SAND2011-5356P

Comparison of pinhole camera intensity with power pulses

Can use intensity on MCP images as a confidence test of image timings

- Models of stagnation have utilized growth rates diagnosed from end on imaging, so we need to have high confidence in those diagnostics
- We can use intensity integral from MCP as a sanity check on image timing.
- At best Z now strives for ± 0.5ns timing for each diagnostic, hence ± 1.0ns for cross timing
  - Per M. Jones
- I'm not sure what quoted timing uncertainty for old Z diagnostics was ?
- Itsic is about to submit a PRL on work that uses core growth rates calculated from end on image data.
  - Checking interpretation of data is self-consistent prior to submission

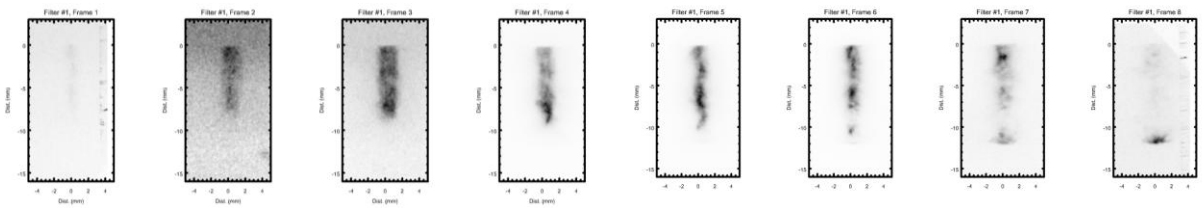
Slide from D. Ampleford DZP 2011

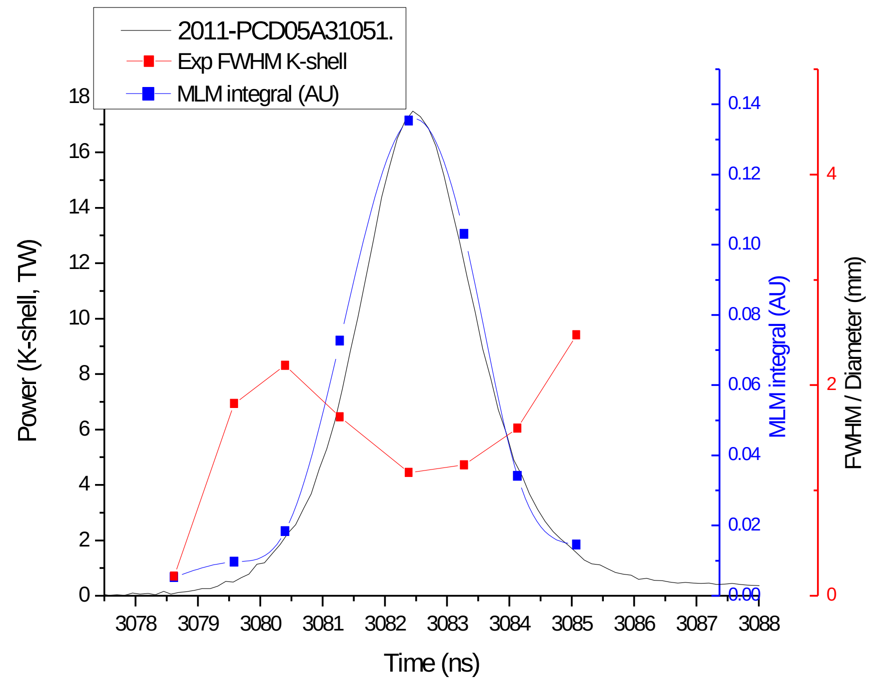
Analysis of Z2011 shows MLM intensity follows x-ray pulse, and FWHM of K-shell emitting region is compressed during x-ray rise

Shot 2011 – 70mm SS nested

- Integral of K-shell filtered pinhole camera strongly follows K-shell x-ray pulse
- This analysis was used to confirm NSTec suggested timing correction
- Rise of x-ray pulse coincides with decrease in FWHM of K-shell region
- Reason for earlier rapid expansion unclear
  - Very low emitted power at that time
  - First frame is likely time-integrated transmission of MCP
- From images, expansion post-peak is representative of column break-up
  - Instability growth
  - Angular momentum
  - Hot spot formation

5 mils Kapton + 2500 Angstroms Al



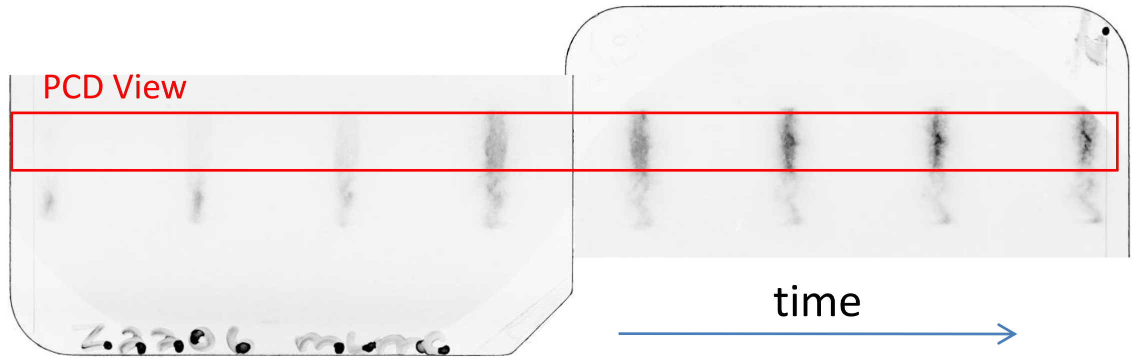


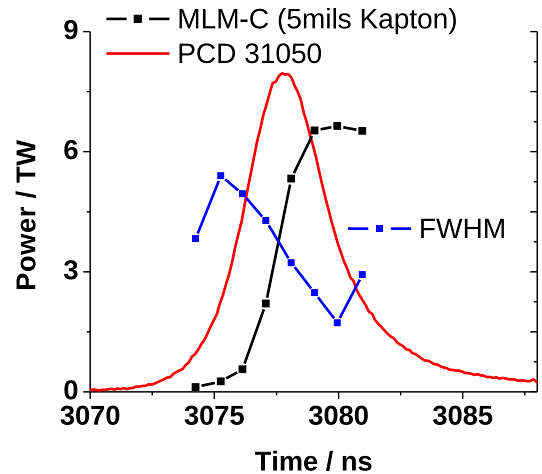
Question: Is this consistent across different loads?

For Al on Ni-clad Ti 'stagnation physics' array compression of column also seen on x-ray rise

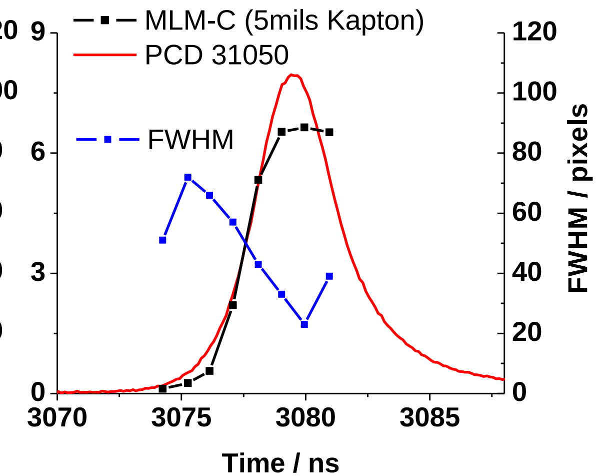
New Data – MLM camera C on 2206 - stagnation physics series, Al on Ni-clad Ti

- Using MLM-C, filtered with 5mils Kapton
- Apply full step wedge correction to data
- Integrate intensity in PCD view to give reality check on timing
- Compare to PCD with same filter
- Must apply 1.7ns correction
- Measure FWHM of emitting region in PCD view
- FWHM drops during x-ray rise, minimizing at peak x-rays.





