IAEA FEC 2020 Contribution

Helium doped plasmas on FTU

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Results of FTU Experimental Campaign C1

Maximum peaking by impurity injection (F04)

WIP 30/01/2020

C. Mazzotta

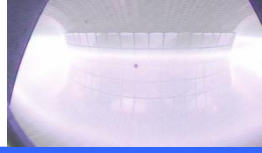
IFP

ENEA

CONSORZIO RFX

Ricerca Formazione Innovazione

Goals of the experiments



- Understand the transport mechanism that leads to spontaneous density peaking when plasma is doped by Neon and Helium.
- Characterization of doped plasma in order to set the parametric dependence in: q, density and peaking, collisionality, amount of impurity and species.
- Achieve a well high peaking, up to the highest value reaching with doped experiment in MST.
- Explore current dependency
- Understand the role of the edge cooling in triggering the transport barrier.

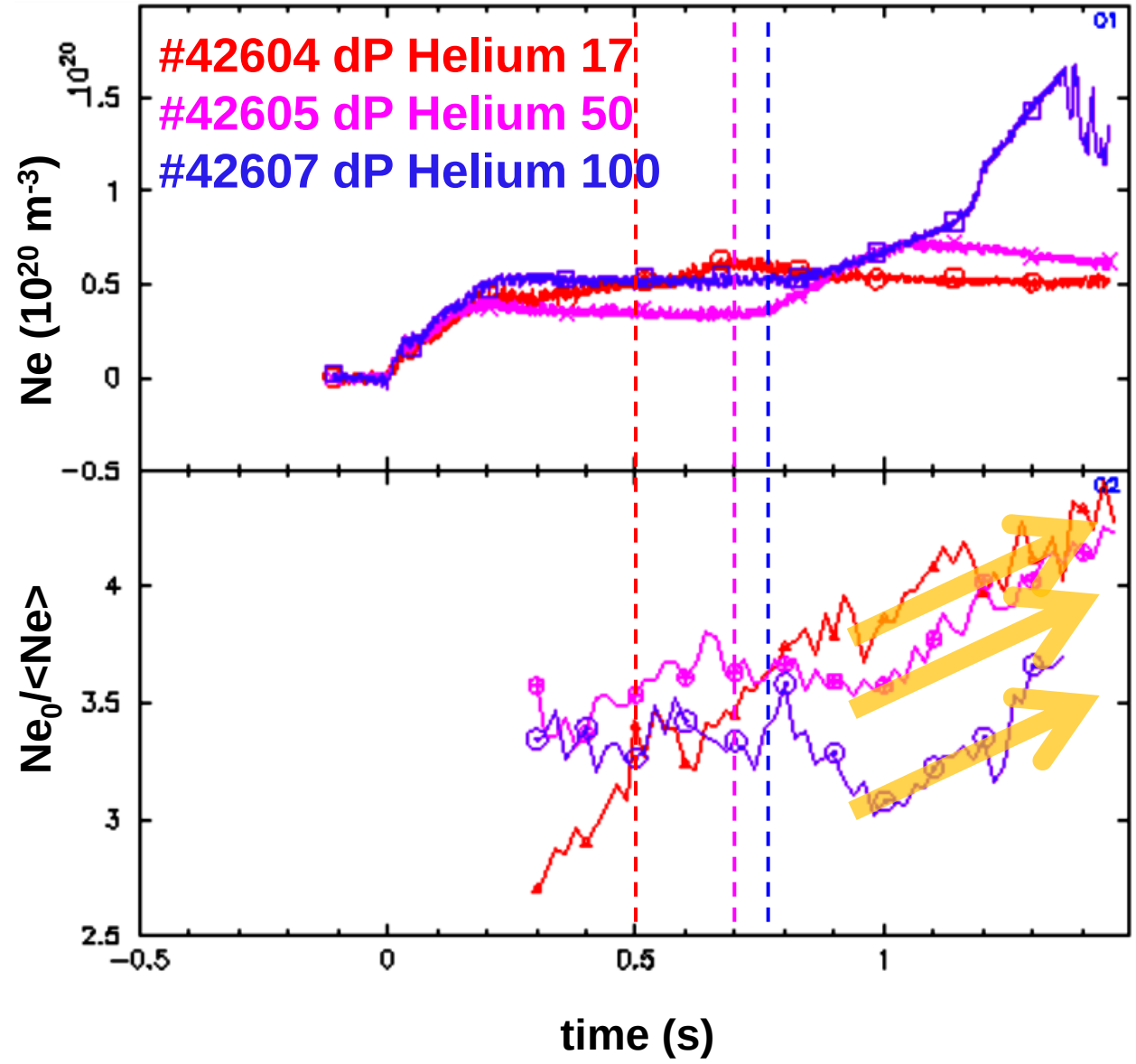
Schedule and progress of the experimental program

- He amount behaviour in term of accumulation and preliminary He amount scan √
- Starting density scan √
- Combining doping He+Ne and Ne+He x
- Current scan (250-360-500 kA) √
- Record of spontaneous maximum peaking (~5) √
- Edge effect x
- Study transport behaviour when the pulse is heated x

Paper content

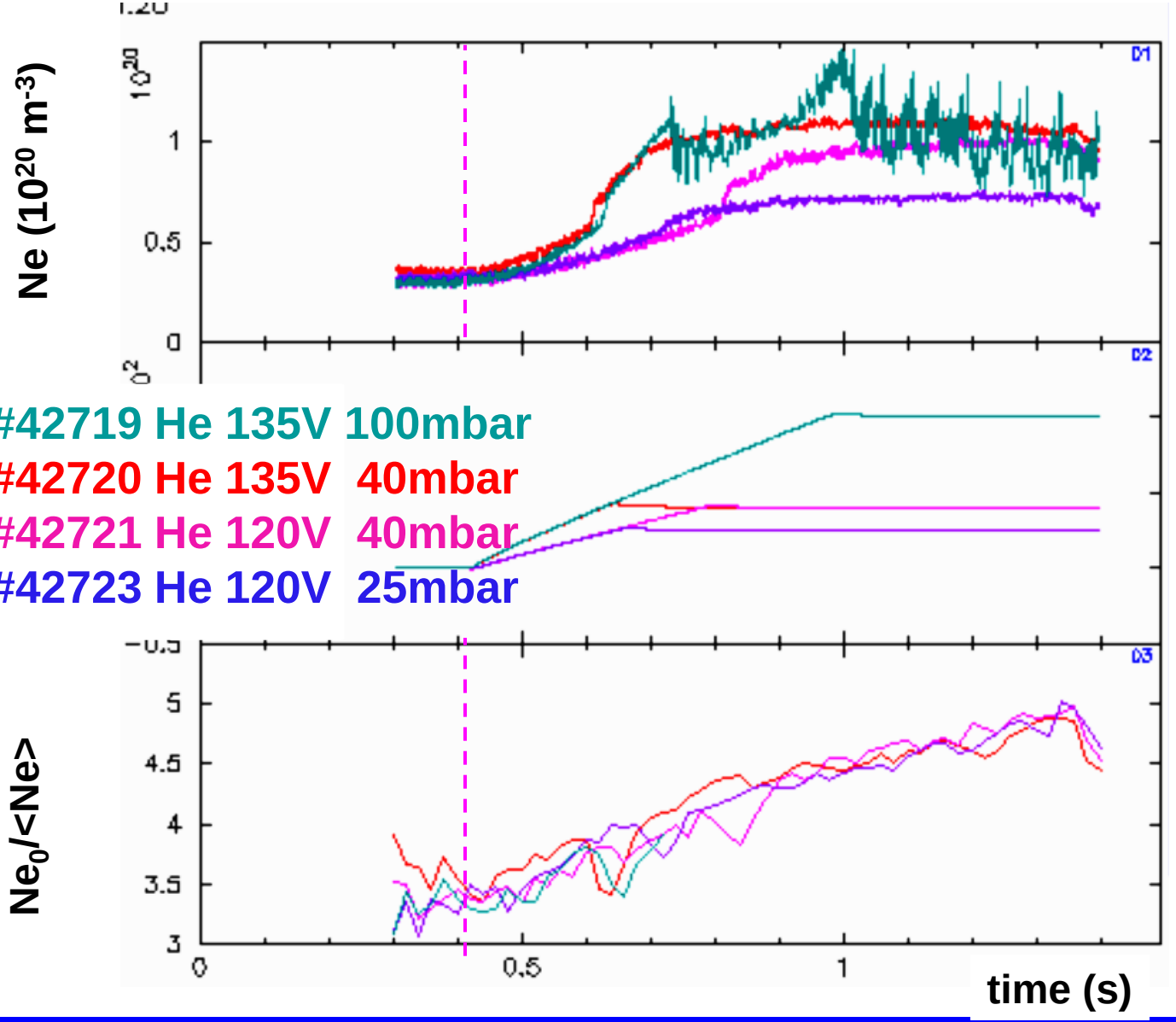
- Helium behaviour: Spectroscopy estimation, MARFE presence, temperature profiles, MHD
- He amount scan (influx dynamic) and Δ Zeff and Δ Prad and ΔT/T
- Record of spontaneous maximum peaking (~5)
- Current scan (250-360-500 kA)
- Edge effect x
- Study of transport with JETTO: ion thermal diffusivity and confinement time

Spontaneous peaking

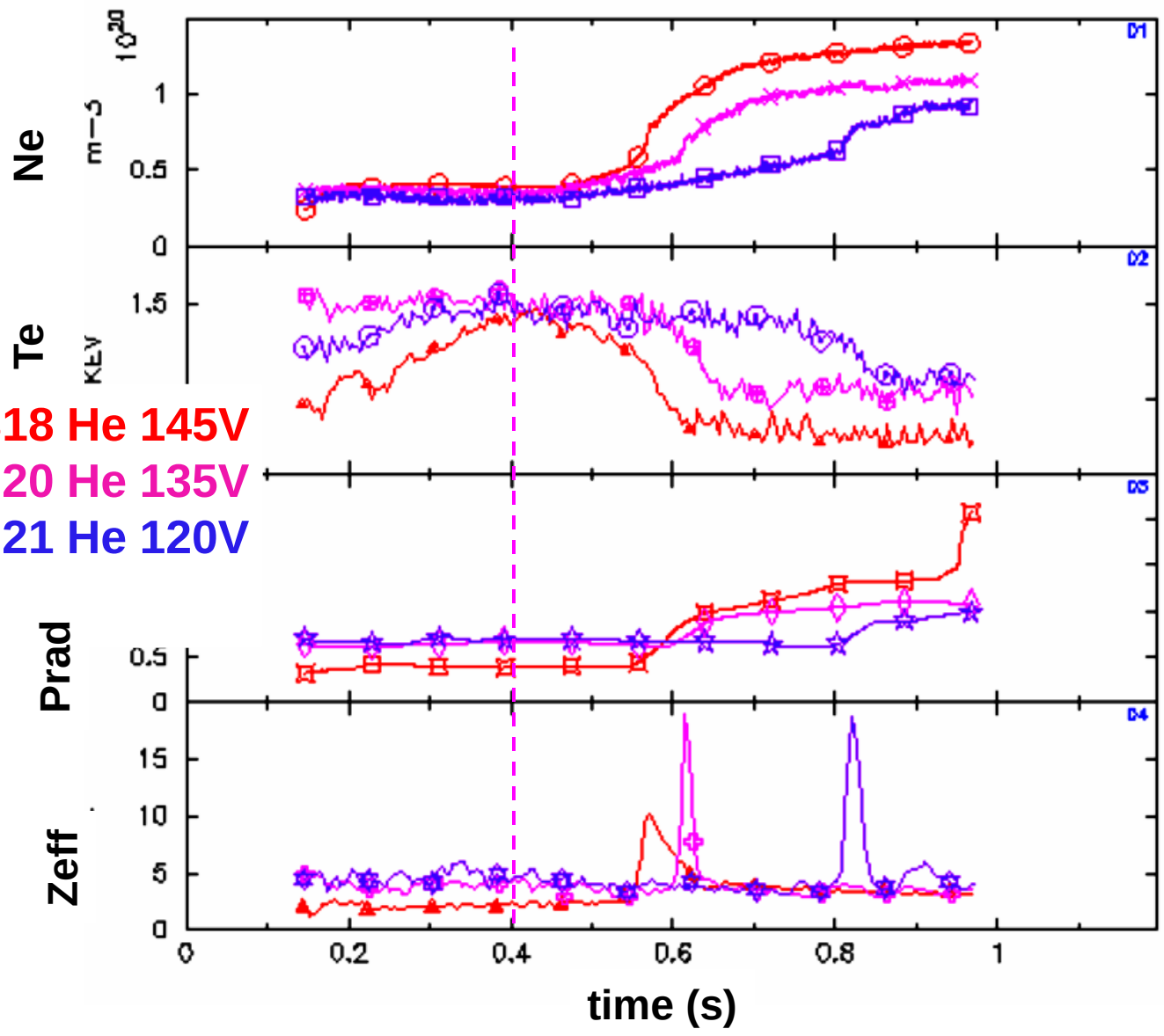


- Observation of sponteneous density rise as for Neon doping
- Helium visible from the begininng of the pulse (the machine is contaminated by He).
- The growth rate of the peaking seems the same

