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Neutron Displacement Damage Sensors

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Radiation Effects and Reliability of Microelectronics

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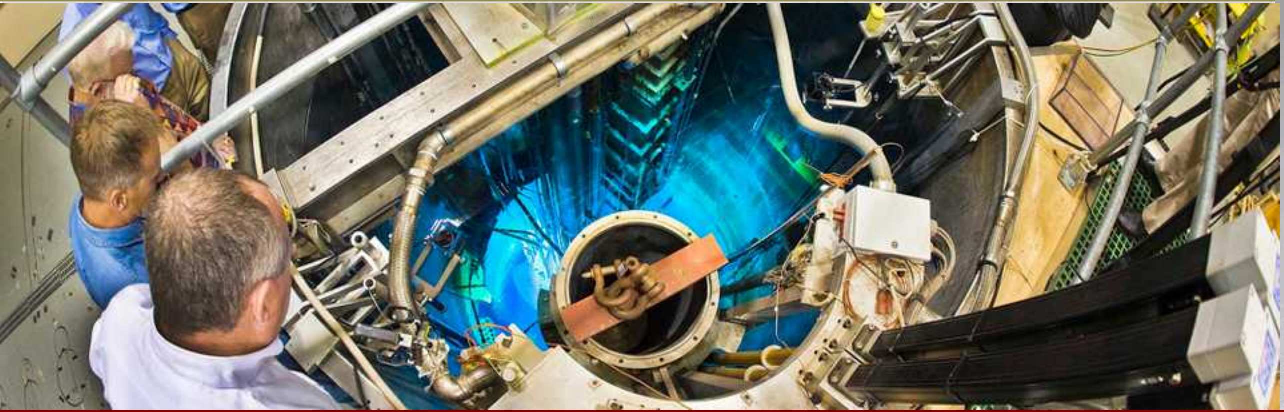
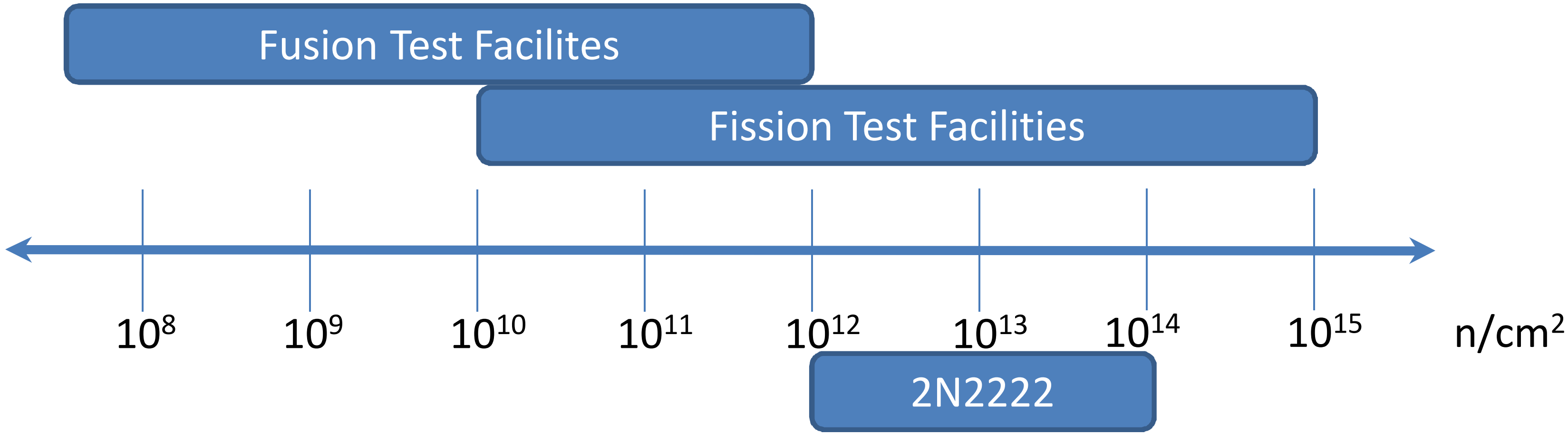


