

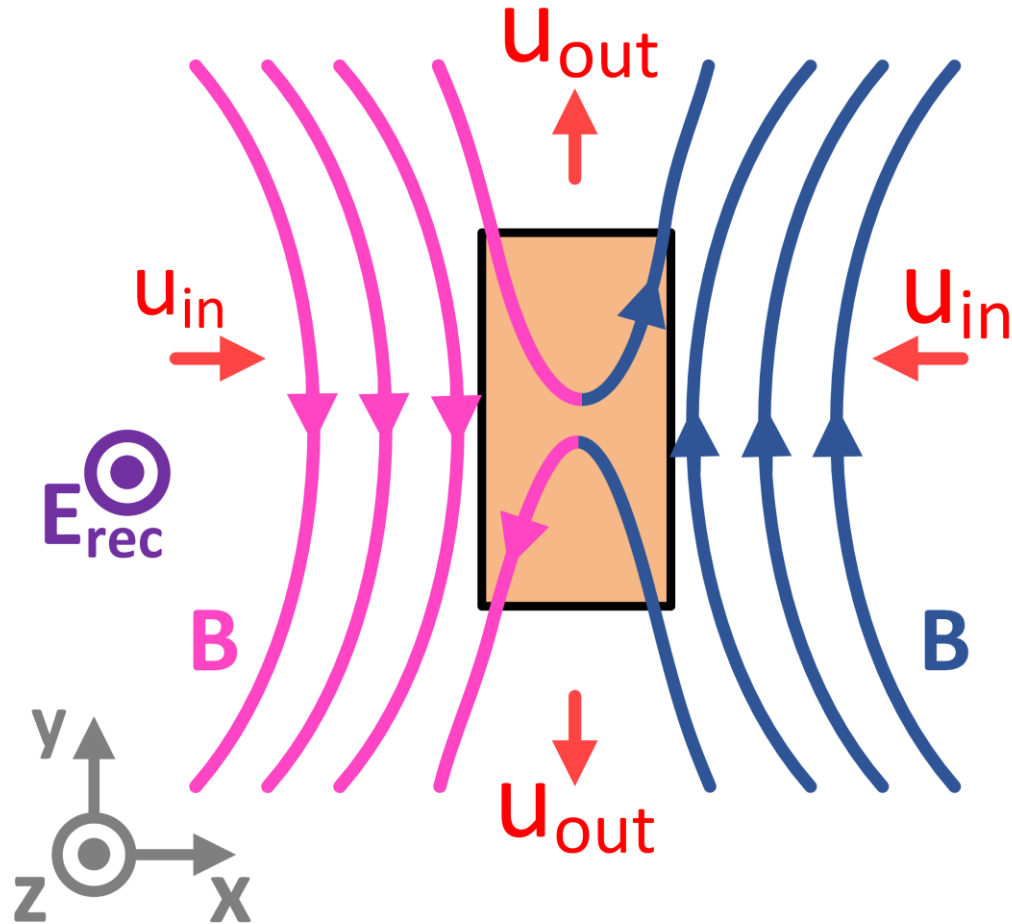
Particle Acceleration in Pulsed Power Driven Magnetic Reconnection

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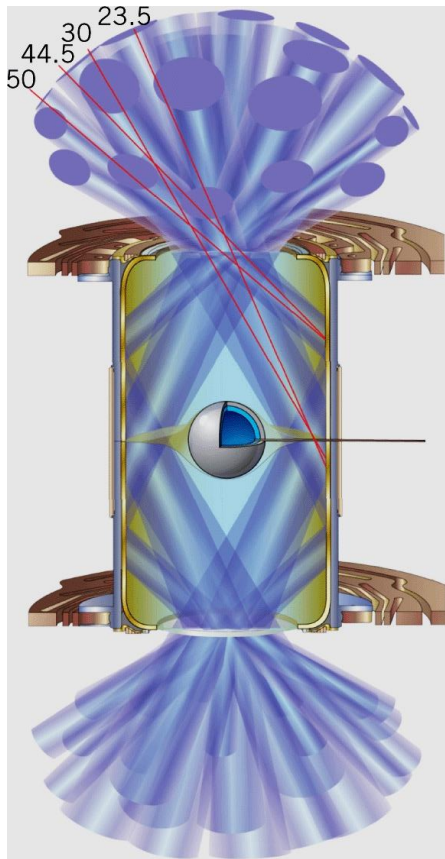
Imperial College: J. D. Hare, L. G. Suttle, S. V. Lebedev, S. N. Bland, E. R. Tubman, D. R. Russell, T. A. Clayson, F. Suzuki-Vidal

Cornell University & Lebedev Institute: S. A. Pikuz, and T. A. Shelkovenko.

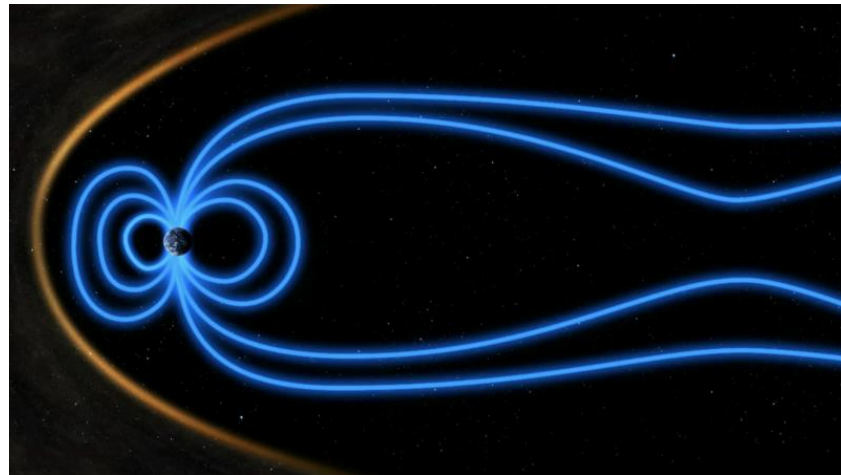
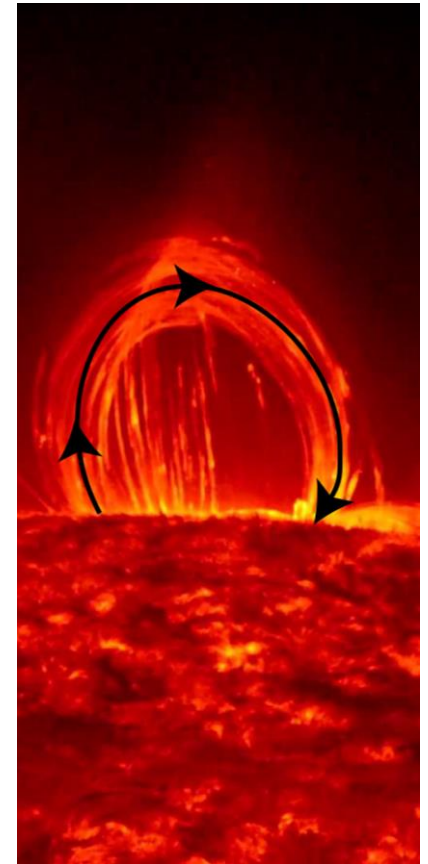
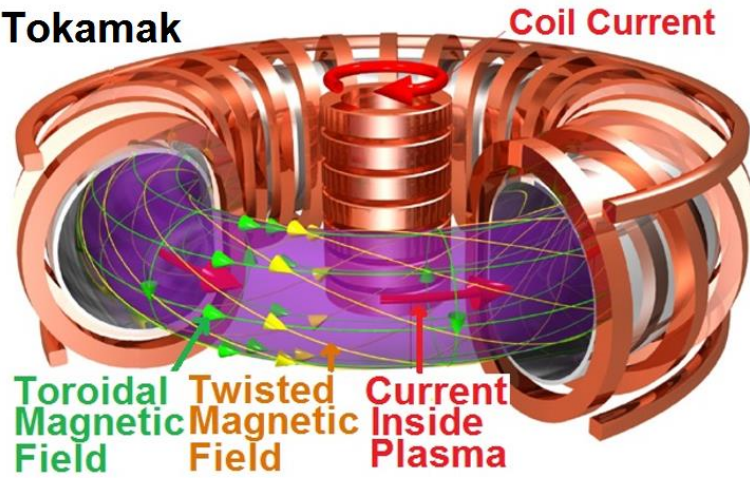
Magnetic Reconnection



