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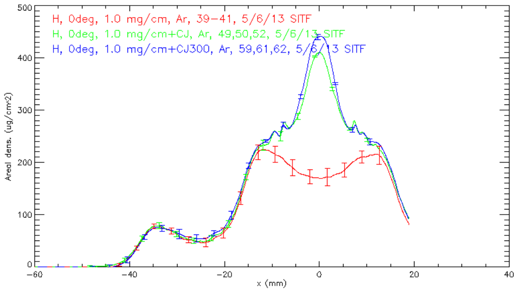

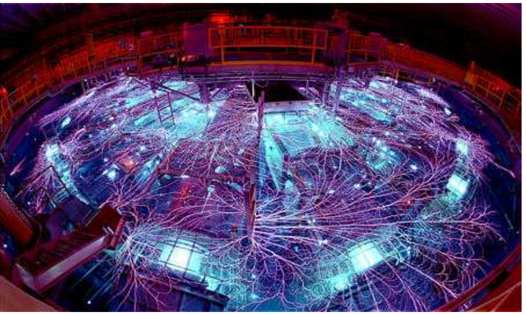

The effect of adding a center jet to Argon gas puff implosions at the Z facility

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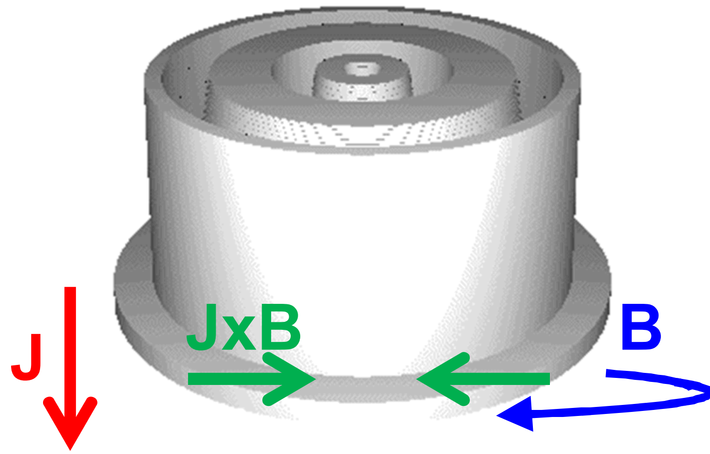
The Z generator implodes the Argon gas to produce large amounts of Argon K-shell emission at stagnation

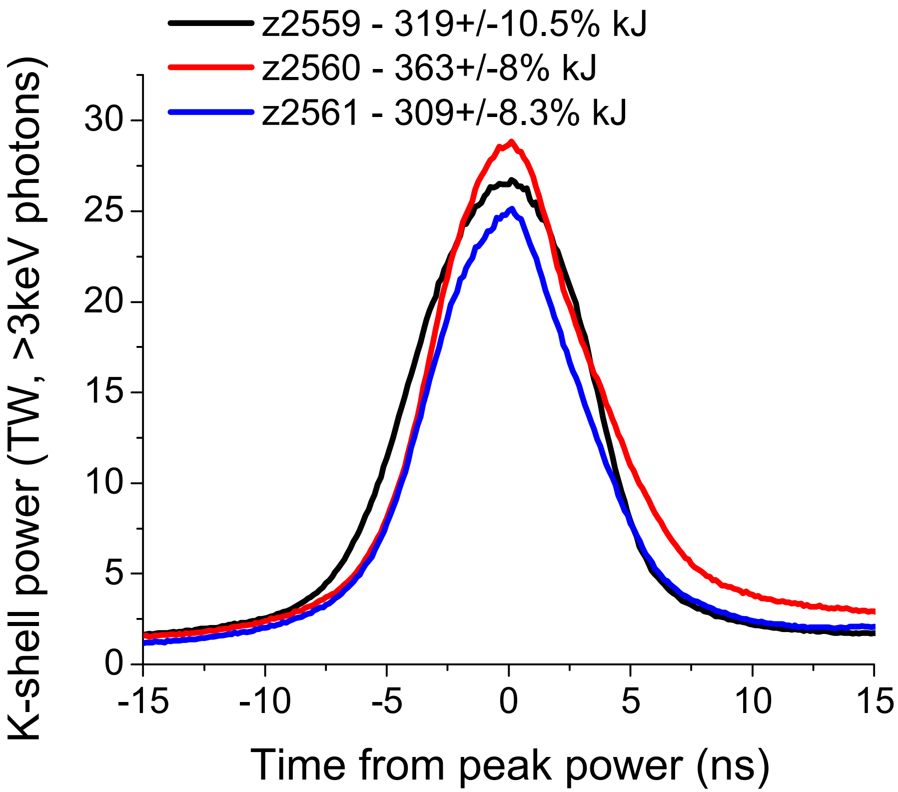
- Supersonic jets establish azimuthally symmetric shells of gas of Argon gas
- The Z generator current (up to 24 MA in 100 ns) implodes the Argon towards the axis
  - 25 mm pinch height – height of wire mesh
- A hot, dense Argon plasma is created at stagnation that radiates efficiently in the K-shell (>3 keV photons)
- We are able to alter the mass released in each shell to control the implosion – we can add mass to a center jet