Background

- Radiation effects testing hinges on accurate measurement of radiation environments
- A currently applied method is stated in ASTM 1855
- ASTM 1855 uses a 2N2222 transistor as a displacement damage monitor in Silicon by monitoring gain degradation

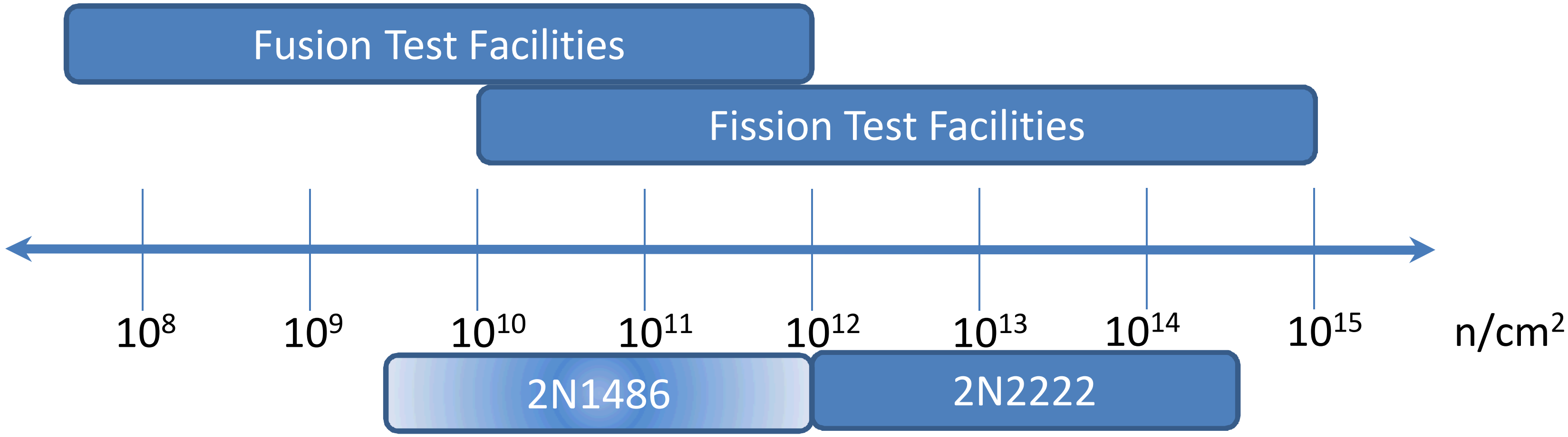
Motivation

- Radiation effects testing at fusion facilities requires displacement damage monitoring at fluences lower than the 2N2222's sensitive range



Motivation

- The 2N1486 transistor is presented as a lower fluence displacement damage monitor



Why the 2N1486?

- The 2N1486 transistor has a larger base width and according to the Messenger Spratt Relationship should be more sensitive to displacement damage

