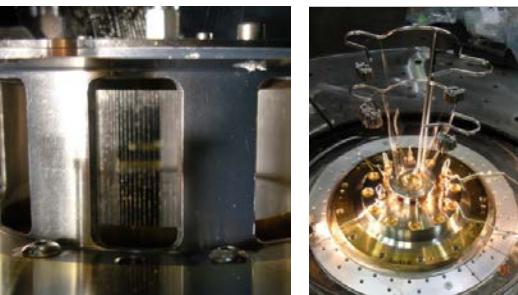
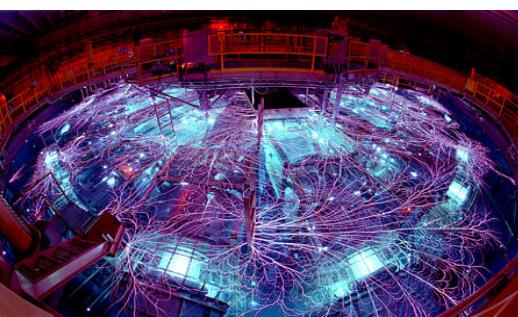


SNL perspective on the nTOF workshop



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NISP meeting, March 8, 2016



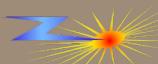
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Exceptional
service
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national
interest

Two major topics emerged from the nTOF workshop

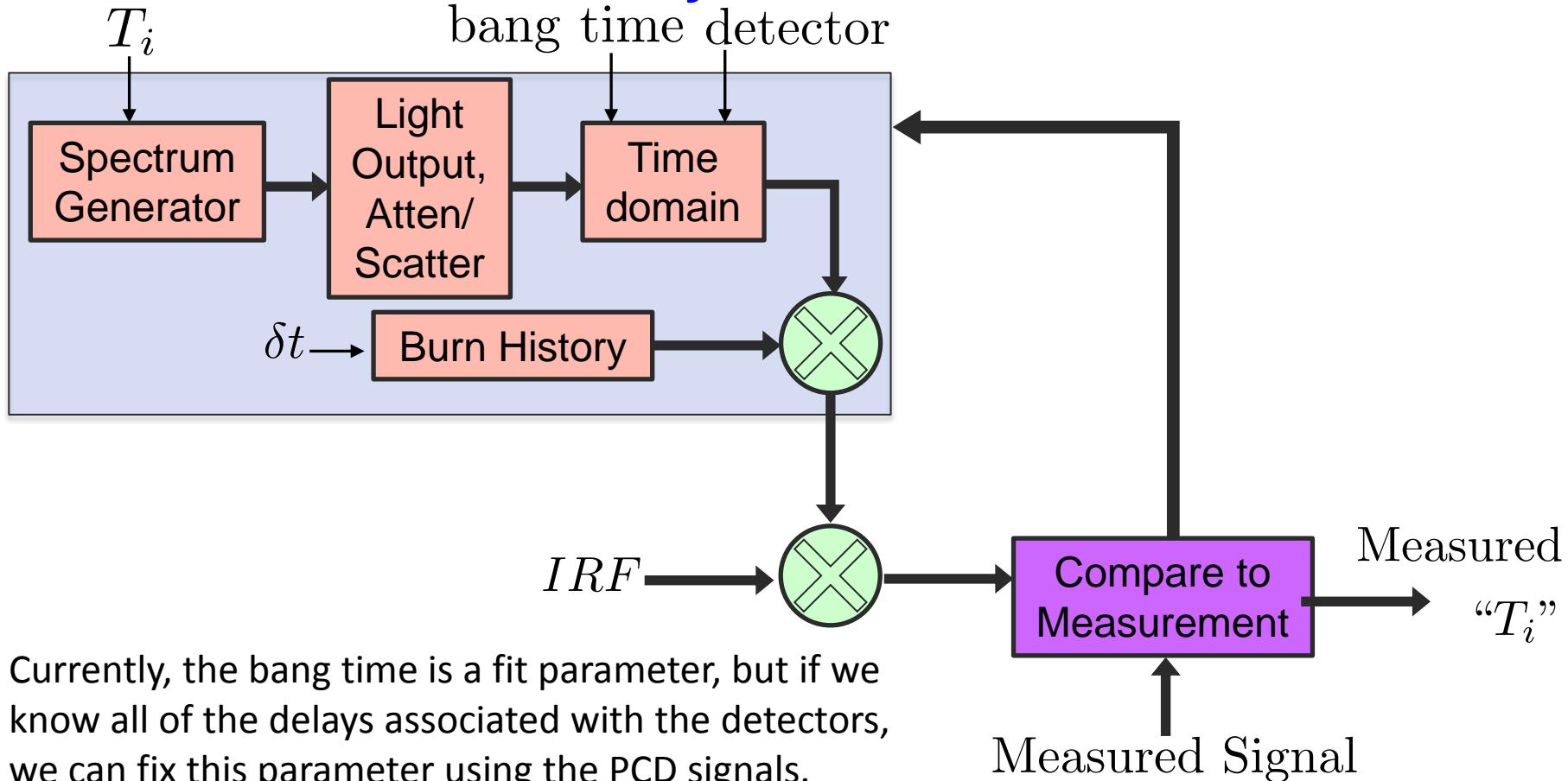
- LLNL, LLE, and SNL are all pursuing forward models to extract T_{ion} (and other moments/parameters) from nTOF data
 - Agreement looks good (LLNL/LLE analysis comparison)
 - Must continue to pay attention to details/assumptions
 - Analysis is sensitive to instrument response function (IRF)
- National interest in accurate IRF determination
 - Need to understand response of detectors to neutrons
 - Scattering in the fielding or calibration environment important
 - Utility of surrogates for neutrons (light, x-rays, gammas, cosmics)
 - Collaboration on IRF will make our analyses stronger



We are now developing a forward model approach to infer T_{ion}

Initial nTOF forward analysis workflow

Assumption: Ballabio functional form represents the neutron spectrum



Currently, the bang time is a fit parameter, but if we know all of the delays associated with the detectors, we can fix this parameter using the PCD signals.