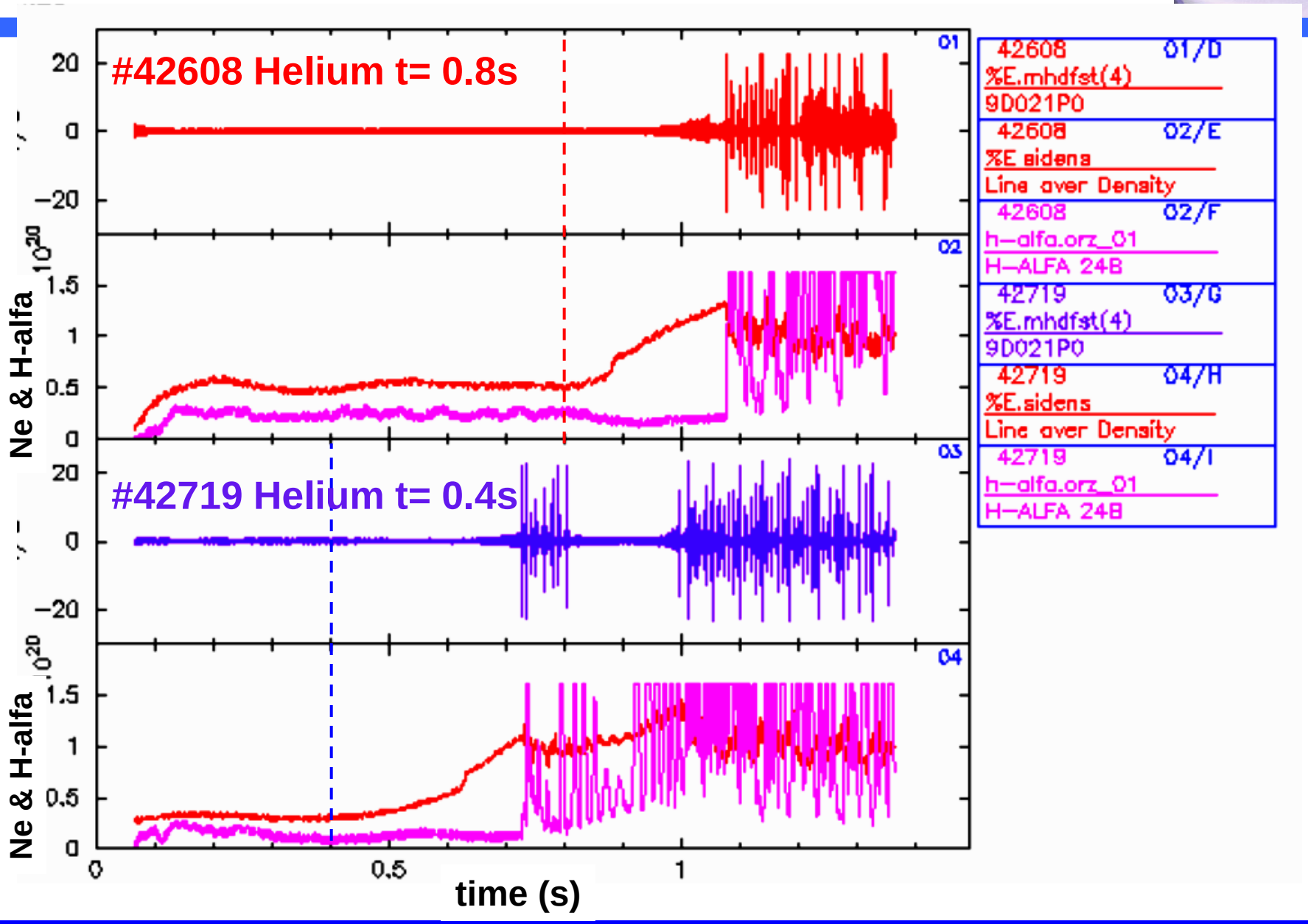
Helium amount scan



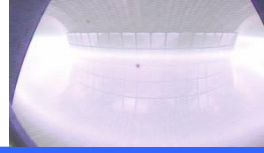
Helium amount scan & spectroscopy



Instabilities



MARFE



#42608 t= 1.14 / 1.15 s

Ne (10^{20} m^{-3})

R (m)

42608 /A
%E.SIDLVR(0.35,0,1)
DLin(1t.0.35001)

42608 /B
%E SIDLVR(0 35,0,2)
DLin(2t·0.34994)

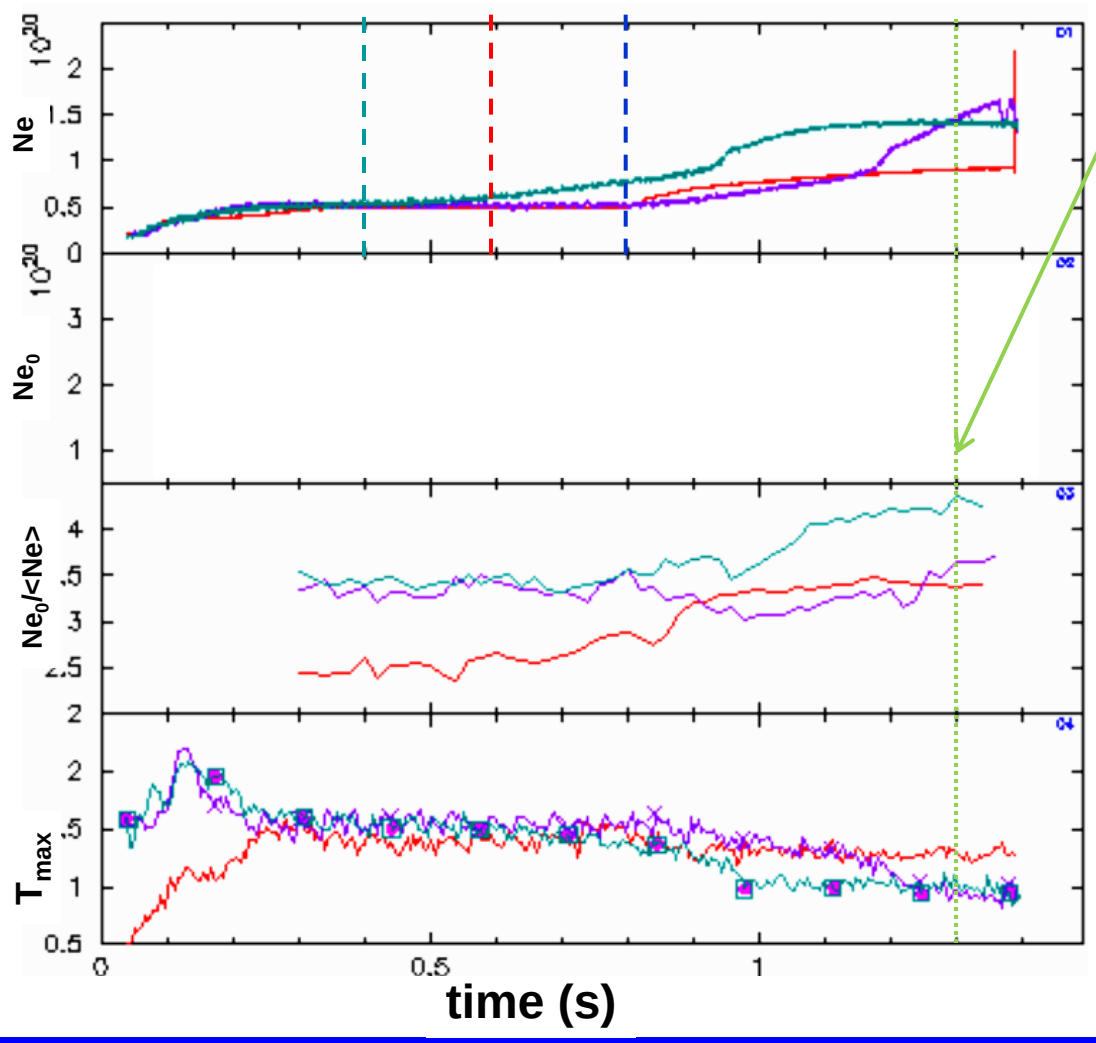
42608 /C
%E SIDLVR(1 14,0,2)
DLin(2t·1.13999)

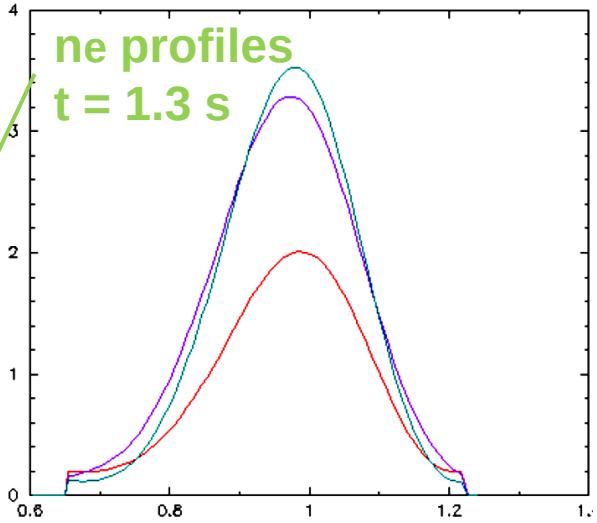
42608 /D
%E.SIDLVR(1.14,0,1)
DLin(1t:1.14005)

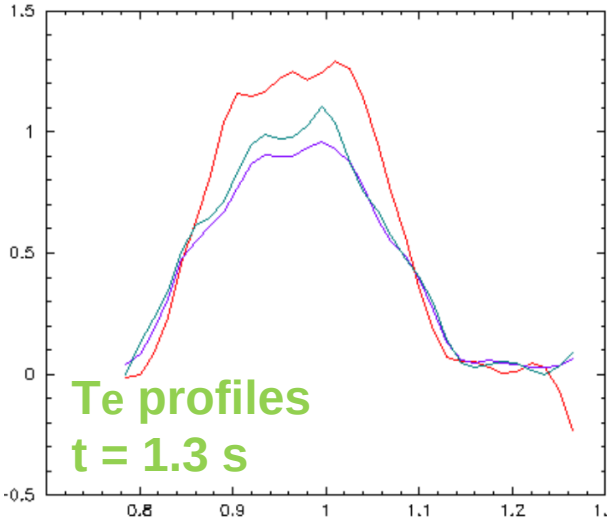
42608 /E
%E.SIDLVR(1.15,0,1)

