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Turbulent transport analysis of JET H-MODE and hybrid plasmas using Qualikiz, TGLF and GLF23

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OBJECTIVES AND PLANNED WORK

UNDERSTANDING THE KEY ASPECTS AND NUMERICALLY REPRODUCE TOKAMAK **ADVANCED SCENARIOS** FOR JET

-> to carry out the same analysis on advanced scenarios of different existing and future machines (JT60U, ITER..)

- **Qualikiz**
- **TGLF**

- validation:
  - in their stand alone version;
  - coupled with CRONOS for H-modes, comparison with **GLF23**
- study of advanced scenarios

ON GOING WORK

TGLF: benchmark needed: - stand alone version
- TGLF + CRONOS with TGLF + ASTRA, TGYRO and JETTO in progress

- **Coupling of TGLF to CRONOS and validation:**
  -> simulated 2 JET H-mode discharges (73342, 73344): Ti, Te
  -> simulated 2 JET hybrid discharges (75225, 77922): Ti, Te

- **Validation of coupling of QuaLiKiz to CRONOS:**
  -> simulated 2 JET H-mode discharges (73342, 73344): Ti, Te
  -> simulated 2 JET hybrid discharges (75225, 77922): Ti, Te

- **Comparison with GLF23**

QUALIKIZ, TGLF AND GLF23 FEATURES

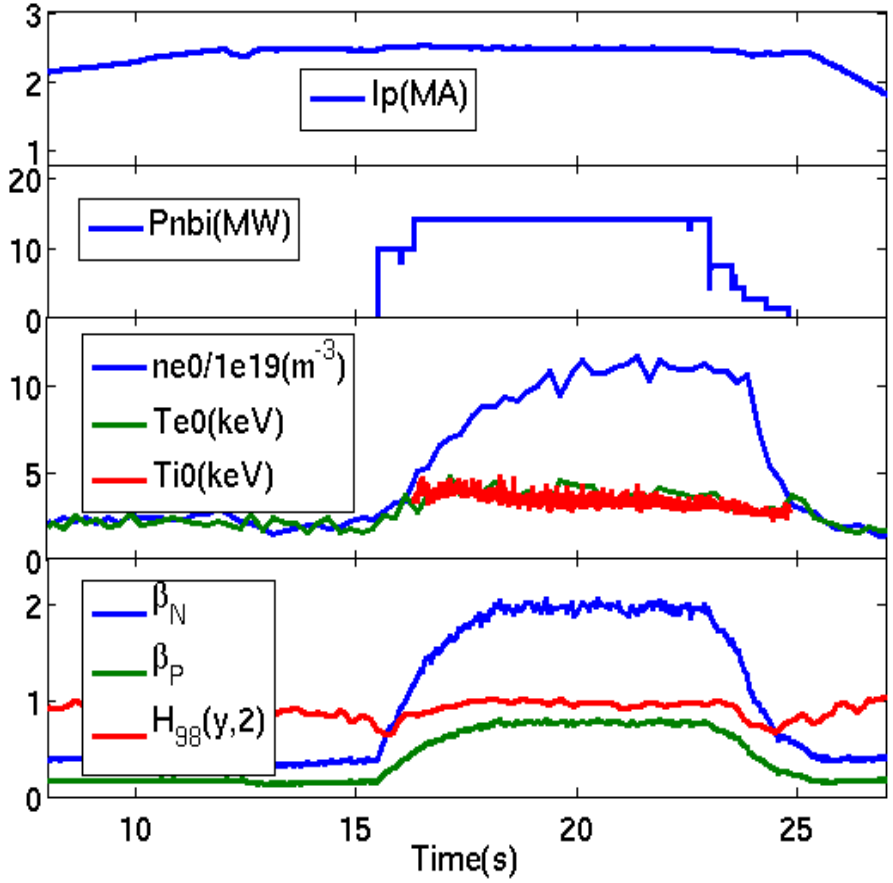
specifics of the transport models in the simulations done until now :

- **Qualikiz**: - electrostatic
  - s-alpha geometry
  - no effect of rotation;

- **TGLF**: - electromagnetic
  - Miller geometry
  - no effect of rotation (not included yet in the version for CRONOS);

- **GLF23**: - electrostatic
  - s-alpha geometry
  - ExB shear effect.

