LONG-PULSE OPERATION OF THE NEW 800 kW, 140 GHz GYROTRON ON TEXTOR

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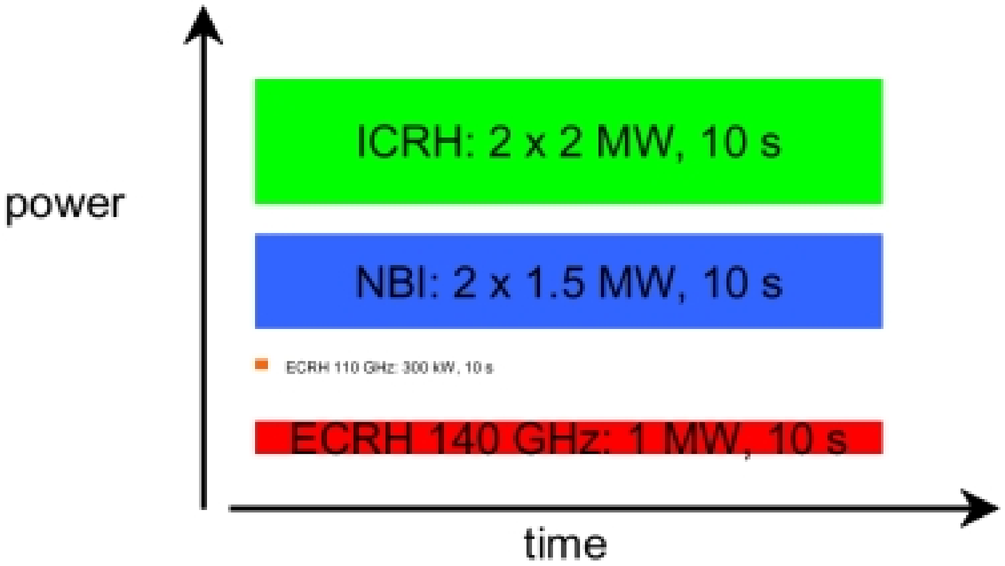
CONTENTS

- Progress towards high power (1 MW) long pulse length (10 s) ECRH/ECCD
  - New 140 GHz Gycom gyrotron
  - Launcher and windows
  - Transmission line
- Physics studies with high power, localised ECRH/ECCD
  - Confinement and transport
  - Control of sawtooth oscillations
  - Control of tearing modes

The new 140 GHz gyrotron

- Full CW design (limited only by power supply)
  - CVD diamond window
  - design values: 800 kW, > 3 s
- brings ECRH on TEXTOR at comparable power and pulse length as NBI and ICRH



  - achieved on stone dummy load: 670 kW, 10 s
  - achieved on plasma: 800 kW, 2.7 s (limited by arcing)

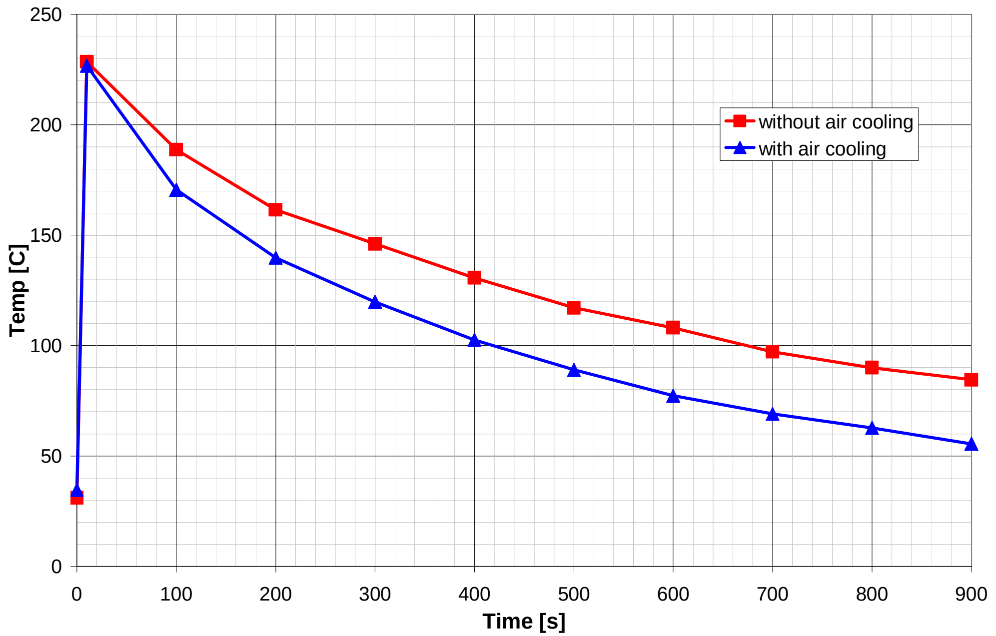
Critical components: the launcher

- Increased surface losses (3%) on old stainless steel mirror due to deposition
  - Expected surface T rise for 3 s pulse: 2000 K
  - Solution: copper insert reduces ΔT to 600 K
- Observed bulk temperature rise for 1.5 s: 7 K
  - Surface losses ~0.2%, consistent with a *clean* copper surface

Conclusion:
present launcher does not limit pulse length

Critical components: the TEXTOR vacuum window

- Current window: water free quartz
  - Observed rise in window temperature (1.5 s, 800 kW): 200 K
  - Estimated absorption in window: 1.8%



  - Sets the limits for current operation:
    - maximum pulse length to 3 s
    - Duty cycle 1:500 (a 25 min wait after each 3 s ECRH pulse)

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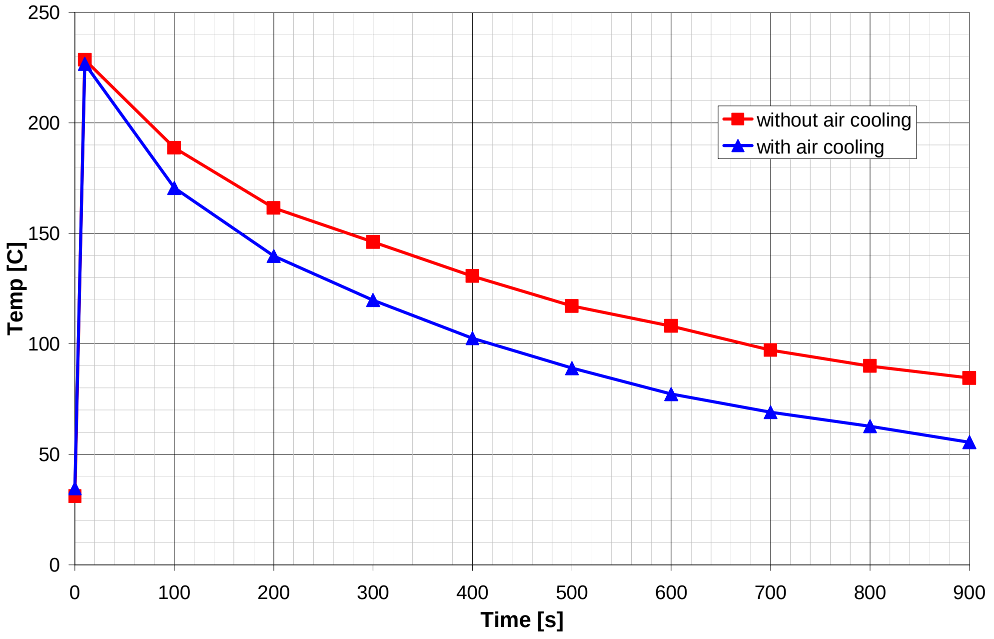
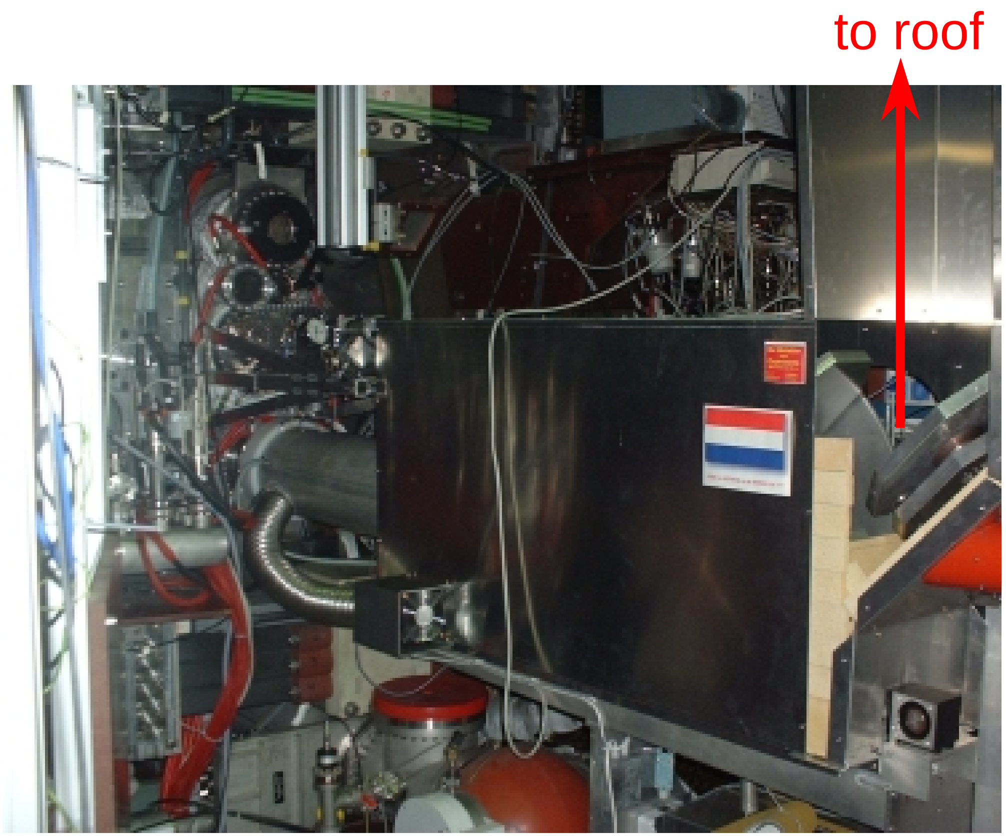