$$\frac{1}{\beta} = \frac{1}{\beta_0} + \frac{K_1 \Phi_n}{2\pi f_T}$$

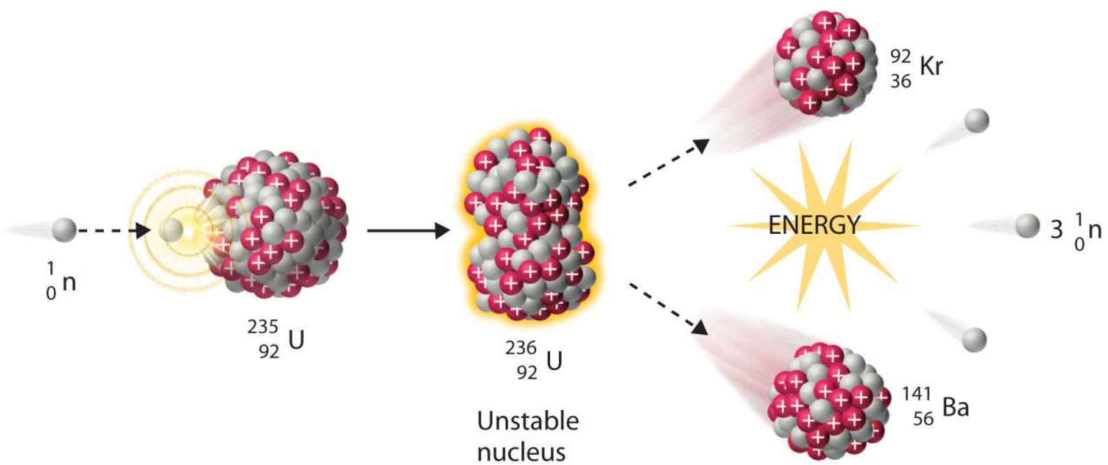
Gain after irradiation

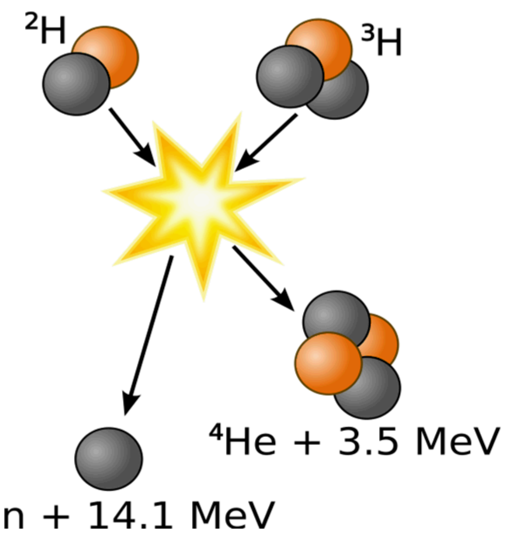
Initial Gain

$$f_T \propto \frac{1}{base\ width}$$

Fission vs. Fusion

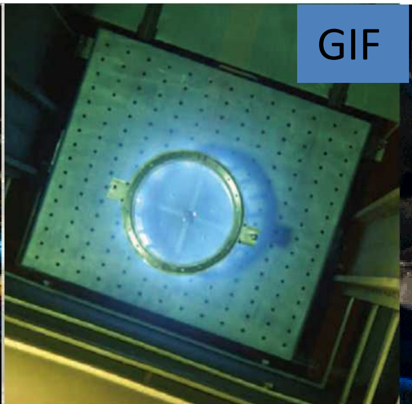
- Besides the difference in the fluence that fusion and fission sources currently produce they also produce a different *energy spectrum*

