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Title: Plasma Jet-Driven Magneto-Inertial Fusion (PJMIF)

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Web

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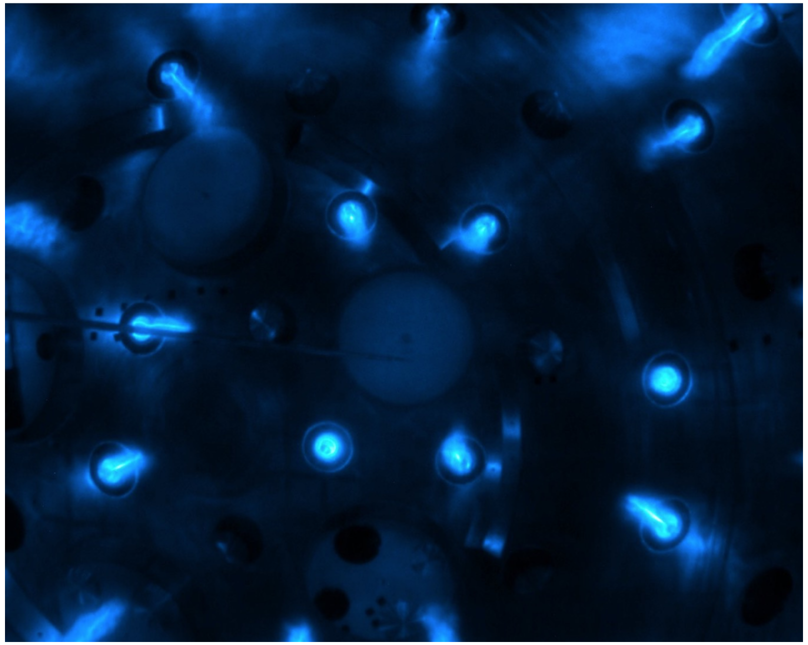
Los Alamos NATIONAL LABORATORY

CHANGING WHAT'S POSSIBLE

Plasma Jet-Driven Magneto-Inertial Fusion (PJMIF)

Fusion Review Meeting
April 26-27, 2022

Samuel Langendorf, Los Alamos National Laboratory
F. Douglas Witherspoon, HyperJet Fusion Corporation
Mark Gilmore, University of New Mexico
Jason Cassibry, University of Alabama in Huntsville



Team members and roles

- **LANL / University of New Mexico**
  - Sam Langendorf
  - Feng Chu
  - Andrew Lajoie
  - Lucas Webster
  - John Dunn
  - Mark Gilmore
- **HyperJet Fusion Corporation**
  - Doug Witherspoon
  - Edward Cruz
  - Andrew Case
  - Marco Luna
  - Chris Faranetta
- **University of Alabama Huntsville**
  - Jason Cassibry
  - Sumontro Sinha
  - Aalap Vyas

Special thanks to:

ARPA-E BETHE Capability Teams:

- **University of Rochester / LLE**
  - Petros Tzeferacos
  - Eddie Hansen
  - David Michta
  - Chuang Ren
  - Han Wen
  - Adam Sefkow
- **Virginia Tech / PPPL**
  - Bhuvana Srinivasan
  - Petr Cagas
  - Ammar Hakim
- **Saipentai LLC**
  - Craig Michoski
  - Todd Oliver
  - Steph Louis
  - Dongyang Kuang
  - Siwei Luo
- **LLNL / UCSD**
  - Clement Goyon
  - Simon Bott
  - Jacob Banisek

