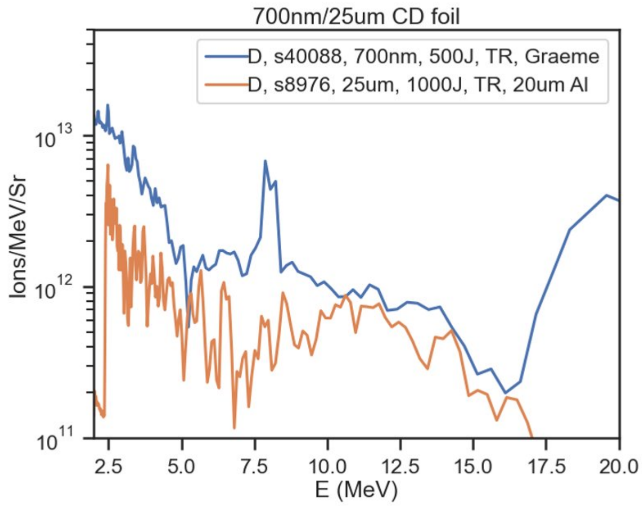


Shot	Ions/sr	Ions	Total ion energy (J)
40082 (<16MeV)	3.34e15	1.04e12	0.51
40092 (<16MeV)	2.25e15	6.98e11	0.34

Comparison of 500nm CD film results for 250 J and 500 J shows similar performance, indicating that film may be too thin.



Shot	Ions/sr	Ions	Total ion energy (J)
40090 (<16MeV)	6.29e15	1.96e12	0.90
40088 (<16MeV)	1.53e16	4.76e12	1.91
40092 (<16MeV)	2.25e15	6.98e11	0.34



Shot	Ions/sr	Ions	Total ion energy (J)
40088 (<16MeV)	1.53e16	4.76e12	1.91
40092 (2<E<16MeV)	1.13e14	3.52e10	0.024

Need double-check

700nm CD film appears to significantly outperform the 25um CD film in the high fluence TNSA regime.

