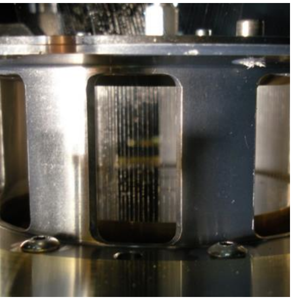
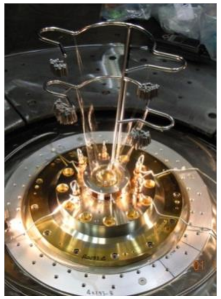
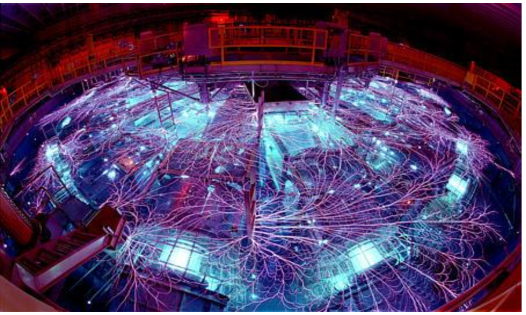
SAND2013-4863C







Effect of wire material on wire array implosions

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Summary

- Typically on Z, different wire array setups are used to optimize specific spectral output for different wire array materials
  - Soft x-ray from compact W arrays and dynamic hohlraums
  - K-shell emission from mid-Z elements (increase diameter with Z)

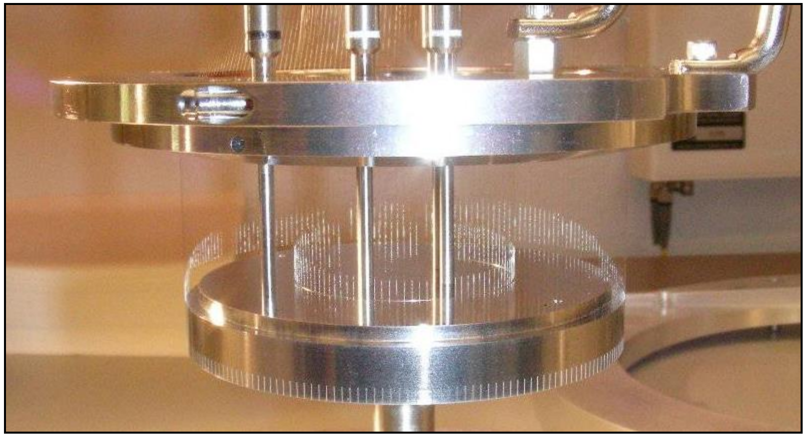
- Keeping array mass and diameter fixed can more readily see affect of wire material

- Pinch size changes considerably for different setups, with lower Z (Al) having much larger stagnation diameters than high Z (W)

- Width of radiation pulse correlates strongly with pinch size

Setup

- All shots use
  - 65mm diameter
  - ~2.5mg total mass
  - 20mm height
- Wire number varies with material due to availability



Matieral		Z	Diameter	Wire Number
Al (2.0mg)	[1]	13	13.51 µm	176 (outer) + 88 (inner)
Stainless Steel	[2]	26	8.15 µm	200 (outer) + 100 (inner)
Cu	[3]	29	10.35 µm	112 (outer) + 56 (inner)
W	[4]	74	5.22 µm	220 (outer) + 110 (inner)

Hotter than optimal setup (Al)

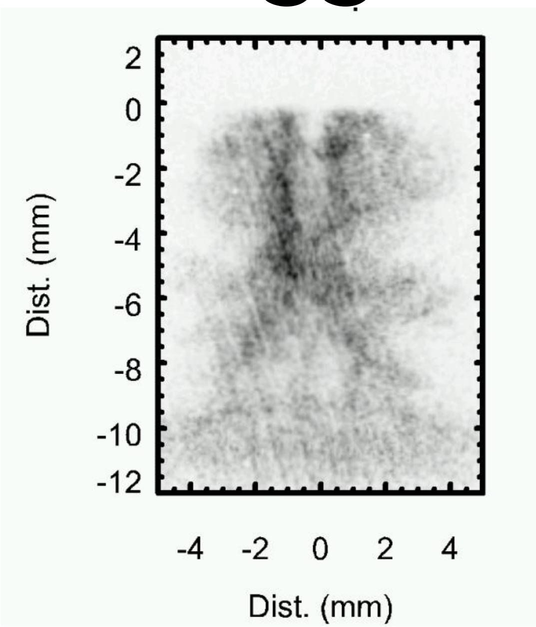
Colder than optimal setup (Stainless Steel, Cu)

Brightest z-pinch soft x-ray source (W)

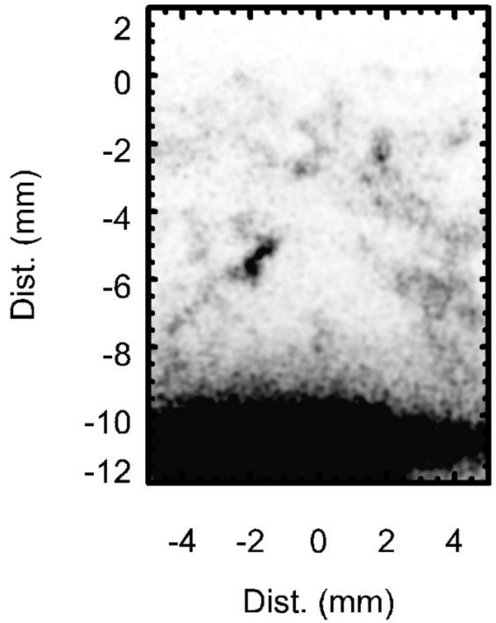
1. D.J. Ampleford et al., presented at Radiation in High Energy Density Physics (2013), in preparation for Physics of Plasmas
2. D.J. Ampleford, presented at International Conference on Plasma Science (2010), submitted to Physics of Plasmas (2013)
3. B. Jones et al, presented at International Conference on Plasma Science (2009, 2010)
4. M.C. Jones et al., presented at International Conference on Dense Z-pinches (2009); in preparation for Review of Scientific Instruments

