NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

Integral Experiments Accomplishments
IER-252 Flattop Field Measurement and Upcoming NAD Exercise (IER-253)

Presented at the NCSP Technical Seminar at LLNL on March 28-29, 2018

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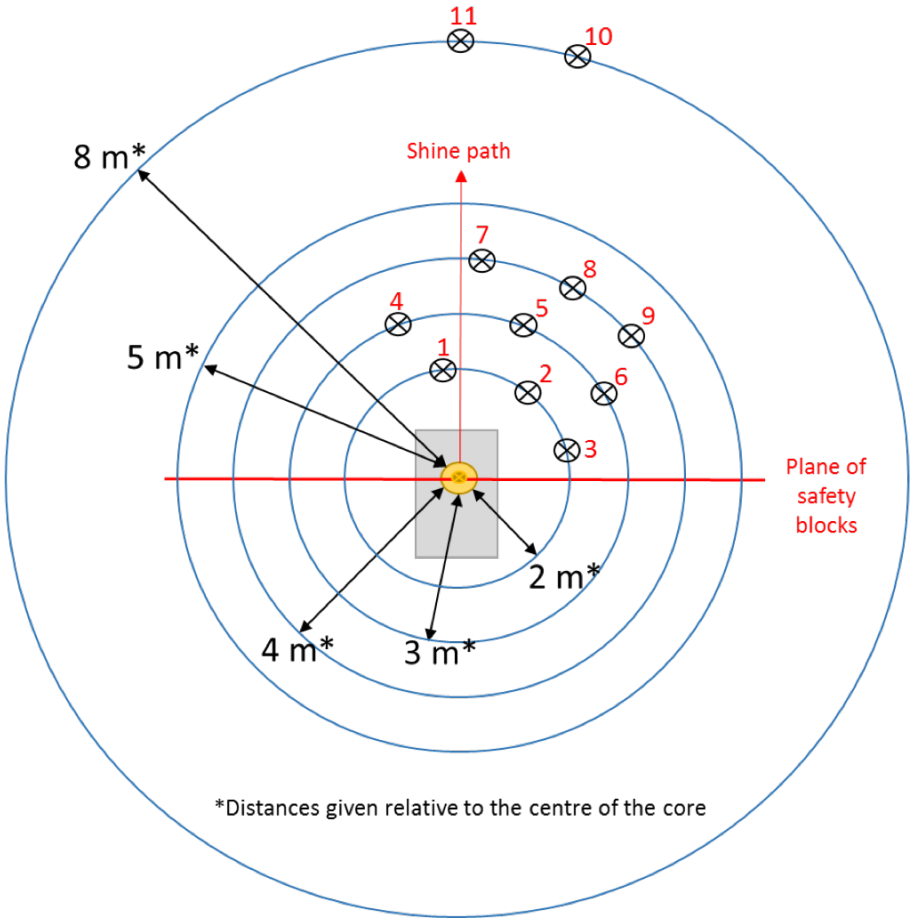
Collaborators

- **Atomic Weapons Establishment (Philip Angus, Leo Clark, Mark Jackson, Phill Scivier, Verity Woodhead, Chris Wilson)**
  - Passive Bonner Sphere Spectrometer measurements(PBSS)
  - AWE NAD Lockett measurements
- **Lawrence Livermore National Laboratory (Dave Heinrichs, David Hickman, Becka Hudson, Todd Matz, Paul Yap-chiongco, Soon Kim, Gary Slavik, Donny Kavanagh, Brian Musick, Scott Richardson, John Scorby, Radoslav Radev, Karen Jeffers, Lydia Tai, Will Zywiec)**
  - LLNL NAD measurements
  - Gamma dose measurements
  - Work controls
  - Escort
  - Assistance to all other participants
- **Sandia National Laboratory (Elliot Leonard, Dan Ward)**
- **Los Alamos National Laboratory (David Hayes, Tim Beller, & Crew)**
  - Flattop Operations
  - Retrieval of materials
- **NSTEC**
  - Contamination control and personnel dose monitoring
  - Assistance with retrieval of materials from Flattop
  - Gamma dose rate measurements
  - Material Transportation & Shipping

Ambitious & Successful 2 Week Campaign

to evaluate and characterize the Flattop spectral fluence and dosimetry to be used for past, current, and future research and intercomparison efforts



May 15 – 19, 2017 - Low dose active measurements

May 22 – 26, 2017- High dose passive measurements

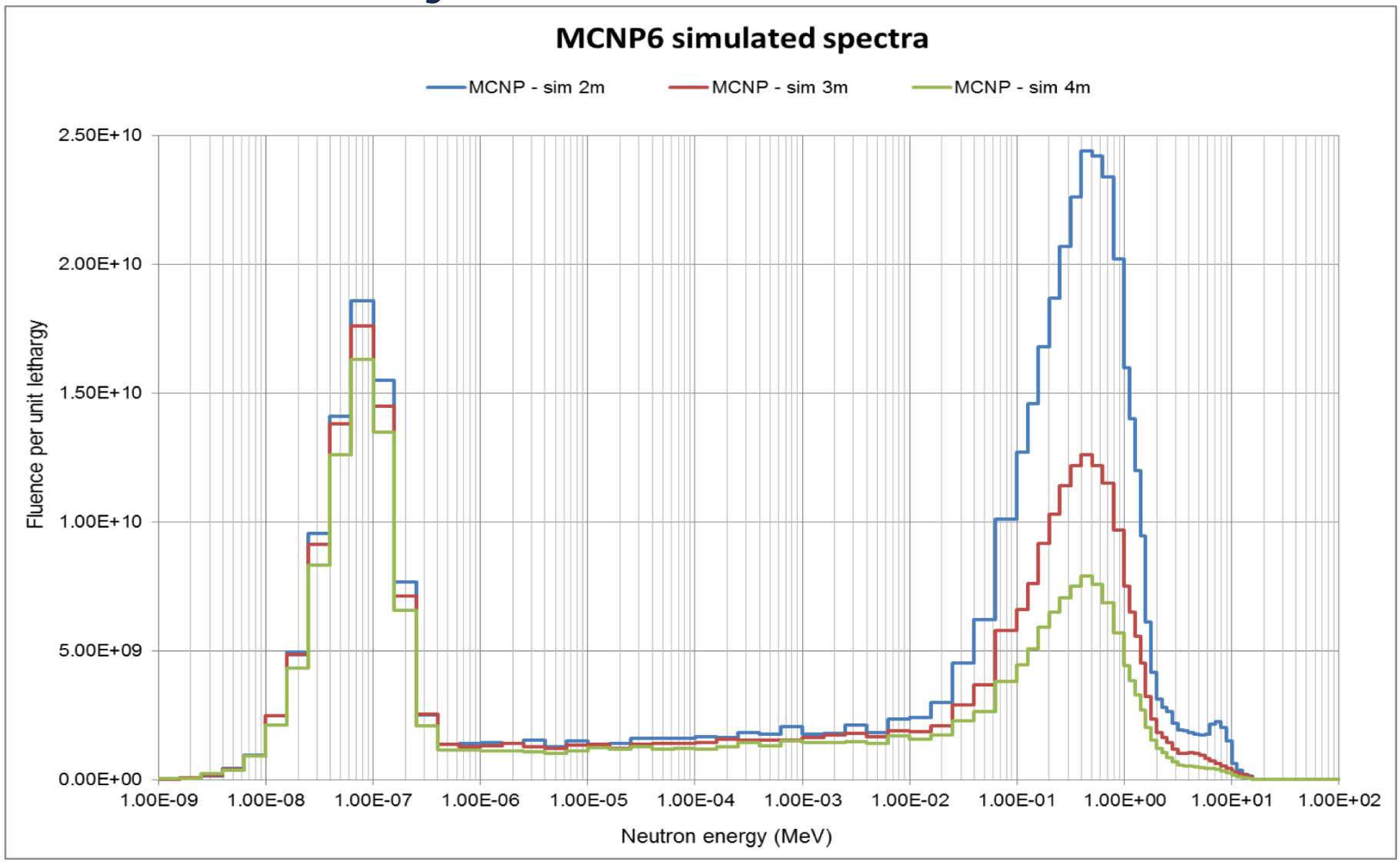
Summary of an Ambitious Measurement Plan

