CONSORZIO RFX
Ricerca Formazione Innovazione

High density regimes in RFX

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Outline

- High density regimes and confinement
- Radiation mantle in RFPs
- High density limits
- Summary

High Density Regimes Correspond to Higher τ_E

- The reason is not well understood
- Experimentally Increasing density, :
  - –Bt fluctuations increase, core $|\nabla T_e|$ decreases
  - – edge D decreases , edge $|\nabla n_e|$ increases , edge $|\nabla T_e|$ increases
- If, schematically, the RFP is divided in two regions - core and edge - :
  at high density, the increase of edge confinement apparentlycompensates for core confinement degradation

- density source modification?
- (Bohm-like transport D≈Te/eB)?
- increased Er shear?

High Density Regimes Favourable to the Creation of a Radiative Mantle

In Tokamaks

Edge plasma radiation cooling: an efficient method to reduce the peak heat load and a promising candidate to solve the problem of the power exhaust in a reactor grade device.

In RFPs

Is the Radiative Mantle Concept compatible with:

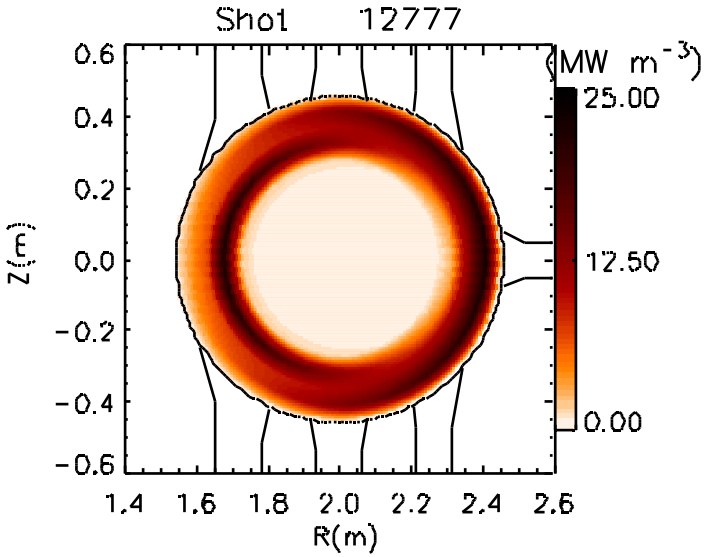
- plasma edge good confinement?
- RFP equilibrium = intense edge poloidal currents driven by the dynamo?

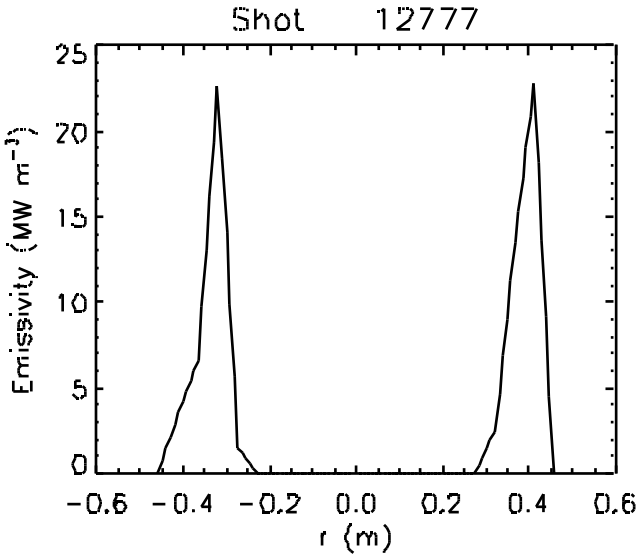
Neon injection experiments in RFX: radiation properties

- In neon seeded discharges the radiated power density is more poloidally symmetric than with intrinsic impurities only.

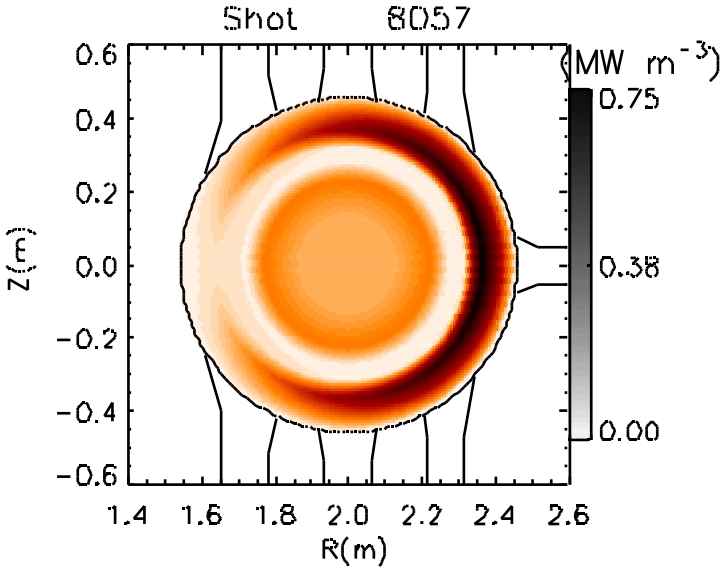
- A nearly homogeneous radiative mantel can be achieved only at the highest plasma densities

