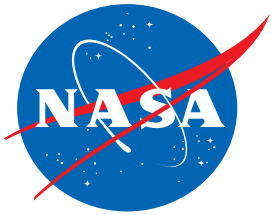
National Aeronautics and Space Administration



Heavy Ion Microbeam- and Broadbeam-Induced Current Transients in SiGe HBTs

Jonathan A. Pellish[1], R. A. Reed[2], D. McMorrow[3], G. Vizkelethy[4], V. Ferlet-Cavrois[5], J. Baggio[5], O. Duhamel[5], K. A. Moen[6], S. D. Phillips[6], R. M. Diestelhorst[6], J. D. Cressler[6], A. K. Sutton[7], A. Raman[8], M. Turowski[8], P. E. Dodd[4], M. L. Alles[2], R. D. Schrimpf[2], P. W. Marshall[9], and K. A. LaBel[1]

1. NASA Goddard Space Flight Center, Code 561, Greenbelt, MD 20771 USA
2. Department of Electrical Engineering and Computer Science, Vanderbilt University, Nashville, TN 37235 USA
3. Naval Research Laboratory, Washington, DC 20375 USA
4. Sandia National Laboratories, Albuquerque, NM 87185-1083 USA
5. CEA, DAM, DIF, F-91297 Arpajon, France
6. School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332 USA
7. IBM SRDC, 2070 Rte 52 MS 32A, Hopewell Junction, NY 12533
8. CFD Research Corporation, Huntsville, AL 35805 USA
9. NASA Consultant, Brookneal, VA 24528 USA

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

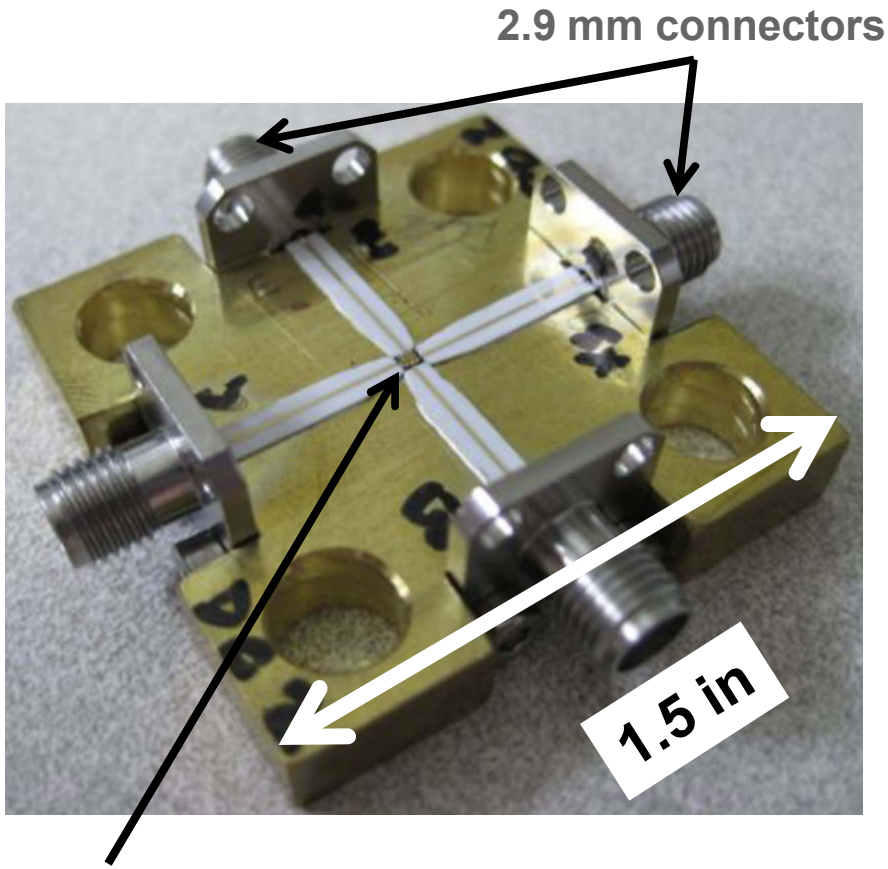
To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

Acknowledgement

- NASA Electronic Parts and Packaging program
- NASA Radiation Hardened Electronics for Space Environments project
- DTRA Radiation Hardened Microelectronics program under *IACRO* #08-4343I to NASA
- AFOSR MURI program and AFOSR DURIP award
- SiGe teams at the Georgia Electronic Design Center and IBM
- Naval Research Laboratory
- CEA/DIF (Arpajon, France)
- Sandia National Laboratories **(SNL)**
- Department of Physics at the University of Jyväskylä, Finland **(JYFL)**
- Grand Accélérateur National d'Ions Lourds, France **(GANIL)**

Heavy ion transient overview

- IBM 5AM SiGe HBT is device-under-test
- High-speed measurement setup
- Low-impedance current transient measurements
  - SNL, JYFL, GANIL
- Microbeam to broadbeam position inference
- Improvement to state-of-the-art



