(N)TM control by ECH/ECCD

Milestones:

- Test and debugging (M0)
  - test of the control system (detection+powered actuator) in open loop
  - tuning of the control parameters
- Test of closed loop mhd control (Milestone 1)
- Tuning/optimization of the control strategy (M2)
- Characterization of the control dynamics (M3)
- Exploration in a range of parameters: Ip, ne, B, ECRH power and power density (M4)
- Comparison of the effect of pure ECRH and ECCD (M5)
- MHD Destabilization via ECRH (M6)

Experimental strategy: M0 to M1 and M2

- Tuning of the plasma target (triggering of lasting MHD via Ne injection on fixed Bt plasma, ~5.3 T, ~360 kA and ~500 kA)
- in parallel: open loop ECRH control
- M1 (technical milestone):
  - closed loop using fast equilibrium as main island locator
  - closed loop using MHD RT detection as main island locator
- Once a reasonable knowledge of the control dynamics is reached, the two broad techniques can be merged and used with different weights (=control configurations), keeping as constant as possible the plasma target. Effective MHD stabilization should be obtained at least for one control configuration (M2)

Optimization (with fixed target)

- M3 consists in a wider exploration of the parameter's space of the control and in the variation of the initial conditions of the experiments (e.g. timing, Ne injection, beam trajectories...).
- Again, the plasma target should be kept as similar as possible.
- The outcome of M3 should be:
  - a reasonable understanding of the interplay between control parameters and plasma reaction
  - Exploration of alternatives
  - If successful: a small set (2-3) of working control configurations

Extension of the application

- Using one (or two) of this control configurations the plasma main parameters should be scanned:
- Ip (q location at the same B): 3 values
- Ip/B (same q location, different current and resonance position): 2-3 values
- density: 3 values
- Bt (island displacement in the space of the ECE channels)
- For each case the goal is to reach the stabilization only varying the ECRH power. Alternatively, since ECRH power variations other than 1 or 2 gyrotrons can be technically unsuitable, one can fix the power and vary the three quantities above to find a threshold of stabilization/no stabilization.
- The output of this process should be a raw scaling of the stabilization power (M4).
- Variations of Ip, Ip and Bt at constant Ip/Bt, Bt at constant Ip and ne (every else constant) can be performed using (relatively) slowly ramps of each (pair of) parameter.

ECCD vs ECRH

- In one of the previous cases (preferably near threshold) one can compare co-ECCD, cnt-ECCD and ECRH results keeping everything fixed (M5).
  - (Full exploration of this subject (which imply the optimization process applied to the control configuration for ECCD) can be the subject of a later proposal).

ECRH (ECCD) de-stabilization

- The MHD triggering recipe with Ne injection is intrinsically non stationary. A plasma target which spontaneously develops MHD and, when the stabilizing action has been performed again develops MHD would be of significant interest (M6). Such objective can be pursued with ECRH deposition slightly inside a given rational q surface (see #27864).
- The development of such target requires at least 2 (3) gyrotrons available with pulse duration of 500 ms.
- For a given plasma target (typically 350 kA at 5.3 T) perform a radial scan of the ECRH power deposition with slow power modulation ~10 Hz, duty cycle 50% (50ms on/ 50ms off). Repetition with higher current (500 kA) and with co/cnt ECCD.
- Analyse data looking for (possible) ECRH-induced MHD. Select the correspondent plasma and ECRH parameters and verify in steady conditions, using one ECRH URS (2 gyrotron time-coupled) for the destabilization phase and 1 (or 2, being the second in a suitable fixed radial position) in the stabilization phase.
- Apply a suitable (hopefully already available) control scheme and study the dynamics of destabilization/stabilization which hopefully should occur twice or more times...

