Full flux closure and equilibrium state during simulations of Coaxial Helicity Injection in NSTX-U

Fatima Ebrahimi

Dept. of Astrophysical Sciences, Princeton University and Princeton Plasma Physics Laboratory

R. Raman

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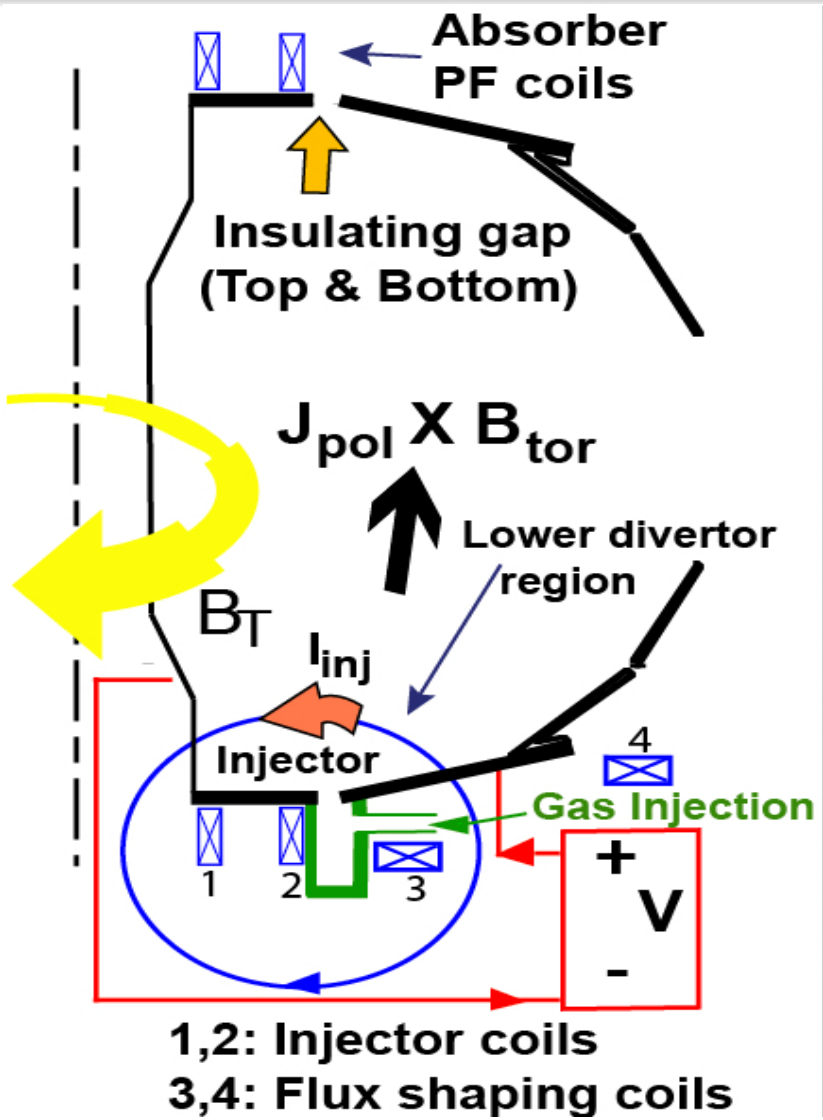
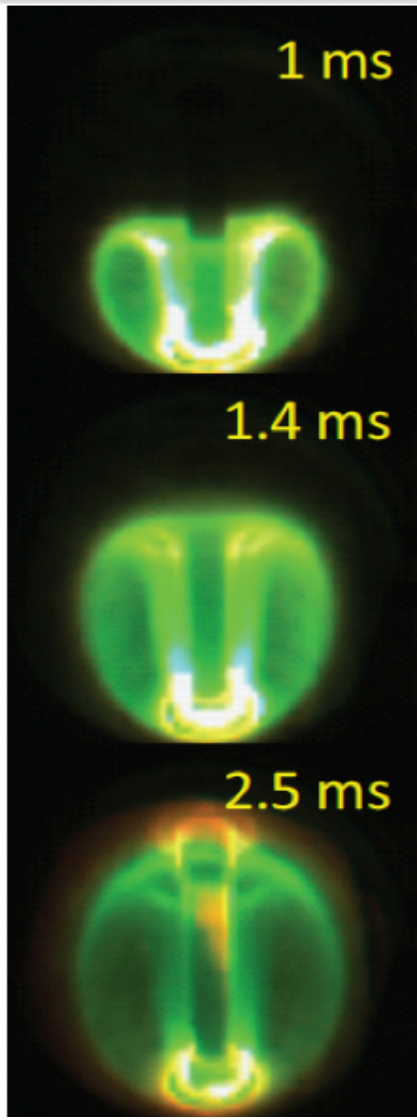
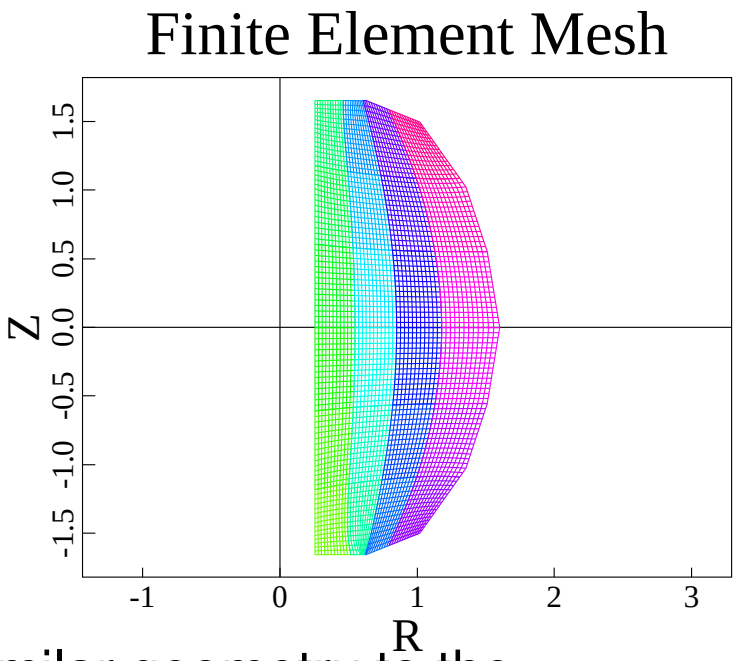
In transient CHI, axisymmetric reconnection generates a high quality closed flux start-up equilibrium in NSTX

