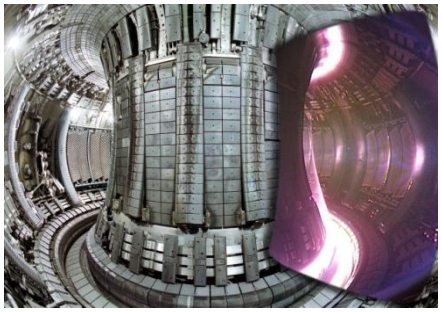
Radiation Modelling in DEMO Systems Studies

Hanni Lux

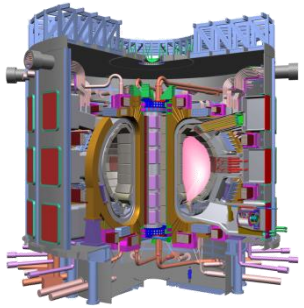
R. Kemp, D.J. Ward, M. Sertoli (IPP)

CCFE is the fusion research arm of the **United Kingdom Atomic Energy Authority.**
This work was part-funded by the RCUK Energy Programme [grant number EP/I501045] and the European Union's Horizon 2020 research and innovation programme.

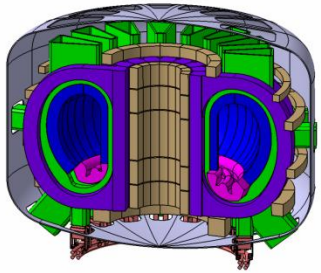
A Fusion Power Plant



- **JET**
  - 1983, Culham, UK
  - 1997 world record of 16 MW fusion power for 1 s
  - 3x10^19 m^-3, 6 keV



- **ITER**
  - 2020s, Cadarache, France
  - 10^20 m^-3, 9 keV
- **DEMO**
  - 2040s (fast track)
  - 10^20 m^-3, 15 keV

