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Facing the challenge of power exhaust on the way to a future power plant with experiments in the JET and ASDEX Upgrade tokamaks

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[1]See the author list of "Overview of the JET results in support to ITER" by X. Litaudon et al. to be published in Nuclear Fusion Special issue: overview and summary reports from the 26th Fusion Energy Conference (Kyoto, Japan, 17-22 October 2016)

[2]See the author list of "Overview of progress in European Medium Sized Tokamaks towards an integrated plasma-edge/wall solution" by H. Meyer et al., to be published in Nuclear Fusion Special issue: overview and summary reports from the 26th Fusion Energy Conference (Kyoto, Japan, 17-22 October 2016)

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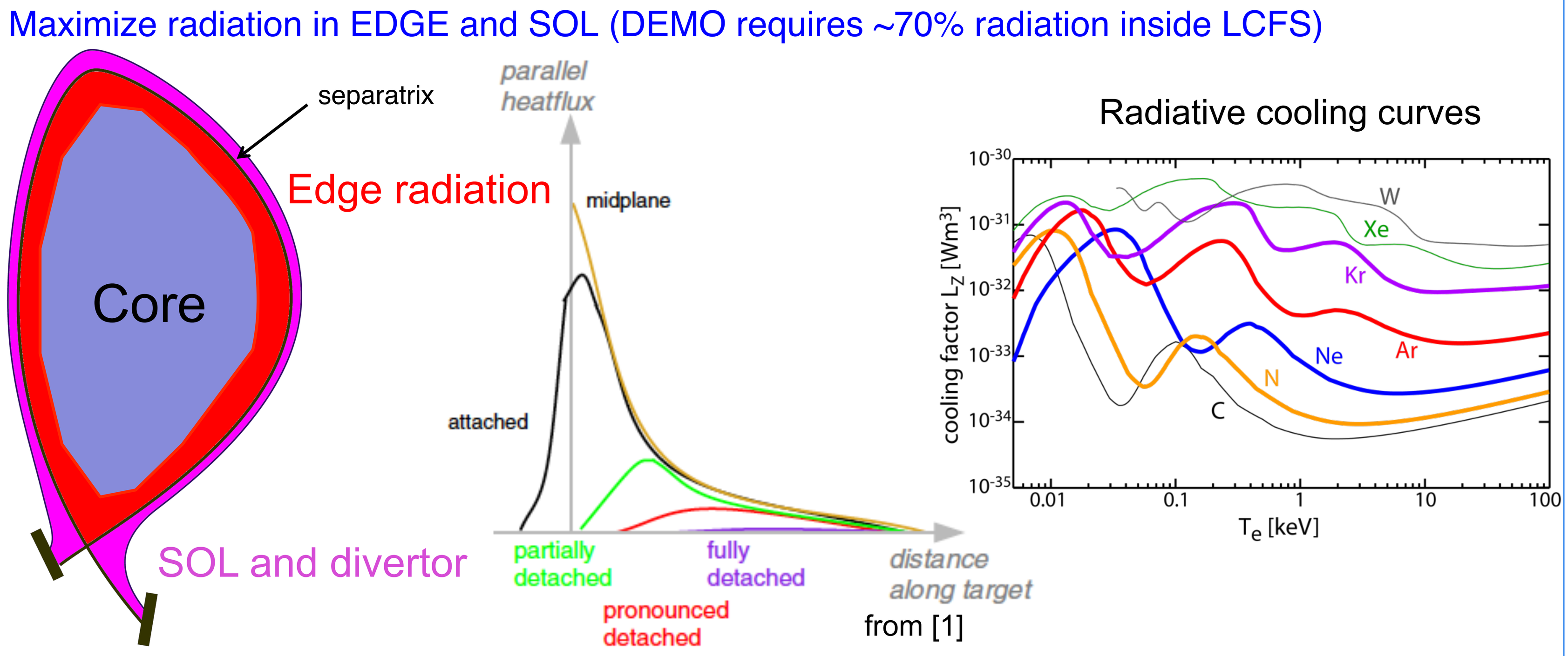
Motivation

- Total power dissipation required sums to > 90% - 95% of P_{heat} for DEMO type device and (70-80%) for ITER
- Maximize radiation in EDGE and SOL (DEMO requires ~70% radiation inside LCFS)



