Japan-US Workshop on Fusion Power Plants and Related Advanced Technologies with participation of EU

EU Power Plant Conceptual study „Near Term“ models (A,B,AB)

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Power Plant Conceptual Study (stage 3)

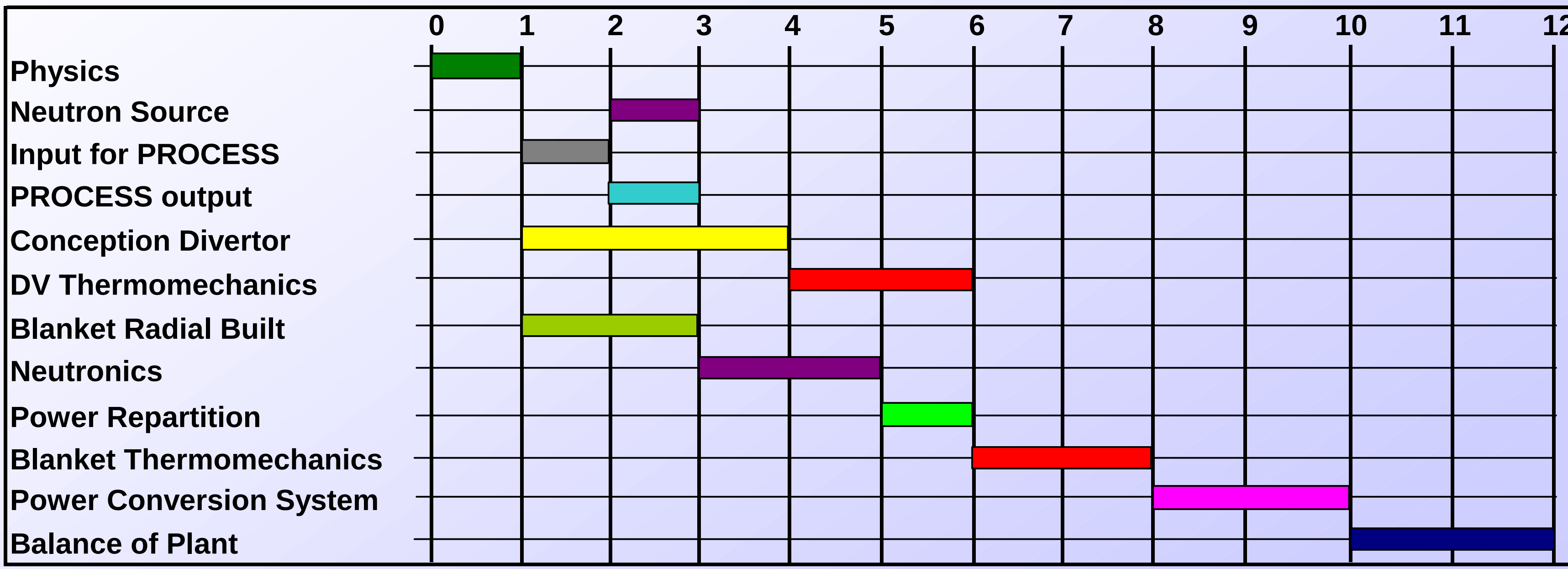
- Demonstration of:
  - Credibility of fusion power plant design
  - Safety and environmental advantages of fusion power
  - Economic viability of fusion power
- Set of requirements issued by industry and utilities
  - Safety
  - Operational aspects
  - Economic aspects
- Four models (+1) studied as examples of a spectrum of possibilities, ranging from near term to advanced
- Economic safety and environmental analyses of these models were made

Main specifications of models A, B and AB

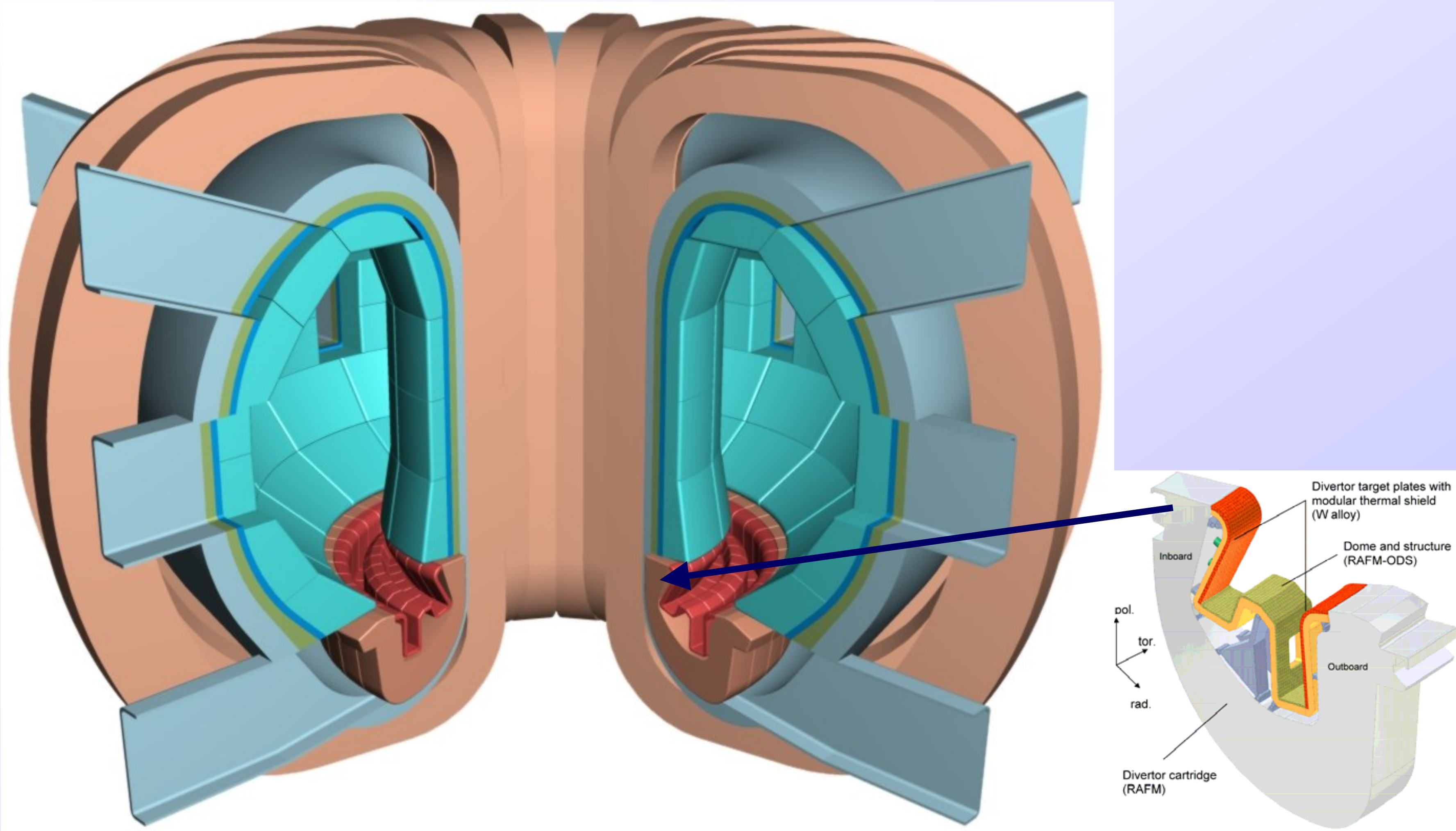
- A small extrapolation from present-day knowledge is assumed for both physics and technology
- In order to maintain the steady state operation, current drive will be used
- Performances of the divertor: relatively high peak loads (up to 15 MW/m^2)

PPCS : course of the studies

- Systems code varied the parameters of the possible designs, subject to assigned plasma physics and technology rules and limits, to produce economic optimum.