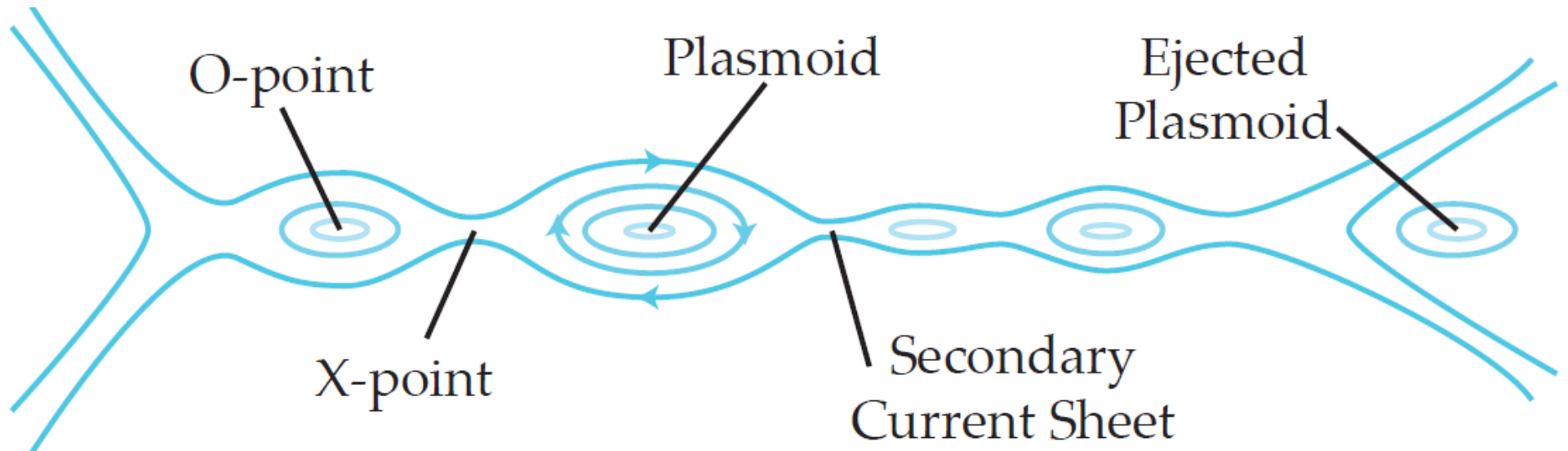
- Adjusts B field topology
- Heats plasma
- Accelerates plasma flows
- **Generates fast particles**



Tokamak

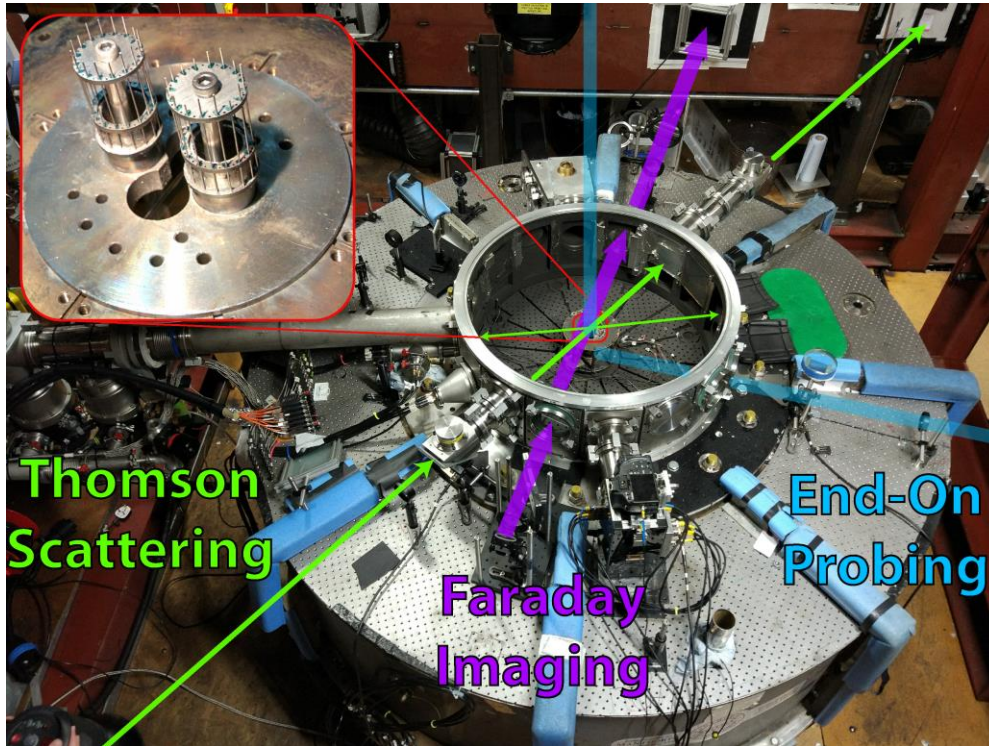


The Plasmoid Instability



Instability causes layer to break up into magnetic islands.