Helium vs Neon Ne and Te profiles at 360 kA

#37342 Neon at 0.6s
#42724 Helium at 0.4s
#42607 Helium at 0.8s



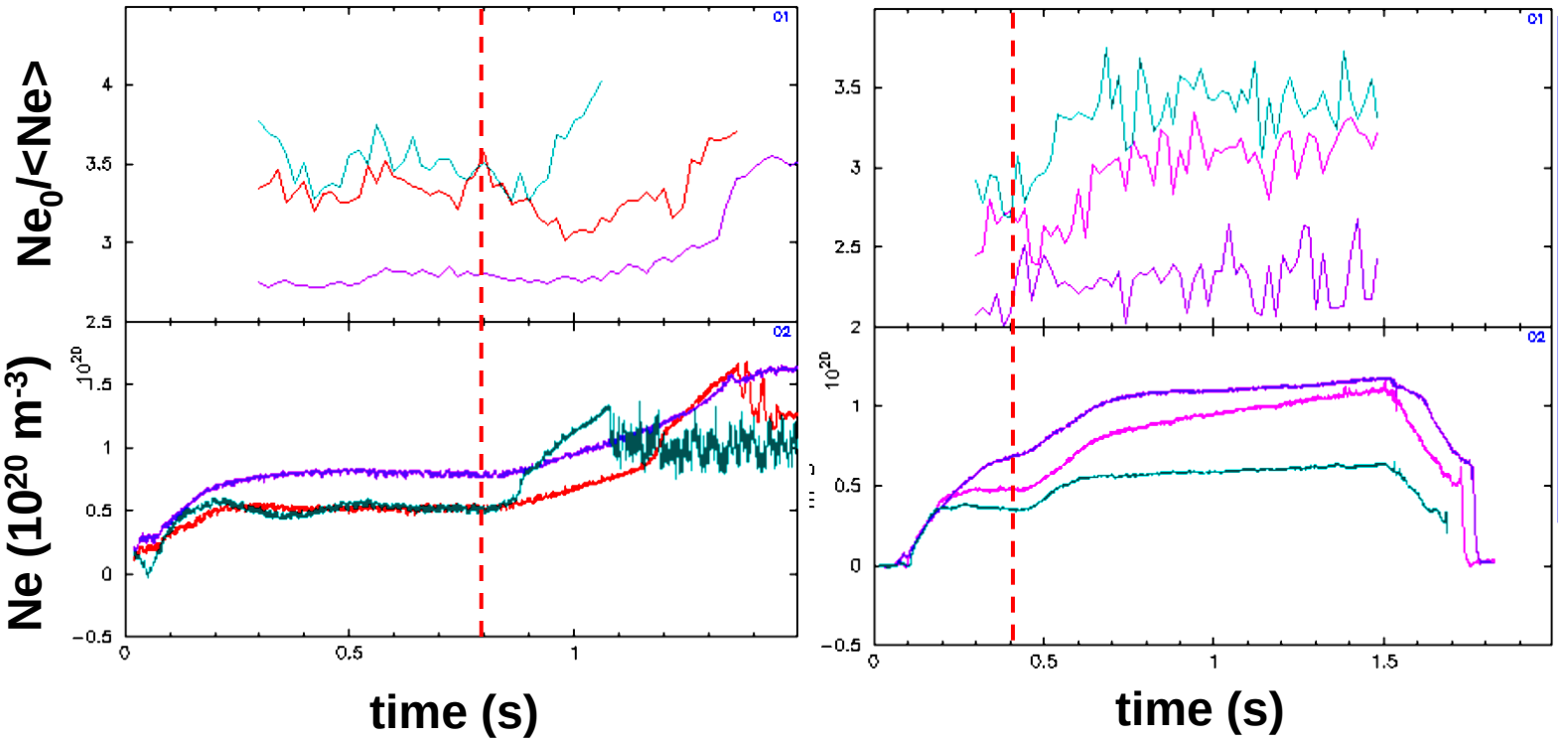




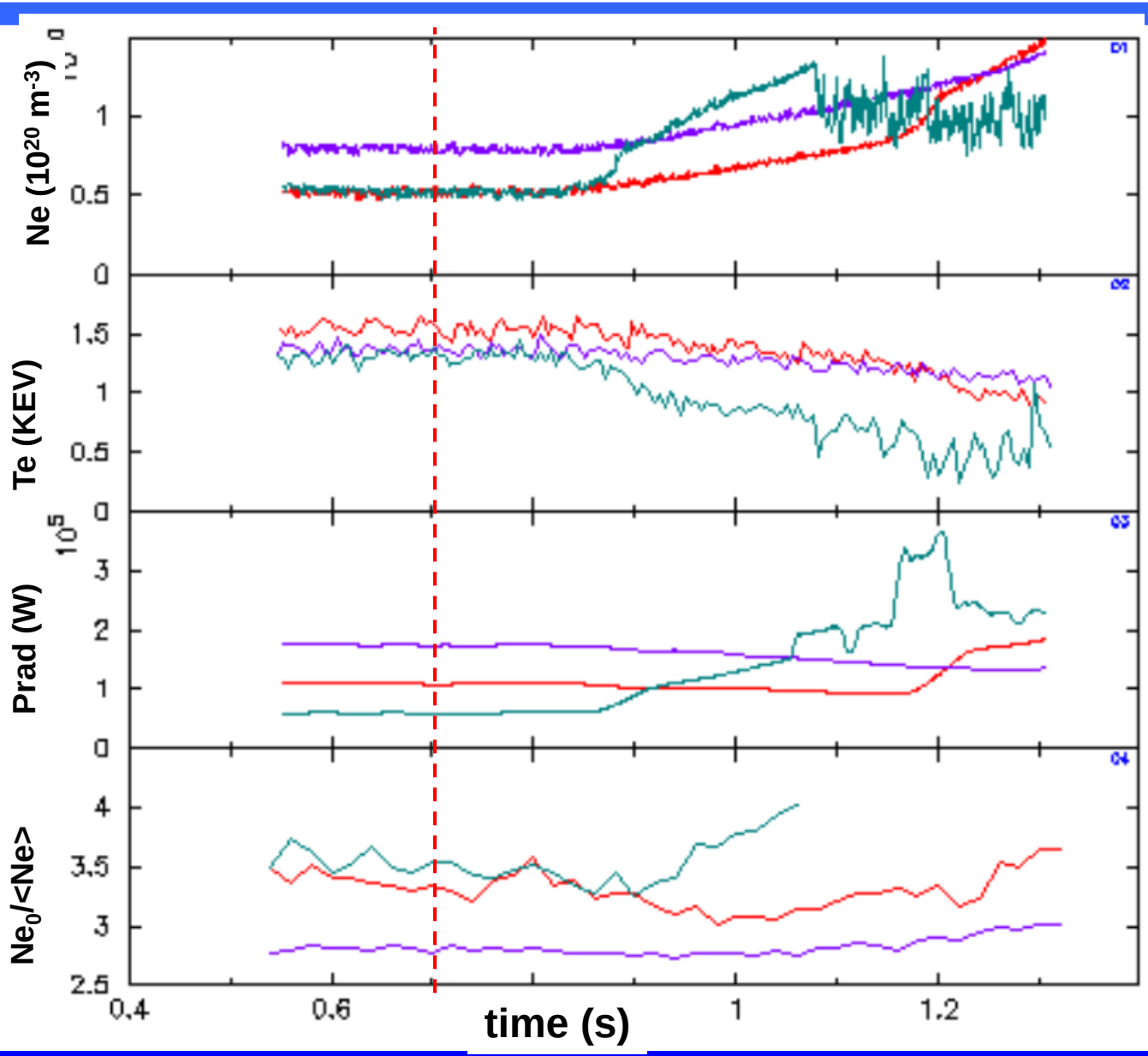
Current scan

#42608 250 kA
#42607 360 kA
#42609 500 kA

#43334 250 kA
#43336 360 kA
#43337 500 kA



Current scan

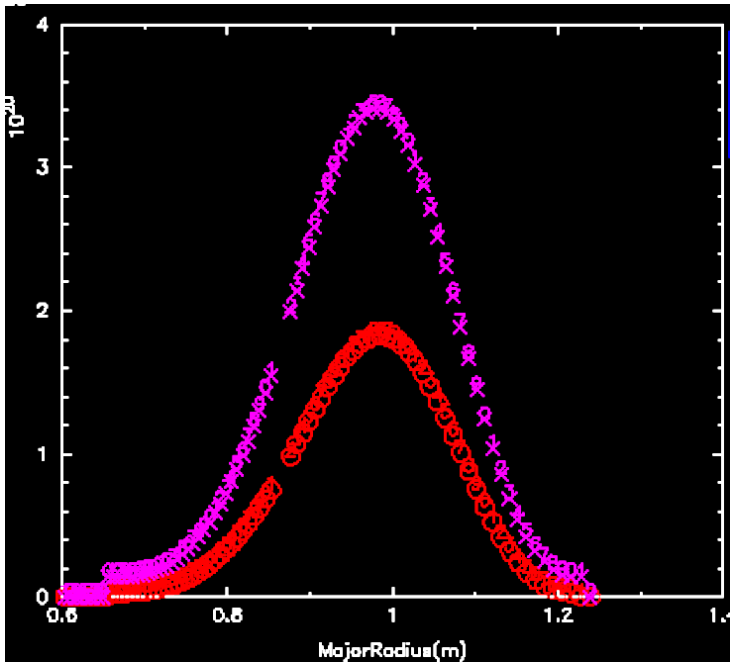


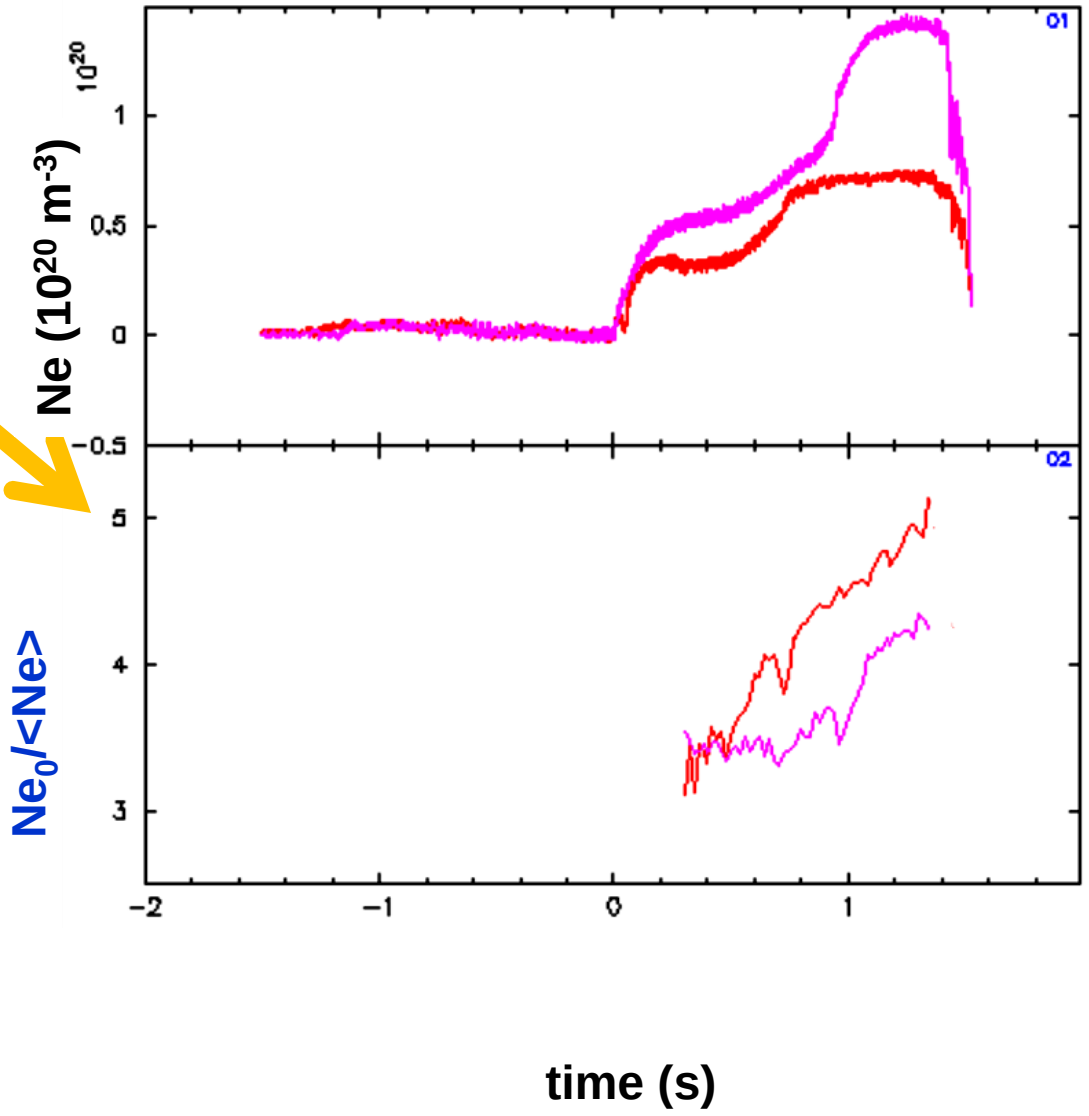
#42608 250 kA
#42607 360 kA
#42609 500 kA

