High temperature plasma facing component designs for biomass hybrid reactor: GNOME

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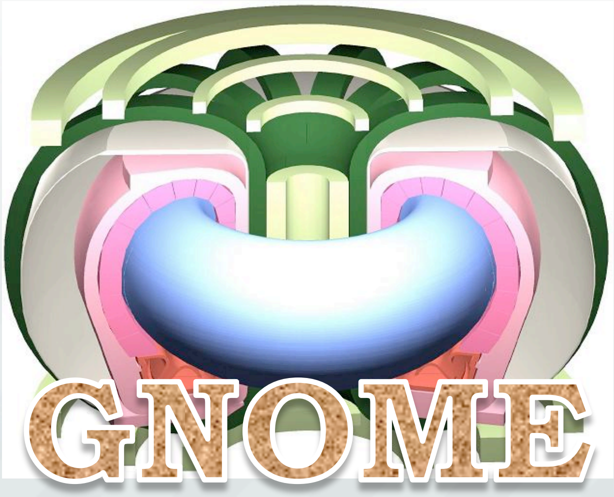
Introduction

- GNOME: Fuel production plant using fusion nuclear heat.
- Gasification of biomass (garbage, forest thinning.)
- High Net energy conversion (η~2)
- P_{fus} = 300 MW – 500 MW, Q ~ 5 will be enough.

- High temperature coolant output is requested.

→ Updates in blanket design.
→ Wider operation windows.



Outlines of talk

High temperature components with liquid PbLi coolants.

<u>Neutronics</u>

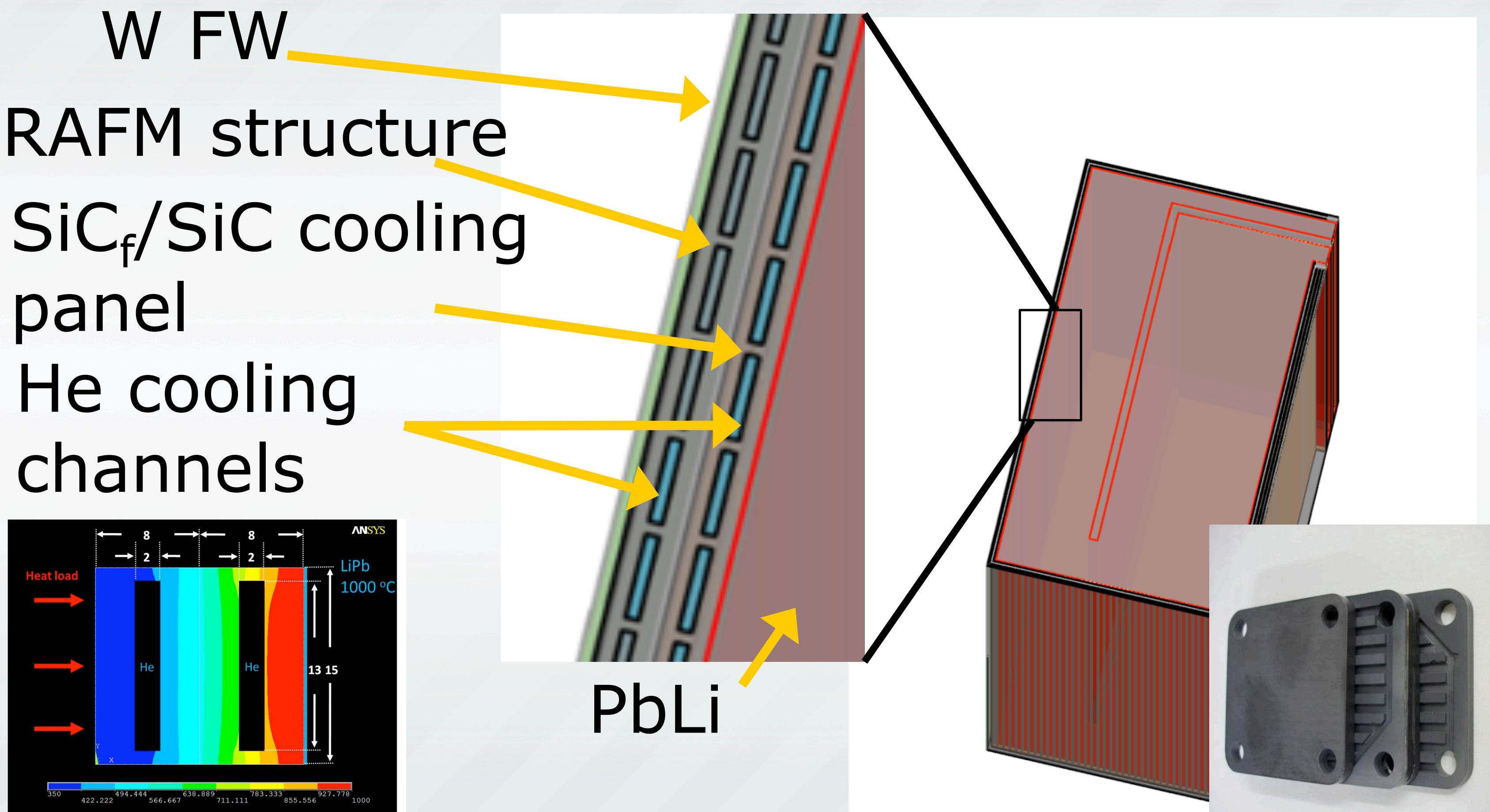
TBR
Nuclear heat
Energy
Multiplication

<u>Coolant flow</u>

Pressure loss/
Pump power
Blanket
Divertor

Feasibility of PbLi cooled components for the high temperature operation were studied.

