

MISK Calculations for F. Poli's ITER cases

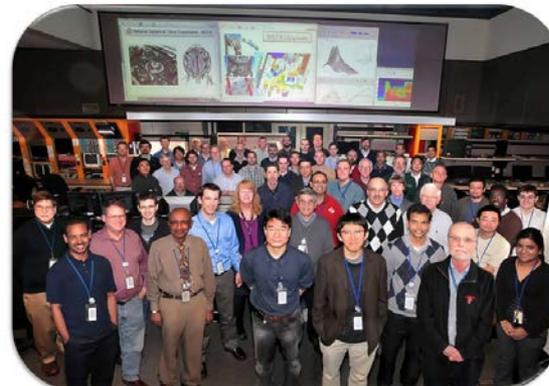
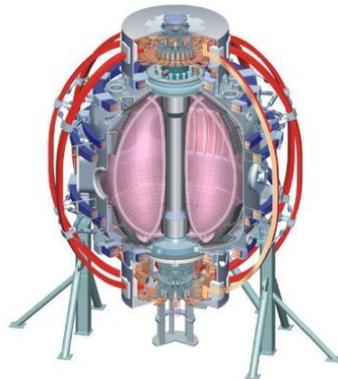
J.W. Berkery

Department of Applied Physics, Columbia University, New York, NY, USA

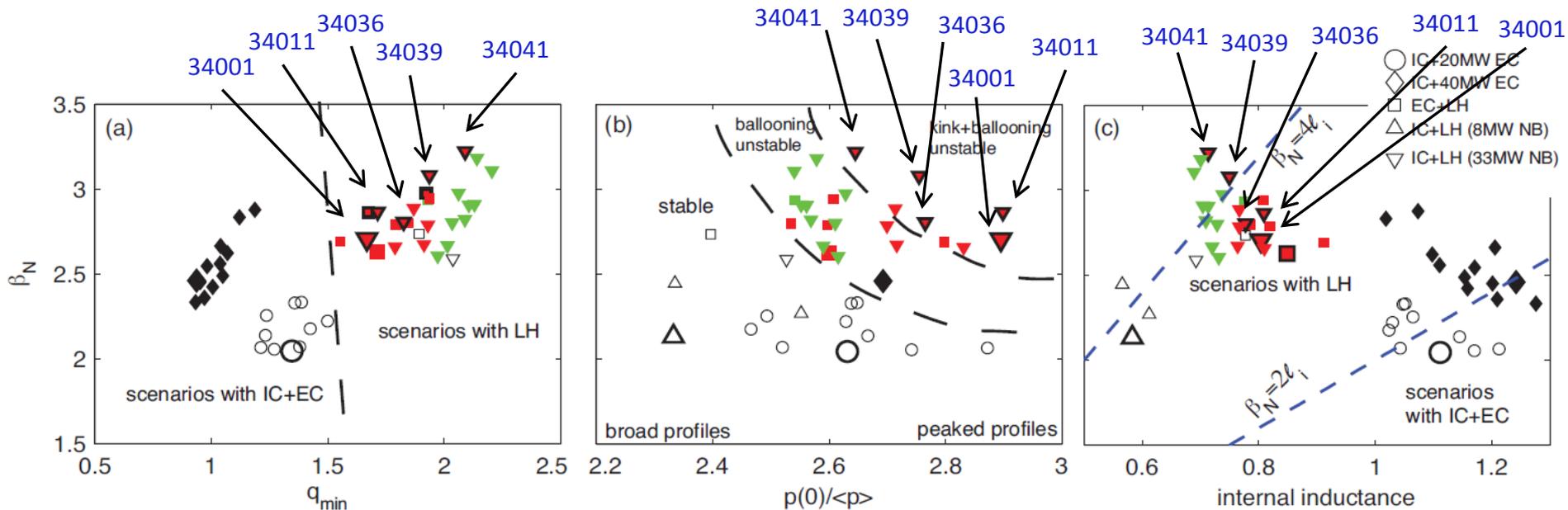
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 Columbia U
 CompX
 General Atomics
 INL
 Johns Hopkins U
 LANL
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 MIT
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 New York U
 Old Dominion U
 ORNL
 PPPL
 PSI
 Princeton U
 Purdue U
 SNL
 Think Tank, Inc.
 UC Davis
 UC Irvine
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 U Maryland
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 U Washington
 U Wisconsin*

*Culham Sci Ctr
 U St. Andrews
 York U
 Chubu U
 Fukui U
 Hiroshima U
 Hyogo U
 Kyoto U
 Kyushu U
 Kyushu Tokai U
 NIFS
 Niigata U
 U Tokyo
 JAEA
 Hebrew U
 Ioffe Inst
 RRC Kurchatov Inst
 TRINITY
 KBSI
 KAIST
 POSTECH
 ASIPP
 ENEA, Frascati
 CEA, Cadarache
 IPP, Jülich
 IPP, Garching
 ASCR, Czech Rep
 U Quebec*

February 17th, 2012



Five ITER discharges with NBI, IC and LH are between the no-wall and with-wall limits



[F. Poli *et al.*, submitted to Nucl. Fusion (2012)]

Five discharges selected

Heating mix: 33MW NBI, 20MW IC, 40MW LH

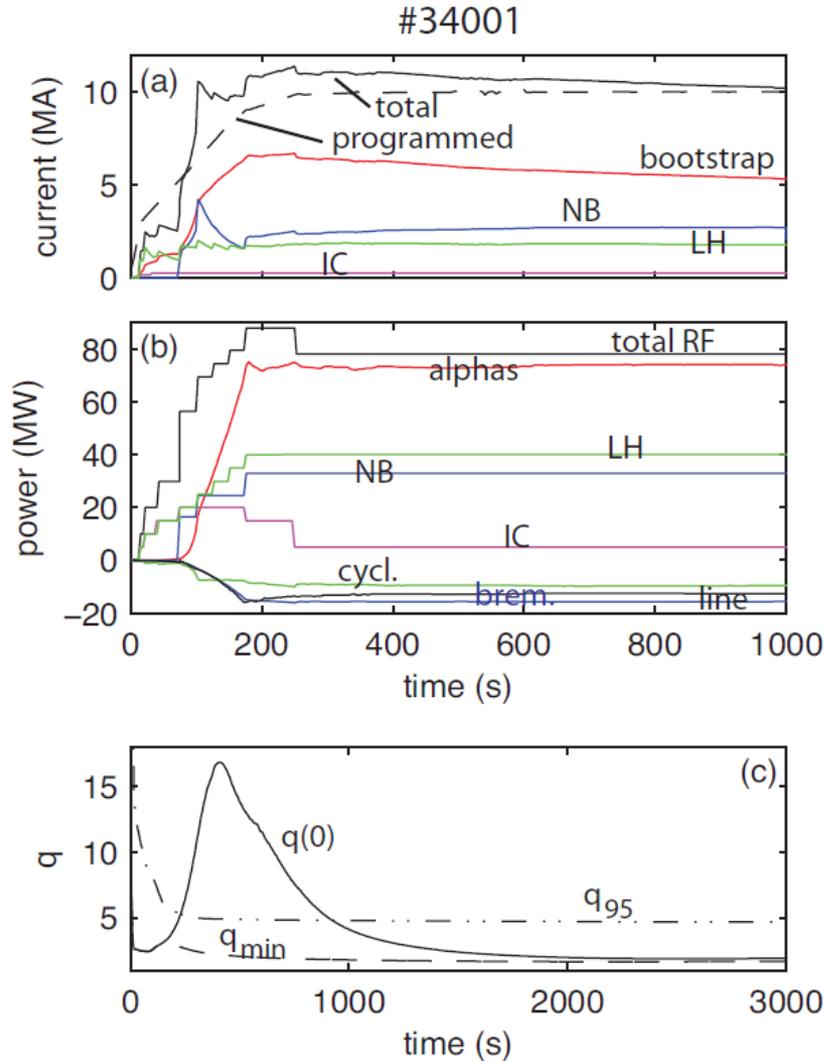
Kink unstable, but stabilized by the wall (between no-wall and with-wall limits)

Notes:

- TRANSP run without rotation
- n_i is split between 50% deuterium and 50% tritium
- All at time = 2500s

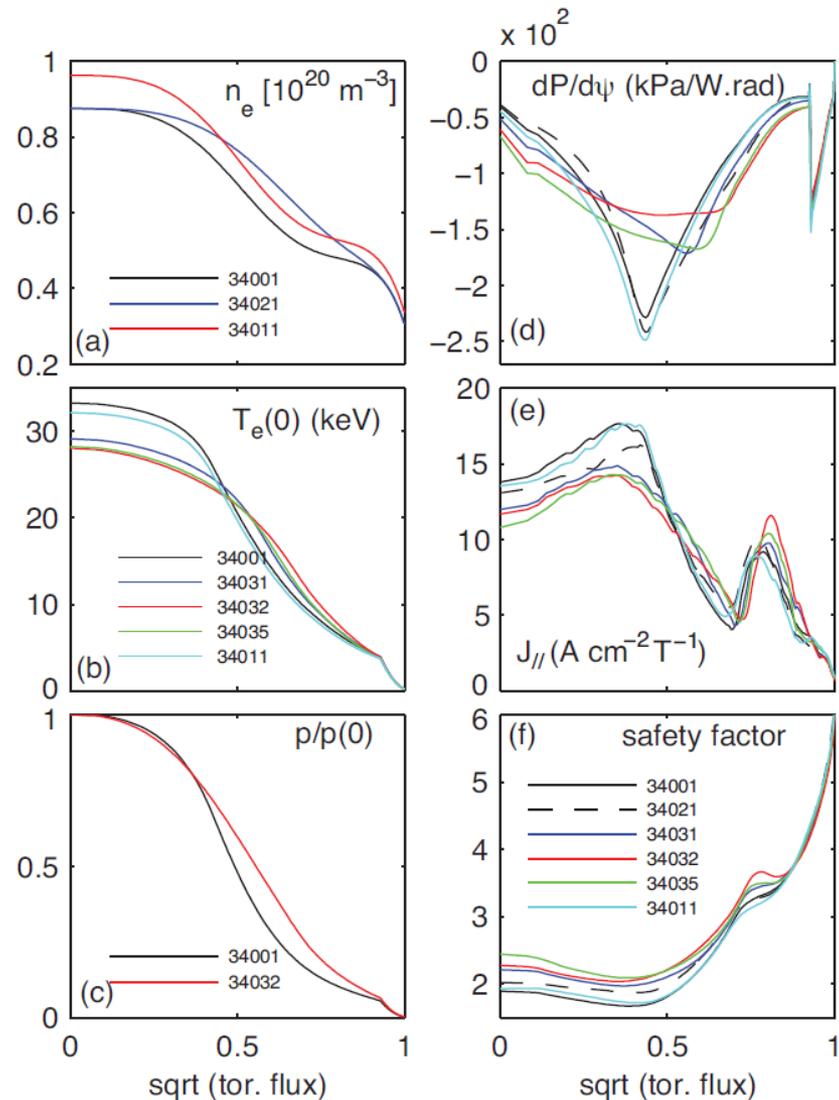
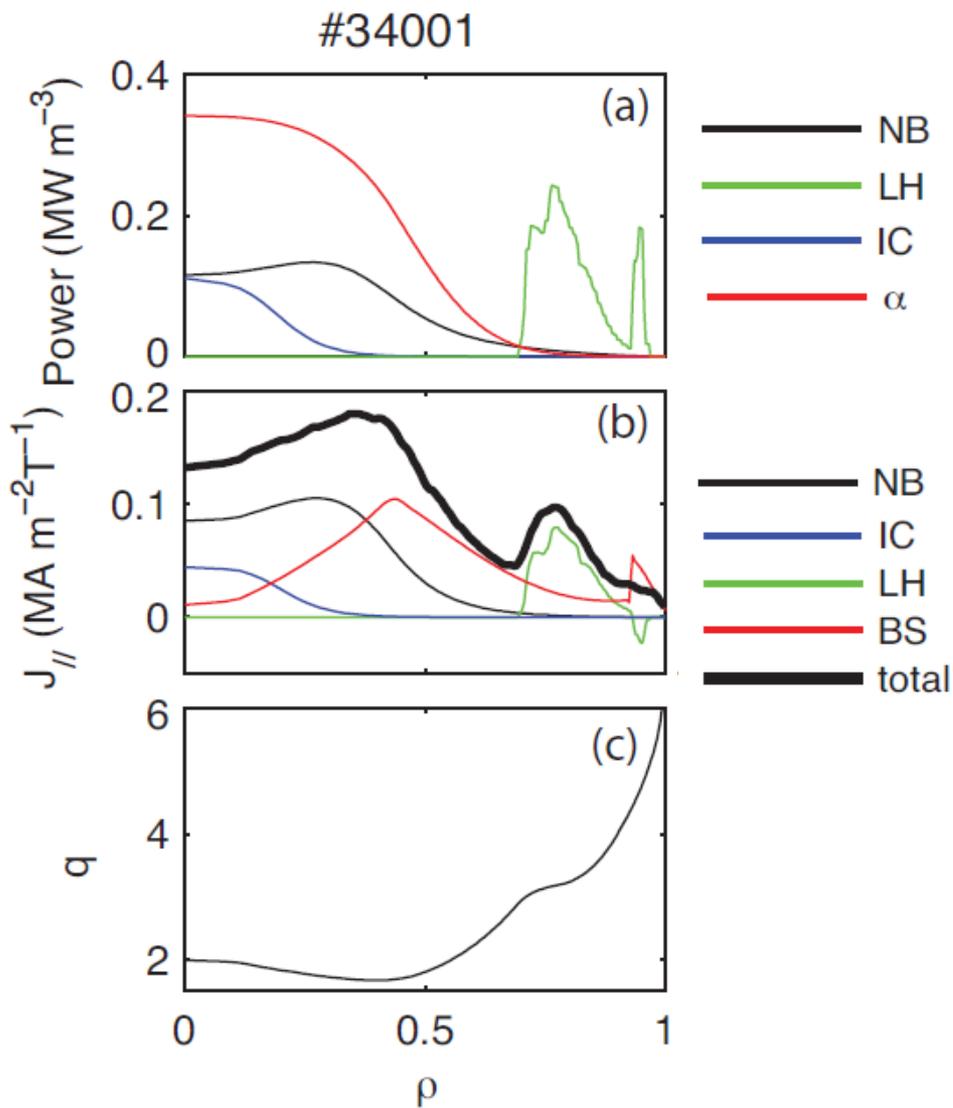
Some figures from Francesca's paper

