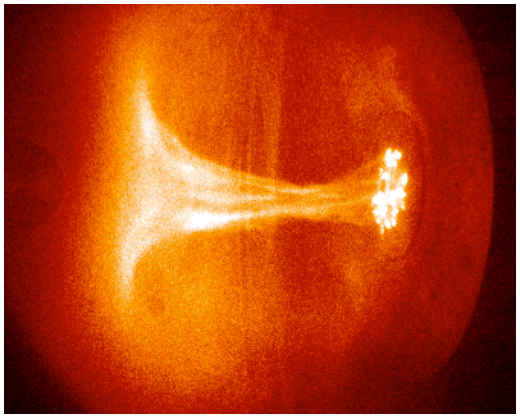
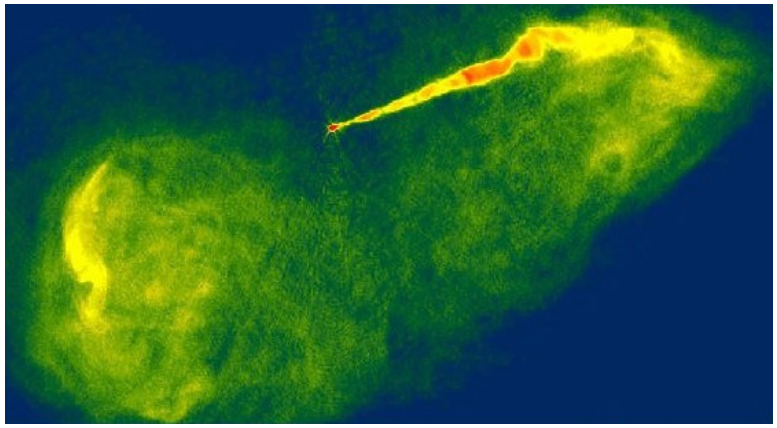




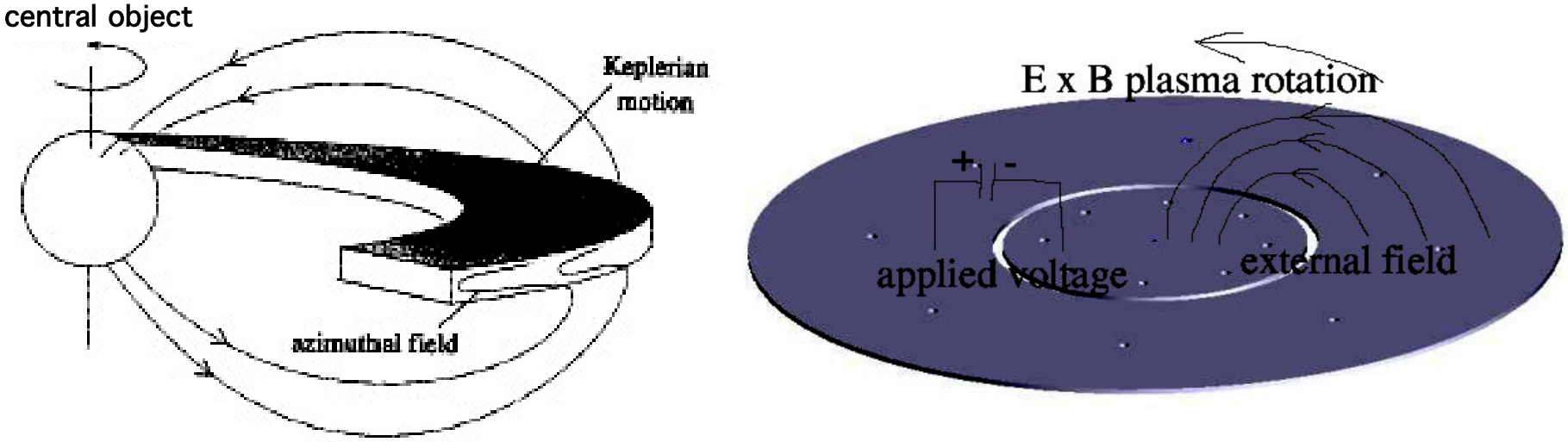
Experiments on the Plasma Physics of Galactic Jet Formation

