USTC SNST 2015 Spring Semester Lecture Series

Title: Introduction to Plasma-Facing Component (PFC) and Plasma-Material Interaction (PMI) R&D for Tokamak Fusion Energy

Lecture 1: Room 1617, 1030-1130, **Saturday** March 21, 2015

L1A: What are the Special Features of this Lecture Series? What topics to select?

L1B: Overview: from plasma core, to edge, to interface, to material surface, to component, then to outside

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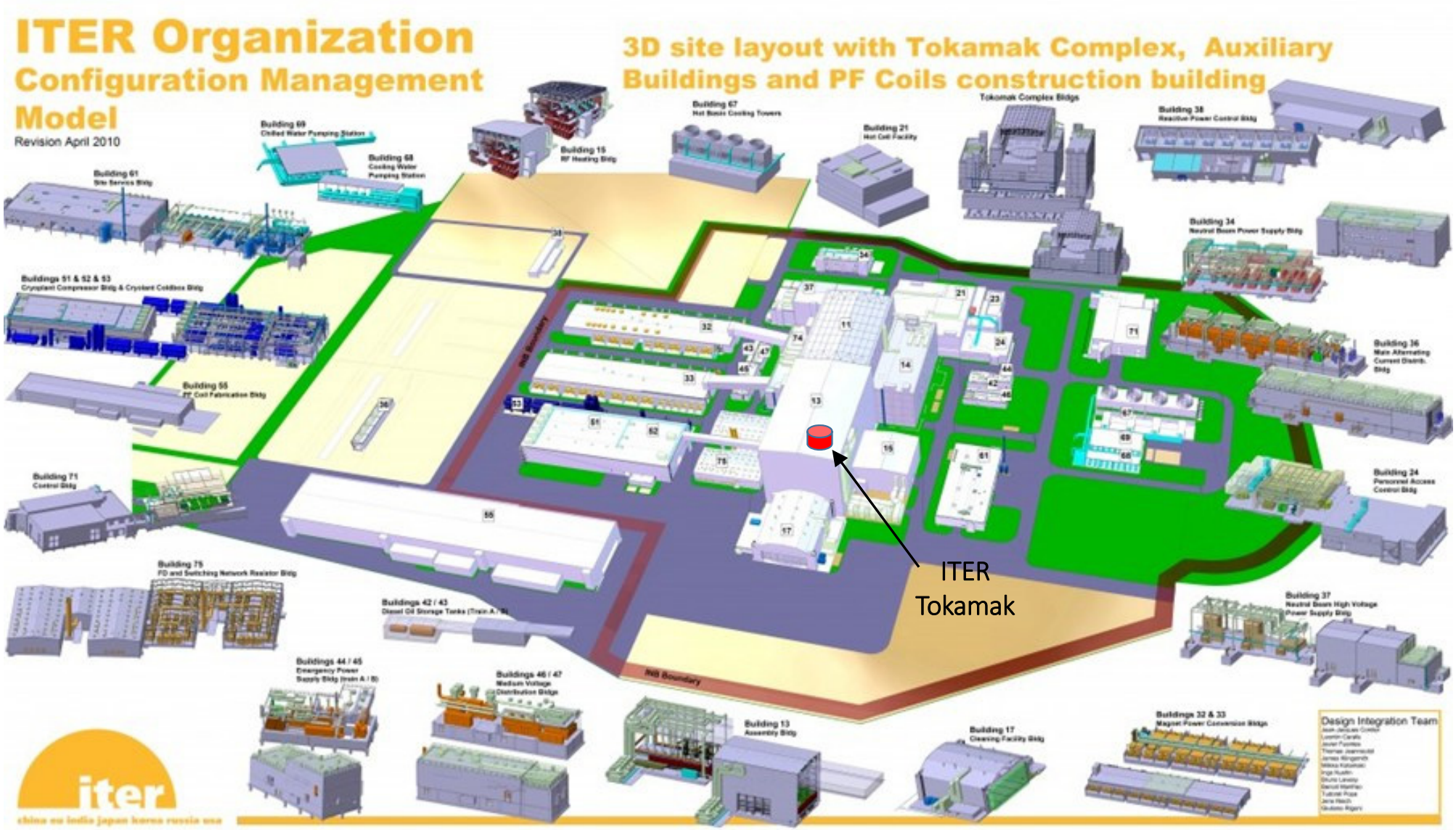
Class assistant: 徐国梁
Webpage assistant: 王伸吉

