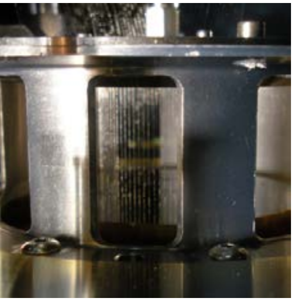
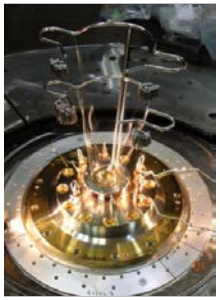
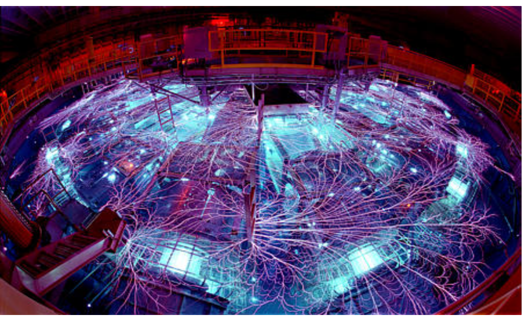






Sandia National Laboratories

Exceptional service in the national interest

SNL perspective on the nTOF workshop

Brent Jones*, Kelly D. Hahn, Carlos L. Ruiz, Gordon A. Chandler, David L. Fehl, Joel S. Lash, Patrick Knapp, Matt Gomez, Stephanie B. Hansen, Eric C. Harding, L. Armon McPherson, Alan J. Nelson, Greg A. Rochau, Paul F. Schmit, Adam B. Sefkow, Daniel B. Sinars, José A. Torres, and Jim Bur

Sandia National Laboratories

Gary W. Cooper, Michael A. Bonura, Joel L. Long, and Jedidiah D. Styron

Department of Chemical and Nuclear Engineering
University of New Mexico

Rob Buckles, Irene Garza, Ken Moy, Brent Davis, Jim Tinsely, Rod Tiangco, Kirk Miller, Ian McKenna

National Security Technologies, LLC

* bmjones@sandia.gov

NISP meeting, March 8, 2016

U.S. DEPARTMENT OF ENERGY   NNSA National Nuclear Security Administration

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.

Two major topics emerged from the nTOF workshop

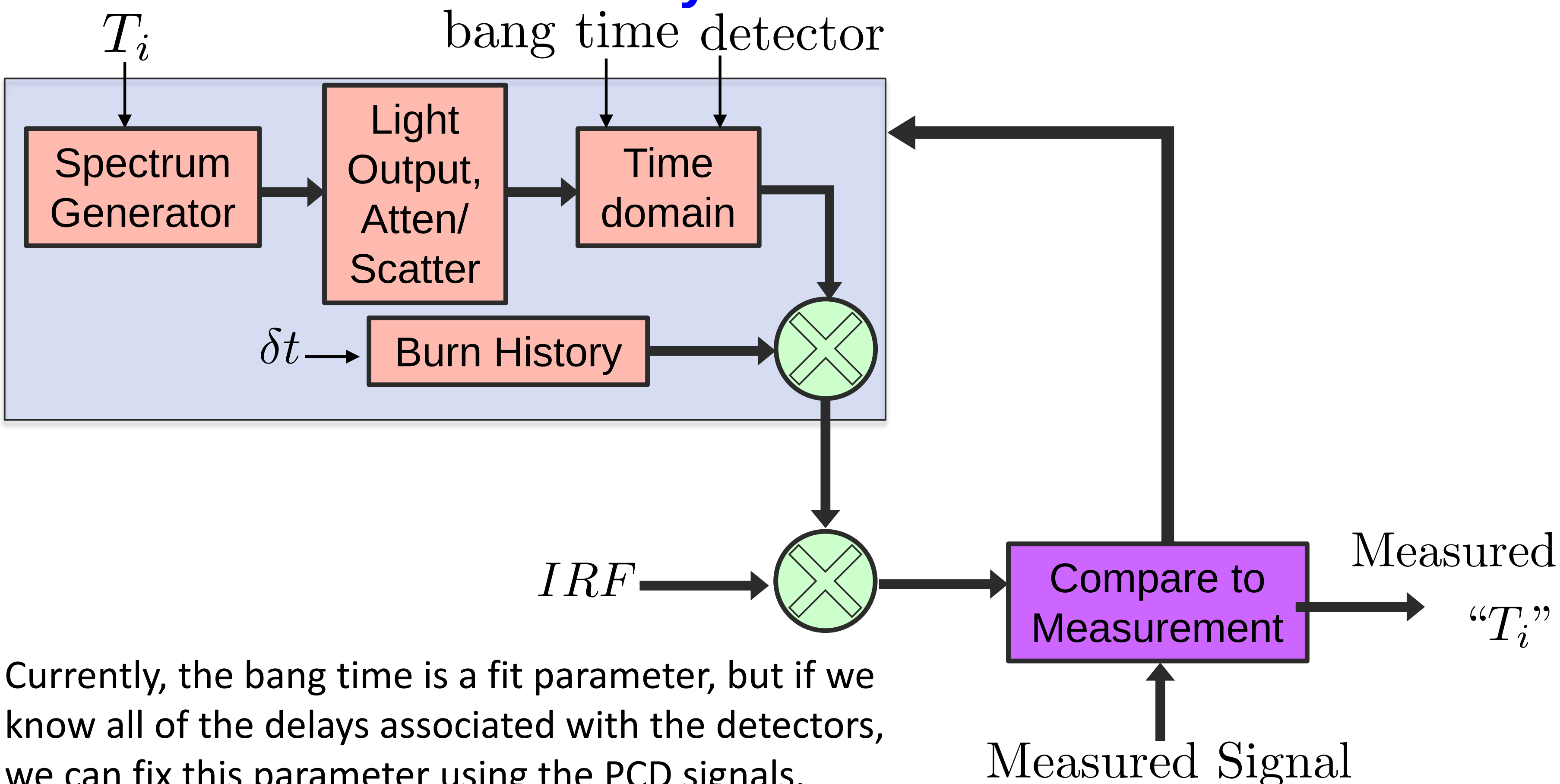
- **LLNL, LLE, and SNL are all pursuing forward models to extract T_{ion} (and other moments/parameters) from nTOF data**
  - **Agreement looks good (LLNL/LLE analysis comparison)**
  - **Must continue to pay attention to details/assumptions**
  - **Analysis is sensitive to instrument response function (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}

