Transport scaling experiments in non H-mode NSTX discharges (XP223)

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and the NSTX Team

XP goals

- Develop 'transport grade', MHD quiescent, long pulse, *non H-mode* discharges

- Explore the effect of changes in B_t, I_p, n_e, *momentum and power input* on transport, in preparation for ρ*, beta and flow shear scaling experiments on NSTX

- Develop and use fast Neon injection for independent probe of ion transport

- Look for ρ*/flow shear effects in peripheral ion turbulence (M. Gilmore, S. Kubota, UCLA)

- Obtain higher power discharges with/without CAEs for anomalous ion heating assessment

- Data may be relevant also for H-mode (L, H scaling similar at large A)

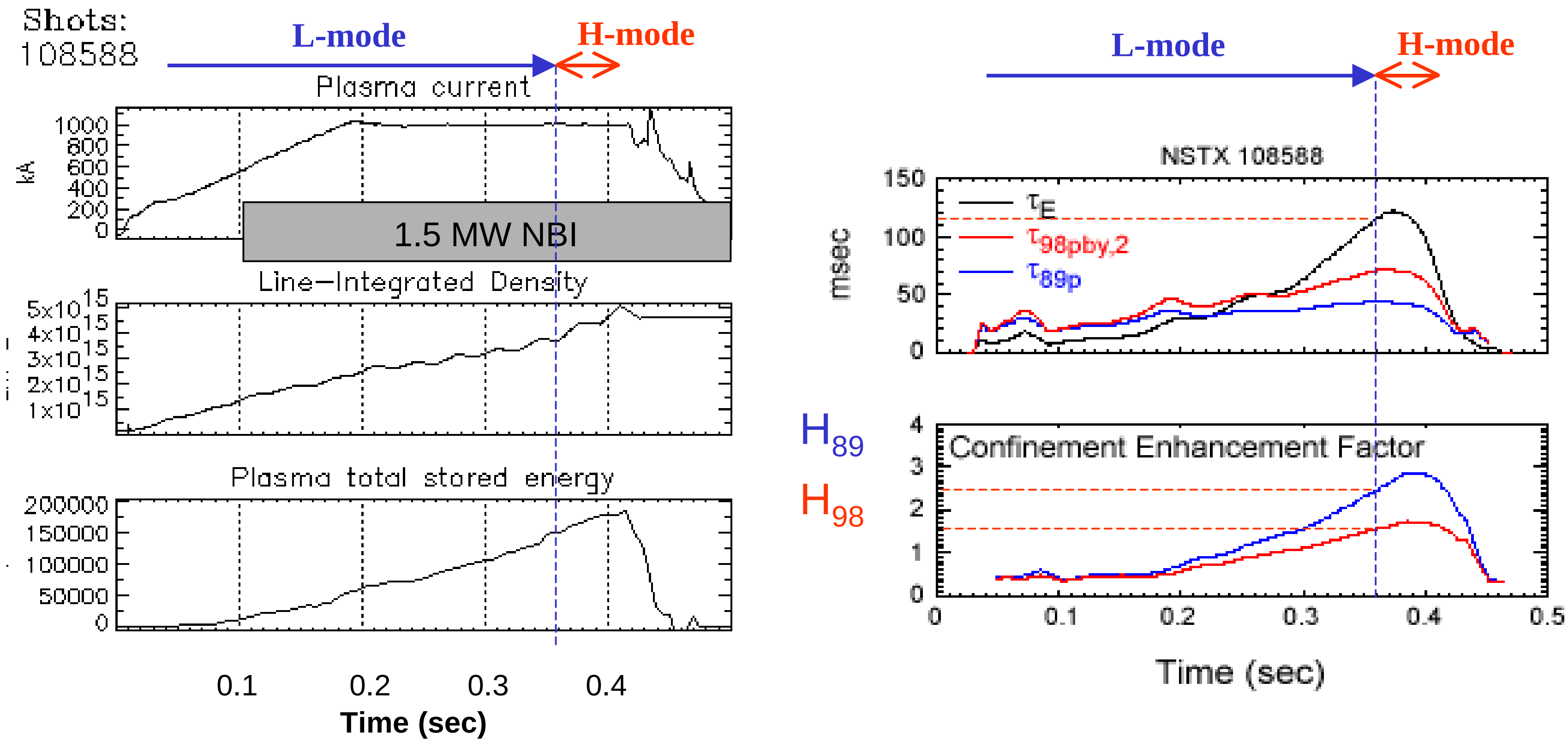
Scans performed

Base discharge: DND, k ≈1.9, δ ≈0.7, n_e <2.5 10^{13} cm^{-3}>, 1.5 MW NBI

- B_t scan and momentum input change (source A/R=.7 m vs. C/R=.5 m) at fixed I_p/B_t (q_{cyl}) and n_e
- I_p scan at fixed B_t, n_e (A and C)
- B_t scan at fixed I_p, n_e (A and C)
- n_e scan at fixed B_t, I_p (A and C)
- Power scan at fixed B_t, n_e, I_p

Initial results based on global confinement and Neon injection
TRANSP/NCLASS/microstability analysis awaits CHERS data

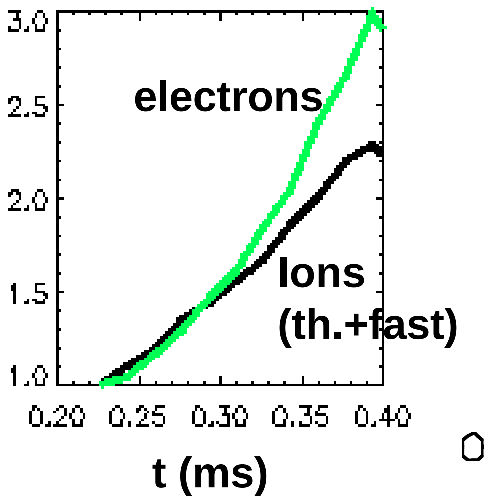
Typical discharge evolution



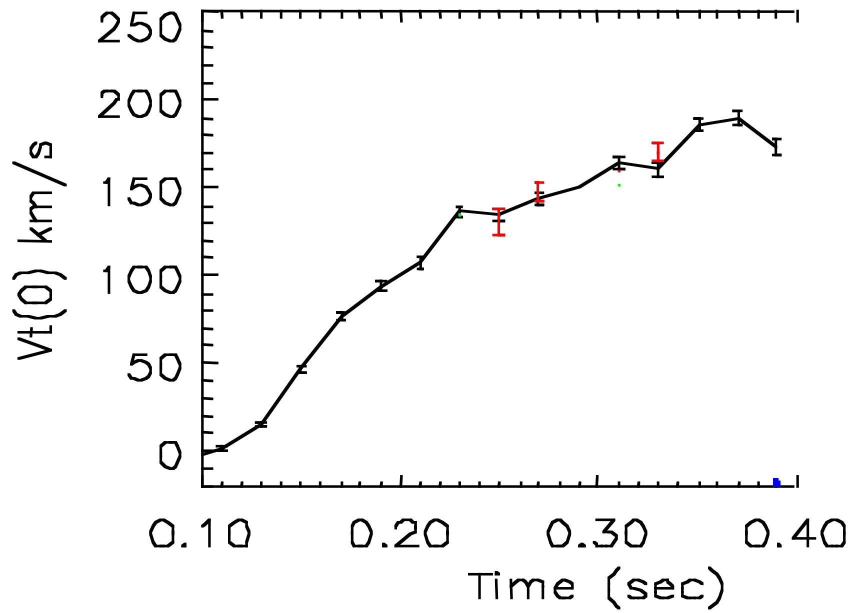
- Stored energy and τ_E increase steadily with time
- Up to 2.5 x L-mode and 1.5 x H-mode conventional confinement
- Little increase in confinement from L- to H-
- Why the confinement increase ? (n_e increase effect rather than cause)
- Confinement change related to current relaxation ? (≈ same time scale)

