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Sandia National Laboratories

Quantifying data constraints for velocimetry-based load current determination for inertial confinement fusion targets

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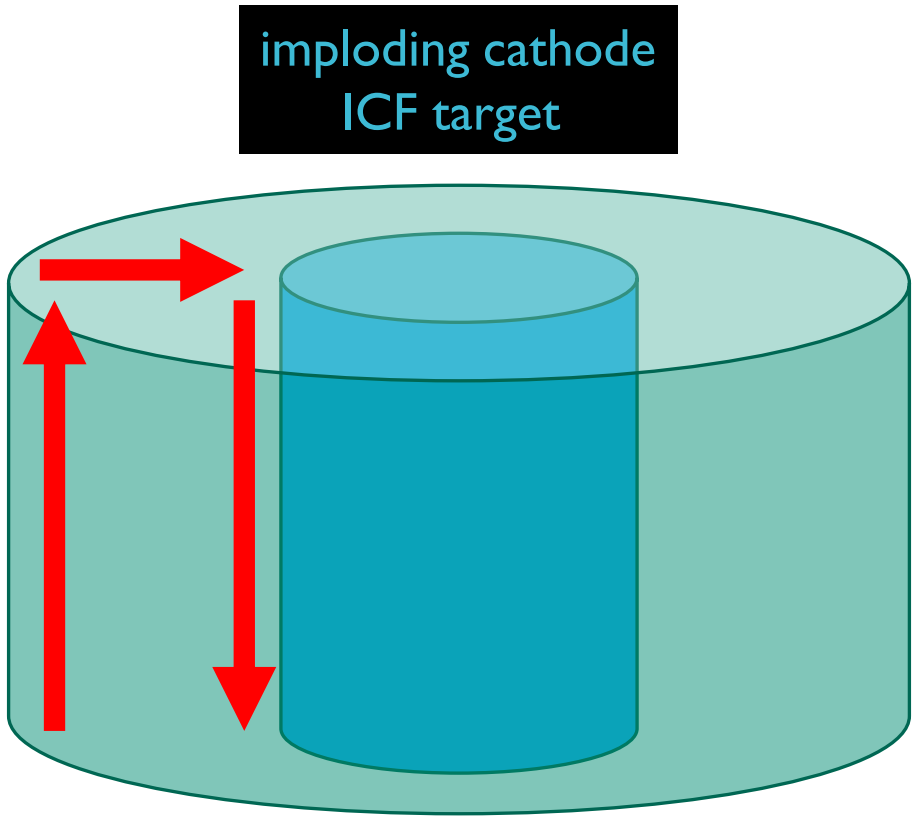
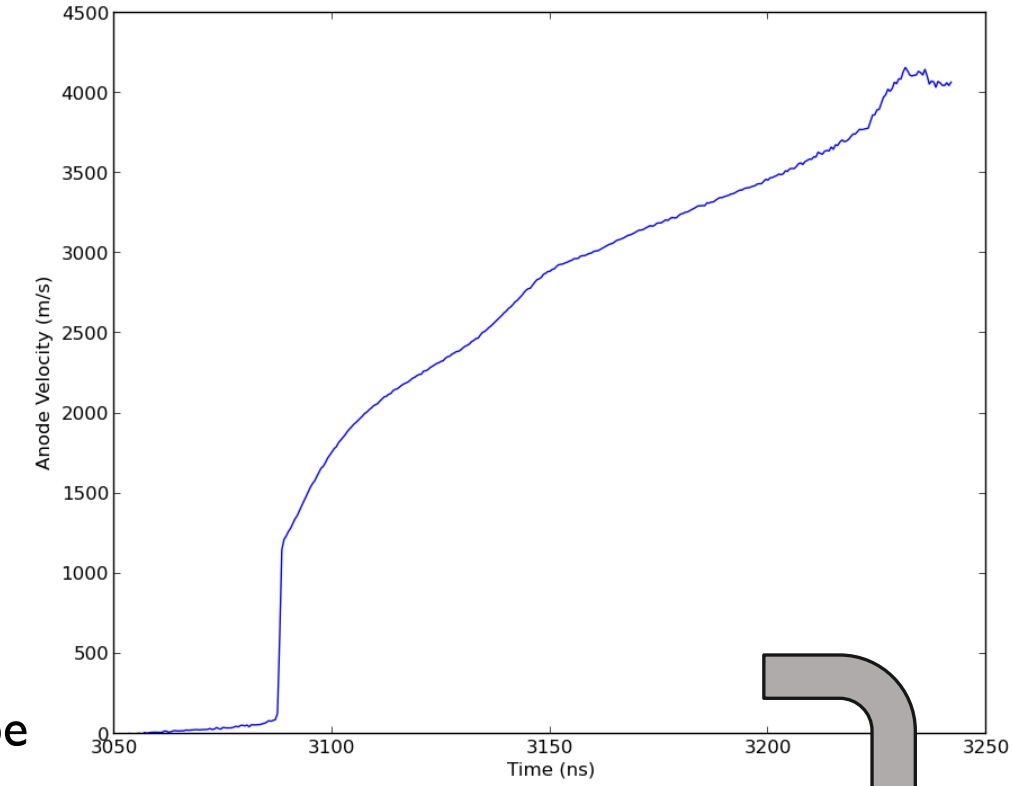
Motivation