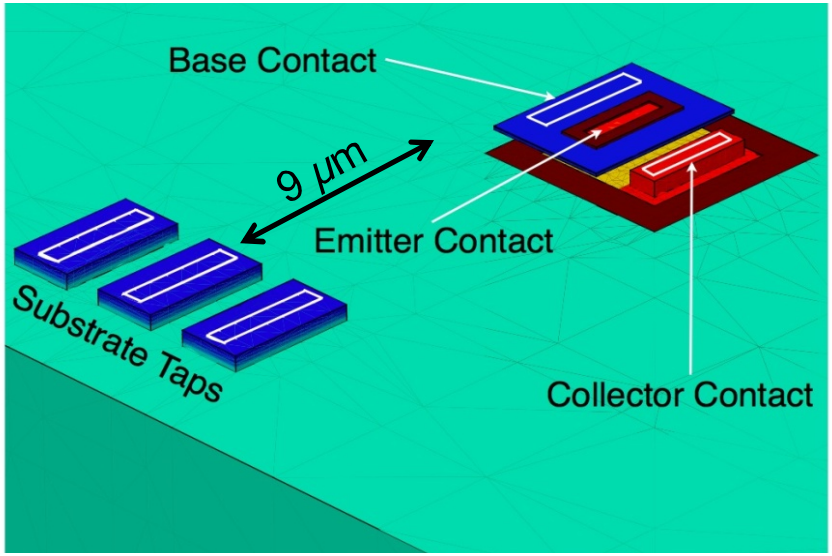
Single SiGe HBT device under test (1 mm^2)

R. S. Wagner, *et al.*, *IEEE Trans. Nucl. Sci.*, vol. 33, no. 6, pp. 1651–1655, Dec. 1986.

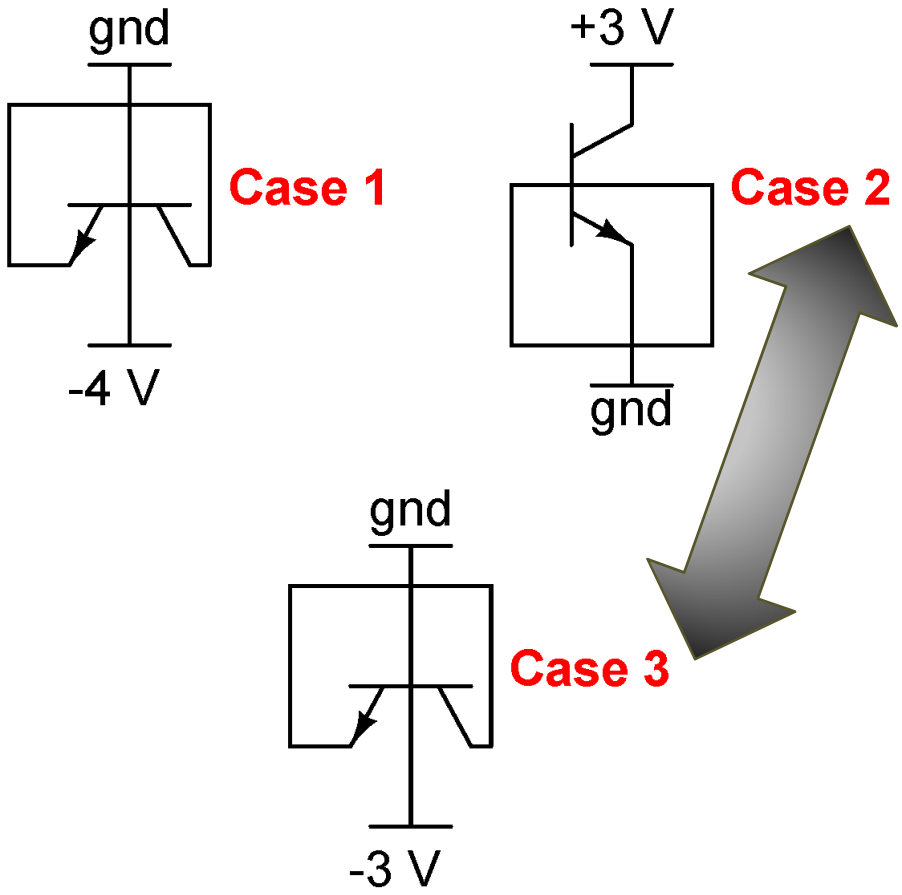
To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

