

# **X-point Configurations for the Ignitor Experiment**

**G. Cenacchi, F. Bombarda**  
(Ignitor Project-ENEA,Italy)

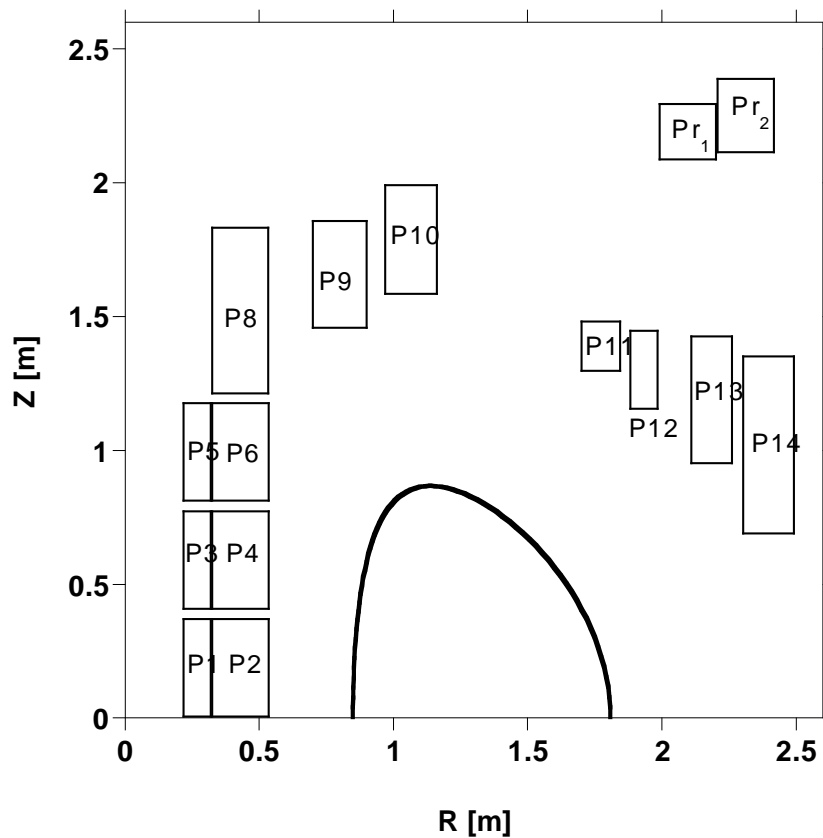
**A. Airoidi**  
(IFP-CNR, Milan,Italy)

**B. Coppi**  
(M.I.T.)

## Abstract

For many reasons the “limiter solution” has always been considered the most suitable to attain ignition in Ignitor at the nominal machine parameters ( $I_p=11\text{MA}$  and  $B_t=13\text{T}$ )(A. Airoidi, G. Cenacchi, Nucl.Fus.41,687,2001). H modes, usually accessed with X-point configurations, are considered as not being efficient for the purpose of ignition, because of the characteristic flat density profiles, but they are an interesting physics option. Thanks to the flexibility of the machine, single or double null configurations can be produced at somewhat reduced plasma current, as shown in recent evaluations (G. Cenacchi and A. Airoidi, IFP-CNR Report FP 01/1, Feb.2001, Milan, Italy). The present work, carried out with the equilibrium-transport code JETTO, analyzes the possibility of obtaining high confinement conditions in the presence of double null configurations around 10MA. The threshold power required for the L- to H-mode transition is consistent with the power of the auxiliary heating system, delivering 18-24 MW at the ion cyclotron frequency, already included in the machine design.

Thanks to the flexibility of Ignitor the poloidal field system can produce also X-point configurations, besides to the limiter ones of the reference scenario.



