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High-speed velocimetry inside imploding cylindrical liners

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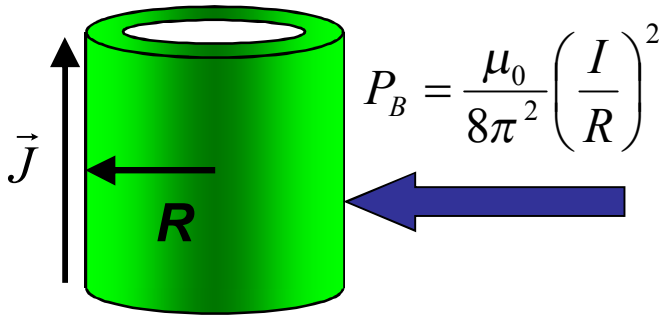
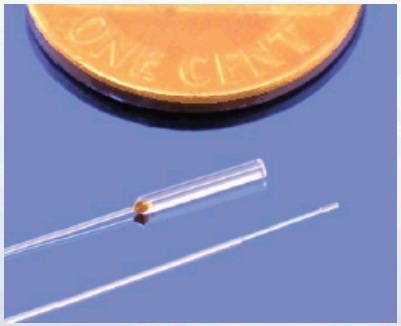
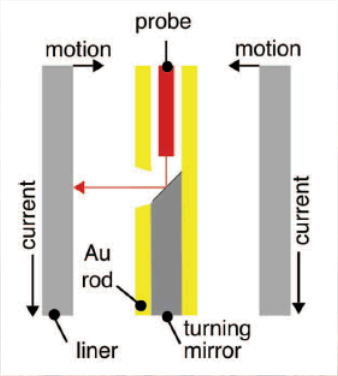
Cylindrical Implosion Reaches Extreme Pressures

- Much higher pressure than can be achieved in planar geometry
- Shockless compression through current pulse shaping
- Quasi-isentropic compression to peak stresses ≈20 Mbar



I=20 MA; R=0.1 cm;
P_B≈64 Mbar.



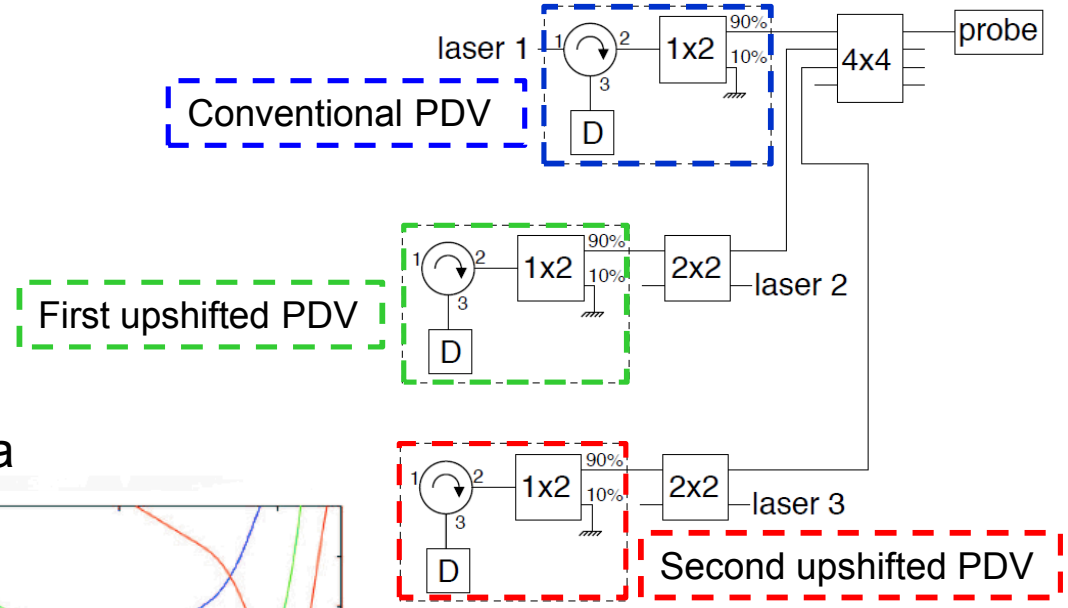


- Diagnosing the compressed state is the key challenge
- Very limited space constraints
  - Miniature PDV probes
- Velocities beyond 40 km/s
  - 52 GHz bandwidth required (real time)

