PLX-α: Development of spherically imploding plasma liners as a novel fusion driver

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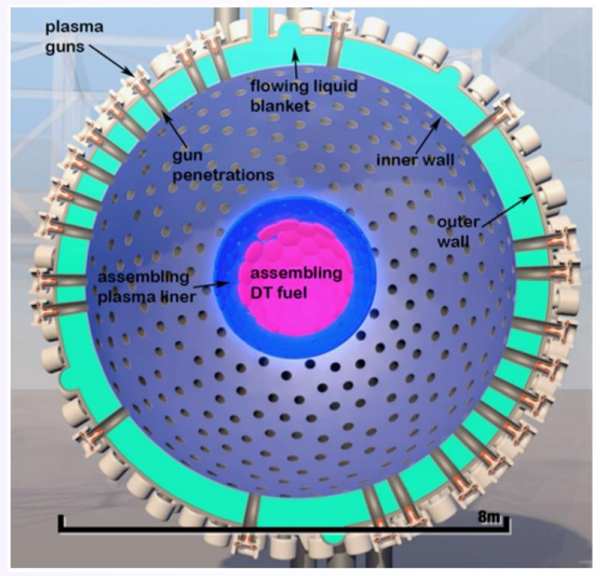
Concept Overview

- Supersonic imploding plasma liner for compressing magnetized plasma fuel to fusion conditions
- Advantages:
  - Low-cost, robust plasma guns avoid repetitive hardware destruction
  - High shot rate for rapid R&D
  - Fast implosion speed for overcoming thermal losses of the target
  - Compatible with liquid metal blankets for neutron management



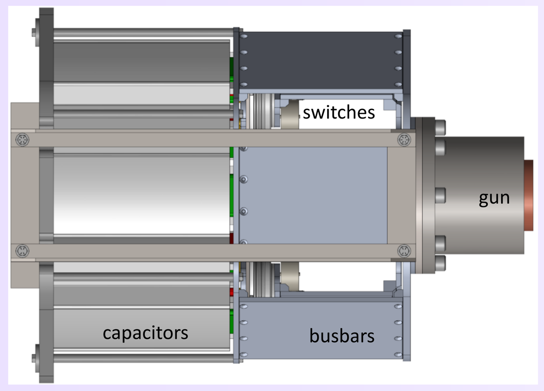
PLX-α Goals:

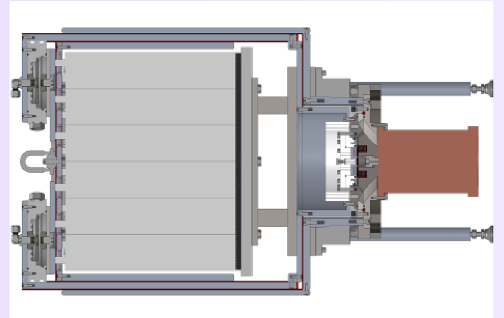
1. Develop robust plasma guns launching jets of ~1 mg, 50 km/s, ~2×10^{16} cm^{-3}.
2. Experimentally measure ion shock heating and liner uniformity of a sub-section of a liner.
3. Demonstrate spherical liner formation with up to 60 jets, and obtain empirical information on peak ram-pressure scaling.

Goals 1 and 2 have been accomplished. A facility upgrade is underway towards the accomplishment of goal 3 (with up to 36 guns).

Gun Engineering Upgrade

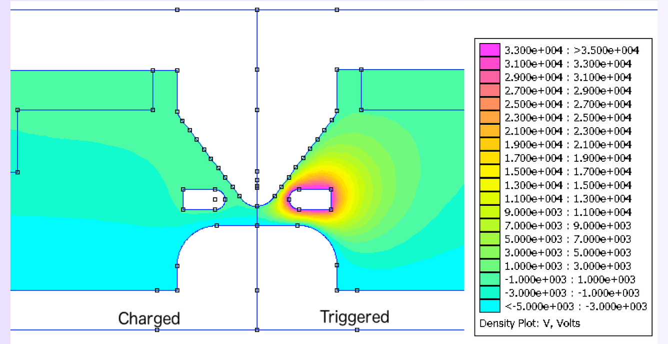
Novel high-density hypersonic plasma guns are a key enabling technology for PJMIF

