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Detachment studies in JET unseeded H, D, T and DT L-mode plasmas (H16-09, M18-27, M21-15)

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JET

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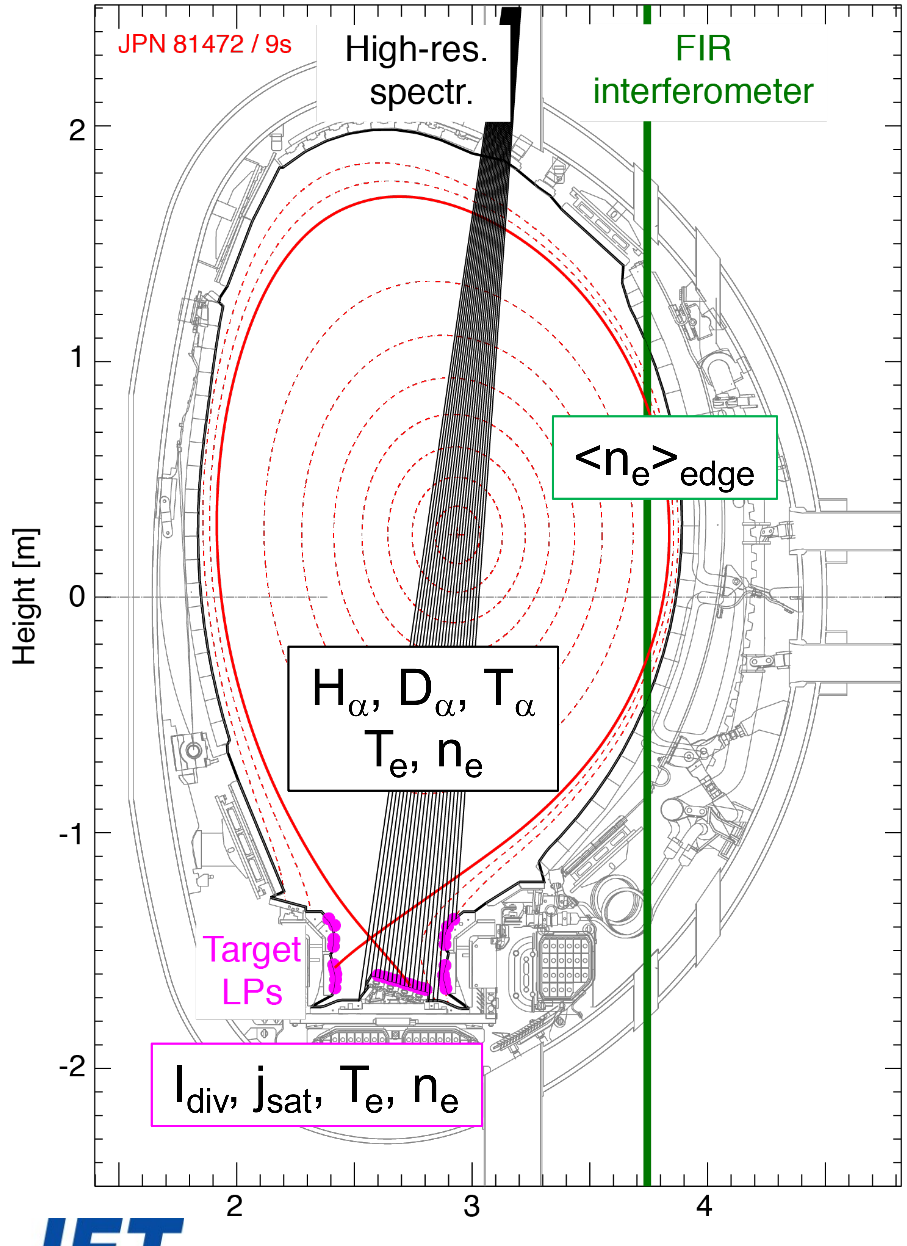
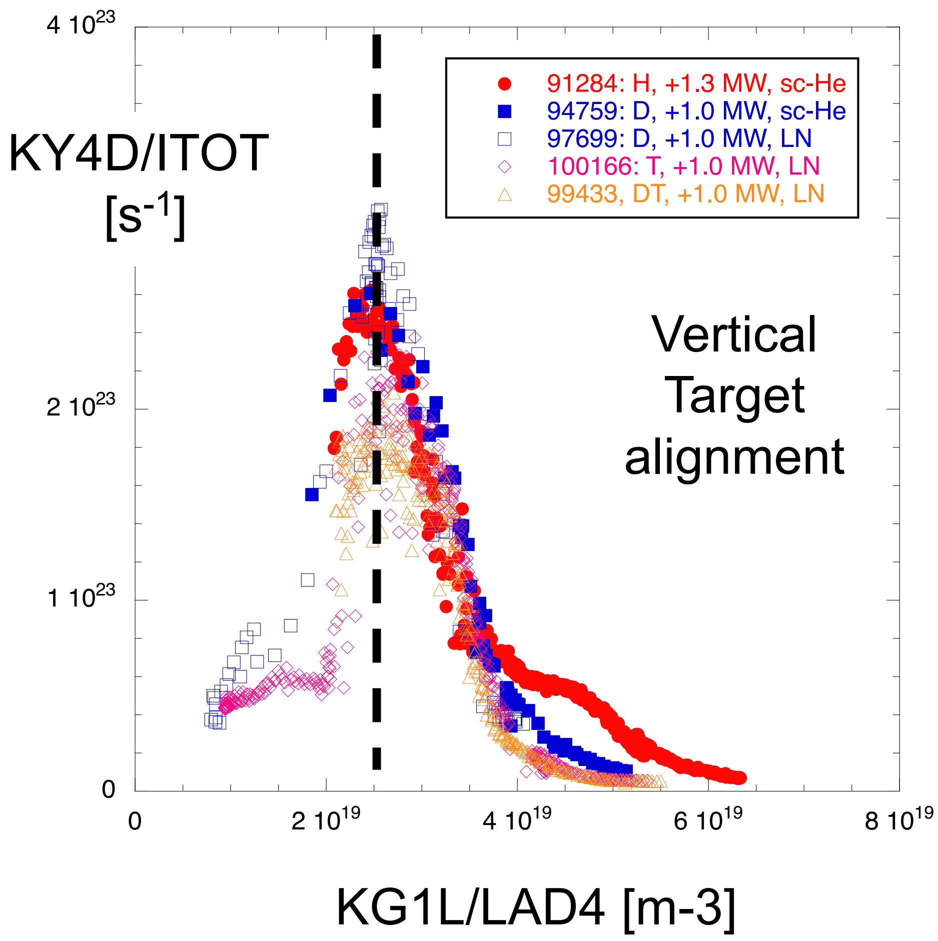
Characterisation of the SOL in H, D and T L-mode for detachment physics and edge code validation