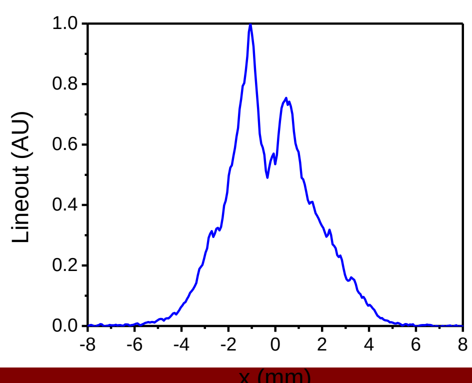
Low Z show significantly more structure in imploding shell and larger shell width pre-stagnation

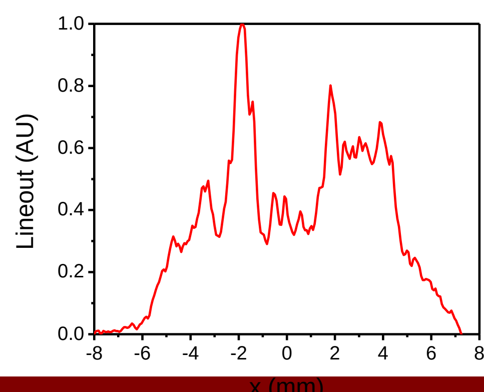
SS



Al

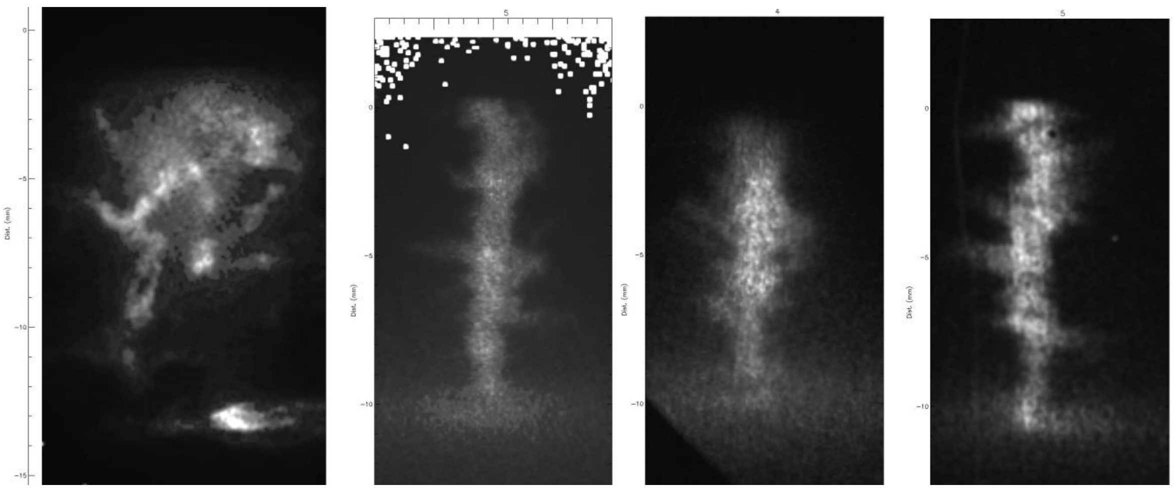




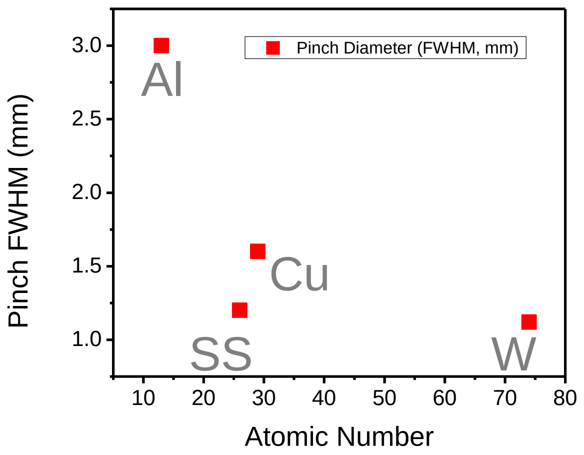


- 277eV monochromatic imaging pre-stagnation
- Stainless steel maintains clear imploding shell immediately prior to stagnation
- Al wire array implosion is much more disrupted, creating much less defined shell