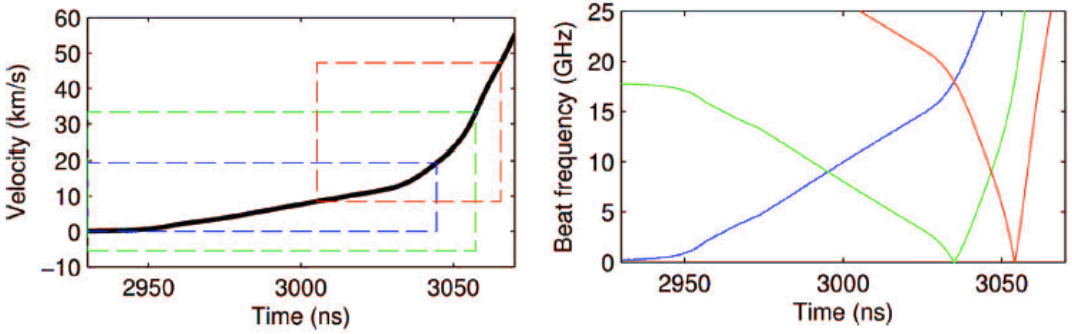
Leapfrog* PDV Technique

$$B = \left| \frac{c}{\lambda_1'} - \frac{c}{\lambda_2} \right| \approx \left| \frac{c}{\lambda_1} - \frac{c}{\lambda_2} + \frac{2u}{\lambda_1} \right|$$

B = beat frequency
u = reflector velocity
c = speed of light



Conceptual Data



- Three 25 GHz channels could measure up to 97 km/s
- Overlap eliminates null point ambiguities (48 km/s)

1GHz in beat frequency = 775 m/s

*D.H. Dolan, R.W. Lemke, R.D. McBride, M.R. Martin, E. Harding, D.G. Dalton, B.E. Blue, and S.S. Walker, Rev.Sci. Instrum. 84, 055102 (2013).

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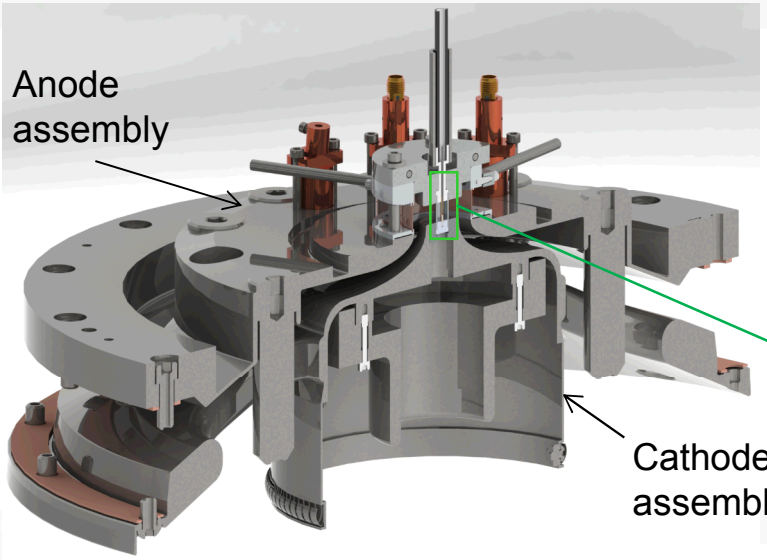
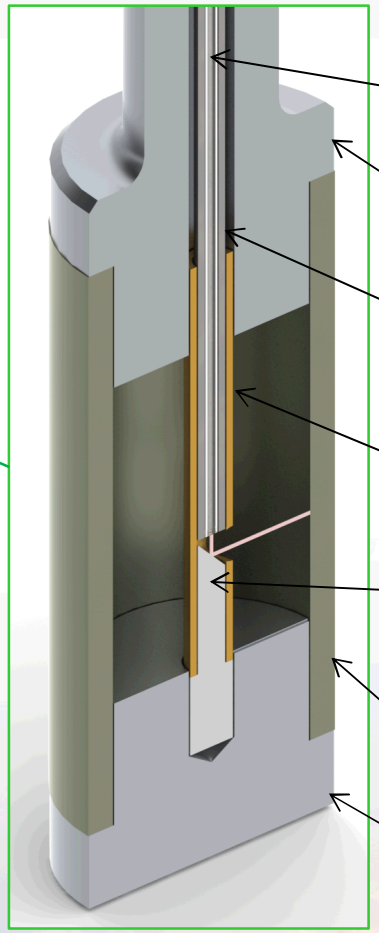
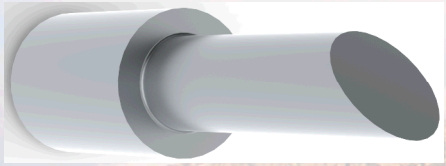
Initial Design Tracks a Single Location