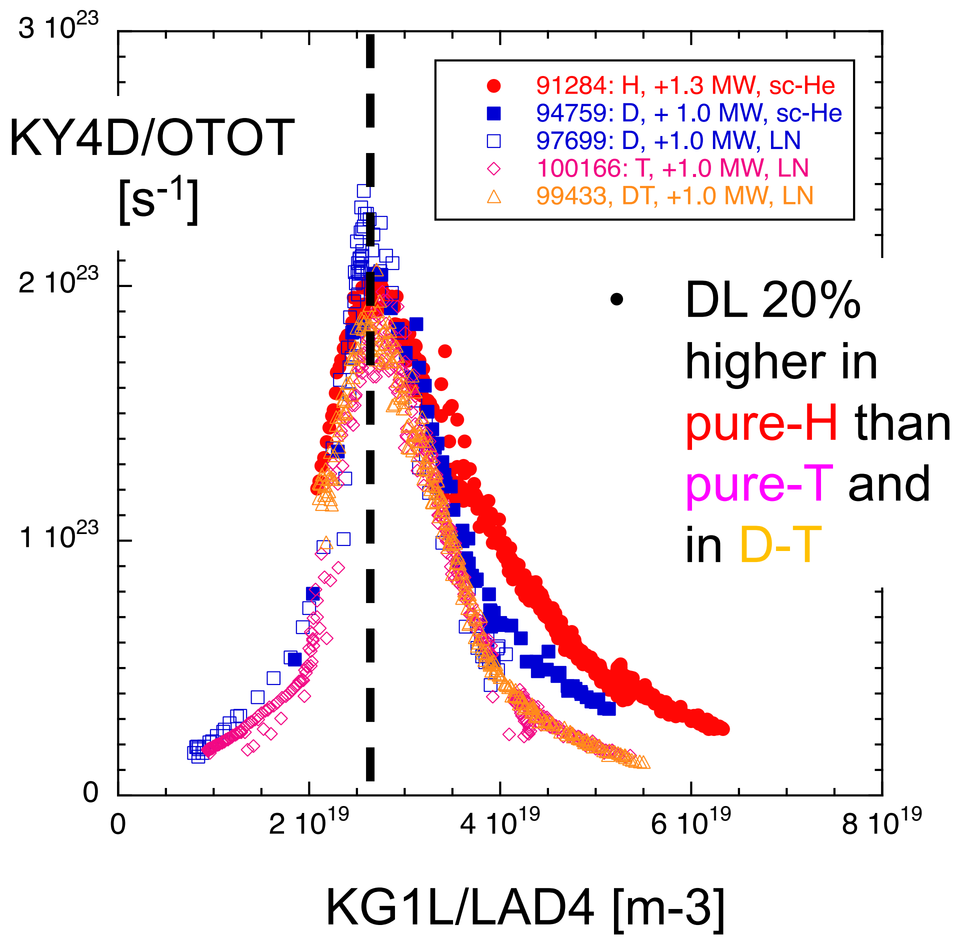


- Single I_P / B_T pair: 2.5 MA / 2.5 T
- V5/C configuration, optimized for diagnostics and edge modelling
- 1MW NBI, **cryo at sc-He and LN_2**
- H_2, D_2, T_2 through divertor G/TIMs: low-recycling, ionising (> 30 eV) → high-recycling (≈ 2-4 eV) → recombining, detached (< 2 eV) → density limit
- Used $\langle n_e \rangle_{edge}$ ($\langle n_e \rangle_{LAD4}$) as proxy for upstream SOL plasma profiles
- Measure target plasma conds. and fluxes + atomic and molecular emission → particle influxes ⇒ **primary focus on better diagnosed outer divertor**

PSI 2022: within measurement uncertainties, same det. onset density on both HFS (vert.) and LFS (horiz.)

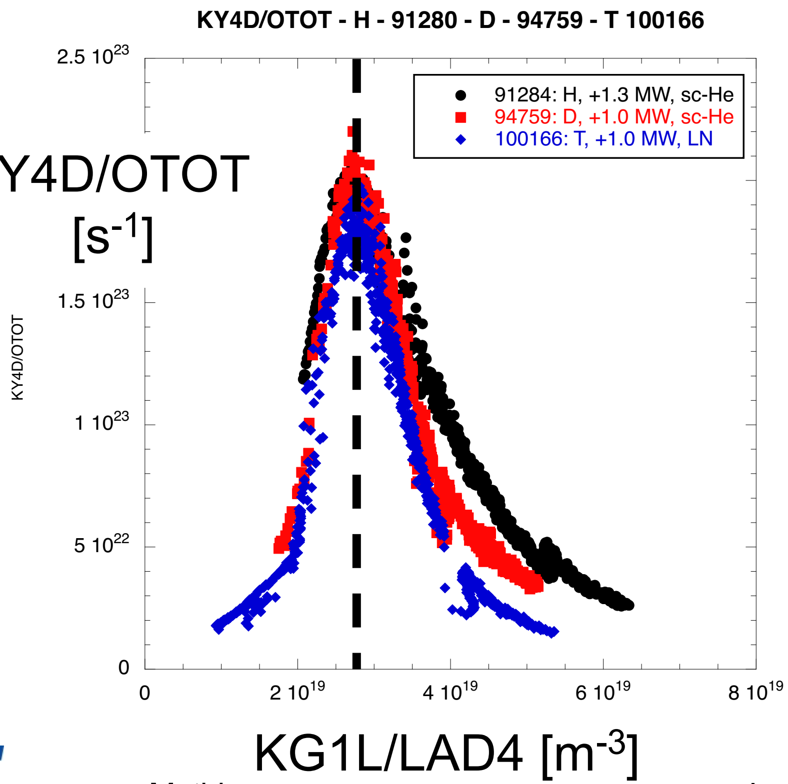
- Invariant detachment onset density for hydrogen (pump), deuterium (pumped and unpumped), tritium (unpumped) and 40%-60% DT (unpumped)

