Simulations of fast ions in ITER

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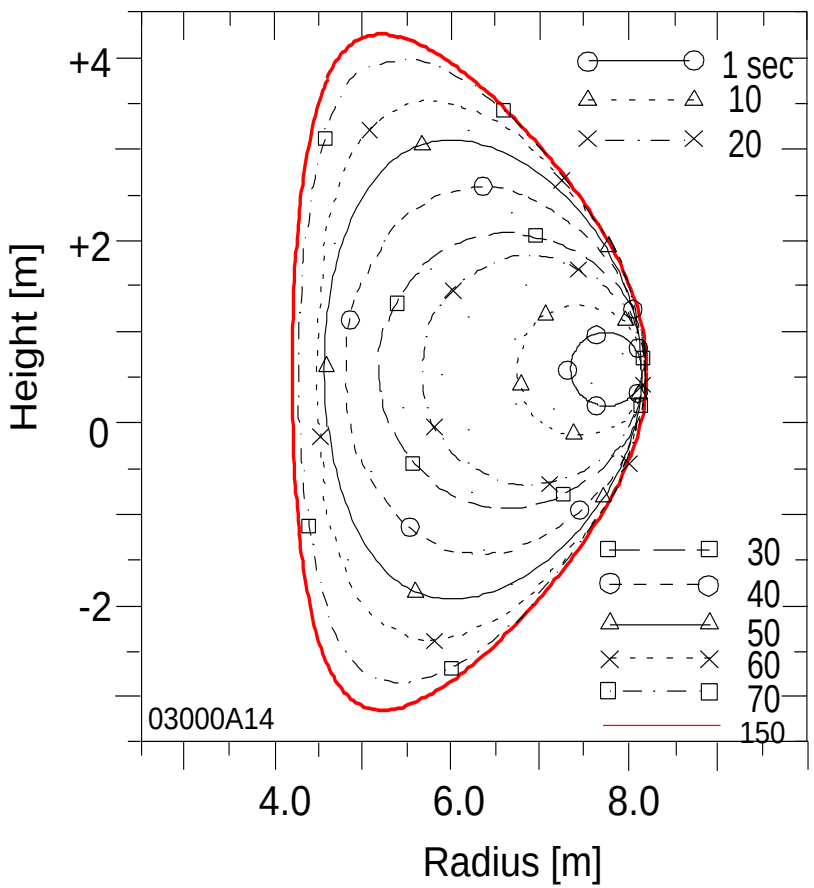
R.V. Budny (PPPL)

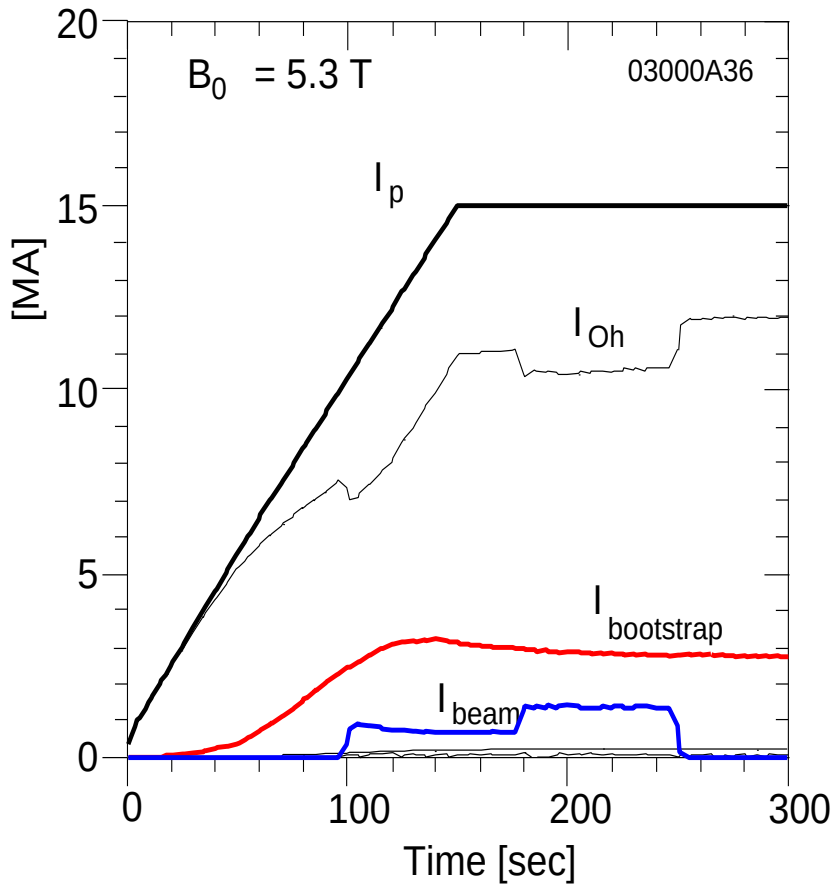
- Accurate simulations of fast ion parameters are needed for predicting heating, transport, and stability in ITER
- The goal of this research is to provide comprehensive simulations of fast ions in an ITER ELMy H-mode plasma [1]
- The TRANSP plasma analysis code provides:
  1. Monte Carlo techniques [2] for fusion alpha and NNBI ions
  2. The SPRUCE full-wave, reduced-order package [3] for He^3 minority ICRH