Bias conditions of interest

All biases based on device isolation



3-D TCAD from DUT GDSII
IBM 5AM npn SiGe HBT

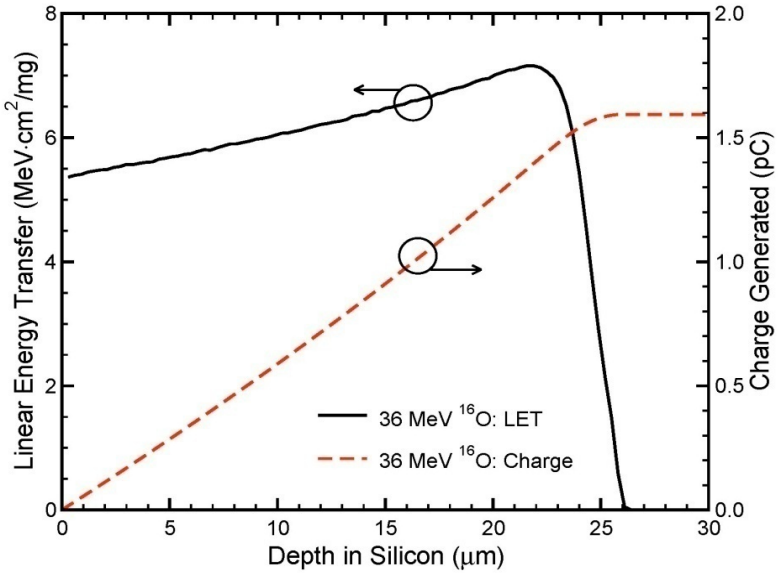


Bias conditions chosen to represent “circuit-like” experiments

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

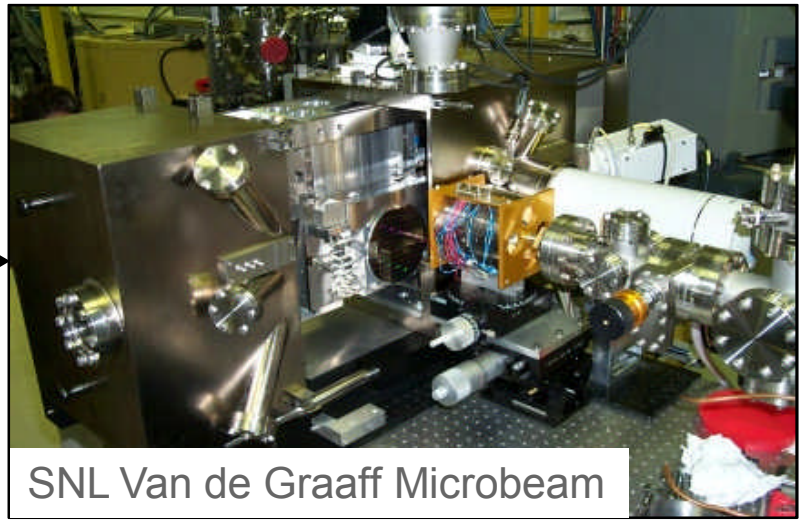
Typical experimental setup

Different than broadbeam

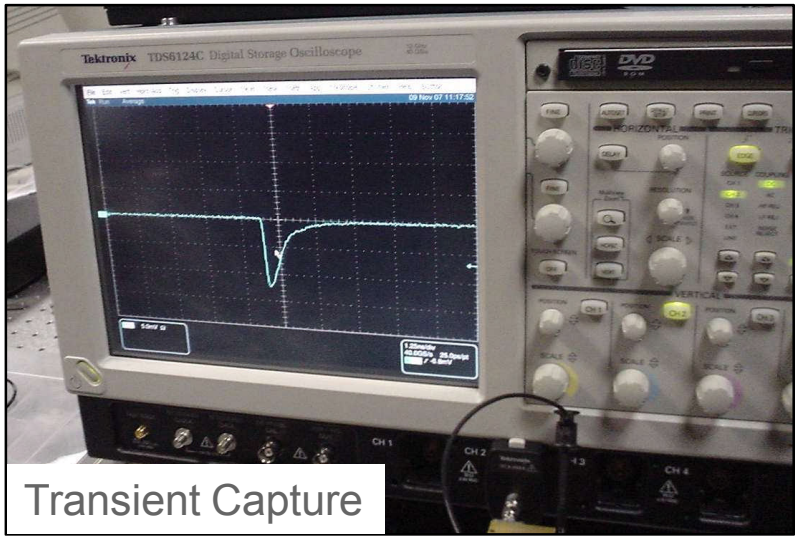