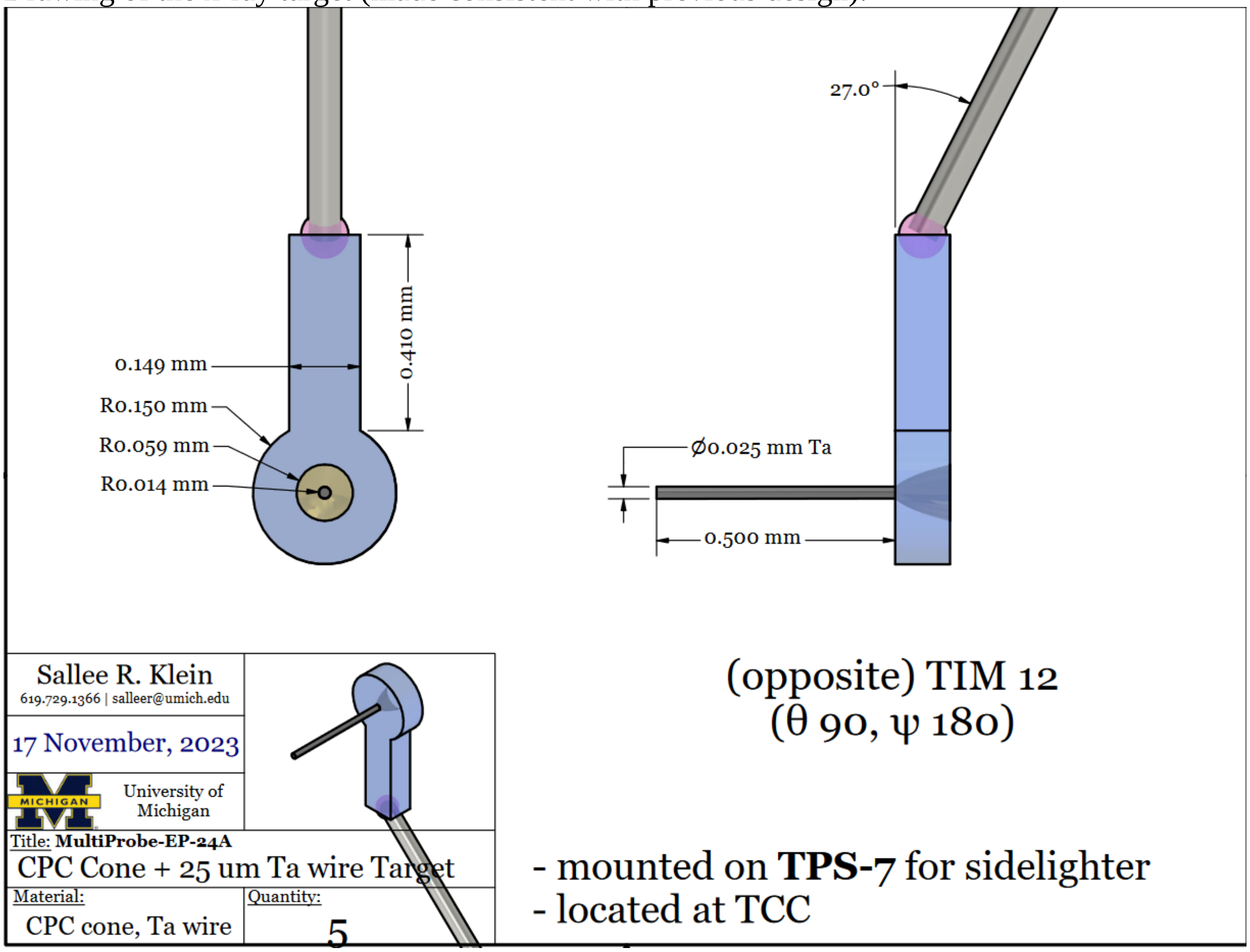
Acknowledgements

This work was supported by the U.S. Department of Energy through the Los Alamos National Laboratory (LANL). LANL is operated by Triad National Security, LLC, for the National Nuclear Security Administration of the U.S. DOE (Contract No. 89233218CNA000001). This work was initiated under the LANL LDRD 20180732ER program and continued under OES ADP.

