RT11/M21-05:
Fast-ion studies with three-ion ICRF scenarios

Yevgen Kazakov and Massimo Nocente

With contributions from Agata Chomiczewska, Andrea Dal Molin, Dani Gallart, Jeronimo Garcia, Vasily Kiptily, Giu Marcer, Marica Rebai, Žiga Štancar and M21-05 team

TE Task Force Meeting, 13 January 2025
RT-11 2024 Review and 2025 Strategy

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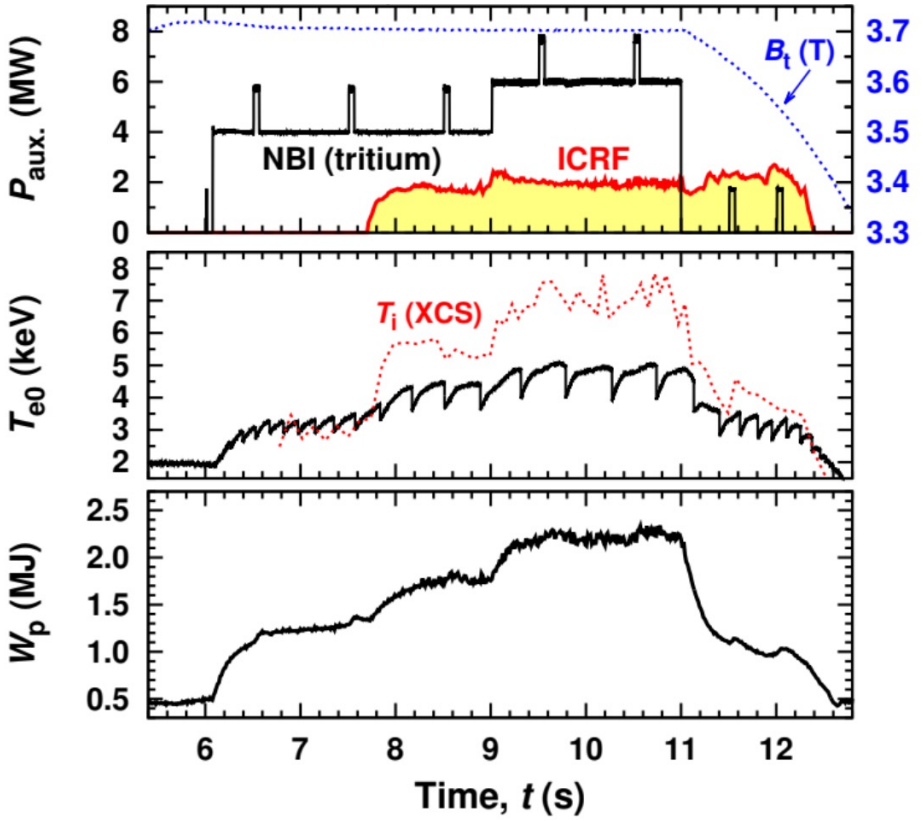
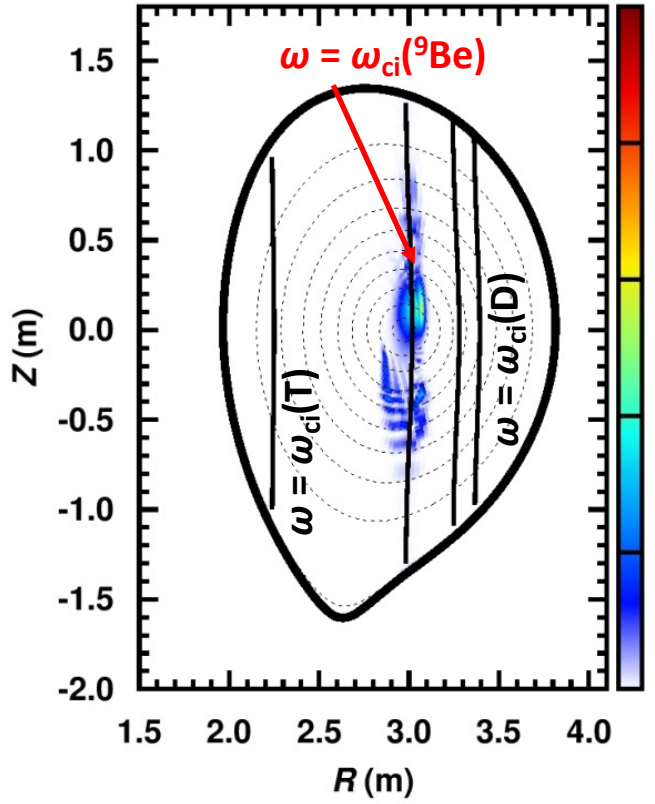
M21-05 in DTE2:
a new ICRF scheme for increasing T_i in D-T ~ 50%-50% demonstrated

#99608: 3.7T/2MA, D-T ~ 50%-50%, ICRF ~ 2.0-2.5MW (25MHz)

^{9}Be concentration ~ 0.5-1.0% (intrinsic level)

