LA-UR- 02-6832

Title: **HIGH-DENSITY FRC FORMATION STUDIES ON FRX-L**

Author(s): J.M.Taccetti(147103), T.P.Intrator(152598),
S.Y.Zhang(179386),
G.A.Wurden(094597,),R.J.Maqueda(117929),
D.Begay(120756), E.
Mignardot(065380),B.Waganaar(098192),R.Siemon, P-24 -
M. Tuszewski(09102) NIS-2,P.Sanchez(099255) Fabtek,
Inc.,J.H. Degnan,W.Sommars,C.Grabowski, AFRL

LOS ALAMOS NATIONAL LABORATORY

3 9338 01045 7835

• Los Alamos
NATIONAL LABORATORY

High-Density FRC Formation Studies on FRX-L

Abstract

FRX-L (Field Reversed configuration eXperiment - Liner) is a magnetized-target injector for magnetized-target fusion (MTF) experiments. It was designed with the goal of producing high-density $n\sim10^{17}$ cm^{-3} field reversed configurations (FRCs) and translating them into an aluminum liner (1-mm thick, 10-cm diameter cylindrical shell) for further compression to fusion conditions. Although operation at these high densities leads to shorter FRC lifetimes, our application requires that the plasma live only long enough to be translated and compressed, or on the order of 10-20 µs. Careful study of FRC formation in situ will be done in the present experiment to differentiate between effects introduced in future experiments by translation, trapping, and compression of the FRC. We present current results on the optimization of the FRC formation process on FRX-L and compare the results with those from past experiments.
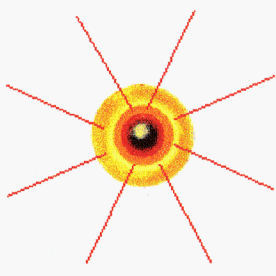
1. Why High-Density Field-Reversed Configurations?

A. High Density?

Magnetic Confinement Fusion
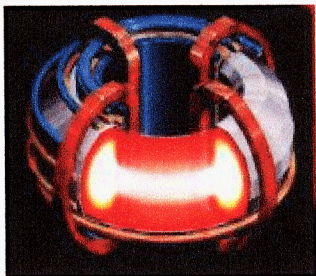
Inertial Confinement Fusion

By high density, we mean somewhere between MFE and ICF, or $n \sim 10^{17}$ cm^{-3}

higher n

B. Magnetized Target Fusion

A preheated and magnetized target (an FRC, for example) is compressed to fusion conditions

STEP 1:

Target Formation

Density ~ 10^{17}-10^{18} cm^{-3}
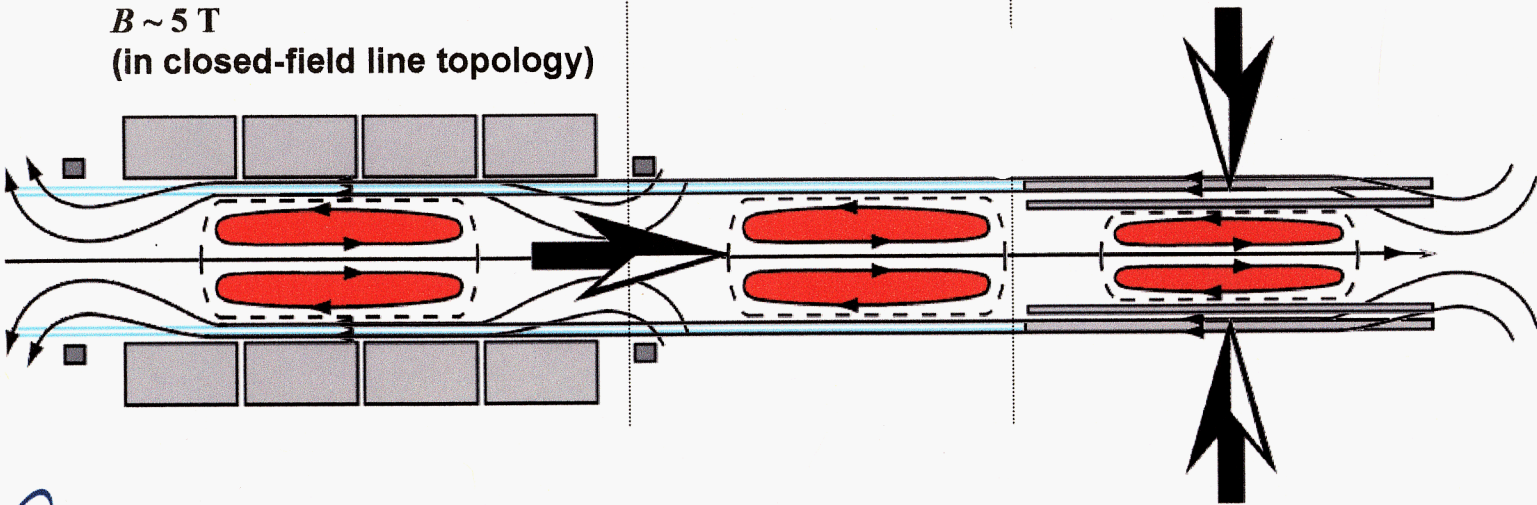$T \sim 50$-300 eV
$B \sim 5$ T
(in closed-field line topology)

