NSTX

Fusion Energy Sciences

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ITER / Cross-cutting TSG proposals

V. A. Soukhanovskii (LLNL)

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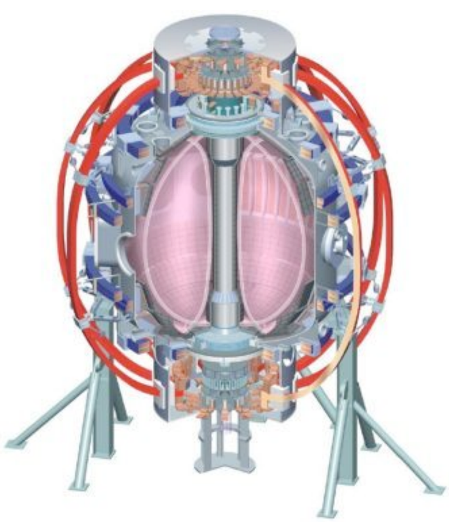

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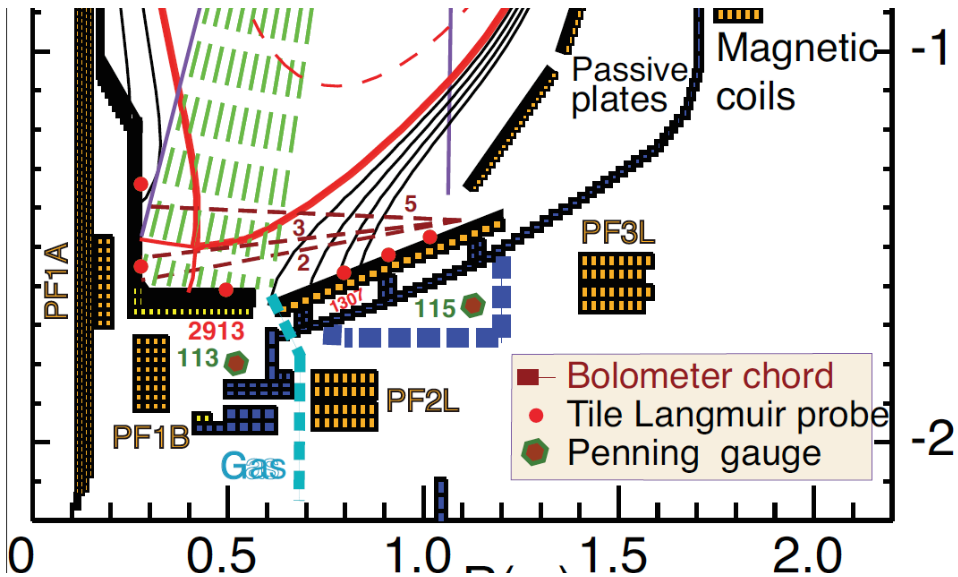
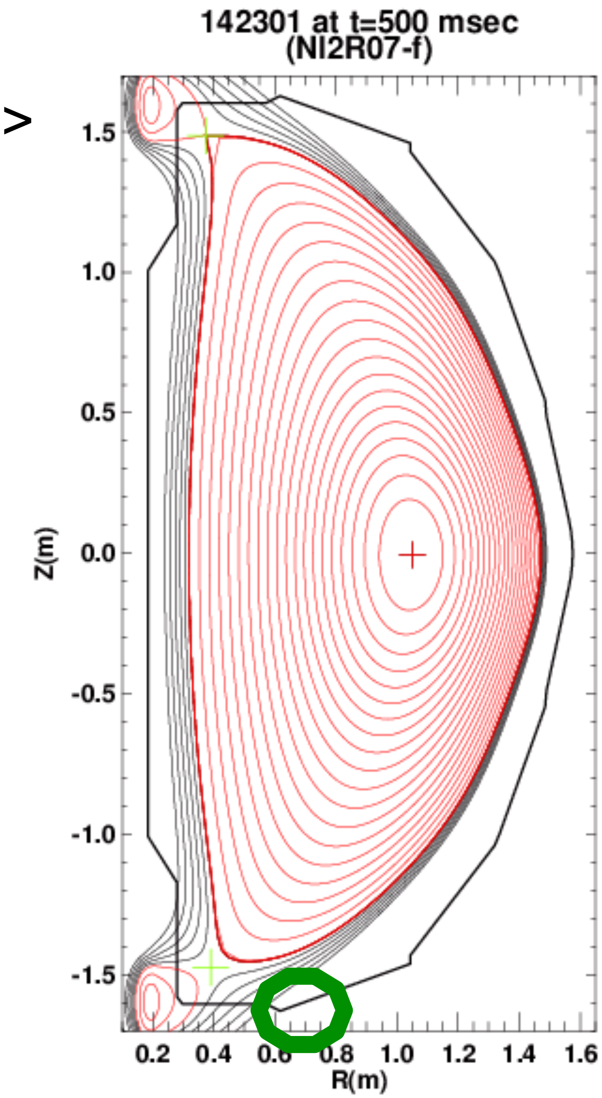
XP 1: Experiments to support NSTX-U divertor PFC design and operation critical to the NSTX program