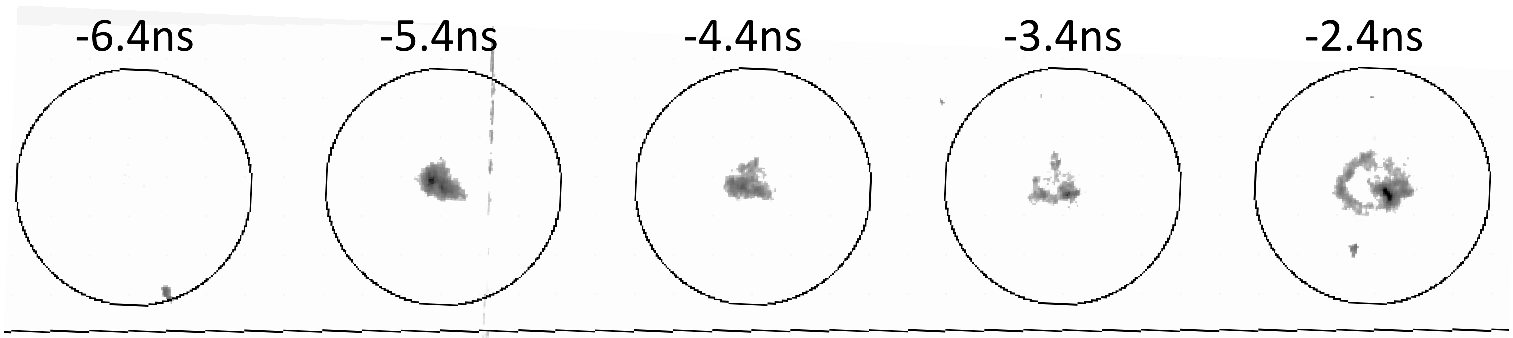
1.7ns time shift



Z2206 also shows compression during rise, consistent with Z2011

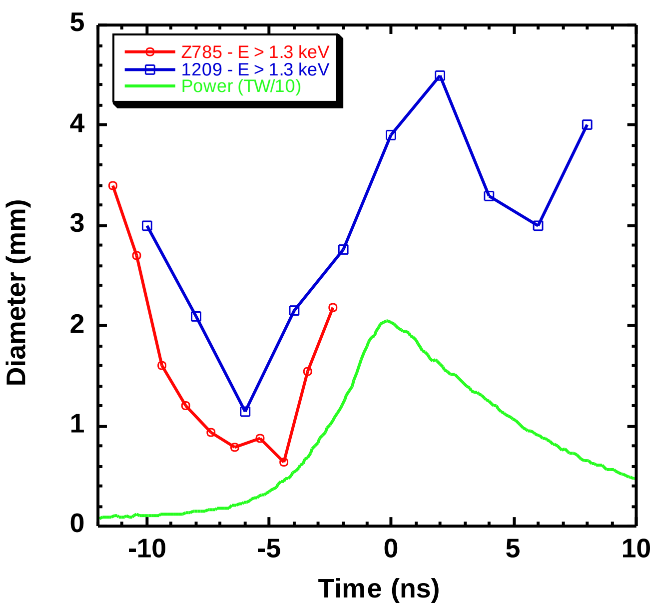
For 785 (Al on Ni-clad Ti), end on diagnostics show the core region expanding during start of x-ray pulse (assuming stated timing)

Core region seen to expand on the run up to peak x-rays



End on pinhole camera – 4 micron Al kimfoil + 8 micron kapton (10% transmission at 1.3keV)

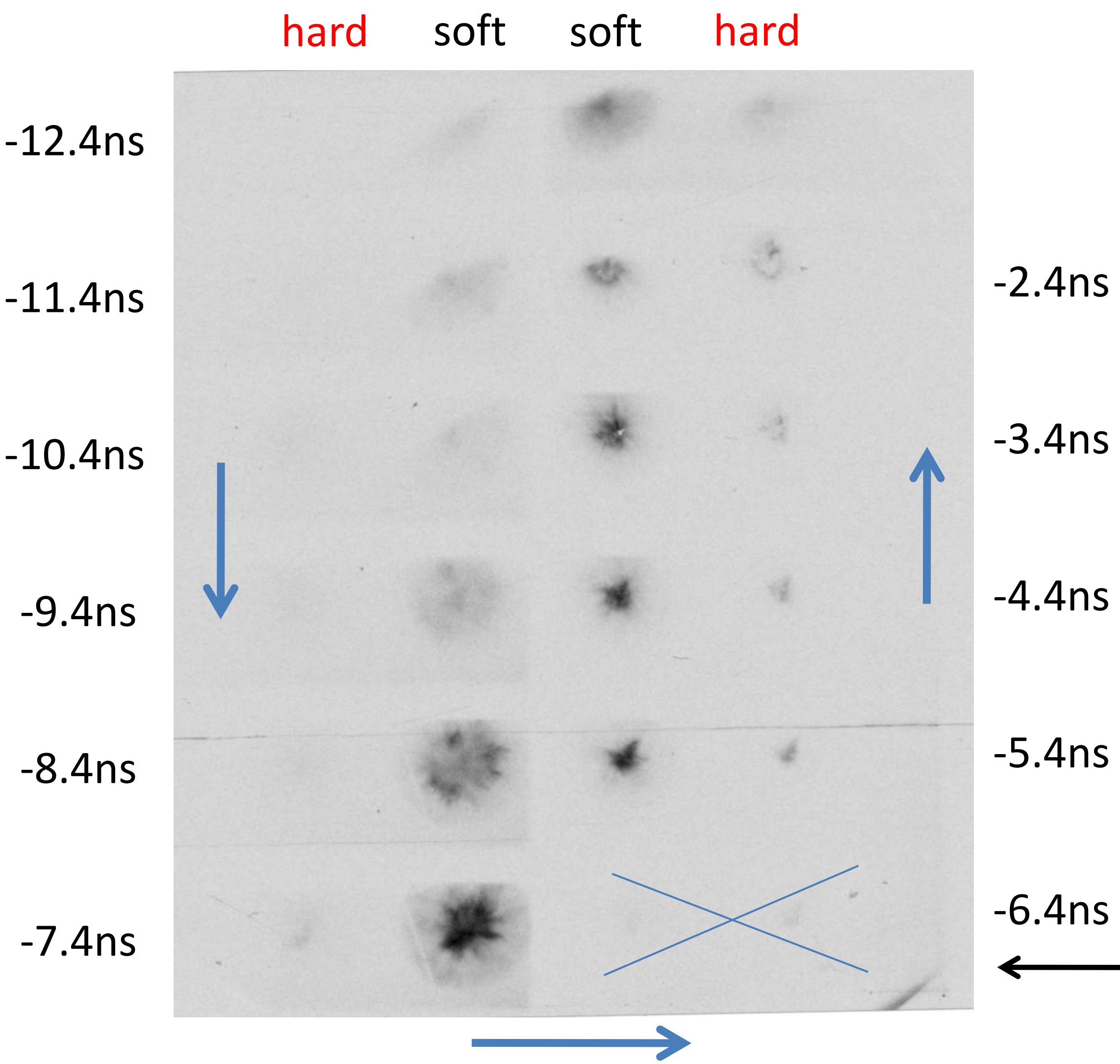
Plasma diameter expands as output increases



Graph taken from M. Cuneo Wire array workshop presentation 2009. This core expansion process is also being used as part of a draft PRL by Itsic Maron.

Experimental timings either taken from presentations, which are consistent with pinhole imaging data archive (courtesy of G. Rochau): \\Cerberus\Projects\Z_Diagnostics\1ShotData\PHC\OnaxisPHCs

For 785 end on imaging also recorded stagnation on a softer filter (same camera and film)

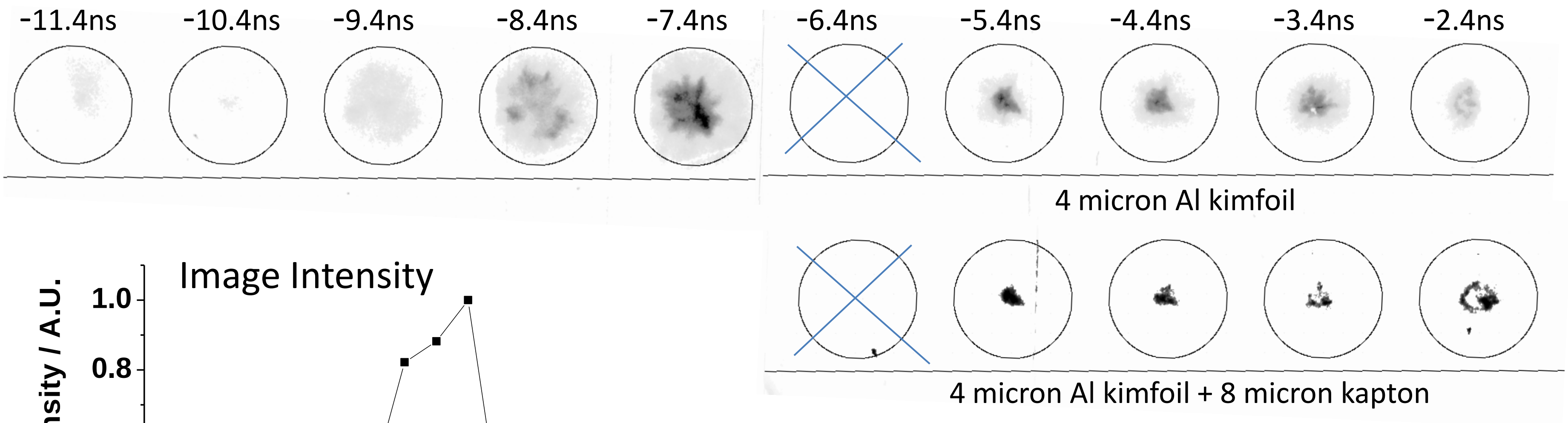


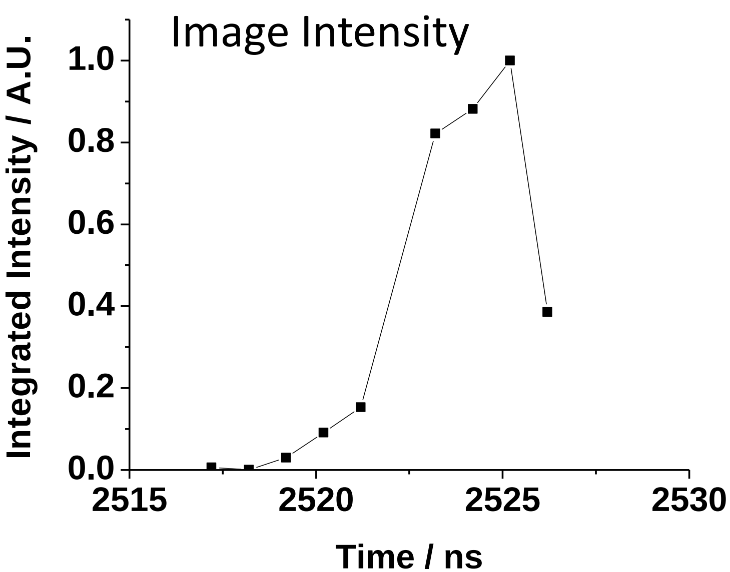
Going back to original data (JM2 785), the camera also recorded good data on a softer filter (4 micron Al Kimfoil inner frames), over a longer time sequence

Seems quite likely that frame 7 didn't record useable data?

