Fusion Reactor Technology II
(459.761, 3 Credits)

Prof. Dr. Yong-Su Na

(32-206, Tel. 880-7204)

Contents

Fusion Plasma Technology

Reactor Technology

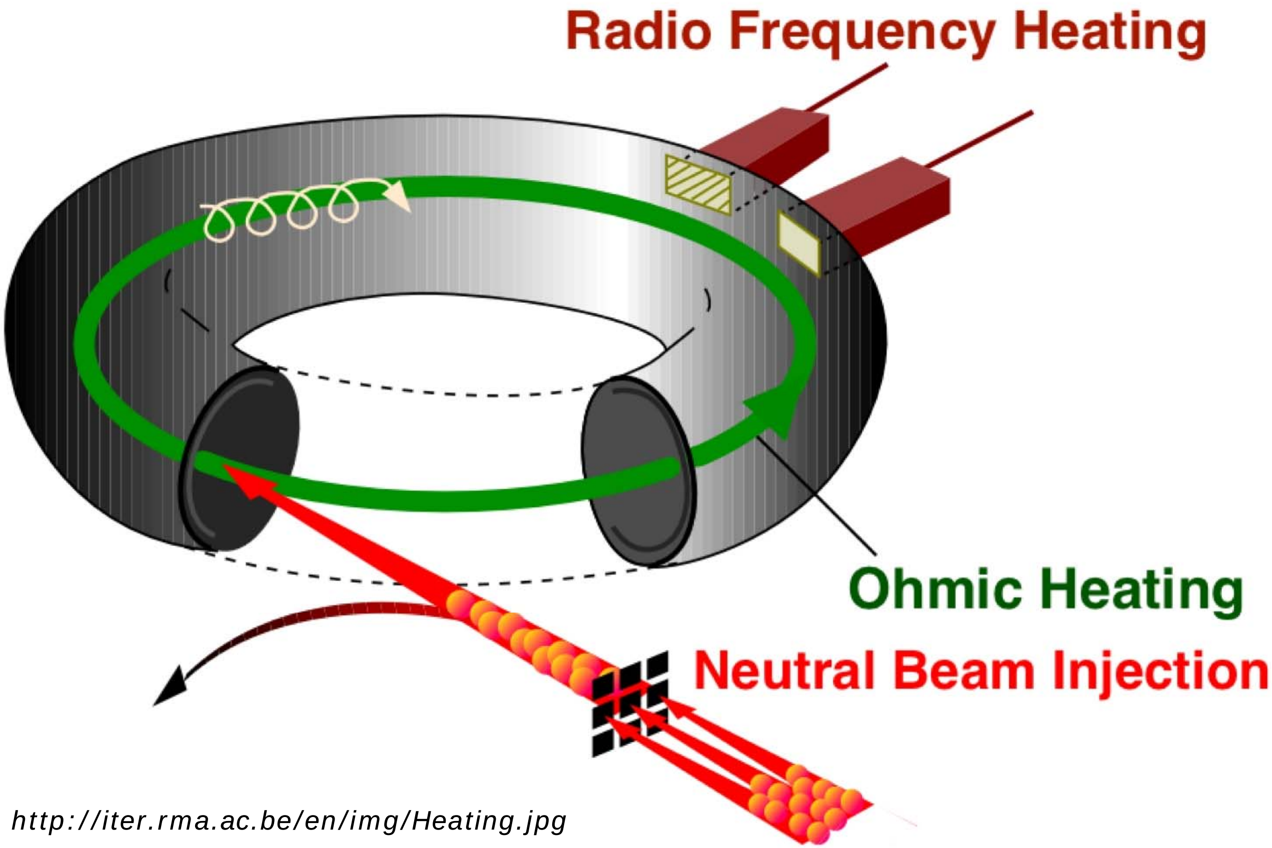
Blanket and Material Technology

Safety Technology

Operation and Maintenance Technology

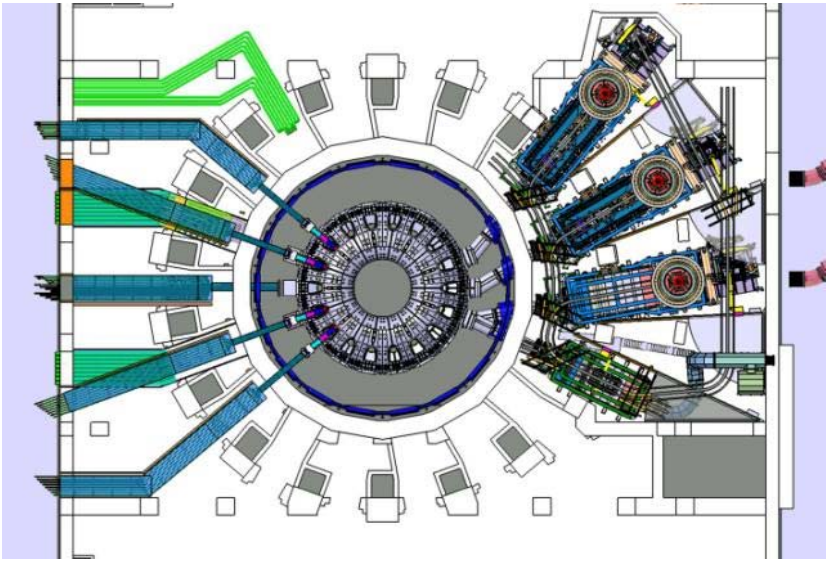
Issues and prospects towards steady-state operation