Assumption: Ballabio functional form represents the neutron spectrum

Initial nTOF forward analysis workflow



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

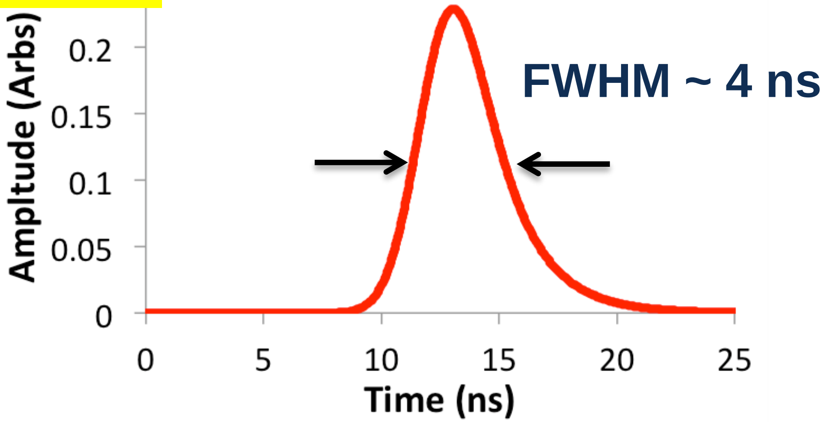
The instrument response is constructed from measurements and calculations

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

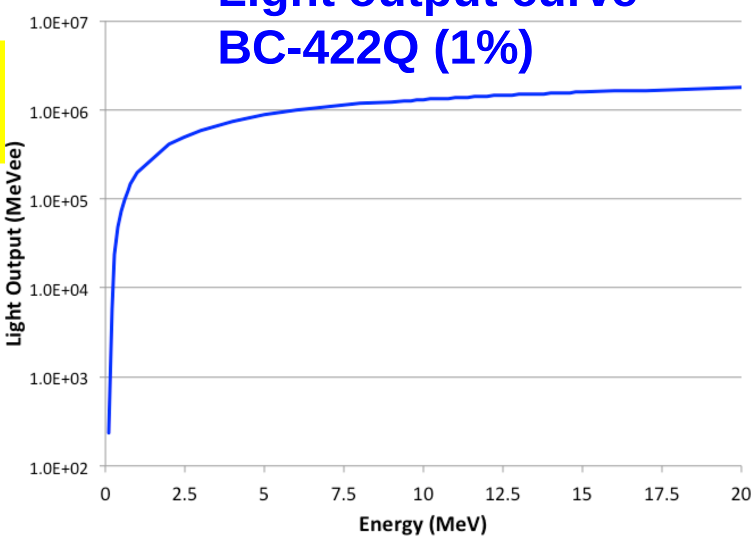
- **PMT response**
  - **From 100-ps, 5 MeV brems at Idaho State accelerator (> 6 years ago)**
  - **Testing cosmic/coincidence technique**
- **Light output**
  - **From modified Stanton code**
- **Neutron attenuation/scattering**
  - **From "simple" MCNP model of LOS materials (does not yet capture scatter from outside LOS)**
  - **Note, we have lots of Pb in LOS to shield from brems**

Assumption: Insignificant scatter from environment outside LOS

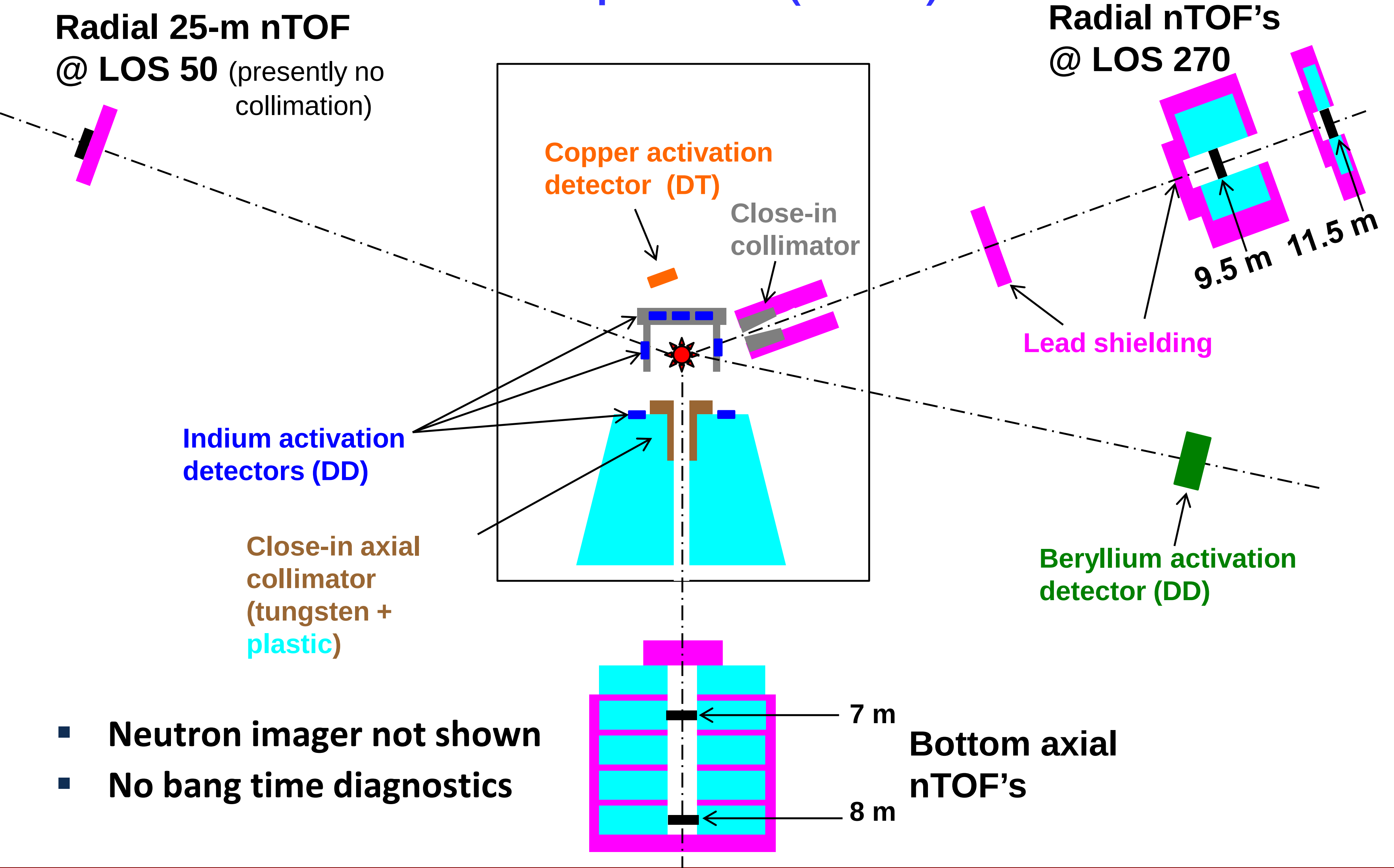
PMT Instrument Response to x rays (from Idaho State)



