Fission Product Yield Measurements Supporting Nuclear Forensics

Los Alamos National Laboratory
Lawrence Livermore National Laboratory
Pacific Northwest National Laboratory
NCERC

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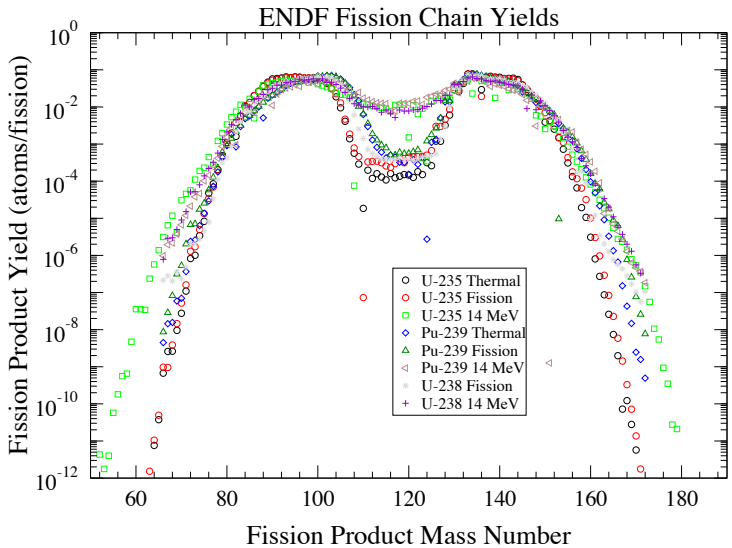
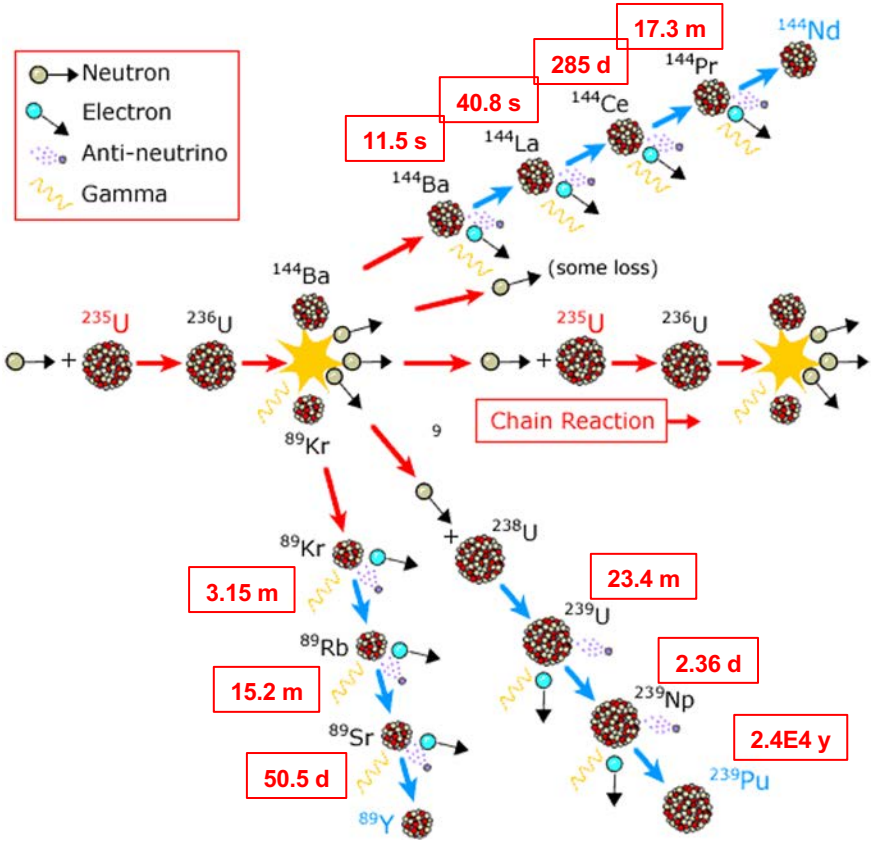
Why is nuclear physics / nuclear data important to the mission

The defining signature of a nuclear detonation is the presence of nuclear reaction products in the debris.

These can be from

- Fission products (FP) from the fuel.
- Activation products (AP) from the fuel or nearby materials.
- Production/Destruction depends on fuel type and neutron spectrum.