Variation in pinch size and uniformity with material



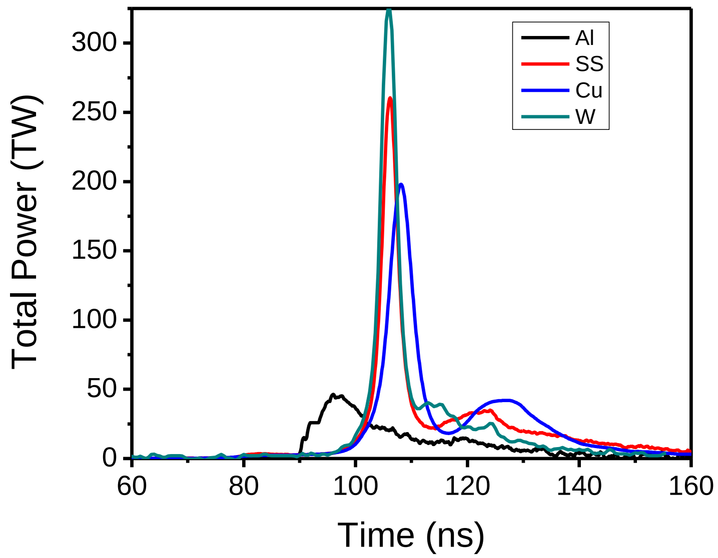
Al **SS** **Cu** **W**

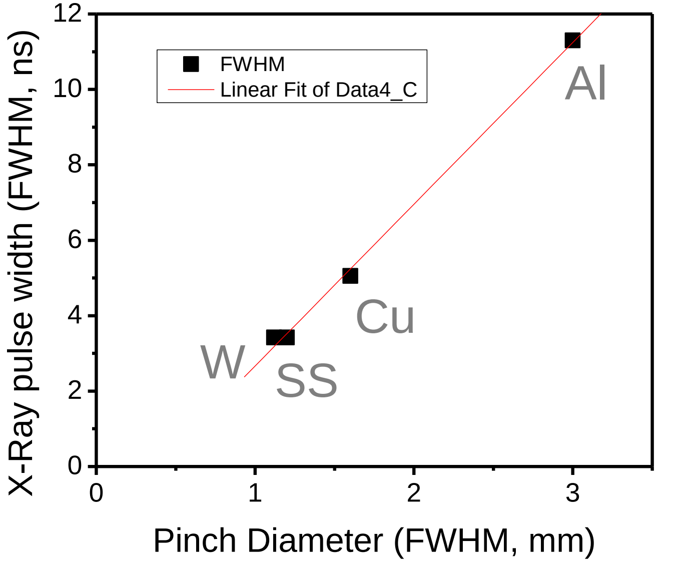


- All monochromatic images at 277eV
- Stagnation for Al is severely disrupted
- SS, Cu and W all show quasi-uniform plasma column with small scale structures

Pinch size directly correlates with x-ray pulse shape

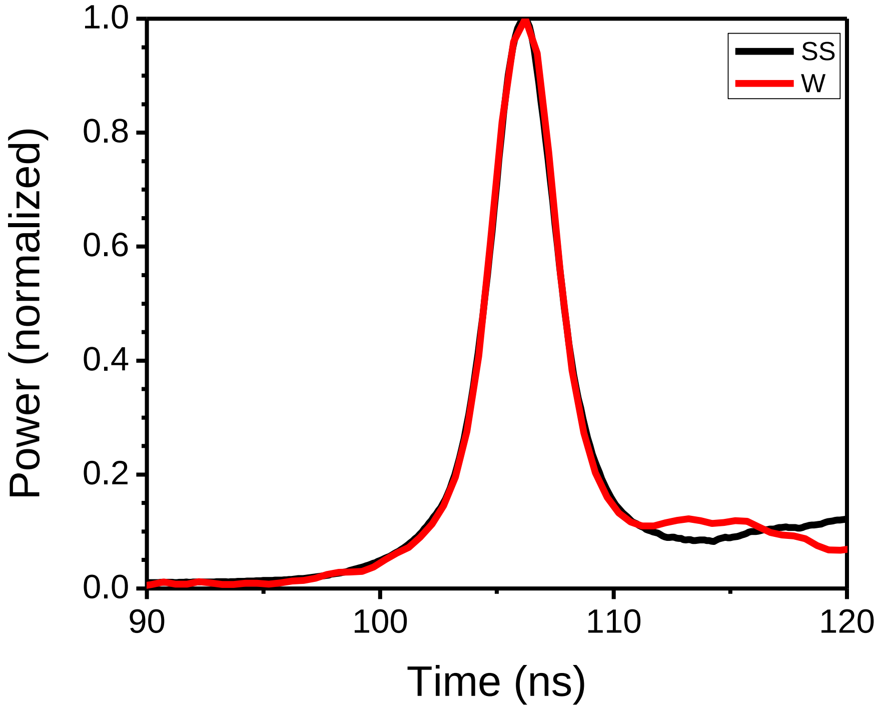
- X-ray pulse shapes vary significantly between the different experiments
  - FWHM varies from <4ns to >10ns
- Very strong correlation between stagnated pinch size and radiation FWHM
- Peak power also varies significantly