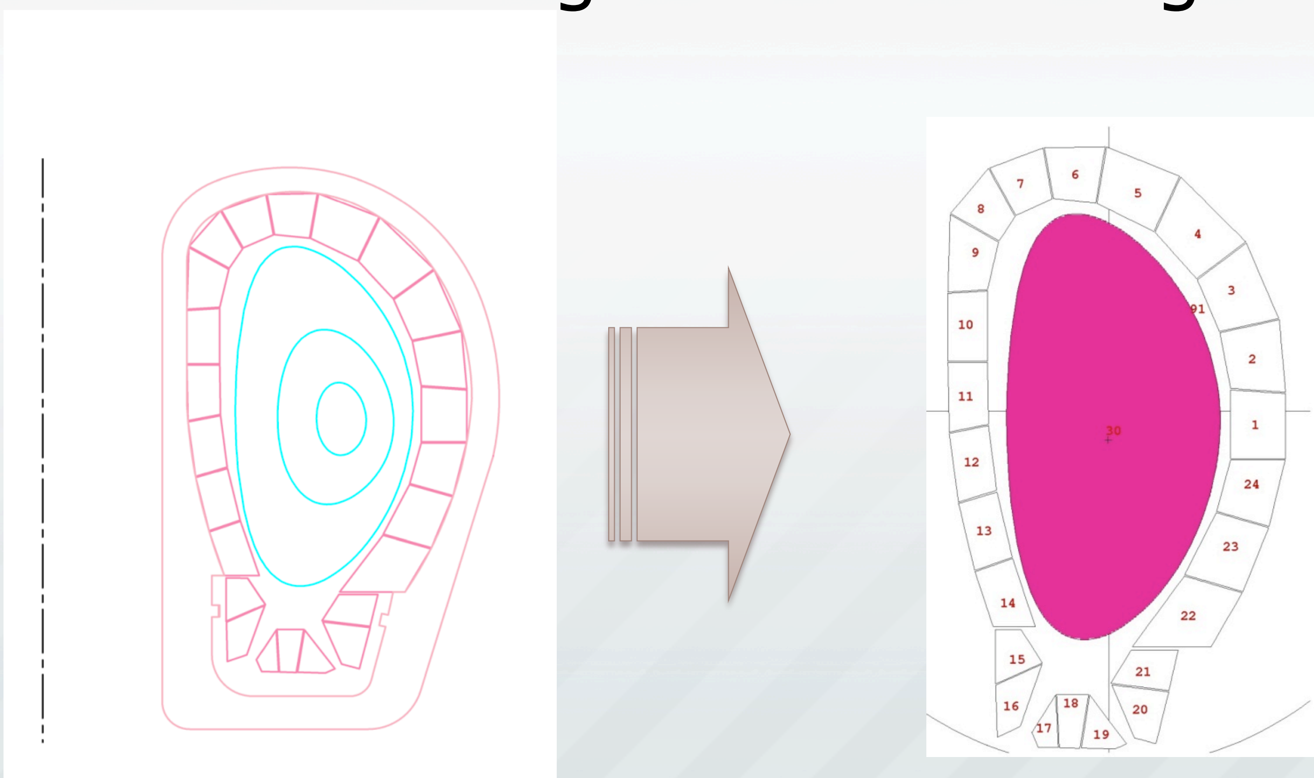
Blanket component



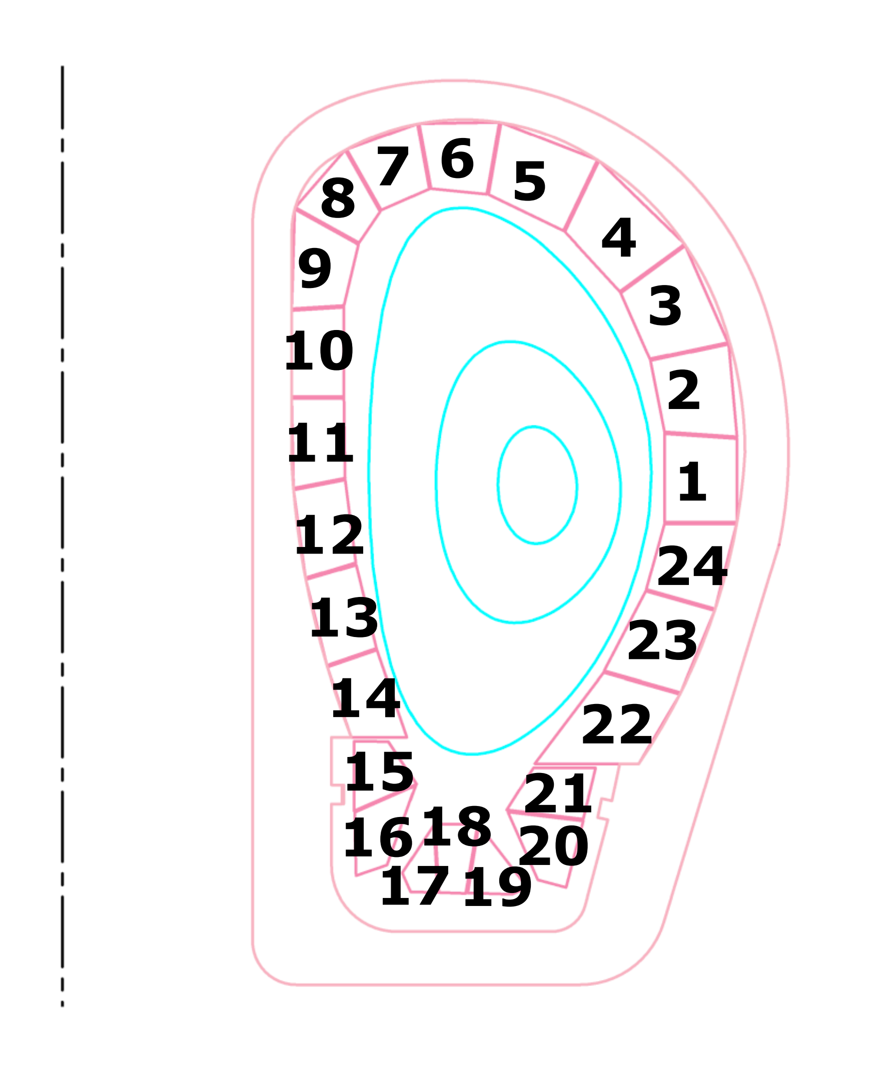
High temperature (>900 °C) PbLi coolant operation for the high biomass-gasification efficiency.

