ProtoDUNE-SP CFD Update

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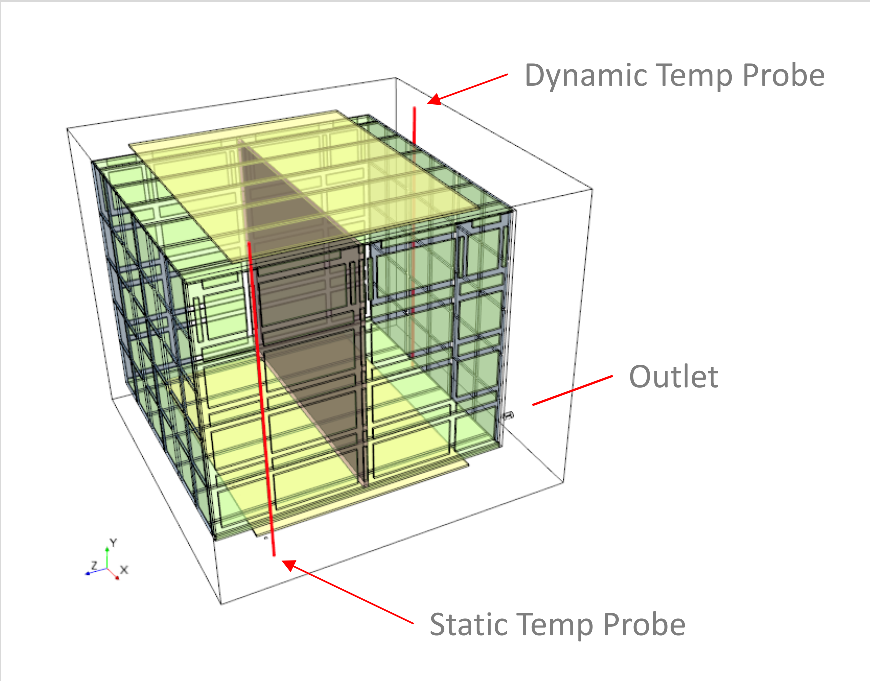
April 2, 2020

ProtoDUNE Modeling

Overview of Current Work: "Fine tuning" existing CFD model input parameters to better represent actual detector operation

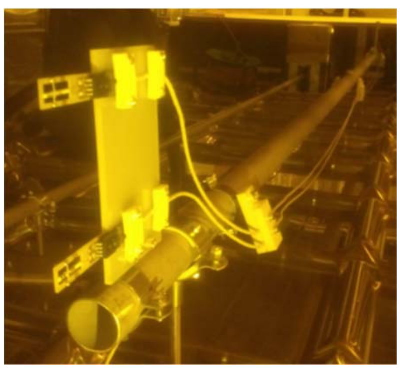
<u>Model Inputs</u>

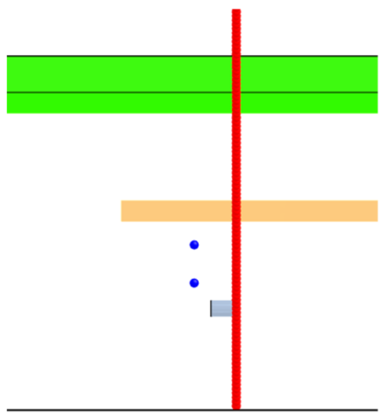
Surface temperature:	87.593 K
Liquid argon inlet temp:	87.793 K = Surface + 0.2 K
Liquid argon height:	7.50 m
Liquid argon flow rate:	0.415 kg/s per pipe

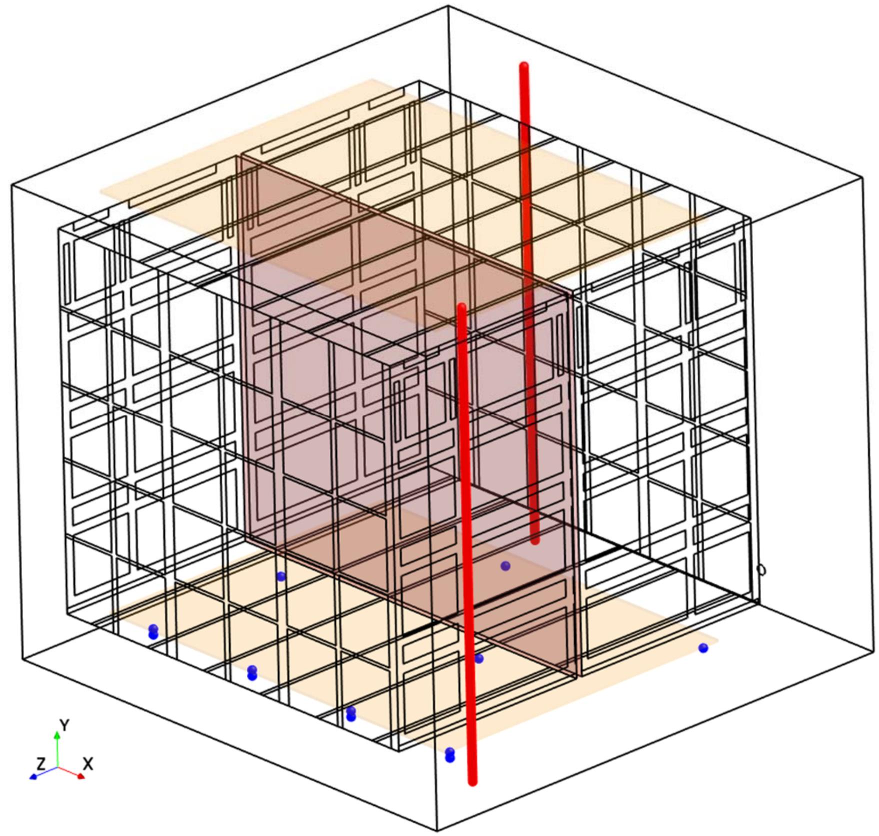


ProtoDUNE Model Updates

- Update model inputs to match new experimental operating conditions
  - Shorter **LAr height** (7.5m -> 7.401m)
  - Include **pipe probe** temperature sensors (Qty 8, height = 39cm, Qty 4, height = 30cm)