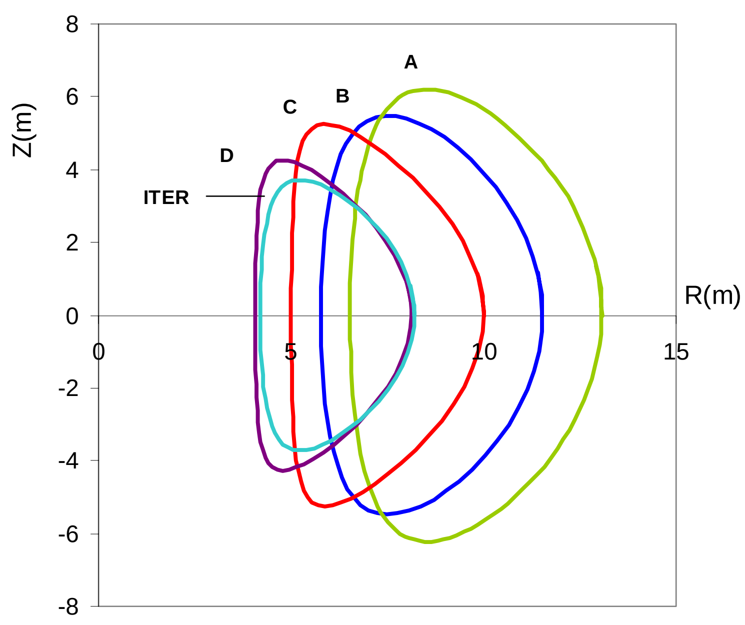


Fusion reactor



Key parameters

- 1500 Mw_e
- Fusion power is determined by efficiency, energy multiplication and current drive power
- Given the fusion power, plasma size mainly driven by divertor considerations

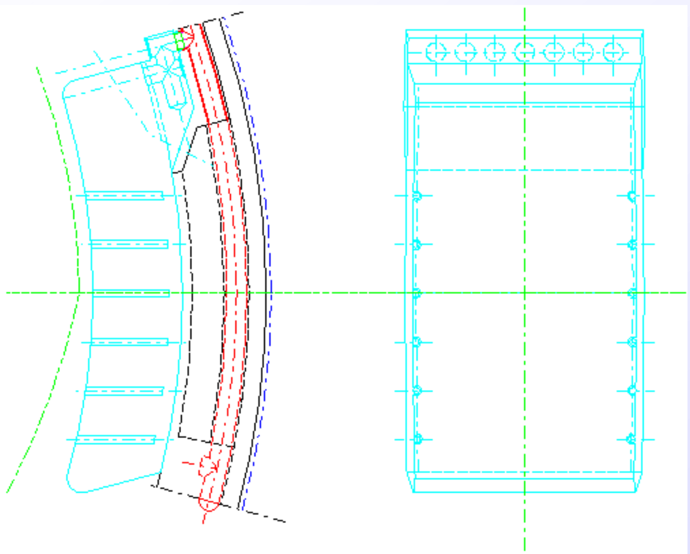


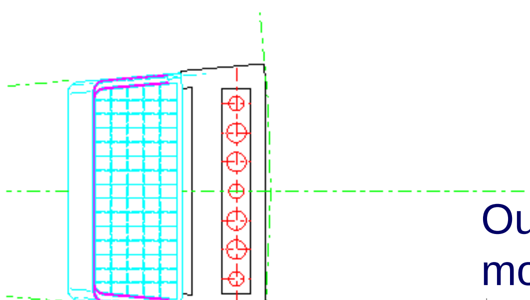
Plants main features

		Model A	Model B	Model AB
	Net Electric Power (GW)	1.55	1.33	1.50
	Fusion Power (GW)	5.00	3.60	4.29
	Blanket Gain	1.18	1.39	1.18
	Plant Efficiency	0.31	0.37	0.35
	Bootstrap Fraction	0.45	0.43	0.43
	P_{add} (MW)	246	270	257
	DV Peak load ($MW.m^{-2}$)	15	10	10
	Average neutron wall load	2.2	2.0	1.8
	Major Radius (m)	9.55	8.6	9.56
Blanket	Structural material	Eurofer	Eurofer	Eurofer
Blanket	Coolant	Water	Helium	Helium
Blanket	Breeder	LiPb	Li4SiO4	LiPb
Blanket	TBR	1.06	1.12	1.13
DV	Structural material	CuCrZr	W alloy	W alloy
DV	Armour material	W alloy	W alloy	W alloy
DV	Coolant	Water	Helium	Helium
	Conversion Cycle	Rankine	Rankine	Rankine

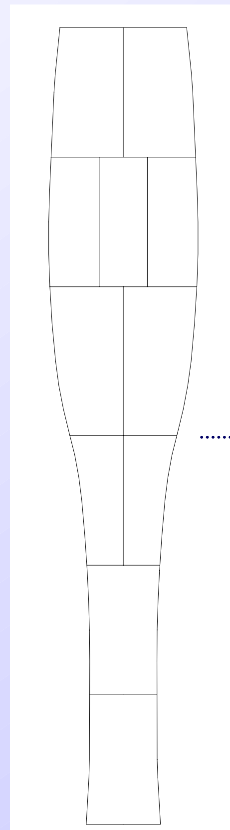
WCLL Blanket Concept (model A)

Eurofer as structural material, water as coolant, LiPb as breeder and neutron multiplier