Assumption: PCD x-ray pulses reasonably represent neutron burn history

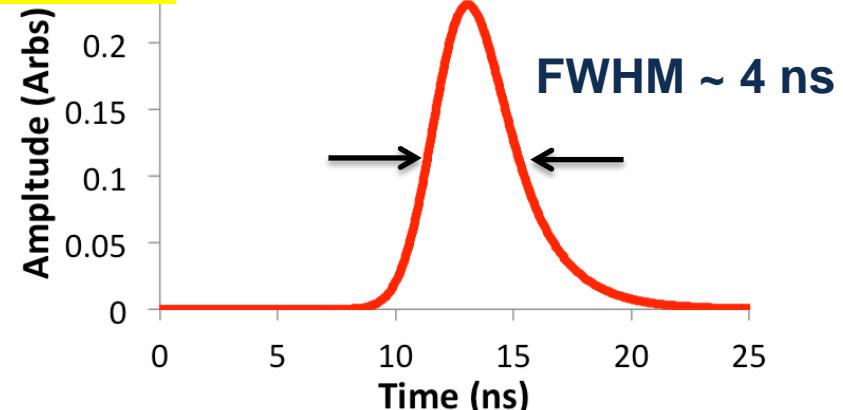
The instrument response is constructed from measurements and calculations

- **PMT response**

- From 100-ps, 5 MeV brems at Idaho State accelerator (> 6 years ago)
- Testing cosmic/coincidence technique

Assumption: X-ray/gamma PMT response is representative of neutrons

PMT Instrument Response to x rays (from Idaho State)



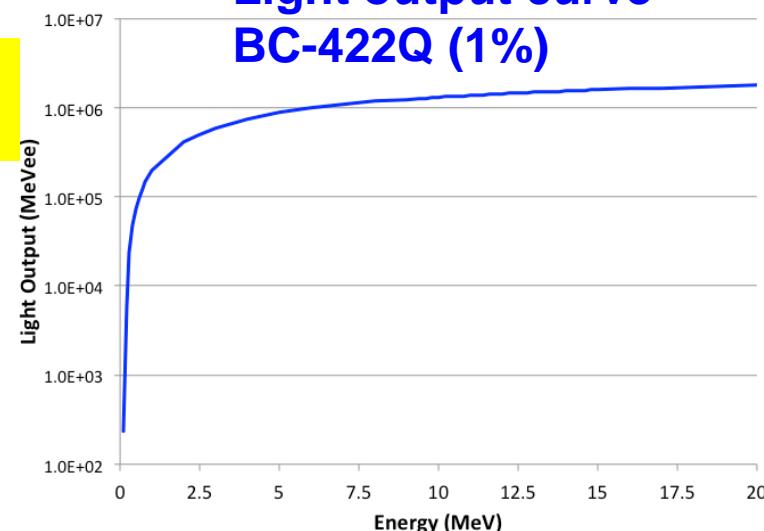
- **Light output**

- From modified Stanton code

- **Neutron** Assumption: Insignificant scatter from environment outside LOS attenuation/scattering

- From “simple” MCNP model of LOS materials (does not yet capture scatter from outside LOS)
- Note, we have lots of Pb in LOS to shield from brems

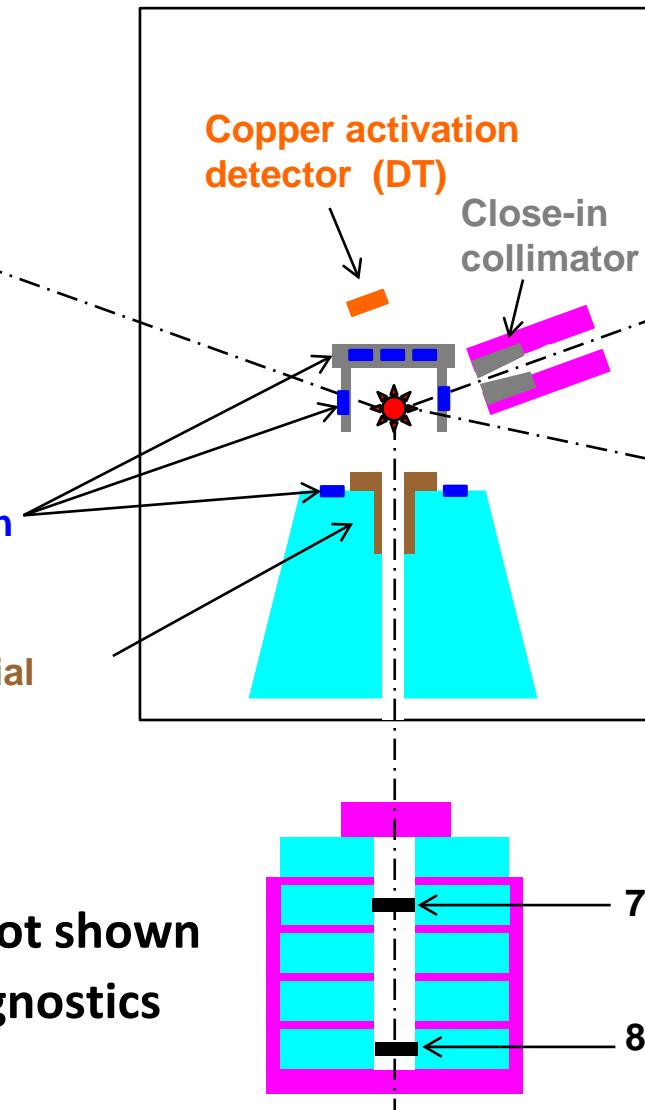
Light output curve BC-422Q (1%)



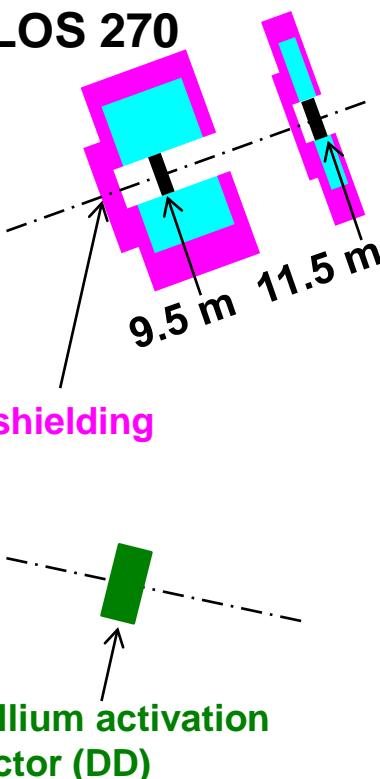
The Z neutron diagnostic suite characterizes yield (activation) and spectrum (nTOF)

Radial 25-m nTOF

@ LOS 50 (presently no
collimation)