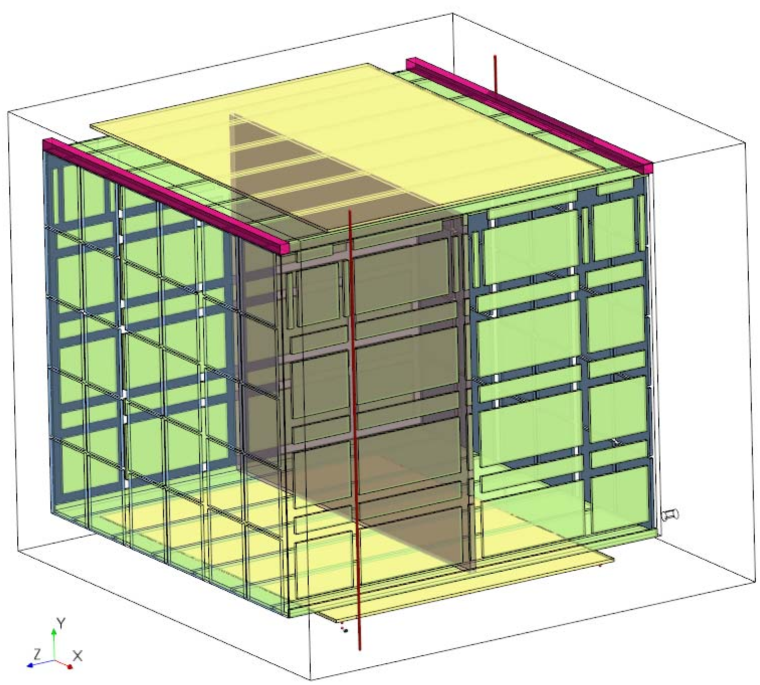






ProtoDUNE Model Updates

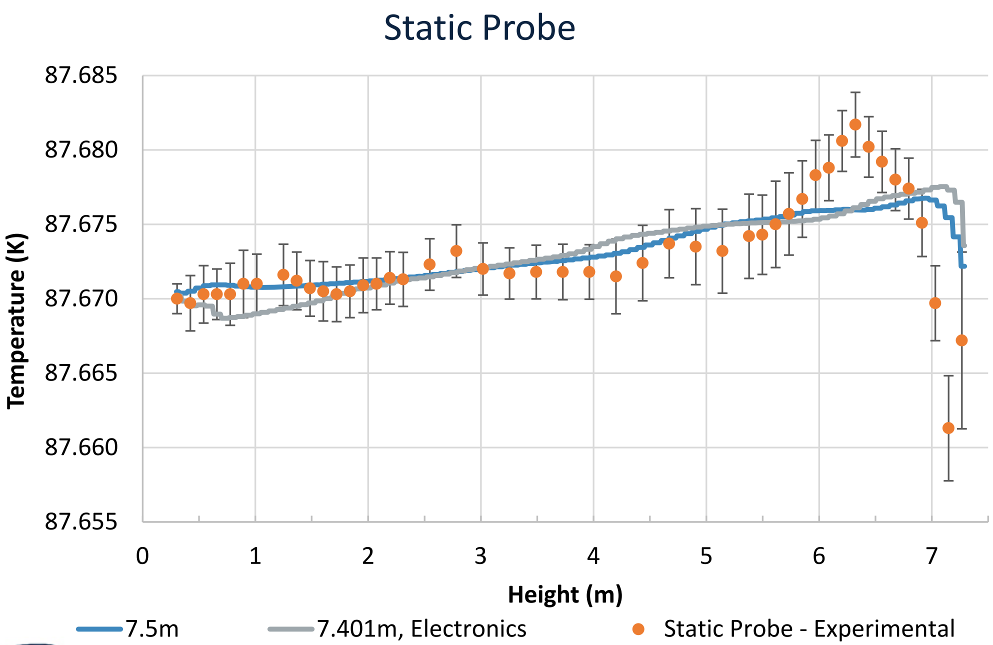
- Update model with new features
  - Electronics Heat Source- 2 regions along +y APA
  - 366W on each
- Investigate other sources of discrepancy
  - Other heat sources
  - Iteration-to-iteration

