# Enhanced confinement and thermal transport decoupling in H-mode plasmas with impurity seeding

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W.L. Zhong[1], X.L. Zou[2], G.L. Xiao[1], A.S. Liang[1,2], G.Q. Xue[3,1], L. Liu[1], X.X. He[1], D.L. Yu[1], M. Jiang[1], Z.C. Yang[1], K.R. Fang[1], Z.B. Shi[1],J.M. Gao[1], J. Li[3], M.K. Han[3], J.Q. Dong[1,4], Z.X. Wang[3], C.Y. Chen[1], J. Yin[1], B.B. Feng[1], C.H.Liu[1], J. Wen[1], P.W. Shi[3], Y.P. Zhang[1], N. Wu[1], T.B. Wang[1], X.M. Song[1], Yi Liu[1], Q.W. Yang[1], L.W. Yan[1], X.T. Ding[1], M. Xu[1], and X.R. Duan[1]

[1]Southwestern Institute of Physics, Chengdu 610041, People's Republic of China
[2]CEA, IRFM, Saint-Paul-lez-Durance F-13108, France
[3]Key Laboratory of Materials Modification by Beams of the Ministry of Education, School of Physics, Dalian University of Technology, Dalian 116024, People's Republic of China
[4]Institute for Fusion Theory and Simulation, Zhejiang University, Hangzhou, 310027,People's Republic of China

Email: zhongwl@swip.ac.cn

## ABSTRACT

•It has been observed that the energy confinement of the H-mode plasma is improved by the edge-deposited impurities in the HL-2A tokamak.

•Both the edge and core ion temperatures are increased by a factor of 20-40% after the SMBI. The reduced edge ion thermal transport leads to the formation a higher edge ion temperature, which is a boundary condition for further increasing the core temperature through the profile stiffness.

•However, the electron temperature is almost unaffected. The results suggest that the ion and electron thermal transport are decoupled by the impurity ions.

## BACKGROUND

◆In magnetically controlled fusion devices, improving plasma performance is crucial for enhancing the confinement efficiency H-mode has been chosen as the standard operating scenario for ITER.

◆Recently, the energy confinement can be further improved by externally seeeded low or medium Z impurities in the H-mode plasmas as observed in several tokamaks.

◆The impurity seeding experiments suggest that the core-edge plasma coupling is a key process needed to be understood, especially for actively improving plasma confinement.

## SMBI system for impurity seeding

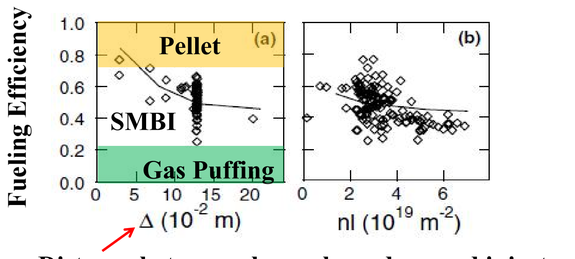
☐Supersonic Molecular Beam Injection (SMBI)

