NSTX

Fusion Energy Sciences

Supported by

U.S. DEPARTMENT OF ENERGY

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Development of advanced scenarios with advanced divertors

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Acknowledgements: NSTX Team

NSTX Research Forum
Princeton, NJ
Wednesday, 16 March 2011

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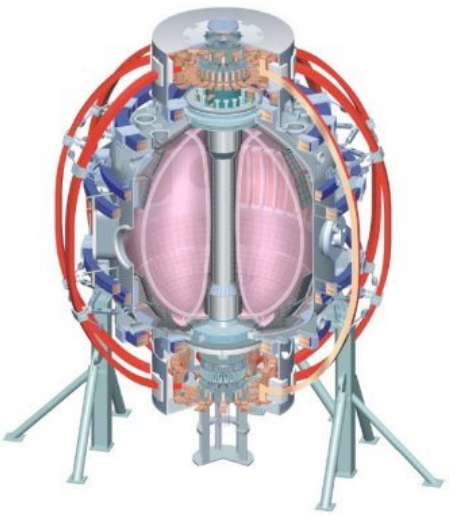

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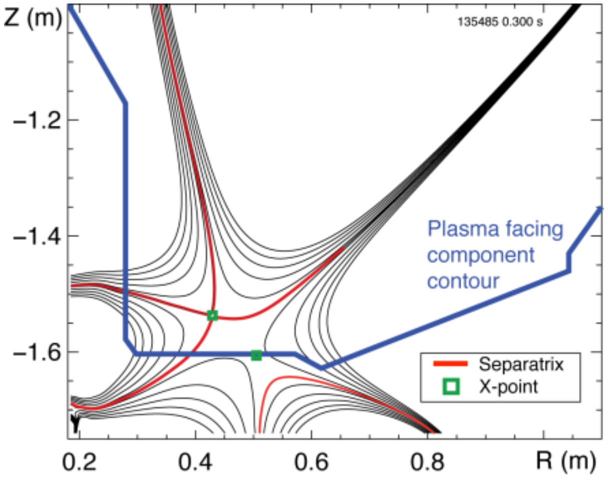
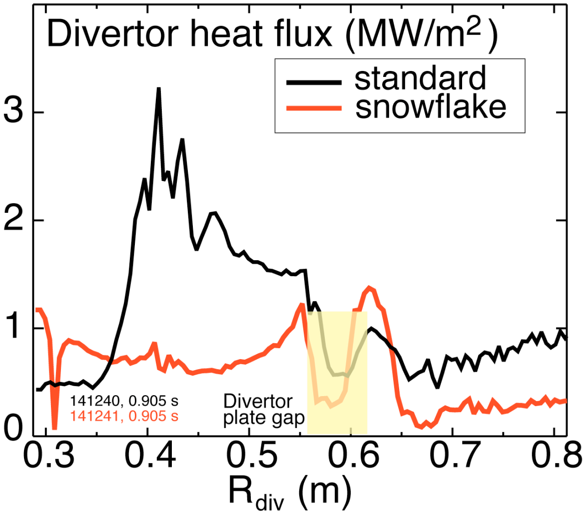
NSTX studies suggest the snowflake divertor configuration may be a viable solution for present and future tokamaks

- Steady-state snowflake (up to 600 ms, many τ_E's) with three coils
- Good H-mode confinement (H98(y,2) ~ 1)
- Reduced core/pedestal carbon concentration
- Change in pedestal MHD stability and ELMs
- Significant reduction in peak steady-state divertor heat flux (from 4-8 to - 0.5-1 MW/m^2)
- Reduction in ELM heat and particle fluxes
- Potential to combine with radiative divertor for increased divertor radiation





