Thermal ion loss from confined QH-mode plasma in the presence of Alfvén eigenmodes

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Abstract

During QH-mode discharges in DIII-D, in the upper single-null configuration, we use infrared cameras to observe heating of the upper outer baffle far outside the strike point. We attribute this heating to impact by moderate energy (~ 5 keV) ions lost from the core plasma, with supporting data from Charge Exchange Recombination (CER) measurements and fixed Langmuir probes. Examining millimeter-wave scattering data, we find correlation of the baffle heating with the presence of core Alfvén eigenmodes. In this presentation we show this correlation and explore the characteristics of Alfvén modes that may be contributing to warm ion losses.

Review of QH mode

Definitions

QH-mode: Quiescent H-mode

- An ELM-free H-mode with density and radiated power control and extended duration
- Achieved with strong pumping, counter neutral beams, large outer gap (~10 cm)

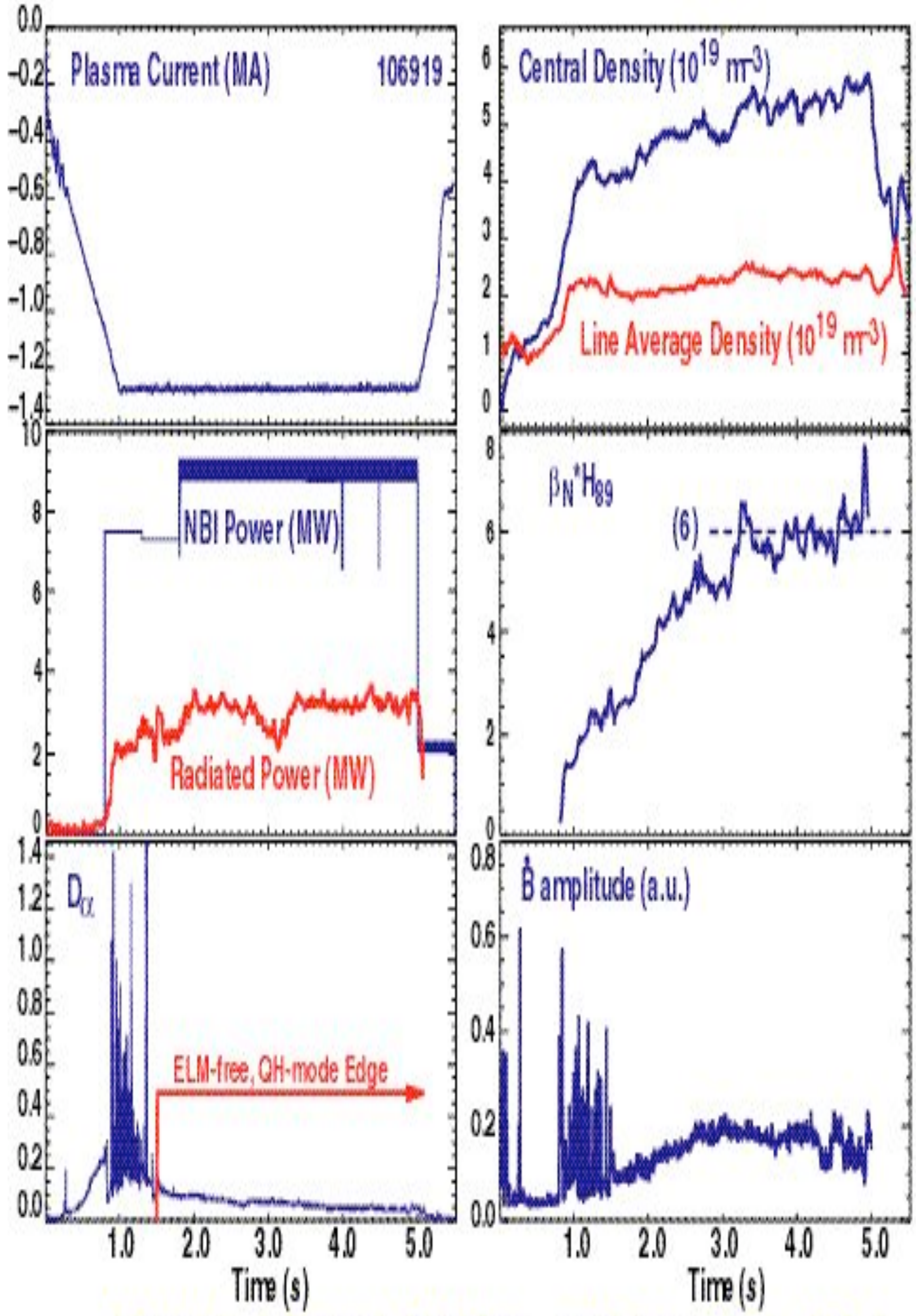
QDB: Quiescent Double Barrier

- An internal transport barrier (ITB) and a QH-mode edge

EHO: edge harmonic oscillation

- A continuous MHD mode usually associated with QH-mode operation

Sustained ELM-free H-mode operating regime obtained with density and radiated power control

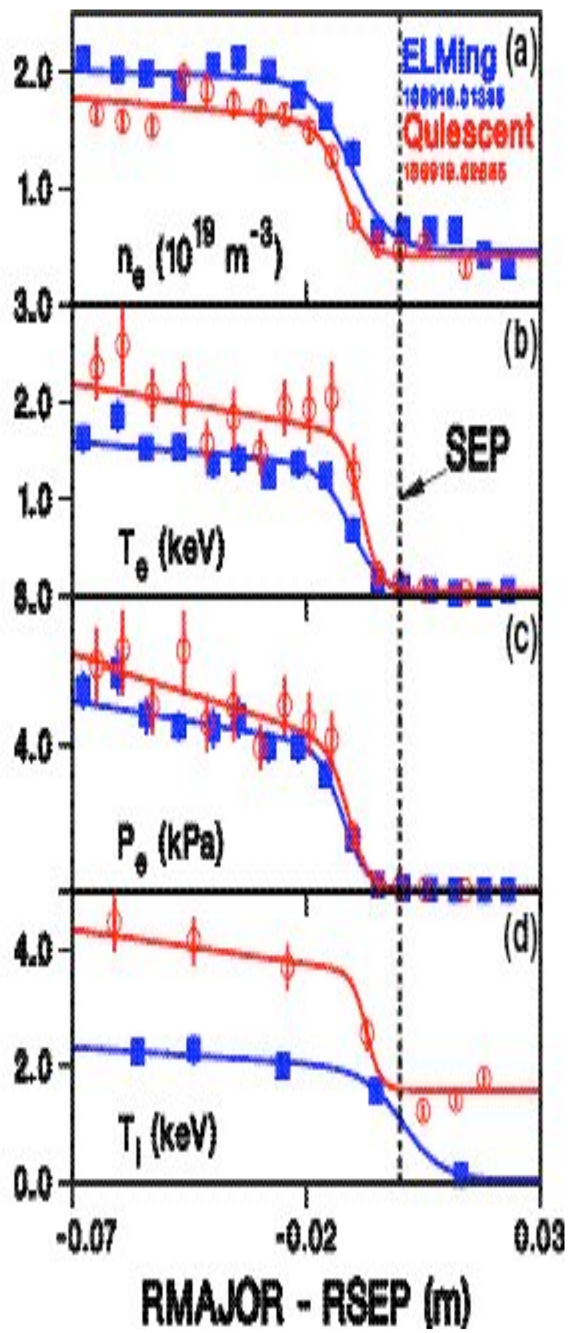


B_T = 2.0 T
q_{95} = 4.45

- Maintains quiescent ELM-free edge for >3.5 s, ~25 τ_E

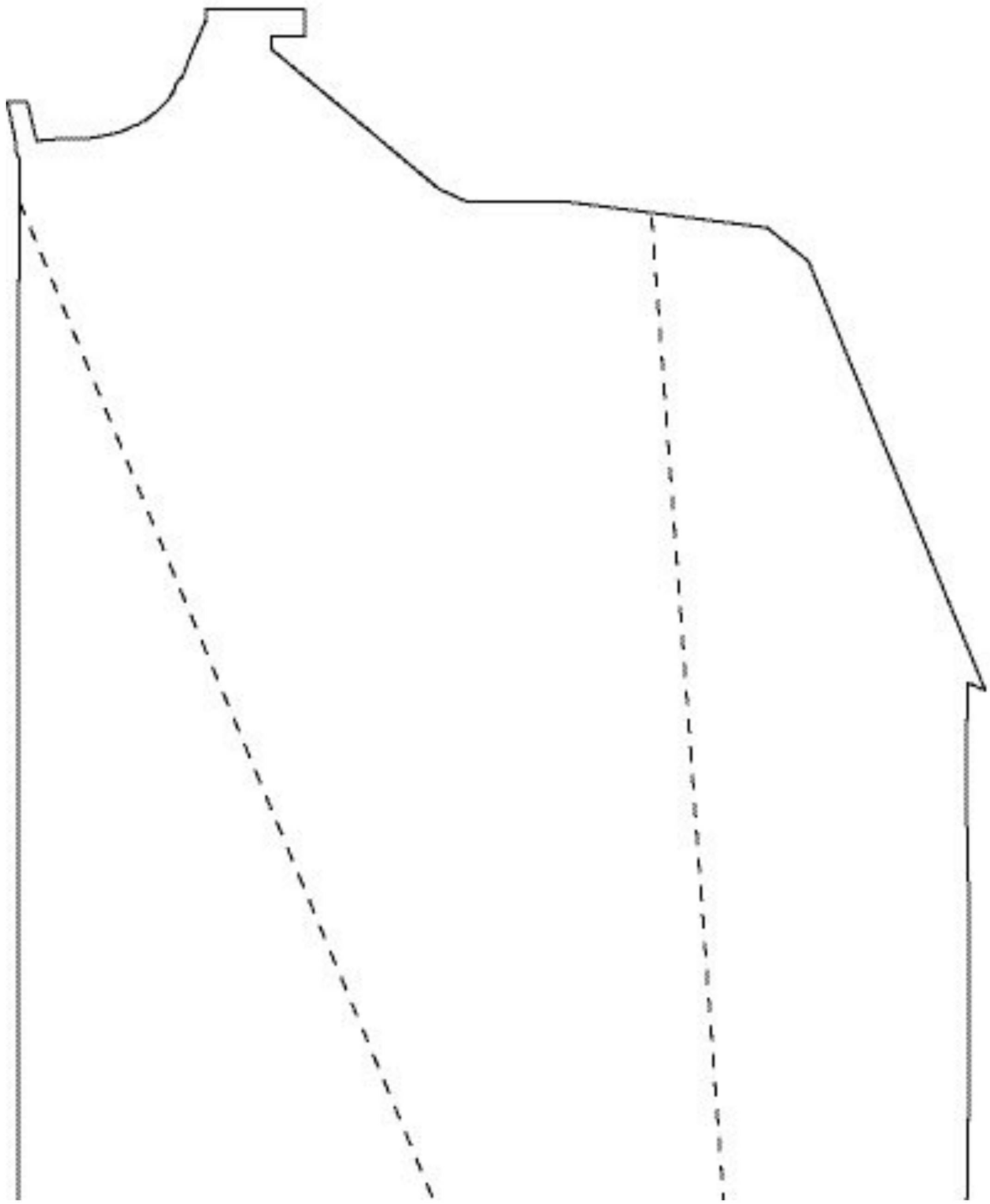
The plasma edge during the quiescent phase is an H-mode edge