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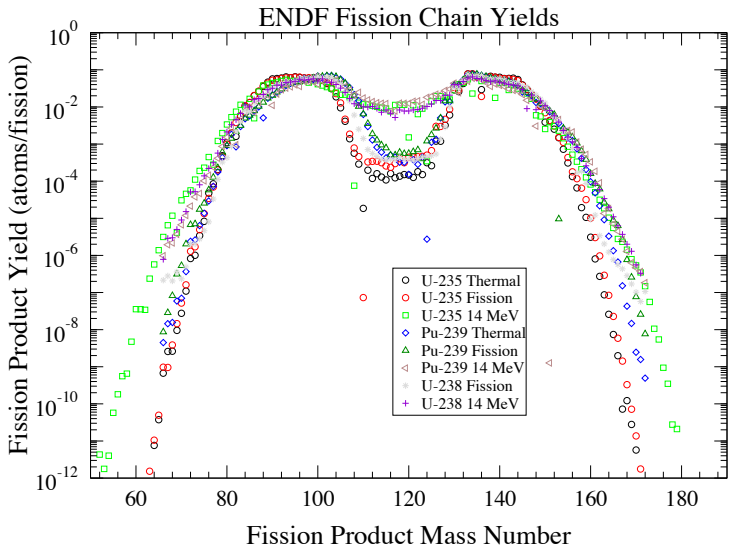

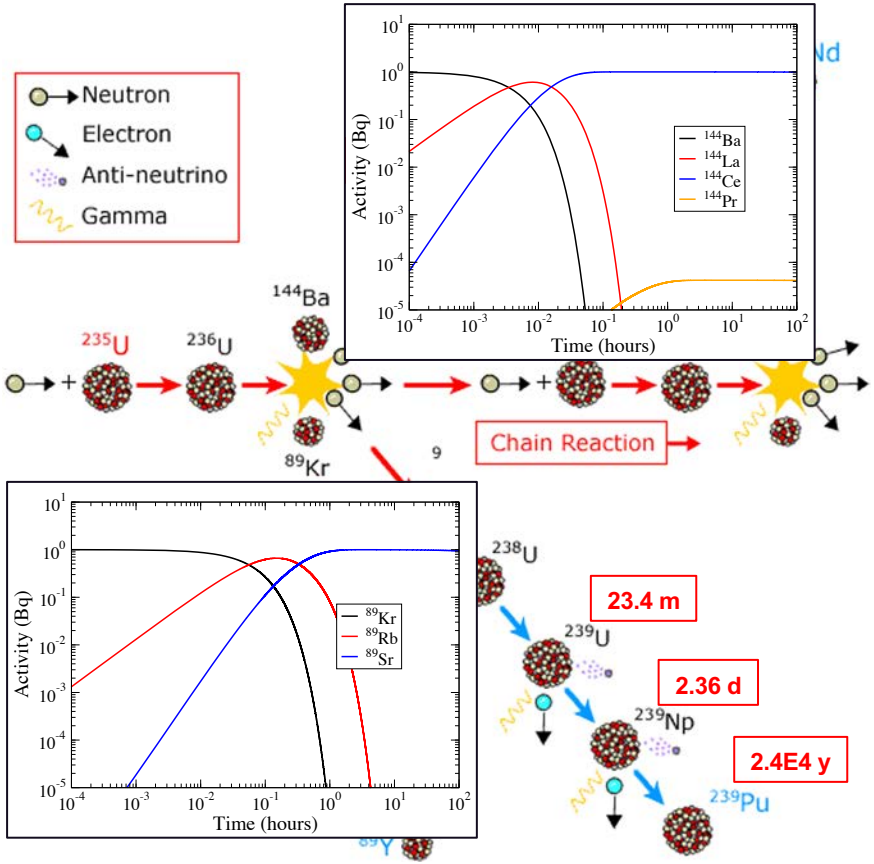

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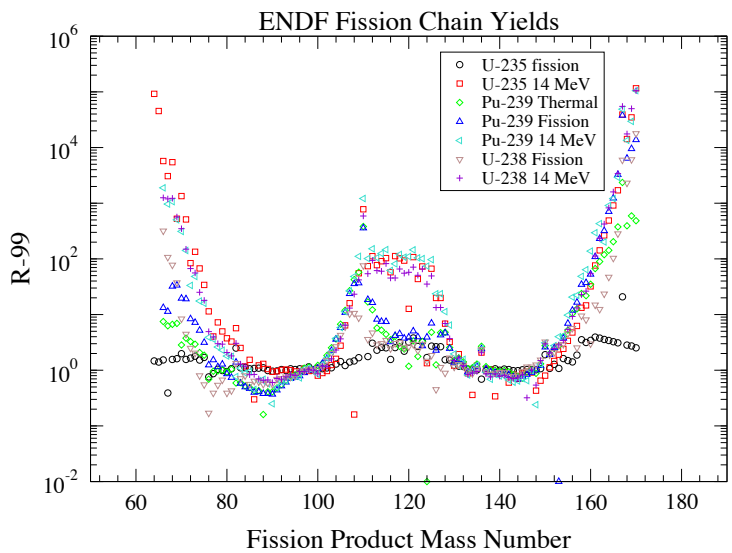