I - ELMy H-mode plasma in ITER

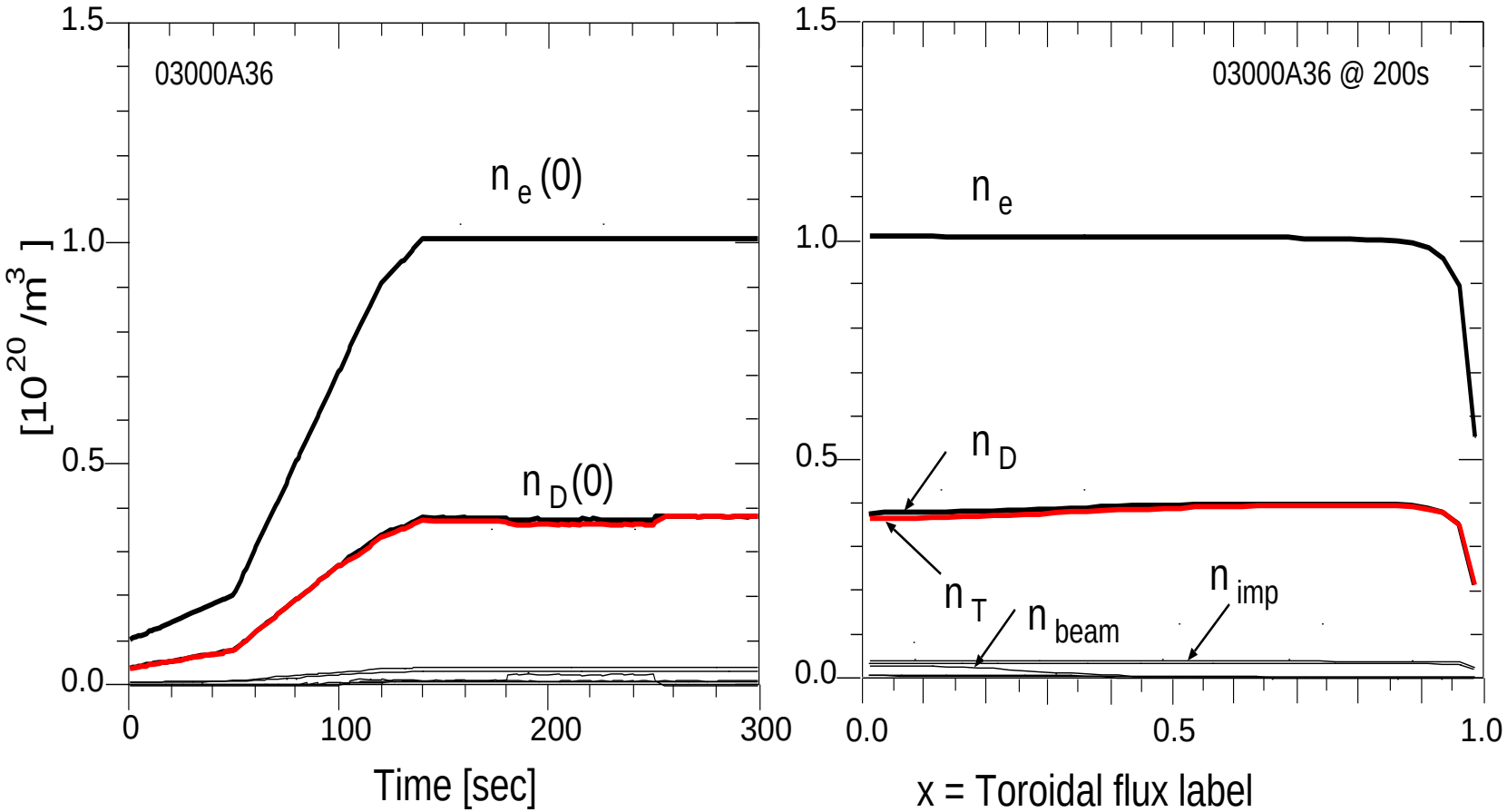
A standard ITER ELMy plasma generating P_{DT} = 400 MW [4]

