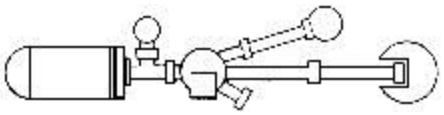

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Sandia National Laboratories

MicroPIXE mapping of the metal content of microbial communities

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Outline
- The new Sandia IBL and the Pelletron-microbeam beam line
- The scattering chamber and the high accuracy positioning stage
- Sinergetic detection: the high sensitivity PIXE SSD, the luminescence detection
- How to handle biosamples
- a case study: the metal content of microbial communities. Usage of Quantum Dots

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

ion beam lab

The IBL facility, located in Albuquerque, New Mexico

The Ion Beam Lab, or IBL, at Sandia National Laboratories, Albuquerque, NM, is a new and state of the art facility that uses both ion and electron accelerators to study and modify material systems.

The purposes of the IBL are diverse, ranging from basic research into defect physics, materials science, metallurgy and solid state physics, to highly applied R&D into radiation effects, aging phenomena and manufacturing quality affecting the US stockpile and upgrades of nuclear weapons.

By using the set of nuclear and electron techniques, virtually every element in the periodic table can be measured or implanted and every radiation environment, natural or man-made, can be simulated at the micro scale. Four end stations in the IBL have combined ion and electron capabilities.

The IBL also emphasizes the controlled generation of defects in materials, and the study of their effect on electronic and mechanical properties.

The staff of the IBL

On the cover;
A backscattering image of the SNL logo on a gold integrated circuit.
A beam line from the Tandem-Pelletron Accelerator.

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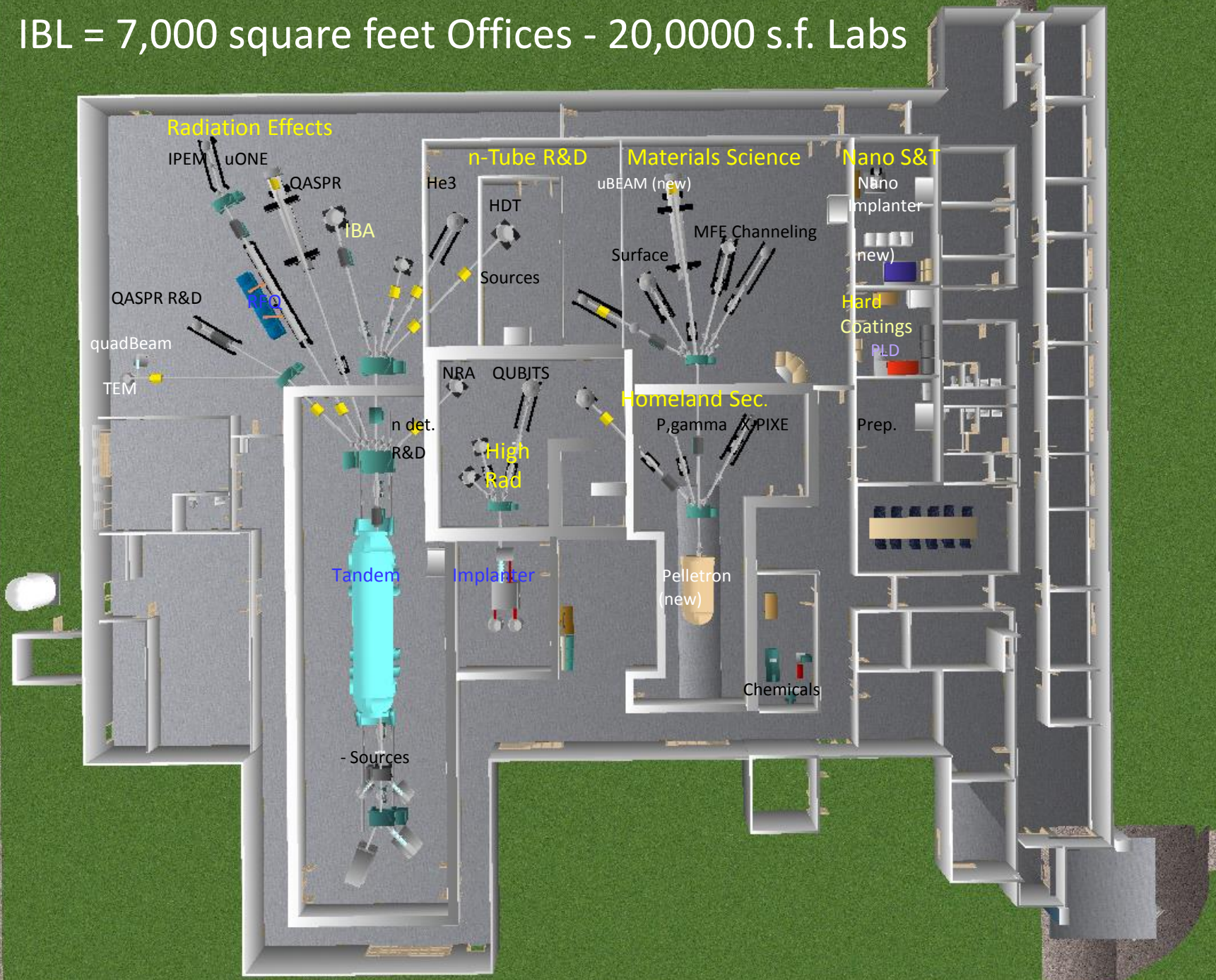
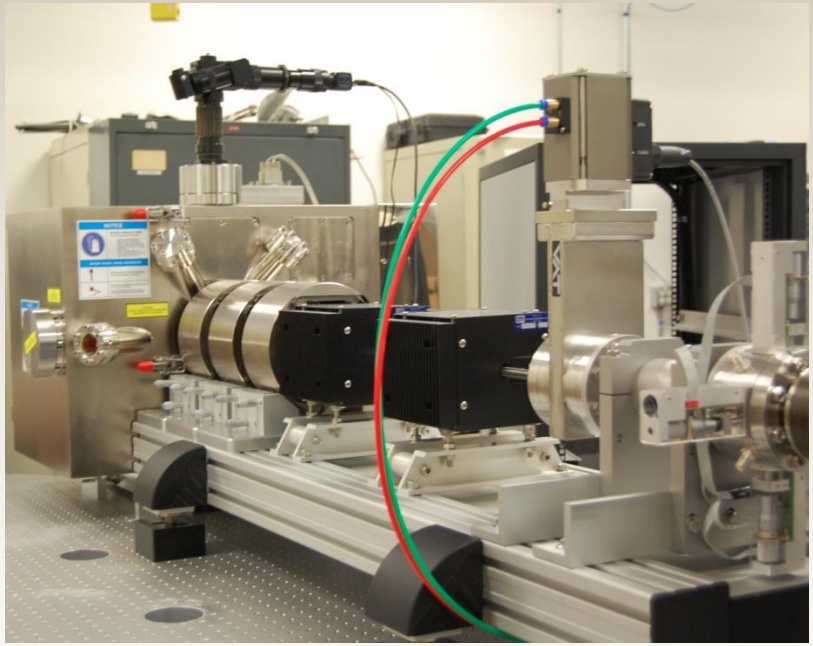
Sandia National Laboratories