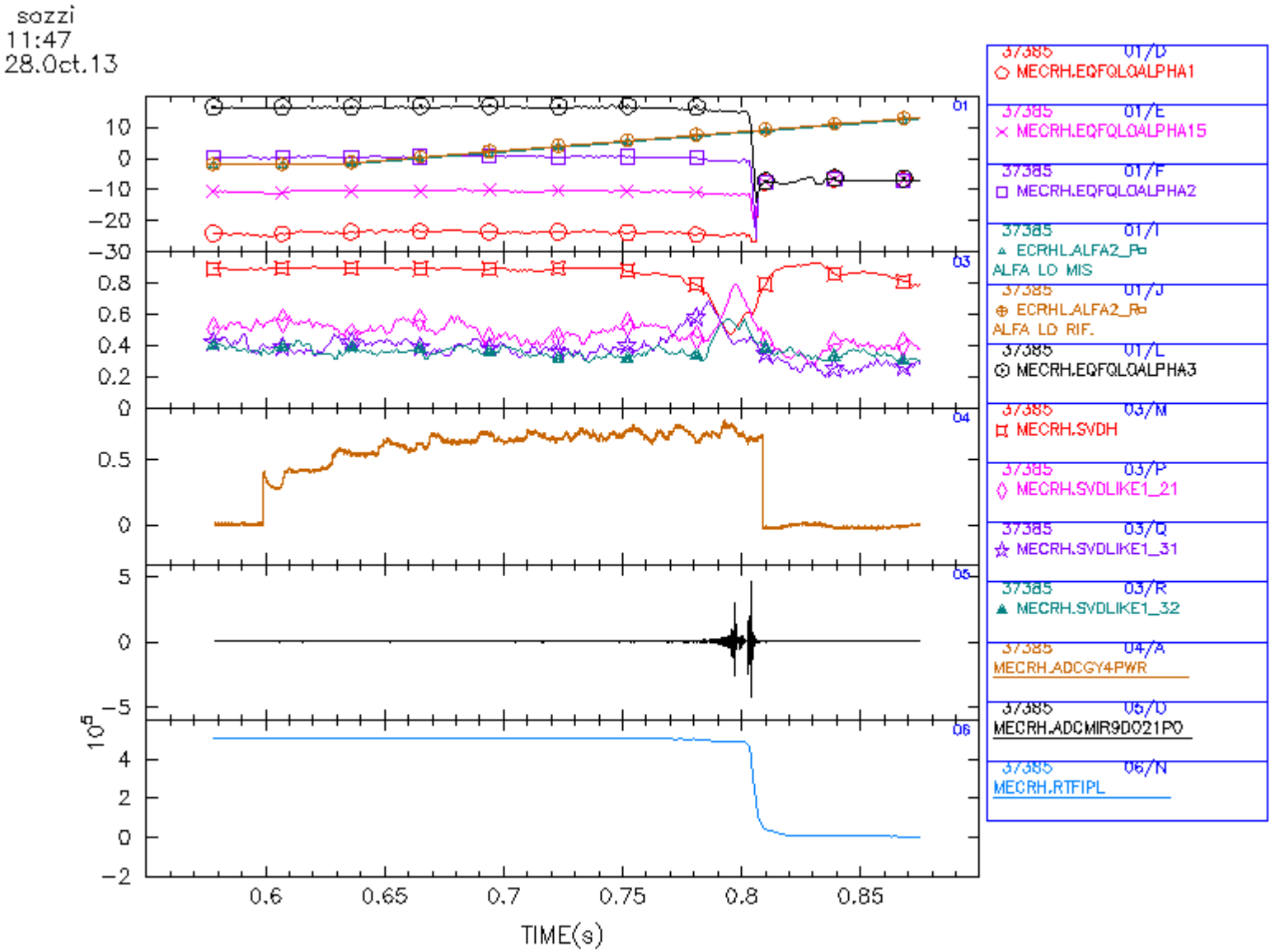
Programma e riferimenti per la settimana in corso

- Il programma e' di iniettare neon, provocare mhd e poi individuarla e intervenire con l'ecrh in feedback.
- Una prima fase sara' di tuning del target e di debugging del sistema, che va in scena per la prima volta in modo attivo
- Scariche di riferimento
  - per campo e corrente: 5.3 T, 0.5 MA: 37384, 37385 (S53M50A002).
  - ne_lin=$0.6*10^{19}$
- Da evitare o comunque controllare partenze con profili bucati.
- Per l'iniezione neon i riferimenti sono 37342 (S51M36A001) e 37347 (S52M50A002).
- L'iniezione di neon dovra' essere ottimizzata (V, durata apertura valvola) per produrre mhd non esplosiva
- Gli altri parametri costanti. La scansione sara' sulla modalita' di deposizione ecrh e sui criteri di chiusura del loop (soglie, tempi di attesa)
- La 37342 e' anche un possibile riferimento se decidiamo di scendere in corrente.
- Infine, anche se probabilmente non la useremo, sarebbe meglio guardare le rampe di campo (36252, S64M36RAM1).
- Se avanza tempo e se abbiamo disponibile il secondo girotrone in posizione fissa possiamo provare a triggerare mhd con quello (vedere shots 37384, 37385)