SHOT#	31001	32001	33001	34001	35001
NB (MW)	33	33	33	33	8
IC (MW)	20	20	/	20	20
EC (MW)	20	40	20	/	/
LH (MW)	/	/	20	40	40
I_p (MA)	7.0	9.0	8.85	10.0	7.25
I_{NI} (MA)	7.04	9.09	8.90	10.20	7.5
I_{BS} (MA)	3.4	3.8	4.8	5.2	4.9
I_{NB} (MA)	2.6	3.1	2.4	2.8	0.56
I_{EC} (MA)	0.74	1.66	0.73	/	/
I_{IC} (MA)	0.25	0.40	/	0.25	0.25
I_{LH} (MA)	/	/	0.83	1.8	1.75
f_{BS}	0.48	0.41	0.54	0.51	0.65
P_α	28	52	64	76	33
Q	2.4	3.3	4.3	4.9	2.4
P_{rad}	22	31	35	38	27
n/n_G	1.00	0.86	0.95	0.85	1.0
$n(0)[10^{19}m^{-3}]$	7.0	7.5	8.5	8.7	7.2
$T(0)$ (keV)	19	32	25	32	18
$n(0)/\langle n \rangle$	1.44	1.4	1.44	1.5	1.3
$p(0)/\langle p \rangle$	2.63	2.56	2.6	2.90	2.33
ρ_{ITB}	0.55	0.55	0.65	0.45	0.65
$l_i(1)$	1.07	1.22	0.85	0.80	0.58
$l_i(3)$	0.87	1.00	0.69	0.66	0.48
H_{98}	1.55	1.58	1.63	1.63	1.55
$q(0)$	1.61	1.67	3.3	1.88	6.05
q_{min}	1.35	0.96	1.71	1.67	4.5
q_{95}	7.0	5.4	5.2	4.7	6.78
β_N	2.0	2.4	2.6	2.7	2.13
Ballooning	S	S	U	U	S
$n=1$, no wall	S	U	S	U	S
$n=1$, wall	S	U	S	S	S



33 MW NB	34011
20 MW IC	
40 MW LH	
I_{NI} (MA)	9.9
I_{NB} (MA)	2.3
I_{BS} (MA)	5.5
P_α	87
Q	5.5
$p(0)/\langle p \rangle$	2.5
$n(0)/\langle n \rangle$	1.4
$n(0)[10^{19}m^{-3}]$	9.6
$T_e(0)$ (keV)	32
ρ_{ITB}	0.45
β_N	2.86
$q(0)$	1.95
q_{min}	1.72
H_{98}	1.64
n/n_G	0.93
ballooning	U
$n=1$, no-wall	U
$n=1$ wall	S

Some figures from Francesca's paper



Some figures from Francesca's paper

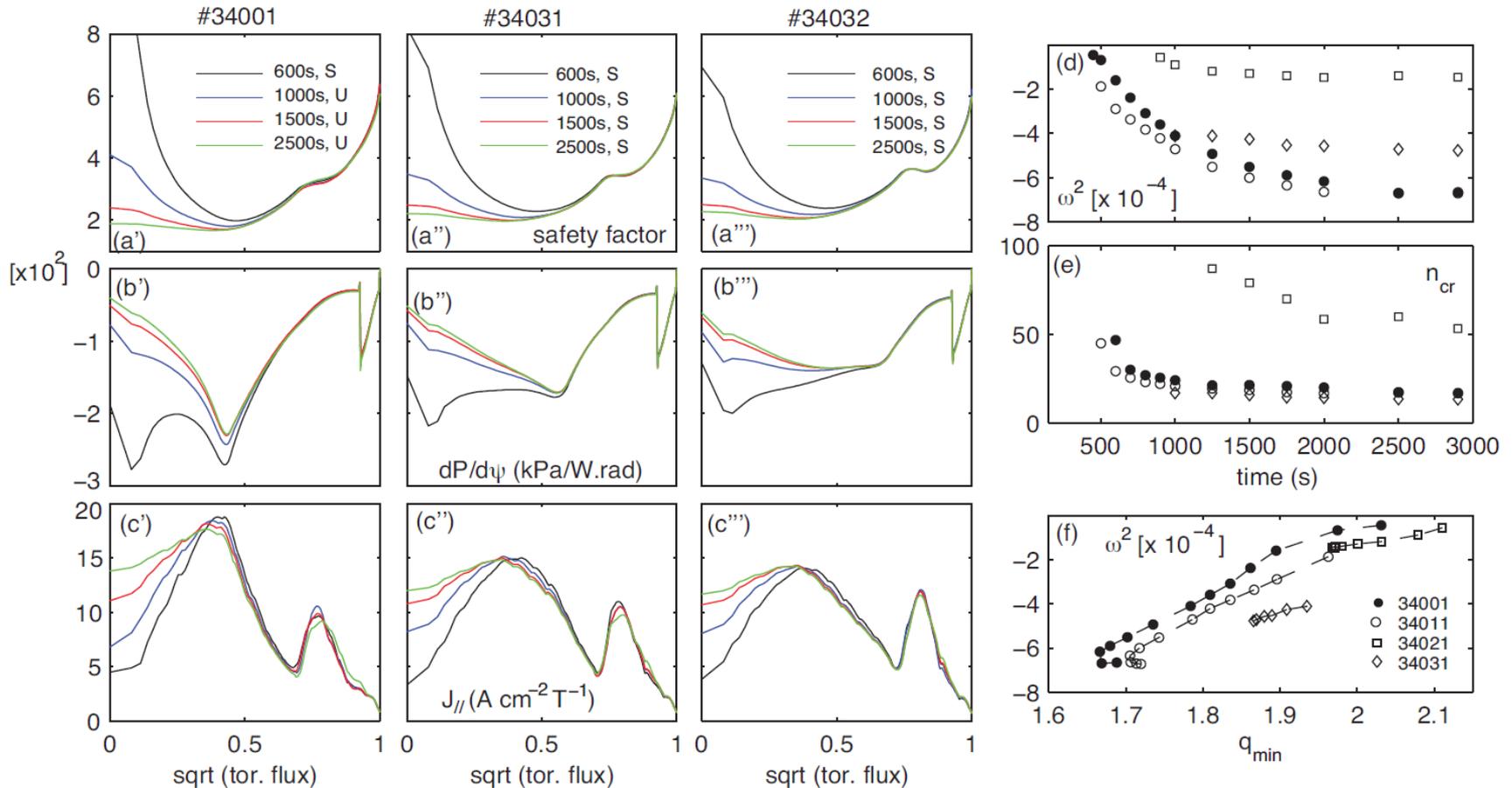
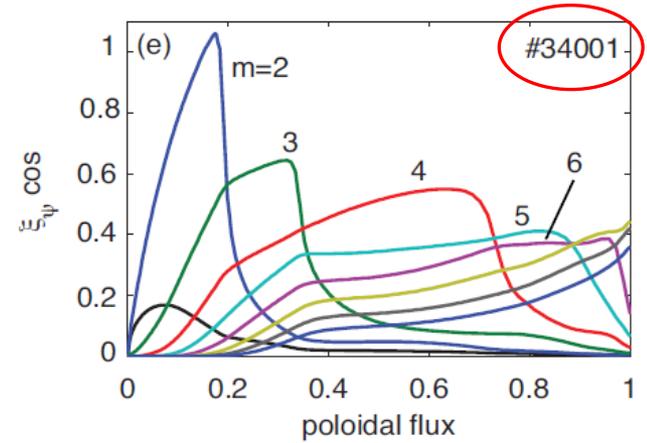
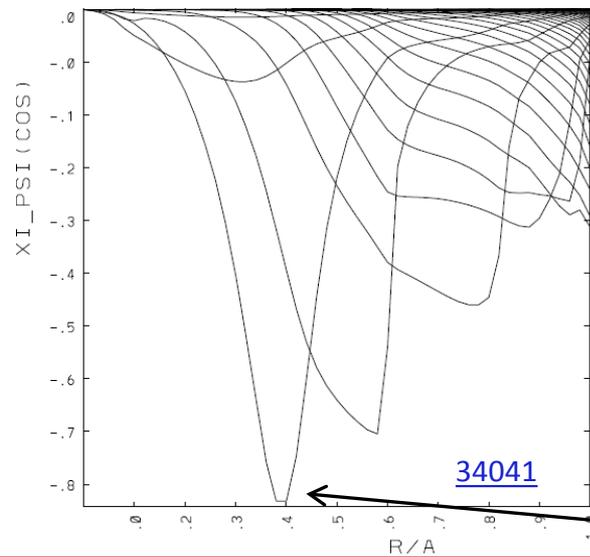
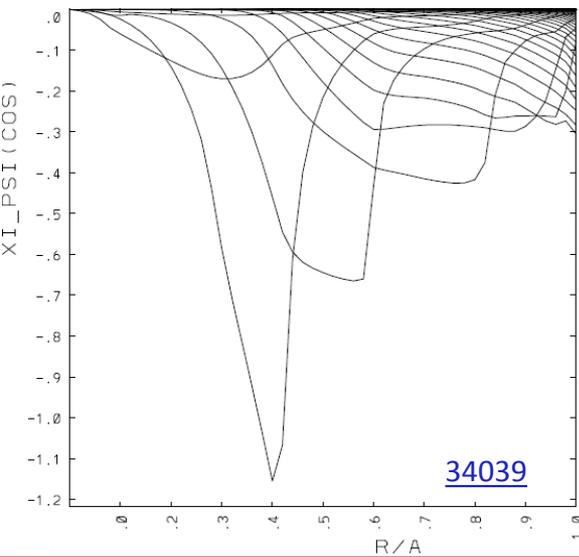
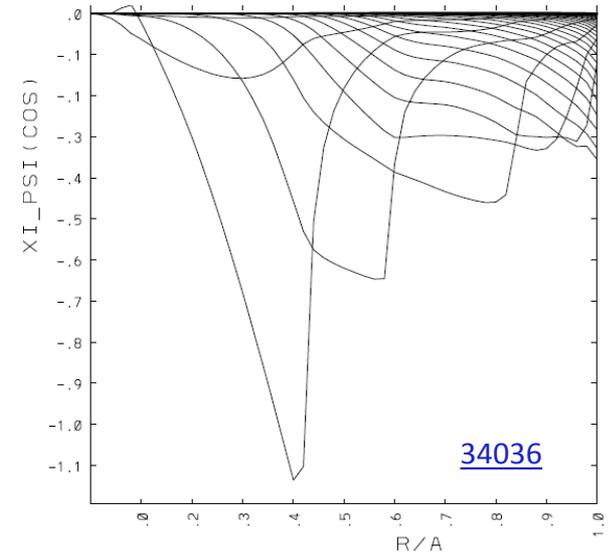
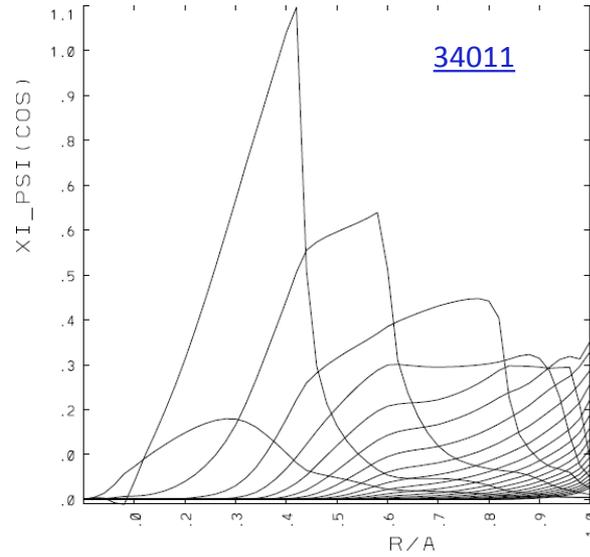
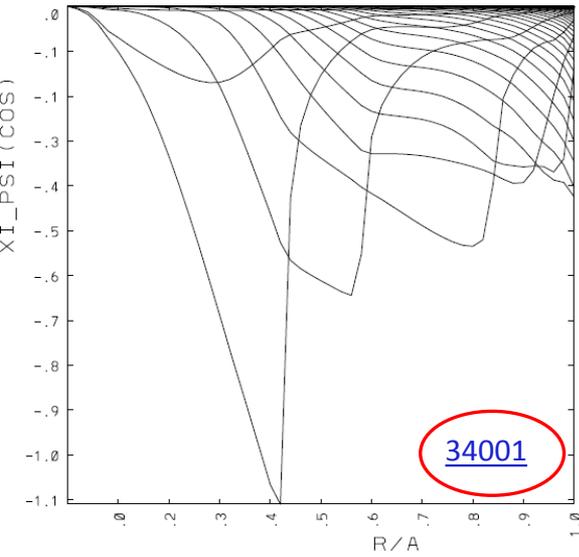


FIG. 16: (Colour online) Scenario with IC, LH and 33 MW NB. (a) Safety factor profile, (b) pressure derivative, (c) parallel current density profiles, calculated at four time slices during the flat-top phase. For each time it is noted whether the plasma is stable (S) or unstable (U) to $n = 1$ kinks. (d)-(e) Solutions of the ballooning equation calculated for the reference scenario (\bullet), for broader density profile (\diamond), for ITB at $r/a = 0.60$ (\square) and for central density 10% larger (\circ). (f) dependence of the eigenvalues ω^2 on q_{min} .

