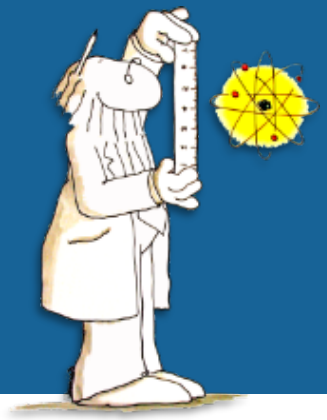
Establishing a Canadian-traceable calibration of high-dose rate sources



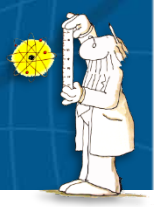
Iymad Mansour[1,2], Malcolm McEwen [2], Chris Howard[3]
(1) Carleton University
(2) National Research Council
(3) Nordion
April 2018
CIRMS

National Research Council Canada
Conseil national de recherches Canada
Canada

Outline

1. High dose standard
   - Historical approaches
2. Development of high dose methodology
   - Low dose alanine
   - Verification of protocol
3. Industrial dosimetry
   - Collaboration process

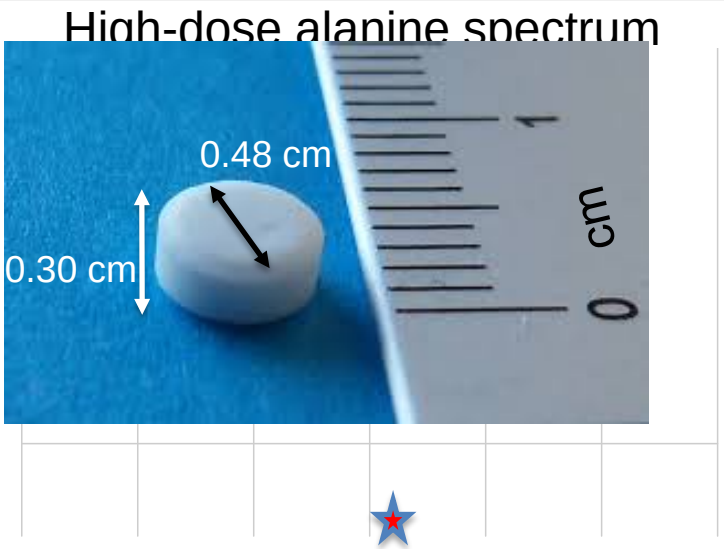
What you need to know



- Currently no high dose standard traceable to a Canadian facility
- Goal is to develop a high dose dosimetry program traceable to the NRC

Possible solutions

Alanine



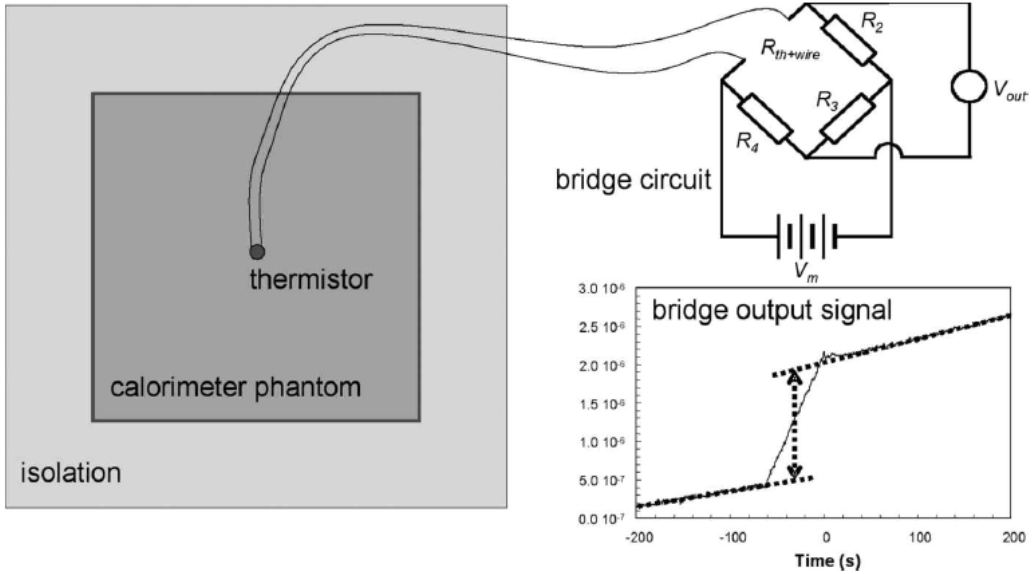
- Alanine is a neutral non-polar amino acid
- Z_{eff} of 6.8, close to water
- Density of 1.42 g/cm^3
- Radiation induced free radicals can be determined using EPR