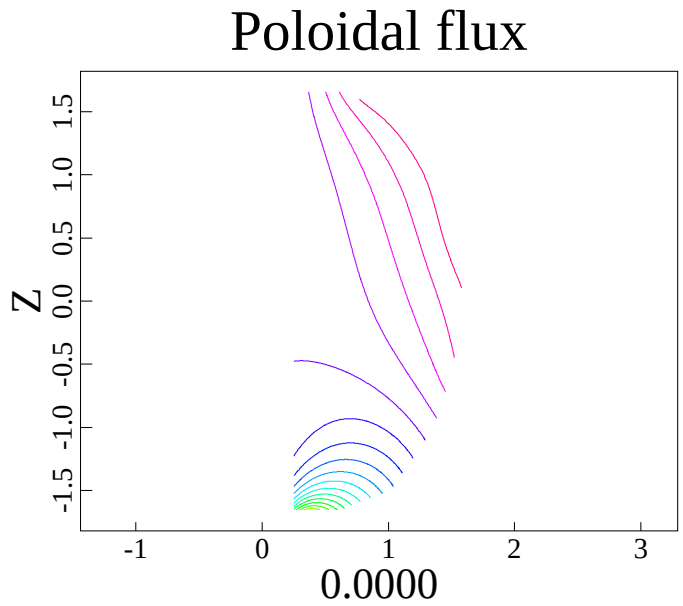
- Solenoid free non-inductive techniques to form a startup plasma enable lower aspect ratio configurations and simplify tokamak design.
- Transient CHI is a promising candidate for plasma start-up current formation in NSTX-U.





