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Title: LANL evaluation of the Fuji NSN3 neutron remmeter

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Tom McLean, Alan Justus, Dave Seagraves, Tom Voss and Nancy Lowe-Henderson

HPIC Meeting

April 11-13 2016, Las Vegas, NV

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Talk outline

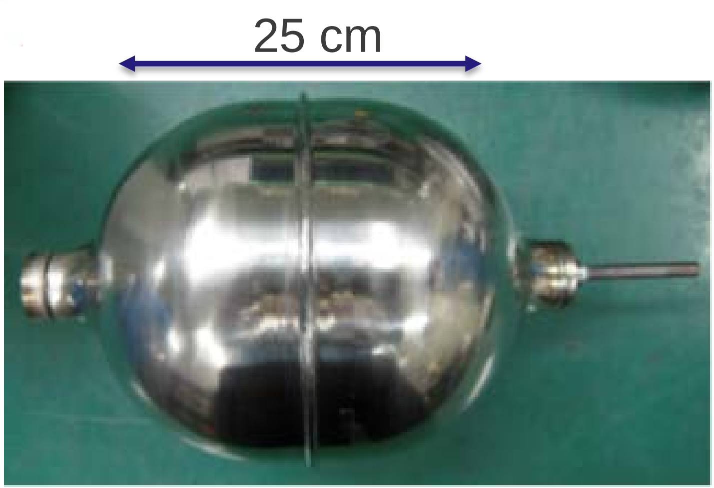
- Introduction
- Evaluation data
- Summary

Selected Instrument properties

Detector type	Gas proportional counter
Weight	2.3 kg (5.1 lbs)
Gas Filling	CH_4 (4 atm) + N_2 (1 atm)
Chamber volume	1.4 L
Nominal sensitivity	21 cpm/µSv (210 cpm/(mrem/h))
Dose rate range	0.1 – 1000 mrem/h (5 decades)
Dose range	0.01 – 1000 mrem (6 decades)
Conformity with H*(10) ICRP-74	±20% from thermal to 15 MeV
Gamma interference	Reads 0.8 mrem/h in a 1R/h field
Power options	6 x (AA alkaline or Ni-MH) or 12v AC
Data logging	1200 records uploaded via USB

N3NS probe

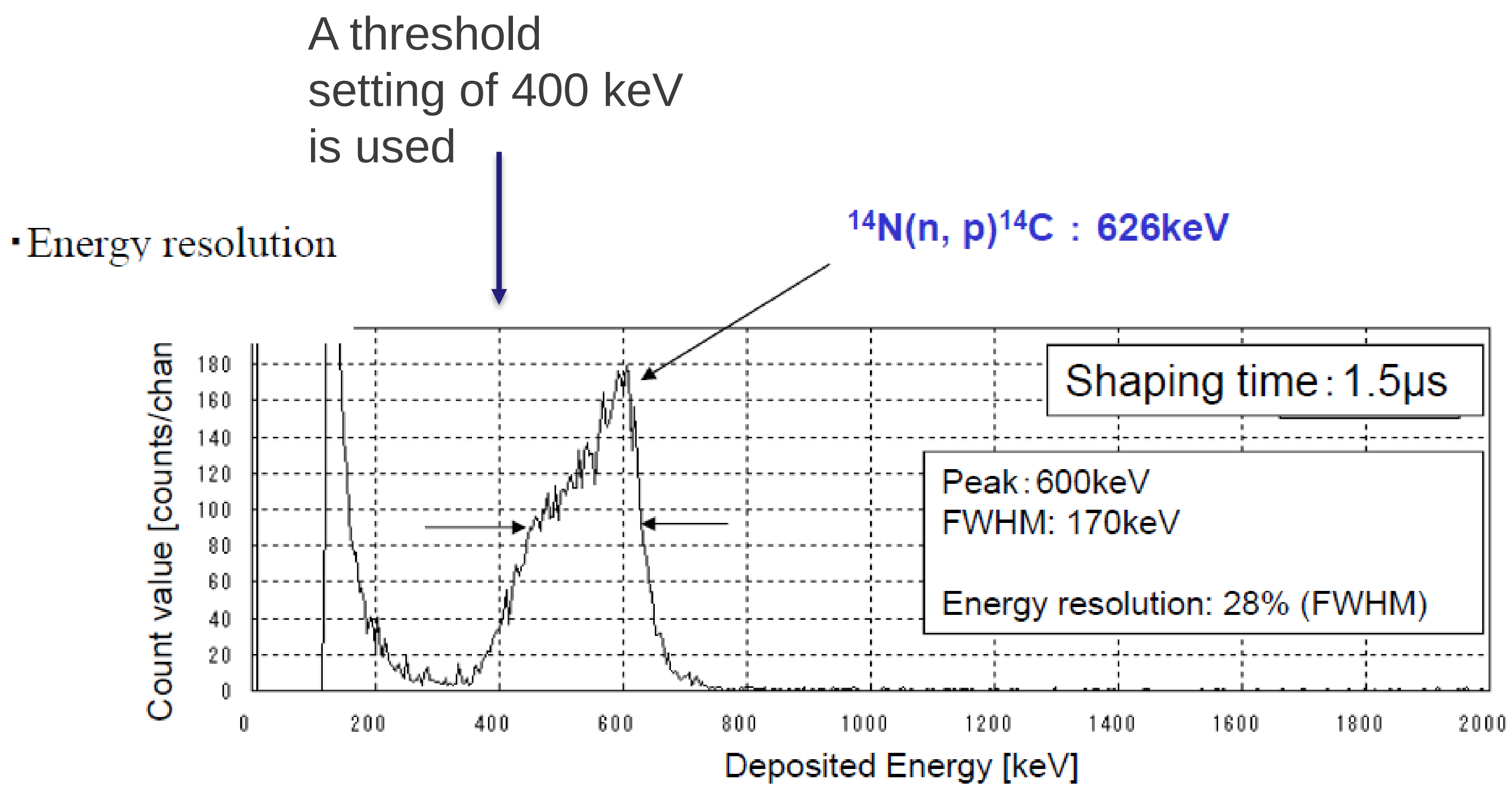
Navigate menu options using just 3 buttons