H-MODE: JET SHOT 73342

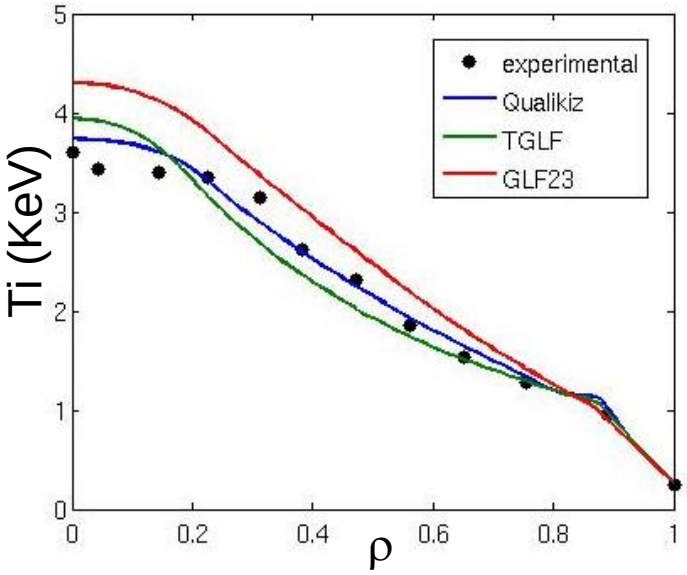


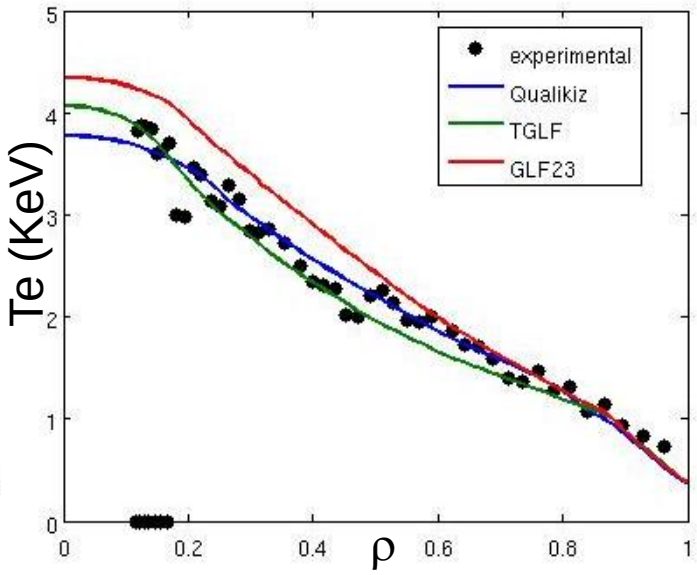
Ip (MA)	2.5
Bt (T)	2.7
q_{95}	3.4
κ/δ	1.74/0.42
β_N/β_p	2.0/0.80
f_{Gw}	1.0
$H_{98}(y,2)$	1.0
P_{nbi}(MW)	15

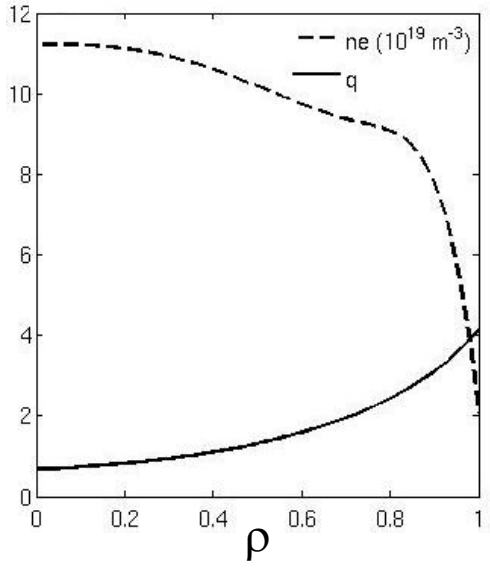
High density H-mode

H-MODE: JET SHOT 73342

t = 20.1 s





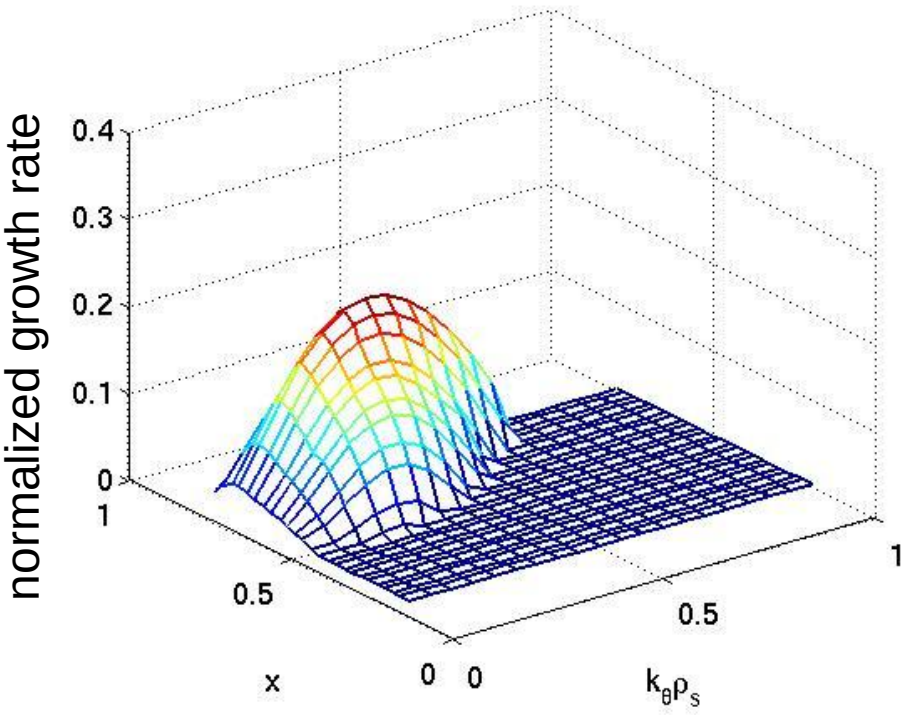


- Very good agreement between **Qualikiz** and experimental data
- **TGLF** is in good agreement (experimental data slightly underestimated)
- **GLF23** overestimates slightly the data
- $\rho_{tn} < 0.3$: presence of sawteeth that are not simulated

