Fast Ion Transport Studies using Beam Blips

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ABSTRACT. Short $\sim$ 3 ms pulses of 80 keV deuterium neutrals are injected into NSTX. The jump in neutron emission during the pulse is used to infer prompt losses of beam ions. The decay of the neutron emission following the blip is compared to the expected classical deceleration to detect losses on a 10 ms timescale. Beam-ion loss detectors at the wall and neutral particle measurements also diagnose the beam behavior. The beams inject at three different tangency radii from nearly perpendicular to nearly tangential. The confinement is studied as a function of tangency radius, plasma current (between 0.4-1.0 MA), and toroidal field (between 2.0-4.5 kG). The presence or absence of MHD

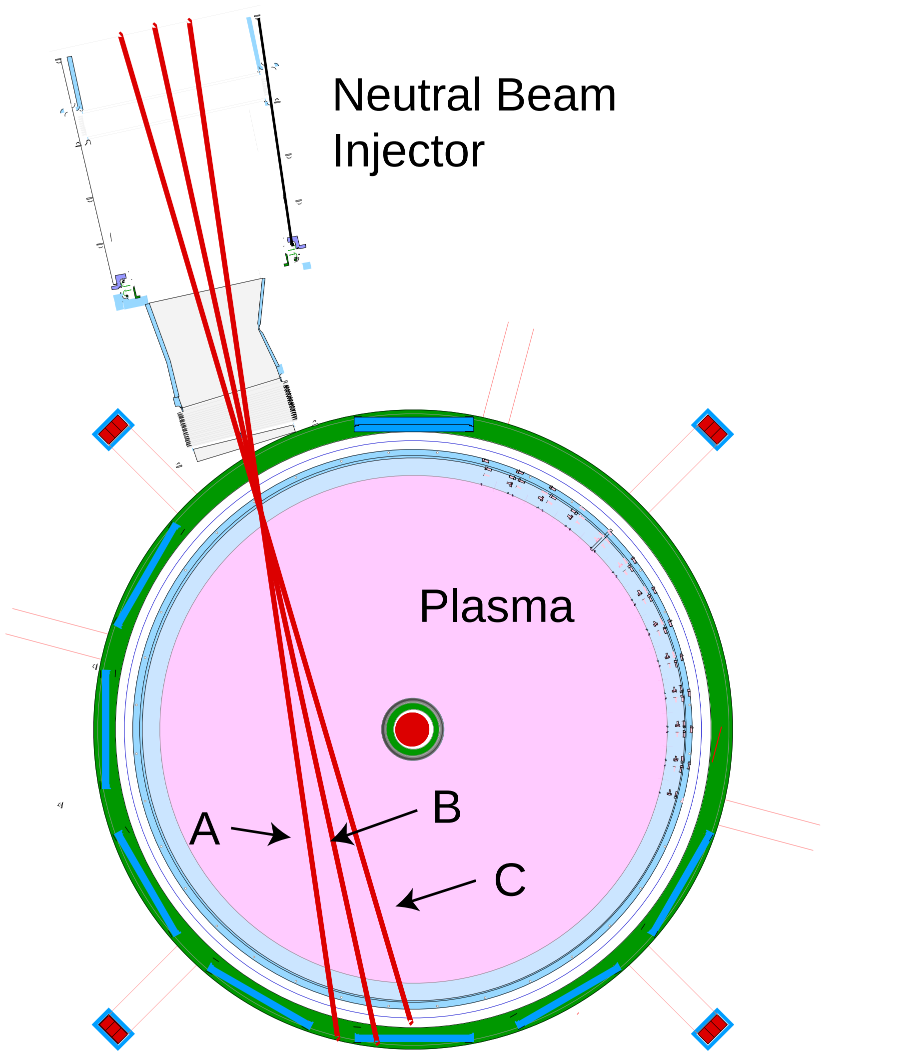
activity also has an important effect on the beam-ion behavior. Preliminary analysis shows the expected qualitative dependencies on beam angle and magnetic field.

Motivation

- The beams are a major heating system on NSTX–need to confirm their performance.
- Beam ions in NSTX are like alphas in a ST reactor.
- In a ST, conventional tokamak drift-orbit theory may break down for energetic ions because μ is not conserved.

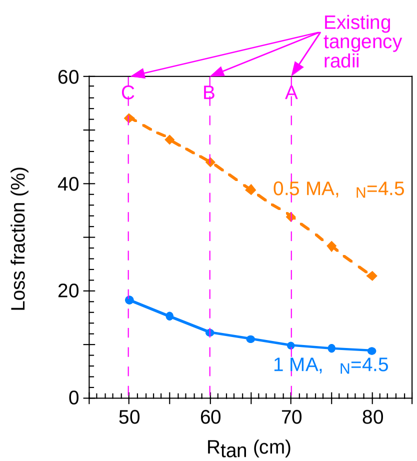
Neutral Beams Inject at 3 Angles on NSTX

- 80 keV D° beams.



