Plans for SOL and Target Parameter Estimates: 1D Modeling and Field Line Tracing with Diffusion

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SOL upstream and target parameters can be estimated using a 1D parallel conduction model ("Two point model")

- Assumptions:
  - Conduction parallel to field lines dominates over convection.
    - Good assumption for attached target conditions
    - Breaks down when target detaches
  - Stagnant flow upstream (midplane) and M=1 flow at target.
  - Te = Ti at the target
  - Pure hydrogen plasma
  - No radiative losses along the SOL
  - Power enters into the SOL uniformly along flux tube
- Equations for T_upstream, T_target, n_target can be formulated in terms of P_injected, n_upstream, connection length (Lc)
  - We follow Stangeby, The Plasma Boundary of Magnetic Fusion Devices, IoP Publishers, 2000 (Chapters 4 and 5).

Two-Point Open Field-Line Model (e.g., Stangeby)

(Subscript u is at core boundary; t is at material target)

- **Parallel momentum balance gives:**

$$n_t T_t = n_u T_u / 2$$

- **Electron parallel thermal conduction gives:**

$$T_u = \left(\frac{7}{2} \frac{q_\parallel L_c}{K_{0e}} + T_t^{7/2} \right)^{2/7}$$

- **Energy lost to through target sheath gives:**

$$q_\parallel = \delta_E n_t k T_t C_s$$

where $q_\parallel = (P_{core}/A_{pol})(B/B_{pol})$**,** $C_s = (2T_t/m_i)^{1/2}$**, and** $\delta_E \approx 7$

- **For** $T_t < T_u/2$

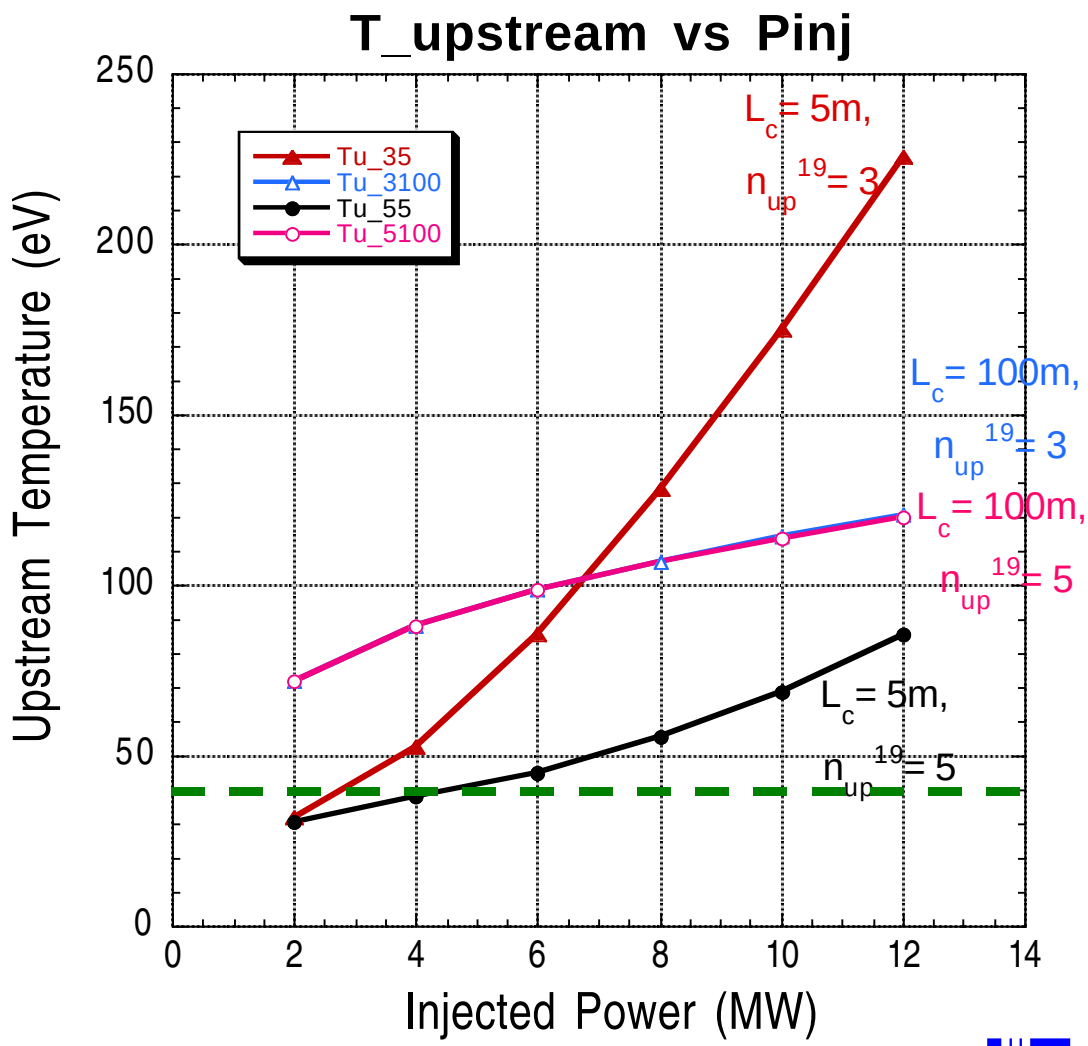
$$T_u = \left(\frac{7}{2} \frac{q_\parallel L_c}{K_{0e}} \right)^{2/7}$$

