first light

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Multiphysics Code Validation and Sensitivity Analysis through Integrated Modelling of Convergent Shock Tube Experiments

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Motivation

- Previous work[†] highlighted treatment of heat flux at material interfaces to be the largest handle on modelling of Derentowicz-Kaliski[‡] conical target fusion performance

- Desire for more validation cases to understand if similar (or more) sensitivities exist in modelling of other experiments

Physics of Plasmas

A preliminary assessment of the sensitivity of uniaxially driven fusion targets to flux-limited thermal conduction modeling

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COLLECTIONS

Paper published as part of the special topic on Transport in Non-Ideal, Multi-Species Plasmas

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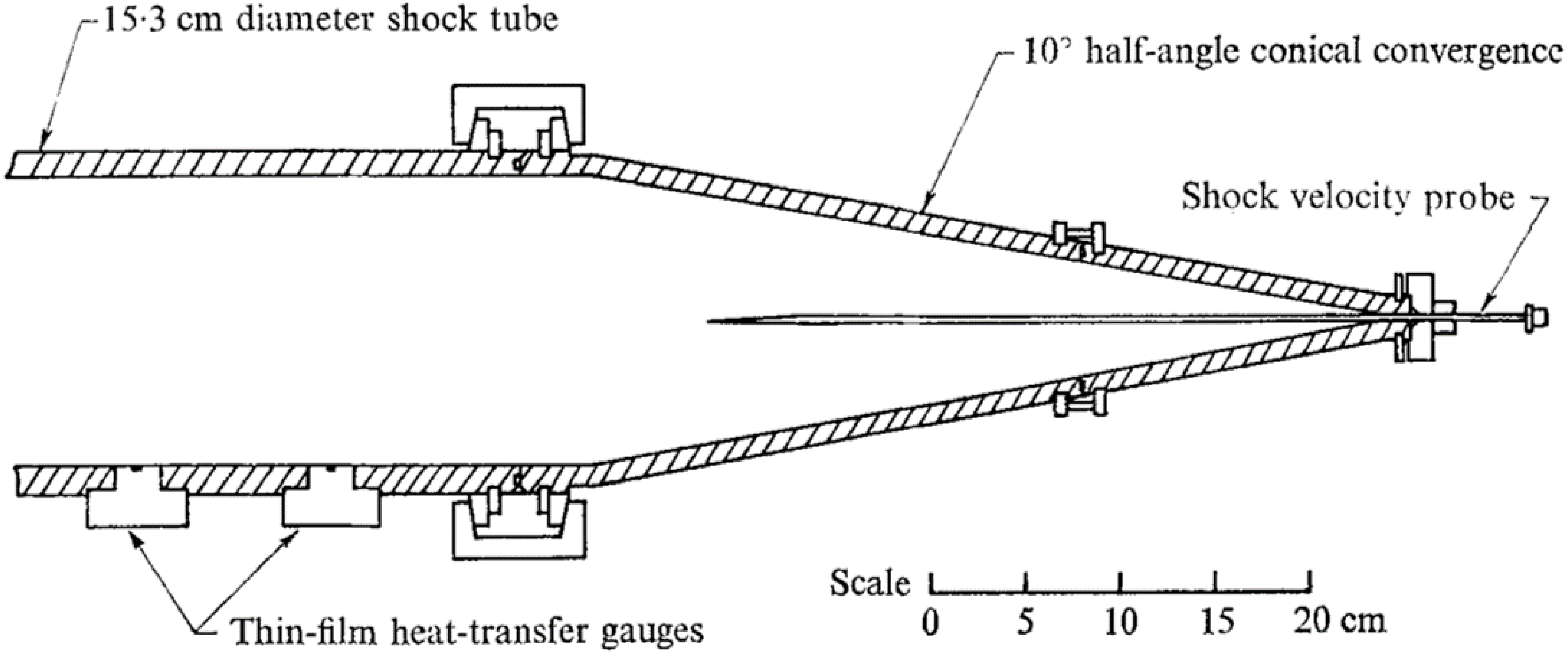
[†] Chapman et al. *Phys. Plasmas* 28, 072702 (2021) and TO07.00002
[‡] Derentowicz et al. *J. Tech. Phys.* 25, 135 (1977)

The experiments of Setchell et al.†

- Low-density argon filled shock tube leading onto conically convergent end section