One day in 2020's, ITER facilities are ready



All systems supporting the ITER tokamak are ready

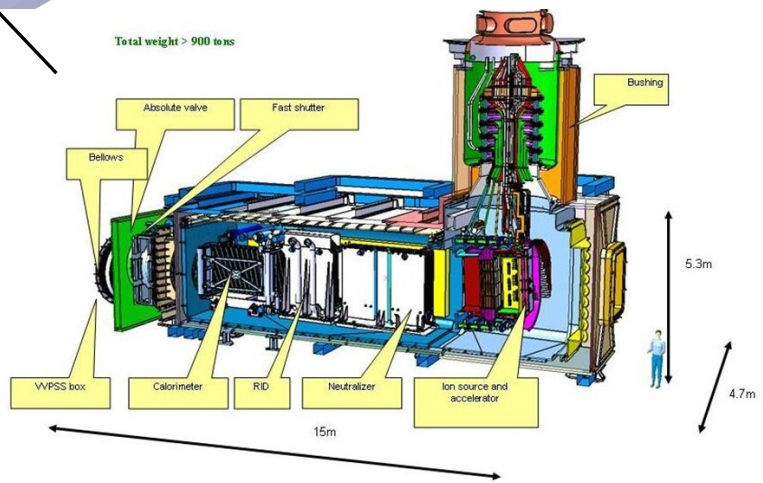
RF Heating system

Test Blanket Modules

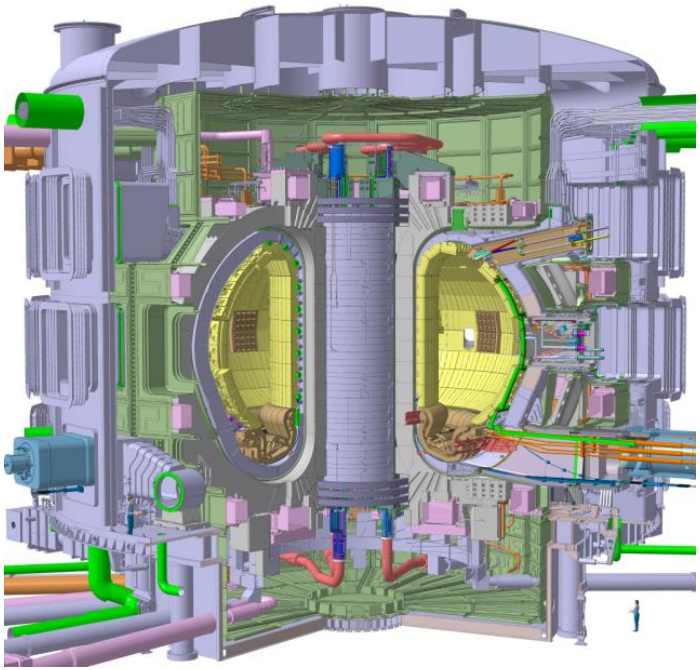
Others, such as
Cryogenic system
Water system
Gas system
Electrical system
Etc.