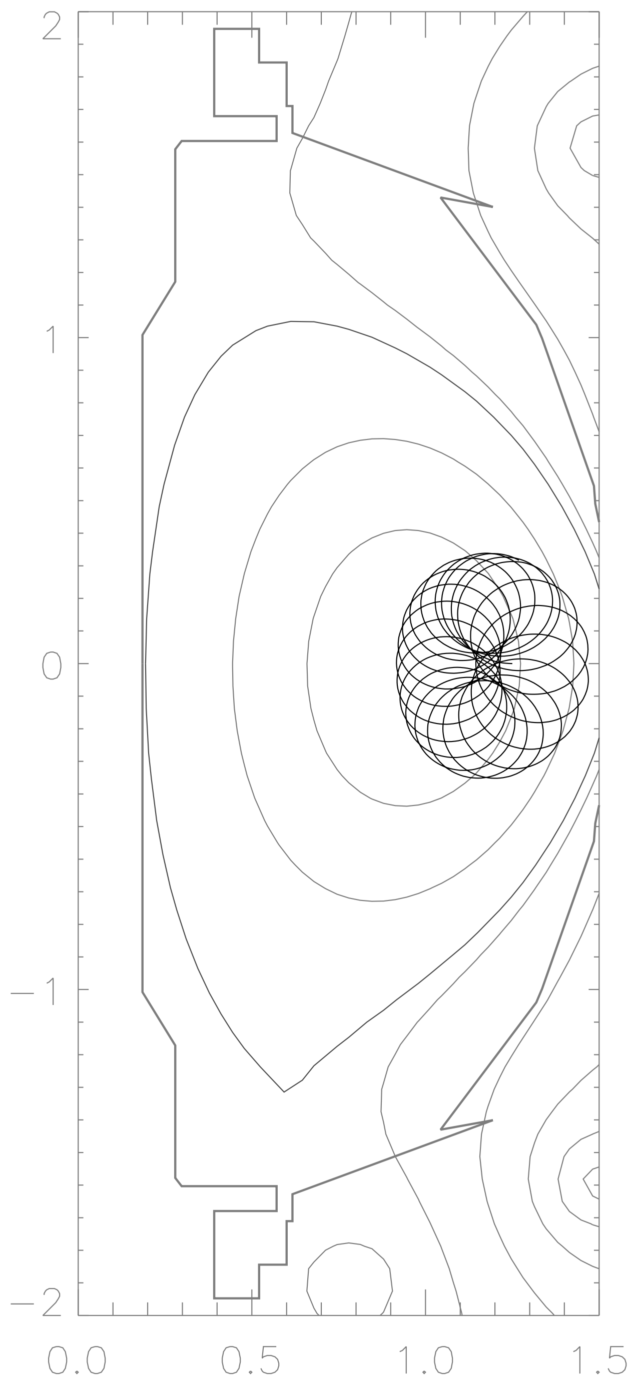
Beam ion loss rate model shows strong dependence on I_p and R_{tan} of beamline