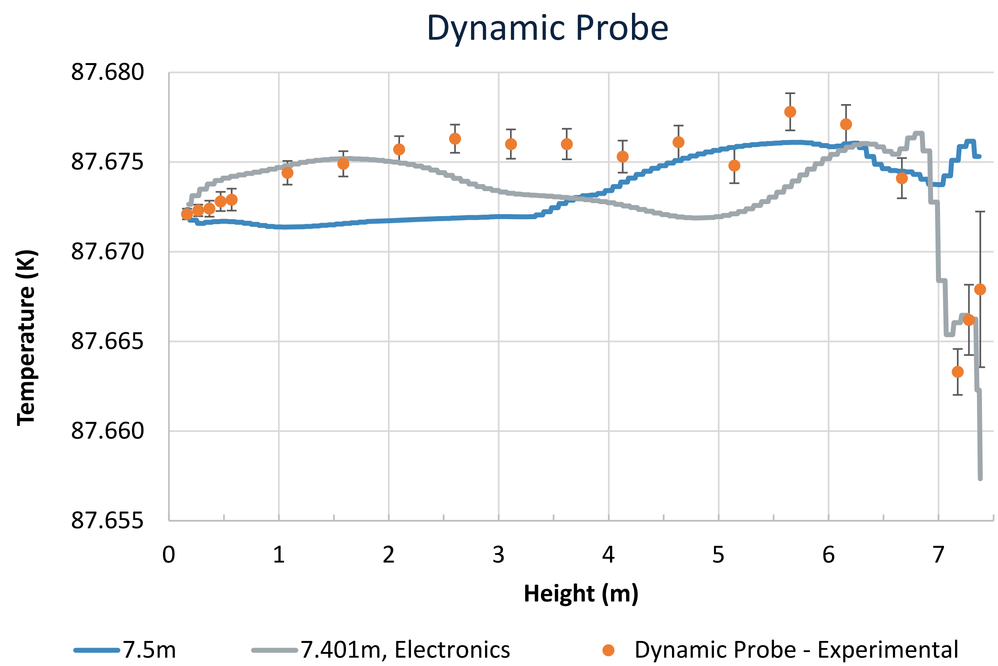


Updated Model Temperature Results

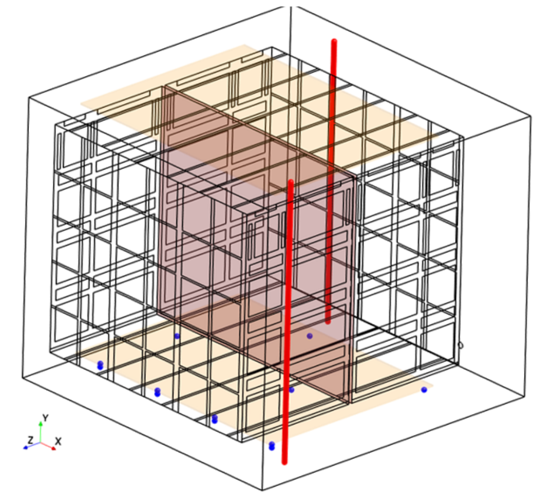
LAr Height (m)	Electronics
7.5	No
7.401	Yes