IBL = 7,000 square feet Offices - 20,0000 s.f. Labs

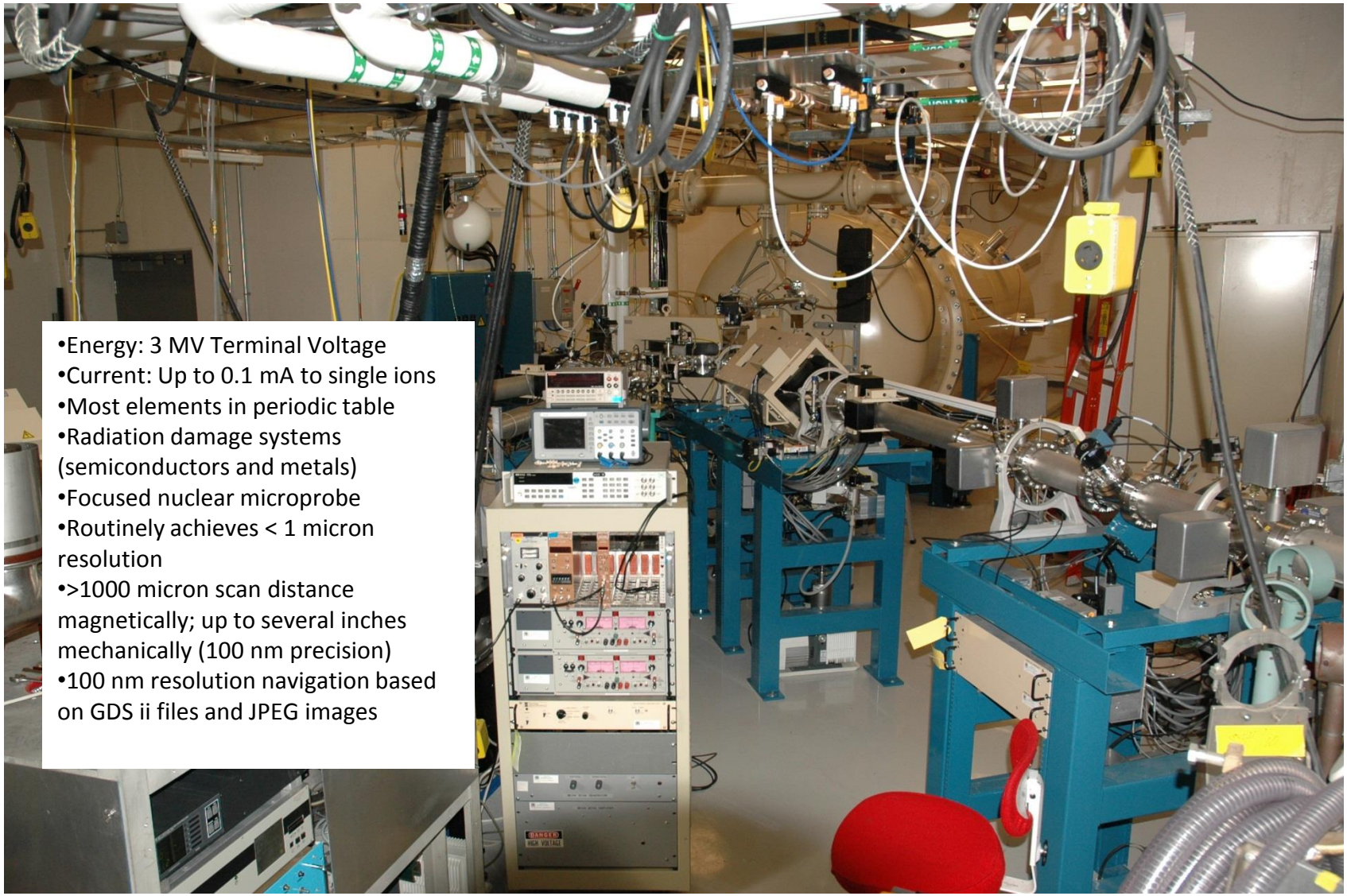


Ion Beam Laboratory

The new uBEAM on the Pelletron demonstrated .5um spots for 2 MeV He with currents approaching 1 nA. Virtually every element in the periodic table will be measured with high sensitivity in 3D at this resolution.