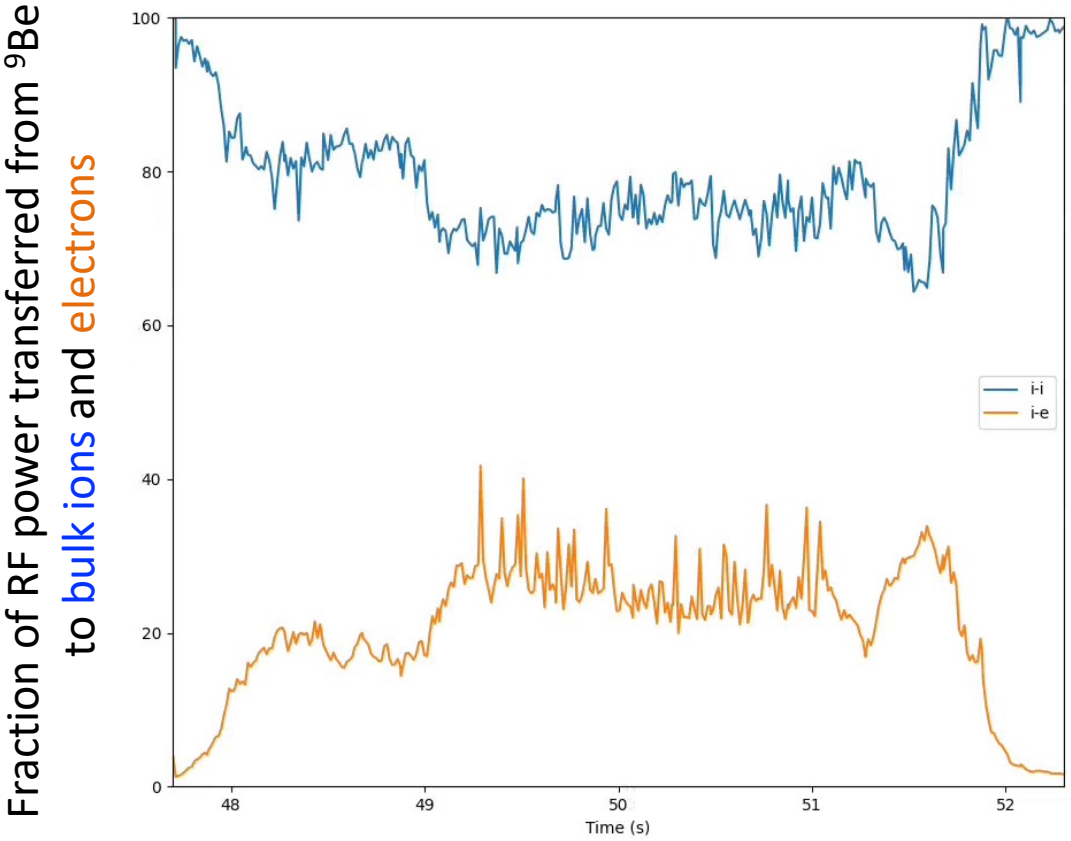




- JET DTE2: a significant increase of T_i observed in D-T ~ 50%-50% plasmas with the application of the three-ion T-(^{9}Be)-D scheme

Y. Kazakov et al., *AIP Conf. Proc.* **2984**, 020001 (2023)

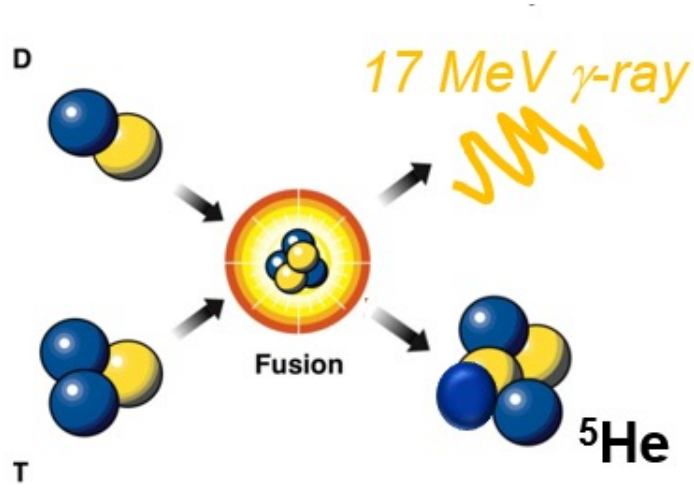
PION modeling of M21-05 pulses in DTE2 (2024)

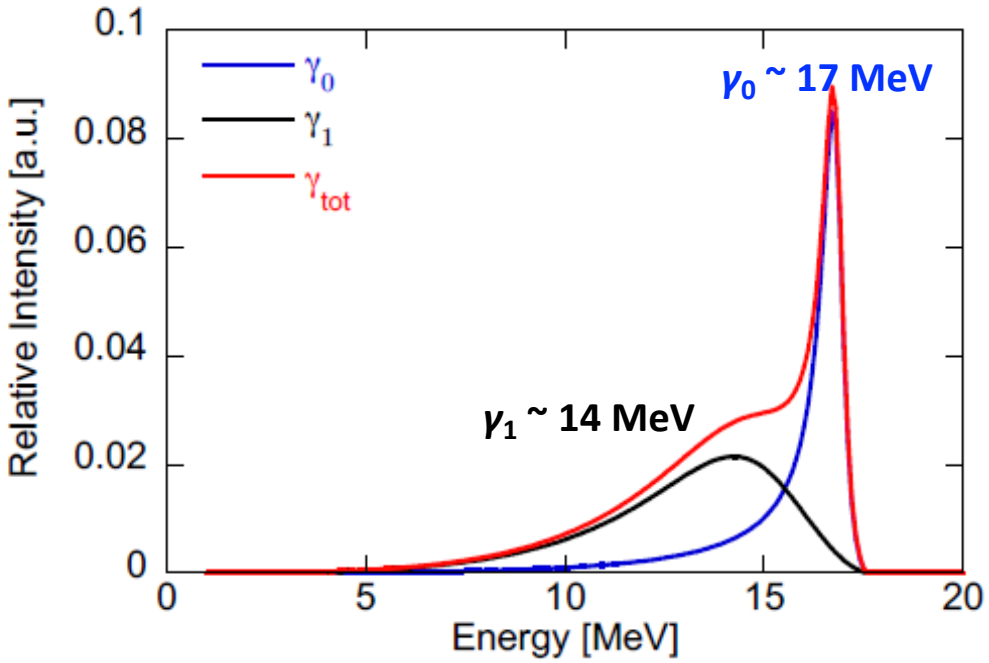


- Bulk ion heating with the three-ion T-(^{9}Be)-D scheme:
  ~70-80% of RF power absorbed by ^{9}Be impurities is transferred to bulk ions

PION analysis: D. Gallart (BSC, Barcelona)

The DT branching ratio inferred from DTE2 data





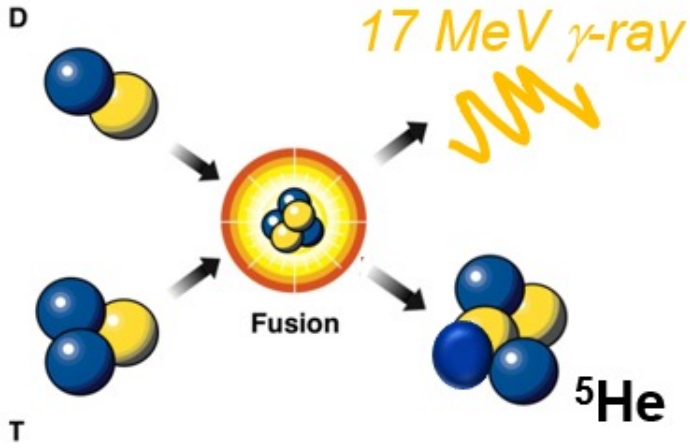
D + T -> ^{4}He (3.5MeV) + *n* (14.1 MeV)

