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Solenoid-Free Plasma Start-up

NSTX

D. Mueller and the Solenoid-Free Plasma Start-up ET

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February 22-24, 2006

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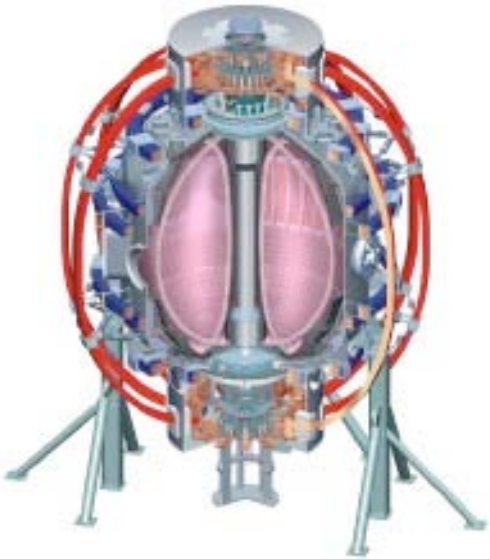
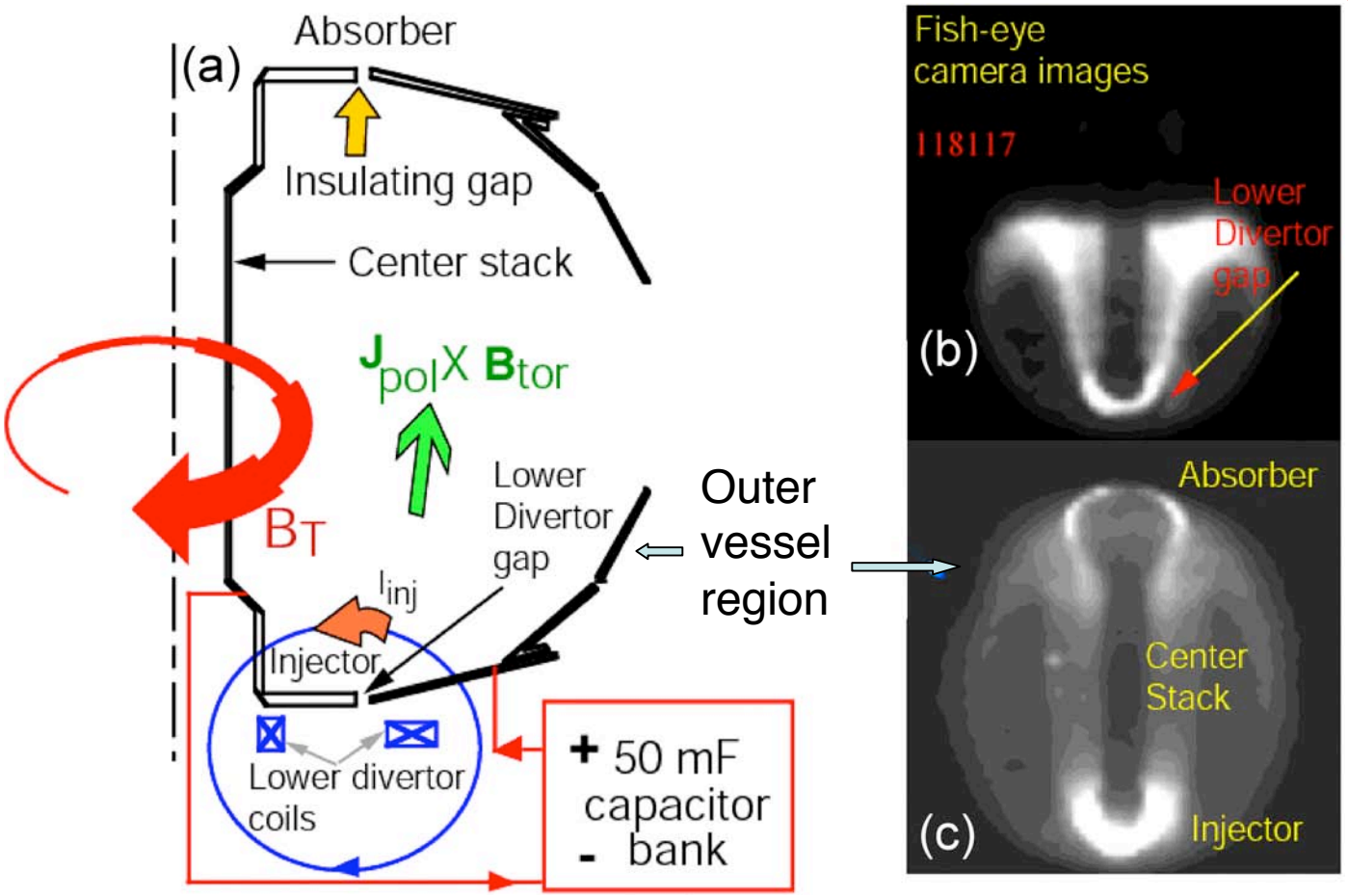