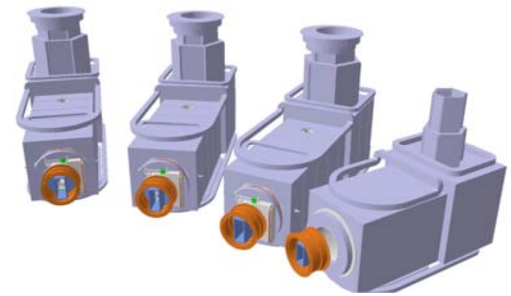
Current drive and current profile control

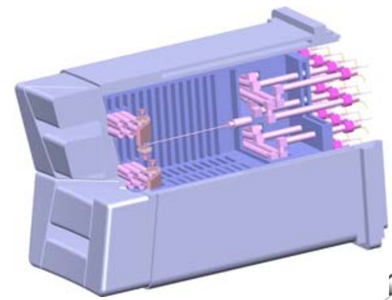


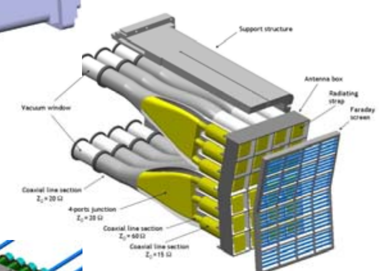
http://iter.rma.ac.be/en/img/Heating.jpg

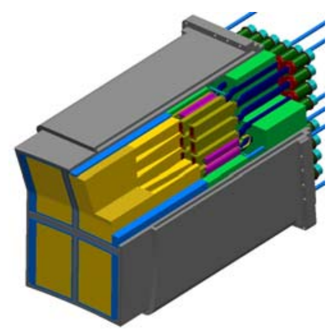
Current drive and current profile control











- Heating and CD system in ITER
  - 1 MeV NBI
  - 170 GHz ECRF
  - 40-70 MHz ICRF
  - 5 GHz LHRF

Current drive and current profile control

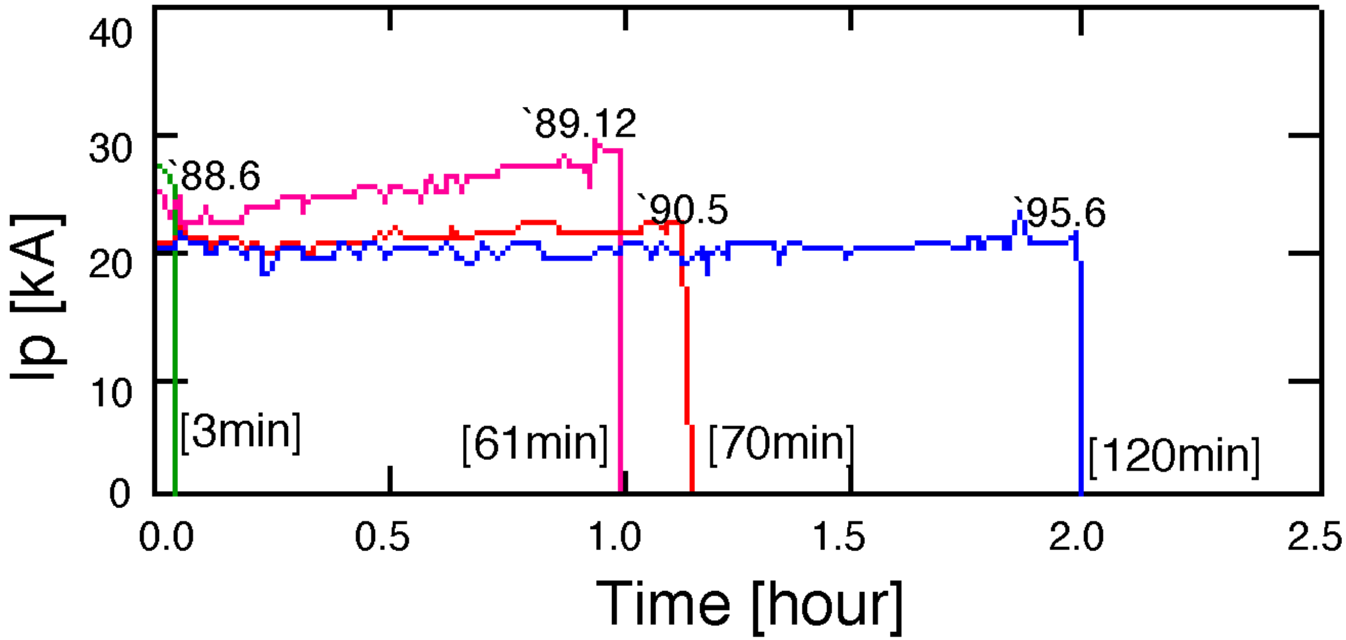
	Efficiency
LHCD	0.35-0.4
ICCD	0.1xT_e [10keV]
ECCD	< 0.1xT_e [10keV]
NBCD	0.2xT_e [10keV]

- Efficiency

Theory: $$\eta_{th} = \frac{j}{p} = \frac{e \cdot n_{e\parallel} \cdot v_{\parallel}}{\left(n_{ell} \cdot m_e v_{ll}^2 / 2\right) \cdot \nu_{coll}} \propto \frac{1}{v_{\parallel} . \nu_{coll}}$$