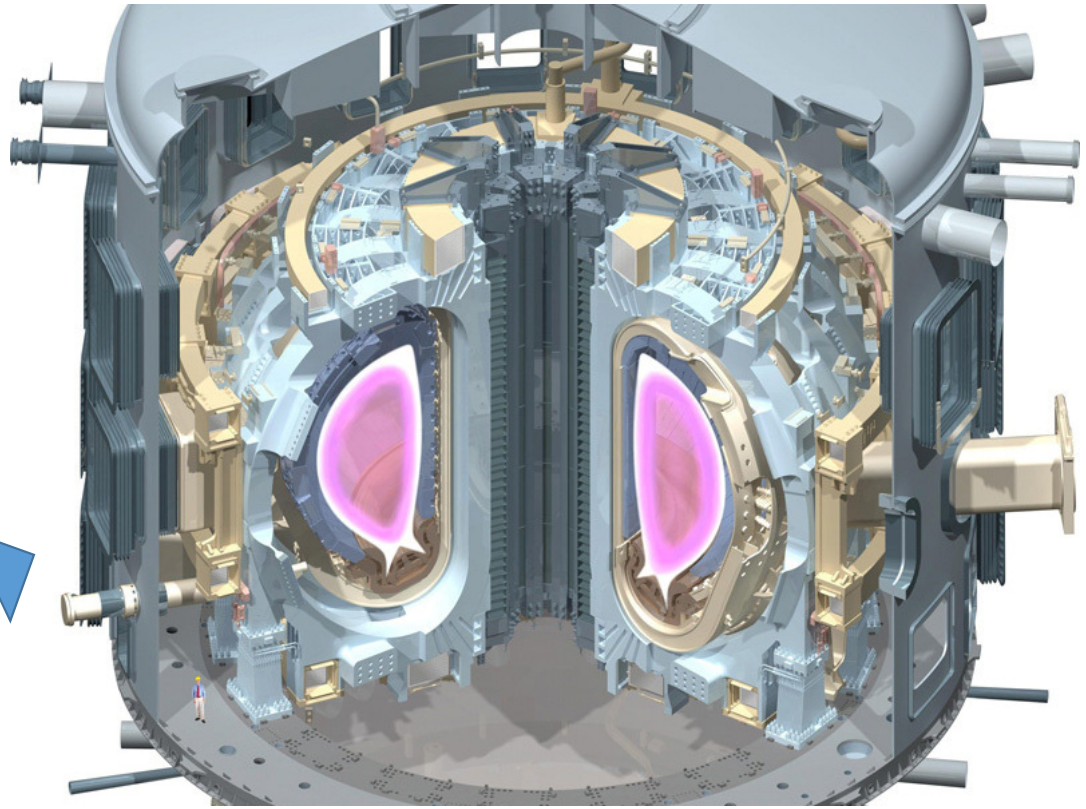
Location for
ITER Tokamak

Neutral Beam Injector



All components of the ITER tokamak device are finally ready to start the first, fully diverted tokamak plasma in H