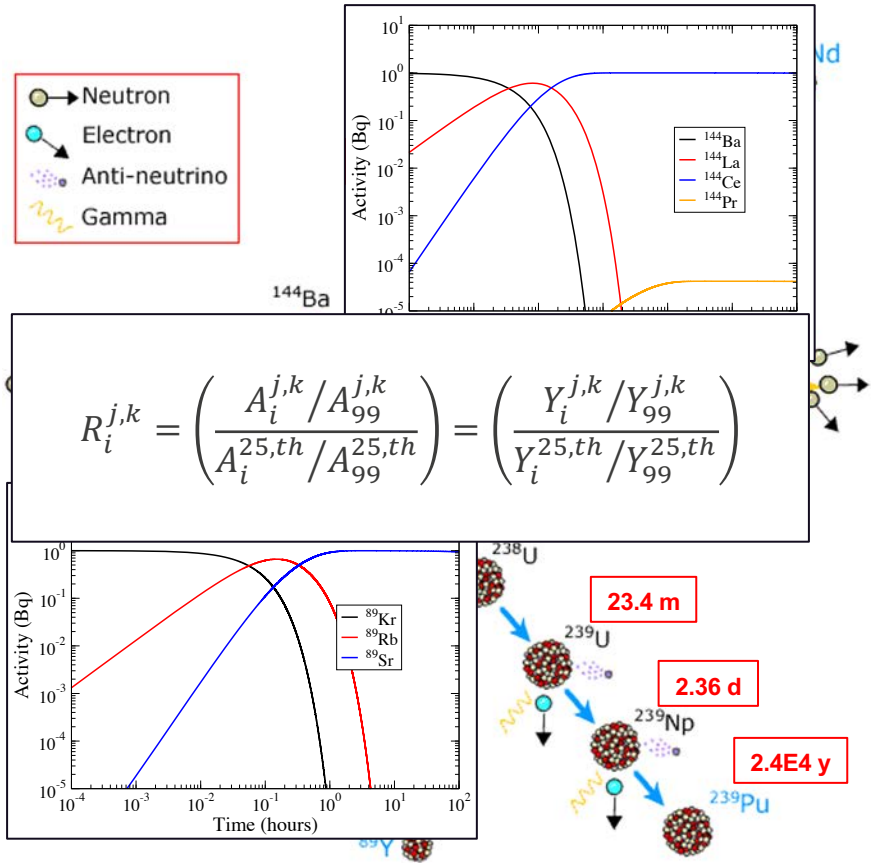

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Neutron Sources

Flattop (NCERC)

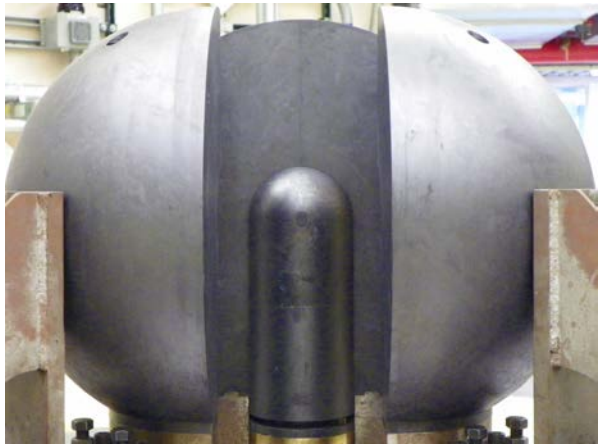
- Fast/fission Spectrum
- U(93) (17.7 Kg) & WG Pu (6 kg) cores / ^{Nat}U Reflector (~1000 kg)
- Horizontal ("traverse") glory hole
- 10^{13} fissions/g on samples

Godiva IV (NCERC)

- Fast/fission neutron spectrum
- U(93) (65.5 kg, 1.5% Mo by weight)
- Super-Prompt Critical Operations
- Vertical glory hole for samples
- 1-4 $\times$ 10^{16} Total Fissions / burst

