

SEPTEMBER 2026

UT-AUSTIN NETL COMBINED ELECTROMAGNETIC AND NEUTRON ENVIRONMENTS TESTING CAPABILITIES

Nicholas Crenshaw^{1,2}, Michael Sheridan¹, Josh Young², William Charlton¹
¹University of Texas at Austin, ²Sandia National Laboratories

Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC (NTESS), a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration (DOE/NNSA) under contract DE-NA0003525.

Outline

- Introduction
- NETL
- Test Devices and Set Up
- Data
- Data Interpretation
- Conclusion

Introduction

- The Nuclear Engineering Teaching Laboratory (NETL) at UT-Austin is developing the capability to test electronics via combined neutron and RF stress via direct pin injection
- Work is in collaboration with Sandia National Laboratories (SNL) to study how neutron displacement damage (nDD) modifies the RF response of electronic devices
- Tests can be performed actively (device biased in-situ with RF in reactor cavity) or passively (RF injection on previously irradiated parts)

Why

- In many extreme environments, noisy EM fields are present
- Ionizing radiation exposures over the mission lifetime may alter the response of sensitive electronics to EM/RF induced noise and coupling.
- Relevant in satellites, lunar and military reactors, accelerators, fusion, defense applications



Example Lunar (top) and Military (bottom) Reactor

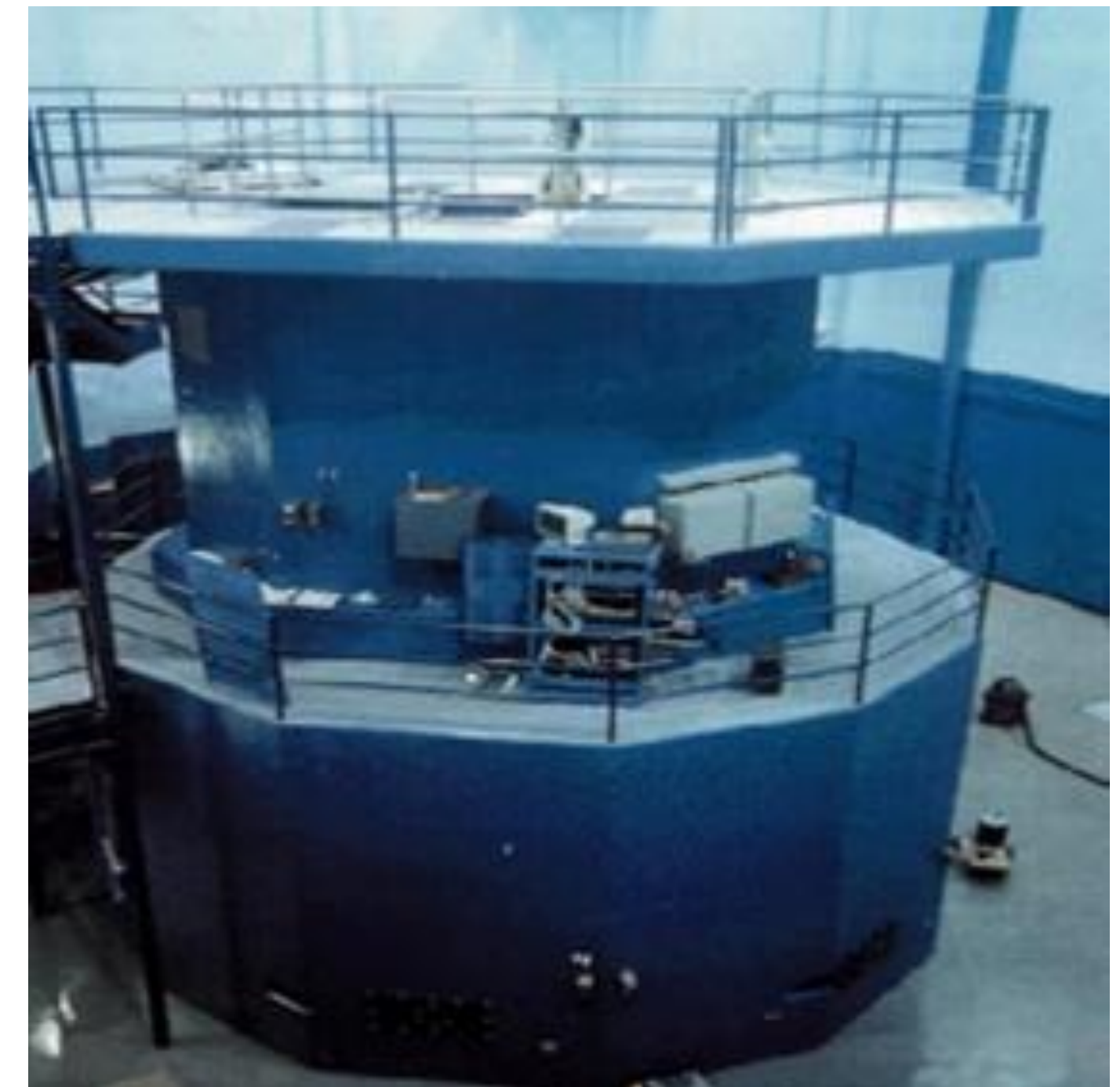
TEXAS ENGINEERING

NETL

- NETL is a 1.1 MW TRIGA MKII research reactor
- Reactor is operated in steady-state and pulsing mode
 - Max pulses is 3 with a total reactor energy of 21 MJ and pulse width of 10 ms



NETL TRIGA Core

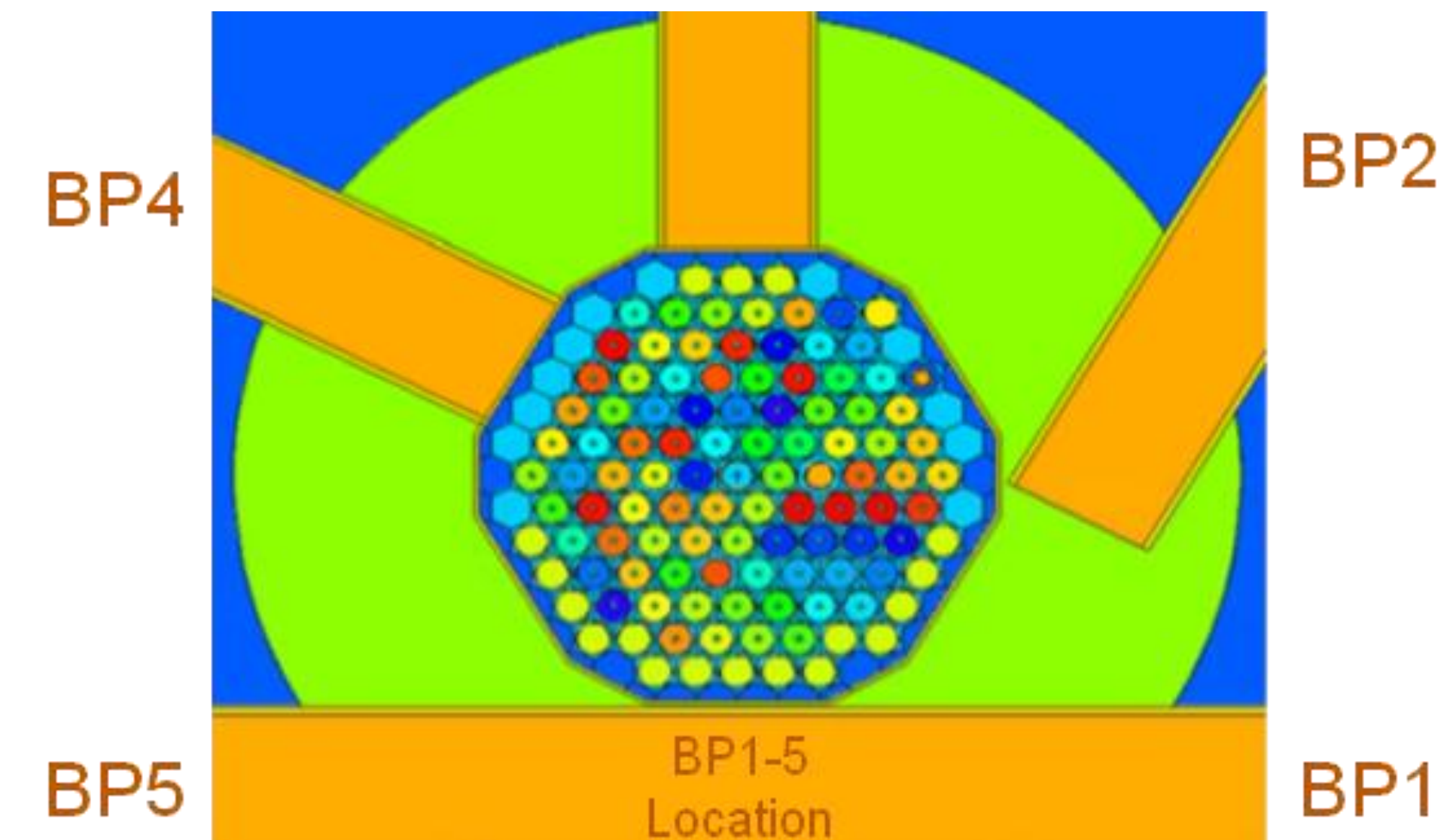


NETL Reactor Bay

TEXAS ENGINEERING

NETL

- 5 lateral beam ports used for different experiments
- Radiation effects testing mainly done in BP1
 - Dry beam port ~6 in diameter
 - Allows passive and active irradiations
- Significant gamma flux in BP1
 - Lead shield is often used to cut down gamma dose to test device



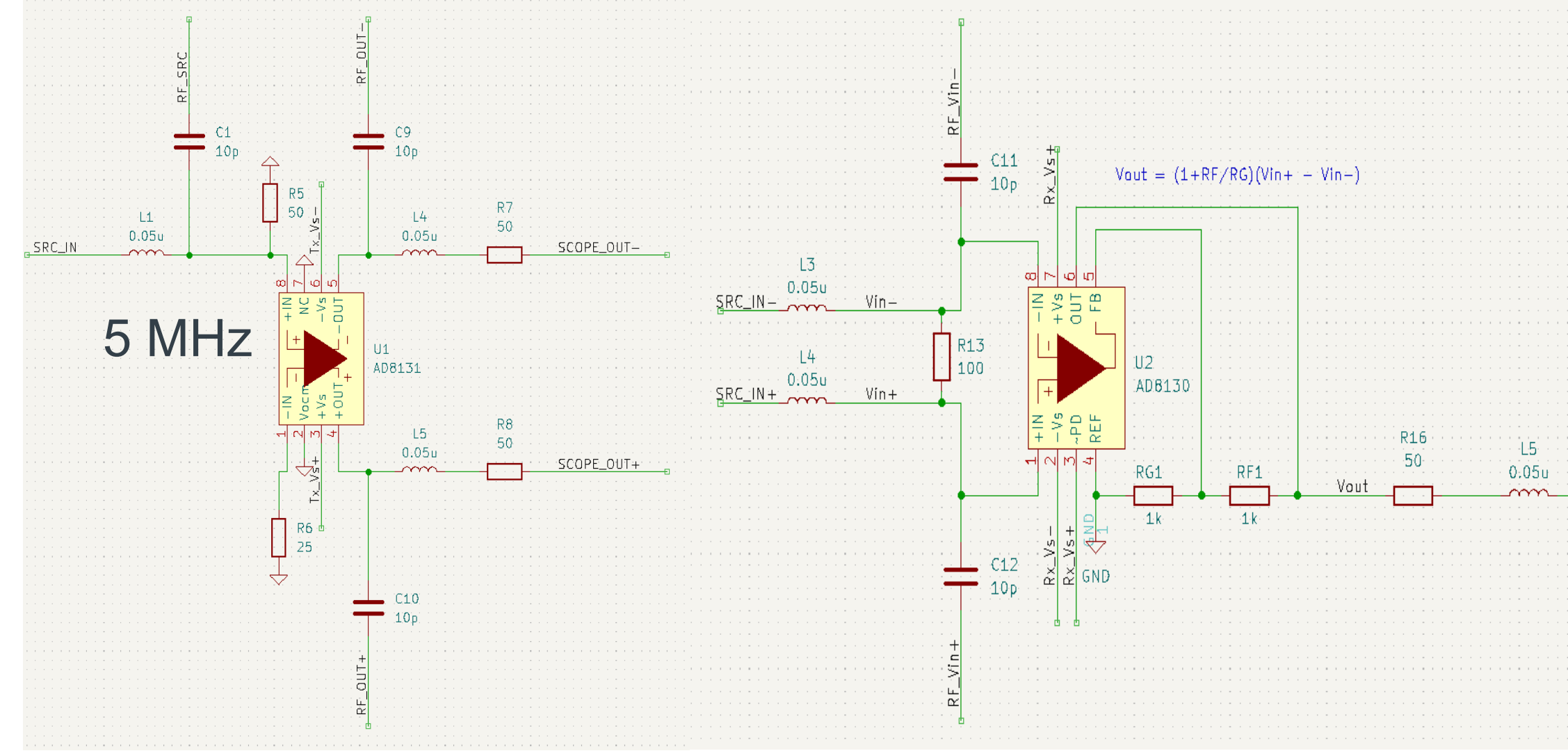
Beam Port Locations



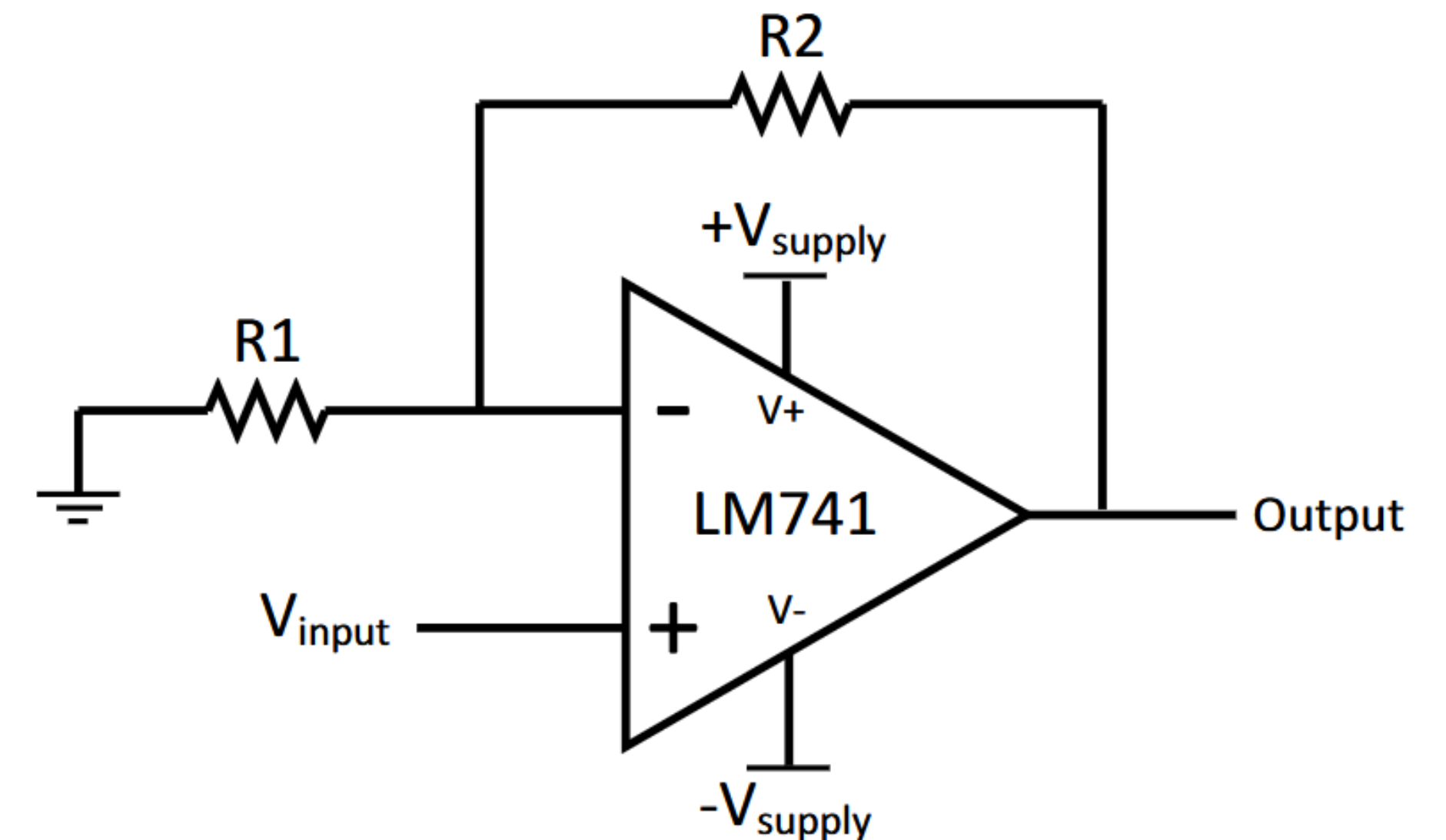
Lead Shield

Test Devices and Set Up

- All devices were irradiated up to neutron fluence levels of $3 \times 10^{13} \text{ n/cm}^2$ 1-MeV(Si).
- RF voltage injected directly onto the circuit pin ranging from 10 MHz to 10 GHz and -40 – 20 dBm (2.2 mV – 2.2 V rms on a 50-ohm load)
- LM741
 - Common Operational Amplifier
 - Biased to 15 V
- AD8130 & AD8131
 - Differential Amplifiers
 - 5 MHZ signal used as input to represent a databus



