# DIFFERENTIAL NUCLEAR DATA MEASUREMENTS AT ANL/IPNS

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# OVERVIEW: DIFFERENTIAL NUCLEAR DATA MEASUREMENTS AT ANL/IPNS

GOAL:

It is to measure differential cross sections and resonance parameters for heavy actinide isotopes.

FACILITY:

The facility used is Argonne National Laboratory – Intense Pulsed Neutron Source.

INL MEASUREMENTS:

Use multi-detector arrays and coincidence methods developed in other areas of low-energy nuclear physics in the past 25 years but as yet not applied to cross section measurements.

RECENT RESULTS:

During the FY-05 LDRD funds were used to take data with the INL system at ANL-IPNS and these preliminary results are presented as demonstration of the capability that has been developed.

SUMMARY

# SITUATION:

Limited quantities of isotopes are available for targets and facilities to fabricate the material into targets are few in the United States. INL has a source of targets from Russia.

"In-beam" experimental methods are used and a facility not previously used for cross section measurements provides an additional capability.

Multi-detector and coincidence methods can overcome mixed reaction channels and backgrounds; IPNS spallation neutron source provides intense beam to allow coincidence methods.

Some measurement problems that are overcome:

- Fewer segmented measurements over small energy ranges are made and "normalized" to be joined together. Continuous measurement from ~0.001 eV to ~1 MeV.
- Complex resonances can be separated into single resonances.
- Target contaminates are can be rejected to reduce errors. Corrections are made in sorting.
- Reaction channels cross contaminate in the actinides and can be separated.

# IPNS - a spallation neutron source

A usable neutron energy from ~1 meV to ~1 MeV.

An integrated flux of ~5.3 x $10^6$ n-cm-2-s-1 at 12 m.

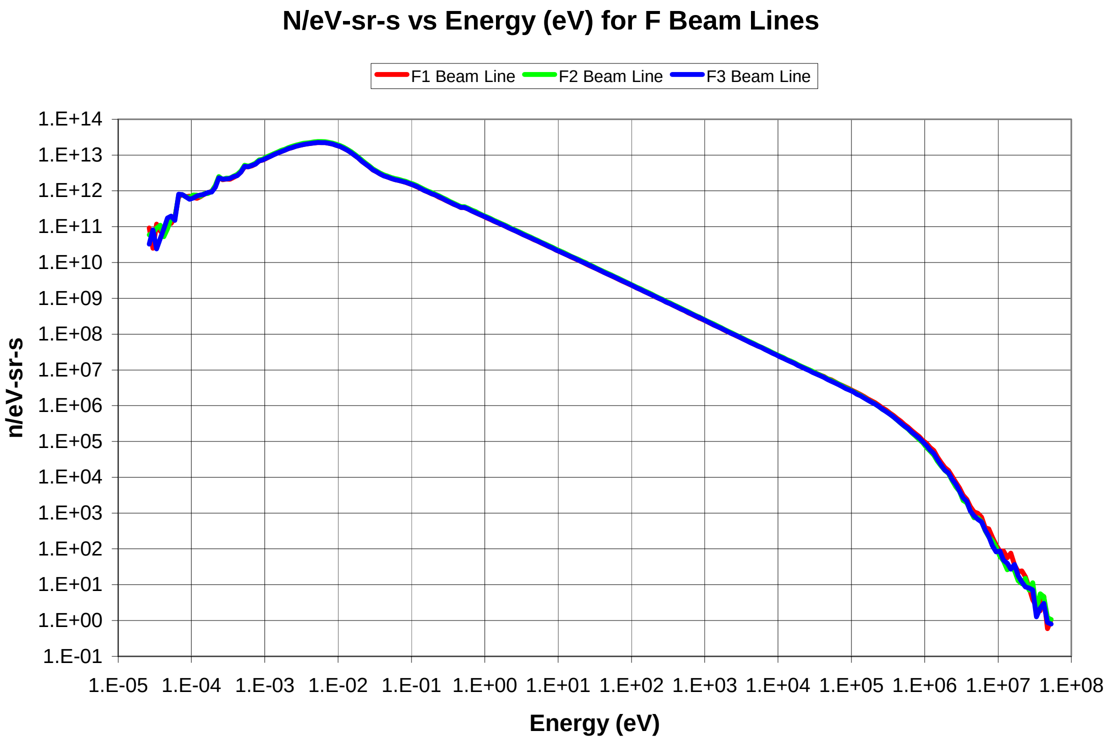
Beam is available ~23 weeks per year.

Neutron beam is moderated with a cryogenic methane moderator.

The incident proton pulse width, ~70 nanoseconds.

IPNS is a user facility, versus a cost recovery facility.

Gram quantities of most actinides can be used in IPNS.



# In-beam physics methods are employed

Arrays of detectors, multiple detectors of multiple types.

Fast electronics capable of short time resolution, ~1 ns.

Detectors and electronics are operated in fast coincidence mode.

Data are collected on an event-by-event basis.

Data are stored in list mode for offline sorting or gating based analysis.

These methods of data collection and analysis result in several things.

# The methods of data collection and analysis allow:

Clean separation of reaction channels.

Minimization of unwanted backgrounds due to contaminates and scattering in surrounding material is possible.

Post processing allows multiple passes through the data.

Correlations of experimental parameters are used to explore the underlying nuclear physics.

Nuclear physics research carried on in recent years depends on correlated measurements for new information about nuclear structure and reaction processes.

# The INL experimental setup

Complete supporting electronics for each detector channel.

