

Reinhard Seiser¹ (rseiser@nrel.gov), Anne Starace¹, Gui Zheng¹, Ryan Ness¹, Mario Alejandro Sánchez², Brennan Pecha¹, Meagan Crowley¹, Peter Ciesielski¹

¹National Renewable Energy Laboratory, Golden, CO ²Universidad EIA, Envigado, Colombia

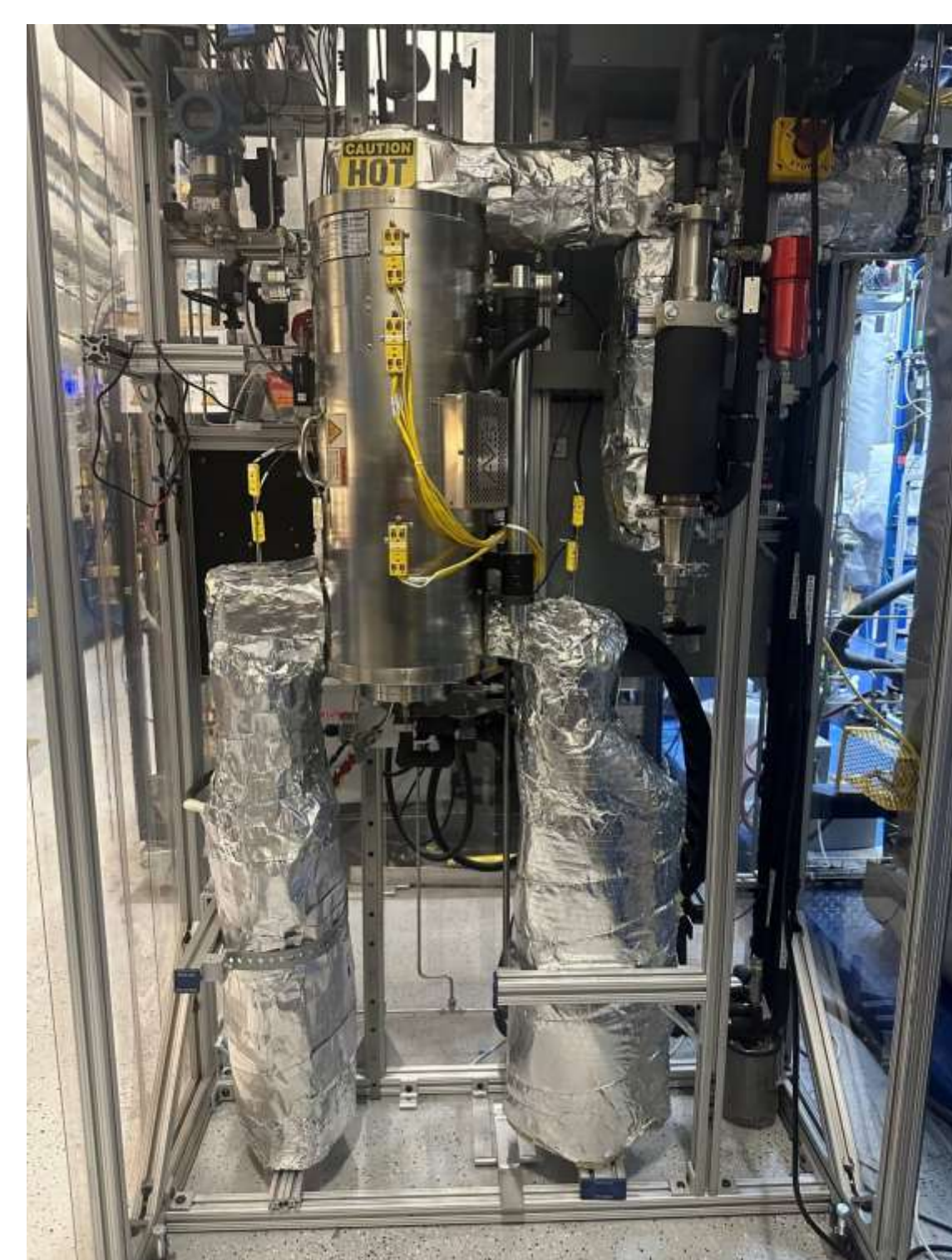
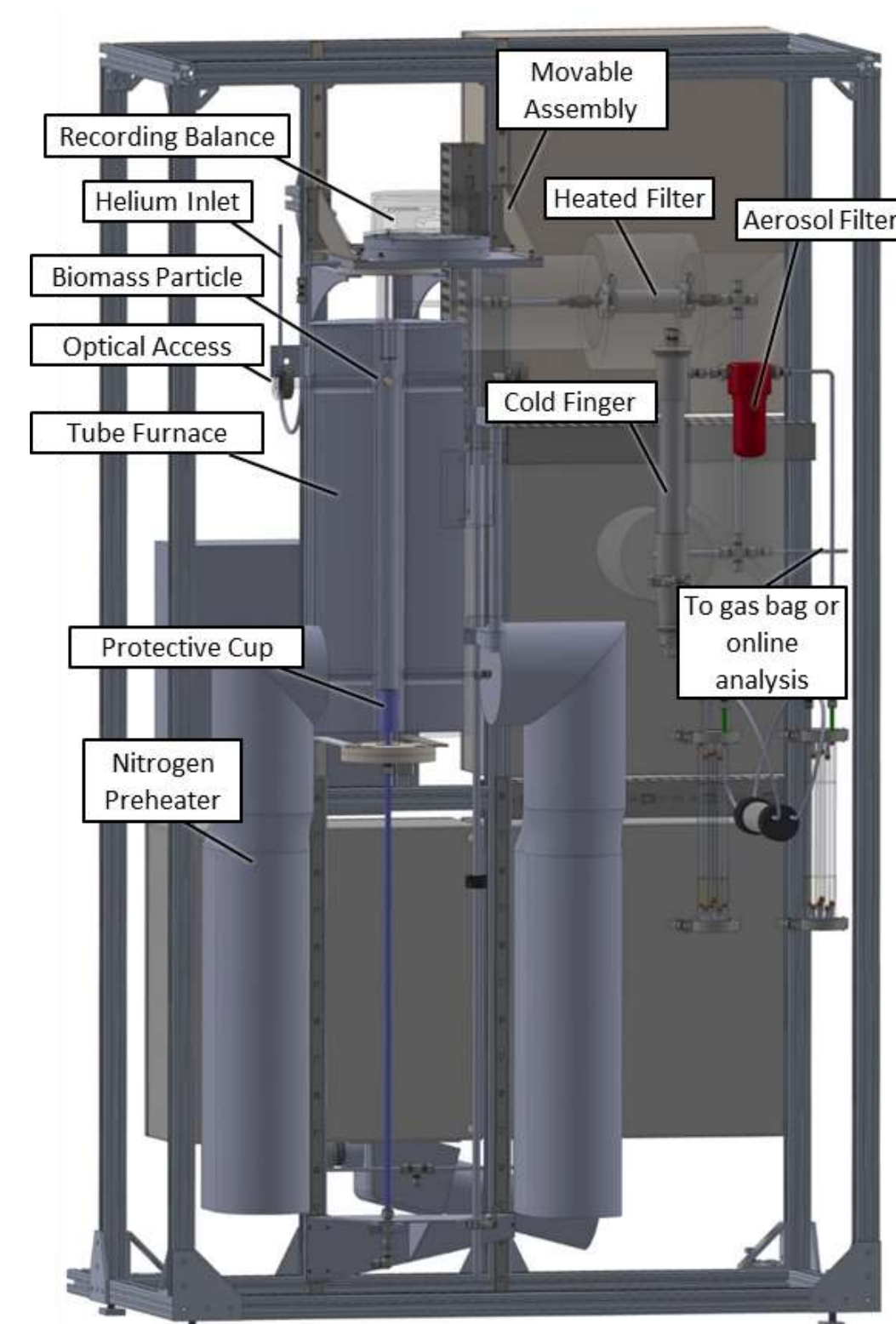
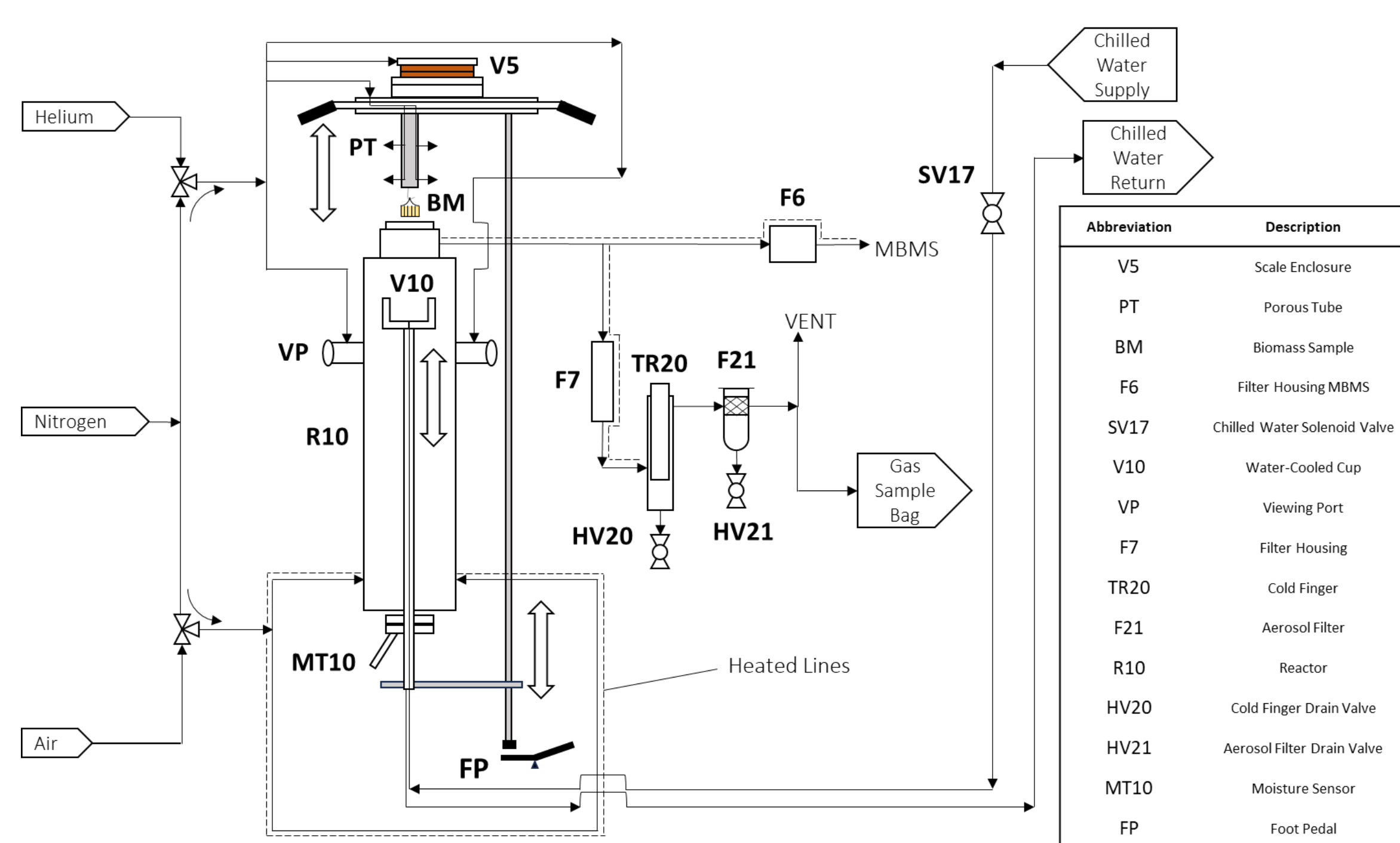
Background