- Document divertor and pedestal conditions in “NSTX-U shape”
  - With standard divertor with and without D_2 or impurity seeding
  - With snowflake-minus divertor configuration
  - …as functions of collisionality (via LITER), P_{SOL} and gas puffing rate
- For cryo-pump design calculations, attempt to measure radial midplane and divertor profiles (and neutral pressures)
  - In high-recycling (low lithium) and in low-recycling divertor (high lithium)
- Assess divertor geometry implications in this shape
  - High κ, medium δ, + snowflake – destabilizing for ELMs?
  - Connection length, field angles, plasma-wetted area – acceptable?
  - Equilibria to be used in UEDGE modeling for NSTX-U projections
- Potential issues
  - large inner gap - inner wall recycling and impurity source different
  - P_{SOL}, ν_{ei} too different?

Highly-shaped NSTX-U-like shape will be used for SOL/divertor database for NSTX-U projections

- NSTX-U-like shape
  - ISOLVER modeling done by S. P. Gerhardt ->
  - I_p=0.8-1.0 MA, 2-6 MW NBI
  - Large outer gap (high PF1A current), A=1.6=1.7
  - LSN if possible
  - Good divertor diagnostic coverage



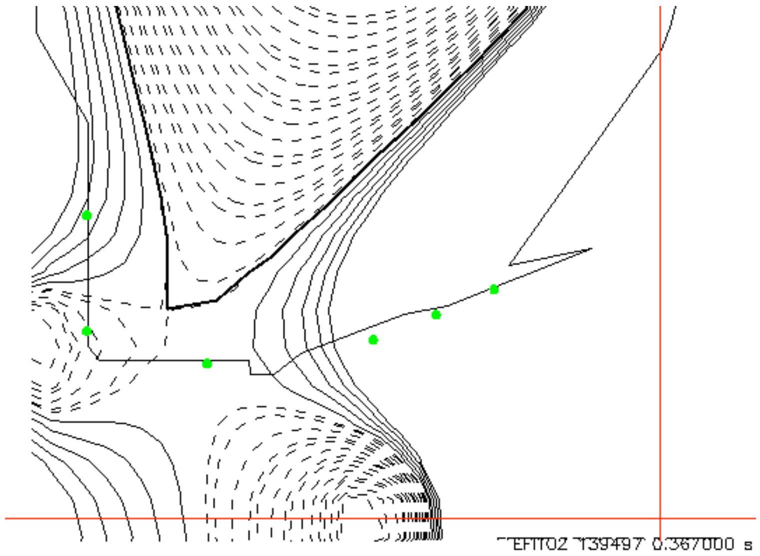


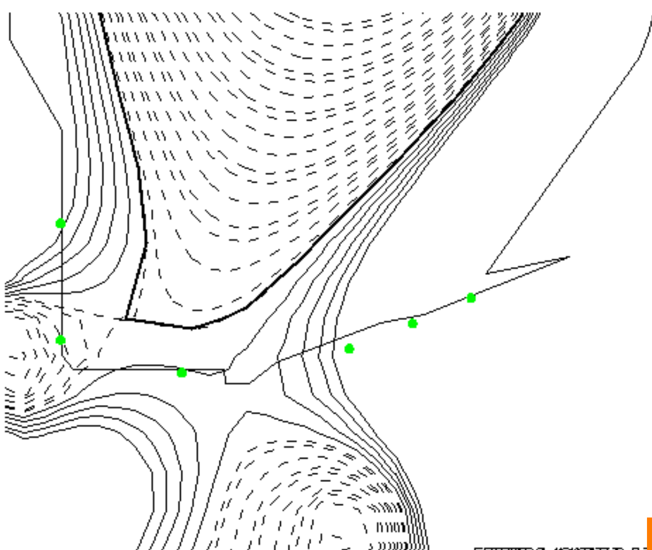
Possible cryopump

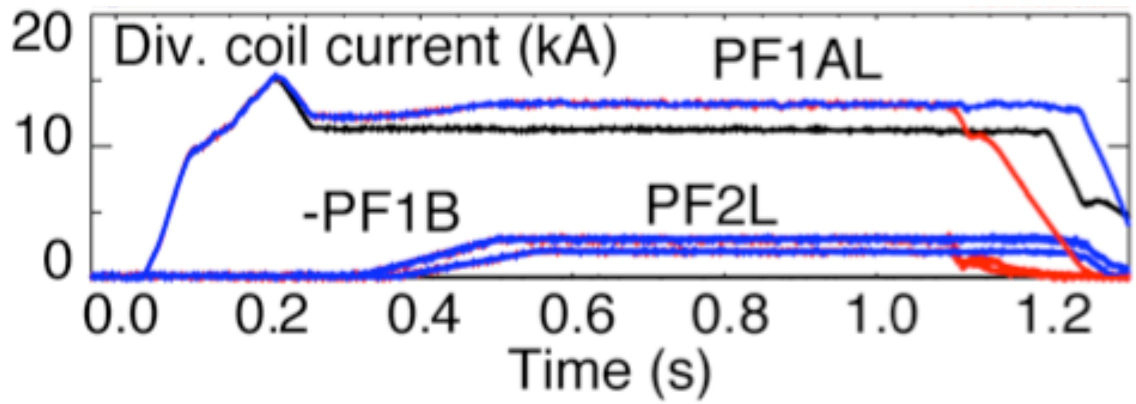
XP 2, 3: Further development of impurity reduction techniques

- **Early divertor deuterium puffing (next step from XP 1002)**
  - Successful reduction of carbon concentration and Zeff by up to 30 % using moderate gas puffing rates
  - Attempted as early as ~ 250 ms
  - Propose to try as early as X-point formation at 80-150 ms
  - Potential issues
    - Overfueling – need to re-develop total gas fueling
    - H-mode access – L-H threshold may be higher (need to document)
- **Early snowflake-minus configuration (ASC TSG, BP TSG?)**
  - Snowlfake-minus initiated at 500-600 ms reduced carbon concentration (but also induced ELMs) in 1.2 s discharges
  - Goal - avoid standard divertor period at early times
  - Before 300 ms – full P_{NBI} power, high P_{SOL}, low n_e, divertor likely in sheath-limited regime with high T_e, Γ_i, -> high sputtering rate ?

XP 2: Early snowflake-minus development may bring considerable benefits for impurity handling







