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UNIVERSITY OF MICHIGAN

Photoionization Fronts on the Z-Machine

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Center for Laboratory Astrophysics, University of Michigan

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Collaborators

Sandia National Laboratory

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Photoionization (PI) Fronts Overview

PI Fronts on Z-Machine

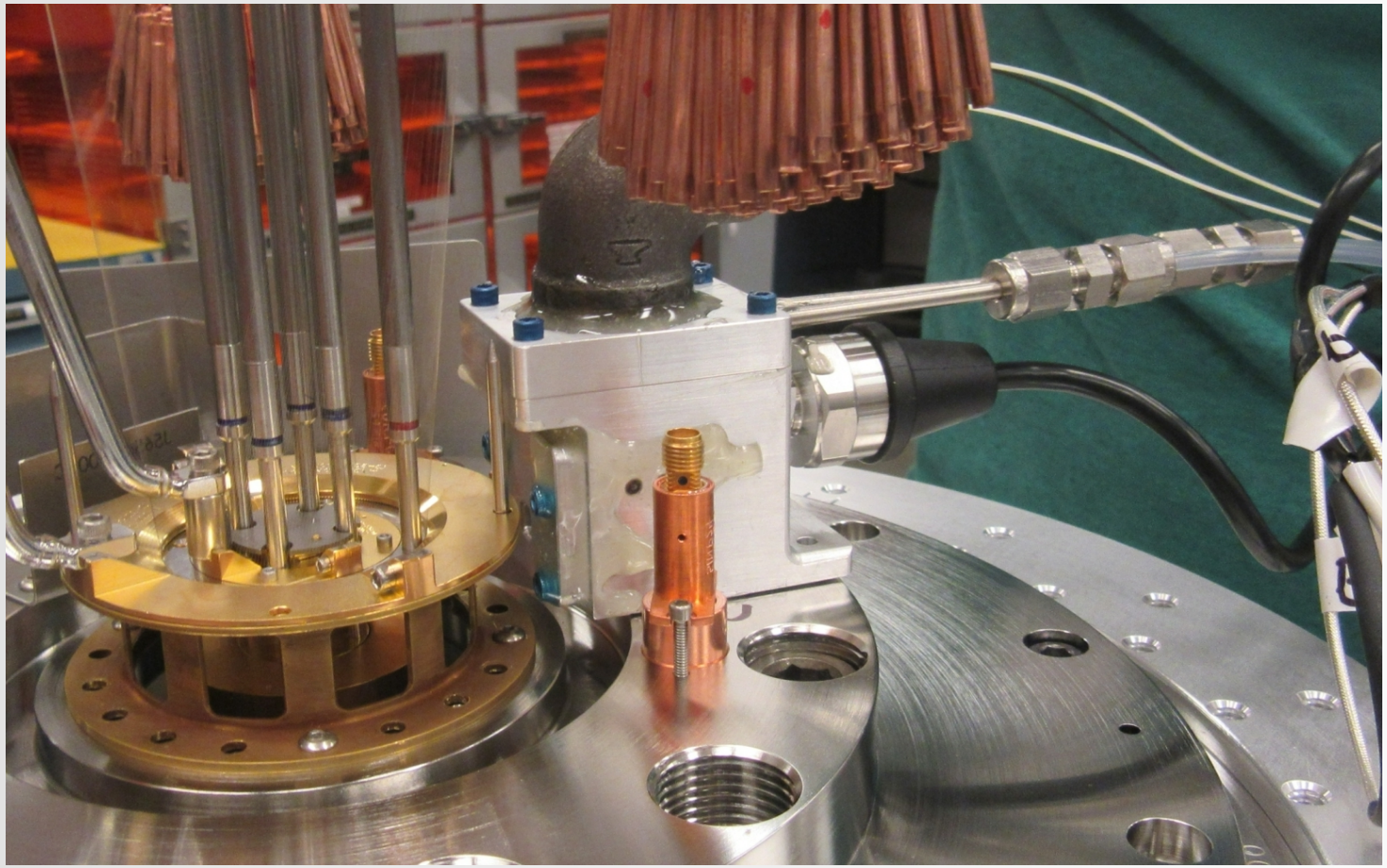
- Astro Motivation
- Z-Machine
- ZAPP Platform

SHARK Experiment

- SHARK Design
- Diagnostics

Future Work

- Gas Composition
- MAIZE



Z-Machine Experimental Setup

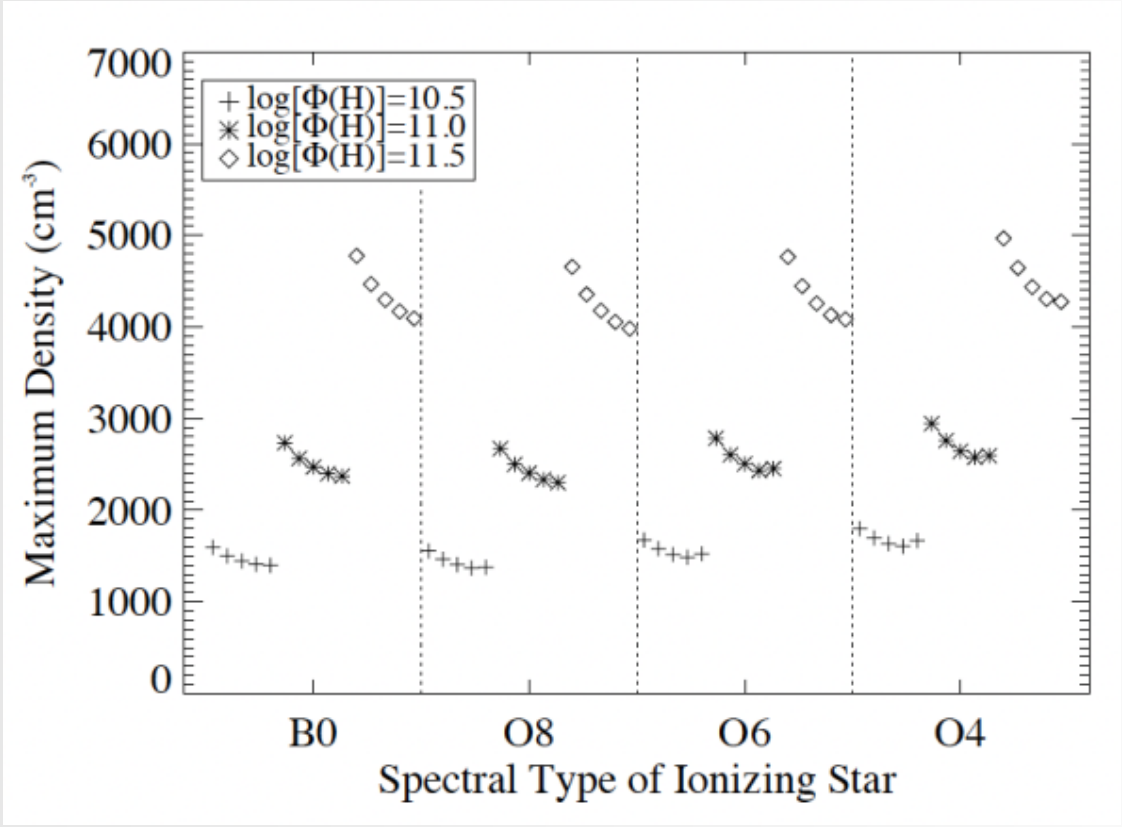
Eagle Nebula has Photoionization Fronts in the Elephant Trunks

