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

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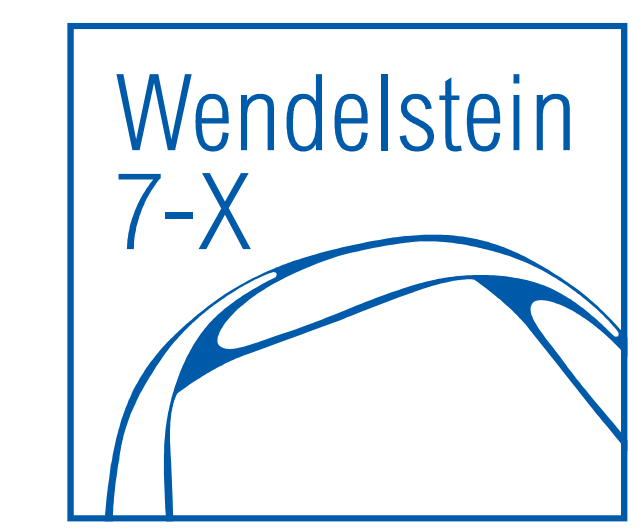
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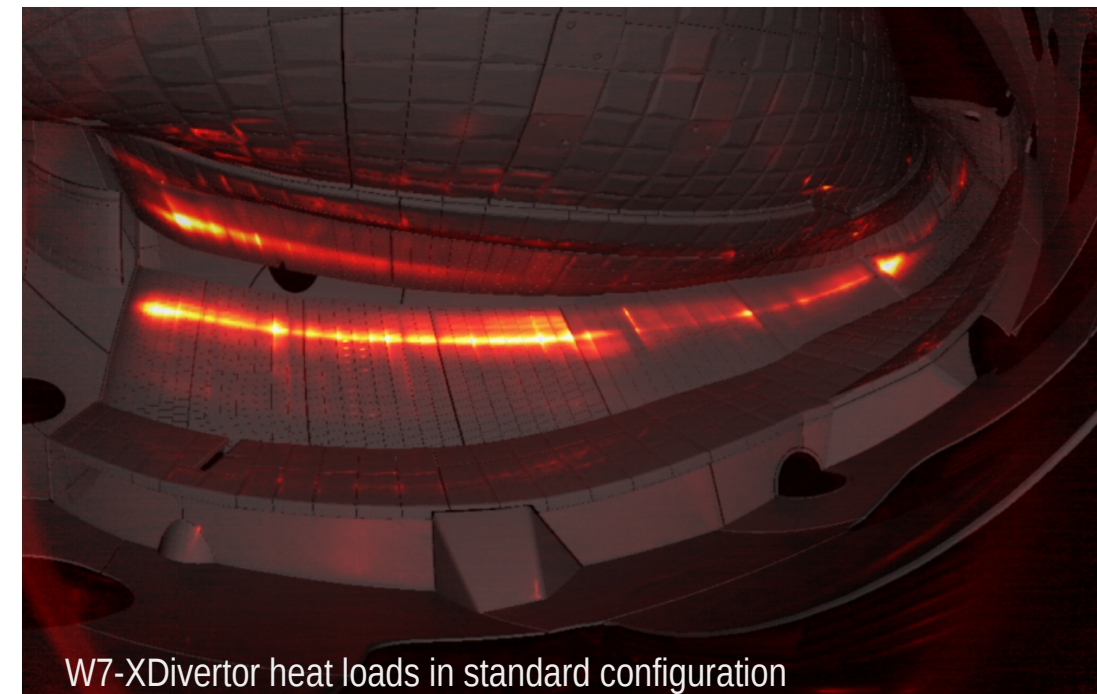
# Development of impurity seeding for divertor power flux handling in Wendelstein 7-X long pulse scenarios



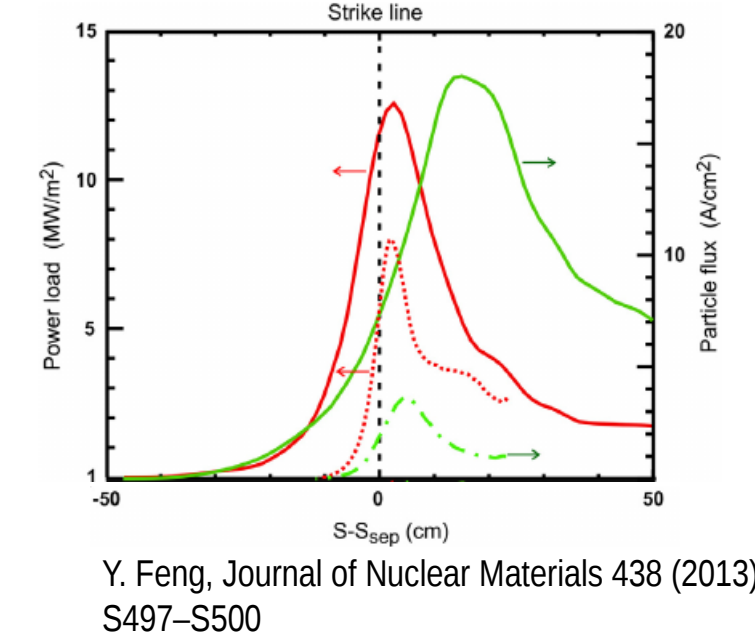
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## High power fluxes predicted for future W7-X reactor scenarios and next-step 3D devices

