Impurity Seeding for Radiative Power Exhaust in the W7-X Island Divertor

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Content

Power exhaust and impurity seeding in the 3D island divertor

Effects of Neon seeding

Effects of Nitrogen seeding

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Effects of Neon seeding

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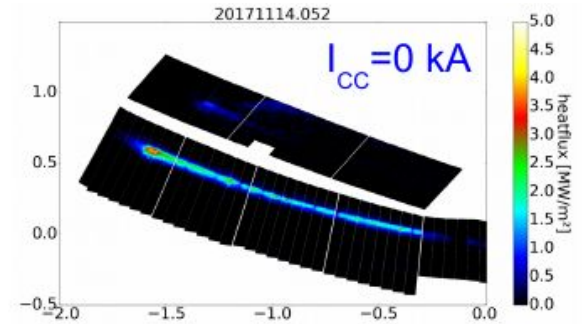
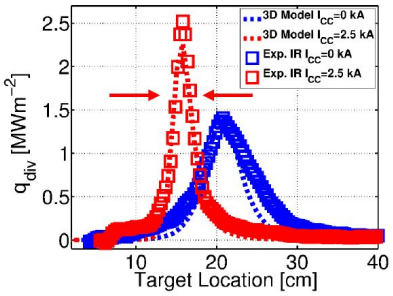
Power exhaust is a 3D issue in the perspective of quasi-stationary high performance operation

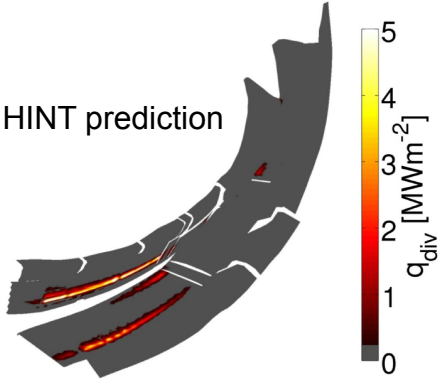
Potential overloading in attached plasmas



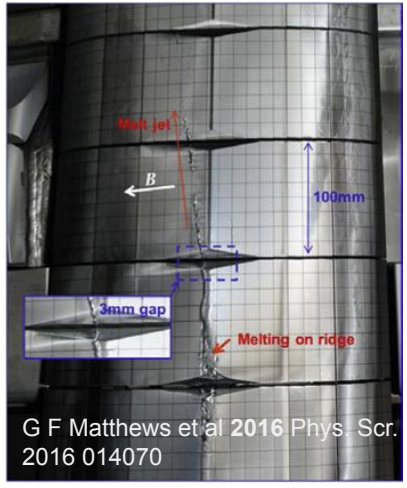
Overloading of divertor edges during transient phases or due to β effects