Profiles: current scan and peaking record

#42723 I = 250 kA He at 0.4s
#42724 I = 360 kA He at 0.4s

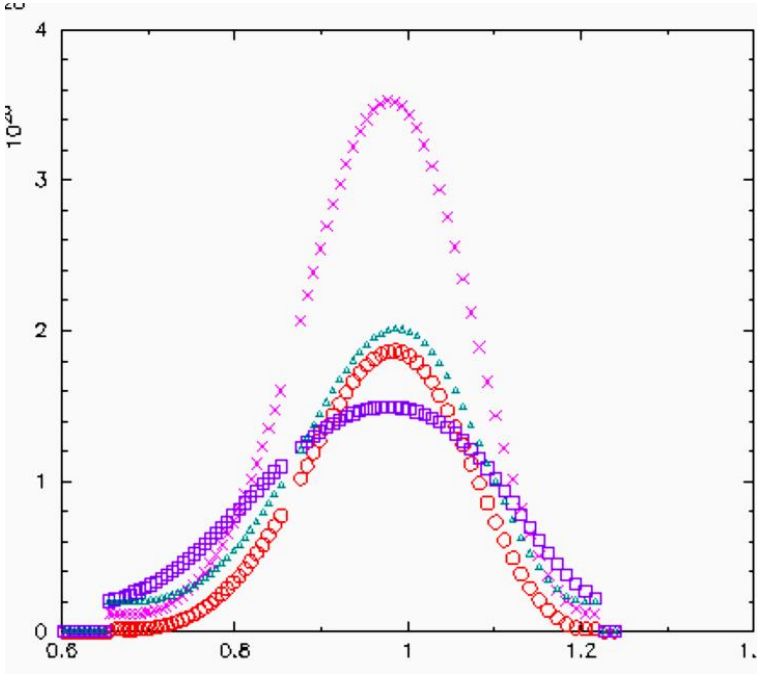
Please note peaking value

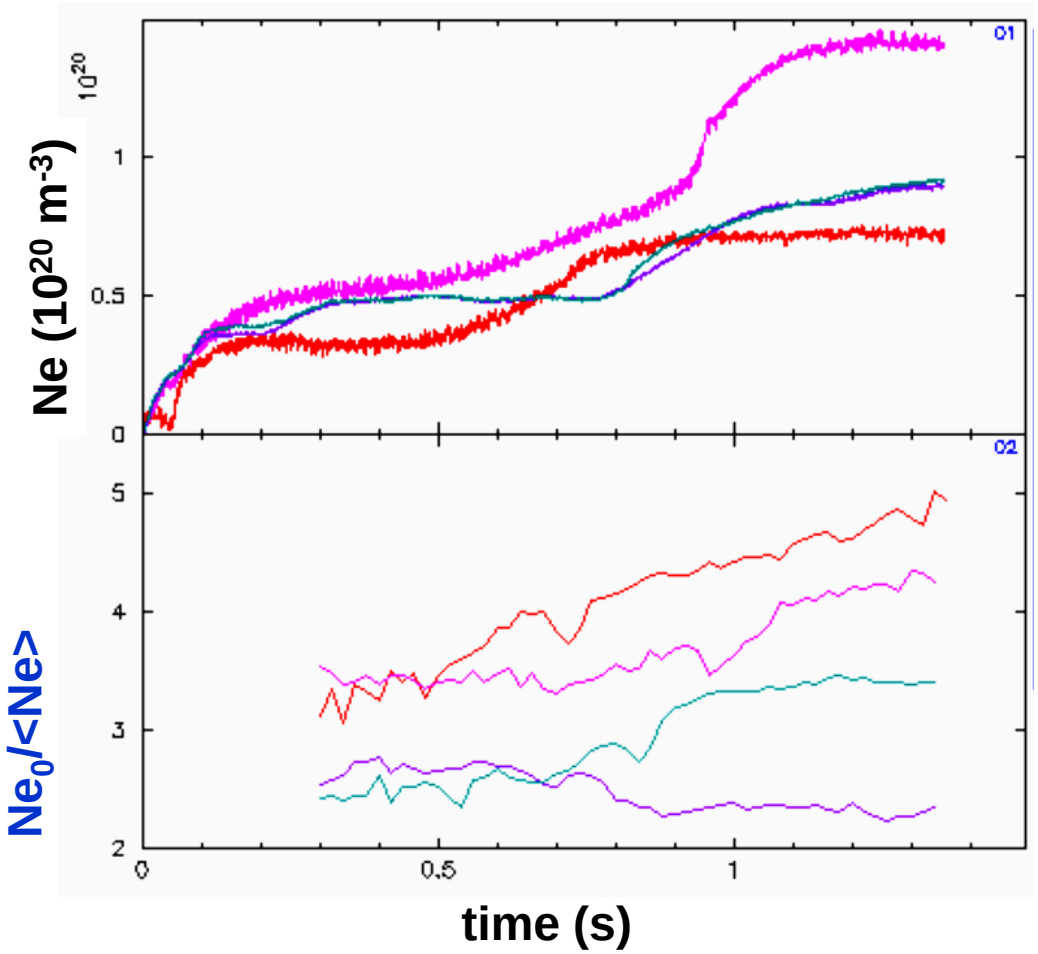




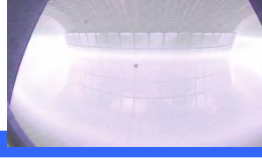
Peaking record

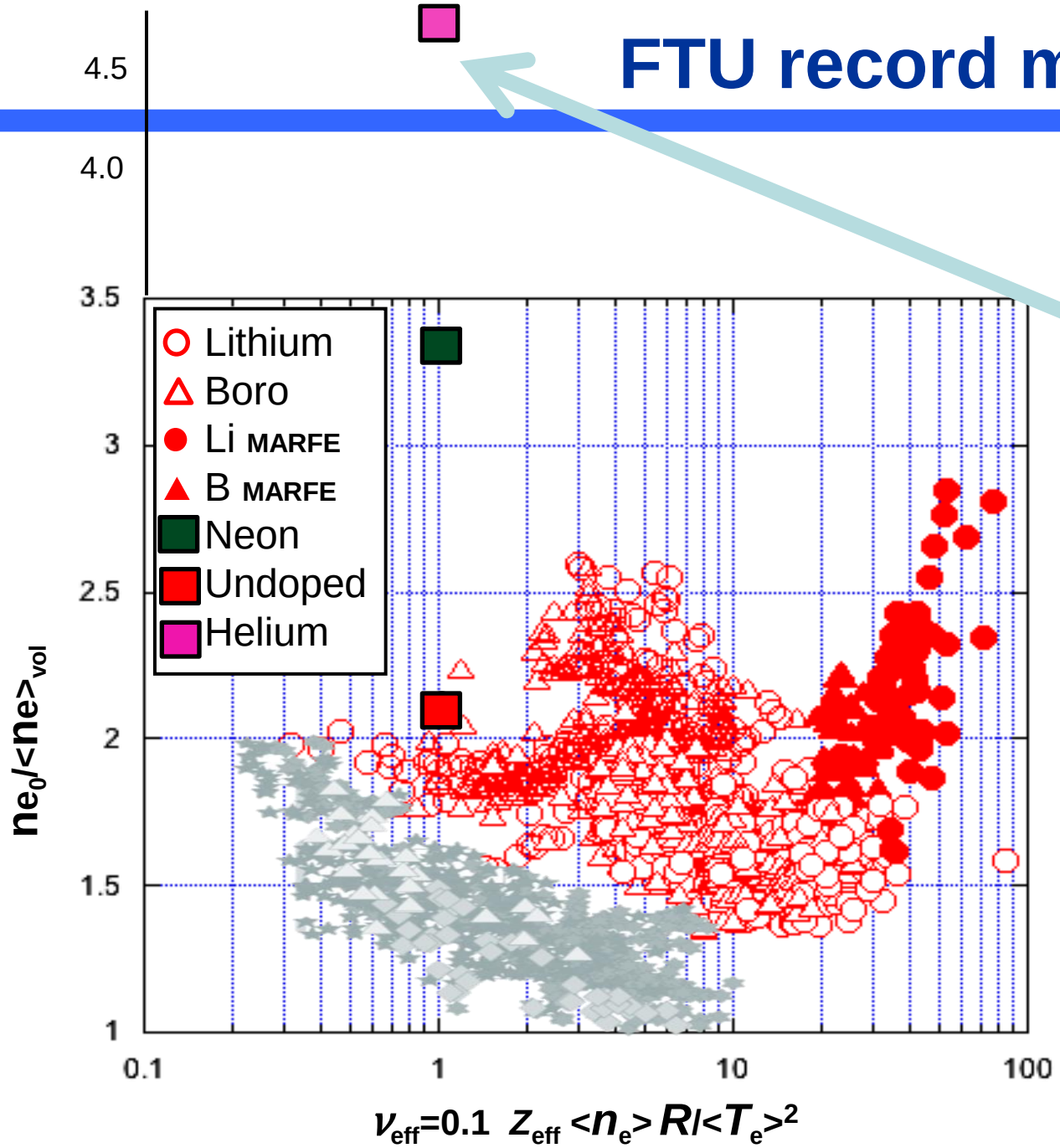
#42723 I = 250 kA He at 0.4s
#42724 I = 360 kA He at 0.4s
#37344 I = 360 kA No doping
#37342 I = 360 kA Ne at 0.6s





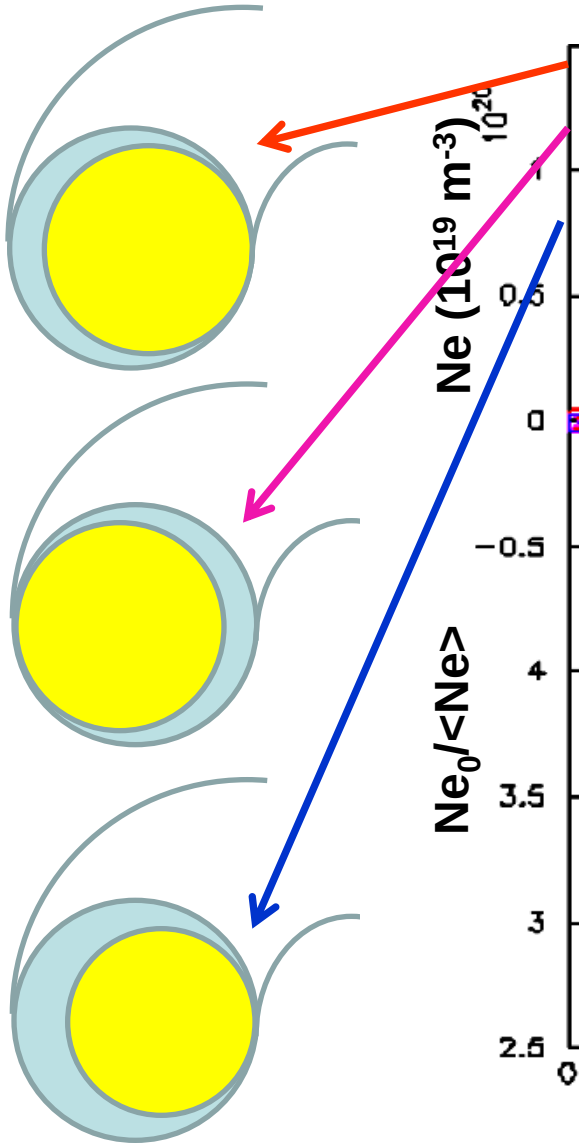
FTU record machine

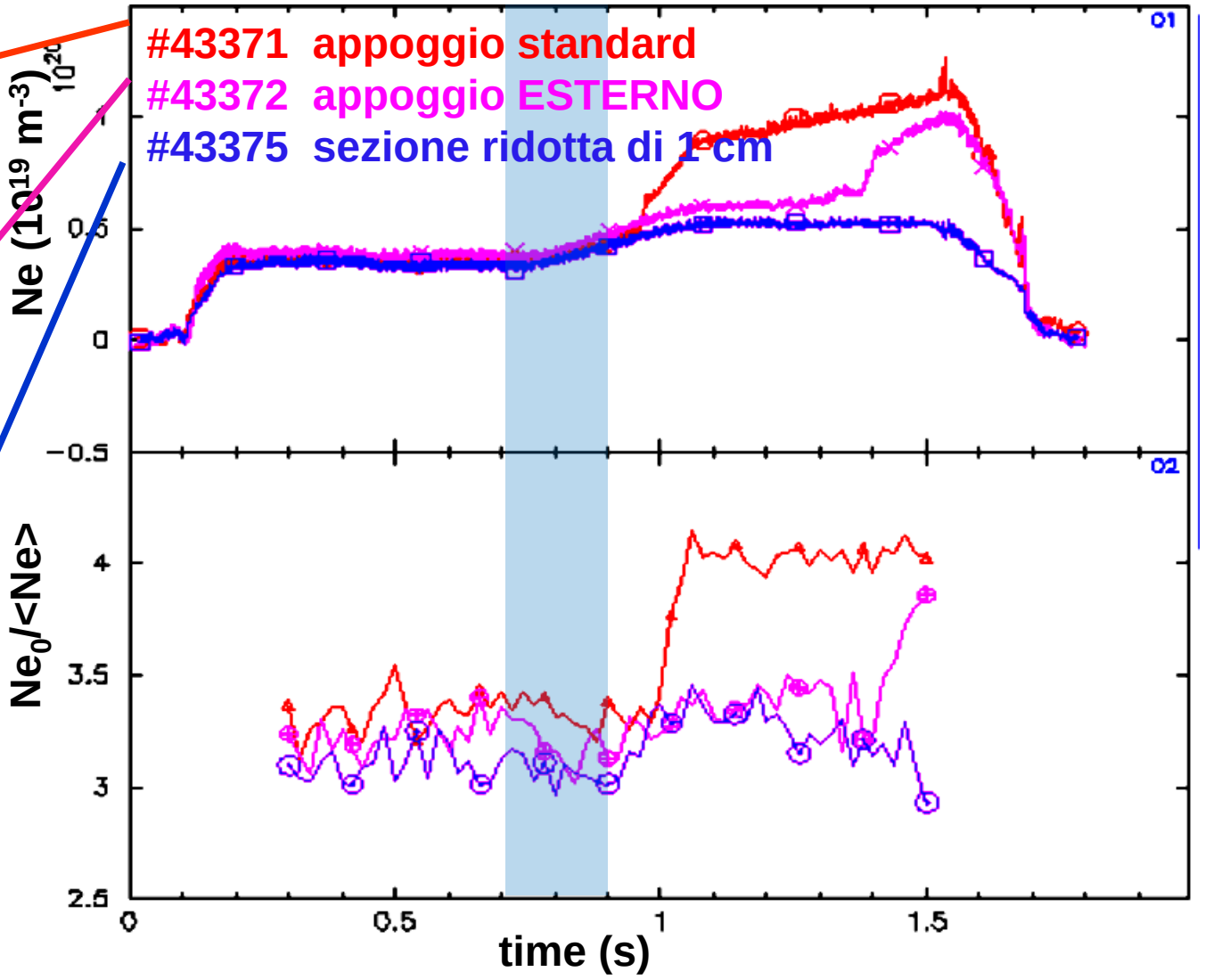




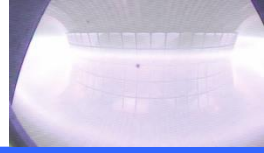
42723 Helium doped 250 kA

Edge effect



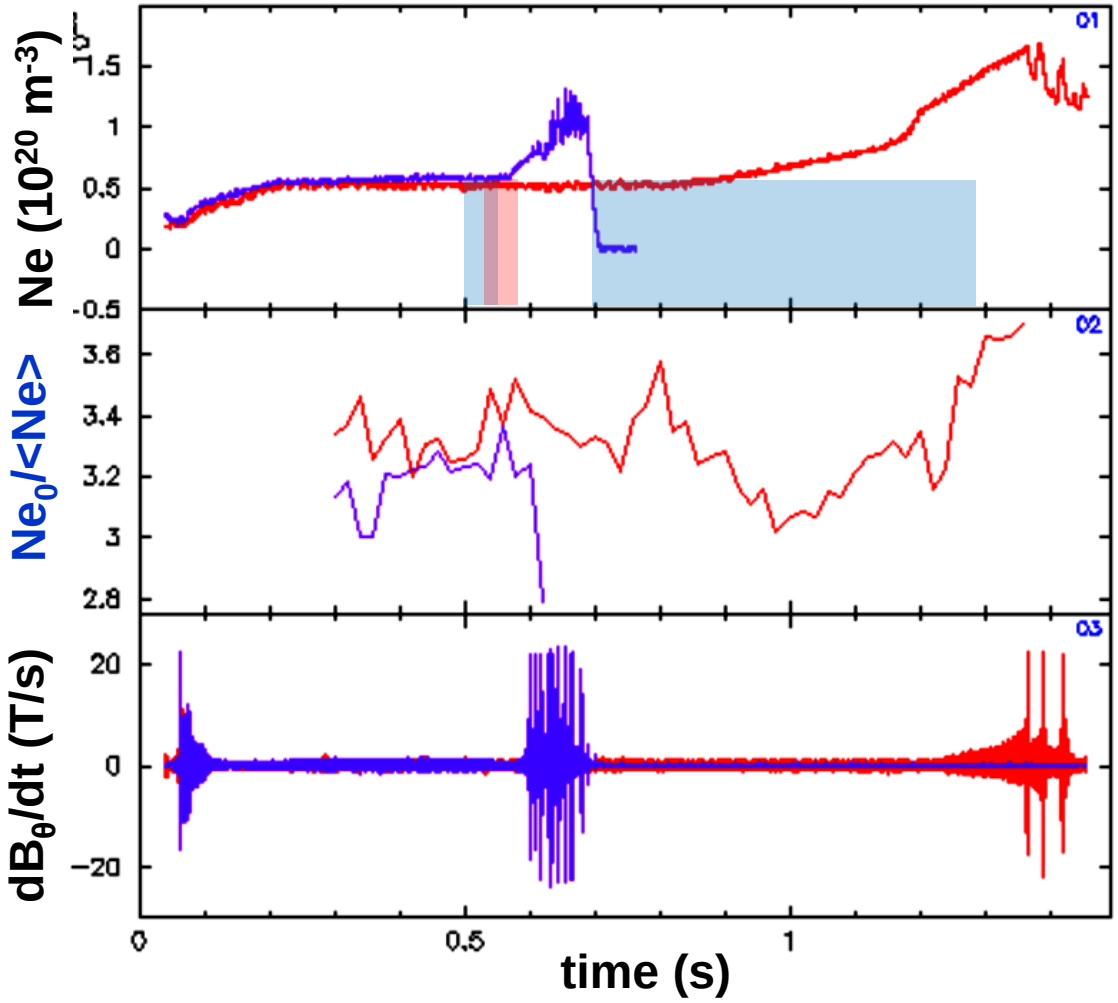

#43371 appoggio standard
#43372 appoggio ESTERNO
#43375 sezione ridotta di 1 cm
Ne (10^19 m^-3)
10^20
1
0.5
0
-0.5
01
02
Ne0/<Ne>
4
3.5
3
2.5
0
0.5
1
1.5
time (s)

Combined doping He+Ne



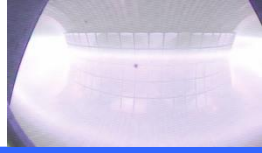
#42607 I = 360 kA Helium at 0.7s

#42610 I = 360 kA Helium+Neon at 0.5s



- As foreseen the MHD activity triggered by Neon is higher.
- This pulse must be repeat injecting less Helium and delay Neon injection.
- We cannot say if the record of maximum peaking can be reached with combined doping or Helium alone.