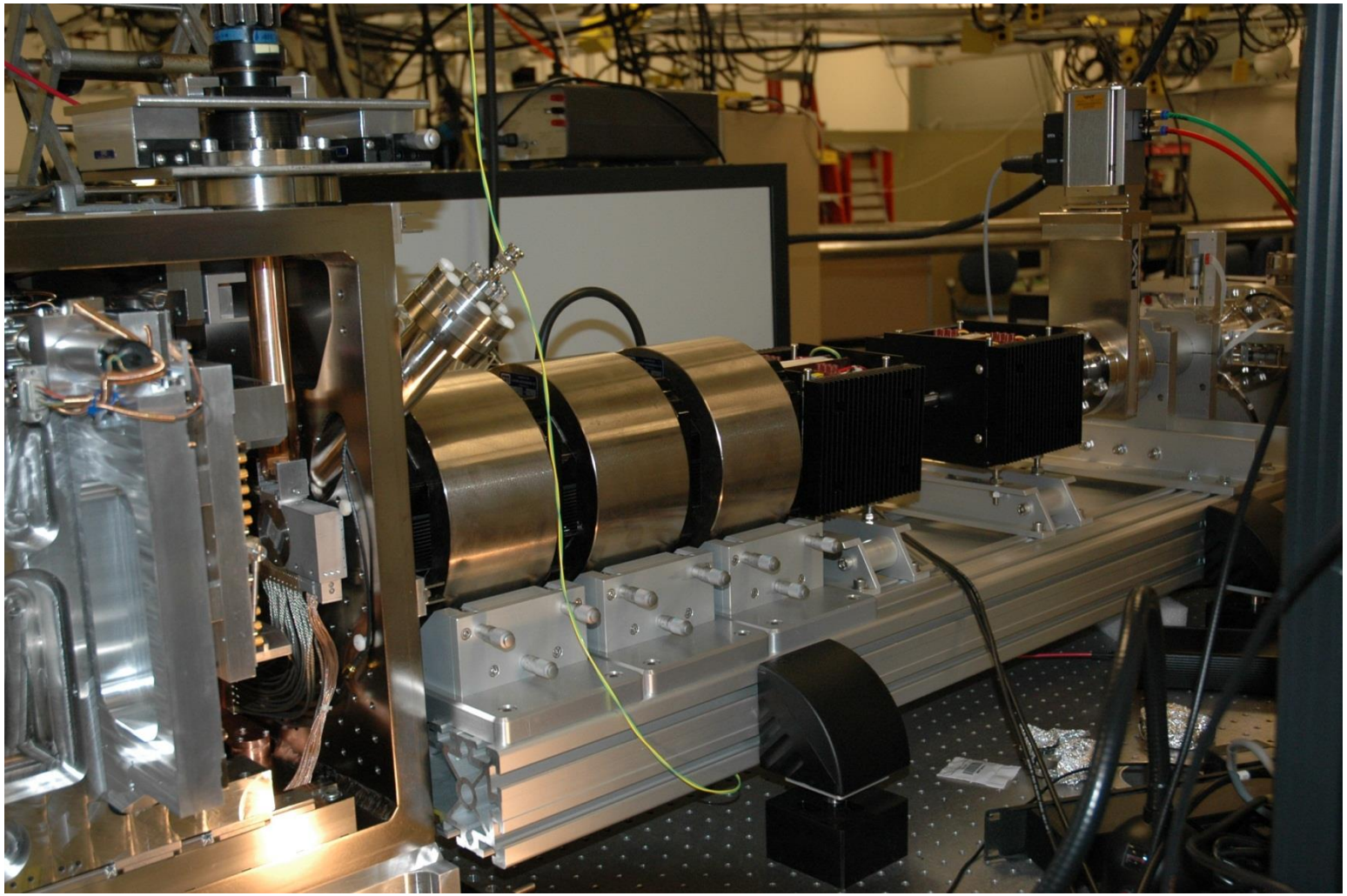


Pelletron

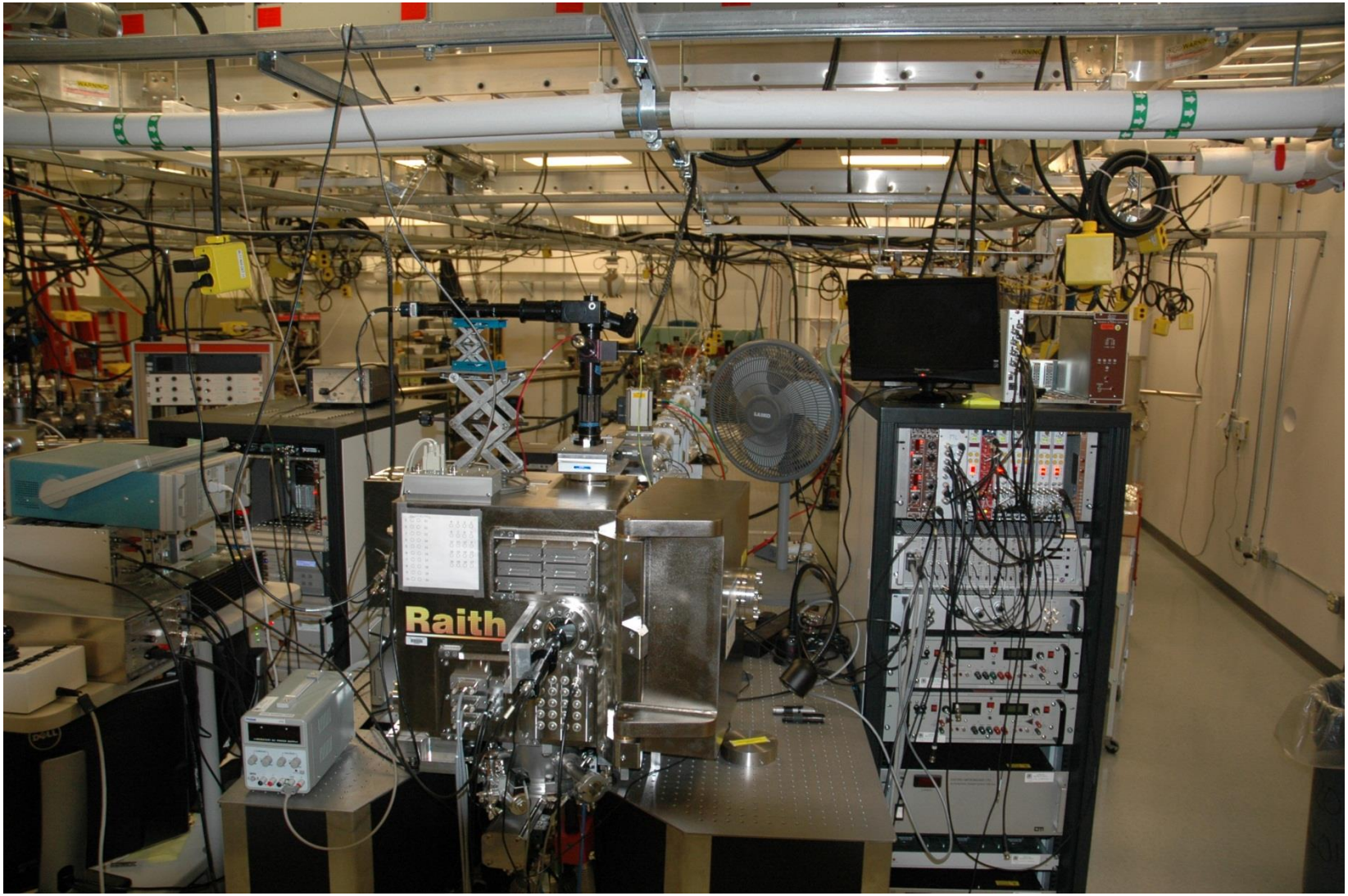


- Energy: 3 MV Terminal Voltage
- Current: Up to 0.1 mA to single ions
- Most elements in periodic table
- Radiation damage systems (semiconductors and metals)
- Focused nuclear microprobe
- Routinely achieves < 1 micron resolution
- >1000 micron scan distance magnetically; up to several inches mechanically (100 nm precision)
- 100 nm resolution navigation based on GDS ii files and JPEG images