Introduction: principles of operation

- Chamber is filled with mixture of methane (4 atm.) and Nitrogen gas (1 atm.)
- Low energy response (<10 keV) utilizes the following reaction
  - $^{14}N(n,p)^{14}C$ $E_p = 626$ keV   (range of about 2mm in the gas mixture)
- High energy response (>400keV) relies on proton recoil
  - Overlap with gamma–induced signal determines minimum energy
  - Wall effects determine the upper limit
- The relative amounts of the two gases and their respective reaction cross-sections determine the overall neutron response
  - This response should ideally mimic the H*(10) dose curve

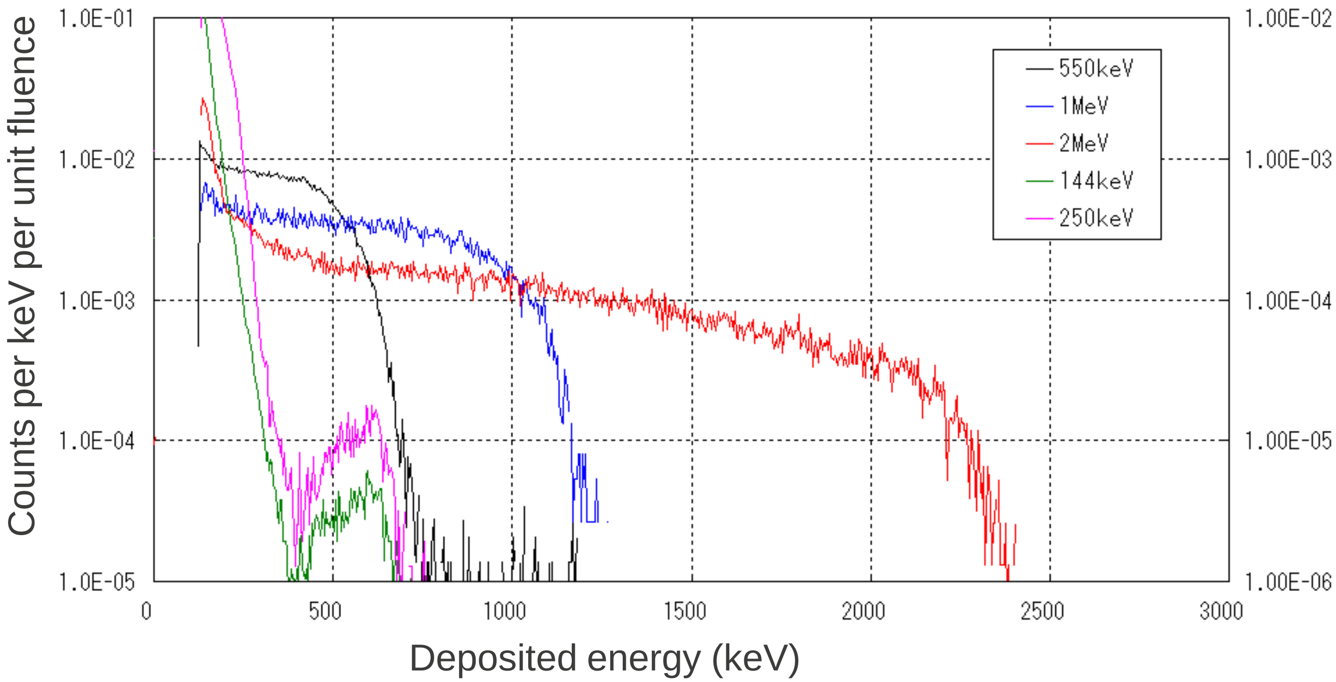
Thermal response



- The pulse height of the thermal peak is fixed but its magnitude varies with neutron energy (i.e. reaction cross-section)

