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Impact of load variations on the stagnation of nested stainless steel and copper z pinches

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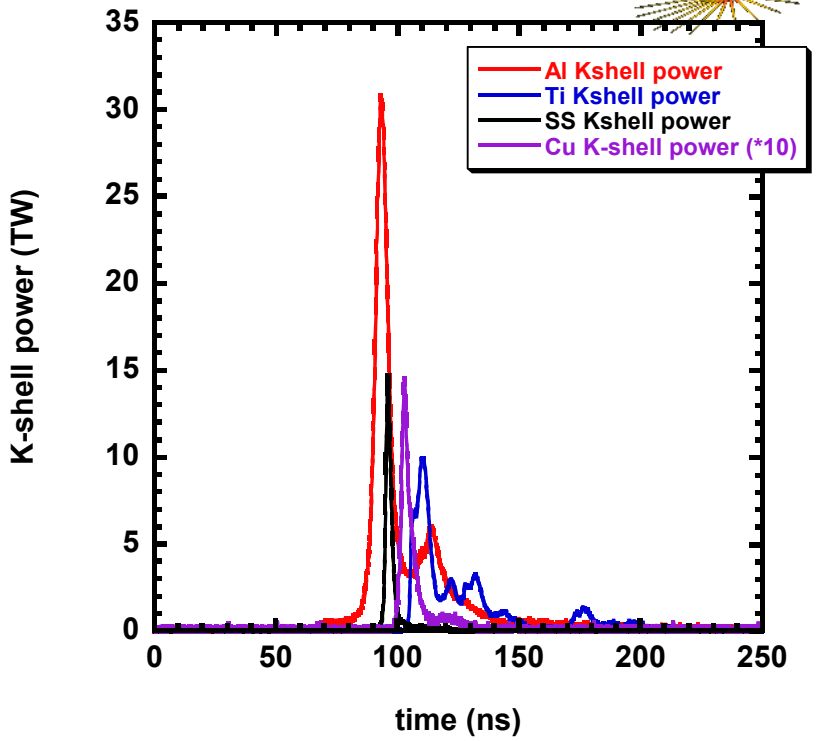
A variety of K-shell sources have been studied at Z

matl	load	K-shell energy (kJ)	K-shell FWHM (ns)
Al (1.6 keV)	40mm nested	~400	7
Ti (4.7 keV)	50mm nested	~100	7
SS (6.7 keV)	55mm nested	~50	3
Cu (8.4 keV)	60mm nested	~20	4



Total radiated energy typically 1-1.3 MJ

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Variations in initial load configurations have been fielded to assess impact on K-shell output

- Investigate physics that may impact K-shell output
  - Many of the sources are "inefficient" radiators
  - Regions of appropriate T_e and n_i for producing K-shell, but not global
- Interwire gap
  - Previous experiments have indicated that smaller IWG results in higher radiated power
- Clocking of nested wire arrays
  - Changes transparency of inner array, and interaction of inner and outer arrays
- Gap closure
  - Is gap closure limiting current that is delivered to load, and thereby limiting K-shell output?
  - Will this change field asymmetries predicted in calculations?

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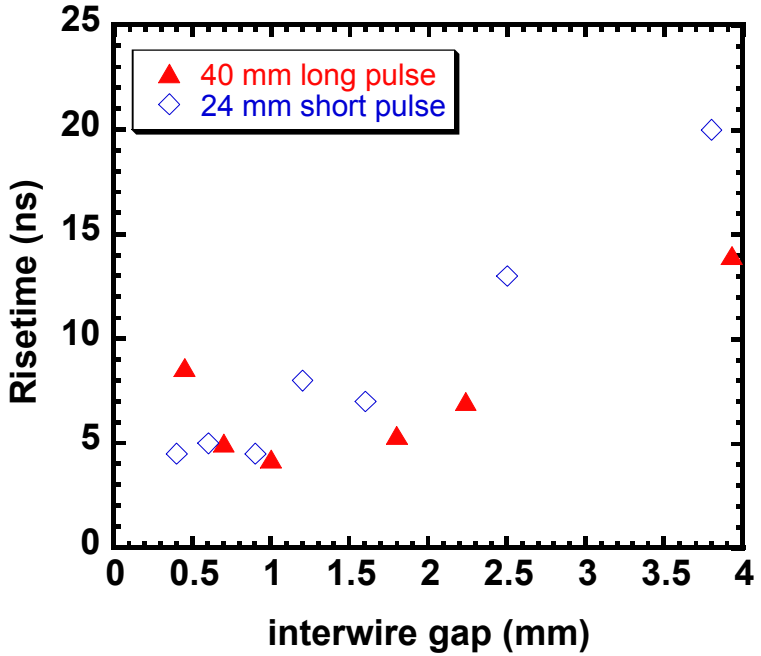
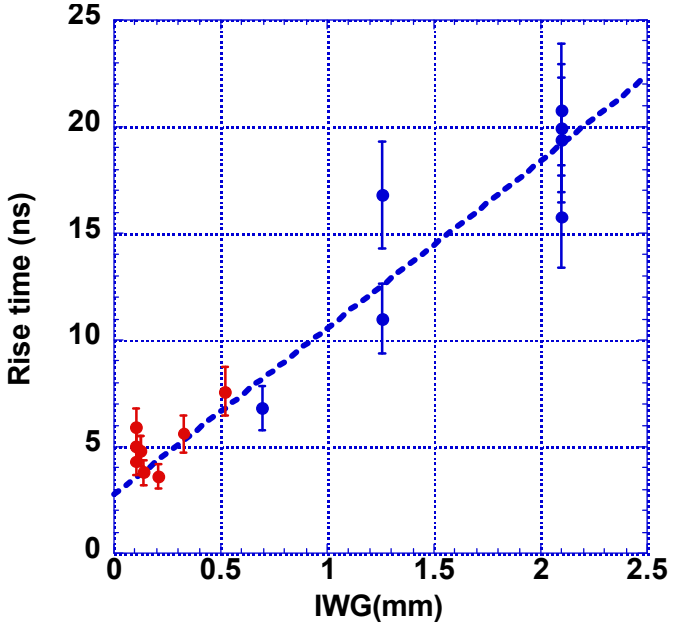
Previous IWG studies have been shown to significantly impact wire array performance