Scott C. Hsu
Los Alamos National Laboratory

Collaborators: Paul Bellan (Caltech) and Xianzhu Tang (LANL)

CMSO Disk/Jet/Lobe Workshop
PPPL, April 27, 2005

How We Study Jet Formation in the Laboratory



disk/corona obeys (to first approx.) ideal MHD Ohm's law:

$$\mathbf{E} + \mathbf{V} \times \mathbf{B} = 0 \rightarrow E_R = -V_\theta B_Z + V_Z B_\theta$$

applied voltage (lab)

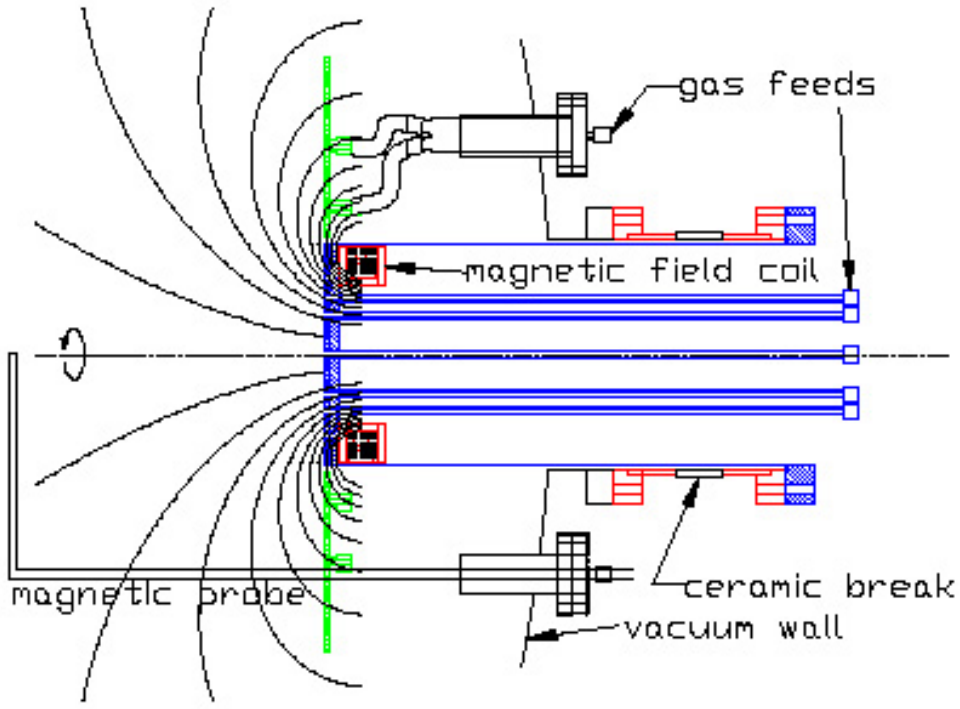
Keplerian rotation (disk)