		Position											
Run		1	2	3	4	5	6	7	8	9	10	11	*
1		SSS	FNS		BGO 1				BGO 2	TEPC	R2	R1	
2				BGO 1	SSS	FNS					BGO 2 /TEPC		R1/R2
3			BGO 1					R2	SSS	R1	FNS	BGO 2	
4		R1	BGO1	R2		BGO 2		SSS	FNS				
5		R2	SSS	R1	BGO 1	FNS			BGO 2				
6			FNS		R1	BGO 1	R2		BGO 2			SSS	
7					SSS	BGO 1		R1	BGO 2	R2		FNS	
8-i						BGO 2			BGO 1	FNS	R1	R2	SSS
8-ii						BGO 2			BGO 1	FNS	R1	R2	SSS
8-iii						BGO 2			BGO 1	FNS	R1	R2	SSS
8-iv						BGO 2			BGO 1	FNS	R1	R2	SSS
8-v						BGO 2			BGO 1	FNS	R1	R2	SSS
8-vi						BGO 2			BGO 1	FNS	R1	R2	SSS
9		TREE	PNS		TREE	PNS		TREE	PNS		TREE	TREE	
11			TREE	PNS		TREE	PNS		TREE	PNS	TREE	TREE	
13		PNS	TREE		PNS	TREE		PNS	TREE		TREE	TREE	
14			PNS			PNS			PNS		PNS		
15		PNS	PNS	PNS								PNS	

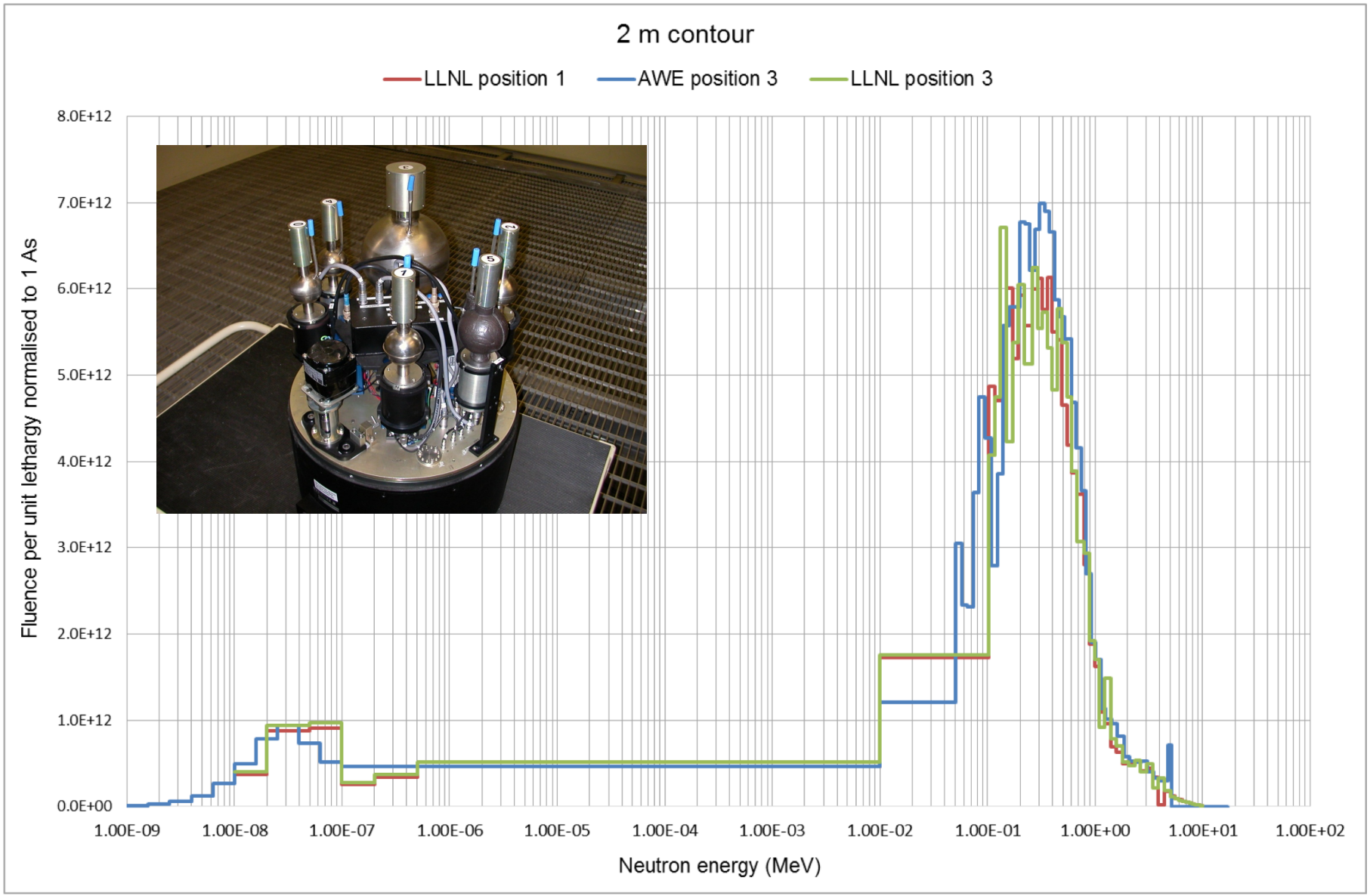
Data for each excursion of Flattop

	Run	Start	Stop	Duration		Integrated current	Current
LOW DOSE	#	time	time	hh:mm:ss	sec	As	A
	1	-	14:24:40	-	-	2.21E-08	4.80E-12*
	2	10:03:40	11:04:00	01:00:20	3.62E+03	1.79E-08	4.94E-12
	3	12:22:00	13:22:40	01:00:40	3.64E+03	1.77E-08	4.86E-12
	4	14:56:24	16:26:28	01:30:04	5.40E+03	2.72E-07	5.03E-11
	5	09:36:00	11:05:00	01:29:00	5.34E+03	2.99E-07	5.60E-11
	6	12:35:00	13:35:00	01:00:00	3.60E+03	4.14E-07	1.15E-10
	7	14:46:00	15:32:00	00:46:00	2.76E+03	5.36E-07	1.94E-10
	8i	09:09:20	-	00:21:35	1.30E+03	6.00E-09	4.63E-12
	8ii	09:30:55	-	00:18:38	1.12E+03	5.40E-08	4.83E-11
	8iii	09:49:33	-	00:11:47	7.07E+02	6.70E-08	9.48E-11
	8iv	10:01:20	-	00:12:15	7.35E+02	1.32E-07	1.80E-10
	8v	10:13:35	-	00:09:25	5.65E+02	3.97E-07	7.03E-10
	8vi	10:23:00	11:14:40	00:51:40	3.10E+03	3.50E-06	1.13E-09
HIGH DOSE	13	11:26:50	13:42:52	02:16:02	8.16E+03	2.90E-02	3.55E-06
	11	09:38:00	10:22:00	00:44:00	2.64E+03	2.00E-02	7.58E-06
	9	09:22:20	10:06:00	00:43:40	2.62E+03	2.05E-02	7.82E-06
	14	12:42:00	14:13:00	01:31:00	5.46E+03	2.89E-02	5.29E-06
	15	11:13:20	12:24:00	01:10:40	4.24E+03	2.90E-02	6.84E-06

