Analytic Analysis of Convergent Shocks to Multi-Gigabar Conditions

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Motivation and results

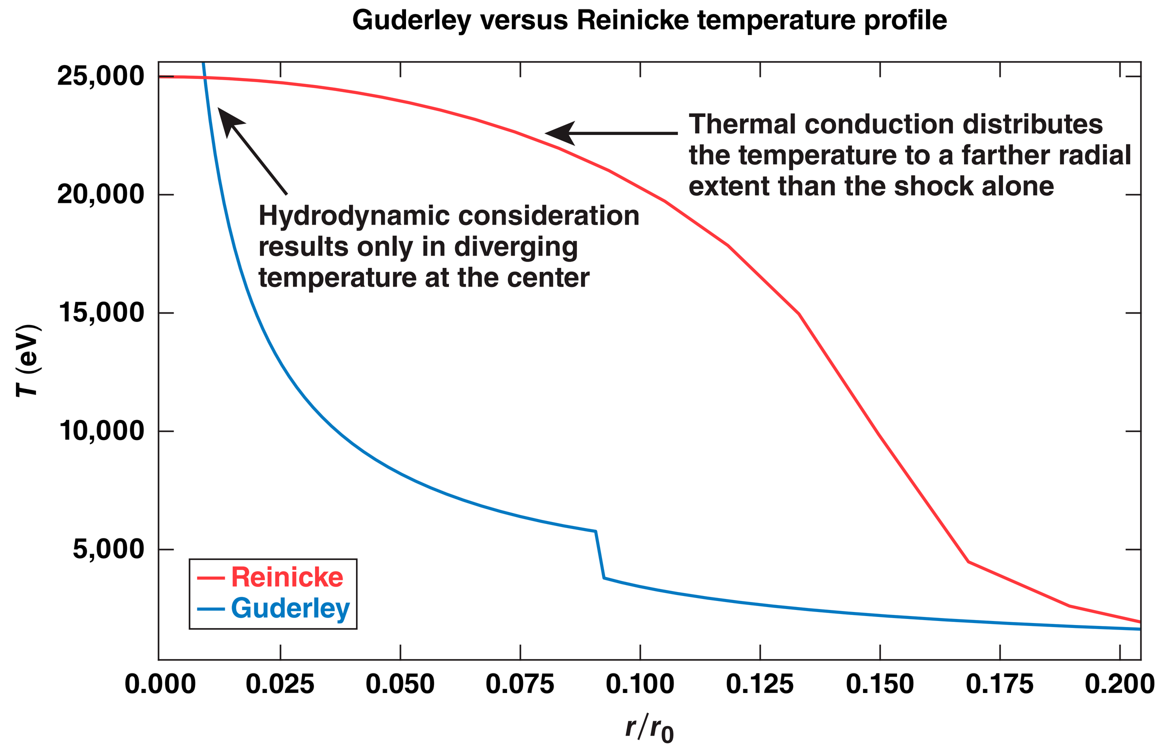
- The Gigabar Platform at the National Ignition Facility created states of 1.2 keV, 100 g/cm^3, and 10 s
- Self-similar solutions to hydrodynamic systems offer intuition and simplicity that cannot be achieved with hydrodynamic codes
- Understanding experiments in the context of self-similar solutions allows insight into the state variables and transport properties of the system
- The Guderley self-similar hydrodynamic solution accurately recreates experimental results and offers insight into the energy partitioning between ions and electrons in spherical implosions
- Electron–ion energy partitioning plays an important role in what is observed during these types of experiments and is not well understood

