**COMBINED MEETING OF DOE / JAERI
TECHNICAL PLANNING OF TOKAMAK
EXPERIMENT AND IEA LARGE TOKAMAK
WORKSHOP ON EXPERIMENTAL PLANNING**

7-8 February 2001 at JAERI Naka

Heat and Particle Control Research

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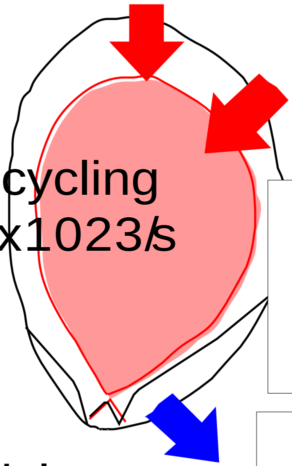
Naka Fusion Research Establishment

What is different for a long pulse operation?

JT-60U

GAS PUFFING
1.3x1022 /s

Beam fueling
1.0x1021 /s



Recycling
2.5x1023/s

wall absorption
6.0x1021 /s
(2.3%)

Divertor exhaust
8.0x1021 /s
(3%)

Particle balance

Total Energy 400MJ

JT-60SC

Conditions close to saturation of wall absorption and Divertor target temperature

- almost 100% recycling
- Characteristic times;
  Saturation time to wall absorption >10 s
  Satulation time to divertor plate temperature ~10 s

Enhanced exhaust speed
5.0x1022 /s(~6 times)
(100 m3/s at 1Pa)

Total Energy 2400MJ

Basic Concept of Divertor

Purpose of the JT-60SC Machine

- Steady state research with a break-even condition
- Control a high performance plasma sufficiently long time (exceeding a current diffusion time)

For the Divertor

- Compatible with high β
- Good heat and particle controllability

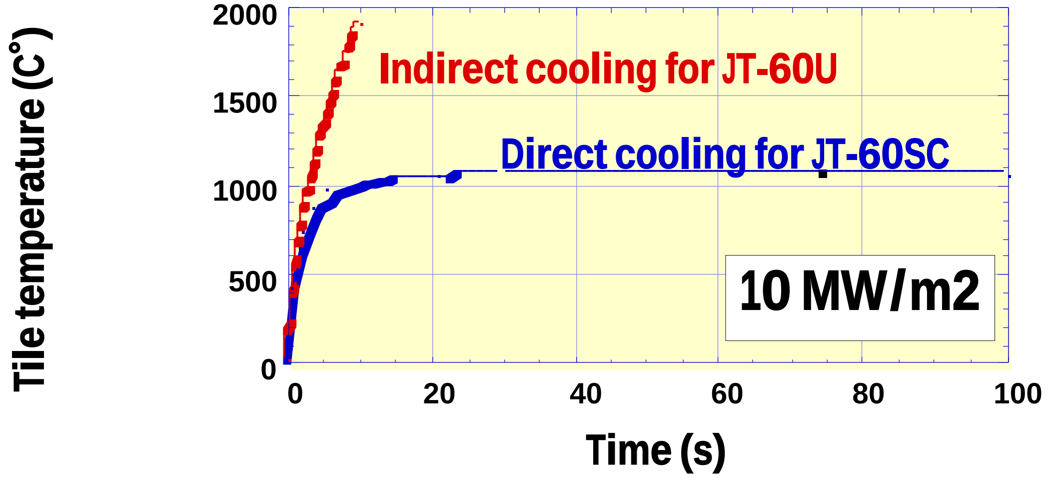
Divertor Concept

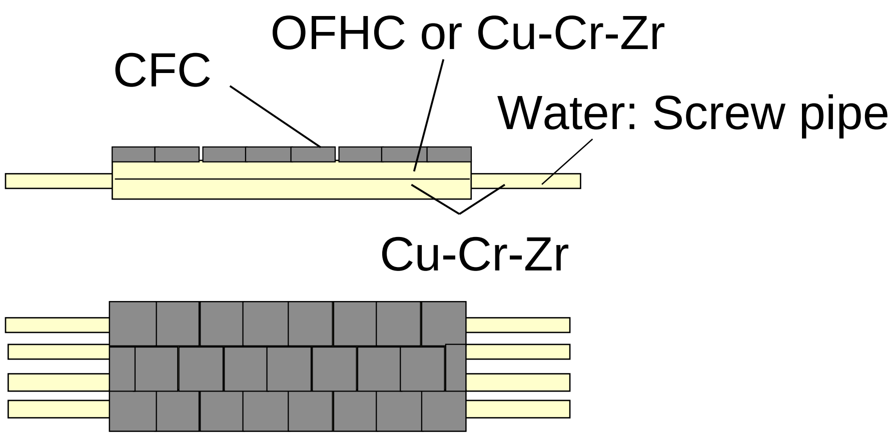
- Vertical target with forced water cooling
  - Surface temperature ~ 1000 degree C at10MW/m^2
- Carbon target (does not exclude metal target)
- Strong pumping

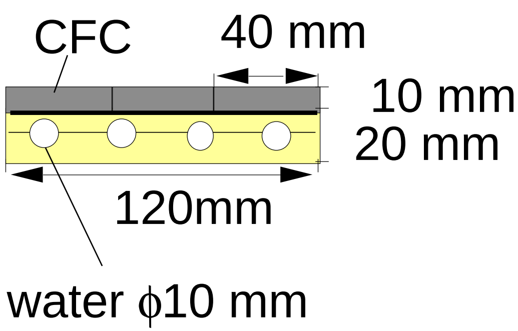
Divertor Tiles : Forced Water Cooling

- Heat Flux of 10MW/m^2 may be the maximum
 (P$_{NBI}$=40MW, heat flux SOL length 1cm at mid-plane with in/out asymmetry of 1/2)

- Surface temperature would be kept about 1000 degree C with forced water cooling.