Single Al arrays at Saturn, short and long pulse showed improvements in power and pulseshape, but very similar K-shell emission



C. Deeney *et al.*, Phys. Plasmas 5, 2431 (1998)
T.W.L. Sanford *et* al., Phys. Plasmas 6, 1270 (1999)
C.A. Coverdale *et al.*, Phys. Rev. Lett. 88, 065001 (2002)

Single W arrays at Z (short pulse) showed similar trends



M.G. Mazarakis *et al.*, Plasma Dev. Op. 13, 157 (2005)
T.W.L. Sanford *et al.*, IEEE Trans. Plasma Sci. 26, 1086 (1998

Will same effect be observed with nested arrays?
What will impact on K-shell radiation be?

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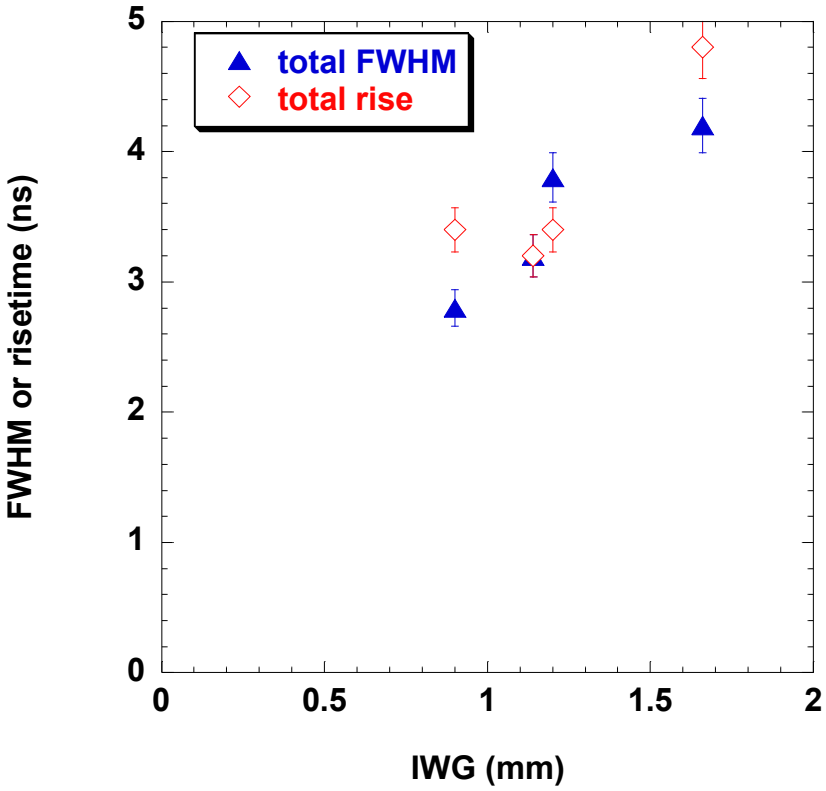
IWG was decreased on SS wire arrays to evaluate effects on K-shell emission

55mm nested, SS arrays (2:1)

Z shot	Wire number	IWG (mm)	Total power (TW)
1412	104 on 52	1.66	163.3
1595	144 on 72	1.2	196.7
1622	152 on 76	1.14	192.8
1480	184 on 92	0.9	187.2

Array mass same, all loads fielded multiple times



- Total output behaves as expected
  - Higher power
  - Faster risetime
- Suggests reduced instability growth
  - M.R. Douglas et al., Laser and Particle Beams 19, 527 (2001)

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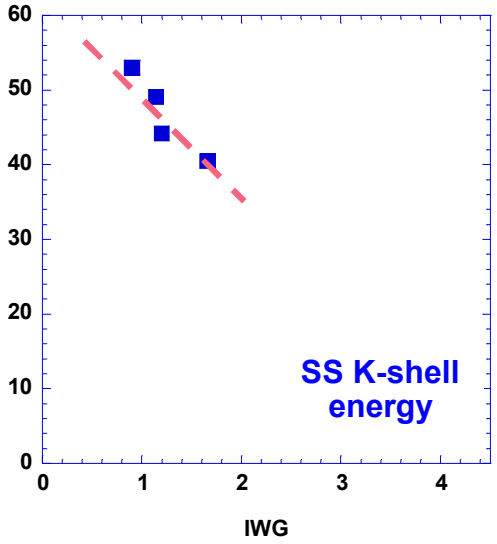
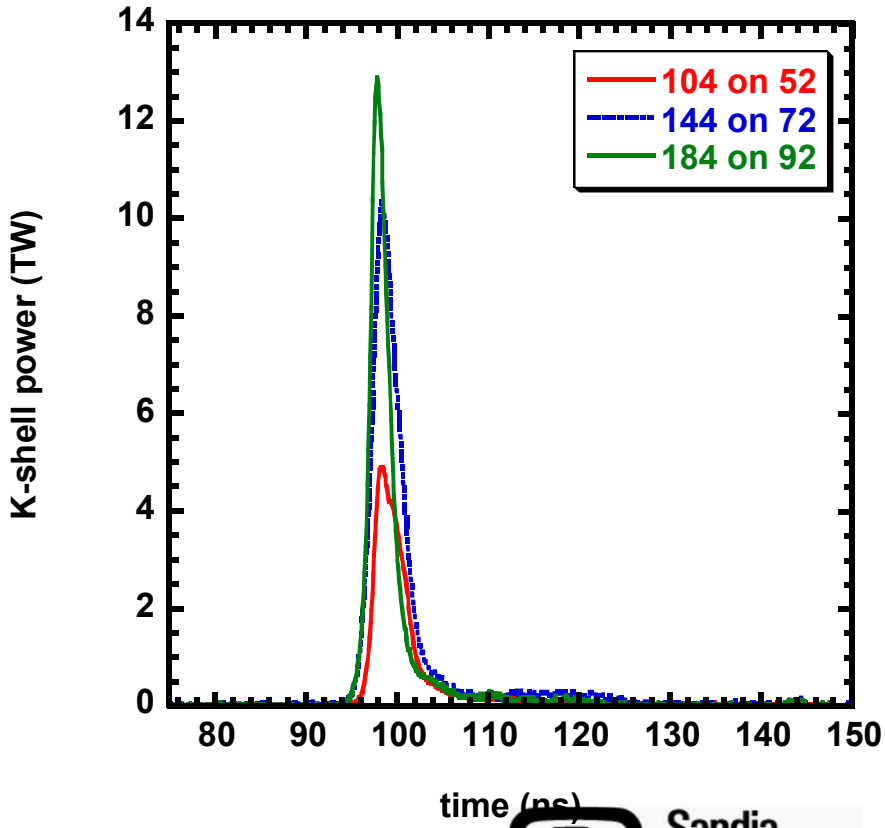
K-shell yield and pulseshape improved with higher wire number loads

