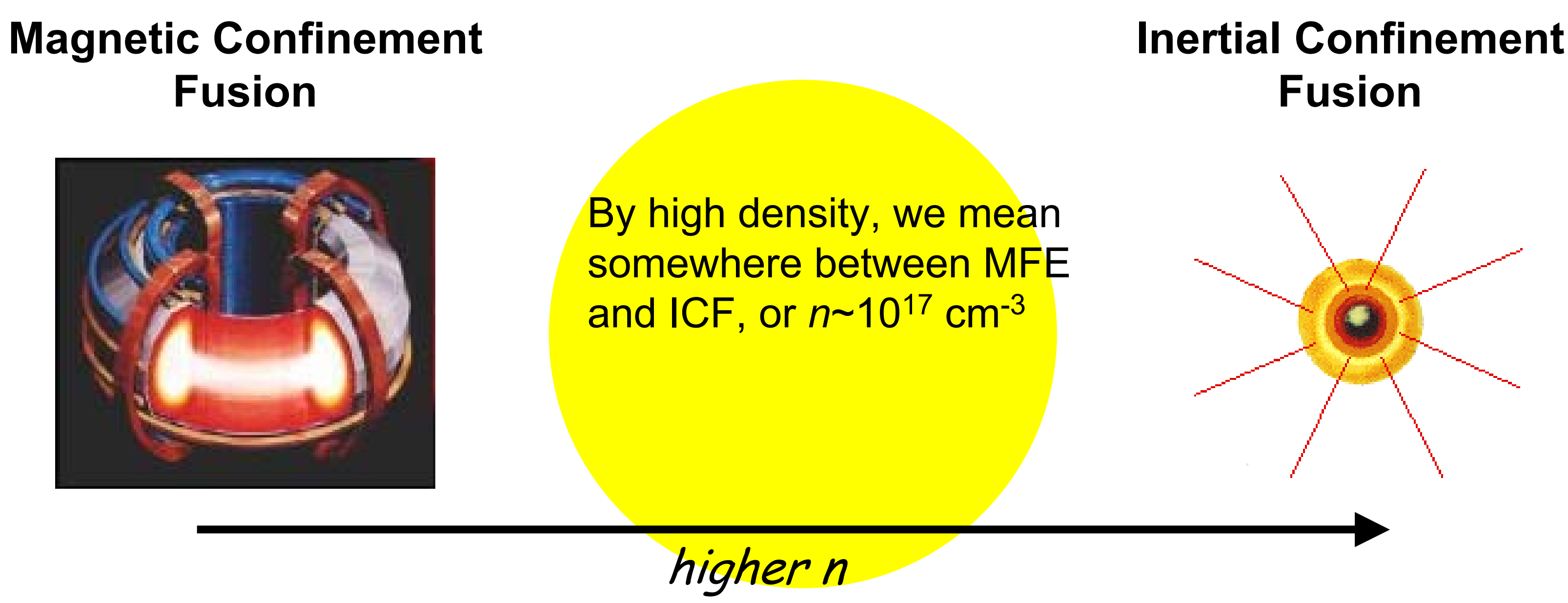
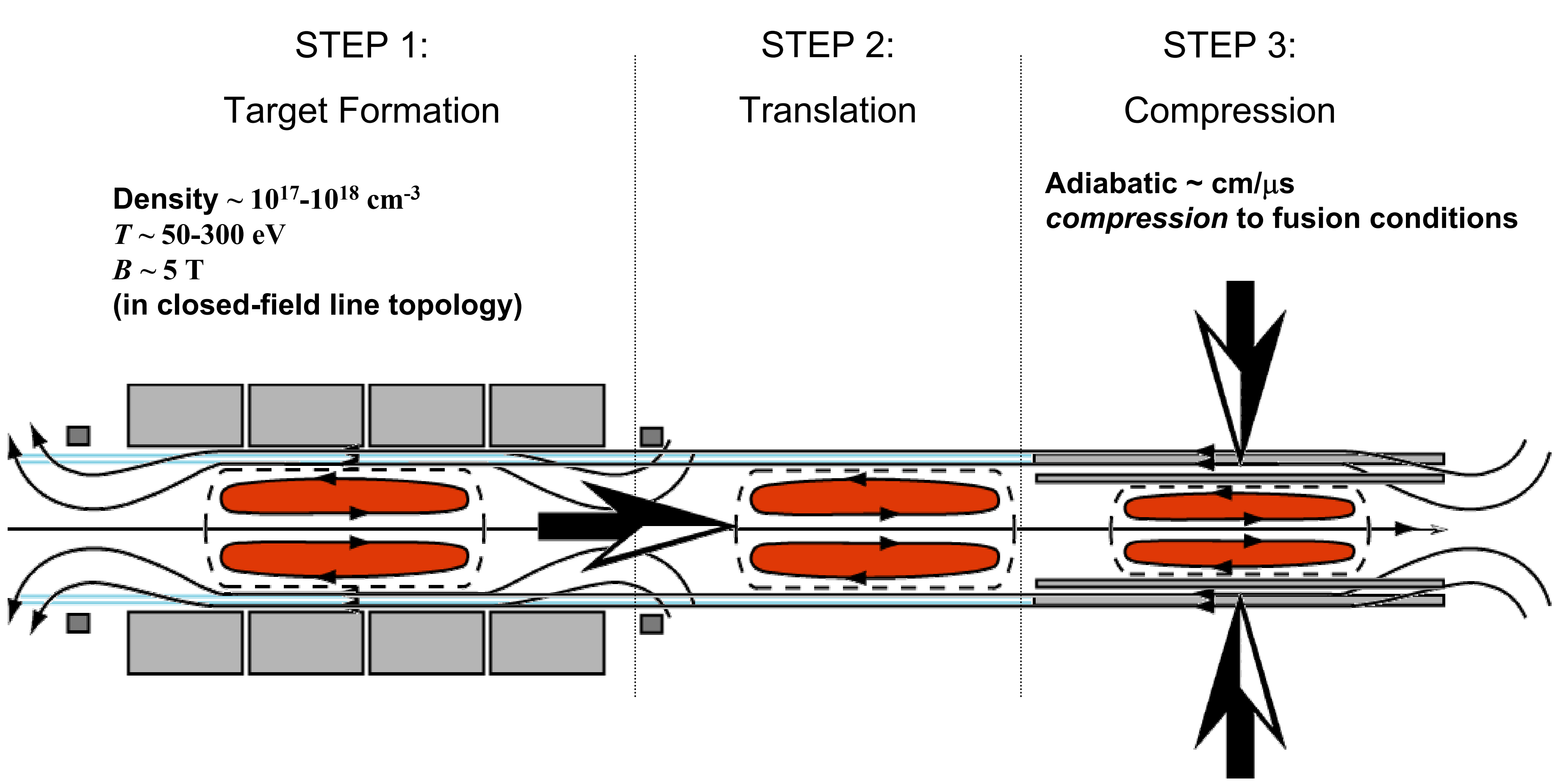
1. Why High-Density Field-Reversed configurations?

A. What Do We Mean by High Density?



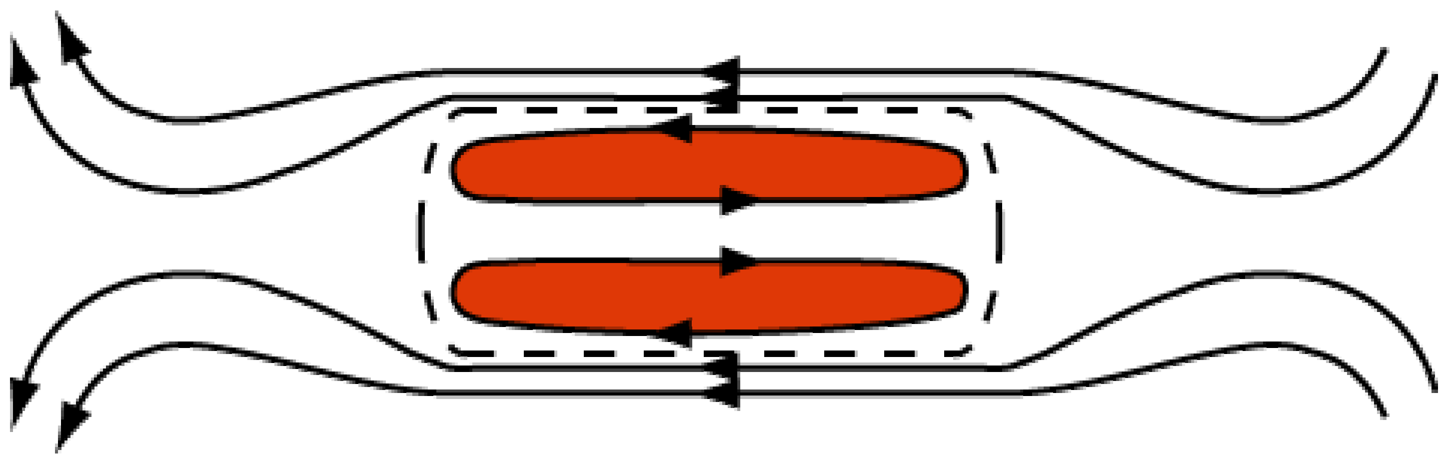
This density regime is quite different from that of current FRC experiments.