E26512

G. Guderley, Luftfahrtforschung 19, 302 (1942);
P. Reinicke and J. Meyer-ter-Vehn, Phys. Fluids A 3, 1807 (1991).

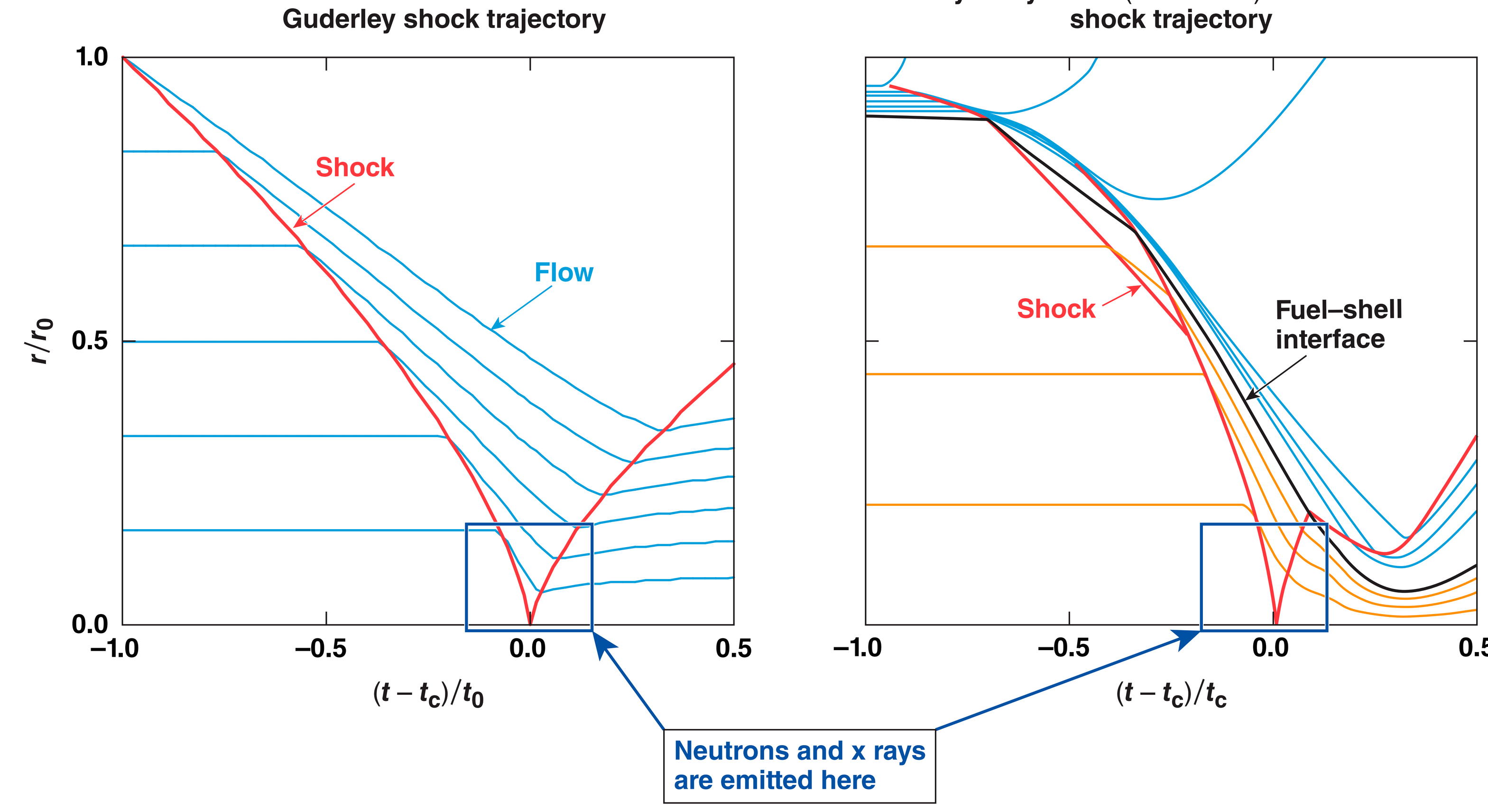
Creating a model that makes experimental sense

Guderley versus Reinicke temperature profile



- Diverging temperature at the center means a large thermal gradient
- Larger thermal gradients give rise to heat waves
- Thermal conduction is dominated by electrons
- Hydrodynamic transport is carried out by ions
- How they equilibrate becomes very important

Guderley shock trajectory | Hydrodynamic (1-D *LILAC*) simulation shock trajectory



- Within the region of observable emission, the Guderley and hydrodynamic codes have the same behavior
- The Guderley and Reinicke solutions are used as a benchmark for hydrodynmic codes*