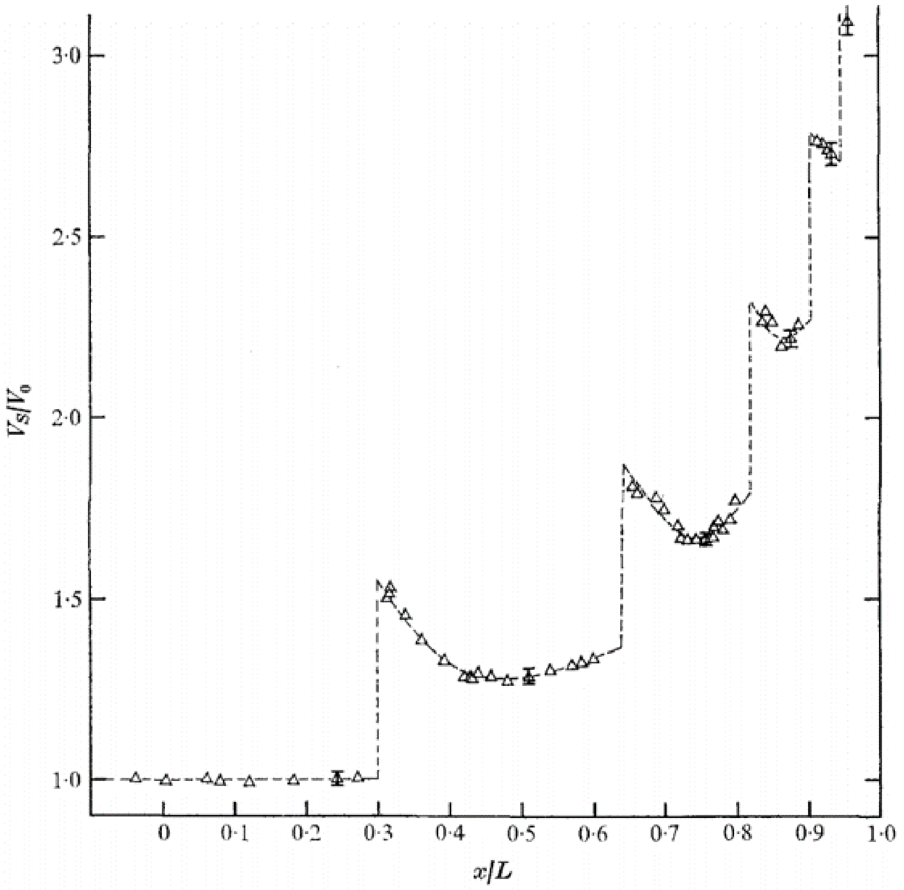


- Initial shock velocities with Mach numbers of 6 and 10.2

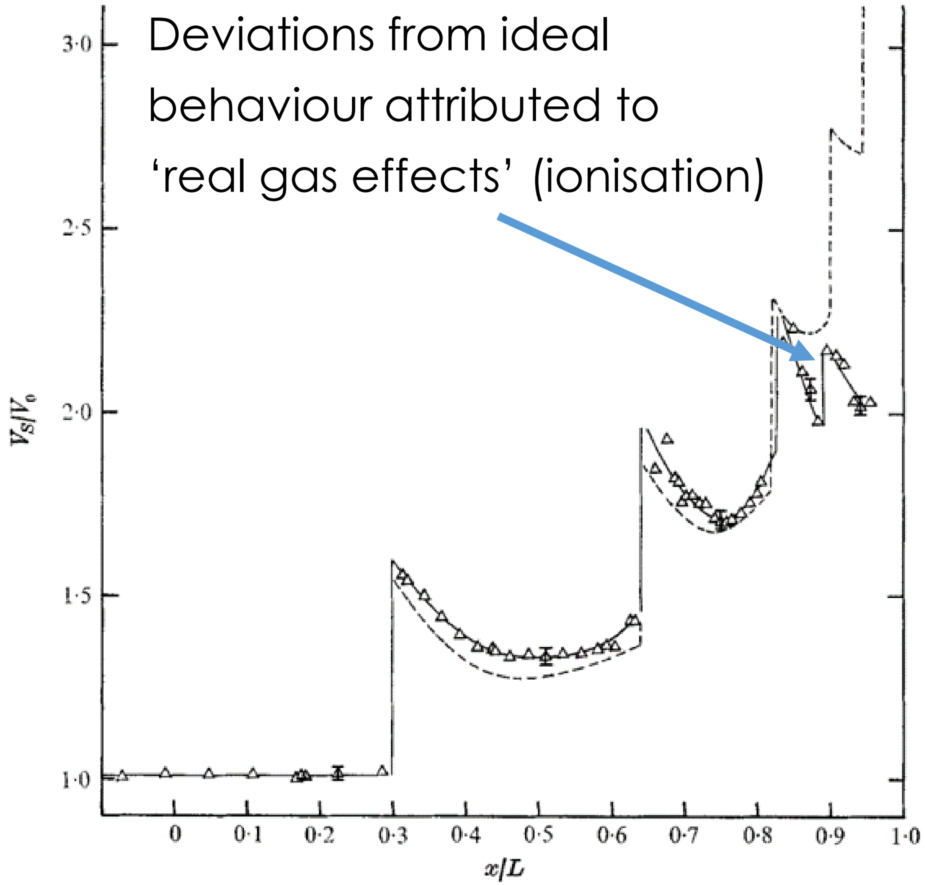
† Setchell et al. *J. Fluid Mech.* 56, 505 (1972)

The experiments of Setchell et al.†

Mach 6



Mach 10



Deviations from ideal behaviour attributed to 'real gas effects' (ionisation)