<u>Weak branch</u>:
D + T -> ^{5}He + ***γ***

$\gamma_1/\gamma_0 \sim 1.1 \pm 0.3$

M. Rebai et al., *Phys. Rev. C* **110**, 014625 (2024)

The DT branching ratio inferred from DTE2 data



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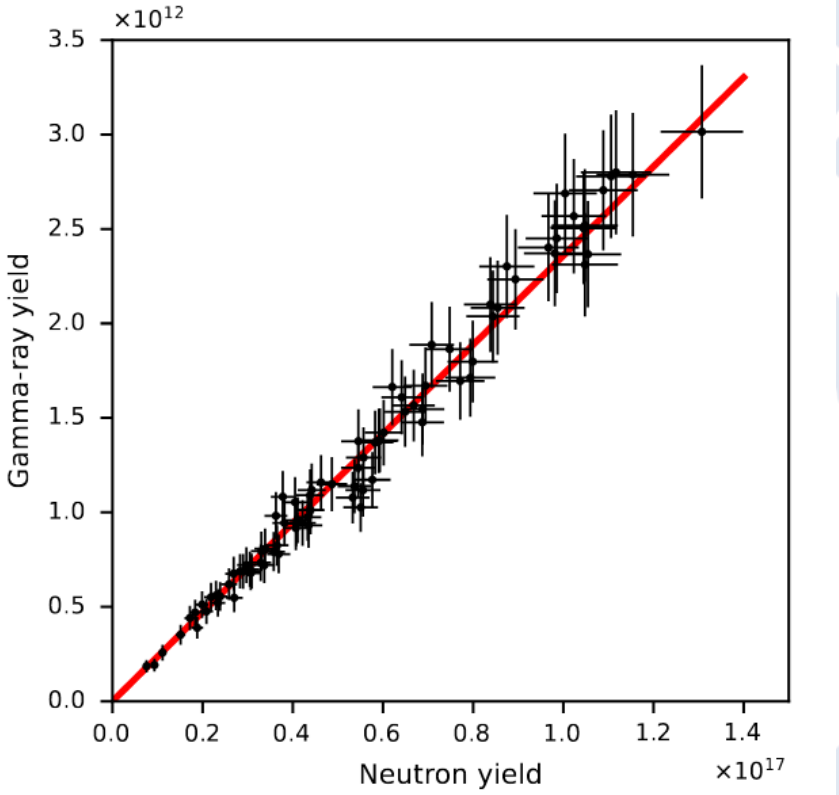
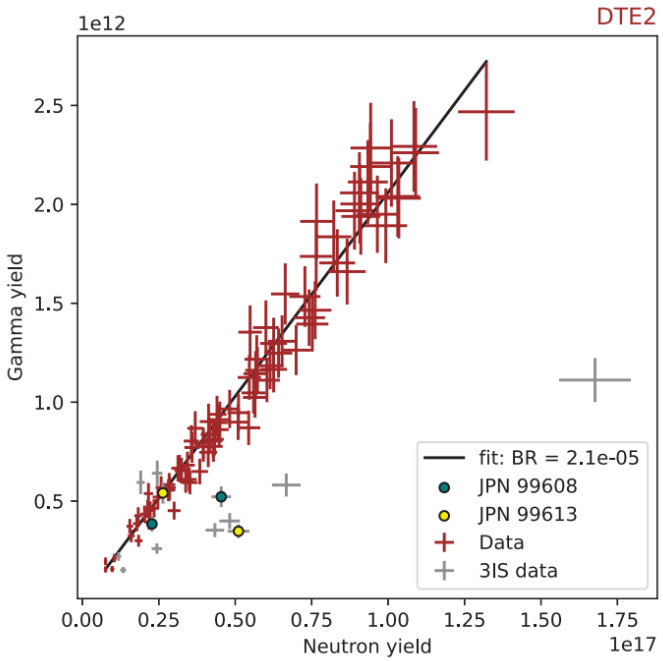
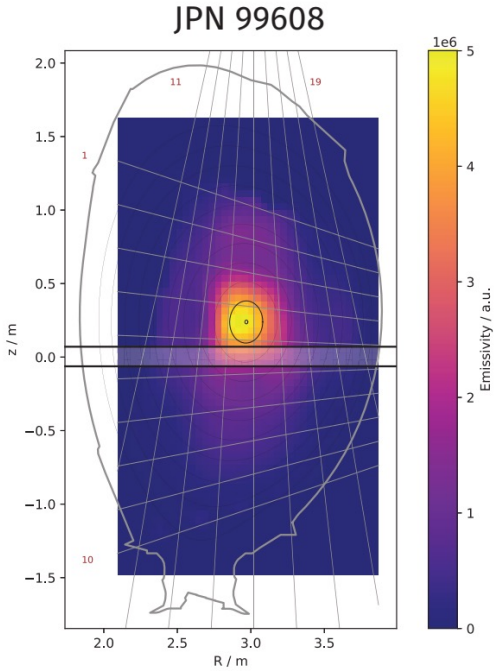


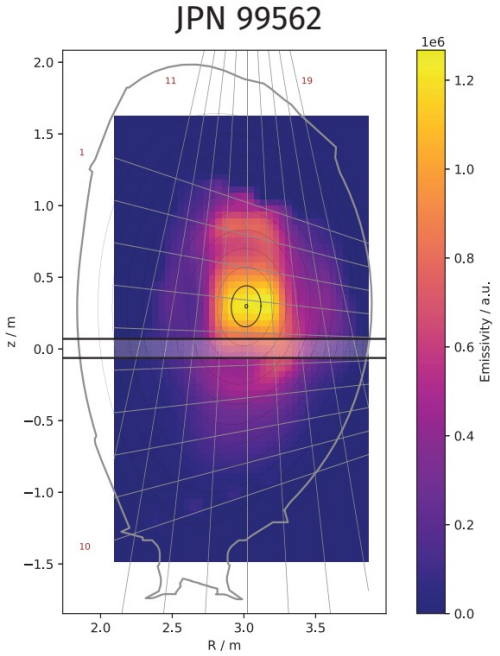
Branching ratio: $(2.4 \pm 0.5)\times10^{-5}$

A. Dal Molin et al., *Phys. Rev. Lett.* **133**, 055102 (2024)

17MeV gamma-ray analysis (2024)