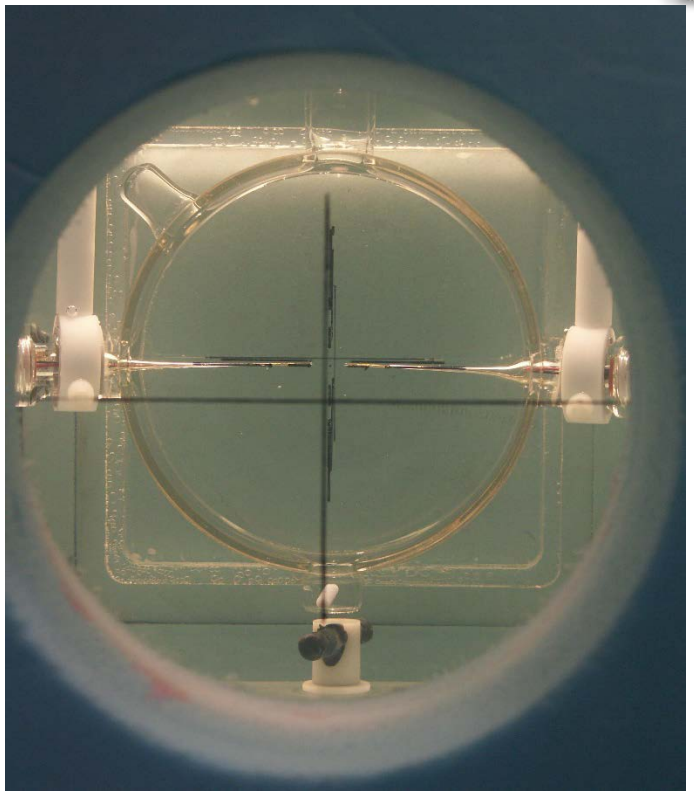
Signal-to-dose conversion

$$D = \frac{S \cdot k_t \cdot k_T \cdot c}{m}$$

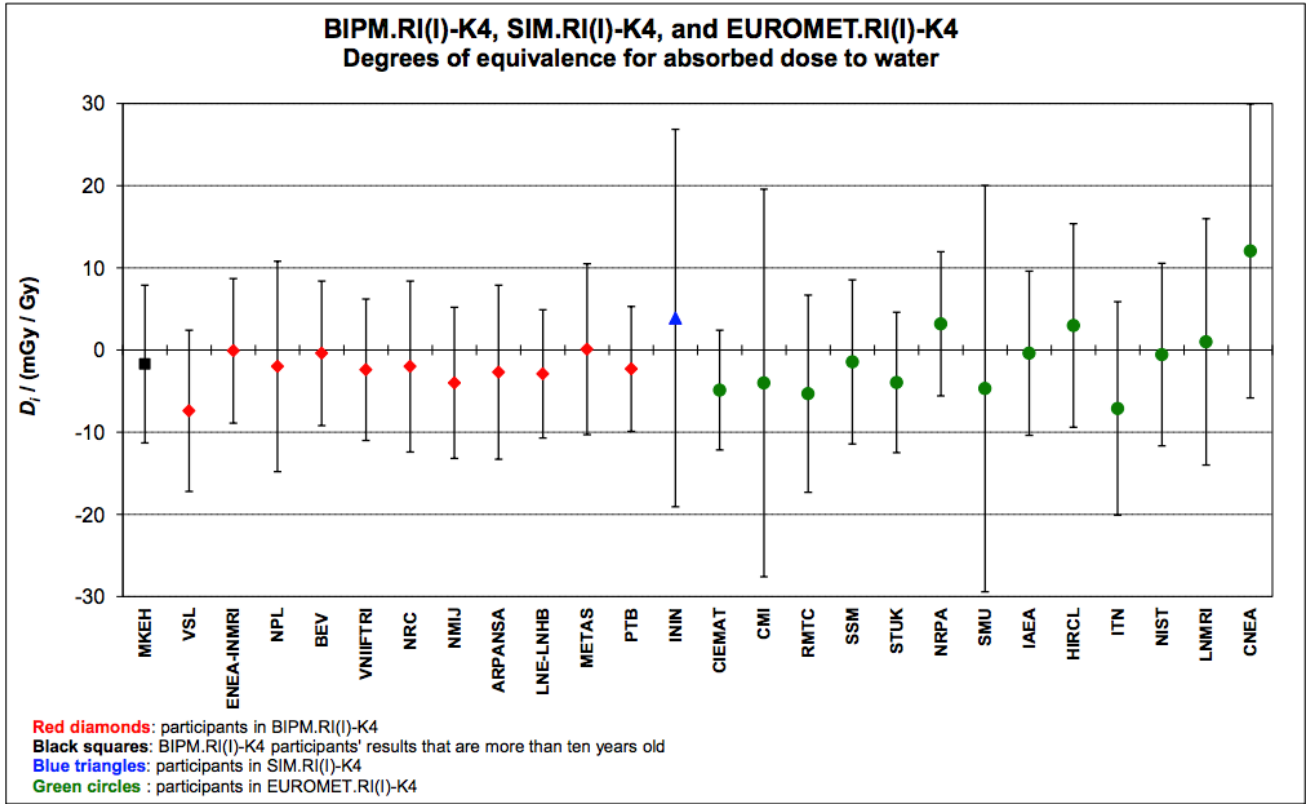
- S is the “peak to peak” height from the EPR spectrum
- k_t and k_T represent temperature corrections for time of readout and time of irradiation respectively