VME based data acquisition and equipment control system.

Automatic liquid nitrogen fill system for HPGe detectors.

A custom CAMAC Multi-stop Time-Of-Flight TDC was built.

All components of the measurement are computer controlled, remotely monitored (including visually).

Incident neutron beam monitoring.

Setup is on beam line F3 at ANL-IPNS at a 12 meter distance.

# The INL experimental setup

- From eight to 32 fully depleted Si–detectors are used, depending on the number of target foils.
- Eight liquid scintillator fast-neutron detectors.

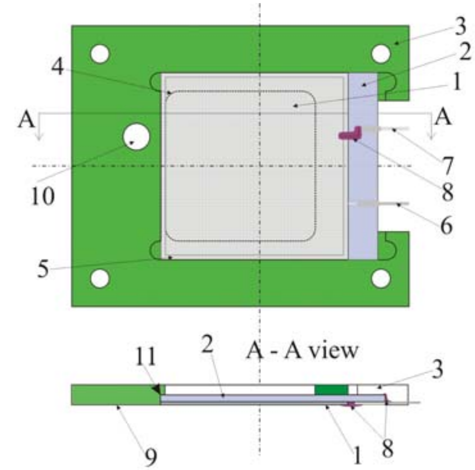
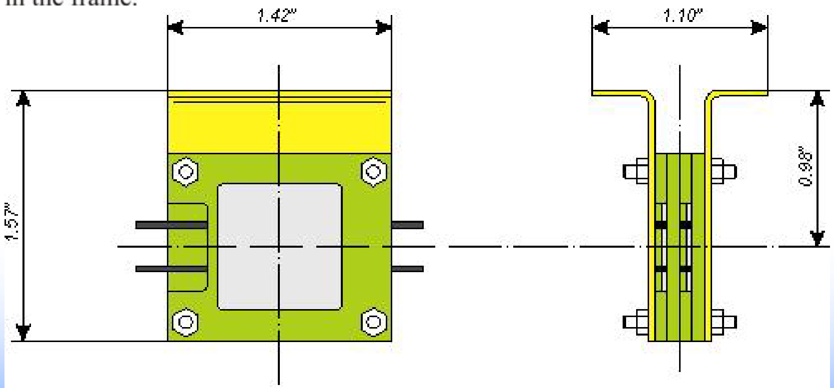
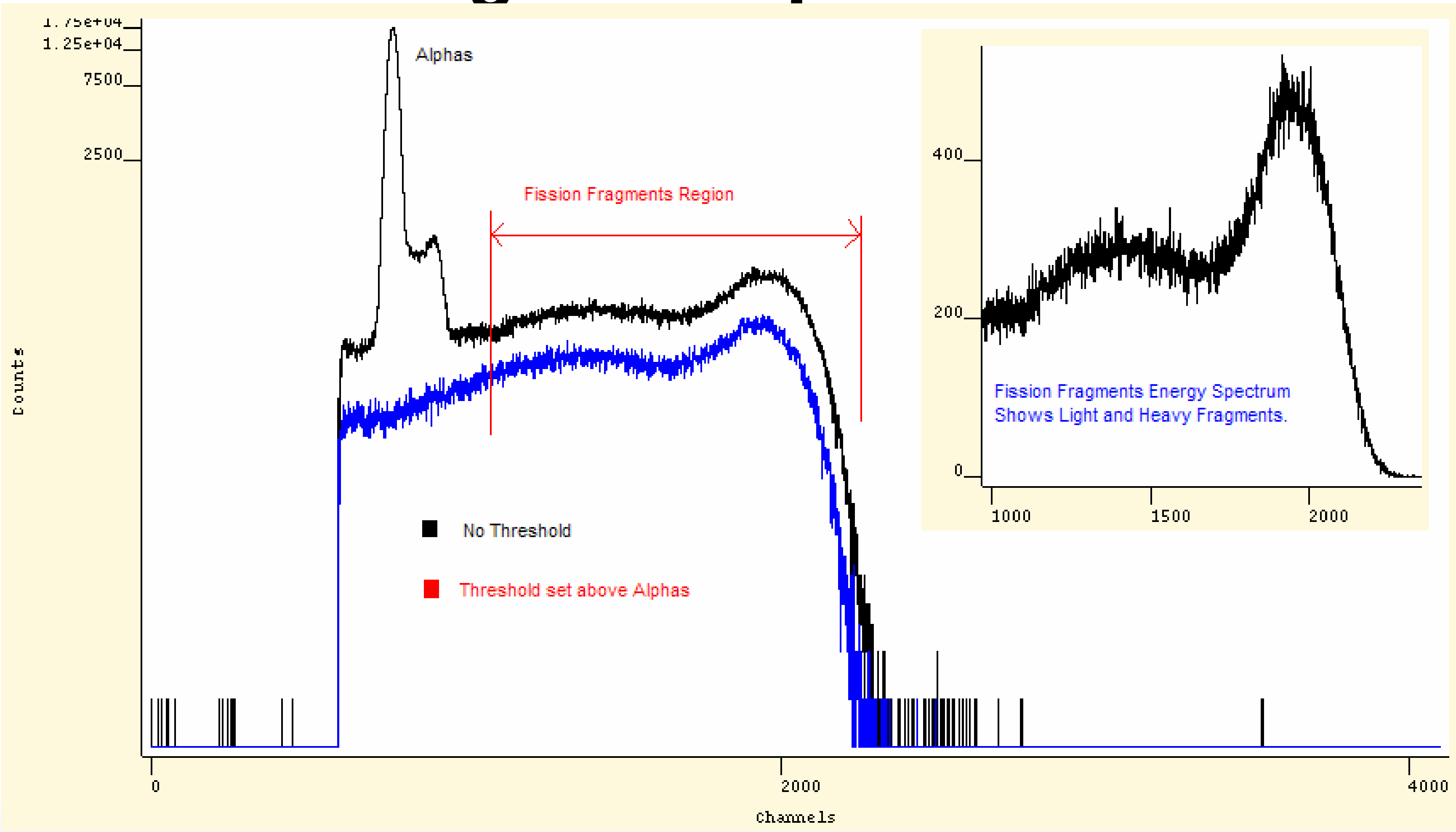