Heat Flux by an ELM (from ITER Divertor Expert Group)

- All ELM heat flux width is less than ~2cm at the mid-plane

From N.Asakura

- ΔW^{ELM}_{loss}: Energy loss by an ELM

  $\Delta W^{ELM}_{loss}/2W^{e}_{pad}$=0.03-0.18(DIII-D), 0.1-0.2(JET), 0.03-0.1 5(ASDEX-U)

- S^{ELM}_{dep} : Width of heat flow by an ELM

  1-2 x$S_{steady\text{-}state}$ (JET, ASDEX-U)

  4-5 x$S_{steady\text{-}state}$ (DIII-D)

- τ^{ELM}_{dep} : The dureation of an ELM

  0.1-0.2ms (JET) , 0.2- 0.6ms (DIII-D), 0.3-1 ms (ASDEX-U)

JT-60U W shaped-Divertor

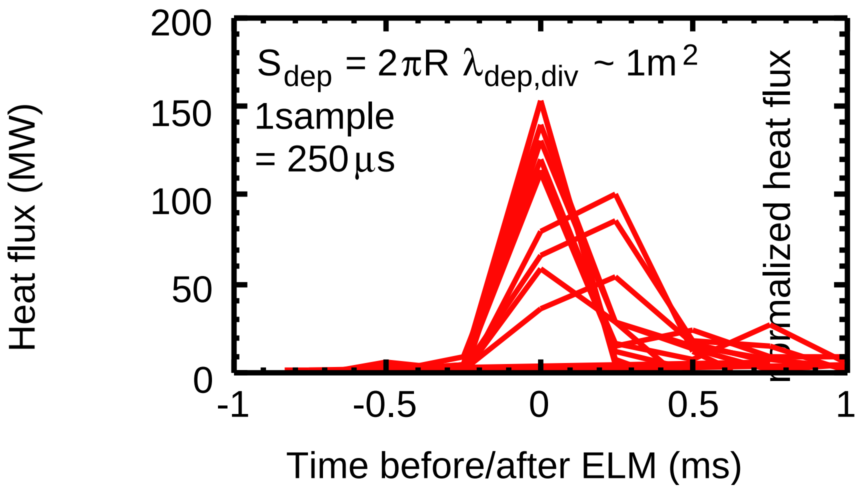
$\Delta W^{ELM}_{loss}/W^{e+i}_{ped}$ = 0.08-0.12

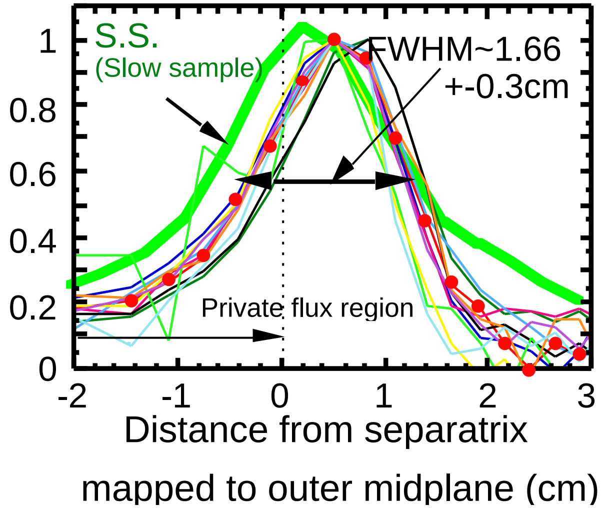
ΔW^{ELM}_{dep} (IRTV) = 1/2-3 ΔW^{ELM}_{loss}

1-1.5x$S_{steady\text{-}state}$

~0.25ms (IRTV measurement)