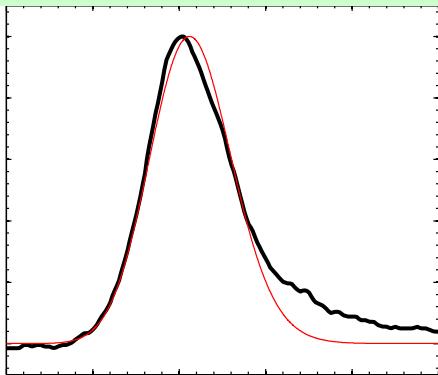
Radial nTOF's @ LOS 270



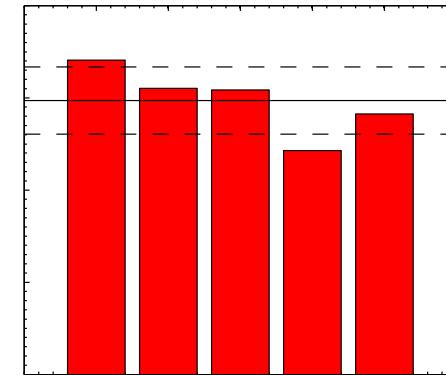
- **Neutron imager not shown**
- **No bang time diagnostics**

T_{ion} is determined reasonably, but poor fits to some non-Gaussian nTOF pulses suggest instrumental effects

Axial @ 7 m, 3.4 keV



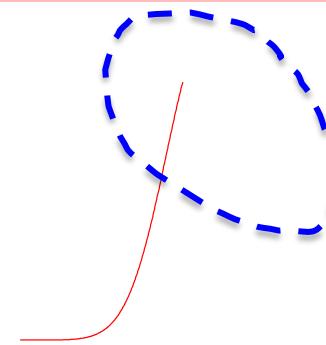
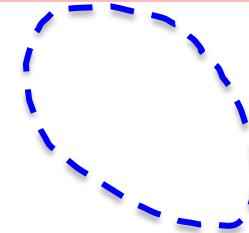
Axial @ 8 m, 3.1 keV



Radial @ 9.5 m, 3.1 keV

Radial @ 11.5 m, 2.4 keV

Radial @ 25 m, 2.8 keV

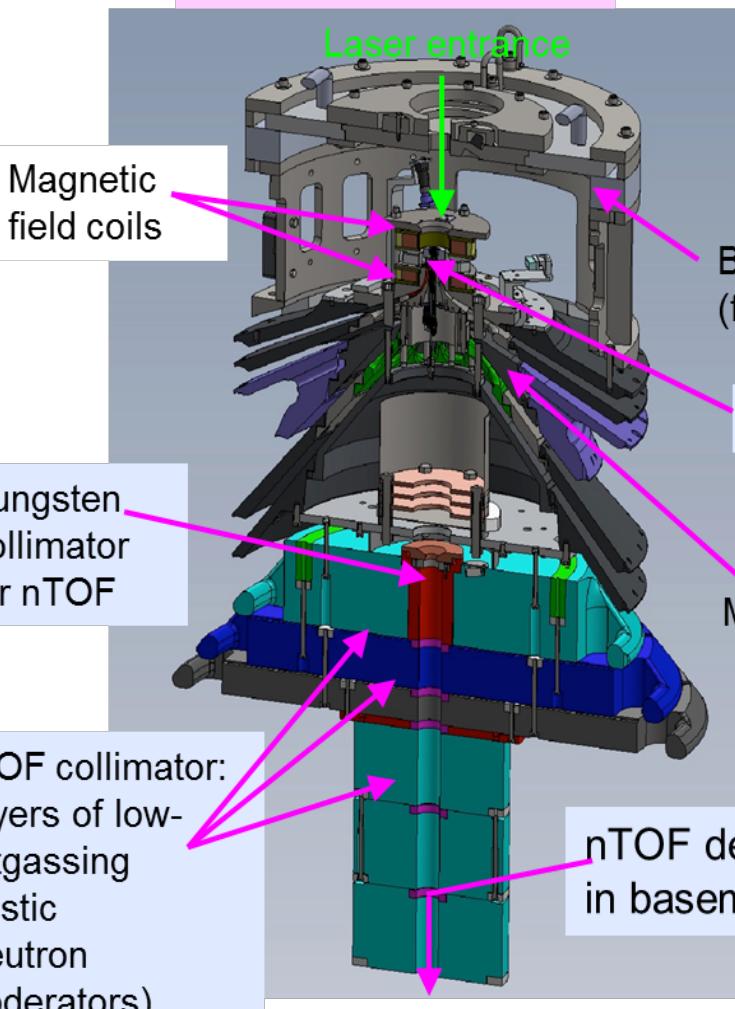


Time [μ s]

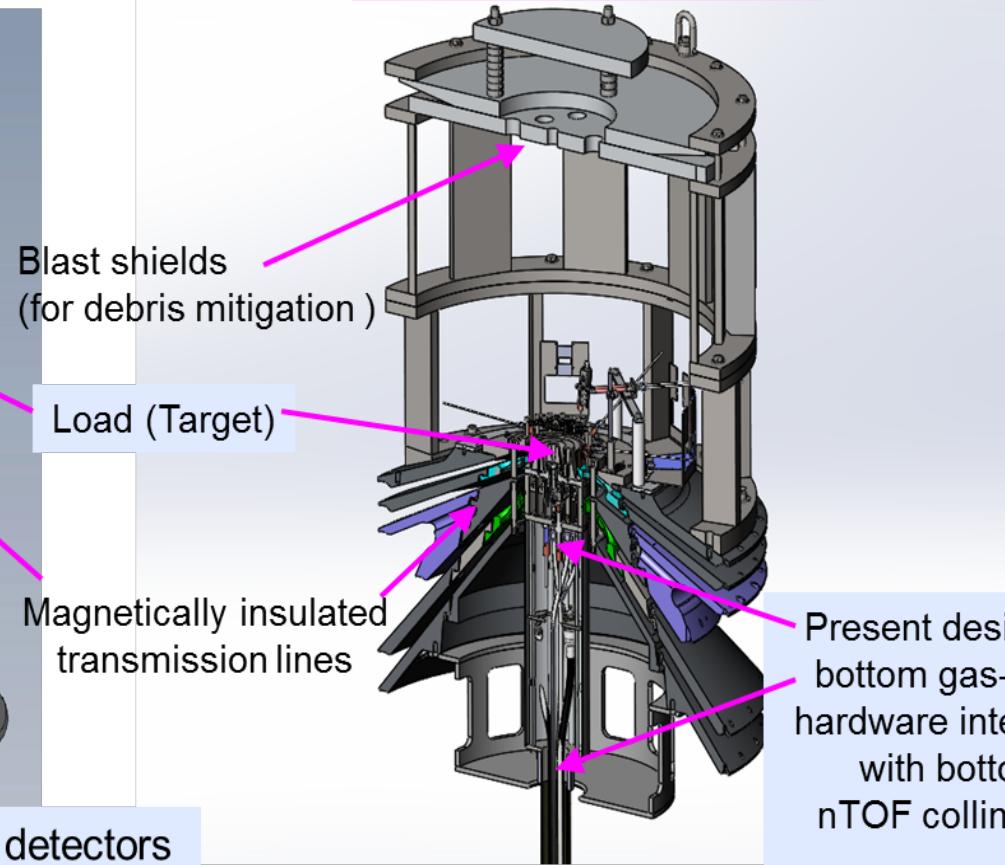
MagLIF shot 2850: 3e12 DD neutron yield, $T_{ion} \sim 3$ keV

