Searching for a Flux Expansion Divertor in TJ-II.

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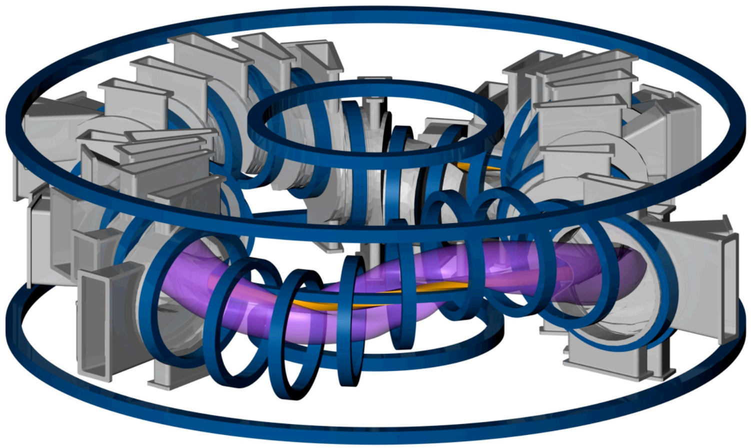
Outline

- Introduction and Motivation.
- The chosen configuration in TJ-II.
- ISDEP code and the plasma conditions.
- Results.
- Conclusions and future work.



Divertor Concepts

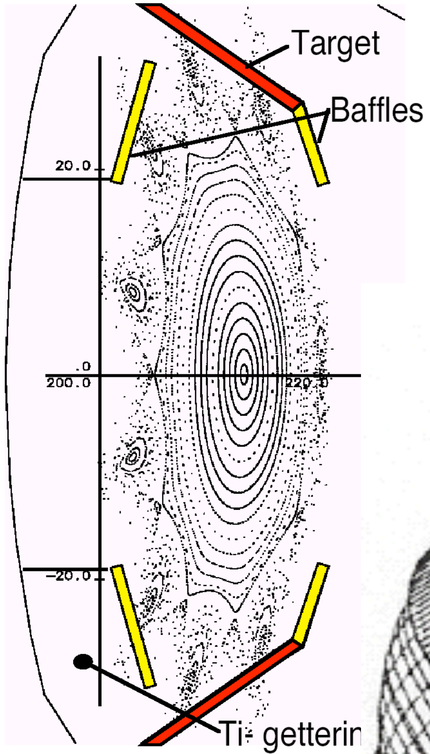
Power exhaust and density control are mandatory for a stellarator-reactor (R. König et al. PPCF,2002). Concepts:

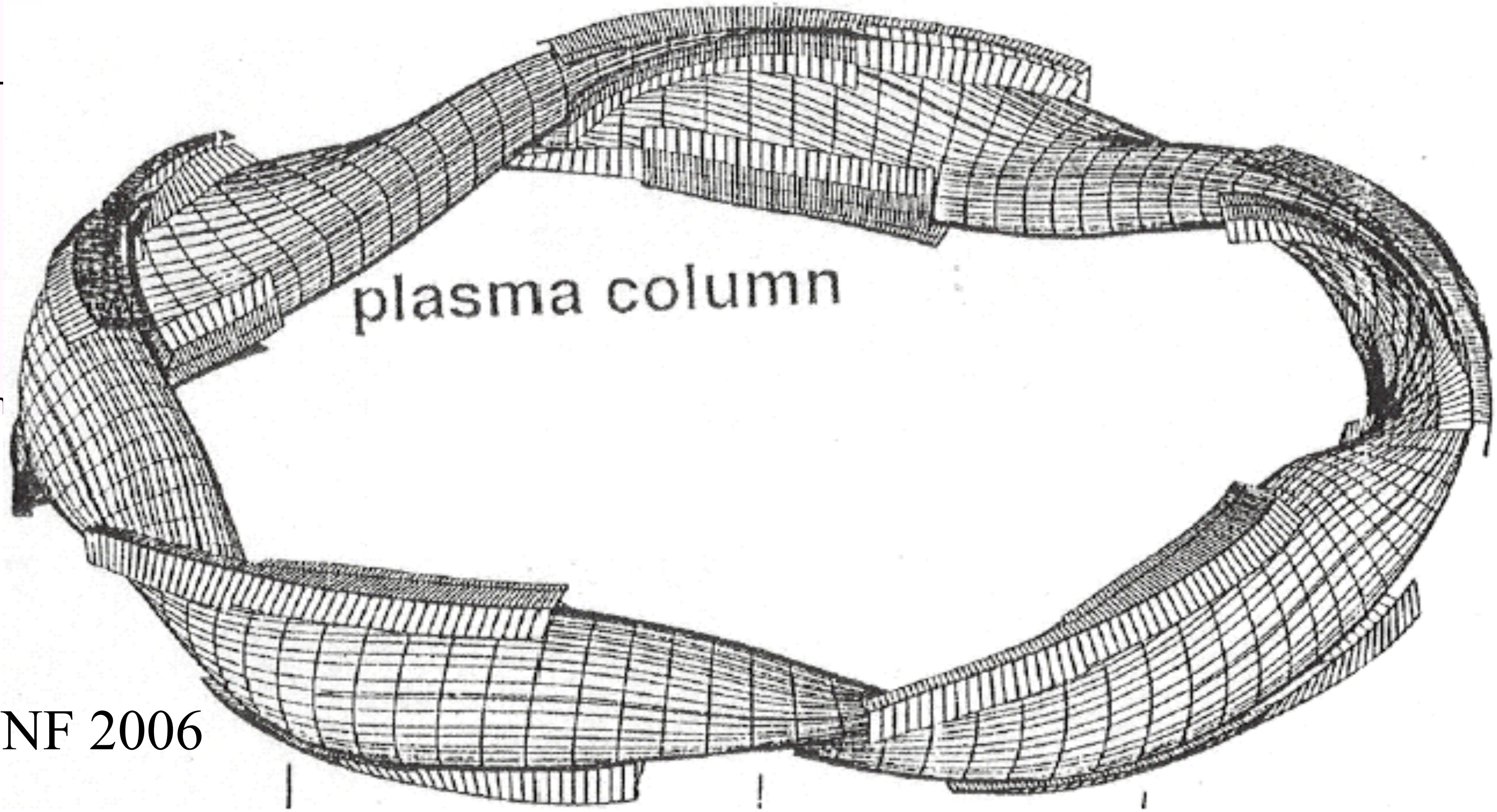
- X- point (Tokamaks).
- Helical Divertor.
- Island Divertor.
- Flux Expansion Divertor

- The goals:
  - Concentrate plasma-wall interaction in favourable zones (with plates and pumping).
  - Diminish the incoming fluxes on the plates (ad hoc magnetic configuration; increasing the plate size).
  - Hinder the neutrals to enter the plasma: Long path or steep gradient pressure profile.