- c is a constant that converts from E_{dep} to spectrum output
- m is the mass of the dosimeter

Canadian absorbed dose primary standard





Absorbed dose standard comparison



Limits of water calorimetry

Limited to:

- Dose rates less than 10 Gy/min
- Doses less than 10 Gy

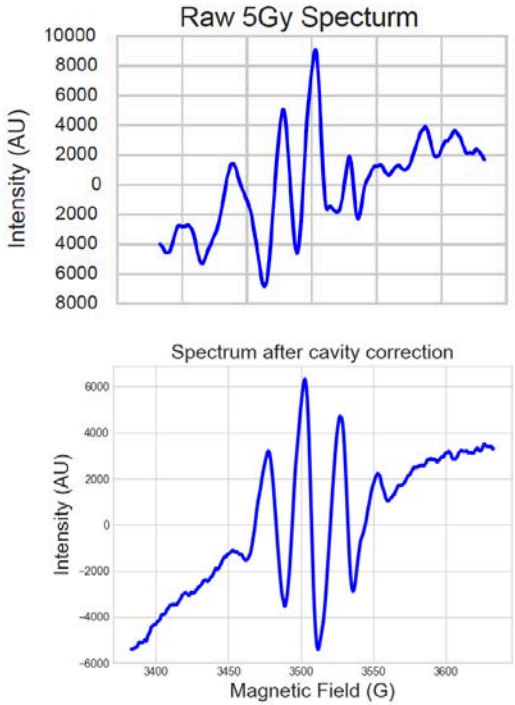
Need:

- Transfer dosimeter

Low dose alanine

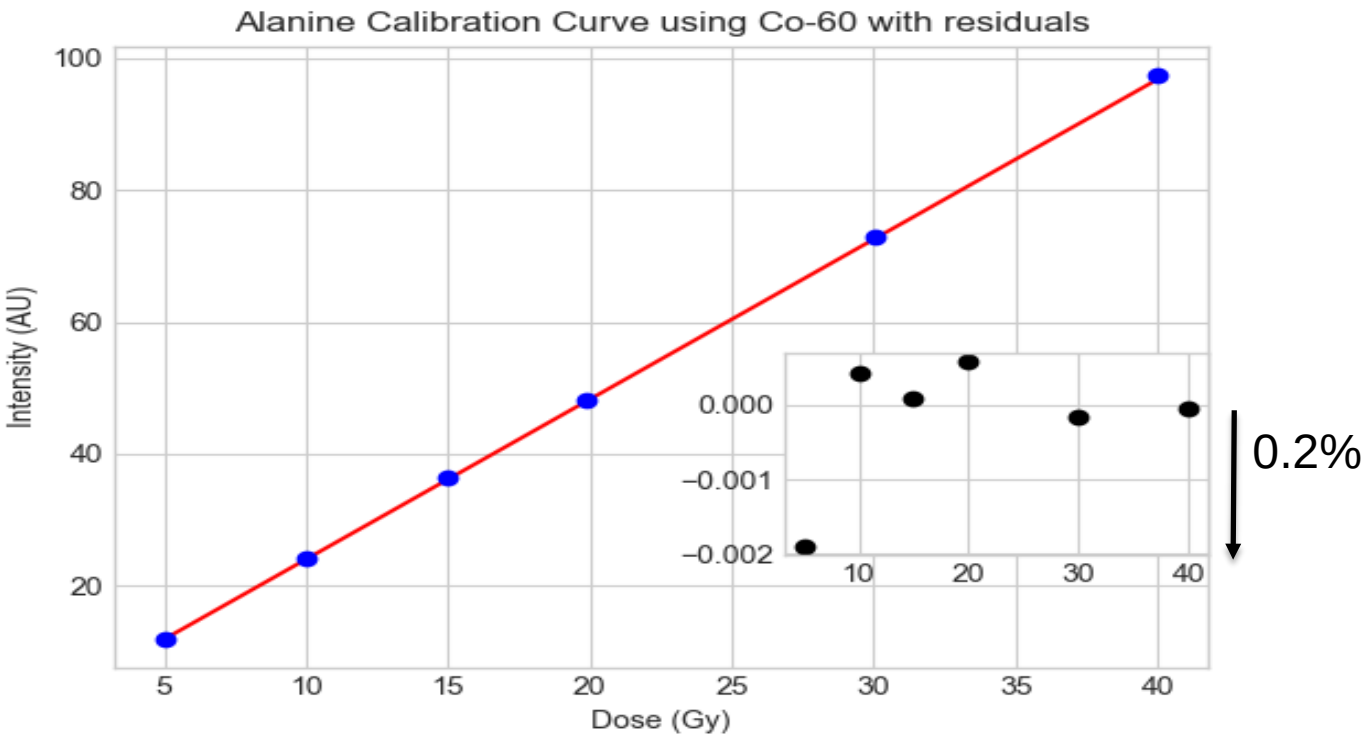
- Historically alanine has been used primarily for doses in the kGy range
- Low dose alanine is dominated by background signal

Low dose background subtraction

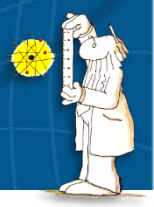


- Remove cavity background
- Removes alanine based background
- Exploits linearity of alanine response

