Modelling radiative power exhaust in view of DEMO relevant scenarios

2nd IAEA Technical Meeting on Divertor Concepts, Suzhou, China
November 14th 2017

Acknowledgements
Contents

• Power & particle exhaust: basic physics

• Important specialty for future reactors (DEMO): enhanced dissipation by core radiation required

• Implications on core/pedestal plasma: fueling & confinement

• Reduced models: detachment scaling criteria

• Alternative divertor geometries: double-null, snow-flakes, optimized divertors
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Power exhaust in a Nutshell

\[ q_{\parallel}^{up} = \frac{P_{SOL}}{A_{\parallel}} = \frac{P_{SOL}B}{2\pi RB_p \lambda_q} \]

\[ q^t = (1 - f_{diss}) q_{\parallel}^{up} \]

Minimum dissipation:

\[ f_{\text{diss}}^{\text{min}} = 1 - \frac{q_{\perp}^{\text{max}}}{q_{\parallel} \sin \Theta_t} \]

for given \( q_{\perp}^{\text{max}} \) (wall material dependent)
Power exhaust in a Nutshell

Upstream power fall-off length: $\lambda_q$-scalings

T. Eich et al NF 2013

R. Goldston JNM 2015

Theoretical (heuristic) Drift model reproduces experimental $\lambda_q$ scaling

$$q_{||}^{up} = \frac{P_{SOL}}{A_{||}} = \frac{P_{SOL}B}{2\pi RB_p\lambda_q} \propto \frac{P_{SOL}B_{tor}}{R}$$

- $\lambda_q$-scaling independent of wall material selection
- From the $\lambda_q$-scaling: upstream $q_{||}$ in ITER ~ 5 GW/m² and >30 GW/m² in DEMO.
- Unmitigated $q_{\perp \text{target}}$: 50 MW/m² for ITER and 300 MW/m² for DEMO
  $\rightarrow$ Clearly exceeds the tolerable material limit $q_{\perp \text{max}}$ of 5-10 MW/m² (actively cooled W-PFC).

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Concept of a detached divertor for power dissipation

**Impurity radiation:**
→ heat-flux and temperature reduction in SOL

**Neutral zone (cushion):**
→ plasma pressure & temperature reduction

**Volumetric recombination:**
→ particle loss to reduce plasma particle flux → roll-over

**Particle Recycling:**
→ surface recombination

---

Heat conduction zone

Impurity radiation zone

$D_0$ ionization zone ($T_e > 5$ eV)

Neutral friction zone

Recombination zone ($T_e < 1$ eV)

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Concept from [M. E. Fenstermacher, PPCF 1999]
H-mode detachment transition classification

**Without seeding:**

1. Onset of detachment at inner divertor

2. **Fluctuating state:** radiative fluctuations at X-Point (c.f. Manz PSI2016); Establishment of a HFS high-density (HFSHD) region (c.f. Reimold, PSI2016)

**With N-seeding:**

3. Partial detachment of LFS divertor
   - N-radiation at X-point
   - (HFSHD region disappears)

4. **Complete detachment:** also Balmer radiation inside confined plasma → X-point radiation condensation → impact on pedestal → upstream pressure loss

Pötzl et al. JNM2012
Detachment regimes

A. Kallenbach et al. NF 2015 / FEC 2014
What processes control power dissipation?

Impurity radiation

Ionization and dissociation of recycling Atoms and molecules

Recombination

\[ q^t_\parallel = q^u_\parallel - q^{imp}_\parallel - q^{rad}_\perp - q^{recy}_\perp - q^{recom}_\perp \]

Wall geometry: divertor, baffling of neutrals....

