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Development of impurity seeding for divertor power flux handling in Wendelstein 7-X long pulse scenarios

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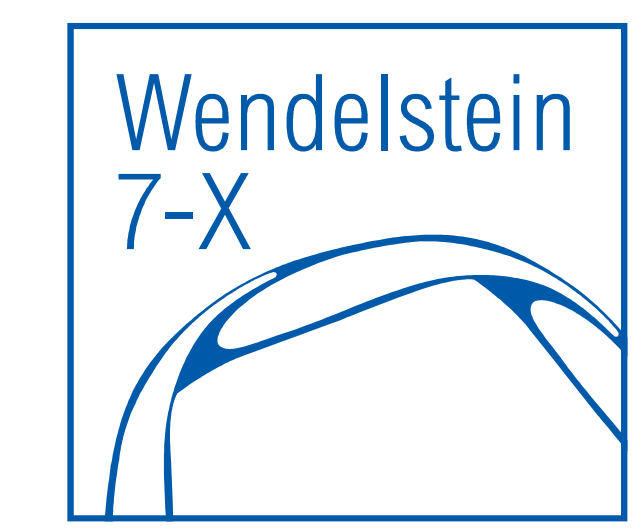
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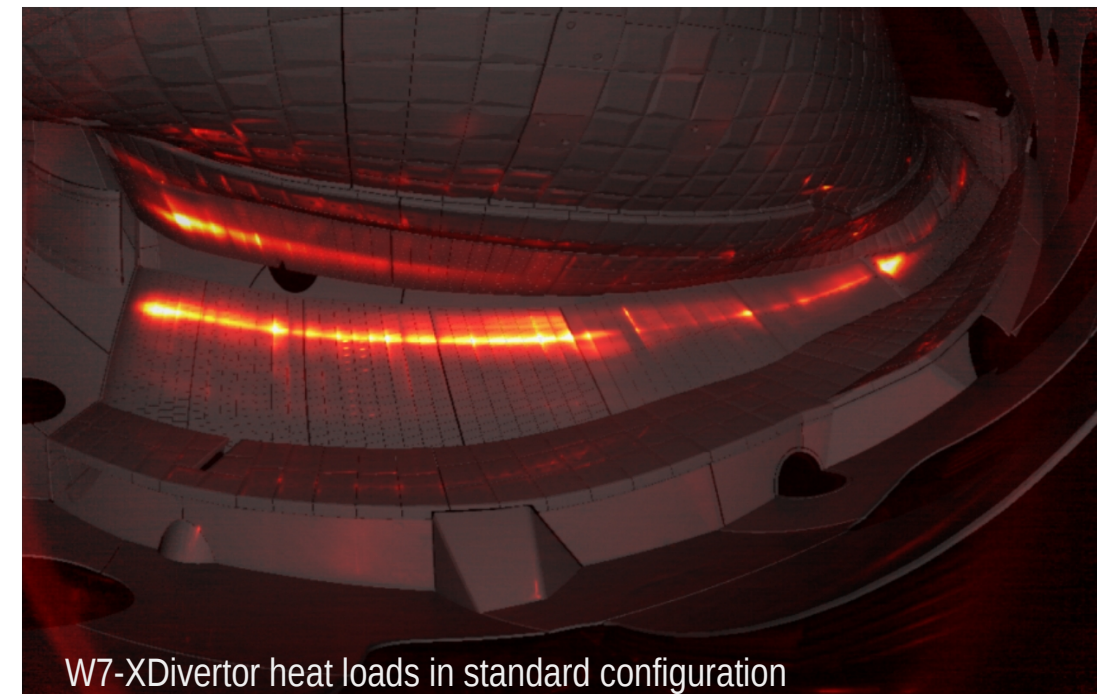
Development of impurity seeding for divertor power flux handling in Wendelstein 7-X long pulse scenarios



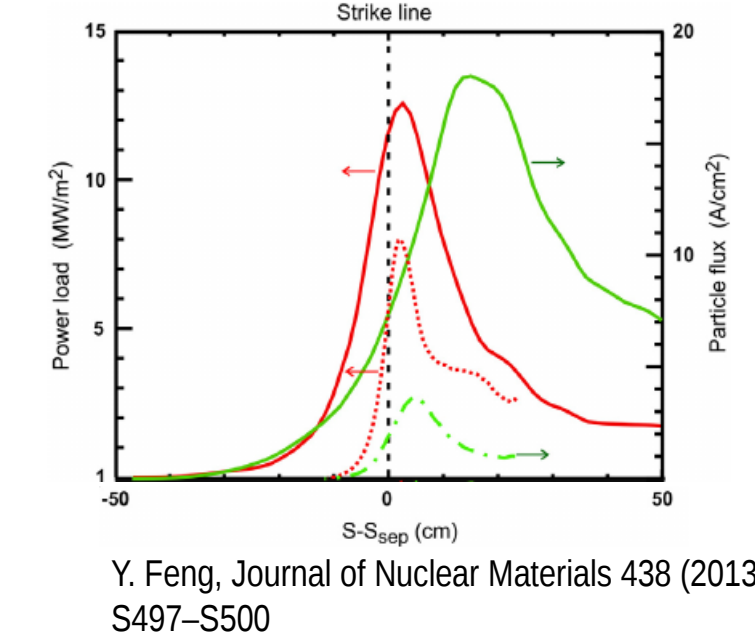
F. Effenberg^{1*}, T. Barbui¹, S. Brezinsek³, Y. Feng⁴, H. Frerichs², J. Geiger⁴, M. Jakubowski⁴, R. König⁴, M. Krychowiak⁴, J.D. Lore⁵, D. Naujoks⁴, H. Niemann⁴, F. Reimold⁴, J.C. Schmitt⁶, O. Schmitz², T. Sunn Pedersen⁴, G.A. Wurden⁷, D. Zhang⁴ and the W7-X team⁴