The eigenfunctions (from PEST) all look like infernal modes



[F. Poli *et al.*, submitted to Nucl. Fusion (2012)]

Note scales are different: this one has the smallest peak

PEST Fluid δW results

34001 @ 2500s

Marginal $b = 1.20$

Marginal eigenvalue = $-0.1883e-5$

$\delta W_{inf} = -0.2246451e-2$

$\delta W_b = 0.3334449e-1$ ($b = 0.35$)

$\beta_N = 2.7038$

$\rho_0/\langle p \rangle = 2.8950$

$q_{min} = 1.66856$

$l_i = 0.8036$

34011 @ 2500s

Marginal $b = 0.561$

Marginal eigenvalue = $-0.2105e-5$

$\delta W_{inf} = -0.1098658e-1$

$\delta W_b = 0.1593027e-1$ ($b = 0.35$)

$\beta_N = 2.8645$

$\rho_0/\langle p \rangle = 2.8984$

$q_{min} = 1.71432$

$l_i = 0.8088$

34036 @ 2500s

Marginal $b = 0.555$

Marginal eigenvalue = $-0.9399e-5$

$\delta W_{inf} = -0.1035962e-1$

$\delta W_b = 0.1456835e-1$ ($b = 0.35$)

$\beta_N = 2.8045$

$\rho_0/\langle p \rangle = 2.7648$

$q_{min} = 1.82644$

$l_i = 0.7772$

34039 @ 2500s

Marginal $b = 0.414$

Marginal eigenvalue = $-0.3469e-5$

$\delta W_{inf} = -0.15478102e-1$

$\delta W_b = 0.53414071e-2$ ($b = 0.35$)

$\beta_N = 3.0790$

$\rho_0/\langle p \rangle = 2.7543$

$q_{min} = 1.93668$

$l_i = 0.7493$

34041 @ 2500s

Marginal $b = 0.789$

Marginal eigenvalue = $-0.6606e-6$

$\delta W_{inf} = -0.72005936e-2$

$\delta W_b = 0.30589234e-1$ ($b = 0.35$)

$\beta_N = 3.2207$

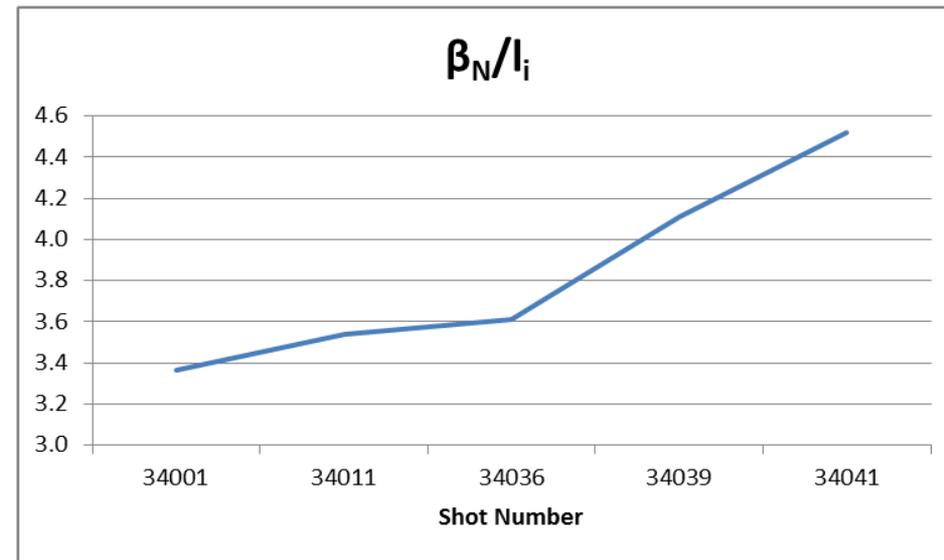
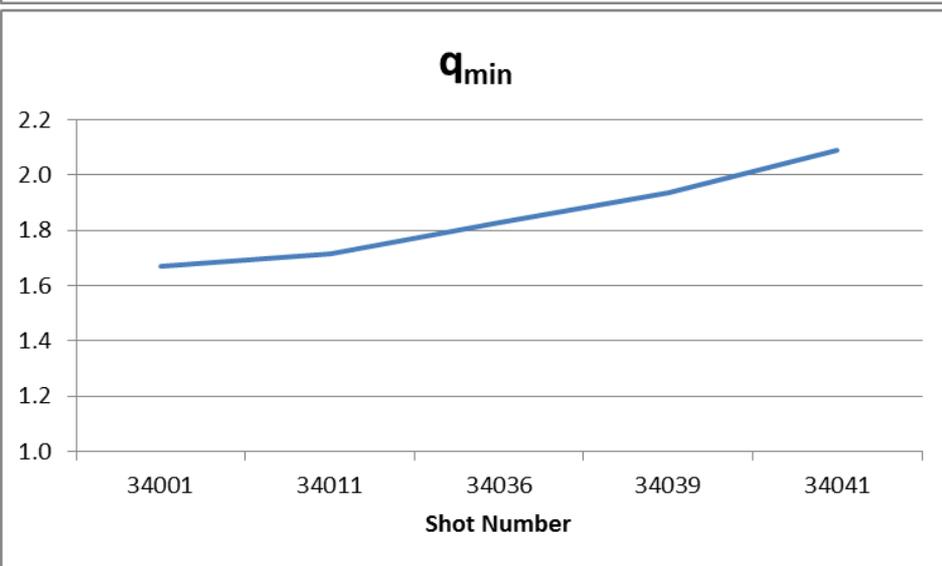
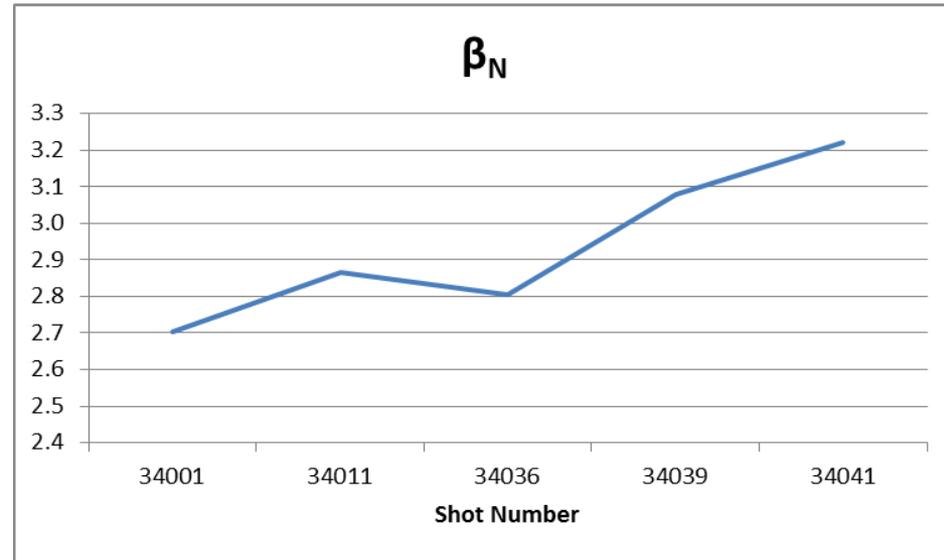
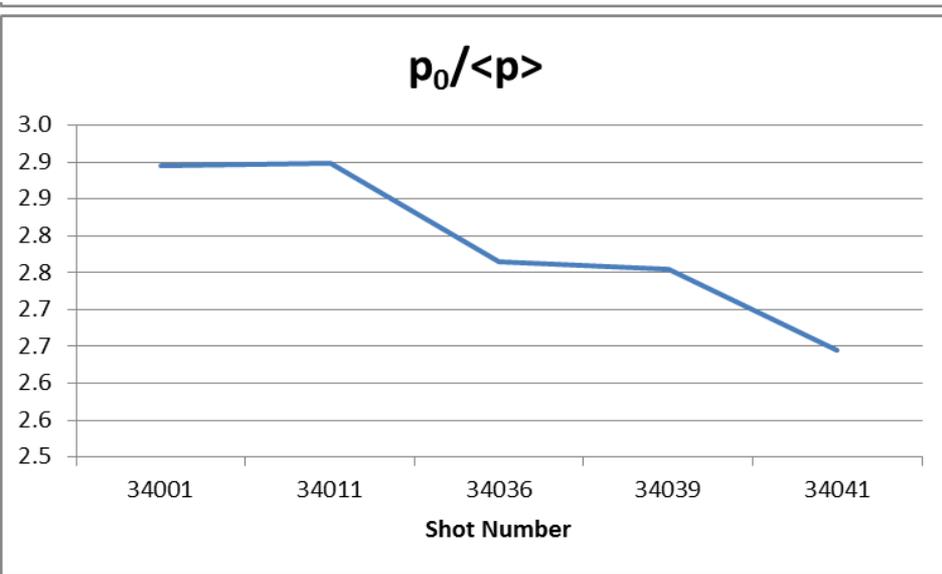
$\rho_0/\langle p \rangle = 2.6452$

$q_{min} = 2.09046$

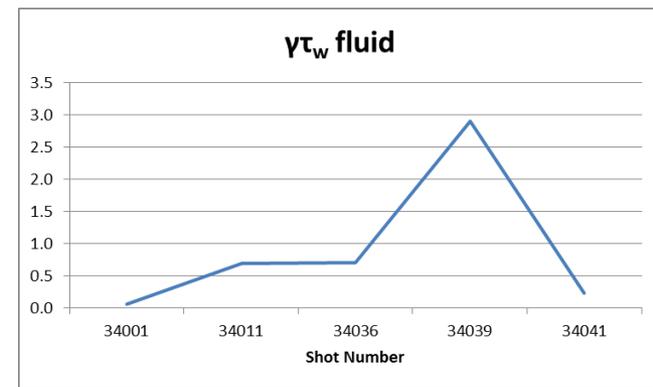
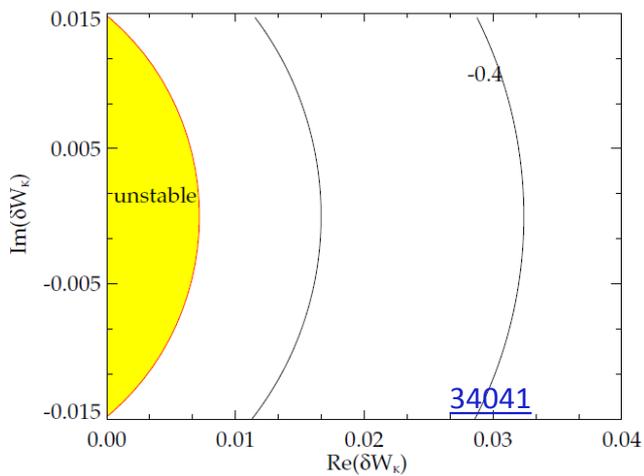
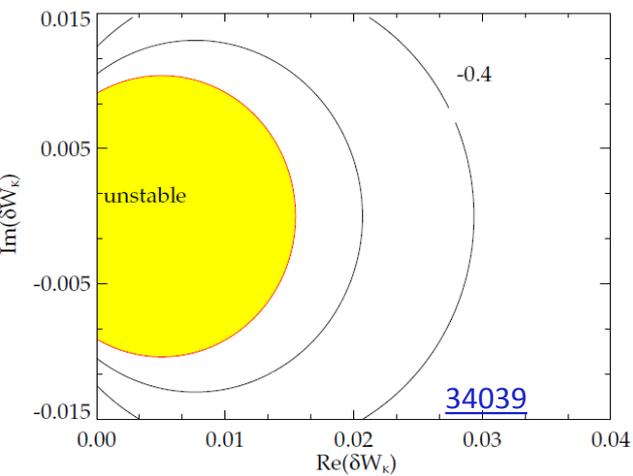
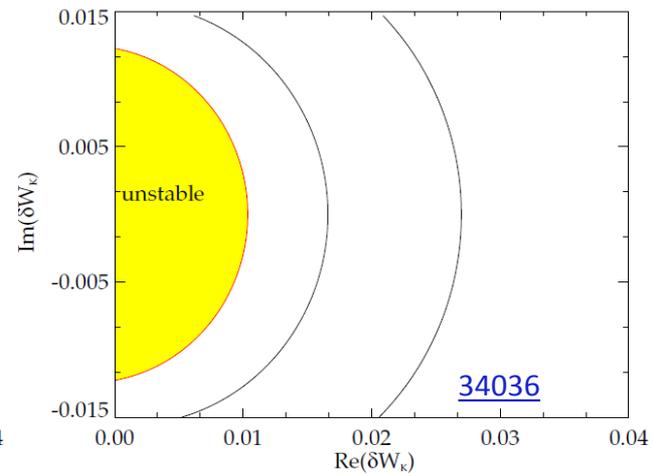
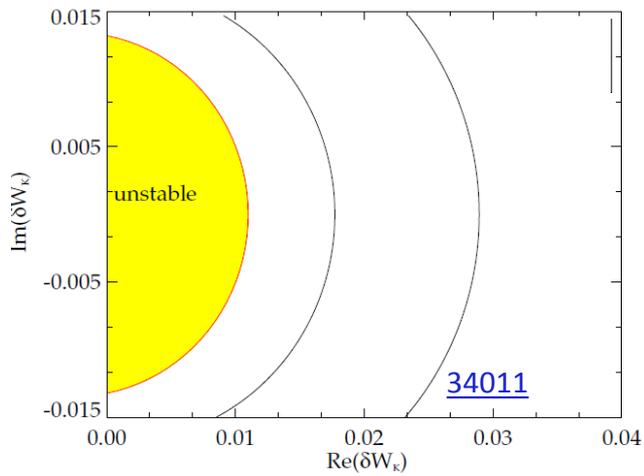
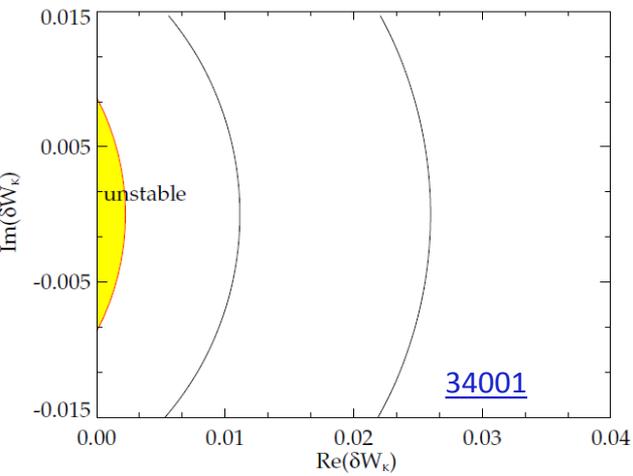
$l_i = 0.7130$

Results with the real wall are very similar to a conformal wall at $b = 0.35$, so we have used the conformal wall.