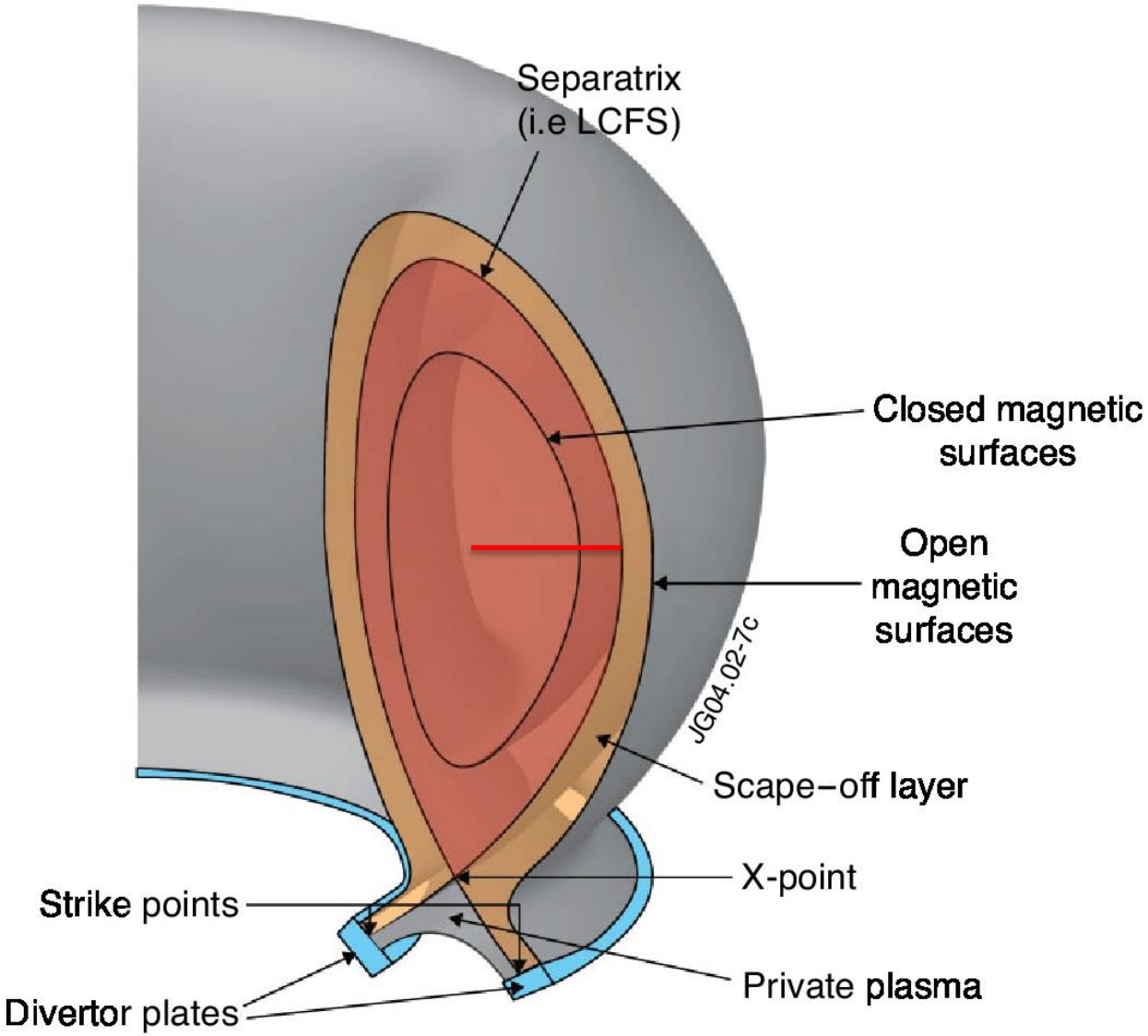


Systems Studies

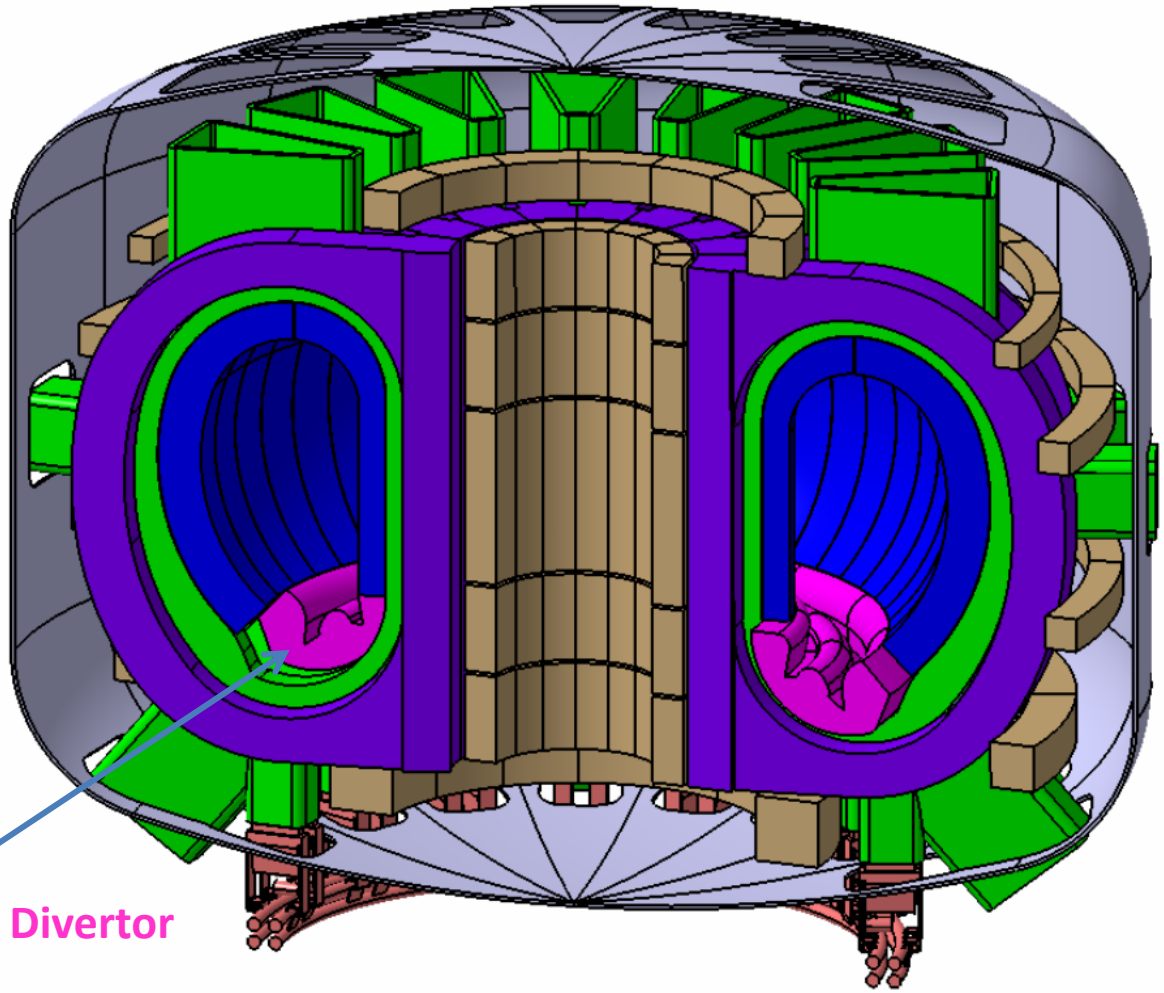
- How to find an optimal power plant design that fulfils physical laws and engineering constraints?
- What is the smallest possible plant to produce 500 MW of net electricity?

=> **Simple** models that capture **all significant interactions to the necessary accuracy** for conceptual power plant design