Shell-on-shell profile – no center jet



Illustrative 3D MHD GORGON sim. by Chris Jennings

We have established a 1:1.6 outer:inner mass ratio, 1 mg/cm configuration as a reliable, well performing load



- 3-shot average K-shell yield (>3 keV photons) for 1:1.6 without center jet config:

  330 kJ ± 9% (3 shot Av. yield)

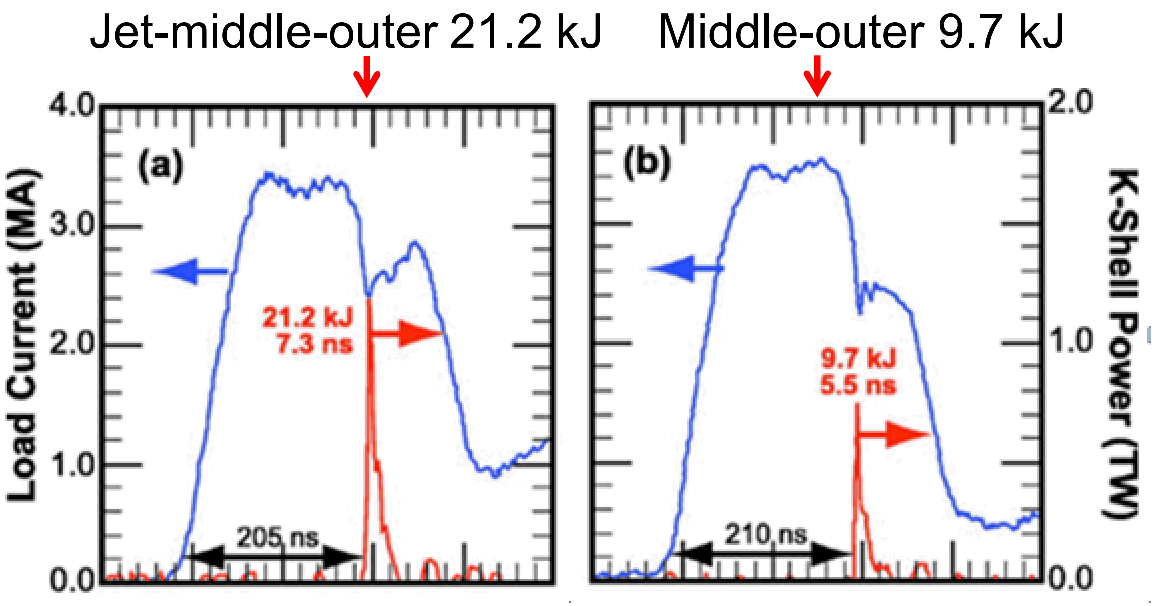
- Average peak power: 26.7 TW

- Average FWHM: 7.85±0.56 ns

Can we improve upon this yield by changing the gas profile used – adding a center jet?
(Not much – so far!)

Shot	2559	2560	2561
K-shell yield, >3 keV	319 kJ ± 10.5%	363 kJ ± 8%	309 kJ ± 8.3%
K-shell peak power	26.4 TW	29.0 TW	26.9 TW
K-shell FWHM	8.5 ns	7.6 ns	7.5 ns

Increased yields have been measured at smaller, 200 ns risetime facilities when adding a center jet



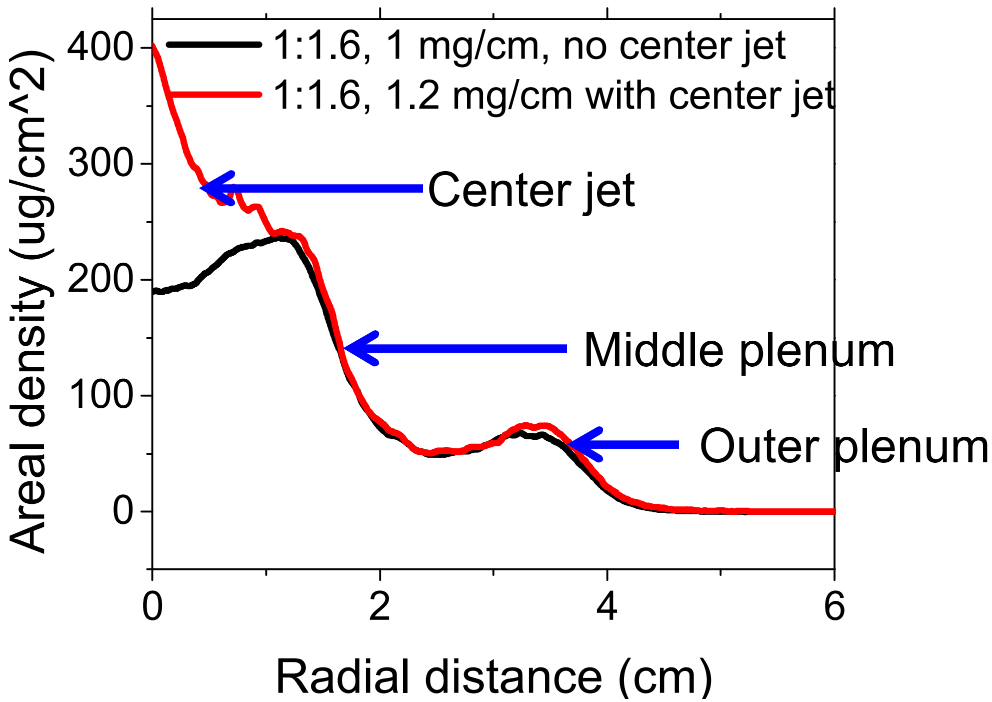
Experiments on Double-Eagle, H. Sze et al., PoP, 2007