- **Future solution:**

  replacement by edge cooled CVD diamond window

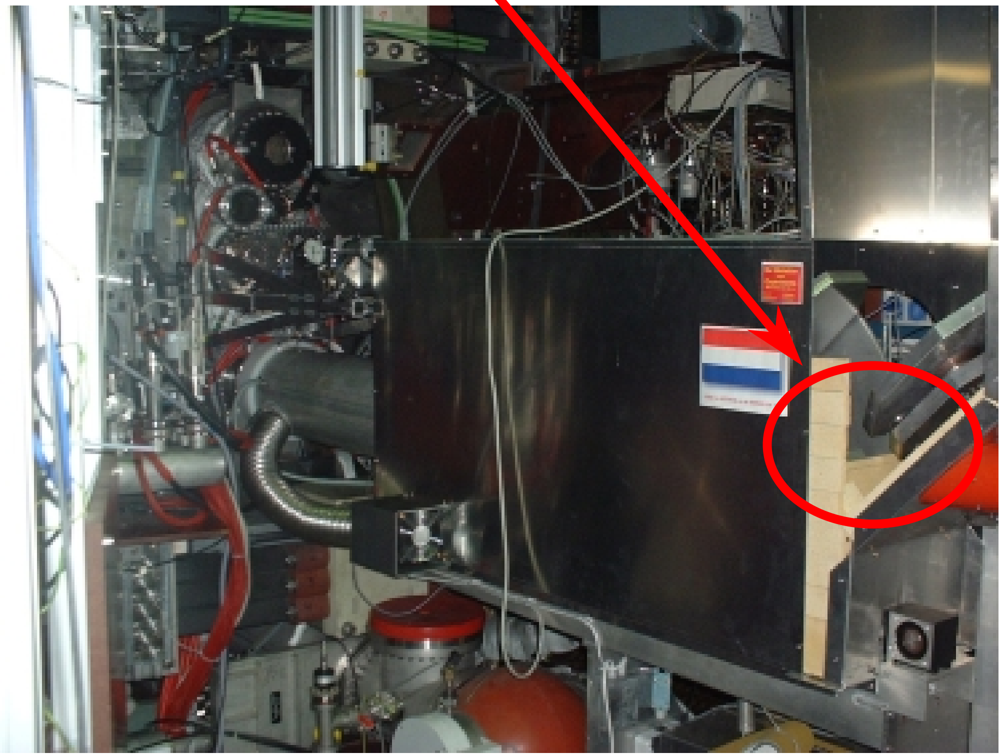
Critical components: quasi-optical transmission line

- Stray radiation from vacuum window reflection
  - produced burn pattern on wooden roof of TEXTOR bunker



Critical components: quasi-optical transmission line

- Stray radiation from vacuum window reflection
  - estimated at 2%
  - cause of arcing in transmission line



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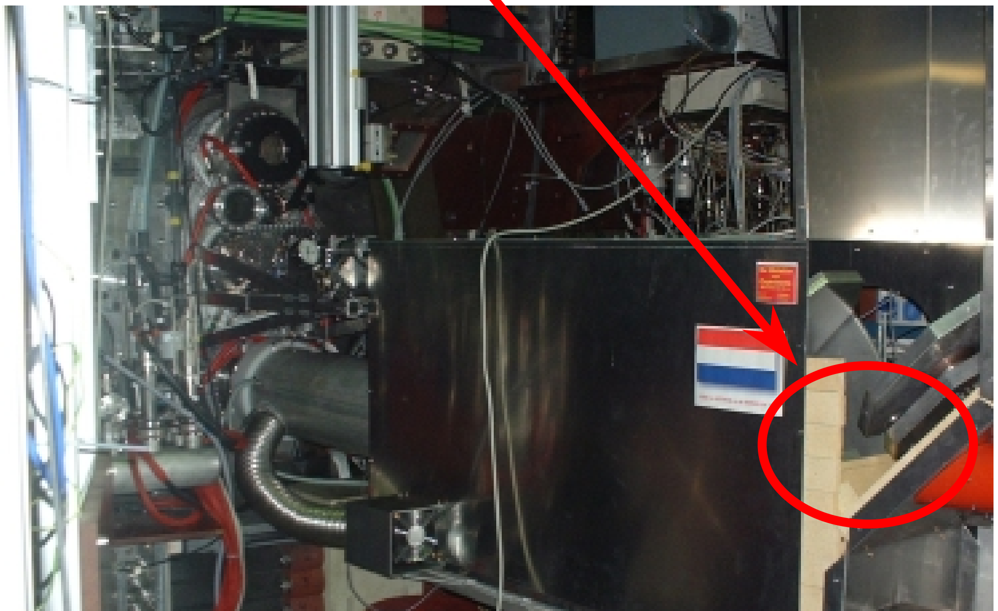
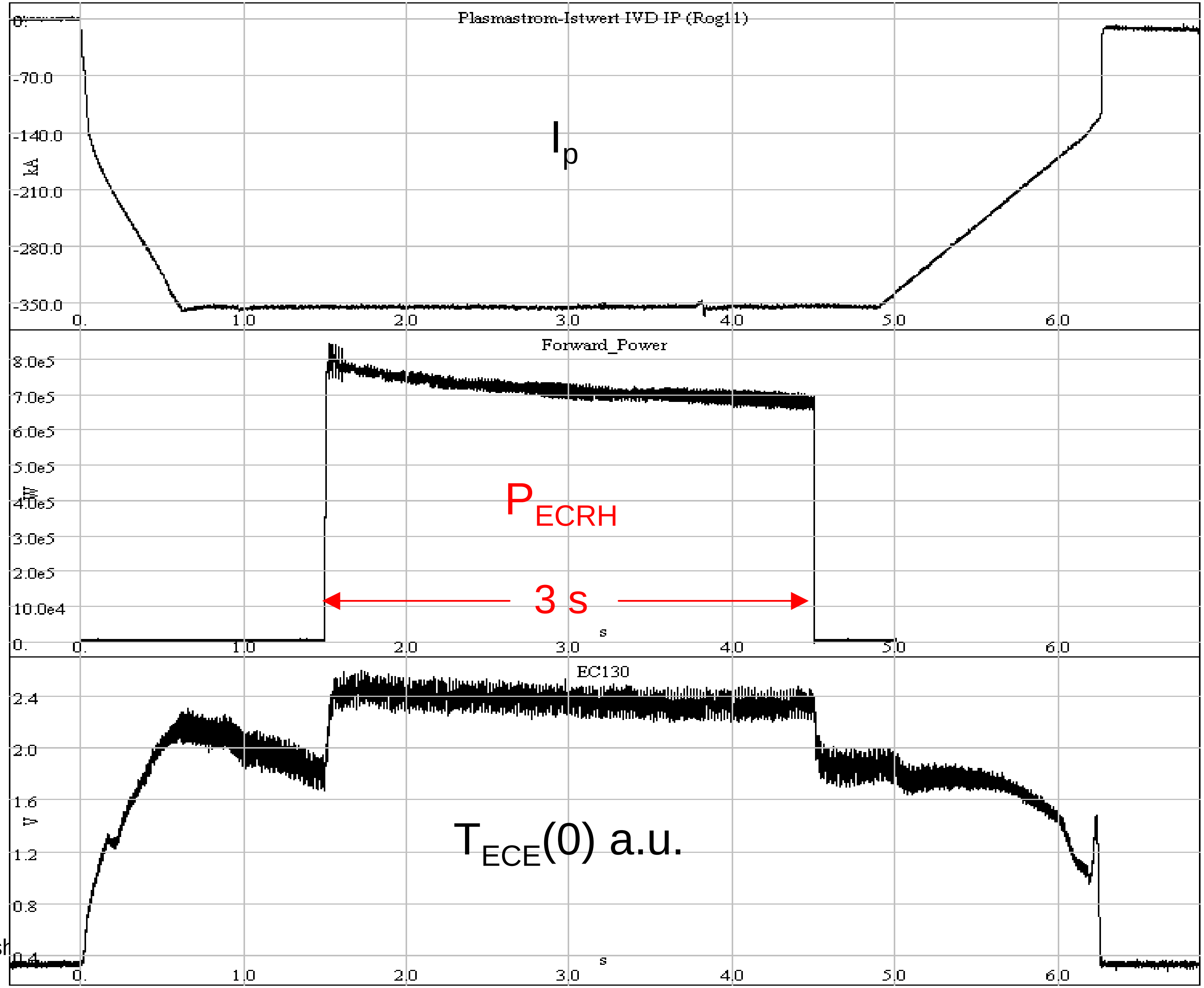


- **Solution** (recently partly implemented):
  - removal of “zoom”
  - absorption of stray radiation by water circulating in teflon hoses
  - later: reduction of stray radiation from new CVD window