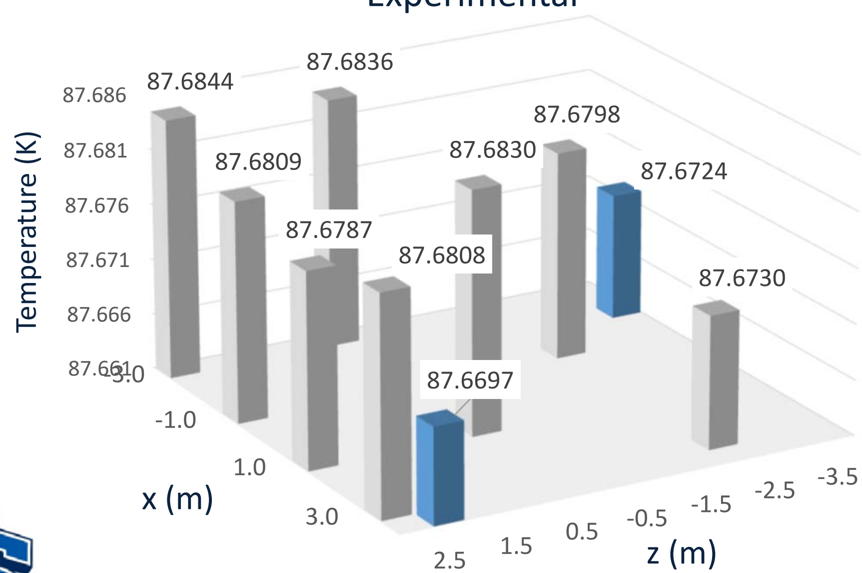
Pumps On Condition

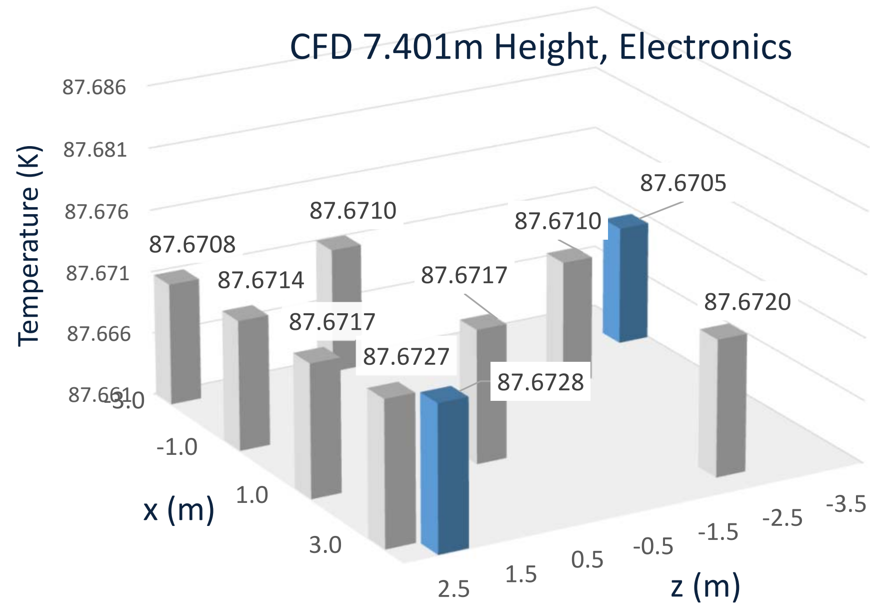




Pipe Probe Results

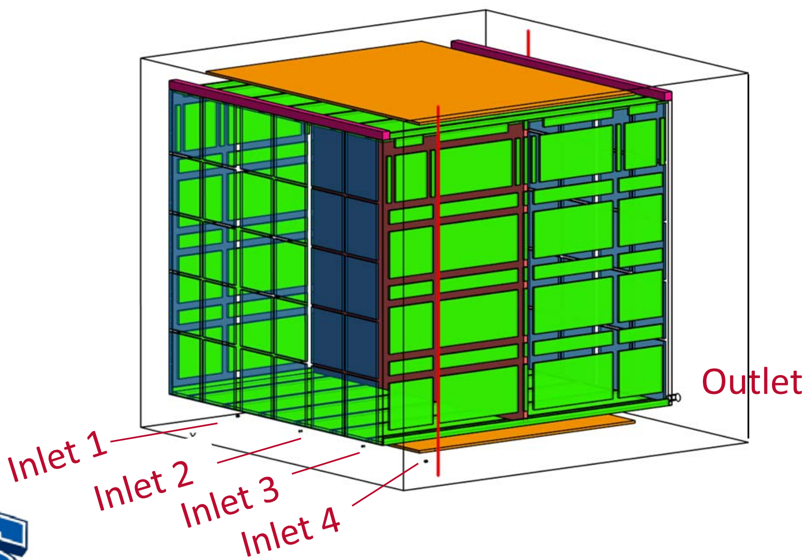






Distributed Inlet Temperature & Flow Rate

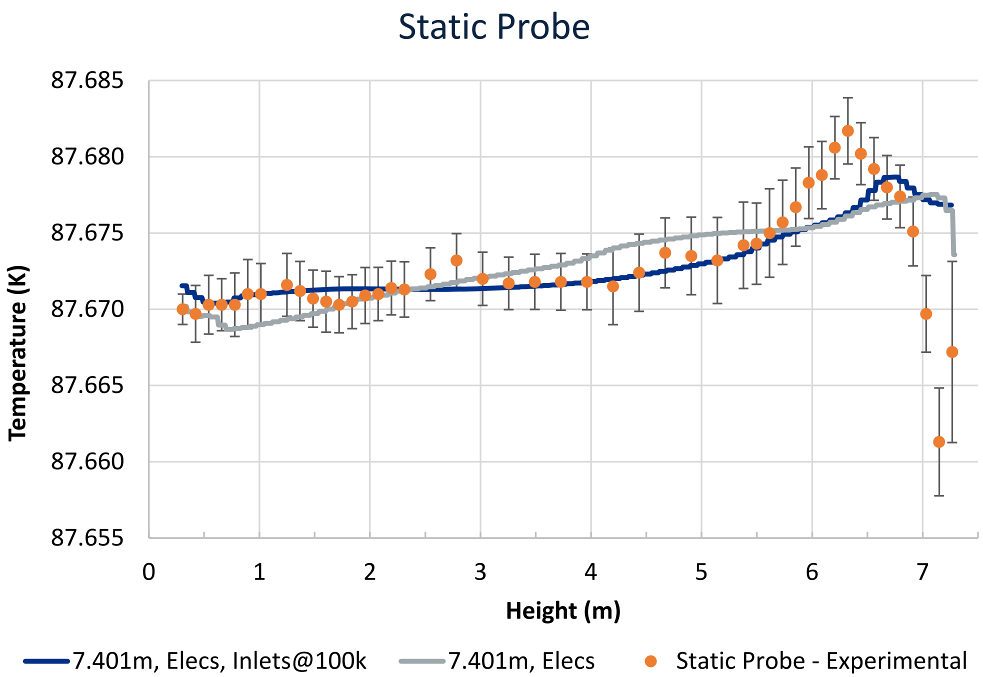
- Inputs based on "Inlet Pipe Network" Simulation by Erik Voirin
  - Given Flow %: distributed total inlet mass flow rate (1.66801 kg/s)
  - Distributed inlet temperatures based on given (weighted avg. based on mass flow rate = existing model inlet temp = 87.793K)

