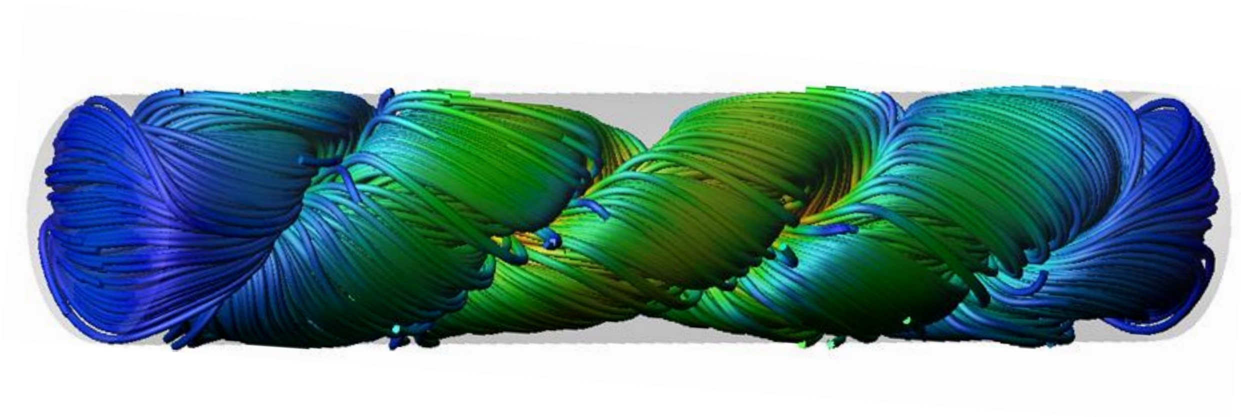
# Accelerated Taylor State Plumes in SSX

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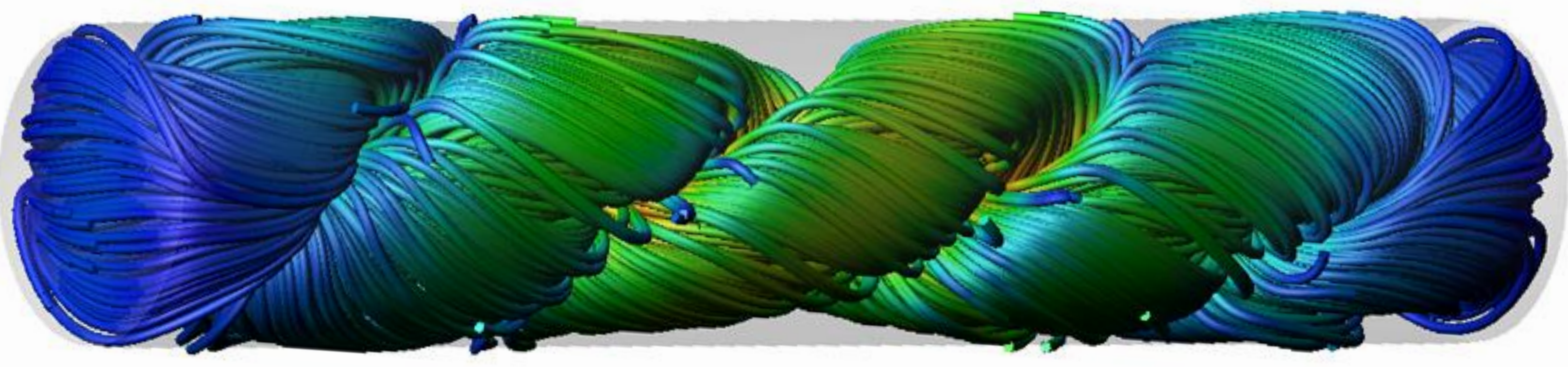
# Our goal

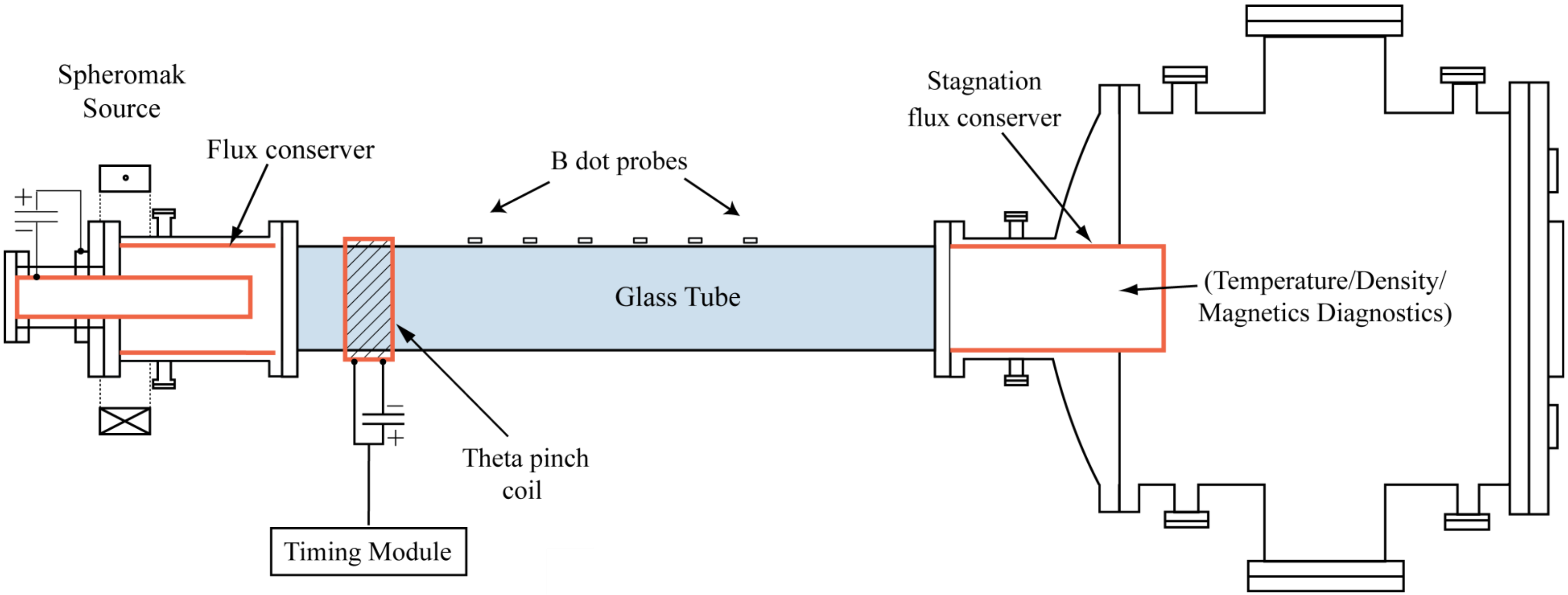
- **Twisted Taylor state** → A magnetic plasma object exhibiting minimum energy state
- First observed in SSX lab (Gray *et al.*, PRL, 2013)
- **Our goal** is to **accelerate** a Taylor state to high velocity, then stagnate and **compress** the object into a suitable MIF target

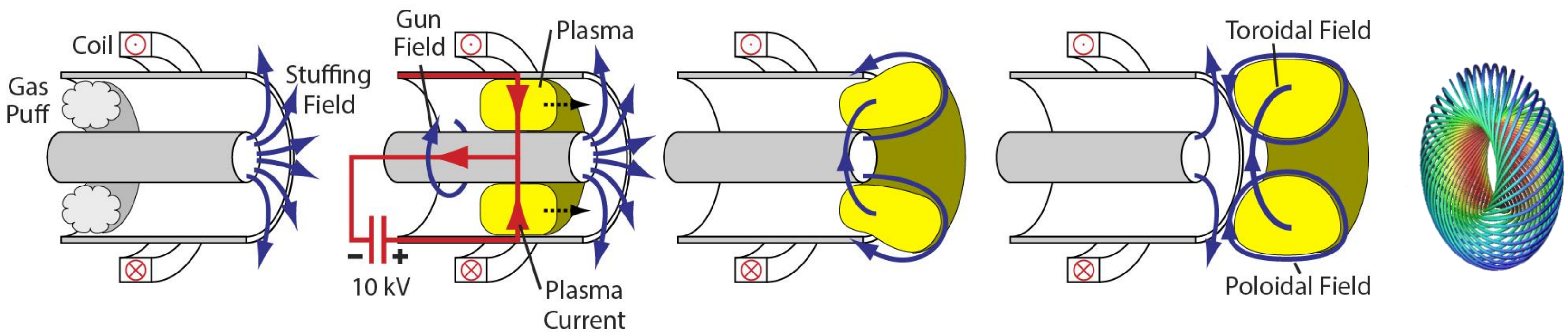


# Overview of talk

- System description
- Un-accelerated SSX plasma
  - Injected into glass tube with different **liners**
  - Baseline velocity, density and temperature
- Accelerated SSX plasma
  - Velocity predictions
  - Experimental progress
- Summary