Island Divertor

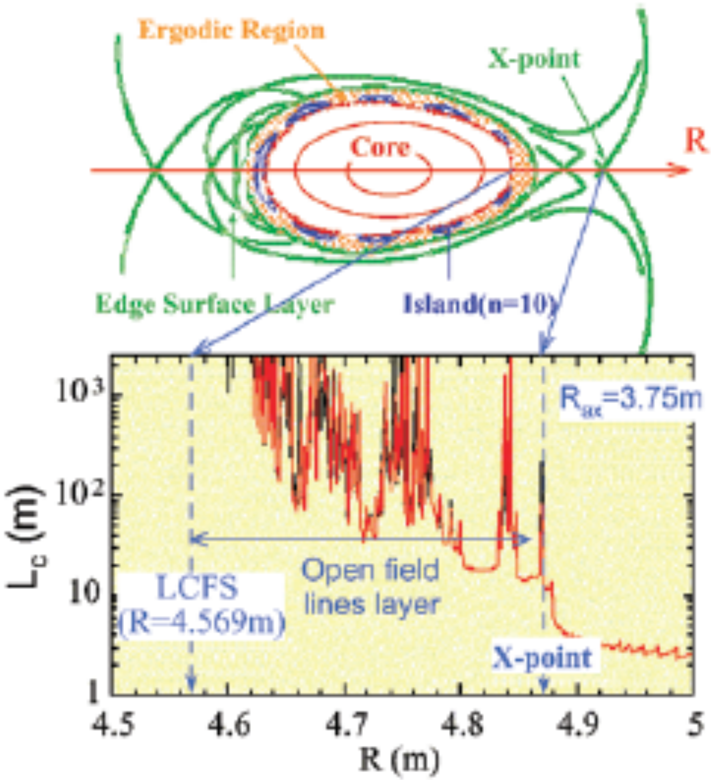
W7-AS -> W7-X



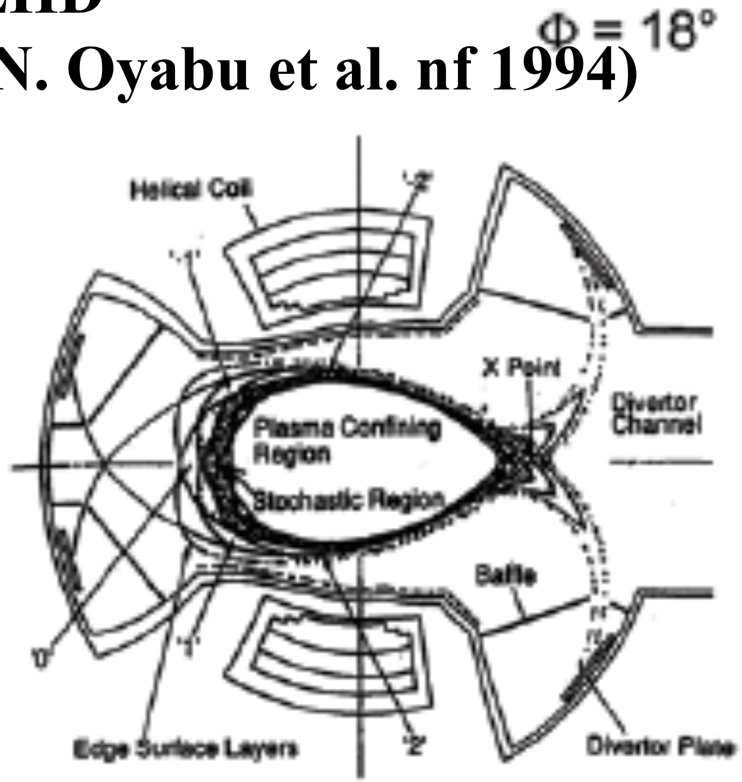


Y. Feng et al. NF 2006

Helical Divertor



LHD
(N. Oyabu et al. nf 1994)



X-point

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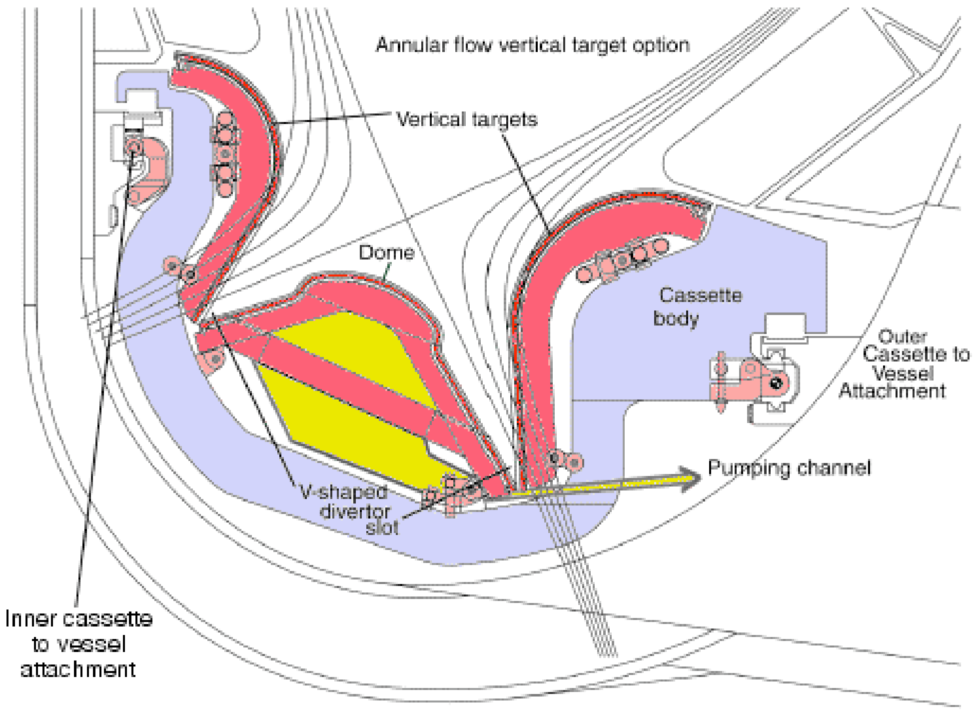
H- mode obtained in JET with the X-point on the limiter plate= Flux Expansion?



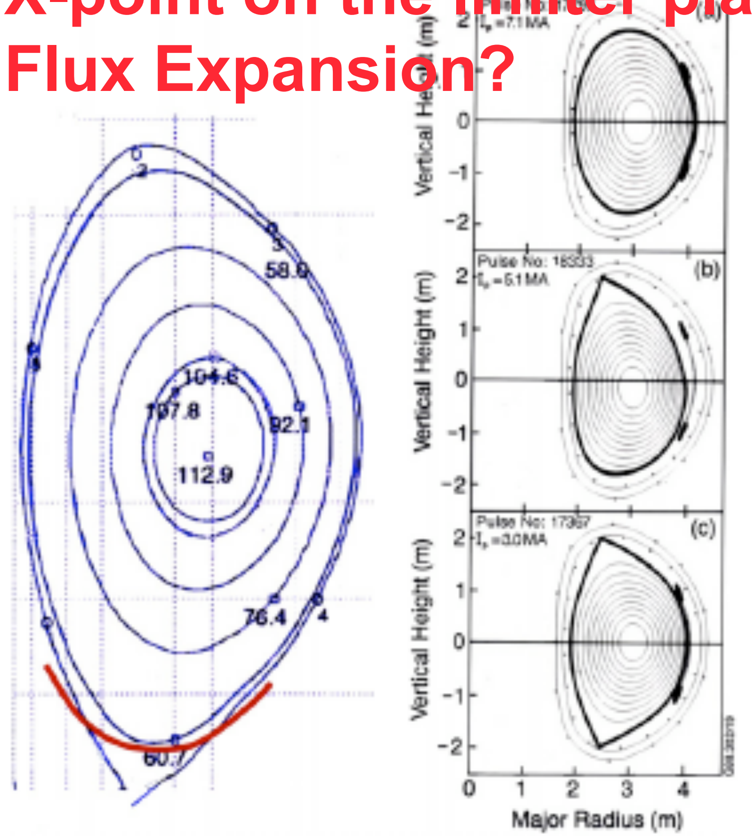


Figure 3. Plasma cross-section. The cross-sections on the right were produced on JET with the X-point just at the limit of the plasma wall. In these conditions, H-modes have been obtained. On the right, the plasma cross-section shows the approximate position of an X-point limiter in red; this plasma cross-section corresponds to an ITER cross-section shape, in fact the plasma shown in figure 2.

