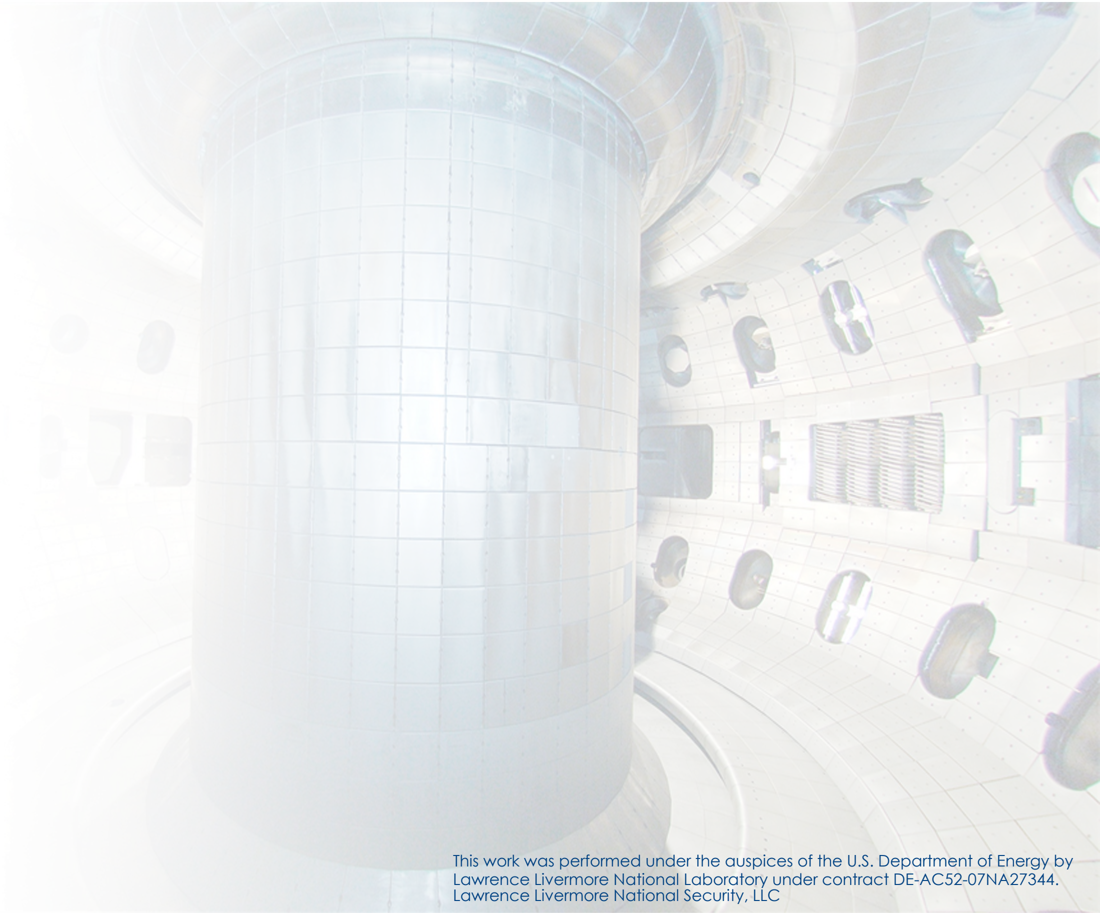
Effect of wall changeout on radiative divertor studies