Qualikiz , TGLF and GLF23 reproduce reasonably well the T profiles

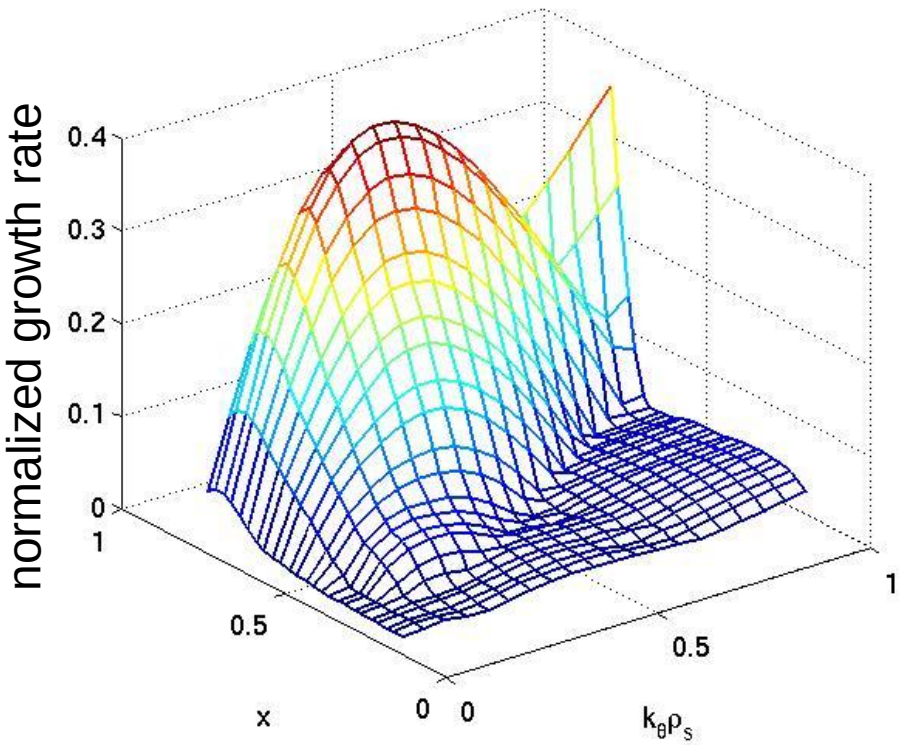
H-MODE: JET SHOT 73342

Qualikiz



Electrostatic, s-alpha geometry

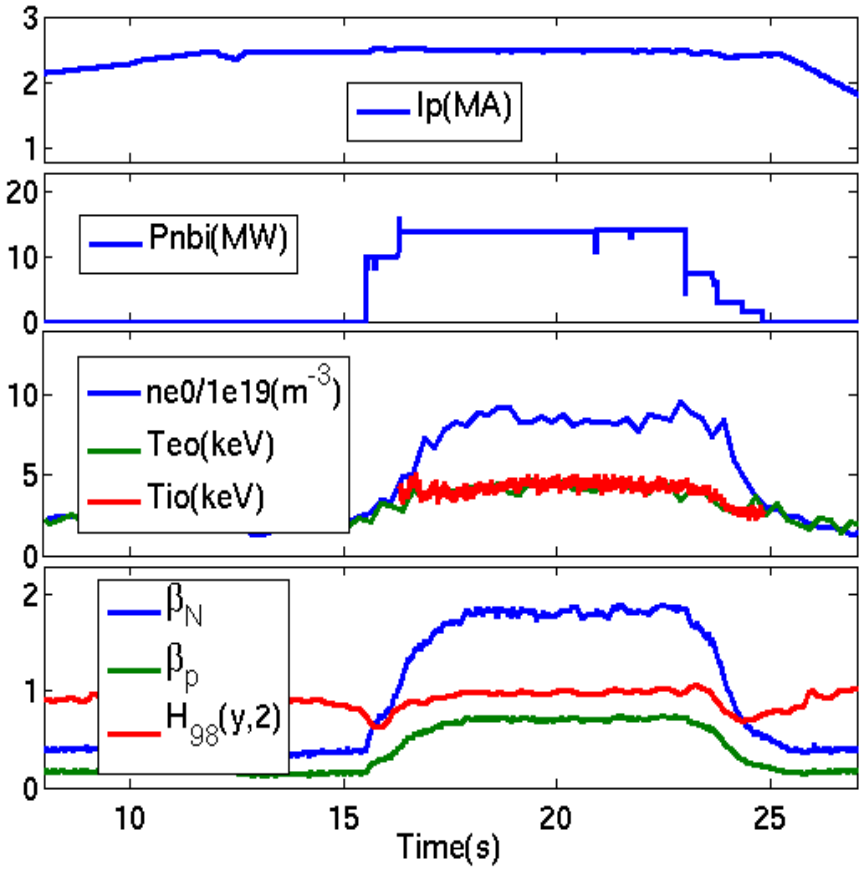
TGLF



Electromagnetic, Miller geometry

Qualikiz tends to be more stable in the central part of the plasma

H-MODE: JET SHOT 73344

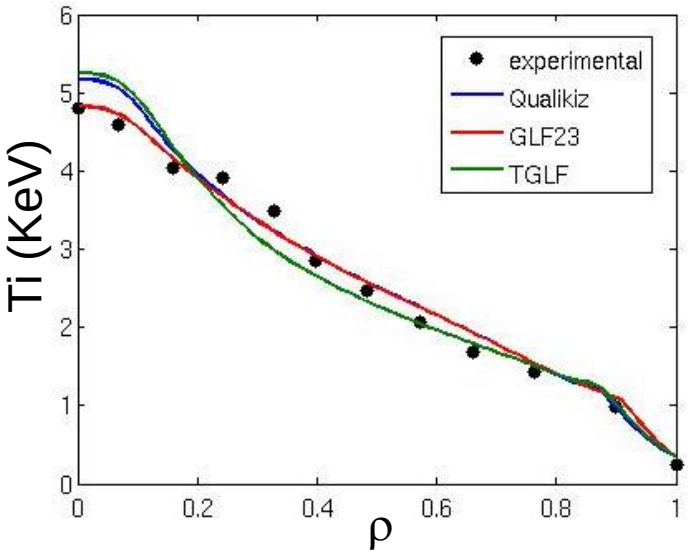


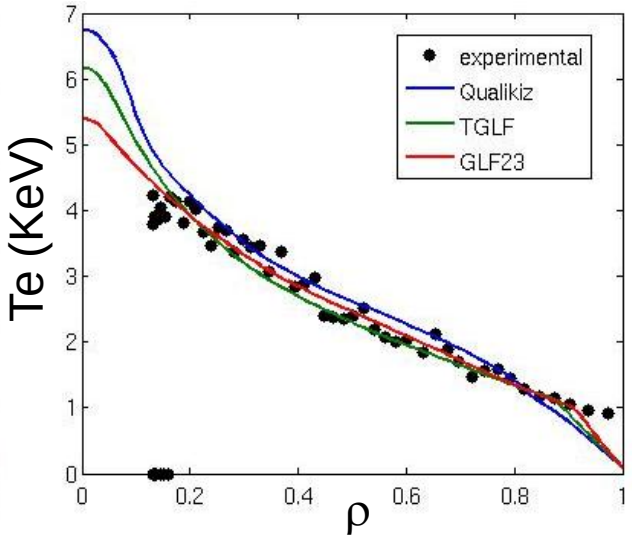
Ip (MA)	2.5
Bt (T)	2.7
q_{95}	3.4
κ/δ	1.74/0.39
β_N/β_p	1.5/0.85
f_{Gw}	0.75
$H_{98}(y,2)$	0.95