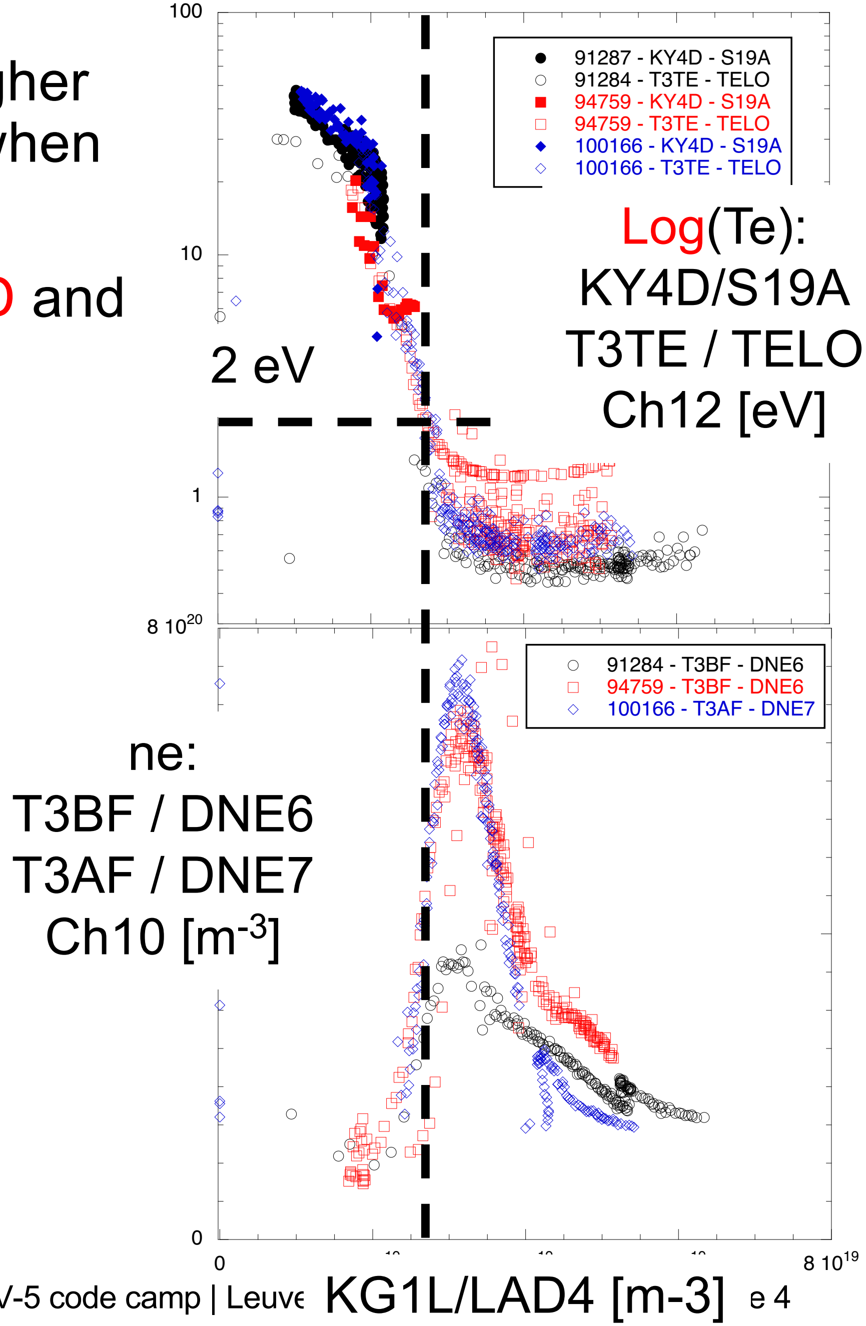




Non-linear dependency of the div. T_e with LAD4, onset of detachment coincides with $\langle T_e \rangle_{LFS\text{-}div}$ < 2 eV in H, D and T

- Rollover of $\langle n_e \rangle_{LFS\text{-}div}$ occurs at 20% higher upstream density than the I_{div} rollover, when $\langle T_e \rangle_{LFS\text{-}div}$ is < 1 eV
- At peak value, $\langle n_e \rangle_{LFS\text{-}div}$ 2x higher for D and T than for H





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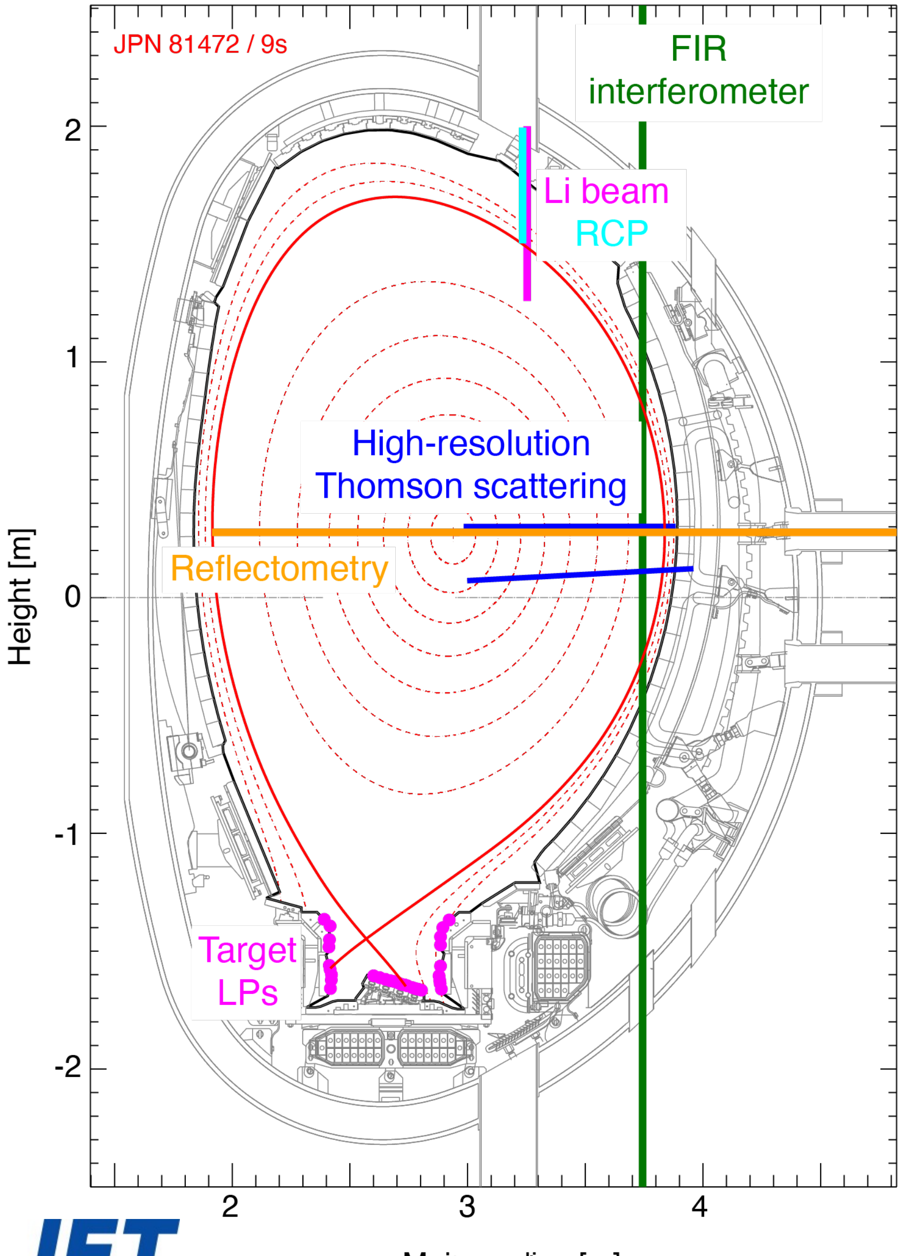
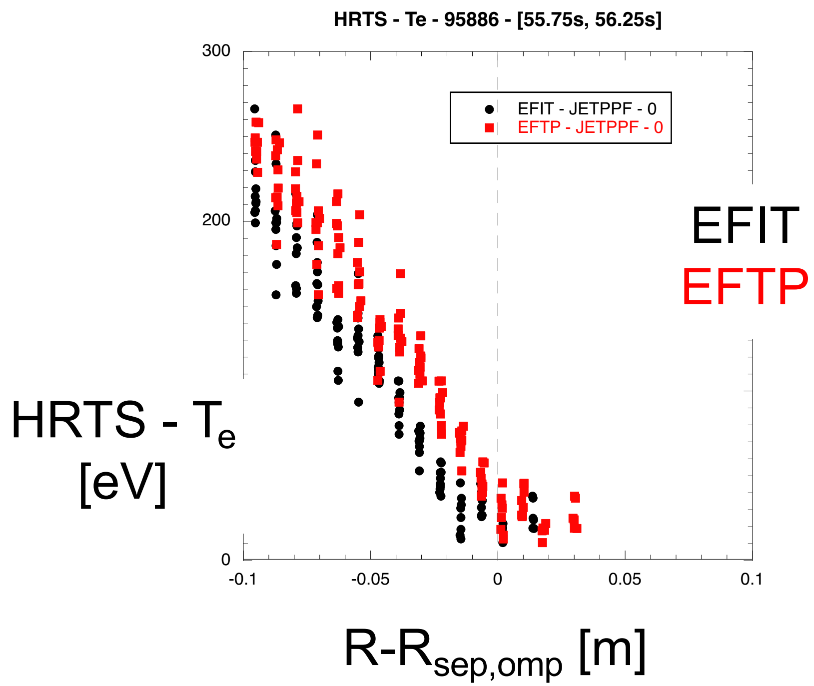
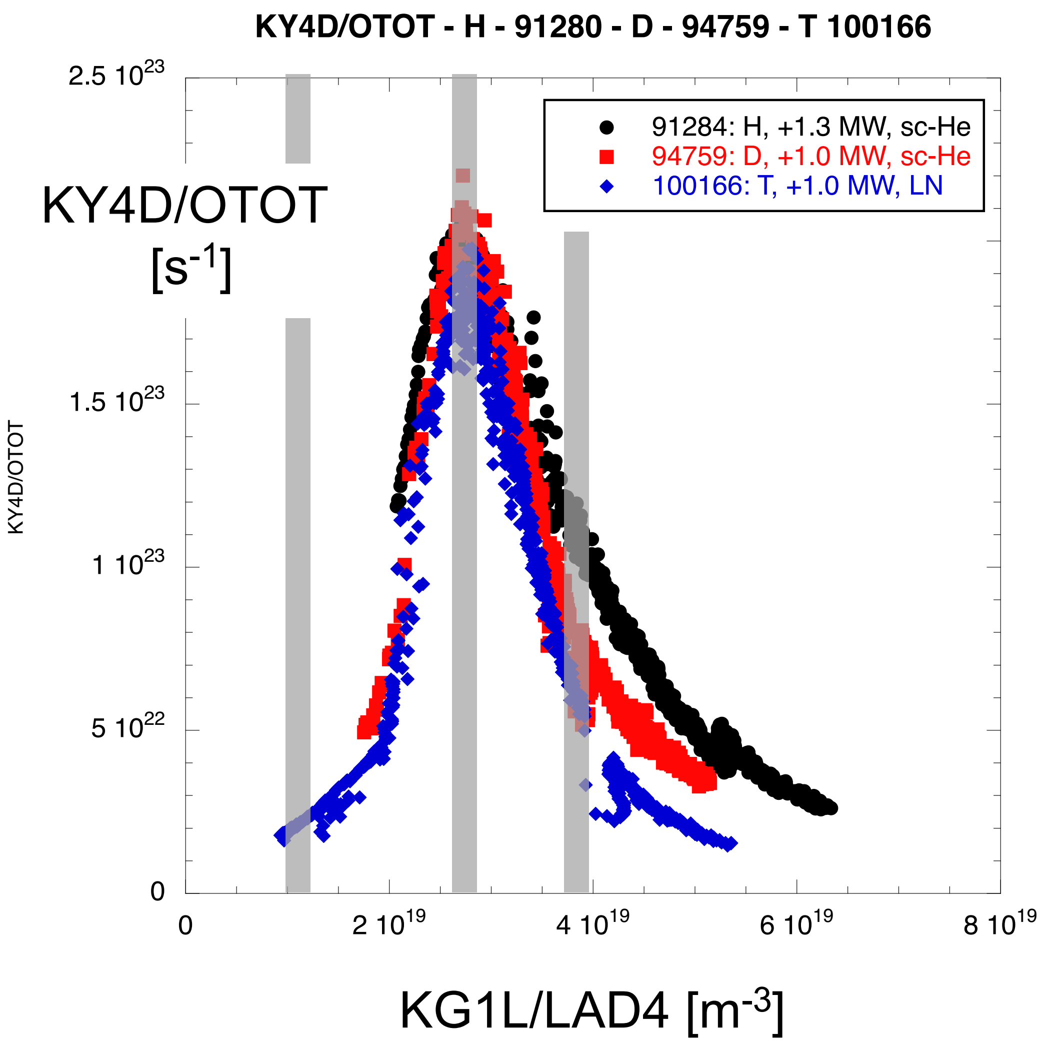
Transitioned from using $\langle n_e \rangle_{LAD4}$ to upstream profiles from HRTS, KY6 Li beam and KG10 reflectometer