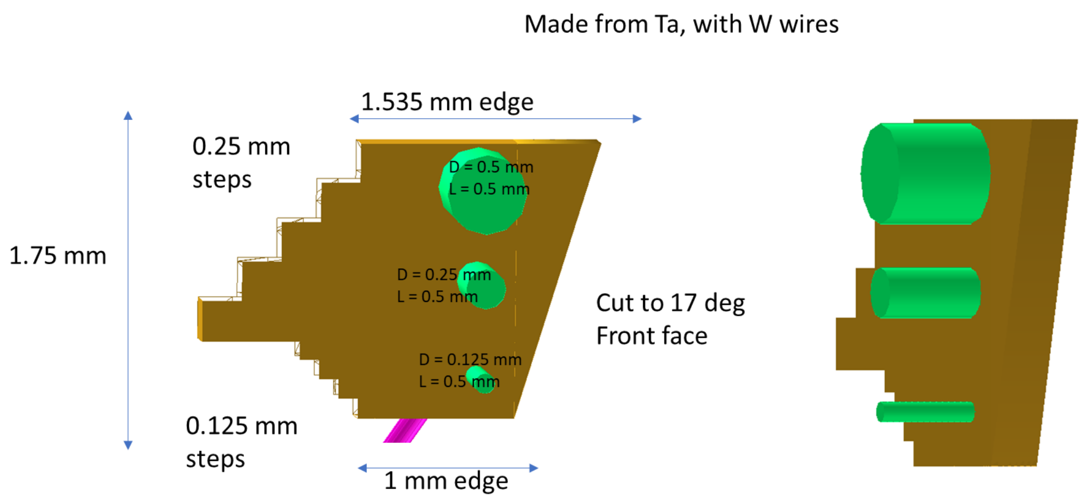
Appendices

Appendix A: Target Drawings

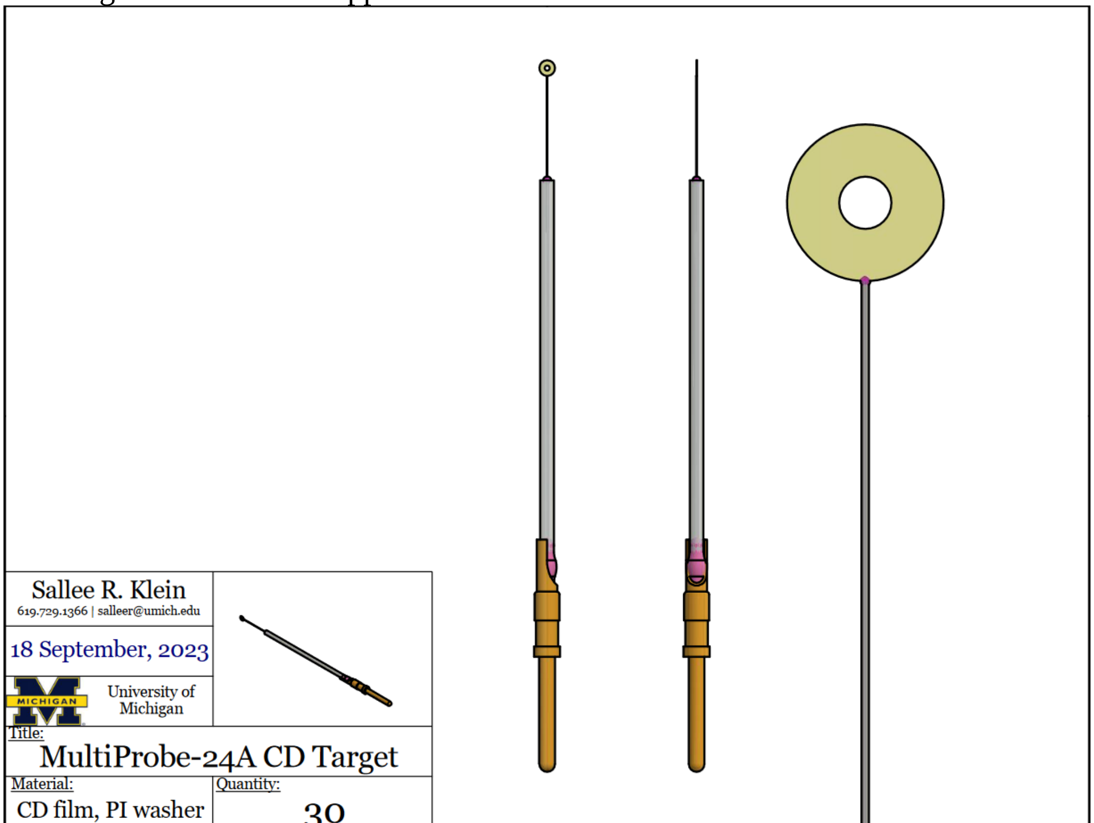
Drawing of the x-ray target (made consistent with previous design).