Necessity of pulsed power transmission lines and blast shields leads to >30% scattering corrections

MagLIF Hardware



Gas-puff Hardware



Neutron testing is needed along with understanding scattering environments

End state

IRF of nTOF systems are understood, including PMT, scintillator, shielding, scatter in housing; Accurate IRFs enable extracting physics from nTOF data

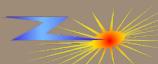
Neutron exposure of nTOF of scintillator/PMT

Tests with neutrons on Omega	Excitation directly by neutrons Requires deconvolution with CVD Not the Z scattering environment
------------------------------	--

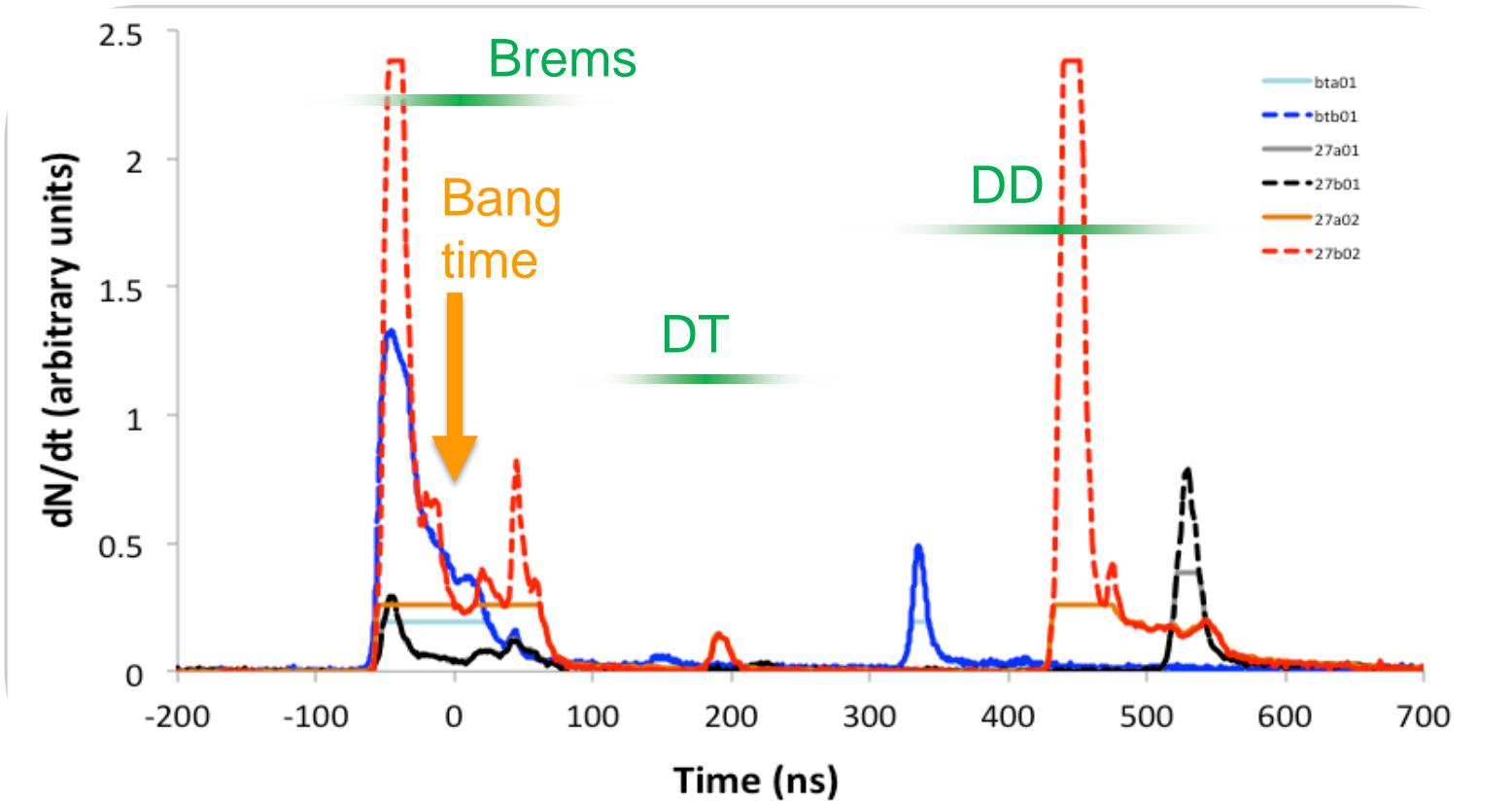
Tests with neutrons on Z	Requires developing a source May require CVD deconvolution Brems may be too large Actual Z scattering environment
--------------------------	--

Model of neutron environment at Z

MCNP modeling of Z nTOF housings, collimators, shields	Requires resources/collaboration Model validation
--	--



Large hard x-ray/brems signals on Z are a challenge for capturing smaller DD and very small DT signals on nTOF



- Brems overdrives PMTs and scopes, which may not recover
- ~100 ns brems makes it difficult to field close-in detectors
- DT signal overlaps with scintillator recovery decay
- Dynamic range needed to record both DT and DD peaks

Use of surrogate sources provides more data, but also requires understanding surrogacy

End state

IRF of nTOF systems are understood, including PMT, scintillator, shielding, scatter in housing; Accurate IRFs enable extracting physics from nTOF data

Surrogate experiments

Gammas/x-rays	Idaho State LINAC, Omega-EP, Z-Petawatt (target chamber or in Z)
Light	NSTec impulse response of PMTs
Cosmic rays	Convenient, but accurate enough?