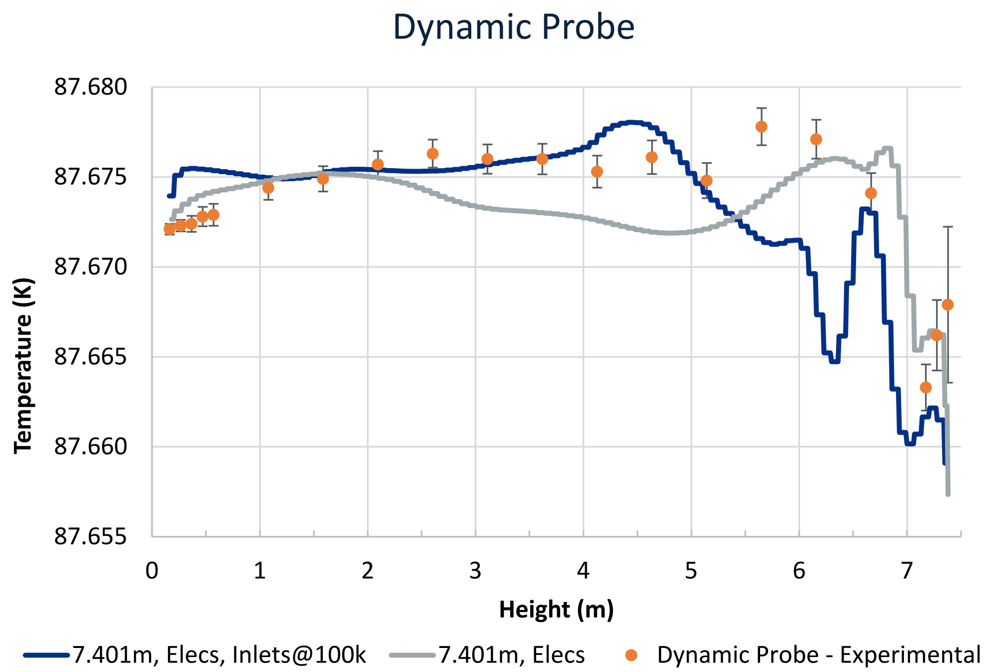


	From Voirin		Model Inputs	
Inlet	Flow %	Temp (K)	Flow Rate (kg/s)	Temp (K)
1	25.20%	88.327	0.42034	87.794
2	28.50%	88.333	0.47538	87.800
3	25.40%	88.326	0.42367	87.793
4	20.90%	88.316	0.34861	87.783
Weighted Average (K)		88.3255	-	87.793

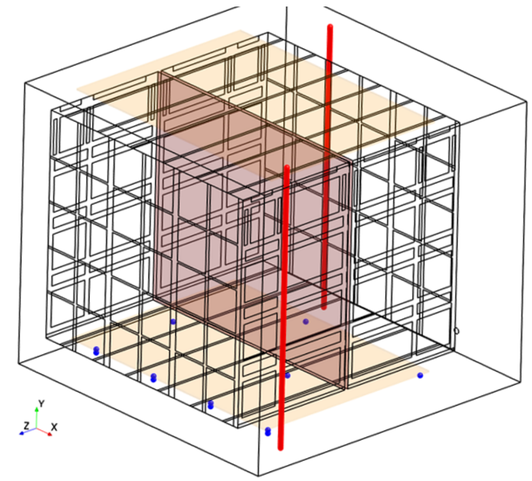
Distributed Inlet Temperature & Flow Rate