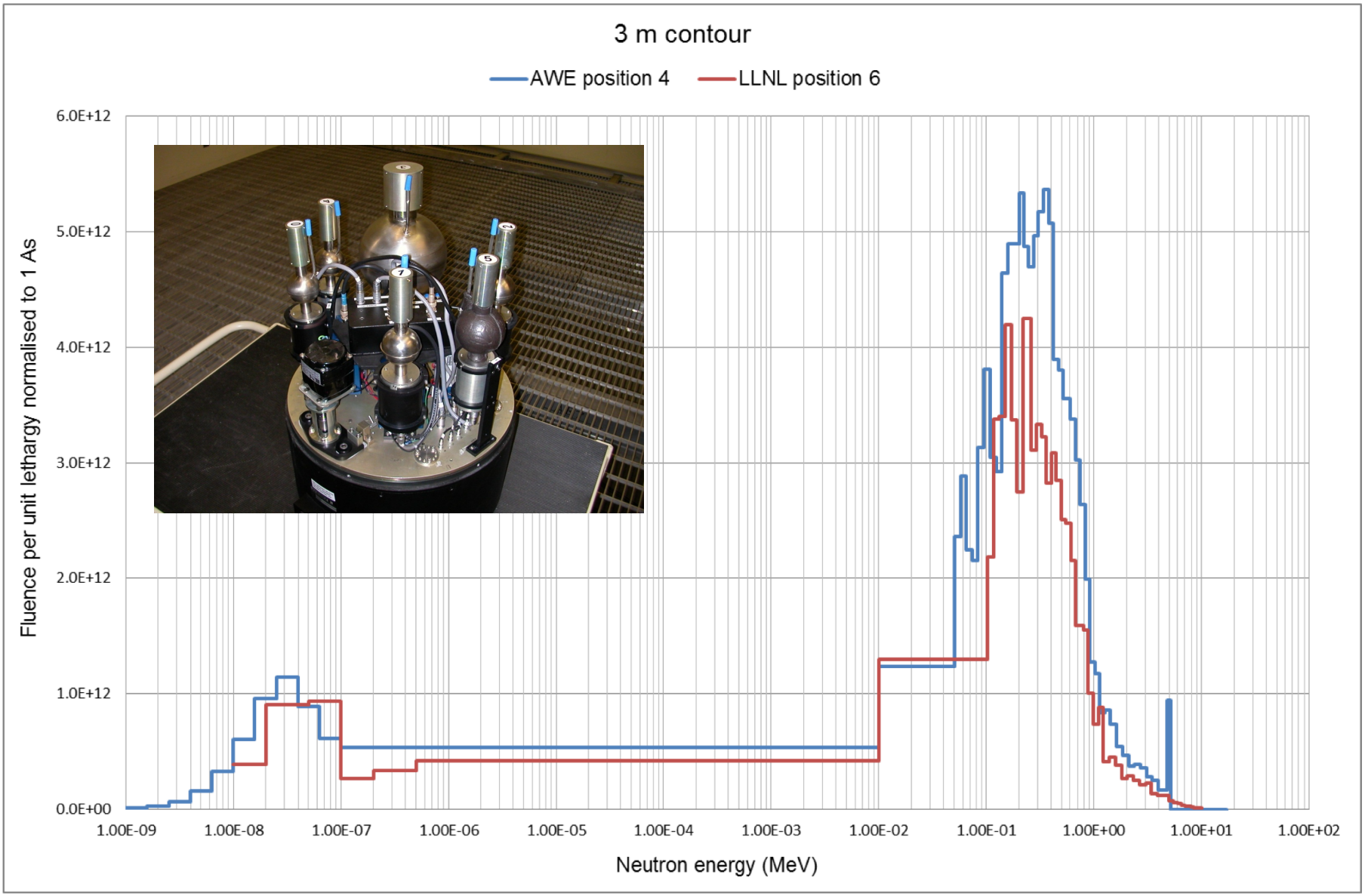
Calculated spectra at 2, 3, and 4 m from Flattop critical assembly



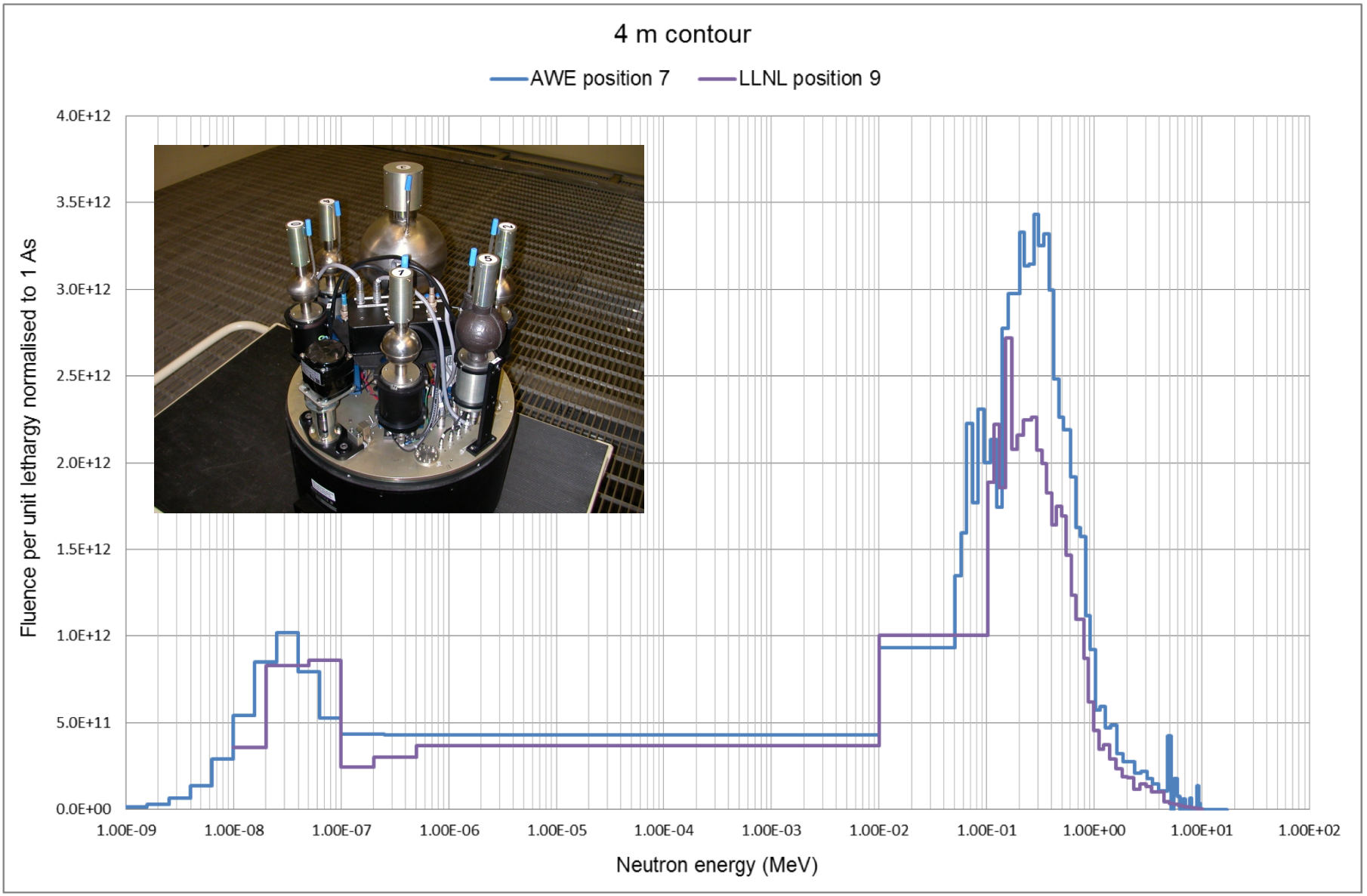
Measured 2-meter ROSPEC spectral contour