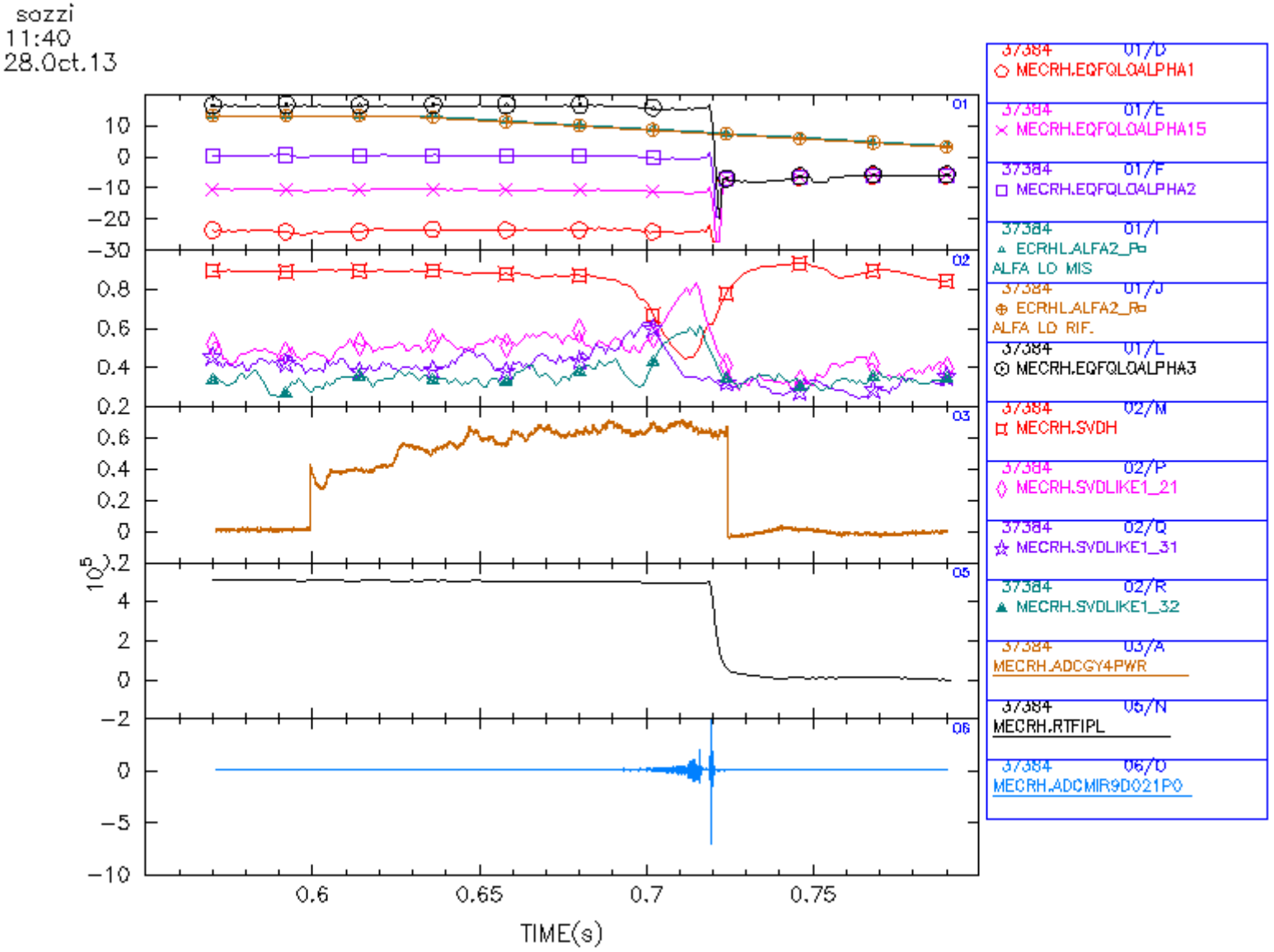
Diagnostiche

- ECE (policromatore + Mich)
- Mirnov
- Densita' (con inversione profili)
- Spettroscopia (Neon)
- SoftX

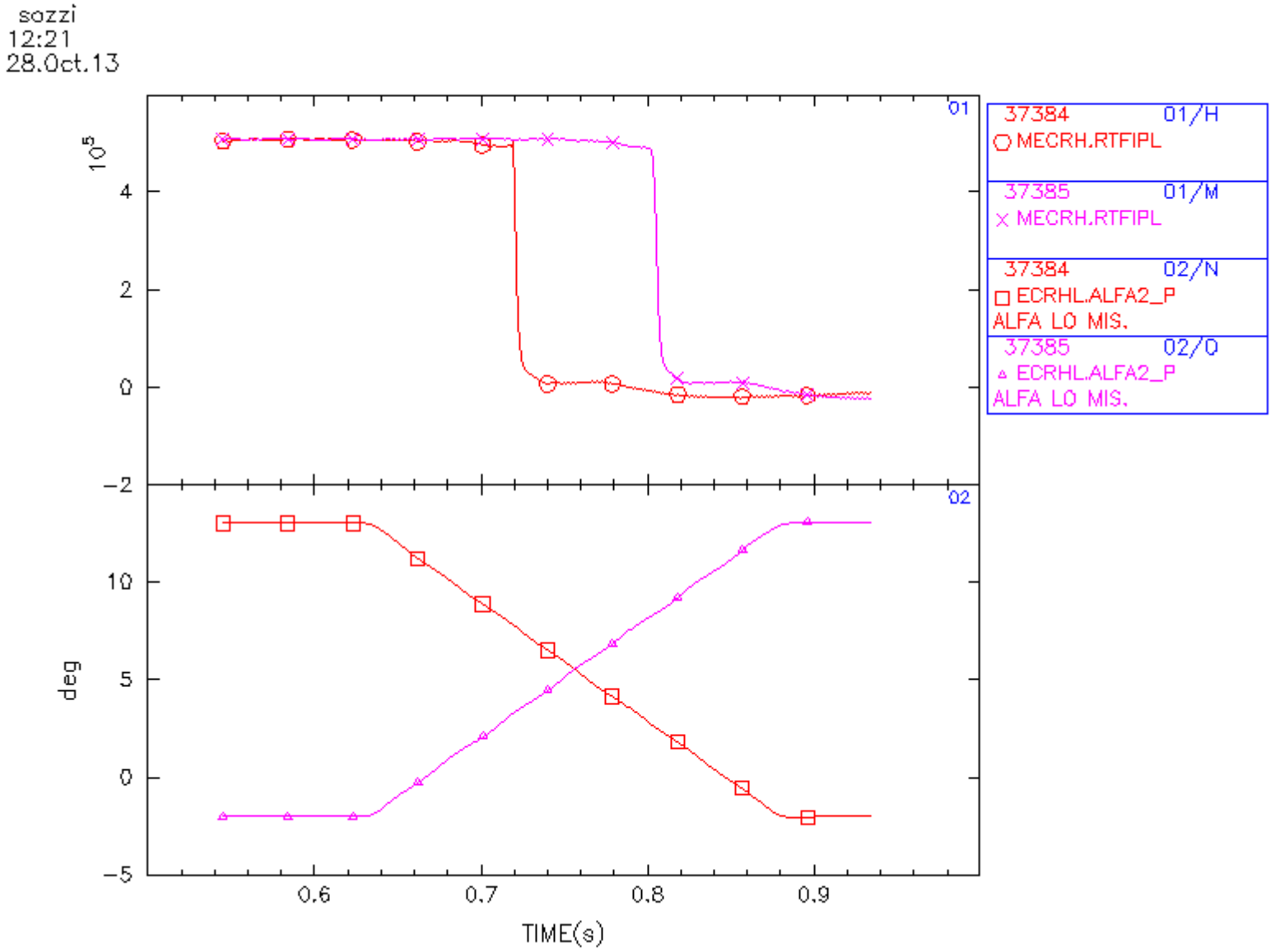
Modo triggerato da ecrh (?)
scansione interno-esterno