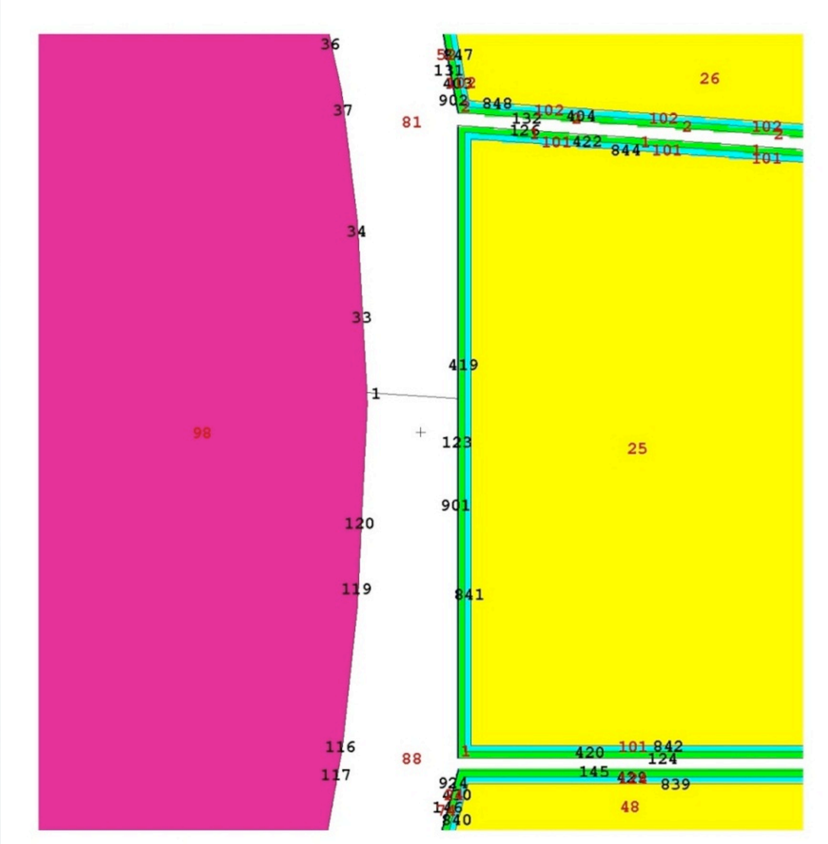
Neutornics

- MCNP5
- FENDL-2.1
- MCNPX converting CAD to MCNP geometry



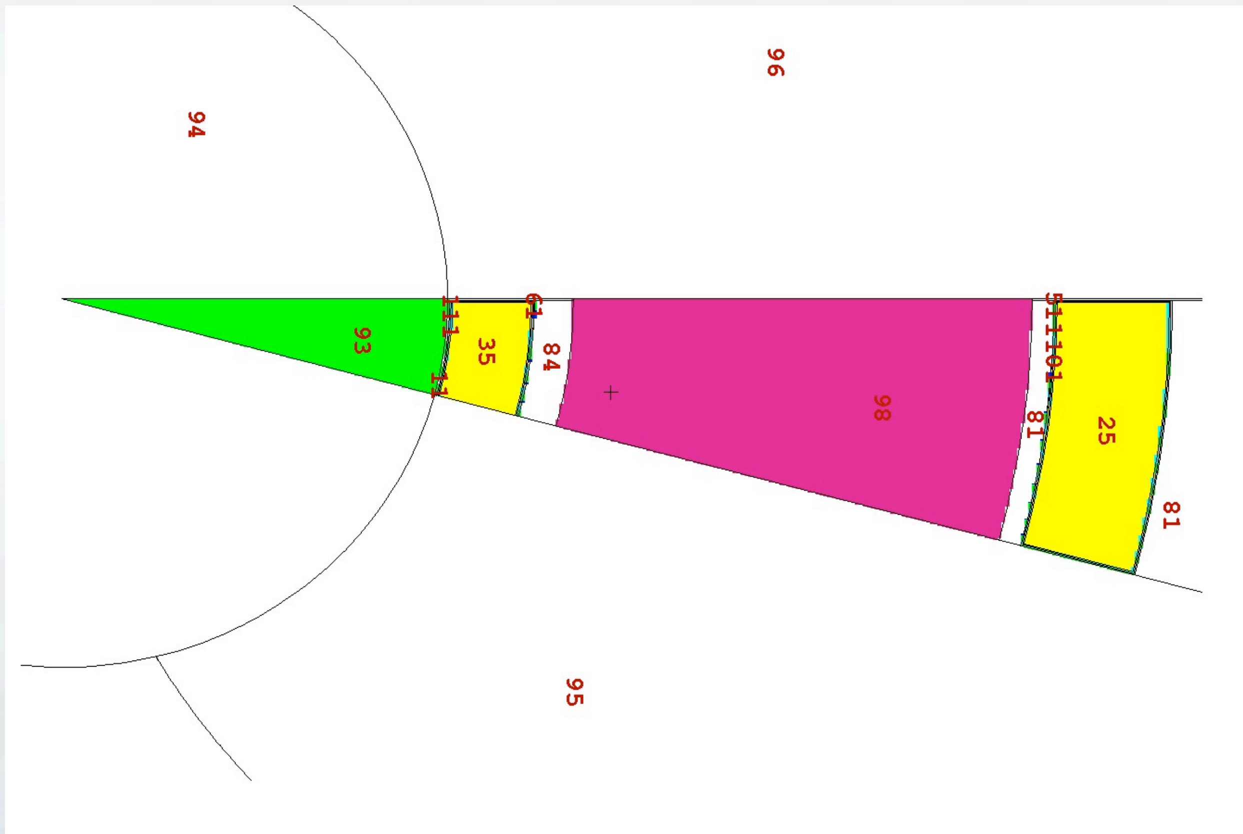
Neutronics –Tokamak-





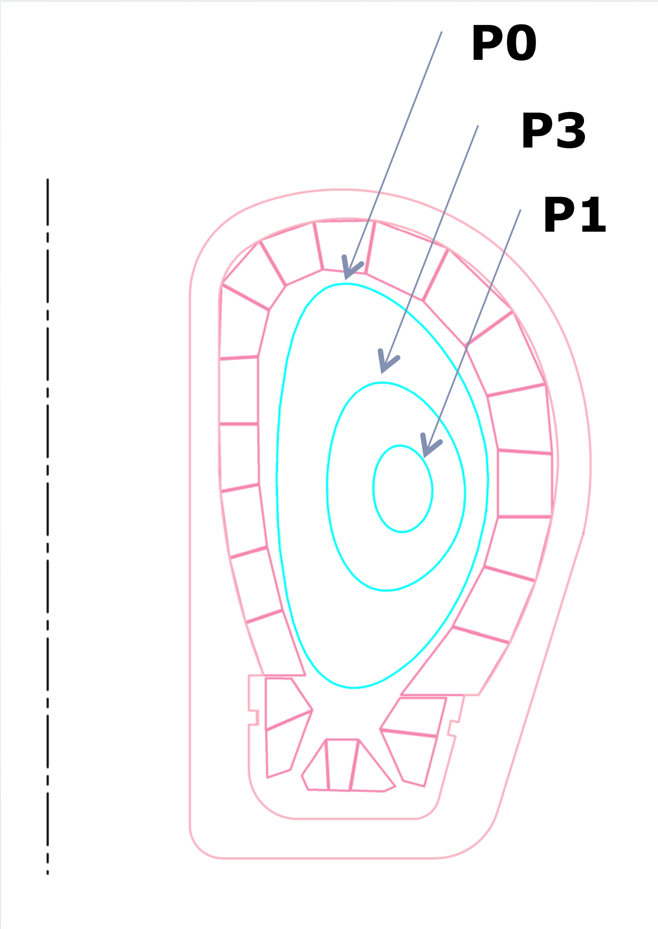
Neutronics –Tokamak-

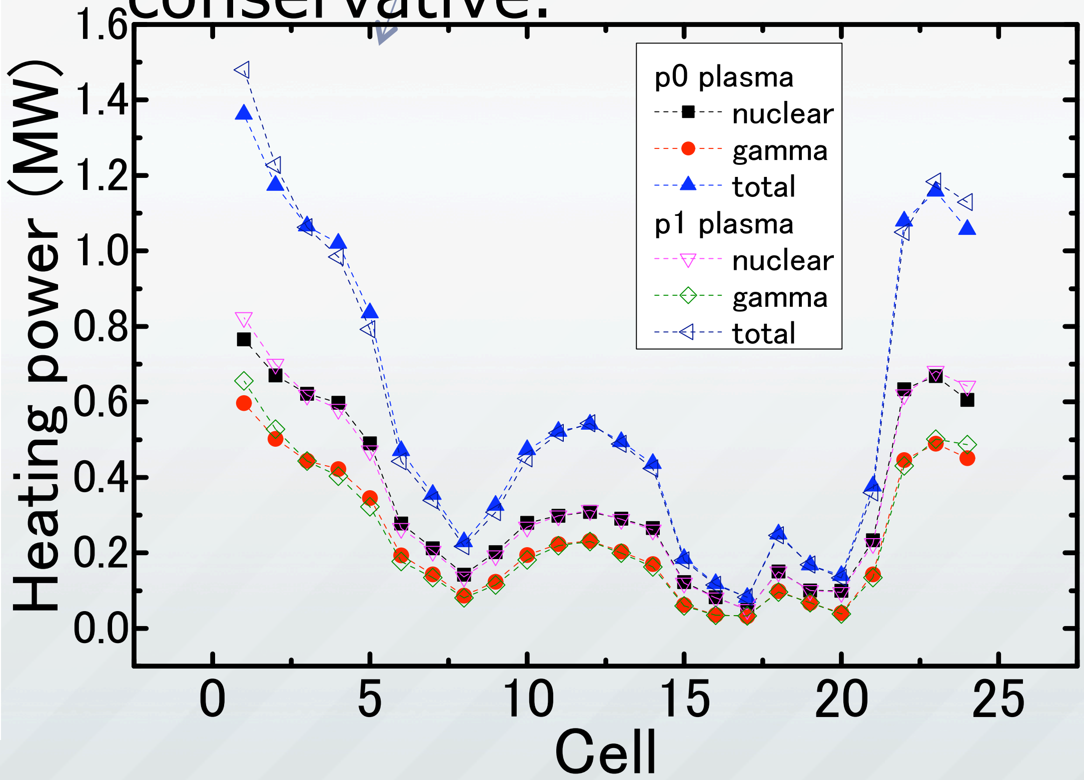
- Geometry



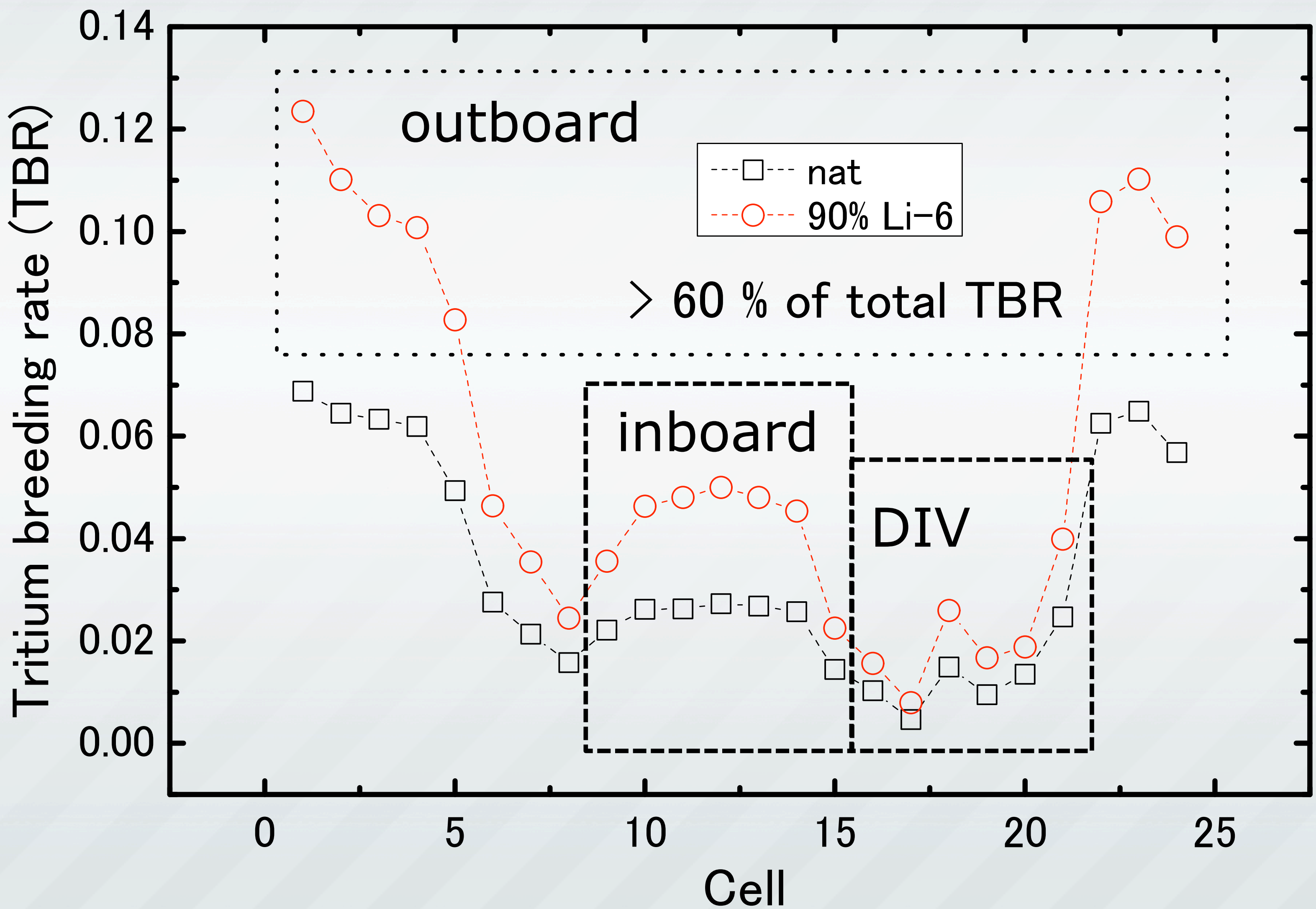
Neutron source

Analysis are taken based on the result to be conservative.