- Utilize EFTP: typical inward shift of separatrix by 2 cm compared to EFIT ⇒ more consistent with expected values for $T_{e,sep,omp}$ and $n_{e,sep,omp}$ (see TFM Dec 13, 2012)
- Map profiles to outer midplane and $R-R_{sep,omp}$ ⇒ **EDGE2D-EIRENE input!**



Examine the upstream T_e and n_e profiles for low-recycling, high-recycling and partially detached conds.



- Ion current to outer plate similar for H, D and T in attached plasmas

⇒ HRTS, KY6 and KG10 upstream SOL profiles are identical within uncertainties of measurements and magnetic equilibrium reconstruction (see backup slides)

⇒ T cases had consistent 10% higher core density

- 50% higher ion current in H than T plasmas in partially detached conds. Coincides with broader upstream profiles for T versus H and D

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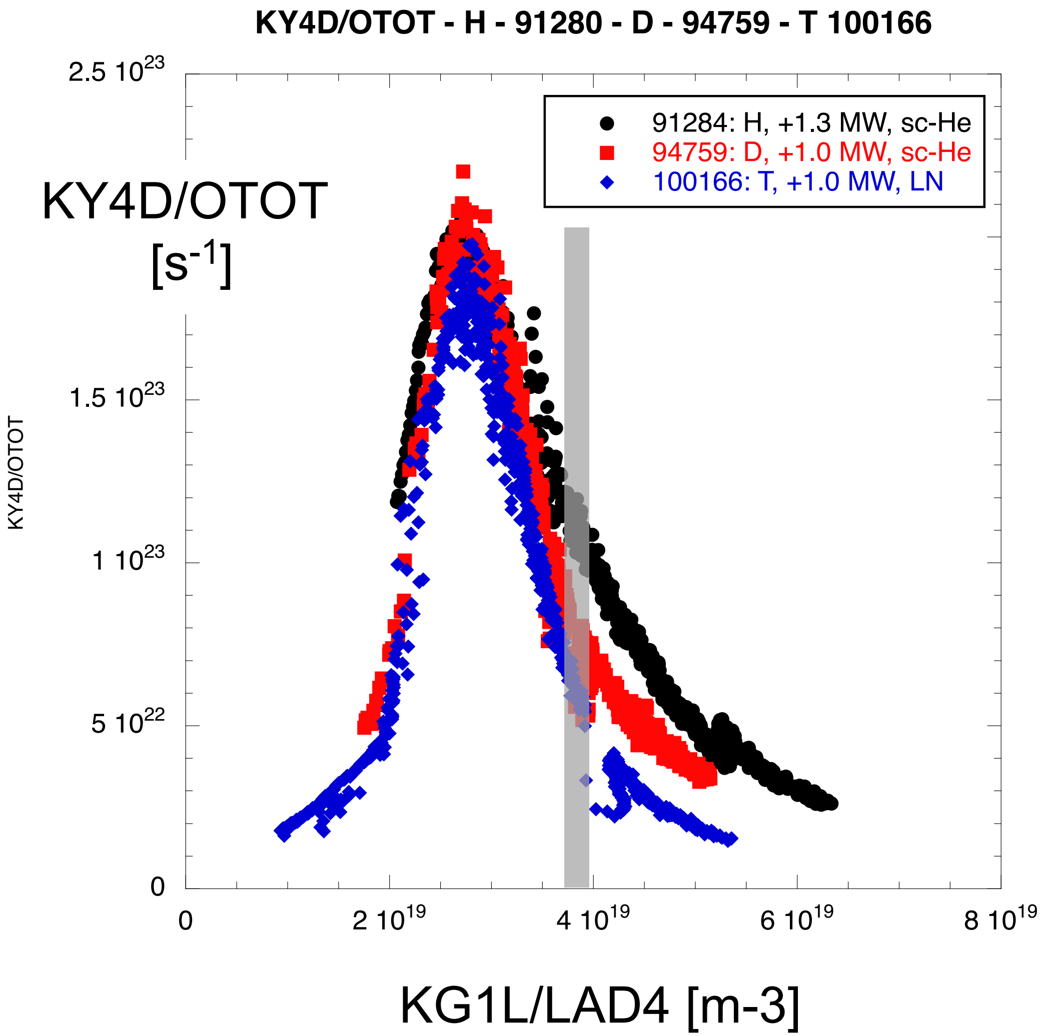
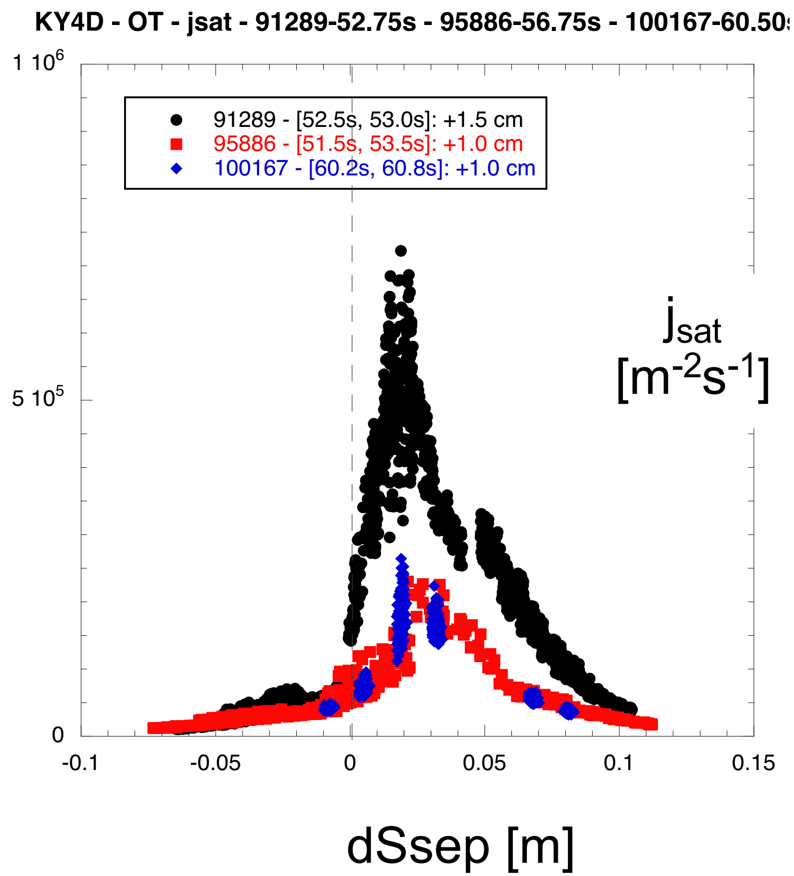
In partially detached conds., peak j_{sat} for H is 3x higher than for D and T, indicative of lower degree of detachment in H

