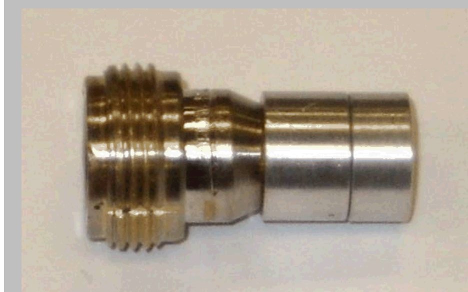
SAND2017-11398C



Utilization of Neutron Bang-time CVD diamond detectors at the Z Accelerator

59th Annual Meeting of the APS Division of Plasma Physics: October 23-27, 2017; Milwaukee, Wisconsin

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2011-XXXXP

Abstract: Utilization of Neutron Bang-time CVD diamond detectors at the Z Accelerator

GORDON CHANDLER, KELLY HAHN, CARLOS RUIZ, BRENT JONES, PERRY ALBERTO, JOSE TORRES, MATTHEW GOMEZ, ERIC HARDING, ADAM HARVEY-THOMPSON, MARK HESS, PATRICK KNAPP, Sandia Natl Labs,

GARY COOPER, JEDEDIAH STYRON, University of New Mexico,

KEN MOY, IAN MCKENNA, Special Technologies Laboratory,

VLADIMIR GLEBOV, Laboratory for Laser Energetics

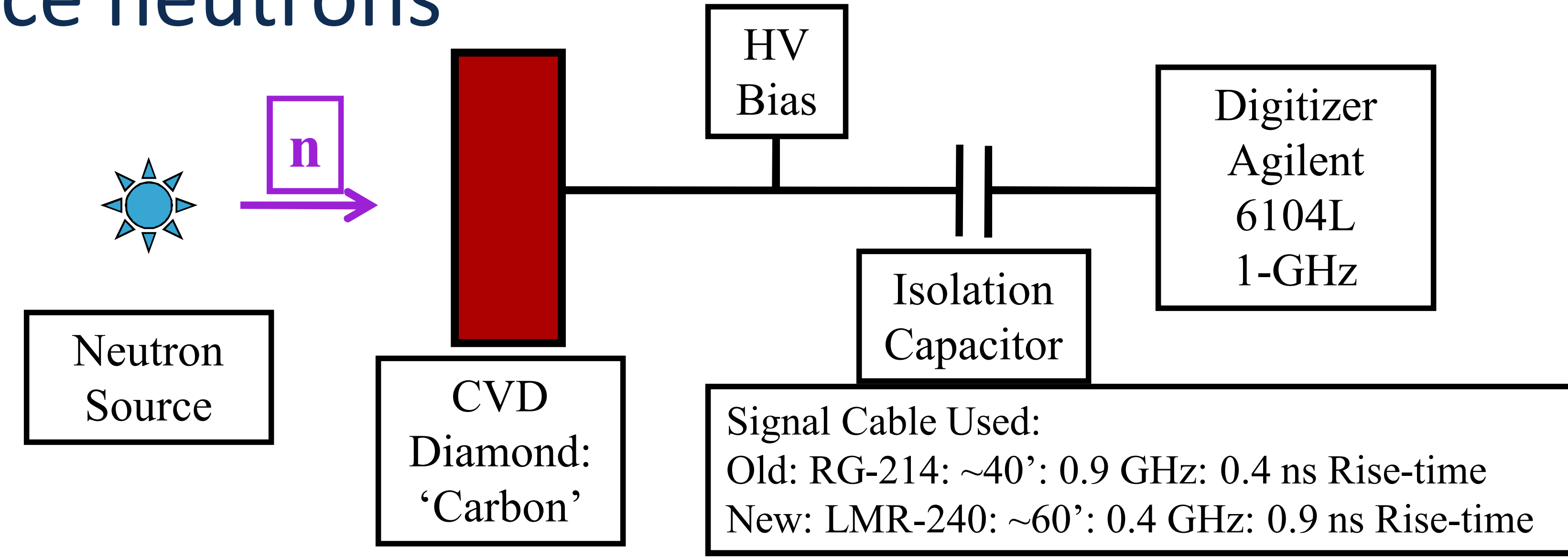
DAVID FITTINGHOFF, MARK J. MAY, LUCAS SNYDER, DAN BOWERS, Lawrence Livermore National Laboratories

We are utilizing Chemical Vapor Deposited (CVD) Diamond detectors at ˜ 2.3 meters on the Z accelerator to infer neutron bang-times from Magnetized Liner Inertial Fusion (MagLIF) sources yielding up to 3e12 DD neutrons and to bound the neutron time history of Deuterium Gas Puff loads producing 5e13 DD neutrons. The current implementation of the diagnostic and initial results will be shown as well as our future plans for the diagnostic.

Neutron Bang Time Detector Status

- Detector Concept
- Present Detector Layout
- Some Data: MagLIF
  - Bang-time Estimates
  - Simple fits
  - Noise
  - Future needs for collimation
- Collaboration with LLNL
  - Reduce EMP induced Noise
  - Look into a Cherenkov Based detector

The present NBT detector is based on the use of CVD diamonds to detect source neutrons

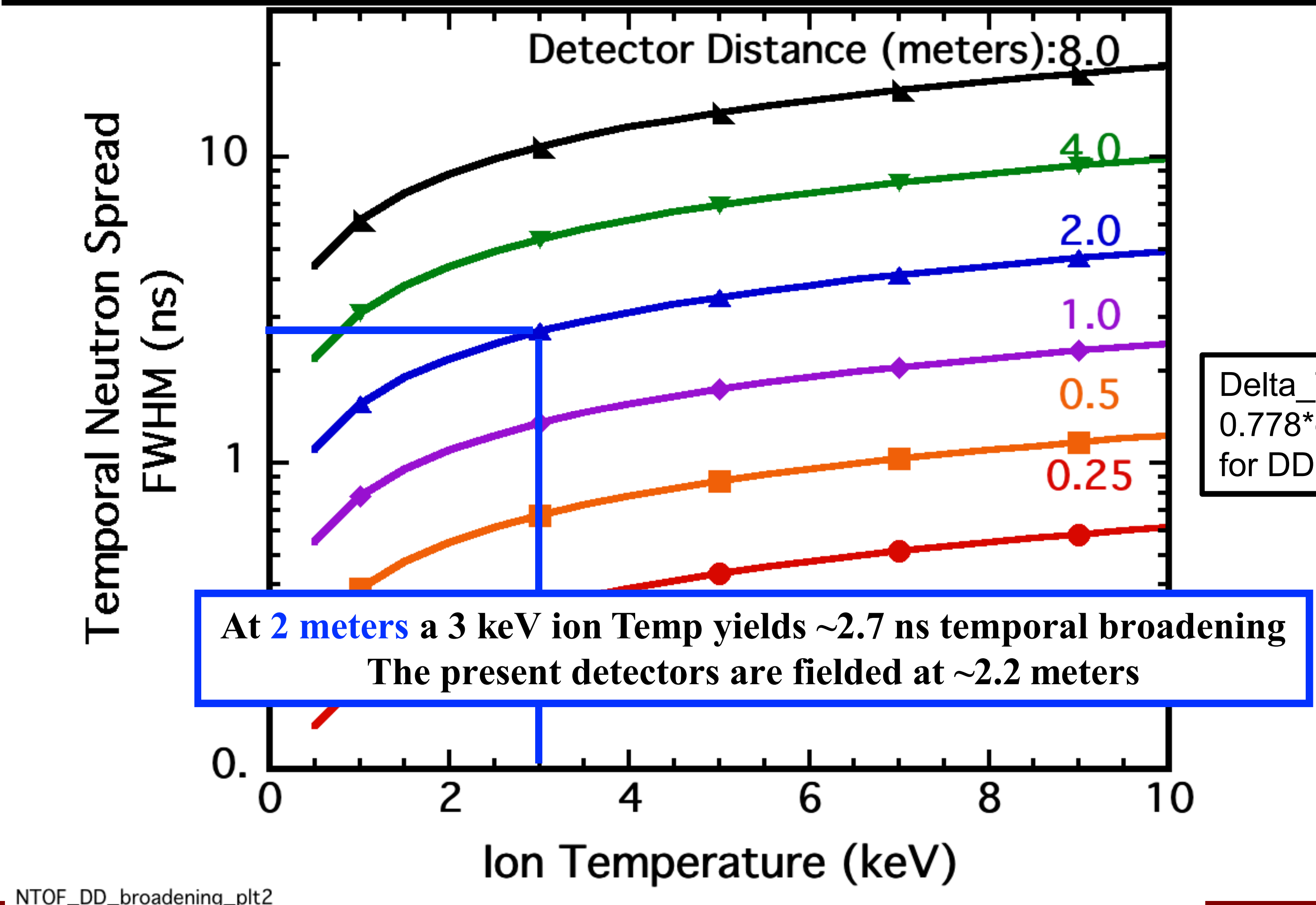


- DD neutrons elastically scatter off the carbon depositing ~0.37 MeV per interaction
- Electron-hole pairs created under the applied electric field create the observed electrical signal

- The detectors have a relatively fast time response
  - Fall time dominated by carrier lifetimes
- Fast recovery time
- They have demonstrated a large dynamic range ~ 5 orders of magnitude
- Relatively high neutron / gamma sensitivity for a solid state detector
- NOTE the Neutron Bang-time is made with respect to X-ray signals from other detectors!