Physics Models



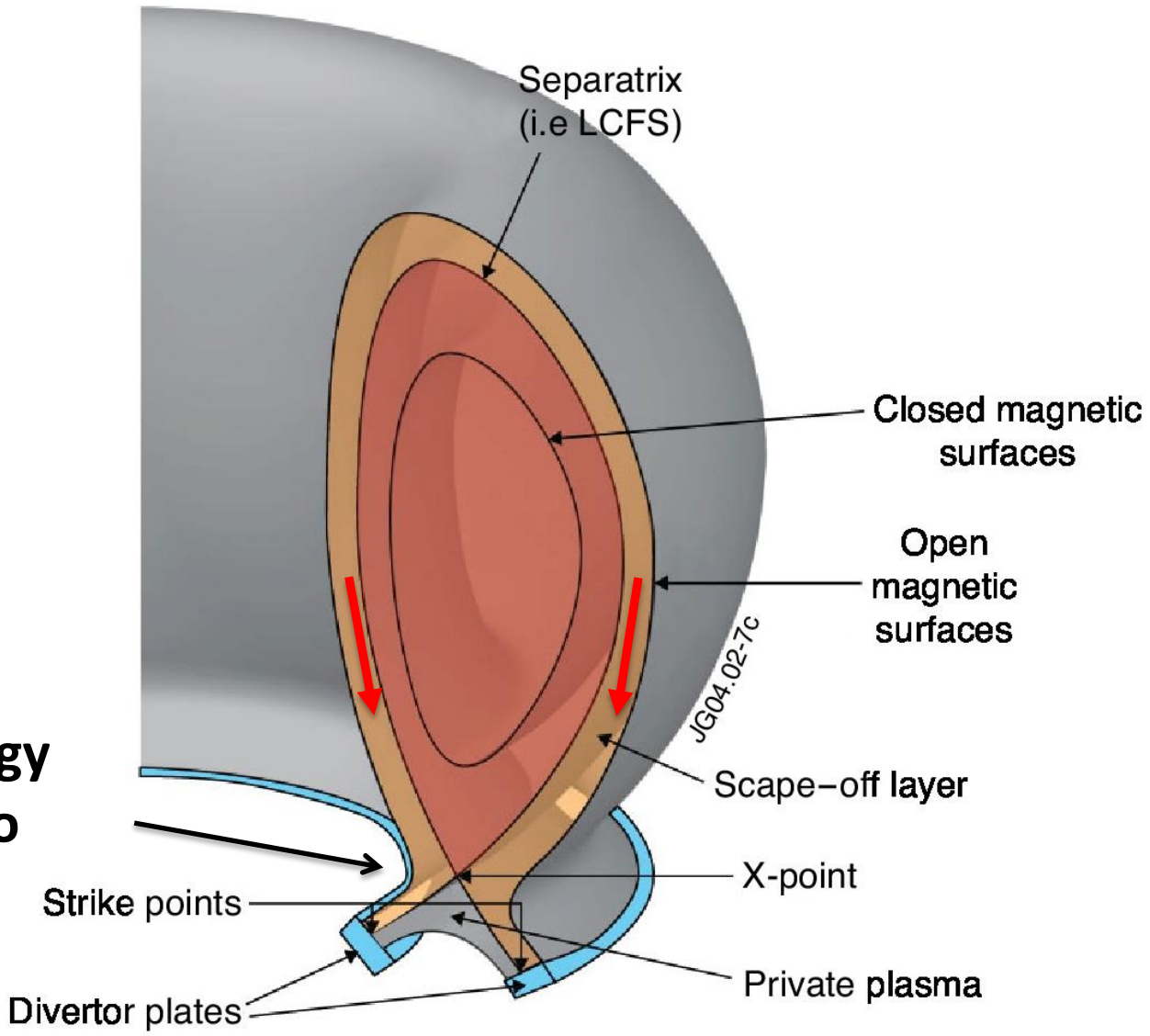
Engineering Models



Power Exhaust = Divertor

Physics Models

Particle/Energy Transport into Divertor



Relevance for Power Plant Design

- DEMO design
  - P_net,e ~ 500 MW
  - P_fus ~ 2 GW
  - P_alpha = P_fus/5 ~ 400 MW
  - P_aux ~ 100 MW (CD in ss)
  - R ~ 9 m
  - P_heat/R = (P_alpha +P_aux)/R>~ 40 MW/m
  - Allowed value ~ 20 MW/m
- Need to radiate P_heat away or increase size to forbiddingly large values!