- Knowledge of detailed feedstock properties is desired for fundamental understanding and modeling of pyrolysis processes.
- A single particle reactor (SPR) was designed and built to investigate the pyrolysis process on biomass and MSW feedstock particles and pellets.
- The SPR allows for experimental validation of single particle pyrolysis model which will inform industry on effects of particle size, shape, density, and composition on the reaction kinetics.

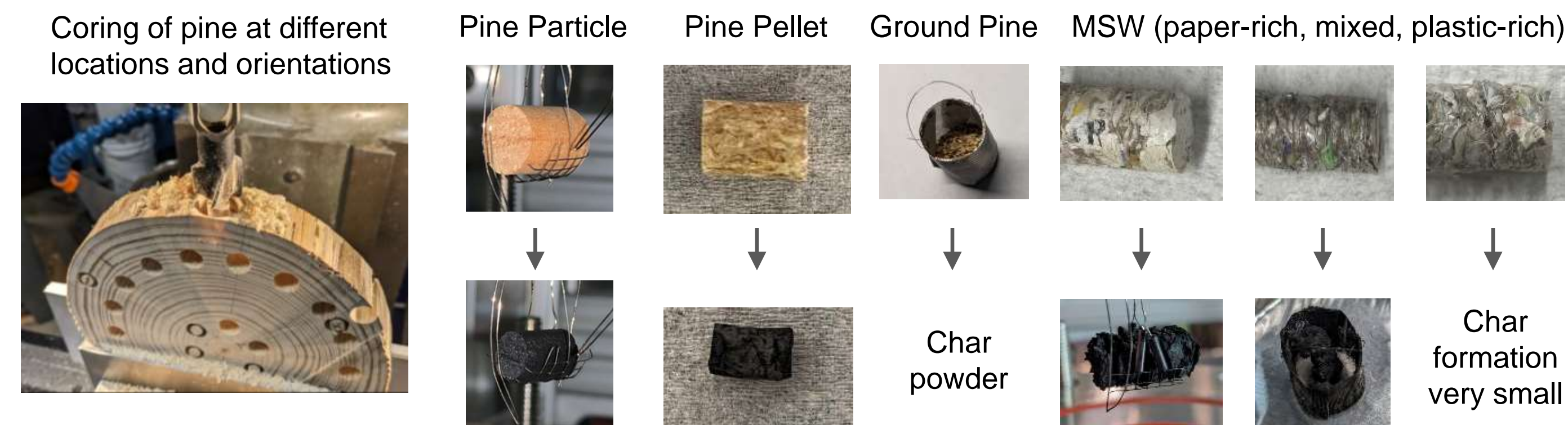
SPR Features

- Pyrolyzing single particles with mass up to 2g and size up to 12mm.
- Loss-of-weight recording over time as in a Thermogravimetric Analyzer (TGA) [1,2].
- External heating rates of 50°C/s by fast exposure to convection and radiation via removal of water-cooled cup. Exposed to nitrogen flow rate of ~1 m/s.
- Temperature range 500-700°C, measured by free-stream thermocouple.
- Possibility of internal temperature measurement with embedded thermocouple.
- Available side ports for optical observation of pyrolysis process.
- Analysis of product gas composition.