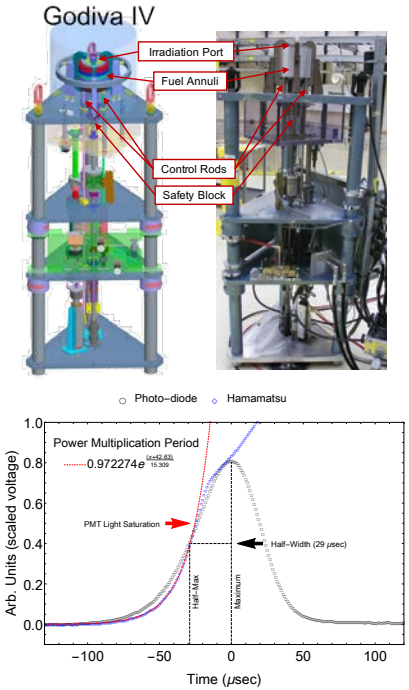
D-T Generator (PNNL)

- Thermo D711 neutron generator
- Low scatter facility at PNNL
- Max neutron flux of 1×10^{9} n/cm^2/s

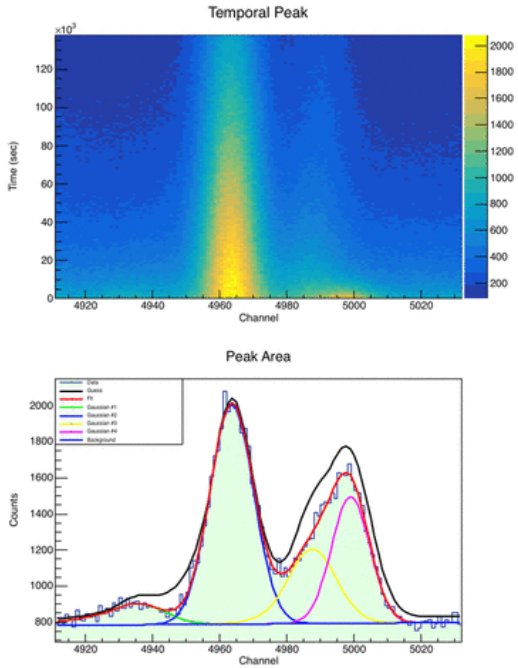


Short-Lived Fission Product Yields (FASTER)

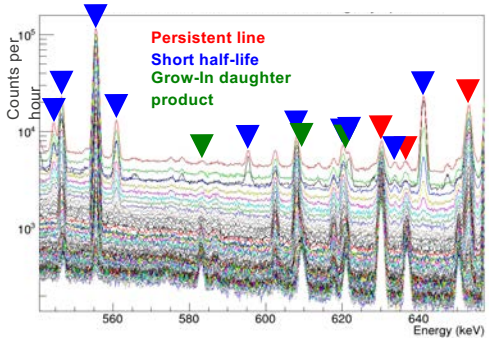
Fabricate High Quality Targets → Pulse Irradiate at NCERC → Acquire γ spectral data → Symmetric Temporal Spectral Analysis (LLNL) → Asymmetric Temporal Spectral Analysis (PNNL) → Evaluate Neutron Fluence & Fissions → Publish Fission Yields in Nuclear Data Sheets for NNDC



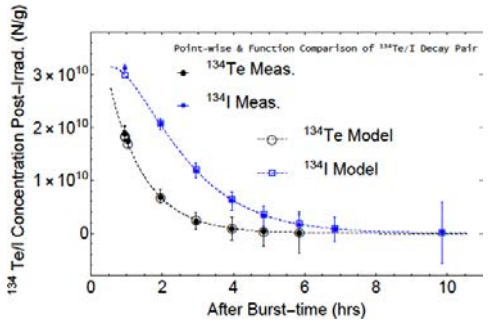
Godiva Irradiation Pulse Width



Symmetric Temporal Fit of ^{112}Ag & ^{134}I



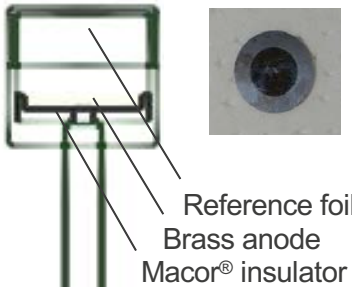
Very rich high-resolution spectroscopy allows us to unfold the time dependent behavior of FPs