Alanine calibration using NRC Cobalt-60



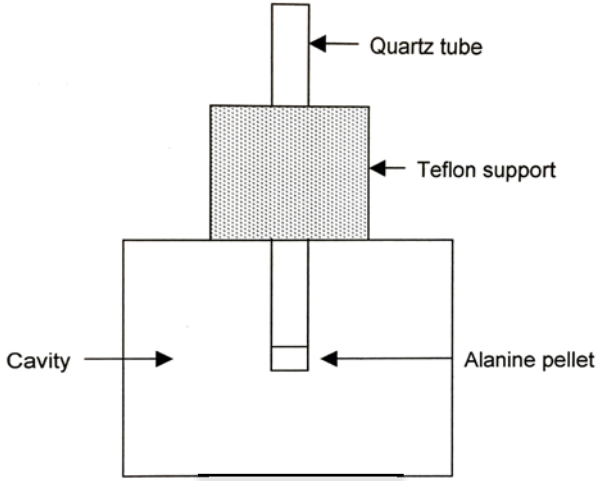
Uncertainty mitigation

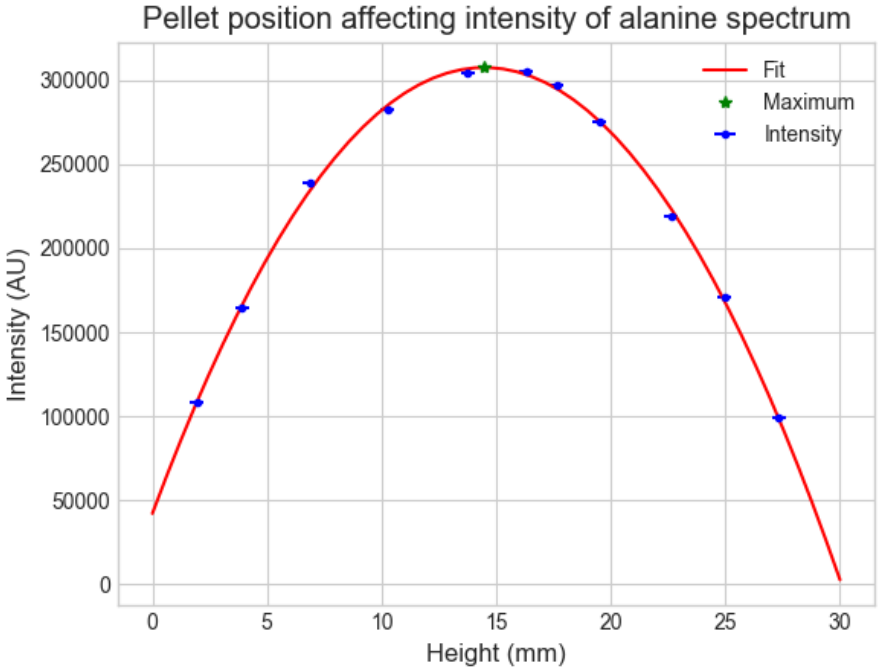


Target: Sub 1 %

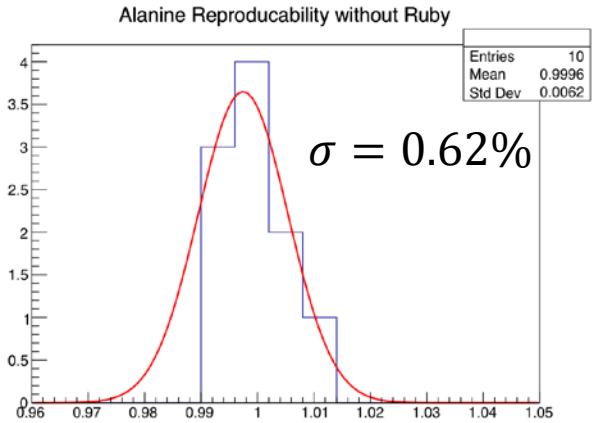
Reproducibility

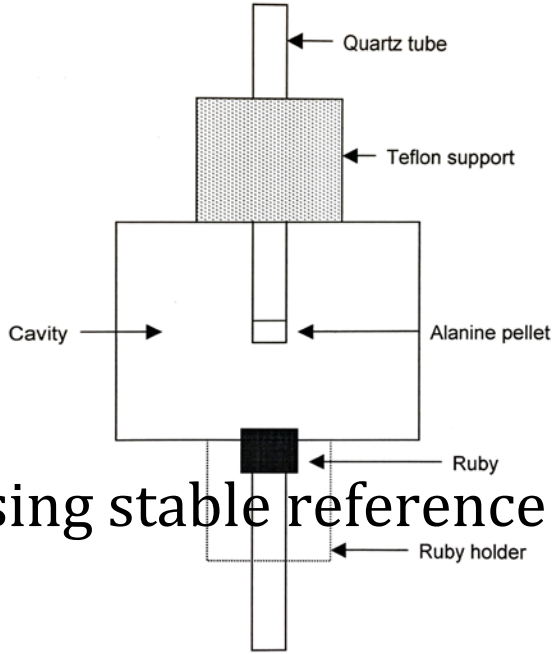
Reproducibility from pellet positioning





Reproducibility of spectrometer



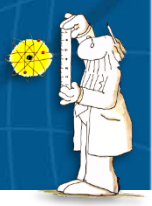


- Normalization of pellet signal using stable reference sample to increase reproducibility

Uncertainty budget

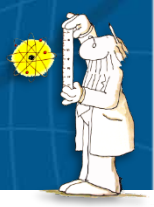
Component	Std. Unc (10 Gy)(%)
Primary standard realization of dose	0.4
Alanine readout Positioning, Precision (5 Pellets), Mass	0.16
Spectrometer reproducibility	0.24
Overall:	0.49 (σ = 1)