- Radial Velocity Hardware
- 17.1-19.7 MA Load Current
- >45 km/sec Liner Velocity



Flat mirror design

Static pre-shot radiograph of target assembly

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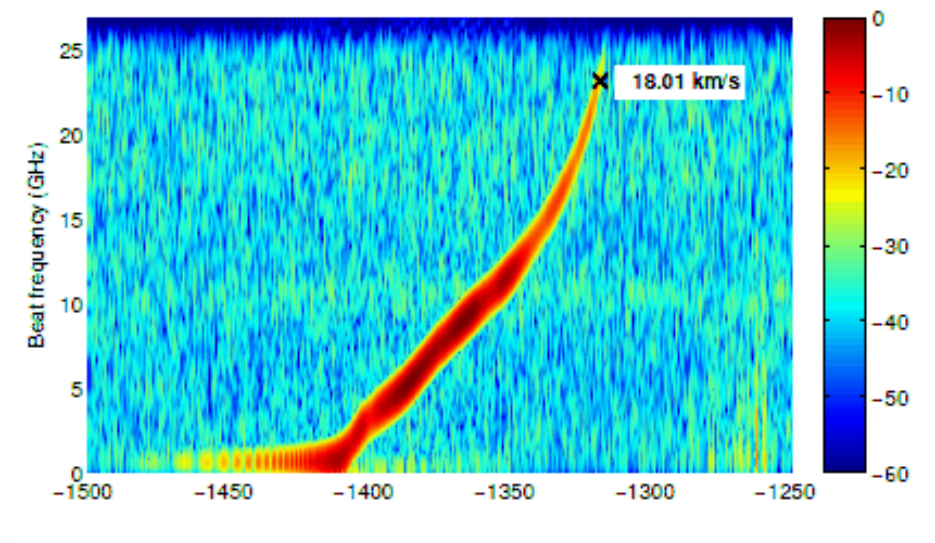
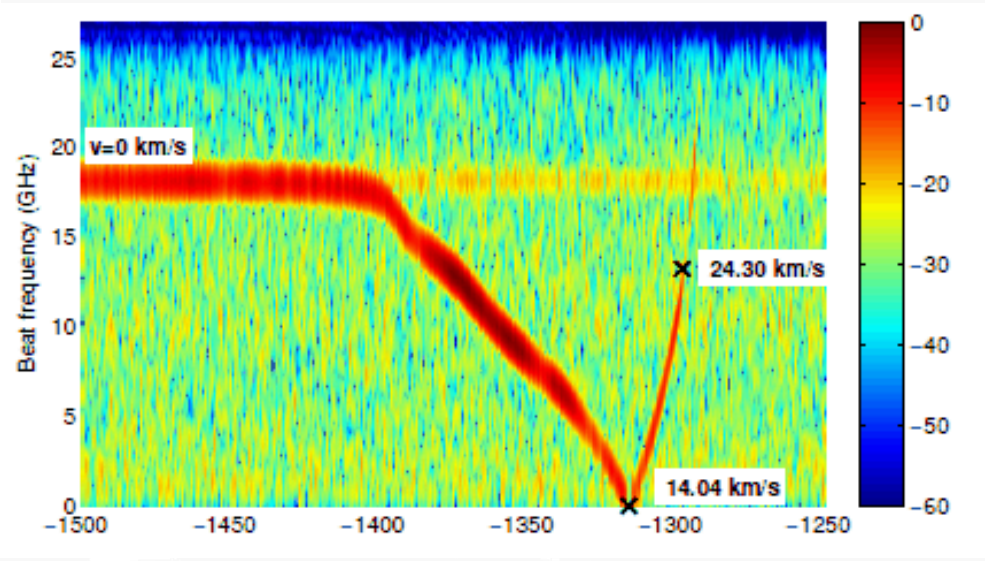
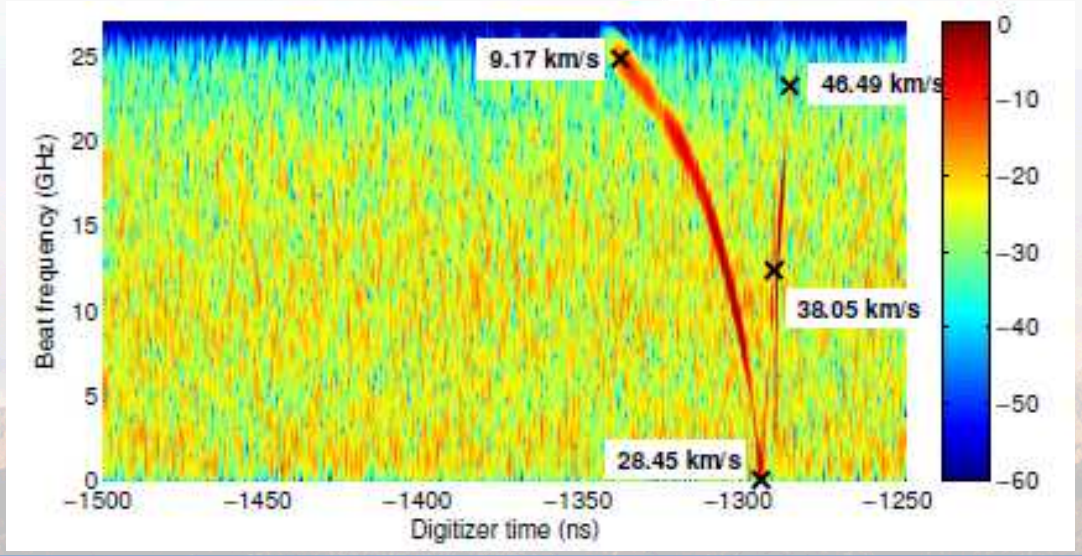
Single-point Results (Be)