Softer filter has larger temporal coverage. Intensity as function of time can be recovered directly from data.

Examining softer frames (4 micron Al kimfoil – inner on JM2, shot 785) we apply step wedge correction to work more directly with intensities





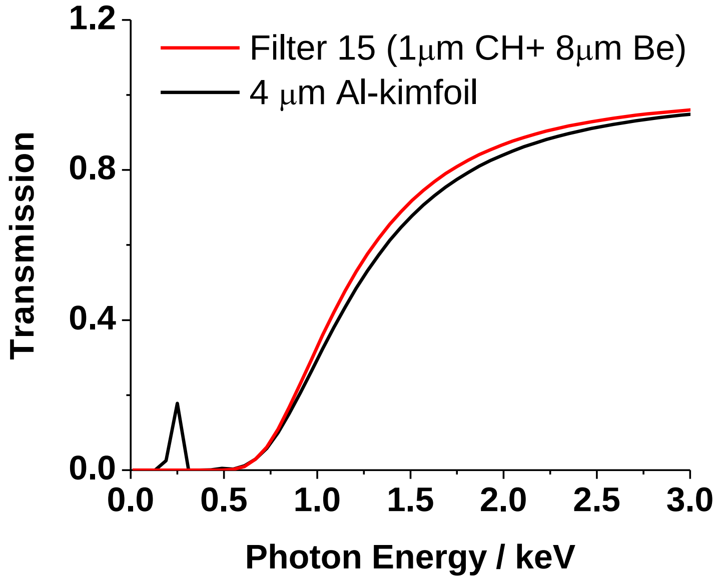
As with side on MLM, the intensity in these images can be integrated over image to recover pulse shape

Later frames had a different bias (350/200), so relative intensity for pulse shape corrected assuming factor of 2 intensity change for every 31V D.C. bias (ref. Rochau. Rev. Sci. Instrum. 77 10E323). Frame 6 has been dropped as it appears to have had problems

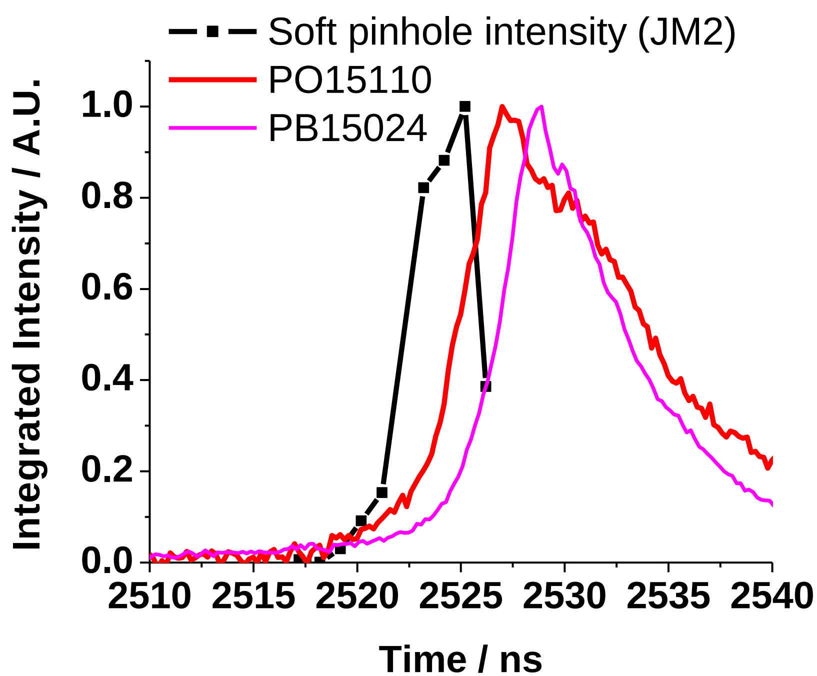
Timing discrepancy between end on camera and PCD measurements may have complicated interpretation

Softer filter (4 micron Al kimfoil) very similar to filter 15, with which as end on PCD was fielded on this shot

Transmission for pinhole images, and end on PCD



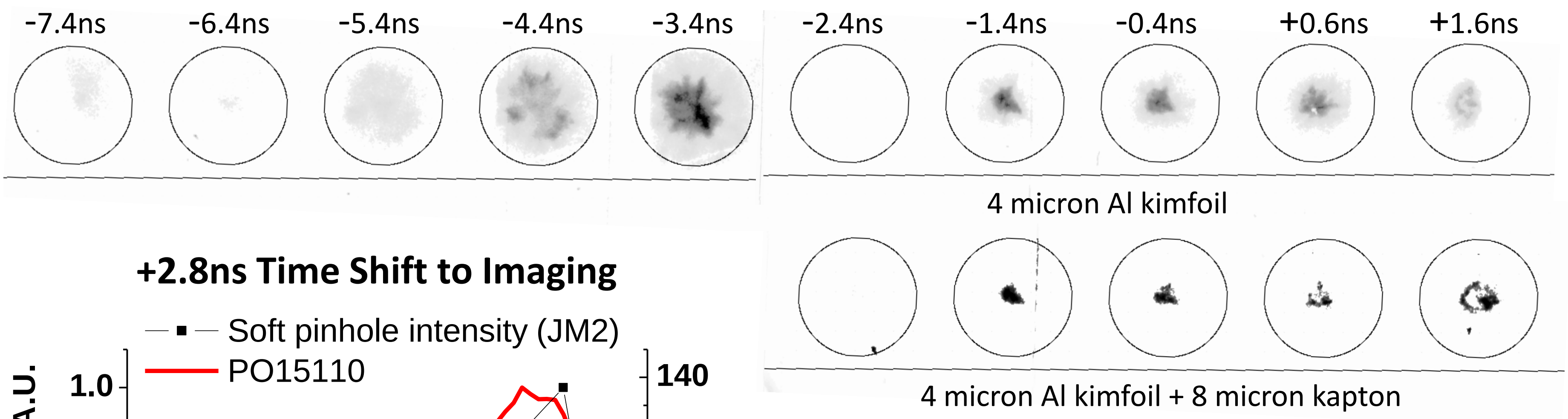
Intensity in imaging peaks before PCD signal for same view and photon energy

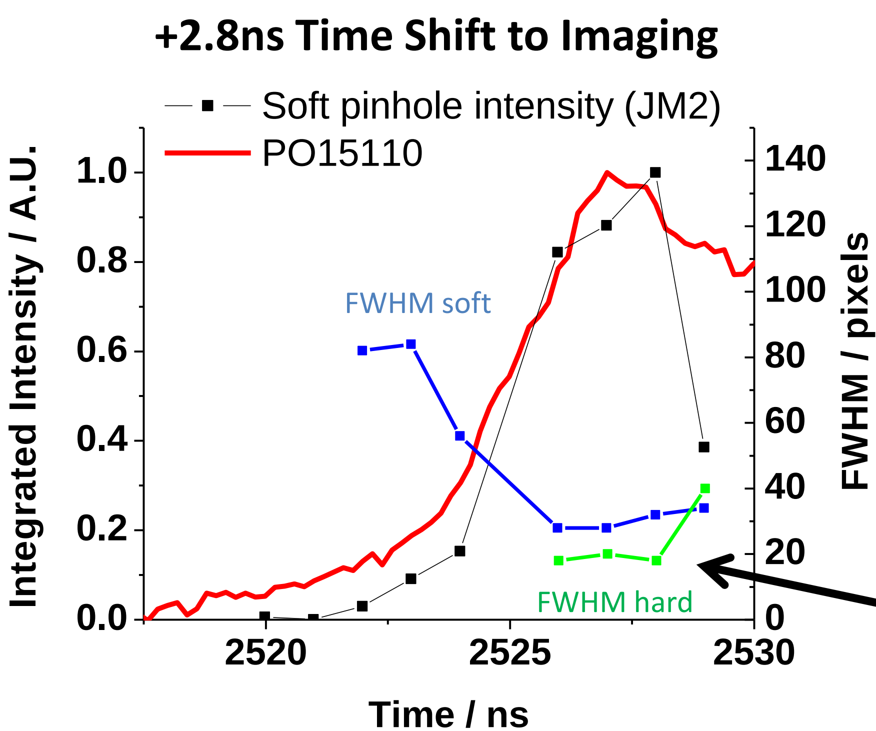


Since both PO15110 and pinhole camera have the same view of pinch there are no concerns of side on vs. end on pulse shape differences, or specific end on opacity effects. We can therefore compare normalized pulse shape with pin hole camera intensity. (for comparison side on PCD with the same filter is also shown)

Time corrected Z785 imaging shows contraction pre-peak (soft filter) and expansion post-peak (both filters)