- Experiments conducted at the 2-6 MA, 200 ns risetime facilities Double-Eagle[1], Decade-Quad[2] and Saturn
- All experiments used 12 cm diameter 1:1 mass ratio nozzles

[1] H. Sze et. al., Phys. Plas., (2007)
[2] H. Sze et al., Phys. Rev. Lett. (2005)

We simulated and tested four configurations to investigate the effect of adding mass to a central jet

- 1:1.6, 1 mg/cm no central jet
  - Our most well studied configuration that has given consistently good yields
- 1:1.6, 1.2 mg/cm with central jet (0.2 mg/cm in center jet)
  - Central jet comparison point with an already well-behaved setup



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- 1:1.6, 1 mg/cm no central jet
  - Our most well studied configuration that has given consistently good yields
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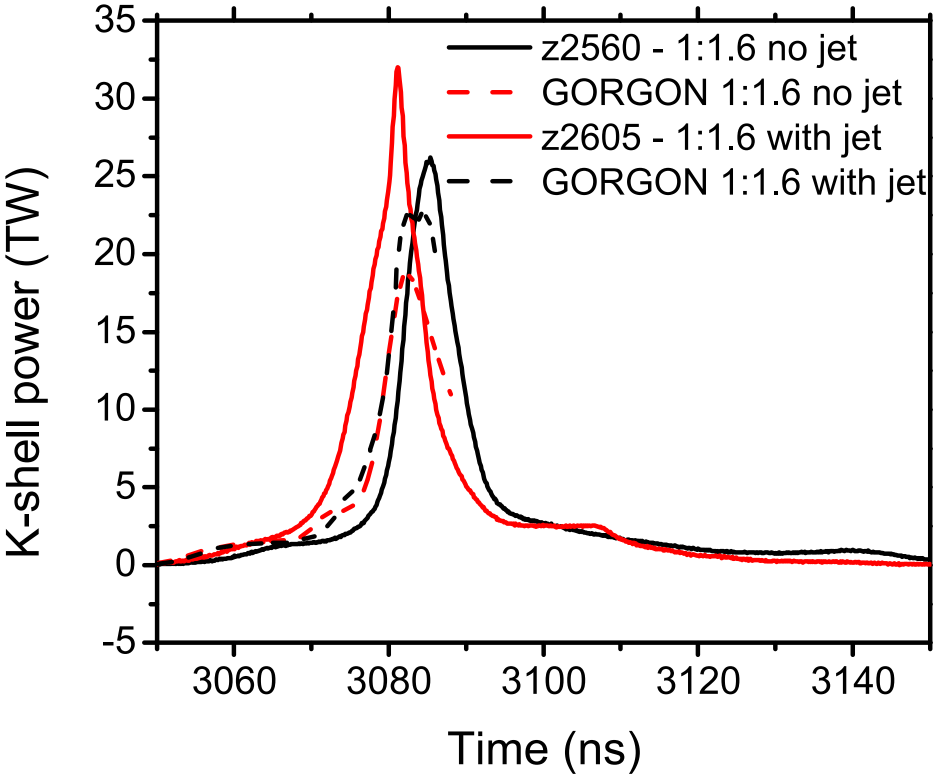
  - Central jet comparison point with an already well-behaved setup