- Velocimetry-based current inferences yield the most accurate load currents at multi-MA levels
- Uncertainties of $< 2\%$ achievable for 20 MA targets
- Accurate load currents are necessary inputs to any high fidelity rad-MHD ICF simulation
- Velocimetry information routinely returned from exploding anode "return cans" encircling the ICF target
- **Velocity data record often extends beyond experimental relevance; how do we quantify the quality of the data and the resulting current inference?**
- We present a **variance-based sensitivity analysis** to quantify the constraints on the inferred current based on sensitivity to velocity fluctuations

Experiment Geometry & Load Current Inference



velocimetry probe
PDV/VISAR



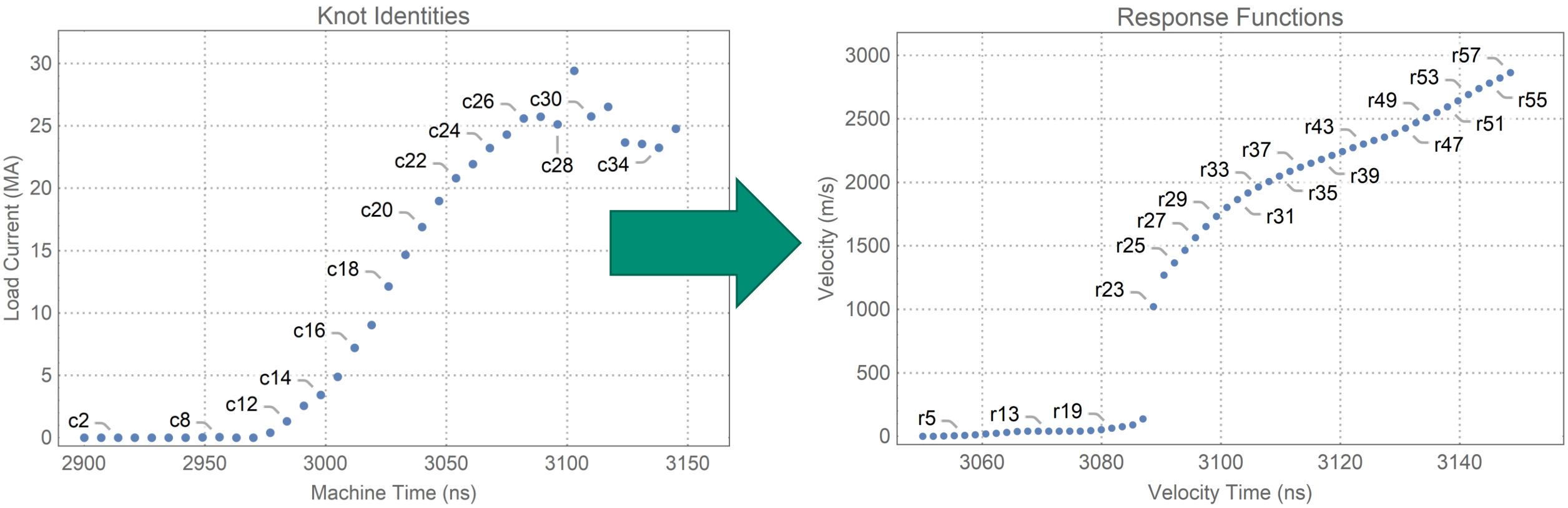
1D anode MHD

adjust applied
current drive

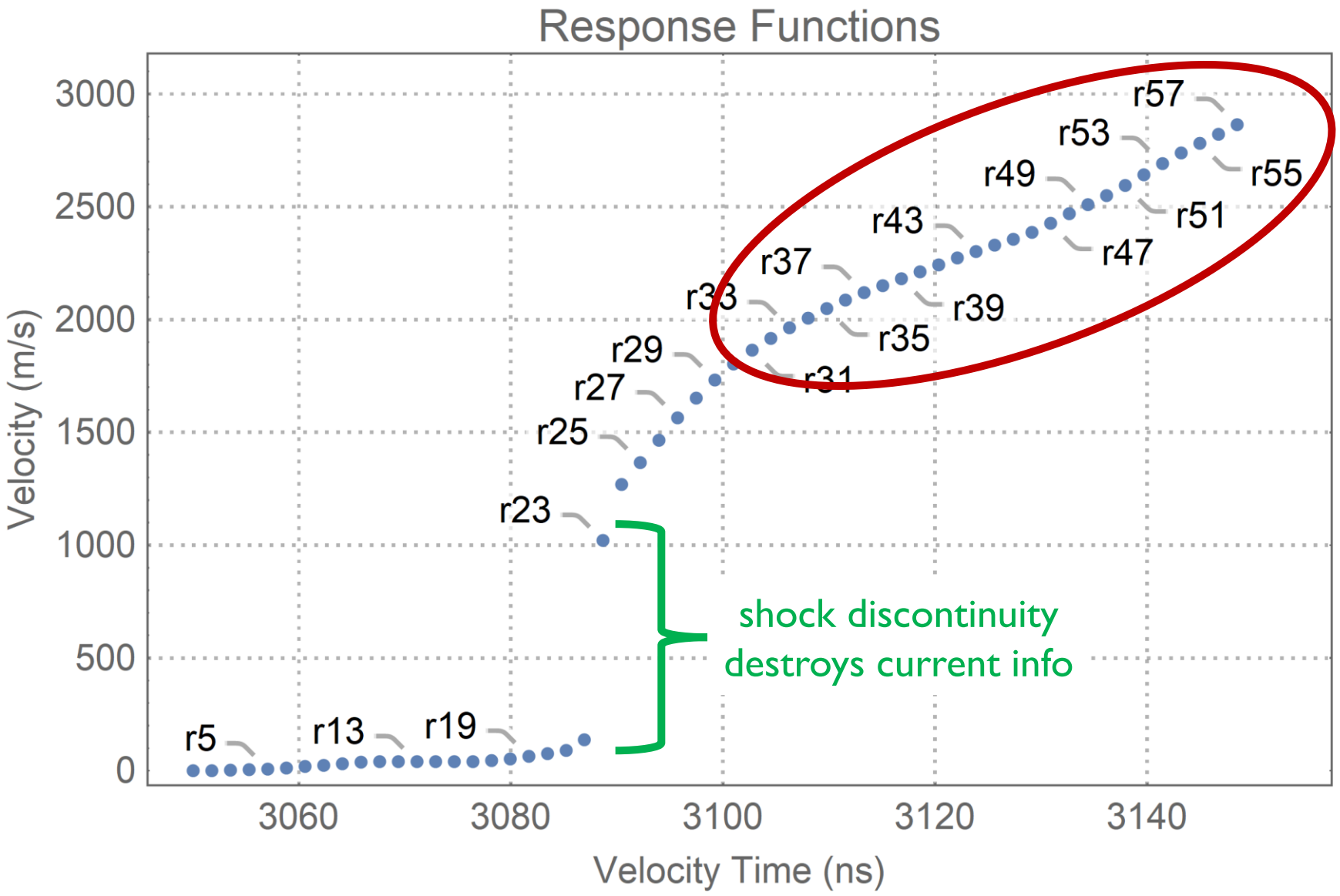
synthetic
velocity

Sobol Indices Determination

- Variance-based sensitivity analysis uses perturbations to input parameters to quantify "response function" sensitivity
- Input: current spline knot magnitudes → Response Functions: 1D cylindrical anode velocity spline knots
- **Sensitivity of each velocity knot to each current knot is determined and quantified via Sobol indices**
- 0.5% current variations used to not radically alter shock position