Figure 1

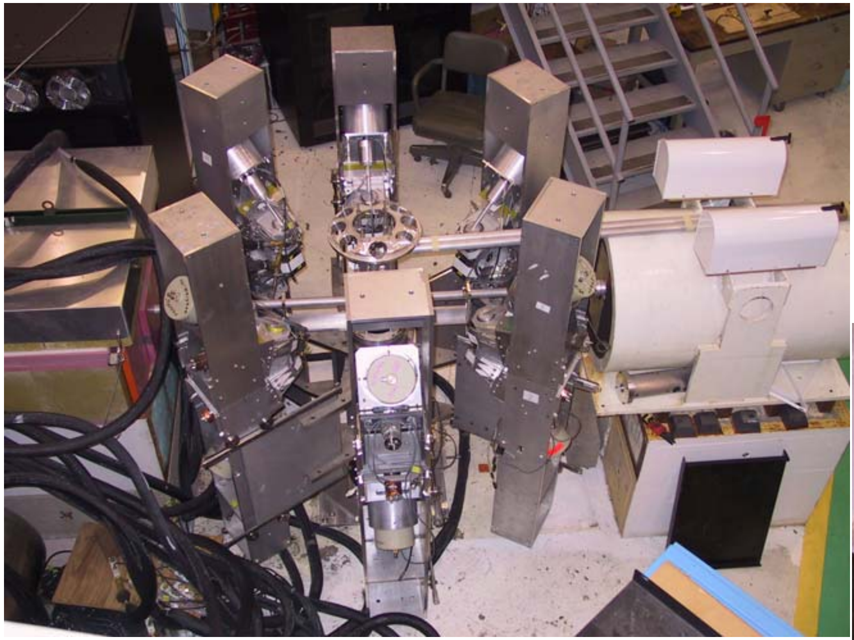
1 - active area of the Si detector; 2 - ceramic backing; 3 - frame (glass fibre laminate); 4 - contour of a hole made in the frame; 5 - guard ring of the Si detector; 6 - electrical contact to the detector back side; 7 - electrical contact to the detector active area; 8 - resin covering the thin wire welded to the conductor layer covering the active area; 9 - frame surface; 10 - hole in the frame giving space for resin 8; 11 - the corner on the bottom of a cavity milled in the frame.