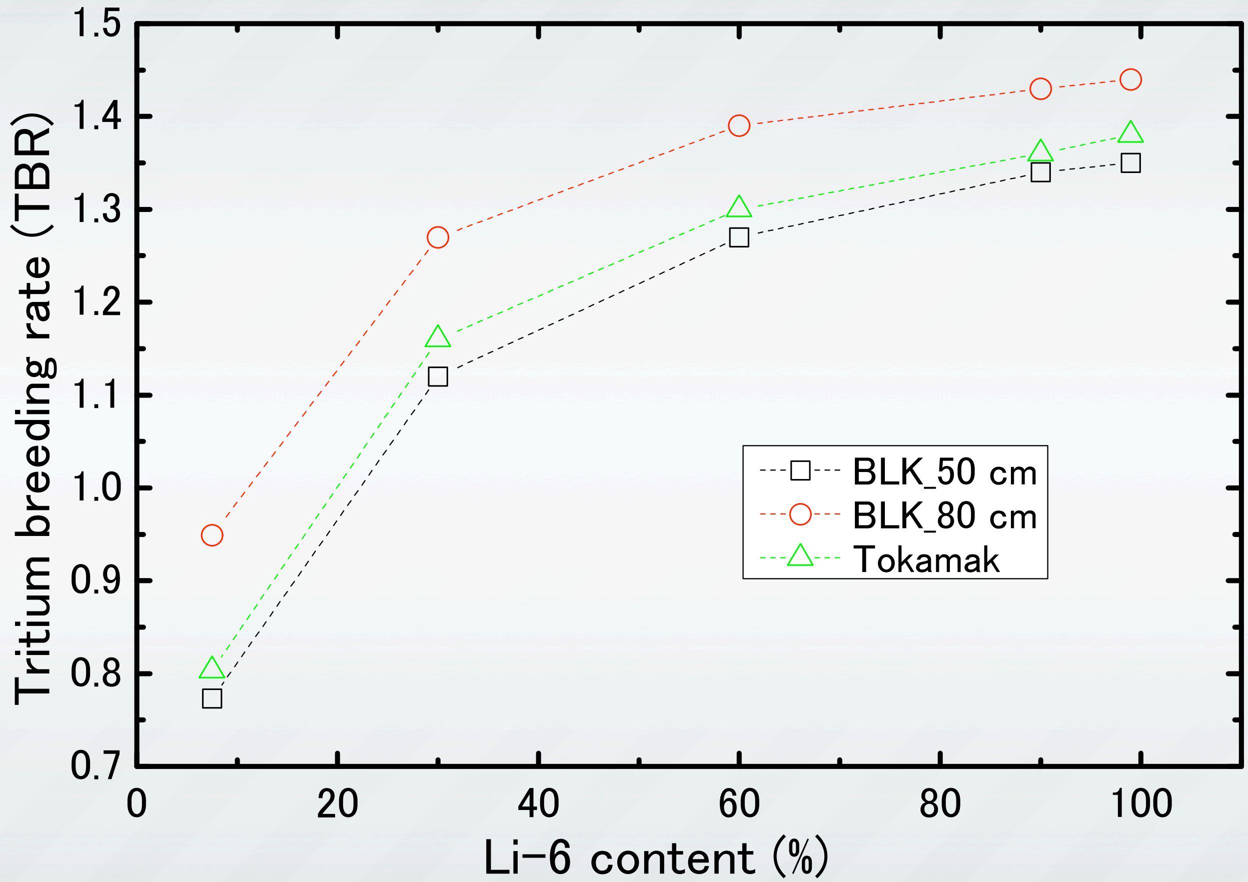




Neutronics –Tokamak-



Neutronics –Tokamak-

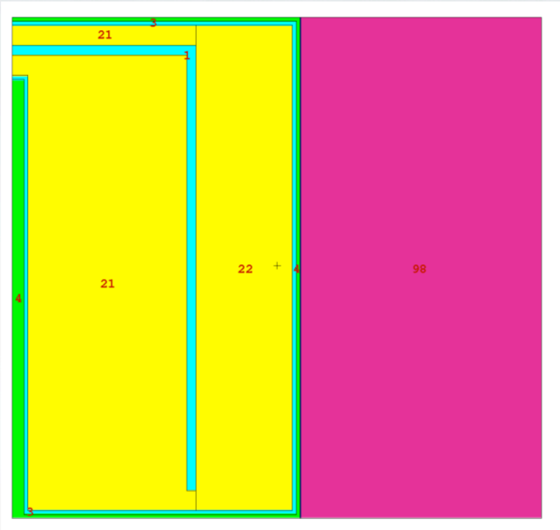


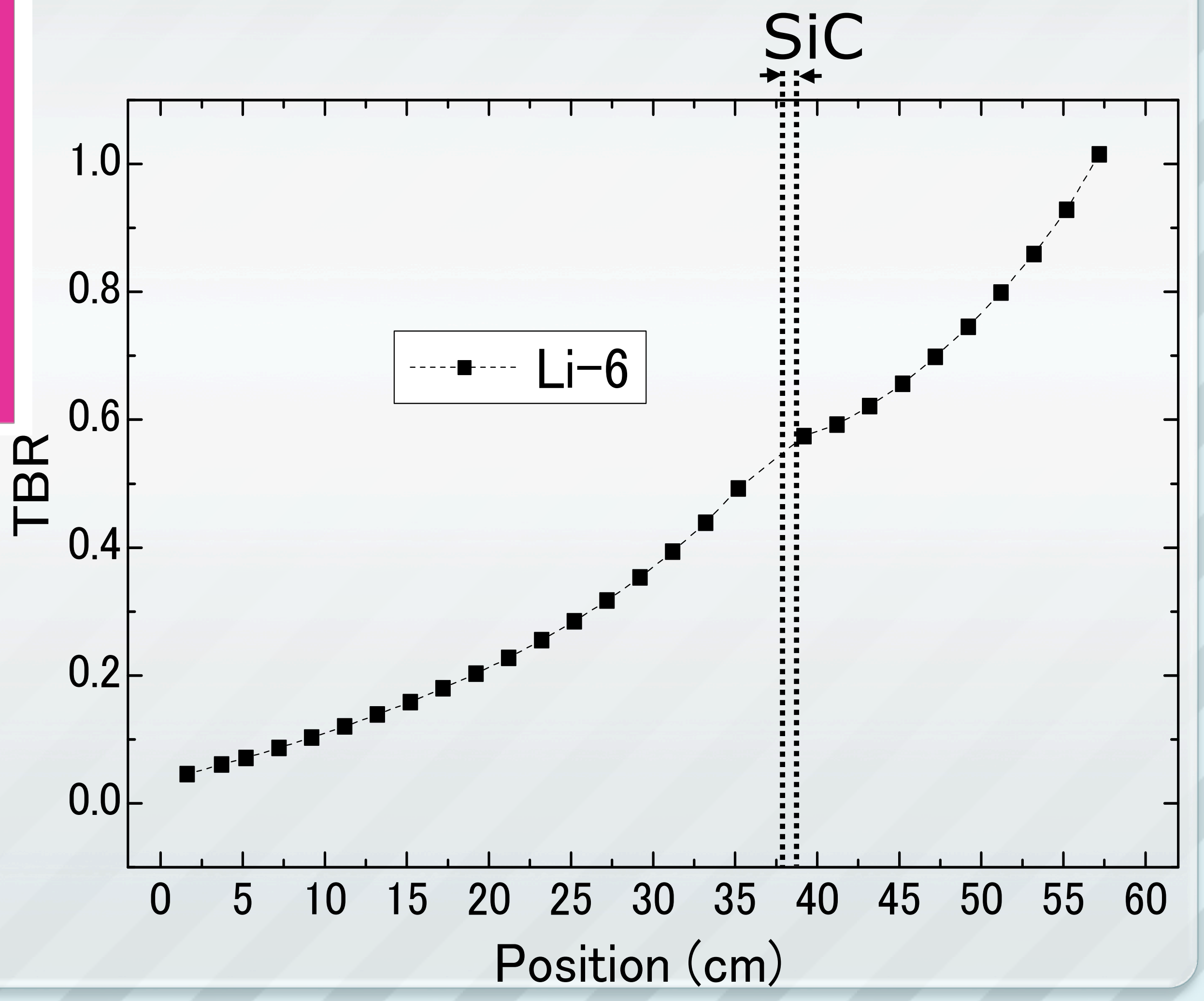
TBR was higher than other calculations.

→Simplified BLK structure. (no SiC inserts)

→Detailed analysis should be taken.

