Parallel-plate avalanche counter (PPAC) fabrication for ^{240}Pu PFNS measurement

NCSP Technical Program Review

Feb 15 - 17, 2022

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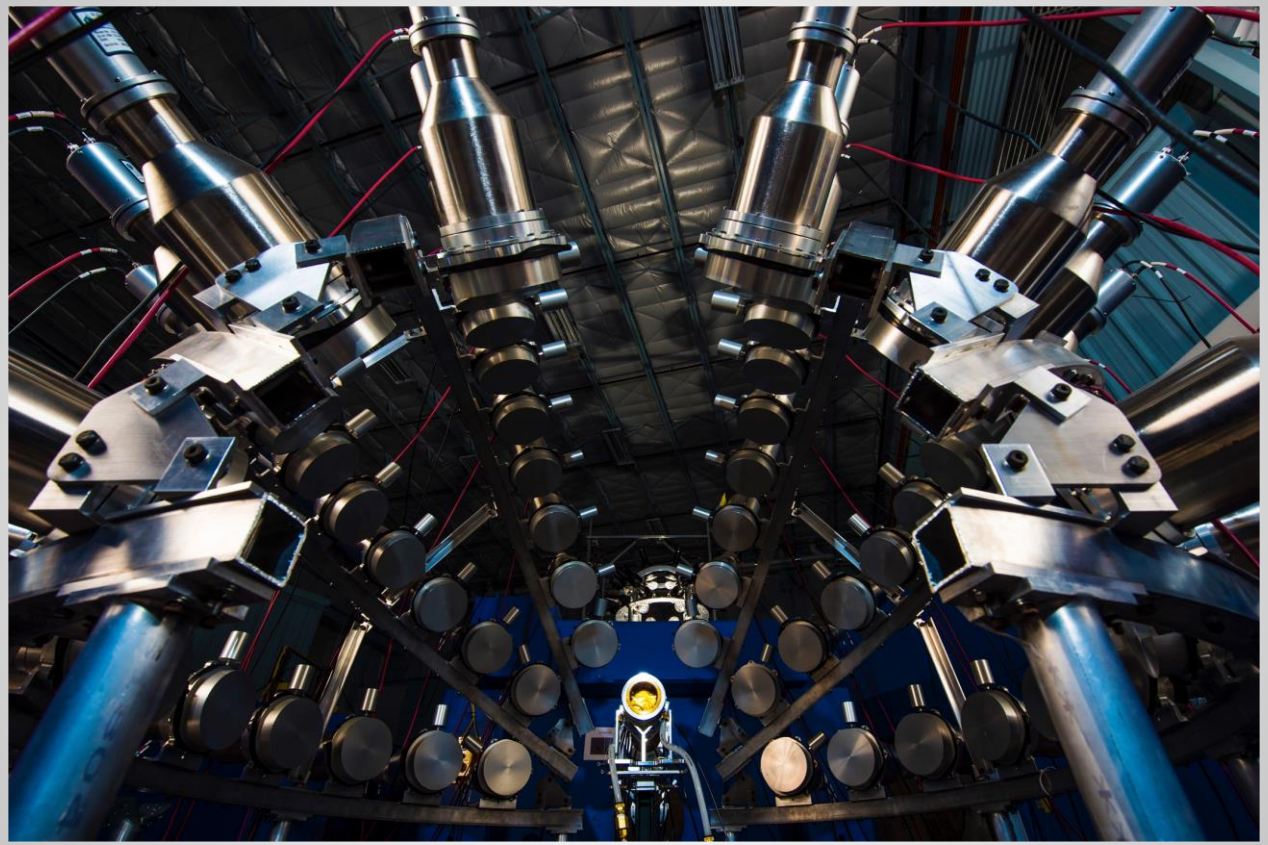
LLNL-PRES-831600