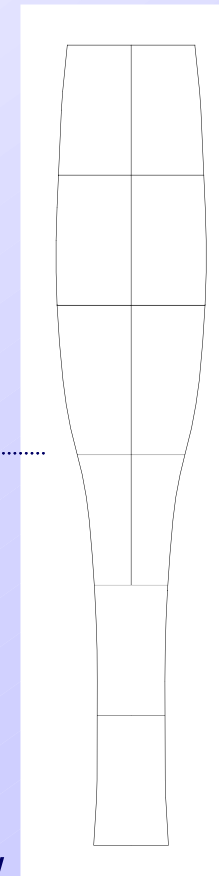


Outboard module



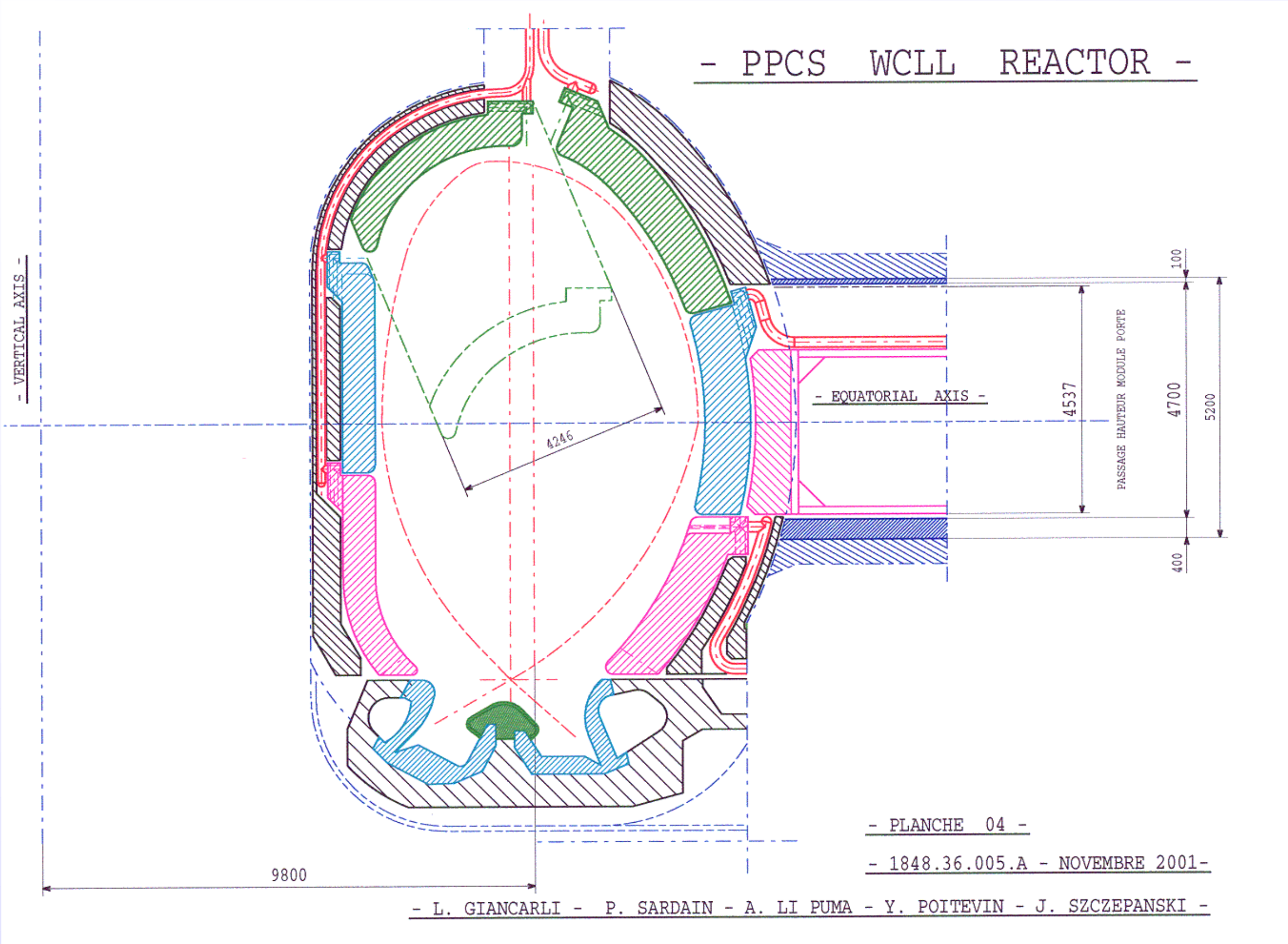
outboard

inboard

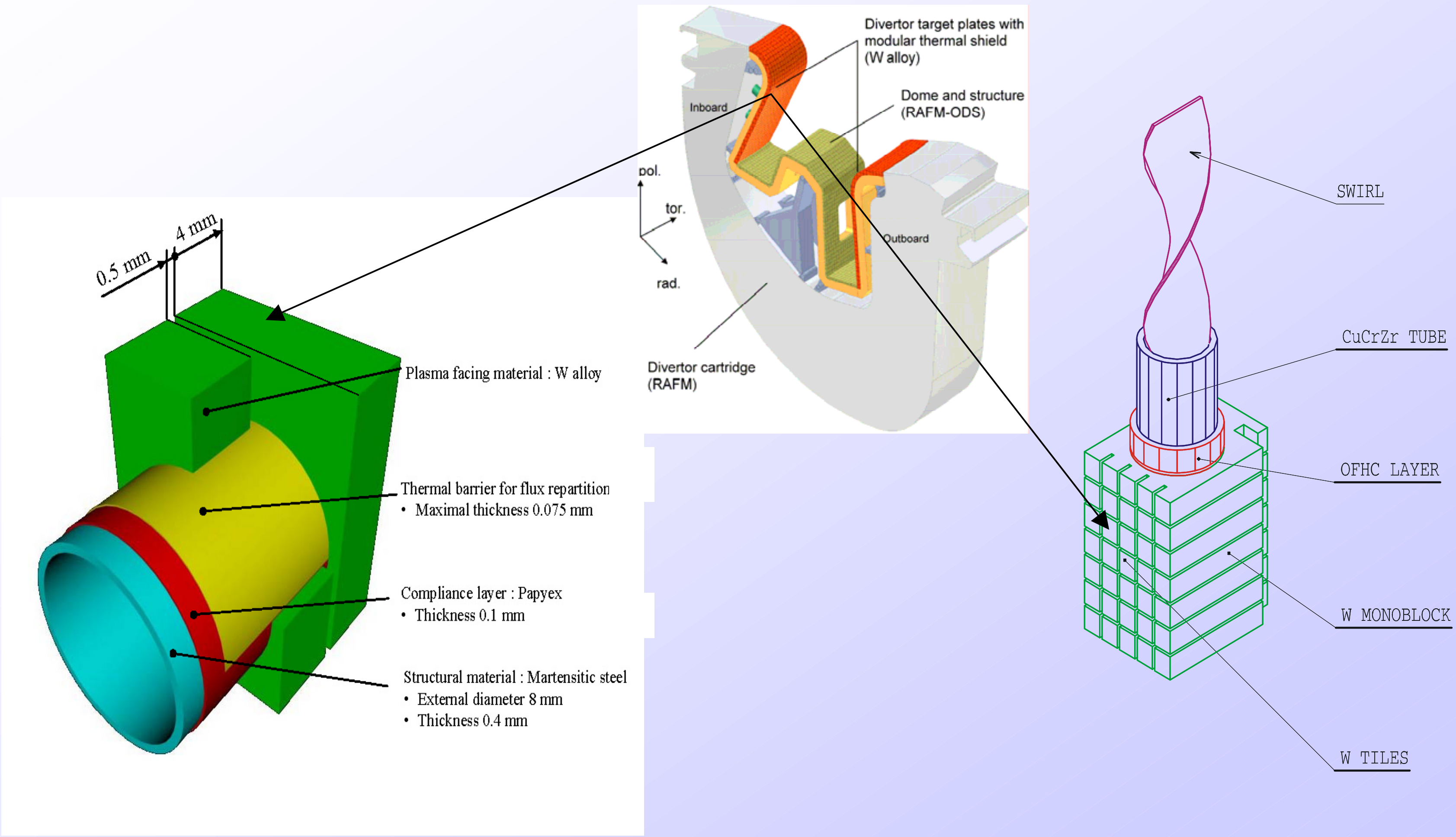


Developed view
Of a 20° sector

Model A: Segmentation



Model A: Water-cooled Divertor



High temperature Dv

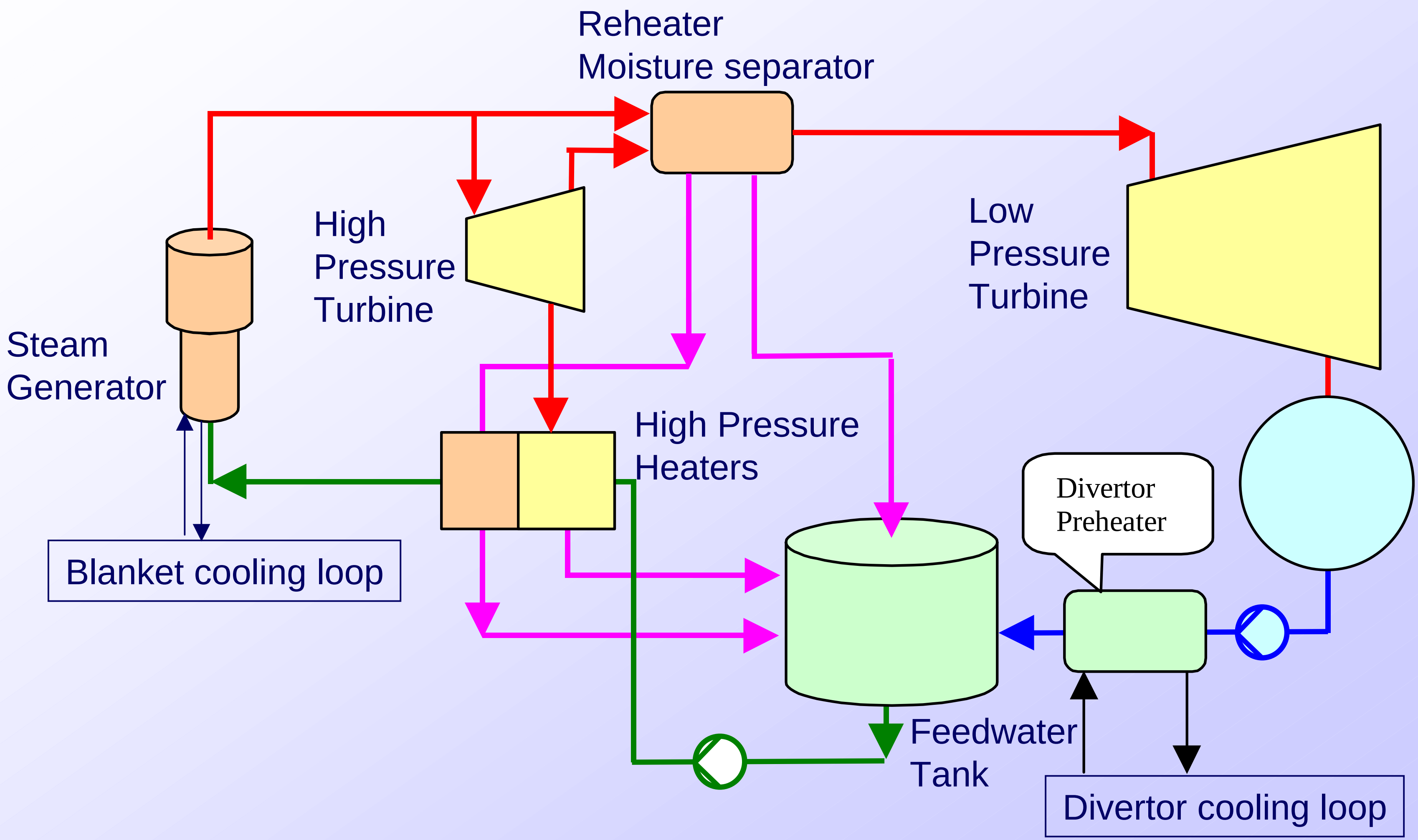
Low temperature Dv

Model A: Power repartition and primary system

Blanket Breeder Zone (MW)	3892
Blanket First Wall (MW)	1438
Divertor (MW)	984

Number of loops (blanket)	6
Number of loops (divertor)	2
Inlet/Outlet temperature (blanket) (°C)	285/325
Inlet/Outlet temperature (divertor) (°C)	140/167
Operating pressure (blanket) (MPa)	15.5
Operating Pressure (divertor) (MPa)	4.2
Heat Sink (blanket)	Steam Generator
Heat Sink (divertor)	Preheater
Maximum velocity in pipes (m/s)	20

