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Solenoid free plasma start-up in NSTX by Coaxial Helicity Injection

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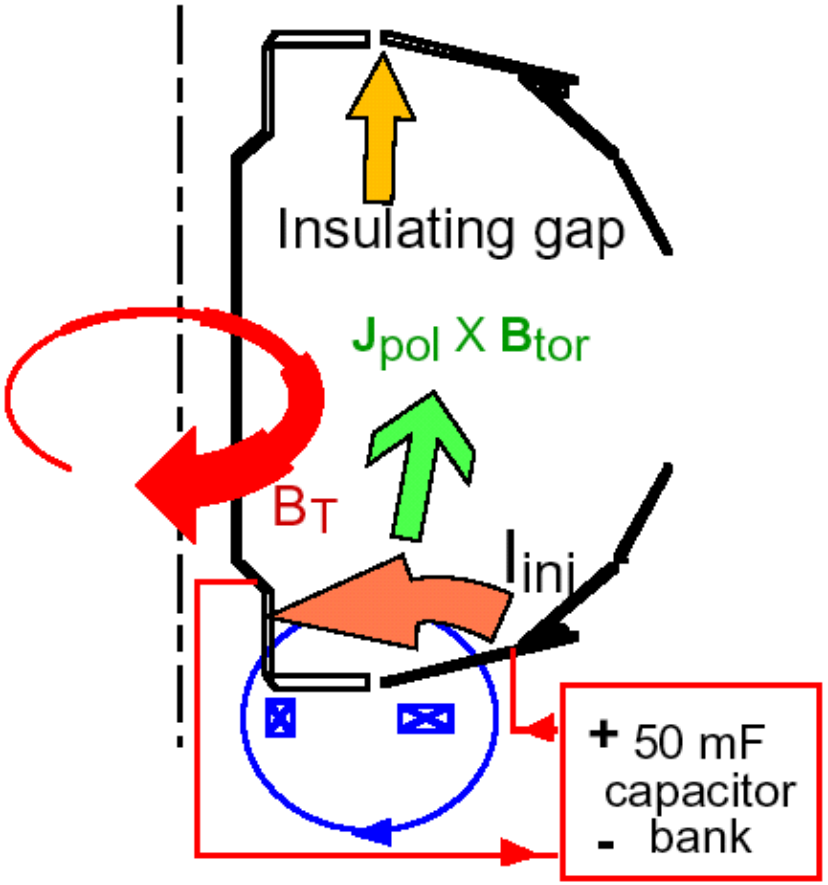
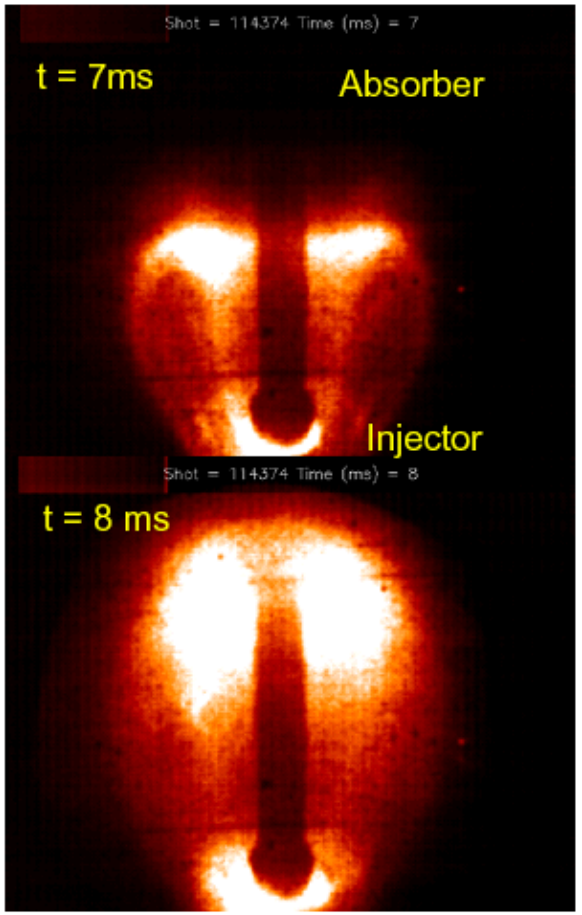
Implementation of Transient CHI

