A Parametric Sensitivity Study for Exploding Wires Using ALEGRA Integrated with DAKOTA

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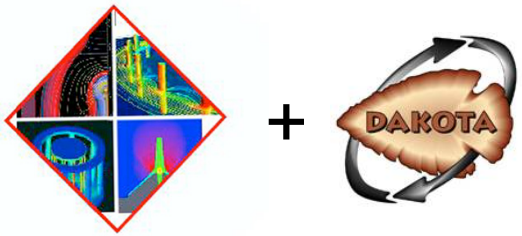
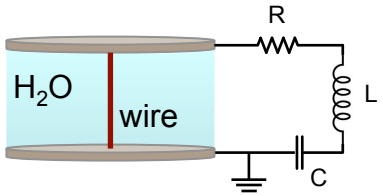
UQ is the future...

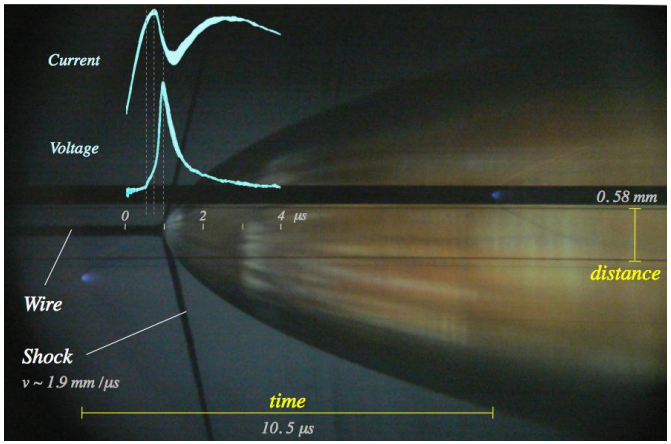


- Uncertainty Quantification (UQ) is essential for achieving confidence in computational results
  - Incorporation of uncertain input parameters
  - Sensitivities to algorithmic choices and parameters
- Becoming more feasible due to increased compute resources
- ALEGRA has recently been integrated with DAKOTA
- We perform a UQ study modeled after Doney et al. using integrated ALEGRA-DAKOTA
- Goal: exercise & evaluate the integrated UQ capability

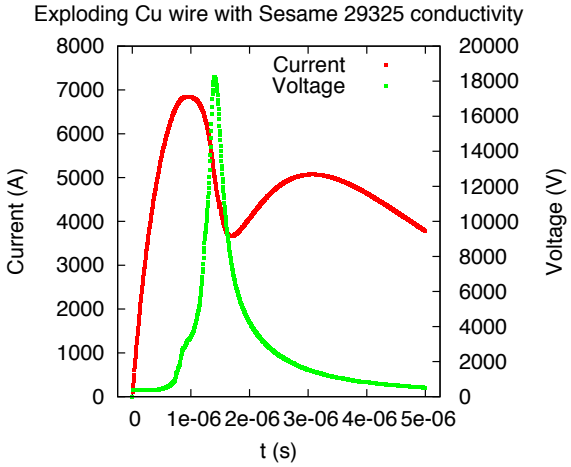
R. L. Doney, G. B. Vunni, and J. H. Niederhaus. Experiments and simulations of exploding aluminum wires: validation of ALEGRA-MHD. Technical report ARL-TR-5299, U.S. Army Research Laboratory, 2010.