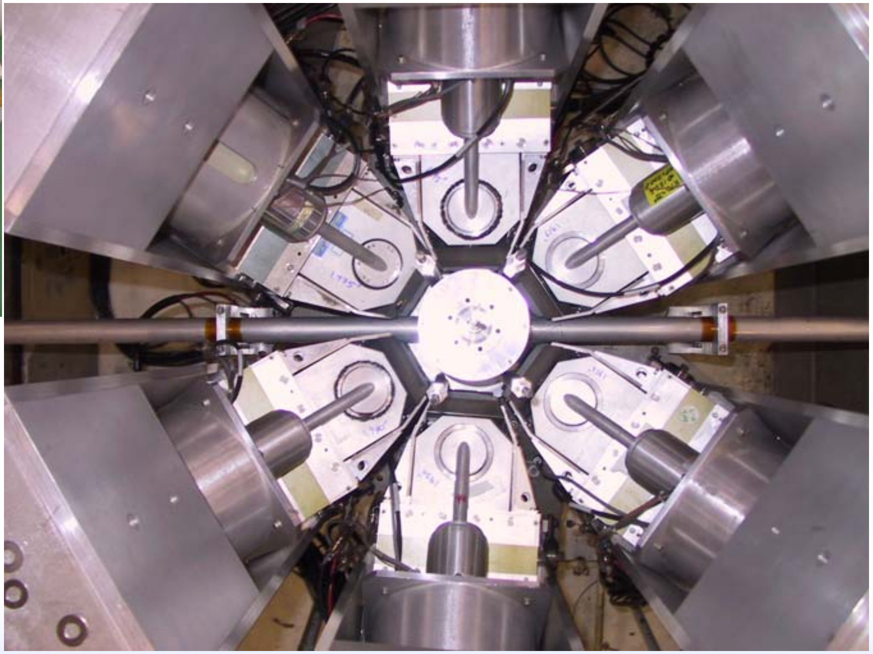


# Fission Fragment Spectrum

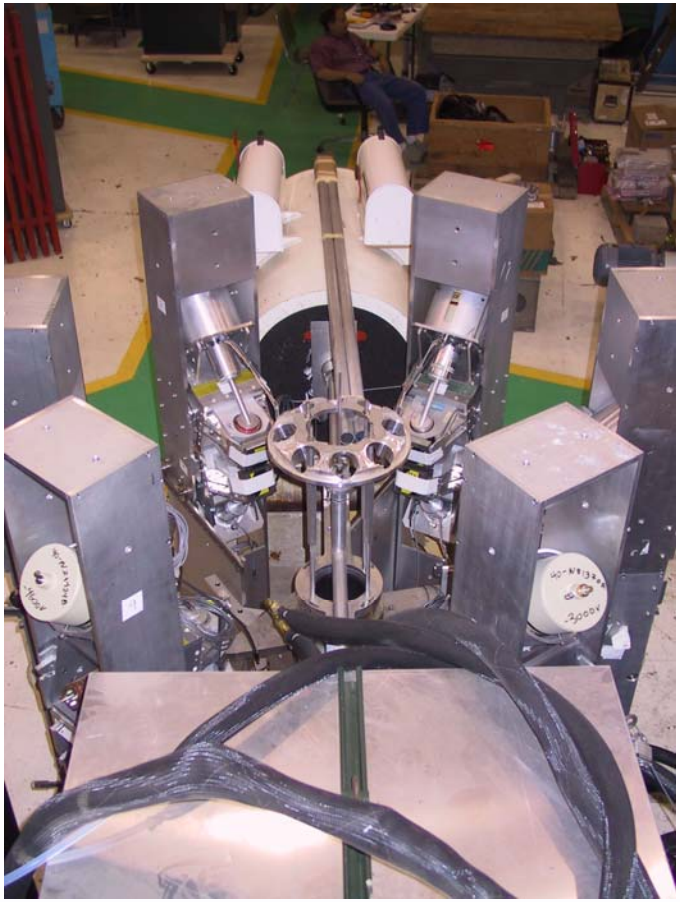


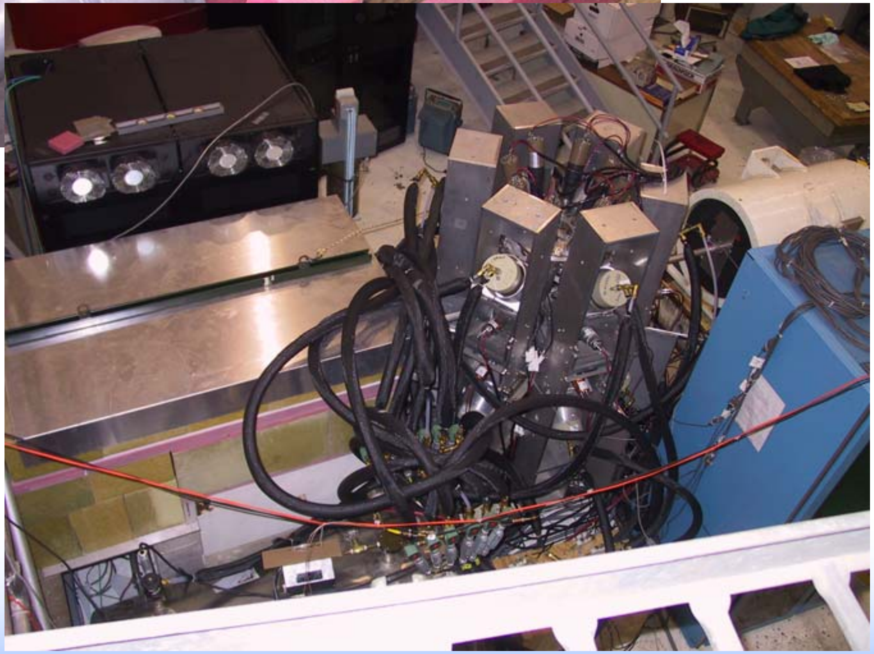
# The INL experimental setup



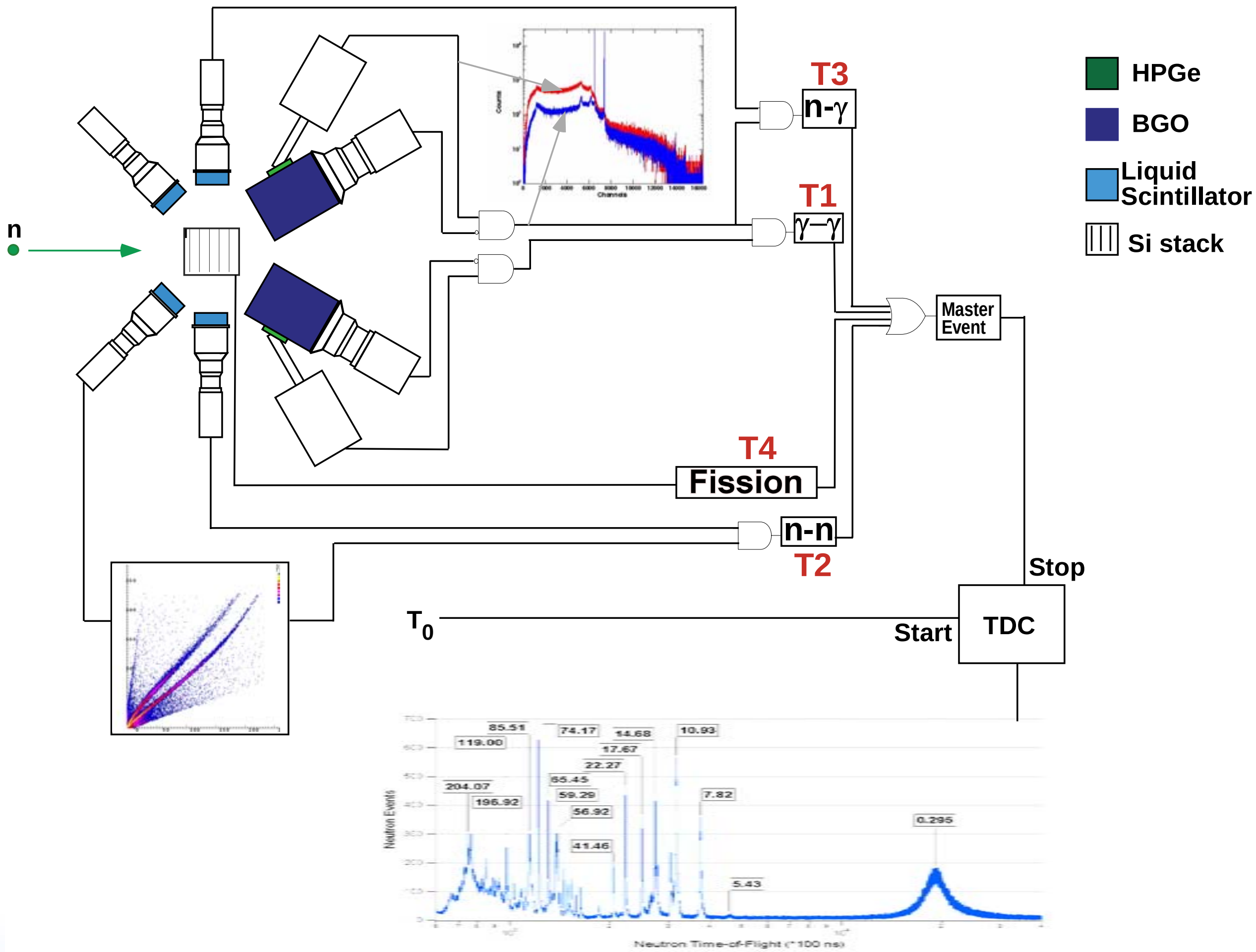