Raith chamber, SDD and triplet

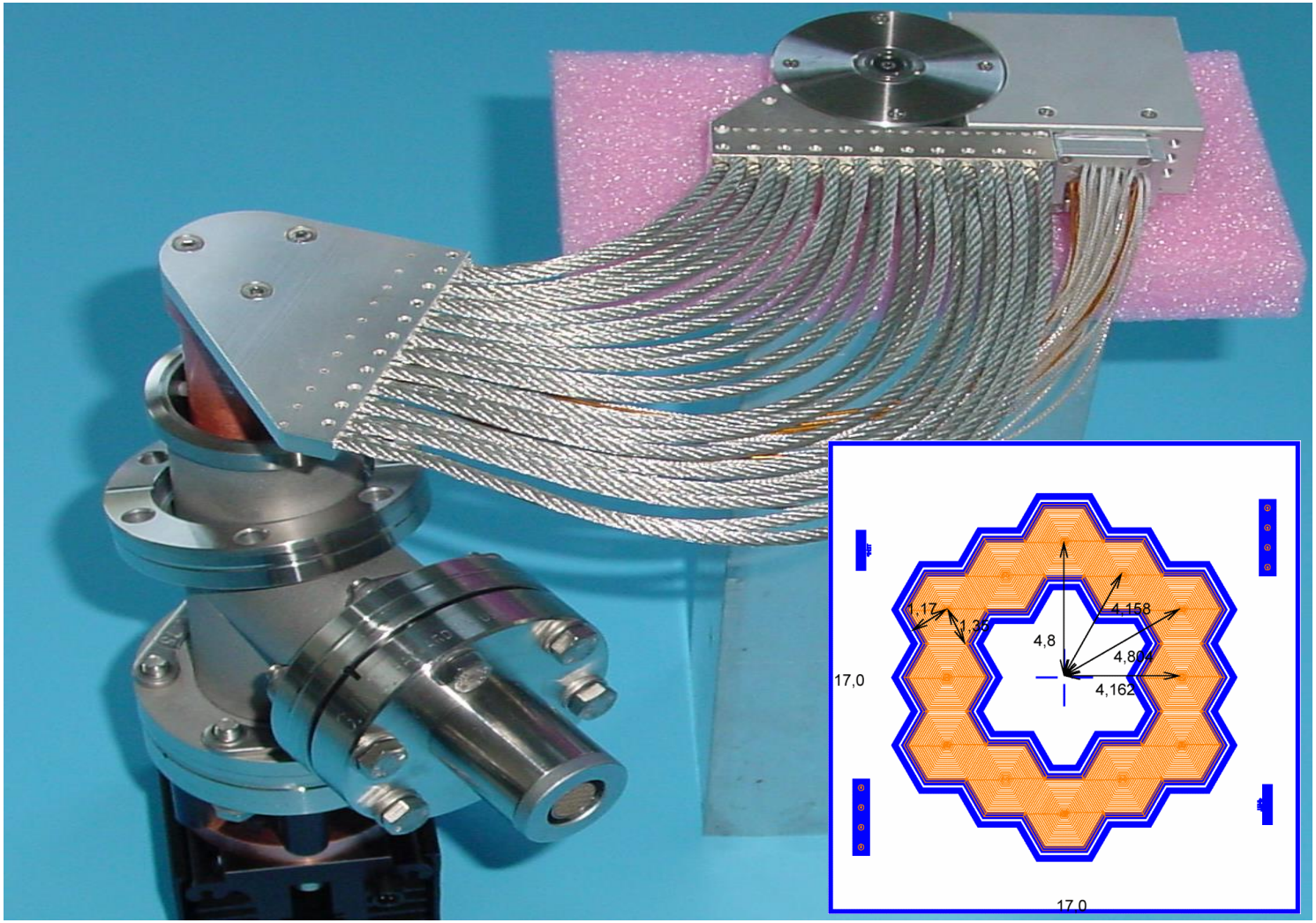


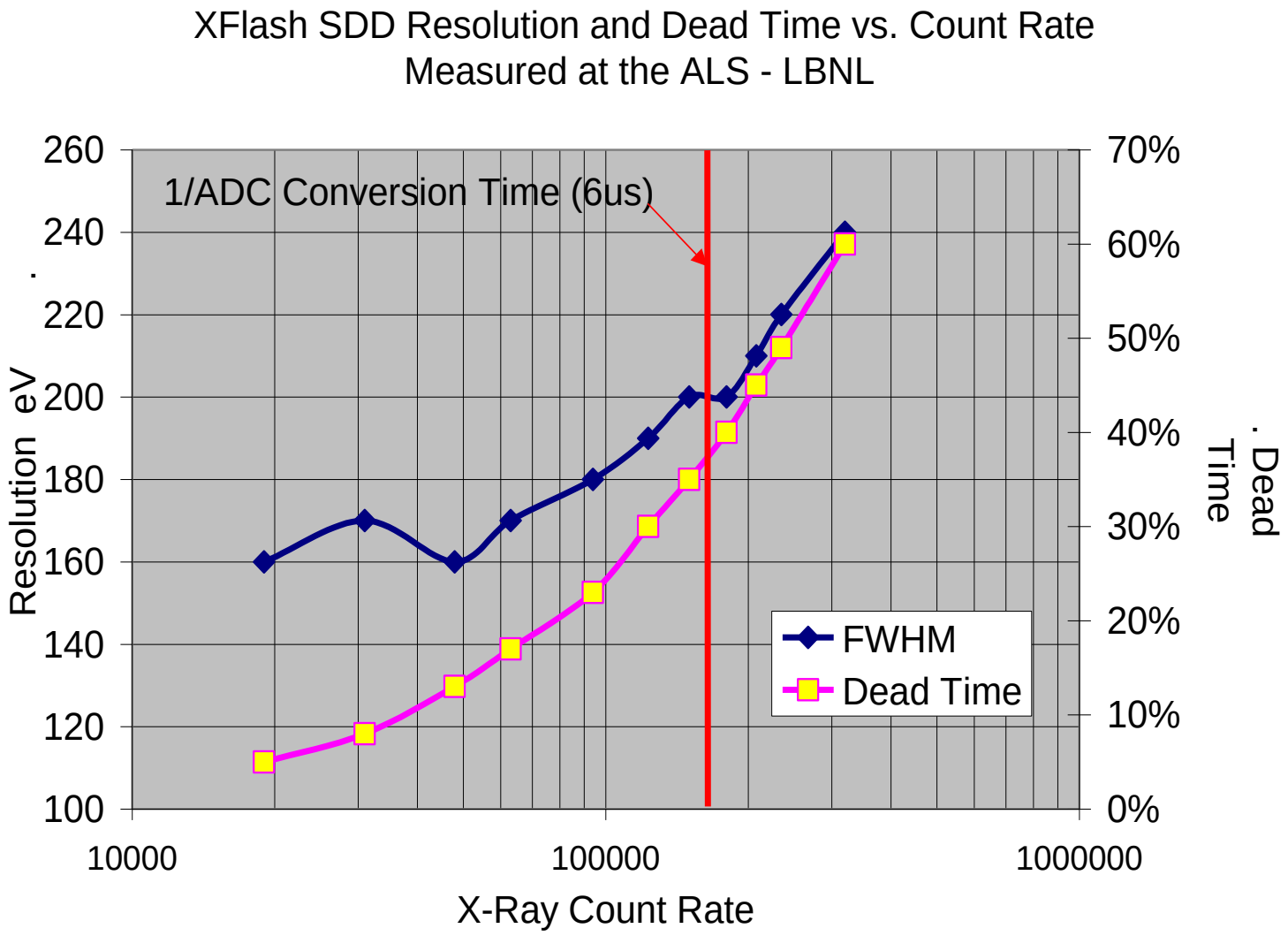
Line, OM40 and Raith Chamber



12 channels SDD Data Acquisition

The Sandia-Rontec annular 12-channel Silicon Drift Detector – SDD12




XFlash SDD Resolution and Dead Time vs. Count Rate
Measured at the ALS - LBNL
1/ADC Conversion Time (6us)
Resolution . eV
. Dead Time
260
240
220
200
180
160
140
120
100
70%
60%
50%
40%
30%
20%
10%
0%
10000
100000
1000000
X-Ray Count Rate
FWHM
Dead Time

Application to Bio-Samples, a case study: Analysis of the metal content of microbial communities

We propose to employ an ion microbeam to map the metal content in infectious disease applications (macrophage response to Francisella tularensi LVS infection) and samples from distinct microhabitats of the Sevilleta Long Term Ecological Research site in central NM. The