Light output curve BC-422Q (1%)



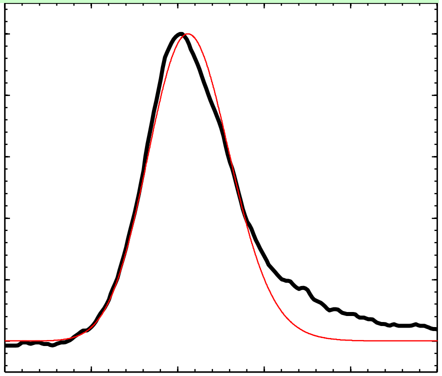
The Z neutron diagnostic suite characterizes yield (activation) and spectrum (nTOF)



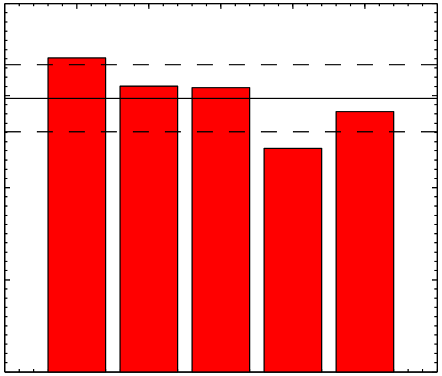
- Neutron imager not shown
- No bang time diagnostics