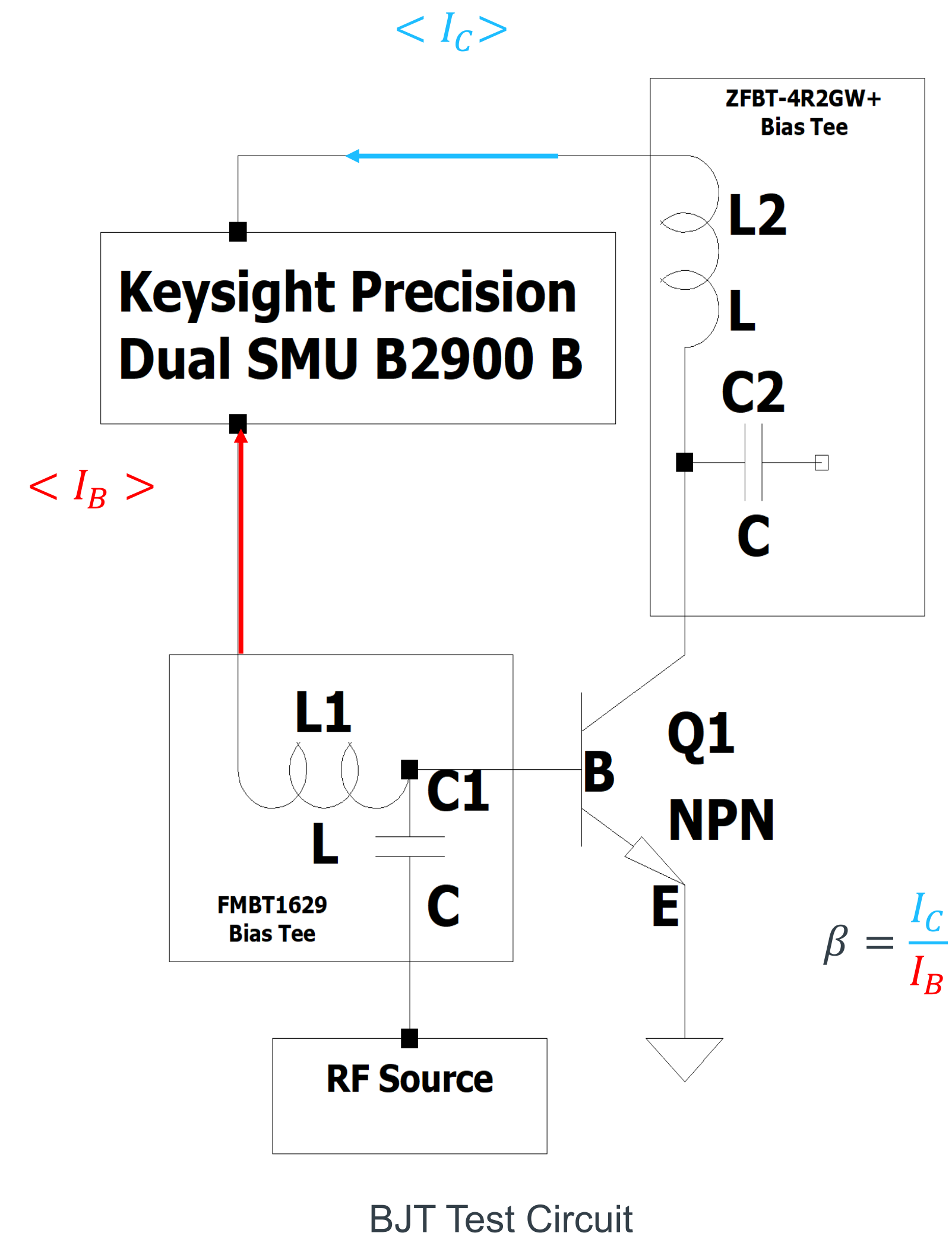
AD8131 (left) and AD8130 (right)



LM741

Test Devices and Set Up

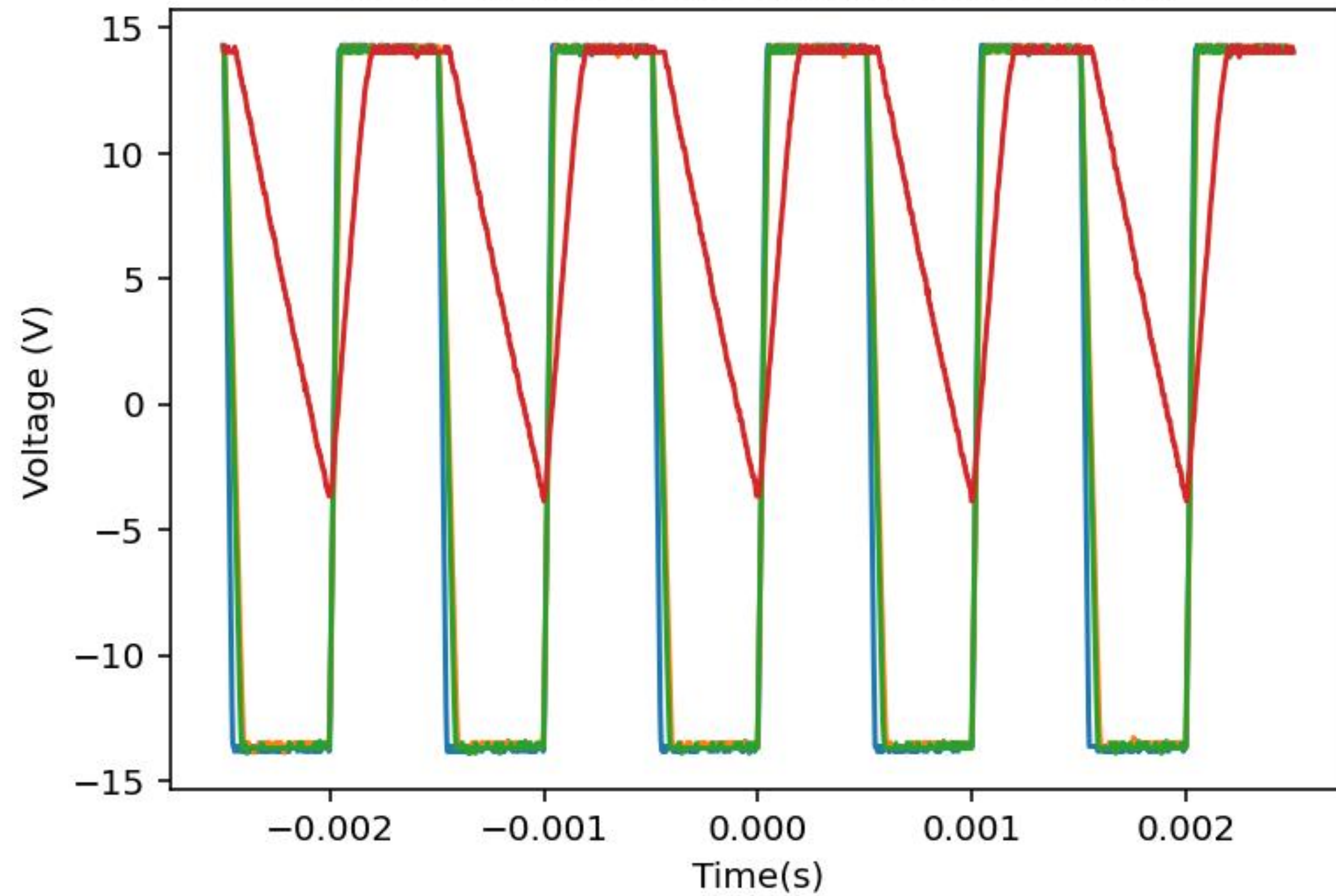
- 2N2222A
 - Commonly tested NPN BJT
 - $V_{CE} = 1\text{ V}$
- 2N5179
 - RF NPN BJT
 - $V_{CE} = 1\text{ V}$
- Bias tees used to inject RF and protect source and SMU
 - Inductor in bias tee will time average measured currents
- LM741 was tested at NETL and the rest were irradiated at SNL Annular Core Research Reactor (ACRR)



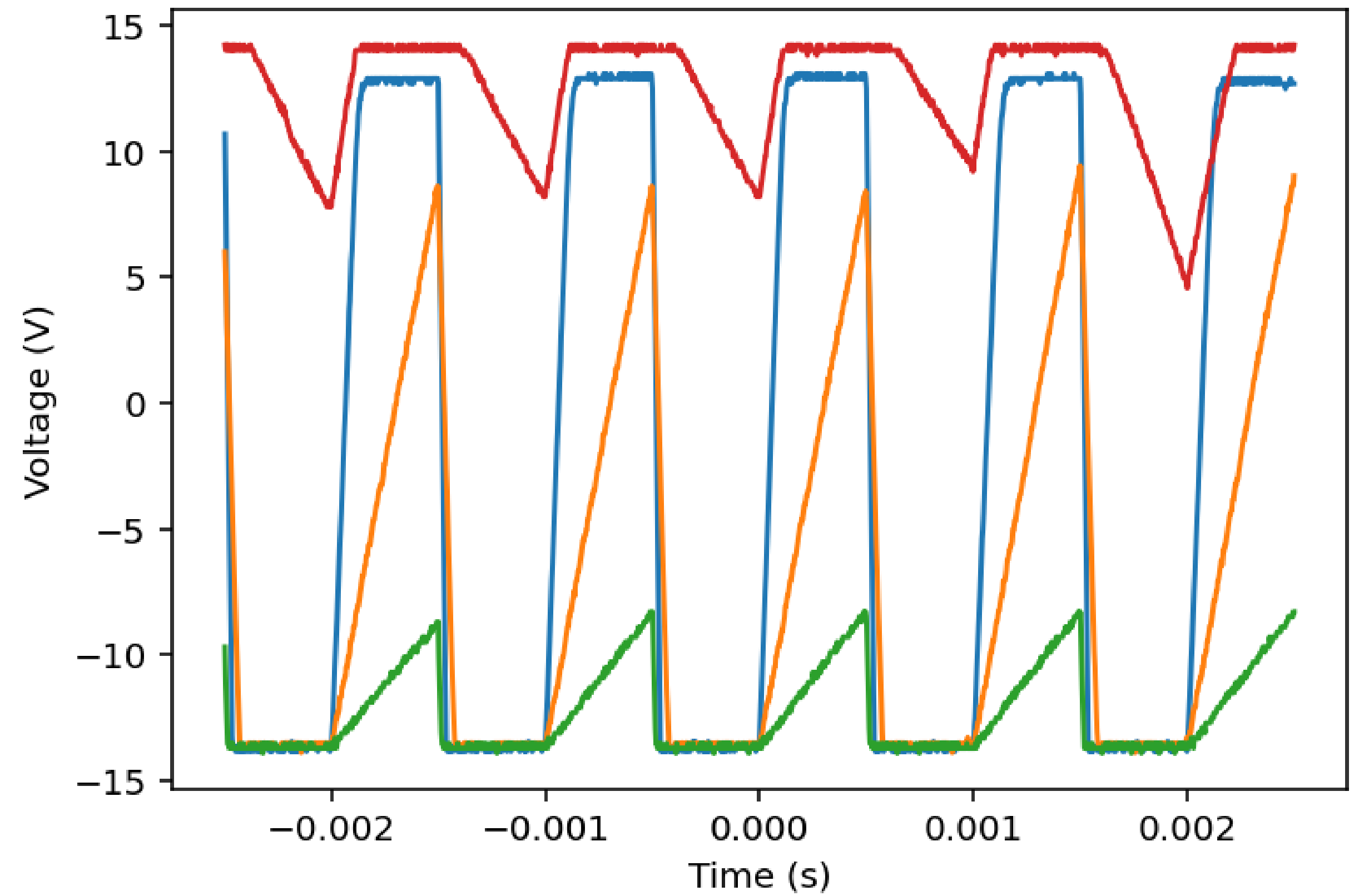
TEXAS ENGINEERING

LM741 Data

No RF at various Neutron Fluences Pin 1



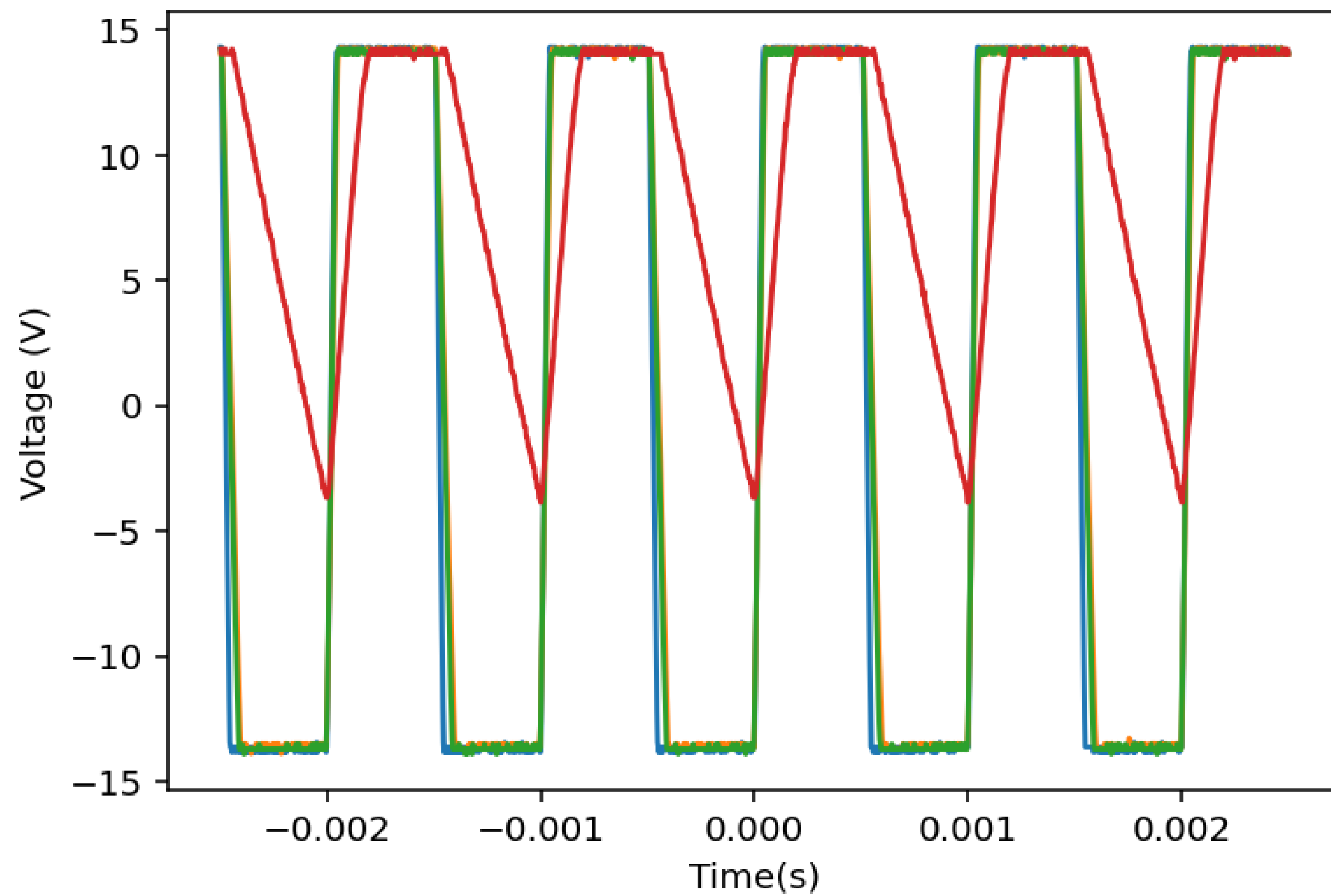
10 MHz 0 dBm at various Neutron Fluences Pin 1



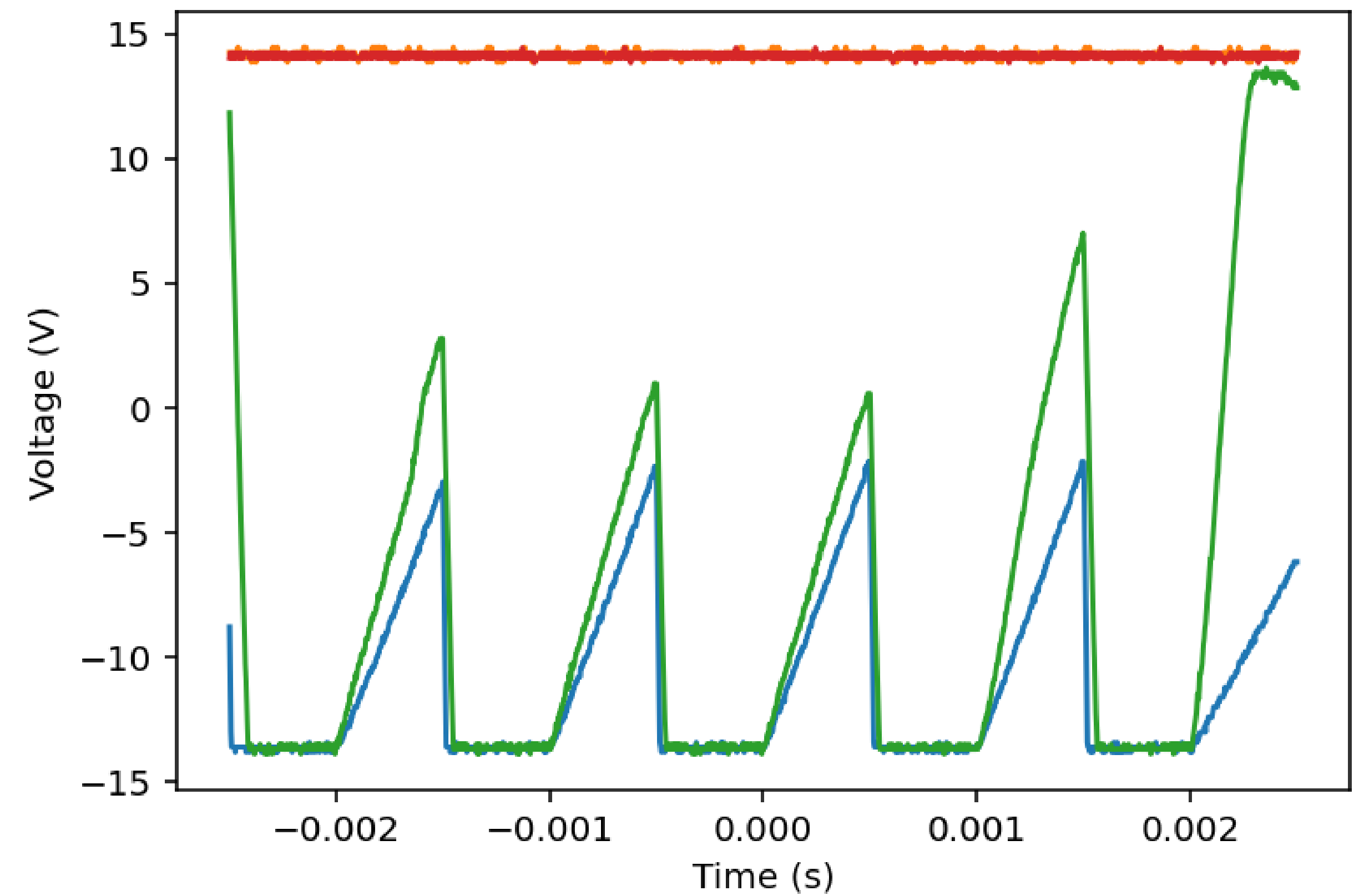
TEXAS ENGINEERING

LM741 Data

No RF at various Neutron Fluences Pin 1



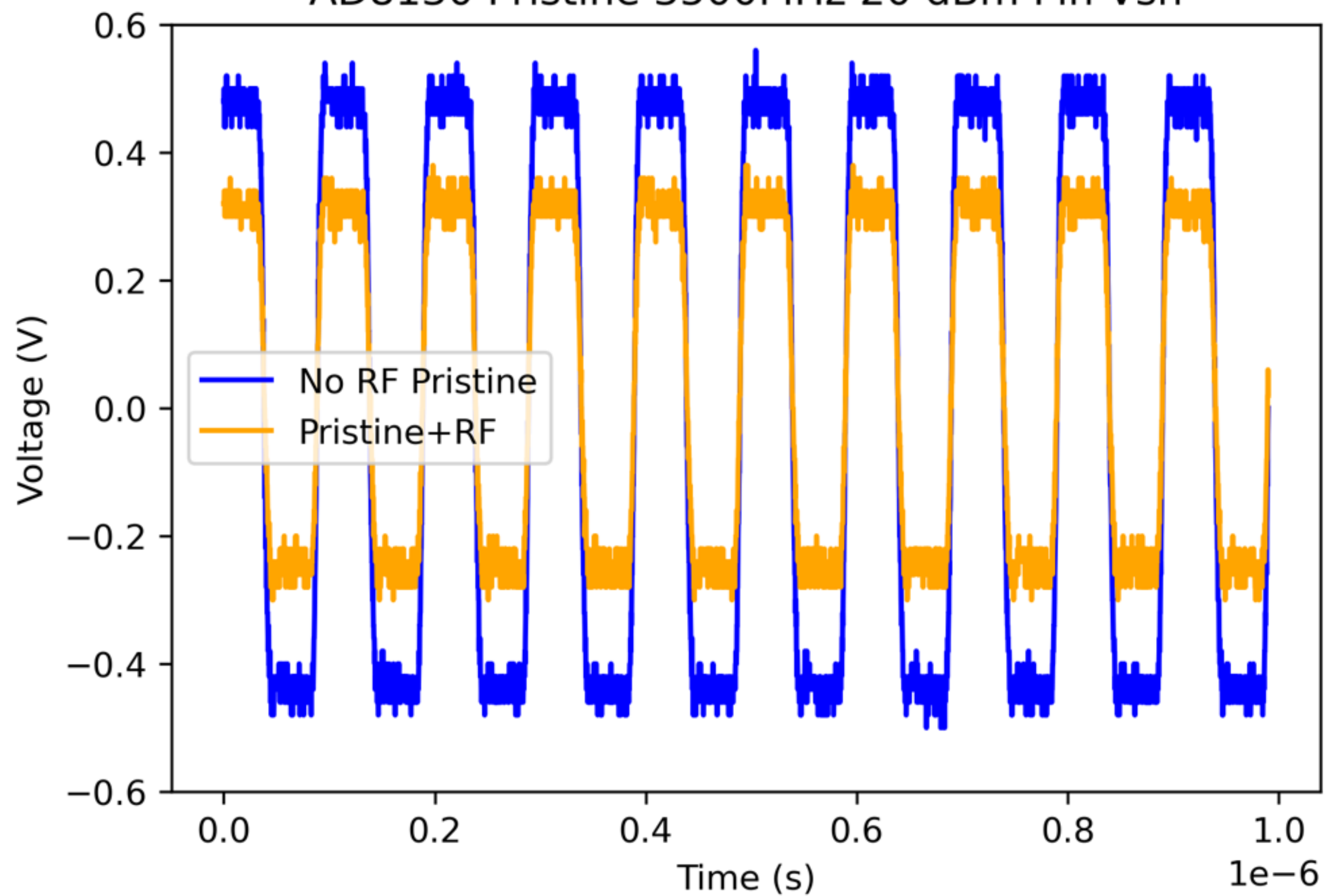
10 MHz 5 dBm at various Neutron Fluences Pin 1