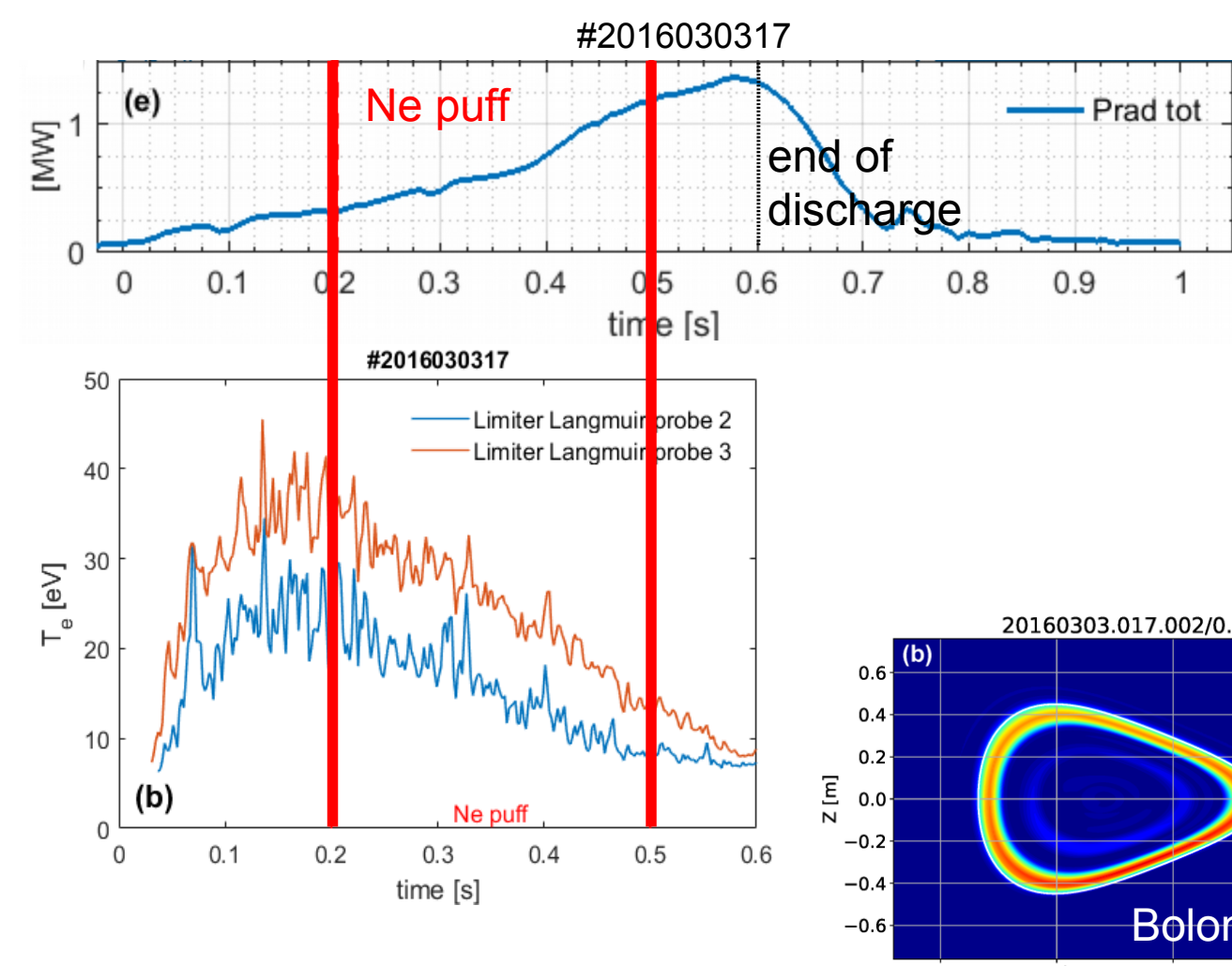


Reactor extrapolation  
(still low power:  $P_{SOL} = 200 \text{ MW}$ )

