An Undergraduate Ion Beam Analysis Laboratory

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Outline

- Motivation
- Hope College Approach
  - RNB studies
  - Ion Beam Analysis Laboratory
- Representative science:
  - Lake sediment chemistry
  - Metalloprotein biochemistry
  - Luminescence & forensic geology
- Conclusions

The Need for Change in the US?

- **Traditional Undergraduate Approach:**

Lectures (and labs)

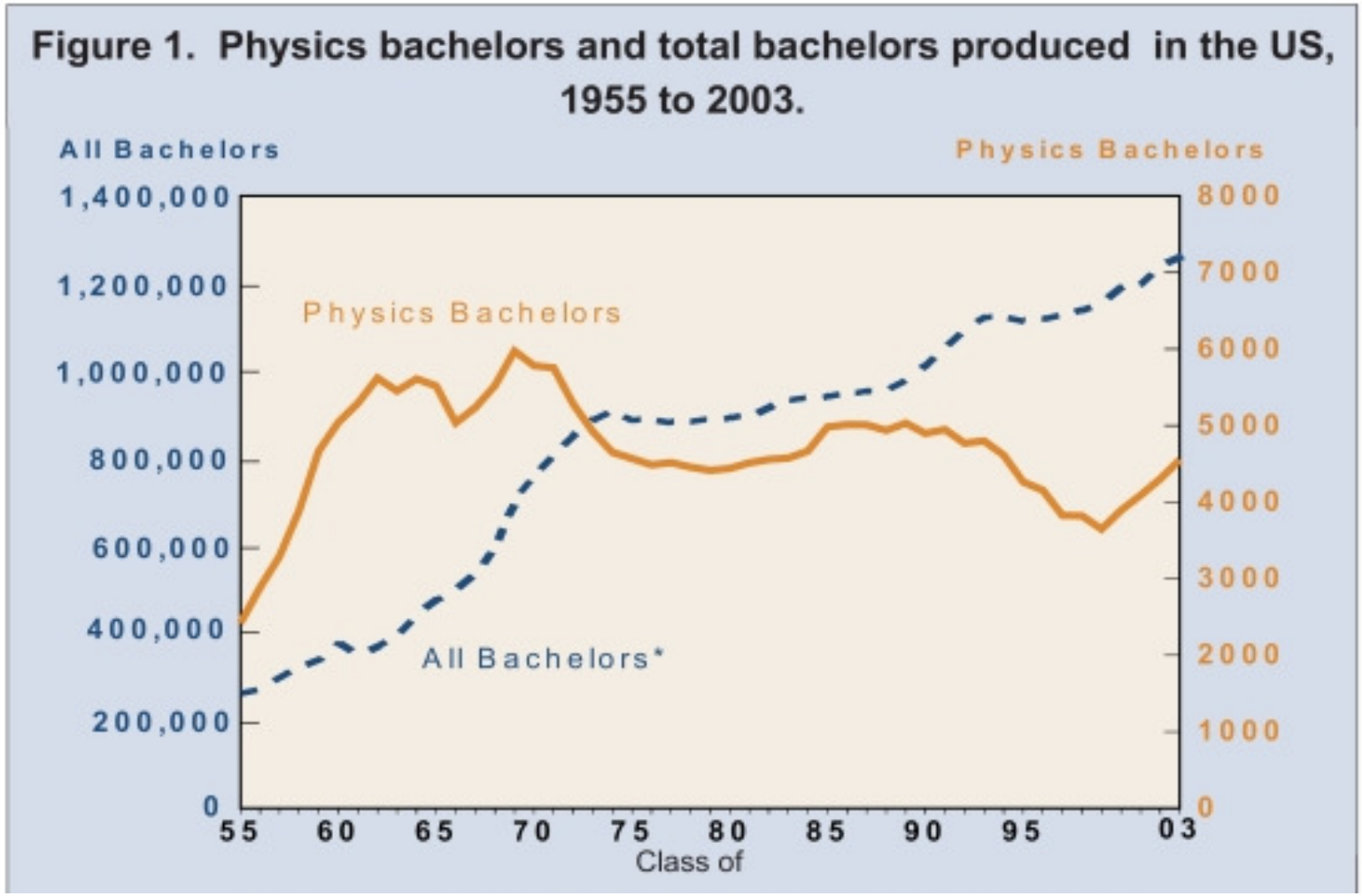
This approach is limited/threatened by:

(a) Changing demographics

(b) Changing student interests

(c) Years since discovery…

There hasn't been a sputnik recently…



- **SOURCE: AIP Statistical Research**

International Perspective?

