Systems Code Status

J. F. Lyon, ORNL

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Topics

- Status at January meeting and requested revisions and additions
- Systems code changes since last meeting
- Parameters for present ARE case
- Effect of parameter variations
- Work in progress, further refinements needed

Completed Action Items from Last Meeting

1. Use 50 MWe for Miscellaneous Reactor Plant and BOP Power -- *added 5 MW per Laila*

2. Adopt 5 cm for cryostat thickness

3. Use 76% plant availability until a detailed availability assessment is conducted.

6. Try to increase radiated power fraction with the goal of >70%.

7. Add 0.5 cm to coil-coil distance.

9. Update coverage fractions for full blanket, transition, and shield-only zones.

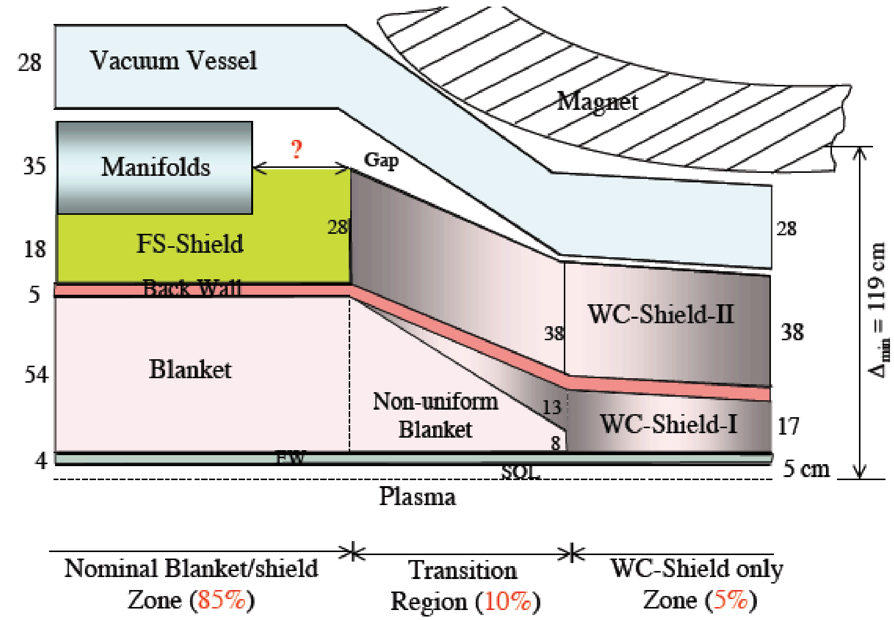
10. Increase FS shield thickness: 18 cm $\Rightarrow$ 28 cm

Code Changes Since Last Meeting

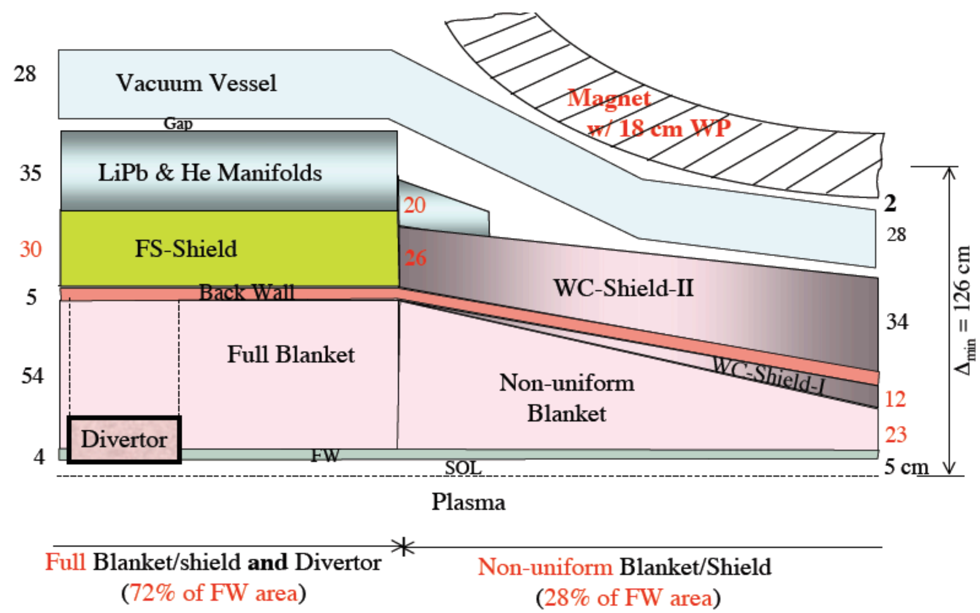
- **Replaced 3-region blanket/shield/manifold model with newest 2-region tapered model including divertor region**
- **Optimized Fe % to maximize radiated power fraction and decrease power to divertor**
- **Two interpretations of ISS-95 stellarator scaling**
- **Variation of TBR, % full blanket coverage with $\langle R \rangle$; new calculation of R_{min}**
- **Added cryostat, lowered maximum $p_{n,wall}$, increased divertor fraction**