NSTX milestone R(11-3) to assess high-flux-expansion divertor operation

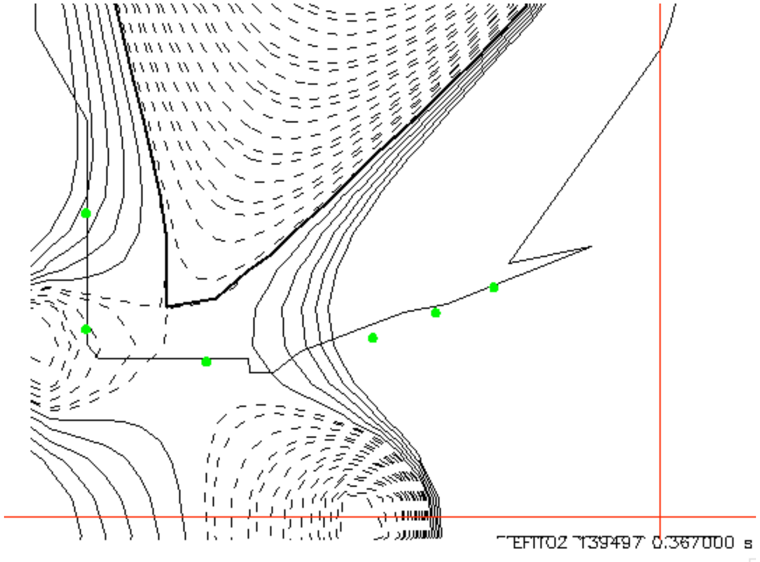
The exploration of high flux expansion divertors for mitigation of high power exhaust is important for NSTX-Upgrade, proposed ST and AT-based fusion nuclear science facilities and for Demo. In this milestone, high flux expansion divertor concepts, e.g. the “snowflake”, will be assessed. **The magnetic control, divertor heat flux handling and power accountability, pumping with lithium coatings, impurity production, and their trends with engineering parameters will be studied in this configuration. Potential benefits of combining high flux expansion divertors with gas-seeded radiative techniques and ion pumping by lithium will be explored.** Two dimensional fluid codes, e.g. UEDGE, will be employed to study divertor heat and particle transport and impurity radiation distribution. Further, **H-mode pedestal stability, ELM characterization, as well as edge transport will also be studied in the experiment** and modeled with pedestal MHD stability codes, e.g., ELITE, and transport codes, e.g. TRANSP and MIST. This research will provide the foundation for assessing the extrapolability of high flux expansion divertors for heat-flux mitigation in next-step devices.

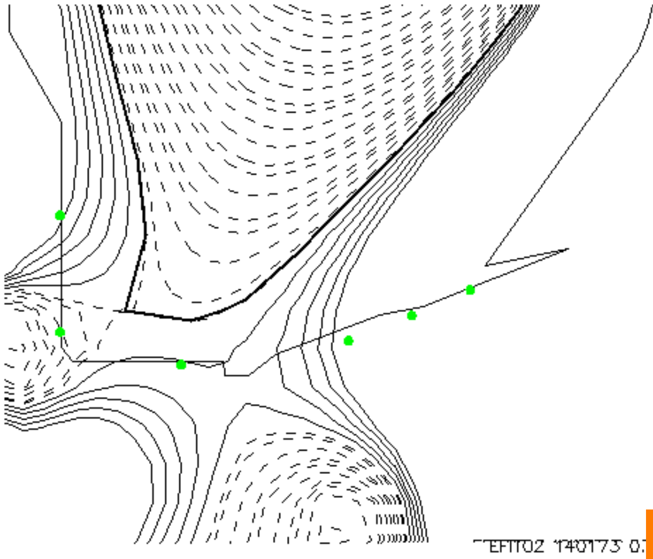
Development of high-performance plasma scenarios with snowflake configurations

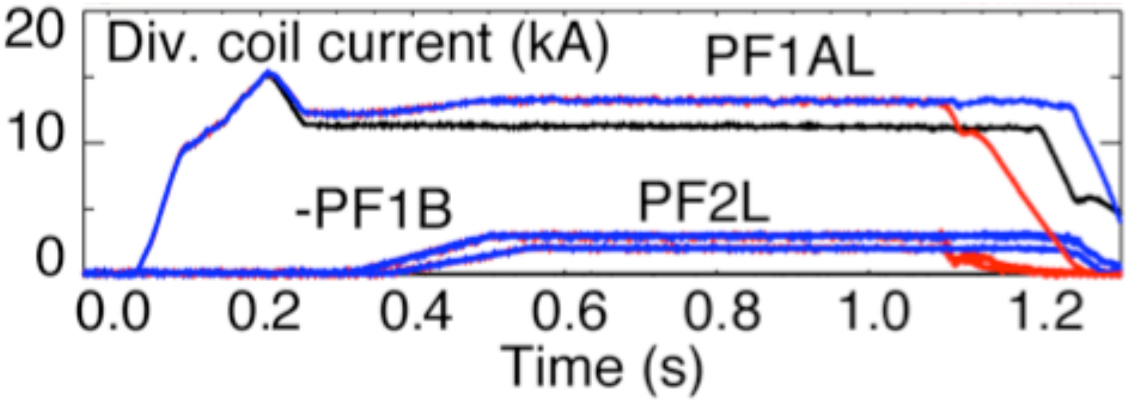
- High-performance plasma
  - B_t=0.45 T, I_p=0.8-0.9 MA, P_{NBI}=4 MW
  - H98(y,2) ≥ 1.1, τ_E~60 ms
  - High bootstrap current fraction (0.5-0.6)
  - High β_N (4-5 ?)
  - Highly-shaped ($\kappa \geq 2.4$, δ~0.6-0.8)

- …with snowflake divertor configurations
  - Early snowflake-minus
  - Snowflake-minus with drsep ~ 0
  - Double-snowflake-minus
  - Steady-state snowflake-plus

Develop new front-end to form snowflake-minus from 150-250 ms avoiding standard LSN as much as possible







- Snowflake-minus with three coils (w/ reversed PF1B) transformed from a standard medium-δ LSN at ~ 500 ms
- Snowflake with three coils (w/ reversed PF1B) transformed from a standard high-δ LSN at ~ 500 ms
- Possible benefits of early snowflake
  - Divertor peak heat flux never high
  - Reduced carbon sputtering in early H-mode phase
  - New pedestal stability operating point ?