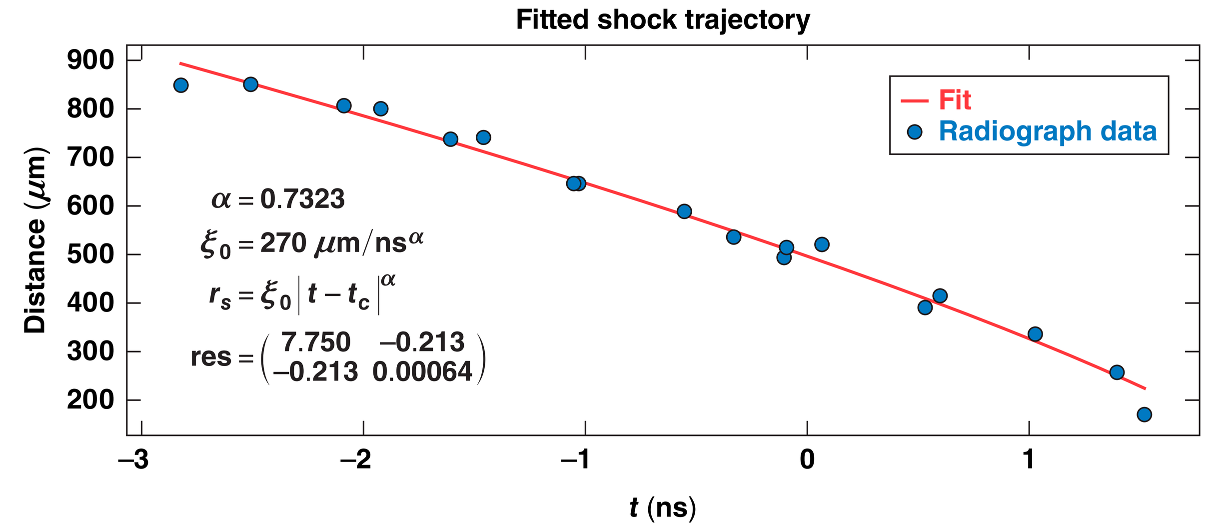
E26513

J. R. Rygg, Ph.D. thesis, Massachusetts Institute of Technology, 2006.
*https://github.com/lanl/ExactPack (2 October 2017).

Using the Guderley solution to understand experimental results

- Guderley has free parameters set by experiment
  - initial density
  - outer radius
  - shock trajectory
- Shock trajectory is set to fit to the experimental trajectory in the radiograph
- The time of shock collapse is determined from the location of peak emission in the radiograph
- There is qual energy partitioning between ions and electrons

