# Direct NTM stabilisation attempts on JET

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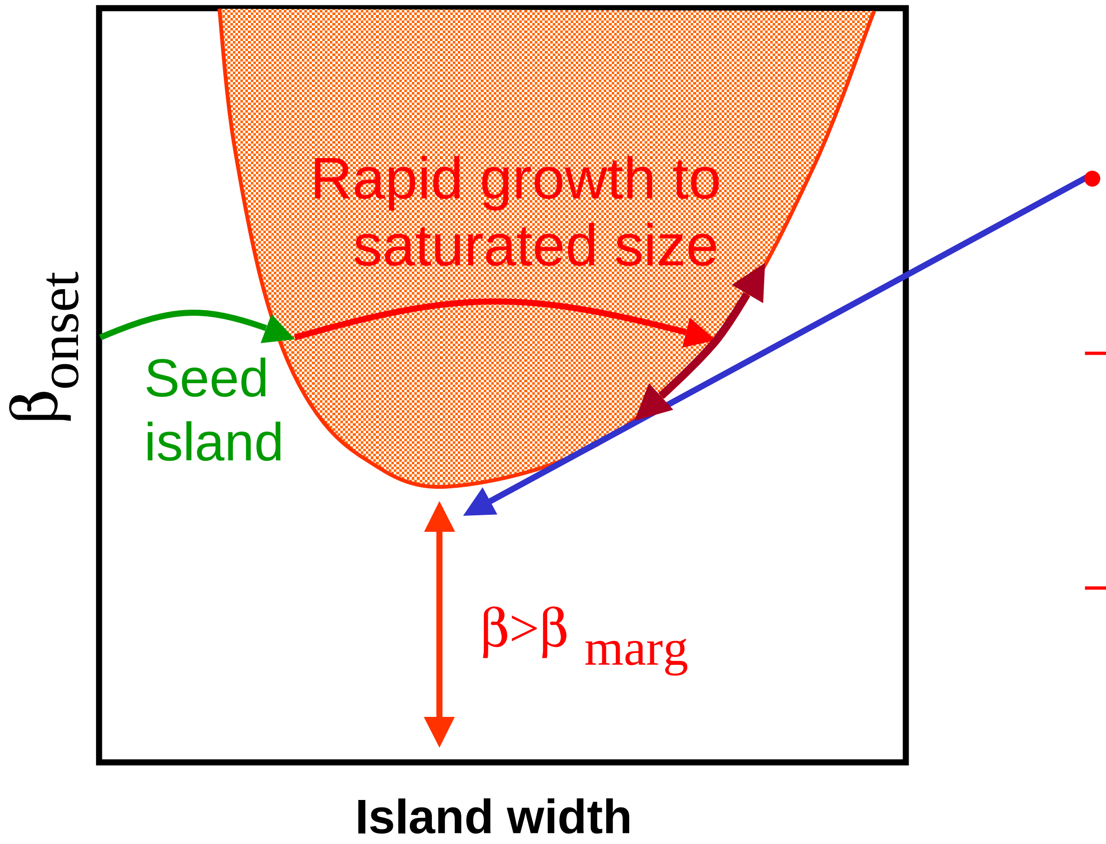
[6] Annex 1 of Pamela, J., 2003 Proc. 19th Int. Conf. on Fusion Energy (Lyon, 2002, IAEA).

# Outline

- Real time β ramp-down techniques
- ICCD at q=3/2 NTM control scans
- Possibilities for LHCD NTM control
- Conclusions