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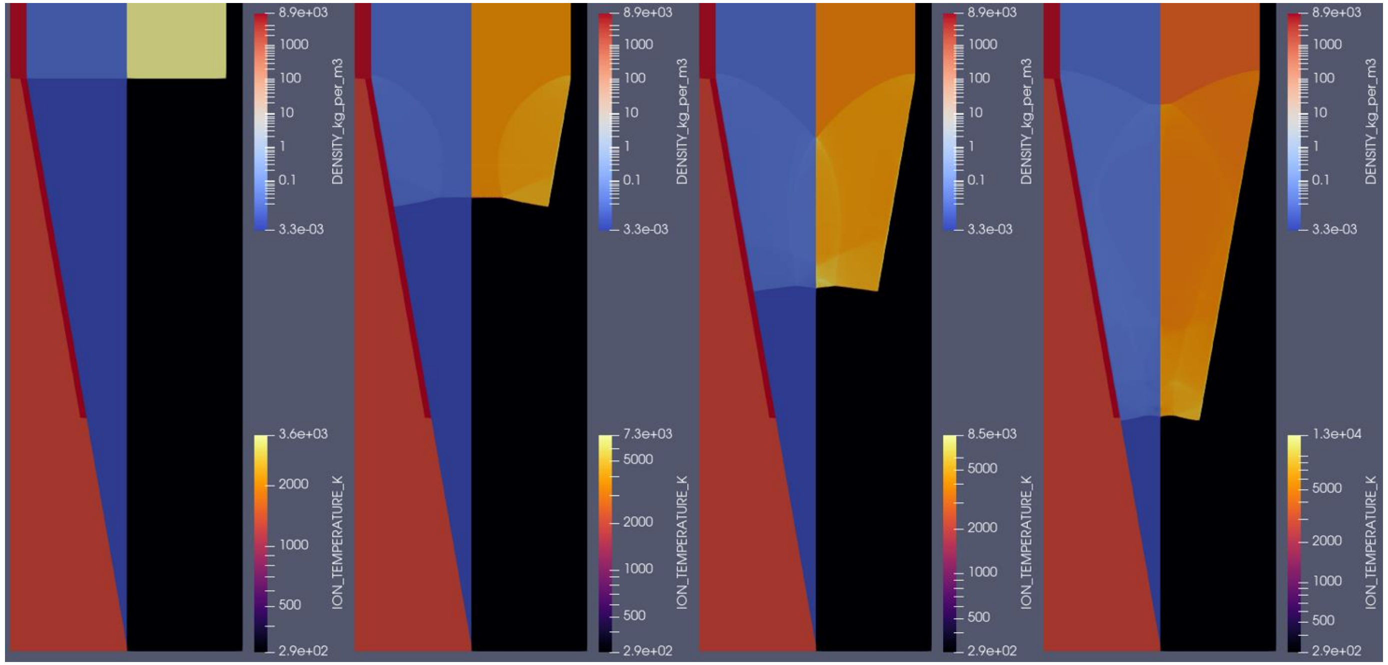
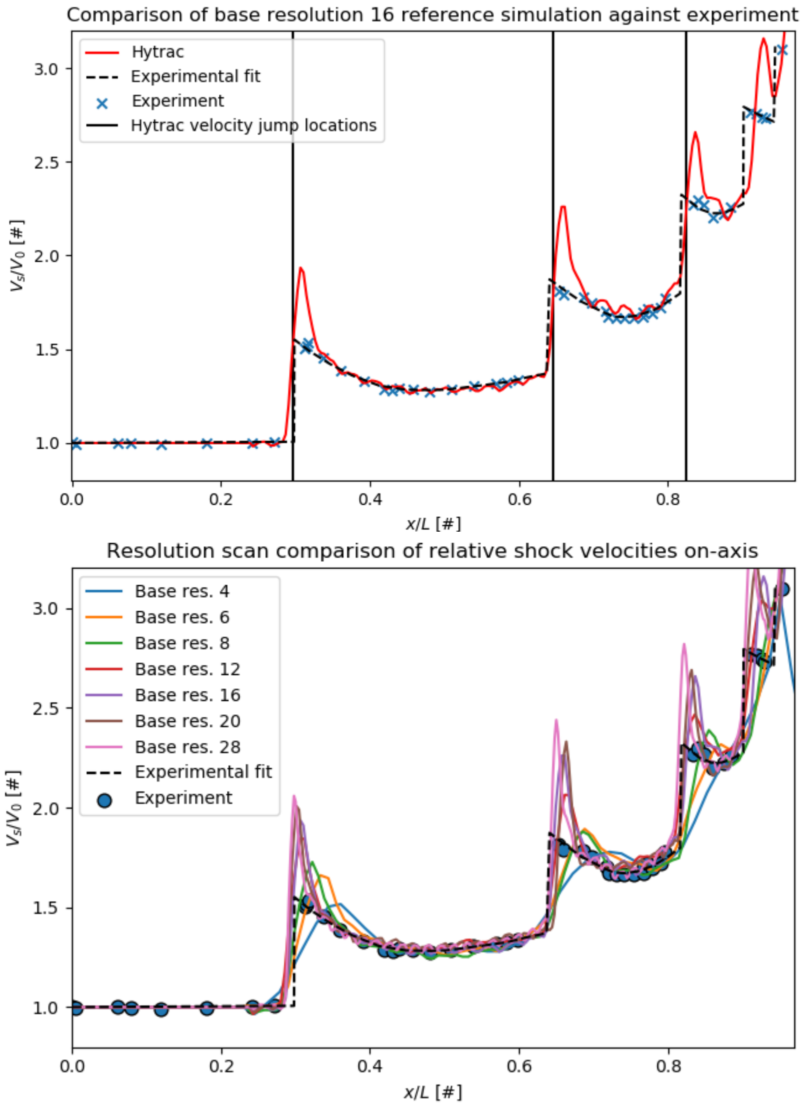
Reference simulation and convergence study

- Reference case chosen to use an ideal gas model for the argon and thermal conduction disabled





Sensitivity study: configuration variables and options

Microphysics model configuration:
- Gas equation of state model

~~Radiation transport~~

Conduction operator configuration:
- Flux model
- e/i flux limiter coefficients
- Cell face averaging methods

Hytrac

Transport property scaling factors:
- Electron thermal conductivity
- Ion thermal conductivity
- e-i energy exchange rate
- Ion dynamic viscosity