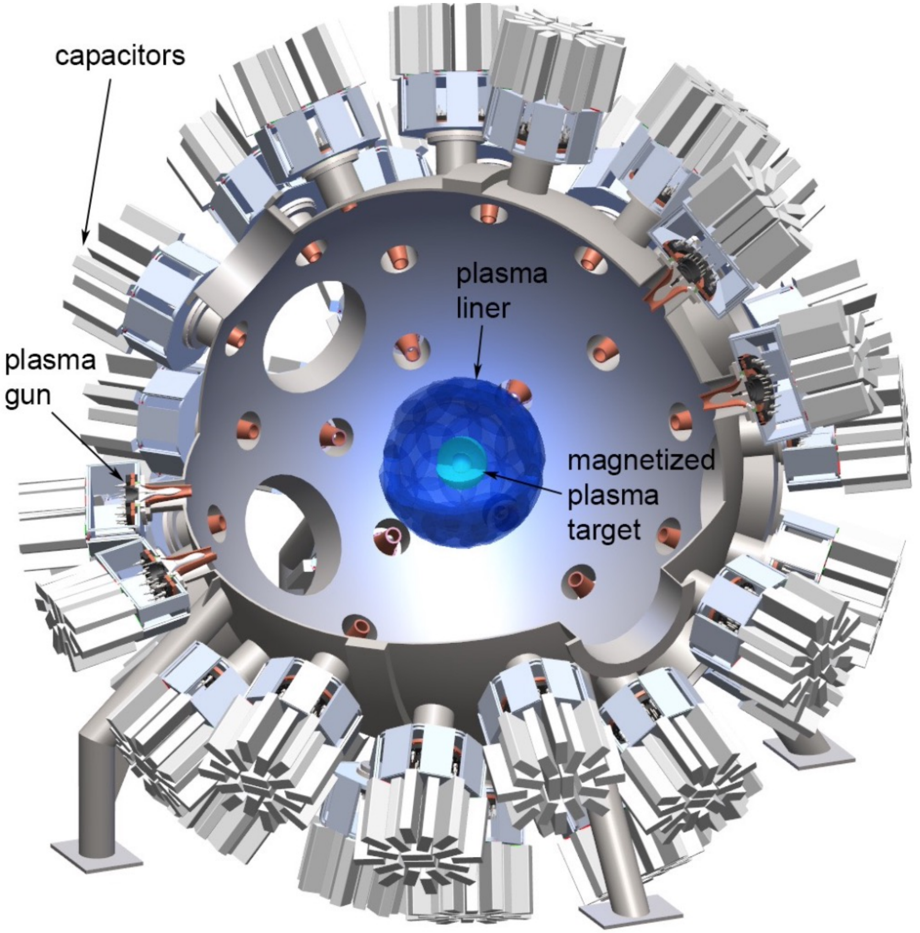
And many other community members

Plasma Jet-Driven Magneto-Inertial Fusion (PJMIF) is a "reactor-friendly" alternative approach to fusion energy

- Magneto-inertial fusion (MIF) or magnetized target fusion (MTF) – blend of magnetic and inertial confinement concepts.

- A magnetized plasma target is injected into the target chamber, and then compressed and heated by a heavy high-velocity plasma liner, assembled from discrete jets.

  – Spherical compression
  – All-gas / all-plasma architecture -- no repetitive hardware destruction
  – Physical "standoff" distance from burn location



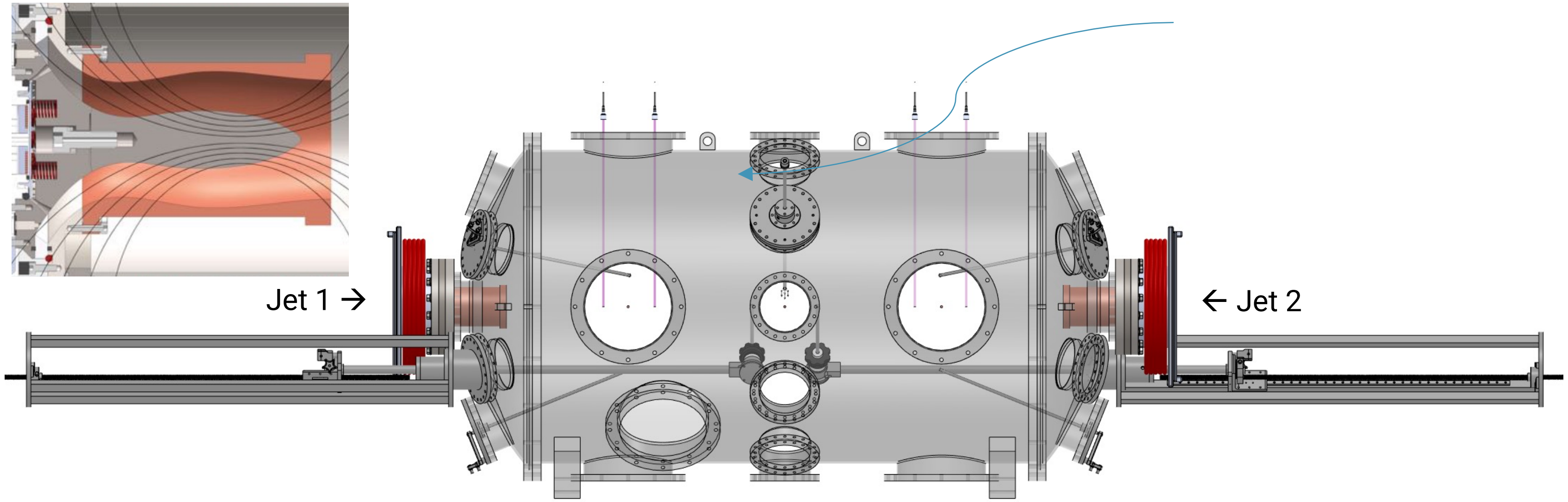
Thio, YC Francis, et al. "Plasma-jet-driven magneto-inertial fusion." *Fusion Science and Technology* 75.7 (2019): 581-598.
Hsu, Scott C., et al. "Spherically imploding plasma liners as a standoff driver for magnetoinertial fusion." *IEEE Trans. Plasm. Sci.* 40.5 (2012): 1287-1298.