Change in Blanket/Shield/Manifold Model

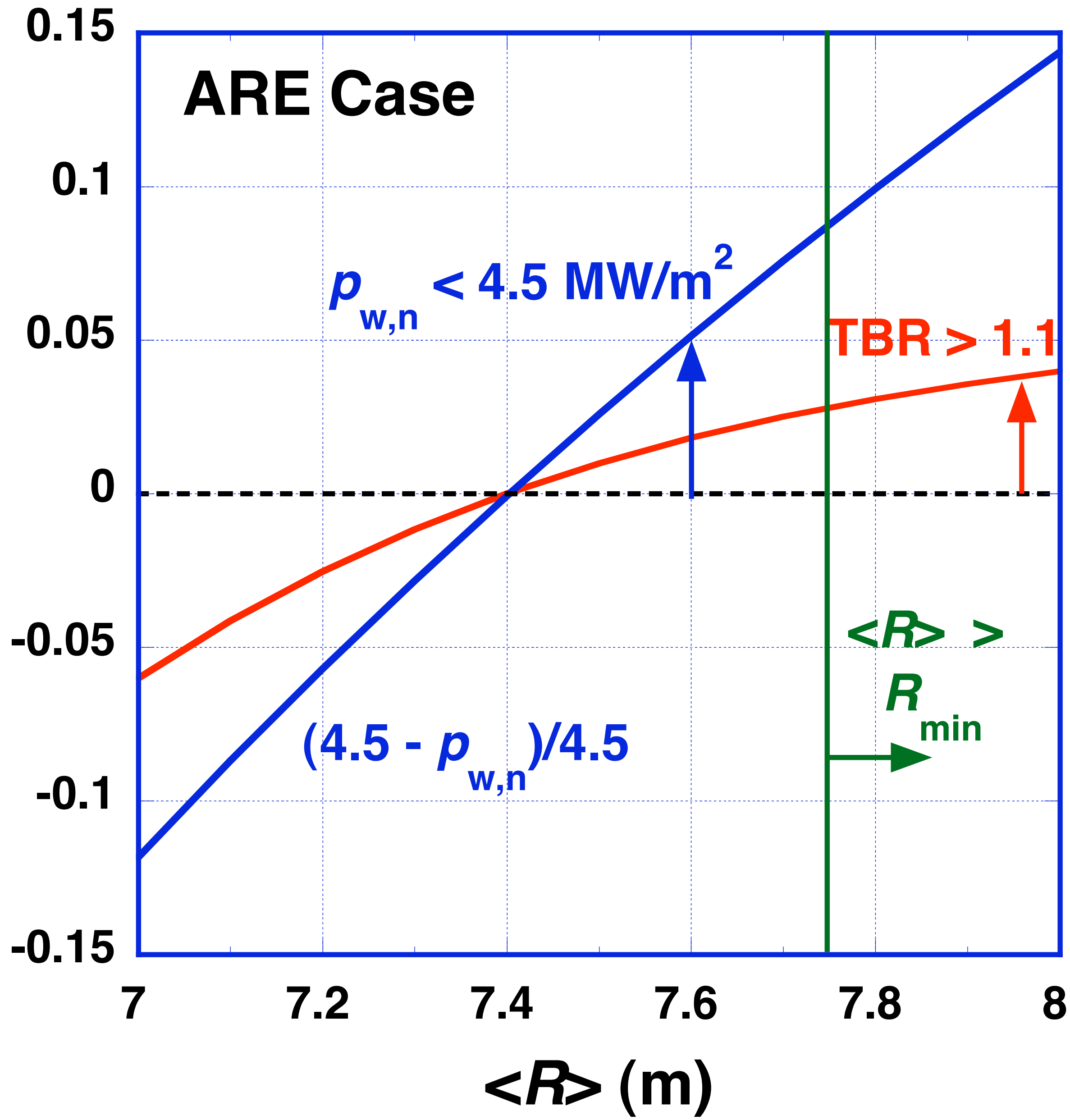
- **3-region blanket/shield/ manifold model**