Exploding Wire Experiments

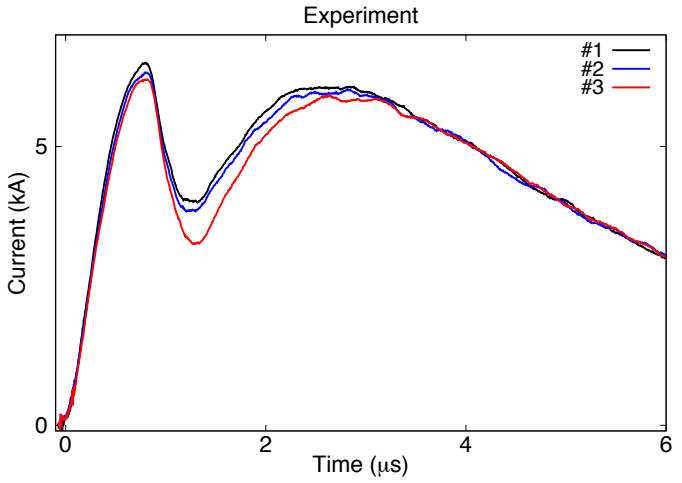




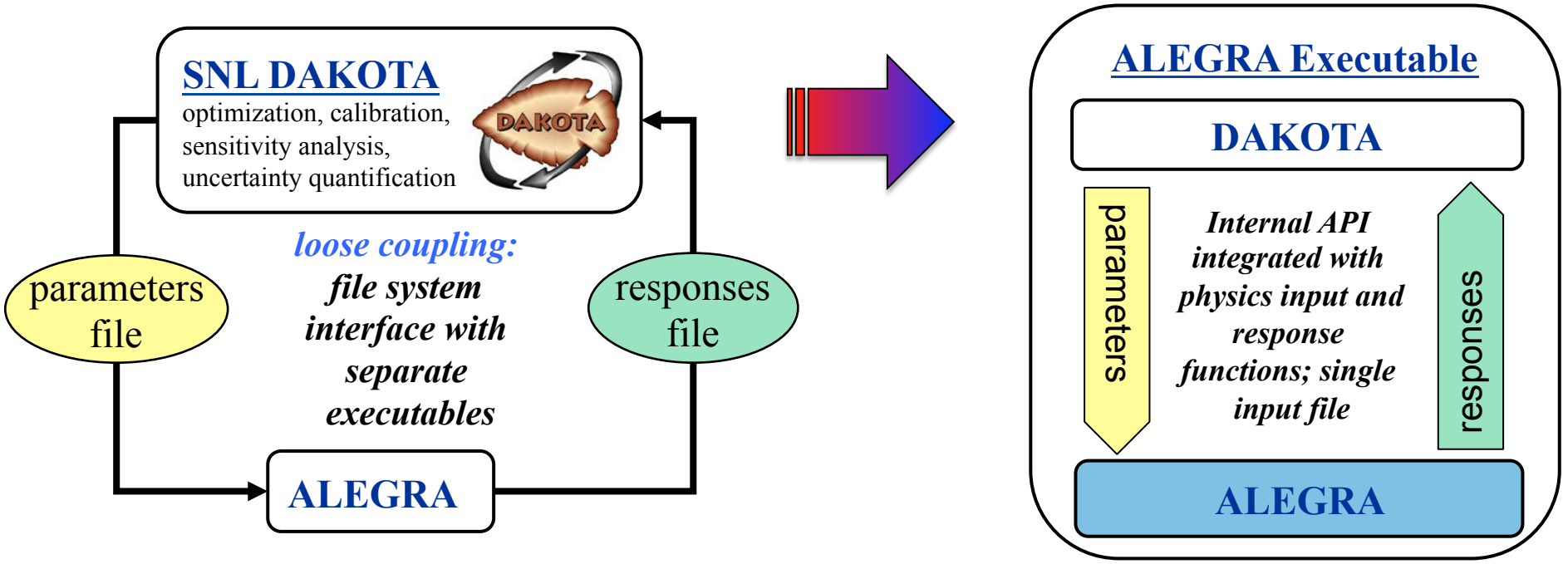
Doney



- The timing of the current & voltage peaks depend on the timing of the material phase changes
- Experiments contain uncertainties
- Computational equation of state and conductivity models are stressed
- Aluminum wire analyzed previously, we look at copper