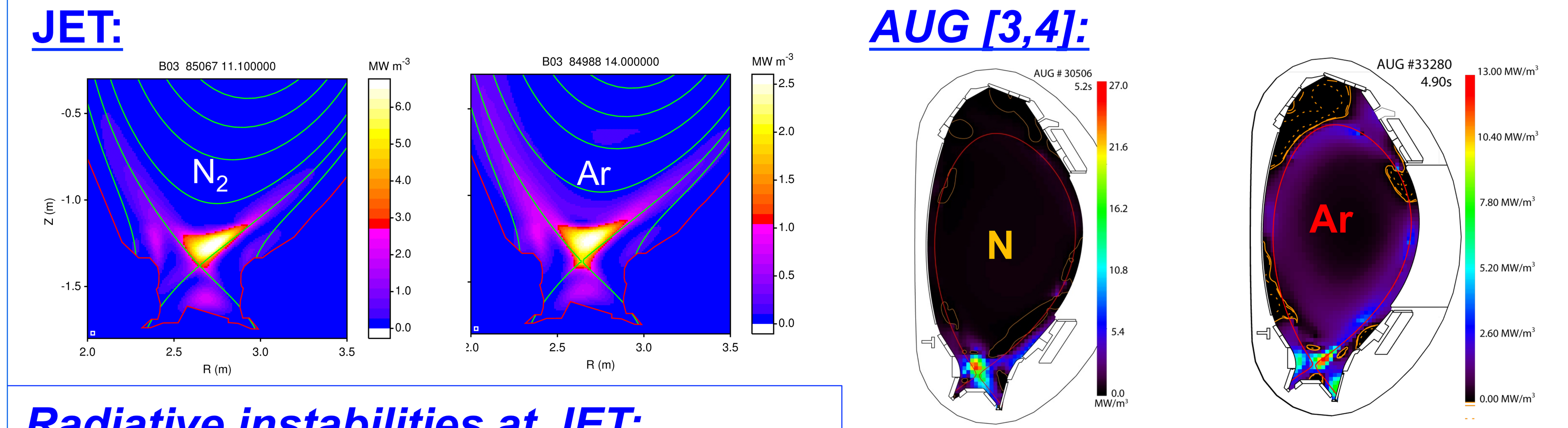
from [1]

- Enhance lifetime of divertor by minimizing erosion in an impurity seeded plasma → T_e<2-5eV
- Plasma facing components in divertor limit deposited power to 5MW/m²- 10 MW/m² for DEMO
- Operate with a pronounced or completely/fully detached divertor in a DEMO type device [1,2]

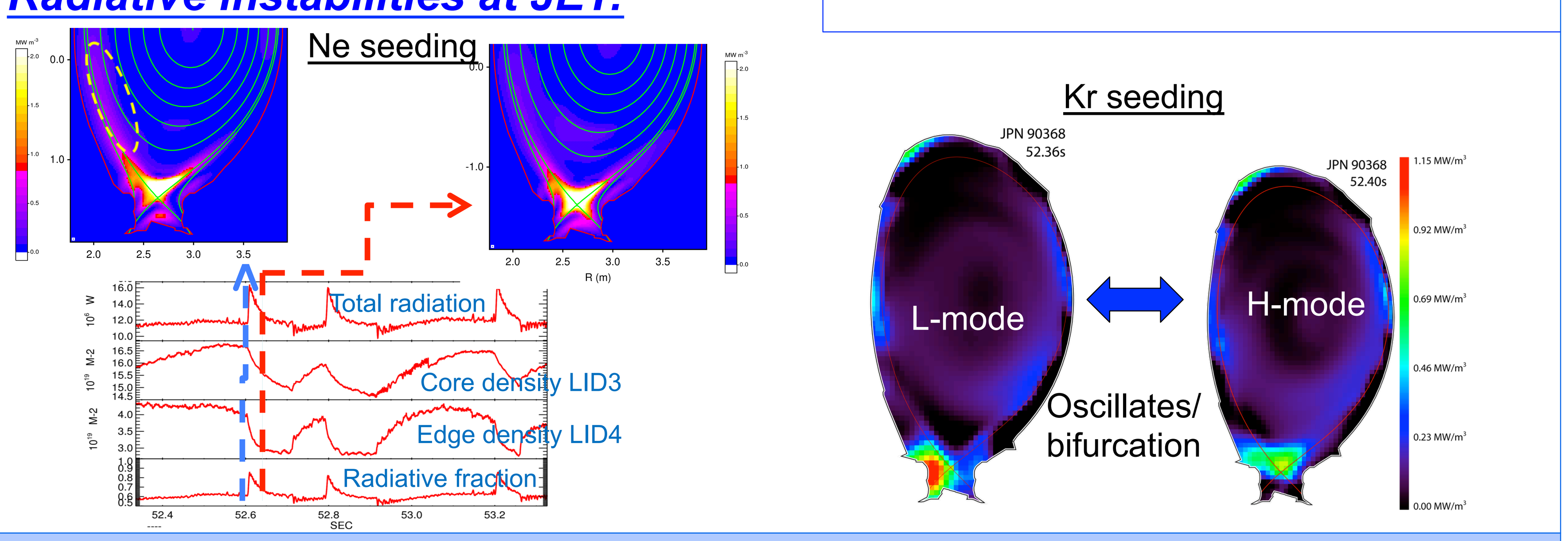
Maximizing radiative power fraction for minimizing divertor load

