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Analysis of ITER hybrid scenarios

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Hybrid scenario

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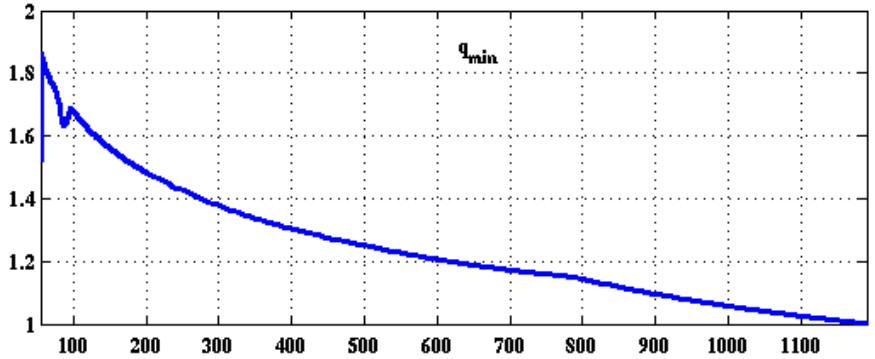
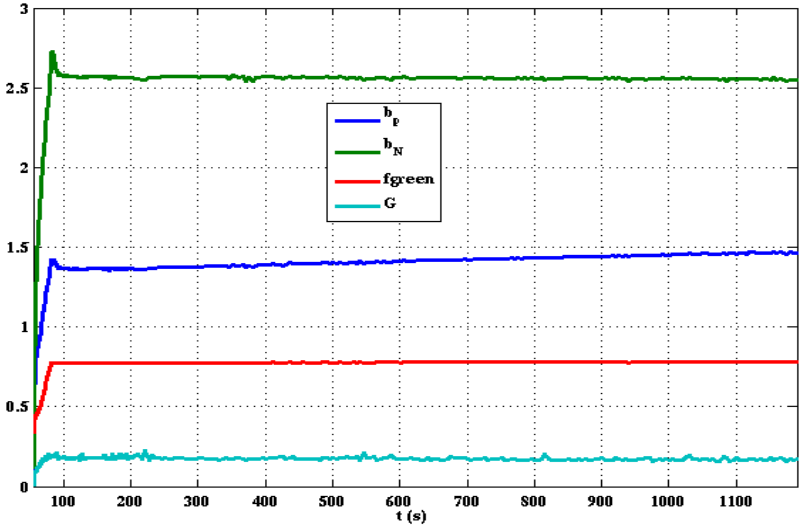
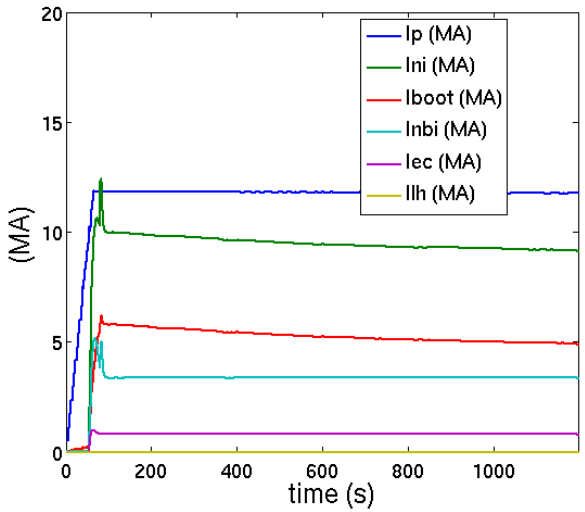
• Simulation parameters