Discharge evolution cont'd

Estimated stored energy normalized to t=200 ms

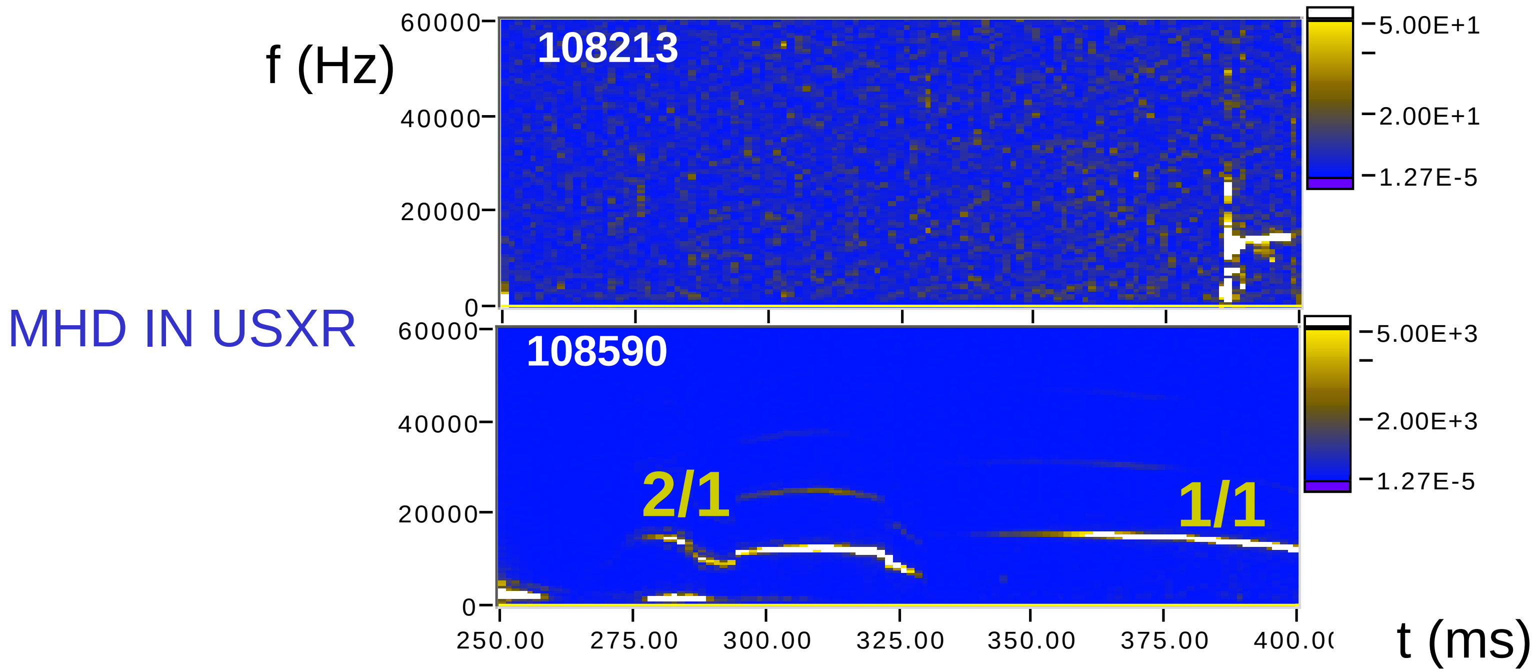


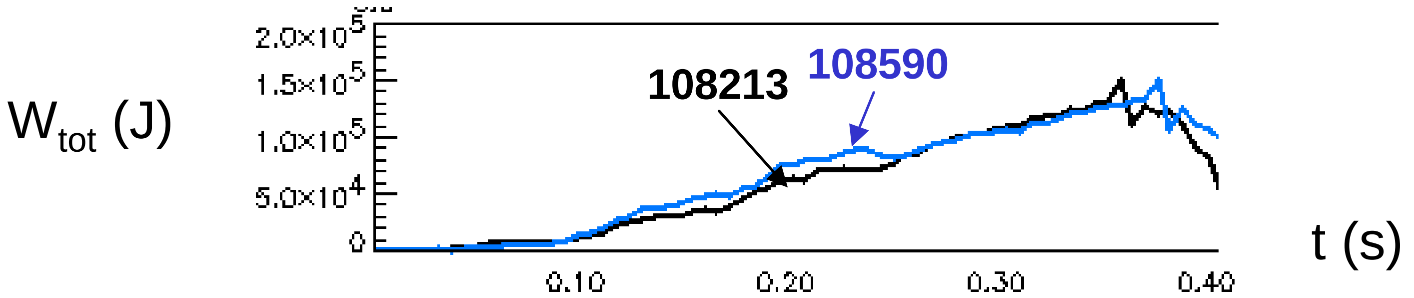
Central toroidal rotation



- Faster increase in electron stored energy suggests electron channel improves the most
- Toroidal rotation also increases, but at a significantly slower rate
- Momentum/ion confinement may be closer to an equilibrium value
- Lack of steady-state an issue for confinement analysis

MHD behavior





- Both MHD quiescent and MHD active (NTMs) discharges observed
- MHD active discharges have ≈ same stored energy as quiescent ones

-> transport characteristic scale larger than typical NTM size (several cm)

Parameter scans: what should we expect

L-mode scaling in engineering parameters (Nucl.Fusion **39**, 1999)

$$\tau_{E\,th} \approx 0.025\ I^{1}\ B^{0}\ P^{-3/4}\ n^{0.4}\ R^{2}\ (1/A)^{0}\ k^{3/5}$$

L-mode scaling in 'physics' parameters

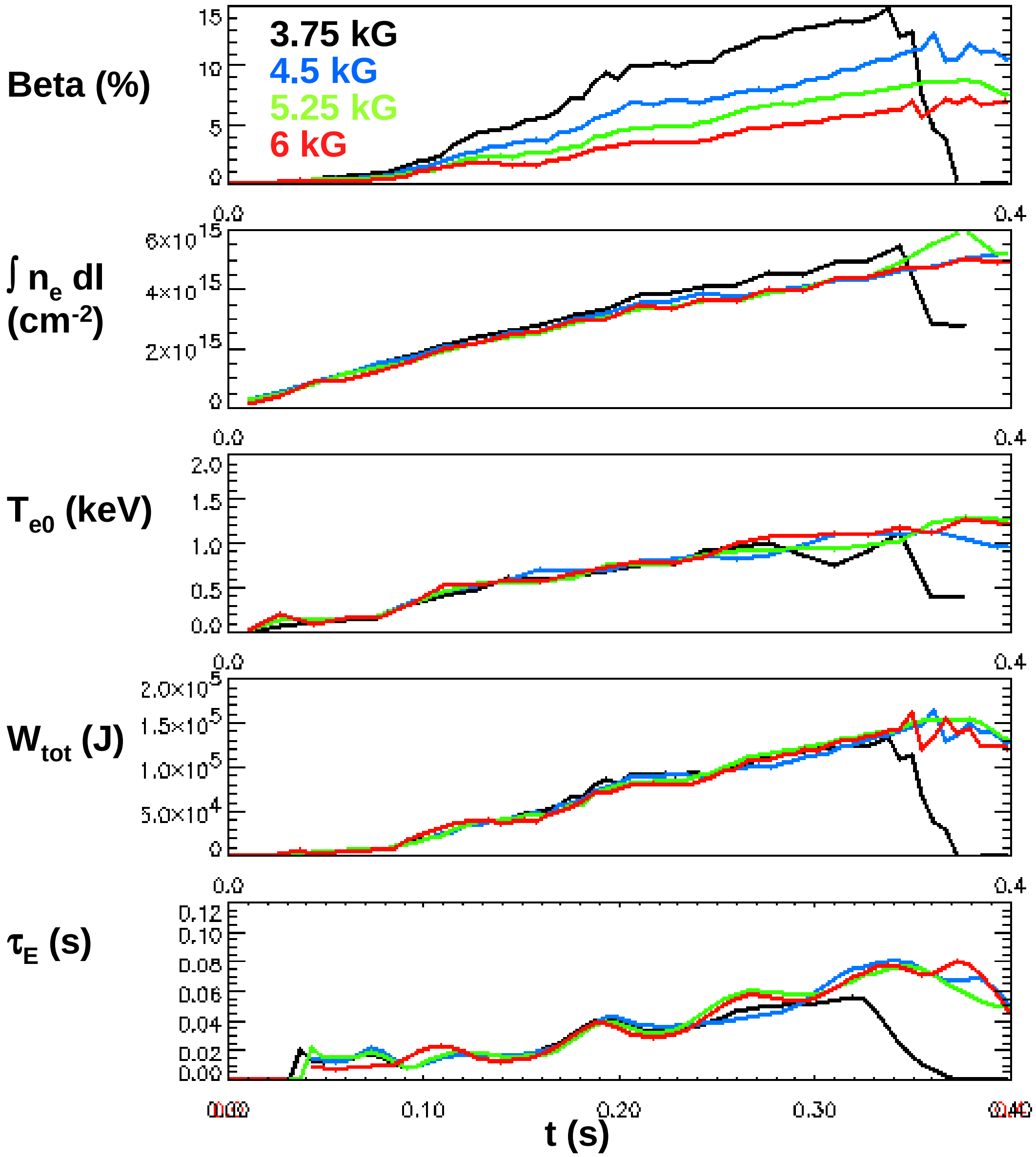
$$\tau_{E\,th} \approx \tau_{B}\ \rho^{*\,0.15}\ \beta^{-1.4}\ \nu^{*\,0}\ q_{cyl}^{-3.75}$$

τ_B: a^2B/T

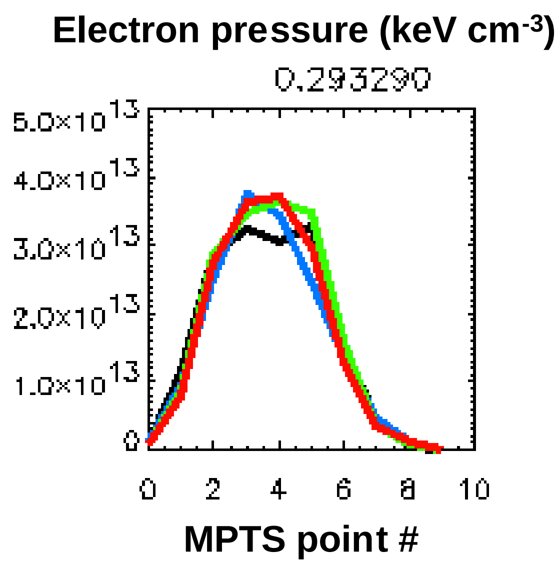
$\rho^{*\,0.15}$: $\approx$ Bohm scaling

- Conventional L-mode confinement: χ_i and χ_e comparable
- Two-fluid scaling: worse than Bohm ions and $\approx$ gyro-Bohm electrons
- β scaling contradicted by dimensionless experiments on DIII (at low β)

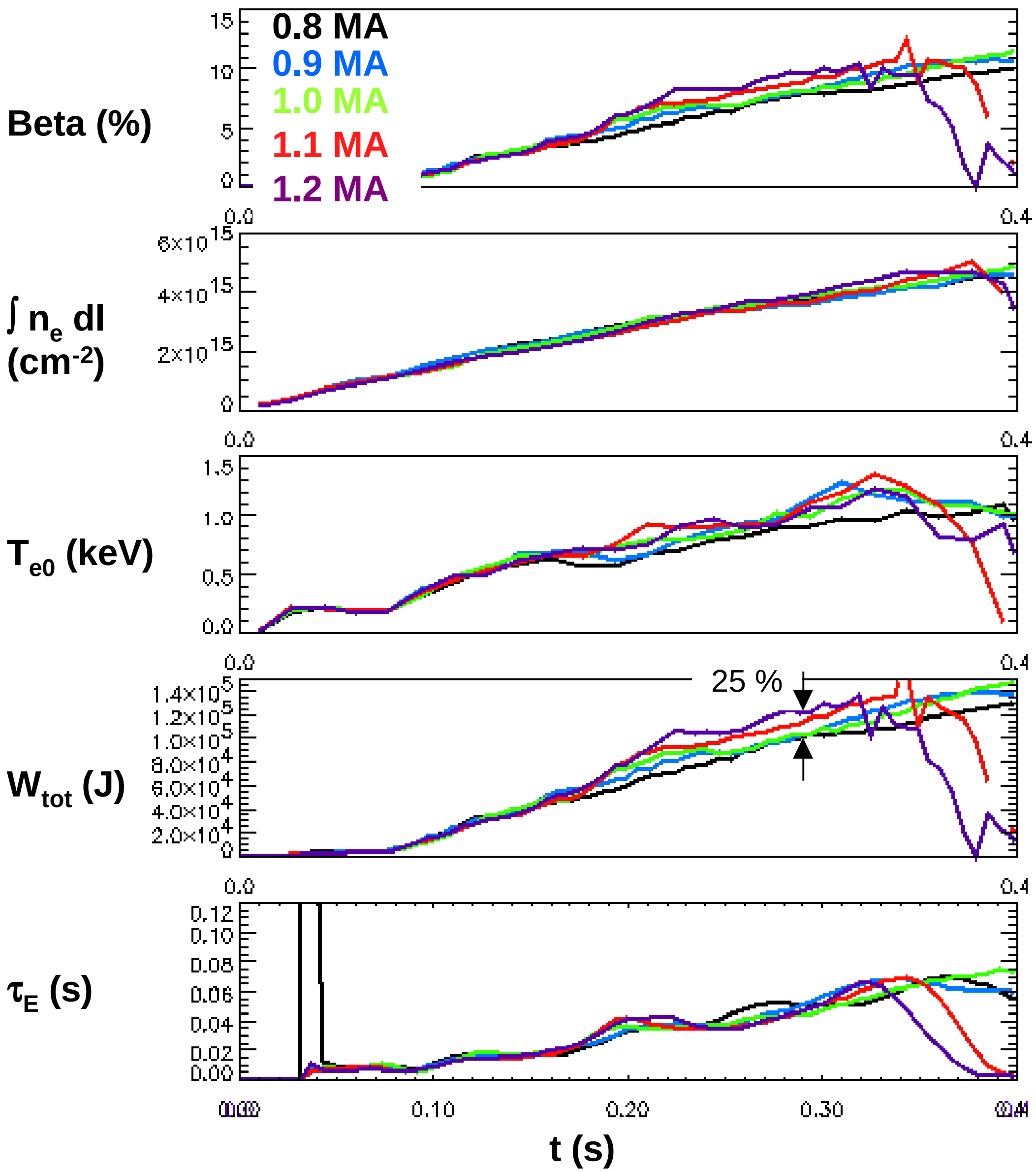
B_t scan at fixed I_p (1 MA) and n_e - source A



