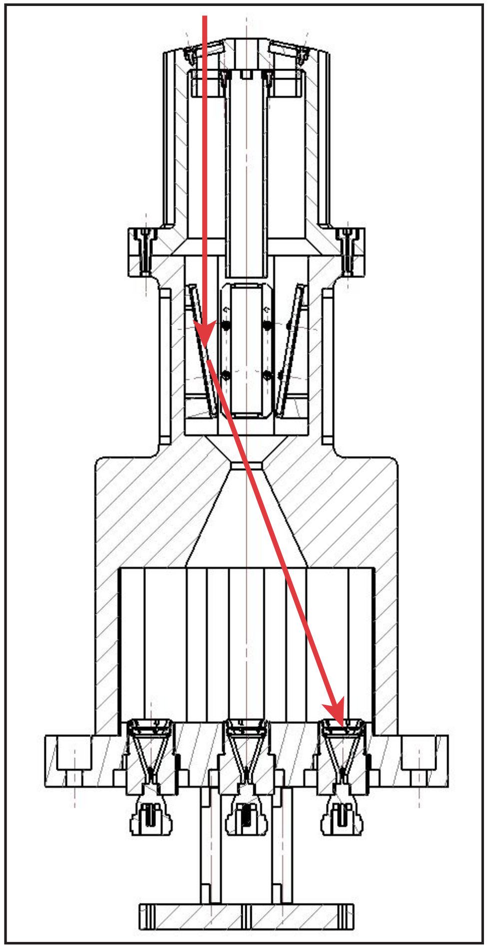
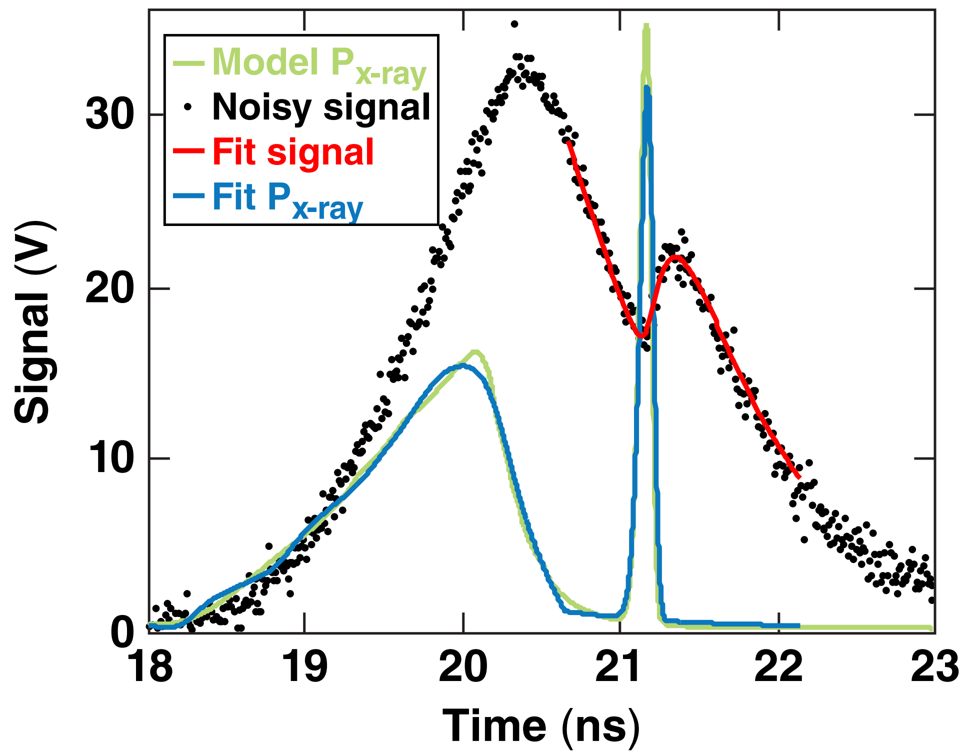
The South-Pole Bang-Time X-ray Diagnostic for the NIF





D. H. Edgell
University of Rochester
Laboratory for Laser Energetics

52nd Annual Meeting of the
American Physical Society
Division of Plasma Physics
Chicago, IL
8–12 November 2010

Summary

The south-pole bang-time has been designed to provide an x-ray bang-time measurement with 30-ps accuracy on the NIF

- An accurate bang time for NIF implosions is essential for validating implosion modeling and tuning performance
- The south-pole bang-time diagnostic* has
  - a view straight up along the NIF's south pole into the LEH
  - four high-bandwidth channels with different filtration to cover a range of THD and DT shots
  - HOPG monochromators to maximize signal:background
- The SPBT analysis combines deconvolution and forward fitting to determine the bang-time signal
- The SPBT is scheduled to be deployed in December 2010

*A. G. MacPhee *et al*., "A Diamond Detector for Quasi Monochromatic ICF X-Ray Bang-time Measurement," submitted to Journal of Instrumentation.