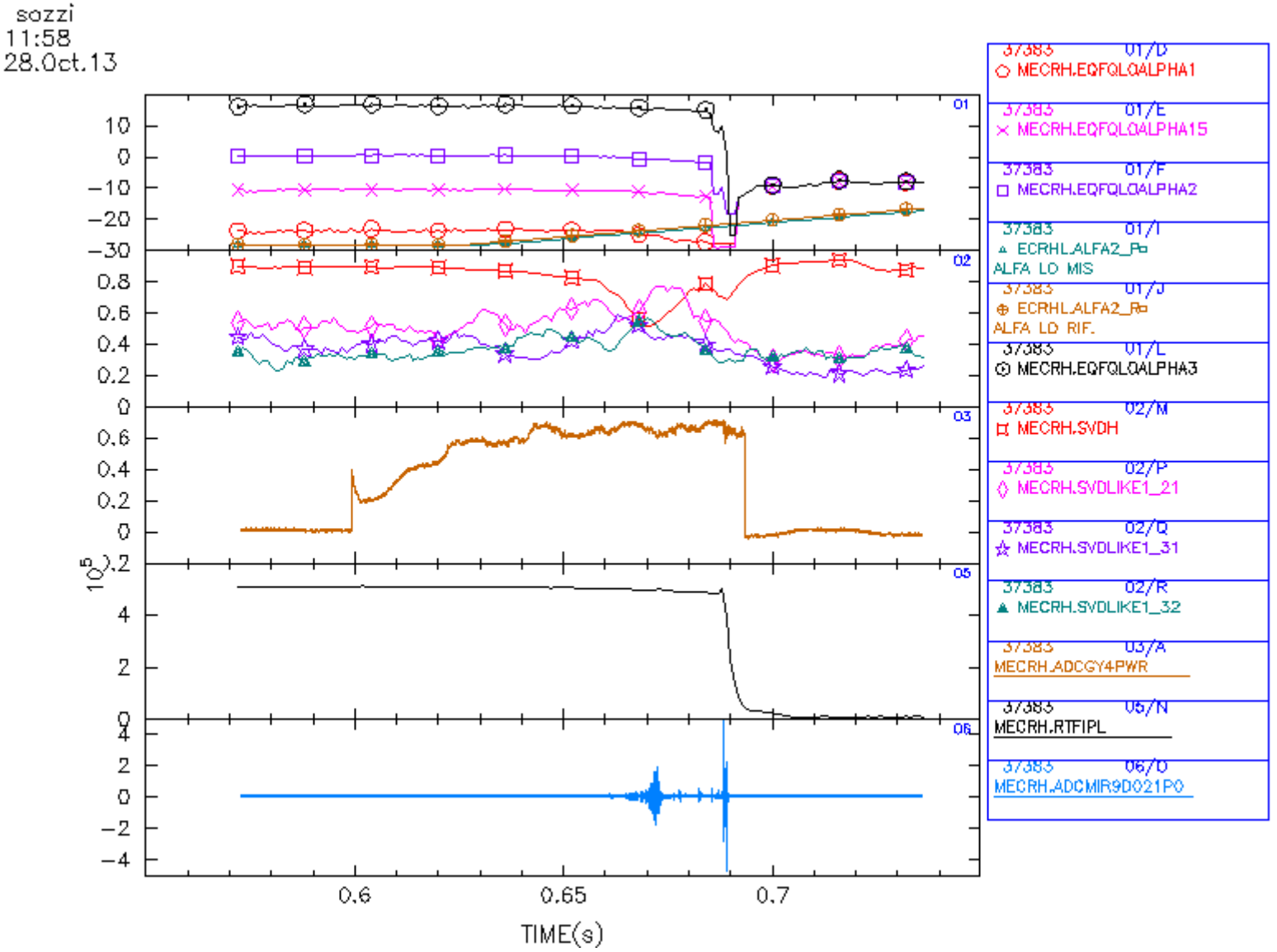
Modo triggerato da ecrh (?)
Scansione esterno-interno