P. Rebut. PPCF 2006

Flux Expansion Divertor: NCSX

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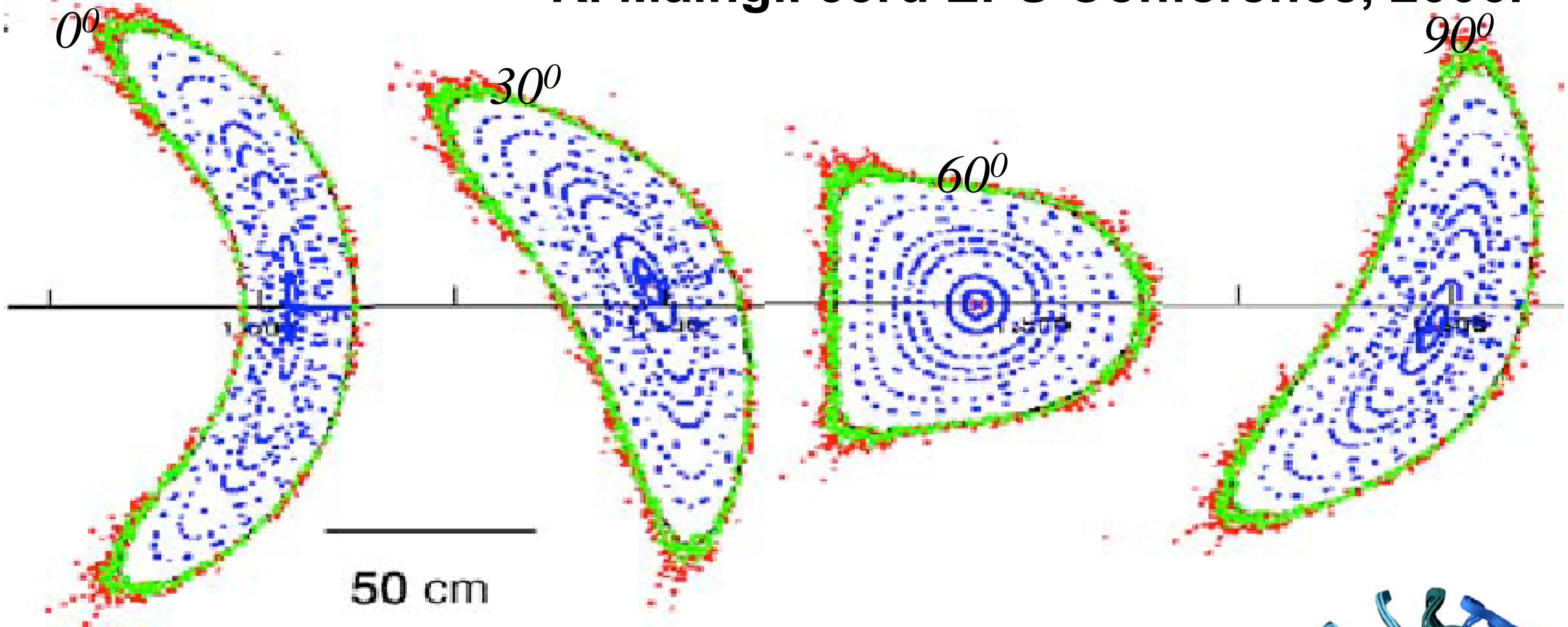
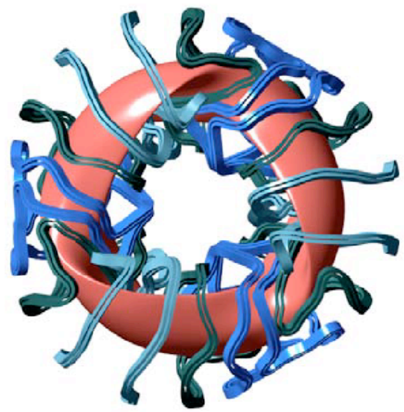
R. Maingi. 33rd EPS Conference, 2006.



- Most flux expansion at 0^0 - best for divertor plates
- Green field lines launched at inner midplane
- Red field lines launched at outer midplane



Requirements

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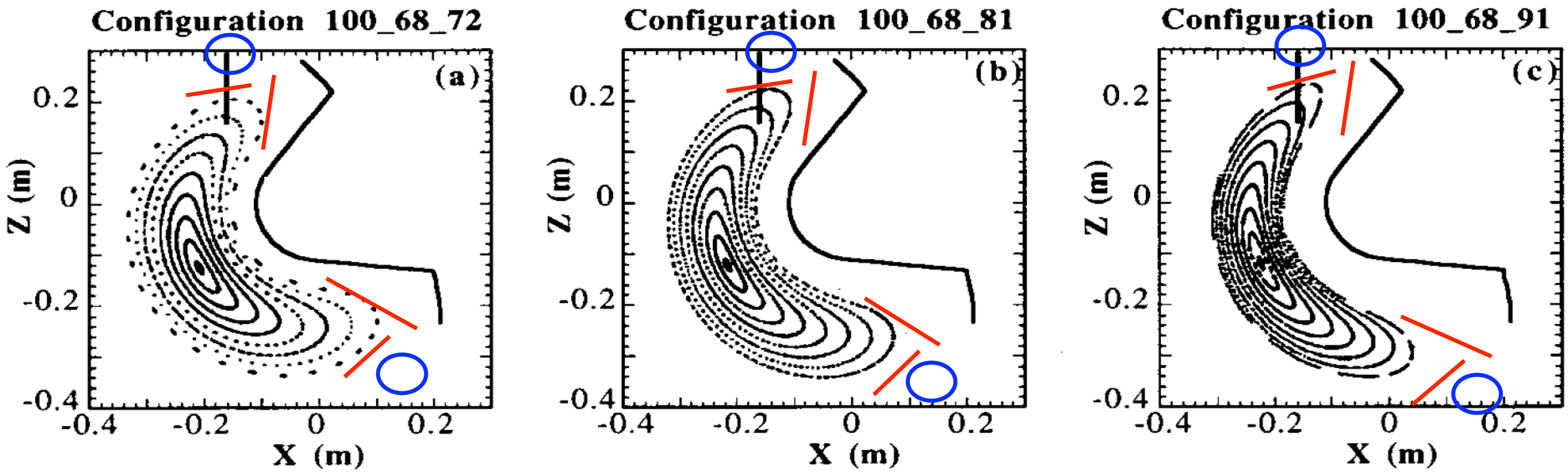
- **Helical Divertor and Island Divertor require robust magnetic topology, almost unchanged during plasma operation.**
- **Those concepts are not suitable for:**
  - –Configurations based on bootstrap current (NCSX, QPS).
  - –Equilibrium topology strongly dependent on beta.
  - –Flexible devices that can vary the rotational transport profiles (TJ-II).
- **Flux Expansion Divertor could be the solution.**

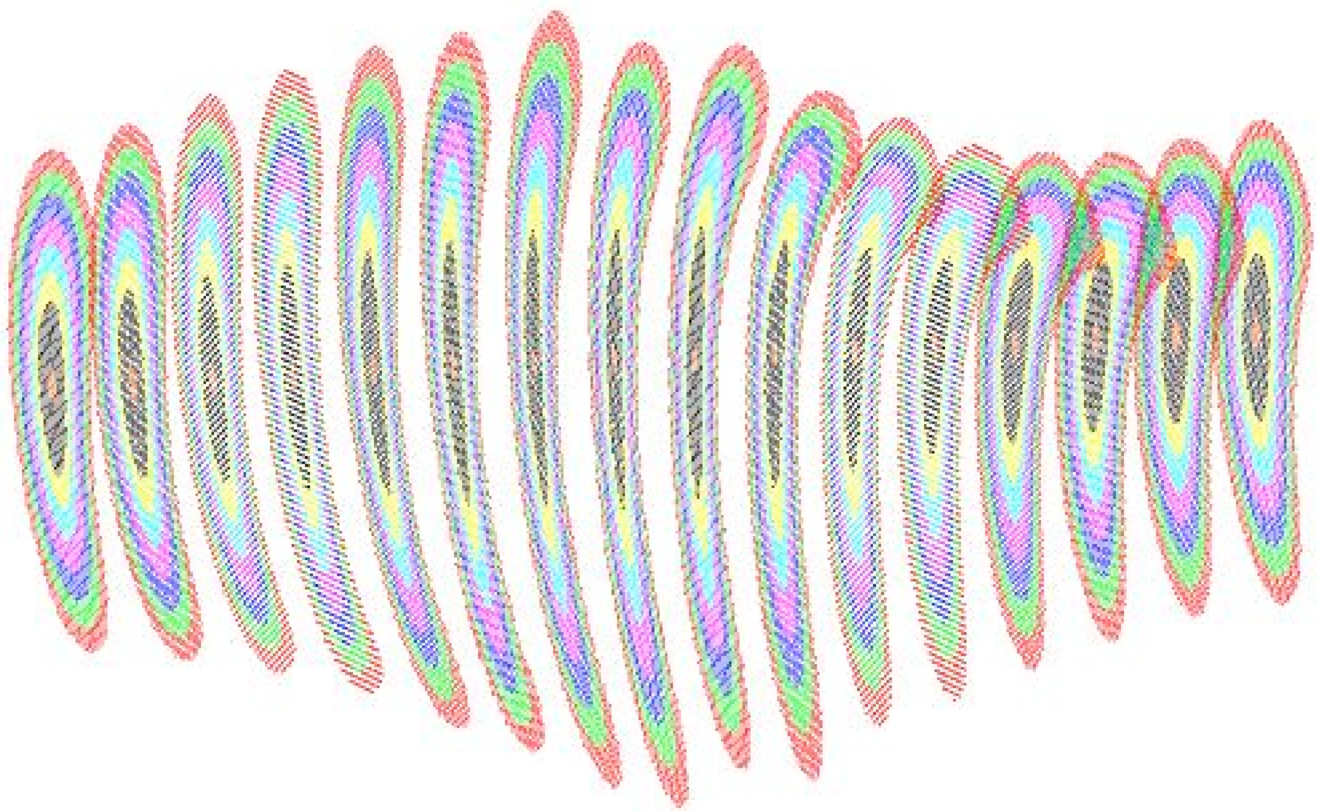
Flux Expansion Divertor in TJ-II?