The MAGPIE Pulsed Power Generator



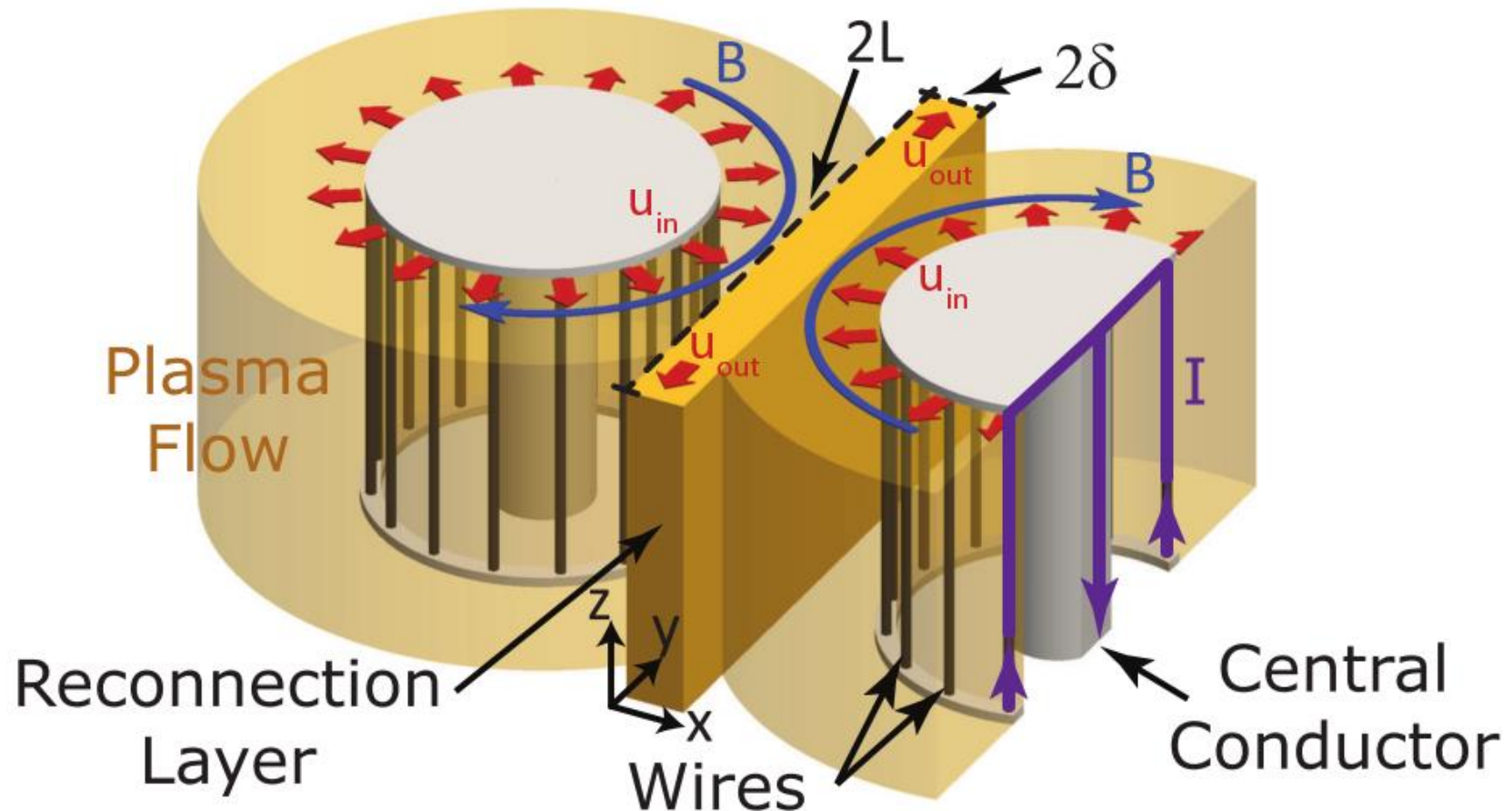
Mega-Ampere class pulsed power generator.

High Impedance → Flexible Loading.

Open Design → Good diagnostic access.

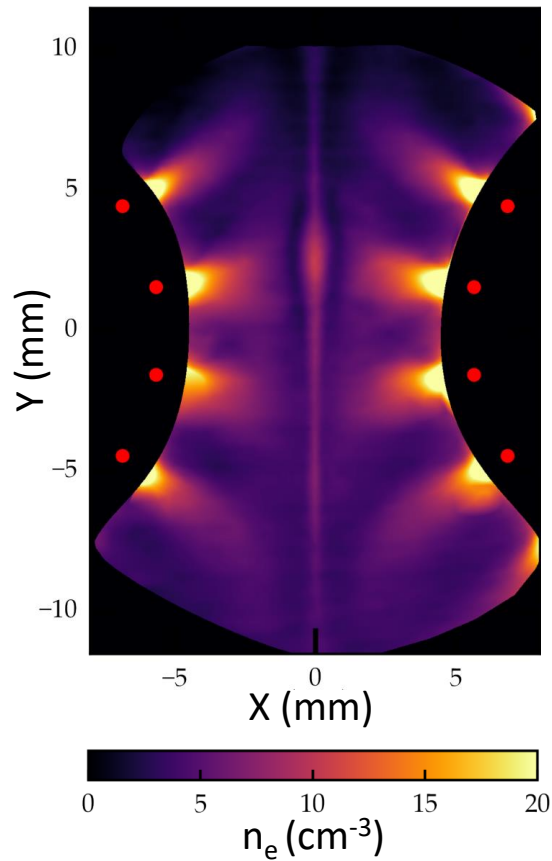
T_{drive}	L	B_{in}	β_{ram}	β_{thermal}	S
500 ns	~10 mm	3 T	~ 1	~ 1	~ 100