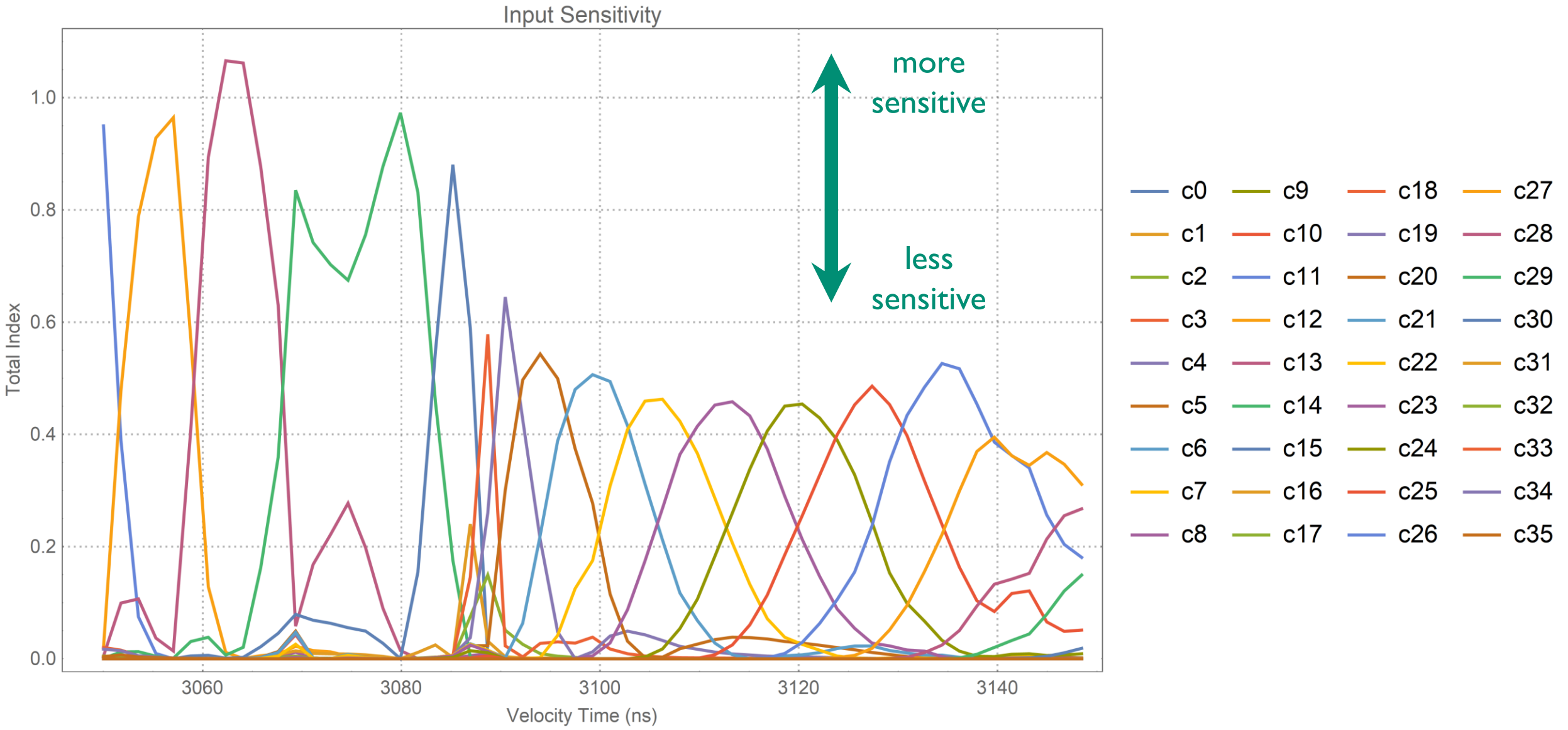


Relevant Velocity Features