- **Same observations for the "traditional" undergraduate educational approach**

  Lectures (and labs)

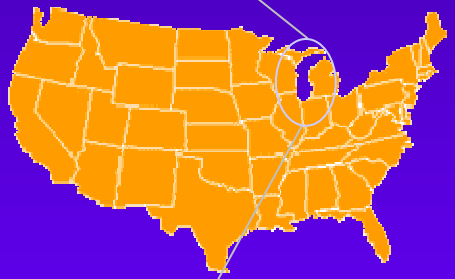
- **New instrumentation and connectivity allow new collaborative approaches**

- **Interdisciplinary and non-proliferative**

Where is Hope?

U.S.News Best Colleges 2003

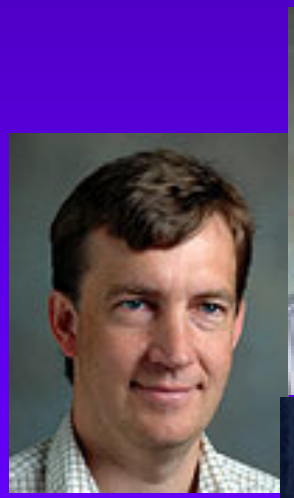
~3200 undergraduates



Holland, MI

The Hope College Nuclear Group

- The integration of research and education
- Publication–driven, NSF funded
- An interdisciplinary expansion



70 undergraduates / 16 years

Our Research Model (#1)

- Heavy Ion Reactions

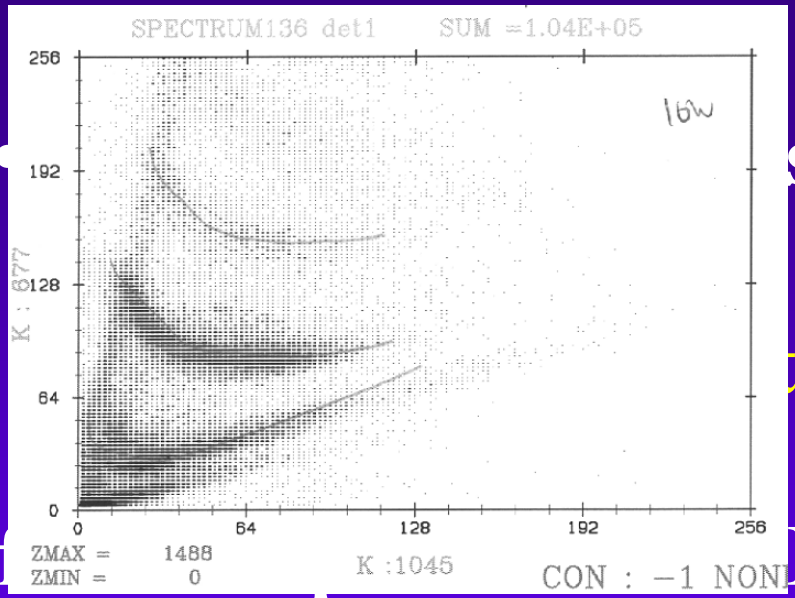
Radioactive Nuclear Beams

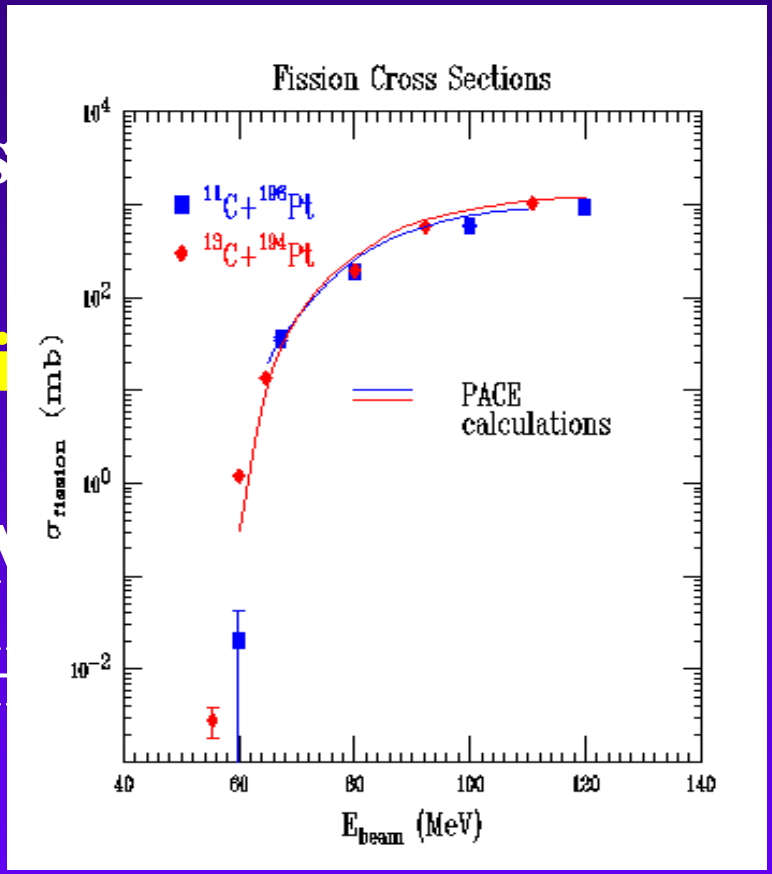
- Off-site experiments at MSU & Notre Dame
- Equipment building at Hope
- Data analysis at Hope
- Small to medium-sized collaborations
- Multi-year projects