The detector system is designed to be fielded near the load to minimize temporal broadening of the neutrons

DD temporal neutron spread due to the source ion-temperature

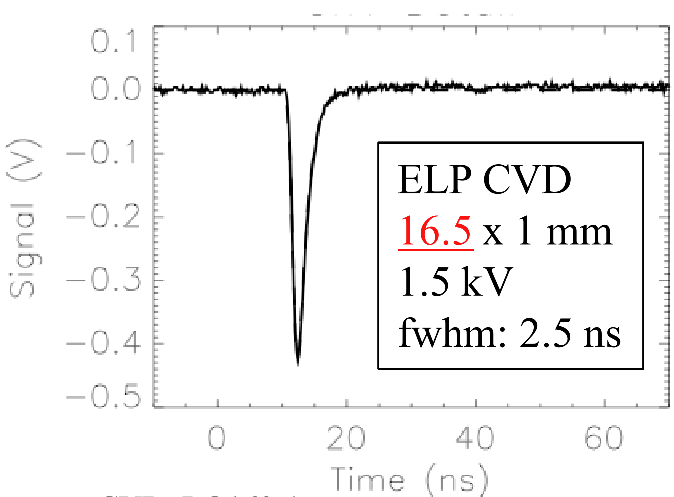


Delta_T (ns) = 0.778*d(meters)*Ti(KeV)^0.5 for DD neutrons

The present NBT detectors were fabricated and tested for their x-ray IRFs on Omega by Vladimir Glebov

Omega Shot 51874

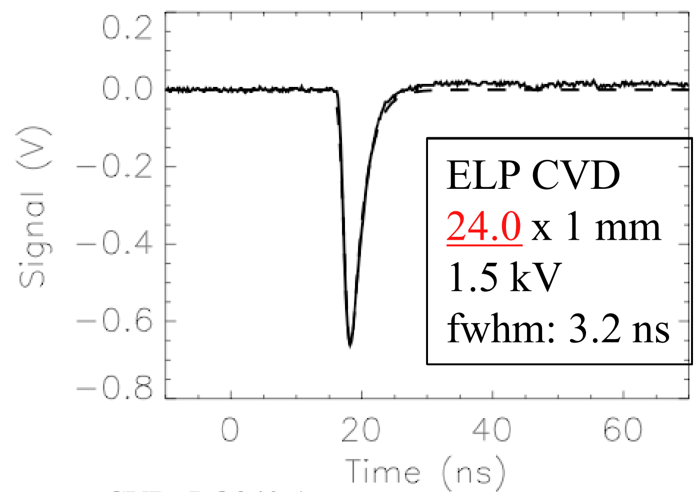
CVD: 16 mm



CVD: RO160-1

Signal	Rise	Fall	FWHM
−0.79	0.57	1.48	2.52

CVD: 24 mm



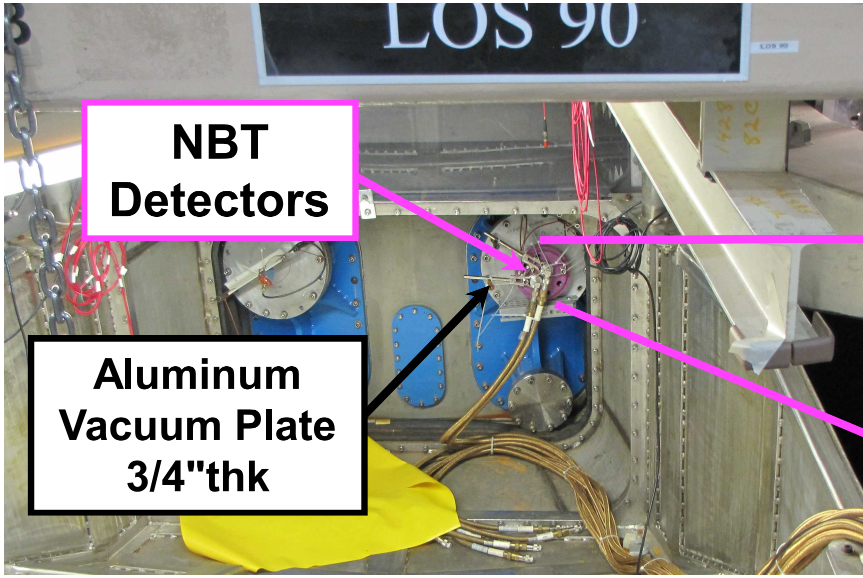
CVD: RO240-1

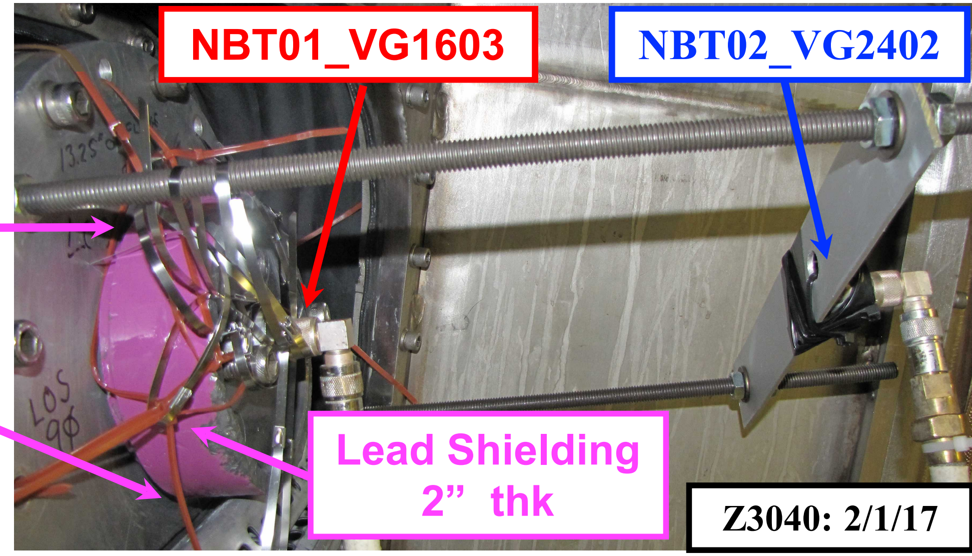
Signal	Rise	Fall	FWHM
−1.19	0.70	1.99	2.67

Large 16 and 24 mm diameter 1 mm Thick Electronic Grade CVD diamonds were used for enhanced sensitivity

Impulse response from x-ray signal obtained at ~50 cm from TCC

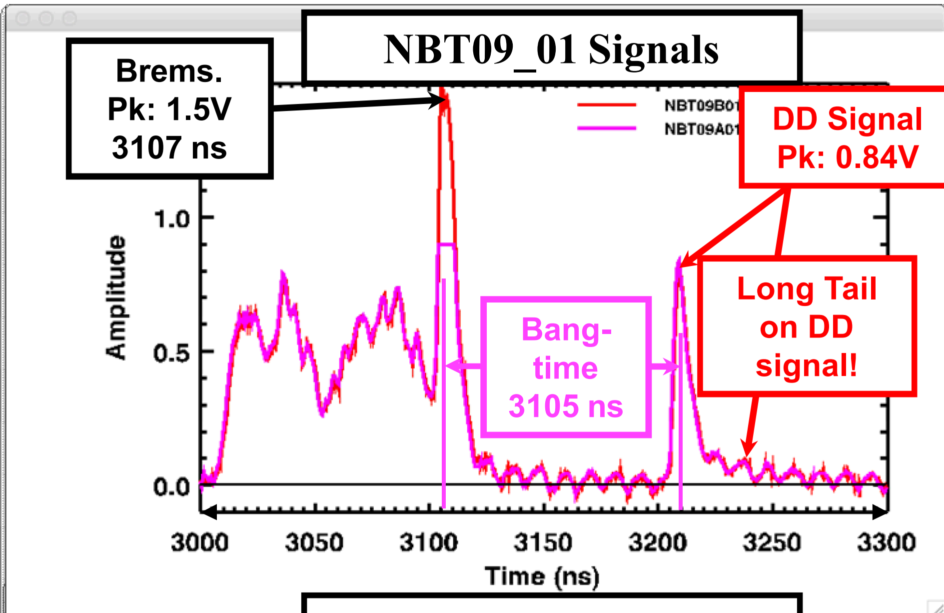
The NBT diagnostic is presently setup on Z on a 12 degree Vacuum port flange