NSTX



- Beamline with largest R_{tan} (A) is best confined

PPPL PRINCETON PLASMA PHYSICS LABORATORY

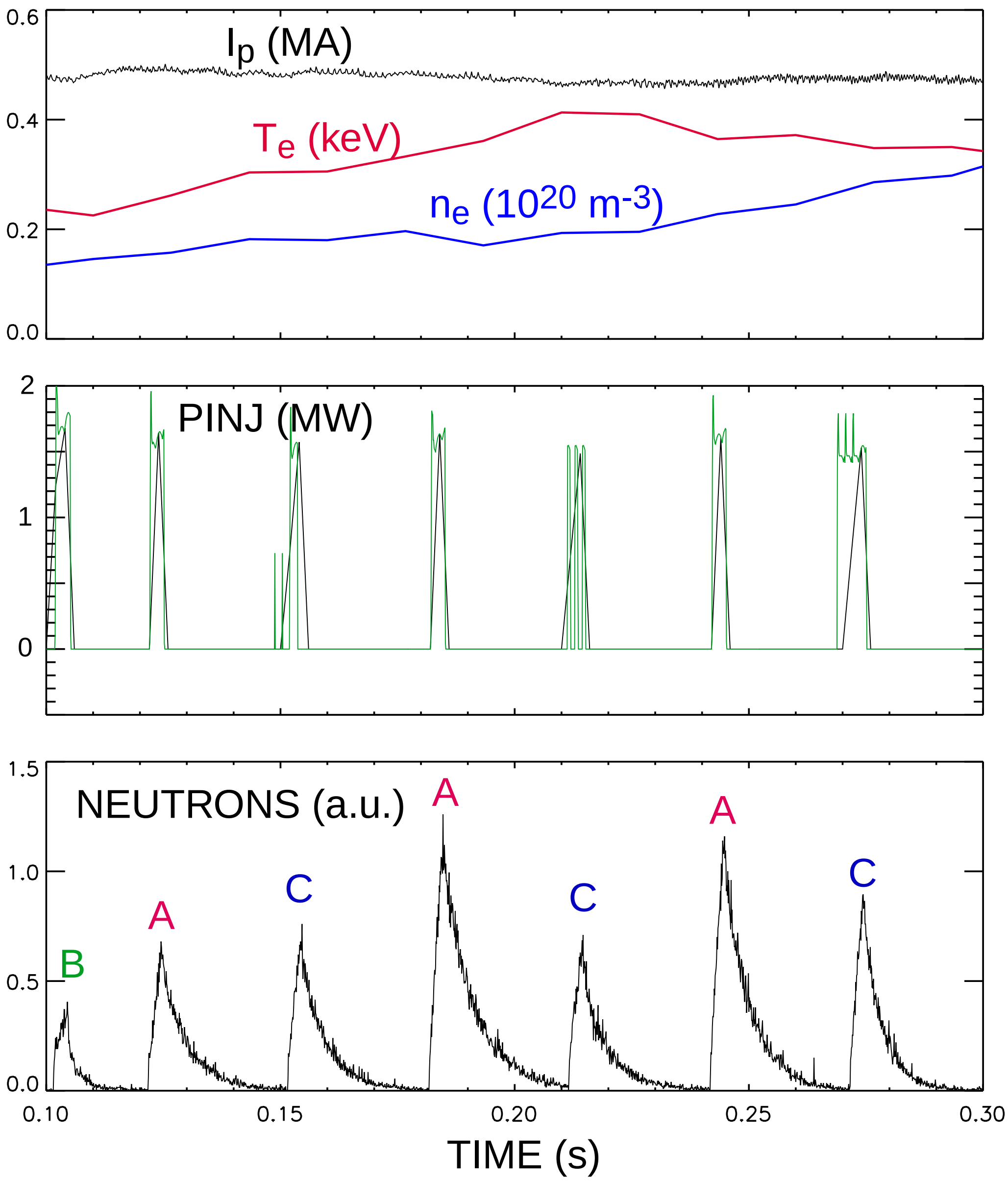

2
1
0
−1
−2
0.0
0.5
1.0
1.5

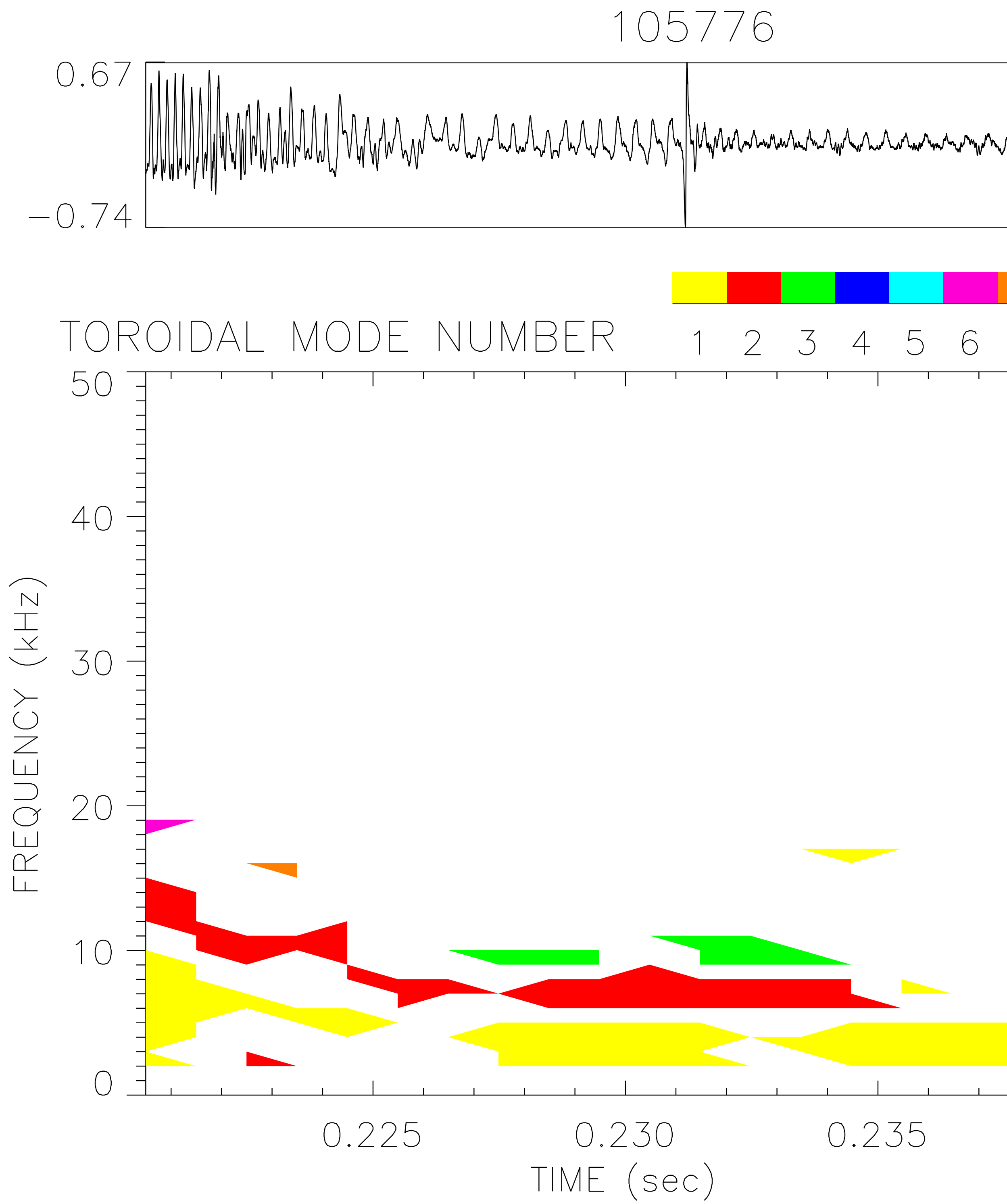
(not the actual figure)