- **Target** T_e **is then**

$$T_t = \frac{2 m_i}{\delta_E^2 n_u^2 e^3} \, q_\parallel^2 \left(\frac{7}{2} \frac{q_\parallel L_c}{K_{0e}} \right)^{-4/7} \propto (q_\parallel)^{10/7}$$

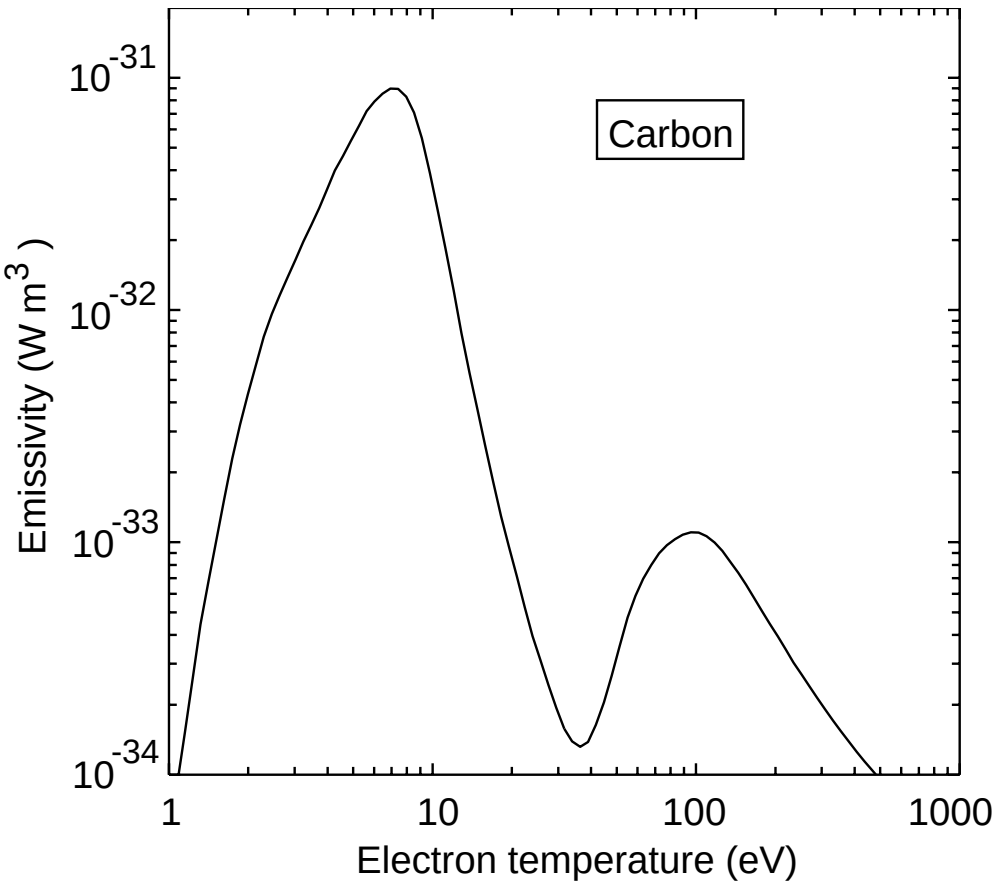
The Two Point Model indicates low power or short connection length may lead to core radiative collapse.

- Initial field line tracing results from Art Grossman showed that for a 4cm conformal wall Lc might be as low as 5 m (field line strikes 4cn wall within one field period).
- Wall at 10 cm allows many toroidal transits (Lc > 100m)
- Calculation assumptions:
  - R_{eff}=1.7, a_{eff}=0.35 m
  - $\lambda_{||}$ = 2 cm, γ=7
  - $Iota_{edge}$ = 0.5
  - $T_e = T_i$, f_{rad} = 0.2