Complex physics → coupled fluid-kinetic 2D/3D edge plasma codes
EDGE2D-EIRENE reproduces JET-ILW H-mode detachment transition (at least qualitatively)

![Graph showing radiative power fraction, simulation and experiment](image1)

![Graph showing nitrogen concentration and qLFS](image2)

- **Unseeded (attached)**
- **Partially detached**
- **Pronounced detached**

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A. Jaervinen PSI 2014
C. Giroud NF 2015

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Quantitative assessment of dominant processes governing neutral dynamics

OSM-EIRENE interpretative modelling
S. Lisgo et al.
PSI 2004

Modelling of “ITER-like” C-mod divertor (high density, vertical targets)
- Neutral pressure & $D_\gamma$ (and $D_{\alpha}$) emission within x2
- Calculated neutral pressure sensitive to volume recombination, Ly$\alpha$ opacity, viscosity and ion-molecule elastic collisions
Edge codes → identify ITER divertor engineering parameter: e.g. peak target heat flux vs. divertor gas pressure

ITER has to be operated in partial-/complete detached mode → neutral A&M physics significant

![Graph showing relationship between peak target heat flux and divertor gas pressure](image)

- 1996 (ITER physics basis 1999)
- 2003 (neutral-viscosity added)
- 2004 (refined molecular collision kinetics added)
- 2005 (Lyman radiation trapping)

SOLPS4 modelling
V.Kotov, D.Reiter, Wiesen et al
Lyman-opacity important for stable Xpoint radiator: SOLPS4 modelling for JET-C

Reduction of upstream temperature (thus pressure)

Reduction of upstream temperature (thus pressure)

\[ n_{e_{mid}} = 1.6 \times 10^19 \text{ m}^{-3} \quad f_{rad} = 81 \% \text{ (D: 28 \%, C: 72 \%)} \]

Ionization source \( \Rightarrow \) enhanced convective energy flux \( \Rightarrow \) reduced parallel gradient

Deeper detachment after formation of MARFE

\[ n_{e_{mid}} = 1.62 \times 10^19 \text{ m}^{-3} \]

V. Kotov, D. Reiter, S. Wiesen
JNM2013
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• Important specialty for future reactors (DEMO): enhanced dissipation by core radiation required

• Implications on core/pedestal plasma: fueling & confinement

• Reduced models: detachment scaling criteria
Why impurity seeding?

Future reactors:

• Unmitigated power fluxes \( \geq 300 \text{ MW/m}^2 \)
• Material limit \( \sim 5 \text{ MW/m}^2 \)

⇒ Increase power dissipation to more than 95%

Impurity seeding:

Increase radiation  
ɳ Cool down divertor plasma  
ɳ Induce detachment

Higher power dissipation  
Reduced W sputtering (\( T_e < 5\text{eV} \))  
Reduced particle fluxes (i.e. surface recomb.)
Why impurity seeding?

Future reactors:
- Unmitigated power fluxes $\geq 300$ MW/m$^2$
- Material limit $\sim 5$ MW/m$^2$

$\Rightarrow$ Increase power dissipation to more than 95%

Desired radiation pattern:
- $\geq 30\%$ in SOL & divertor
- $\leq 65\%$ inside confined region
- minimal central radiation
What limits power dissipation by radiation?

\[ f_{rad}^{achieve} = 1 - K \frac{p_u}{q_u} (1 - f_{mom}) \]

\[ K = \frac{c_s}{4} \left[ \gamma T_t^{1/2} + \frac{E_{pot}}{T_t^{1/2}} \right] \]

weak for \( T_t > 5 \text{ eV} \)

- decrease with \( p_u \)
- increase with \( q_u \)
- requires momentum removal, i.e. pressure loss along field, to achieve high impurity radiation

\[ \frac{p_t}{p_u} = (1 - f_{mom}) \]

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What limits power dissipation by radiation?

\[ f_{\text{achieve}}^{\text{rad}} = 1 - K \frac{P_u}{q ||}(1 - f_{\text{mom}}) \]

Pressure loss by divertor detachment → both, recombination & radiation reduce \( \Gamma_t \) (→ roll-over)

\[ \Gamma_t \sim \frac{p_t}{\sqrt{T}} \sim \frac{p_u(1 - f_{\text{mom}})}{\sqrt{T}} \sim \frac{q_u - q^{\text{imp}}}{E_{\text{pot}}} - \Gamma_{\text{rec}} \]

\[ q_{||}^{t} \sim p_t \sqrt{T} \sim q_{||}^{u} - q^{\text{imp}} - q_{\text{rec}} - q^{\text{recyc}} - q_{\perp} \]

In case of \( (1-f_{\text{mom}}) \ll 1 \) & for \( T < T_{\text{crit}} \) → power starvation, i.e. not enough power available to keep up counter-balancing total divertor pressure \( p_t \) (plasma & neutrals)