Scintillator response

Decay measurements at IBL, Transit and scatter models

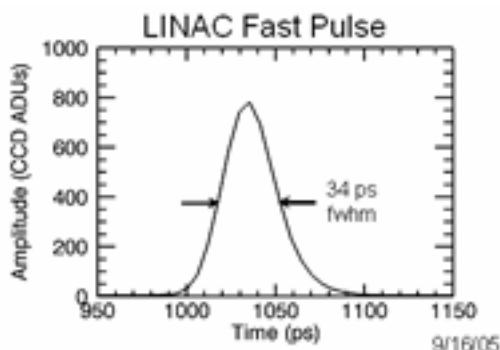
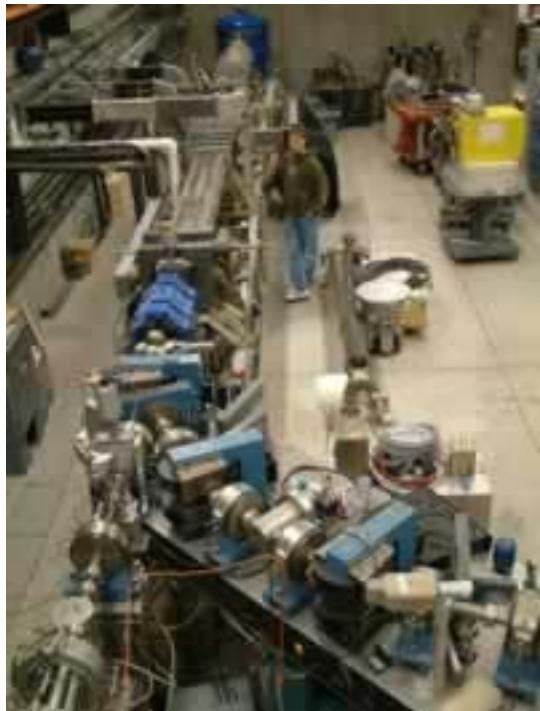
Neutron exposure of nTOF of scintillator/PMT

Validate surrogate experiments against neutron experiment at least once

Model of neutron environment at Z

MCNP modeling of Z nTOF housings, collimators, shields	Requires resources/collaboration Model validation
--	--

SNL uses gamma IRF calibrations performed on the Idaho State University Fast Pulsed Linac

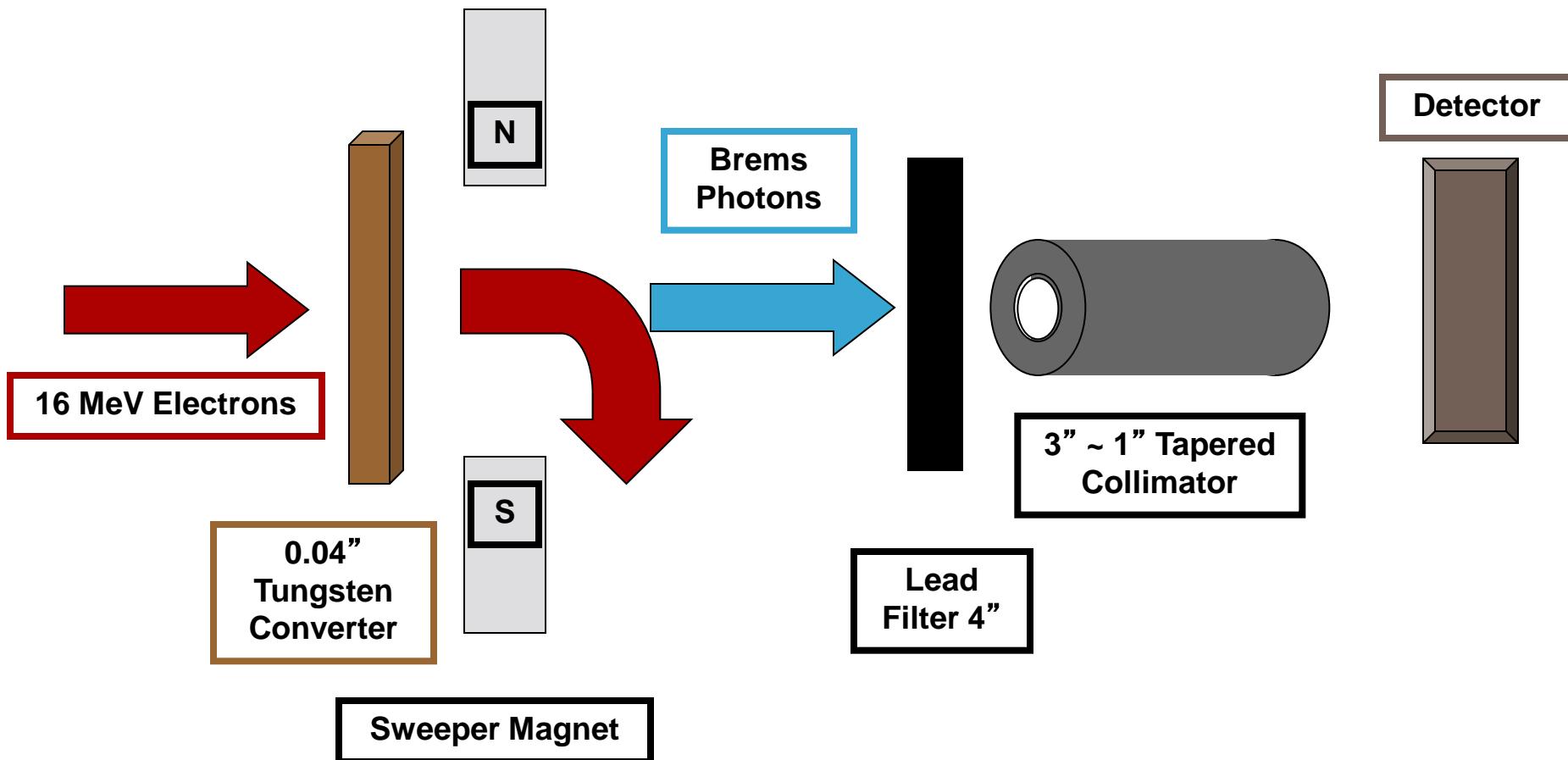


Pulse Width	Maximum Current (Amps)	Charge / Pulse (nC)	Peak e-Dose (Rads / Sec)	Peak Gamma Dose on-axis @ 1 meter (rads/sec)
50 ps	100	5	2E13	2.5E8
20 ns	3	60	6E11	7.5E6
100 ns	1	100	2E11	2.5E6
4 μ s	0.5	2000	1E11	1.25E6