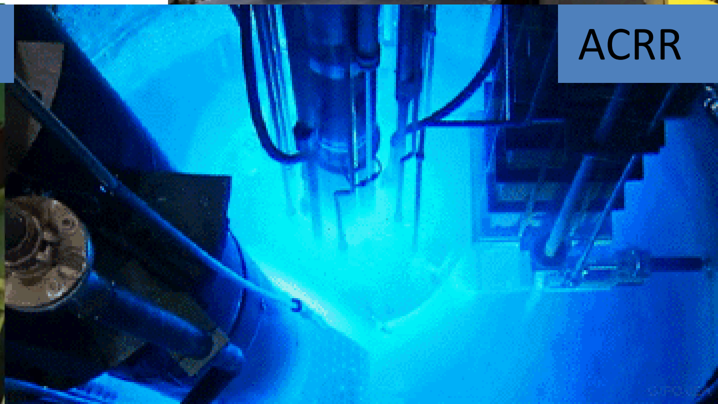




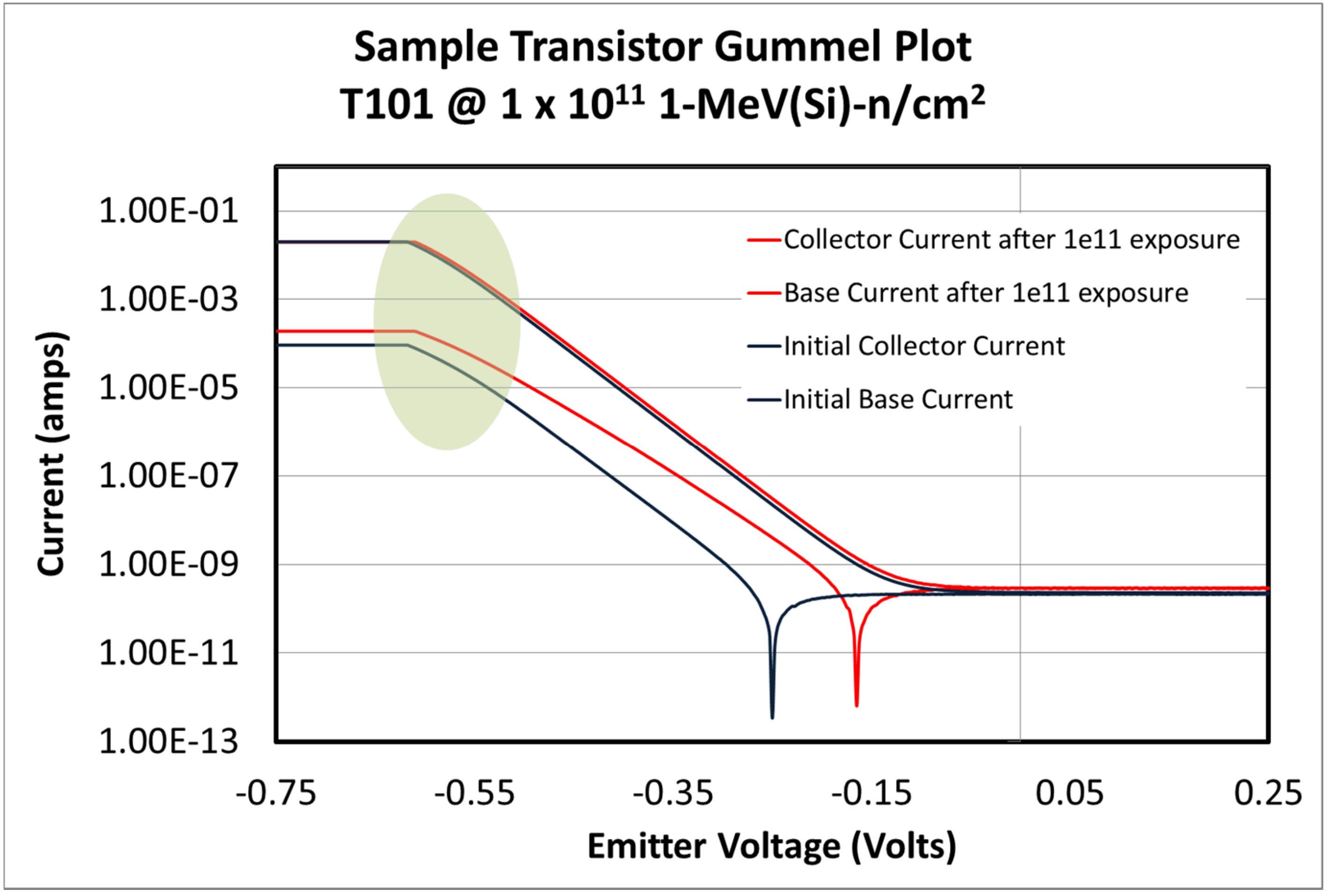
Experimental Facilities

- Annular Core Research Reactor
  - Large central cavity
  - Well-characterized epithermal flux
  - Wide range of fluences
    - Extended capability of operation's low power level monitoring allows fluences as low as 1 x 10^8 n/cm^2

