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Title: Piezoelectric Transformer Neutron Generator (PTNG) Neutron Source for Well Logging

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Piezoelectric Transformer Neutron Generator (PTNG) Neutron Source for Well Logging

Gregory E. Dale

The purpose of this project is to develop a neutron source well-logging tool to replace radioisotope neutron sources currently used in industry. The new tool is based on a novel Piezoelectric Transformer Neutron Source (PTNG) under development at the University of Missouri. LANL will use its experience in the field of well logging to develop this novel neutron source into a robust tool that will be acceptable to industry. Also under development is a data tool to aid in the analysis of the well-logging data and comparison to the historical well-logging record. This presentation reviews the progress on this project to date.

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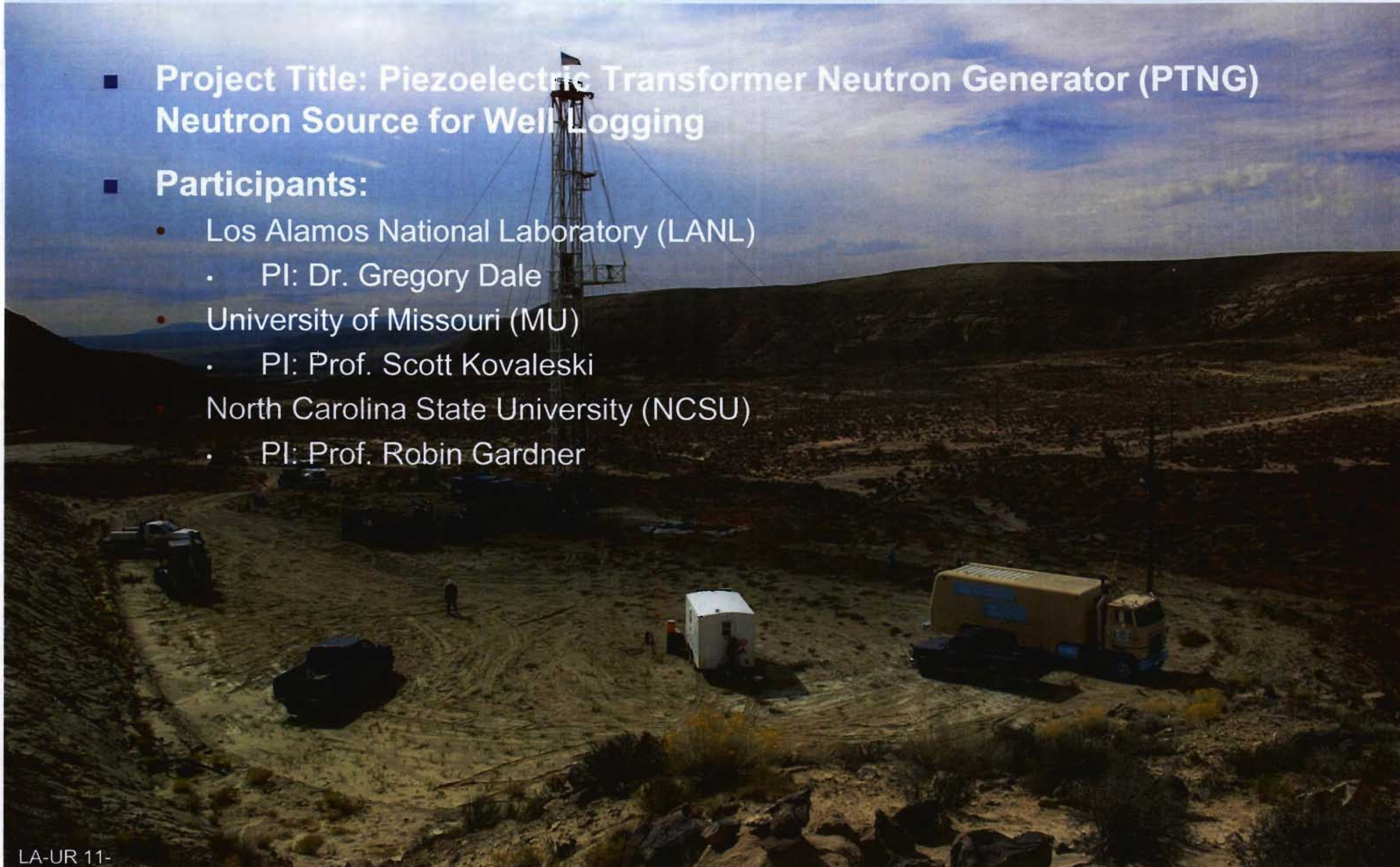
PTNG Neutron Source for Well Logging
Overview



- **Project Title: Piezoelectric Transformer Neutron Generator (PTNG) Neutron Source for Well Logging**
- **Participants:**
  - Los Alamos National Laboratory (LANL)
    - PI: Dr. Gregory Dale
  - University of Missouri (MU)
    - PI: Prof. Scott Kovaleski
  - North Carolina State University (NCSU)
    - PI: Prof. Robin Gardner

PTNG Neutron Source for Well Logging
Background

Photograph of an Am-Be neutron source used in well logging.

DOT Type A shipping cask for a 5 Ci AmBe neutron source. 13.5" diameter, 15" length, weight 90 lbs.

- **Neutron sources are used by the oil and gas industry to measure important properties of the well bore, such as formation porosity, hydrogen content, and elemental composition.**
- **^{241}AmBe is by far the most common isotopic source used in neutron well logging. ^{252}Cf and ^{239}PuBe have also been used.**
- **These well-logging sources can contain in excess of 16 Ci of radioactive material.**

Present Neutron Generator Technology

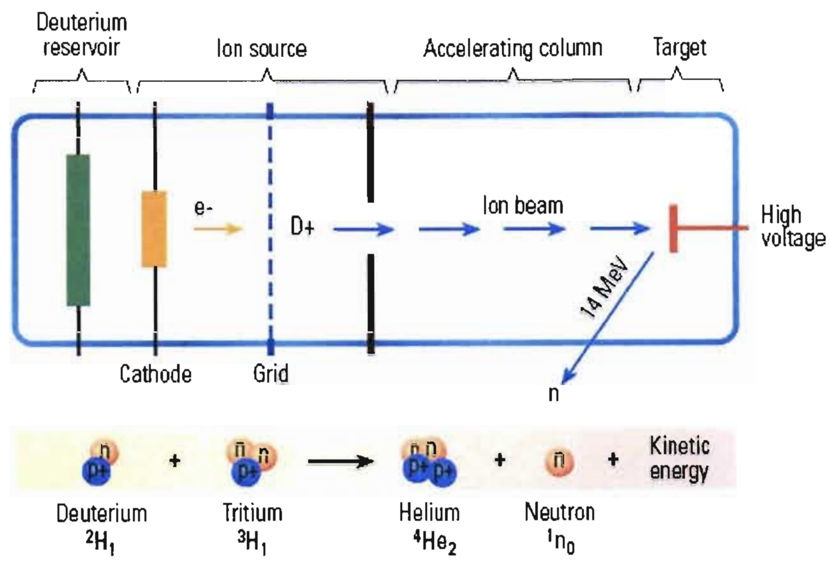
Fuse isotopes of hydrogen together in a sealed neutron tube.

Beam of deuterium ions created with an ion source is accelerated up to a potential of 100 kV and directed onto a metal halide target.