SPR Diagram / Pictures

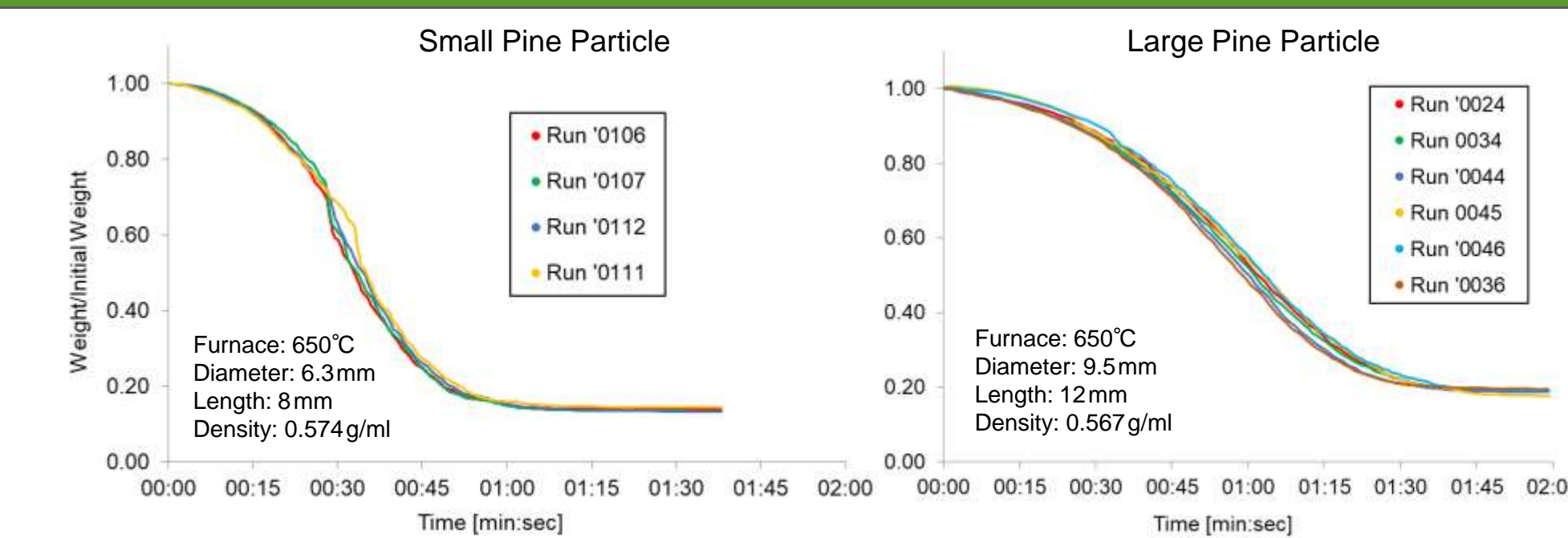


Feedstocks

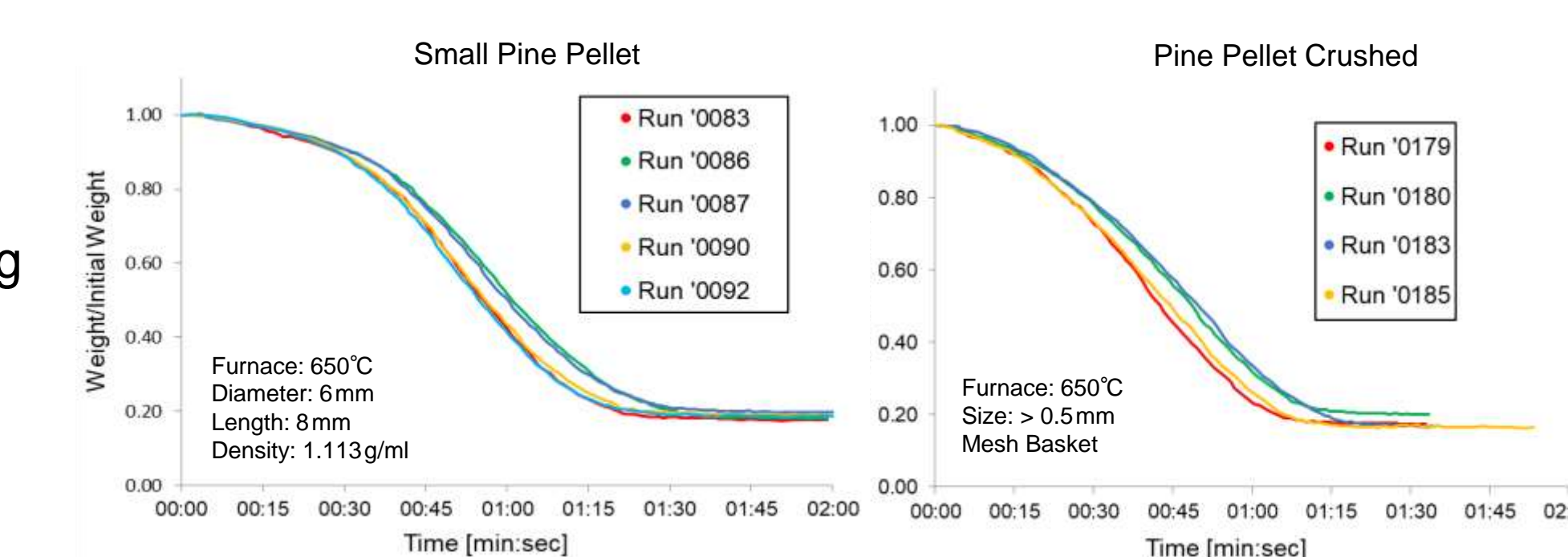


Results