The MAGPIE Reconnection Platform

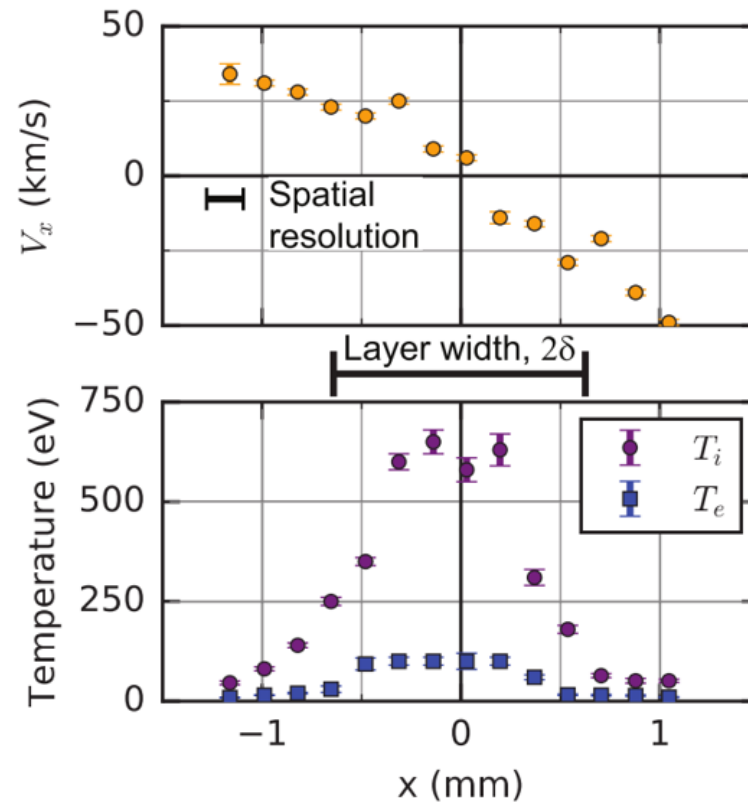


Diagnosing Plasma Flows

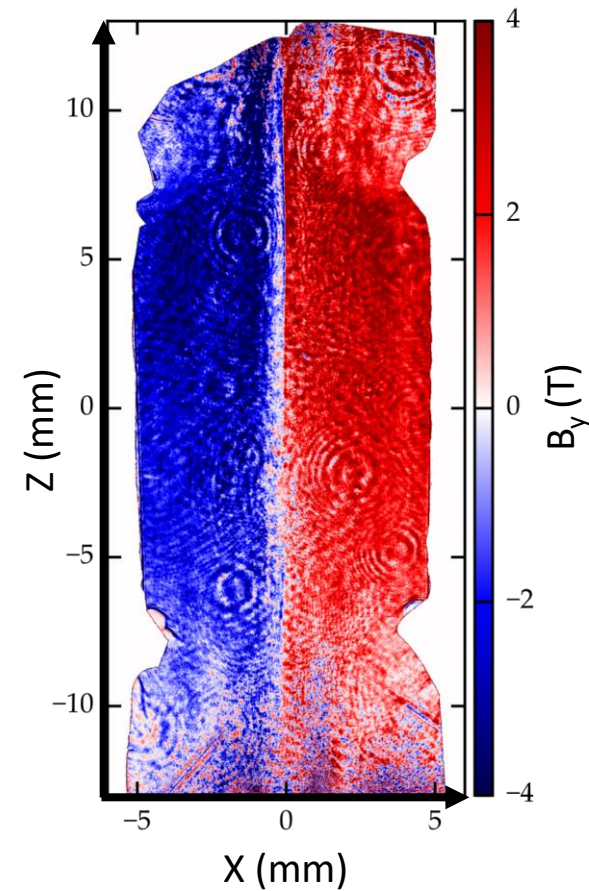
Interferometry



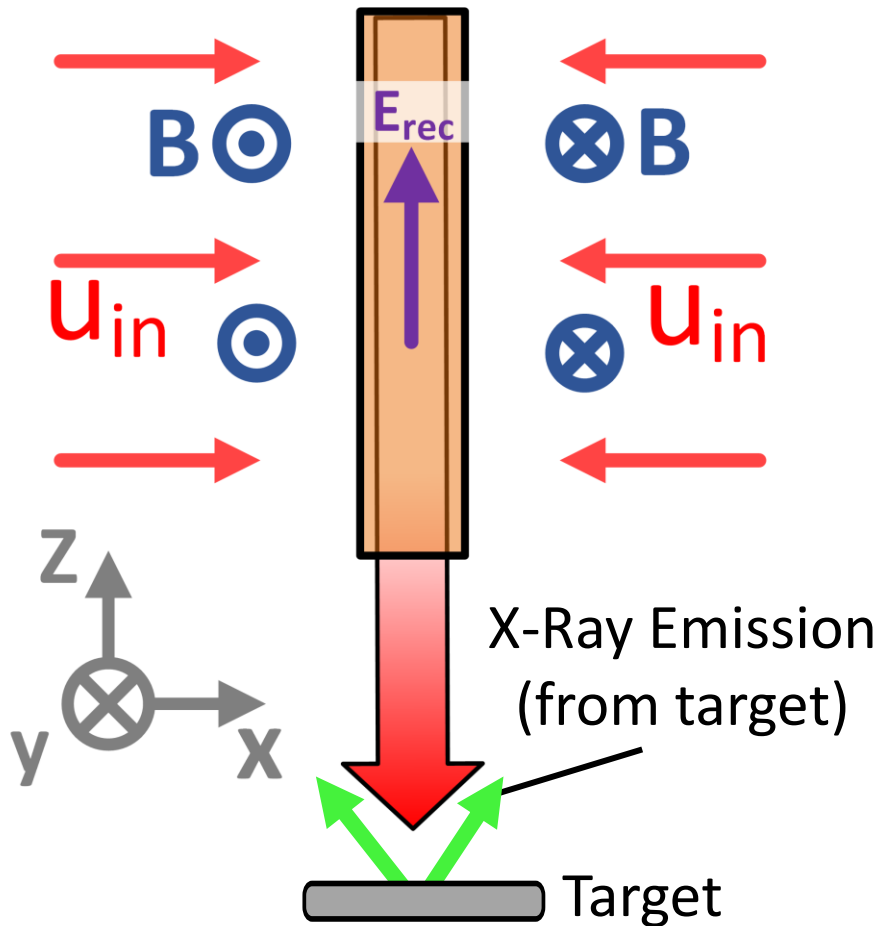
Thomson scattering



Faraday-Rotation Imaging



Particle Acceleration by Electric Fields



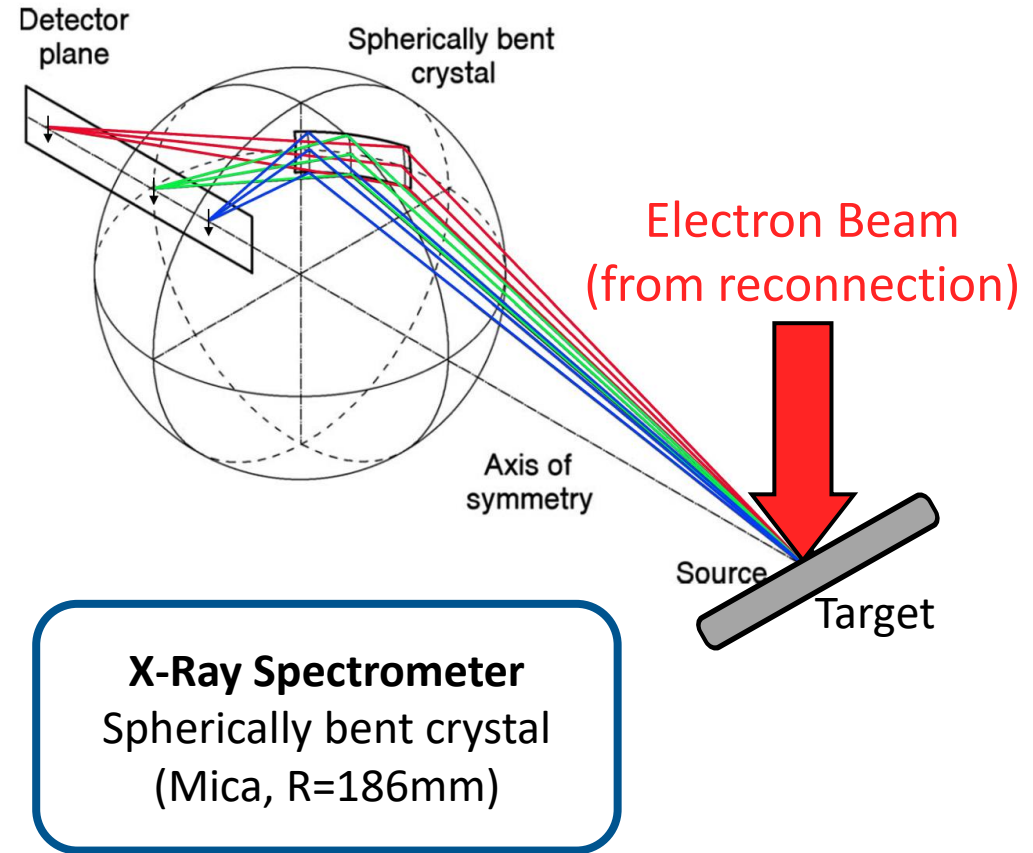
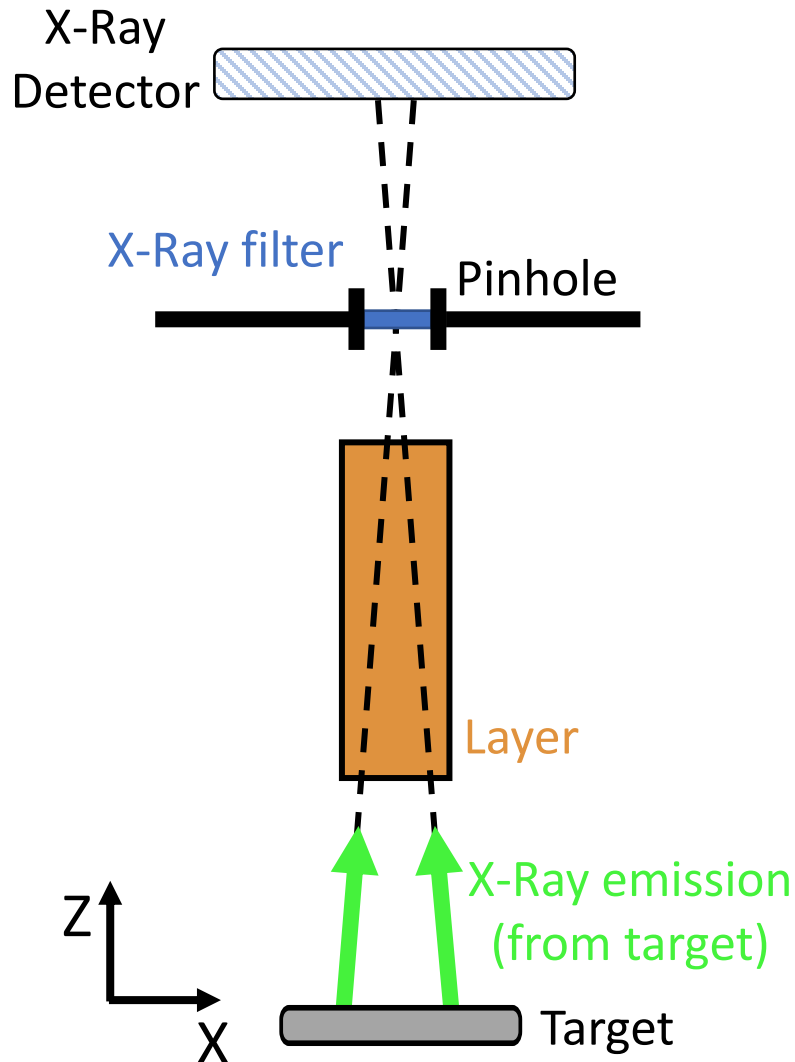
Parameter	Value	Diagnostic
u_{in}	50 km/s	Thomson Scattering
B_{in}	3 T	Faraday Rotation
L_z	16 mm	Interferometry