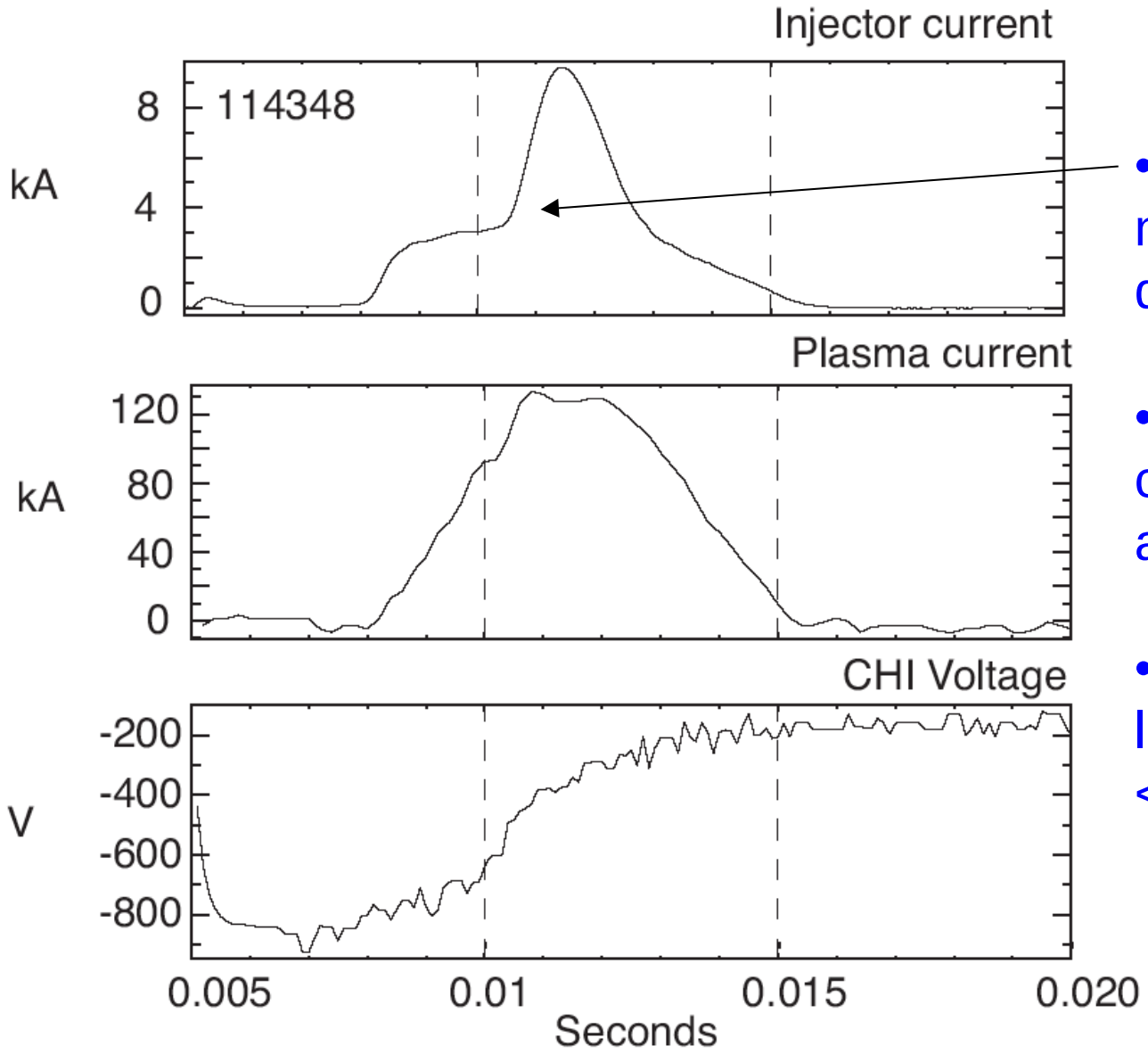




Expect axisymmetric reconnection at the injector to result in formation of closed flux surfaces