dynamics and properties of both systems are traced through the measurement of variations in the metal concentration and location during various states of the system.

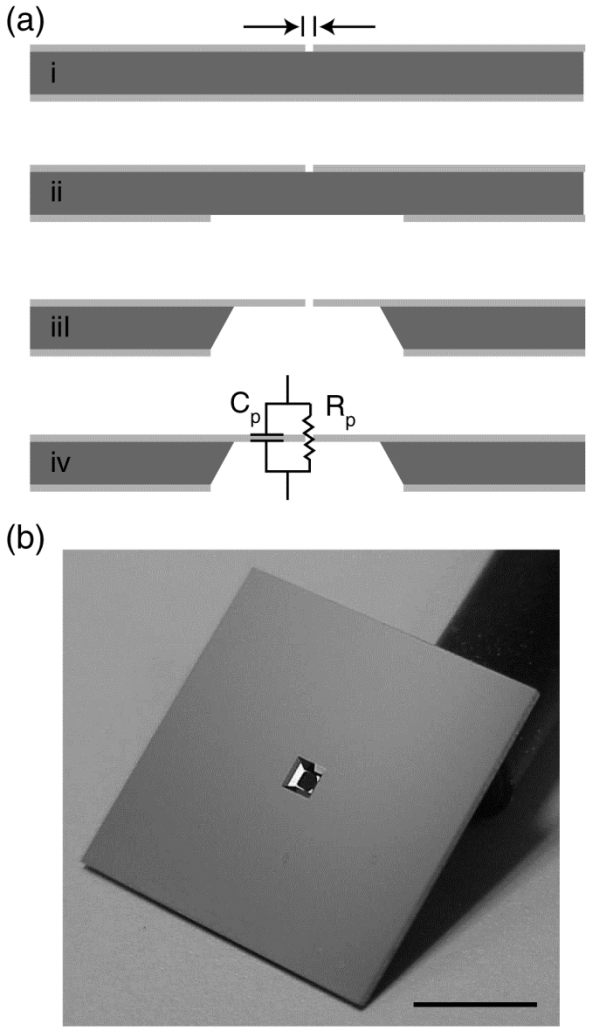
The role of Quantum Dots (10-15 nm CdSe sphere shelled with ZnS)

Cells are let to intake functionalized QD's, in order to track the dynamics of bio-systems through Fluorescence Microscopy. Optical imaging of QD's, taken directly through our OM40 optical microscope, can drive the micropixe to aim at specific sites in the bio-sample to assess localized metal contents.

Calculations and early measurements show that direct uPIXE targeting of the QD's, in physiological concentrations in cells, is hardly possible, but uIBL or fluorescence microscopy in the uBEAM chamber will be explored.

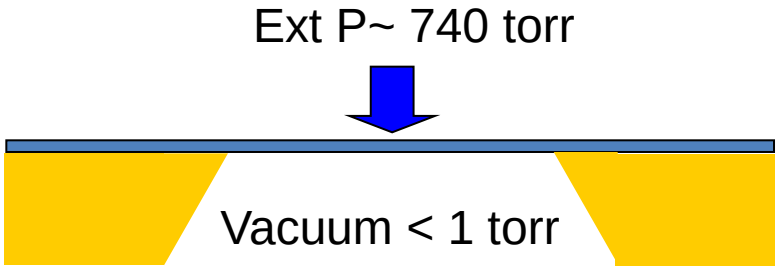
Sample Holder for dry and wet bio samples