This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Motivation and method

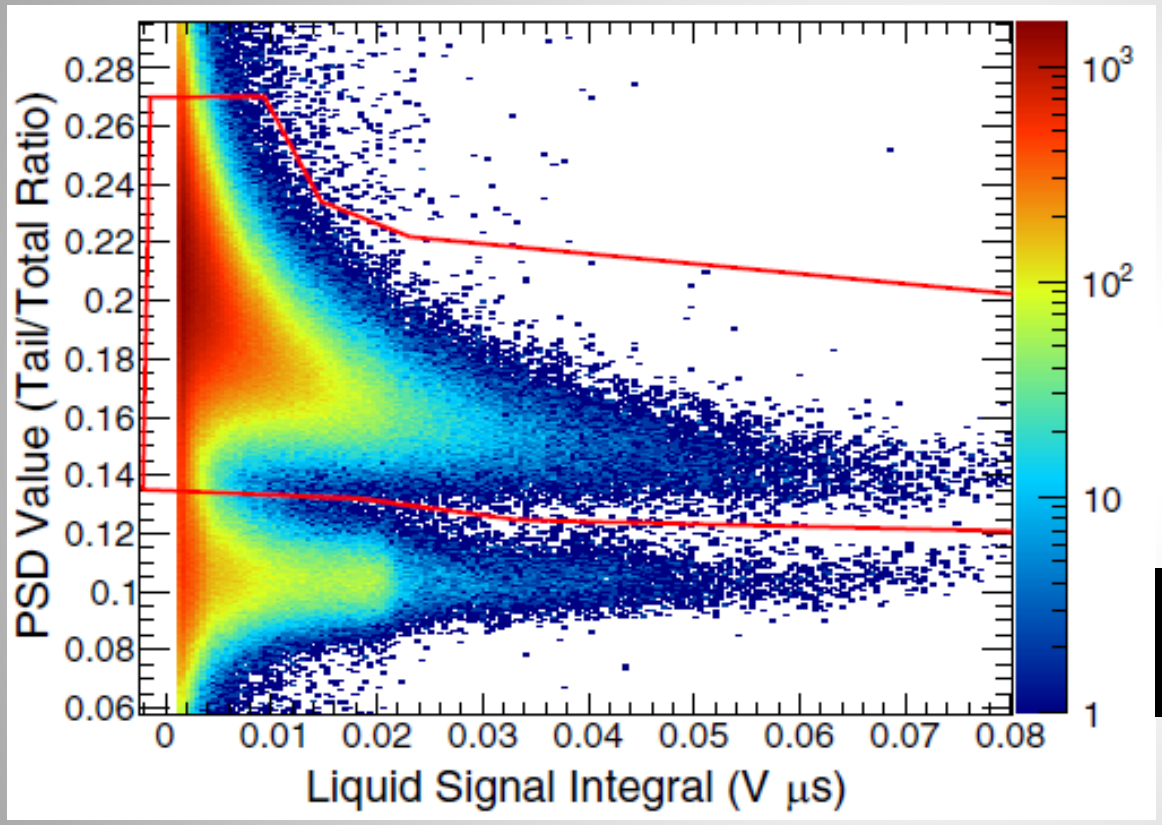
- Prompt fission neutron spectrum (PFNS) is one of major observables for fission that are fundamental to our understanding of fission mechanism. An accurate PFNS measurement is highly demanded for many practical applications
- A joint LANL-LLNL program was initiated to measure PFNS to improve the quality of χ matrices for ^{235,238}U and ^{239}Pu for programmatic need
- The measurement was carried out at LANL/WNR facility using two neutron arrays, developed by LANL, and a multiple-foil PPAC, developed by LLNL for the fission fragments detection

A neutron array of 54 liquid scintillators with PPAC



For the outgoing neutrons with energy above ~ 700 – 800 keV with a distance of one meter from PPAC

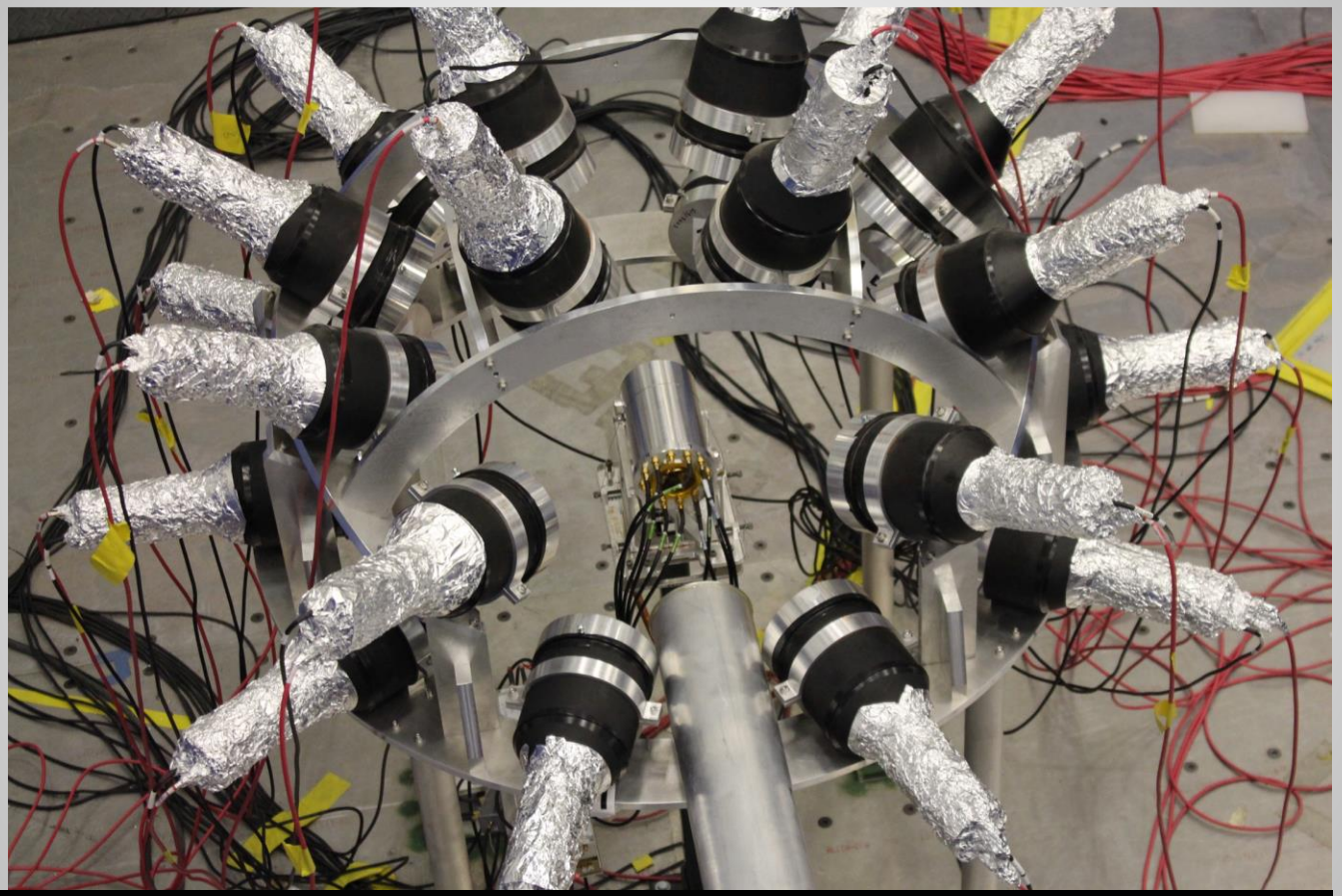
Performance – Liquid scintillator



K.J. Kelly *et al*., PRC 102, 034615 (2020)