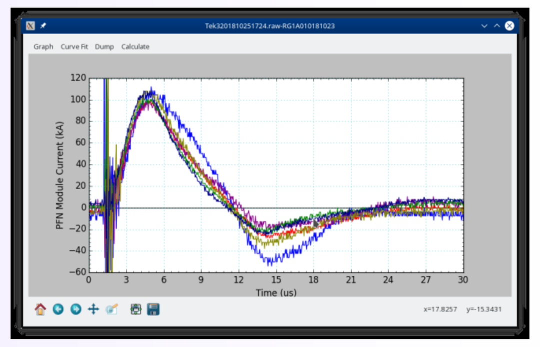




After completing 6- and 7-gun experiments with 2nd-generation coaxial guns ("Alpha2"), we have upgraded to a 3rd generation design ("HJ1") in order to achieve sufficient engineering robustness to facilitate spherical experiments with up to 36 guns. New guns have:

- Improved layout for better compactness, high voltage insulation
- New self-switching glow pre-ionization system for reduced experimental complexity
- Rotatable flange, easing chamber mounting
- Lower inductance current feed
- Improvements to spark gap switches and gas valve, switches life-tested to 1000+ shots at full current 150 kA

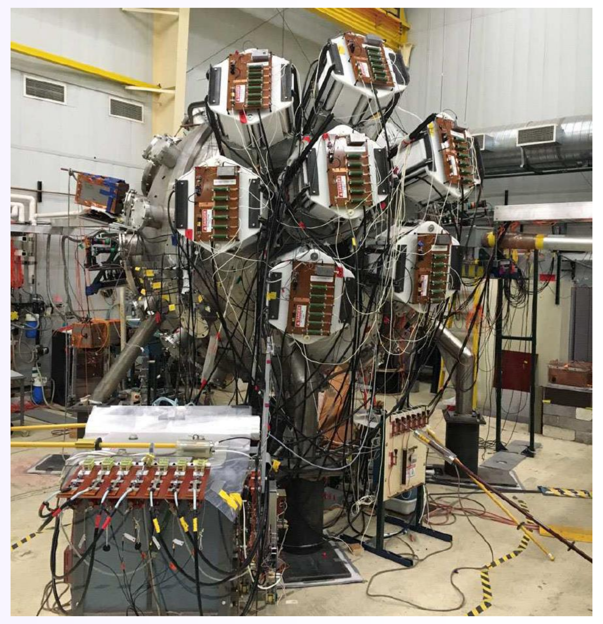