→ depending on device, the SOL alone not capable to achieve required \( f_{\text{diss}}^{\text{min}} \)

→ radiation inside core required to reduce \( p_u \)

c.f. S. Krashenninikov PoP 2016
The different radiators

Various seeding impurities possible

- Nitrogen: Divertor
- Neon: SOL
- Argon: SOL & pedestal
- Krypton: Pedestal & core
- Xenon: Future machines, pedestal

\[ q_{\text{rad}}^{\text{imp}} = n_e n_z L_z (n_e, T_e, \tau) l \]

\[ f_{\text{rad}}^{\text{imp}} = \frac{q_{\text{rad}}^{\text{imp}}}{q_{\parallel}^{\text{u}}} < f_{\text{diss}} \]

M. Bernert
PSI2016

N
Ne
Ar
Kr

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X-point radiation condensation with N-seeding at detachment recovered

N\textsubscript{2}: divertor radiation dominant, propagation to Xpoint (with condensation), and stable

F. Reimold PSI2014, NF 2015
X-point radiator universal

Strongly localized radiation at the X-point present for:

AUG

JET

M.Bernert
PSI2016
X-point radiation triggers loss in pedestal pressure

- Depletion of $T_{e,\text{ped}}$, $n_{e,\text{ped}}$ with N seeding
- Driven by poloidal gradients into X-point region
- Similar observations in JET and AUG

Wischmeier IAEA2014

SOLPS model recovers pressure loss mechanism:
- $T_{e,\text{sep}}$ decreases with seeding
- Further reduction at complete detachment
- Stronger impact on $T_{e,\text{sep}}$ with Ne-seeding radiation loss $L_z(T_e)$
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Divertor geometry does play a role in pressure loss & H-mode plasma fueling.

EDGE2D-EIRENE: VT vs semi-HT, N₂ seeded

- Upstream pressure/density loss depends on $f_{\text{rad}}$ & divertor geometry
- recovered with EDGE2D-EIRENE

EDGE2D-EIRENE:
- In semi-HT: LFS fueling increases significantly with N-seeding
  $\rightarrow$ Combination of upstream pressure loss & increased penetration of kinetic neutrals

A. Jaervinen
EPS 2013
PPCF2016

Increase radiative fraction

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Metal PFCs are able to sustain specific kinetic transport effects

- Competition between slow moving particles (reemitted from the surface as recycling neutrals) and fast ballistic neutrals (e.g. from charge-exchange processes, surface reflections or ELMs)

- Expected: pronounced impact of divertor geometry (including gaps) on pumping & neutral particle distribution and thus on the poloidal ionization profile

S. Wiesen
PSI2016

asymmetric semihorizontal (VT/HT)
symmetric (VT or corner only)
The HFS High-Density (HFSHD)

- In the fluctuating detachment state a High-Field Side High Density (HFSHD) region develops above a heating power threshold in AUG and JET
  [Potzel JNM 438 (2013)]
  [Potzel NF 64 (2014)]
  [Potzel EPS (2015)]

- The spatial extent and maximum density changes with heating power, nitrogen seeding and divertor neutral pressure
  [Potzel EPS (2015)]

- High-field side high density (HFSHD) can extend up to the midplane and lead to strong poloidal asymmetries
  [Guimarais EPS (2015)]
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- In the fluctuating detachment state a High-Field Side High Density (HFSHD) region develops above a heating power threshold in AUG and JET
  
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- The spatial extent and maximum density changes with heating power, nitrogen seeding and divertor neutral pressure
  
  [Potzel EPS (2015)]

- High-field side high density (HFSHD) can extend up to the midplane and lead to strong poloidal asymmetries
  
  [Guimarais EPS (2015)]

- Correlation of a confinement change with the high-field side high density is observed
  
  [Potzel EPS (2015)]
  [Dunne APS (2015)]
Basis model requirements for the HFSHD formation

Initial seed for high density in inner divertor set by:

- **Mag. geometry**
  - area, flux expansion, connection length
  - → lower power density & high density

- **Vessel geometry**:
  - closure, inclination
  - → high density

- **Radial transport**:
  - ballooning, filamentary transport, shafranov shift
  - → lower power density

- **Parallel transport**:
  - temperature gradient force, friction
  - → larger (impurity) retention