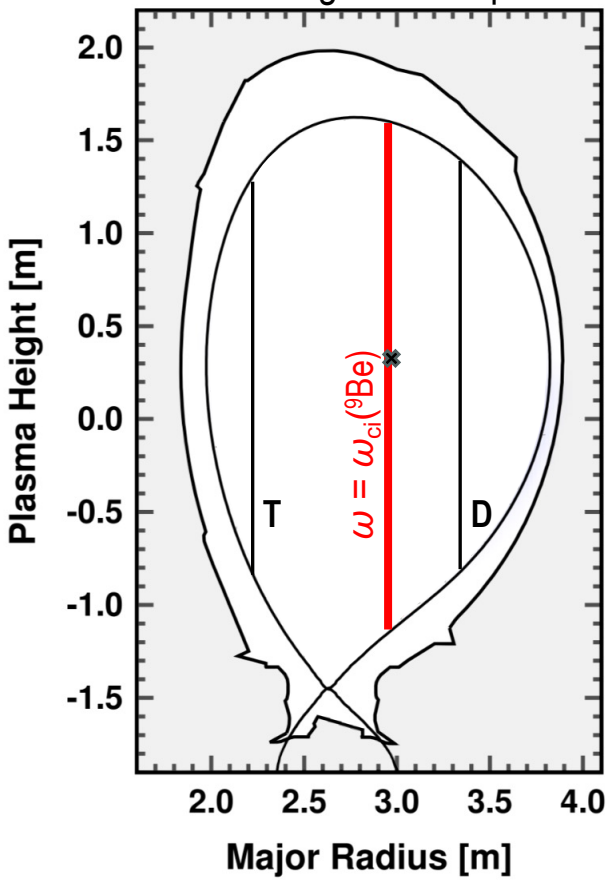


- A few pulses with the three-ion ICRF scheme hint at a different branching ratio
- 2025 plans: a pile-up effect or a difference in the emission profile shape (?)

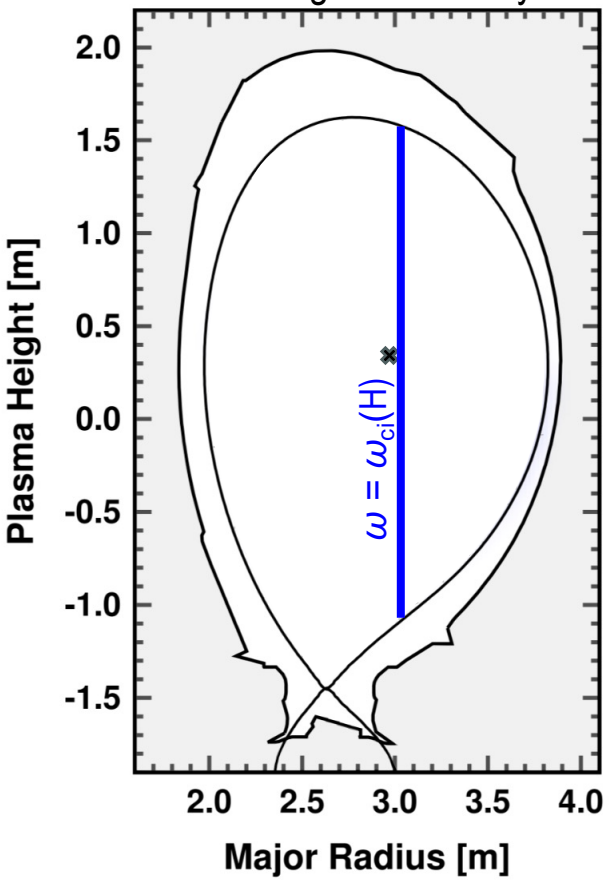
Gamma-ray analysis: G. Marcer and M. Nocente (Univ. Milan, Italy)

M21-05 studies in DTE3: bulk ion vs. electron heating with ICRF

B_t = 3.7T, f = 25MHz:
ICRF heating of **^{9}Be** impurities

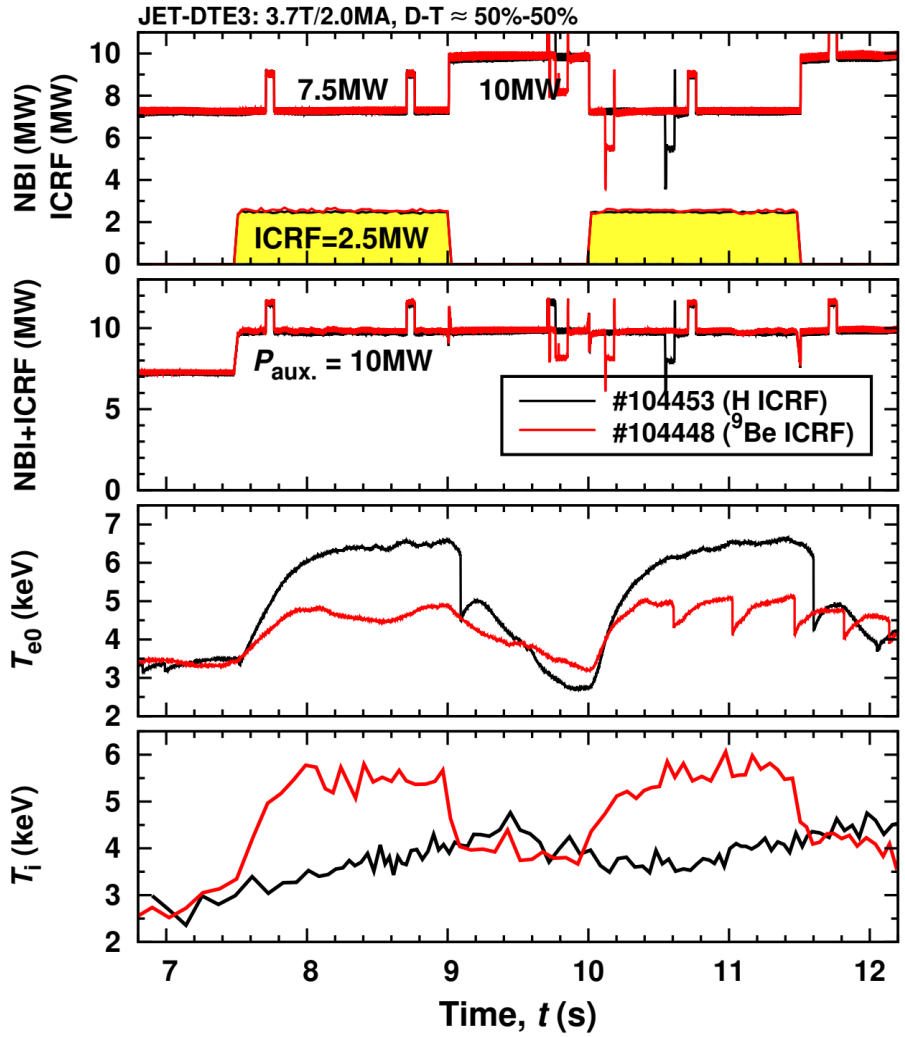


B_t = 3.7T, f = 55MHz:
ICRF heating of **H** minority ions



Comparison of **bulk ion** vs. **electron** heating with ICRF
in D-T ~ 50%-50% plasmas