Power conversion (model A)

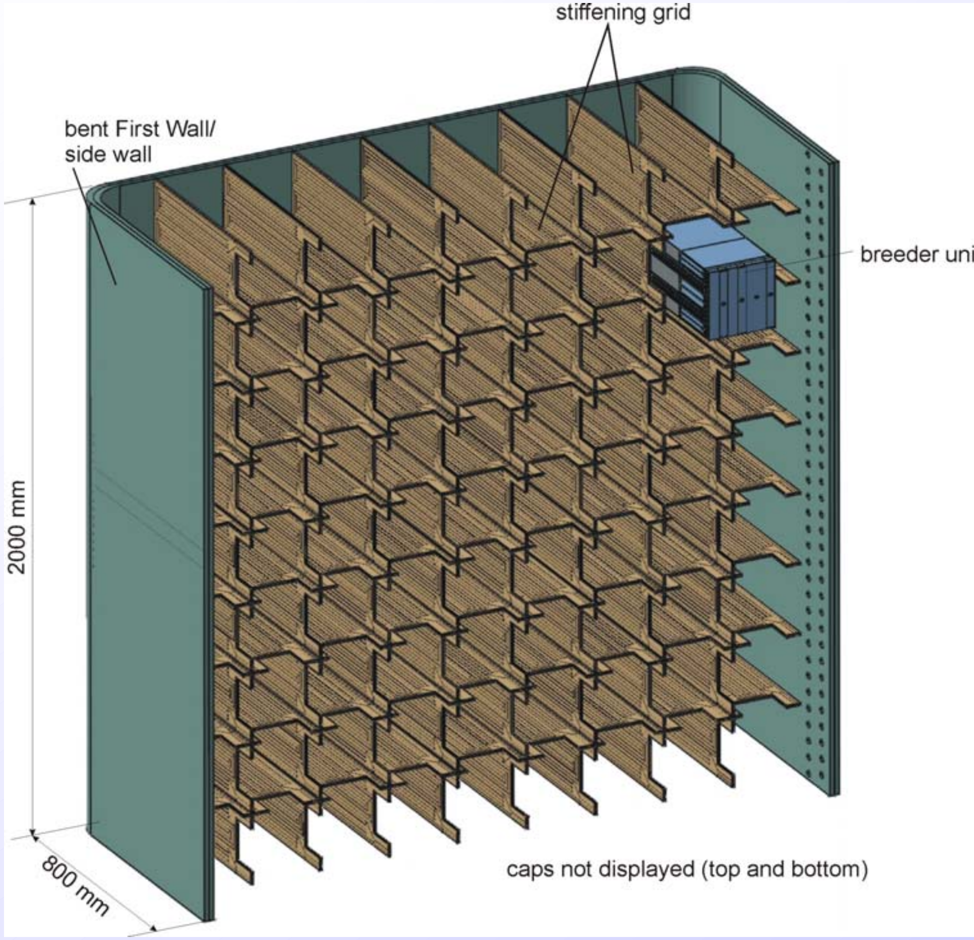


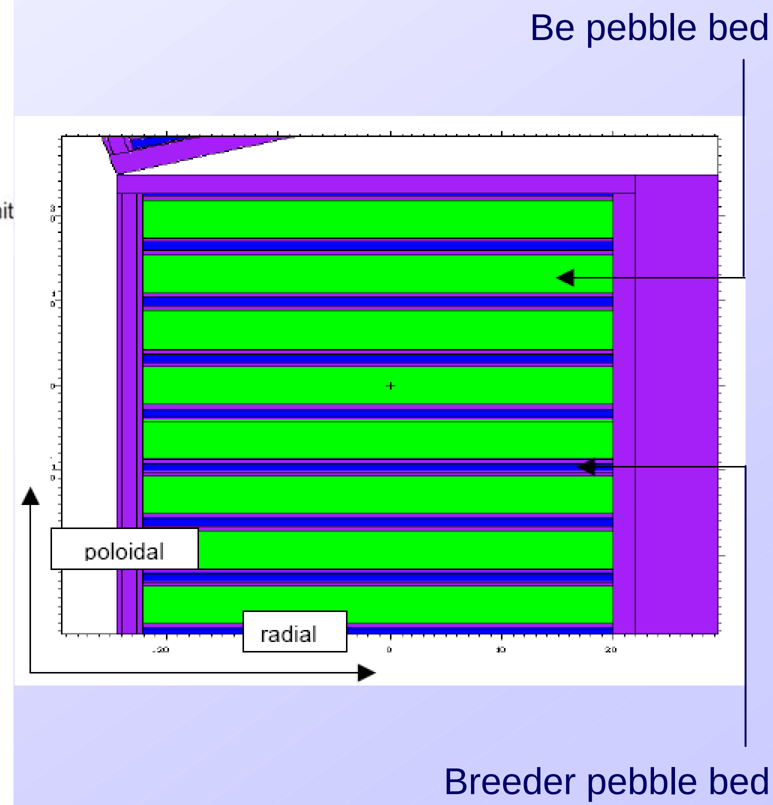
Model A: R&D needs

- Development of a HHF water-cooled divertor concept operating at the same coolant temperature as the blanket cooling loop ➔ higher efficiency
- Optimization of the attachment system
- Materials

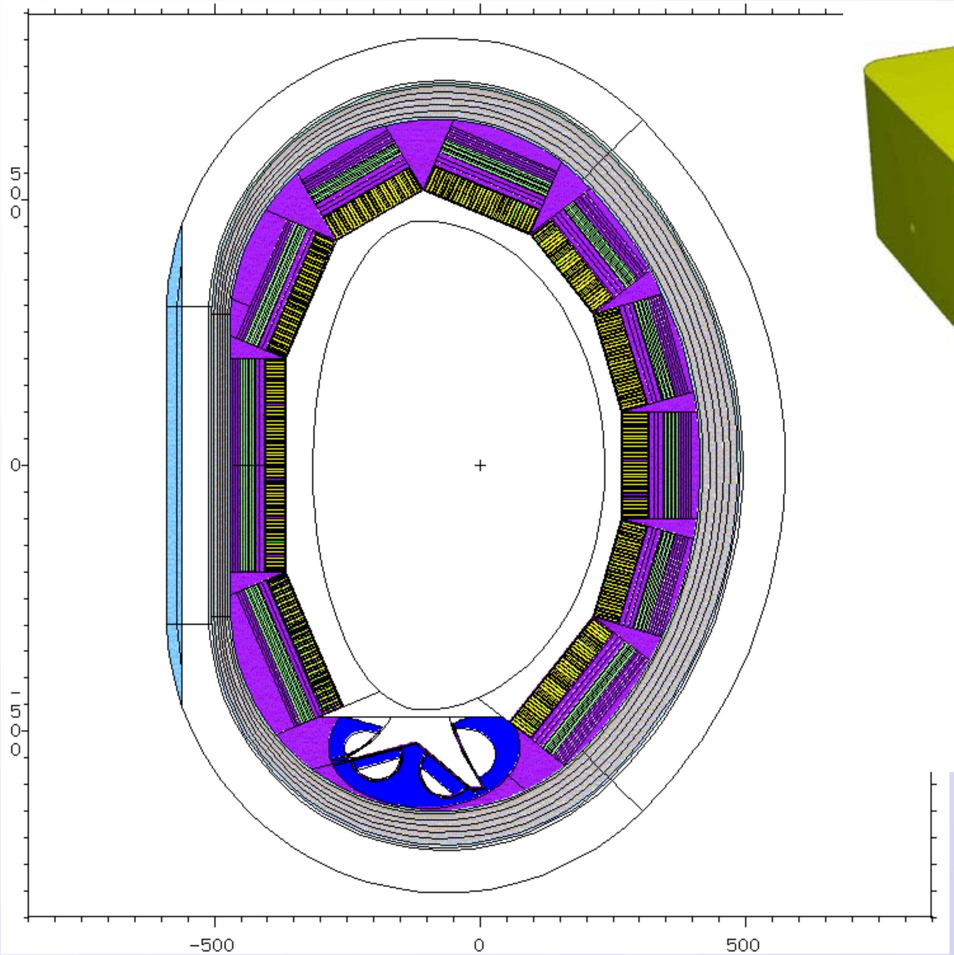
HCPB blanket concept (model B)