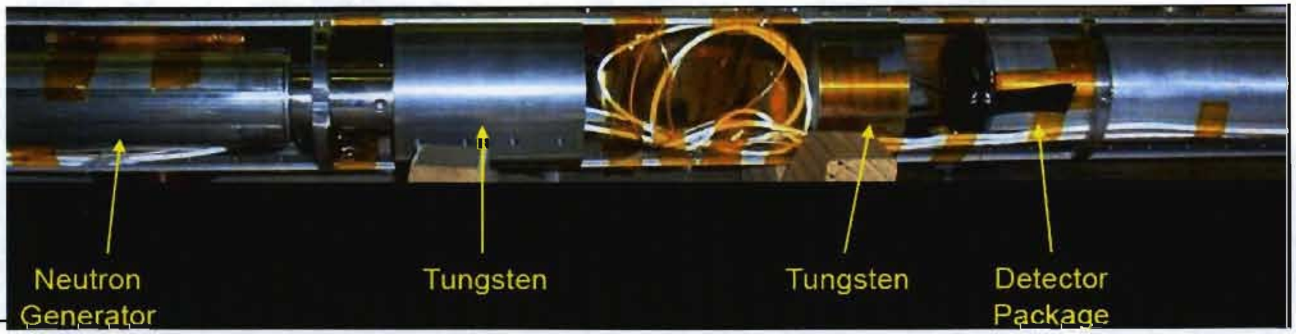
Target is hydrated with either deuterium or tritium.

DD and DT reaction energies are 2.5 and 14.2 MeV respectively.

DT reaction has 100 times higher neutron yield than DD.



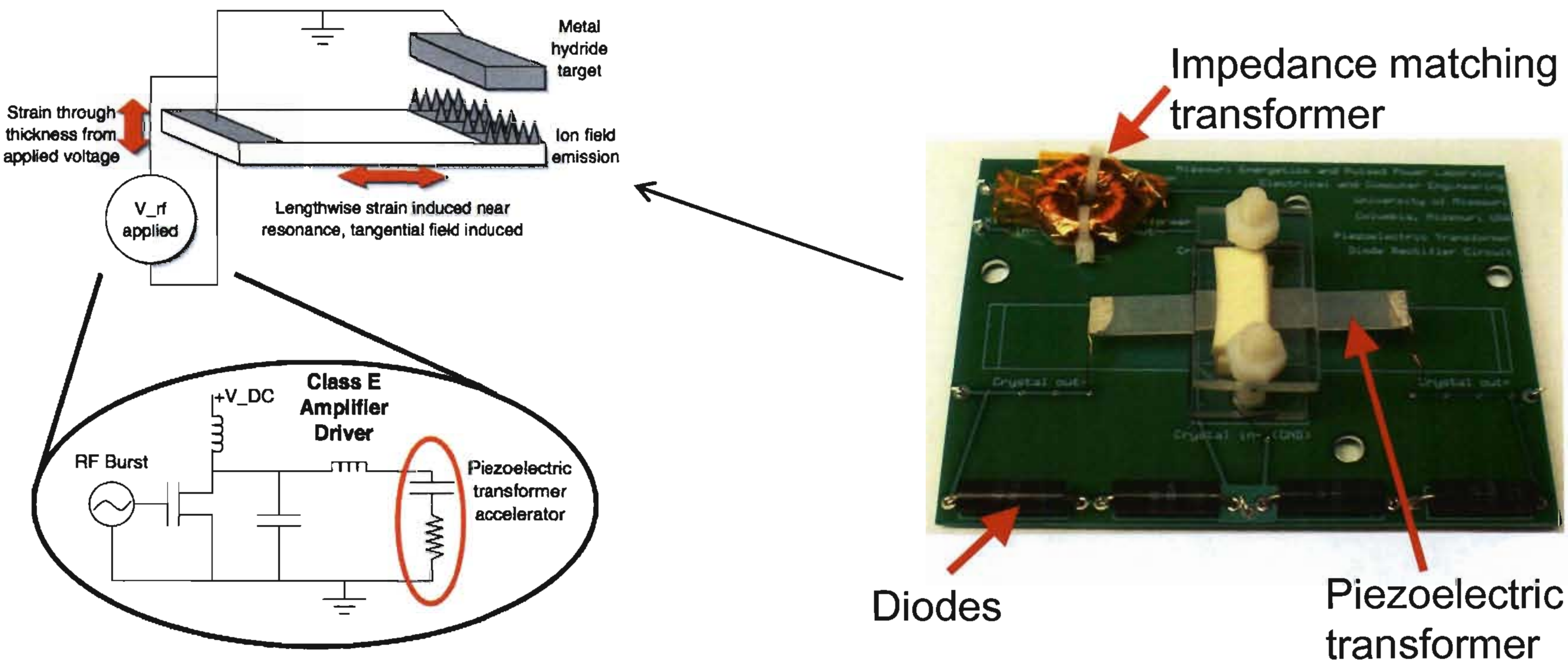
Minitron Pulsed Neutron Generator



Graphics Courtesy of Brad Roscoe, Schlumberger Doll Research

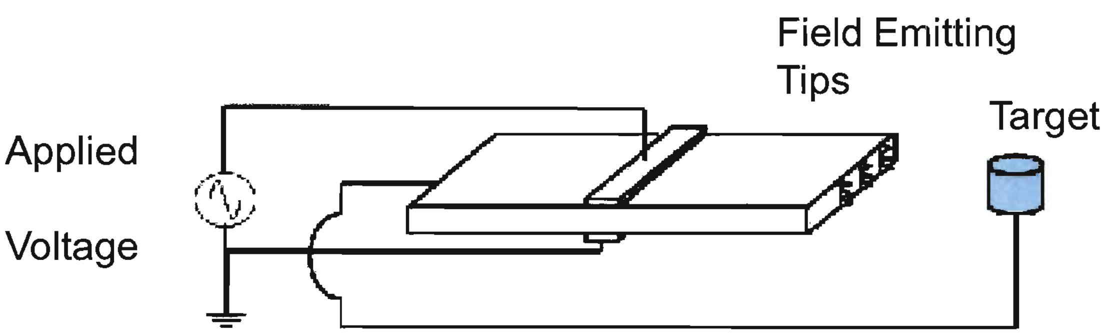
Neutron Source and Power Supply Technical Approach

- **The PTNG utilizes a field ion desorption source for the creation of ions. This source benefits from its inherent compact size and lack of ancillary components such as heaters and ion focusing systems.**
- **We will couple the field ion desorption source to a piezoelectric high-voltage generator, which is more compact than the traditionally used methods of high-voltage generation.**

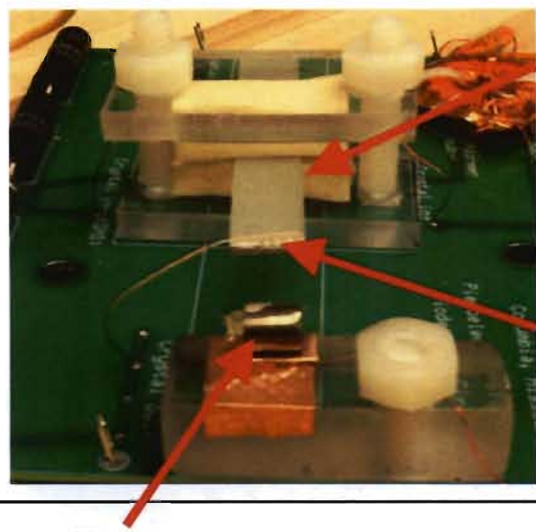


Piezoelectric HV Power Supply

- **Piezoelectric materials are able to convert mechanical signals into an electric potential, and vice versa.**
- **A piezoelectric transformer is a type of AC voltage multiplier. Unlike a conventional transformer, which uses magnetic coupling between input and output, the piezoelectric transformer uses mechanical (vibrational) coupling.**
- **When the applied excitation frequency is equal to the mechanical resonant frequency of the material, a higher output voltage is generated across the output section by the piezoelectric effect.**