HINT prediction



F. Effenberg et al. 2019 Nucl. Mater. Energy 18 262

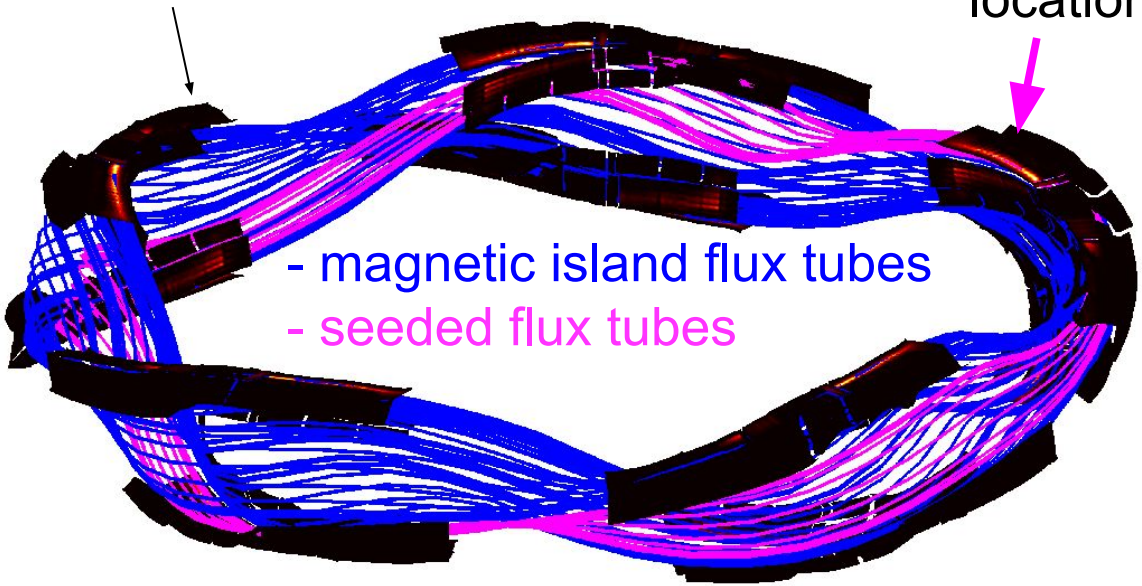


G F Matthews et al **2016** Phys. Scr. 2016 014070

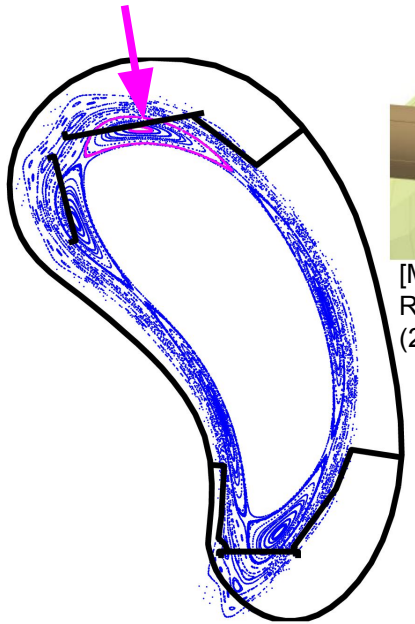
Future: Detachment with high *Z* divertor?
→ no intrinsic imp.
→ higher heat loads

Local impurity seeding in the 3D island divertor

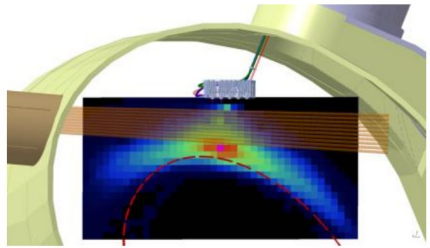
5 upper + 5 lower divertor units



Single seeding location



Seeding location:



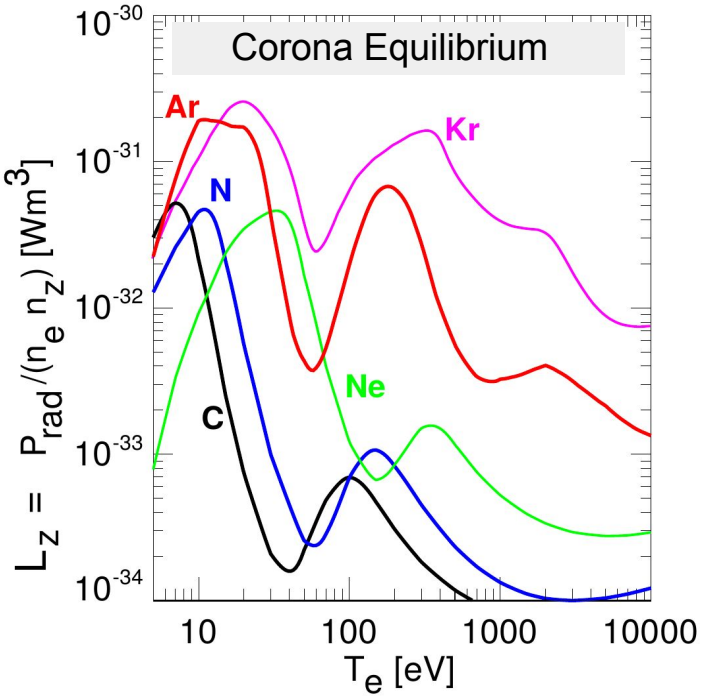
[M. Krychowiak et al., Review of Scientific Instruments 87, 11D304 (2016)]