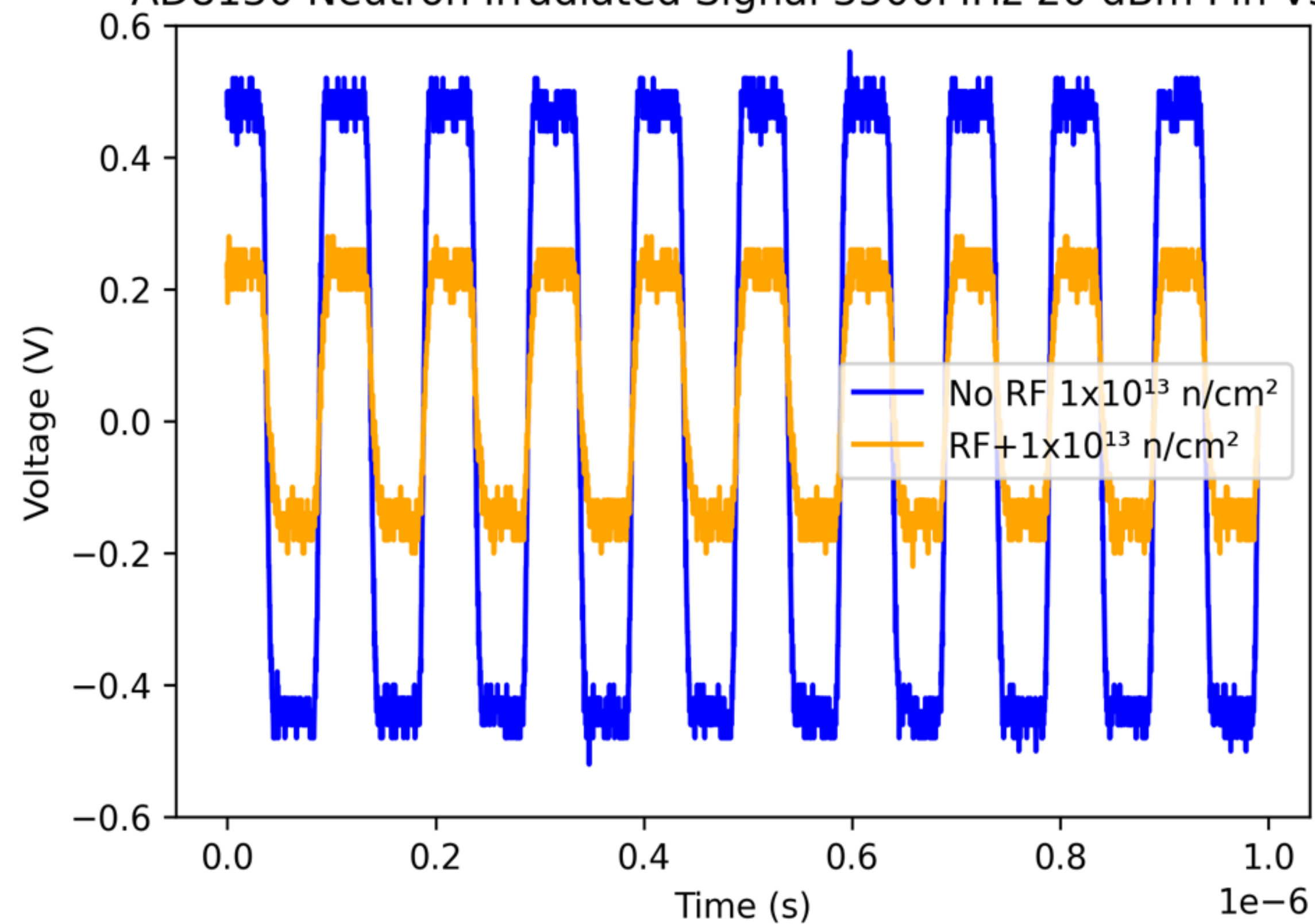
TEXAS ENGINEERING

AD8130 Data

AD8130 Pristine 3500MHz 20 dBm Pin Vsn

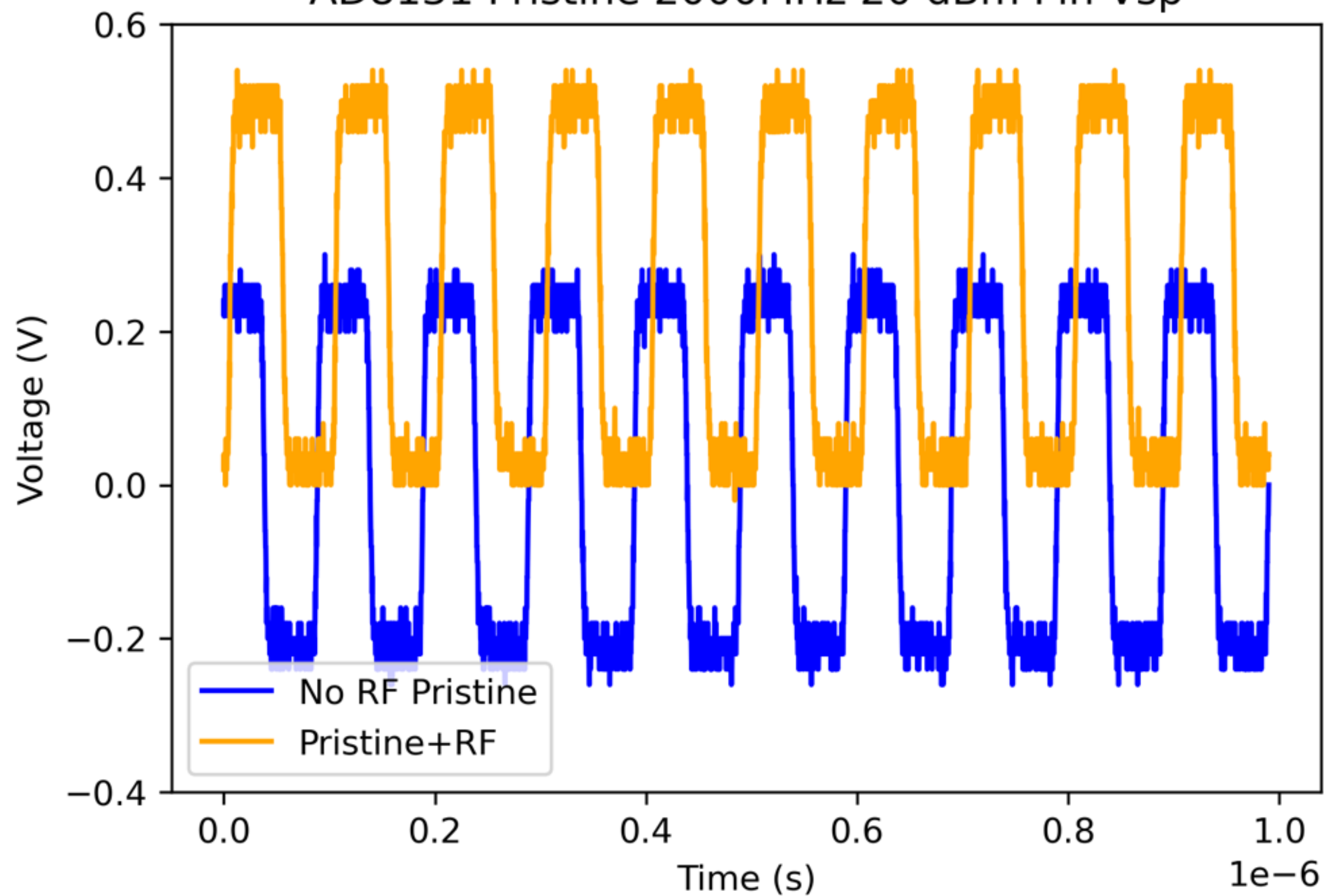


AD8130 Neutron Irradiated Signal 3500MHz 20 dBm Pin Vsn

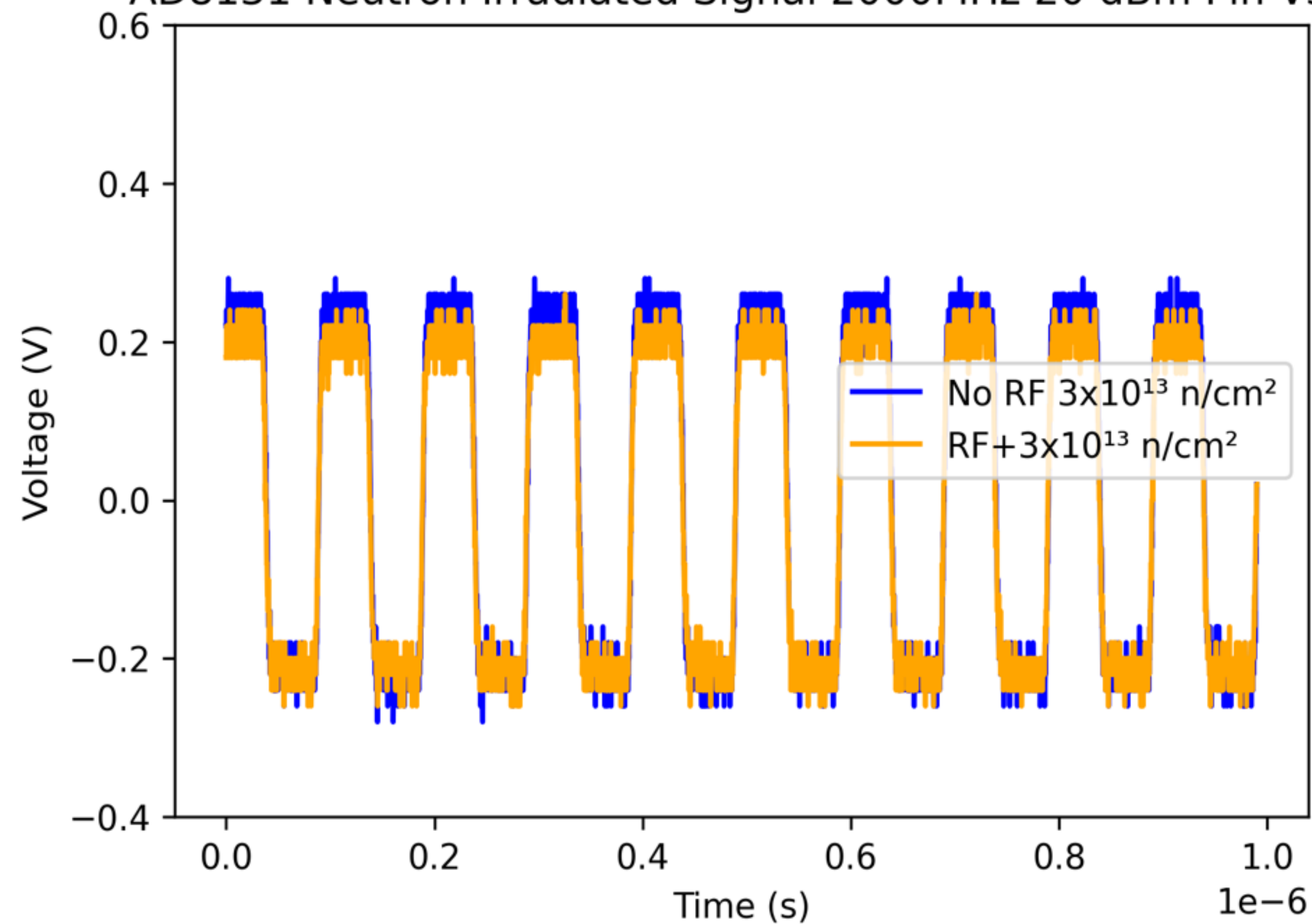


AD8131 Data

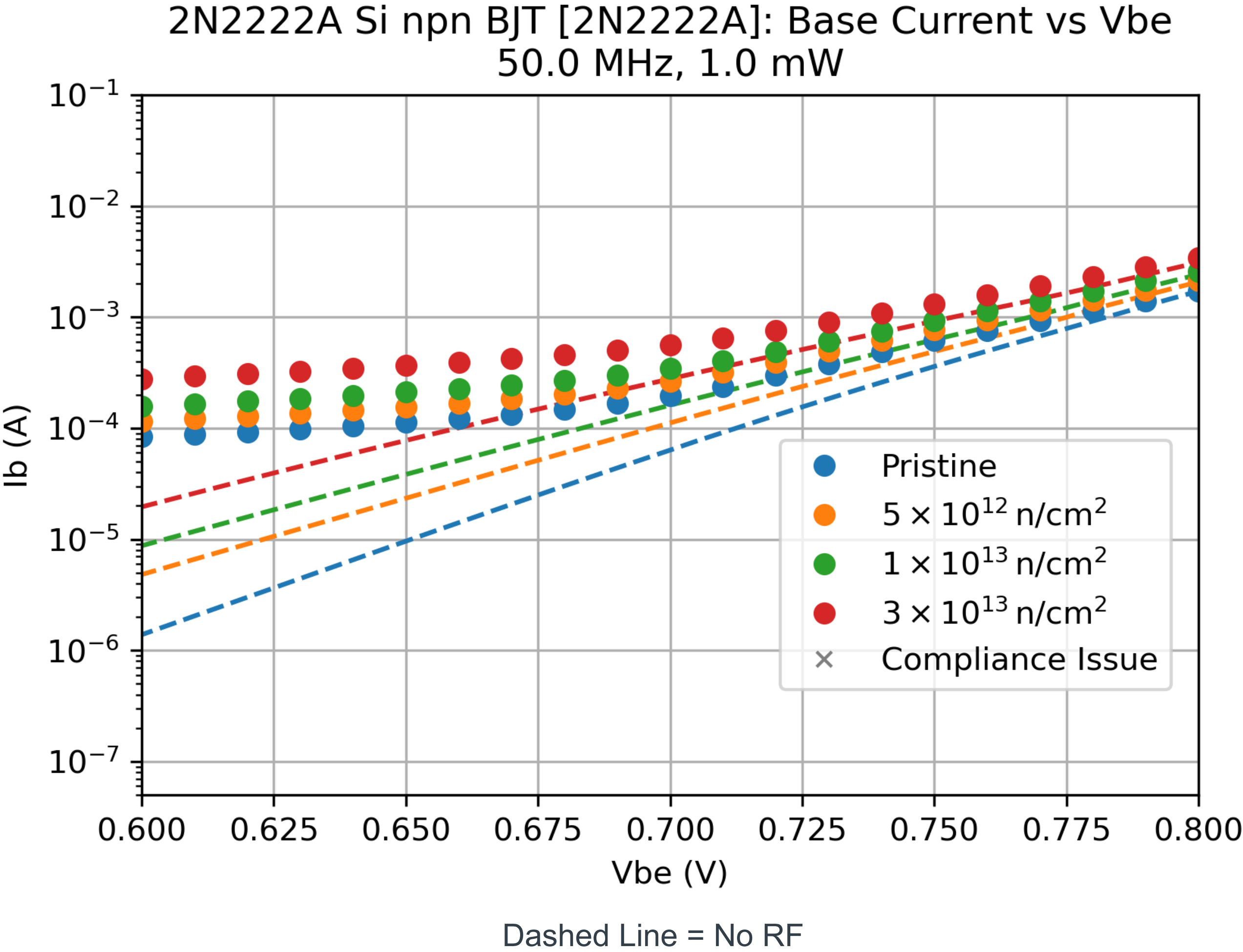
AD8131 Pristine 2000MHz 20 dBm Pin Vsp



AD8131 Neutron Irradiated Signal 2000MHz 20 dBm Pin Vsp

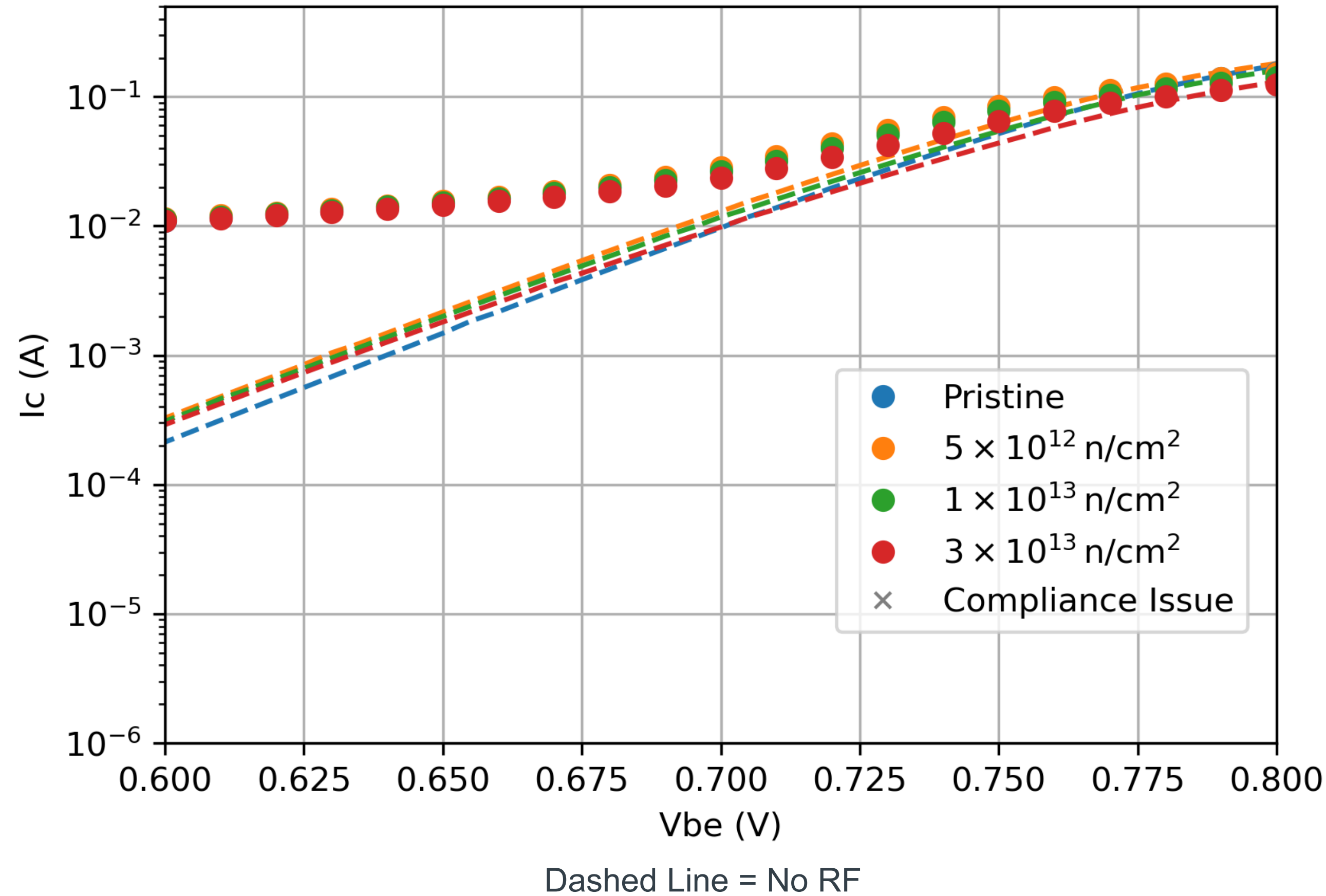


2N2222 Data

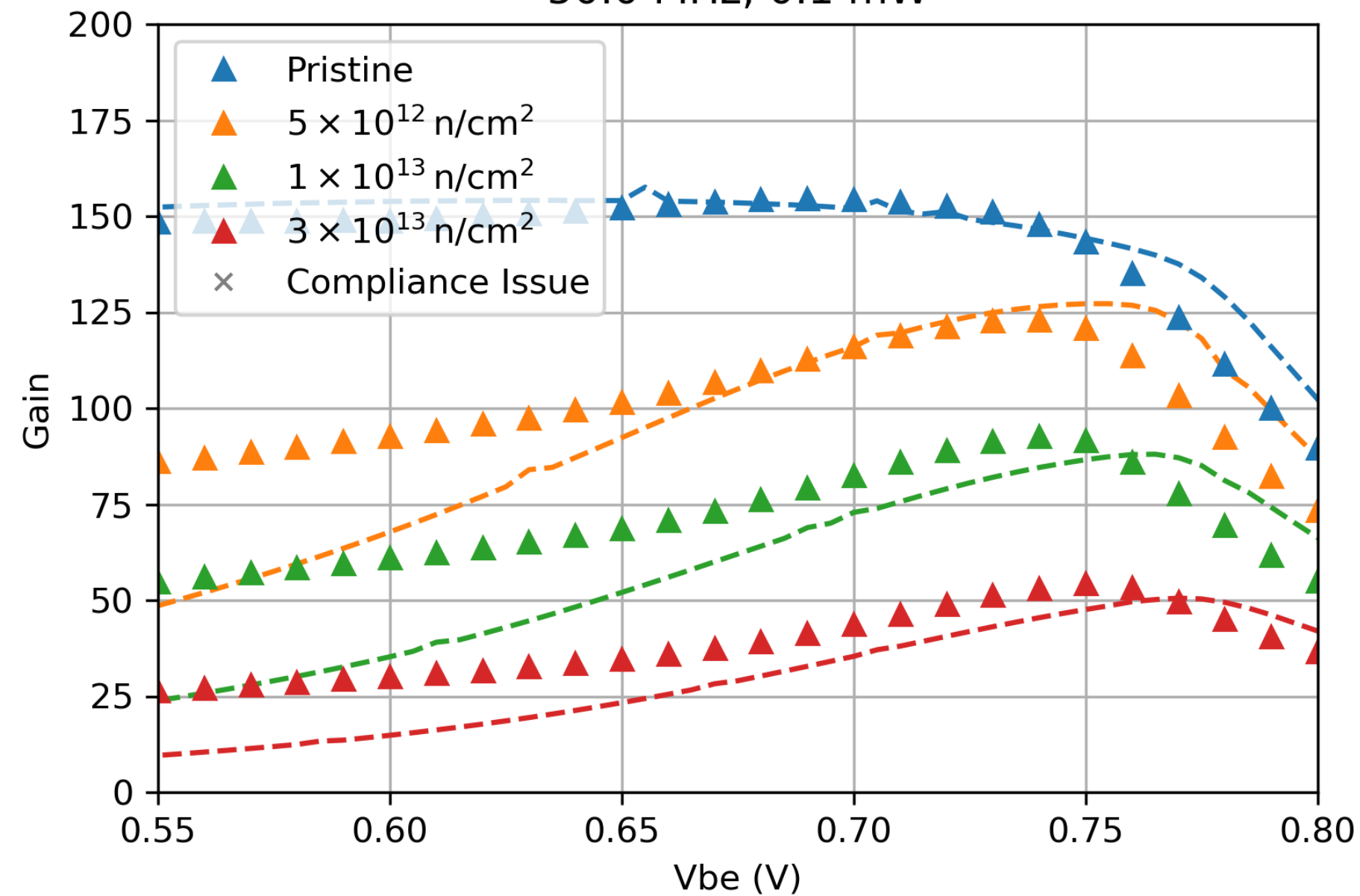


2N2222 Data

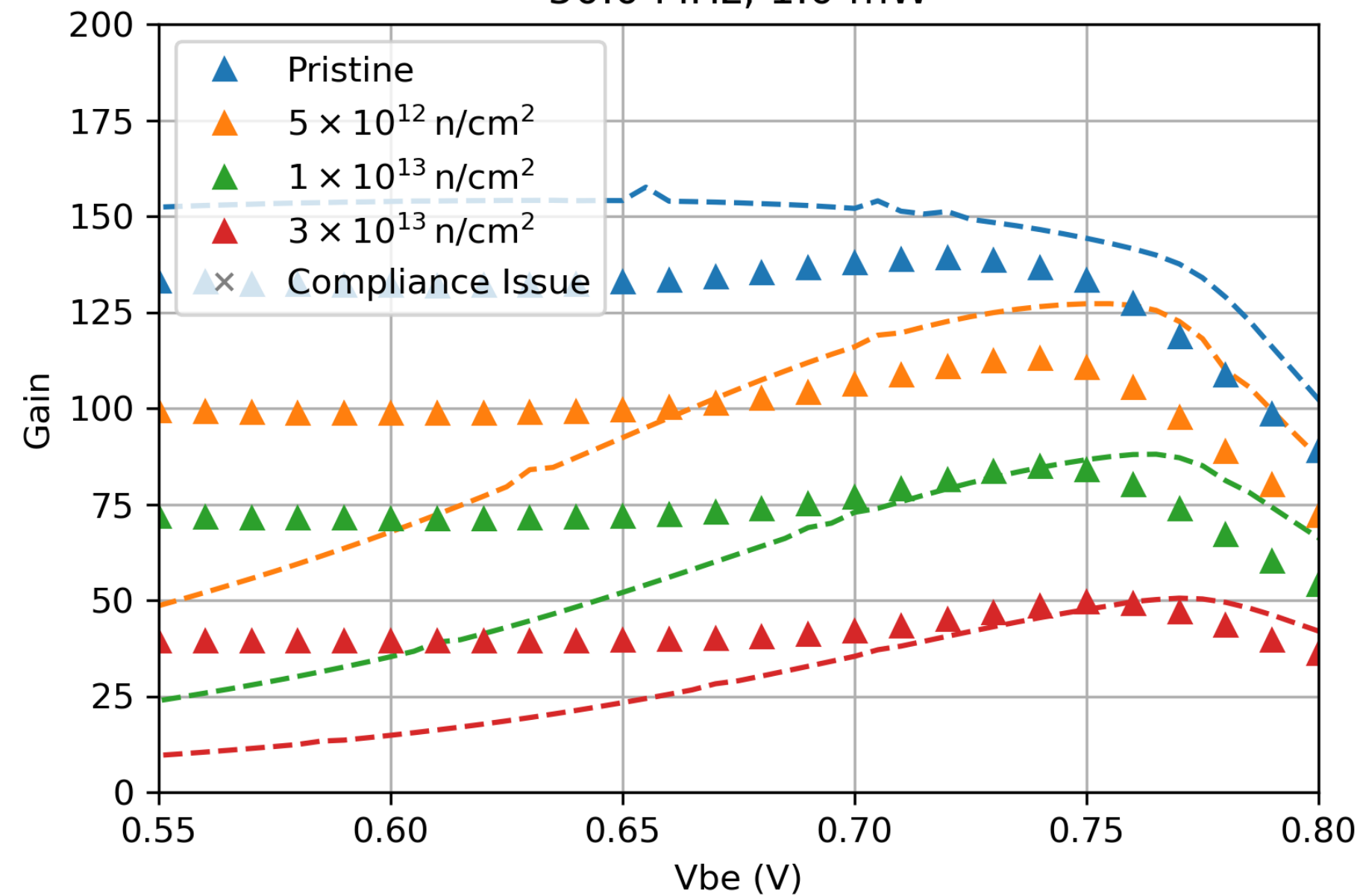
2N2222A Si npn BJT [2N2222A]: Collector Current vs Vbe
50.0 MHz, 1.0 mW