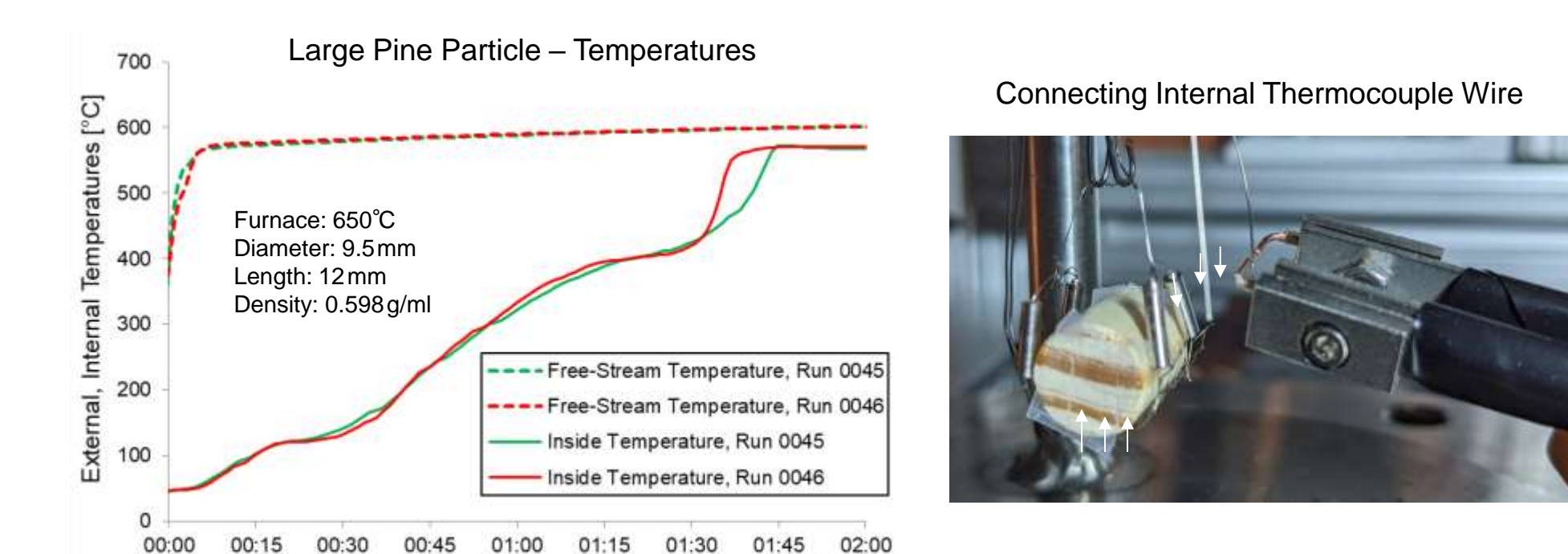
- Comparison of particle size – smaller particle decrease pyrolysis time. Experiments show good repeatability of multiple runs.