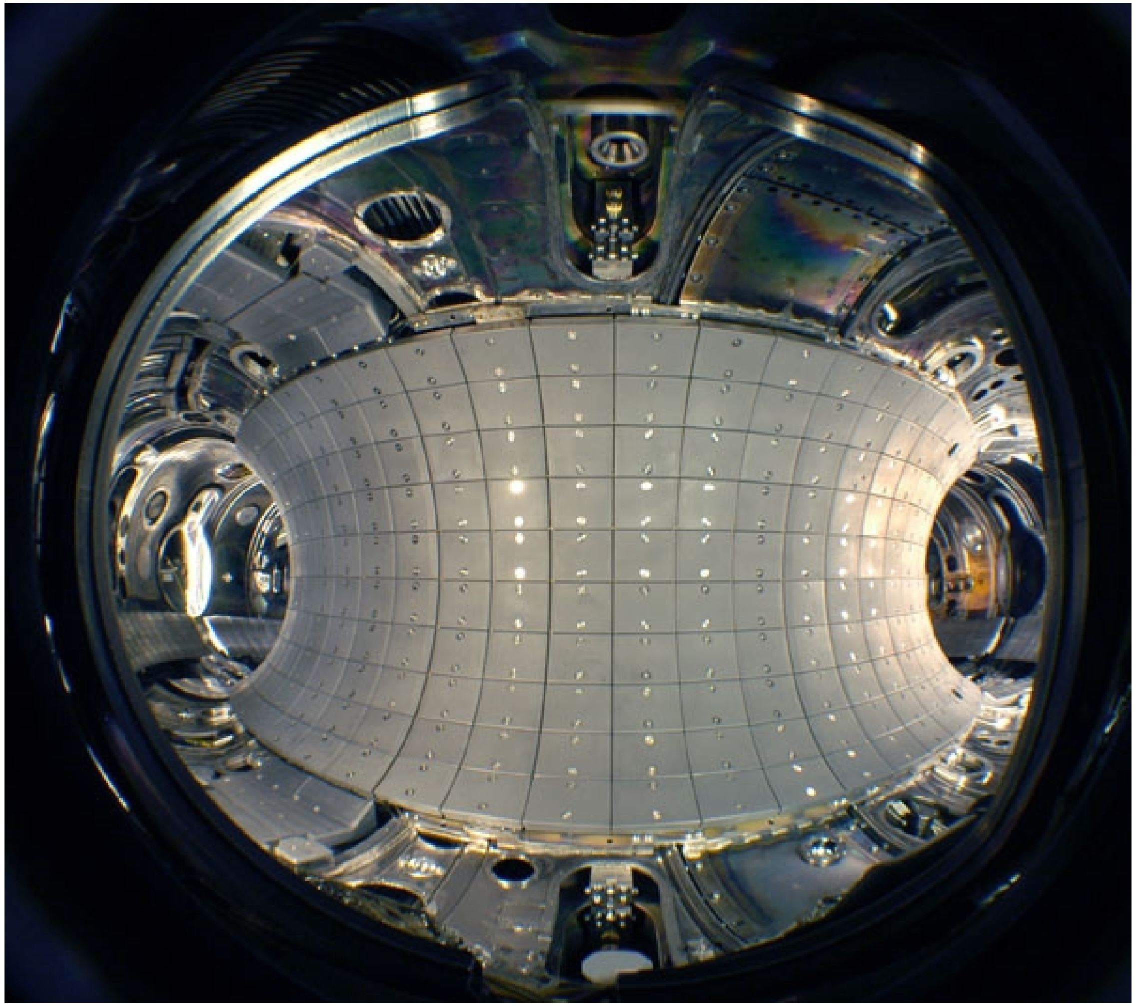
Breaking news: #94929 13 May 2004

3s pulse with closed transmission line



Machine safety issue

- DED coils on high field side of tokamak protected by Carbon tiles on Zyrconium Oxide isolation
  - to be protected from ECRH radiation in case of low absorption
  - ECRH radiation can enter gaps between tiles



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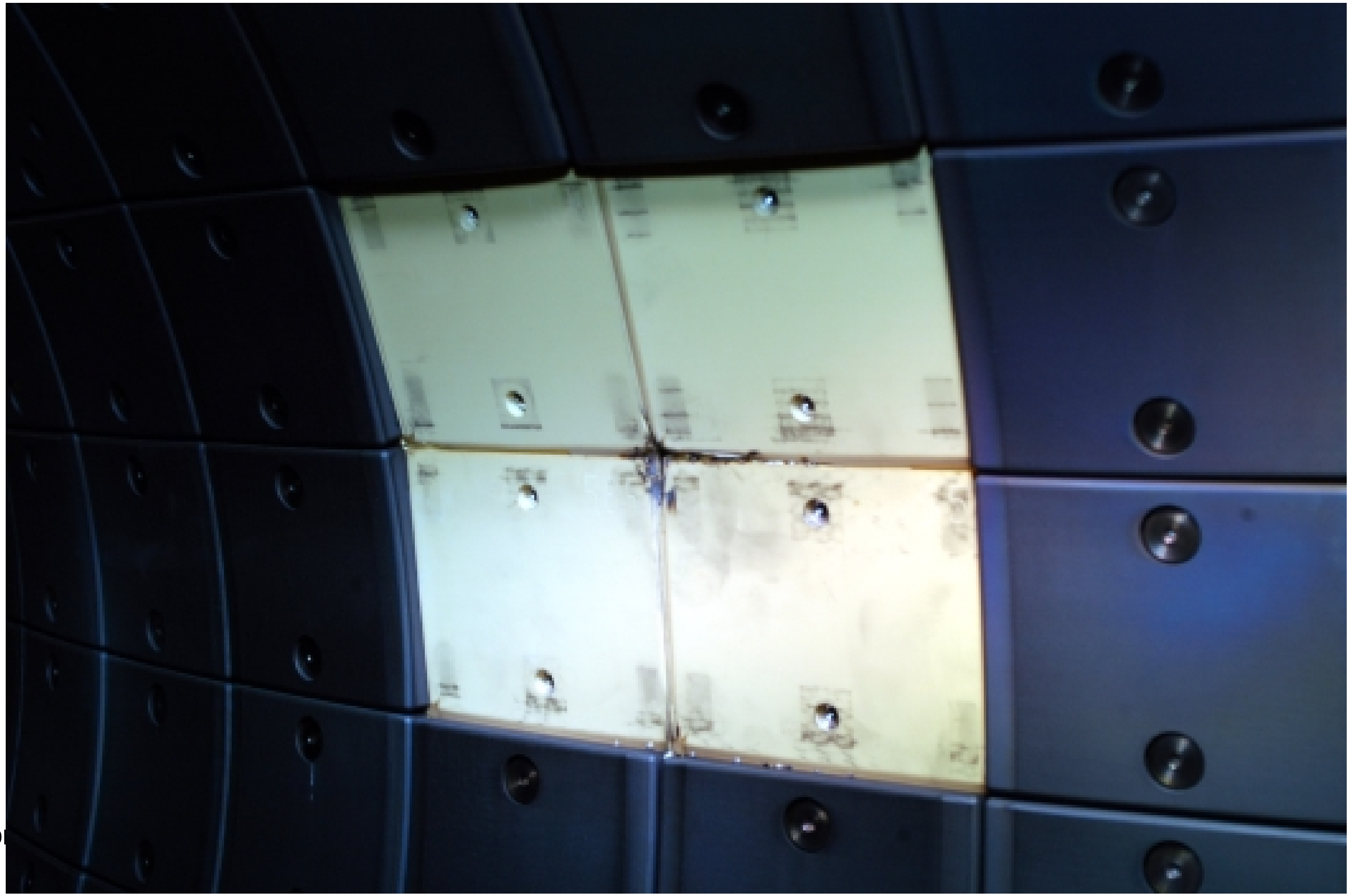
  - Leading to “Zyrconium events”



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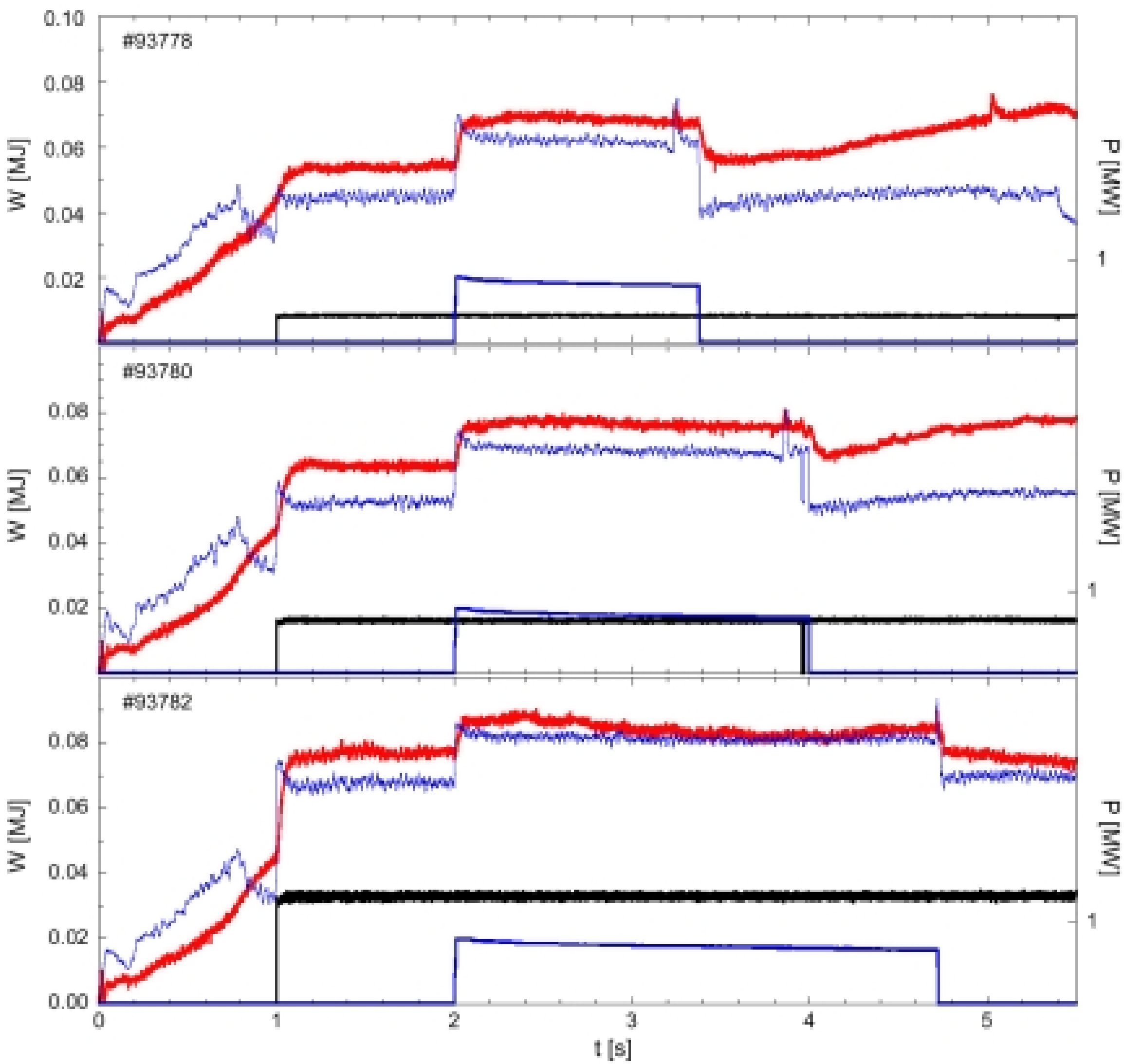
  - to be protected from ECRH radiation in case of low absorption
  - ECRH radiation can enter gaps between tiles: cause arcing
  - Leading to “Zyrconium events”
  - Protective measures:
    “plasma present module”
    “sniffer probe” (2) to measure level of non-absorbed radiation