F. Scotti, others…

Wall Changeout Workshop
June 12, 2024



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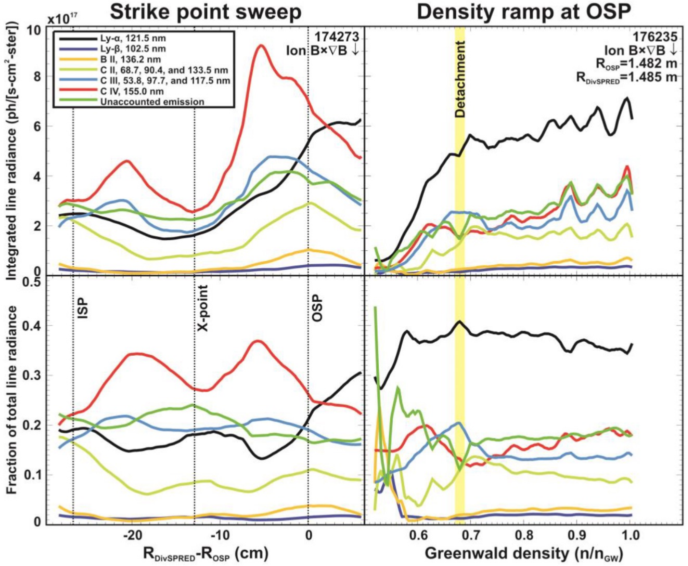
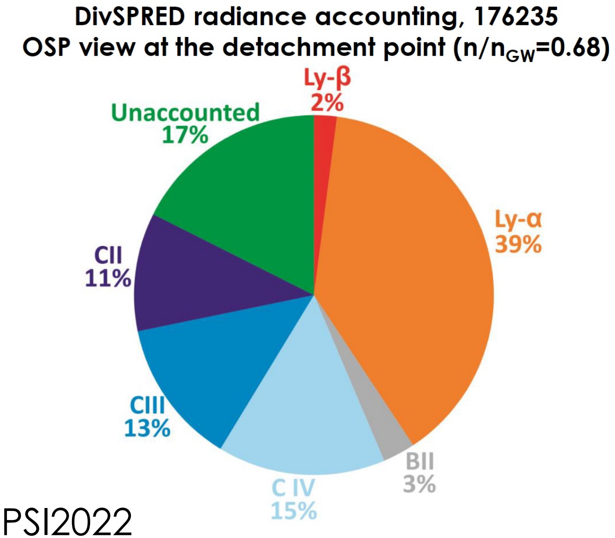
Reduction in low Z intrinsic impurity will require seeding for detachment, re-optimization of spectroscopic divertor diagnostics

- Reduction in low Z intrinsic impurity source with wall changeout brings the necessity of impurity seeding for divertor dissipation studies
- Non-forgiving nature of metallic wall → high collisionality or seeding could be the default way of operation in some regimes
- N provides most seamless transition (similar radiation/compression to C) with added controllability, different scenarios to rely on different mixes (B, N, Ne, Ar)
- Move to higher Z radiators needs a re-optimization of diagnostics for radiative divertor studies (shorter wavelengths)

Sputtered C provides dominant divertor radiation fraction in DIII-D

- **Radiative divertor/detachment studies typically rely on intrinsic rad. in DIII-D**
  - Impurity concentration ~ sputtering yield $Y_{phys}(T_e, T_i)+Y_{chem}$ (no threshold on Y_{chem})
  - Divertor detaches above a certain $n_{e\text{-}sep}$ relying on intrinsic impurity sputtering
  - Typically >60% of divertor radiation is due to C (dominantly C IV, C III)
  - T_e dependence of Y_{phys} provides stabilizing effect





McLean PSI2022

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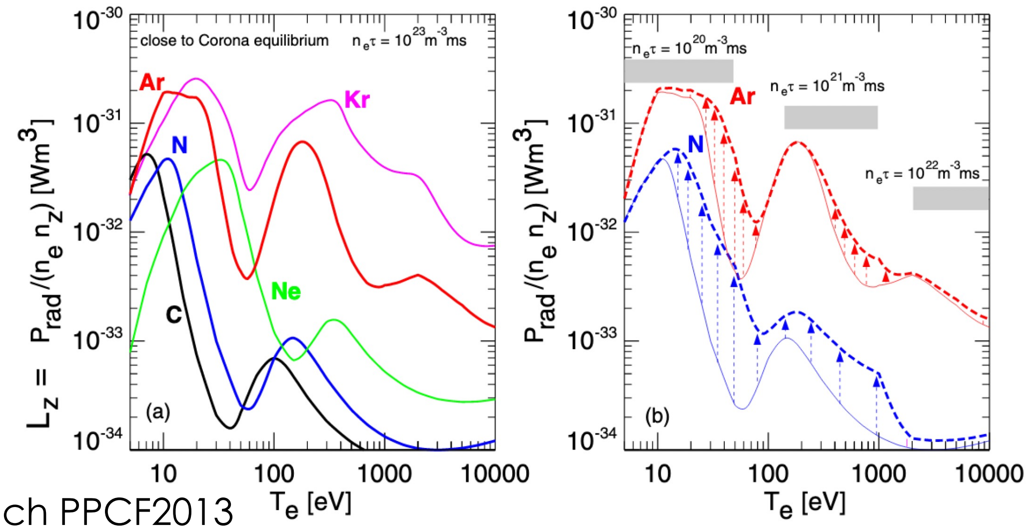
Low/mid Z seeding will be required to replace C radiation for radiative divertor studies

