Modeling of Low-frequency MHD-induced Beam-ion Transport In NSTX

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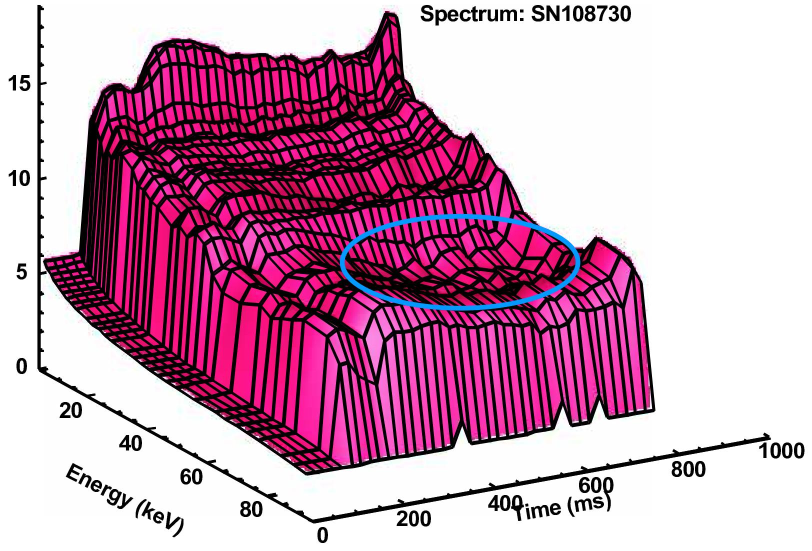
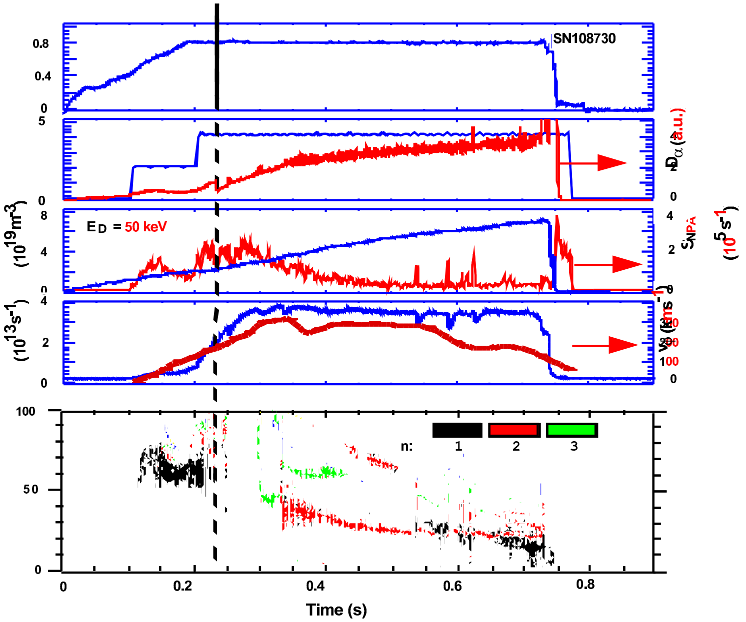
NSTX PPPL PRINCETON PLASMA PHYSICS LABORATORY