Piezoelectric transformer



Piezoelectric Transformer X-ray Spectra Measurements

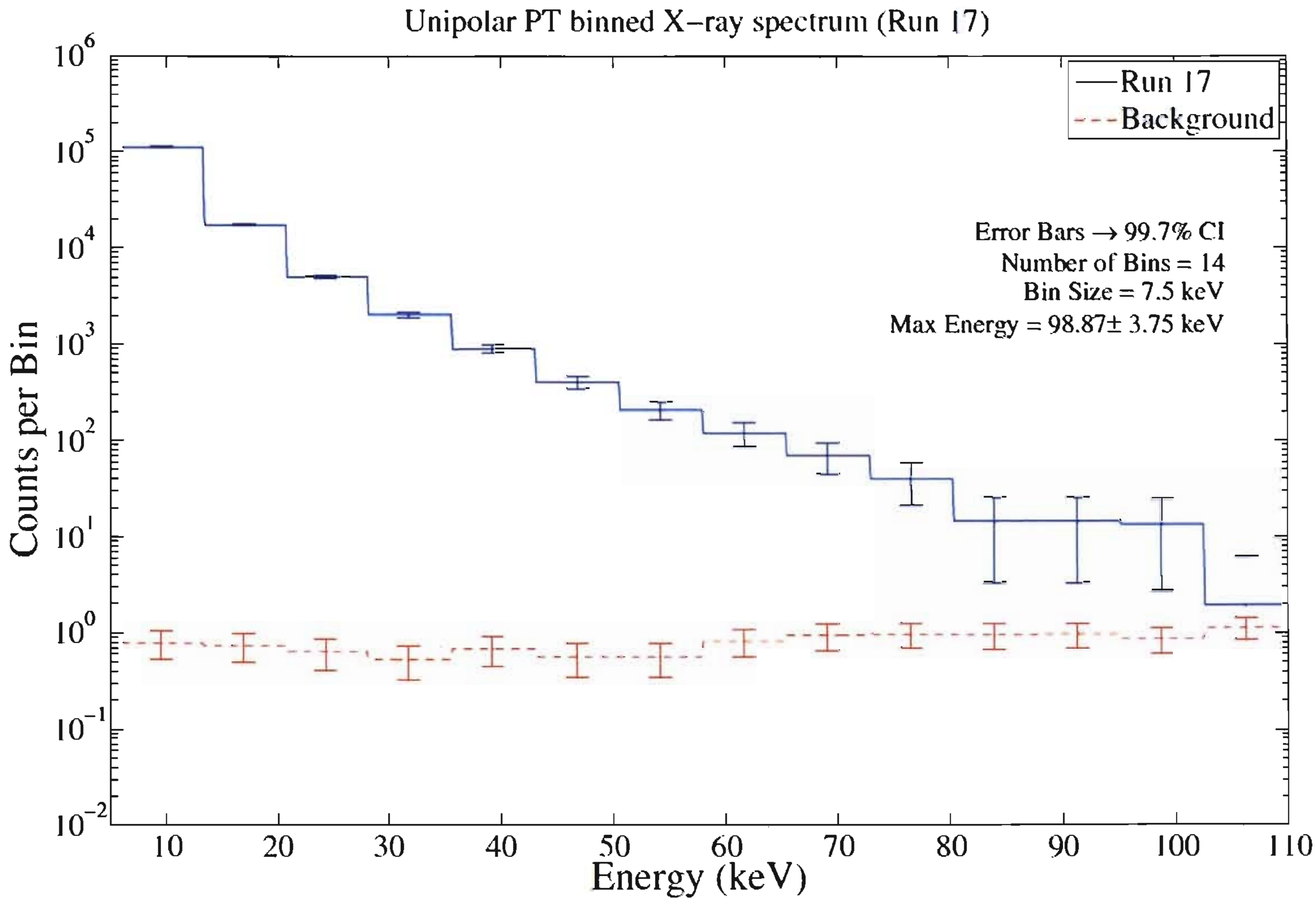
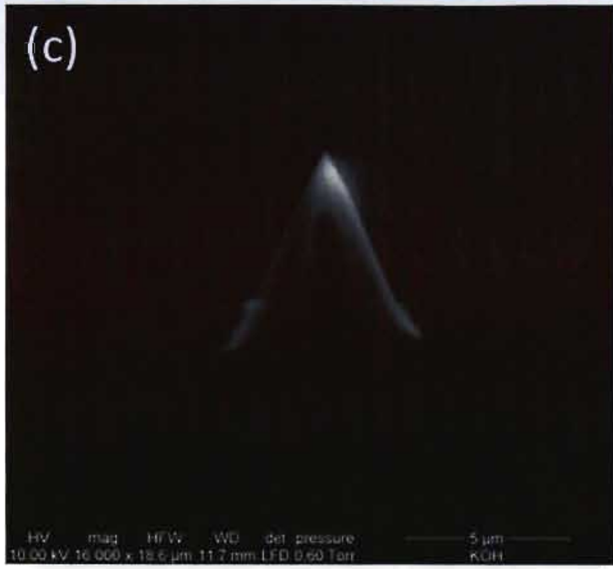
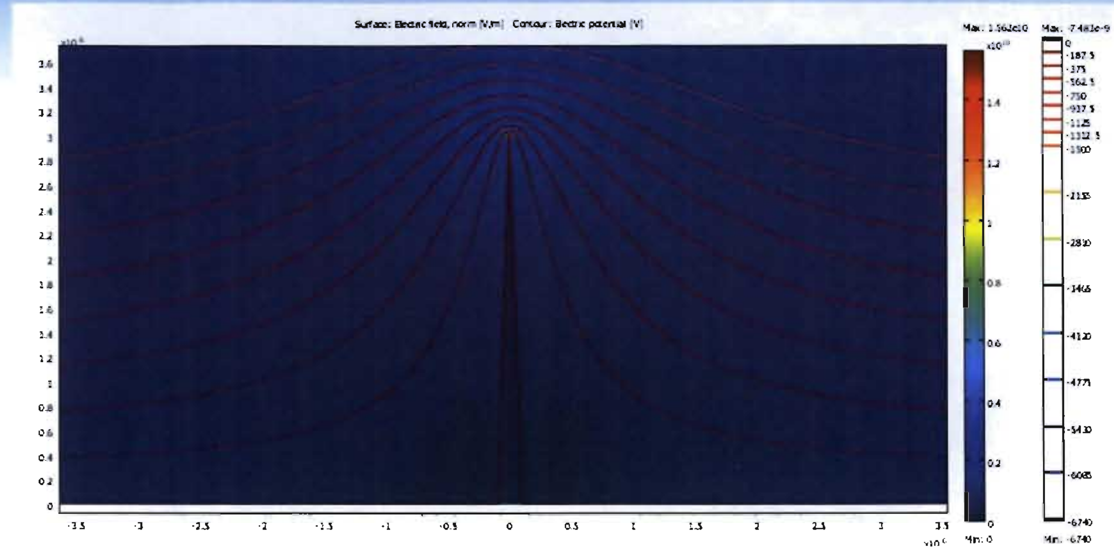
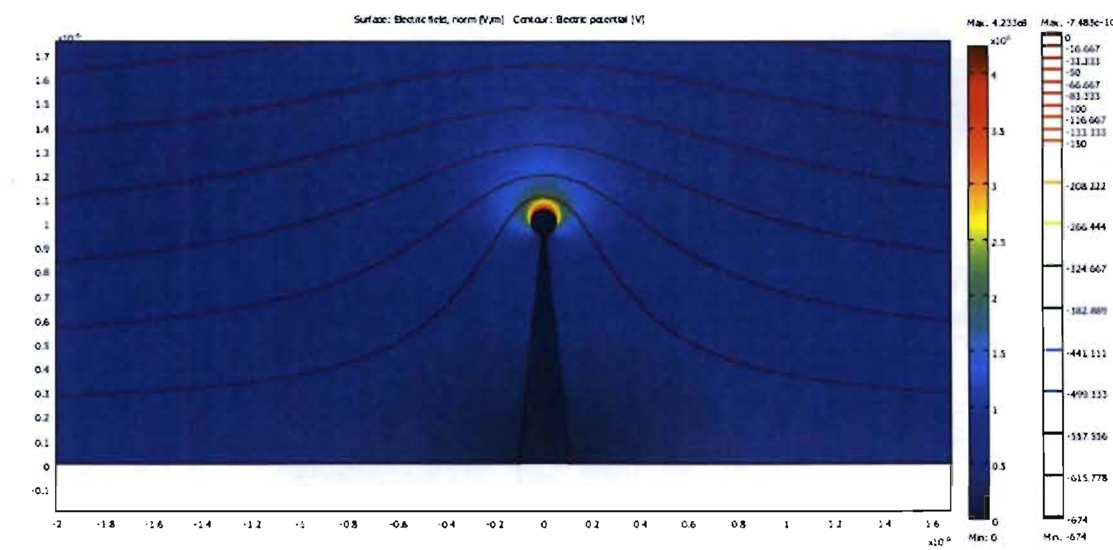