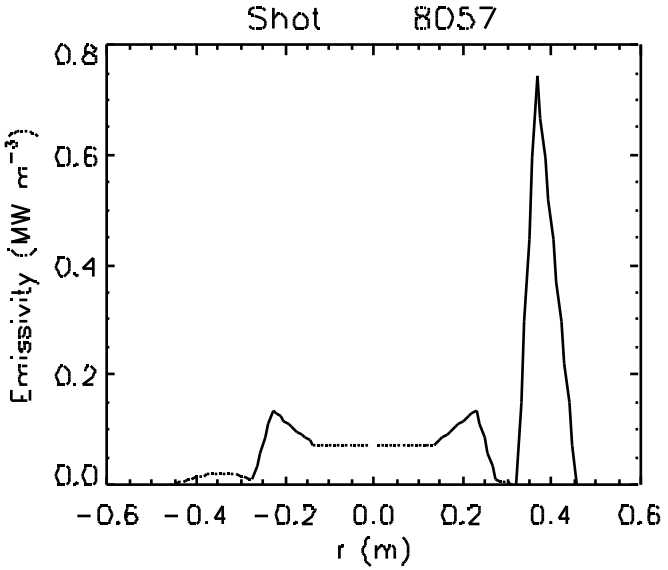
Neon injected





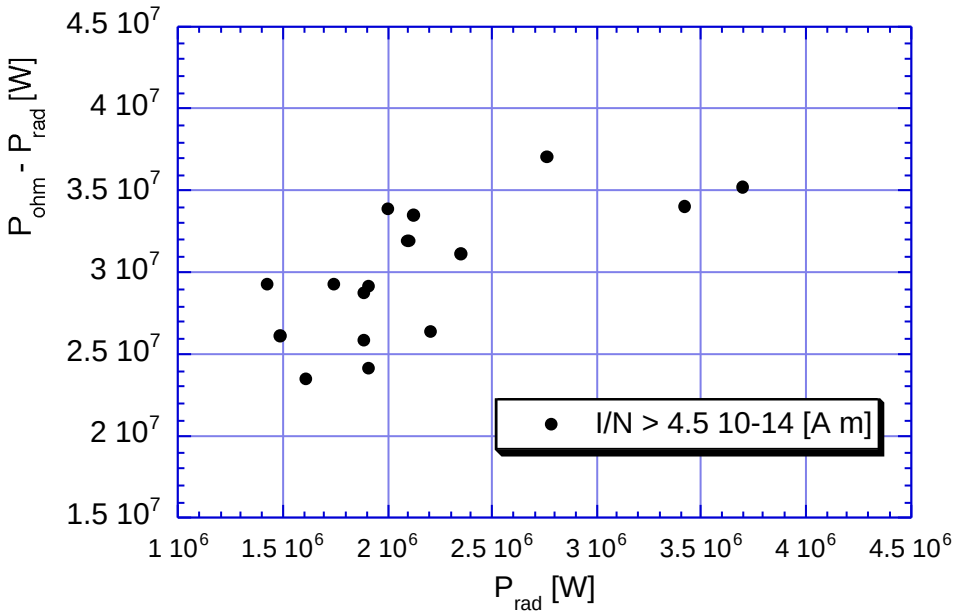
Intrinsic impurities



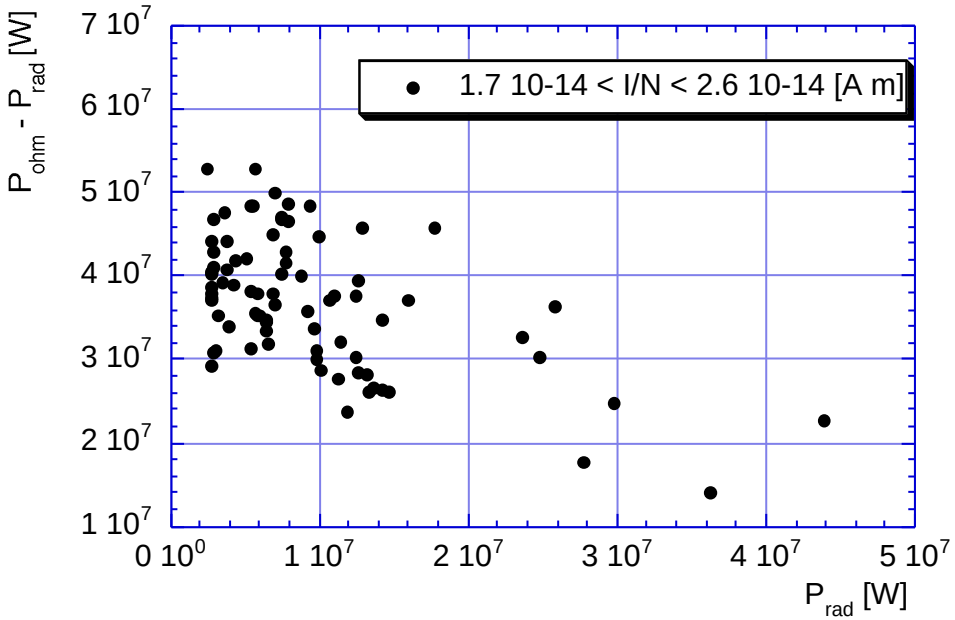


Neon injection and convective load

Low density

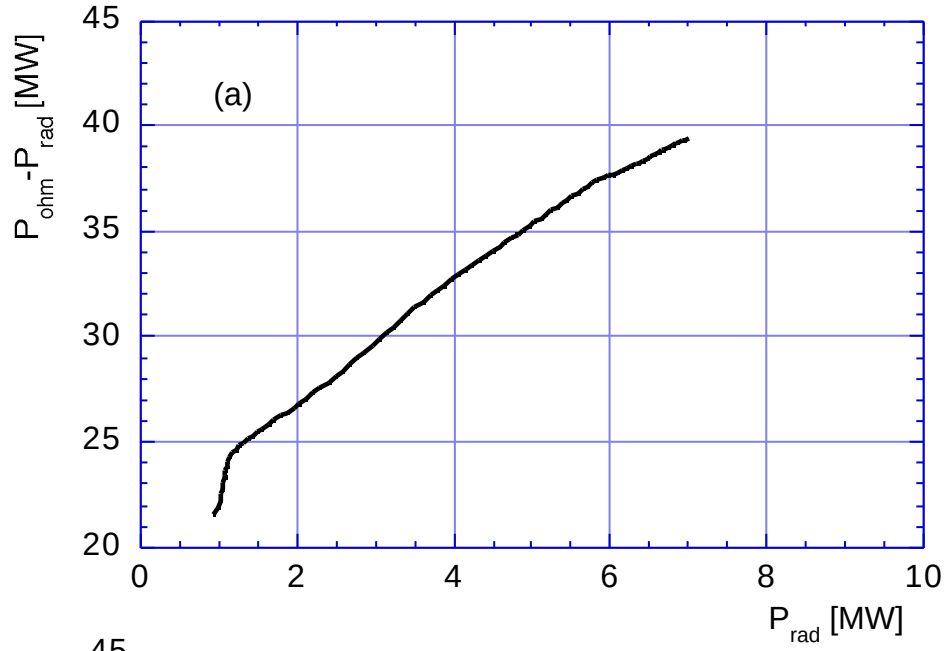


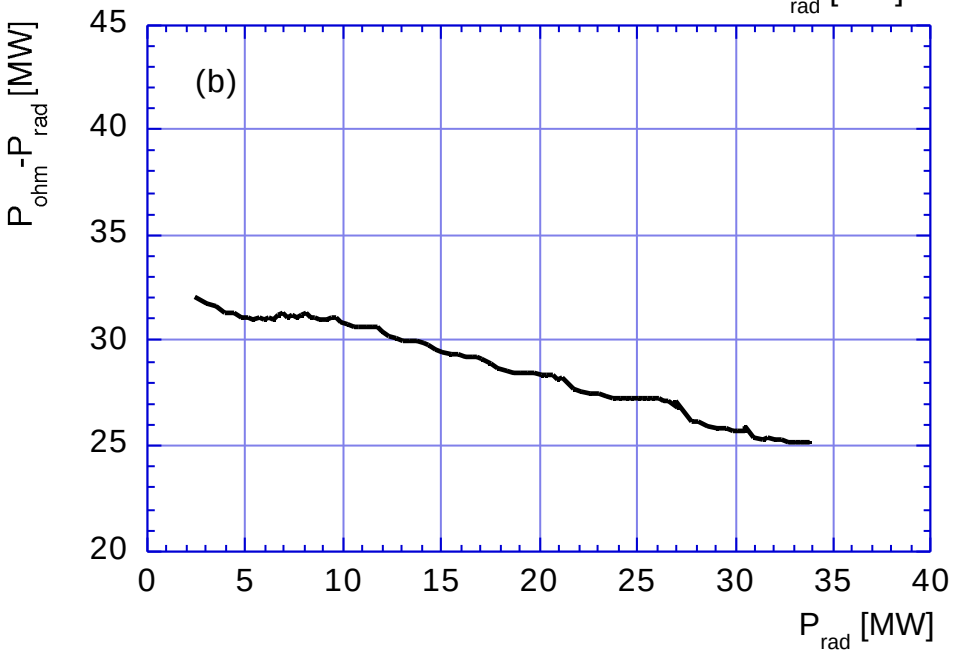
High density