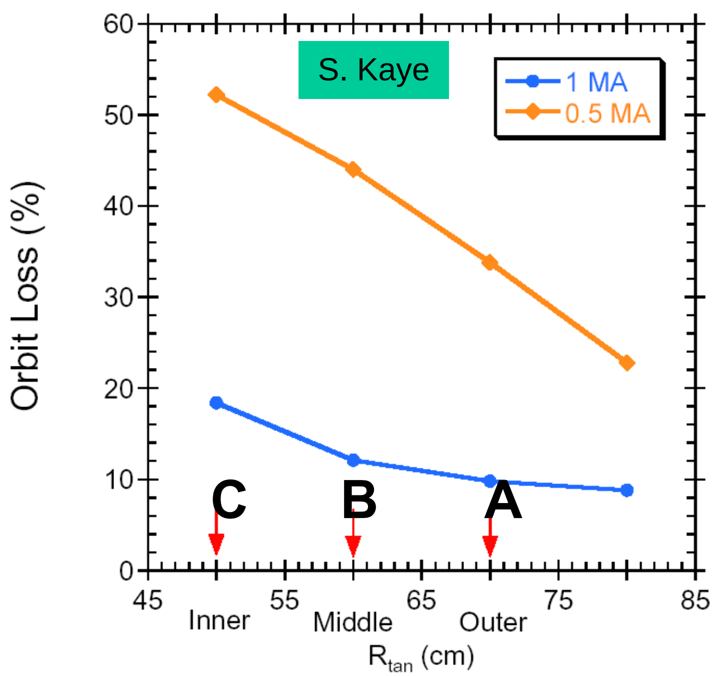
- No global confinement change for 160% variation in B_t and 280% variation in β_t
- Electron profiles do not change much with B_t



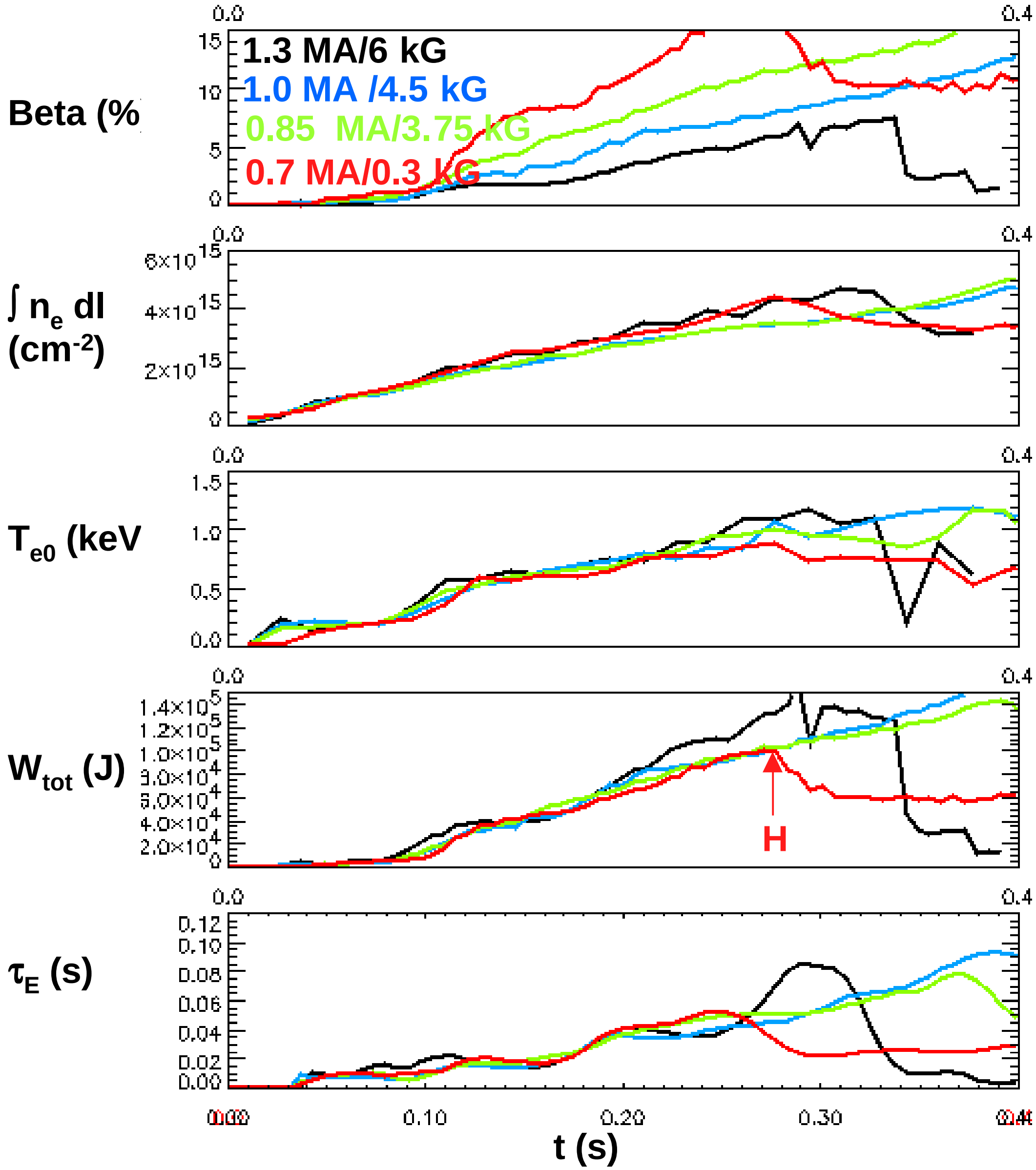
I_p scan at fixed B_t (4.5 kG) and n_e - source A



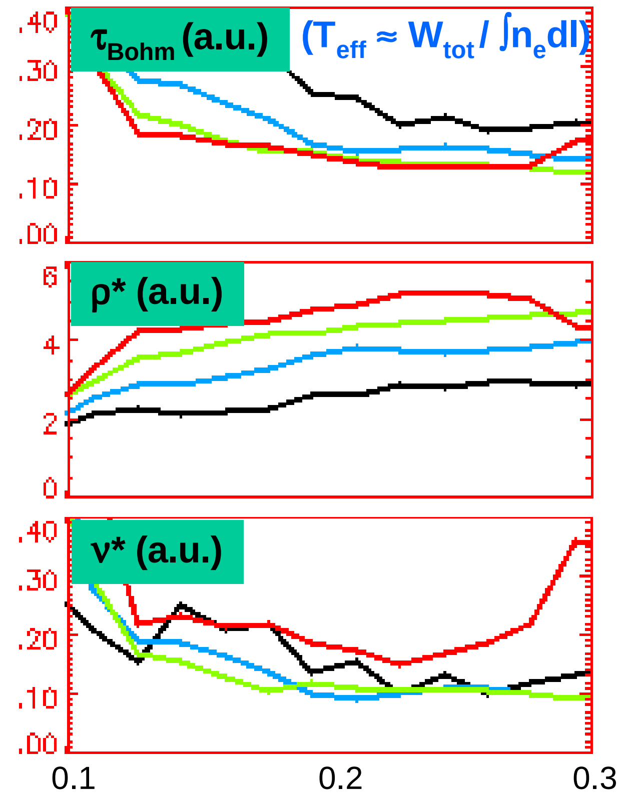
- No significant τ_E change for 150% variation in I_p
- W_{tot} increase ≈ consistent with decrease in orbit loss with I_p
- Some net confinement increase with source C