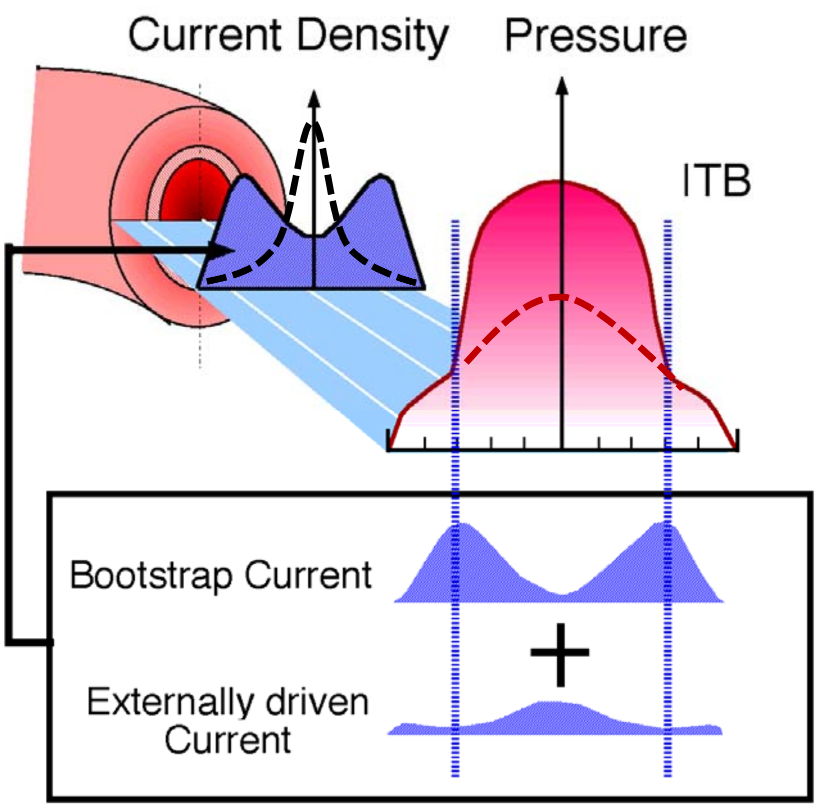
Experiment (Figure of merit): $$\gamma = \frac{n_e\left[10^{20} m^{-3}\right] \cdot R[m] \cdot I[A]}{P[W]} \propto \eta_{th}$$