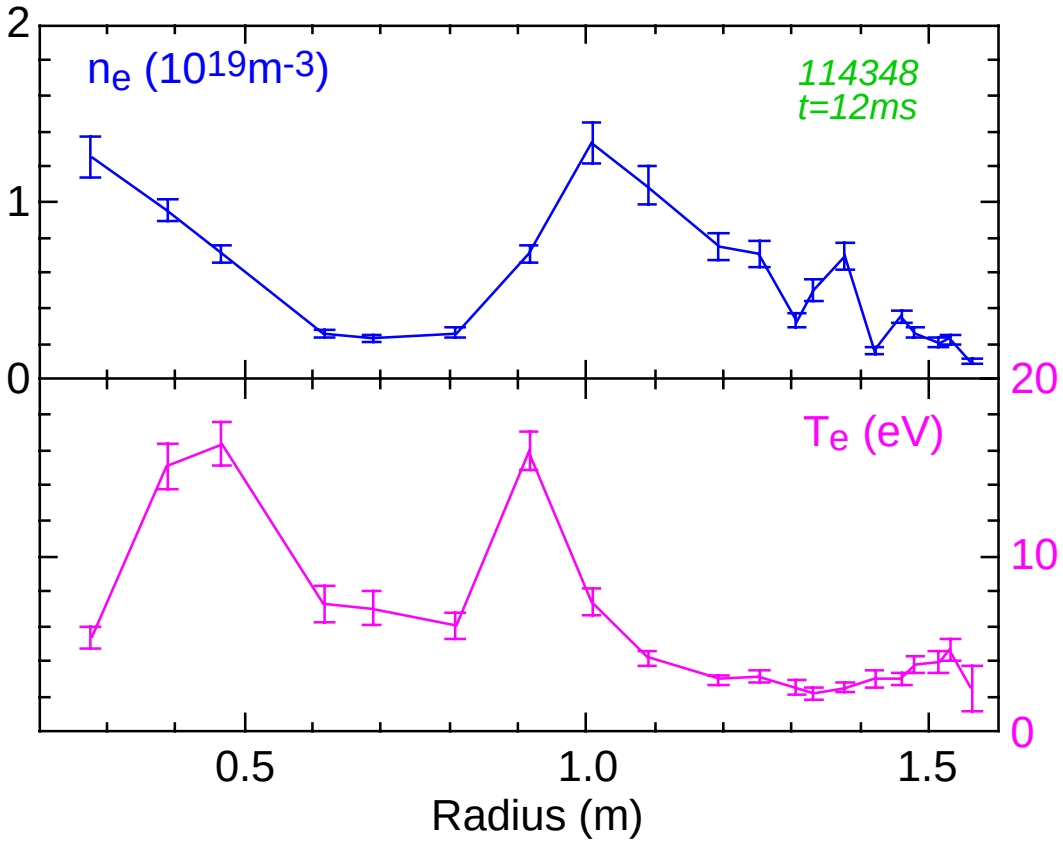
Fast camera: C. Bush (ORNL)