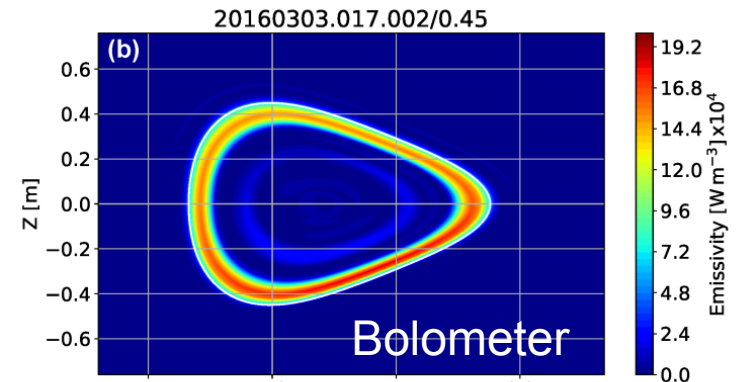


- Avoid overload of PFCs during high-performance/long pulse scenarios
- Stable, high-radiating divertor to be developed for reactor scenarios
- Substitute intrinsic radiators when using high Z materials (e.g. W)

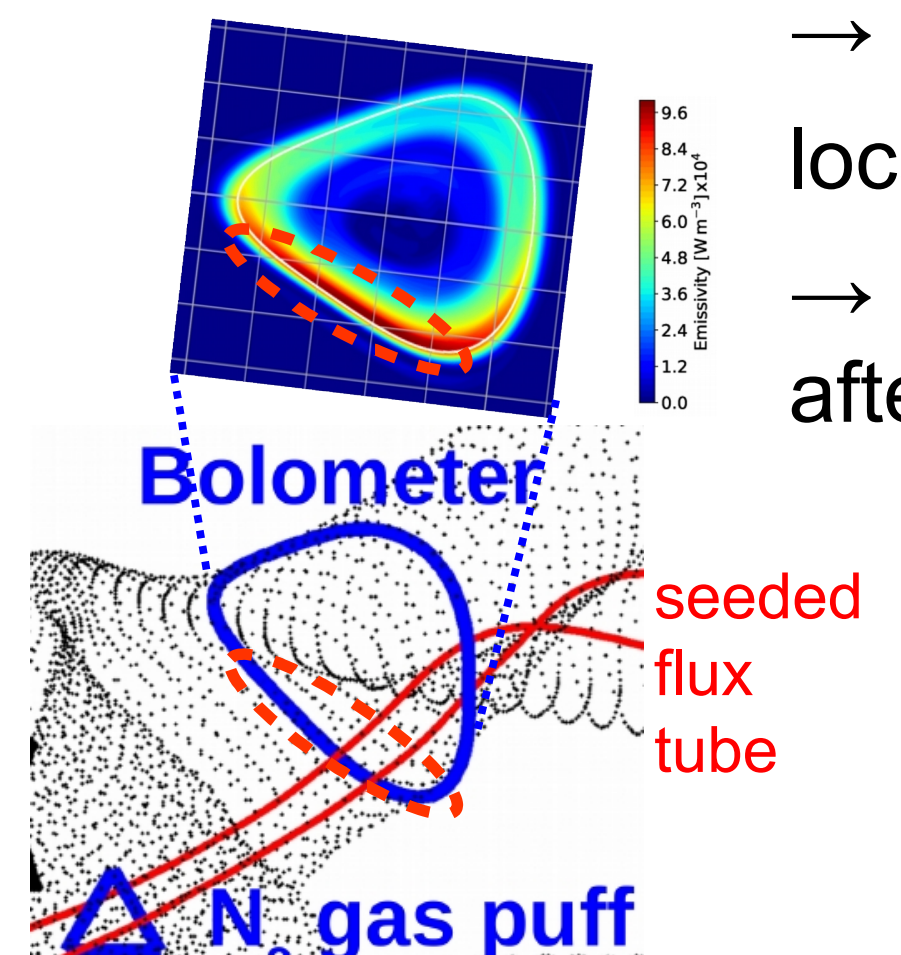
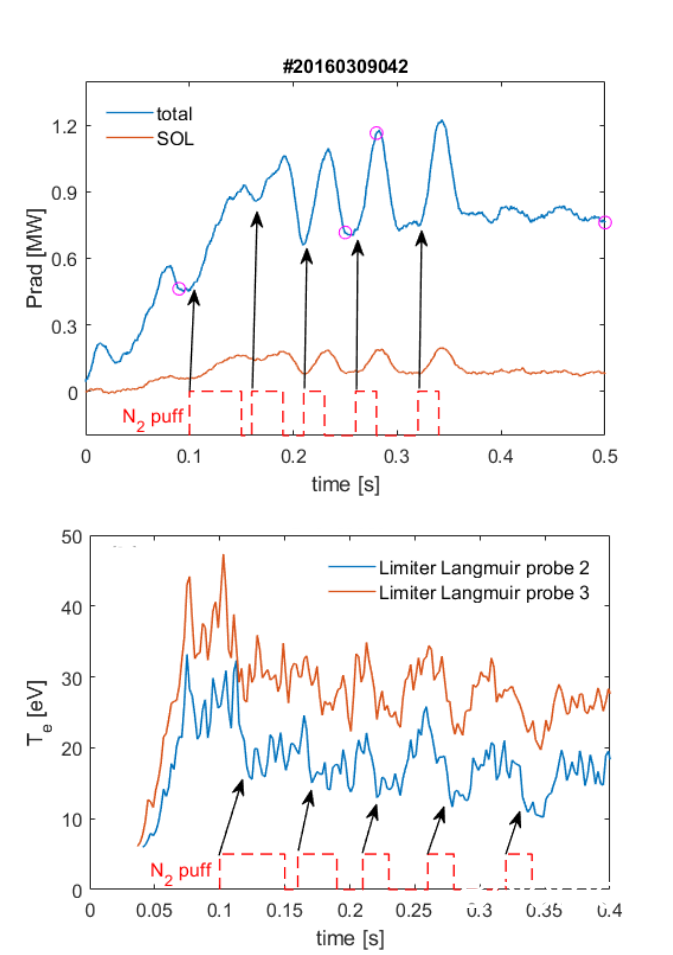
## Limiter: Neon showed high recycling and radiation efficiency