The south-pole bang-time (SPBT) diagnostic is a collaborative effort between LLE and NIF/LLNL

D. H. Edgell, J. Magoon, T. C. Sangster, M. J. Shoup III, F. J. Marshall, C. Stoeckl, V. Yu. Glebov, and many others

University of Rochester
Laboratory for Laser Energetics

A. MacPhee, J. Celeste, M. Eckart, S. Burns, J. R. Kimbrough, J. D. Kilkenny, J. Parker, T. Thomas, and many others

Lawrence Livermore National Laboratory
National Ignition Facility

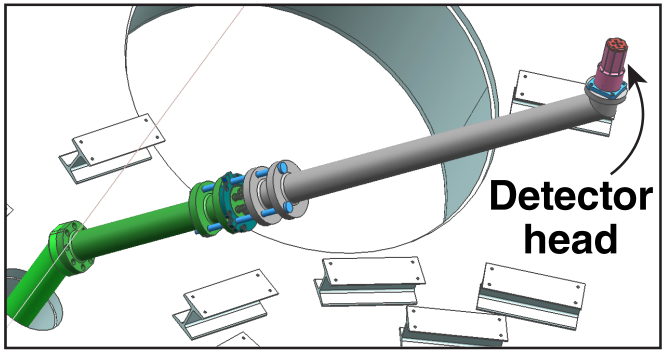
The SPBT diagnostic is needed to measure the bang time of NIF implosions with ~30-ps accuracy

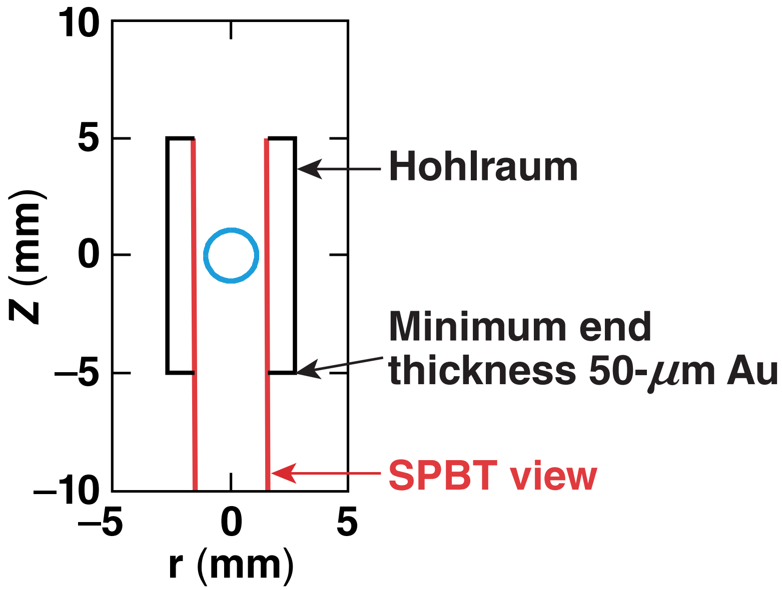
- NIF x-ray bang times from GXD vary consistently ~300 ps from DANTE x-ray-drive–based predictions
- The discrepancy is significantly more than the uncertainties
- Is this
  - a hohlraum low-drive issue
  - a capsule hydrodynamics issue
  - or a measurement issue?

Need to verify the bang-time measurements within 30 ps using another diagnostic.