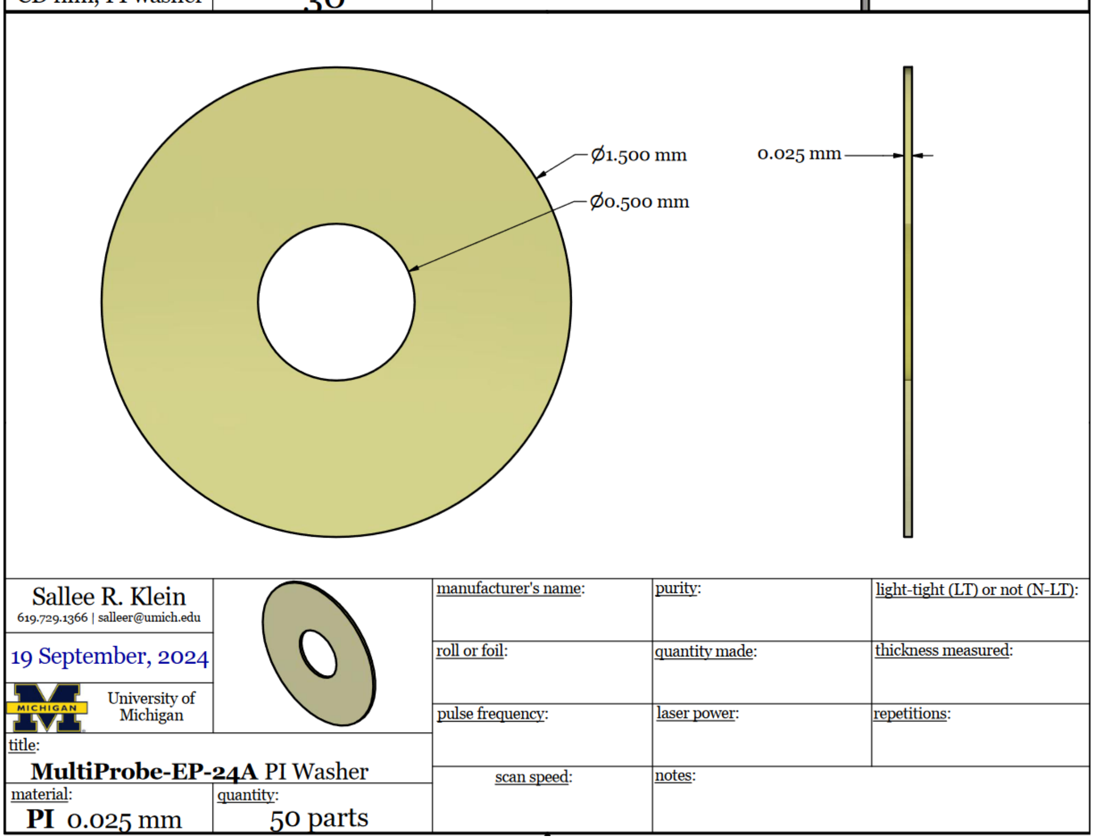


Drawing of the static object used for x-ray radiography resolution.