Frame timing now relative to PO15110





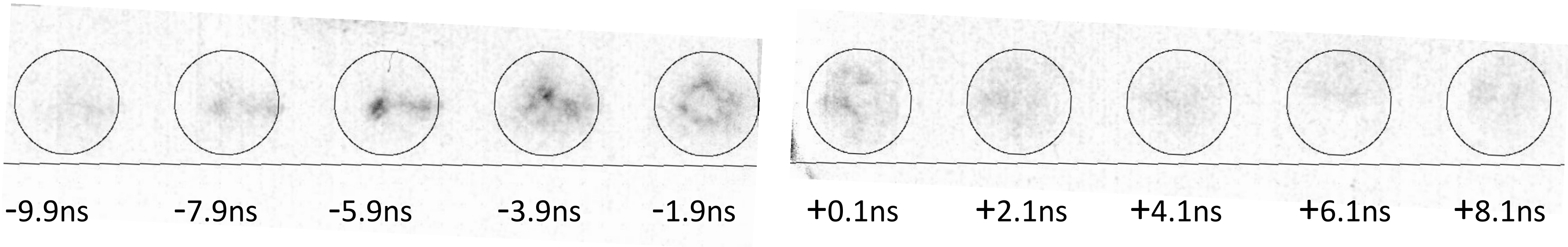
Locating image center (using film spacing between images, so image centers are always consistent), we can construct intensity as a function of radius and calculate FWHM

Expansion seen on harder filter is now post peak expansion

Z785 also shows compression during rise, consistent with Z2206, Z2011

Same analysis on Z1209 (repeat of Z785) also shows timing discrepancy

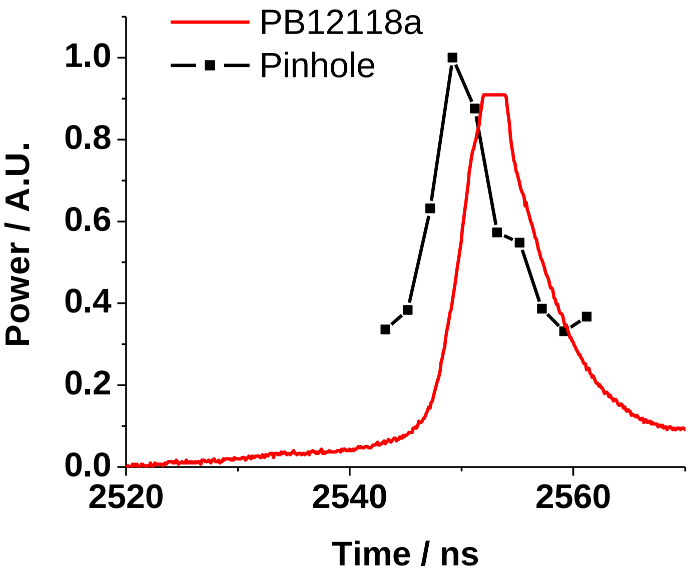
The harder filter end on imaging of 785 (4 micron Al kimfoil + 8 micron kapton) is also available on shot 1209 (repeat of 785). This time fielded on end on camera 1 (JM1)



Early and late frames had the same DC bias in this case, so no bias correction required for intensity.

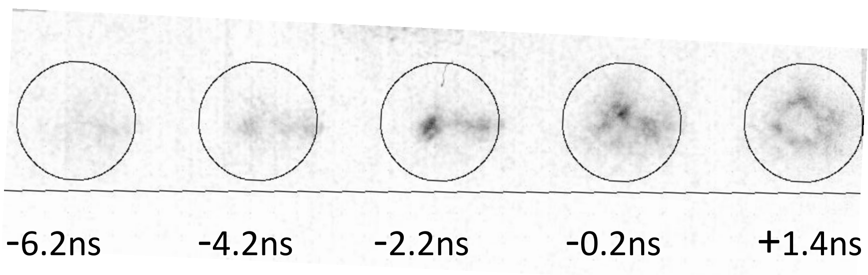
PCD filter 12 (1/3 mil kapton) is comparable to image filter, although in this case the PCD was fielded side on rather than end on.

Comparable 3.3 ns timing discrepancy seen between PCD and pinhole camera image

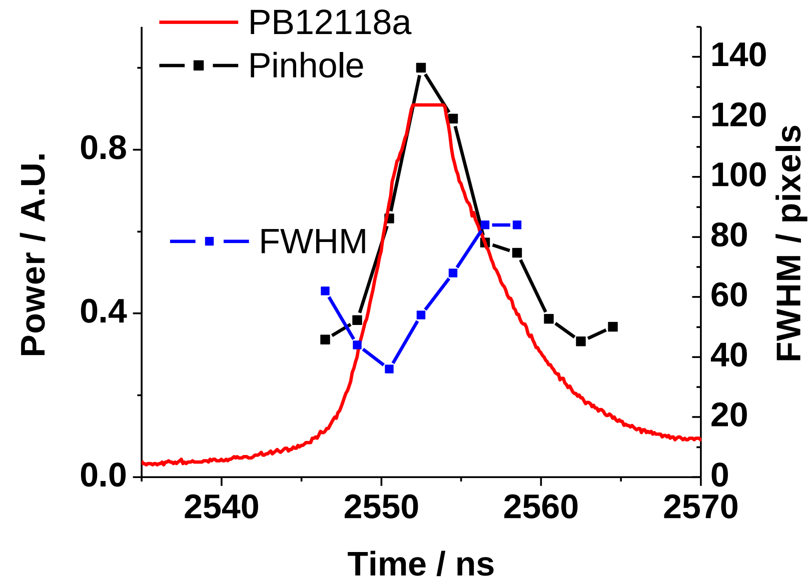


Correcting for 3.3ns time shift FWHM of emitting region shrinks as output increases

Applying 3.3ns time shift to better line up integrated intensity with PCD, the core region compresses to peak x-ray then expands

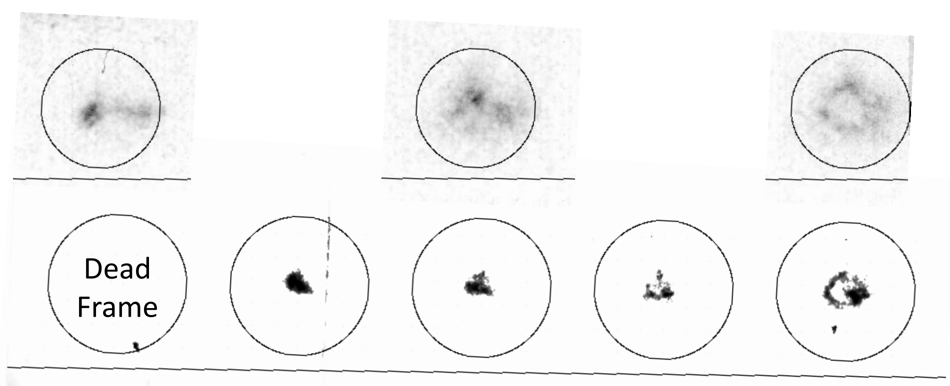


Corrected time base



1209

785

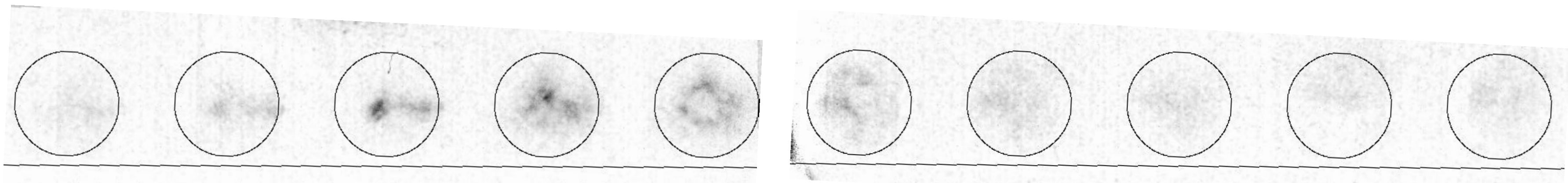


4 micron Al kimfoil + 8 micron kapton

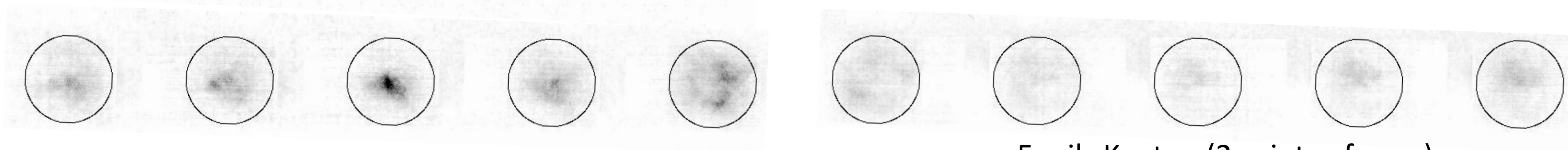
Comparing 785 and 1209 on the same filter, and using corrected time base, the same structures and behaviors are observed

Same timing discrepancy seen on Z1209 camera 2 at harder photon energy

1209 JM2 fielded a harder (5mils Kapton) filter, the same as side on pinhole camera imaging used recently on Z2206



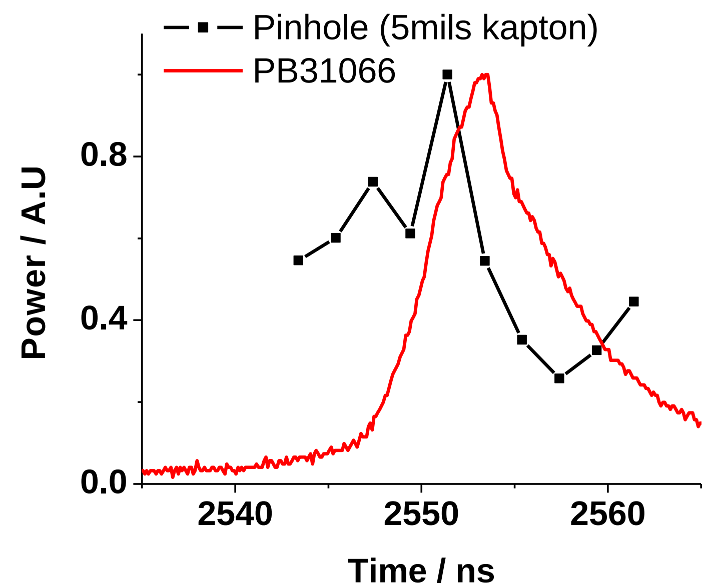
4 micron Al kimfoil + 8 micron kapton (2ns inter-frame)