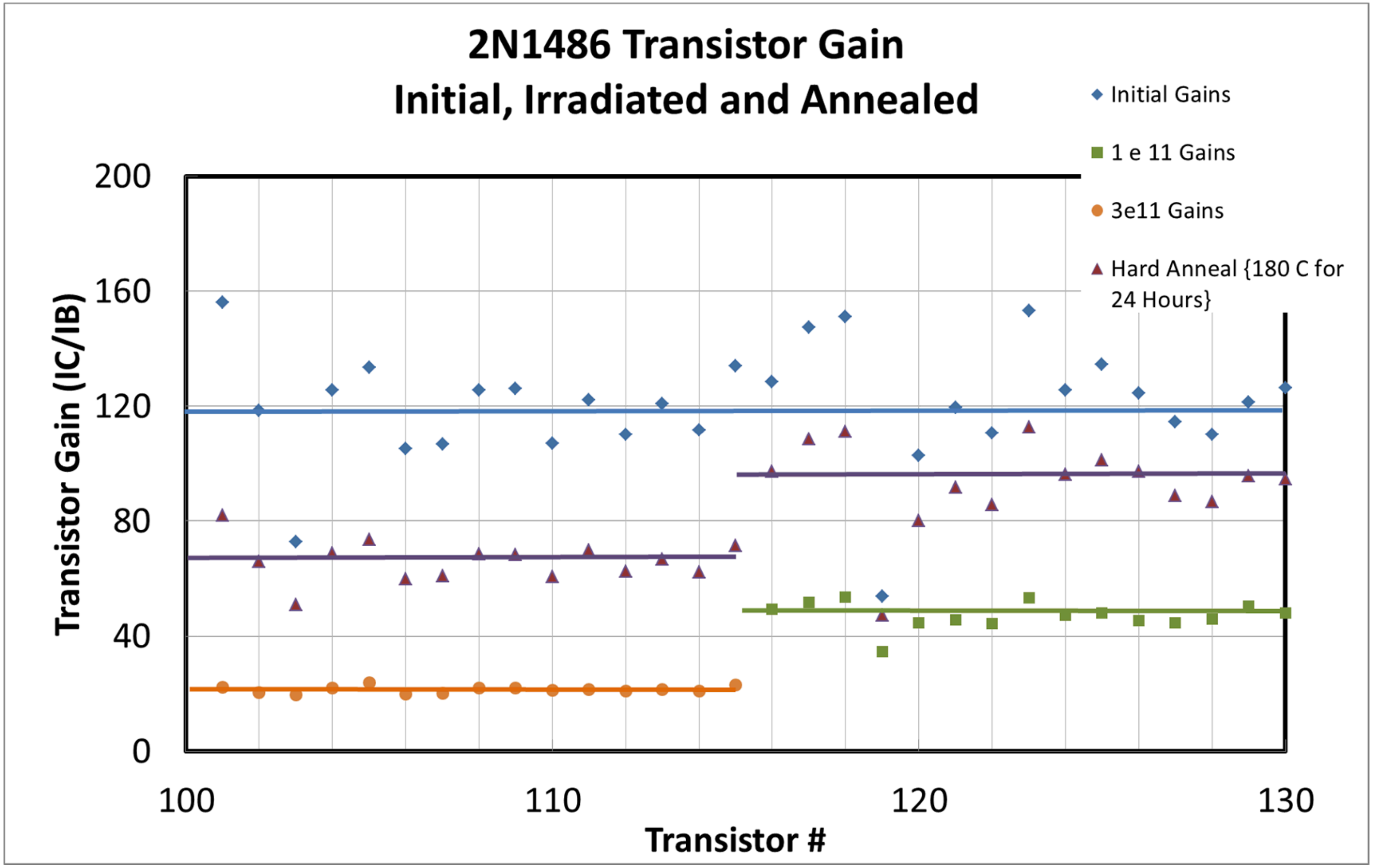




Initial 2N1486 Characterization



Gain Degradation in 2N1486