ELM heat flux (left): time hestory, (right) profile

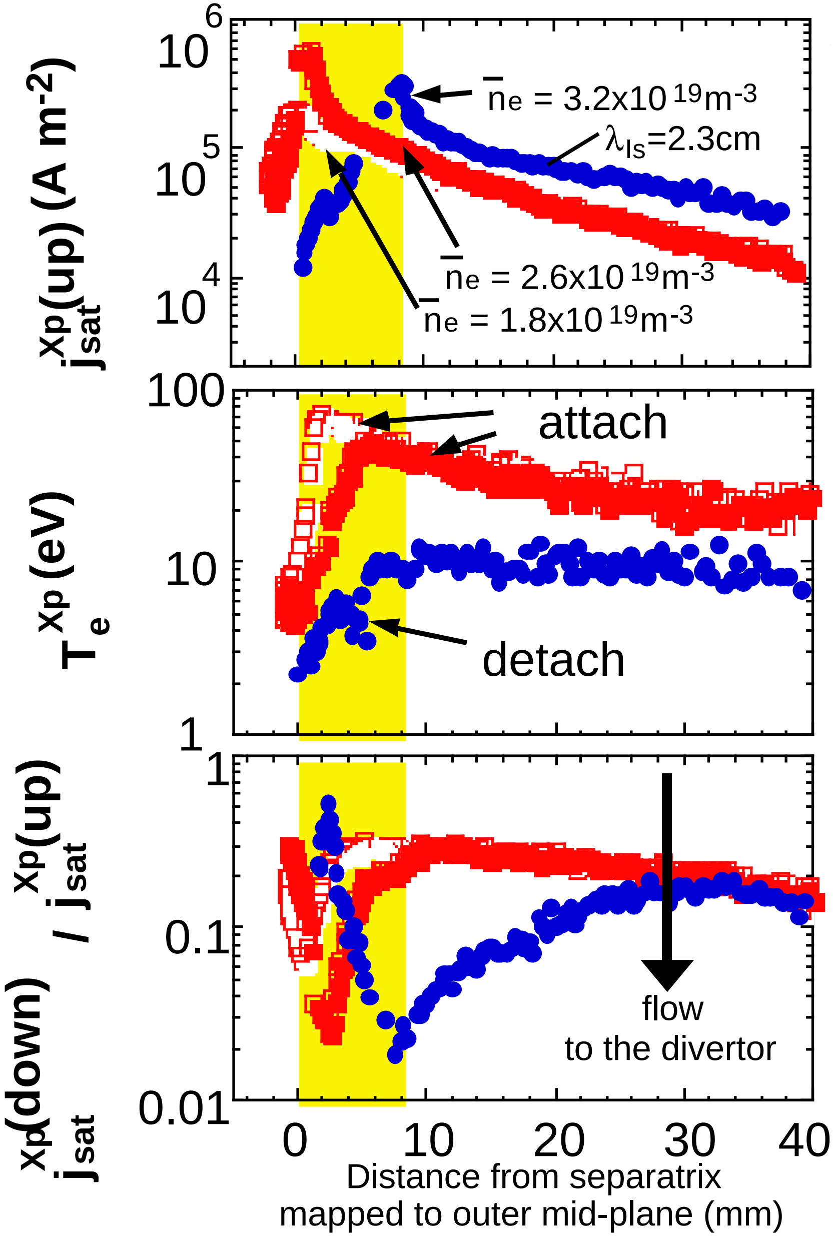




(x 2.3 at target)

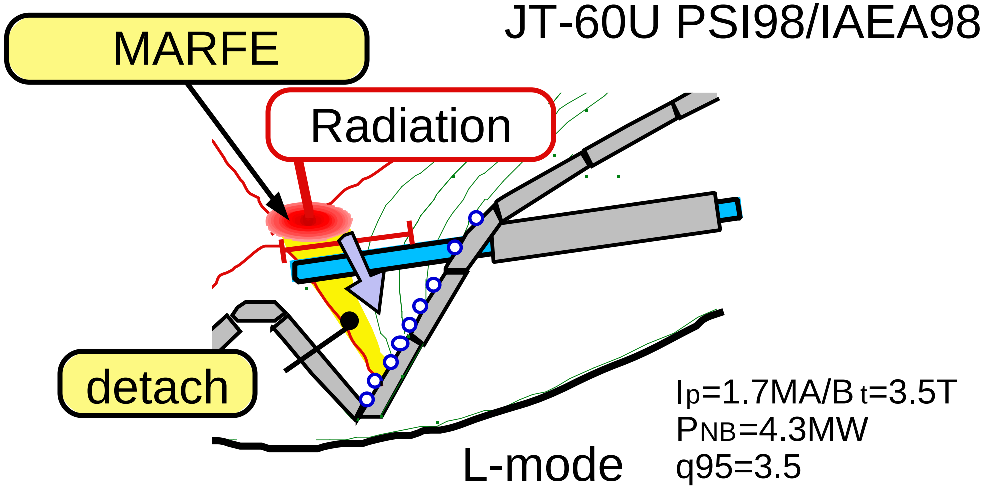
SOL width at outer mid-plane

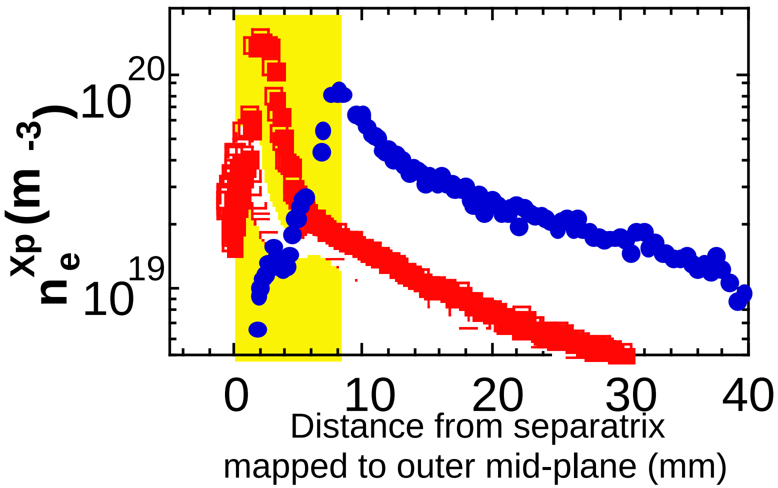
- ~3-4 cm SOL on the outer mid-plane should be inside baffle



- After detachment (X-point MARFE), peak particle flux moves outward about 1cm.
- The e-folding length is about 2.3cm.

JT-60U PSI98/IAEA98





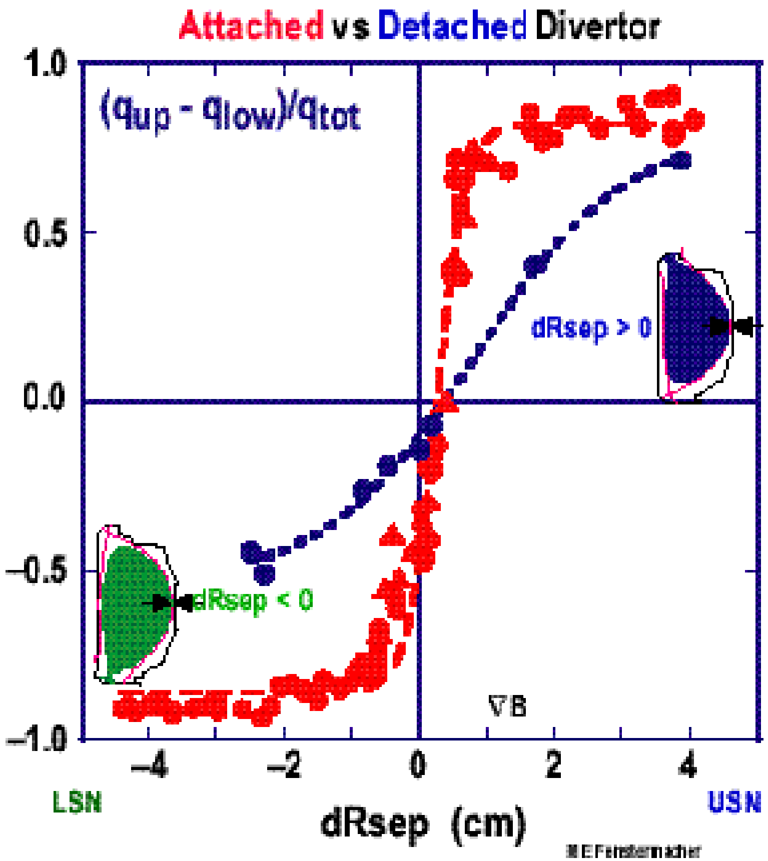
2nd X-point

- DIII-D shows excellent results for the 2nd X-point
- dRsep>3cm may be necessary

Variation in heat flux sharing is large near DN for ne/nGr ≤ 0.7; less sensitive for high density.