Poincare plot: 5 independent magnetic islands

Island divertor: efficient for impurity exhaust and screening

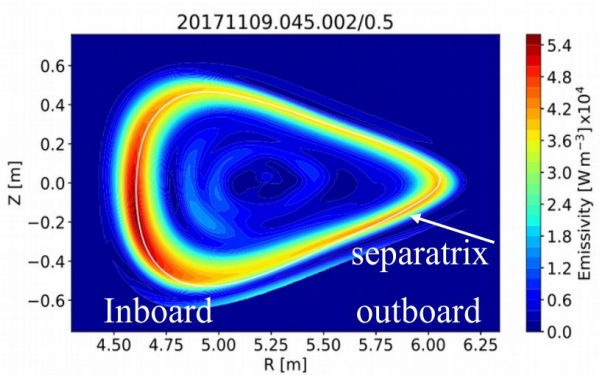
F. Effenberg et al 2019 Nucl. Fusion 59 106020

Distribution of radiative losses determined by radiation potential and source location



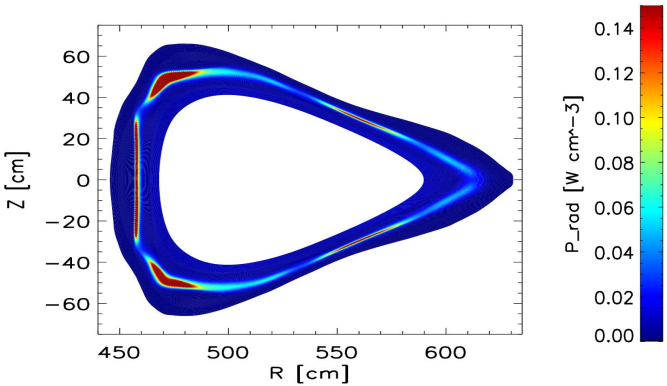
A. Kallenbach et al., Journal of Nucl. Mat., 415(1), 2011

Measured radiated power



Tomographic inversion:
S. Kwak & J. Svensson

Modelled radiated power



W7-X has a C divertor and wall interface: → intrinsic radiation potentials are comparable to those of Ne and N_2

F. Effenberg et al, 23rd PSI Conference, Princeton, 2018
D. Zhang et al, 23rd PSI Conference, Princeton, 2018

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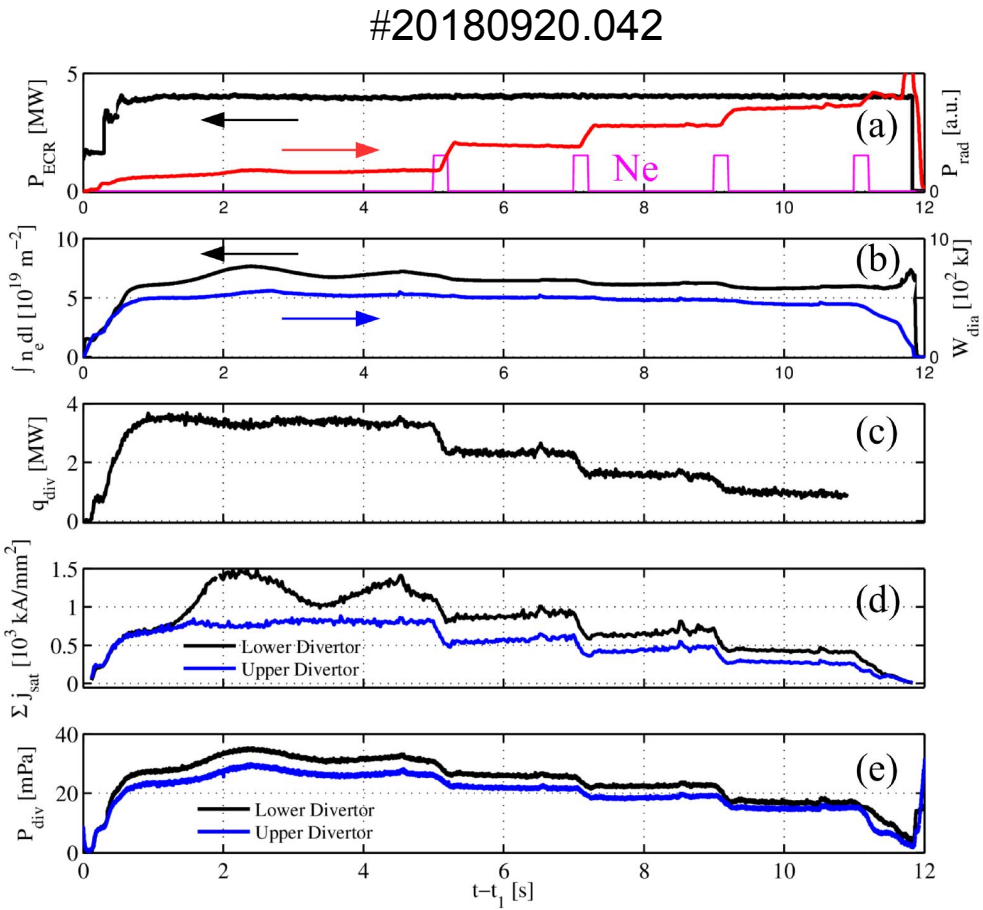
Power exhaust and impurity seeding in the 3D island divertor