Experimental Technique

- Short beam pulses ("beam blips") produce a convenient population of approximately monoenergetic beam ions $\longrightarrow$ deconvolves beam-ion thermalization and confinement.
- Thomson scattering measures the T_e and n_e profiles. These data are used to calculate classical deceleration.
- Magnetics monitor MHD activity.
- A database is formed of beam blips that satisfy two conditions: 1) similar Thomson profiles before and after the blip and 2) no major MHD activity.

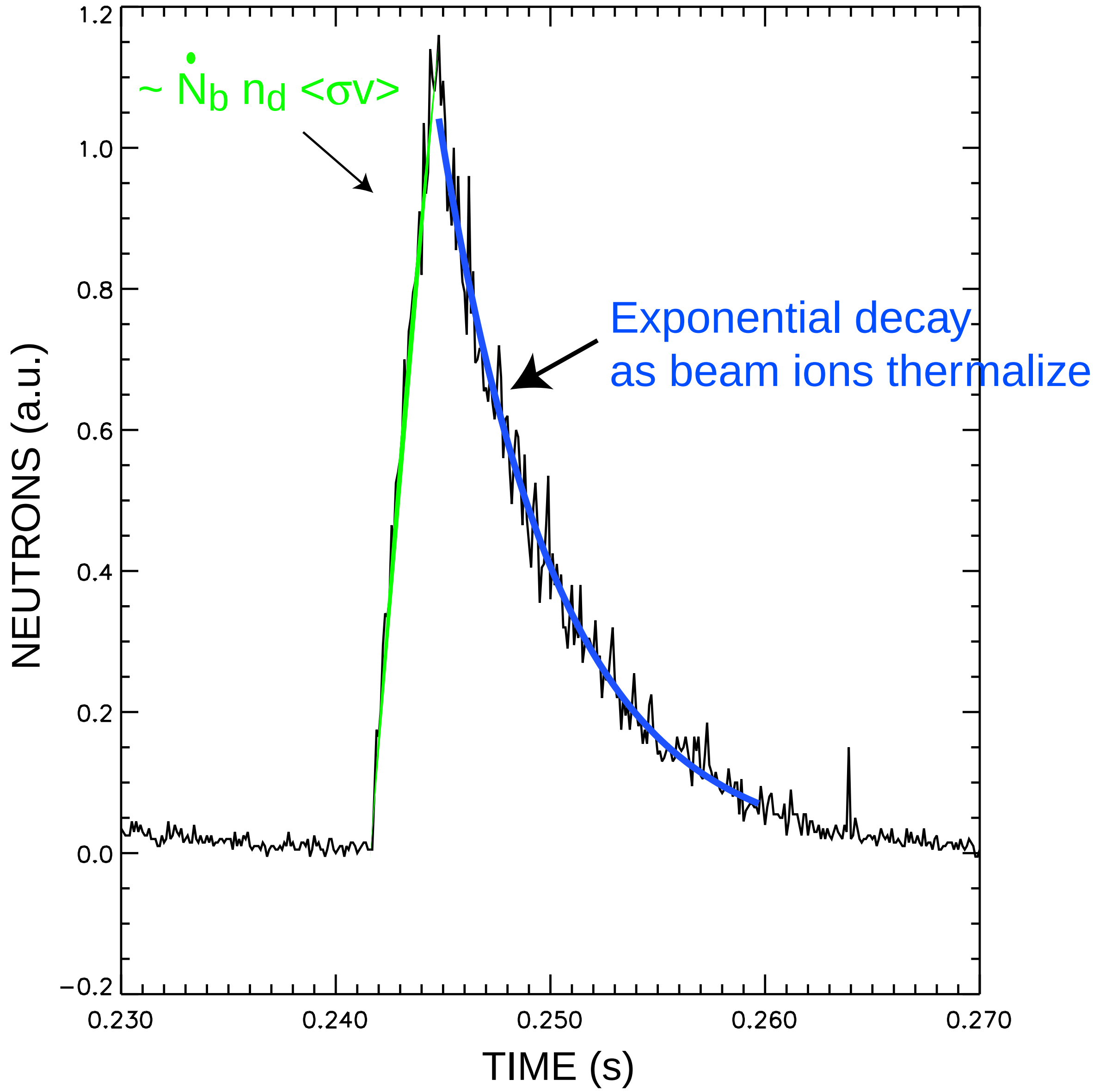
~ 3 ms Beam Blips Injected into Ohmic Plasma to study Beam-Ion Confinement