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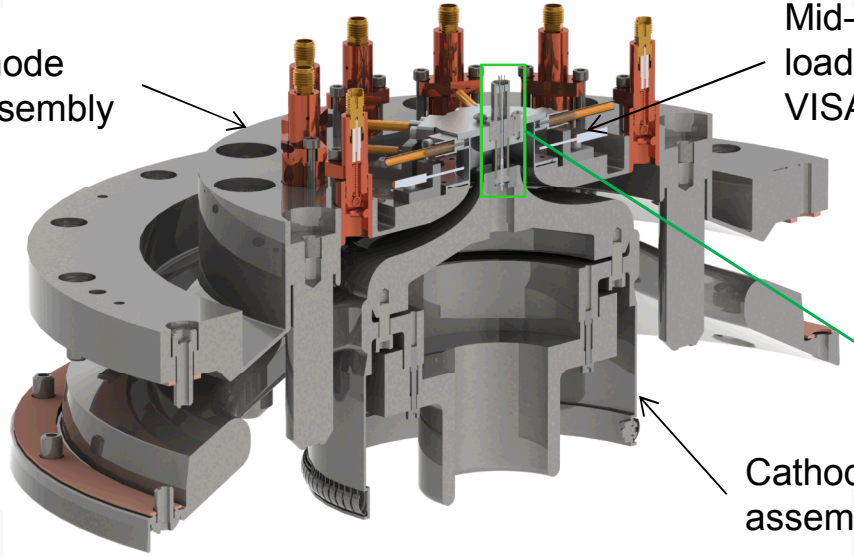
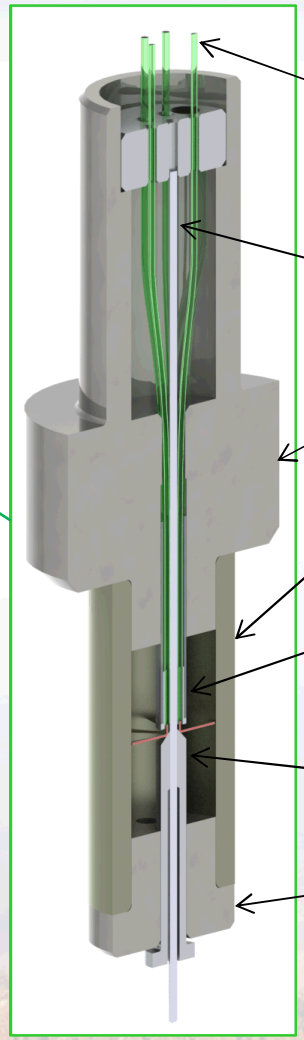
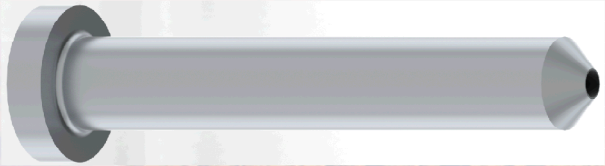
Multi-point Radial PDV Design to Evaluate Implosion Symmetry



