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ACCESSING TERAPASCAL PRESSURES ON A TWO-STAGE LIGHT GAS GUN USING A NOVEL SHOCK AMPLIFICATION PLATFORM

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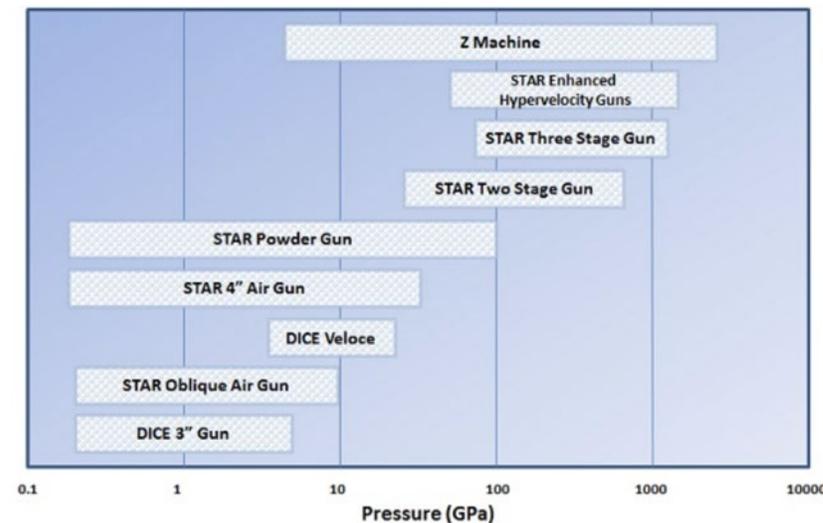
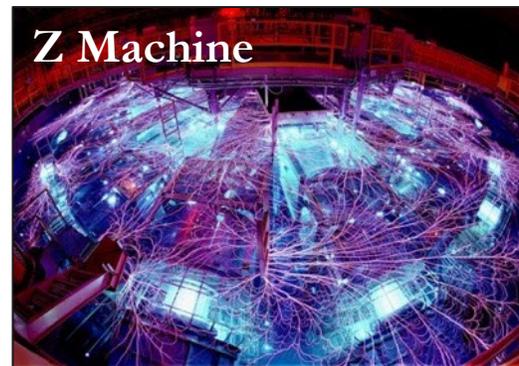
BACKGROUND AND MOTIVATION



“ZEndor: a shock amplification EOS platform for STAR and Z”
accepted proposal under Z Fundamental Science (ZFS) program

- Hydrodynamic amplification system to increase attainable pressures from Z Machine driven flyer plates up to ~ 10 TPa over mm scale sample sizes.
- Use established flyer plate and diagnostic hardware isolates amplifier performance and ensures high quality data collection.
- Demonstrate EOS platform on STAR 2-stage gas gun before testing on Z Machine.

Dynamic compression facilities at SNL

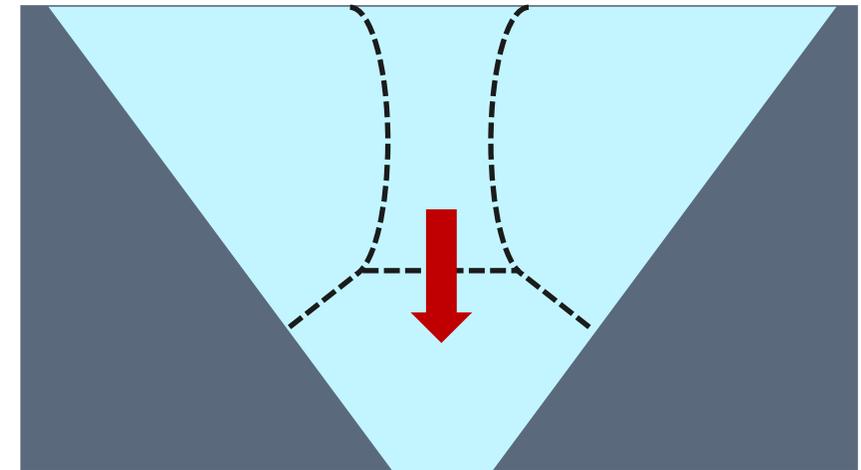
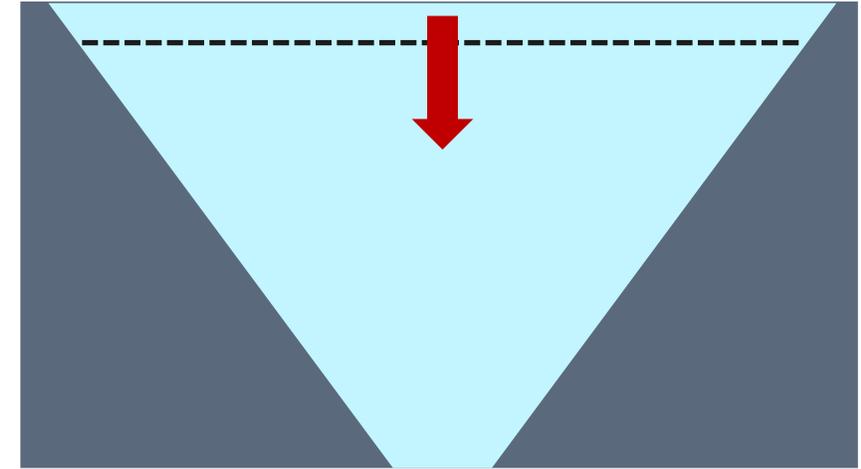


SHOCK PRESSURE AMPLIFICATION



Two distinct processes are combined to increase shock pressure

1. Shock amplification via Mach reflections.
 - Mach reflections sequentially form between the anvil walls and symmetry axis.
2. Shock reflections along the z-axis in addition to the channel walls to increase the output shock pressure.
 - This z-folding (or shock multiplexing) is achieved using alternating layers of high and low impedance material.