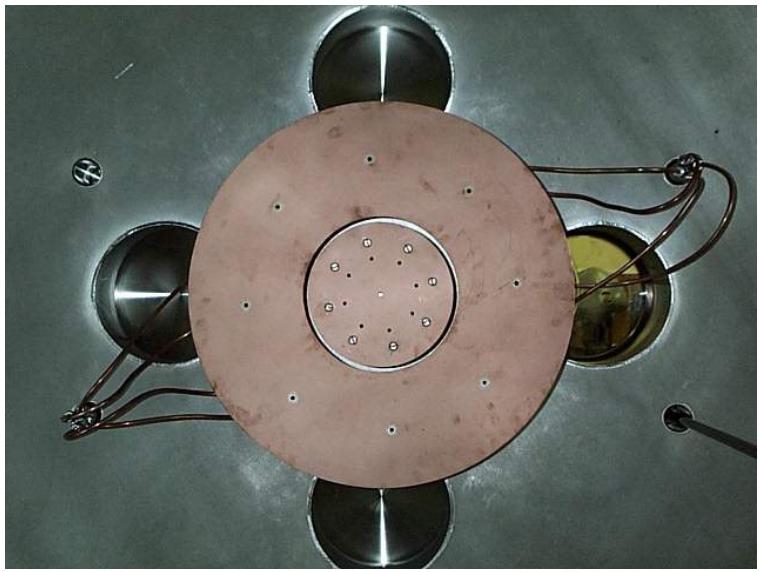
Field-aligned current twists up background magnetic field and injects magnetic helicity

Caltech Experimental Results

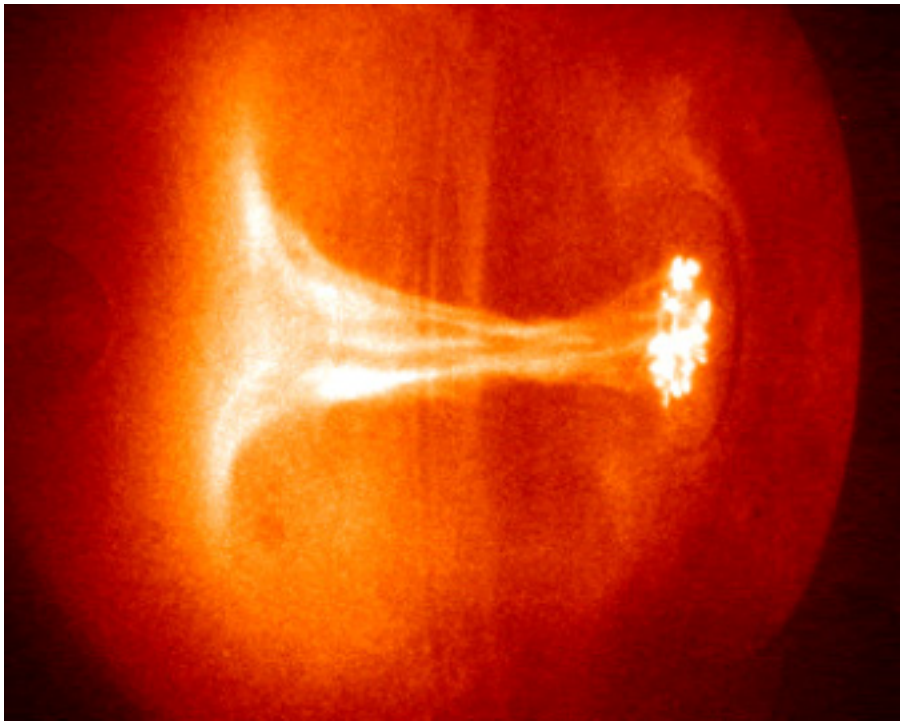
(in collaboration with Paul Bellan)