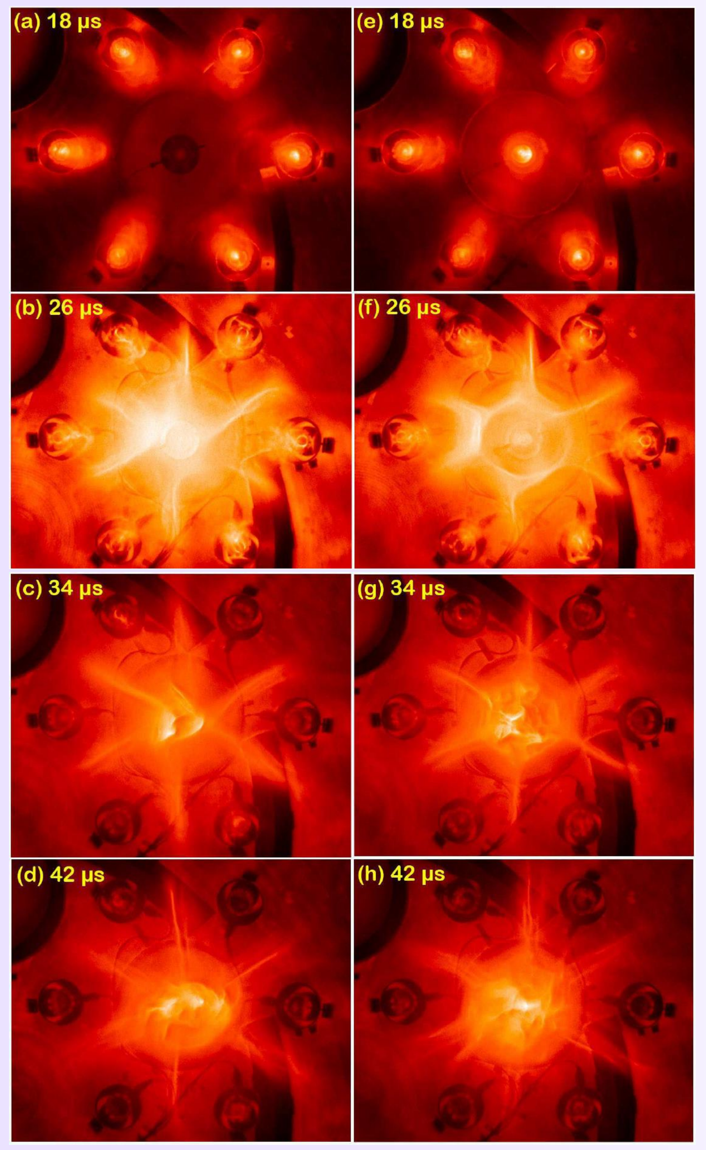


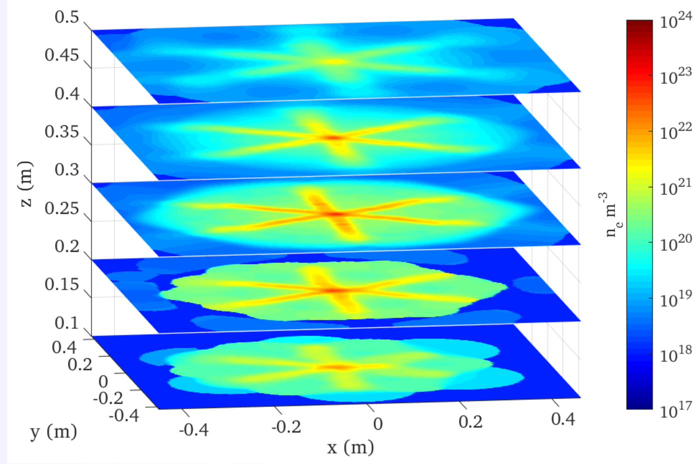
Liner subsection formation results

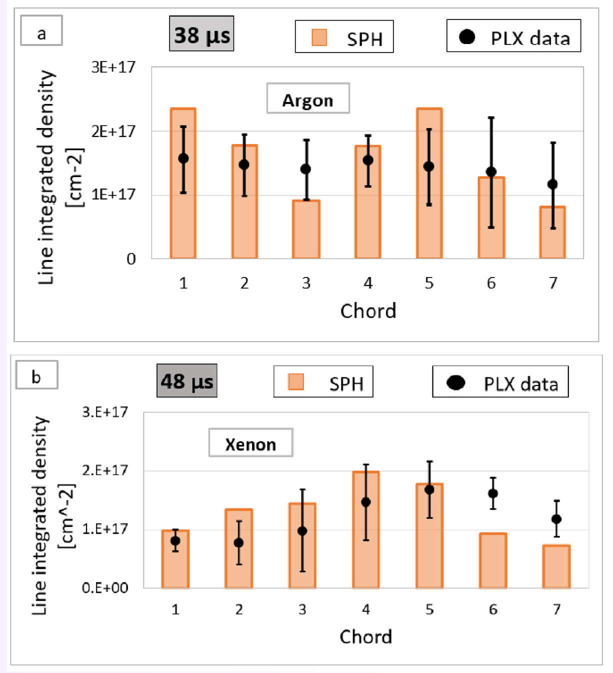
Experiments have been performed merging up to seven plasma jets, studying the formation of a subsection of a hypervelocity plasma liner.

- We have studied the ion heating occurring in formed plasma shock waves, and found largely classical heating and ion-electron equilibration in both collisional and interpenetrating regimes.
- Current studies resolve the merged structure of the liner, and compare line-integrated density measurements to synthetic diagnostics from smooth-particle-hydrodynamics modelling.

