iNFORMATION tECHNOLOGY eLECTRICAL eNGINEERING Ph.D

Vincenzo Paolo Loschiavo

Tutor: Prof. Eng. Raffaele Albanese

XXIX Cycle – I year presentation

Addressing the power exhaust

in the next generation fusion reactor

Background

From Mechanical Engineering

To

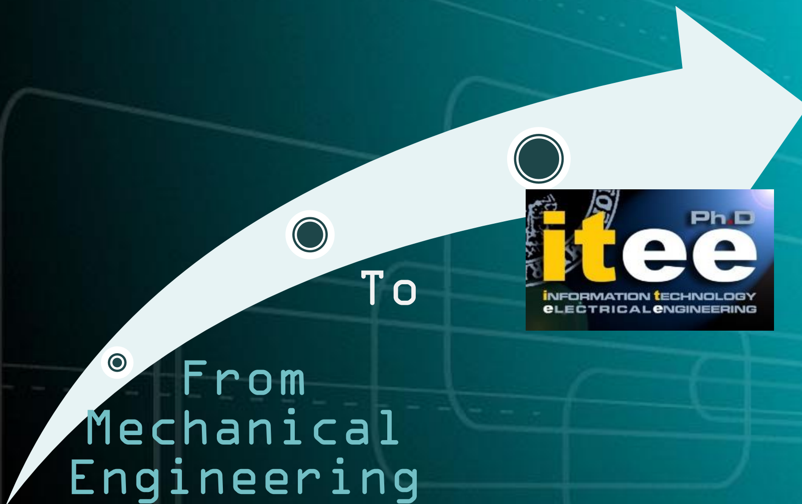
WHY????

- Discover the secrets of the thermonuclear fusion
- Improve knowledge and skills

Question: is it so strange????

Answer: well...probably not!

Background



WHY????

- Discover the secrets of the thermonuclear fusion
- Improve knowledge and skills

Question: is it so strange????

Answer: well...probably not!

2 thesis carried out (bachelor and M.Sc. degree) on the thermonuclear fusion

Background

%Research Group Topic:

- Tokamak Divertor Definition and Design

(Prof. Raffaele Albanese is the Project Leader for DTT II facility - Divertor Test Tokamak)

%Fellowship:

- PhD supported by grant

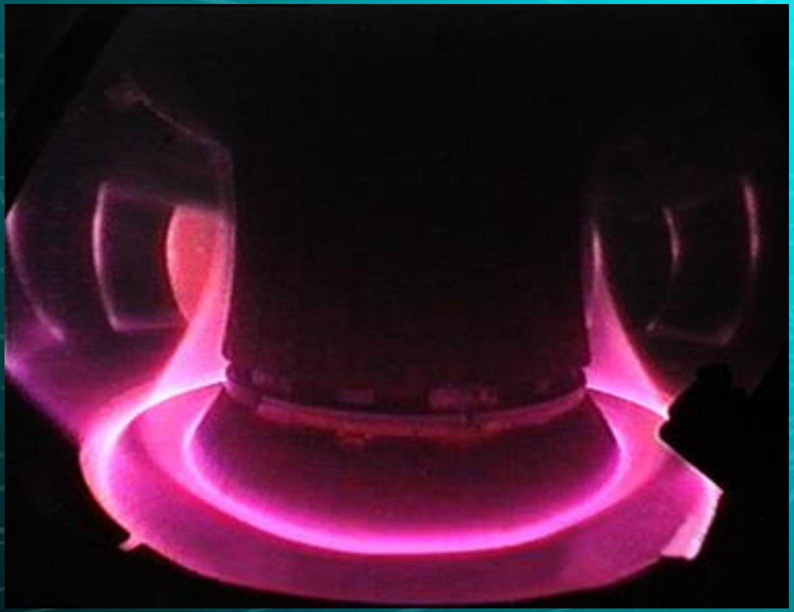
%Cooperations:

- EUROfusion (Garching - Max Planck Institut fur plasma physics)
- ENEA (Brasimone - Frascati)
- ….and many more!