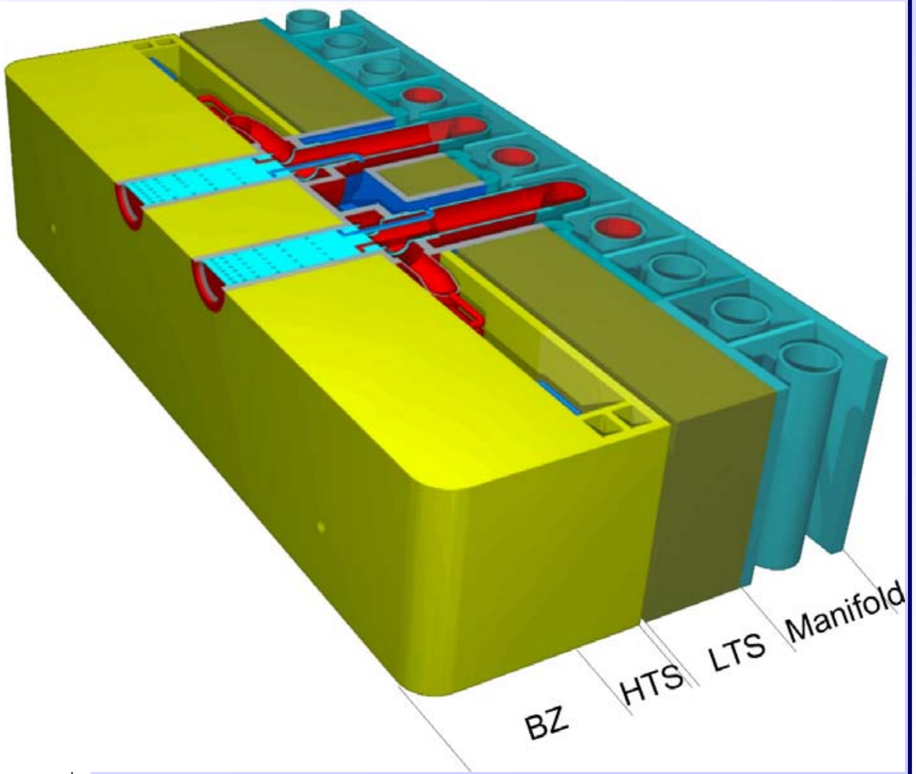
Eurofer as structural material, He as coolant, Li4SiO4 as breeder, Be as neutron multiplier





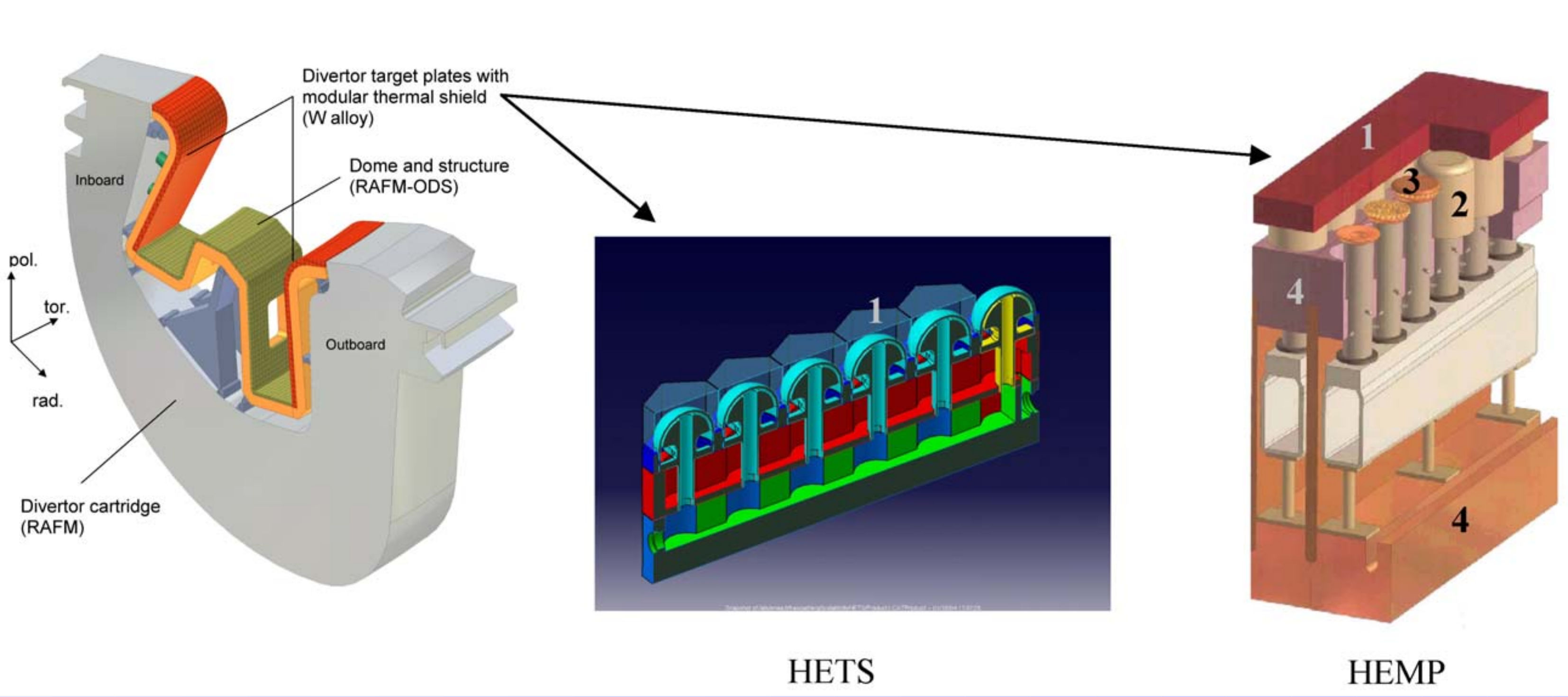
Model B: Segmentation





Model B: He-cooled divertor

- Divertor concept using helium as coolant and W as structural material
- Peak load of 10 MW/m^2 ➔ necessity to optimize the heat exchange

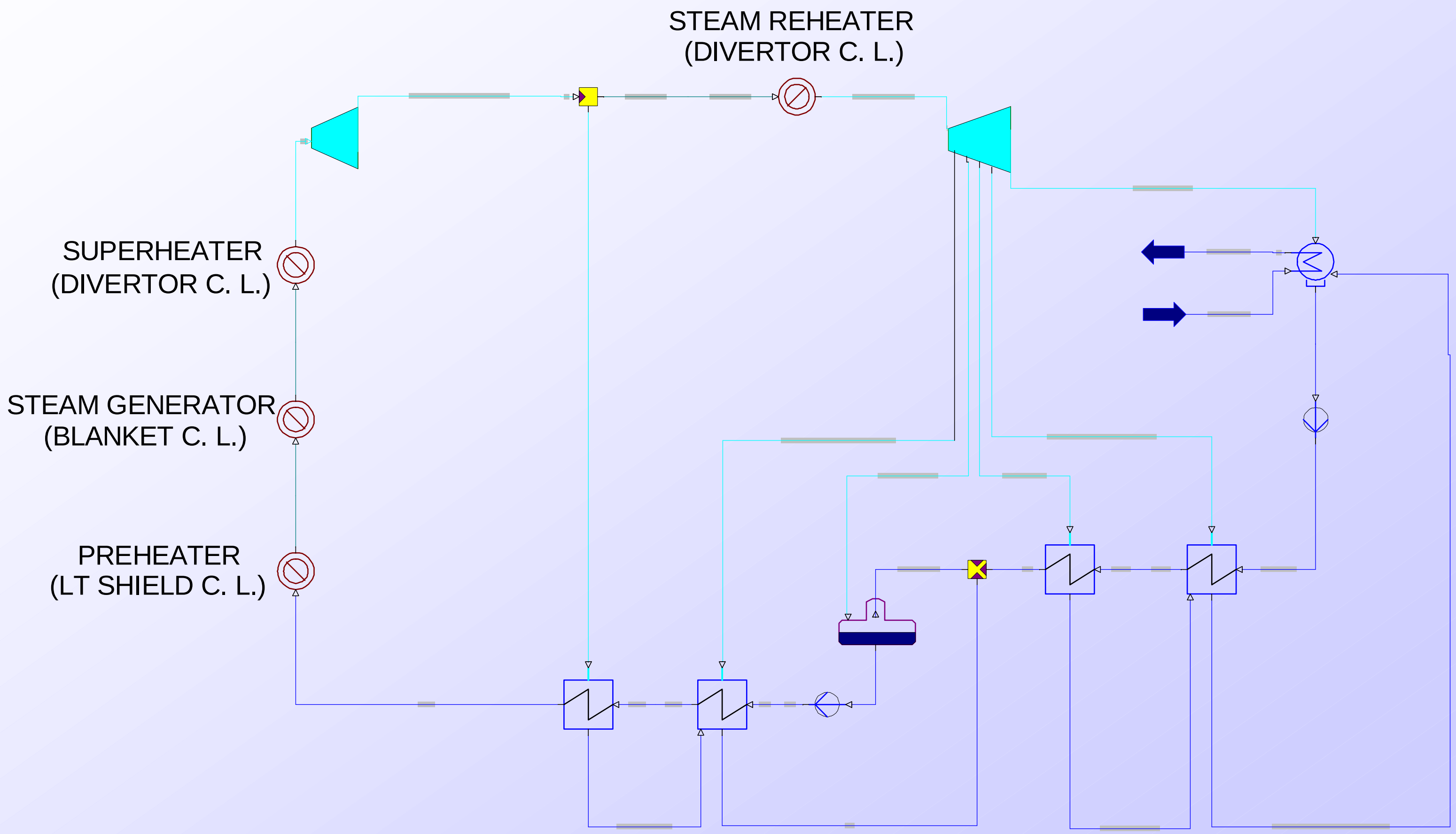


Model B: Power repartition and primary system

Blanket Breeder Zone (MW)	3596
Blanket First Wall (MW)	656
Divertor (MW)	604
LT Shield	189