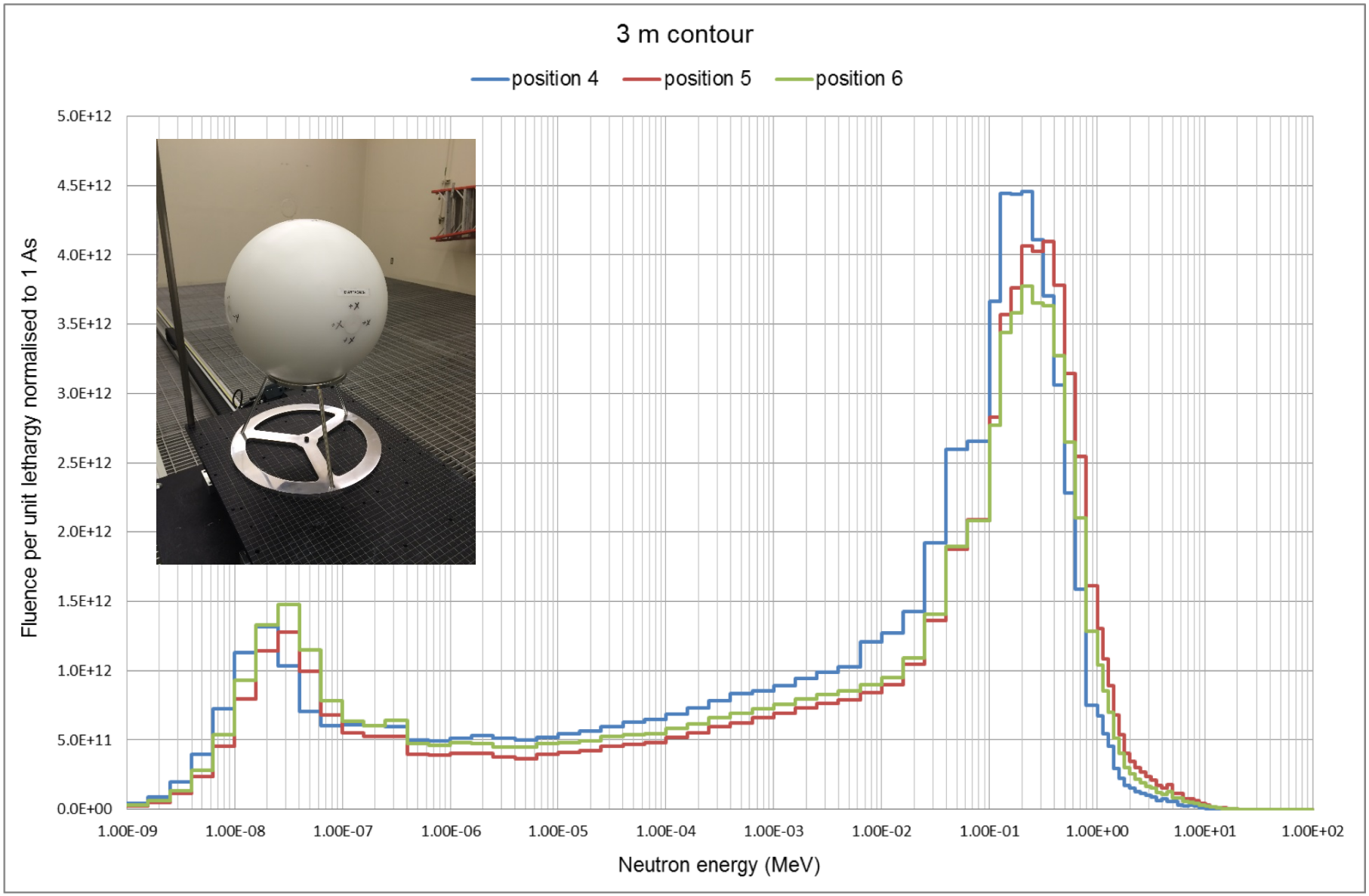
Measured 3-meter ROSPEC spectral contour



Measured 4-meter ROSPEC spectral contour



PNS Spectral data was similar but….



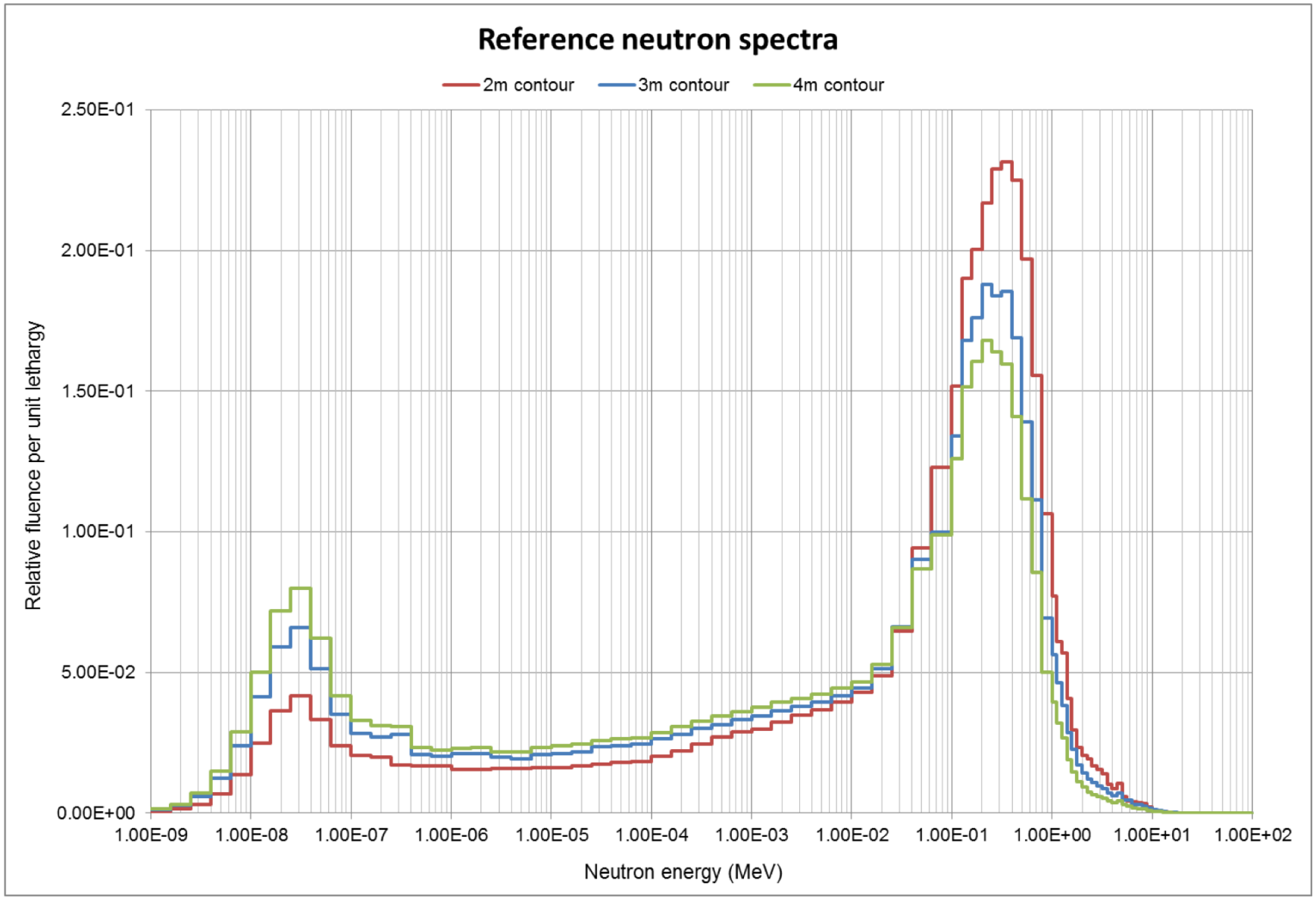
PNS Data – Positions 3, 4, and 7

- Results for position 4 demonstrated more scatter coming from behind the PNS sphere.
- Results from position 7 demonstrated more scatter from the side of the sphere.
- PNS results for position 3 appear to be unreliable.