B. Magnetized Target Fusion



1. Why High-Density Field-Reversed configurations?

C. FRCs Ideally Suited for MTF



- Closed field line topology
- Translatable
- Compressible
- Existing empirical database

and…

- High-beta
- Natural divertor

2. FRC History

A. Past high-density 'FRCs'

Originally, FRCs were simply theta-pinches with an initial bias field anti-parallel to the main magnetic field.

When this bias magnetic field was included, researchers observed enhanced heating and higher neutron yields.

B. Evolution to lower density experiments

[from M.Tuszewski, Nucl. Fusion **28**, 2033 (1988)]

Early experiments (1959-64)

$l_c \sim$ 10-30 cm

$d_c \sim$ 5-10 cm

$n \sim$ (1-5) x 10^{17} cm^{-3}

Intermediate experiments (1965-71)

$l_c \sim$ 50-180 cm

$d_c \sim$ 11-19 cm

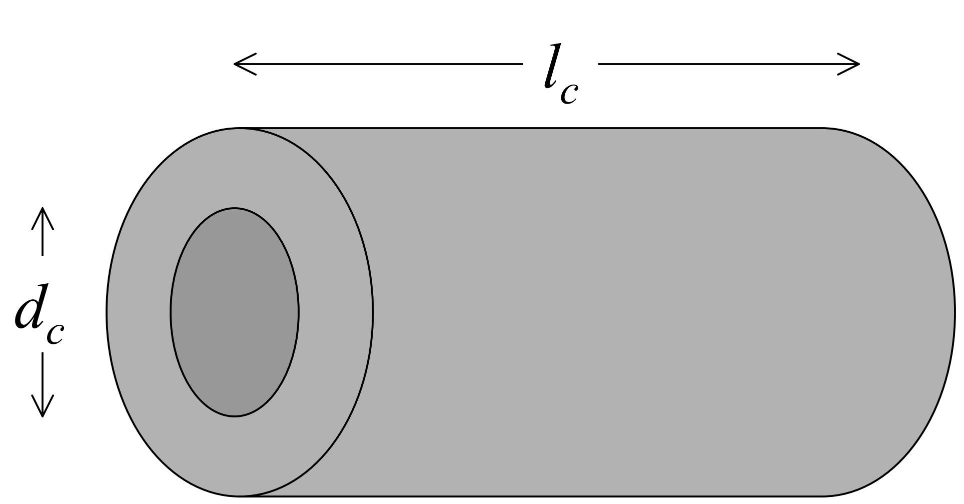
$n \sim$ (1-5) x 10^{16} cm^{-3}

Modern experiments (1975-02)