Fitted shock trajectory



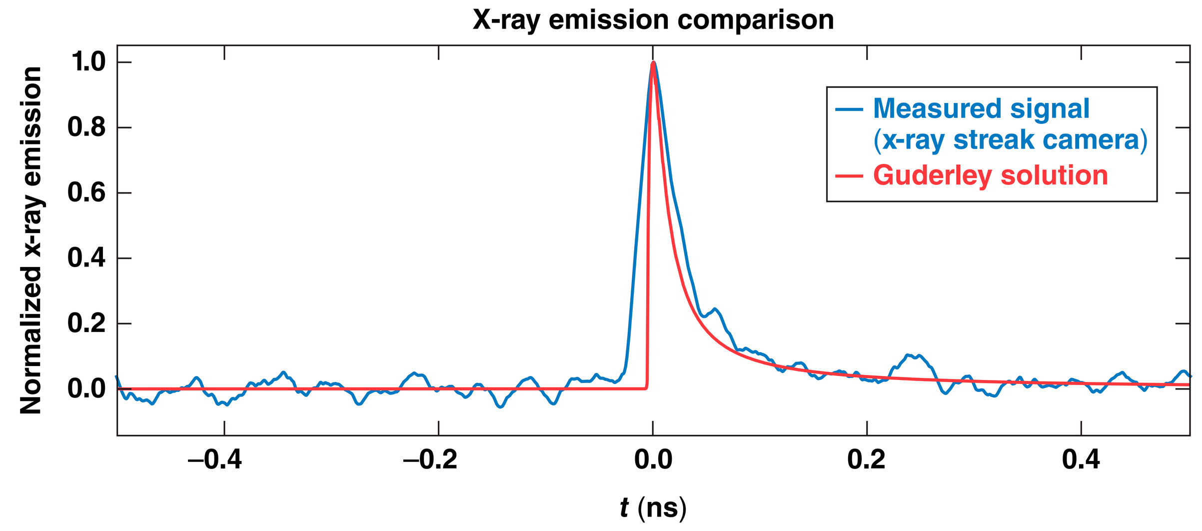
$\alpha = 0.7323$

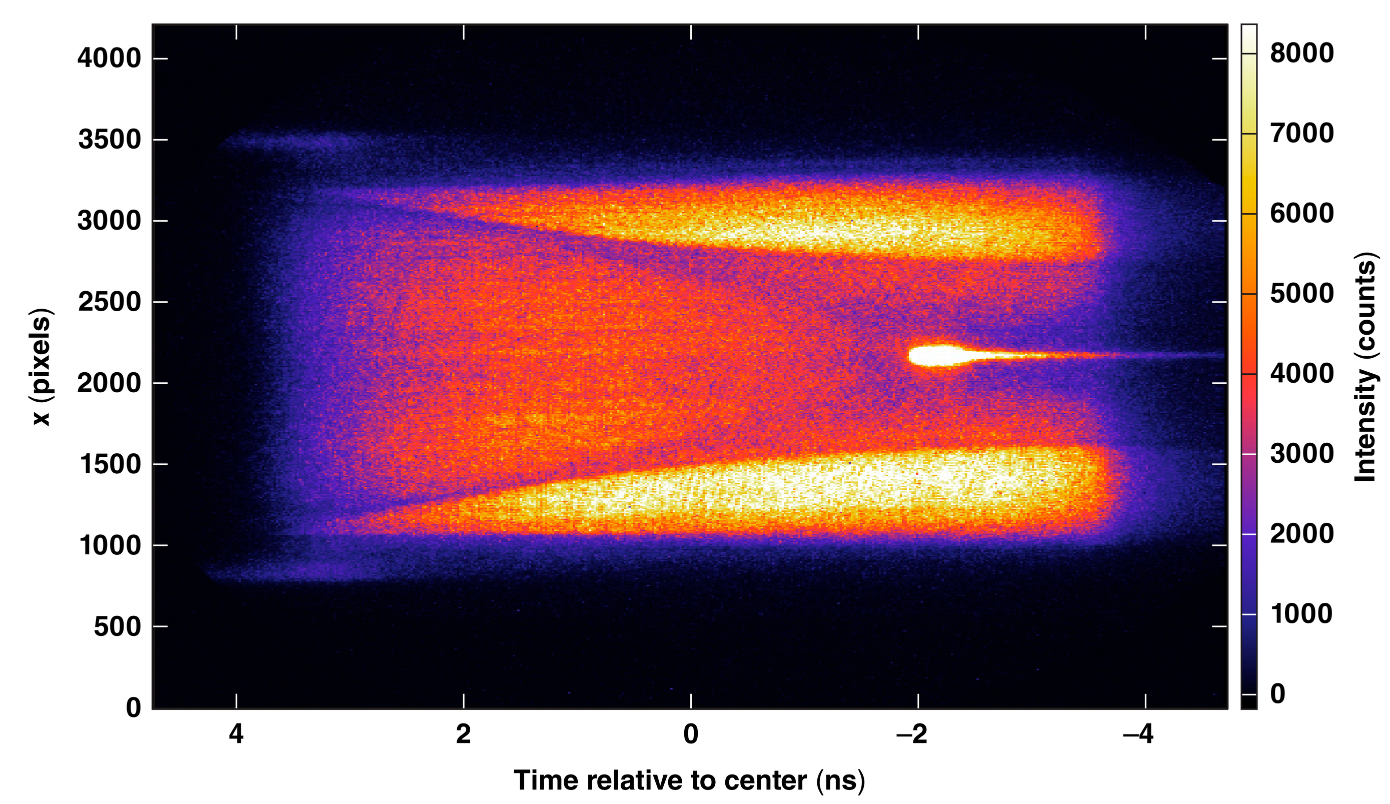
$\xi_0 = 270\ \mu\text{m/ns}^\alpha$

$r_s = \xi_0 |t - t_c|^\alpha$

$\text{res} = \begin{pmatrix} 7.750 & -0.213 \\ -0.213 & 0.00064 \end{pmatrix}$

X-ray emission comparison





- The Guderley model does a good job of predicting experimental observables
- The question of how to partition ion and electron energies is still present
- Development of a heat-conduction treatment is ongoing

Value	Guderley	Experiment
Neutron yield	1.74×10^{10}	7×10^9
⟨Ion temperature⟩	1.2 keV	0.94 keV
X-ray yield	4.3 mJ/sr (>8 keV)	9.3 mJ/sr (filtered)