Coaxial Helicity Injection (CHI) in NSTX



a) NSTX machine components for transient CHI

b) TV image early in discharge

c) Later when the discharge nearly fills vessel

- Starts as helical discharge following B
- J_{pol} X B_{tor} is up into vessel

Relaxation dynamics and flux amplification in NSTX CHI experiments

- CHI plasma relaxation through helical instability cascade
  - Open flux kink to closed flux MHD modes
- For CHI plasmas
  - Dynamo probe can verify dynamo and anti-dynamo loop voltages
  - Mirnov coils measure helical perturbations (required for relaxation)

X. Tang and Boozer, Phys. Plasmas **11**, 2679 (2004);
Phys. Plasmas **12**, 042113 (2005);
Phys. Rev. Lett. **95**, 155002 (2005)..

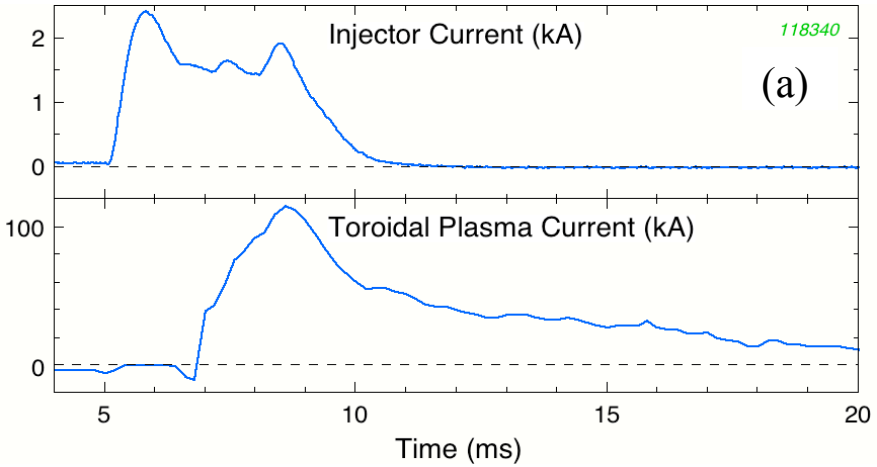
Solenoid-free start-up is important for the ST

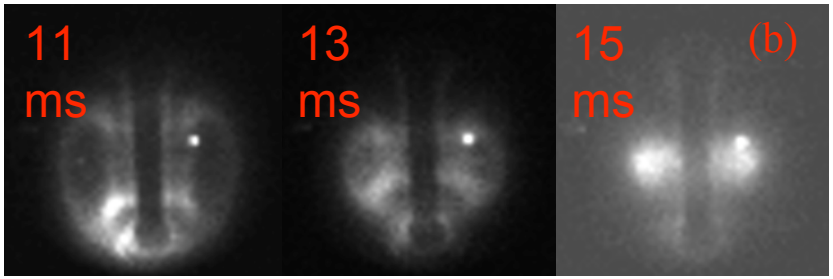
- Limited space for the center column in an ST necessitates alternative start-up and current drive
- Favorable scaling of current multiplication for Transient CHI observed between HIT-II and NSTX