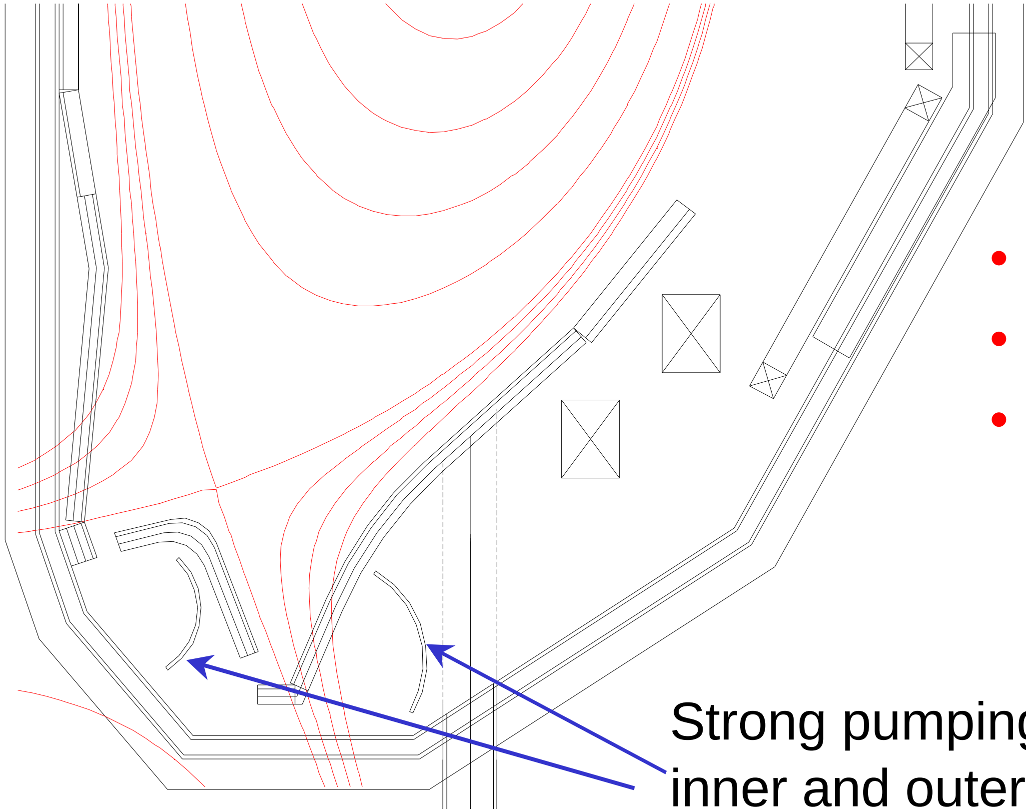
dRsep Study, n_e/n_{Gr} ≤ 0.7 and > 0.7

- Peak heat flux sharing for ne/nGr ≤ 0.7:
  - Switches divertors within dRsep ± 0.4 cm
  - Balance at dRsep = +0.3 cm
  - Consistent with SOL energy conduction and ExB drifts.
- At higher density:
  - Less sensitive to dRsep variation
  - Broader than implied by SOL conduction
  - Divertor detachment important
    - Upstream radiation
    - Convection



δ~0.35 with strong pumping

- Strong pumping from inner and outer divertor separately.
- The triangularity of ~ 0.35 with strong pumping is planned.