# The INL experimental setup

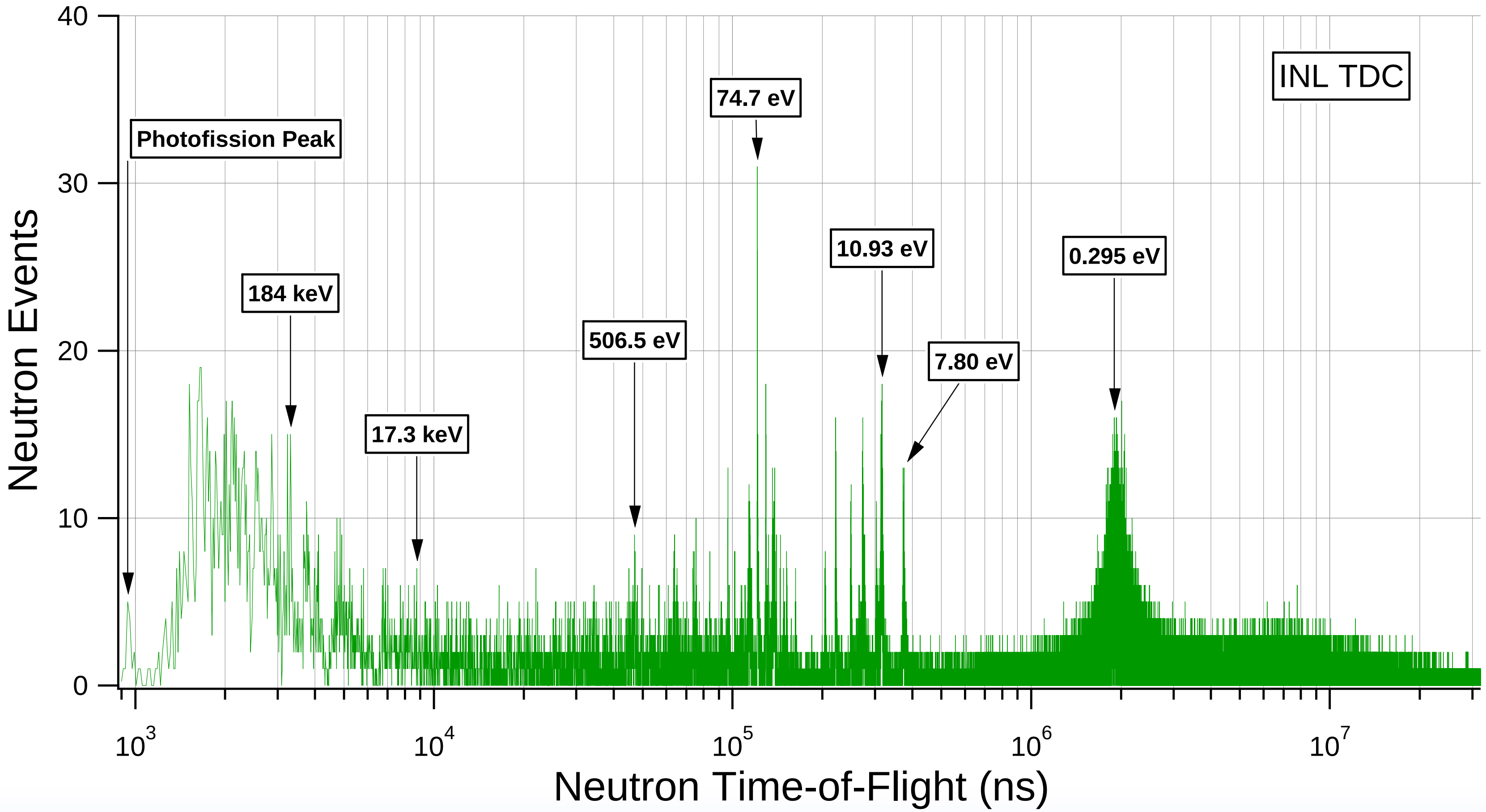




# Event Triggers



# Multi-stop Neutron Time-Of-Flight TDC Spectrum

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