Elephant Trunks located 2,000pc away in M16 Region

- Radiation source distance: 2pc
- ~10^{50} photons/s from O3-6 Stars

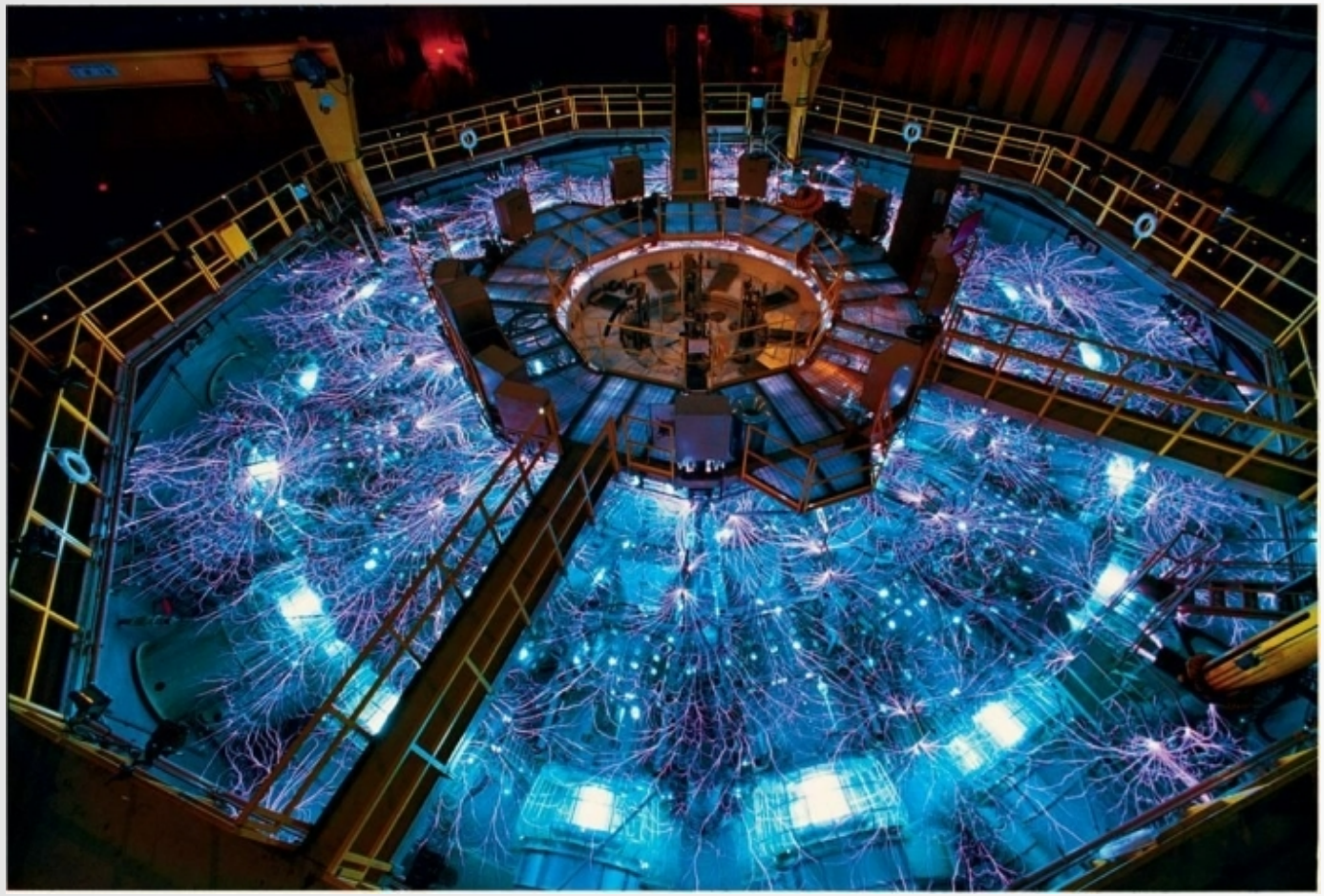
Density of Photoionization Front Dependent on

- Radiation Intensity
- Radiation Spectra
- Elemental Abundance



Sandia Z - Machine

- 26MA Pulsed Power machine
- Large amounts of energy compressed into small volume
- High Power: 85kV, 26Ma, 80TW (electrical)
- High Energy Density Regime (P~100Mbar)
- Astrophysical Experiments
  - Supernova
  - Accretion Disk