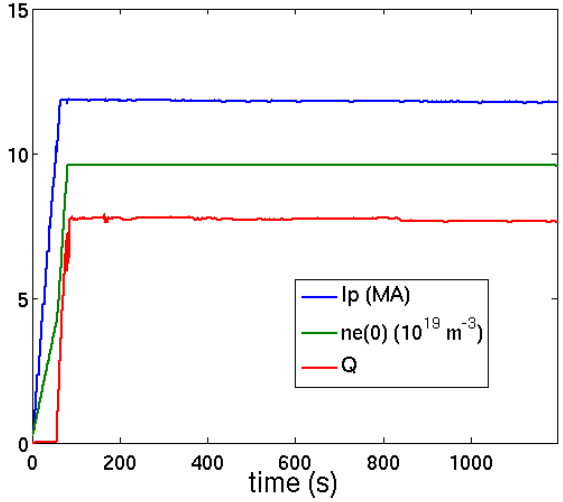
- I_p = 12 MA, B_T = 5.3 T
- dI_p /dt= 0.18 MA/s, B_T = 5.3 T, f_G=0.35 during ramp-up. f_G=0.83 flat-top phase
- EC wave launch: equatorial launchers, 8MW during ramp-up, 20MW flat-top
- ICRH: 20 MW, NBI: 33MW
- n_e profile fixed, picked profile, $n_e(0) \approx 9.5\ 10^{19}\ m^{-3}$
- $\rho_{ped} \approx 0.95$, $n_{ped} \approx 0.5\ 10^{20}\ m^{-3}$, $T_{ped} \approx 4.5$ keV
- L-H transition at t=54s when Ip=10MA
- **Bohm-GyroBohm transport model during ramp-up**
- **Fixed H_{98}=1.3 with Bohm-GyroBohm shape for flat-top phase**

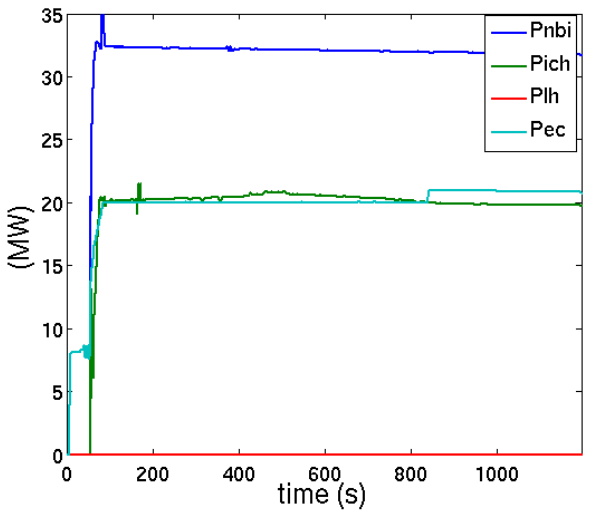




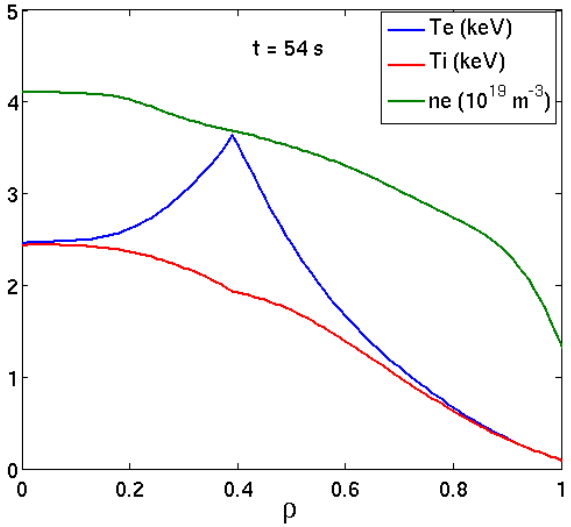
- The q=1 surface is reached at t=1150s
- H_{98}=1.3
- High performance β_N=2.6, β_p=1.45
- f_G=0.83