- Pelletized particles show longer pyrolysis times.

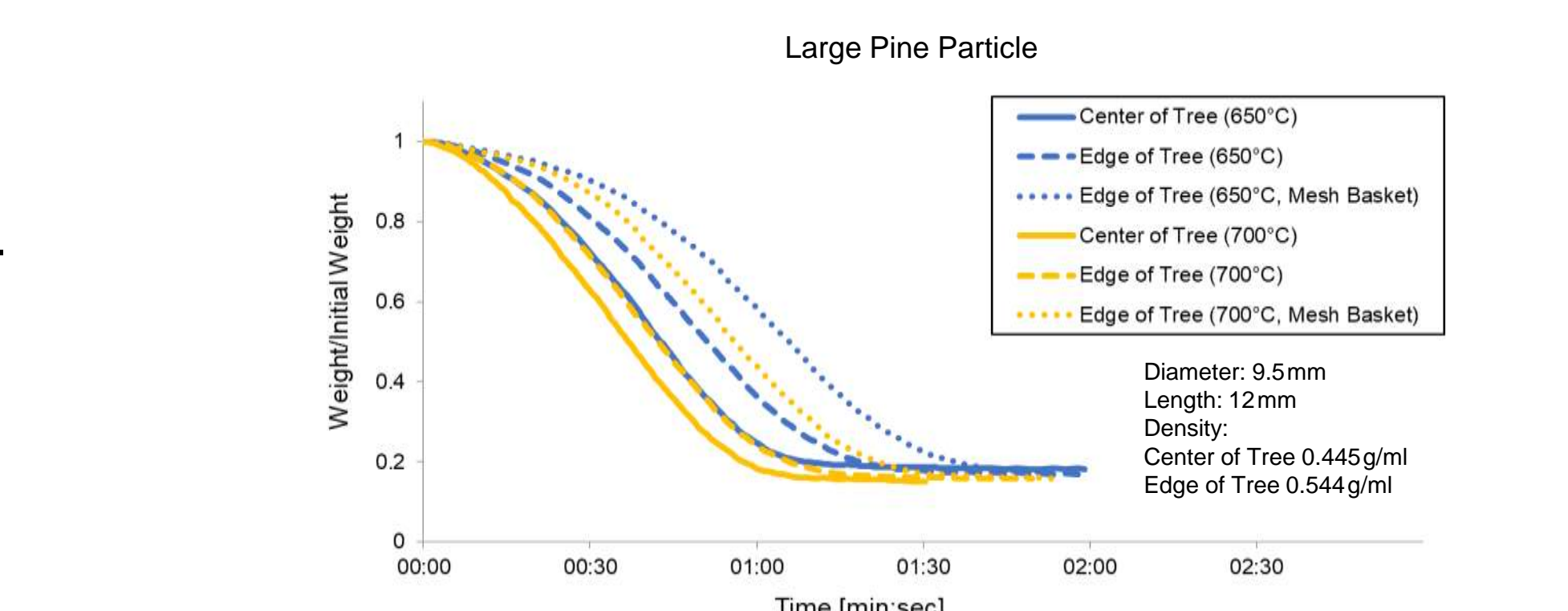


- Ground feeds or crushed pellets have higher heating rates, but use of mesh basket reduces initial heating rate.