Axisymmetric simulations are performed using the extended-MHD NIMROD code



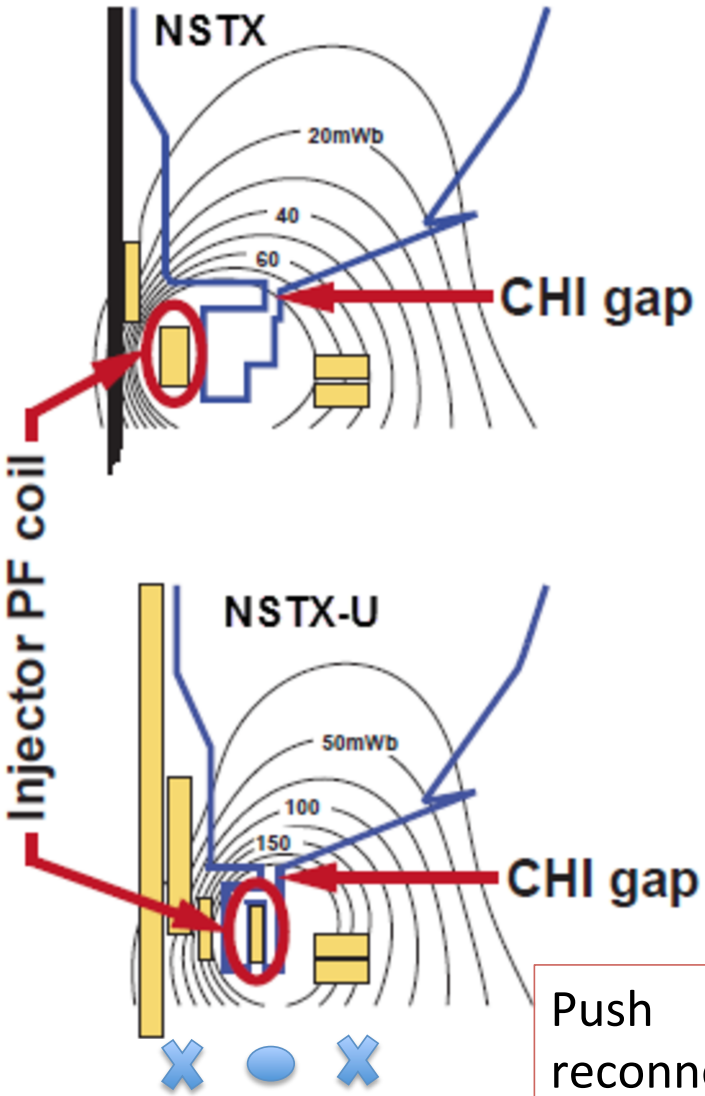


- Similar geometry to the experiment with a narrow slot.
- Initial Ψ_{inj} generated by including NSTX poloidal coil currents (with fixed boundary field)
  - Voltage is applied across the injector gap (V_{inj}).
  - $E \times B$ normal flows at the injector and absorber gaps

In NSTX-U, injector flux footprint is narrower.