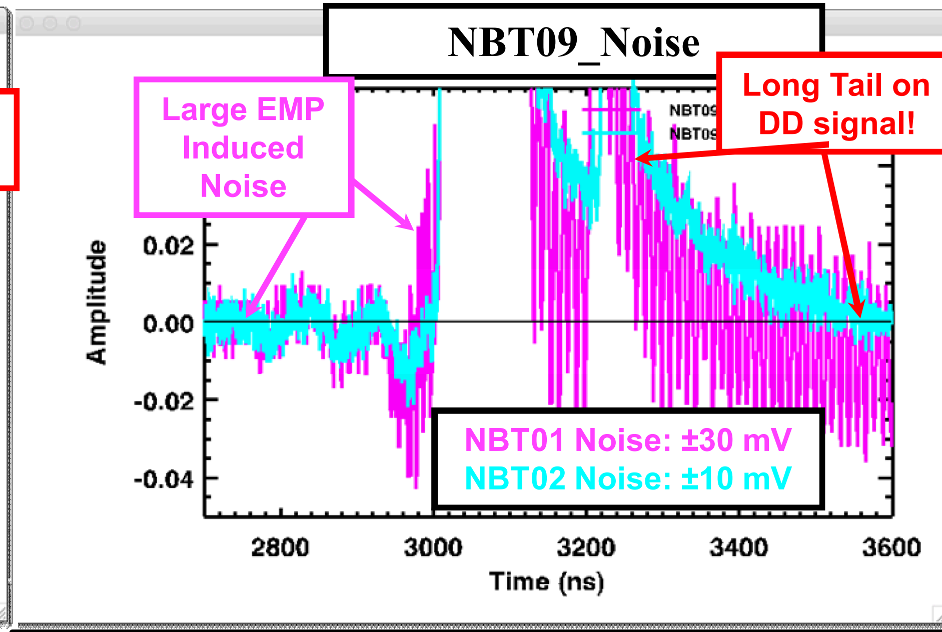


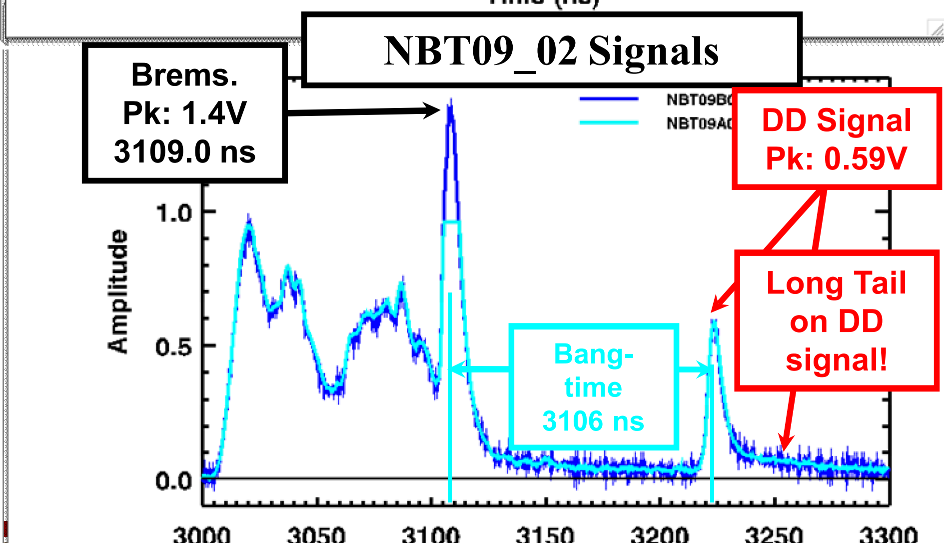


- The NBT01 and NBT02 Detectors are ~2.4 and ~2.7 meters from the source (~111 ns & 125 ns)
- The NBT01 and NBT02 detectors are separated by a foot to allow ~14 ns DD neutron TOF separation
- The ¾” Thk Aluminum Vacuum Plate & the 2” Thk lead Brems Shielding shown here attenuate the DD neutrons by: ~4.5x

Very good NBT signals were obtained on MagLIF Shot 3040 with a DD yield of 4.1E12



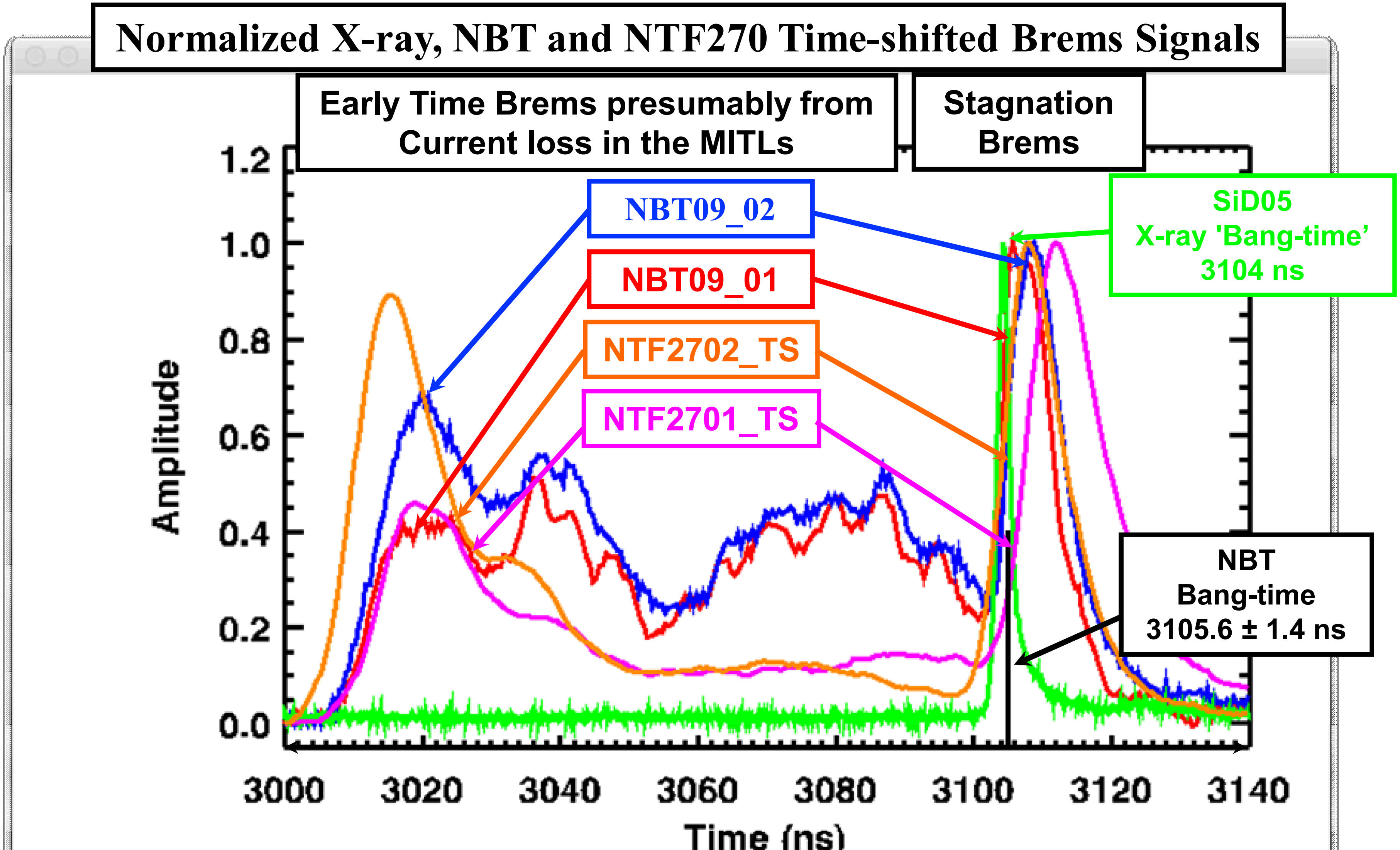




Shot Date: 2/1/17

- The NBT signals are taken with the photon TOF in the header
- The time delay between the NBT09_01 and NBT09_02 nTOF signals indicates a DD neutron signal is being observed
- The Neutron Bang-time is taken from the peak of the nTOF signals and time-correcting them for the photon & DD neutron TOF and ~1 ns detector through-put and rise-time

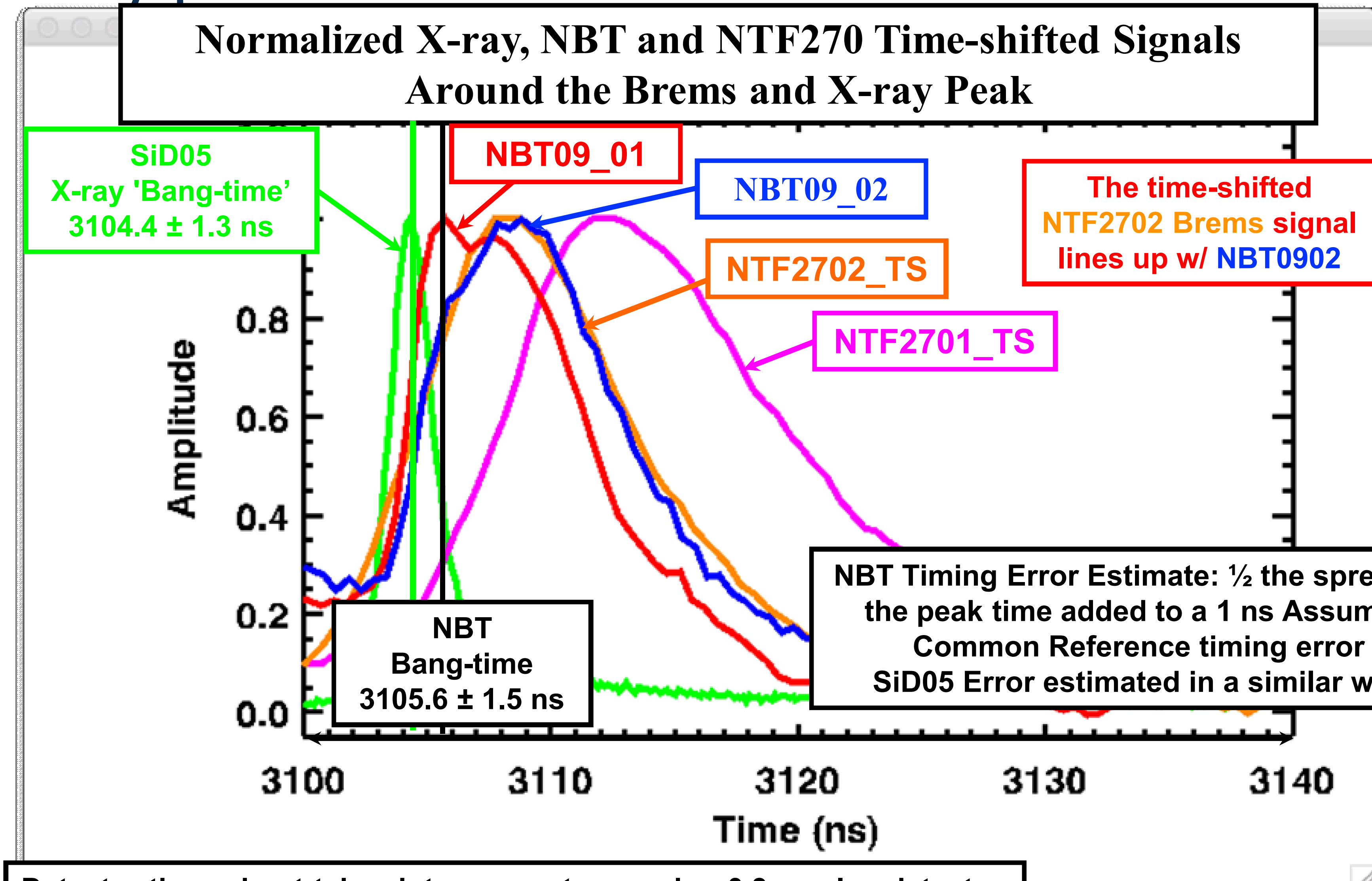
Normalized NBT and nTOF signals indicate the detectors see similar Brems structure