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

Axial @ 7 m, 3.4 keV



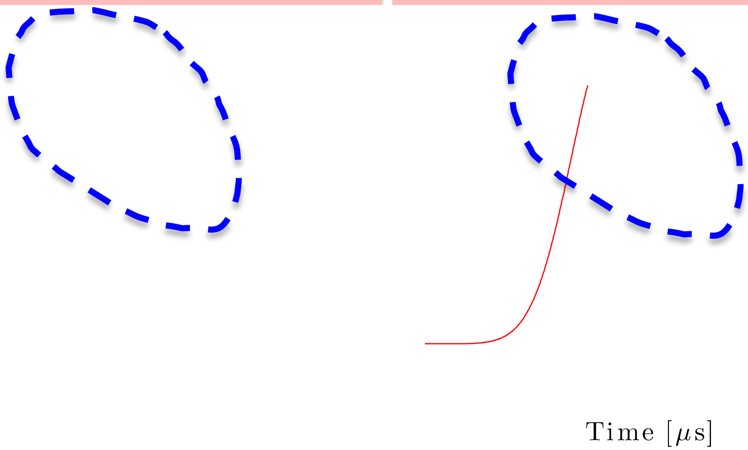
Axial @ 8 m, 3.1 keV



Radial @ 9.5 m, 3.1 keV

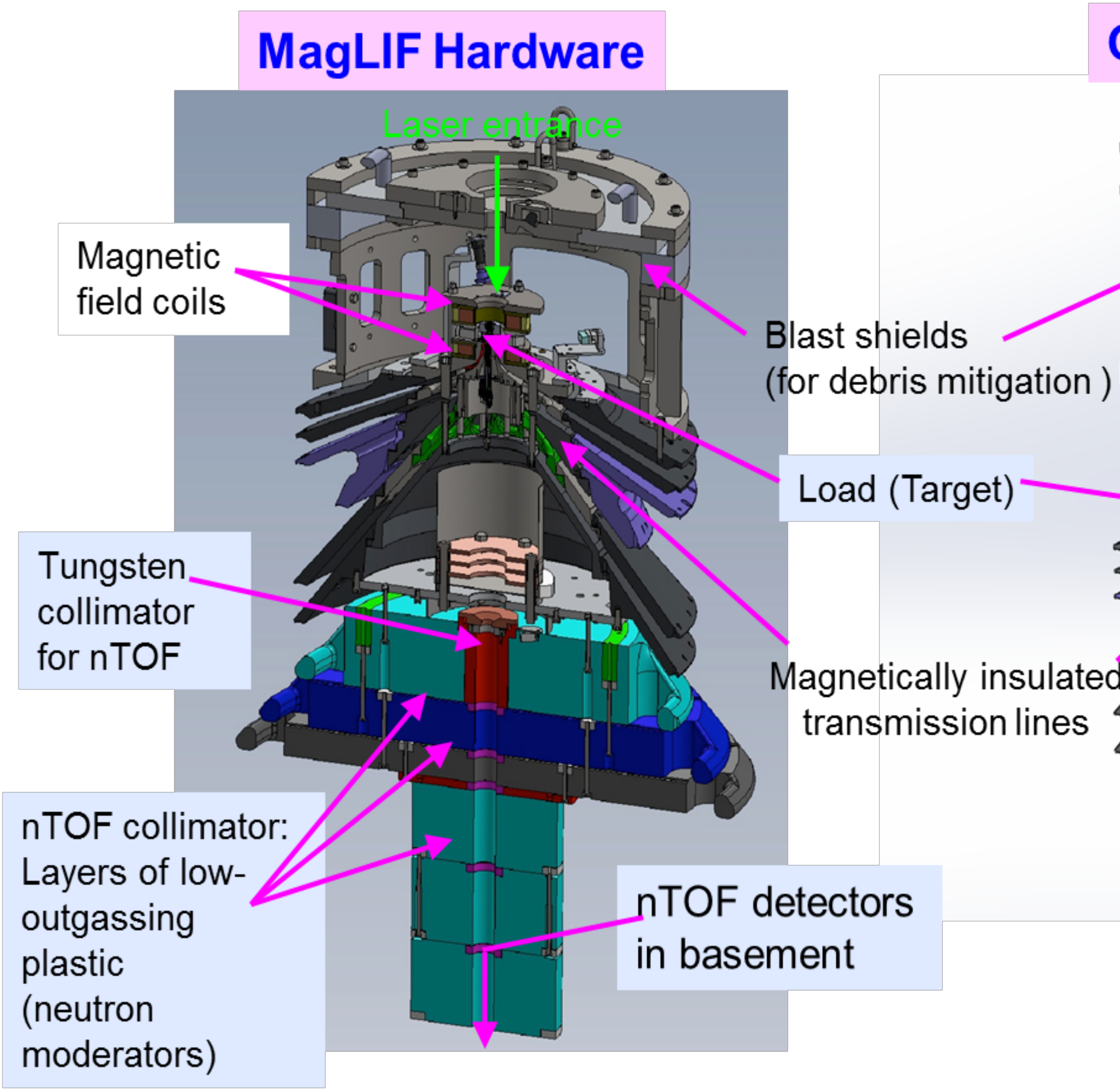
Radial @ 11.5 m, 2.4 keV

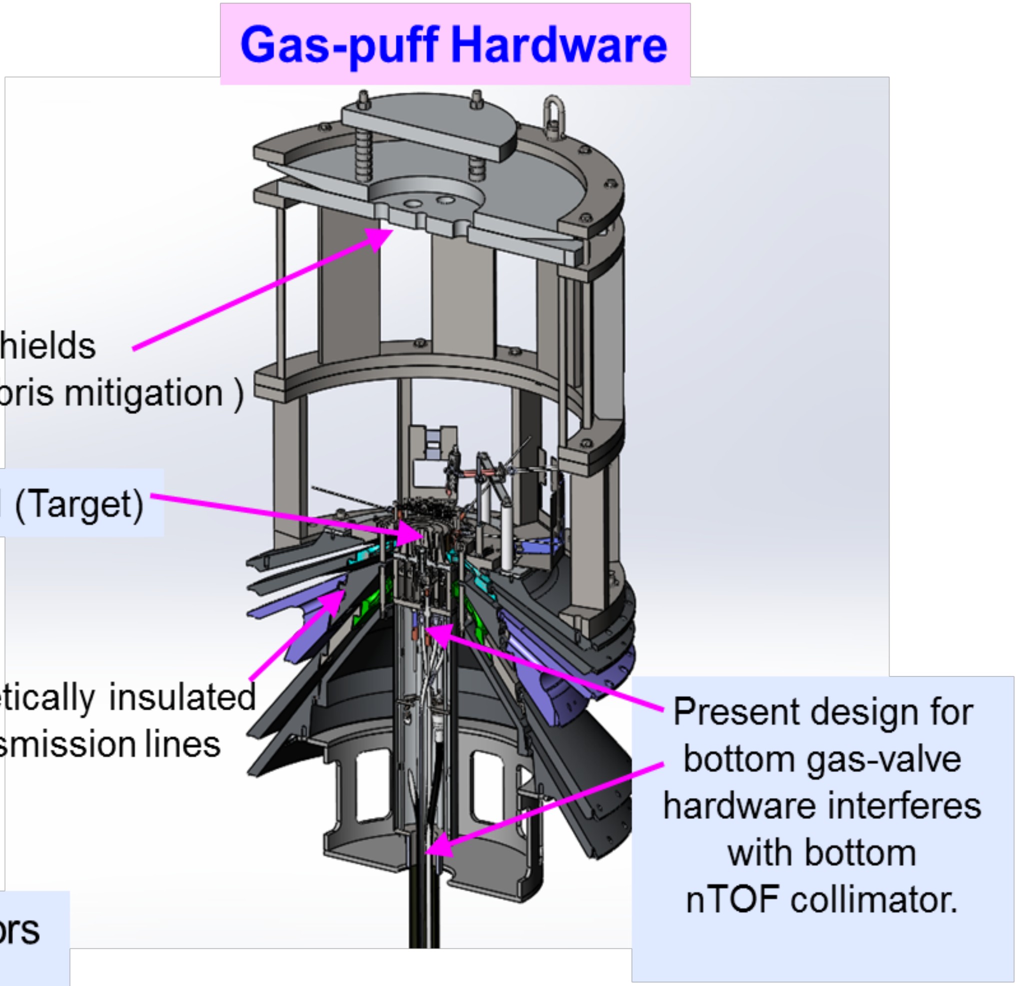
Radial @ 25 m, 2.8 keV



MagLIF shot 2850: 3e12 DD neutron yield, T_{ion} ~ 3 keV

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