¹Princeton Plasma Physics Laboratory, Princeton University, Princeton, New Jersey 08543, USA, ²Department of Engineering Physics, University of Wisconsin, Madison, WI 53706, USA, ³Forschungszentrum Jülich GmbH, 52425 Jülich, Germany, ⁴Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany, ⁵Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA, ⁶Department of Physics, Auburn University, Auburn, AL 36849, USA, ⁷Los Alamos National Laboratory, Los Alamos, NM 87545, USA

High power fluxes predicted for future W7-X reactor scenarios and next-step 3D devices

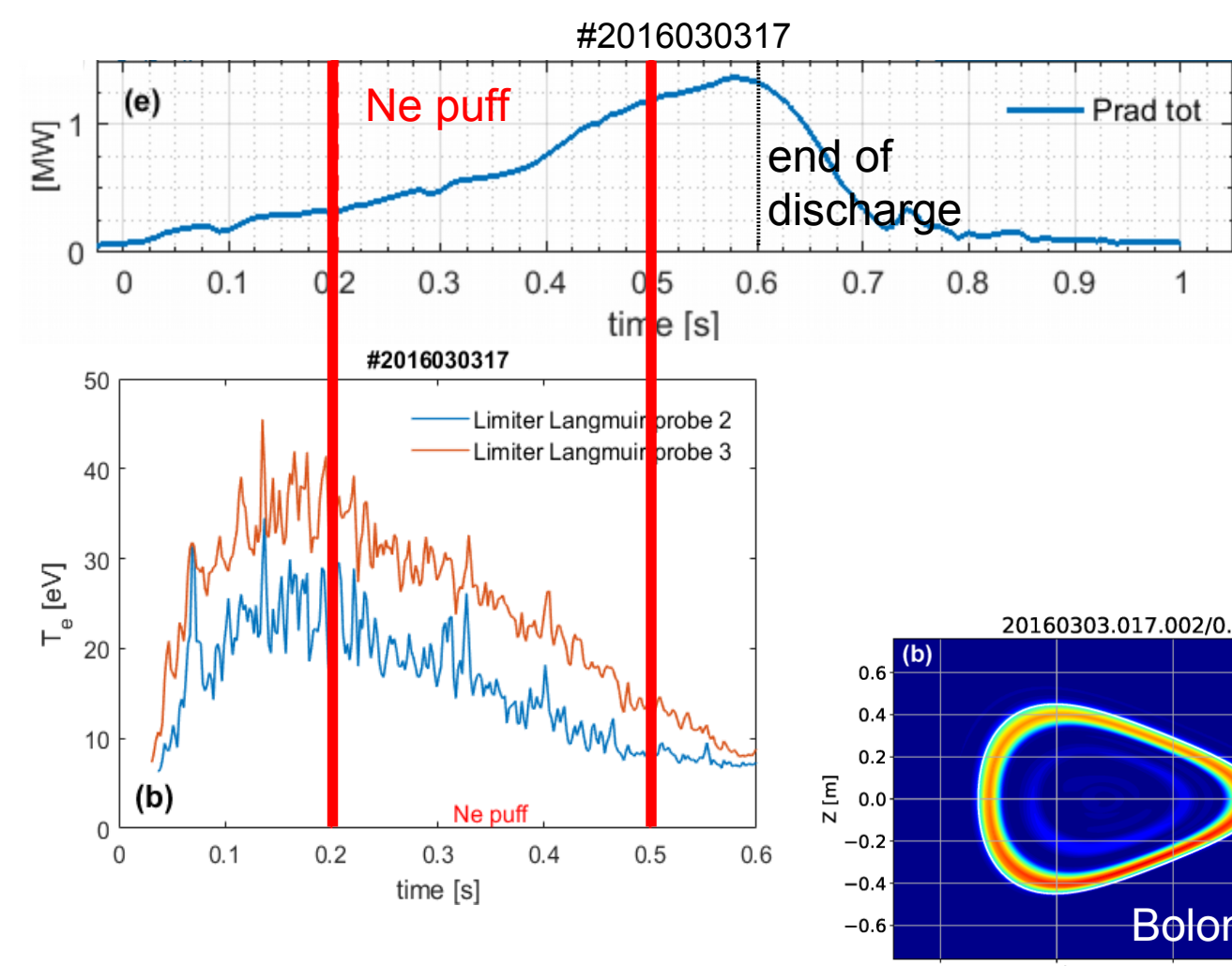


Reactor extrapolation
(still low power:
 $P_{SOL} = 200 \text{ MW}$)