55mm nested, SS arrays (2:1)

IWG (mm)	K-shell yield (kJ)	K-shell risetime (ns)	K-shell FWHM (ns)
1.66	40.5	2.7	4.2
1.2	44.2	2.1	3.5
1.14	49.1	2.1	2.8
0.9	53	1.5	2.4





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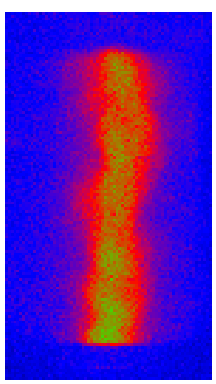
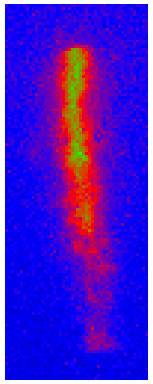
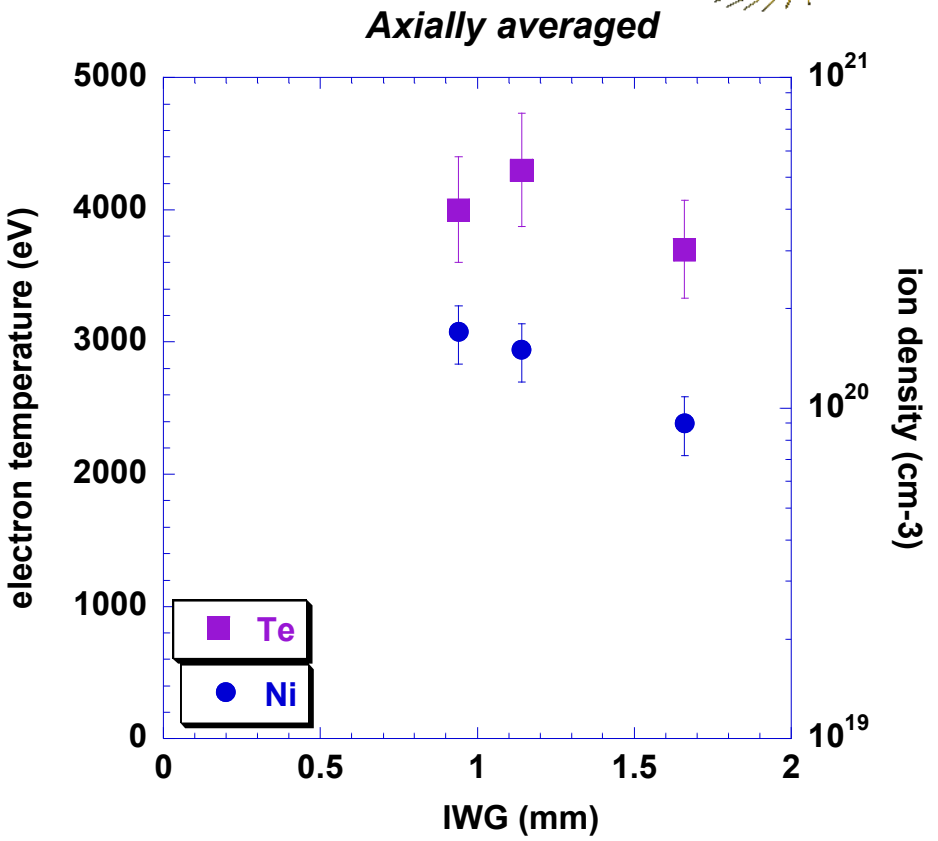
Higher wire number resulted in higher density, higher temperature z pinch

- Reduction in instability growth results in improved implosion and higher K-shell output
  - Faster risetime
  - Improved T_e and n_i
  - Pinhole images show tighter pinch at peak K-shell output
- Consistent with observations of total x rays
- Consistent with observations of single arrays