Sandia Z - Machine

PI Experiment on Z Astrophysical Plasma Properties (ZAPP) Platform

Cylindrical Wire Array

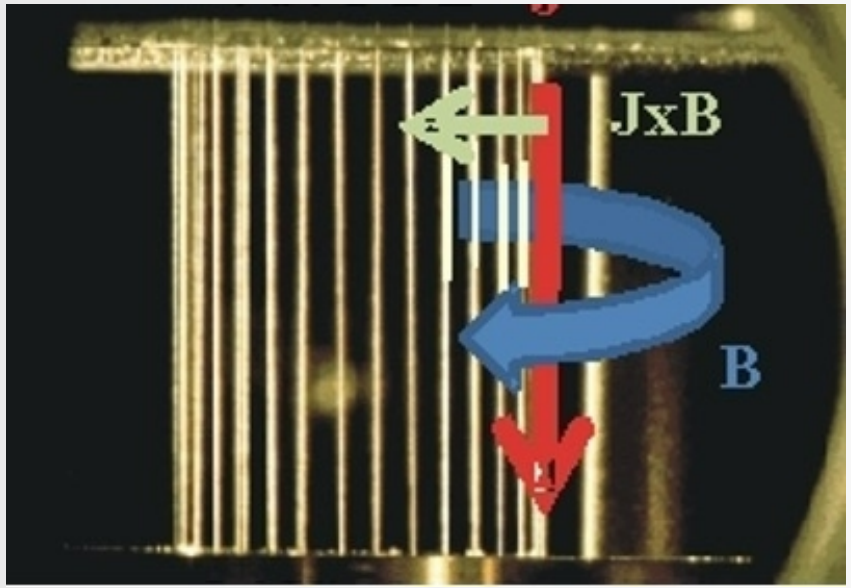
- Radially inward Lorentz Force

Z-Pinch Dynamic Hohlraum (ZPDH)

- 240 outer W wires (⌀ =11.4µm at r = 40mm)
- 120 inner W wires (⌀ =11.4µm at r = 20mm)
- Plastic core (14.5mg/cc CH_2)
- Marx Charge: 20.3MJ
- Current: 25.8MA

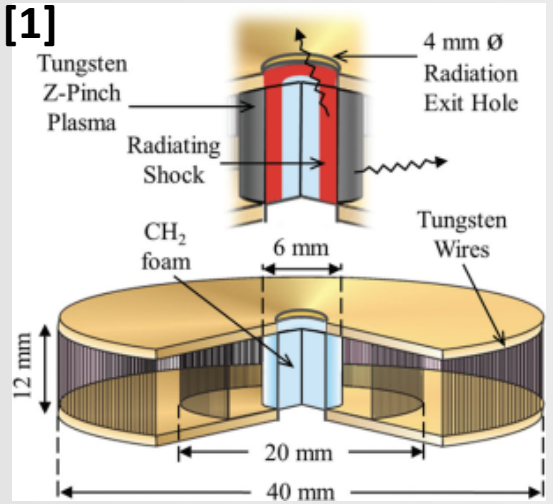
X-Ray Emission

- Total X-ray Energy: 1.57MJ
- Duration: 3.5ns FWHM
- X-ray Power: 218TW



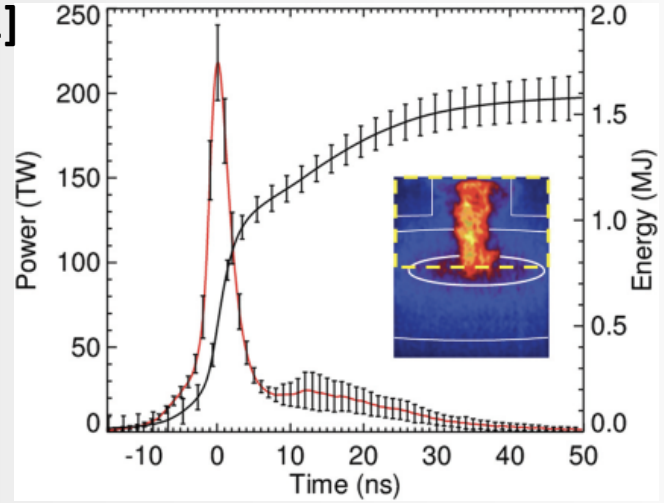
Wire Array (F.Beg UCSD)

[1]



Z-Pinch Dynamic Hohlraum

[1]



ZPDH X-ray Power

[1]

ZAPP: The Z Astrophysical Plasma Properties collaboration[a)]

G. A. Rochau,[1,b)] J. E. Bailey,[1] R. E. Falcon,[1] G. P. Loisel,[1] T. Nagayama,[1] R. C. Mancini,[2] I. Hall,[2] D. E. Winget,[3] M. H. Montgomery,[3] and D. A. Liedahl[4]