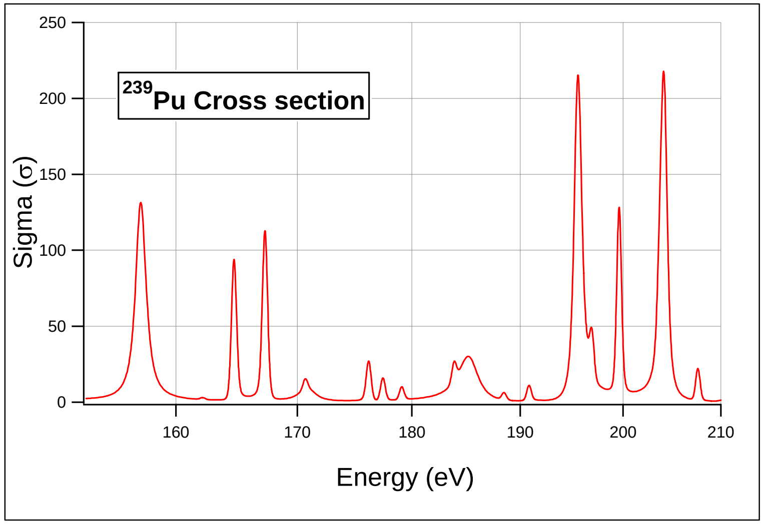
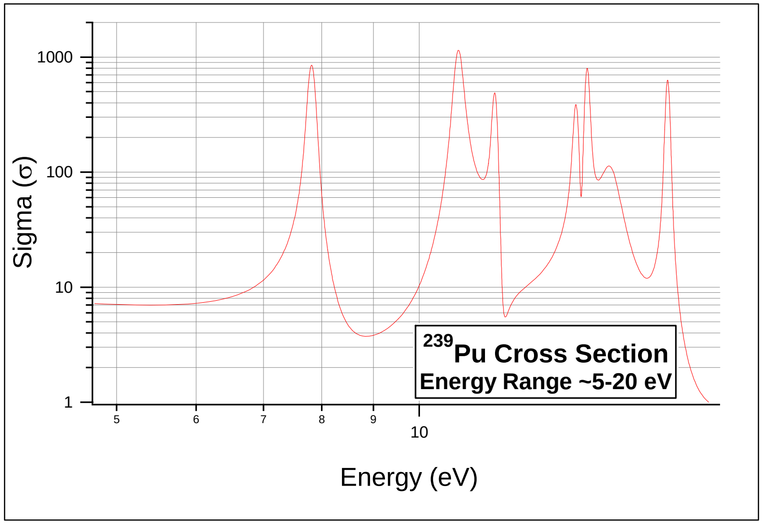
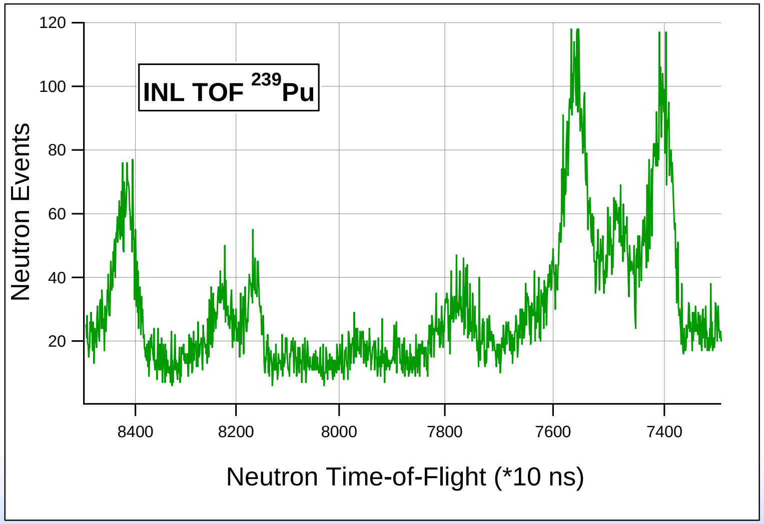
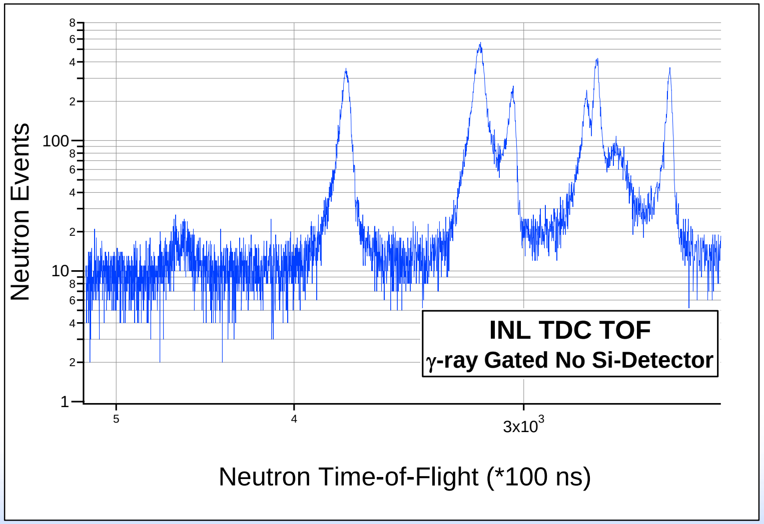
# Resonance Resolution