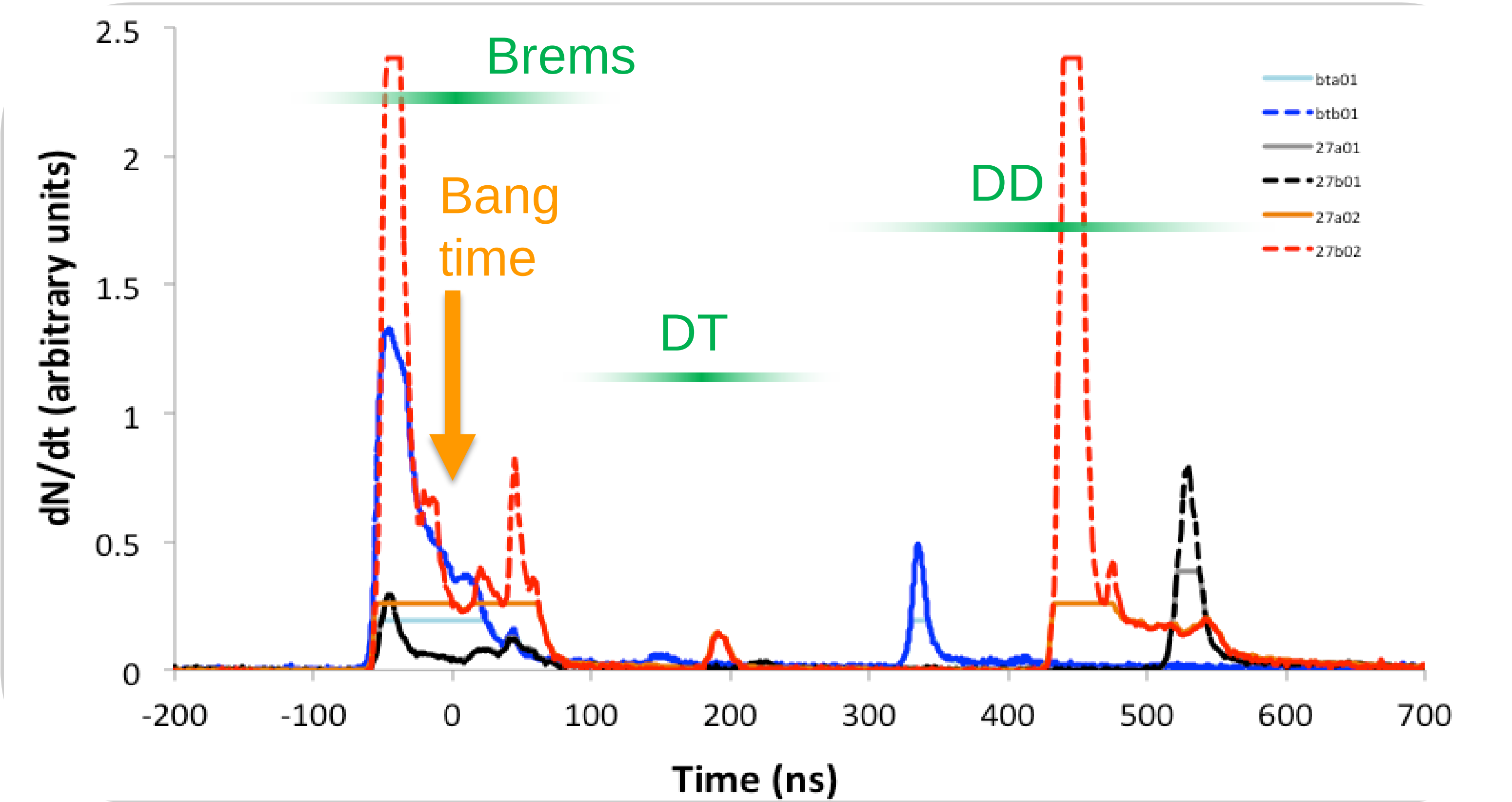
Neutron testing is needed along with understanding scattering environments

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	

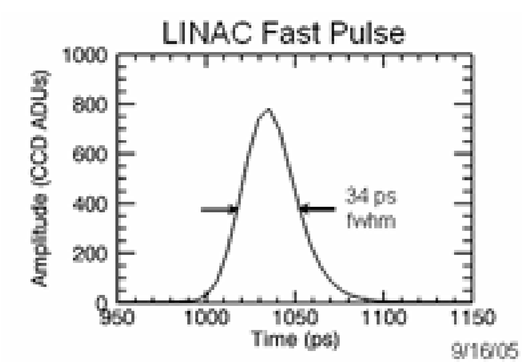
Surrogate experiments	
Gammas/x-rays	Idaho State LINAC, Omega-EP, Z-Petawatt (target chamber or in Z)
Light	NSTec impulse response of PMTs
Cosmic rays	Convenient, but accurate enough?