# NTMs have a metastable threshold



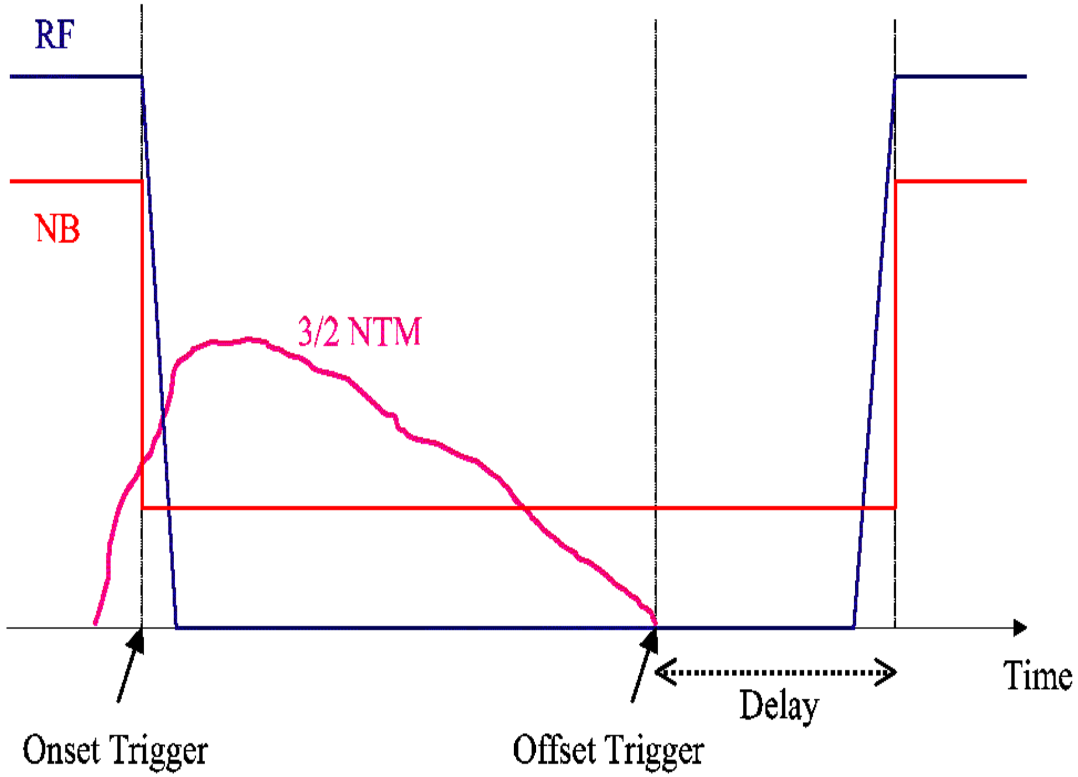

- NTMs metastable above a certain $\beta_{marg}$

→If β ramped down enough NTM can be removed

→Particularly useful if you get anomalous seed

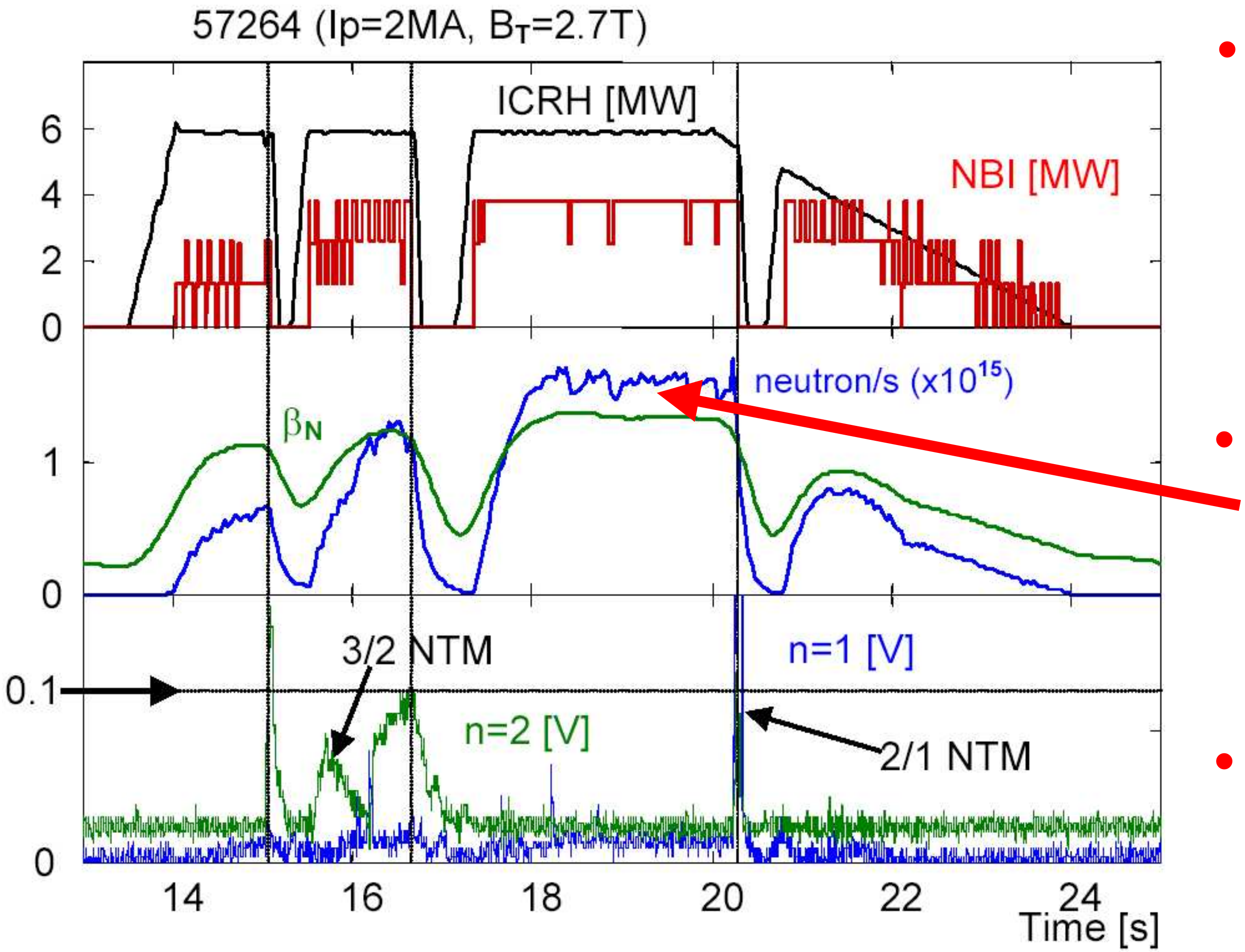
– such as large sawteeth with entry into H-mode

# ...then real time control can help




- Real time system takes β down until mode decays...

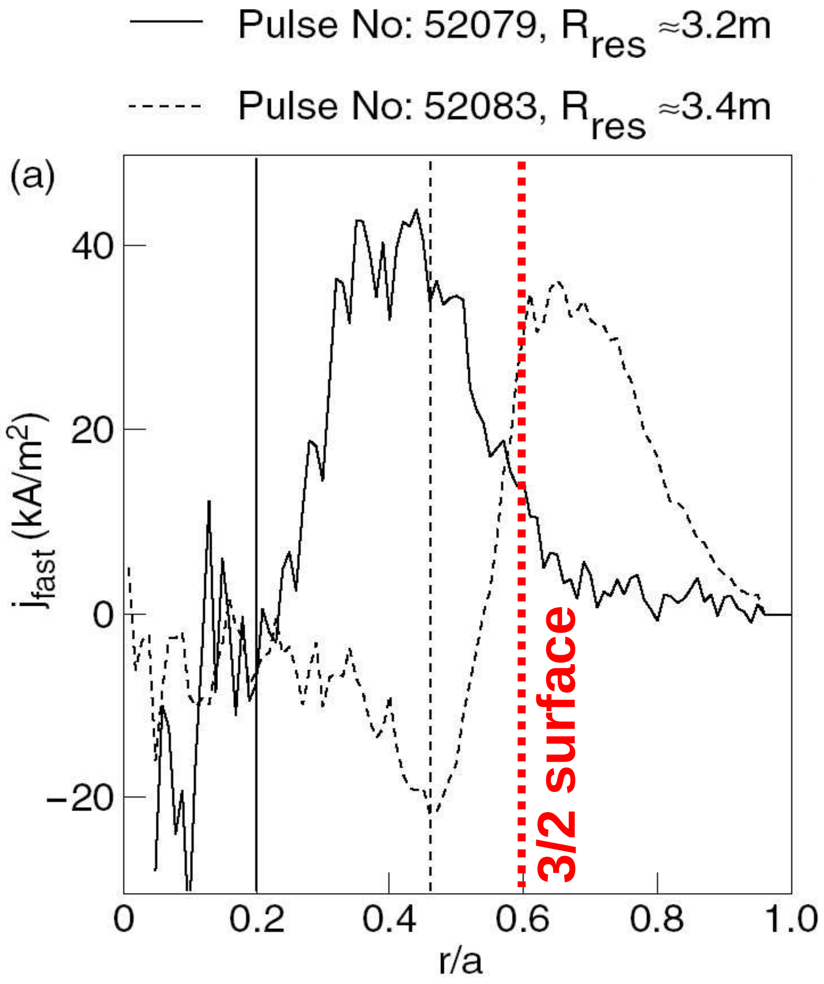
# Real time β notch for NTM removal

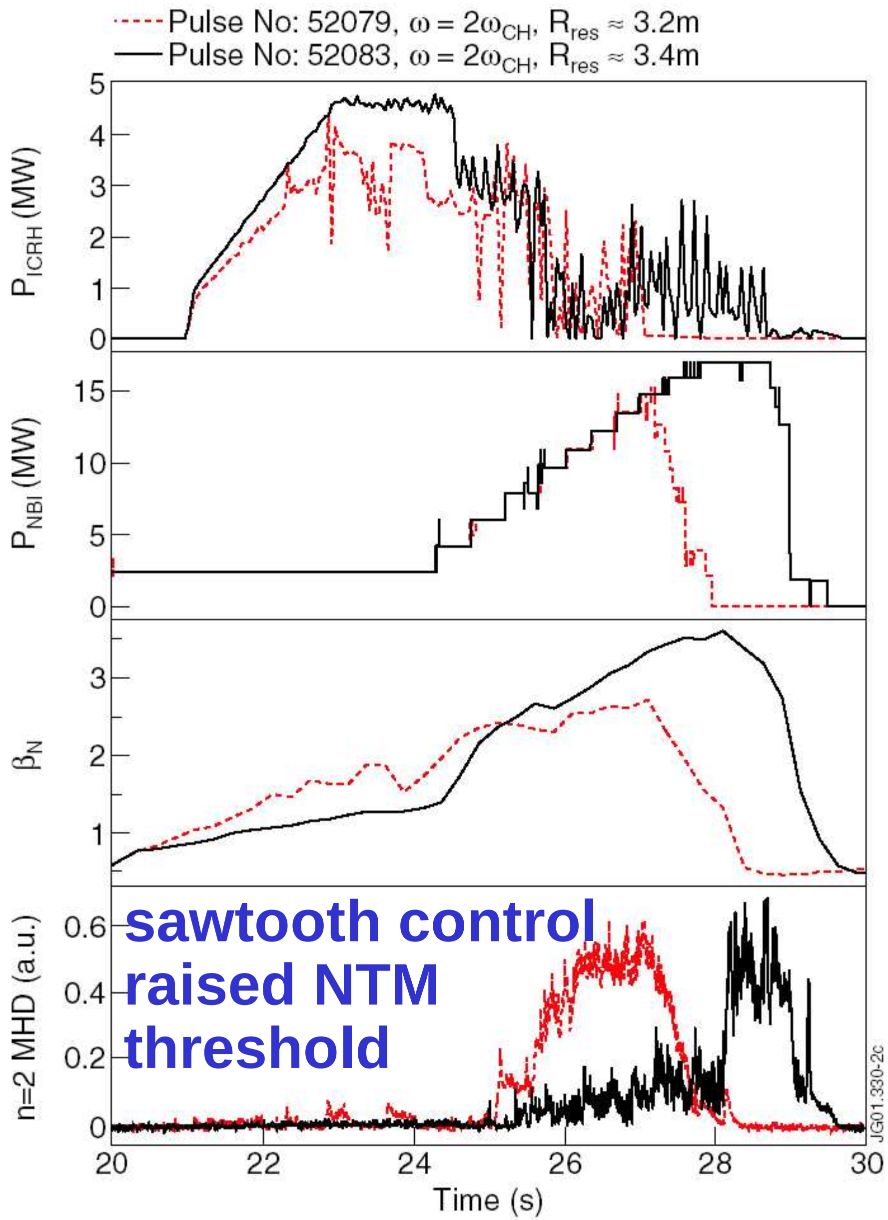



- Exploits metastable nature of NTM
  - – first sawtooth often the worst
- Recovery to higher β and neutron rate after **3/2 NTM**
- Disruption prevention after **2/1 NTM**