Grow plasma boundary from circular to lower null

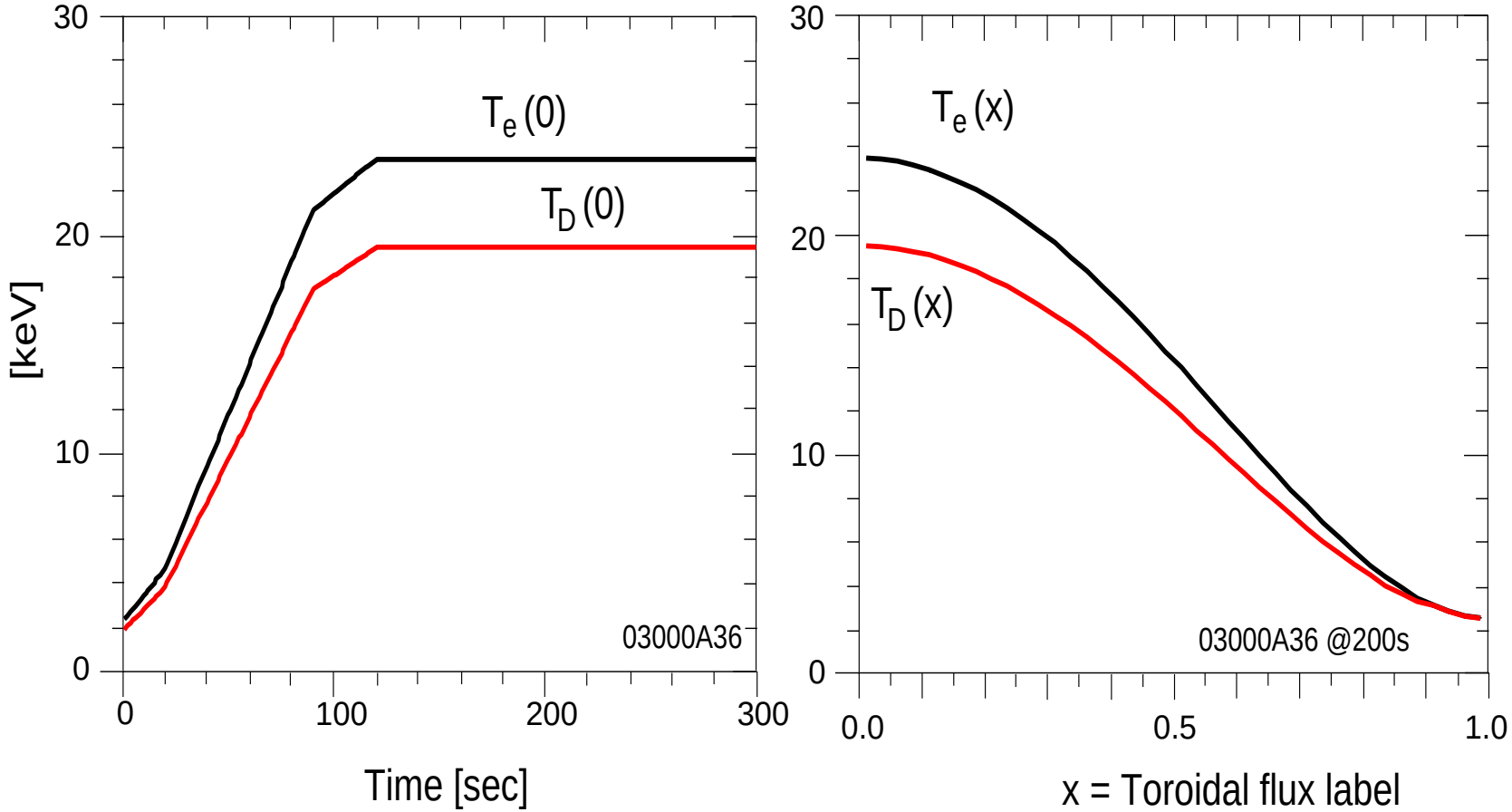




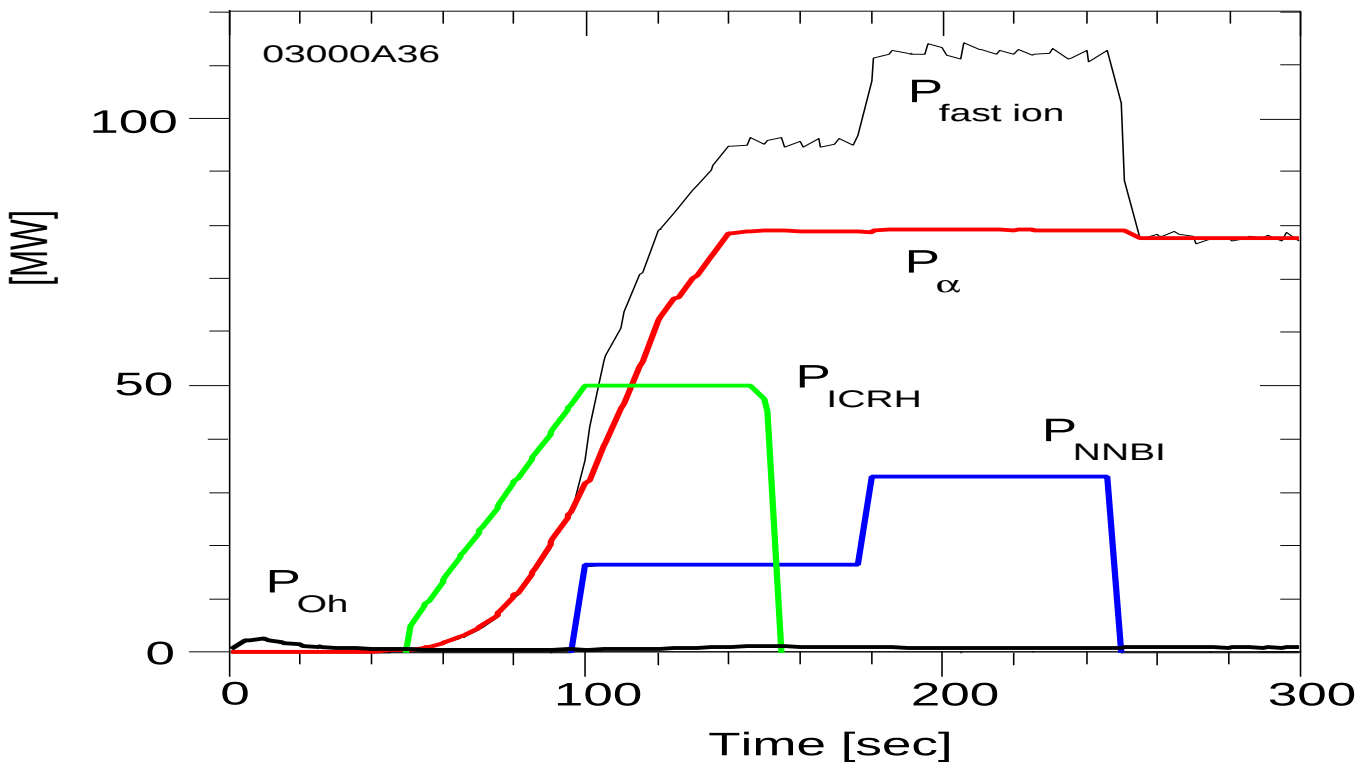
Rampup density to steady state



Rampup temperatures to steady state

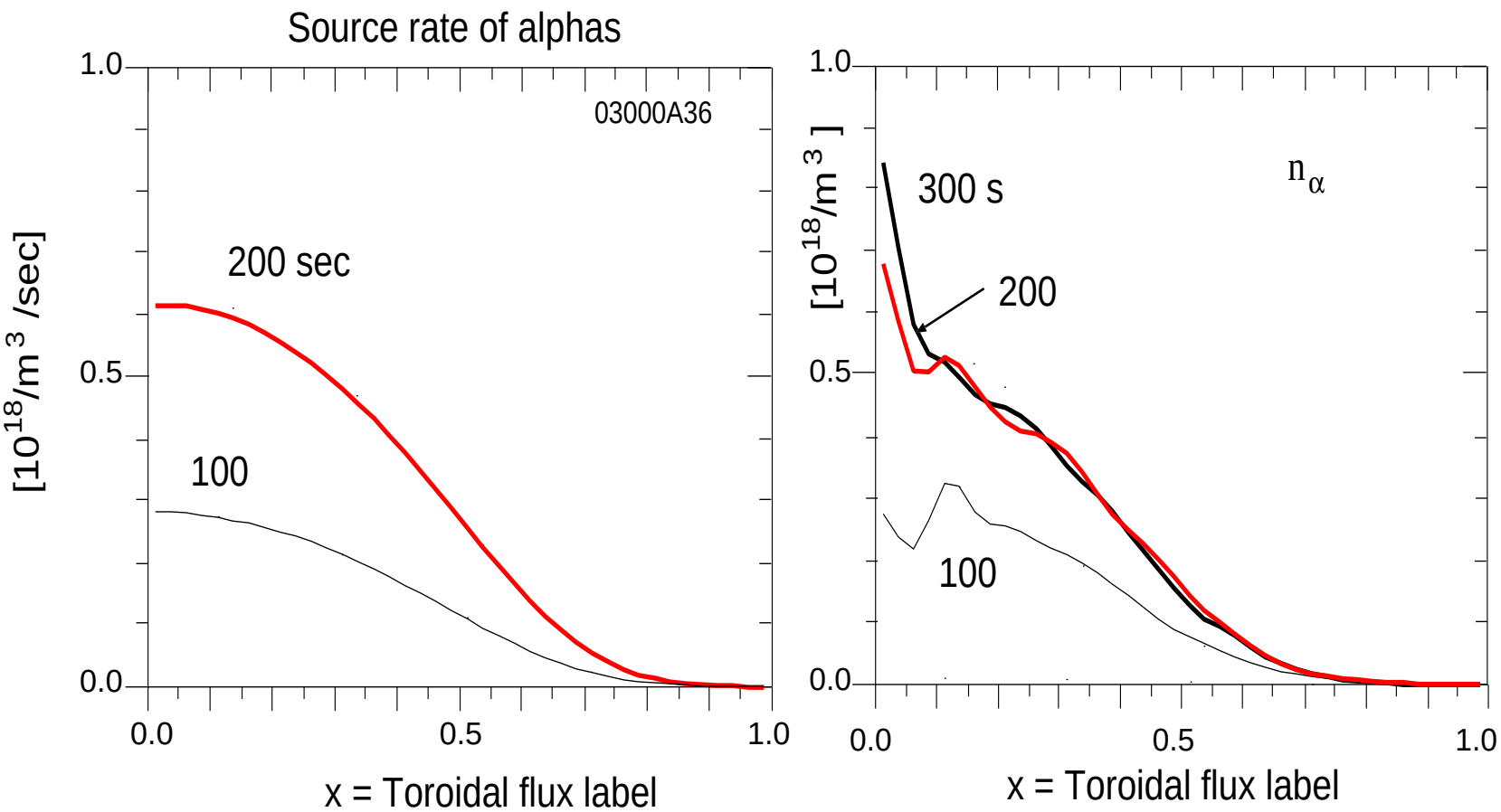


Heating phases

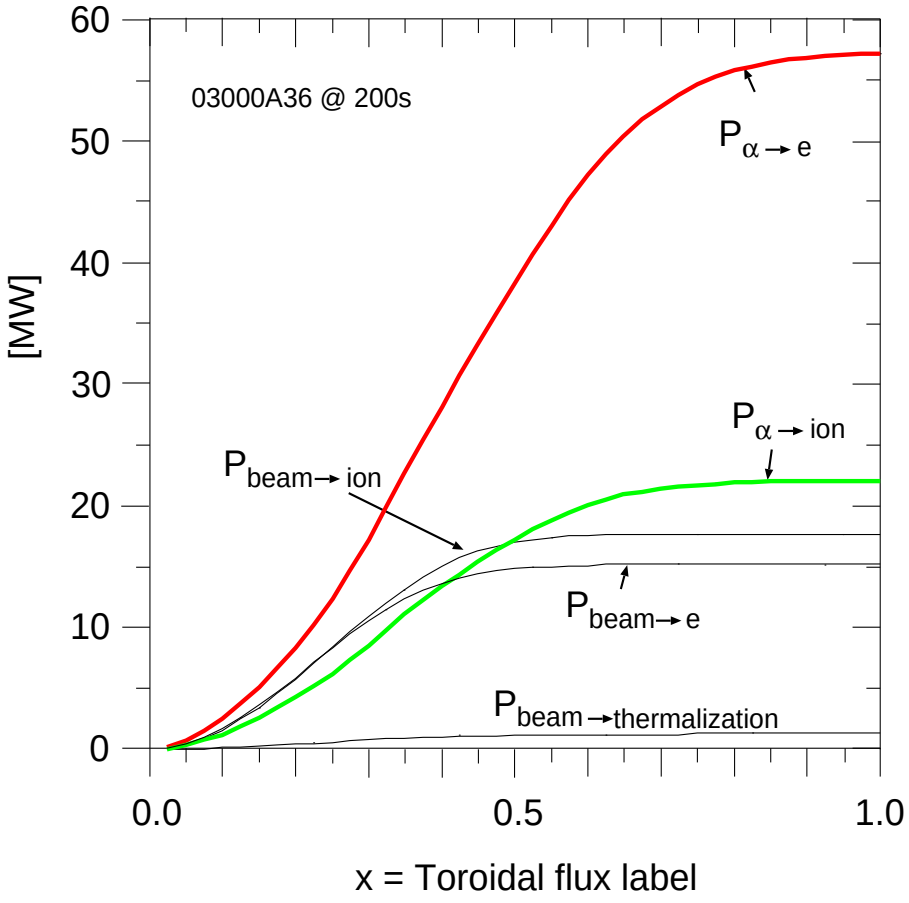