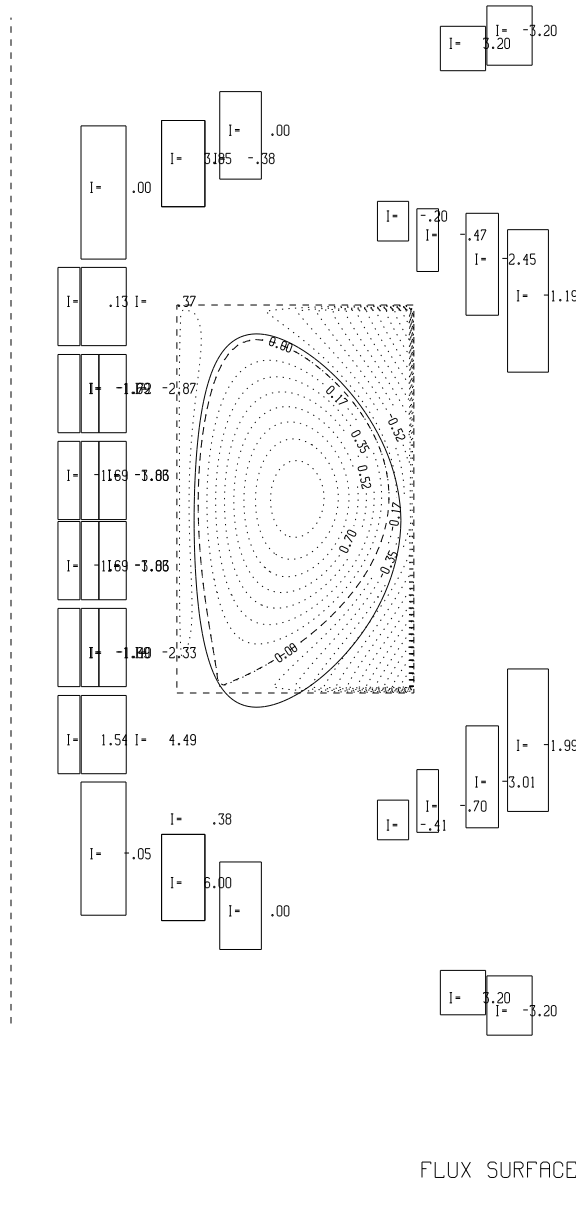
*Layout of the poloidal field coils and first wall of the vacuum chamber*

Single and double null configurations have been analyzed.

In both cases the plasma poloidal cross-section is decreased to allow space for the scrapeoff layer and the plasma current is somewhat reduced to satisfy the condition  $q_{95}=3$ .

For the single-null case the current is 9MA and the lower X-point is located just on the first wall.

The current relevant to the double-null case is 10MA and the X points are just outside the first wall.



$I_p = 8.95$  MA

$k = 1.75$

$\beta_p = .190$

$R_0 = 133.06$  cm

$Z_0 = 10.00$  cm

$a = 44.29$  cm

$b = 80.72$  cm

$q_{axis} = 1.14$

$q_{95} = 2.99$

$I_{coils}$  (MA)

-1.685 -0.471 4.486

-1.832 -2.449 -0.050

-3.057 -1.193 6.001

-1.685 3.200 .000

-1.717 -3.200 -.408

-2.868 -1.685 -.701

.126 -1.832 -3.015

.366 -3.057 -1.989

.000 -1.685 3.200

3.855 -1.403 -3.200

.000 -2.334

-.199 1.539

$I_{coils}^{feedback}$  (MA)