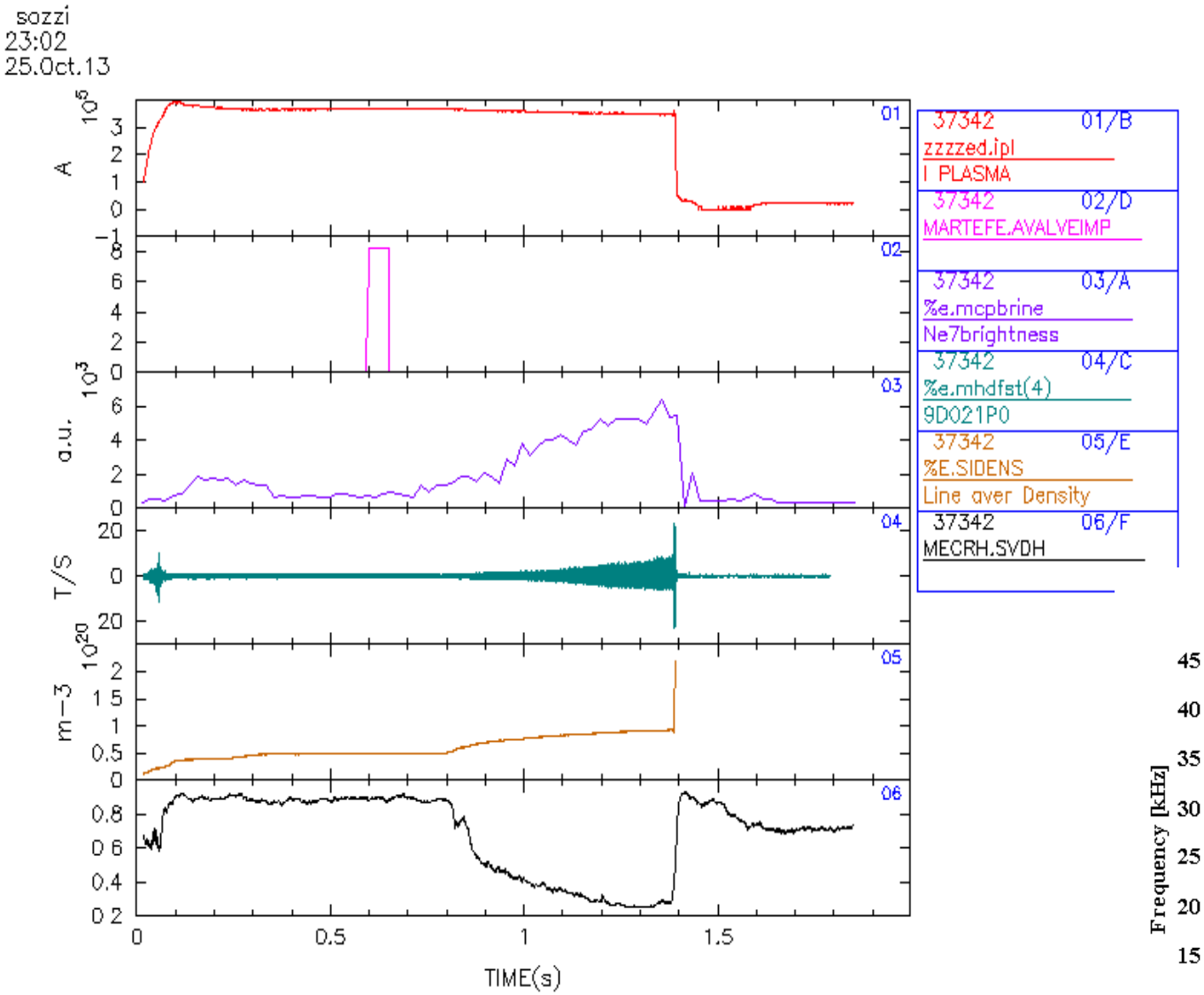
Disruzione allo stesso angolo di iniezione