- He^3 ICRH during density rampup
- P_{NNBI} from 2 beamlines with 16.5 MW each

II - Alpha parameters

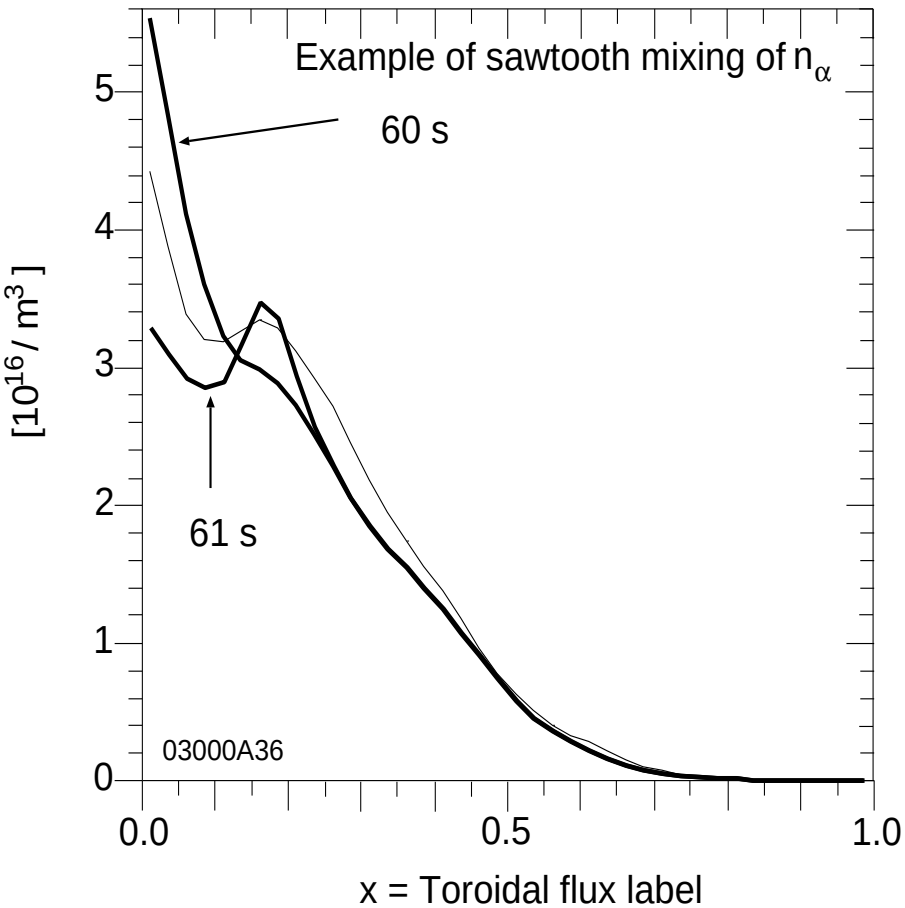


Alpha heating



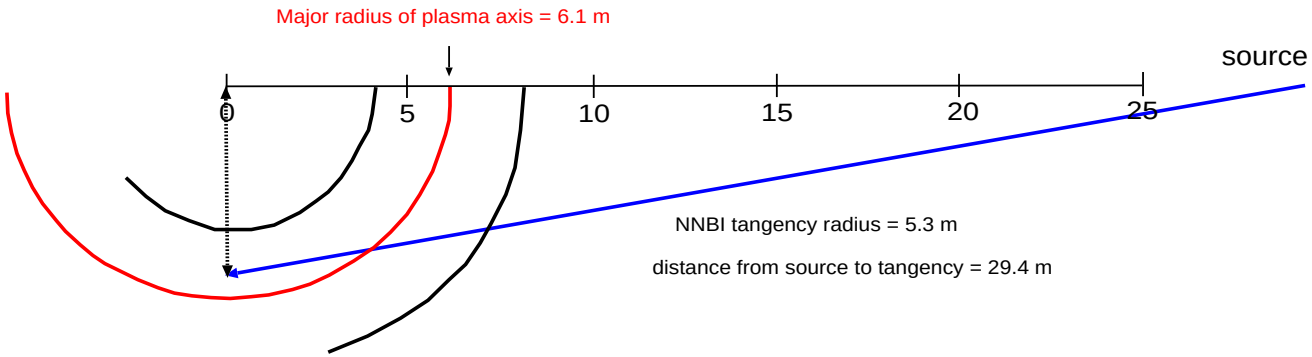
Sawtooth effects on alpha density

- Assume Kadomtsev mixing of helical flux and fast ions