M21-05 studies in DTE3: bulk ion vs. electron heating with ICRF



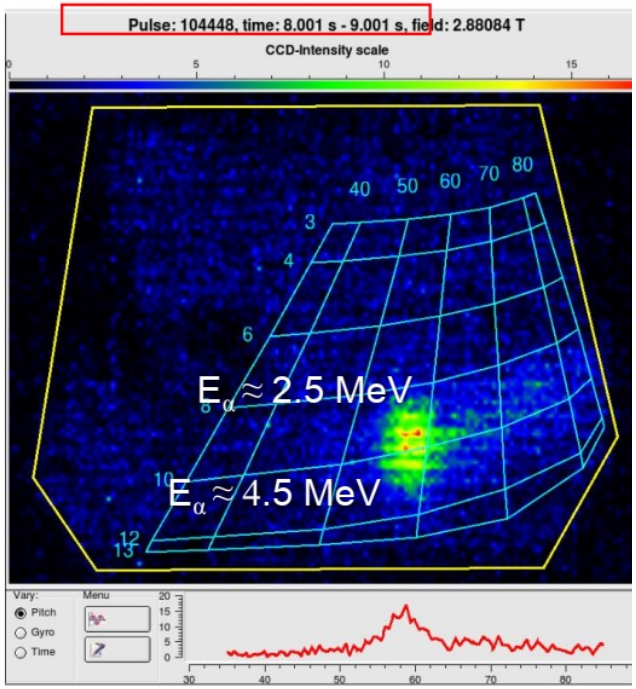
NBI power = 7.5MW (Deuterium, 100kV)
ICRF = 2.5MW (dipole, 25MHz / 55MHz)

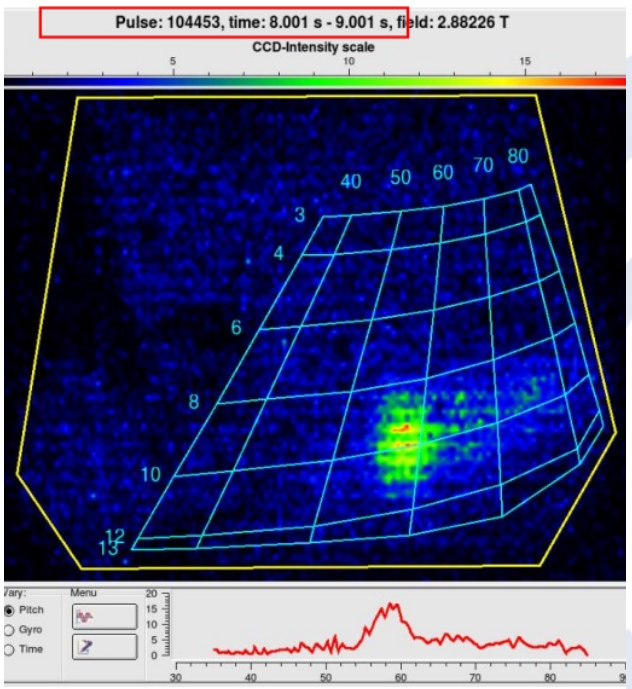
#104448 vs. #104453:
NBI + ICRF = 10MW = constant power

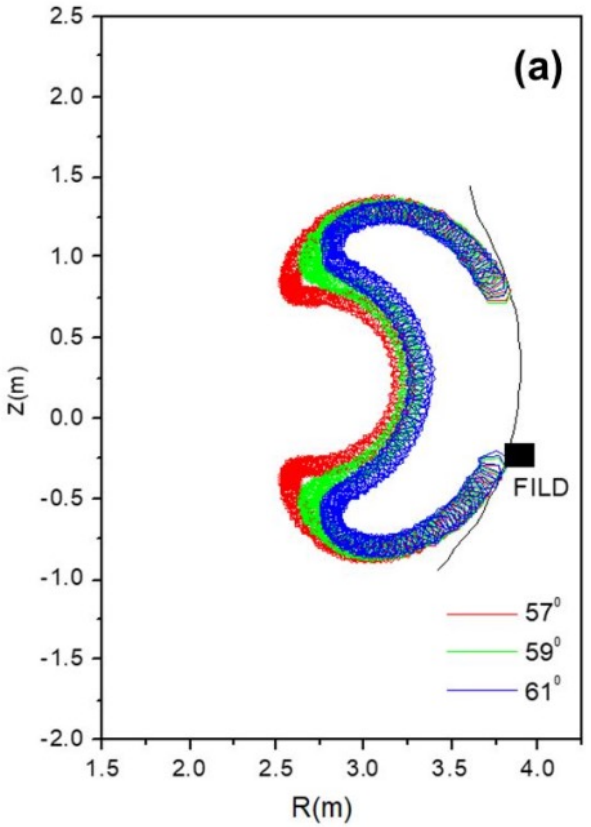
- ✓ **Higher T_{e0} with H minority ICRF scheme (#104453)**
- ✓ **Higher T_i with ^{9}Be three-ion ICRF scheme (#104448)**

Y. Kazakov et al., EPS-2024

FILD and alpha-particle analysis (2024)







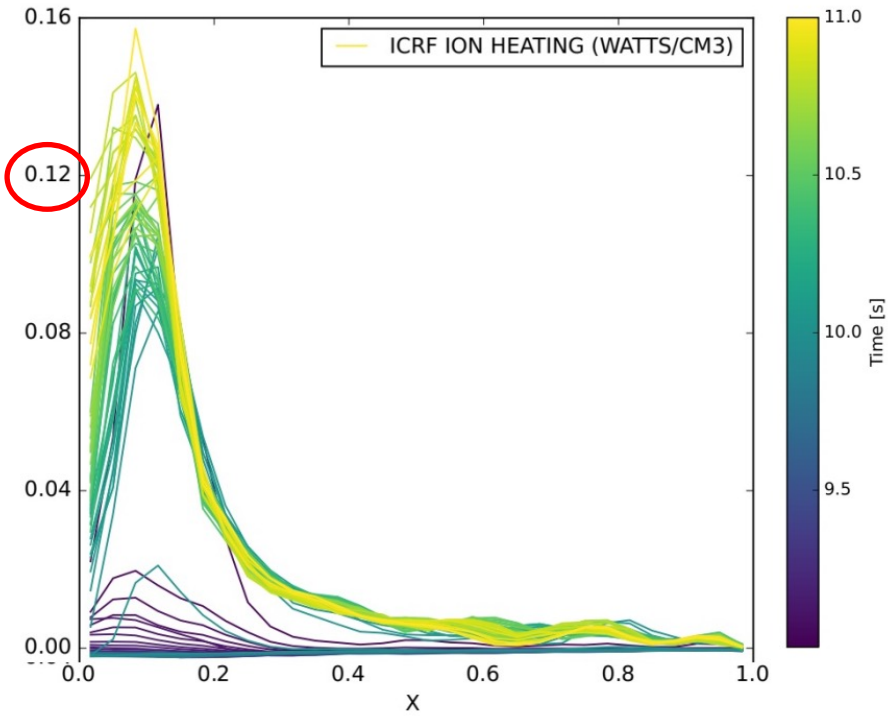
- #104448 and #104453: very similar FILD patterns
- Core generation of alpha particles with both ICRF schemes

