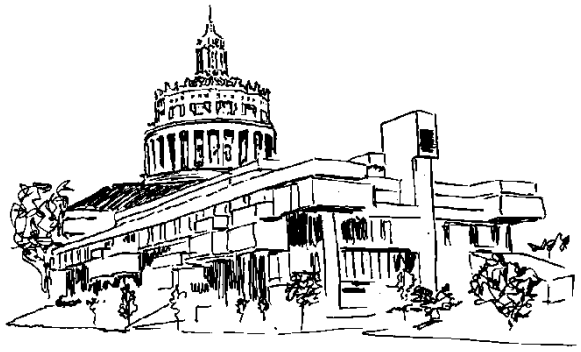
UNIVERSITY of ROCHESTER



Advanced Nuclear Science Education Laboratory Experiment Summary

ANSEL Faculty Instructors

Prof. Frank Wolfs

Research:
Large Underground Xenon (LUX) collaboration, preparation for dark-matter experiment with (2-phase xenon) detector@ DUSEL,
Advanced trigger (DDC-8DSP) development@Rochester

Prof. Udo Schrőder

Research:
Heavy-ion reactions @ LNS Catania/Italy.
Development of radiation detectors and electronics.
Collaboration with UR Laboratory for Laser Energetics:
* Radio-chemical tritium transport, fusion@fission energy issues
* Neutron diagnostics for high energy density research

There will be guest lectures and instruction on various topics by additional expert faculty and professionals.

Nuclear Science Education at UR

≥ ST 2010 (ANSEL long term commitment by chemistry and physics)

Physics x Chemistry, Undergraduate/Graduate Course+Lab

Offered every year (< 12 students)

Advanced Nuclear Science Educational Lab (**ANSEL**)

Lecture (1.5 h/week) + Lab (2 x 2.5h/week)

Chemistry x Physics, Graduate Course

Alternating with ANSEL, one semester every AY (5-10 students?)

Nuclear Science & Technology (Intro to nuclear structure, scattering & reactions, applications, selected special topics)

Physics x Chemistry (Eng) UG Courses with Nuclear S&T Component

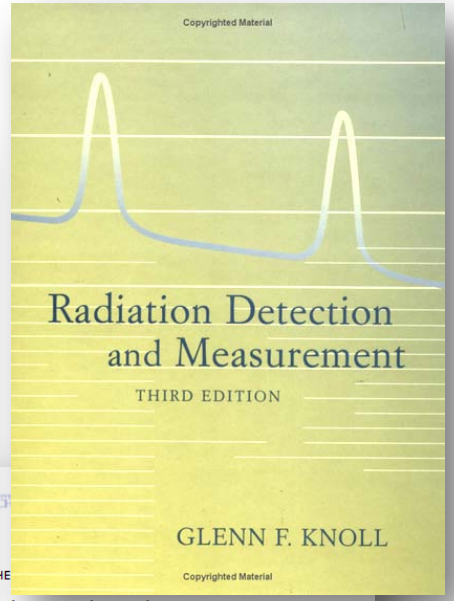
Offered every other year: *20th Century Particle Physics*

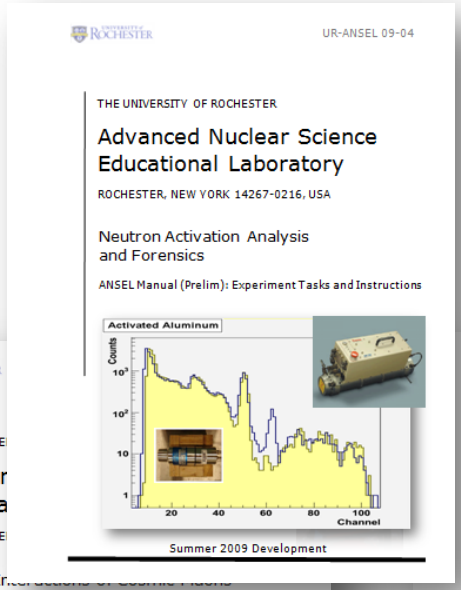
Offered once each year: *Energy: Science, Technology & Society*