My problem

"Addressing the power exhaust

in the next generation fusion reactor"

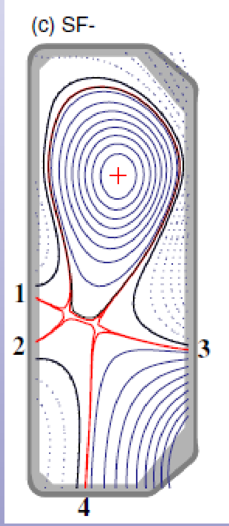
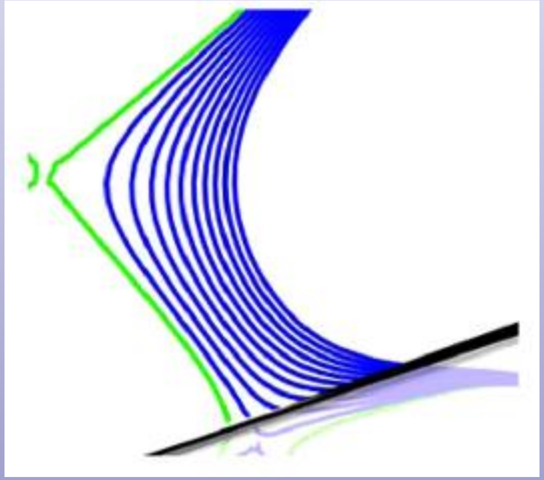


Find the best way to spread the huge heat load -POWER EXHAUST- (up to transient 30 MW/m2) impinging on the material surfaces in a next generation fusion reactor.

My problem

- State of the art (possible solutions)

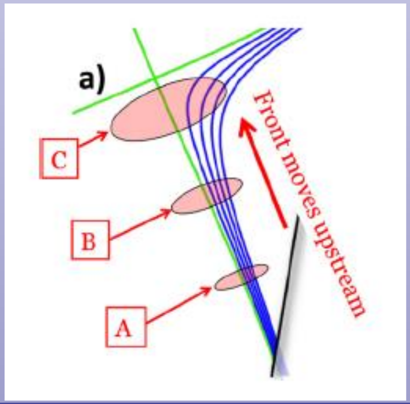
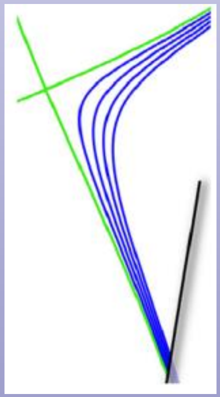
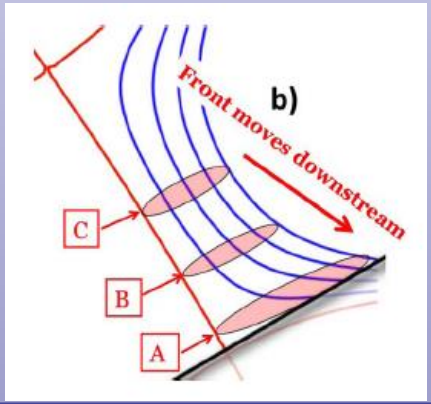
1) Advanced divertors

Snowflake	X-Divertor
$d_{xpt} \to 0$ $0 \leq \theta_{xpt} \leq \pi/2$	$d_{xpt} \cong d_s$ $\theta_{xpt} \cong \theta_s$
	

My problem

- State of the art (possible solutions)