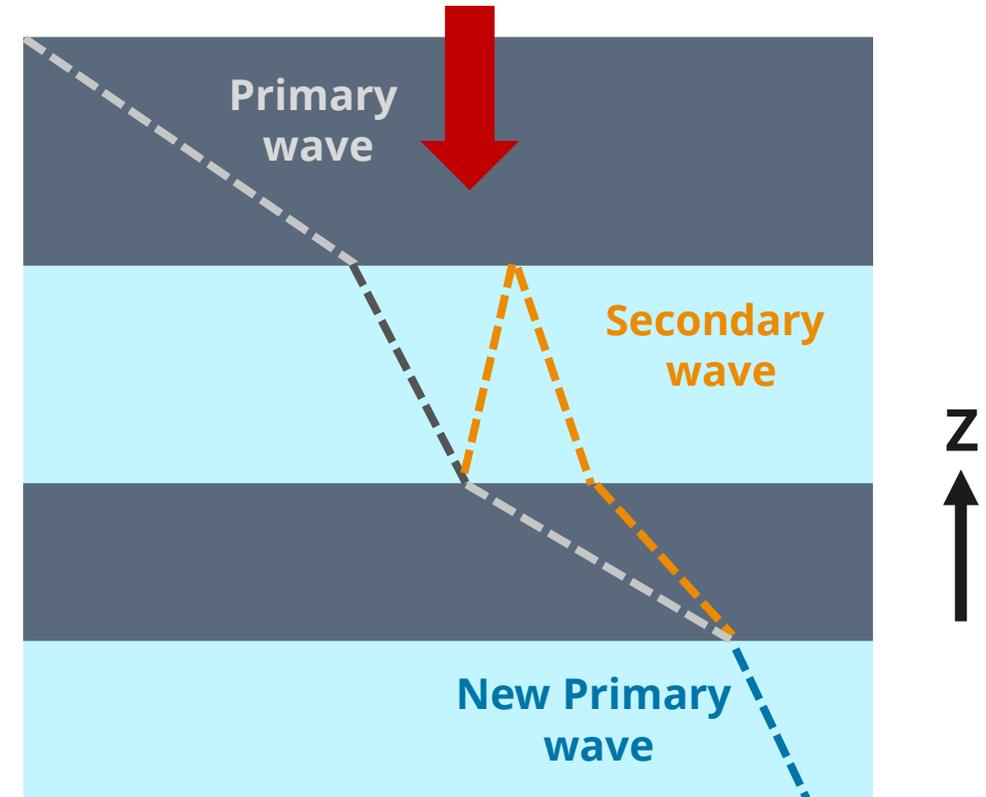


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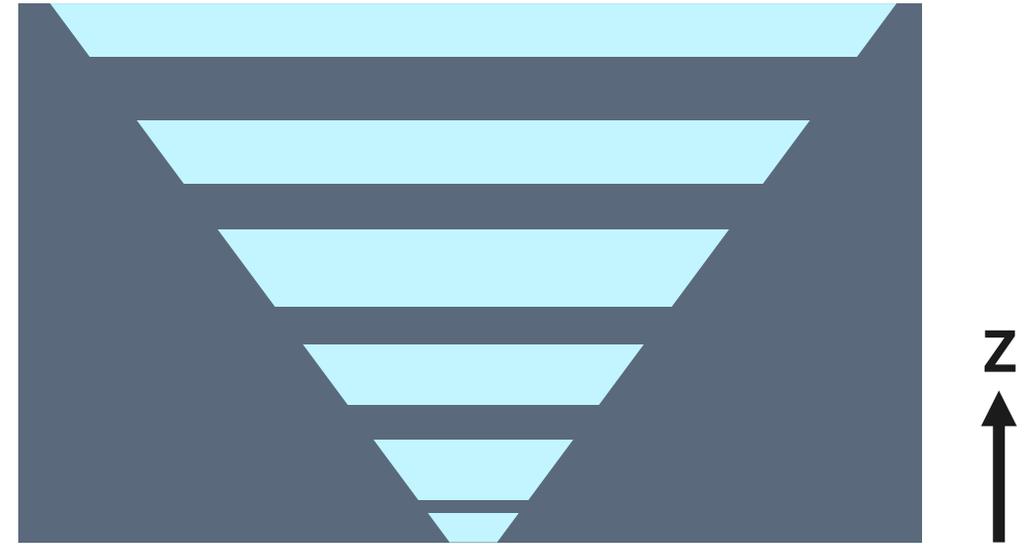


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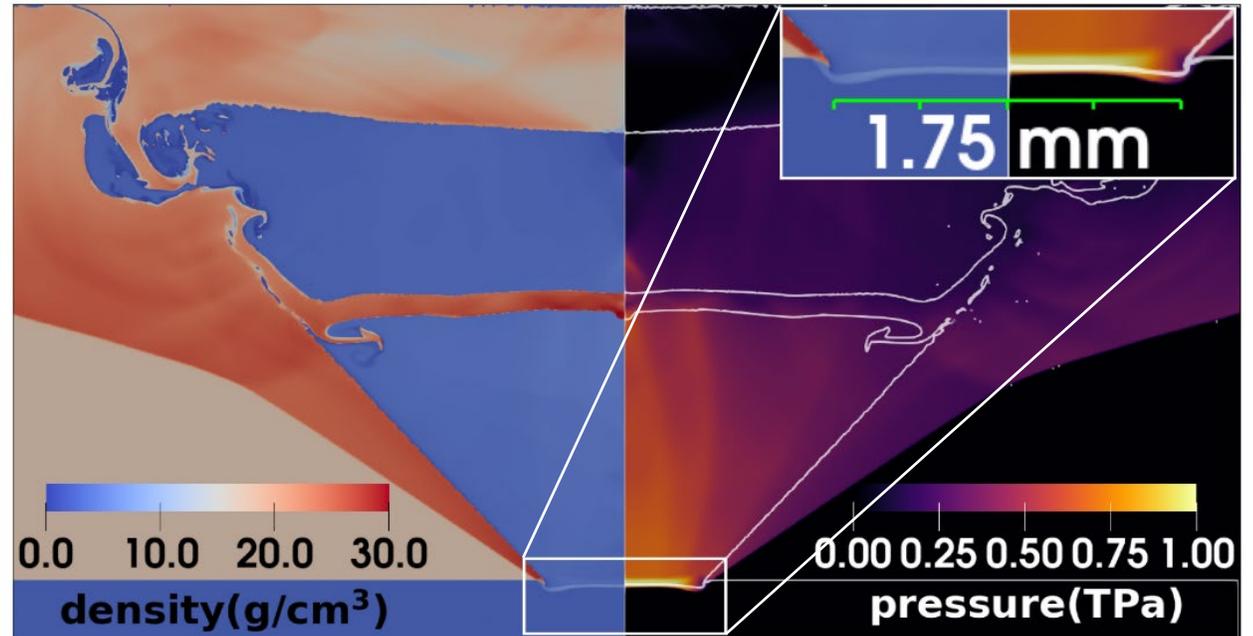
Due to number of degrees of freedom, numerical optimisation is required.

AMPLIFIER DESIGNS



Amplifier uses manipulation of shockwaves to increase pressure delivered to sample

- Amplifier is formed from conically converging high-impedance anvil, filled with a low-impedance fill material.
- This low-impedance fill is then stratified with high-impedance layers of varying thickness.