# ICCD: diversify sawtooth control

- Take LFS 2nd harm H result, and move further off axis:




[Mantsinen, PPCF, 44 1521]

# NTM control with ICCD

- Strike mode with ‘standard NTM recipe’
- Apply $B_{\Phi}$ ramps to move the ICRH deposition over the NTM
- Vary power
- Vary phasing of ICRH
  - dipole and -90° degrees

# Effect of local ICRF on 3/2 NTM

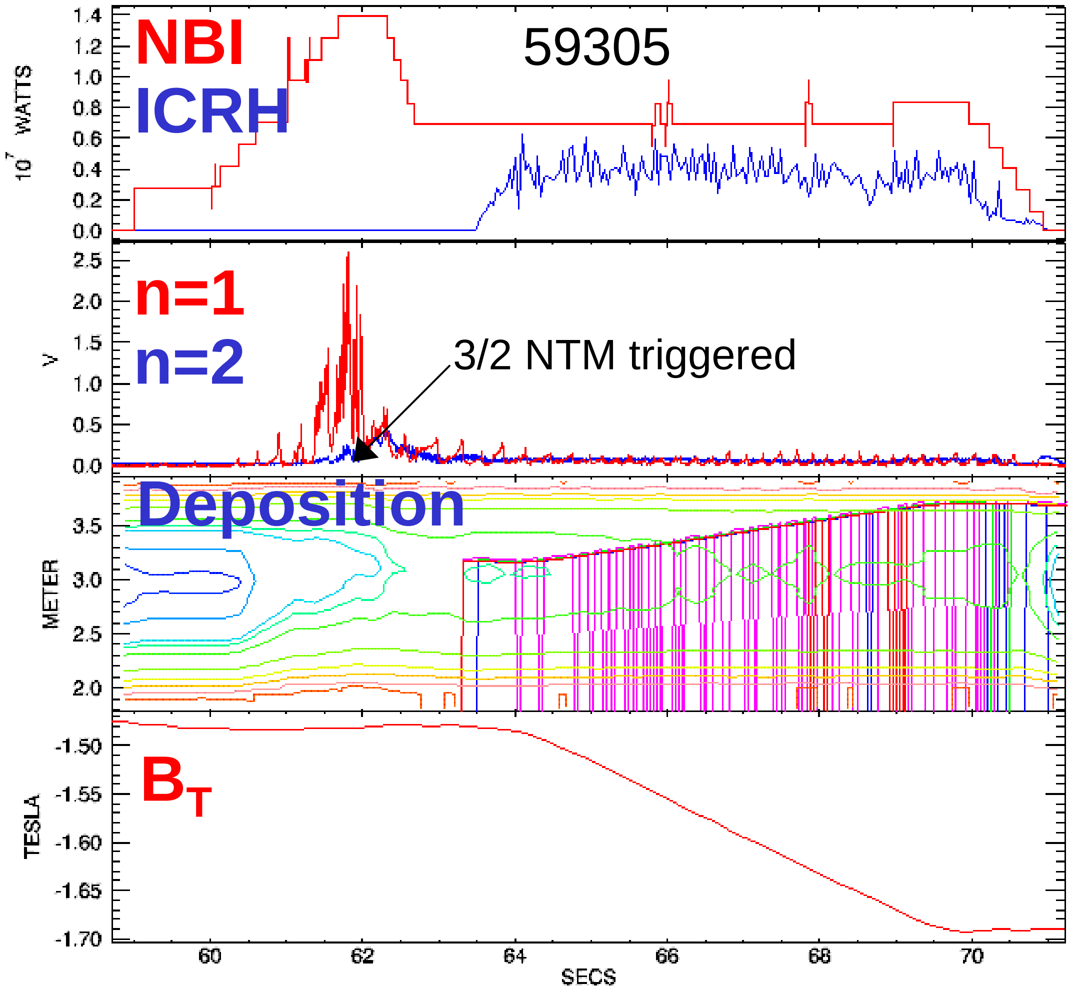
- Rutherford equation for island growth

$$\frac{dw}{dt} = 1.22\eta\left[\Delta' + a_1 \varepsilon^{1/2} \beta_p f(w) + c_1 j_{1,ICCD} + c_2 \eta_{1,ICRH} j_0\right]$$

- thus, three ways in which the NTM is affected
  - affect Δ’: local current profile changes directly through ICCD or indirectly through ICH
  - create $j_{1,ICCD}$ by local ICCD inside the island
  - create $\eta_{1,ICH}$ though the local heating of the island
- we expect relatively broad (15-20 cm) RF deposition profile, so Δ’ effects may dominate