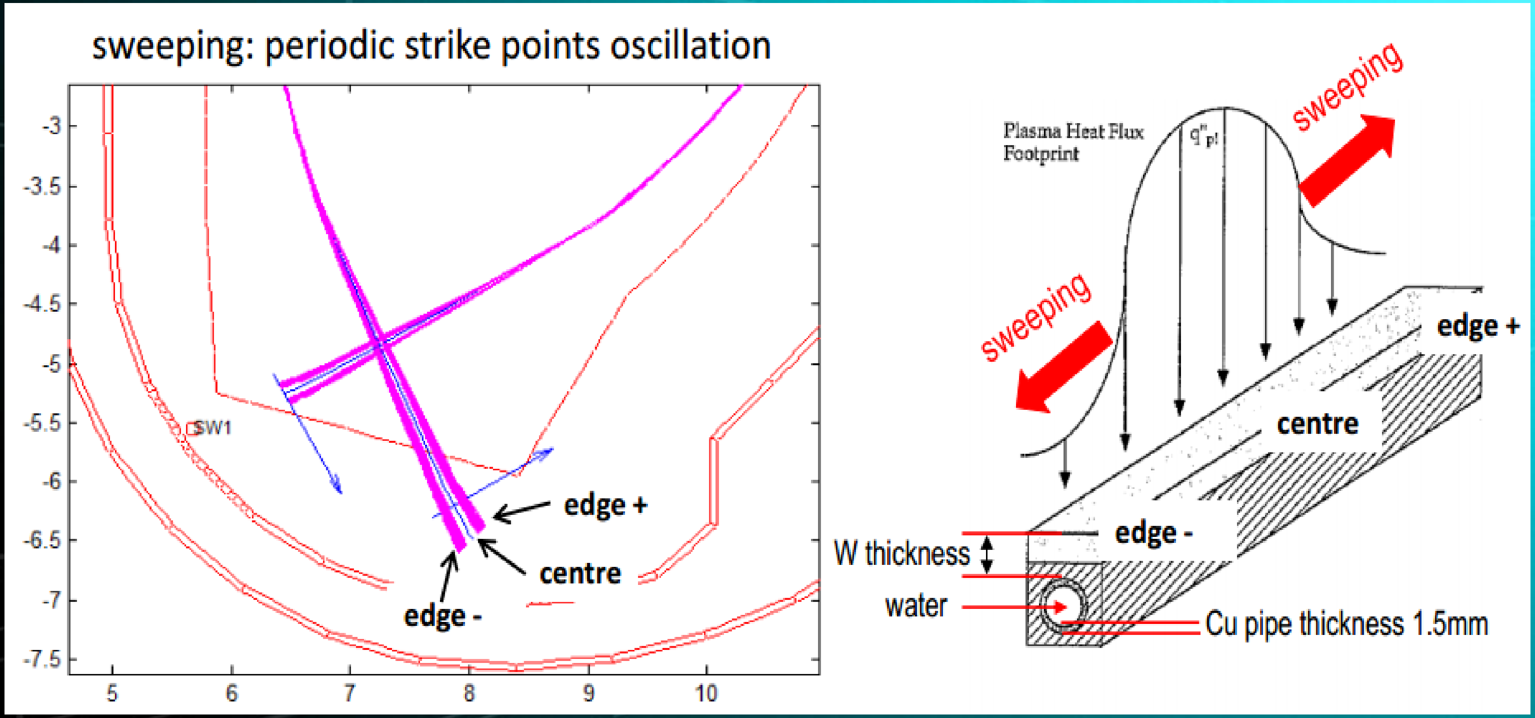
2) Plasma Detachment

The Snowflake (DI < 1)	The Standard Divertor (DI = 1)	The X-Divertor (DI > 1)
The Snowflake Divertor ACCELERATES the movement of the detachment front towards the main X-point.	Reference	The X-Divertor RETARDS the movement of the detachment front towards the main X-point.
		