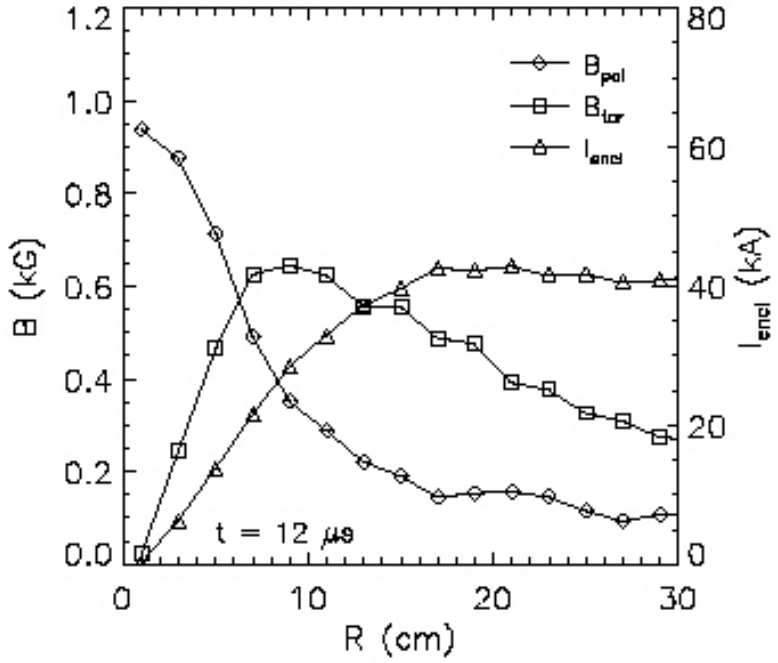
A Simple Magnetic Helicity Injector: Biased Concentric Electrodes





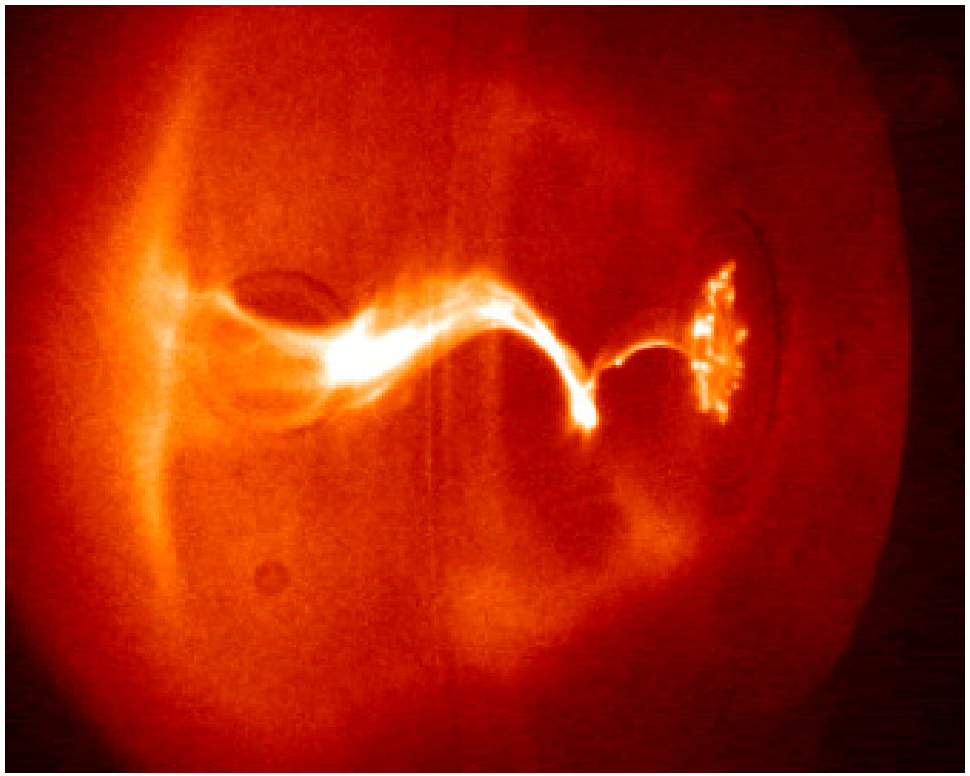
Helicity Injection Leads to Collimated Screw Pinch