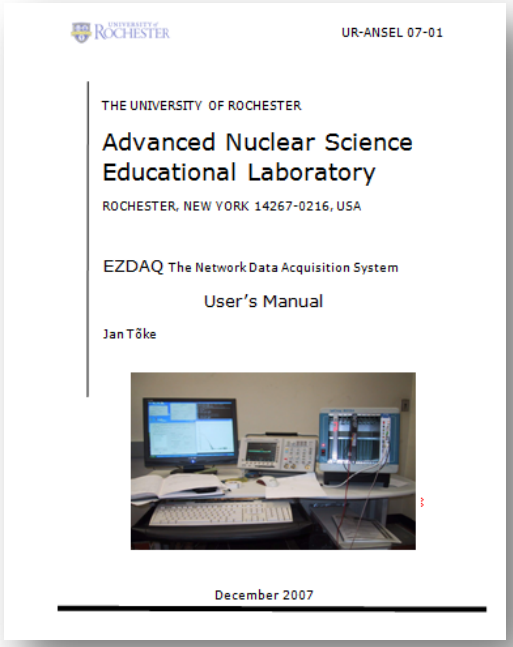
Advanced Nuclear Science Educational Laboratory

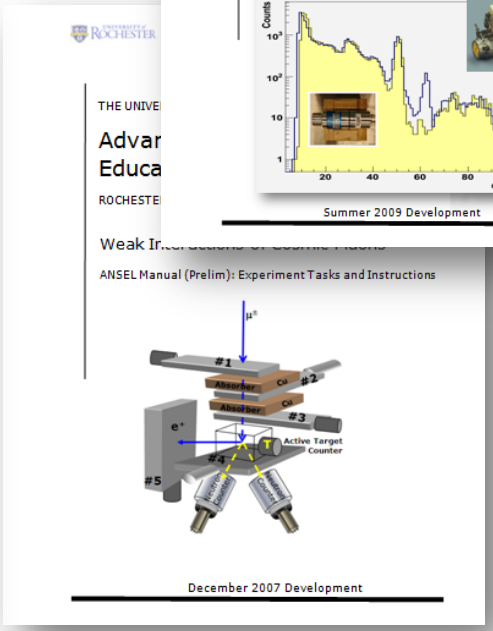
Funded by the Nuclear Regulatory Commission
(NRC-38-07-508, Co-PI with F. Wolfs (PAS))

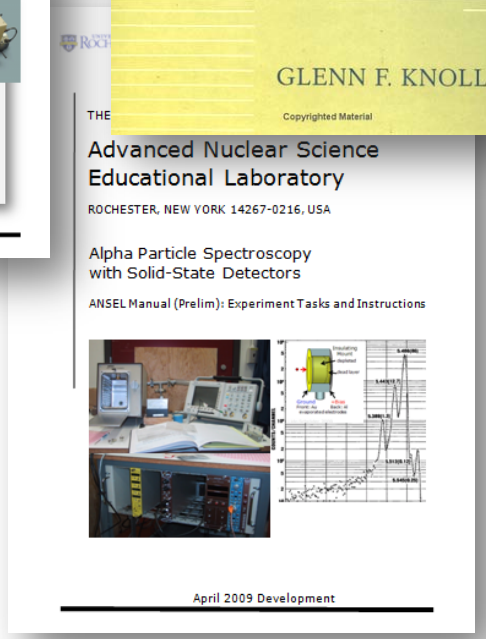
To provide students with hands-on experience in nuclear experimentation-detection and analysis











ANSEL Lab/Lecture Plan

Intro to nuclear properties, radiation, detection

Weeks 1-5

- Basic properties of nuclei, nuclear decay.
- Principles of interactions of nuclear radiation with matter, radiation protection.
- Response of scintillation, gas and solid-state detectors to radiation.
- Use of oscilloscopes, basic nuclear counting electronics.
- Signal processing, data acquisition, data analysis.

Measurements of activities and lifetimes

6-7

- Measurements of source activities.
- Lifetime measurements β-delayed γ emission, long and short (ns/ms →min/d).
- Lifetime of μ^+ in weak decay (μs), μ^- in weak capture (50-100 ns, for heavy nuclei).