Conlusions

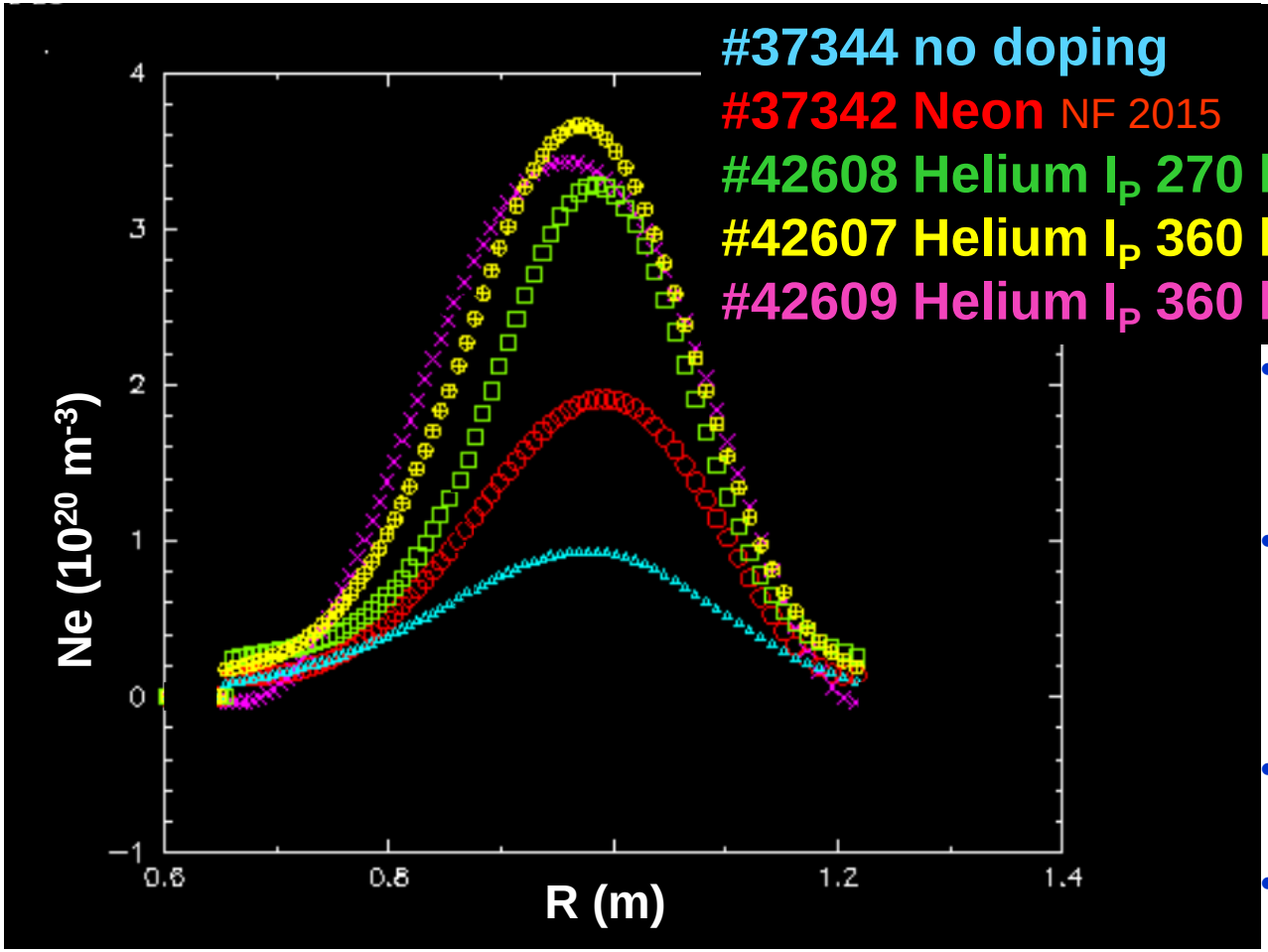


- The Helium doping provokes spontaneous peaking, some performances are better than Neon ones.
- The Helium amount as well as the growth rate of the injection influence the density rise, radiation etc.
- The current scan, as expected, highlight best peroformances at low currents.
- The collisionality vs peaking data are extended.
- The edge (wall) affects the behaviour.

Work in progress

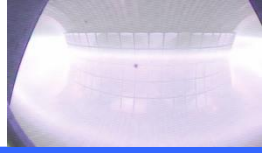
- The spectroscopy have to be assess
- The instabilities can be more investigated
- The edge role is evident but not completely clear
- Helium vs Neon and combined pulse can be added
- The transport analysis by JETTO will add more results to reveal the effect on particle transport.

Peaking record



- In respect of experiments with Neon alone higher peaking was reached.
- In particular the maximum peaking, as expected, was reached by the discharge at lower current.
- It worths to have more discharges (see last slide).
- To obtain a record of peaking must be tuned the amount of Helium and its speed of injection

Timetable pulses: session 3 April



- Due to a technical problem only late session (first program pulse at 16:30)
- All pulses (7) at 5.4 B_T

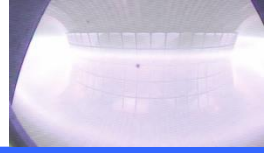
Pulse	I_P	T_e	n_e	Ne t	He t - dp	MHD t	n_e max	Comments
42604	0.36	1.4	0.50		0.50 - 17			Ok – effetto limitato su segnali globali, la riga a 303A si vede bene su MCP e rimane costante fino a fine scarica.
42605	0.36	1.9	0.35		0.70 - 50			OK – densità sale, temperatura scende, nessun MHD
42606	0.36	1.6	0.35		0.77 - 11			Sparo OK, ma la valvola non si è aperta propriamente, solo 11 mbar erogati rispetto ai 100 richiesti
42607	0.36	1.55	0.5		0.77-100	1.20	1.55	OK – rompe per MHD con soft stop
42608	0.25	1.3	0.5		0.77-100	0.98	3.0	OK – rompe per MHD
42609	0.50	1.4	0.8		0.77-100	-----	1.7	OK – non rompe
42610	0.36	1.4	0.6	0.5	0.50-100		1.0	Rompe a 0.65 s per Ne+He : errore di programmazione valvole

Helium amount scan

Current scan

Add Ne and change inj time

Ne and Te profiles Helium vs Neon



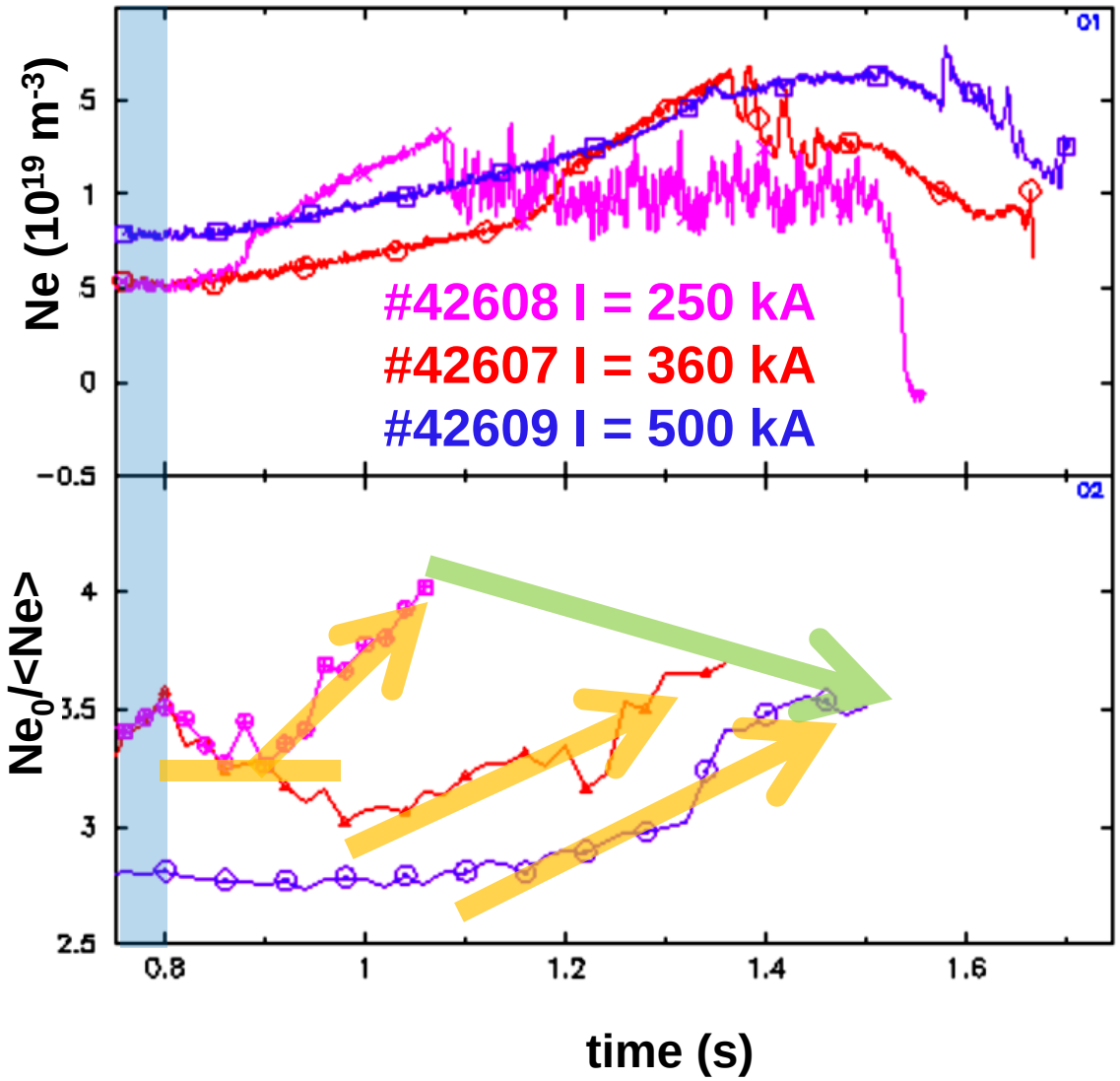
#42608 250 kA
#42607 360 kA
#42609 500 kA

$Ne_0/<Ne>$

Ne (10^{20} m^{-3})

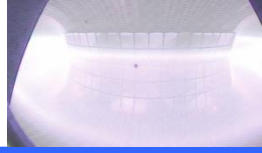
time (s)

Current scan



- The growth rates of the peaking seems decrease with I_P if the referring density is the same (250-360 kA)
- But, If the starting density is less high the peaking steep is the same between 360 and 500 kA, as in the previous amount scan.
- Again we cannot say if the behavior is the same if the pulse was cleaned before with a recovery pulse
- The maximum peaking reachable decrease with the current?

Impurity Injections



Background

- The particle confinement increase due to light and medium impurity injection; FTU, in respect of other MST has shown a better response to doped plasma .
- The effect of Neon (campaigns 2011-2013) and Lithium (since 2009) on density peaking has been explored under different plasma conditions; It has been shown an improved particle confinement, achieved by Neon impurity seeding (IAEA 2014 contribution and more).
- Textor experiment has added Helium combining this with Neon one, reaching an impressive density peaking (Razomova 2017 and Kirneva 2015-2017).