The SPBT is designed to have a high-bandwidth, low-background signal to achieve 30-ps accuracy

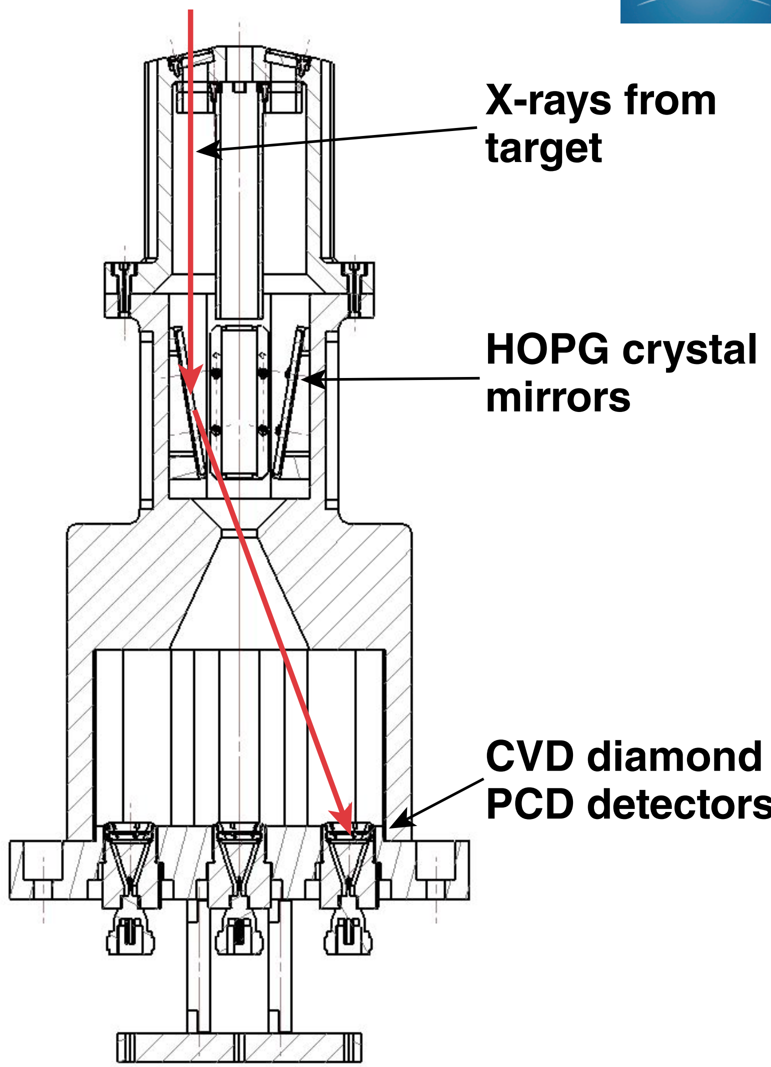
- SPBT is not DIM-mounted and has a permanent dedicated fixture
- SPBT views straight up the south pole and sees little of the hohlraum wall
  - should have low background
- High-bandwidth scopes, cables, and connectors are used
- Optical fibers will be used to connect to NIF mezzanine to reduce cable effects





The signal-to-background levels are maximized using HOPG monochromators to select an appropriate energy band

- HOPG (highly ordered pyrolytic graphite)
  - grade ZYB: ~1-μm crystallites, parallel to within ~0.8°
- Reflects x-rays that satisfy the Bragg condition: 11 keV
  - predictions indicate that the capsule bang-time x-ray spectrum peaks in the 9- to 12-keV range
- Four PCD channels with different filtration on each channel to cover a range of THD and DT shots