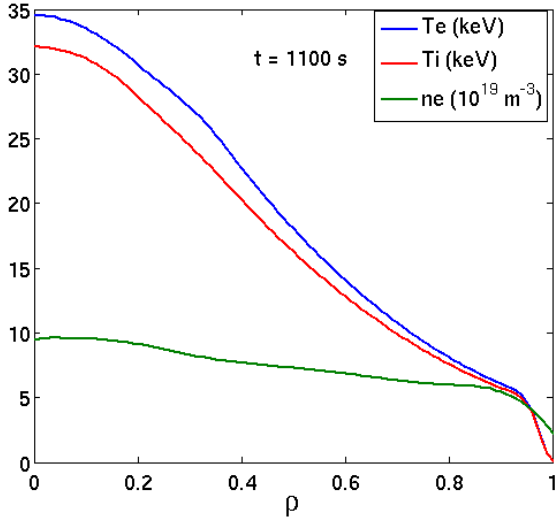


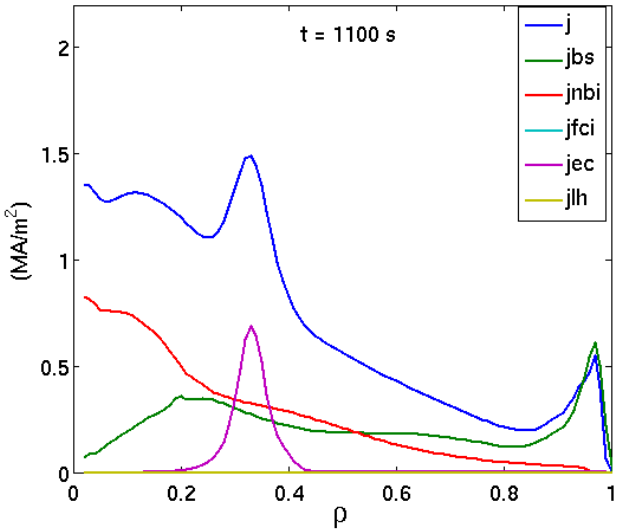




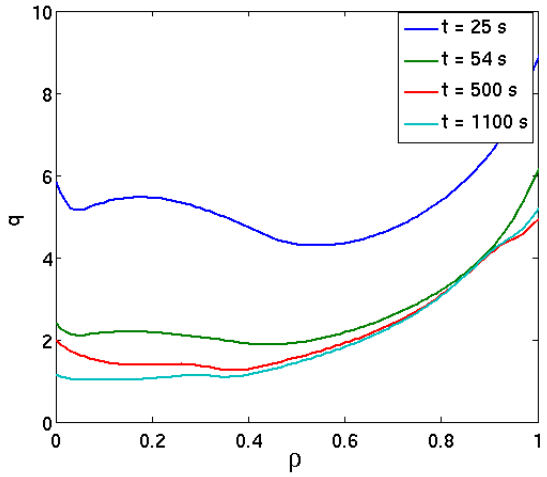
- L-H transition at t=54s when Ip=10 MA
- 33MW of NBI with on-axis and off-axis configuration to avoid current hole
- Ini=9.1 MA, Iboot=5.0 MA, Inbi=3.3MA, Ieccd=0.8 MA
- **Density ramp of 25s**
- **Q=7.5**