-.380

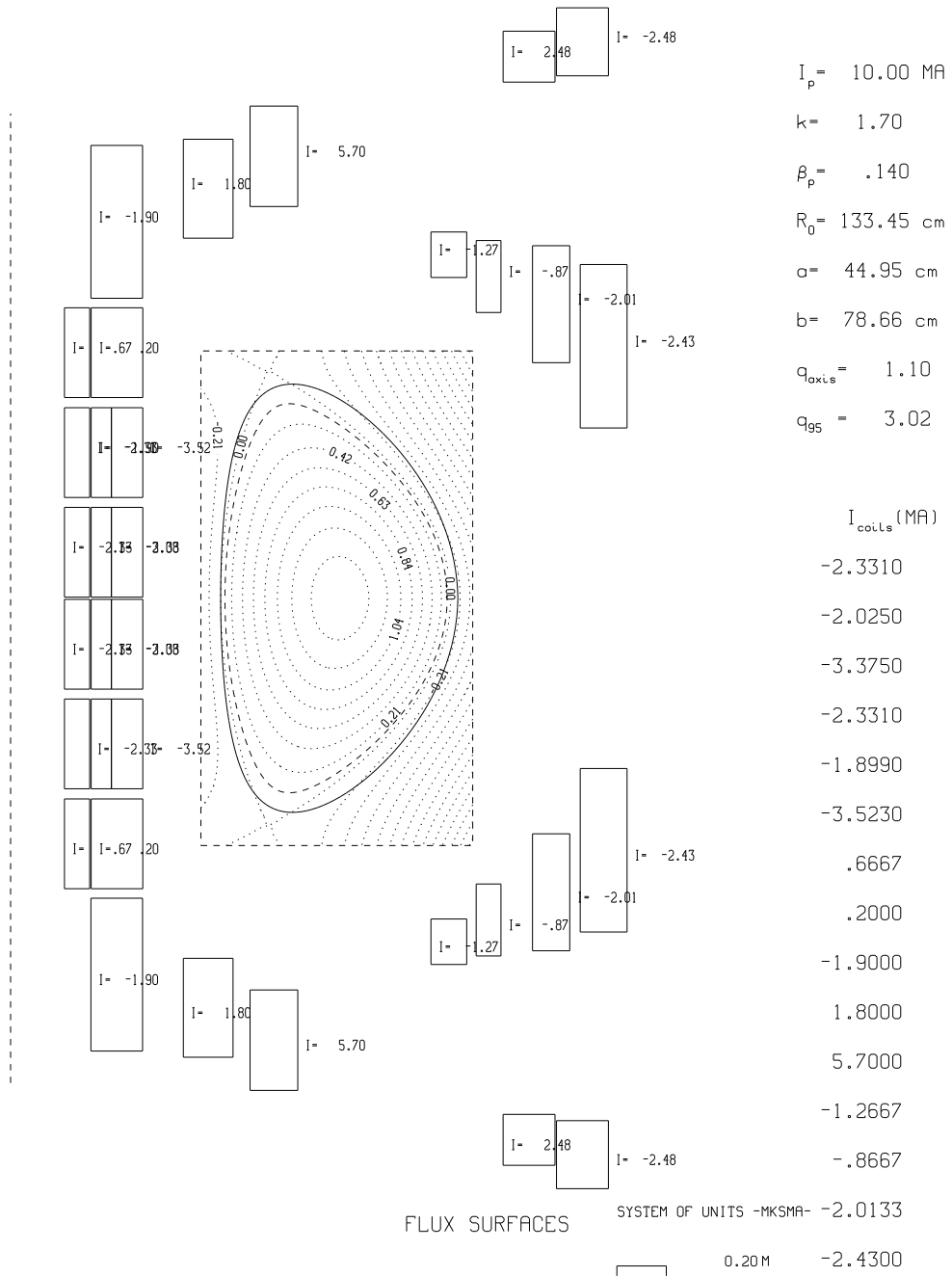
.380

$I_{ch} = .00$  kA

FLUX SURFACES SYSTEM OF UNITS -MKS-

0.24 M

*Single-null configuration*

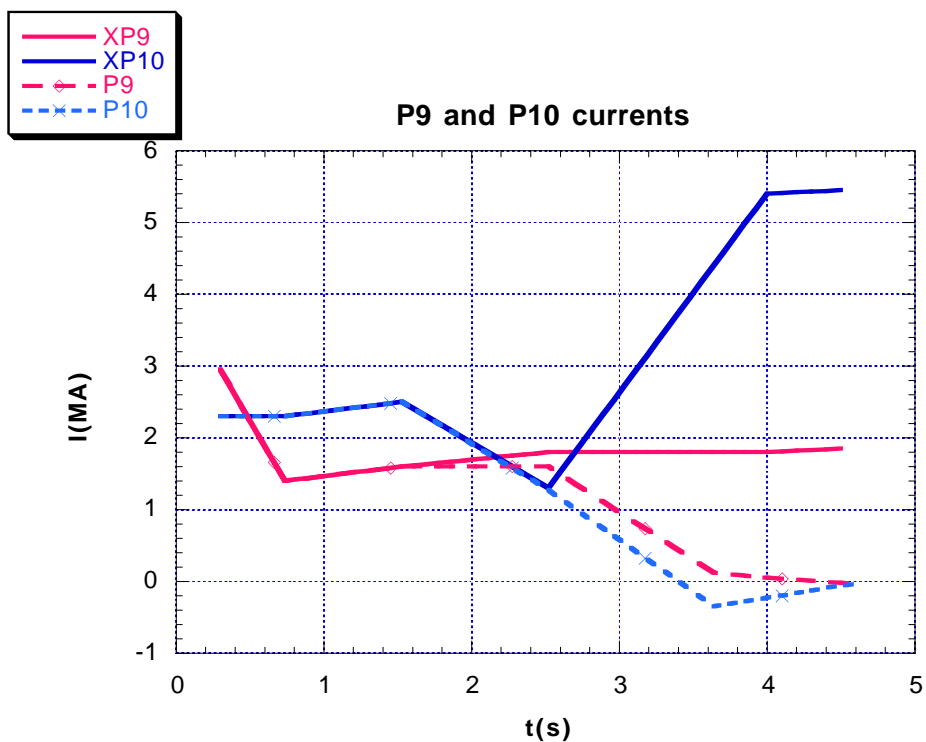


$I_p = 10.00$  MA  
 $k = 1.70$   
 $\beta_p = .140$   
 $R_0 = 133.45$  cm  
 $a = 44.95$  cm  
 $b = 78.66$  cm  
 $q_{axis} = 1.10$   
 $q_{95} = 3.02$

$I_{coils}$  (MA)  
 -2.3310  
 -2.0250  
 -3.3750  
 -2.3310  
 -1.8990  
 -3.5230  
 .6667  
 .2000  
 -1.9000  
 1.8000  
 5.7000  
 -1.2667  
 -.8667  
 -2.0133  
 -2.4300

*Double-null configuration*

A common feature of these configurations is the requirement of currents higher than the nominal ones in the coils nearest to the X-ponts. This could possibly require modifications in the design of some coils. A comparison between the P9 and P10 currents for the reference limiter scenario (see Poster QP1.073) and for the X-point scenario is here shown.