~~Numerical methods~~

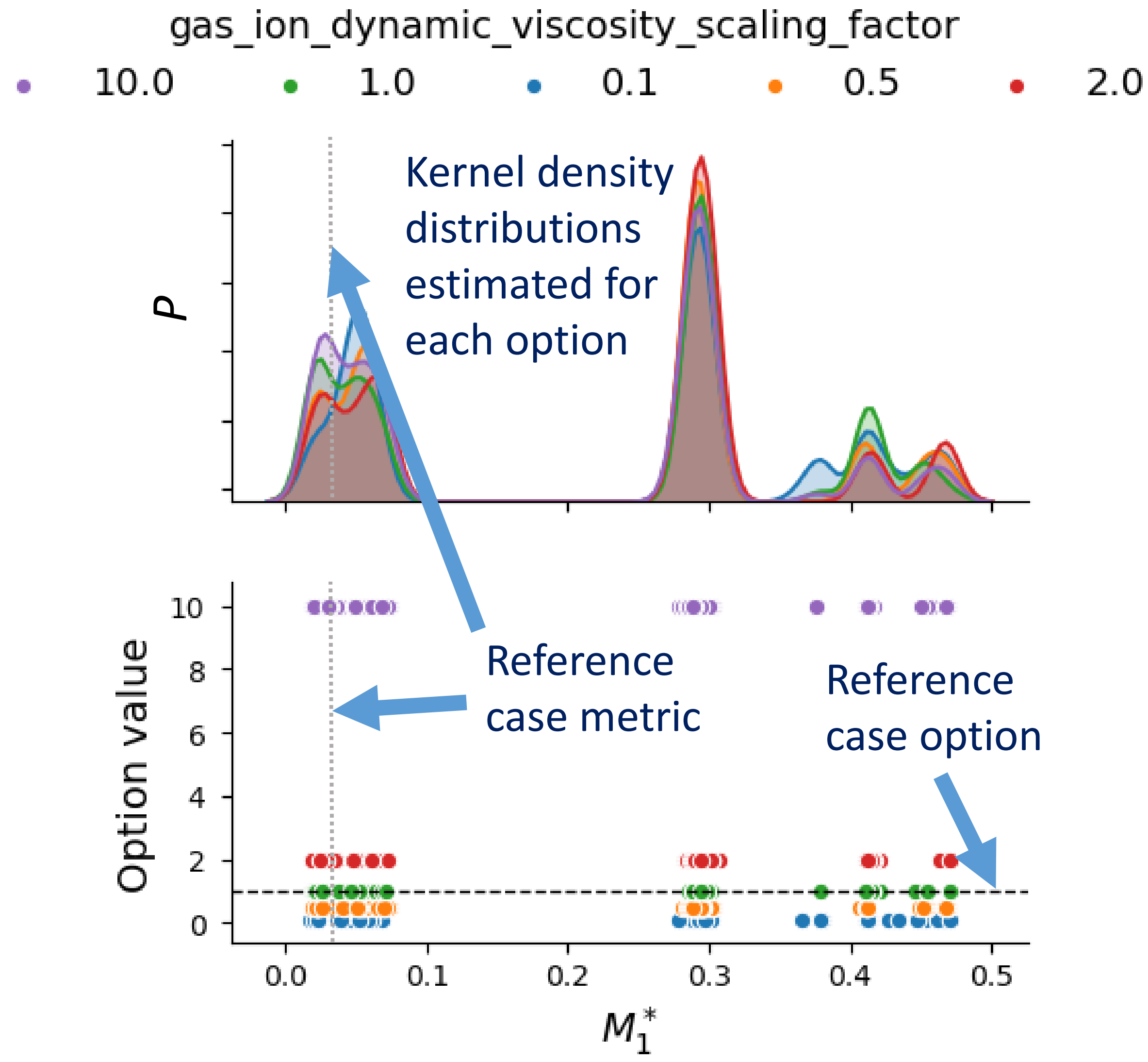
Viscous operator configuration:
- Flux model
- Cell face averaging methods

20 configuration variables → > 2.3 trillion possible configurations

- Coupled nature of physical phenomena supports simultaneous variation of configurations
- Efficient stochastic sampling needed to effectively sample configuration space
- Data science methods (Latin Hypercube Sampling) were employed to do so
- See Dave Chapman's recorded talk for more details (**TO07.00002**)

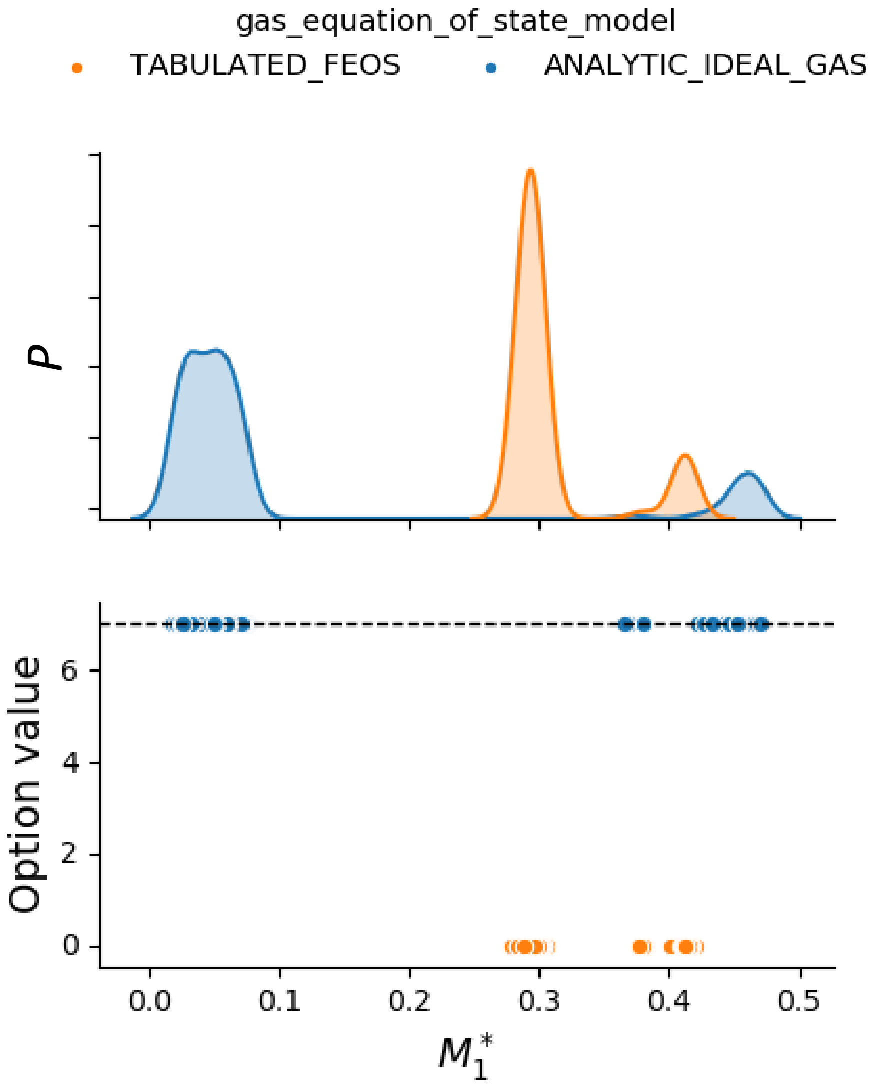
Sensitivity metrics → kernel density distributions for each variable