P_{nbi}(MW)	15

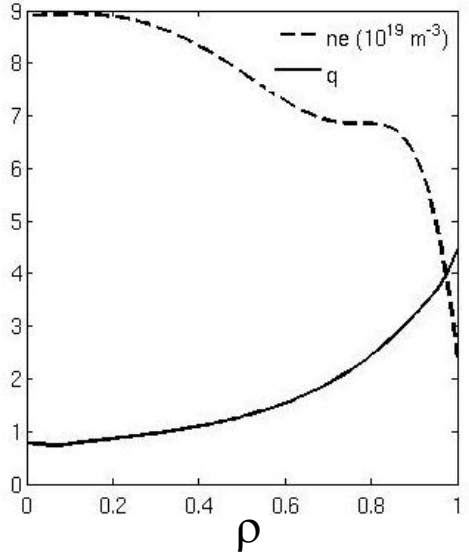
Standard H-mode

H-MODE: JET SHOT 73344

t = 18,8 s





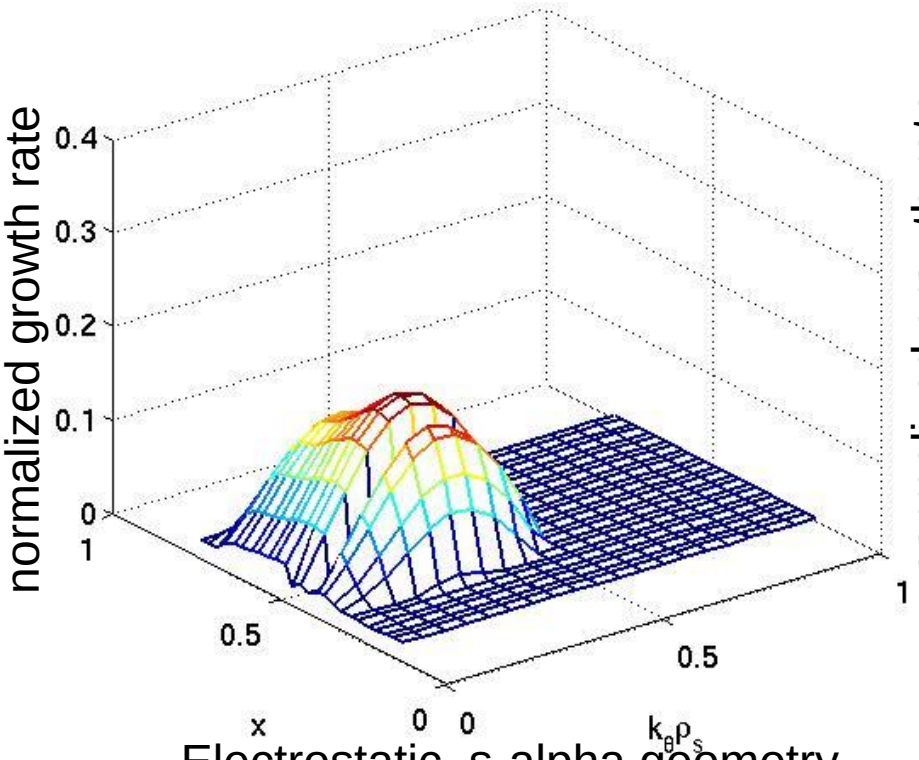


- $0.2 < \rho_{tn} < 0.8$: - **Qualikiz** and **GLF23** very similar behaviour, good agreement with data
  - experimental points are well reproduced by **TGLF** too
- no 'artificial' anomalous coefficients imposed in the centre
- $\rho_{tn} > 0.8$: qualikiz suffers at high s

Qualikiz , TGLF and GLF23 agree with experimental T profiles in the core ($0.2 < \rho_{tn} < 0.8$)