- 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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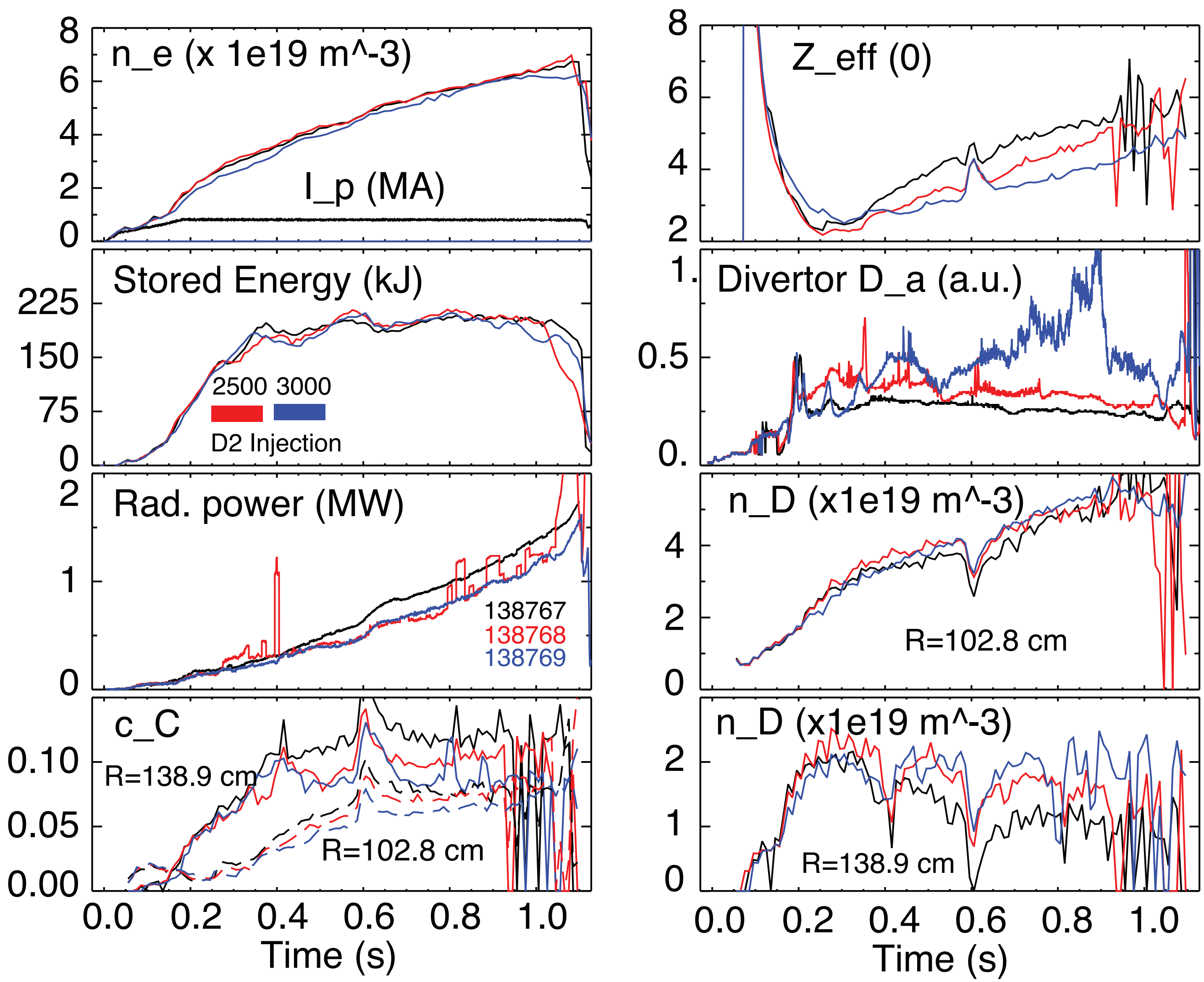
XP 3: Early divertor gas puffing may bring considerable benefits for impurity handling



XP 4: Radiative divertor with impurity seeding (also presented in BP TSG)

- Request 1 day (0.5 day with neon, 0.5 day with argon)
- Perform divertor gas seeding at several rates and several P_{SOL} (crude NBI and / or I_p scan) to define several operating points with reduced divertor peak heat flux and no confinement degradation
  - 0.8 MA, 4 MW and 1.0-1.2 MA, 6 MW to compare to previous experiments with D_2 and CD_4 puffing
- Use standard high-δ fiducial with outer gap ~ 10 cm