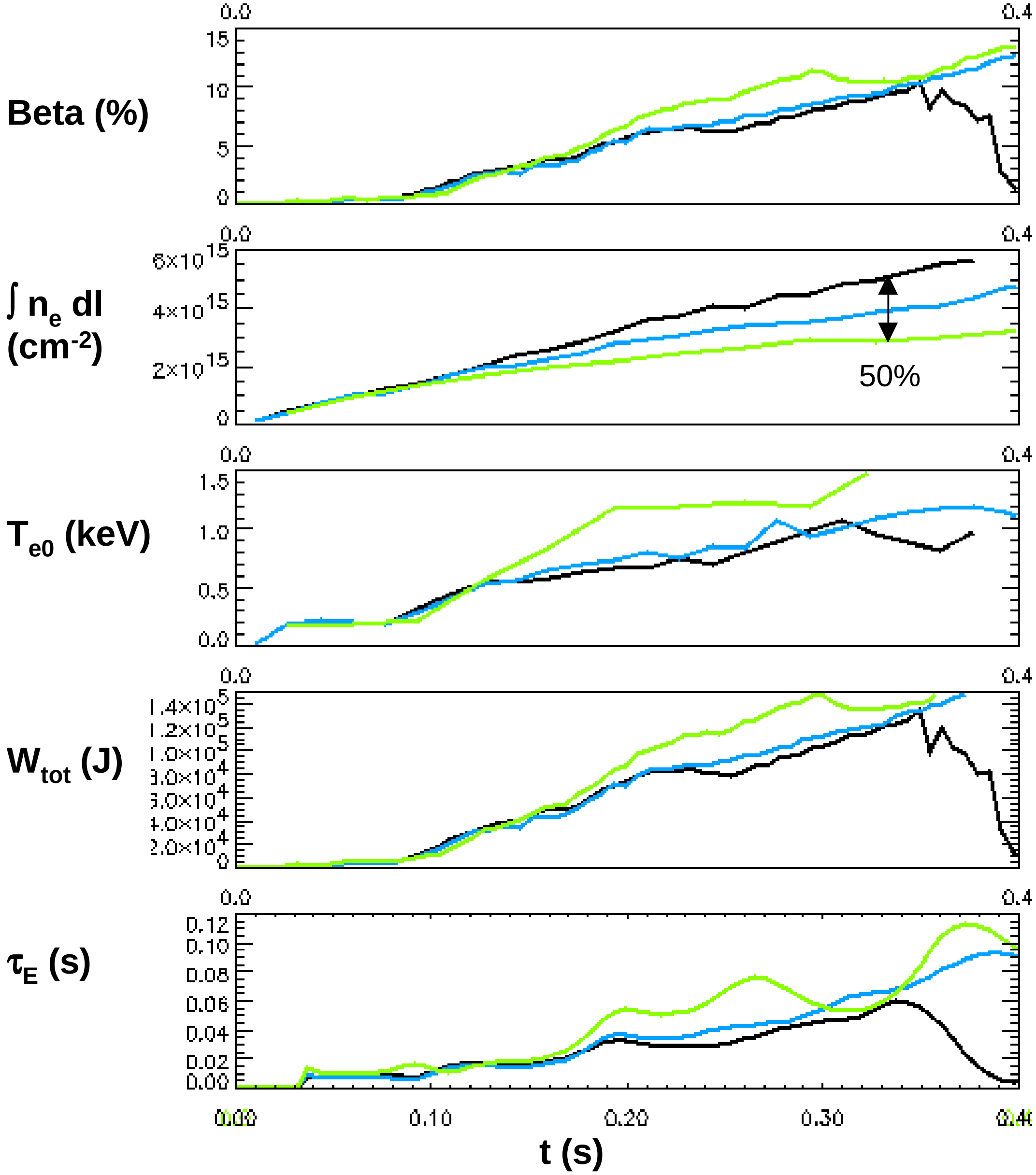
B_t scan at fixed q_{cyl} (B_t/I_p) and n_e - source A



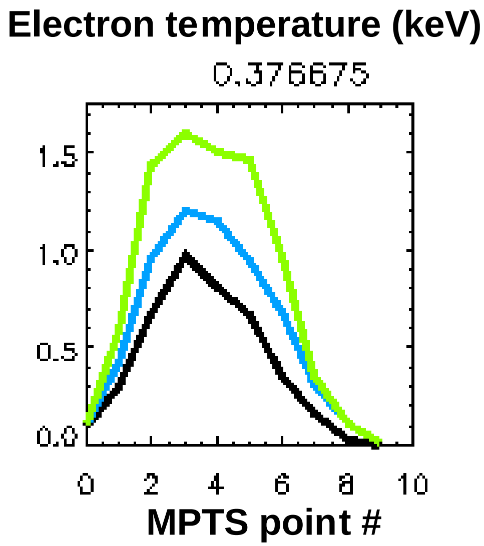
- No change in global confinement (except 1.3 MA/6 kG)



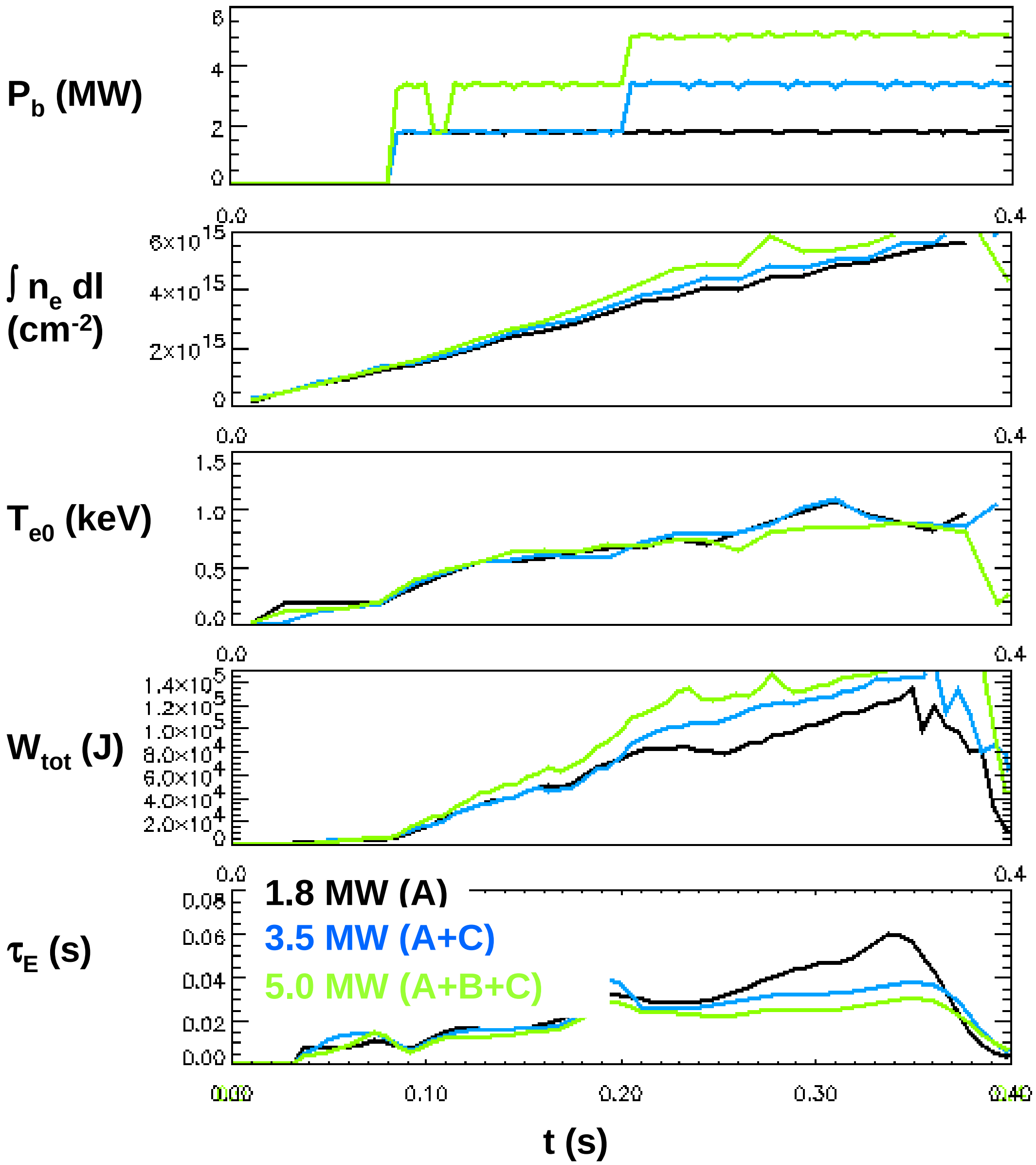
n_e scan at fixed B_t (4.5 kG) and I_p (1MA) - source A



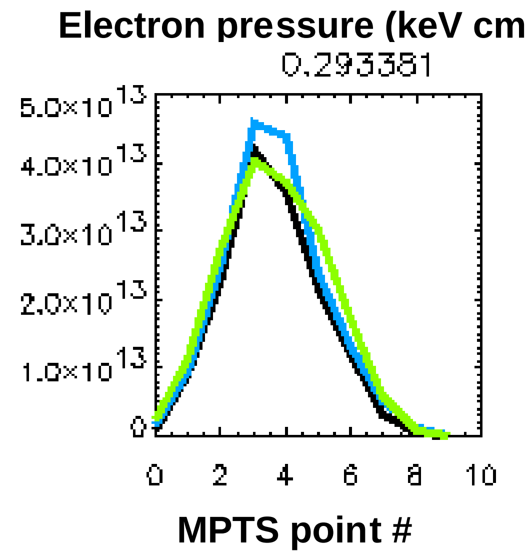
- No W_{tot} change at higher n_e
- Significant increase at low n_e
- T_e increase/broadening suggests χ_e improves
- Shear reversal (USXR data) may however be a cause