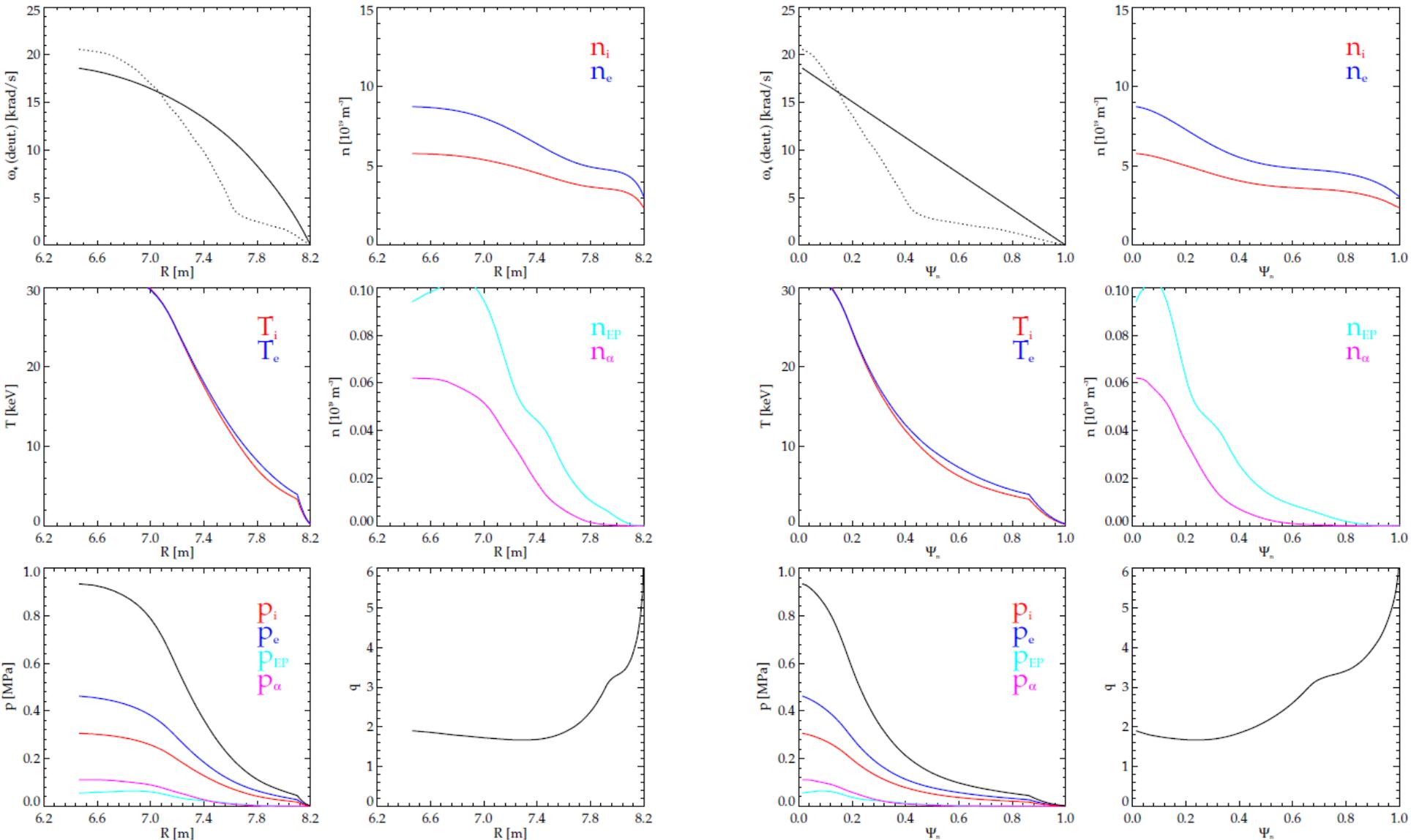
Various parameters vs. shot number



PEST Fluid δW results



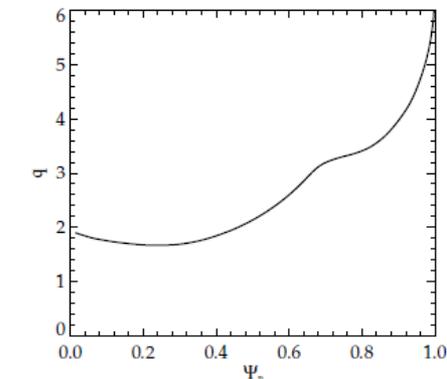
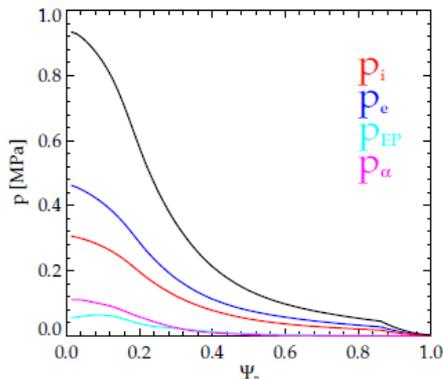
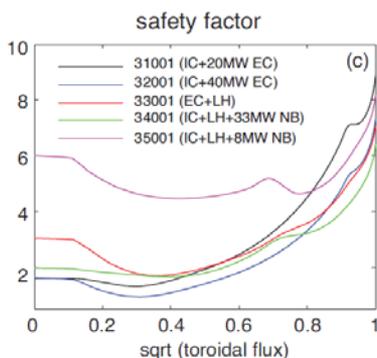
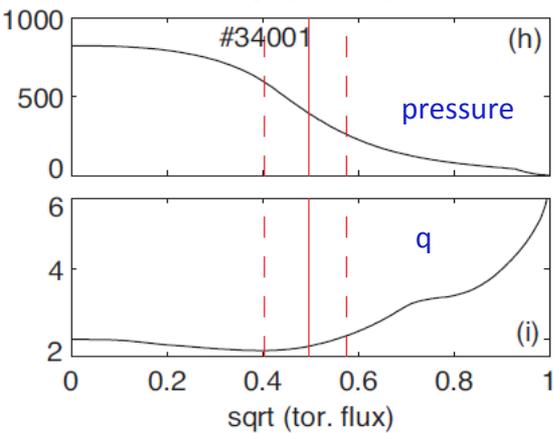
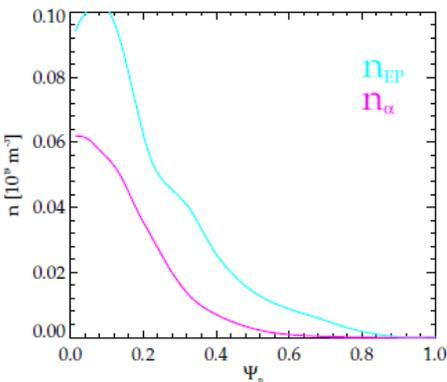
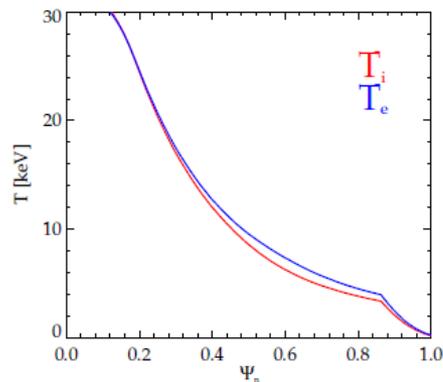
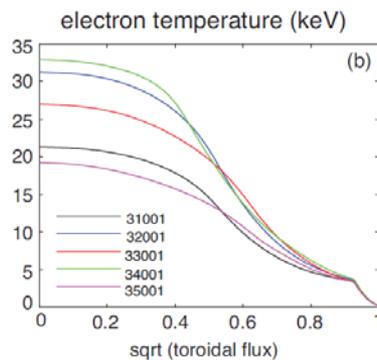
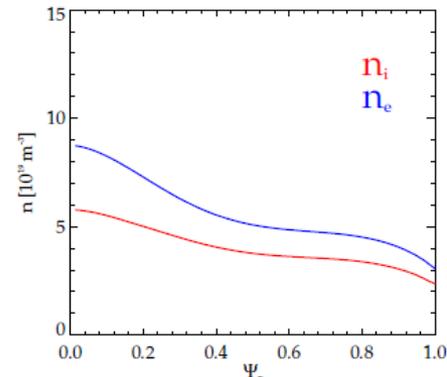
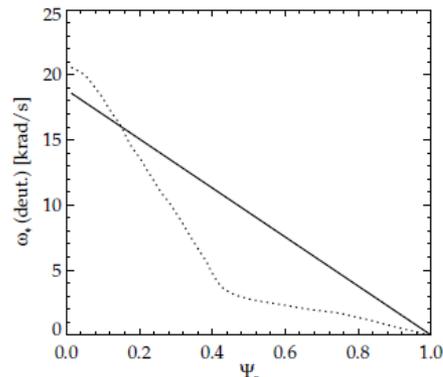
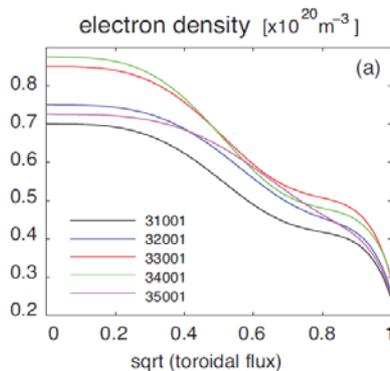
Profiles, 34001 @ 2500s



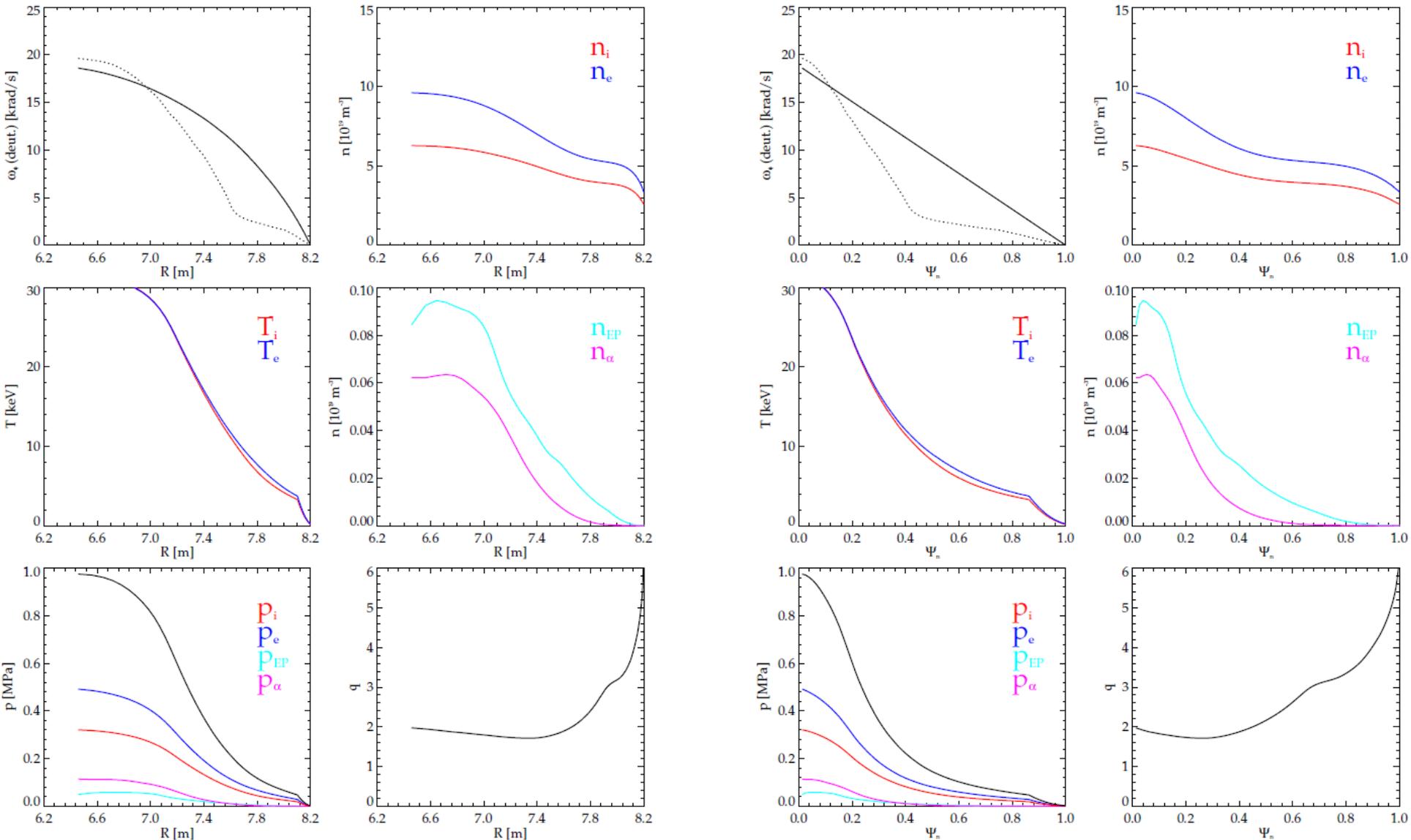
Profiles, 34001 @ 2500s

Compare to figures from
[F. Poli *et al.*, submitted to
Nucl. Fusion (2012)]