V. Kiptily et al., *Nucl. Fusion* **64**, 086059 (2024)

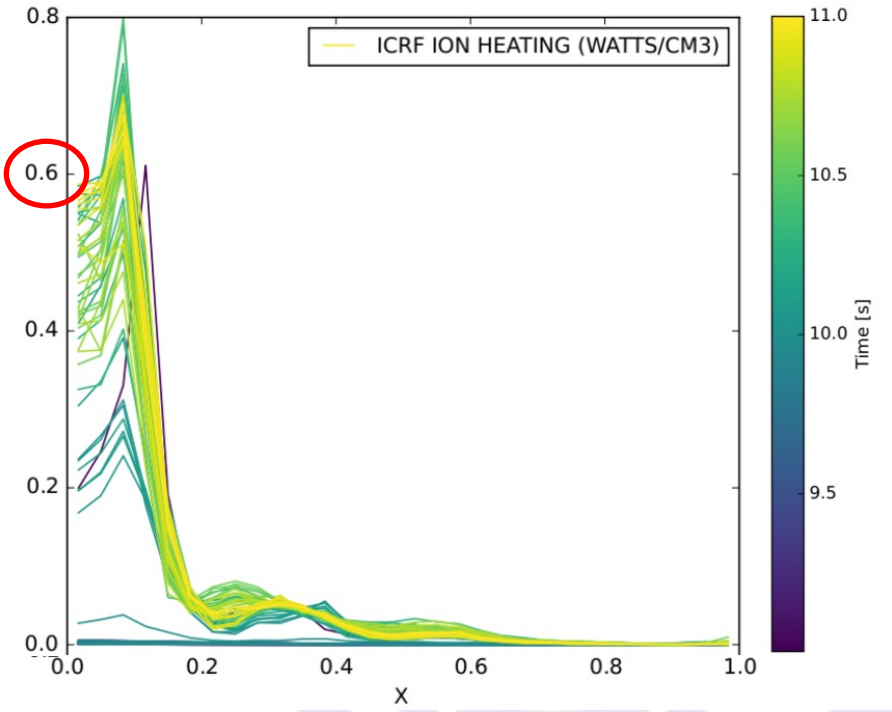
FILD analysis: V. Kiptily (UKAEA)

TRANSP modeling results (2024)

#104453: **hydrogen minority**



#104448: **^{9}Be three-ion scheme**

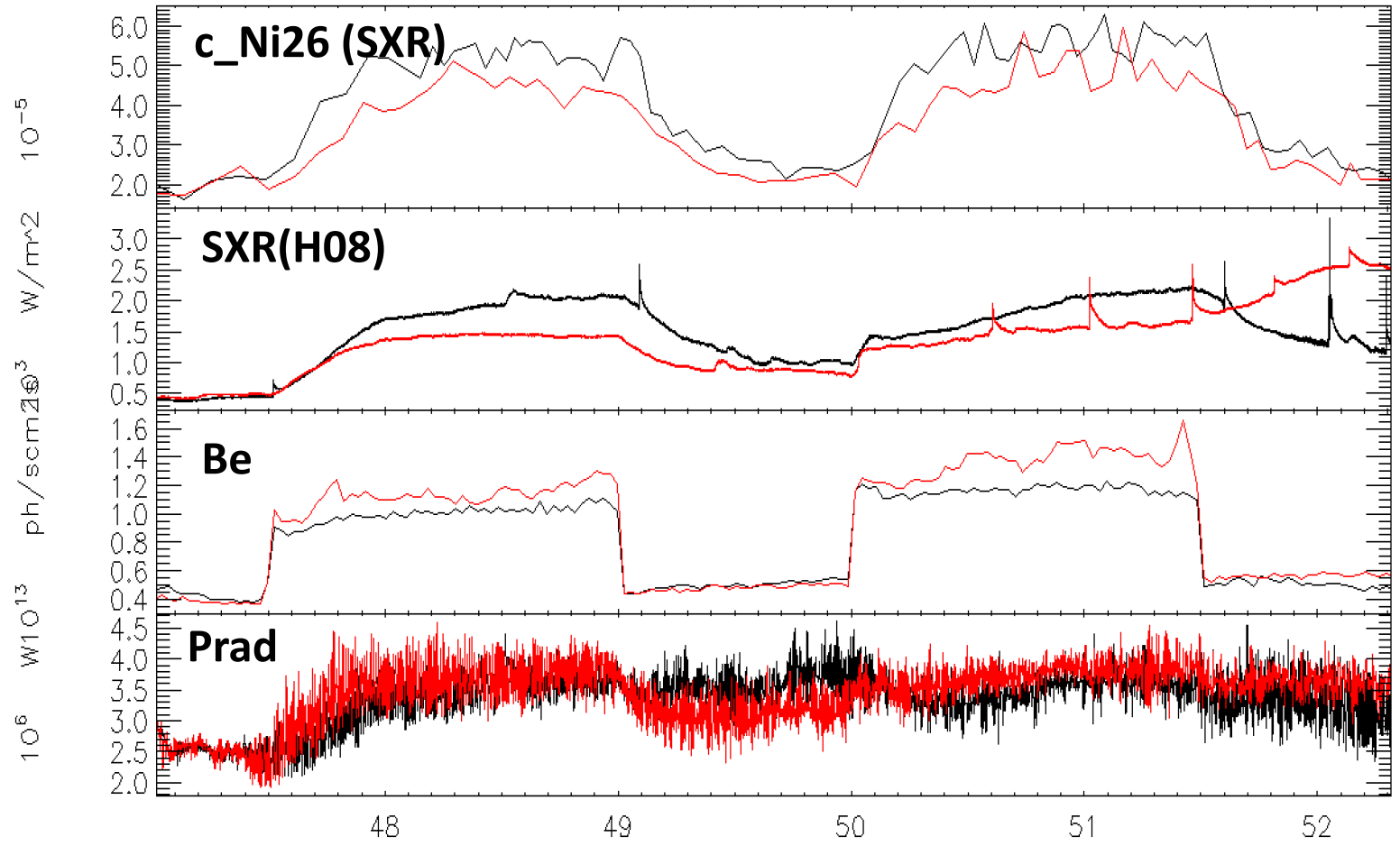


- #104453: dominant collisional electron heating from ICRF (p_e/p_i ~ 2)
- #104448 vs. #104453: much higher collisional ion heating with the ^{9}Be three-ion ICRF scheme, in line with higher T_i observed