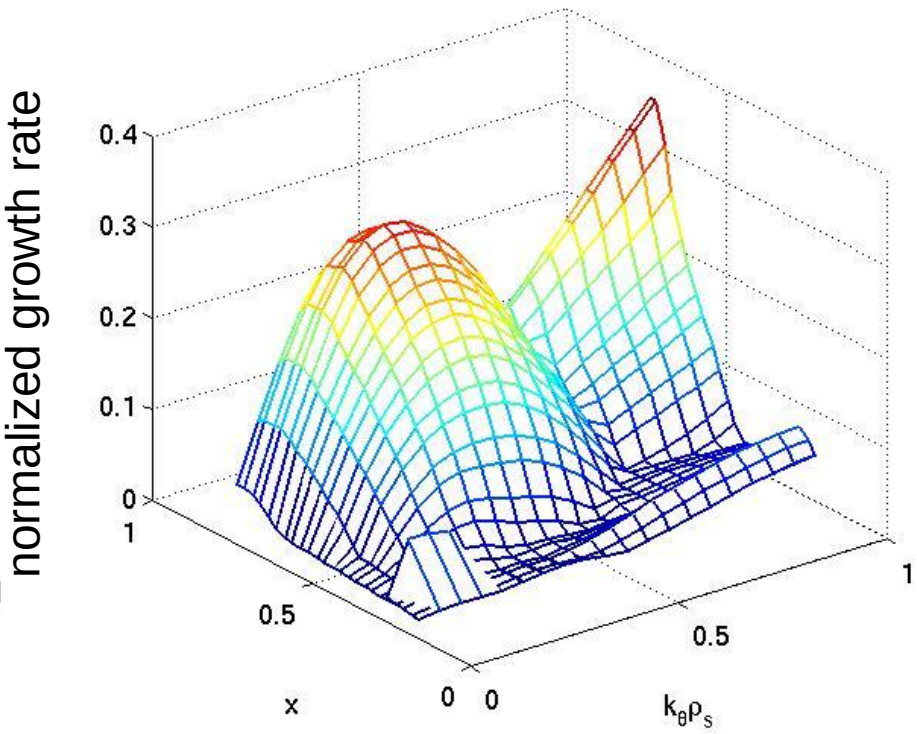
H-MODE: JET SHOT 73344

Qualikiz



Electrostatic, s-alpha geometry

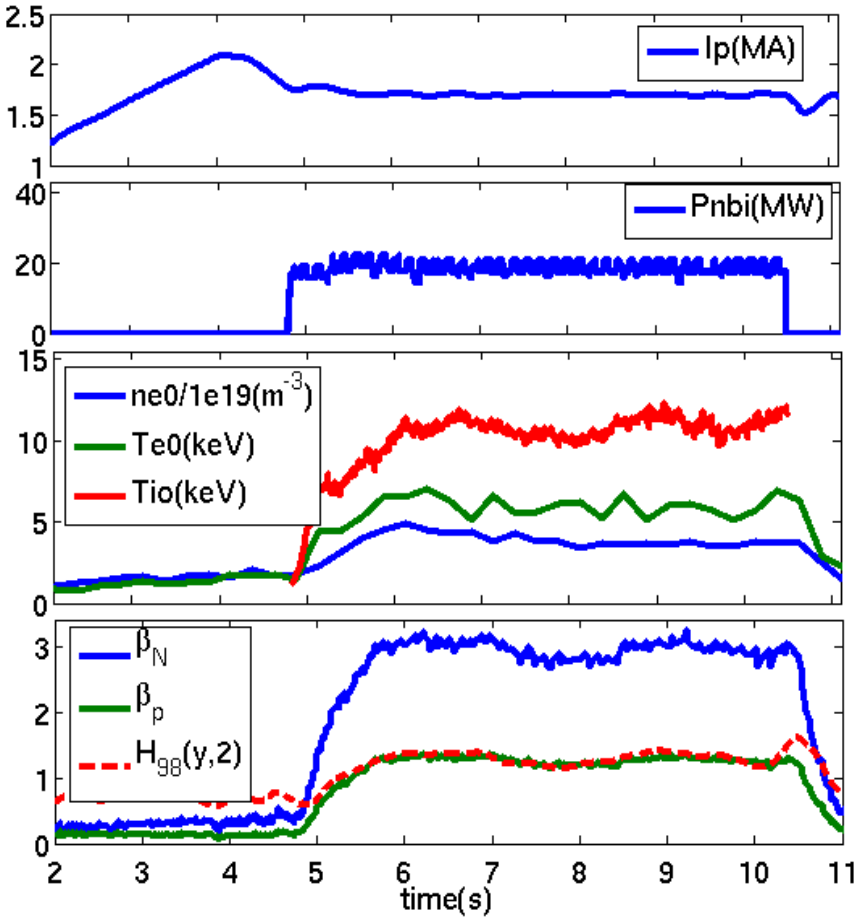
TGLF



Electromagnetic, Miller geometry

Qualikiz tends to be more stable in the central part of the plasma

HYBRID: JET SHOT 75225

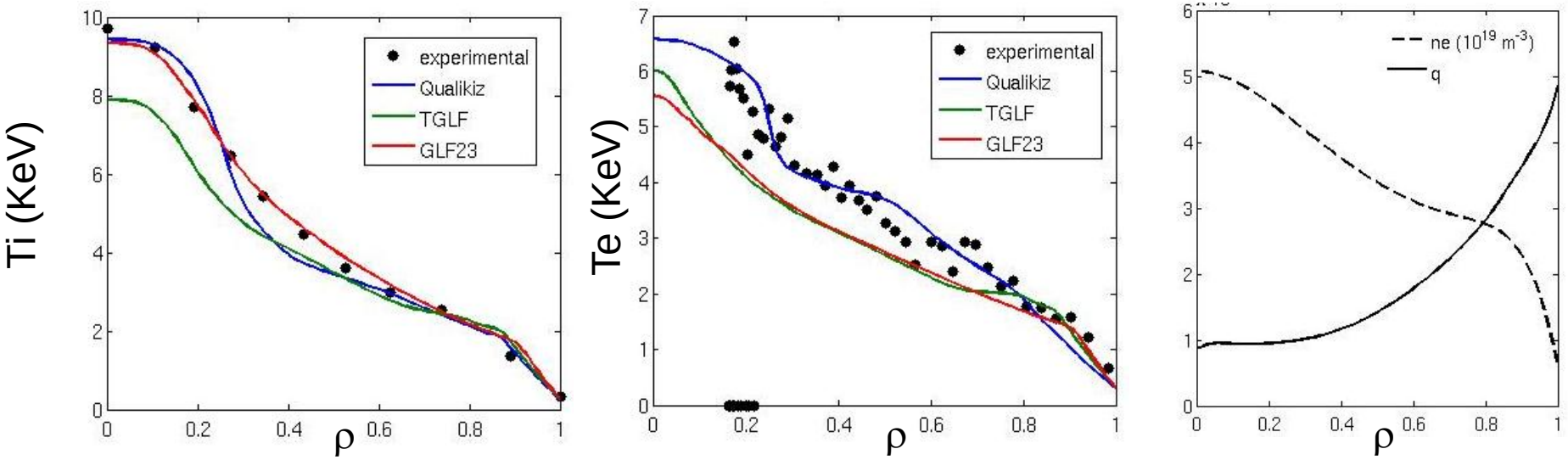


Ip (MA)	1.7
Bt (T)	2.0
q_{95}	4.1
κ/δ	1.64/0.23
β_N/β_p	3.0/1.30
f_{Gw}	0.45
$H_{98}(y,2)$	1.30
P_{nbi}(MW)	17