E26719

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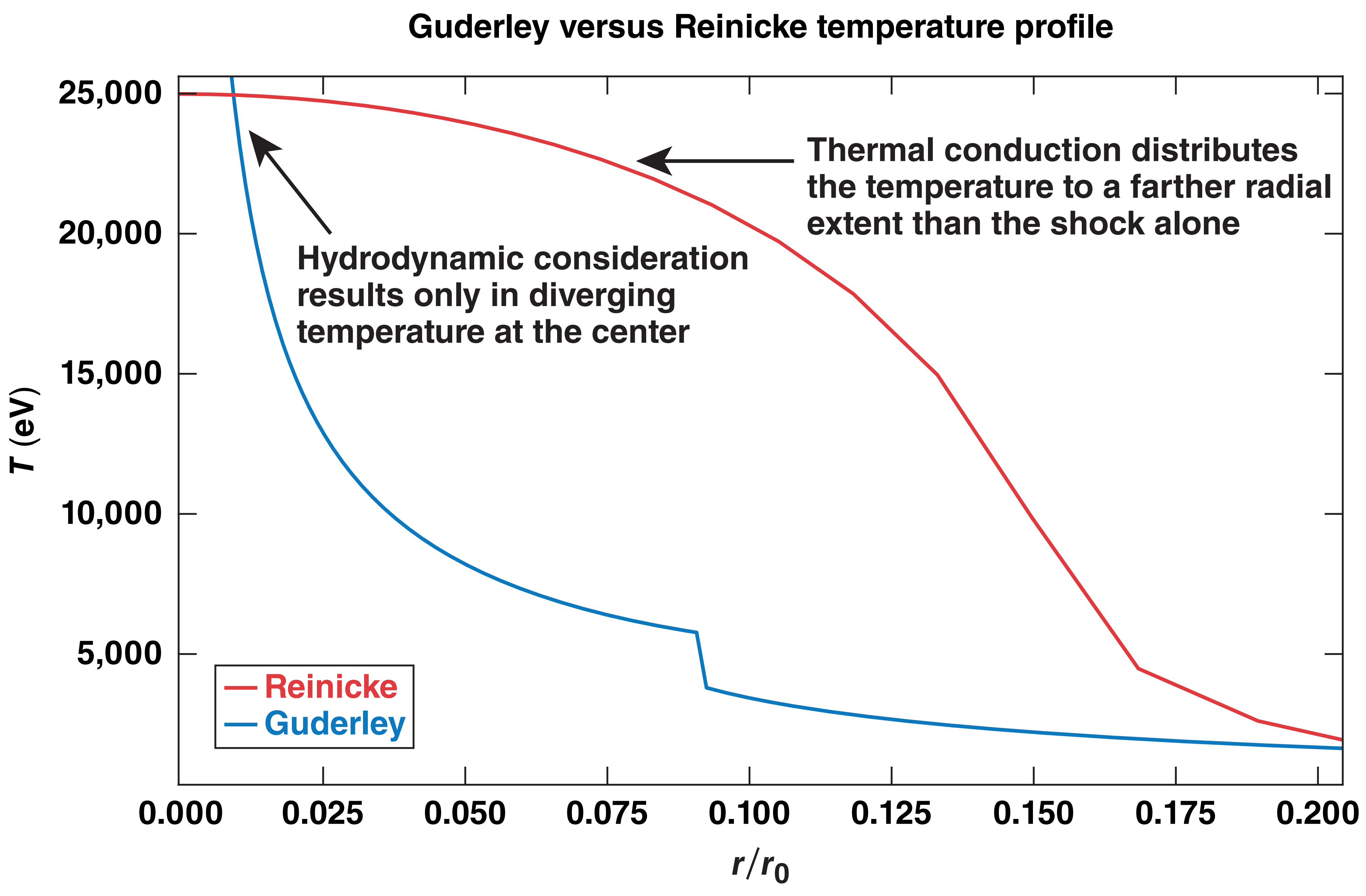