Integrating DAKOTA and ALEGRA

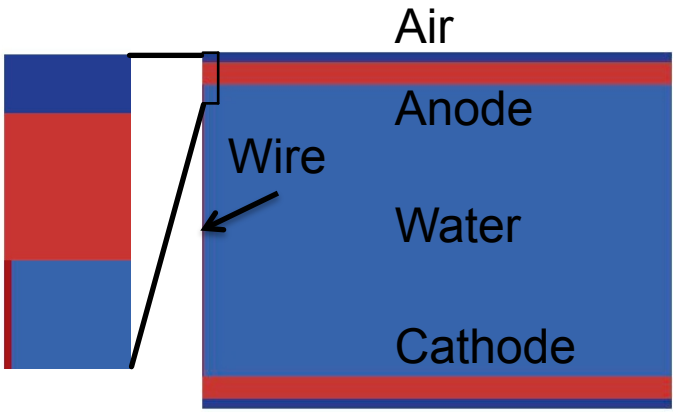


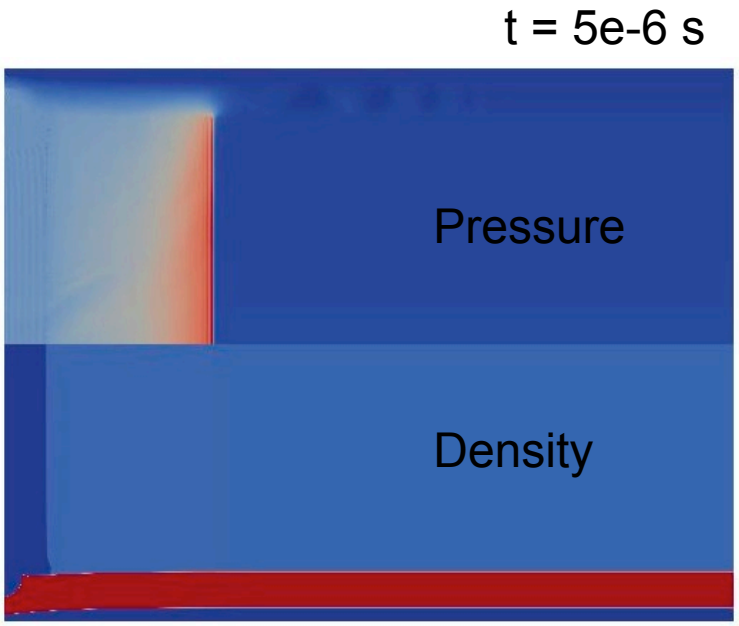
- Very flexible
- Can be fault tolerant
- Variable simulation resources are possible
- Requires scripting
- Relies on file system

- Easier to use
  - One input deck
  - No scripting
  - Single job launch
- Limited response functions
- Less fault tolerant (single MPI job)

ALEGRA-MHD

- **Resistive magnetohydrodynamics**
- **Operator split magnetics & hydrodynamics**
- **Operator split Lagrangian time step plus remap**
- **Multi-material, multiphase**
- **Thermal & electrical conductivity models**
- **Lumped circuit models (Sundials)**
- **Initialization by material insertion**
- **2D cylindrical geometry**