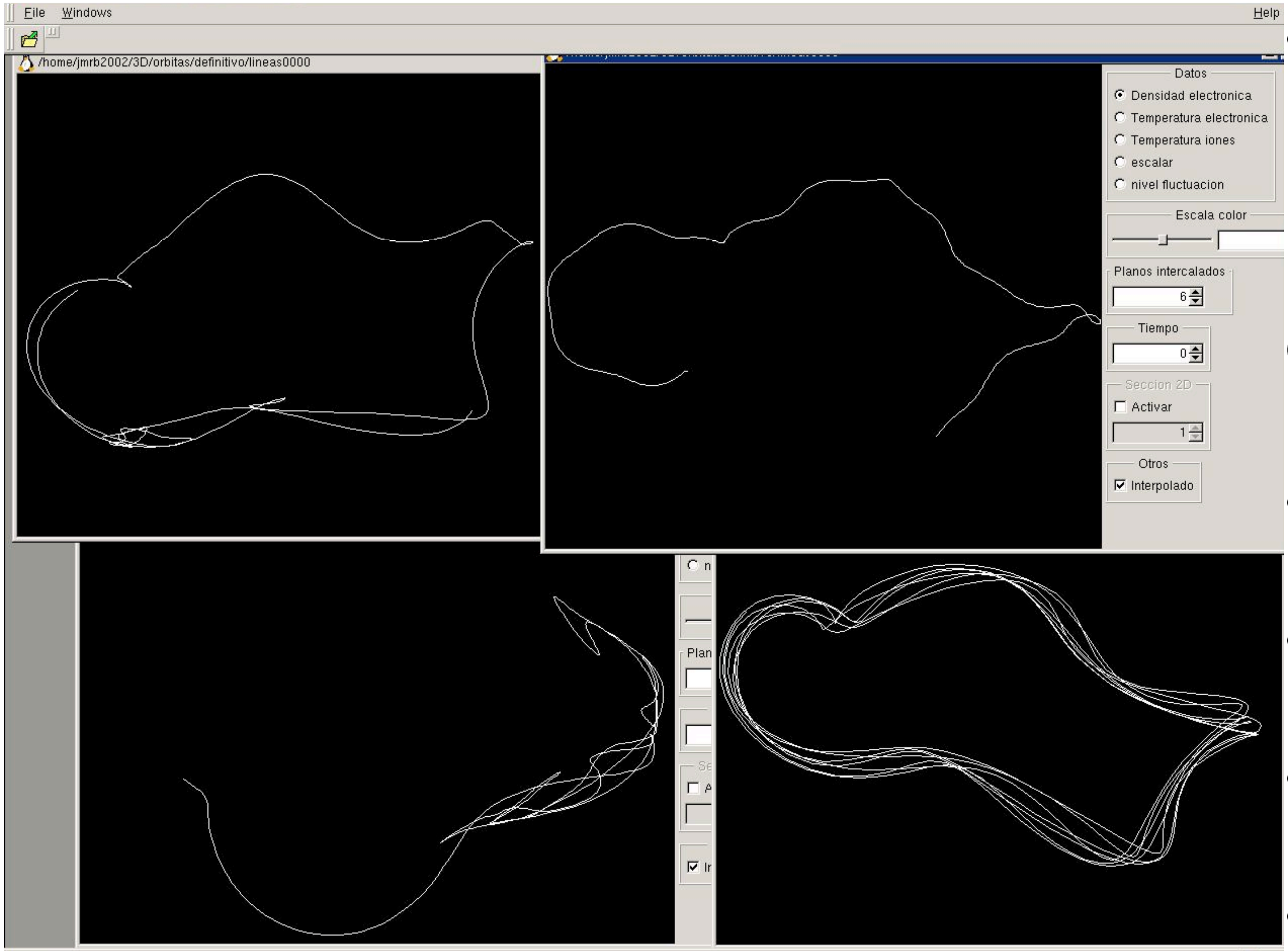
- Large flux expansion configurations do exist.
- No ergodic zones appear in TJ-II. Look for a strategy for creating them.
- The inner part of the configuration should be unaffected.
- Lithium evaporation onto these target plates?
- Pump behind plates?

The Magnetic Configuration

- Poincaré plots of the magnetic surfaces (rotated 4ϕ to be compared).
- Maximum flux expansion around $\phi=\pi/4$ and $\theta=\pi/2$. Although wide ϕ–range envisaged.



ISDEP code: Examples of 3D orbits



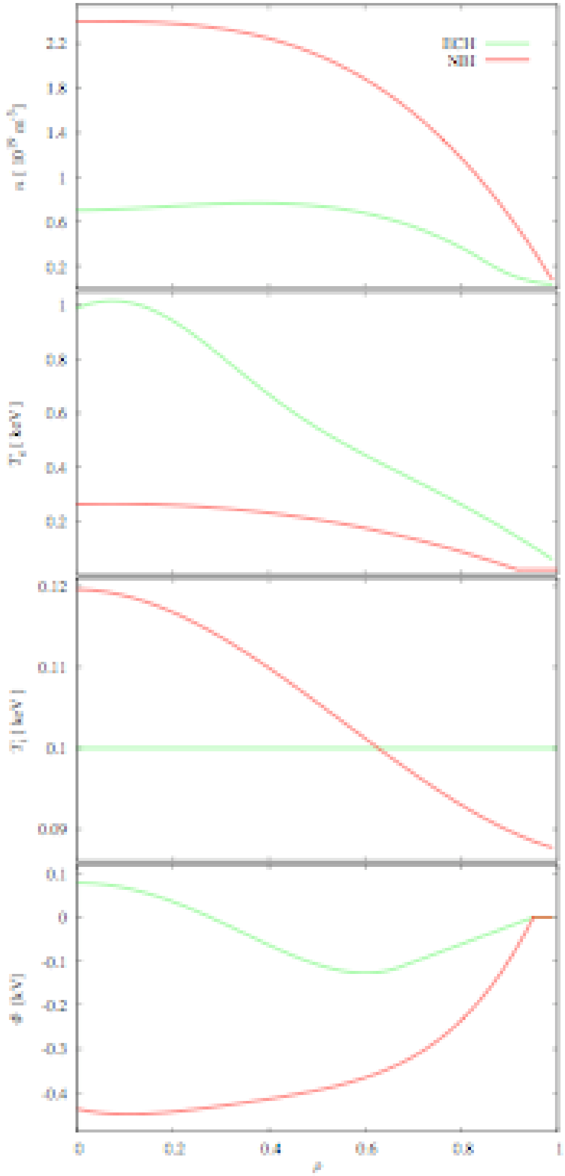
- Following particle trajectories rather than field lines (10^5-10^6 particles). Grid computing inside EGEE.

