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Title: Analysis of the 237Np neutron capture cross section at DANCE

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Los Alamos
NATIONAL LABORATORY
EST.1943

Analysis of the ^{237}Np neutron capture cross section at DANCE

Neptunium-237 is a major constituent of spent nuclear fuel. Estimates place the amount of ^{237}Np bound for the Yucca Mountain high-level waste repository at 40 metric tons. The Department of Energy's Advanced Fuel Cycle Initiative program is evaluating methods for transmuting the actinide waste that will be generated by future operation of commercial nuclear power plants, thereby reducing or possibly eliminating the need for a second repository beyond Yucca Mountain. The critical parameter that defines the transmutation efficiency of actinide isotopes is the neutron fission-to-capture ratio for the particular isotope in a given neutron spectrum. The calculations of transmutation yields therefore require accurate fission and capture cross sections over the range of neutron energies in both the reactor, in which the actinides are produced (typically thermal systems), and the transmuter (most likely a fast spectrum system). Current ^{237}Np evaluations available for transmuter system studies show significant discrepancies in both the fission and capture cross sections in the energy regions of interest. Therefore, the ^{237}Np capture cross section was measured with the Detector for Advanced Neutron Capture Experiments (DANCE). The results and data analysis methods used to extract them will be presented in this talk.

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Analysis of the ^{237}Np neutron capture cross-section at DANCE

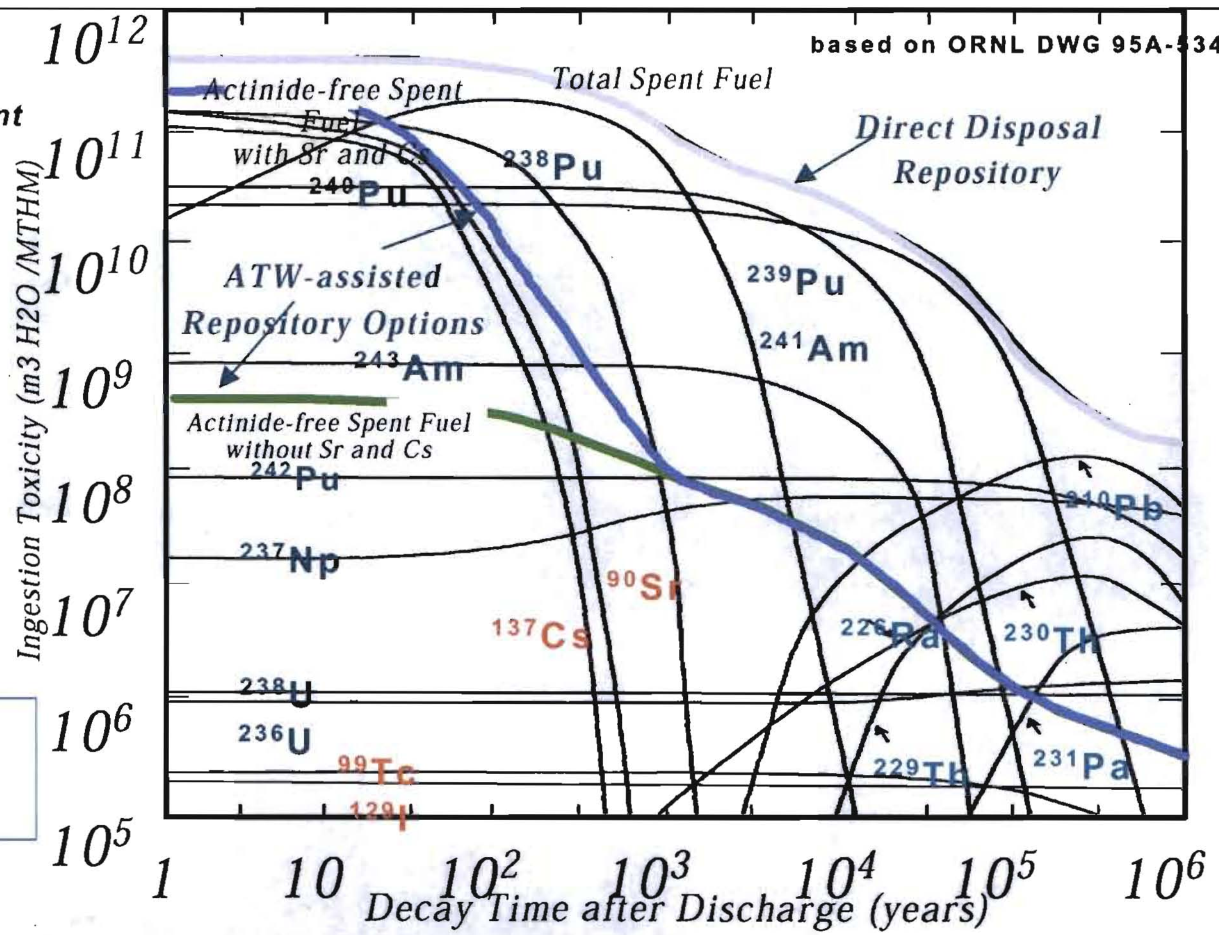
IEEE 2008

Ernst-Ingo Esch

AFCI Motivation: Transmutation

Ingestion Toxicity of spent fuel

^{237}Np $T_{1/2}$ = 2.1E6 a



Dennis Slaughter (LLNL) RIA Workshop 2000

Why another Capture Experiment Technique?

- Most cross sections are not known better than 30%
- Some cross sections are not known at all
- Available material is limited (~mg amounts)
- Interest from different field: Weapons technology, astronomy, Gen-4 reactors ...

Problems with radioactive samples

- very ***small samples*** (~ mg)
- low ***count rate***
- neutron reactions with sample ***backing***
- ***radioactivity*** of the sample
- sample-independent background