2N2222A Si npn BJT [2N2222A]: Gain vs Vbe
50.0 MHz, 0.1 mW

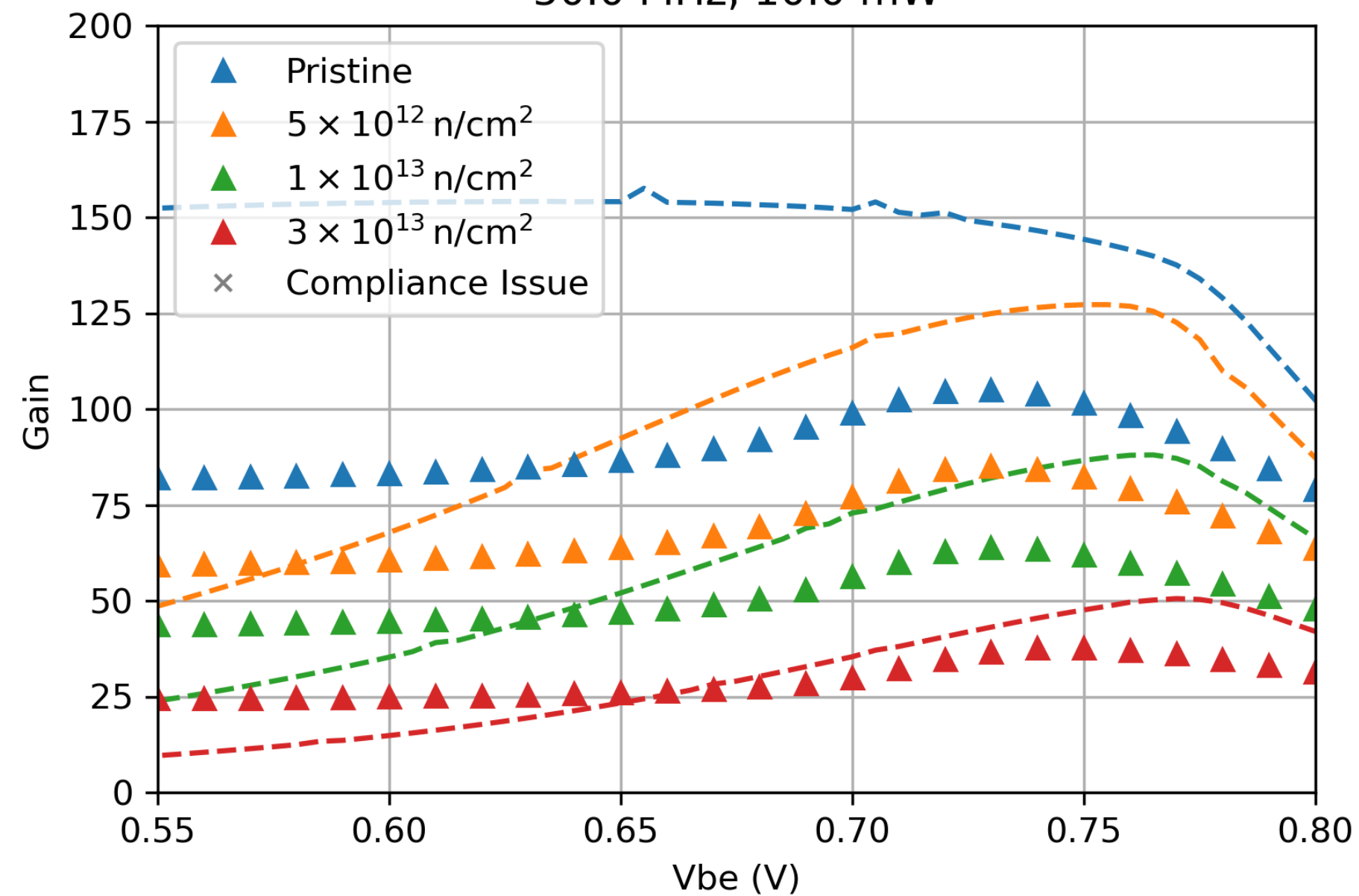


2N2222A Si npn BJT [2N2222A]: Gain vs Vbe
50.0 MHz, 1.0 mW

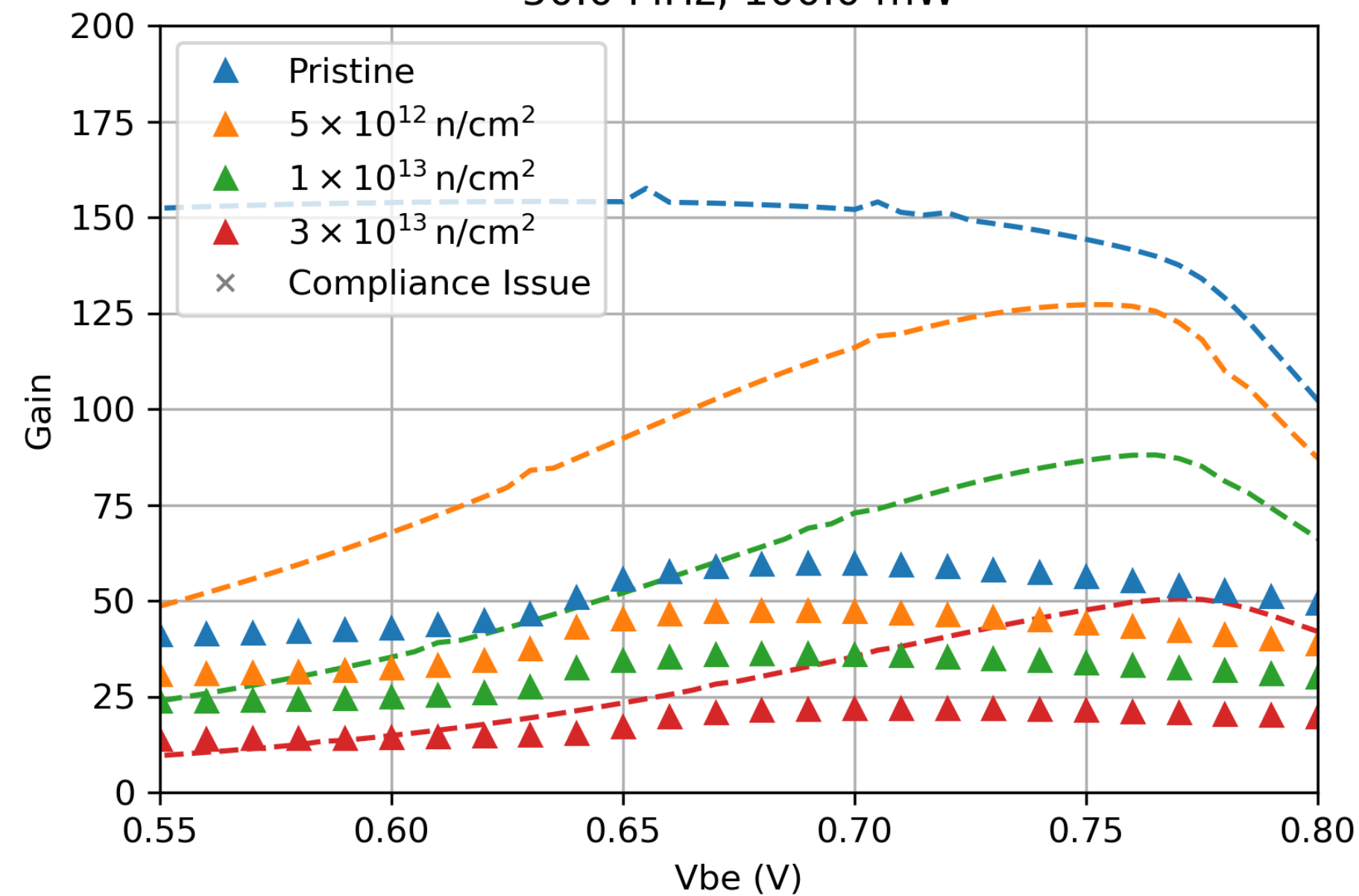


Dashed Line = No RF

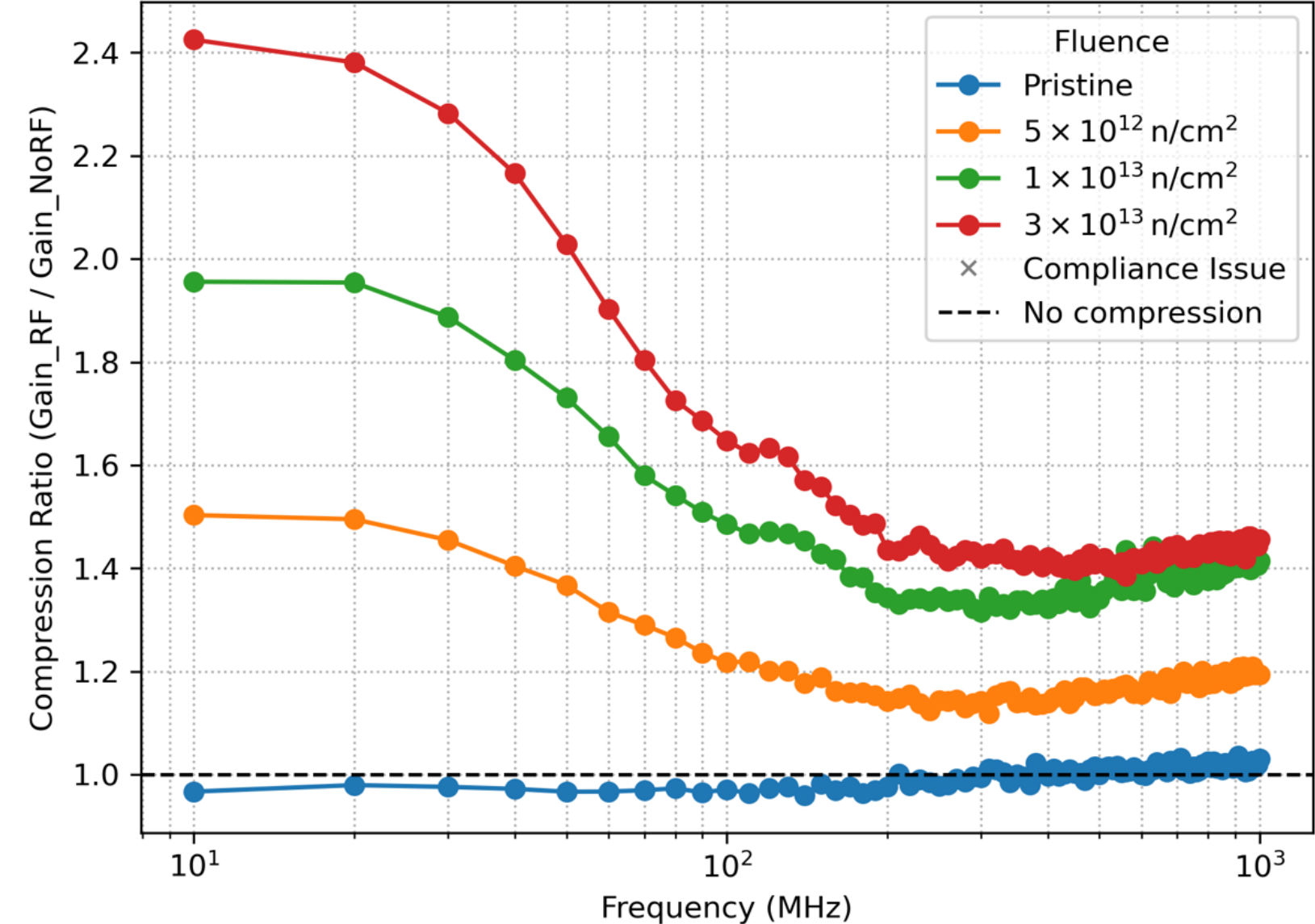
2N2222A Si npn BJT [2N2222A]: Gain vs Vbe
50.0 MHz, 10.0 mW



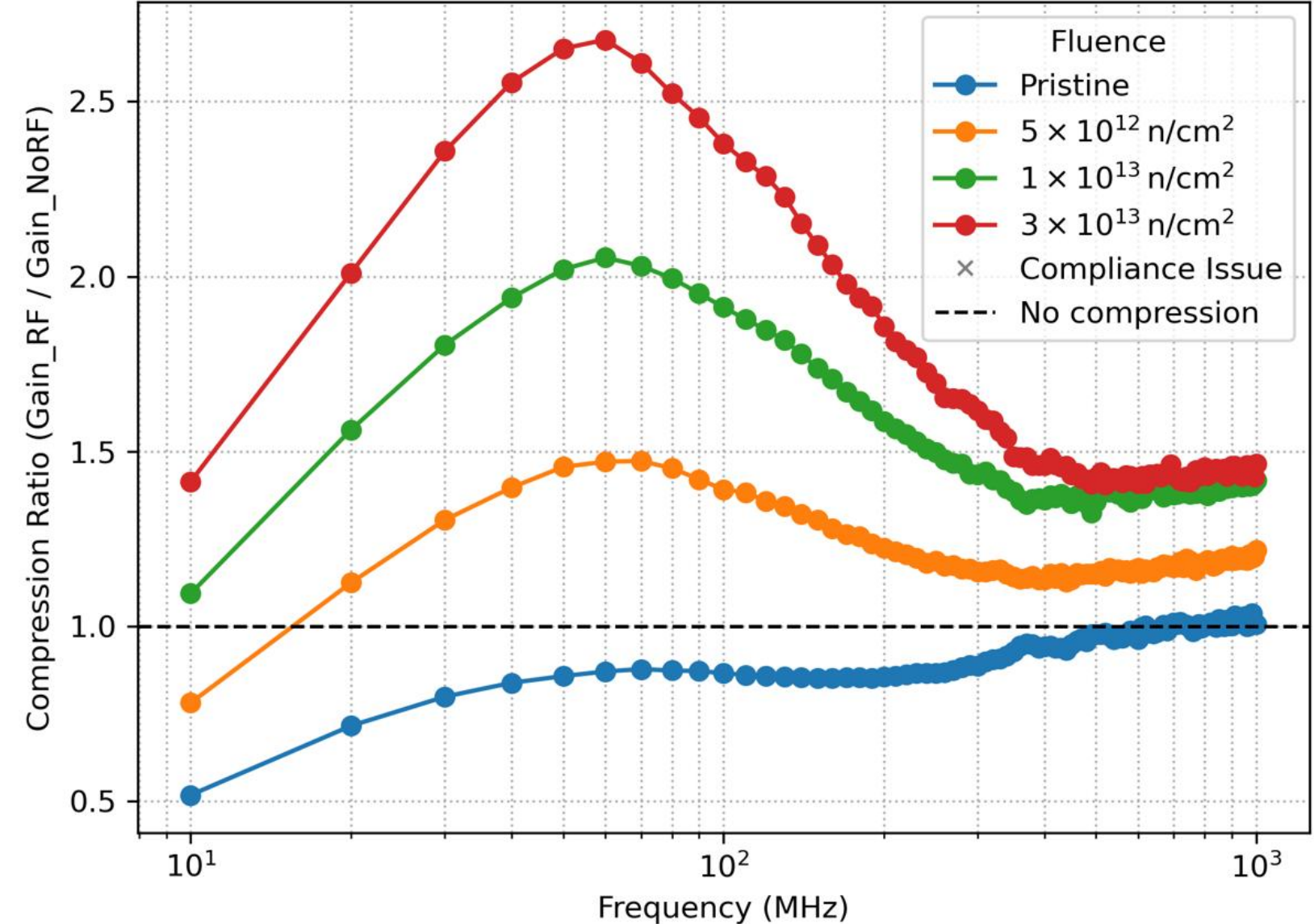
2N2222A Si npn BJT [2N2222A]: Gain vs Vbe
50.0 MHz, 100.0 mW