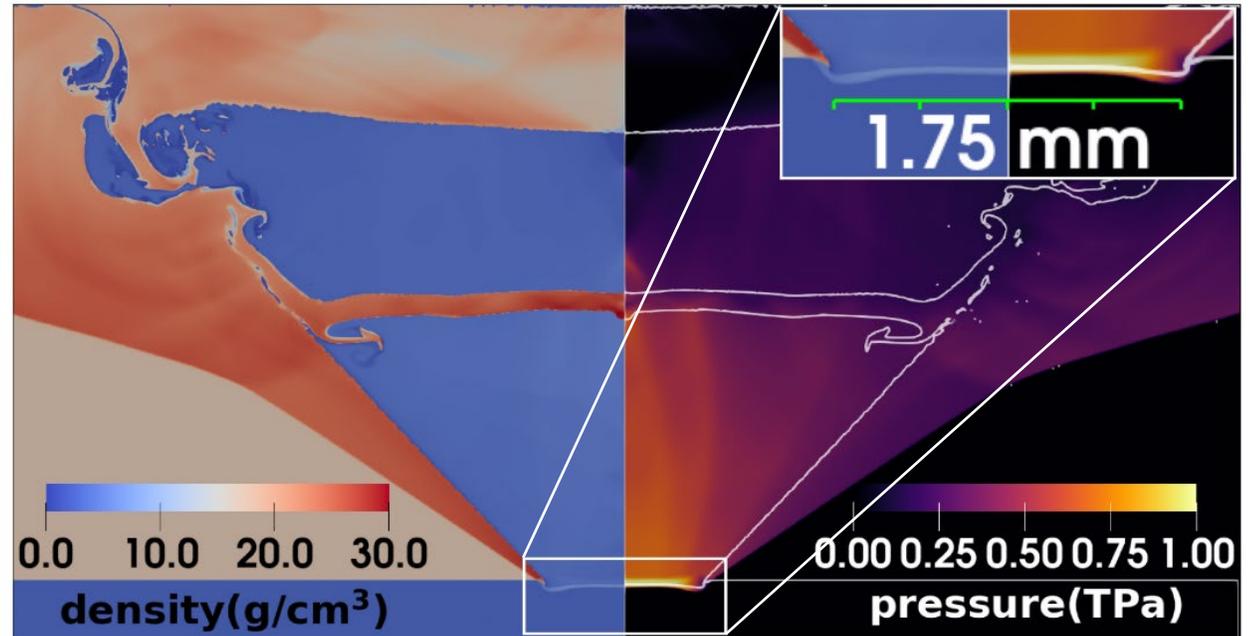
Two amplifier variants (“Naboo” and “Endor”) were developed for campaign that differ in complexity and output pressures.

AMPLIFIER DESIGNS



Amplifier uses manipulation of shockwaves to increase pressure delivered to sample

- Design pressures in Quartz sample:
 - 550 GPa for Naboo amplifier
 - 1040 GPa for Endor amplifier
- For reference, the STAR 2-stage gas gun can reach ~ 200 GPa in Quartz.



Uniformity and dwell time of amplifier output maintained for in excess of ± 0.5 km/s, allowing pressure range of over 200 GPa to be studied from a singular design point.

CAMPAIGN OVERVIEW



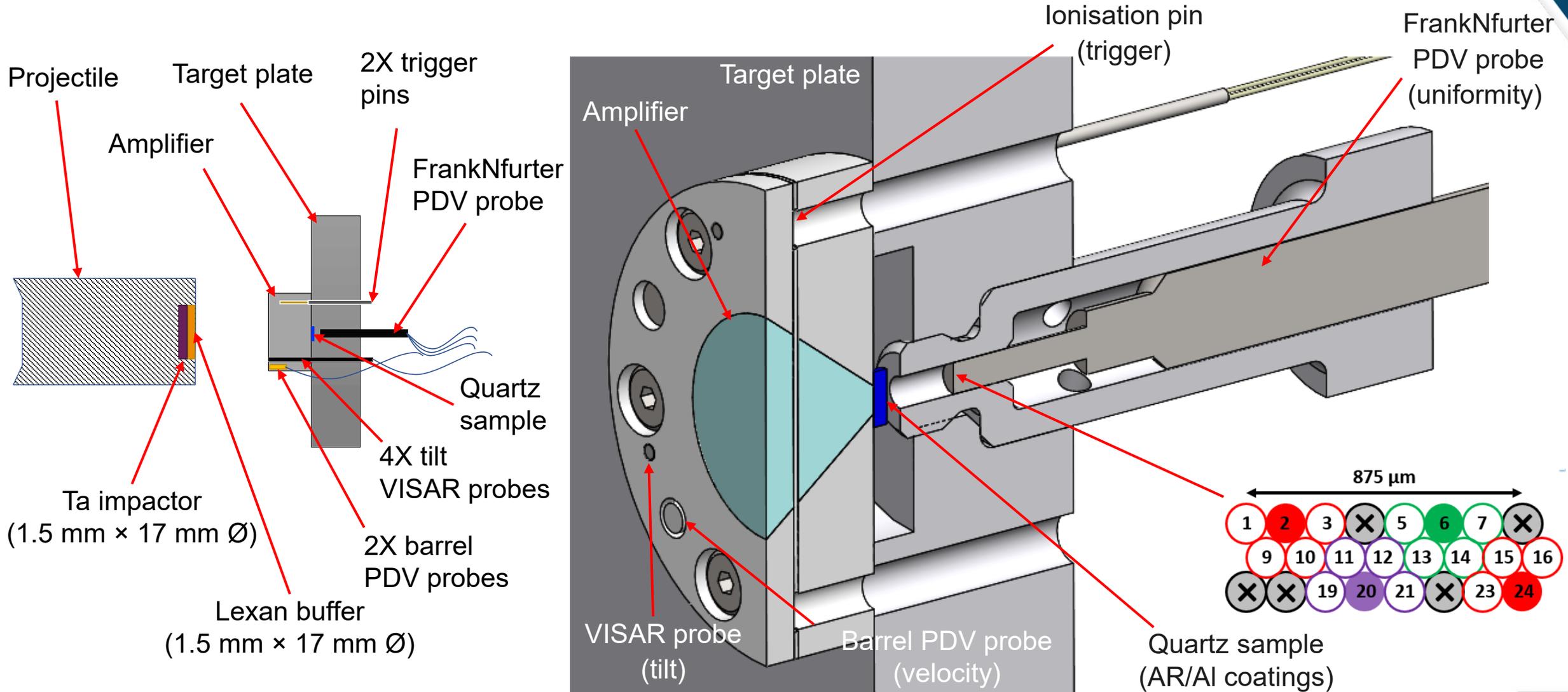
Shock amplifier platform performance requirements:

1. Amplifier should demonstrate $< 2\%$ standard deviation in spatial pressure uniformity over sample region accounting for projectile tilt.
2. Amplifier should demonstrate $< 2\%$ standard deviation in temporal pressure uniformity for ~ 10 ns hold over sample region accounting for projectile tilt.
3. The amplifier should produce ~ 1 mm planar region to drive sample.