$l_c \sim$ 50-500 cm

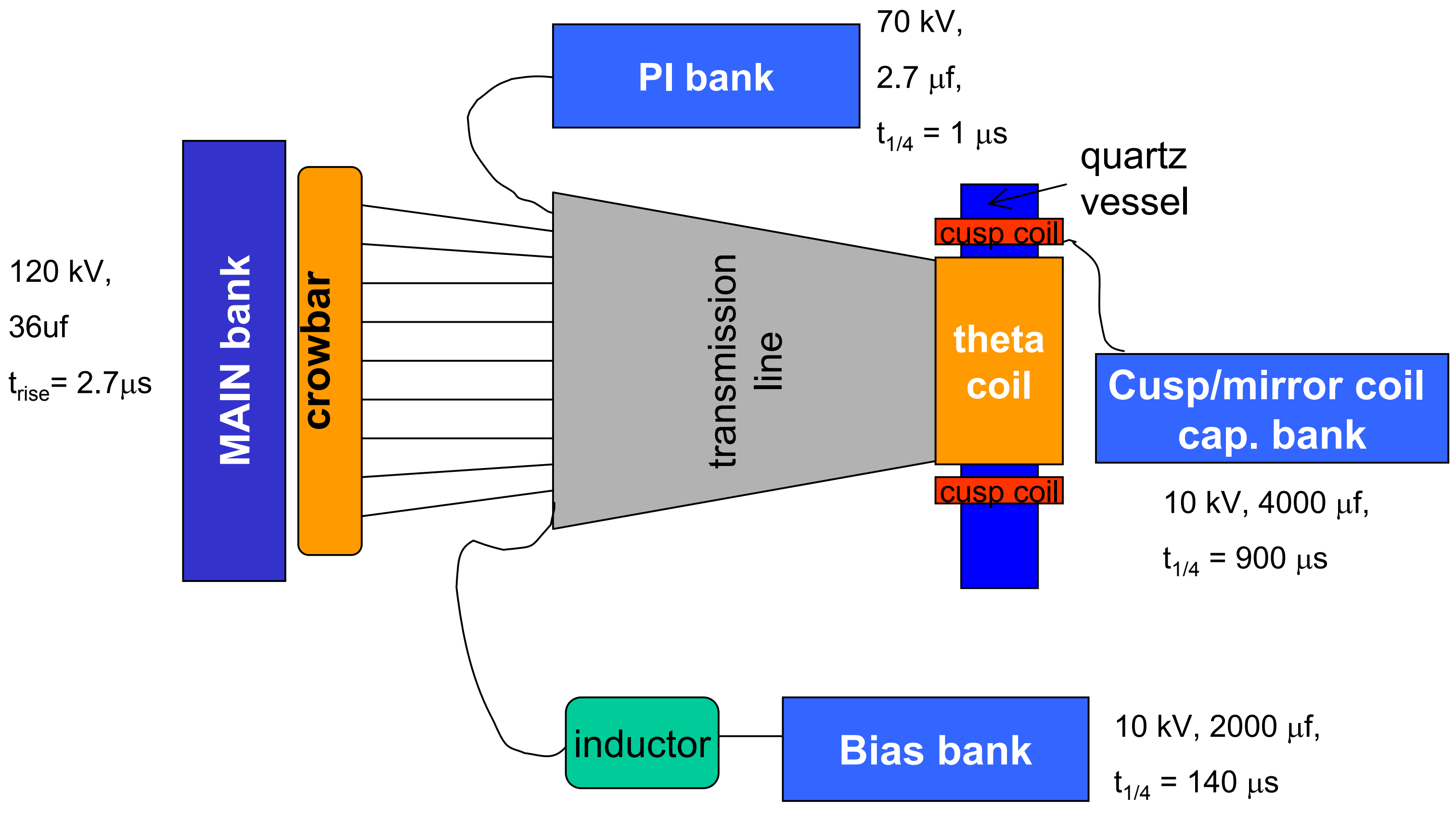
$d_c \sim$ 12-90 cm

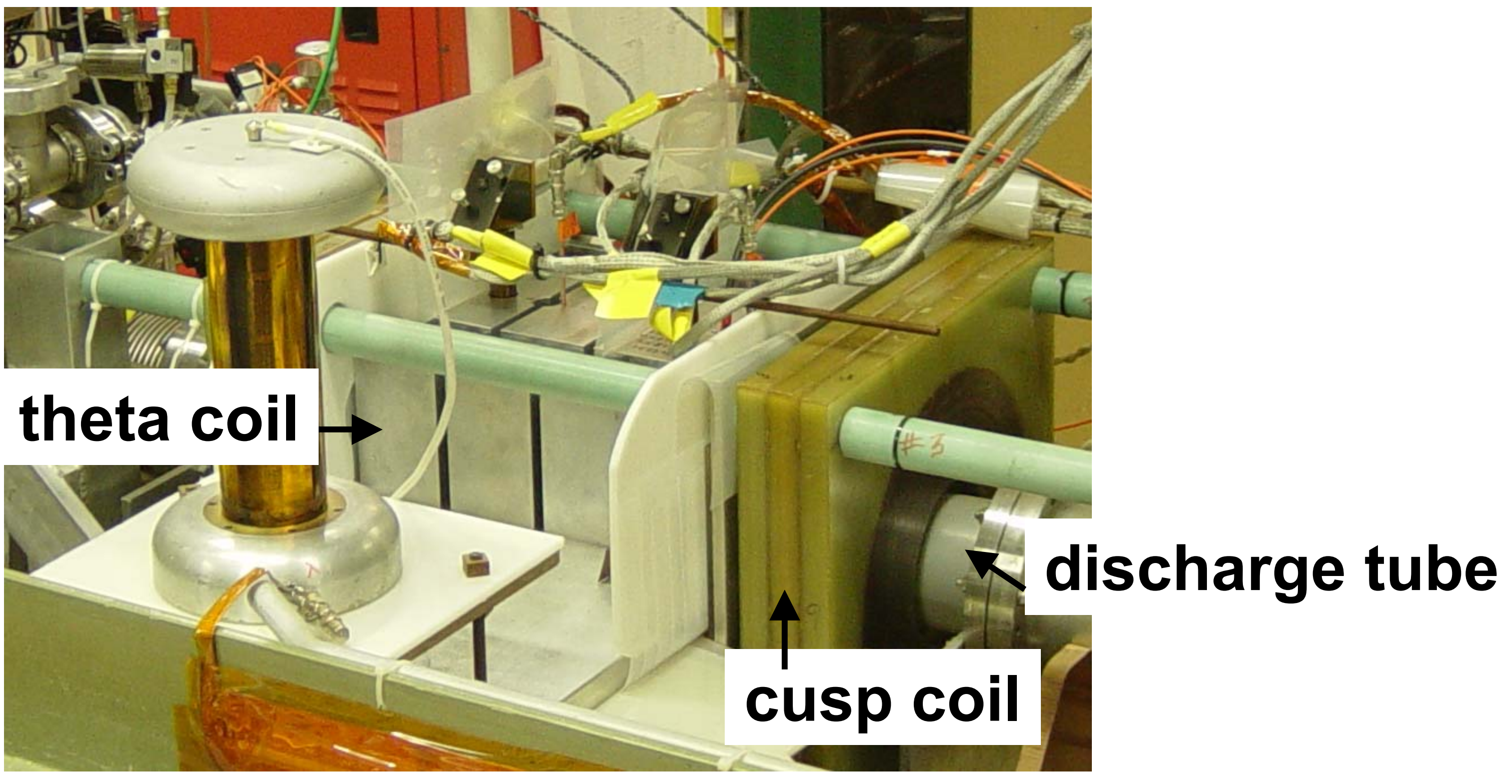
$n \sim$ (1-5) x 10^{15} cm^{-3}



3. FRX-L Experimental Setup

A. Circuit

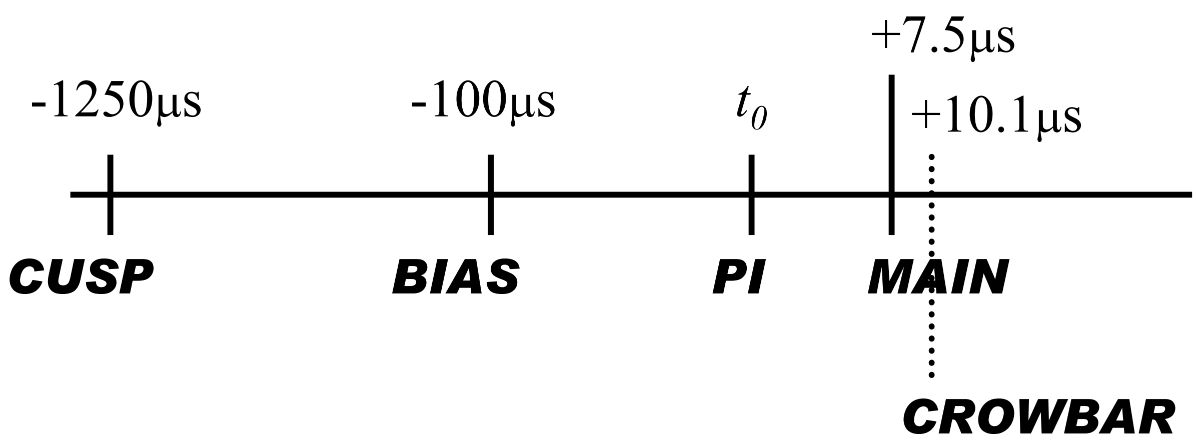




Closeup view of segmented theta coil, cusp coil, and discharge tube

3. FRX-L Experimental Setup

B. Timing of various capacitor banks



C. Experimental Parameters

Physical constraints:

-coil radius	r_c = 6.2 cm
-coil length	l_c = 36.0 cm
-discharge tube radius	r_t = 5.25 cm
-reversal electric field	E_θ = 0.15 (1.0*)
kV/cm	
-fill pressure	p_0 = 20-40 mTorr
-crowbar field	B_c = 1.5 T (5 T*)

(*max operating values)

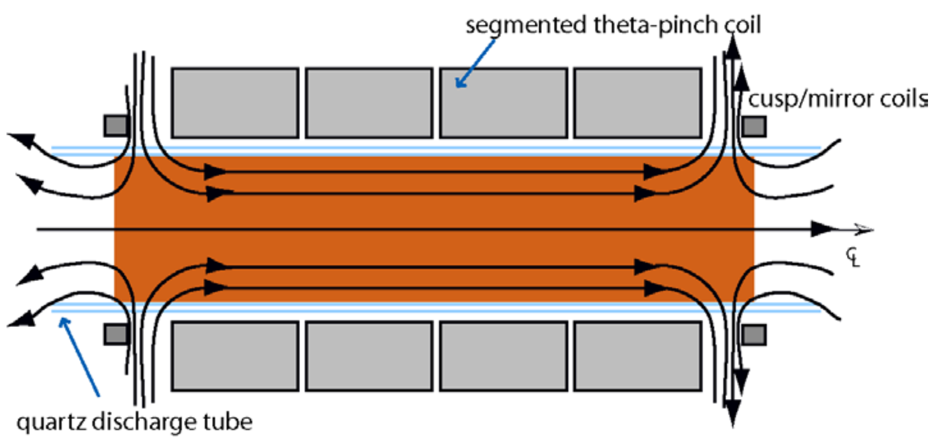
Desired plasma parameters:

- separatrix radius	$r_s \sim$ 3 cm
-plasma	l_s = 30 cm
-excluded flux	ϕ_{ex} = 10 mWebers

4. FRC Formation Theory

A. Stages of FRC formation

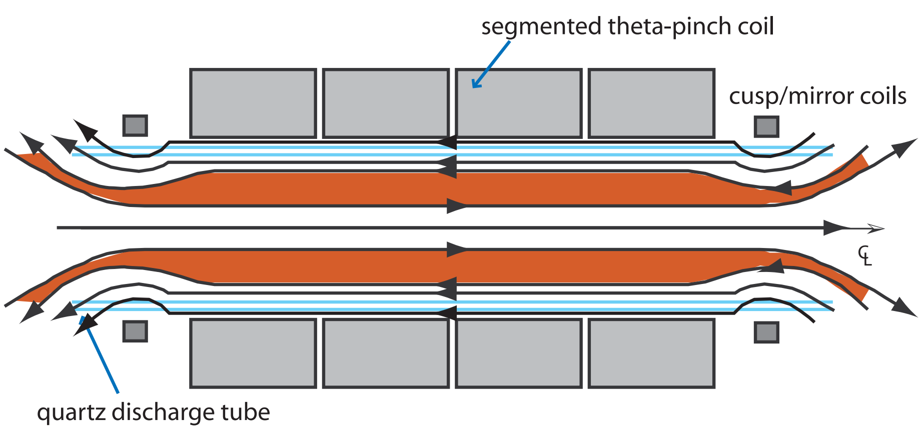
We use what's known as the FRTP (field-reversed theta pinch) method



Fill with neutral gas (D_2)