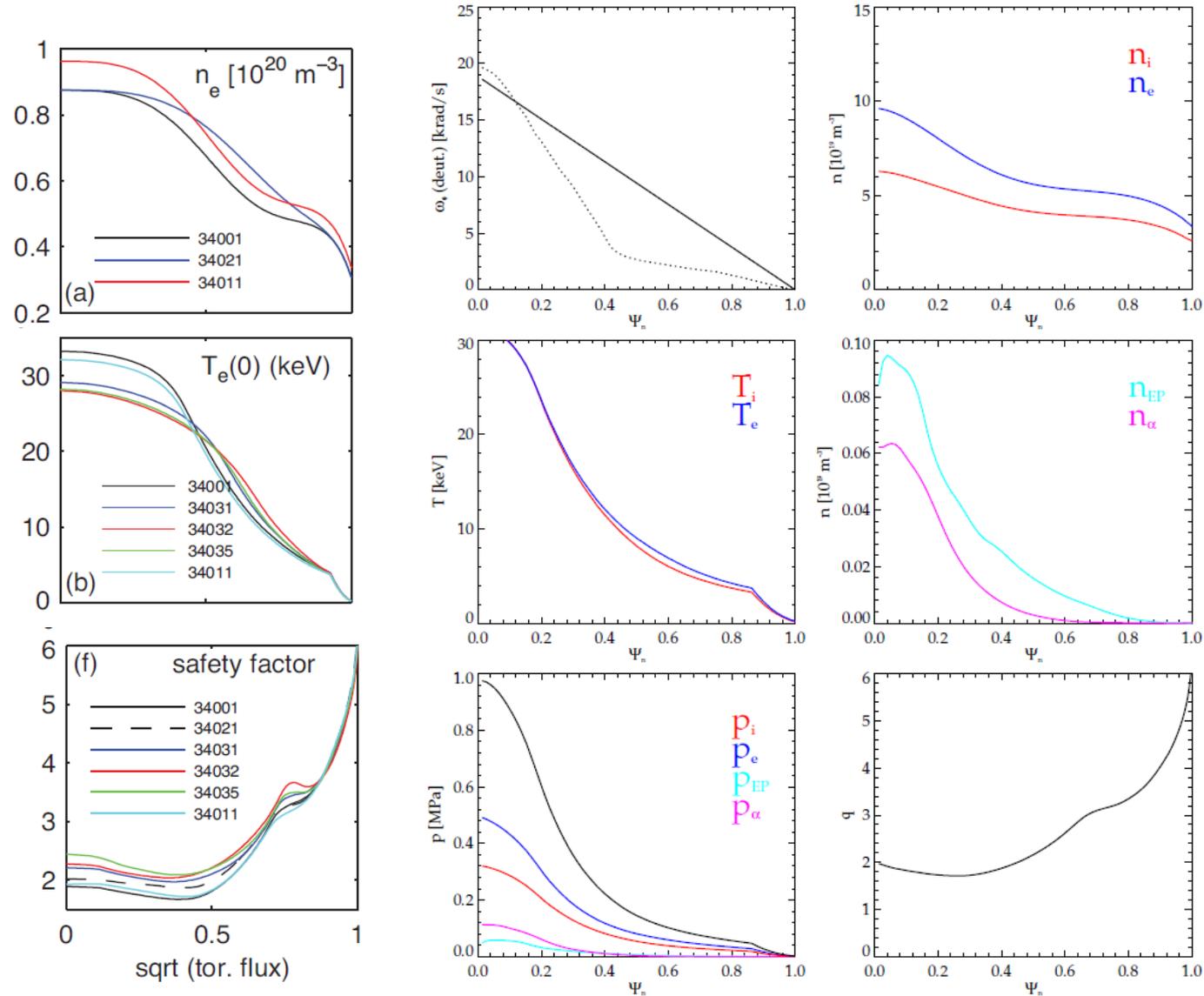
(green profile is same shot,
but at $t = 2000s$)