My problem

The strike point sweeping

a periodical movement of the strike points



My problem

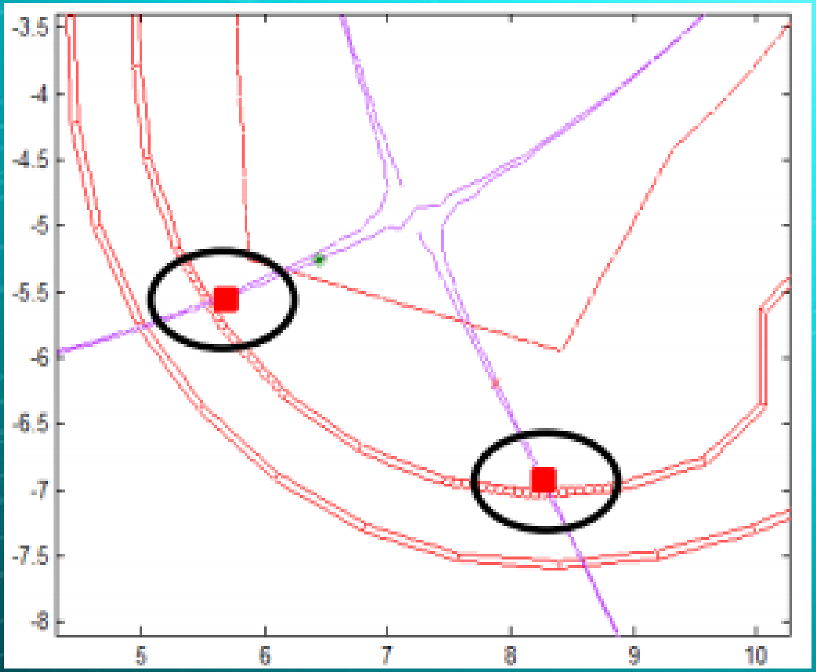
The strike point sweeping

a periodical movement of the strike points

The strike point sweeping is produced by dedicated in-vessel coils connected in antiseries

The power needed for sweeping in the above conditions (240 kAt amplitude, 120 kAt rms) is:

- active power of 0.30 MW at 0.2 Hz, 3.3 MW at 1 Hz
- reactive power of 3.5 MVAr at 0.2 Hz, 16 MW at 1 Hz



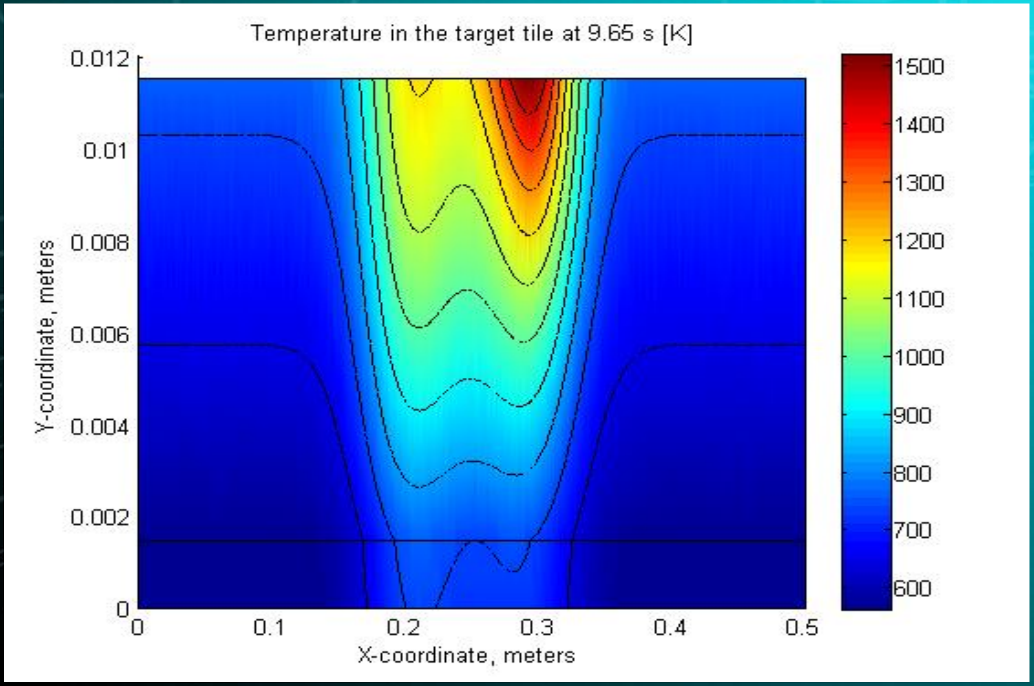
My research activity

Idea

Investigate the strike points sweeping effect on the material surfaces temperature reduction