- **Self-amplification**:
  - [impurity] radiation, neutral opacity, transport
H-mode simulation improved

F. Reimold
PSI 2016

Match (x2)
Too Low
Too High

Neutral Flux Comparison

\[ P_{\text{div}} = 2.0 \text{ Pa} \]
Drifts change the balance…

In fwd-field drifts are essential to get access:

- $\nabla B$-drift amplifies density in-out asymmetry
- $\nabla B$-drift leads to add. perpendicular fluxes
  [Chankin JNM 1997]

- ExB-drift changes power sharing of divertors
- ExB-drift redistributes particles from outer to inner divertor via PFR
  [Aho-Mantila EPS (2014)]
  [Aho-Mantila IAEA (2013)]
- ExB-drift redistributes particles in the perpendicular direction into the farSOL
  [Reimold Thesis (2015)]

→ Increased recycling above X-point

- Neutral conductances moderate the effect of farSOL (neutral) density
  (numerically & physically)

→ Effect stand-alone not sufficient
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→ Effect stand-alone not sufficient
Plasma fueling of core

- Diffusive and advective drift transport of plasma from SOL into confined plasma:
  - Amount of plasma fueling similar to effective neutral influx across separatrix
- Different fueling mechanisms affects different radial regions:
  - Plasma fueling mainly determines separatrix density
  - Neutral fueling mainly determines core boundary density
SOL asymmetries due to HFSHD identified

- High densities in the HFS scrape-off layer in the direct vicinity of the separatrix
  - Large inverted radial density gradients at the HFS separatrix (diffusive inward flux)
  - Change in balance of up-down asymmetry (advective drift-driven fluxes)
- Additional perpendicular transport, heat flux or deuterium fueling increases the radial and poloidal extent of the HFSHD
  - Increased inward transport
Scaling of HF$SHD$ recovered

Heating power
- Increase of max. density and spatial extent with increased heating power up to reattachment of inner strikepoint

Impurity Seeding
- Decrease of max. density and spatial extent with increased seeding
  - Less energy for ionization
  - Change in upstream profiles
  $\rightarrow$ connection to confinement improvement

See talk by E. Wolfrum
PSI2016
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The Quest for Power Exhaust Criteria

In order to interpret and compare results one requires a criterion, e.g. for H-mode detachment:

- E.g. R. Goldston PPCF 2017 (based on HD model \( \lambda_q \sim 2\varepsilon_p \)):
  (similar to B. Lipschultz NF2016)
  \[
  c_{z,\text{detachment}} \propto \frac{P_{\text{sep}}}{BP(1 + h^2)^{3/2}f_{GW}^2}
  \]
  → how much should one vary the impurity concentration in the SOL in order to maintain detachment if one of the r.h.s. parameters is changed? (here: no dependence on R!)

- Or: M. Reinke NF Letter 2017
  (assumes \( P_{\text{sep}} \) expressed in terms of \( f_{GW} \) & \( P_{LH}^{\text{Martin}} \) \( q_{||} \sim B_T^{2.52}R^{0.16} \))
  \[
  c_{z,\text{detachment}} \propto B_T^{0.88}R^{1.33}
  \]
  → dto, for one wants to maintain detachment in H-mode if \( B_T \) or \( R \) are changed at constant shape?

Based on 2-Point model assuming \( P_{\text{rad}} = P_{\text{SOL}} \) and \( T_t \sim 1 \text{eV or lower} \)
### Example taken from Goldston 2017