5 mils Kapton (2ns inter-frame)

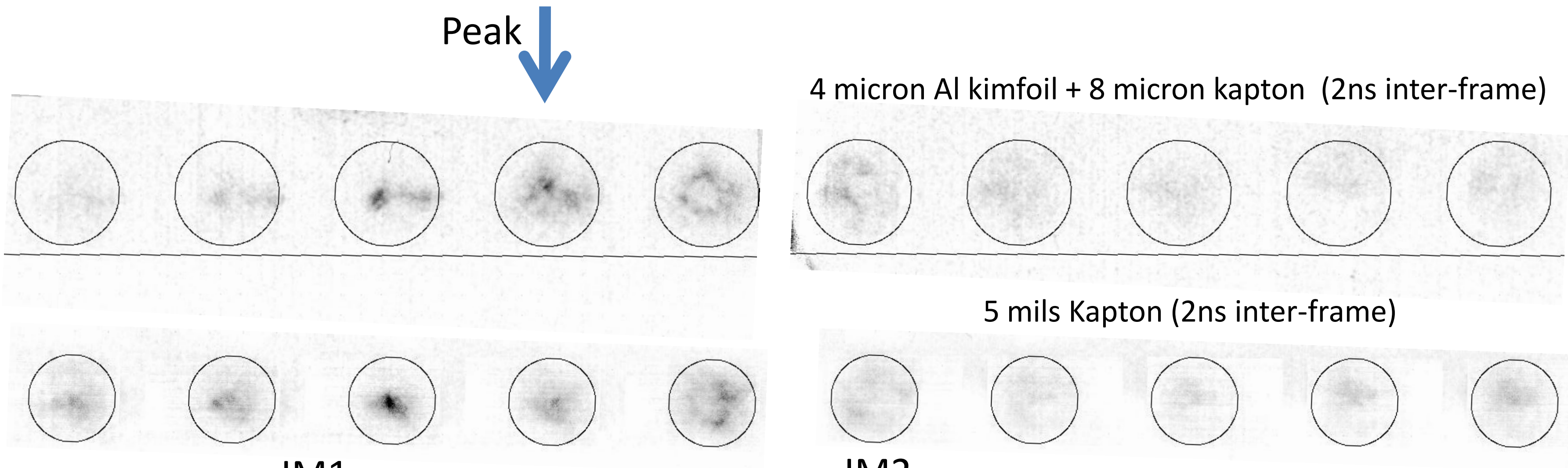
Cameras JM1 and JM2 on this shot were set to the same timing, and there seems to be good agreement on the structures observed, so timing between cameras appears consistent

Pinhole image behind 5mils Kapton again integrated and compared to PCD with the same filter (side on PCD). Again there appears to be a plausible timing discrepancy (although frame 4 intensity does seem relatively low on this camera compared to JM1)

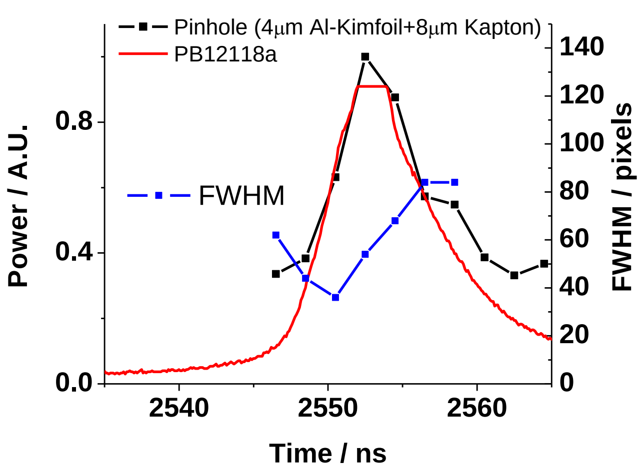


Applying 3.3ns time shift to both cameras on Z1209 shows contraction and brings intensity pulse shapes into better agreement

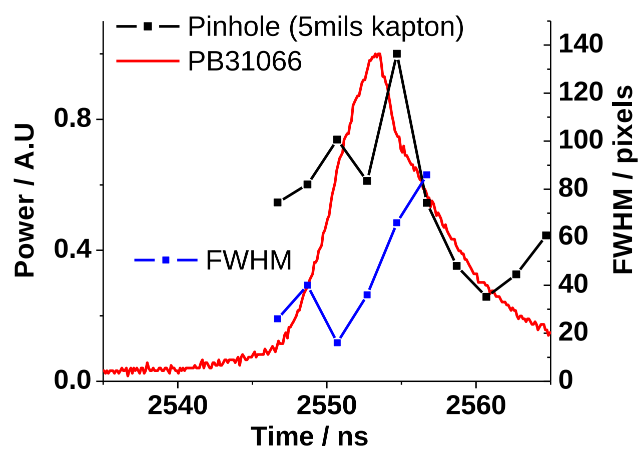
If we apply the same 3.3ns time shift to 1209 camera JM1 and JM2 then we can recover better agreement with pulse shape measured on PCD’s filtered to the same photon energies



JM1



JM2

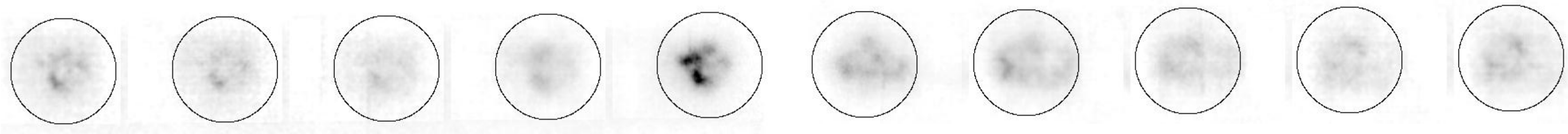


In both cases peak x-rays now occur at about the time of peak compression.

Z1209 also shows compression during rise, consistent with Z785, Z2206, Z2011

Repeating this process for 1210 (repeat of 1209 and 785) again shows more consistent behavior when time shift applied

1210 – 5 mils Kapton filter (JM2 inner frames)

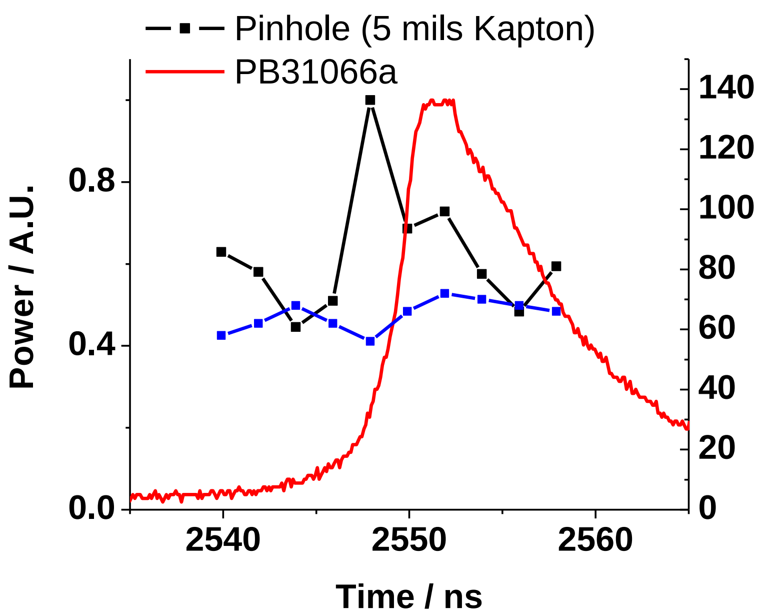


-12.2ns	-10.2ns	-8.2ns	-6.2ns	-4.2ns	-2.2ns	-0.2ns	+1.8ns	+3.8ns	+5.8ns

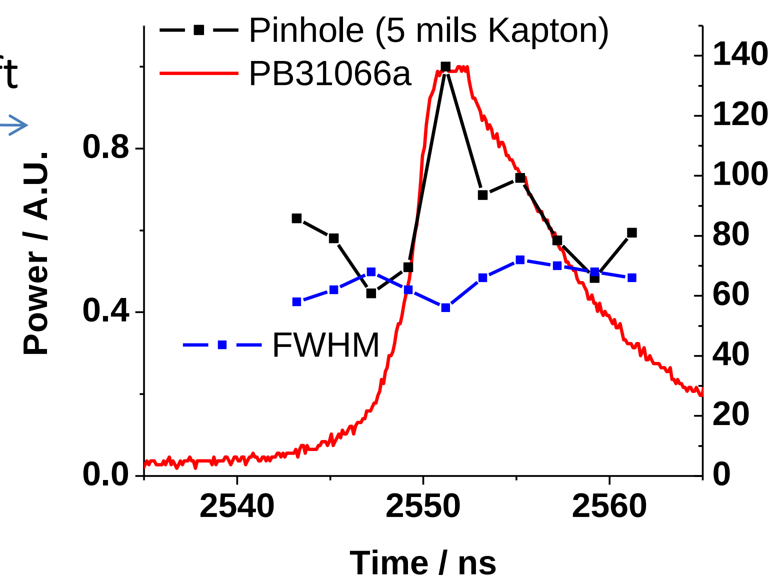
Timing corrected by 3.3ns

-8.9ns	-7.9ns	-5.9ns	-3.9ns	-1.9ns	+0.1ns	+2.1ns	+4.1ns	+6.1ns	+8.1ns

Again, a 3.3ns time shift recovers better agreement with side on pulse shape through the same filter, with pinch compressing up to peak x-ray