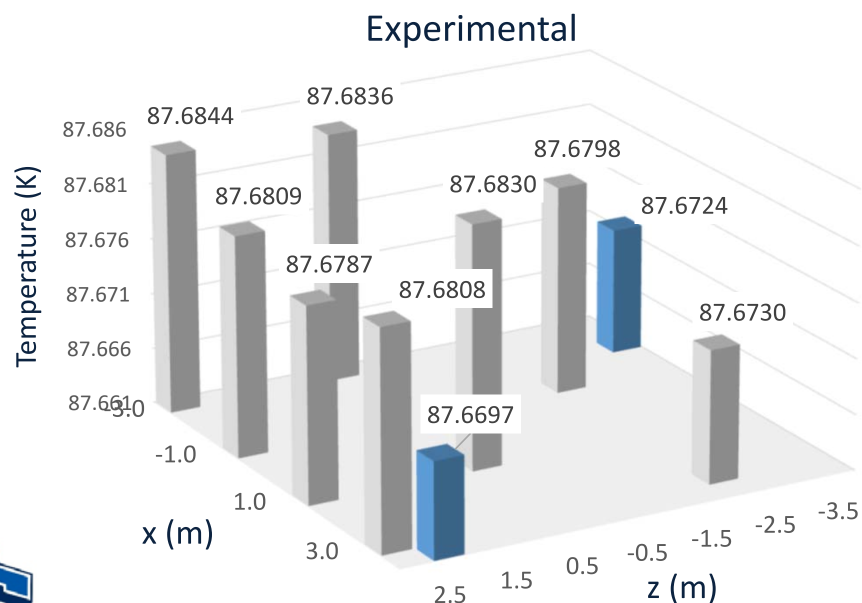
Pumps On Condition

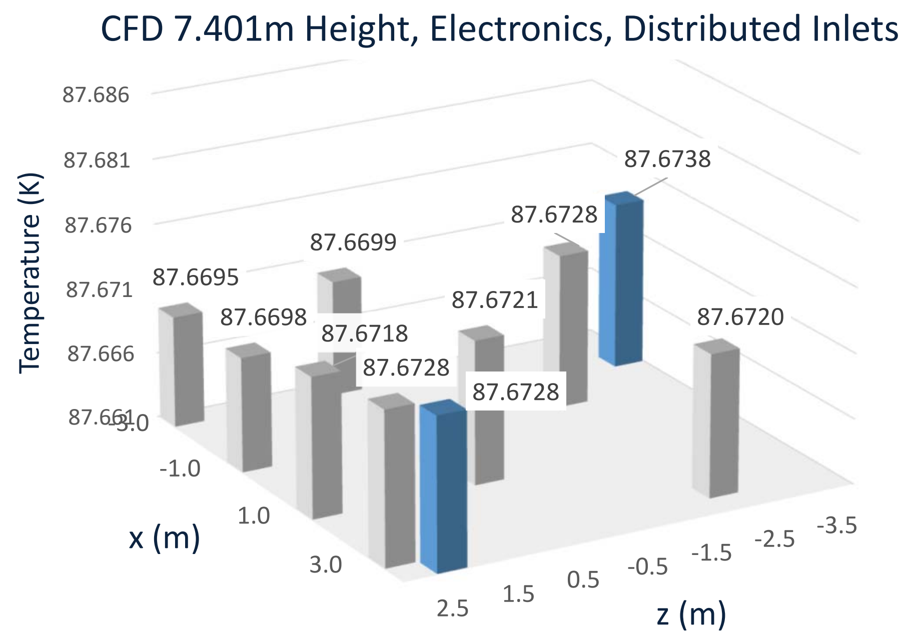




Pipe Probe Results







Quasi-Steady State Solution Effects

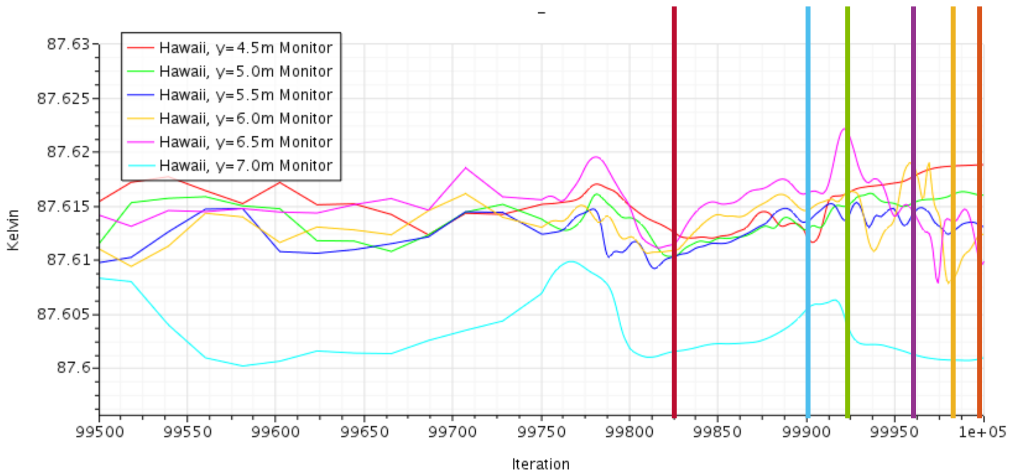
- CFD models are calculated out to a “converged solution”- where the calculated simulation is relatively constant
  (satisfying the governing equations and boundary conditions)

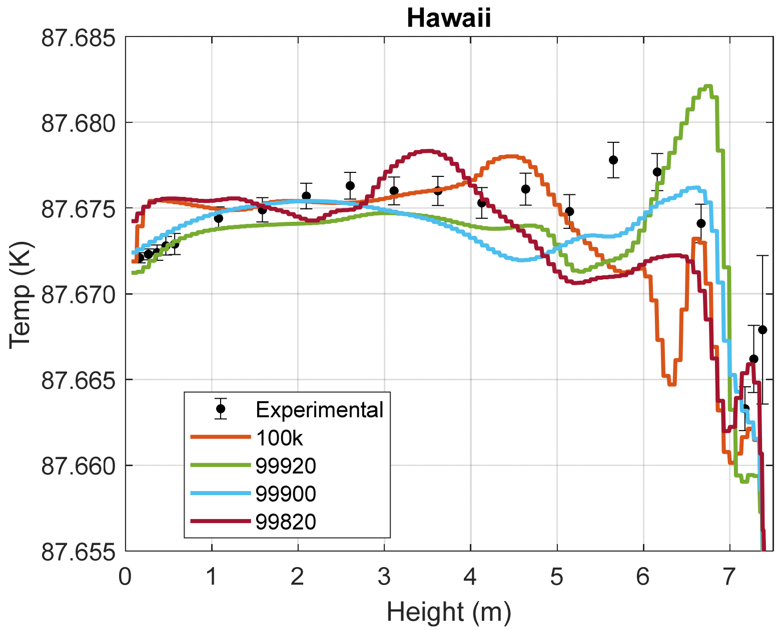
- Even at convergence, **slight variations occur between subsequent calculations** -> “quasi” steady-state

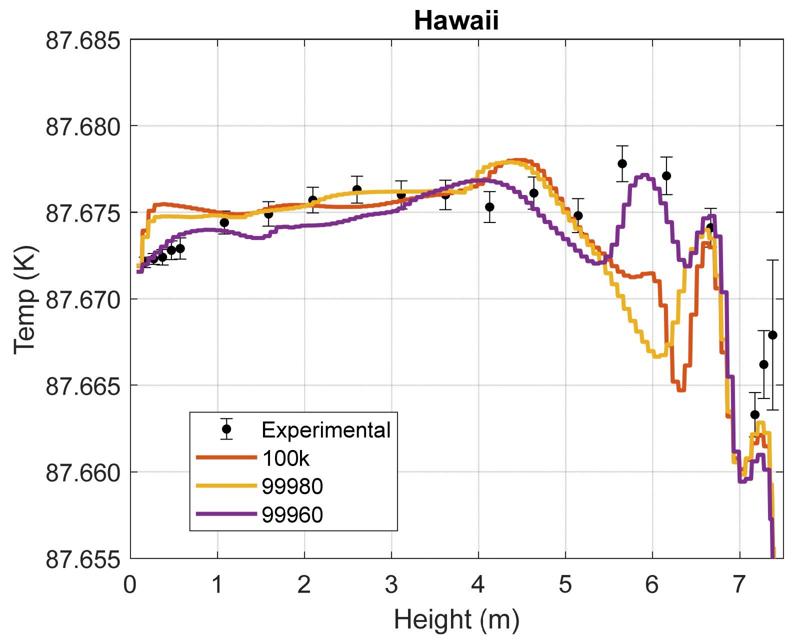
Iteration-to-iteration variation studied in previous “distributed inlet” simulation