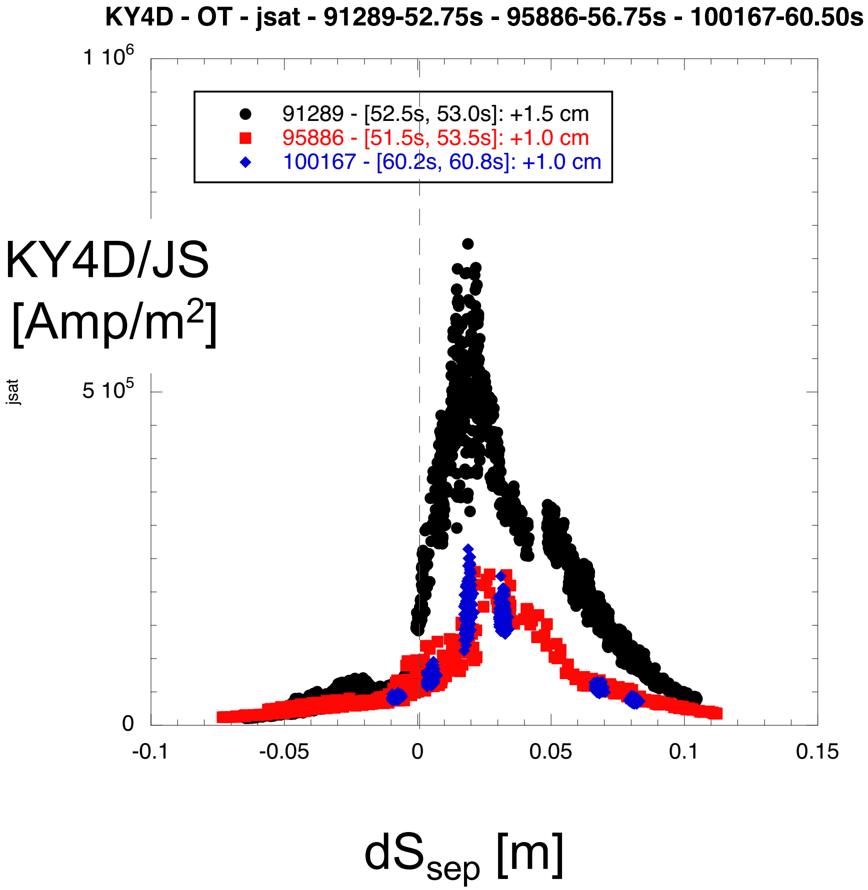
- 30% higher $\langle n_e \rangle_{LAD4}$ required for same degree of detachment in H