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

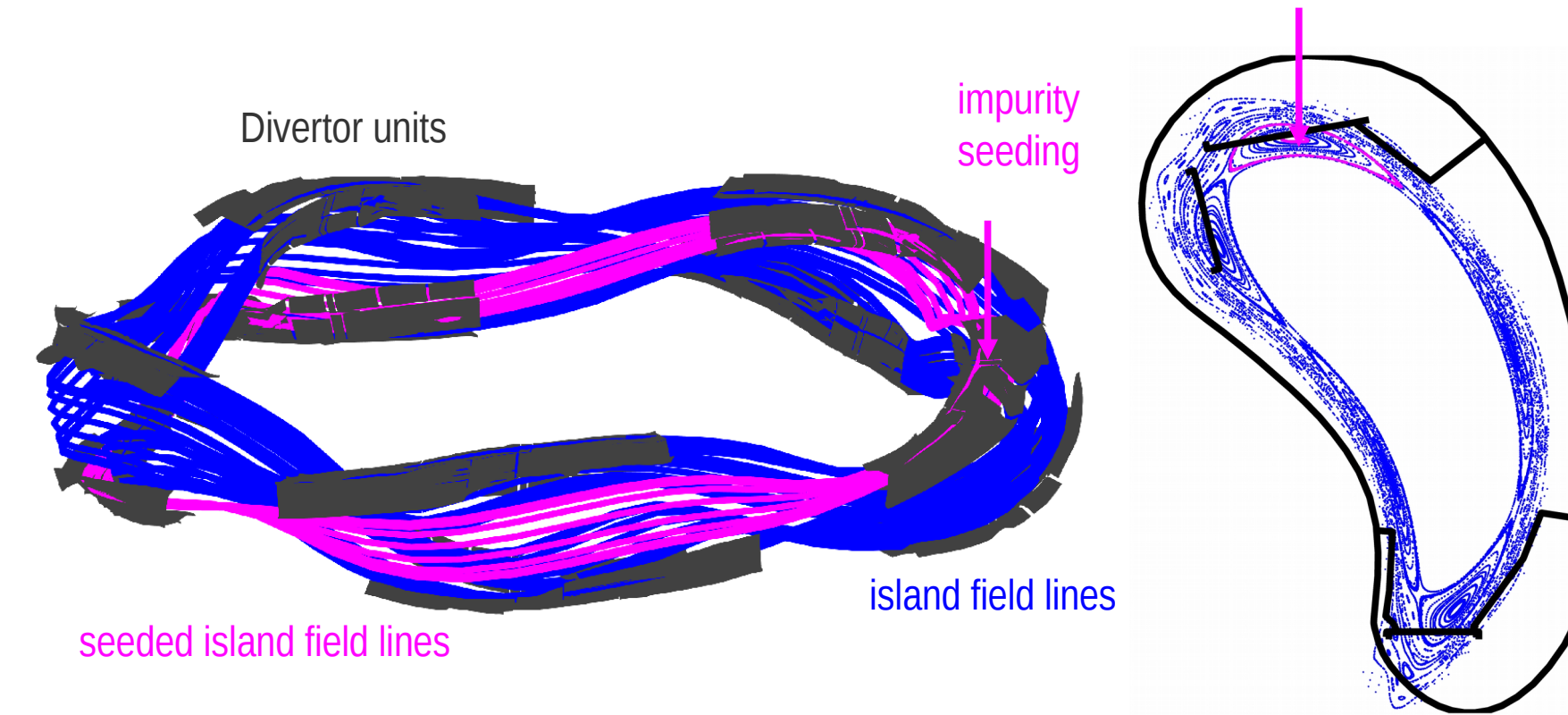
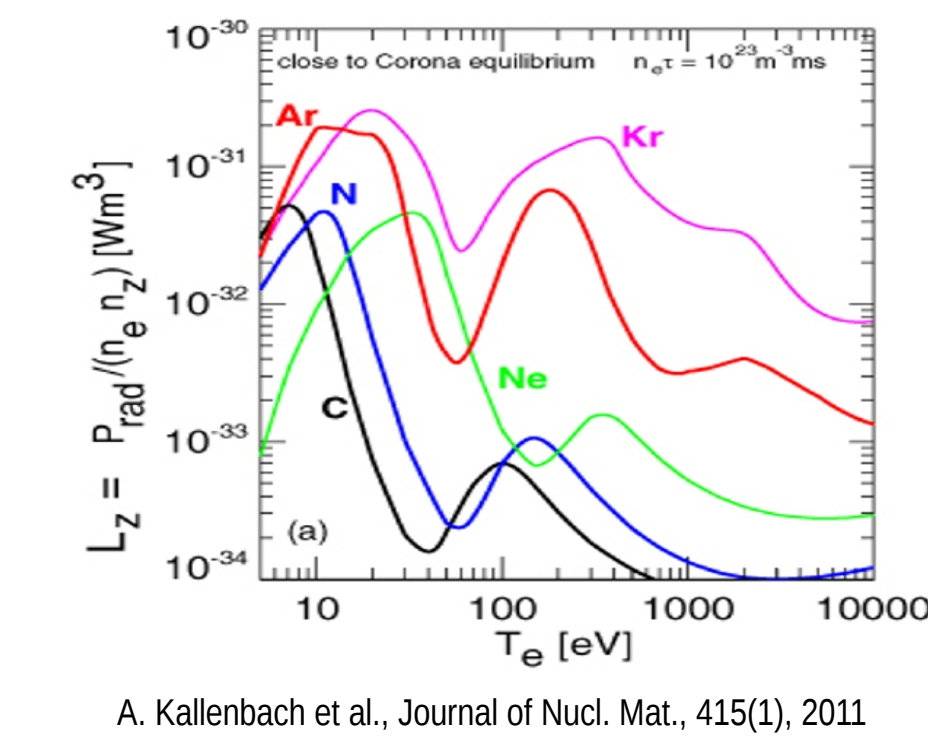