- **Full wall changeout aims to reduce intrinsic impurity levels**
  - Seeding will be necessary for radiative divertor studies to replace C radiation
- **Metallic divertor PFCs not forgiving (melting, sputtering, high core P_{rad}), operation at high collisionality or with impurity seeding might be necessary for some scenarios**
- **Low/medium Z radiators will be needed to reduce heat flux, access detached divertor conditions**
  - N closest in Z, radiation curves to C
  - Standard in many tokamaks AUG, JET, C-Mod, WEST, etc.
- **Ar, Ne can complement with also radiation inside confined plasma**
- **Powders (B, Li)**



Kallenbach PPCF2013

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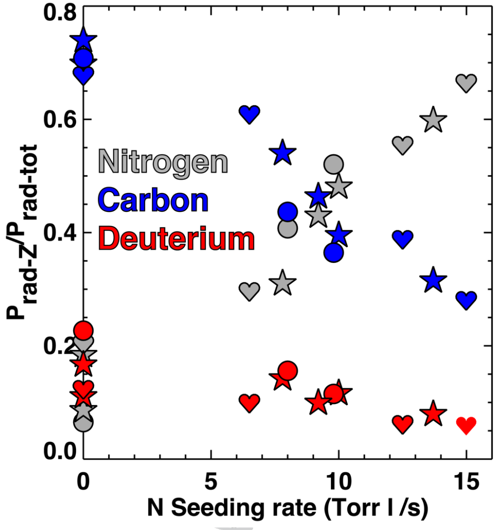
Divertor conditions with dominant extrinsic divertor radiator typically achieved in DIII-D with increased dilution unchanged intrinsic impurity

- **We already routinely achieve conditions where extrinsic impurity is the dominant divertor radiator (e.g., N)**
  - Achieved at increased dilution with an unchanged intrinsic impurity concentration
  - Seeding adds external control, but complicated by wall retention

- **Higher T_e at peak P_{rad} of possible seeded radiators should reduce confinement degradation for deeply detached conditions (e.g. X-point radiator)**



Fraction of VUV line radiation in outer divertor leg

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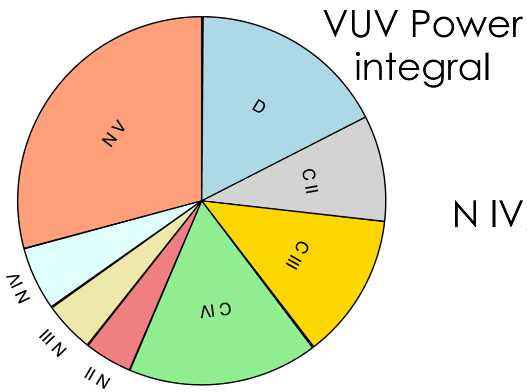