36 MeV ^{16}O d*E*/d*x* profile [SRIM-2008]

Sandia National Laboratories' Microbeam Chamber



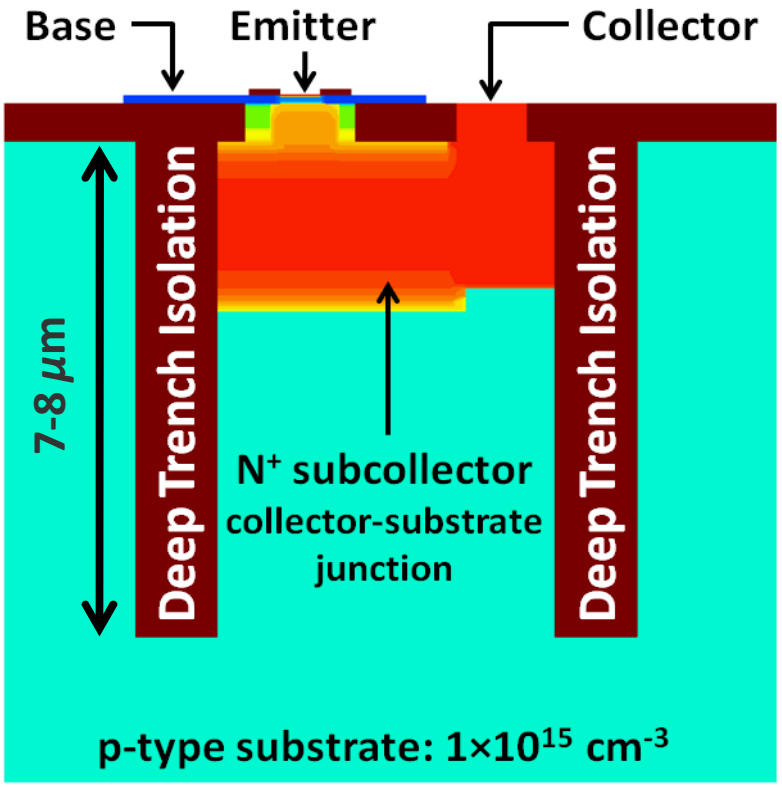
SNL Van de Graaff Microbeam



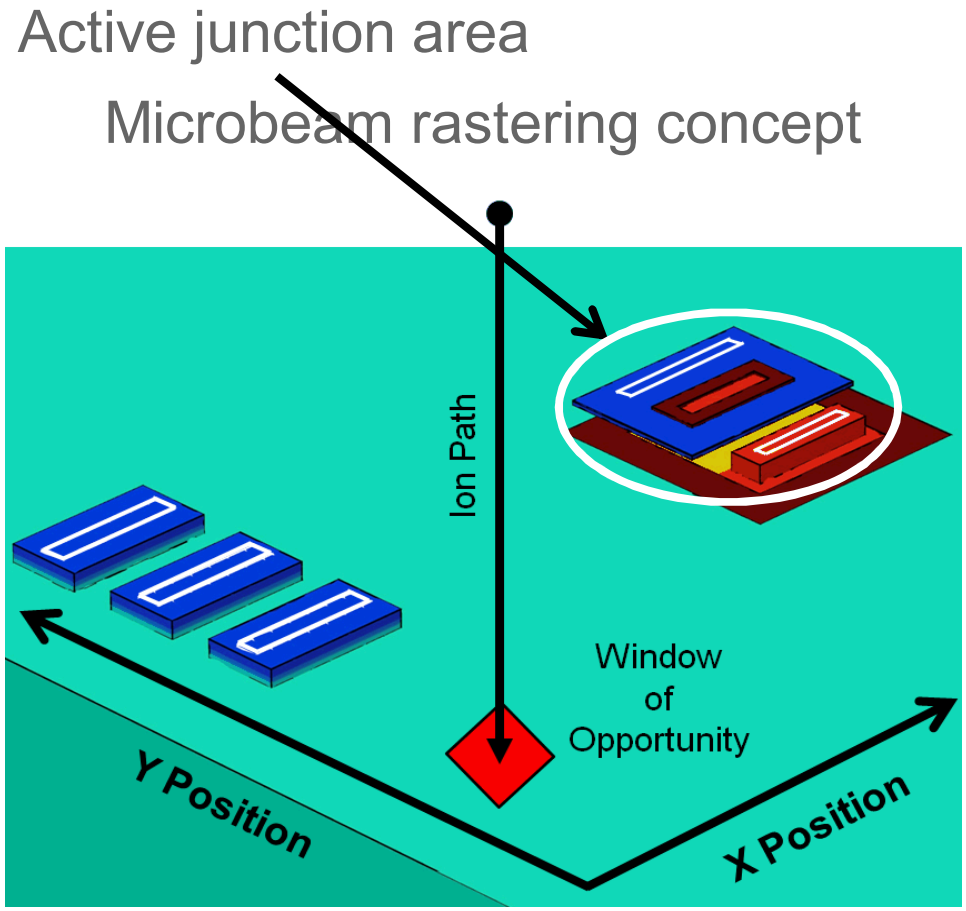
Transient Capture

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

Device under test and microbeam irradiation



IBM 5AM npn SiGe HBT



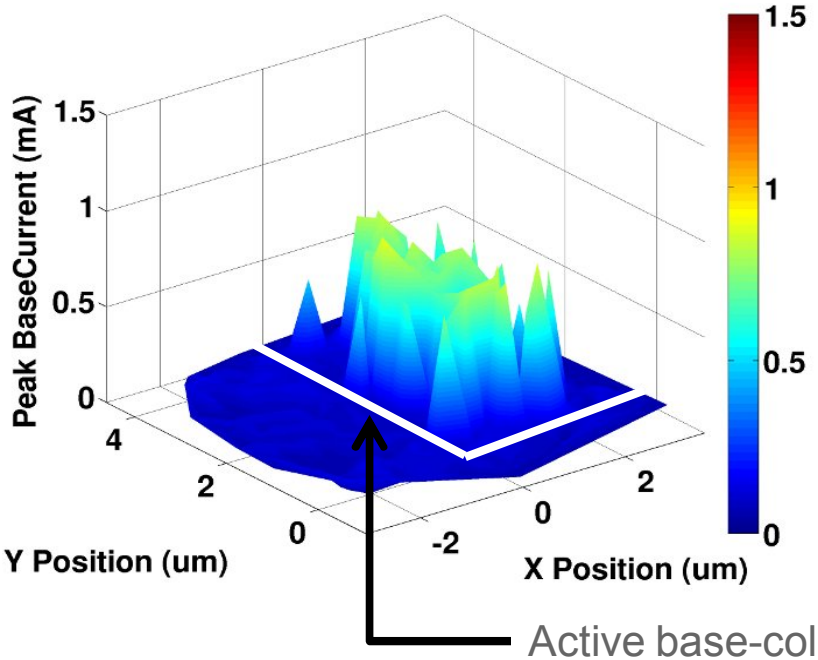
Microbeam data allows position correlation