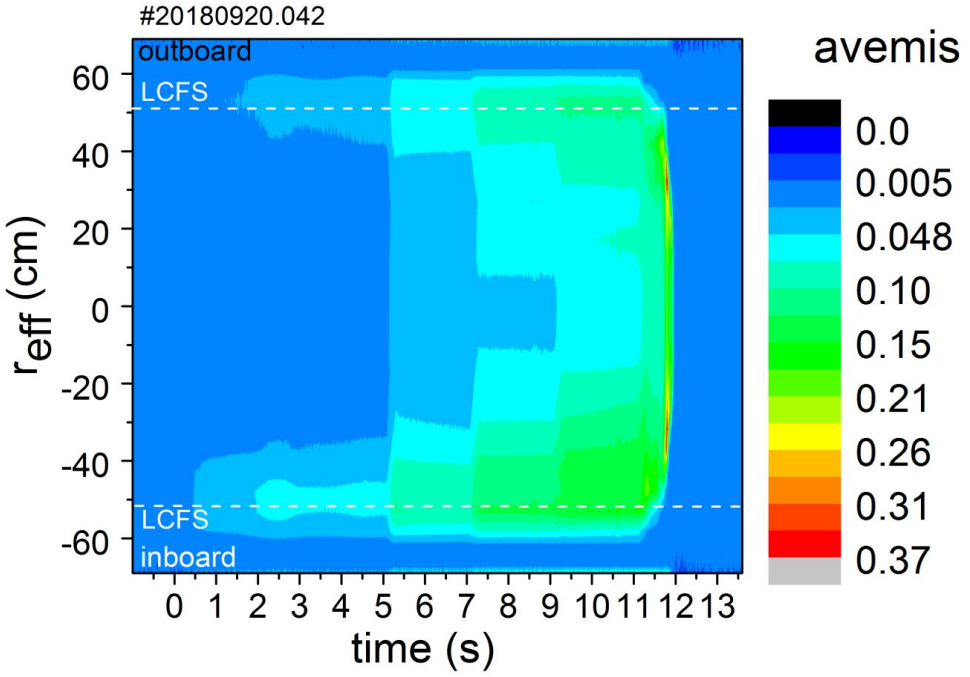
Effects of Neon seeding

Effects of Nitrogen seeding

Short Neon injections causes rapid and sustained radiative power enhancement



Impurity Spectroscopy: Ne recycles in divertor after injection



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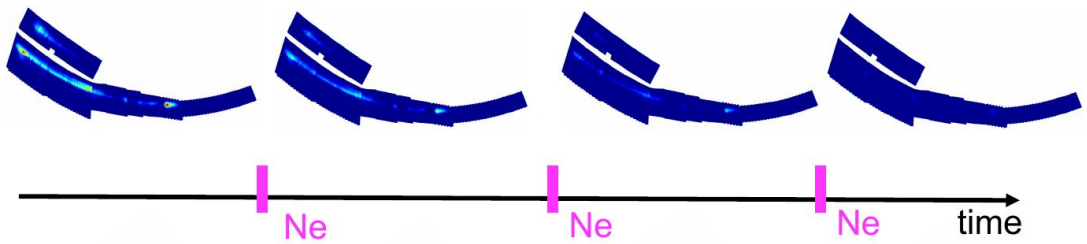
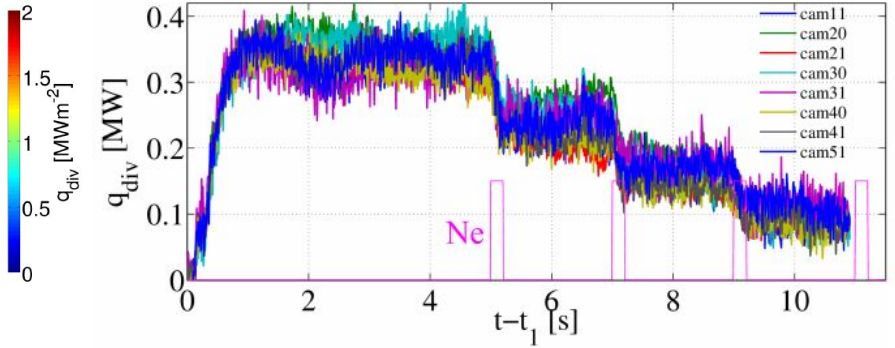
Neon seeding causes uniform reduction of divertor heat loads as predicted by 3D modeling

Measured heat fluxes (IR):