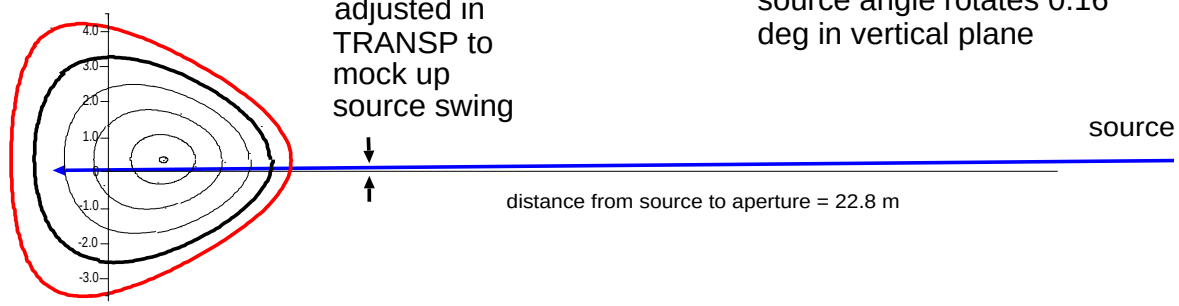


III - NNBI geometry [5]

Plan view

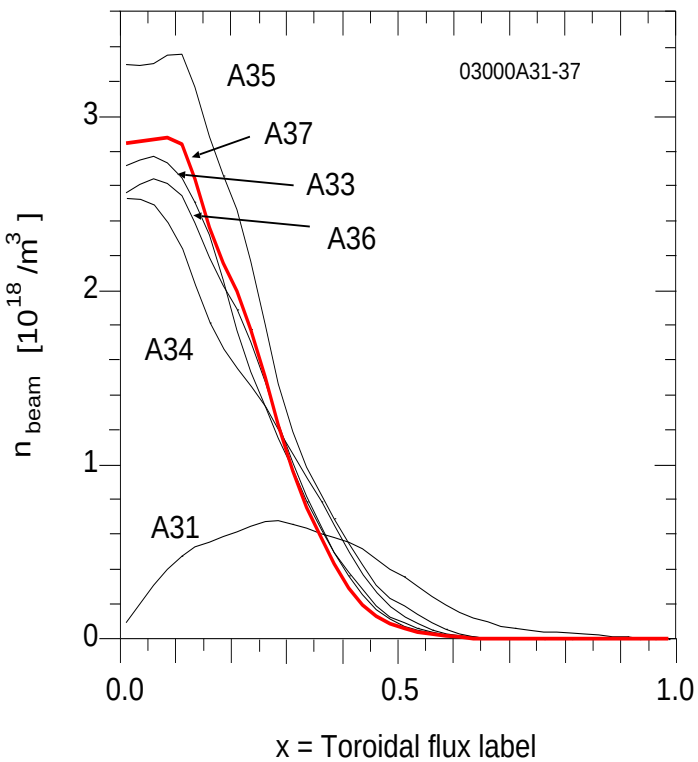


Vertical view along beam



Effects of aiming angles and excited states ionization

- Aiming angles strongly effects beam density
- Excited-states ionization model [6] reduces shine-through from 50 to 4 kW