Low density: the increase of P_{ohm} (mainly due Zeff) exceeds that of P_{rad} in spite of a slight increase of γ

High density: a little amount of Ne required for a high radiation fraction, with little Zeff increase (i.e. little Pohm increase)

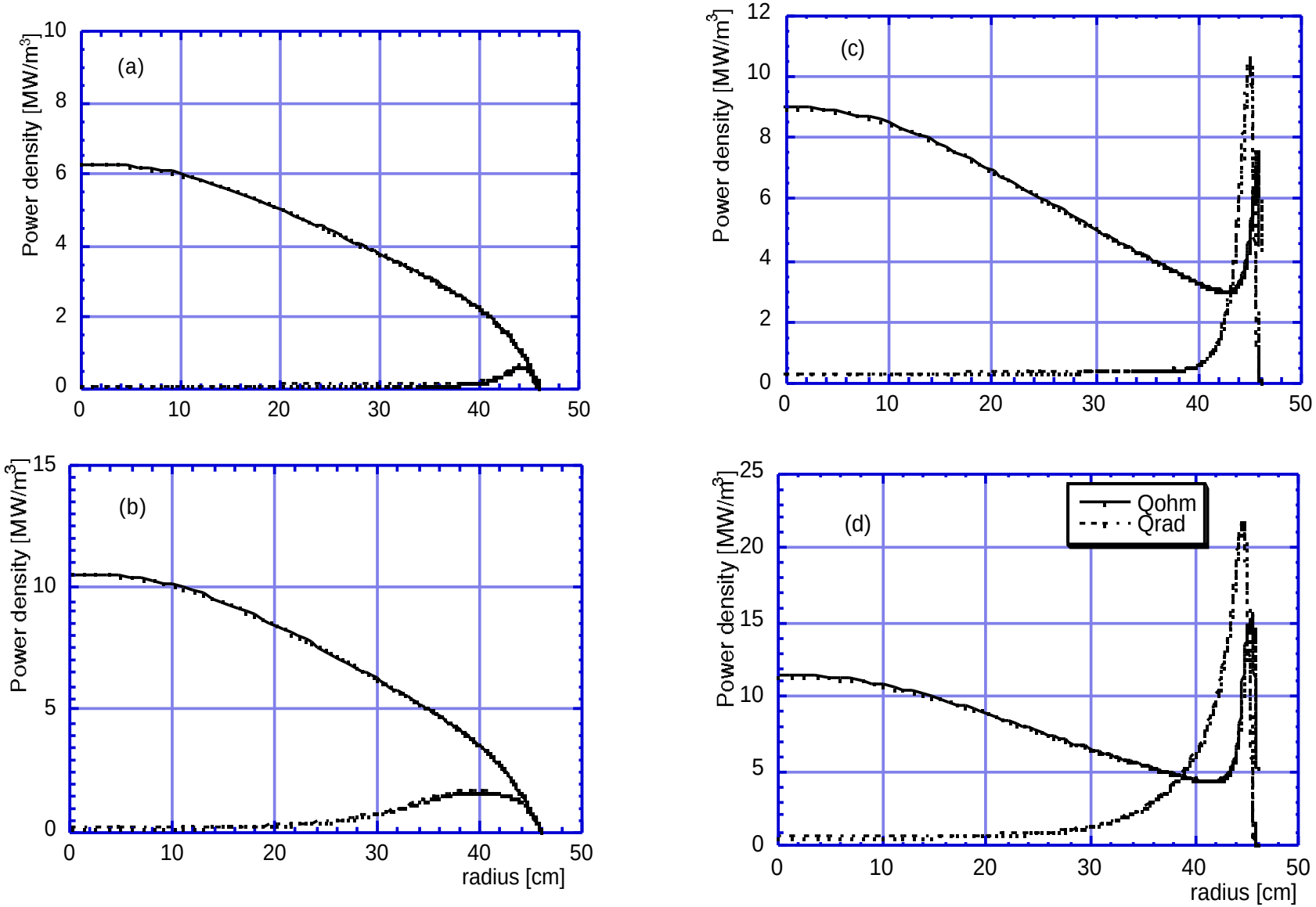




RITM code Simulations of Prad - Pohm for two density levels :