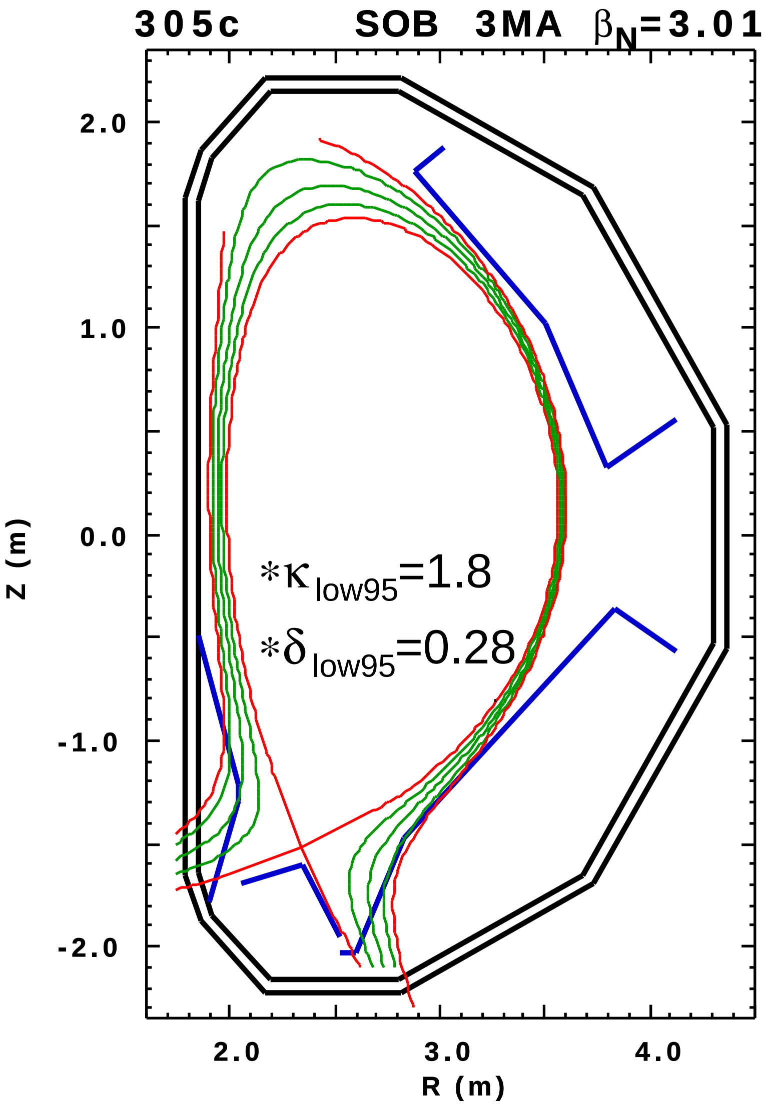


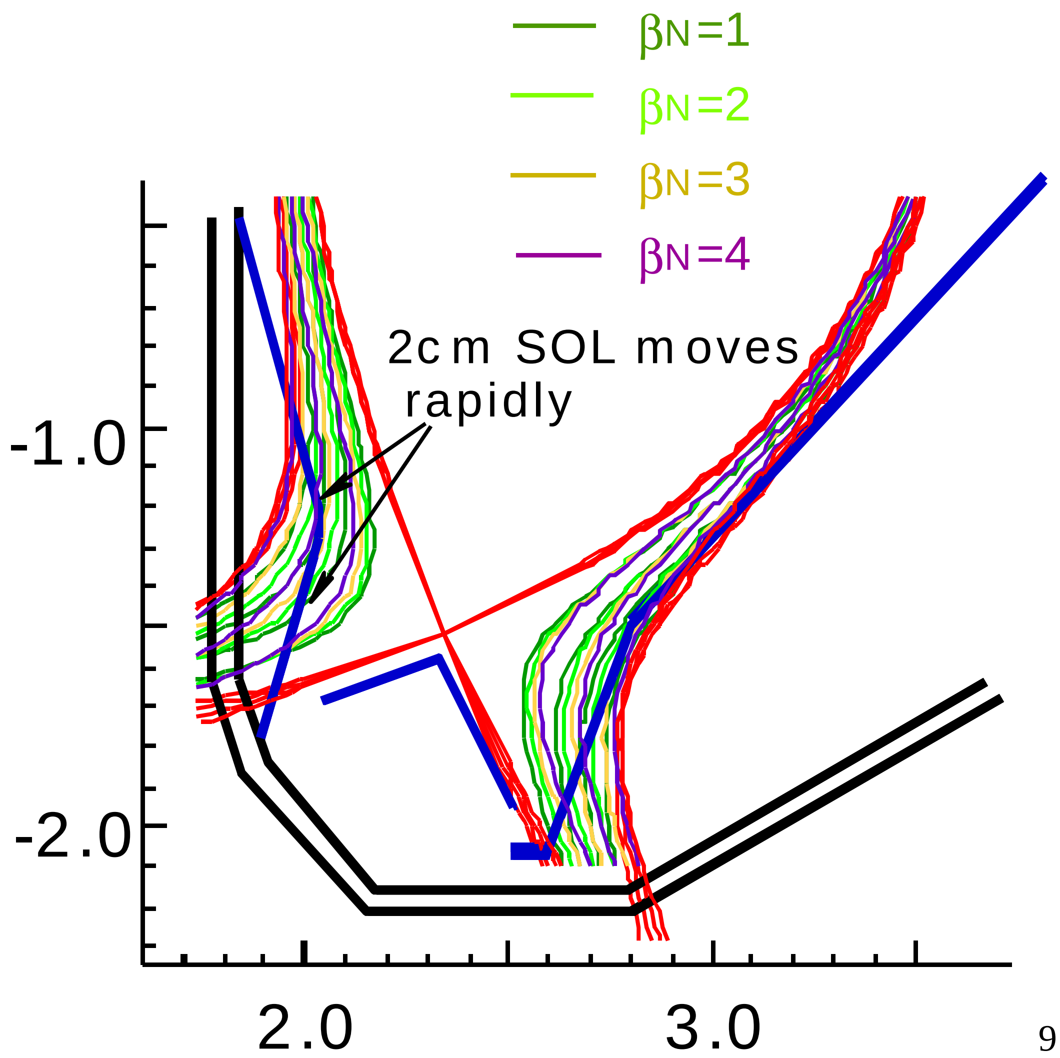
- κ_{95}= 1.83
- δ_{95}=0.36
- β_p=1.28

Strong pumping separately from inner and outer

Inside SOL is rapidly expanding with high β_N

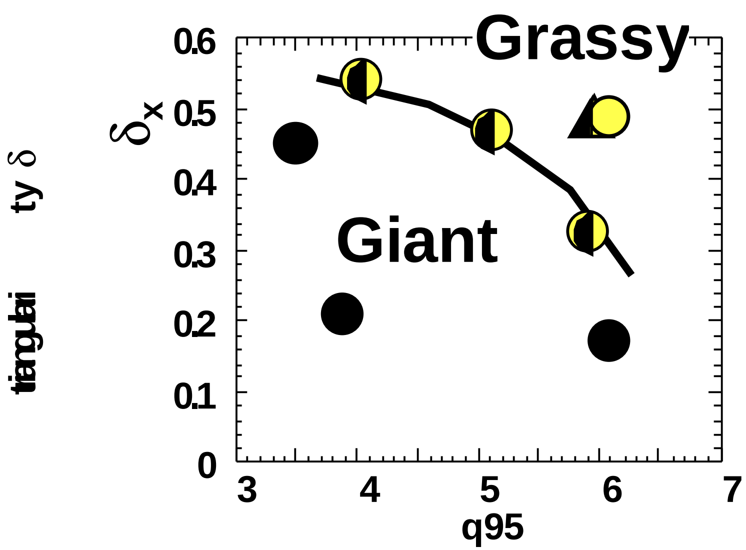
- In the present poloidal coil setting, it may be difficult to put about 3cm SOL into the inner baffle.
- dRsep can be set larger than 3cm.