Current drive and current profile control



- The world's longest discharge obtained in TRIAM-1M by means of LH full-CD

Current drive and current profile control



Non-monotonic current profile

Turbulence suppression

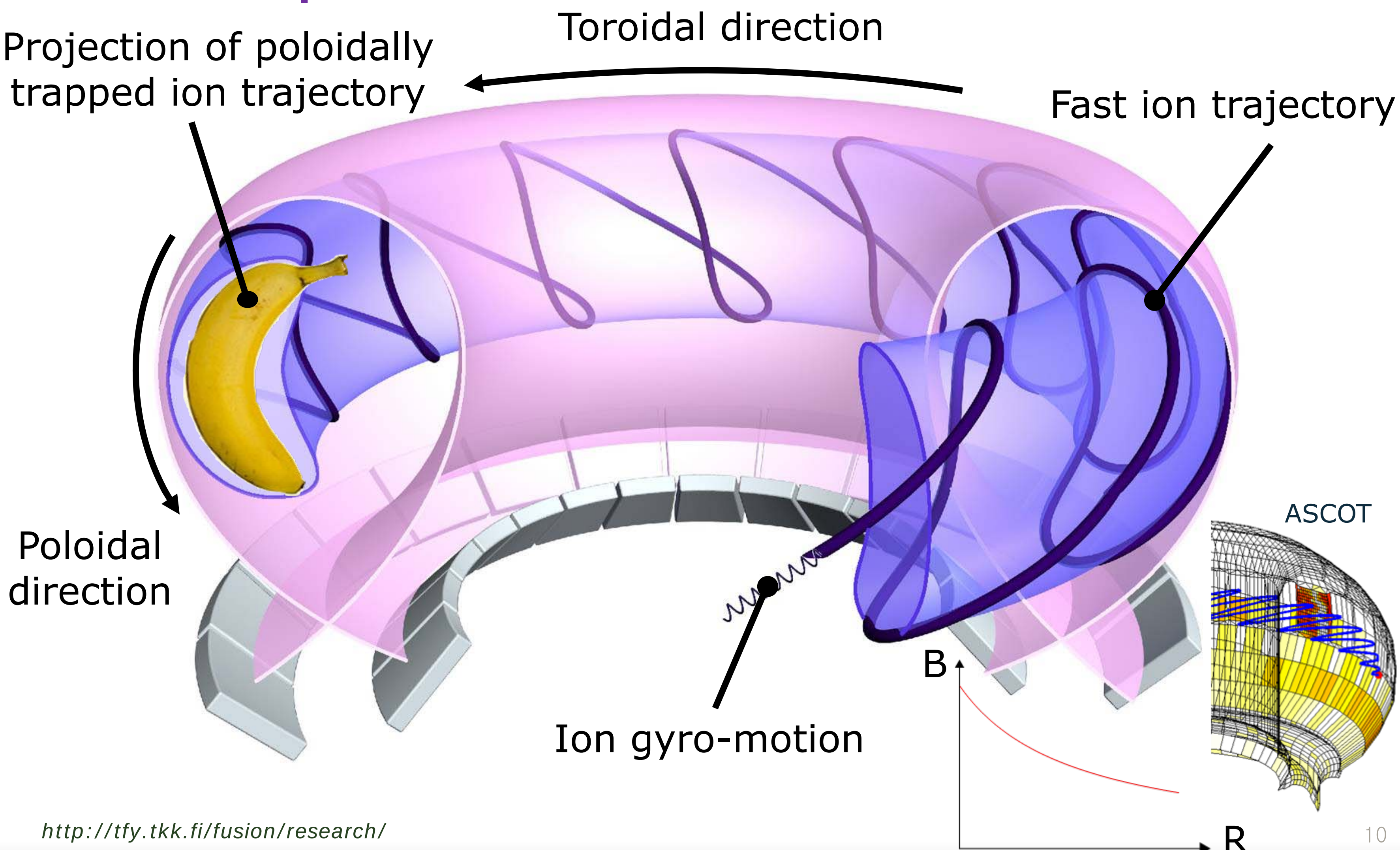
High pressure gradients

Large bootstrap current

Non-inductive current drive

Current drive and current profile control