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

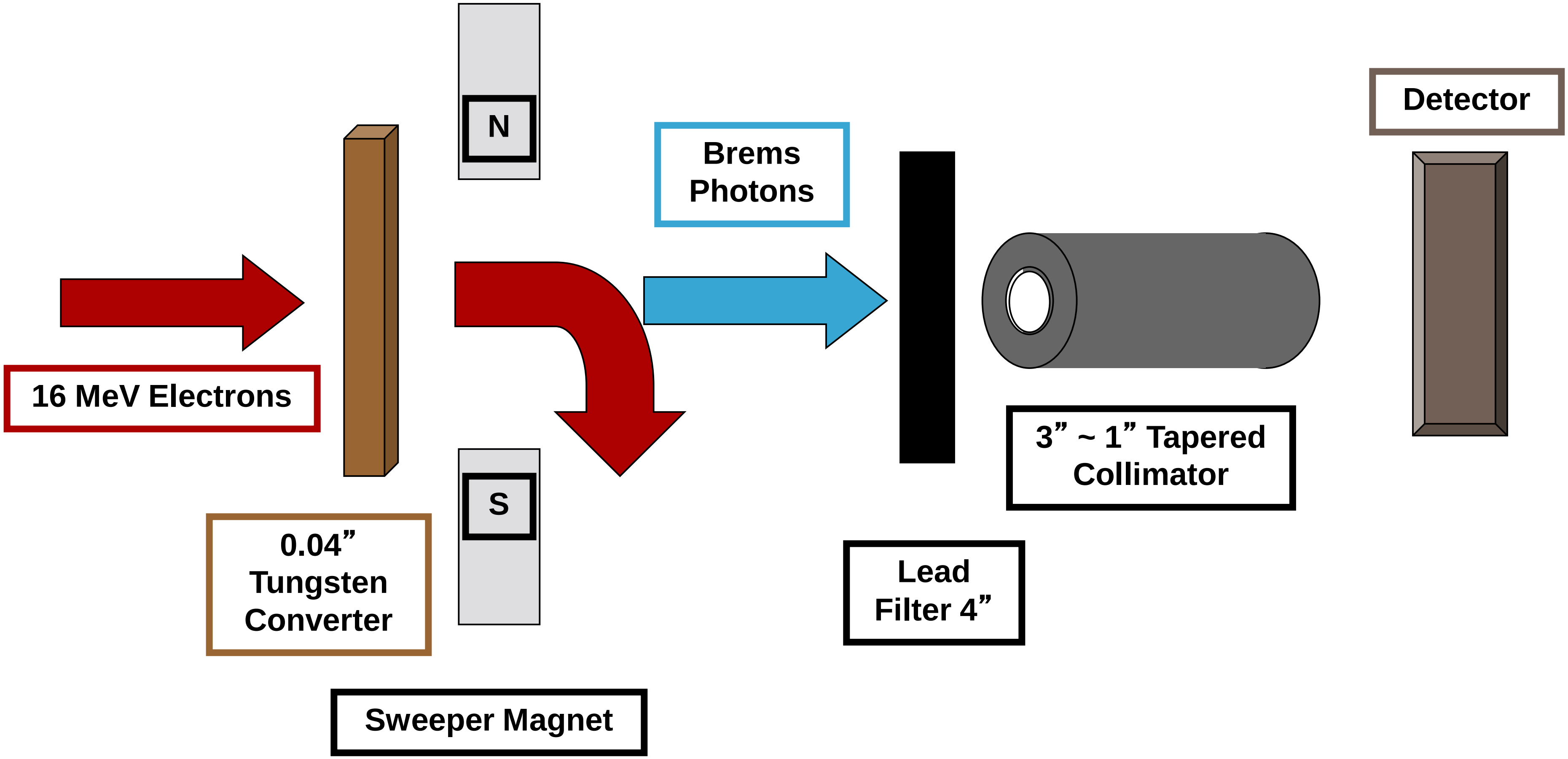


Pulse Width	Maximum Current (Amps)	Charge / Pulse (nC)	Peak e-Dose (Rads / Sec)	Peak Gamma Dose on-axis @ 1 meter (rads/sec)
50 ps	100	5	2E13	2.5E8
20 ns	3	60	6E11	7.5E6
100 ns	1	100	2E11	2.5E6
4 μs	0.5	2000	1E11	1.25E6

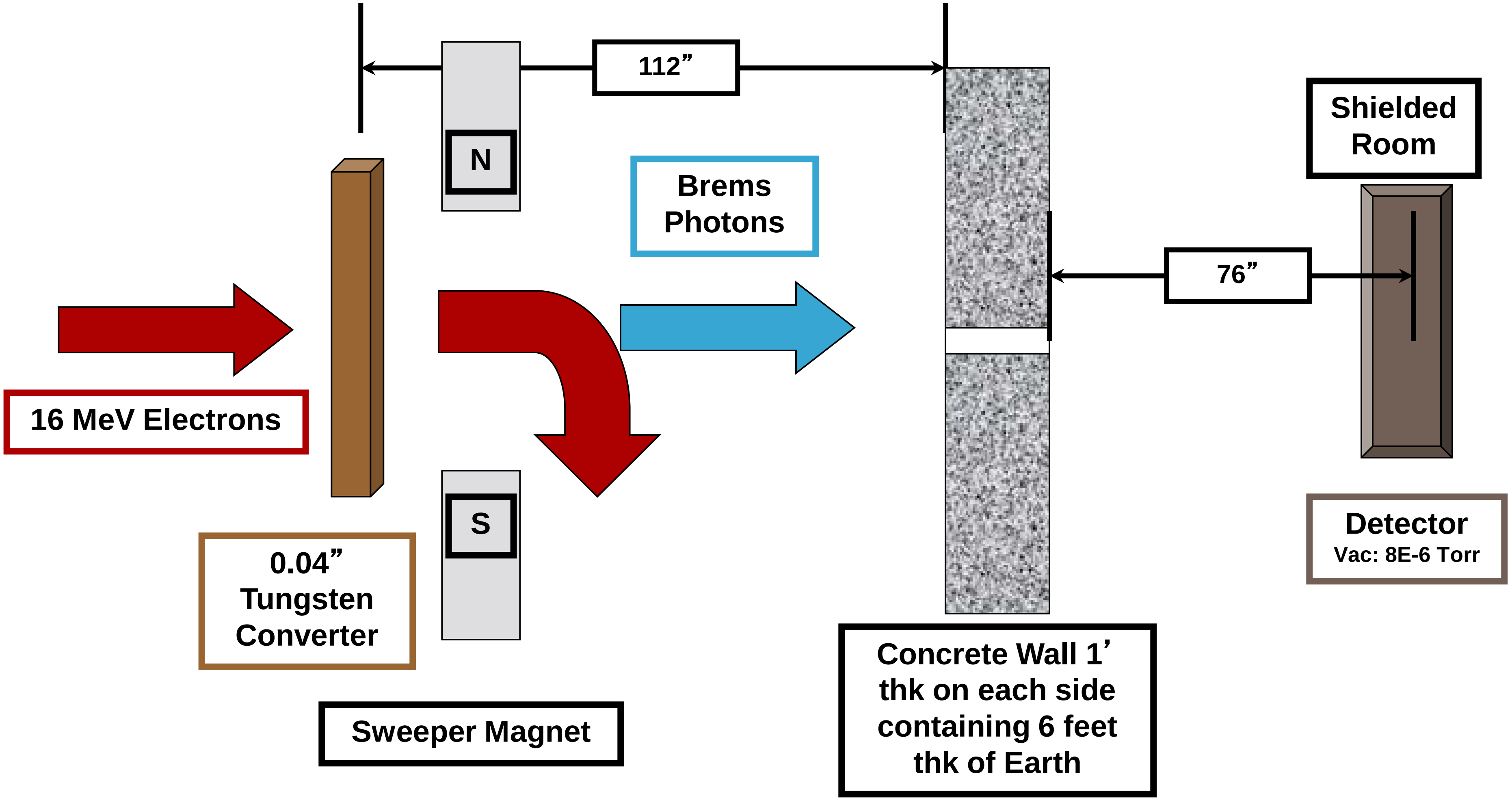
Mode	Energy Range or Dose Rate	Pulse Width (ns)	Rise Time (ns)
Bunched e-beam	0.5 - 28 MeV (16 MeV used)	0.050	0.005
Short Pulsed Non-bunched	1E12 Rad (Si)/s	2 - 50	0.2
Long Pulsed Non-bunched	2E11 Rad (Si)/s	100 - 2E6	Function of pulse width

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.