- **New 2-region tapered model including divertor**
  - **New R_{min} value**



$\langle R \rangle$ set by R_{min} = 7.75 m



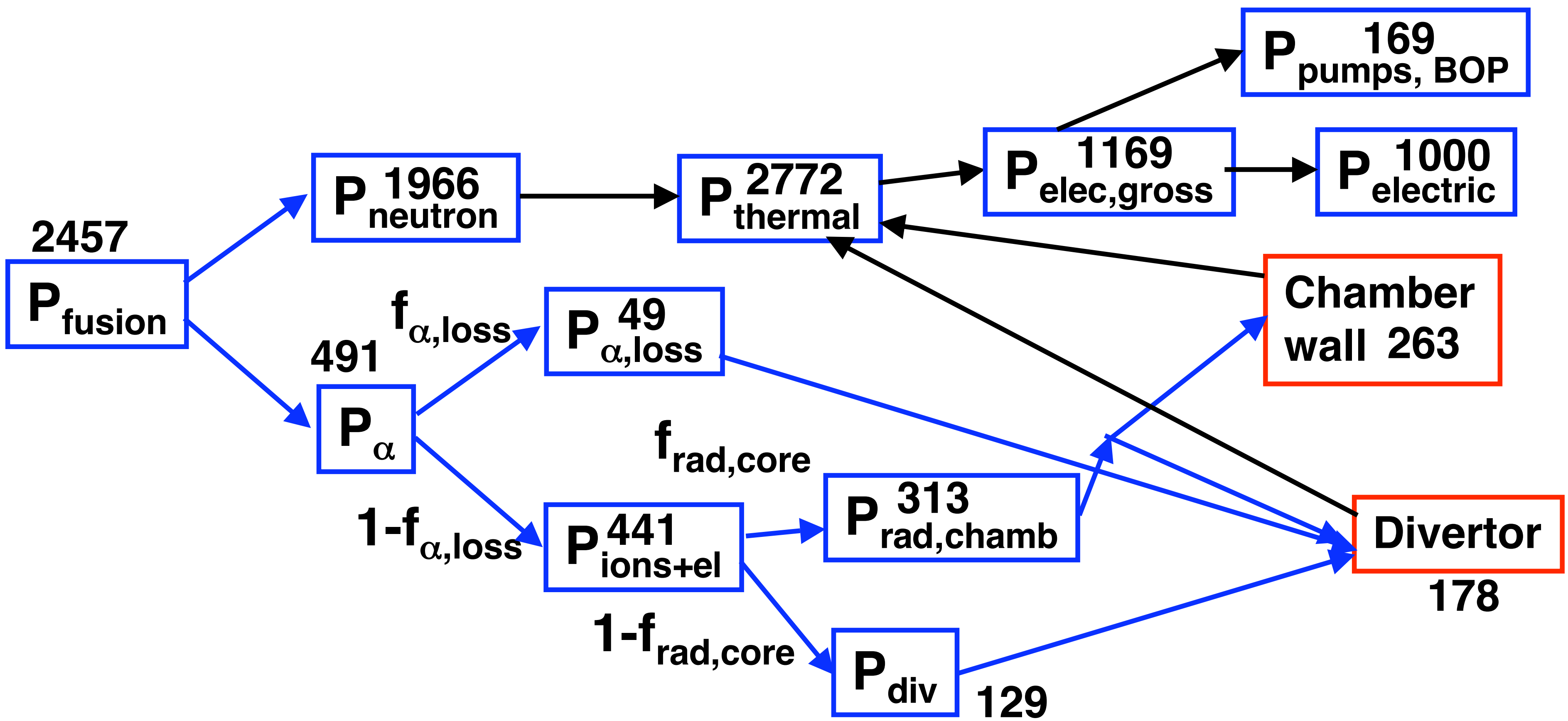
Present vs Previous ARE Case

- Larger $\langle R \rangle$ due to TBR constraint and new blanket/shield/manifold geometry

	April	January		April	January
$\langle R \rangle$ (m)	**7.75**	**7.06**	% P_{rad}	**75.0**	**37.9**
$\langle B_{axis} \rangle$ (T)	5.41	5.93	TBR	**1.128**	**<1.1**
$\langle n \rangle$ 10^{20}m^{-3}	2.11	3.11	R/R_{min}	**1.000**	**1.005**
$\langle T \rangle$ (keV)	8.88	7.16	COE	98.3	81.7
H-ISS95	1.83*	2.02	τ_E (s)	0.88	0.79
% Fe	**0.062**	**0.005**	P_{rad} (MW)	**368**	**188**
$p_{n,max}$ MW/m^2	4.11	5.00	P_H (MW)	141	154
$n/2n_{Sudo}$	0.57	0.70	P_{Fe} (MW)	225	33.4
j_{SC}/j_{max}	1.00	1.00	P_{cond} (MW)	73.6	259
B_{max} (T)	14.71	15.67	P_{div} (MW)	**178**	**328**