100 TEM grid (stride=254 μm).
Internal square side ~ 1250 micron

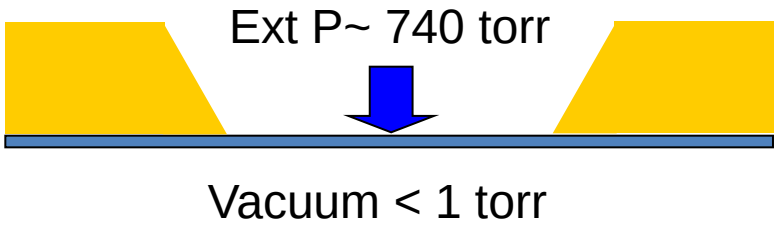


*C.D. James, et al., Biosens. Bioelec. 2008, **23**, pp. 845.*

Vacuum tests on Si3N4 1 micron windows
14s time from 740 to 20 torr
14s time from 20 to 1 torr



vaconflat = vacuum on the flat side



vaconpit = vacuum on the pit side

Quantum Dots
(Drawing from Invitrogen Molecular probes)

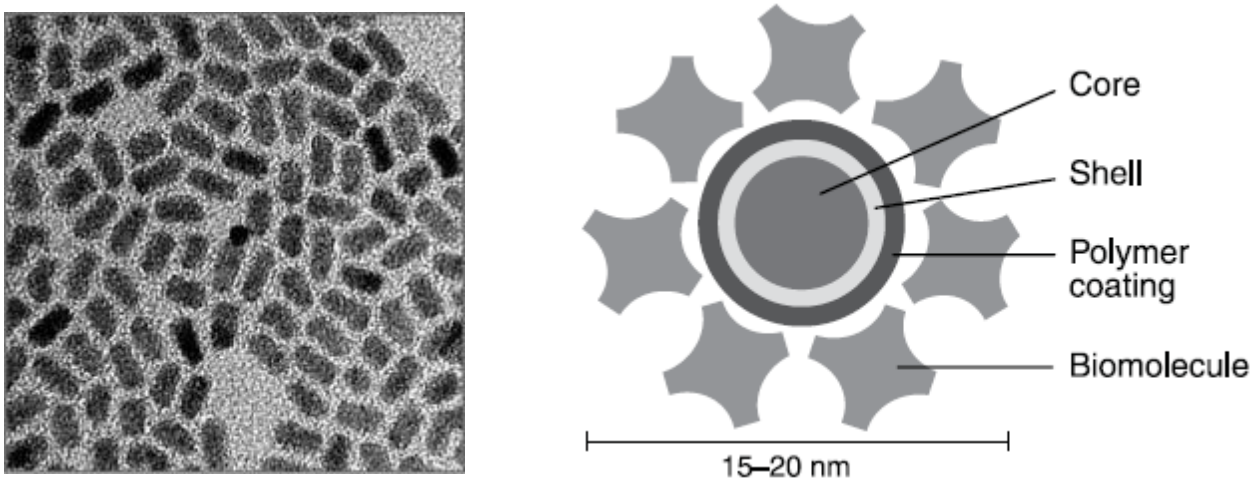
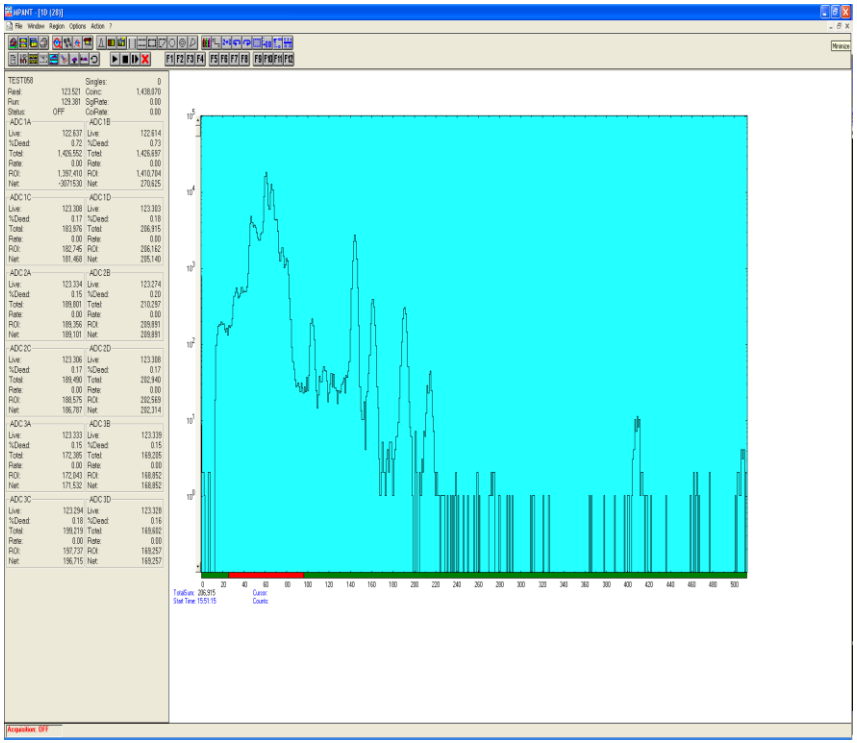
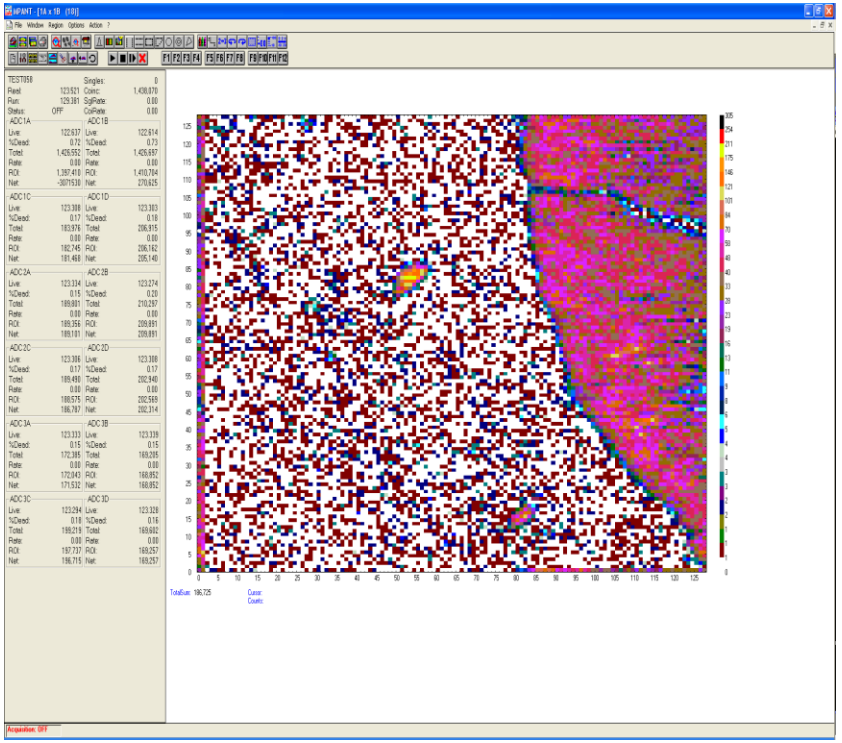