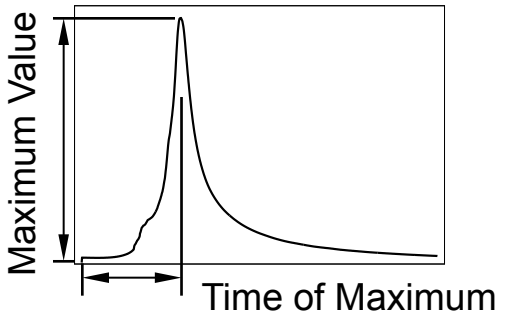


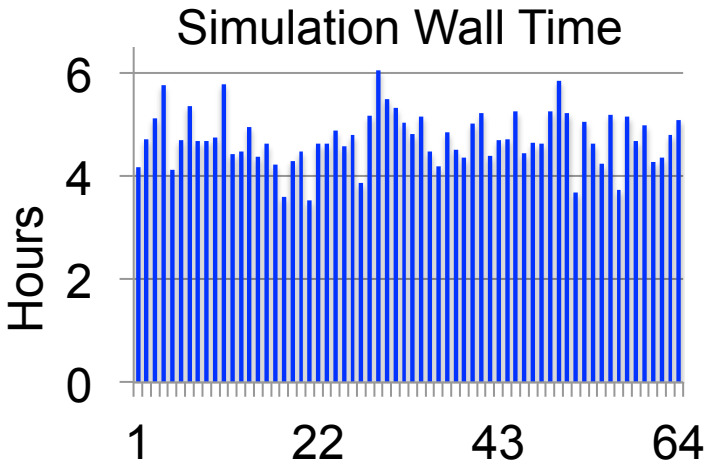


Integrated DAKOTA and ALEGRA

- **DAKOTA specification placed in ALEGRA input deck**
- **We chose a normal (Gaussian) distribution for the input parameters (actual distributions are unknown)**
- **Used maximum and time of maximum built-in response functions**
- **Performed for LMD and QLMD conductivity models**
- **64 samples using Latin Hypercube Sampling**
- **Each sample used 64 processors with 4 running concurrently (~18,500 CPU hours)**

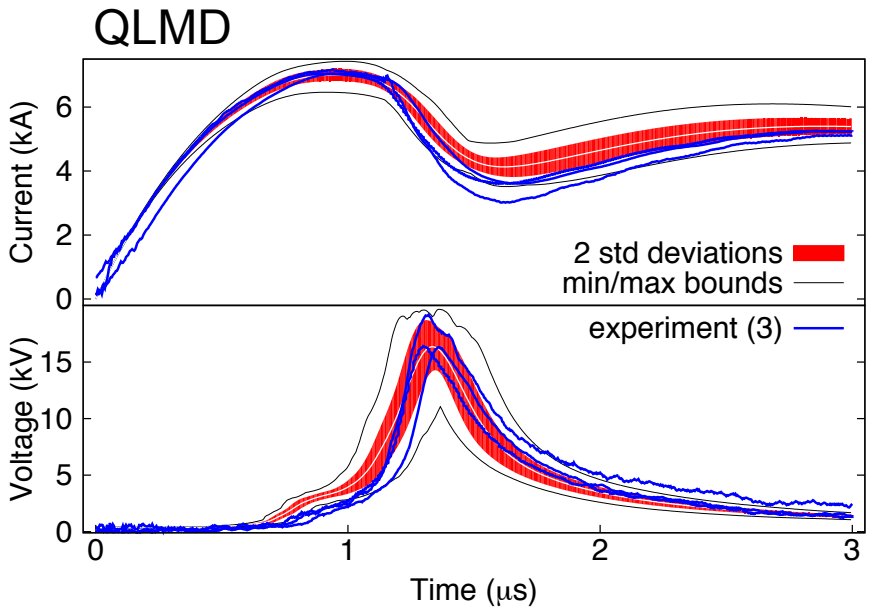
	Mean	σ
Wire Length	16.5 mm	0.83
Wire Diameter	0.126 mm	0.00189
Resistance	2.00 Ω	0.10