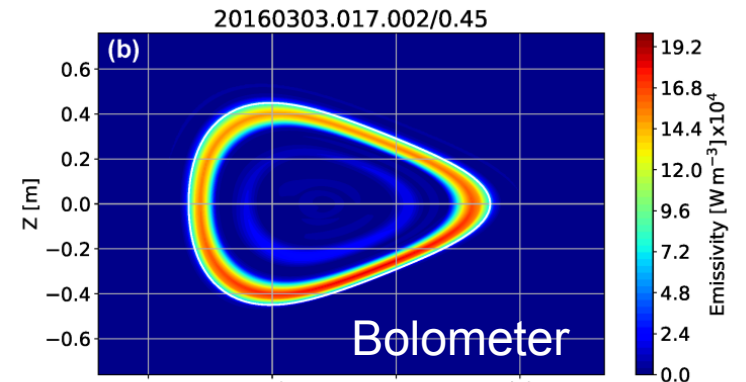


- Avoid overload of PFCs during high-performance/long pulse scenarios
- Stable, high-radiating divertor to be developed for reactor scenarios
- Substitute intrinsic radiators when using high Z materials (e.g. W)

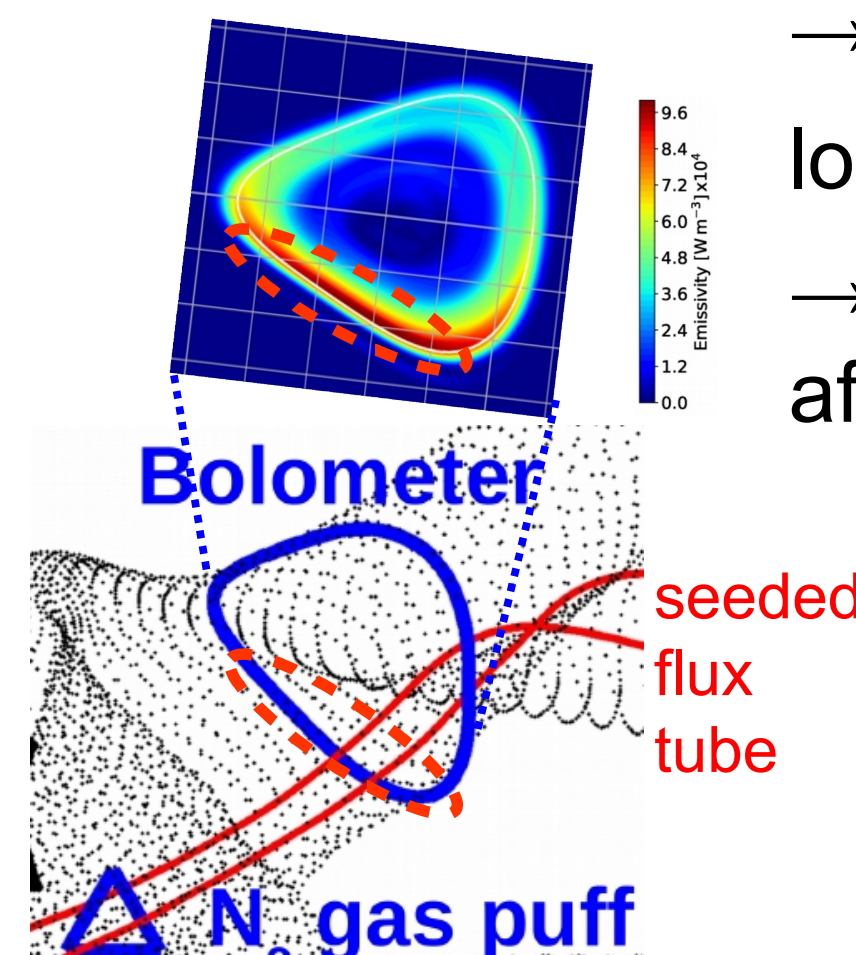
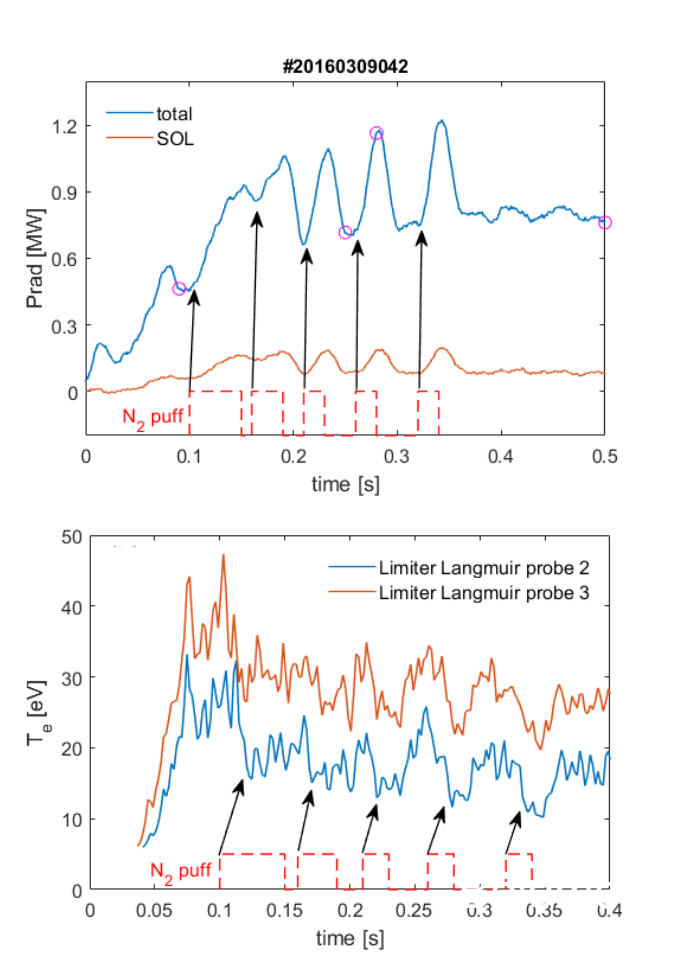
Limiter: Neon showed high recycling and radiation efficiency