IWG = 1.66 mm 0.9 mm



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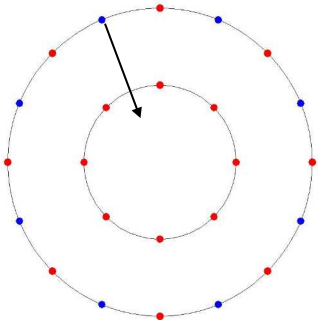
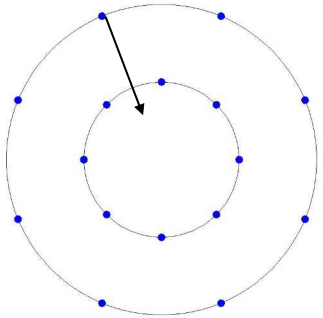
Transparency of nested wire arrays was varied through clocking of inner and outer arrays

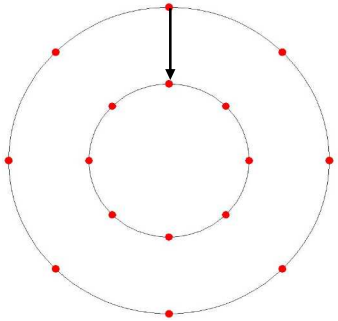
Usual configuration: would suggest 50% transparency



"Anti-Clocked": would suggest 100% transparency

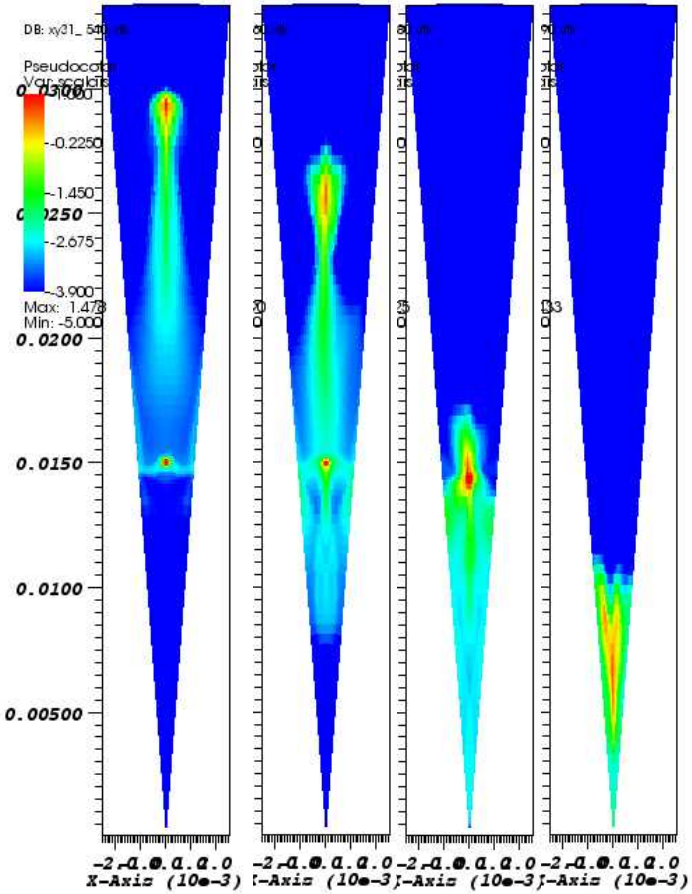


"Clocked": would suggest 0% transparency



Clocked

t =40ns 60ns 80ns 90ns



- Precursor indistinguishable between clocked & anti-clocked configurations
- Current switch to inner array differs in the two configurations
  - when clocked, looks more like flux compression
  - when anti-clocked, very sudden switch when outer nears inner

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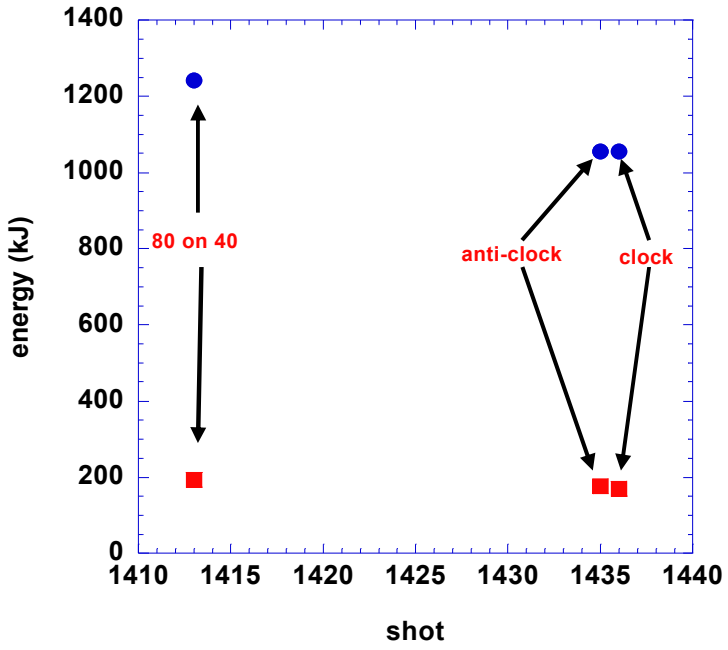
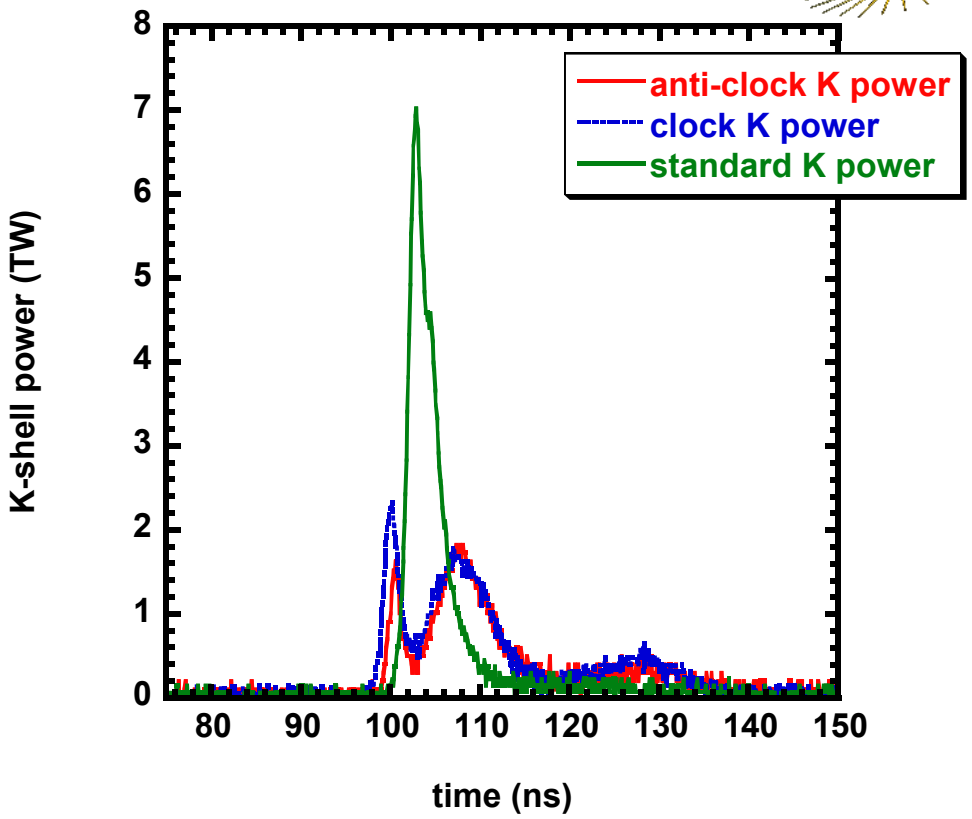
J. Chittenden