(F. Castejón et al. PPCF 2007)

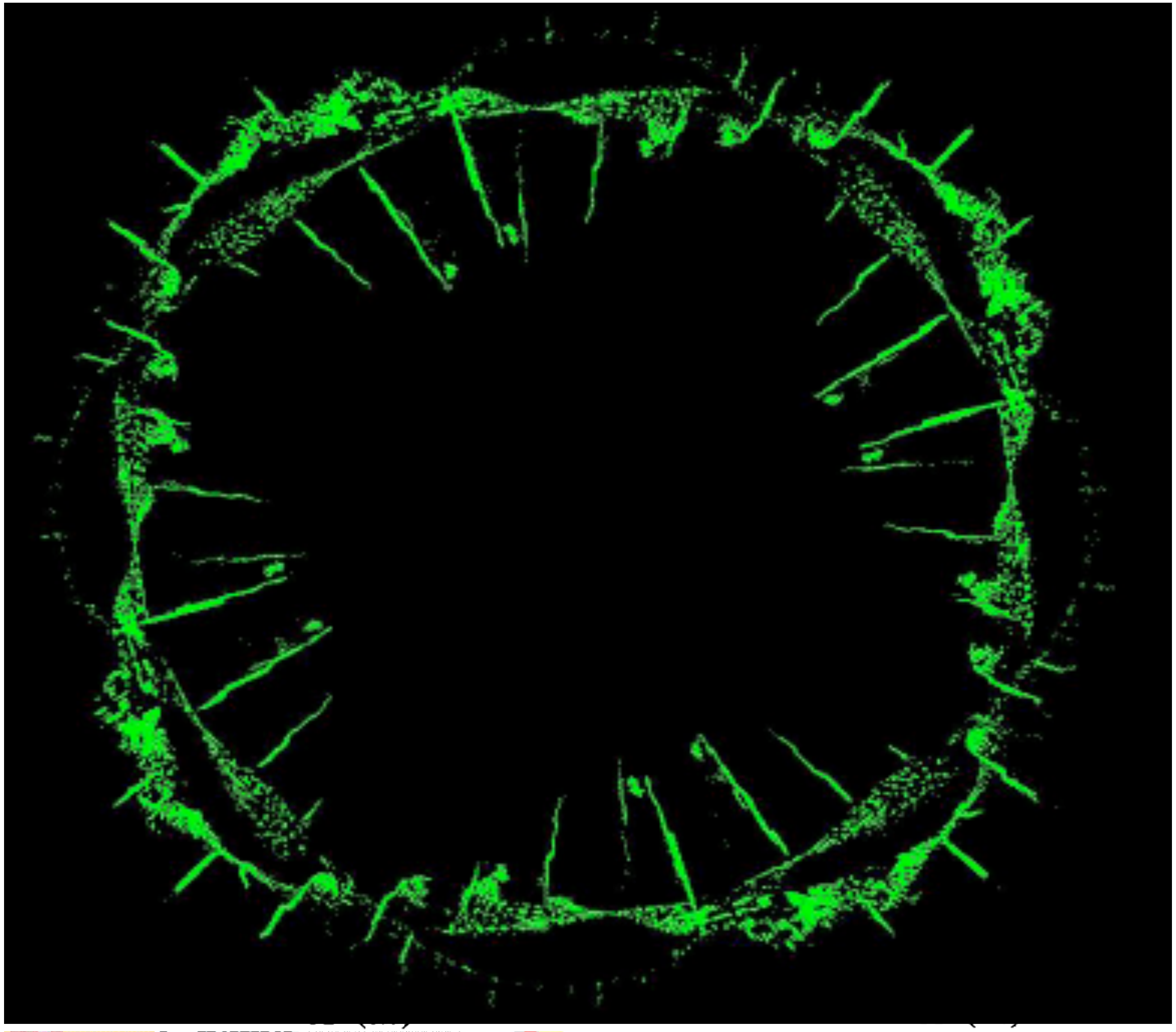
- Guiding centre approximation.
- i-i & i-e Coulomb collisions.
- Considering electrostatic potential.
- No assumptions on orbit size or diffusive transport

Measured Profiles (used in the simulatiuon)

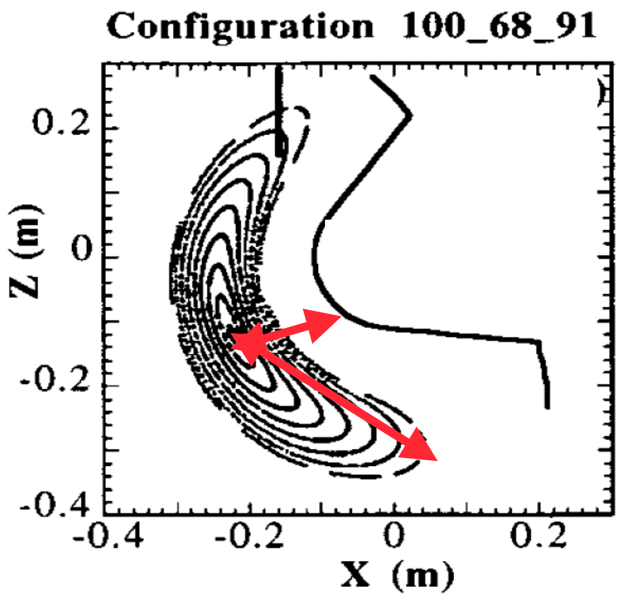
- Two regimes: low density ECRH plasma and high density NBI plasma.
- Simulations valid for a wide range of parameters.
- n_e and T_e, from Thomson Scattering.
- T_i from CX-NPA.
- Potential from HIBP.



The Map of Losses



- Maximum plasma-wall interaction on the groove.
- PWI close to the plasma bulk.
- Up-down asymmetric flux.

