Divertor conditions near double null in Alcator C-Mod

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Double-null proposed to have benefits

• Core plasma preferentially exhausts power into boundary on the low-field side

• Double-null (DN) provides sharing of power between two outer divertors, with little getting to inner divertors
  • More total area, heat flux decreases with total magnetic field (1/R)
  • More room for ‘advanced’ magnetic divertors

• DN isolates inner scrape-off layer from intense boundary plasma
  • Excellent location for RF actuators
  • Reduced impurity penetration

• Few systematic studies, e.g., DIII-D (Petrie JoNM 2001) and MAST (Temmermen JoNM 2011)
Distance between separatrices mapped to the outer midplane ($S_{\text{sep}}$) is used to quantify degree of double-nullness

$S_{\text{sep}}$: distance between primary and secondary separatrix mapped to the outer mid-plane, also known as $\delta R_{\text{sep}}$

$\rho$: position of probe in flux space mapped to outer mid-plane
Use embedded Langmuir probes and strike-point sweeps to measure heat flux arriving at all divertor target plates

- Intra-shot sweep of x-points at fixed $S_{\text{sep}}$ to map out divertor profiles in $\rho$
- Shot-to-shot scan of $S_{\text{sep}}$ to map divertor profiles through double-null
- Perform in sheath-limited regime:
  - Minimal power dissipated in SOL
  - Langmuir probe heat flux measurements verified
Integrate probe parallel heat flux profiles to calculate power balance

• Sheath heat flux:
\[ q_\parallel = \gamma T_e J_{\text{sat}} \]

• Sheath heat flux transmission coefficient:
\[ \gamma = 2.5 + 2(1 - J_{\text{gnd}}/J_{\text{sat}}) - 0.5 \ln \left[ 4\pi m_e/m_i (1 - J_{\text{gnd}}/J_{\text{sat}})^2 \right] \]
Assessment of 0.8 MA L-Mode

- Power fluxes balanced at double-null ($S_{\text{sep}} \sim 0$ mm)
- $<10\%$ of total power fluxes to inner divertors at double-null
- For fixed $S_{\text{SEP}} \sim 0$ program, jitter is $+/-1$ mm, maintaining low power to inner divertor surfaces
As SOL heat flux width narrows, sensitivity to $S_{SEP}$ balance increases

- $I_p=0.55$ MA
- $\lambda_q \sim 4$ mm
- $\sim 12\%$/mm sensitivity

- $I_p=0.8$ MA
- $\lambda_q \sim 3$ mm
- $\sim 15\%$/mm sensitivity

- $I_p=1.1$ MA
- $\lambda_q \sim 2$ mm
- $\sim 17\%$/mm sensitivity
Qualitatively similar results for L- and H-modes

- Similar trends in L- and H-modes
- H-mode profiles steeper
- H-mode confinement degraded in ‘unfavorable’ drift direction
Inner/outer divertor power sharing in I-mode becomes more balanced near double-null

- I-modes found to have larger energy flux to inner divertor than outer (at large $S_{\text{sep}} \sim -10\text{ to } -20\text{ mm}$)
- Near-double-null has much better balance
  - <10% to inner divertors
  - 2:1 power sharing between lower and upper outer divertors

![Graph showing power sharing between inner and outer divertors](image-url)
Conclusions

• At double-null power ~equally shared between two outer divertors
• At double-null power significantly reduced to inner divertors (<10%)
• Can maintain acceptable power balance within control system jitter in magnetic balance
• Sensitivity of power balance varies with SOL width (i.e., plasma current)
• Similar results in L- and H-modes
• Can operate I-mode close enough to double-null to significantly reduce power to inner divertors and have a reasonable (2:1) balance between outer divertors