STEP 2:

Translation

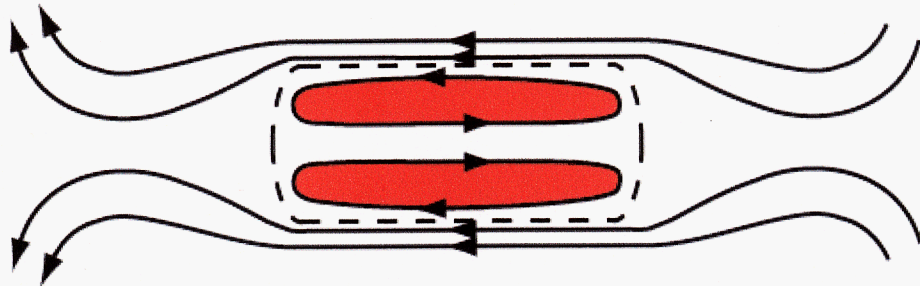**STEP 3:**

Compression

Adiabatic ~ cm/μs
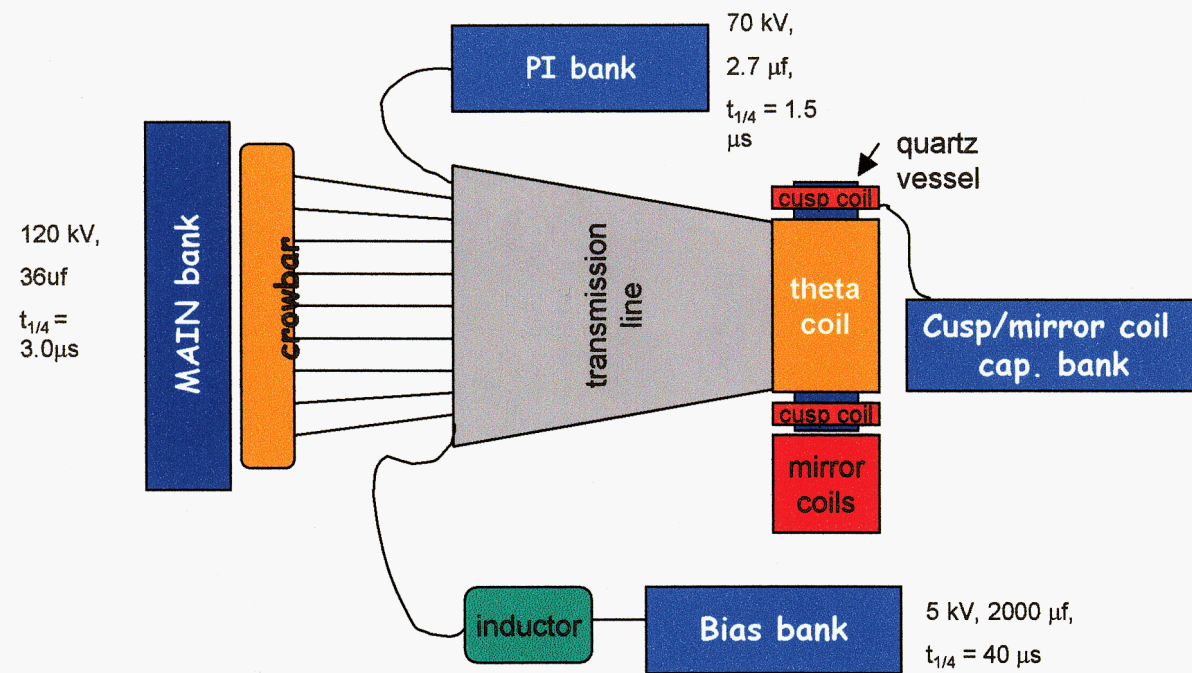*compression* to fusion conditions