- Sensitivity metric M_1^* relating to differences between simulations and experimental data
- Some variation seen from option to option
- Distributions split similarly between options implies significant sensitivity to other options



Culprits: gas EoS model and cell face conductivity averaging

- Blatant differences between EoS option distributions
- Likewise for the cell face conductivity averaging method
- Closer looks reveal the errors caused by using tabulated FEOS data for the argon gas and the arithmetic mean for the conductivity averaging



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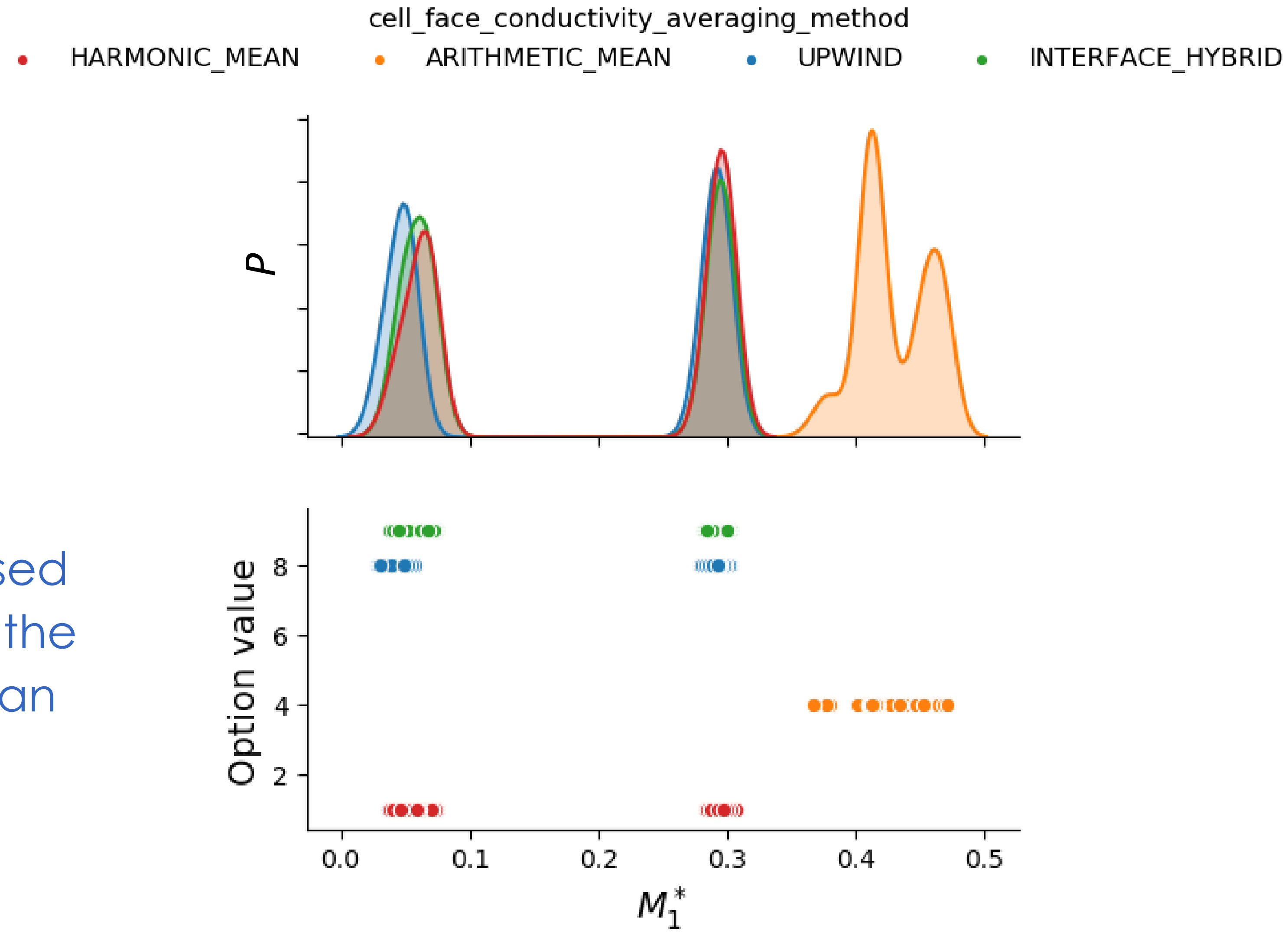

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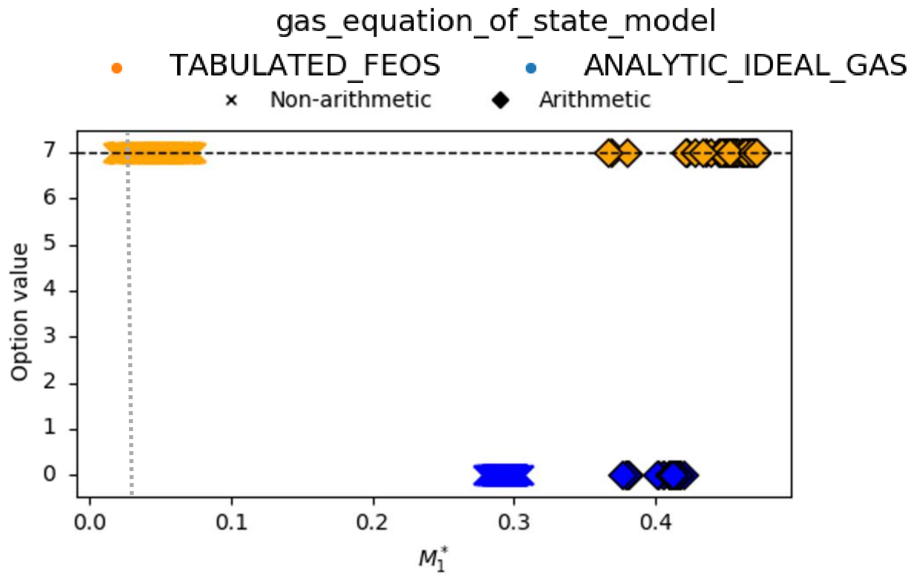