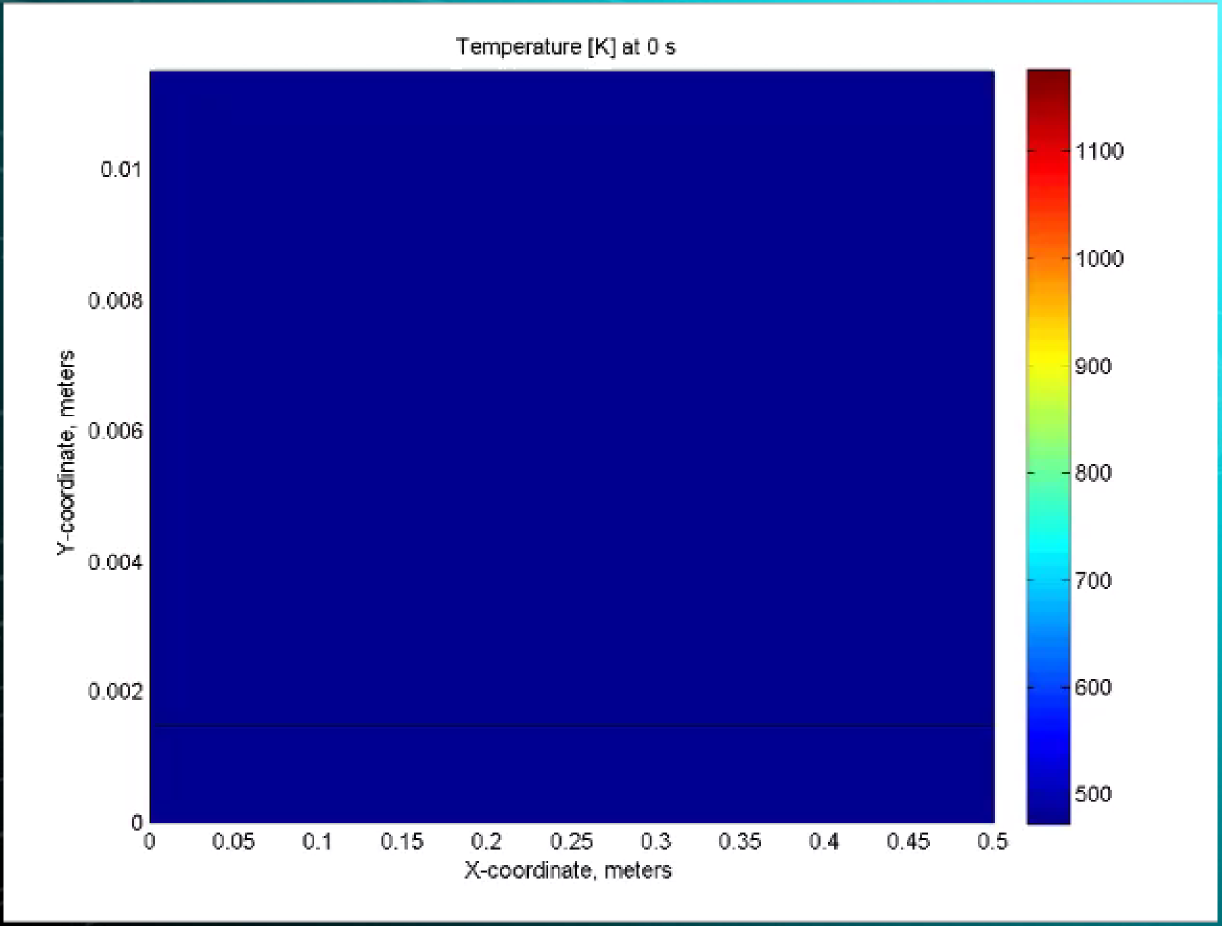
Methodology:

2-D FEM model implementation (my main contribution)