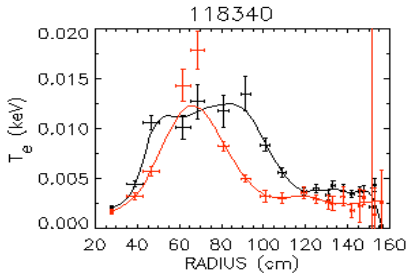
	HIT-II	NSTX
ϕ_{tor}	0.17Wb	1.5Wb
I_{inj}	≥15kA	≥2kA
I_p	~90kA	~120kA

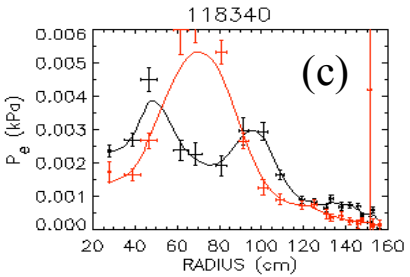
- CHI extrapolates to larger, high-current machine, e.g. CTF, with low injector current if
  - Apparent scaling with toroidal flux is maintained
  - Plasma temperature is adequate to achieve reasonable injector voltage

NSTX results in 2005 show clear evidence of current on closed field lines









NSTX - I_p > 60 I_{inj}

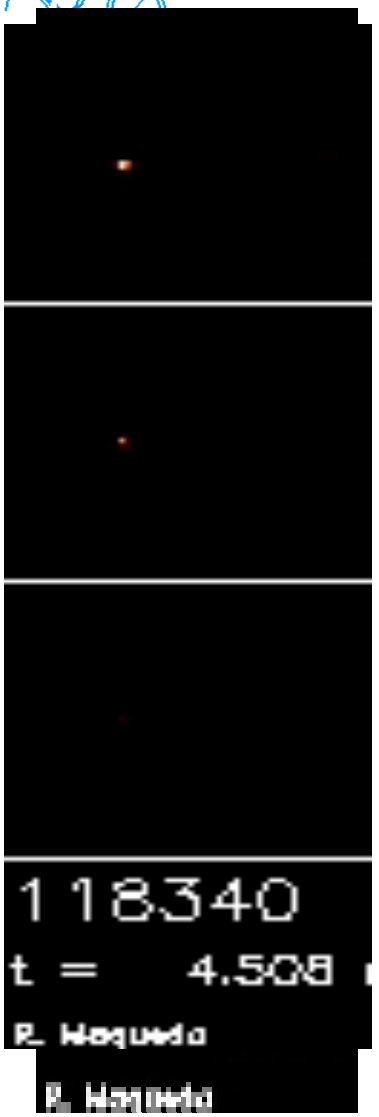
(HIT-II - I_p > 6 I_{inj})

Plasma position agrees with magnetic analysis

T_e, n_e profiles

13 ms (black)