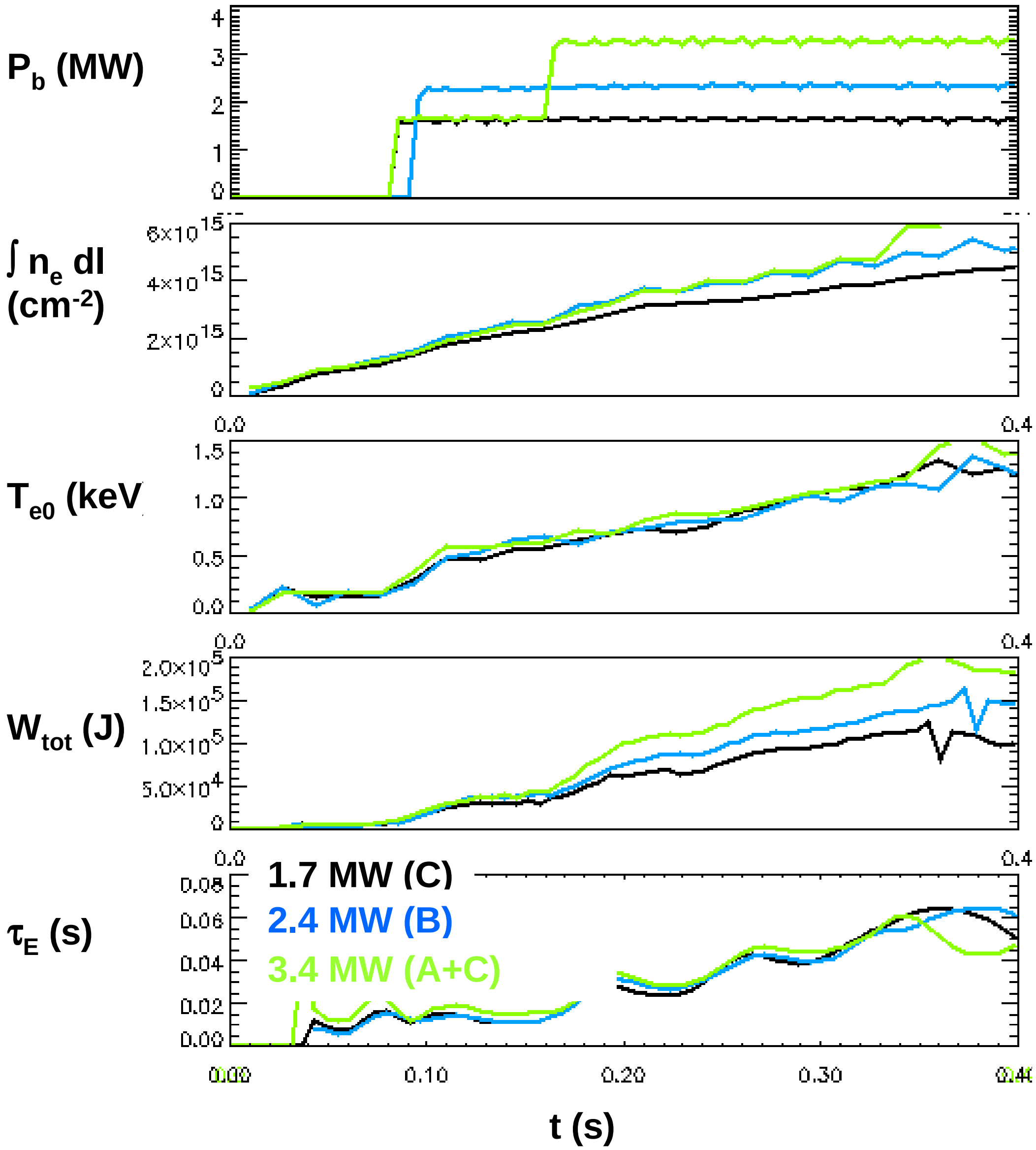
Power scan at 1MA and 4.5 kG



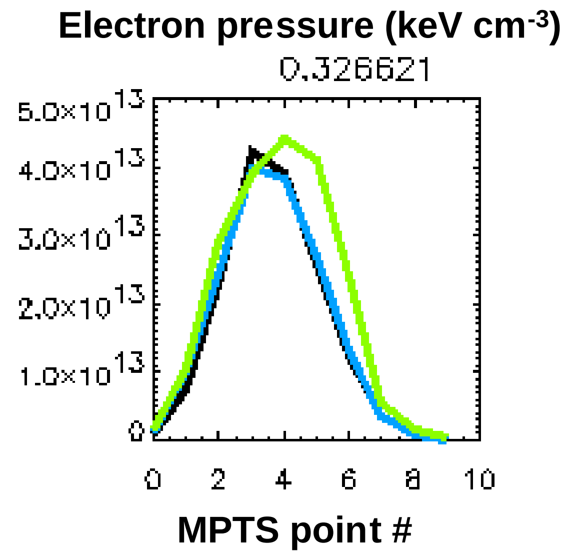
- Quite fast degradation at 4.5 kG ($\tau_E \approx P^{-1}$)
- Electron profiles do not respond to increased power



Power scan at 1MA and 6 kG



- *Hint of slower confinement degradation with power at higher field (up to a threshold)*
- Electron profiles broaden at highest power



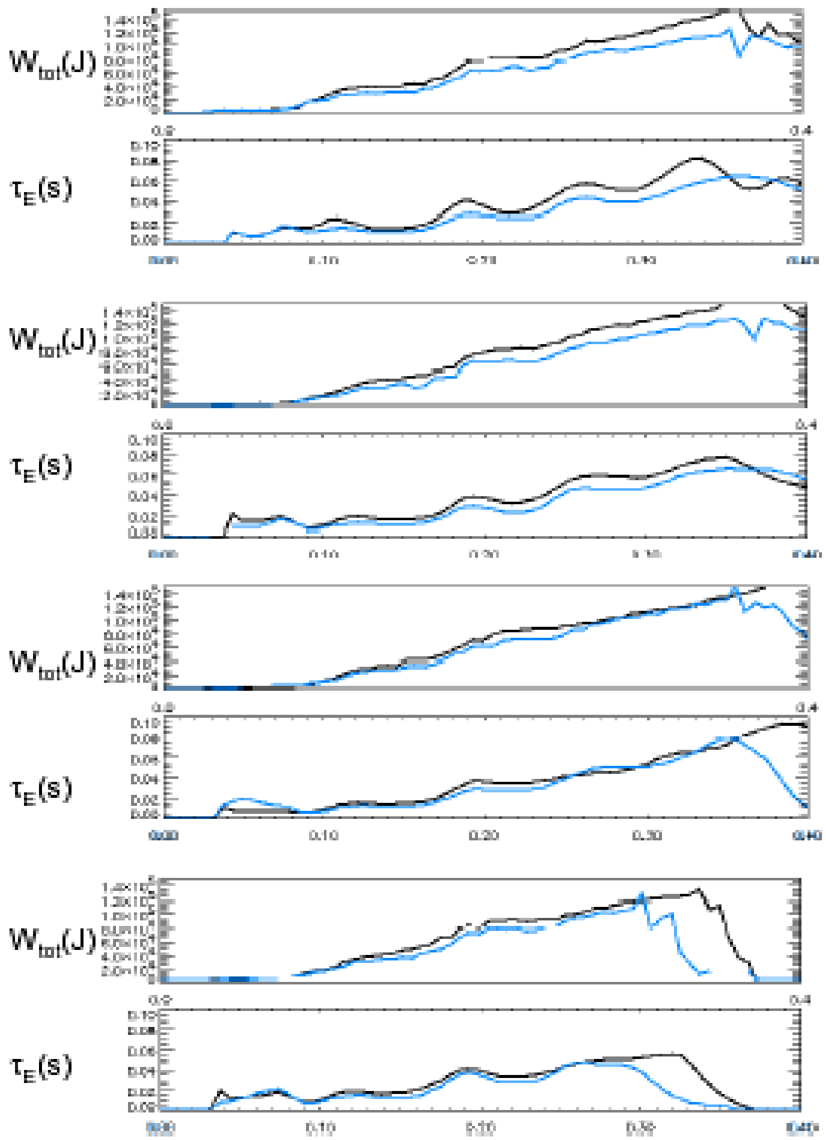
Change in momentum input (source A vs. C at 1 MA)