TRANSP analysis: Ž. Štancar (UKAEA)

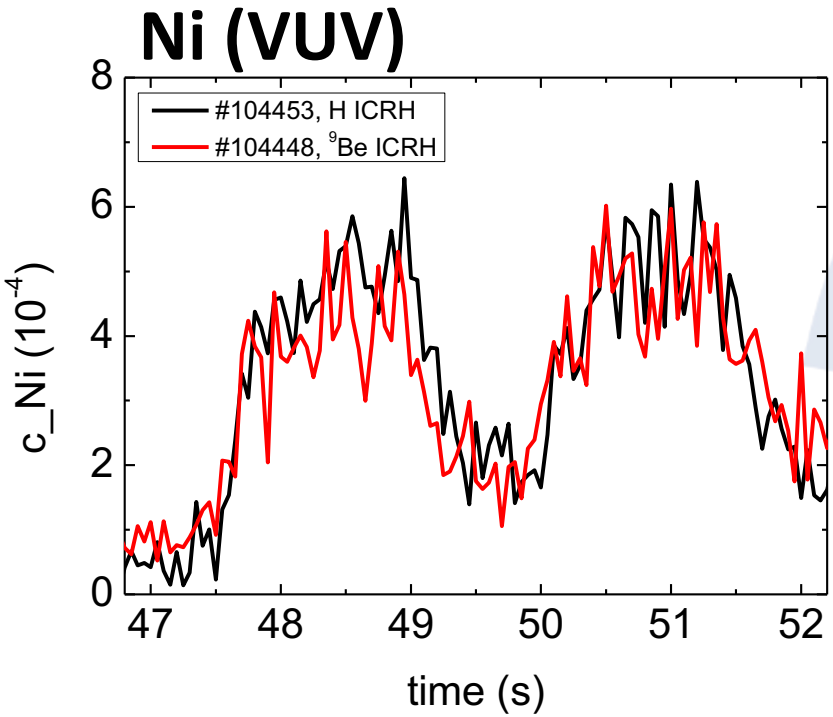
Impurity analysis results (2024)

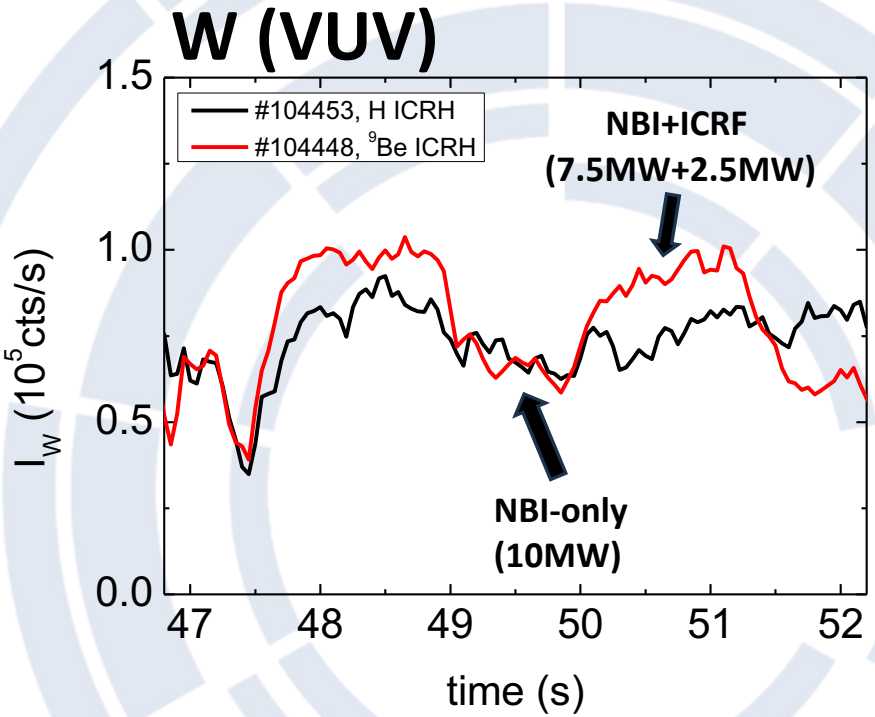
#104448 (^{9}Be three-ion scheme) vs. #104453 (**H minority** scheme)



Impurity analysis: A. Czarnecka (IPPLM, Poland)

Impurity analysis results (2024)