- Model Inputs: LAr Height = 7.401m, With Electronics, Inlet flow Rates and Temperatures Weighted

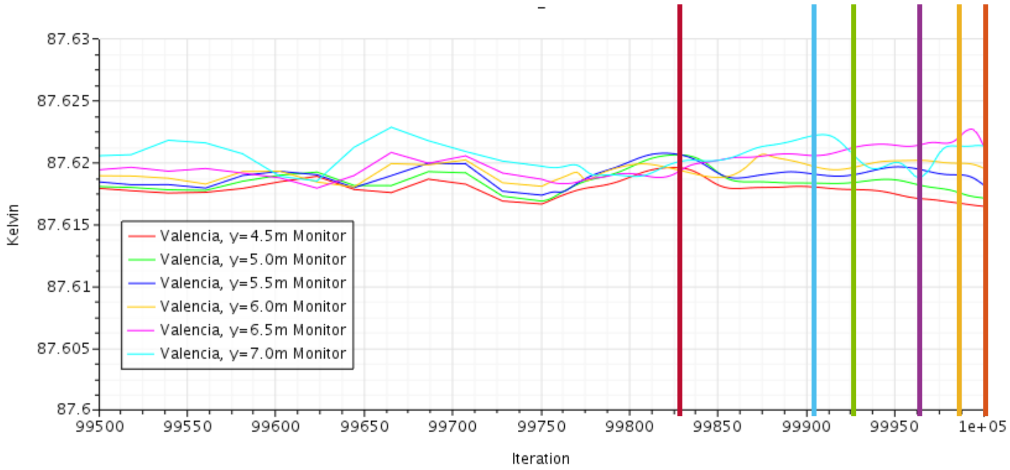
Hawaii temperature profiles at multiple simulation points (iterations)

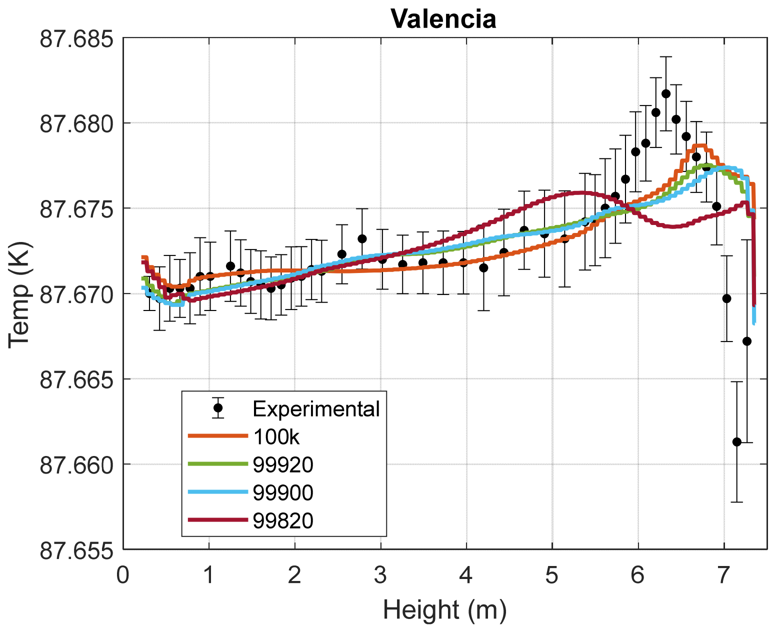


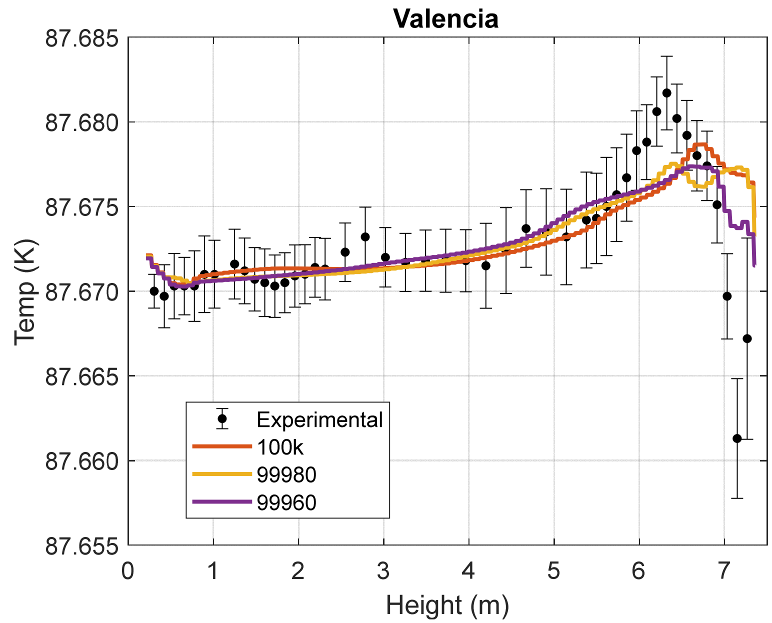




Valencia temperature profiles at multiple simulation points (iterations)