* 3.73 if P_{rad} subtracted from $P_\alpha(1-f_{loss})$

Power Flows for Present ARE Case



Use of ISS-95 Stellarator Scaling

- Using $\tau_E = W_{pl}/P_{heating} = \mathrm{H}\tau_{ISS\text{-}95}$ where

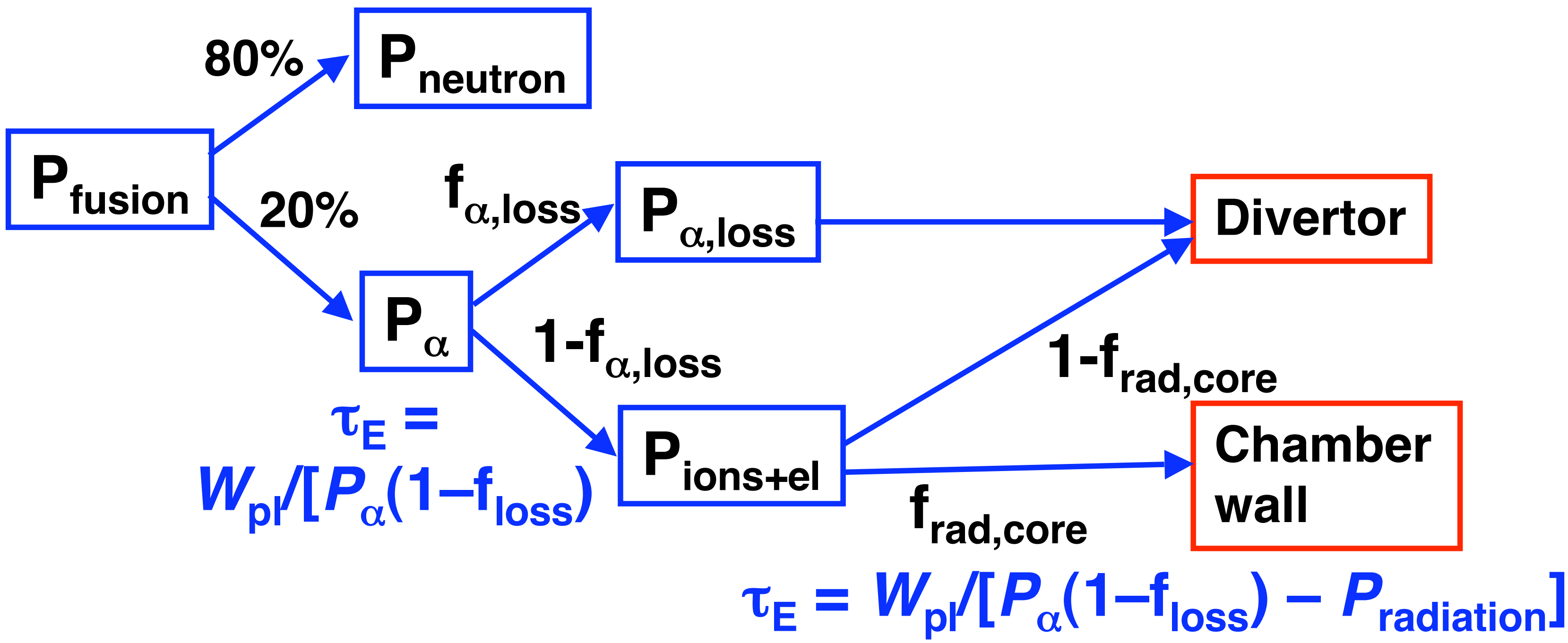
  $\tau_{ISS\text{-}95} = 0.079\ a^{2.21} R^{0.65} P_{MW}^{-0.59} n_{19}^{0.51} B^{0.83} \iota^{0.4}$

- ISS-95 scaling was obtained from a large number of stellarator discharges with *low* radiated power

- We want *high* radiated power fraction (>70% if possible) to reduce power load on divertor
  - W 7-AS had 90% f_{rad} in high density H-mode
  - accomplished in code by increasing n_{Fe}/n_e