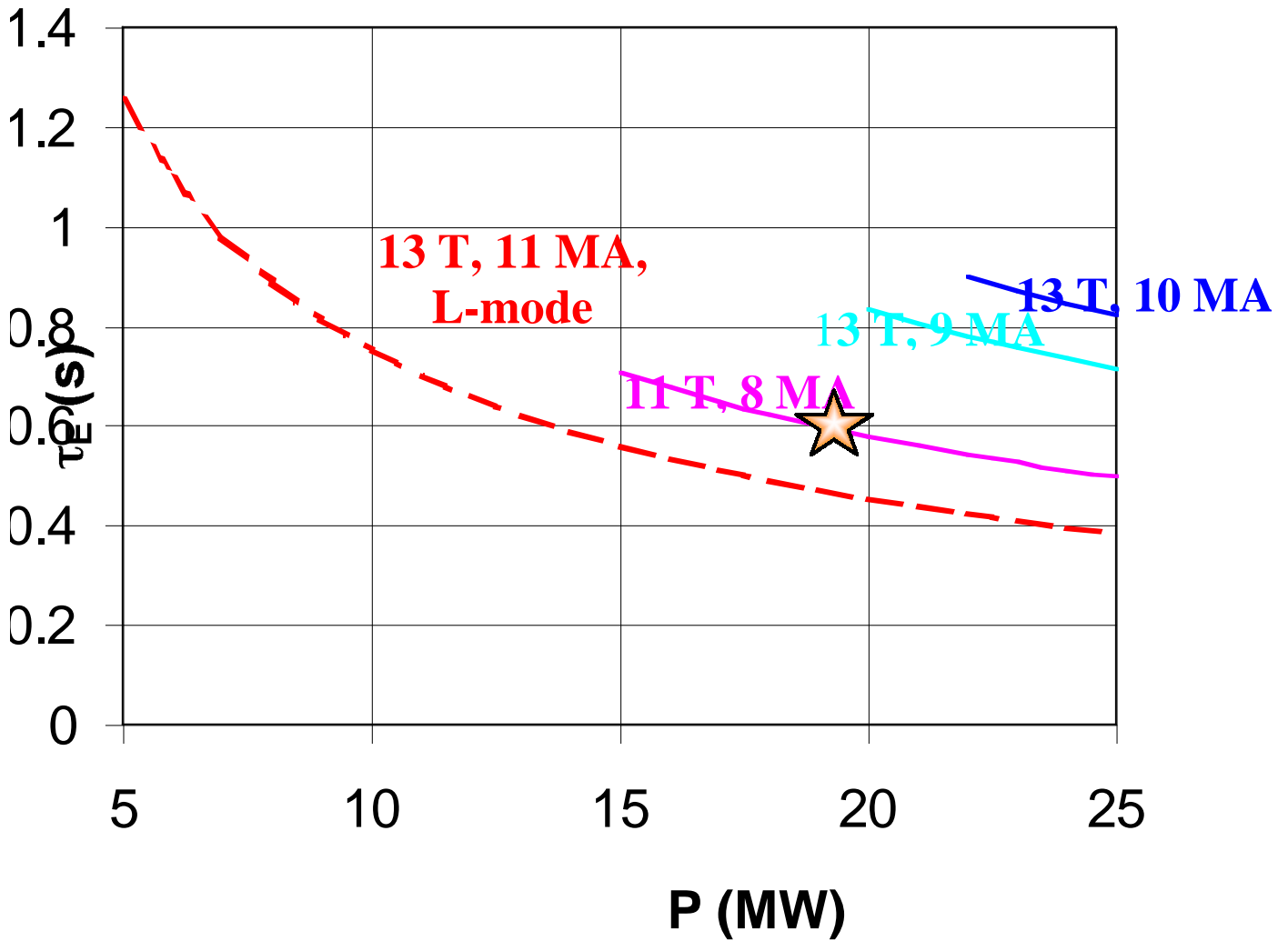
*Time evolution of P9 and P10 currents for the reference scenario and for the X-point scenario*

In the single-null case the asymmetry of the configuration can require feedback currents to face vertical displacements of the plasma column.

The choice of the relevant coils among the existing ones has been optimized and the coils P9 have been found to better fit the demand.

The currents required to avoid such displacements have been evaluated.

The single-null configuration obtained is in agreement with the one computed at Livermore by the CORSICA code.



*Expected values of the energy confinement time according to the IPB98(y,2) scaling for ELMY H-mode as a function of power, for different values of the magnetic field  $B_T$  and plasma current  $I_p$ . The density is assumed to be  $0.5 n_G (= I_p / \pi a^2)$ . The red curve refers to the standard limiter configuration. The star is the reference ignition point for ohmic ignition.*