The Nominal 2" Thick lead Attenuation of the Detectors limits direct photon transmission to ~≥ 1 MeV

Z3040 Shot Date: 2/1/17

A simple analysis of the NBT data indicates a neutron bang-time 1.2 ± 1.5 ns after the X-ray peak but within error estimates



Detector throughput taken into account assuming 0.3 ns plus detector rise-time of ~0.65 ns

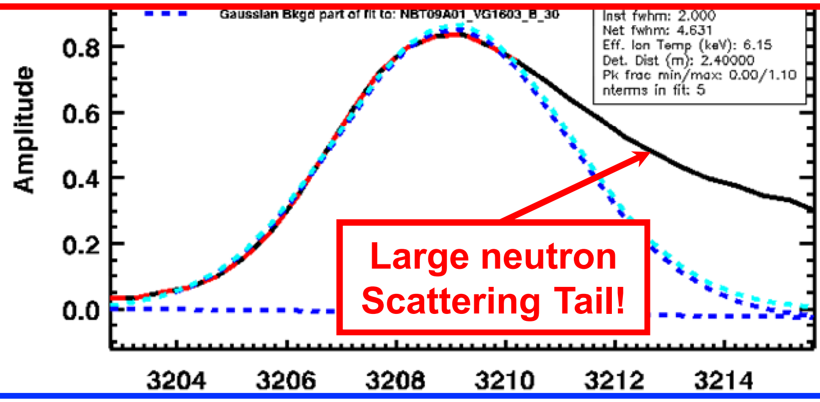
Z3040 Shot Date: 2/1/17

The NBT DD neutron signals recover the ~2.5 keV nTOF Detector Ion Temp with a 3.5 ns IRF and a 2 ns emission time

NBT09_01

Gaussian Fit to DD peak leading edge Indicates:

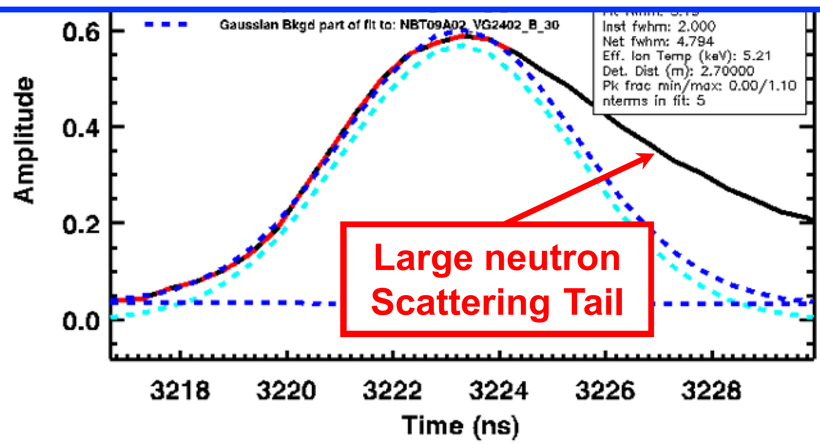
- **An Ion Temp of 2.5 keV & A Large scattering Tail**



NBT09_02

Gaussian Fit to DD peak leading edge Indicates:

- **An Ion Temp of 2.4 keV & A Large scattering Tail**



Gaussian Fits to the leading edge of the signal Indicate:

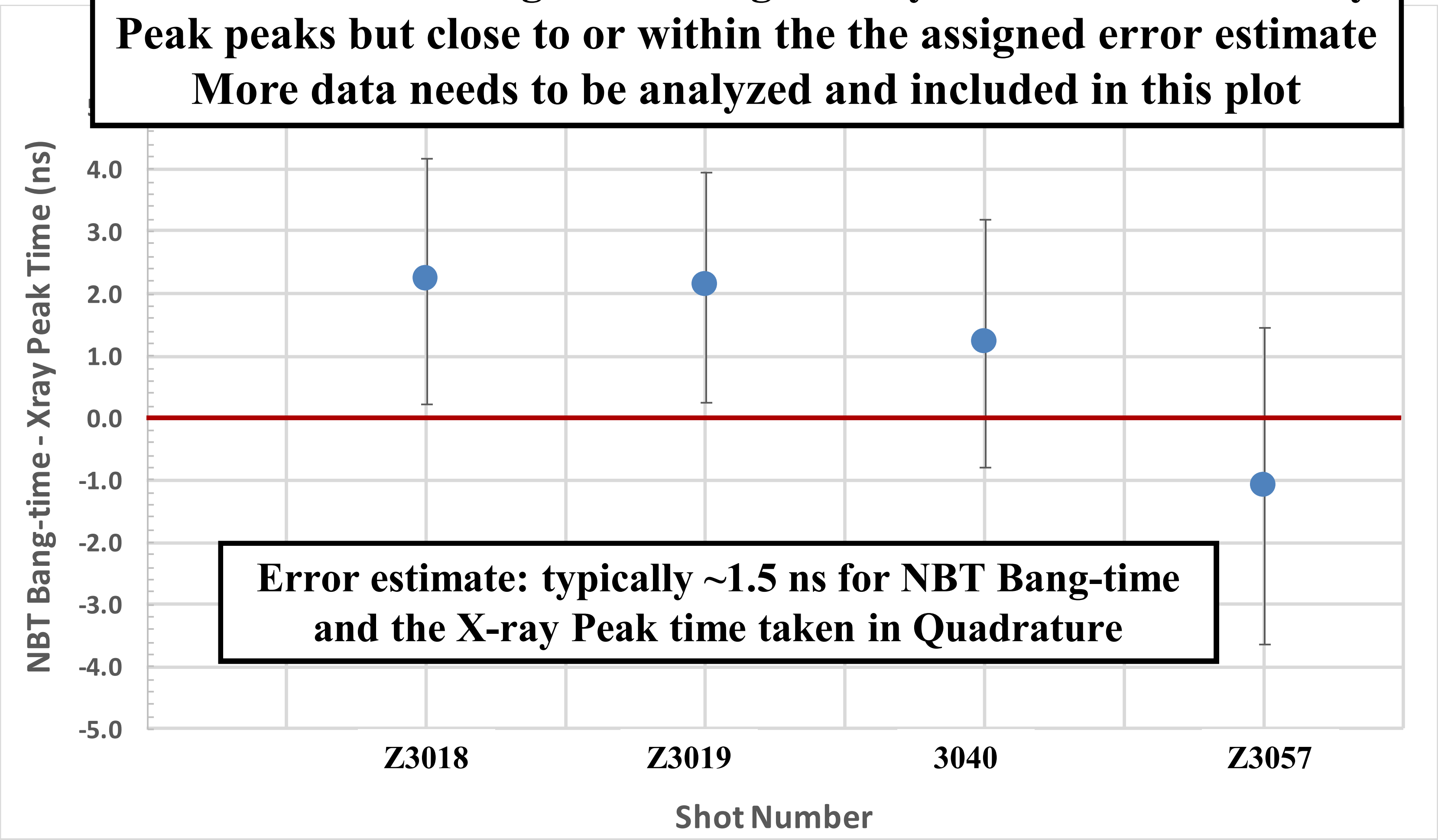
- **A large scattering Tail on the signals… We need to look at neutron collimation to improve these signals**
- **With an assumed 2 ns neutron Emission Time (x-ray emission time used) and a 3.5 ns IRF for the detectors taken out in quadrature from the Gaussian fit width an Ion-temp of ~2.5 keV can be inferred…**
- **nTOF inferred ion-temp: 2.6 keV**

Thermal Broadening
@ 2.3 meters at:
~1 keV is ~1.8 ns
~2 keV is ~2.5 ns
~3 keV is ~3 ns

Z3040 Shot Date: 2/1/17

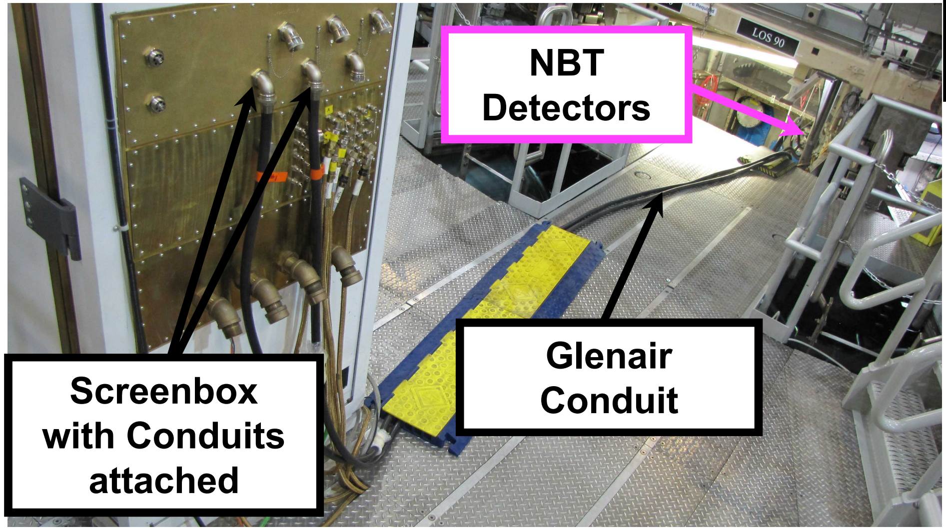
The Difference in the NBT Neutron Bang-time to the peak of the X-ray Signals for a few MagLIF shots