6 kG

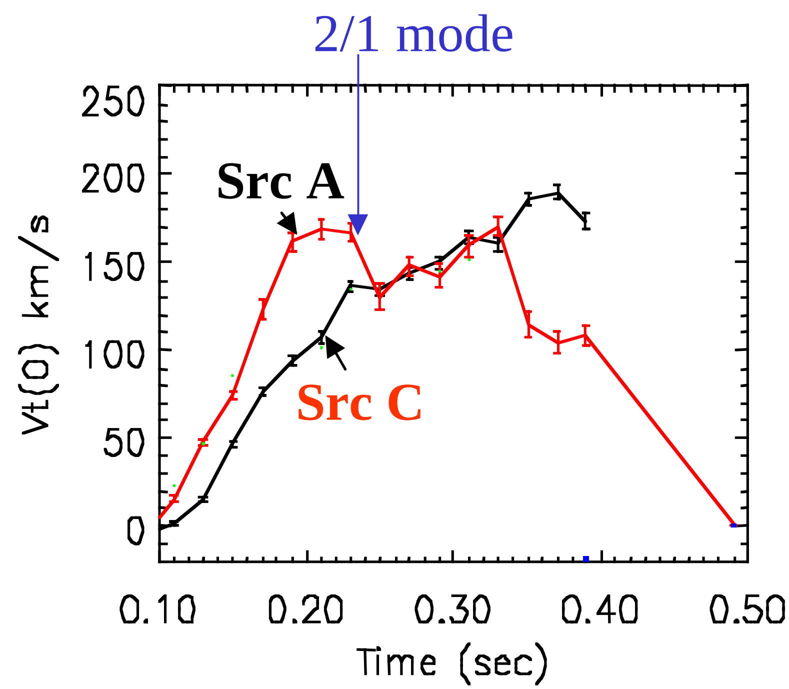
5.25 kG

4.5 kG

3.75 kG

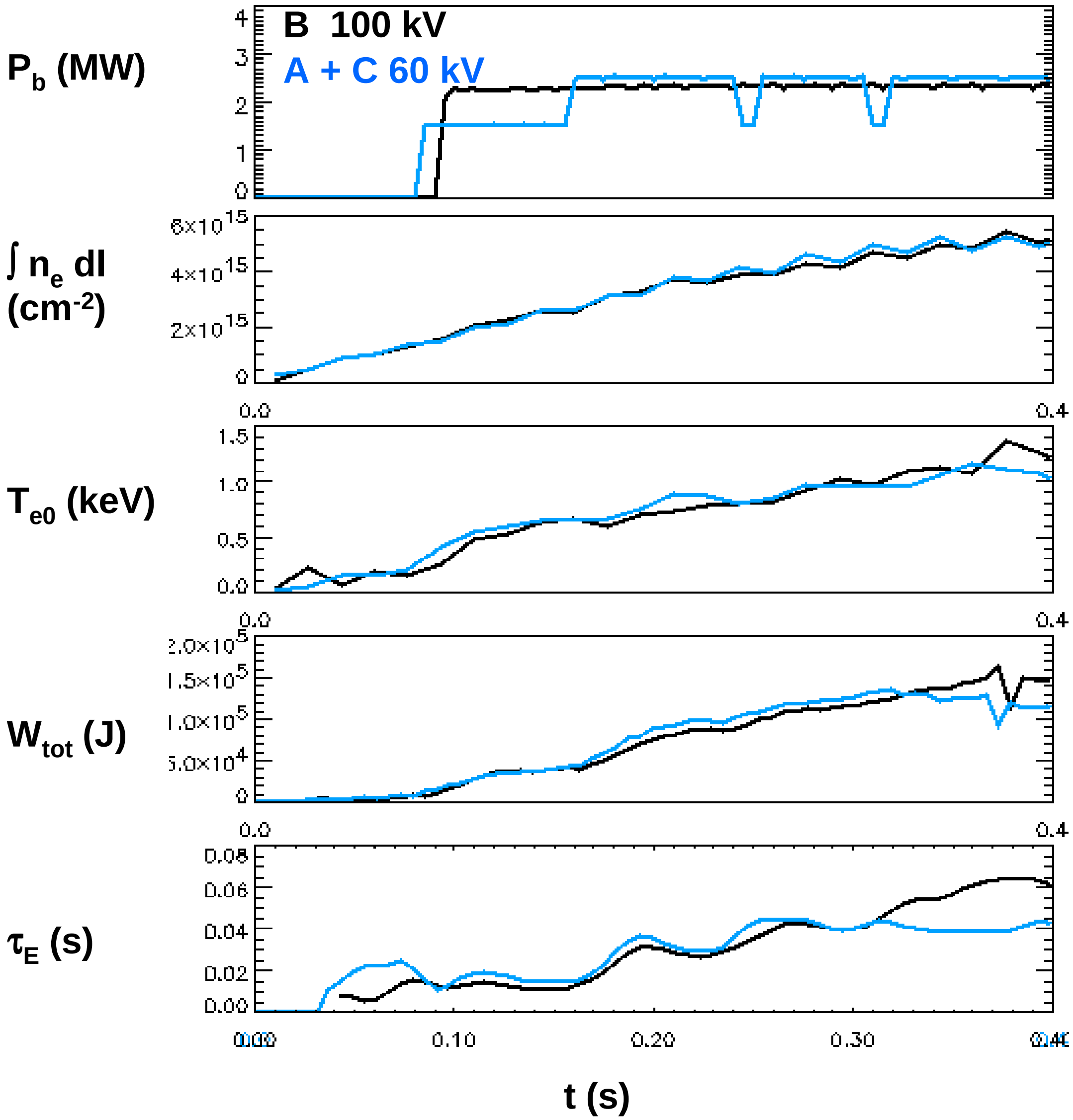


• At lower field no confinement change, but also only small differences in rotation

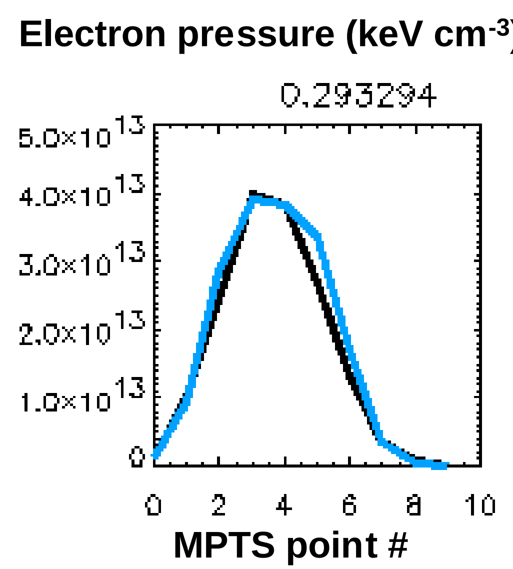


• Hints of improved confinement with source A (25% more momentum) at higher field (no rotation data)

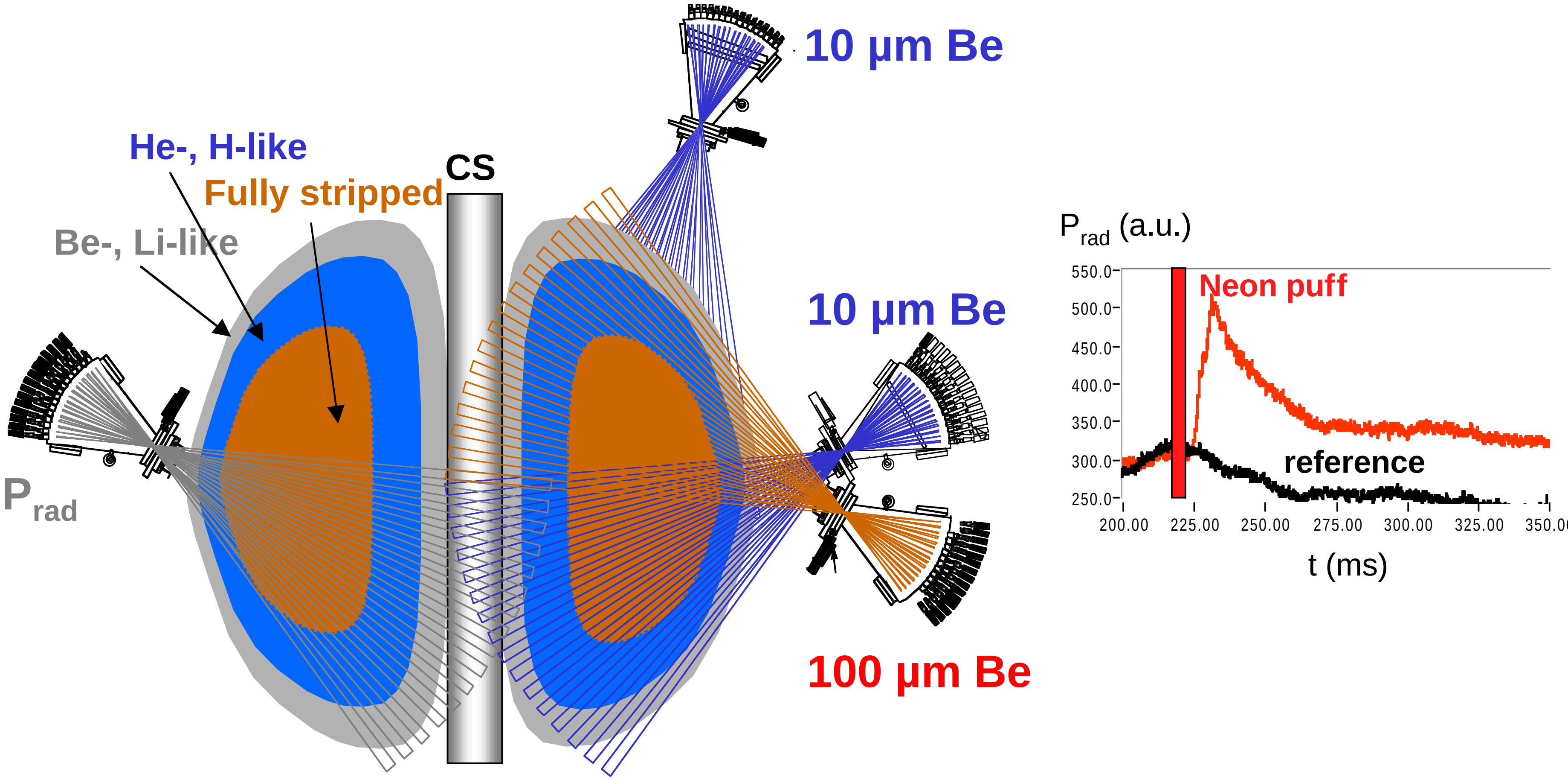
Higher power shots with/without CAEs



- Of interest for anomalous ion heating studies
- No significant change in W_{tot} and electron profile with/without CAEs