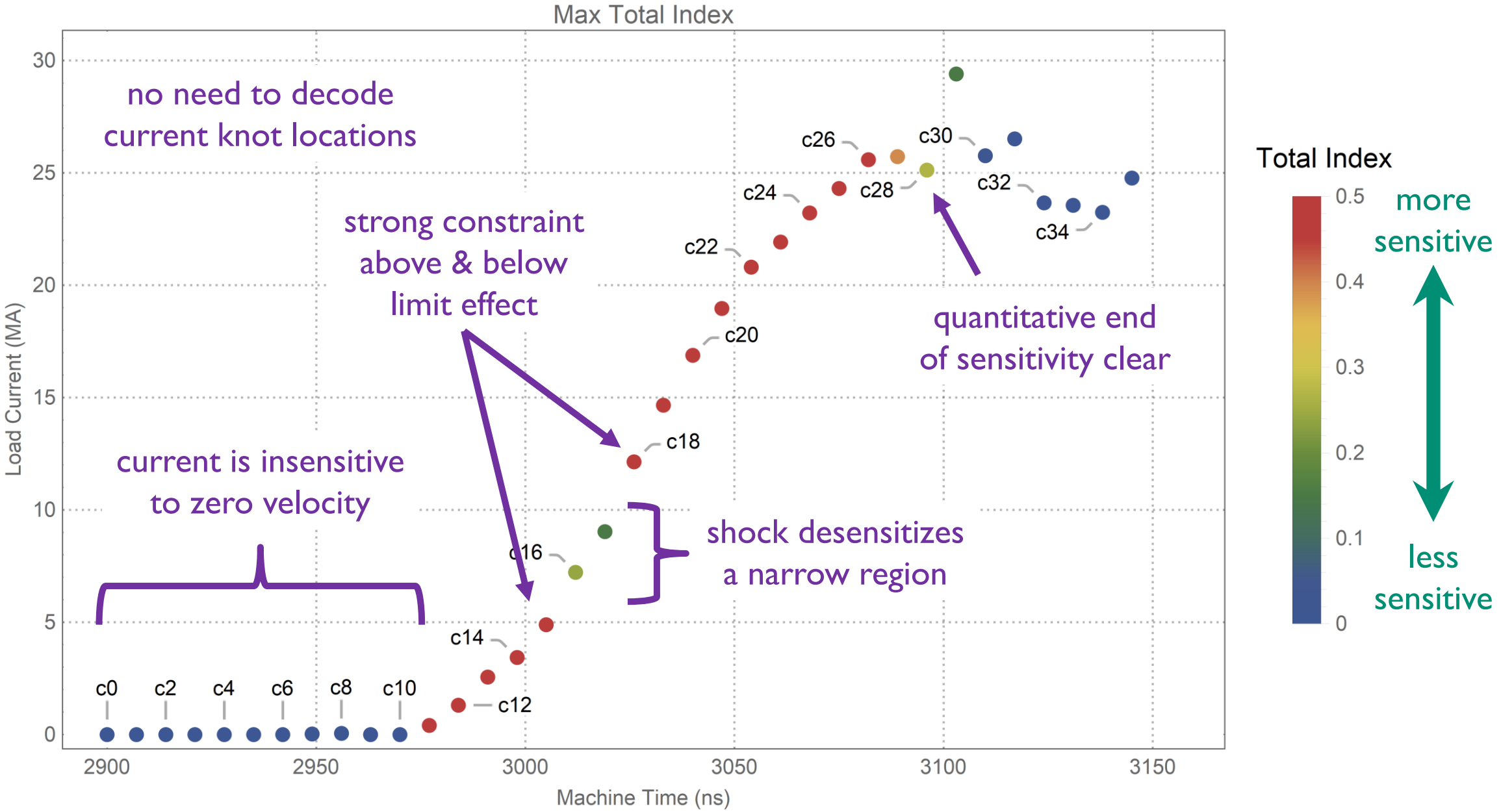


where does relevant data end?