2N2222A Si npn BJT [2N2222A]: Compression Ratio vs Frequency at Fixed Power
P = -10 dBm, Vbe = 0.60 V

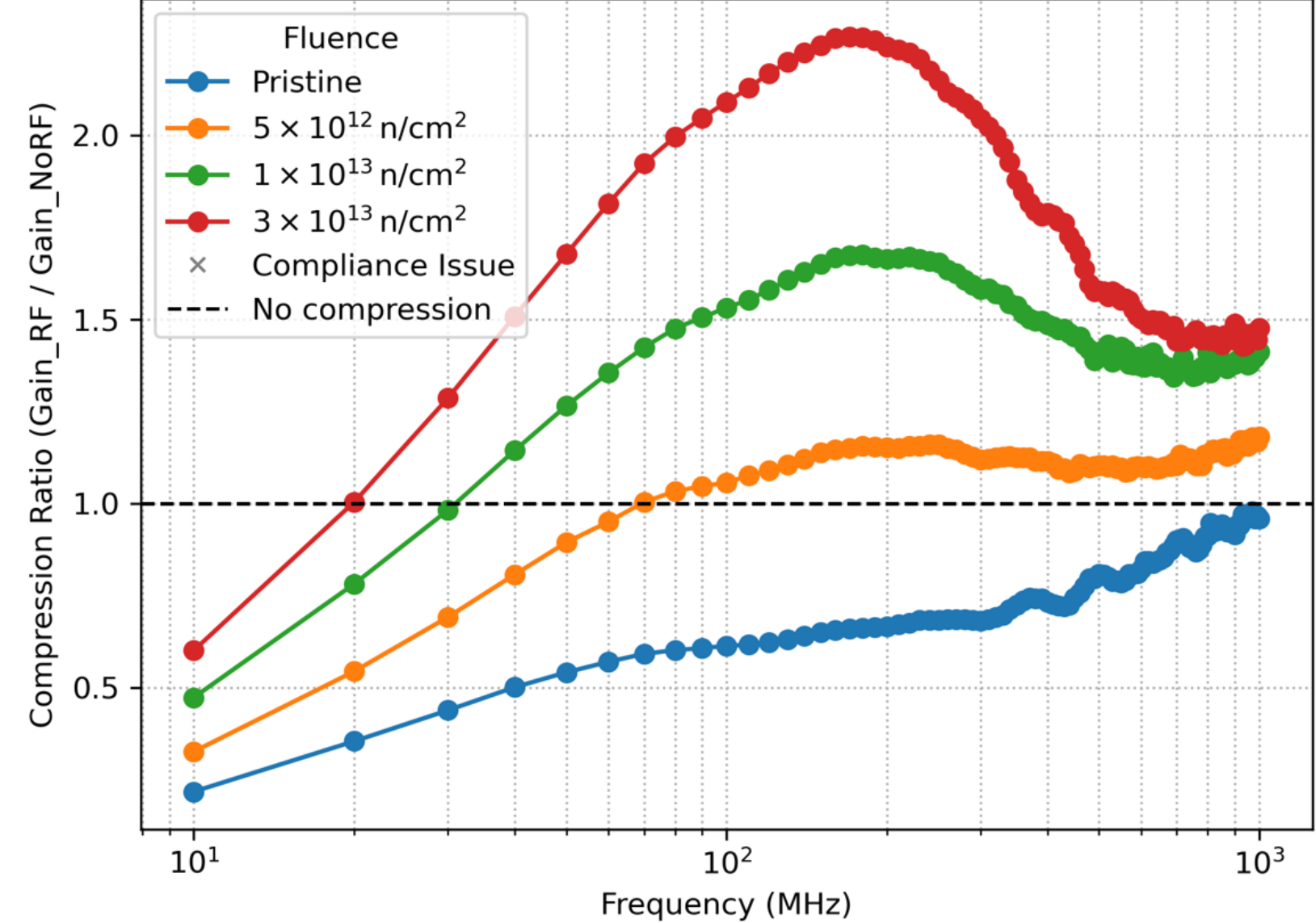


2N2222A Si npn BJT [2N2222A]: Compression Ratio vs Frequency at Fixed Power
P = 0 dBm, Vbe = 0.60 V

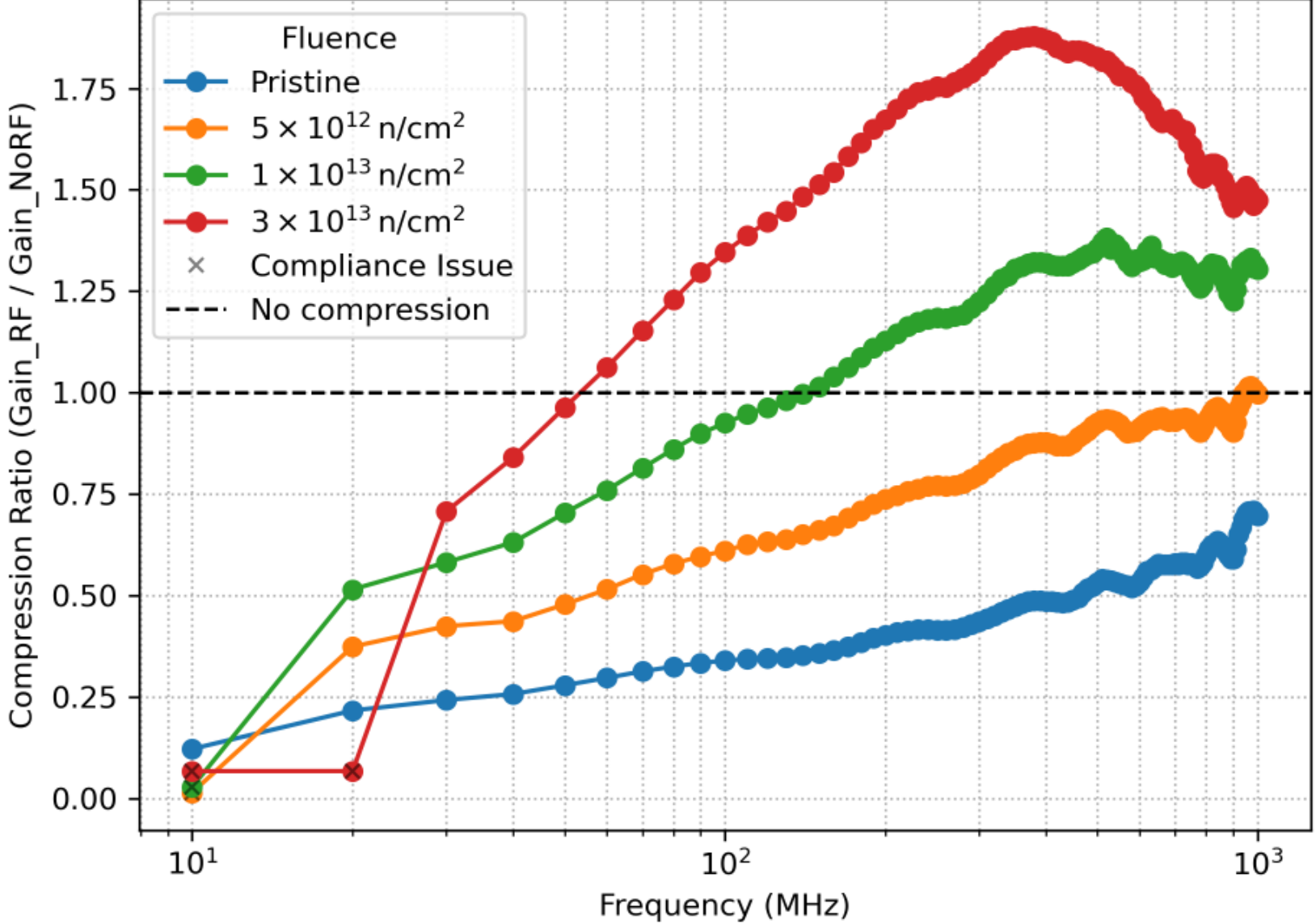


Gain compression
ratio: $\frac{\beta_{RF}}{\beta_{No-RF}}$

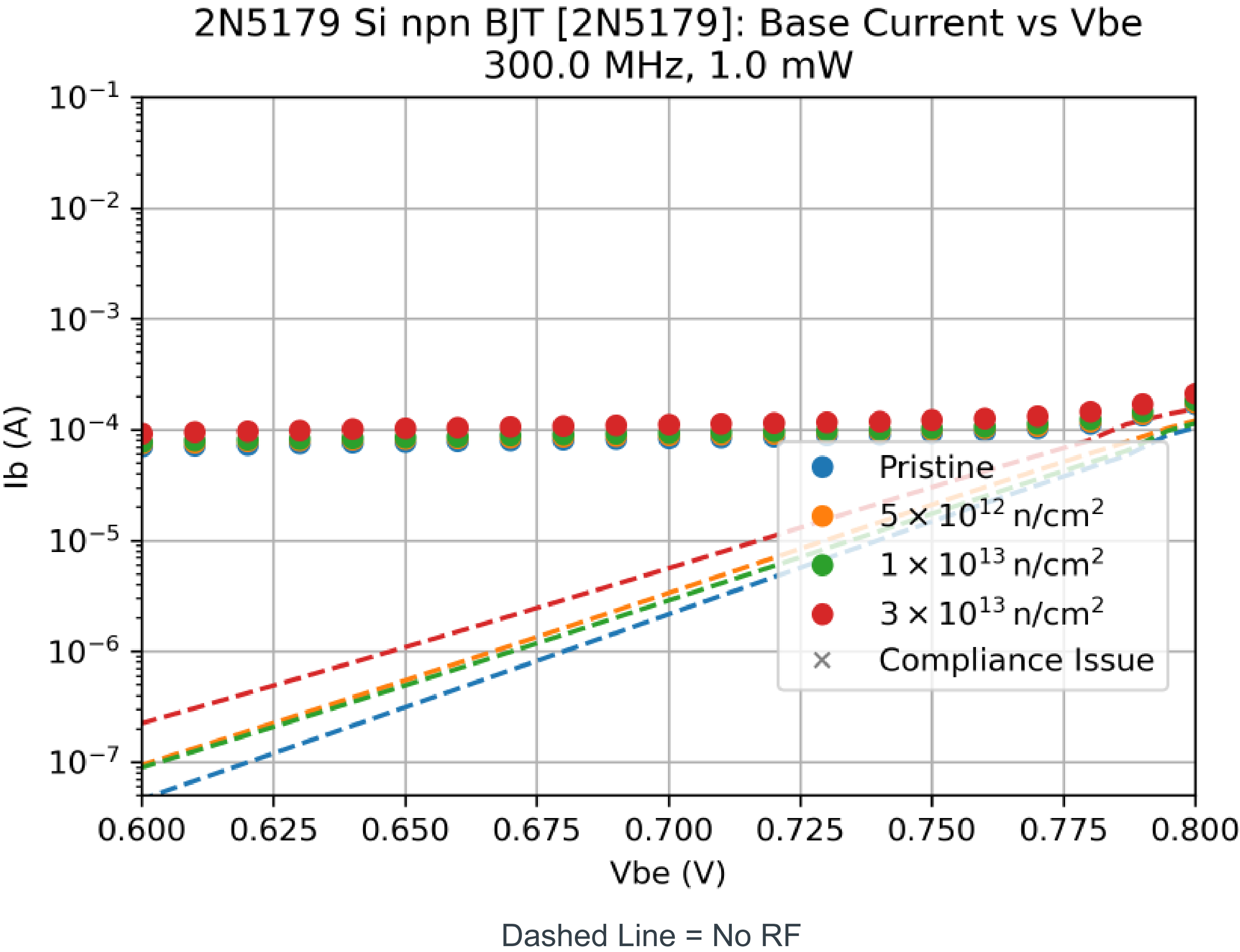
2N2222A Si npn BJT [2N2222A]: Compression Ratio vs Frequency at Fixed Power
P = 10 dBm, Vbe = 0.60 V