3.3ns shift

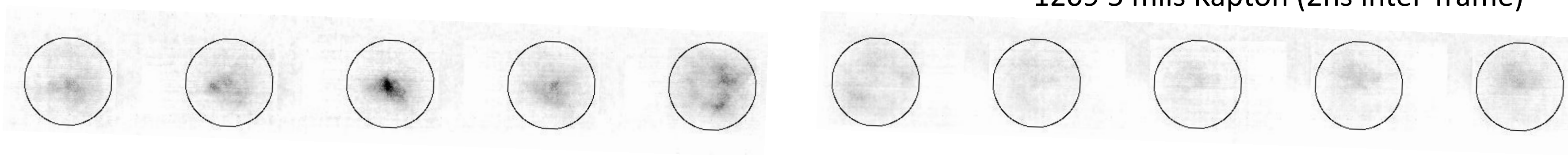


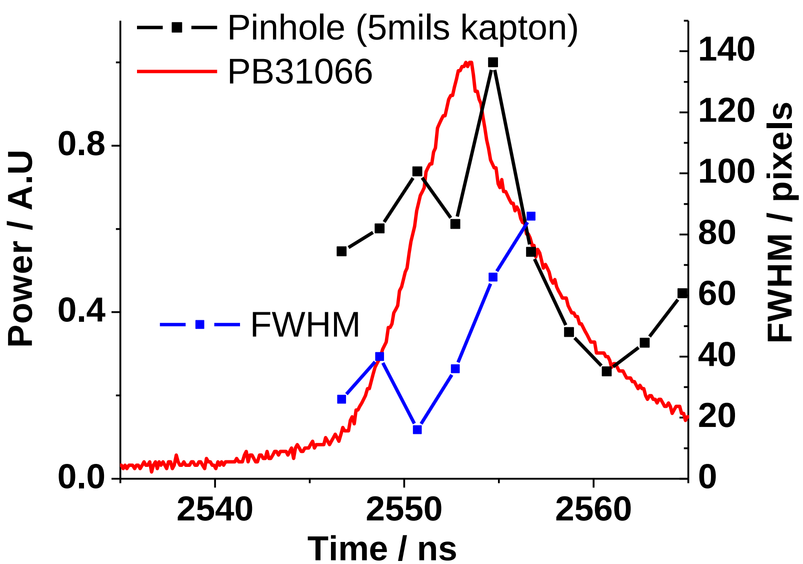
Z1210 also shows compression during rise, consistent with Z1209, Z785, Z2206, Z2011

Structure seen on weakest frames may have a component of time-integrated transmission

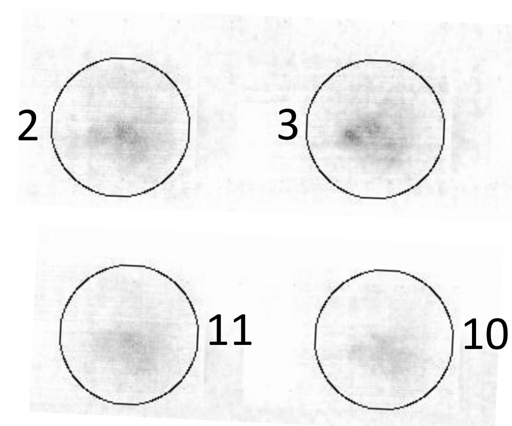
(suggested by D.Ampleford, and hopefully tested on upcoming shots)

1209 5 mils Kapton (2ns inter-frame)





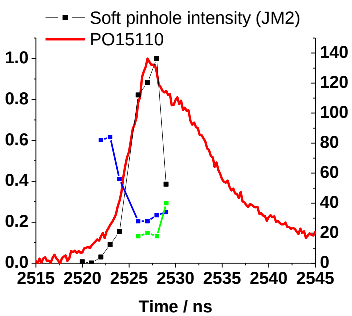
High intensity in very early and very late frames

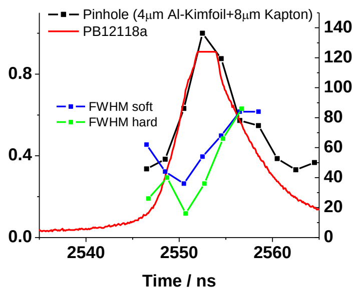


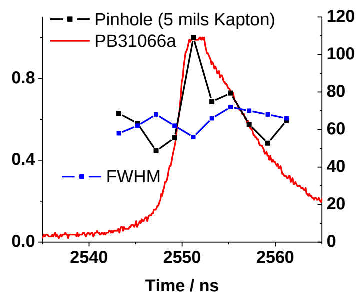
Structures in these frames look suspiciously similar – potential for time integrated component of signal ?

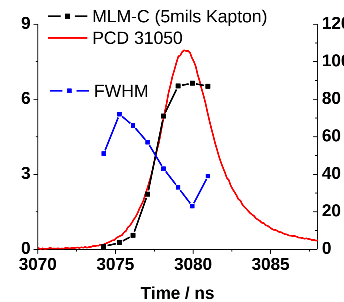
Conclusion: Data is consistent with contraction during rise then expansion post peak

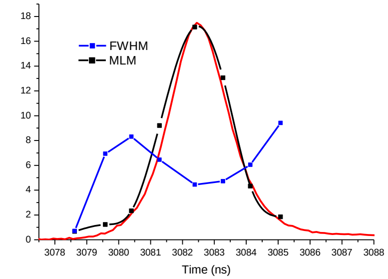
Mixed Materials				Stainless Steel
Z785	Z1209	Z1210	Z2206	Z2011











Soft shows contraction, hard is after peak	Soft and hard show contraction to peak then expansion	Hard shows contraction to peak then expansion	Hard shows contraction to peak then expansion	Hard shows contraction to peak then expansion

Old and New Z – mixed material Al on Ni-clad Ti, all seem to show the same stagnation behavior. Pinch compresses through to peak x-rays and then expands

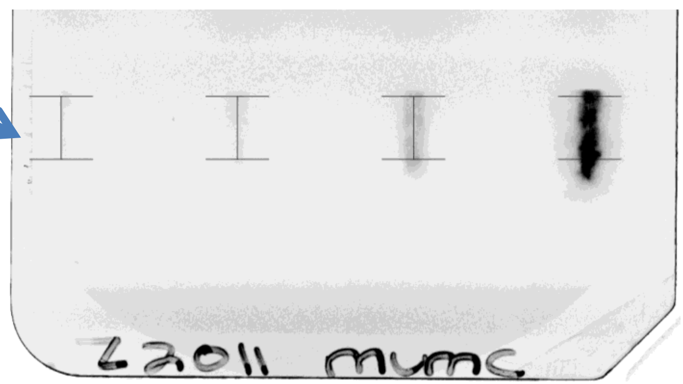
ZR, stainless and stagnation series MLM-C power comparisons

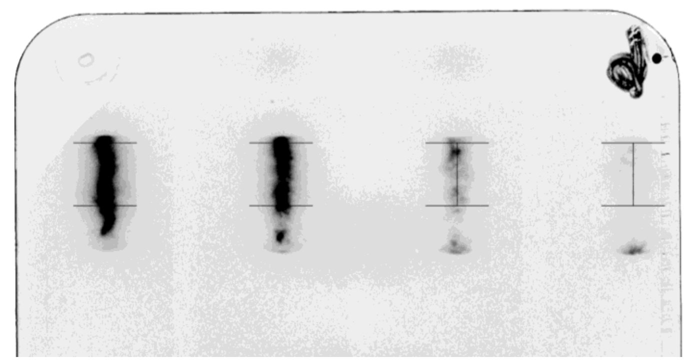
2011 shows consistent timing between MLM-C and PCD's

Z2011 – Stainless Steel, 70/30 mm 104/52, 7.95 micron wires

MLM-C intensity can be integrated and compared to PCD (same filter) to provide timing consistency check

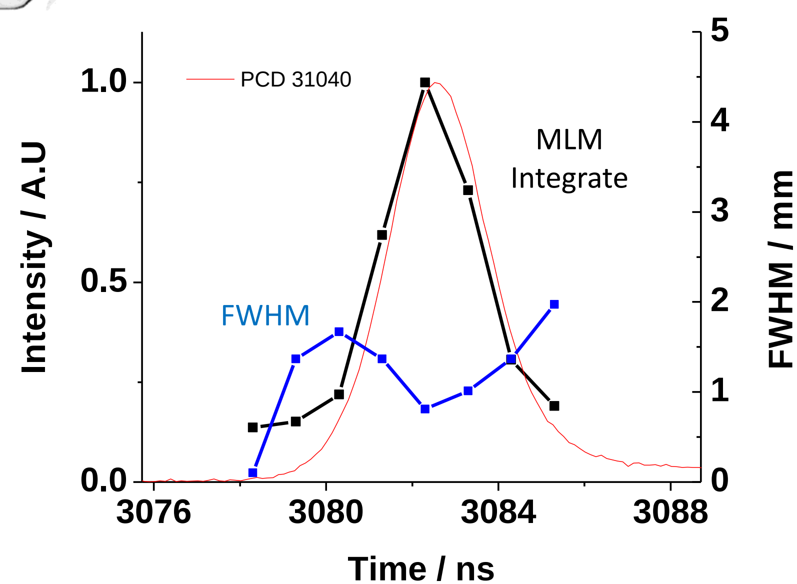
Integrate over ~PCD view (top 5mm)





This reproduces the analysis of 2011 performed by D. Ampleford, ensuring the method I'm employing is consistent with his.