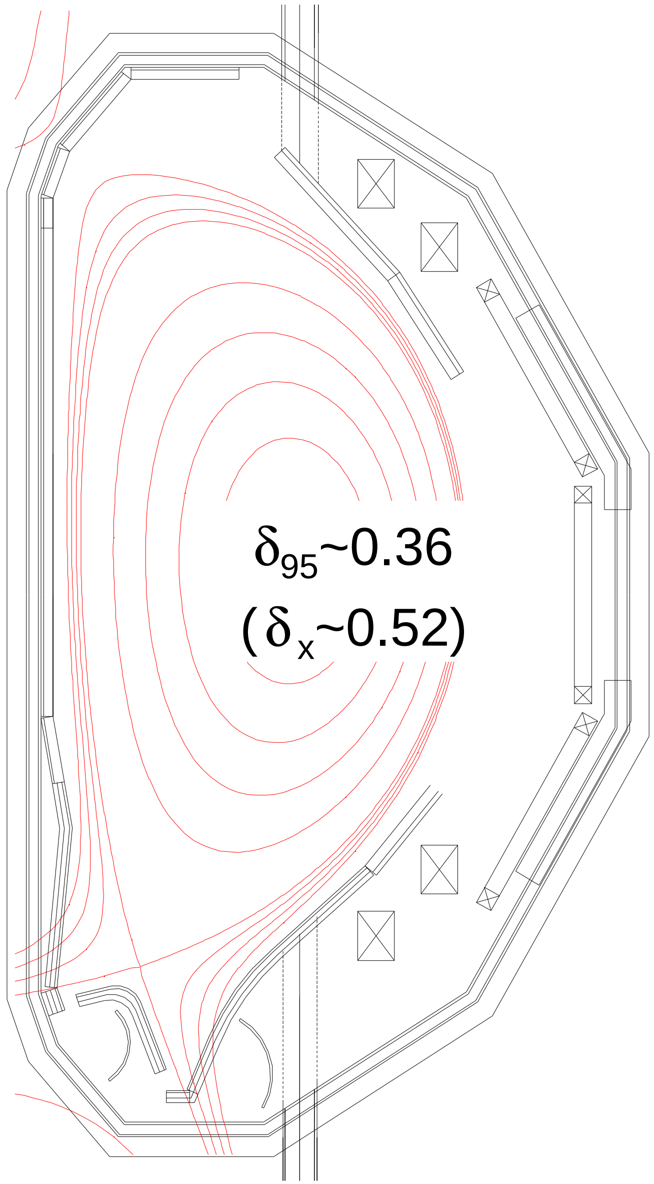




Study of Type II (Grassy) ELM with high δ

- In JT-60U, Grassy ELMy H-mode with Full CD and HH_{y2}~1.2 is achieved.
- The parameter region of the appearance of Grassy ELM is clarified.
- δ > ~ 0.4 & q_{95} > ~ 5, β_p> ~ 1.6