Goals

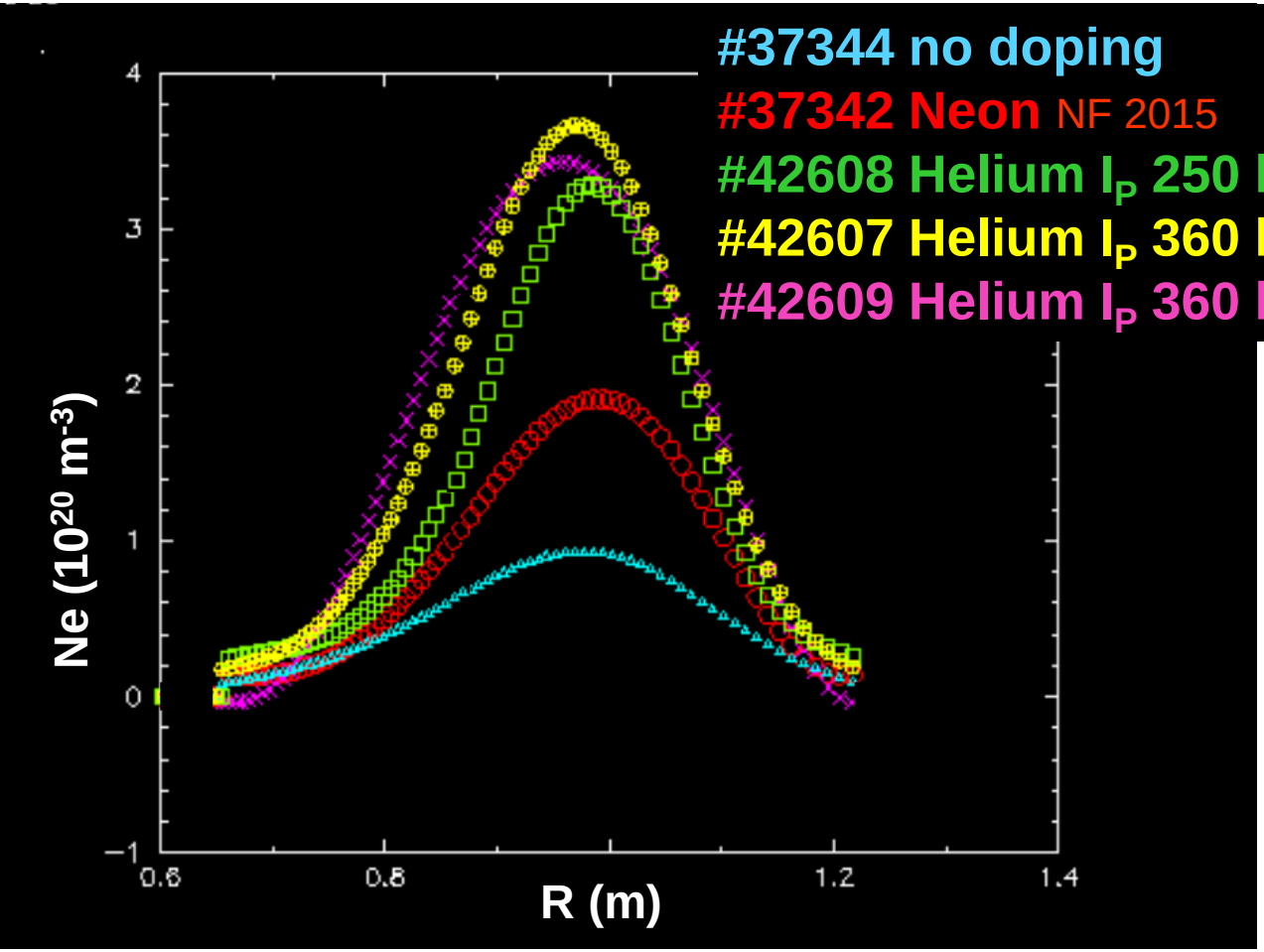
- Understand the transport mechanism that leads to spontaneous density peaking when plasma is doped by Neon and Helium.
- Characterization of doped plasma in order to set the parametric dependence in: q, density and peaking, collisionality, amount of impurity and species.
- Achieve a well high peaking, up to the highest value reaching with doped experiment in MST.
- Explore current dependency. How much the peaking can increase?

Strategy

Helium (Neon) injection in a relevant quantity to obtain strong density peaking, seen by interferometry and all the other diagnostics.

- Amount He scan
- Current scan (same He amount)
- Repeat combining doping (Helium + Neon)
- Find maximum density and peaking (record)

Peaking record



$n_{e0}/<n_e>=4$ max peaking

- In respect of experiments with Neon alone higher peaking was reached.
- In particular the maximum peaking, as expected, was reached by the discharge at lower current.
- To obtain a record of peaking must be tuned the amount of Helium and its speed of injection (now: 1 mbar / 6 ms).

Timetable pulses: session 12 April

- Critical target: due to IC1 switch, the length of the pulses was set at 1.35s, so we decided to inject He at 0.4s, but at 250kA we found difficult to obtain a density pleteau bofore the injection (v. next slide)

Pulse	Time	B (T)	Ip (MA)	Te* (keV) (*)	n20 (m-3) (*)	Ne V-t-dp (V-s-mb)	He V-t-dp (V-s-mb)	Comments
42711	9:42							Prova impianti
42712	10:20	5.3						Sparo di zero
42713	10.55	5.3	0.5					Sparo standard – manuale – plasma ok
42714	11:12	5.3	0.25	1.	0.6			Sparo target – densita oscillante – da rifare
42715	11:31	5.3	0.25	1.	0.6			Sparo target – ancora densita oscillante – da rifare
42716	11:48	5.3	0.25	1.	0.5			Sparo target – ancora densita oscillante – da rifare
42717	12:09	5.3	0.25	1	0.5			Sparo target – ancora densita oscillante - si prova con He
42718	12:28	5.3	0.25	1.3	0.35		135-0.4-100	OK per programma
42719	12:59	5.4	0.26	1.5	0.30		135-0.4-100	OK per programma
42720	13:16	5.4	0.26	1.5	0.35		135-0.4-40	OK per programma
42721	13:34	5.4	0.26	1.5	0.31		120-0.4-40	OK per programma
42722	13:58	5.4	0.26	1.5	0.33	90-1.1-5	120-0.4-40	OK per programma
42723	14:20	5.4	0.26	1.5	0.32		120-0.4-25	OK per programma
42724	14:39	5.4	0.38	1.6	0.52		120-0.4-60	OK per programma

lost shot

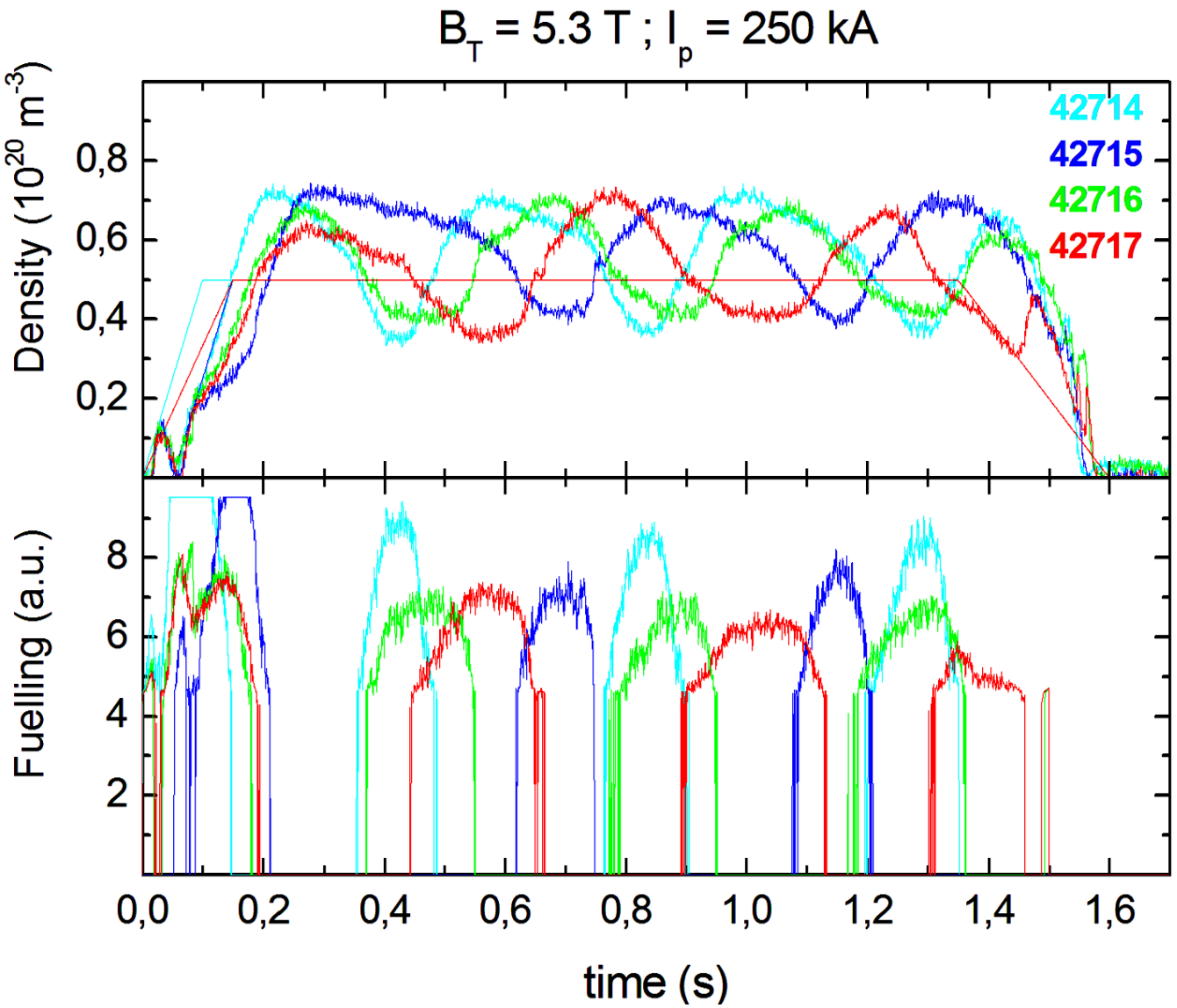
Same behaviour of ref. shot 42608 in term oh He accumulation

He amount scan

360 kA to compare at higher current

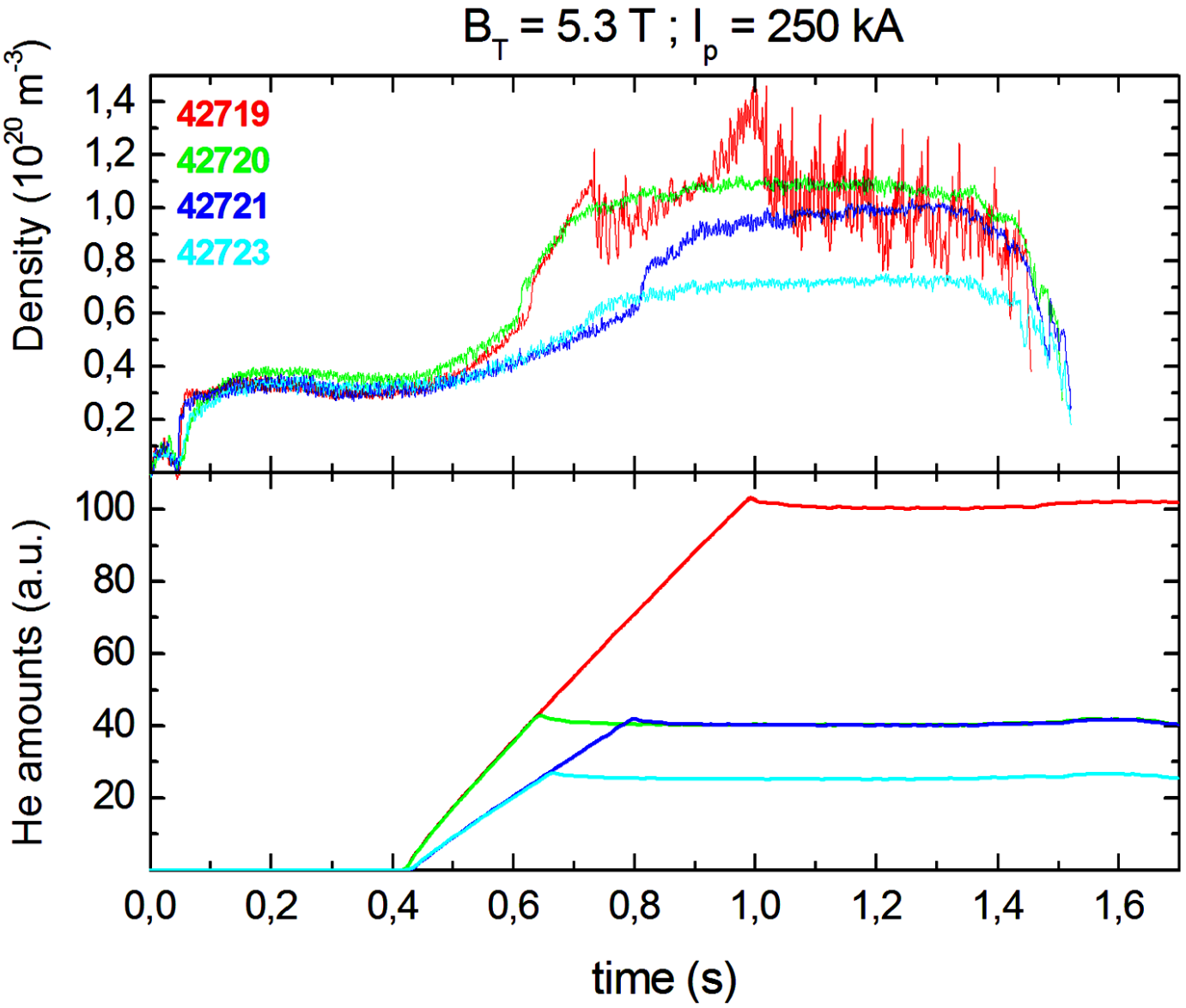
- Helium amount scan both in absolut quantity and in rate of injection
- Only one shot with combined injection Helium + Neon, no relevent result
- Strategy part A completed.