# System schematic




(a) Stuffing field applied by external coil, gas is puffed in

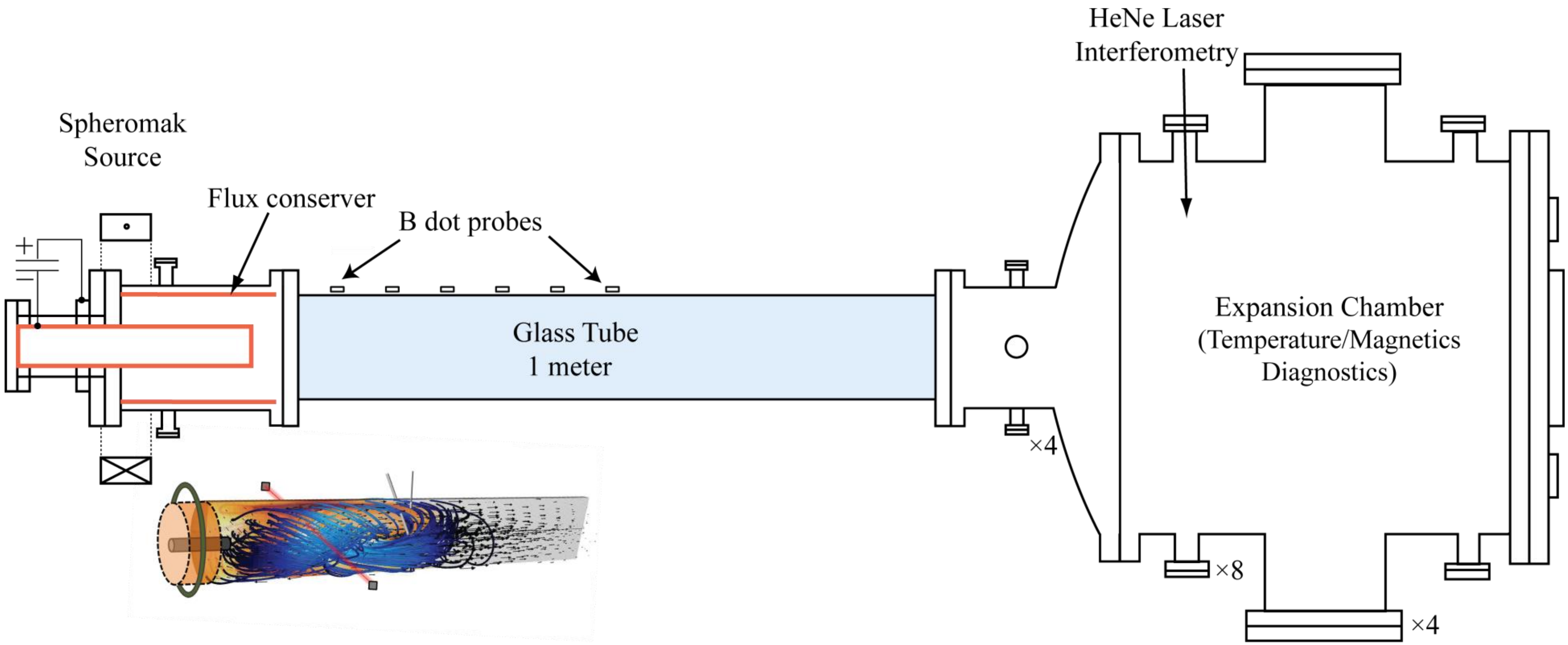
(b) Bank circuit switched on, gas is ionized