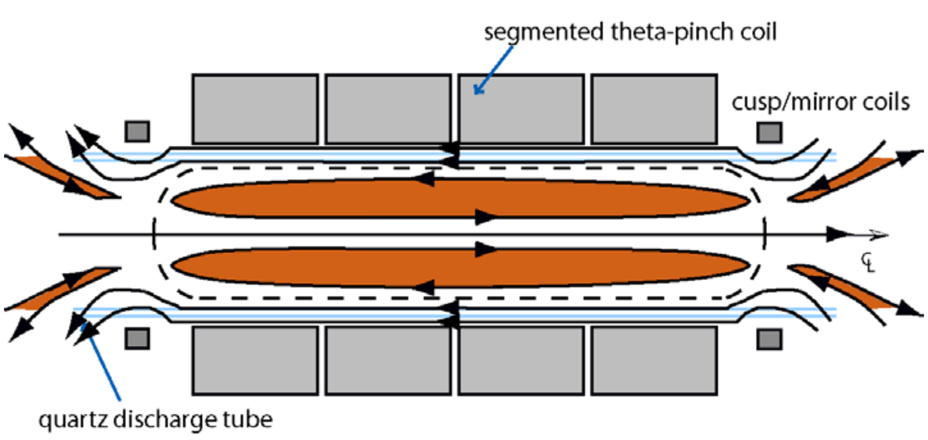
Apply bias magnetic field

ionize the gas

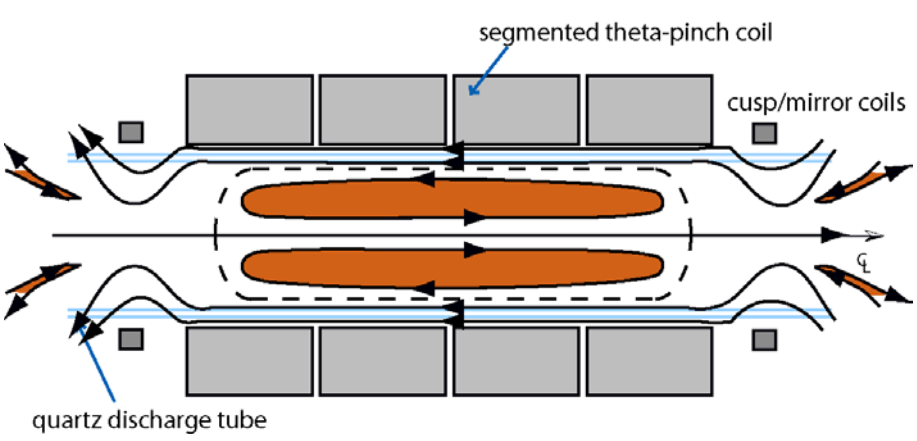


Quickly reverse current in theta pinch coil

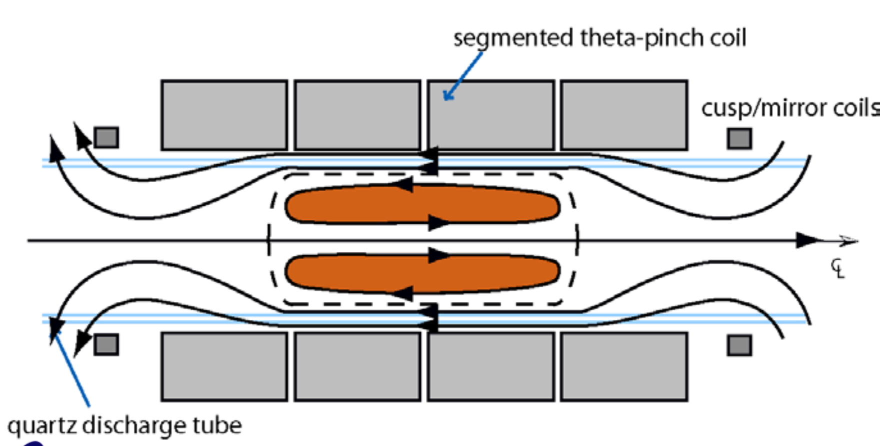
Gas implodes



magnetic field lines connect



FRC to contracts axially

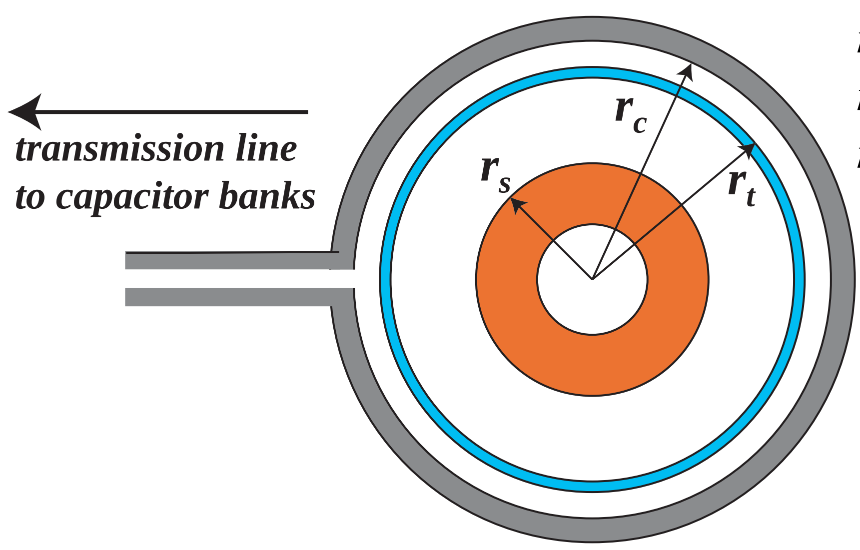


FRC reaches equilibrium

4. FRC Formation Theory

B. Excluded Flux Radius

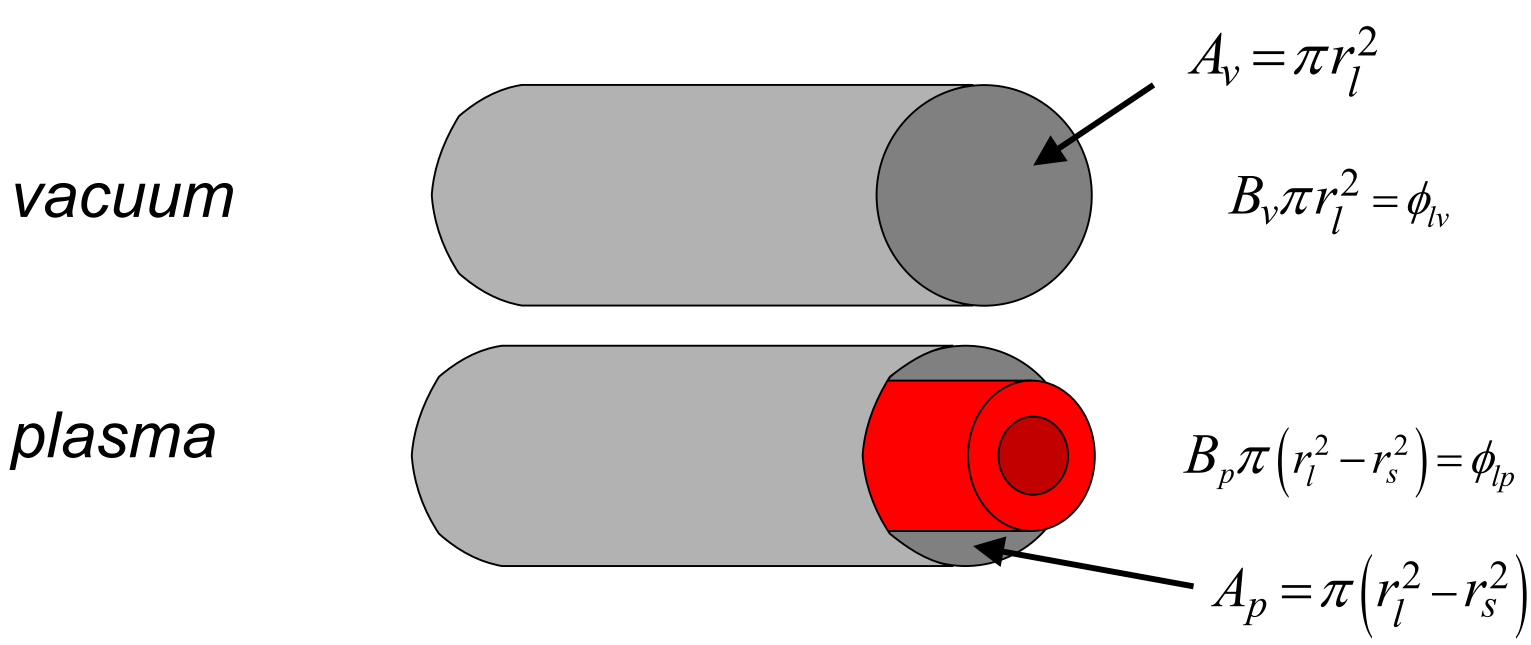
Cross-section at midpoint of theta pinch coil:



r_c = theta coil inner radius
r_t = discharge tube radius
r_s = separatrix radius
~ excluded flux radius near midpoint of coil