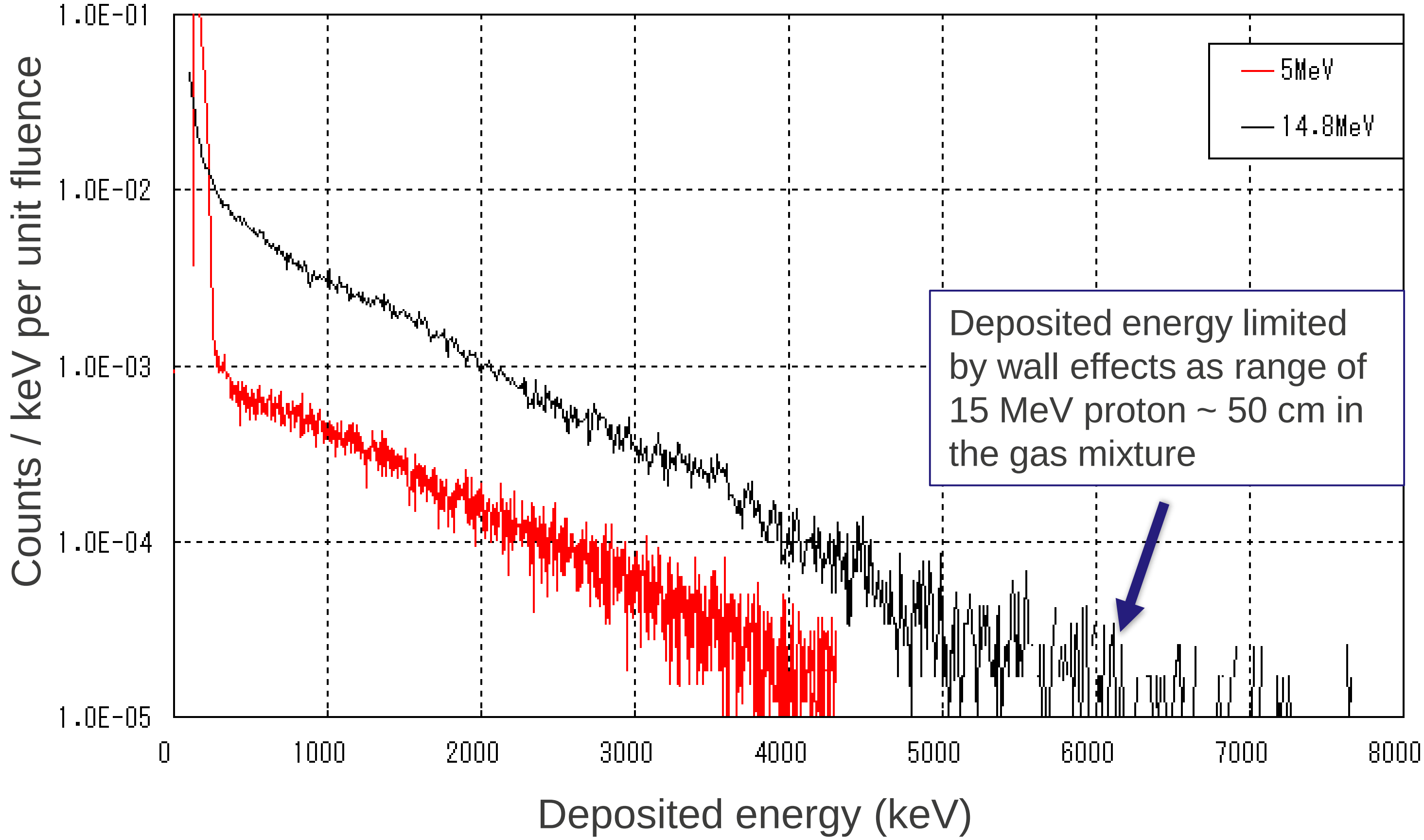
Monoenergetic neutron response at relatively low energies

- Neutrons below the threshold energy (e.g. 144 and 250 keV) are only observable via the thermal channel
- Higher energy neutrons show classic proton recoil energy distribution