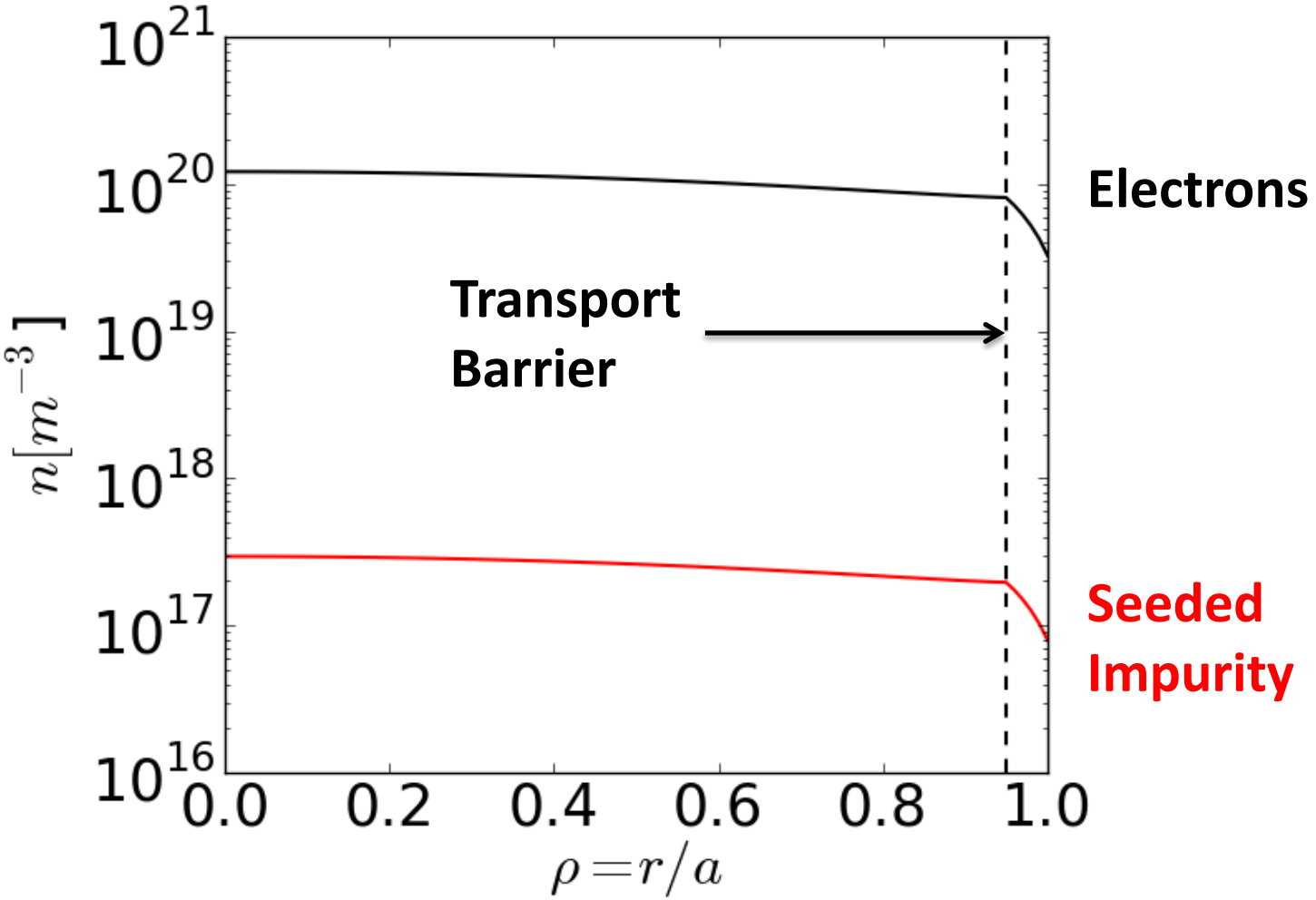
D+T = He4 + n

Federici et al. (2014)