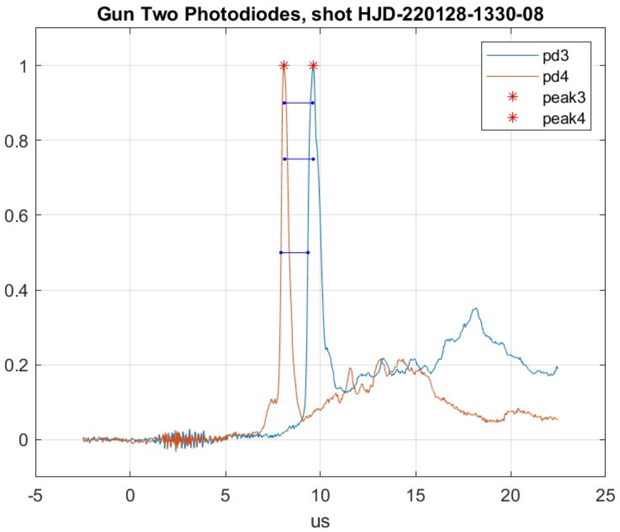
BETHE Program Milestones and Objectives

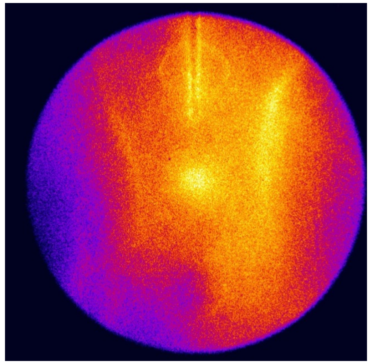
- Target Plasma Development
  - Develop and demonstrate a CT Injector capable of producing accelerated magnetized plasmas meeting the desired criteria: **>10 eV, >20 μg, >100 km/s**
  - Study Target CT Merging (Two Jets) Verify achieved parameters are in desired range of dimensionless plasma parameters **(β > 1, $\omega\tau$ > 1).**
- Plasma Liner Optimization
  - Scan parameters of PLX liner implosions with 36 jets, guided by previous parameter studies to maximize **liner uniformity** and achieved **ram pressure**
- Integrated Experiments
  - **Demonstrate compression and heating** of MIF target plasmas using a plasma liner to >100 eV electron temperature at subscale