Low triangularity, low density hybrid

HYBRID: JET SHOT 75225

t = 6 s



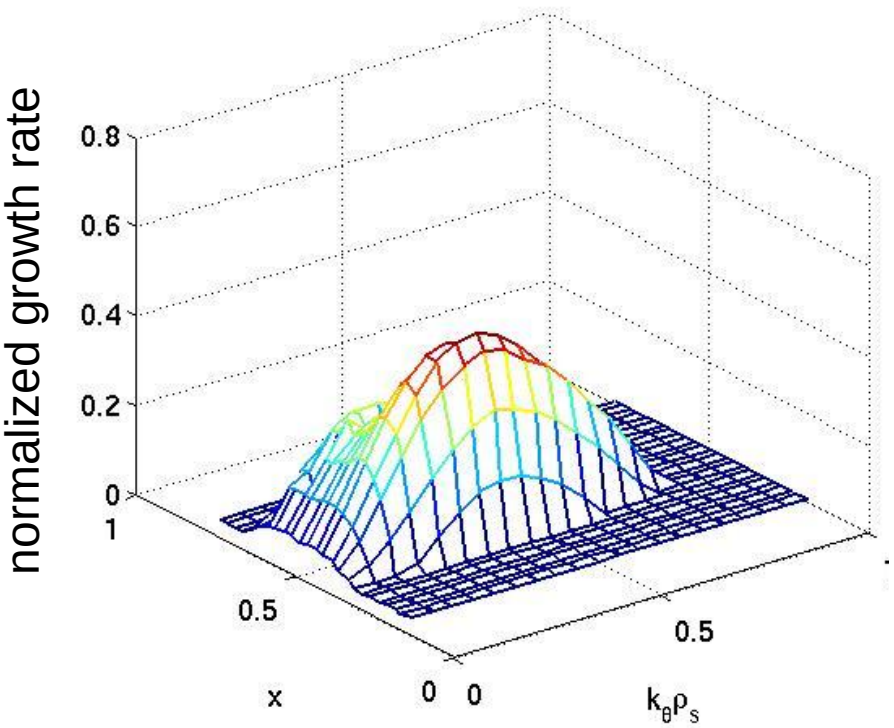
Low density, <ne> = 3 10^{19} m^{-3} High rotation, v_{tor} = 1 10^{5} rad/s

- **GLF23** is good to reproduce ions, and not too far from electron experimental profile
- **TGLF** underestimates ions (it doesn't include any rotation effect), it is similar to GLF23 for electrons
- **Qualikiz** overestimates the reduction of the transport in the centre for ions and electrons; in the electron pedestal region it doesn't reproduce the data

where s = 0 or s is high Qualikiz has problems; TGLF maybe better with the rotation effect?