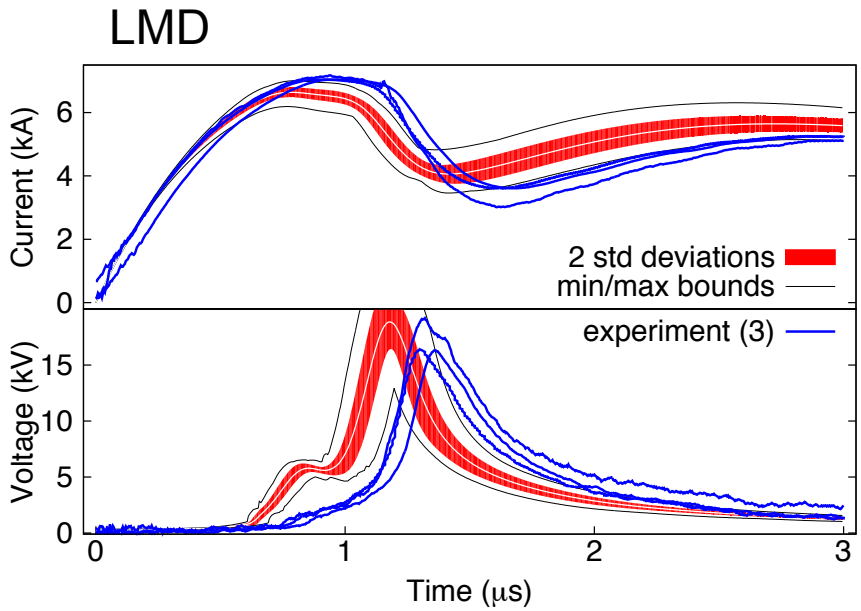




Comparison with Experiment

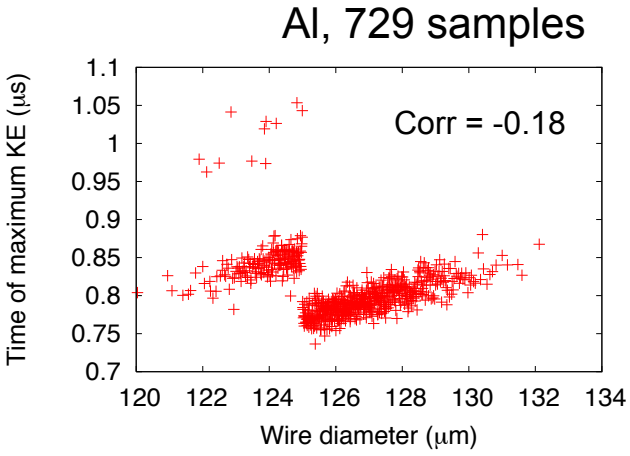
- Computed the mean and standard deviation for each time across the 64 samples
- Overlaid with experimental values
- (Data collection done independent of DAKOTA)