(c) JxB forces push plasma to the right, stuffing field bulges

(d) Field lines reconnect, spheromak structure is formed

# Un-accelerated Plasma

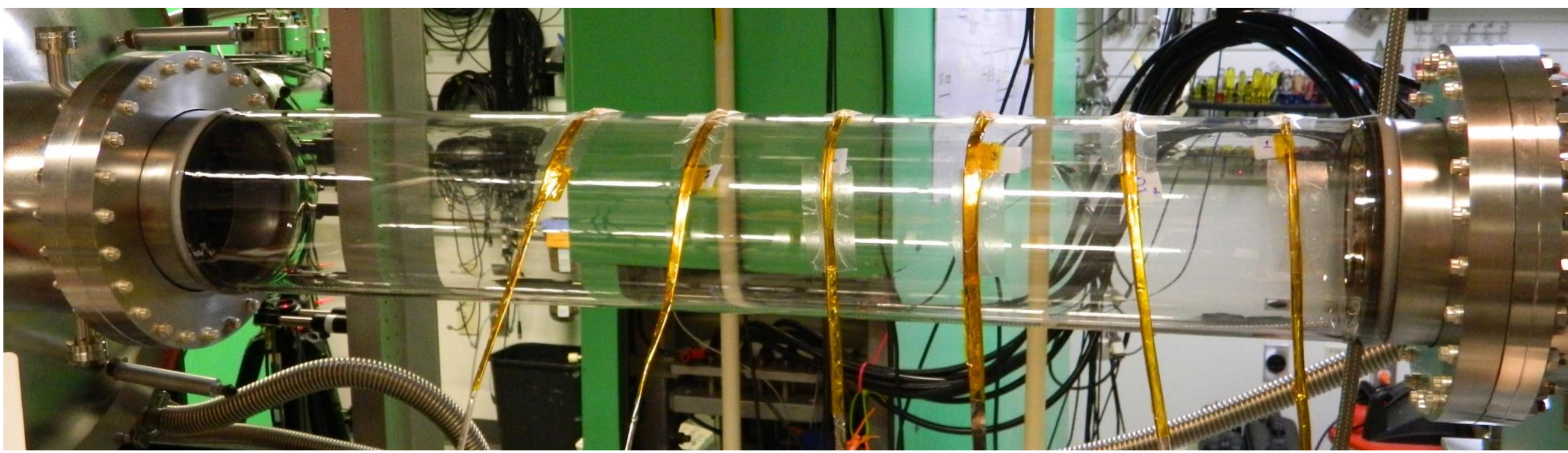
# Current set-up



# Velocity Measurements

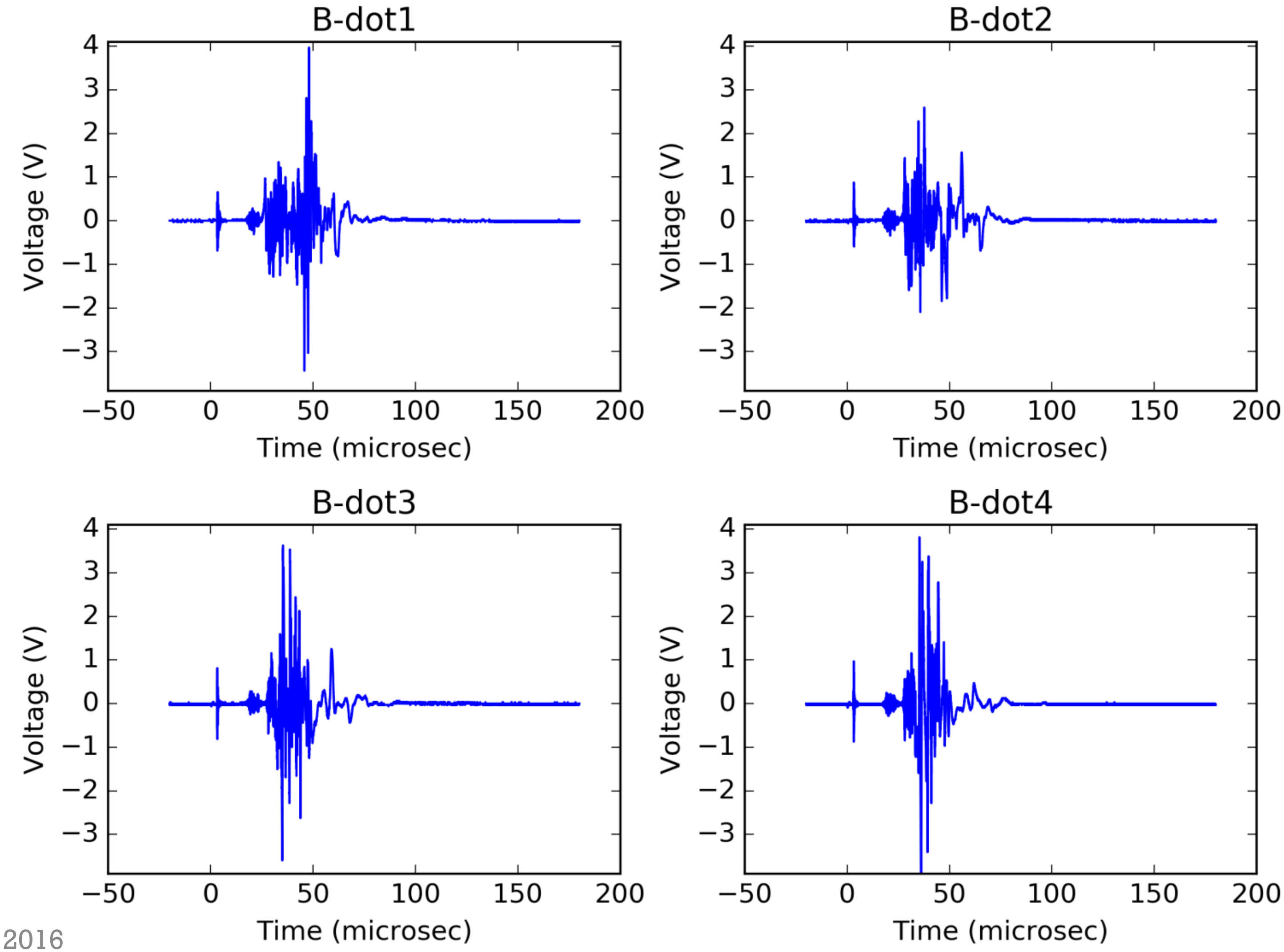
# $\dot{B}$ probes installed on glass

- Single turn wire loops
- Separated by 10 cm each

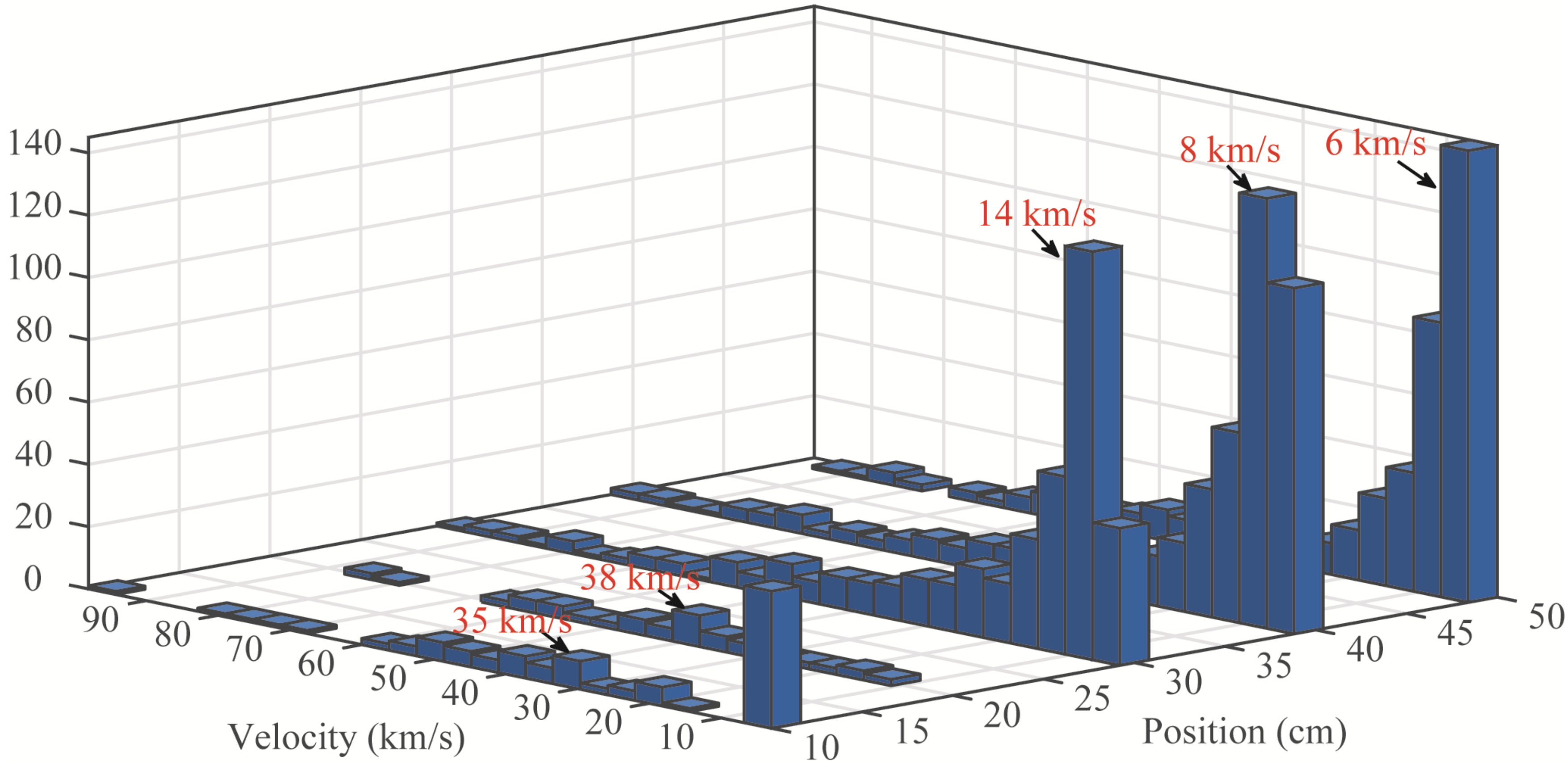


# Time of Flight measurements

Time travelled by the structure at different locations