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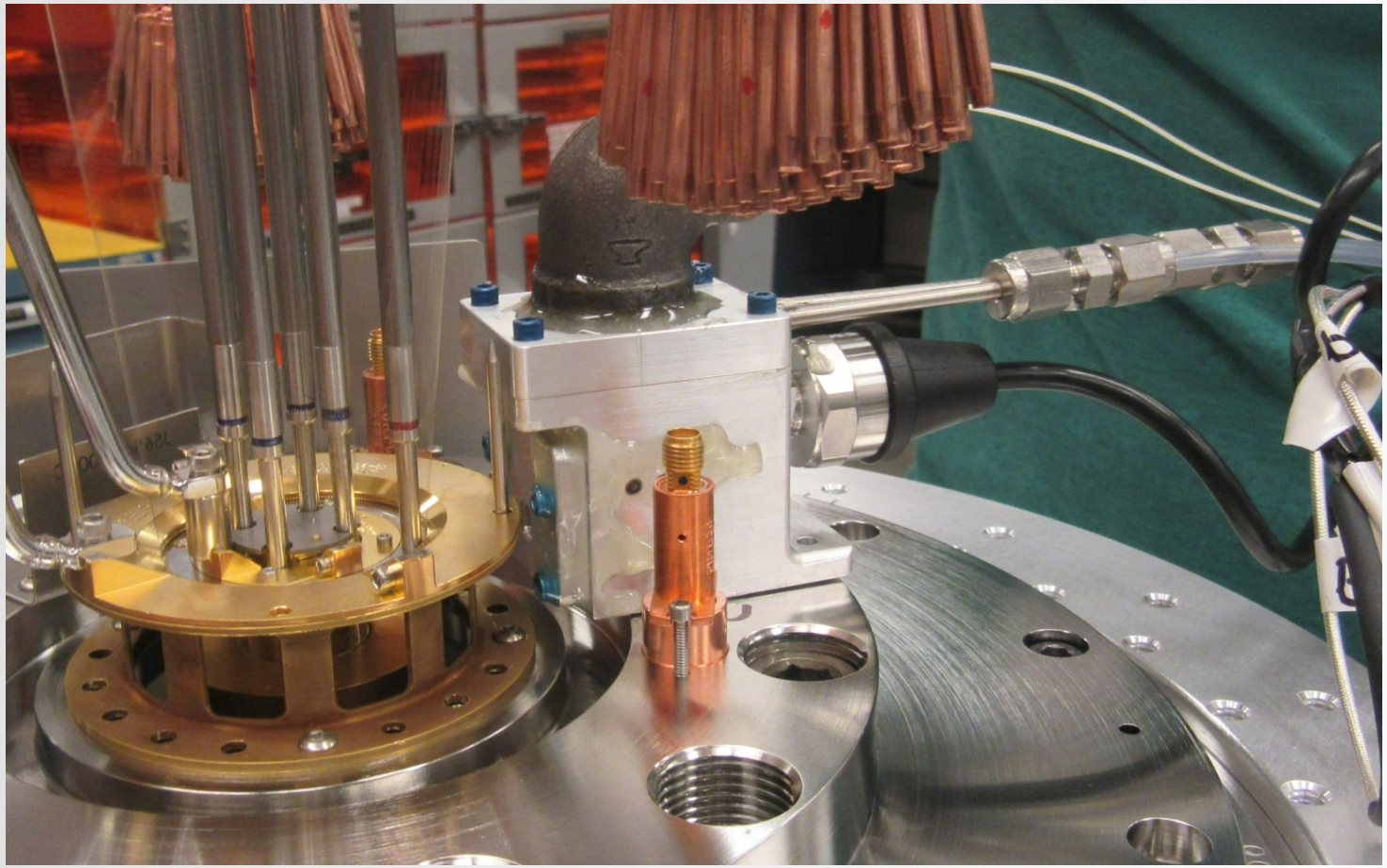
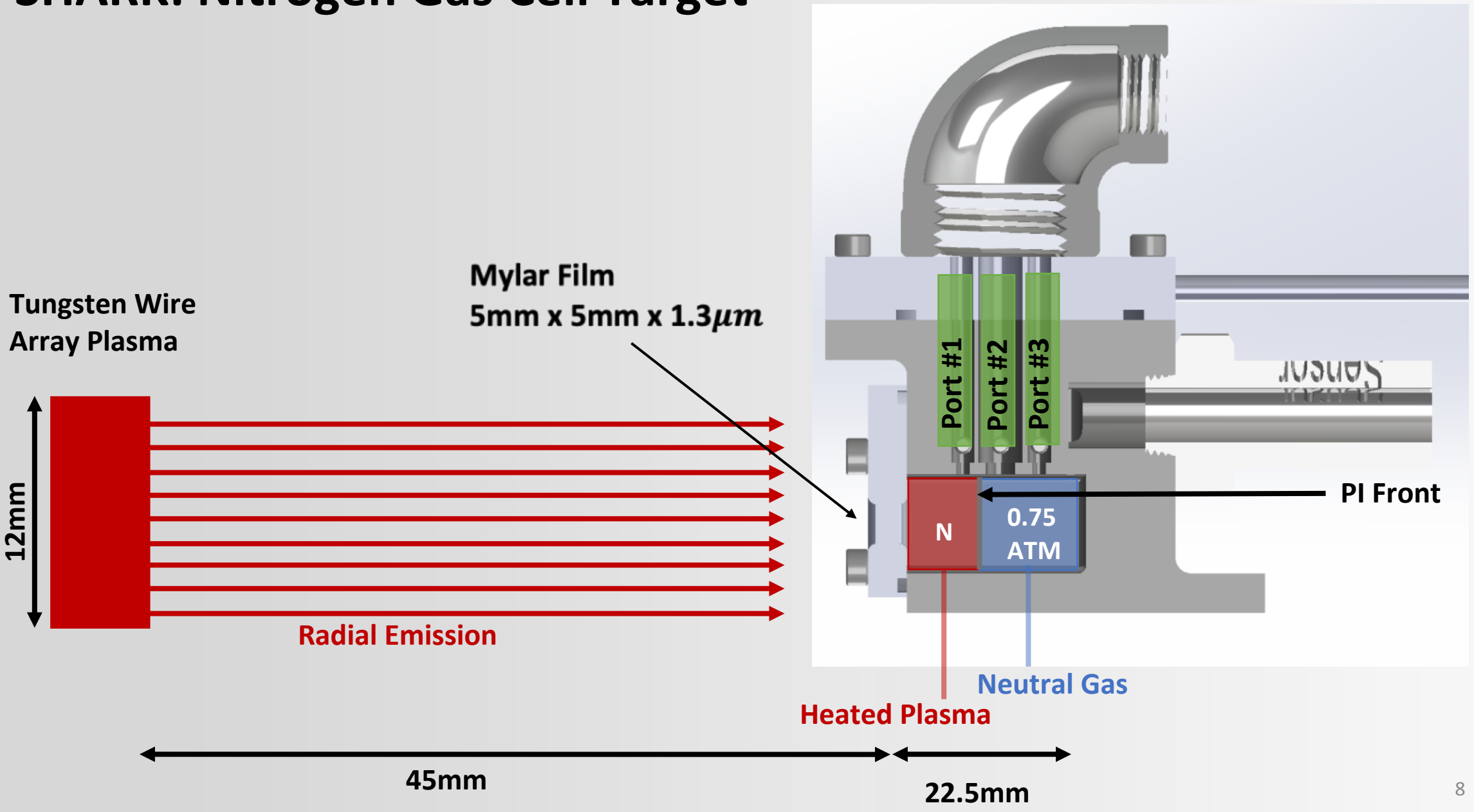