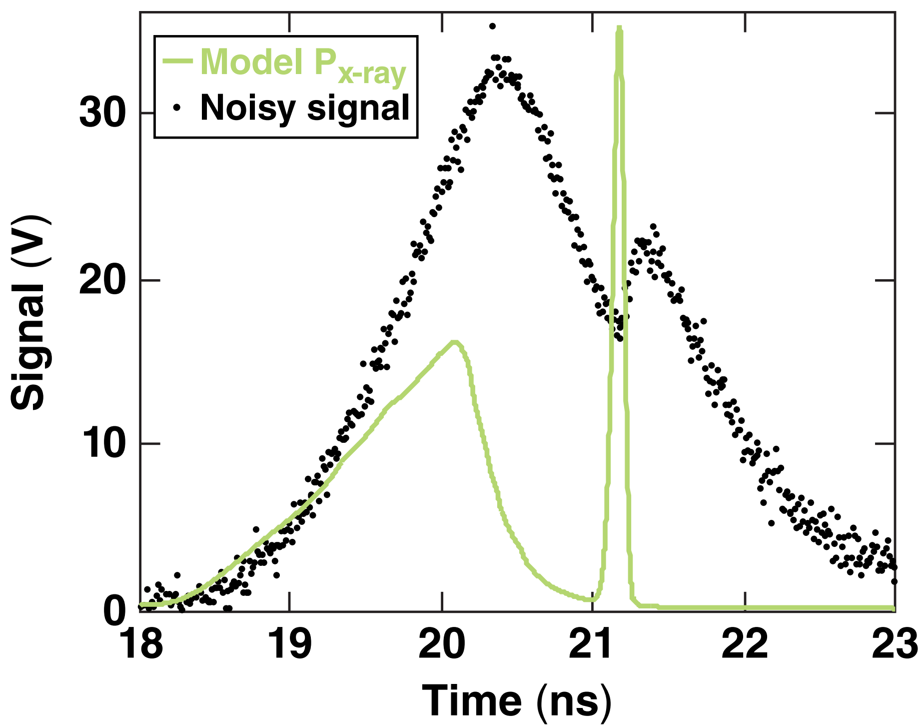


E19457

The expected SPBT signal is modeled by applying instrument response functions (IRF's) to the predicted x-ray source

- X-ray power $P_{x\text{-ray}}(t)$ includes
  - detector solid angle
  - spectral IRF
  - modeled x-ray spectral fluence
  - integrated over spectrum
- Detector signal $S(t)$ includes
  - convolution of temporal IRF with $P_{x\text{-ray}}(t)$
  - nonlinearity of bias circuit
  - attenuators
  - simulated noise

The bang-time analysis uses a forward fit of test $P(t)$ to the observed signal.



E19458

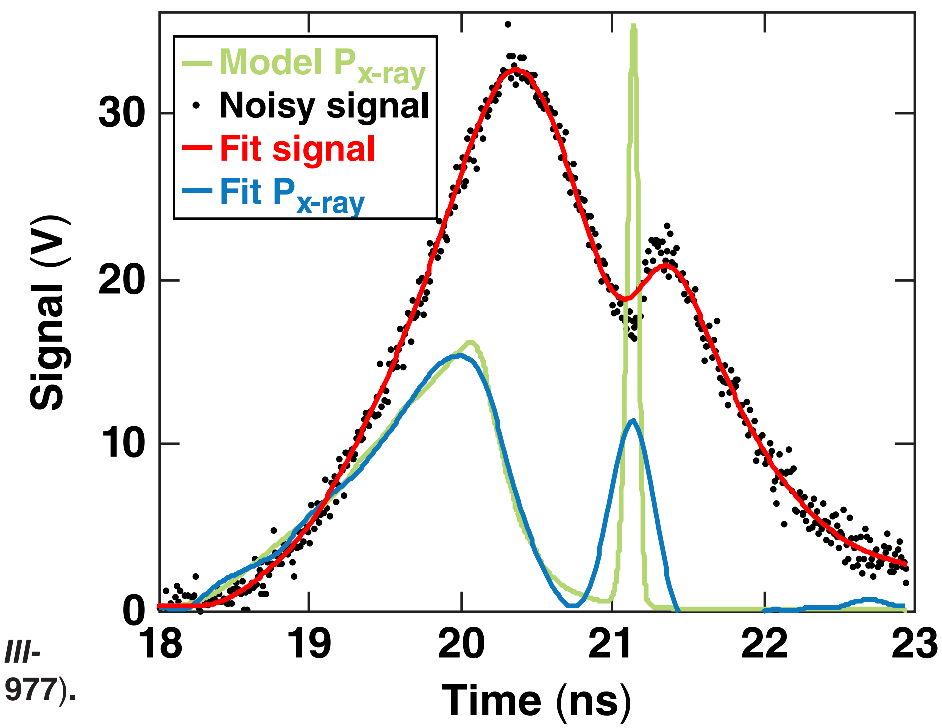
The x-ray background signal during the laser pulse is fit by deconvolution with Tikhonov regularization*

UR LLE

NIF

- Tikhonov regularization with a derivative operator enforces smoothness

- This allows one to determine the background signal driven by the laser pulse (LPI, etc.) without any assumptions as to how it varies with time