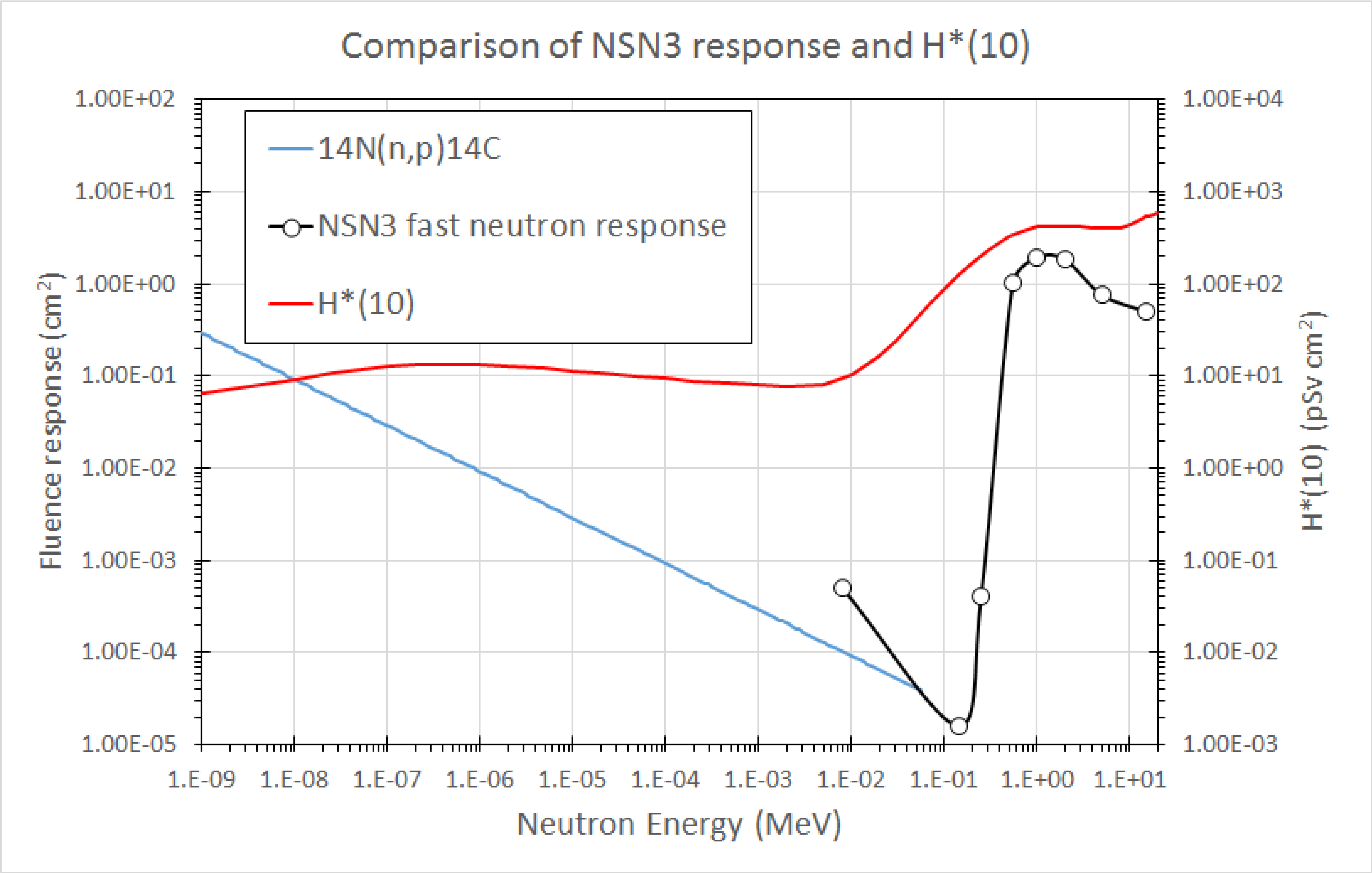


Monoenergetic neutron response at relatively high energies (wall effects become increasingly evident)

- **Introduction**



NSN3 energy response compared with H*(10)



NSN3 energy response

- Overall instrument response is not an ideal match with H*(10)

- Instrument software compensates by filling the region below 0.5 MeV based on typical power plant spectra and the counts observed in the 1-2 MeV window

- Dose software also uses three ROIs to calculate individual contributions to total dose
  - An advantage of the pulse height approach
  - Utilizes the G-value method to get optimum scaling factors for each ROI

NSN3 evaluation: neutron dose rate measurements

- Measurements made on the neutron reference range in the Central Health Physics Calibration Facility at TA36.
  - Bare ^{252}Cf, D_2O-moderated Cf and AmBe measurements recorded

- NSN3 calibrated using AmBe

AmBe data

AmBe source	Distance (cm)	CTV dose rate (mrem/h)	NSN3 reading (mrem/h)	Normalized response
8969NK	50	104.4	100.13	0.959
8969NK	100	27.46	27.28	0.993
8969NK	150	12.95	12.61	0.974
8969NK	200	7.815	7.66	0.980