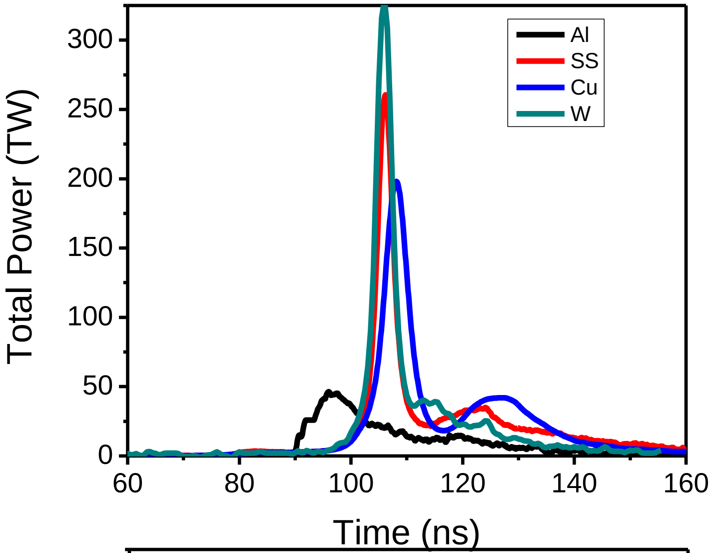


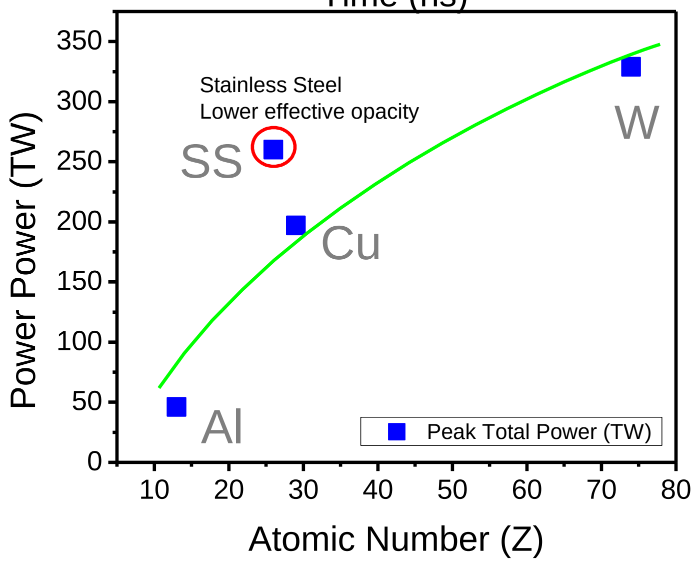
SS and W have very similar pulse shape

- For tightest pinches its interesting to see how the material affects the actual pulse shape
- Power pulses are normalized to peak power
- SS and W have identical pulse shapes despite large difference in Z



Higher Z materials are much more effective at radiating soft x-rays

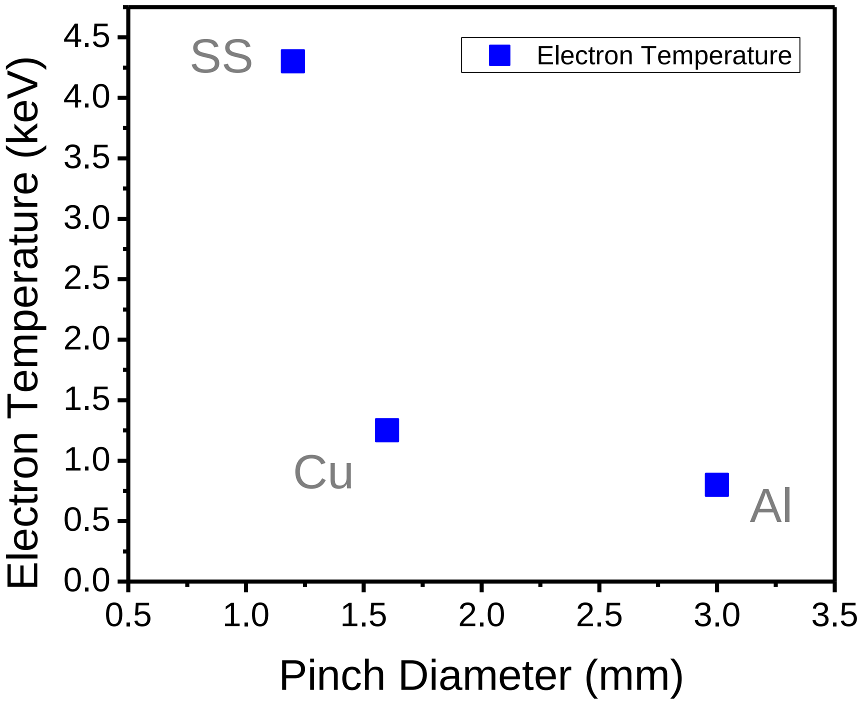




- Peak powers and yields are much higher for higher Z materials
  - Al radiates just ~865kJ compared to >2.0MJ for other materials
- Stainless Steel is very effective at radiating despite moderate Z
  - Number of materials present significantly reduces the effective opacity

Electron temperatures depend on convergence

- K-shell spectra provide measures of electron temperatures[1-3] for Al, SS, Cu
- SS, with smallest pinch, achieves much higher temperature than other materials
- Unfortunately temperatures can be dependent on spectral range analyzed