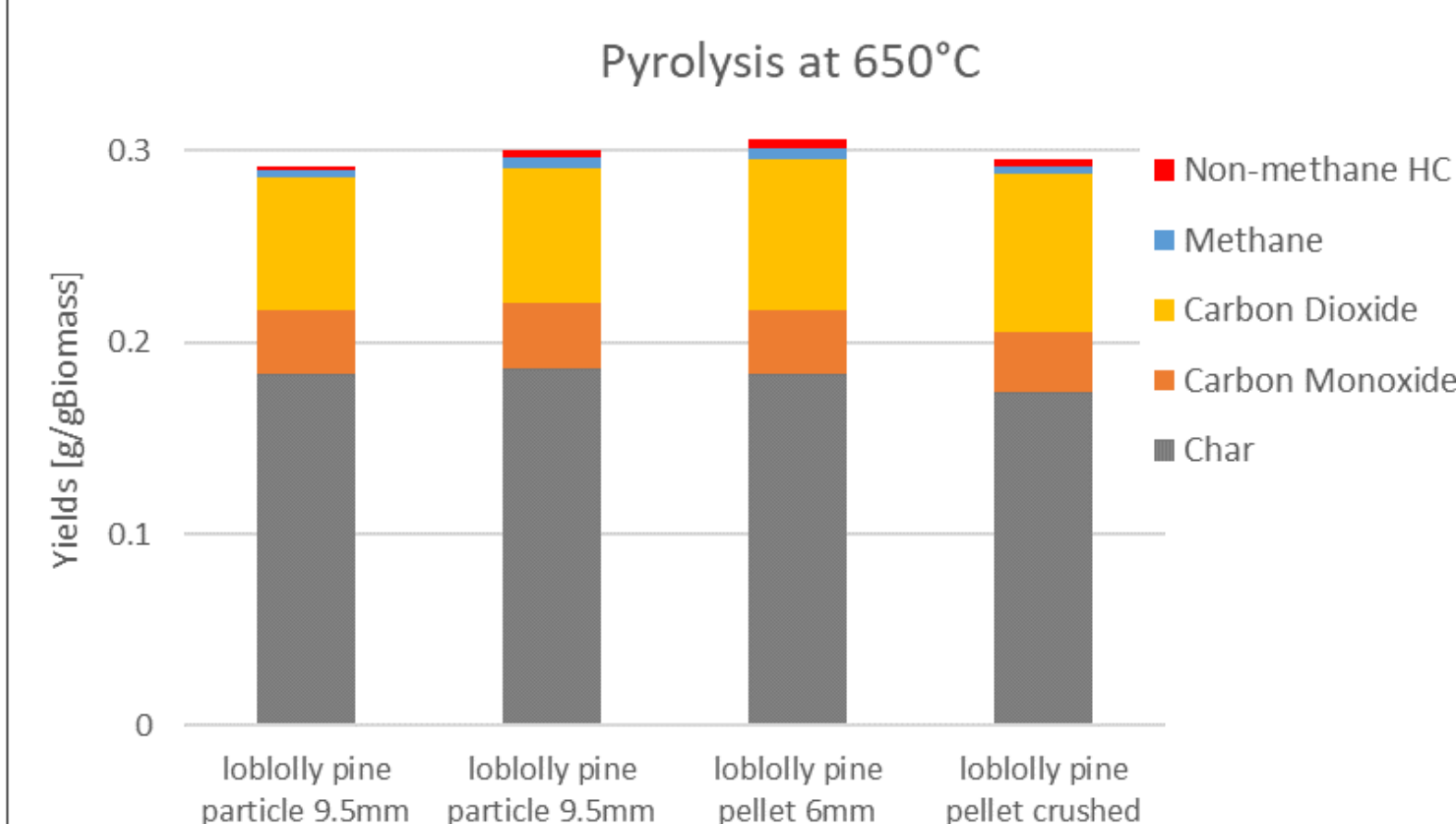


- Temperature Measurement in center of particle (0.001" thermo-couple wire) shows significantly lower values than outside temperature during the pyrolysis process.

- Lower density feeds (center of tree) show shorter pyrolysis time. Experiments using mesh basket (90 mesh) show profile shifted later in time.



- Gas composition and yields were similar between different pine experiments.