- Edge gradientsin quiescent phase are comparableto those in ELMing phase
  - Note high T_i pedestal
- QH-mode edge also has other standard H-mode signatures
  - Edge E_R well
  - Reduced turbulence

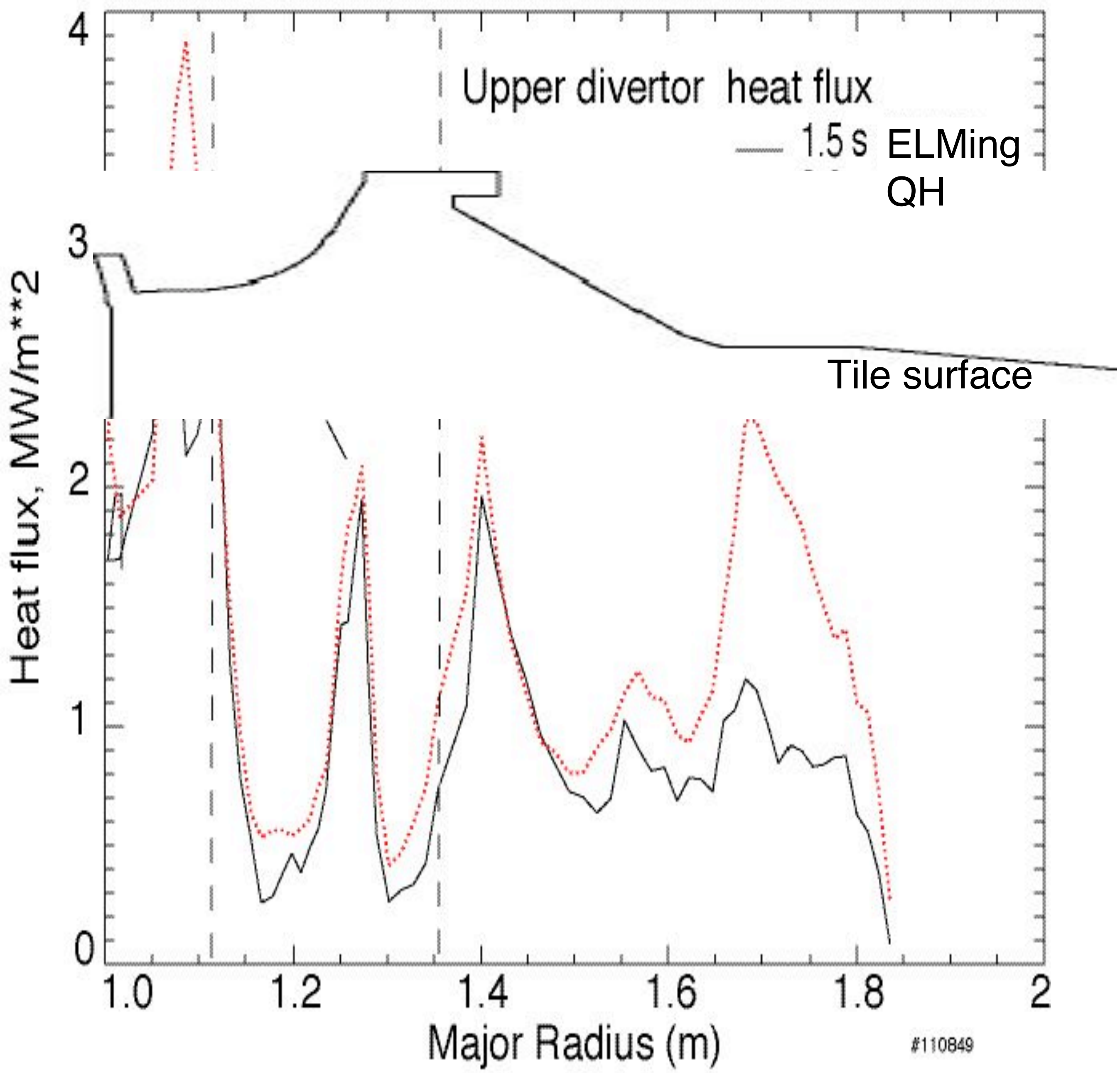


Heat flux appears on upper outer baffle far from strike point

An IR camera views the



More heat past R=150cm during QH (after ELMing phase)



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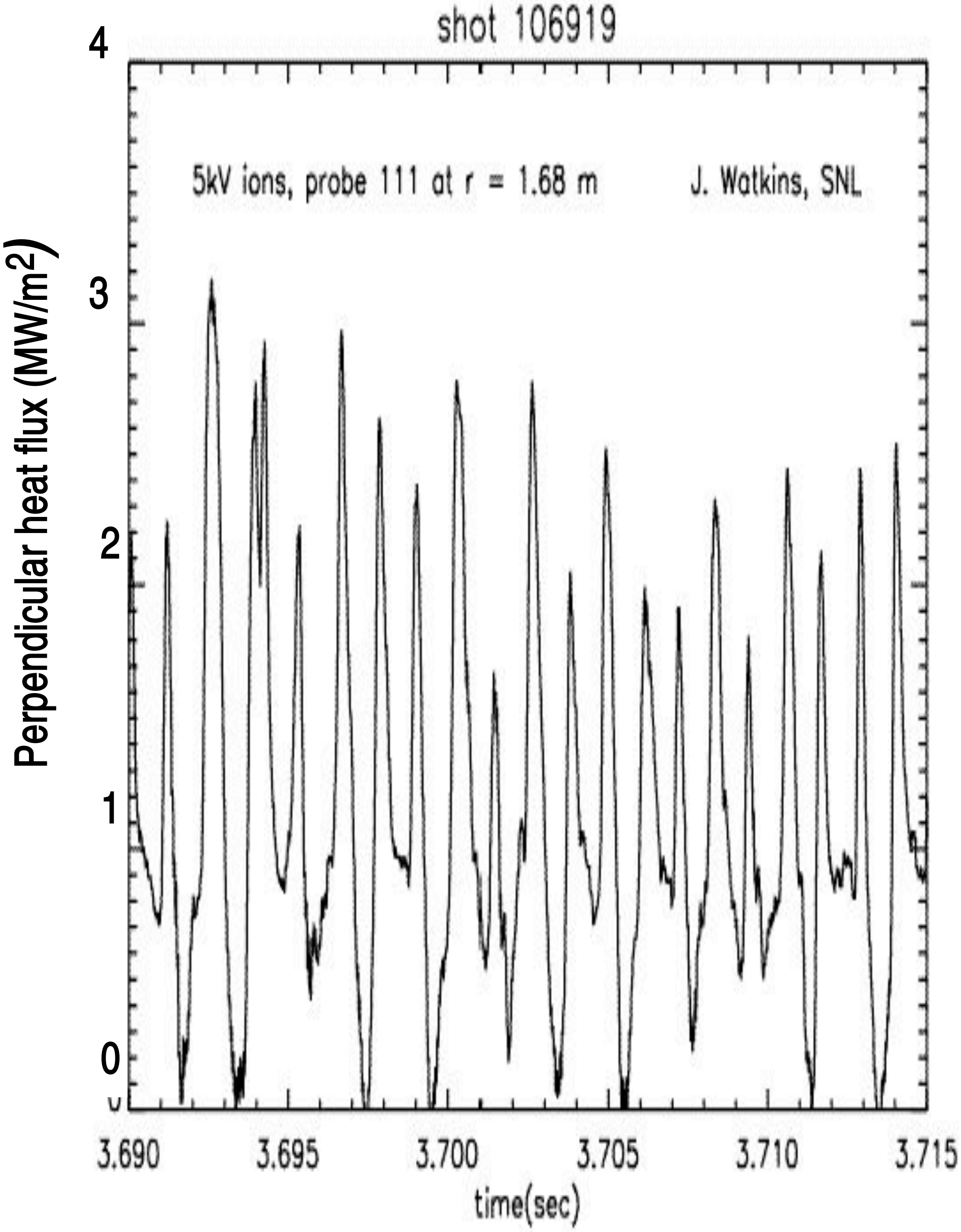
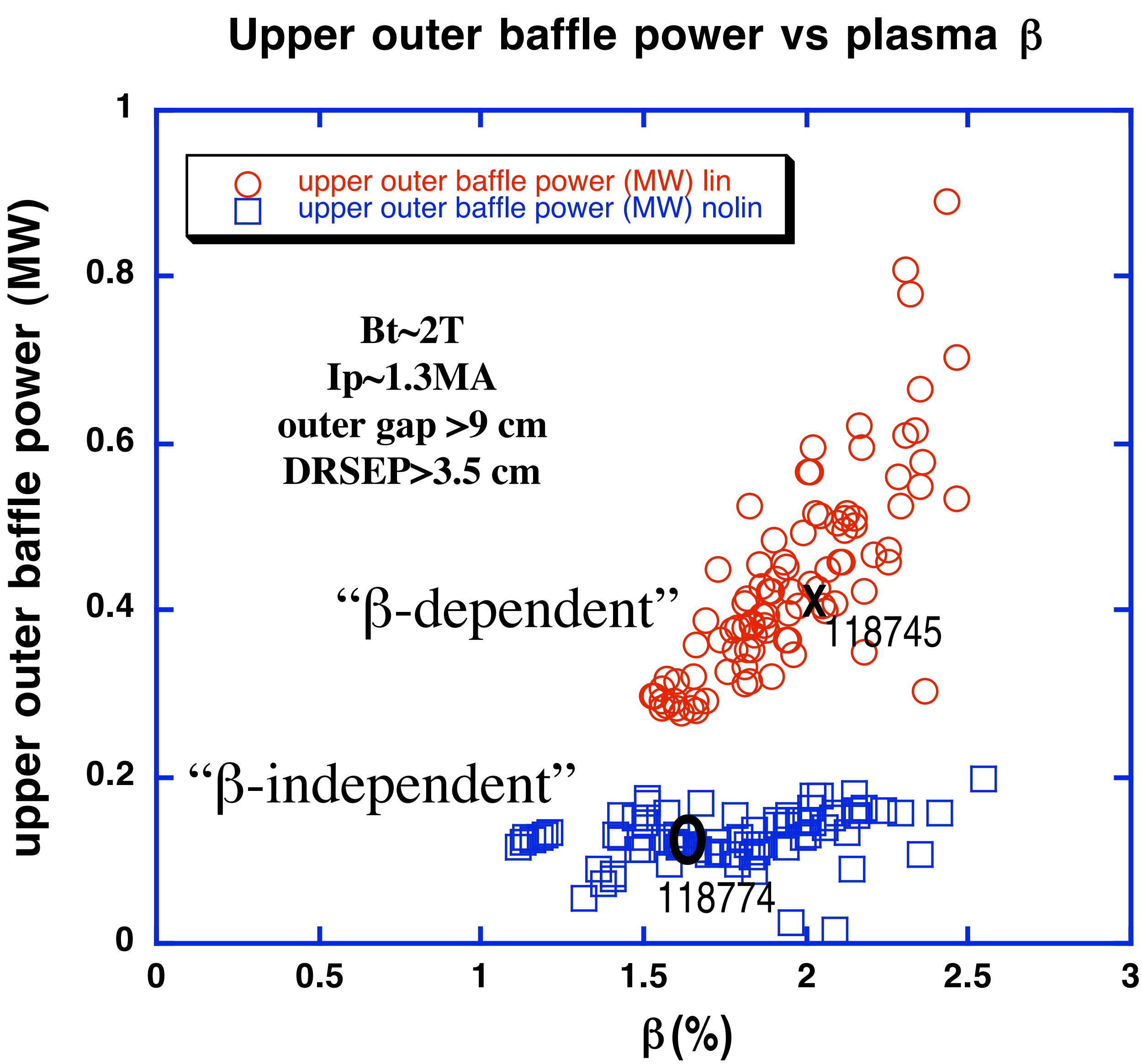
Particle flux with CER energy approximates IR heat flux