**Preliminary evaluations of the X-point scenario have been carried out by the equilibrium-transport code JETTO.**

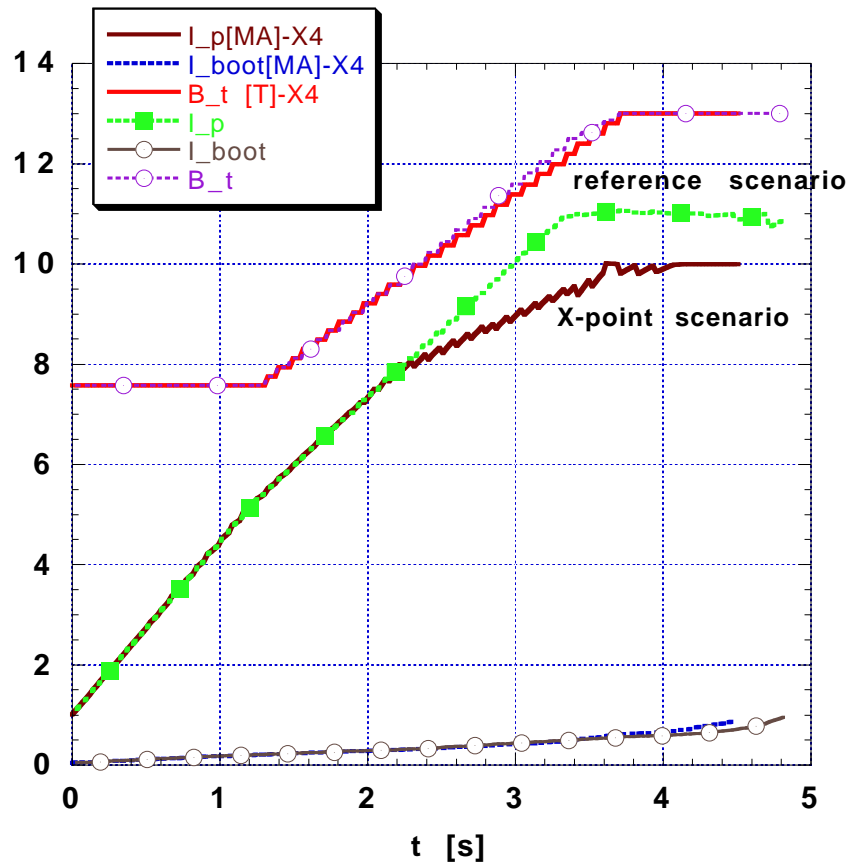
**The double null, 10MA configuration has been considered.**

**4MW of auxiliary power is applied from 2.9s to 3.8s**

**The simulation setup is the one described in Poster QP1.076, with the Coppi-Mazzucato transport model**

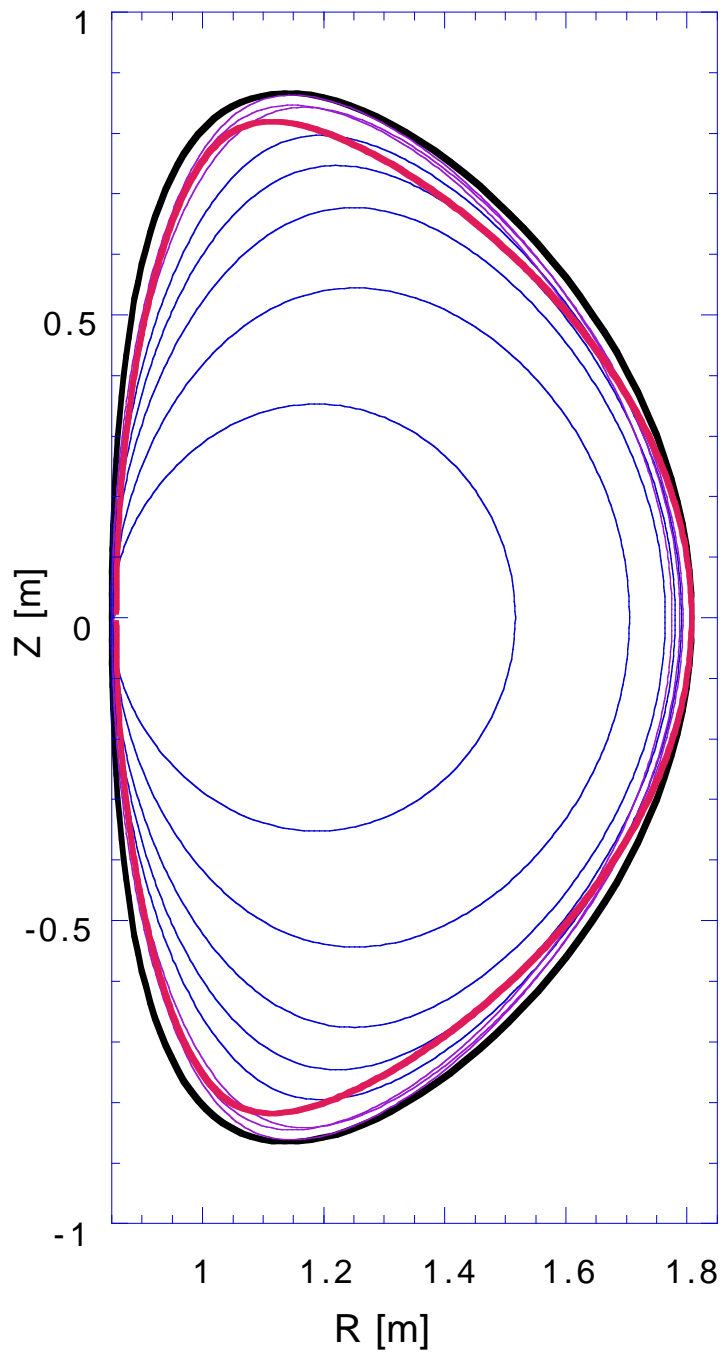
**The threshold power for L-H transition is evaluated (*J.A.Snipes, Plasma Phys. Control. Fusion* **42**, 2000, A299) together with the input power**