Bdot probes measure axial field between theta coil and discharge tube

Flux loops wrapped around discharge tube measure the flux through coil (assume flux loop radius $r_l = r_c$)



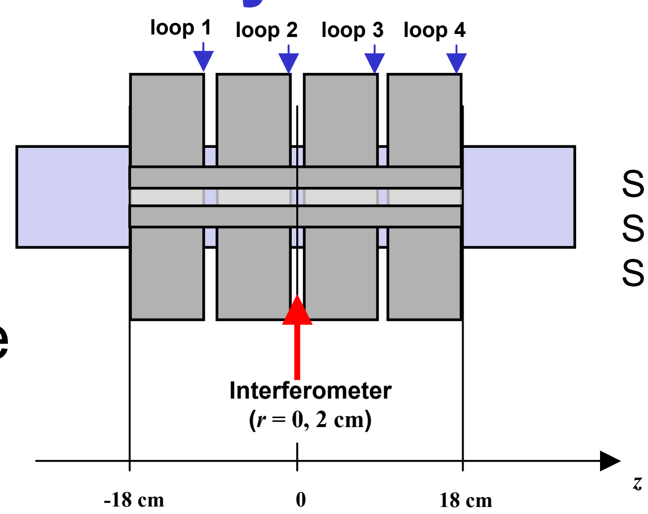
Compare vacuum and plasma cases to find how much flux is 'excluded' by the plasma. This translates into an 'excluded flux radius, r_s.

$$r_s = r_l \left(1 - \frac{\Phi_{lp}}{\Phi_{lv}} \frac{B_v}{B_p}\right)^{1/2}$$

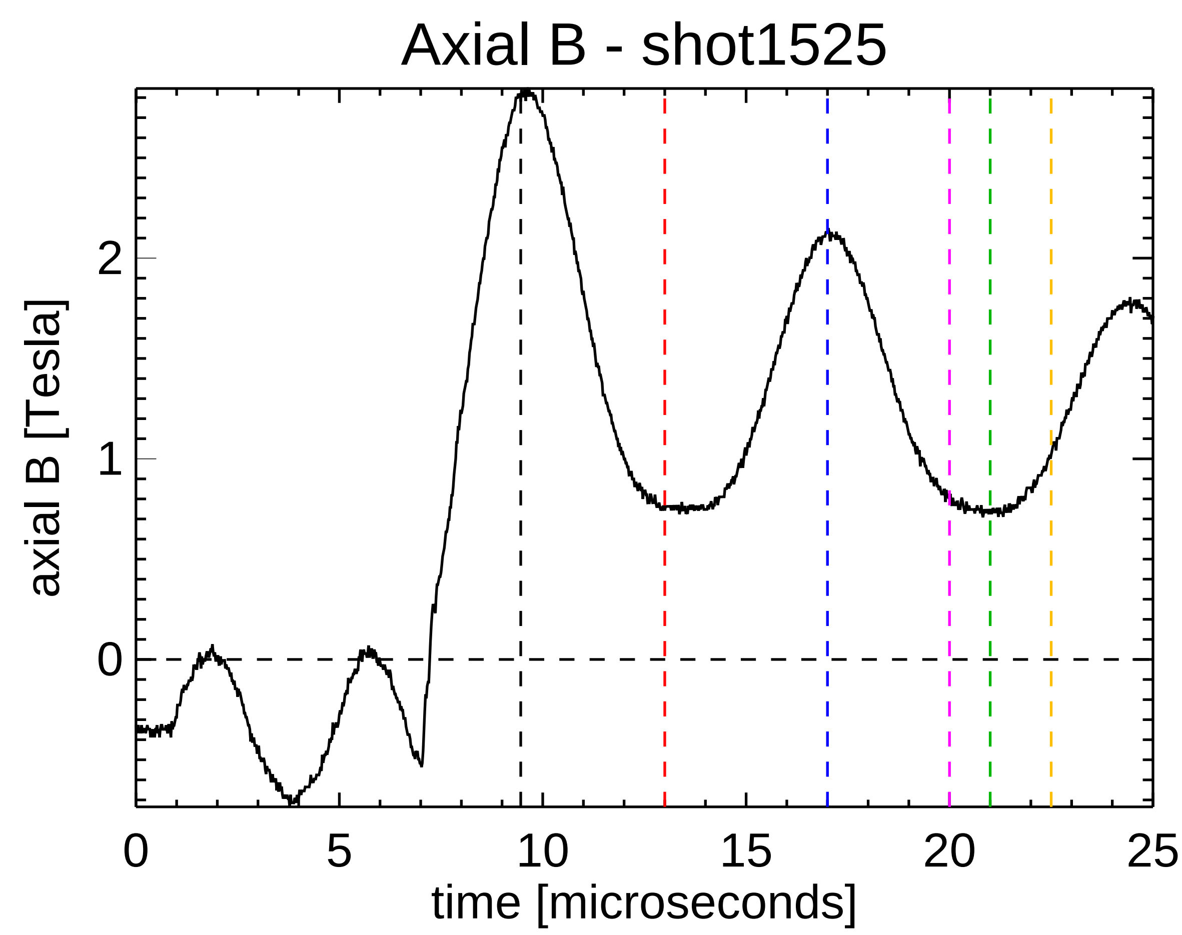
5. FRC Formation Results

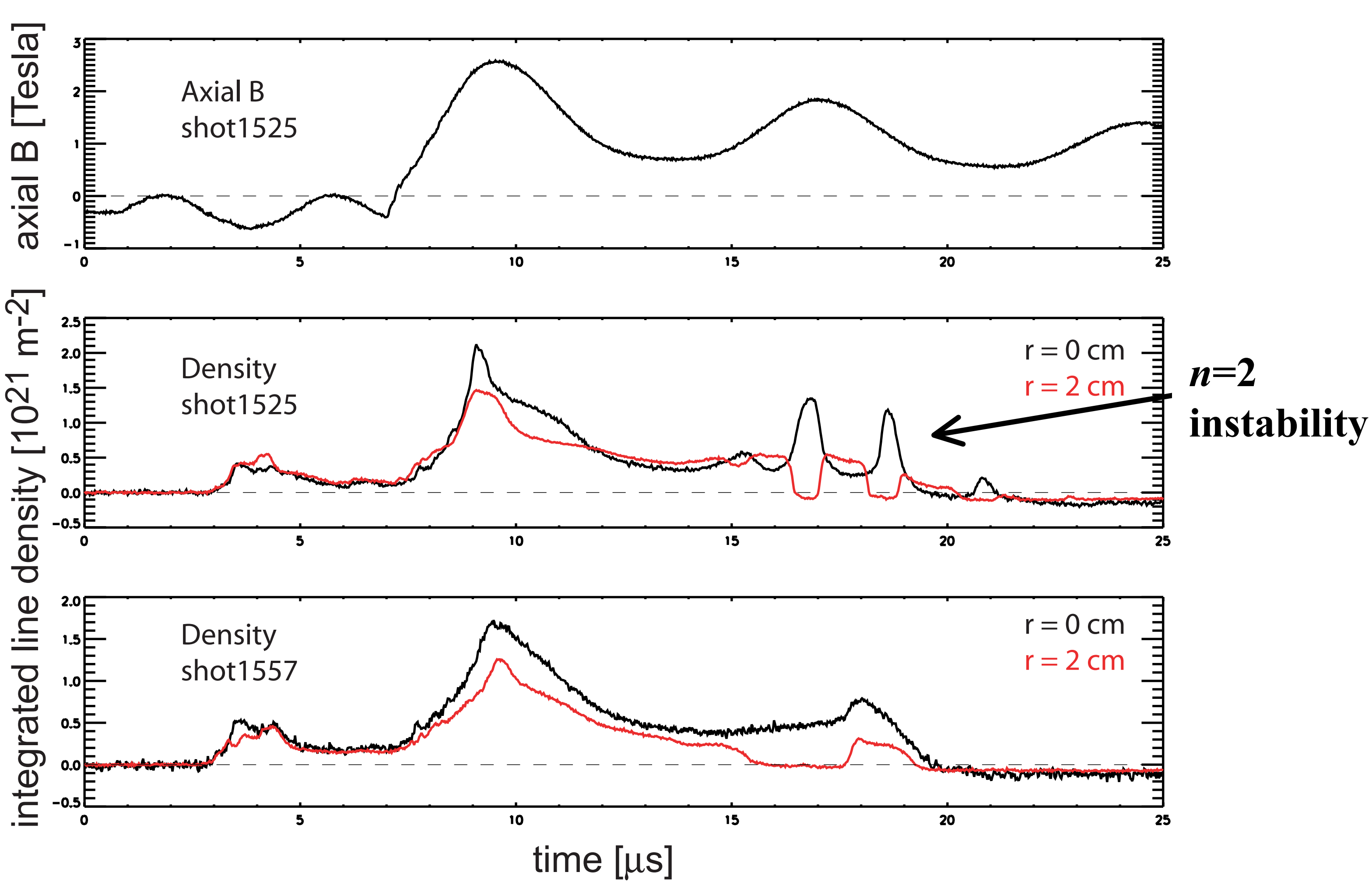
A. Magnetic field and density

Compare shots 1525 and 1557, for which late-time behavior varies. One shows n=2 instability, while the other does not.