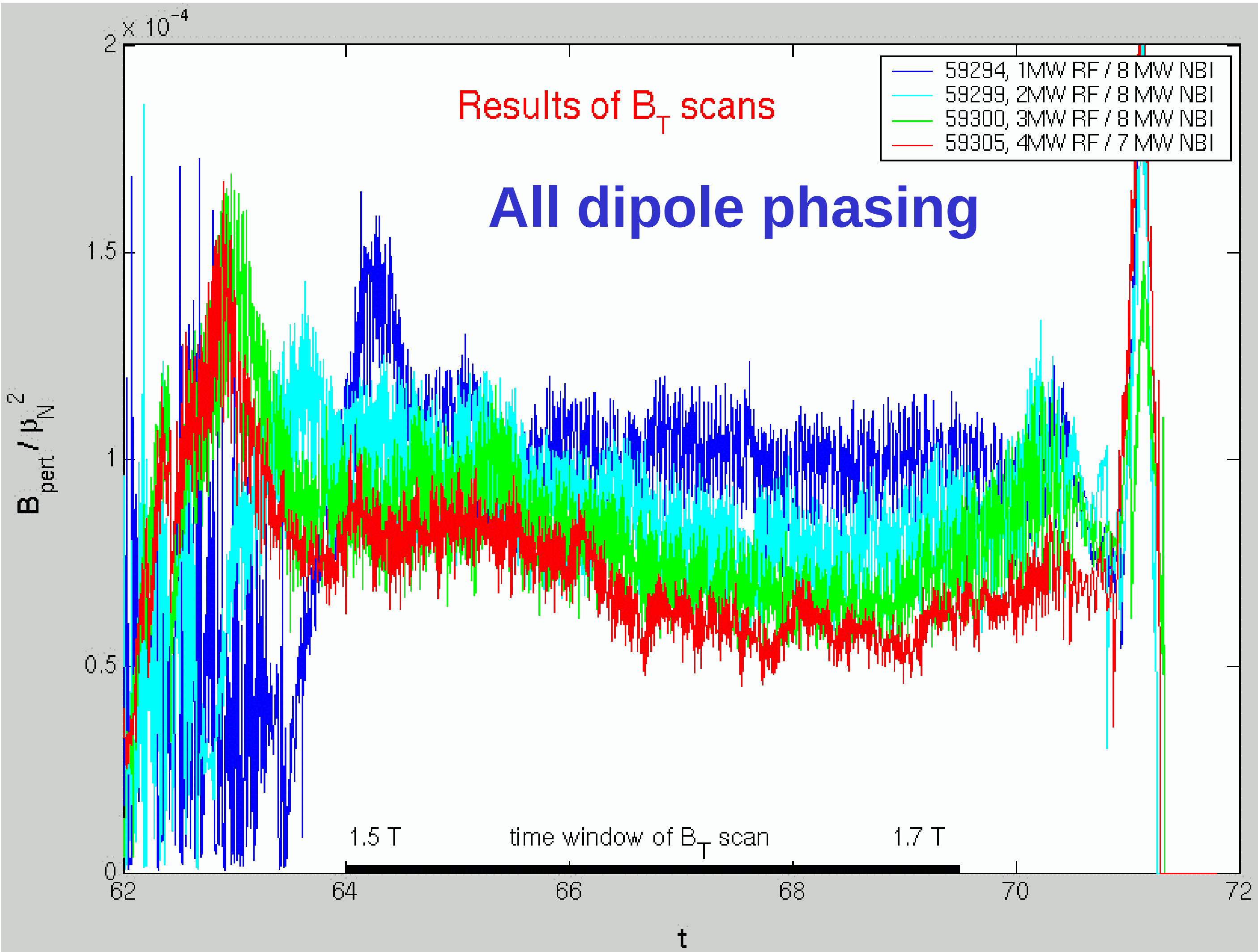
# Type I pulse shape

q = 3/2 expected near R = 3.6 m

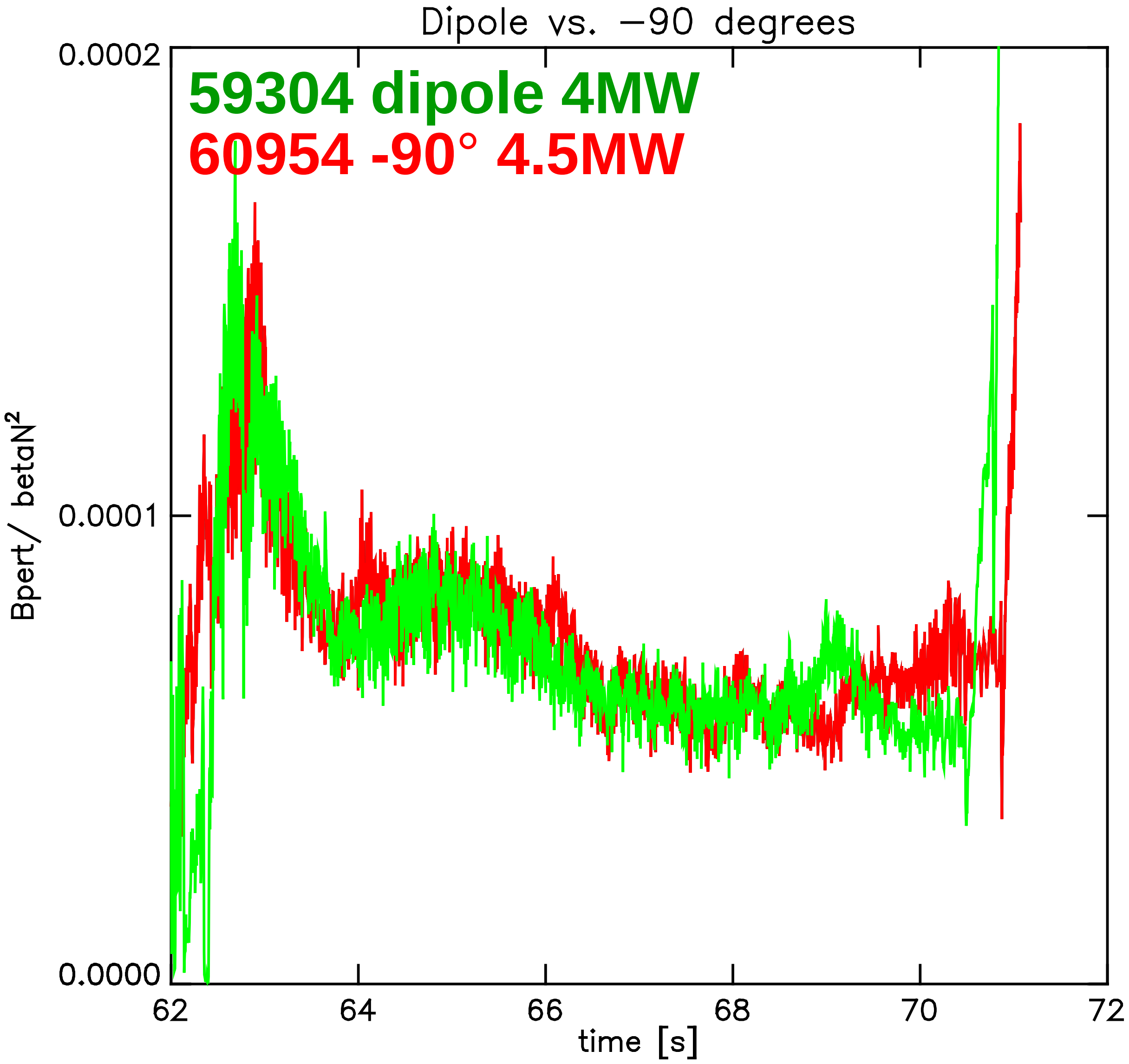



- by ramping $B_T$ = 1.48-1.69 T the 42.3 MHz 2$^{nd}$ H resonance is scanned from R = 3.17 to 3.70 m