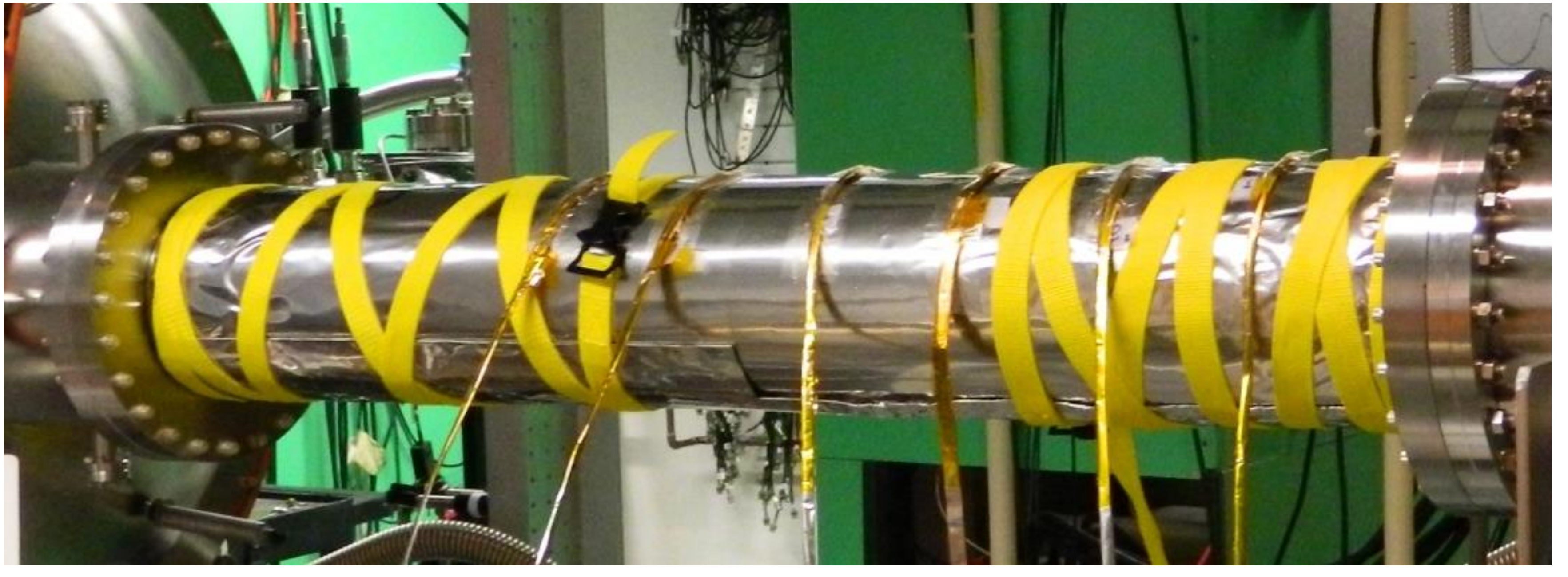


# Plume velocity with glass

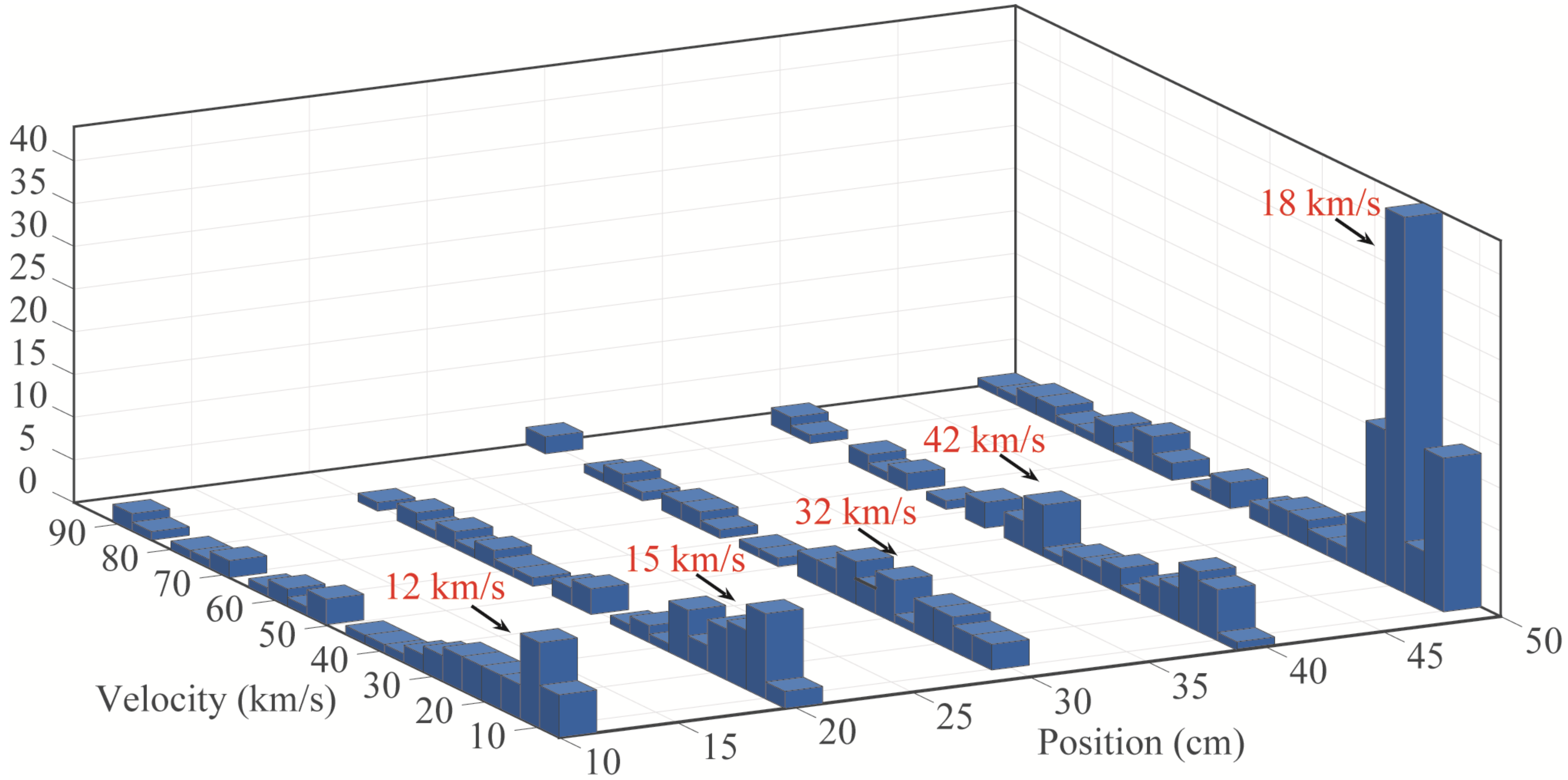


# Resistive flux conserver

- SS309 foil, thickness ~ 50 $\mu m$
- Magnetic soak time ~ **3 $\mu s$**

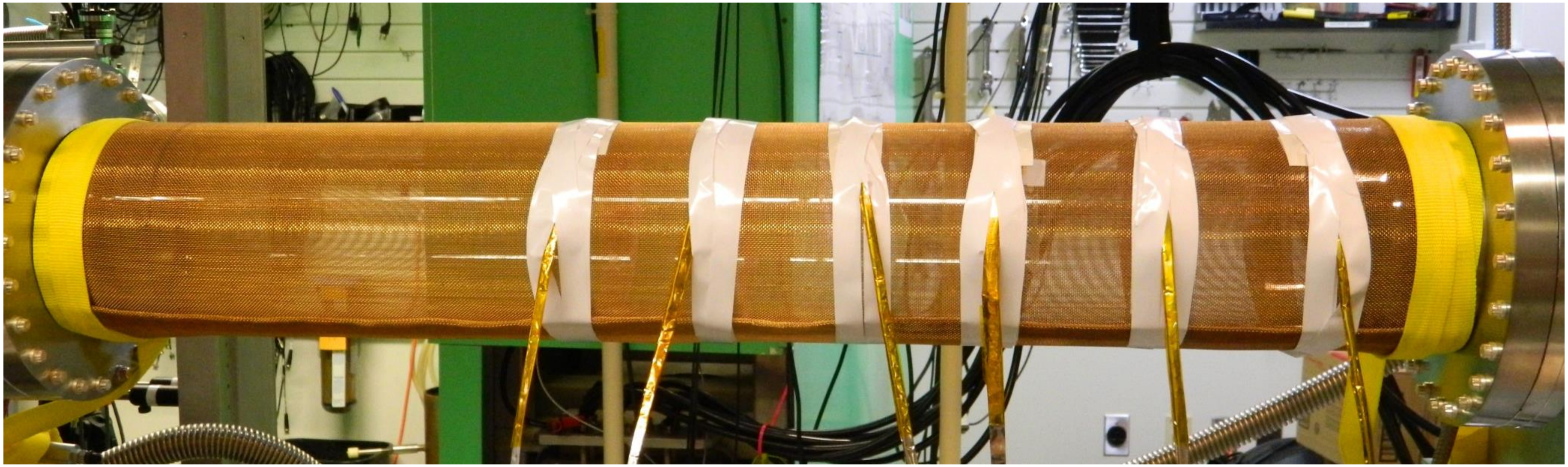


# Plume velocity with resistive liner

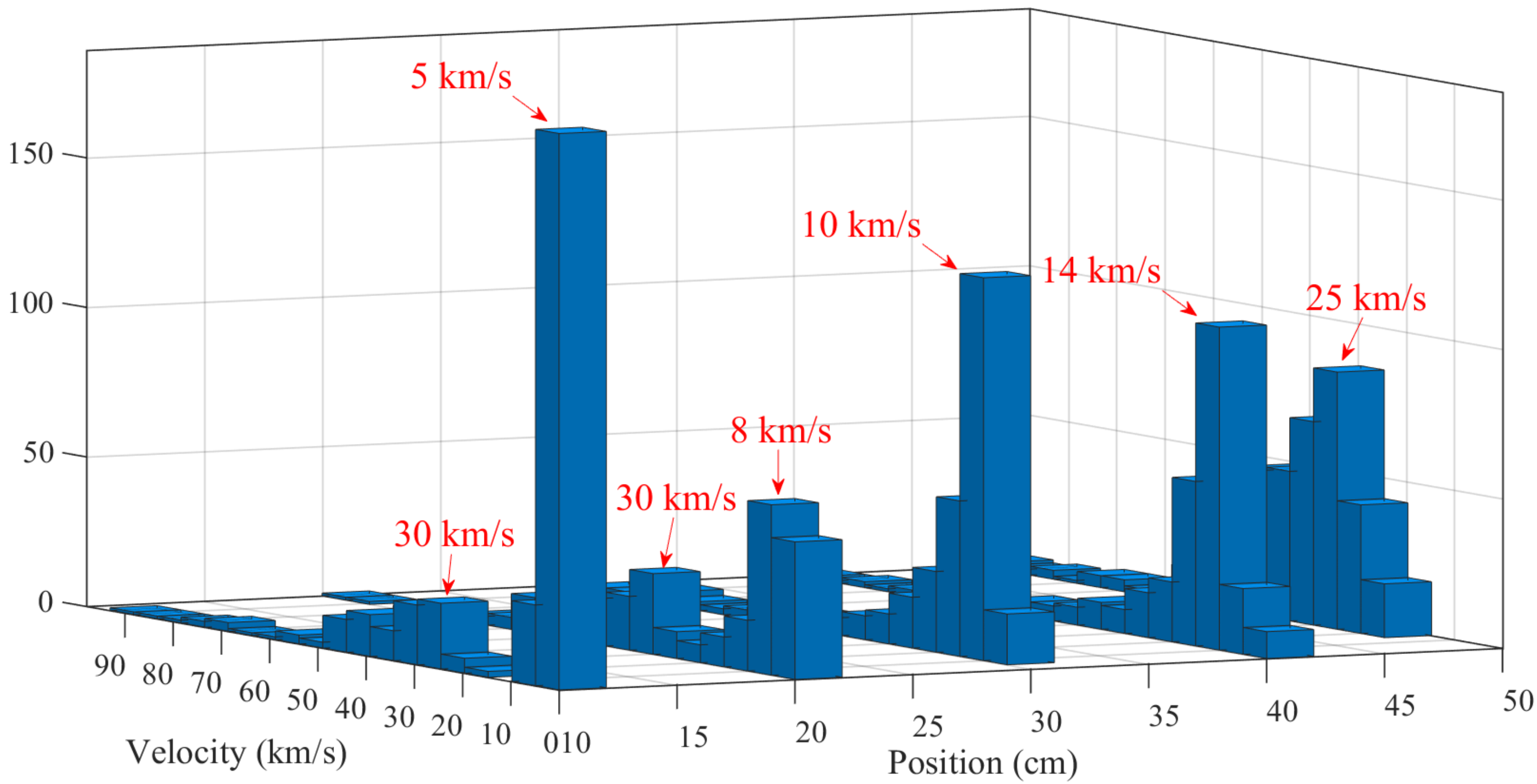


# Mesh flux conserver

- Bronze mesh, thickness ~ $450\ \mu m$, transparency ~ $42\%$
- Magnetic soak time ~ $245\ \boldsymbol{\mu s}$