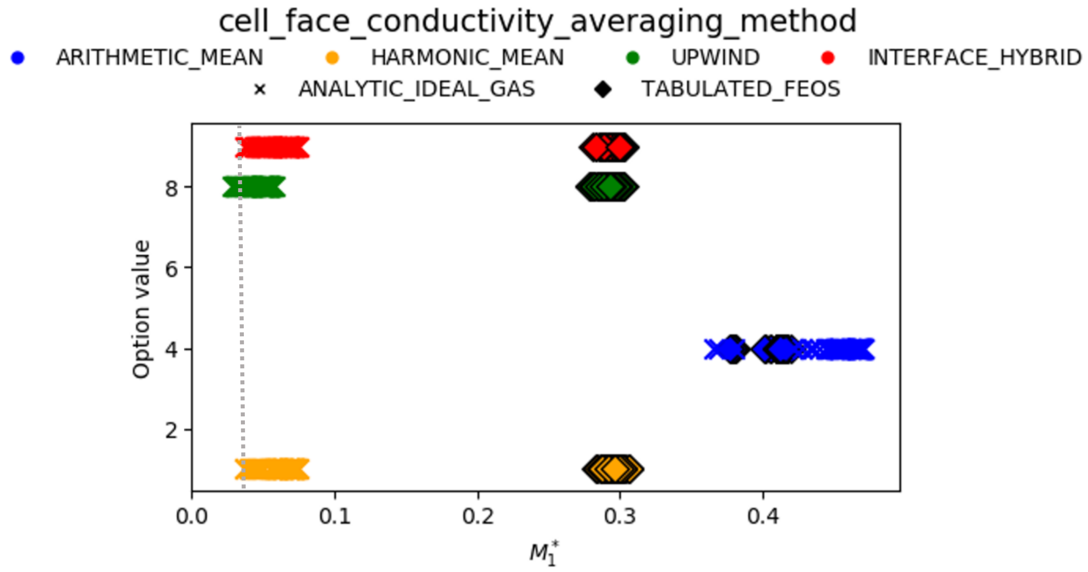

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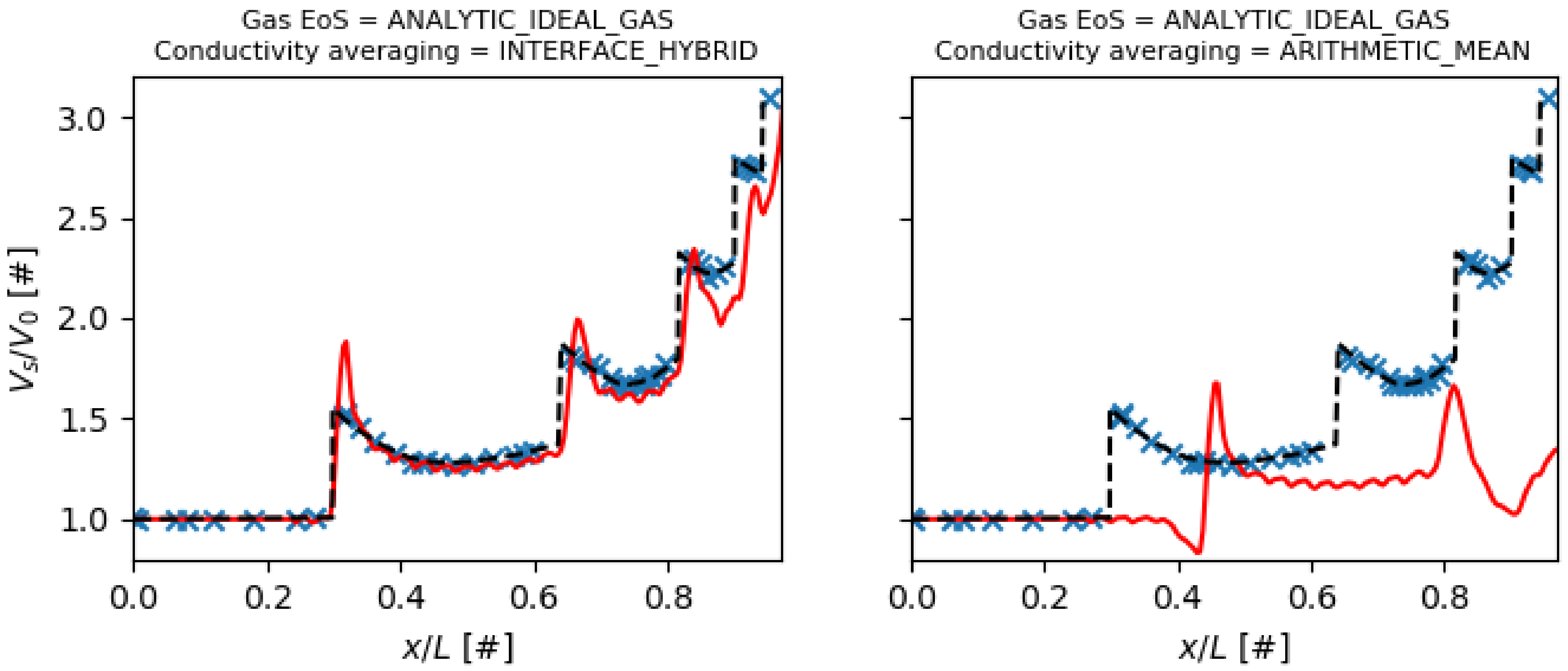
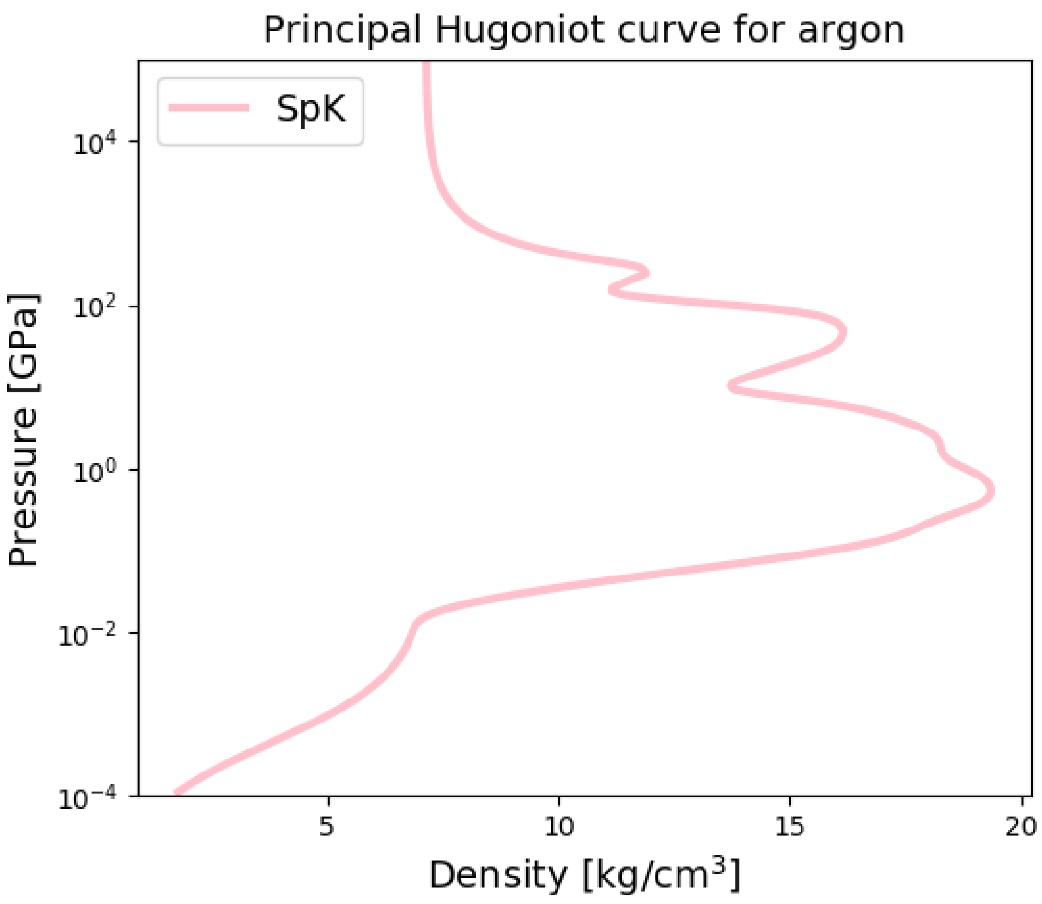


Interface hybrid = arithmetic mean everywhere but at material interfaces (interface hybrid)

→ improved treatment + understanding of transport across interfaces is required

Ongoing work

- Consultation with Grisha Kagan (Imperial College) to develop more accurate interfacial transport models
- Improved Saha-based EoS capabilities using SpK
- Preliminary simulations promising