## Limiter: low level N2 seeding showed fast and local response in edge parameters



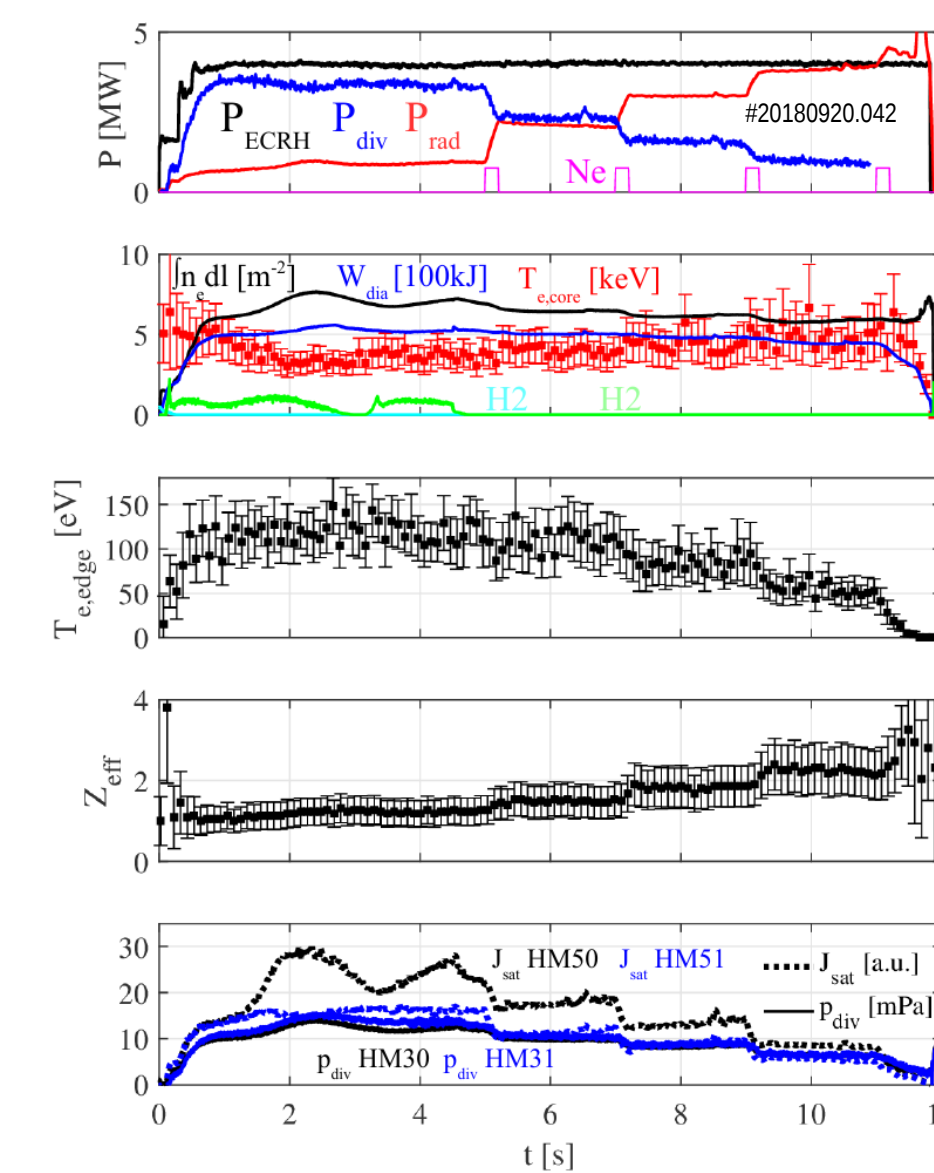
- Short N<sub>2</sub> injections show local increase in  $P_{rad}$
- prompt decay in Prad after each N<sub>2</sub> pulse