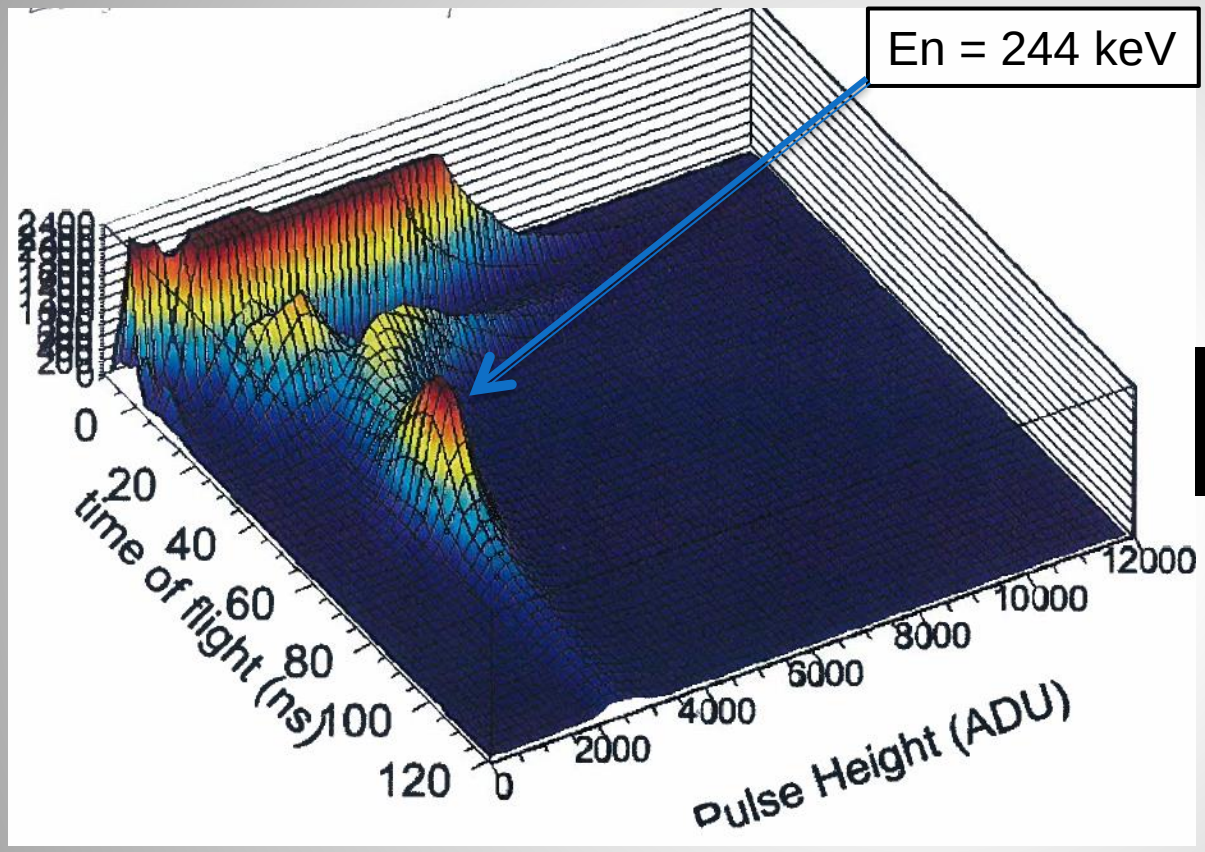
- Neutron identification is made by PSD spectrum encircled by red line
- Neutron energy is determined by the time-of-flight (ToF) measurement

A neutron array of 22 Li-glass scintillators with PPAC



For the outgoing neutrons with energy below ~ 2 MeV with a distance of 40 cm away from PPAC