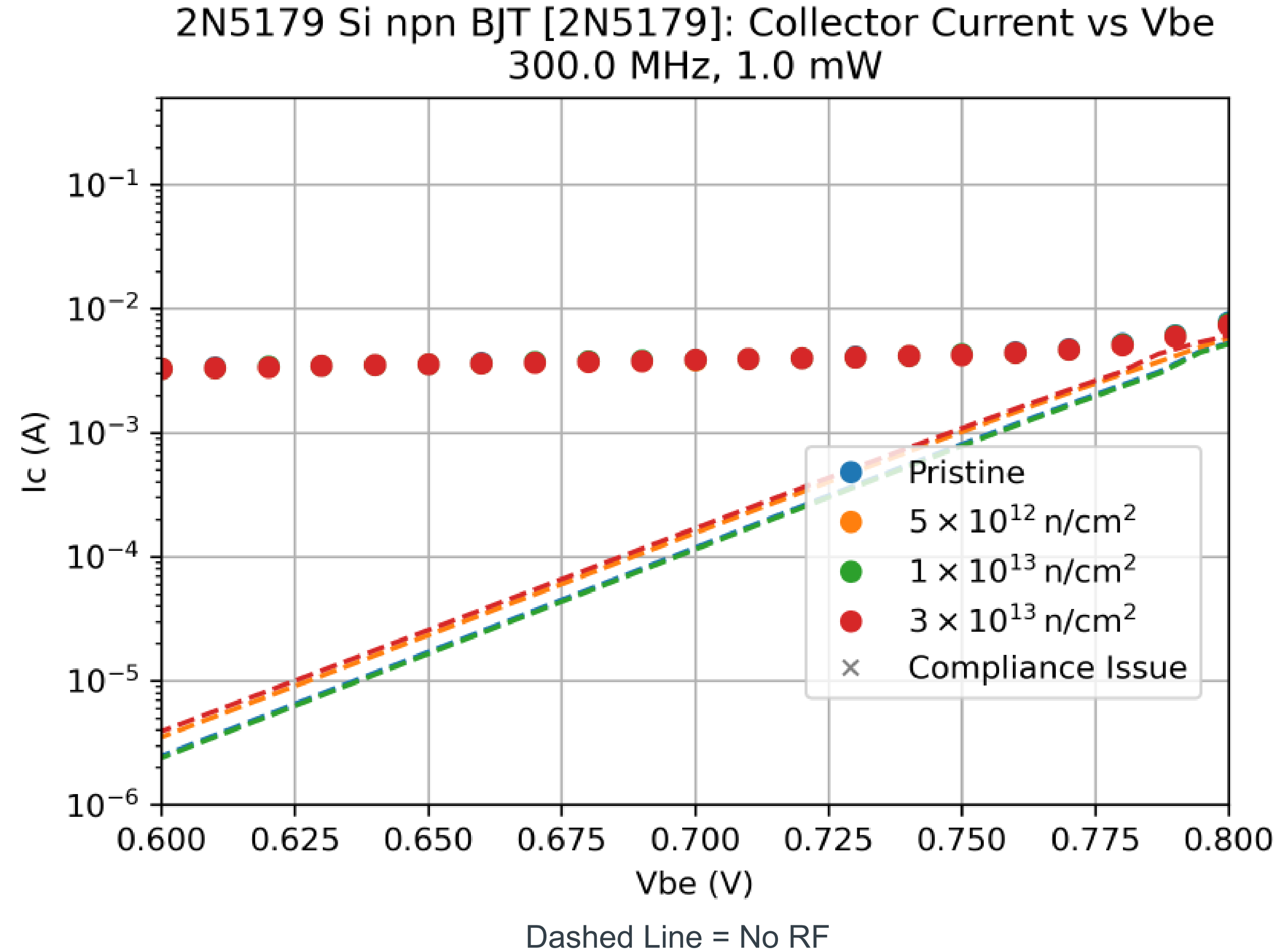
2N2222A Si npn BJT [2N2222A]: Compression Ratio vs Frequency at Fixed Power
P = 20 dBm, Vbe = 0.60 V

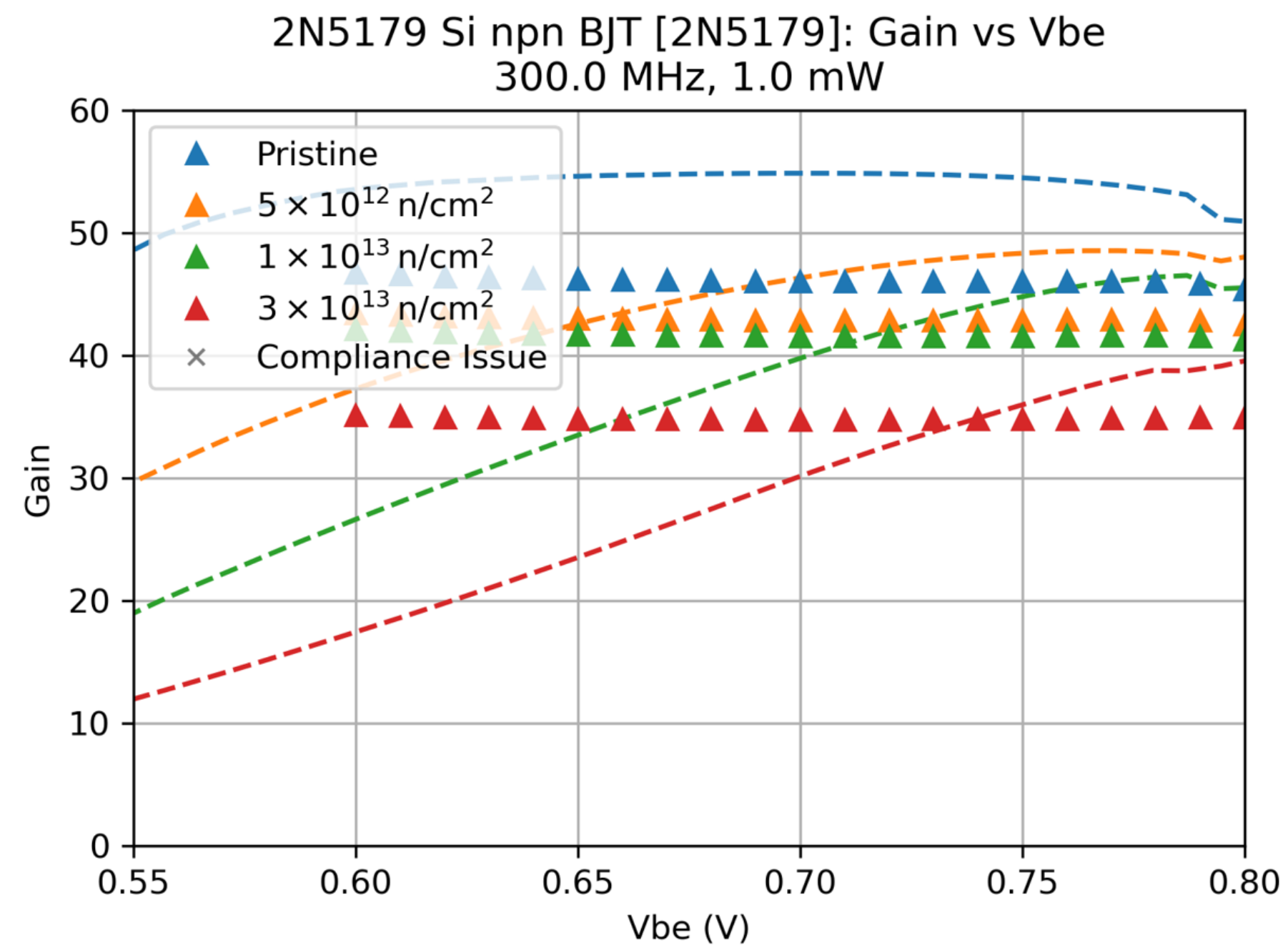
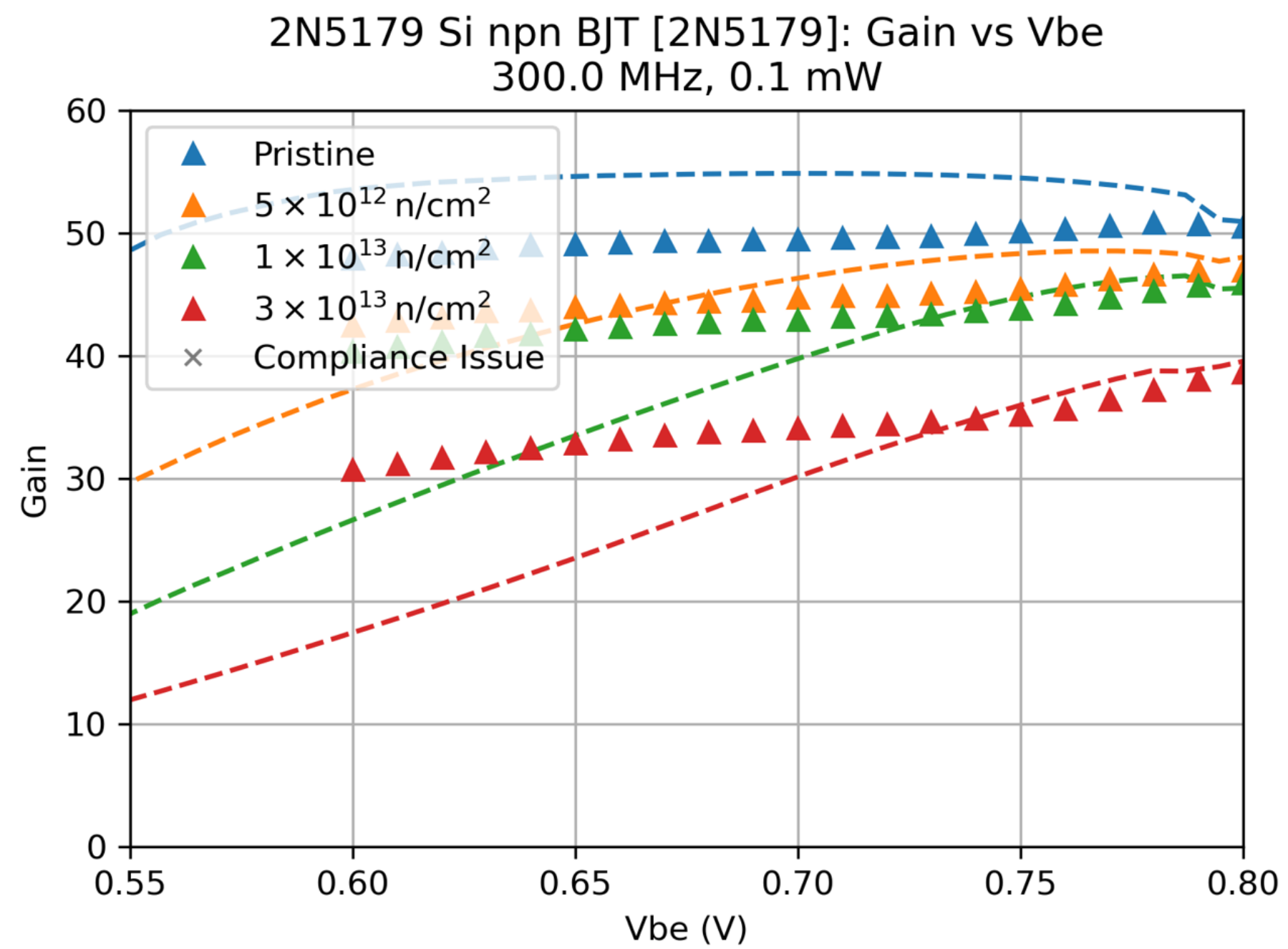


2N5179 Data

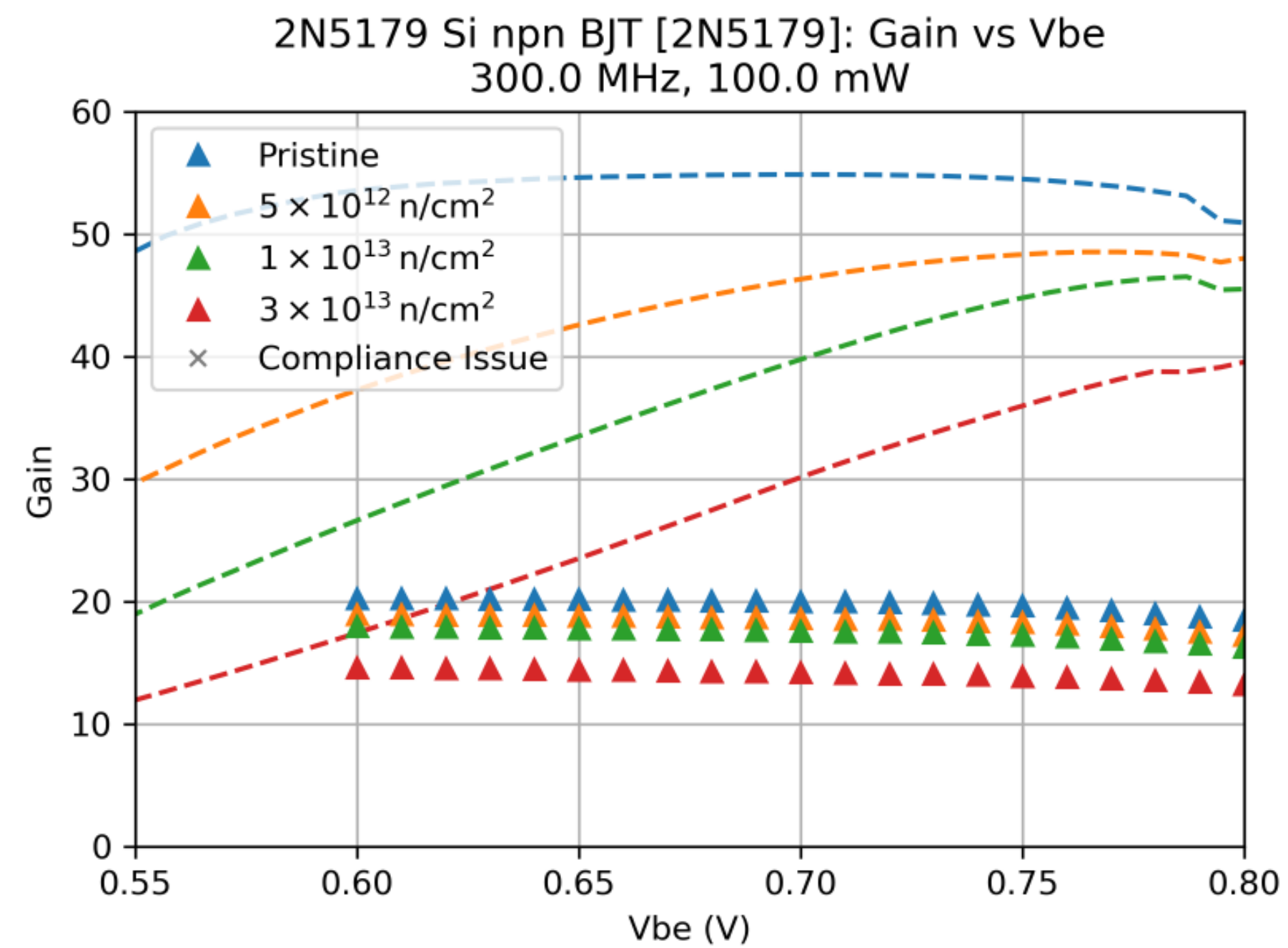
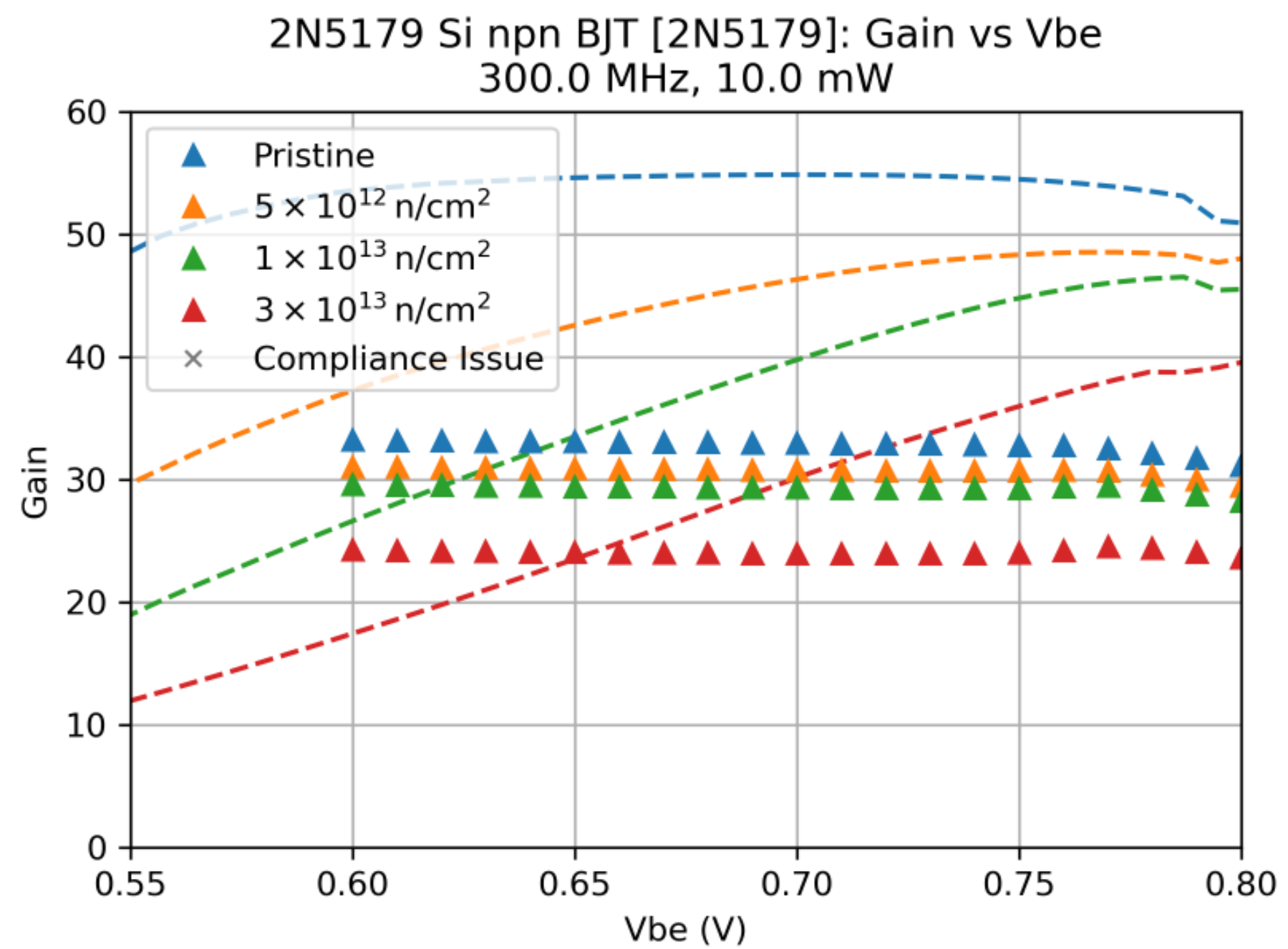


