Reactor Issues

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REACTOR CONSTRAINTS

- **A configuration is characterized by the shape of the LCFS and the aspect ratios $A_p = R_0/\langle a \rangle$ and $A_\Delta = R_0/\Delta$**

  Here A_Δ is a geometrical quantity for a given coil configuration, and Δ is the minimum *space* between the coil winding surface and the LCFS for a given R_0

- **A minimum *physical* distance D is needed between the LCFS and the center of the coil centers**

  Assume $D \geq 1.6$ m for plasma scapeoff + wall + blanket + shield + thermal insulation + coil case + assembly distance + half the coil radial depth, etc.

- **P(fusion) = $[P_f]$**, usually a fixed goal, corresponding to 1 or 2 GW electric.
  $[P_f] \quad \beta^2 \times A_\Delta^3/A_p^2 / (B_{max}/B_0)^4$.

  This follows from $[P_f] \quad \beta^2 \times B_0^4 \times$ Volume
  $\beta^2 \times [B_{max}^4] \times (B_0/B_{max})^4 \times R_0 a^2 \quad \beta^2 \times R_0^3/A_p^2 / (B_{max}/B_0)^4$
  $\beta^2 \times A_\Delta^3/A_p^2 / (B_{max}/B_0)^4$.

- **Average neutron wall loading $[p_w] \quad [P_f] / (A_p/A_\Delta^2) \quad (p_w \leq 5\ MW/m^2)$**

  This follows from $[p_w] \quad [P_f]/R_0 a \quad [P_f] \times A_p/R_0^2 \quad [P_f] / A_p/A_\Delta^2$.

- **Maximum field on the coils ($B_m \leq 16$ T)**

- **Volume-average beta ($\beta \leq 5\%$)**

WHAT CONSTITUTES AN ATTRACTIVE COMPACT REACTOR?

- **The minimum reactor size R_0 = A_Δ x [D] A_Δ**

- **The minimum reactor cost [Cost] A_Δ^2/A_p $[P_f]/[p_w]$**

  This follows from Reactor Cost (blanket + shield area) x [thickness]

  R_0 x a R_0^2/A_p A_Δ^2/A_p

- **So minimum A_Δ^2/A_p gives the minimum [COE] (cost of electricity) for fixed $[P_f]$, which means maximizing β^2 x A_Δ/A_p / $(B_{max}/B_0)^4$**

- **If $[P_f]$ can vary, the minimum COE A_Δ^2/A_p / $[P_f]$ 1 / $[p_w]$, which is the same result**

  β^2 x (A_Δ/A_p) / $(B_{max}/B_0)^4$ $[p_w]$ 1 / [COE]

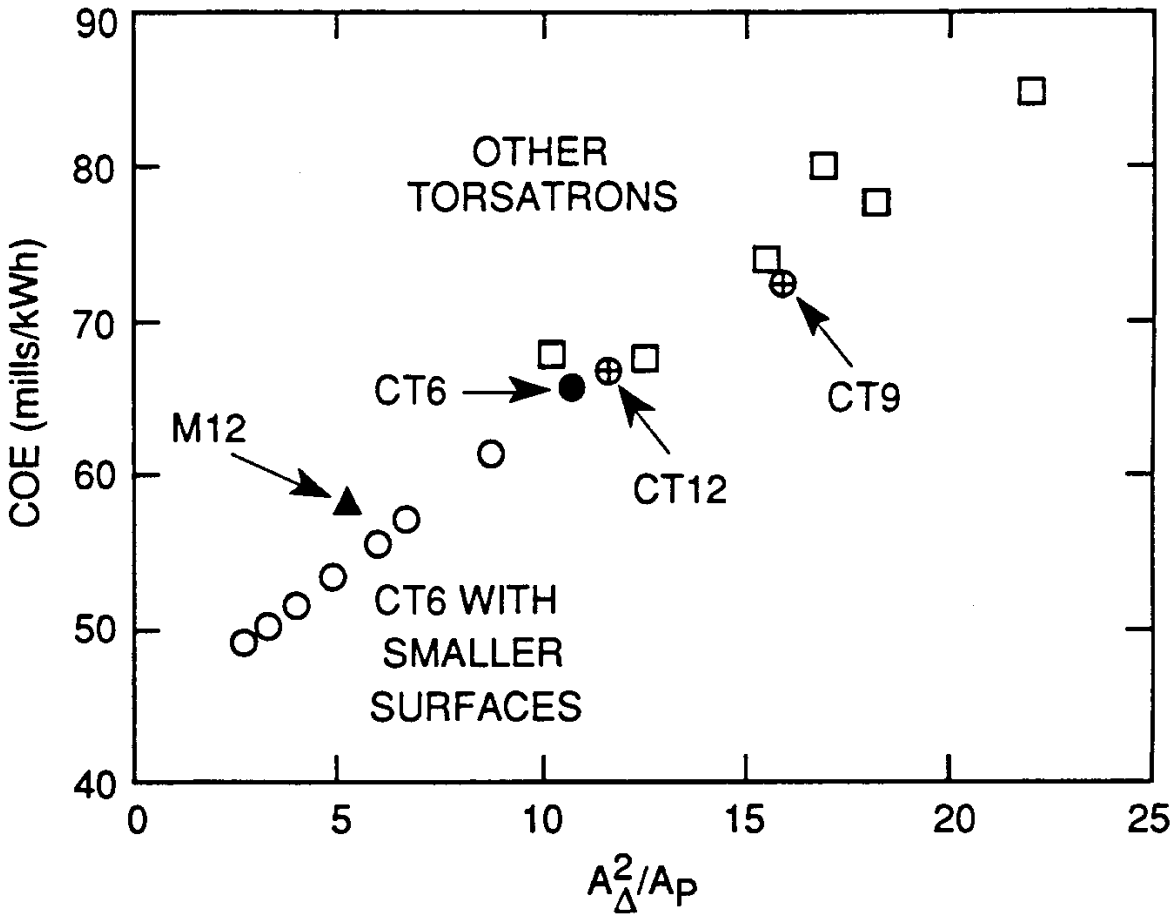
So increasing reactor attractiveness means minimizing