C. FRCs Ideally Suited for MTF

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

Los Alamos
NATIONAL LABORATORY

P-24 Plasma Physics

2. Experimental Setup

A. Circuit

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

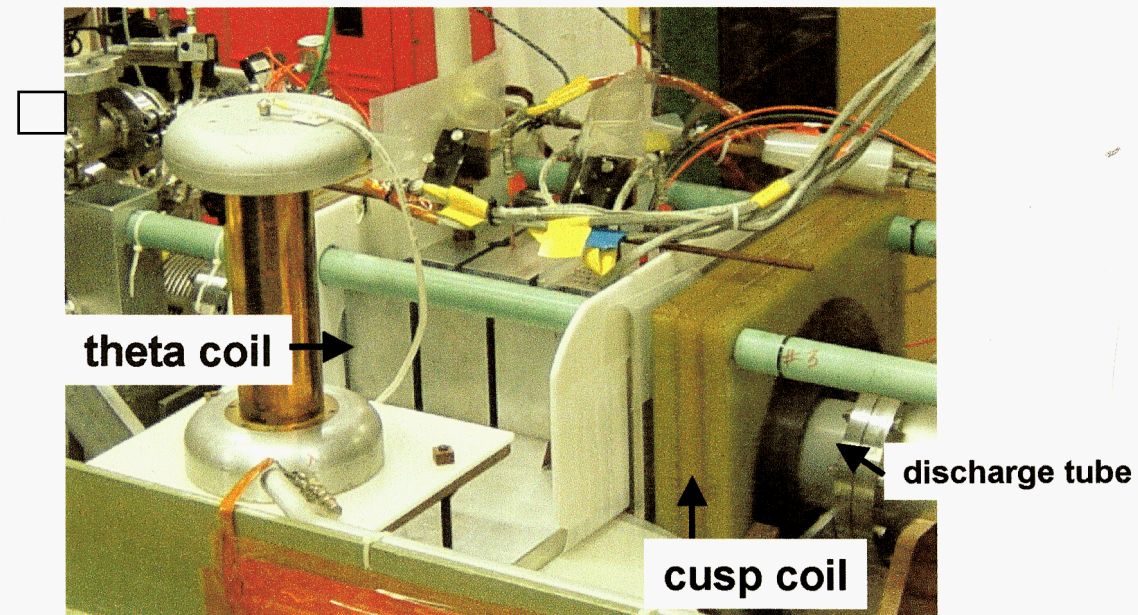## B. Experimental Parameters

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 $E_\theta = 0.15$ (1.0*) kV/cm
- fill pressure $p_0 = 20\text{-}40$ mTorr
- crowbar field $B_c = 1.5$ T (5 T*)

(*max operating values)