Number of loops (blanket)	9
Number of loops (divertor)	9
Inlet/Outlet temperature (blanket) (°C)	300/500
Inlet/Outlet temperature (divertor) (°C)	540/720
Operating pressure (blanket) (MPa)	8
Operating Pressure (divertor) (MPa)	10
Heat Sink (blanket)	Steam Generator
Heat Sink (divertor)	Superheater
Heat Sink (LTS)	Preheater

Power conversion (model B)



Model B: R&D needs

- Development of a HHF Helium-cooled divertor

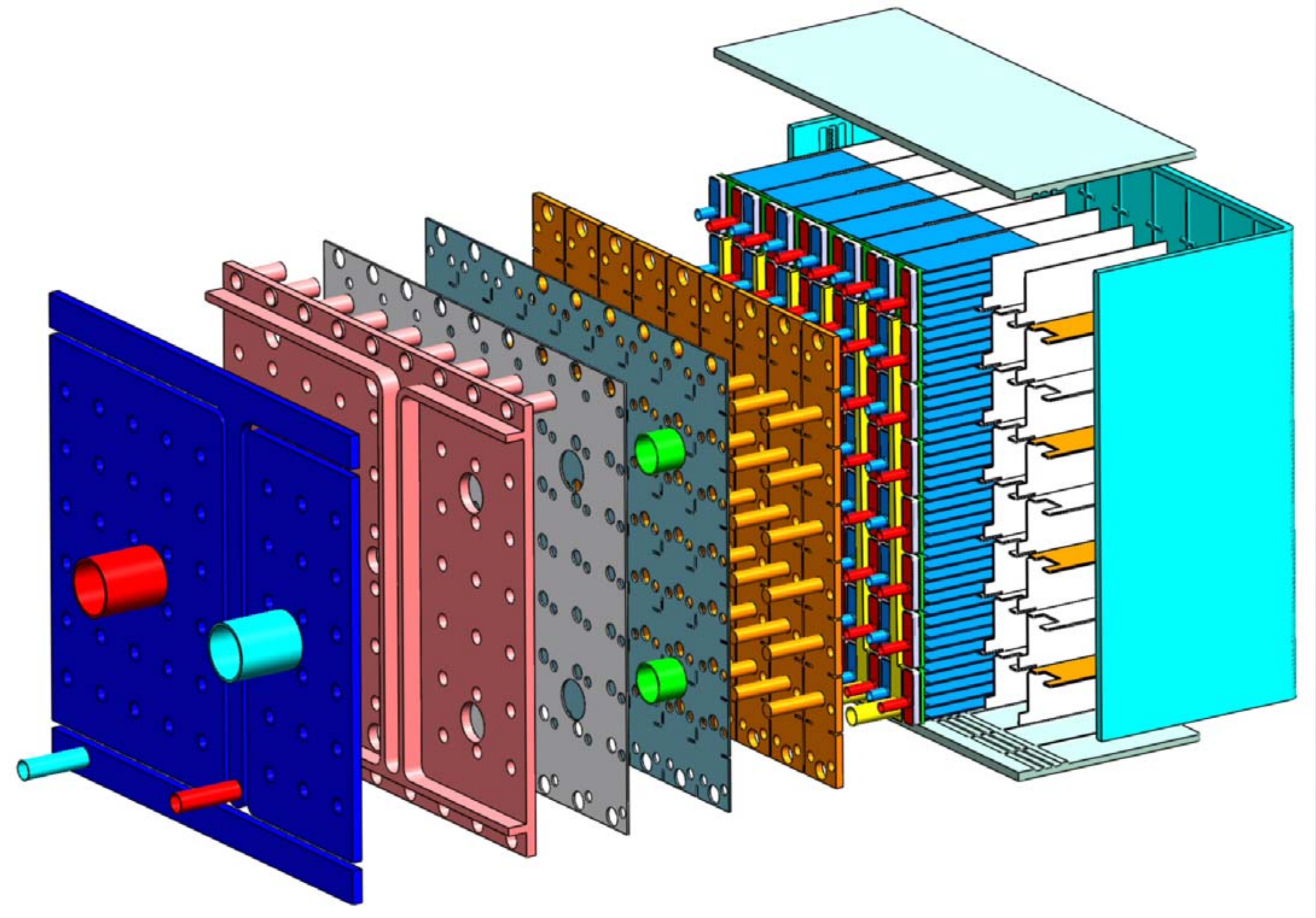
- Design update of the HCPB blanket with the aim of supporting blanket box pressurisation at full coolant pressure

- Open questions related to technology
  - blanket fabrication issues
  - the thermo-mechanical behaviour of the used pebble beds
  - Tritium retention in irradiated Beryllium
  - Beryllium material grade/alloy to use

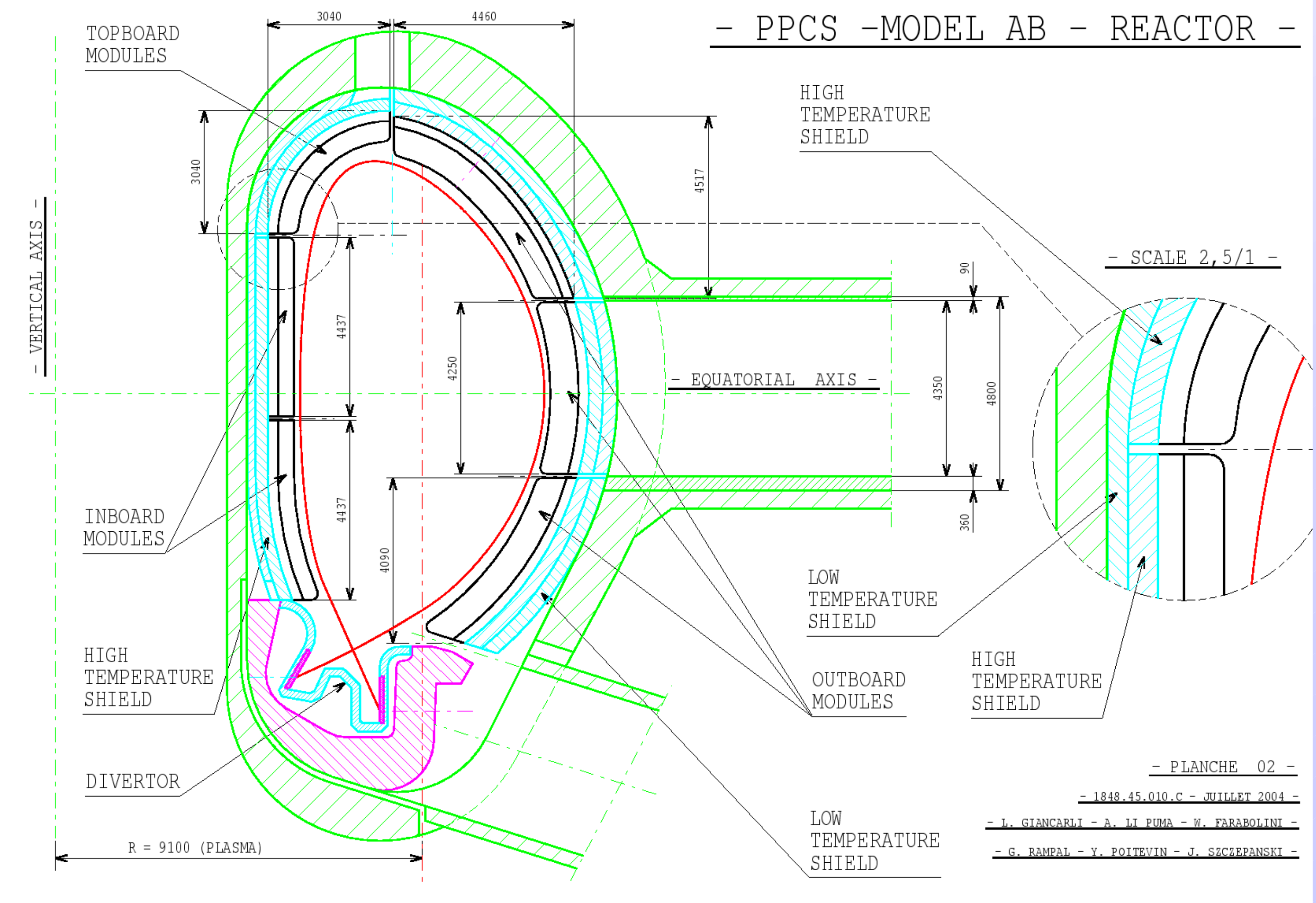
- Materials

HCLL blanket concept (model AB)