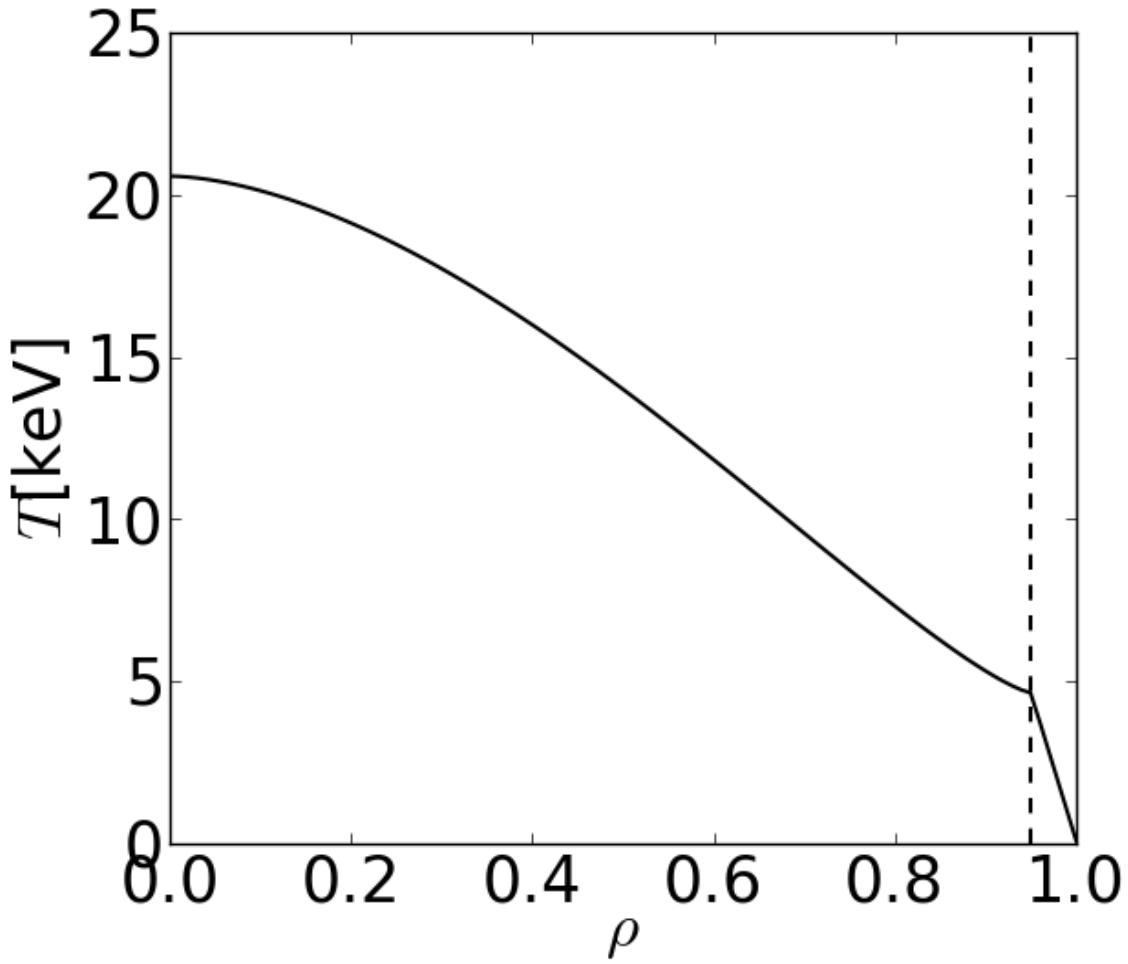
Radiation

- Radiation types:
  - Synchrotron
  - Bremsstrahlung (ADAS + analytic formula)
  - Line and recombination induced radiation (ADAS)
- Radiation sources:
  - Hydrogen fuel (deuterium, tritium), He ash
  - Sputtered (from plasma facing components) and seeded (for divertor protection) impurities