CAMPAIGN OVERVIEW



Experimental setup on STAR 2-stage gas gun



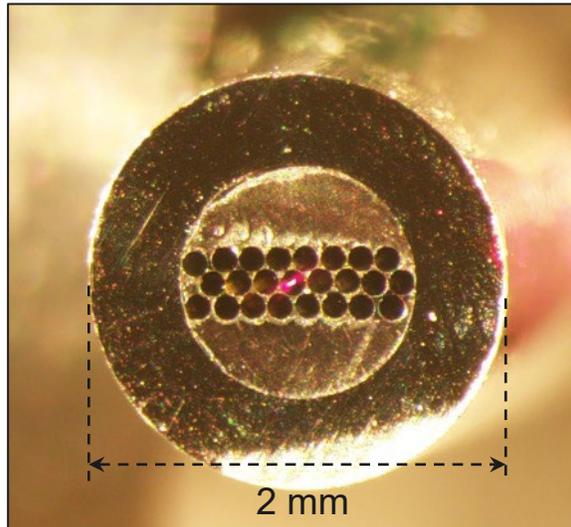
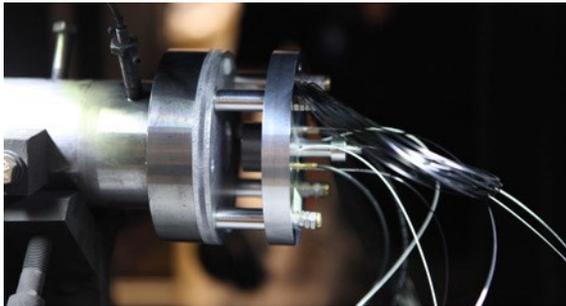
PDV SETUP

Laser parameters

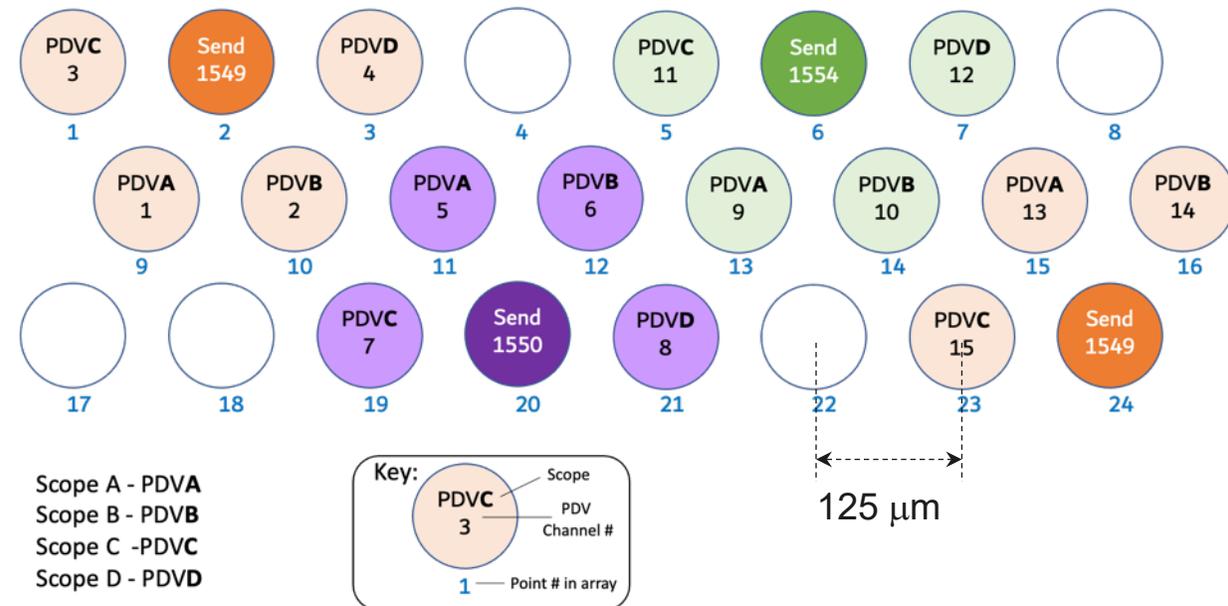
- 4 target lasers and 4 reference lasers: 1549, 1549, 1550, 1554 nm
- Downshifted PDV: -21 and -32 GHz

Linear array (FrankNfurter) probes

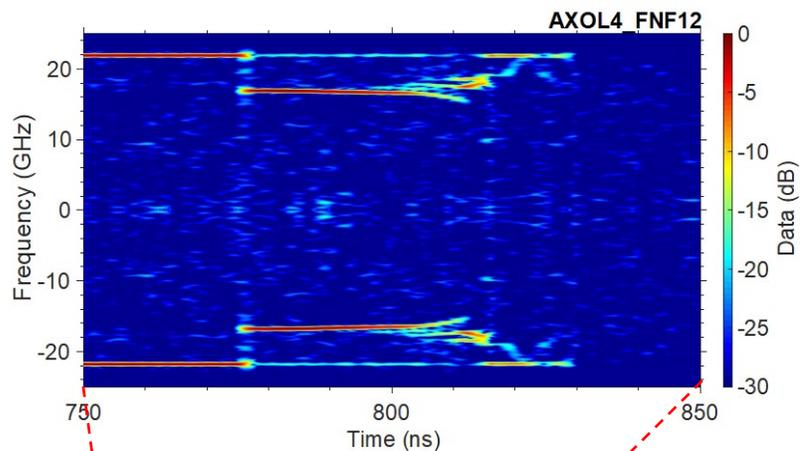
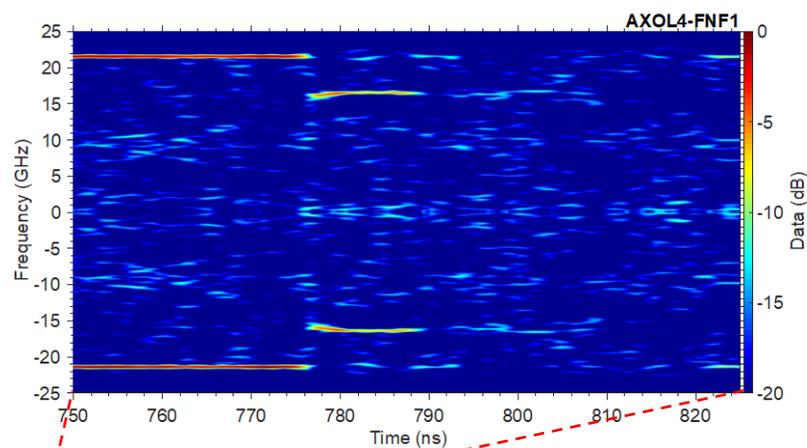
- 24 fibers, stacked 3 rows by 8 columns
- 125 μm spacing