Figure 1. A. Transmission electron microscope image of core-shell Qdot® nanoparticles at 200,000x magnification. Scale bar = 20 nm. **B.** Schematic of the overall structure of a Qdot® conjugate. The layers represent the distinct structural elements of the Qdot® nanocrystal conjugates, and are roughly to scale.

micro-PIXE images of Quantum Dots filled samples

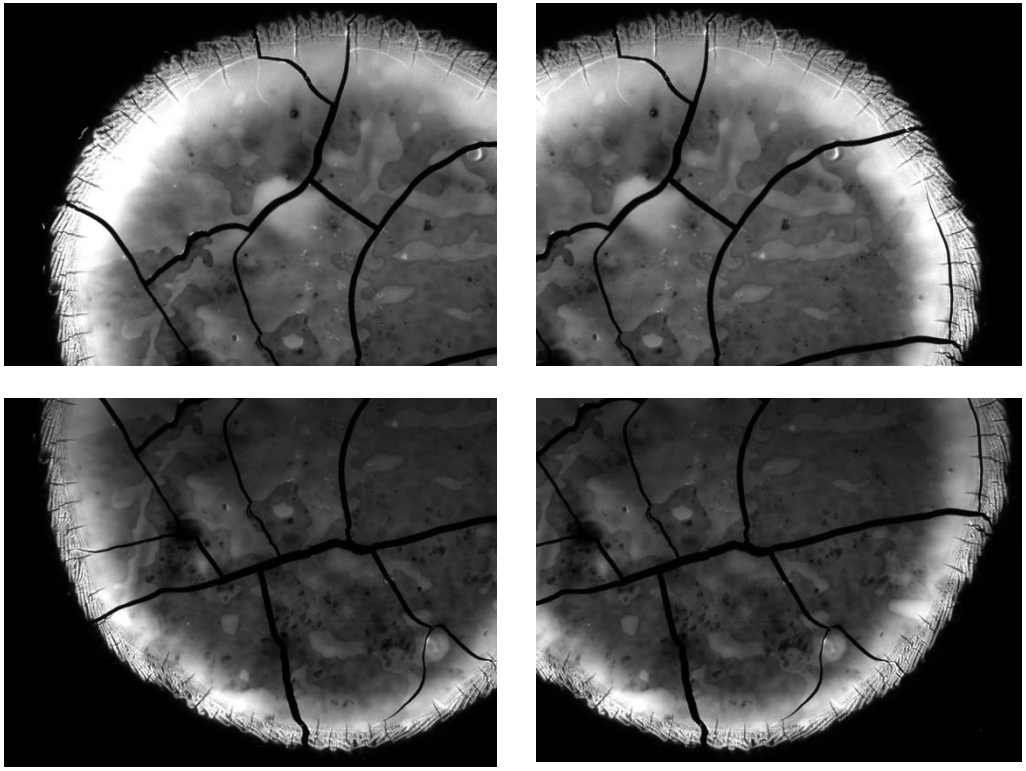




Run 58. Zn, Se and Cd peaks show the presence of Quantum Dots. Maps show pattern of QD distribution comparable to that obtained by fluorescence microscopy

4e-11 mol QD585, on graphite tape, sample 1

Quadrants



Optical Fluorescence images

Conclusion

Sandia micro-beam and detectors setup is able to address a large amount of IBA problems, due to its versatility, high sensitivity and spatial and energetic resolution.

Synergetic measurements of X-Rays, luminescence, RBS and the development of new sample holders allow in particular the assessment of dry and wet biosamples, as in the examples shown here.

The system aiming capability is boosted by using peculiar tracking techniques based on nano-phosphors, and powerful analysis tools like GeoPIXE (U. Melbourne) and AXSIA (Sandia)