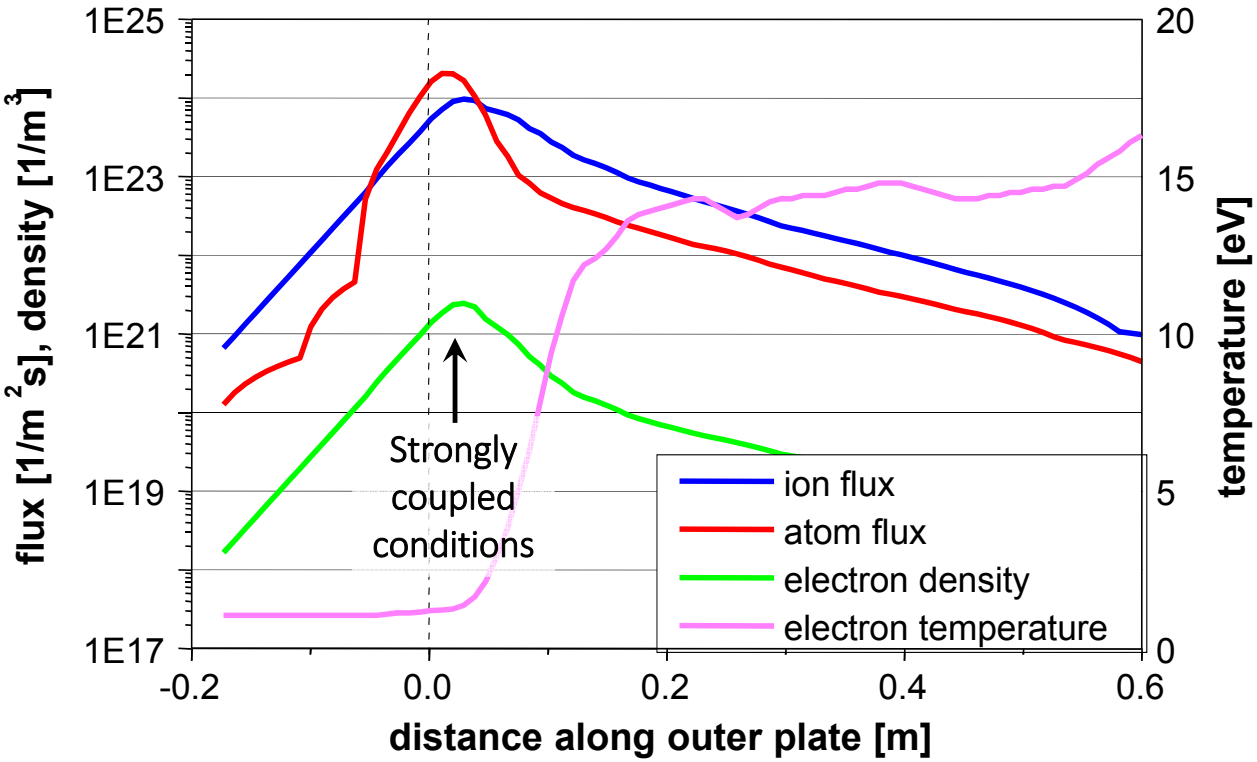


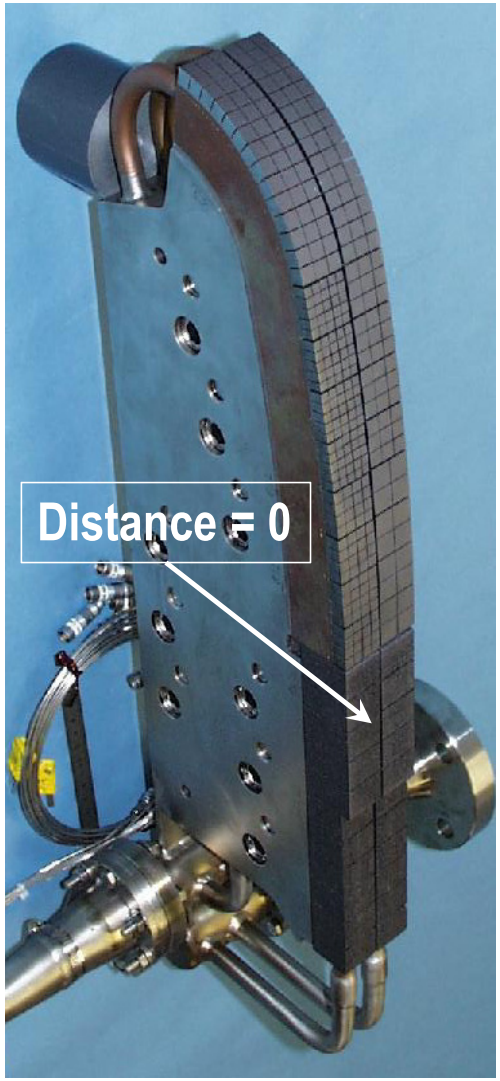


What in-vessel components likely bears the most concern?

ITER divertor operates for 400 – 3000s at a time, under conditions of extremely high heat and particle fluxes

B2-Eirene simulation for the ITER outer divertor, including impurities (A.S. Kukushkin)





- $n_e = 3 \times 10^{21}$ m^{-3}
- $T_e = 1 – 10$ eV
- $\Gamma_{D,T} = 10^{24}$ m^{-2} s^{-1}
- $q_{div} = 10$ MW/m^2
- Surface temperature (up to 1600 ^{o}K)