- JET and AUG: For N_2 stable X-point radiation and complete detachment at highest f_{rad} and modest reduction of confinement (5%-20%) [2,3,4,5].
- JET: Ne and Kr: cyclic X-point radiation related to L→H→L transitions. Maximum f_{rad} for Ne, Ar, Kr with stable X-point radiation and loss of confinement in L-mode, important contribution to f_{rad} from inside pedestal top, detached divertor regime.
- At JET complete detachment for all seeding species but f_{rad} of 60-65% for Ne, Ar ,Kr and 75% for N_2. Discussion on power balance for JET ongoing, see [6,7]
- AUG: Ne leads to uncontrolled W core impurity accumulation at reduced ELM frequency, no stable detachment; Kr f_{rad} of 90% with radiative ring at pedestal & not stable detachmen.

JET: ***AUG [3,4]:***

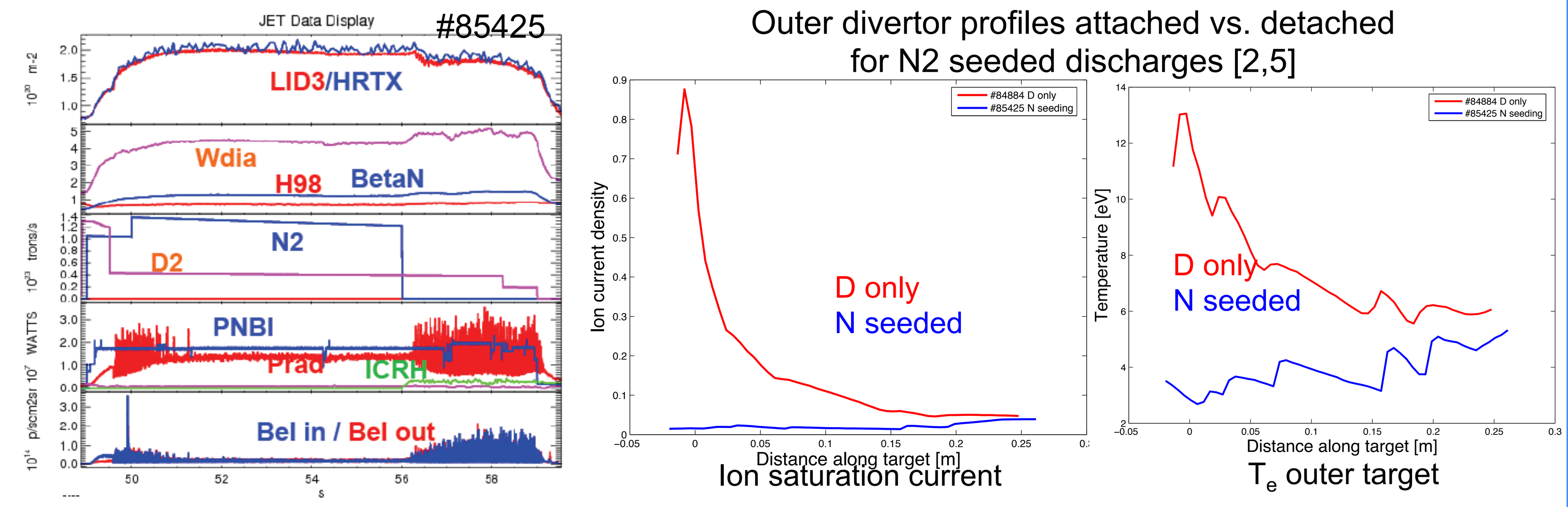


Radiative instabilities at JET:



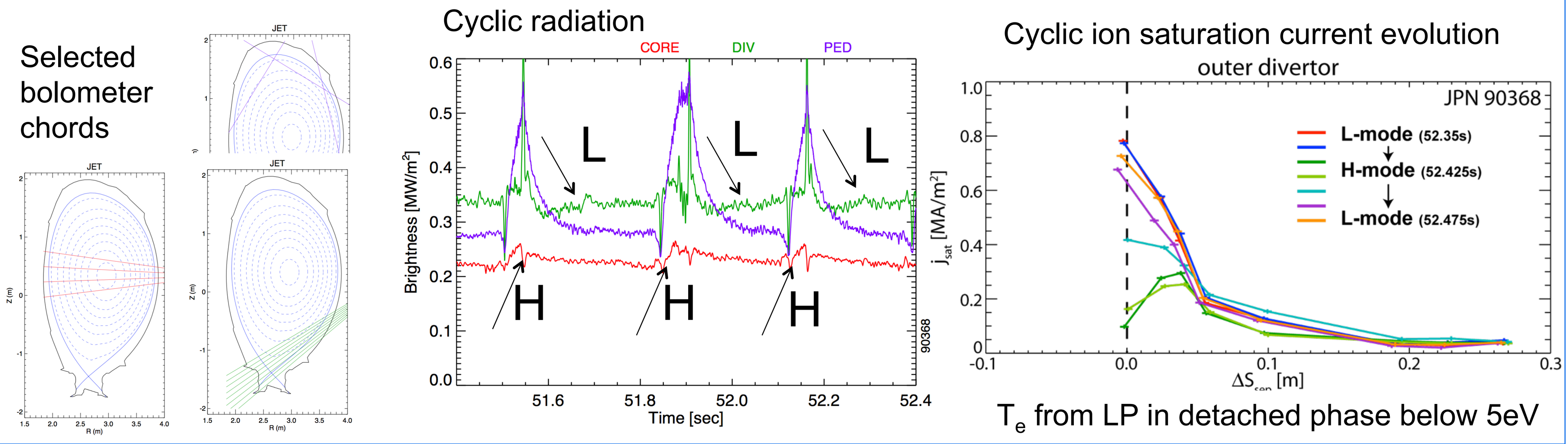
Stable complete detachment at JET (N)

N_2 seeding at 75% f_{rad} , mitigated ELMs close to L-H power threshold, stable completely detached divertor



Cyclic detachment at JET (Kr & Ne)

Kr seeding at 60% f_{rad} with H→L→H mode cycles [4] →detachment correlates with increased pedestal density during H-mode phase, triggers enhanced radiation in pedestal region, visibly X-point radiation → back transition to L-mode and drop in density correlated with re-attachment during L-mode, cycle determined by Kr transport and possibly heating power

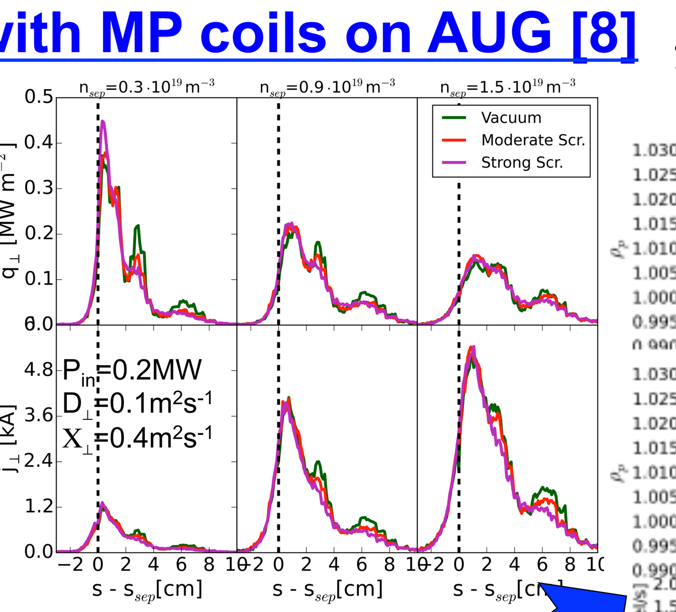


T_e from LP in detached phase below 5eV

Power exhaust with MP coils on AUG [8]