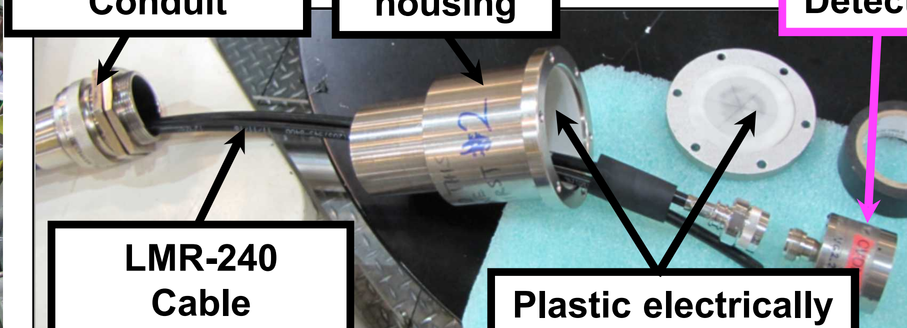
The initial NBT Bang-times are generally a little after the X-ray Peak peaks but close to or within the the assigned error estimate More data needs to be analyzed and included in this plot

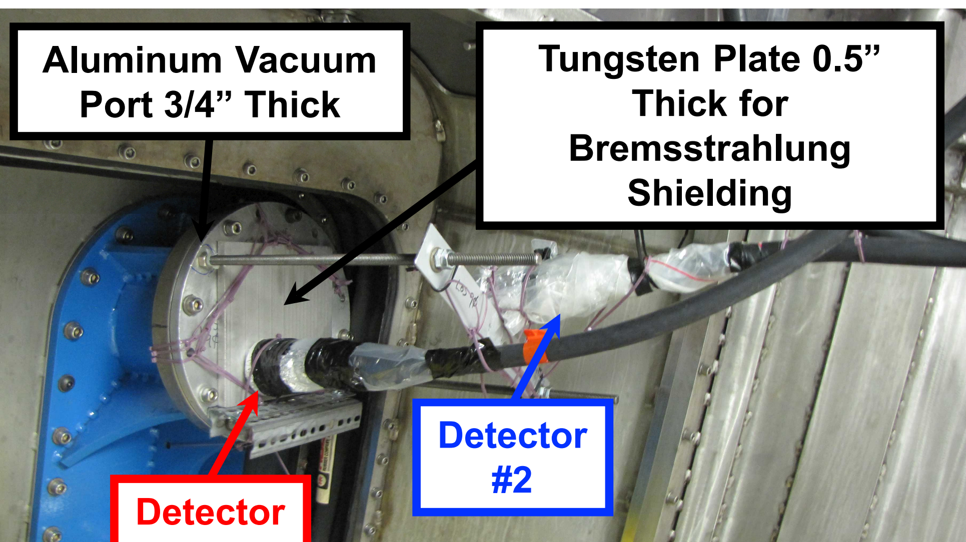


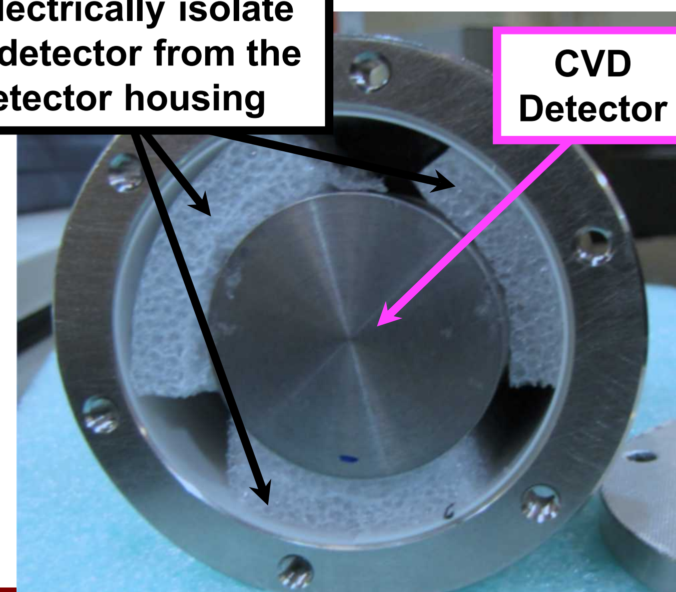
Error estimate: typically ~1.5 ns for NBT Bang-time and the X-ray Peak time taken in Quadrature

To reduce the large EMP induced noise (typically ~100 mV) a single point Screen-box ground was developed

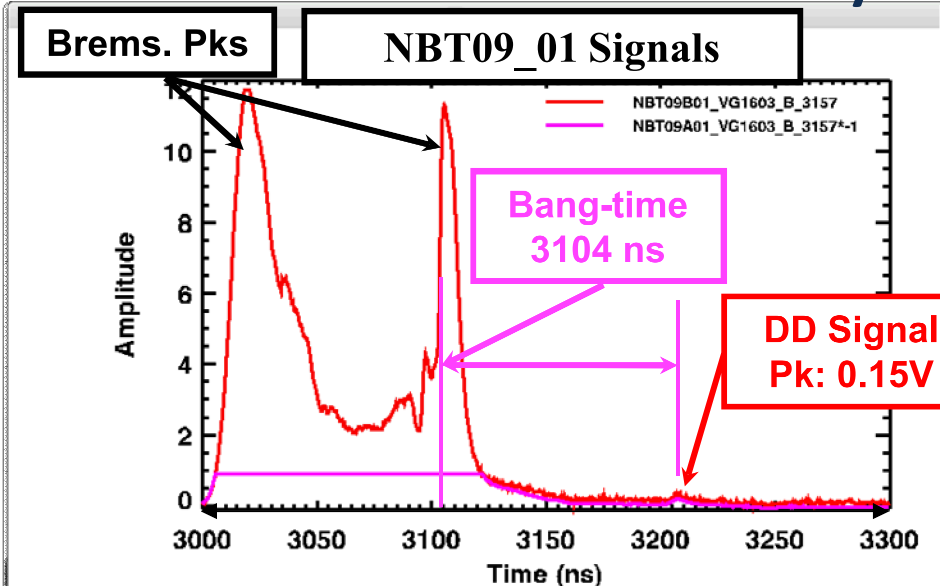


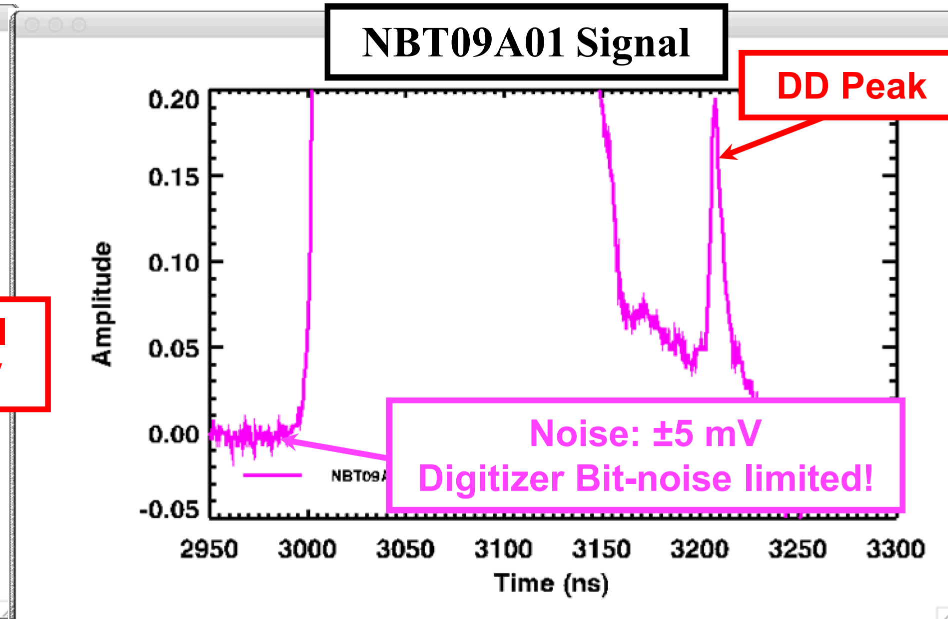


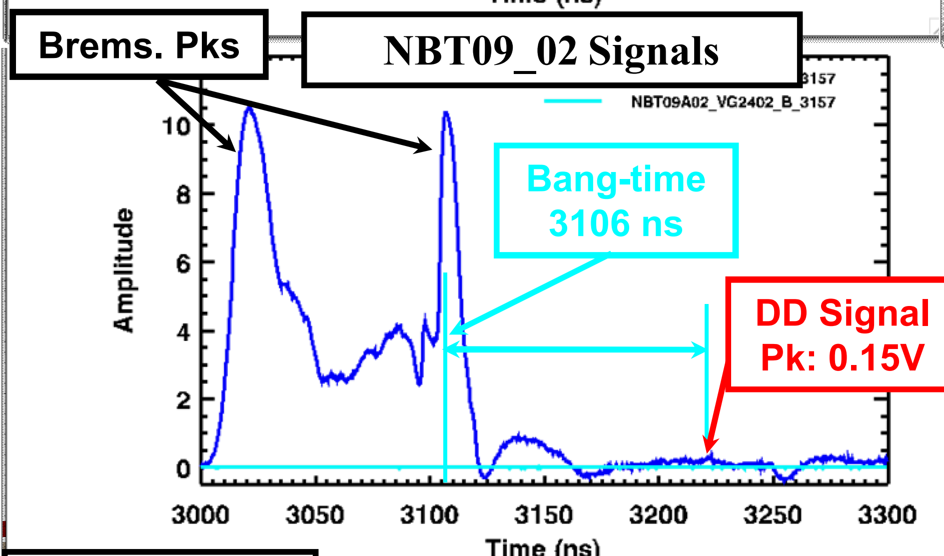




In this low noise setup a ±5mV bit noise limited signal was obtained on MagLIF Shot 3157 with a DD yield of ~6E11