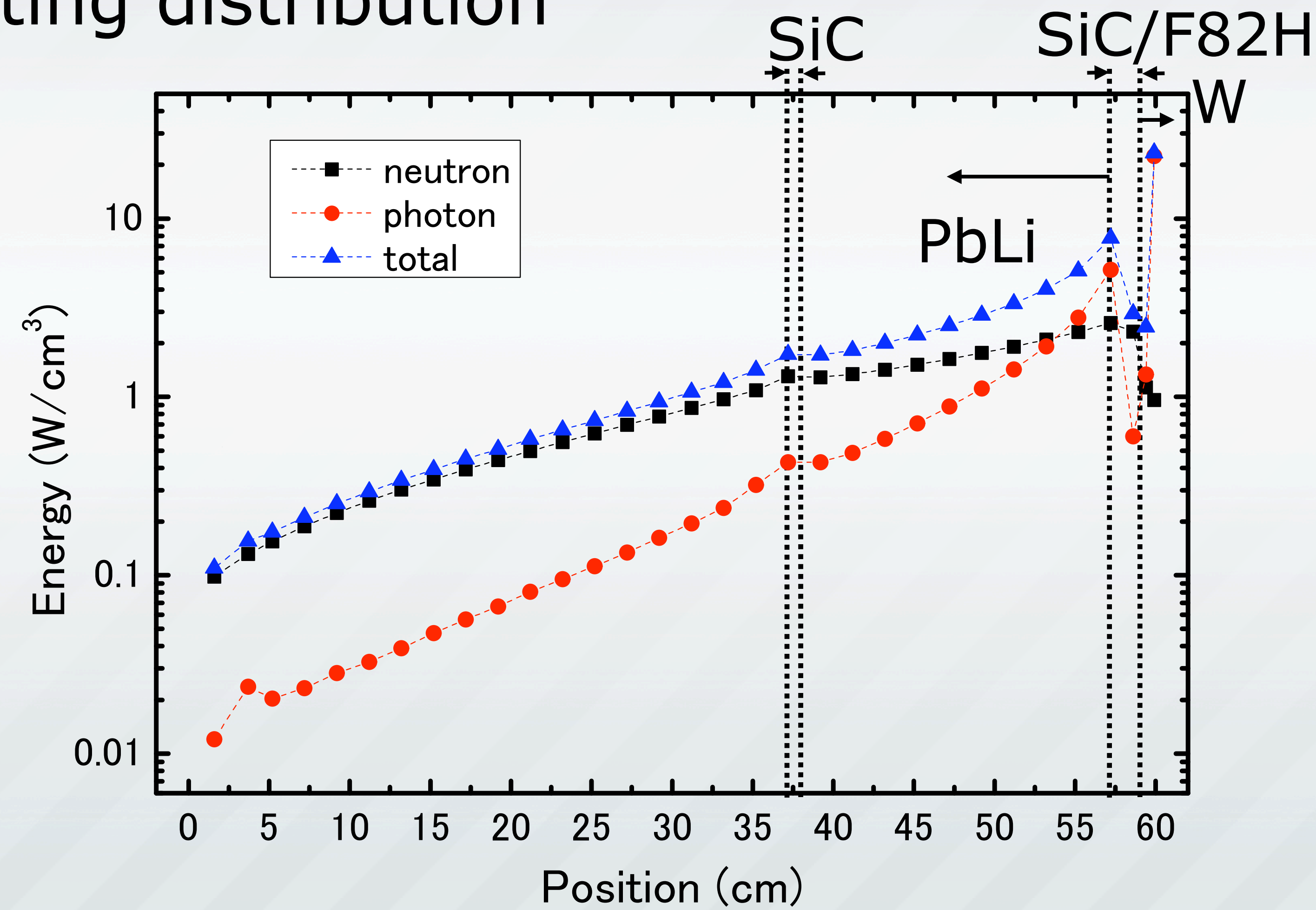
Neutronics –Blanket-





Neutronics –Blanket-

- Heating distribution



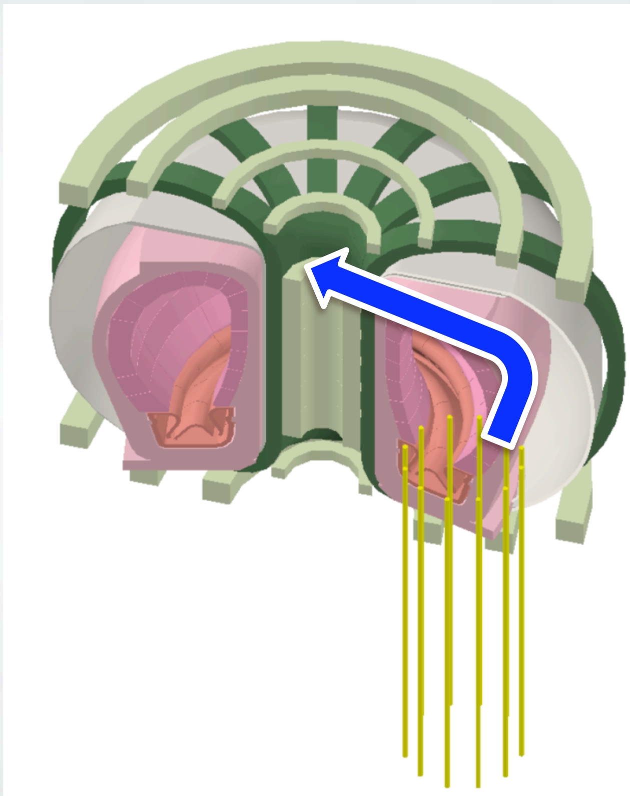
Neutronics summary

- Tokamak analysis tells total TBR & distribtuion of nuclear heat.
- Information from detailed component analysis will be feedback into the entire tokamak analysis and component designs.

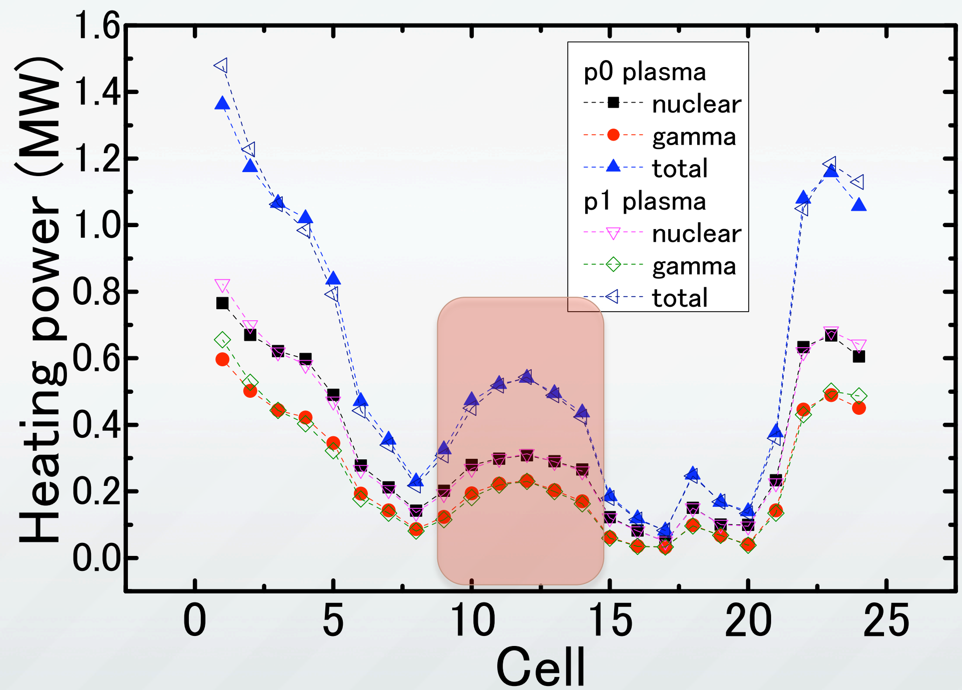
Local TBR → Total TBR analysis
Heating distribution → FEM, CFD

Using these data, the feasibility of PbLi cooled components will be discussed.

Pressure drop at In-board

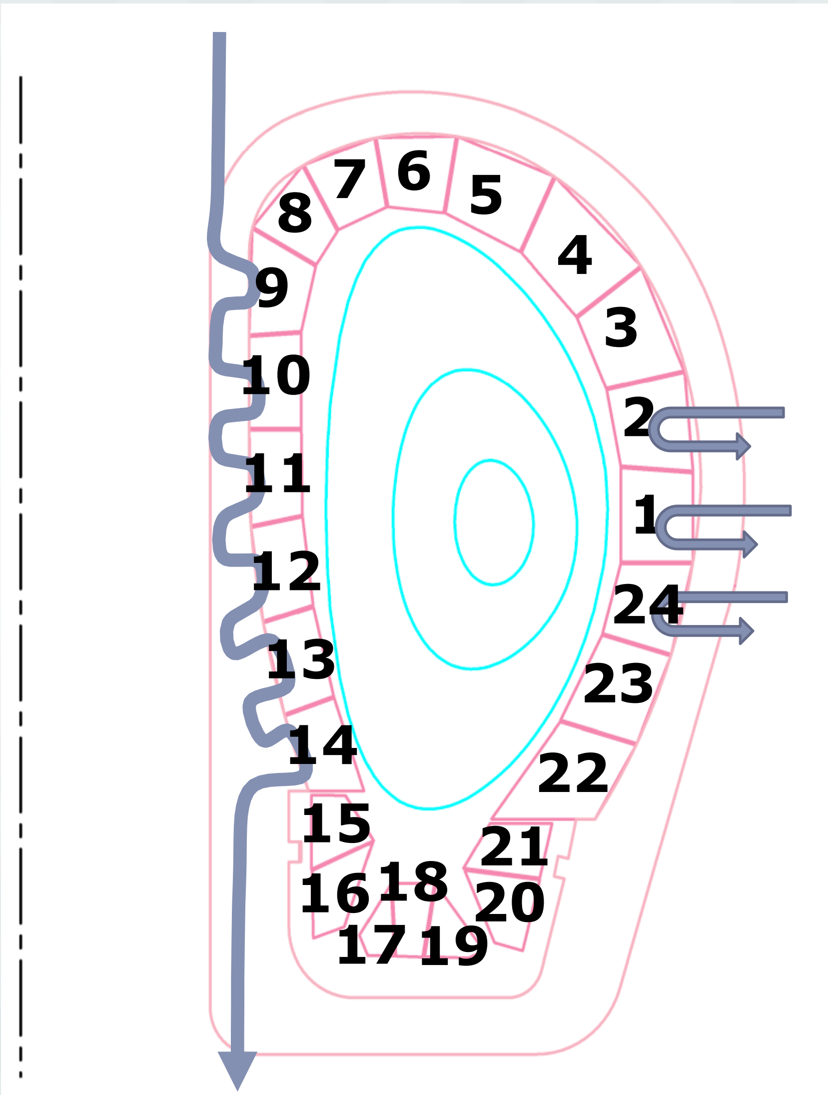


The strongest drop at the inboard ducts.



Neutronics result tells how much fraction of nuclear power will be derived to in-board BLKs.