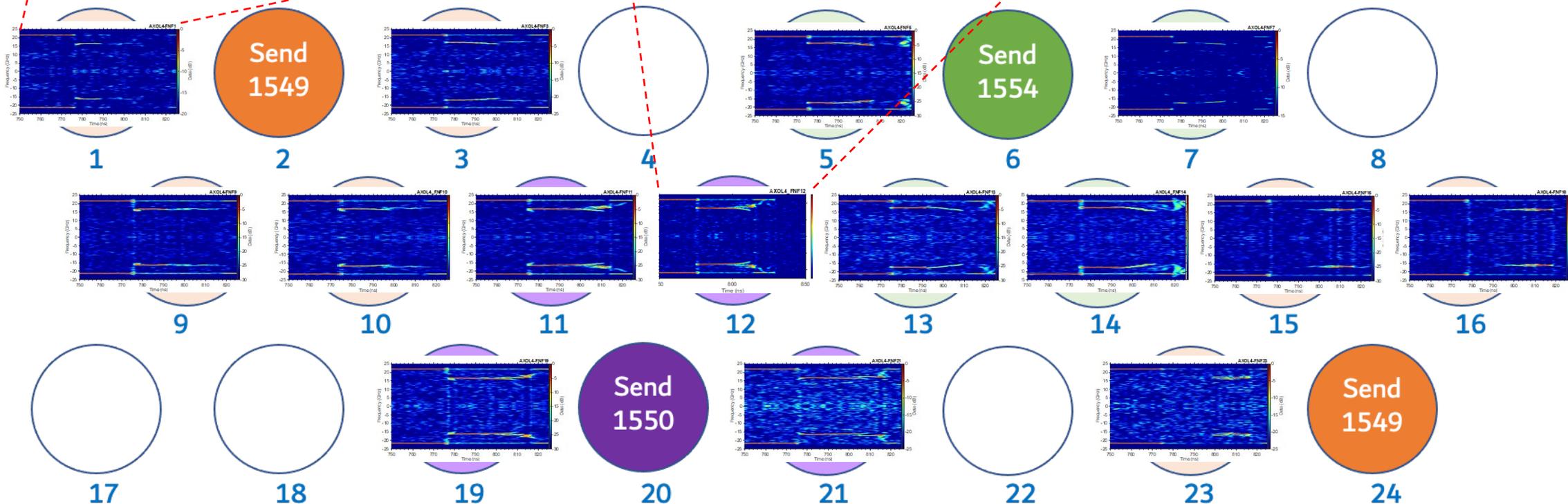
FrankNfurter window probe configuration



RESULTS: NABOO AMPLIFIER



Target	Naboo
Projectile	Ta/Lexan
Impact velocity	6.61 km/s
Tilt	15.9 mrad (0.9°)