n_e 3 x 10^{19} m^{-3}

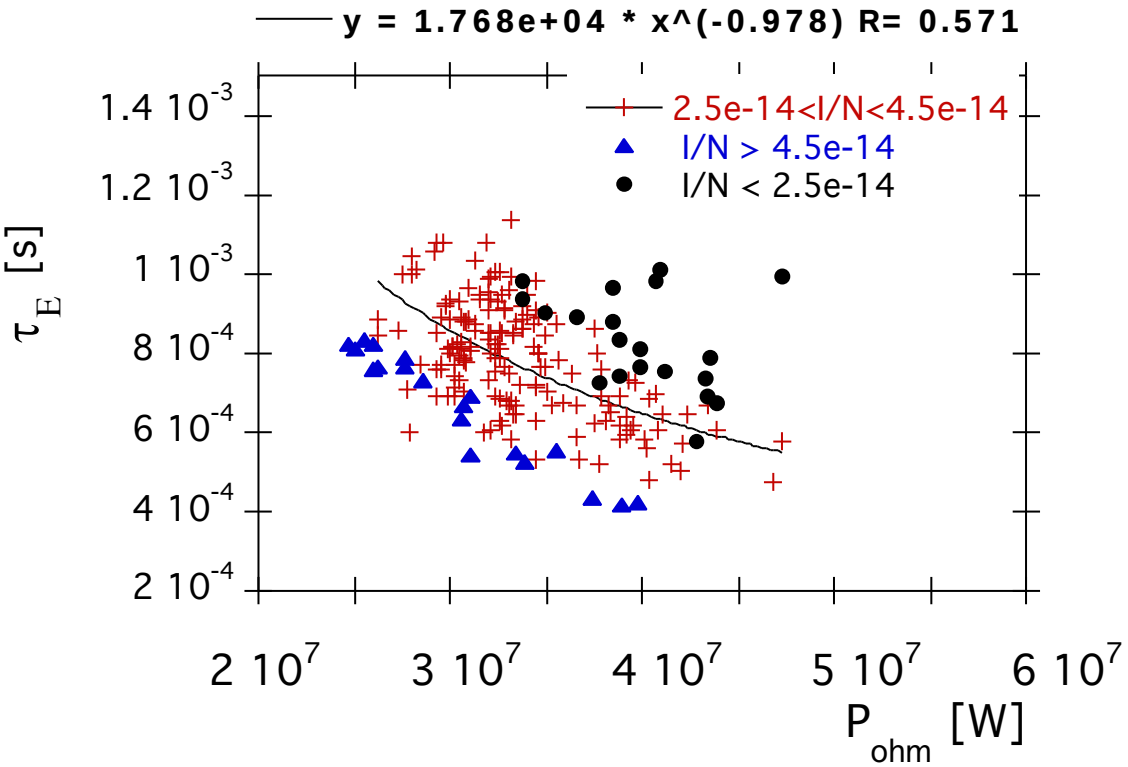
8 x 10^{19} m^{-3}



RITM code Simulations of two density levels

Confinement in neon seeded discharges.

Thomson Scattering data show only minor changes in the electron temperature profile in discharges with and without Ne at similar n_e.

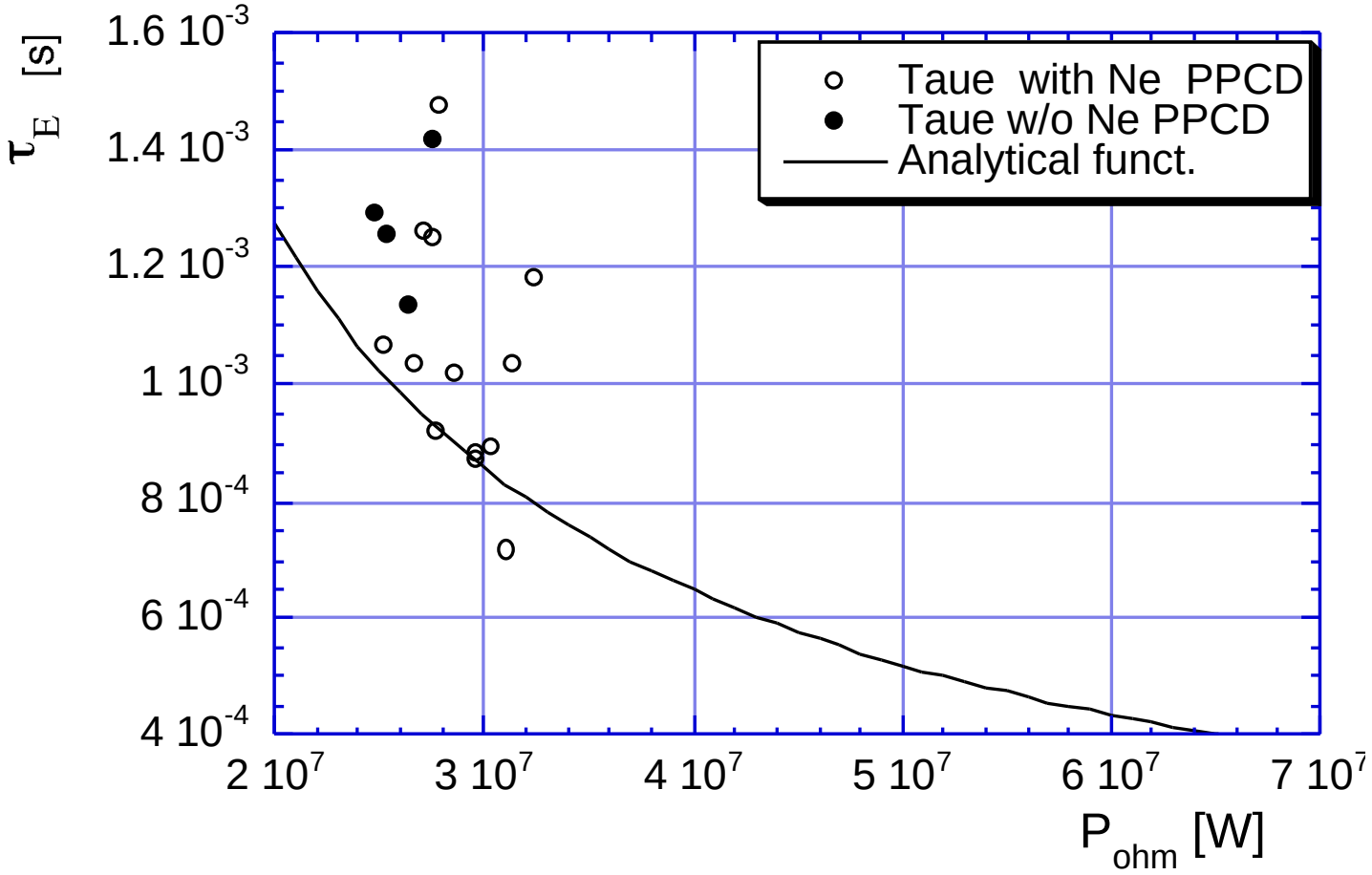


τ_E increases with increasing electron density and, at any given n_e, decreases with increasing the heat power level P_{heat}: $\tau_E \sim (P_{heat})^{-1}$.