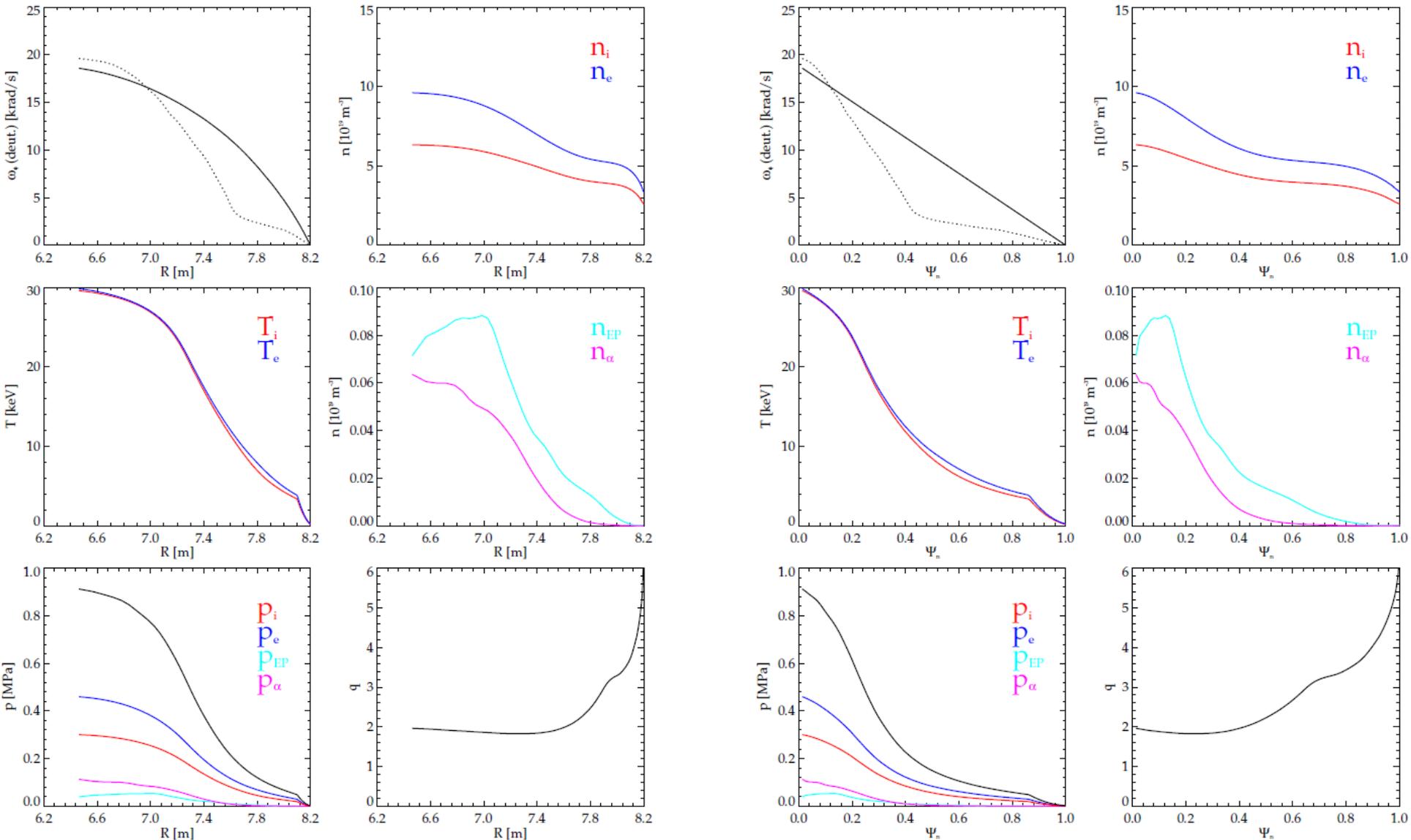
Profiles, 34011 @ 2500s



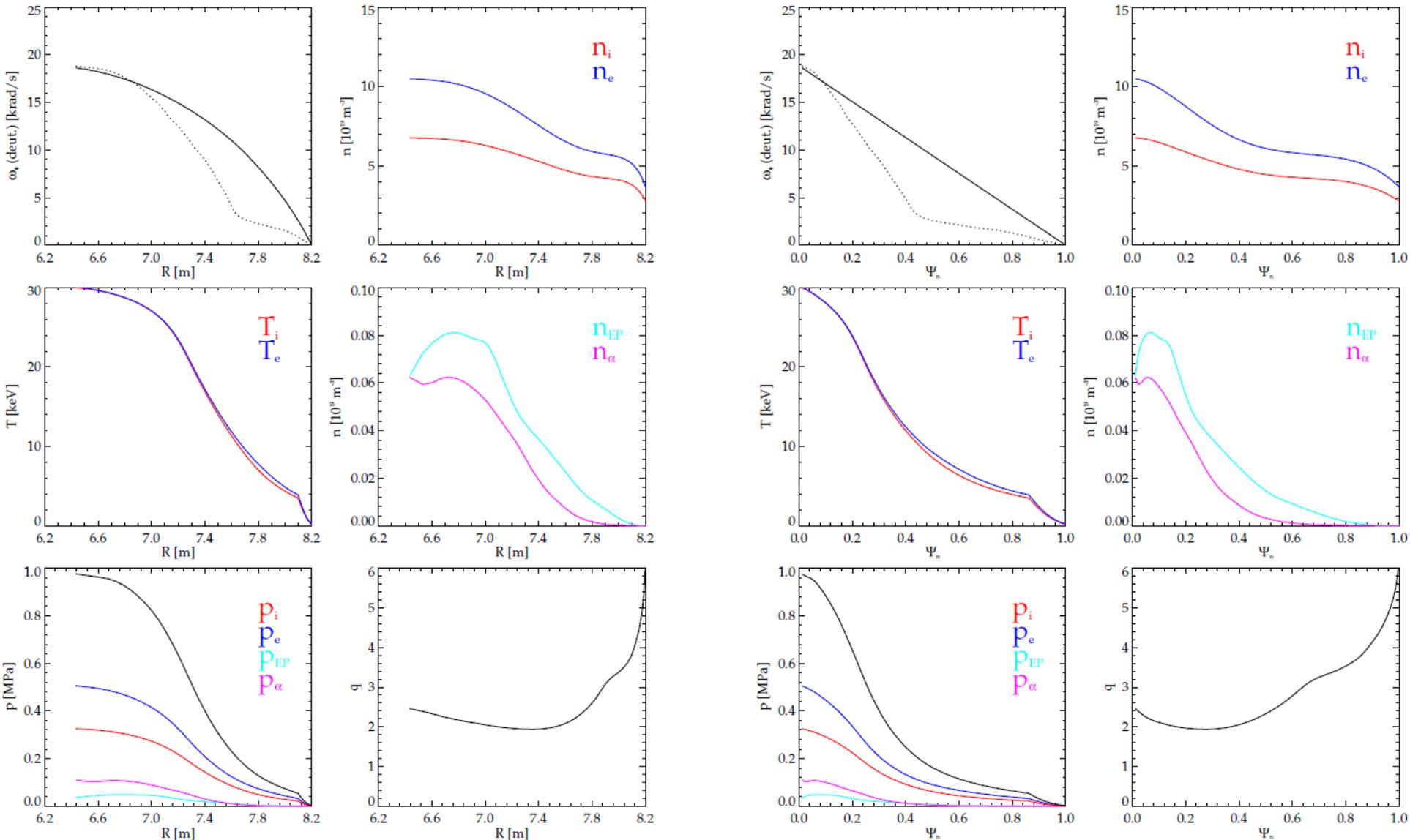
Profiles, 34011 @ 2500s



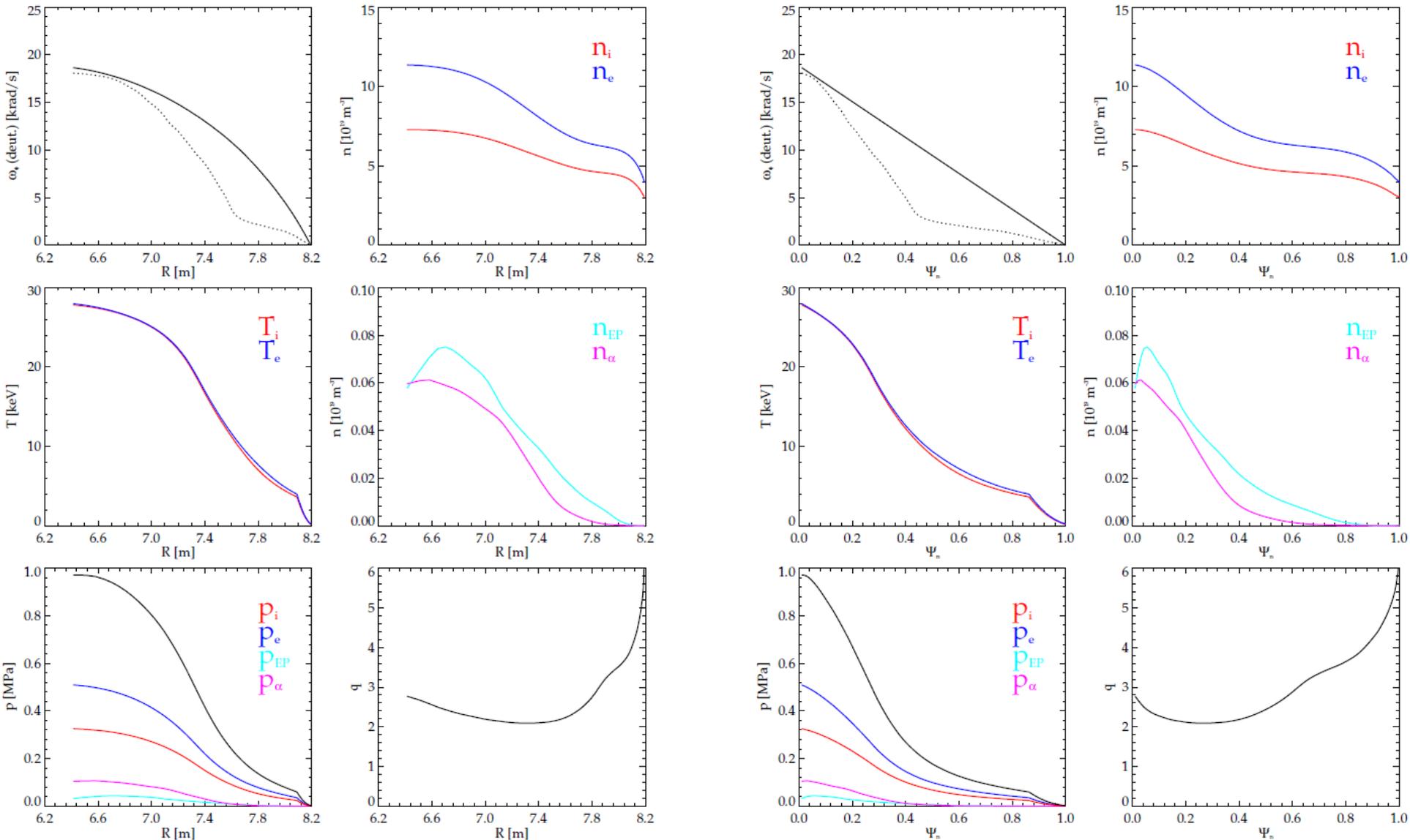
Profiles, 34036 @ 2500s



Profiles, 34039 @ 2500s



Profiles, 34041 @ 2500s



Notes on MISK δW_K results with deuterium and tritium

$$\delta W_K = \sum_j \sum_{l=-\infty}^{\infty} 2\sqrt{2}\pi^2 \int \int \int \left[|\langle H/\hat{\varepsilon} \rangle|^2 \frac{(\omega - n\omega_E) \frac{\partial f_j}{\partial \varepsilon} - \frac{n}{Z_j e} \frac{\partial f_j}{\partial \Psi}}{\underbrace{n\langle \omega_D^j \rangle + l\omega_b^j - i\nu_{\text{eff}}^j + n\omega_E - \omega}_{\text{go like } m^{-1/2}}} \right] \frac{\hat{\tau}}{m_j^{3/2} B} |\chi| \hat{\varepsilon}^{5/2} d\hat{\varepsilon} d\chi d\Psi,$$

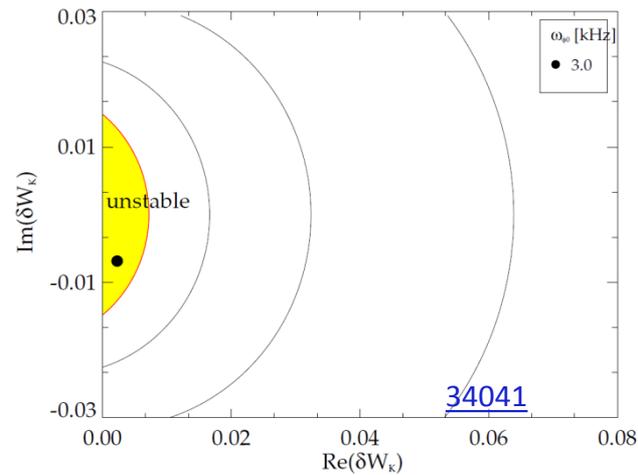
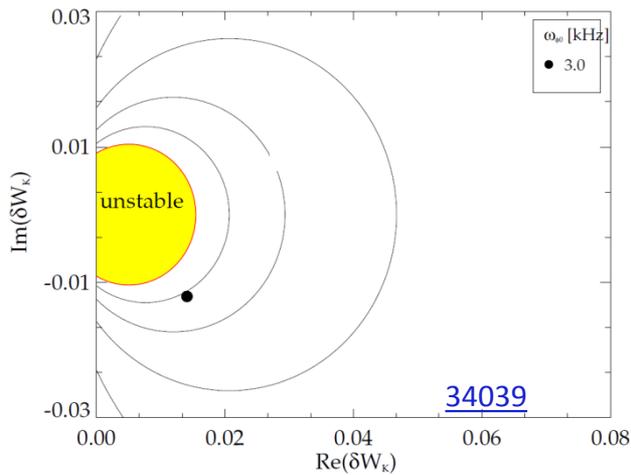
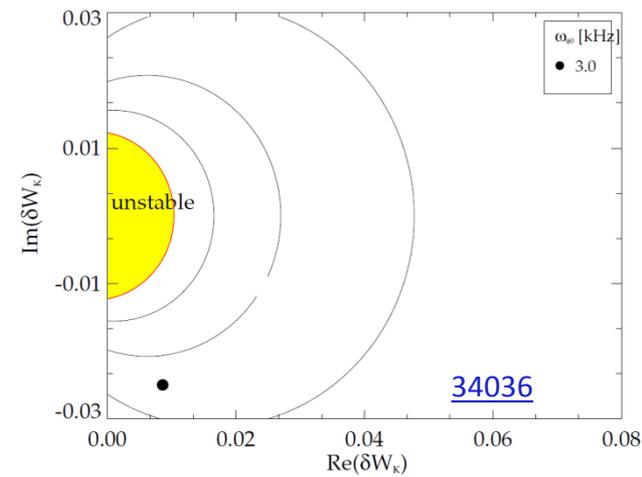
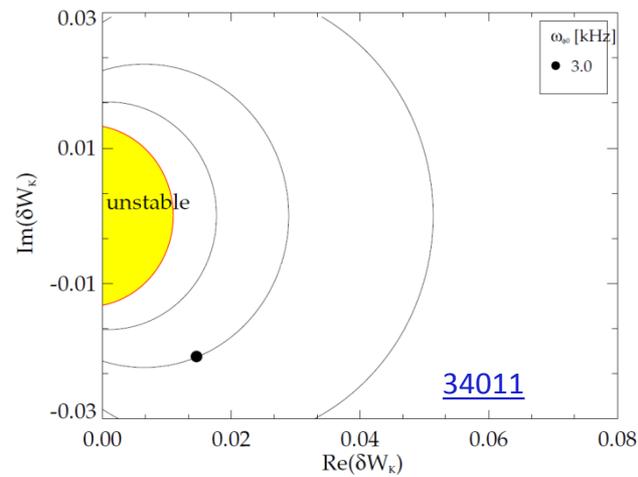
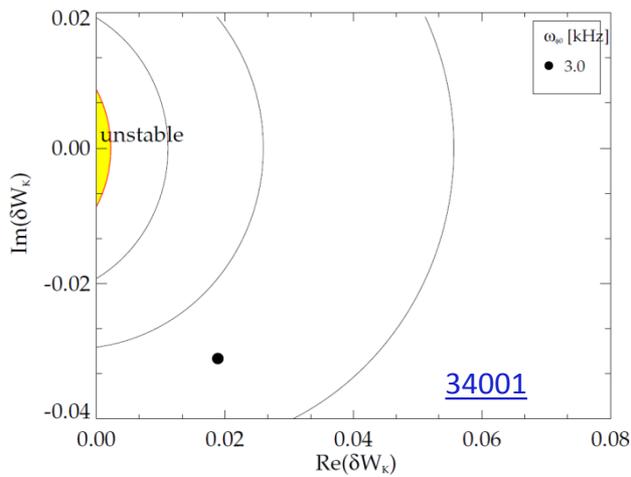
Splitting to 50% deuterium and 50% tritium makes very little difference (vs. 100% deuterium). Need to recheck the effect on Alfvén layers.

When including alpha particles, I had to pay close attention to the 50% deuterium and 50% tritium mix, because it matters for the alpha's slowing-down distribution:

$$f_j^\alpha(\varepsilon, \Psi) = n_j A_\alpha \left(\frac{m_j}{\varepsilon_\alpha} \right)^{2/3} \frac{1}{\hat{\varepsilon}^{3/2} + \hat{\varepsilon}_c^{3/2}} \quad \varepsilon_c = \left(\frac{3\sqrt{\pi}}{4} \right)^{2/3} \left(\frac{m_j}{m_e} \right) \left(\frac{m_e}{n_e} \sum_i \left(\frac{n_i Z_i^2}{m_i} \right) \right)^{2/3} T_e$$

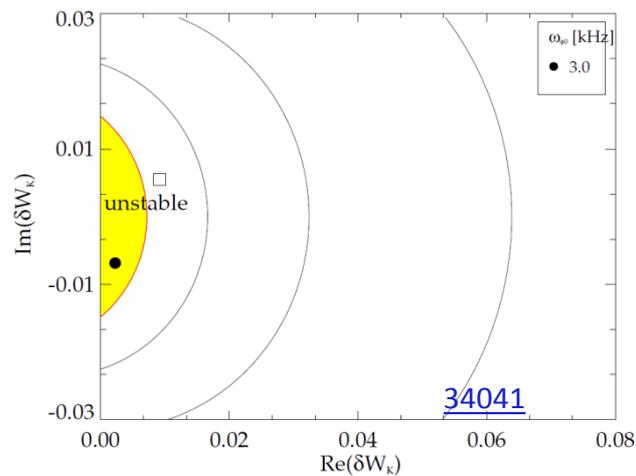
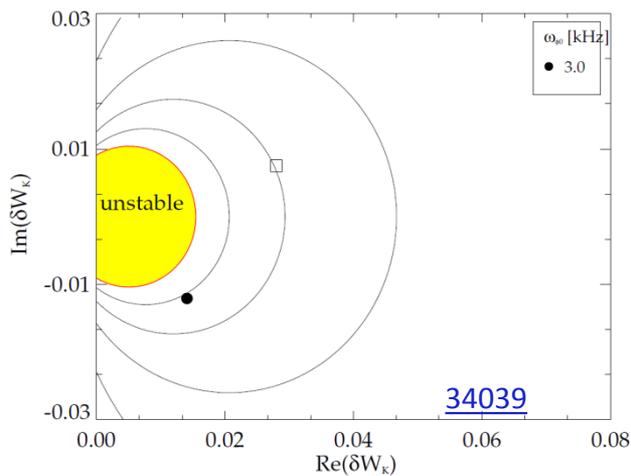
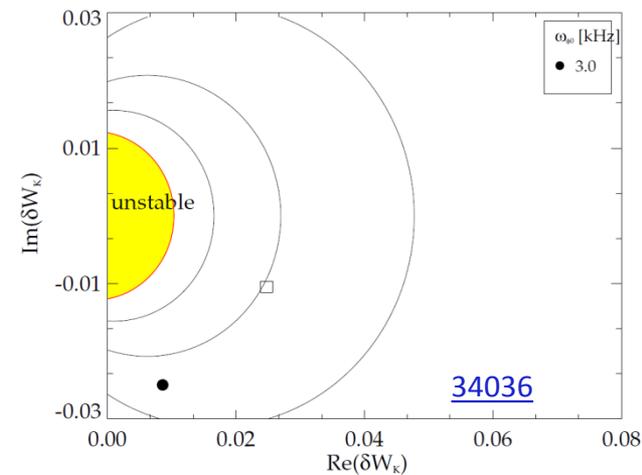
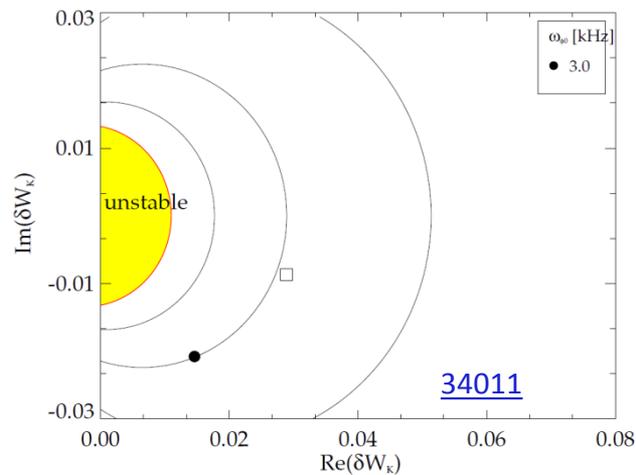
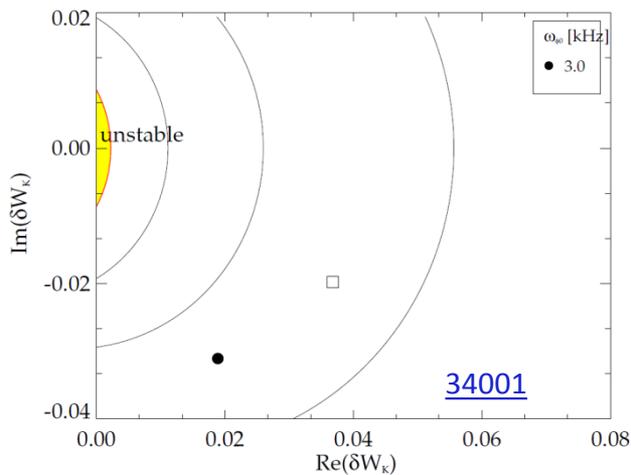
Note: I assumed alpha particles were isotropic (as usual). Nikolai has said that alphas can be beam-like in ITER, especially near the edge. I should ask him about that.

MISK Kinetic δW_k results, thermal particles only



Kinetic effects basically continually decrease with shot number. What is causing this? Have to look in detail.