$$E_{rec} = u_{in} B_{in} = 150 \text{ kV/m}$$

$$\int \mathbf{F} \cdot d\mathbf{l} \sim e E_{rec} L_z = 2.4 \text{ keV}$$

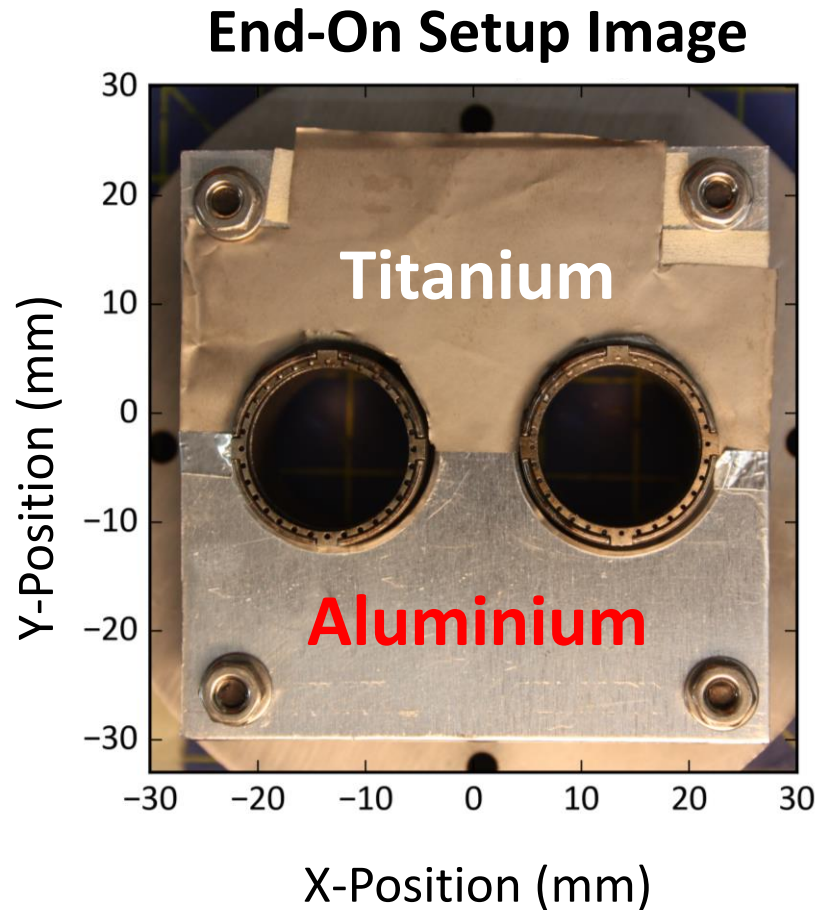
Steady State \rightarrow Electrons accelerated to more than 2 keV

X-Ray Imaging and Spectroscopy



(Figure adapted from S. A. Pikuz et al. 2008. Rev Sci Instr. 79, 013106)

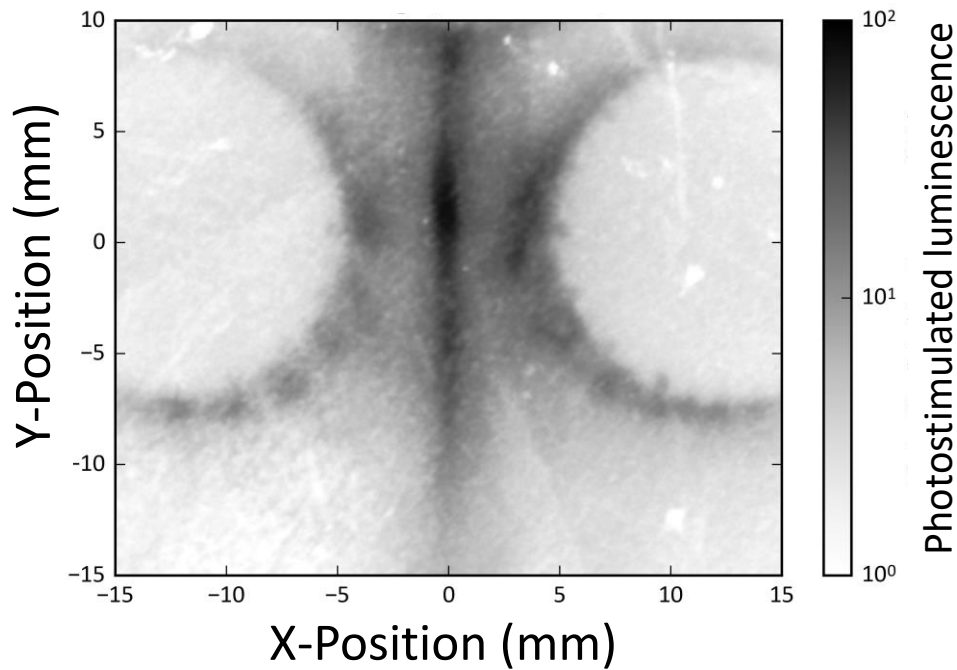
Time Integrated Pinhole Imaging



X-Ray filtering sets spectral range of emission captured in images.

Thomson Data $\rightarrow T_e \leq 100$ eV.