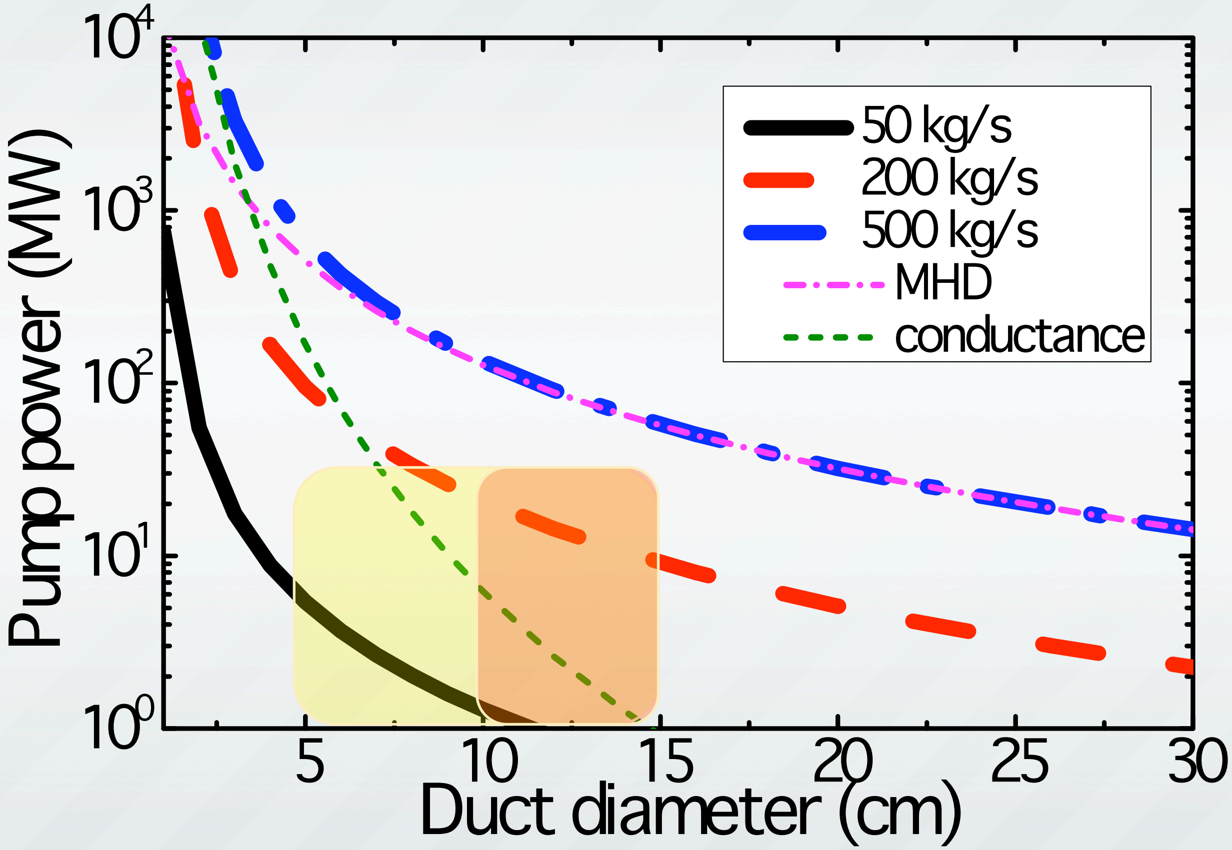
In-board coolant path



- Unlike out-board, in-board blankets should share a path for one sector to avoid complex wiring.
- Plus, really limited space for the coolant ducts.
  → duct diameter should be small as possible.

Coolant flow

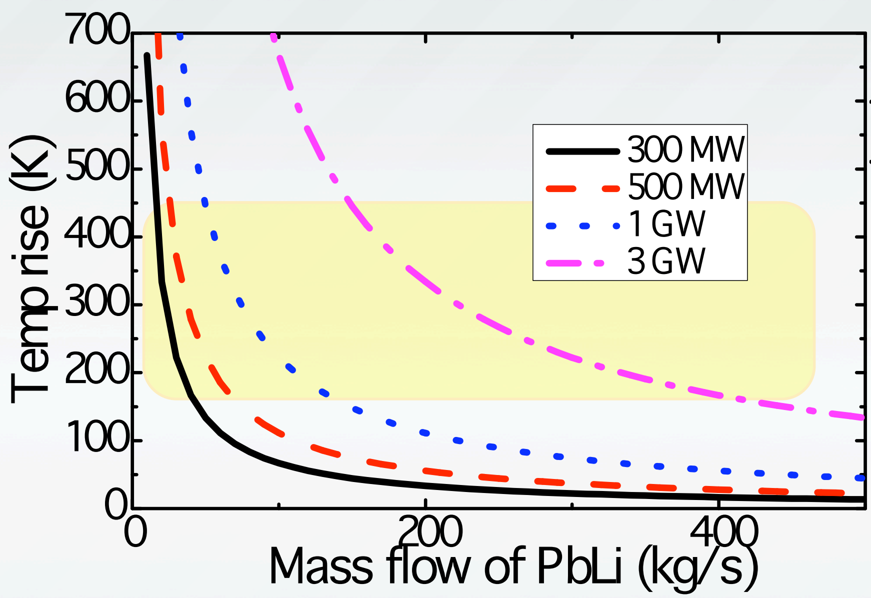
P_{pump} normalized by P_{fus} will be used for following discussion.

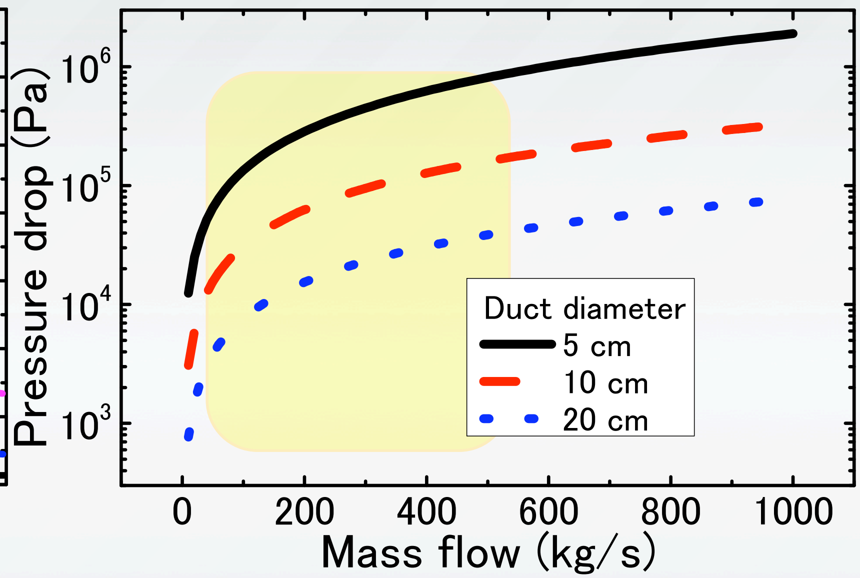


Pressure drop = MHD + conductance drop

$\propto v_{PbLi}(d_{duct}, m_{PbLi}(dT))$

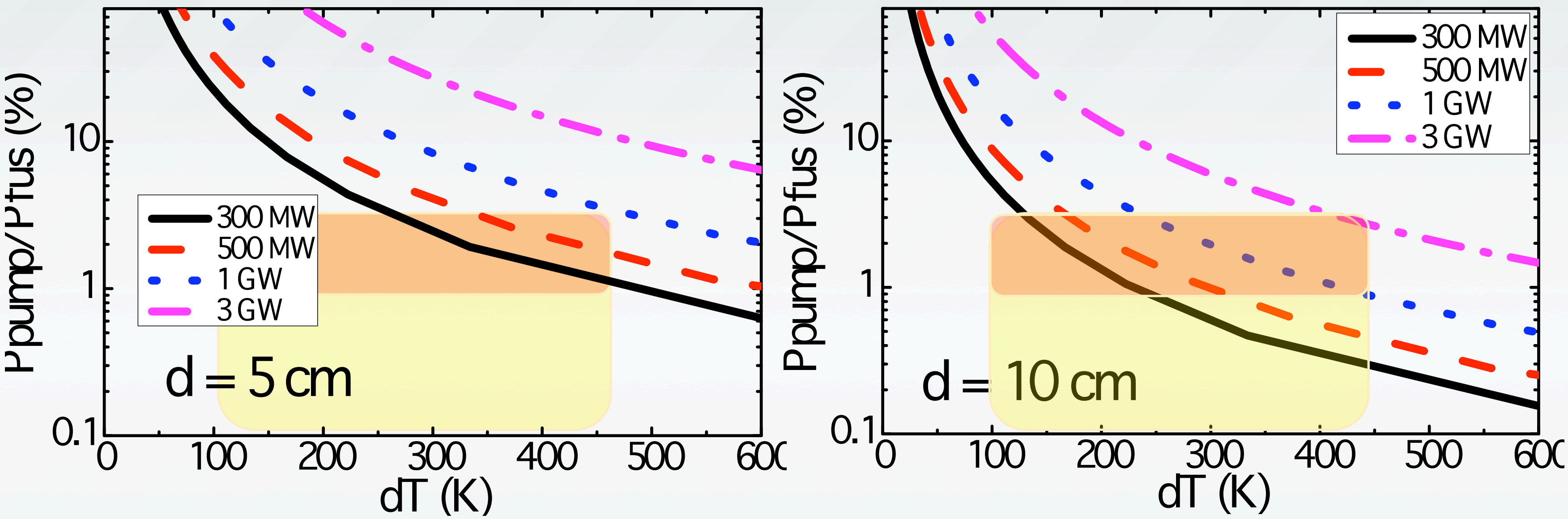
Coolant flow





- Assuming one path to each 15 deg. (total 24 ducts)
- Turn into d*P* vs d*T*.