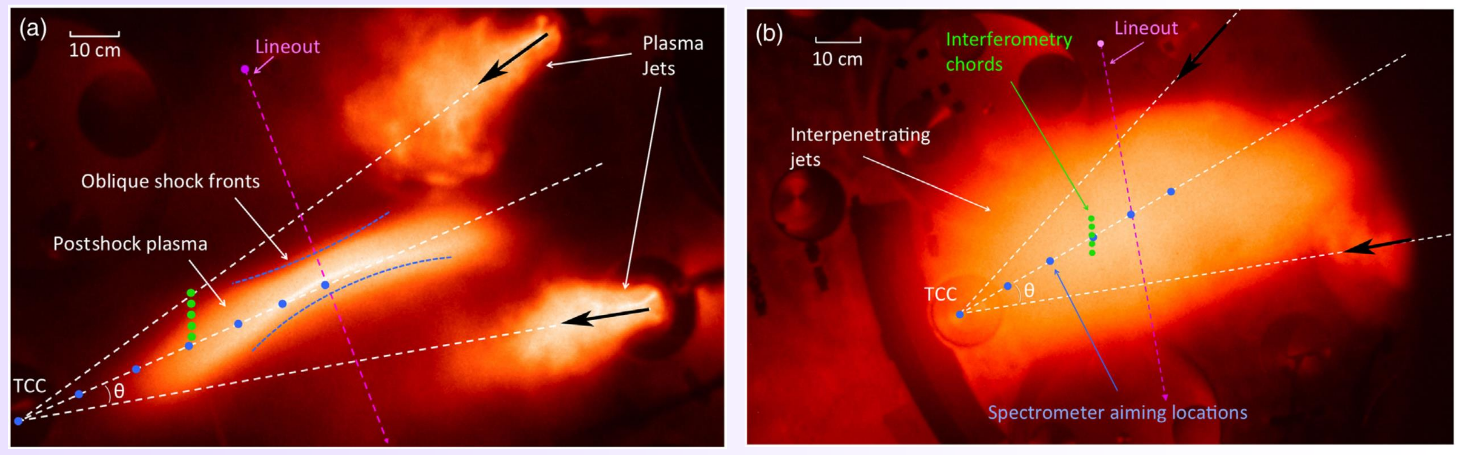








Results show broad agreement with hydrodynamic calculation, although a smoother and more diffuse structure is observed experimentally. At higher velocities, this disagreement intensifies, indicating the important role of kinetic interpenetration of the jets.

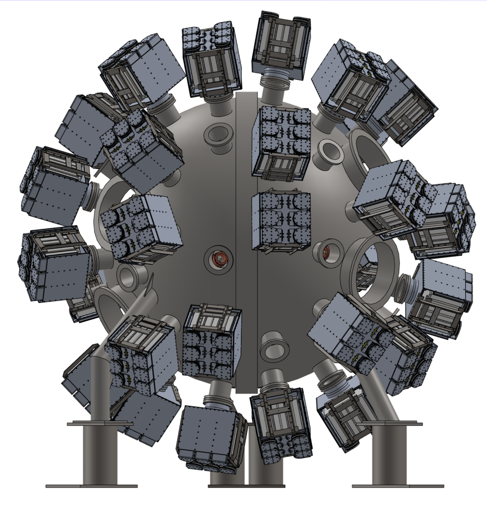


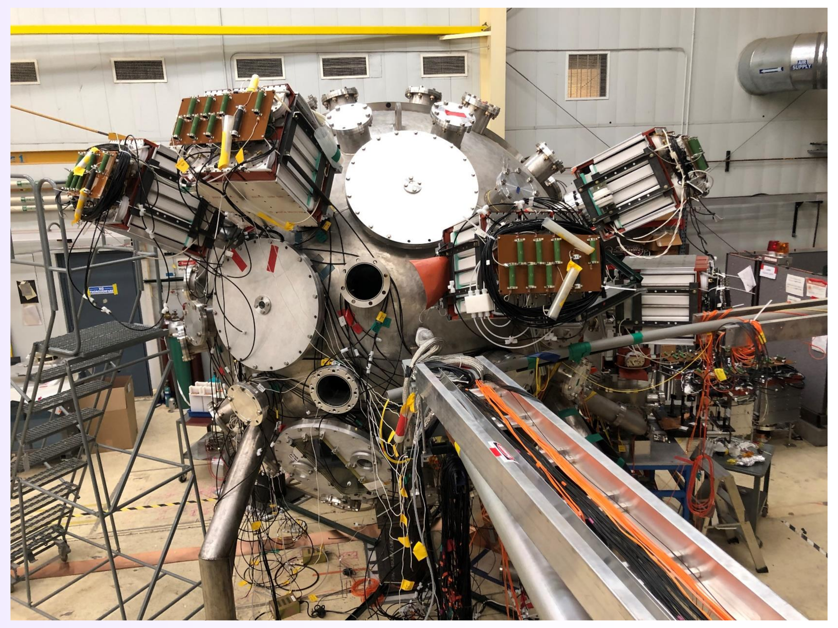
Based on the obtained understanding of the jet merging, we project that smooth liners can be formed at fusion-relevant scale by taking advantage of kinetic interpenetration occurring at higher jet velocities of 100+ km/s.