## Impurity seeding explored for radiative power exhaust and detachment control



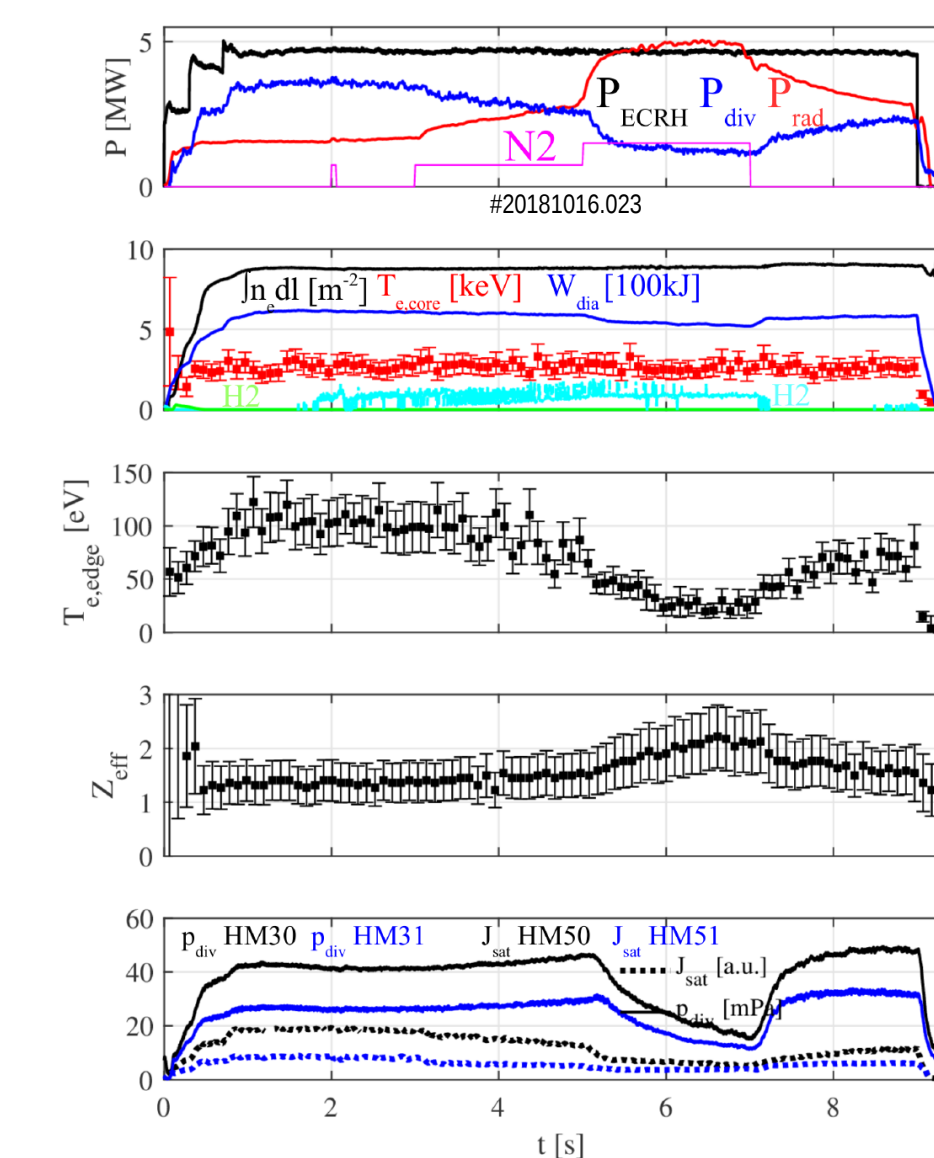
- Control divertor loads:  $q_{div} \sim q_{SOL} - P_{rad}$
- Optimize trade-off between performance & safety by choice of impurity species

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



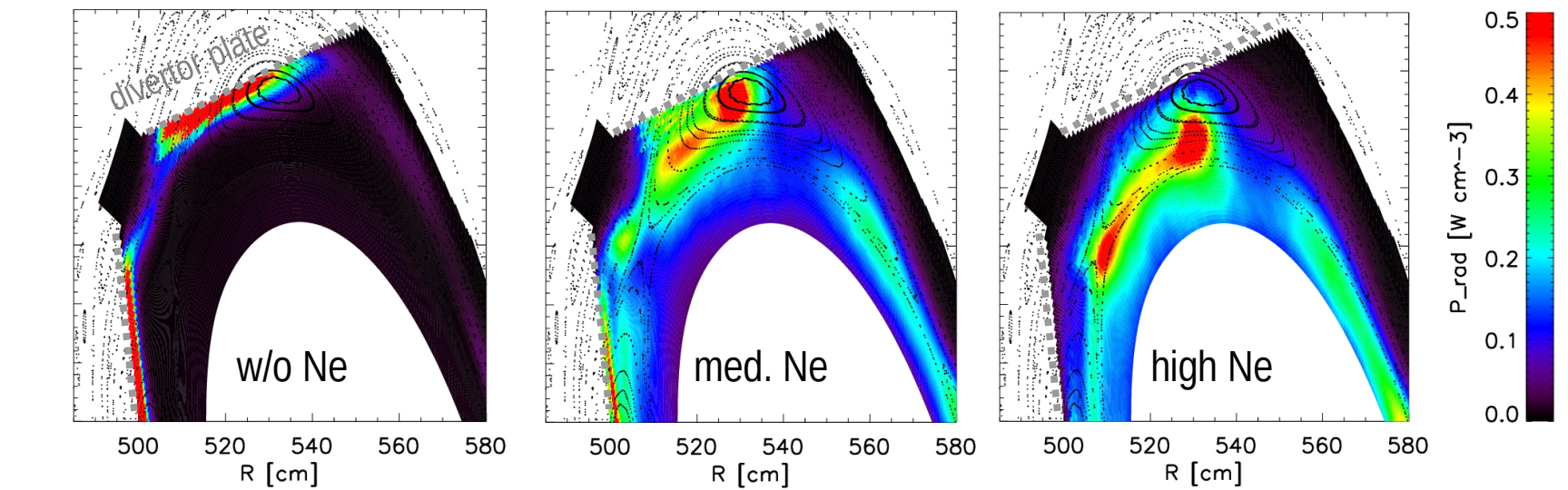
- stationary 'steps' in power balance  $\sim O(10s)$  due to high recycling of Ne
- $\Delta W_p \sim 15\%$  at highest  $f_{rad}$  of  $\sim 80\%$
- $Z_{eff}$  increases from 1.2 to 2.2
- $\sim 75\%$  of injected Ne particles retained in SOL
- reduction of divertor particle fluxes and neutral pressure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