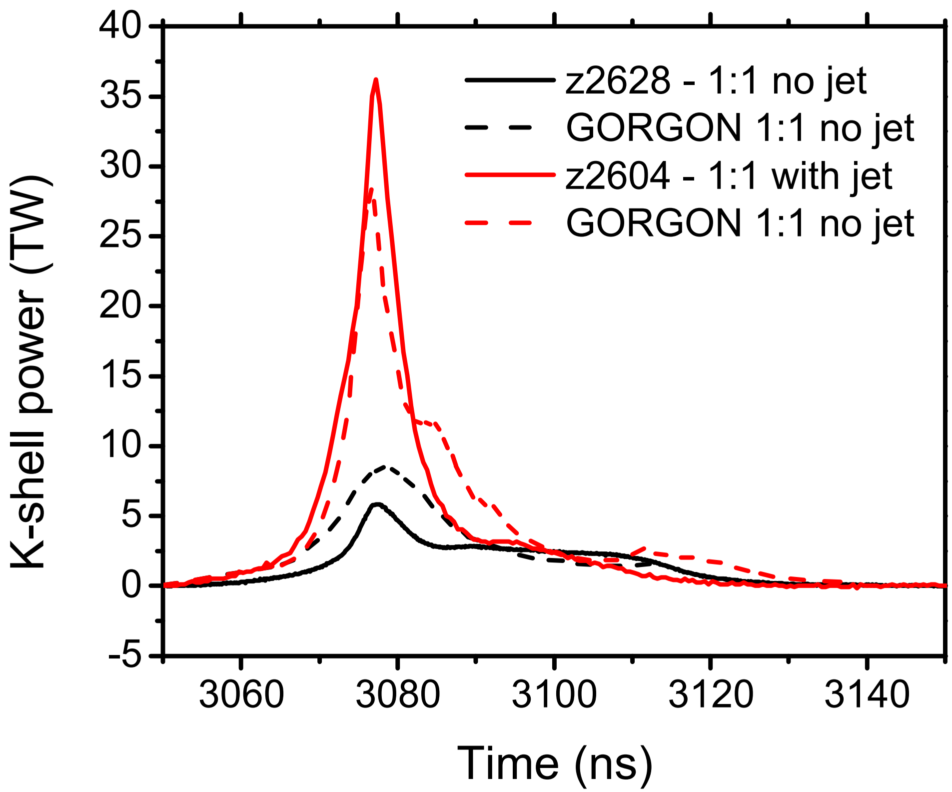
- 1:1, 0.77 mg/cm no central jet
- 1:1, 0.97 mg/cm with central jet
  - Configuration more similar to previous center jet experiments
  - A lighter, faster imploding experiment – increased implosion velocity and temperature at stagnation
  - Simulations show large improvement in yield with center jet – slightly greater than 1:1.6 config.

Central jet added to 1:1.6 config. shows little improvement in K-shell yield



- 1:1.6 without center jet yield:
  330 kJ ± 9% (3 shot Av. yield)
- 1:1.6 with center jet yield:
  373 kJ ± 9% (single shot)

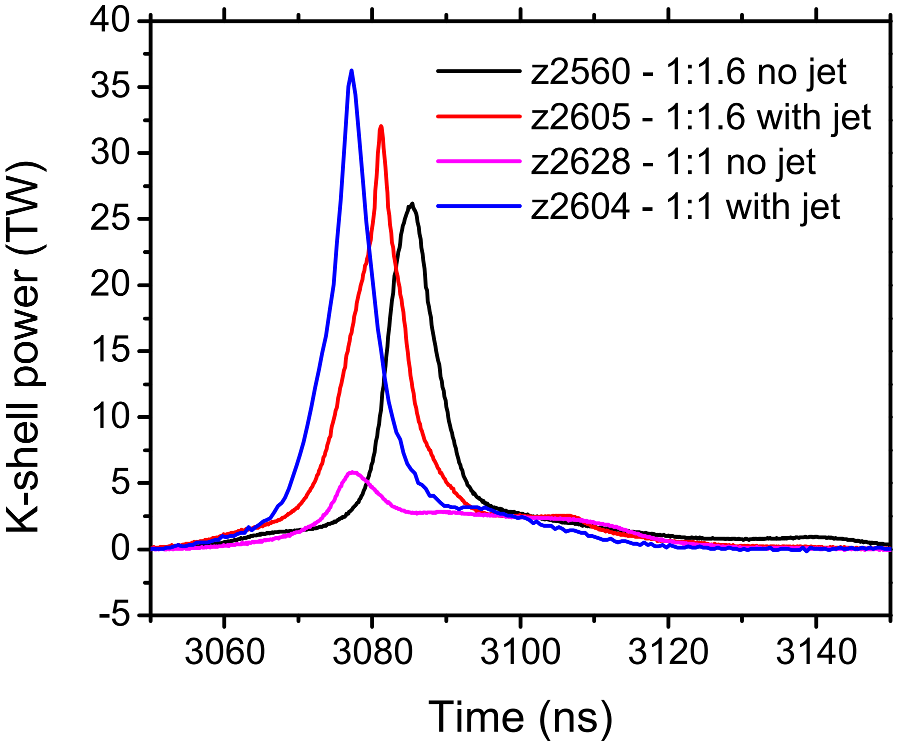
Central jet added to 1:1 config. shows significant improvement in K-shell yield and power



- 1:1 without center jet yield:
  144 kJ ± 9%
- 1:1 with center jet yield:
  375 kJ ± 10%
- Substantial increase in yield and power with central jet as predicted by GORGON

Center jet shots do not show significant improvement in yield

- 1:1 with center jet shows highest peak power
- Yields similar (except for 1:1 without center jet) and in-line with GORGON simulations