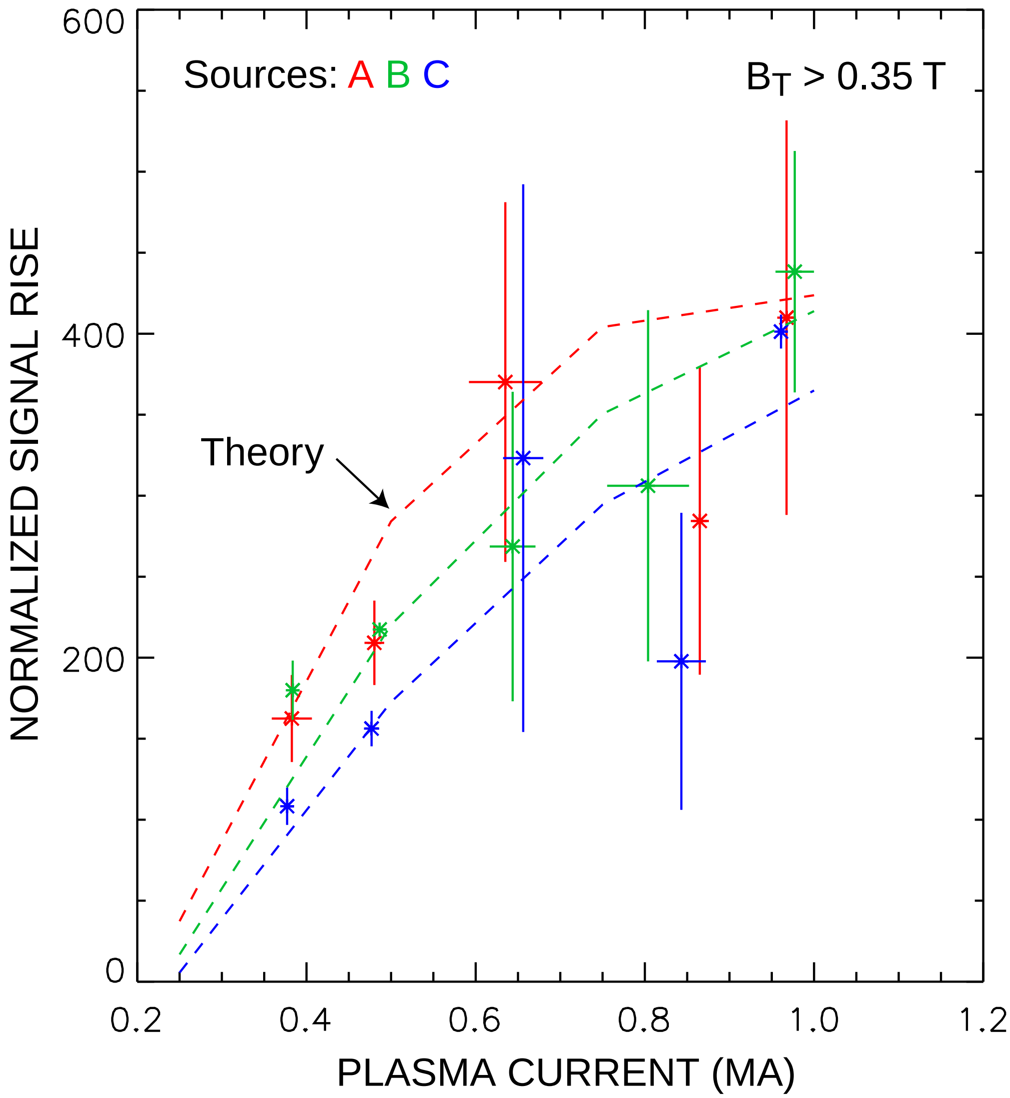

105776
0.67
−0.74
TOROIDAL MODE NUMBER
1 2 3 4 5 6
50
40
30
20
10
0
FREQUENCY (kHz)
0.225
0.230
0.235
TIME (sec)