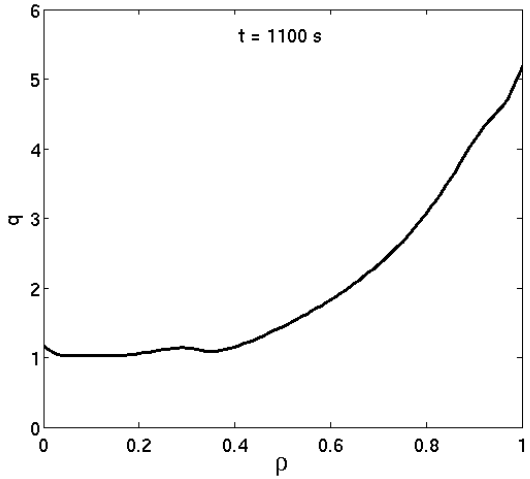


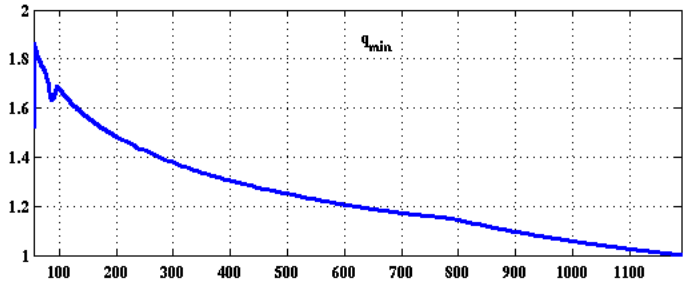




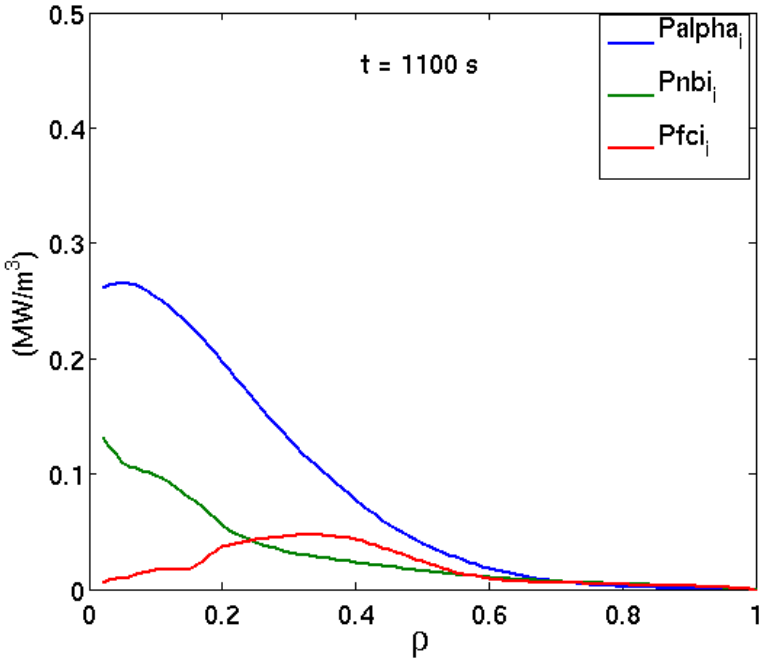
- At t=54s the electron temperature is already rather high off-axis
- Eccd at ρ≈0.35
- NBCD is clearly on-axis
- Bootstrap current maximum at ρ≈0.2
- The eccd current still looks too picked, there is some margin to reduce the ECRH power, or to broaden it

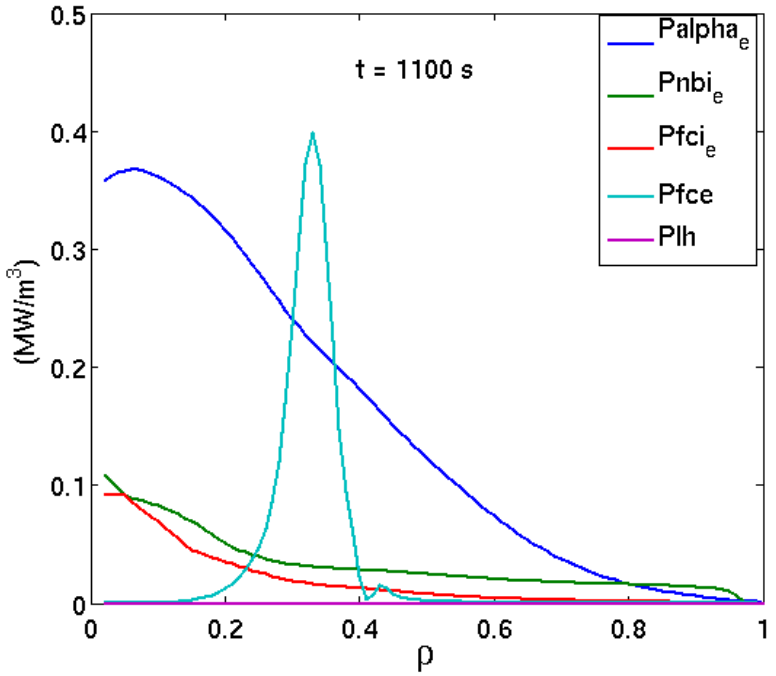






- At t=54s the q profile is just above 2
- At t=1150s is just 1 although still dropping
- q95=4.5
- The q profile is rather flat in the plasma core up to ρ≈0.4 as it could be expected from JET hybrids