**Once a X-point configuration is established, the thermal diffusion coefficient is reduced to simulate the access to the H-mode regime.**



*Reference scenario and X-point scenario*

*here analysed*

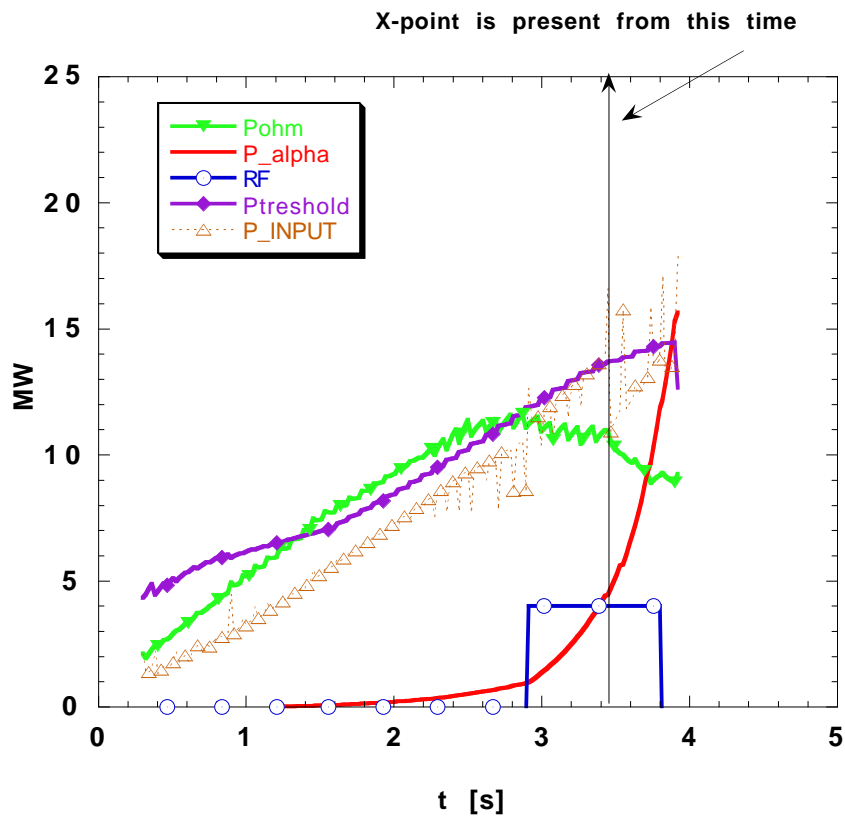


*Plasma boundary throughout the current ramp-up and flat-top:  $I_p=1,2,3,\dots,10\text{MA}$*