Critical target

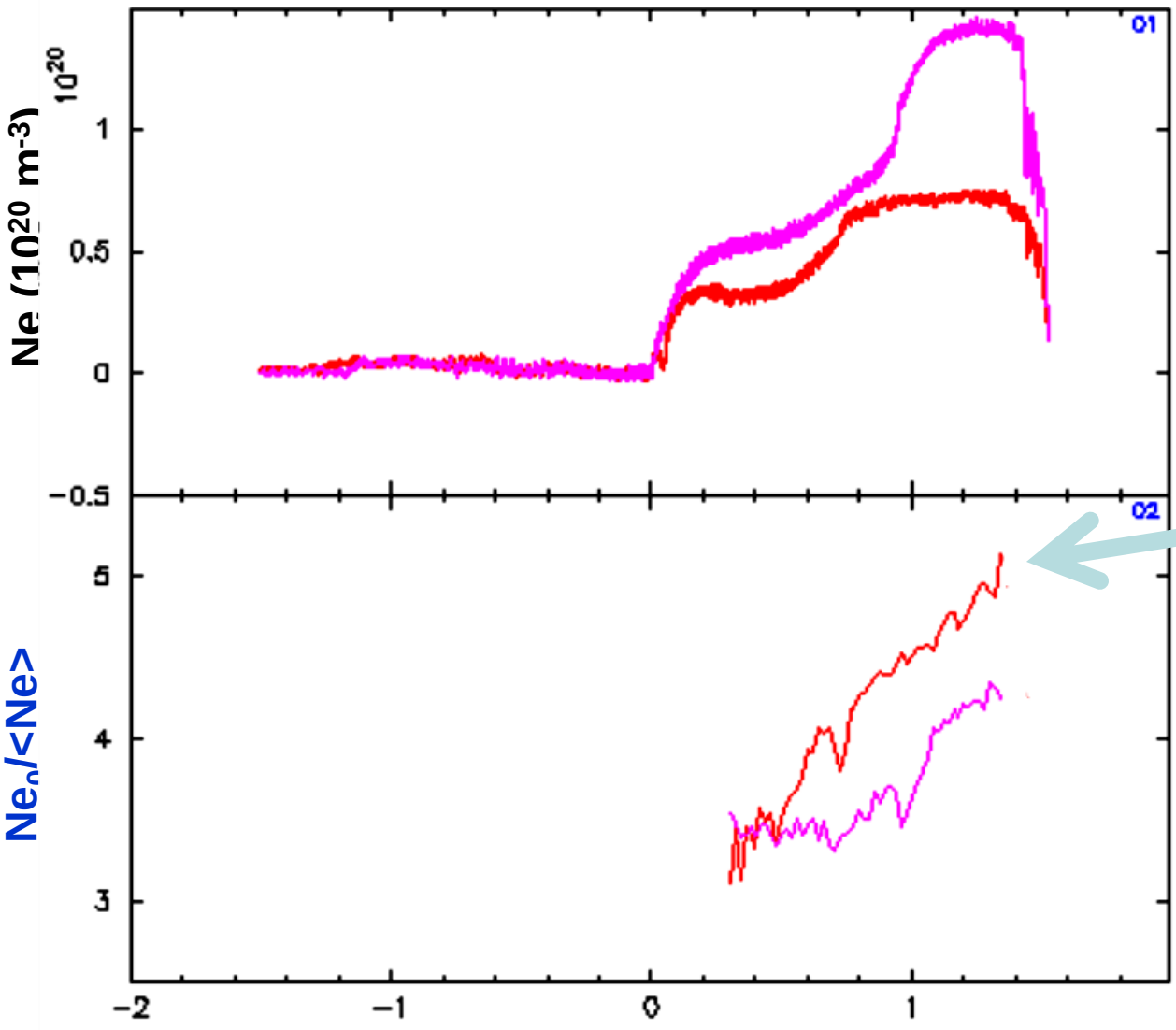


- It's not clear why the pleateau of reference shot was hard to obtain
- We managed on fuelling
- At the end we decided to "surf" on the first oscillation and starting with injection at the end of this.

Helium amount scan



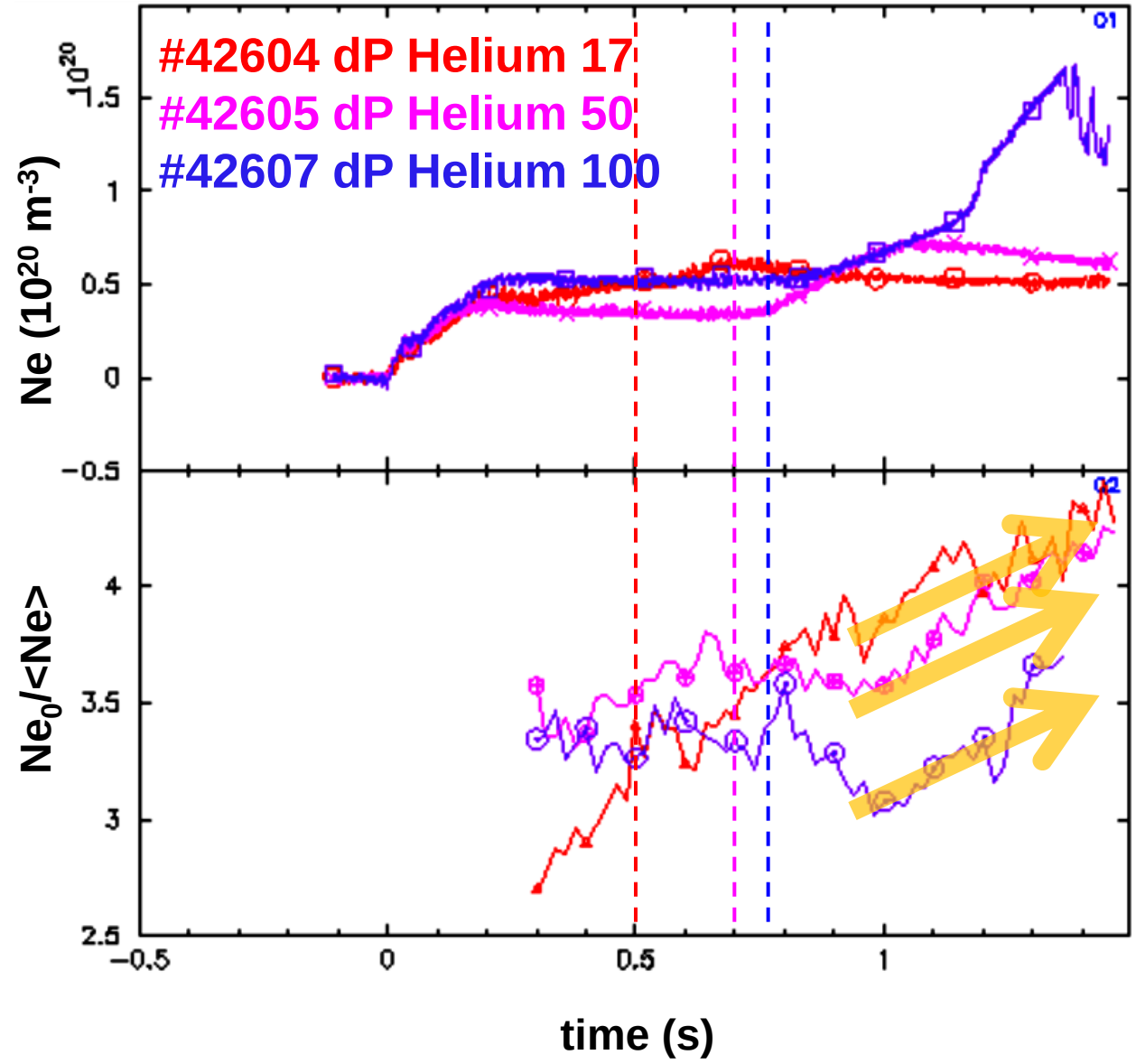
Helium current scan



#42723 I = 250 kA
Helium at 0.4s
#42724 I = 360 kA
Helium at 0.4s

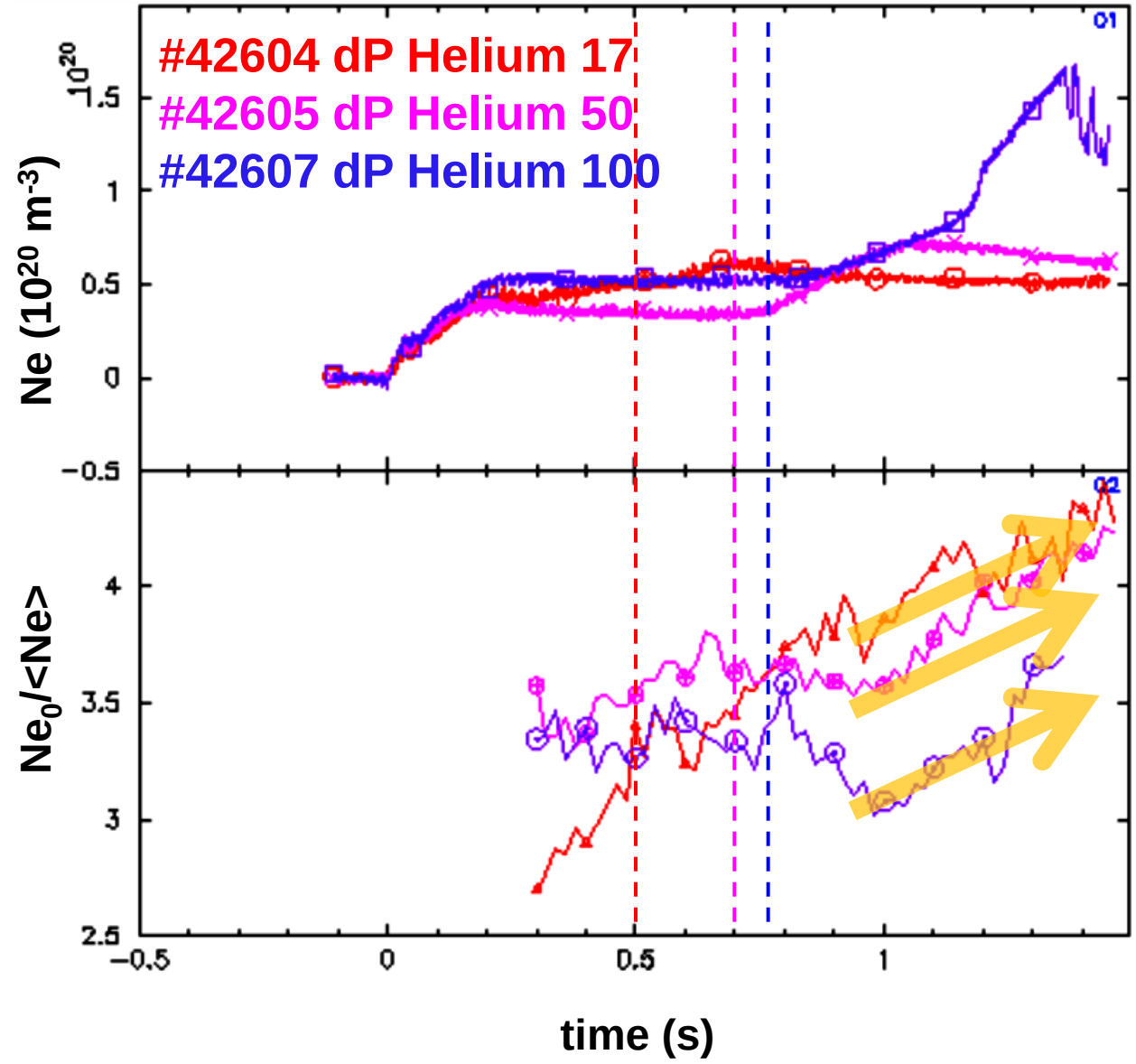
Please note peaking value

He amount scan



- Helium visible from the begininng of the pulse (the machine is contaminated by He).
- We cannot say if the behaviour is the same if the pulse was cleaned before with a recovery pulse.
- The growth rate of the peaking seems the same

He amount scan



- Helium visible from the begininng of the pulse (the machine is contaminated by He).
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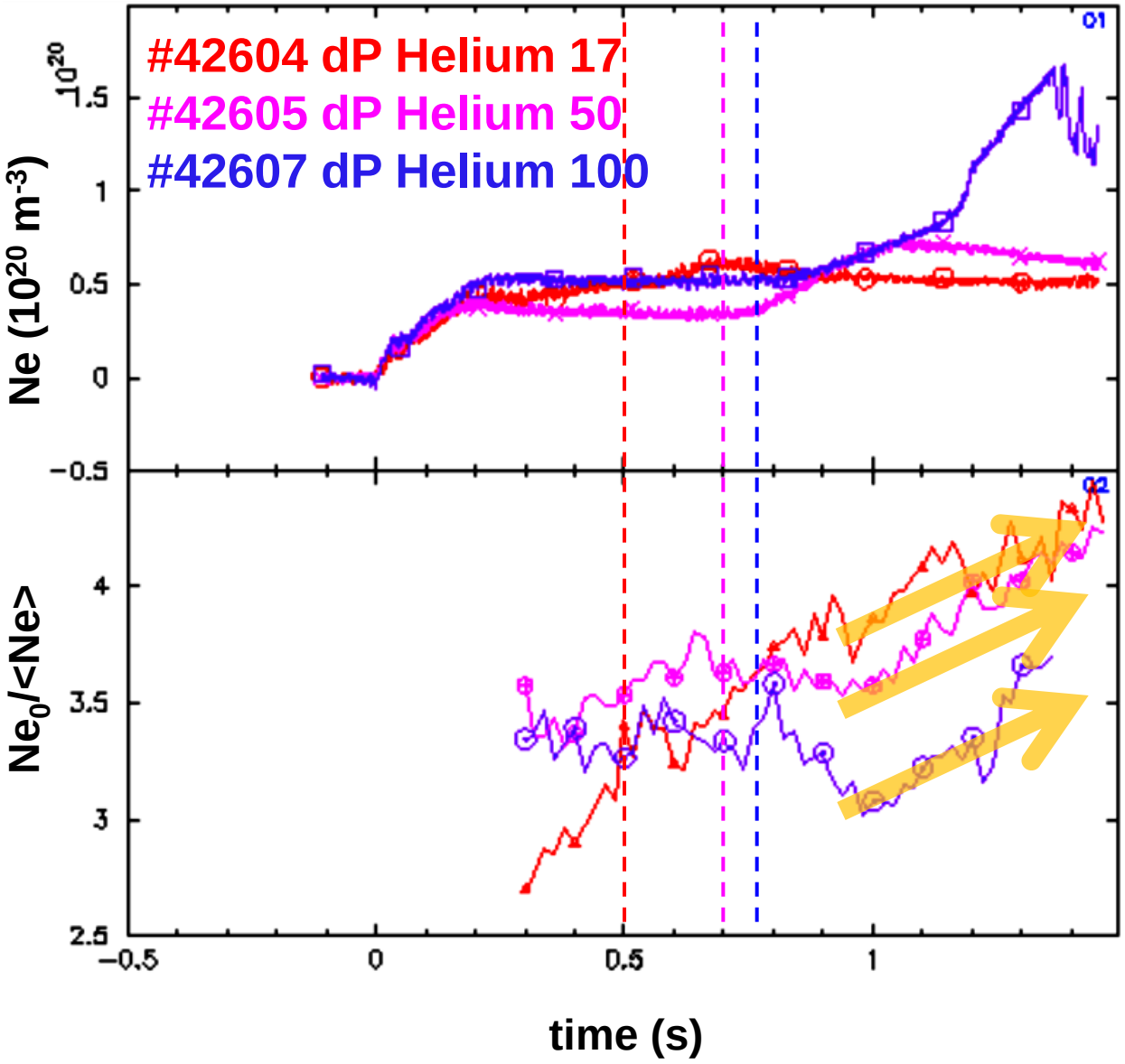
Spectroscopy