(not the actual figure)

Prompt Confinement from Initial Rise; Delayed Losses from Subsequent Decay

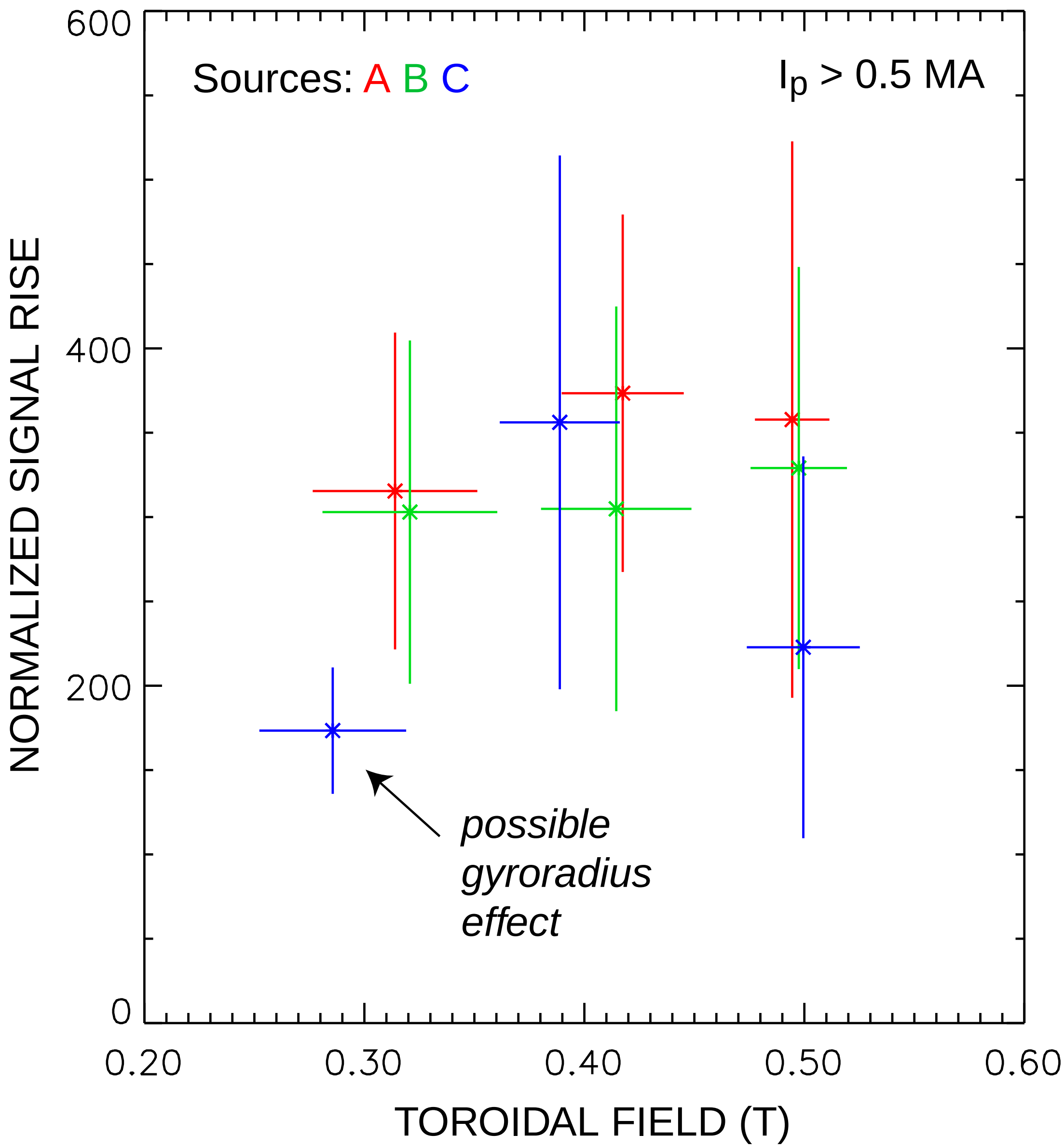


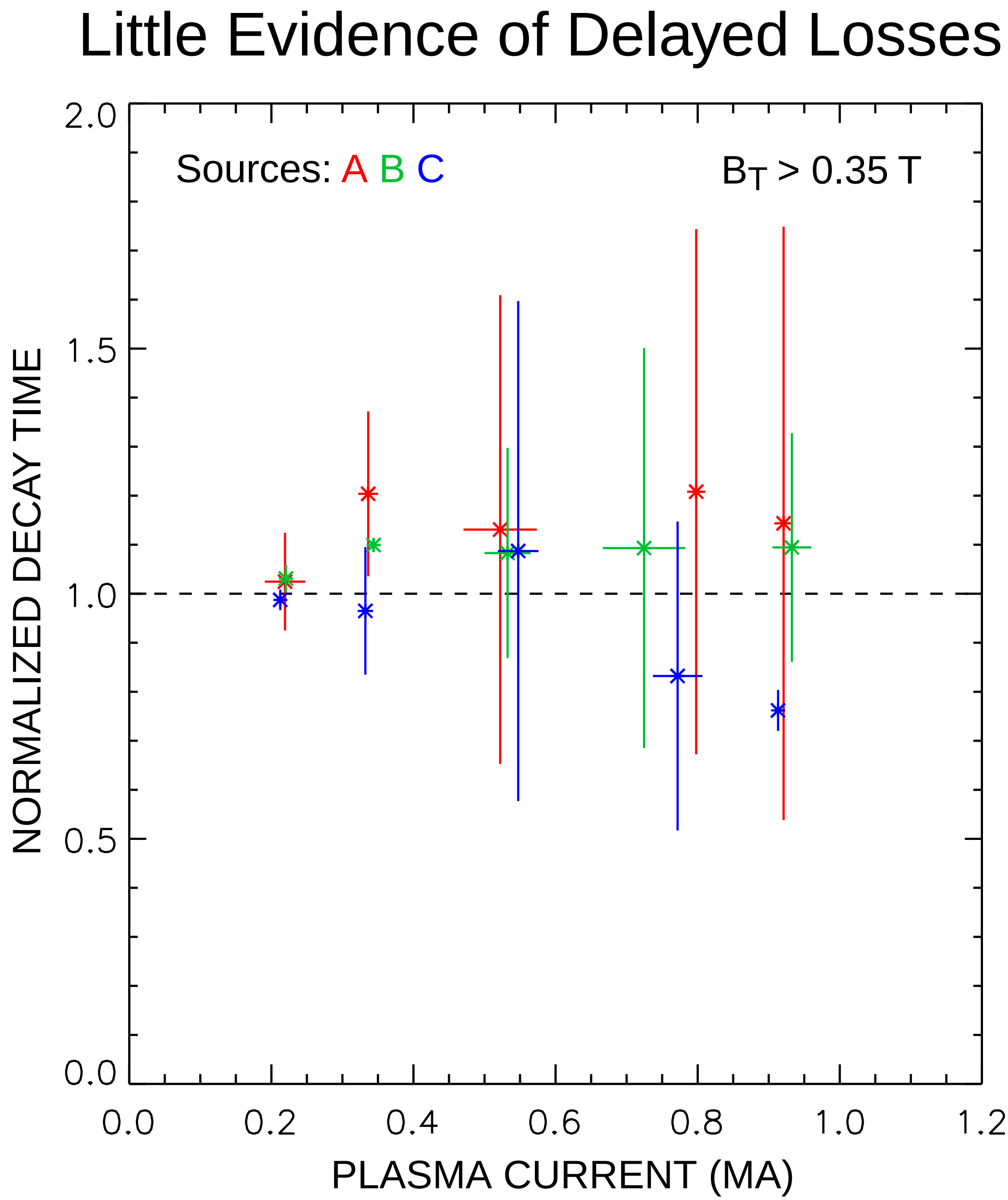
More Prompt Losses at Low Current: Expected Drift Orbit Effect