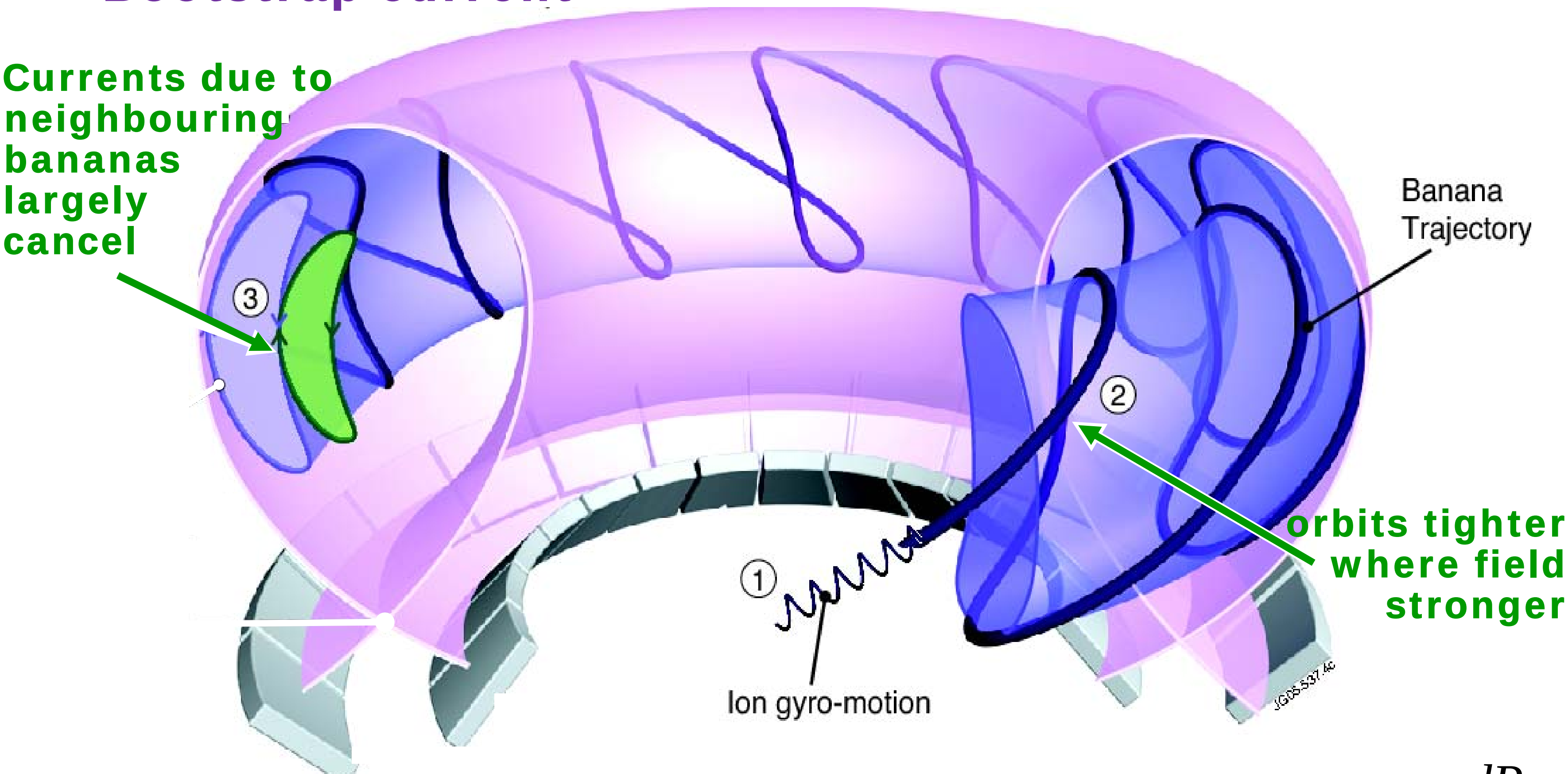
- **Bootstrap current**



http://tfy.tkk.fi/fusion/research/

Current drive and current profile control

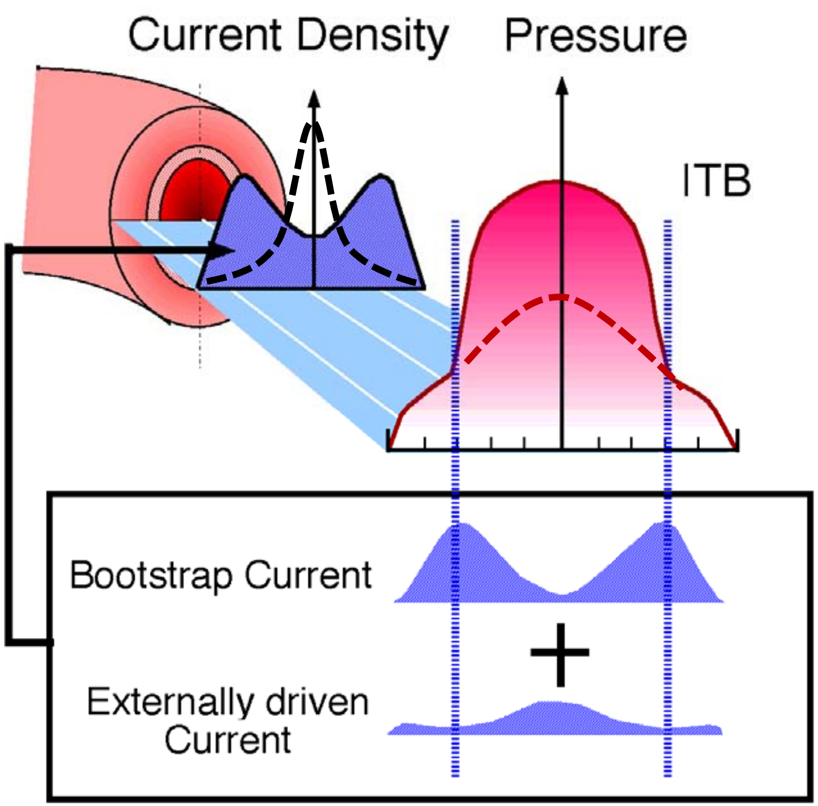
- **Bootstrap current**



- But more & faster particles on orbits nearer the core (green cf blue) lead to a net "banana current"
- this is transferred to a helical bootstrap current via collisions