Noticeable differences in pulseshape were observed





- Double-pulse, although radiated energy similar (Kshell & total)
- Both 40 on 40 cases similar
  - Suggests change in waveshape due to different dynamics resulting from 40 wires

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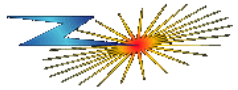
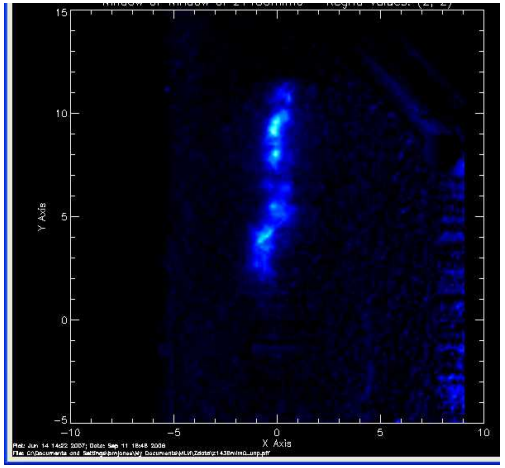
Lower wire number array shows more structure in the K-shell emissions



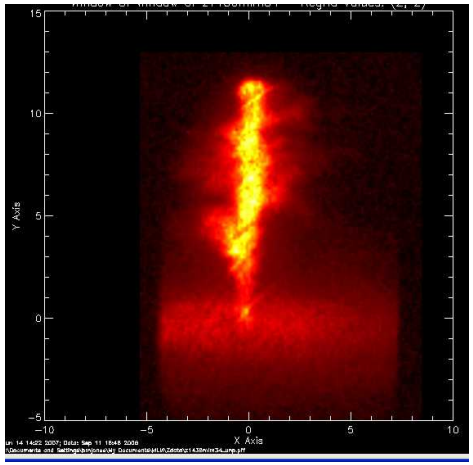
B. Jones

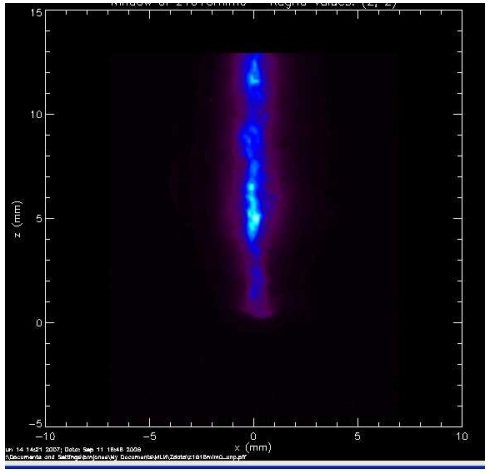
~ -3 ns



Z1436

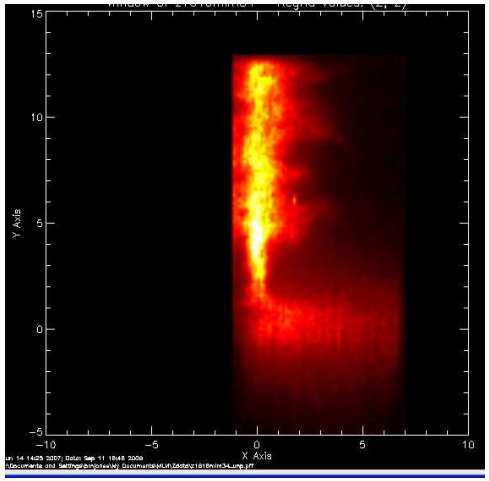
40 on 40 wires





Z1616

80 on 40 wires