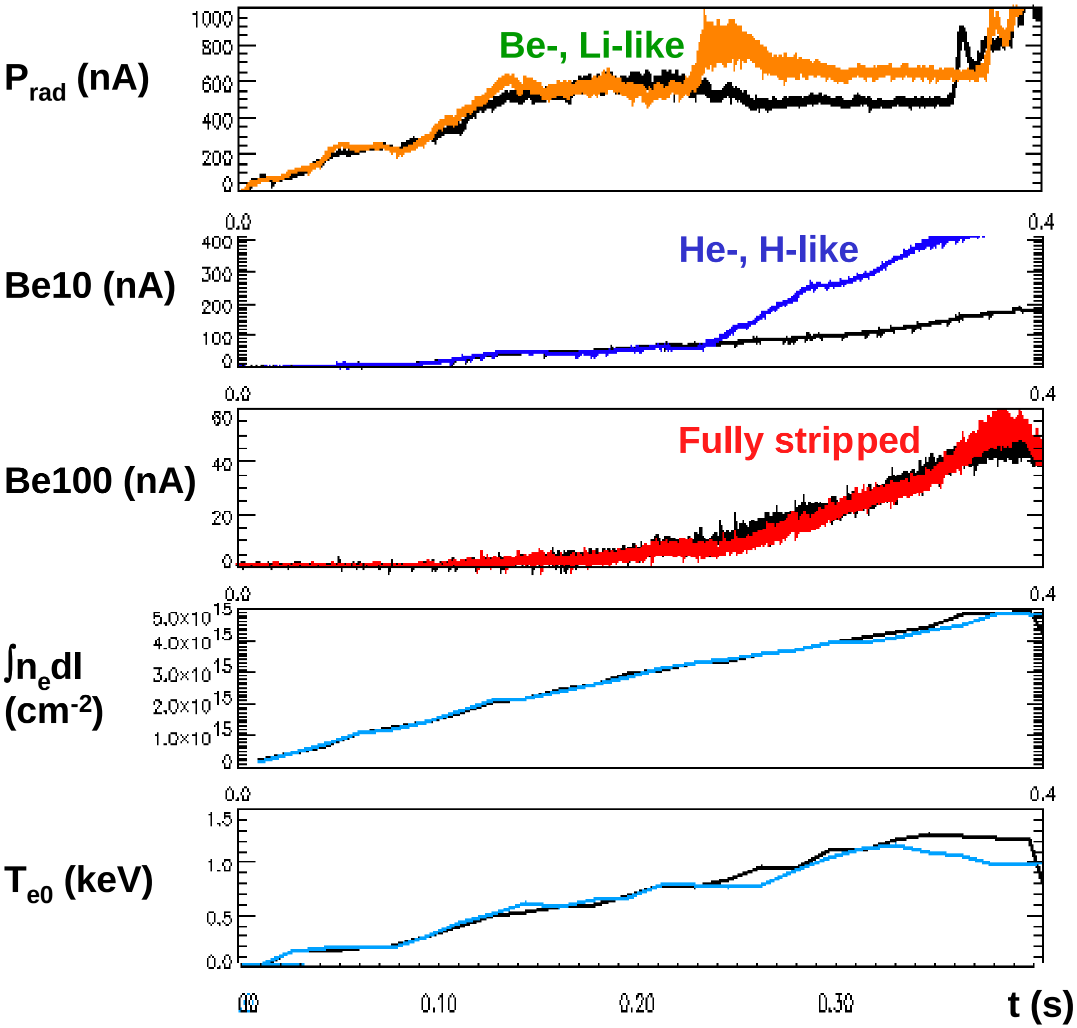


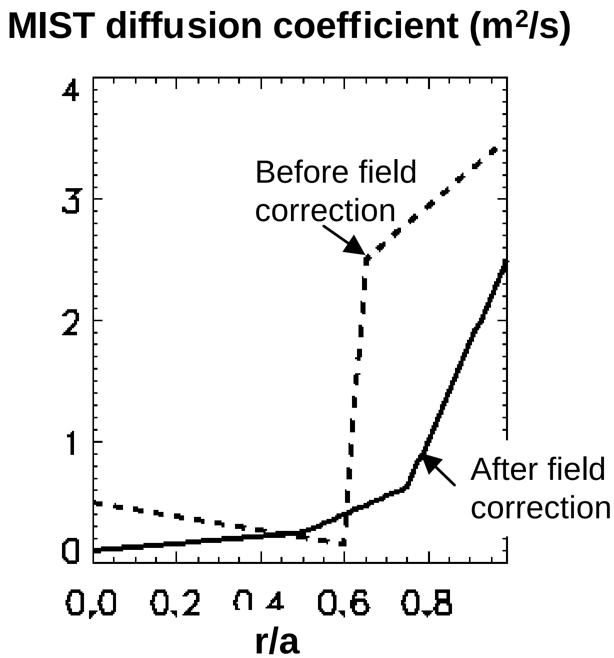
Neon injection experiments



- Four arrays used to measure profiles of core and peripheral Neon emission
- Fast injection developed to enhance diffusive contribution

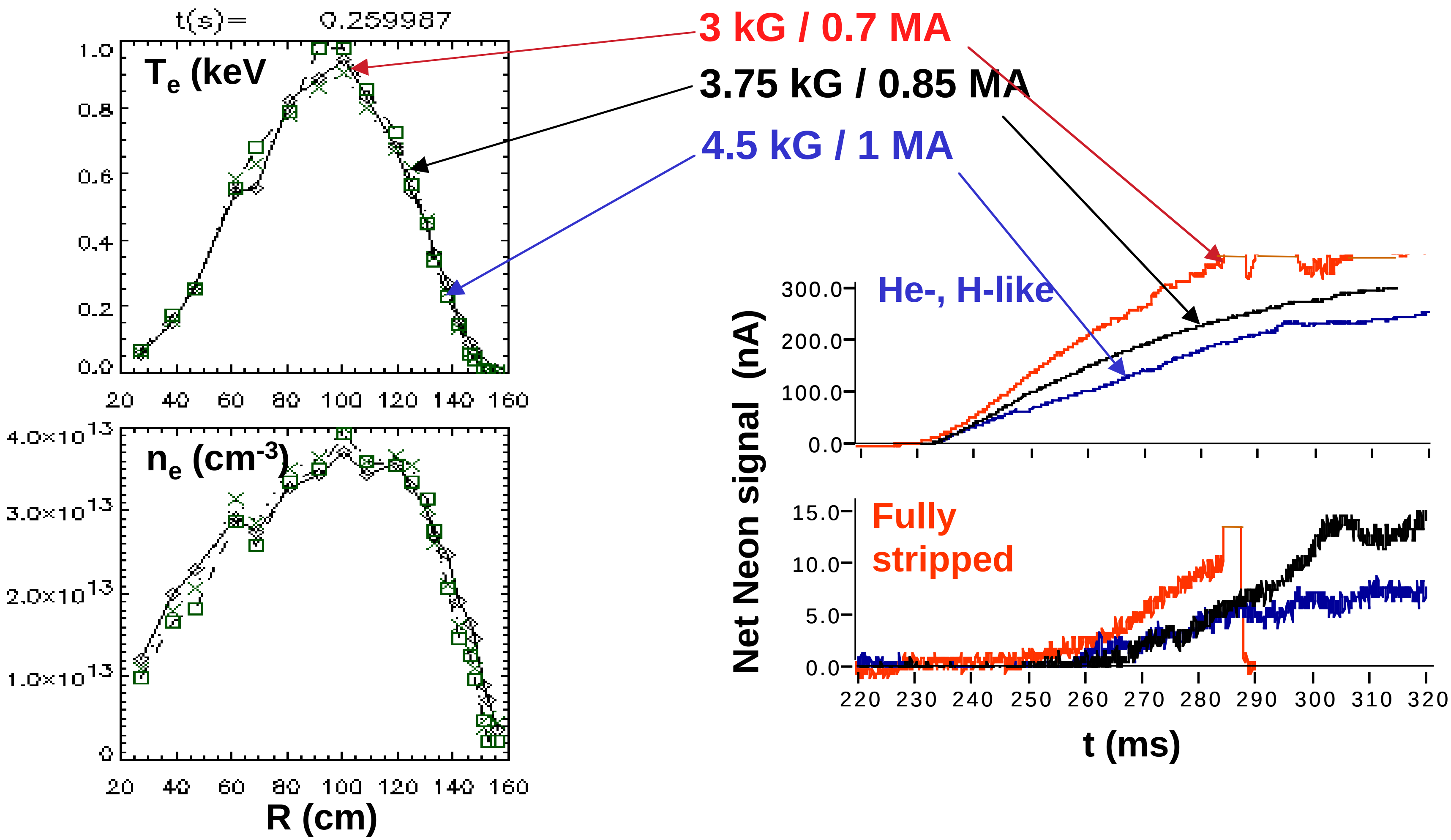
Neon injection experiments





- Lack of Neon penetration to the core observed for even longer times
- Inclusion of P_{rad} in MIST modeling enables better estimate of peripheral D
- MIST results suggest reduced peripheral transport after field error correction

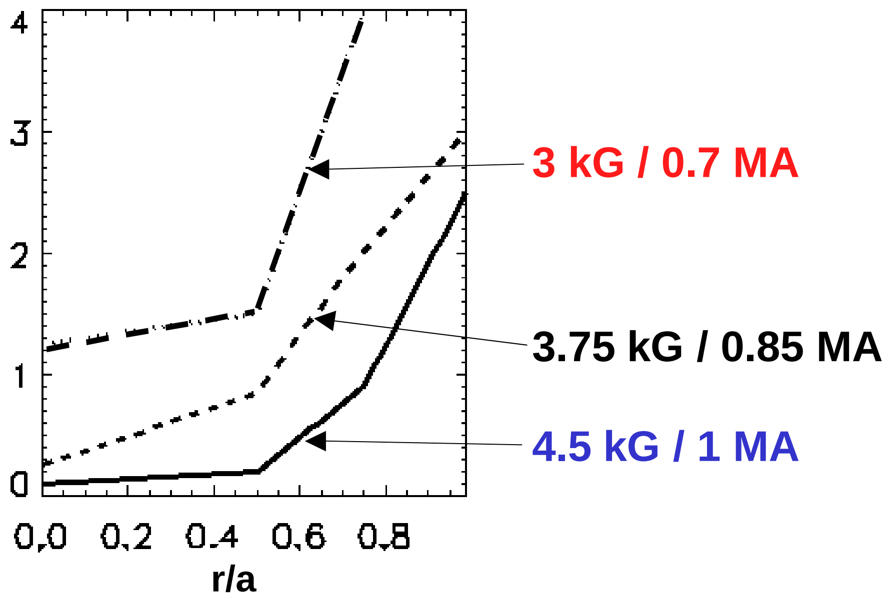
Scaling of Neon penetration : B_t scan at fixed q_{cyl}



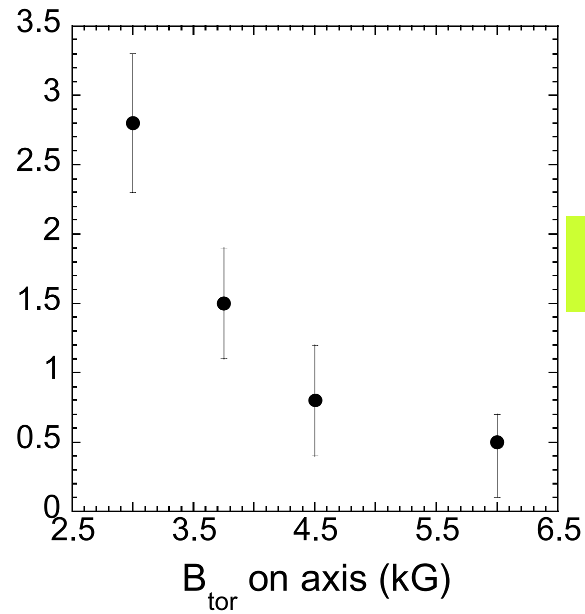
• Slower Ne penetration through nearly identical electron profiles indicates reduction in transport at higher field

B_t scan at fixed q_{cyl} cont'd

MIST diffusion coefficient (m²/s)



Δn_e correlation length (cm)