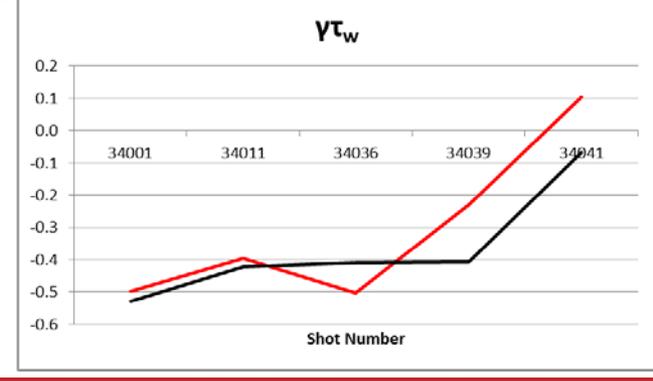
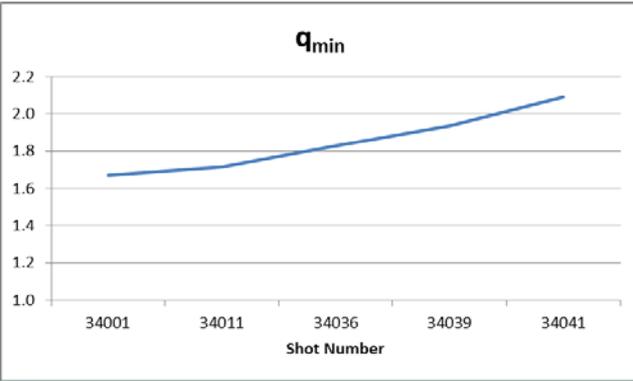
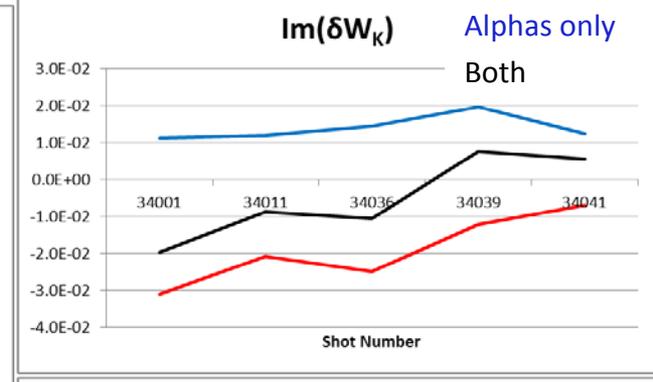
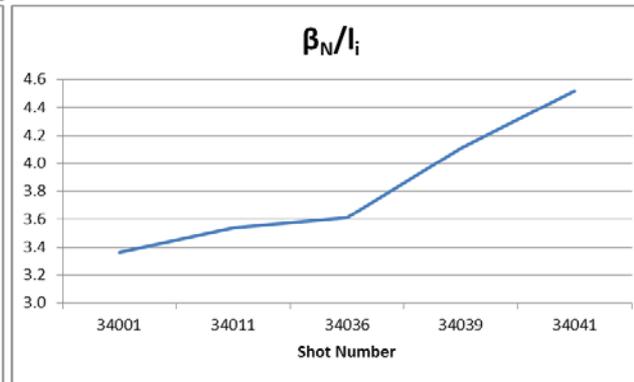
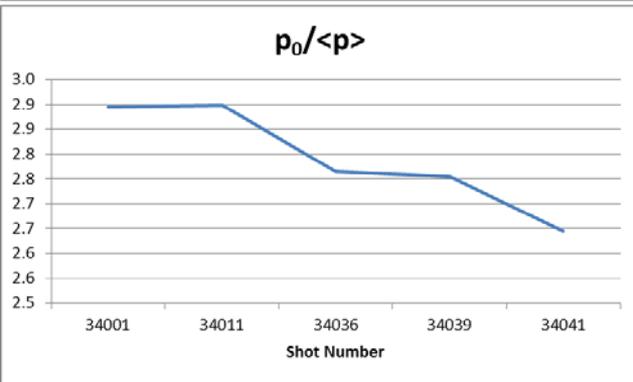
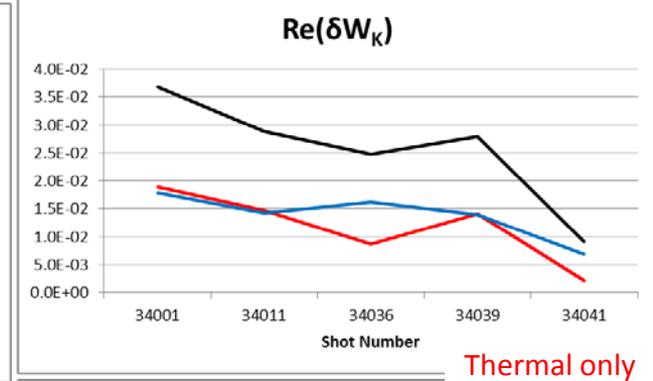
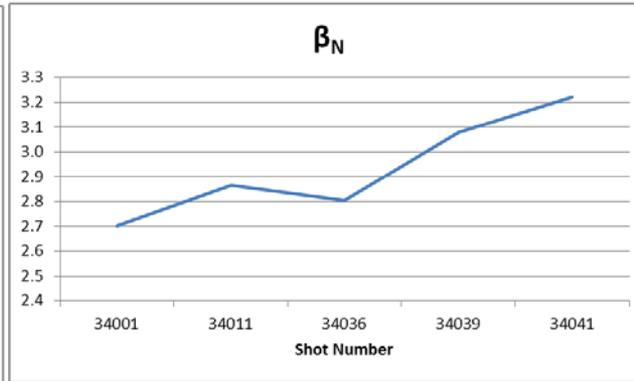
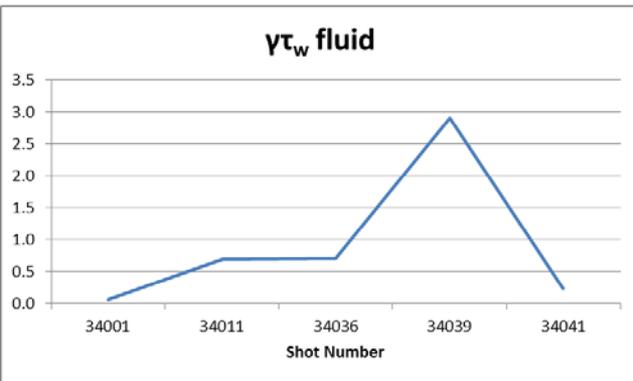
Results with alpha particles included



Alpha particles provide a roughly constant increment to δW_K , as expected.

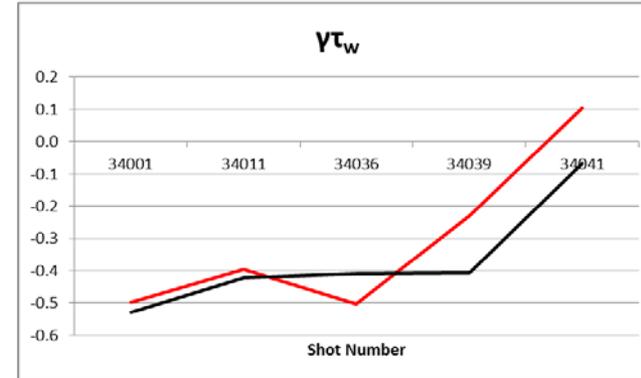
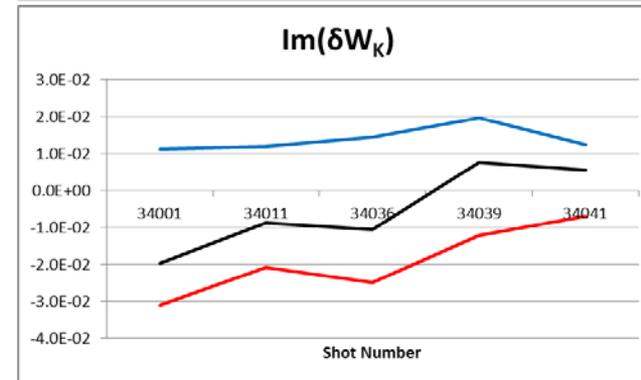
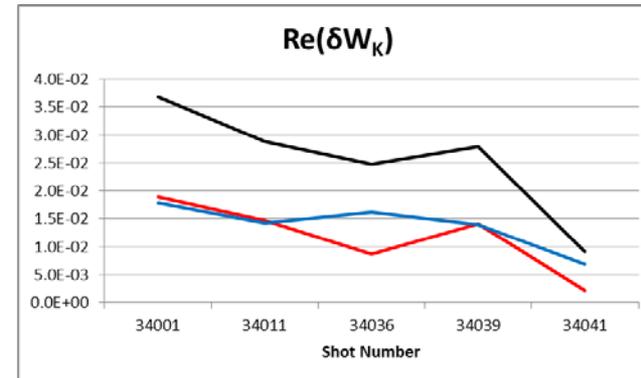
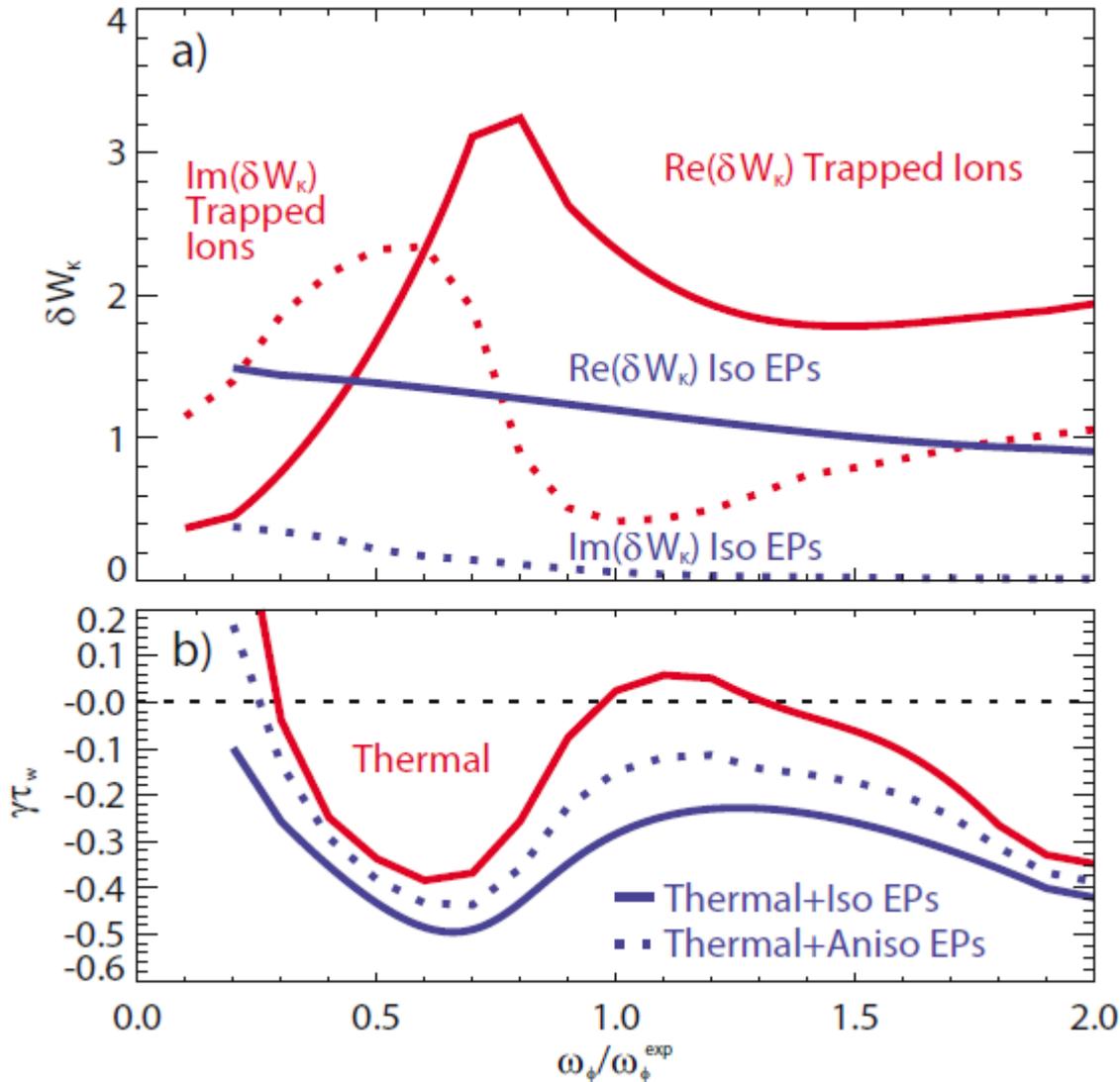
Interestingly, the imaginary increment is roughly the same as the real increment, which is unexpected.