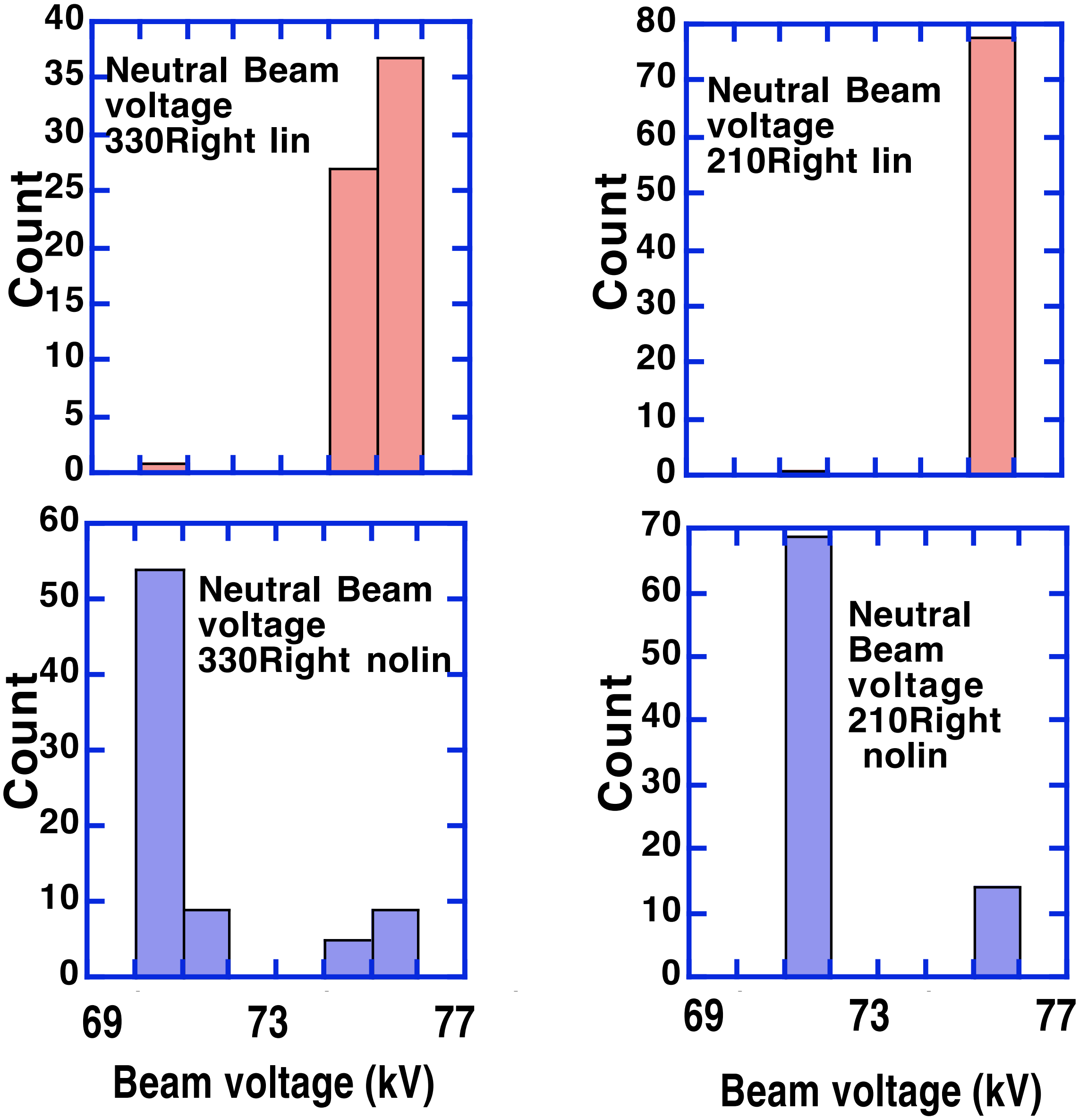


Scaling of Upper Outer Baffle (UOB) heat

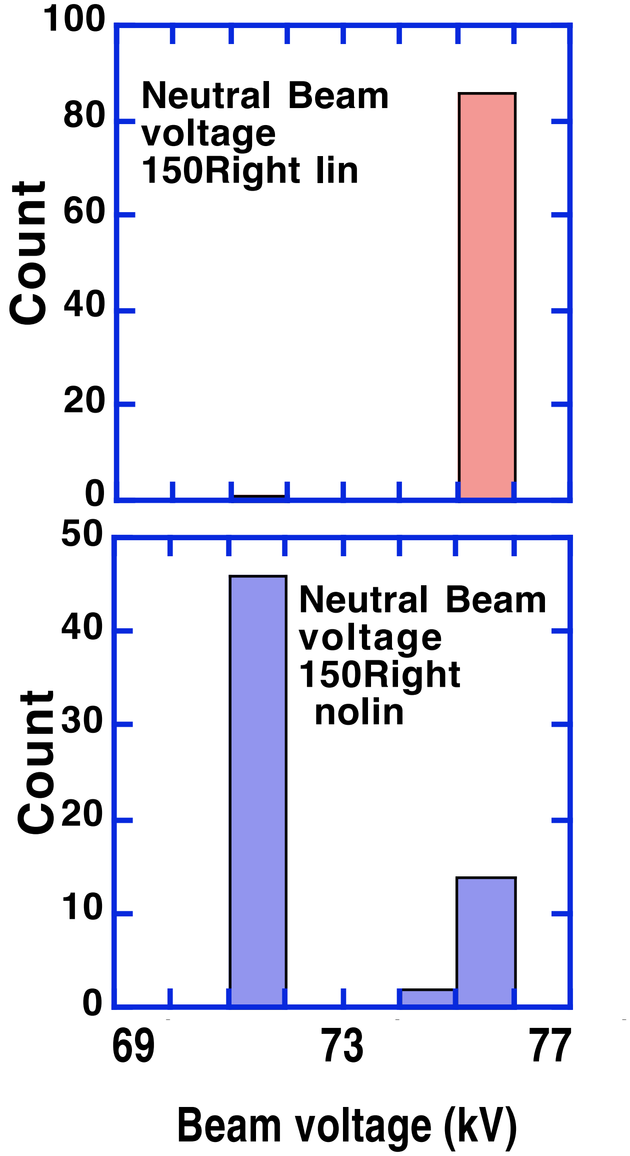
One set of UOB powers scales with β



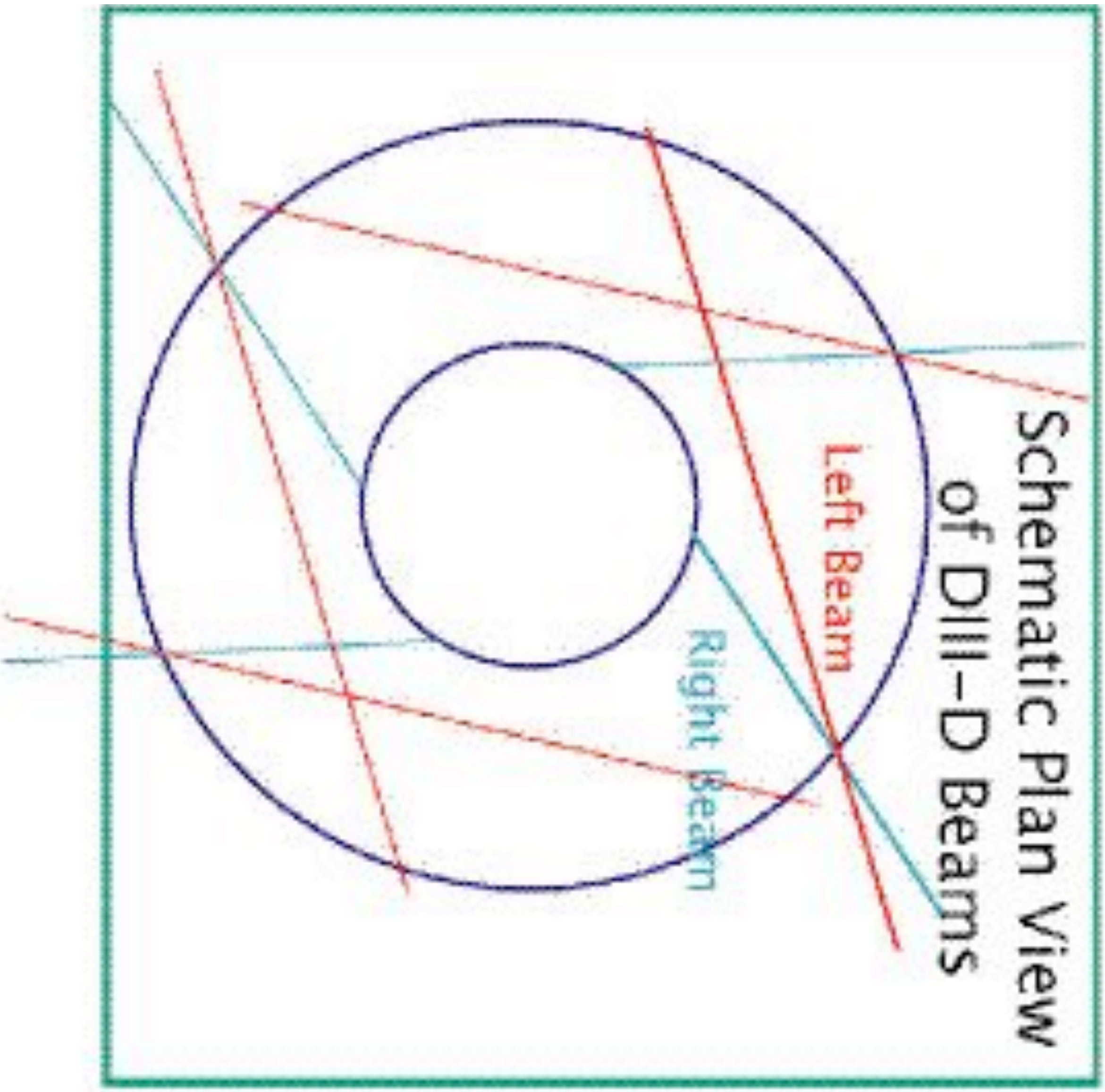
UOB power dependence correlates with 330Right, 210Right beam voltage