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



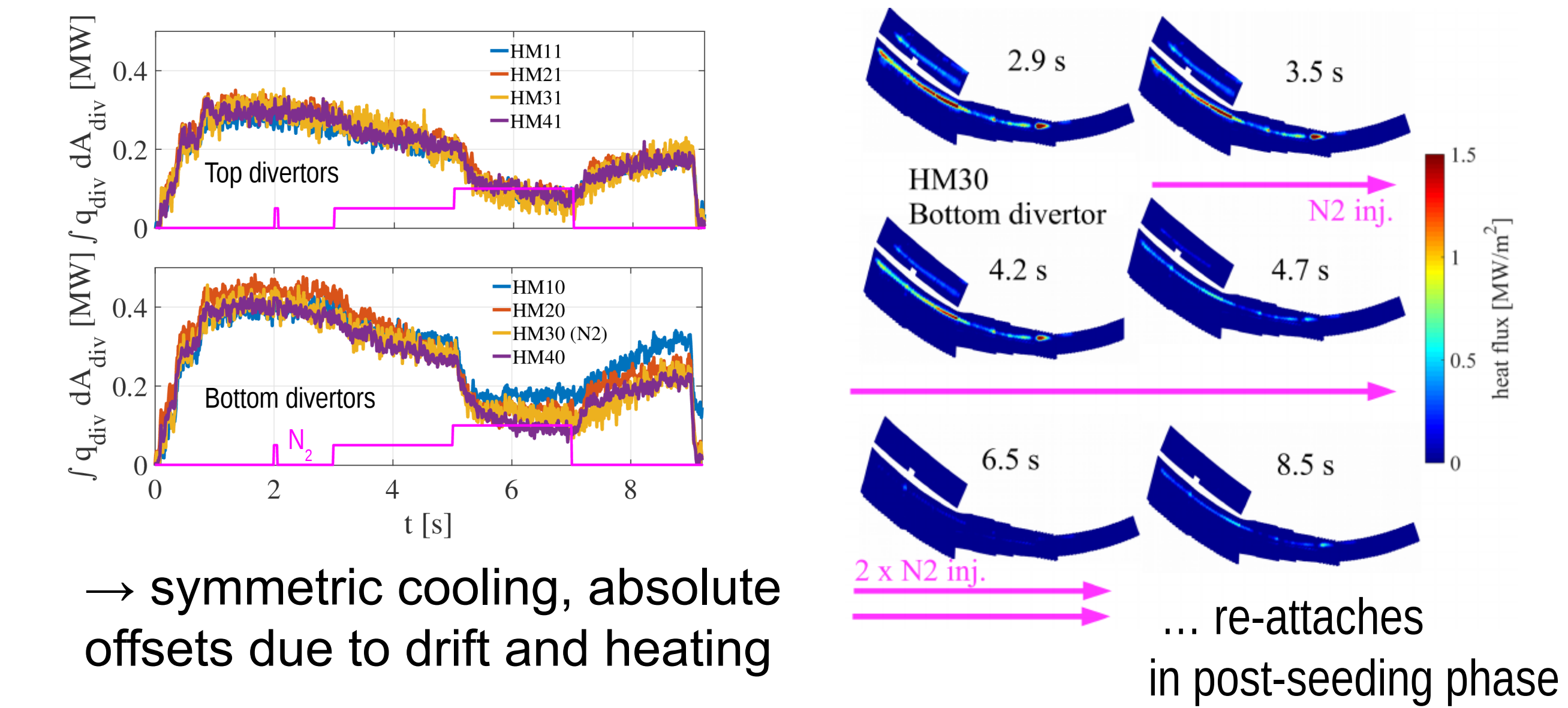
- $\Delta W_p \sim 12\%$  at maximum  $P_{rad}$
- $Z_{eff}$  increases from 1.2 to 2.1 suggesting a max. core impurity concentration of  $\sim 2.5\%$
- divertor particle fluxes drop, neutral pressure increases first, drops at high  $P_{rad}$  (w/ density control)
- Plasma parameter recover after N<sub>2</sub> puff

## Predictive and interpretative 3D modeling for radiative divertor scenarios



- Island divertor scenarios with C and Ne/N<sub>2</sub> 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 N<sub>2</sub> 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 N<sub>2</sub> shows better neutral compression and lower recycling → N<sub>2</sub> 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