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

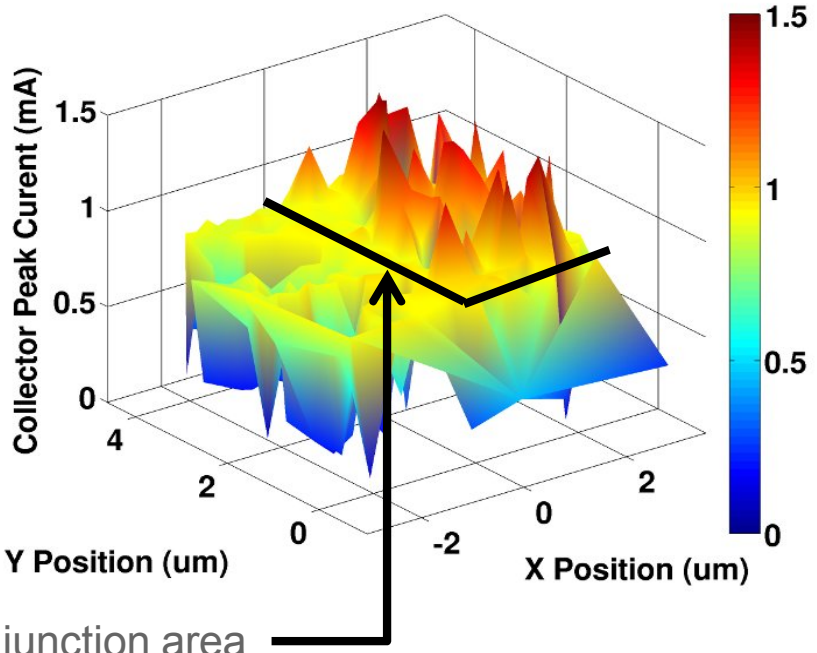
36 MeV ^{16}O SNL microbeam: Case 1

Peak current magnitude

Base



Collector



Active base-collector junction area

- V_{sub} = -4 V; all other terminals grounded
- Base terminal images base-collector junction
- Collector terminal images base-collector junction and subcollector

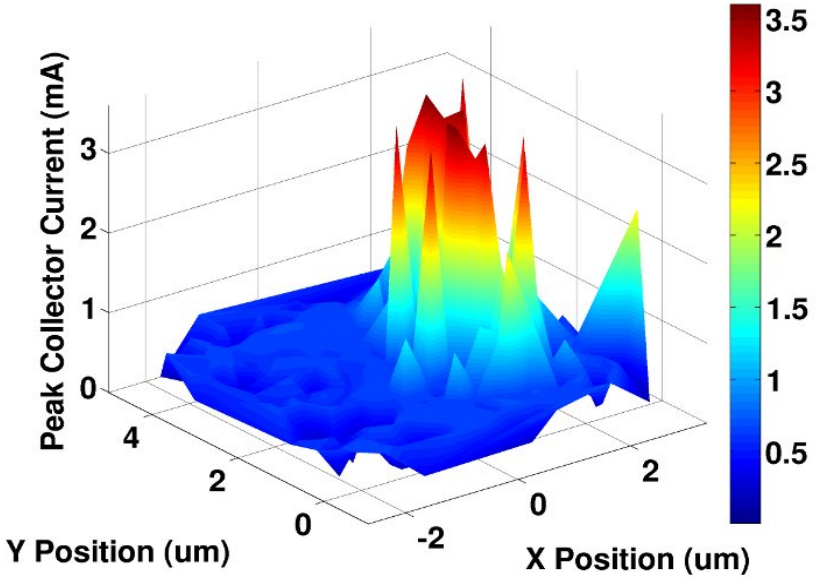
Imaging provides information about position and current

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

36 MeV ^{16}O SNL microbeam: Case 2 *vs.* 3

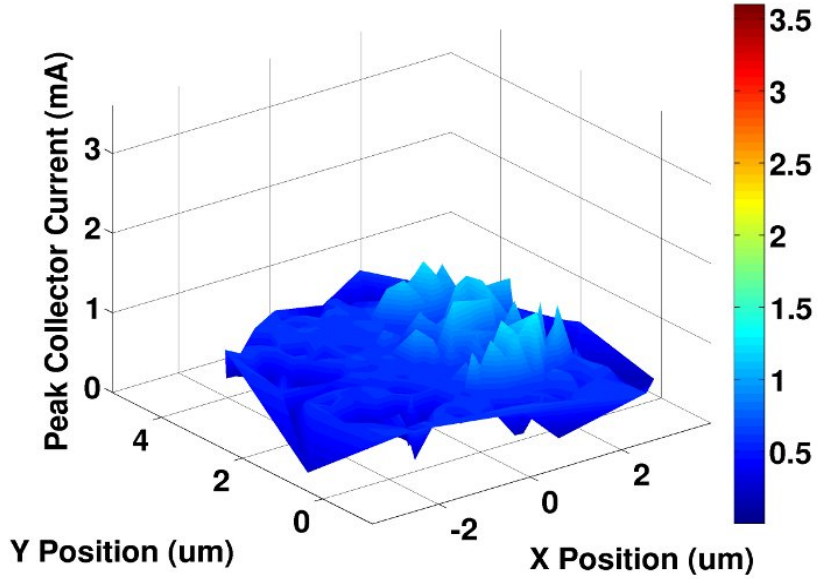
Peak current magnitude

Collector



V_C = +3 V (Case 2)