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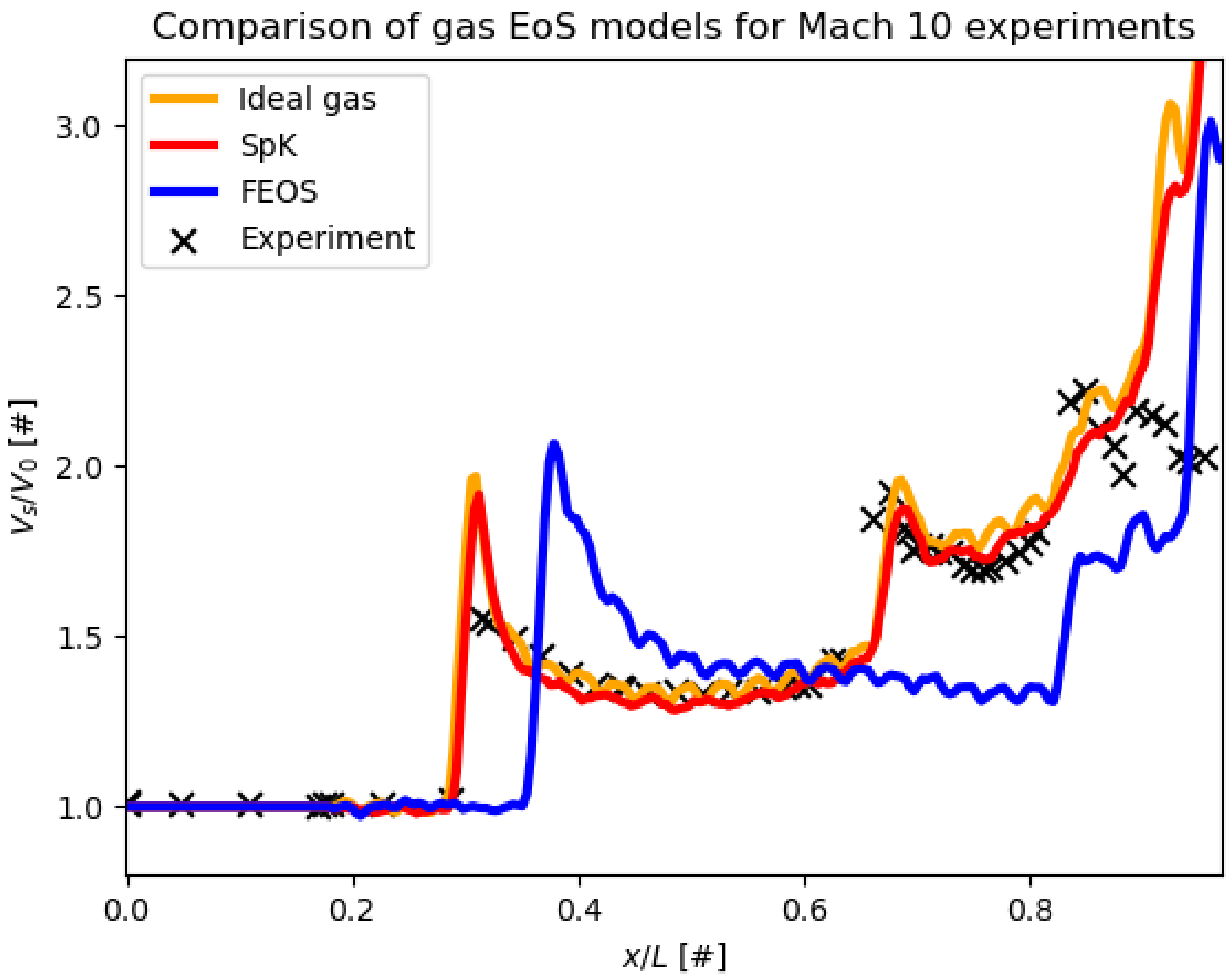
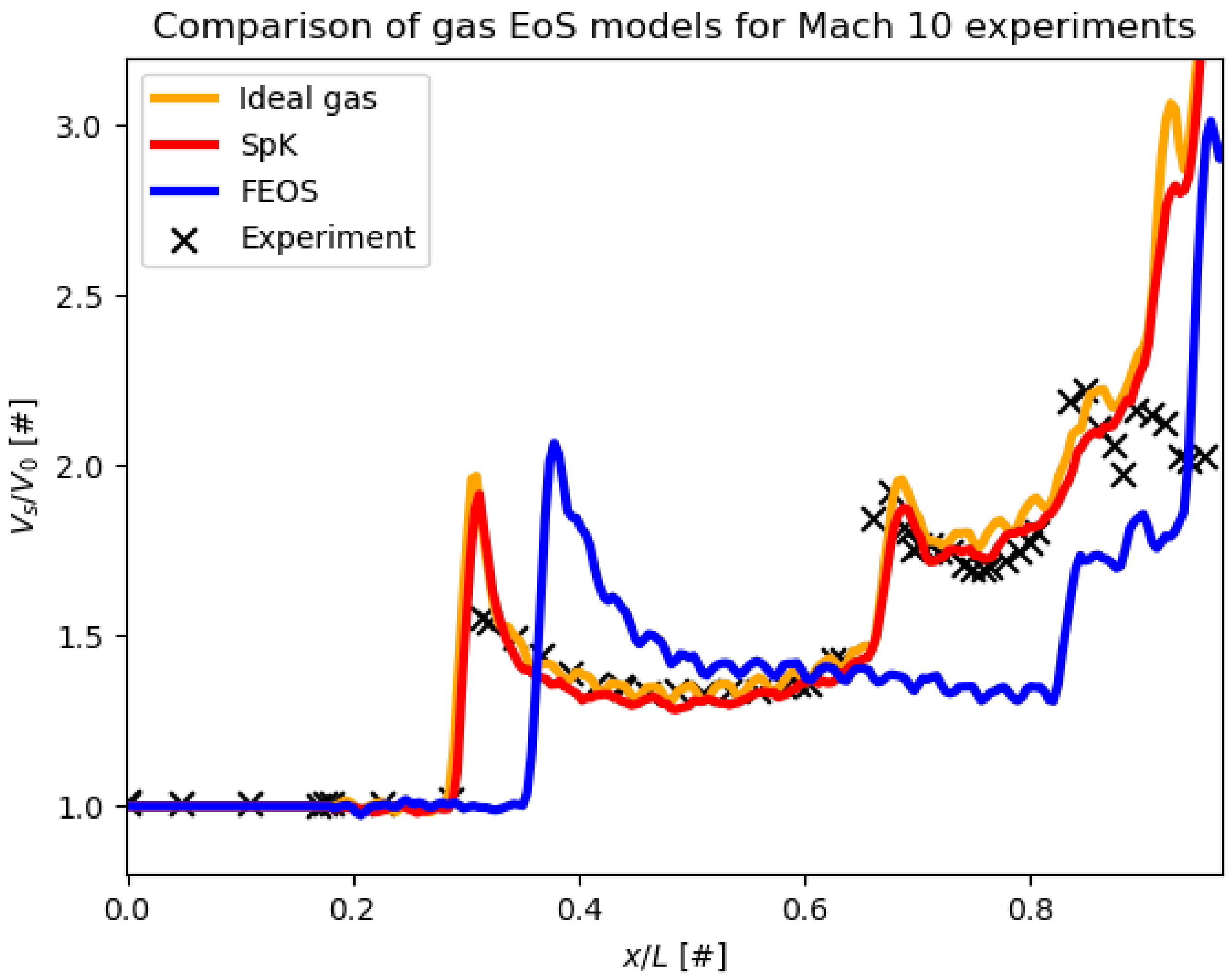


Summary

- Sensitivity study performed on physics model configurations for the experiments of Setchell et al.
- Overwhelming sensitivity found to gas EoS model and modelling of thermal conduction across material interfaces
- Ongoing parallel projects to improve modelling capabilities on these fronts



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Thank you for your attention
Please get in touch

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