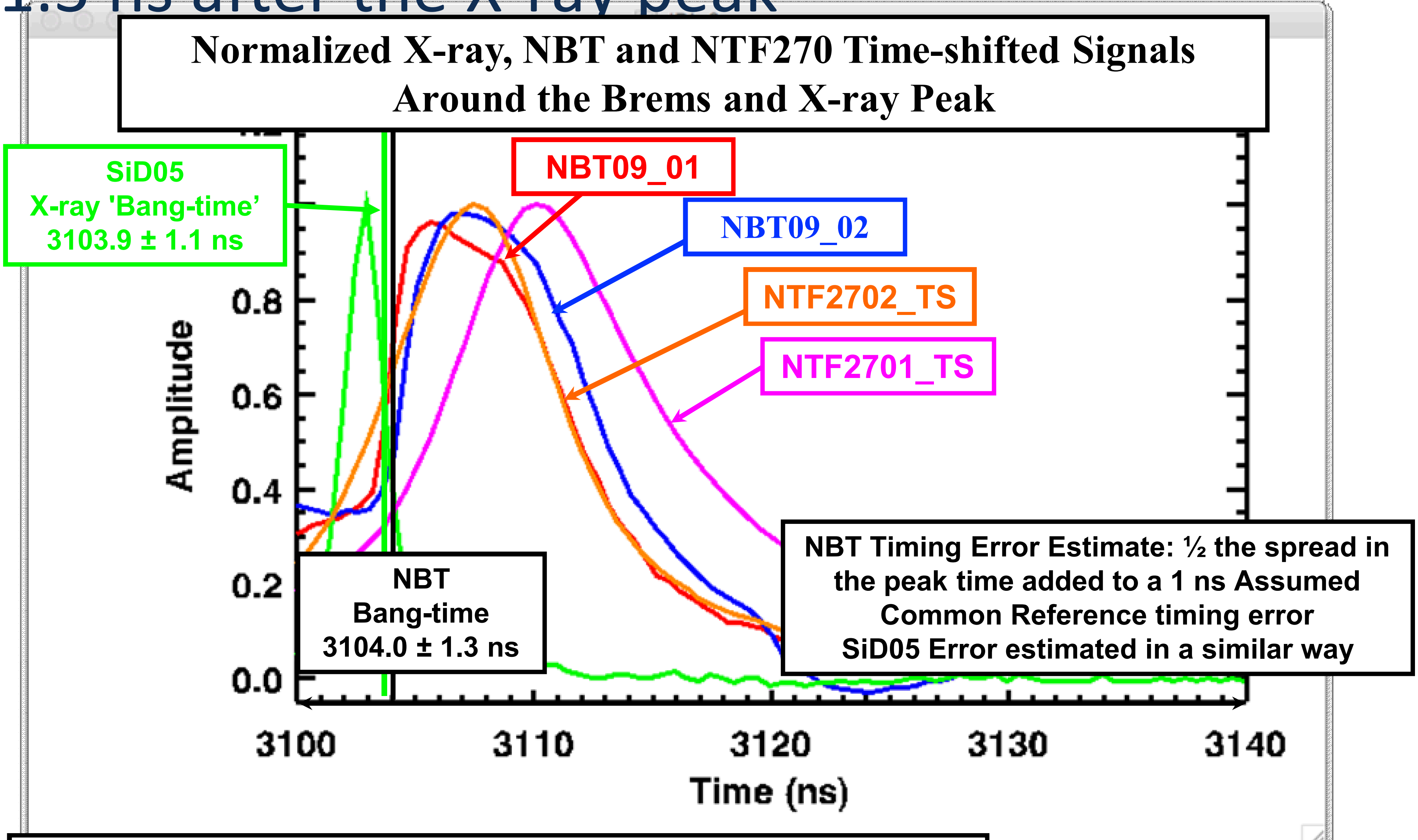




- The NBT signals are taken with the photon TOF in the header
- The time delay between the NBT09_01 and NBT09_02 nTOF signals indicates a DD neutron signal is being observed
- The Neutron Bang-time is taken from the peak of the nTOF signals and time-correcting them for the photon & DD neutron TOF and ~1 ns detector through put and rise-time

Shot Date: 10/11/17

A simple analysis of the Z3157 MagLIF NBT data indicates a neutron bang-time 0.1 ± 1.3 ns after the X-ray peak



Detector throughput taken into account assuming 0.3 ns plus detector rise-time of ~0.65 ns

Shot Date: 10/11/17

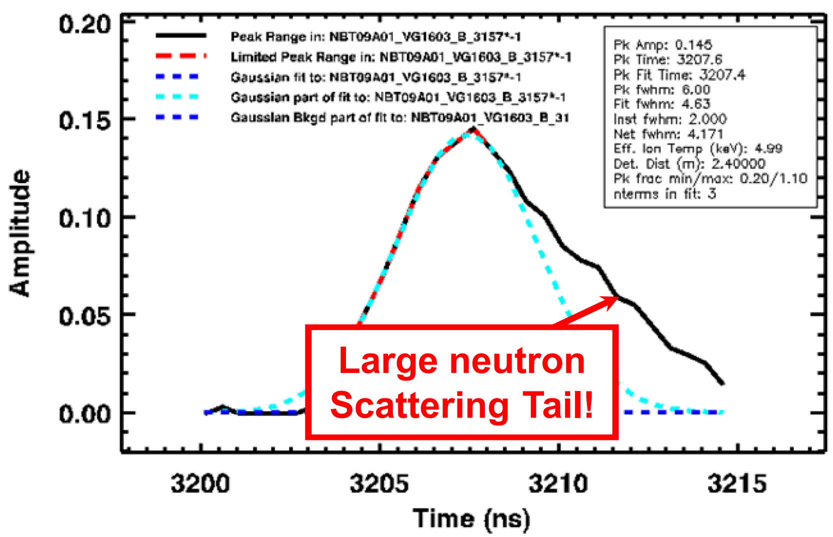
NBT DD neutron nTOF signal implies a ~3.2 keV nTOF Detector Ion Temp assuming a 2.5 ns IRF and a 2 ns emission time

Sandia National Laboratories

NBT09_01

Gaussian Fit to DD peak leading edge Indicates:

- **An Ion Temp of 3.2 keV & a Large Scattering Tail**

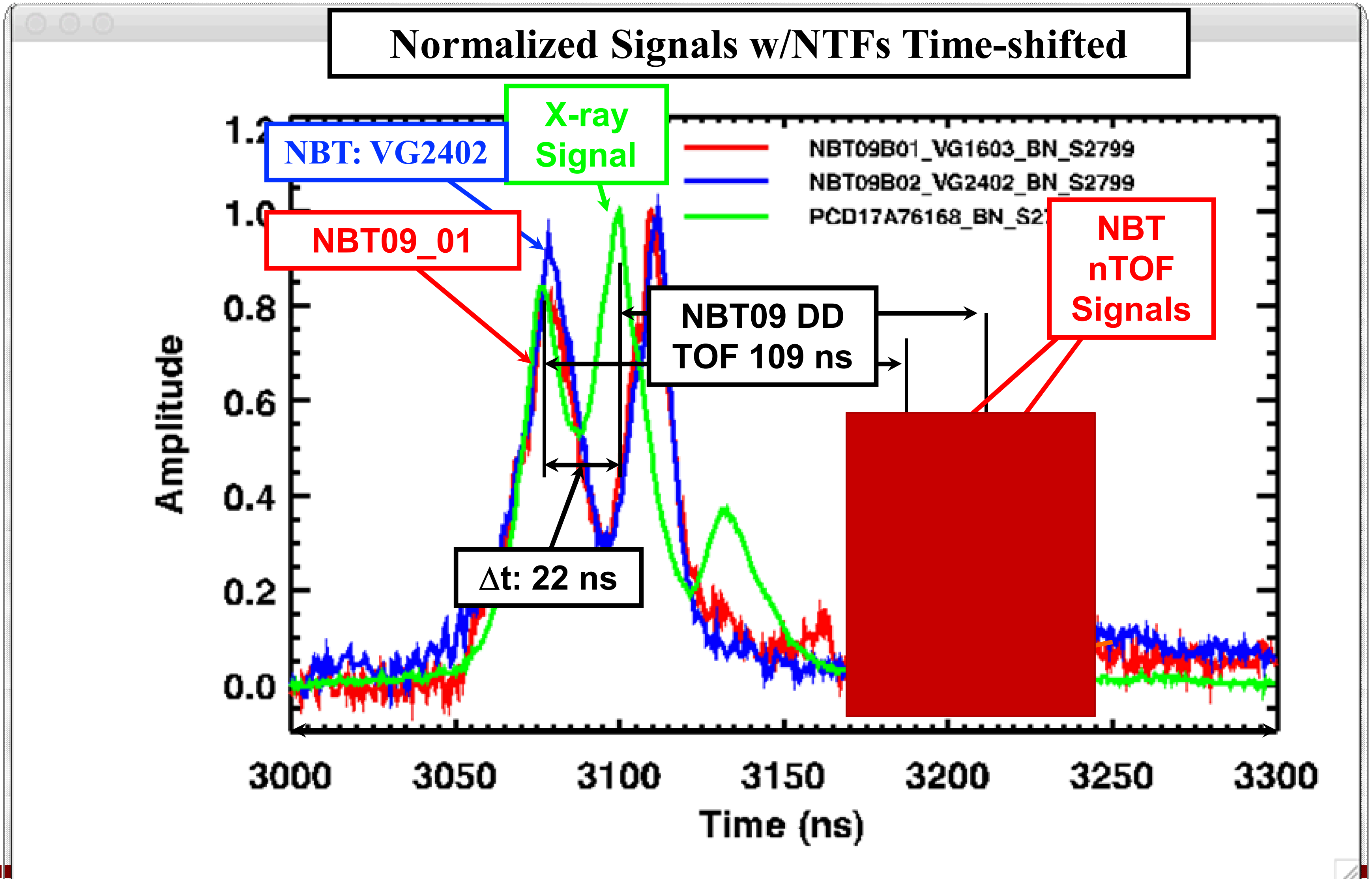


Gaussian Fits to the leading edge of the signal Indicate:

- **A large scattering Tail on the signals… We need to look at neutron collimation to improve these signals**
- **With an assumed 2 ns neutron Emission Time and a 3.5 ns IRF for the detectors taken out in quadrature from the Gaussian fit width an Ion-temp of ~2.5 keV can be inferred…**
- **nTOF inferred ion-temp: 2.6 keV**

Thermal Broadening @ 2.3 meters at:
~1 keV is ~1.8 ns
~2 keV is ~2.5 ns
~3 keV is ~3 ns

NBT data from a D2 Gas Puff shot on Z indicates two neutron bursts were generated: Yield ~4.2×10^{13}



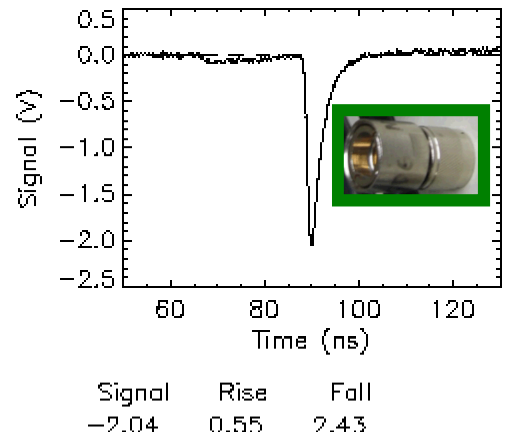
Z2799: Shot Date: 4/20/15

Faster CVD Diamond detectors can be fielded on Z but with reduced Sensitivity

Det: LLE

Shot 52068, DT yield 3.5 E12

Det: SNL: 05



Sens: 1.0x

EP CVD
10.0 x 1 mm
1.5 kV
fwhm: 2.9 ns

Potential New Detector

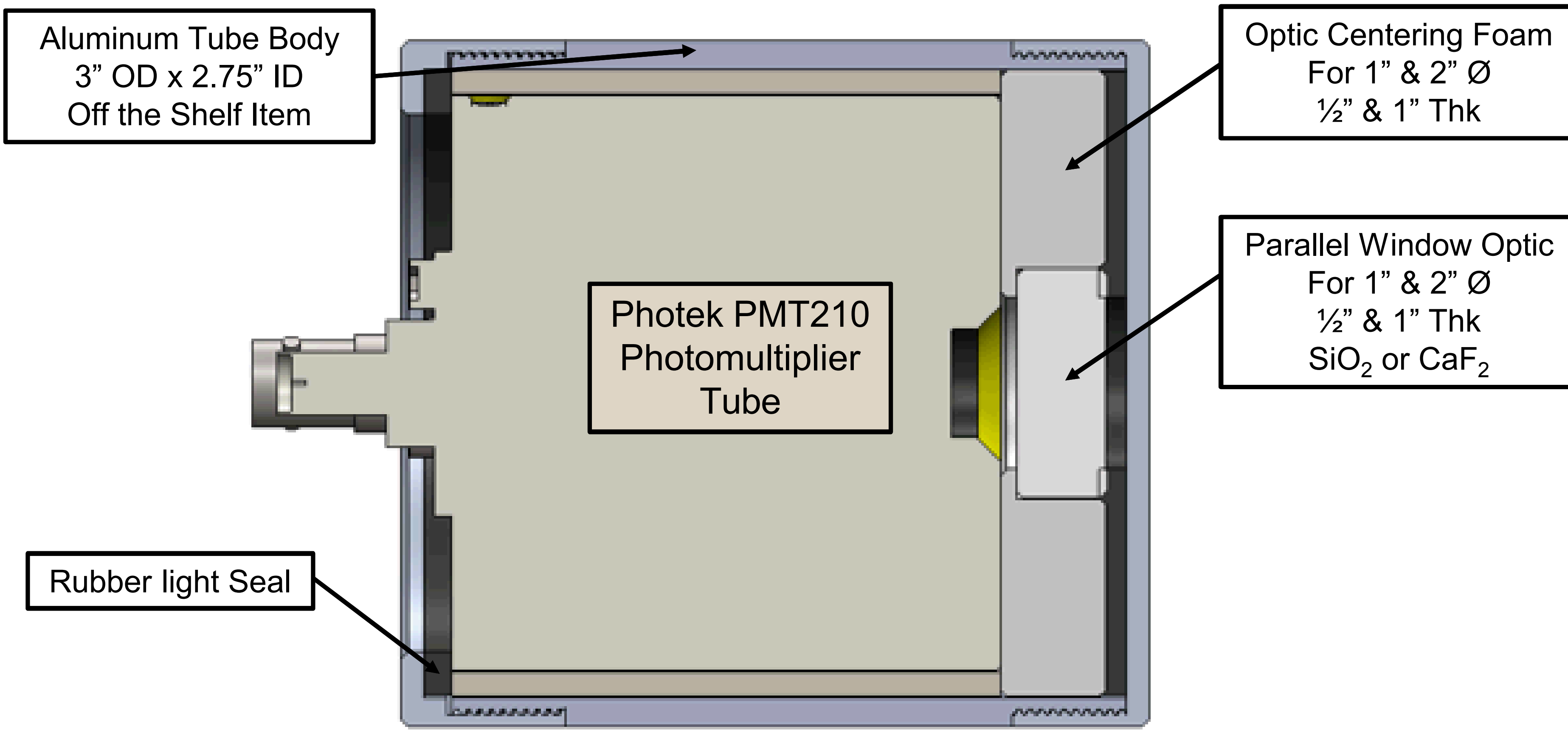
Similar to our present Detectors

Four different CVD diamond detectors were compared side by side at 292 cm from TCC in DT shots on OMEGA
The Sensitivity and time response of CVD detectors can be widely adjusted

We are exploring Cherenkov detectors which appear to allow for sub-ns IRFs

Sandia National Laboratories

This Detector Design has 1” Diameter ½” Thick Optical Window

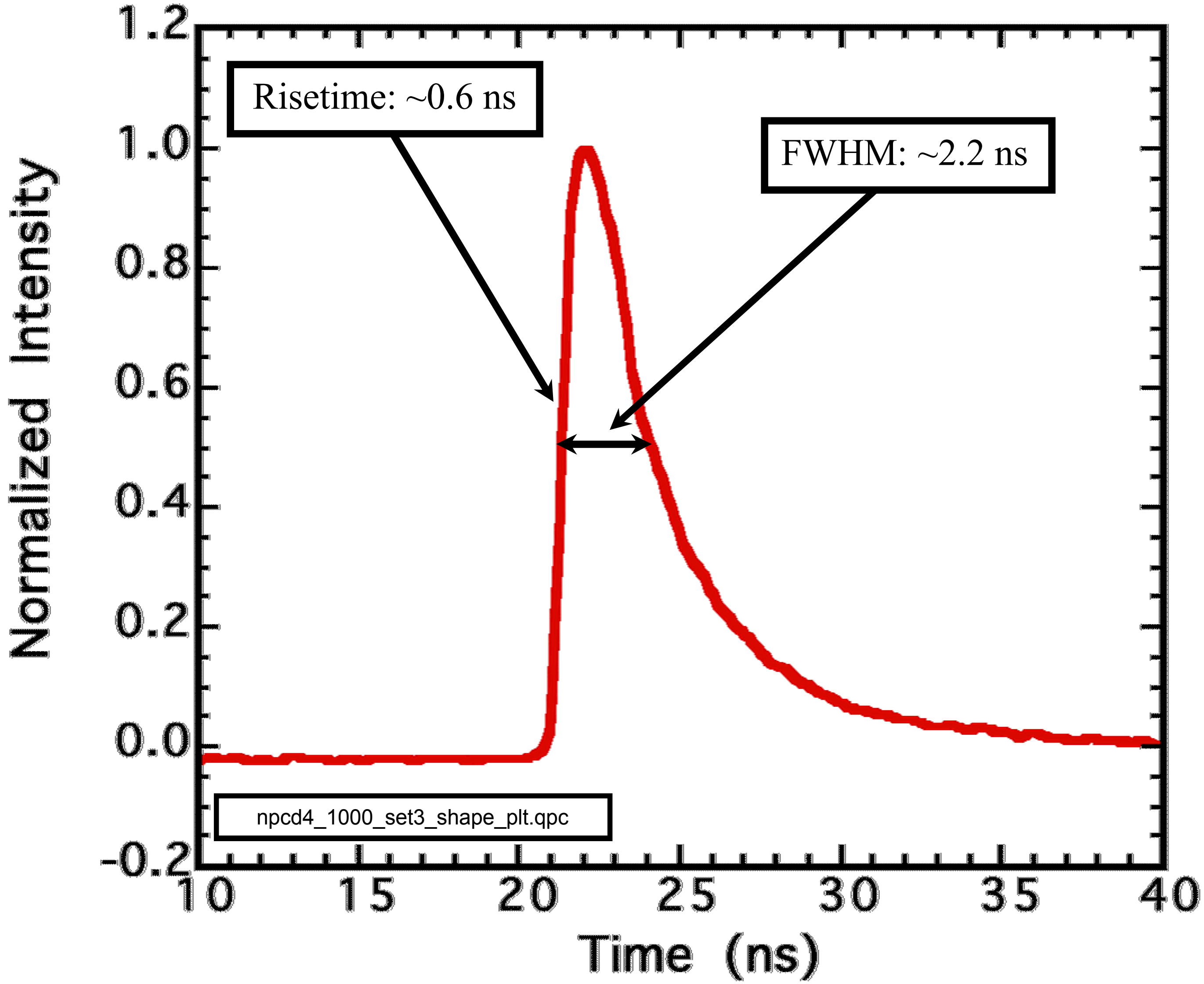


For a talk on Neutron based Cherenkov detectors see David Scholossberg Talk: U07.00013: Precision Neutron Time-of-Flight Detectors Provide Insight into NIF Implosion Dynamics