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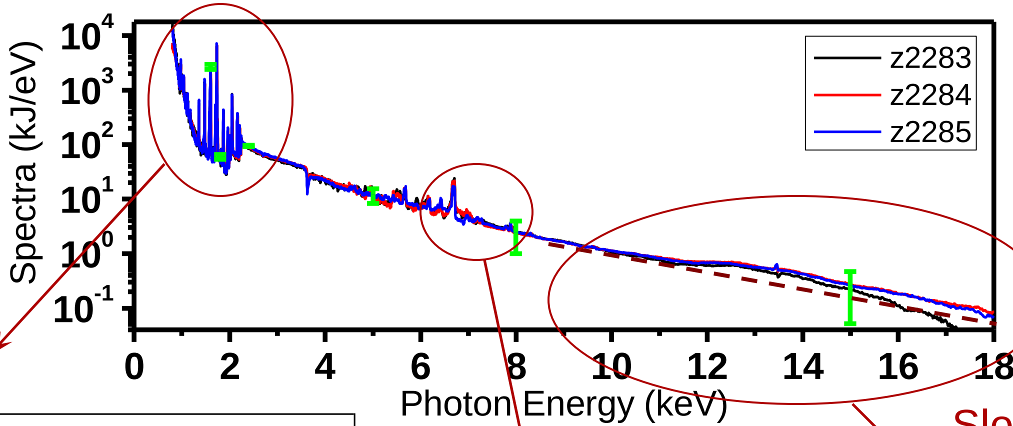
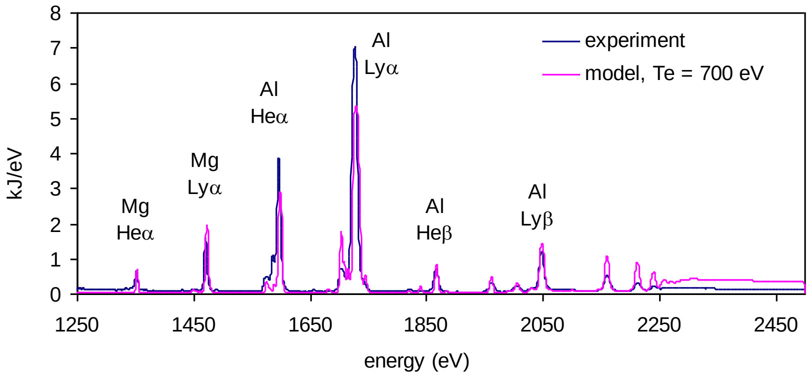
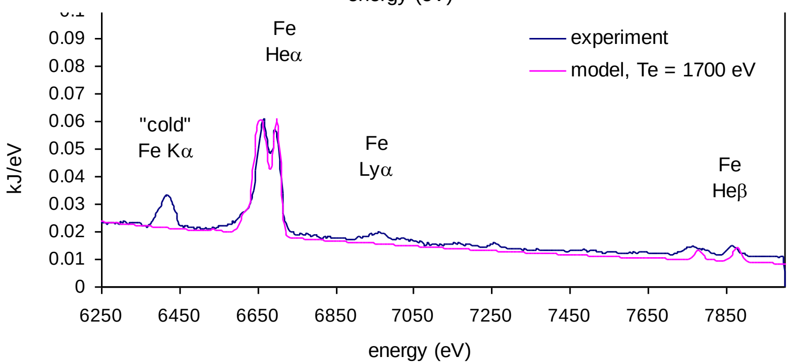
Different plasma conditions can be inferred from analysis of different spectral regions, indicating significant gradients



Line ratios of Mg impurities: Te ~ 0.7keV

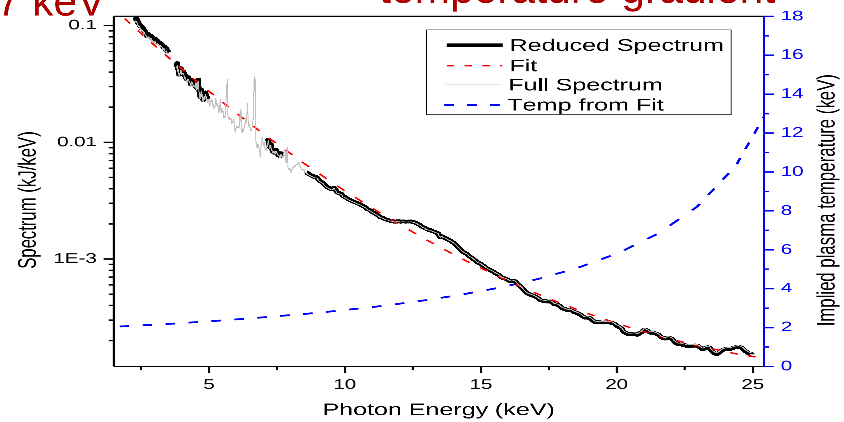




Line ratios of Fe impurities: Te ~ 1.7 keV

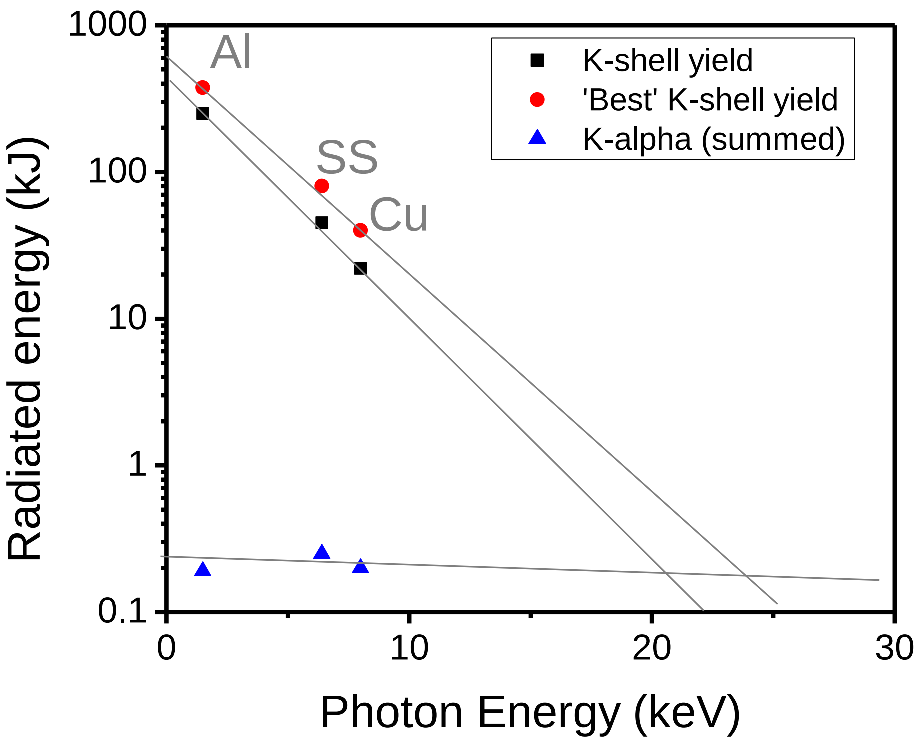
Slope of free-bound continuum: Tc varies from 2 – 12 keV depending on region