Thermal loads

PWR

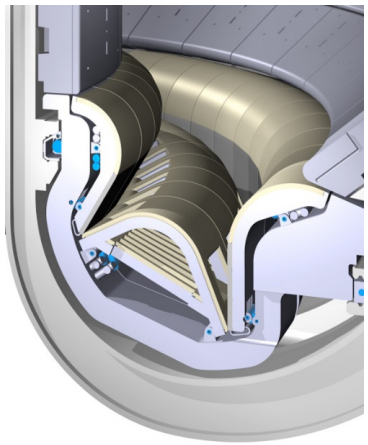
Re-entry vehicle

Space Shuttle rocket nozzle

~1 <10 85 2000

Power load [MW/m^2]

GE90-115B



ITER steady-state

Outer divertor:

1200 C

Inner divertor:

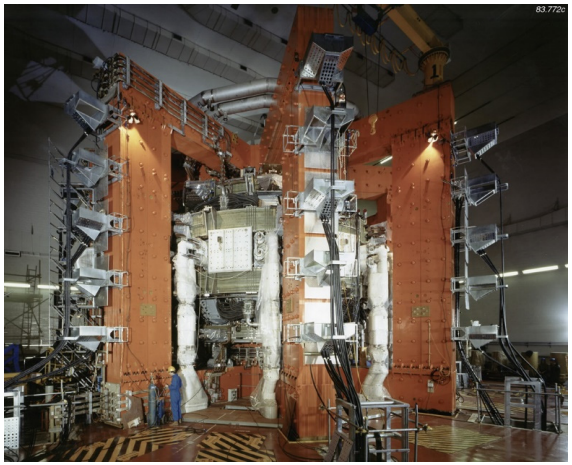
800 C

ITER transients

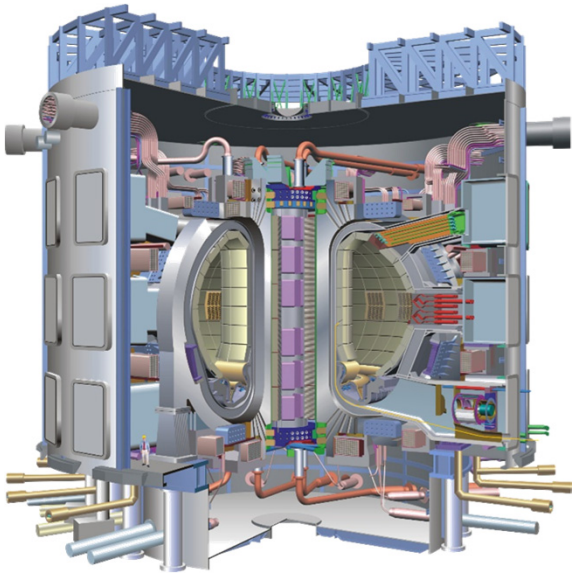
(1ms lifetime)