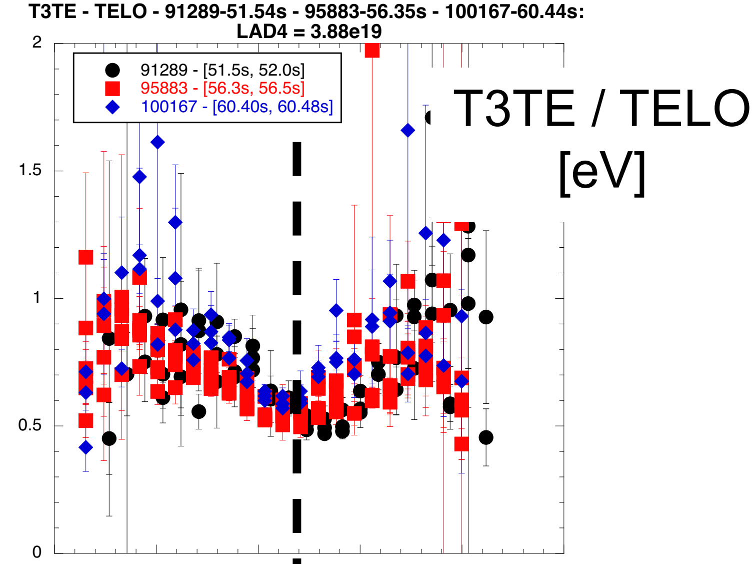


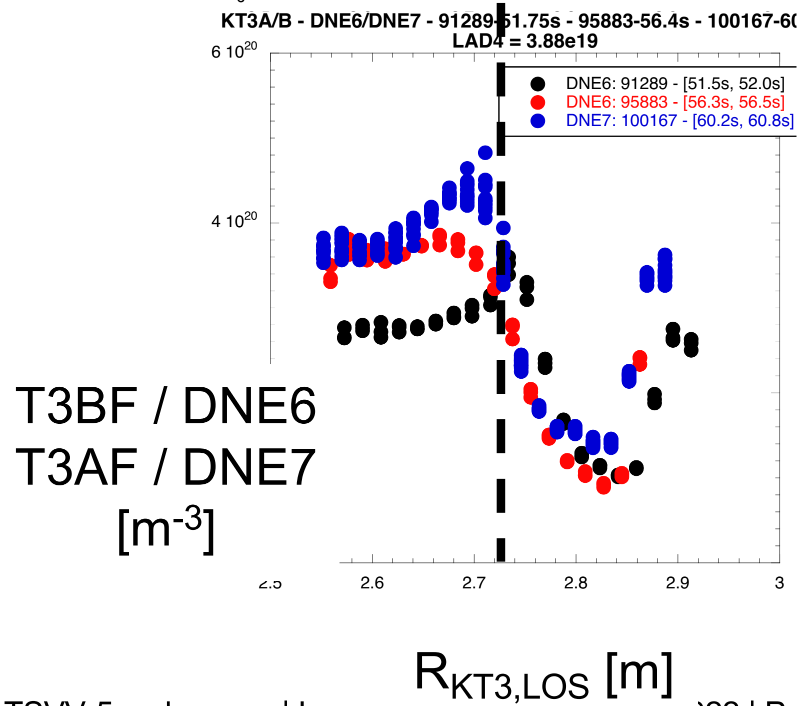


In partially detached conds., $\langle n_e \rangle_{LFS\text{-}div}$ builds up poloidally upstream, close to the separatrix, and is 50% higher for T than for H

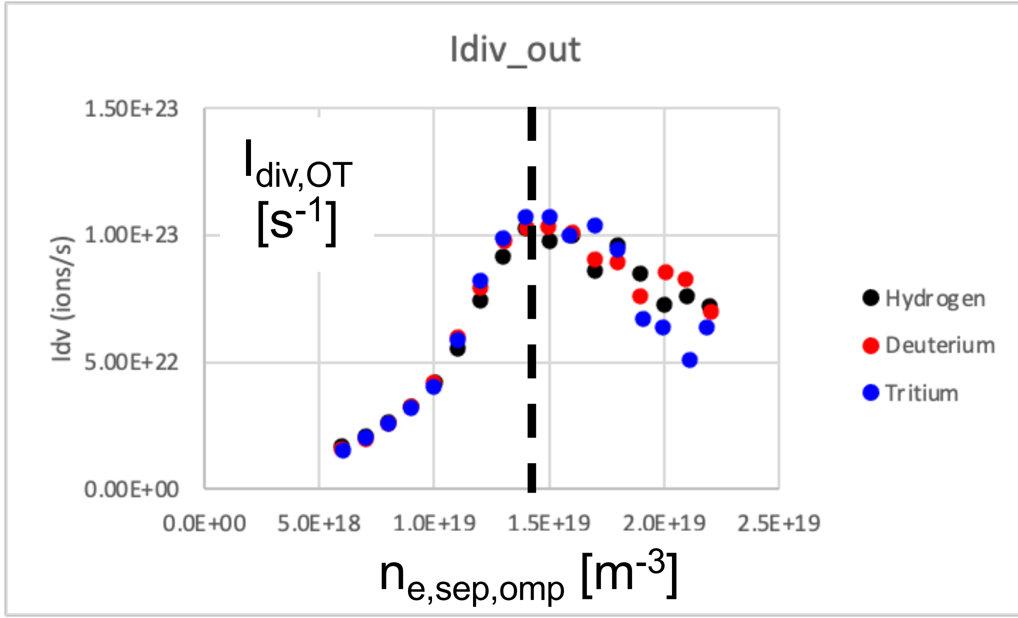
- $\langle T_e \rangle_{LFS\text{-}div}$ is reduced to 0.5 eV at the OSP for all three hydrogenic species

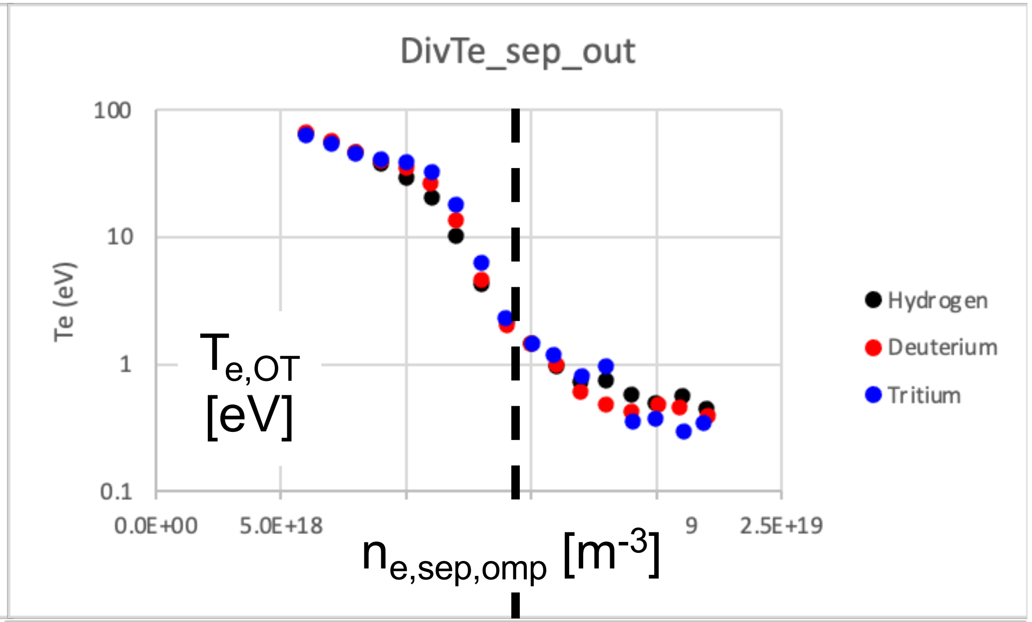




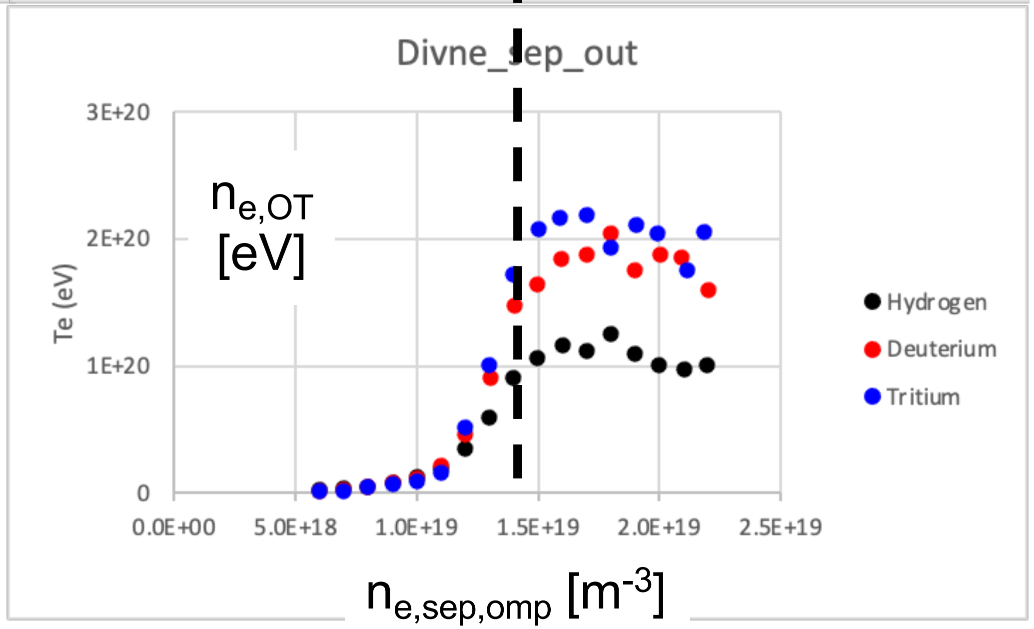


EDGE2D-EIRENE predicts higher divertor densities in T than in H and D in high-recycling and partially detached conds.