Expected plasma parameters:
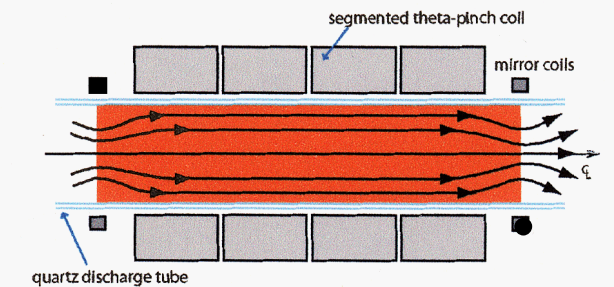
- separatrix radius $r_s \sim 3$ cm
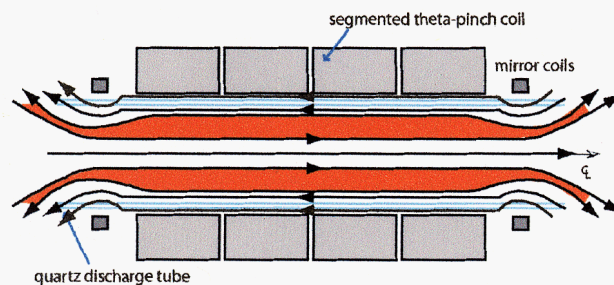- plasma $l_s = 30$ cm

3. Formation Theory

A. Stages of FRC formation

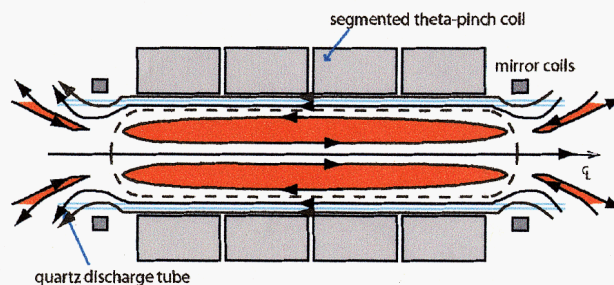We use what's known as the FRTP (field-reversed theta pinch) method

Fill with neutral gas (D_2)

Apply bias magnetic field
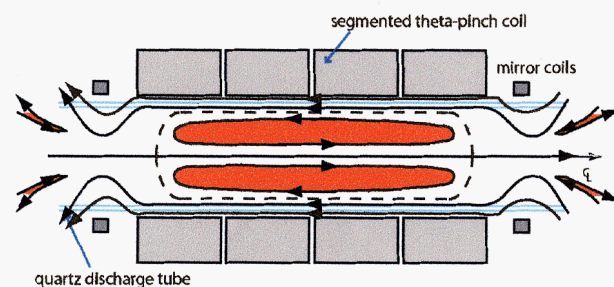
ionize the gas

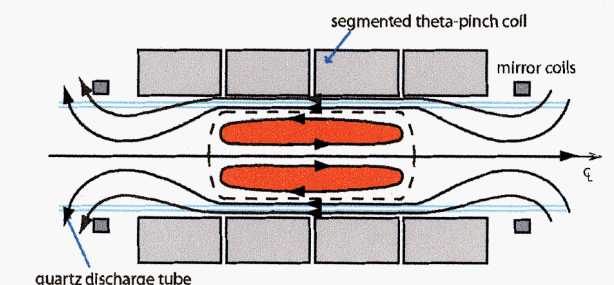Quickly reverse current in theta pinch coil

Gas implodes

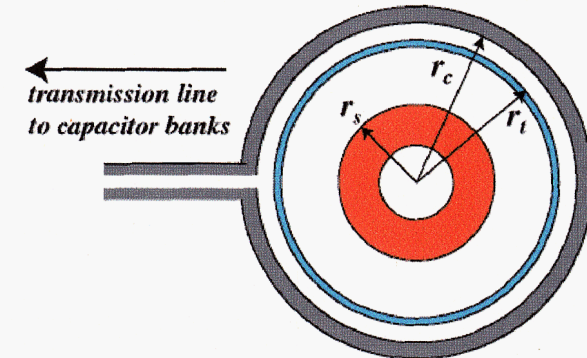magnetic field lines connect

FRC to contracts axially

FRC reaches equilibrium

B. Excluded Flux Radius

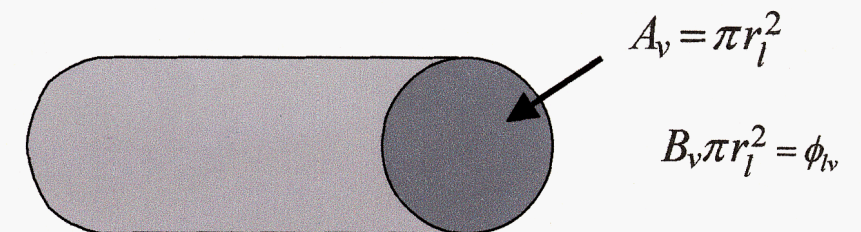Cross-section at midpoint of theta pinch coil:

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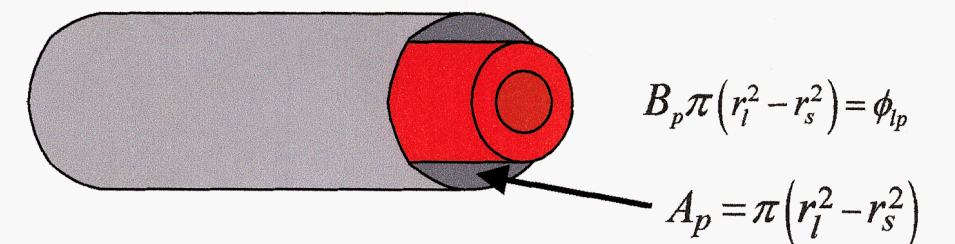r_s = separatrix radius ~ excluded flux radius near midpoint of coil

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 $r_l = r_c$)

vacuum

$$A_v = \pi r_l^2$$

$$B_v \pi r_l^2 = \phi_{lv}$$

plasma

$$B_p \pi \left(r_l^2 - r_s^2 \right) = \phi_{lp}$$
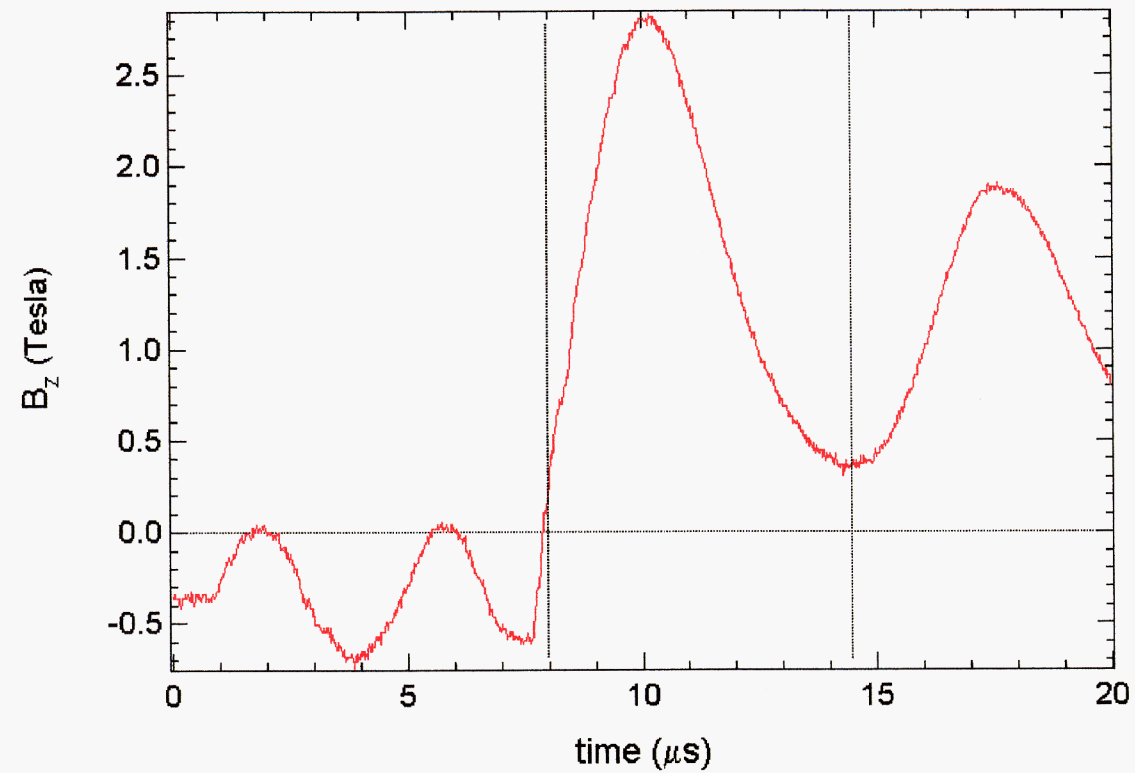
$$A_p = \pi \left(r_l^2 - r_s^2 \right)$$