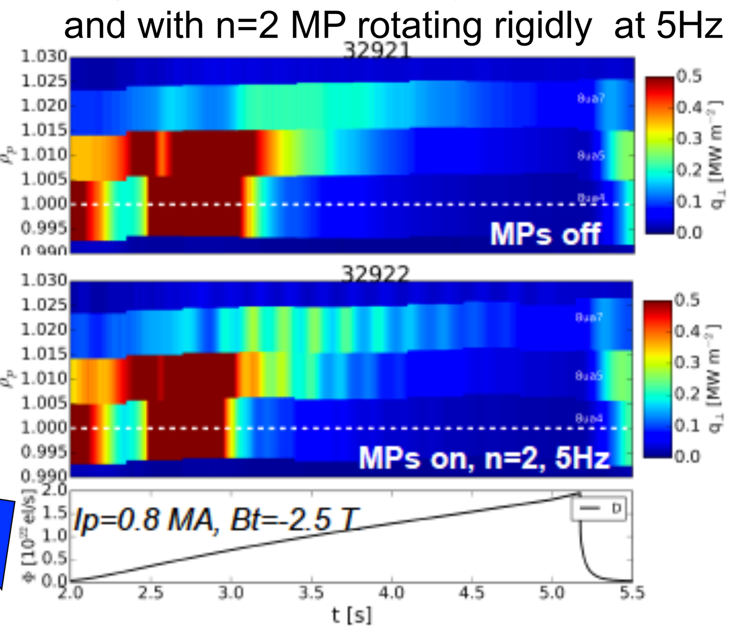
Model: High density: lobes wash out → small effect of screening

EMC3-EIRENE results of outer divertor heat flux and particle for different separatrix densities and screening strengths



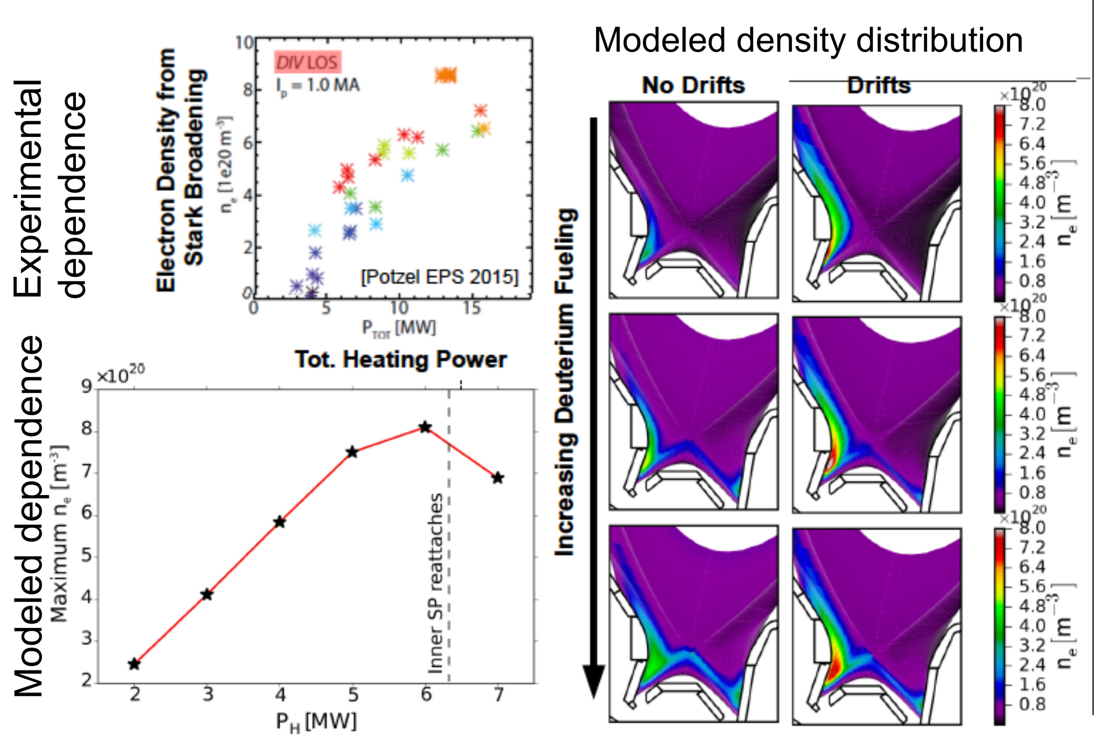
Experiment: Under detached conditions lobe structures vanish, no reattachment (no "burn through" of lobes)