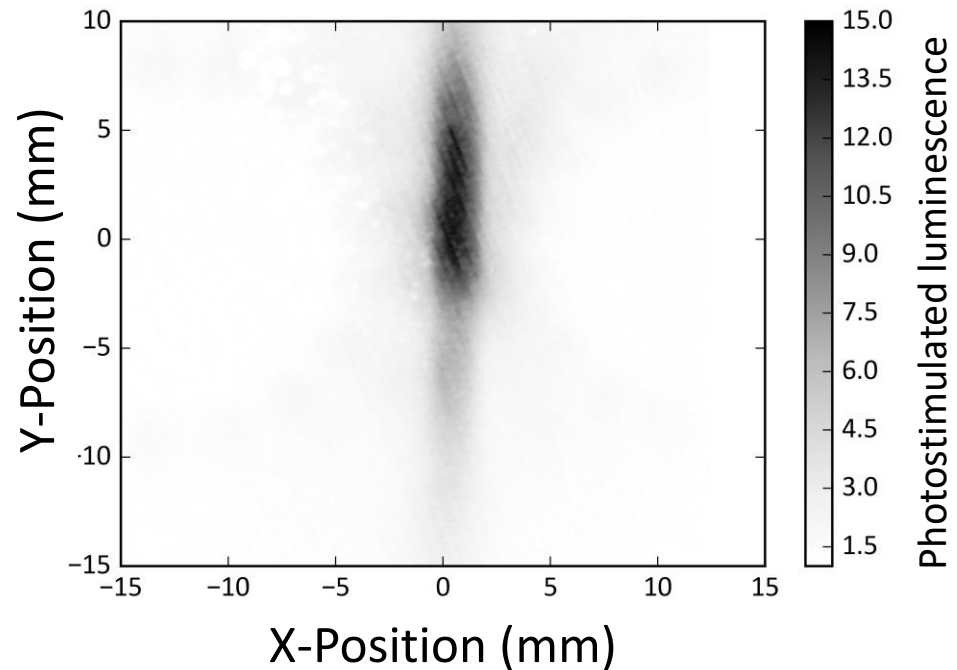
Emission at much higher energy is from non-thermal electrons.



XUV Image [100 – 400 eV]

Dominated by thermal emission from the plasma.

Structure of layer consistent with laser probing diagnostics.