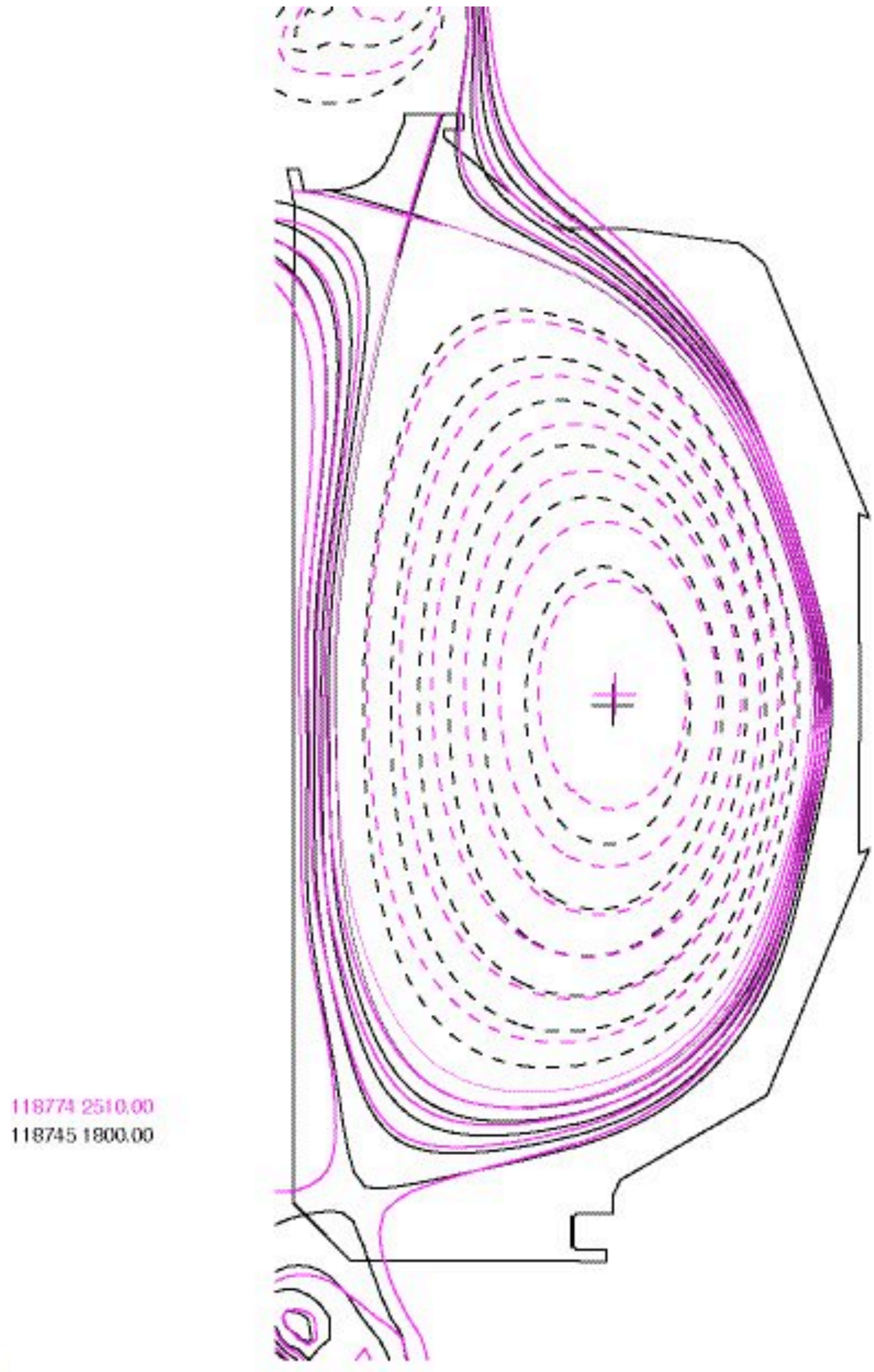
UOB power dependence correlates with 150Right beam voltage



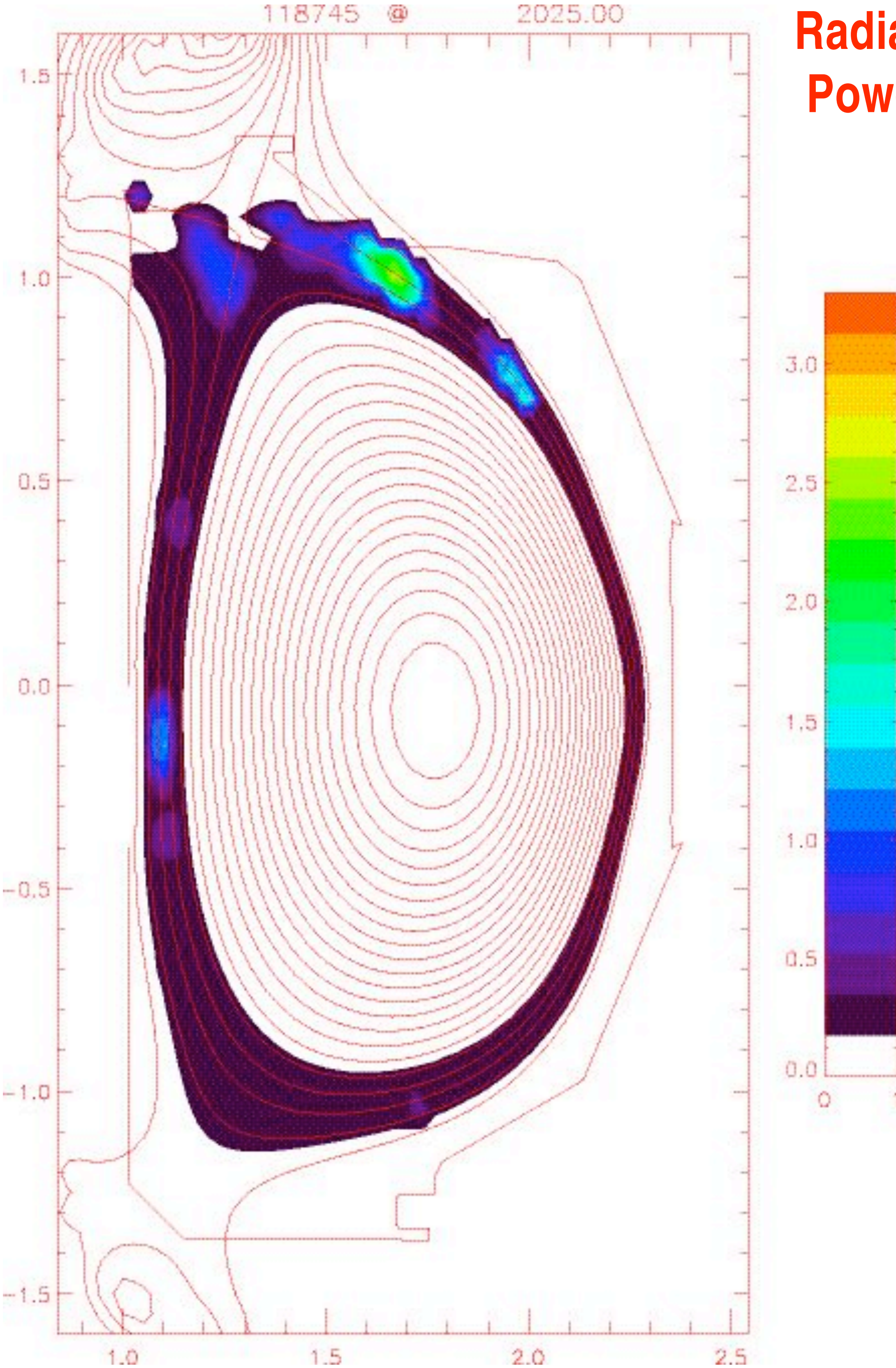
No voltage variation 330Left, 30L 30R not used