# $B_T$ scans with 1,2,3,4 MW ICCD

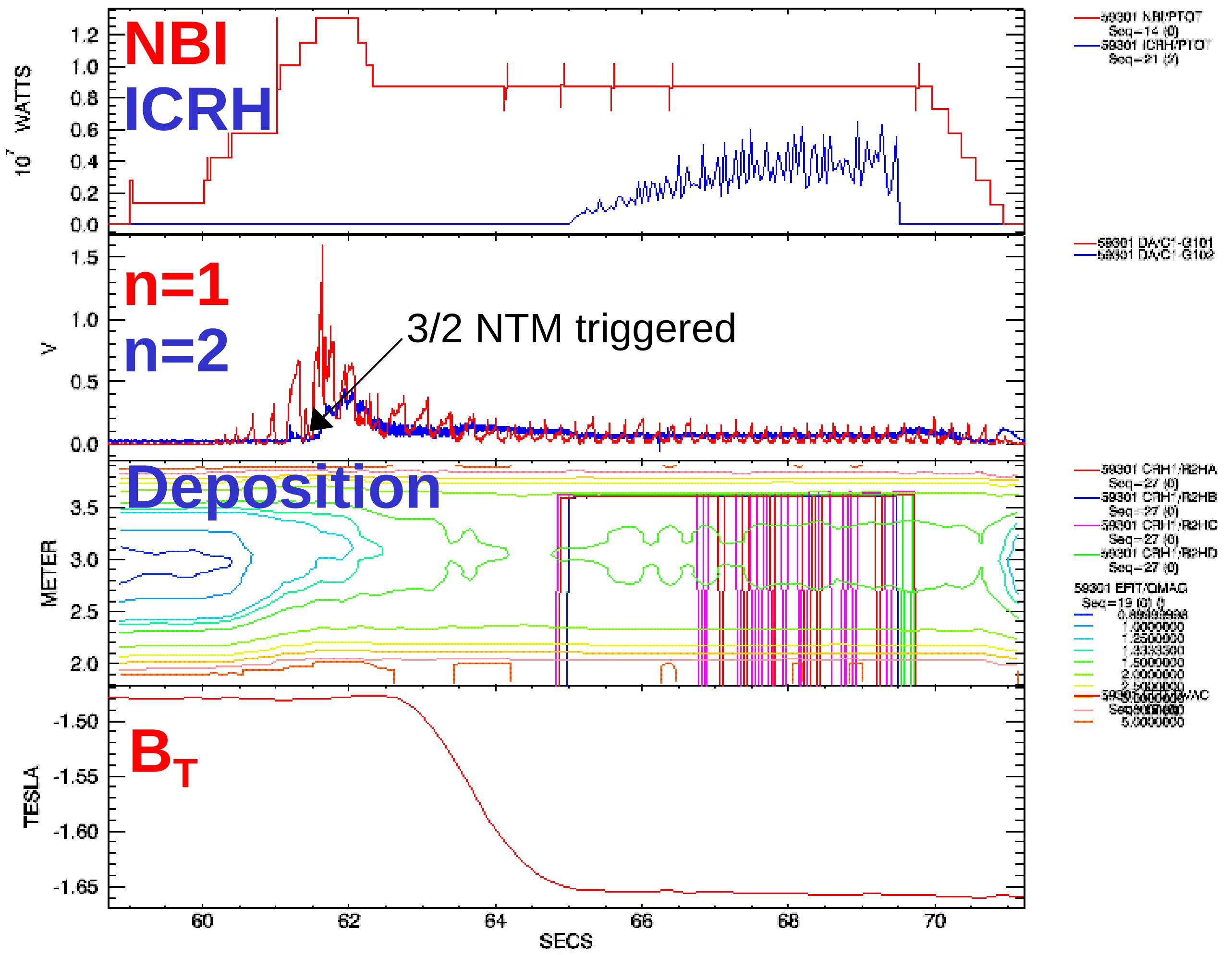


# Same effect with dipole & -90° phasing

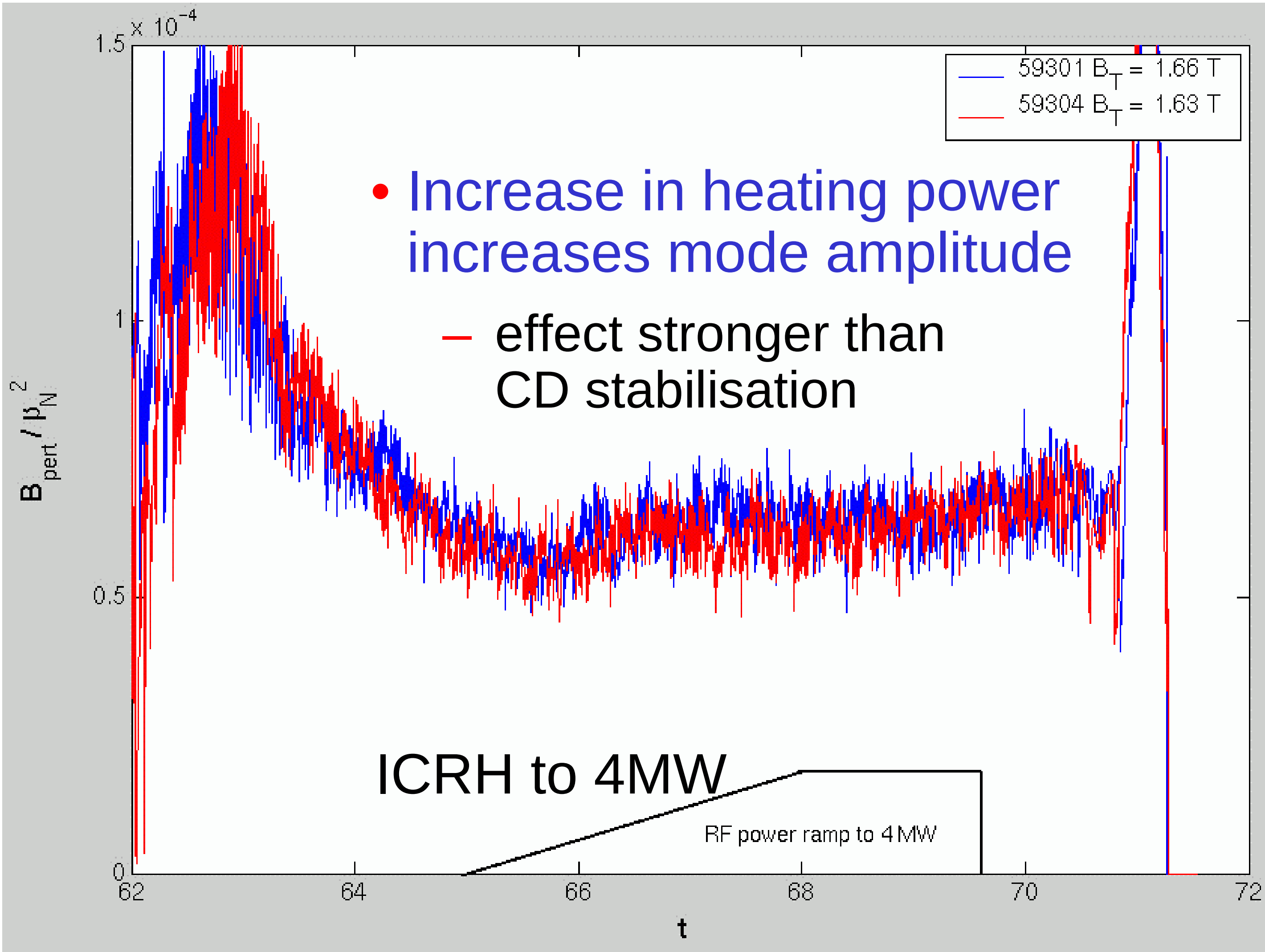



Scans extended in -90° to cover full width of mode

# Type II pulse: fixed $B_T$



# Results with fixed $B_T$

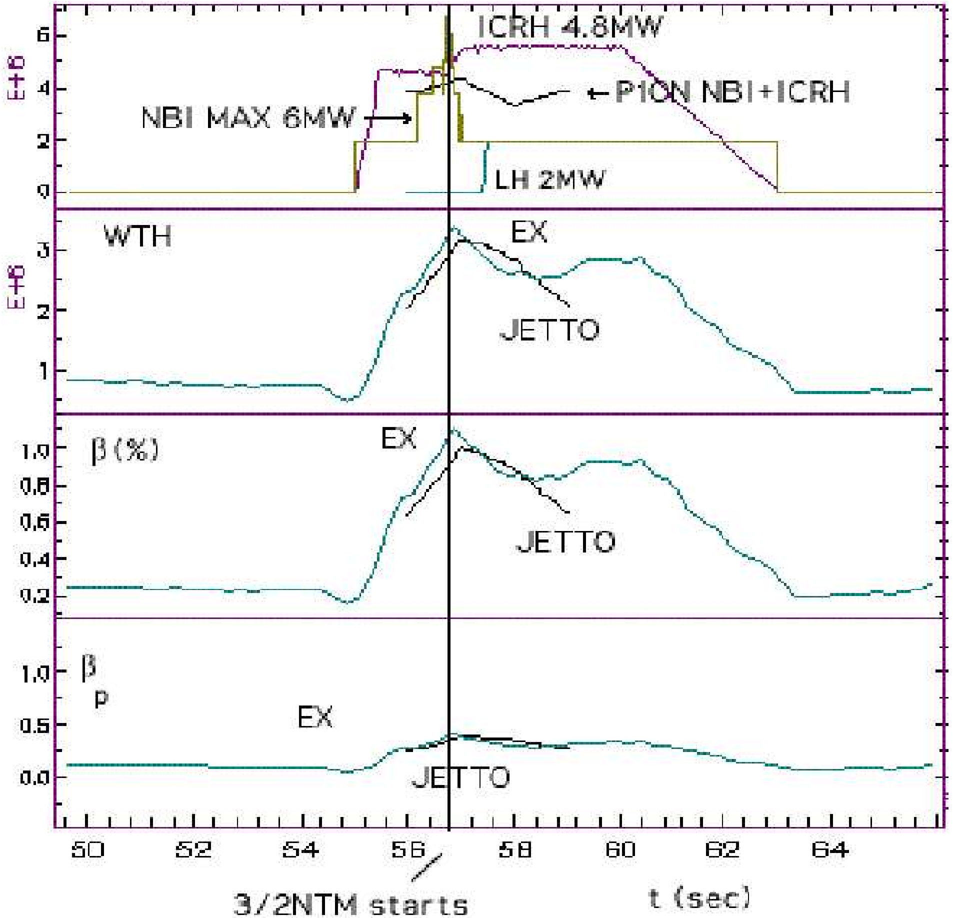


# Conclusions

- $B_\phi$ ramps carried out
- Dipole and -90° phasing
  - Up to 1.7 T in dipole
  - Up to 1.75 T in -90°
- 3 power levels
- Modest effect only