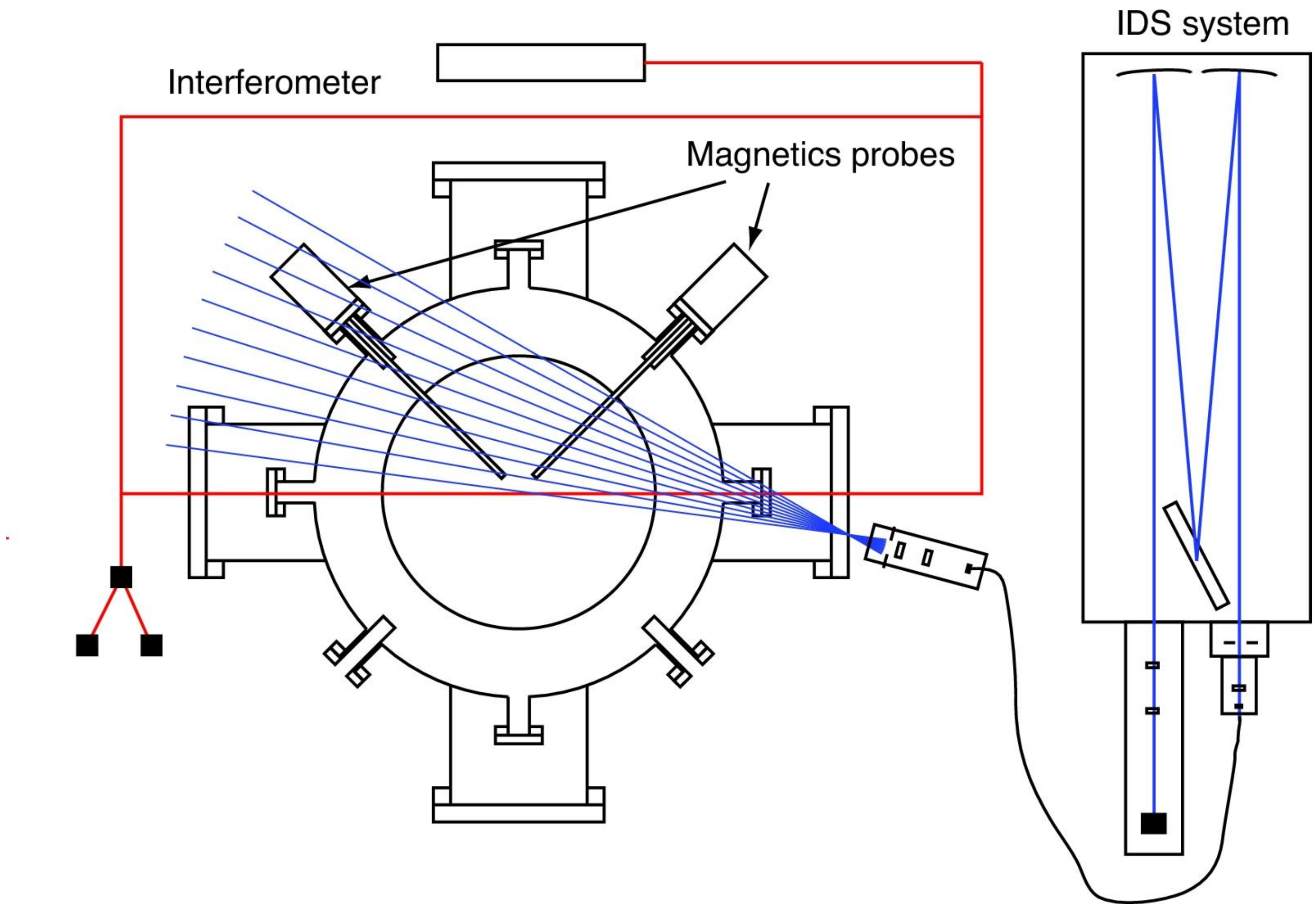


# Plume velocity with mesh conserver



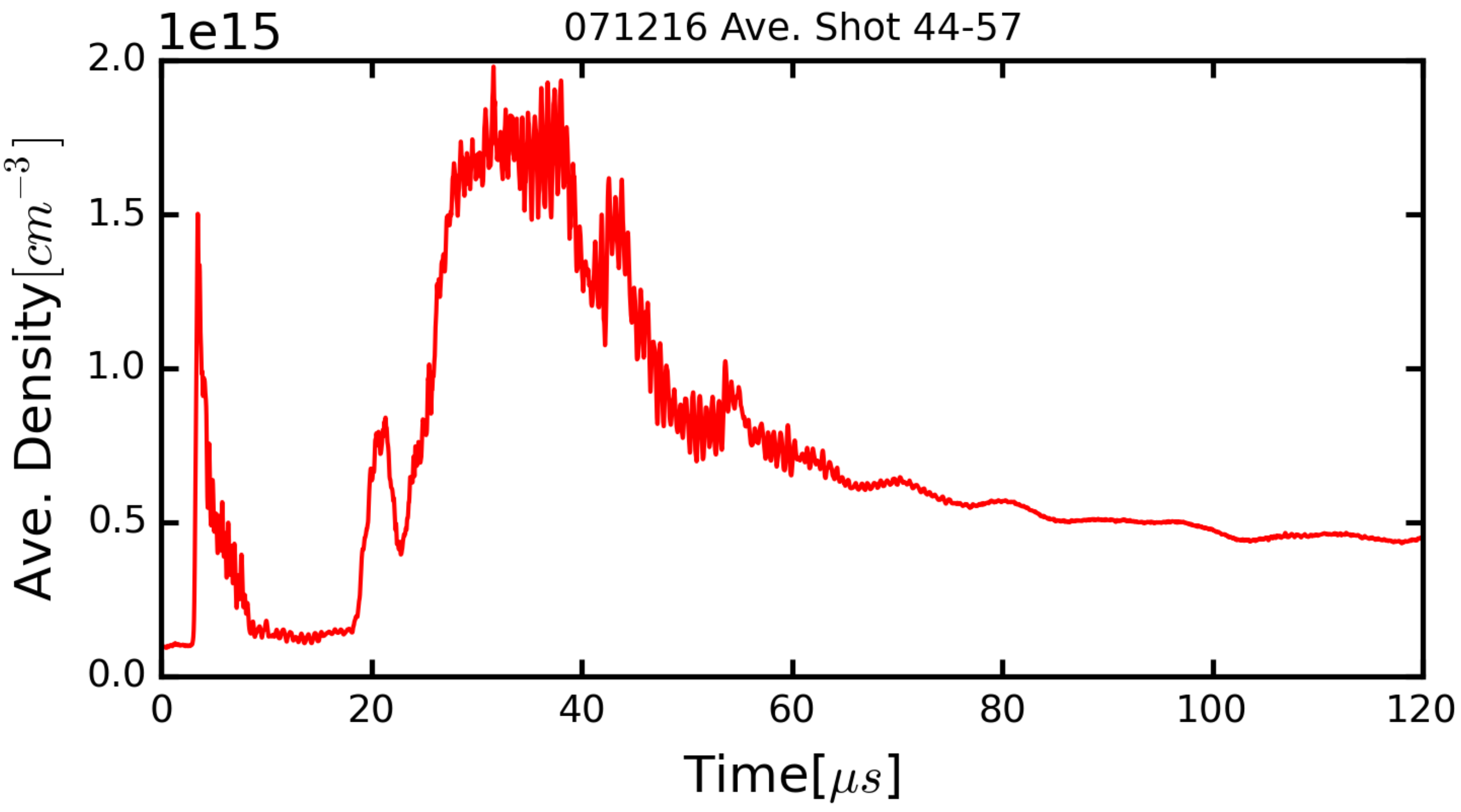
# Density & Temperature measurements

# Characterization in expansion chamber

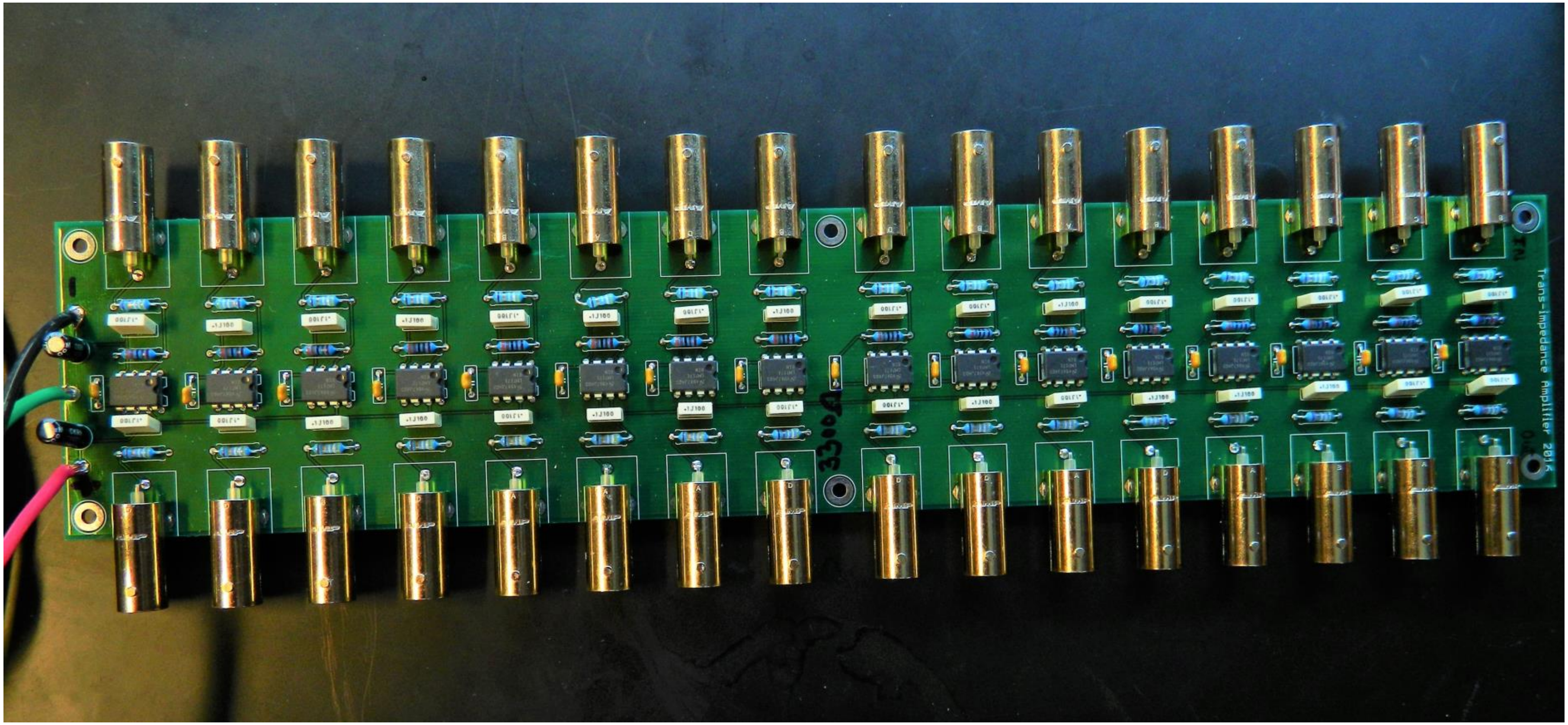



Interferometer chord, different chords of IDS and two magnetic probes also shown in the expansion chamber