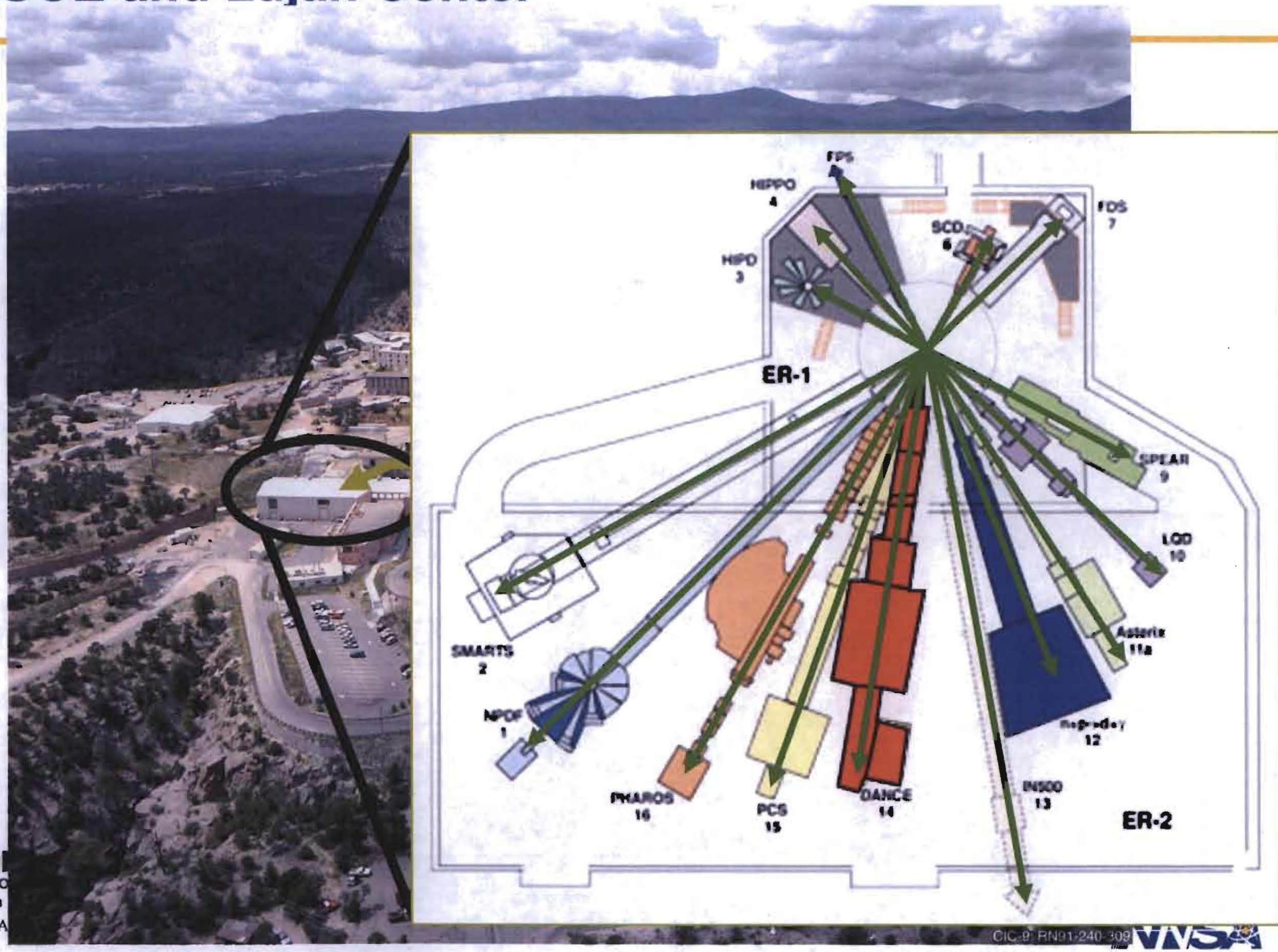
Evidence for neutron capture

$$^{A}X + n \Rightarrow {}^{A+1}X + Q + \varepsilon$$

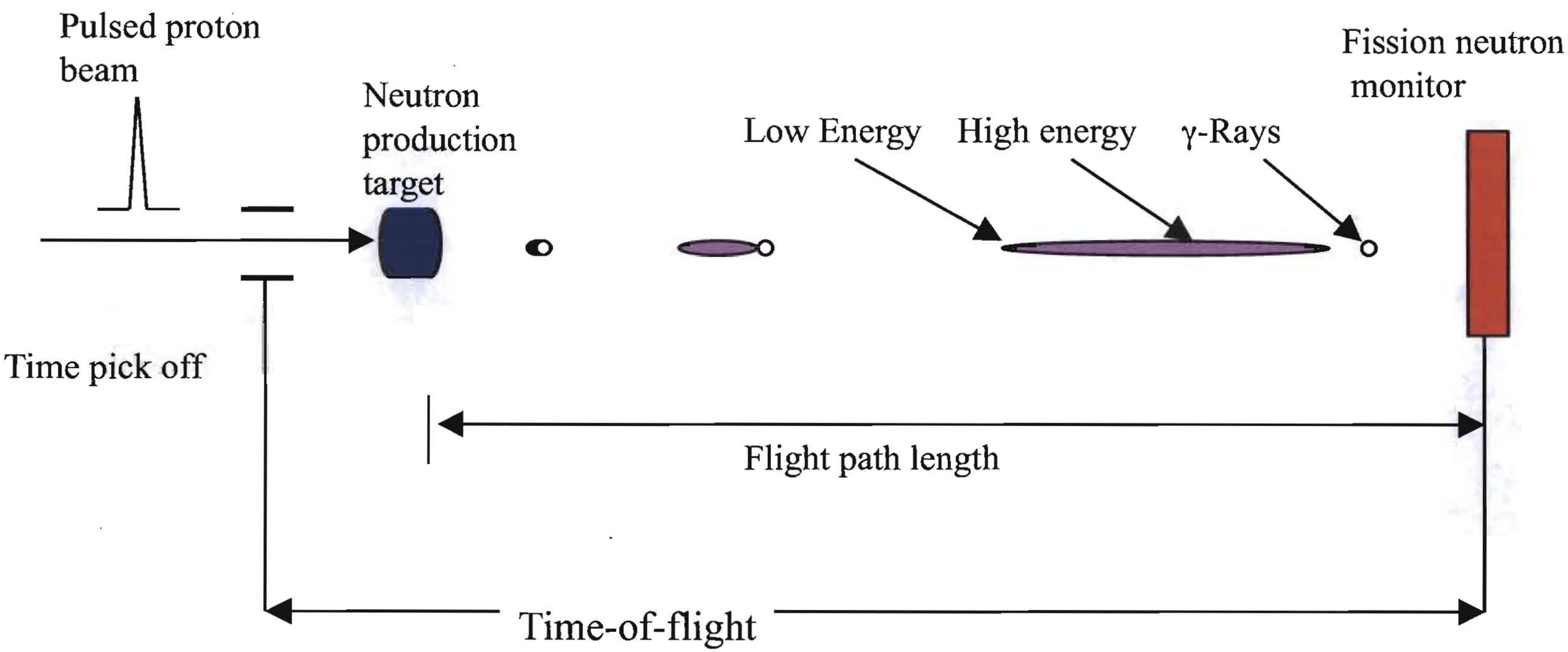
$$Q = \sum \gamma_i$$

⇨ "monoenergetic" if
100 % efficiency

LANSCE and Lujan Center



Time-of-Flight techniques



Neutron TOF = $\frac{72.3\,L}{\sqrt{E_n}}$ (non-relativistic)