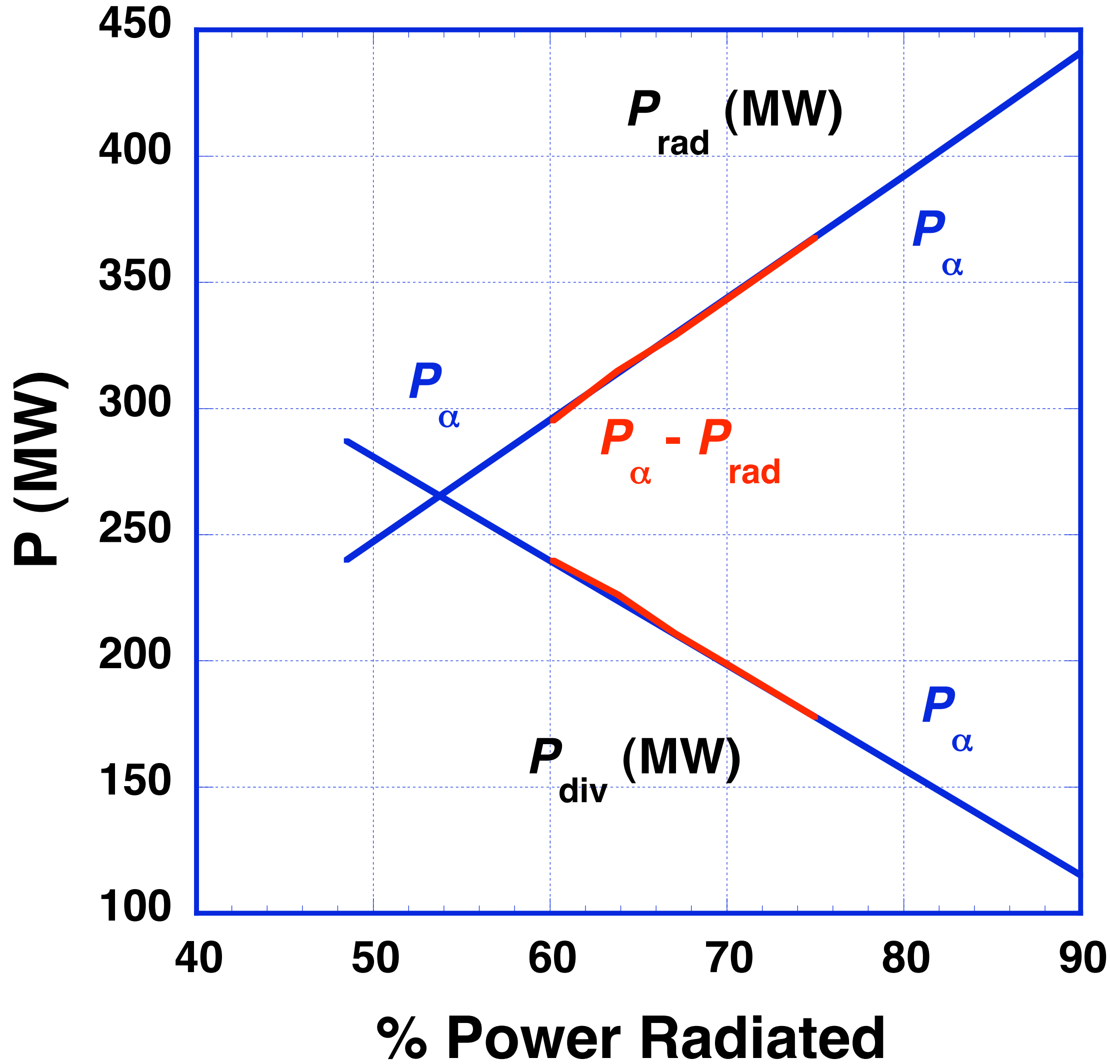
Systems Code Power Flows

- **Two ways to use ISS-95 stellarator scaling**
  - $P_{heating} = P_{\alpha}(1-f_{loss})$ **standard**
  - $P_{heating} = P_{\alpha}(1-f_{loss}) - P_{radiation}$