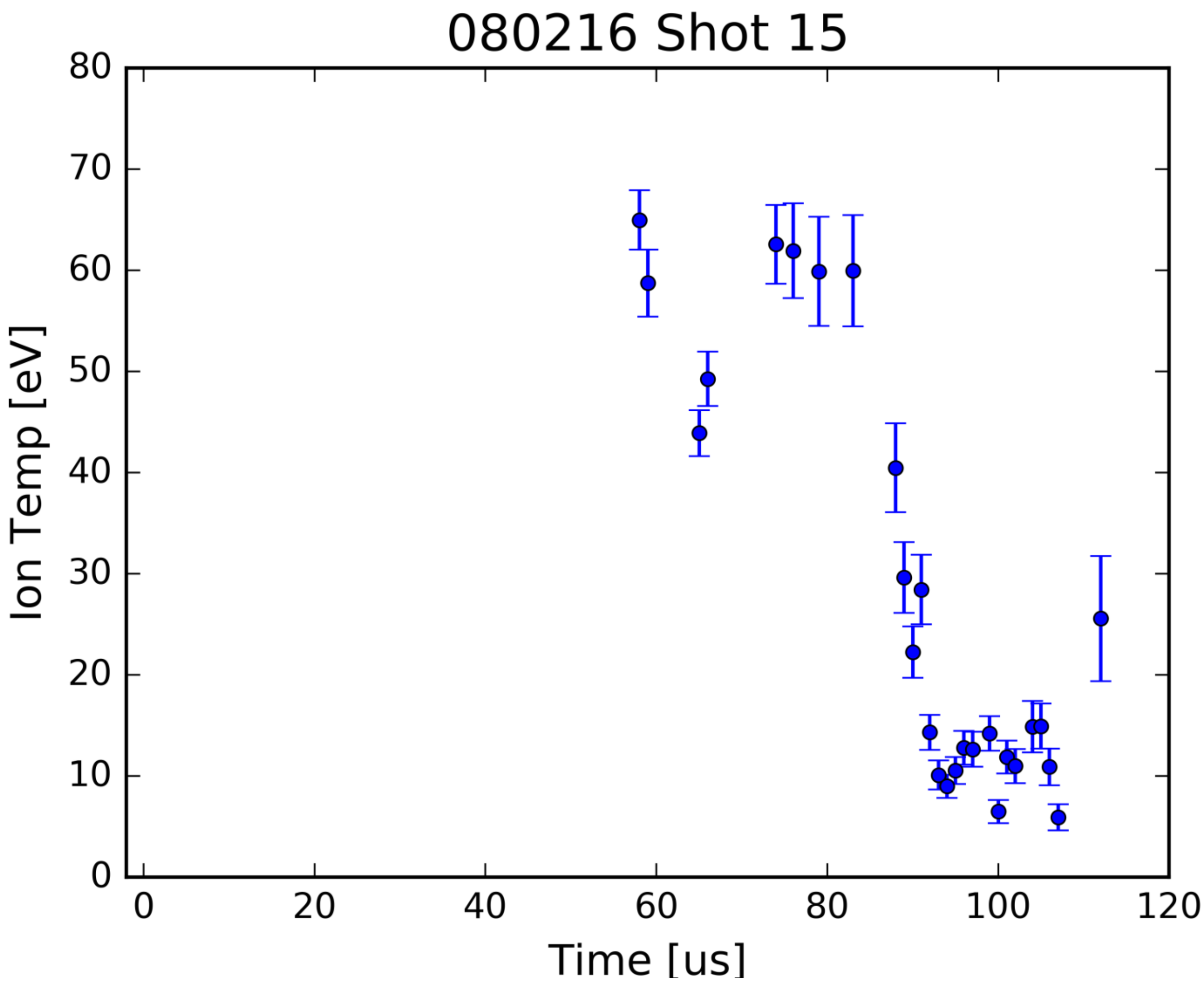
# Density of Taylor plume



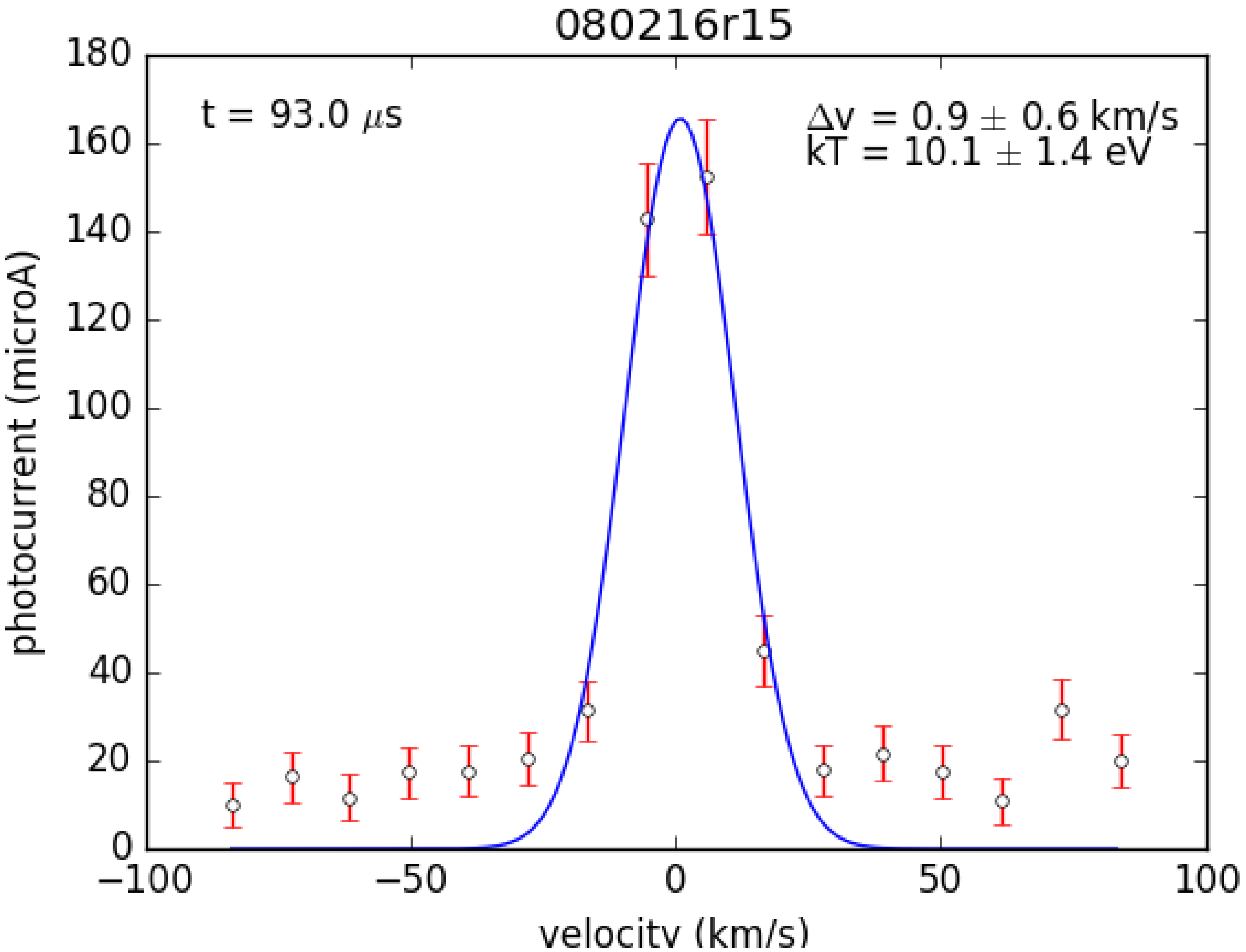
# 16-channel trans-impedance amplifier circuit