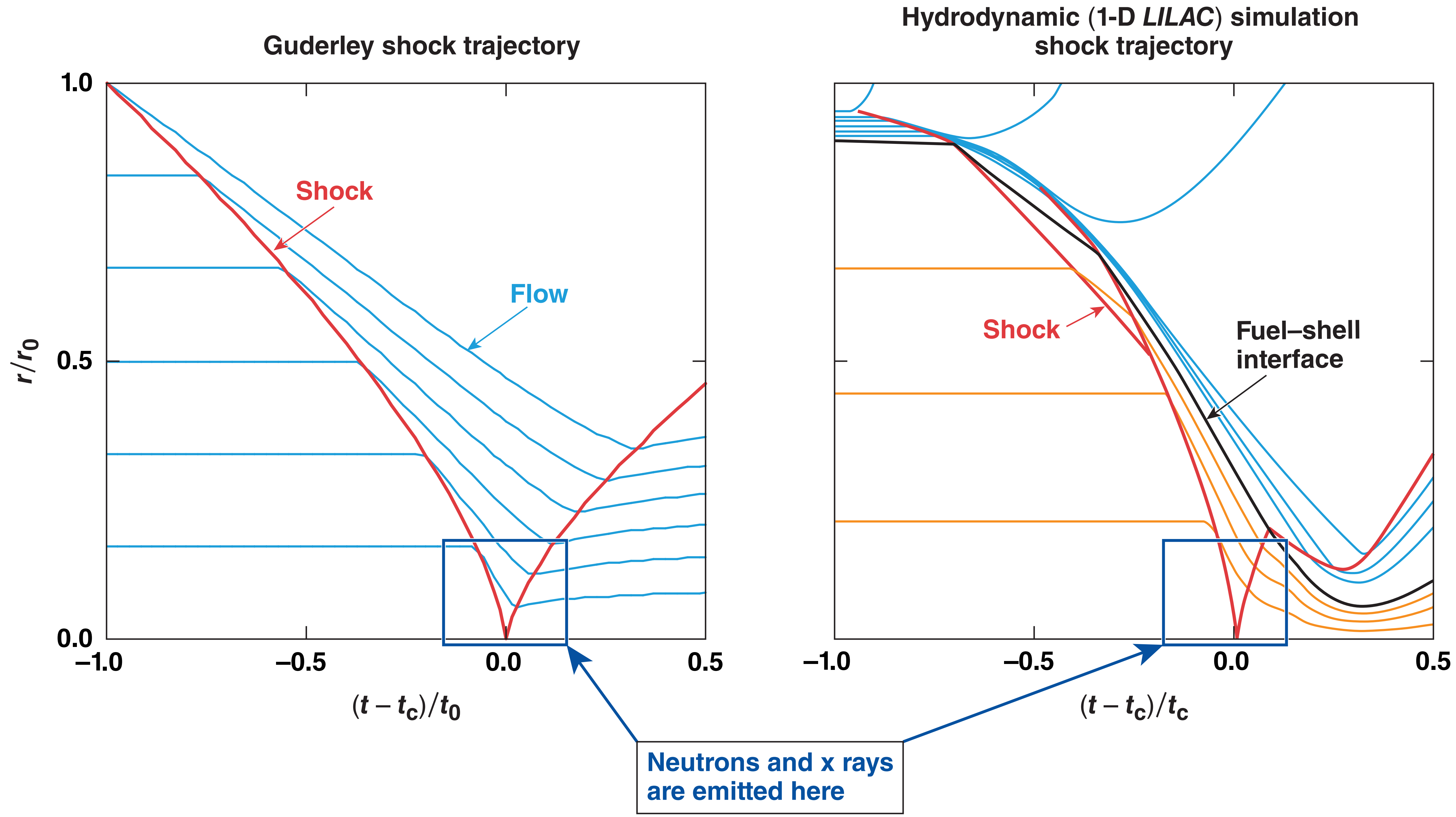