Schematic Plan View
of DIII–D Beams
Left Beam
Right Beam

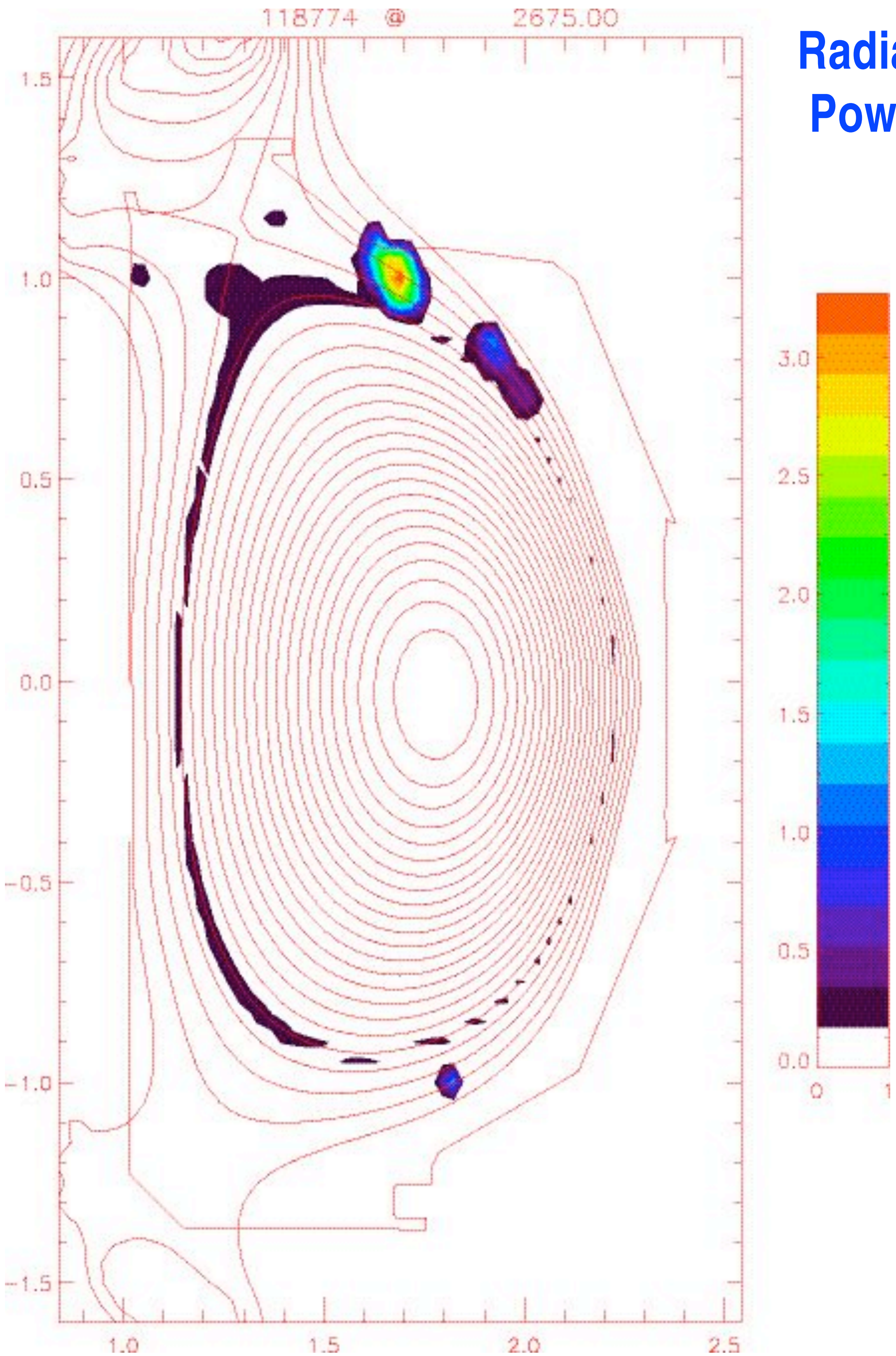
Slight differences in equilibrium do not account for variations in heat flux on upper outer baffle.



Radiated Power



β- dependent

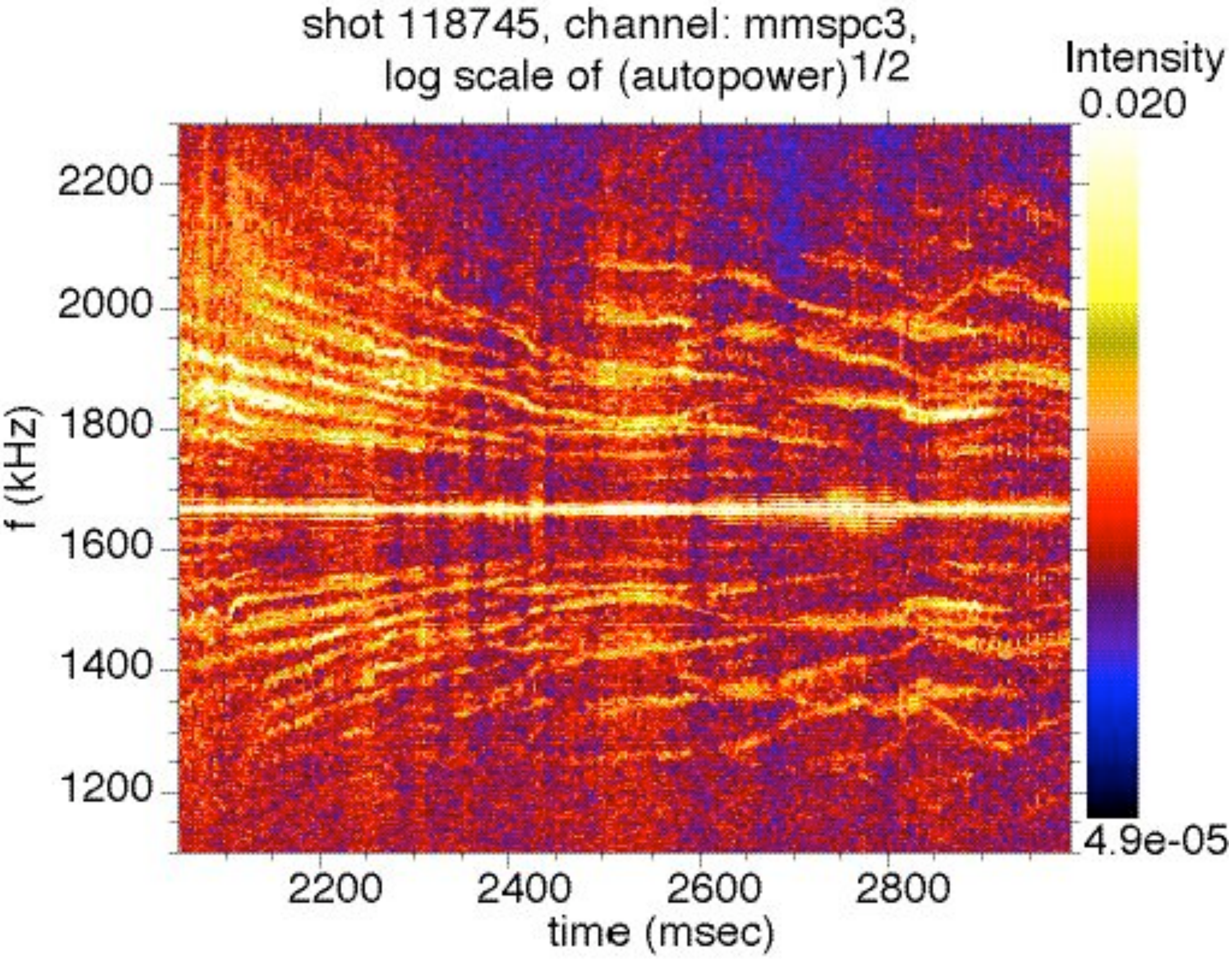


Radiated Power

β-independent

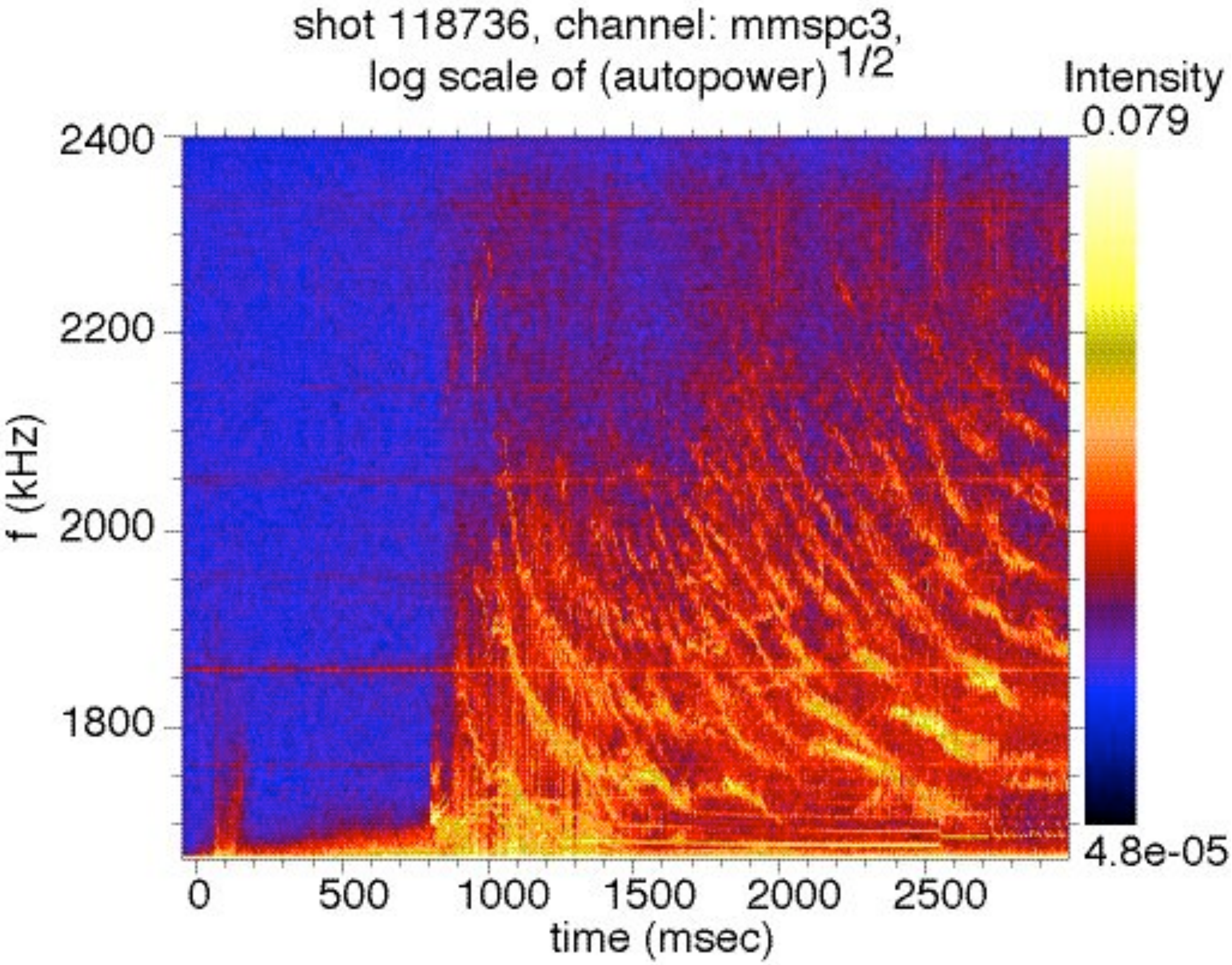
Reversed Shear Alfvén Eigenmodes (RSAE) dominate in β-dependent case