Configuration	GORGON yield	NRL yield	Experimental yield
1:1.6 no center jet	323 kJ	350 kJ	330 kJ ± 9% (3 shot Av. yield)
1:1.6 with center jet	356 kJ	460 kJ	373 kJ ± 9% (single shot)
1:1 no center jet	205 kJ	260 kJ	144 kJ ± 9% (single shot)
1:1 with center jet	383 kJ	350 kJ	375 kJ ± 9% (single shot)

Time resolved pinhole images near stagnation show qualitatively improved compression and uniformity in center jet shots

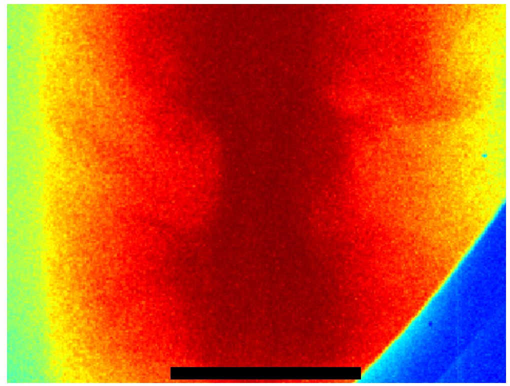
Camera sensitive to photons >3 keV

Center jet reduces pinch diameter from 3-4 mm to < 1 mm

Compression appears well collimated – little zippering or instability feed-through

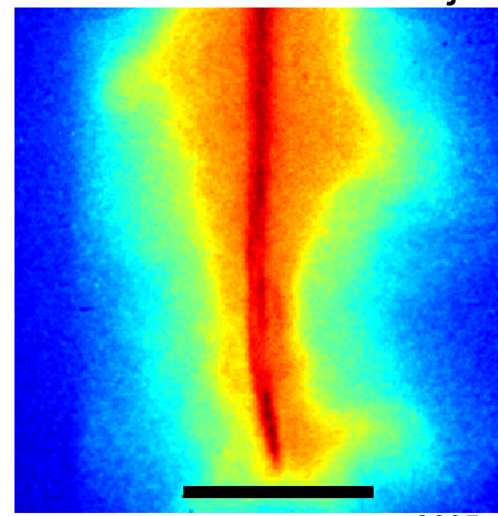
Higher convergences could indicate lower temperatures on axis