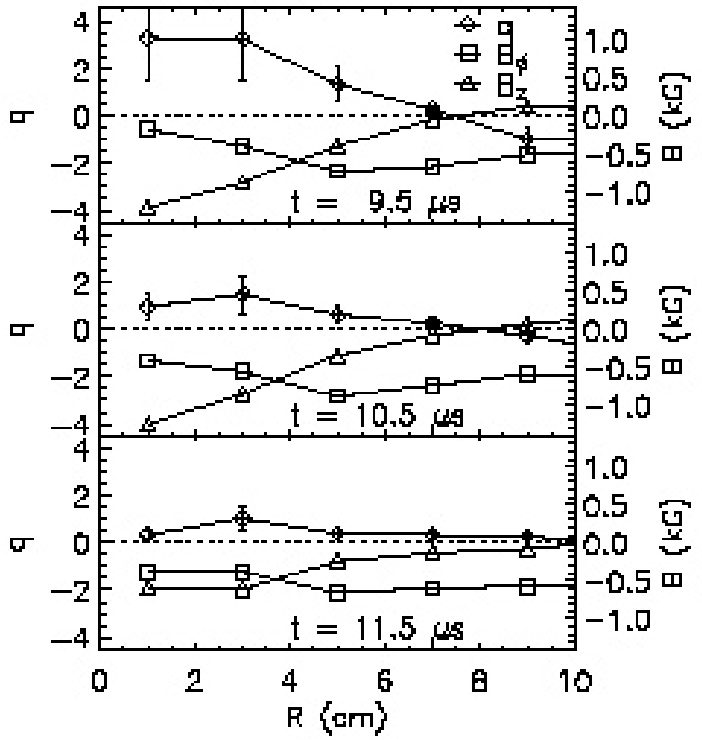




Hsu & Bellan, MNRAS (2002) & PoP (2005)

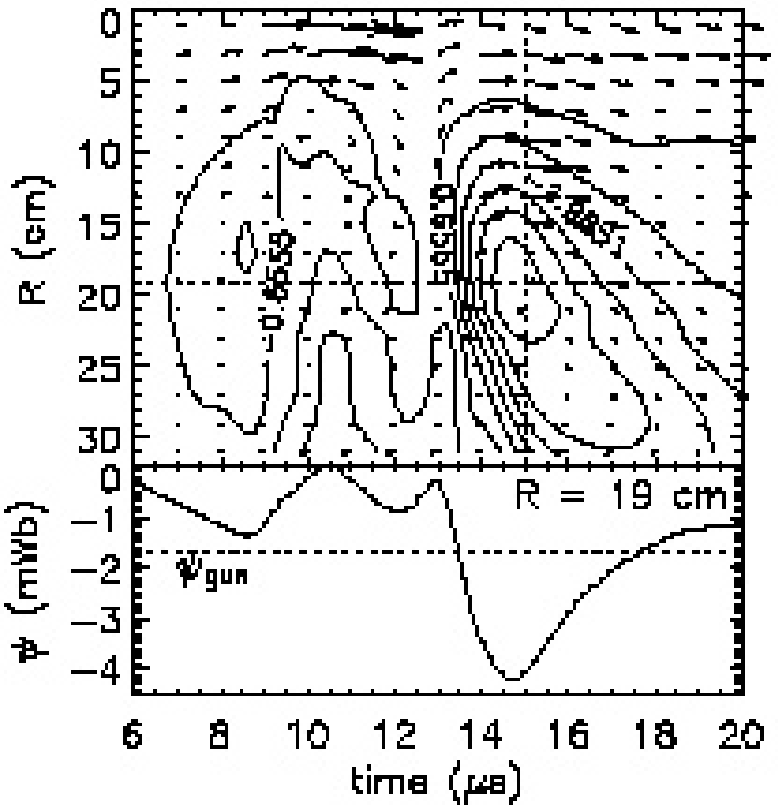
Jet Develops Kink When Kruskal-Shafranov Limit Satisfied

