An update on work undertaken by AWE using subcritical assemblies in the DAF

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What we will cover

- Our Role
- Why we are working with the US labs and NCSP
- Specific focus areas –security and safety
- The Campaigns
    - Supported by LLLNL and LANL
- Hopes for the future

Purpose of the Exchange

- Major Experimental facility at AWE has closed prior to replacement with New building
  - Very desirable, planned to have photon/neutron interrogation cells, low scatter neutron labs, easy access to SNM, isotopic sources and portable accelerators.
  - Major investment, design and building effort with a long lead time
- Still have a need to underwrite current and develop new techniques and hardware application to support Nuclear Security Operations
- In similar periods of Facility closure in the late 1990s and early 2000s we worked with US Labs (TA18 and Superblock)
- We now work with the NCSP and Labs to allow continued improvement

AWE National Nuclear Security†

- At AWE, we make a real difference to the national security of the United Kingdom - providing expertise to the Ministry of Defence and other UK Government departments in a number of critical areas.

- AWE's unique skills and capabilities position us as leaders in our fields of expertise, providing support to UK Government with specialist national nuclear security, threat reduction and counter-terrorism solutions.

- Our nuclear threat reduction programme maximises AWE's nuclear weapons expertise to support the Ministry of Defence (MOD) and other Government departments working to identify worldwide and UK-based nuclear threats - using cutting-edge scientific methods and instrumentation to assist with threat reduction and counter-terrorism. Our work also contributes to ensure non-proliferation and responding to national nuclear situations.

AWE National Nuclear Security (cont) †

- All of our work is undertaken in the utmost interests of national security and non-proliferation ensuring no information is made available that could lead to the proliferation of nuclear weapons technology.

- Our experts are on-call 24/7 as part of the Government's national emergency response arrangements - ready to deal with any nuclear accident or incident in the UK.

- And in the field of nuclear forensics, we identify the origin of materials and recover traditional forensic information from crime scenes where exhibits have been contaminated with radioactive material.

† Taken Verbatim from AWE Website

Introduction

- Our part in AWE - Non-destructive Assay

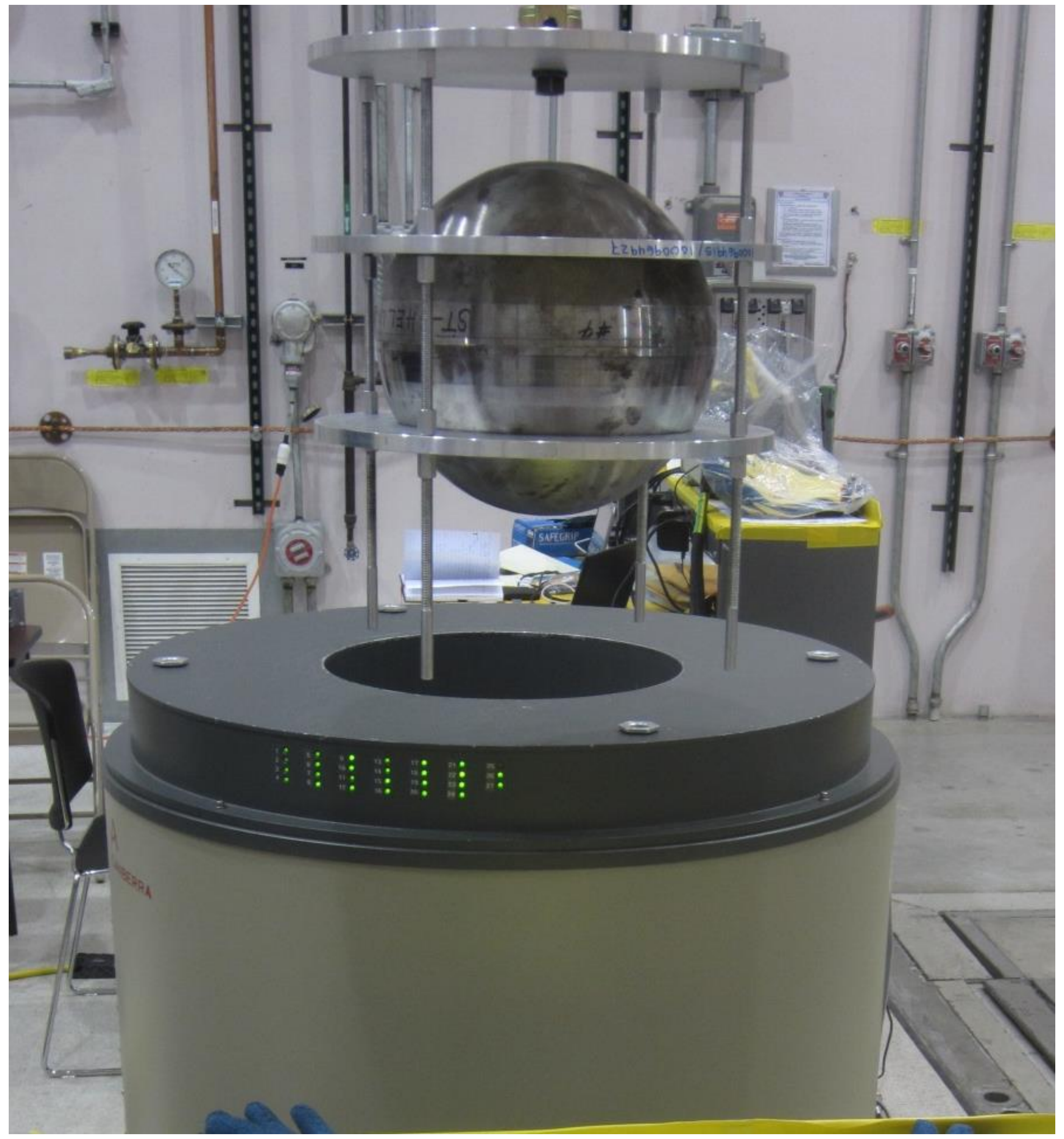
- Support Criticality safety by ensuring Total Material Control
  - Mass and neutron Multiplication determination to aid Assessment of risk from material
    - (i) in-process, waste, decommissioning
    - (ii) bringing out of regulatory control material to safety - the National Security mission
  - Specifically to provide information for static and dynamic Criticality calculations
    - Neutron analysis, Gamma ray Spectrometry, Imaging of SNM (γ and n)
    - High efficiency neutron counters, Calorimetry, In-line systems including complex integrated systems

Role at AWE

- Which areas are supported by our work
  - Smuggling
    - Border Protection
    - Data Analysis, Supporting by providing follow on detailed assay capability
  - Terrorism
    - R&D
    - In field support to First Responders – supply hardware and software solutions, Specialist Advisors and data analysts
  - Forensics
    - Currently in a developmental phase, very R&D heavy
  - Total Material Control
    - Maintain regulatory control and criticality safety

First element of work with NCSP

- Shipped the NDA 50% efficient neutron counter (LEMC) to DAF for NCSP use (LLNL custodians) ~$1.5M
- Provided US training in operation and management of the system at AWE
- The concept was that any NCSP user could make use of the counter for their measurements without AWE needing to be present and the instrument would not be shipped to and from UK



What have we done so far

- We have undertaken a series of trials in order to
  - Understand benefits otherwise of triggered vs random measurements
    - LEMC Trial, analysis, data gathering formats (LLNL)
  - Revalidation and extension of M values LANL collaboration
    - Extend current op window (M was <6) want up to or greater M=20
  - Help develop a fast neutron assay capability (LLNL)
  - Extend validated operation to a wider range of SNM which might not be as well understood as Pu and HEU (LLNL)

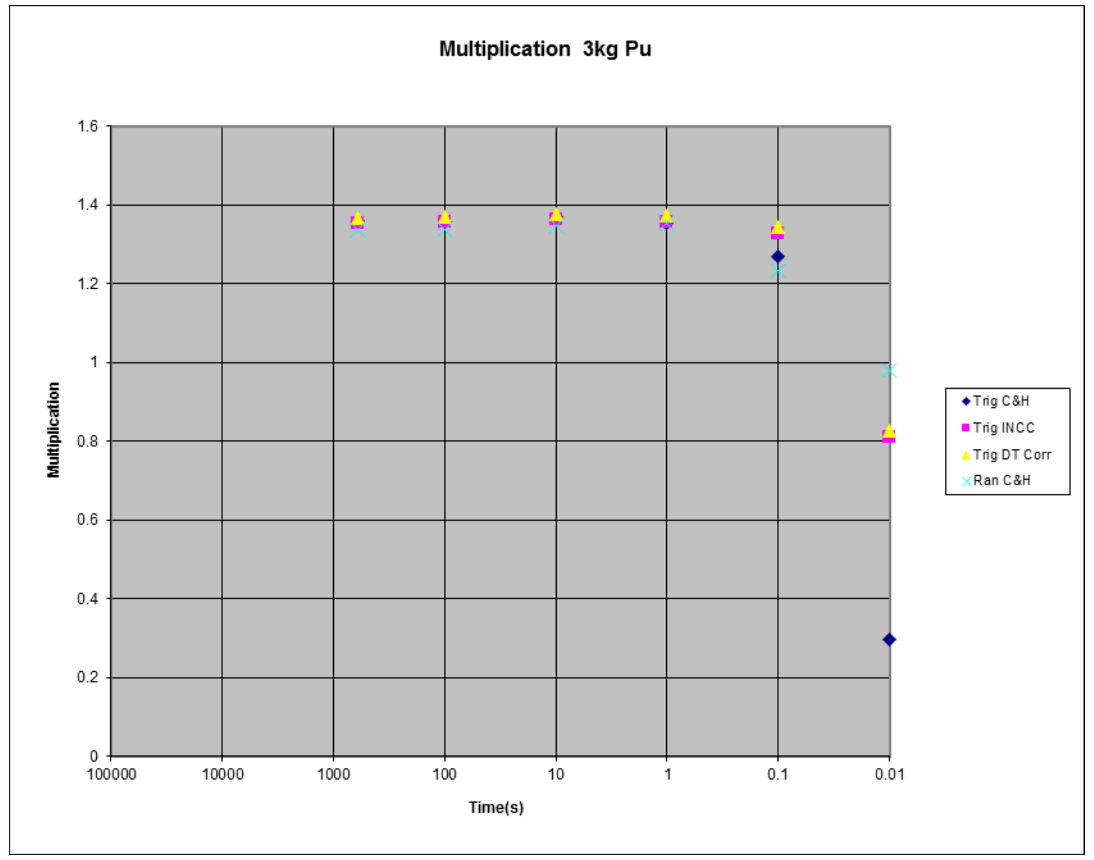
LEMC Trial (LLNL supporting)

- High Efficiency data gathered for a range of materials
- Gathered as
  - time Stamp List Mode (TSLM)
  - hardware specific triggered and generator triggered multiplicity histograms

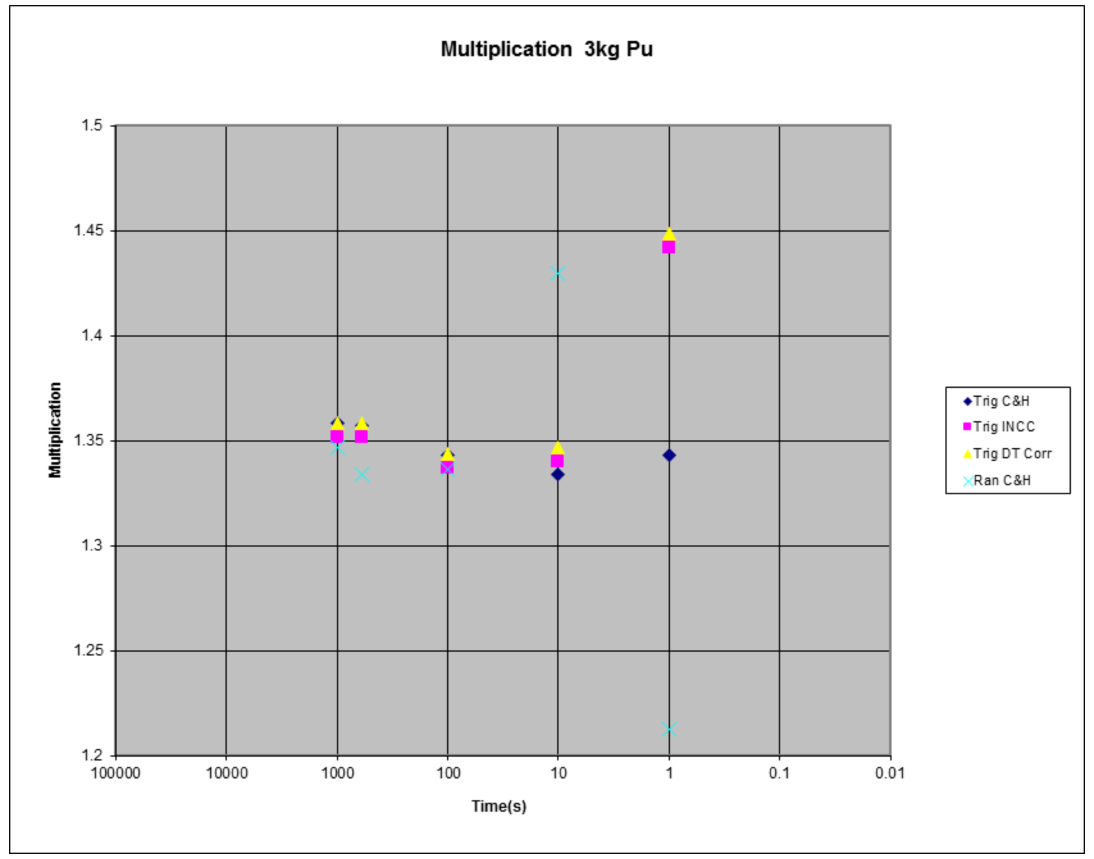
- Comparison between Triggered and Generator Triggered as a function of time at a range of different efficiencies from 50% downwards
  - Done by randomly sampling the TSLM data
  - Is one approach better for certain material/shielding options?

LEMC Trial (LLNL supporting)

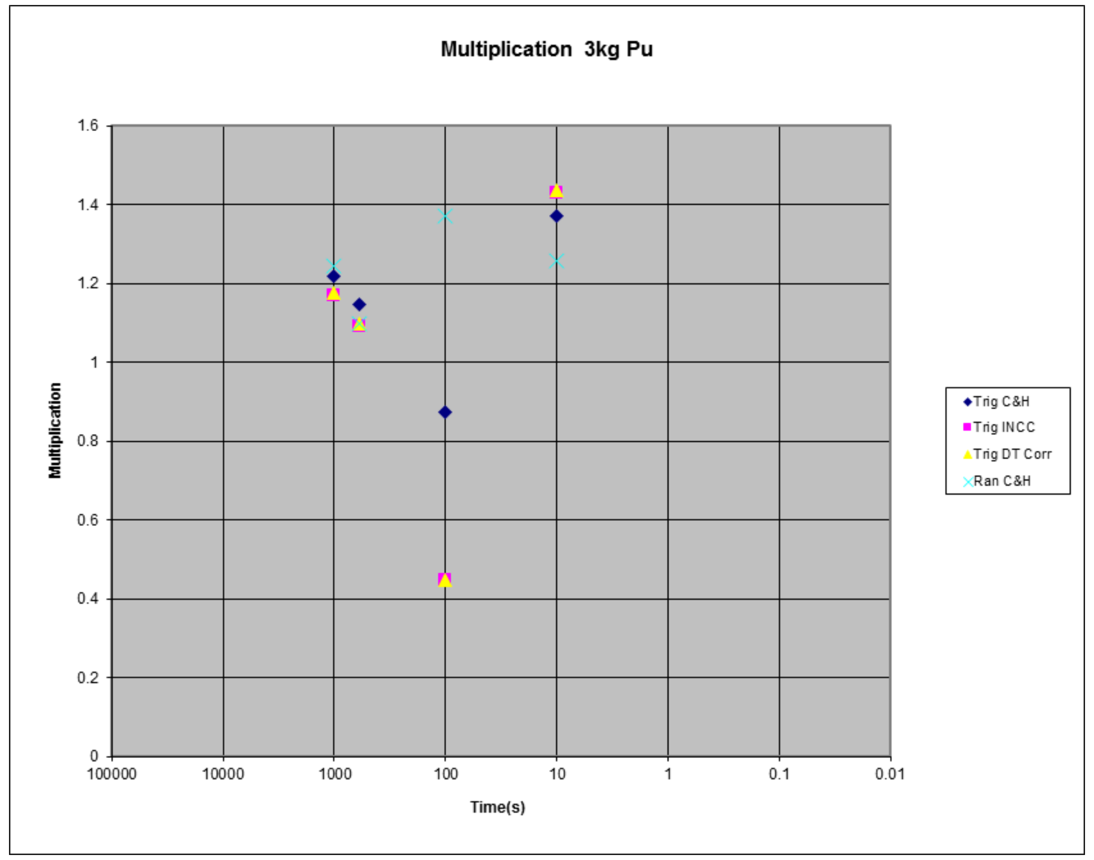
- Data still being analysed but initial results look promising



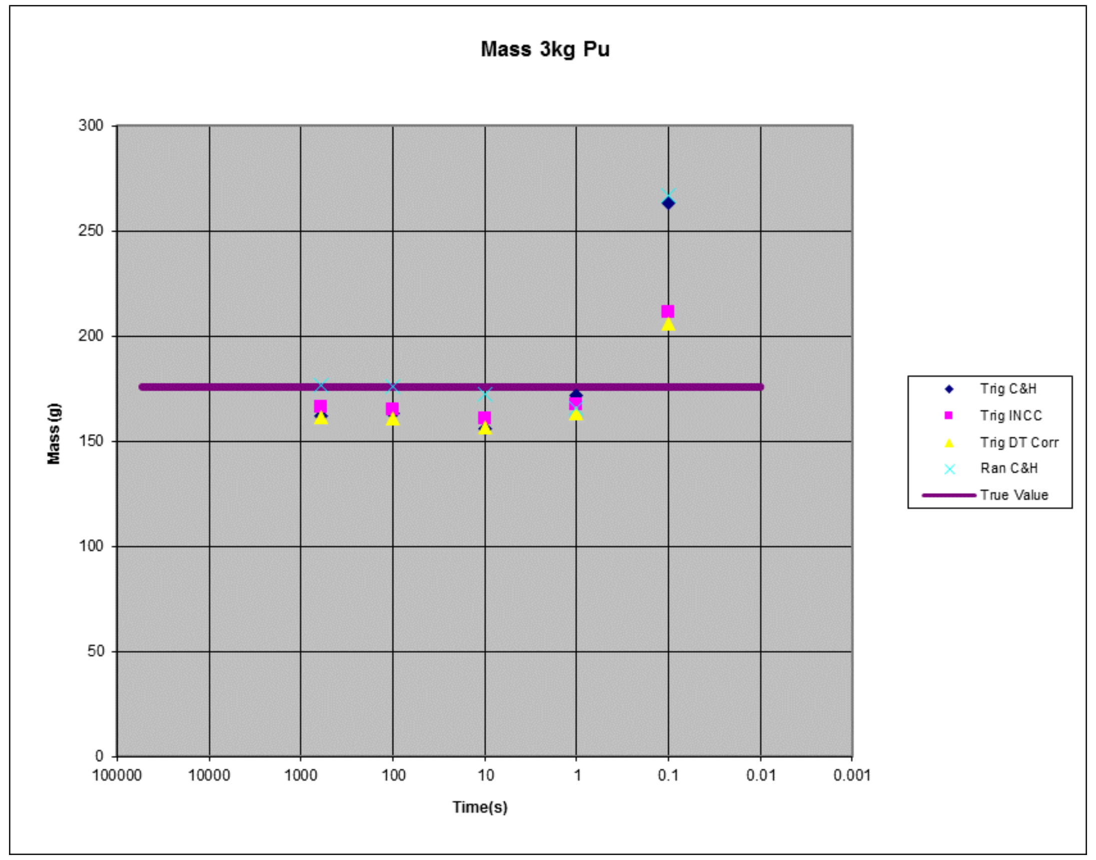
50% efficient

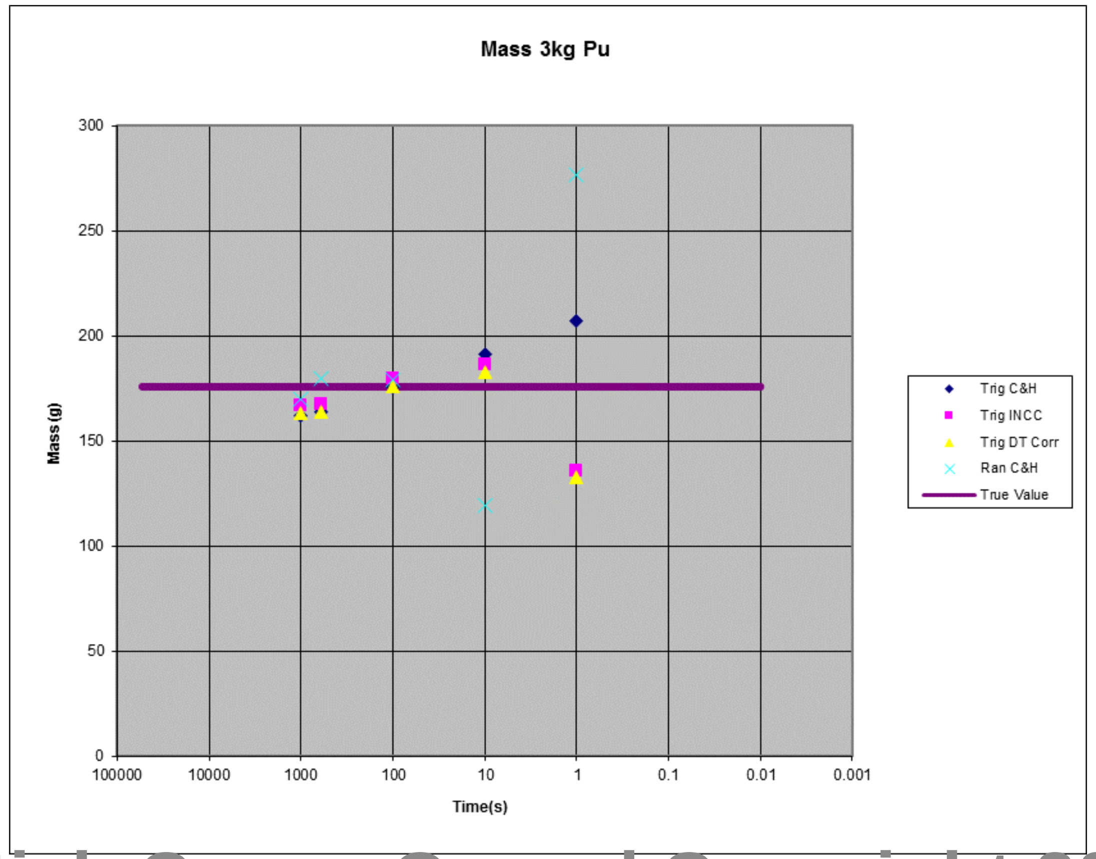


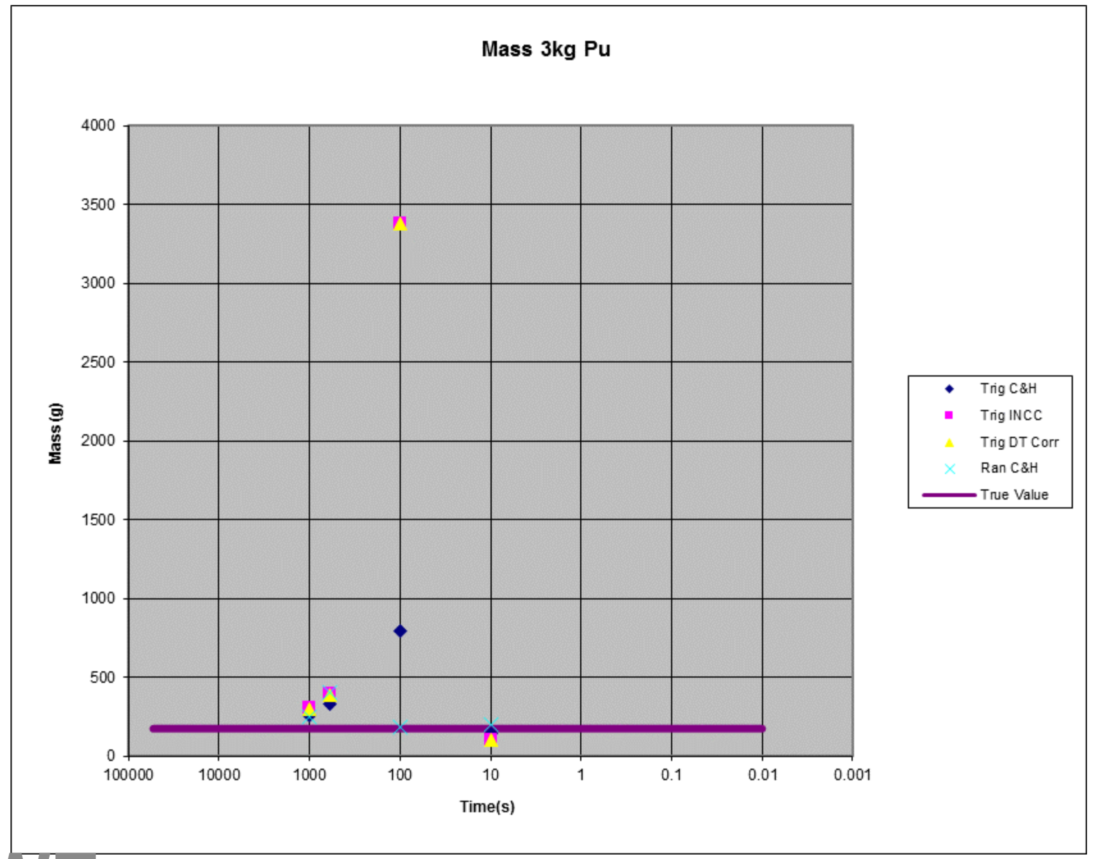
10% efficient



1% efficient

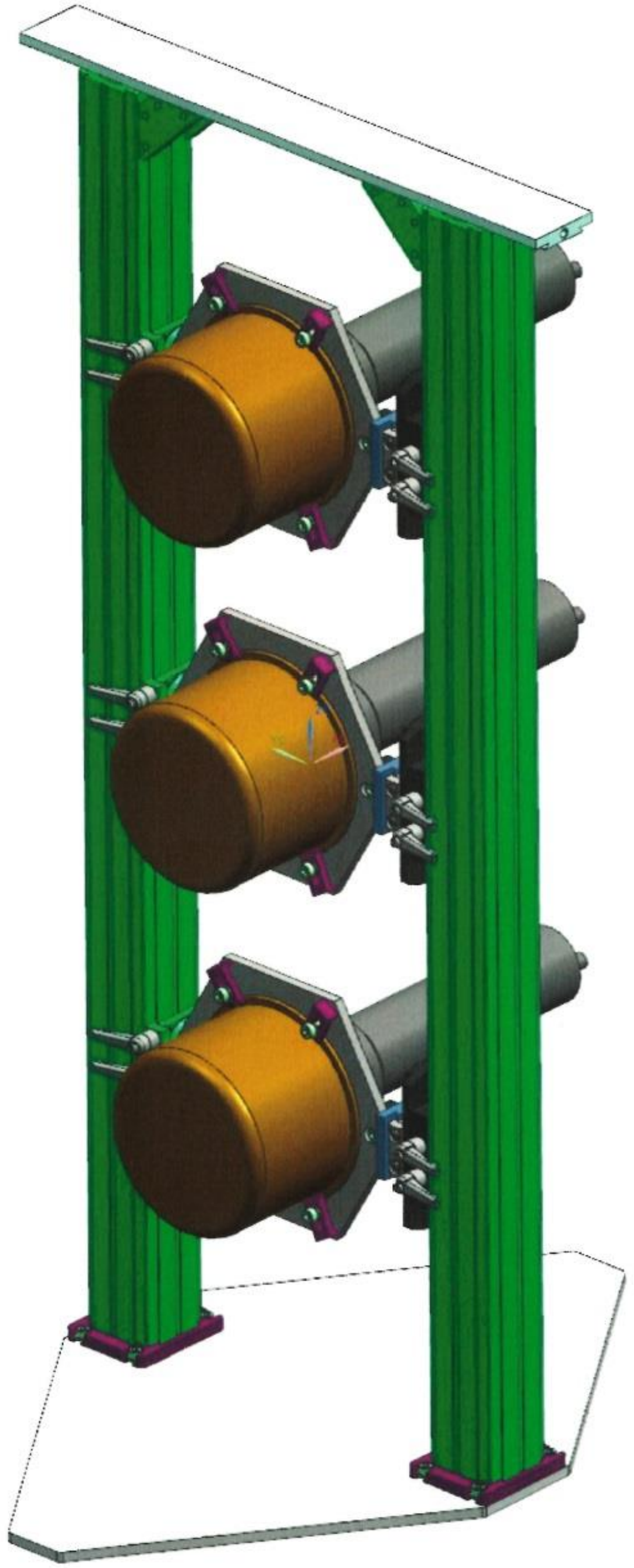




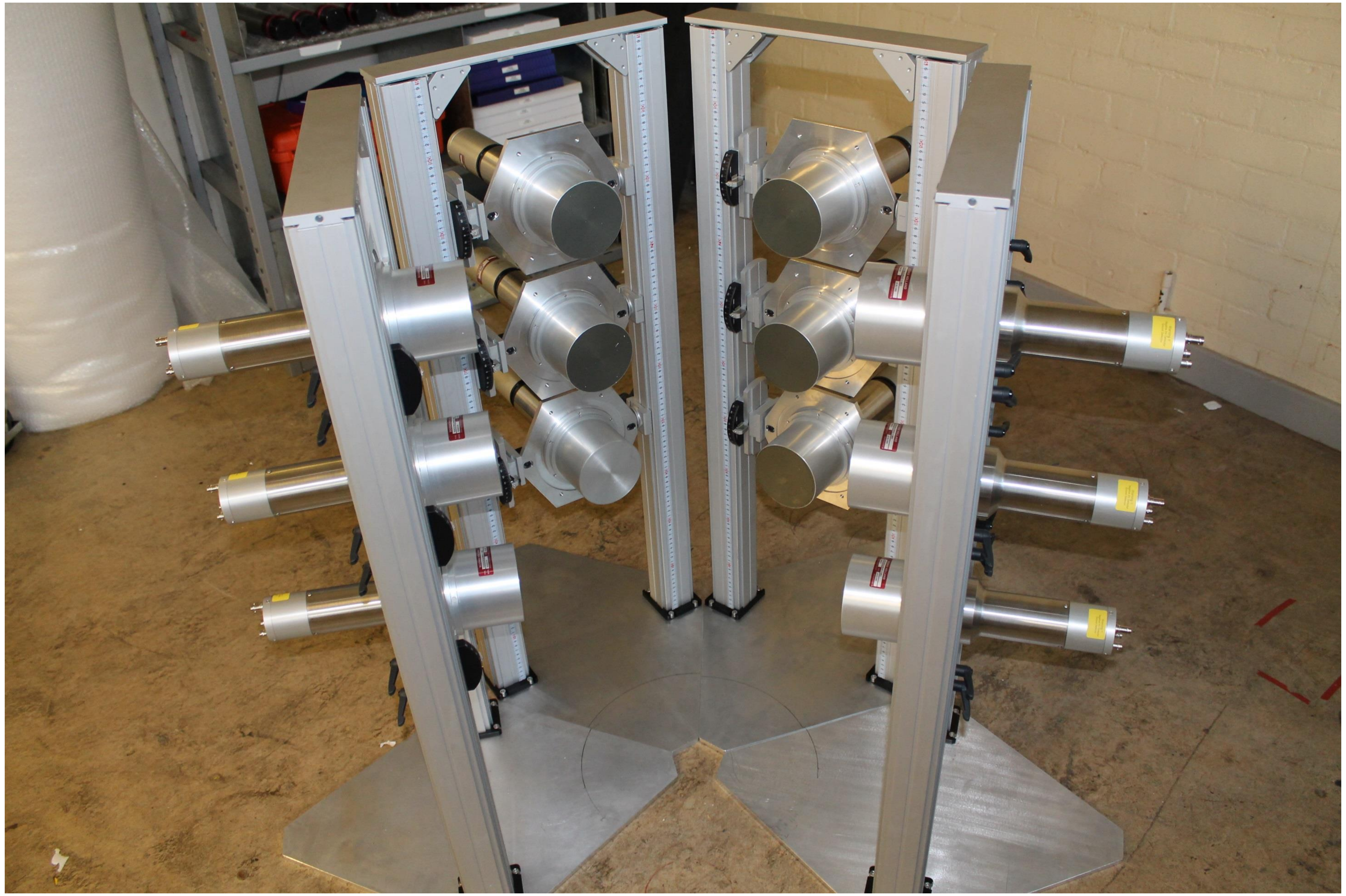


Fast Neutron Detection (LLNL Supporting)

- Liquid Scintillator study using EJ309
  - Potentially assay reduction times of 10 to 20
  - Issues- more complicated, fragile but has the potential to vastly outweighs the issues
  - Imaging capability in the future and/or be integrated with an active system
  - XIA LLC, Hayward PXI electronics

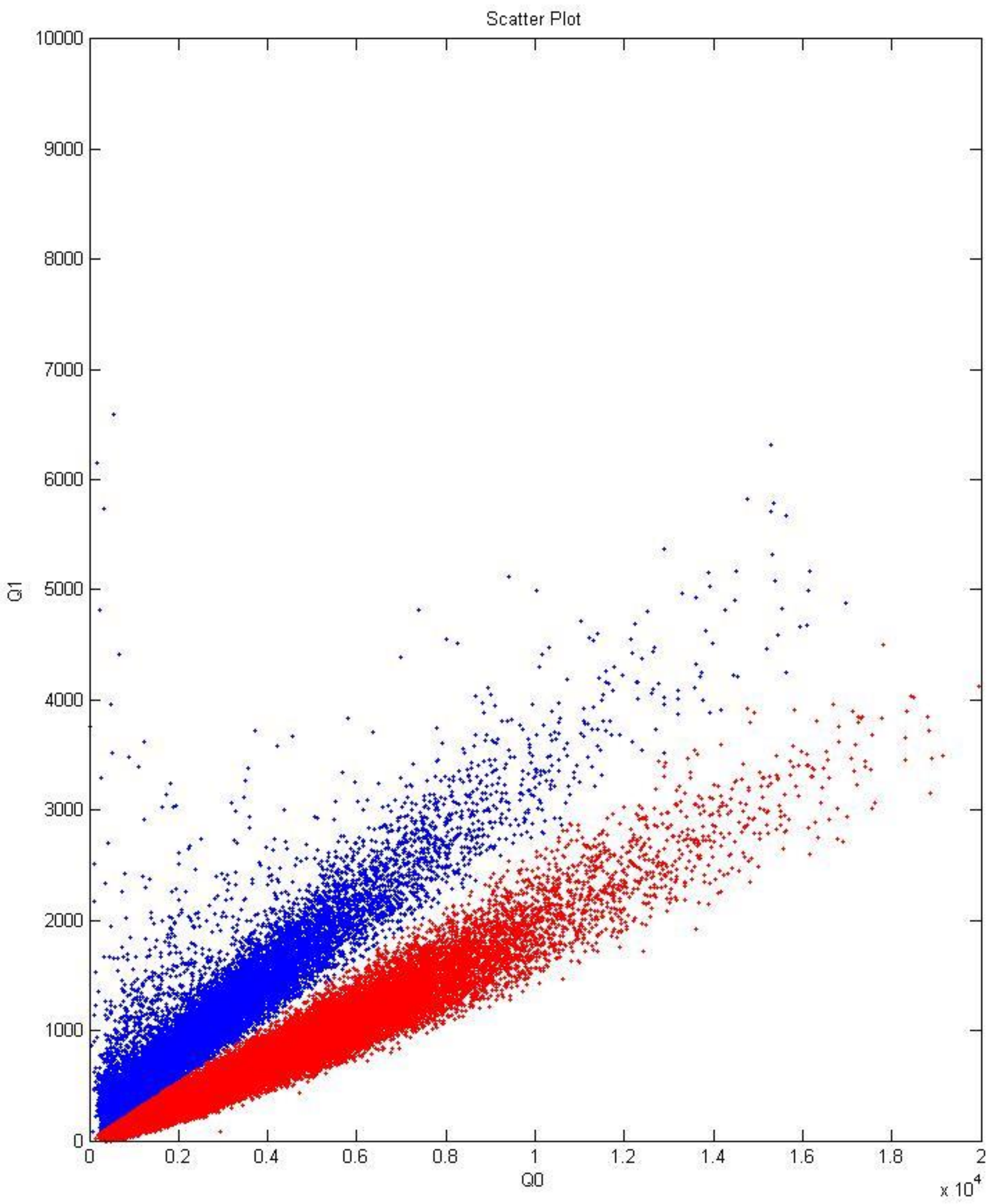


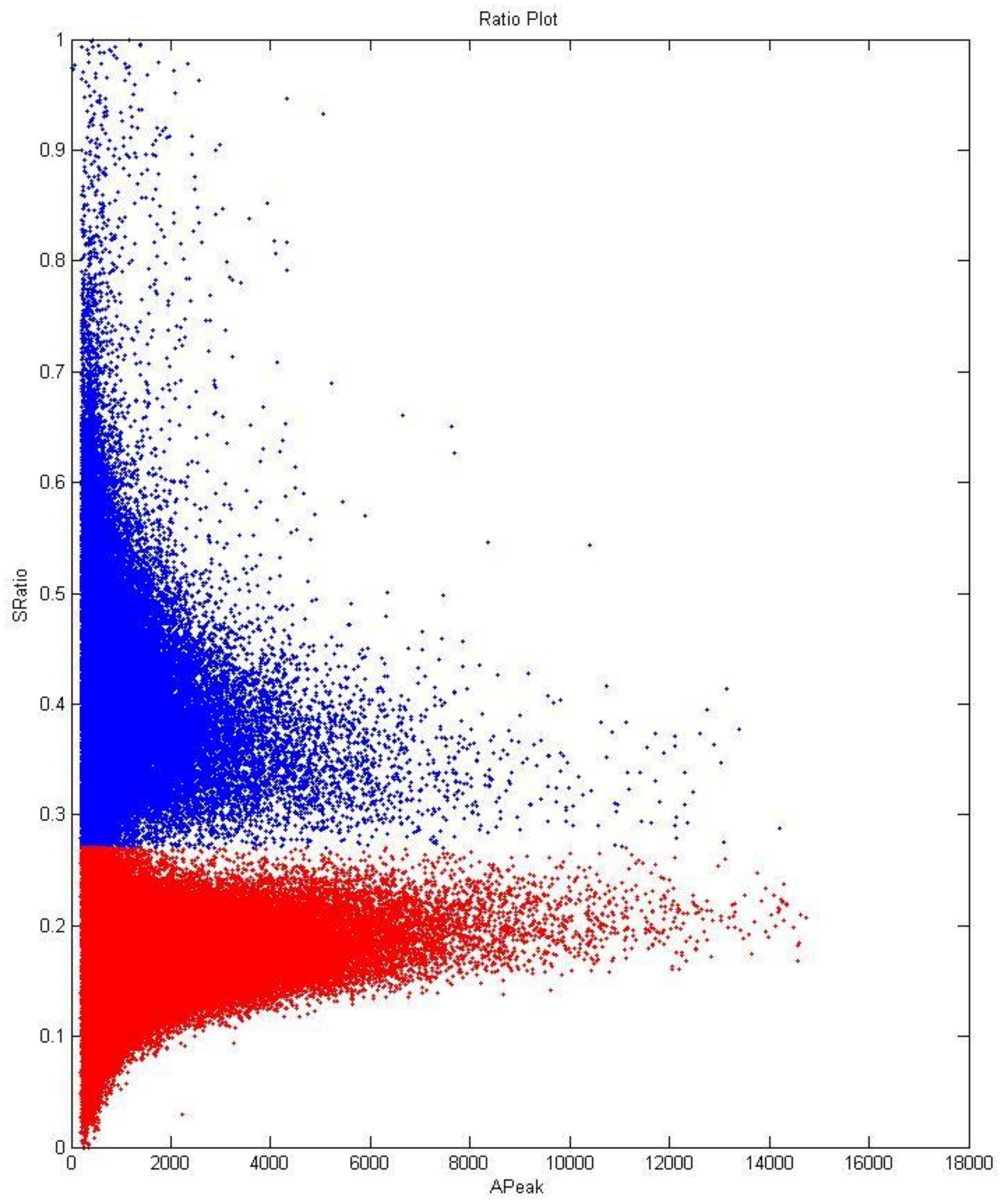
System



Fast Neutron Detection (LLNL Supporting)

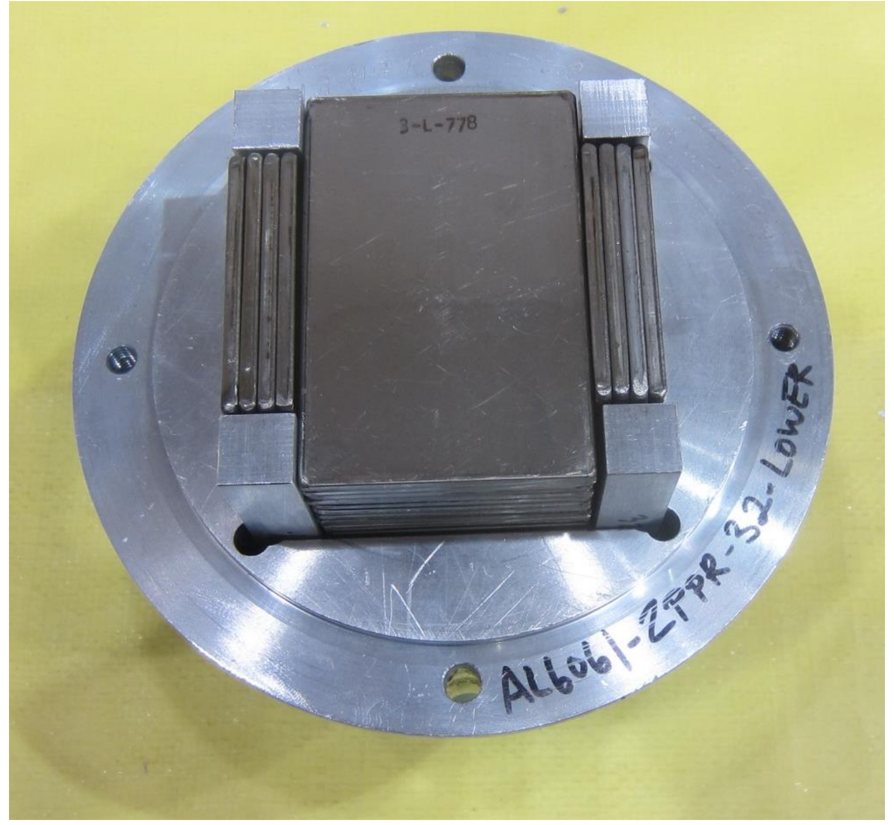
- Data acquired with 60s Cf-252 run
- Run conducted with “well” counter geometry
- Separation between neutrons and gammas observed

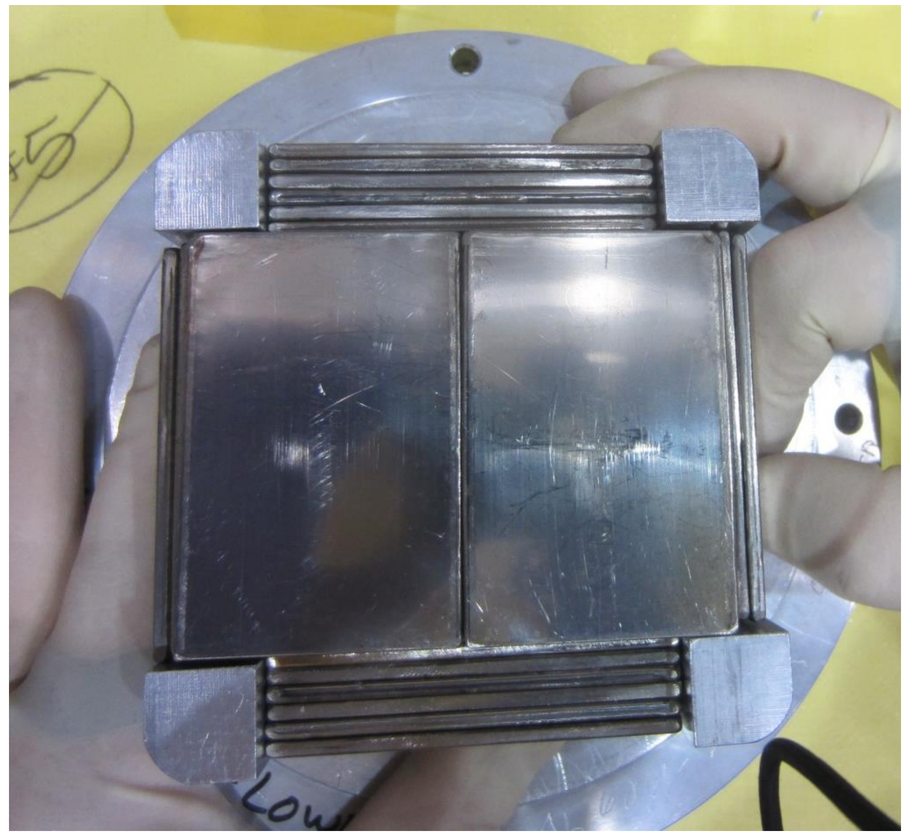




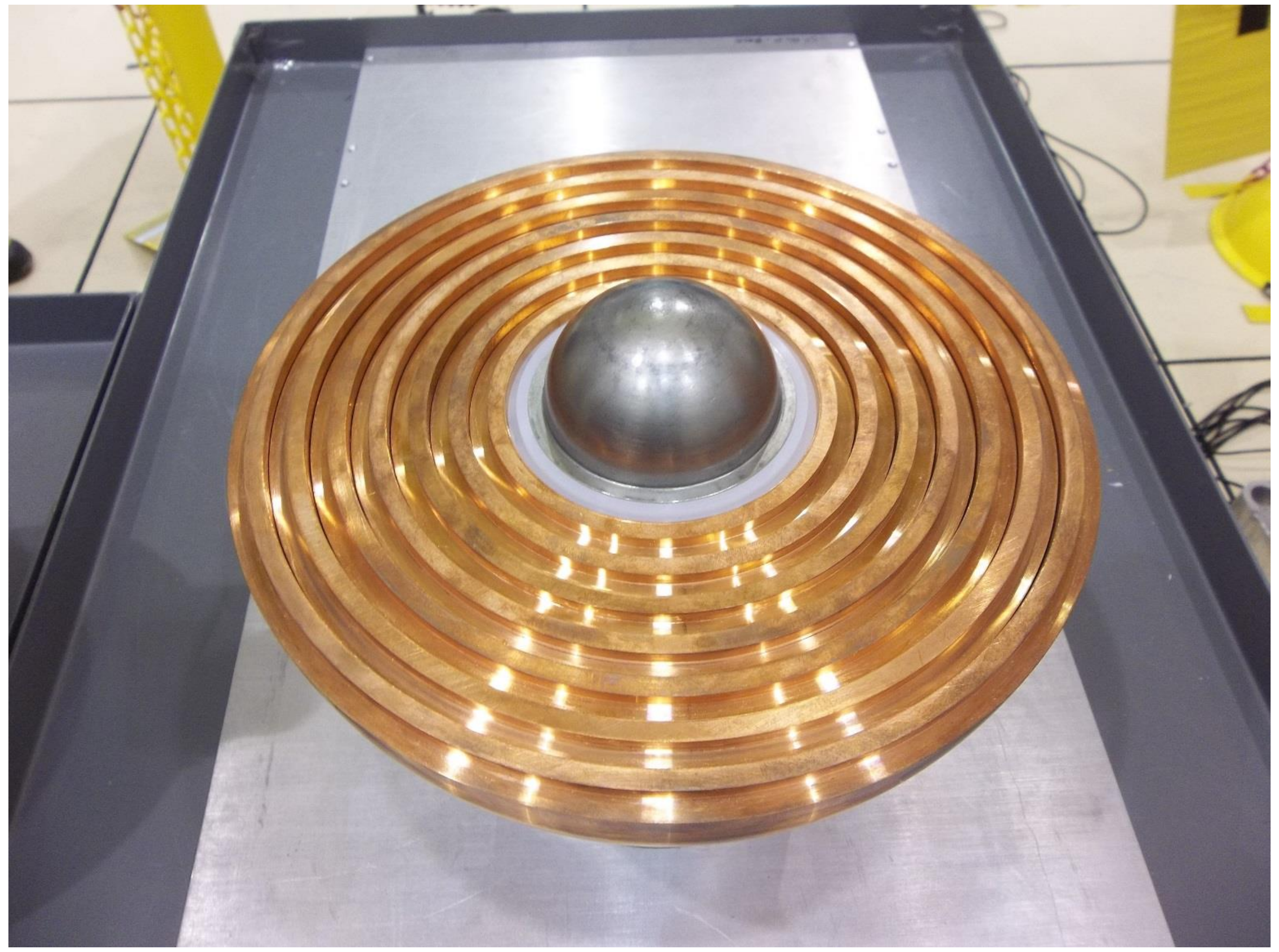
Pu ZPPR Plate Trials (LLNL Supporting)

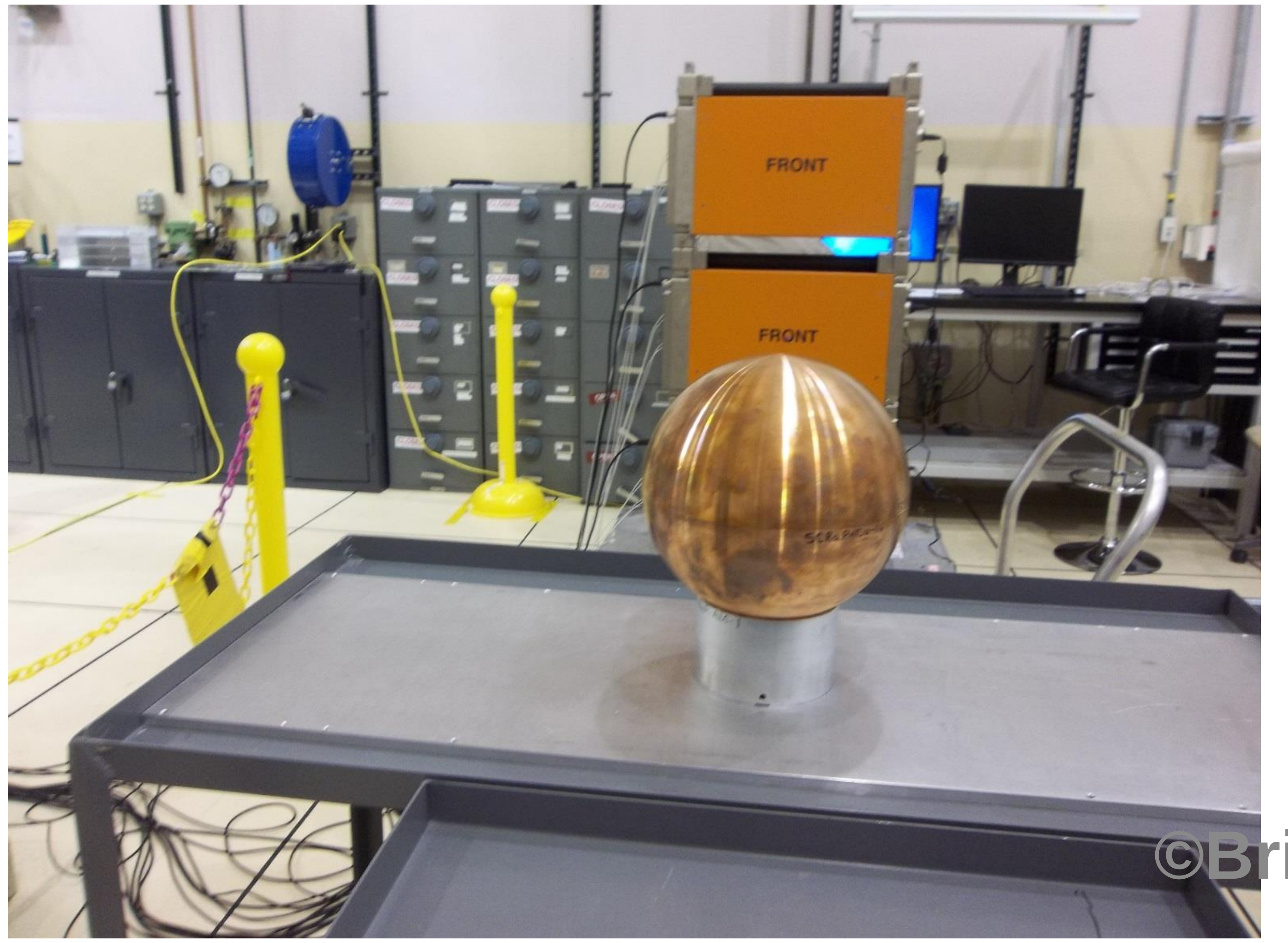
- Zppr Plates
  - 4.7% ^{240}Pu with ~1% Aluminium
  - 105g per plate
  - Maximum mass over 10kg
- What did we use this for
  - Use the high efficiency neutron counter
  - Point model analysis
    - how does this work for non point systems
    - Analysis methodology applied to TSLM (variety of analysis systems)
  - Trialling operational equipment





High Multiplication Trial (LANL Supporting)





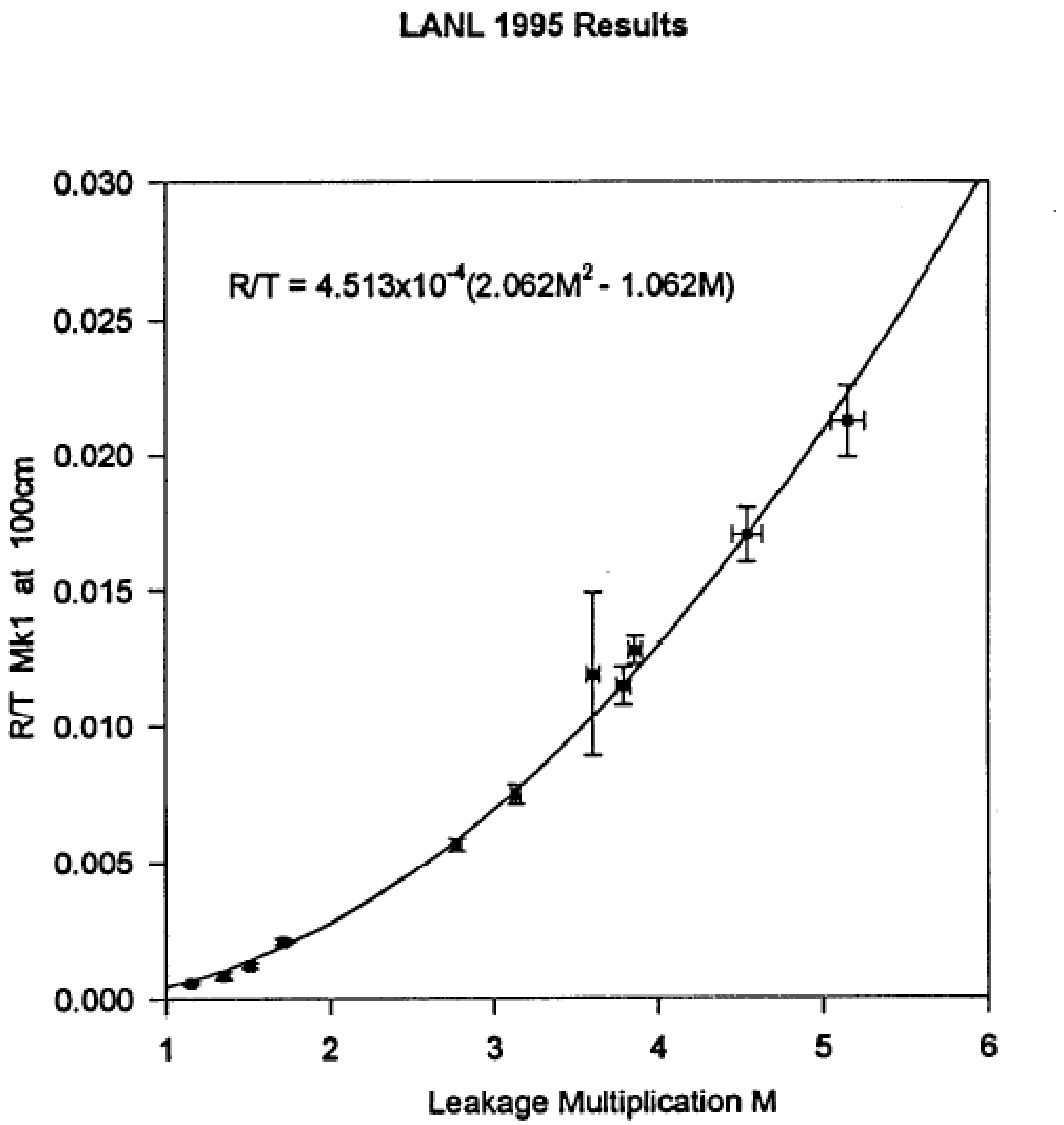
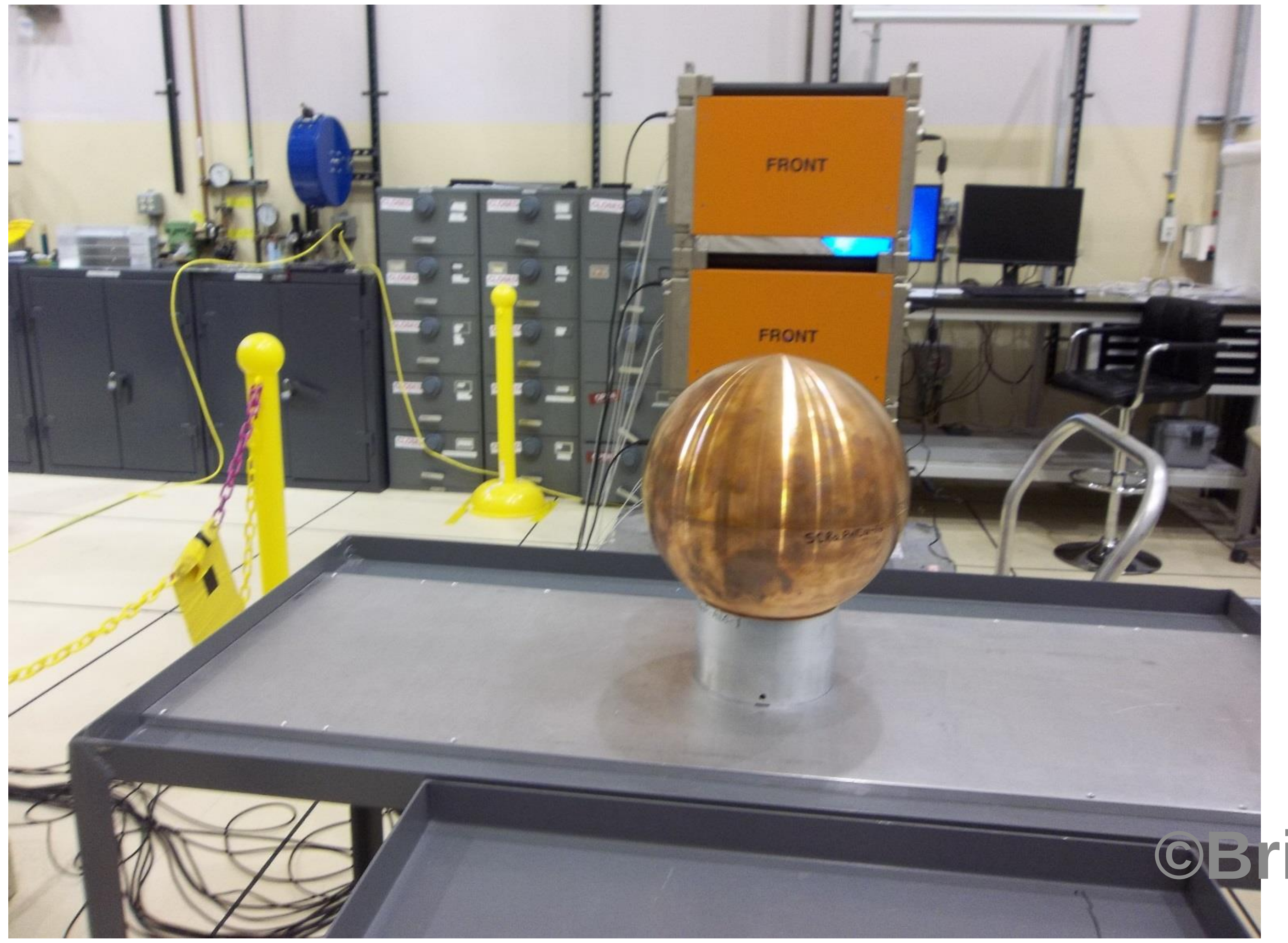
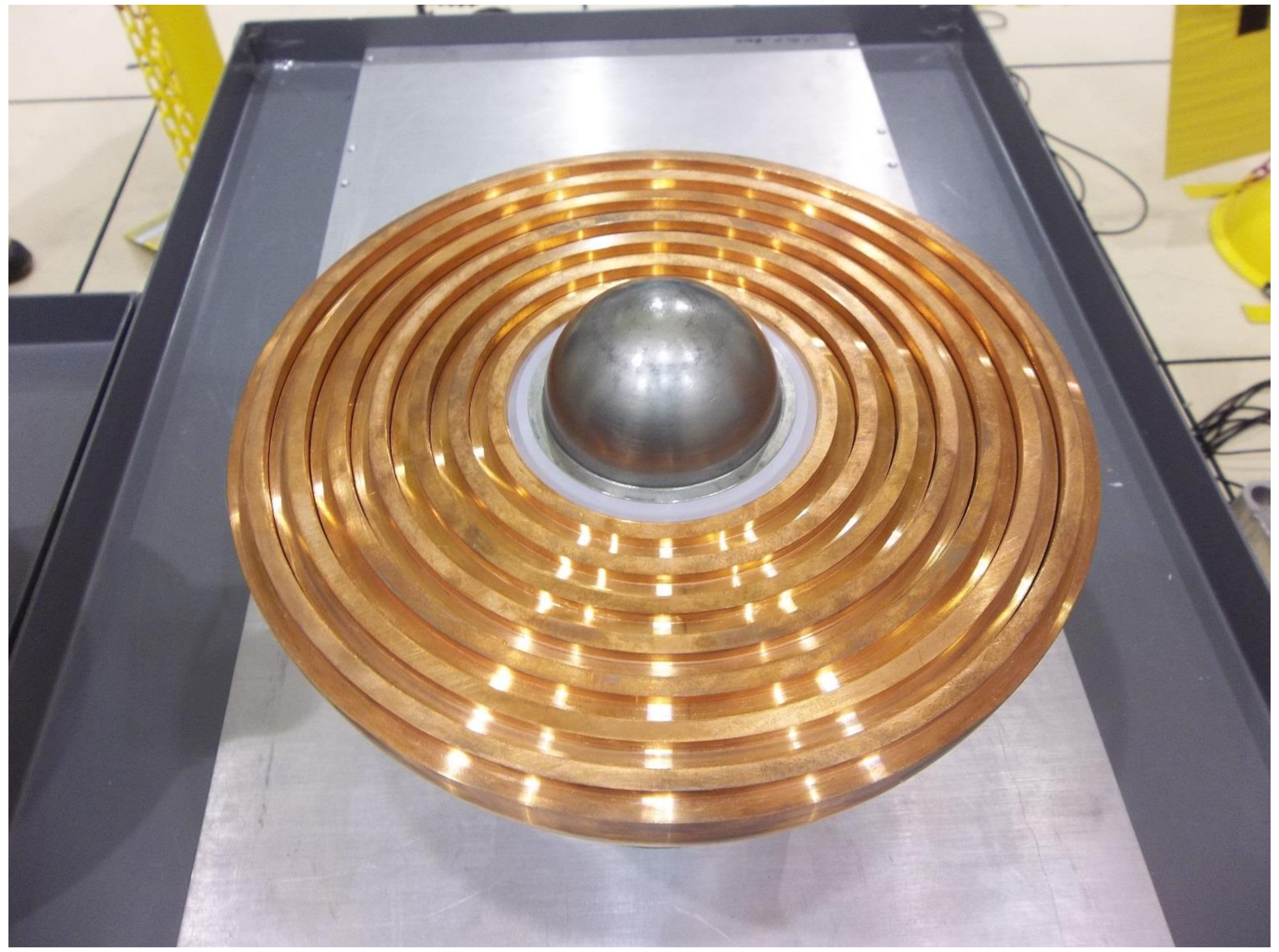
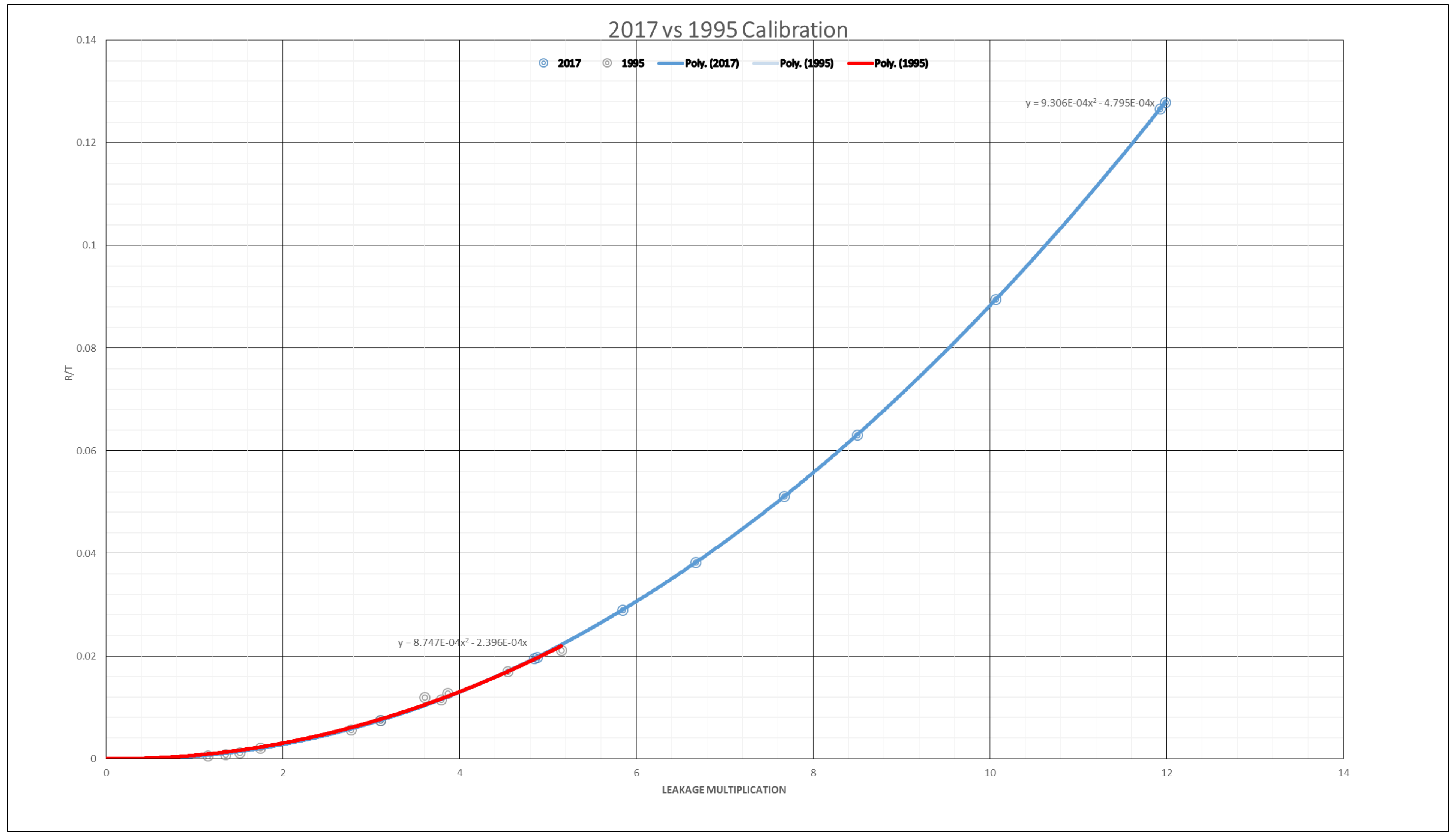


Figure 1. Graph showing the analyser response (R/T) for the Mk1 detector at 100cm from the centre of the sample, corrected for scatter, transmission and decay time, as a function of the calculated multiplication of the Pu metal samples. The R/T values are from table 8 and the M values are the calculated values from table 1.

High Multiplication Trial (LANL Supporting)







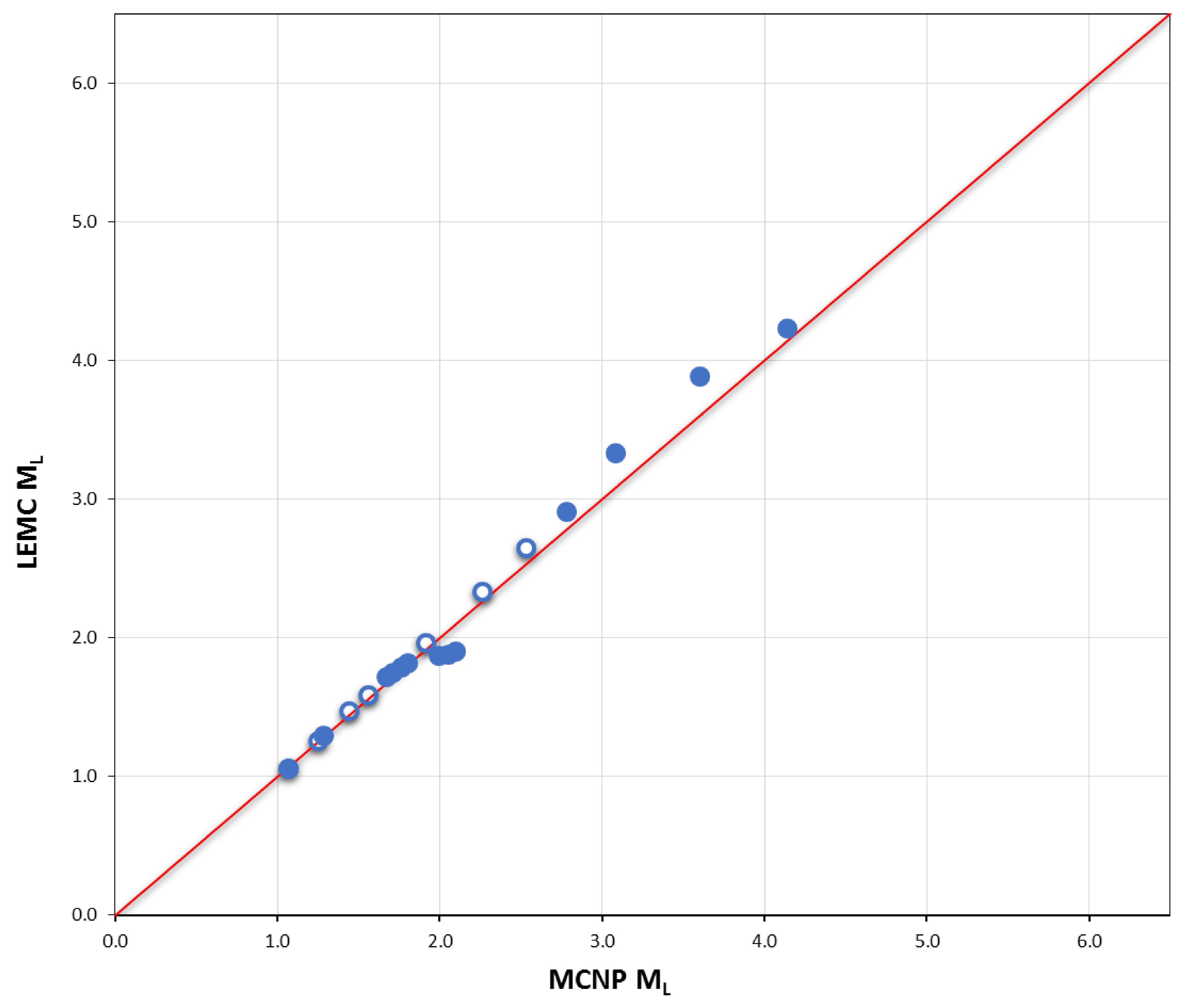
Configuration	Leakage Multiplication	Mass (g)	Mass/272.6
Bare	3.264	286.7	1.052
1” Cu	5.199	290.6	1.066
1” Cu + 2” Poly	7.430	303.5	1.114
4” Cu	10.94	296.3	1.087
1” Poly + 2.5” Cu	14.13	321.5	1.179
0.5” Poly + 3.5” Cu	13.30	303.9	1.115
2” Poly	9.288	330.2	1.211
3” poly	9.252	296.9	1.089
1” poly	5.270	296.7	1.088

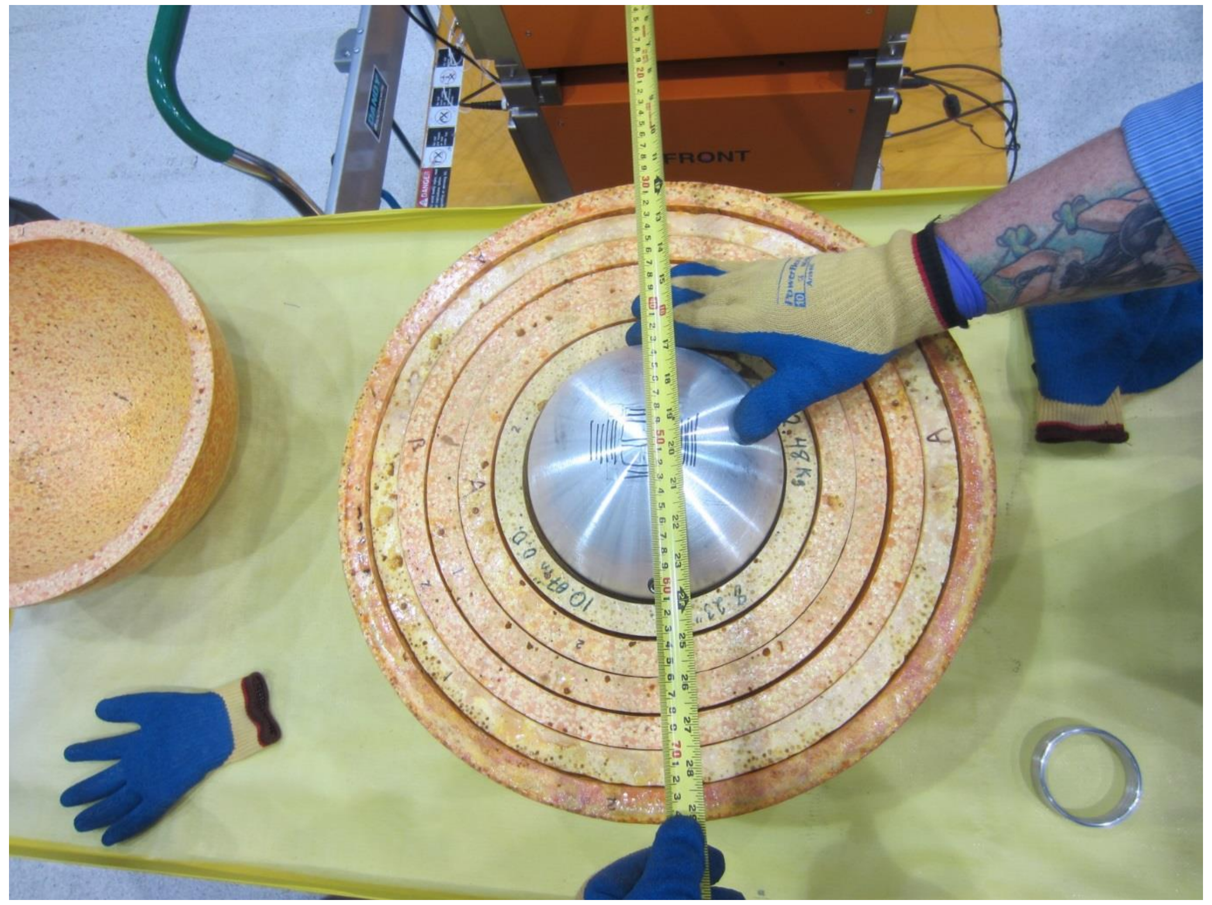
Equipment Validation

Geometries used during experimental campaigns.

- 1x ZPPR plate
- 8x ZPPR plates
- 32x ZPPR plates
  - Bare
  - Inside 0.5”, 1.5” & 2.5” stainless steel
  - Inside 1.725” Poly
  - Inside 1.725” Poly plus 0.5” and 1.5” Stainless Steel
- 104x ZPPR plates
  - Bare
  - Inside 1”, 2” & 3” Moderator
  - Inside 4”, 5” & 6” Moderator (not measured by LEMC)
- Further Measurements taken in Feb ‘17
  - 1x, 16x, 24x, 48x, 72x and 88x ZPPR plates (all bare in LEMC only)

M_L Comparison from LEMC and MCNP





LEMC Calculated Masses (ZPPR plates)

# Plates	Eff	Alpha	M_L	Pu240 Mass (g)	Actual Mass (g)	% Diff
1x	0.5015	1.0020	1.0600	4.825	4.724	2.14
8x	0.5189	1.0344	1.2975	35.687	37.792	-5.57
16x	0.5124	1.1490	1.4839	68.391	75.584	-9.52
24x	0.5124	1.2320	1.6090	96.774	113.376	-14.64
32x	0.5141	1.3867	1.7223	119.705	151.168	-20.81
48x	0.5141	1.3870	1.9890	182.693	226.752	-19.43
72x	0.5141	1.1850	2.3800	224.059	340.128	-34.13
88x	0.5141	1.5450	2.6930	259.035	415.712	-37.69
104x	0.5124	0.9897	2.9282	460.618	491.296	-6.24

LEMC Calculated Masses (Shielded ZPPR)

Geom	Eff	Alpha	M_L	Pu240 Mass (g)	Actual Mass (g)	% Diff
32x & 0.5" Steel	0.5253	1.3277	1.7539	122.378	151.168	-19.05
32x & 1.5" Steel	0.5417	1.2791	1.7917	124.182	151.168	-17.85
32x & 2.5" Steel	0.5555	1.2613	1.8182	124.699	151.168	-17.51
32x & Poly	0.3488	0.4687	1.8212	224.520	151.168	48.52
32x & Poly & 0.5" Steel	0.3133	0.3815	1.8214	243.457	151.168	61.05
32x & Poly & 1.5" Steel	0.2794	0.3261	1.8360	257.807	151.168	70.54
104x 1" Moderator	0.5040	1.0020*	3.3043	479.296	491.296	-2.44
104x 2" Moderator	0.4367	1.0020*	3.3805	531.359	491.296	8.15
104x 3" Moderator	0.3404	1.0020*	3.6642	578.080	491.296	17.66

Future Plans

- 2 Major campaigns a year with 1 additional Fast Neutron Development campaign per year
- Extension to other materials of interest
- UK to supply additional shielding and or moderating materials
- Make UK Material available to the US on Loan
  - Metal Reactor fuel (as Pu sealed sources, lightly shielded Pu plates, and lacquered HEU plates)
  - a 24% Pu240Ce spherical heat source and a 65 year old Pu Sphere

Expression of Gratitude

- It is impossible to express how greatly the UK team were supported by their US colleagues and it is perhaps invidious to pick out particular people to thank.
- However there a number who stand out as providing exceptional support
- Jesson Hutchinson at LANL
- Dave Heinrich, Kathrine Percher, John Scorby, all at LLNL
- But most of all Doug McAvoy and Becka Hudson, LLNL, without whom none of this would ever have happened