Material imaging and testing

8-9

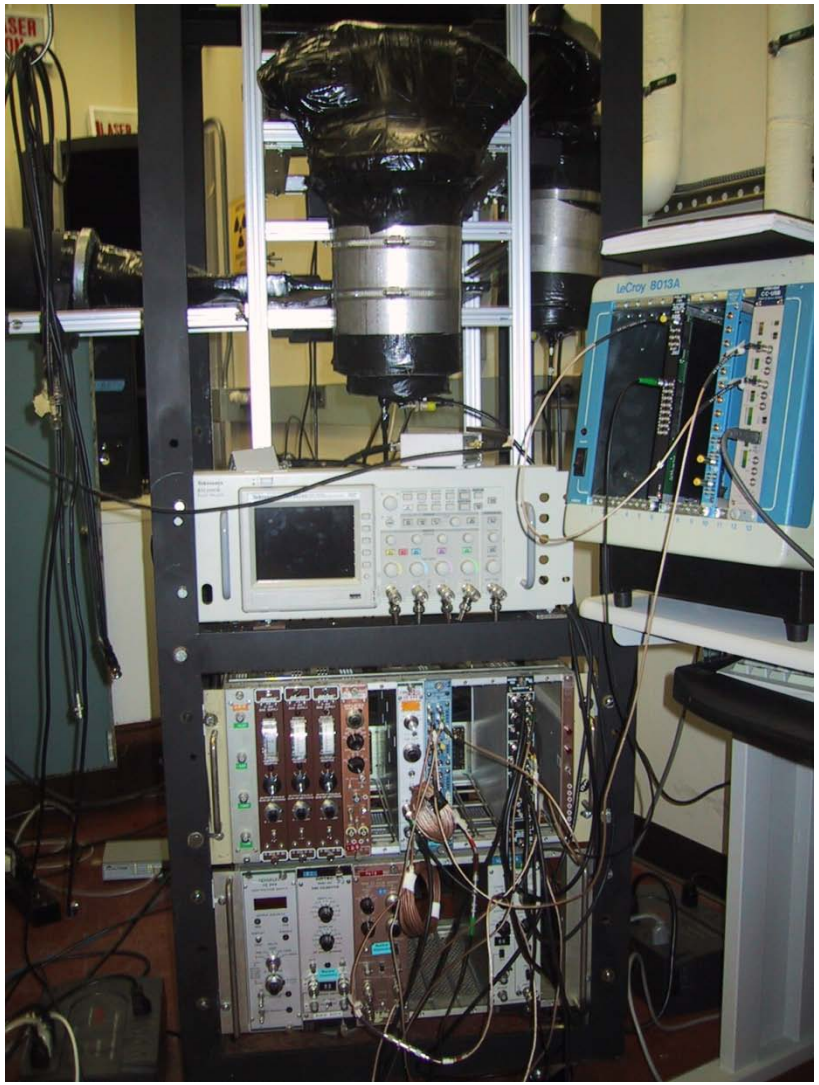
- Material imaging and testing with γ-rays (PET scan, γ-γ angular correlation).
- Neutronics, n detectors, n diffusion.
- Thermal neutron activation with a neutron source, measurement of β or γ and analysis.
- Neutron activation with a neutron generator, "phase-lock" method, fast (n, γ), (n, p), (n, α).

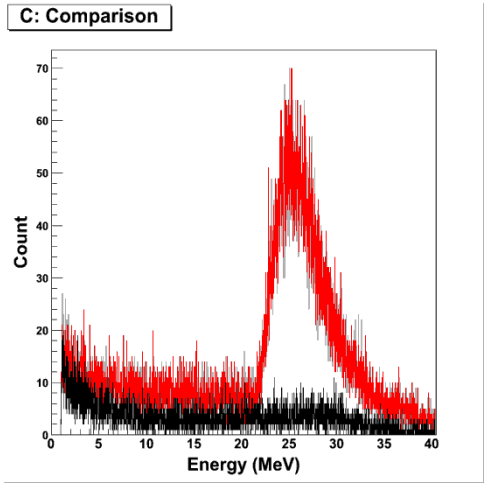
Mössbauer measurements

10-11

- Principle of recoil-less nuclear resonance absorption.
- Mössbauer instrumentation in absorption and emission, Geiger, gas, solid-state detectors.
- Calibration of velocity scale.
- Measurement ^{57}Fe X rays and 14.4-keV Mössbauer γ rays with different absorbers.
- Determination of Fe abundance in mixtures, magnetic splitting in ^{57}Fe enriched foil, isomer shift, chemical shifts for chemical compounds in different oxidation states.

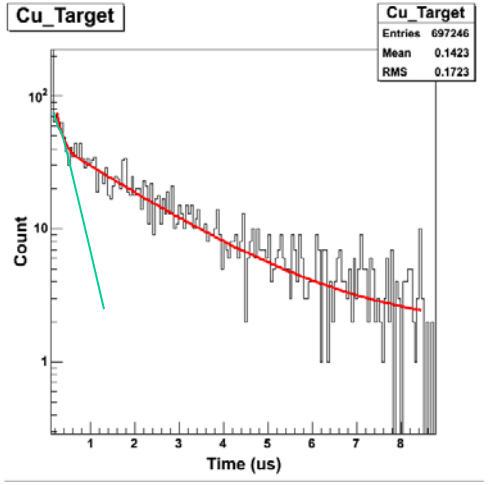
Interactions of Cosmic Muons $\mu^{\pm}$ with Matter





Energy spectrum of transmitted (red) and stopped (black) muons.