NPA measures beam ion signal depletion at $40-80keV$



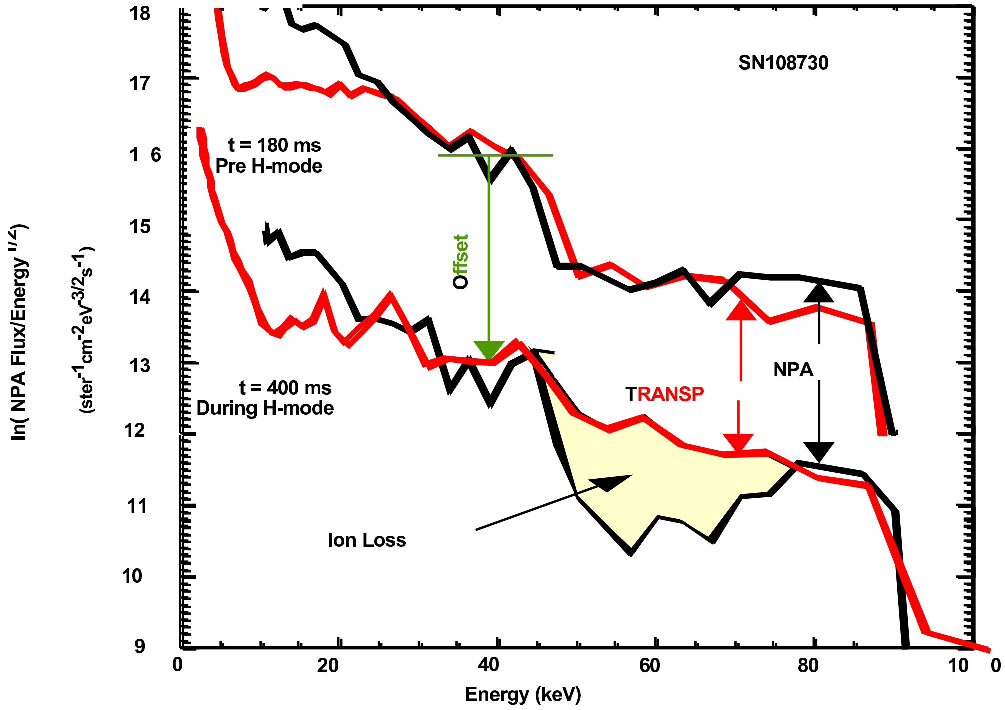


S.S.Medley et.al. NF'04 submitted

After H-mode transition $m = 4/n = 2$ mode is observed

(see S.S.Medley talk tomorrow)

TRANSP slowing down beam ion distribution vs NPA signal



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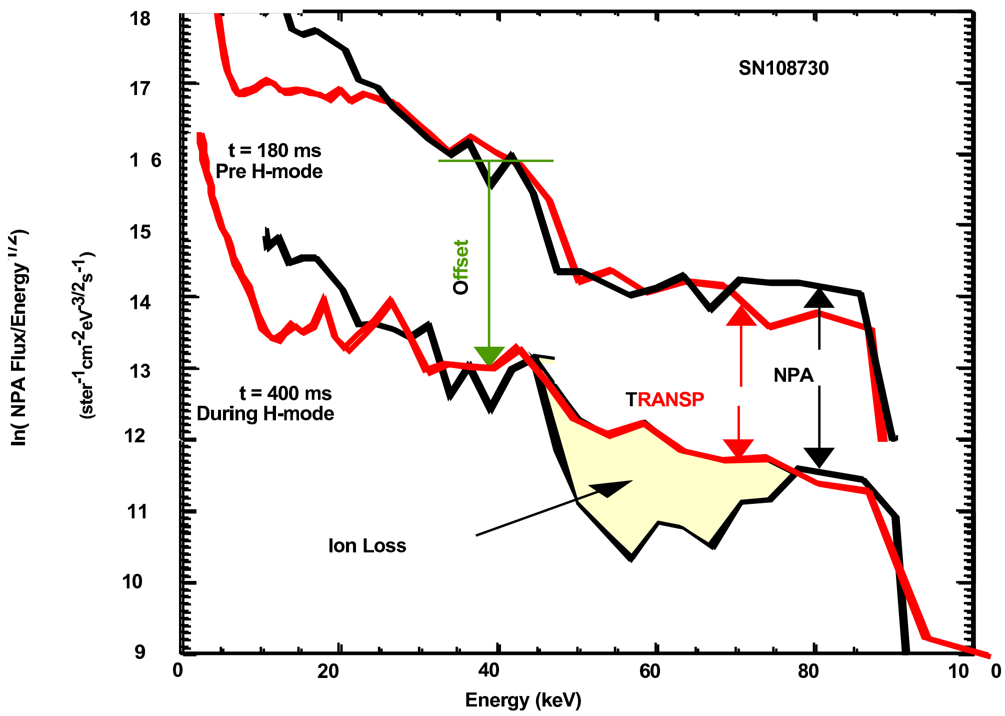