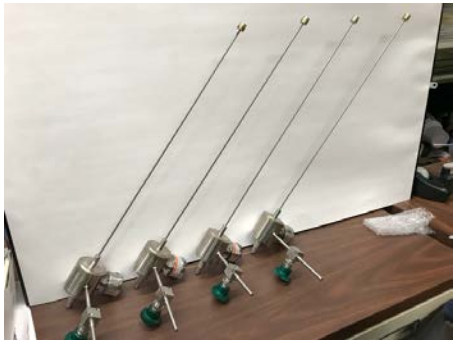


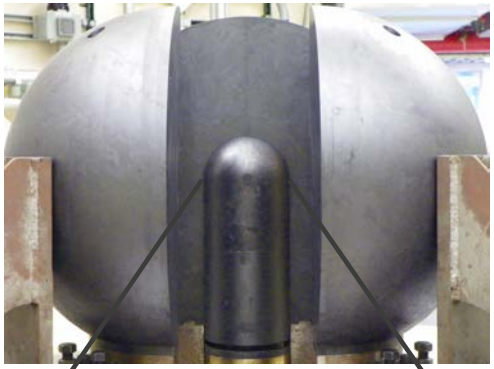
Asymmetric Temporal Assay of ^{134}I

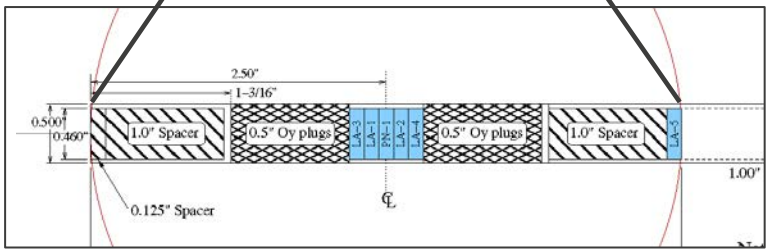
Cumulative Fission Product Yields (BETTER)

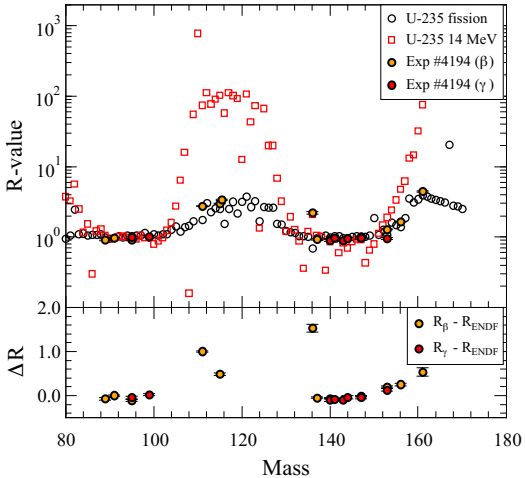
Fabricate Fission Chambers to Determine Absolute FPYs → Prepare High Quality Reference and Macro-foils → Irradiate Samples at NCERC and PNNL → Post-Irradiation Whole Foil γ–Counting → Radiochemical Dissolution and Analysis → R-values ($R_i^{j,k}$) and Absolute FP Yields ($Y_i^{j,k}$) → Publish Results and Post in XFOR