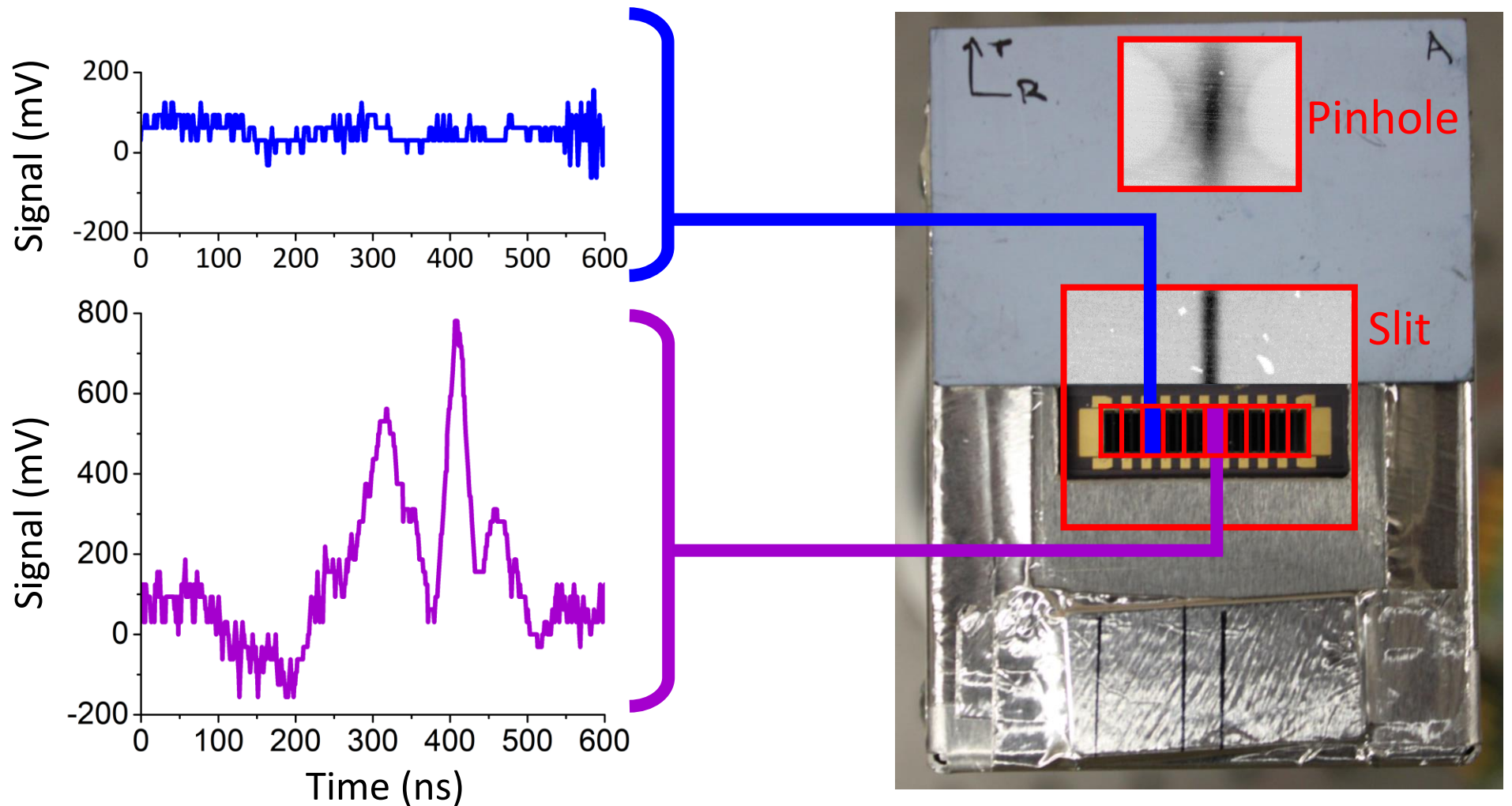


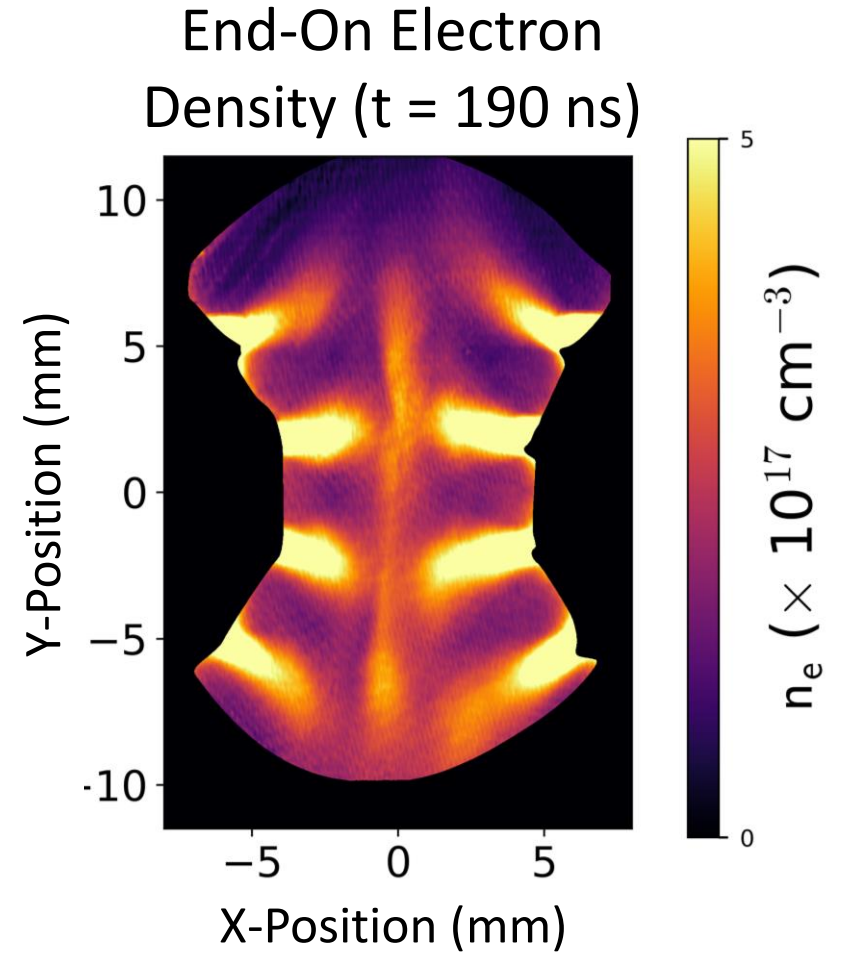
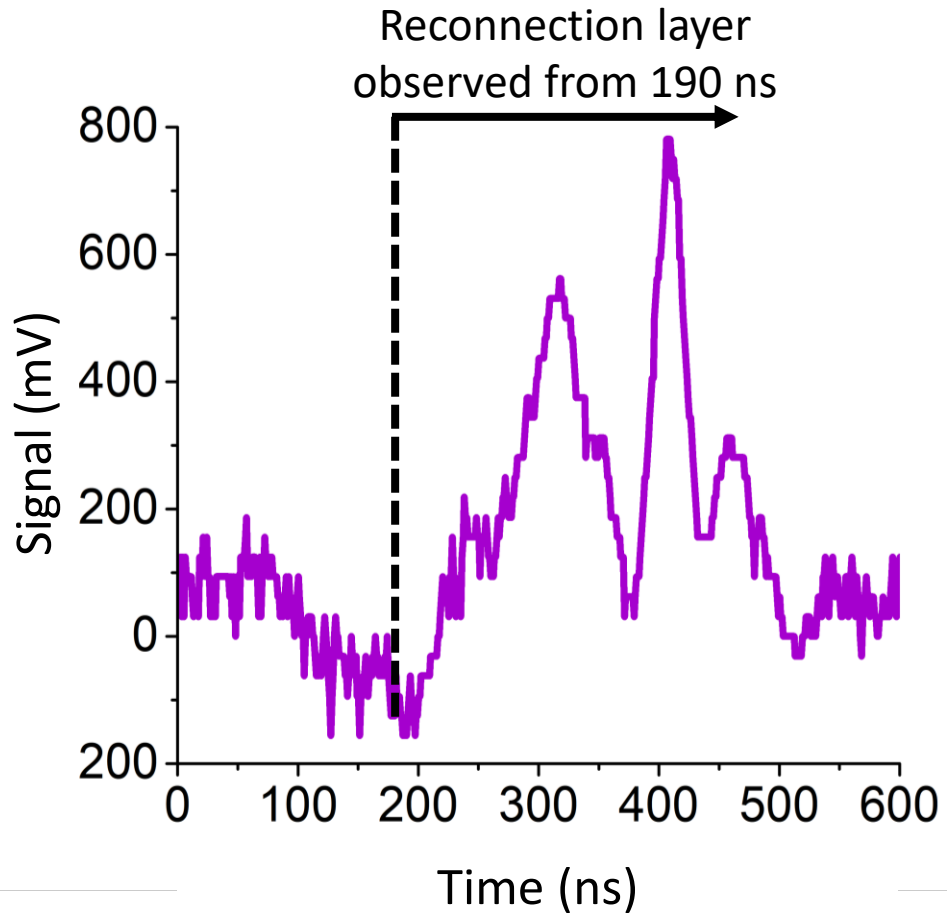
X-Ray Image [> 750 eV]

Change in intensity shows emission is from the target.

Emission is caused by fast electrons accelerated in the layer.

Time Resolved Pinhole Imaging

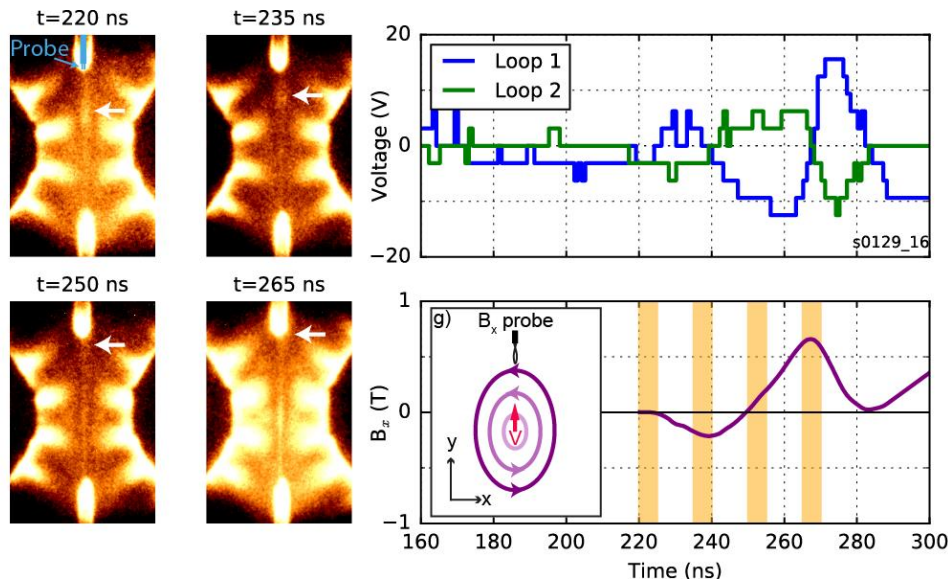




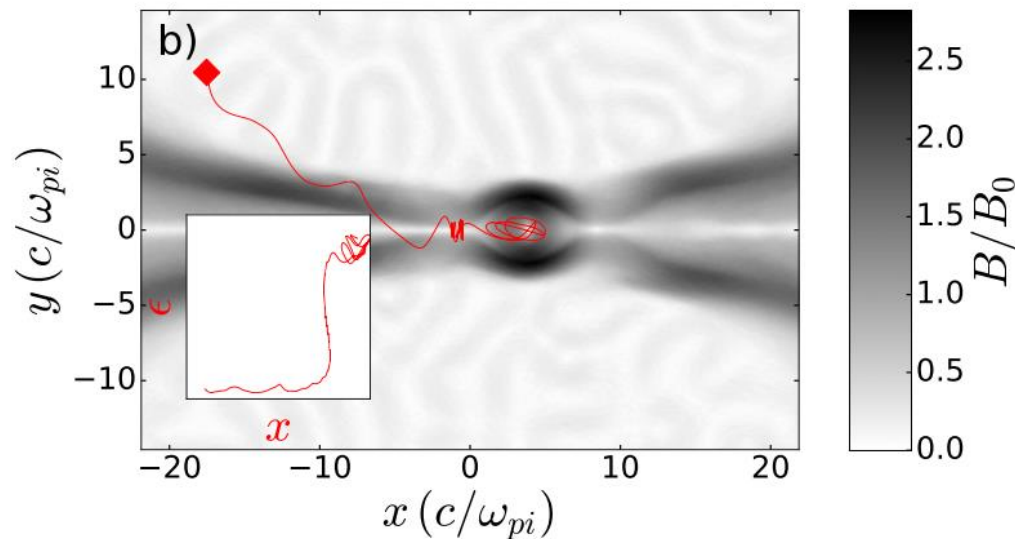
Acceleration occurs after the reconnection layer has Formed.

X-Ray Signal is bursty \rightarrow non steady-state physics / instability.