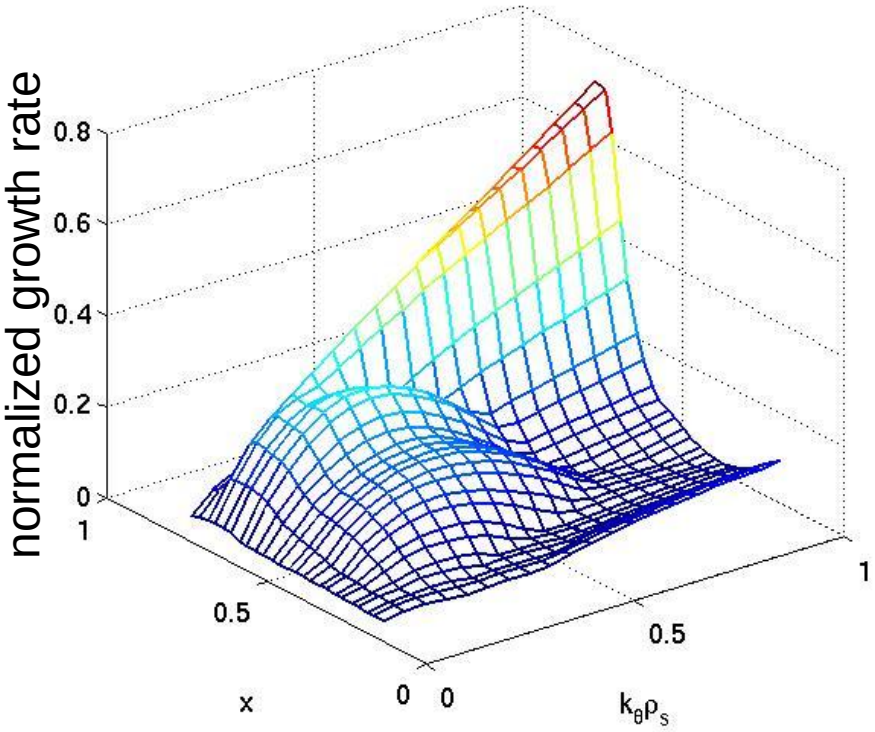
HYBRID: JET SHOT 75225

Qualikiz



Electrostatic, s-alpha geometry

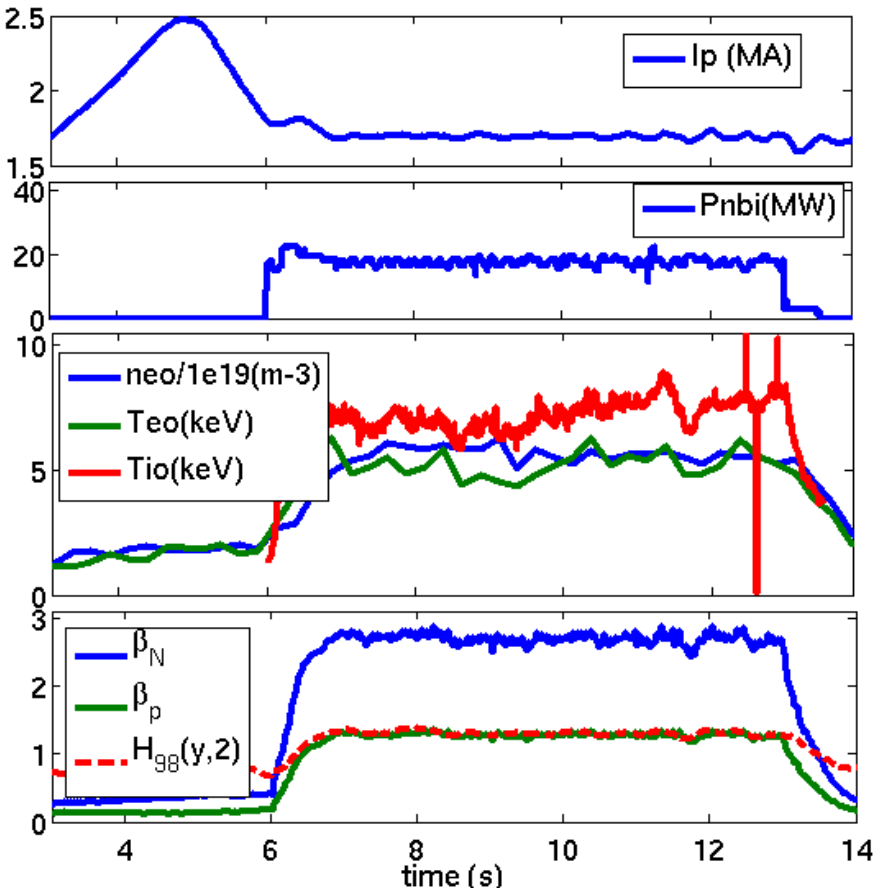
TGLF



Electromagnetic, Miller geometry

At x = 0.3 Qualikiz becomes stable, TGLF no

HYBRID: JET SHOT 77922

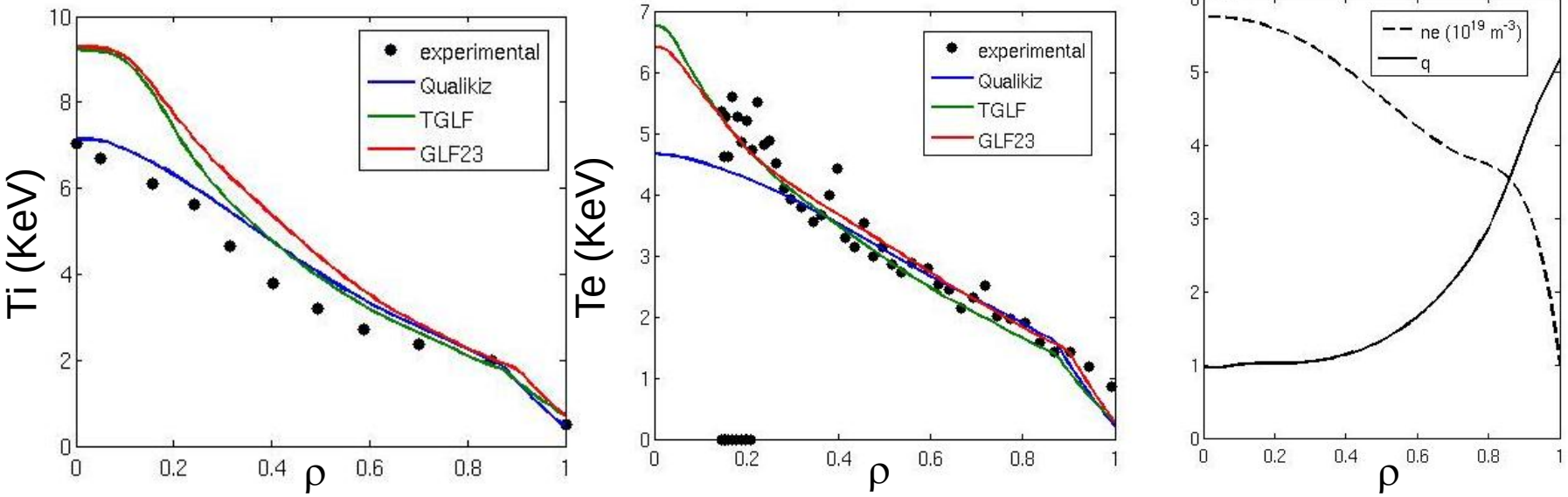


Ip (MA)	1.7
Bt (T)	2.3
q_{95}	4.3
κ/δ	1.7/0.38
β_N/β_p	2.7/1.2
f_{Gw}	0.70
$H_{98}(y,2)$	1.20
P_{nbi}(MW)	17