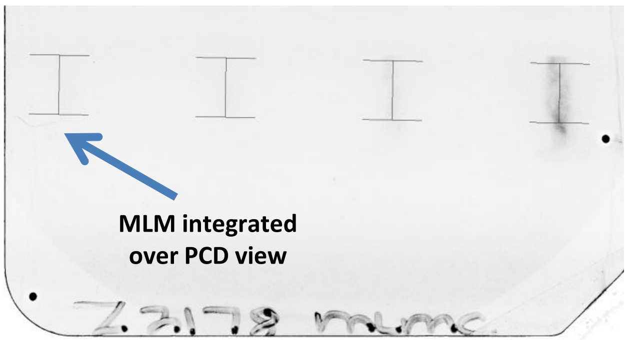
Timing between MLM-C and PCD's is consistent, and pulse shape reproduced from MLM-C

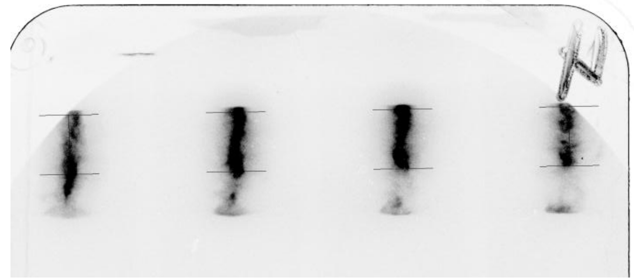


MLM timing taken from Share point, Z diagnostics instruments page

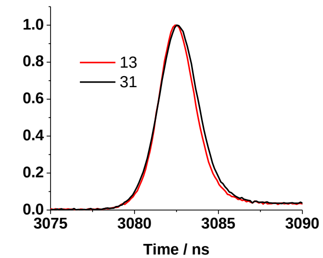
Z 2178 shows 1.3ns timing discrepancy between MLM-C and PCD's for a stainless steel load very similar to Z 2011

Z2178 – Stainless Steel, 70/35mm 108/54, 8.65 micron wires



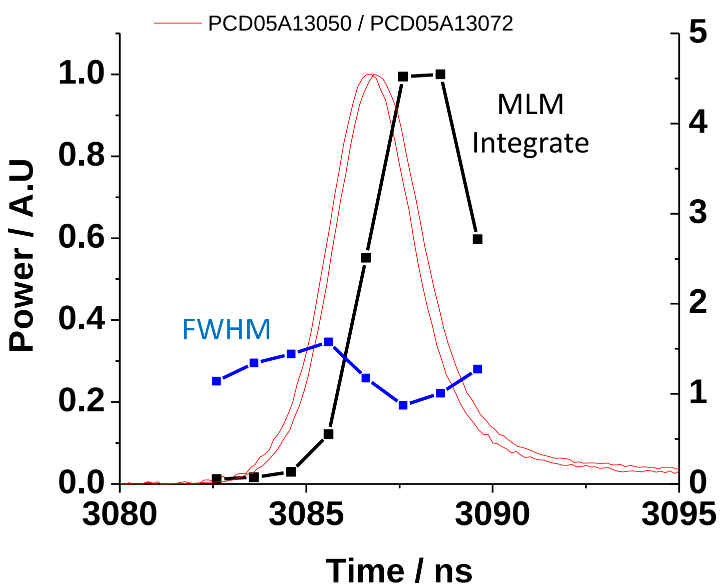


MLM-C covers stagnation (I think 5mils kapton – need to confirm)

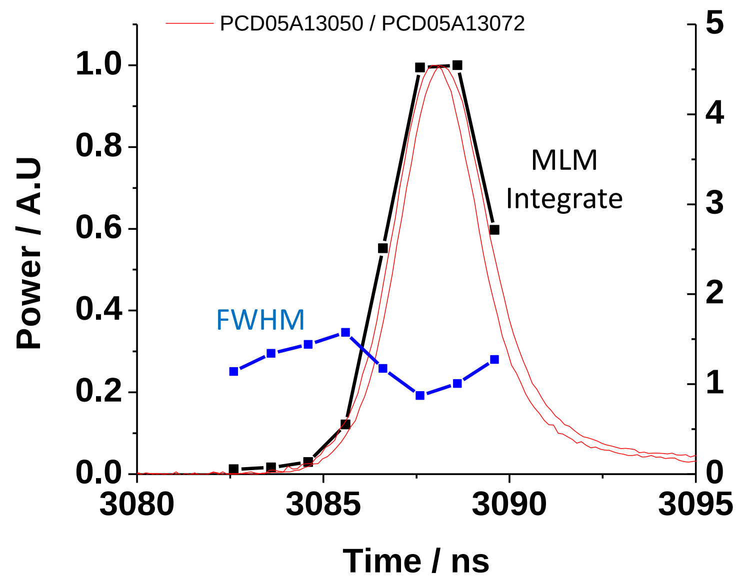


(Normalized pulse shapes of filter 13 and 31 agree for 2011)

Comparison here is to a 10 mils Kapton filtered PCD (13), rather than 5mils Kapton (31) I believe the MLM was filtered by (need to confirm)