- Study divertor detachment characteristics (e.g., Γ_{div}, Γ_{rec}, P_{rad})
- Document pedestal pressure and core confinement changes
- Attempt detachment at higher LITER rate
- If Type I ELMs can be obtained, focus on divertor and pedestal characteristics around the ELM times (re-attachement? Burn-through?)

Use of impurity seeding provide an opportunity to study NSTX-U-relevant radiative divertor

- Radiative divertor experiments used D_2 injection to demonstrate peak heat flux reduction in NSXT with carbon radiation

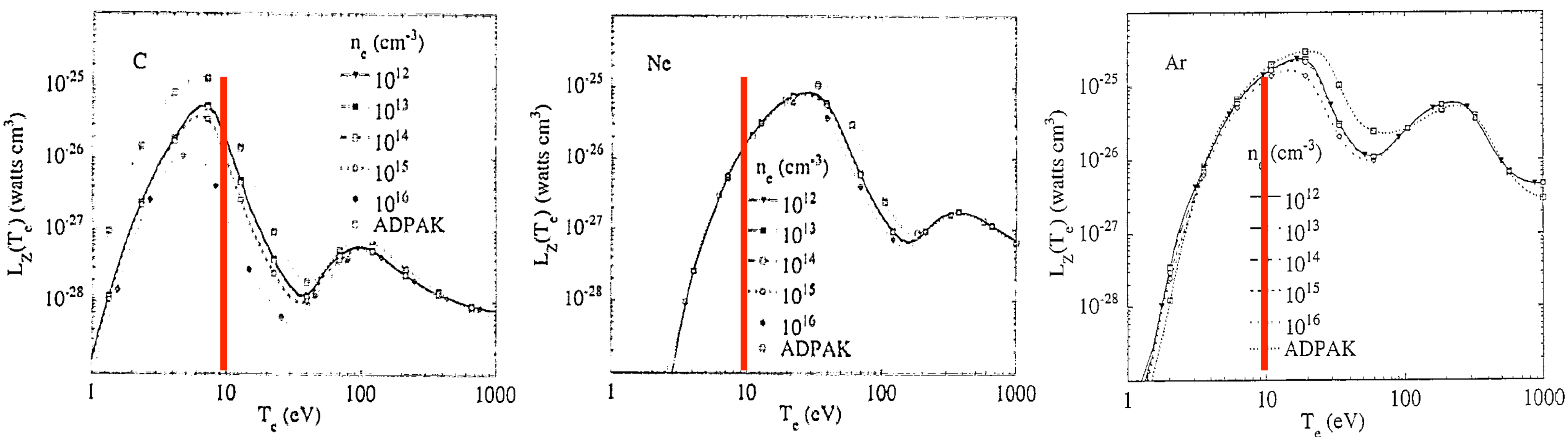
- A significant divertor peak heat flux reduction will be needed in NSTX-U, probably not possible with low Z impurities