NRC-NPL alanine dosimetry verification



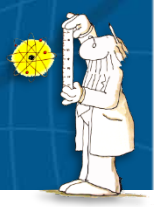
- NPL has been a world leader in alanine dosimetry
- Established program since early 90’s
- Has both industrial and clinical dosimetry service

Protocol verification



- Step one: irradiation at NRC, readout at NPL
- Step two: irradiation at NPL, readout at NRC

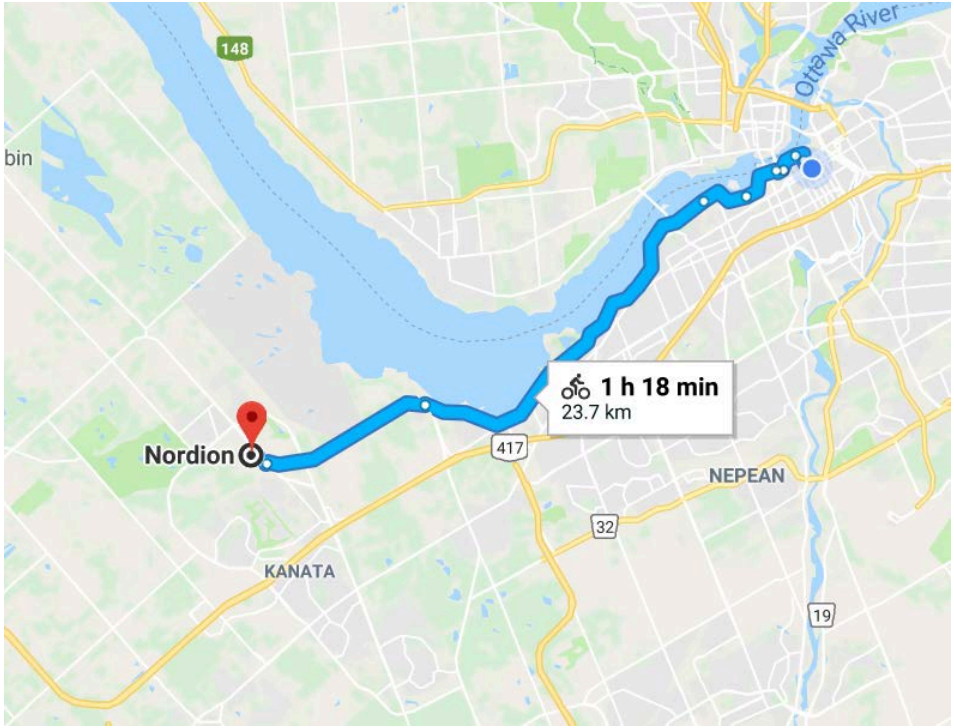
Equipment available at the NRC



- NRC has a Gammabeam irradiator with ~ 1Gy/min doserate

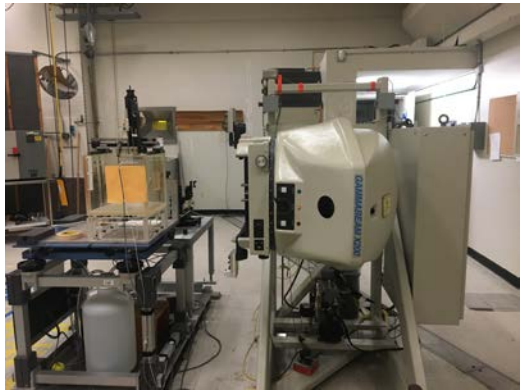
Industrial dosimetry is not feasible at the NRC