Average energy loss $E_{loss} = (25.48 \pm 0.03)$ MeV.



Timing spectra of products following muon stops in a Cu target.

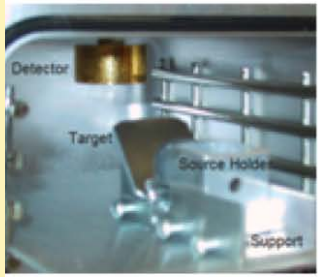
Green: negative-muon capture products

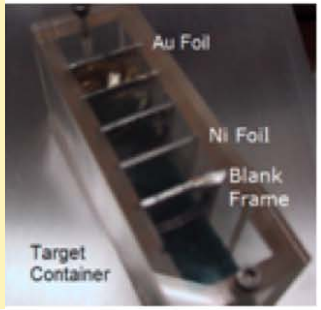
Red: Decay plus capture

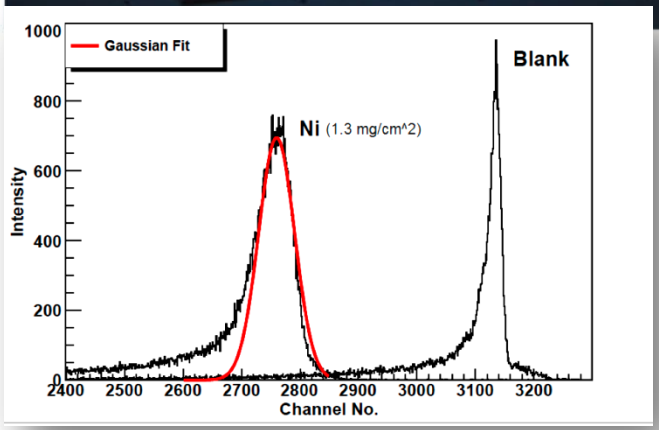
ANSEL: Material Testing with α Particles

Main goals: Z and density dependence of energy loss. Mean and variance of E_{loss} distribution, straggling. Technical: preamp/amp/ DAQ setup in simple experiment source and pulser calibration. Later: backscattering imaging

Experimental setup for α particle spectroscopy. Left: Setup with ORTEC 808 chamber, vacuum gauge and Tektronix scope.
Right: (Top) View of back-scattering test setup, chamber rack and shelf, Si detector.
(Bottom) target container with blank frames and mounted foils.