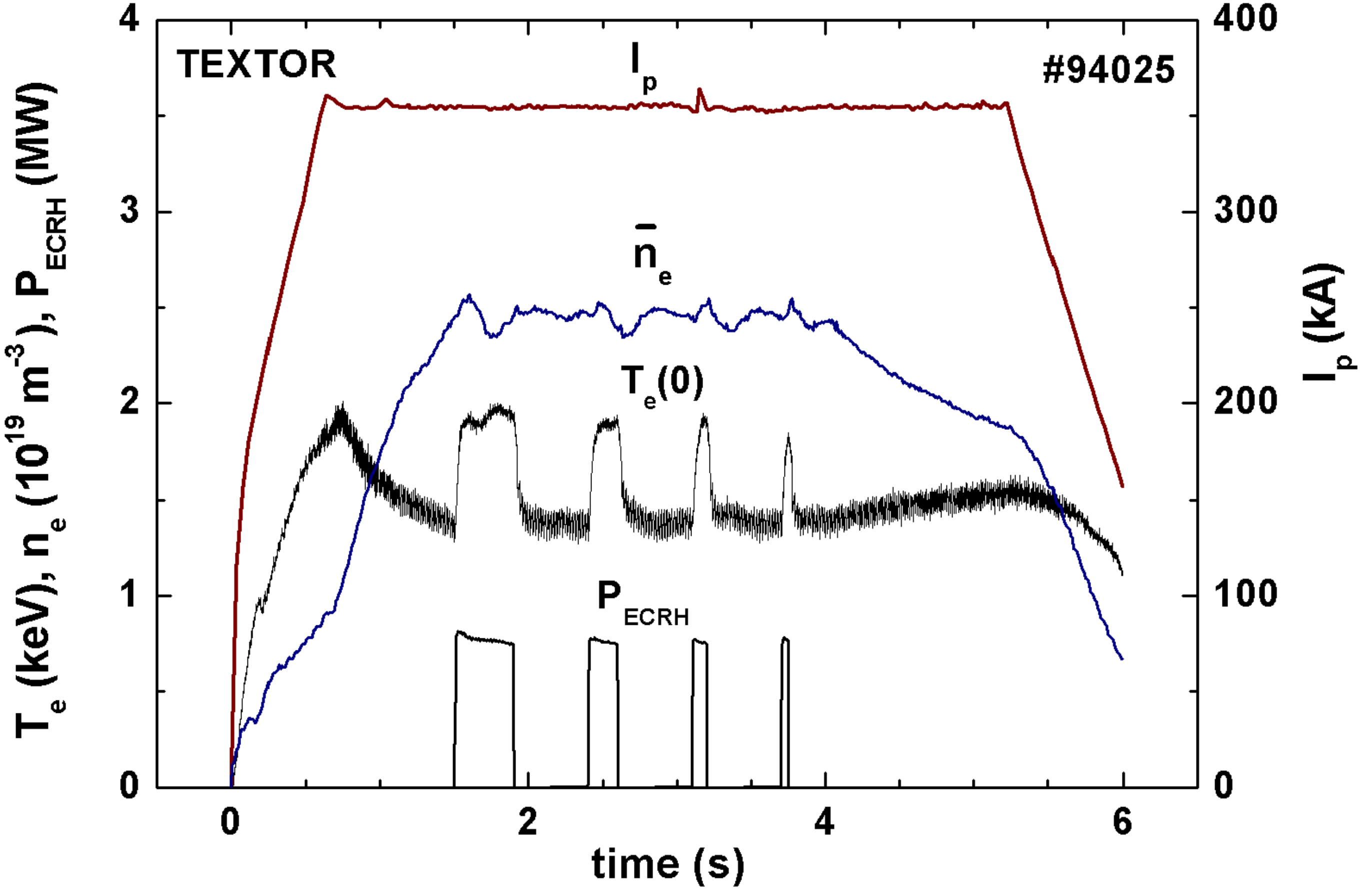
Physics: confinement

- Central ECRH at different NBI powers
  - 2.5 T, 400 kA
- Plotted: W_{dia} P_{NBI} P_{ECRH}
- Close to L-mode scaling
- #93782: 2.7 s ECRH



Physics:Transport barriers

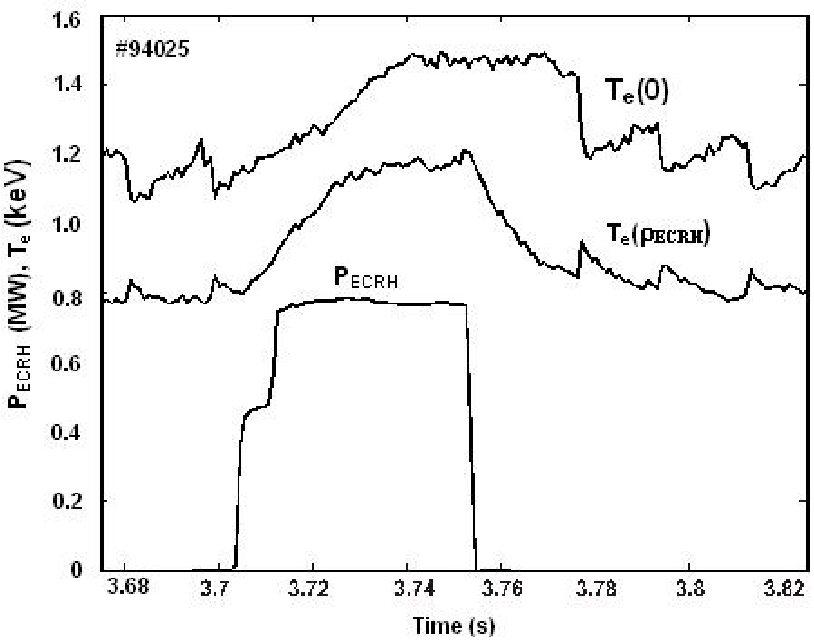
- First observed on T-10: q=1 barrier induced by off-axis ECRH switch-off (see also Poster by M.V. Maslov)
  - signalled by delayed decay of $T_e(0)$
- TEXTOR: test of dependence on ECRH pulse length

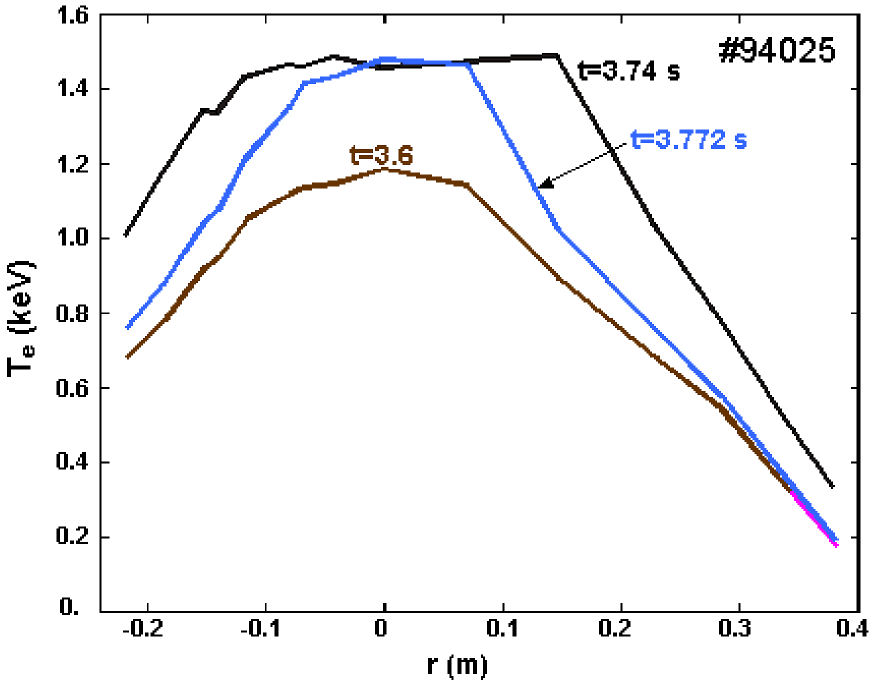


Pulses of 400, 200, 100, 50 ms, with 500 ms between (i.e. a few current diffusion times)

Transport barrier induced by off-axis ECRH switch-off

- Longest delays (up to 23 ms ~ τ_E) observed after the shortest ECRH pulses
  - Effect depends very strongly on r_{dep} relative to $r_{q=1}$