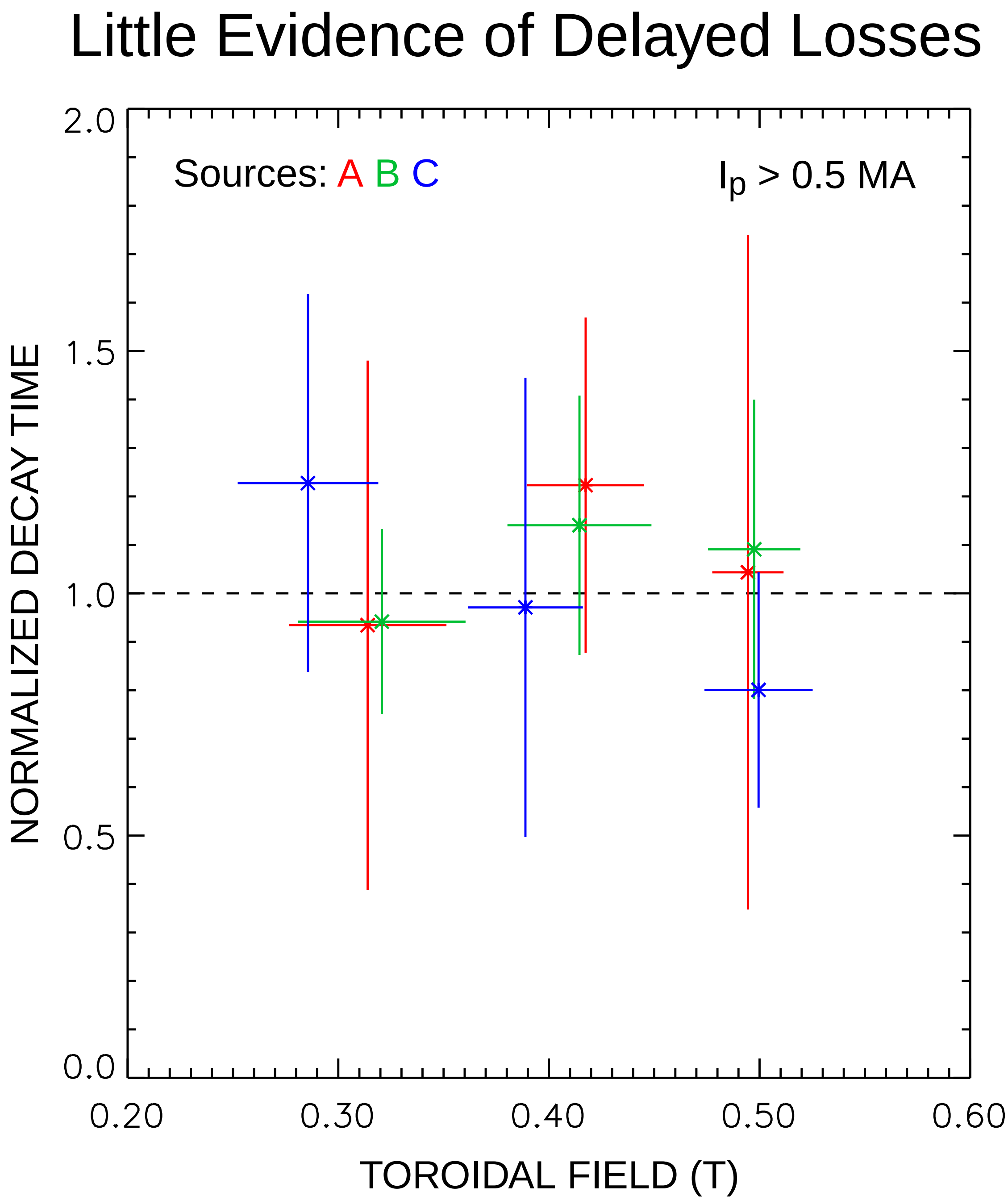


- The theory is only approximate: it is the fraction of full-energy beam ions that are confined on the first drift orbit in a 0.3 T plasma with a relatively broad density profile and $\bar{n}_e = 3.5 \times 10^{19}$ m^{-3}.

Weak Dependence of Prompt Confinement on Toroidal Field




Little Evidence of Delayed Losses
Sources: A B C
B$_T$ > 0.35 T
NORMALIZED DECAY TIME
PLASMA CURRENT (MA)
0.0
0.5
1.0
1.5
2.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2


Little Evidence of Delayed Losses
Sources: A B C
Ip > 0.5 MA
NORMALIZED DECAY TIME
TOROIDAL FIELD (T)
2.0
1.5
1.0
0.5
0.0
0.20
0.30
0.40
0.50
0.60

Results

- For all three injection angles, confinement is degraded for currents below 0.5 MA, as expected.
- The effect is strongest for the most perpendicular injection angle, as expected.
- The dependence of the prompt losses on toroidal field is generally weak, as in conventional tokamaks.
- Possible evidence of additional prompt losses when $\rho > 20$ cm.
- Decay time consistent with classical theory for all parameters $\longrightarrow$ delayed losses relatively unimportant (as expected for classical scattering).
- Strong MHD activity degrades the confinement.

Future Work

Data Reduction

- Analyze neutral particle and loss-detector data.
- Search for correlations with Compressional Alfven Eigenmodes.

Comparison with Theory

- Semi-analytical calculations for every blip.
- TRANSP runs for many discharges.
- Full orbit calculation (for different beam angles) for one or two cases.
- Analytical calculations of expected losses caused by non-adiabaticity of μ as gyroradius increases.