Z-Machine Experimental Setup

SHARK: Nitrogen Gas Cell Target



SHARK Setup on Z-Machine

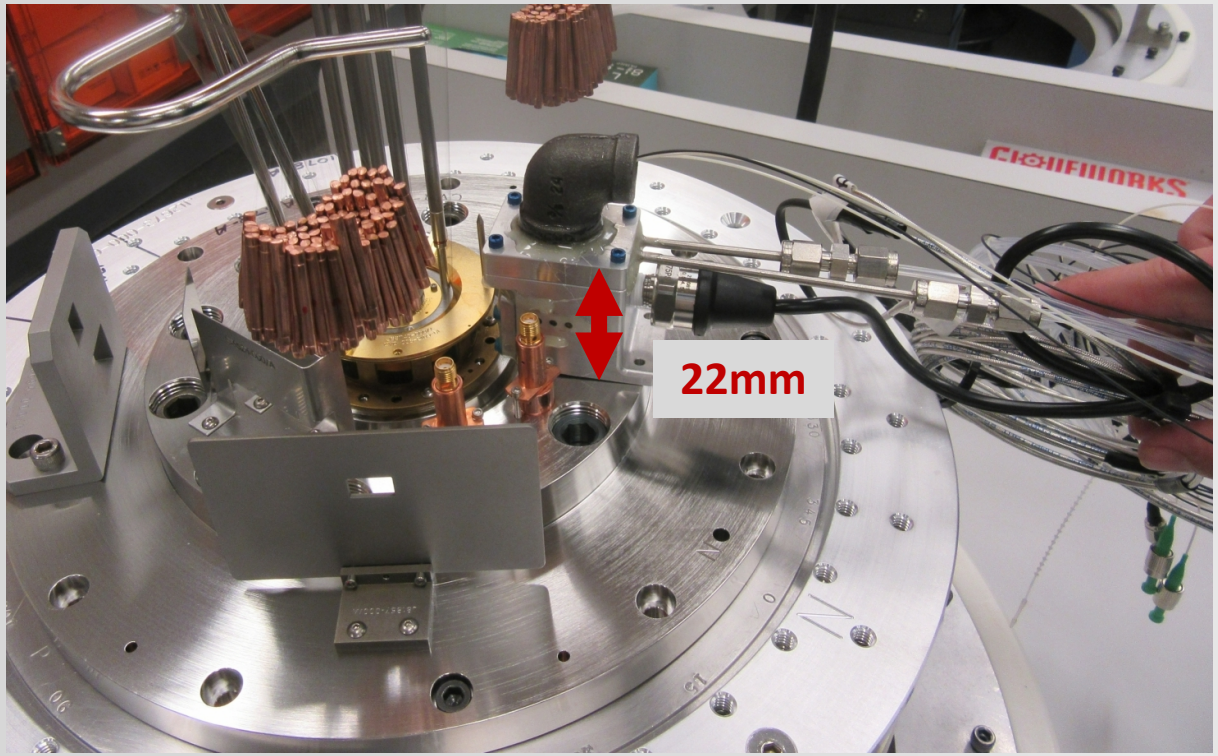


Figure 7a. SHARK on Anode A1078B (Top View)

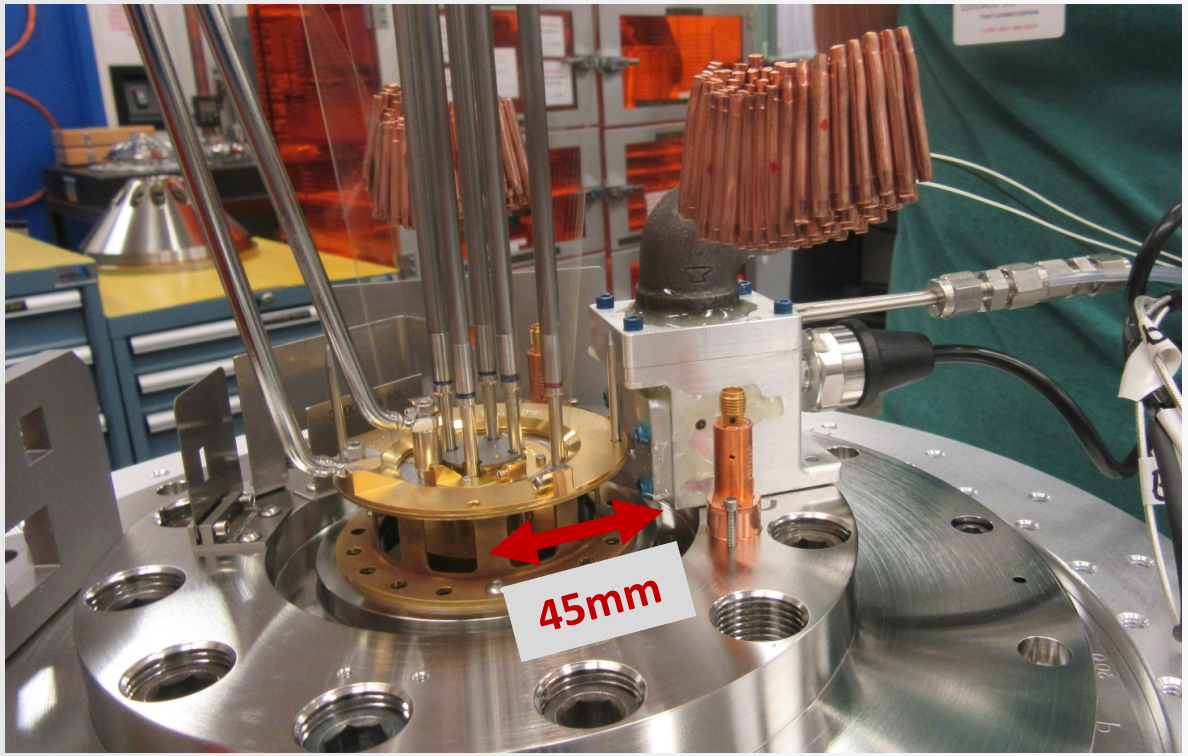


Figure 7b. SHARK on Anode A1078B (Side View)