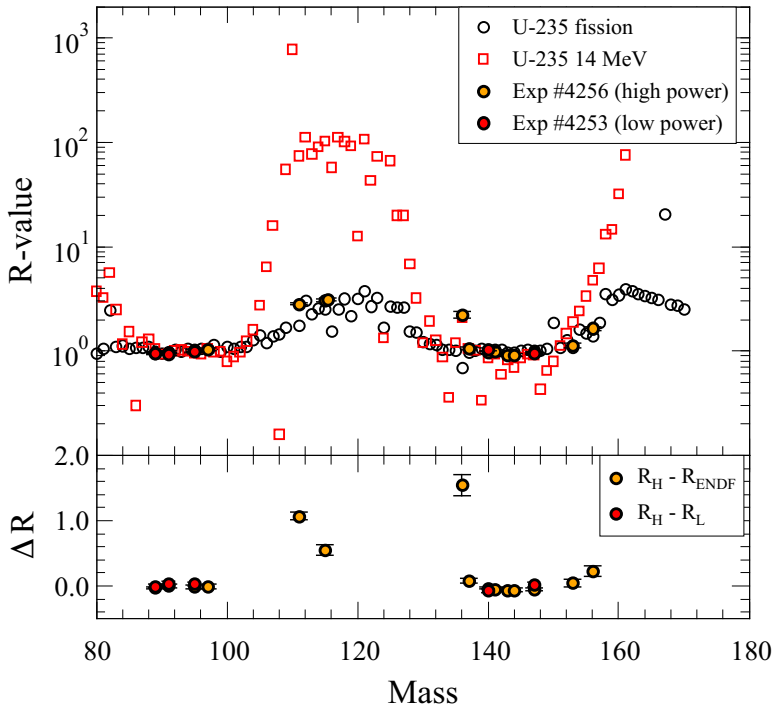


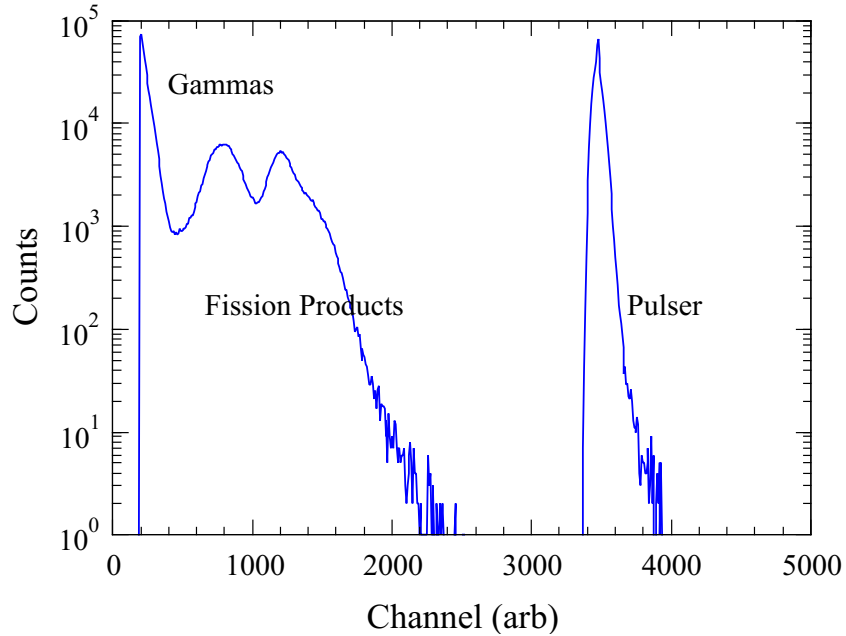






Relative to Absolute Fission Yields





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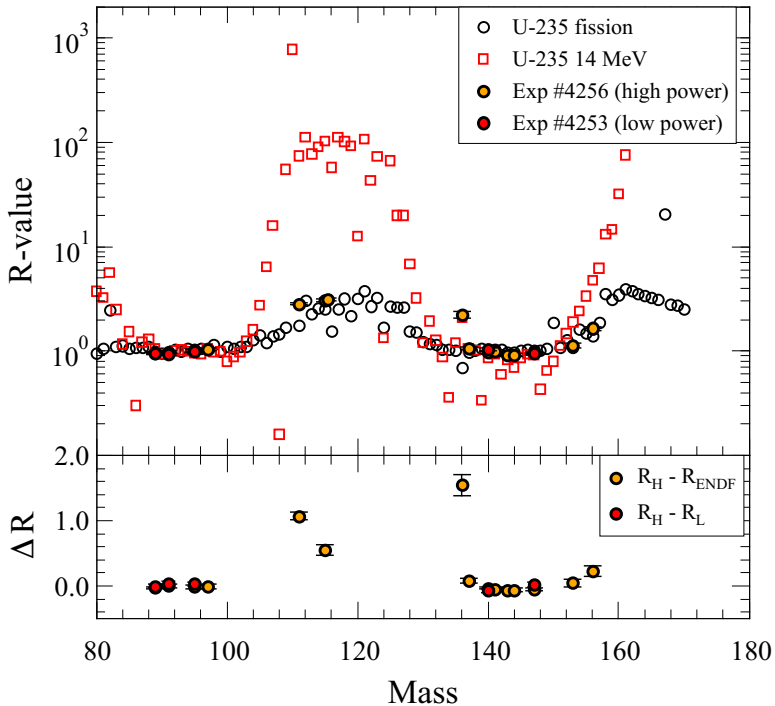
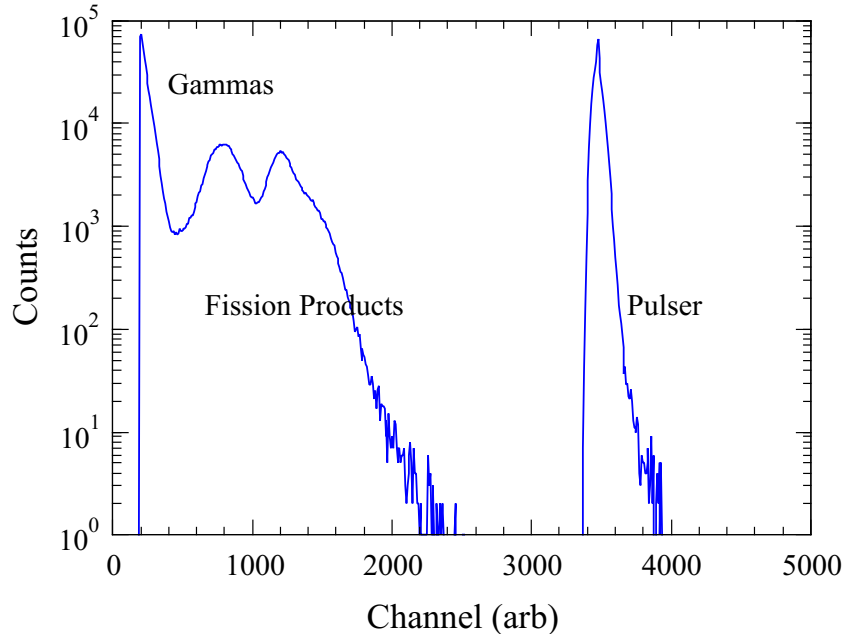
$$Y_i^{j,k} = \frac{(1+\alpha_i) A_i^{j,k}}{\lambda_i \epsilon_i f_i N_f^*}$$