1:1.6 no center jet → 1:1.6 with center jet



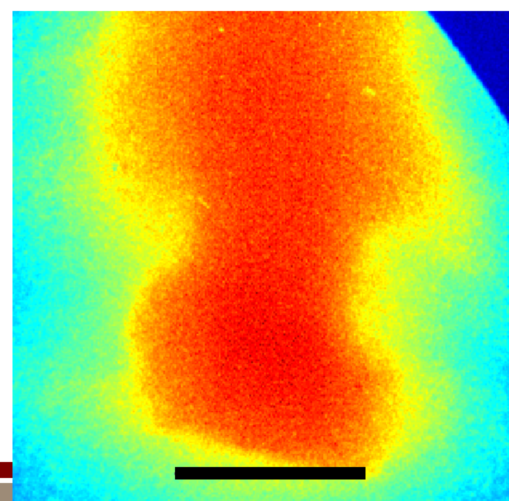
5 mm

z2560

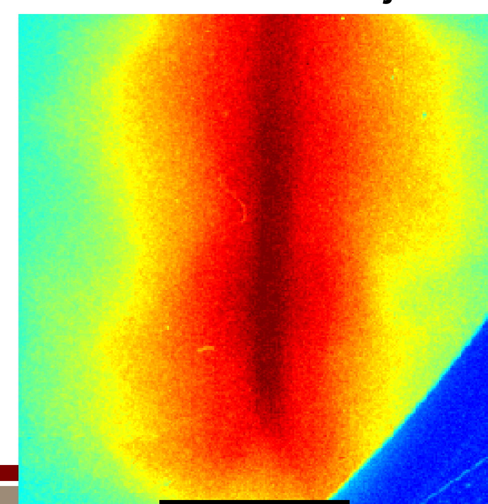


z2605

1:1 no center jet → 1:1 with center jet

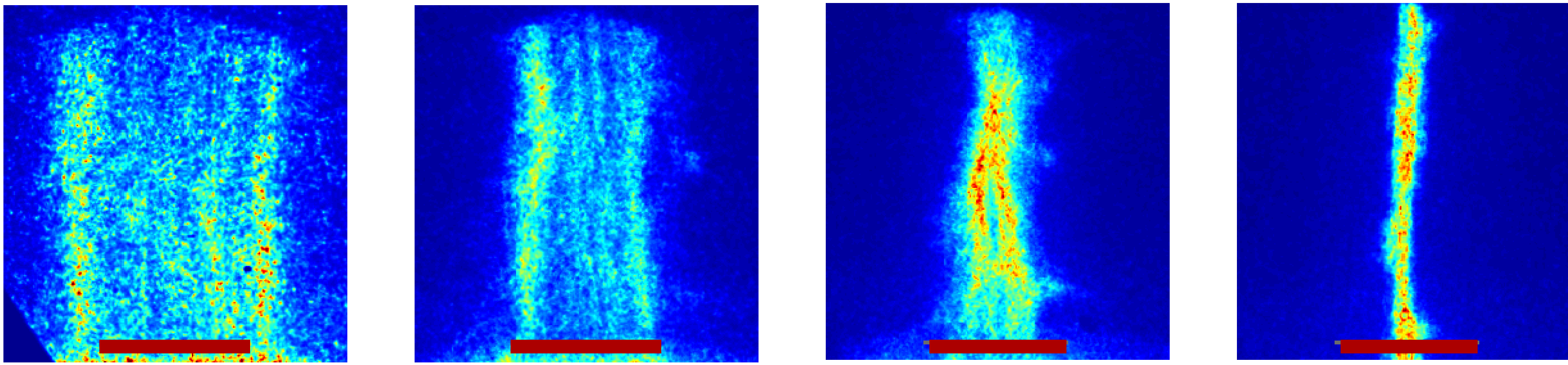


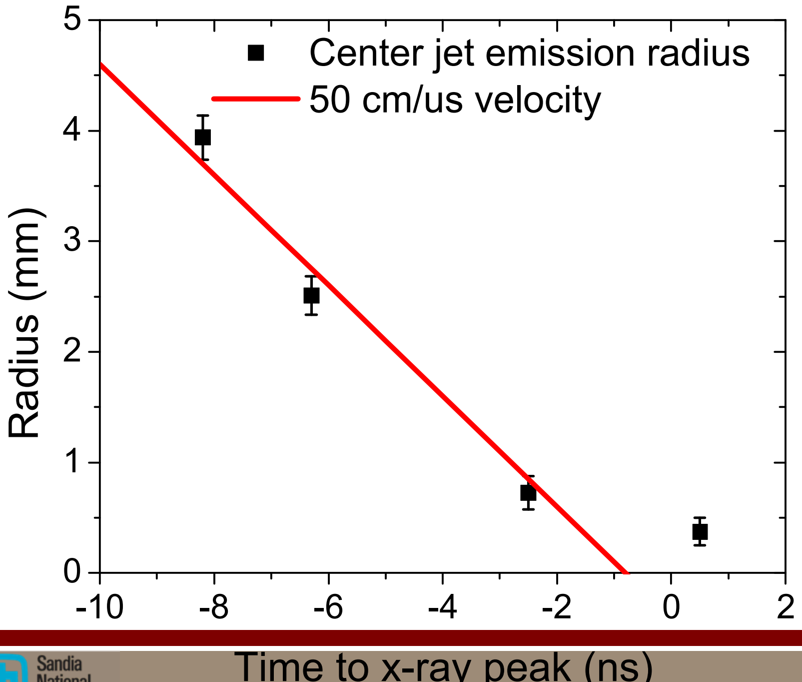
z2628



z2604

Compression of center jet material broadly agrees with GORGON sims.





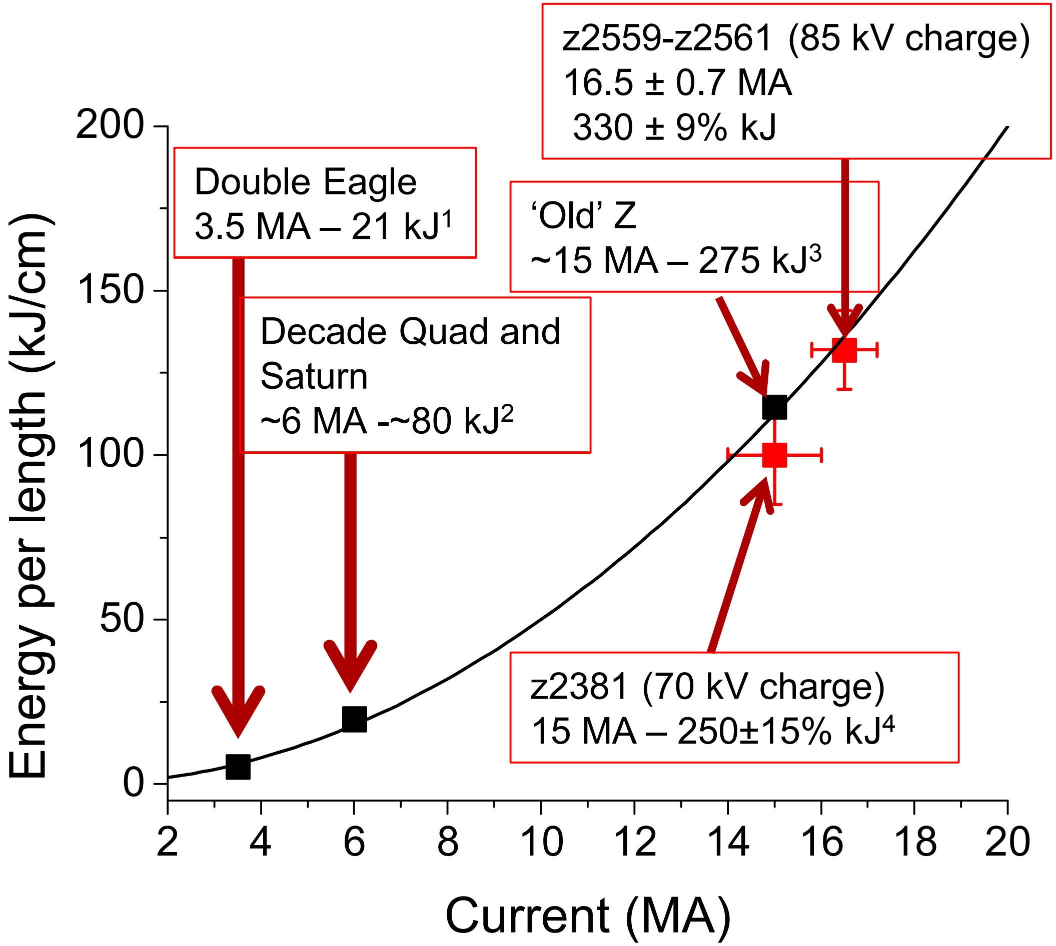
277 eV MLM time resolved camera[1] – 1:1.6 config with Xe dopant in center jet