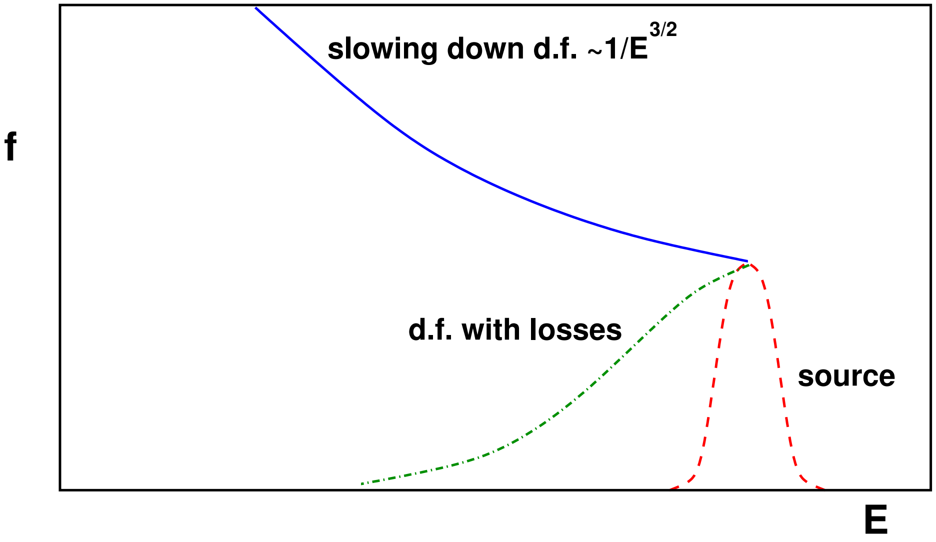
Why beam ions do not fill the gap and where do they go?

In this talk:

(1) what is the confinement time of beam ions

(2) can $m = 4/n = 2$ perturbation explain fast ion losses?

(I) Losses effect the shape of the distribution function



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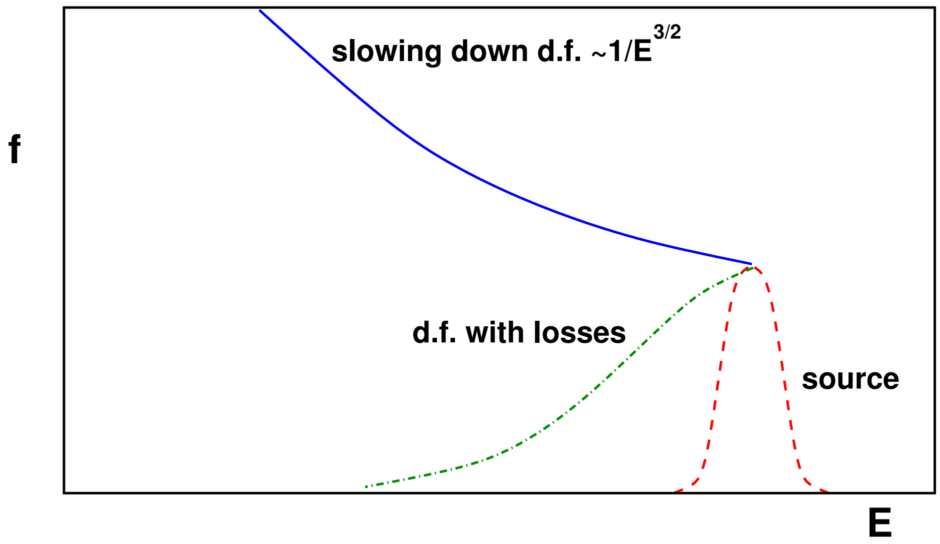

Kinetic equation in steady state (Cordey, Goldston, Mikkelsen, ’81):

$$\frac{1}{\tau_{se} v^2} \frac{\partial}{\partial v} \left(v^3 + v_*^3 \right) f - \frac{f}{\tau_{loss}} + S \delta \left(v - v_0 \right) = 0 \qquad (1)$$

Solution depends on the loss to drag time ratio

At finite τ_{loss} we obtain

$$f = \frac{Cn_b}{v^3 + v_*^3}\left(\frac{v^3 + v_*^3}{v_{b0}^3 + v_*^3}\right)^{\tau_{se}/3\tau_{loss}} \tag{2}$$

and $f \sim 1/\left(v^3 + v_*^3\right)$ if $\tau_{loss} \to \infty$.