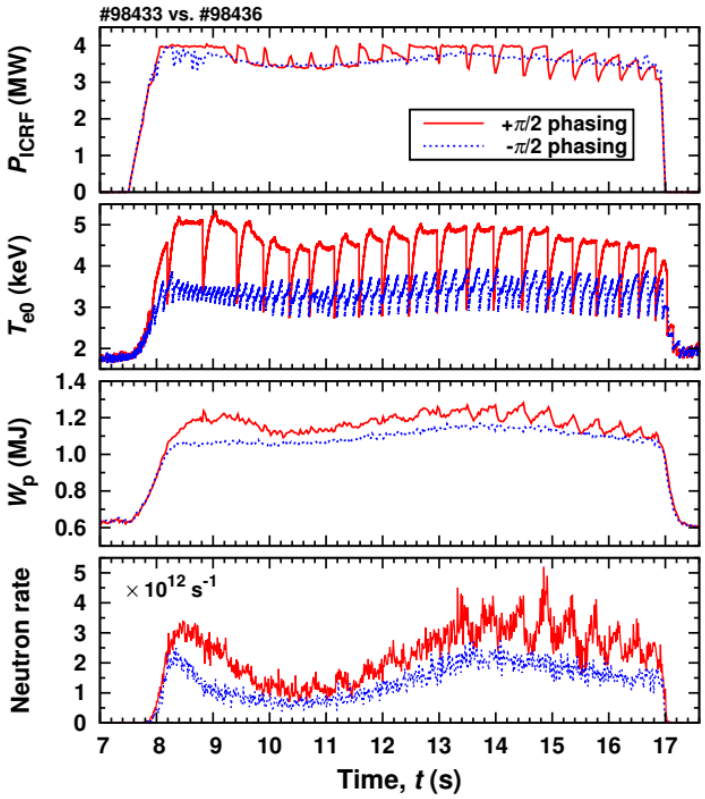


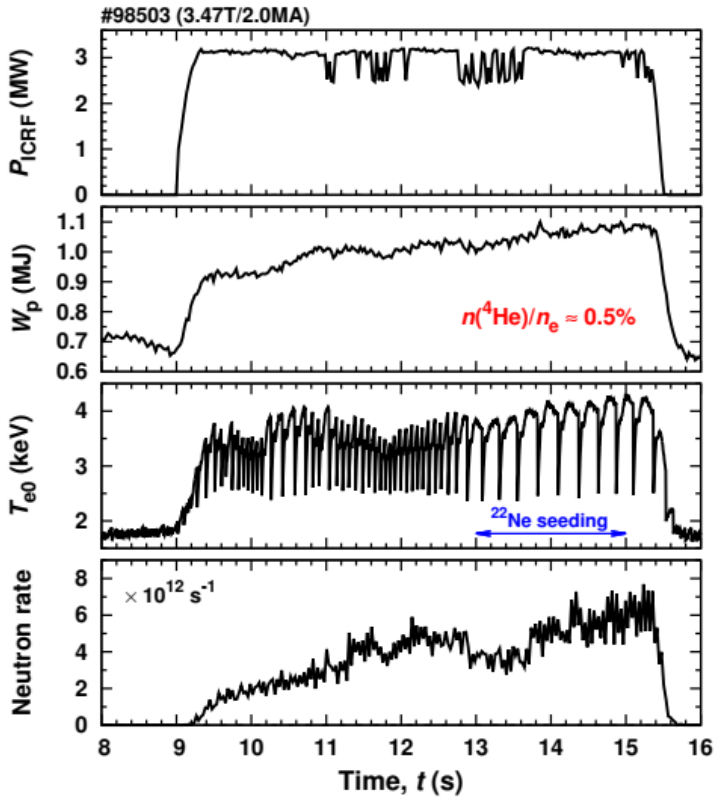


- Higher impurity content during the NBI+ICRF phase, as compared to the NBI-only phase
- Ni concentration is a bit higher in #104453 (with H minority ICRF)
- Somewhat higher W content in #104448 (with ^{9}Be ICRF scenario)

Impurity analysis: A. Czarnecka (IPPLM, Poland)

Plans for 2025 (1)

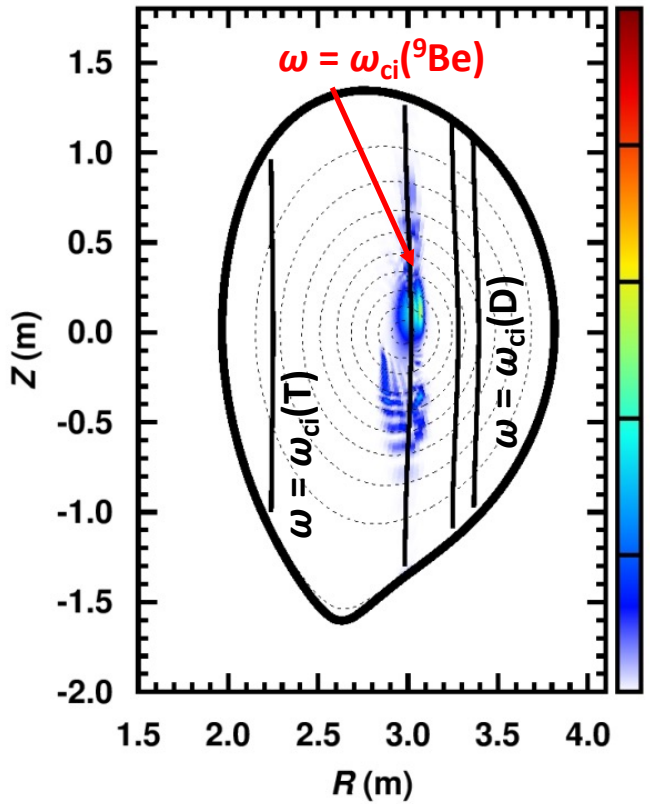


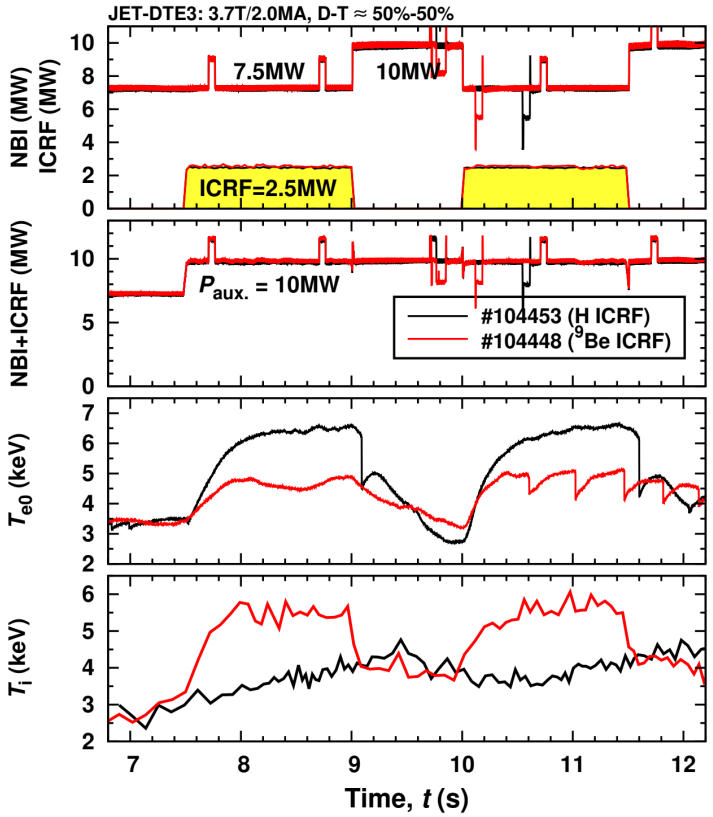


Analysis of ITER-relevant experiments with ICRF-generated ^{3}He and ^{4}He fast ions

- ICRF and plasma heating modeling
- Impurity analysis and the impact of ICRF antenna spectrum
- Fast-ion analysis (gamma-ray spectroscopy, neutrons, FILD, …)
- Interaction between MeV-range fast ions, AEs and turbulence
- Studying the impact of ^{22}Ne impurity seeding

Plans for 2025 (2)





- Finalize the analysis of the T-(^{9}Be)-D ICRF studies and comparison with other schemes
- Analysis of the 17MeV gamma-ray branching ratio
- Prepare and submit a manuscript