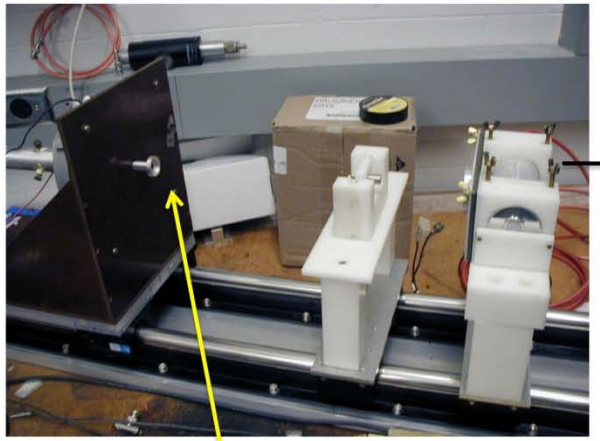


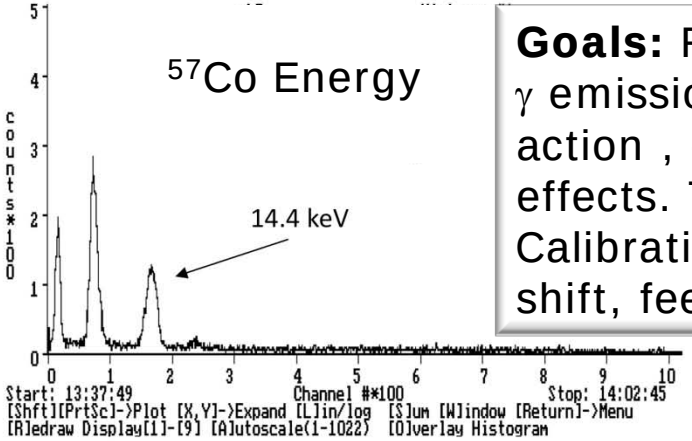




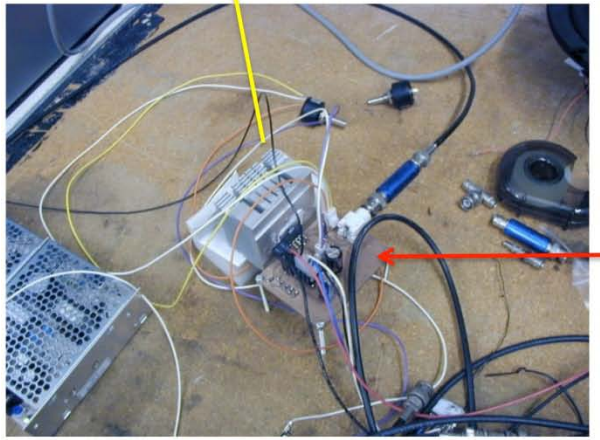
Energy spectrum of 5.4-MeV alpha particles from a ^{241}Am (100-nCi) alpha source. Peak on right: un-attenuated (Blank). Peak on left: transmission through a 1.3-mg/cm^2 Ni foil. Red curve: Gaussian fit curve.

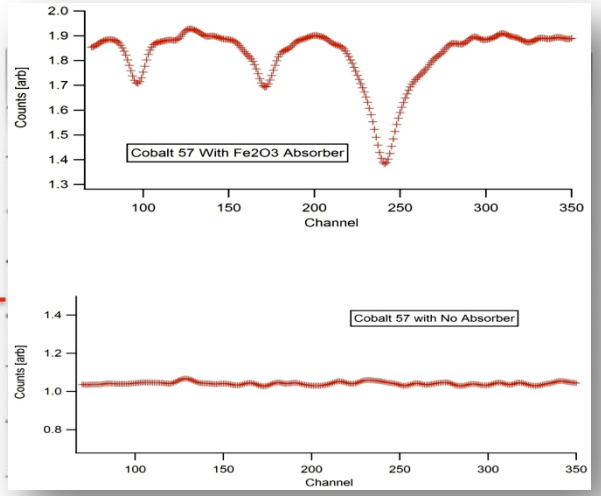
ANSEL: Mössbauer Spectroscopy





Goals: Recoilless γ emission, HF interaction , chemical effects. Technical: Calibrating Doppler shift, feed back loop.





Mössbauer Spectrum Number of counts vs. driver signal amplitude (source speed).

Top: Fe_2O_3 absorber

Bottom: No absorber.