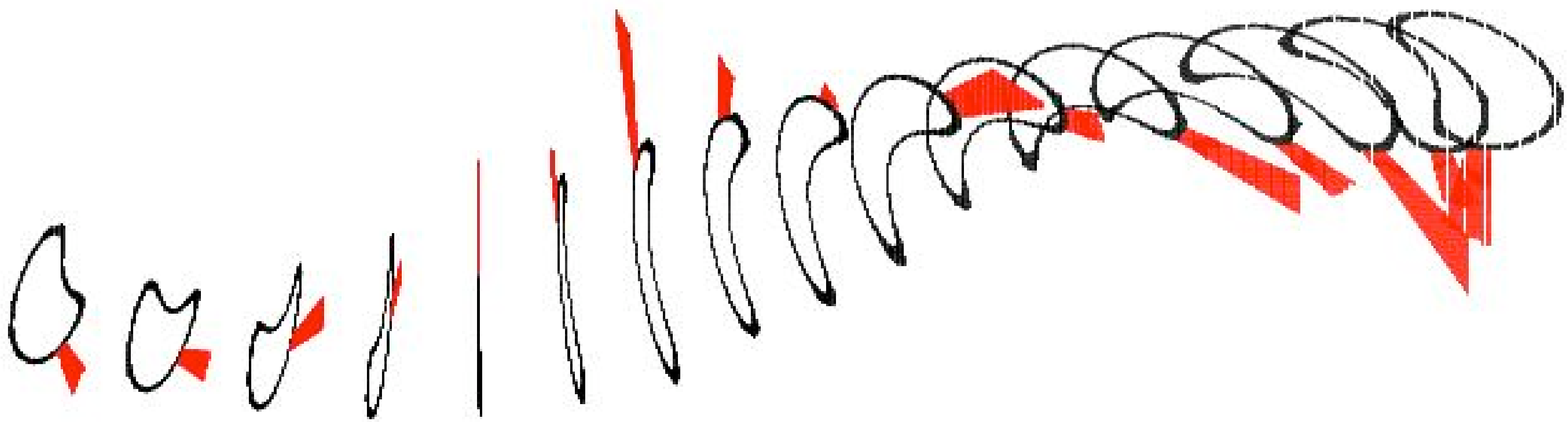


Obtaining the Map of Fluxes

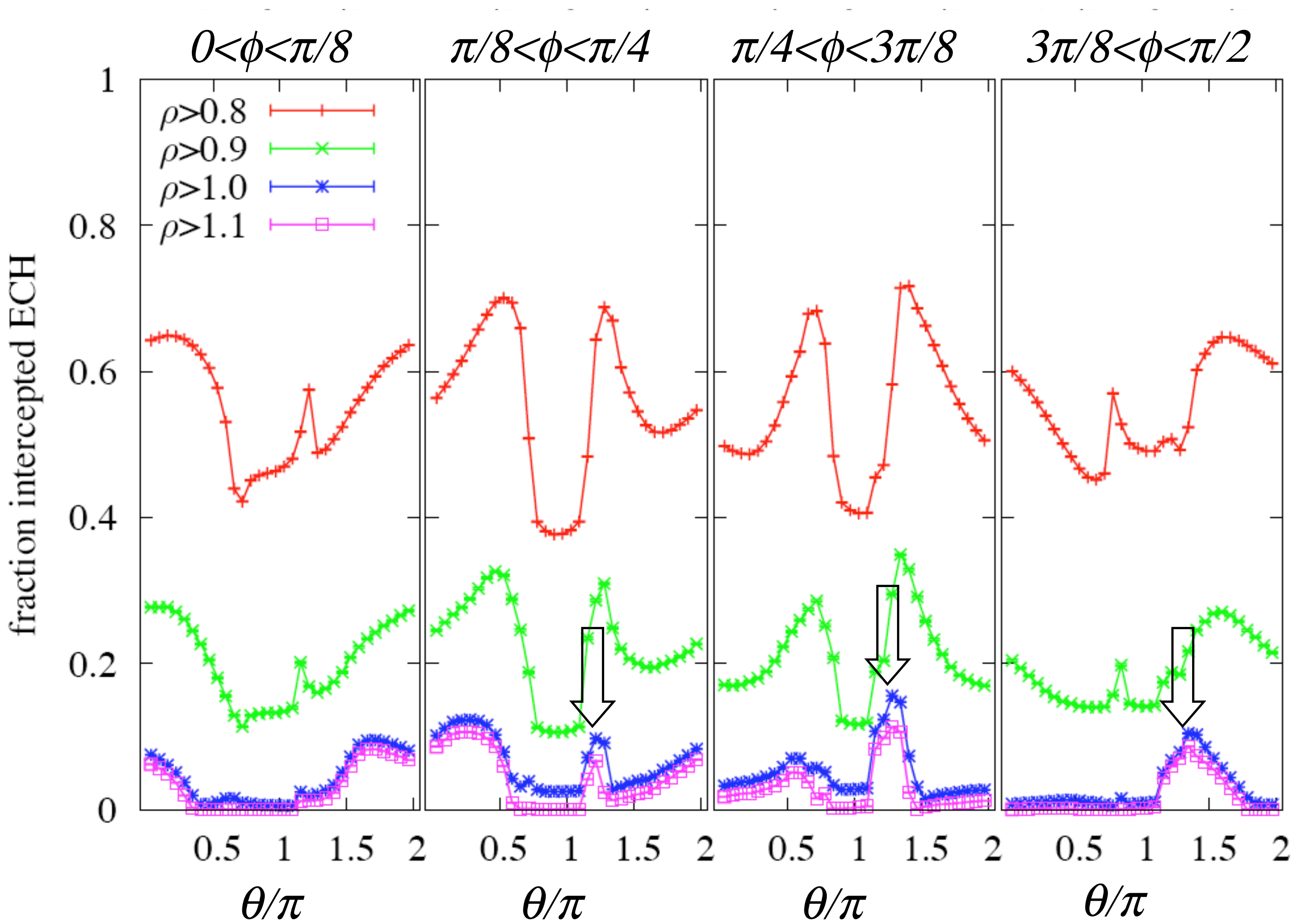
- **We locate N_ϕ x N_θ = 4 x 32 = 128 plates in each period.**
- **A single plate (ρ,i,j):**

$$\rho > \rho_0; \quad \frac{2\pi}{N_\phi} i < \phi < \frac{2\pi}{N_\phi}(i+1); \quad \frac{2\pi}{N_\theta} j < \theta < \frac{2\pi}{N_\theta}(j+1)$$

- **θ rotated -4φ with respect to the horizontal plane (groove-magnetic axis line: θ=0).**
- **The toroidal range of θ=−π/2 :**

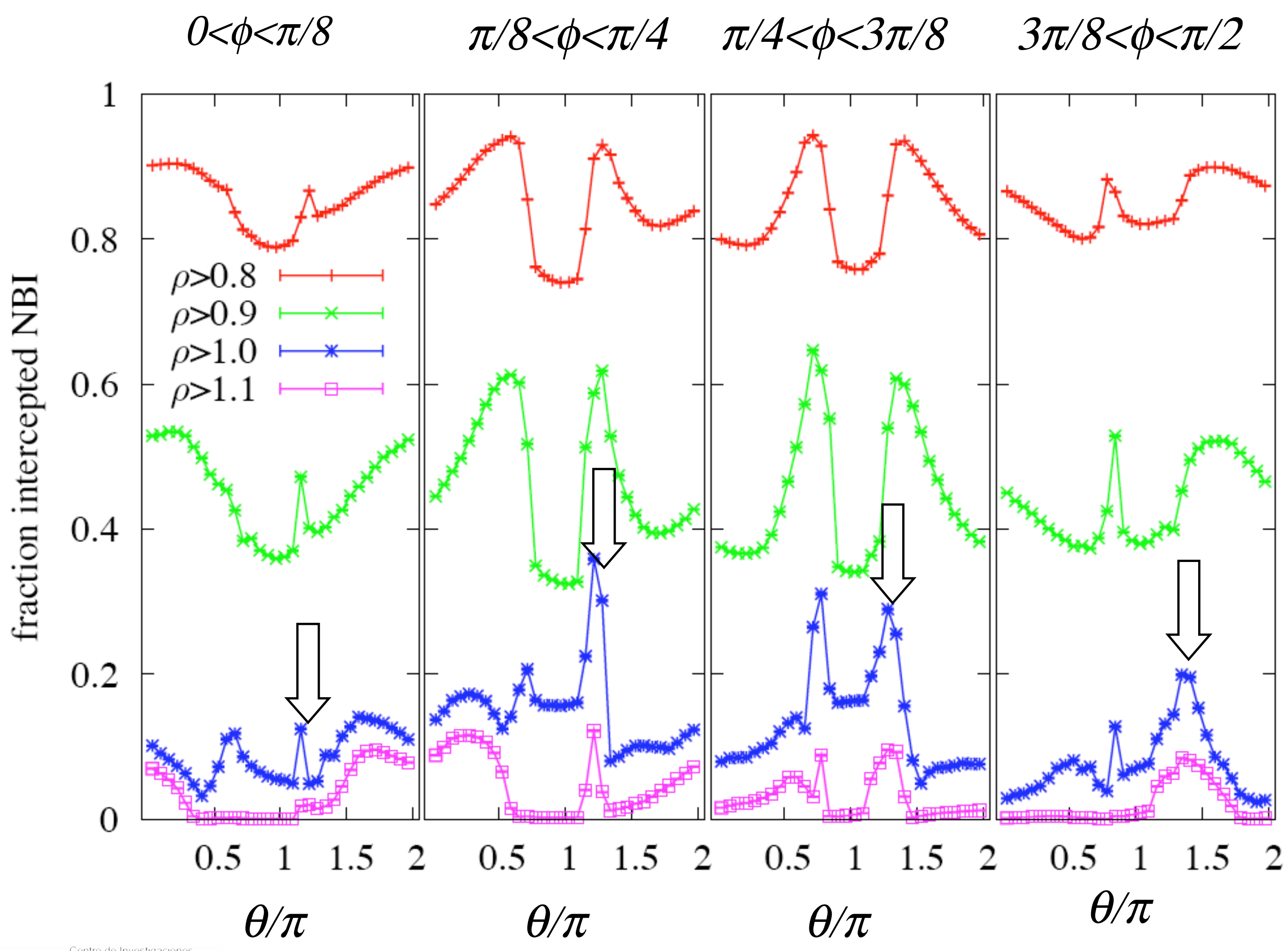


Flux Map: ECRH



- The plates are independent.
- The shadow effect is not considered in this calculation.
- Clear poloidal and toroidal structure.
- Small changes for $\rho > 1$.

Flux Map: NBI



0<ϕ<π/8
π/8<ϕ<π/4
π/4<ϕ<3π/8
3π/8<ϕ<π/2
fraction intercepted NBI
ρ>0.8
ρ>0.9
ρ>1.0
ρ>1.1
1
0.8
0.6
0.4
0.2
0
0.5
1
1.5
2
θ/π