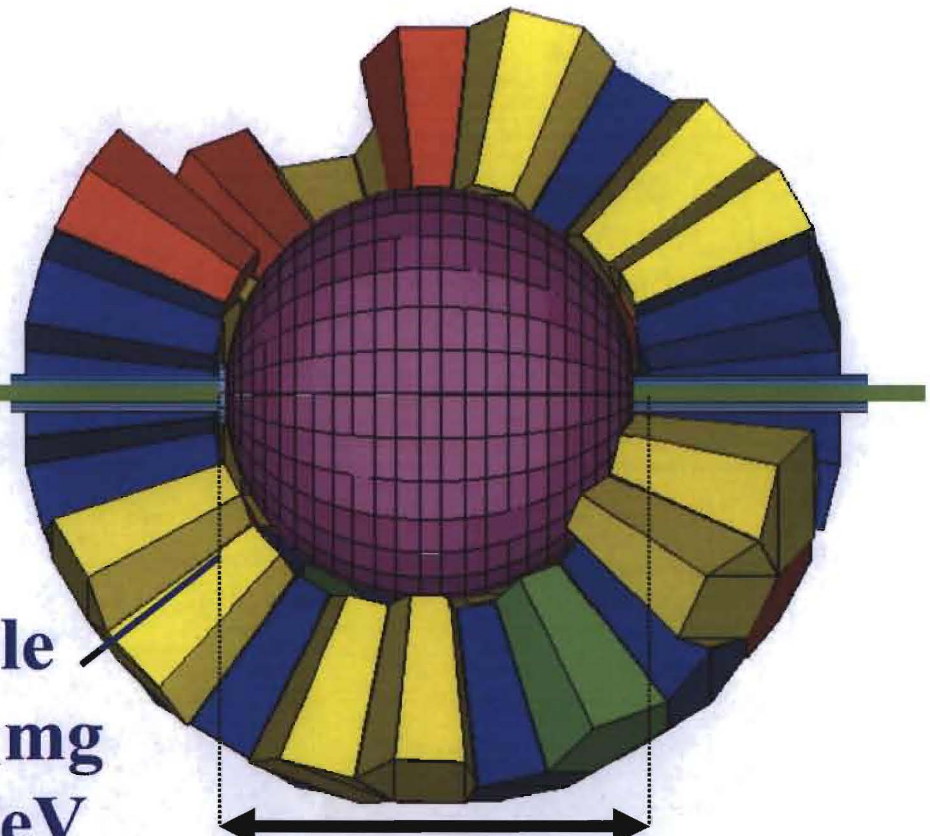
γ-ray TOF = $\frac{L}{c}$

Example: L= 20m

E_n= 1 MeV
TOF_n= 1.5 μs
TOF_γ = 67 ns

E_n = 100 MeV
TOF_n= 150 ns

*D*etector for *A*dvanced *N*eutron *C*apture *E*xperiments



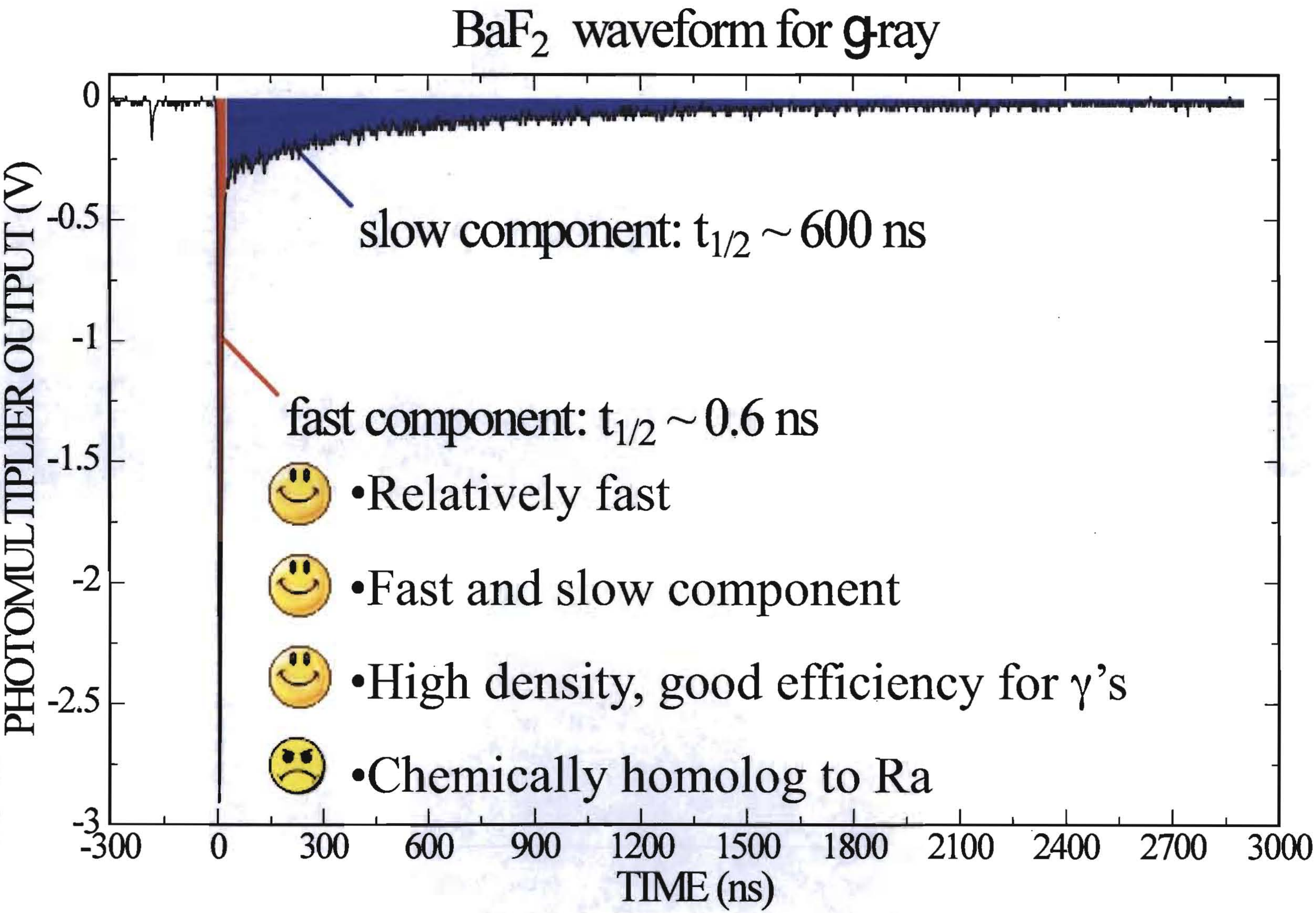
neutrons:

- spallation source
- thermal .. 500 keV
- 20 m flight path
- $3x10^5$ n/s/cm^2/decade

γ-Detector:

- 160 BaF_2 crystals
- 4 different shapes
- R_i=17 cm, R_a=32 cm
- 7 cm ^{6}LiH inside

BaF_2 Characteristics



- Relatively fast
- Fast and slow component
- High density, good efficiency for γ's
- Chemically homolog to Ra

The DANCE Data Acquisition Challenge

	fast component (timing, Particle ID)	slow component (energy res.)
Timing	0.6 ns	600 ns
Energy	10 %	90 %
Amplitude	90 %	10 %

DAQ Requirements:

- **fast (~ 1 ns)**
- **dynamic range (~ 12 bit)**
- **process data within 50 ms (accelerator)**
- **162 channels**