# LH first attempt: high field reference

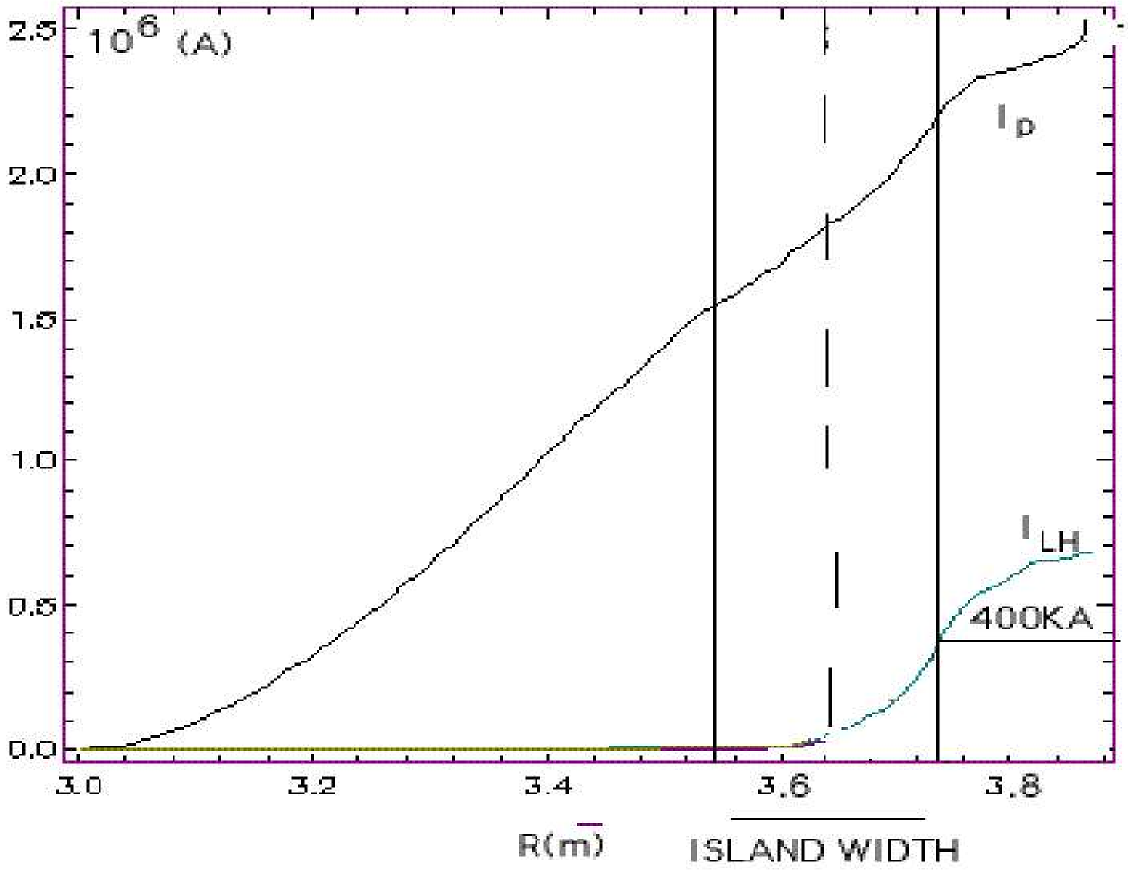
## The reference discharge : #51805




- Ip=2.51MA
- B=2.5T
- <ne> =2.9 10 $^{20}$ m$^{-3}$
- At t=56.8 sec the mode starts
- Full traces are experimental data
- Traces between t= 56 sec and t= 59 sec are from JETTO interpretative run. LH tarts at t=57.5sec.

# Modelling shows worth a try

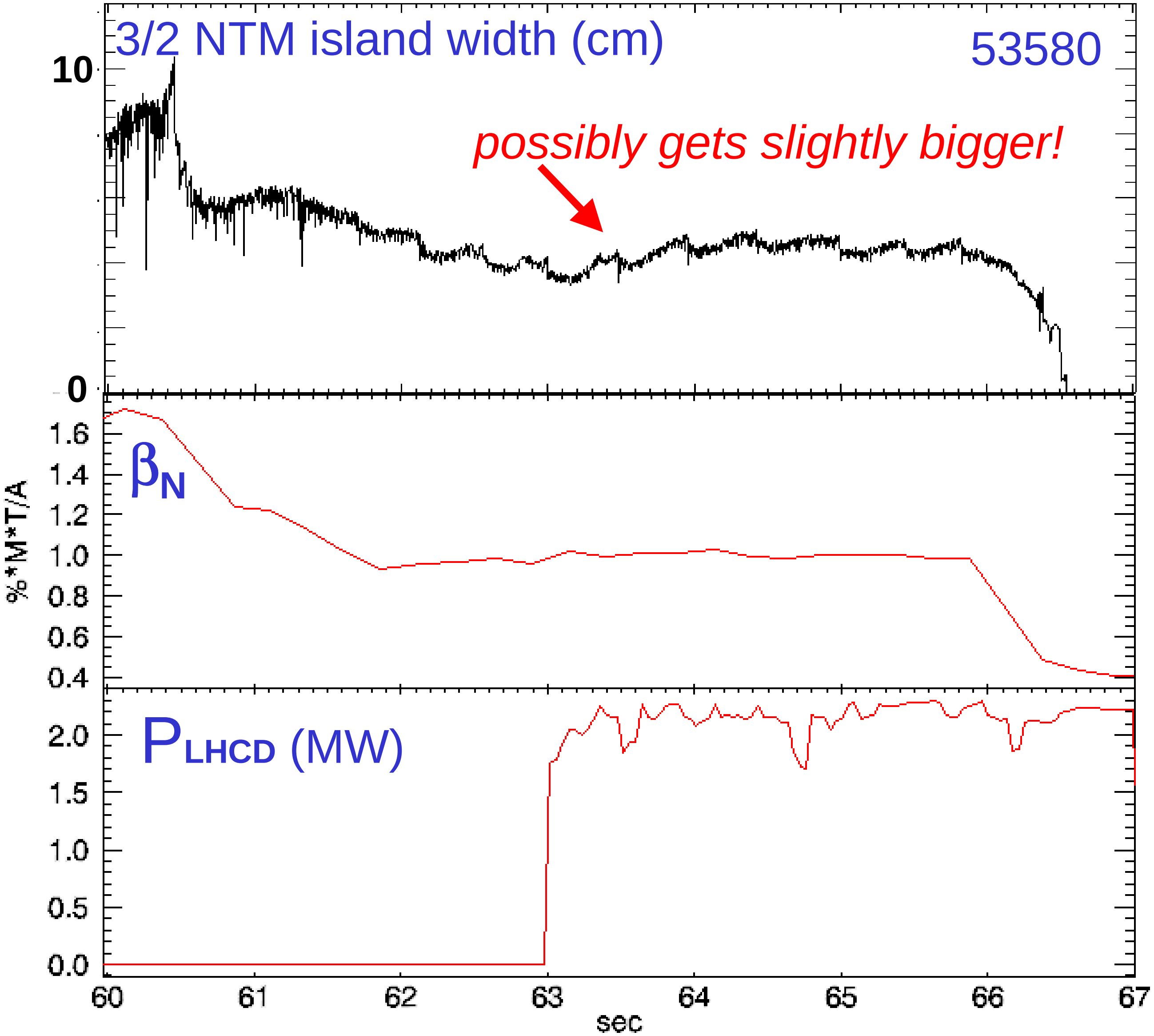
## 400kA are driven by 2MW of LHCD inside the island width