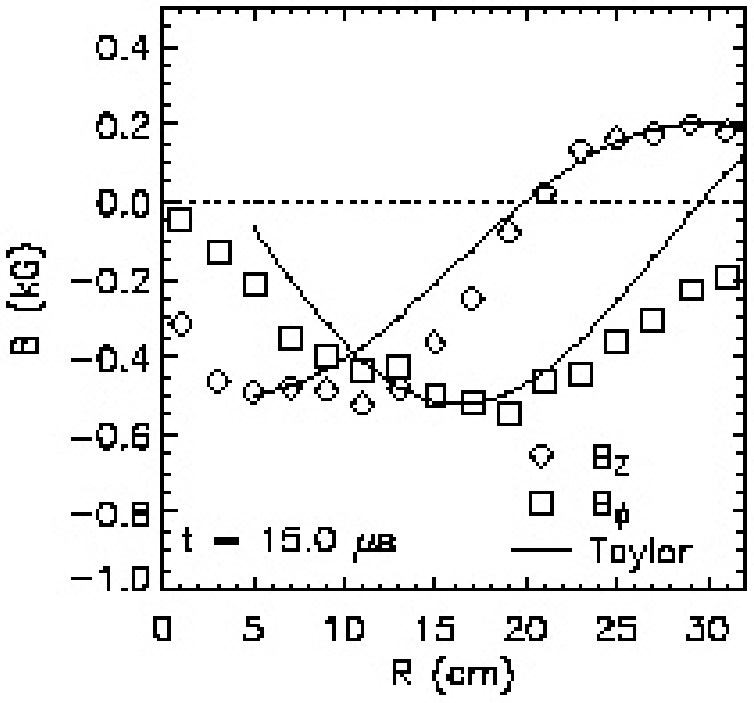




Hsu & Bellan, MNRAS (2002) & PRL (2003)

Kink Provides Flux Conversion Dynamo Leading to Spheromak Formation





Hsu & Bellan, PRL (2003)

Proposed Experiments on LAPD

Hsu & Tang, “Research White Paper for LAPD,” approved by Gekelman and BAPSF Science Council (2004).

Hsu & Tang, proposal submitted to DOE OFES “Opportunities in Basic Plasma Science” (2005).

Key New Features of Proposed Experiments

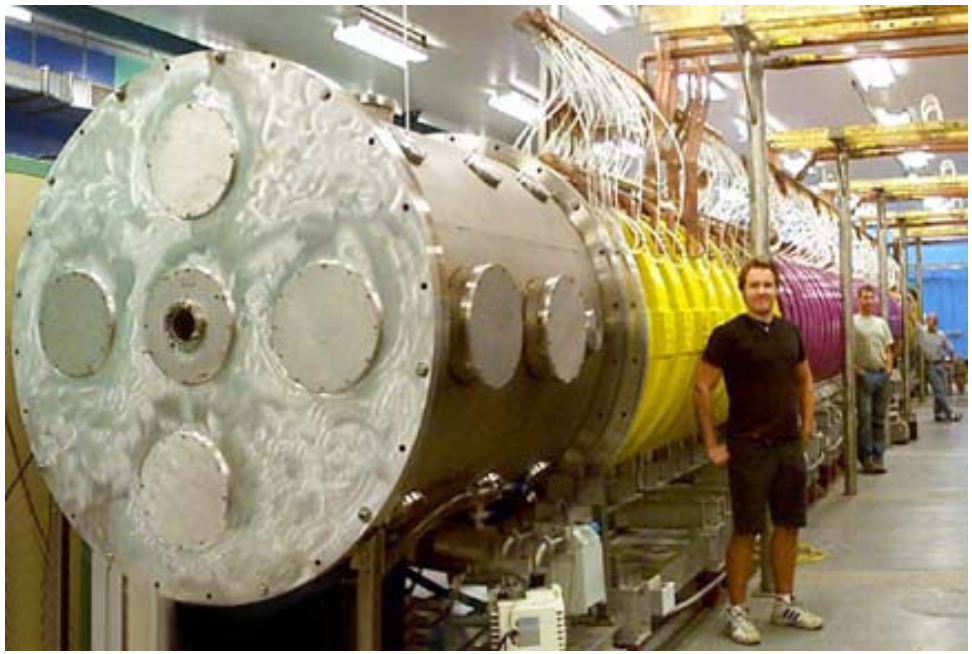
- Very low β (avoid arc discharge, separate plasma formation and helicity injection)
- Helicity injection rate ($\sim E_R$) scannable over wider range (lower voltages possible due to pre-existing plasma)
- 3-electrode configuration allows unipolar, Keplerian rotation profile ($E_R/B_Z \sim R^{-1/2}$)
- Pre-existing plasma allows jet to interact with background
- Longer timescale to allow >20 rotations
- Volumetric diagnostics