FIR scattering for β-dependent case



|-----------------------------------QH---------------------------------|

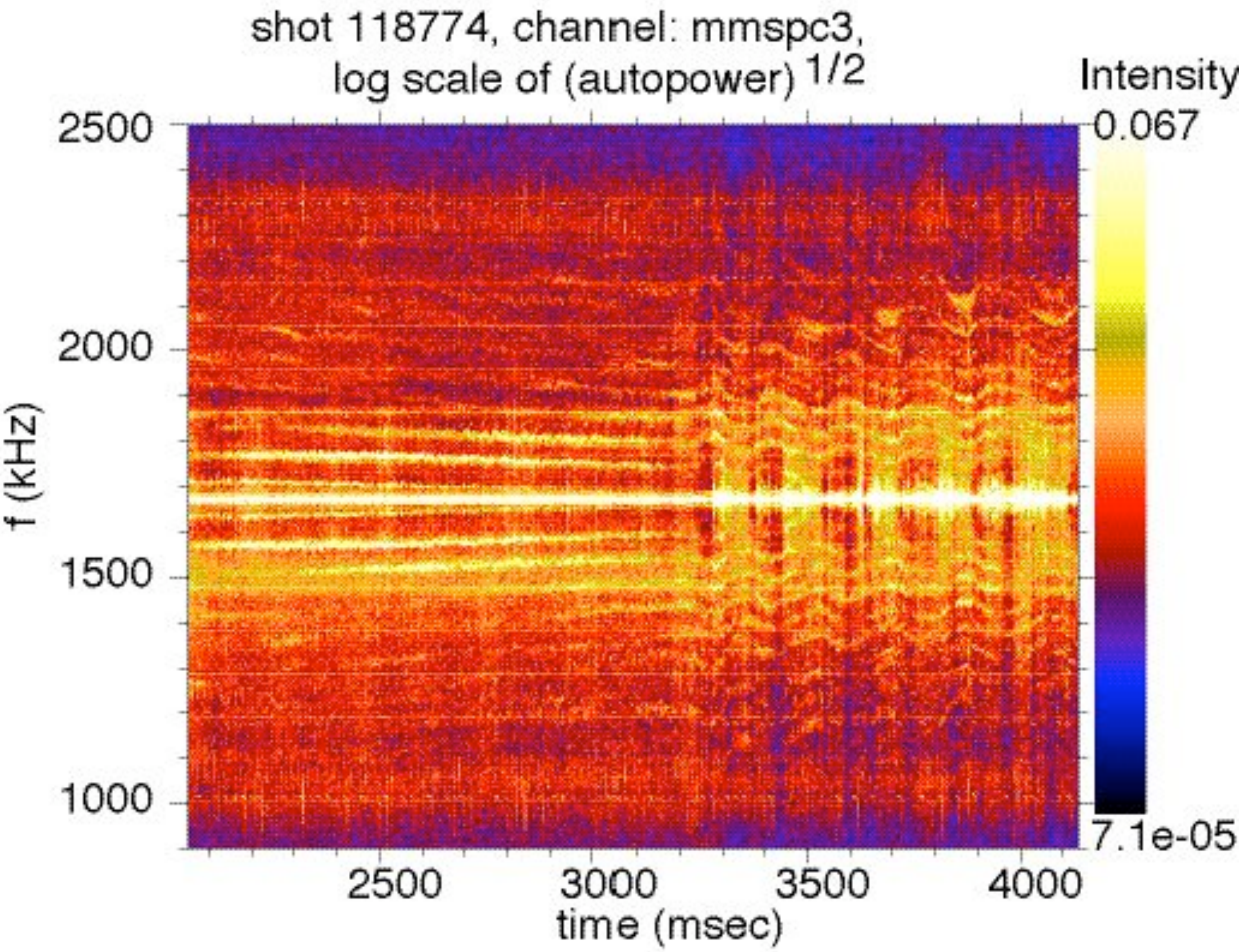
FIR scattering for another β-dependent case



|---------------QH---------------|

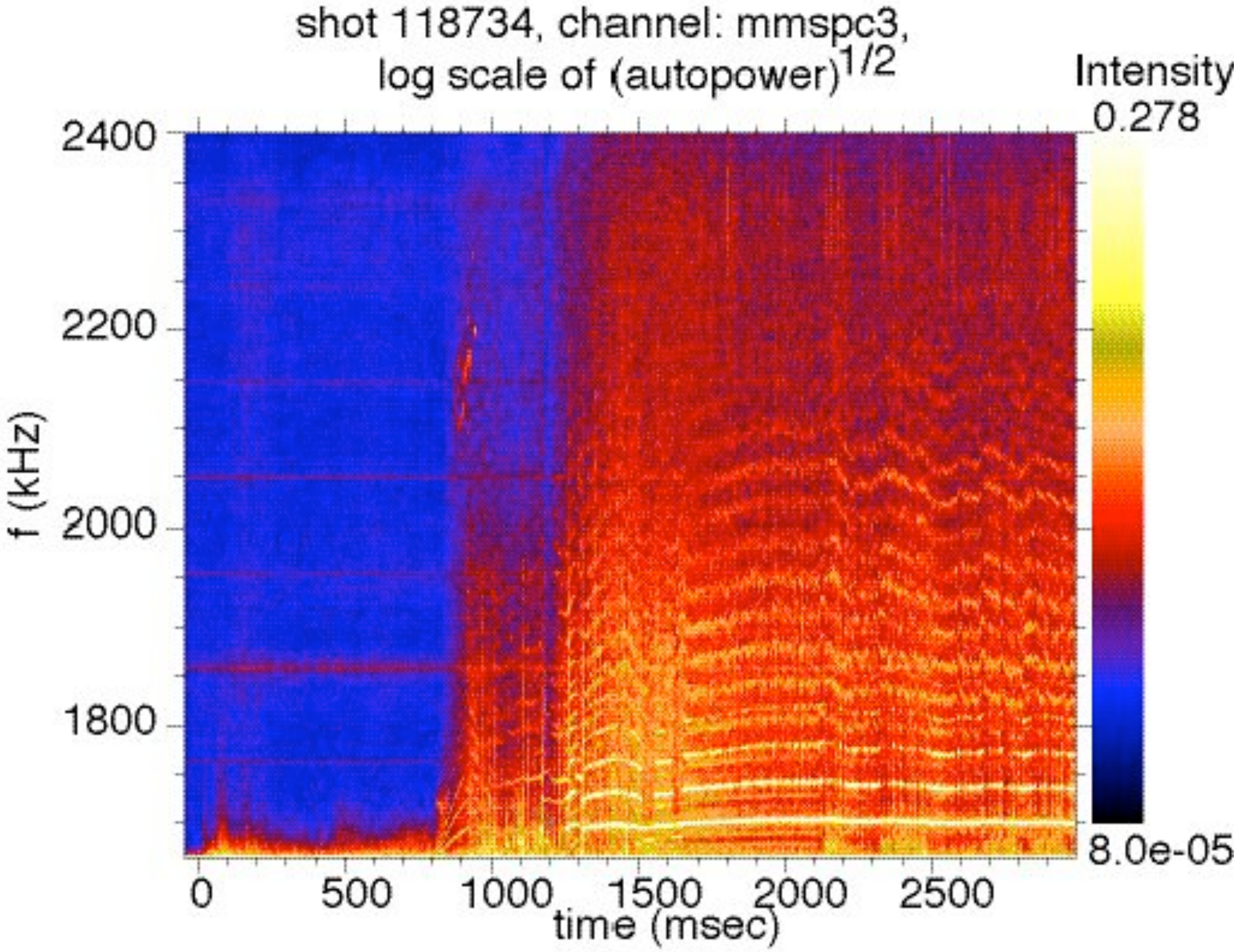
Toroidal Alfvén Eigenmodes (TAE) dominate in β-independent case

FIR scattering for β-independent case



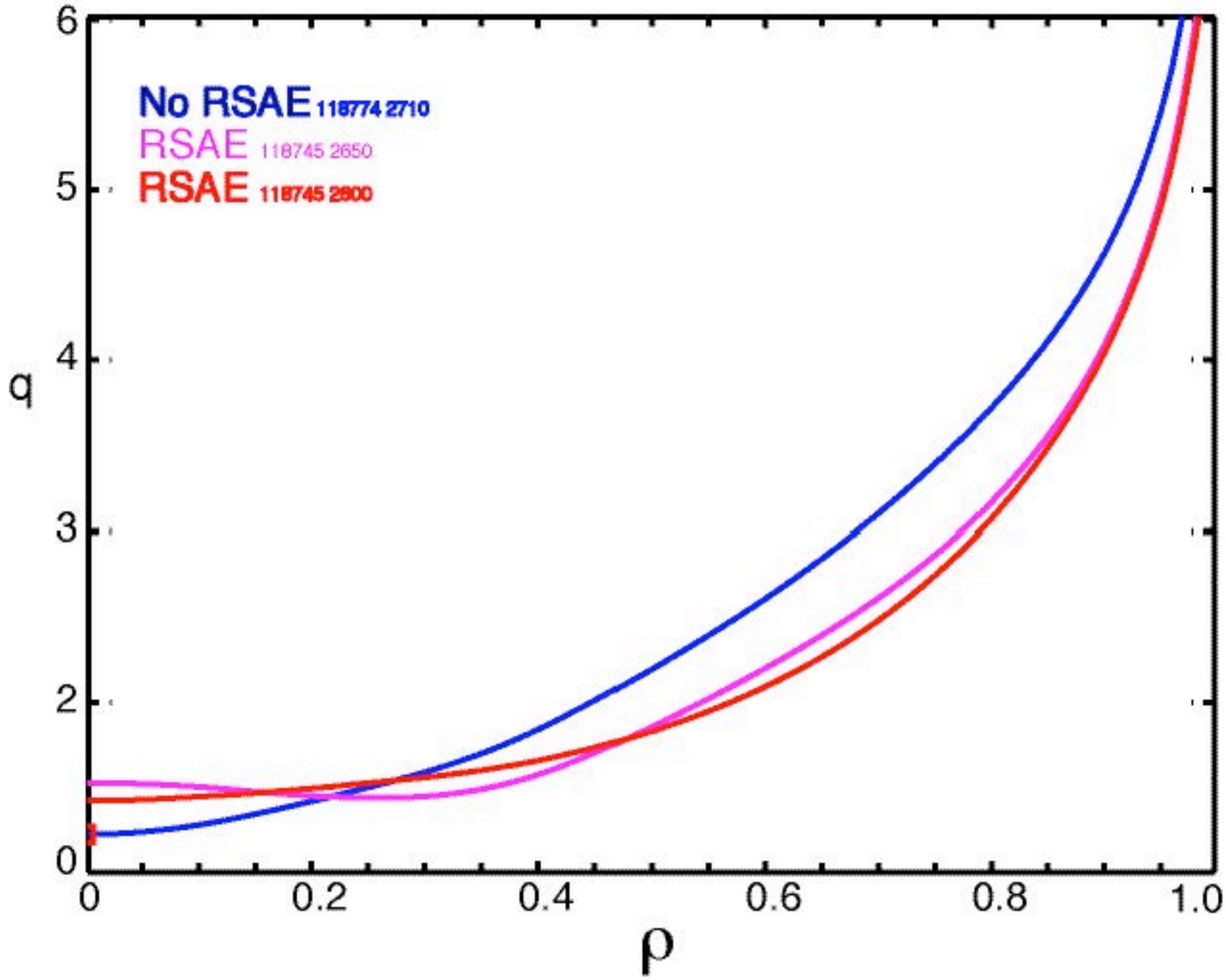
|-------------------------------QH-------------------------------|