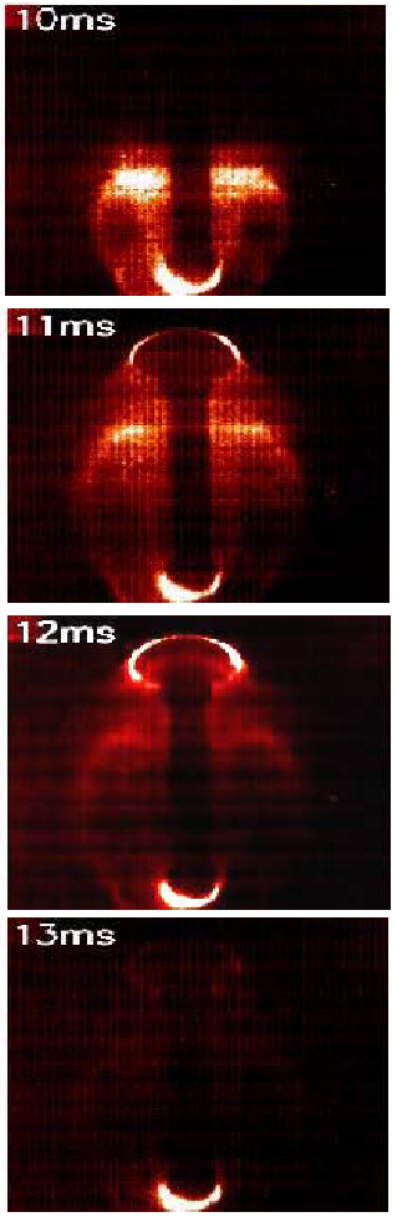
Initial transient CHI discharge in NSTX



- Absorber arcs do not terminate discharge
- Multiplication in current of ≥ 30 achieved
- Divertor power loading is small, < 2.4 MW