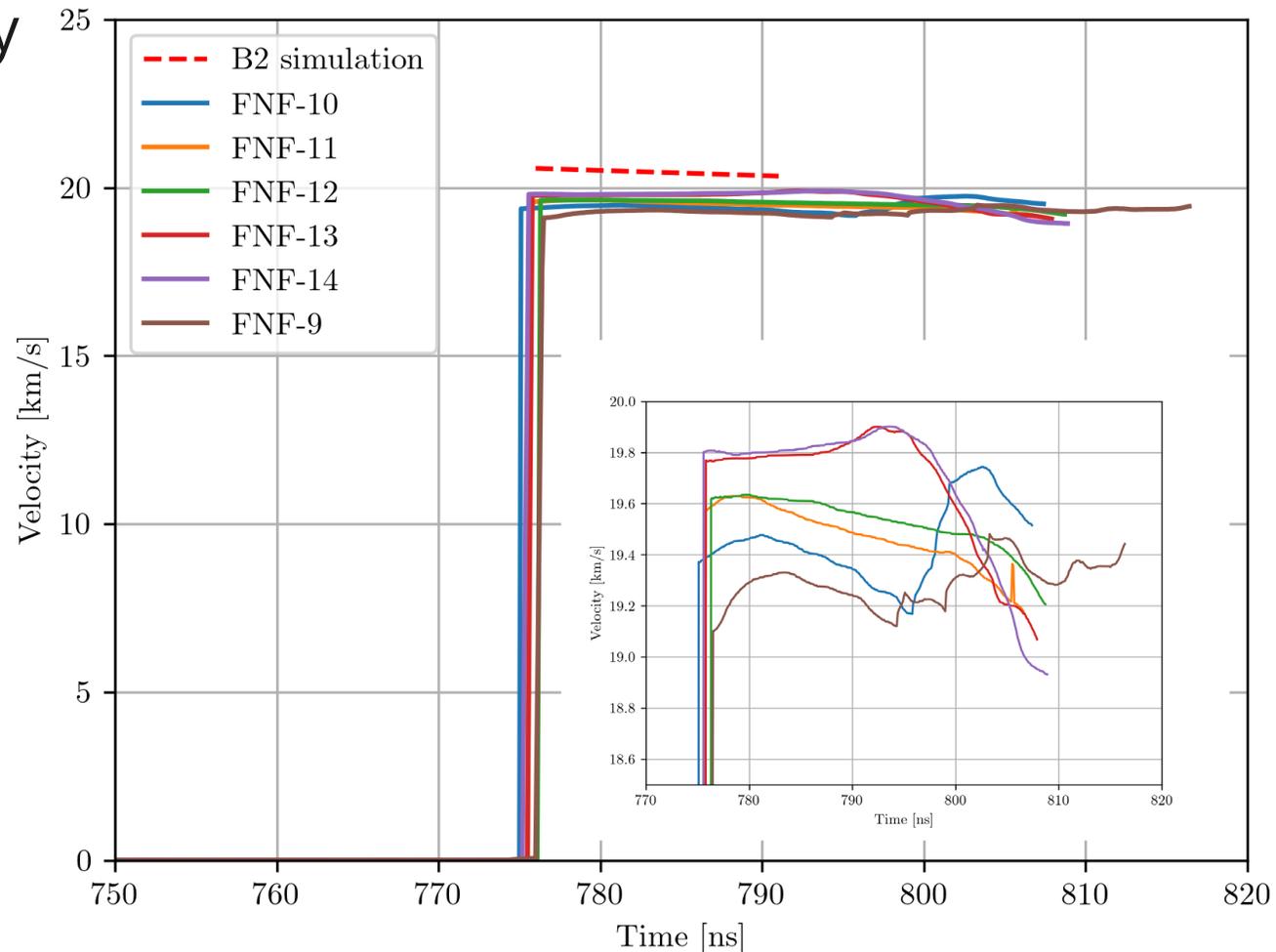
RESULTS: NABOO AMPLIFIER



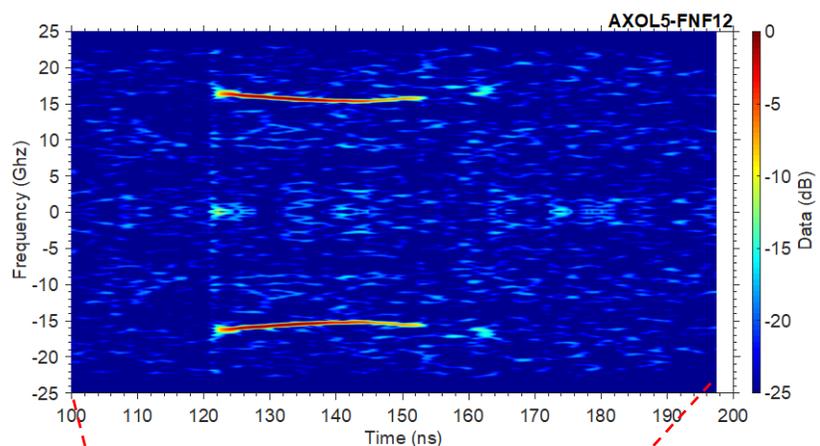
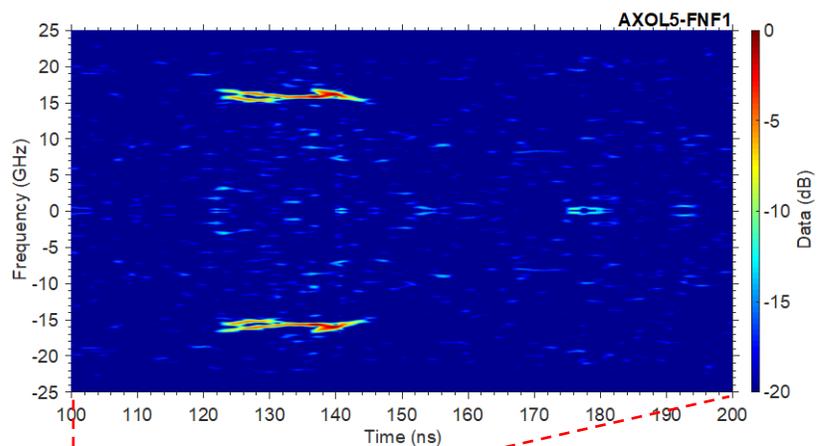
Measured performance

- 0.5% temporal uniformity within each measurement in 10 ns requirement
- 1.7% variation in spatial uniformity between probes
- Uniformity affected by projectile tilt of 0.9°

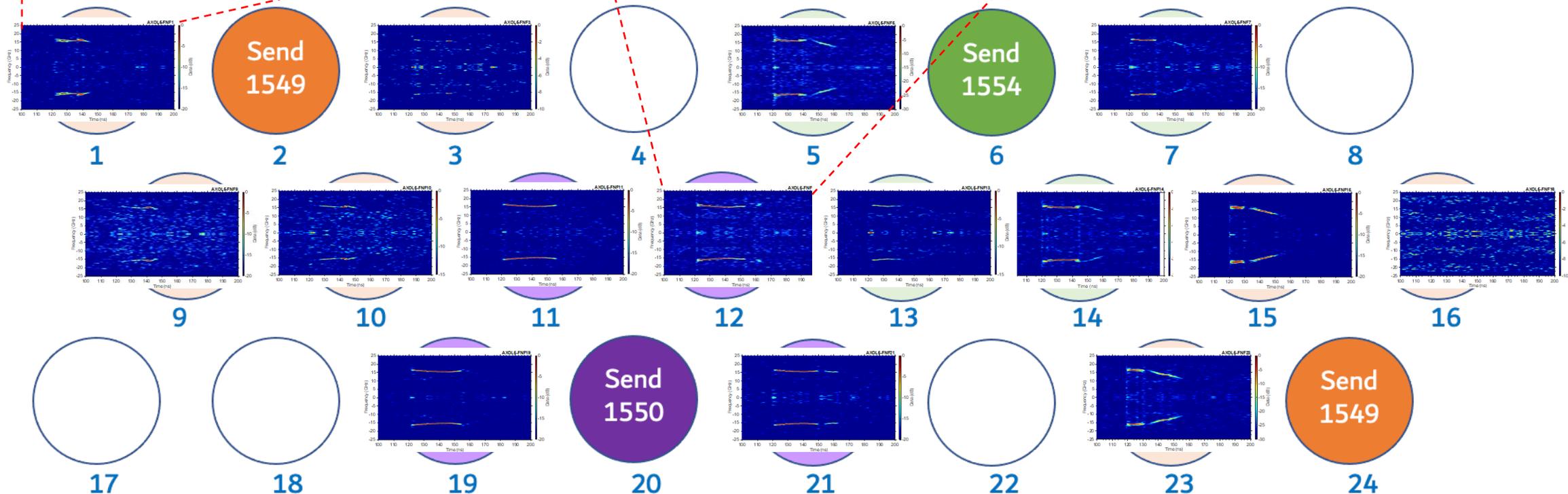
Quartz shock velocity	19.6 ± 0.2 km/s (20.3 km/s simulated)
Quartz pressure	507 GPa (550 GPa simulated)
Direct impact quartz pressure	146 GPa (@ 6.61 km/s)
Pressure gain	3.5X
Planar area	$0.75 \pm 0.4/0.05$ mm
Temporal hold	~ 30 ns (2 %)



RESULTS: ENDOR AMPLIFIER



Target	Endor
Projectile	Ta/Lexan
Impact velocity	6.56 km/s
Tilt	2.9 mrad (0.17°)