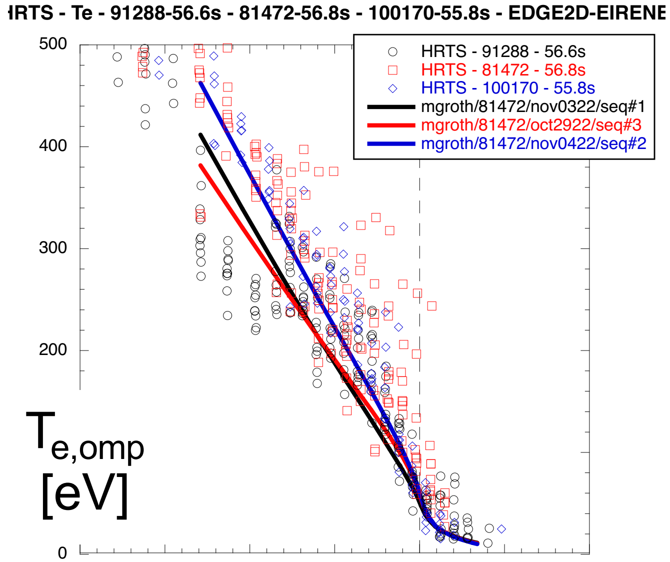




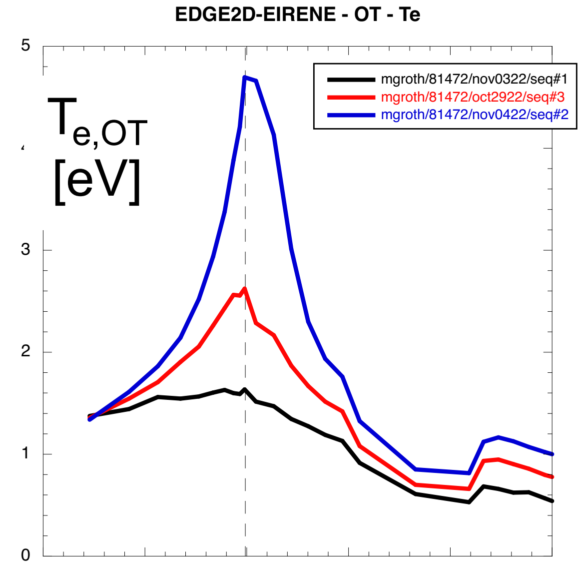
- Generic density scan with identical transport coeffs., models
- Strong reduction in ion current to outer plate not yet reproduced ⇒ likely to require changes to transport coefficients
- T_e least affected by isotope species

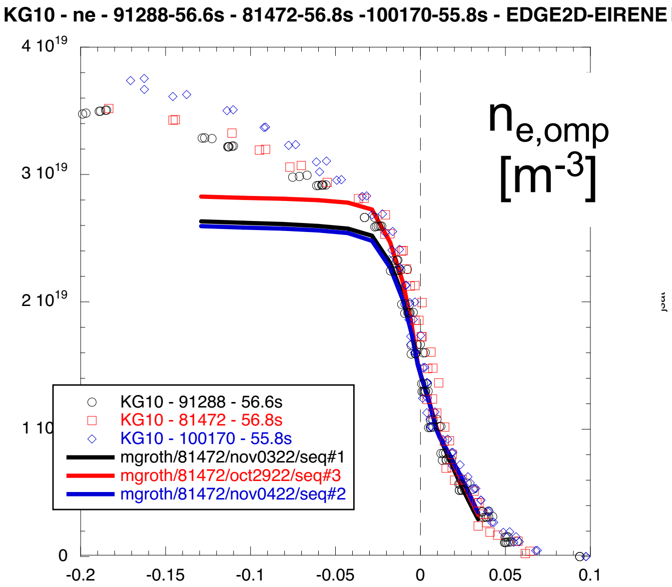


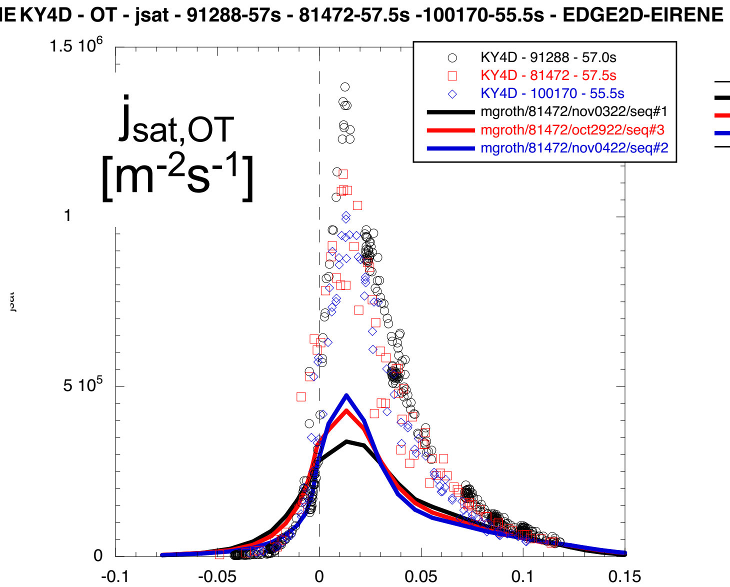
In matched cases for high-recycling conds., EDGE2D-EIRENE generally underpredicts $j_{sat,OT}$ by a factor of 2.5

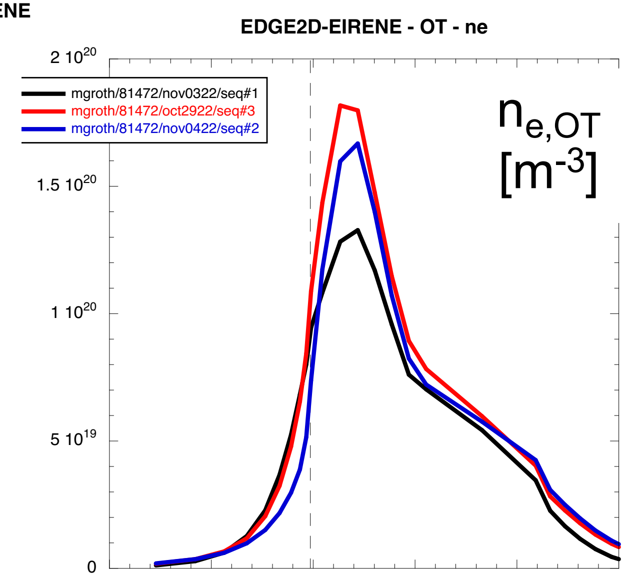


- $T_{e,sep,omp}$ = 48 / 64 / 67 eV determining the higher $T_{e,OT}$ for T
- Further adjustment of $P_{core\text{-}bd}$ and transport coefficients