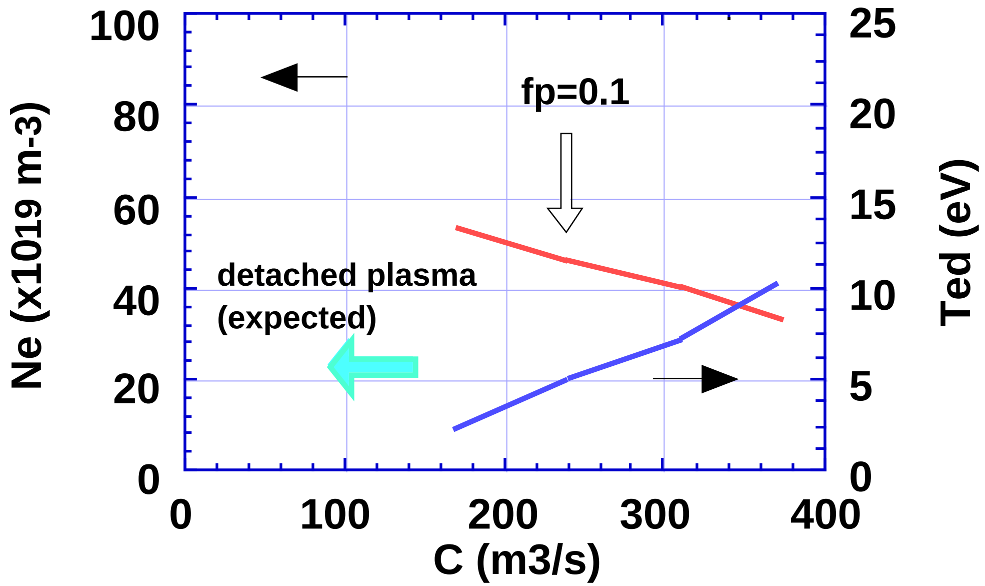


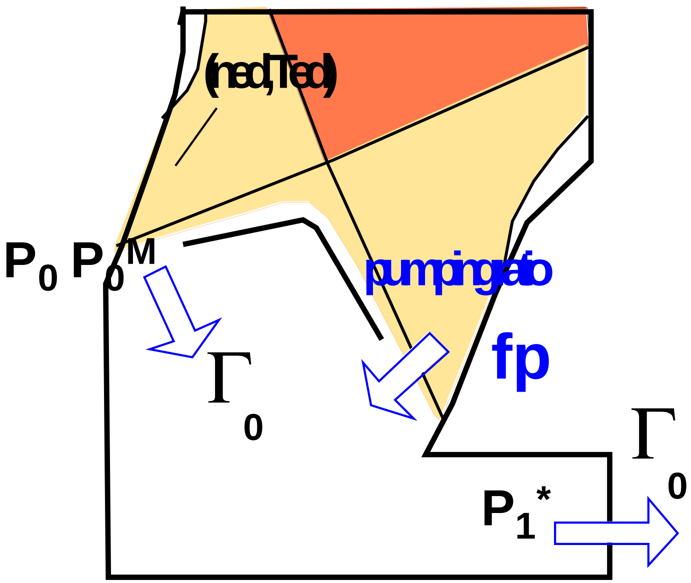


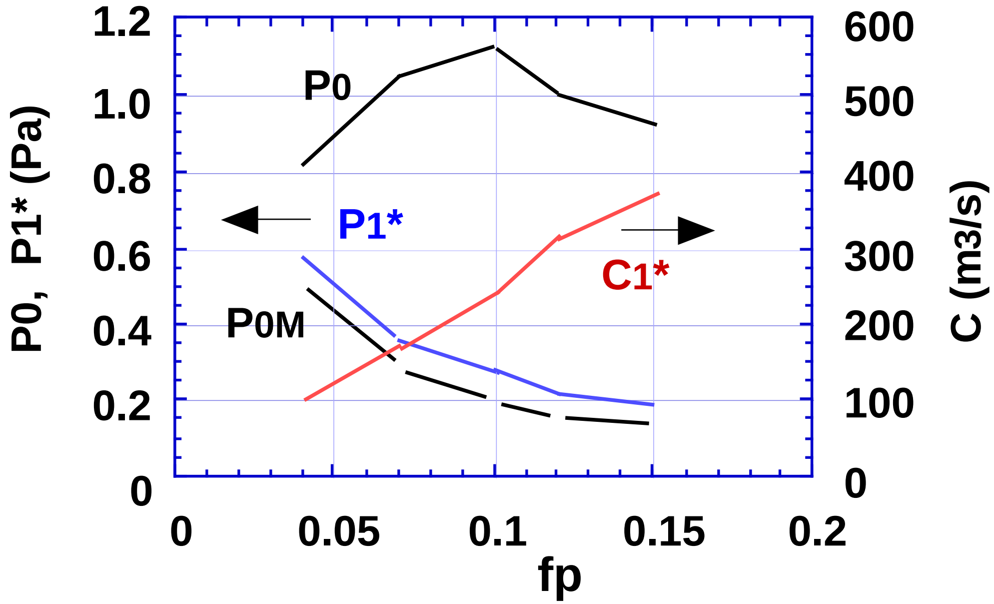
- In JT-60SC, it is necessary to find a way to lower q_{95} with δ~0.35 to have Grassy ELM.

Evaluation of plasma parameters with SOLDOR / NEUT2D code

- With strong pumping, there is a possibility to control detachment.
- High field side pellet injection is planned to be used for a fueling.