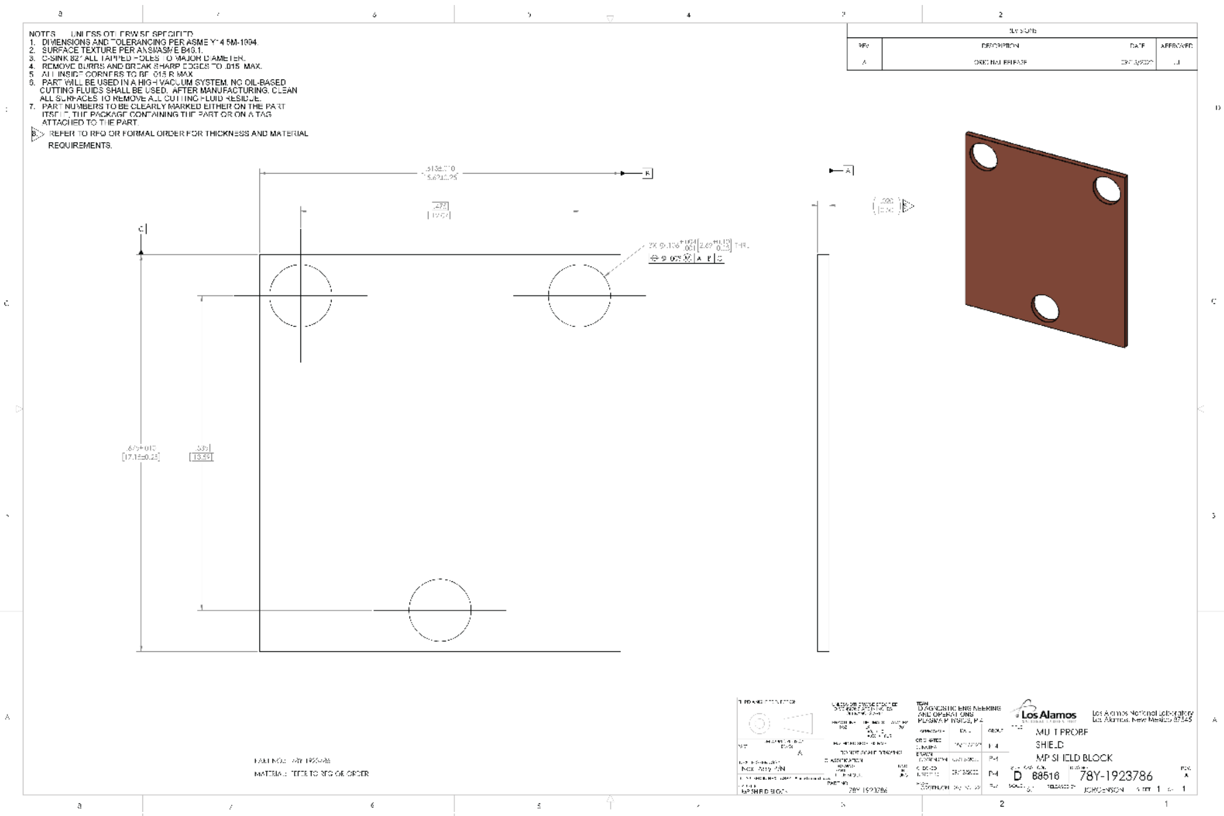


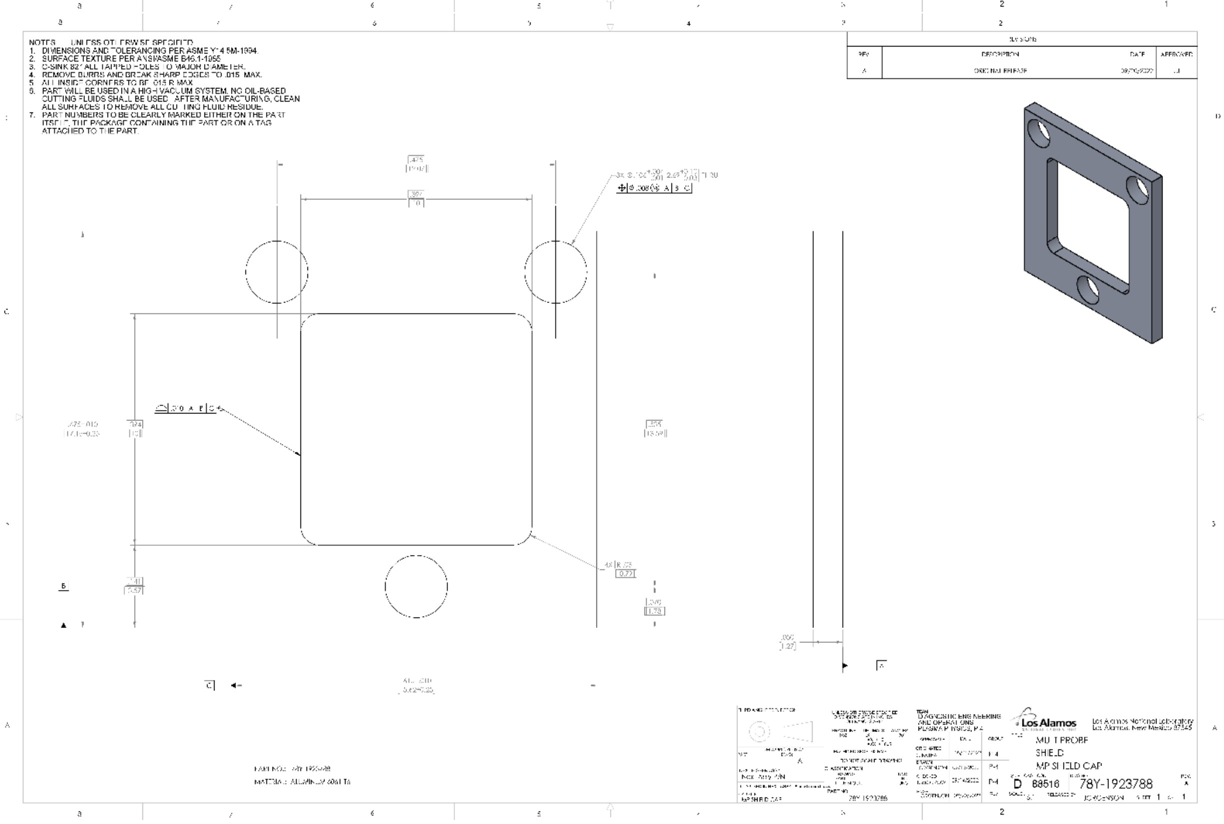
Drawing of the CD film supports.