Figure 4: 98 keV X-ray spectrum, recorded 9-12-11

Silicon Emitter Tip Fabrication at MU



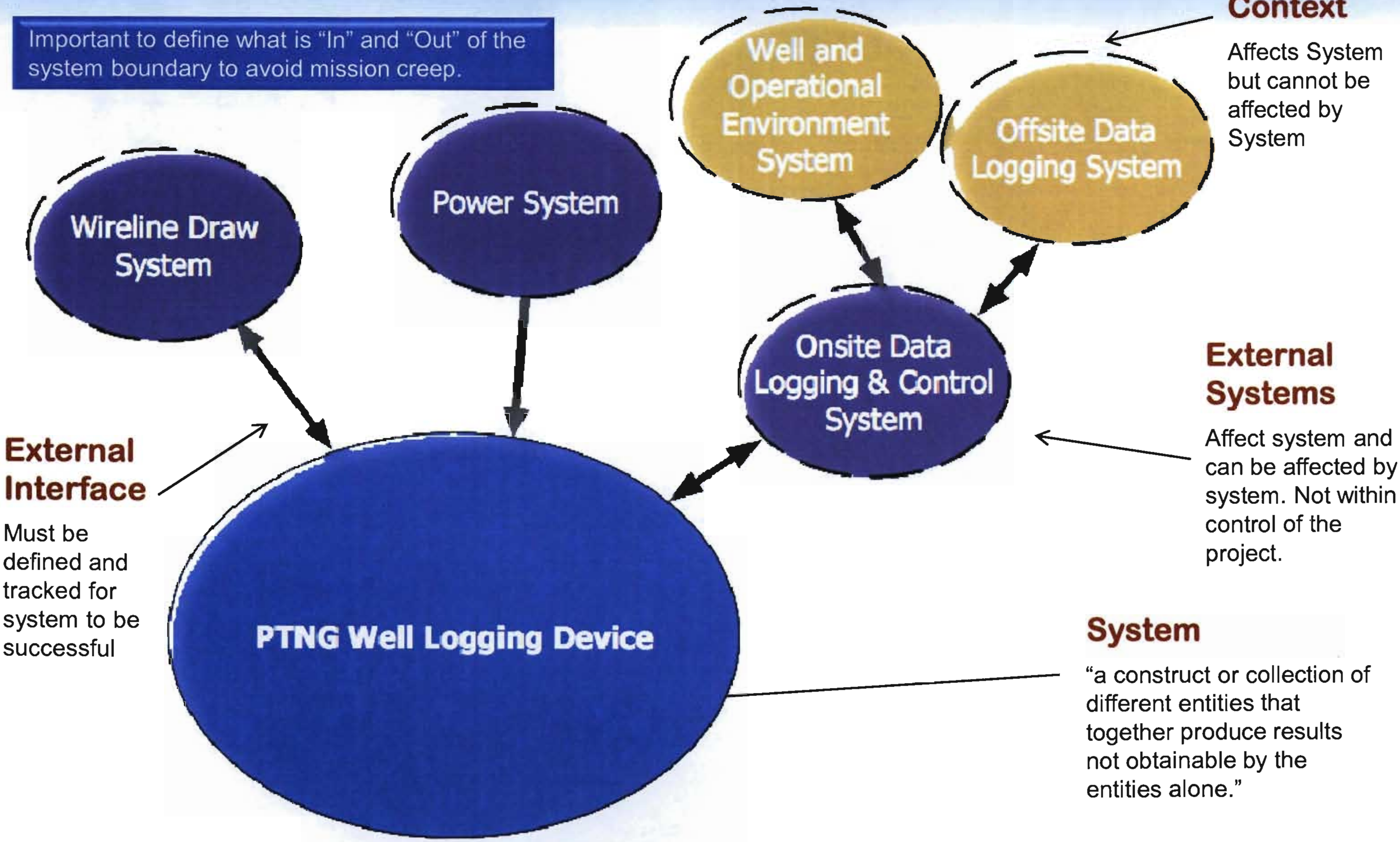




Sharp tips have higher field enhancement, but rounded tips may have higher emission area and more uniformity

PTNG Device System

Important to define what is "In" and "Out" of the system boundary to avoid mission creep.