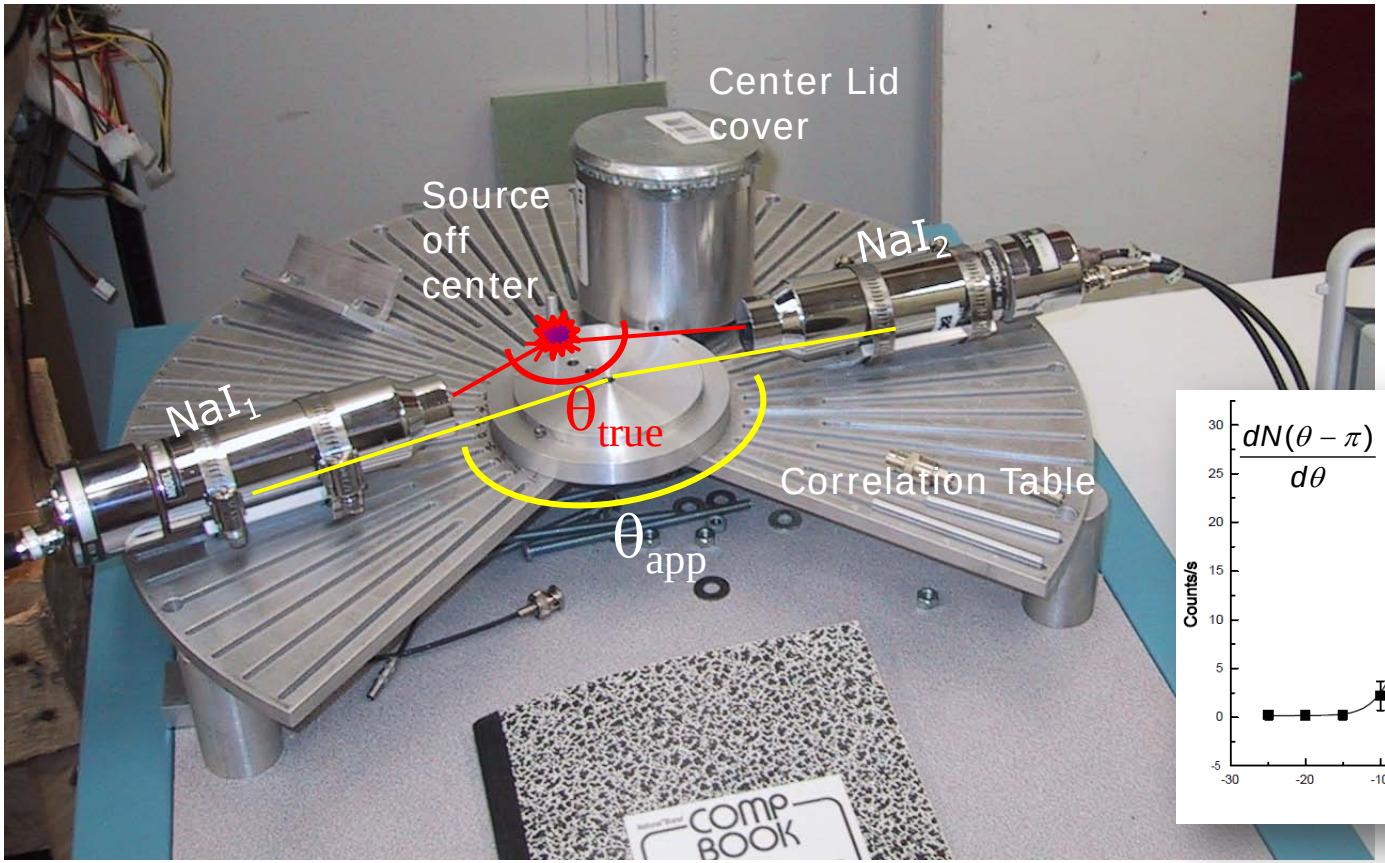
Top left: Mössbauer setup, showing the source driver on the left, the absorber holder in the middle, and the proportional counter on the left. Top right: energy spectrum collected with the Co source. Bottom left: speaker driver .

PET Type Imaging Experiment

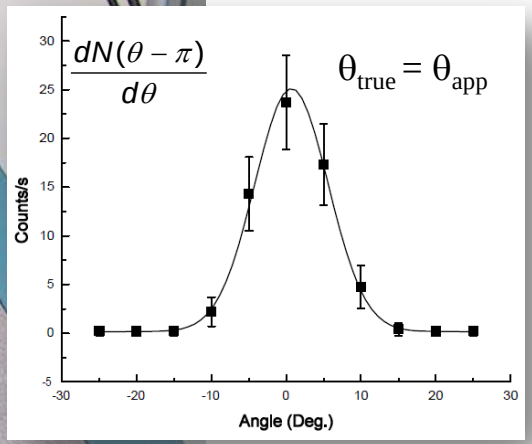
Goals: Introduce coincidence method, fast-slow circuitry, simple PET experiment.