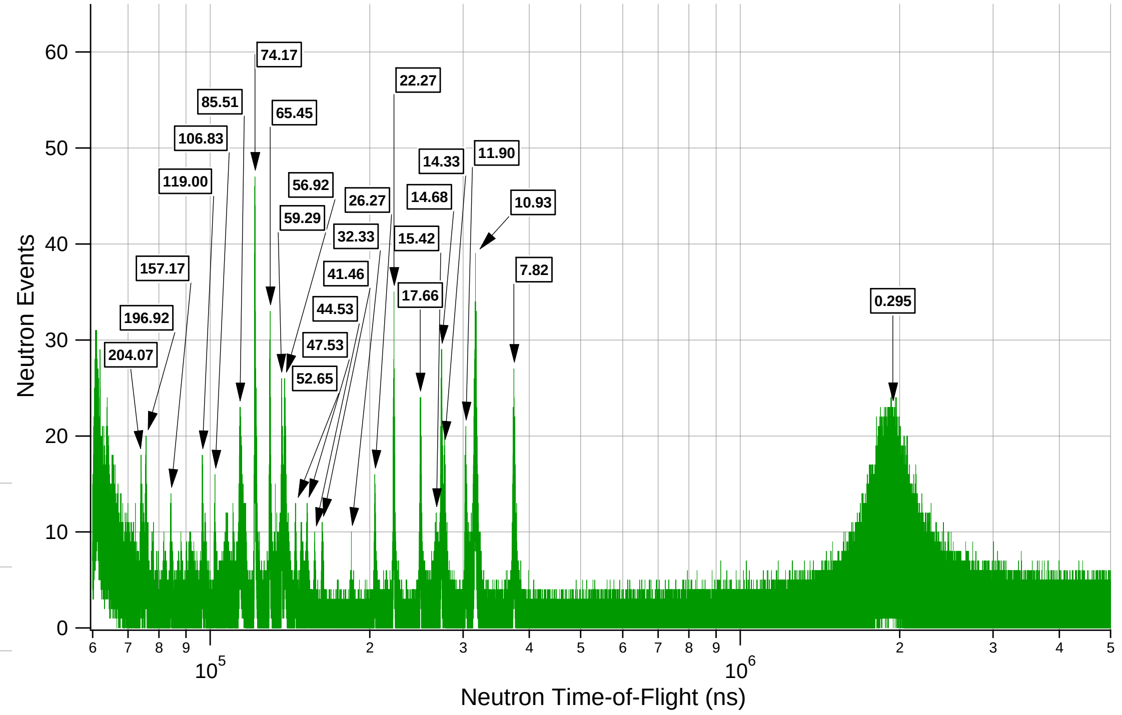



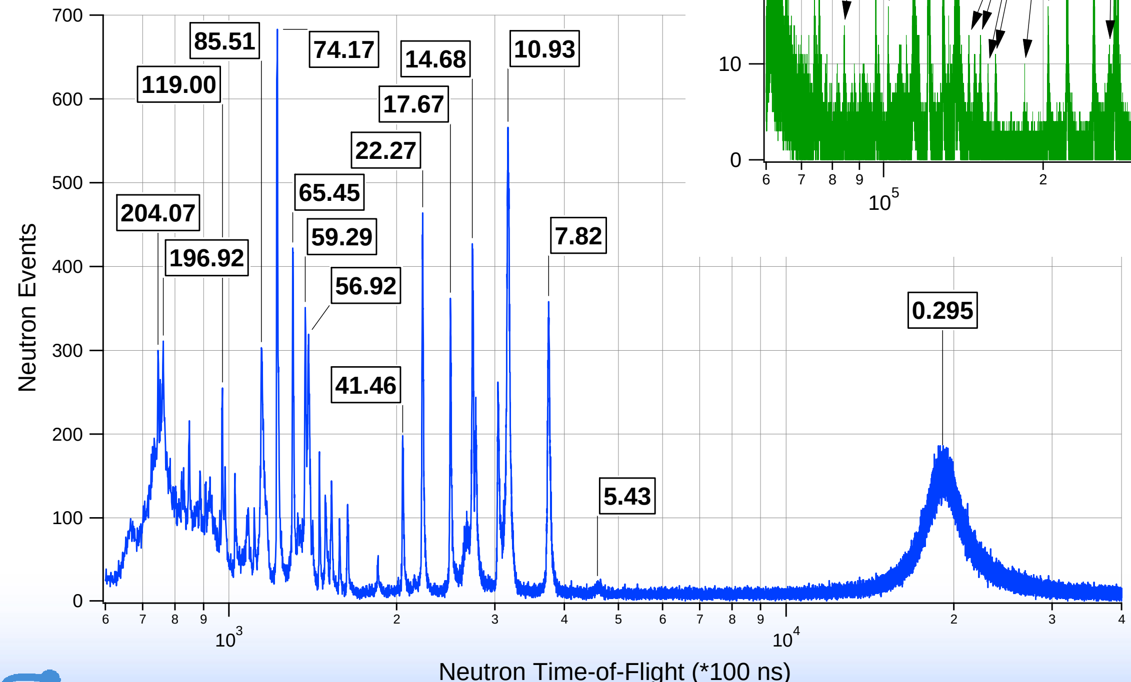
# Separation of Reaction Channels

Competition between capture and induced fission reaction channels are extremely difficult to separate for the actinides.