Opacity may exaggerate temperature gradient



K-shell power drops with atomic number
Non-thermal emission is ~fixed

- K-shell yield drops considerably with increasing atomic number
  - Trend is very similar to trend in the best performing setups
  - Plasma temperature becomes insufficient for bright emission
- Can also see trend in hot-electron driven Kα-lines
  - Drop with photon energy not as pronounces as thermal lines
  - Consistent with CRE simulations with hot-electron fraction
  - Experiments underway to study controlling Kα emission



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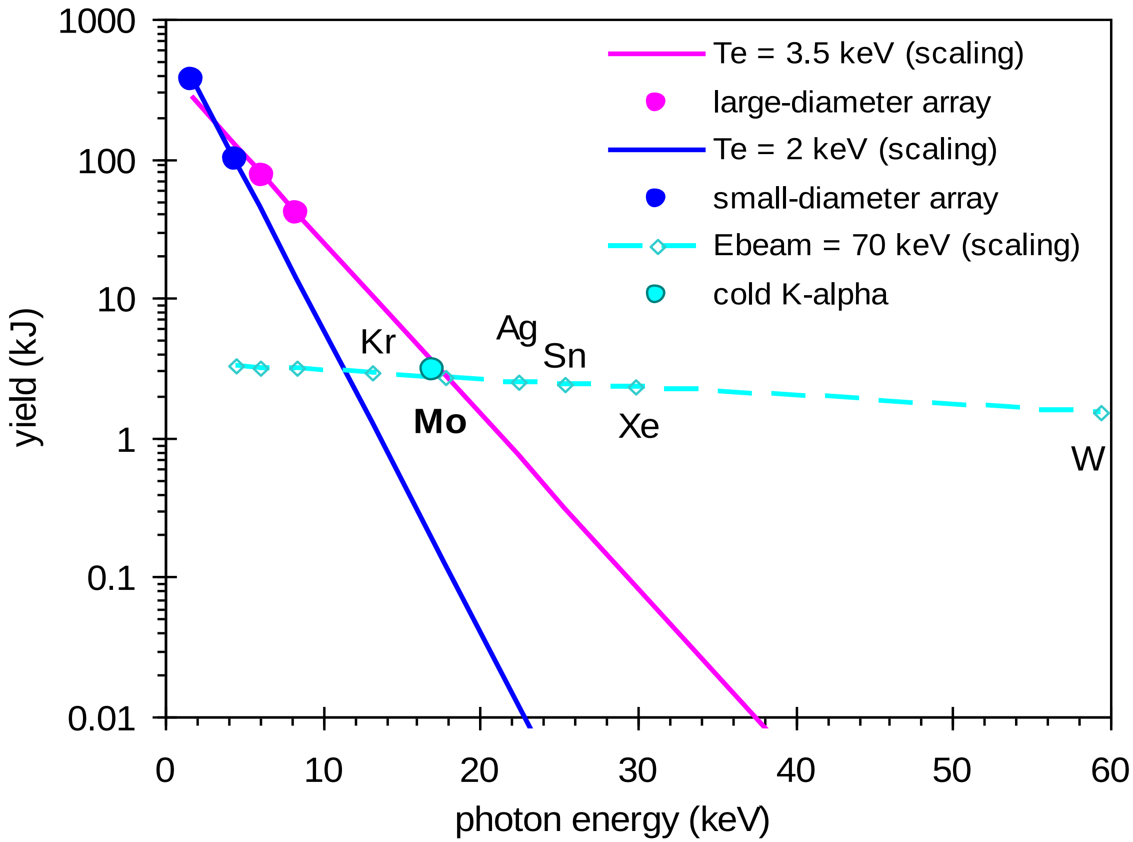
BACK UP

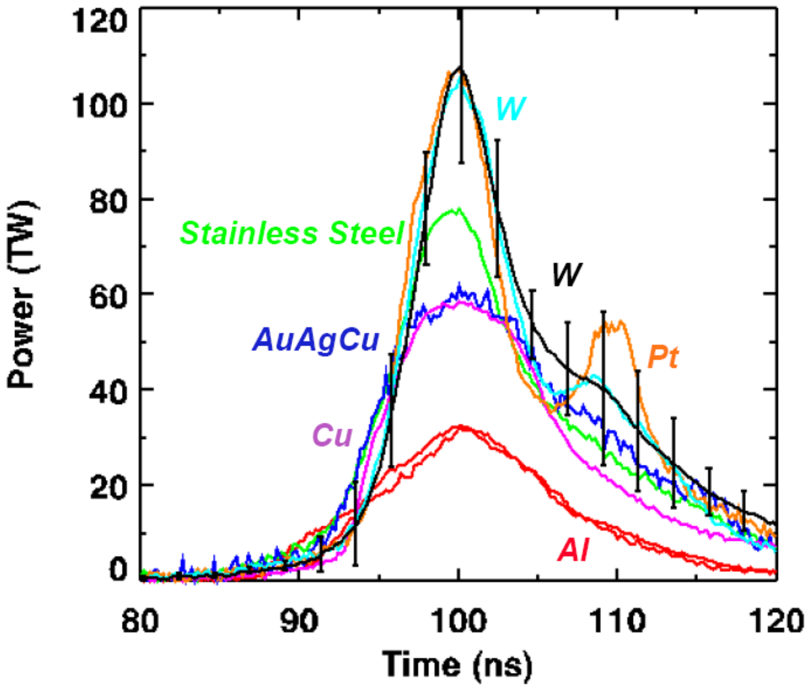
Calculations indicate Kα line emission scales well to higher photon energies