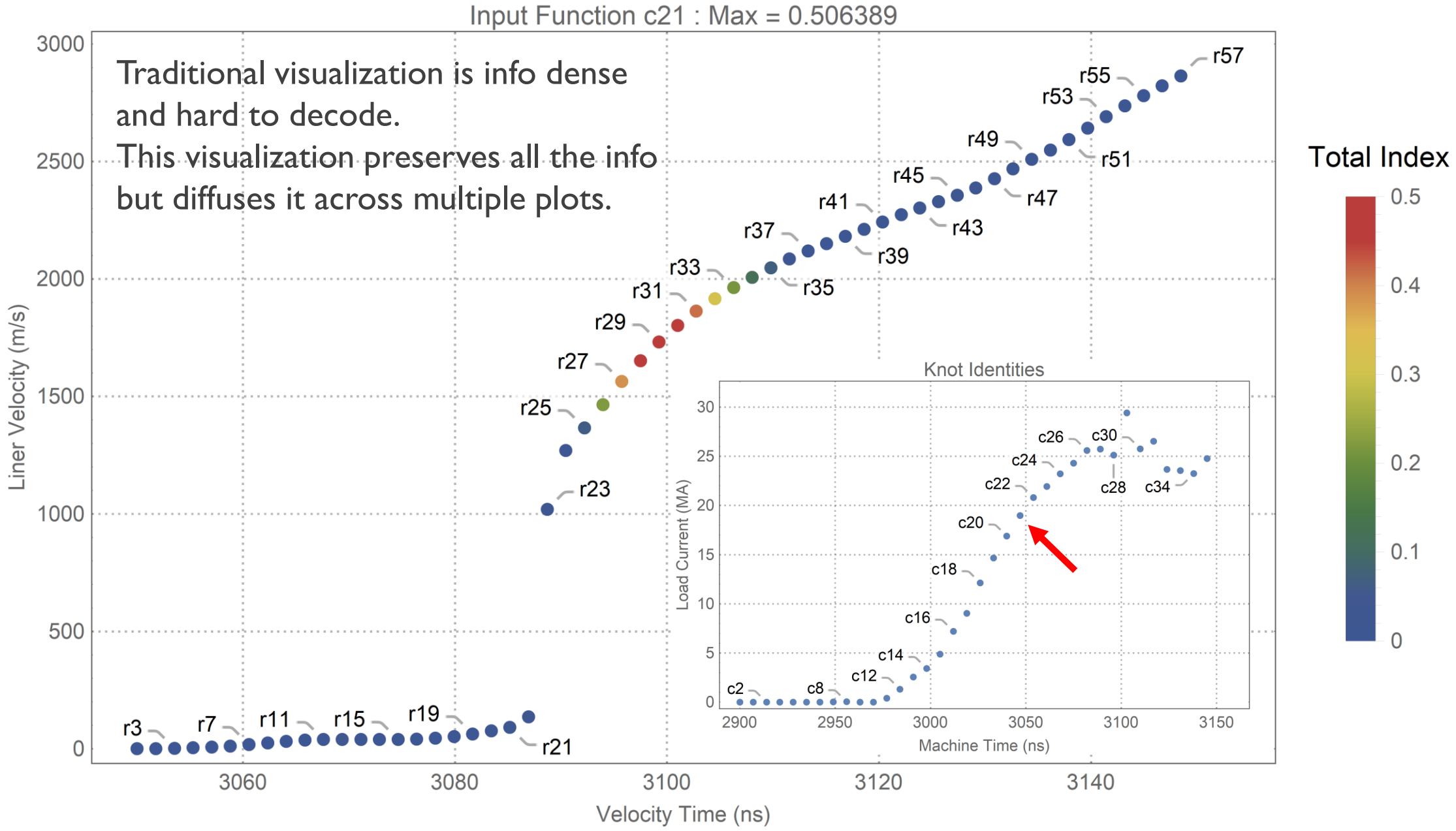
Traditional Visualization… is awful