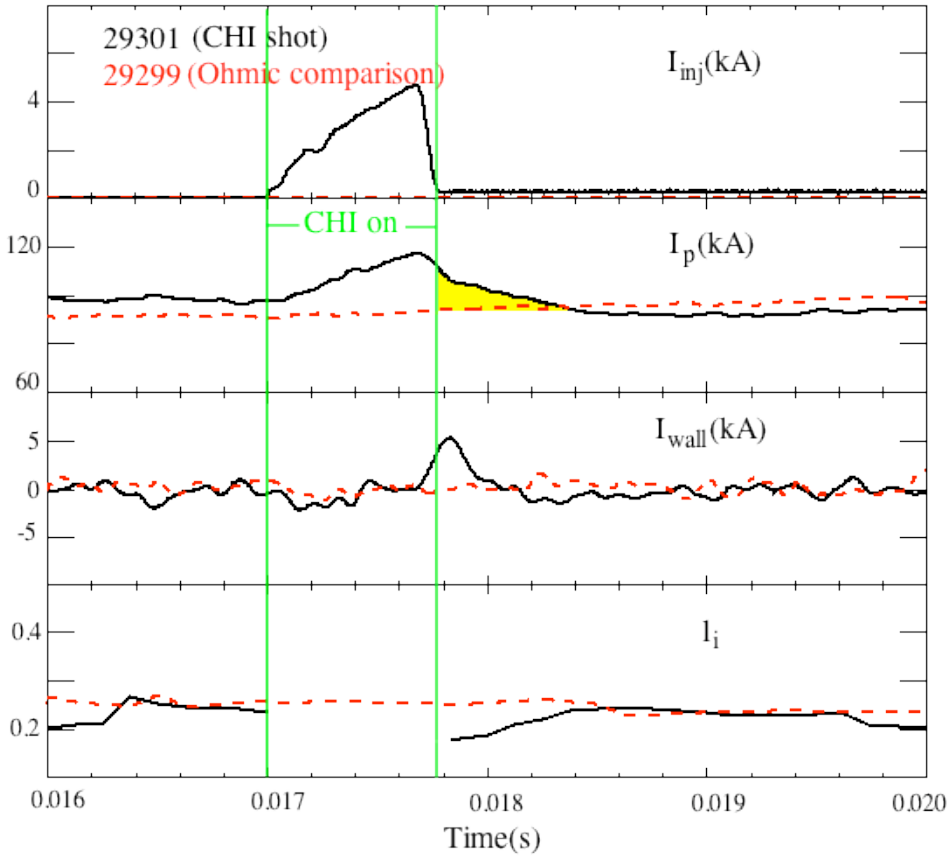
15 ms (red)



Produced persistent edge current drive by CHI on HIT-II

$\lambda_{inj} > \lambda_{tok}$

- CHI edge current drive can
  - Provide means to study reconnection
    - Persistent current
    - Well-characterized plasma
  - Control edge SOL flows
  - Improve stability limits
  - Induce edge rotation



- In NSTX, CHI applied to ohmic discharge produced an increase in total toroidal current

Plan to measure signatures of reconnection during edge current drive with CHI

- Apply constant V_{loop}, using feedback on I_{OH}
- Measure j(r), using NB source A for MSE
- Look for non-axisymmetric modes during reconnection (X. Tang, LANL)
- "Dynamo probe" tip on fast reciprocating probe will measure

  $\tilde{n}_e, \tilde{T}_e, \tilde{\Phi}_s$ at 2 poloidal and radial positions

  $\tilde{B}_\theta, \tilde{B}_r, \tilde{B}_\phi$ at one location
  - Provides information regarding models of the CHI reconnection by directly measuring the fluctuations

Solenoid-Free Plasma Start-up Plan for 2006

- Transient CHI (3 days)
  - 1 day before introduction of lithium evaporator, 2 after
  - Increase V_{CHI} to 2 kV
  - Investigate B_T scaling
  - Diagnose with fast camera, soft x-ray array, Thomson scattering, spectroscopy, bolometer
  - Study effects of conditioning (Li, He GDC, NB cryo-pumping)
- Edge current drive (1 day)
  - Study reconnection physics
- HHFW coupling study (Piggyback)
- Develop control for hand-off to inductive operation
- Assess alternative pre-ionization sources such as CT-Injection, EBW, Plasma Gun (PEGASUS), and high $k_{||}$ HHFW for PF-only start-up

Solenoid-Free Plasma Start-up Plans for 2007 & 2008

- Extend CHI scaling studies to full TF
- Physics studies of reconnection during CHI
- Couple Transient CHI to ramp-up
- Continue development of PF-only start-up
  - Pre-ionization selection (incremental in 2008)