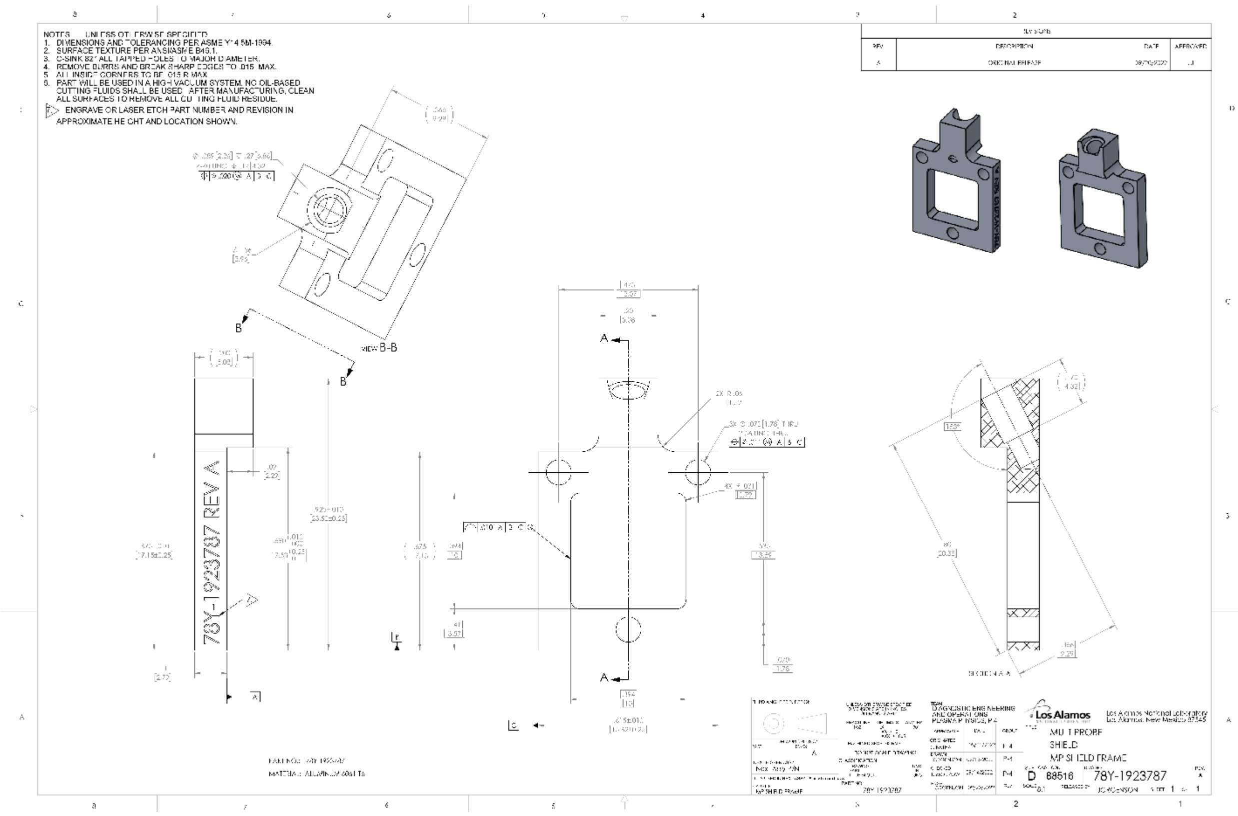




Drawings of XBLK.