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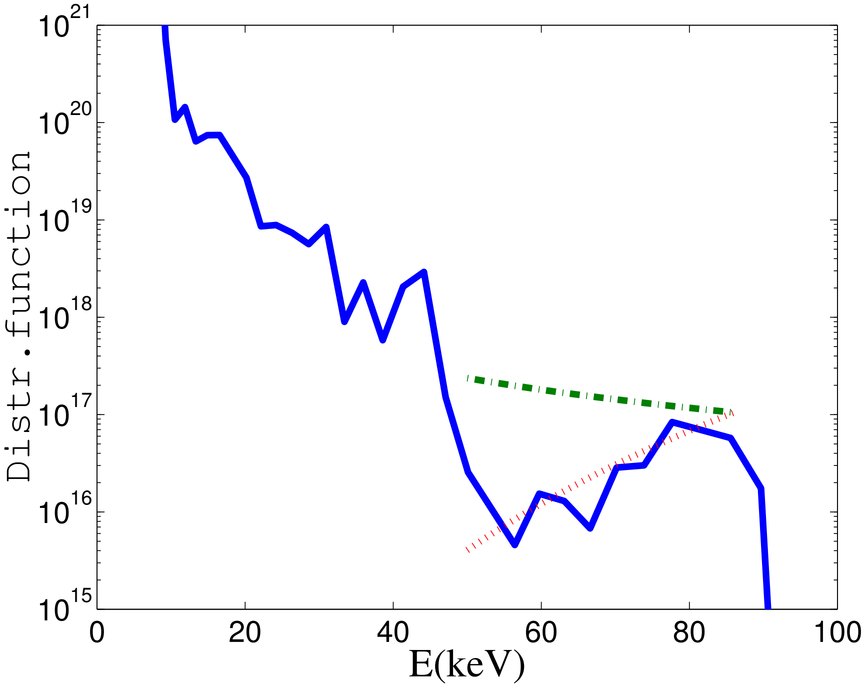

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NSTX

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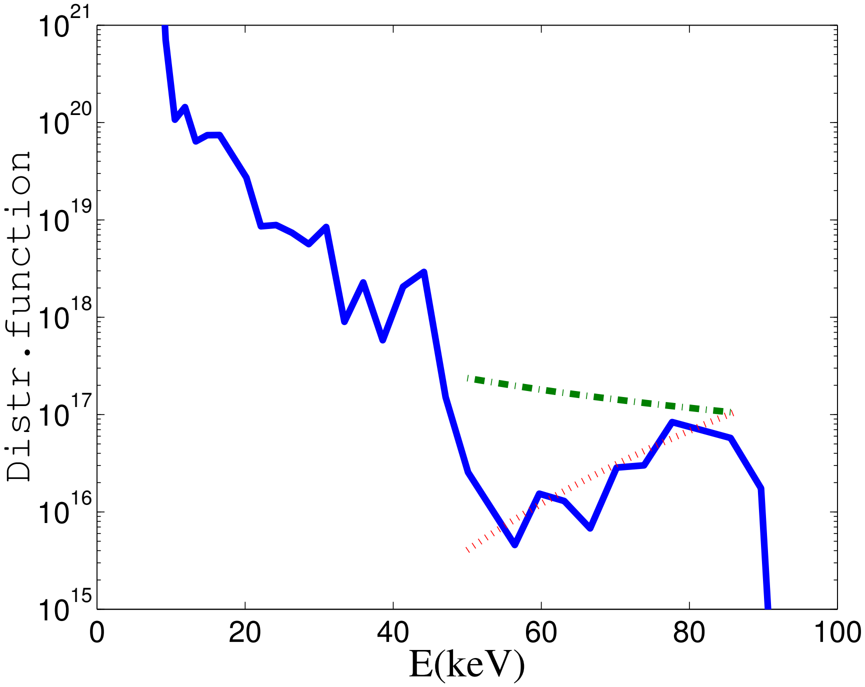

Implies that $\tau_{loss} = \tau_{se}/15$, i.e. $\tau_{loss} = 4msec$.

(II) What mechanism is behind the "losses"/redistribution

We do numerical study. Modeling includes

1. plasma zero frequency $m = 4/n = 2$ perturbation
2. amplitude on the order of $\delta B/B \sim 10^{-4}$
3. plasma sheared rotation
4. investigate NPA sight line
5. realistic equilibrium and ORBIT code