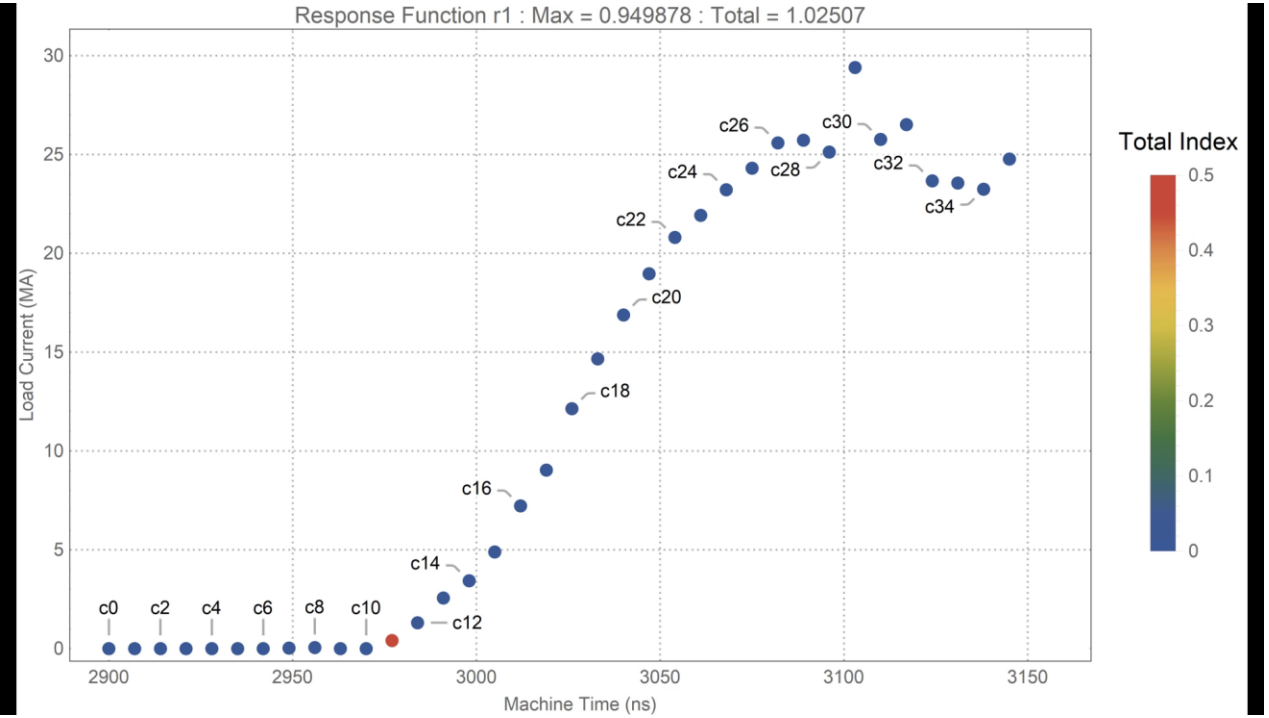
Color-based visualization compresses information intuitively