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2. SURFACE TEXTURE PER ANSI/ASME B46.1.
3. C-SINK 82° ALL TAPPED HOLES TO MAJOR DIAMETER.
4. REMOVE BURRS AND BREAK SHARP EDGES TO .015 MAX.
5. ALL INSIDE CORNERS TO BE .015 R MAX.
6. PART WILL BE USED IN A HIGH VACUUM SYSTEM. NO OIL-BASED CUTTING FLUIDS SHALL BE USED. AFTER MANUFACTURING, CLEAN ALL SURFACES TO REMOVE ALL CUTTING FLUID RESIDUE.
7 ENGRAVE OR LASER ETCH PART NUMBER AND REVISION IN APPROXIMATE HEIGHT AND LOCATION SHOWN.
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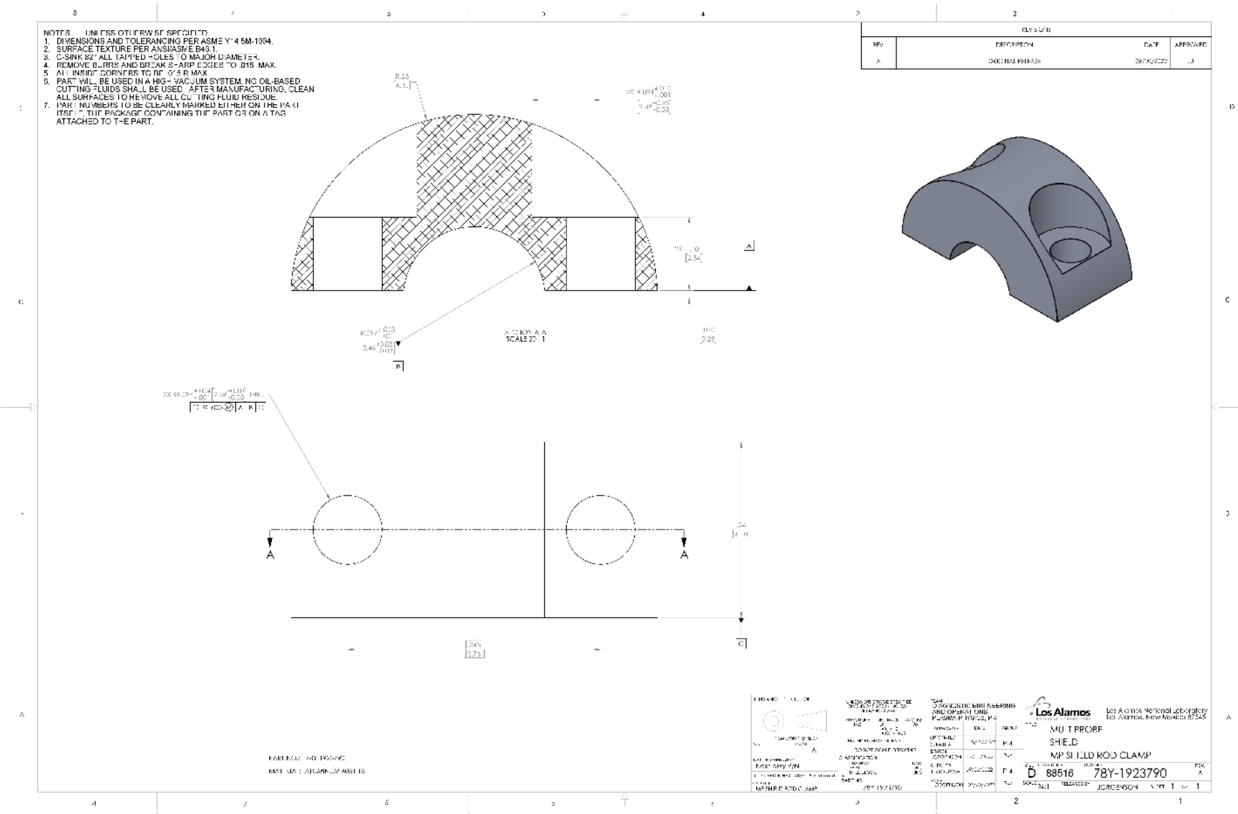
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7. PART NUMBERS TO BE CLEARLY MARKED EITHER ON THE PART ITSELF, THE PACKAGE CONTAINING THE PART OR ON A TAG ATTACHED TO THE PART.
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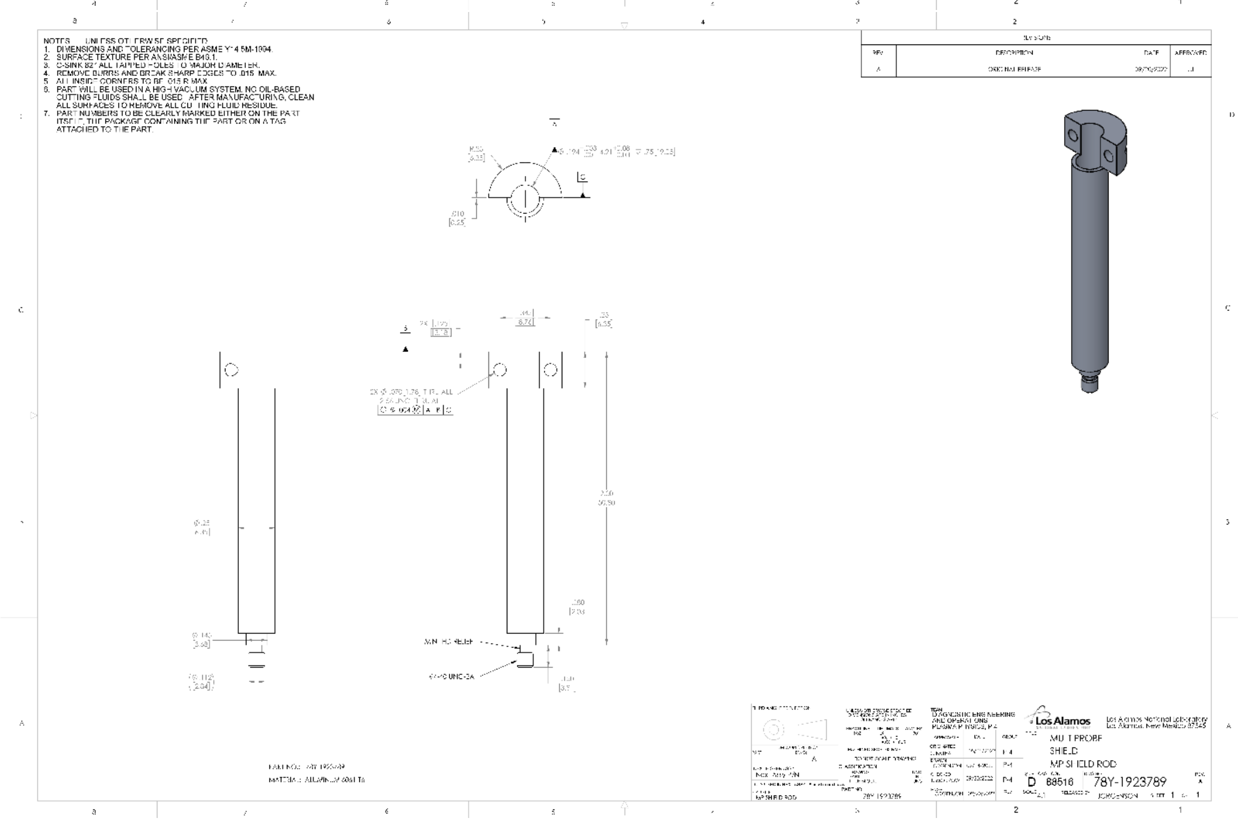
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Appendix B: Raw BMXS-25 IP data

The following show the BMXS IP data. This diagnostic was a ride-along and it is clear specifically for shots 40083-40087 the source-collimator alignment is not ideal and resulted in clipping of the beam.

40082

40083

40085

40087

Appendix C: Raw TPIE data

Relevant parameters (additionally, all used TR IP, 5.6 kG magnetic field, 10 kV electric field)

	TPIE settings	TP analysis settings (TP_o_matic)			Filter	Scan		Target
Shot	Drift distance (from end of magnet, mm)	Offset angle (deg)	Overlap energy (MeV)	Relativistic solver	material/thickness	Pixel size (um)	delay (min)	
40082	324	0.45	p:57	Yes	Al (Graeme)	25	33.1	500nm CD film
40086	724	0	p:150	Yes	Mylar	50	36.78333	500nm CH fillm
40088	324	0.45	p:57	Yes	Al (Graeme)	50	30.1	700nm CD film
40090	324	-0.15	p:57	Yes	Al (Graeme)	50	26.71667	800nm CD film
40092	324	-0.6	p:57	Yes	Al (Graeme)	50	23.06667	500nm CD film

40082

40086

40088

40090

Scan 1

Scan 2

40092