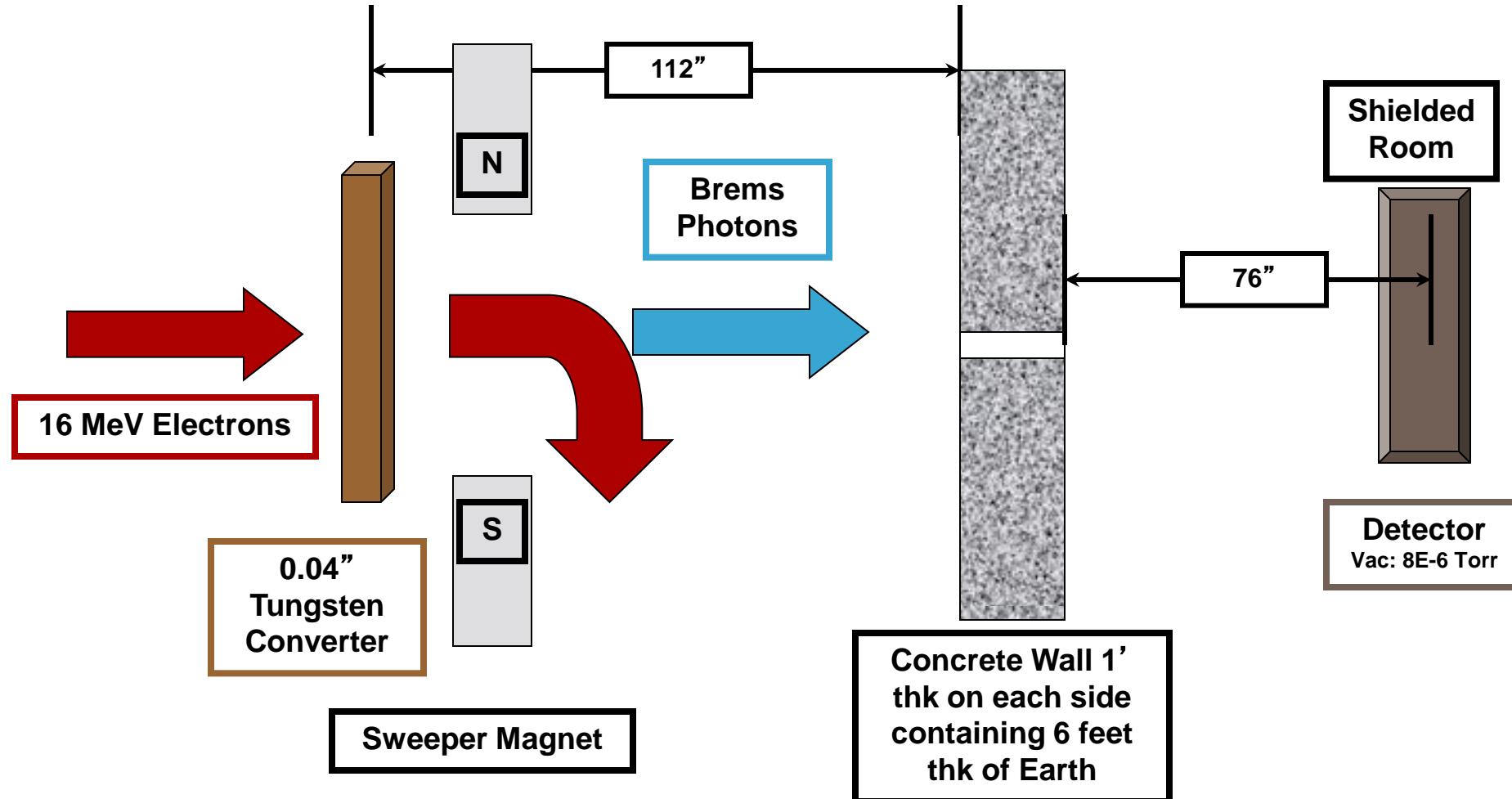
Mode	Energy Range or Dose Rate	Pulse Width (ns)	Rise Time (ns)
Bunched e-beam	0.5 - 28 MeV (16 MeV used)	0.050	0.005
Short Pulsed Non-bunched	1E12 Rad (Si)/s	2 - 50	0.2
Long Pulsed Non-bunched	2E11 Rad (Si)/s	100 - 2E6	Function of pulse width

Note that, because of the 1300 MHz rf structure, all pulse widths longer than the 50 ps short pulse are composed of a string of 50 ps-wide pulses, each separated by 770 ps.