Fission Chamber

Radiochemistry

Relative to Absolute Fission Yields





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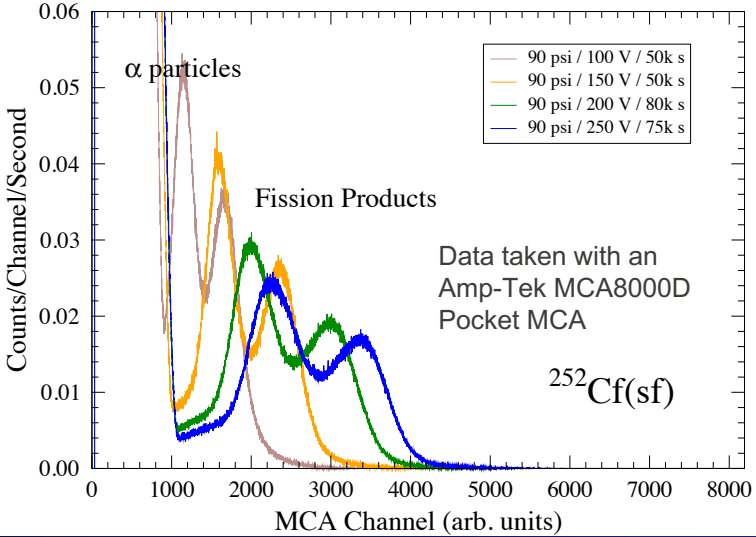
Fission Chamber