Flux on the chamber: ECRH

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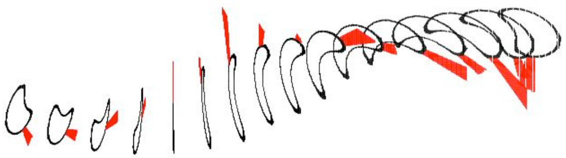
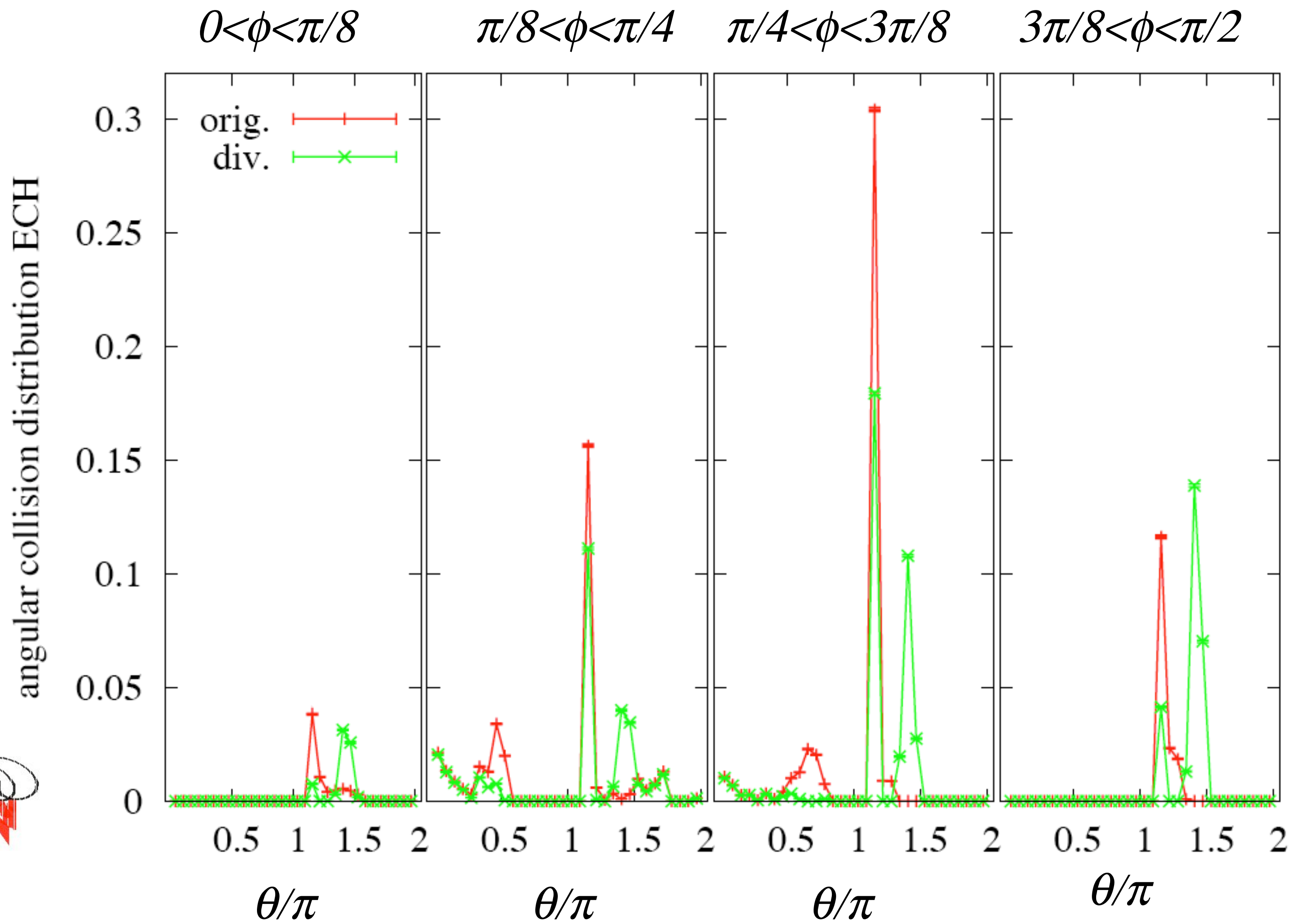
- Fraction of trajectories on the plates: **50%.**

- Fraction of collisions on the groove: **from 60% to 35%**





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Flux on the chamber: NBI

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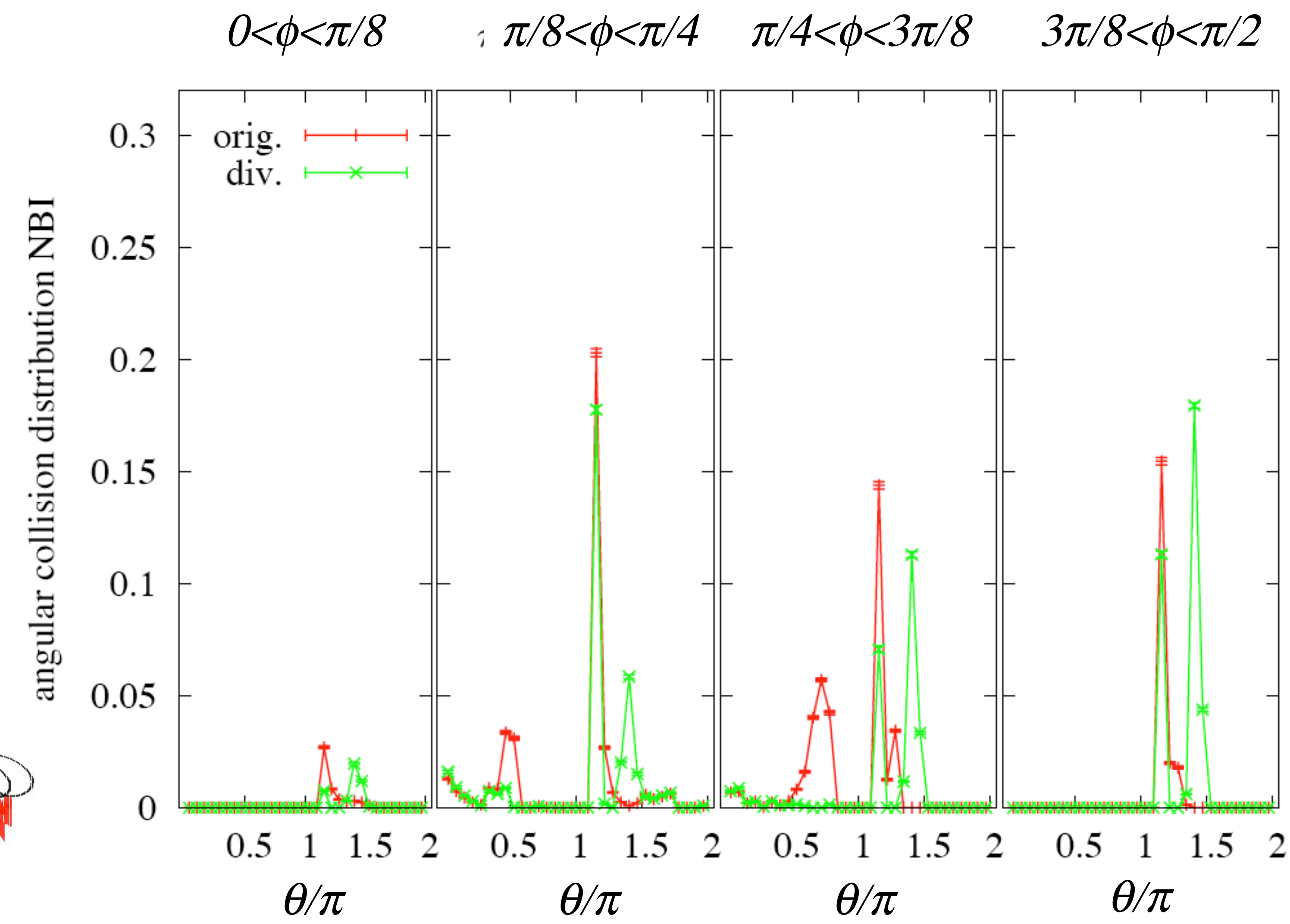
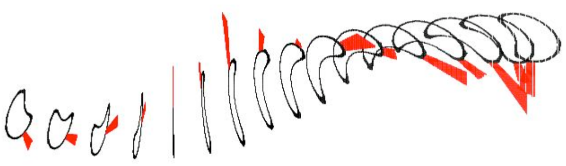
- Fraction of trajectories on the plates: **63%.**