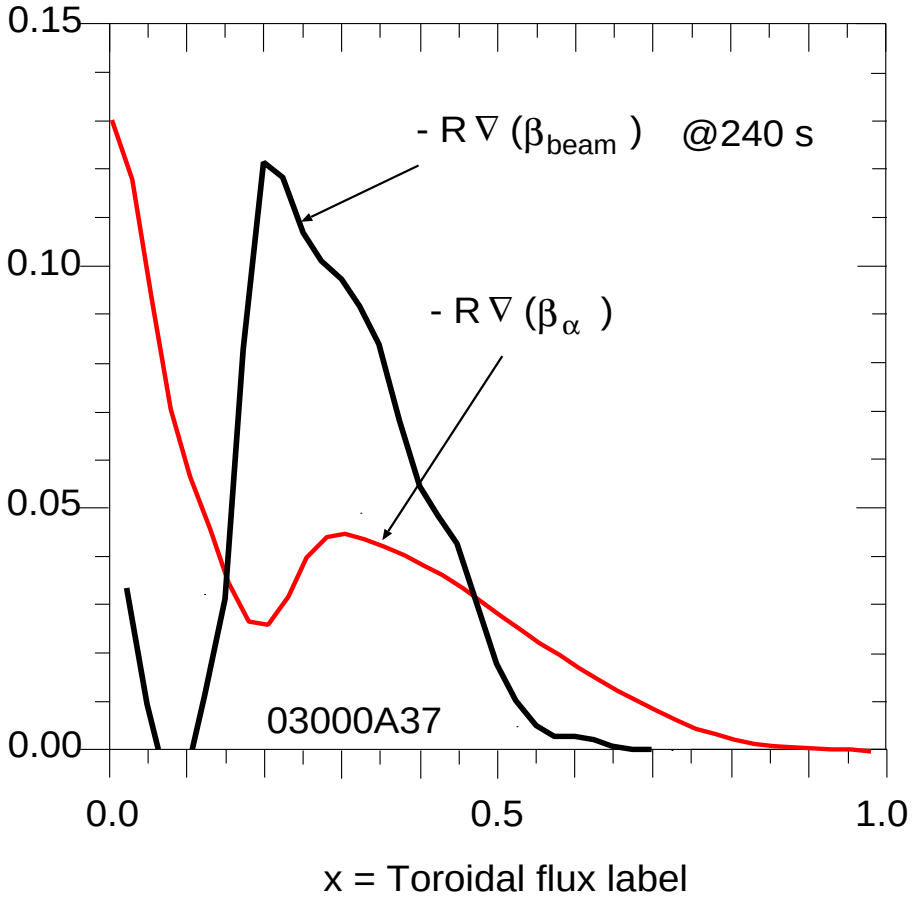
A31 aimed 1.5 m off axis

A34 aimed 0.5m off axis

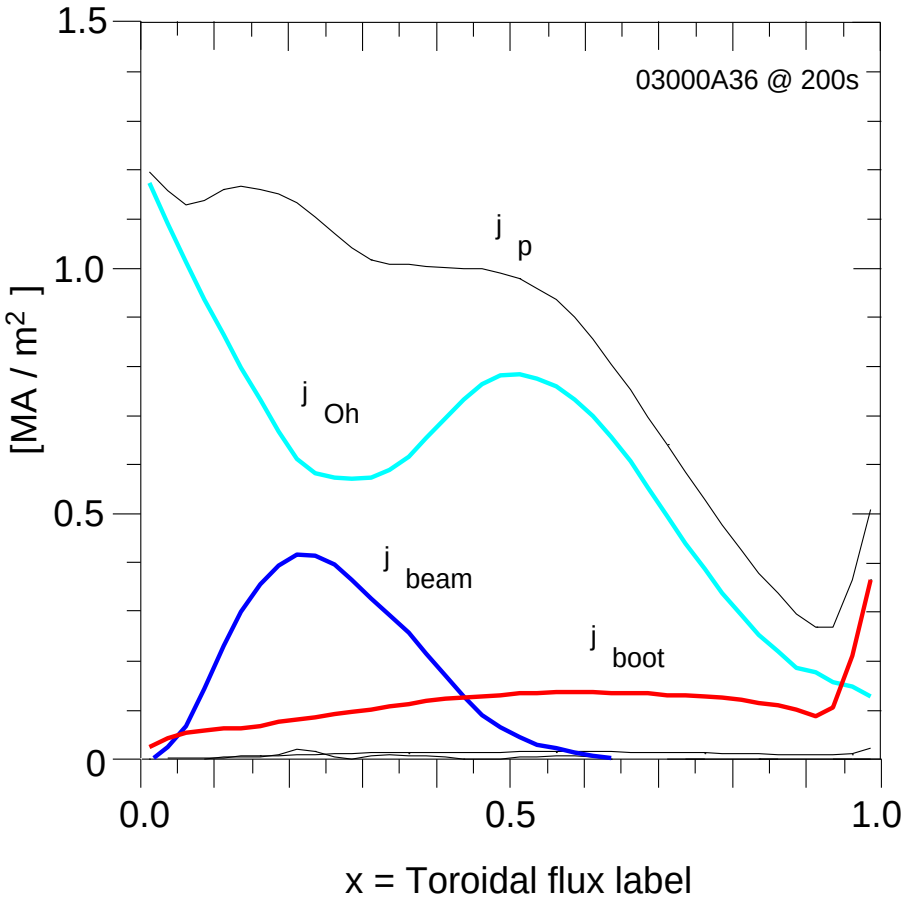
A35-A37 aimed near axis

A37 = A36 w excited state ionization

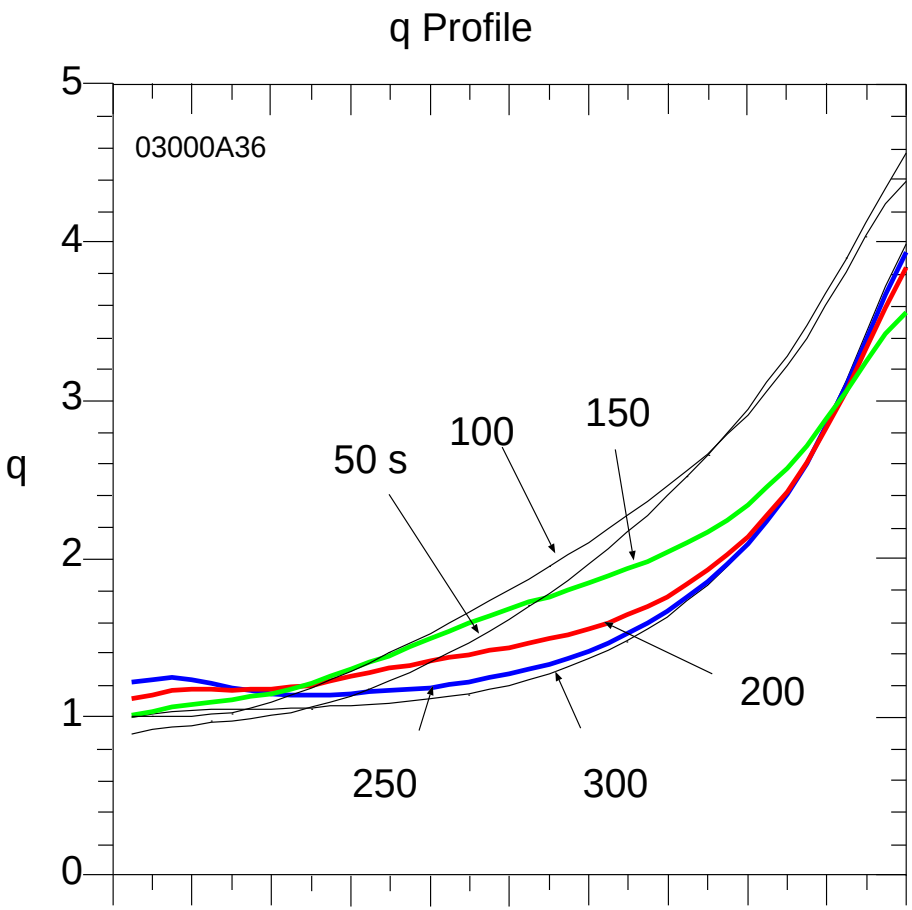
NNBI drive can exceed fast alpha drive locally