Shot1525 – 40mTorr D_2 fill
Shot1535 – 40 mTorr D_2 fill
Shot1557 – 50mTorr D_2 fill



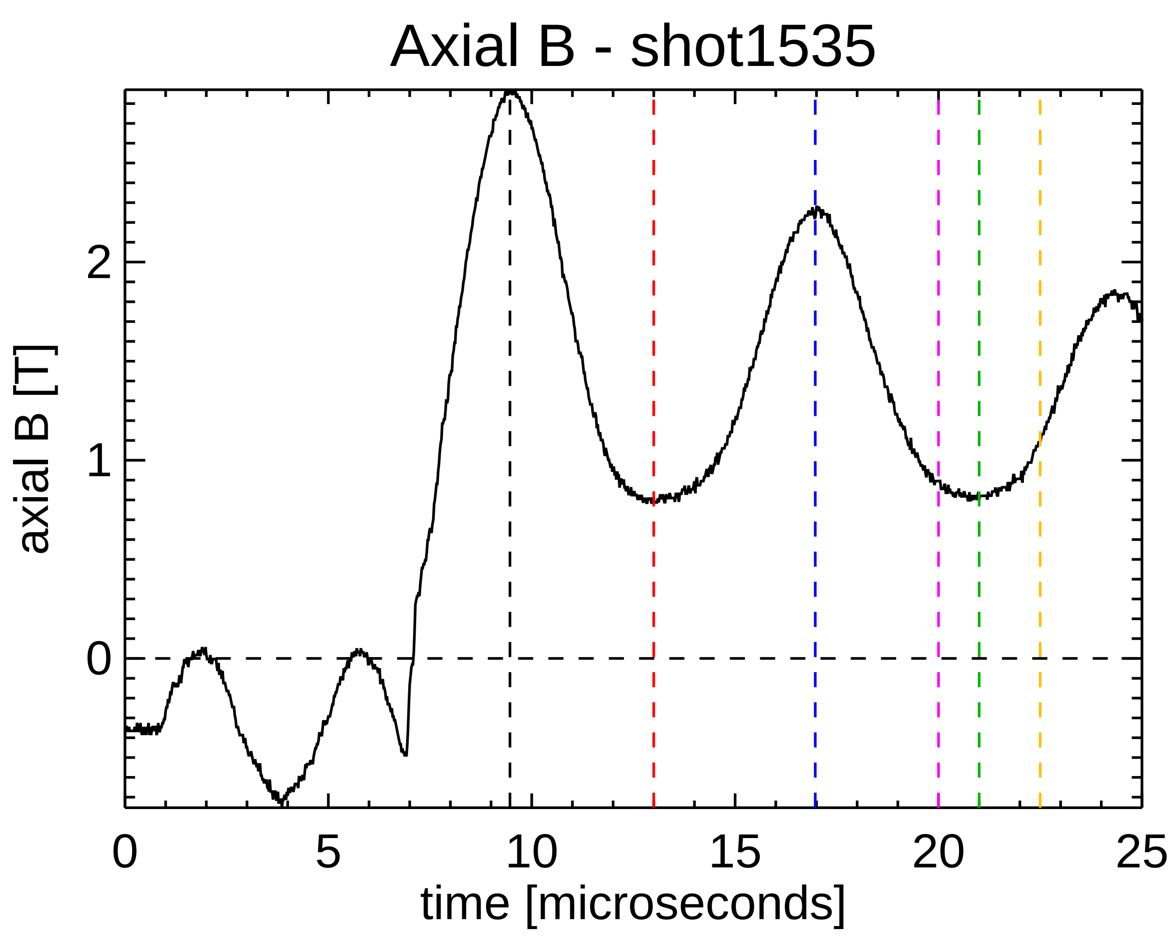


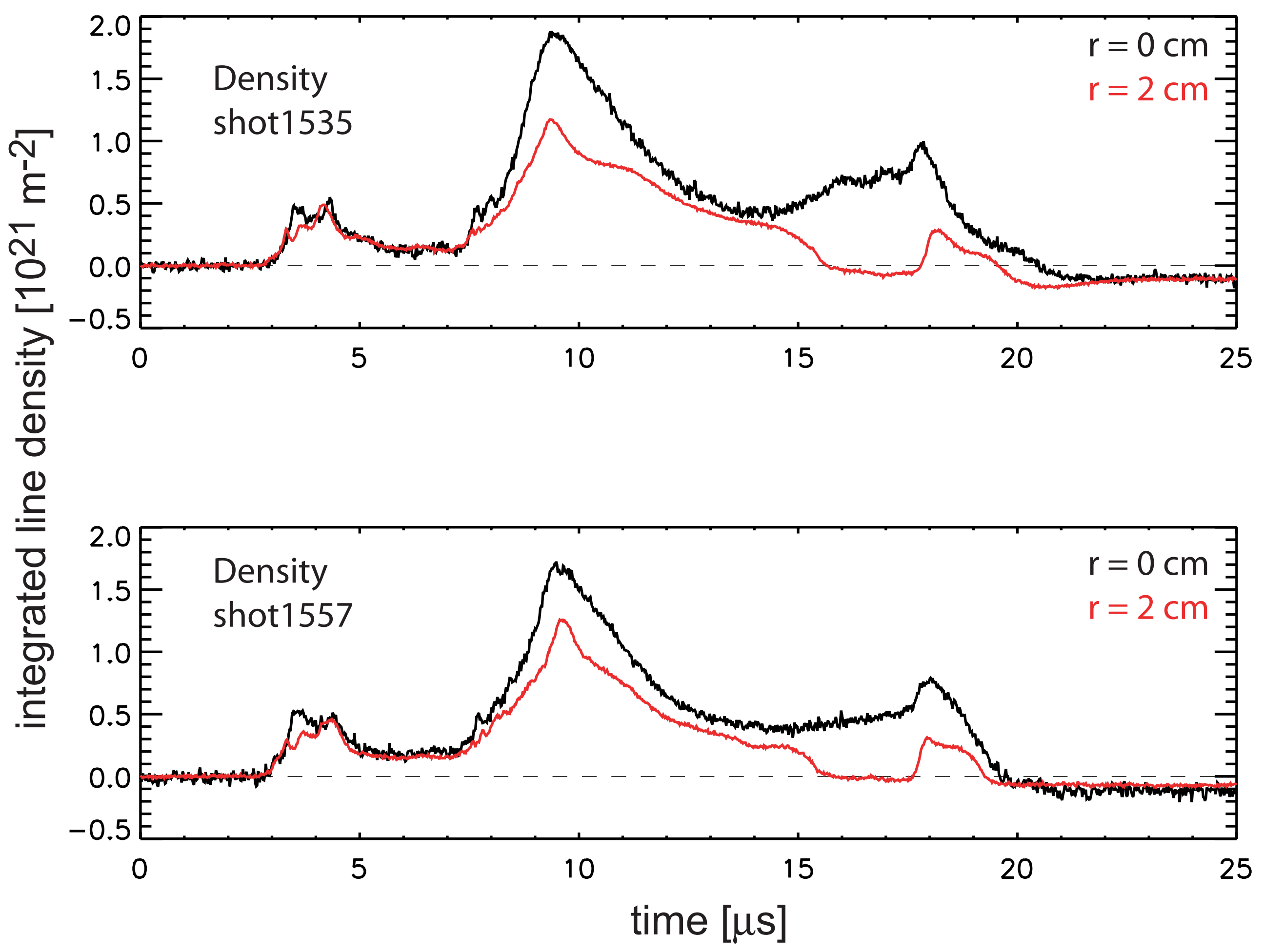
(note: 'negative density' is an artifact due to slow vibration of interferometer)

5. FRC Formation Results

A. Magnetic field and density (cont.)

Instability can be suppressed in our case by ensuring similar initial pre-ionization conditions – ionization fraction and PI to Main bank delay (shots 1535 and 1557 shown, for example).