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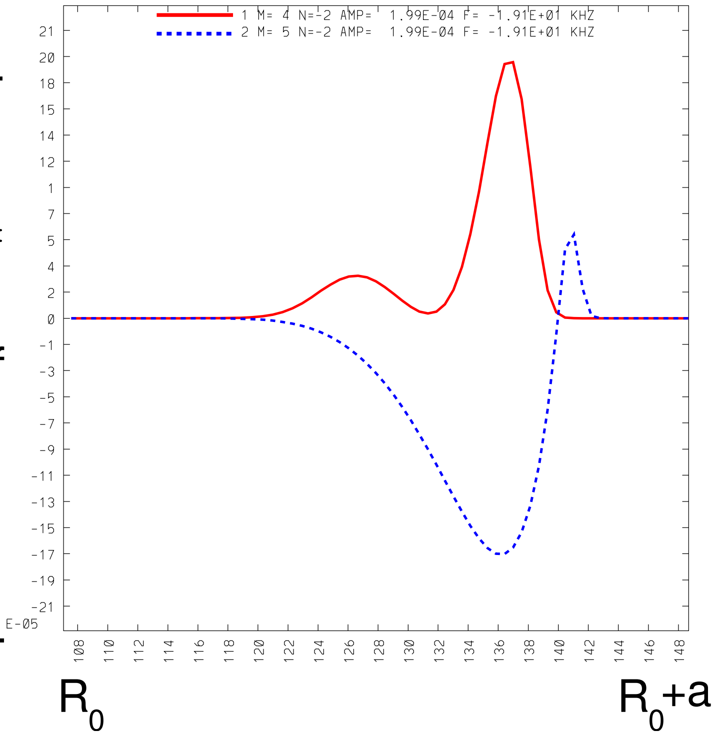


mode structure consistent with ideal MHD

Approximate resonance condition

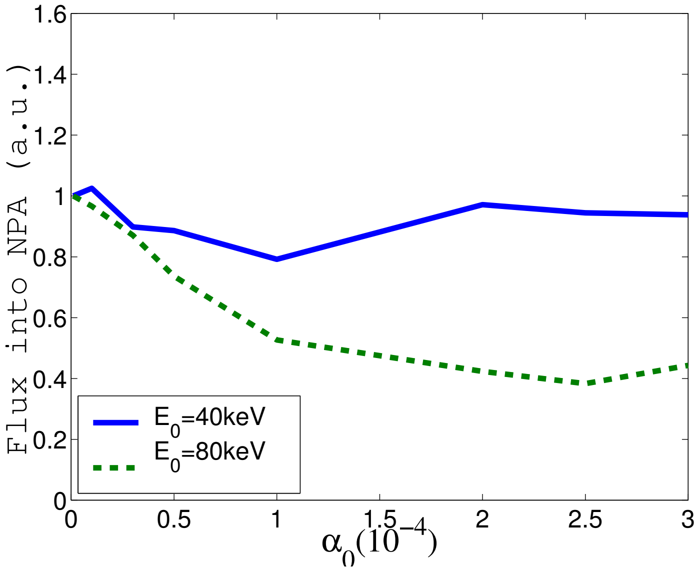
$$\omega - \omega_{E\times B} - \left(k_{\parallel} + l/qR\right) v_{\parallel} = 0, \qquad (3)$$

where l is integer.

- If $\omega = 0$ and there is no electric field, resonance is $k_{\parallel} + l/qR = 0$ - in real space
  If $\omega \neq 0$ and $\omega_{E\times B} \neq 0$ resonance involves phase space.
- In zero orbit width case $l = \pm 1$ due to its toroidal drift velocity $\cos\theta$ like modulation.
- If orbit size is large, parts of particle orbit interact with the mode and $l > 1$ appears.
- Since $\left|\omega - \omega_{E\times B}\right| \ll \left|v_{\parallel}\right|/qR$ the resonance is possible if $\left|k_{\parallel} qR + l\right| \ll 1$ at a given location.
  Thus the resonance is selective for low energies and broad for high energies.

Numerical results for injected ions at 40 and $80kev$

Allow for ion thermalization untill $E = E_0/2$:



Fluxes vs.

perturbation amplitude

Particles are effected above $40keV$.