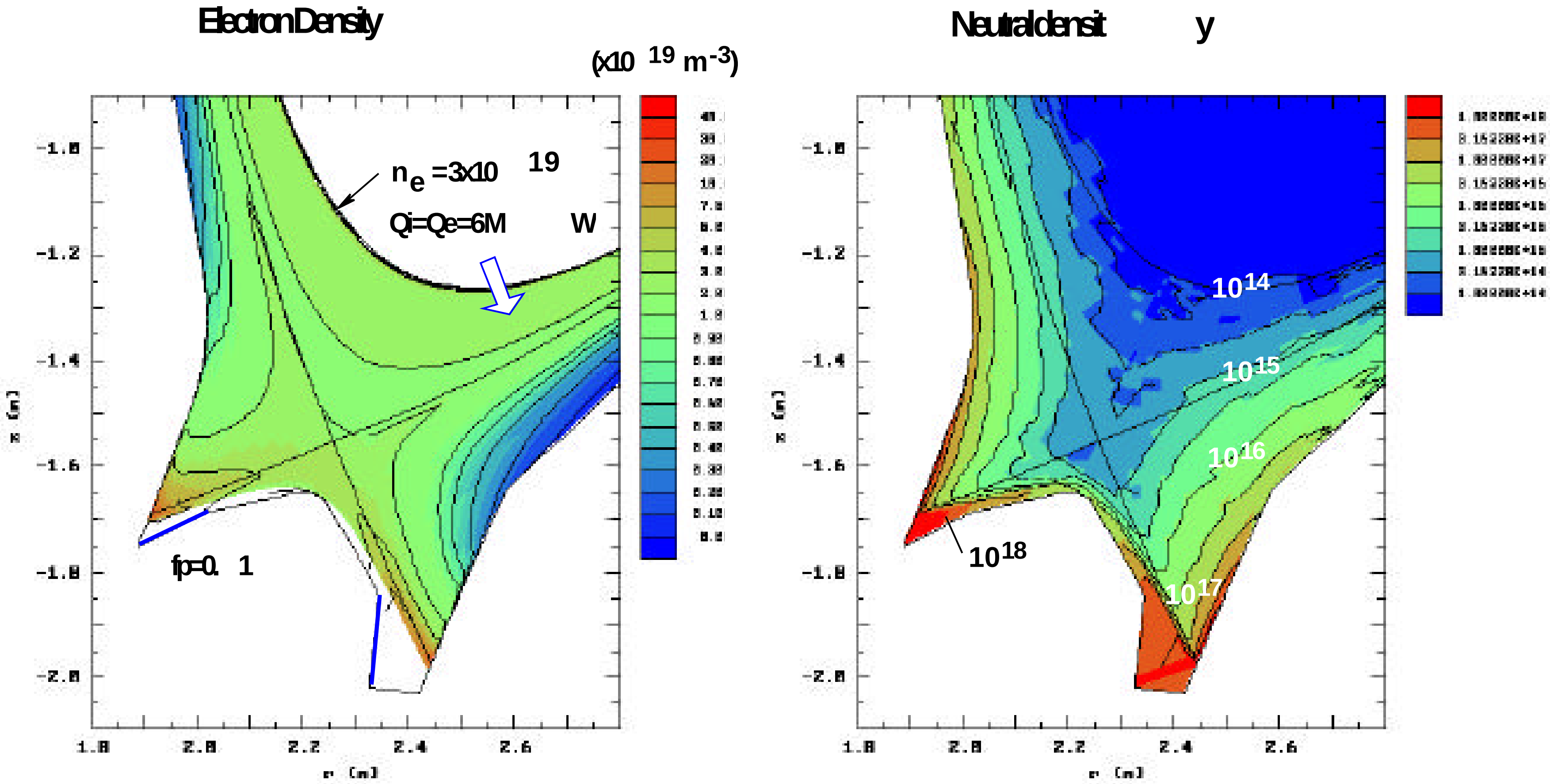






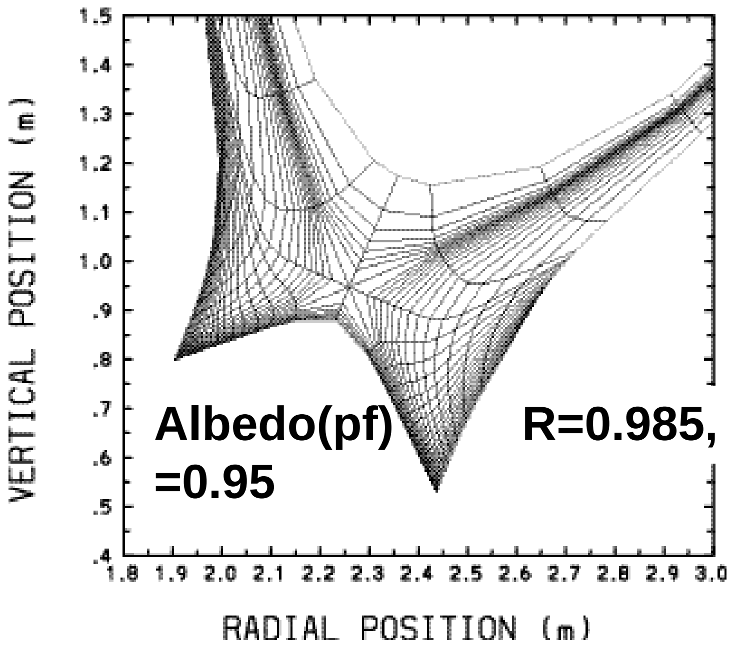
By K.Shimizu and T.Takizuka

Simulation Result of n_o and n_e



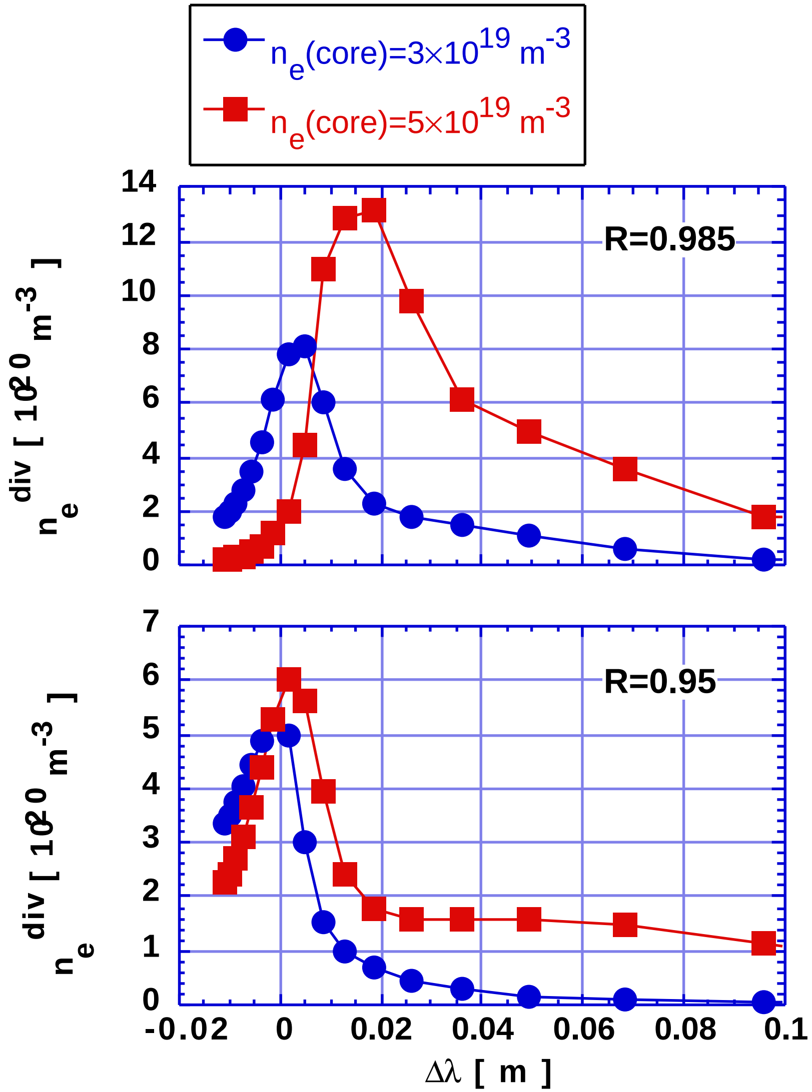
Simulation with UEDGE code

- UEDGE can include the drift and carbon impurity, but treats the neutral as fluid. Then, we are using UEDGE code near the condition of detachment.



Albedo(pf) =0.95

R=0.985, 0.95



D=0.25 m²/s

χ=1.0 m²/s

Carbon (Haasz yield mode)

Without drift model

Summary

(1) Divertor with high beta under steady state condition.

- Vertical target with forced water cooling .
  - 1000 degree C with heat flux of 10MW/m^2 .
- Rather open configuration with strong pumping .
- To operate with Grassy ELM, it is necessary to find a way to lower q_{95} with δ~0.35.

(2) Evaluation of plasma parameters with SOLDOR / NEUT2D code shows that the strong pumping has a possibility to control detachment.