Collector



V_{sub} = -3 V (Case 3)

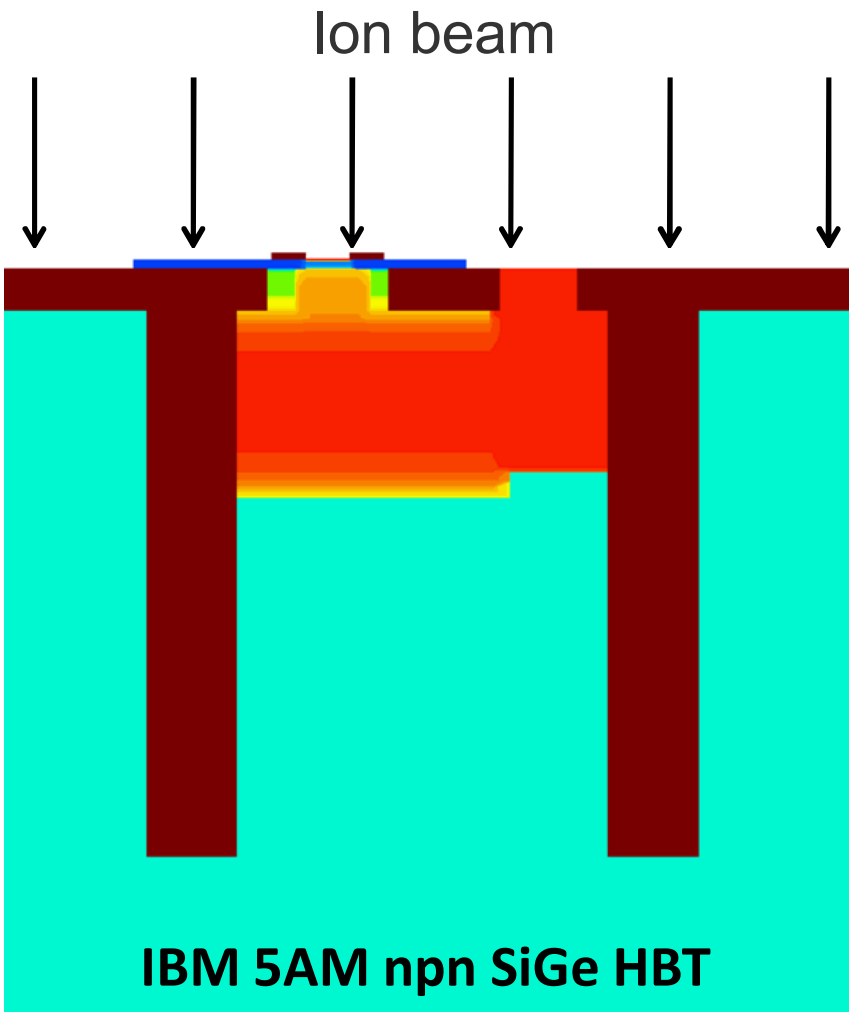
- Same result was observed in two-photon pulsed laser testing