NSN3 evaluation: neutron dose measurements

Bare ^{252}Cf data

^{252}Cf source	Distance (cm)	CTV dose rate (mrem/h)	NSN3 reading (mrem/h)	Normalized response
Z3899	50	1319	1281	0.971
Z3899	100	350.1	331.5	0.947
Z3899	150	166.8	155.3	0.931
Z3899	200	101.6	94.81	0.933
1899	50	77.78	74.76	0.961
1899	100	20.65	19.92	0.965
1899	150	9.838	9.44	0.960
1899	200	5.991	5.67	0.946

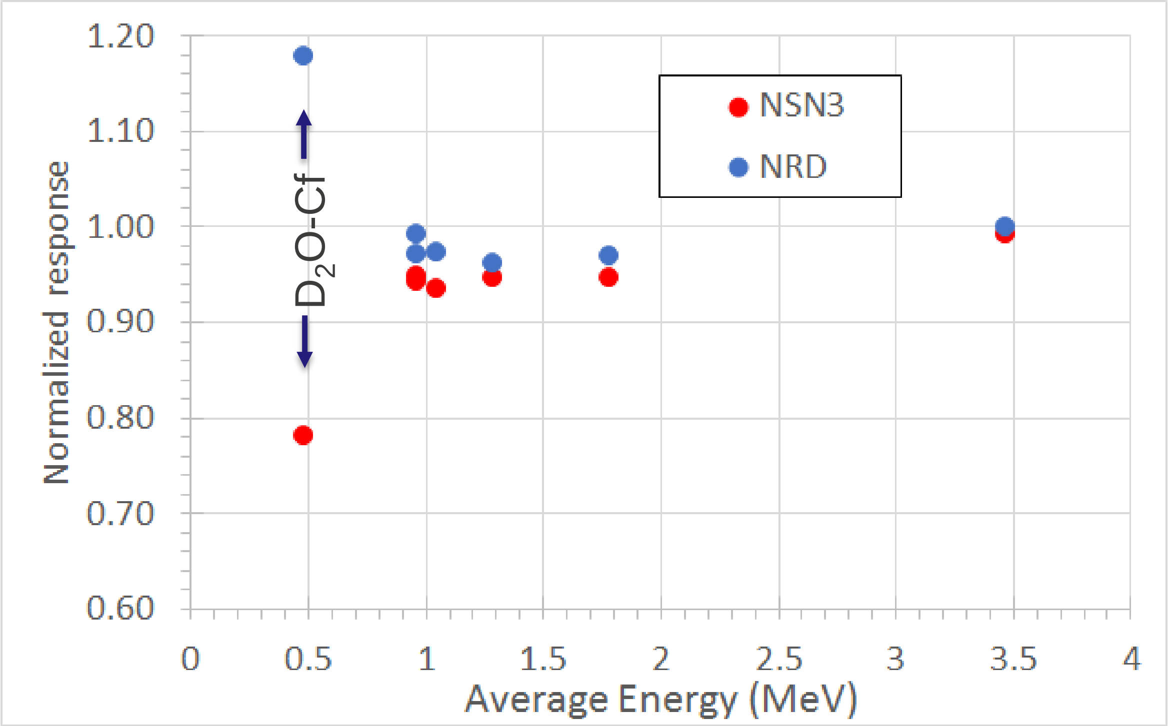
NSN3 evaluation: neutron dose measurements

D_2O-moderated ^{252}Cf data

^{252}Cf source	Distance (cm)	CTV dose rate (mrem/h)	NSN3 reading (mrem/h)	Normalized response
Z3899	50	317.8	260.8	0.821
Z3899	100	85.03	66.49	0.782
Z3899	150	41.1	32.48	0.790
Z3899	200	25.4	20.07	0.790
1899	100	5.016	3.73	0.744
1899	150	2.424	2.33	0.961