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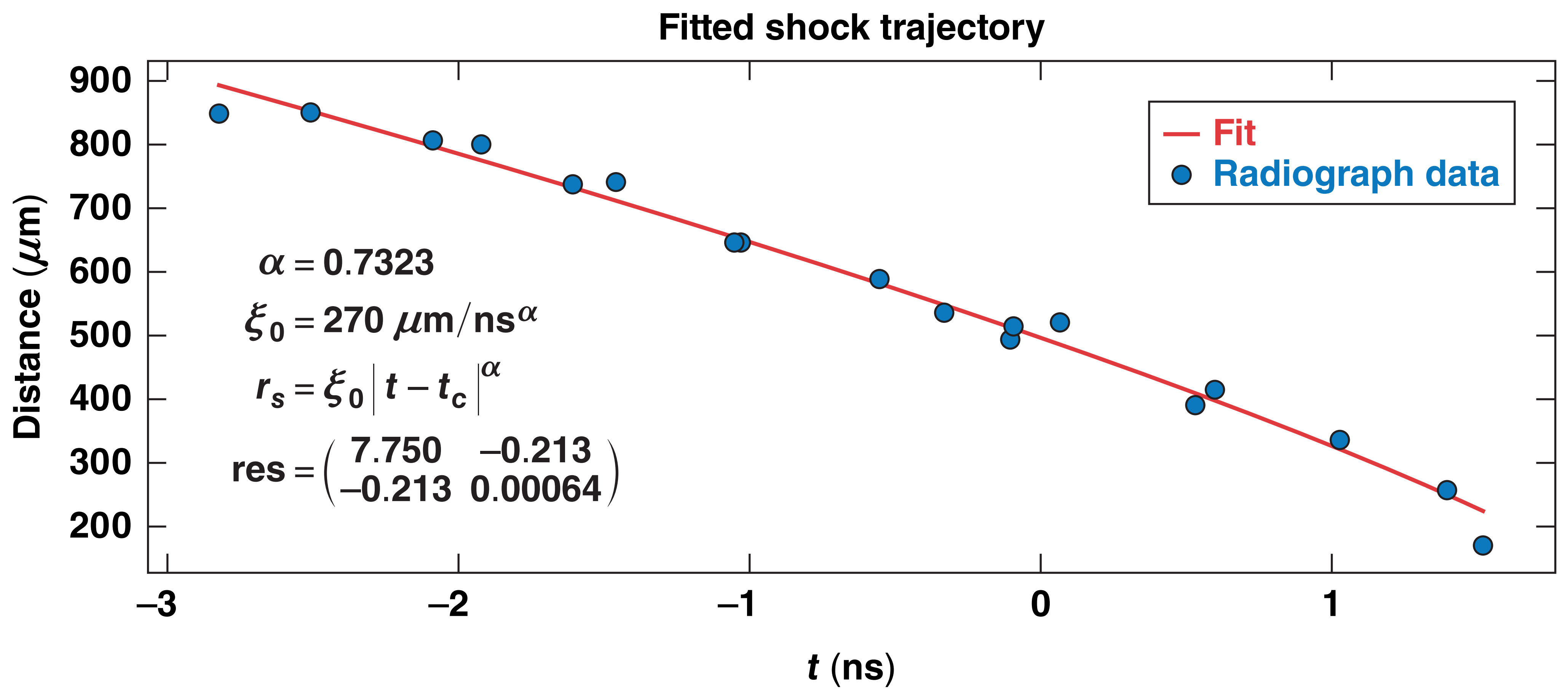