Particle fluxes and fluence

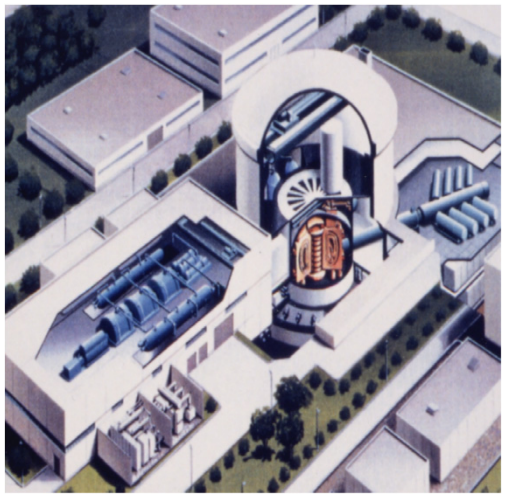
JET



ITER



Fusion Reactor



50 x higher ion fluxes

5000 x higher ion fluence

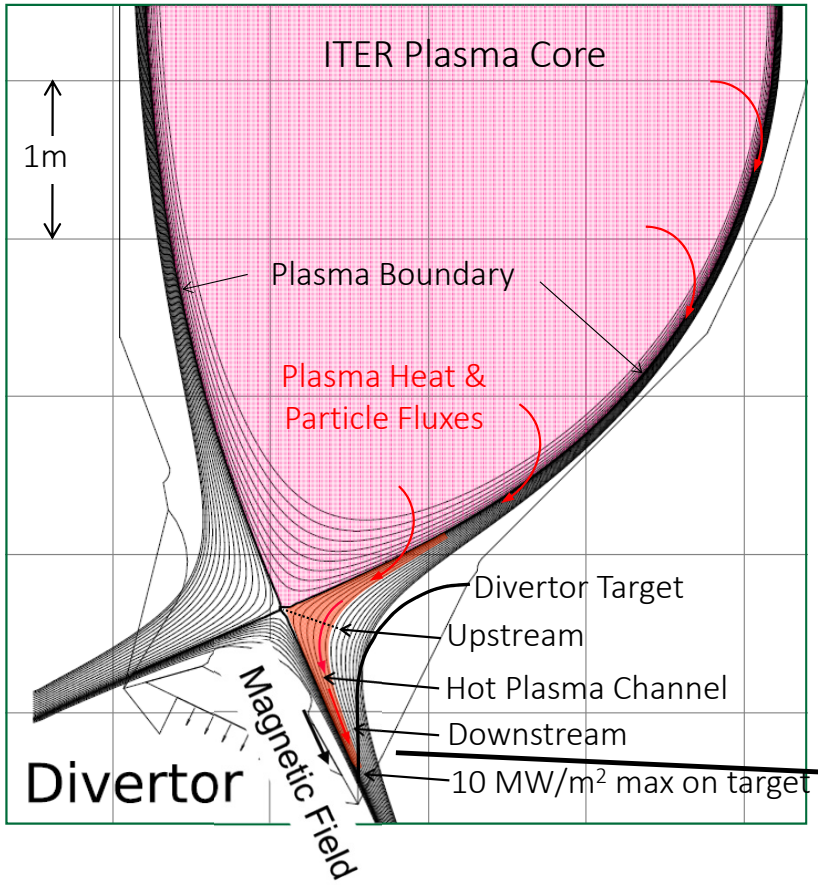
10^6 x higher neutron fluence (~1dpa)

up to 5 x higher ion fluence

100 x higher neutron fluence (~150 dpa)

Strongly coupled plasma-material interaction (PMI) occur at the interface of plasma and divertor target surface

ITER plasma core, to edge, to interface plasma, to divertor

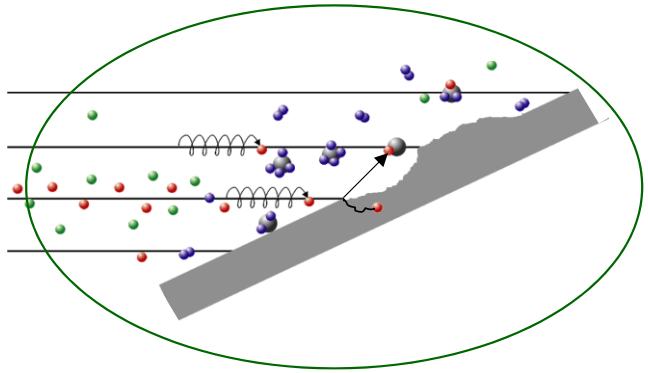


Even when target temperature is maintained, how fast would

- Material surface be eroded?
- Dust accumulate, and where?
- Bulk material properties change?
- Impurities invade the plasma core?
- Etc.