- Uniform increase in edge line radiation during Ne puff
- Frequent radiative instabilities in limiter configurations

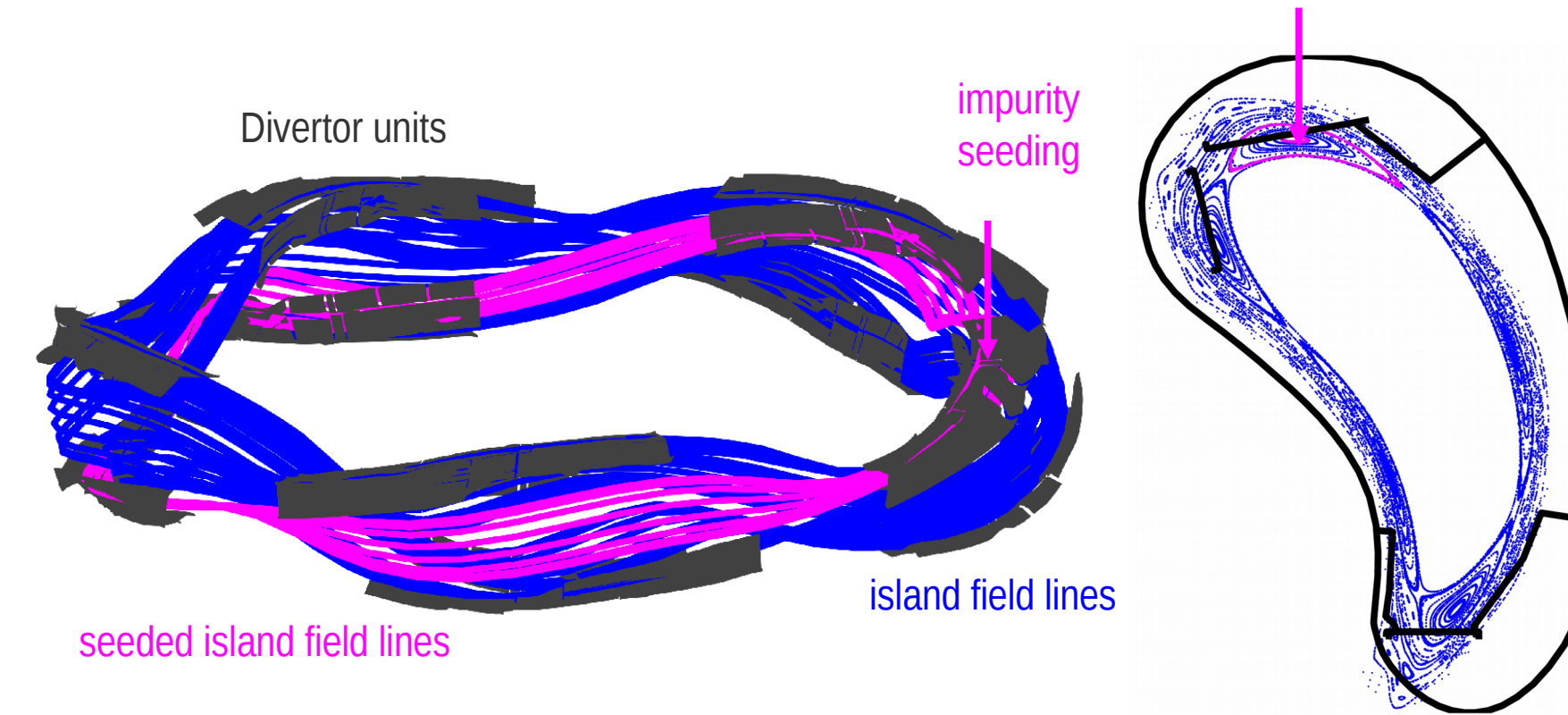
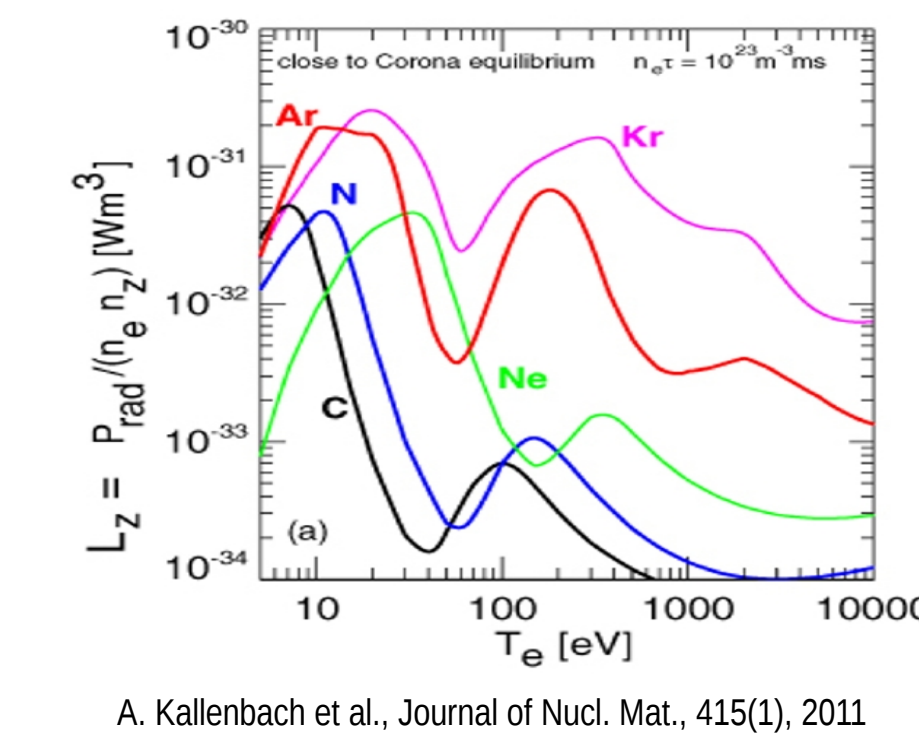