$$J_{boot} \sim \frac{dP}{dr}$$

Current drive and current profile control



Cf. NTM control

Non-monotonic current profile

Turbulence suppression

High pressure gradients

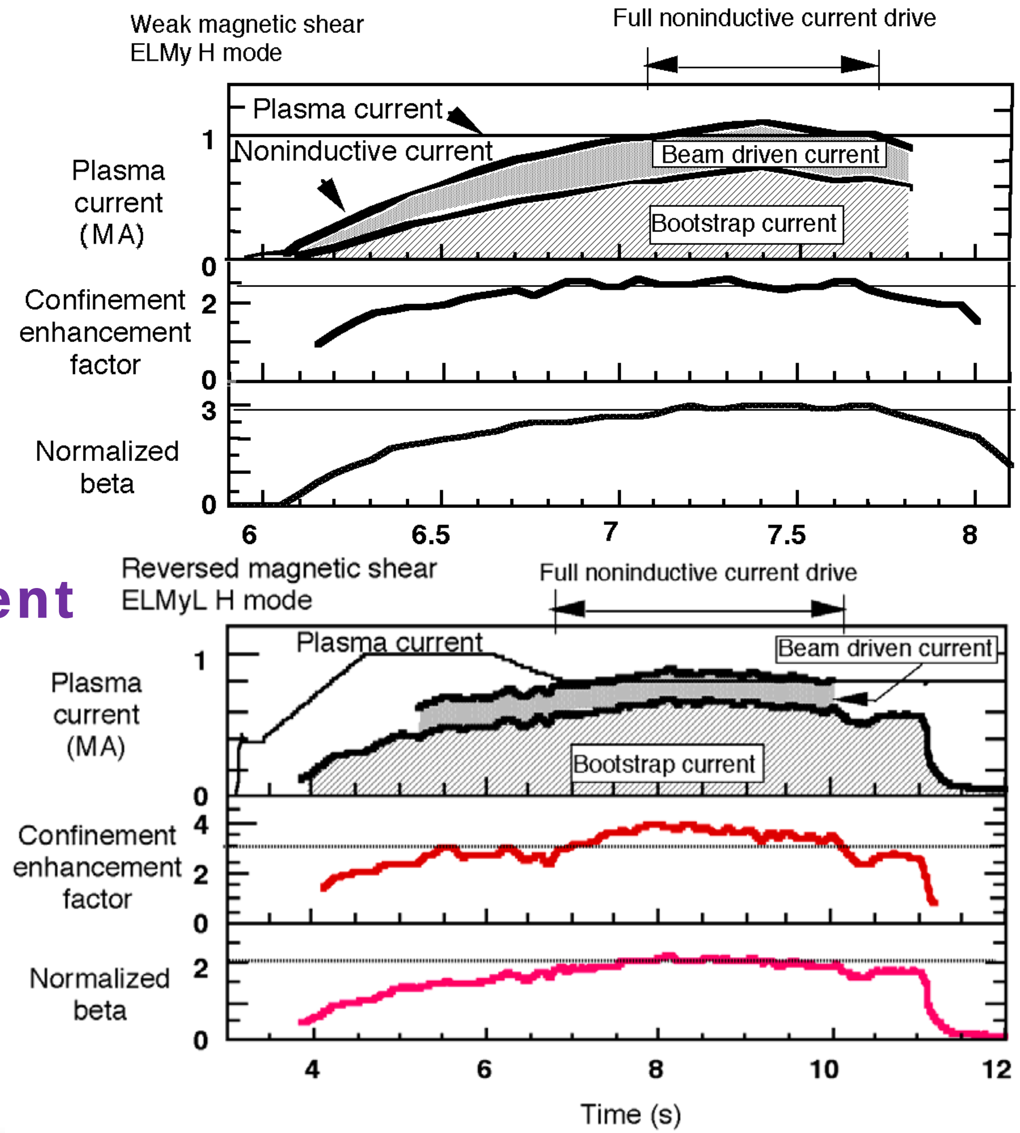
Large bootstrap current

Non-inductive current drive

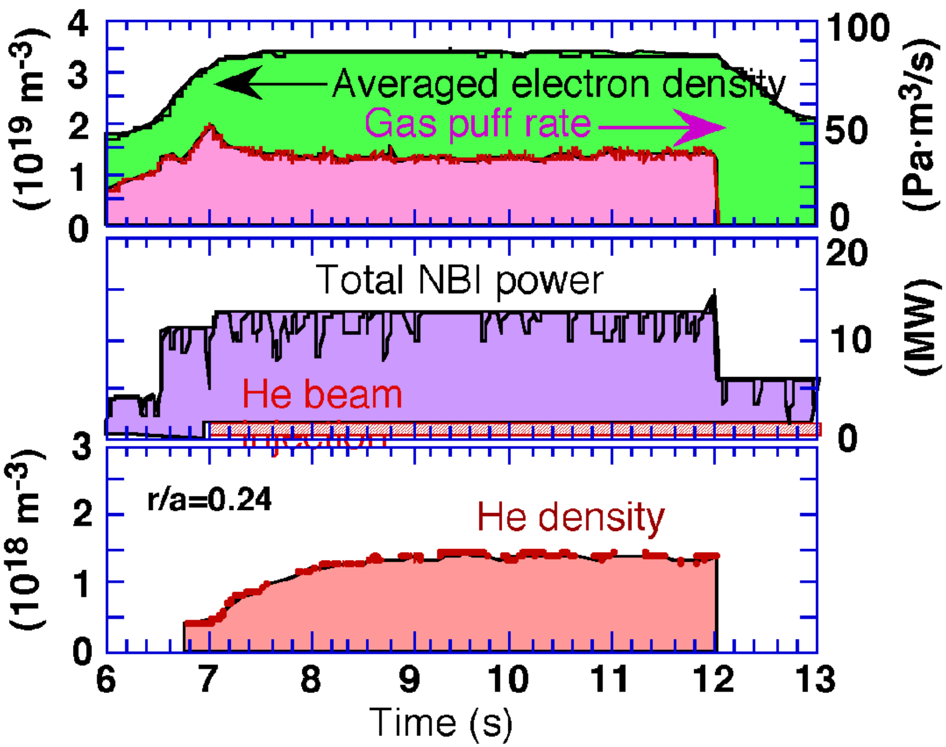
HW: Which heating & CD sources for fusion reactors?