Performance – ^{6}Li-glass scintillator

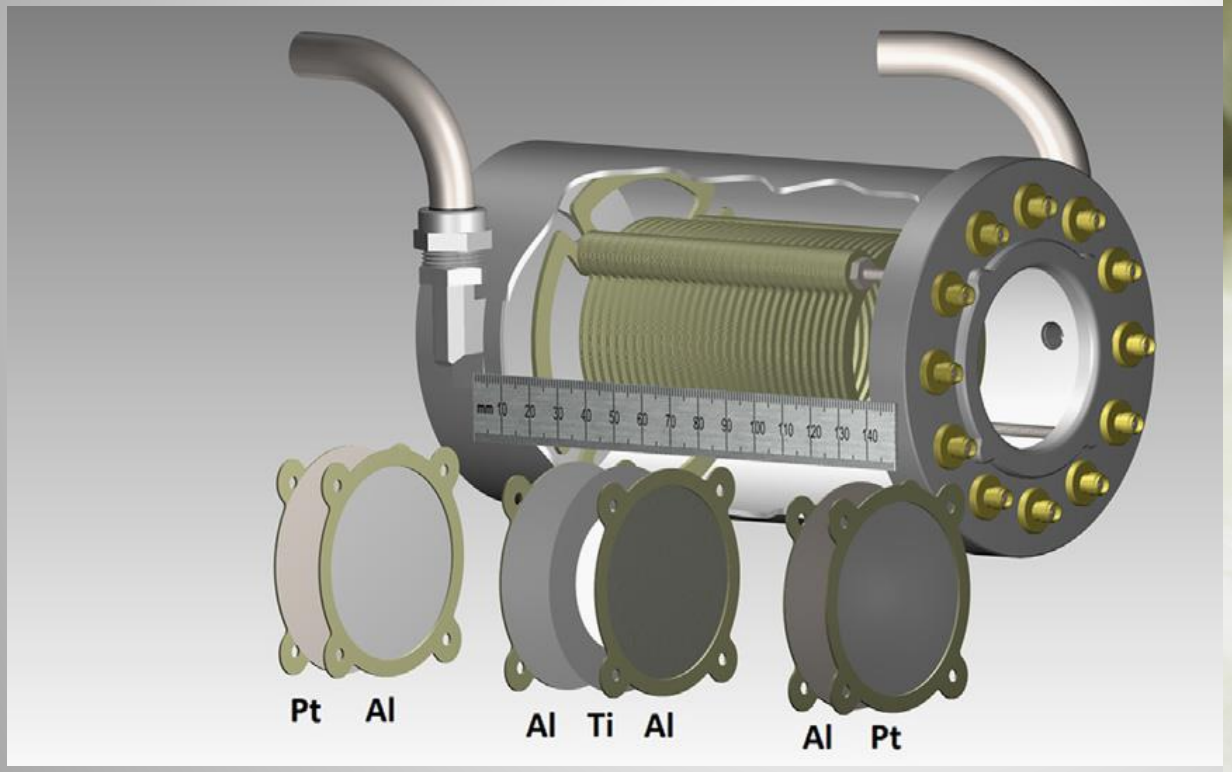


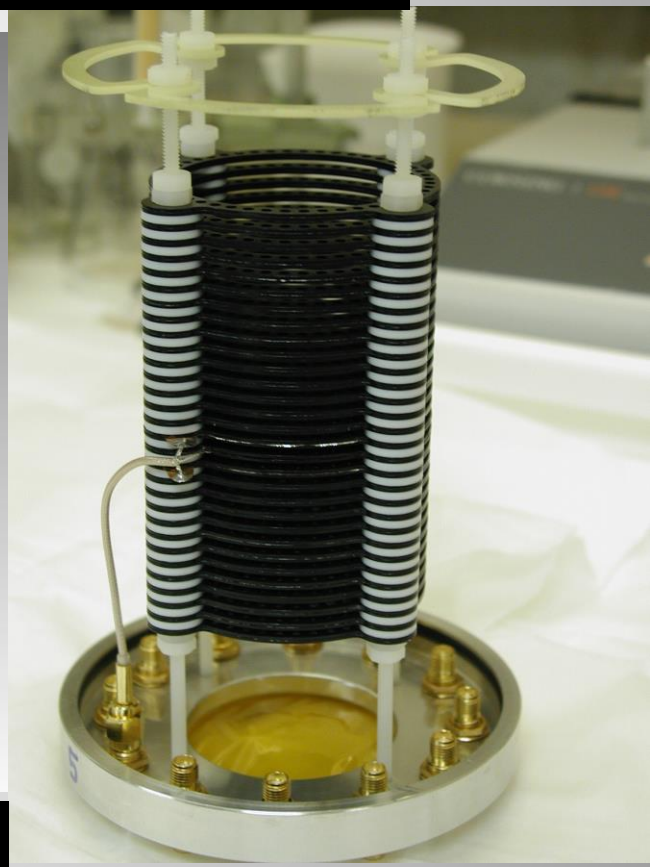
H.Y. Lee et al., NIMA 703, 213 (2013)

- Neutron identification is made by the reaction Q-value of ^{6}Li(n,α) channel
- Neutron energy is determined by the ToF measurement

A 10-foil PPAC for fission-fragment detection

C.Y. Wu, R.A. Henderson, R.C. Haight *et al*., NIMA 794, 76 (2015)