J. A. Pellish *et al.*, *IEEE Trans. Nucl. Sci.*, vol. 55, no. 6, pp. 2936-2942, Dec. 2008.

Difference in peak current results from non-zero V_{CB}

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

Heavy ion broadbeam transients



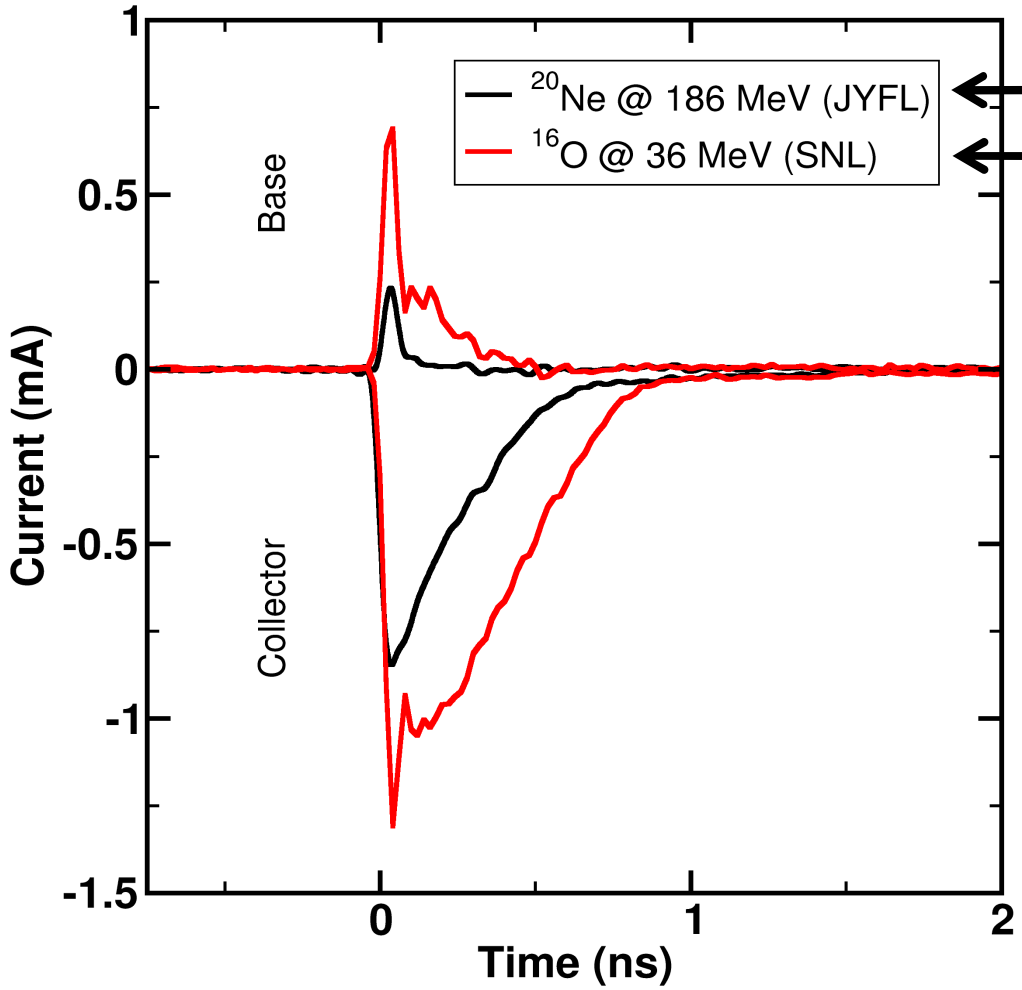
University of Jyväskylä
K-130 Cyclotron

No position correlation with broadbeam irradiation

- Data collection at JYFL and GANIL
- 9.3 MeV/u cocktail including ^{20}Ne, ^{40}Ar, ^{82}Kr, and ^{131}Xe and 45.5 MeV/u ^{136}Xe