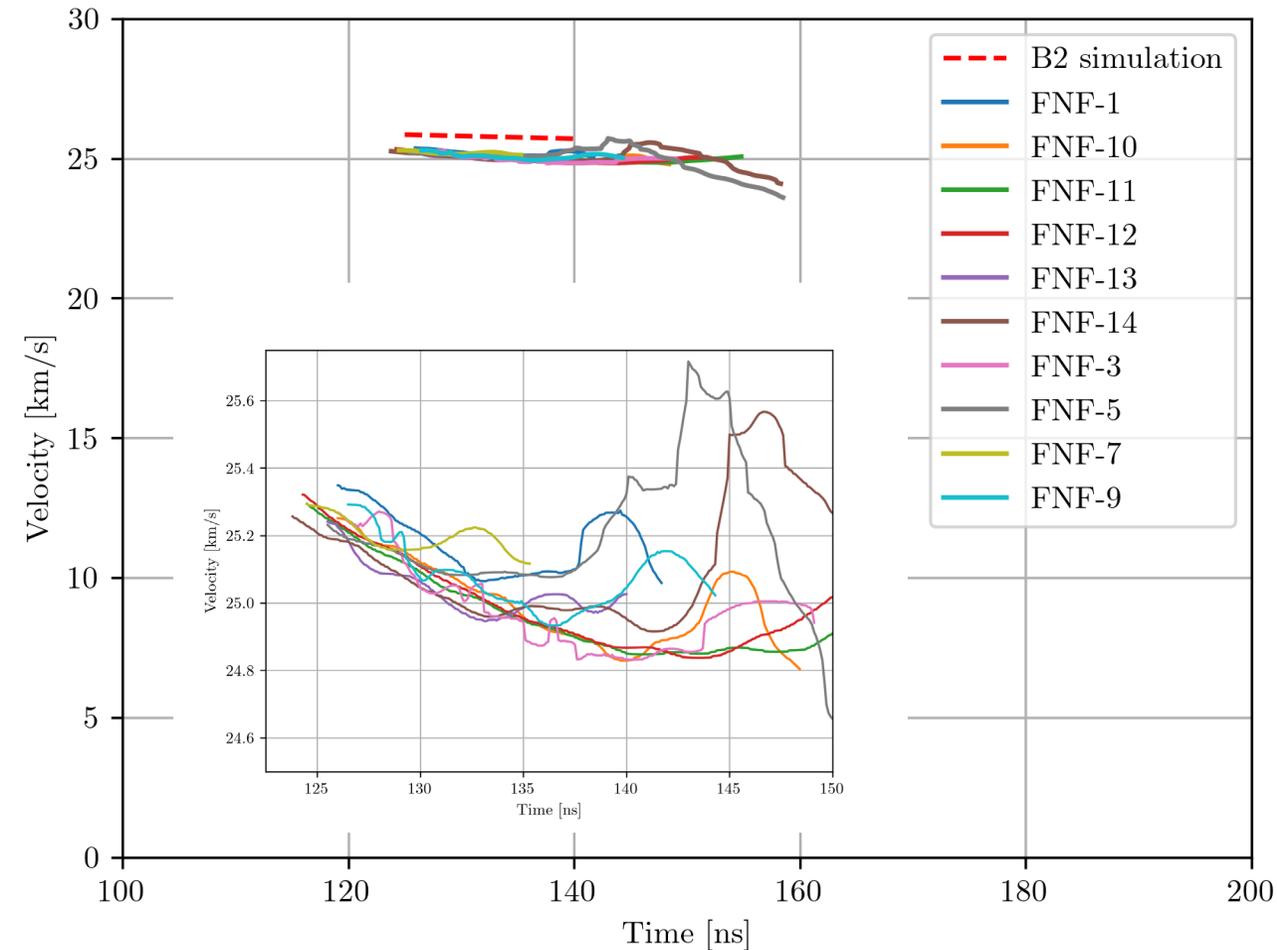
RESULTS: ENDOR AMPLIFIER



Measured performance

- 1.6% temporal uniformity within each measurement in 10 ns requirement
- 1.2% variation in spatial uniformity between probes

Quartz shock velocity	25.1 ± 0.2 km/s (25.7 km/s simulated)
Quartz pressure	1085 GPa (1040 GPa simulated)
Direct impact quartz pressure	142 GPa (@ 6.56 km/s)
Pressure gain	7.6X
Planar area	$0.75 \pm 0.4/0.05$ mm
Temporal hold	~ 20 ns (2%)