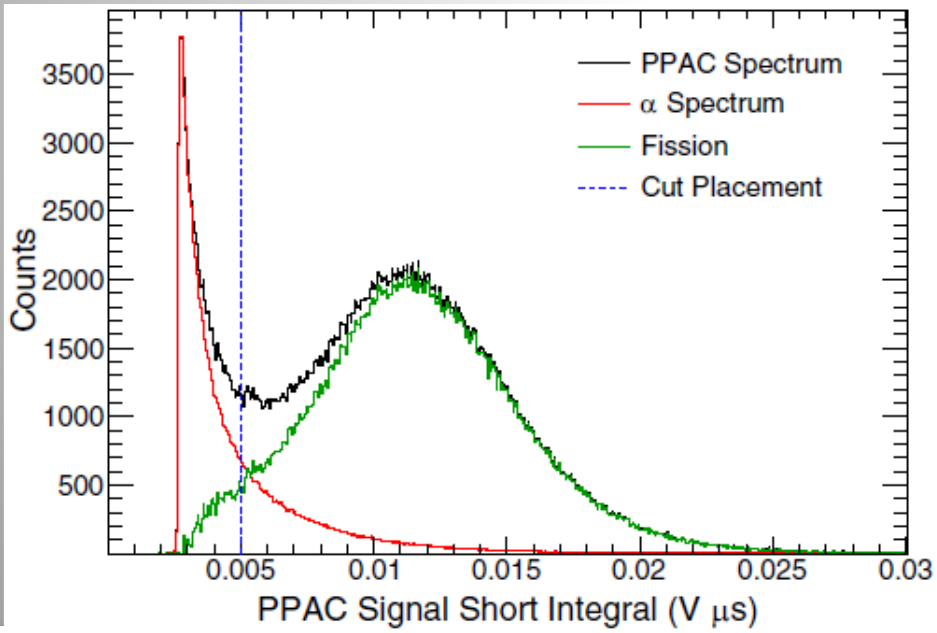




Total foil thickness is less than 200 μm

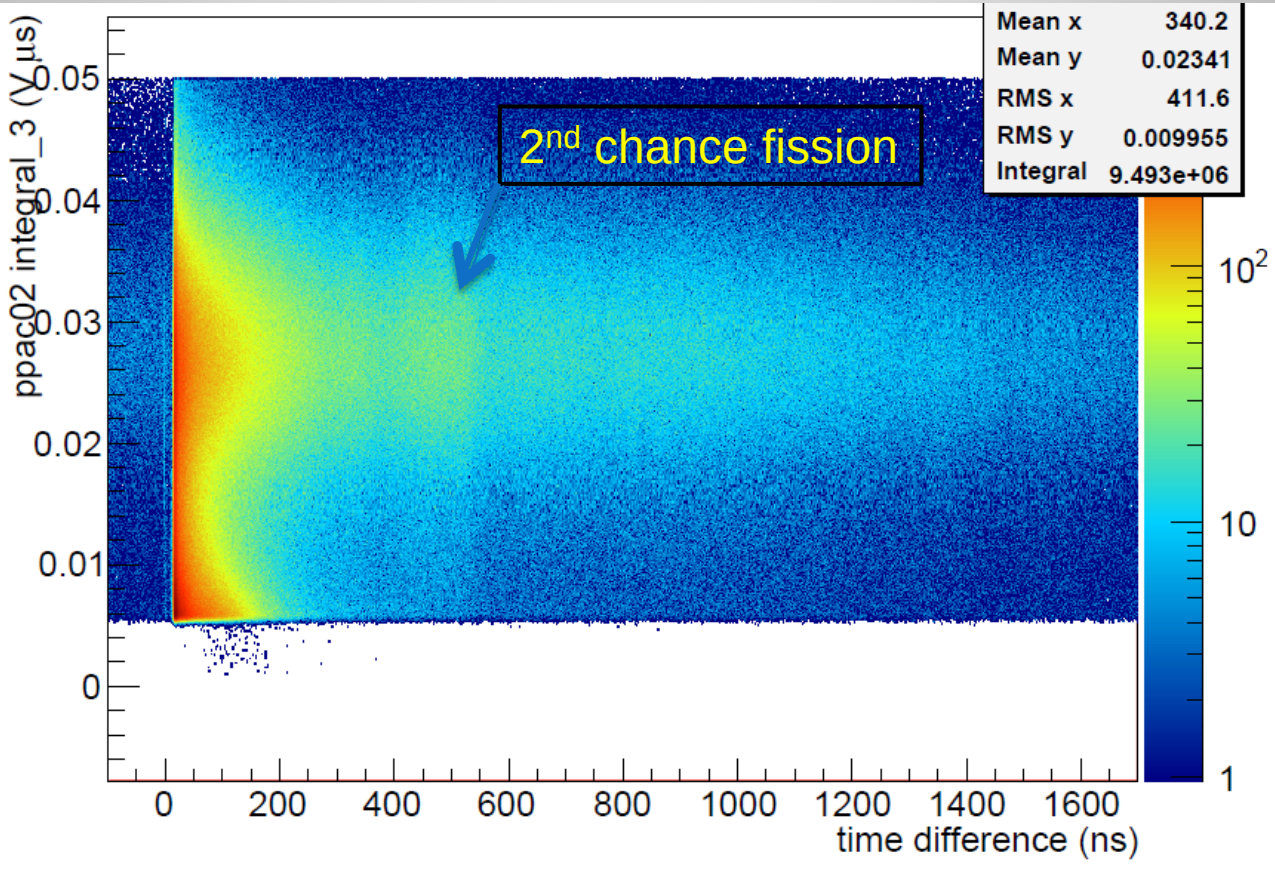
Why PPAC?

- Can be operated at high counting rate in a hostile environment of very high α-decay rate (~ 10^7 /s) from highly radioactive fissile materials
- Can be built with minimum construction material in a compact package to minimize the neutron scattering