- Fraction of collisions on the groove: **from 50% to 35%**





Conclusions…

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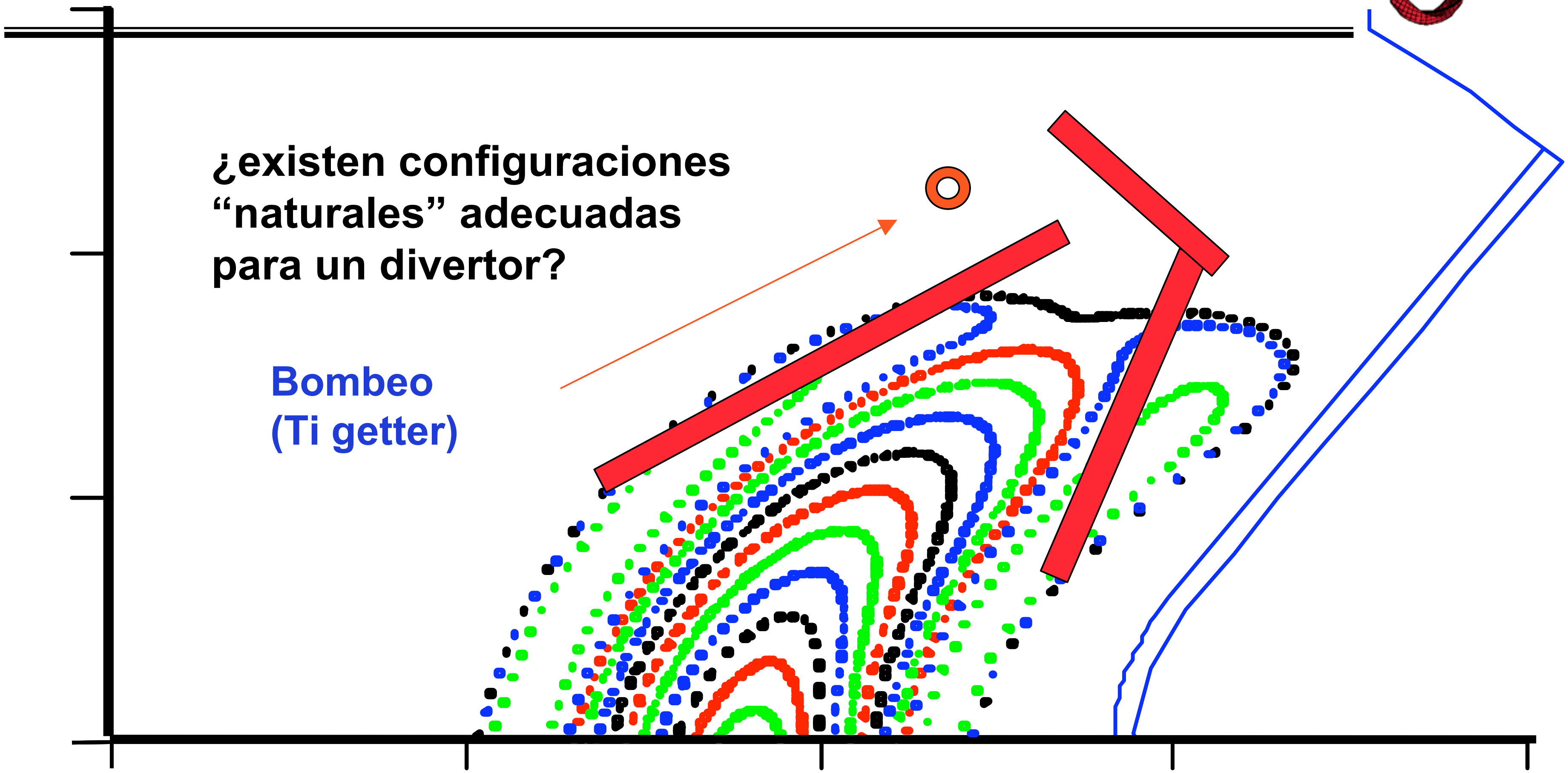
- **A promising configuration for Flux Expansion Divertor has been found in TJ-II.**
- **ISDEP code has been used to calculate the maps of the fluxes in ECRH and NBI plasmas.**
- **The flux map shows a strong poloidal structure: It is possible to locate divertor plates to suppress a large fraction of the total flux onto the wall.**
- **The flux on the groove can be strongly reduced, which is critical to diminish the plasma-wall interaction in TJ-II.**

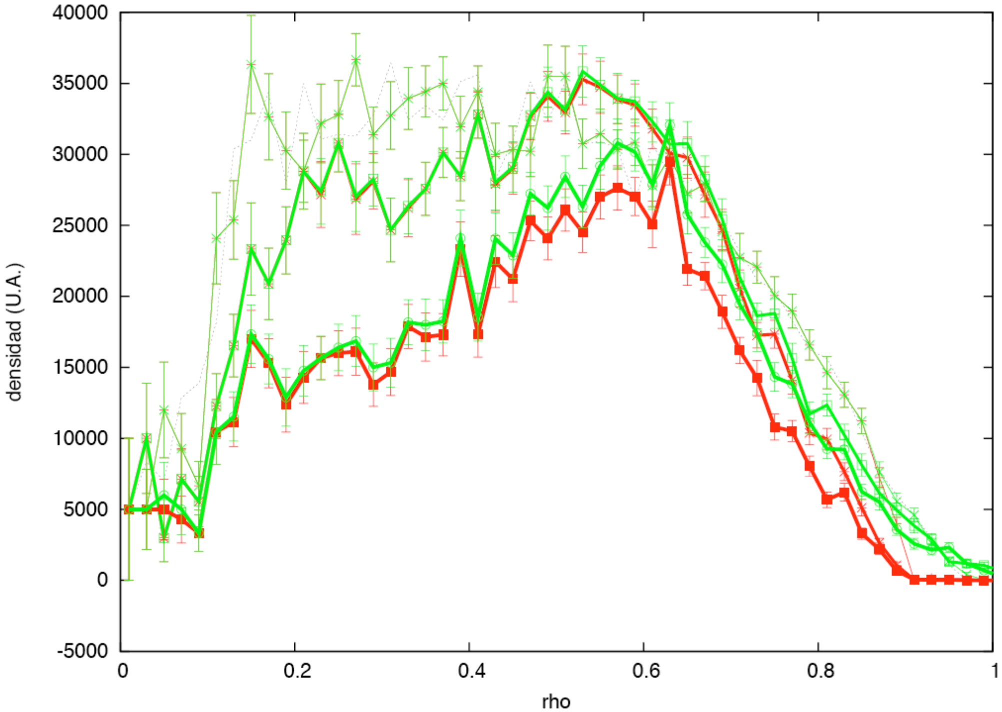
… and Future Work

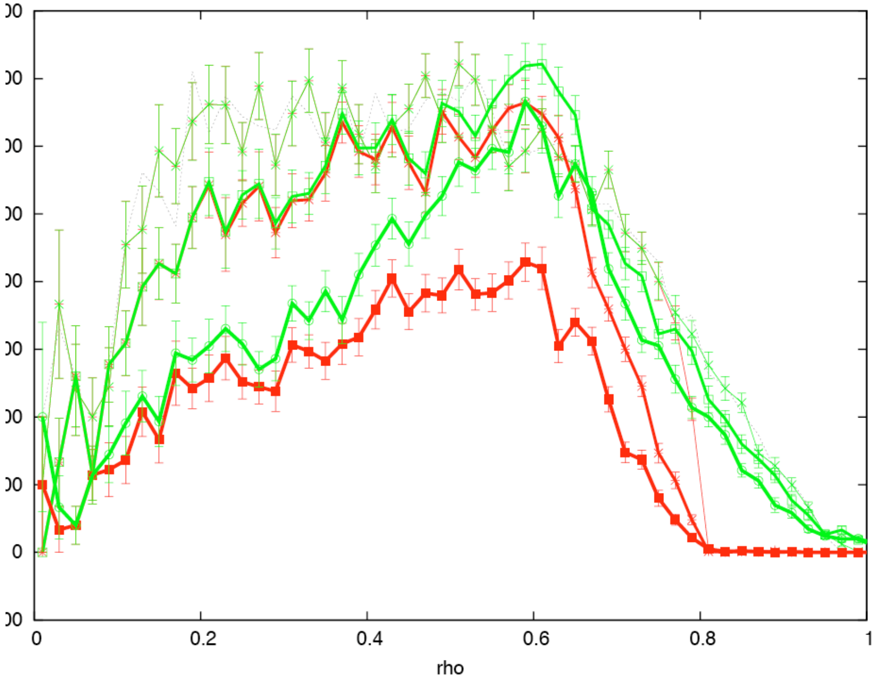
- Refine the design of the plates.
- Explore the possibility of creating an ergodic layer outside the LCFS.
- Estimate the recycling & transport of neutrals.
- Consider the Li coating?
- Thinking of experiments.

DIVERTOR: aplicación a TJ-II



Equivalente Limitador rho=0.8, 0.9





DIVERTOR: aplicación a TJ-II

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Divertor sin "islas",
Utiliza la expansion de flujo