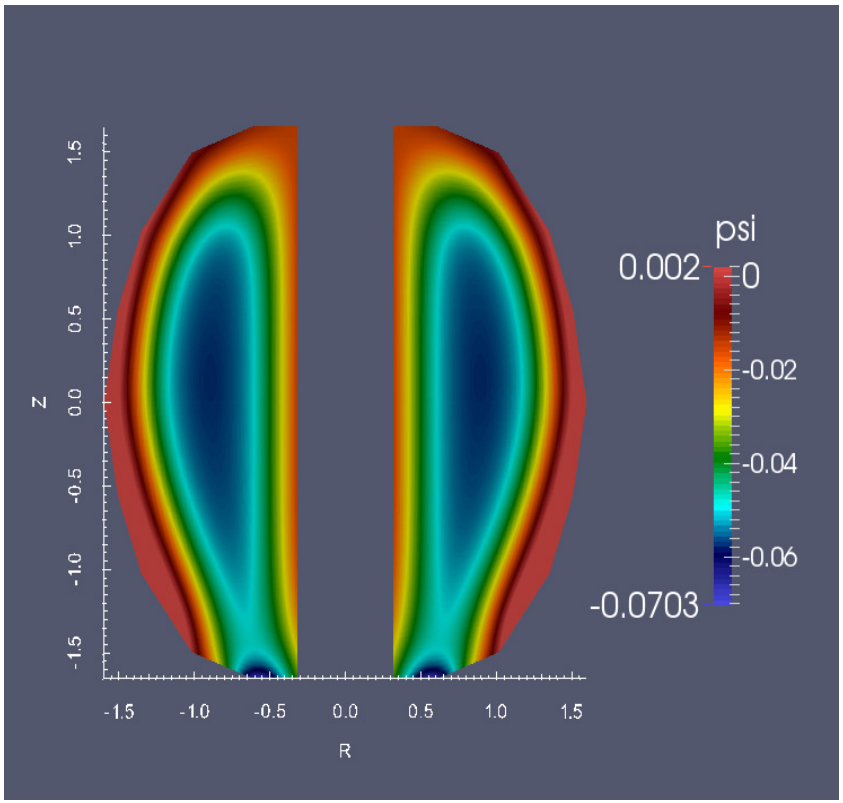
Important upgrades for transient CHI in NSTX–U

- Better shaping due to the location of CHI injector coil in NSTX-U
- Because of improved positioning of injector flux and shaping coils in NSTX-U, the volume of flux closure is large.
- Double injector flux ($\Psi_{inj} \approx 0.25 Wb$), CHI-generated current will be more than 2 times of that in NSTX

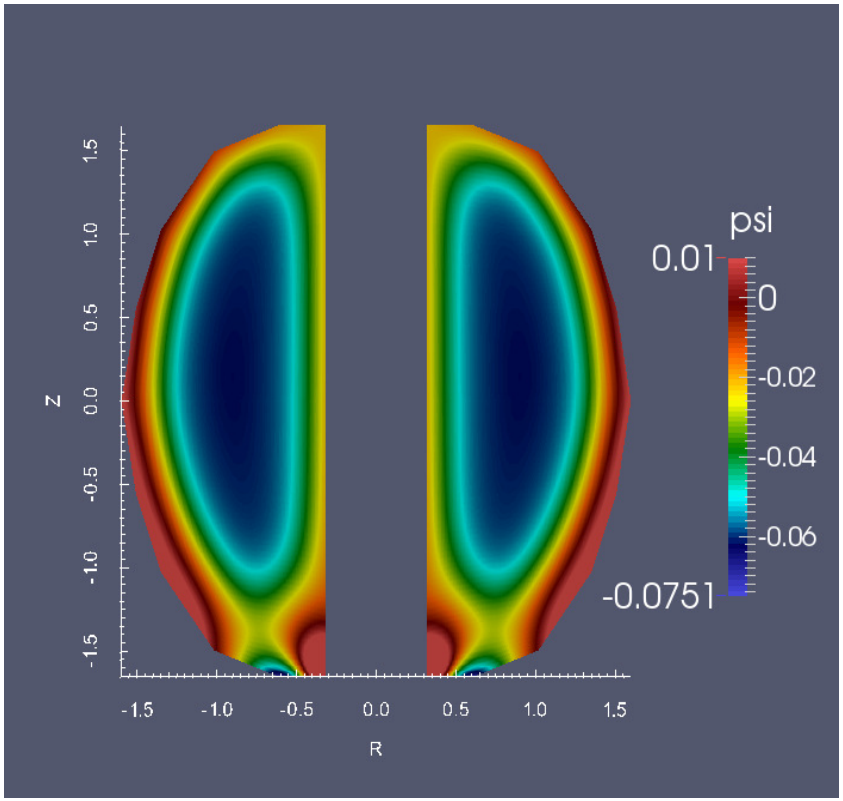


Flux closure increases with narrow flux footprints in MHD simulations of NSTX-U.