Te ~ 16eV measured in lowest neutral pressure discharge

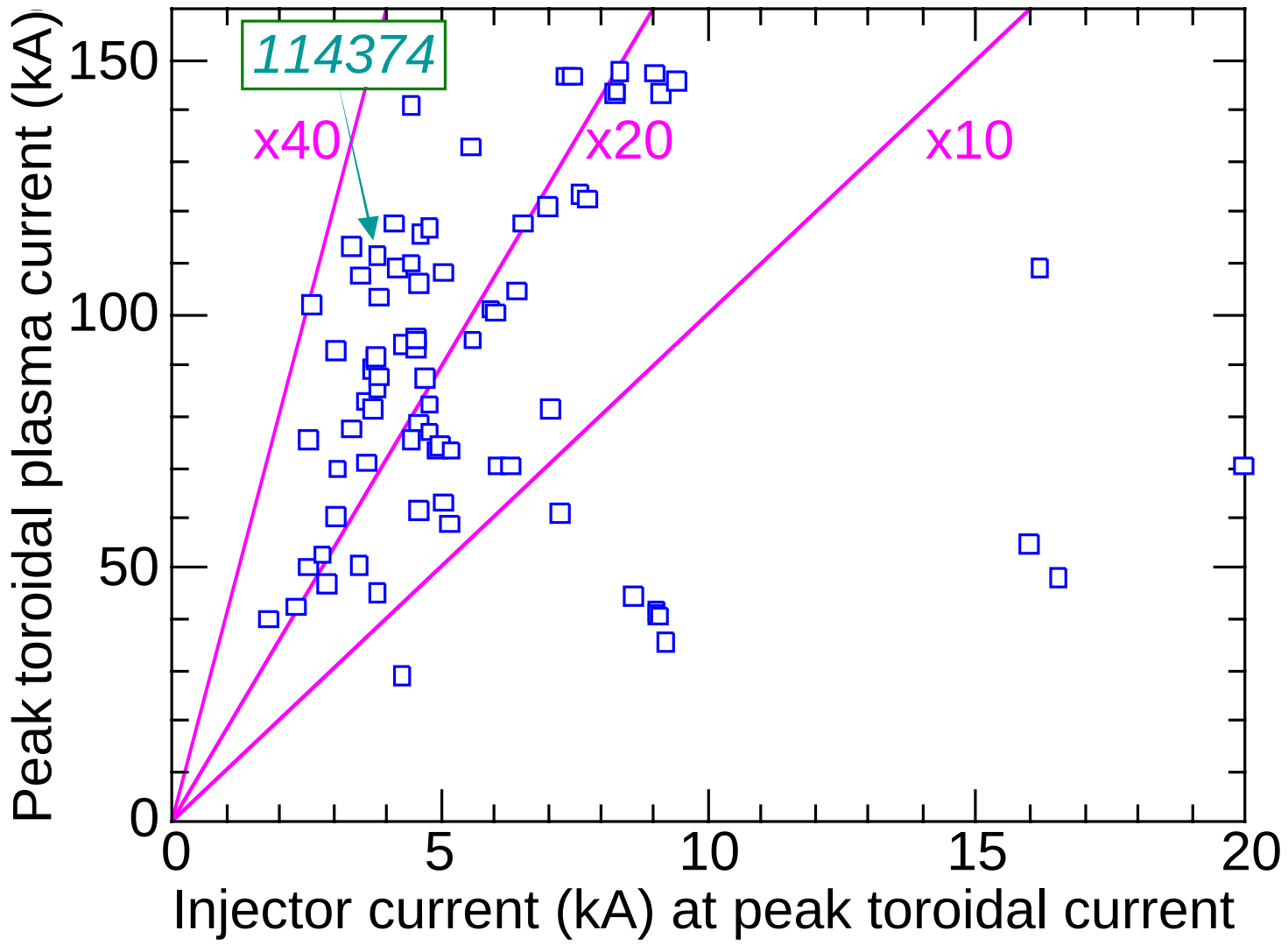




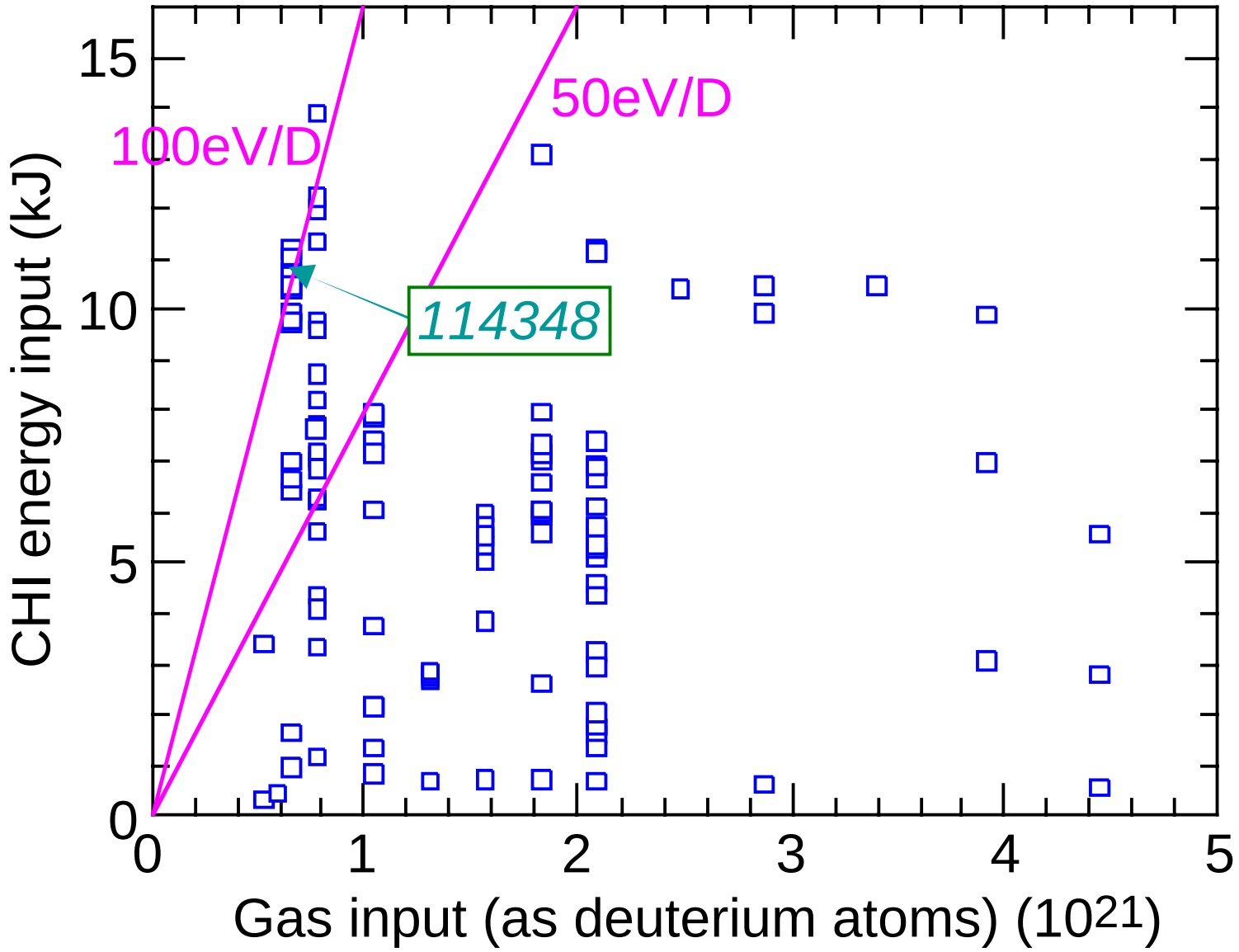
- Te increases with reduction in fill pressure
- Lowest fill pressure discharges limited by breakdown limitations