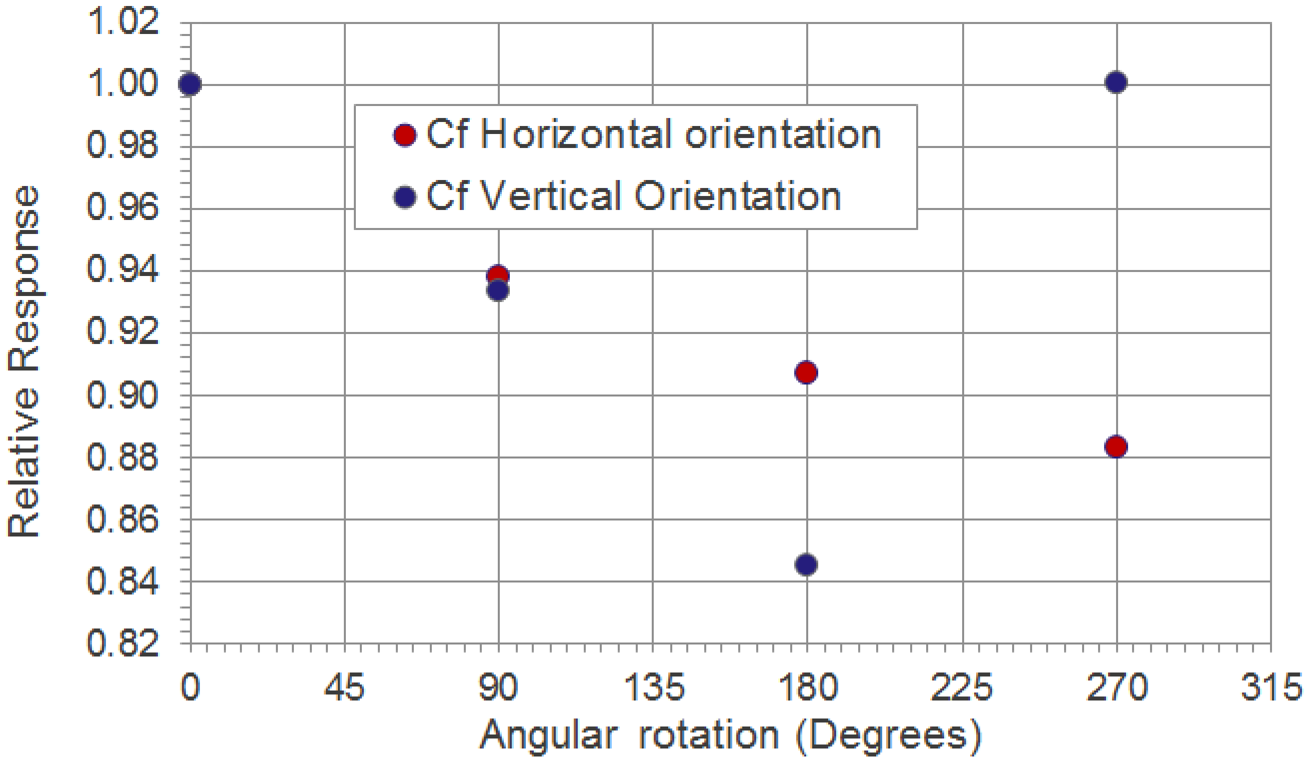
NSN3 vs NRD normalized dose response

- NSN3 response compared with NRD using PE-moderated Cf (spheres with 1”,2”,3” and 4” wall thicknesses) in addition to previously mentioned sources.
- All data collected at distance of 1m from each source.