In shots without Xe, little emission seen on this camera

1% by particle no. Xe dopant reduced K-shell yield substantially

~50 cm/us implosion agrees with GORGON simulation

Summary – our yields are already consistent with an I^2 scaling from previous machines



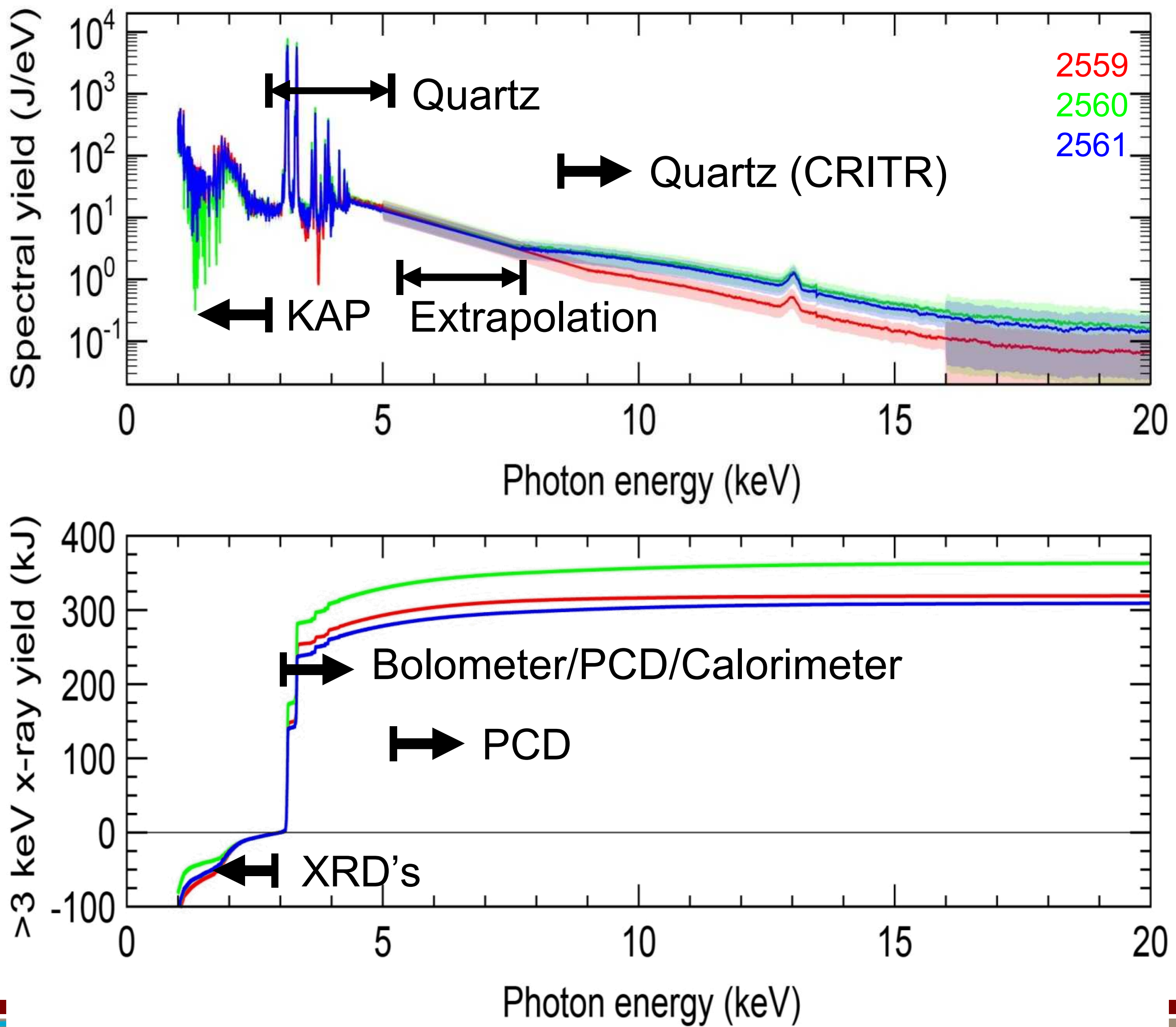
- Peak current delivered in Z experiments ~16.5 MA
- Gas puff loads develop high voltages leading to large current losses
- We are working to make loads more robust to current loss