^{22}Na (2 back-to-back 511-keV γ-rays) source placed off center

Triangulate unknown (hidden, off center) source position

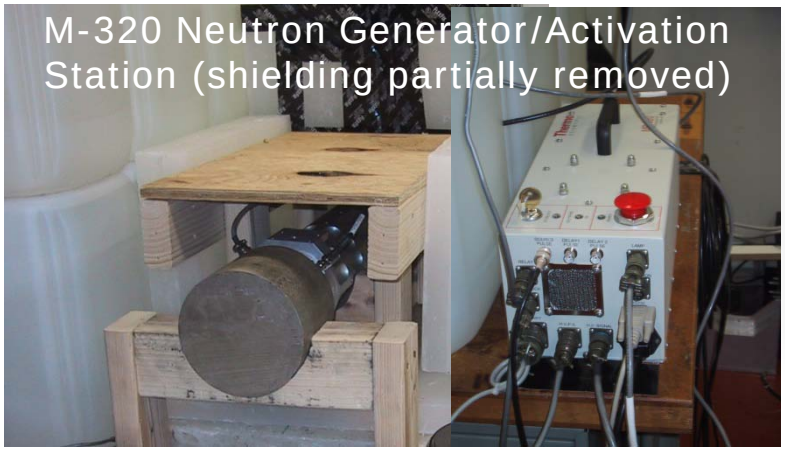


$$\theta_{true} \neq \theta_{app}$$

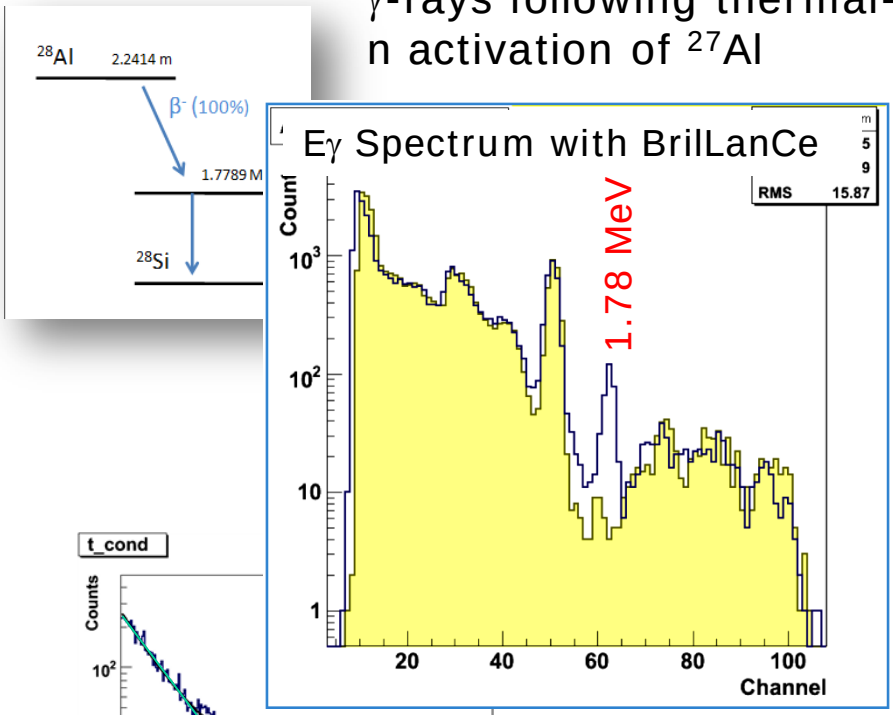


ANSEL: Neutron Activation Analysis

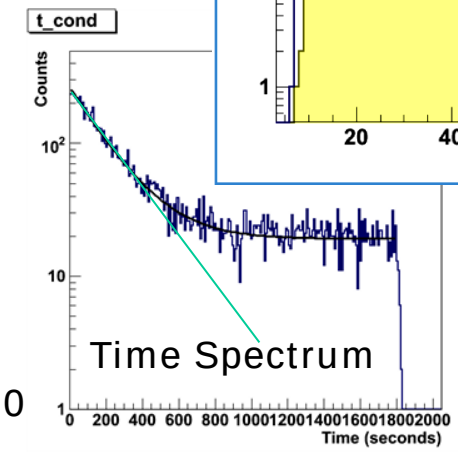
Goals: Transmutation of nuclei, β delayed emission of characteristic γ-rays. Thermal-n activation of materials using n source, pulsed n-generator. Technical: Pulsed n beam, mode-locked detection, coincidence electronics.