Various parameters vs. shot number

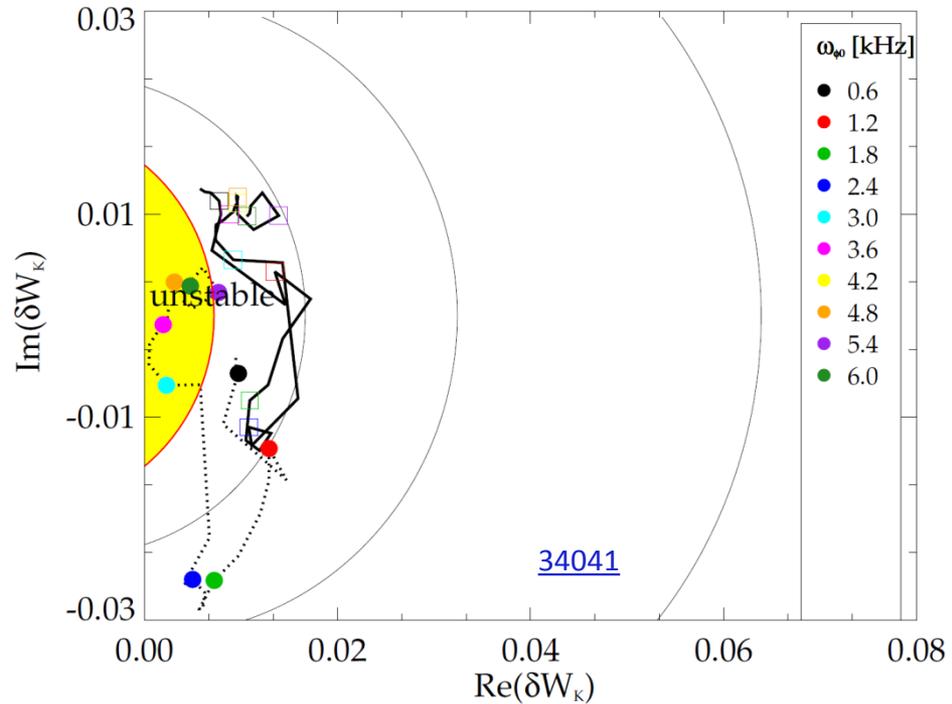
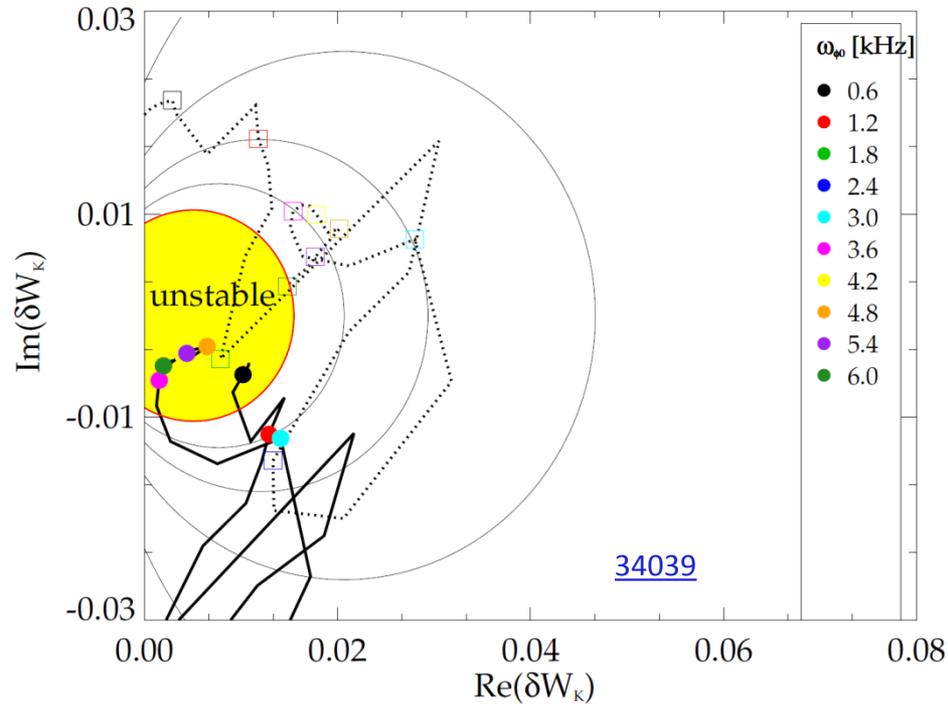


Thermal only
Alphas only
Both

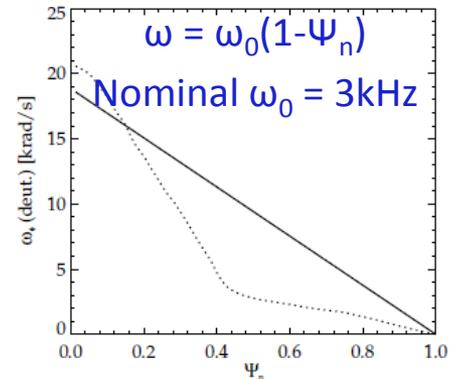
Various parameters vs. shot number



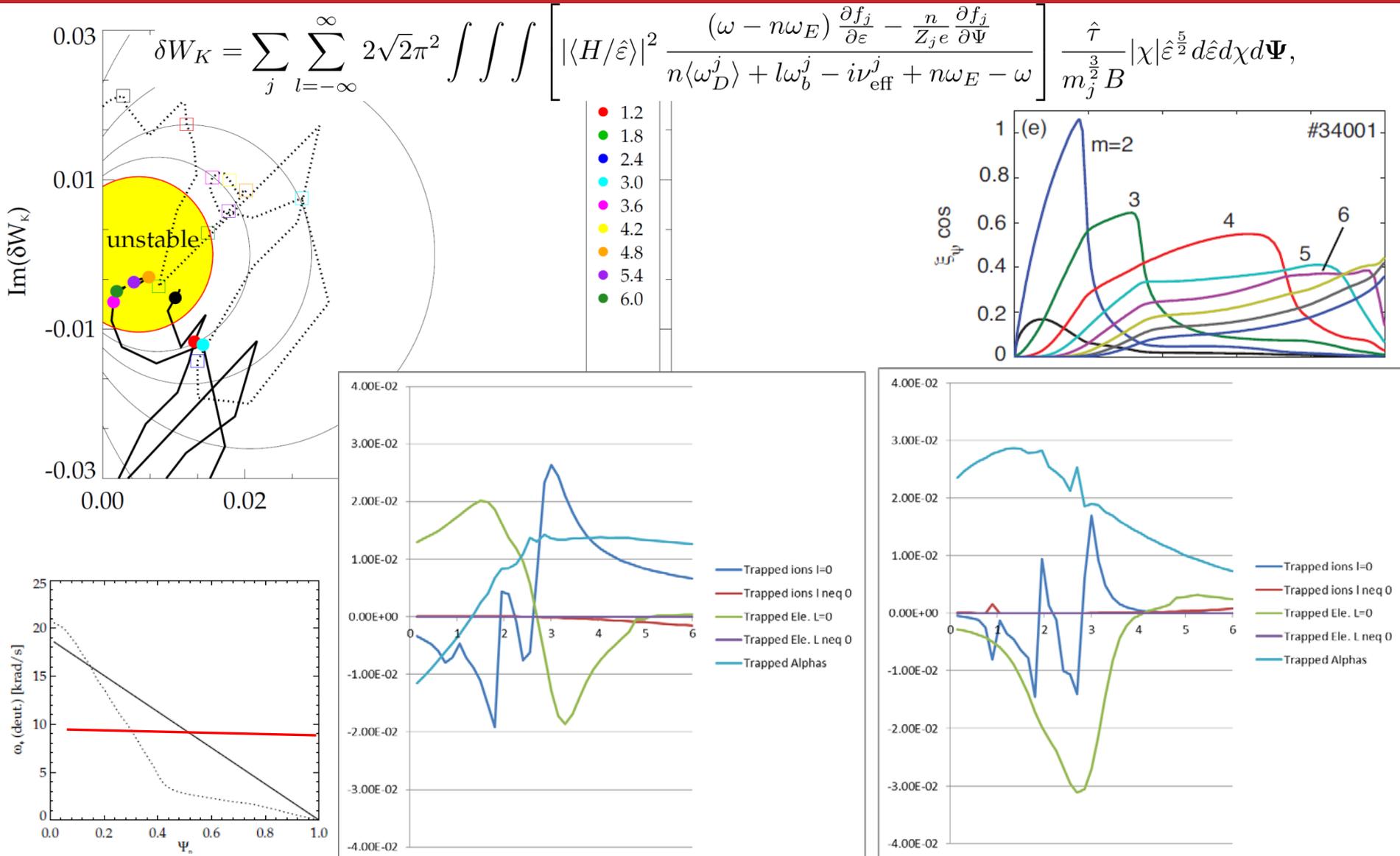
Results with scaled rotation profiles



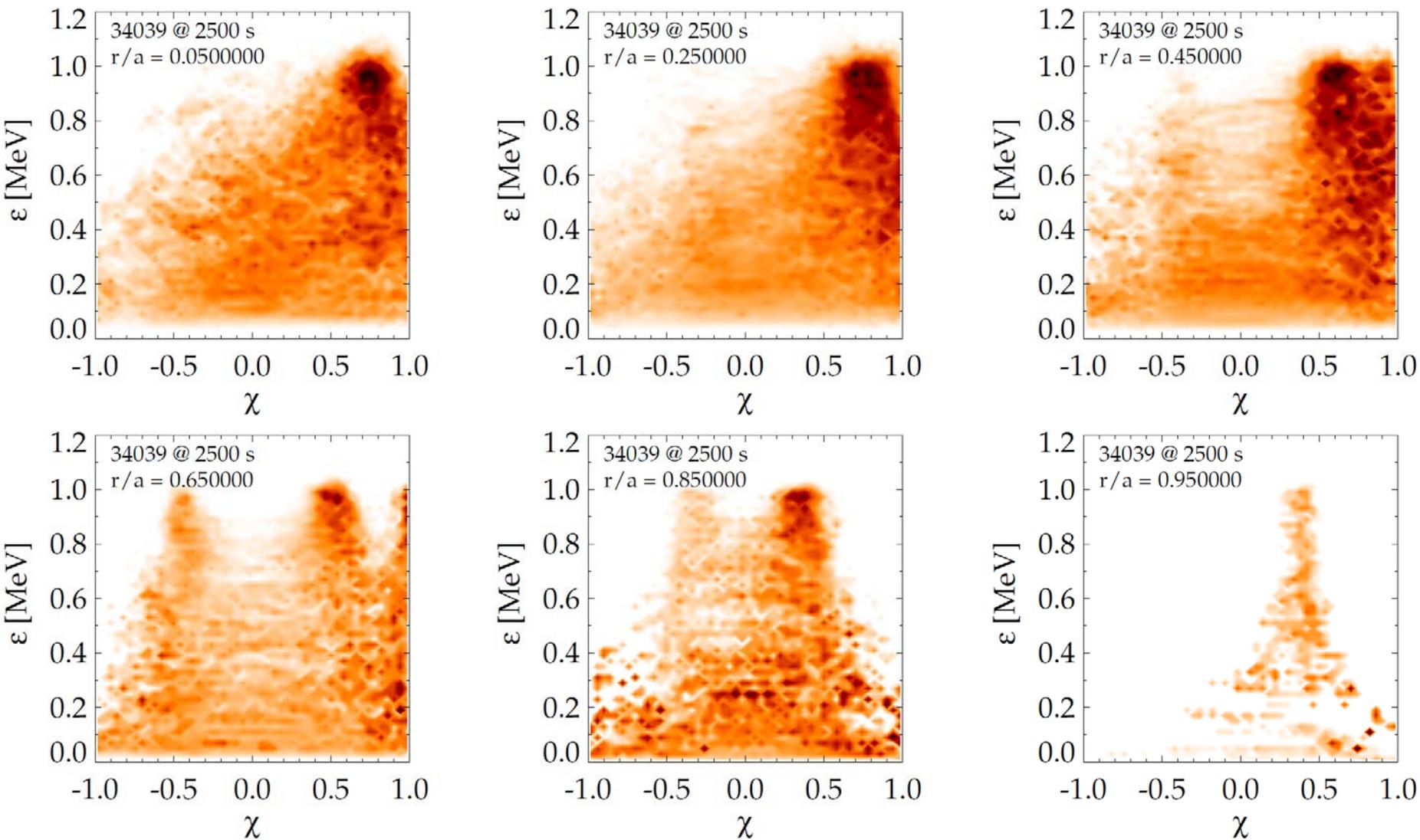
Still working on this



What the hell is going on here?

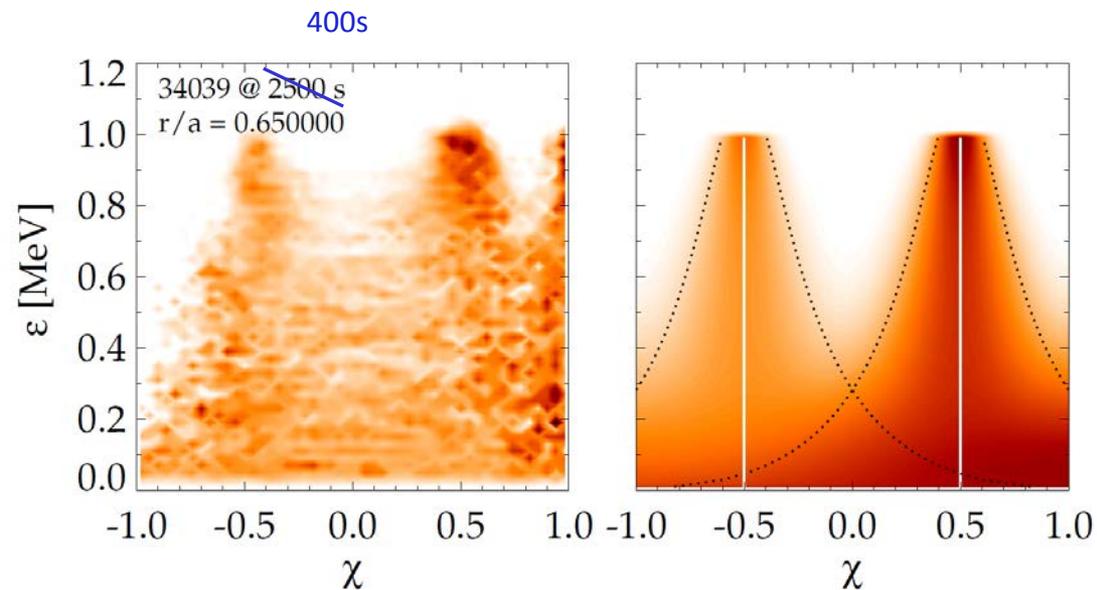


Energetic particle distribution function 34039 @ 400s



Energetic particle distribution function 34039 @ 400s – crude attempt to model (need to refine)

Should we get the distribution function at the correct time? Will it be any different?



Energetic particle distribution function 34041 @ 400s