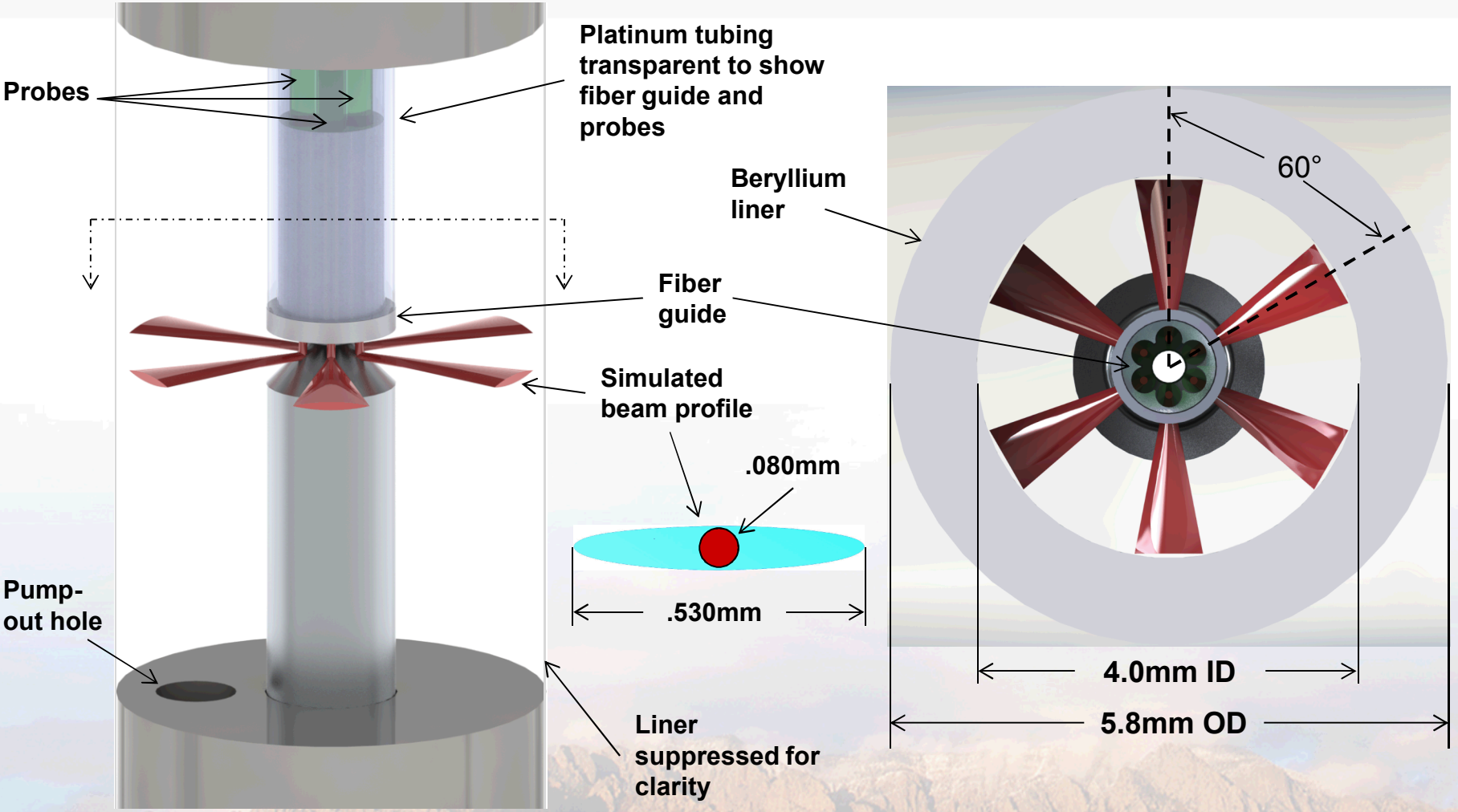


- Union IV Hardware
- ≈18.6 MA Load Current
- >42 km/sec Liner Velocity

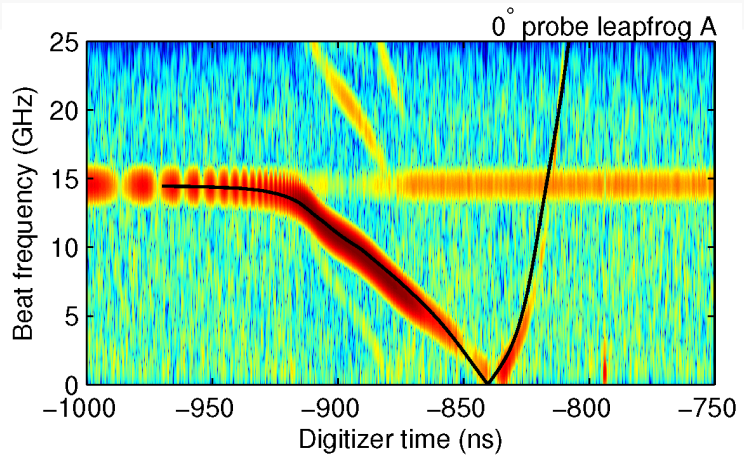