The DANCE DAQ Solution:
Fast Transient Digitizer

14 Acqiris-Crates

- 500 MHz PIII
- 500 MS / s
- MIDAS frontend
- 8 bit / channel
- 2 channel / crystal
- 128000 samples memory

Reduced Data

2x2 GHz PC

- MIDAS server
- ROOT interface
- 2.4 TB storage

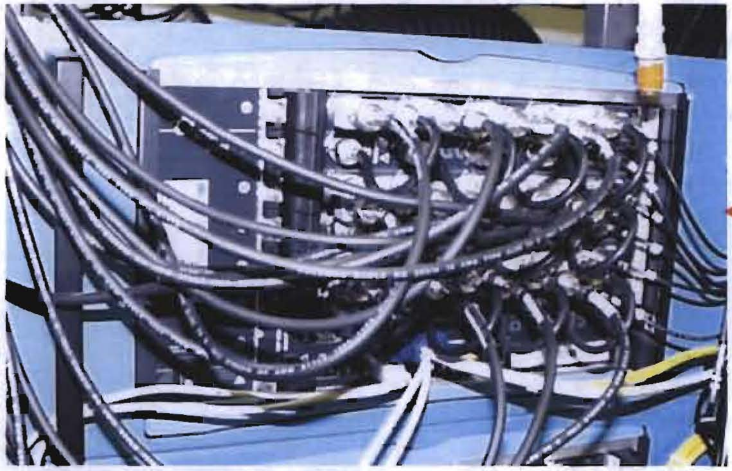
FTD 4 channels

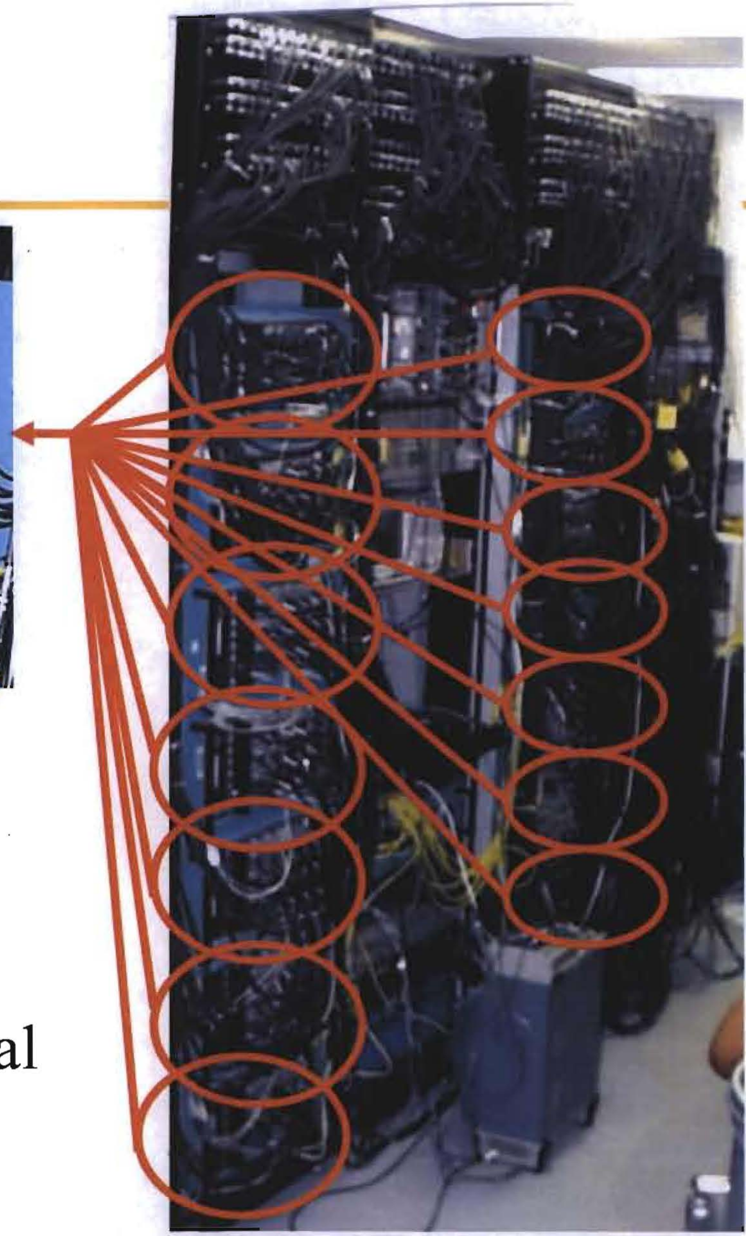
12 channels high gain
12 channels low gain

Total:
168 channels fast comp.
168 channels slow comp.
336 channels total.