Thomson: B. Leblanc (PPPL)

Highest current multiplication obtained in low injector flux discharges



Highest electron temperature seen in discharges with lowest gas input



Capacitor bank requirements for Transient CHI

Bubble burst current that is equal I_{inj}

- Iinj $\propto \Psi^2_{inj}/\Psi_{toroidal}$ (easily met)

Volt-seconds to replace the toroidal flux

- For $\Psi_{toroidal}$ 600 mWb, at ~500V need ~1.2ms just for current rampup - *OK, but will improve at higher voltage*

Energy for peak toroidal current ($LI^2/2$, L=1μH)

- Maximum possible Ip (at 17.5 kJ) ~ 190 kA (achieved ~ 140 kA)
- *Need to increase Ecap*

Energy for ionization of all injected gas and heating to 30eV (~90eV/D)

- At lowest gas pressure 16.8 Torr.L injected, need ~17kJ just to ionize and heat – *Need to reduce total injected gas*

Equilibrium and pre-ionization requirements

The equilibrium coil currents provide the following:

- An equilibrium for the target closed current when the open field line current is back to zero
- The initial injector flux with a narrow enough footprint and high enough value so that λ_{inj} is higher than the target λ_{ST}.

$$\lambda_{inj} = \mu_o I_{inj} / \Psi_{inj} \quad \lambda_{ST} = \mu_o I_p / \Psi_{toroidal}$$

Gas puff provides the following:

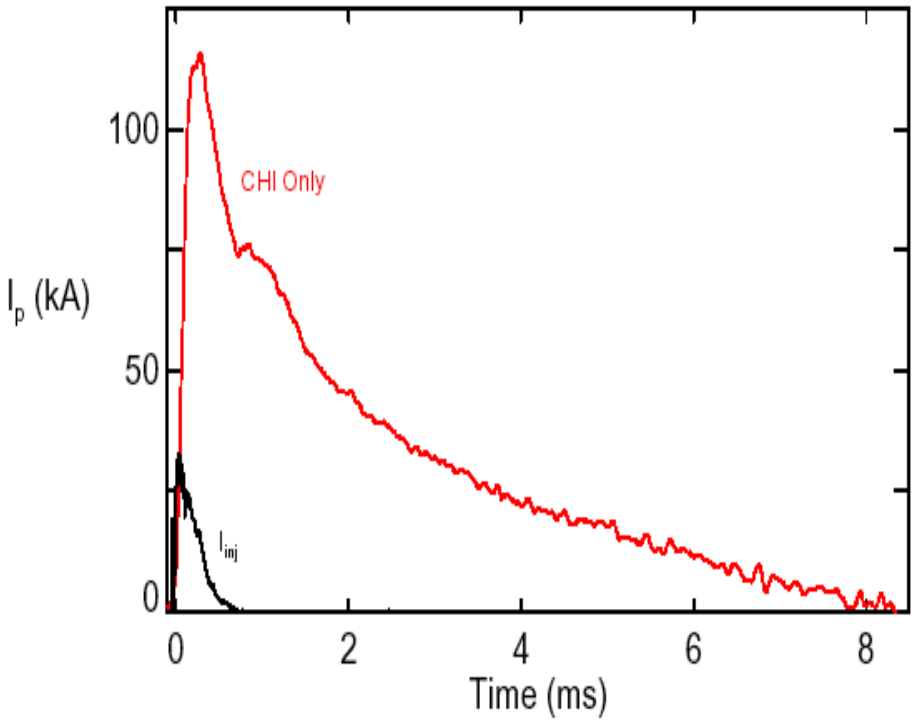
- Just enough gas for breakdown (need $j/n > 10^{-14}$Am, Greenwald)
- Highest density at the injector

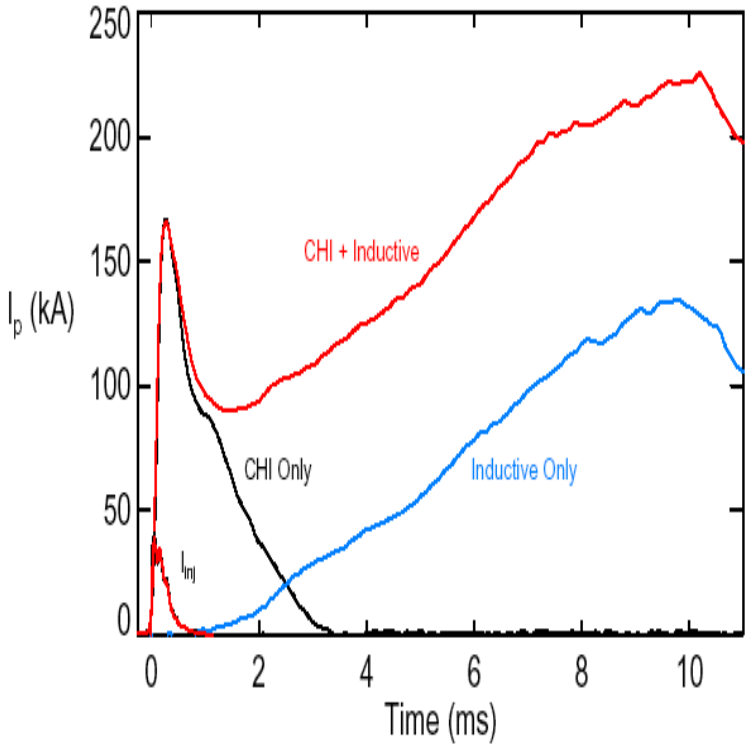
ECH provides the following:

- Pre-ionization for rapid and repeatable breakdown
  - Initial plasma in the injector gap

In HIT-II, nearly all Transient CHI produced closed flux current couples to the subsequent inductive drive

HIT-II





- Note the persistence of CHI plasma current after the injector current has been reduced to zero
- Both discharges have identical loop voltage programming

Conclusions

- The physics capability of CHI has been clearly demonstrated on HIT-II
- Transient CHI results on NSTX are consistent with our understanding and point to the need for certain technical improvements in NSTX
  - Reduced gas injection, while increasing gas pressure in the injector *(inject gas below divertor plates)*
  - Pre-ionize the injected gas and provide conditions similar to that from the SSI injectors on HIT-II *(redirect one of the ECH wave guides into the lower divertor region)*
- Technical improvements being implemented on NSTX should allow reproduction of HIT-II results

[Related HIT-II posters on Thursday afternoon – session PP1]