(A_p/A_Δ) x $(B_{max}/B_0)^4$ / β^2 for COE, not A_p.

- **Minimizing A_p/A_Δ and $(B_{max}/B_0)^4$ are as important as maximizing β^2.**
- **A_Δ and (B_{max}/B_0) are inversely related because increasing Δ reduces A_Δ and increases (B_{max}/B_0)?**

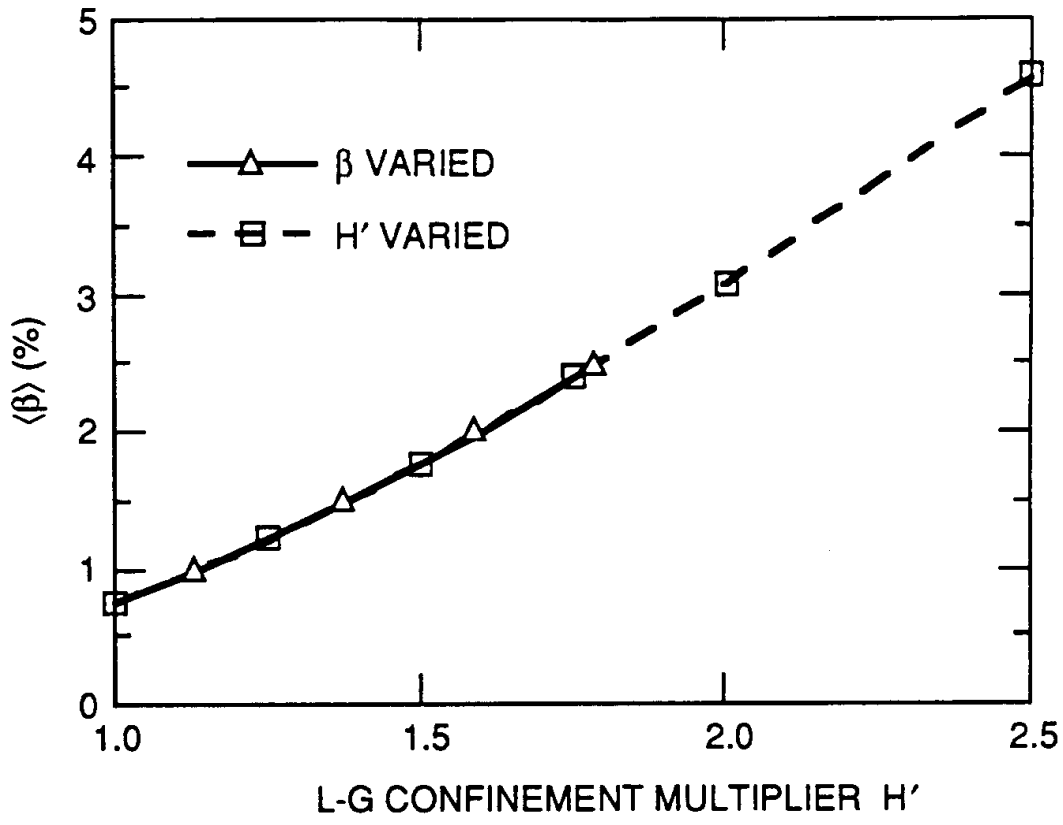
  Need to study variation of (B_{max}/B_0) with A_Δ