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

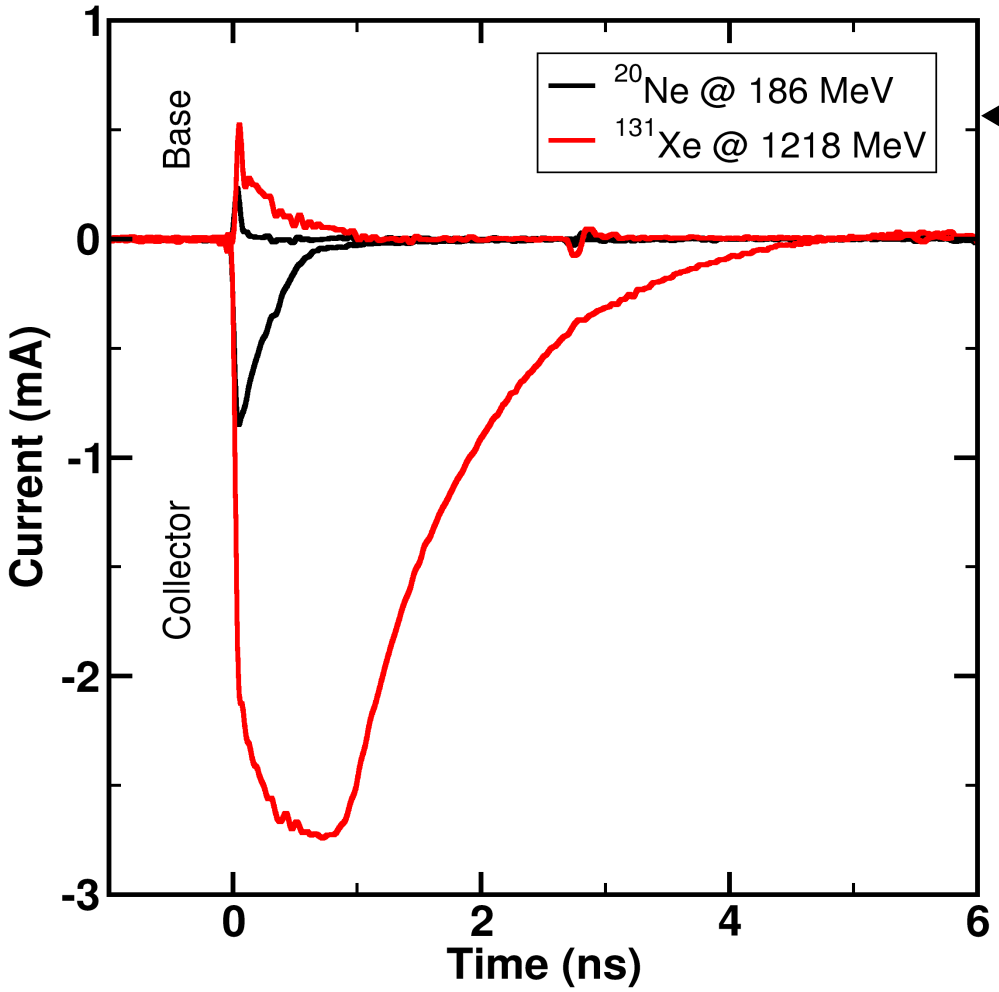
JYFL *vs.* SNL: LET scaling



A ^{20}Ne and ^{16}O transients are similar – related by LET

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

JYFL: LET extremes



9.3 MeV/u

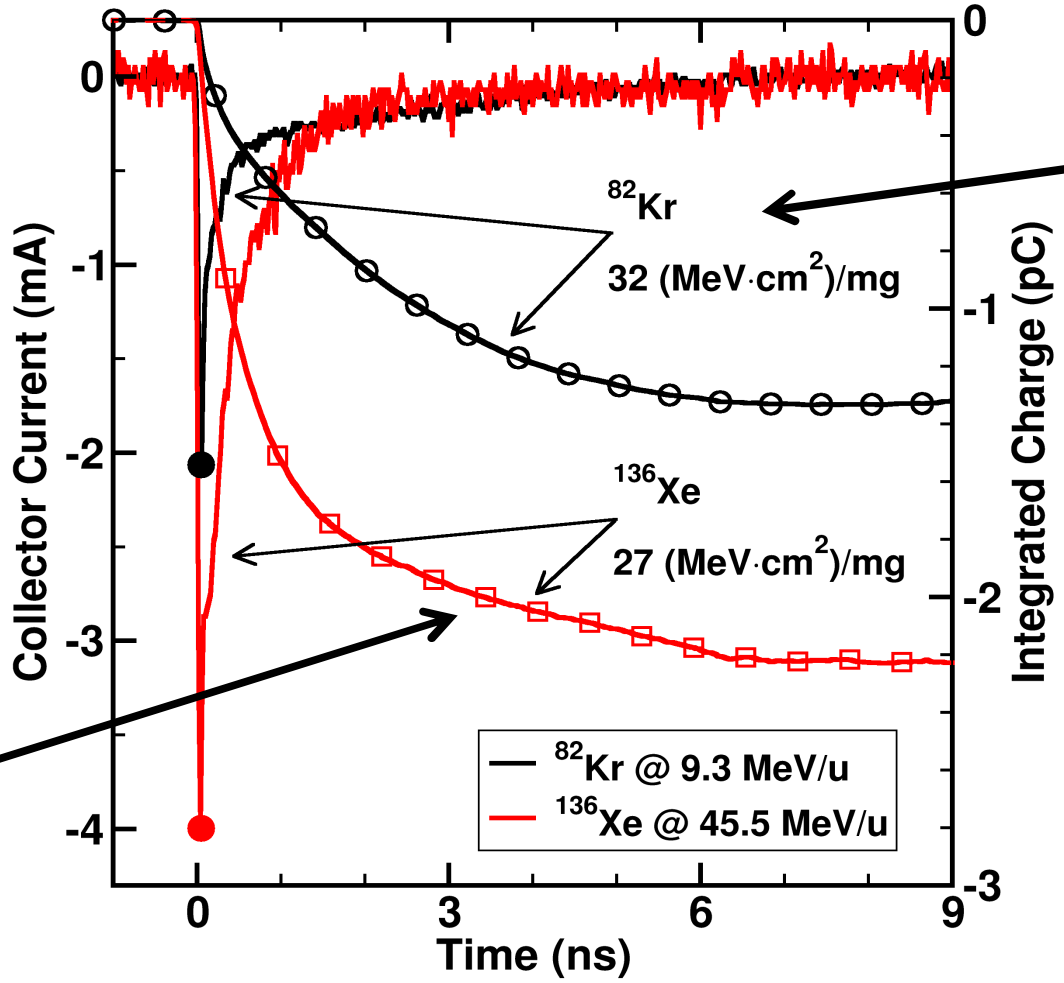
^{20}Ne LET
3.6 (MeV·cm^2)/mg

^{131}Xe LET
60 (MeV·cm^2)/mg

Position correlation made possible with microbeam data

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

JYFL *vs.* GANIL transients



Ma Similar LET values produce different transient responses ty

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.

Conclusions

- Microbeam (SNL) transients reveal ***position-dependent*** heavy ion response
  - Unique response for different device regions
  - Unique response for different bias schemes
  - Similarities to TPA pulsed-laser data
- Broadbeam transients (JYFL and GANIL) provide ***realistic*** heavy ion response
  - Feedback using microbeam data
  - Overcome issues of LET and ion range with microbeam
  - **Angled ^{40}Ar data in full paper
- Data sets yield ***first-order*** results, suitable for TCAD calibration feedback

To be presented by Jonathan A. Pellish at the 2009 NSREC, July 20-24, 2009, Quebec City, Quebec Canada and published on http://nepp.nasa.gov/ and http://radhome.gsfc.nasa.gov/.