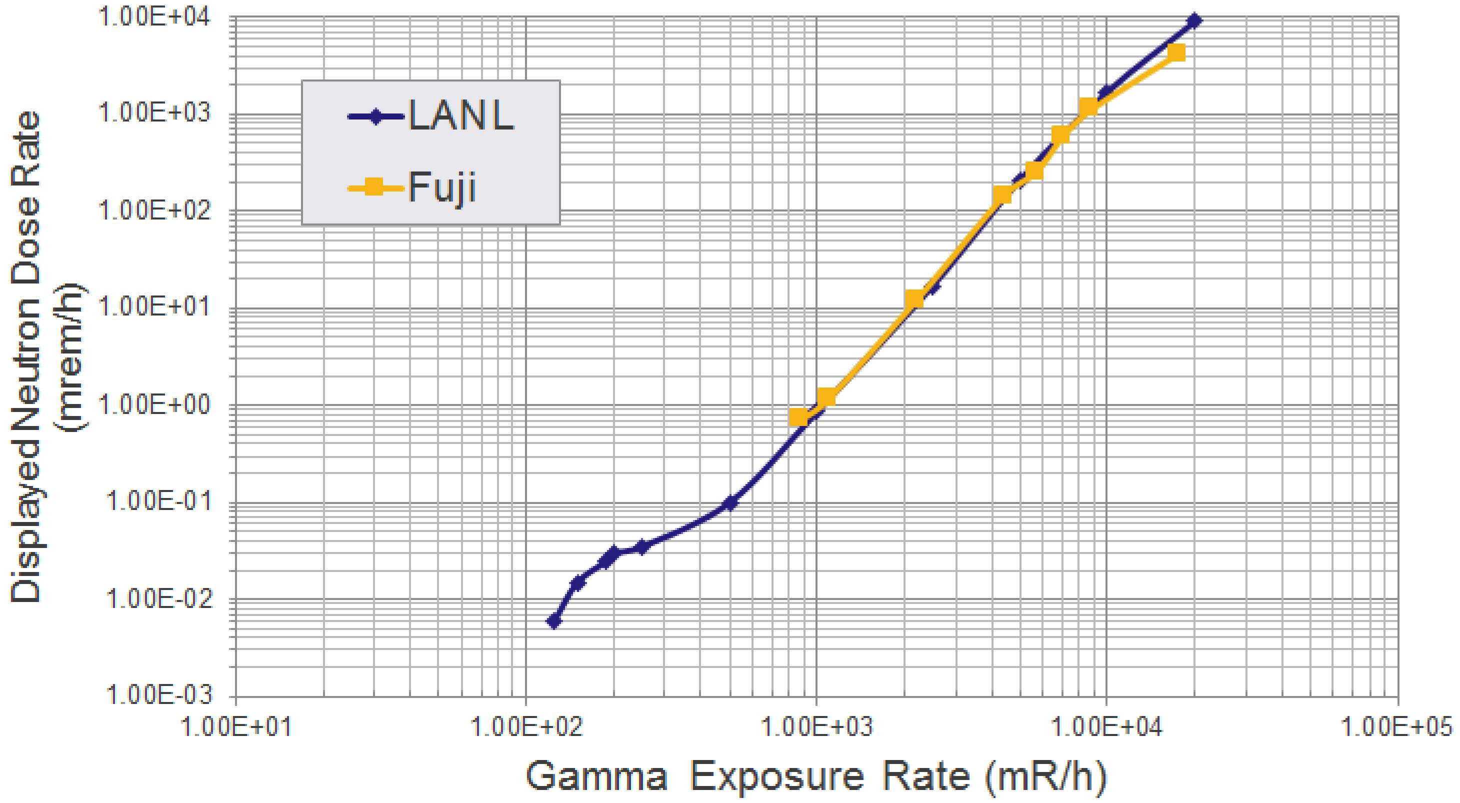
NSN3 angular response

- NSN3 angular response in vertical and horizontal directions using bare Cf source.
- Data normalized at 0º.
- Agreement with Fuji supplied-data.



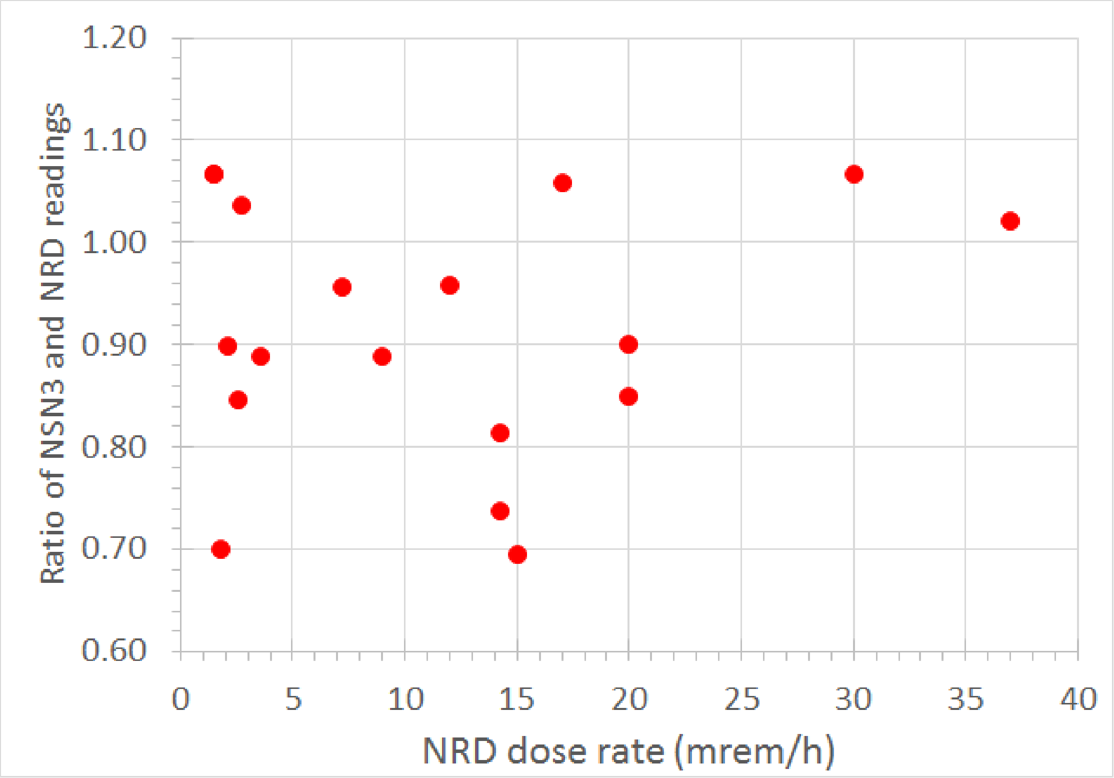
NSN3 gamma response

- Data again collected at TA36 using the gamma (^{137}Cs) calibration facility.
- Our results fully consistent with data supplied by Fuji.