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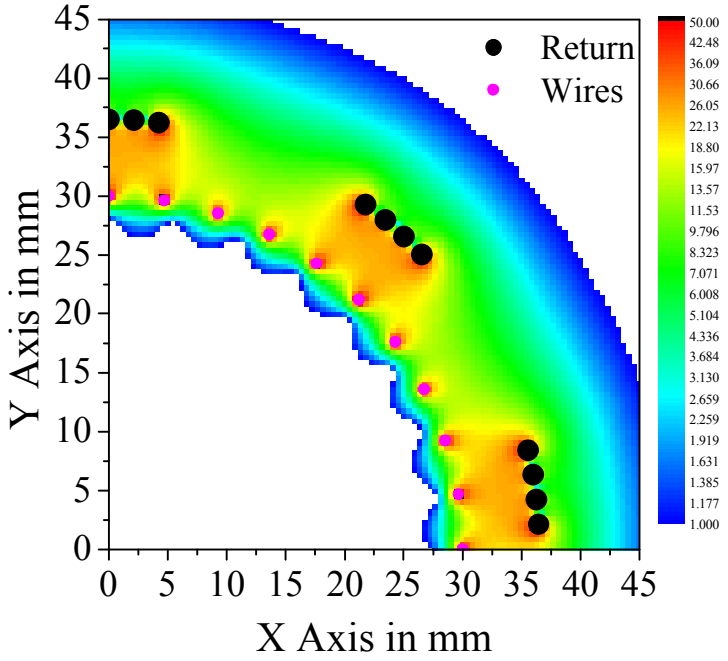
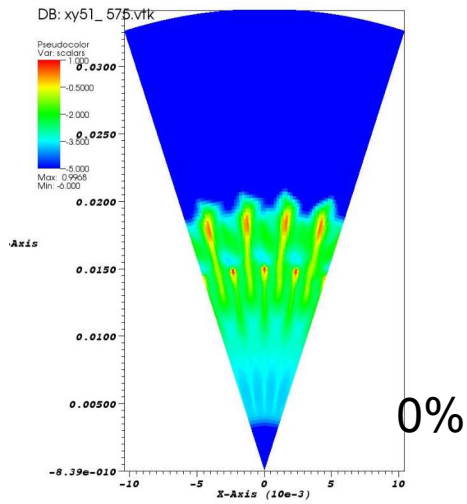
Axially averaged pinch diameters similar

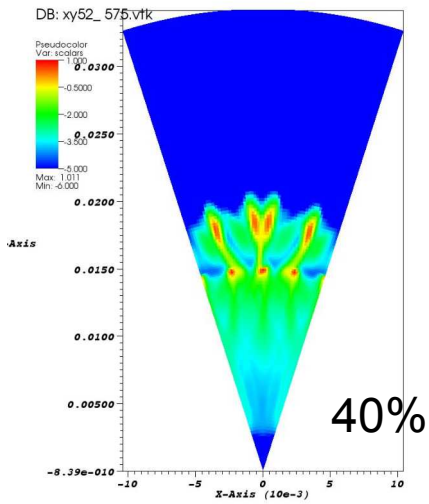
Post-shot calculations suggested dominant physics in the configuration

J. Chittenden





0%



40%

- magnetic field asymmetry associated with return can
  - Slightly higher currents and faster ablation rates on wires opposite wall material vs. slots

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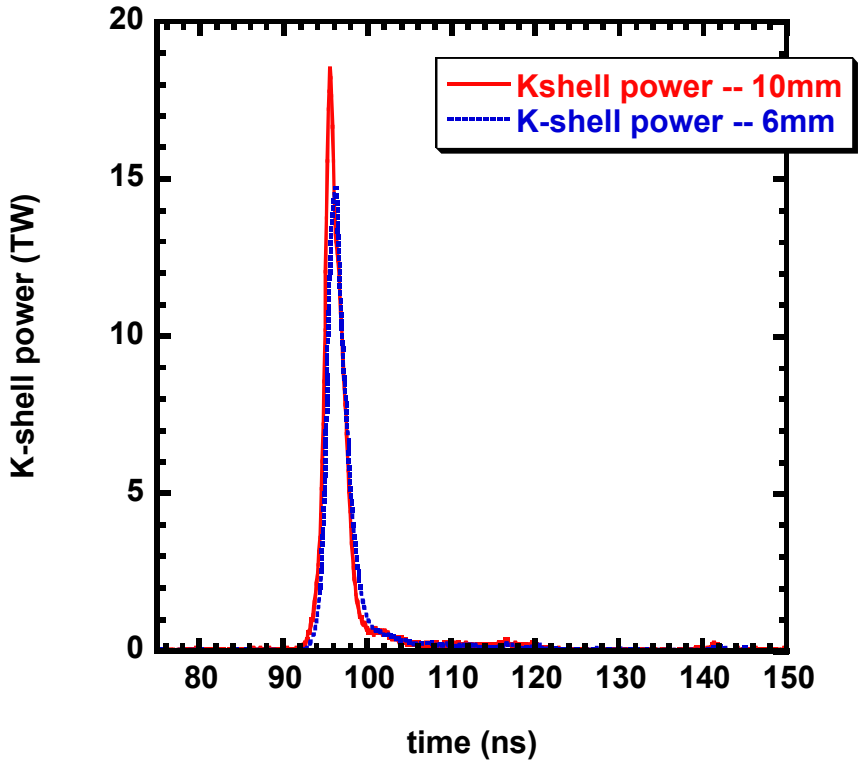
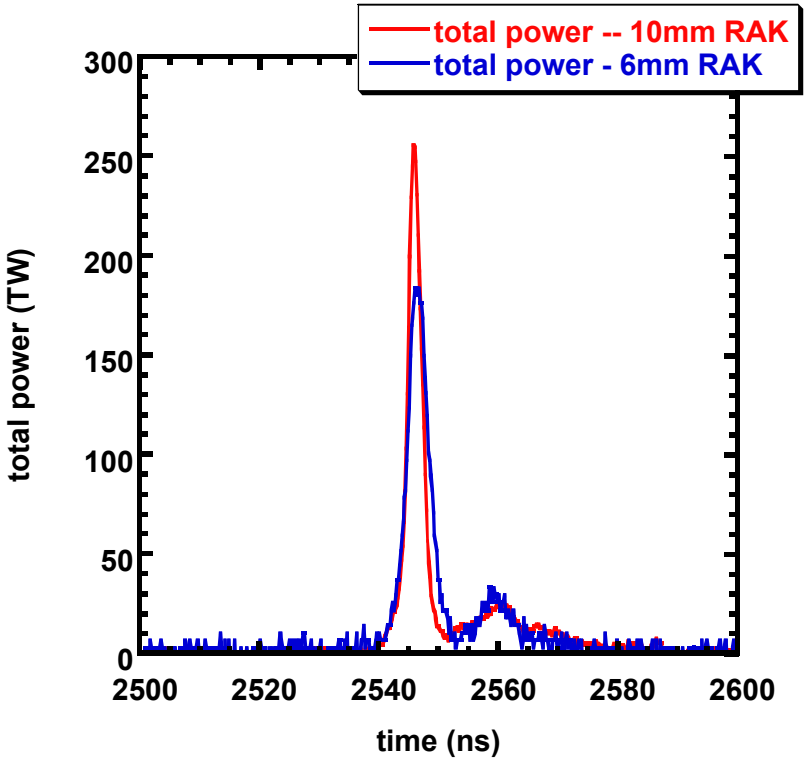
The RAK gap was increased from 6mm to 10mm to vary magnetic field and gap closure