Normalized integral data for PNS-measured spectra

Distance	Position	Fluence	Ambient dose	Tissue kerma
m	#	n cm^{-2} A^{-1} s^{-1}	Sv A^{-1} s^{-1}	Gy A^{-1} s^{-1}
2	1	2.943E+13	4388	245
	2	3.128E+13	4265	239
	3	2.908E+13	3486	198
3	4	2.326E+13	2146	119
	5	2.069E+13	2489	139
	6	2.106E+13	2195	122
4	7	1.607E+13	1462	79.7
	8	1.549E+13	1258	69.0
	9	1.560E+13	1319	71.6
8	10	2.881E+12	338.1	18.8
	11	9.792E+11	67.2	3.6

Reference neutron spectrum to evaluate dose

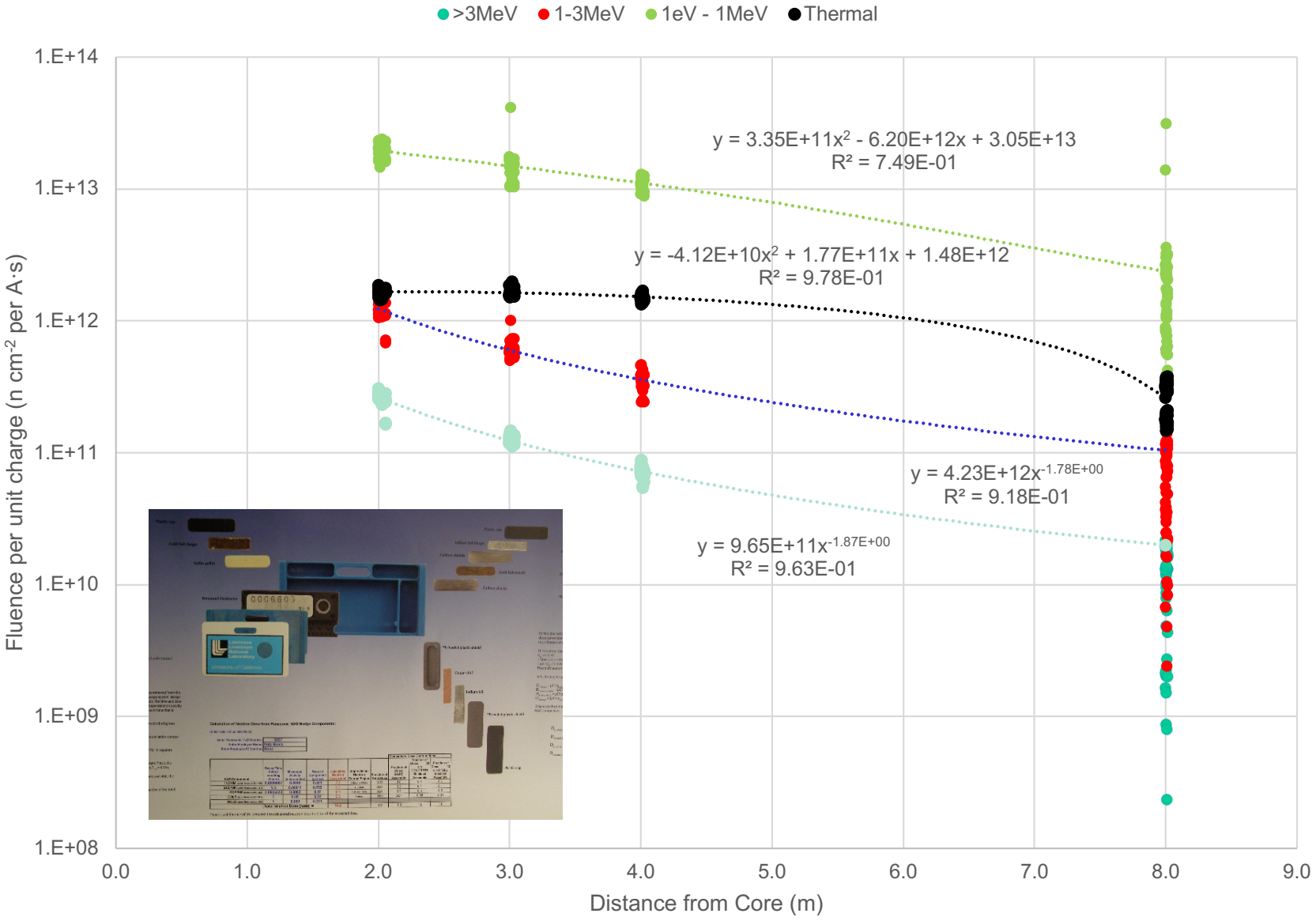


Passive Neutron and Gamma Dosimetry using NADs and CaF_2 gamma detectors

- Three different high dose irradiations at 0.029, 0.020, and 0.0205 Amp·s
- 130 LLNL combination NAD/γ dosimeters
- 542 SNL CaF_2 gamma dosimeters

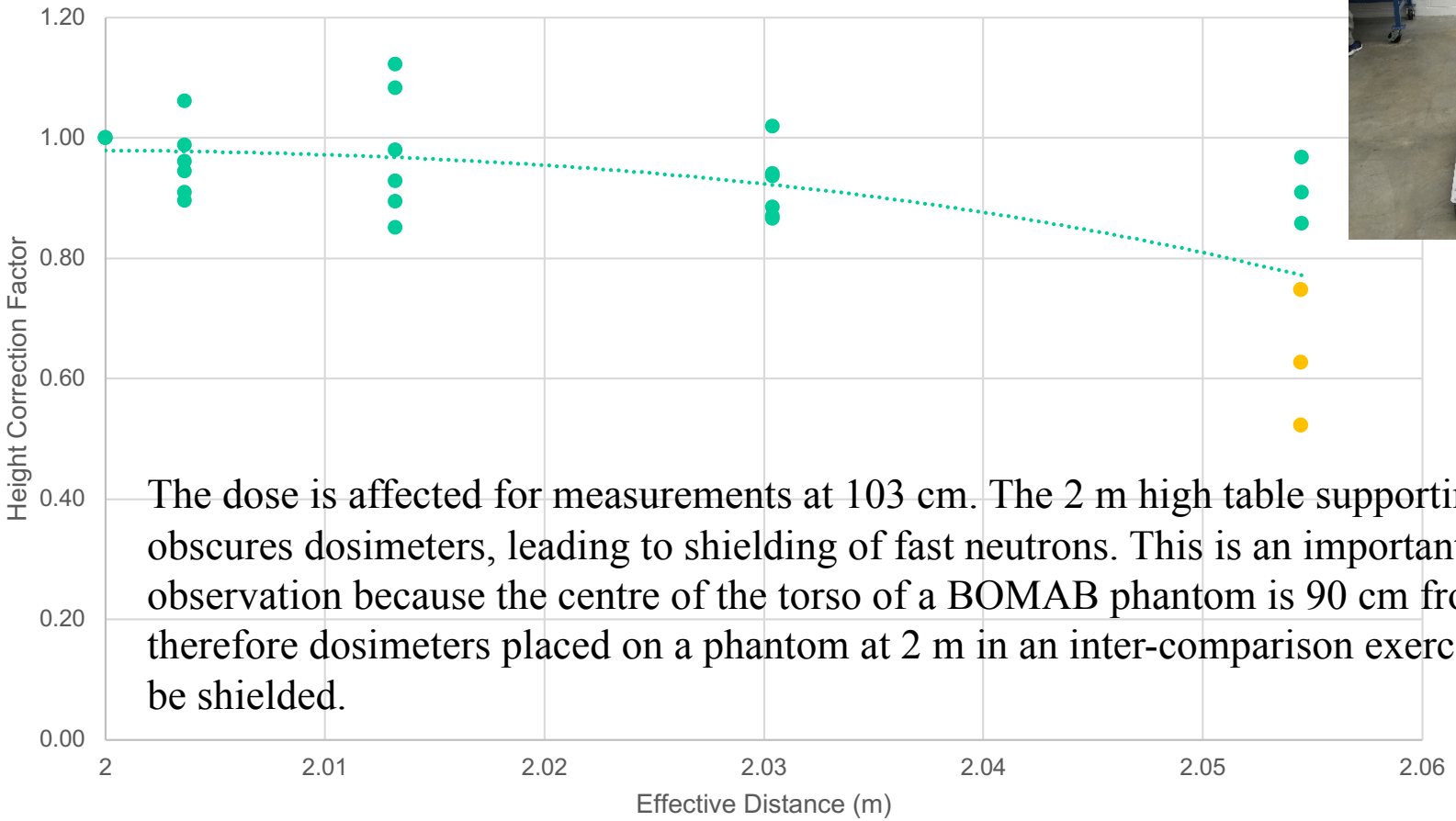
Date	Irradiation ID	Charge Start Time	Charge End Time	Amp-s
22May2017	Flattop-13	11:26	13:42	2.90E-2
23May2017	Flattop -11	09:38	10:22	2.00E-2
24May2017	Flattop -9	09:22	10:06	2.05E-2

Normalized neutron fluence as a function of distance using NAD measurement data



Height correction factors for neutron energies greater than 1MeV

- No corrections needed beyond 2 meters
- No correction needed @ 2m if >103 cm above floor



The dose is affected for measurements at 103 cm. The 2 m high table supporting Flattop obscures dosimeters, leading to shielding of fast neutrons. This is an important observation because the centre of the torso of a BOMAB phantom is 90 cm from the base therefore dosimeters placed on a phantom at 2 m in an inter-comparison exercise would be shielded.

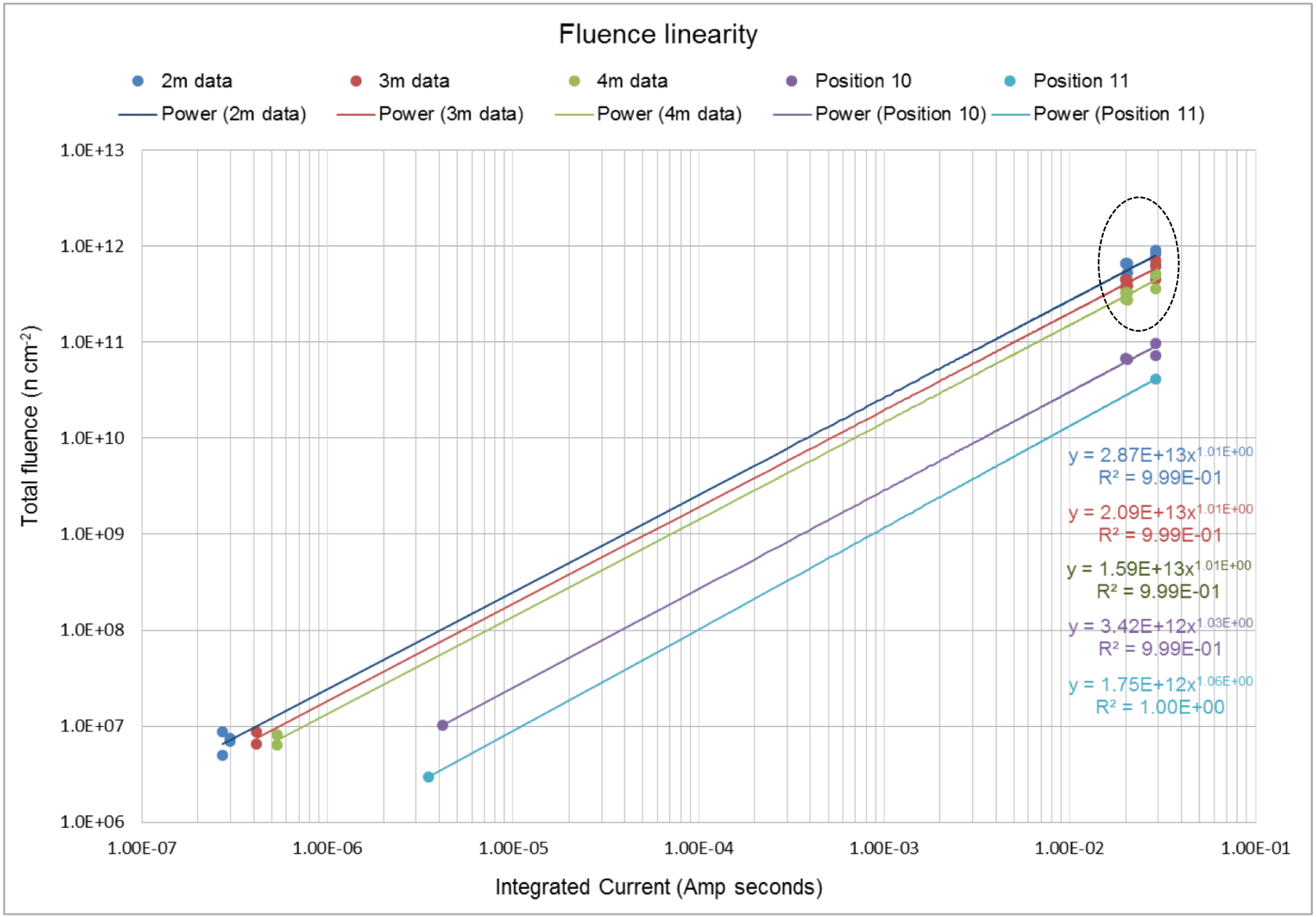
Normalized gamma dose as a function of distance

Distance	CaF_2: Mn		^7LiF: Mg, Ti		IRSN badge		GD-351 RPL rod	
m	Dose (Gy A^{-1} s^{-1})	RSD	Dose (Gy A^{-1} s^{-1})	RSD	Dose (Gy A^{-1} s^{-1})	RSD	Dose (Gy A^{-1} s^{-1})	RSD
2	38.2	0.4%	37.7	4.8%	38.1	4.0%	46.5	4.4%
3	33.8	0.7%	33.1	5.0%	32.5	12.3%	38.5	5.9%
4	29.3	0.6%	28.4	11.6%	28.1	4.9%	34.1	3.7%
8	6.6	0.5%	6.1	10.5%	6.5	6.5%	7.7	6.6%
Position 11	-	-	3.3	12.0%	3.5	1.2%	4.4	9.4%

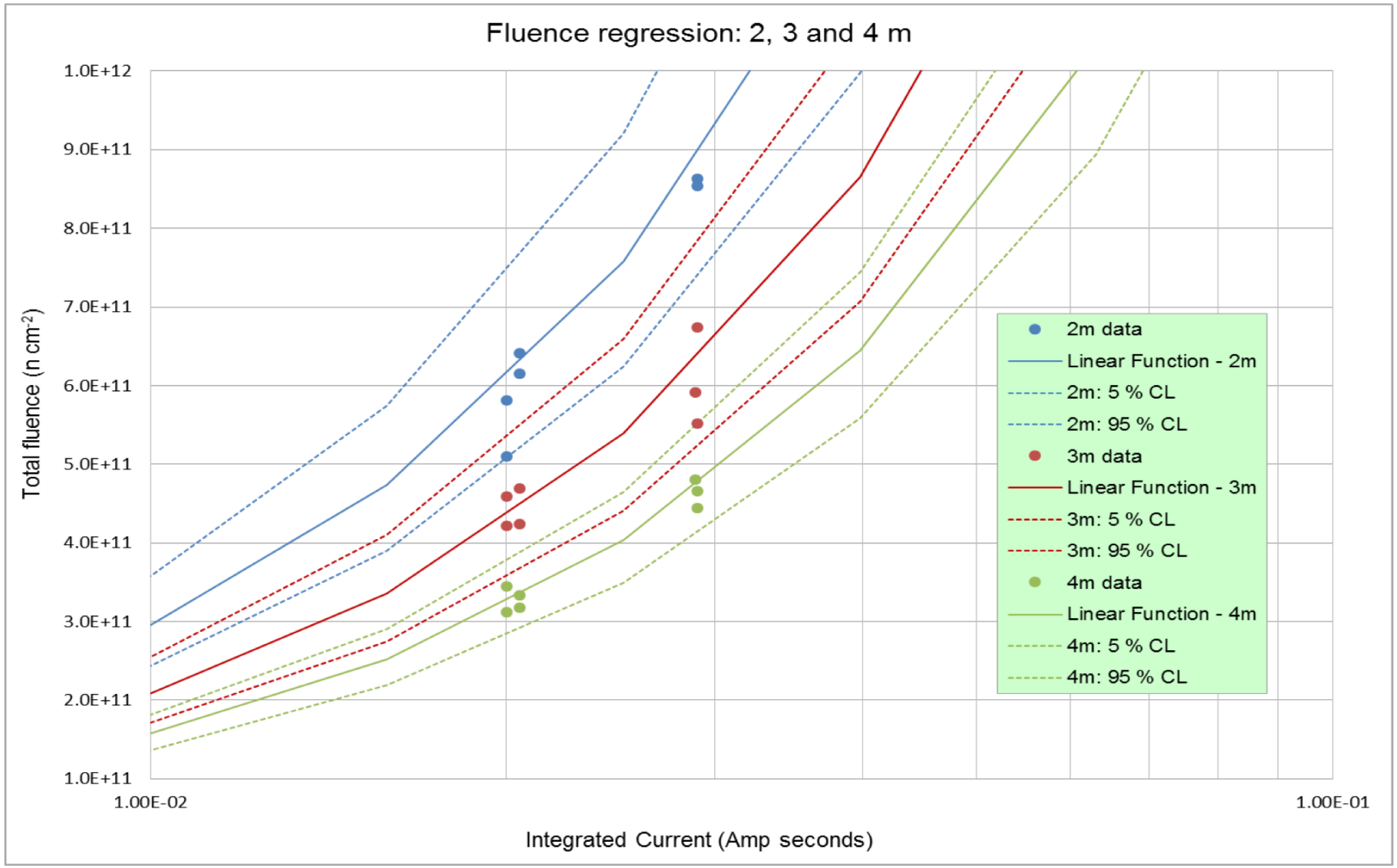
Summary of fission foil data

	No. of fissions - Foil 33			No. of fissions - Foil 34	
Isotope	Count 1	Count 2	Count 3	Count 1	Count 2
Zr-95	3.72E+10	4.45E+10	4.02E+10	4.22E+10	4.18E+10
Zr-97	3.69E+10	4.63E+10	4.07E+10	3.98E+10	4.29E+10
Mo-99	3.75E+10	4.54E+10	4.11E+10	3.85E+10	4.04E+10
Ru-103	3.81E+10	4.65E+10	4.18E+10	3.78E+10	4.32E+10
Ba-140	3.10E+10	3.69E+10	3.37E+10	3.34E+10	3.47E+10
Ce-141	3.00E+10	3.20E+10	3.12E+10	3.08E+10	3.38E+10
AWE (Av. Fissions)	3.81E+10 ± 11.78% RSD			3.83E+10 ± 10.63% RSD	
LLNL (Av. Fissions)	2.74E+10 ± 27.27% RSD			3.73E+10 ± 14.57% RSD	

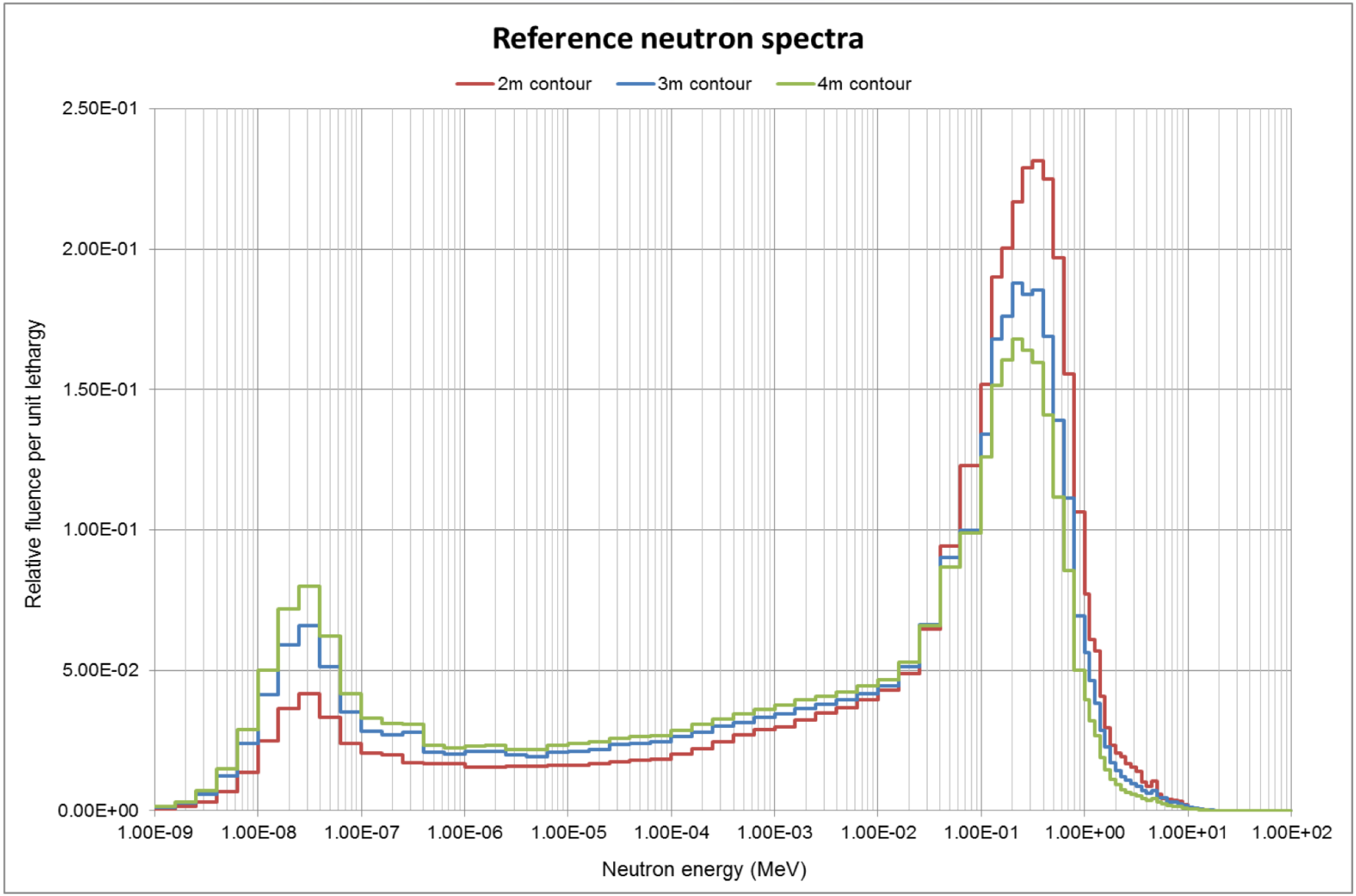
Plot of the linearity for a subset of the neutron fluence data



Linear expansion of neutron prediction function in NAD test range

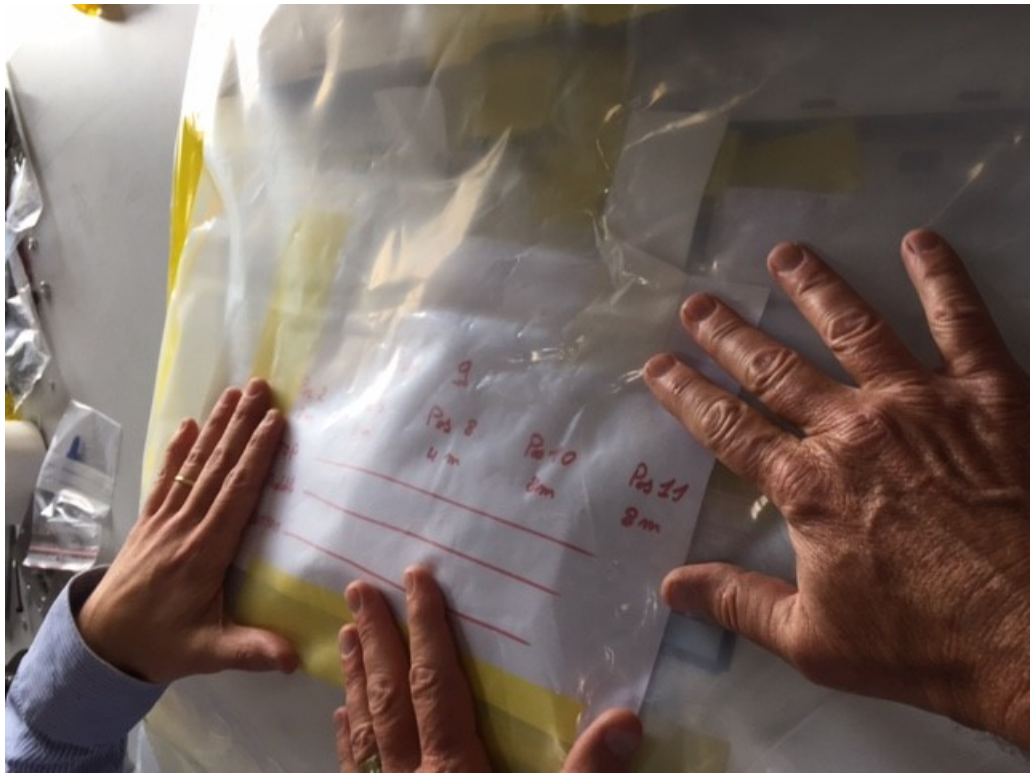


Reference neutron spectrum to evaluate dose



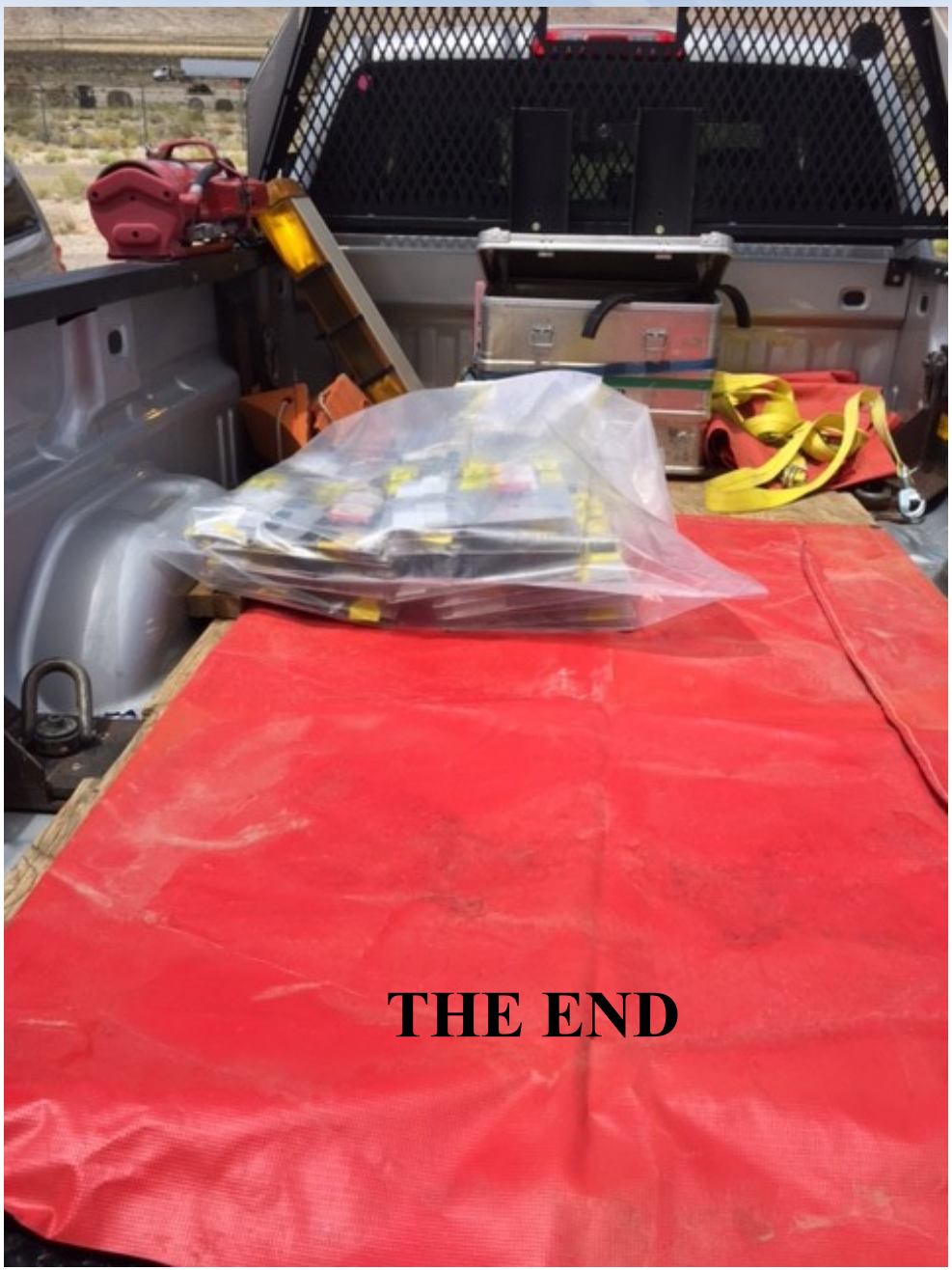

Gamma dose regression: 2, 3 and 4 m
Tissue kerma (Gy)
2.0E+00
1.8E+00
1.6E+00
1.4E+00
1.2E+00
1.0E+00
8.0E-01
6.0E-01
4.0E-01
2.0E-01
0.0E+00
0.01
0.1
Integrated Current (Amp seconds)
2m data
Linear Function - 2m
2m: 5 % CL
2m: 95 % CL
3m data
Linear Function - 3m
3m: 5 % CL
3m: 95 % CL
4m data
Linear Function - 4m
4m: 5 % CL
4m: 95 % CL

NOW WHAT??????



IER 253 - an International Intercomparison Exercise (May 2018)

- Blind Testing – Participants will have no knowledge of the positioning, orientation, or dose levels used to expose their dosimeters (similar to a real criticality accident).
- Slow dissemination of information about the irradiation and conditions of exposure will occur over 24 hours (also what is expected to happen in a real criticality accident).
- Will monitor changes in doses as time progresses.
- Biological dosimetry will be available (blood simulant & hair). This could help participants understand the exposure conditions.
- US Participants report dose based on ANSI 13.3 (2013) requirements:
  - New dose factors
  - Reporting of results within 24 hours
- Laboratories will have a three week time frame after exercise to finalize dose values.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