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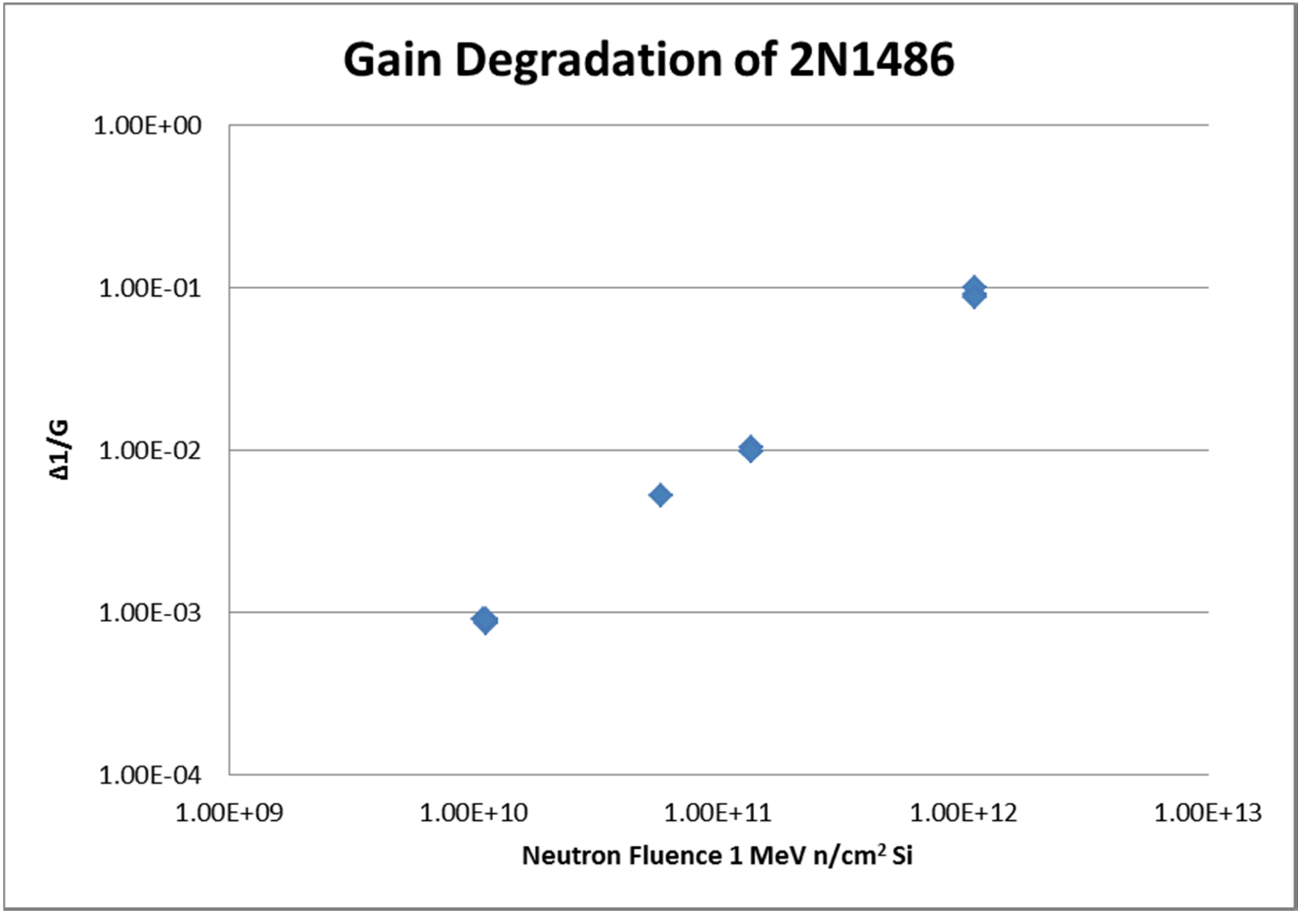
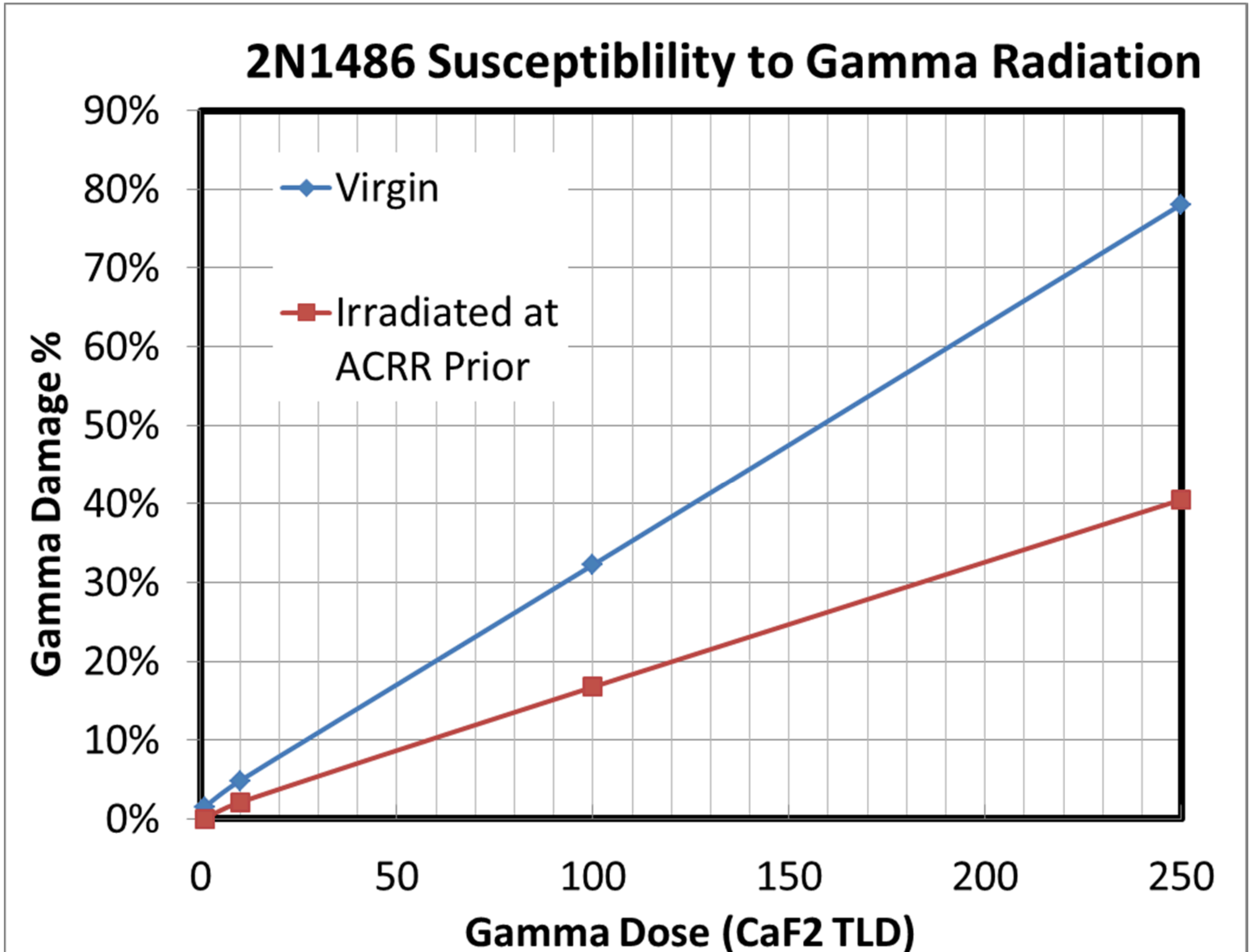