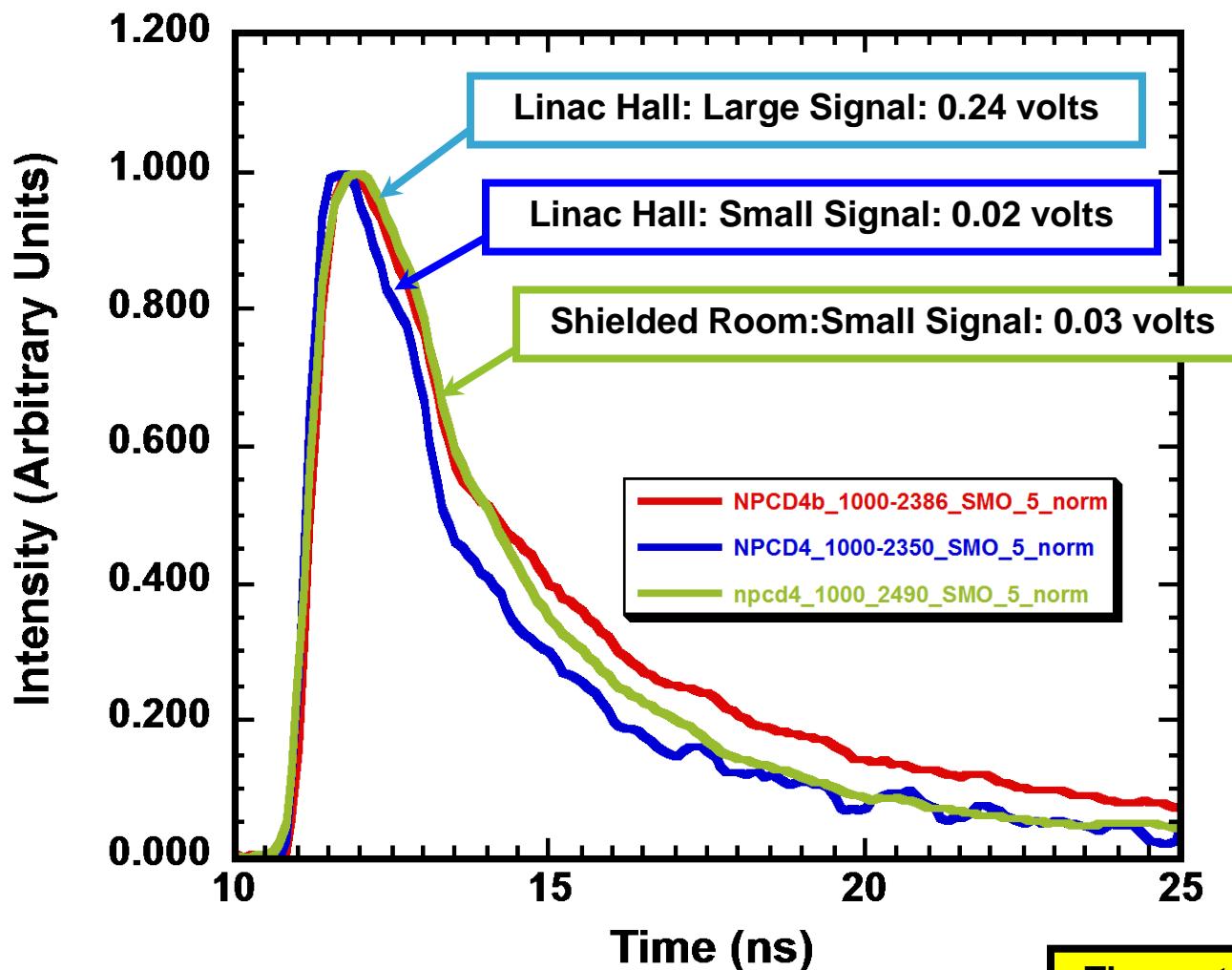
Schematic of LINAC calibration configuration setup with and without lead filter



Schematic of calibration configuration in shielded room



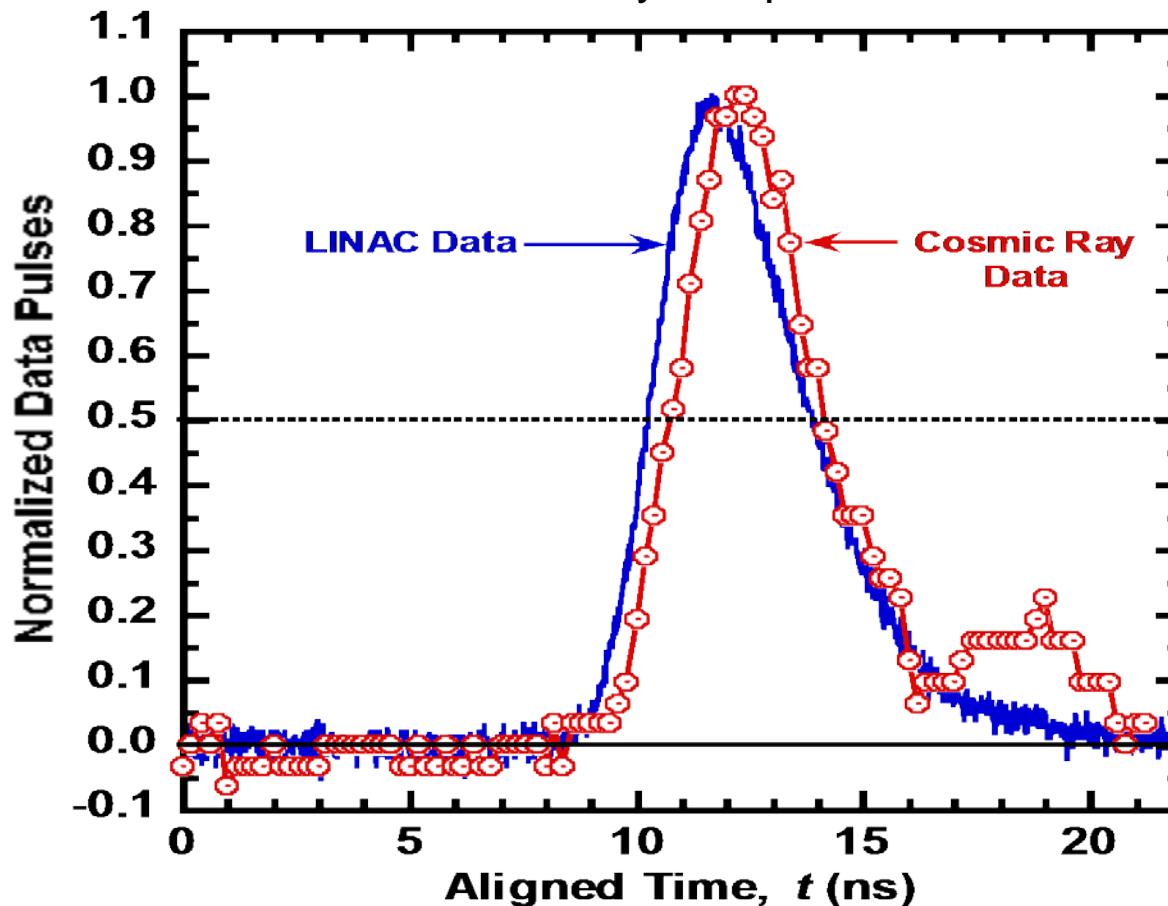
The shape of the tail of the pulse is observed to vary with the signal amplitude and detector location



The scattering environment apparently matters

Cosmics provide a convenient, tabletop IRF check, but making them accurate enough would be a research project