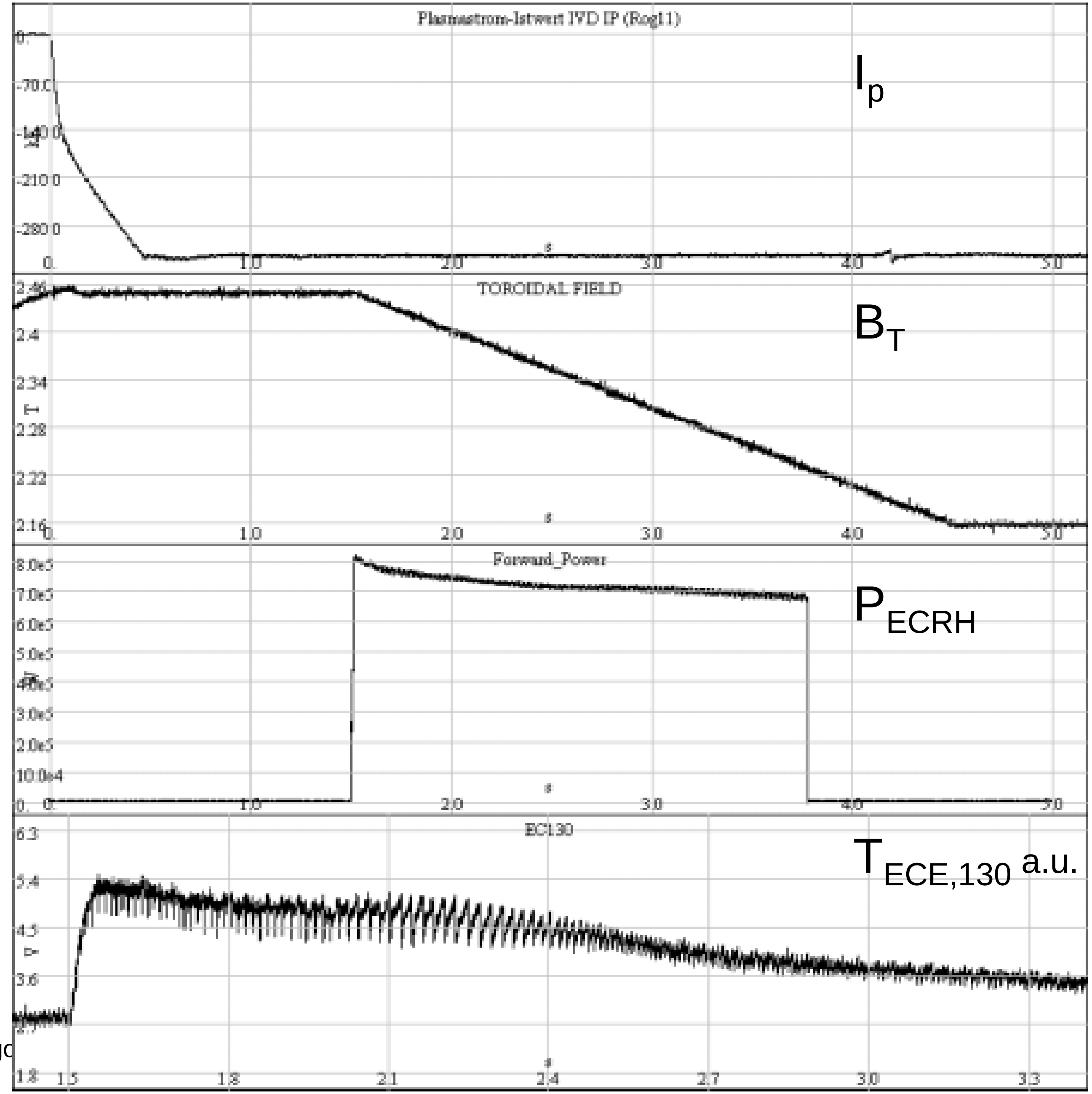




Physics: sawtooth control

- Slow B-field ramp to scan ECR through q=1 surface

- #94175 ECRH



Physics: sawtooth control

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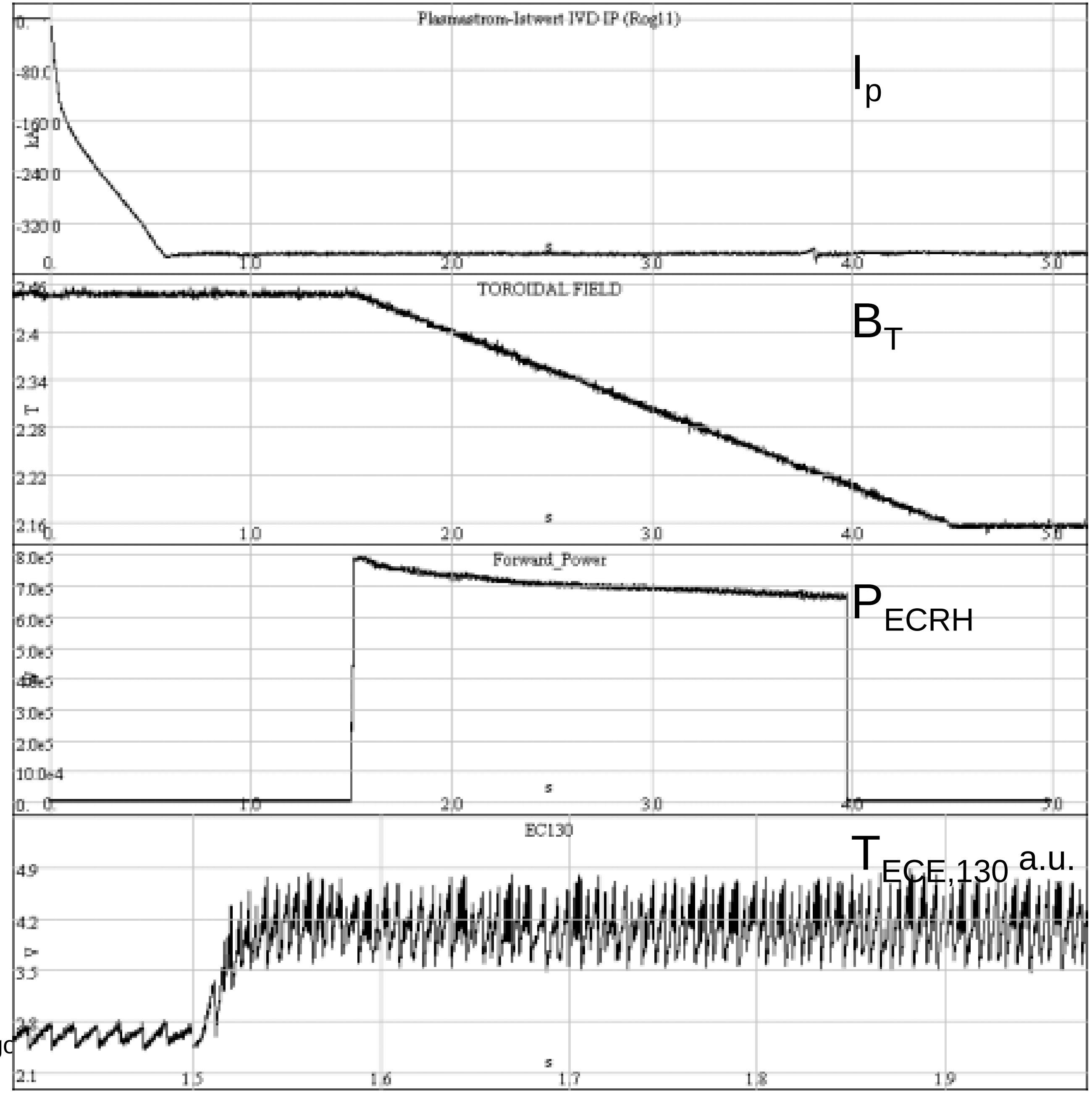
- #94175 ECRH

- #94044 co-ECCD
  - angle $\phi = -20^{o}$



Physics: sawtooth control

- Slow B-field ramp to scan ECR through q=1 surface
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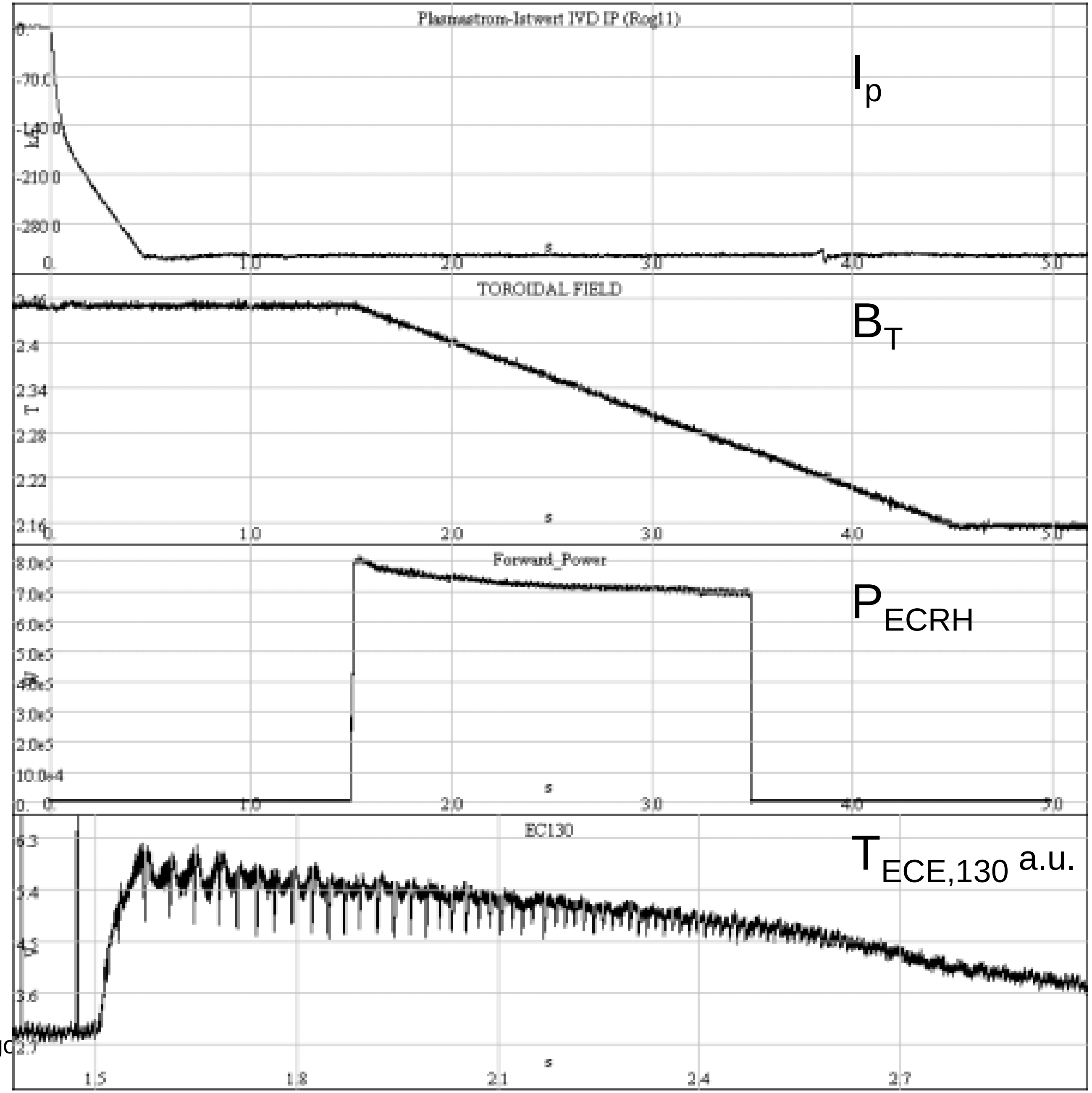
- #94044 co-ECCD
  - angle $\phi = -20^o$
- #94166 cnt-ECCD
  - angle $\phi = +10^o$