My research activity

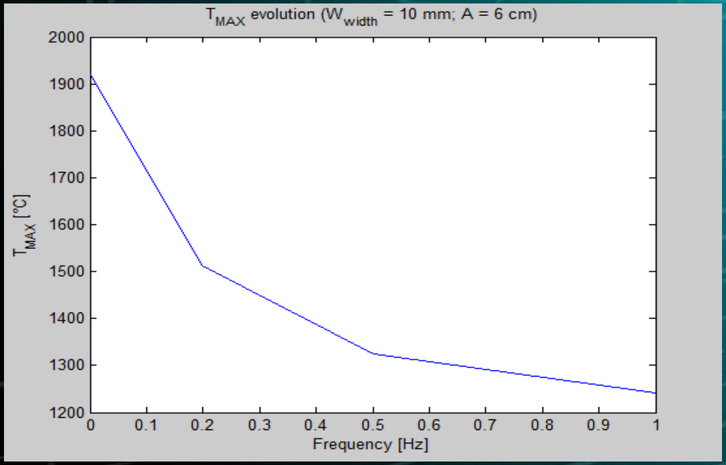
Effected results

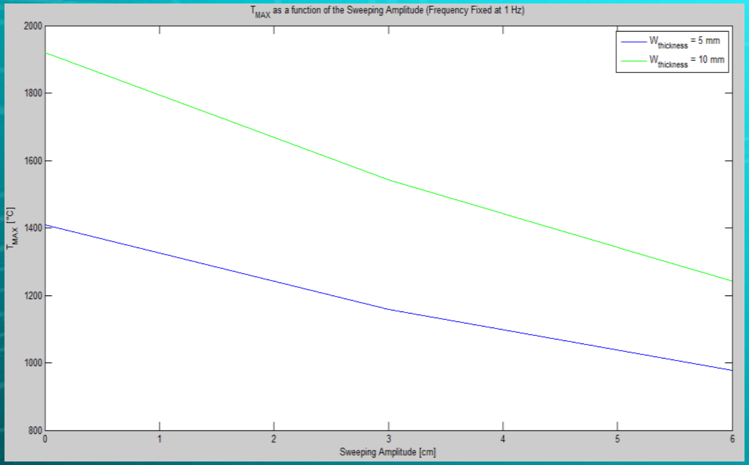


My research activity

Effected results

- sensitivity analysis of the material surfaces temperature reduction depending on the main sweeping parameters (amplitude and frequency)