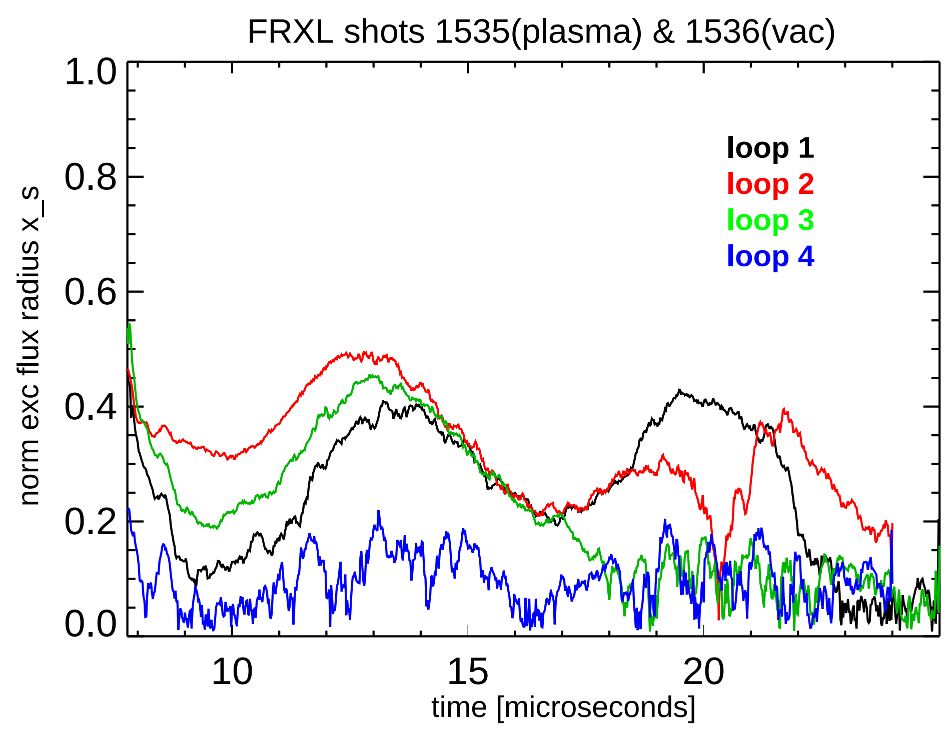


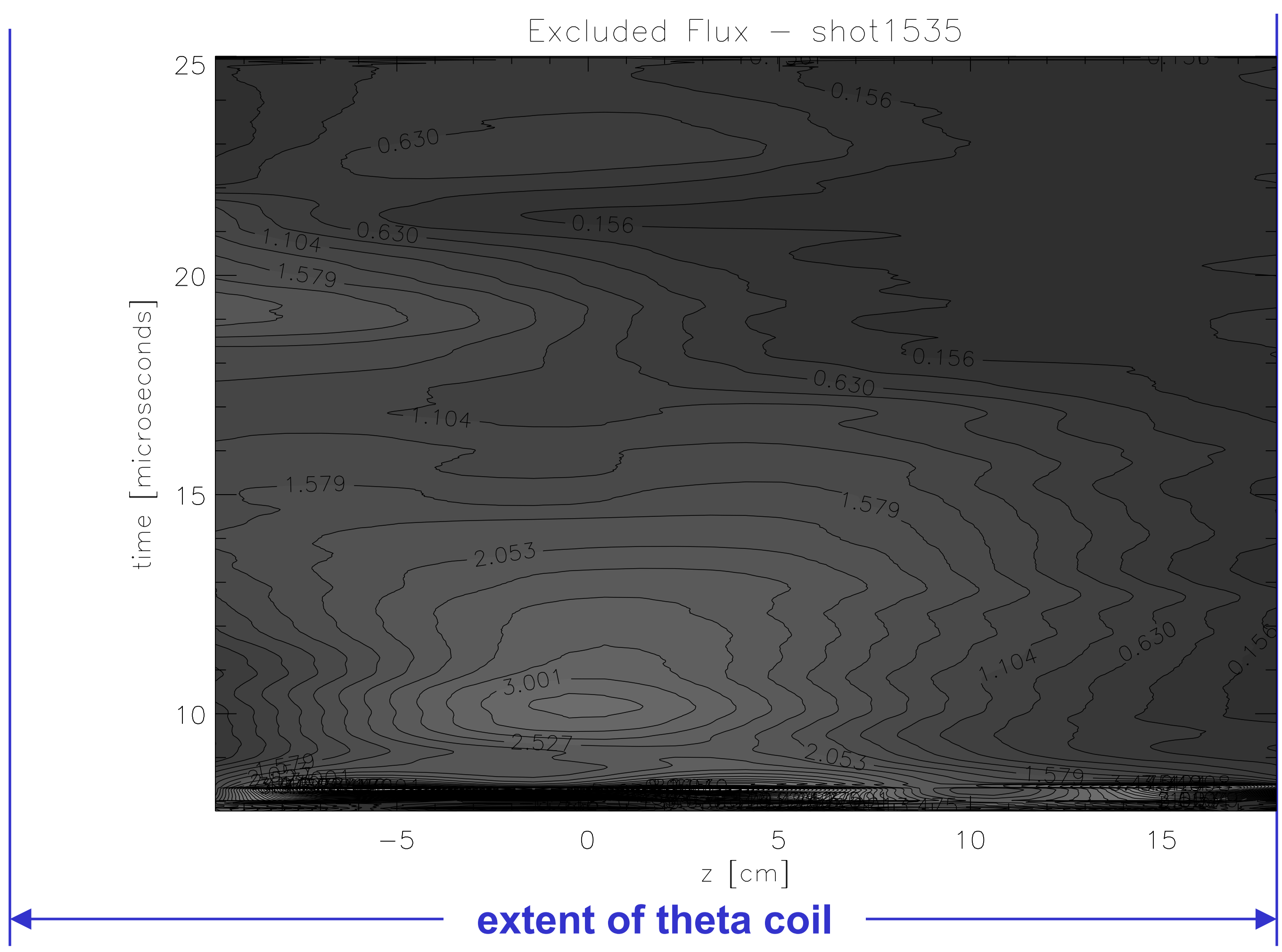
(note: ‘negative density’ is an artifact due to slow vibration of interferometer)