<table>
<thead>
<tr>
<th></th>
<th>ASDEX-U</th>
<th>JET</th>
<th>ITER</th>
<th>FNSF (A=4)</th>
<th>EU Demo1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{sep}$</td>
<td>14</td>
<td>14</td>
<td>100</td>
<td>107</td>
<td>150</td>
</tr>
<tr>
<td>$B_t$</td>
<td>2.5</td>
<td>2.5</td>
<td>5.3</td>
<td>7.5</td>
<td>5.7</td>
</tr>
<tr>
<td>$R_0$</td>
<td>1.6</td>
<td>2.9</td>
<td>6.2</td>
<td>4.8</td>
<td>9.0</td>
</tr>
<tr>
<td>$P_{sep}/R$</td>
<td>8.8</td>
<td>4.8</td>
<td>16.1</td>
<td>22.3</td>
<td>16.7</td>
</tr>
<tr>
<td>$P_{sep}B_t/R$</td>
<td>21.9</td>
<td>12.1</td>
<td>85.5</td>
<td>167.2</td>
<td>95.0</td>
</tr>
<tr>
<td>$l_p$</td>
<td>1.2</td>
<td>2.5</td>
<td>15</td>
<td>7.9</td>
<td>20</td>
</tr>
<tr>
<td>$a$</td>
<td>0.52</td>
<td>0.90</td>
<td>2.00</td>
<td>1.20</td>
<td>3.00</td>
</tr>
<tr>
<td>$\kappa_5$</td>
<td>1.63</td>
<td>1.73</td>
<td>1.80</td>
<td>2.10</td>
<td>1.70</td>
</tr>
<tr>
<td>$&lt;B_p&gt;$</td>
<td>0.34</td>
<td>0.39</td>
<td>1.03</td>
<td>0.80</td>
<td>0.96</td>
</tr>
<tr>
<td>$q^*$</td>
<td>3.16</td>
<td>2.79</td>
<td>2.42</td>
<td>3.85</td>
<td>2.77</td>
</tr>
<tr>
<td>$n_{GW}$</td>
<td>1.44E+20</td>
<td>9.82E+19</td>
<td>1.19E+20</td>
<td>1.75E+20</td>
<td>7.07E+19</td>
</tr>
<tr>
<td>$c_2 \propto P_{sep}/(&lt;B_p&gt;(1+\kappa^2)^{3/2})$</td>
<td>1.00</td>
<td>0.77</td>
<td>1.91</td>
<td>1.83</td>
<td>3.52</td>
</tr>
</tbody>
</table>
Towards model-based detachment criteria?

Improved 1D model: c.f. A. Kallenbach PPCF 2015:

- non-coronal model for impurities
- AUG specific flux-tube geometry
- $\lambda_q$ & $\lambda_{int}$ scaling (HD/Eich model)
- stepwise increase of heat flux bundle assuming fixed ratio $L_d/L_m$, assume $\Delta_d=\lambda_{int}$
- simplified 2-energy recycling model
- inclusion of momentum loss parameter
- other simplifications and assumptions (e.g. taking into account flow estimates for $p_0$)

$$P_{sep}/R|_{det.point} = \frac{1}{1.3}p_0(1 + f_z c_z) \cdot (\lambda_{int}/0.005 m) \cdot (R/1.65 m)^{r_z}$$

<table>
<thead>
<tr>
<th>Element</th>
<th>Nitrogen</th>
<th>Neon</th>
<th>Argon</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_z$</td>
<td>18</td>
<td>45</td>
<td>90</td>
</tr>
<tr>
<td>$r_z$</td>
<td>0.038</td>
<td>0.033</td>
<td>0.043</td>
</tr>
</tbody>
</table>

$\Rightarrow c_{z,div} \sim c \cdot p_0 + P_{sep}/(R\lambda_{int})$

---

JET Upscaling

JET, VT, $\lambda_{int}=5\text{mm}$

<table>
<thead>
<tr>
<th>$P_{sep}/R$</th>
<th>$p_0$</th>
<th>C$_N$</th>
<th>C$_{Ne}$</th>
<th>C$_{Ar}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>5 Pa</td>
<td>2.9%</td>
<td>1.2%</td>
<td>0.6%</td>
</tr>
<tr>
<td>6</td>
<td>10 Pa</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>10</td>
<td>5 Pa</td>
<td>8.6%</td>
<td>3.4%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>
SOLPS recovers empirical scaling laws for $P_{\text{rad}}$ for N-induced L-mode detachment within ~ factor 2


- Using well validated simulations for low recycling unseeded L-mode
- ASDEX Upgrade and JET
- Increase N2 seeding
- Compare with scaling law for N2 divertor radiation by A. Kallenbach et al. IAEA FEC 2012
- Final increase in $f_{\text{rad}}$ @ formation of Xpoint radiation outside divertor volume
- Probable important role of drift terms
Similarity studies useful to benchmark scalings