Eurofer as structural material, helium as coolant, LiPb as breeder and neutron multiplier



Model AB: segmentation



Model AB: Power repartition and primary system

Blanket (+HTS) (MW)	4478
Divertor (MW)	983

Number of loops (blanket)	9
Number of loops (divertor)	9
Inlet/Outlet temperature (blanket) (°C)	300/500
Inlet/Outlet temperature (divertor) (°C)	540/720
Operating pressure (blanket) (MPa)	8
Operating Pressure (divertor) (MPa)	10
Heat Sink (blanket)	Steam Generator
Heat Sink (divertor)	Superheater

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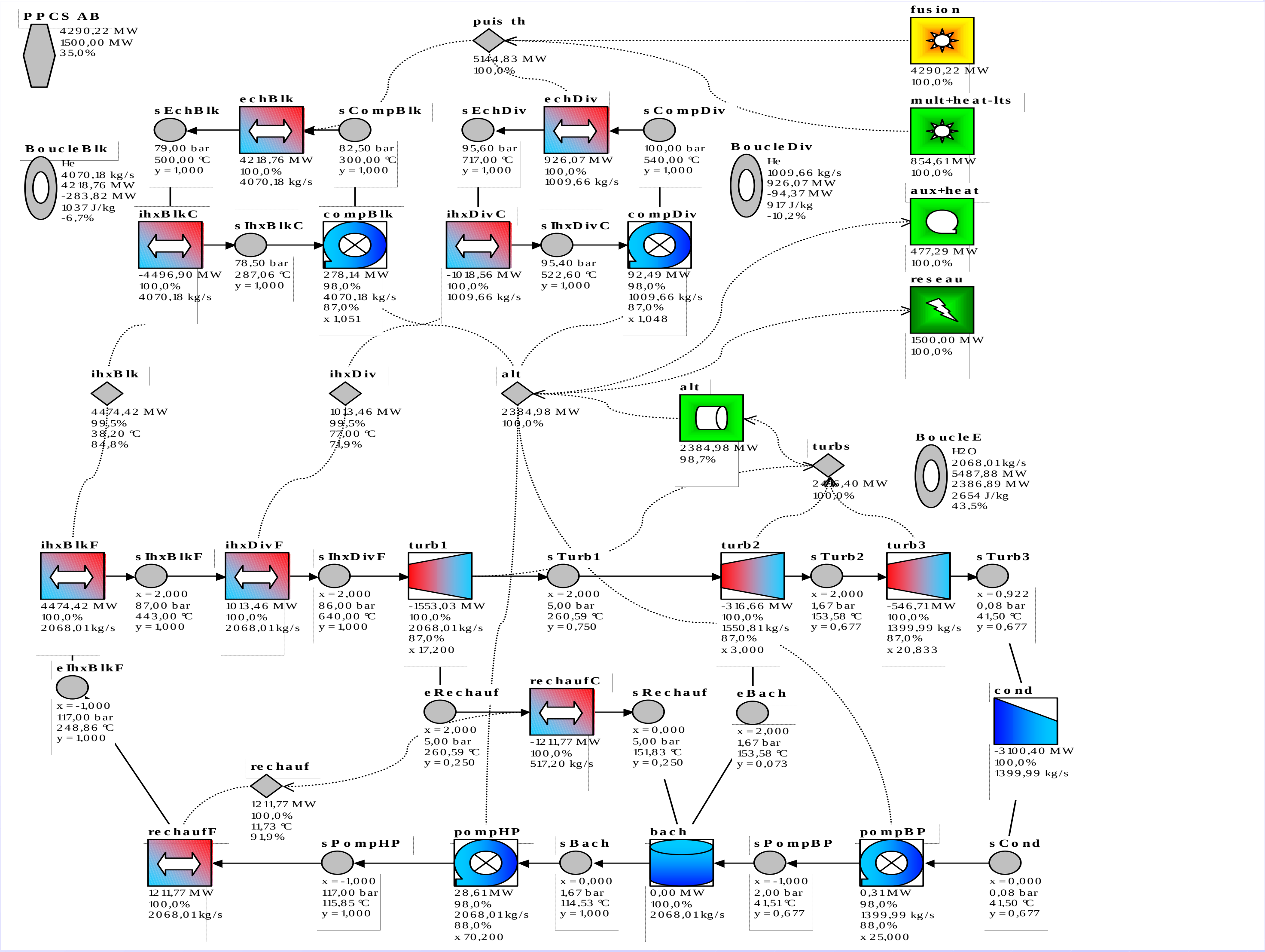
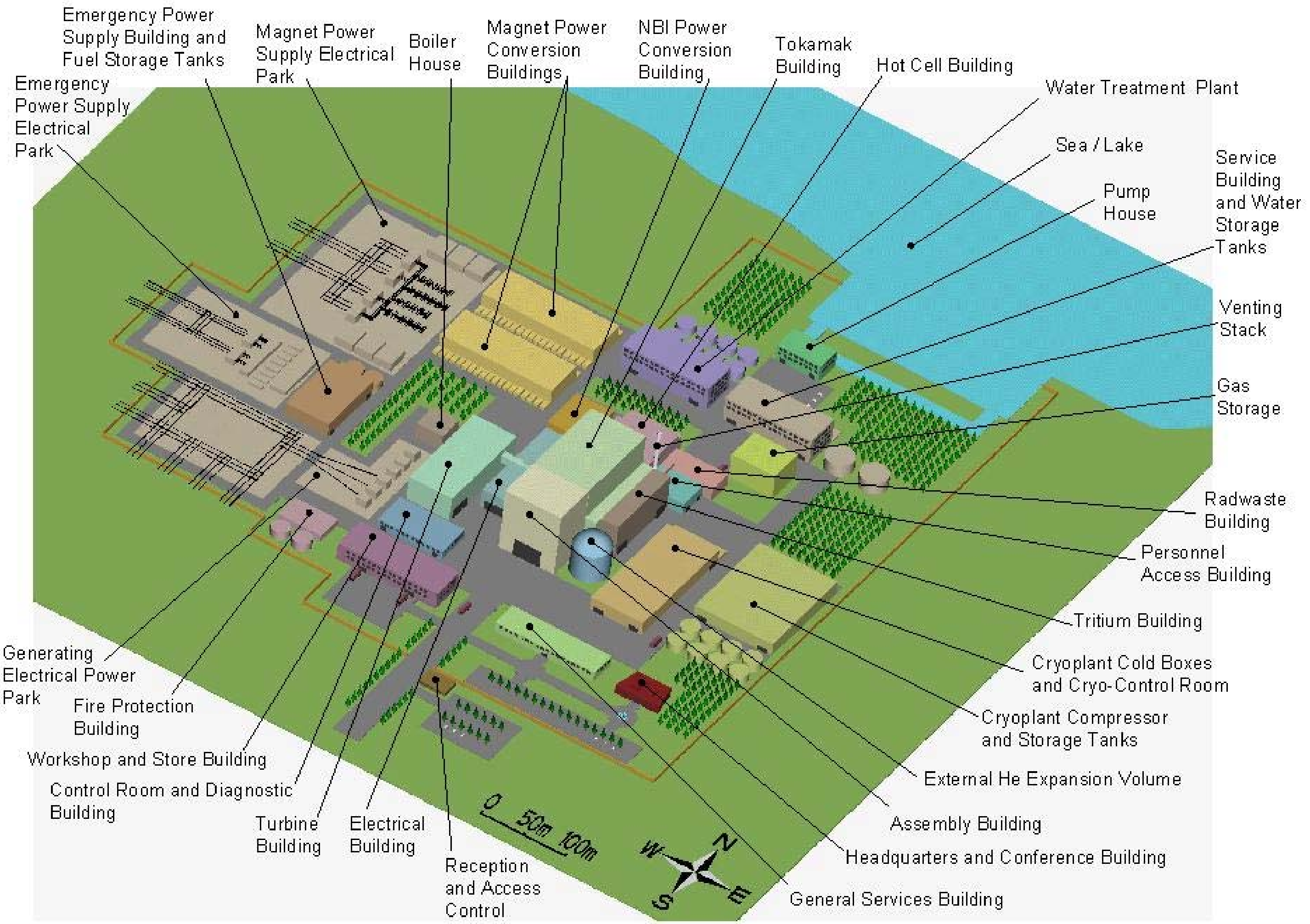
Power conversion (model AB)