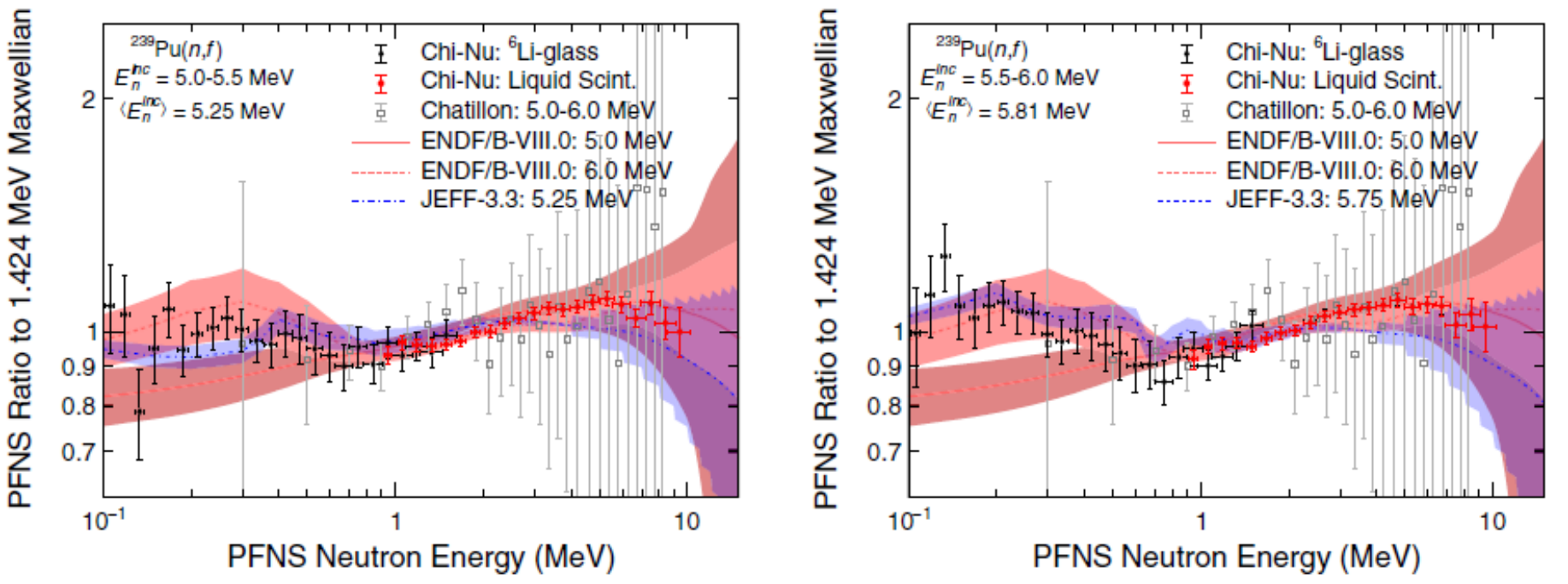
K.J. Kelly *et al*., PRC 102, 034615 (2020)

Performance – incident neutron energy



- Incident neutron energy is determined by the ToF measurement between PPAC and beam pulse
- Absolute time calibration by photo-fission event

PFNS measurement for ^{239}Pu



K.J. Kelly *et al.*, PRC 102, 034615 (2020)

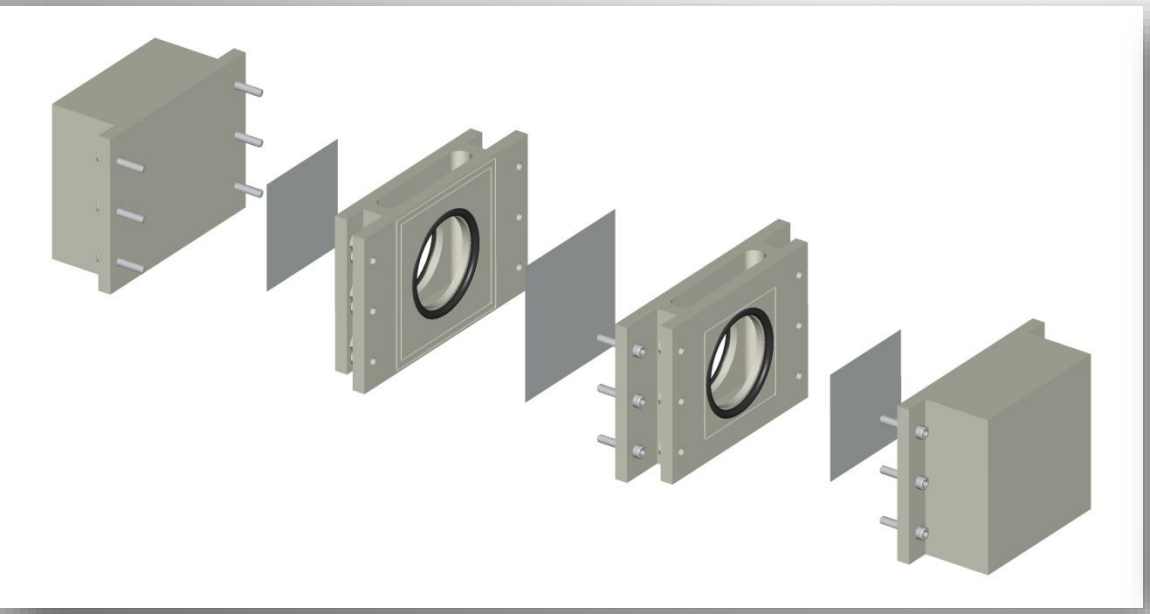
- PFNS ratio to 1.424 MeV Maxwellian for incident neutron energy 5.0 – 5.5 and 5.5 – 6.0 MeV
- The data quality is improved dramatically in precision and energy range

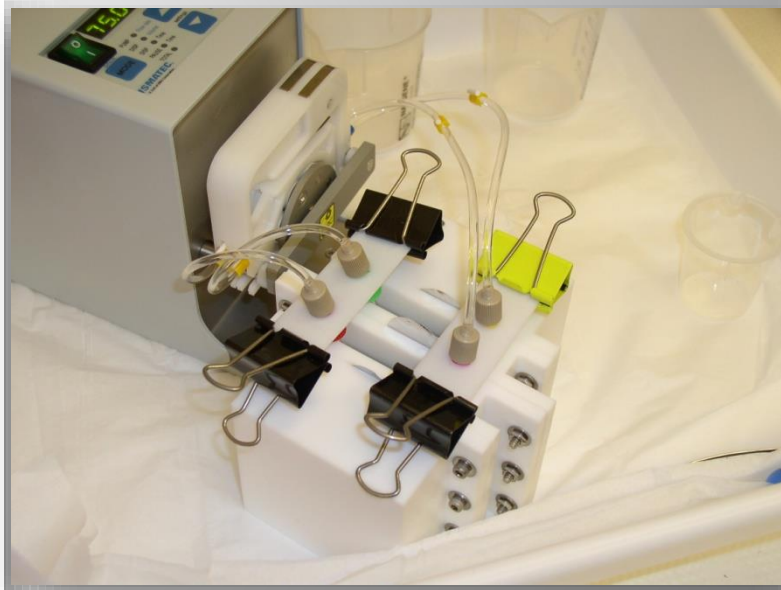
Target fabrication – ^{239}Pu, chemistry