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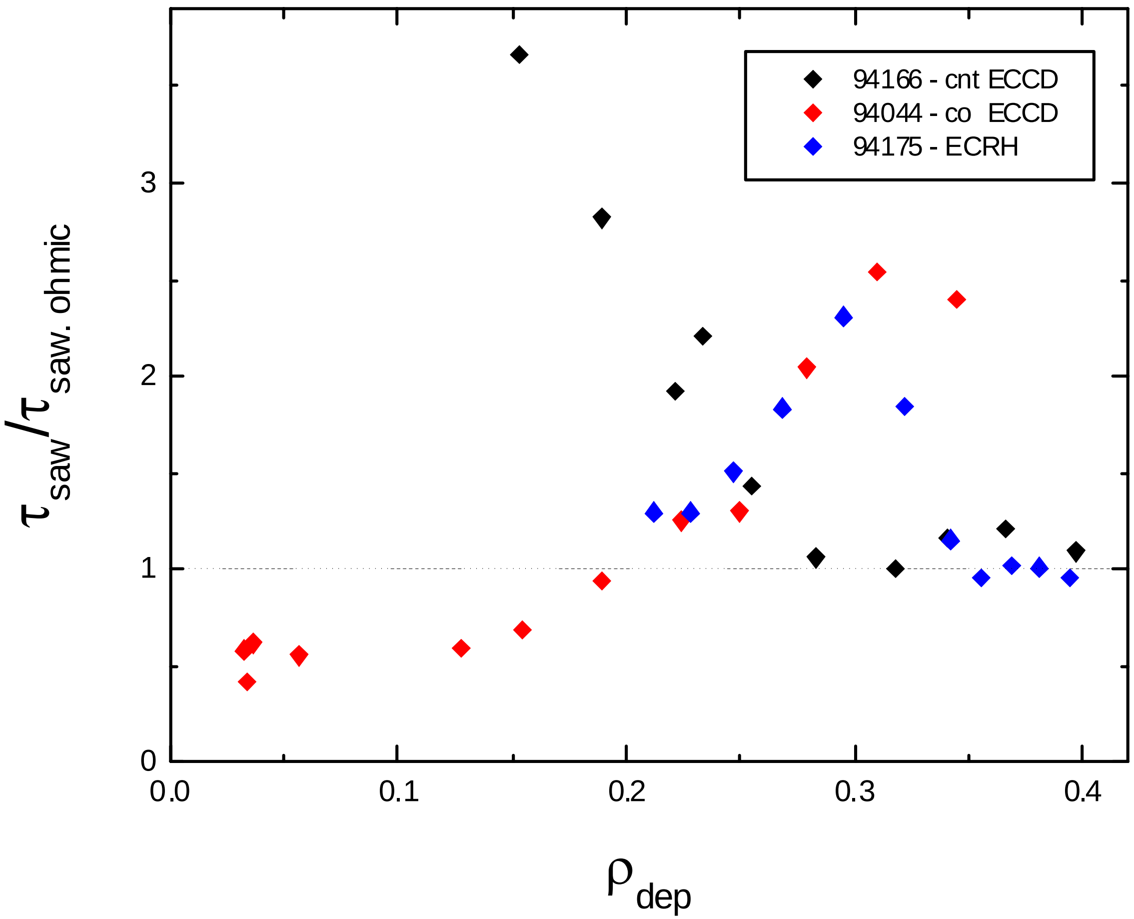
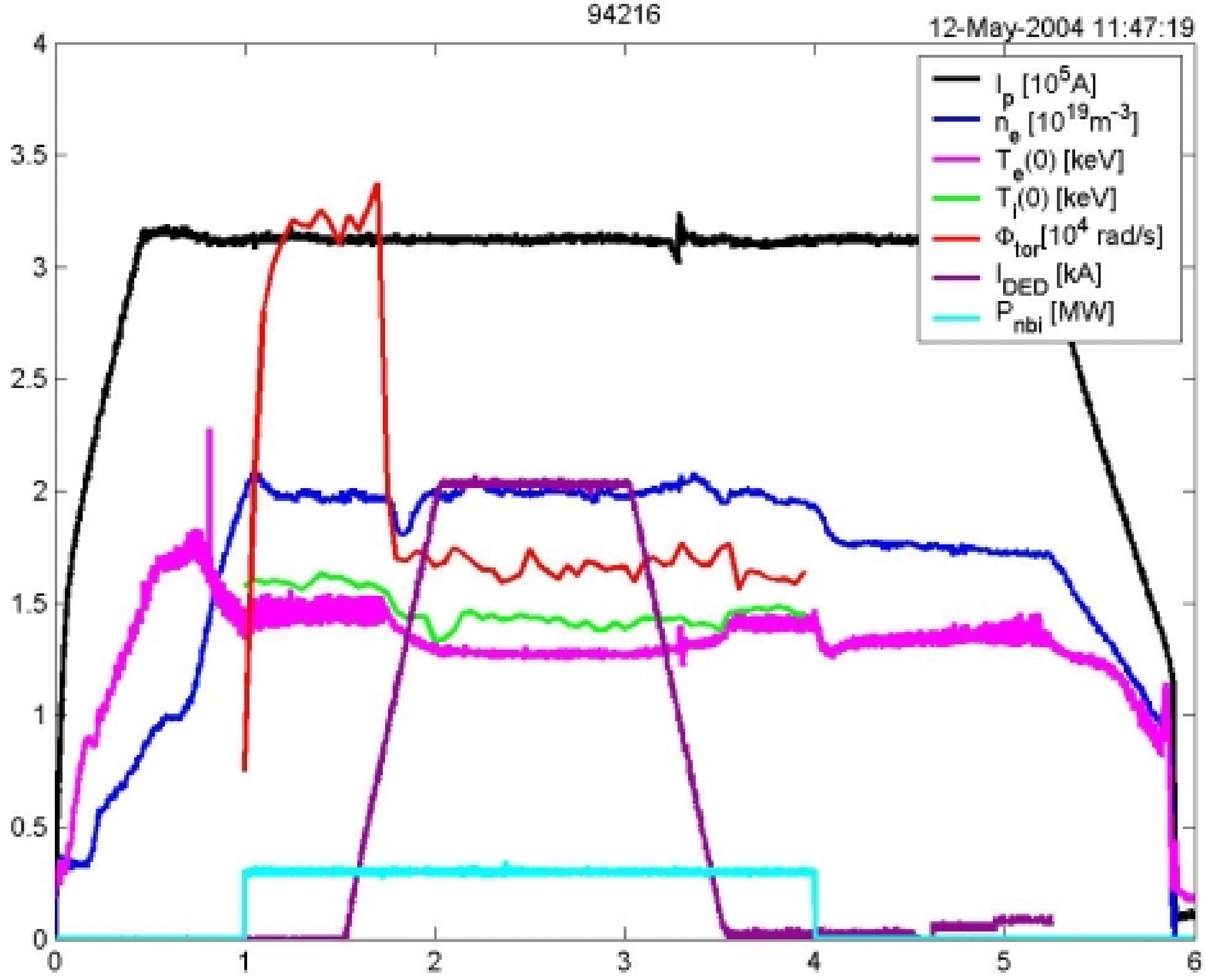


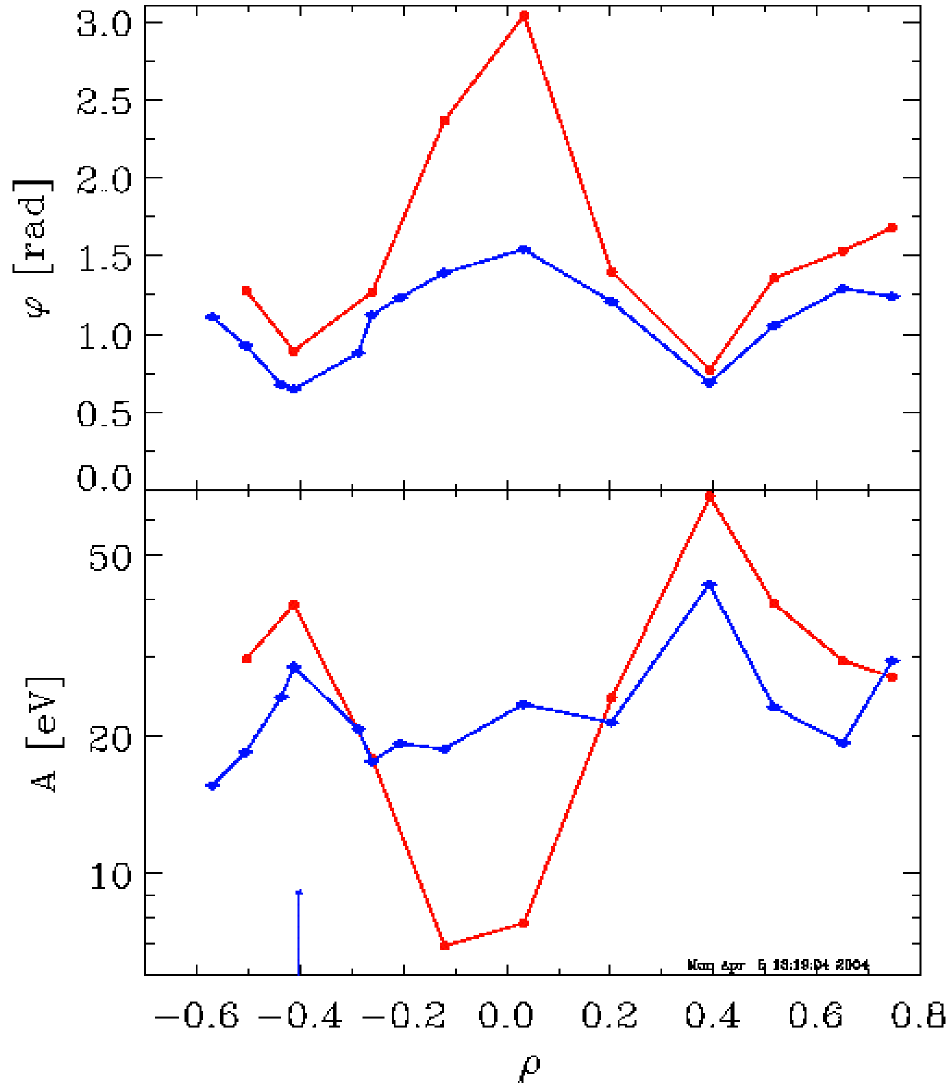
Physics: MECH to probe transport with DED