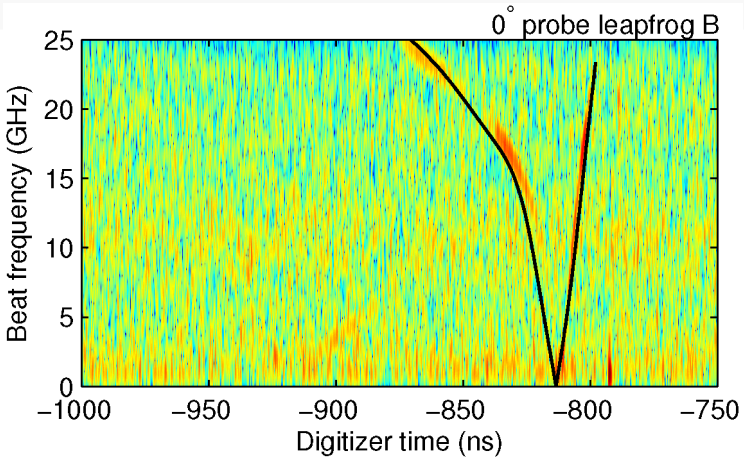
Conical mirror design

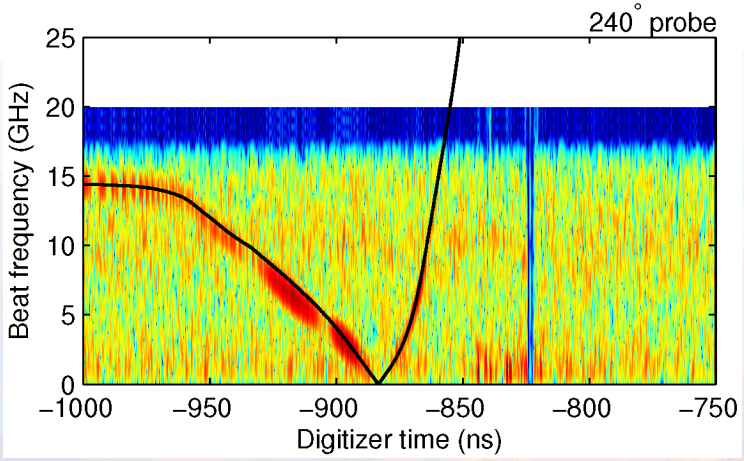
Multi-point Radial PDV Target Design Can Provide Six Simultaneous Velocity Profiles