Limiter: low level N2 seeding showed fast and local response in edge parameters



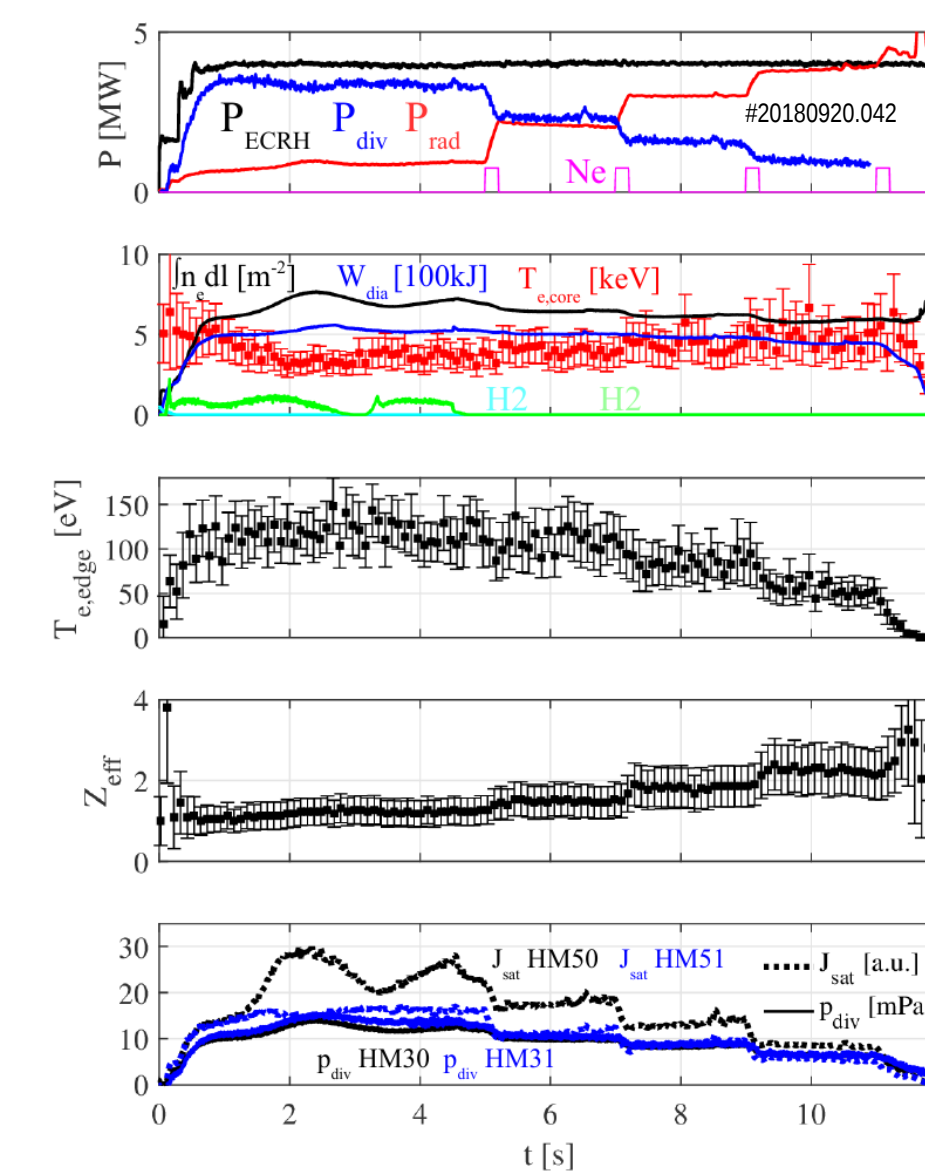
- Short N₂ injections show local increase in P_{rad}
- prompt decay in Prad after each N₂ pulse