*Time evolution of powers*

$$P_{thresh} = 0.108 \bar{n}_e^{0.49} B_t^{0.85} S^{0.84} / M$$

$$P_{input} = P_{\Omega} + P_{\alpha} - dW / dt$$

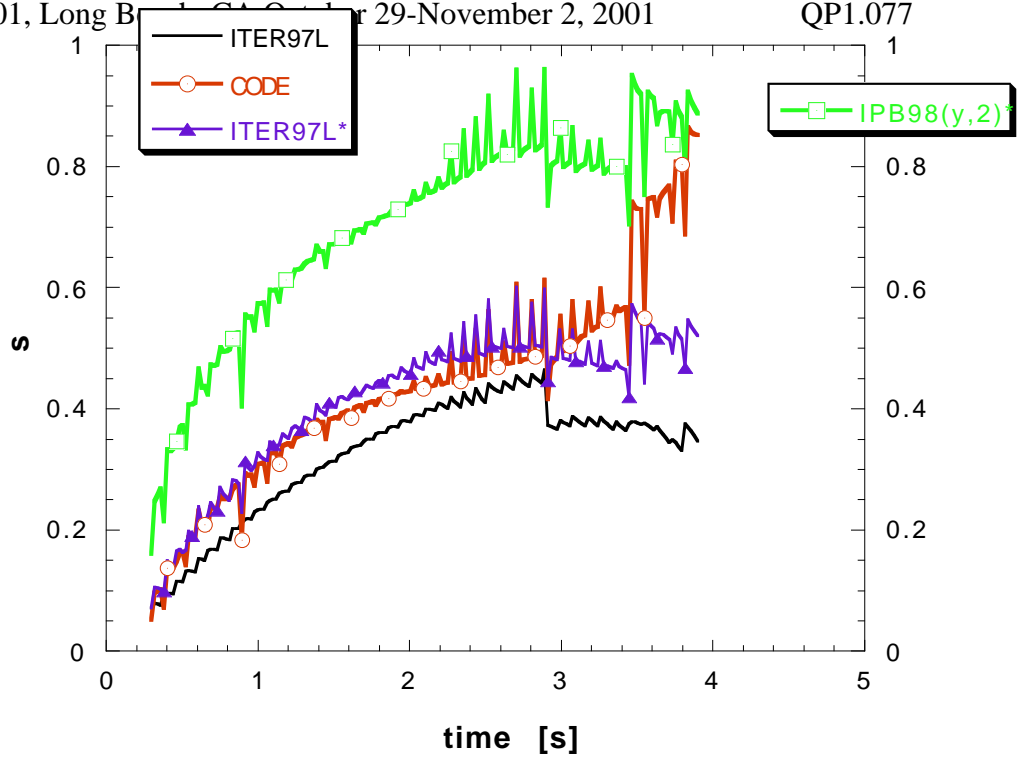


## **Preliminary results**

**The input power here evaluated is marginal, but ignition is reached.**

**Notice that the resulting confinement time is below the  $\tau_e$  calculated according to the IBP98(y,2) scaling.**

**The heating pulse can be optimized as far as the position, amount and time of application are concerned.**



*Energy confinement times*

$$\tau_E^{CODE} = \frac{W_e + W_i}{P_\Omega + P_\alpha + P_{AUX} - dW / dt}$$

$$\tau_E^{ITER97L} = 0.023 A_i^{0.2} k^{0.64} I_p^{0.96} \bar{n}_{19}^{-0.4} a^{-0.06} R^{1.89} B^{0.03} P_{IN}^{-0.73}$$

$$P_{IN} = P_\Omega + P_\alpha + P_{AUX}$$

$$\tau_E^{ITER97L*} = 0.023 A_i^{0.2} k^{0.64} I_p^{0.96} \bar{n}_{19}^{-0.4} a^{-0.06} R^{1.89} B^{0.03} P_{NET}^{-0.73}$$

$$P_{NET} = P_\Omega + P_\alpha + P_{AUX} - dW / dt$$

$$\tau_E^{IPB98(y,2)*} = 0.0562 A_i^{0.19} k^{0.78} I_p^{0.93} \bar{n}_{19}^{-0.41} \epsilon^{0.58} R^{1.97} B^{0.15} P_{NET}^{-0.69}$$

## **Conclusion**

**X-point configurations can be produced in Ignitor by reinforcing some of the existing poloidal field coils.**

**A first analysis by transport simulations makes us confident that enhanced confinement conditions may be obtained and ignition can be reached.**

**Further analyses are under way.**