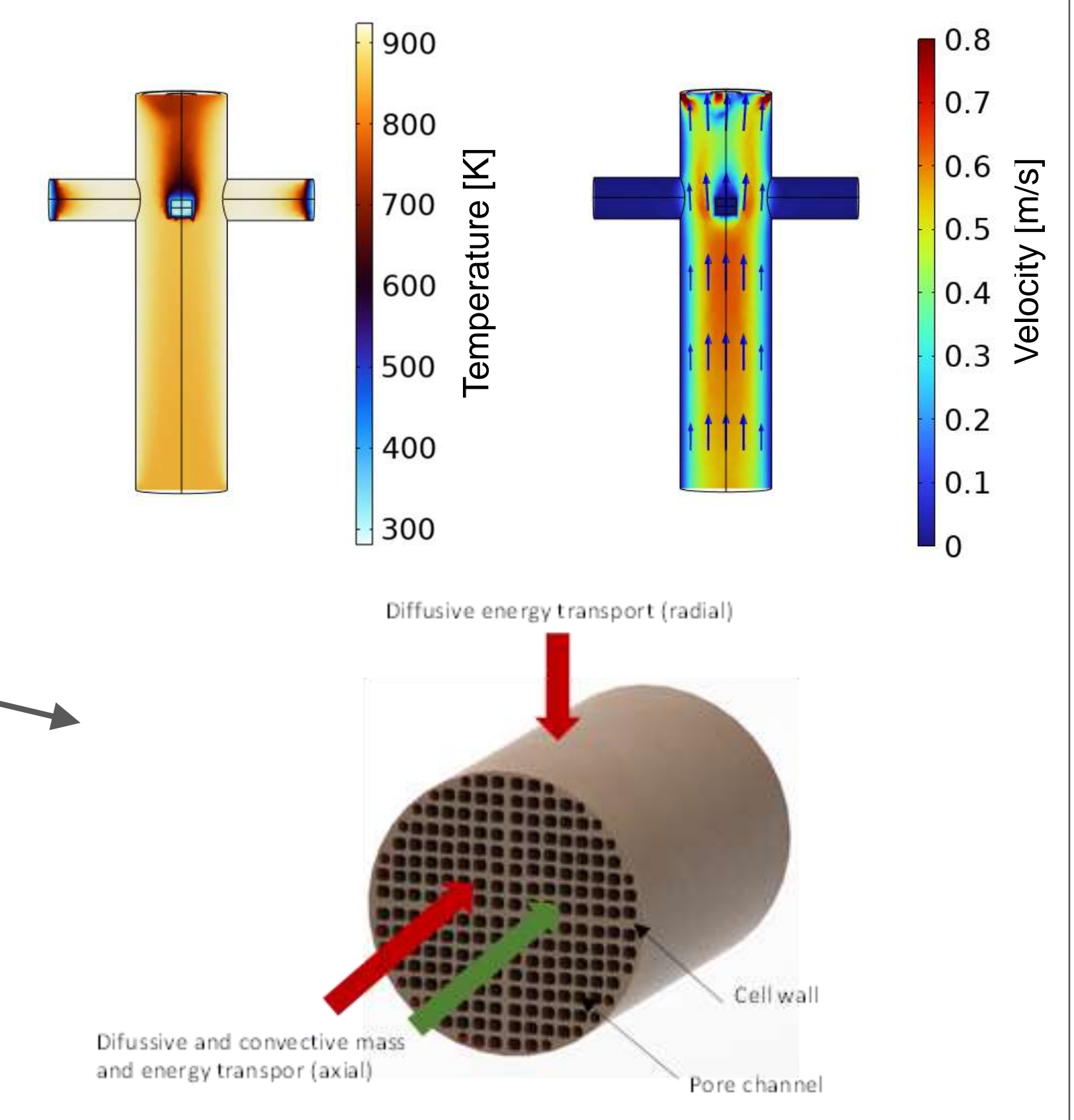


- Optical observation shows occasional cracking of particles during pyrolysis (perpendicular to tree rings).



Modeling

- Reactor models directly matched to the SPR configuration and operating conditions were developed in COMSOL Multiphysics.
- A particle model to predict the conversion of the biomass particle and the main products yields was developed. The model considers a shrinking anisotropic cylindrical particle containing biomass pseudo-components, with the formation of liquid intermediates, intra-particle mass and heat transport, and secondary volatile reactions.
- COMSOL Multiphysics simulations were conducted using physical particle attributes including dimension, porosity, and permeability to investigate the impact of the change in transport properties of milled and pelletized pine particles [3].



Conclusions

- In both model and experiment, the rate of conversion to char during pyrolysis was slowed for the pelletized pine particles due to the decreased porosity and permeability, limiting heat and mass transfer and impeding the pyrolysis conversion process. The results emphasize the impact of intraparticle heat and mass transport on biomass conversion.
- Experiments consistently showed faster pyrolysis for lower density particles, such as the type of wood or center of the tree.
- Experiments on ground feedstocks or plastic-containing feeds had to be conducted on a bed of quartz wool inside a wire-mesh basket. The basket slowed down the initial heatup, but the time for the proceeding pyrolysis process was similar to the tests with the wire basket.

Future Work

- Coupling of heated vapor outlet to Molecular Beam Mass Spectrometer (MBMS).
- Increase of reactor temperature to 800C and allowing for steam/oxygen atmospheres for gasification experiments.
- Including in-situ catalysts with milled feedstocks inside mesh basket for catalytic fast pyrolysis.

References / Acknowledgments

References

- [1] P. Sommersacher et al., "Simultaneous Online Determination of S, Cl, K, Na, Zn, and Pb Release from a Single Particle during Biomass Combustion," Energy & Fuels, 2015, 29.
- [2] K. Cong et al., "The investigation of co-combustion characteristics of tobacco stalk and low rank coal using a macro-TGA," Fuel, 2019, 237.
- [3] M. Crowley et al., "Impacts of biomass feedstock pre-processing on heat and mass transfer during pyrolysis using X-ray computed tomography and multiscale modeling," poster presentation TCBiomass 2024.

Acknowledgments

- The authors would like to acknowledge Oluwafemi Oyediji for leading the high-temperature conversion task as part of FCIC.
- Special thanks also go to Callanen Swaty, Albert Chang, Zachary Manfredi, and Dylan Barton for their help in designing, building, and operating the SPR.