- TEXTOR operation with Dynamic Ergodic Divertor
  - 2/1 island created above threshold DED current



Physics: MECH to probe transport with DED

- TEXTOR operation with Dynamic Ergodic Divertor
  - 2/1 island created above threshold DED current
  - Transport probed below and above threshold



no DED / below threshold

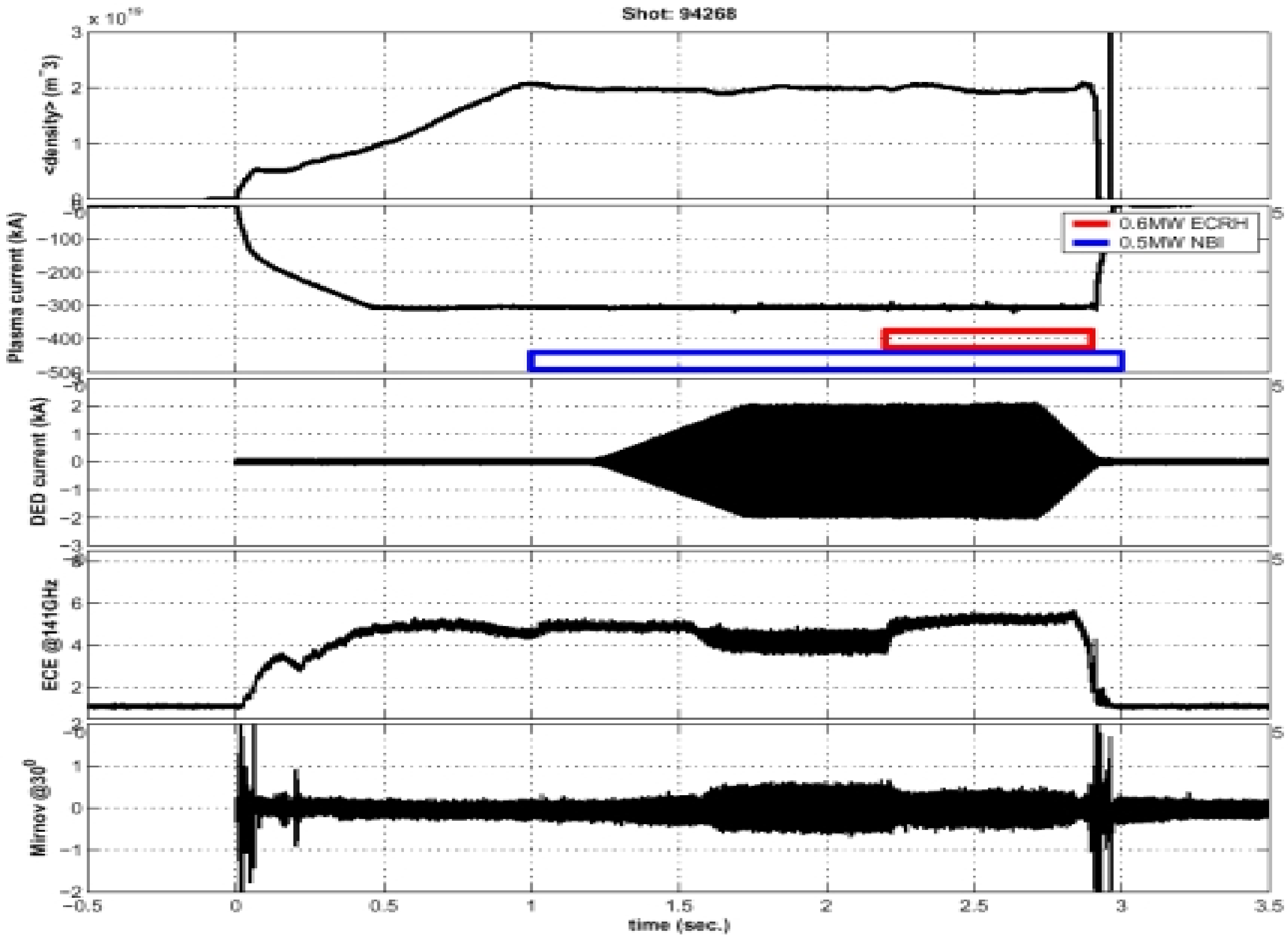
above threshold for 2/1 mode

- Transport strongly increases upon 2/1 generation
  - little or no effect below threshold

Physics: control of tearing modes

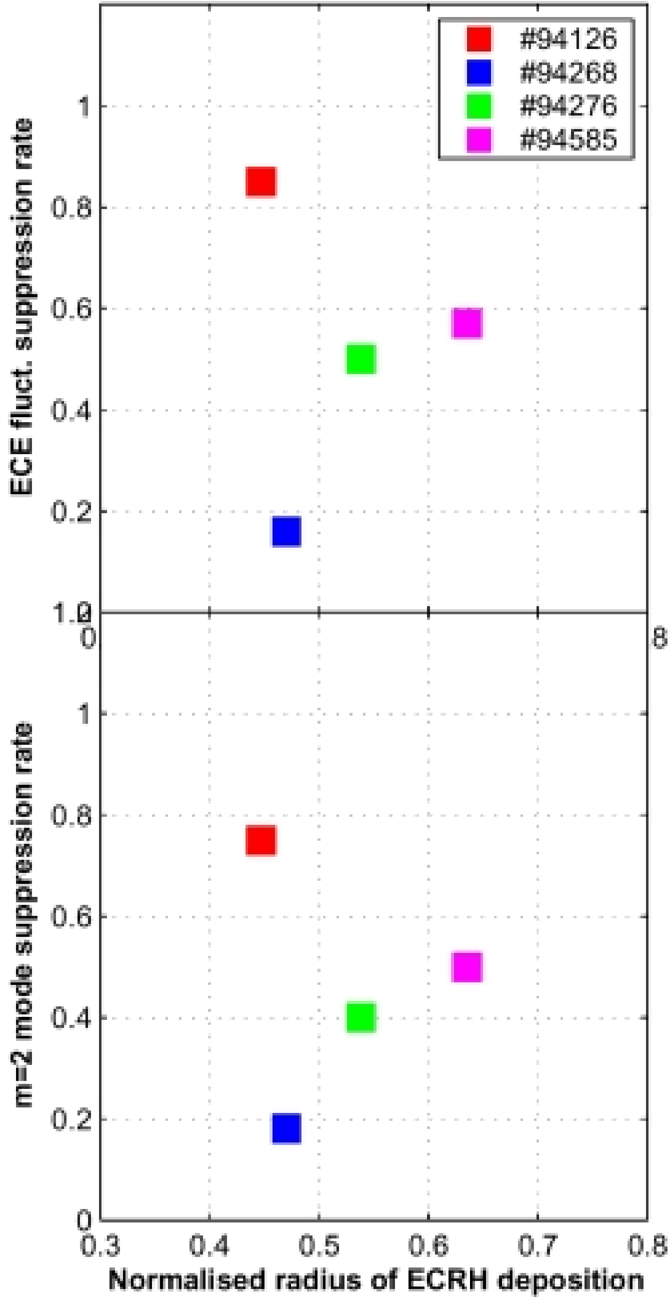
- DED in 3/1 AC (1kHz) mode triggers 2/1 tearing mode
  - localised ECRH used to suppress 2/1 tearing mode

discharge scenario



Control of tearing modes: ECRH deposition scan

- ECRH affects 2/1 tearing mode (DED generated)
  - measure of suppression by ratio of 2/1 amplitude during over amplitude before ECRH
  - 2/1 amplitude from 141 GHz ECE and Mirnov coils give consistent results