55mm SS wire array, 184 on 92 wires





- **Radiated yields slightly higher**
- **Pulseshape differences within normal spread of data**
  - **Improvements consistent with previous observations**
    - **W.A. Stygar *et al.*, Phys. Rev. E 69, 046403 (2004)**

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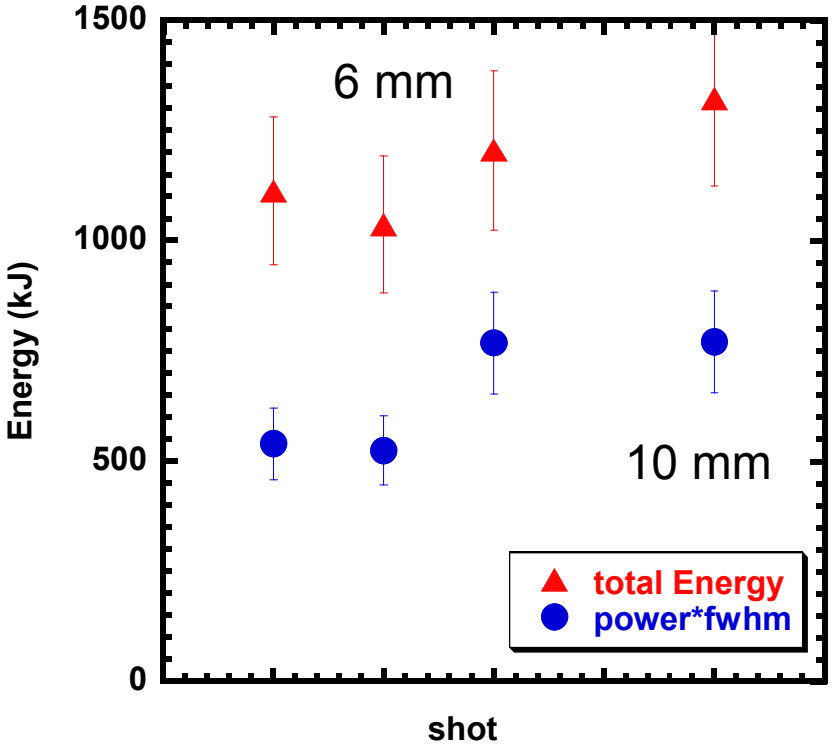
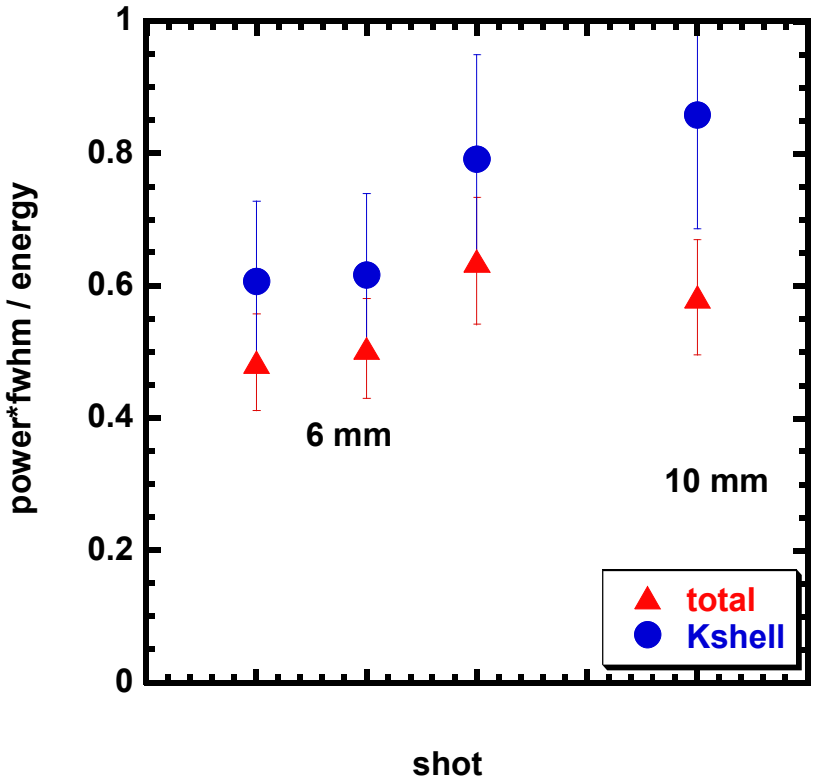
Examination of late time radiation suggests gap closure not affecting output