Two primary modes of decay are observable with the INL system and will allow specific gamma rays and fission fragments to be identified with each resonance.

# Fission & Capture



# SUMMARY:

There is a need for new cross section data, which is being clarified by various sensitivity studies and integral experiments as time goes on.

IPNS is an excellent neutron spallation source, is located at ANL, and has not been previously used for such measurements.

INL has a source of actinide material and high-quality targets for the measurements.

An existing setup of detectors, electronics, computers, and software is in place.

New methods for cross section measurements are available with the INL setup. There is a history of work with this type of measurement to reduce errors and calibrate such systems. This has been proven successful in other low energy nuclear physics measurements and the present work has demonstrated applicability to cross sections.

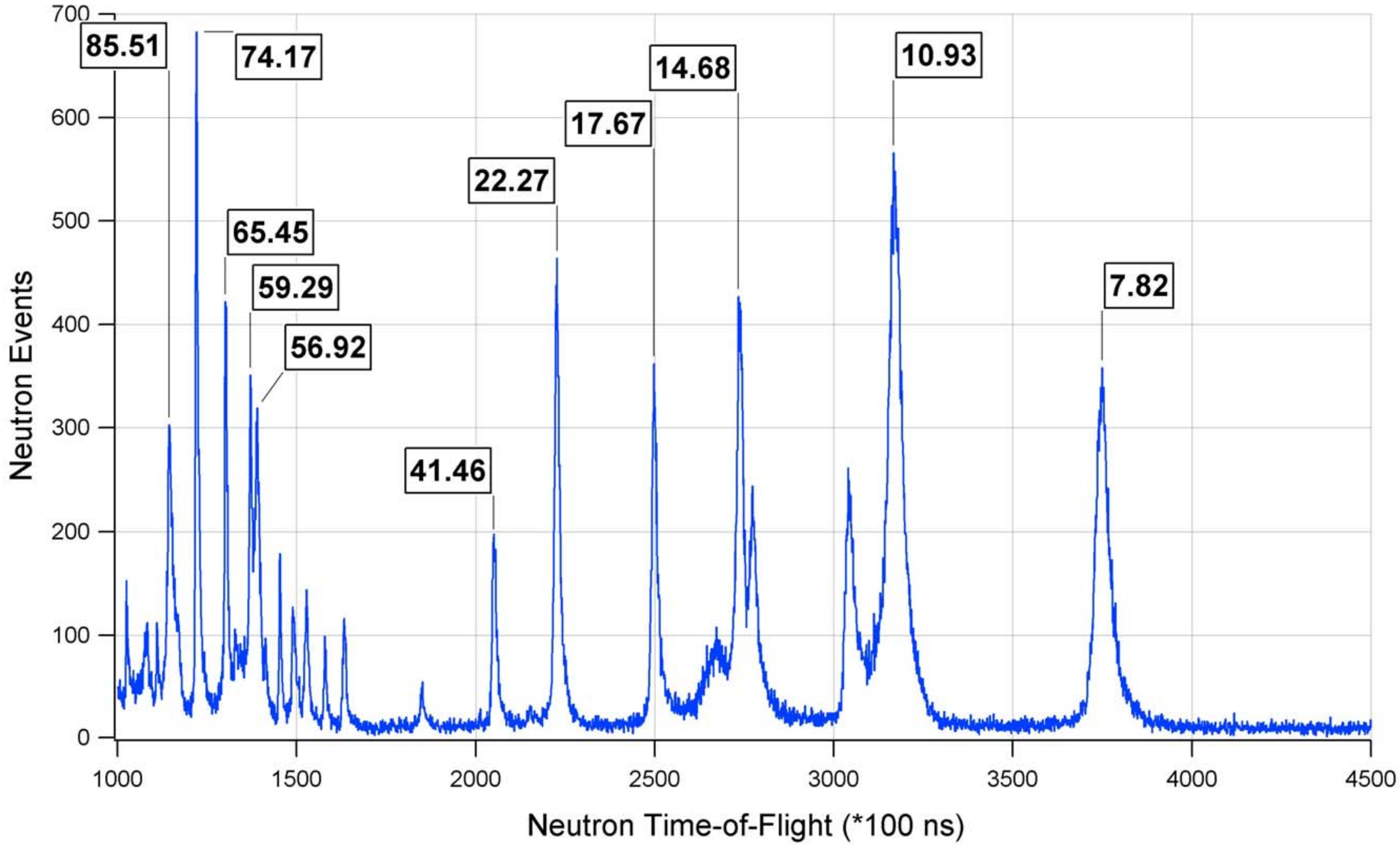
There are new and unique advantages to our techniques as outlined. Much of this lies in the analysis methods to isolate data from different reaction channels and isotopes from the measurement of interest.

Capture, fission, and scattering cross sections can be determined with data sorting and this sorting and coincidence methods provide separation of reaction channels and correction for target contamination.

Initial data show high resolution and clean neutron event spectra over and energy range of 0.001 eV to 1 MeV, as a single continuous measurement.

INL is currently gaining experience with $^{239}$Pu as a “standard”, but sensitivity studies have identified needs to reduce the uncertainty of even this cross section in the low-energy region.

Additional high-priority actinides can also be addressed in the near future.

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