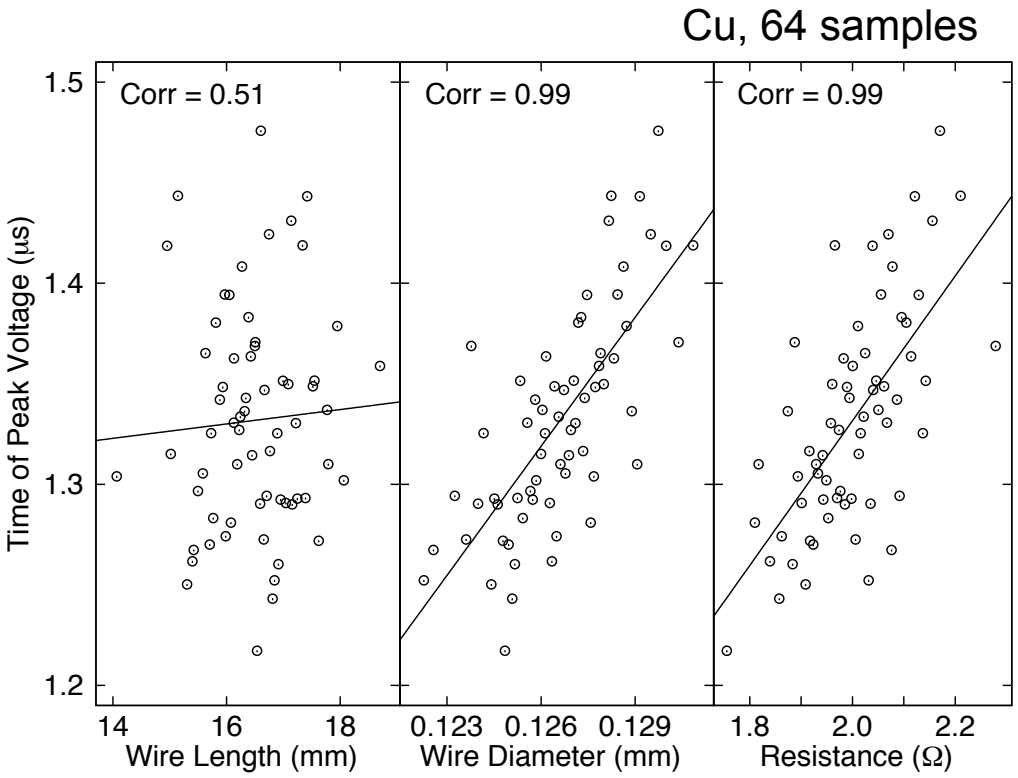




Sensitivity Analysis

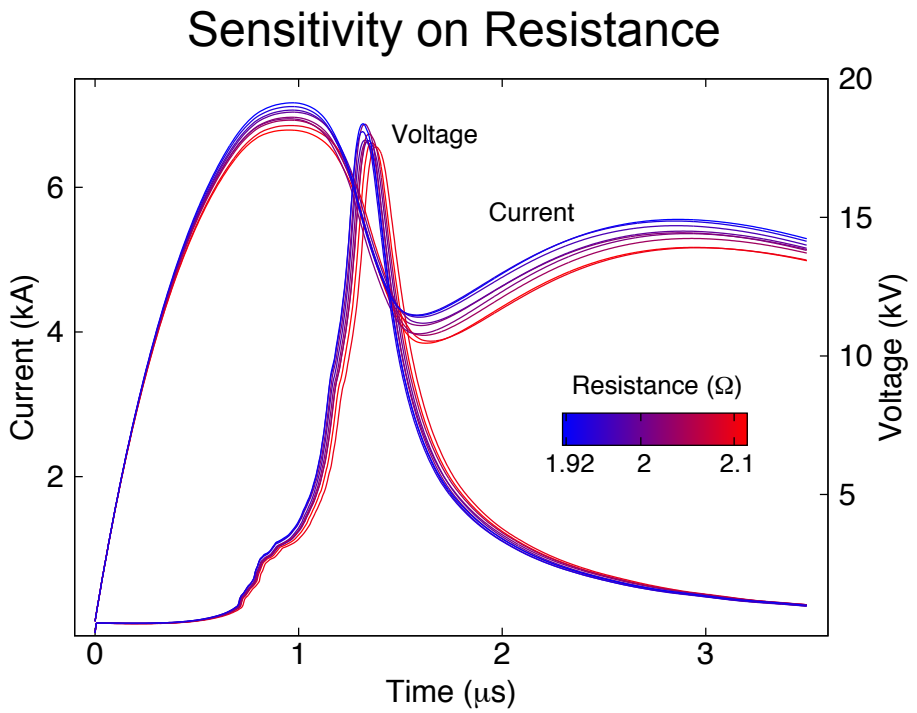
- DAKOTA produces partial correlations
  - Measures dependence between inputs and outputs
  - 0 = not correlated, ±1 = maximum correlation
- Scatter plots useful
- Nonlinearities!