E.g.: JET-ILW H-mode discharge w/ dissipative divertor (JPN 85423, 2.5MA/2.7T, VT, \(P_{\text{NBI}}=20.6\text{MW}\), \(n_{\text{sep}}\sim1.5\times10^{19}\), \(f_{\text{GW}}\sim0.75\), \(T_{\text{plate}}\sim8\text{eV}\), \(q_{95}=3.3\), N2-seeding, \(f_{\text{rad}}\sim45\%\))

→ derive control parameters for AUG discharge to match relevant similarity parameters for power exhaust (w/ N2-seeding)

2 approaches:

A) Strictly Hutchinson/Vlases (1996): match at divertor entrance and target: \(T, n^*, n_{\Delta\text{SOL}}, r^*\) by controlling \(P_{\text{NBI}}, n_{\text{sep}}, f_x, q_{95}\)

→ \(P_{\text{NBI}}=8\text{MW}, n_{\text{sep}}=3.6\times10^{19}, f_x=1.33\cdot f_x^{\text{JET}}, q_{95}\sim4.3\) (\(I_p/B_t \sim 1.0\text{MA}/2.2\text{T}\))

problem: poloidal neutral mfp (pressure) not conserved!

B) Simpler: Match \(q_{||}\) (Lackner, 1994) by controlling: \(P_{\text{sep}}B/R\) (i.e. \(\lambda_q\)), \(T_{\text{e}\text{plate}}\), connection length \(L_c\) (via \(q_{95}\))

→ \(P_{\text{NBI}}=10\text{MW}, n_{\text{sep}}=1.5\times10^{19}, T_{\text{e\text{plate}}}\sim8\text{eV}, q_{95}=6.6\)

(\(I_p/B_t \sim 0.8\text{MA}/2.75\text{T}\) → \(f_{\text{rad}}\sim75\%\) (#33884)
Similarity studies useful to benchmark scalings

E.g.: JET-ILW H-mode discharge w/ dissipative divertor (JPN 85423, 2.5MA/2.7T, VT, $P_{\text{NBI}}=20.6\text{MW}$, $n_{\text{sep}}=1.5\times10^{19}$, $f_{\text{GW}}\sim0.75$, $T_{\text{plate}}\sim8\text{eV}$, $q_{95}=3.3$, N2-seeding, $f_{\text{rad}}\sim45\%$)

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→ $P_{\text{NBI}}=8\text{MW}$, $n_{\text{sep}}=3.6\times10^{19}$, $f_{x}=1.33\cdot f_{x}^{\text{JET}}$, $q_{95}\sim4.3$ ($I_p/B_t\sim 1.0\text{MA}/2.2\text{T}$)

**problem:** poloidal neutral mfp (pressure) not conserved!

B) Simpler: Match $q_{\parallel}$ (Lackner, 1994)

by controlling: $P_{\text{sep}}B/R$ (i.e. $\lambda_q$), $T_{e\text{plate}}$, connection length $L_c$ (via $q_{95}$)

→ $P_{\text{NBI}}=10\text{MW}$, $n_{\text{sep}}=1.5\times10^{19}$, $T_{e\text{plate}}\sim8\text{eV}$, $q_{95}=6.6$

($I_p/B_t\sim 0.8\text{MA}/2.75\text{T}$) → $f_{\text{rad}}\sim75\%$ (#33884)
Conclusions

- Modelling radiative power exhaust requires inclusion of all relevant physics processes (atomic physics, neutral viscosity, plasma drifts, plasma & wall geometry, PWI) and hence validated 2D/3D edge models are required for future reactor predictions.

- For a given device the amount of radiated power in SOL $P_{\text{rad,SOL}}$ is limited by the available momentum that can be removed (otherwise power-starvation at overly depressed divertor).

  for DEMO: upstream pressure $p_u$ reduced through core radiation to achieve $f_{\text{rad}} \sim 95\%$ → consequences on confinement (strong Xpoint radiation, pedestal pressure, LH-threshold)

- An additional impact on confinement is expected from inhomogeneity of the poloidal fuelling profile (HFSHD, drift driven plasma in-flows, neutral kinetics, wall effects).

- Simplified detachment criteria (divertor impurity concentrations) are still in development and need to be challenged against machine size scaling (modelling & similarity studies).
Monday, 13 November:
ADCs

Wednesday, 15 November:
3D-fields and modelling

Thursday, 16 November:
Divertor Dissipation & Confinement