Sensor Performance

	2N1486					
1 MeV NES	Series 200 (1e10 Cal)		Series 200 (5e10 Cal)		Series 300 (Virgin)	
5.77E+08	-8.70E+08	-251%	1.63E+08	-72%	-1.10E+08	-119%
1.68E+09	-1.22E+08	-107%	1.28E+09	-24%	4.67E+08	-72%
1.13E+10	9.99E+09	-11%	1.12E+10	-1%	1.03E+10	-9%
1.36E+11	1.05E+11	-23%	1.13E+11	-17%	1.12E+11	-17%
1.11E+12	1.23E+12	11%	1.12E+12	0%	1.00E+12	-10%

	2N2222			
1 MeV NES	Series 100 (3e12 Cal)		Series V (Virgin)	
1.36E+11	1.33E+11	-2%	1.21E+11	-11%
1.11E+12	1.08E+12	-3%	1.13E+12	2%
1.11E+13	1.08E+13	-3%	1.06E+13	-4%
1.09E+14	1.10E+14	1%	1.10E+14	1%
1.29E+14	1.26E+14	-2%	1.25E+14	-3%
1.02E+15	8.53E+14	-17%	7.98E+14	-22%
1.20E+15	1.04E+15	-13%	1.03E+15	-14%

Susceptibility to Gamma Radiation



Conclusions

- The 2N1486 has been proven as an effective neutron displacement damage sensor
  - Range 1×10^{10}- 1×10^{12} 1 MeV n/cm^2 Si
- Repeated use of the 2N1486 transistor is *not recommended* beyond three times
- Future work will utilize the 2N1486 transistor at fusion facilities and heavy ion accelerators with continued attention to performance
- Modification of ASTM 1855 to allow for use of the 2N1486 at lower fluences will be proposed