Current drive and current profile control

- **Steady state operation utilising the bootstrap current**



Particle exhaust and impurity control

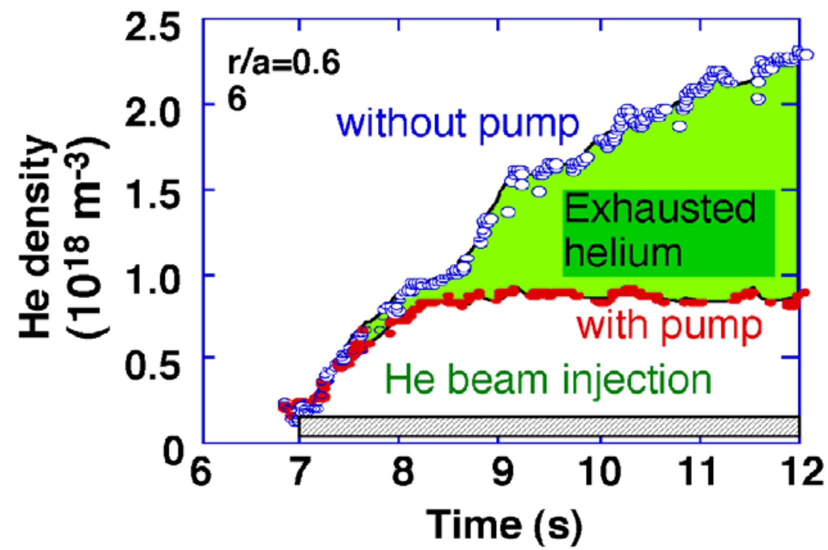


$\tau^*_{He} / \tau_E = 4$

Global alpha ptl. confinement time

ITER: $\tau^*_{He} / \tau_E \le 5$

$Z_{eff} \le 1.8$



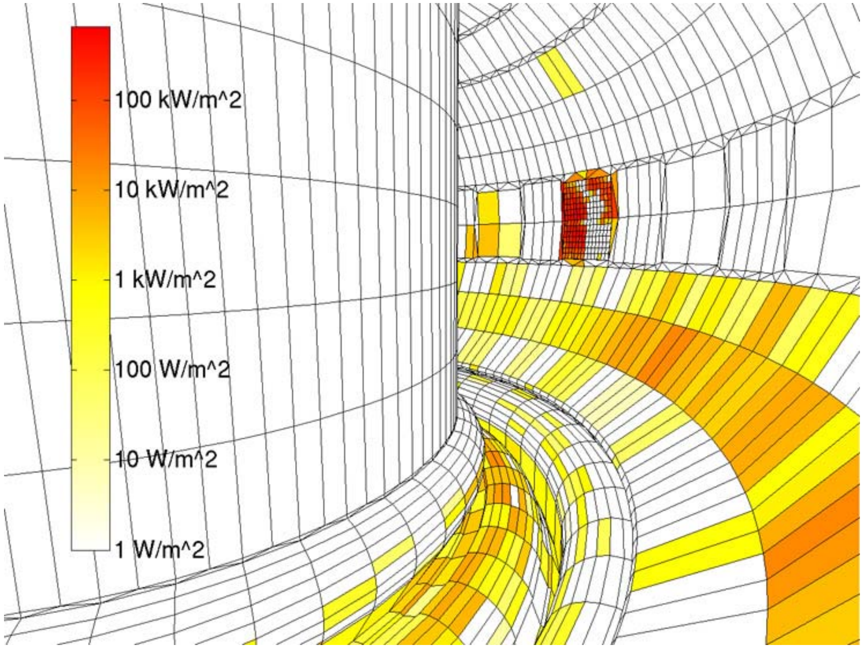
- Simulated He exhaust experiment in JT-60U

- He beam injected into the plasma
- Simulating He ash production by the fusion reaction

$$\eta_{He} = \frac{p_{He} / 2 p_{D_2}}{(n_{He} / n_e)_{main}}$$

Divertor heat flux control

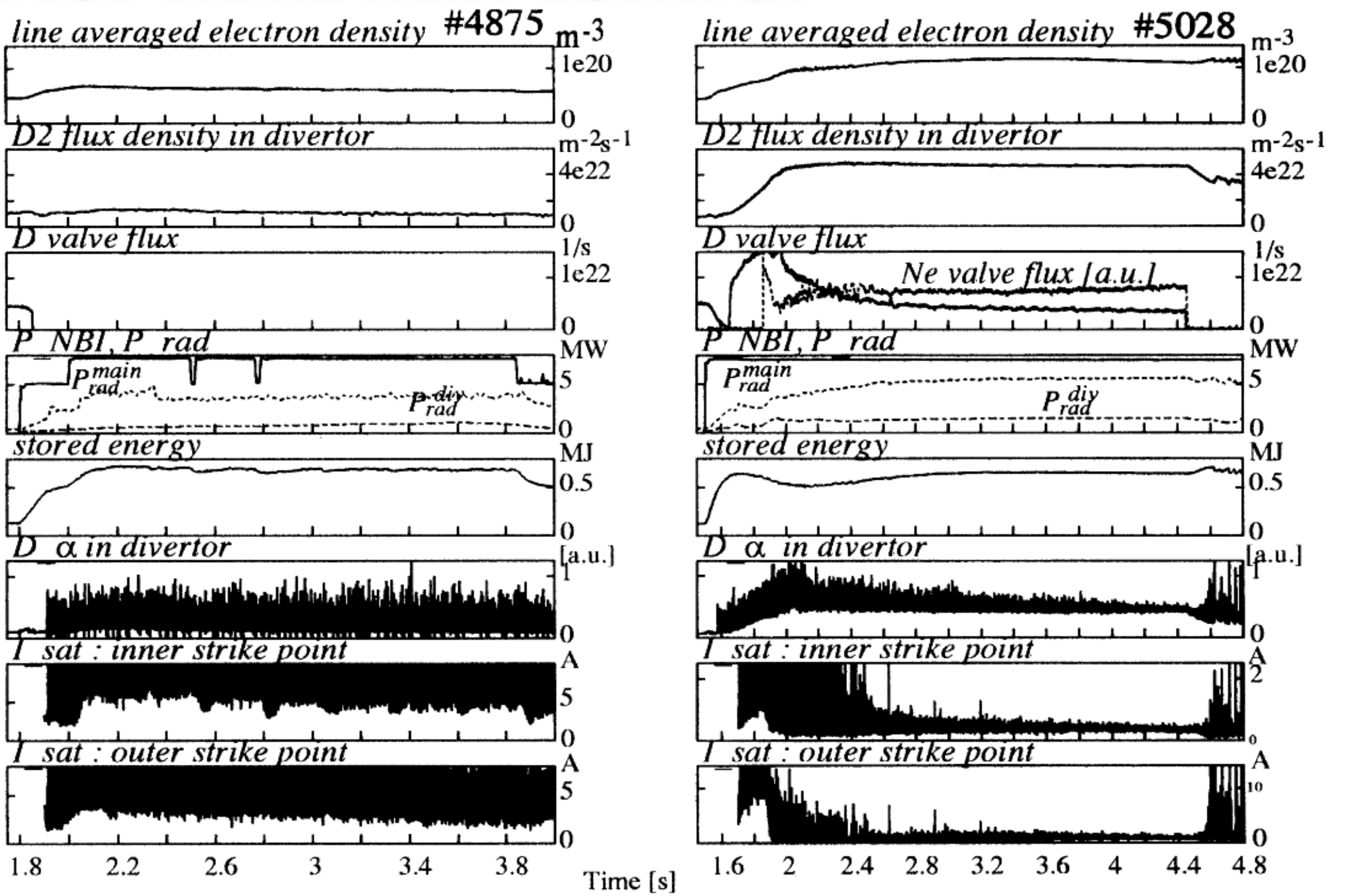
- Requirements in ITER
  - High main plasma density of 80-110% of n_{GW}
  - Radiative divertor plasma of 80-95% of the input power
  - Improved energy confinement of $H_{89} \sim 2$
  - Low $Z_{eff} \leq 1.8$



