Improving Fast-Ion Tomography with Transport Basis Functions

Garrett Prechel[1], Bo S. Schmidt[1], Luke Stagner[2], William Heidbrink[1], Edward Parr[2], Clive Michael[2,3] , Marco Cecconello[4],and the MAST-U Team*

[1]*University of California Irvine, CA, USA*
[2]*General Atomics, San Diego, CA, USA*
[2]*UKAEA, Culham Science Centre, Abingdon, Oxon, UK.*
[3]*University of California Los Angeles, CA, USA*
[4]*University of Durham, Durham, UK.*
* *See author list of J. Harrison et al 2019 Nucl. Fusion 59 112011.*
gprechel@uci.edu

Accurately characterizing fast-ion distributions in fusion plasmas is crucial for understanding and controlling alpha heating and instabilities in future reactors. This work presents a significant advancement in fast-ion tomography by introducing a novel technique that not only reconstructs fast-ion distributions but also identifies the specific transport mechanisms responsible for shaping them.

This capability is achieved by extending the conventional slowing-down basis[1][2] with a set of transport basis functions, enabling the accurate reconstruction of fast-ion distributions even in the presence of complex transport dynamics. To validate this approach, we utilize synthetic fast-ion distributions generated by TRANSP and validated against experimental data from MAST-U.

Furthermore, we advance tomographic inversion techniques by integrating data from multiple[3] diagnostics on MAST-U, including FIDA, Neutron Collimation system, and solid state NPA. To overcome the limitations of individual diagnostics, we combine these measurements in velocity space and compare Bayesian multi-diagnostic techniques with more direct multi-parameter techniques. We also recast the multi-diagnostic problem in orbit space coordinates[4], demonstrating that diagnostics may not need overlapping real-space volumes to provide a comprehensive picture of the fast-ion distribution function.

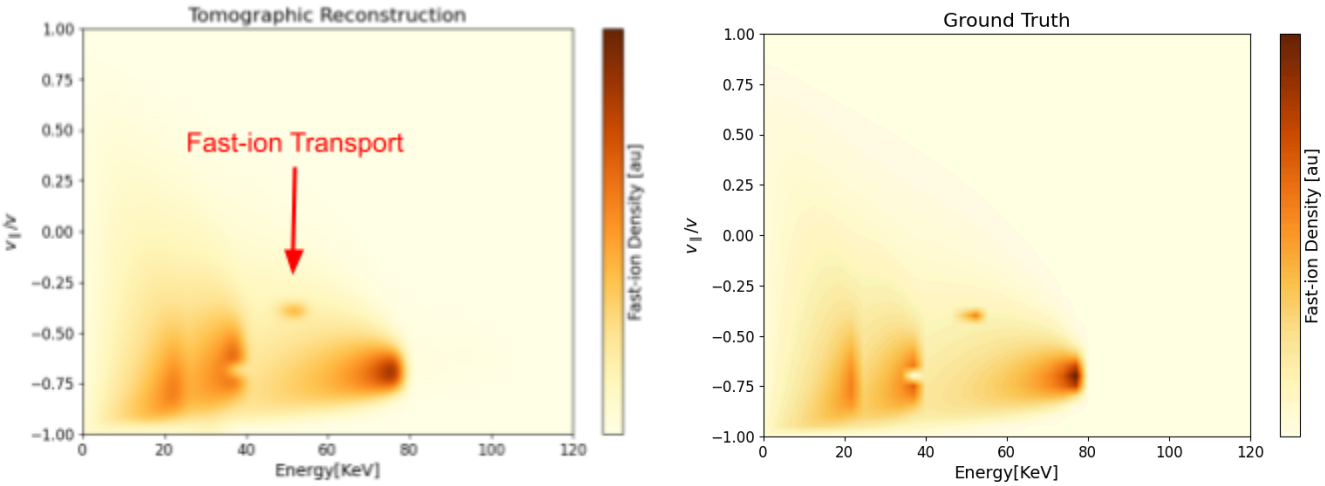

Figure: Tomographic reconstruction of fast-ion distribution with synthetic transport of fast ions from 40keV, -0.7 pitch to 55keV, -0.4 pitch.

[1] B Madsen et al 2020 *Plasma Phys. Control. Fusion* **62** 115019
[2] B.S. Schmidt et al 2023 *Nucl. Fusion* **63** 076016
[3] M. Salewski et al 2013 *Nucl. Fusion* **53** 063019
[4] L Stagner et al 2017 *Physics of Plasmas* **24** 092505

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