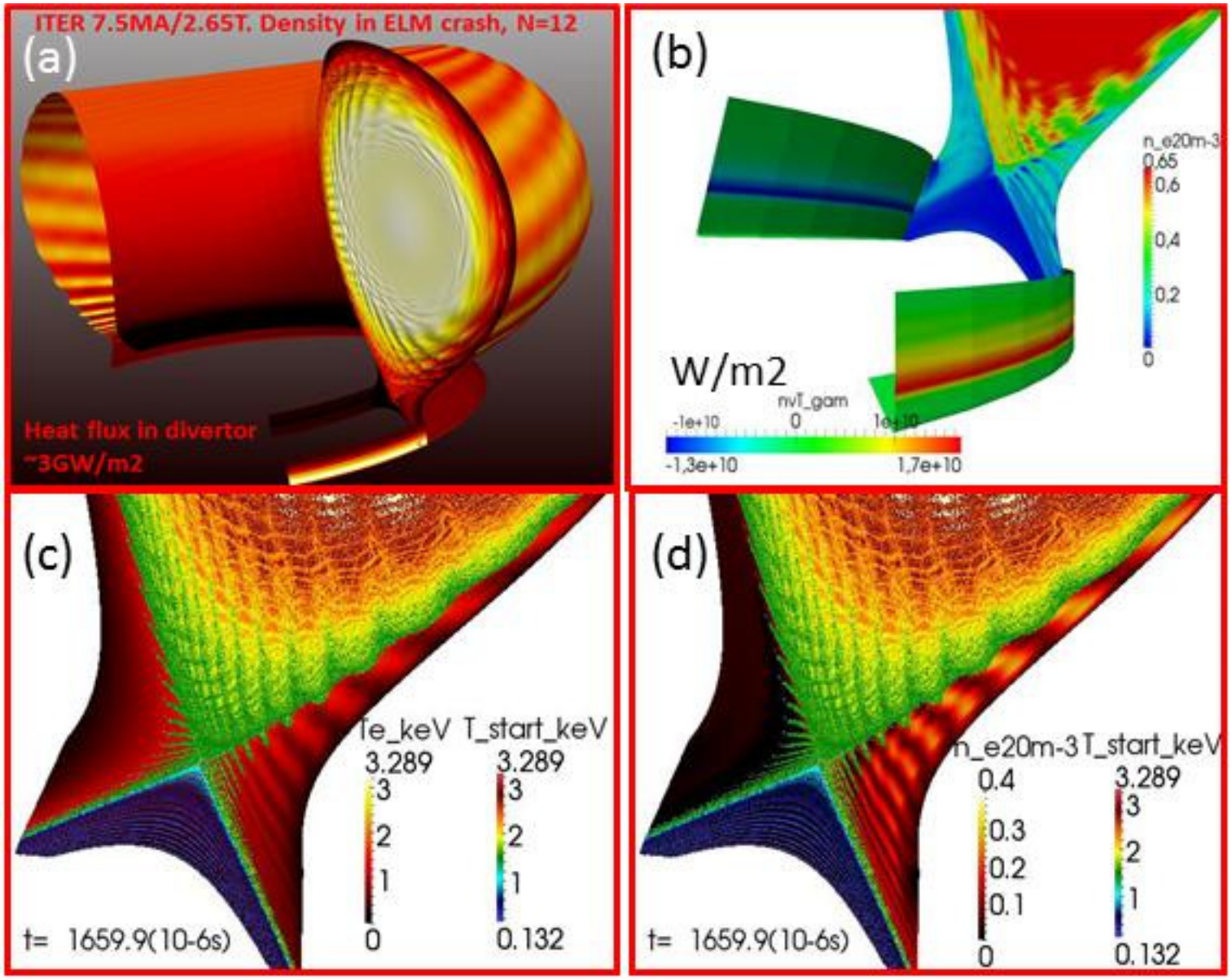
Area of much R&D opportunities

High-recycling, strongly coupled PMI



The divertor also faces high frequency pulsed heat and particle fluxes

(http://irfm.cea.fr/Phocea/Vie_des_labos/Ast/ast.php?t=fait_marquant&id_ast=372)



PMI R&D and PFC design will define condition of initial ITER plasma operation

- PFC capabilities will delimit conditions of initial ITER plasma.
- ITER divertor PMI parameters are unique in the world of extremely high heat and particle fluxes.
- Challenges and R&D opportunities abound in this area.
- Can ancient Chinese wisdom inspire this R&D?.
- “道生一，一生二，二生三，三生万物。万物负阴而抱阳，冲气以为和。...”.
- **Homework/small group project**: In a fusion energy R&D, what do or could “一”, “二”, and “三” represent?
- 鼓励同学发挥创造力和想像力，探索相关的想法，提出来讨论。Send your PPT to 徐国梁 and I ahead of class for inclusion.

L2 on Saturday March 28, same time & place