Experiment: Deposited power load on target in L-mode density ramp without and with n=2 MP rotating rigidly at 5Hz

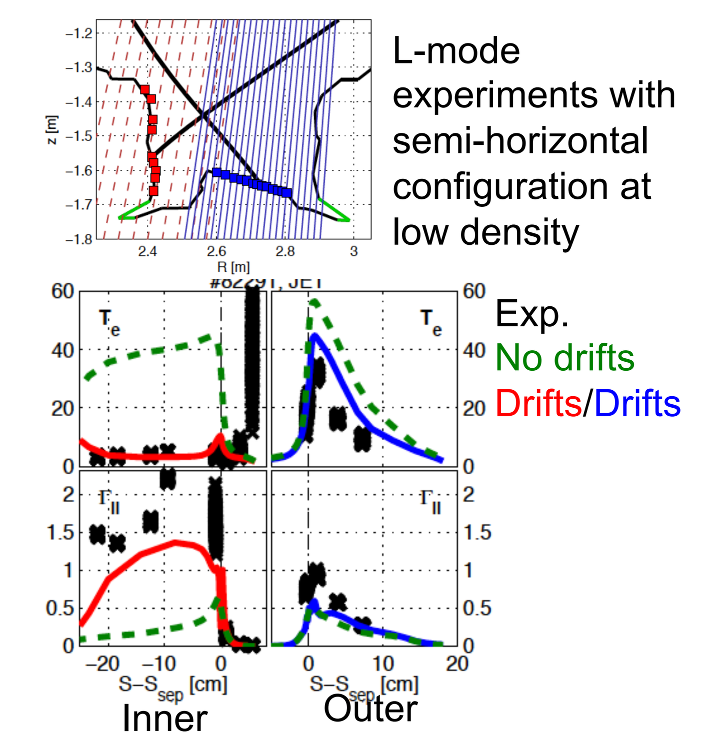


Advancements in modelling power exhaust for AUG and JET by activating drift terms

The High field side high density (HFSHD) in AUG H-mode [9]



Role of drifts in JET L-mode plasmas [10]



Conclusions

- At AUG and JET complete detachment at target correlates with enhanced radiation inside LCFS, most noticeable via X-point radiation. For AUG numerical modeling of N seeded discharges links complete detachment to drop in upstream pressure at separatrix [11]
- Transient detachment can occur during transient H-mode phases with enhanced pedestal density at JET (seen for Ne, Kr), cycles due to impurity transport
- Interrelation of confinement, radiative stability, degree of detachment needs assessment
- Experimentally no "burn through" of lobes is observed in detachment with MP coils on AUG
- Numerical modelling: Role of drift terms decisive at low density and when approaching detachment (AUG and JET) [10,11]
- Use of SOLPS5.0 code reproduces HFSHD and resolves issue of modeling divertor asymmetry [11] → pending for JET
- Modeling of highly radiating scenarios with sophisticated SOL code for JET pending

References [1] A. Kallenbach et al., FEC 2014, St Petersburg, [2] M. Wischmeier et al. Journ. Nucl. Mat. 2015, [3] M. Bernert et al. PSI 2016, [4] F. Reimold et al. Nucl. Fusion 2015, [5] A. Huber et al. EPS 2014, [6] C. Guillemaut et al., PSI 2016, [7] G. Matthews et al. PSI 2016 [8] D. Brida et al PSI 2016, [9] F. Reimold et al. PSI 2016, [10] L. Aho-Mantila, submitted to Nuclear Fusion and IAEA 2014, [11] F. Reimold et al. Journ. Nucl. Mat. 2015

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