- Oxide material sourced from ORNL
- Dissolve in con HNO_3 / 0.005M HF – treat with H_2O_2
- Anion Column; AG-1-X8 100-200 mesh
  - 8 M HNO_3 condition
  - 8 M HNO_3 wash - +3's, U eluted
  - 10 M HCl convert to Cl^-
  - 1:10 con HI : 10 M HCl elution – Pu reduced to +3 and eluted
- Final Prep
  - Evaporate to near dryness – convert back to NO_3^- form
  - Bring up in minimum 0.5M HNO_3

- Remove impurities and decay progeny
- Prevent formation of Pu polymer

Target fabrication – ^{239}Pu, production

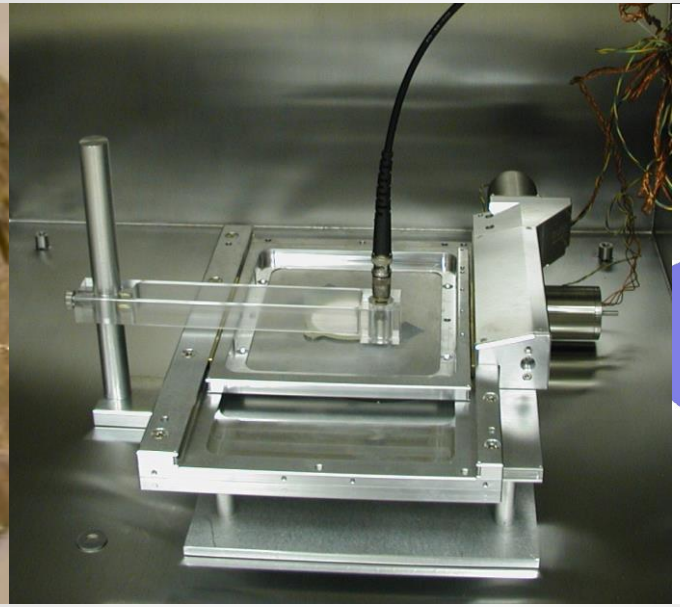


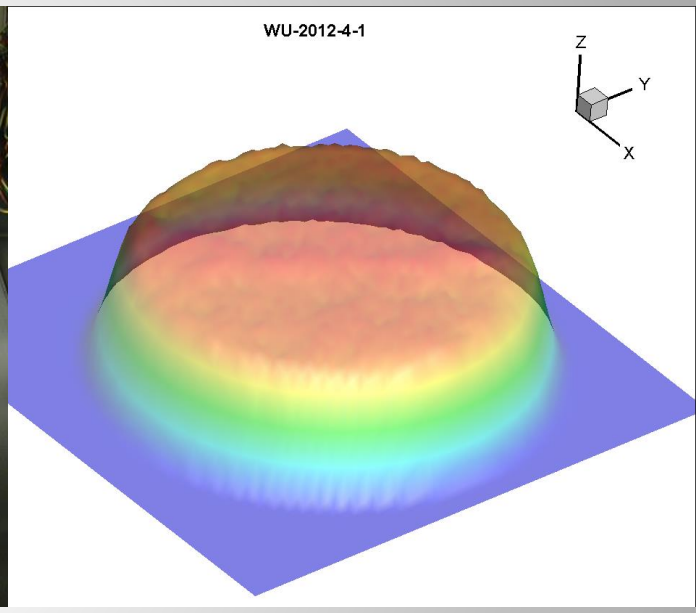


R.A. Henderson *et al*., NIMA 655, 66 (2011)

- Double-sided plating cell
- Plated from IPA at constant current – 3 mA/cm^2 of target area