The wall power flux carried onto the wall of ITER by alpha particles

http://www.csc.fi/english/csc/news/news/ferritic_inserts

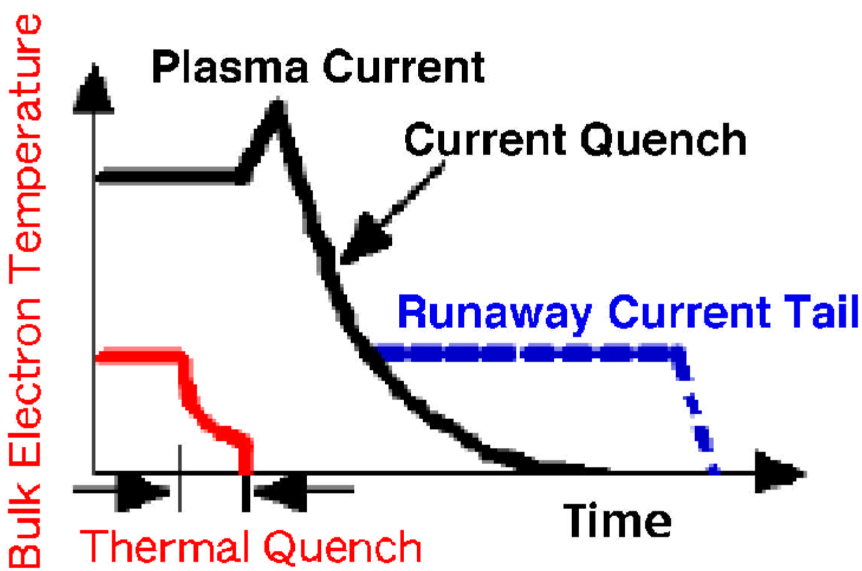
Divertor heat flux control

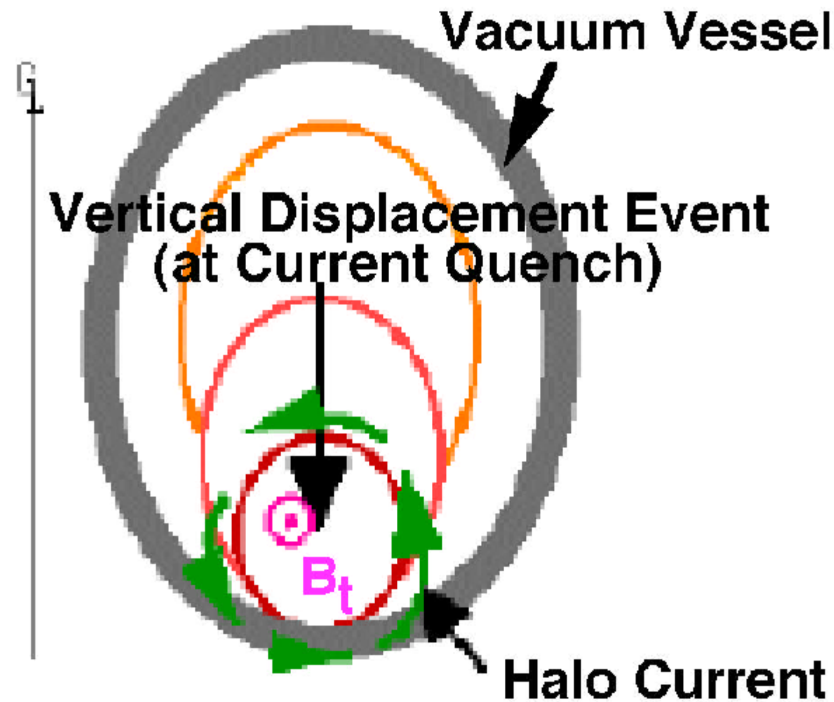


*O. Gruber et al, Phy. Rev. Lett. **74** 4217 (1995)*

- CDH-mode in ASDEX Upgrade
  - Total radiation fraction of nearly 0.95
  - Decreased H_{89} slightly from 1.7 to 1.6 due to the increased density
  - Maximum Z_{eff} of about 2.5

Disruption control





- Injection of neon ice pellet: fast conversion of thermal energy to the radiation energy
- $q < 2$: runaway electrons not produced due to instabilities
- Possible disruption events in the process of the optimisation of operation scenarios, fault operation, failures in hardware, or an emergency interrupt triggered by the safety interlock → 0.5#/year