Achieving high doses through collaboration: Nordion



Equipment used in process

Low dose



Range: 0-500 Gy

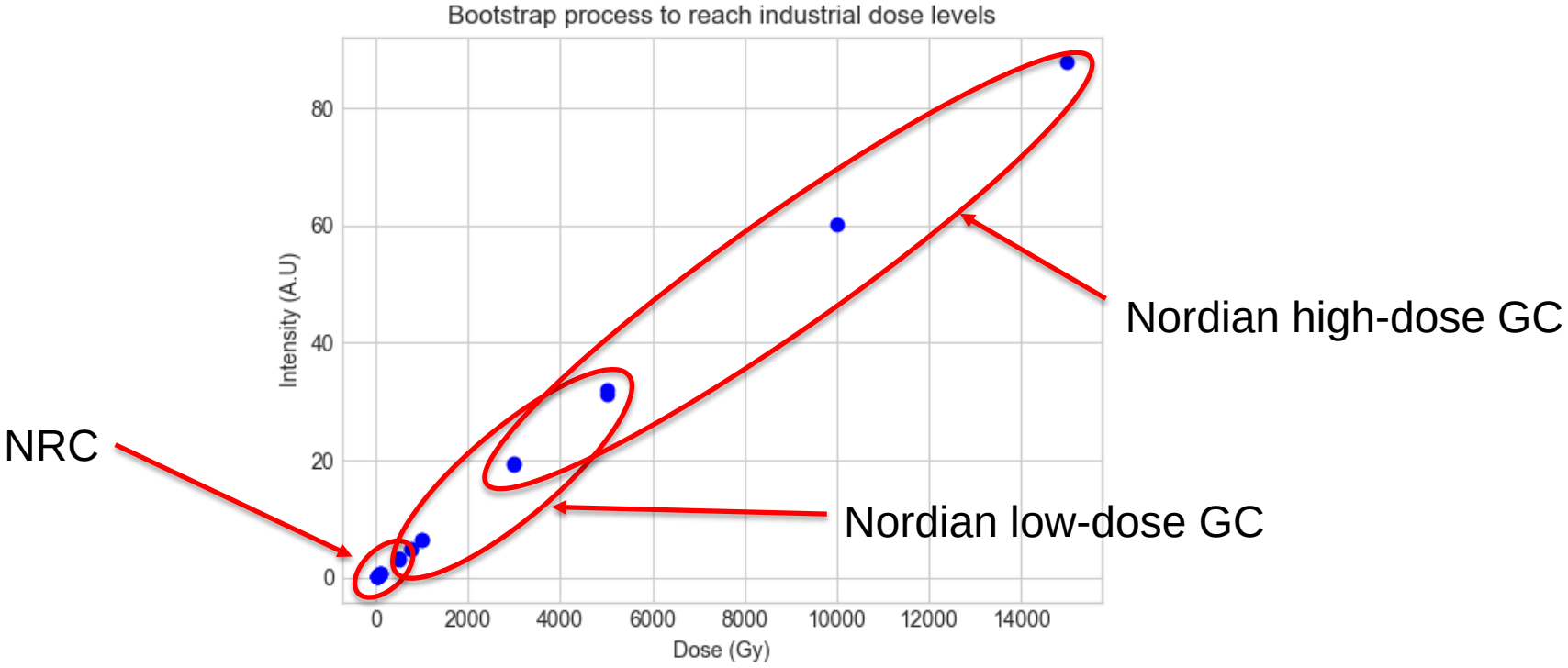
Mid dose

Range: 20 - 5000 Gy

High dose

Range: 20 – 200000 Gy +

Bootstrapping to industrial dosimetry



Summary

Developed low dose program → Verified program with experienced facility → Bootstrap low dose program with help of collaboration

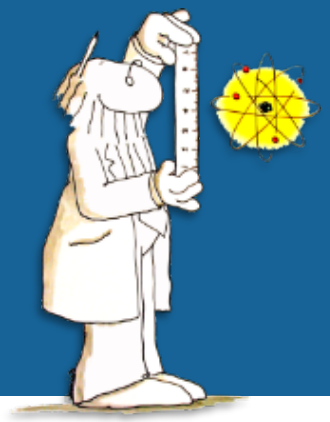
Conclusion

- Alanine has the potential to work as an audit dosimeter with an overall uncertainty below 1% for $\sigma = 1$
- It is a suitable dosimeter on the range from 5 Gy to kGy
- NRC has the capability to offer a high dose rate calibration serive

Thank you

Acknowledgements

Malcolm McEwen, Bryan Muir - NRC
Peter Sharpe, Clair Gouldstone - NPL
Chris Howard - Nordion



Iymad Mansour
MSc student, Carleton university
IymadMansour@cmail.carleton.ca
www.nrc-cnrc.gc.ca