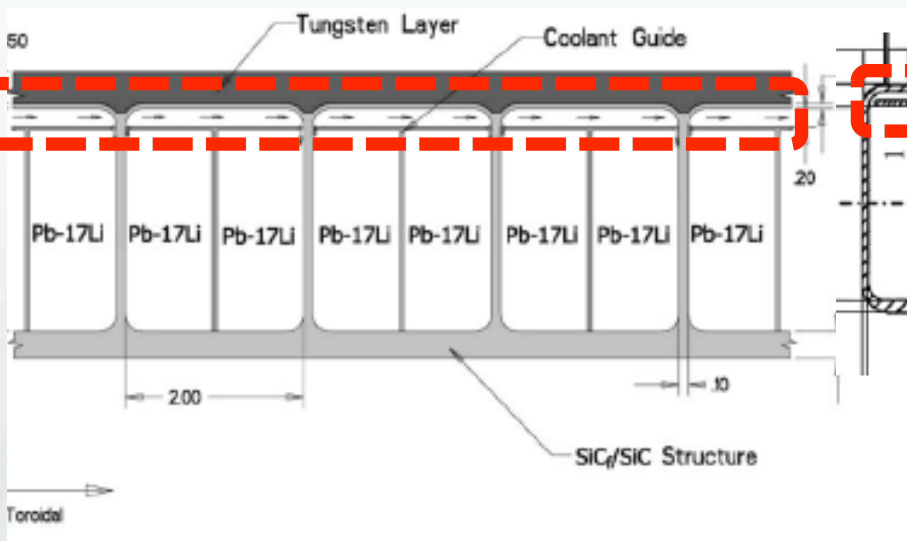
Coolant flow

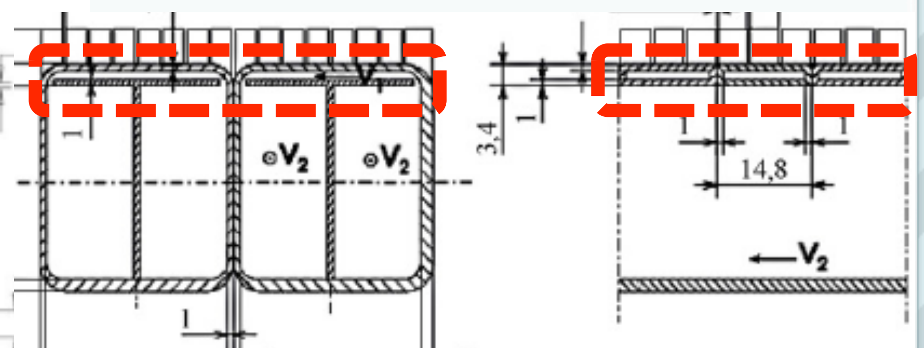


- High temperature operation → larger d*T*
  → smaller *P*pump
- <u>Module cooling should be taken for P_{fus} > 1GW.</u>

Divertor model

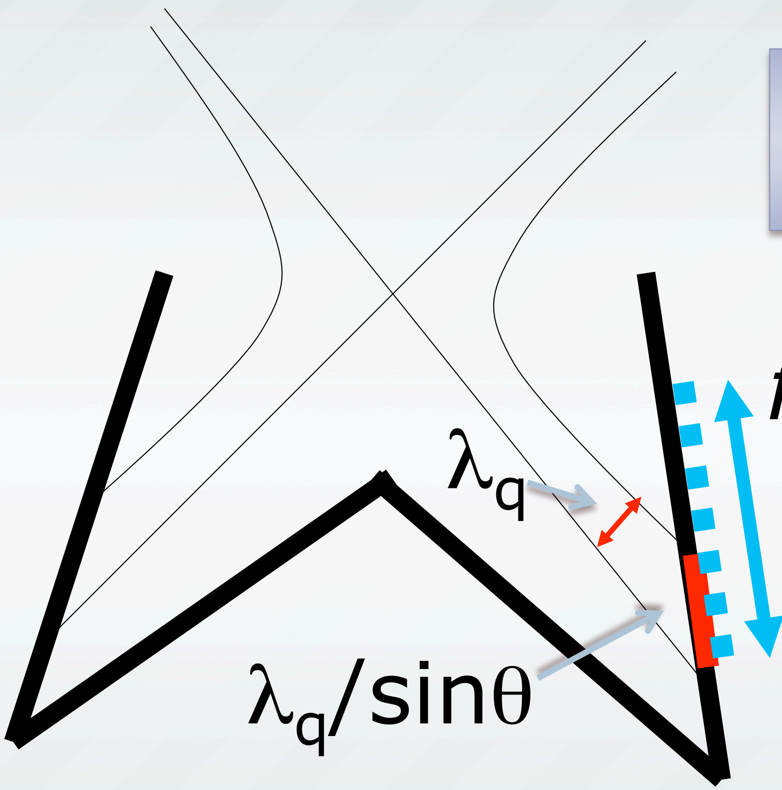
Pressure drop along the poloidal flow and the fast toroidal flow was evaluated.





A.R. Raffray and et.al., FED 55(2001)55   P. Norajitra and et.al., FED 83(2008)893

Divertor model



Changing the target area to relax the peaked heat flux.

f_{exp} ($\lambda_q/\sin\theta$)

Reasonable radiation.