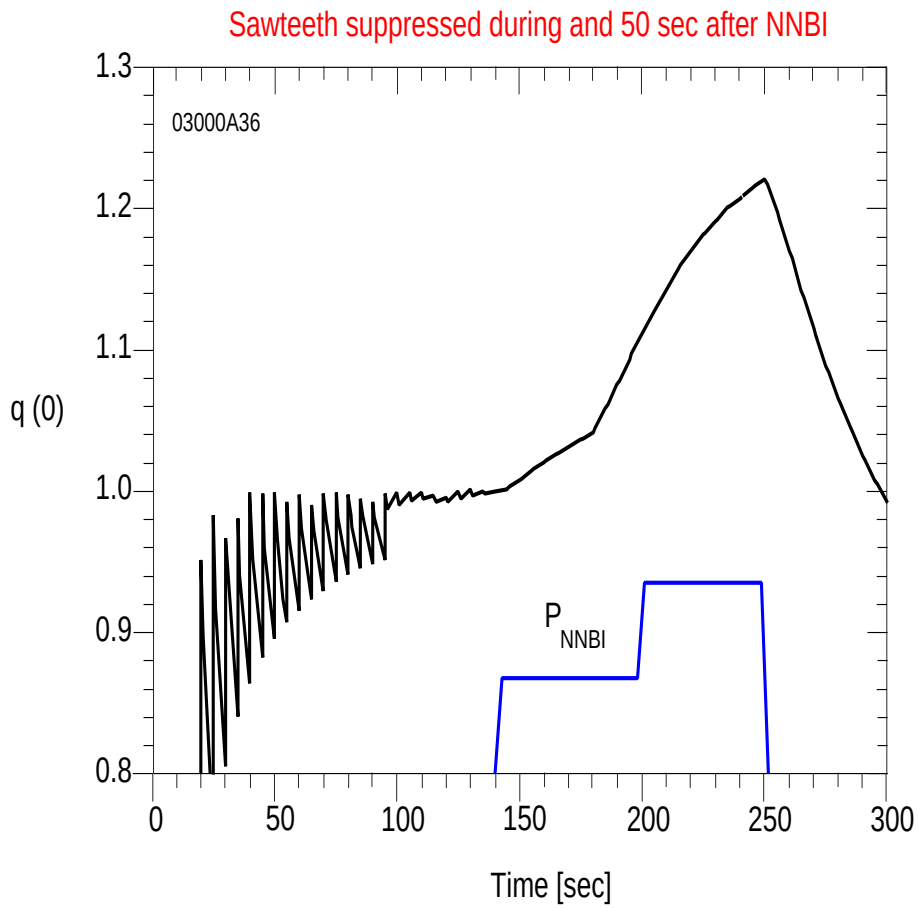
NNBI driven current



NNBI driven current effects q profile

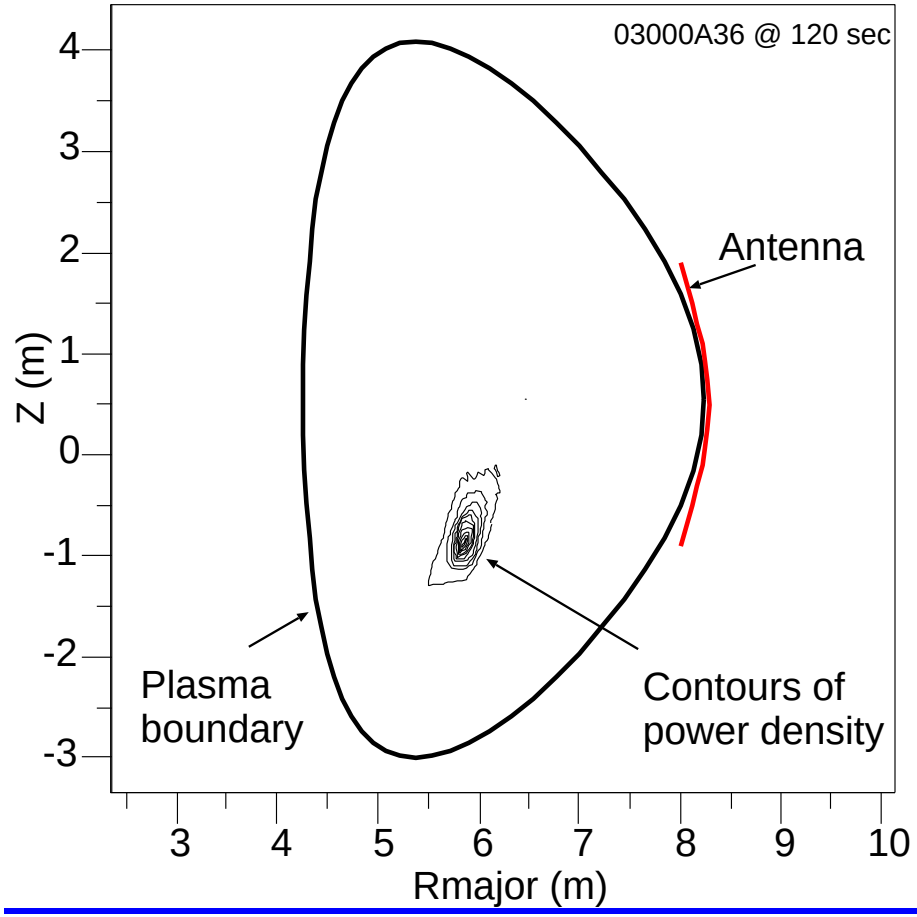


NNBI current changes q(0) sufficiently to suppress sawteeth

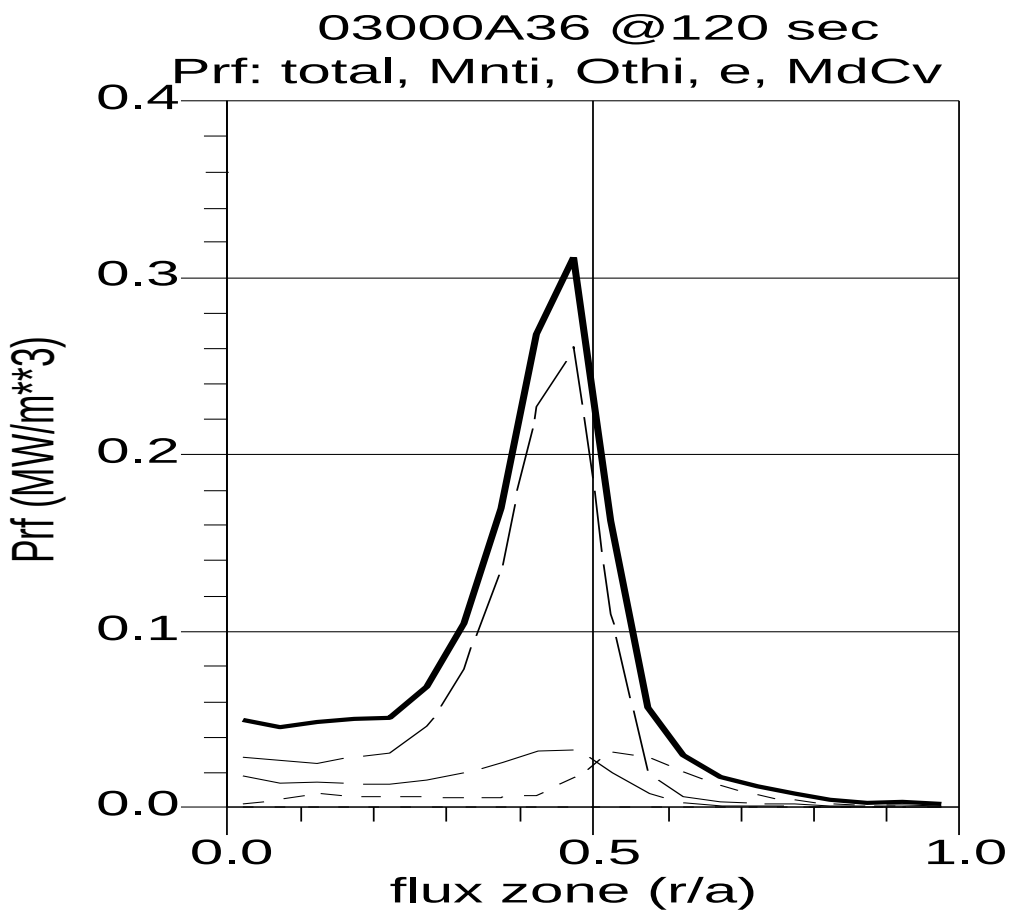


IV - He^3 minority ICRH

- Assume geometry of the antenna
- On-axis resonance with 53 MHz



Split of ICRH heating powers



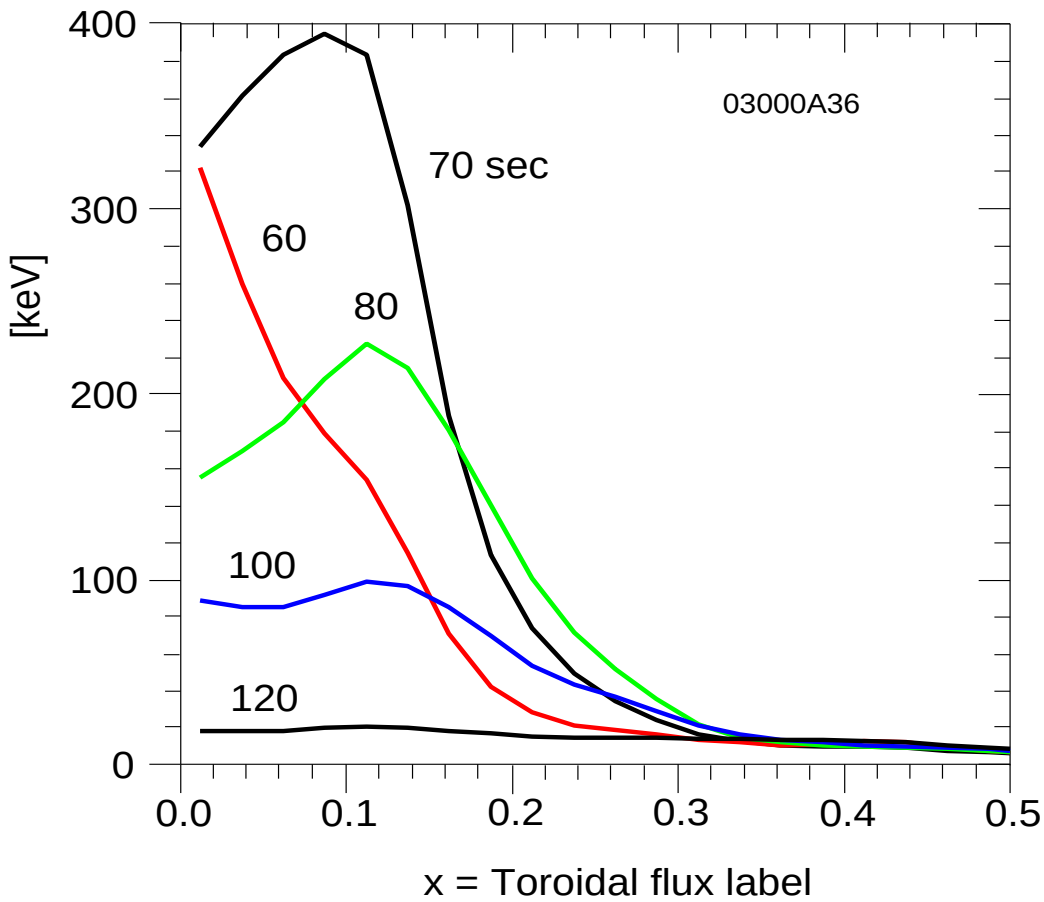
power in = 50 MW

total Prf= 50 MW
minorities: 35.56 MW
other ions: 6.876 MW
electrons: 7.56 MW
mode conv.: 0.000 MW

T : 5.06 %
D : 1.29 %
He4 : 0.03 %
Be8_4 : 0.52 %
D_MCfi : 1.60 %
He3_mino : 71.13 %
He4_MCfi : 5.25 %