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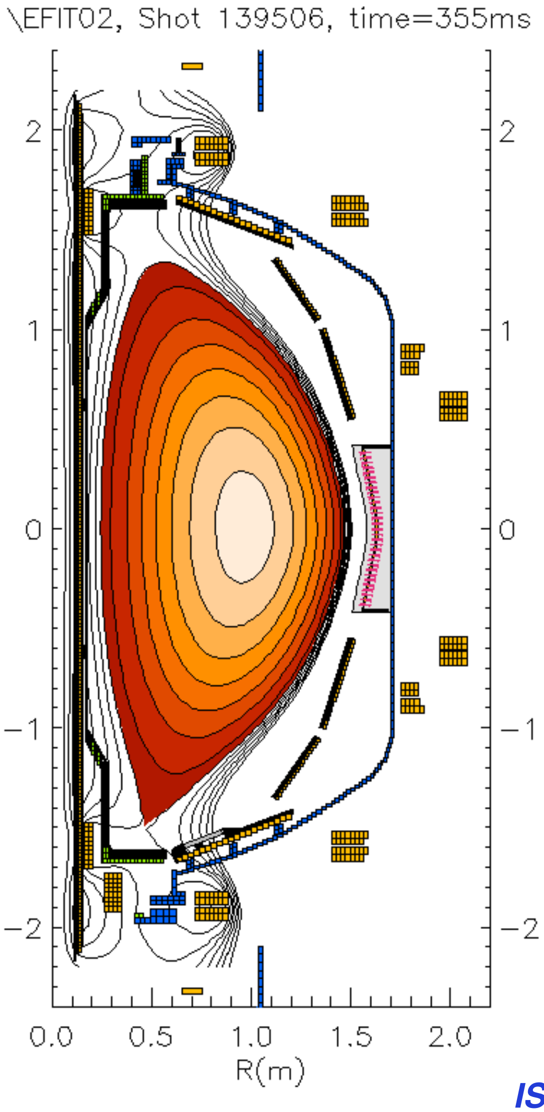
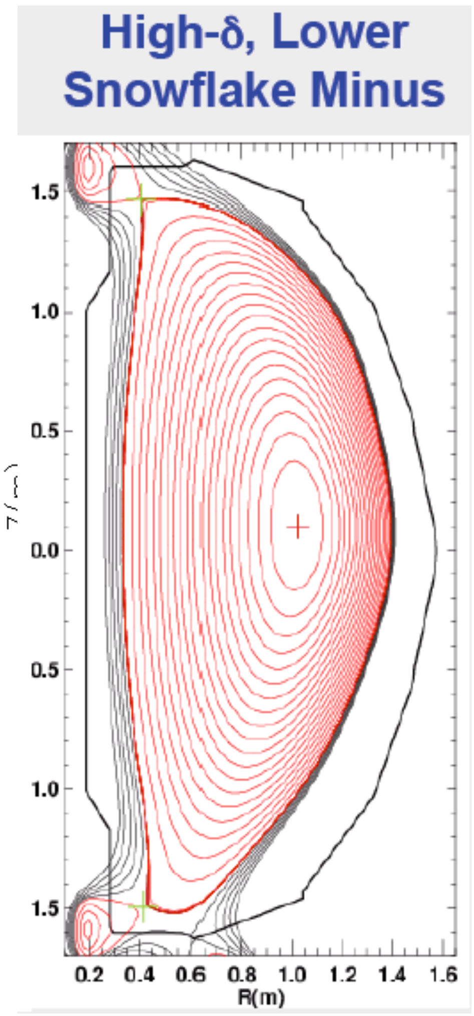
Develop discharge with drsep~0 and lower snowflake-minus or lower-and-upper snowflake-minus