Wide flux footprint

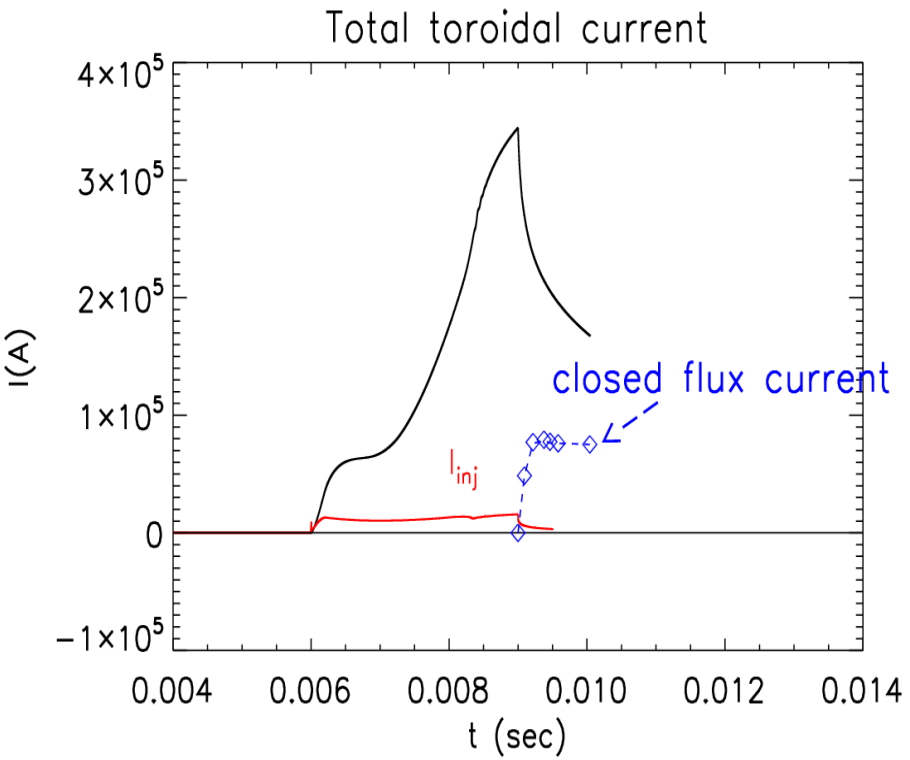


Narrow flux footprint

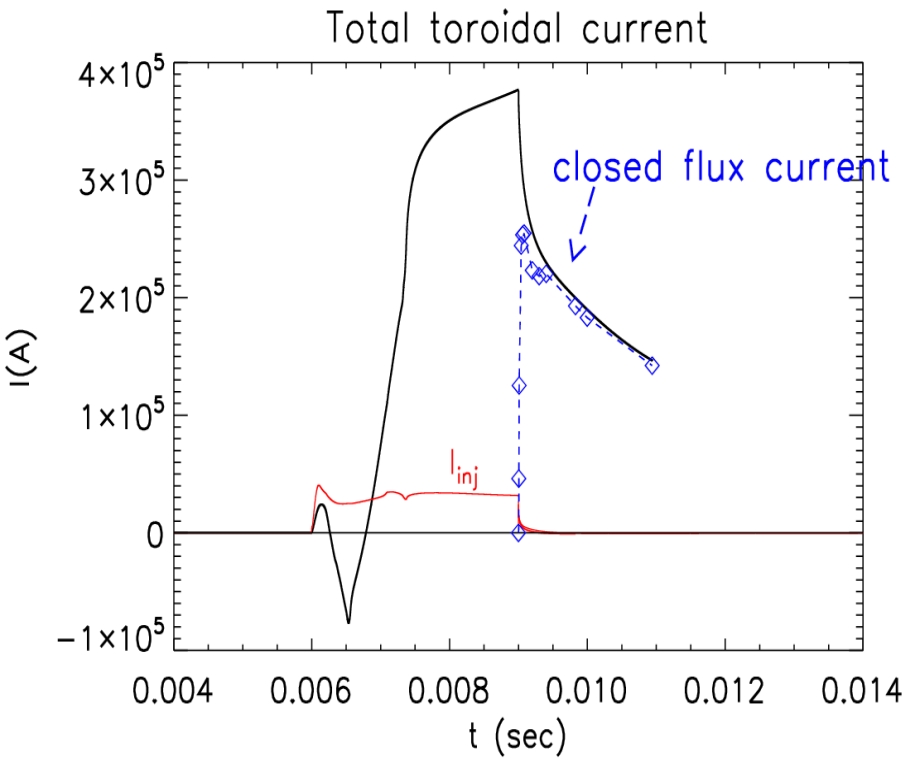


With shaping flux coils, nearly all of the CHI-generated current is closed-flux current.