Shot's unable to be performed due to Z-Machine oil quality issues

Photon Doppler Velocimeter (PDV) Measures PI Front Velocity

Goal: Measure velocity of PI Front

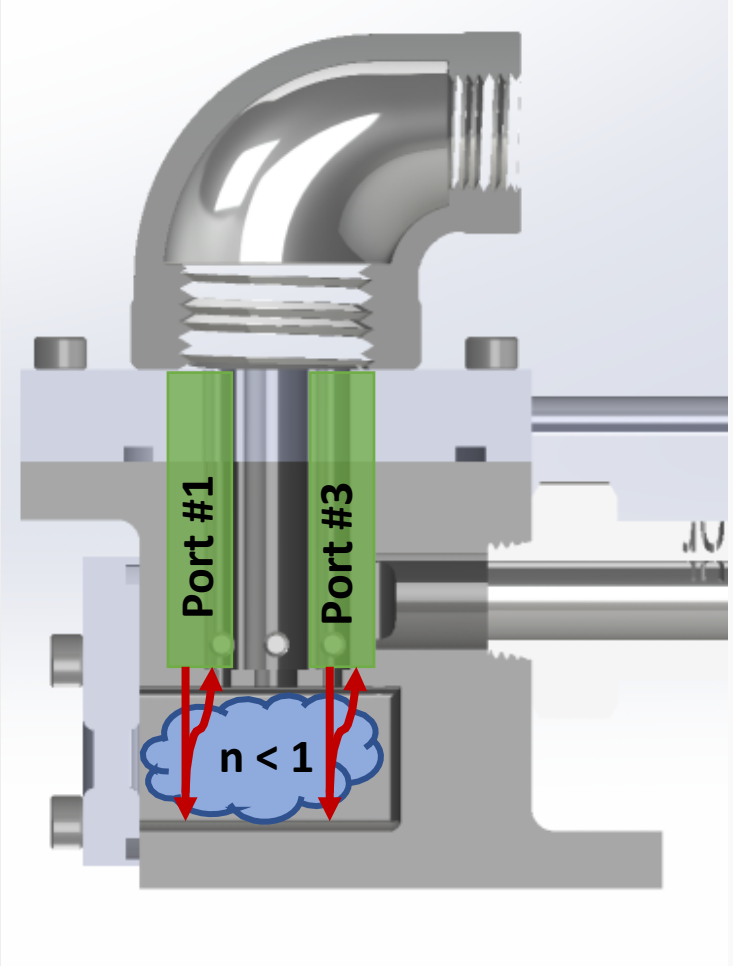
- Measures Apparent Velocity (*v) based on change of index of refraction (n)
- Two Perpendicular PDV Sensors Port 1 & 3

Ionization State: $Z \cong 0.63\sqrt{T_{e,eV}}$

Plasma Electron Frequency: $\omega_p = \sqrt{\frac{n_e e^2}{\epsilon m_e}}$

Index of Refraction: $n = \sqrt{1 - \left(\frac{\omega_p^2}{\omega_2}\right)}$

Apparent Velocity: $\mathbf{v}^* = -\frac{d}{dt}\int n(x,t)dx$

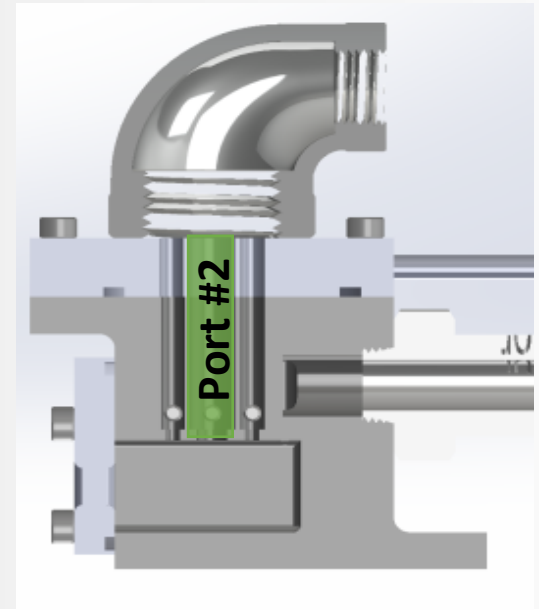


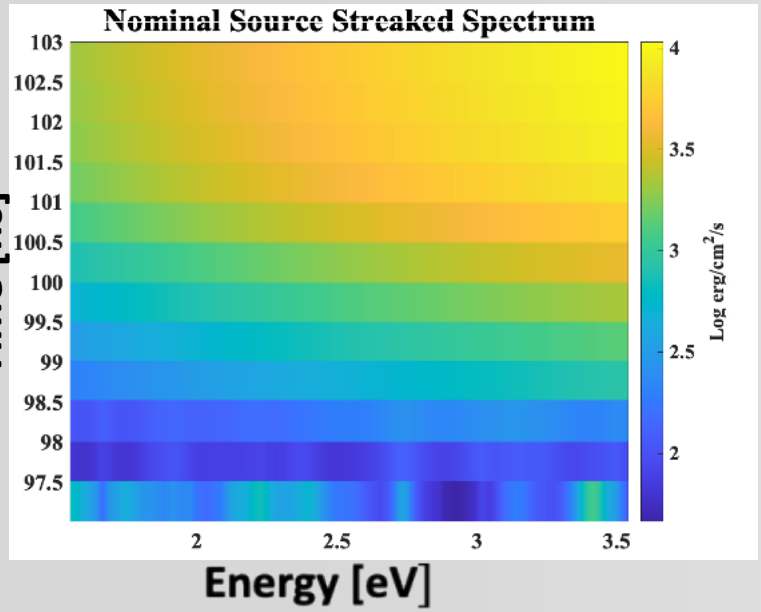
- PI Front Velocity of ~2,100 μm/ns will propagate for ~6.5ns

Streaked Visible Spectrometer (SVS) Measures Plasma Parameters

Goal: Determine Plasma Density and Temperature

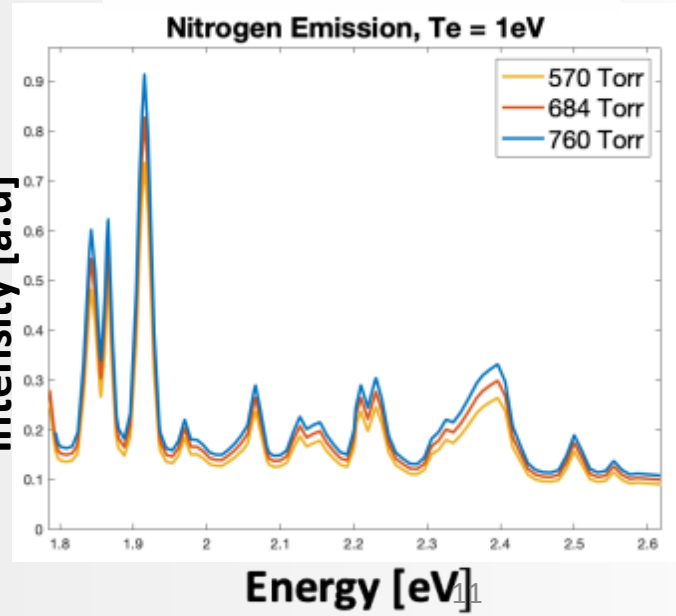
- One Perpendicular SVS Sensor in Port #2
- Emission Spectra from Nitrogen
  - Line Emission Early
  - Continuum Emission Late
  - Line Ratios to determine plasma parameters