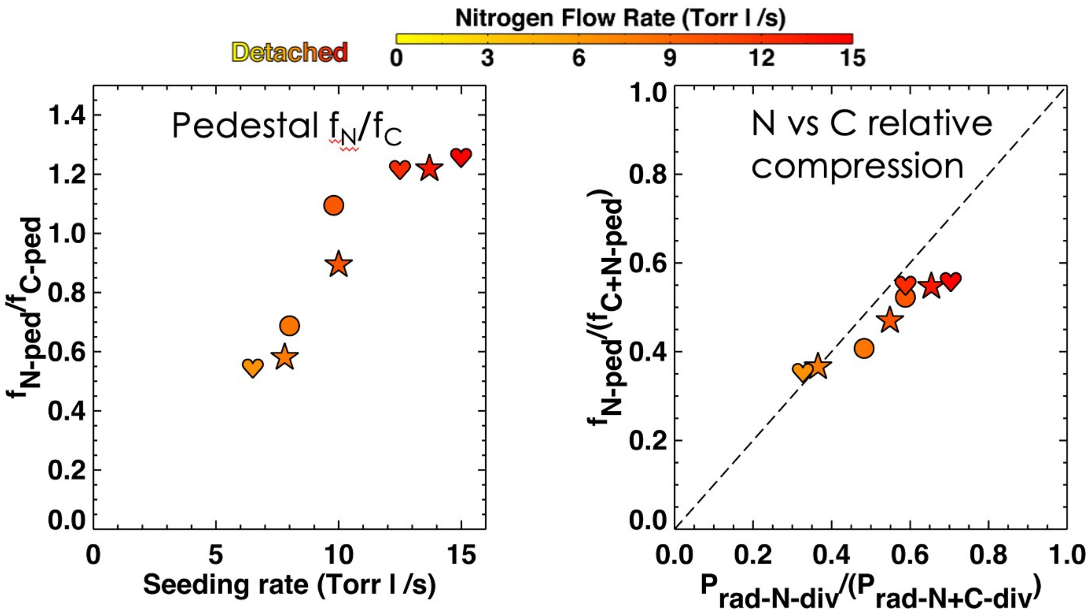
N IV, N V dominant radiators

Detached, N_2 9 Torr l /s
185841

At constant seeding, comparable radial transport and effective compression between C and N should make easy transition

- With constant seeding, $f_{N\text{-}ped}/f_{C\text{-}ped}$ linear with seeding rate, comparable C, N radial transport

- Comparable effective compression for N, C (core concentration/divertor power share)



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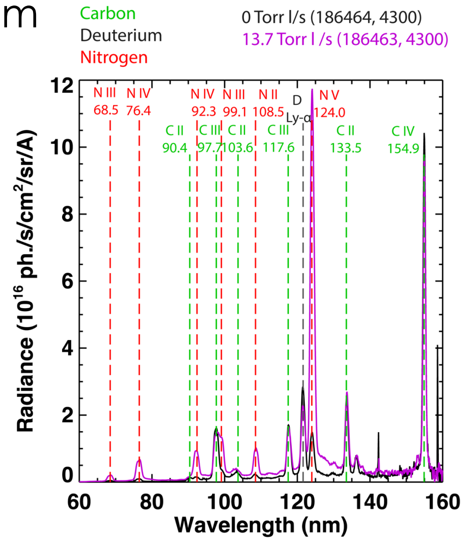
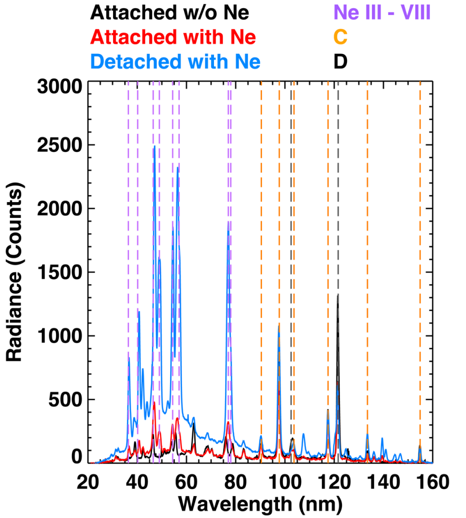
Radiative divertor characterization will need re-optimization of imaging and spectroscopy with transition to seeded impurities

- **DIII-D radiative divertor characterization relies on VIS + VUV spec. and VIS imaging**
  - VUV of resonance transitions for radiated power share
  - VIS spectroscopy + VIS imaging for impurity concentration and radiation front imaging
- **<u>Move to higher Z seeded radiators shifts useful spectral range towards UV</u>**
  - VUV resonance lines will still provide coverage for dominant low Z seeded radiated power
  - Workhorse line for radiation front is C III 465nm (10-12 eV, around VUV C IV emission)
  - N equivalent transition → N IV 348 nm, <u>radiation front imaging in UV</u>
  - Ne, Ar imaging also too challenging in VIS
  - N, Ne, Ar line ratios in UV region as used in AUG





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