- Reduced density LITER operation reduces radiated power achievable with extrinsic impurity seeding

- Control aspects of radiative divertor
  - Identify divertor quantities that can be monitored and used as actuators for feeding into PCS to regulate impurity injection

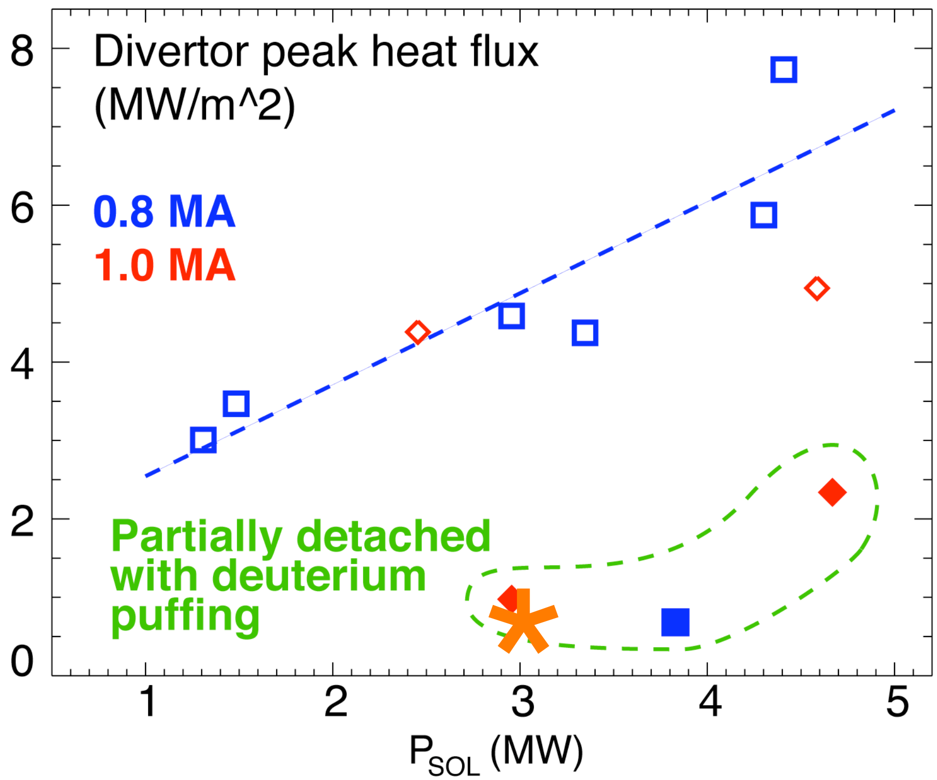
Carbon, neon and argon should provide sufficient radiated power for the radiative divertor

- The coronal impurity cooling curves do not take into account the radial transport and *n*-τ effects
- Ne and Ar more suitable for hotter divertor



R. Clark et al. / Journal of Nuclear Materials 220–222 (1995) 1028–1032

Radiative divertor with CD_4 seeding appears to reduce divertor heat flux as much as PDD with D_2



- Radiative CD_4 divertor (*): P_{SOL}~3-4 MW, q_{peak}~0.5-1.0 MW/m^2
- Similar ≤1-10 % confinement degradation

V. A. Soukhanovskii et. al, PoP 16, 022501 (2009)