Model AB: R&D needs

- Development of a HHF Helium-cooled divertor
- Open questions related to technology
  - blanket fabrication issues
- Materials

Plant general layout

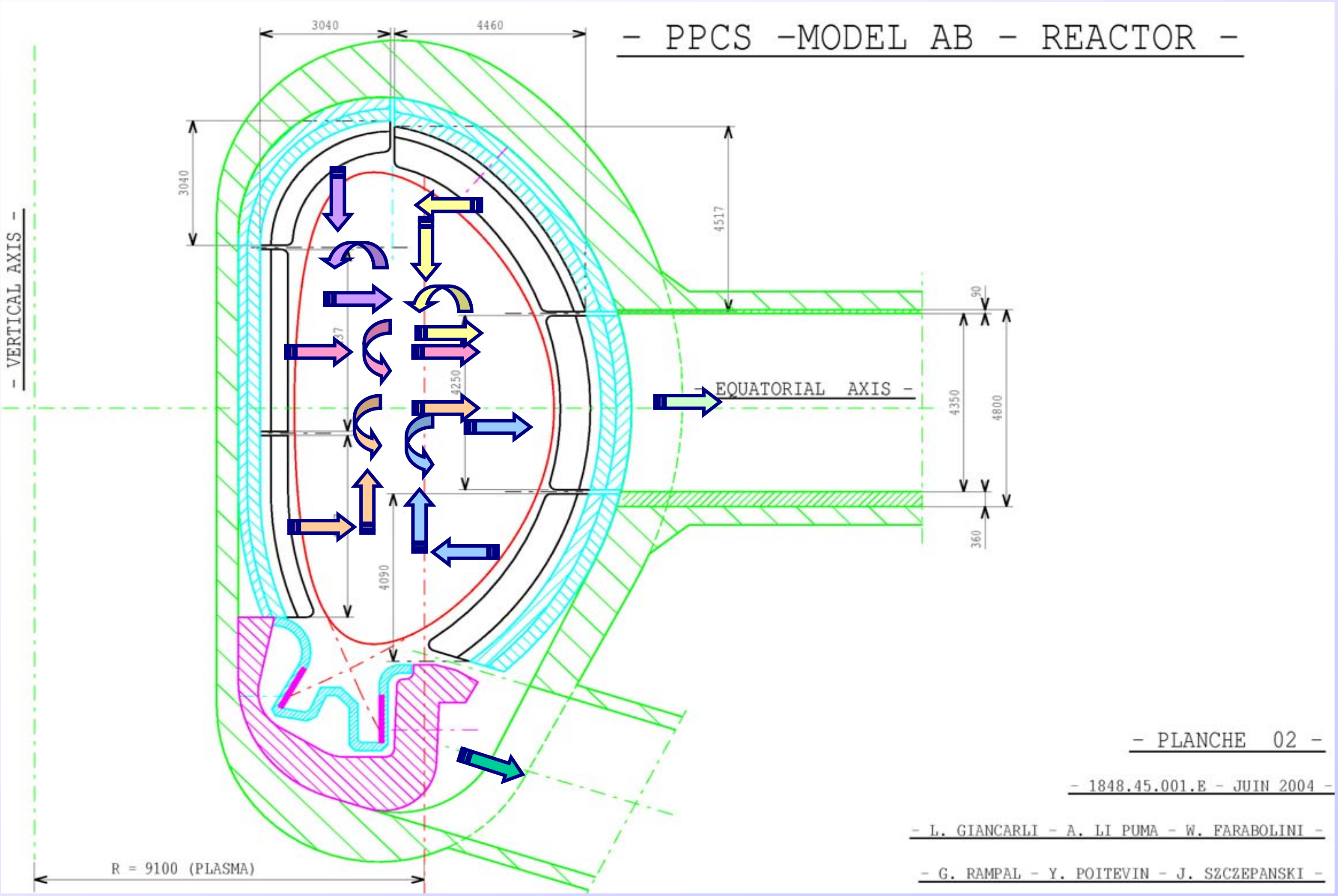


Maintenance scheme

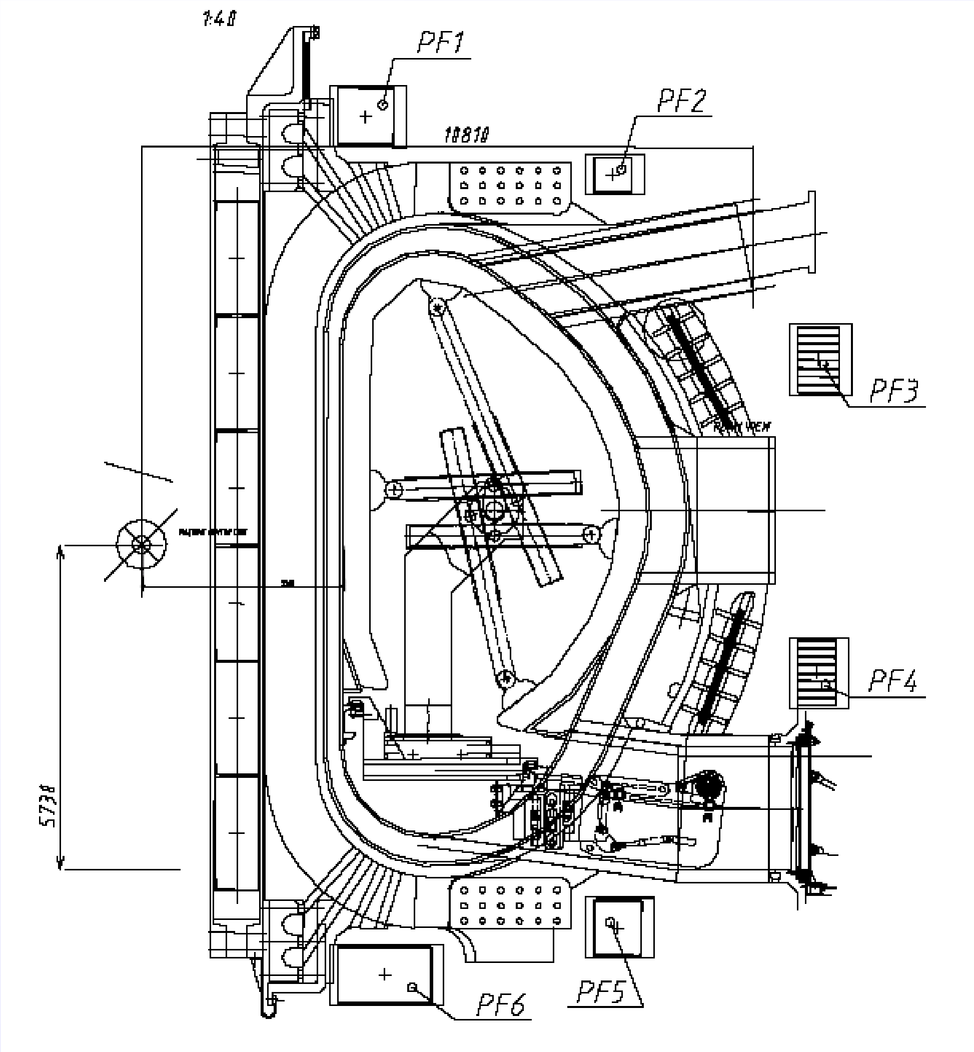
- Large sectors
  - Minimize the number of items to be replaced
  - Availability: 76.5 % - 81.2 % (12 days to replace one sector)

- Segmentation
  - A too large number of modules (like in ITER: 420) would not allow to reach the availability target
  - For the PPCS, the “large modules” maintenance concept has been considered

Handling Sequence



Handling device for large modules



Conclusions

- Models A, B and AB meet the overall objectives of the PPCS (design, safety, economics)
- R&D is needed
  - Materials
  - He cooled divertor
  - Attachment system
  - …