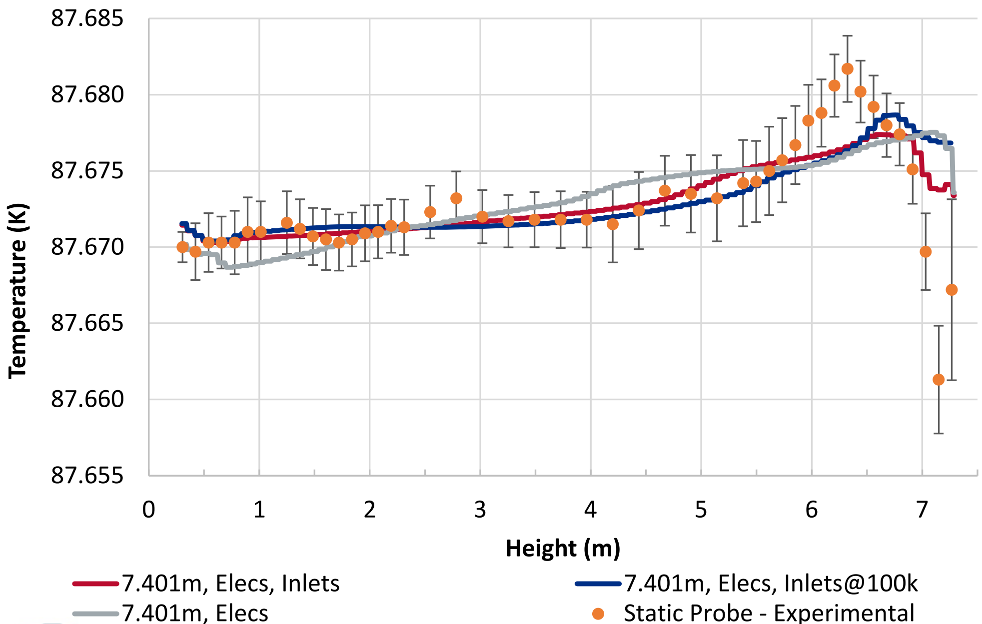


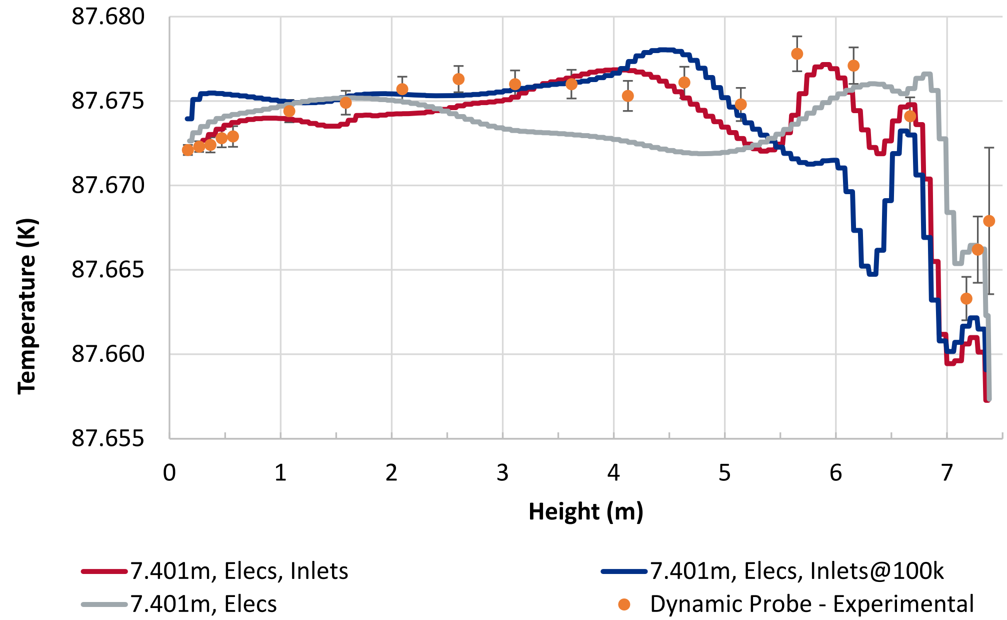




Quasi-Steady State Solution Effects- Case Study

- Compare Profiles for 2 "Quasi-Steady State" points (99,960 and 100,000 iterations)





Quasi-Steady State Solution Effects- Case Study

- Conclusion: Improve Error by selectively choosing simulation stopping point?
  - Edit stopping criteria (iterations > 90,000 AND other criteria satisfied)
  - Anticipate important figures/ data, set up export at iterations “x”, “y” and “z” for while simulation is running
    - Can’t “go back” to previous iterations

Simulation Set up		Temperature Correction (mK)		MSE*10^6		Max Temperature Error (mK)	
LAr Height	# Iterations	Static	Dynamic	Static	Dynamic	Static	Dynamic
7.5m, Constant Inlets	100,000	63.14	63.79	6.57	12.69	14.15	12.45
7.401m, Electronics, Distributed Inlets	100,000	55.85	59.19	7.61	12.24	15.58	11.90
7.401m, Electronics, Distributed Inlets	99,960	55.73	58.17	4.96	4.72	12.44	10.52

ProtoDUNE Modeling – Possible Future Work

- Heat transfer from **inlet pipes**
  - Qty 4 Pipes (Length =6.472m, OD = 42.4mm) deliver "warm" LAr to Cryostat
- Other significant **heat sources** or **flow obstructions** within cryostat?

Big Picture: What level of agreement is required?
How can we prioritize to bring more value?