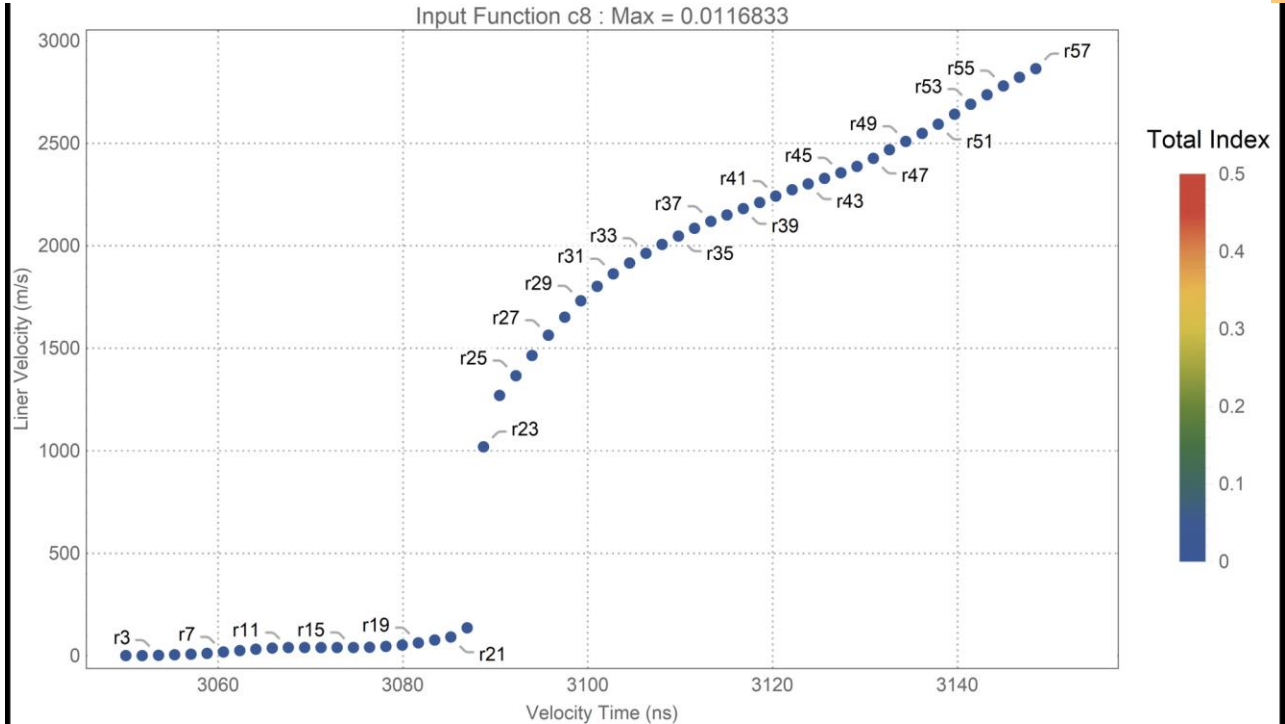
Reversed indices intuitively map current to velocity space



Multiple visualization techniques developed to build intuition



Sobol indices combined with intuitive visualization are powerful tools to decipher complex multiphysics coupling!



Conclusion & Future Work

- We have developed a framework to quantify constraints on velocimetry-based load current inferences for ICF targets on the Z Machine.
- Visual statistical data exploration helps grow intuition for multiphysics coupling.
- Framework can be used to assess sensitivity to various MHD model input parameters.
  - Additional input parameters can be included such as anode thickness, material model choices, etc. Sensitivity can then be determined.
  - Can be used as a predictive tool to design anode thickness & inner radius to determine optimal constraint for given target sensitivity.
- More work needed to set quantitative metrics on Sobol Total Index related to threshold sensitivity (ongoing topic in the field).
- Continues to develop load current velocimetry as the most accurate multi-MA current determination technology.

Abstract

Velocimetry-based load current inferences provide the most accurate method of determining delivered drive current on multi-mega-amp cylindrically imploding inertial confinement fusion platforms, allowing for drive uncertainties of < 2% for 20 MA targets. Low uncertainty current inferences are necessary inputs – along with high quality target metrology – for accurate multiphysics modeling postdictions. Velocimetry information is now routinely returned from cylindrical anode "return cans" concentric to the imploding gas filled cathode target across a wide variety of campaigns on the Z Machine. The standard 100 ns current rise results in shock formation in the return can, and current information is lost as wave characteristics coalesce. Understanding the uncertainty of the velocimetry-derived drive current in the region of the current constrained by the data lost to the shock formation requires advanced computational or mathematical methods. Here we discuss the application of Sobol indices – also referred to as variance-based sensitivity analysis – to identify the level of constraint of various portions of the derived current pulse. The Sobol indices approach is one of several methods under investigation at Sandia National Laboratories for quantifying constraining data of velocimetry-based load current inferences.

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