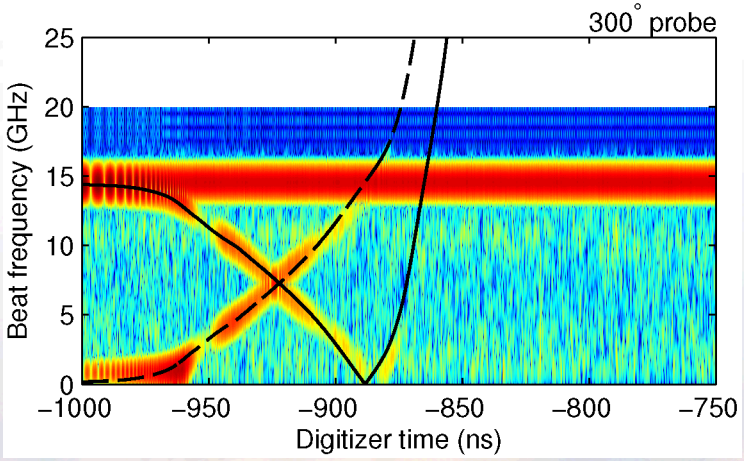


4 out of 6 Probe Locations Returned Data on Initial Six-point Attempt (Be)



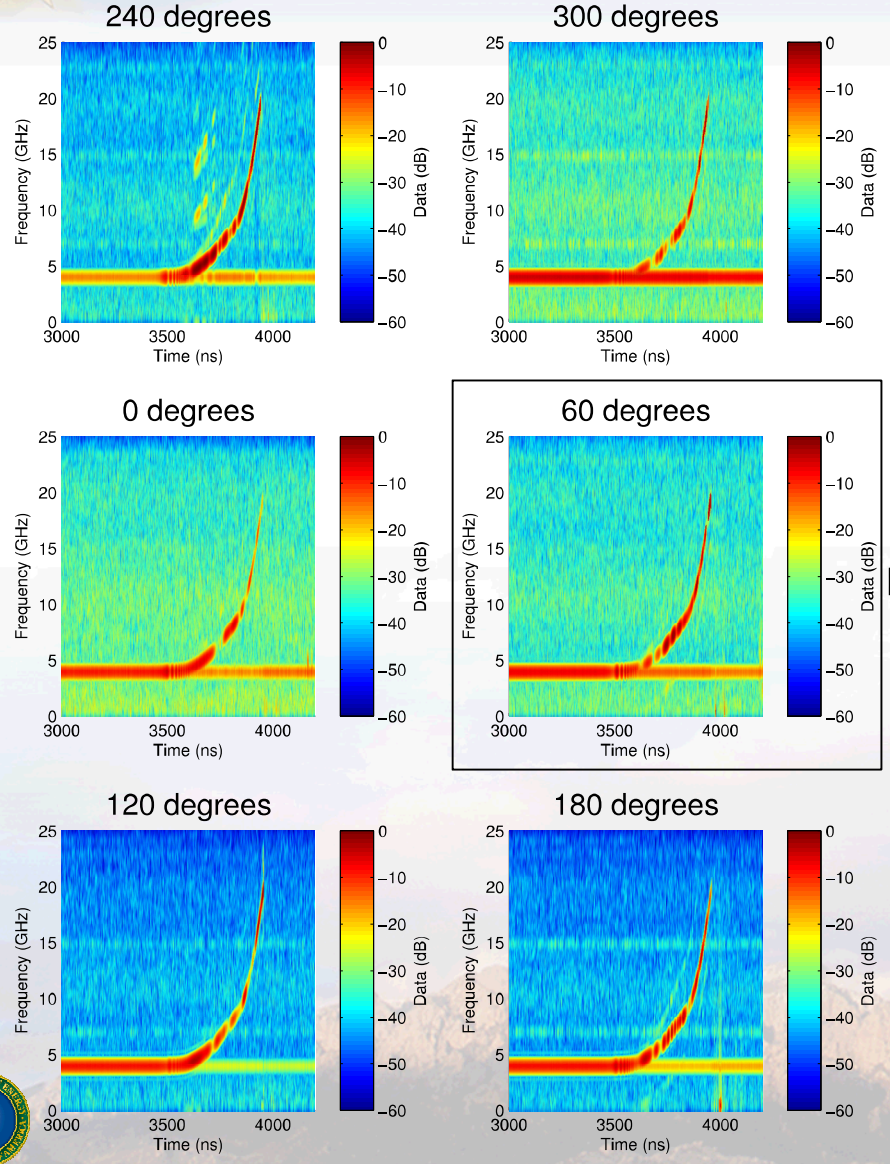


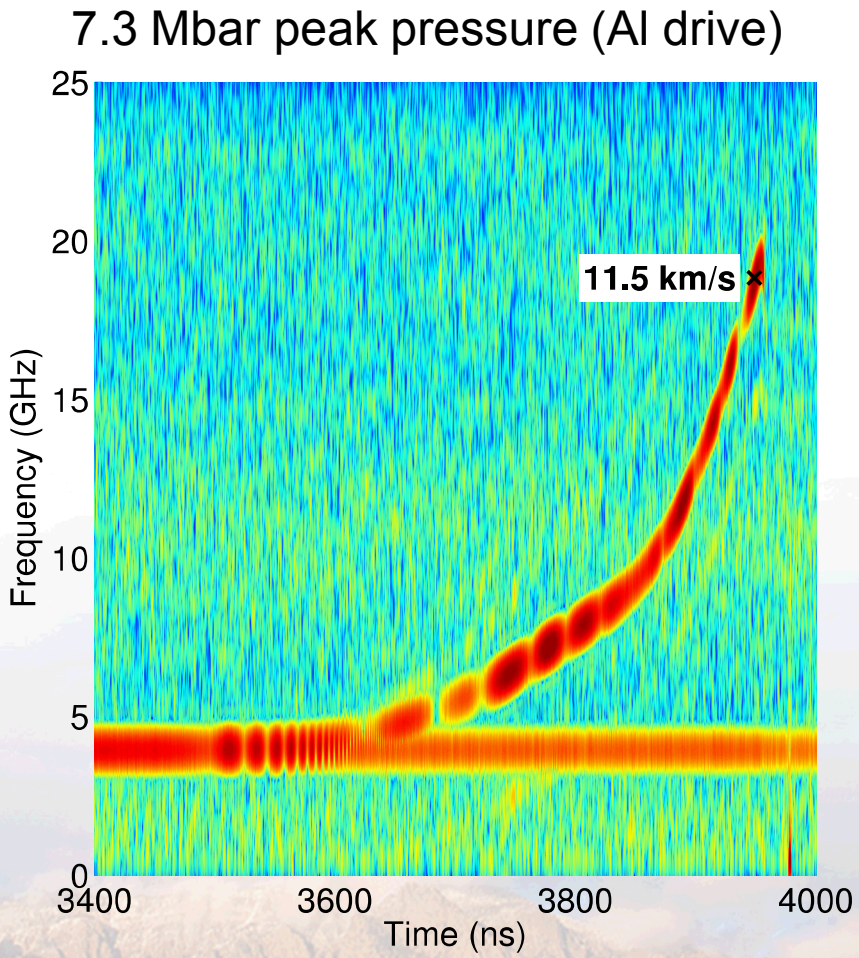




Simulated PDV velocity based on load current VISAR measurements in black

Symmetric results obtained with Ta liners





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Diagnostic developments

- **Measurement timing has been improved**
  - Cross probe timing better than 50 ps
  - Absolute machine time better than 200 ps
- **Smaller probe diameters (0.125 mm diameter)**
  - Six probes inside 0.625 mm housing
- **Liquid filled liners**
  - Track liquid shock and liner wall
  - Preliminary success in deuterium (immersed probe at 25 K!)
- **Time-domain multiplexing under development**
  - Leapfrog all probes

Special Thanks

- **Target Fabrication Group-** General Atomics
  - Robert Stamm
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  - Dustin Romero
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