Cost of Electricity Depends on A_Δ^2/A_p



- **Minimized COE for fixed fusion power**

Beta and Confinement Multiplier are Coupled



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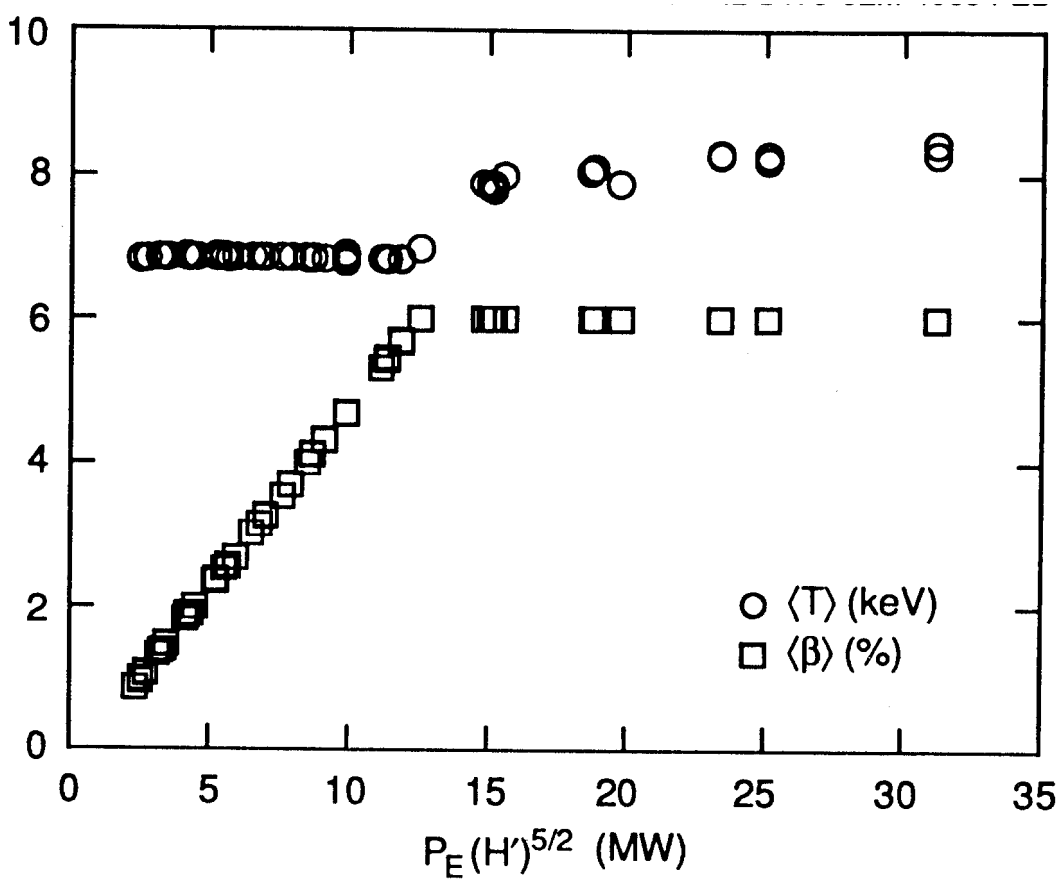
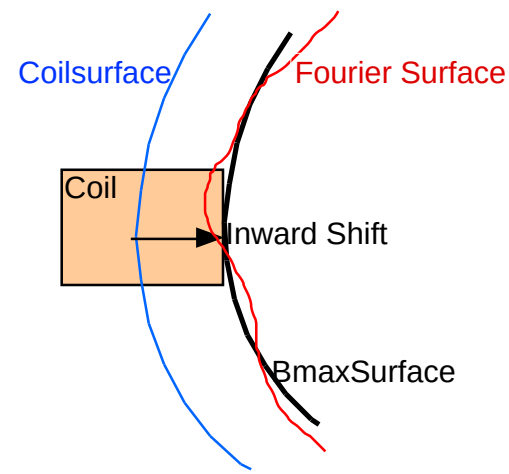


- **Minimized cost of electricity**

Calculation of B_{max} at coil surface / B_o in plasma using nescoil

P. Valanju, D. Williamson, A. Brooks, W. Reirson, Jim Lyon

- Calculation of $B_{max}/\langle B_o \rangle$ has been implemented within Nescoil using modified nescoil green's function.
- This can now be used within an optimizer.
- B_{max} is calculated on a surface generated from the current-carrying surface at coil center by shifting by 1/2 coil radial depth in the inward normal direction.
- $\langle B_o \rangle$ = flux-surface rms of B_o.
- Benchmarked against solid coil model by Dave Williamson.
- Jim Lyon to provide reactor scenarios (A, Δ, coilbuild, B_o etc) to study.



Reactor Scoping Studies

- **Determine B_{max}/B_0 vs Δ for**
  - **QA sheet-current configurations with A_p = 2.1, 3.6, 3.9**
  - **modular-coil QO configurations with A_p = 3.3, 4.8**
  - **modular-coil QA configurations when available**
- **Model variation of B_{max}/B_0 vs Δ for optimization calculations**
- **Simple 0-D spread sheet reactor optimization**
- **Full systems code reactor optimization (OPTOR)**

  (minimize COE: ARIES algorithms, benchmark with ARIES-RS)
  - **simple 0-D transport models**
  - **solve for T_e(r) and T_i(r) for 1-D anomalous $\chi_{e,i}$ and electric-field-dependent $\chi_{e,i}$ with fixed n(r), φ(r): Shaing, Hitchon**
  - **Self-consistent solution for T_e(r),T_i(r), n_e(r), n_i(r), and φ(r) with fixed particle source (pellets or gas)**
  - **study sensitivity to transport models and energetic losses**
- **ARIES group to look at impact of key issues**