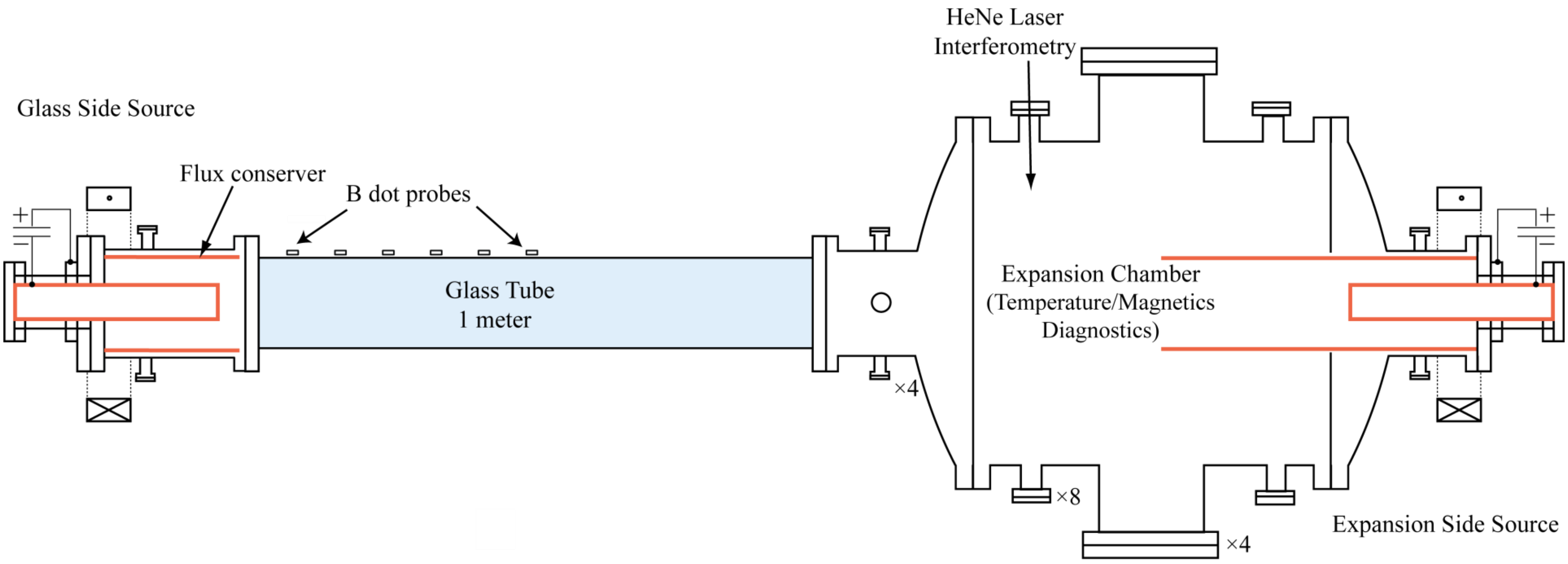
# Ion temperature Profile



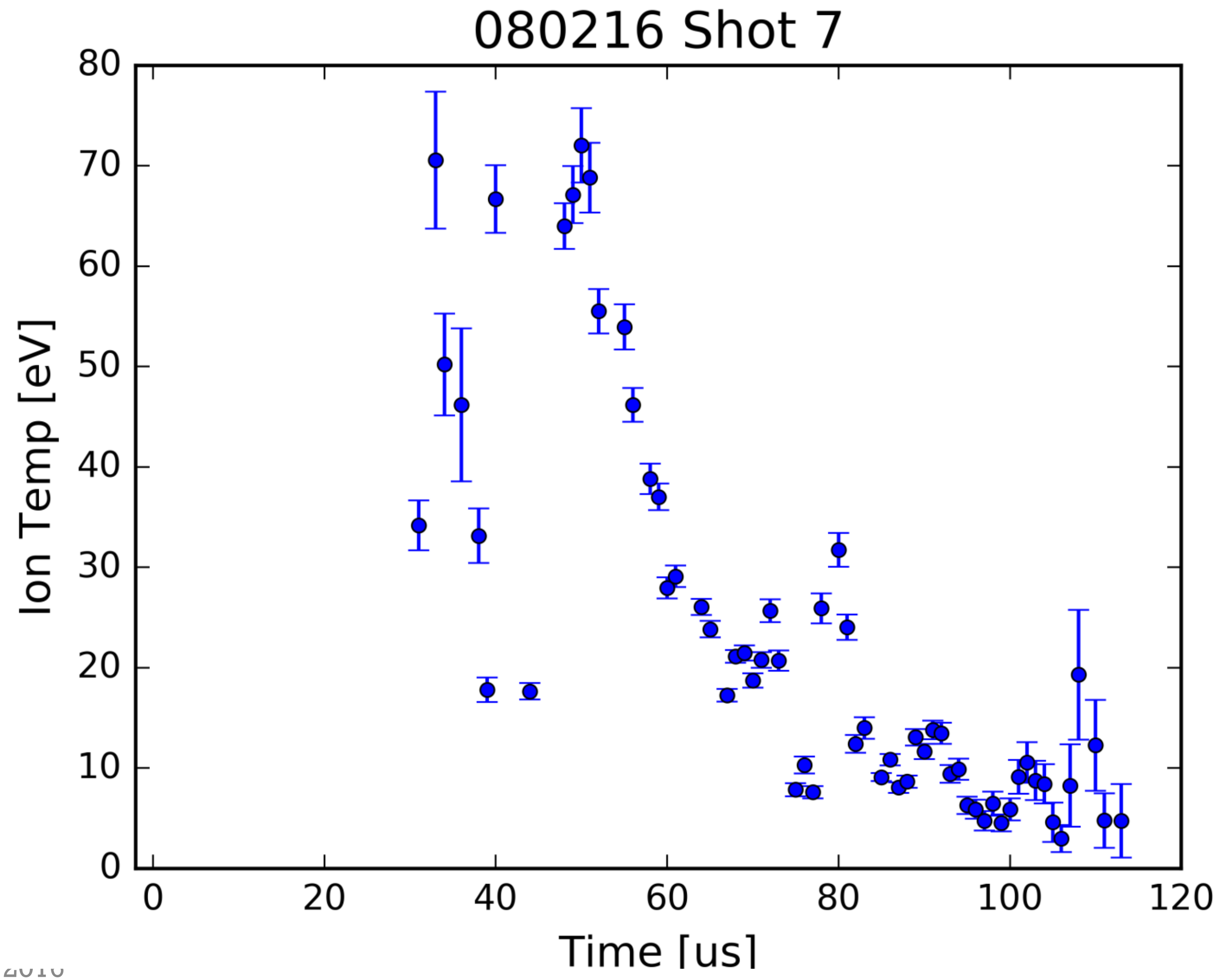
# Line shape from glass



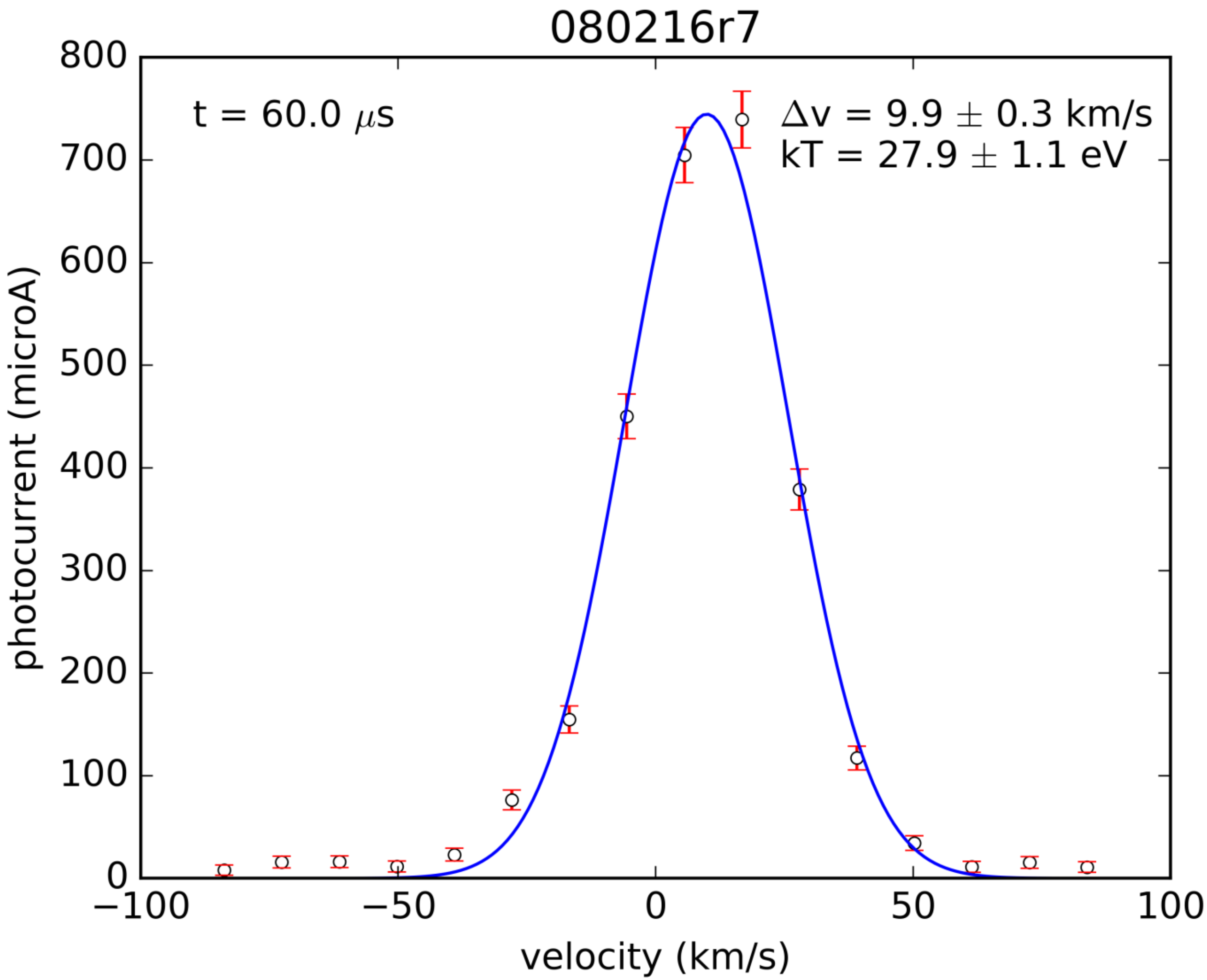
# Plasma production



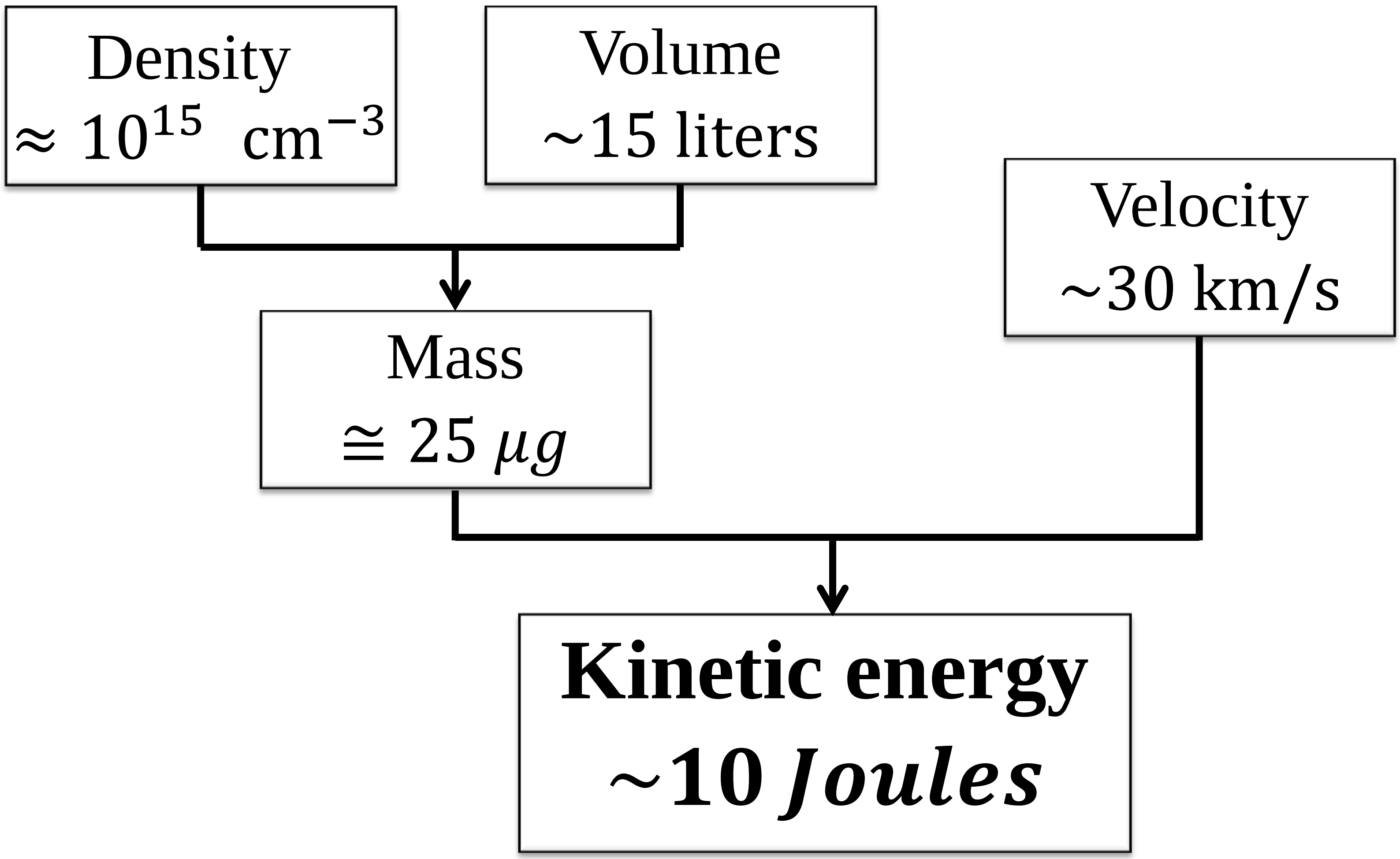
# Ion temperature of expansion side plasma



# Line shape of expansion side plasma



# Un-accelerated Taylor state



# Overview of talk

- System description
- Un-accelerated SSX plasma
  - Injected into glass tube with different **liners**
  - Baseline velocity, density and temperature $\boldsymbol{v = 30\ km/s,}$ $\boldsymbol{n \cong 10^{15} cm^{-3}, T_i = 30\ eV}$
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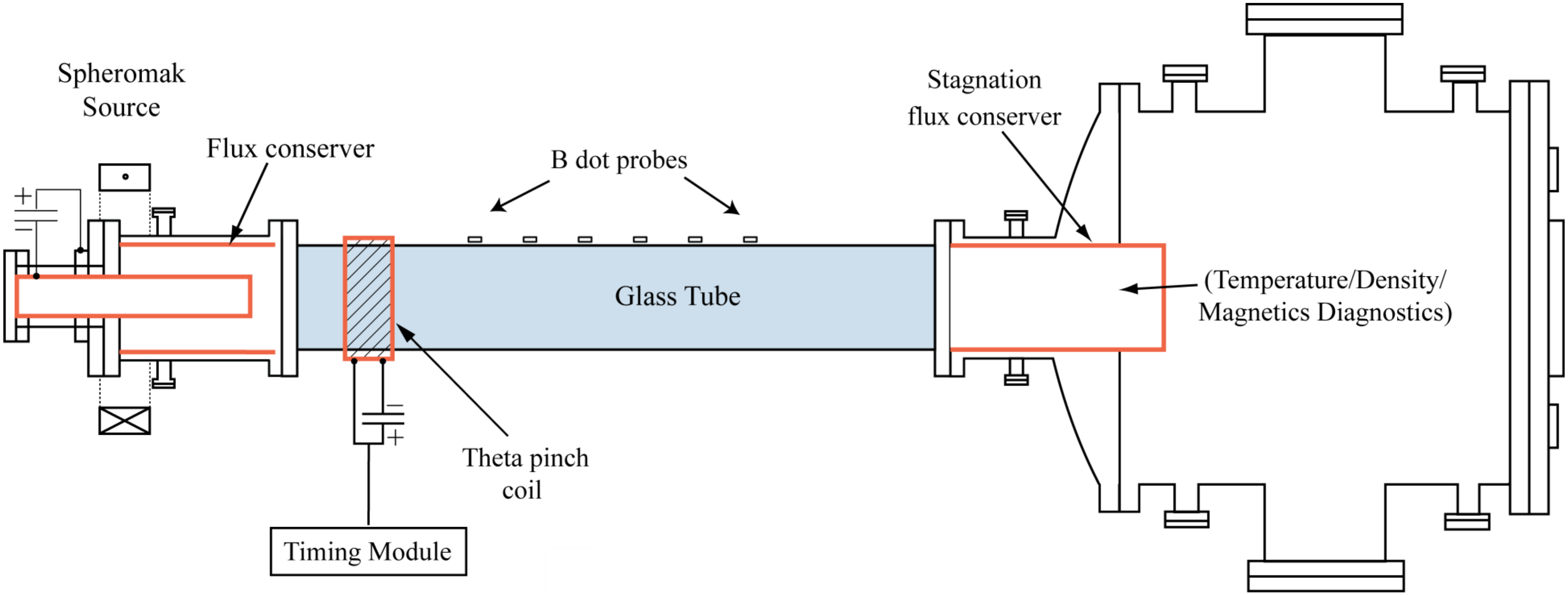
# Accelerated Plasma