- Shots with and without Ne injection, Ip ~ 0.8 MA:
$\tau_E \sim P_{heat}^{-1}$ at a given I/N implies $\beta_\theta \sim$ constant

Confinement in neon seeded discharges with PPCD.

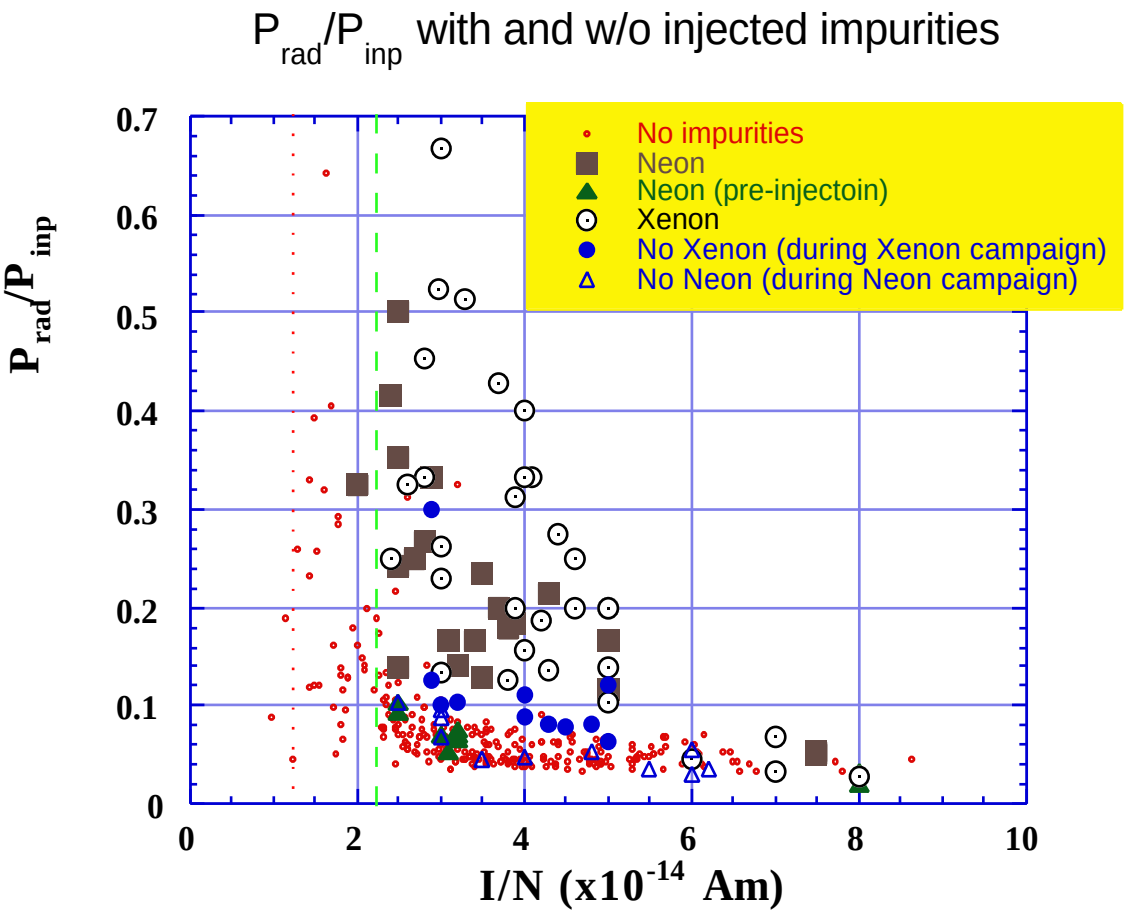
Higher τ_E , lower P_{ohm} for the same I/N (= different transport regime?)



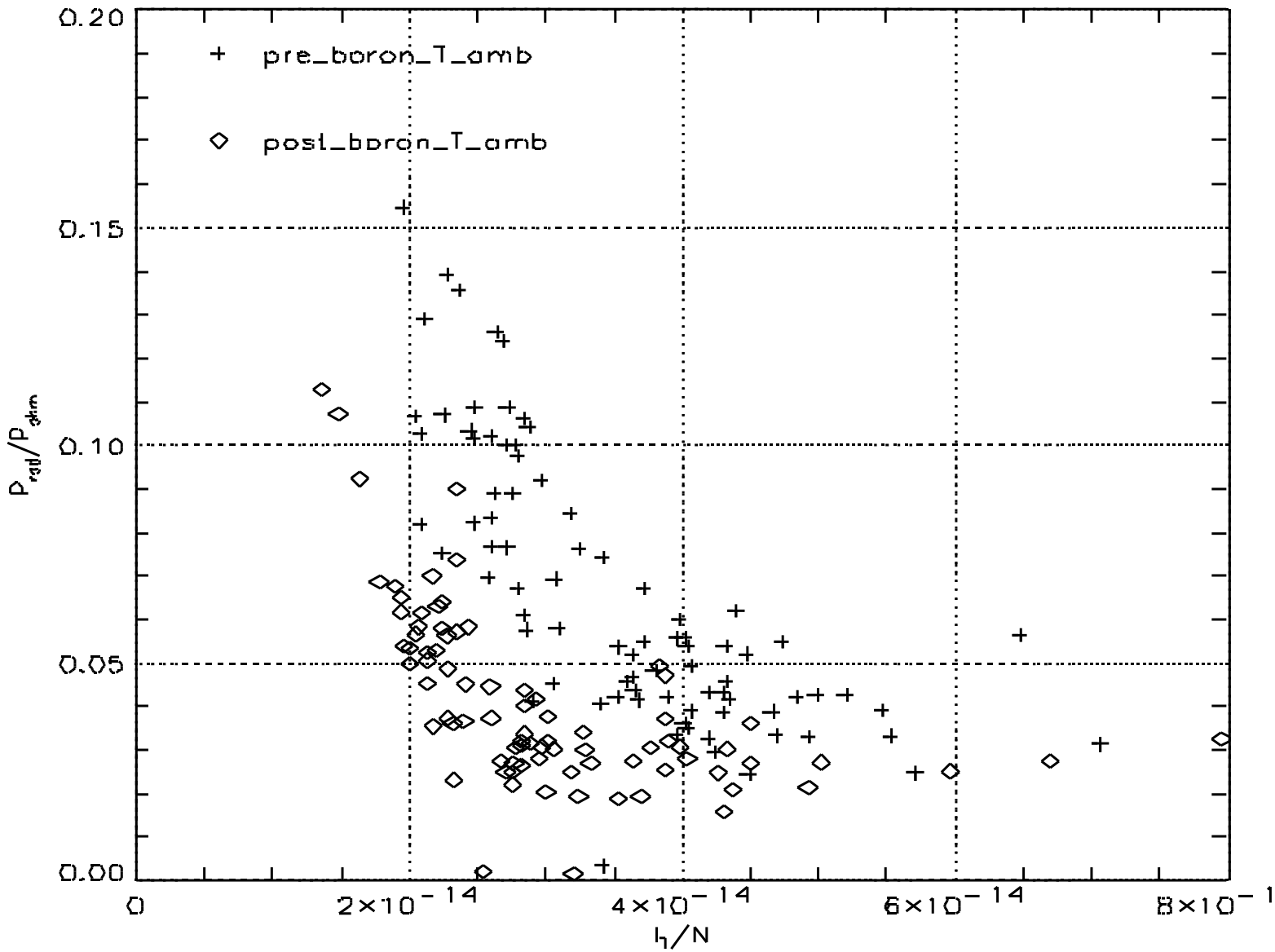
(However , so far only moderate Ne injection , more experiments needed)