Simulated SVS Output

Wavelength [nm]	Intensity	Probe
410.8	Standard	Density
454.3	Strong	Density / Temperature
522.1	Standard	Temperature
647.4	Weak	Temperature



Visible Nitrogen Emission Spectra

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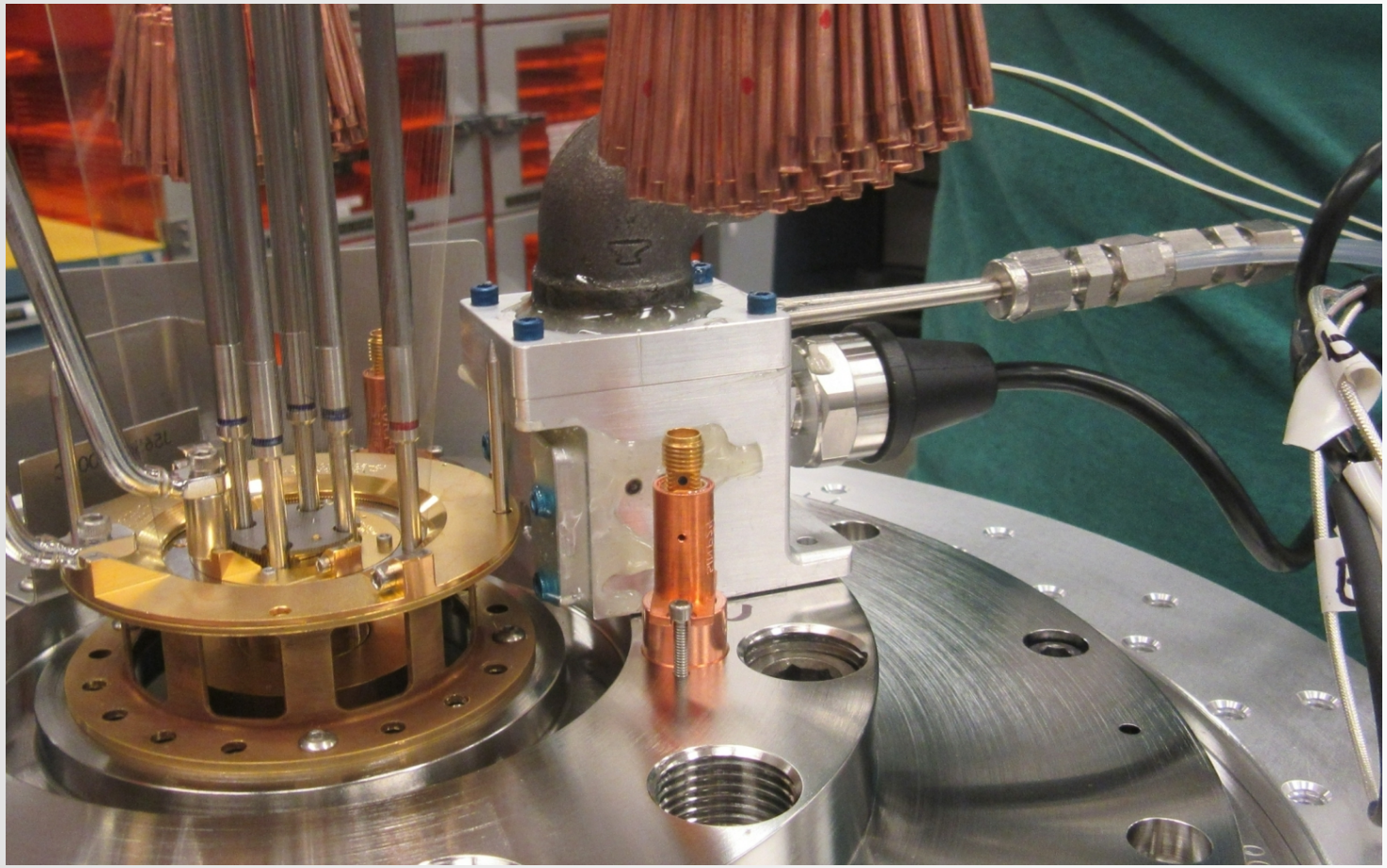


Z-Machine Experimental Setup

Future Work

Continue Collaboration on ZAPP Platform

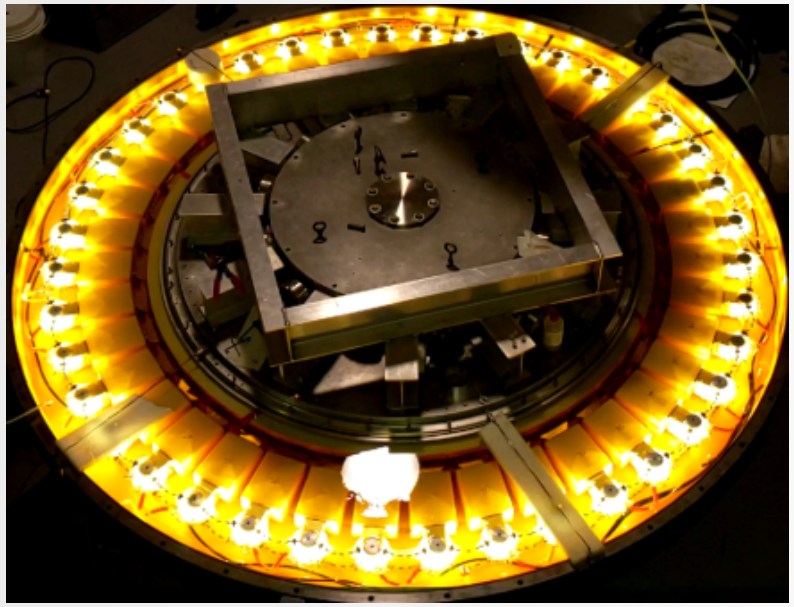
- Refine PI front platform – Less Noise
- High pressure – Sharper PI Front
- Vary Gas– Change atomic mass
- Dopants – Brighter line emission