- The driven current inside the island is 15% of the total plasma current

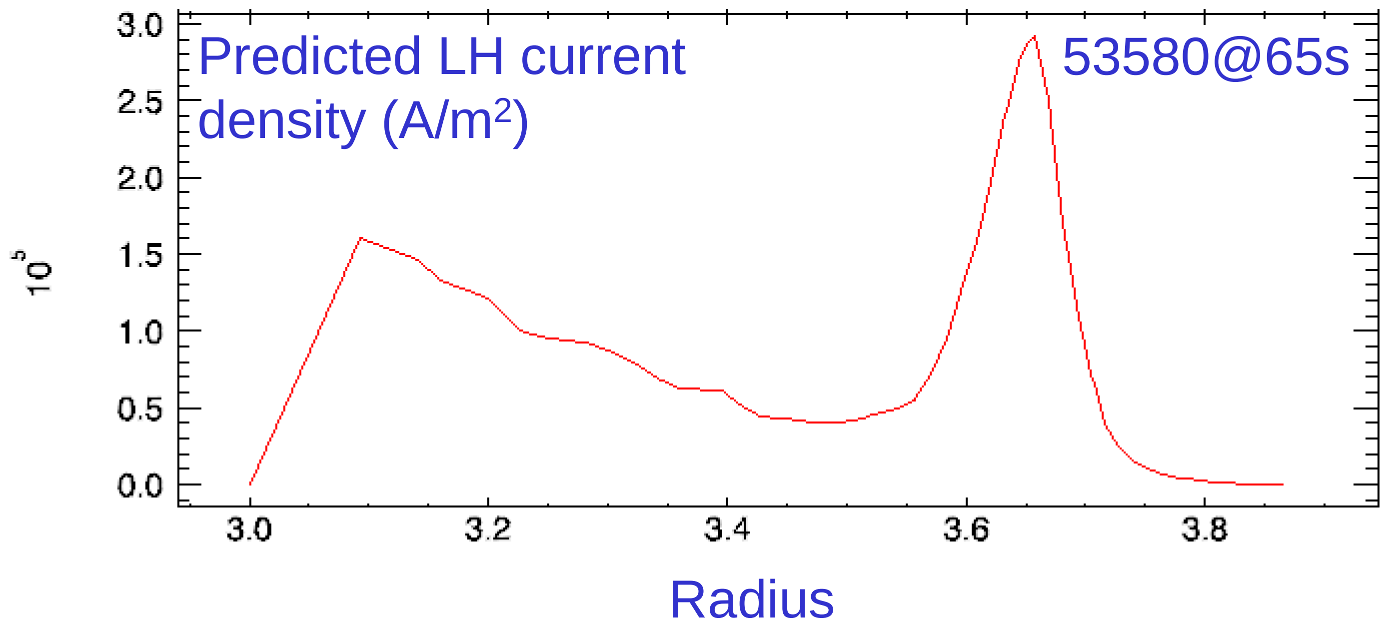
- Some uncertainties and variations expected from plasma profiles, etc.

# Good LH but no clear effect on mode



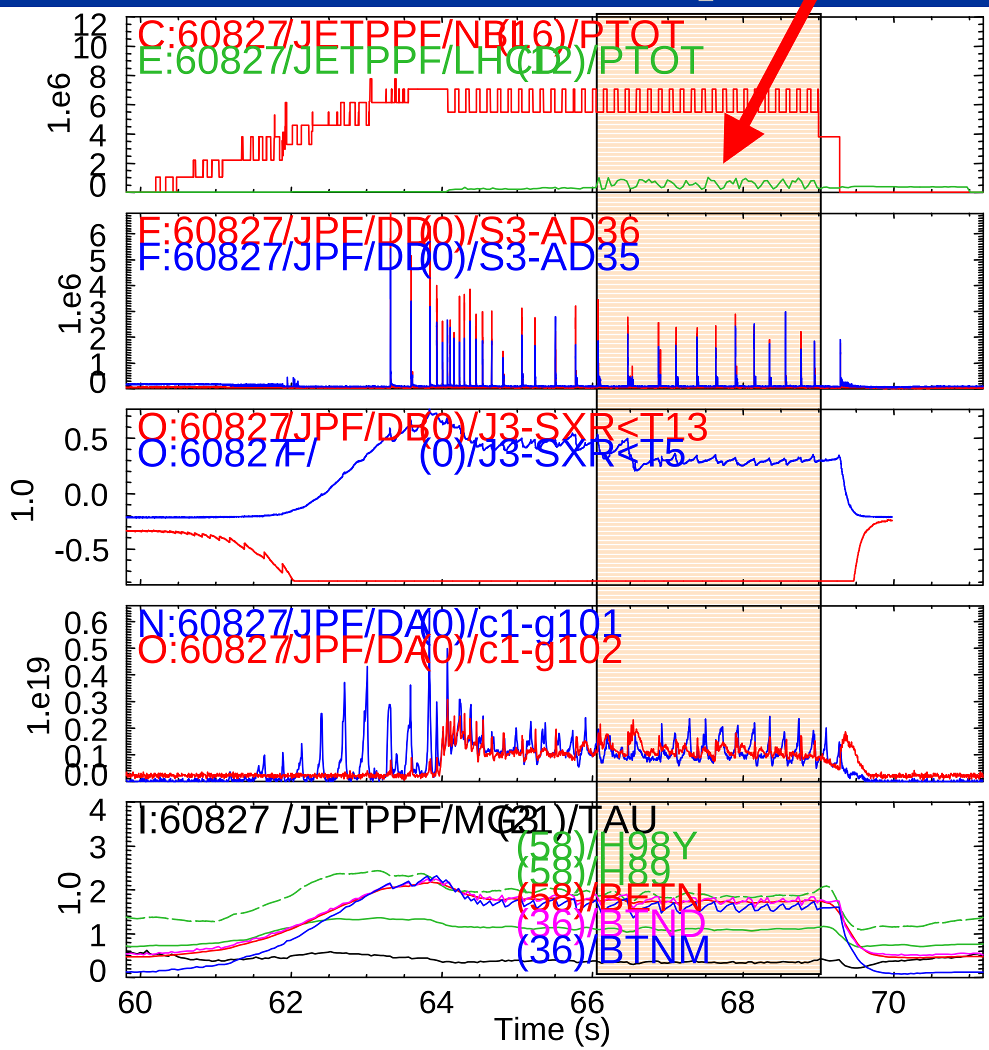
# LH deposition too far out for 3/2

- Modelled current drive based on actual shot run:



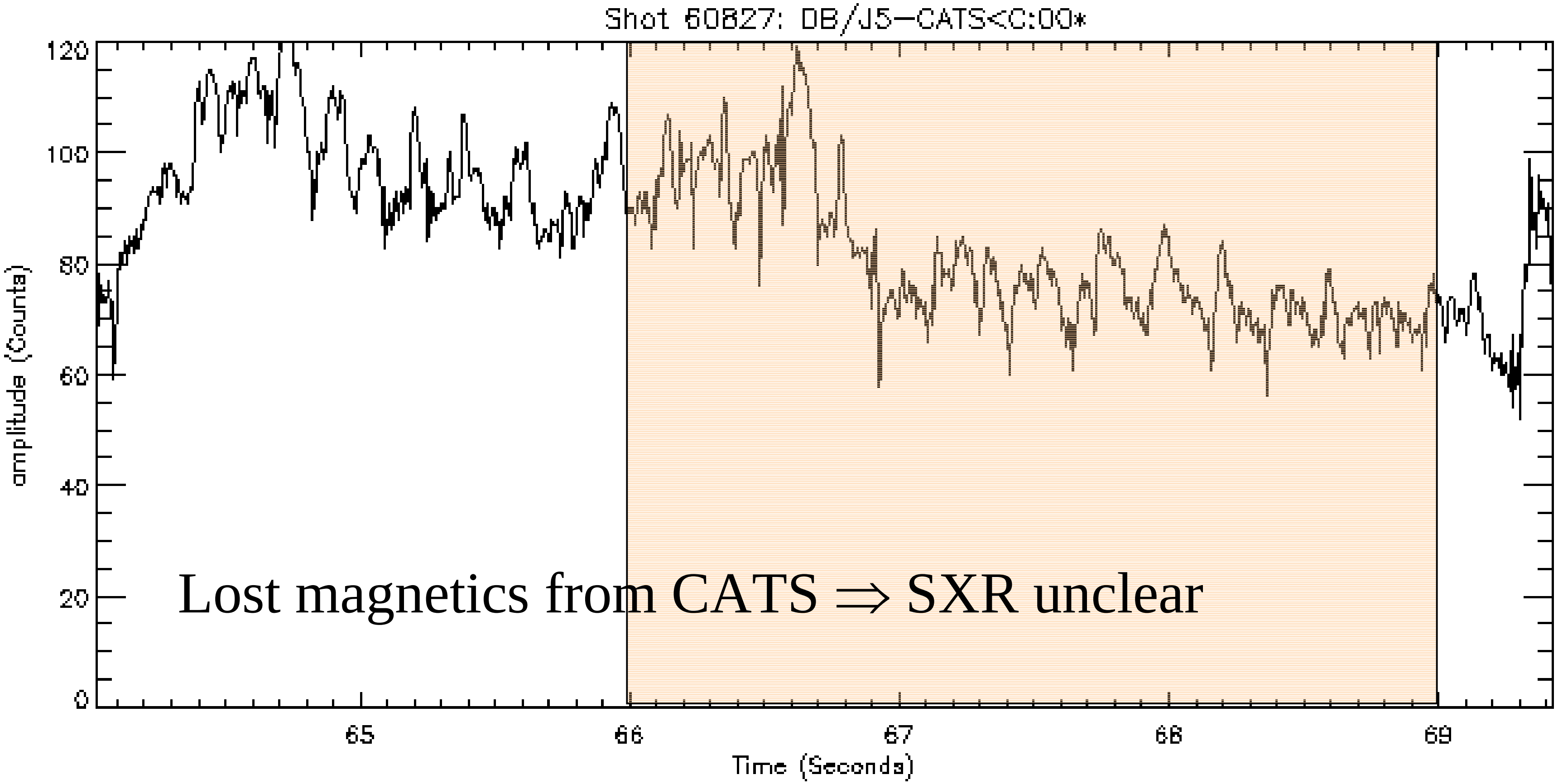

- More suitable for 2/1 mode, but hard to trigger at 2.7MA
  - due to high Ip and low $\beta$