Impurity seeding explored for radiative power exhaust and detachment control



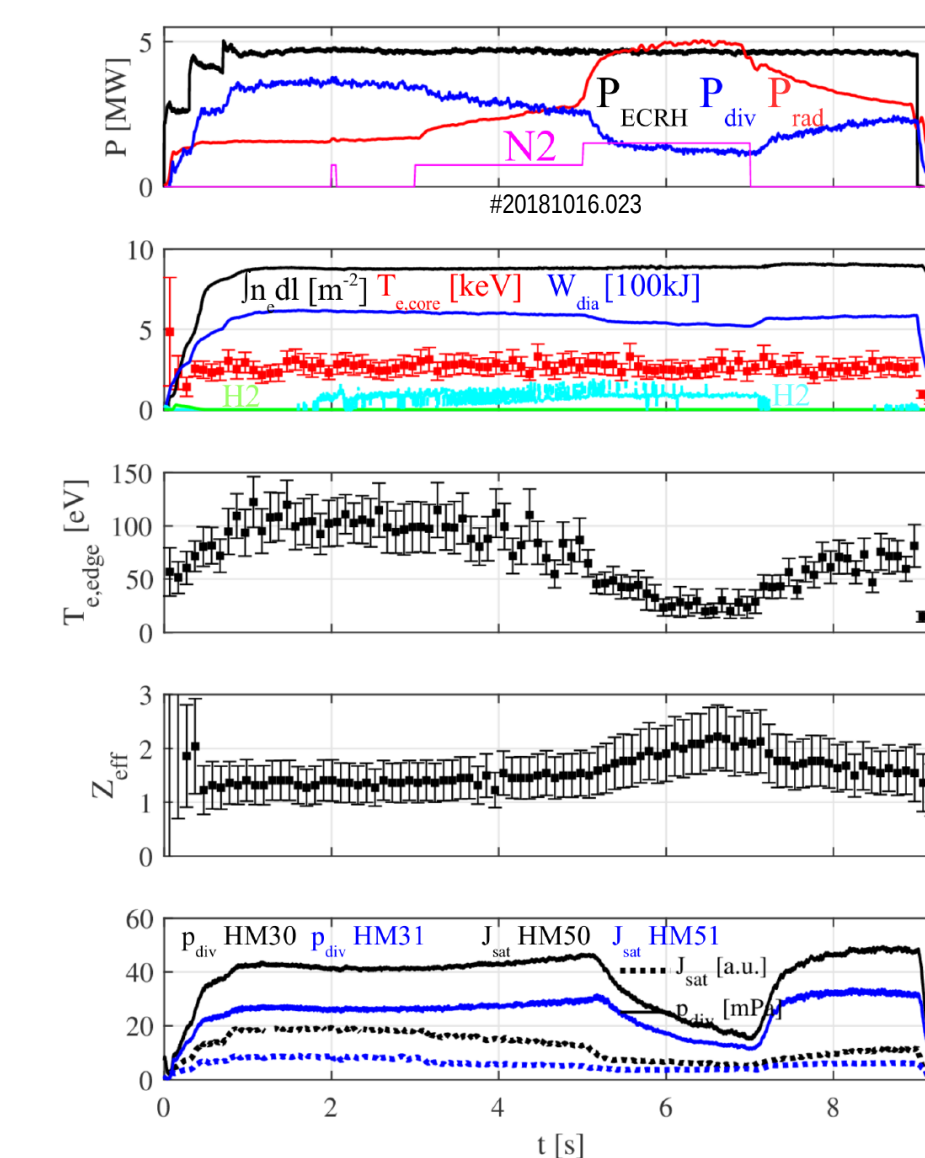
- Control divertor loads: $q_{div} \sim q_{SOL} - P_{rad}$
- Optimize trade-off between performance & safety by choice of impurity species

Divertor: short Neon injections establish sustained radiative mantle and edge cooling