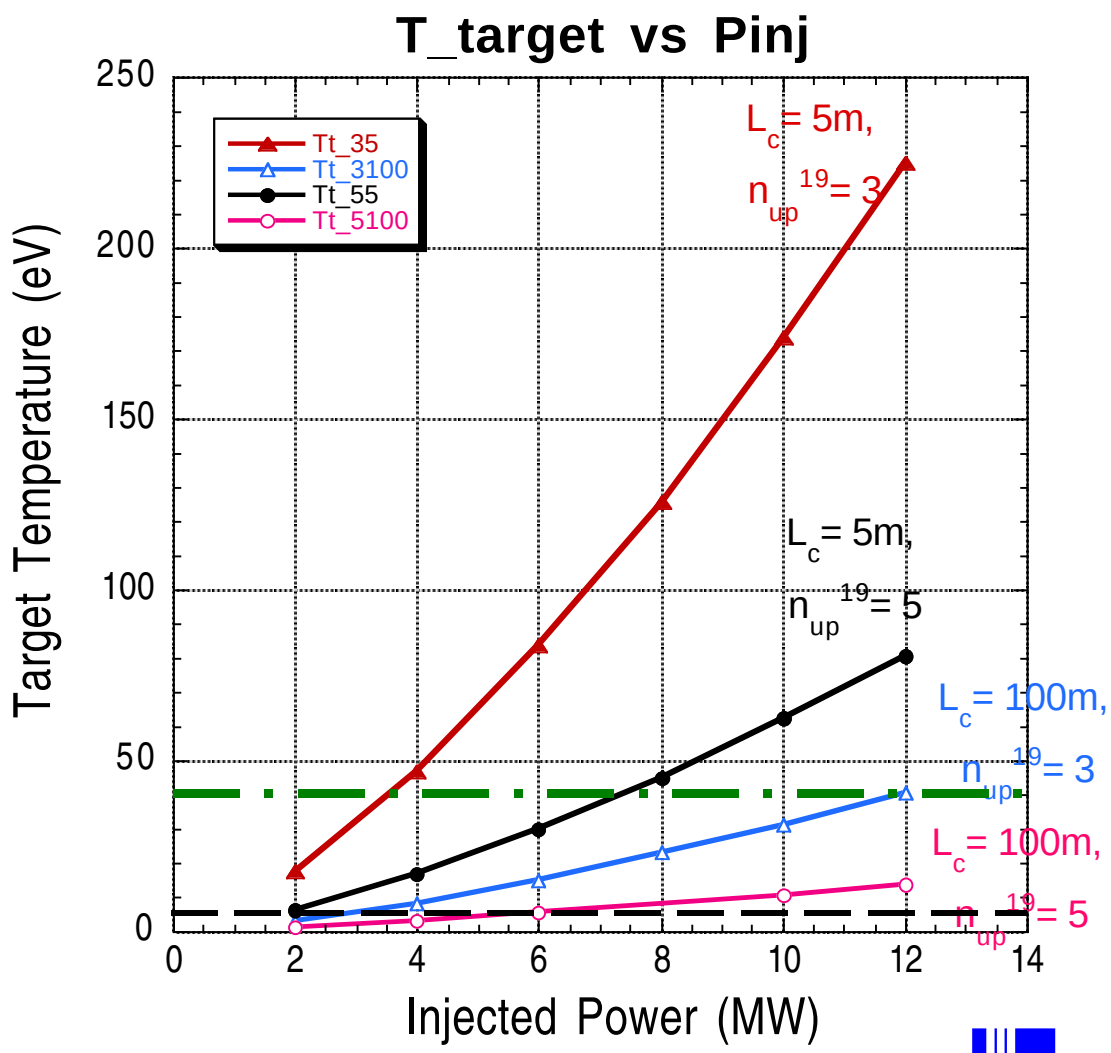
SOL near LCMS must be hot enough to burnout highly radiating charge states of carbon.

- For carbon impurity, upstream temperature must be > 40 eV to avoid negative slope of cooling curve
  - For T<40 thermal instability produces T~7 eV.
- DIII-D experience in high density operation shows core MARFE and sharp reduction of confinement when Tsep falls below 40 eV
  - Petrie PSI96 showed H-factor reduction by 2x concurrent with Tsep < 40 eV
  - SOL MARFE moved inside separatrix



High target temperature results from short connection length

- Target temperature should be kept below ~ 40 eV to minimize carbon sputtering source.
- T_target below 5 eV is likely detached - model breaks down.



Future Plans include continued 1D modeling and field line tracing with diffusion.

- Our 1D modeling work is just beginning.
  - Need to add effect of radiation along SOL flux tube
  - Need to look at particle fluxes and effect of recycling < unity

- Present field line tracing work (Grossman) indicates that Lc may be long enough that diffusive spreading will be important for peak heat flux estimates..
  - Kisslinger's latest version of Gourdon code with diffusion runs at LLNL for W7-X test case.
  - Code must be parallelized to allow ~ 1000 line tracings to wall intersection with diffusion in reasonable time
  - Koniges(LLNL) and Grossman (UCSD) working together to connect field line tracing with diffusion to results of MFBE calculation for Li383 1017a2
  - Need to incorporate wall design from engineering.

Summary: Recommendations a nd PVR writing

- **Recommendations:**
  - Try to achieve long Lc by allowing as much gap as possible between banana tips and nearby material boundary
  - This also prepares for installation of baffles and pumping in banana tips.
  - Improve accuracy of field calculations farther into the SOL so that Lc can be calculated accurately for field lines 2 - 3 cm out from LCMS at the midplane

- **PVR writing (in progress) will include:**
  - Section on long term plans to develop 3D fluid code for SOL plasma and neutrals,
  - 1D estimates of SOL and target plasma parameter scalings (memo to be issued shortly)
  - Other simple estimates of SOL parameters (neutral penetration, heat flux to targets etc.)