PTNG Component Hierarchy

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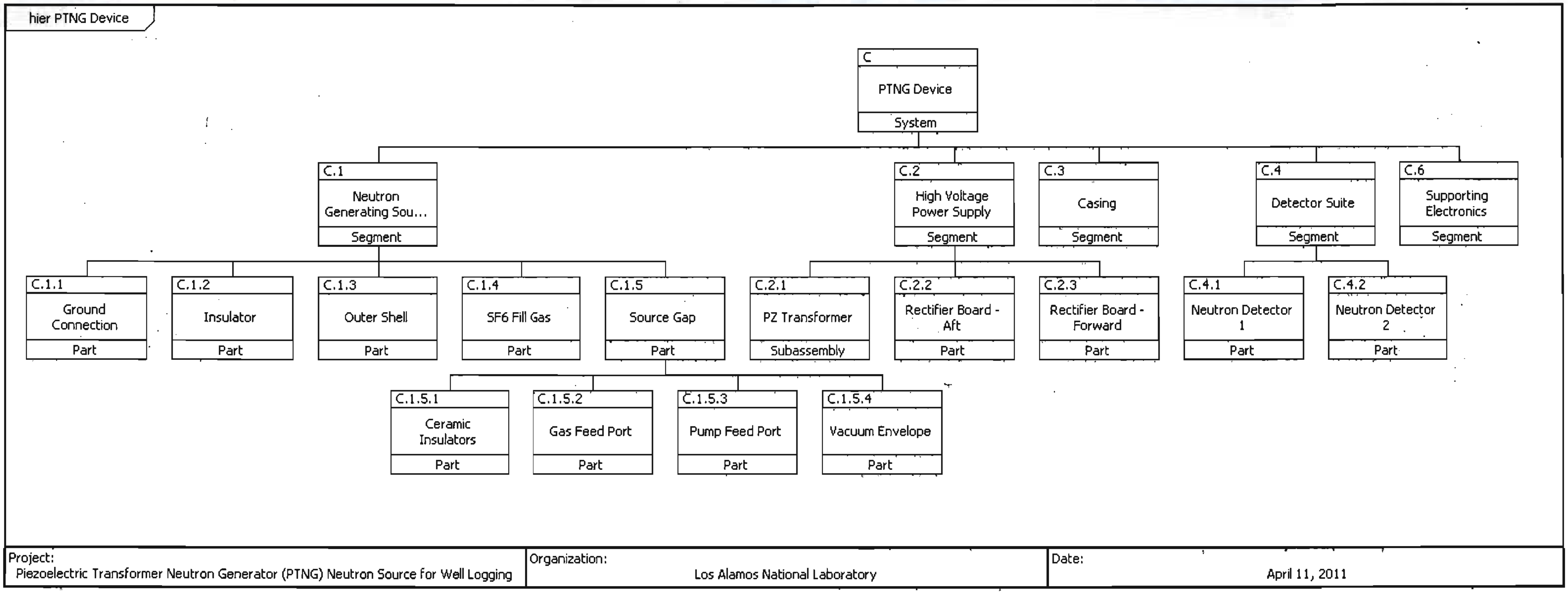
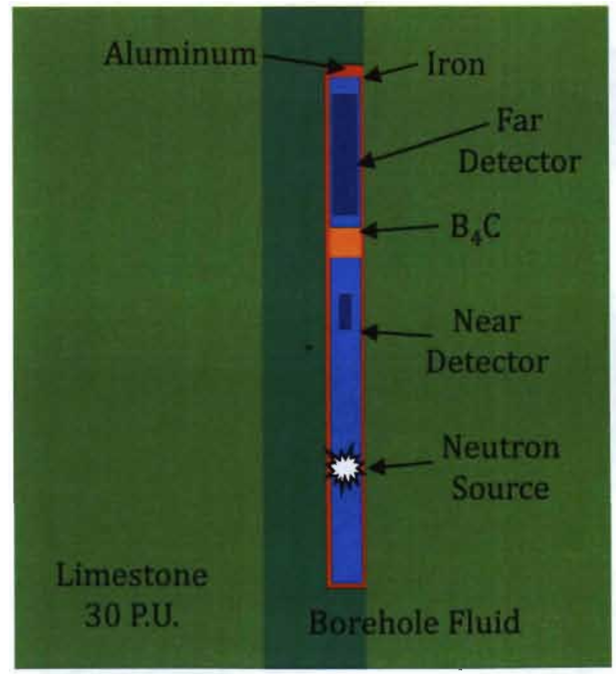


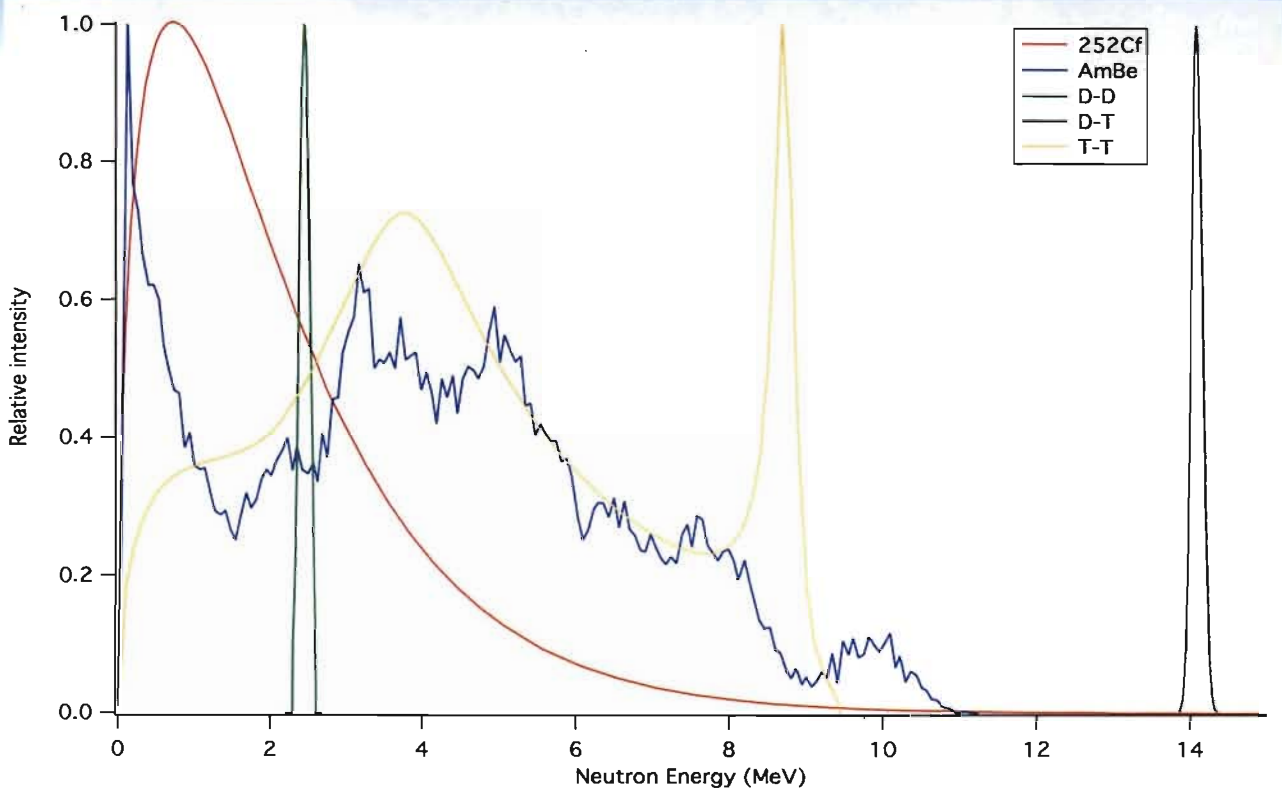
Other Views will be:
Physical Block Diagram
Interface Block Diagram
Functional Flow Block Diagram
Activity Diagram

Well-logging Modeling and Simulation
Starting point: porosity tool

- **We need a porosity tool in the public domain**
- **We chose the Longhorn Nuclear Logging Tool (LNLT) published by Mendoza et al. from the University of Texas**
- **Tool is kept consistent, no effort to optimize tool**
- **Things we compared / considered**
  - Limestone/sandstone
  - Different neutron sources
  - AmBe, ^{252}Cf, D-D, D-T, T-T
  - Materials to modify the D-T spectrum