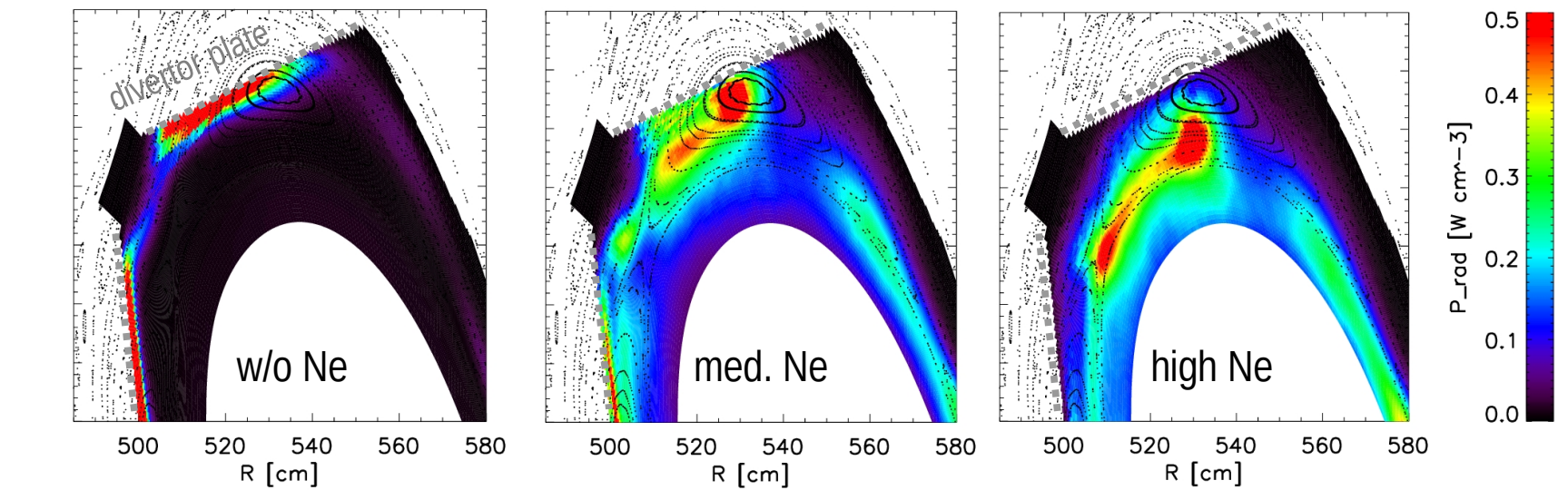
- stationary 'steps' in power balance $\sim O(10s)$ due to high recycling of Ne
- $\Delta W_p \sim 15\%$ at highest f_{rad} of $\sim 80\%$
- Z_{eff} increases from 1.2 to 2.2
- $\sim 75\%$ of injected Ne particles retained in SOL
- reduction of divertor particle fluxes and neutral pressure (w/o active density control)

Divertor: continuous N2 puff causes effective recycling and uniform radiative power exhaust