High Density Limits

A well known high densityexperimental limit exists in RFPs
Question: intrinsic or operational limitation??

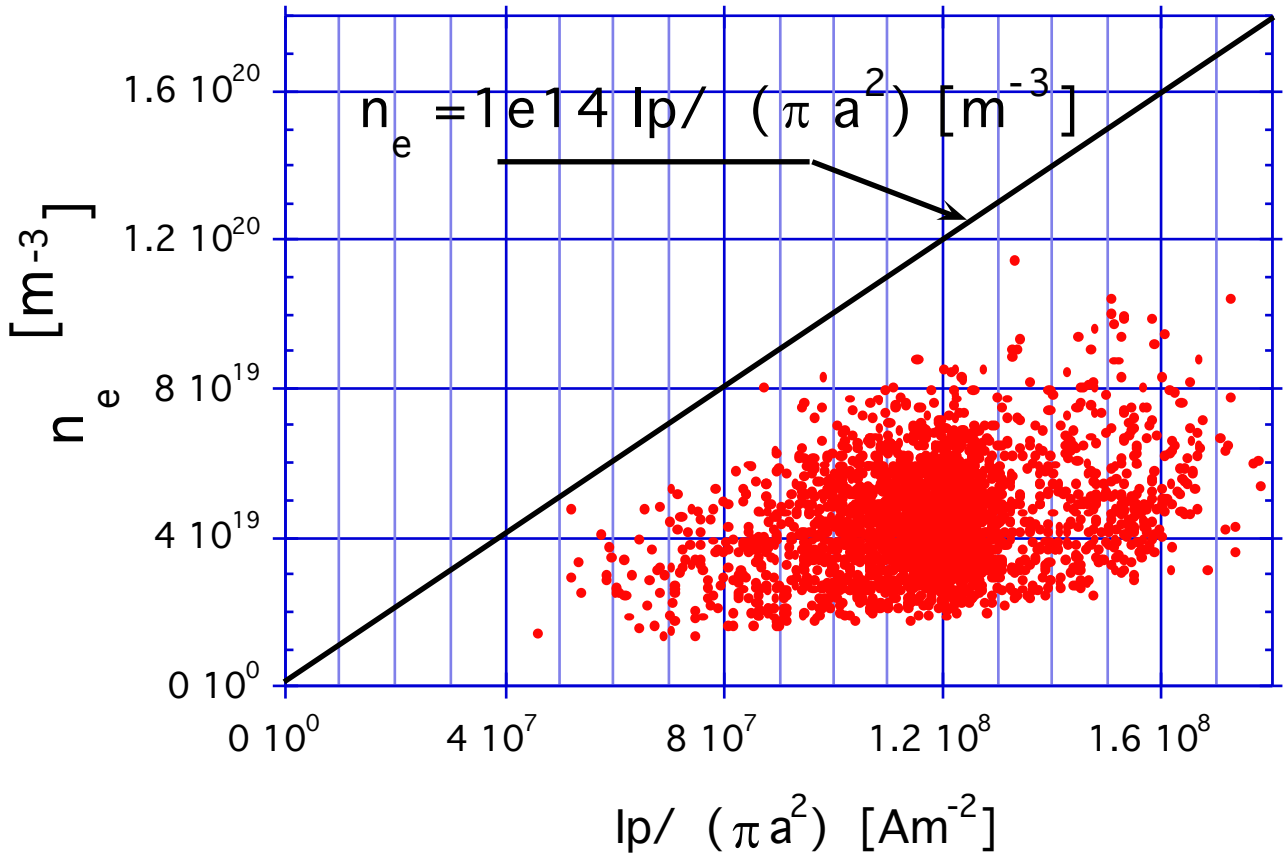


- Radiation limit?
- Role of locking?