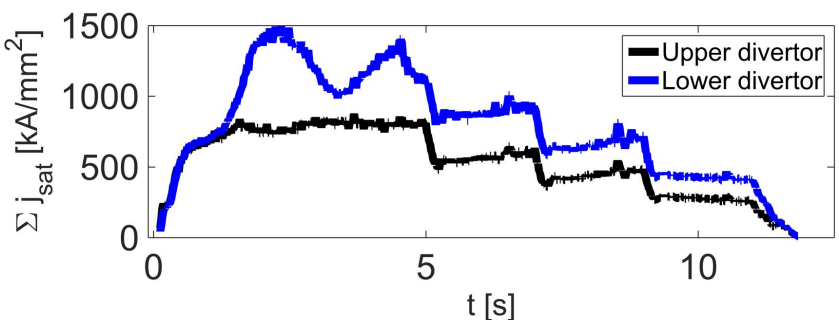


Modelled heat fluxes (EMC3-EIRENE):

$n_{sep}=10^{19}\,m^{-3}$, P=4 MW, $D_\perp=\chi_\perp=1\ m^2s^{-1}$, $\Gamma_{Ne}\sim c(f_{rad})\Gamma_{rec}$



- P_{rad} enhances uniformly
- Stable operation with heat & particle fluxes reduced by 60-70%



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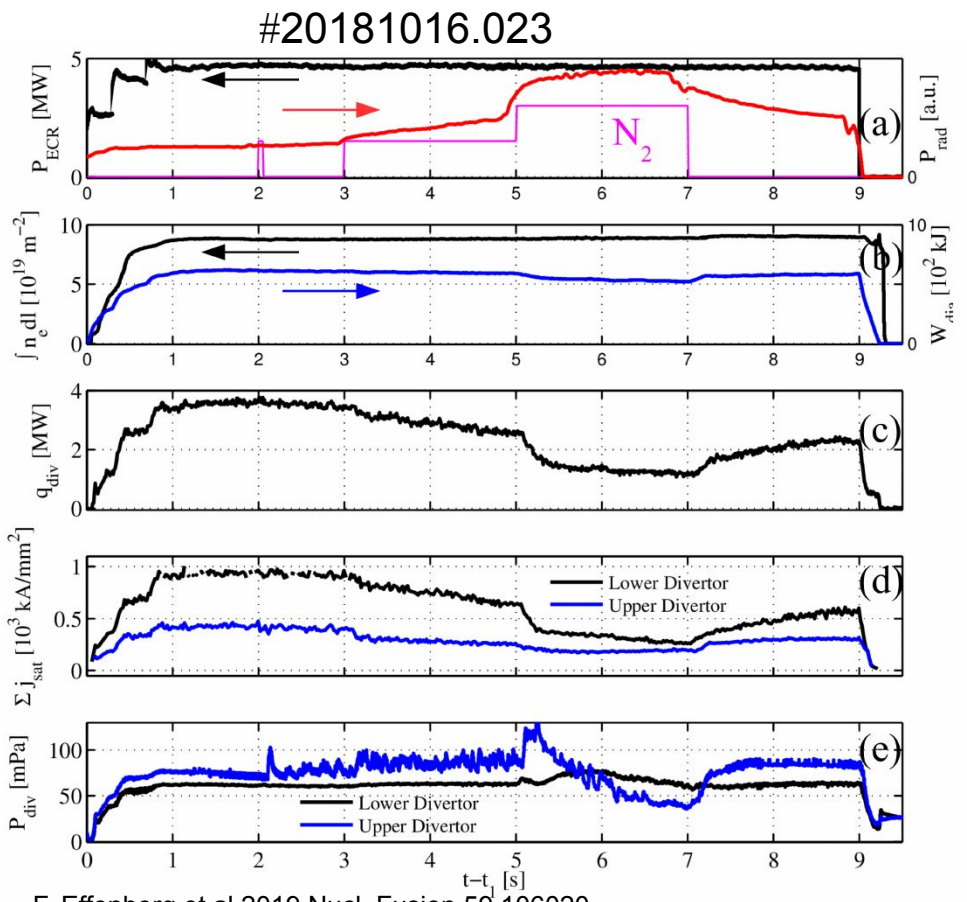
Nitrogen seeding: low recycling requires continous seeding recovery due to low recycling