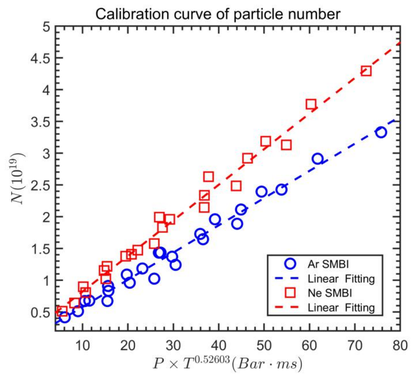
—Better directionality

—Deeper deposition

— Higher fuelling efficiency

— Lower neutral recycling

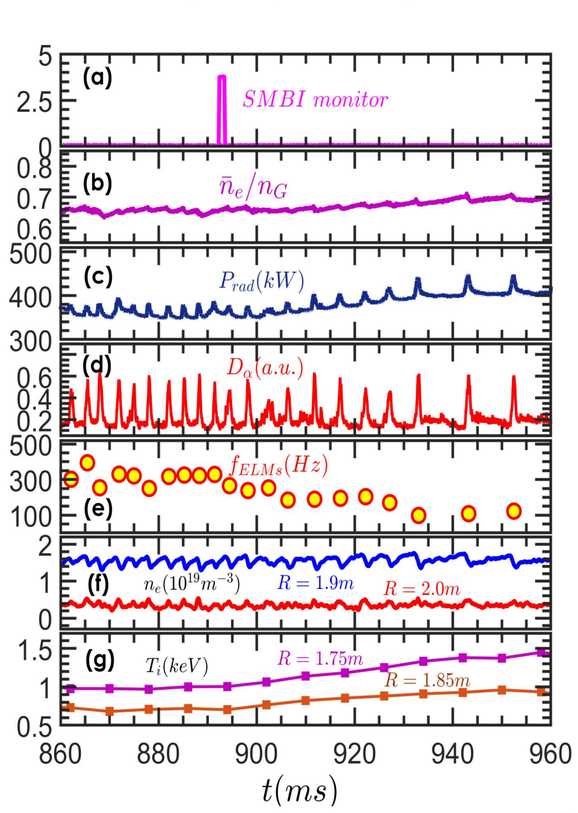


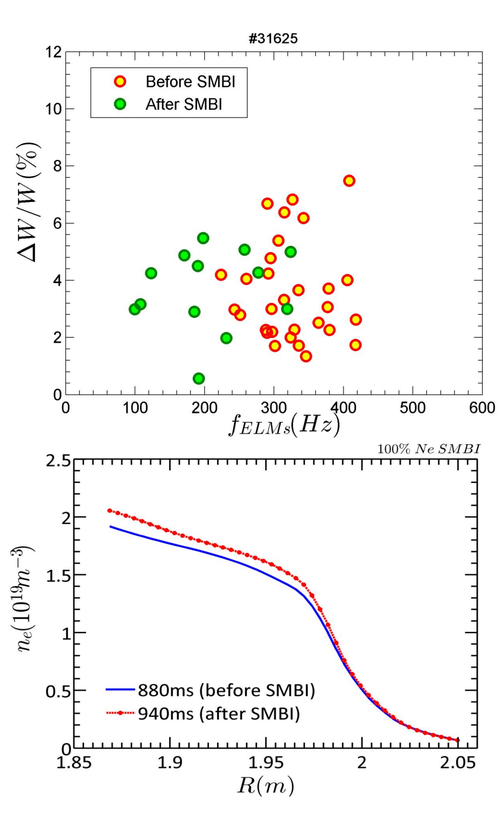




Calibration results of the number of Ar and Ne SMBI.

## OUTCOME

➢**Effect of impurity seeding on ELMs and density pedestal**

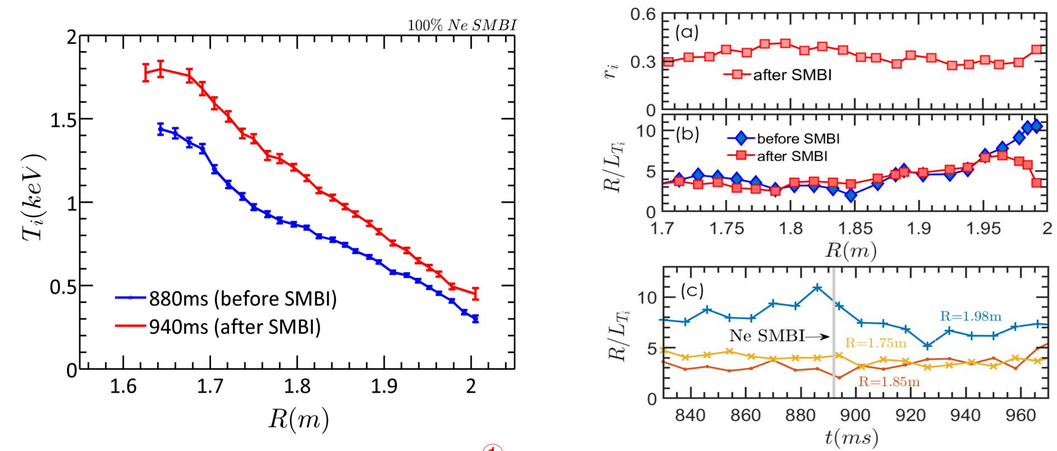



*impurity seeding »» ELM frequency ↓ , amplitude is almost identical »» recovery time of the pedestal ↑ »» the pedestal top electron density ↑ »» pedestal stability ↑*

## OUTCOME

➢**Ion temperature increased by impurity seeding**




☐edge –deposited impurity ① → edge ion thermal transport reduce

① Theoretic work predicted that the growth rate of the ITG instability decreases with the increasing plasma effective charge and quasi-linear heat flux of main ions can be reduced in the presence of impurity ions.

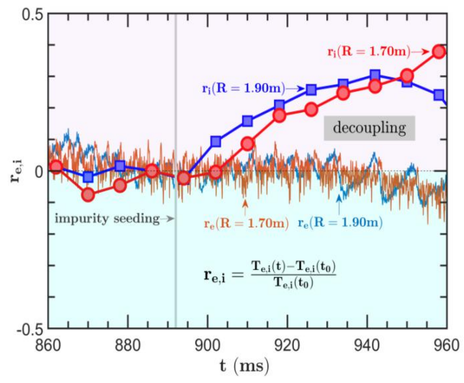
[M.Z. Tokar et al 2000 Phys. Rev. Lett. 84, 895] ;[J. Li et al 2020 Nucl. Fusion 60 126038]

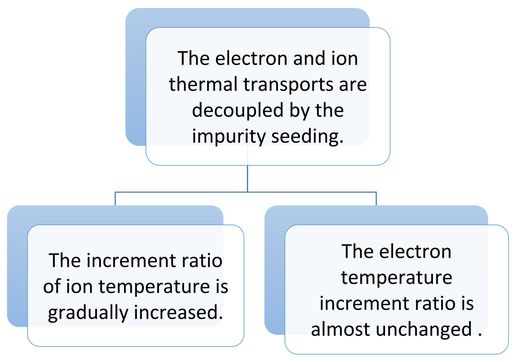
☐The change of the temperature profile could be attributed to the change of the underlying thermal transport, which is mainly associated with the temperature gradient.

☐ Edge R/LTi is reduced but the core R/LTi are almost identical .
It indicates that the core temperature stiffness is unchanged.

→ edge Ti increase **profile stiffnes** → core Ti increase → core energy confinement improve

➢**Electron and ion thermal transport decoupling in H-mode plasmas**




☐ The results indicate that the ion and electron heat flux exhibit distinct responses to the impurity seeding.

## CONCLUSION

•In HL-2A, it has been observed that the seeded Ne or Ar gas can reduce the ELM frequency and improve the plasma confinement.

• Both the edge and core ion temperatures are increased by impurity seeding. The core ion temperature stiffness is unchanged.

•The reduced thermal transport leads to the formation a higher edge ion temperature, which is a boundary condition for further increasing the core temperature through the profile stiffness.

• The electron and ion thermal transports are decoupled by the impurity seeding.

•The thermal transport decoupling could plays a important role in the further improvement of core ion temperature in the H-mode plasmas, which is beneficial for burning plasma operation in the future devices.

## ACKNOWLEDGEMENTS

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