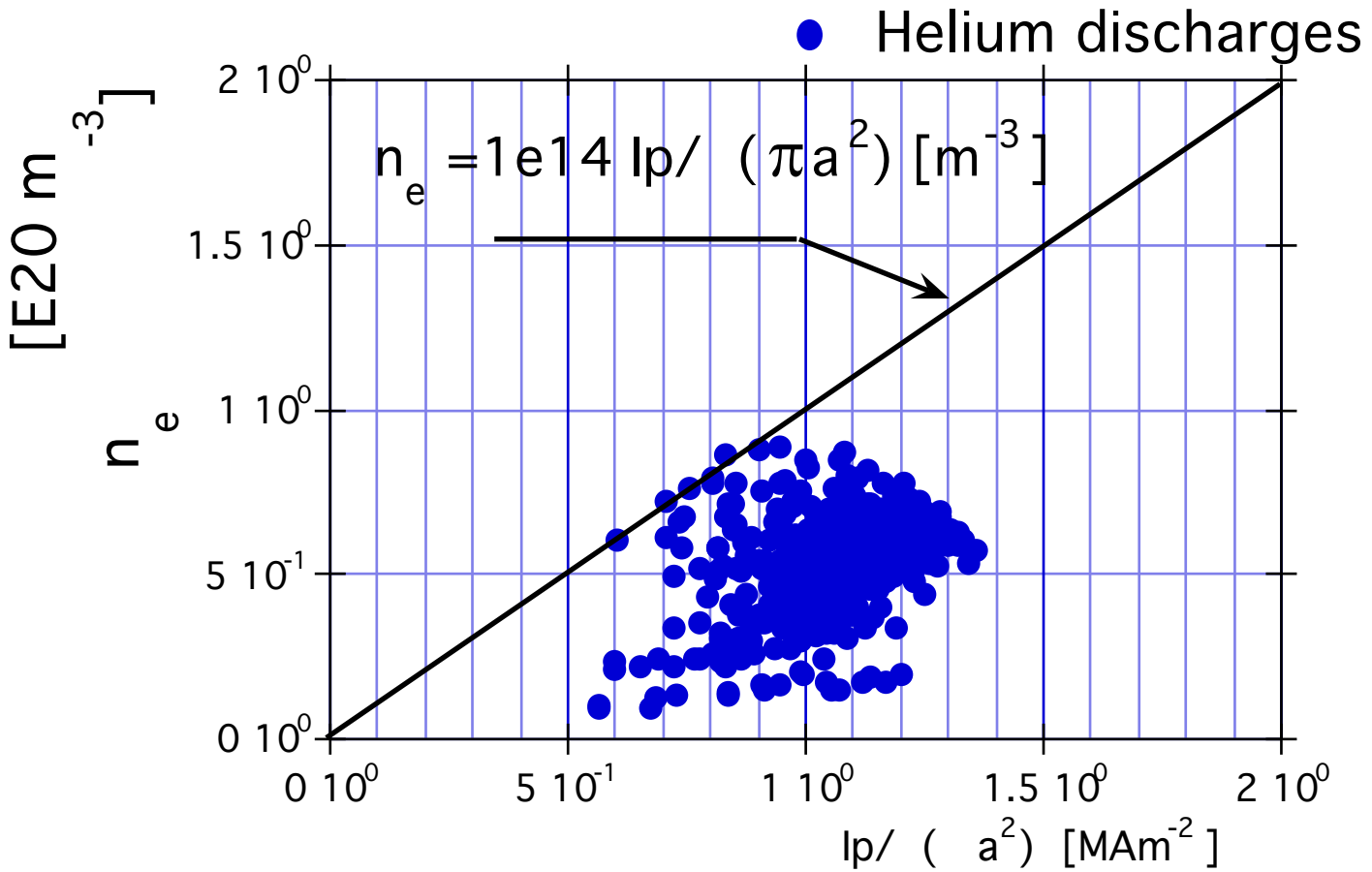

0.20
0.15
0.10
0.05
0.00
pre_boron_T_amb
post_boron_T_amb
P_{rad}/P_{atm}
0
2×10^{-14}
4×10^{-14}
6×10^{-14}
8×10^{-1}
I_1/N

High Density Limits

Greenwald plot



- Power limit?
- Intrinsic limits (pressure driven modes)?



Greenwald plot

Fast Terminations

Especially at high current (>0.9 mMA) " fast discharge terminations" may occur not due to a failure of the external circuits. Some episodes found also for Ip 600 kA.

Phenomenology of fast terminations::

- a drop of the electron temperature over time scales ≈ 1 to several ms
- peaking of ne
- V loop increase
- after several ms reversal is lost , ne and Prad increase and Ip quenches
- Te drop is anticipated by the increase of some of the high n, m=1 modes (n=9 –16).

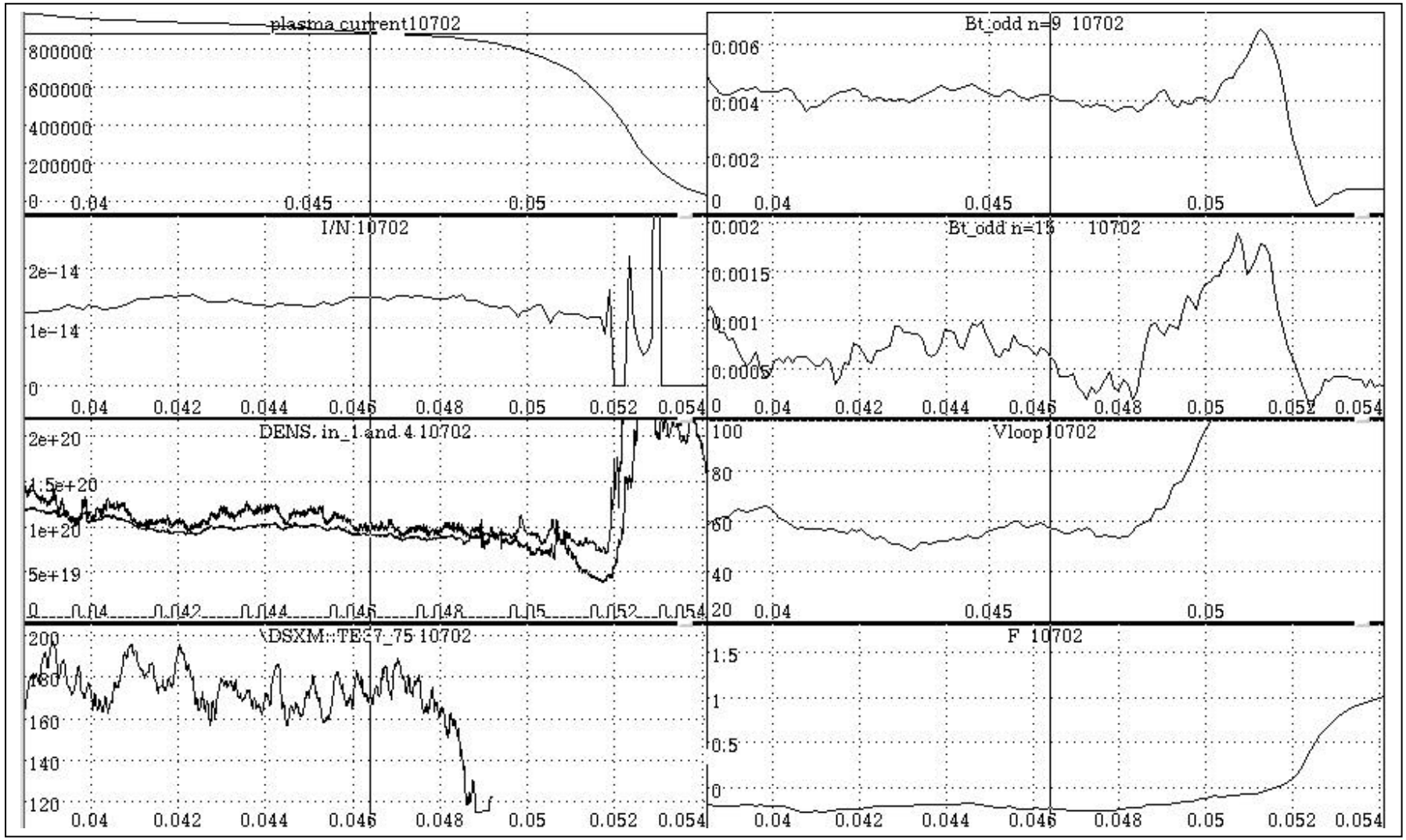
Favourable conditions for Fast Terminations .