- Helium visible from the begininng of the pulse (the machine is contaminated by He).
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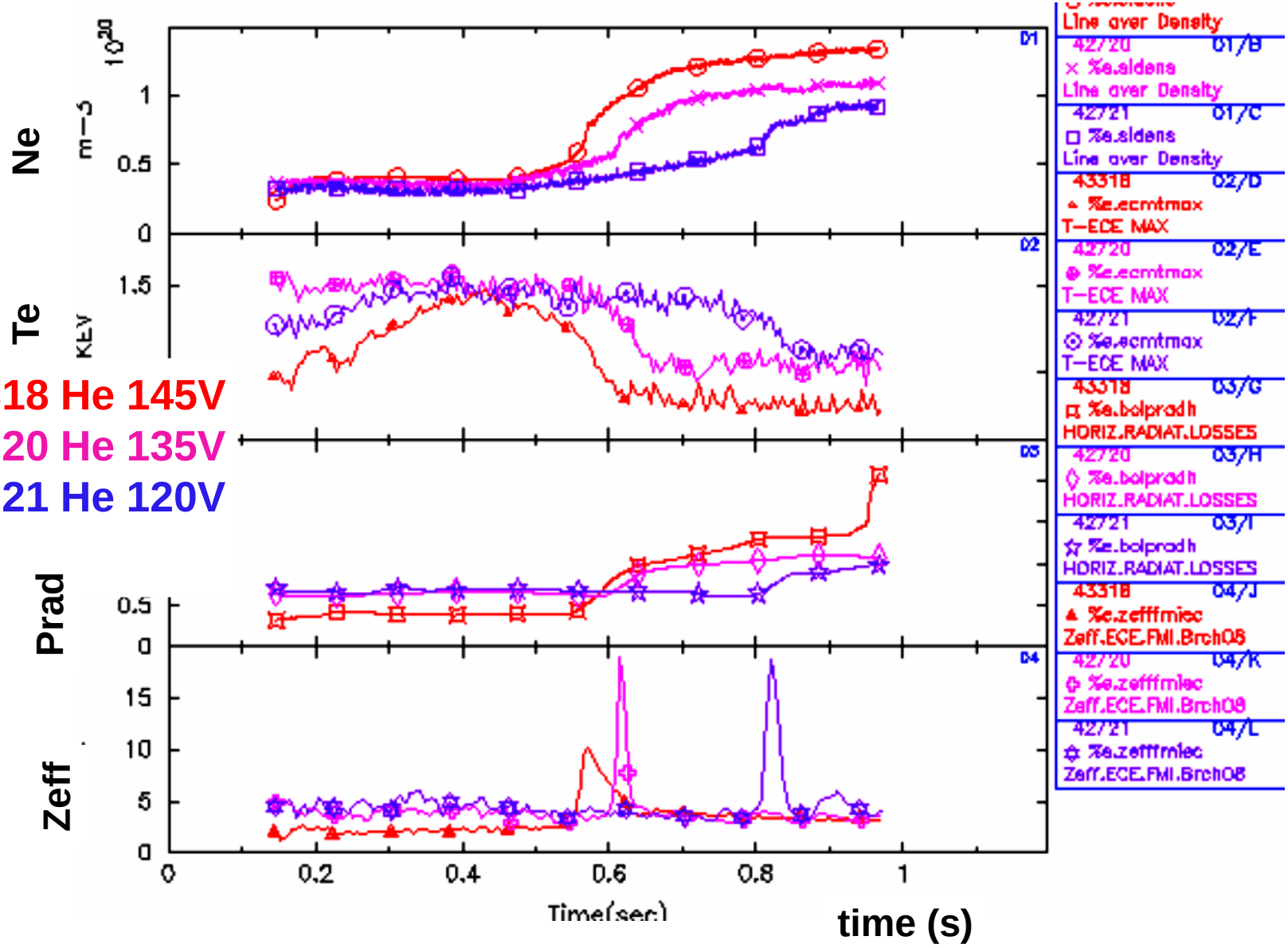
- The growth rate of the peaking seems the same

Helium amount scan & spectroscopy

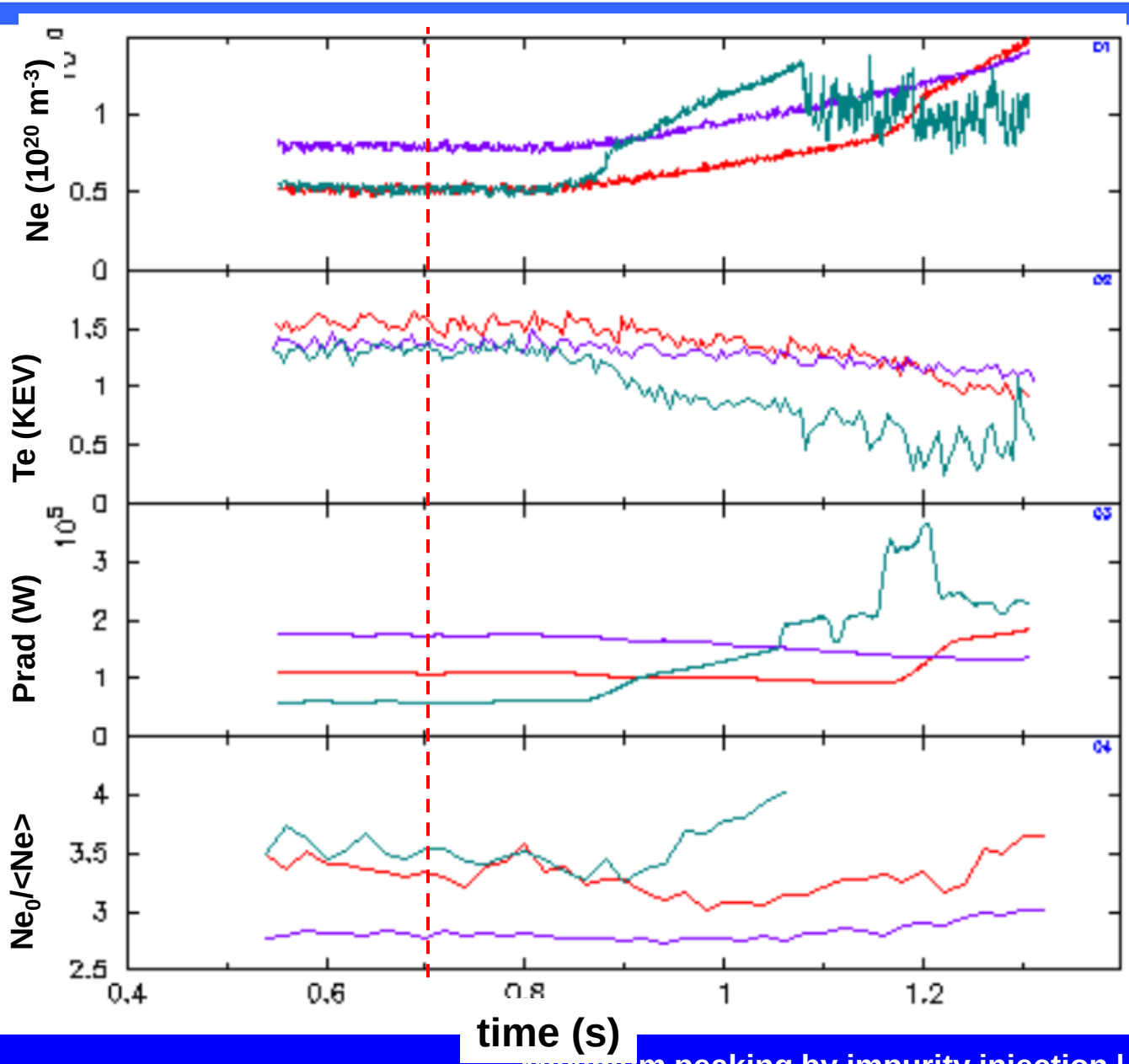


#43318 He 145V

#42720 He 135V

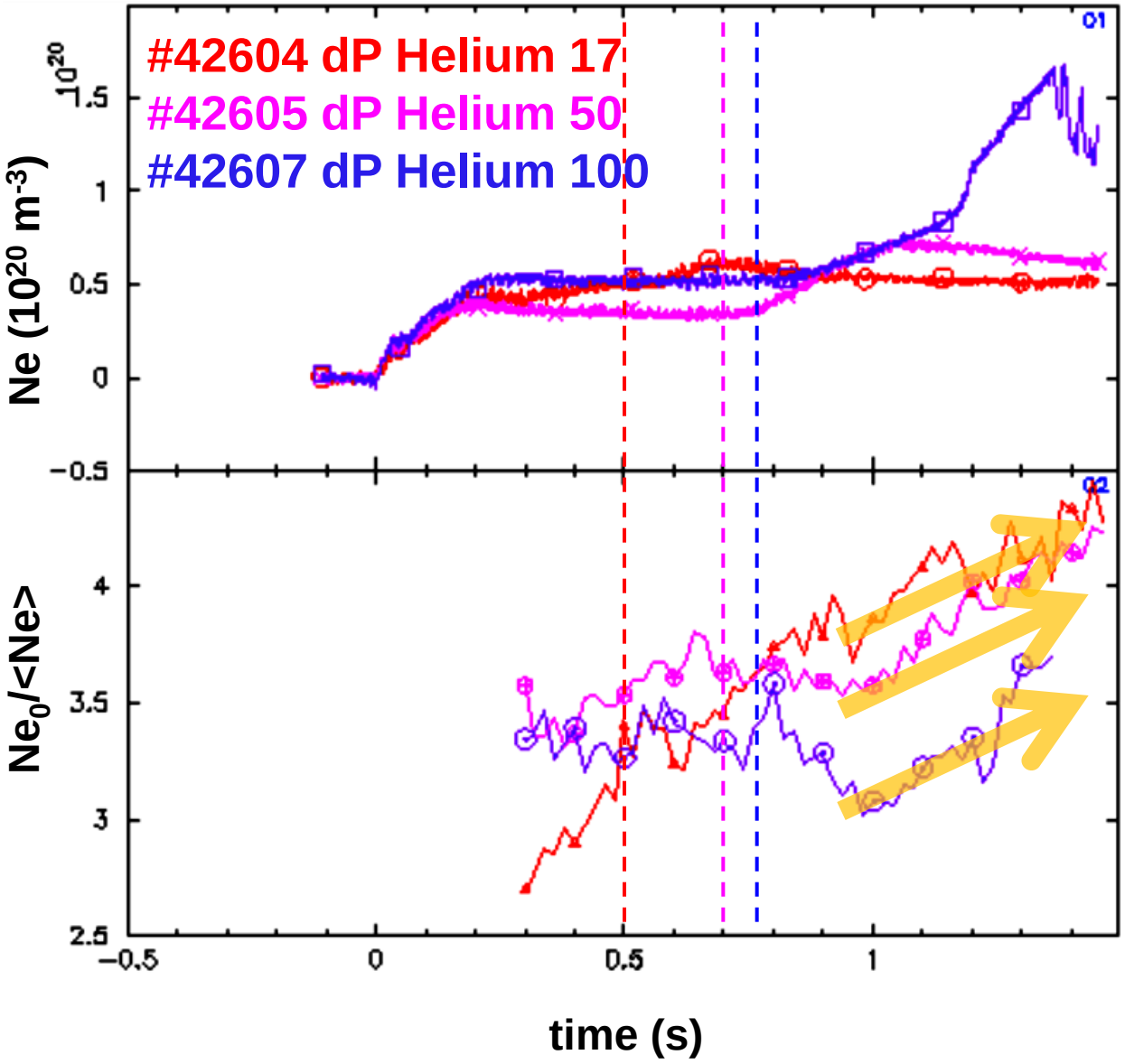
#42721 He 120V

Current scan



#42608 250 kA
#42607 360 kA
#42609 500 kA

Edge effect



- Helium visible from the begininng of the pulse (the machine is contaminated by He).
- We cannot say if the behaviour is the same if the pulse was cleaned before with a recovery pulse.
- The growth rate of the peaking seems the same