FIR scattering for another β-independent case

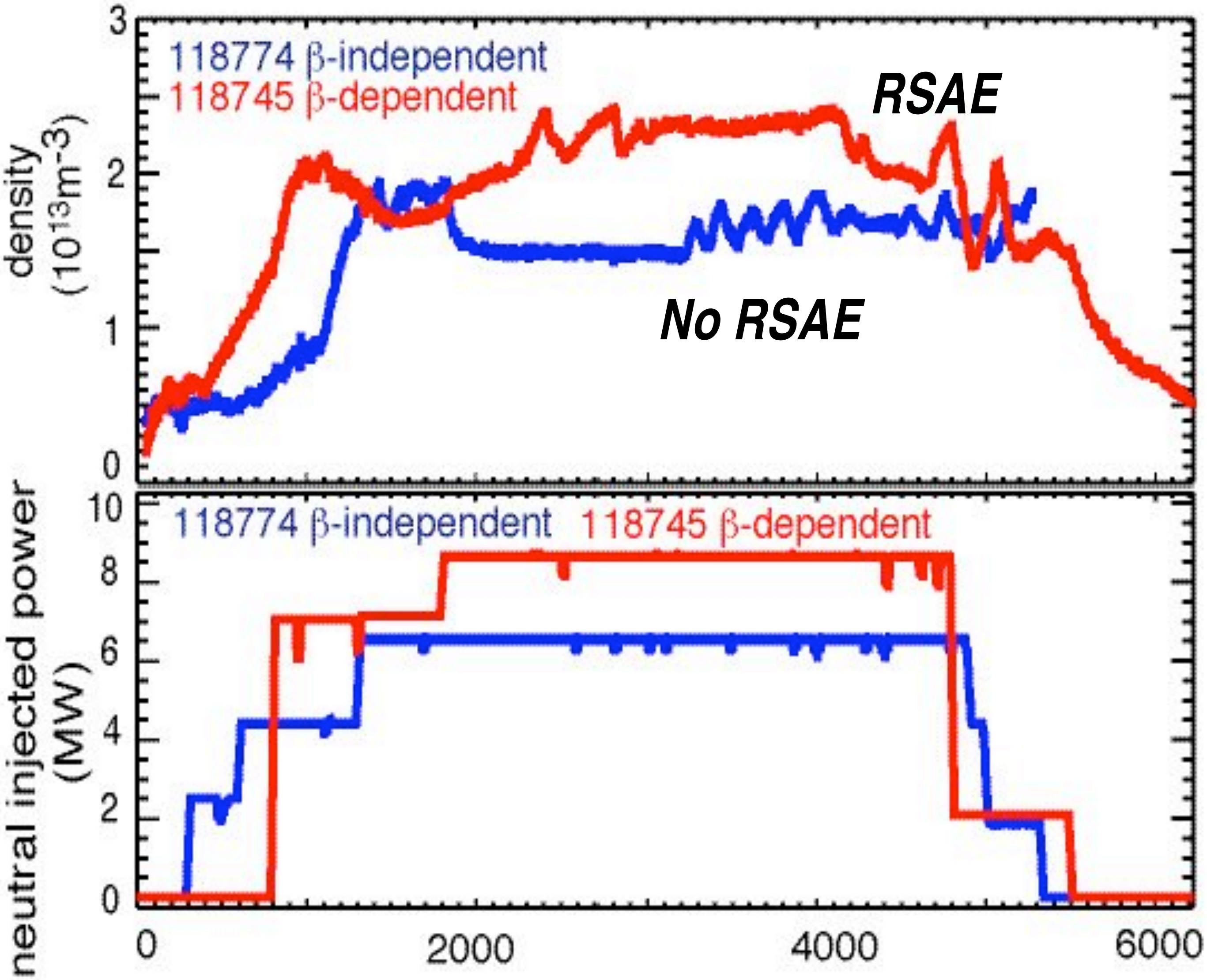


|-------------QH------------|

We see weak or reversed central shear in β-dependent case



Density and power are slightly different for two cases

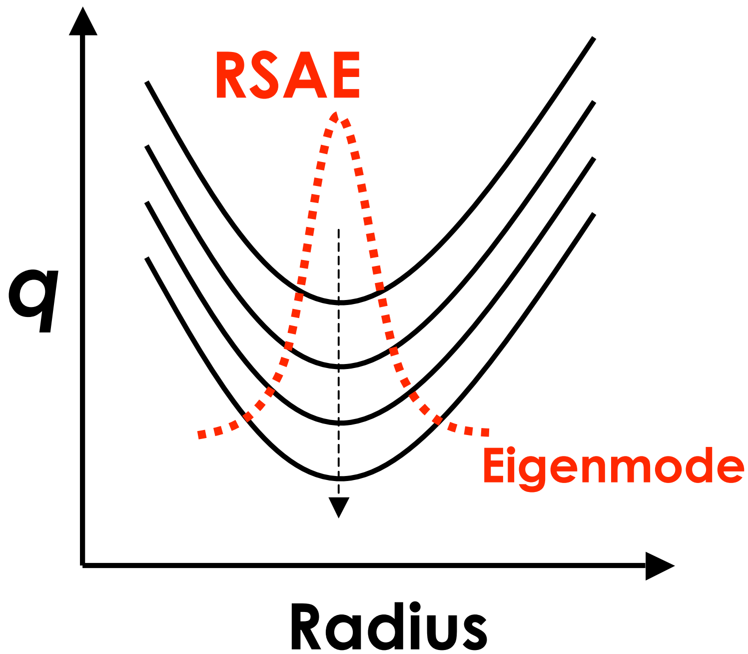


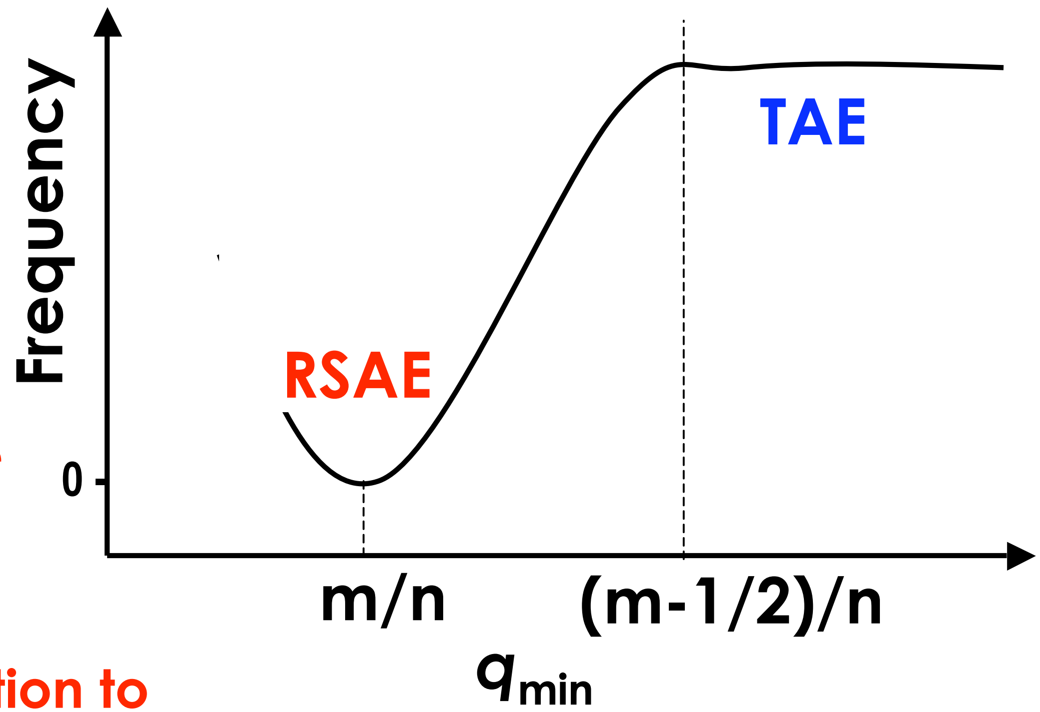
Discussion

- There is one class of QH time slices in with UOB power ~linear with β, and another class with no dependence on β.
- The linear UOB power case is strongly favored by the higher of the two NB voltages used- right beams but not left. This is consistent with increased ion loss due to Alfvén eigenmodes occurring at the higher beam energy.
- TAE modes appear in the β-independent case.
- RSAE modes dominate in the β-dependent case.
- Data is consistent with ions being ejected by RSAE modes and striking the upper outer baffle.

- See invited talk **QI1.0006 by G. Kramer**, 12:00PM Thursday “Interpretation of Core Localized Alfven Eigenmodes in DIII-D and JET Reversed Magnetic Shear Plasmas”

Theory of Alfvén Eigenmodes in Reverse Magnetic Shear Plasmas :RSAE*





- Core localized RSAEs, transition to global TAE with a frequency sweep sensitive to q-min

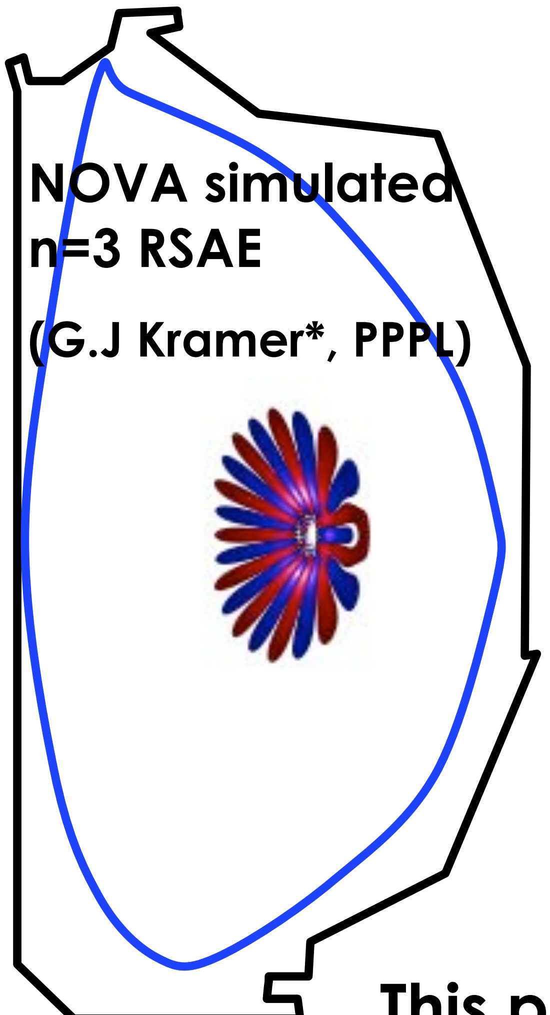
$$\omega = k_{||} V_A = \frac{(m - nq_{min})}{q_{min} R} V_A$$