Upgrade to 2 GHz is completed

DANCE DAQ
Real Life



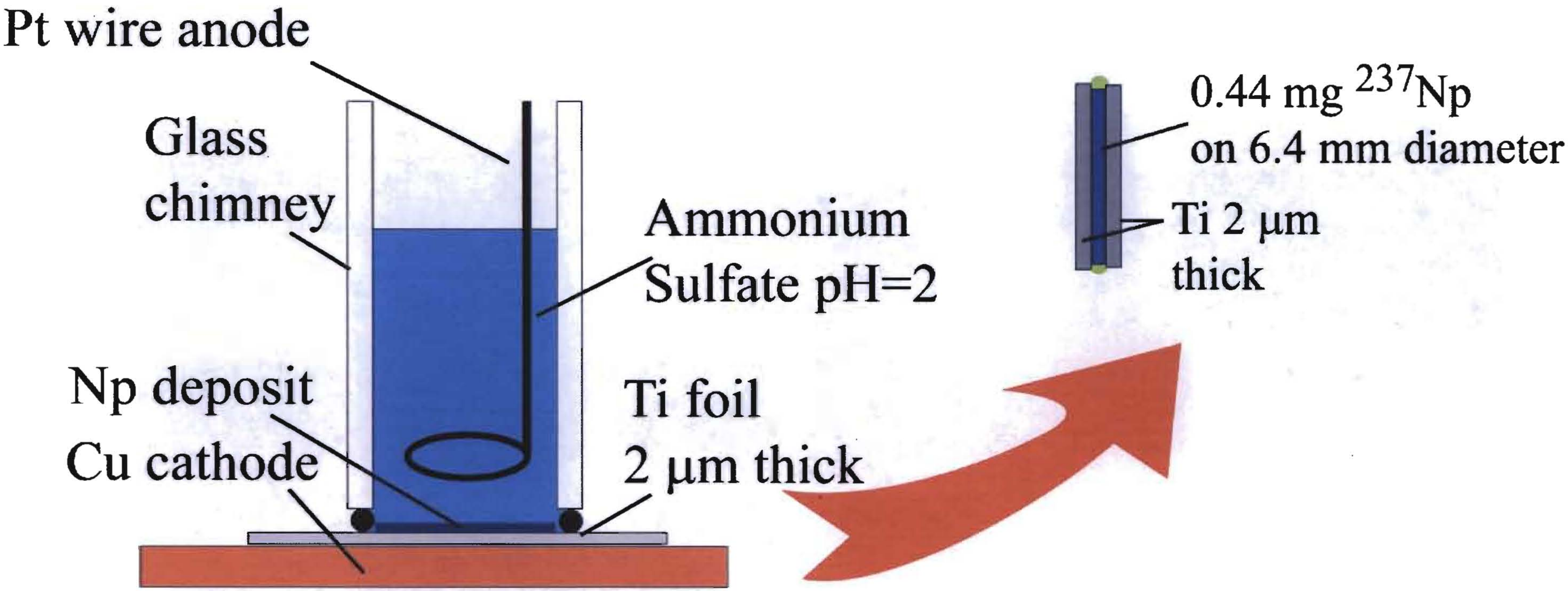


- 320 channels FTD (160 crystals)
- 500 MS/s
- data storage on regular HD
- total file size < 2GB
- Total Cost: 2M Bucks (LANL internal funding)

^{237}Np Analysis Challenge

- 320 +2 input channels
- Front-end requires online analysis for data reduction
- First full data analysis from raw counts to cross-section data
- 5% measurement is required

^{237}Np Preparation Procedure

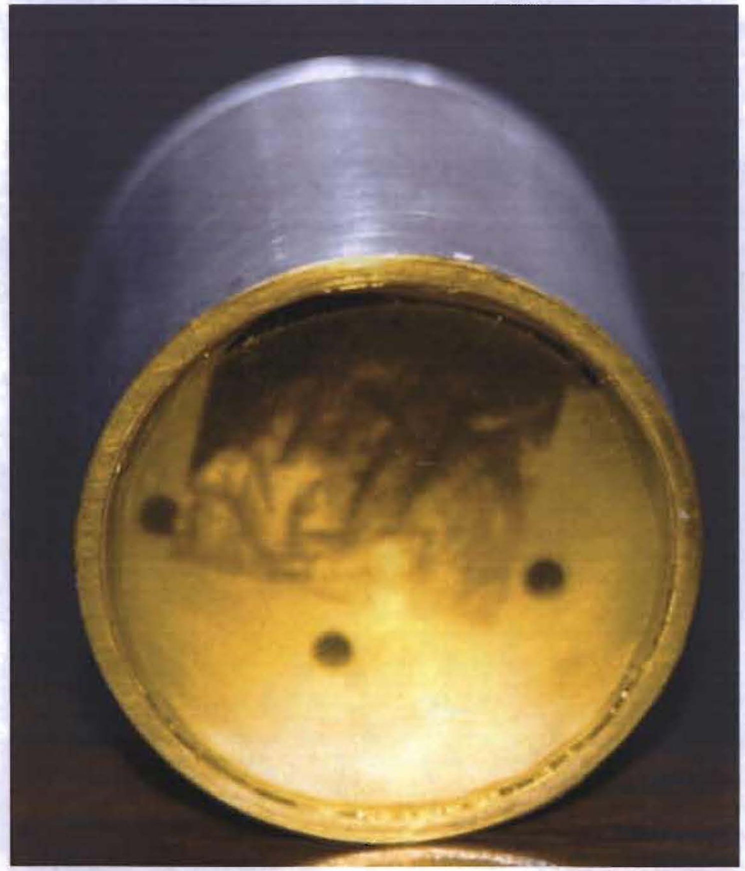


220 mA, 25 minutes

Safety Designs:
Requirements for measuring ^{237}Np capture

Work Scope:

1. Manufacture target (TA-48 C-INC)
2. Transport to LANSCE
3. Measure cross sections

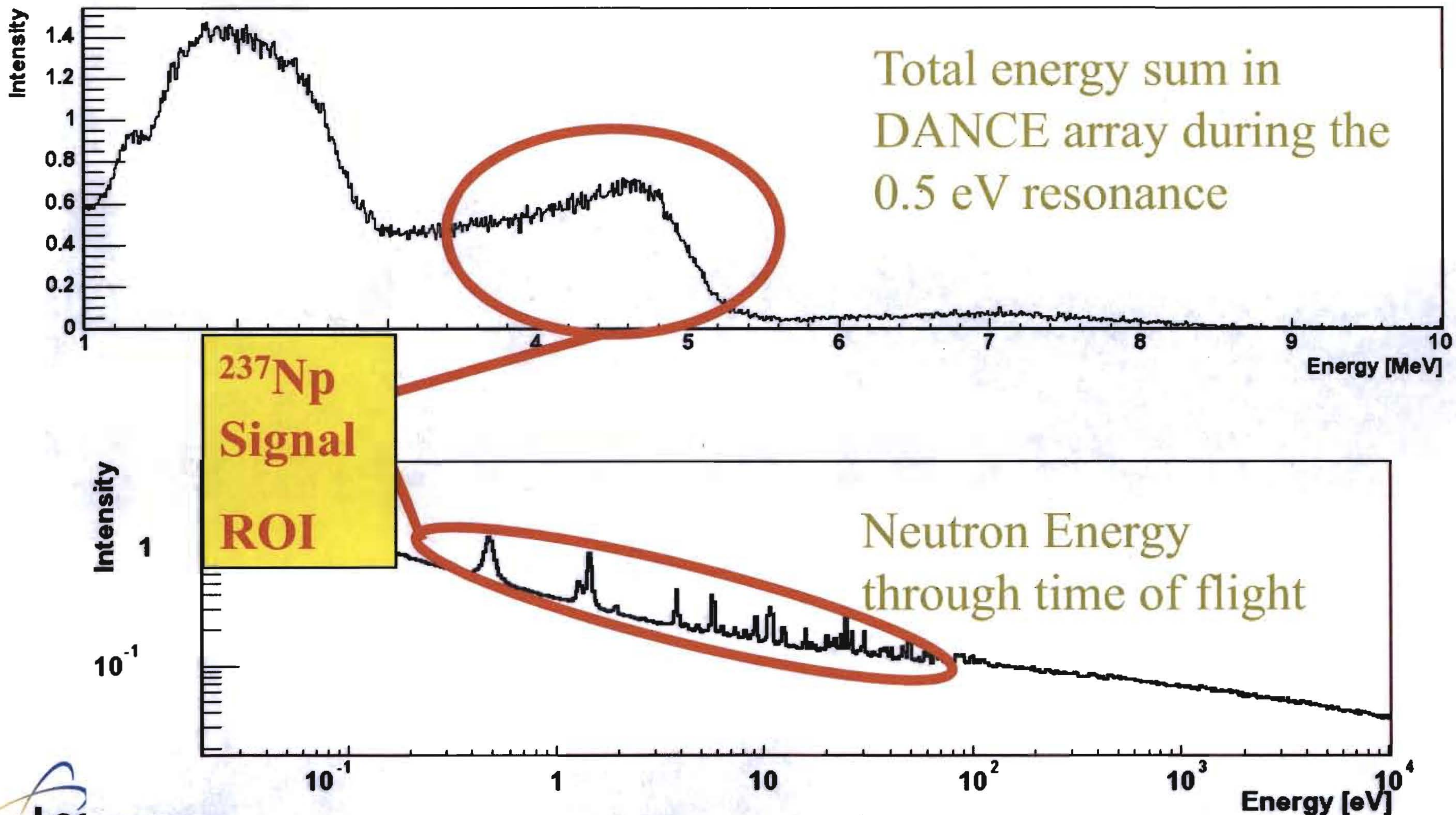


Radioactive Target Holder

And Container

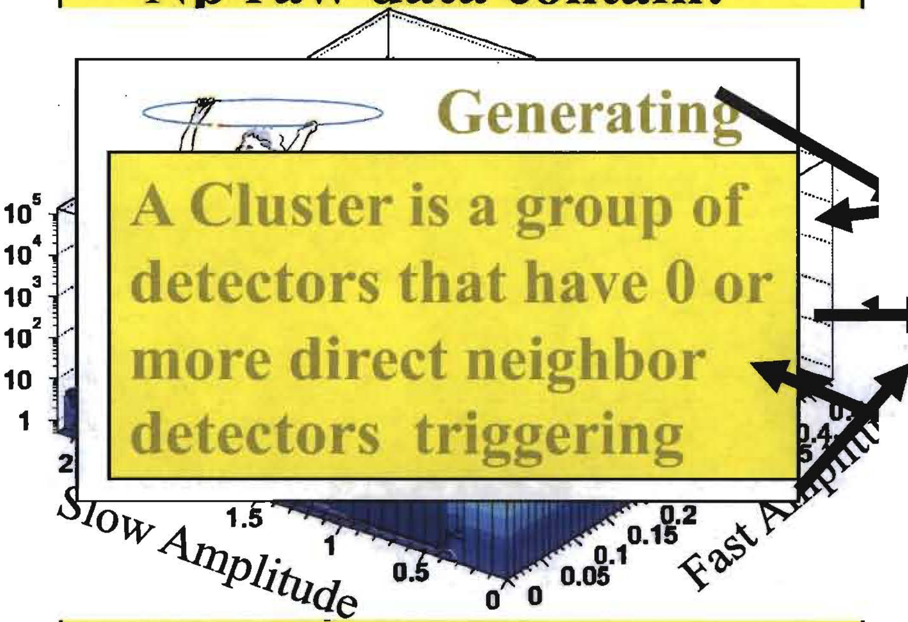
RTH & RTHC

Raw ^{237}Np Data



Subtracting Background - a tricky business -

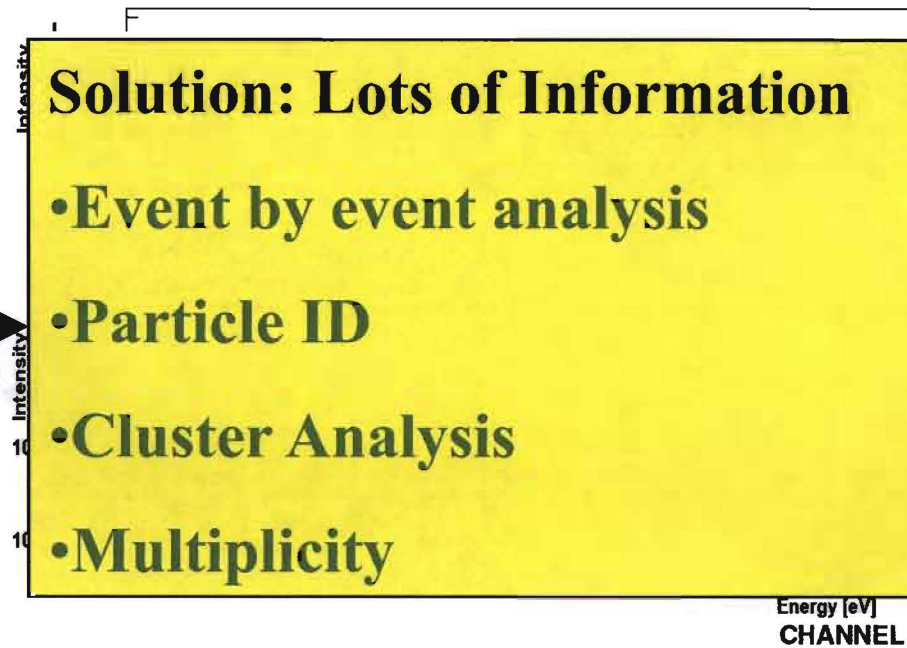
^{237}Np raw data contain:



Generating

A Cluster is a group of detectors that have 0 or more direct neighbor detectors triggering