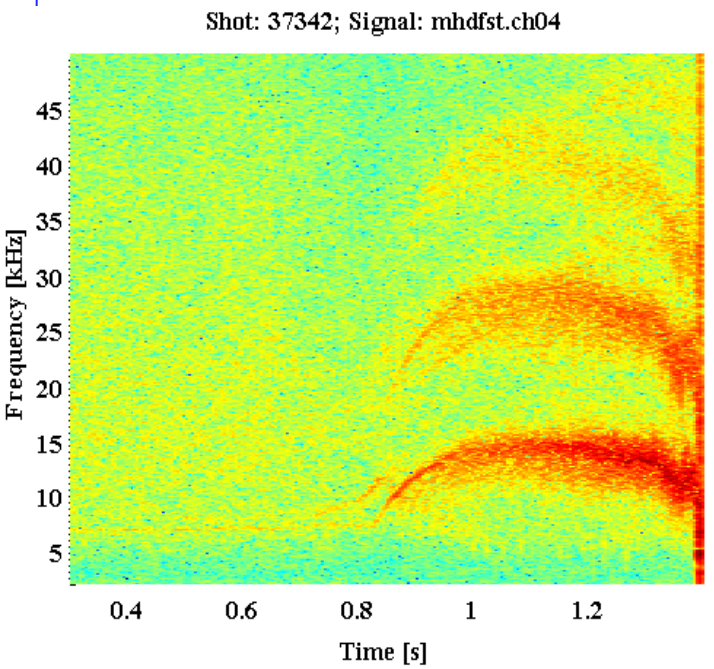


Scansione interna

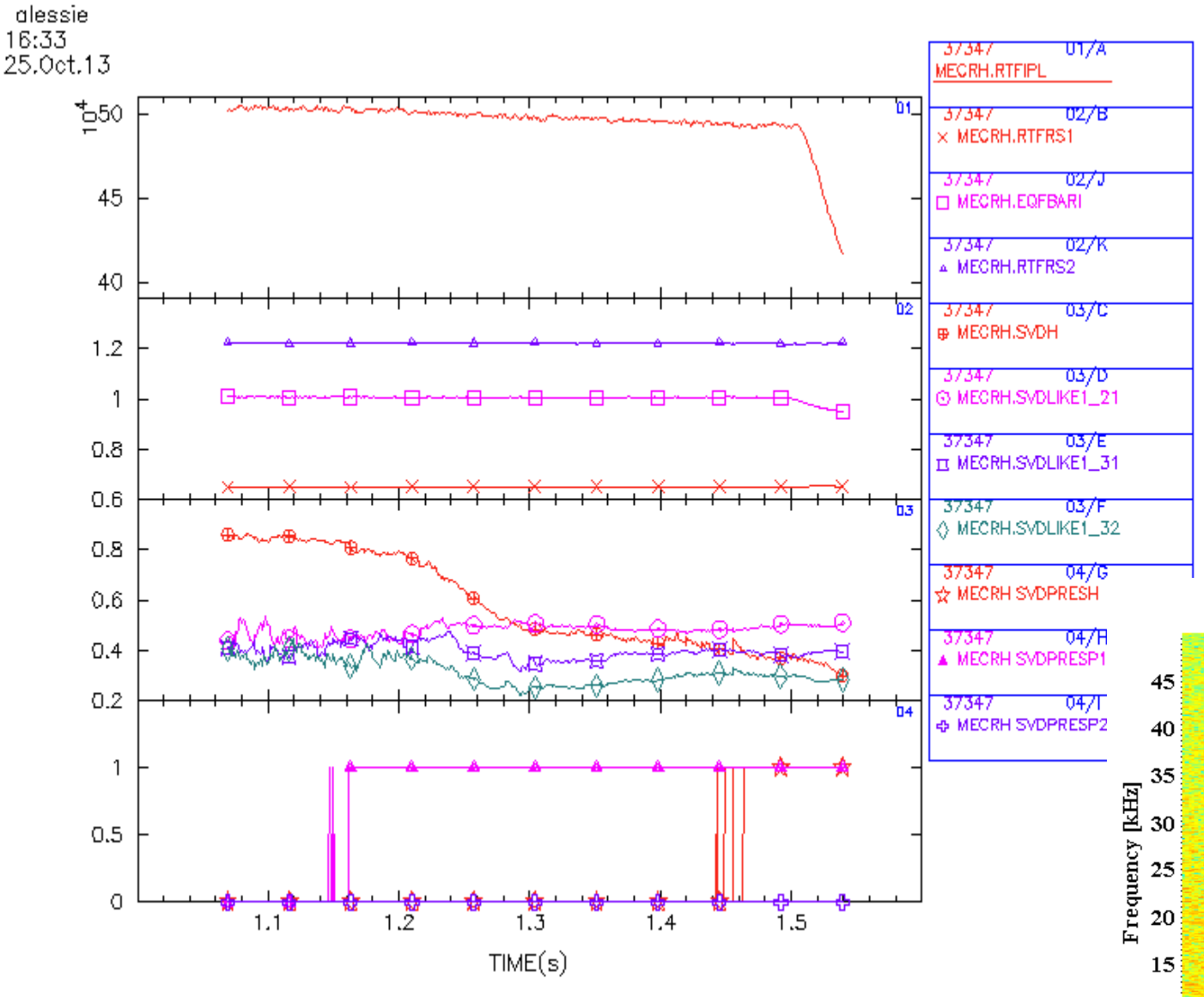


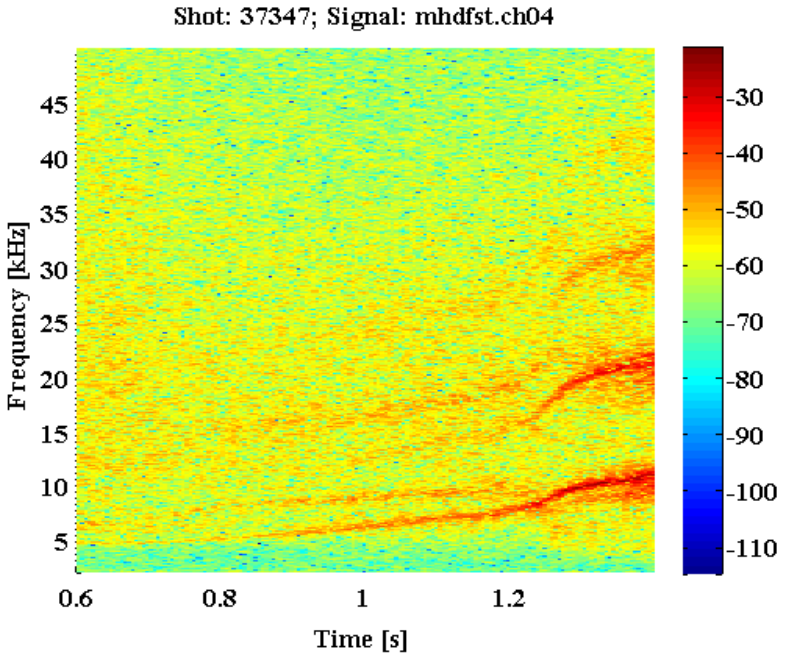
Neon injection





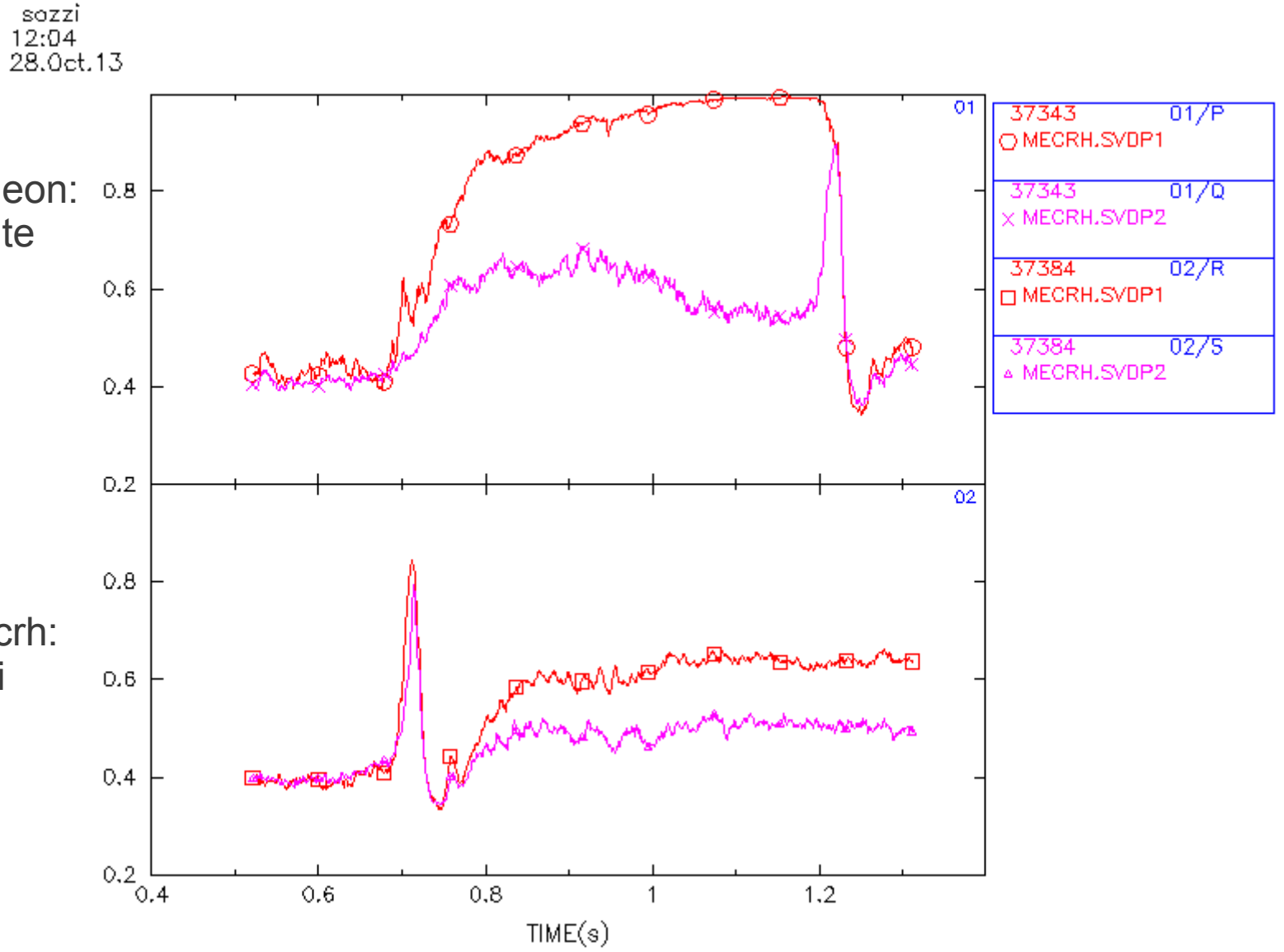
Neon injection

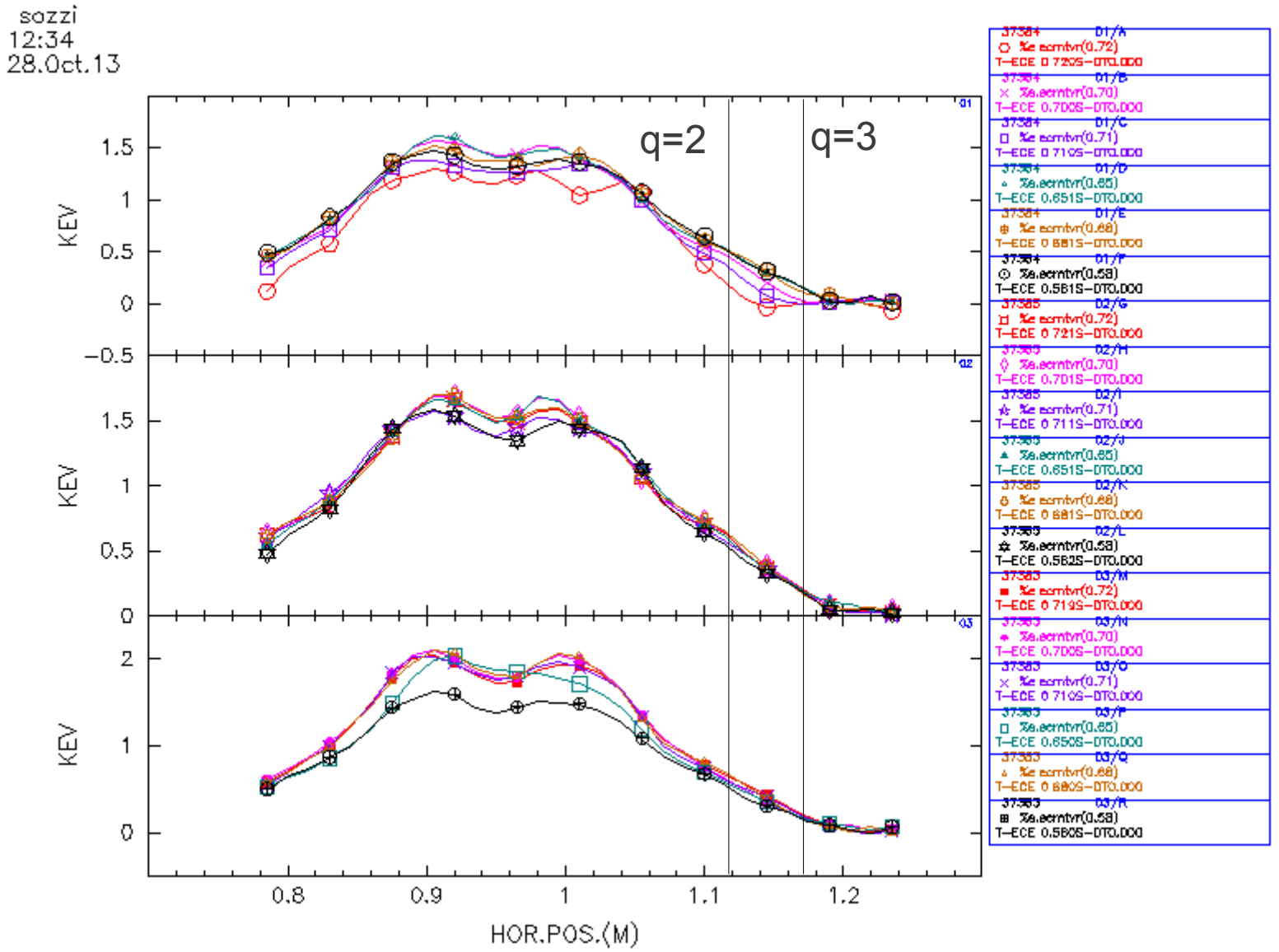




Disruzione con neon:
1 modo dominante

Disruzione con ecrh:
2 modi accoppiati




sozzi
12:34
28.Oct.13
q=2
q=3
KEV
KEV
KEV
HOR.POS.(M)
0.8
0.9
1
1.1
1.2
1.5
1
0.5
0
−0.5
2
01
02
03

(N)TM control by ECH/ECCD

•C. Sozzi, E. Alessi, L. Boncagni, C. Galperti, C. Marchetto, S. Nowak, G. Granucci, A. Moro, S.Garavaglia …....)

•Alcuni punti della proposta di controllo attivo sono stati svolti in plasmi ohmici: messa a punto della parte diagnostica (acquisizione ECE, MHD ed elaborazione dati)

•1) preparazione del plasma target (partendo ad esempi o da S53M36A003 #35804 o simile)