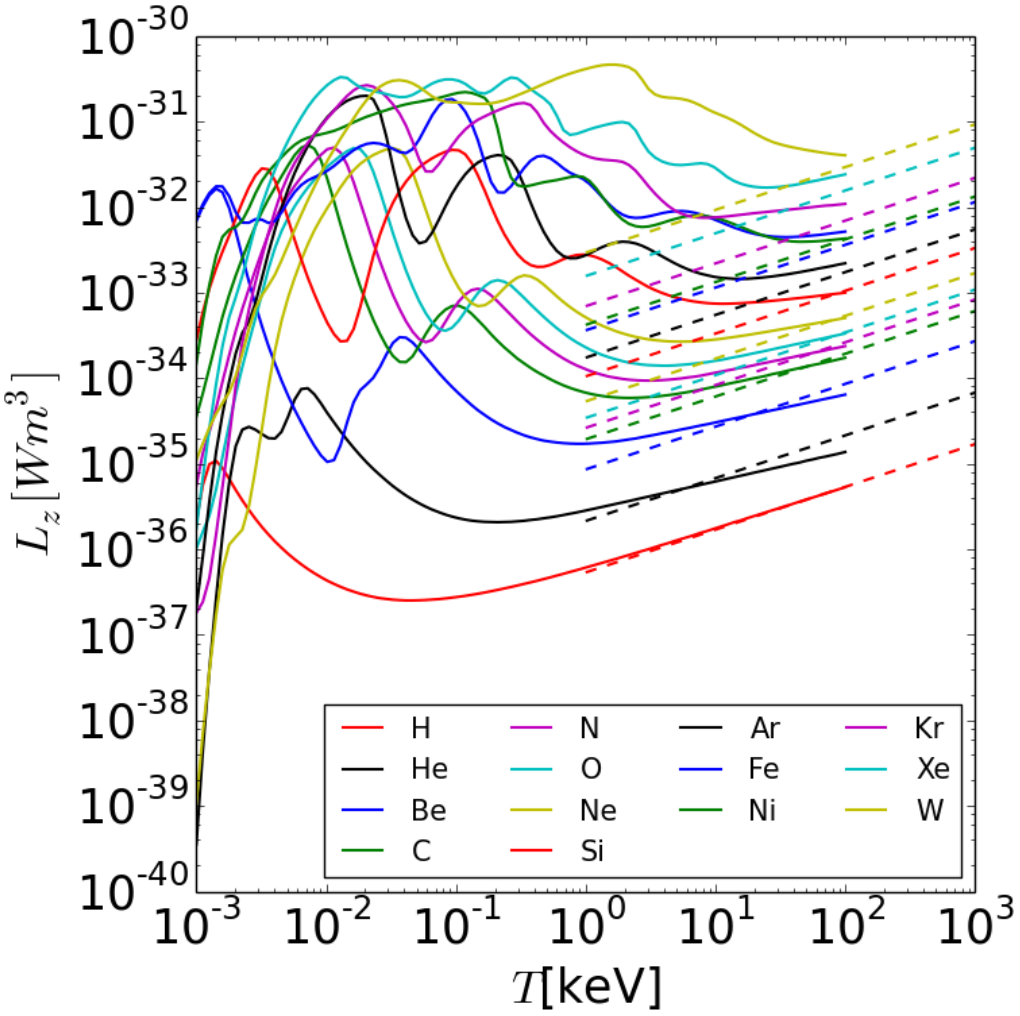
Density Profiles



Temperature Profiles

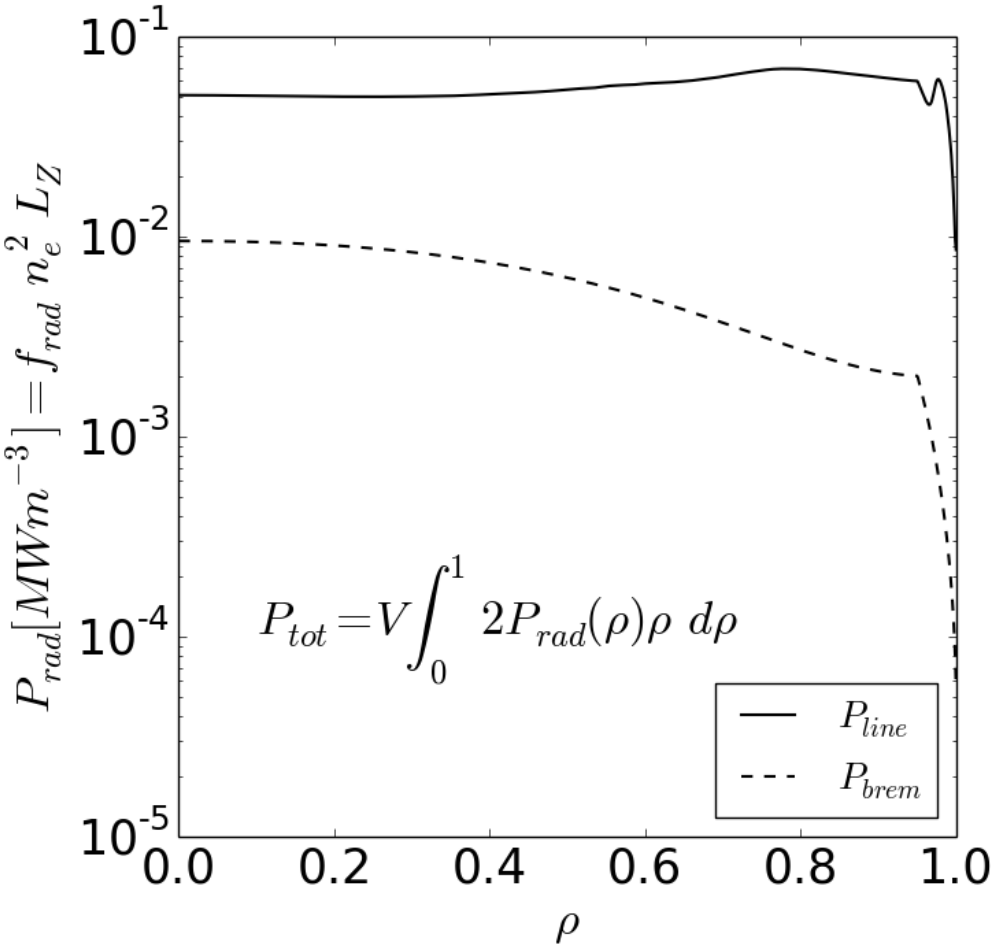


Loss functions



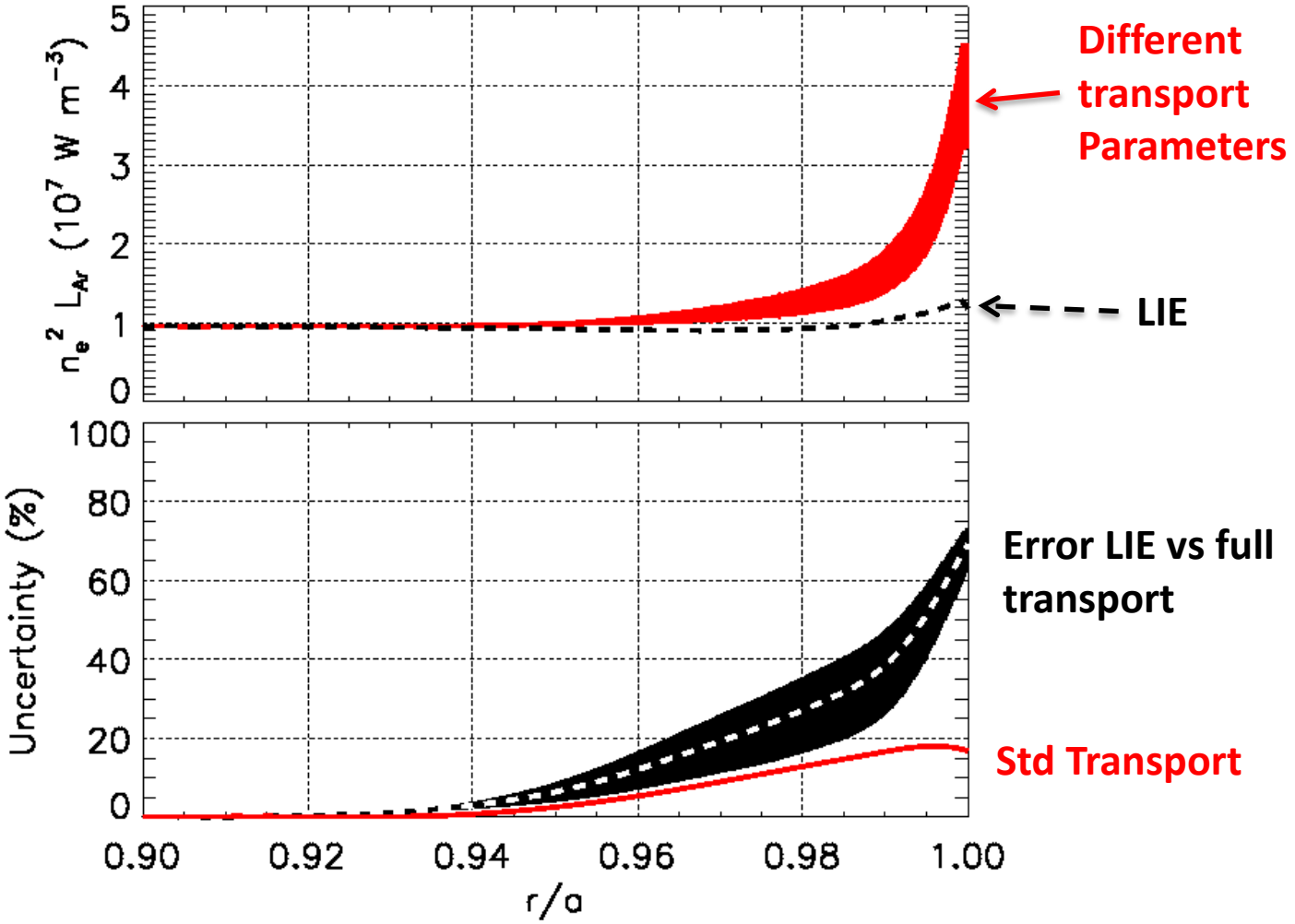
Thanks to Martin O'Mullane

Total Radiation



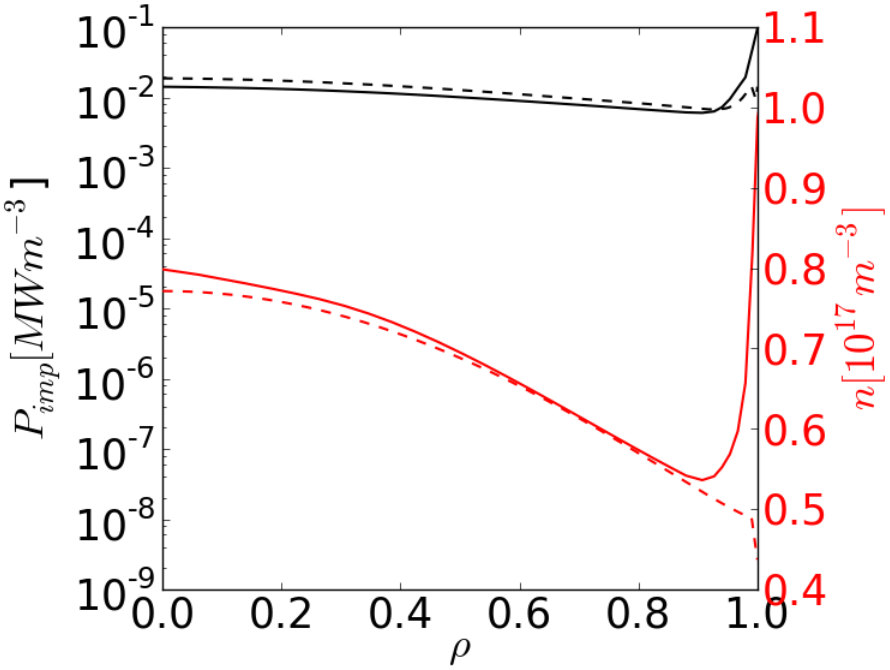
Local Ionisation Equilibrium

Errors on P_tot,rad < 10 %