electrons : 15.12 %
mode conv.: 0.00 %

RF tail temperature decreases as density increases

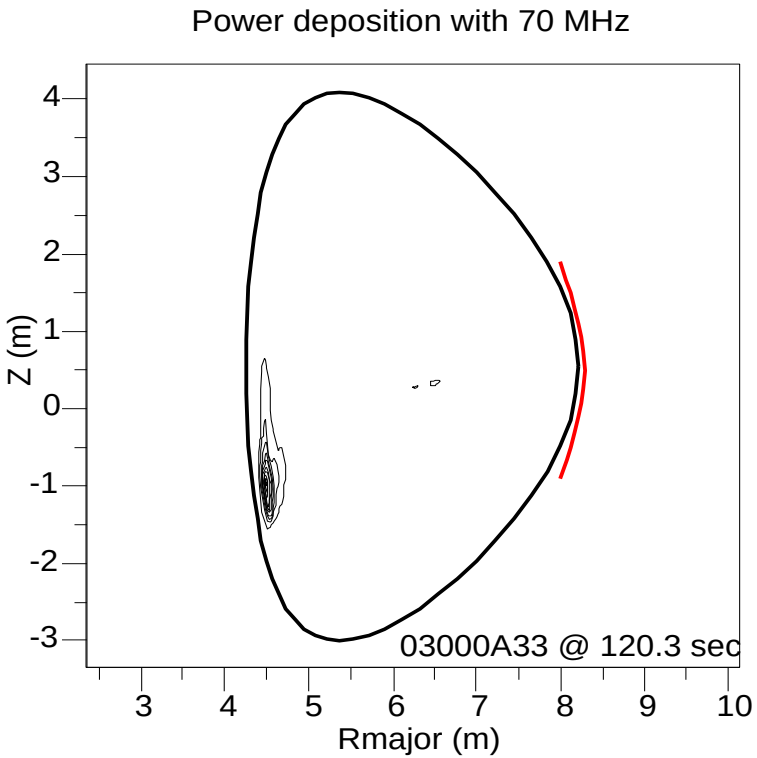
- Assume $n_{He} / n_e = 0.03$



$$T_{RF} = \frac{2\,W_{\perp}}{3\,n_{He^3}}$$

Off-axis resonance

- Explored effects of varying ICRH frequency



References

1 R.V. Budny, Nuclear Fusion **42** (2002) 1383

2 R.J.Goldston, *et al.*,, J.Comput. Phys **43** (1981) 61

3 M.Evrard, J.Ongena, *et al.*, AIP Conference Proc. 335 (1995) 235

4 D.Campbell, Phys. Plasma **8** (2001) 2041

5 "ITER Technical Basis", G A0 FDR 1 01-07-13 R1.0, Chapter 2.5

6 Janev, Boley and D.Post, Nuclear Fusion, **29** (1989), 2125