# Acceleration with single theta pinch coil

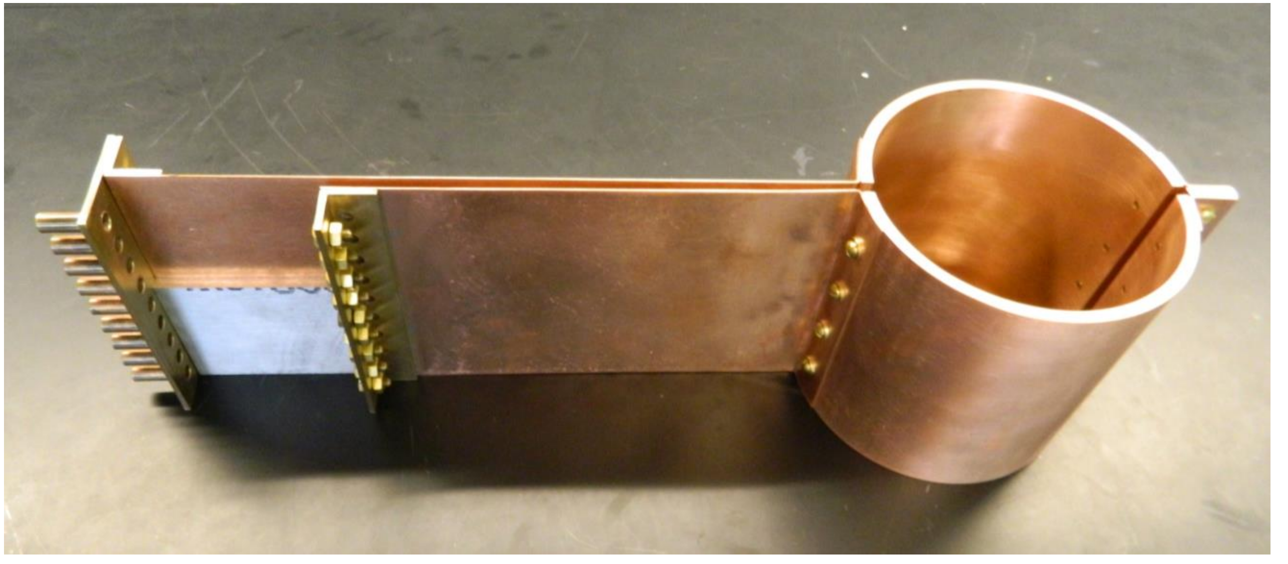


# Acceleration system capabilities

$$C \cong 1.3\ \mu F\ (@100\ kV)$$

| | |
|---|---|
| Power supply output voltage | $40\ kV$ |
| Energy stored, $E_C$ | $1\ kJ$ |
| Acceleration to velocity, $v_{acc}$ | $290\ km/s$ |
| @25% efficiency, $v_{acc}$ | $145\ km/s$ |

# Pulsed theta pinch coil



Multiple parallel coaxial cable connections

to reduce inductance, $L \approx 1\ \mu H$

$$\tau_{1/4} \propto \sqrt{LC} \cong 1\ \mu sec$$

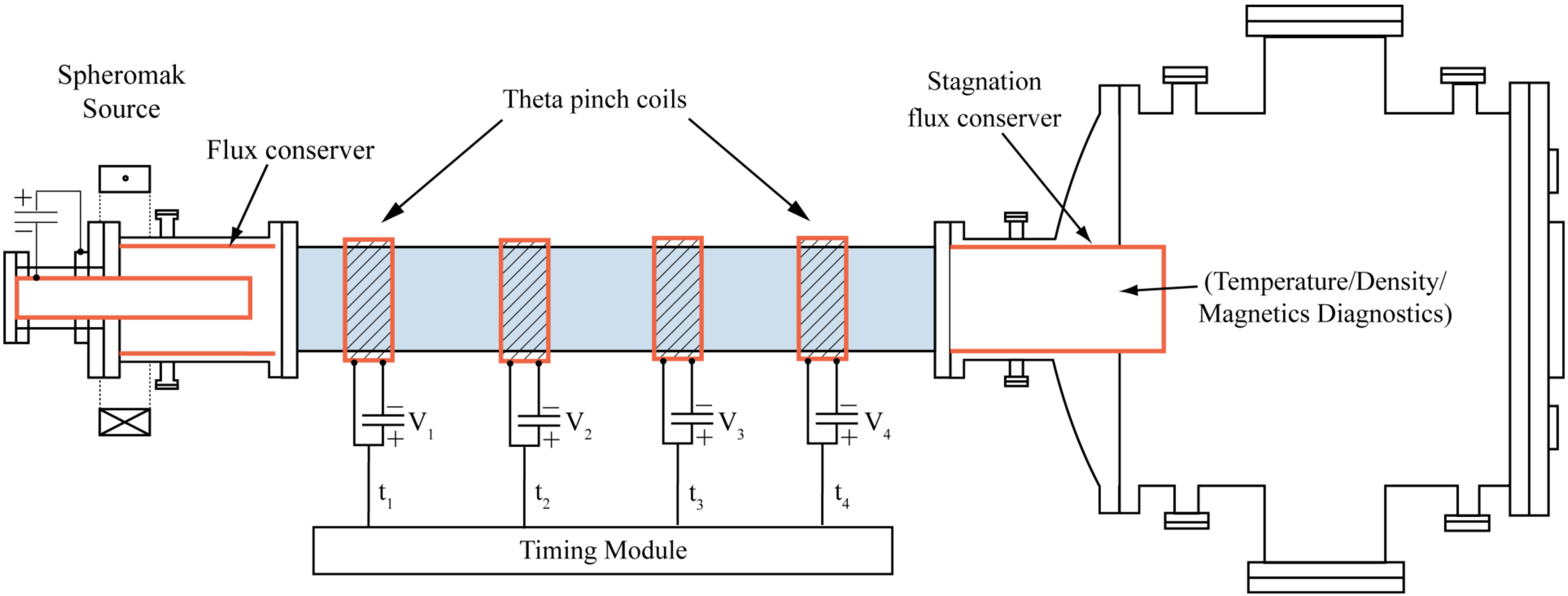
# Progress

- Theta pinch coil & stagnation flux conserver are ready to be installed.

- Assembling the different parts of the Capacitor charging and discharging circuit i.e., Bochkov switches, Ross relay, diodes, resistors, and capacitors and timing modules etc. (Ian Allfrey & Travis Valentine (TAE) are helping us with their useful suggestions)

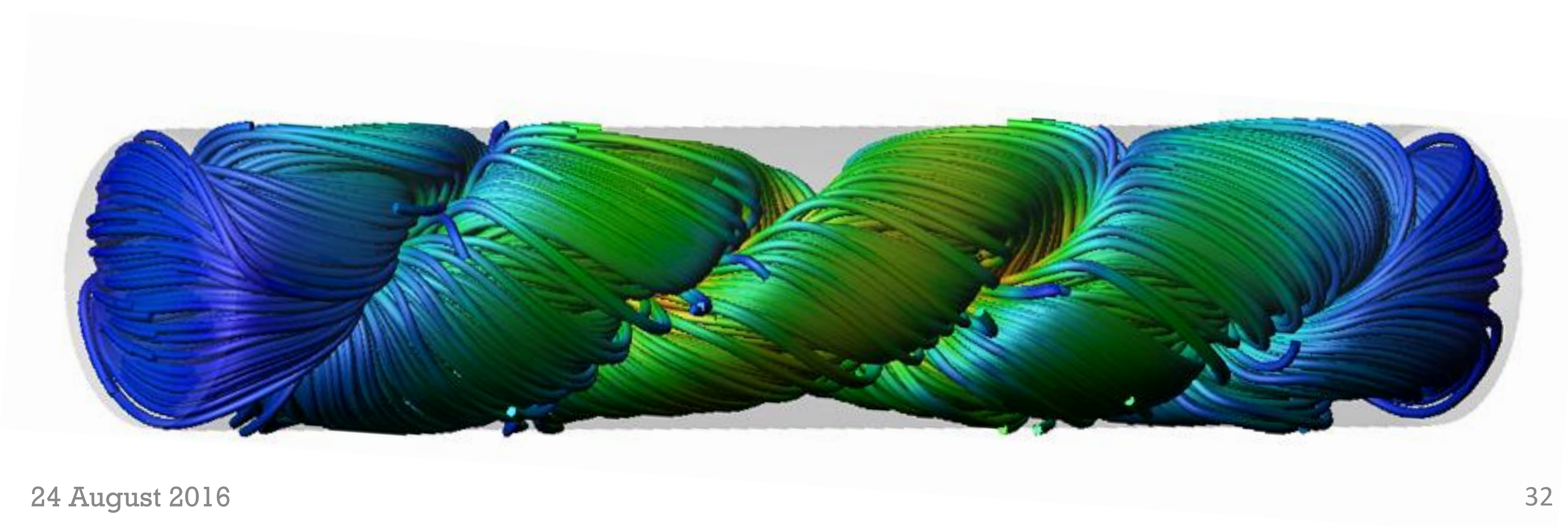
# Ultimate goal

Four theta pinch coils will be triggered **separately** & **sequentially** to accelerate plasma to **velocities over 200 $km/s$** and to achieve **compressional density over $10^{16}$ $cm^{-3}$**



# Summary

- Taylor state characterized in new glass extension with a variety of liners, ready for stagnation experiments
- Theta pinch coil and accelerator test stand ($1\ \mu F$ @ $20\ kV$) nearly ready using TAE components



# Thank you