Without Flux Shaping coils



With Flux Shaping coils



Full flux closure is obtained in MHD simulations of NSTX-U

Flux closure $t > 9ms$

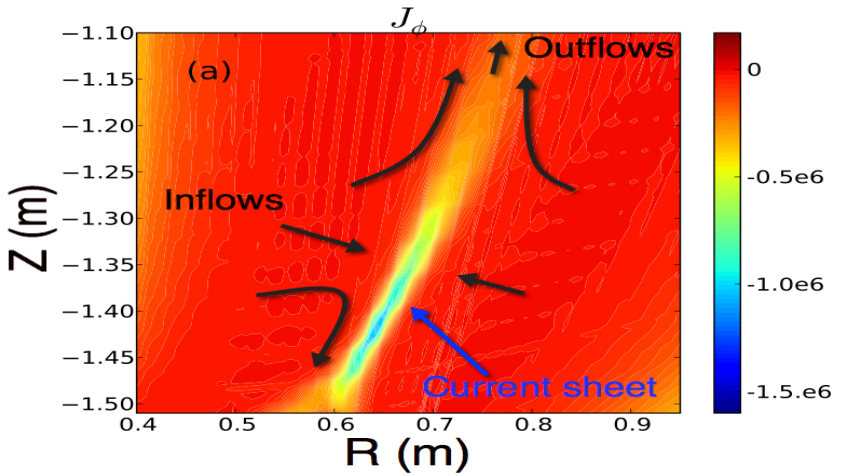
(Loading poloidalflux.mp4)

Reconnection process during CHI is of great importance for formation of closed flux surfaces.

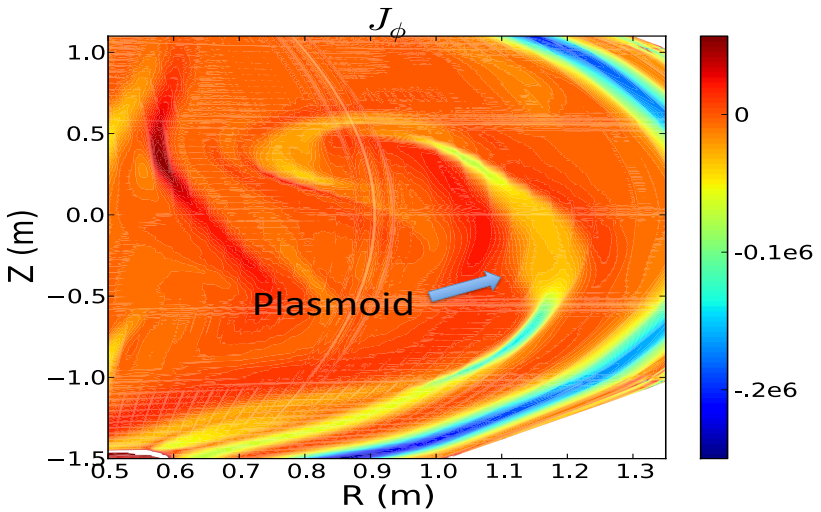
- A local 2-D Sweet-Parker type reconnection is triggered in the injection region.[F. Ebrahimi et al. PoP 2013, 2014]

- At high S, a transition to a plasmoid instability is demonstrated in the simulations. [Ebrahimi&Raman PRL 2015]