- Suggests that no additional current delivered with larger RAK
- Differences may result from change in magnetic field due to location of return can

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Summary

- Experiments have been fielded to examine the impact of load variations on the stagnated plasma and K-shell radiation
- Increasing the wire number of the nested SS arrays showed improvements similar to those observed with single arrays
  - Higher total and K-shell power, narrower pulsewidths
  - Apparent improvement in K-shell output consistent with reduction in instability growth resulting from higher wire number loads
- Wire number effects and magnetic field asymmetries appear to dominate loads designed to study transparency of nested wire arrays
  - Pulseshapes and powers for clocked and anti-clocked arrays very similar, lower than standard array
  - Calculations suggest that magnetic field asymmetry may dominate early stages of implosion
- Evidence of impact of the magnetic field asymmetry introduced by location of return cage relative to wire array observed in experiment with larger RAK gap
  - Improved energy output (total and K-shell) with larger RAK, but no change in relative portion of late time radiation

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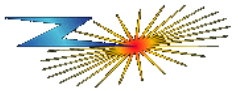
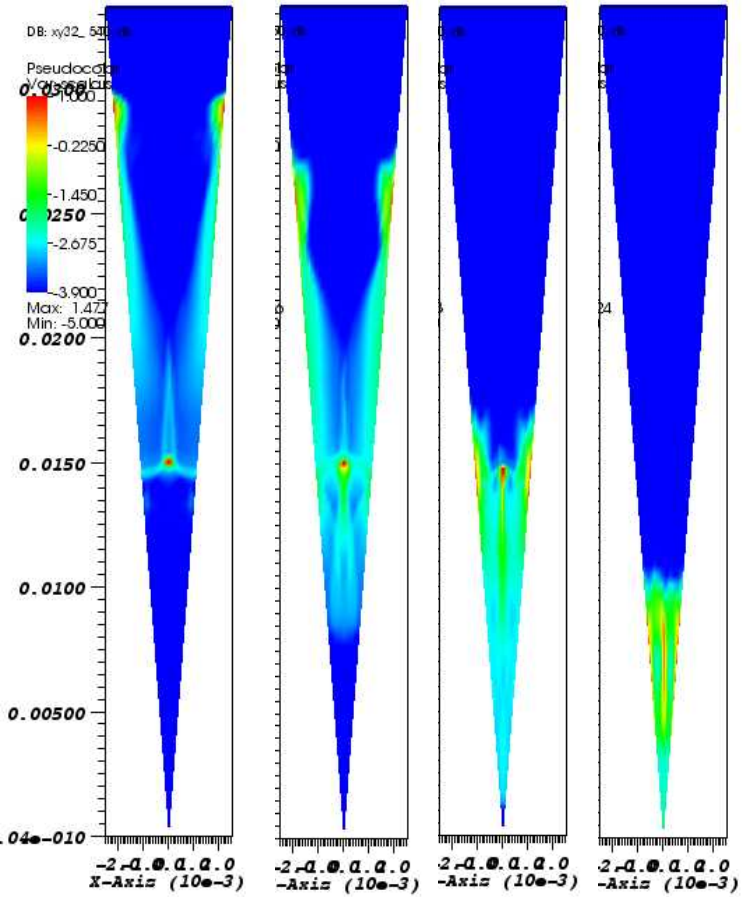
J. Chittenden has performed calculations of the "anti-clocked" and "clocked" configurations



Anti-clocked

t =40ns 60ns 80ns 90ns



Clocked

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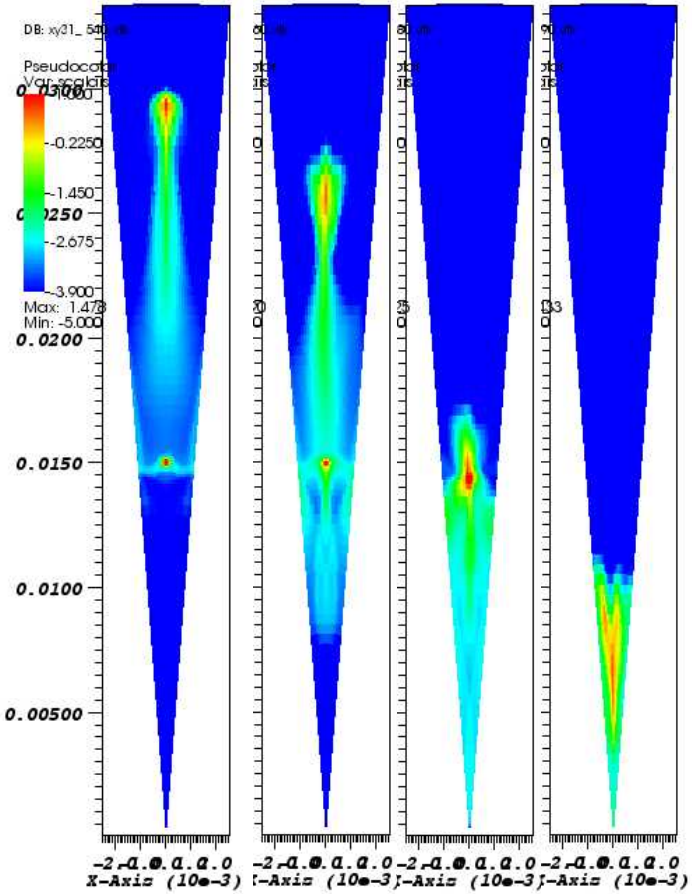

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