2N5179 Data

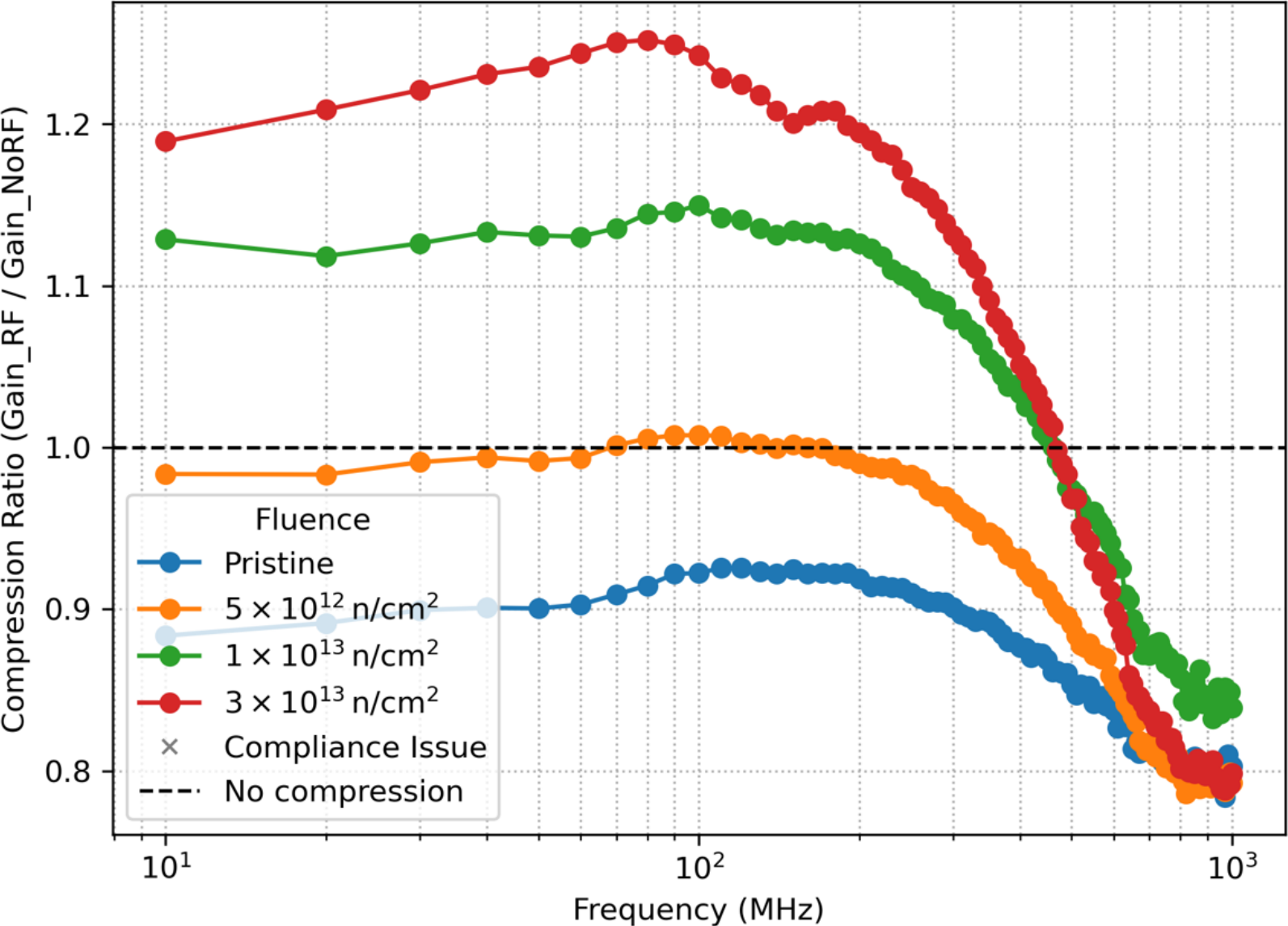




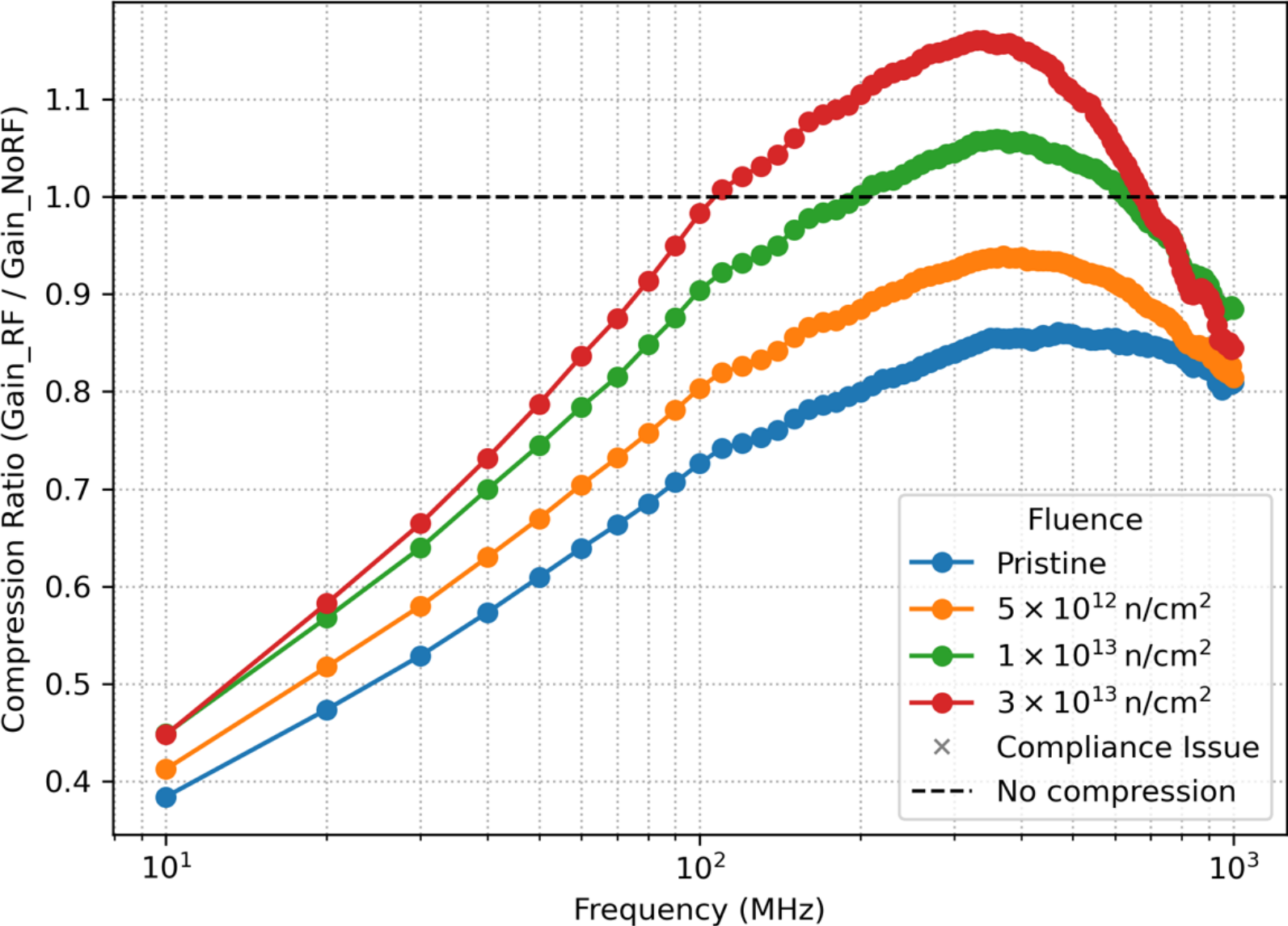
Dashed Line = No RF



2N5179 Si npn BJT [2N5179]: Compression Ratio vs Frequency at Fixed Power
P = -10 dBm, Vbe = 0.70 V

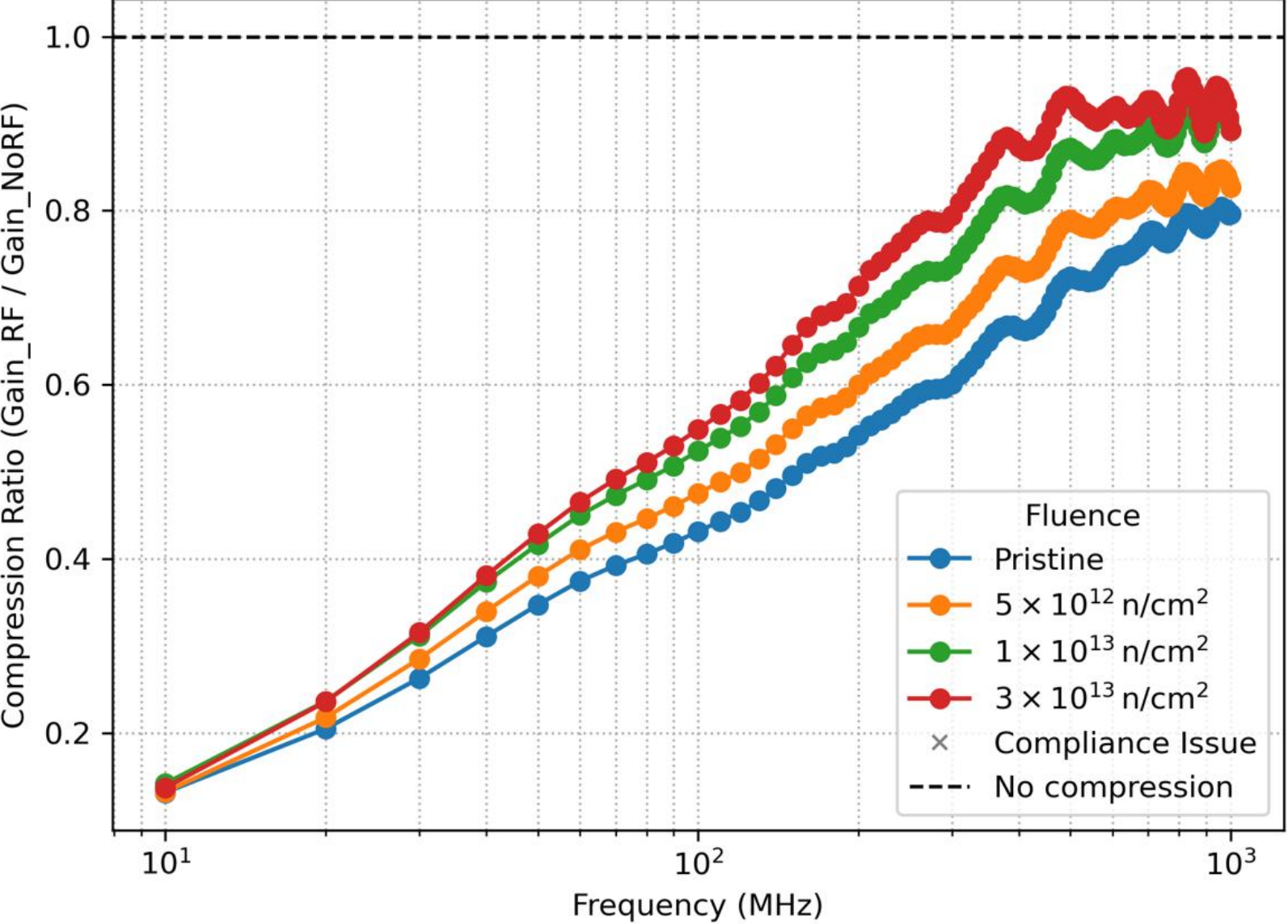


2N5179 Si npn BJT [2N5179]: Compression Ratio vs Frequency at Fixed Power
P = 0 dBm, Vbe = 0.70 V

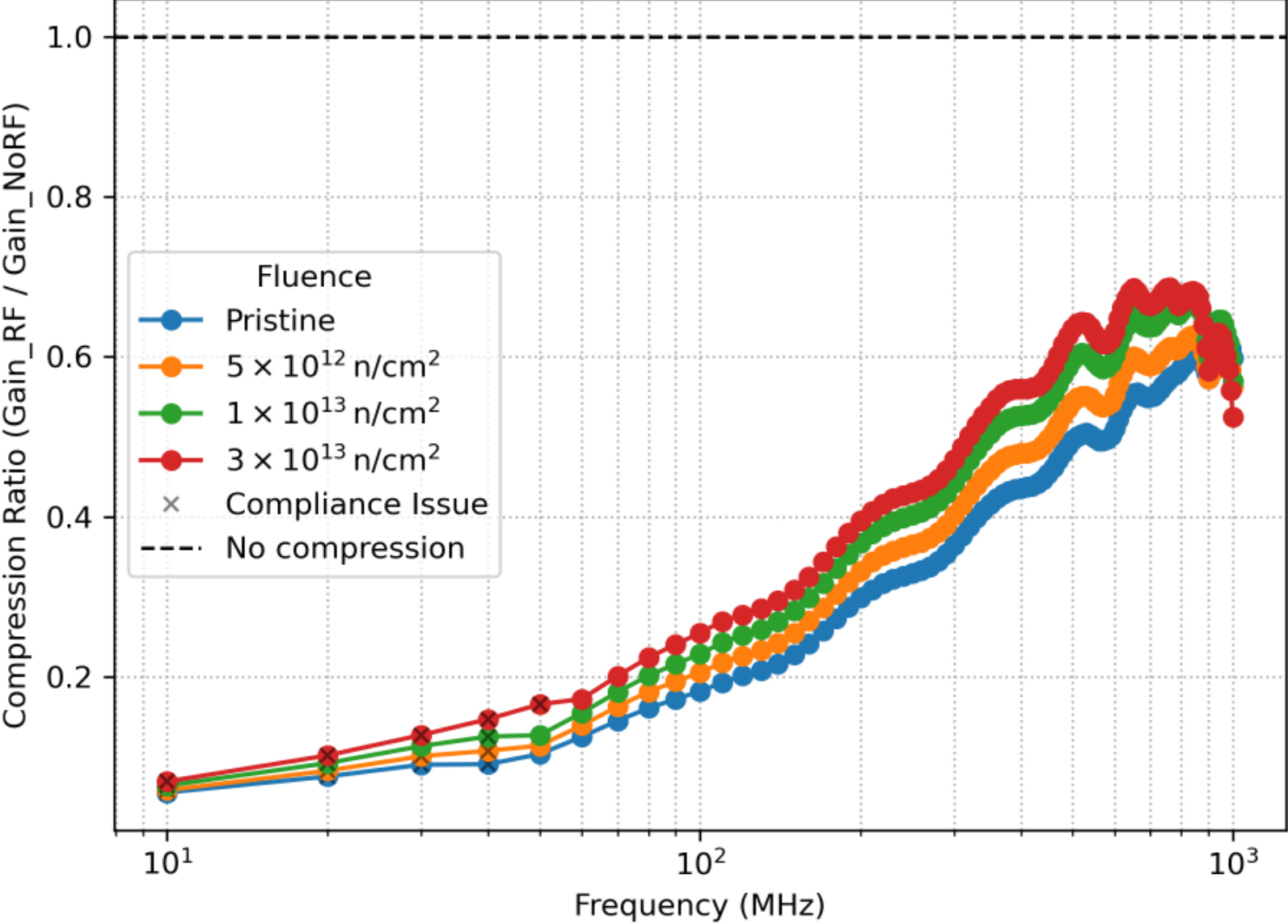


Gain compression
ratio: $\frac{\beta_{RF}}{\beta_{No-RF}}$

2N5179 Si npn BJT [2N5179]: Compression Ratio vs Frequency at Fixed Power
P = 10 dBm, Vbe = 0.70 V