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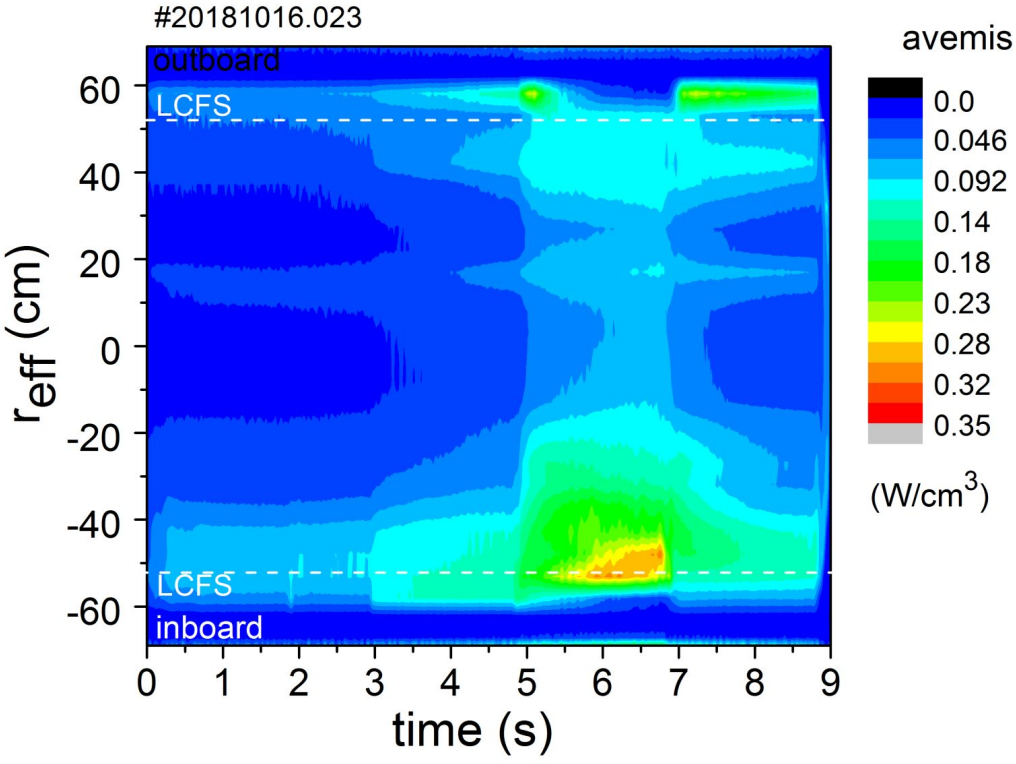
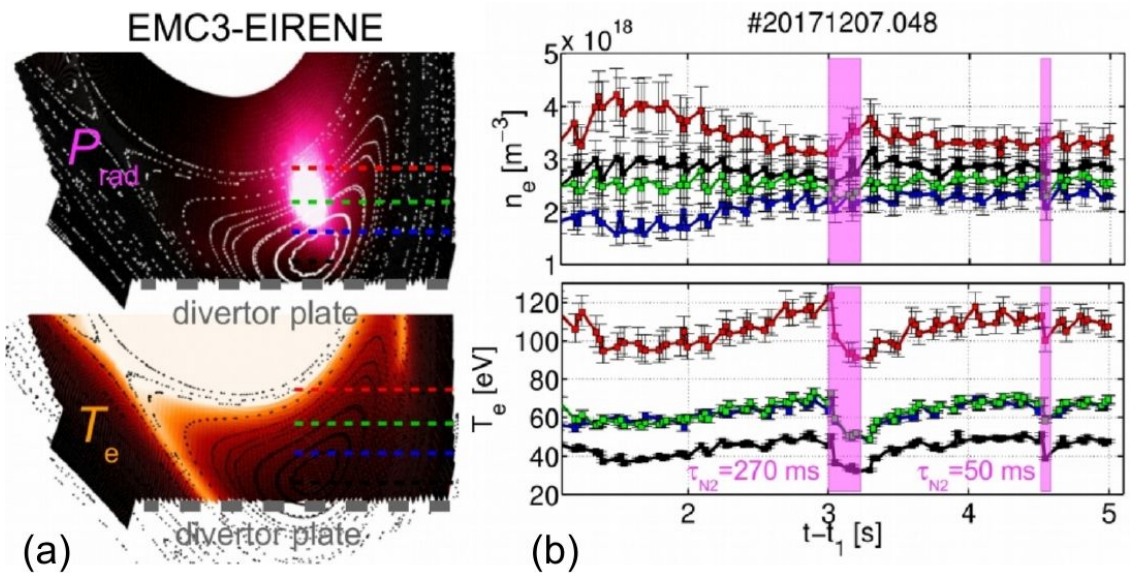
N2 shows asymmetric P_{rad} distribution