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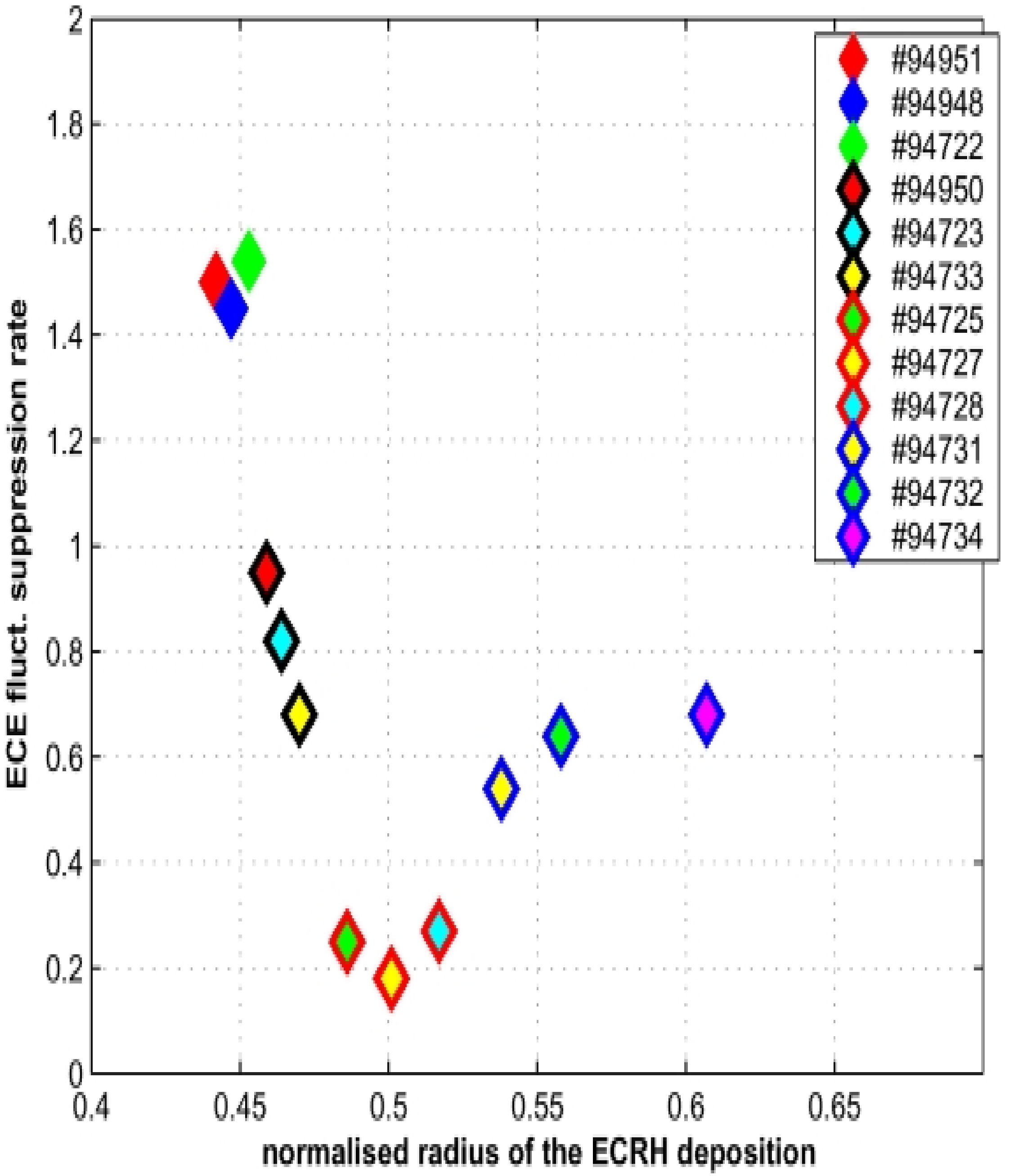
High resolution scan



Control of tearing modes: ECRH power scan

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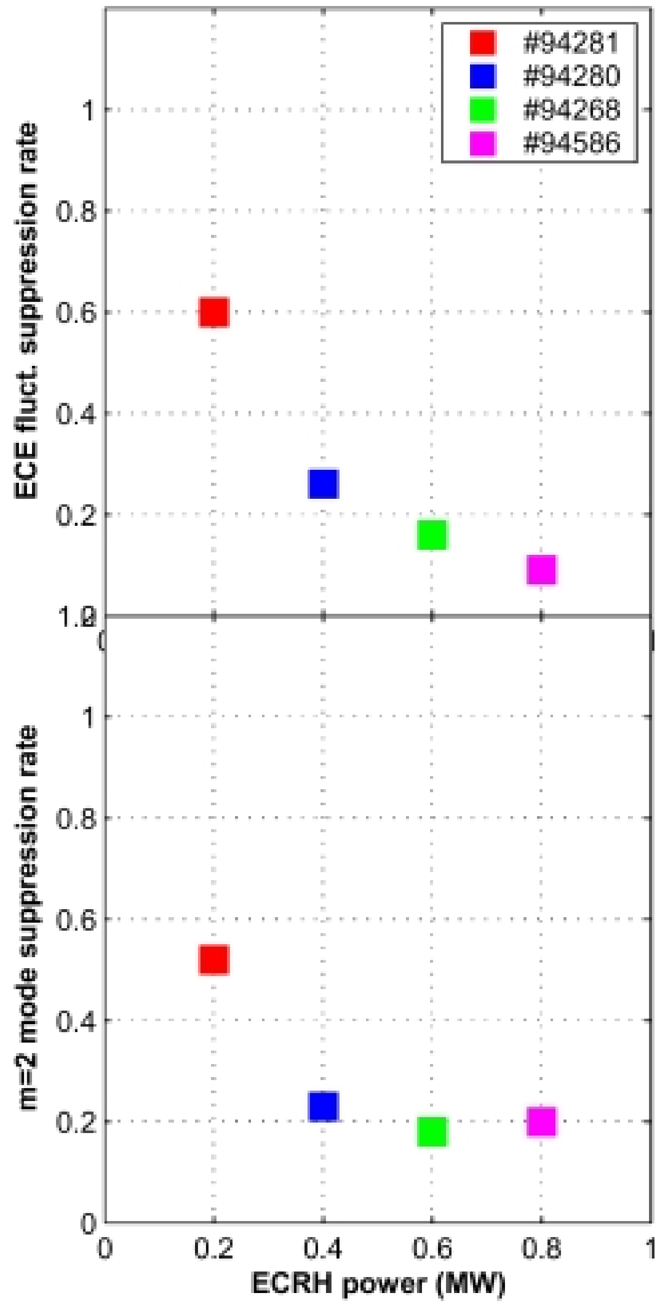
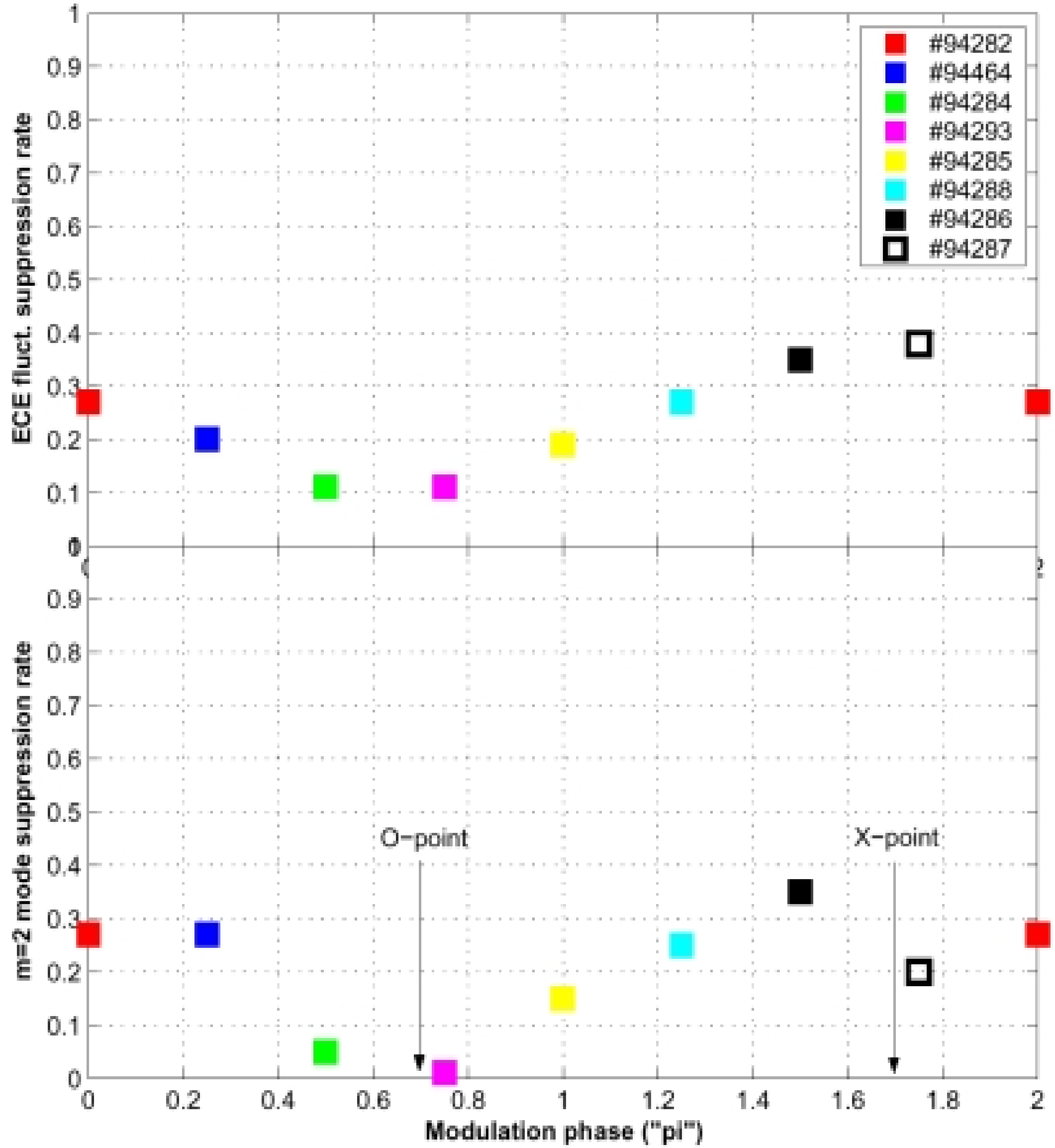


Control of tearing modes: modulated ECRH

- ECRH affects 2/1 tearing mode (DED generated)
  - ECRH modulation phase controlled by AC DED current
  - ECRH duty cycle 50%



Summary

- New high power, long pulse gyrotron brought into operation on TEXTOR plasma
  - 800 kW, 2.7 s (limited by arcing in transmission line)
  - **News:** 3.0 s pulse achieved with new, shielded tra.mi.li.
  - to be extended to 10 s with new CVD TEXTOR
- First successful long pulse ECRH physics campaign
  - T-10 effect: transport barrier by off-axis ECRH switch-off
  - DED: transport analysis by MECH
    - DED increases transport only after 2/1 tearing mode generation
  - DED: magnetic island dynamics with localized ECRH
    - DED generated 2/1 tearing mode suppressed by local ECRH
    - TM suppression very sensitive to phasing of modulated ECRH