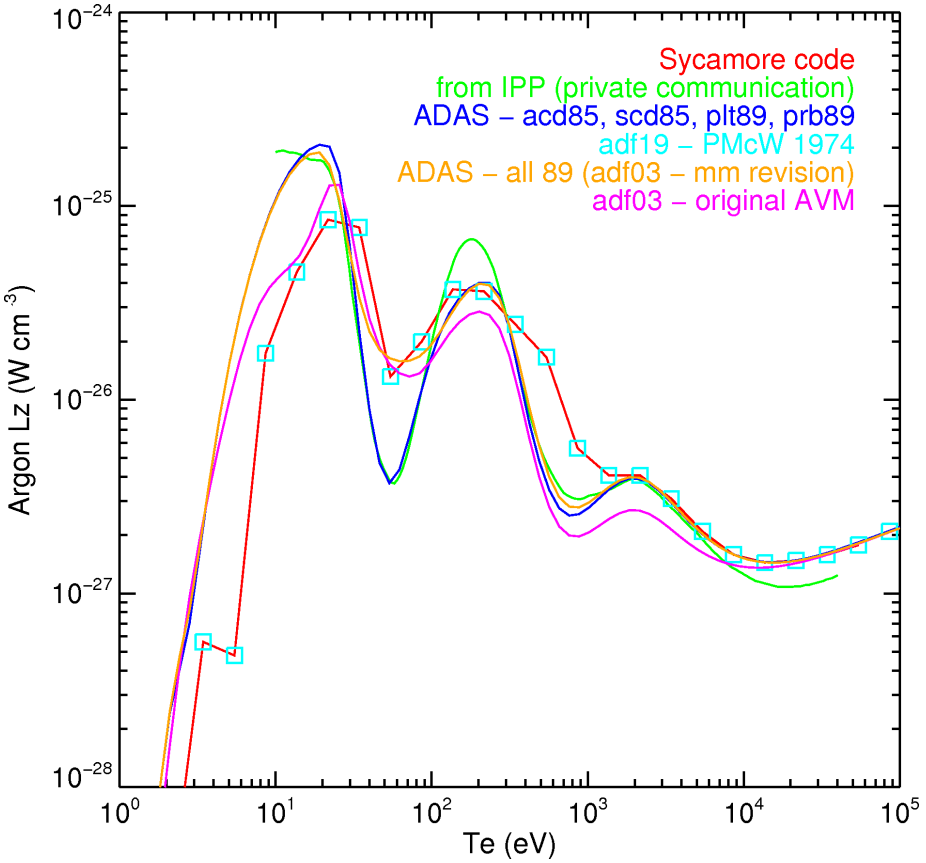


Error sources

~>20% of P_tot,rad

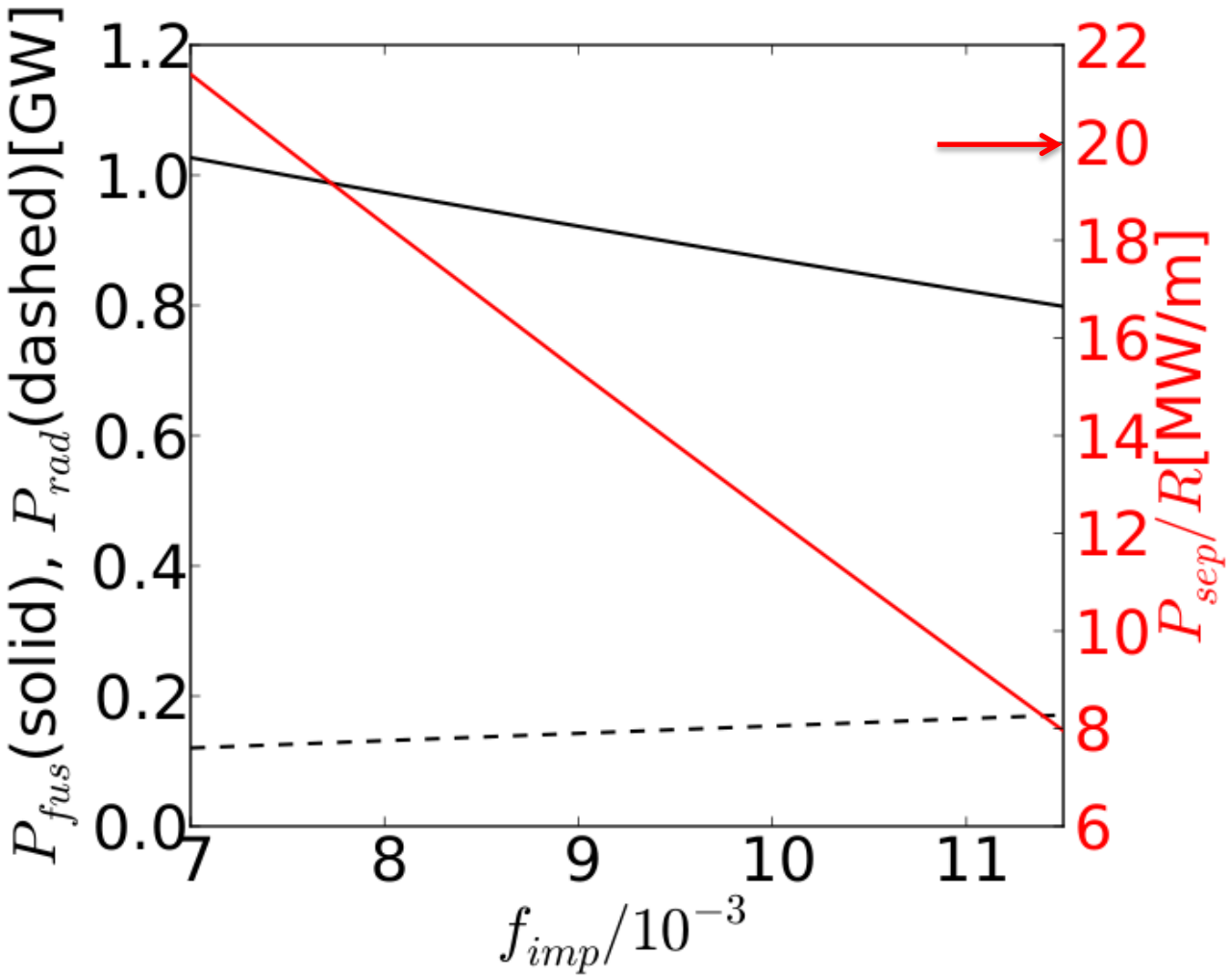


~50% of P_tot,rad



Thanks to Martin O'Mullane

Divertor Protection



Summary

- Systems Studies: Simple models of physics and engineering relevant for power plant design
- Divertor protection is a critical issue in reactor design -> imp. radiation is a possible solution
- ADAS data used in new predictive, physically motivated plasma radiation model
- Main modelling uncertainties: Loss function data and impurity distribution
- We are optimistic that we can achieve divertor protection without significantly reducing the fusion power

Energy Confinement