Calculations by S.B. Hansen

Previous compact wire array data is consistent with trends in powers and pulse shape observed here

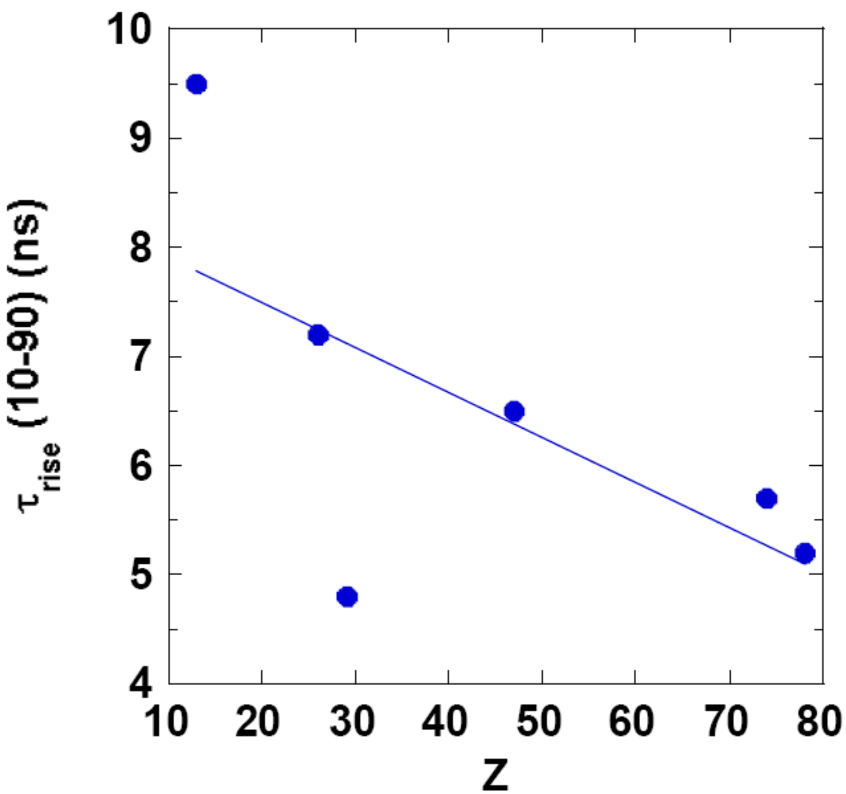
- 20mm diameter arrays of W, Pt, SS, Gu, Cu
- ~6.0mg total mass, 10mm tall,

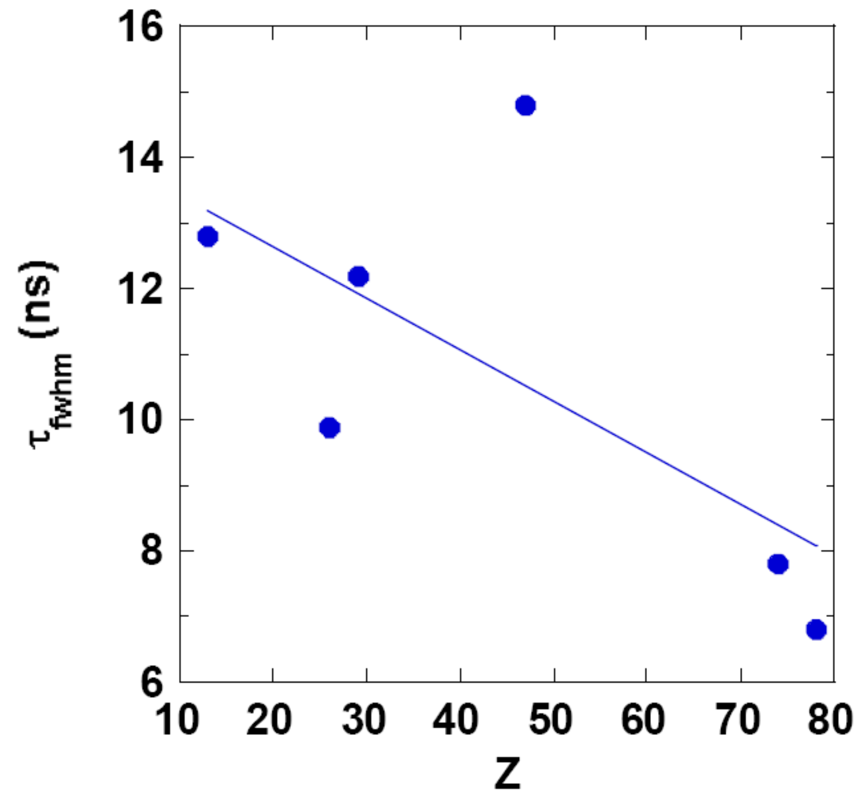


Wire Material (Z)	10-90% τ_{rise} (ns)	10 TW to Peak τ_{rise} (ns)	τ_{fwhm} (ns)	τ_{eff} = E/P (ns)
Al (13)	9.5	8.5	12.8	14.1
Cu (29)	4.8	6.9	12.2	16.6
AuAgCu (47)	6.5	9.0	14.8	16.9
Stainless (26)	7.2	8.7	9.9	14.6
Pt (78)	5.2	6.7	6.8	12.4
W (74)	5.7	6.4	7.8	12.5