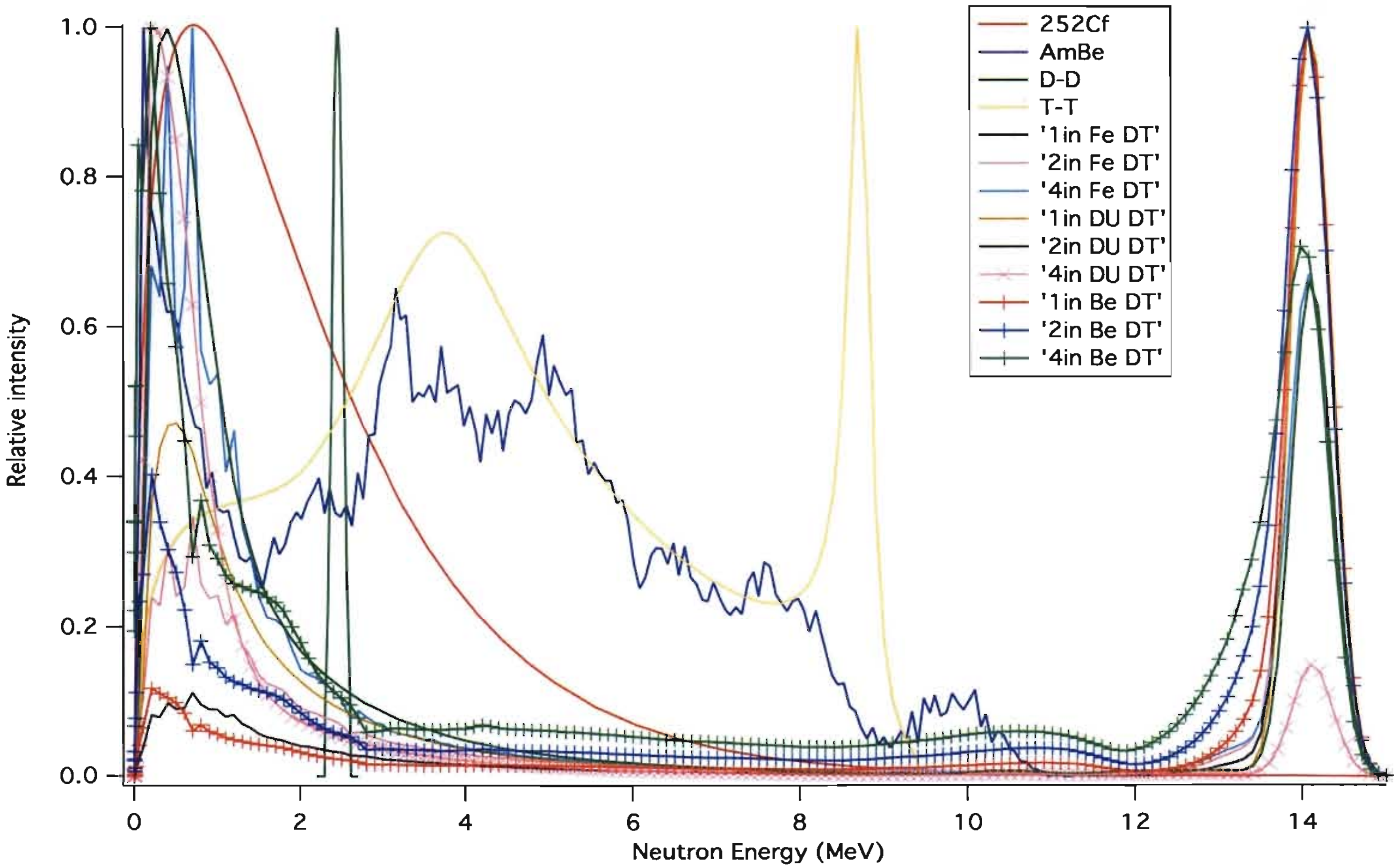


Neutron Source spectra and Yields

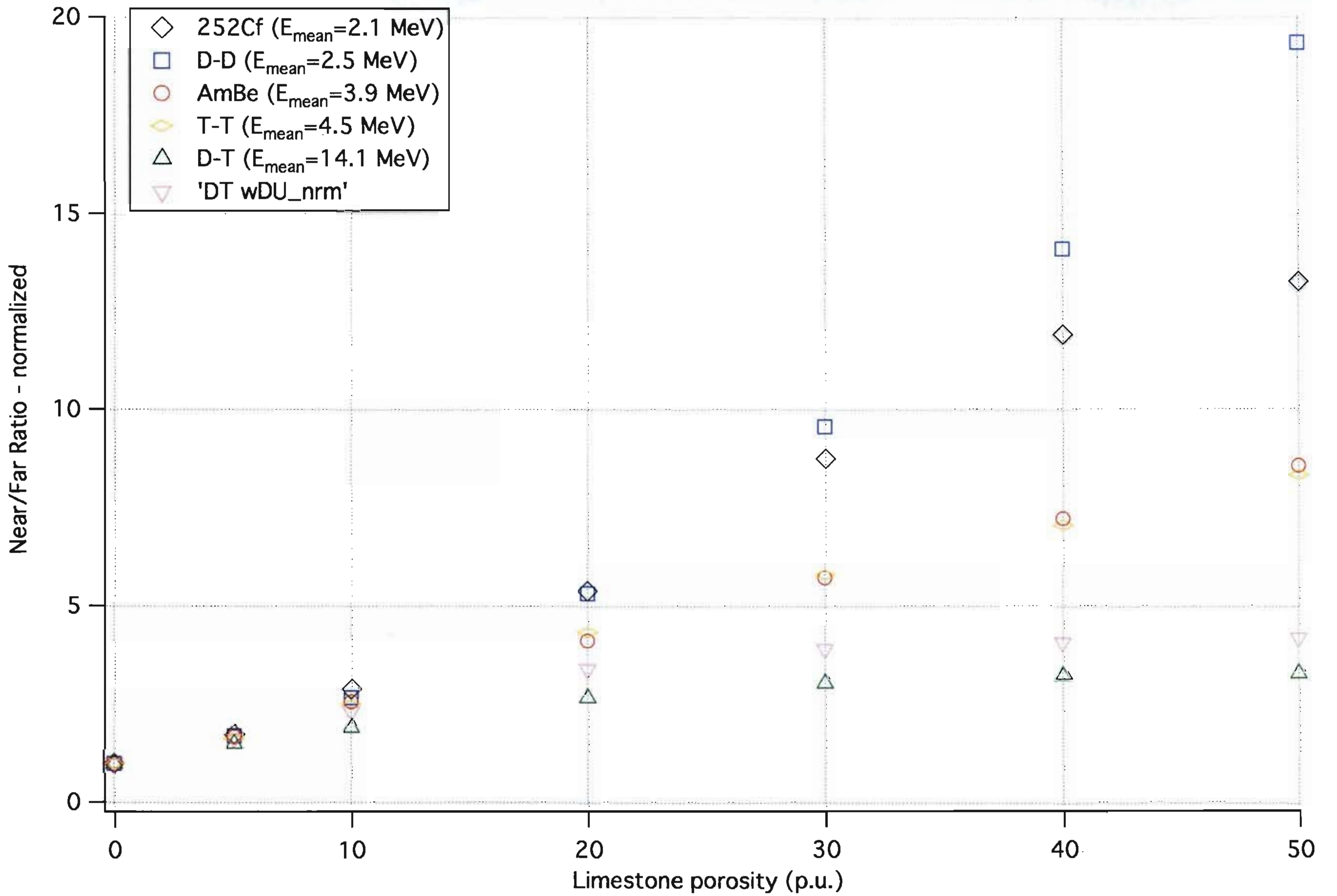


Neutron Source	Nominal Yield	Yield
AmBe	$3x10^6$ n/s/Ci	$1.87x10^7$ n/s
^{252}Cf	$4.33x10^9$ n/s/Ci	$6.7x10^7$ n/s
DT	$4x10^{11}$ n/s/mA	$1x10^8$ n/s
DD	$4x10^9$ n/s/mA	$1x10^6$ n/s
TT	$4x10^9$ n/s/mA	$1x10^6$ n/s