The Plasmoid Instability

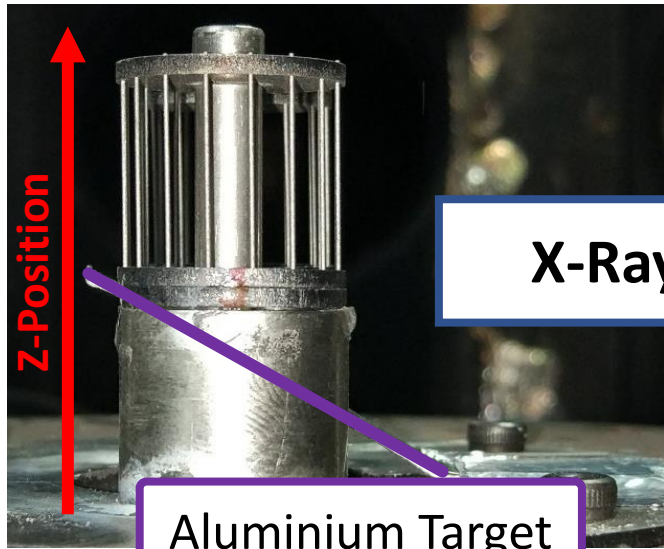


Semi-collisional plasmoid instability occurs in pulsed power driven reconnection experiments.
[J. D. Hare *et al.* PoP 2017]



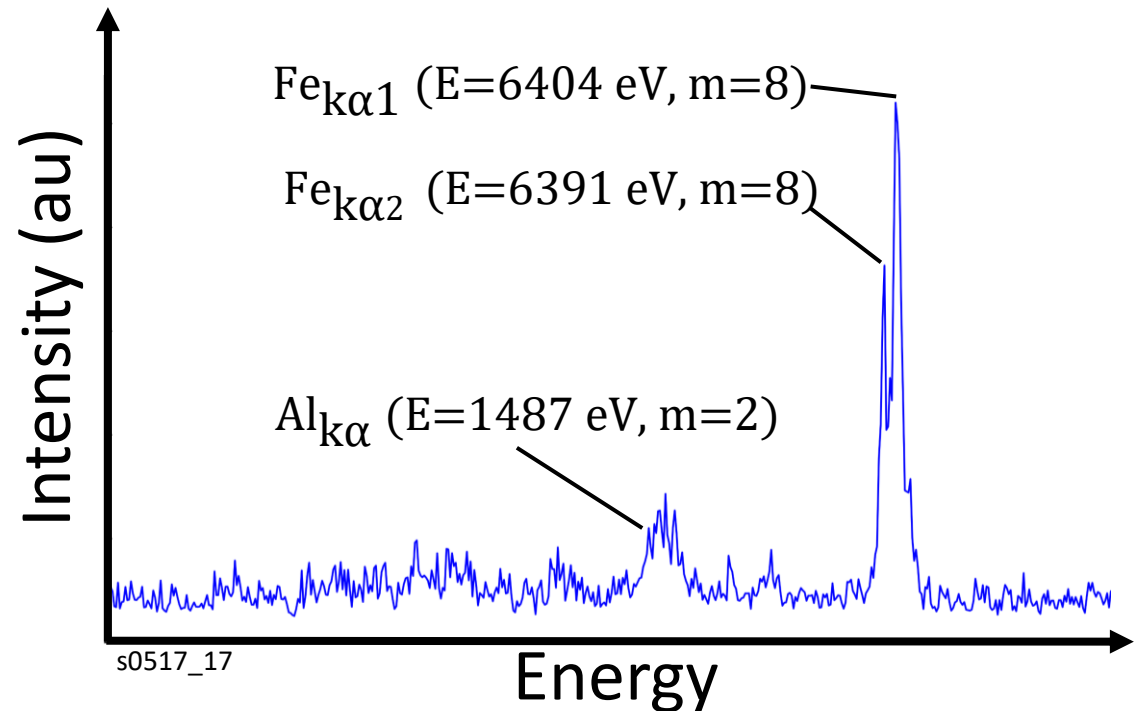
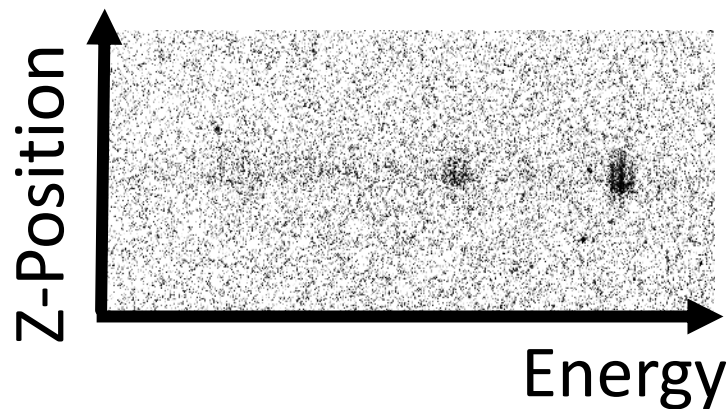
Fermi acceleration in plasmoids is a proposed mechanism for non steady-state electron acceleration.
[S. R. Tatorica *et al.* PoP 2017]

Time Integrated X-Ray Spectra

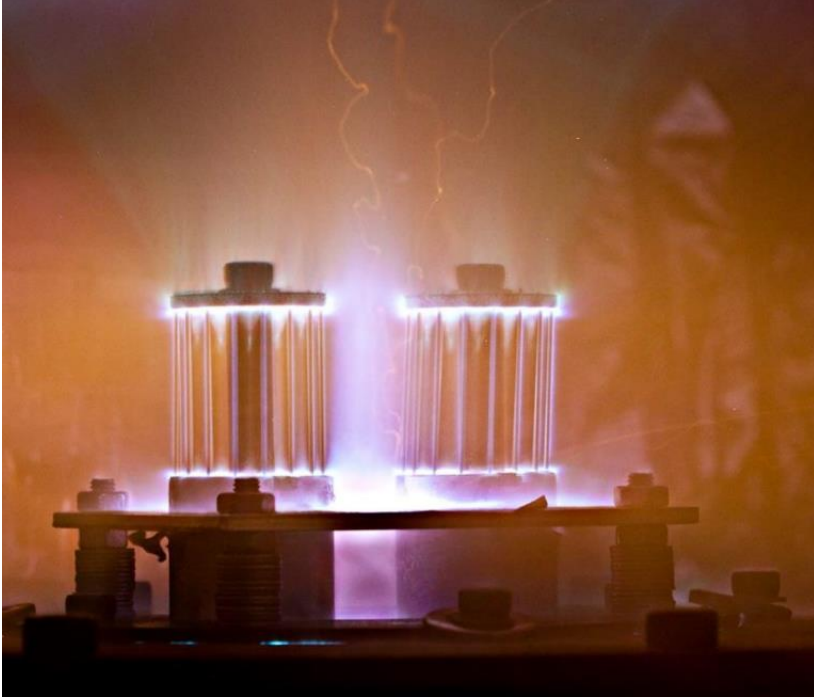


X-Ray Emission (from target)

Spherically Bent Crystal Spectrometer



Conclusions



- Reconnection layer accelerates electrons to energies over 2 keV
- Consistent with acceleration by the reconnecting electric field
- Acceleration bursty \Rightarrow non steady-state physics / instabilities?

[L. G. Suttle *et al.* – PRL 2016; PoP 2018]

[J. D. Hare *et al.* – PRL 2017; PoP 2017; PoP 2018]