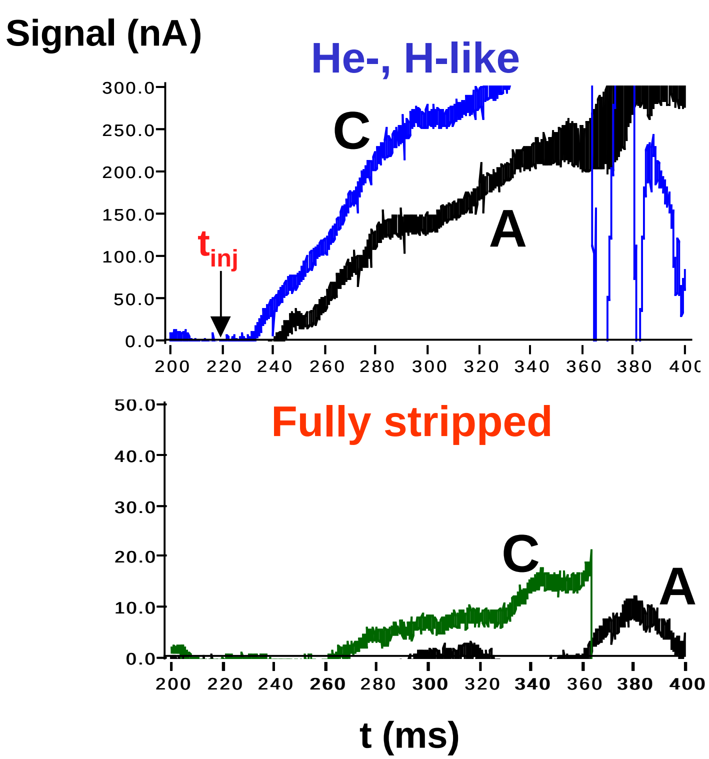


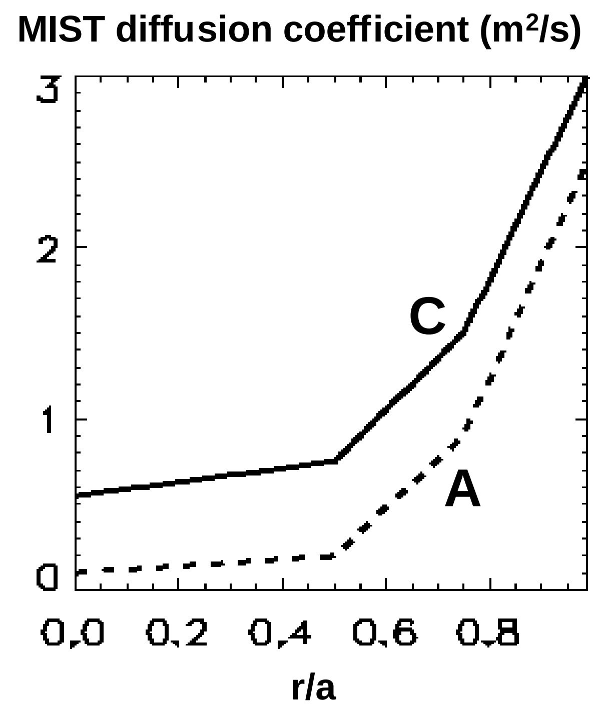
M. Gilmore
UCLA

- Decrease in estimated Ne diffusion looks consistent with the decrease in peripheral turbulence correlation length at higher field

(see Mark Gilmore's talk)

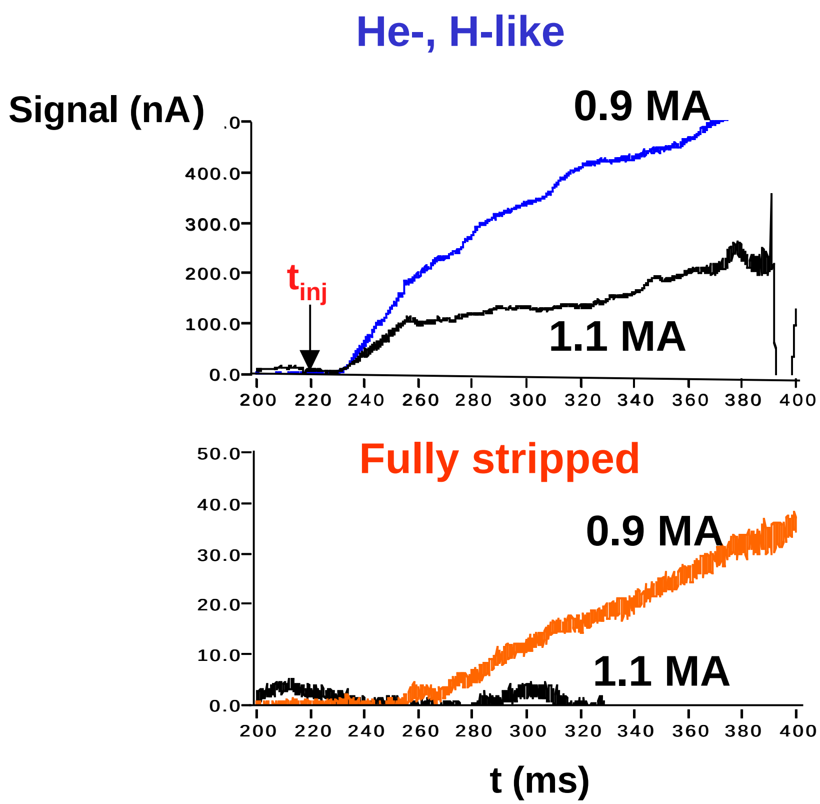
Change in momentum input (source A vs. C at 1 MA)

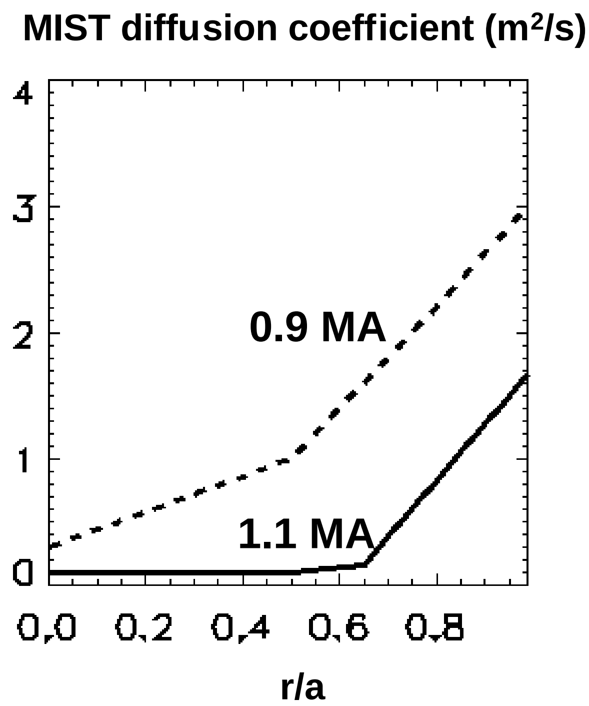




- Reduced Neon penetration and estimated diffusion with more momentum
- No sizable effect in peripheral turbulence though (M. Gilmore)

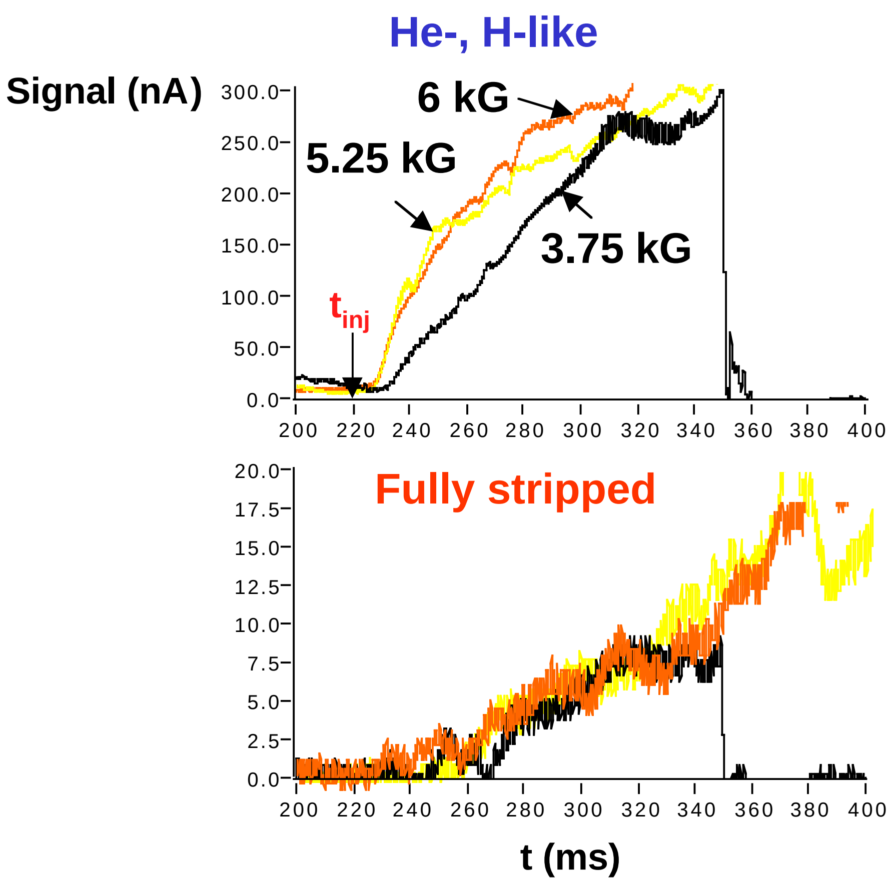
Scaling of Neon penetration : I_p scan at 4.5 kG - src. A

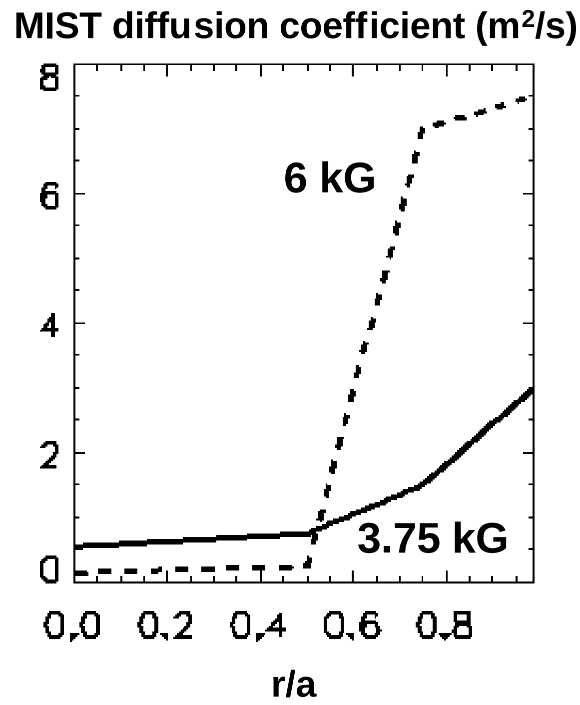




- Large increase in Neon penetration and estimated diffusion at lower I_p
- Possibly non-linear current dependence (threshold)

Scaling of Neon penetration : B_p scan at 1 MA - src. A





- Large increase in peripheral Neon penetration at fields above 4.5 kG, while core penetration is somewhat decreased
- Possibly non-linear field dependence
- Non-diffusive (pinch) transport at higher field, or undetermined MHD ?

Summary

• A good number of shots relevant for transport exploration have been obtained and await TRANSP/microstability analysis (CHERS data needed)

• Non H-mode confinement in NSTX seems to defy conventional L-mode scaling, at least for the present class of discharges; lack of steady state however an issue

•Neon injection scaling suggests ion transport may behave quite differently from global confinement (electrons strongly dominate)

• The scaling of Neon penetration presents puzzles, with the possibility of non-linear/threshold effects; interesting test for microstability computations

• Further analysis and experiments are needed to begin to understand (the surprisingly good) confinement in NSTX