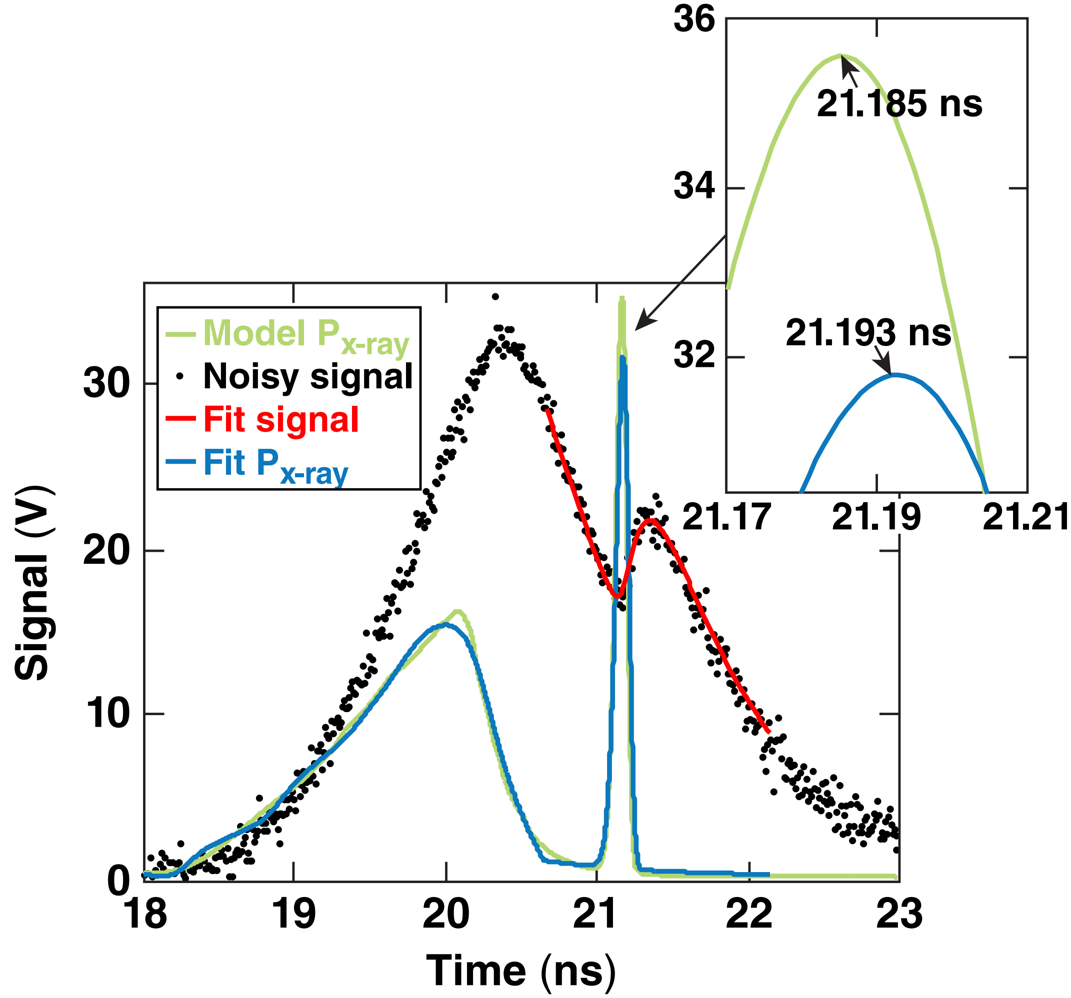


*A. N. Tikhonov and V. Y. Arsenin, *Solutions of Ill-Posed Problems* (Winston, Washington, DC, 1977).

E19459

The bang-time signal is determined by forward fitting with a decaying background and a skewed Gaussian peak

- Combination with deconvolution results provides a good reconstruction of both the x-ray background and the bang-time peak even in the presence of noise
  - 5- to 10-ps accuracy in the data fitting
  - other instrumental timing issues give ~30-ps total accuracy



E19460

Summary/Conclusions

The south-pole bang-time has been designed to provide an x-ray bang-time measurement with 30-ps accuracy on the NIF

- An accurate bang time for NIF implosions is essential for validating implosion modeling and tuning performance
- The south-pole bang-time diagnostic* has
  - a view straight up along the NIF's south pole into the LEH
  - four high-bandwidth channels with different filtration to cover a range of THD and DT shots
  - HOPG monochromators to maximize signal:background
- The SPBT analysis combines deconvolution and forward fitting to determine the bang-time signal
- The SPBT is scheduled to be deployed in December 2010

*A. G. MacPhee *et al*., "A Diamond Detector for Quasi Monochromatic ICF X-Ray Bang-time Measurement," submitted to Journal of Instrumentation.