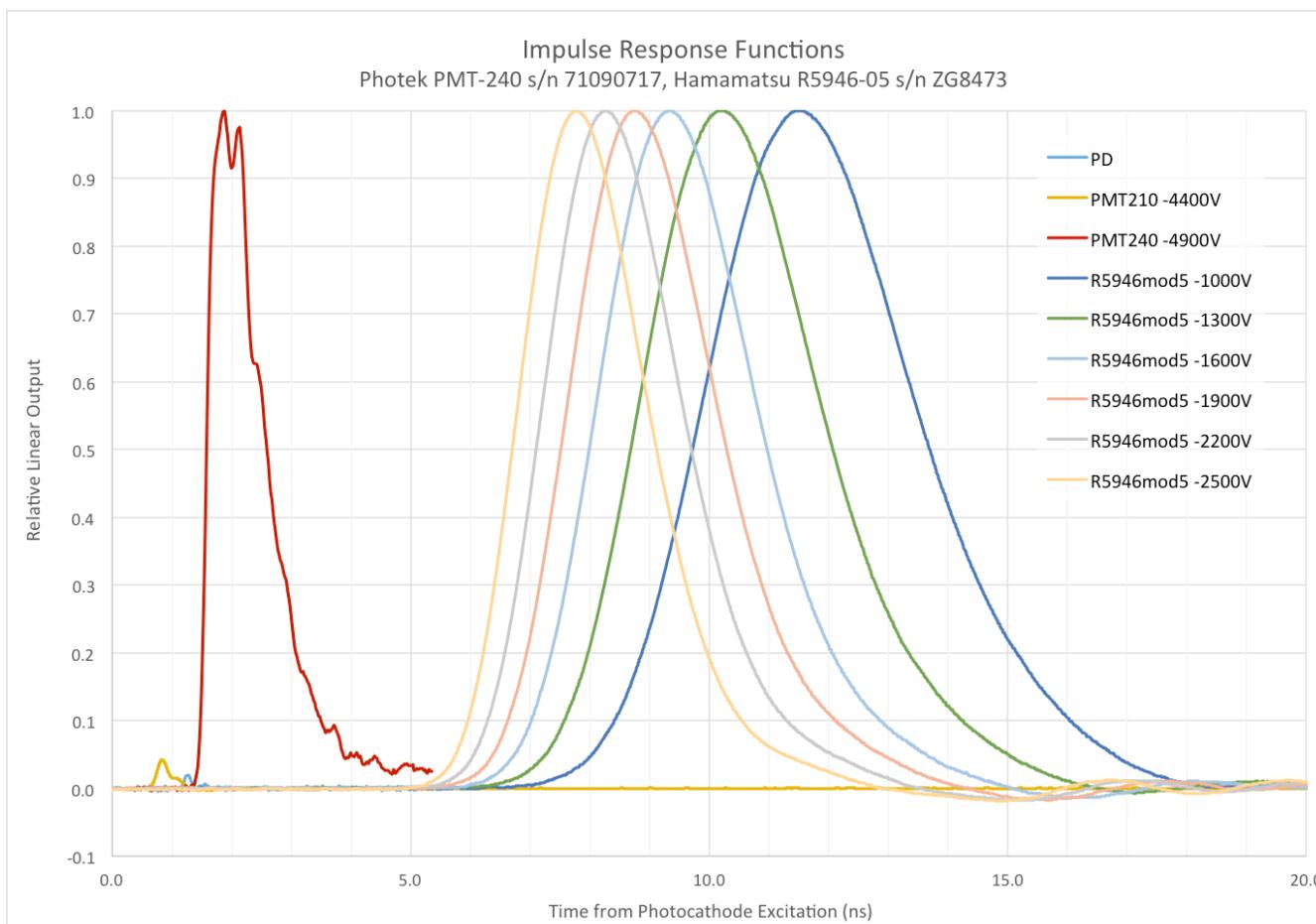
Typical nTOF time response measured at Idaho State Univ LINAC (25 ps photon pulse) and SNL's Cosmic-ray setup



NSTec light pulse testing gives PMT response, useful for tube/delay characterization, one piece of the IRF puzzle

- 403 nm 70 ps Picoquant LD common trigger with scope
- 12.5 GHz Tektronix 71254 DPO locked to Cs Frequency Std
- DG535 locked to DPO triggering split to scope & LD w/step recovery diode
- Transit Time monitor with in-situ beam splitter to Hamamatsu R1328U vacuum photodiode or Photek PMT-210
- Temporal laser alignment at photocathodes
- Acquisitions with 100 averages
- 1 ps rms delay jitter measured on DPO

Photek PMT240 and Hamamatsu R5946-05 IRF



Rob Buckles, Irene Garza, and Ken Moy

Sandia has DD and DT capability for absolute calibration of neutron diagnostics



The "Secondary" Standard Lead Probe is used to Calibrate other Probes

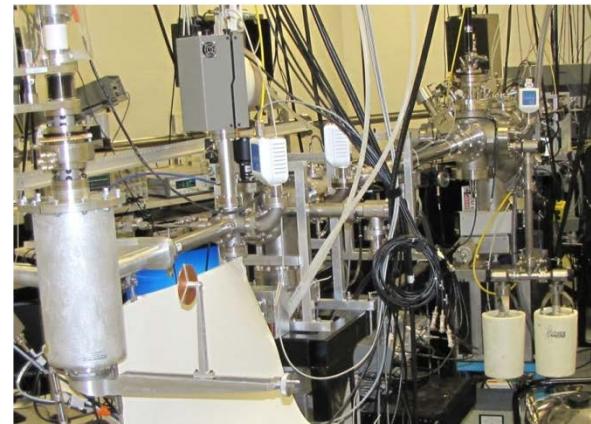
In this case, another Calibrated Probe is Determining Yields (with uncertainty ~ 7%)
To Cross-Calibrate nTOF Detector



350 keV Cockcroft-Walton



Dedicated beam-line and hardware



Data acquisition setup



Summary

- SNL has a need for resources/collaboration in the area of neutron transport modeling
 - Understand scattering surrounding nTOF detectors
 - Understand/improve behavior of collimators/shields
 - Understand scintillator response to connect neutron and surrogate expts
- We should challenge ourselves nationally to develop a deep understanding of nTOF IRF
 - Direct neutron response experiments, e.g. Omega collaboration
 - Connection to gamma sources and other surrogates
- Value in improving nTOF analysis and revisiting comparisons
 - SNL could add Be liner downscatter model
 - Keep informed of LLNL experience in pursuing higher moments
 - Be mindful of role of ion population tail, time/space gradients, etc. that are not captured by Ballabio/Brysk models