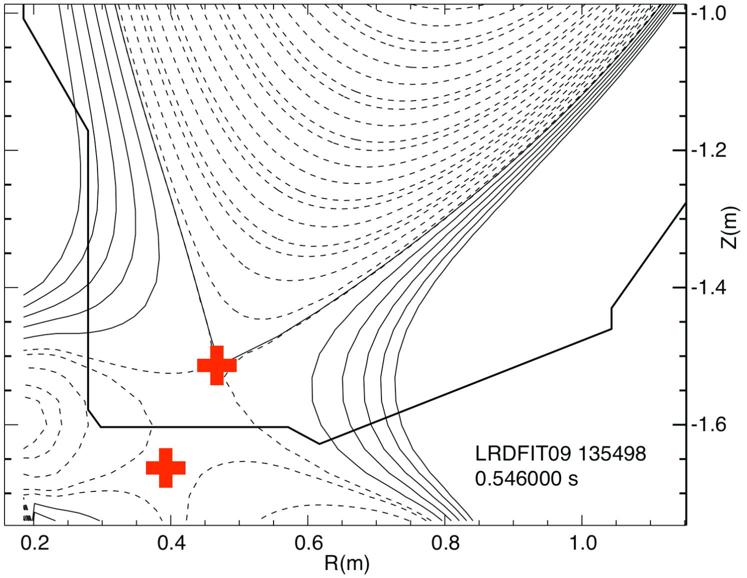


ISOLVER model by S. P. Gerhardt

- In FY 2010, had several discharges with semi-transient periods of snowflake-plus and minus with drsep~0
- Is this doable with PCS controlling upper and lower X-points?
- Possible benefits of the snowflake with drsep~0
  - Divertor power sharing
  - Divertor peak heat flux low
  - Reduced carbon sputtering
  - New pedestal stability operating point ?

Snowflake-plus configuration as laboratory for pedestal MHD stability and parallel SOL transport

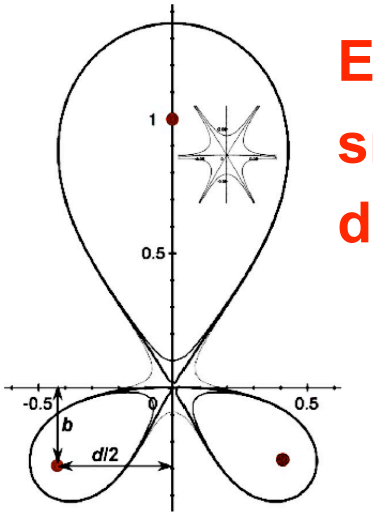
- Obtained with three divertor coils PF1A, PF2L and rev. pol. PF1B
- Properties
  - Overall, same shaping and core plasma parameters as with standard divertor
  - Outer SP flux expansion can be same as in standard divertor !
  - Pedestal magnetic shear and SOL connection length higher than in standard divertor
- Test parallel transport with 3D fields
  - Role of increased line length
  - Role of radial heat diffusion (to common and private flux regions)
- Test pedestal stability models
  - A knob to for peeling-balooning stability



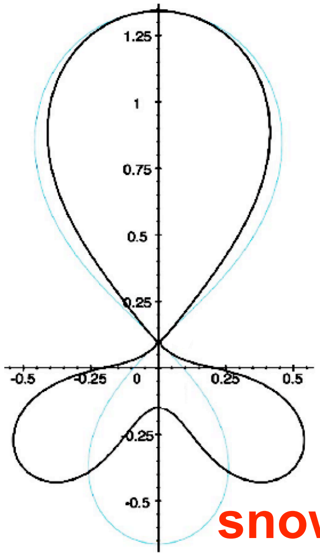
Attractive divertor geometry properties predicted by theory in snowflake divertor configuration

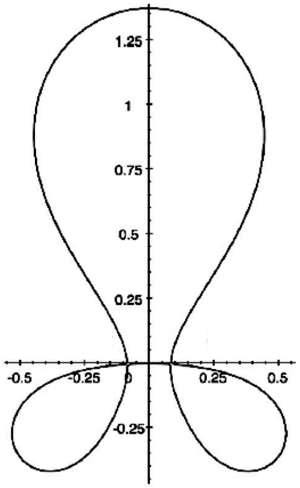
- Snowflake divertor
  - Second-order null
    - $B_p \sim 0$ and *grad* $B_p \sim 0$; $B_p \sim r^2$

      (Cf. first-order null: $B_p \sim 0$; $B_p \sim r$)
  - Obtained with existing divertor coils (min. 2)
  - Exact snowflake topologically unstable
- Predicted properties (cf. standard divertor)
  - Larger low B_p region around X-point
  - Larger plasma wetted-area A_{wet} (flux expansion f_{exp})
  - Larger X-point connection length L_x
  - Larger effective divertor volume V_{div}
  - Increased edge magnetic shear
- Experiments
  - TCV (F. Piras *et. al*, PRL 105, 155003 (2010))



Exact snowflake divertor





snowflake-minus

snowflake-plus

D. D. Ryutov, PoP 14, 064502 2007