Target fabrication – ^{239}Pu, characterization

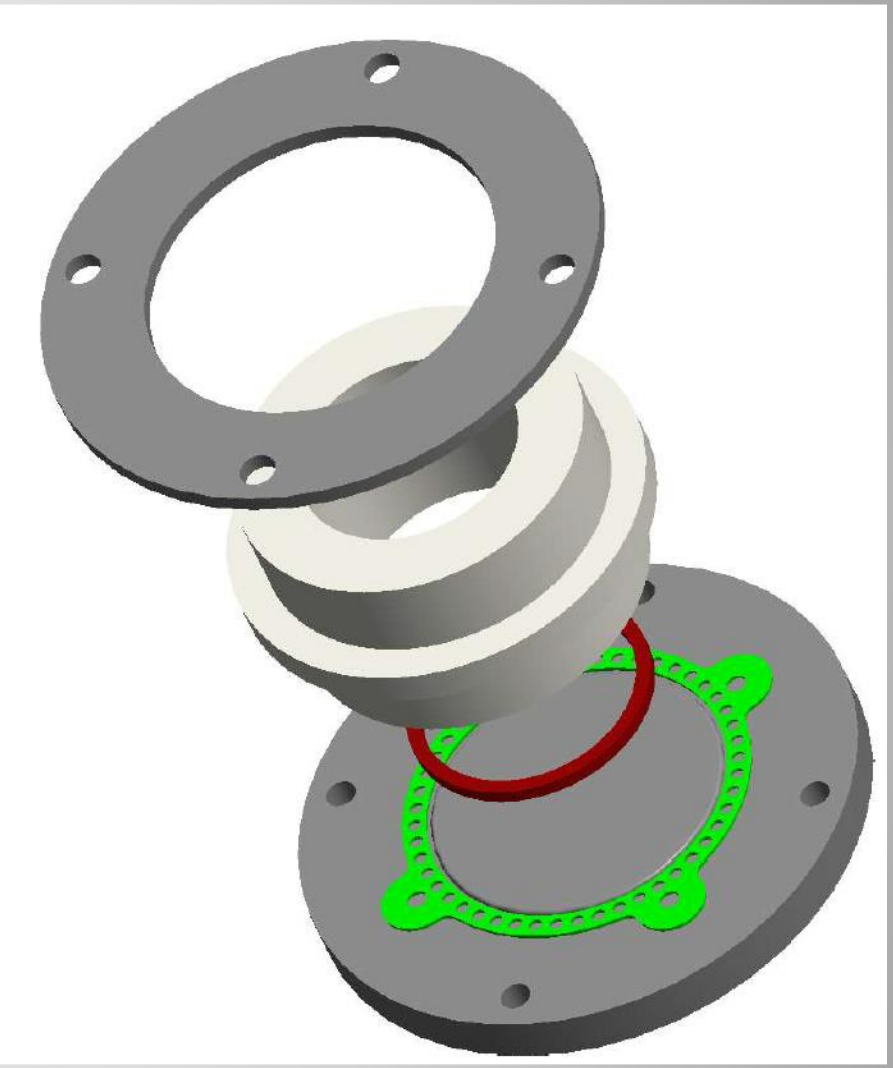




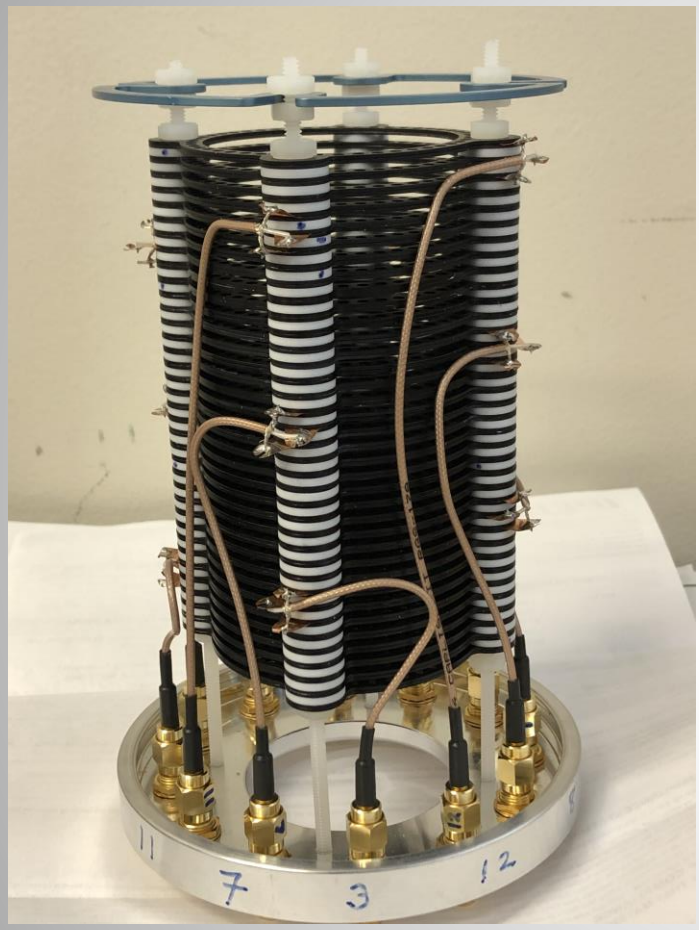
- Double-sided deposition with a total mass about 10 mg
- Mass determined by γ-spectroscopy
- Uniformity – std dev < 4% over the entire area of 4 cm diameter – determined by Target Record Player

^{240}Pu target fabrication

- Chemical process doesn't change
- Single-sided cell used
- Ti foils (not shown) required for target backing
- Pt mesh electrode suspended above target backing



^{240}Pu PPAC



ID	Mass (mg)	σ (%)	Orientation (face upstream or downstream)
1	1.63	3.00	up
2	1.47	3.10	down
3	1.61	2.00	up
4	1.53	2.10	down
5	1.72	2.00	up
6	1.59	3.80	down
7	1.63	1.70	up
8	1.68	4.30	down
9	1.62	1.40	up
10	1.68	2.60	down
11	0.89	2.40	up
12	0.88	2.30	down

A total of 12 single layer targets were fabrication with a total mass of 17.9 mg

Summary

- A LANL-LLNL joint program has been developed successfully to measure PFNS and established the most precisely determined χ matrices for ^{235,238}U and ^{239}Pu
- It has been extended to ^{240}Pu now and possibly to ^{233}U in the future
- An alternative method was developed to fabricate ^{240}Pu and a total of 12 targets were made with a total mass of 17.9 mg
- The PFNS measurement for ^{240}Pu will begin in June, 2022 when the new beam cycle starts and the data analysis follows immediately afterward