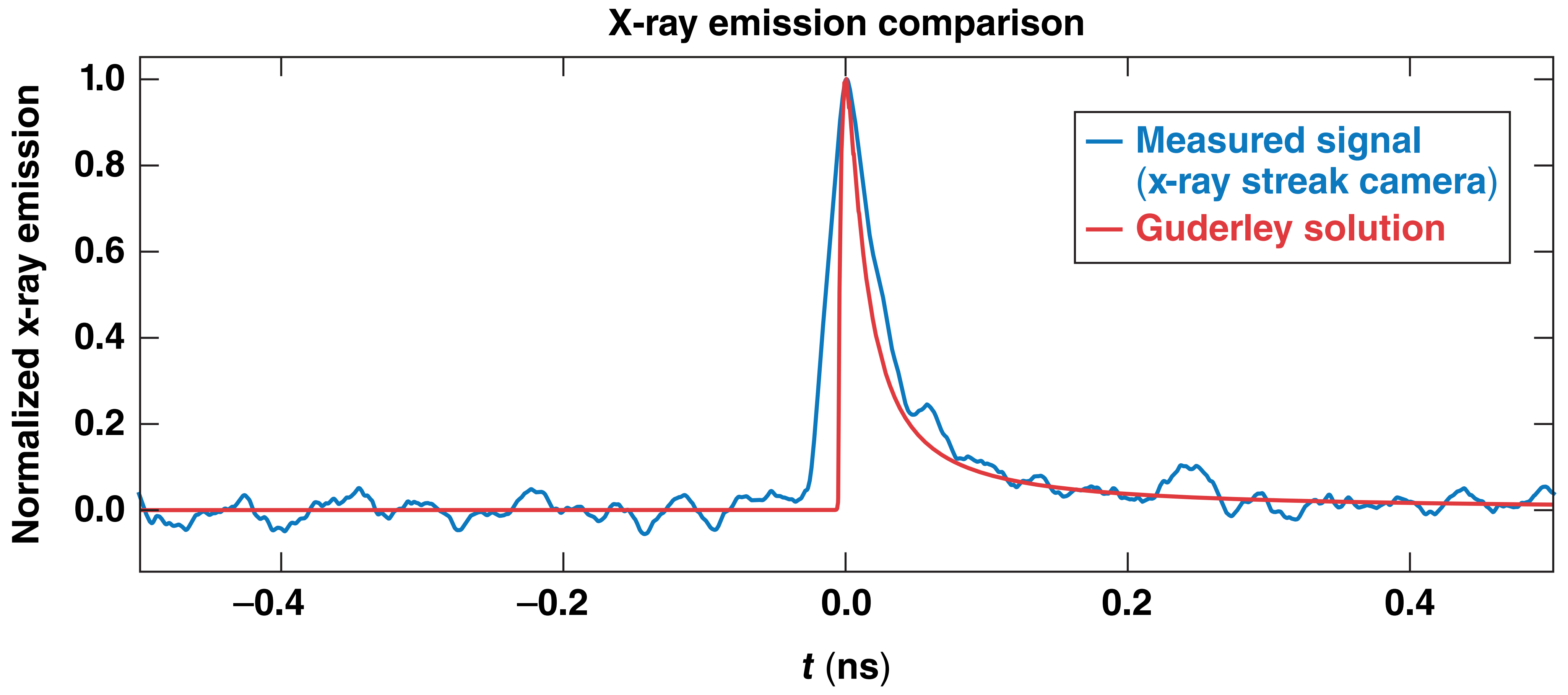

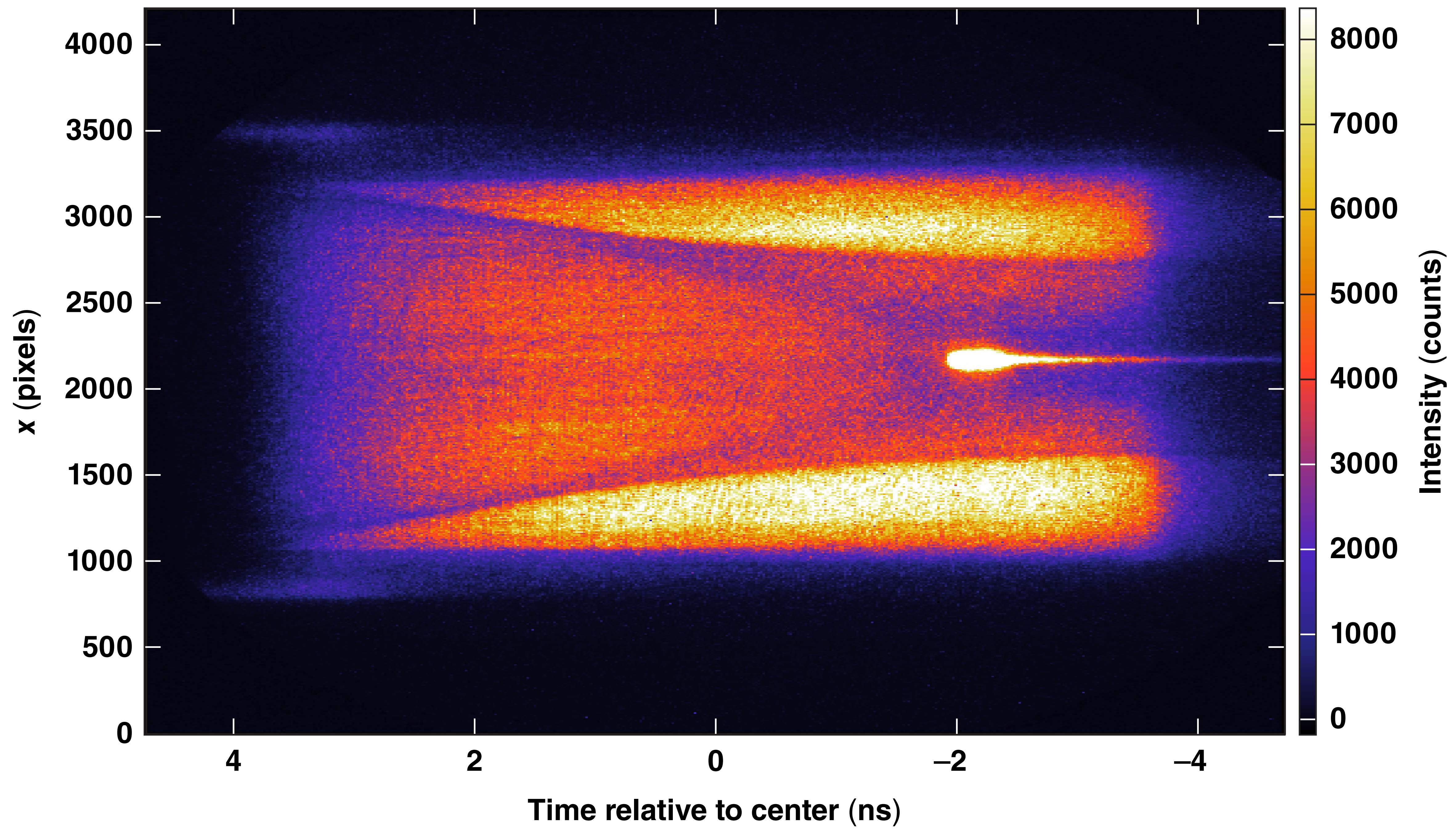

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