• rampe di q (in dipendenza dal funzionamento della macchina a correnti > di 350 kA)

• mhd via iniezione di neon (se MHD non gia' presente), con e senza rampe

• (dds: target tipo #27864 e #27877 a 350 kA e Bt=5.3 T vedere sperimentazione di Silvana)

• Lo scopo e' ottenere attivita' MHD e verificare la capacita' del sistema diagnostico di “vedere” e “inseguire” l'isola (o i dds) variando, nei limiti del possibile Ip e Bt

• Tempo previsto: (ca 2 gg per la messa a punto del plasma + ca 2 gg per il test/debugging della parte RTC-diagnostica):

•2) Chiusura del loop senza potenza ECRH per il debugging dei vari elementi del controllo (circa 2-3 gg)

• sul target 1 si “insegue” con gli specchi ECRH una q predeterminata

• sui target 2 si identifica R e timing (presenza & posizione) delle isole e si verifica la possibilita' di produrre un trigger per ECRH, aggiustando i parametri del loop (soglie ecc)

A-priori and diagnostic algorithms: fast equilibrium and ray tracing, cross-correlation and SVD

- FASTEQ provides (using best fitted data):
  - RT map surfaces fast reconstruction
  - RT q profile reconstruction using Ip(ρ)/Ip best fitted as well
  - plasma axis from RT ECE
- RAYFAST provides
  - “a-priori” beam trajectory and EC Rdep for a pair of pol. α /tor. β injection angles (it requires iterations when integrated in the control loop)
- => Pre-alignment on the target via a-priori (guess values) Rmhd and Rdep
- Cross correlation ECE-MIRNOV, ECE-ECE + SVD (Singular Value Decomposition)
  - Detection (in time) of the MHD activity (t_mhd)
  - Location of the MHD activity (Rmhd)
  - mode number determination (SVD combined with equilibrium reconstruction FASTEQ)
- => Measured Rmhd and t_mhd
- Cross correlation ECE-ECH (requires power modulation)
  - Location of ECRH deposition (Rdep)