High triangularity, high density hybrid

HYBRID: JET SHOT 77922

t = 7.6 s



High density, <n> = 4.3 10^{19} m^{-3} High rotation, v_{tor} = 1 10^{5} rad/s

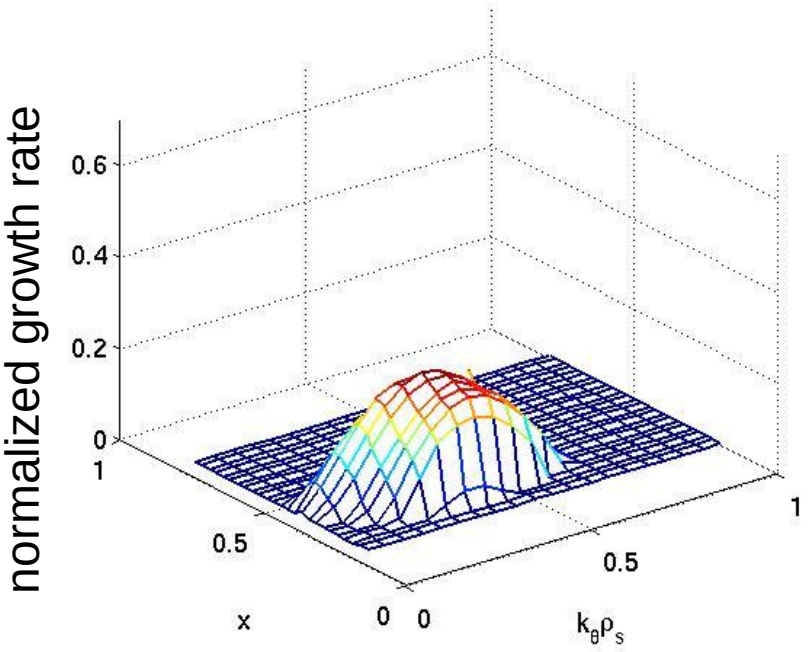
- **GLF23** overestimates ions, good for electrons
- **TGLF** better for ions than GLF23 in the core region, good for electrons
- **Qualikiz** better for ions, good for electrons in the core region

- Rotation seems not very important ->
need to redo simulations with TGLF with rotaton effect

- role of geometry?

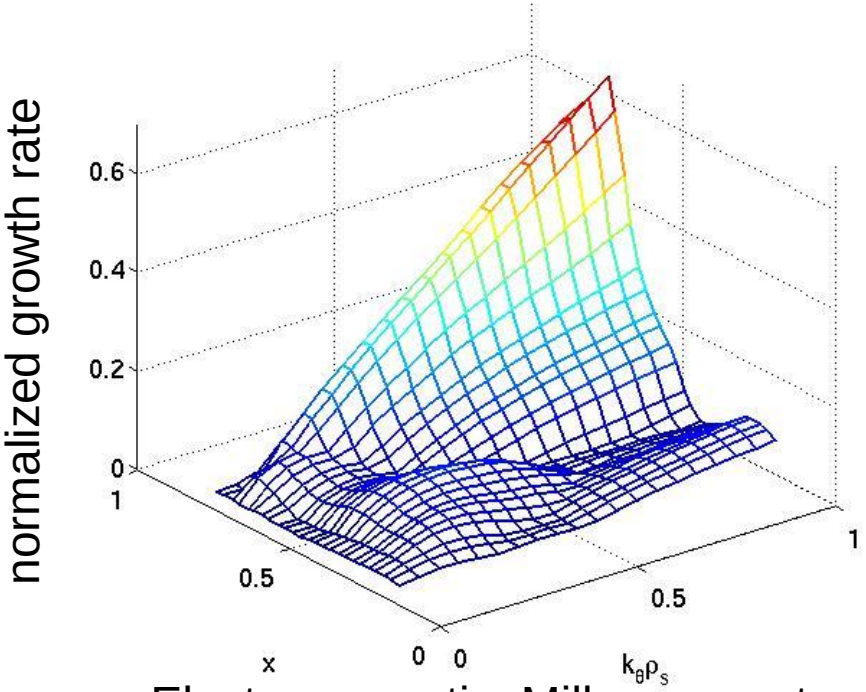
HYBRID: JET SHOT 77922

Qualikiz



Electrostatic, s-alpha geometry

TGLF



Electromagnetic, Miller geometry

In the core Qualikiz seems unstable as TGLF in the low k region

CONSIDERATIONS AND OUTLOOK 1/2

SIMULATIONS WITH CRONOS

- ***H-MODES:***

good agreement of **TGLF** and **Qualikiz** with experimental data and **GLF23** simulations of heat;

next steps: - to investigate better **pedestal problems**;
- to include the evolution of the **density**.

- ***HYBRIDS:***

ions: - **GLF23** gives the best agreement in 75225, the worst in 77922;
- **TGLF** without rotation underestimates the data in 75225, slightly overestimation in 77922;
- **Qualikiz** overestimates the reduction of the transport where s=0 in 75225, better in 77922.

electrons: - **GLF23** and **TGLF** underestimate the data in 75225;
- **Qualikiz** overestimates the reduction of the transport where s=0 and shows problems for high s;
- agreement among the models in the core region for 77922.

next steps: - to simulate **other hybrids** shots, of JET and other machines in order to do a more systematic analysis;
- to include the effect of the **rotation in TGLF**.

CONSIDERATIONS AND OUTLOOK 2/2

SIMULATIONS WITH CRONOS

Problem: Qualikiz+CRONOS is much time demanding:
to simulate one shot for one s: 1.5-2 days needed for TGLF+CRONOS
2.5-3 weeks needed for Qualikiz+CRONOS

STAND ALONE SIMULATIONS

- **Comparison of TGLF and QuaLiKiz (fluxes and growth rates spectra)**

  study of sensibility and dependence on geometrical and physical parameters:

  - scans of s, R/L_T, T_e/T_i, ν_{ei}, Z_{eff} based on the GA-standard case and compared with non linear GYRO expectations are in progress;

  - scans on JET H_mode and hybrid discharges are foreseen.

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