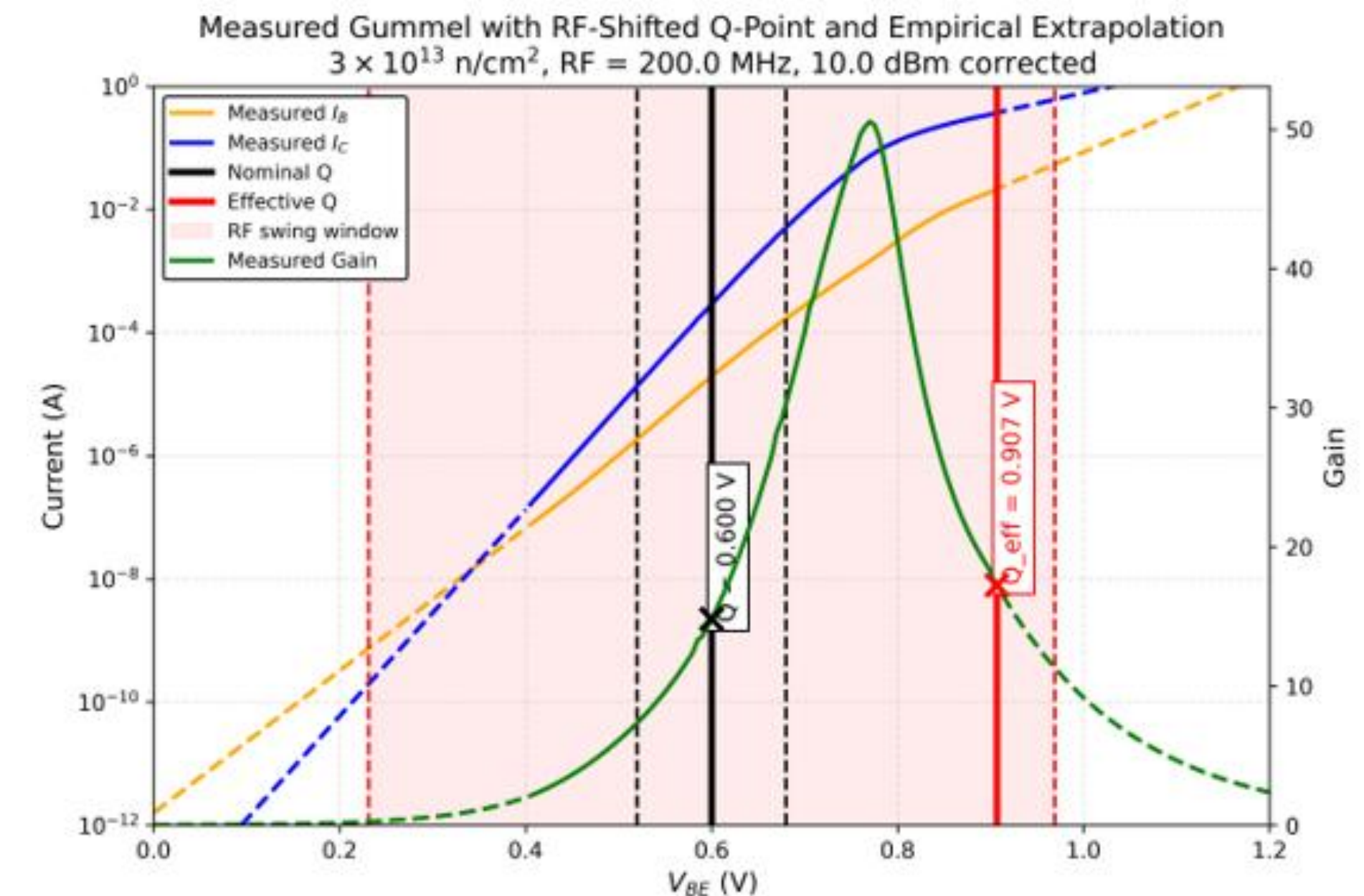
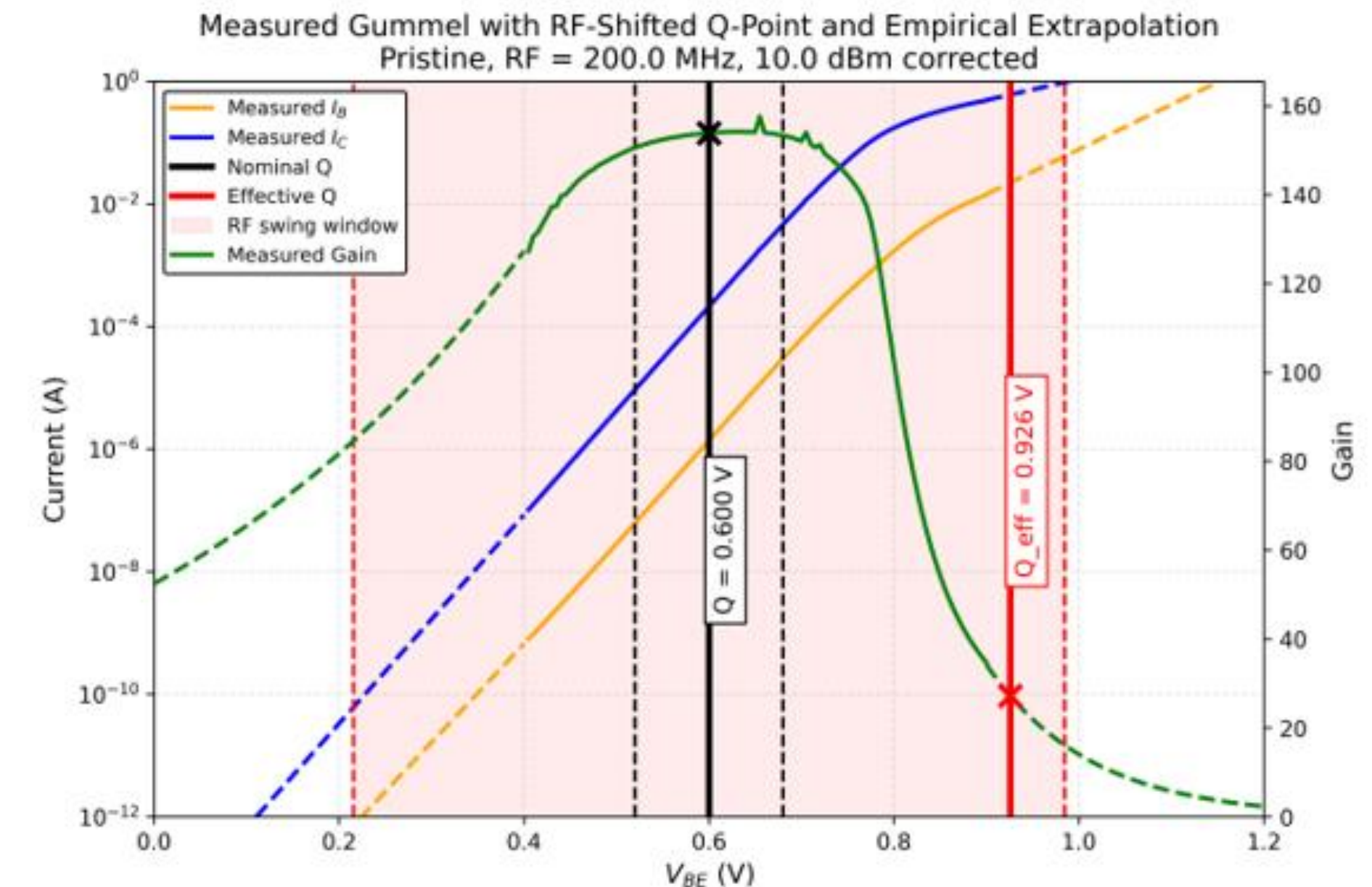


2N5179 Si npn BJT [2N5179]: Compression Ratio vs Frequency at Fixed Power
P = 20 dBm, Vbe = 0.70 V



Data Interpretation

- RF causes shift in quiescent operating point due to junction rectification.
 - Increase in BJT quiescent operating point.
 - BJT acts as if it was biased at a higher voltage.
 - Pushing device out of linear regime.
- nDD enhances RF induced gain compression.
 - nDD gain compression can cause gain with RF to be higher than without depending on power (ratio > 1 as fluence increases).
 - It is also hypothesized that the nDD will modify device input impedance and junction capacitance.



Conclusion

- UT-NETL is working with SNL to study how nDD modifies a device response to RF insult.
- Initial data was taken on the LM741 at NETL
- Additional data was taken on AD813x and BJTs at ACRR
- Results show synergistic coupling between RF and nDD depending on port of input and source parameters (frequency, power)
- Work is on going to better understand physical mechanisms behind observed effects by testing simpler devices (diodes) and performing TCAD modeling.

References

- “LOKI MMR - NANO Nuclear Energy.” Accessed: Mar. 30, 2026. [Online]. Available: <https://nanonuclearenergy.com/loki-mmr/>
- “War, Energy Departments Team up to Advance Future of Nuclear Power, Military Base Energy S,” U.S. Department of War. Accessed: Jun. 30, 2026. [Online]. Available: <https://www.war.gov/News/News-Stories/Article/Article/4407099/war-energy-departments-team-up-to-advance-future-of-nuclear-power-military-base/>
- W. S. Charlton, Radiation Effects Research Capability at the UT-NETL, Austin, TX, January 2025
- W. S. Charlton, NETL: The Nuclear Engineering Teaching Laboratory, Austin, TX, March 2024
- G. C. Messenger and M. S. Ash, The Effects of Radiation on Electronic Systems. Van Nostrand Reinhold Co. Inc., New York, NY, 1986.
- S. M. Sze, Y. Li, and K. K. Ng, *Physics of Semiconductor Devices*, Fourth edition. Hoboken, NJ Chichester, West Sussex: Wiley, 2021.
- D. M. Pozar, *Microwave Engineering*, Fourth edition. Hoboken, NJ: John Wiley & Sons, Inc, 2012.
- Joshua M. Young, Edward S. Bielejec, Nick Asper, William Wampler, Gyorgy Vizkelethy, Using ion beam irradiation as a surrogate for neutron displacement damage in microelectronics: Simple theory and equivalency considerations, Sandia National Laboratories, Albuquerque, NM, May 2026

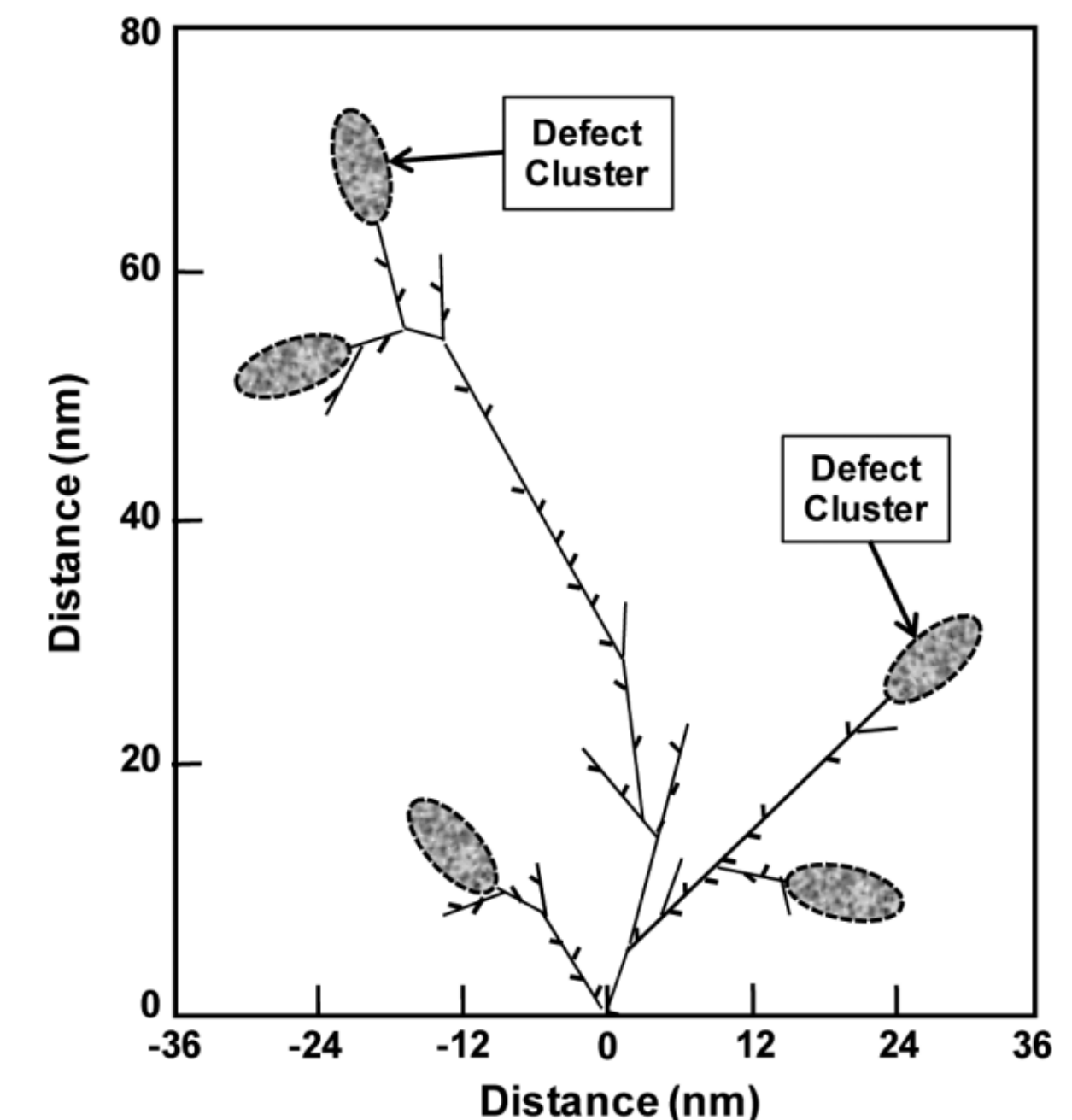
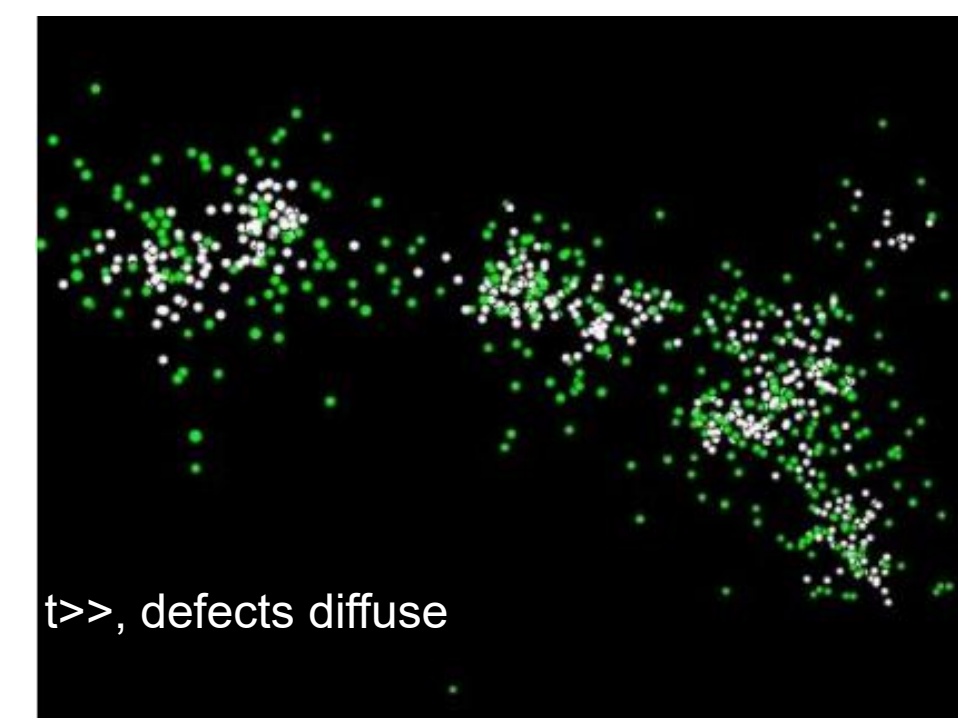
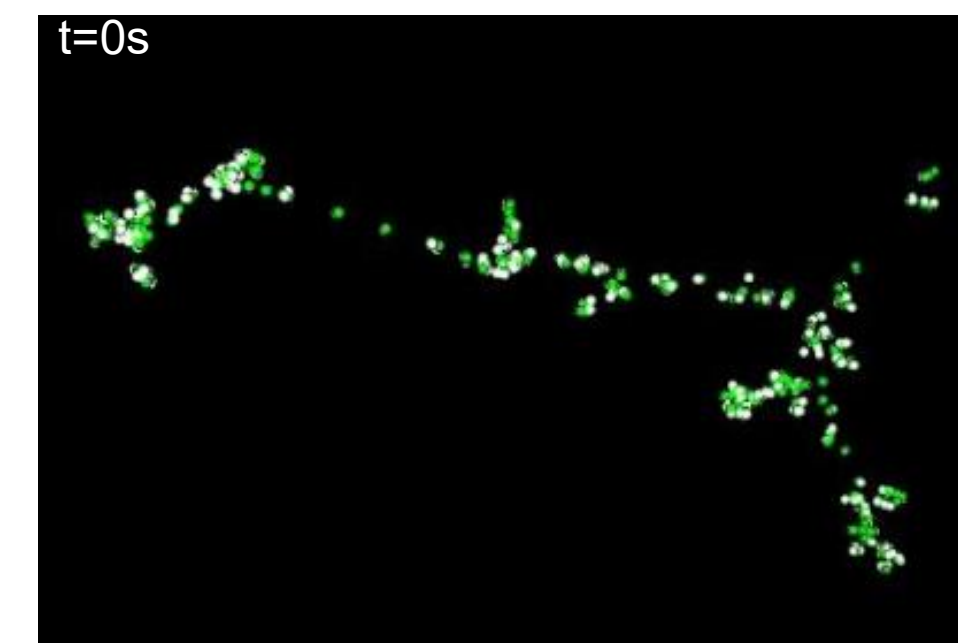
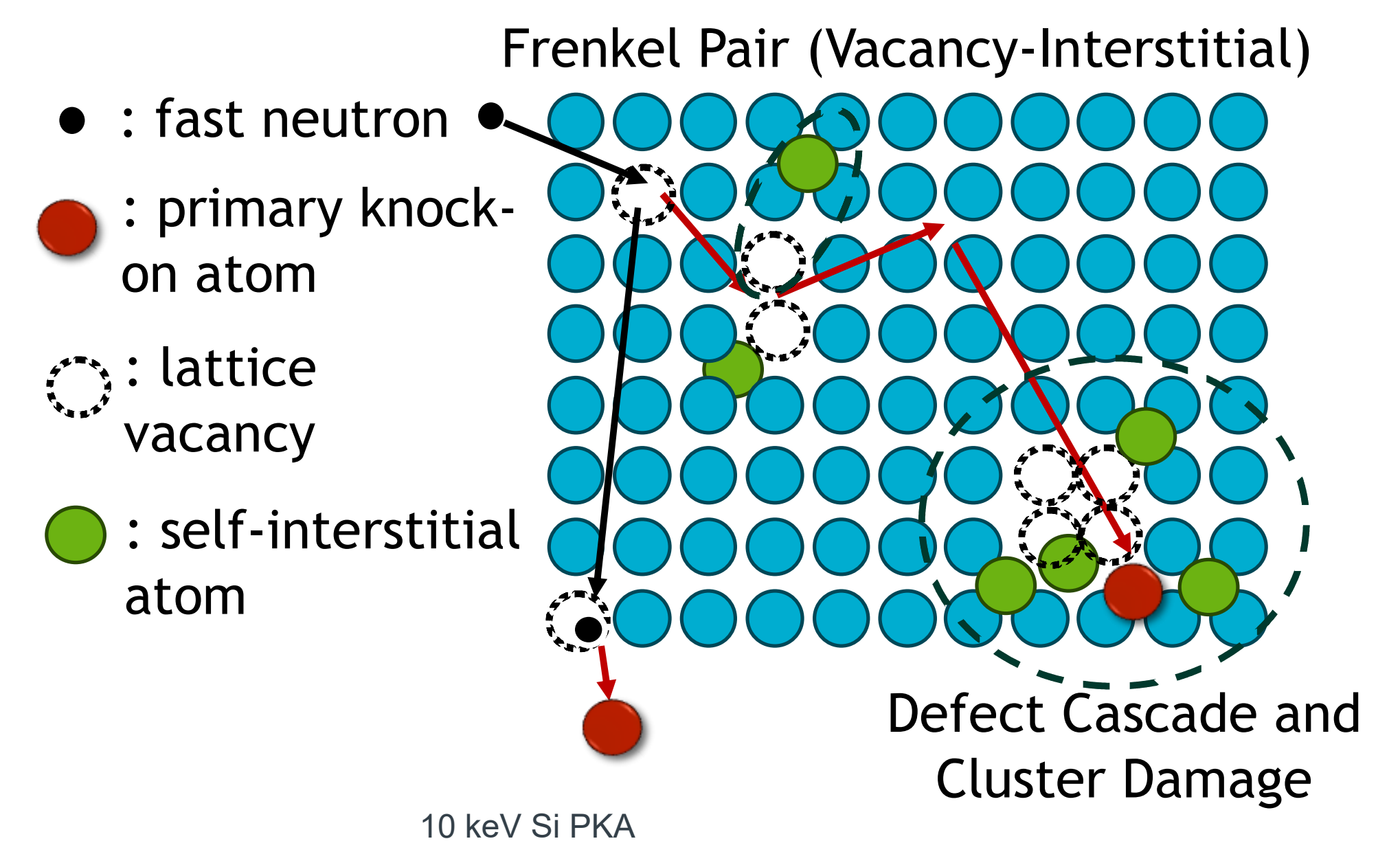


The University of Texas at Austin

Cockrell School of Engineering

Displacement damage radiation effects

- Displacement damage must be accounted for in nuclear reactor, high energy particle accelerator, spacecraft, commercial aviation, medical, and military electronics systems
- Displacement damage is due to the interaction of neutrons or ions with target atoms in the lattice producing a Primary Knock On Atom (PKA)
- A PKA produces a damage defect cascade
 - In electronics this damage degrades carrier mobility (movement of electrons or holes through a semiconductor lattice)
 - Carriers interact with lattice defects via: (1) electron capture (2) electron emission (3) hole capture (4) hole emission



LDRD Report: Analysis of Defect Clustering in Semiconductors using Kinetic Monte Carlo Methods