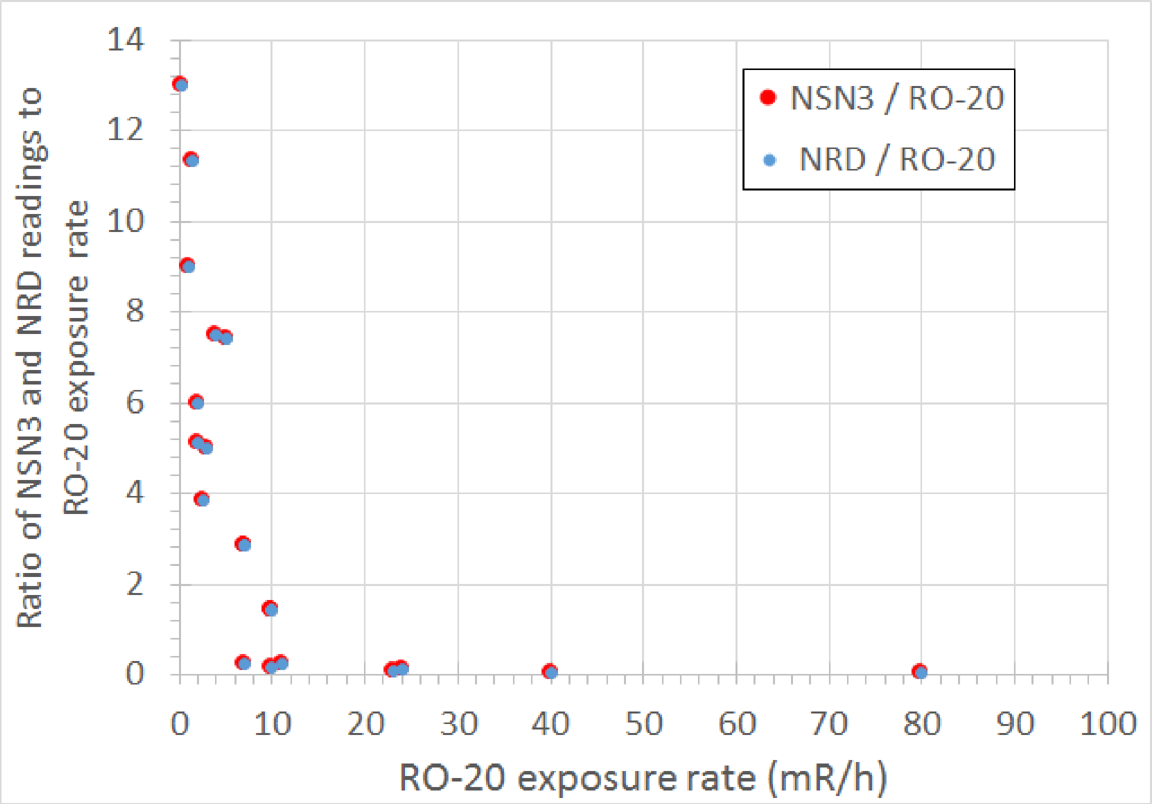
NSN3 field data

- NSN3 readings compared with “official” NRD measurements at TA54.
- Dose rates averaged over 1 minute count times.
- RO-20 data recorded at same time.
- Most NSN3 readings within -20% to +10% of NRD (implying average energies > 1MeV).



NSN3 field data

- Ratio of NSN3 and NRD dose rates to the RO-20 readings were compared.
- Both ratios are in very good agreement.
  - Implies that interference from gamma exposure rates of up to 80 mR/h have no observable effect on NSN3 readings (agrees with gamma response data shown previously).



Feedback from field

- Instrument was easy to use and menu-driven user interference was intuitive.
- Instrument's light weight was a major ergonomic advantage over the NRD.
- Display was readily readable indoors but difficult in sunlight.
- No non-rad interferences (microphonics, RF, etc ...) were noticed.
- Supplied shoulder harness allows hands-free operation.

Feedback from field and other comments

- Display assembly is fragile and was prone to damage (twice).
- Uploading of data from instrument to PC was hit and miss.
  - Repeated efforts required to get all data transferred
  - Incorrect dates logged (e.g. “1899”)
- Pressurized gas considered “hazardous” and requires a DOT special permit for shipping purposes.
- At LANL, a material-of-trade exemption allows transport between Technical Areas
  - Only requirements are that instrument must be labelled and shipped in its protective case and that driver be made aware of requirement.
- Deployment in some facilities an issue due to flammable gas filling.

The End