Additional Measurements

- Transmission/ radian
- Radiation Energy Coupling

MAIZE

- Small Scale
- Photon Flux scaling study

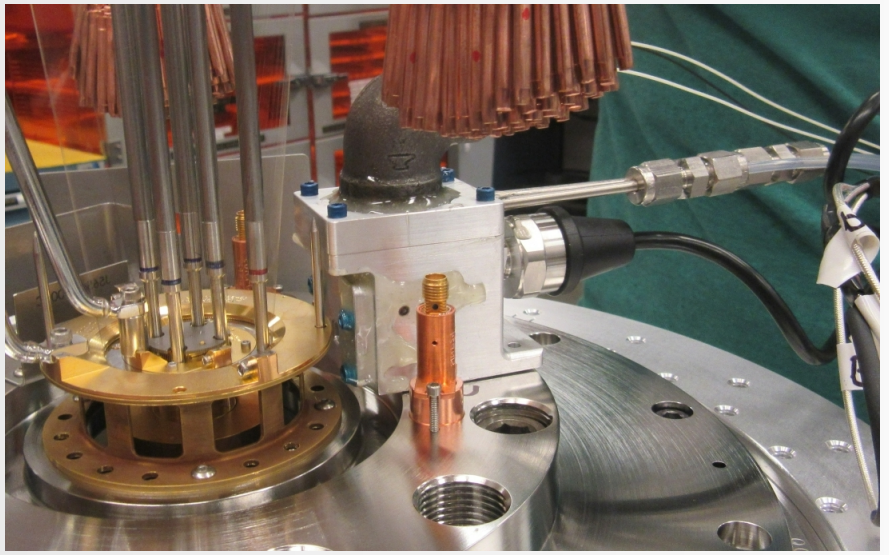


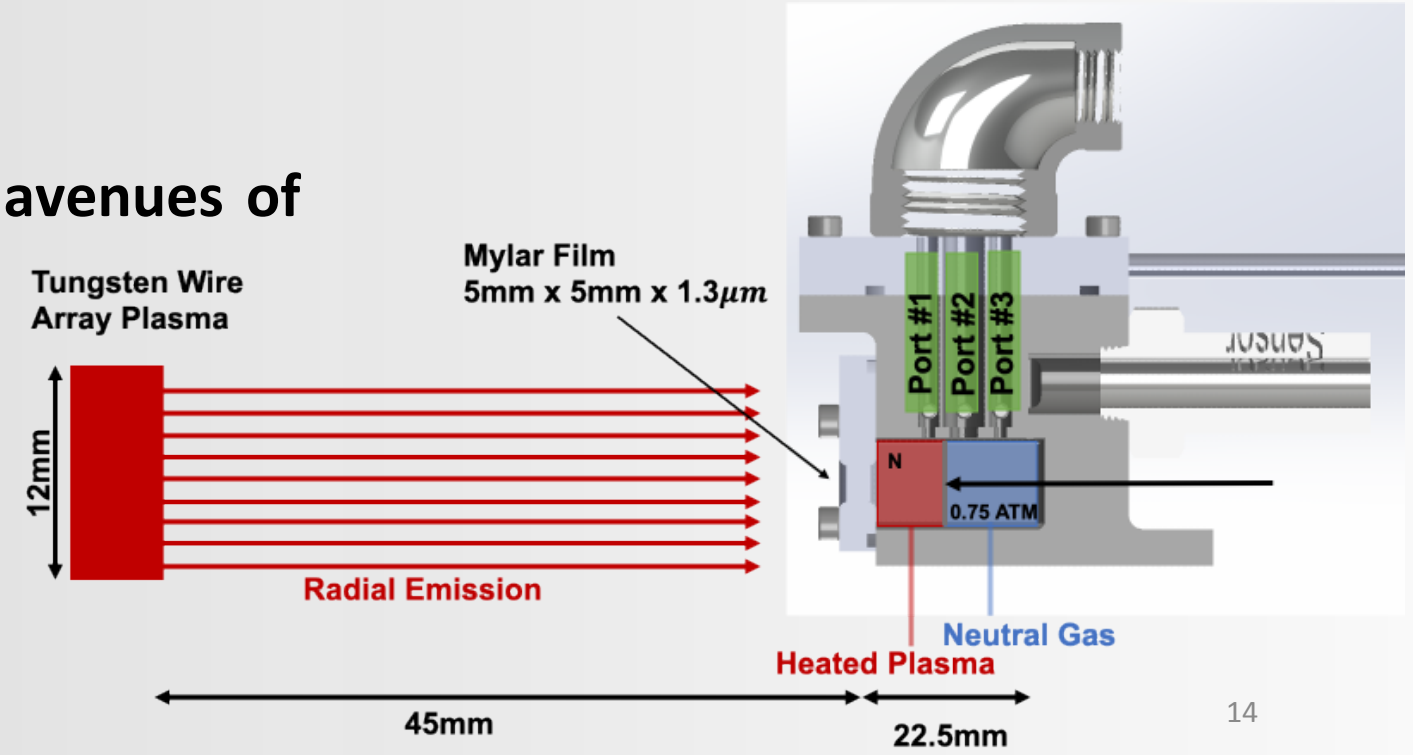
University of Michigan's MAIZE

Facility	Z-Machine	MAIZE
Peak Current	26 MA	0.25 – 1 MA
Photon Energy	200eV	200eV
Radiative Power	200,000 GW	75 – 300 GW
Standoff Distance	45mm	11 - 22mm
Total Number of photons	$4.9 * 10^{22}$ photons	$2.8 – 5.8 * 10^{20}$ photons
Electron Density	$7.8 * 10^{18}$ [e^-/cc]	$4.6 – 9.8 * 10^{16}$ [e^-/cc]
Gas Pressure	570 Torr	23 – 48 Torr

Executive Summary

- The ZAPP Platform on Sandia's Z-Machine offers a unique opportunity to investigate radiation dominated physics
- The SHARK experiment is designed to observe the propagation on a radiation driven heat front through nitrogen gas
- A PI front platform will open many avenues of future research





Questions