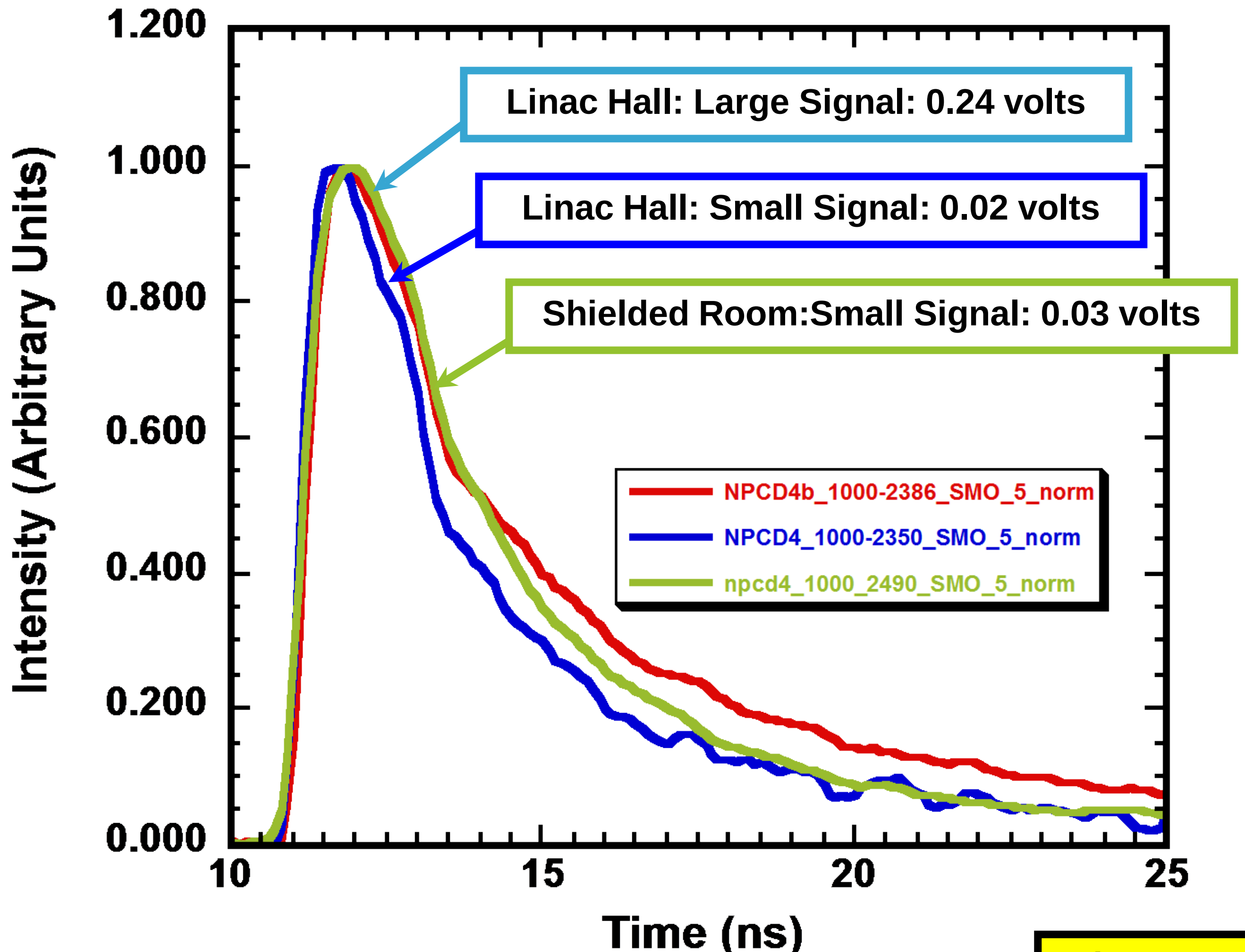
Schematic of LINAC calibration configuration setup with and without lead filter