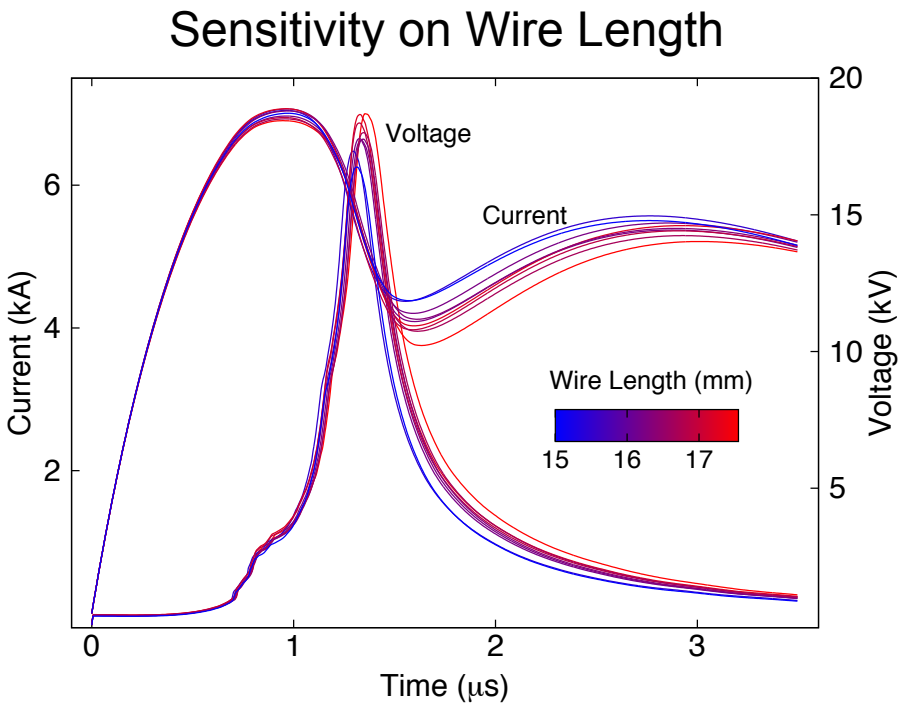




Sensitivity Analysis

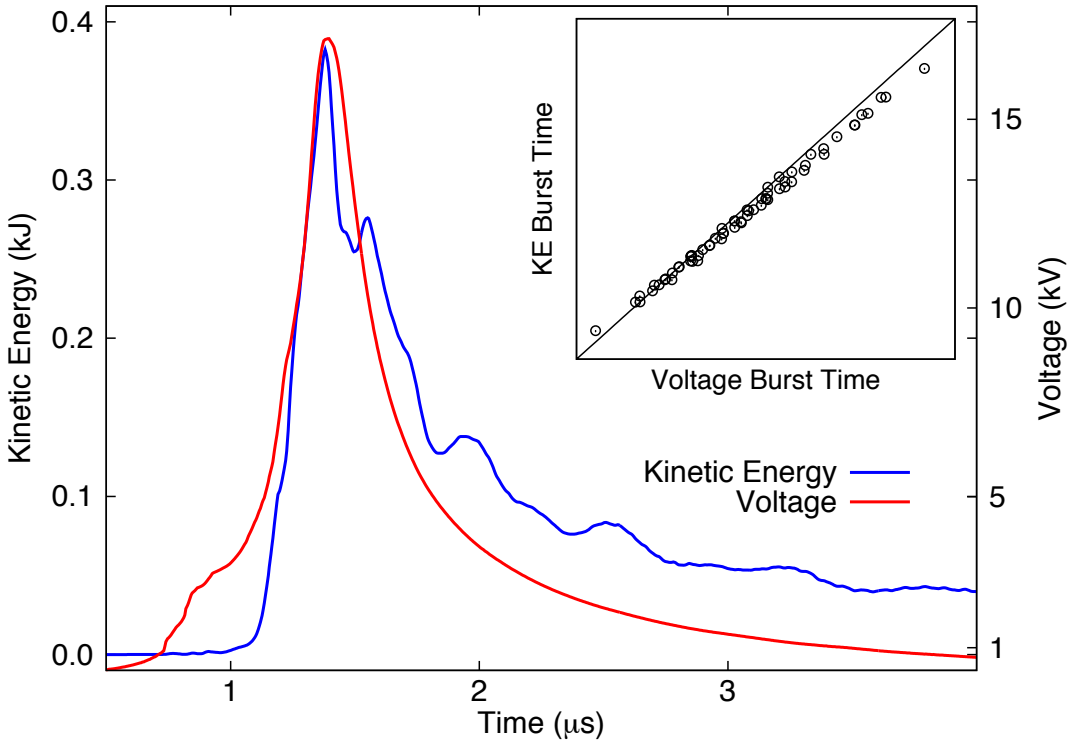
- Traces colored by resistance/wire length
- Confined the other parameters to be within 1 σ of mean





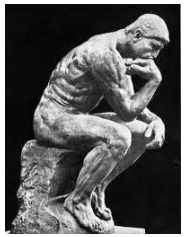
Burst Times

- There is some debate over a definition of burst time
- Time of peak velocity or time of peak voltage?



- Either one! (in this case)

Conclusions



- UQ & SA very helpful !
- Integrated ALEGRA-DAKOTA improves ease of use
  - greatly simplifies execution of UQ sampling simulations
  - Provides useful UQ measures
  - Provides inputs versus outputs table
- Potential use for other DAKOTA capabilities, such as calibration & optimization
- Complete analyses require additional tools, such as history trace reduction, sensitivity scatter plots, histograms
- Additional response functions & generality needed
- QMD-optimized LMD conductivity model much better than LMD
- Voltage or velocity can be used to define burst time
- Burst time depends mainly on resistance & wire diameter