- ICRH (f=49MHz) on-axis for electrons and off-axis for ions
- NBI mainly on-axis
- Powers are well balanced between on-axis and off-axis

Comparison with old GLF23 simulation

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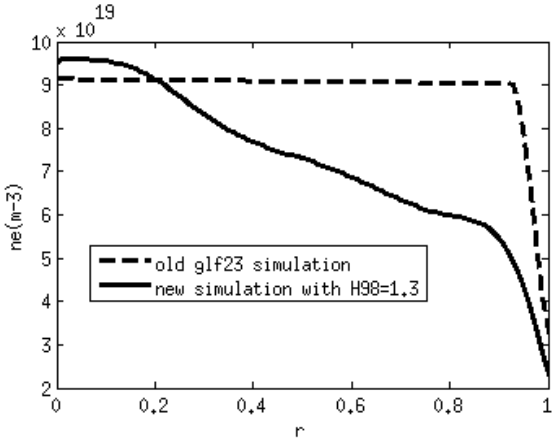

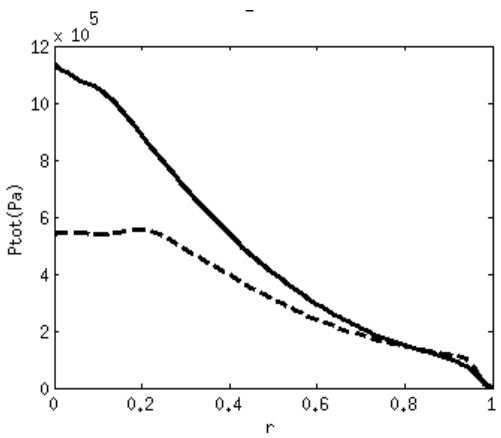

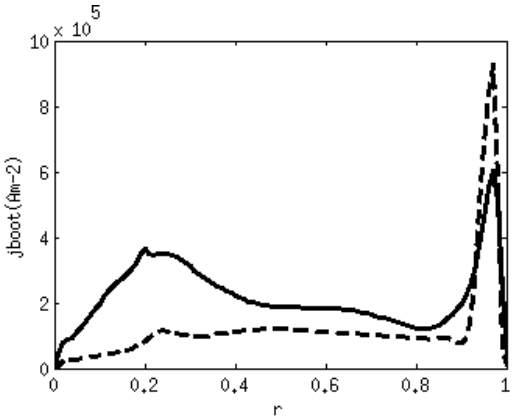

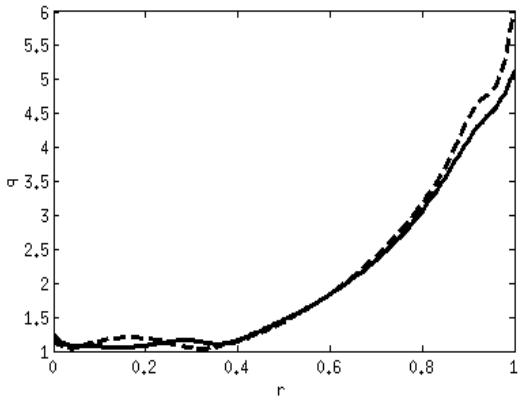

- Peacked density versus flat one
- H_{98}=1.3 versus H_{98}=1.06
- High performance β_N=2.6 versus low performance β_N=2.0
- On-axis and off-axis NBI versus full off-axis NBI
- Different bootstrap current profile
- Similar q profiles but much higher performance

Hybrid Scenario Conclusions

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- q=1 at t=1150s with a flat profile in the core
- High beta of β_N=2.6, β_p=1.4
- The L-H transition is at t=54s when Ip=10MA
- q_{95}>4 is essential
- NBI on and off-axis to avoid current hole
- f_G=0.4 in the ramp-up is important to avoid current hole when NBCD is added
- Peacked density is more important than high pedestal to modulate q profile and increase β_N