5. FRC Formation Results

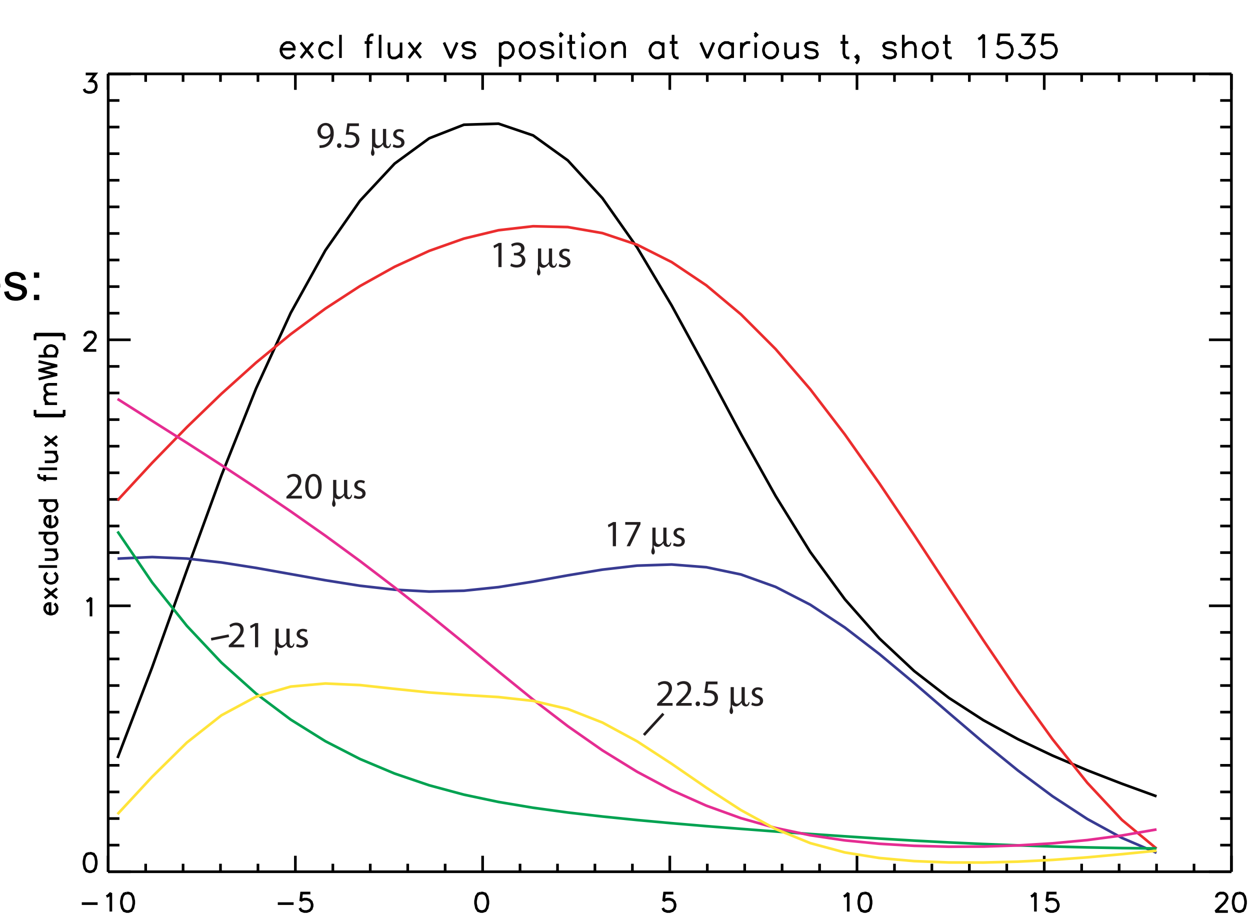
B. Excluded Flux

Excluded flux radius is calculated at four different locations along coil . This is used to calculate excluded flux contours (data is splined along z):





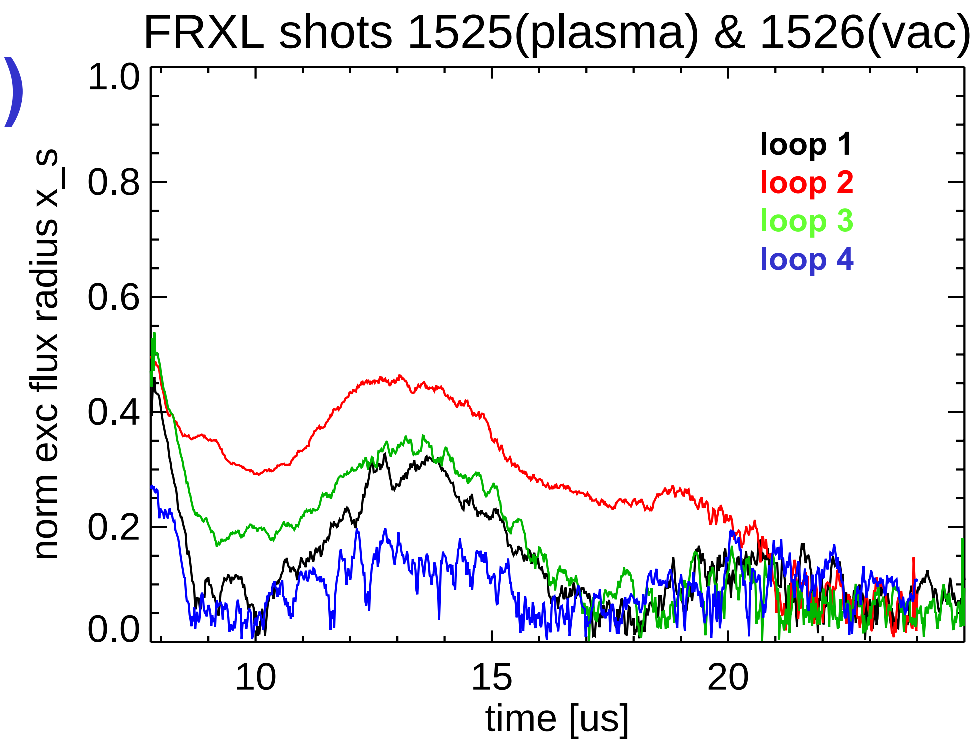
Lineouts of contours at various times:

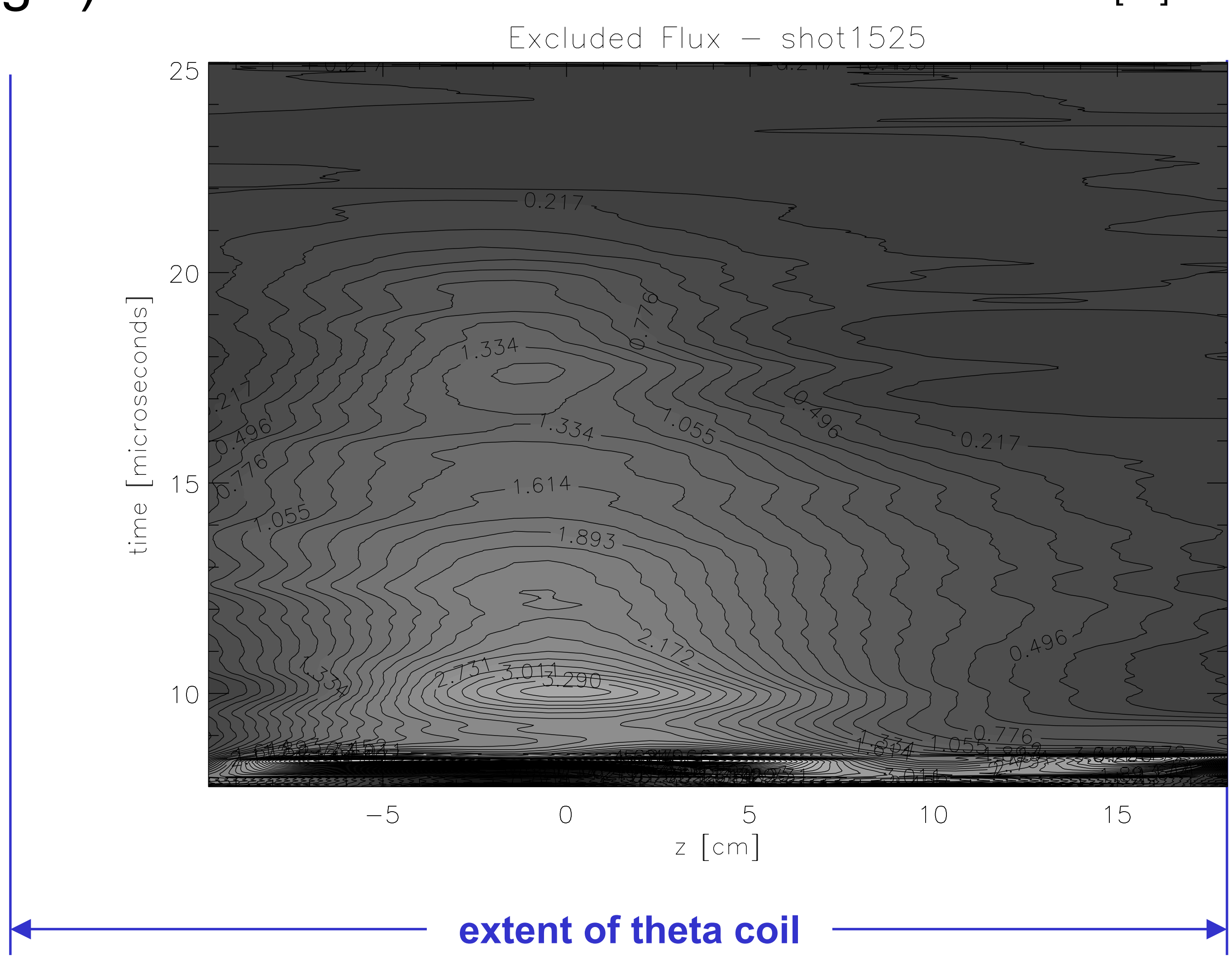


5. FRC Formation Results

B. Excluded Flux (cont.)

Excluded flux radius is calculated at four different locations along coil . This is used to calculate excluded flux contours, this time for shot with *n*=2 instability (data is splined along z):





Lineouts of contours at various times: