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NCSP
NUCLEAR CRITICALITY SAFETY PROGRAM

IER 147 GODIVA STEADY STATE MEASUREMENTS

Nuclear Criticality Safety Program (NCSP) Recent Technical Accomplishments
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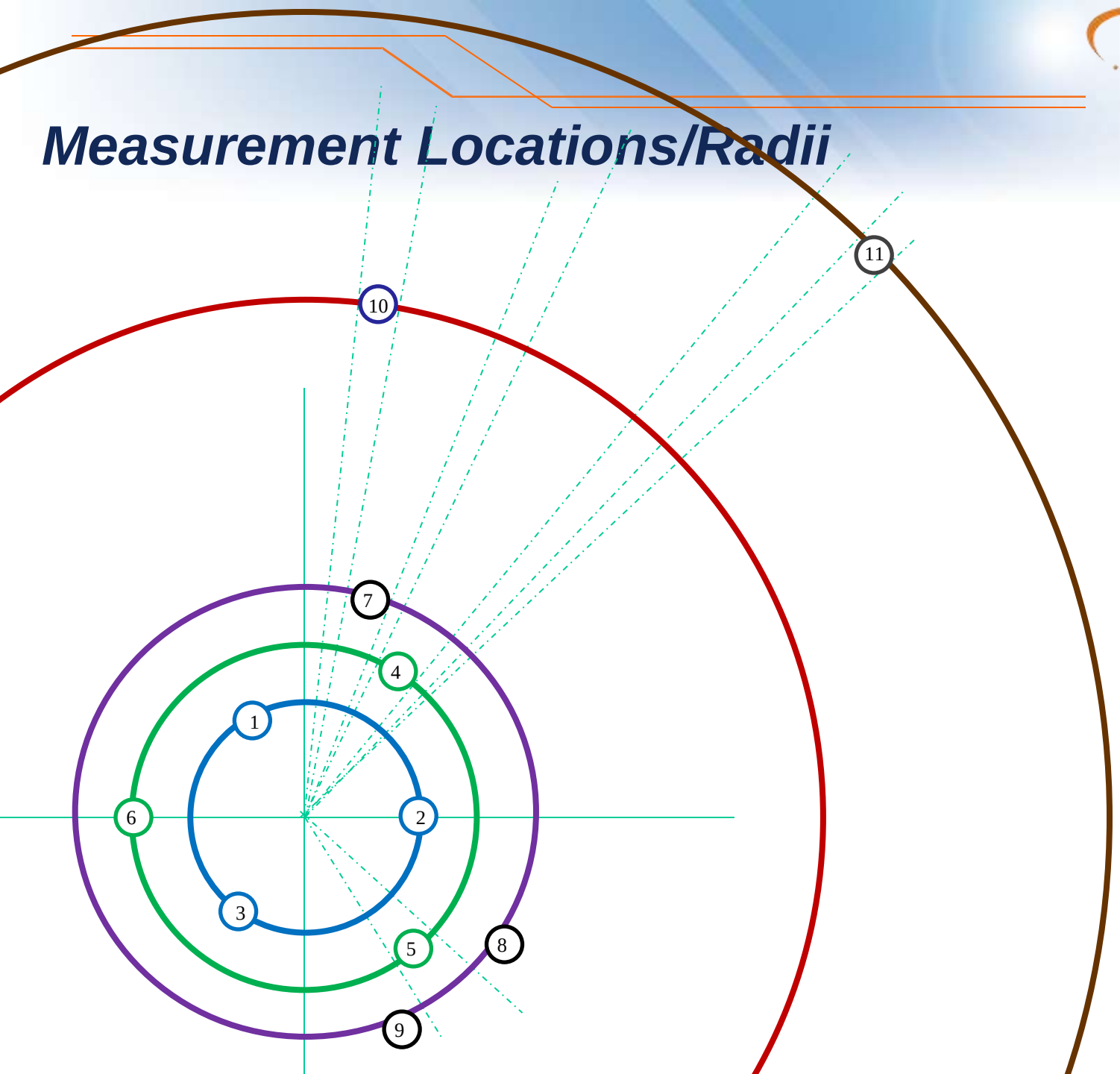
Objectives

- Evaluate Godiva neutron spectral changes that will influence nuclear accident dosimetry intercomparisons.
- Evaluate possible dose variability for NAD (pulse) intercomparisons.
- Evaluate methods for determining gamma doses
- Other:
  - Continuous operation mode evaluation
  - Doses for continuous operation modes

Participating Laboratories

- **LLNL Nuclear Criticality Safety Division**
  - Coordination (Jennifer Burch, Gary Slavik, Scott Richardson, Becka Hudson)
  - Establish test points (Jennifer Burch, John Scorby, Dave Heinrichs)
- **LLNL ES&H Radiation Protection Functional Area**
  - ROSPEC Measurements (Radoslav Radev)
  - Gamma Dose Measurements (Dave Hickman)
  - Dose variability measurements (Dave Hickman)
- **LLNL Physics Group**
  - Time of Flight Measurements (Nathaniel Bowden)
- **AWE - UK**
  - ROSPEC Measurements (Chris Wilson)
  - Bonner sphere spectrometer measurements (Leo Clark)
- **SNL**
  - Gamma Dose Measurements (Dan Ward)
  - N-Spec Measurements (Dan Ward)
- **LANL**
  - Godiva Operation (Joetta Goda, John Bounds & Crew)
  - SSS Measurements (Tom Mclean)
  - NRDS (Jesson Hutchison, Travis Grove)

Measurement Locations/Radii



2m - Blue
3m - Green
4m - Purple
9m - Red
14m - Brown

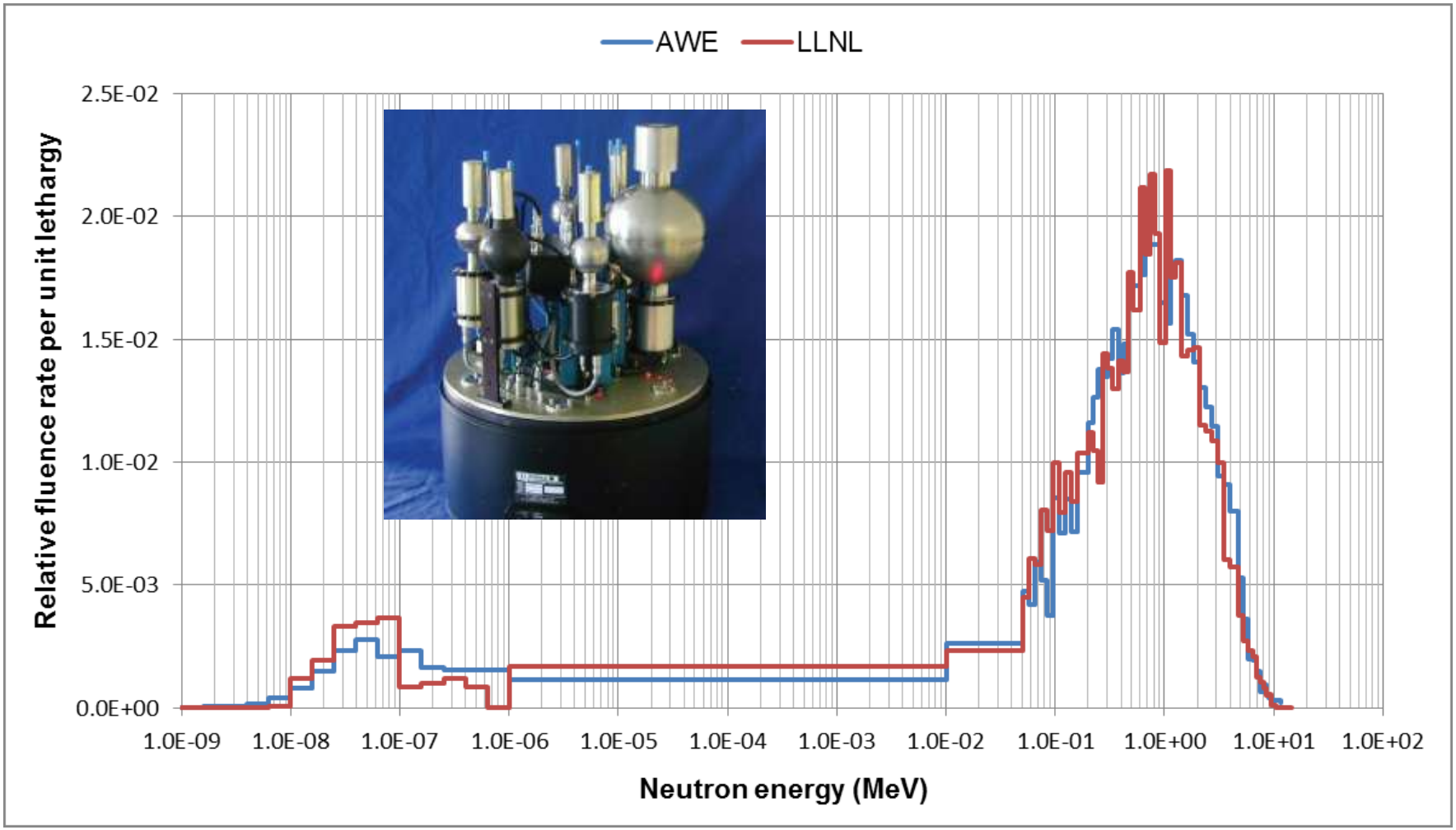
Operational Summary

Operational Data						Measurement Positions for each run								
Run #	Date	Power level (A)	Approx. Run Start Time	Godiva Total Run Operating Time (h)	Godiva Plateau Operating Time (h)	LLNL ROSPEC	AWE ROSPEC	LANL SSS	AWE BSS	SNL N-Probe(1)	LLNL TLD/CR-39/EP Dosimeters	LLNL 451 Ion Chamber	SNL RADCAL Ion Chamber & CaF TLDs	LLNL TOF
1	4-Nov	8.50E-11	11:16 AM	1.70	1.50	7	8				3	3		10
2		8.50E-11	2:18 PM	1.52	1.42	8	9			11	3	3		10
3	5-Nov	7.50E-11	9:05 AM	1.01	0.84	4	5			10	7	10	7	10
4		3.80E-11	10:55 AM	1.55	1.45	5	6			10	8	10	8	10
5		3.80E-11	2:00 PM	1.31	1.18	6	4			10	9	10	9	10
6	6-Nov	1.90E-11	8:52 AM	1.98	1.93	1	2	1		9	6	9	6	10
7		1.90E-11	11:32 AM	2.00	1.90	2	3	3		4	4	8	4	8
8		3.80E-11	2:04 PM	1.46	1.34	3	1	2		8	5	8	5	8
9	7-Nov	8.70E-11	9:09 AM	1.55	1.39	9	8	3		10	2	10	2	8
10		8.80E-11	11:19 AM	1.13	1.01	8	9	2		11	1		1	8
11		8.70E-11	1:12 PM	2.77	2.67	11	5	1		11	1			10
12+	8-Nov	2.60E-12	Multiple				7		1,2,3,6, 7					10

(1) Height of N-Probe is lower than the ROSPEC and TSS units

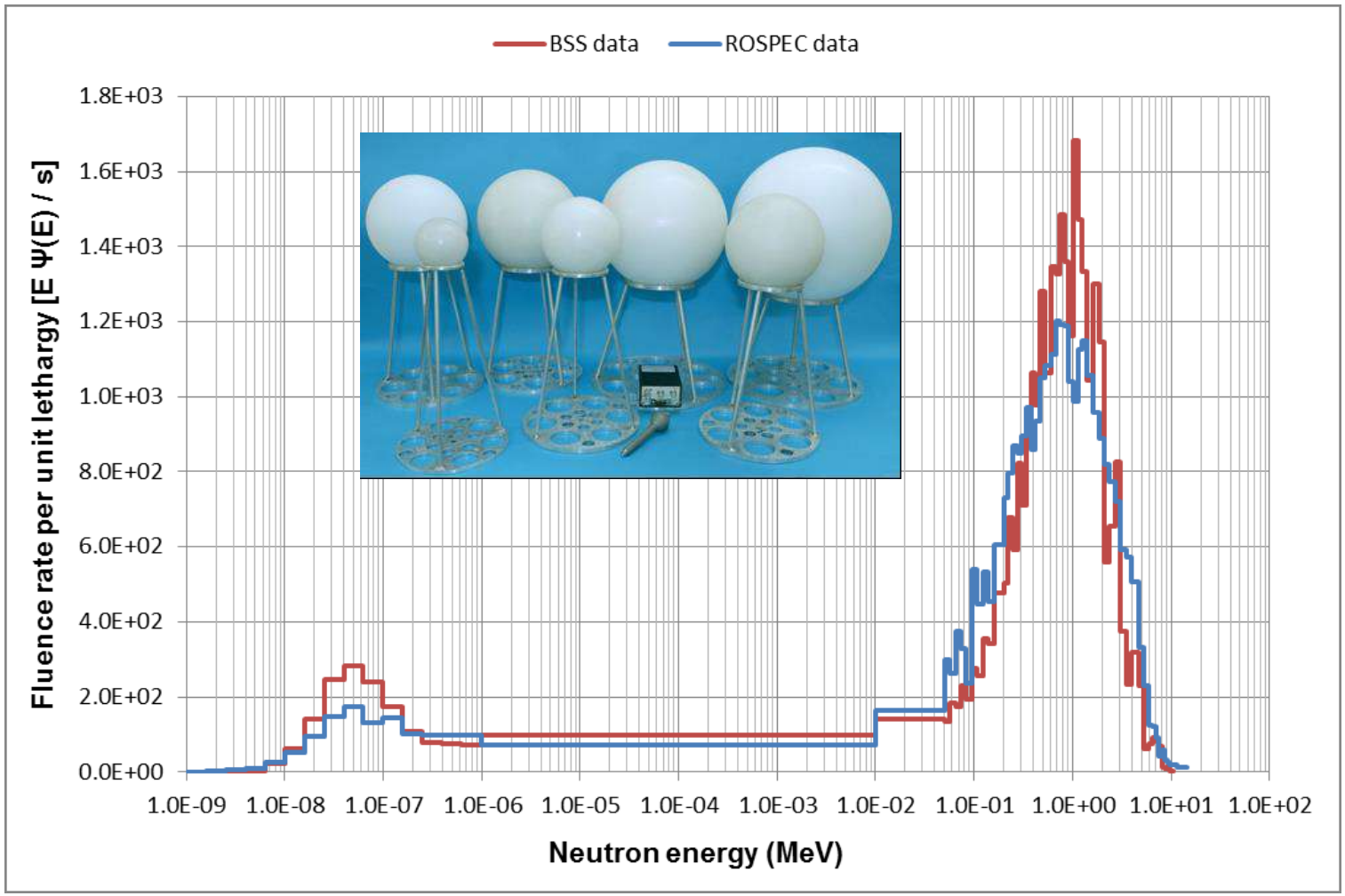
Operational time data based on linear & startup data provided by LANL

Comparison of LLNL & AWE ROSPECs



from: AWE Report 285/14 by Chris Wilson & Leo Clark

Comparison of ROSPEC & BSS data



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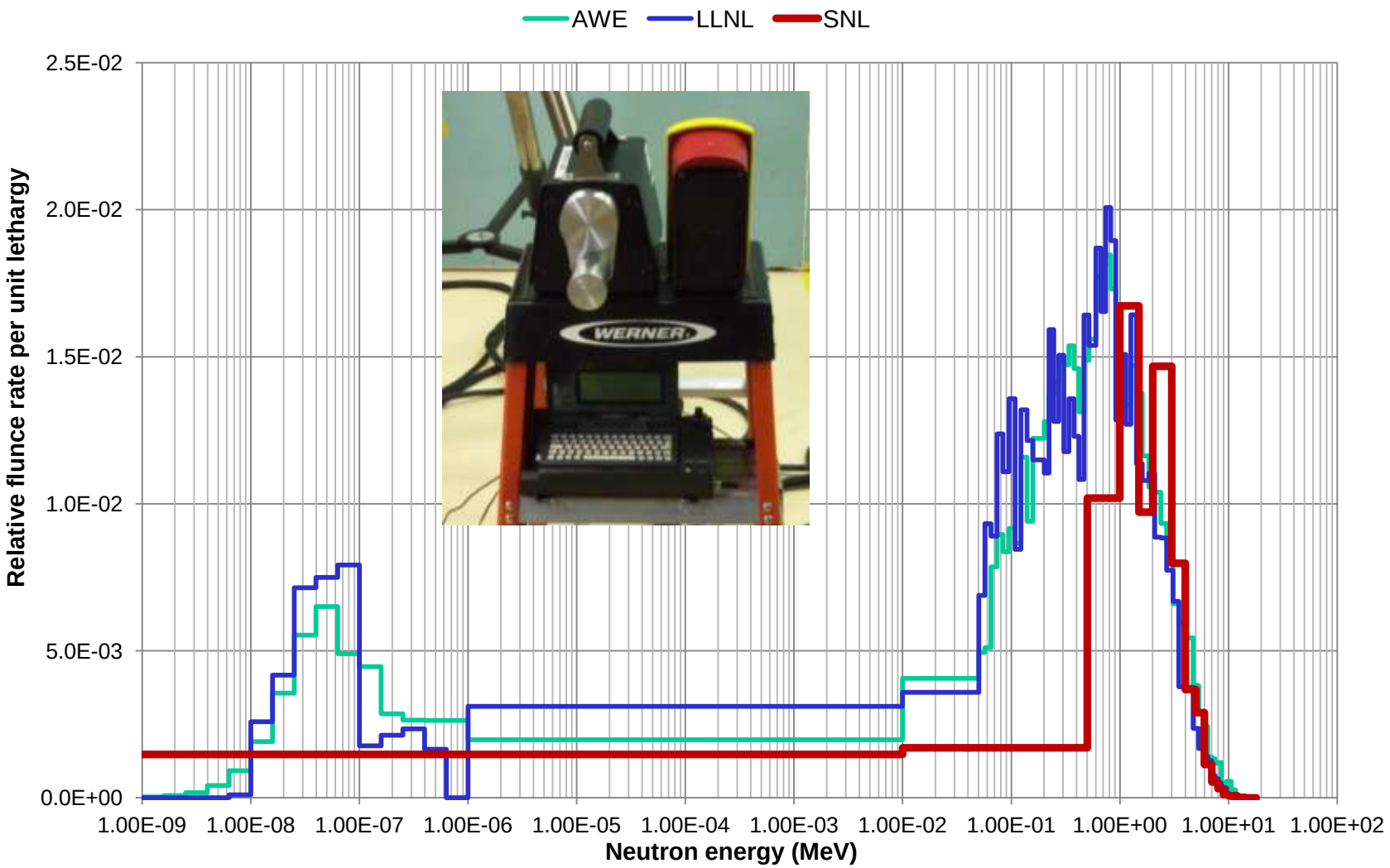
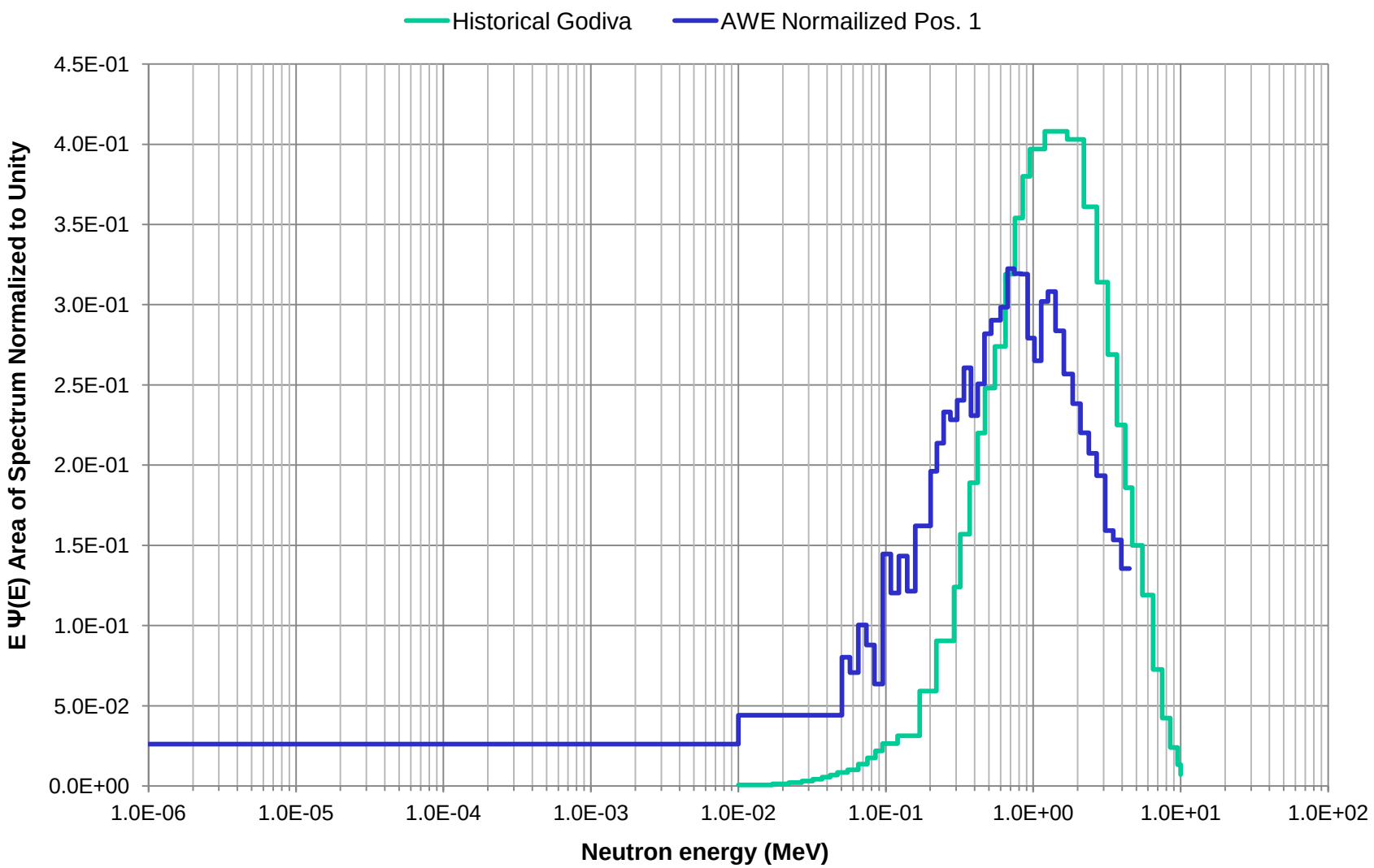
N-Probe comparative



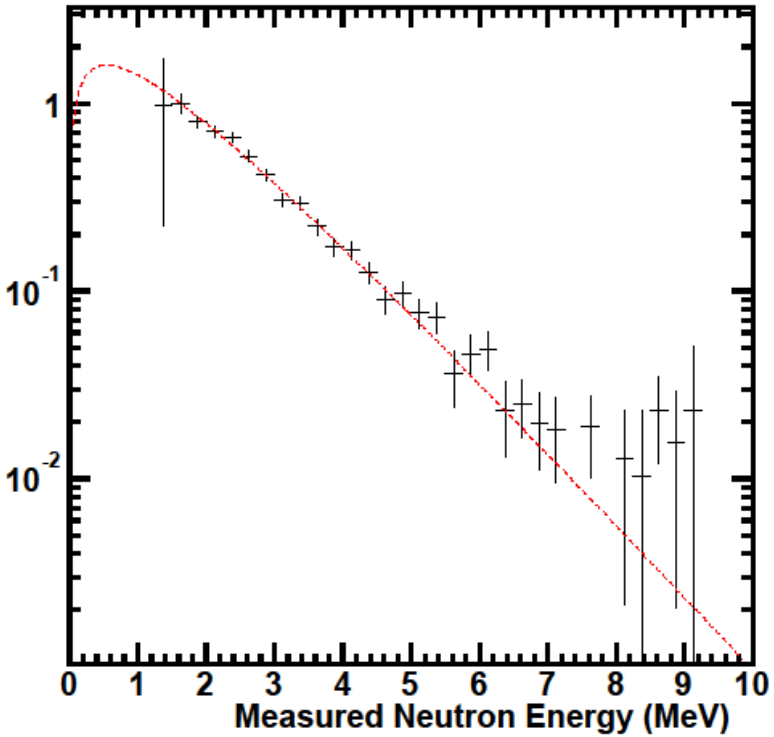
Current vs Historical Godiva Neutron Spectrum



Historical Godiva IV data from Hankins 1967

Time of Flight Measurements

from N.S. Bowden



Red line represents Watt spectrum of temperature 1.07 MeV

Ambient dose equivalent rate H(10) comparison (in mSv/h) normalized to 8.5E-11 A*

Distance from Core (m)	Position	LLNL ROSPEC[1]	LLNL ROSPEC[2]	AWE ROSPEC	AWE BSS	SNL MICROSPEC N-Probe	Average
2	1	4.037	3.999	4.250	4.207		4.13 ± 0.11
	2	4.057	4.017	4.157	4.301		
	3	4.078	4.049	4.190	4.270		
3	4	2.297	2.278	2.241			2.30 ± 0.04
	5	2.323	2.304	2.363			
2.5	6	3.011	2.997	3.016	3.06		3.02 ± 0.03
4	7	1.612	1.610	1.644			1.60 ± 0.03[3]
	8	1.601	1.600	1.652		1.52 1.44	
	9	1.551	1.553	1.569	1.600	1.16	
9	10					0.37 0.33 0.27 0.45	0.36 ± 0.08[4]
14	11	.0072				.037 .081	

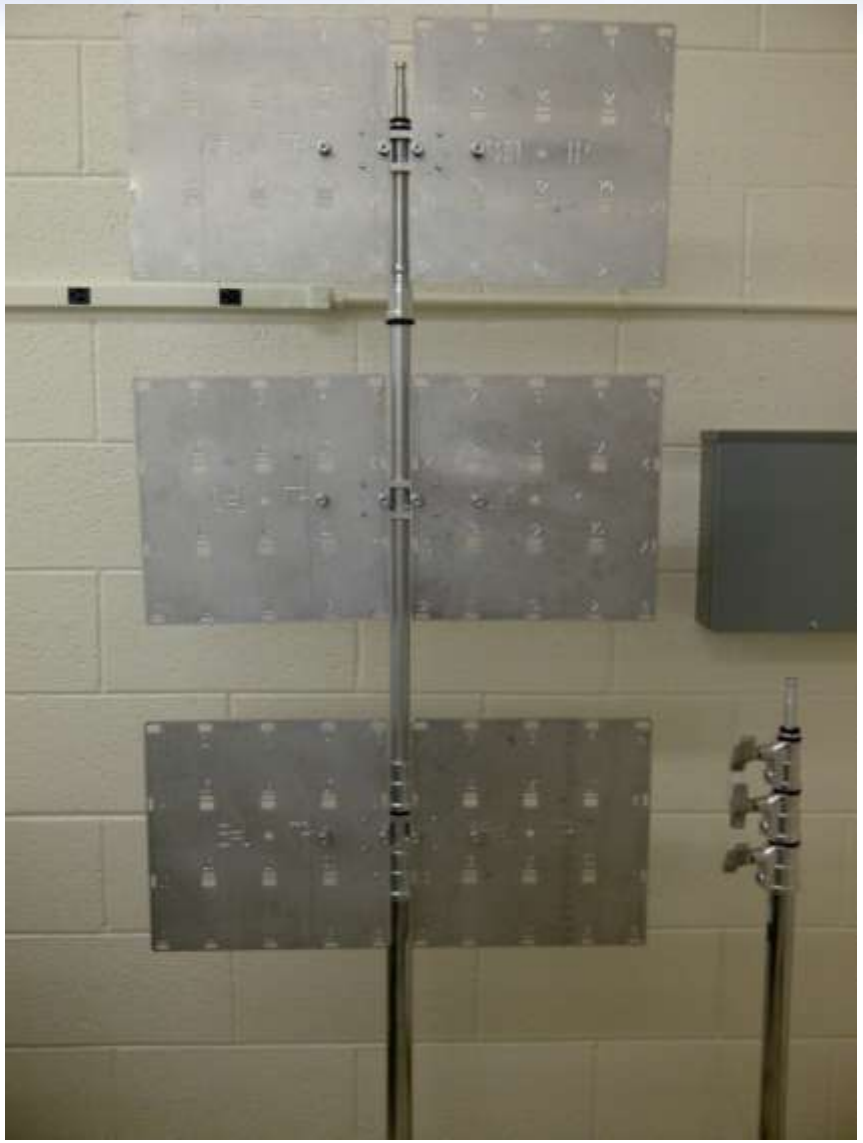
[1] Using ICRU 74 dose conversion factors
[2] Using NCRP 38 dose conversion factors
[3] Does not include N-Probe measurements. With N-Probe value would be 1.71 ± 0.26 mSv/h.
[4] SNL data only

All measurements performed at core height

Dosimeter Sample Holder

- Up to 8 plates to hold NADs
- Adjustable heights
- Can hold up to 20 dosimeters per plate
- Each plate is lettered
- Each dosimeter position is numbered
- Godiva core is approx. 182 cm from floor

What kinds of variations could we expect with dosimeters at varying heights?



Sample Positions for TLD and CR-39 Dosimeters

Run #	Floor Position	Distance from Core (m)	Height from Floor (cm)	Number of Dosimeters
1	3	2	188	4
			144	4
			97	4
			46	4
2	3	2	182	4
			144	4
			96	4
			51	4
3	7	4	174	4
			127	4
			81	4
4	8	4	174	4
			127	4
			81	4
5	9	4	174	4
			127	4
			81	4
6	6	2.5	174	2
			127	2
			81	2
7	4	3	174, 127, 81	1 ea.
8	5	3	174, 127, 81	1 ea.
9	2	2	174, 127, 81	1 ea.
10	1	2	174, 127, 81	1 ea.

Neutron Dose Variations with Dosimeter Height

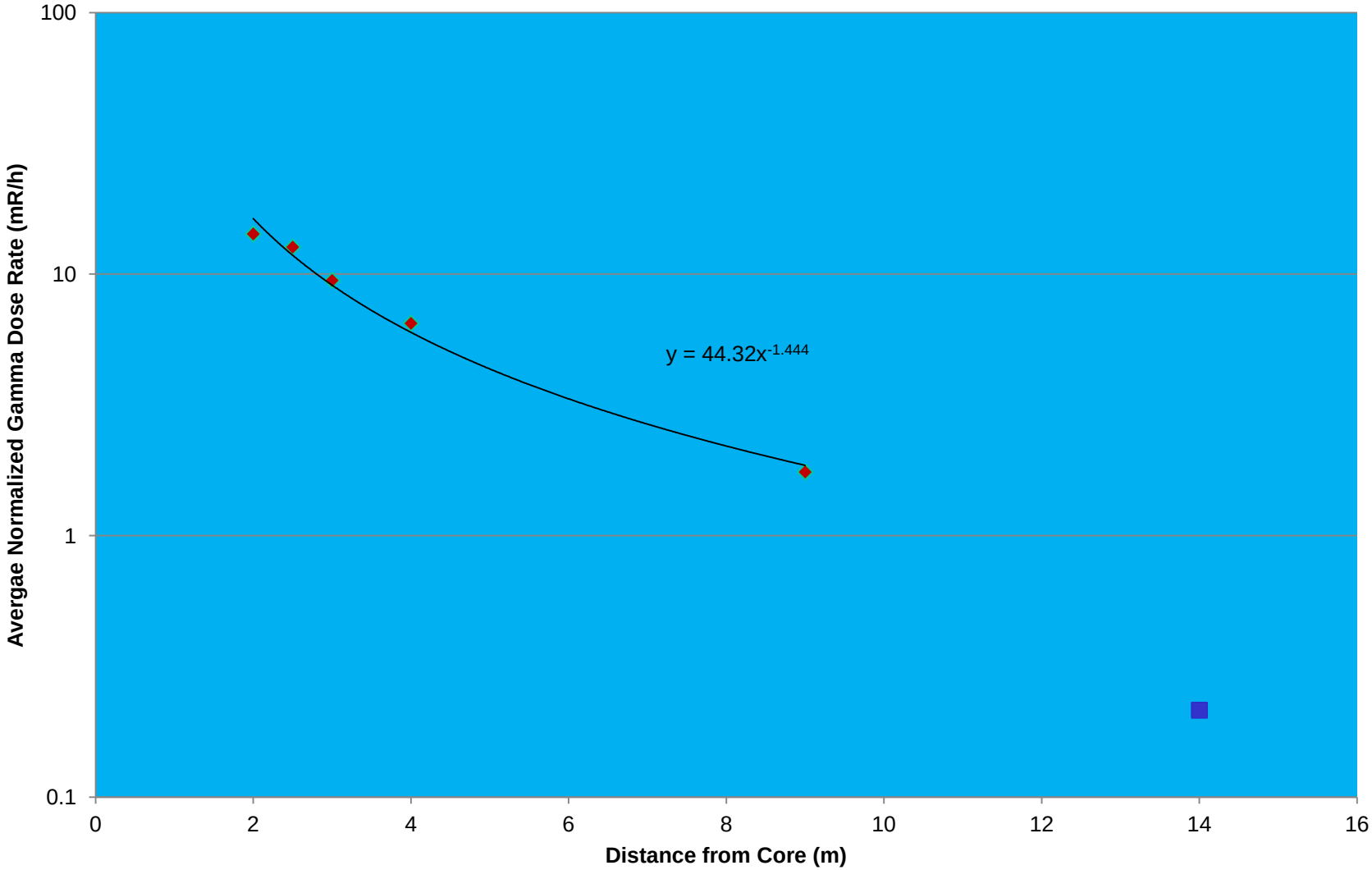
- Test heights varying from 194 cm to 52 cm off the floor
- Compare with theoretical evaluation/approximation

Theoretical Change in Dose Change Based on Simple Inverse Square		
Core Height = 182 cm		
Distance from Core (cm)	Holder Height (cm)	Expected % Dose Change
200	194	<1%
	150	-2.7%
	103	-16.0%
	52	-42.5%
300	194	<1%
	150	1.20%
	103	-7.09%
	52	-19.03%
400	194	<1%
	150	<1%
	103	-3.99%
	52	-10.71%

Experimental vs Theoretical CR-39 Dose Results

Measured vs Theoretical Change in Dose as a Function of Dosimeter Position (theoretical change includes inverse square and angular response correction)				
Distance from Core (cm)	Dosimeter Height (cm)	Expected % Change in Dose (relative to 174 cm)	Average CR-39 Measured % Dose Change	
200	218	+2.2%	+1.0%	
	174	0.0%		
	127	-13.0%	-11.7%	
	81	-45.6%	-49.0%	
	76	-49.6%	-49.0%	
300	174	0.0%		
	81	-25%	+24.8%	n=4
	57	-26%	-13.3%	
400	174	0.0%		
	96	-3.7%	-8.9%	
	51	-13%	-12.7%	

Average normalized Ion Chamber gamma dose rates as a function of distance from the core



Integrated Gamma Dose Rate

- Gamma dose can account for approximately 5 to 30% of the total dose in a criticality event

Positions	Distance from Core (m)	Ion Chamber Average (mR/h)	TLD Gamma Dose Average (mSv/h)[1]
1 - 3[2]	2	0.142	0.229
6	2.5	0.127	0.135
4 – 5	3	0.095	0.169
7 – 9	4	0.065	0.263
10	9	0.018	
11	14[3]	0.0021	

[1] No phantom
[2] Overnight RADCAL background was 4.32 mR (~0.25 mR/h) at 4 meters from core
[3] 14 meter position is a shielded position

Both SNL & LLNL ion chambers had equivalent results when measuring the same position

Preliminary Conclusions

- There is consistency in the neutron spectral and dose data for the different neutron spectral systems
- Slight changes in the spectrum from historical information
- Gamma dose differences with height (and scatter?) are significant
- Gamma dosimetry remains a problem when using accredited dosimeters
- Ion chambers appear to provide better gamma dose readings
- DOELAP accreditation program may find use in evaluating dosimeter response within n-gamma fields generated by Godiva & Flattop.

QUESTIONS?