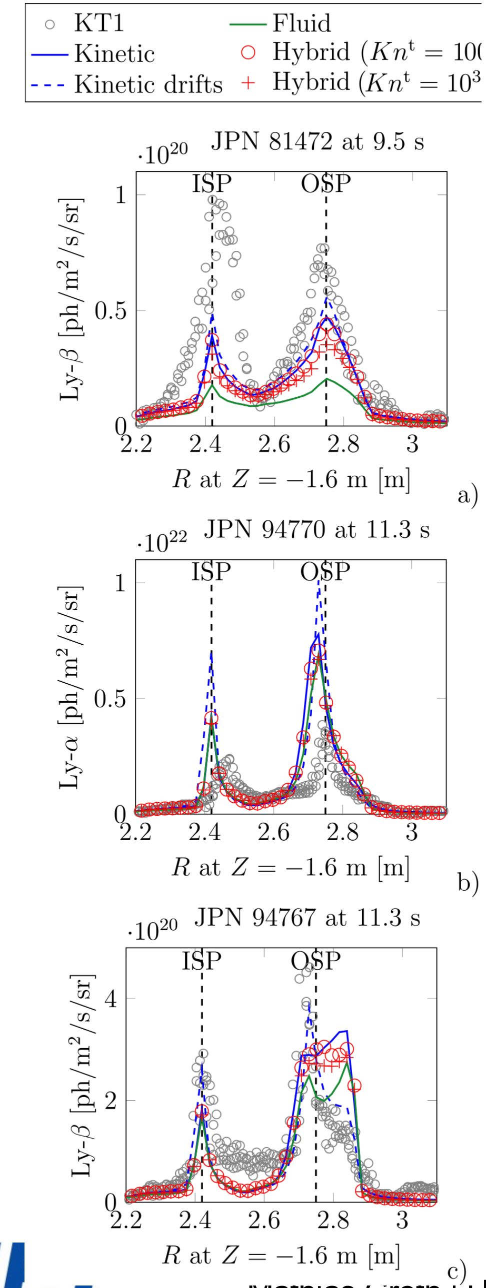
$R\text{-}R_{sep,omp}$ [m]

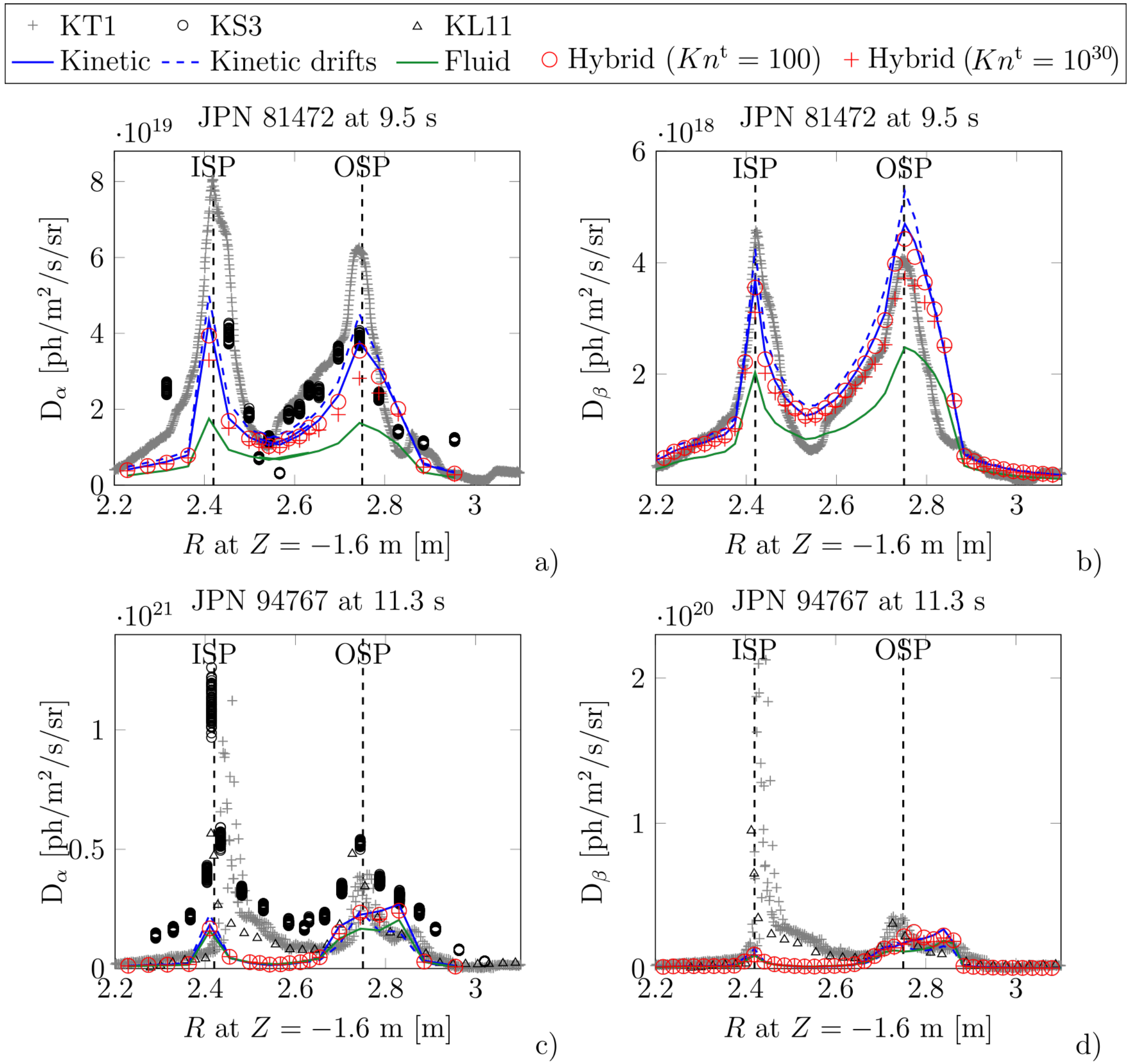
$d\text{-}d_{sep,OT}$ [m]

$d\text{-}d_{sep,OT}$ [m]

First comparison of Ly_α, Ly_β, D_α and D_β indicated Ly-a opacity already for high-recycling conditions

Niels Horsten et al., PSI / NME 2022





Detached tritium divertor plasmas are up to 2x denser than hydrogen plasmas

- Analyses focused on L-mode plasmas, outer midplane and outer target plasma conds. ⇒ open questions on total radiation and line emisison
- In attached (low and high-recycling) plasmas, identical conditions (within measurement uncertainties) were obtained in H, D and T L-mode plasmas
- In partially detached conditions, broadening / shoulder formation more pronounced in T L-mode plasmas ⇒ less upstream density is needed in T to reach DL
- In attached L-mode plasmas, j_{sat} and T_e profiles are similar ⇒ n_e is higher in T
  - Uncertainties in probe measurements, i.e., individual probes in one pulse and across campaigns are of the order 40%, masking out the isotope effect
- Partially detached H plasmas are more weakly detached than D and T plasmas ⇒ more upstream density needed in H to reach DL
  - Tritium divertor plasmas are up to 2x denser than H plasmas (at the peak of the divertor density at the OSP), **likely due to shorter ionization mfp for T**
- For generic $n_{e,sep,omp}$ scan, EDGE2D-EIRENE predicts higher divertor densities for tritium, case-specific comparison work-in-progress, but previously observed inconsistencies in high-recycling conditions continue/d to prevail

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** See Appendices of F. Romanelli, Proc. 24th IAEA-FEC, San Diego, USA, F. Romanelli, Proc. 25th IAEA-FEC, St. Petersburg, Russia, X. Litaudon, Proc. 25th IAEA-FEC, Kyoto, Japan, E. Joffrin et al., Proc. of the 27th IAEA-FEC 2018, Gandhinagar, India, and J. Mailloux, Proc. 28th IAEA-FEC, Nice, France*

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