Radiochemistry

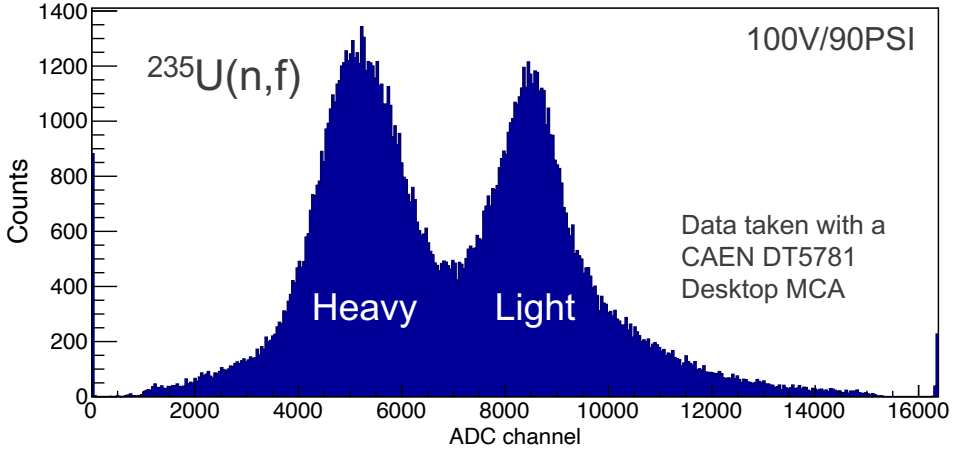
Fission Chamber Performance

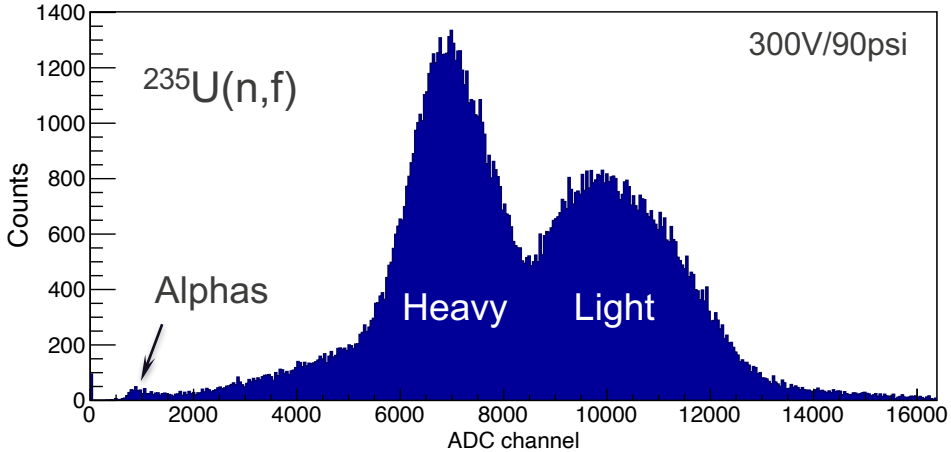
Pulse height spectra from the Mark II fission chamber

- Benchtop testing with ^{252}Cf
- Testing at MIT with ^{235}U

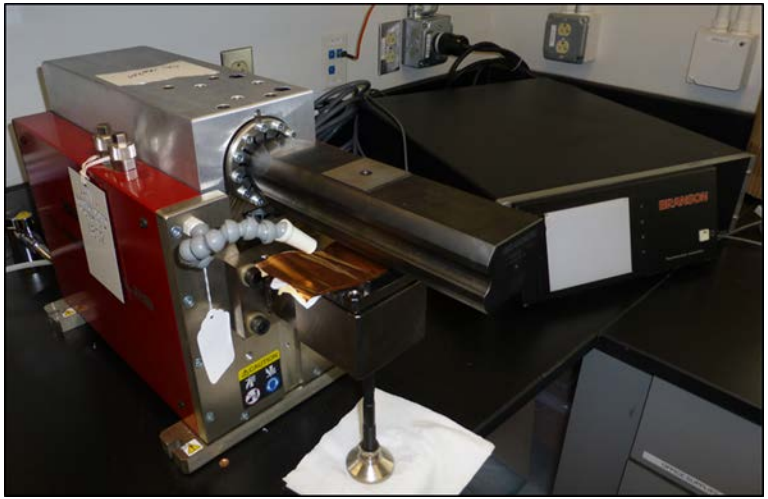


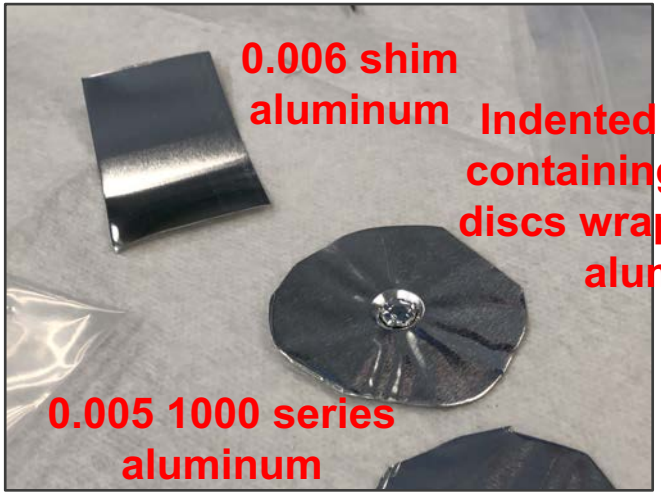
MIT Nuclear Reactor Laboratory





Branson Ultraweld L20





The Ultraweld L20 is set up to weld two pieces of aluminum into a disc with a pocket diameter of 0.455”, and will effectively weld two pieces of 0.003” to 0.006” aluminum shim.

Welded Capsule

Plans for FY21

Cumulative FPYs at NCERC/Flattop:

- FC testing at the MIT Nuclear Reactor Laboratory
  Oct 27 - 29, 2020 – COMPLETED
- FC testing on Flattop at NCERC
  Nov 17 - 19, 2020 – CANCELED
- FC testing at the MIT Nuclear Reactor Laboratory
  Scheduled Mar 2 - 4, 2021
- FC testing on Flattop at NCERC
  Scheduled Mar 30 – Apr 1, 2021
- ^{235}U foil irradiations on the Flattop critical assembly
  Scheduled April 17 - 14, 2021
  Parallel radiochemical analyses at LANL and PNNL
  Direct foil counting <u>and</u> radiochemical analyses to determine relative CFPYs.
  Collocated fission chambers to determine absolute CFPYs.

Short-Lived FPYs at NCERC/Godiva:

- ^{233}U foil irradiations on the Godiva critical assembly
  Yet to be Scheduled

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