Our NBT detector near term plans

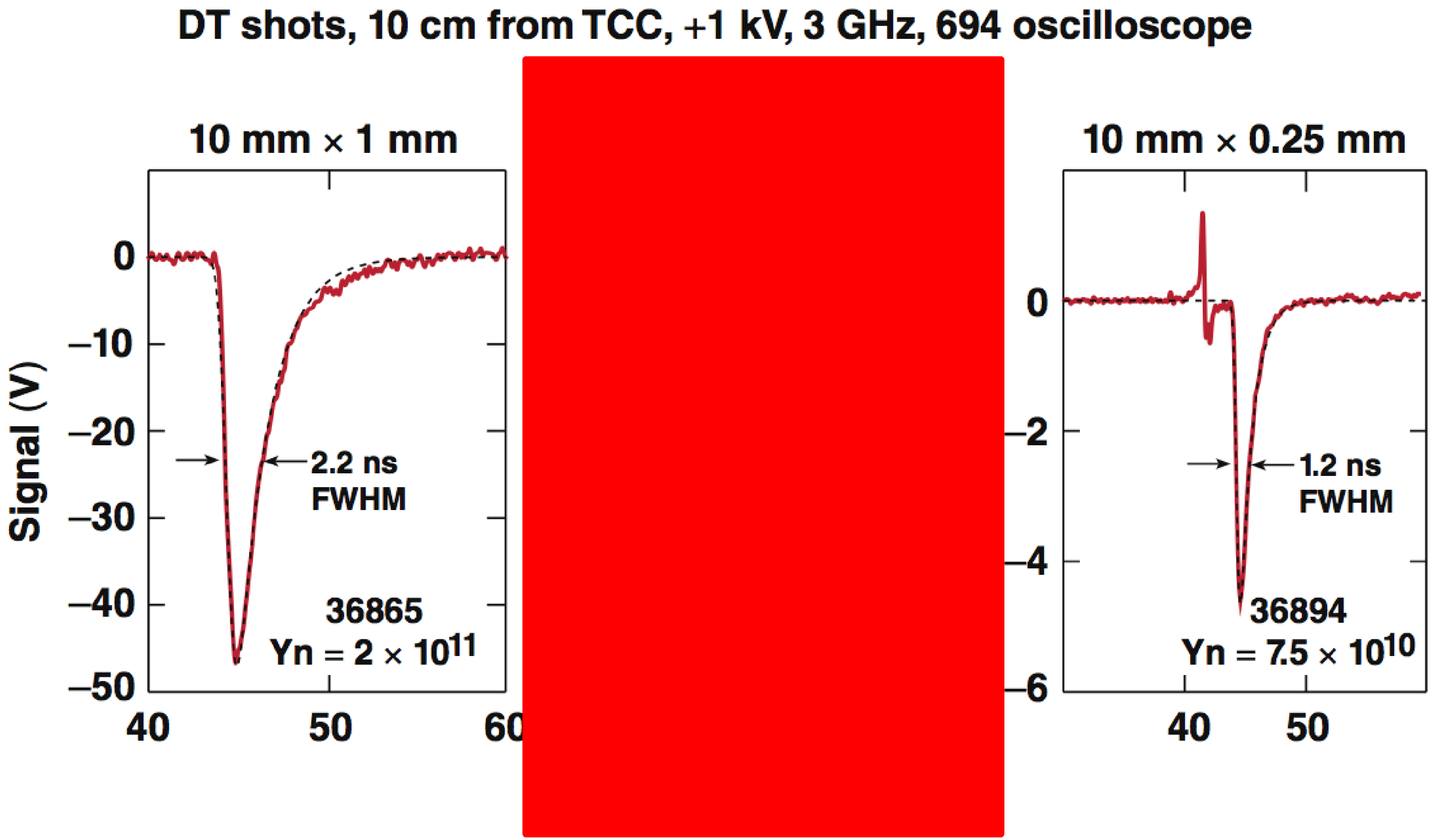
- Look into options for fielding faster CVD diamond detectors
- Implement a prototype Cherenkov detector to see if we can develop a detector with a faster impulse response
- Prototype the use of a CVD diamond detector with a vacuum LOS to the target to allow a simultaneous X-ray and neutron measurement on the same detector minimizing systematic errors associated from separate measurements
- Develop neutron collimation geometries for the NBT detectors to minimize neutron scattering

The intrinsic time response of our NPCD detectors to a short (~50 ps) Bremsstrahlung pulse has been measured at the Idaho State Linac

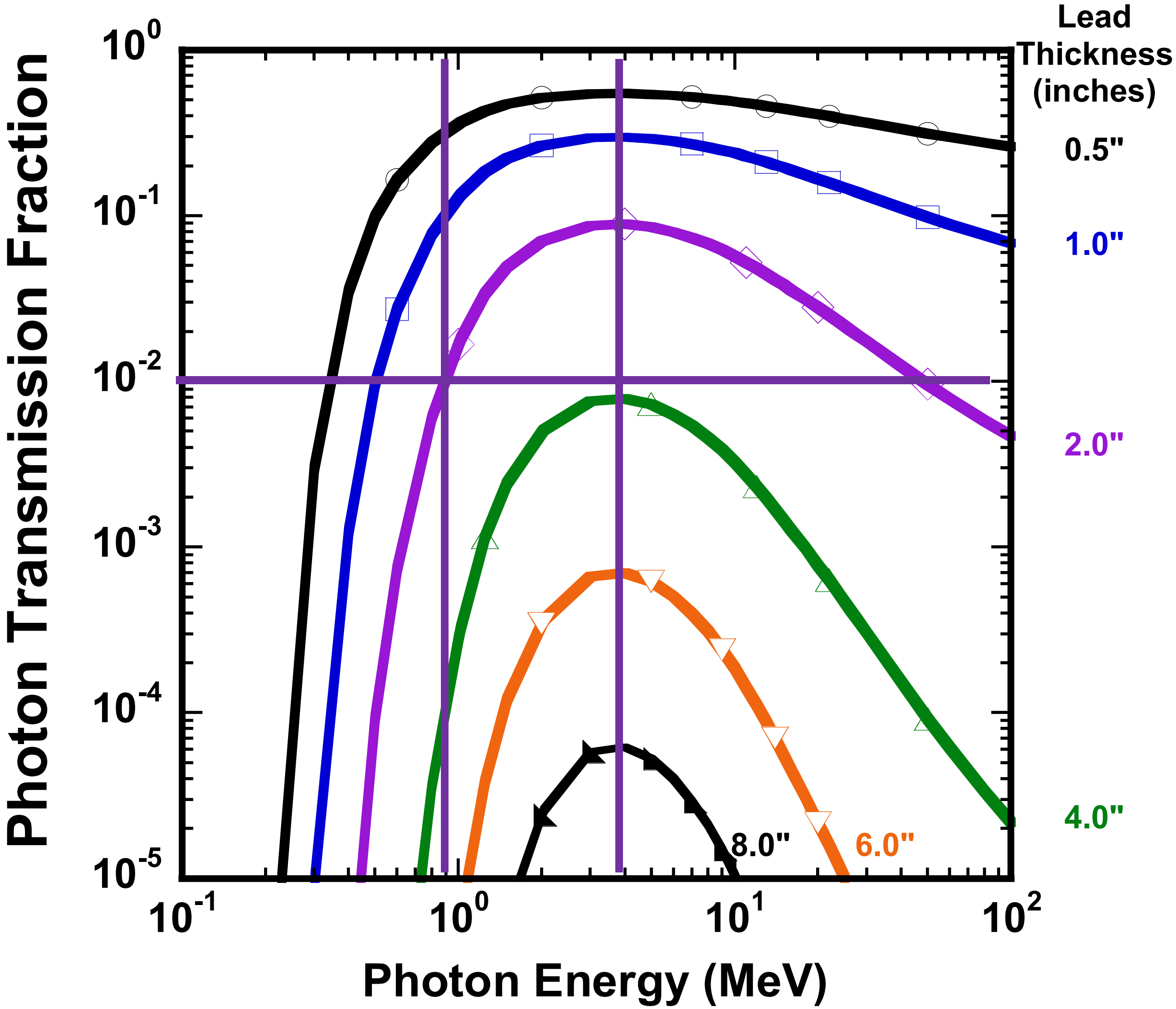


Vladimir demonstrated Radiation-hardened CVD diamond detectors with a fwhm of 0.5 ns are possible but with ~13x less sensitivity to his standard PCD's

Sandia National Laboratories



Lead Photon Transmission vs Lead Thickness: For 2” of Lead it peaks at ~4 MeV and is above 1% at ~0.9 MeV



Lead_transmission_plt3