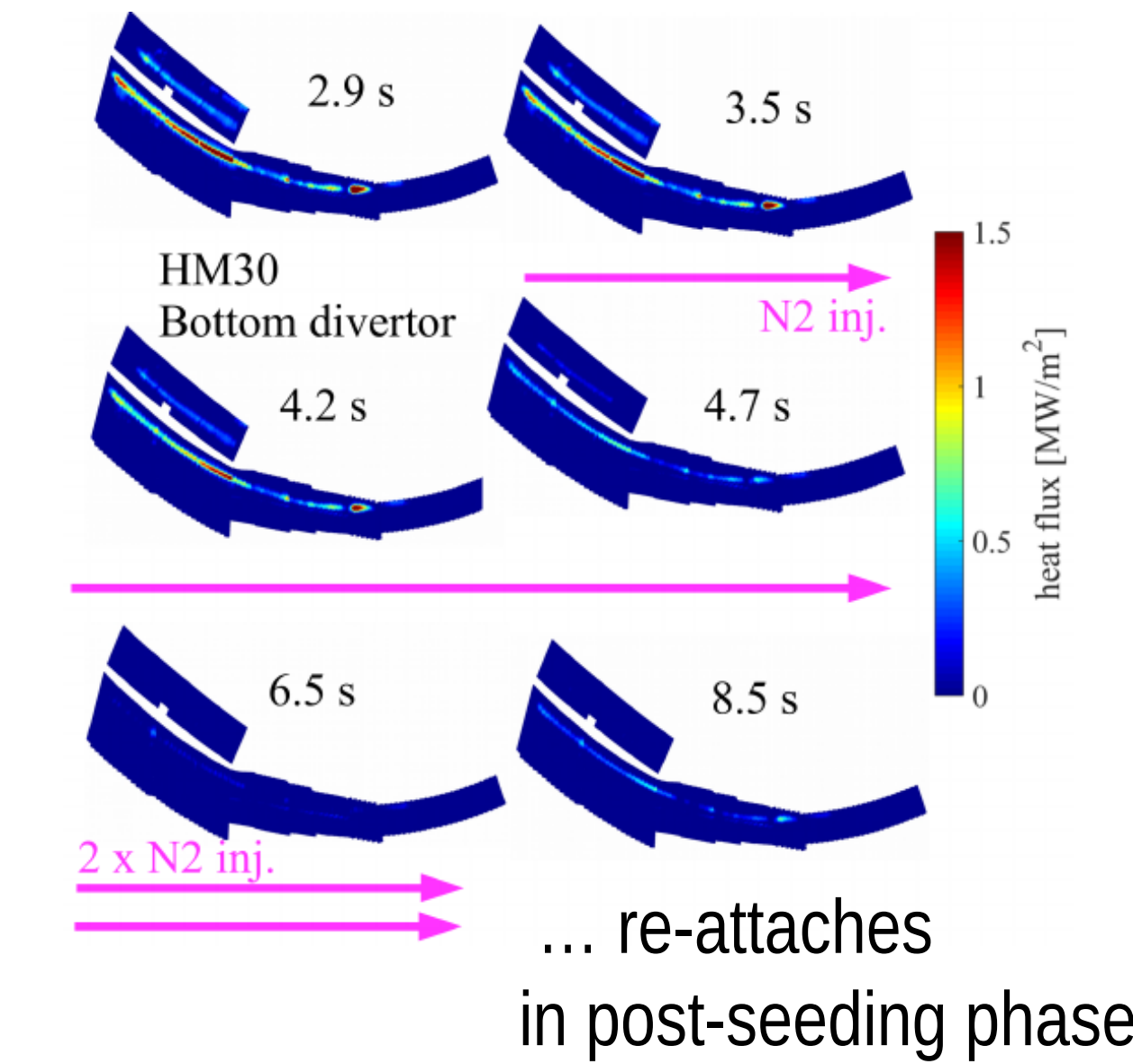
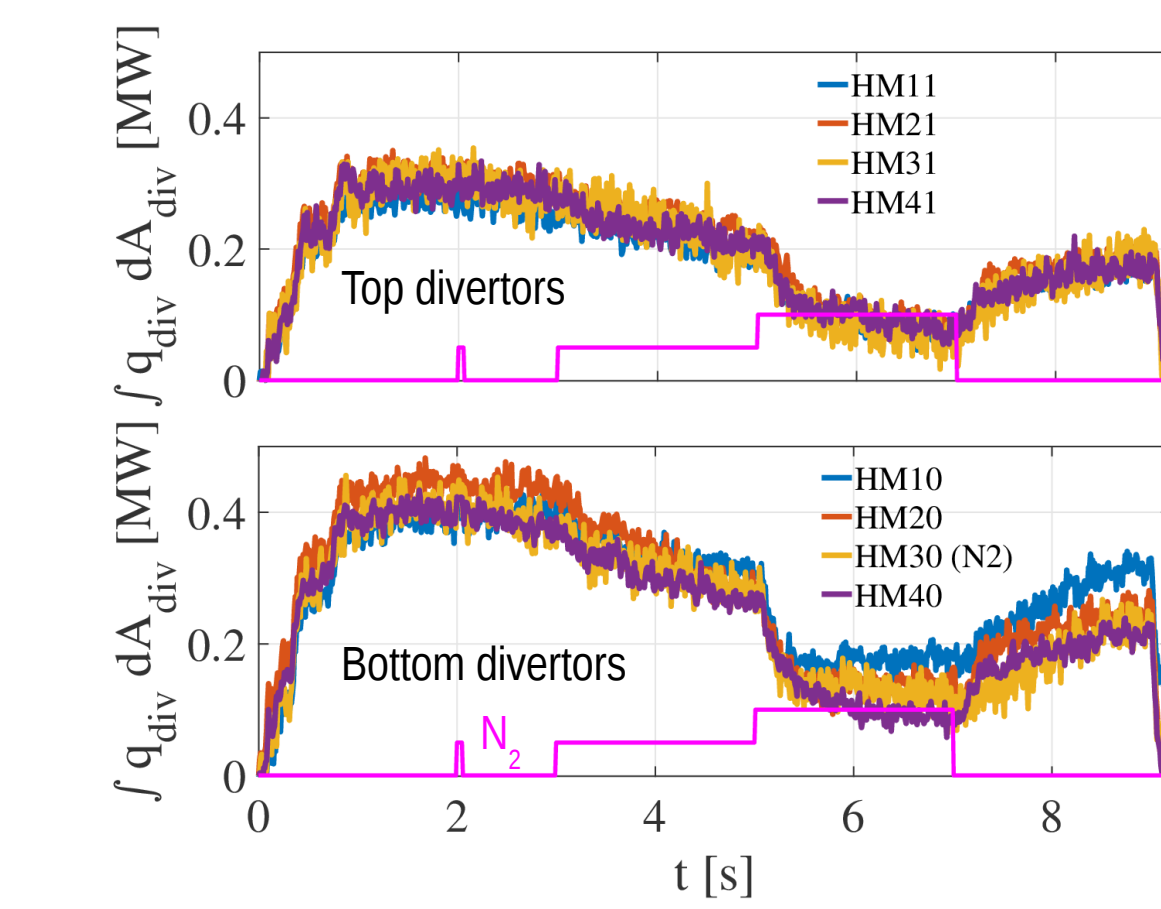
- $\Delta W_p \sim 12\%$ at maximum P_{rad}
- Z_{eff} increases from 1.2 to 2.1 suggesting a max. core impurity concentration of $\sim 2.5\%$
- divertor particle fluxes drop, neutral pressure increases first, drops at high P_{rad} (w/ density control)
- Plasma parameter recover after N₂ puff

Predictive and interpretative 3D modeling for radiative divertor scenarios



- Island divertor scenarios with C and Ne/N₂ modeled with EMC3-EIRENE
- Power losses due to Ne in the island results in reduction of divertor particle and heat fluxes
- Emission layer (C+Ne) moves upstream at high P_{rad}

Detachment and re-attachment with N2 seeding promising for feedback control



- symmetric cooling, absolute offsets due to drift and heating
- ... re-attaches in post-seeding phase

Summary

Radiative power exhaust with Ne and N₂ seeding has been investigated during first limiter and island divertor scenarios

Radiation enhancement in limiter configurations less stable, but strong and stable enhancement with global detachment of heat and particle fluxes has been demonstrated in the island divertor

Ne features a higher radiation efficiency and higher recycling while N₂ shows better neutral compression and lower recycling → N₂ more suitable for feedback control because of pumping

F. Effenberg et al 2019 Nucl. Fusion 59 106020
T. Barbui et al 2019 Nucl. Fusion 59 076008
Y. Feng 2013 Journal of Nucl. Mat. 438 S497-S500