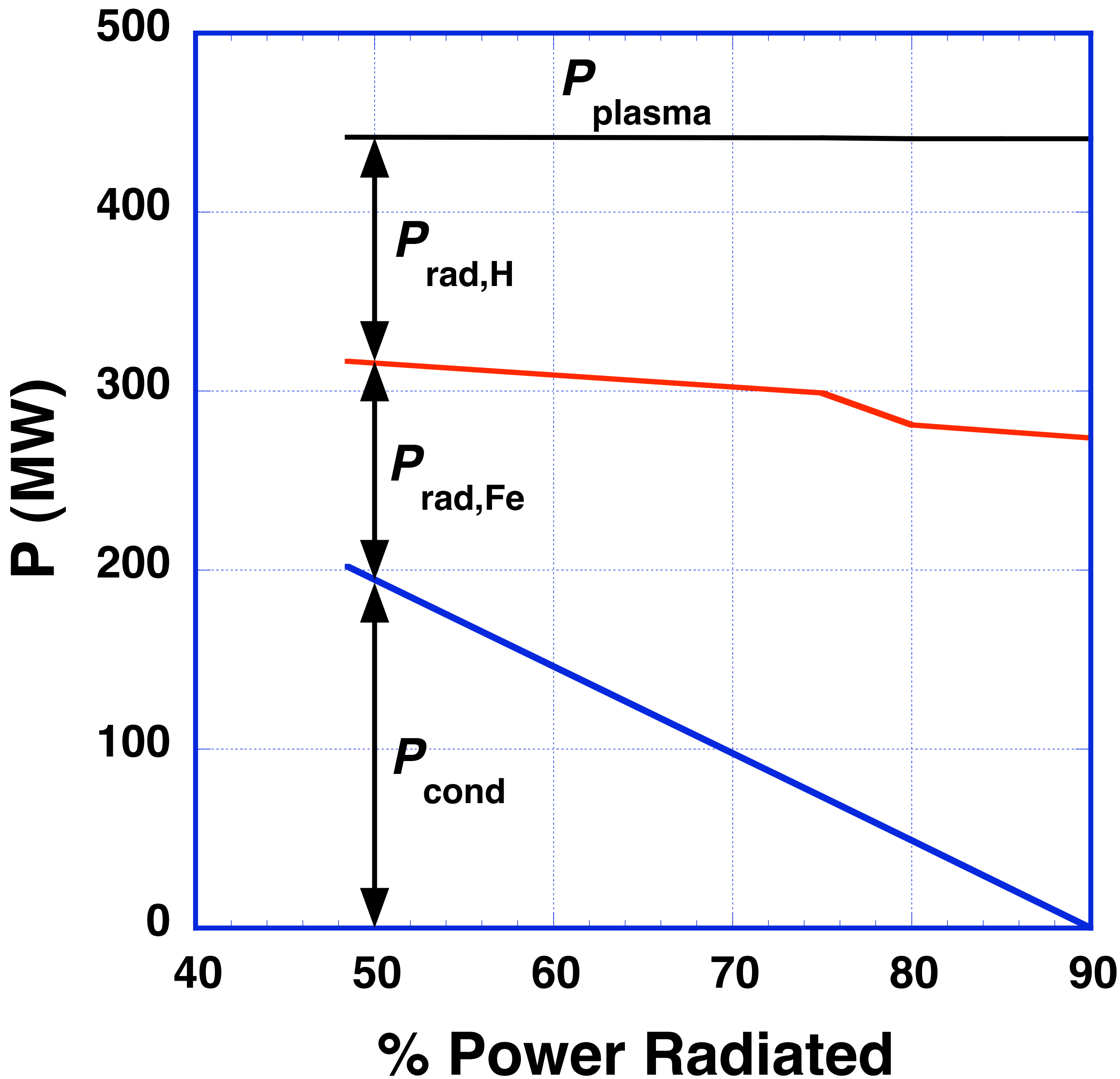


Maximized Radiated Power Fraction

- Optimized Fe % to maximize radiated power fraction and decrease power to divertor