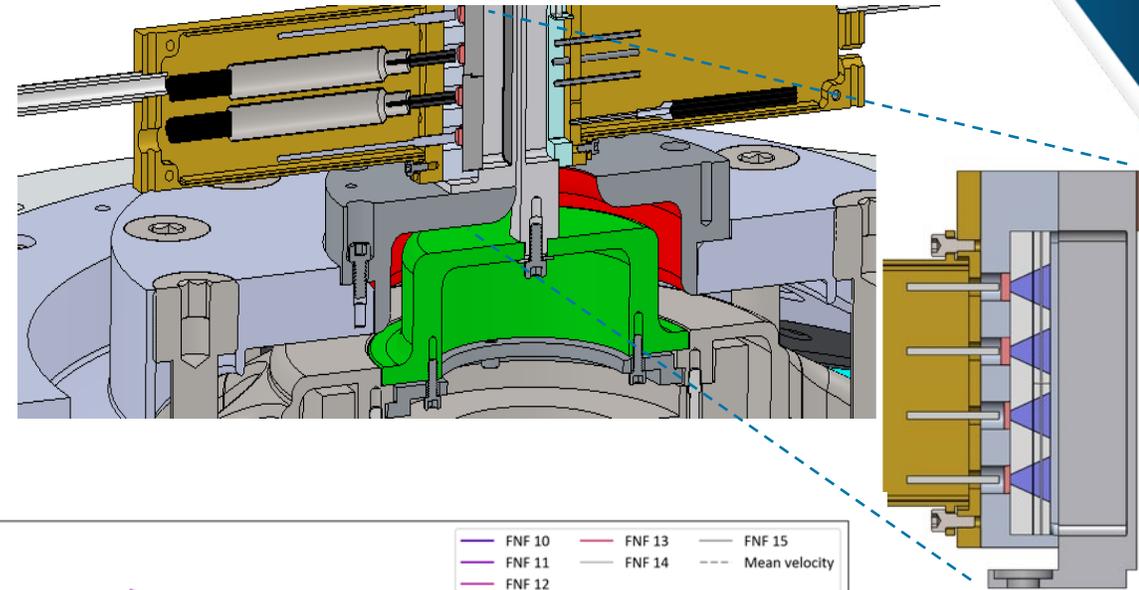


RECENT Z EXPERIMENT OF AMPLIFIER

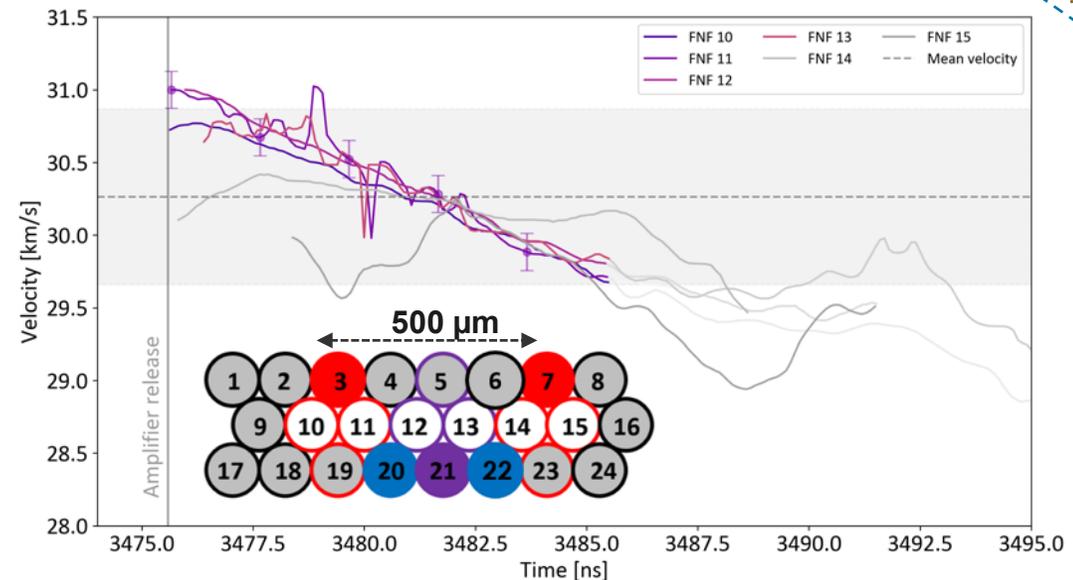


Z3956: Campaign overview

- Pre-existing Z configuration: Al 31 km/s
- 4 amplifiers along flyer length



Quartz shock velocity	30.26 ± 0.125 km/s
Quartz pressure	1.63 ± 0.02 TPa
Direct impact quartz pressure	0.970 TPa (@ 30.26 km/s)
Pressure gain	1.7X
Planar area	$0.375 \pm 0.13/0.05$ mm
Temporal hold	~ 10 ns (2 %)

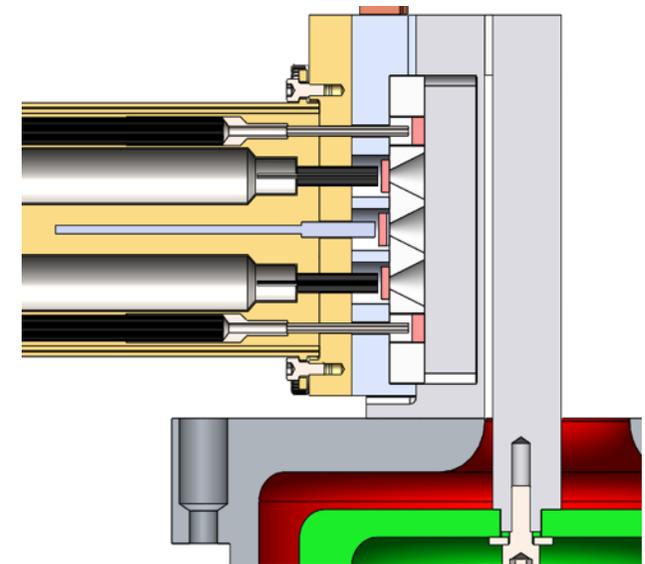
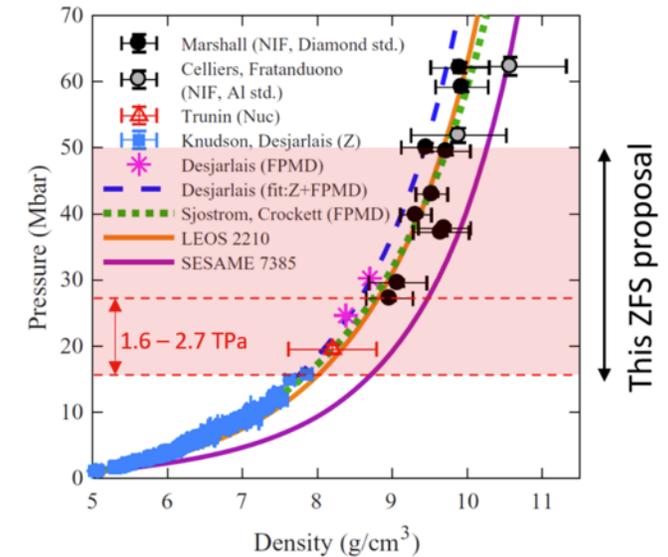
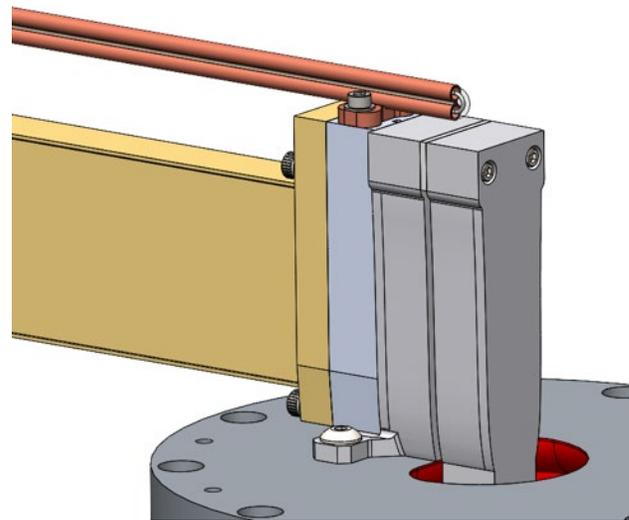


PATH FORWARD



Two Z shots awarded under ZFS program for 2025

- Targeting ~ 4 TPa in Quartz
- Modify asymmetric one-sided flyer: Al 45 km/s
- Increase drive voltage: > 85 kV
- Use low inductance feed
- Radiography of the AK gap to examine MRT growth
- B-dots to help constrain late time current behaviour



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Thank You



Questions ?