•Capture signal from ^{237}Np



Solution: Lots of Information

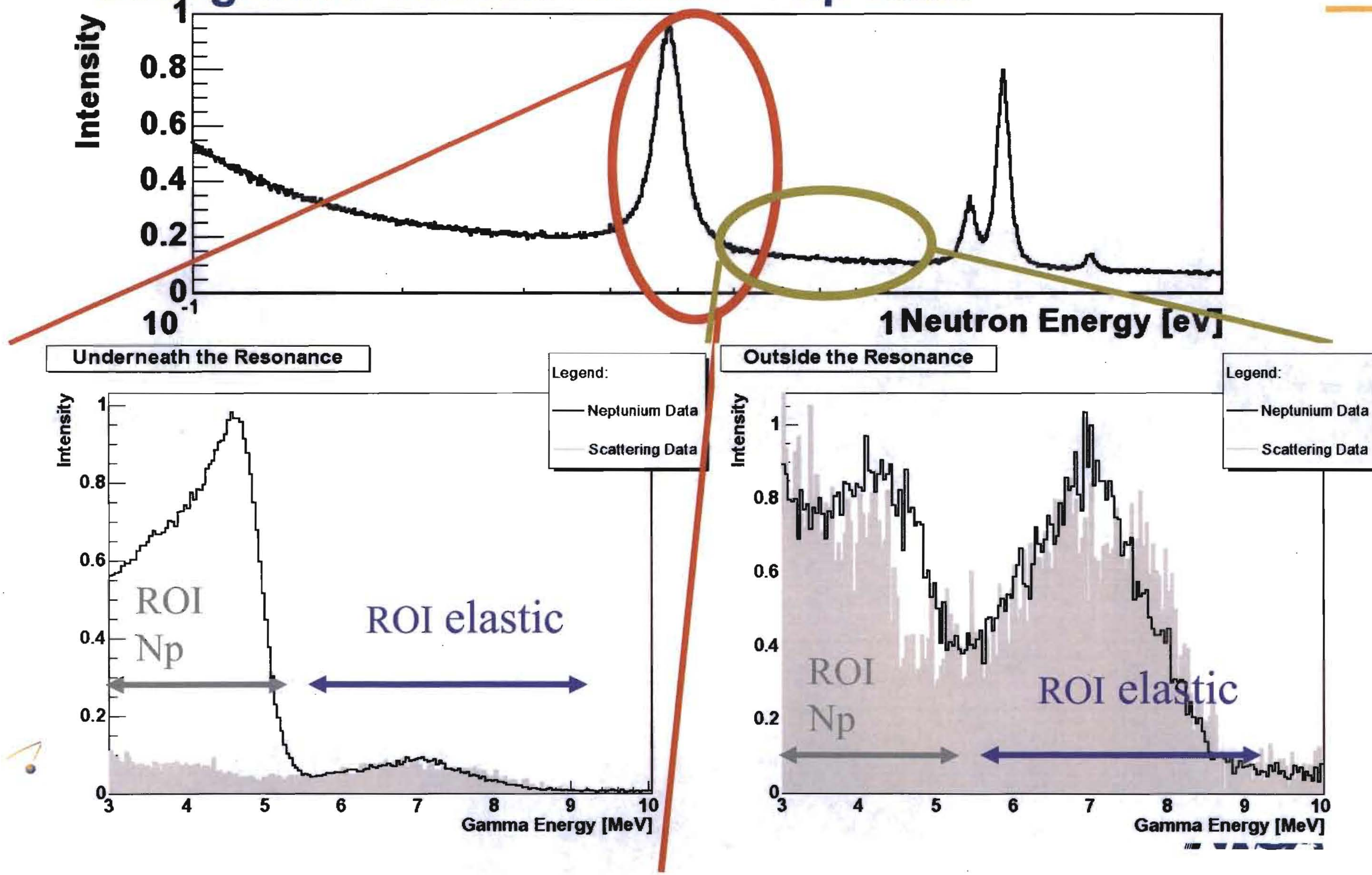
•Event by event analysis

•Particle ID

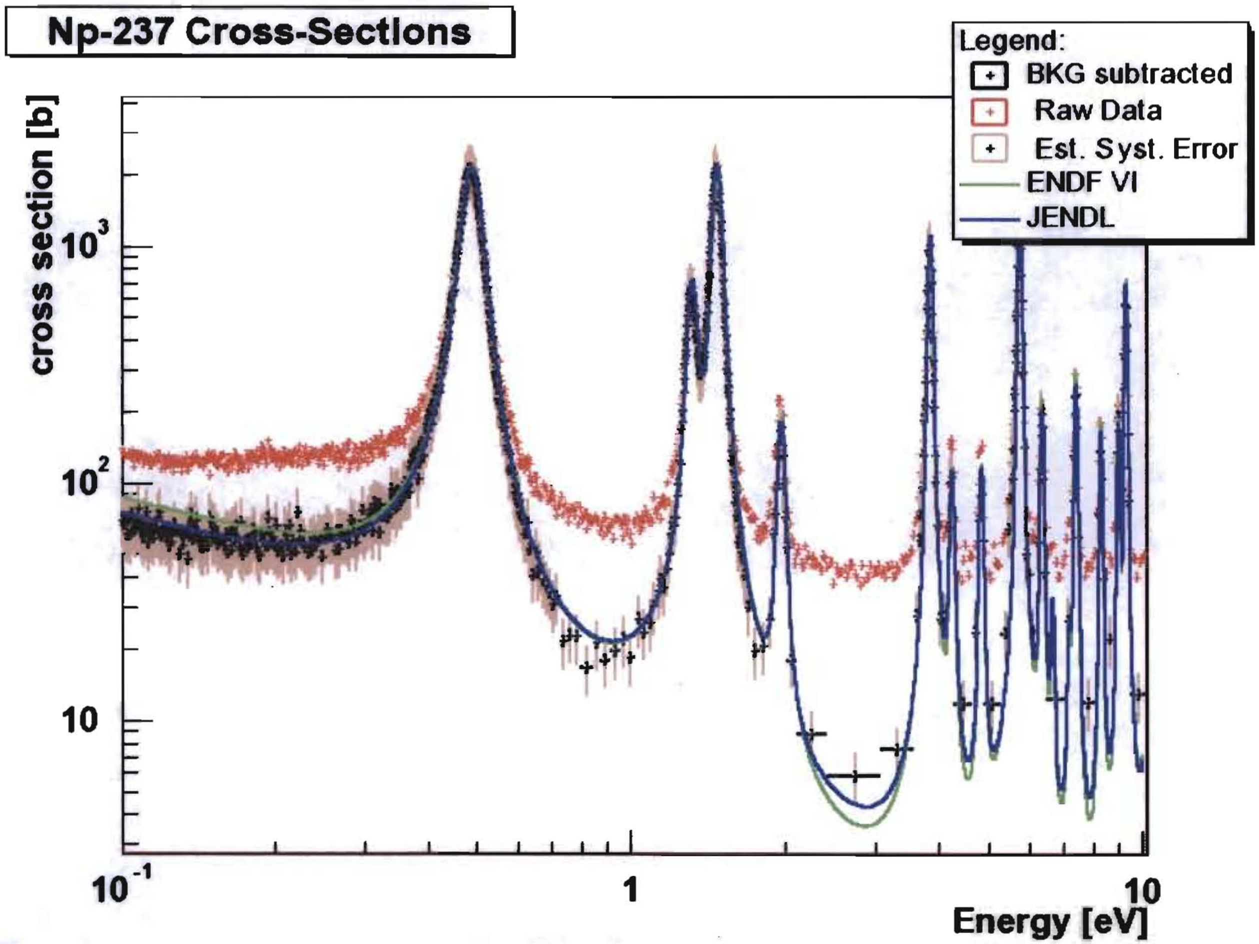
•Cluster Analysis

•Multiplicity

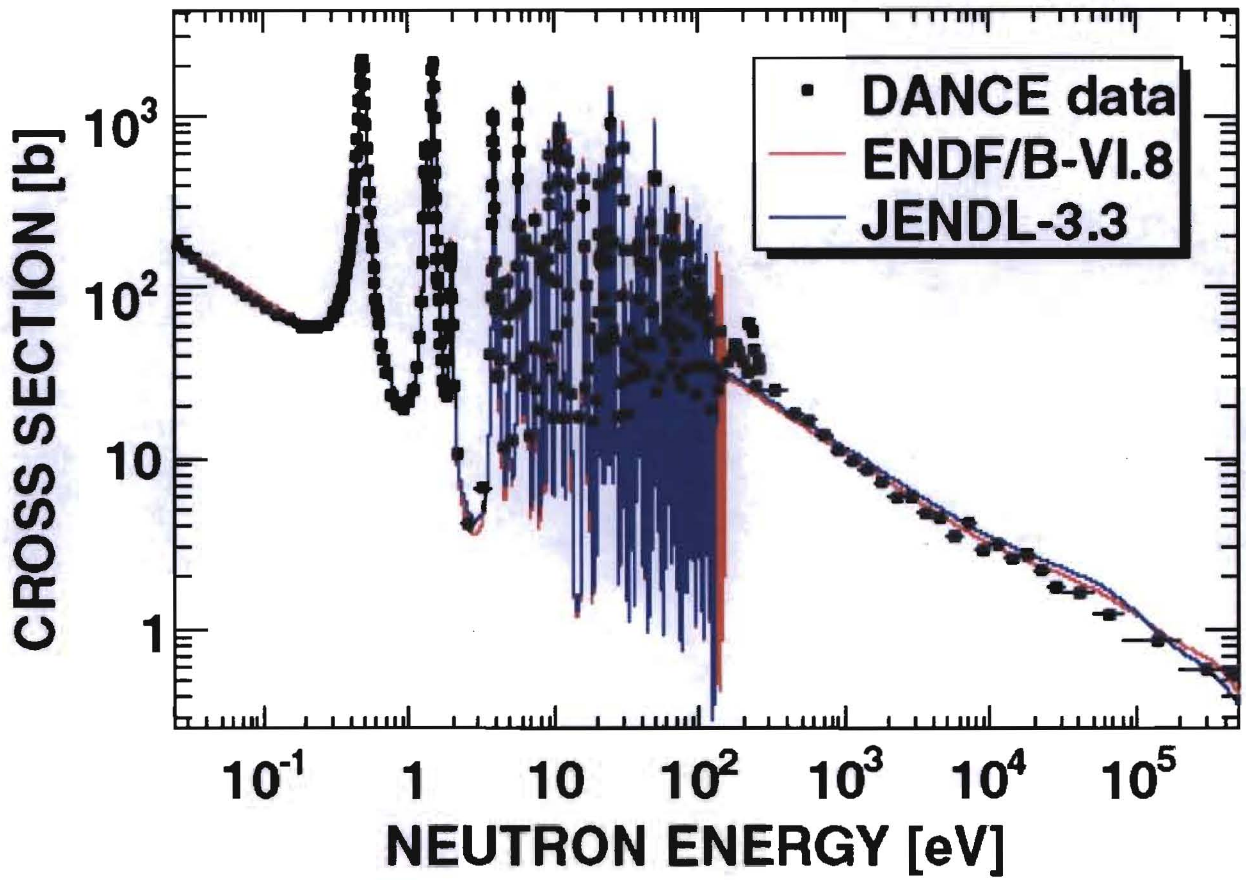
Background Subtraction for ^{237}Np Data



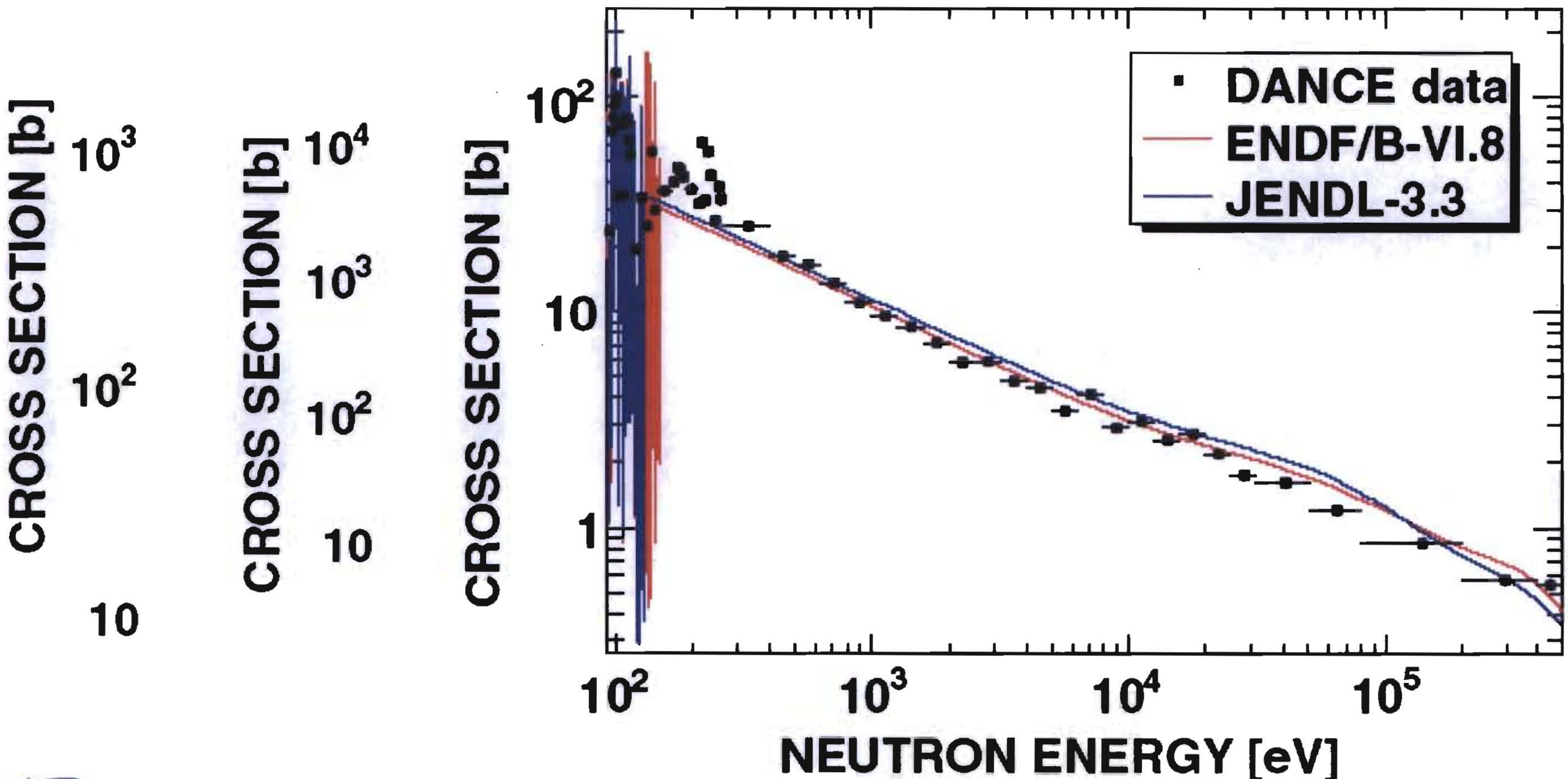
Background Subtraction Status



Analysis of ^{237}Np



Analysis II



CROSS SECTION [b]
10^3
10^2
10
CROSS SECTION [b]
10^4
10^3
10^2
10
CROSS SECTION [b]
10^2
10
1
DANCE data
ENDF/B-VI.8
JENDL-3.3
10^2
10^3
10^4
10^5
NEUTRON ENERGY [eV]

Summary and Outlook

- A flagship analysis to determine energy cross section has been developed
- Preliminary low energy ^{237}Np cross sections were extracted
- The full set of ^{237}Np data has been analyzed
- High energy cross section extraction has been developed for DANCE and used on ^{237}Np
- Final data have to be evaluated

People Involved:

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