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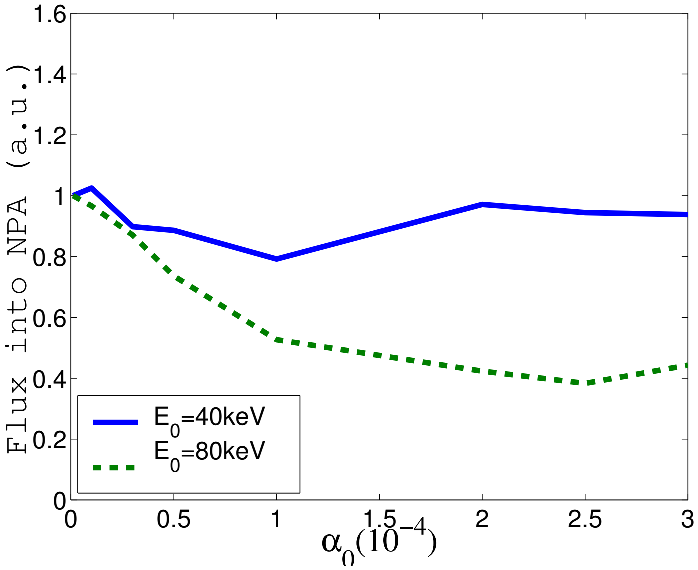
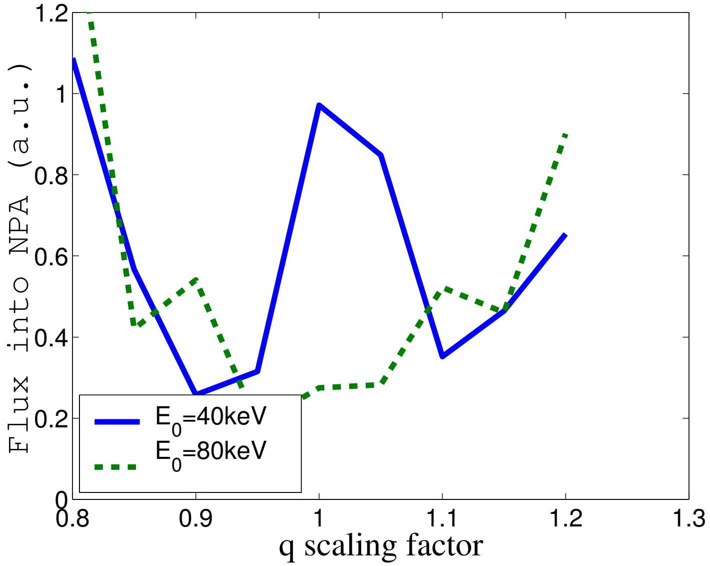




Fluxes vs.

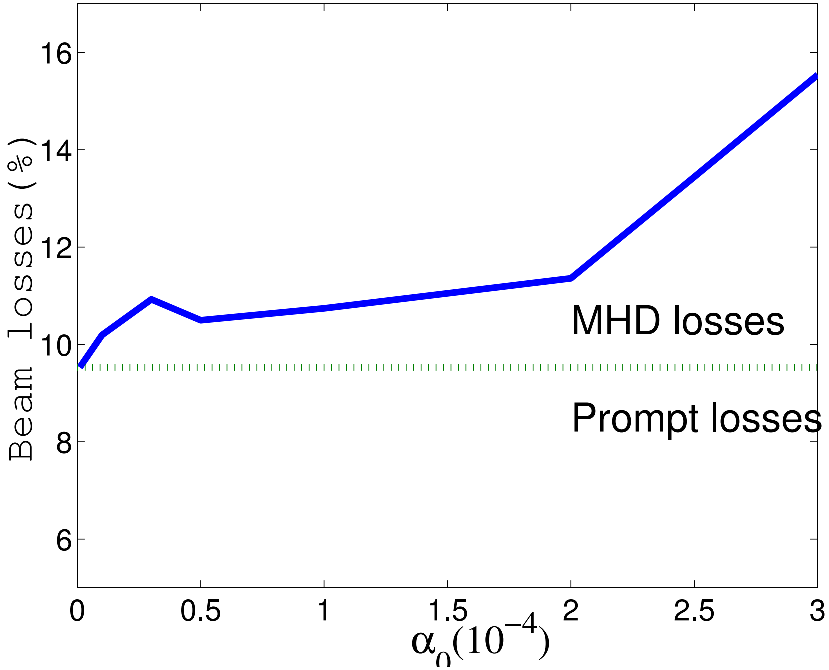
perturbation amplitude

Fluxes vs. q-factor

$(q_{new} = q * q - factor)$

Particles are effected above $40keV$.

Are there any real losses due to MHD



At the expected amplitude, $m = 4/n = 2$ mode can induce losses comparable to prompt losses.

Conclusions

- MHD activity observed in NSTX H-mode plasma is shown to be responsible for the NPA signal loss
- Beam ion redistribution is energy selective affecting ions at $E = 50 - 80 keV$
- Characteristic loss/redistribution time is $\tau_{loss} \simeq 4 msec$