$\underline{f_{rad} \sim 0.6 \text{ at private}}$

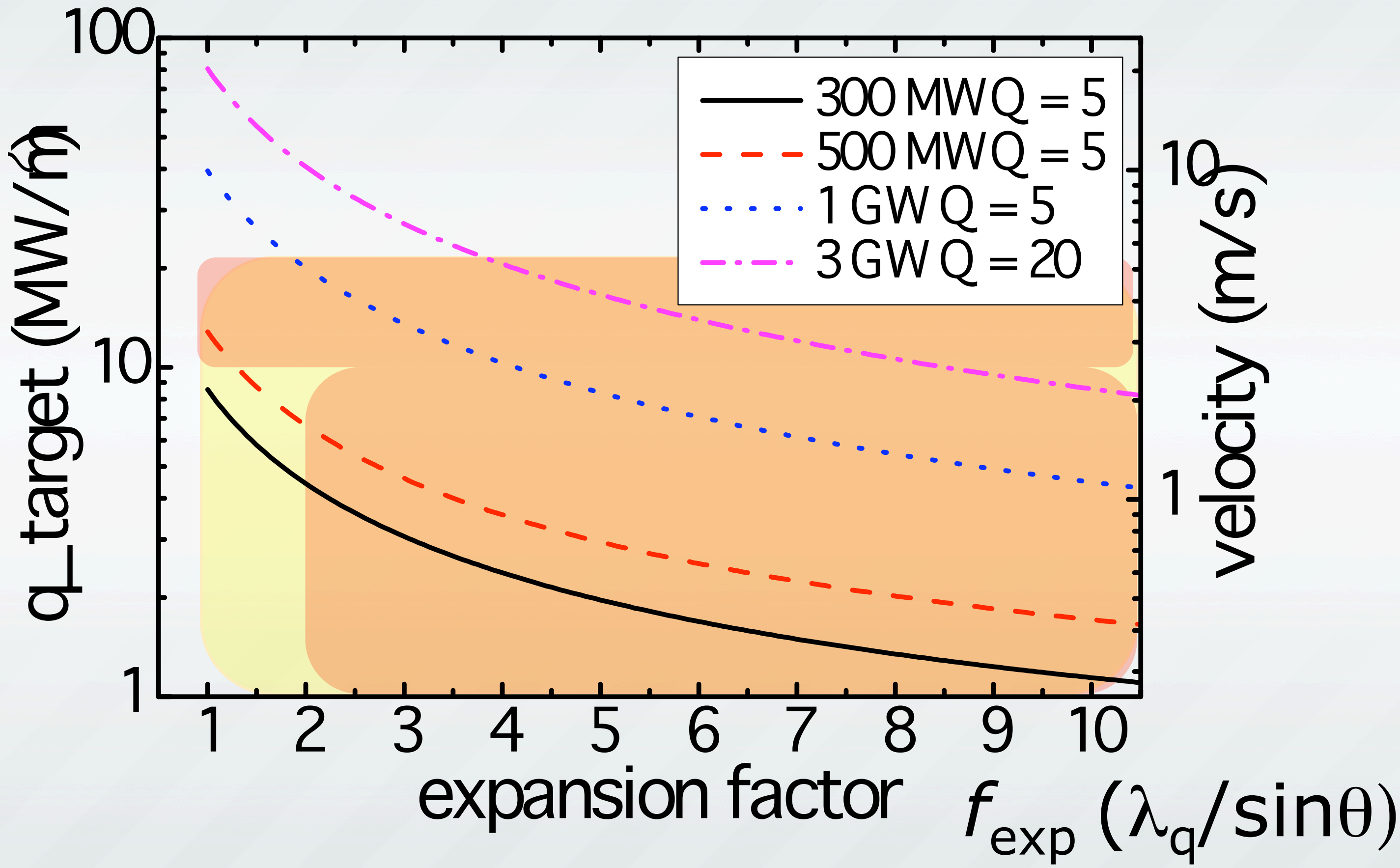
$\underline{n_{rad} < 6\text{MW/m}^3}$

Pressure drop: P_{tot}

$$P_{tot} = P_{target} * A_{target} + P_{rad} * (A_{div} - A_{target})$$

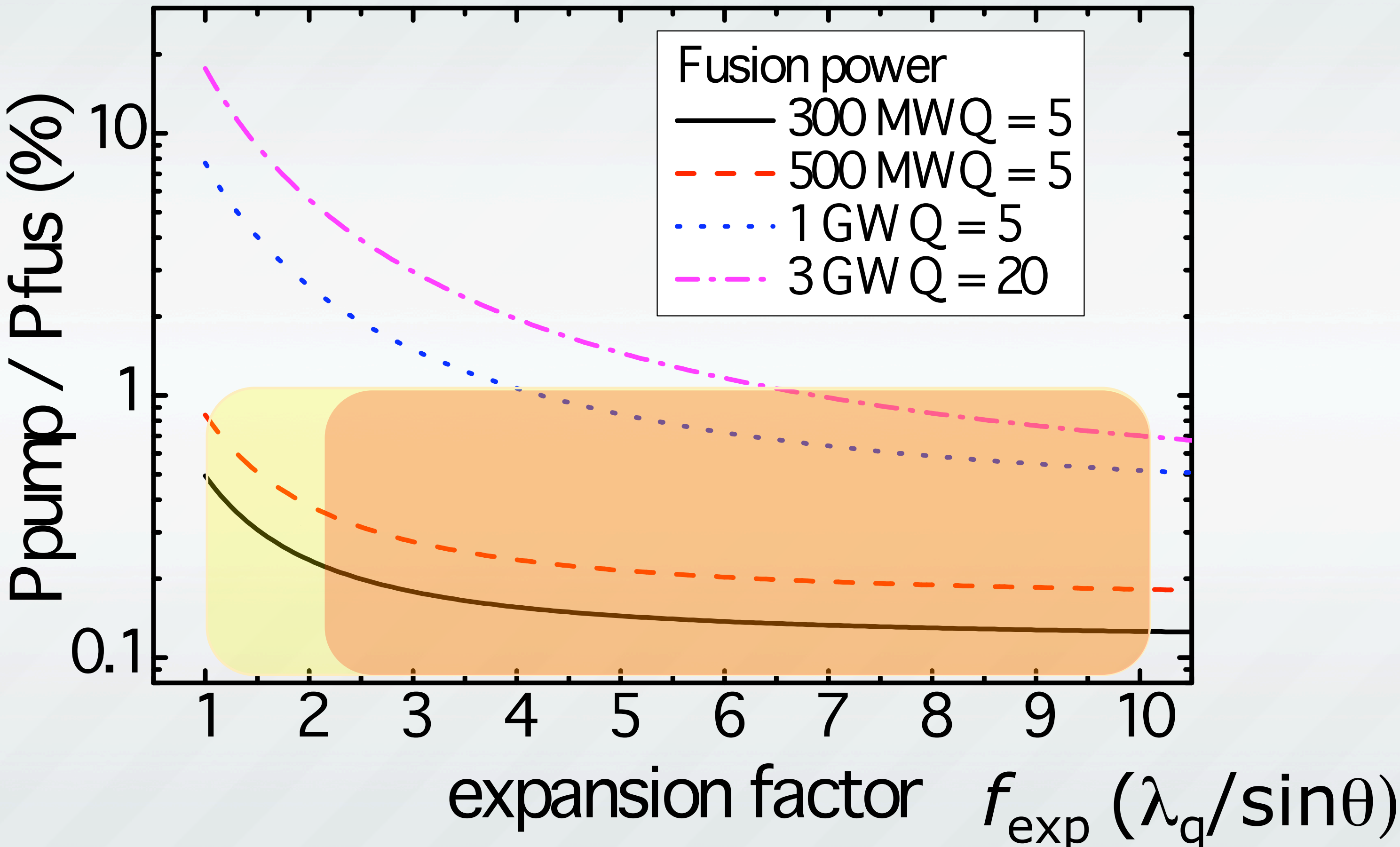
where $P_{target} = P_{peak} + P_{rad}$

Divertor heat flux



- Realistic designs are possible for P_{fus} < 1GW.

Divertor pressure drop



- Pressure drop at the divertor is acceptable for P_{fus} = 300 - 500 MW with SiC.

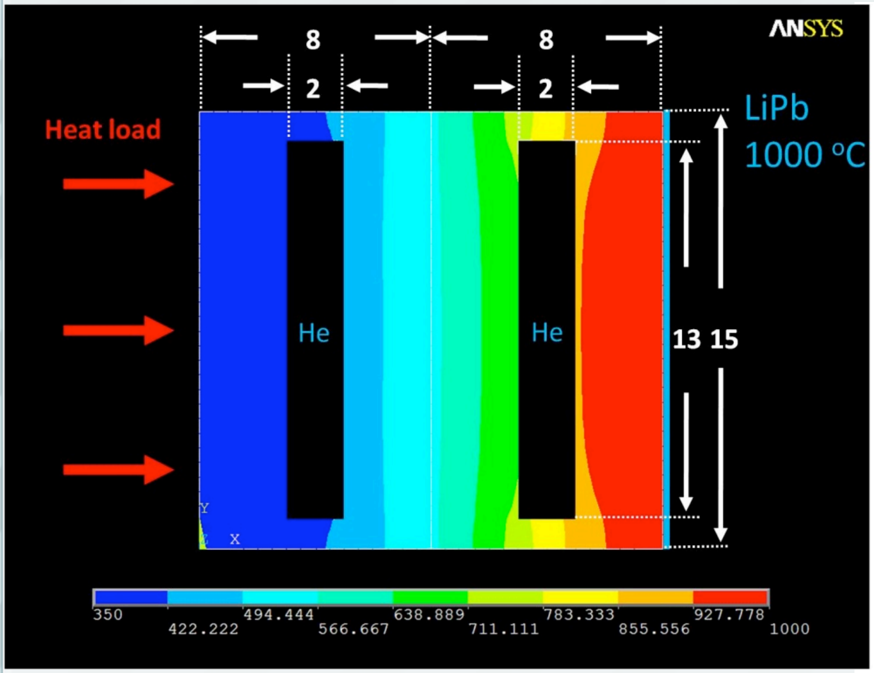
Summary

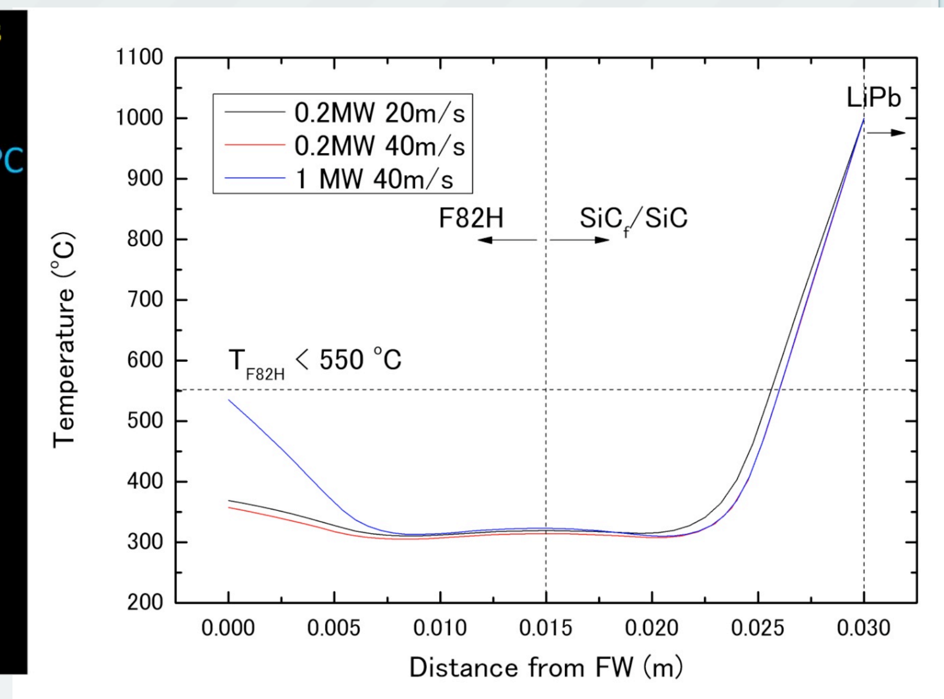
Coolant flow, pressure drop, pump power were studied for various P_{fus} reactors.

$P_{fus} \geqq$ 1GW: advanced performance target, complex structure.
$P_{fus} <$ 500MW : reasonable assumption, simple structure.

Biomass-hybrid ~ 500 MW has a operation window with the PbLi cooled compoents.

ANSYS heat analysis





- RAFM < 550 ºC has been confirmed with PbLi at 1000 ºC by flowing He into the SiC insulator panel.