S-P reconnection



Plasmoid instability



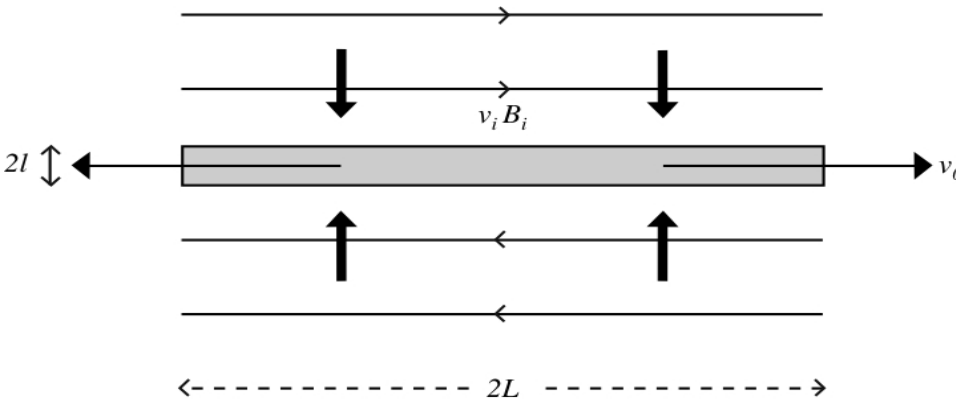
Summary

Major improvements and differences are elucidated in the NSTX-U simulations:

- A better shaping of the initial flux and narrower injector-flux footprints, lead to
  1. large volume of flux closure and nearly all of the CHI-generated current is closed-flux current. [Ebrahimi&Raman 2015]
  2. that reconnection could occur at every stage of the helicity injection.

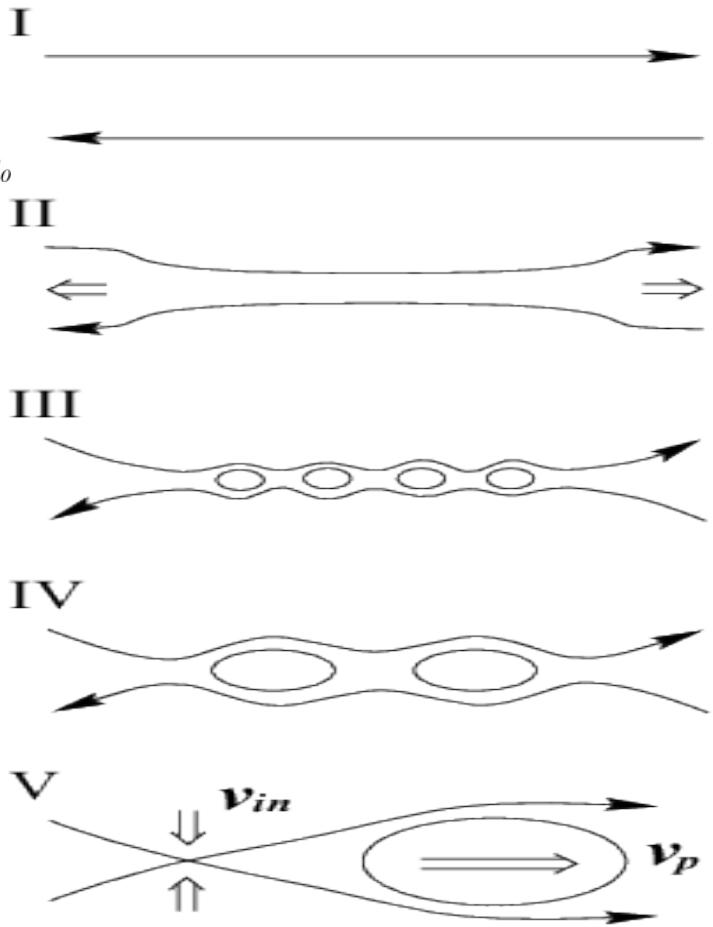
How are the closed flux surfaces formed?

Force reconnection?



- Sweet-Parker type forced magnetic reconnection in laboratory plasmas has been extensively studied. [H. Ji, Yamada et al. 1998]
- $\boxed{V_{in}/V_{out} = S^{-1/2} = \ell/L}$
  $(S = \mu_0 L V_A/\eta)$

Spontaneous reconnection?



Shibata & Tanuma 2001