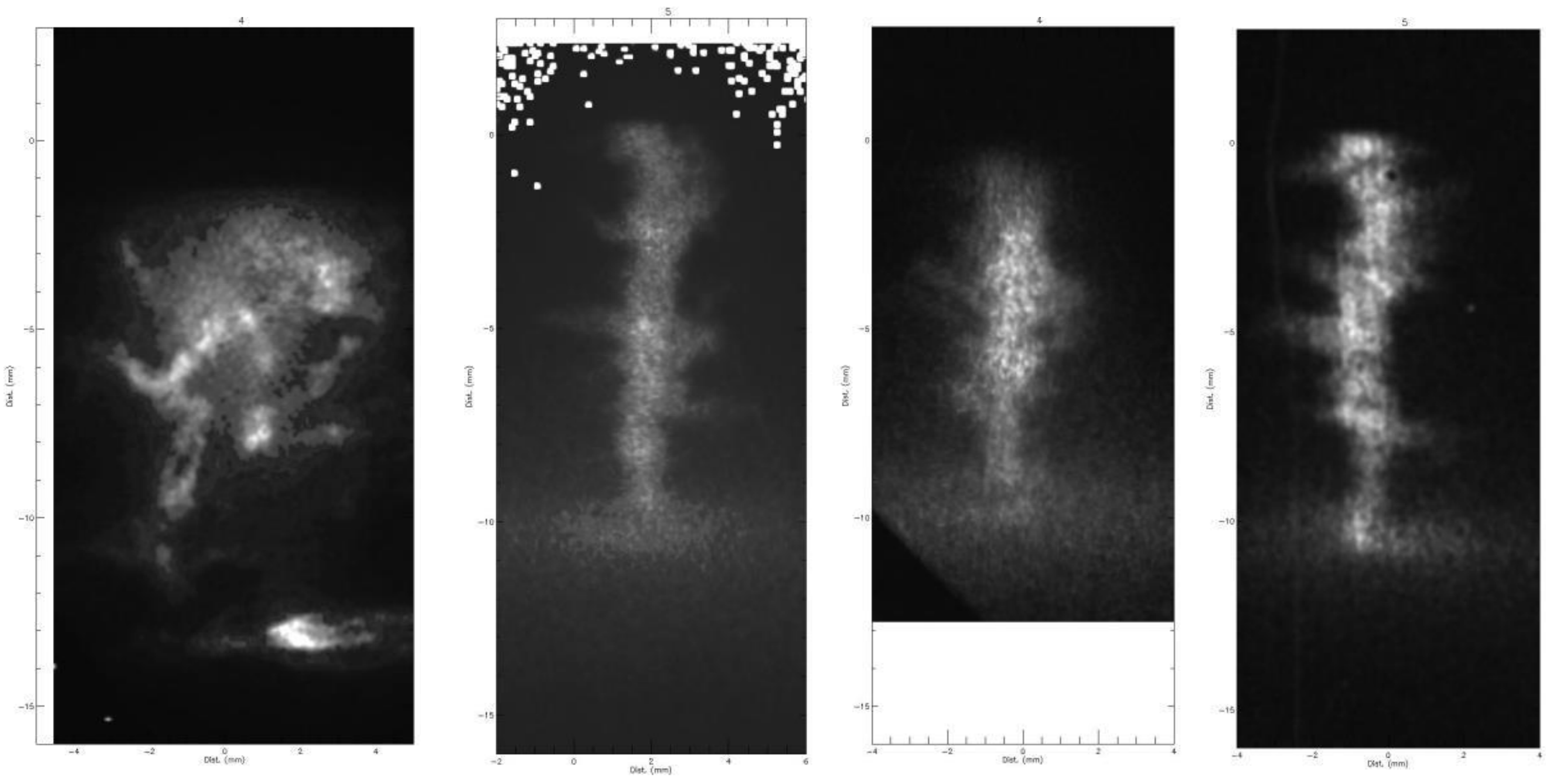
Comparison courtesy of M.E. Cuneo
Shot data from C. Deeney, T.J. Nash, R.B. Spielman, W.A. Stygar, D.B,. Sinars

Higher Z arrays have faster risetime and smaller pulse shape width





Data assembled by M.E. Cuneo
Shot data from C. Deeney, T.J. Nash, R.B. Spielman, W.A. Stygar, D.B,. Sinars


4
Dist. (mm)
Dist. (mm)
5
Dist. (mm)
Dist. (mm)
4
Dist. (mm)
Dist. (mm)
5
Dist. (mm)
Dist. (mm)

Shots are extensively diagnosed with PCDs, calorimeters, imagers, and spectrometers

- We routinely field up to 6 spectrometers on every shot, covering a spectral range from 0.8 to 20 keV with ~ absolute calibration, spatial & temporal resolution, and E/ΔE ~1000