# At 1.65T 1.65MA LH poor coupling




- Bt=1.65T, Ip=1.65MA ⇒ coupling poor (1 / 2.5 MW),
- large ELMs ⇒ trips LHCD ⇒ improvable by power adjustment

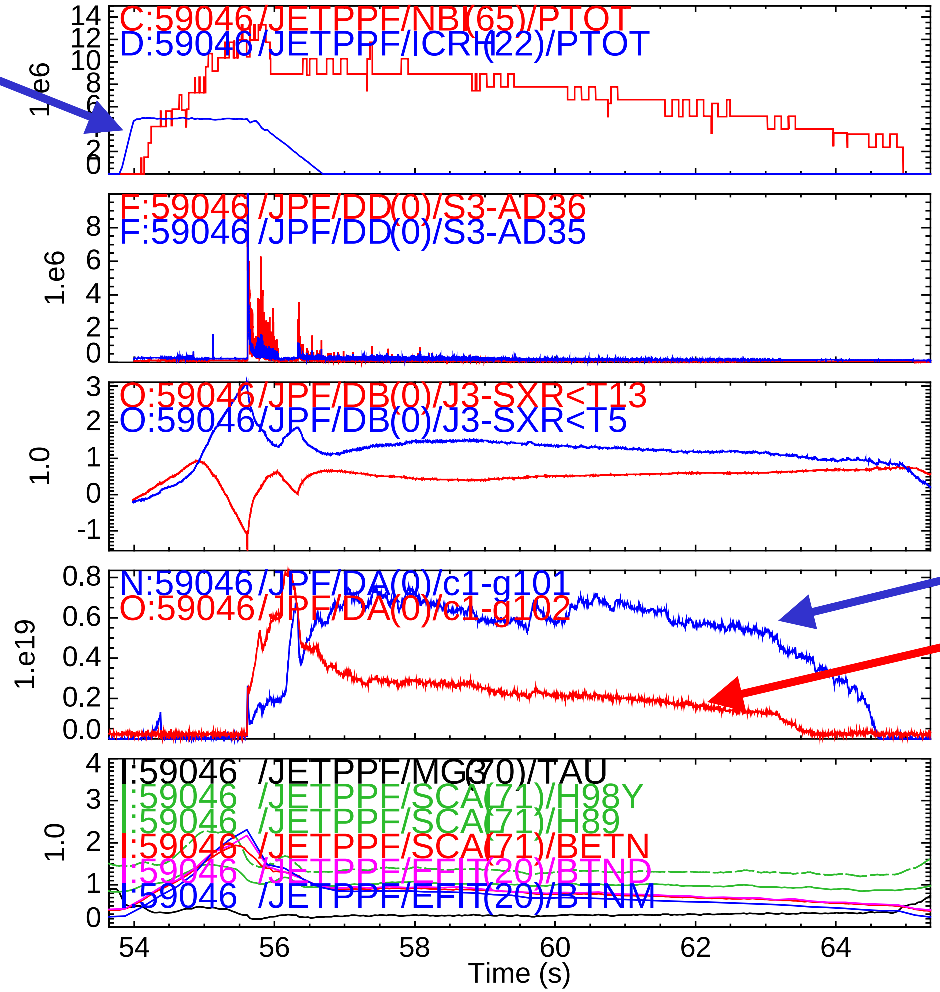
# 1.65T scenario LH little benefit




- ***BUT*** LHCD analysis shows edge density too high in this scenario - LH localised to edge of plasma

# New 2MA target more promising

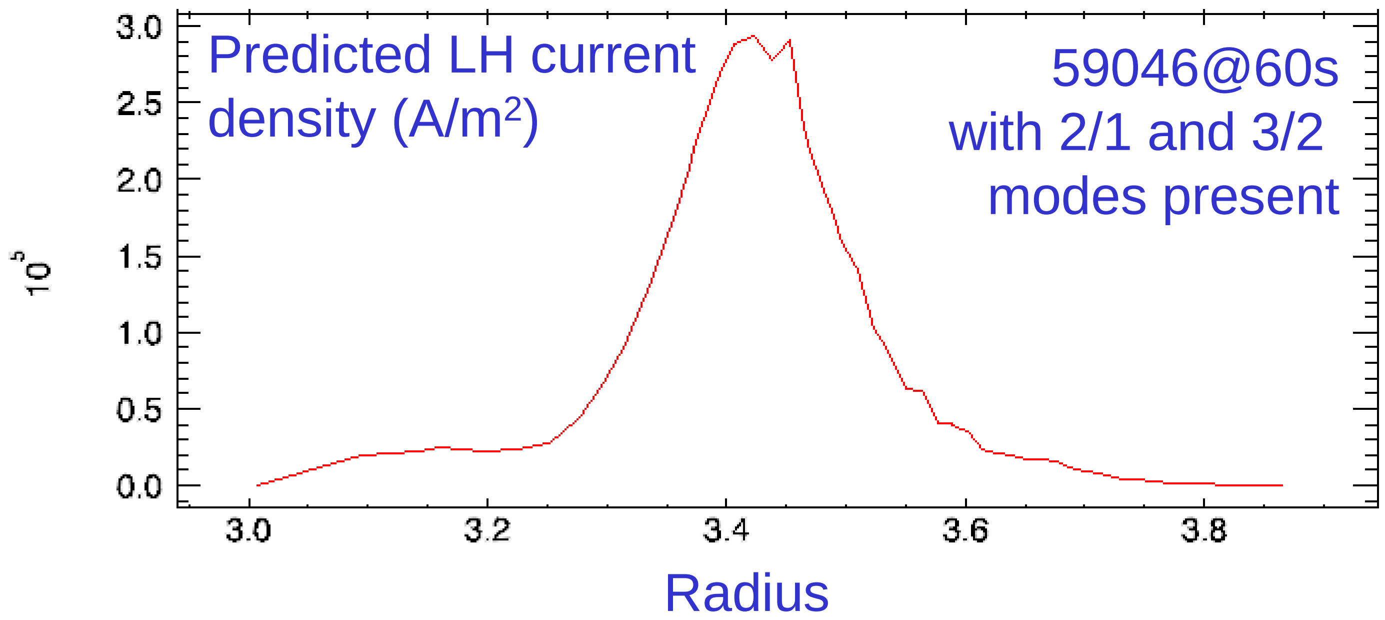
**Use ICRH to help trigger mode**




- Bt = 2.7T, Ip = 2.0MA $\Rightarrow$ coupling ok
- Both (3/2) and (2/1) are possible in this scenario

# New 2MA target more promising

- Modelled current drive penetrates nicely:




- Scope to move further out
  - increased $n_{||}$
  - more gas puff
  - change modes (no 2/1 less $\rightarrow$ pump out)

# Conclusions

- Real time power notches can remove modes and recover β > NTM onset β
- ICCD 3/2 NTM stabilisation now had good attempt
  - very modest effect seen in deposition sweeps
  - outweighed by rise in amplitude due to extra heating
  - dipole and -90 phasing had same effect

  →ICRH not an effective technique for NTM control on JET
- LHCD NTM stabilisation has potential
  - very efficient current drive
  - deposition location is the key - so far not got the right location
  - promising new scenario identified