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

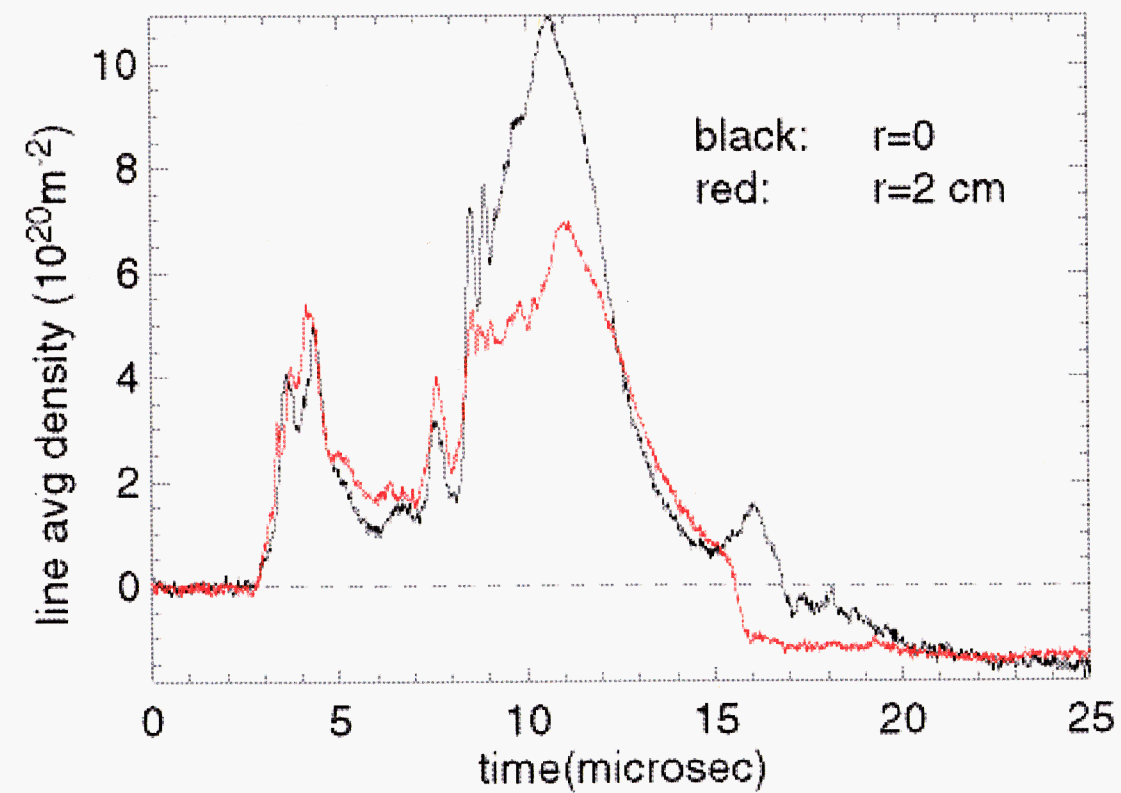$$r_s = r_l \left(1 - \frac{\Phi_{lp}}{\Phi_{lv}} \frac{B_v}{B_p} \right)^{1/2}$$

Los Alamos
NATIONAL LABORATORY

4. Formation Results

A. External B_z

B. Density

FRXL - shot 1514

black: r=0
red: r=2 cm

C. Excluded Flux Radius

r_{s1} (z=8.3 cm)
r_{s3} (z=26.8 cm)
r_{s4} (z=36.0 cm)

Los Alamos
NATIONAL LABORATORY