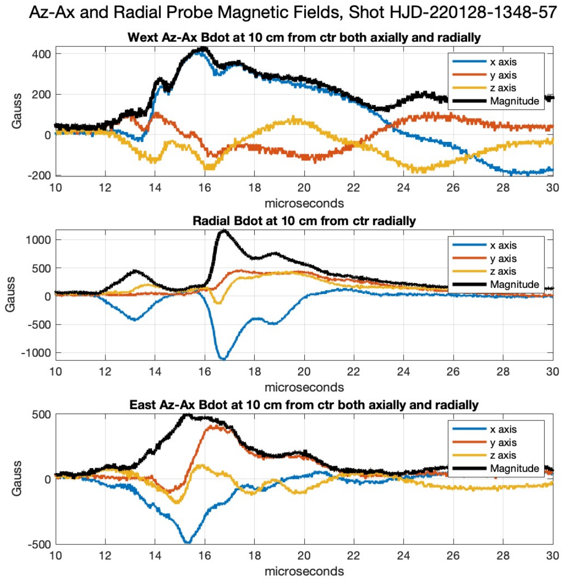
HyperJet has developed a target plasma injector meeting targets of density, velocity, and magnetic field

- Spheromak-gun style formation – coaxial electrodes with external linking magnetic flux
- Achieved velocities of **100 km/s**, embedded magnetic fields of **~1000 Gauss**
- Collision experiments underway, studying stagnation temperature scaling
- Design in progress to decrease insulator impurity fraction









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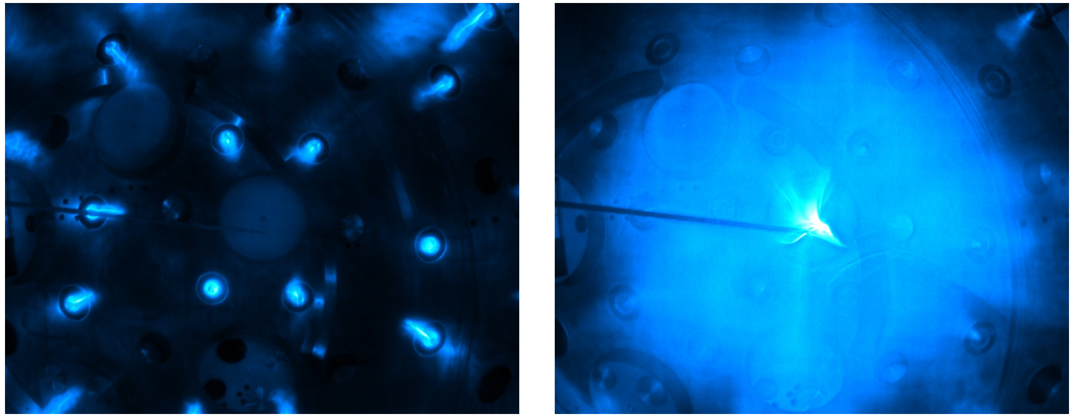
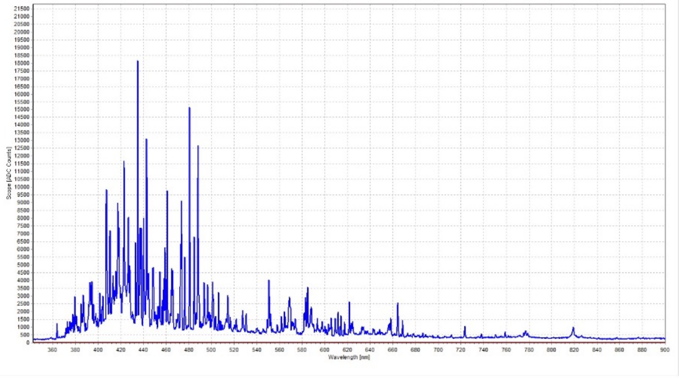
Plasma Liner experiments and comparisons to hydrodynamic modeling are underway at PLX

- Plasma liner shots are repetitively conducted with 36 jets
  - Stored energy ~7 kJ / gun,
  - Total facility stored energy ~0.25 MJ
- Campaign with **argon jets, 55 km/s**
- Experimental observables can be compared with models to benchmark PJMIF liner performance:

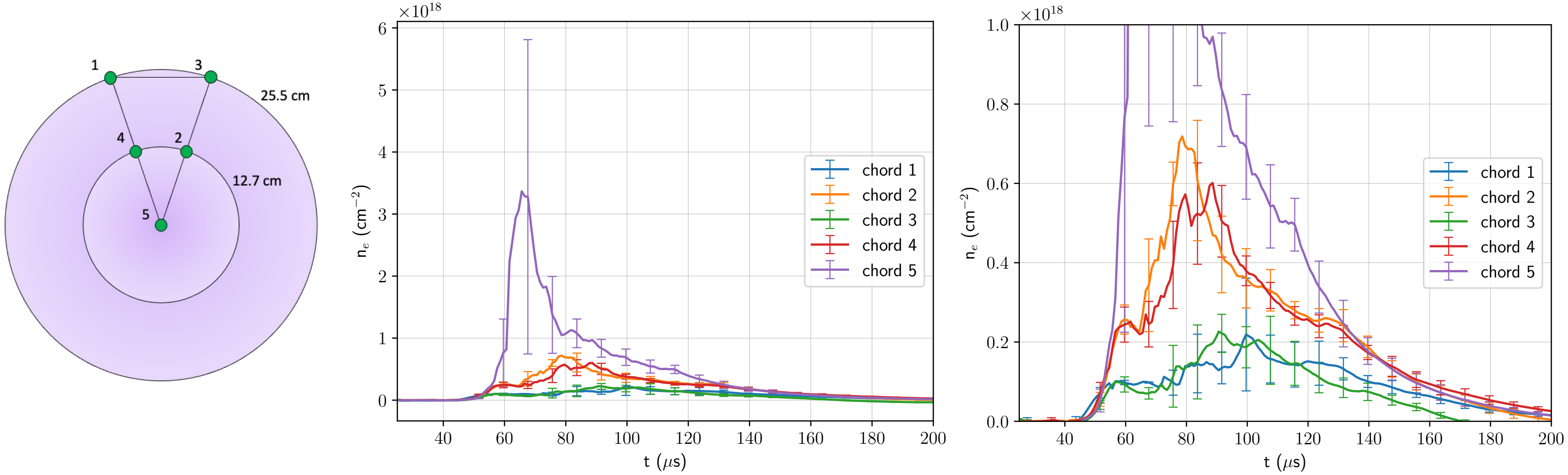
Fast framing camera imaging → global liner structure



Emission spectroscopy: liner electron temperature / Z

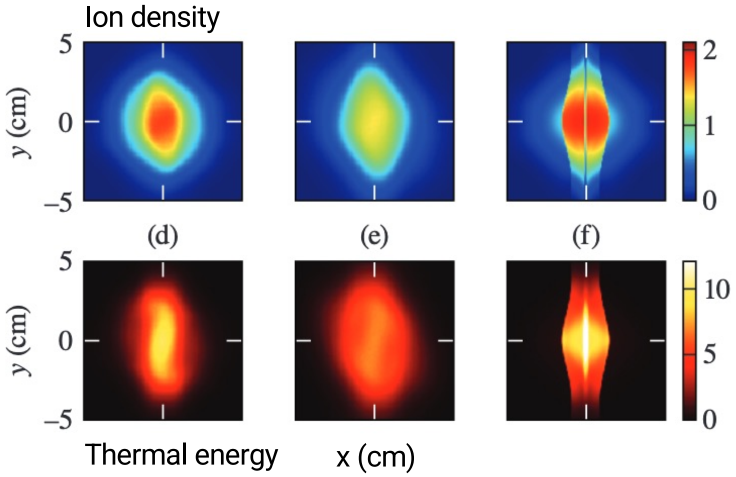


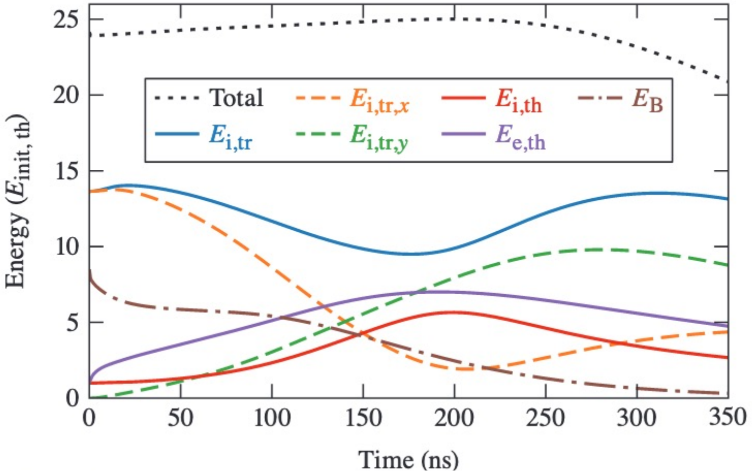
Laser interferometry: Time-resolved line-integrated density profile → radial convergence, ram pressure, symmetry



Collaboration with ARPA-E BETHE Capability Teams has greatly benefitted the study of PJMIF

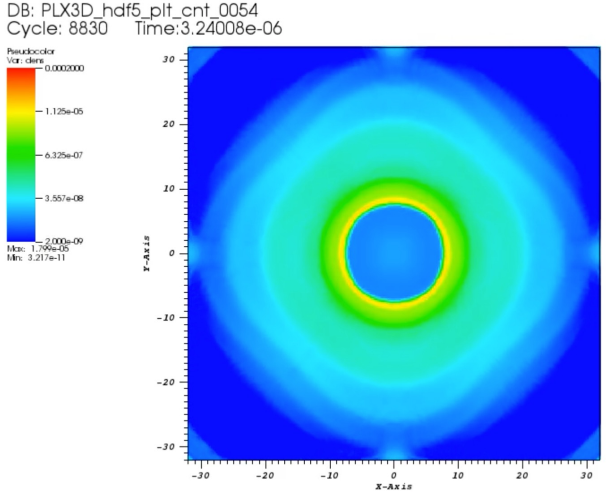
- 2D FLASH hydro and OSIRIS particle-in-cell simulations of target formation experiments at HyperJet, predicted B-field mediated stopping interaction:

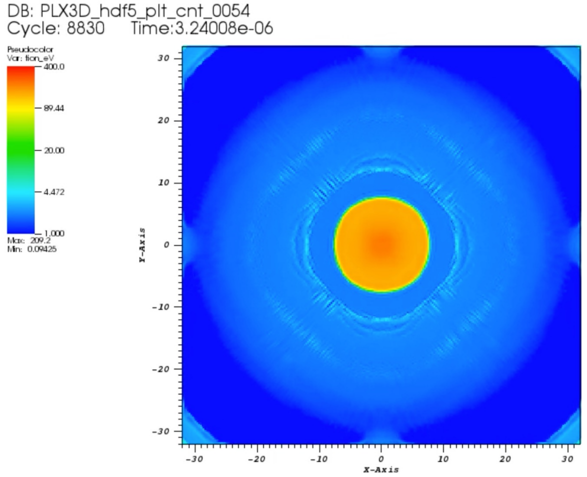




c/o Han Wen et. al.,
LLE / URochester team

- First fully 3D MHD simulations of PJMIF:





c/o Eddie Hansen et. al.,
LLE / URochester team

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PJMIF aspires to provide a pathway that solves the "kopek problem" of pulsed fusion approaches

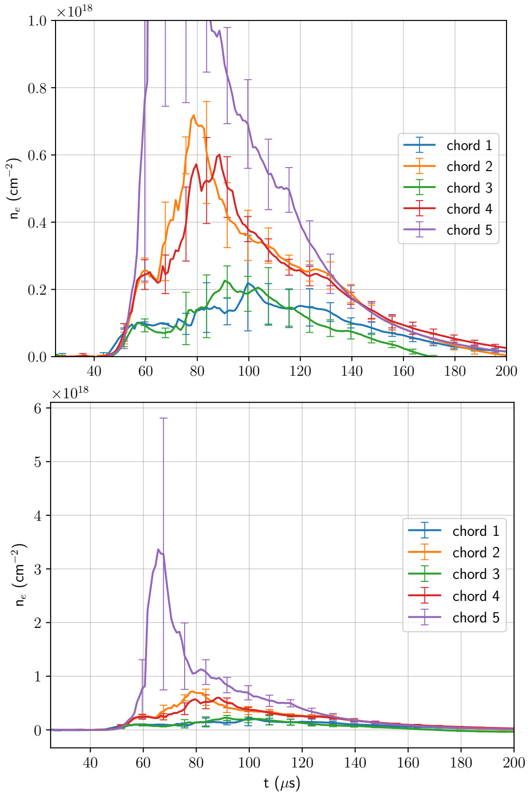
- For pulsed fusion approaches, **cost of target fabrication** is a significant challenge for application to power generation:
  - Current precision-machined ICF targets are ~7-8 orders of magnitude more expensive than the energy they would generate, a formidable gap
  - PJMIF avoids this issue by having no solid target
- PJMIF explores **spherical MIF** configurations, which may enable lower-capital-cost plants
- Follow-on plans:
  - Informed by results of current experiments, study scaling towards breakeven / reactor designs
  - Develop component-scale hardware needed for breakeven designs, e.g., high-energy high-efficiency liner plasma gun
  - Develop reactor-scale fuel target gun & evaluate alternative approaches
  - Seek public/private investment funds to support above

Backup

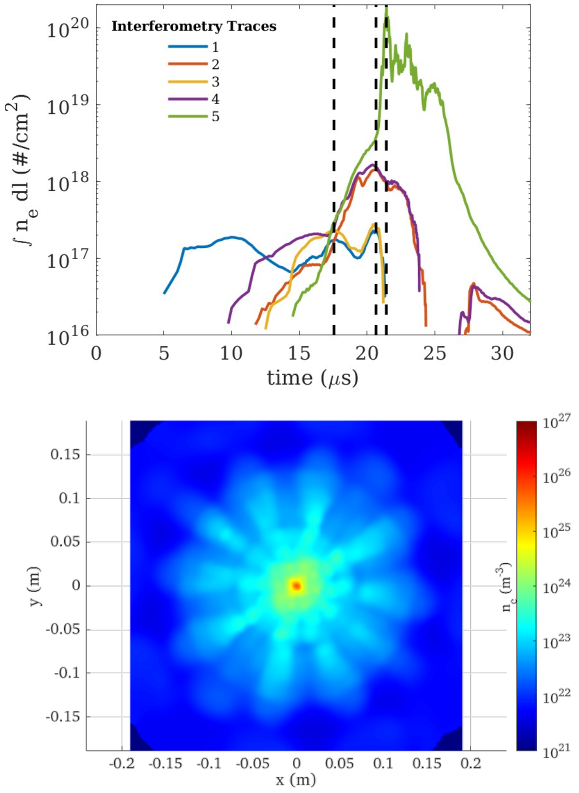
Comparisons of spherical liners campaigns to simulation captures effect of jet-to-jet velocity imbalance and structure

SPH simulations c/o Jason Cassibry / Aalap Vyas, Univ. Alabama Huntsville:

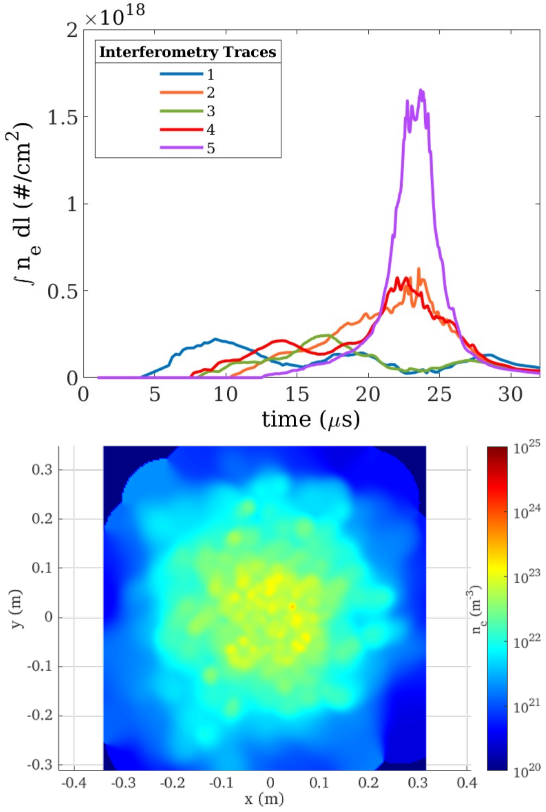
Experimental data:



SPH simulation:
Jets perfectly balanced



SPH simulation:
Jets imbalanced
(+/- 5% velocity / angle)



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