γ-rays following thermal-n activation of ^{27}Al



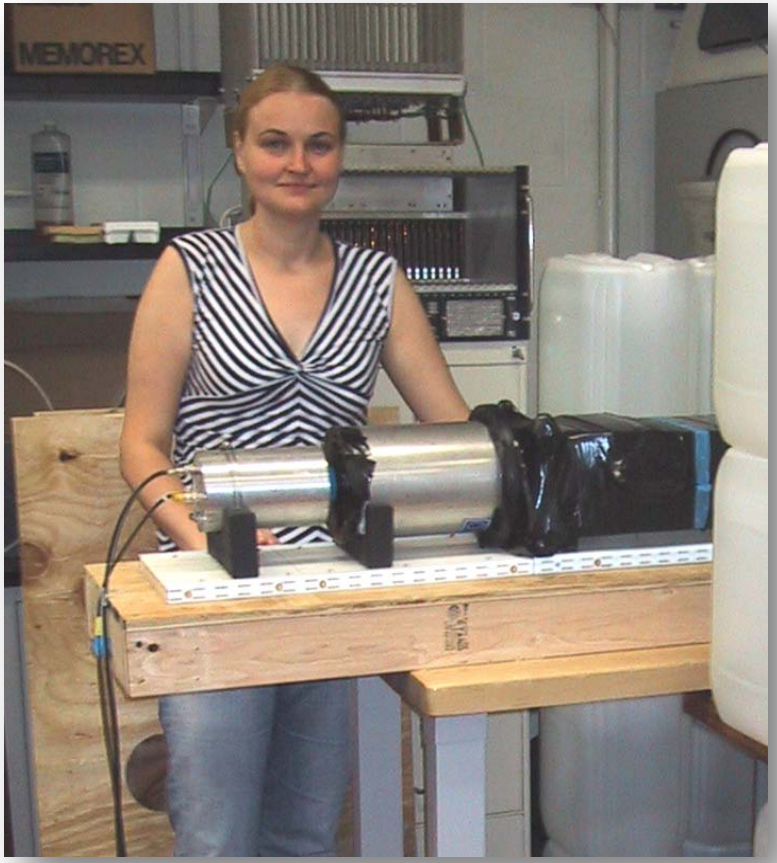
Low-level counting station with NaI counter (shielding partially removed).
Alternative: 1.5"x1.5" $LaBr_3$:Ce, BrilLanCe®380



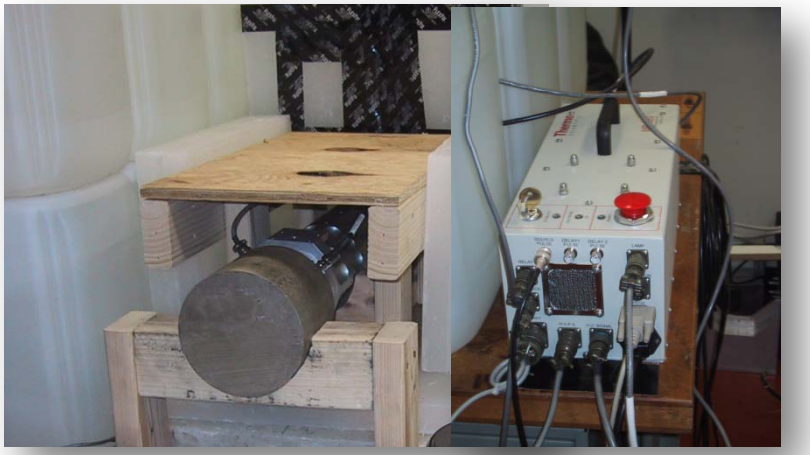
^{28}Al half life of $t_{1/2} = (135 \pm 3)$ s

ANSEL Training Applied in Detector R&D

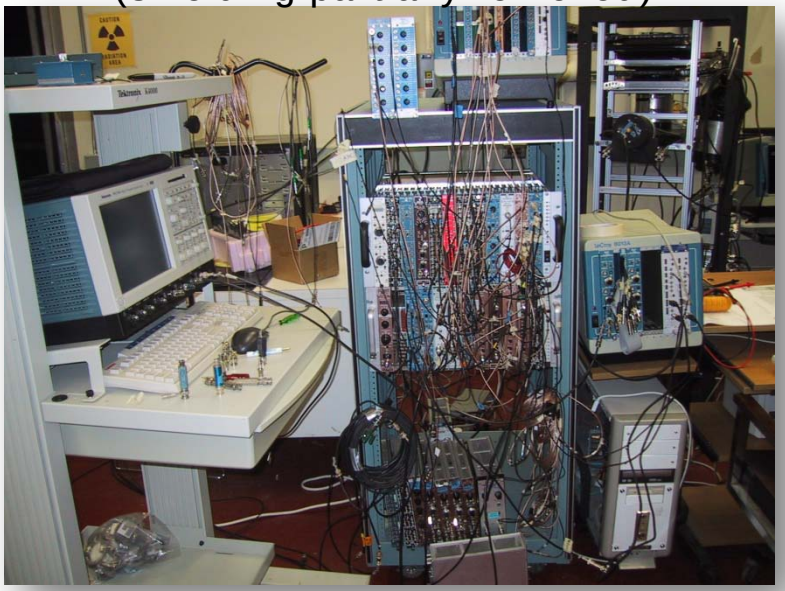
Commissioning runs for n generator served for performance evaluation of new neutron detector N*



Future application in high-energy density plasma diagnostics (LLE)



M-320 Neutron Generator Station (shielding partially removed)



Test stand for n detector development