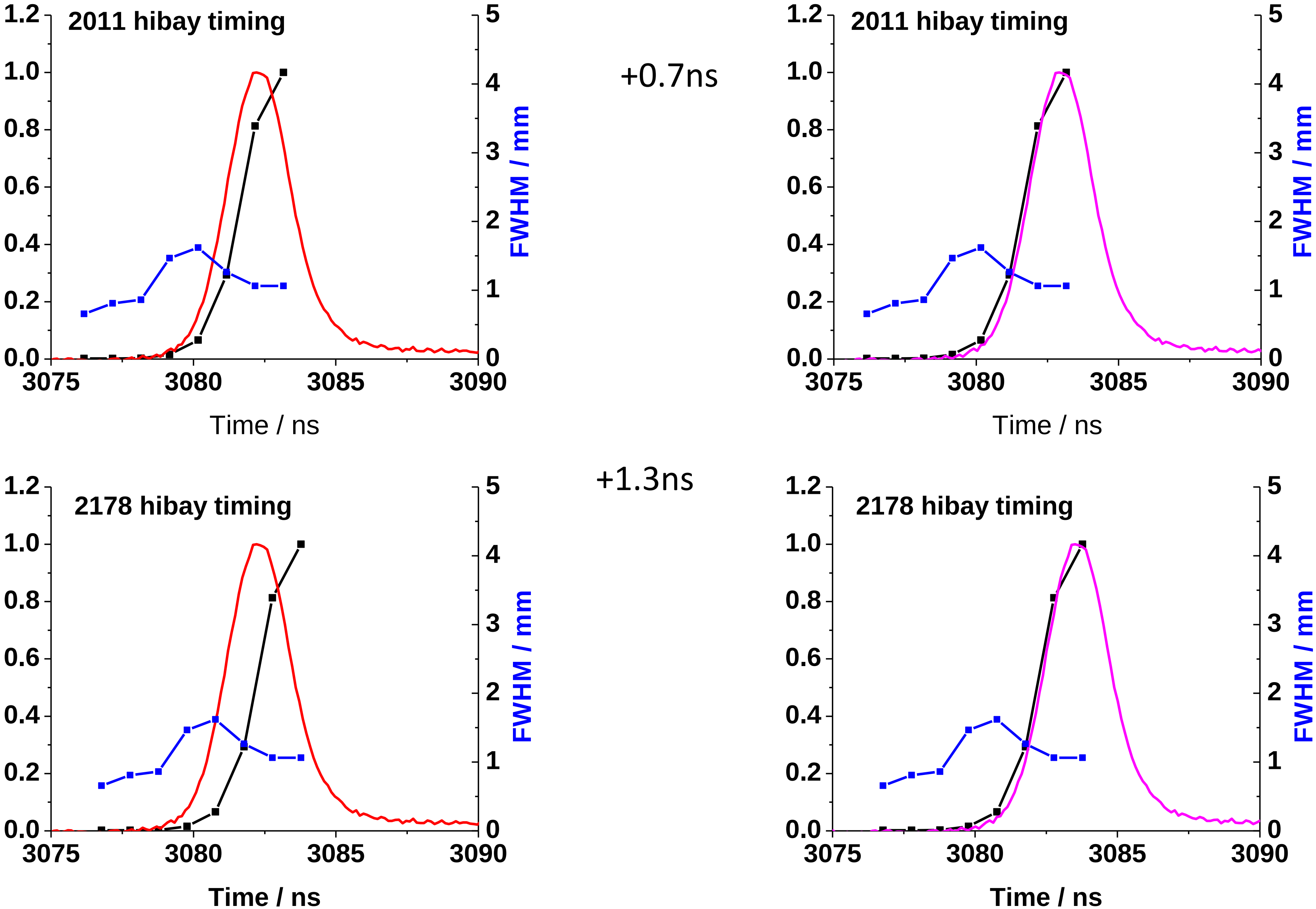


+1.3ns →

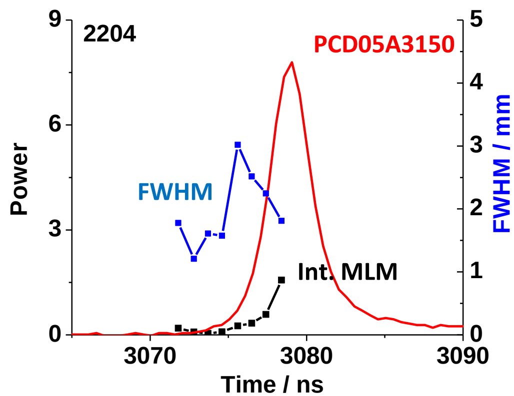


MLM timing taken from Share point, Z diagnostics instruments page

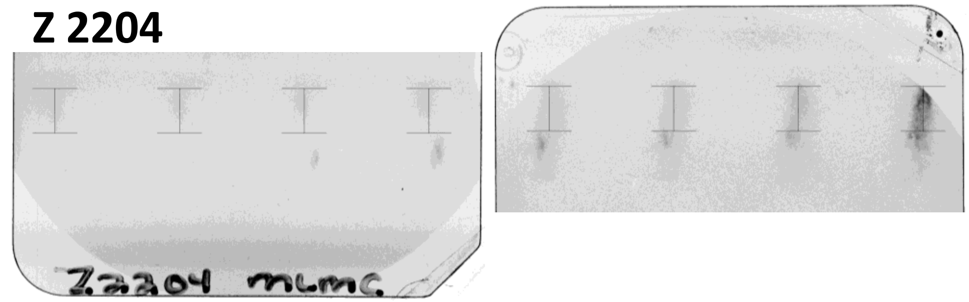
2081 have to use either the hibay timing correction from 2011 or 2178
(2178 is the same as for 2204/5/6)

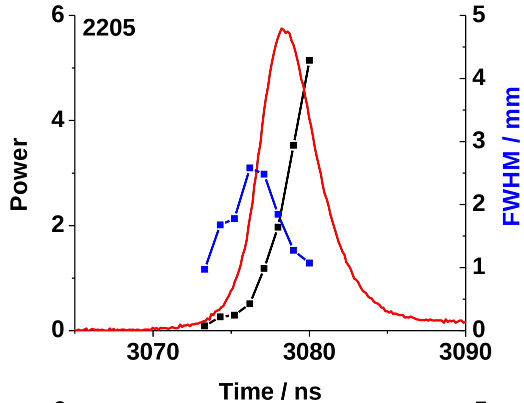


MLM-C records stagnation of Al on Ni-clad Ti loads and shows timing discrepancy with a side on PCD with the same filter

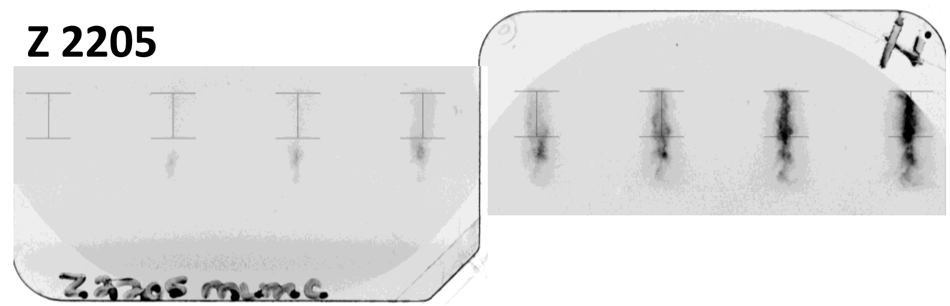


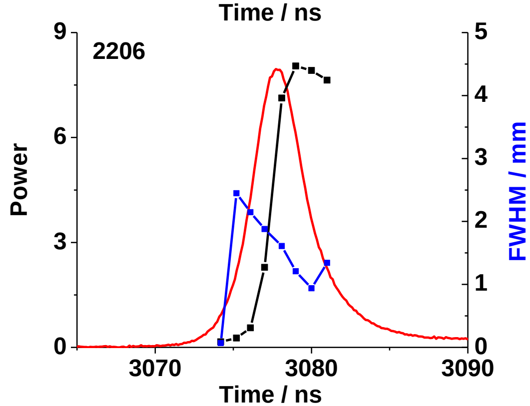
Z 2204



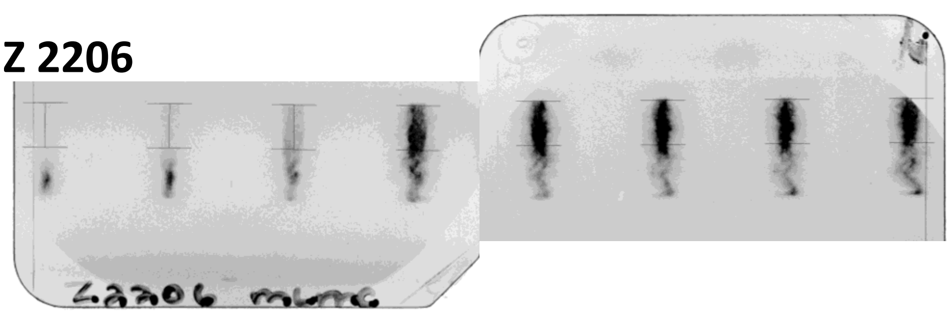


Z 2205



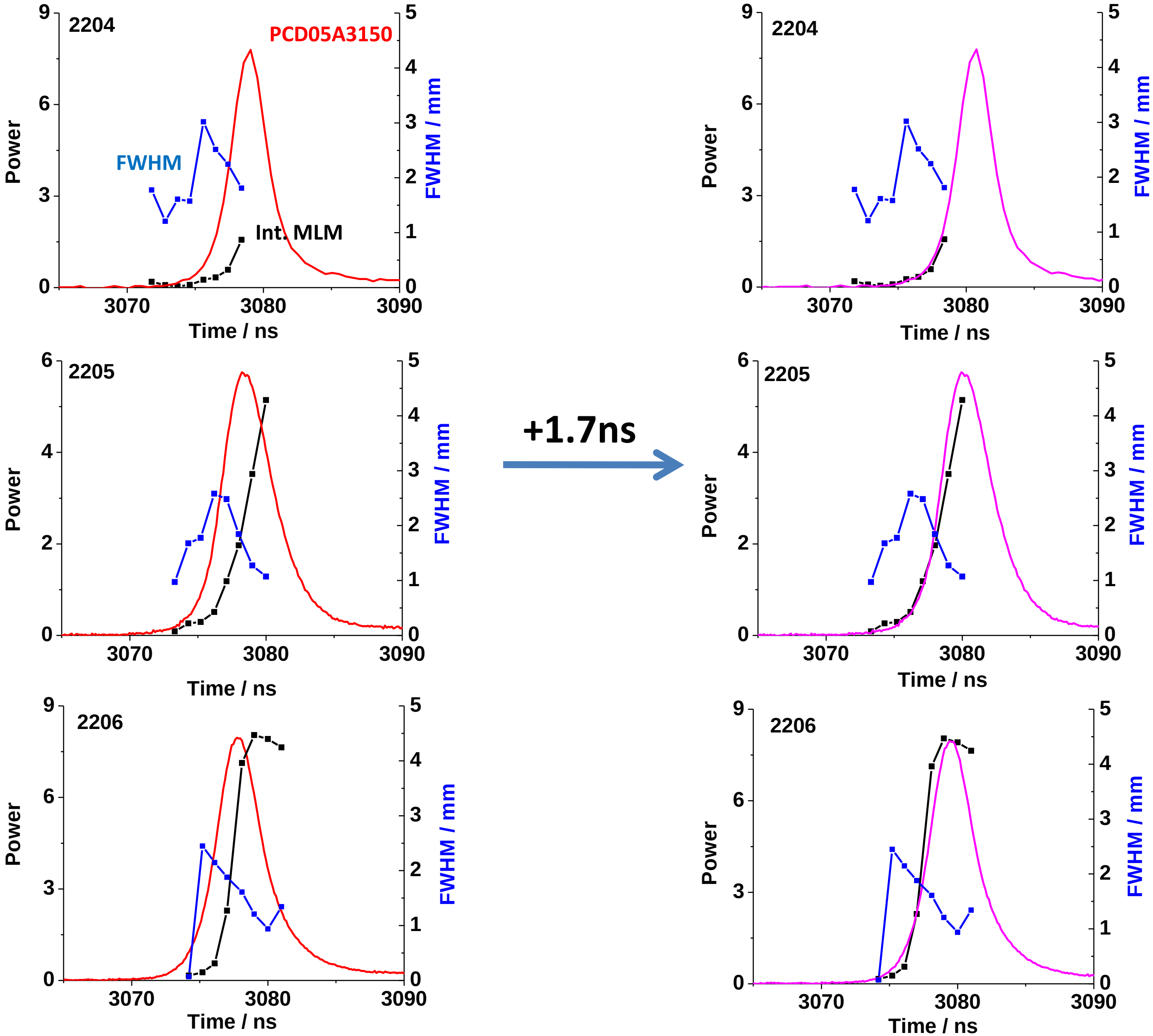


Z 2206



MLM timing taken from Share point, Z diagnostics instruments page

Applying a 1.7ns time shift to all stagnation series shots brings MLM-C intensity measurements into better agreement with PCD traces



Note: when peak not captured on MLM, intensity scaling is somewhat arbitrary, although scale factors are within a factor of 2 over all three shots

1.7ns time shift similar to 1.3ns time shift required on stainless steel load 2178 (probably within intrinsic timing uncertainty)