Research Plan

- Dimensionless parameters identified* to investigate jet morphology and stability
  - Collimation dependence on helicity injection rate ($V_m \sim V_{E\times B}/V_A \sim \rho^{1/2}\ V_{inj}/B_0^2$)
  - Collimation dependence on jet stability ($V_s \sim V_{inj}/\langle V_{drop}\rangle \sim V_{inj} q_0/\eta B_0$)
- Measure magnetic energy and helicity content
- Measure magnetic energy dissipation and angular momentum transfer between jet and background

*Tang et al., BAPS (2002, 2003) and PoP (2004).

New Experiments Will Be Done on LAPD at UCLA



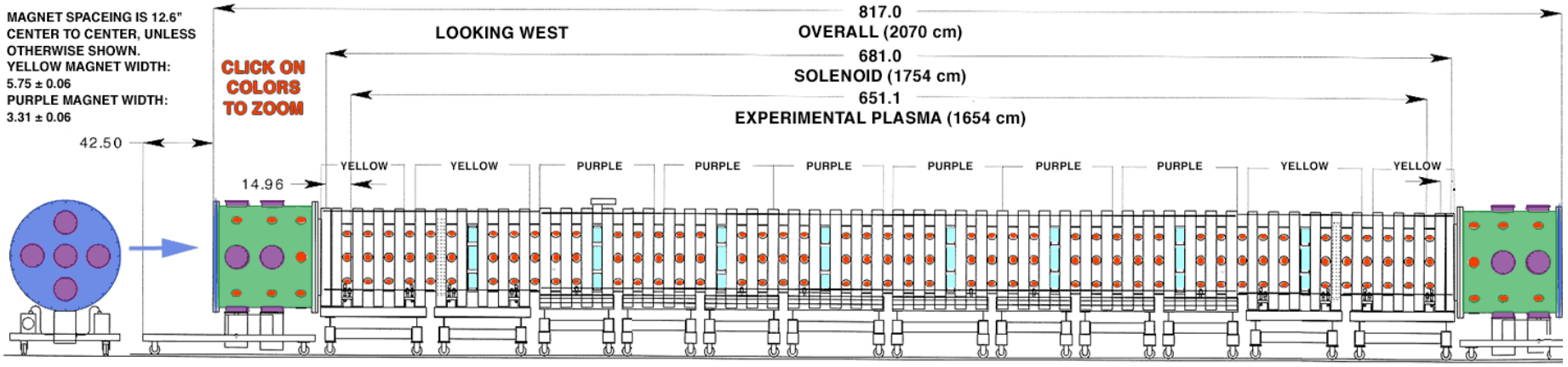
LAPD: Large Plasma Device

$T_e \sim 5$ eV