Case	Current data (a)	Current data(b)	Fusion relevant scale 20 MJ slow	Fusion relevant scale 20 MJ fast
Jet Speed (km/s)	39	39	50	150
Chamber Radius (m)	1.36	1.36	4	4
Number of Jets	(60)	(30)	600	600
Flight Time / i-e equilibration time	2.1	1.9	130	9.6
Jet spot size / interpenetration length	5.7	0.65	460	1.1

PLX Facility Upgrade to 4π

PLX facility configuration is being changed to support spherical experiments, with guns being moved to their locations for optimum uniformity of the merged liner.



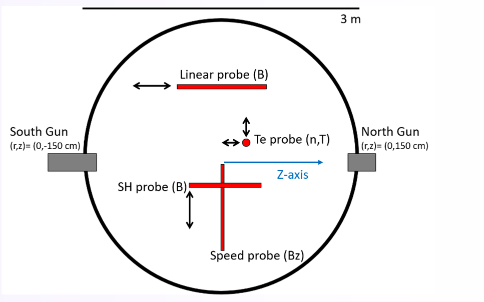


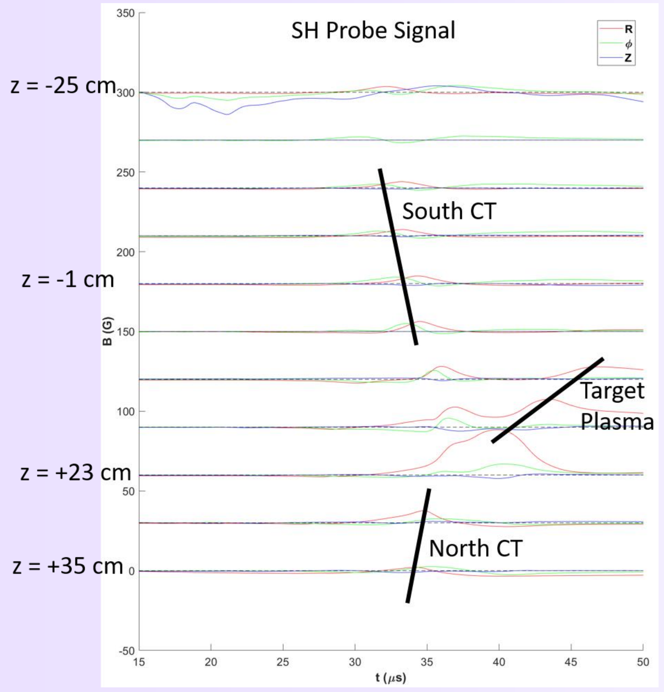
- 12 guns received at Los Alamos
  - 6 on the chamber in position
  - 6 being harnessed / prepared for lifting
- 6 more being shipped this week

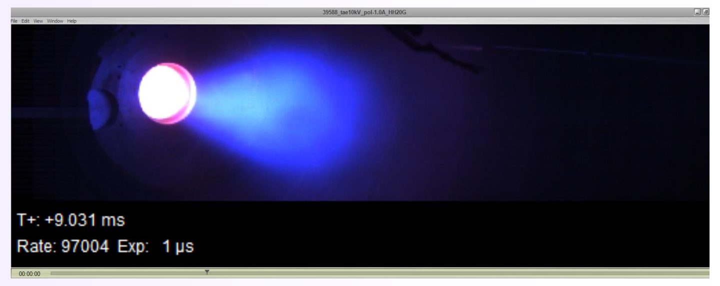
Will conduct experiments with the upper hemisphere of the chamber with 18 guns, en route to fully spherical experiments with 36 guns.

Towards target formation

Preliminary studies of target formation have been conducted, merging two spheromak-gun-formed magnetized jets head-on at the Wisconsin Plasma Physics Laboratory's Big Red Ball user facility.







shot number	n_e (*10^13 cm^-3)	T_e (eV)	B_tot max (G)
39524	1	8.5	27
39527	0.9	6.25	34
39528	1.35	7	31
39529	1.6	8.5	23
39554	1.55	9	33

shot number	beta	ωτ_i	lambda_gun [South,North] (m^-1)
39524	9.327846	1.338203	1167., 642
39527	3.892734	1.180556	384., 207
39528	7.866805	0.85056	2254., 1168.
39529	20.56711	0.712469	2322., 1223.
39554	10.24793	1.149677	1154., 554

Initial data suggests that a stagnated plasma target with greater than unity plasma-to-magnetic pressure ratio (Beta) and degree of magnetization ($\omega\tau_i$) was achieved, with efficient coupling of the jet energy to the stagnated target. Continuation of experiments is planned in September to gather more data in this novel regime.