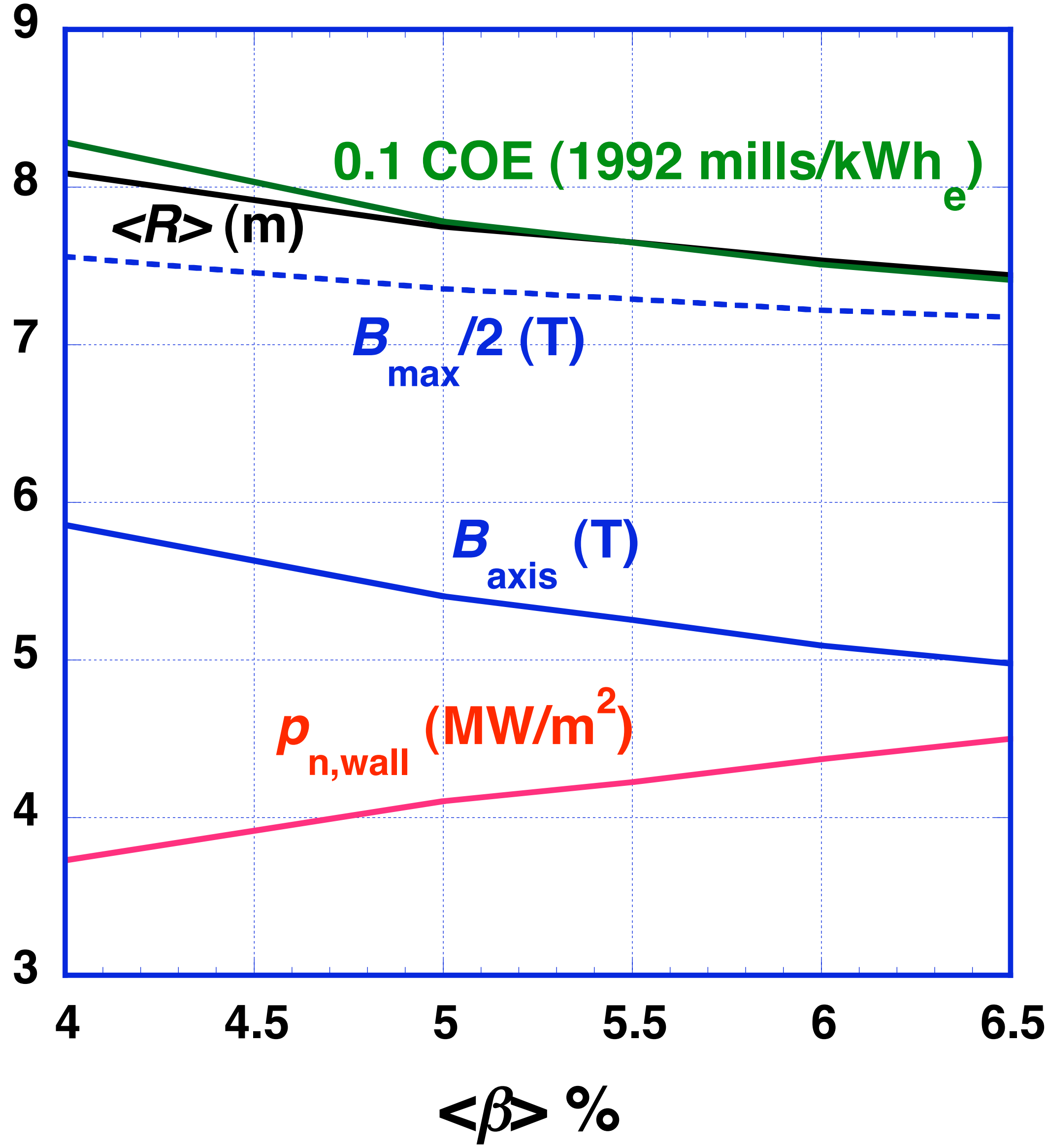


Variation With Radiated Power Faction

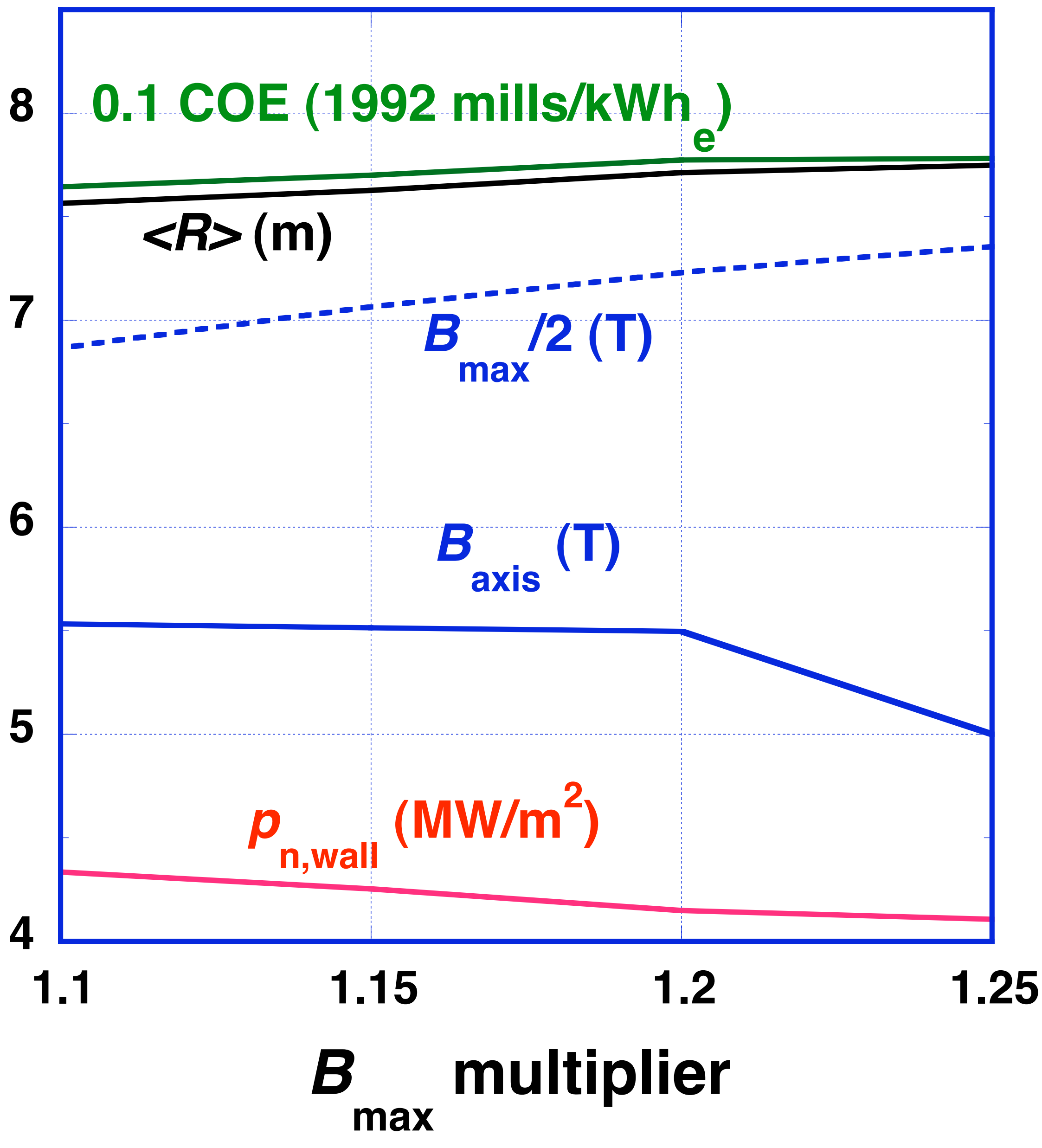


Sensitivity to ⟨β⟩ Limit

- **Constraints meet limits at ⟨β⟩ = 6.5%**



Parameters Relatively Insensitive to B_{max} Multiplier



Calculation of Neutron Source Profile

- **A toroidally-symmetric circular plasma is assumed in calculating the neutron source distribution $S_n(r) = n_D n_T \langle \sigma v(T(r)) \rangle$ inside plasma**
  - a sophisticated UW code then calculates neutron transport to 3-D wall, blankets and shields
  - this gives $p_{n,max}/\langle p_n \rangle_{wall} = 1.52$, which constrains $\langle R \rangle$ and can determine its value

- **A more accurate approach is proposed**
  - use AJAX code to calculate $\psi(x,y,z)$, hence n, T and $S_n(x,y,z)$ for the source sampling used in the UW neutron transport code
  - uses VMEC coefficients from L-P Ku (or from VMEC module inside AJAX)

Pending Action Items from Last Meeting

4. Research and correct replacement cost
5. Estimate COE for full blanket coverage as a reference point to justify complexity of a shield only zone.
8. Use cheaper FW heating approach instead of ECH for plasma startup.

Future Action Items from Last Meeting

1. **Add ν^*, B, R, and β corrections to α-particle loss**
2. **Near end of study, vary $P_{electric}$ up to 1.5 GW or more and look at NbTi at higher β.**
3. **Vary shield thickness with p_{wall}, blanket coverage, radial build, etc. when numbers available from Laila *-- done*.**
4. **Change coil support structure when better model available from Xueren/Les.**
5. **Generate parameters for advanced LiPb/SiC design with 58% thermal conversion efficiency (check with Laila).**
6. **Generate parameters for 2-PF configurations (get radial build from Laila).**

Other Additions, Refinements Needed

- **VF or control coils not considered yet in designs, needed for startup?**
- **Revision of manifold design, wall peaking?**
- **Better calculation of $B_{max}/\langle B_{axis}\rangle$**
- **Divertor power peaking and additional costs?**
- **Geometry for field period maintenance**
- **Calculation/comparison with HSR parameters**

Summary

- Addressed most of the revisions and additions requested at January meeting
- Added new features to systems code
- Revised ARE case
- Effect of parameter variations
- Work in progress, refinements needed