[1] H. Sze et. al., Phys. Plas., (2007)
[2] H. Sze et al., Phys. Rev. Lett. (2005)
[3] H. Sze et al., Plas. Phys. Lett. (2001)
[4] B. Jones et al., IEEE Trans. Plas. Sci., (2014)

Summary

- 1:1.6 without center jet configurations have produced 330 kJ +/- 9% of K-shell yield
- Center jet configurations tested increased yield by ~10-15%
- Center jet configurations showed greater compression at stagnation – little impact of zippering/instabilities was observed
- The Argon configurations are efficiently producing K-shell x-rays given current delivery – in line with results from previous experiments

Spectrometer and power/yield diagnostics combined allow the yield in different parts of the spectrum to be assessed

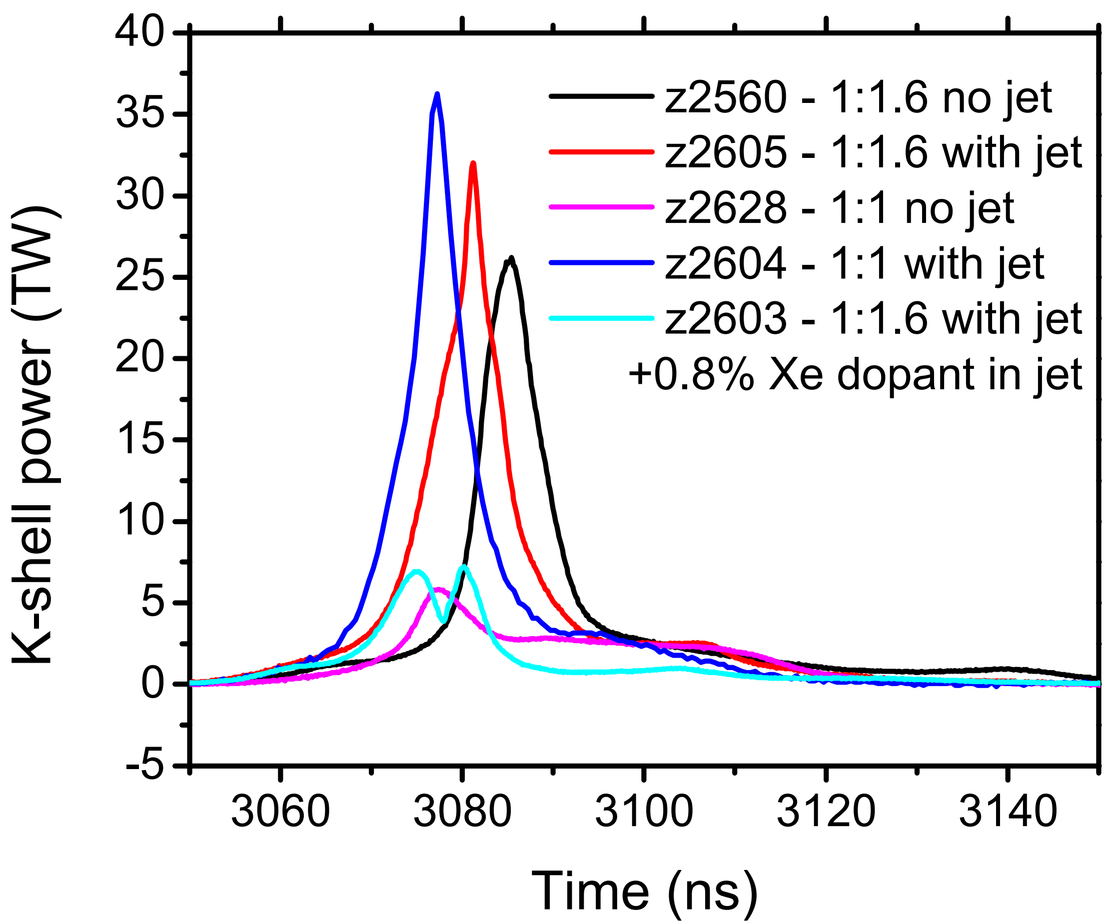


Spectrum is built from a combination of spectrometers

Different filter cuts of calorimeters, PCD's and bolo's constrain regions of the spectra

Spectrum is tweaked until best agreement is found – K-shell yield can be determined

K-shell power including Xe dopant shot



Xe dopant fraction: 0.8% by particle number just in center jet (c.j. has 0.2 mg/cm out of total 1.2 mg/cm mass in puff)

Yield of shot with Xe dopant: 129 kJ +/- 14%