$n \sim 10^{12}$ cm^{-3}

$B \sim 1$ kG

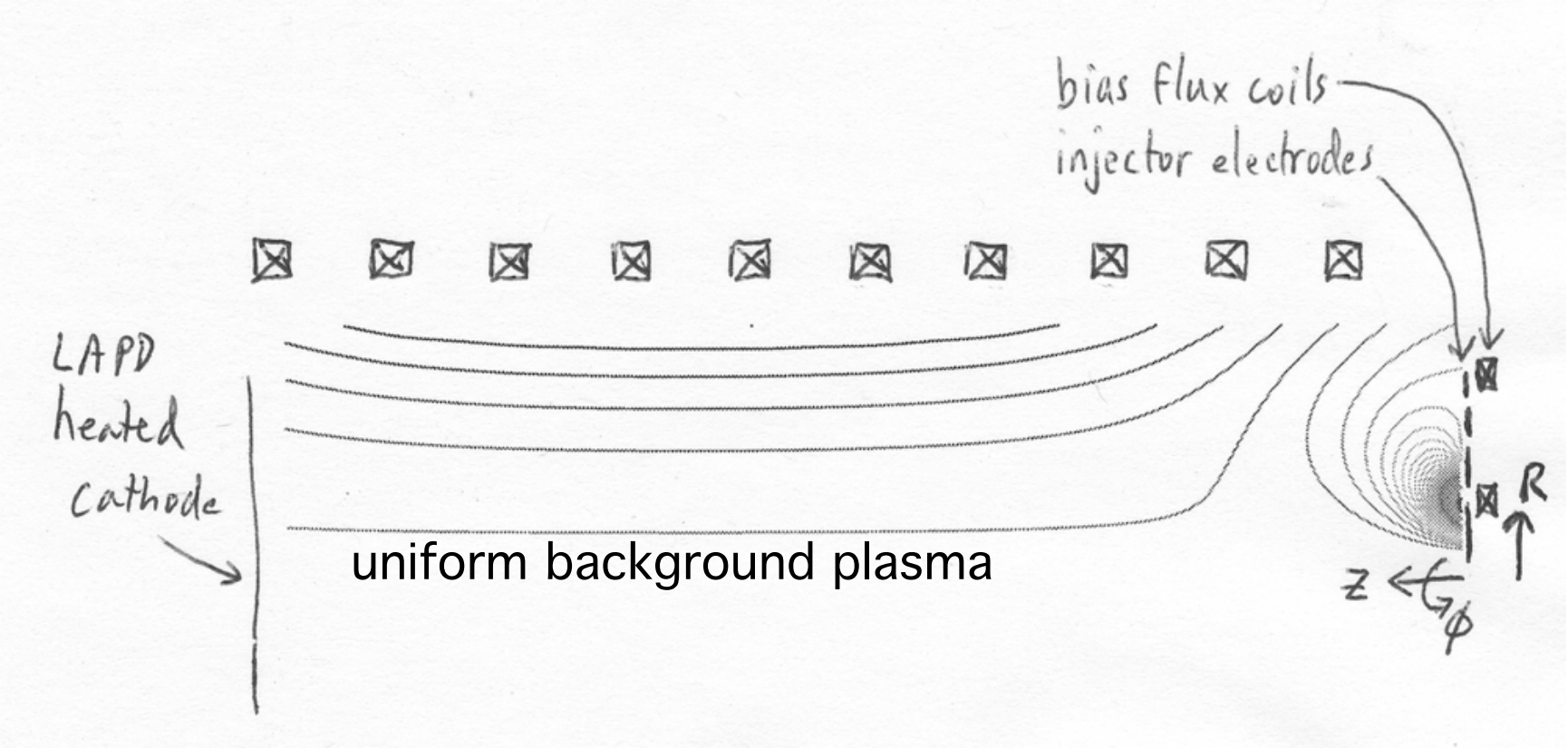
5 ms duration repeated at 1 Hz



LAPD Provides Good Environment for Studying Jet Formation via Helicity Injection

- Uniform quiescent background plasma 5 ms duration
- $L/\rho_i \sim 100$ (well-magnetized)
- magnetic Reynold's number up to 5000 (plasma well frozen into field lines)
- Vacuum chamber ~20:1 length:diameter (allows long collimated jet)
- 1 Hz rep rate (allows acquisition of volumetric data sets)

We Will Install Concentric Ring Electrodes with Coil-Generated "Bias Flux" into LAPD



applied voltage between electrodes generated by switched capacitor banks