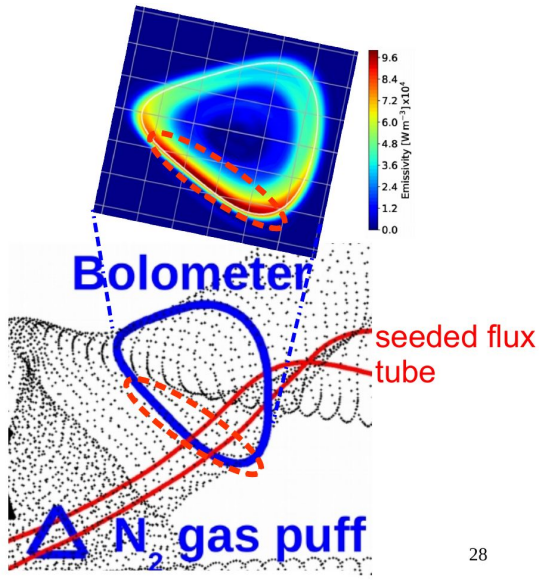


Nitrogen seeding: low recycling requires continous seeding recovery due to low recycling

SOL temperatures recover after short N2 puff

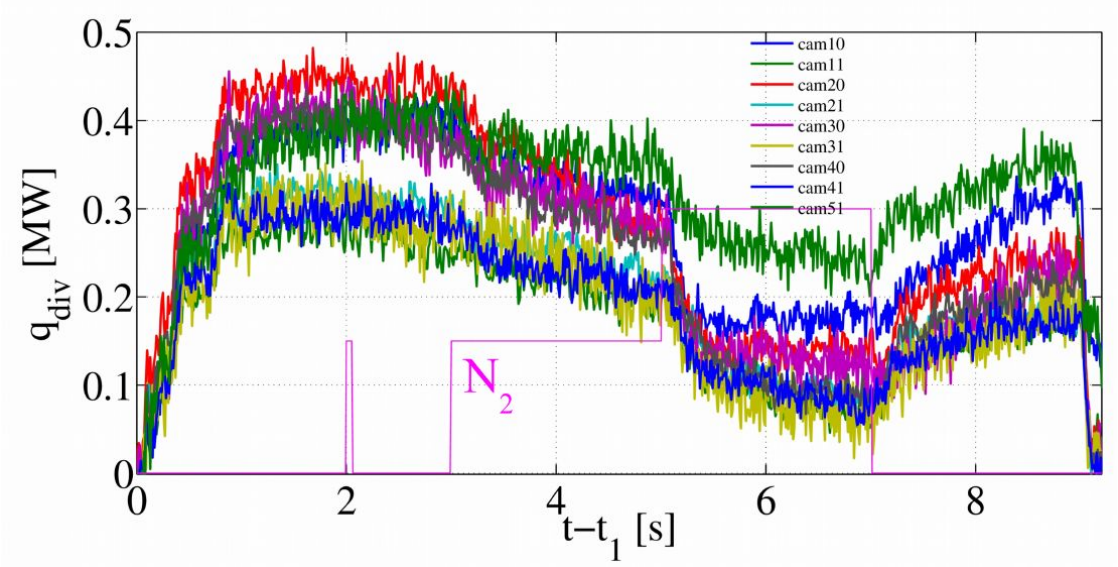


Similar when seeding helical flux tubes in OP1.1



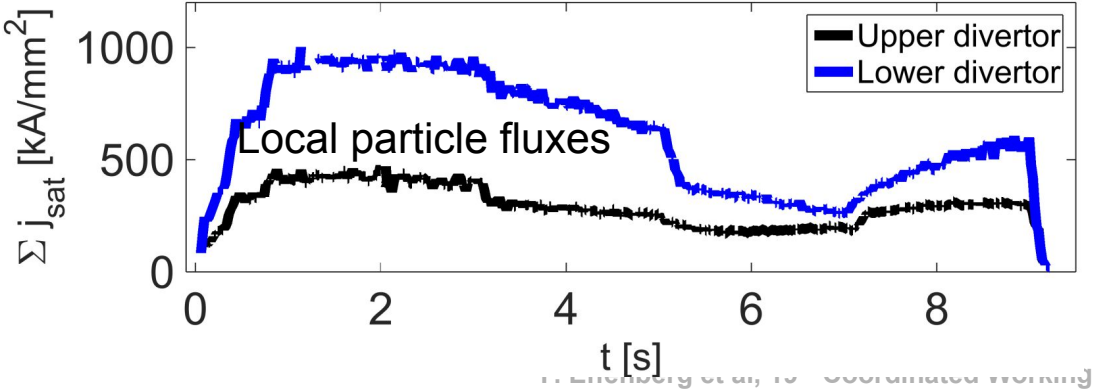
F. Effenberg et al 2017 Nucl. Fusion 57 036021

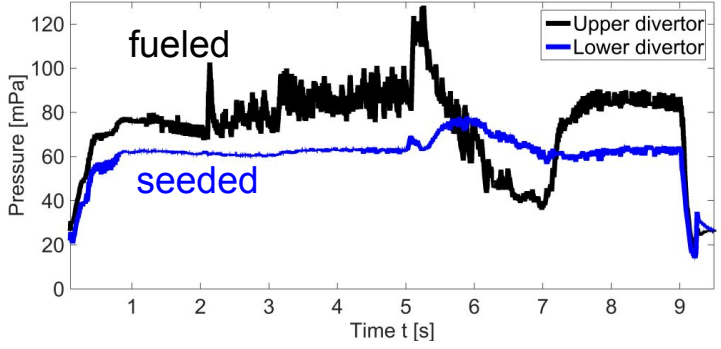
Nitrogen seeding: asymmetric cooling effects on divertor heat and particle transport



- Heat and particle fluxes reduce on all divertors, but slight asymmetries
- Asymmetric neutral pressure response

→ 3D effects on N_2 seeding?





Summary & Outlook

Demonstrated stable high radiation scenarios with heat and particle fluexes reduced by ~2/3

Ne: high recycling radiator, uniform radiative power exhaust
N_2: low recycling, 3D effects on cooling, indication of better neutral compression
→ wall recycling will determine power loss distribution

Next:
Compare with results from first divertor campaign (pre-boronisation)
Investigate effects on energy and particle confinement
Compare with other seeded impurities