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

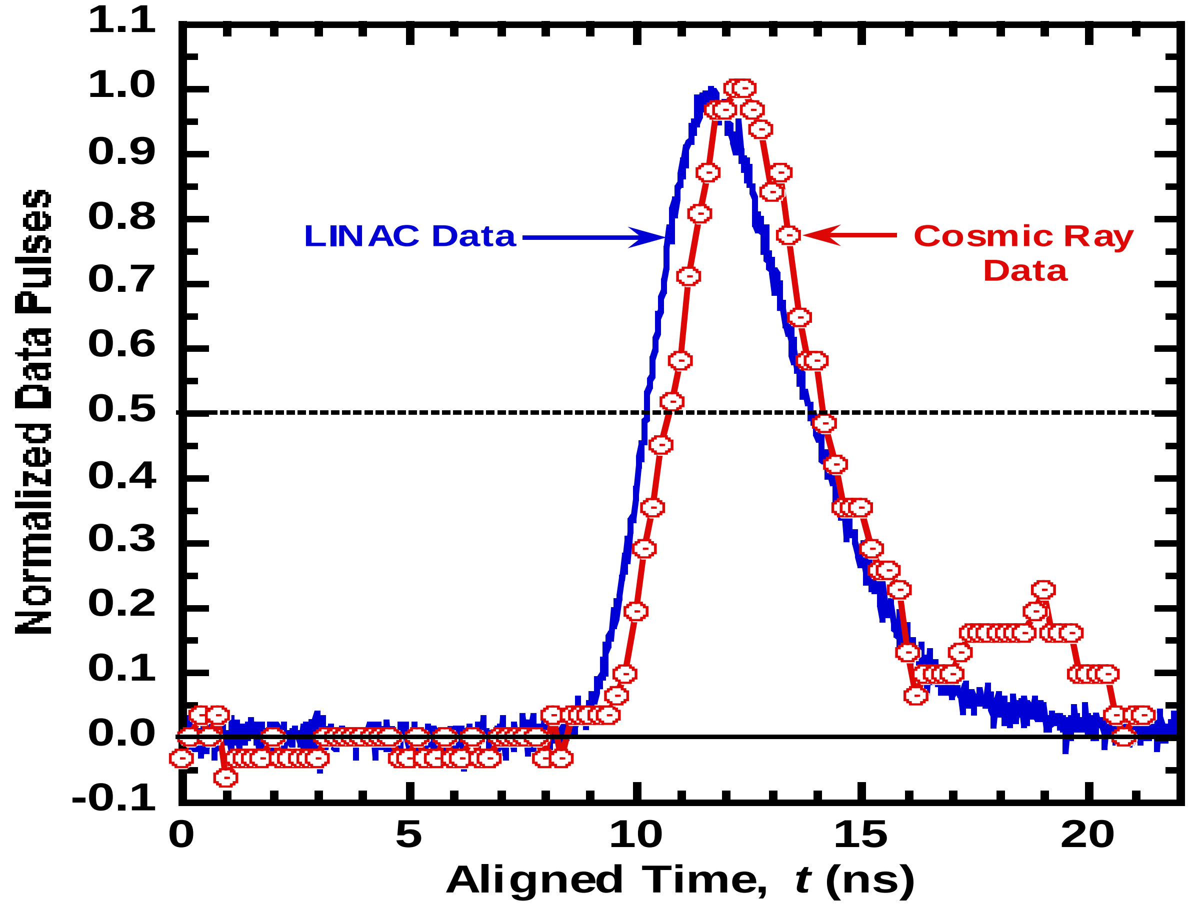


Idaho Cals July 2005

The scattering environment apparently matters

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

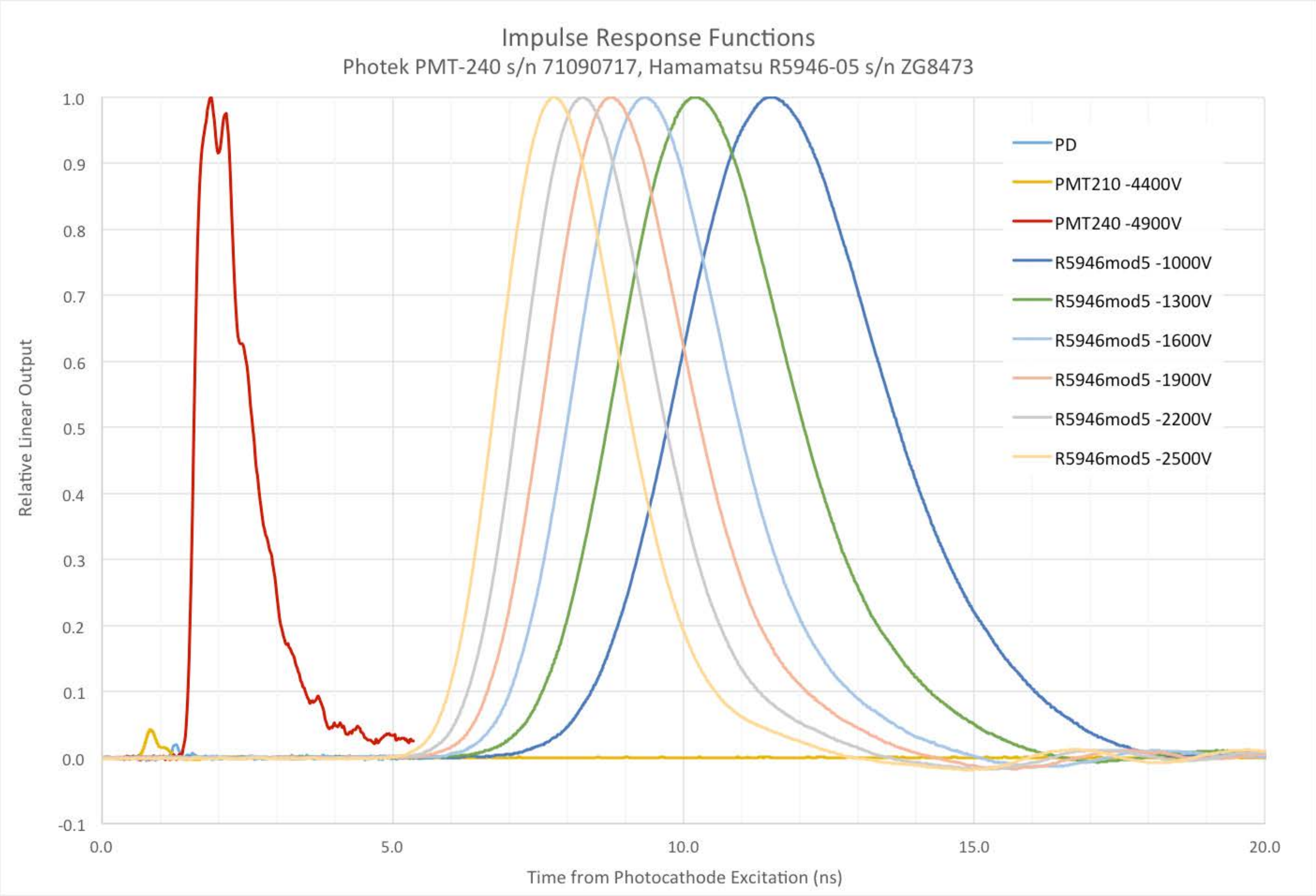
Typical nTOF time response measured at Idaho State Univ LINAC (25 ps photon pulse) and SNL's Cosmic-ray setup



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

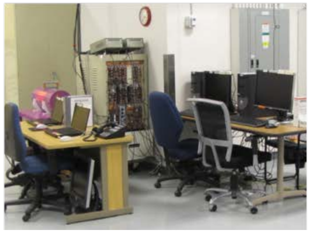


Rob Buckles, Irene Garza, and Ken Moy

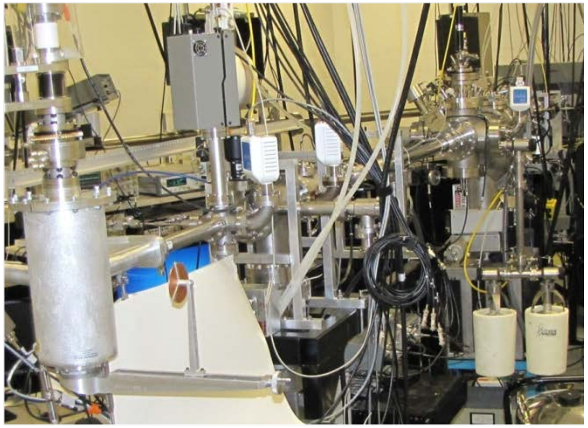
Sandia has DD and DT capability for absolute calibration of neutron diagnostics

350 keV Cockcroft-Walton

Data acquisition setup



Dedicated beam-line and hardware



Primary Standards Laboratory EST. 1950

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

Lead Probe Cross-Calibrated to "Secondary" Standard

nTOF Detector

Controlatron ~ 2 x 10^7 neutrons into 4π

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