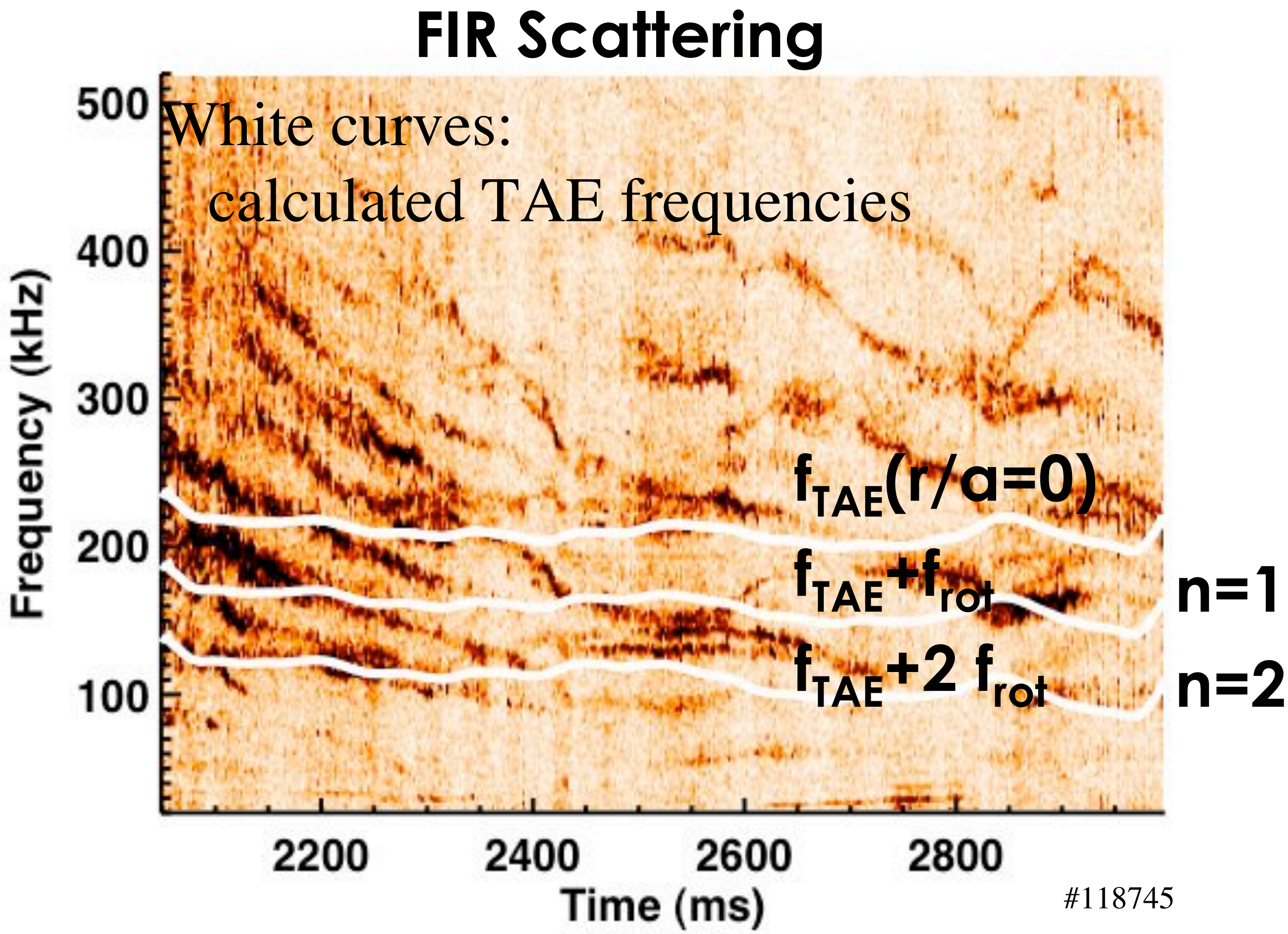
* H.L. Berk *et al*, PRL **87** (2001) 185002

* A. Fukuyama *et al*, IAEA 2002 TH/P3-14

*M.A. Van Zeeland, IAEA 2005

Discharges with β-dependent loss have core RSAE activity and possibly TAE



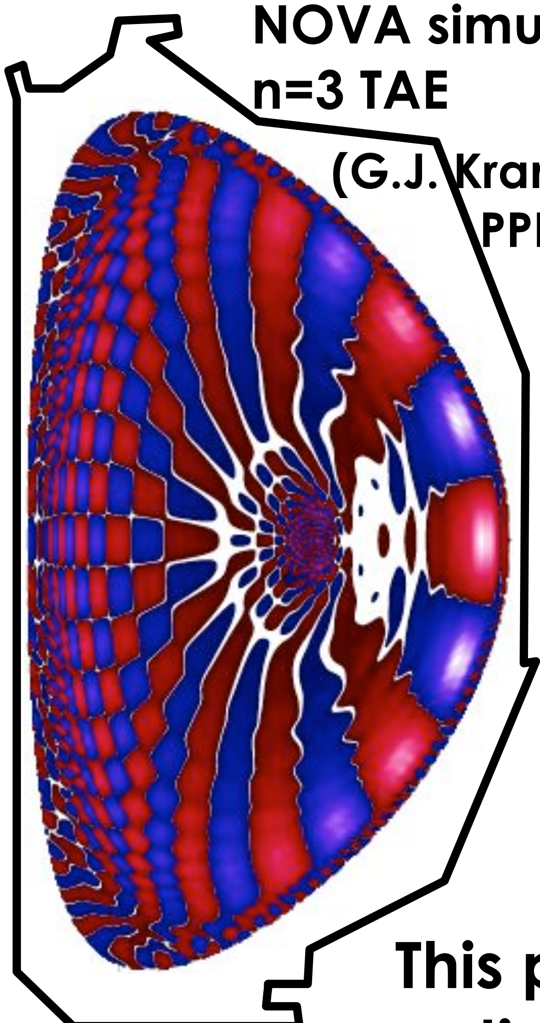


This plasma has weak/slightly reversed central shear and AE activity is dominated by RSAEs localized to region around q_{min}

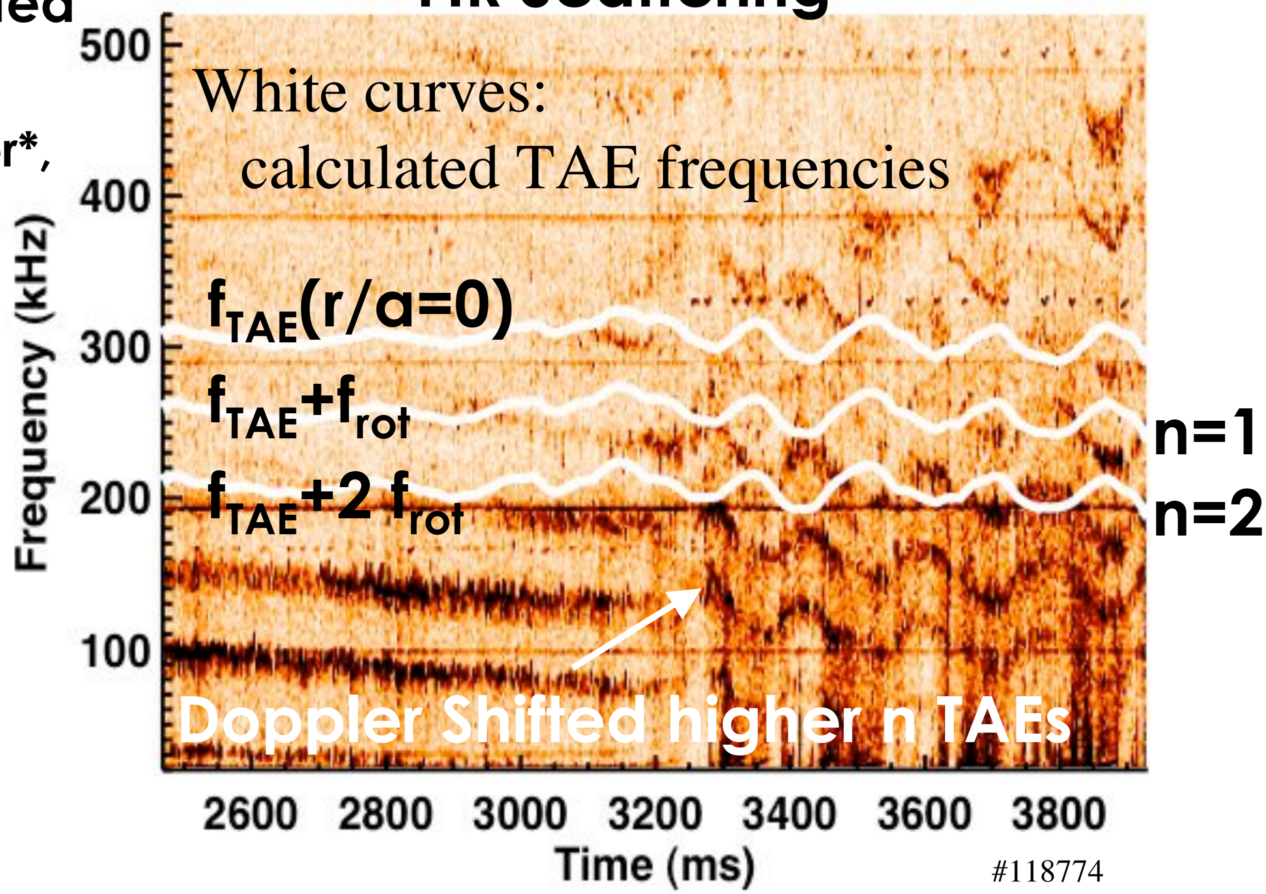
*This meeting, invited talk
QI1.0006 by G. Kramer

Discharges with β-independent loss have no observable RSAE activity - only TAE

NOVA simulated n=3 TAE (G.J. Kramer*, PPPL)



FIR Scattering



This plasma has no reverse shear region and AE activity is dominated by moderate *n (n=5-10)* TAEs with a relatively global structure

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*M.A. Van Zeeland, G.J. Kramer, et al, Plasma Phys. Control, Fusion **47** (2005) L31