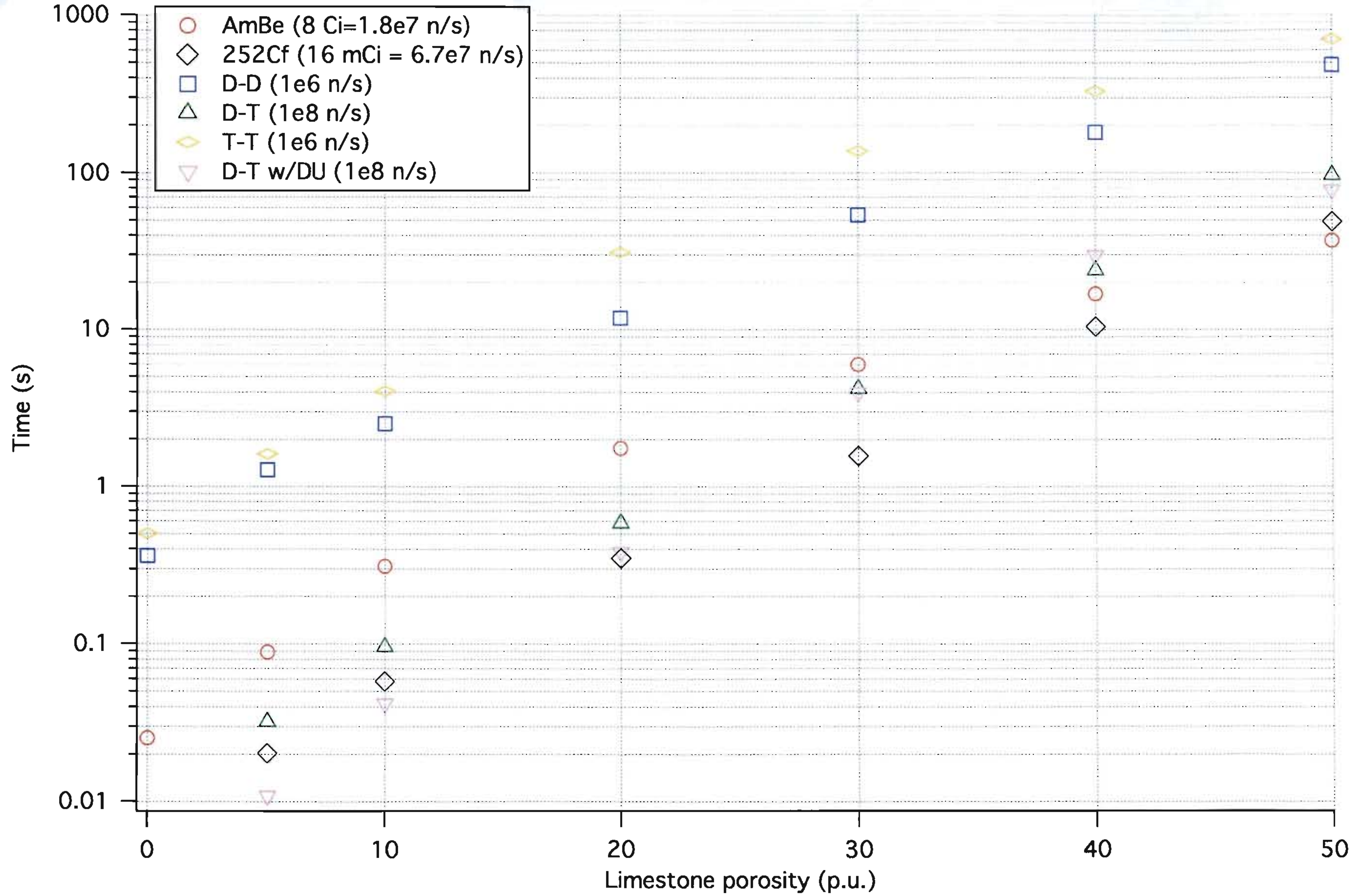
Modified spectra



Limestone porosity with modified source

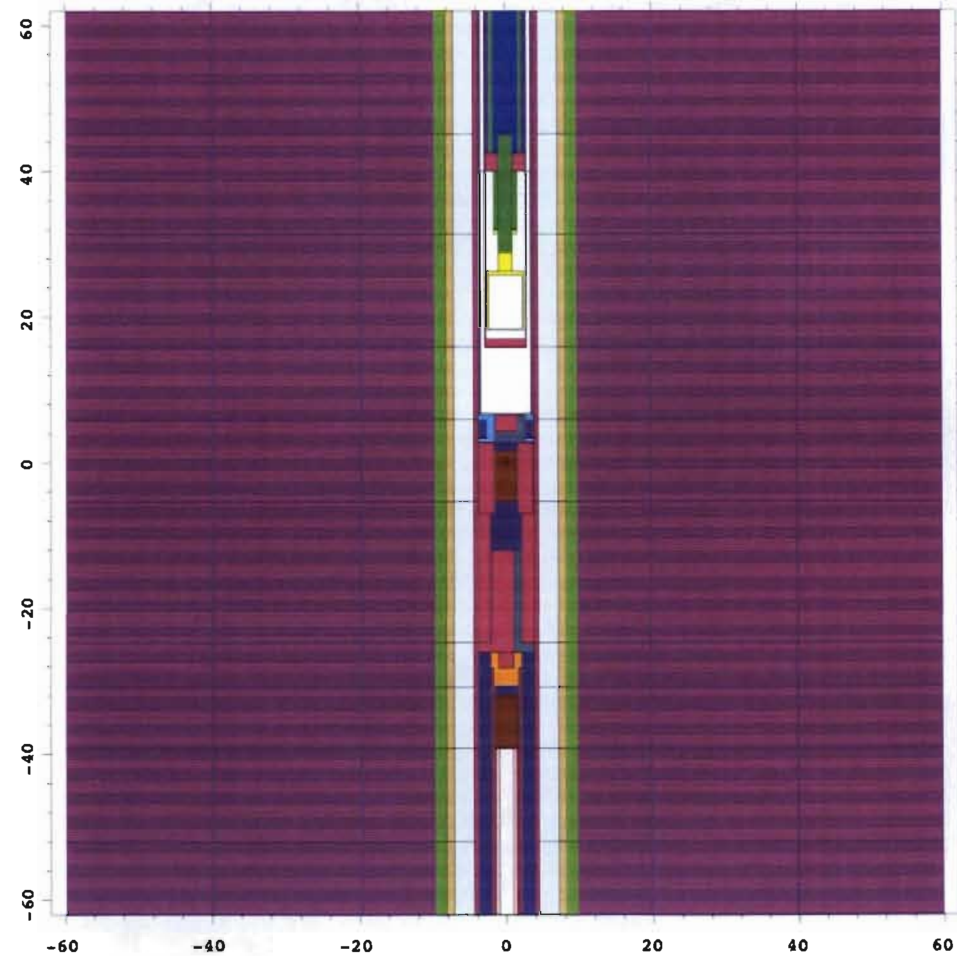


Limestone measurement time

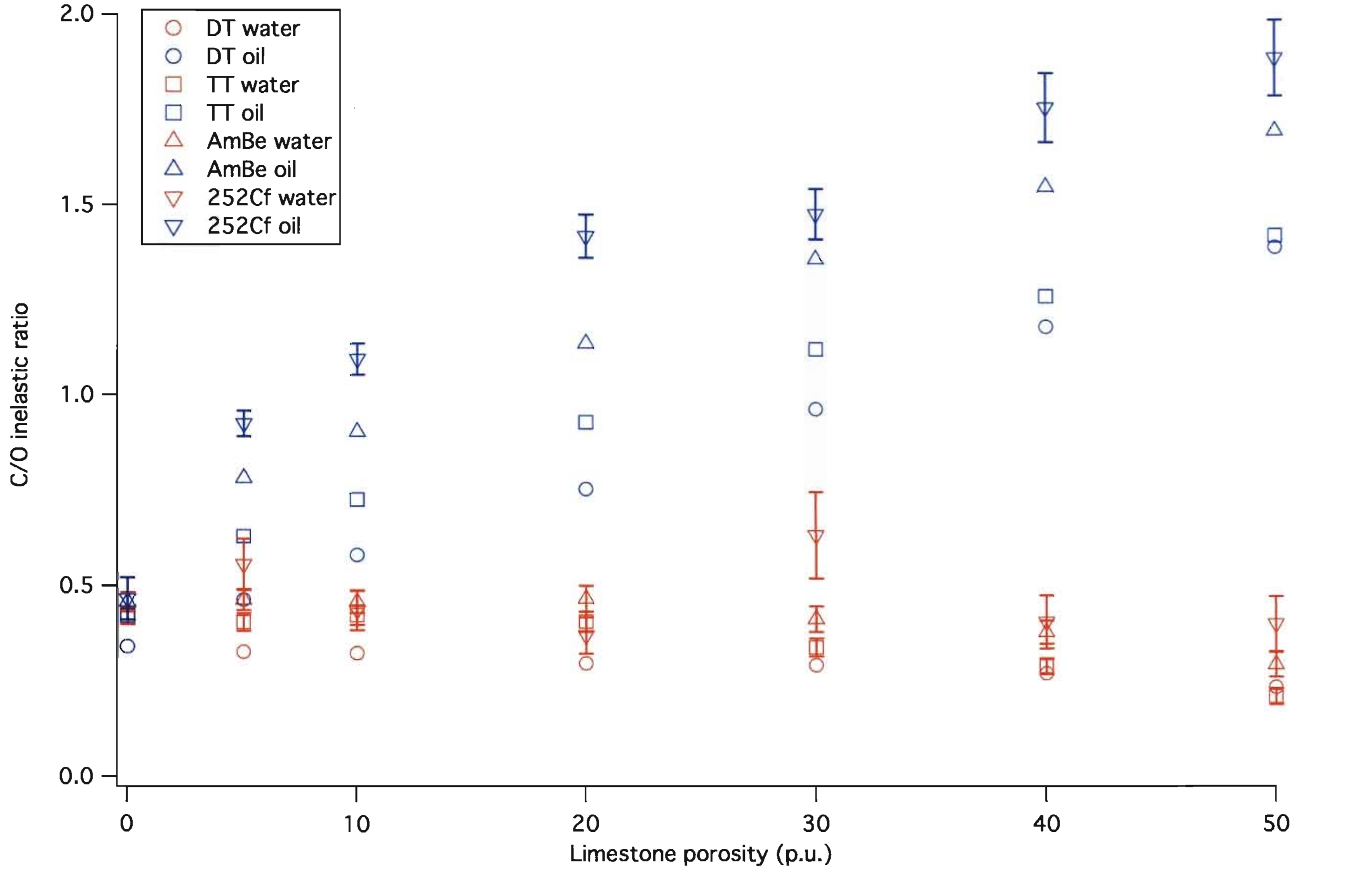


Inelastic Gamma Modeling

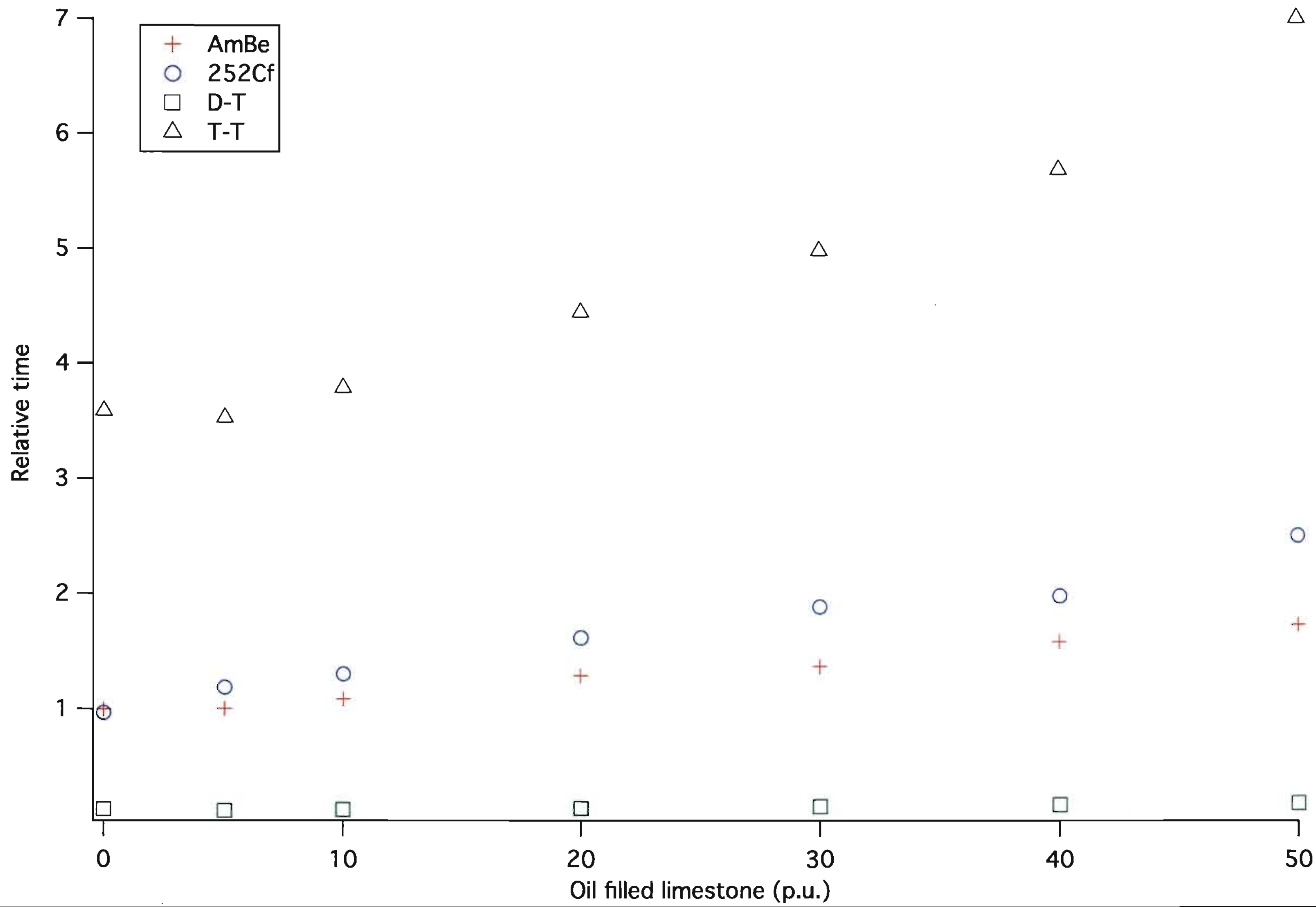
- For C/O ratio simulations we used a tool developed at DOE Grand Junction since, like the Longhorn tool, the design is in the public domain.
- Shown at right is a cross sectional view of the DOE Grand Junction tool model used to simulate the carbon to oxygen ratio response for the different neutron spectra.



Carbon to Oxygen Ratio for Several Different Neutron Sources



C/O Measurement Time Estimate



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Conclusions for the Source Comparison

- **Spectral modification was minimally productive**
- **T-T appears to be a good substitute for AmBe for neutron porosity measurements**
  - Neutron yield of a TT device needs to be substantially increased to reduce logging time.
  - Tritium beam issue will be a challenge
- **Tool modifications may be worthwhile, such as optimizing detector spacing.**