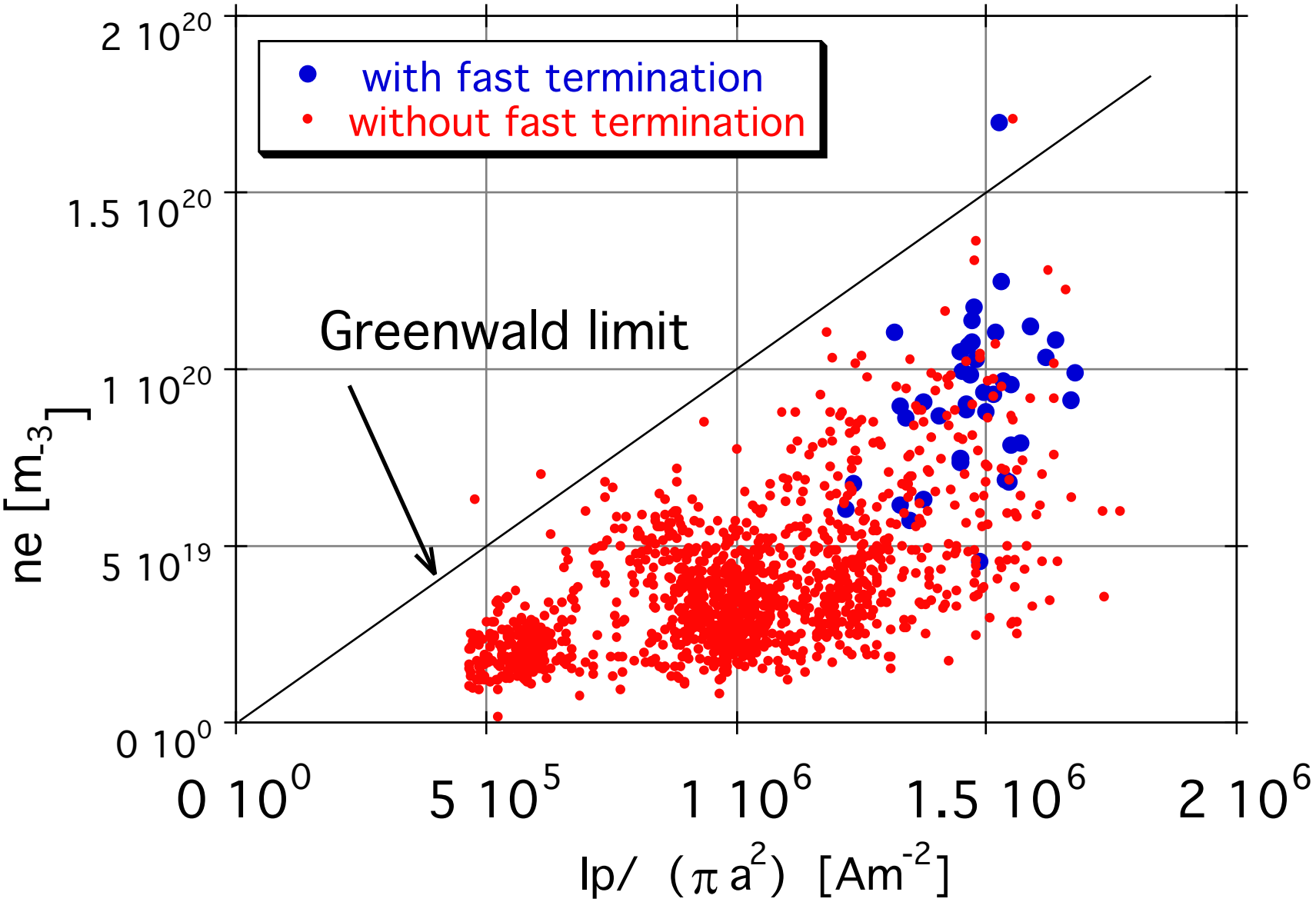
- Always $I/N \leq 2\ 10^{-14}$ Am
- large plasma deformation at the wall locking
- high hydrogen recycling, such as for instance in the hot wall experiments (in that sudden n_e build up have a higher probability)

Other parameters seem not to play a role

- ($H\alpha$ and impurity influxes, total radiation, neutral outfluxes (NPA) seem not to be affected at the time of the Te drop)
- Highly radiative plasmas obtained at 800 kA with neon injection have never ended in a fast termination.

Uncertainties still concern the role of the wall mode-locking region. Similarity with the Marfe phenomenon of Tokamaks, associated to increased recycling/impurities?


plasma_current10702
800000
600000
400000
200000
0
0.04
0.045
0.05
Bt_odd n=9 10702
0.006
0.004
0.002
0
0.04
0.045
0.05
I/N 10702
2e-14
1e-14
0
0.04
0.042
0.044
0.046
0.048
0.05
0.052
0.054
Bt_odd n=1 10702
0.002
0.0015
0.001
0.0005
0
0.04
0.042
0.044
0.046
0.048
0.05
0.052
0.054
DENS. in_1 and 4 10702
2e+20
1.5e+20
1e+20
5e+19
0
0.04
0.042
0.044
0.046
0.048
0.05
0.052
0.054
Vloop 10702
100
80
60
40
20
0.04
0.045
0.05
\DSXM::TE:7_75 10702
200
180
160
140
120
0.04
0.042
0.044
0.046
0.048
0.05
0.052
0.054
F 10702
1.5
1
0.5
0
0.04
0.042
0.044
0.046
0.048
0.05
0.052
0.054


with fast termination
without fast termination
Greenwald limit
2 10^20
1.5 10^20
1 10^20
5 10^19
0 10^0
ne [m^-3]
0 10^0
5 10^5
1 10^6
1.5 10^6
2 10^6
Ip/ (π a^2) [Am^-2]

Summary

- High density regimes correspond to higher energy confinement, possibly associated to improvements of the edge confinement.
- Highly radiative mantle is compatible with the RFP configuration at high densities.
- High density limits seem to exist, qualitatively similar to the Greenwald limit of Tokamaks.
- At high currents (≥850- 900 kA) “fast terminations” restrict the n_e operational boundary,