$f \uparrow \Rightarrow T \downarrow$

$amplitude \uparrow \Rightarrow T \downarrow$

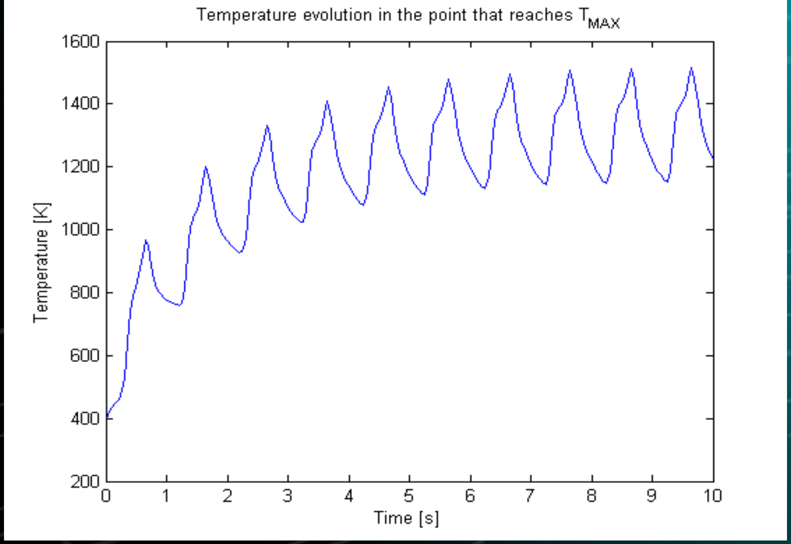
My research activity

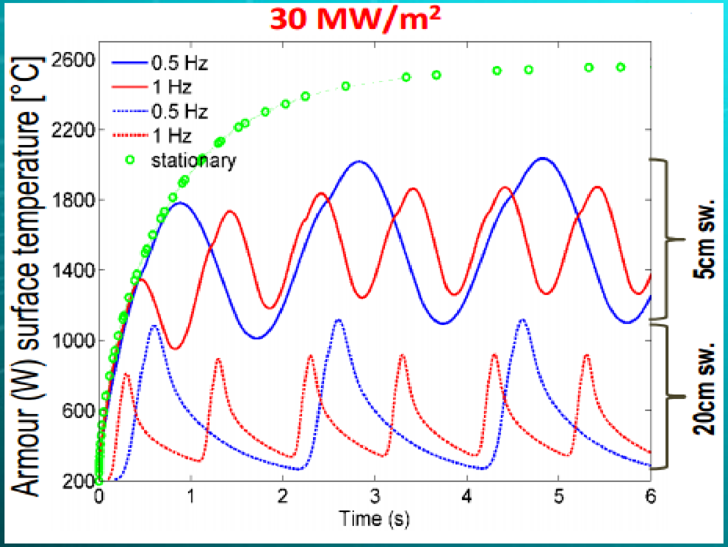
Validation

comparisons with other 1-D and 3-D models

2-D model

3-D model

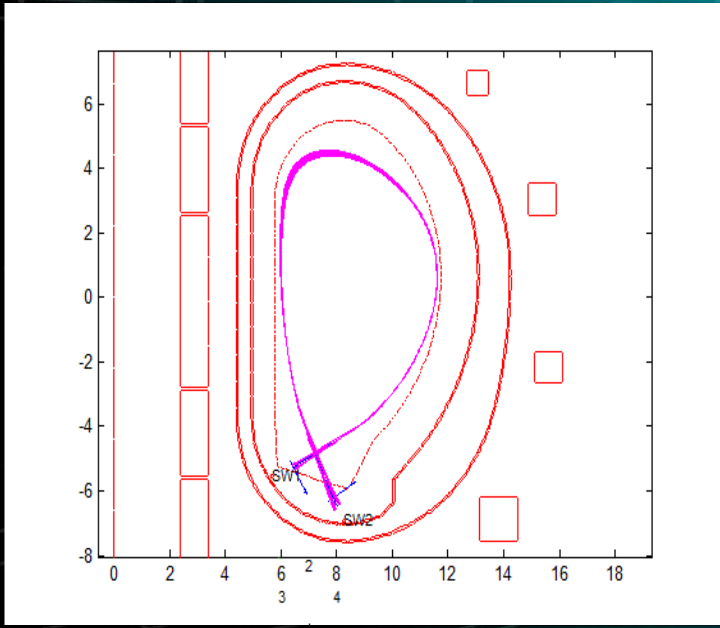




My research activity

Developments

This 2-D model is just the starting point for implementing a 3-D FEM model in order to quantify and whenever possible reduce the effects of:



- the thermal fatigue on the plasma facing components.

Taking into account:

- the AC losses due to the dB/dt on the superconducting coils;
- the motion of the plasma core;
- neutron shielding.

My products

One workshop paper

F. Maviglia

with contribution from:

G. Federici, G. Strohmayer, R. Wenninger, C. Bachmann, R. Albanese, R.

Ambrosino, M. Li, <u>V.P. Loschiavo</u> et al.

"Limitations of transient power loads on DEMO divertor and analysis of mitigation techniques"

Presented at the EFPW, 1 - 3 December 2014, Split, Croatia

My First year credits

	Credits year 1							
	Estimated	1 bimonth	2 bimonth	3 bimonth	4 bimonth	5 bimonth	6 bimonth	Summary
Modules	21			3		3	5	11
Seminars	5	0,4	0,8		1	0,2	2	4,4
Research	34	10	8	8	8	6	3	43
	60	10	8,8	11	9	9,2	10	58

Courses I attended during the first year:

- PLASMAS AND CONTROLLED THERMONUCLEAR FUSION (Section A);
- NUMERICAL METHODS FOR ENGINEERS;
- INTRODUCTION TO QUANTUM MECHANICS;
- EUROPEAN PROJECTS;
- RESEARCH PROJECT MANAGEMENT.

My First year credits

	Credits year 1							
		1	2	3	4	5	6	
	Estimated	bimonth	bimonth	bimonth	bimonth	bimonth	bimonth	Summary
Modules	21			3		3	5	11
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Research	34	10	8	8	8	6	3	43
	60	10	8,8	11	9	9,2	10	58

Courses I expect to attend in the next year:

- FUNCTIONAL ANALYSIS
- DYNAMICAL SYSTEMS BASICS
- CONTROL SYSTEMS
- ENGLISH

Next years

3-D model for evaluating the thermal fatigue of the plasma facing components (PFCs) ---------→ ENEA (BRASIMONE)

Tokamak material structures thermo-mechanical stress analysis

Detachment feasibility evaluation and closed loop control design

Plasma external conductors position optimization for next generation reactors

Comparisons between sweeping and other heat load spreading techniques

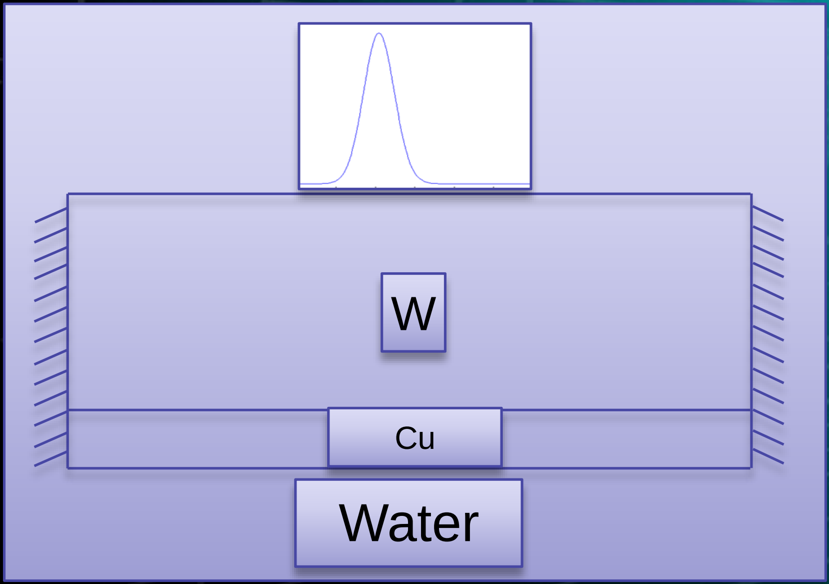
Thanks for your attention!

My research activity

⅋Methodology:

2-D FEM model implementation (my main contribution)

$$\nabla \cdot (k \nabla T) = \rho c \frac{\partial T}{\partial \theta}$$



$T_W(x,y,0) = T_{Cu}(x,y,0) = \mathbf{200°C}$	$0 \le x \le L_x, 0 \le y \le L_y$
$-k_{Cu}\frac{\partial T(0,y,\theta)}{\partial x} = 0$	$0 \le y \le L_{y,Cu}, \theta > 0$
$-k_{Cu}\frac{\partial T(L_x,y,\theta)}{\partial x} = 0$	$0 \le y \le L_{y,Cu}, \theta > 0$
$-k_{Cu}\frac{\partial T(x,0,\theta)}{\partial y} = \bar{h}_{c,eff}(T_{Cu,lower} - T_{water})$	$0 \le x \le L_x, \theta > 0$
$-k_{Cu}\frac{\partial T(x,L_{y,Cu},\theta)}{\partial y} = -k_W\frac{\partial T(x,L_{y,Cu},\theta)}{\partial y}$	$0 \le x \le L_x, \theta > 0$
$-k_W\frac{\partial T(0,y,\theta)}{\partial x} = 0$	$L_{y,Cu} \le y \le L_{y,W}, \theta > 0$
$-k_W\frac{\partial T(L_x,y,\theta)}{\partial x} = 0$	$L_{y,Cu} \le y \le L_{y,W}, \theta > 0$
$-k\frac{\partial T(x,L_{y,W},\theta)}{\partial y} = \dot{q}$	$0 \le x \le L_x, \theta > 0$