Our Research Model (#1)

- e
- **Equipment building at Hope**
- **Data analysis at Hope**
- **Small to medium-sized collaborations**
- **Multi-year projects**

Our Research Model (#1)

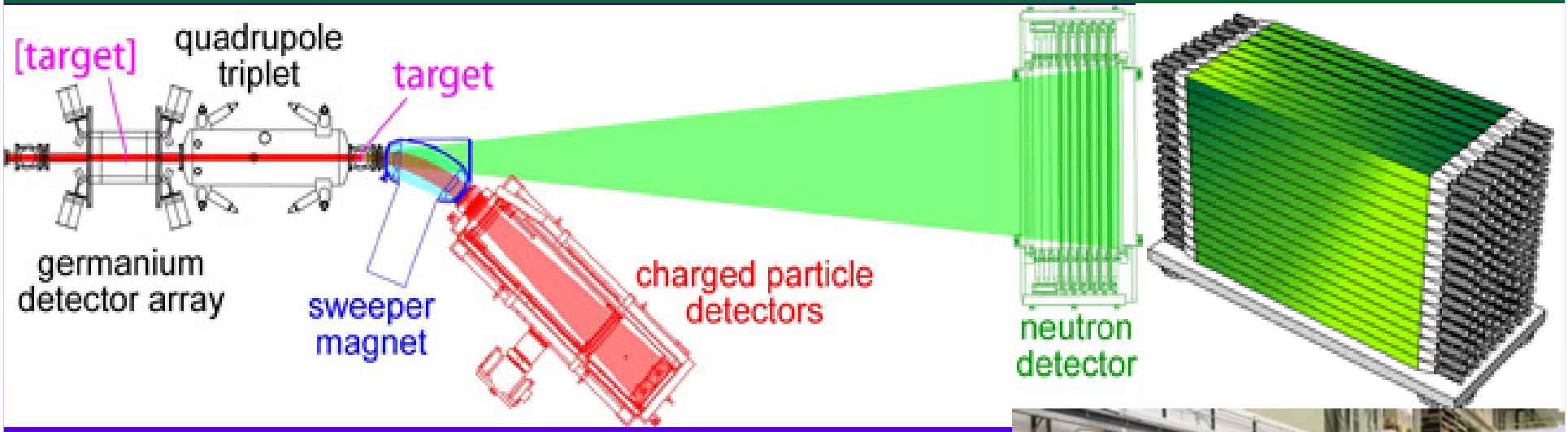




- Equipment building at H
- **Data analysis at Hope**
- Small to medium-sized collaborations
- Multi-year projects

MoNA

The Modular Neutron Array



Phys. Rev. Lett. 100, 152502 (2008)

Nucl. Phys. A801 101 (2008)

Phys. Rev. Lett. 99, 112501 (2007)

Symmetry Vol. 4 Issue 6 Aug. 2007

"Undergraduates as Researchers", The Chronicle Review, Vol. 53, Issue 33, (April 20, 2007).

Our Research Model (#2)

- Ion Beam Analysis

  → PIXE, RBS, PESA, IBIL…

- On-site experiments (HIBAL)
- Sample preparation at Hope
- Data analysis at Hope
- Small collaborations
- Single and multi-year projects
- Very interdisciplinary

Ion Beam Analysis Techniques:

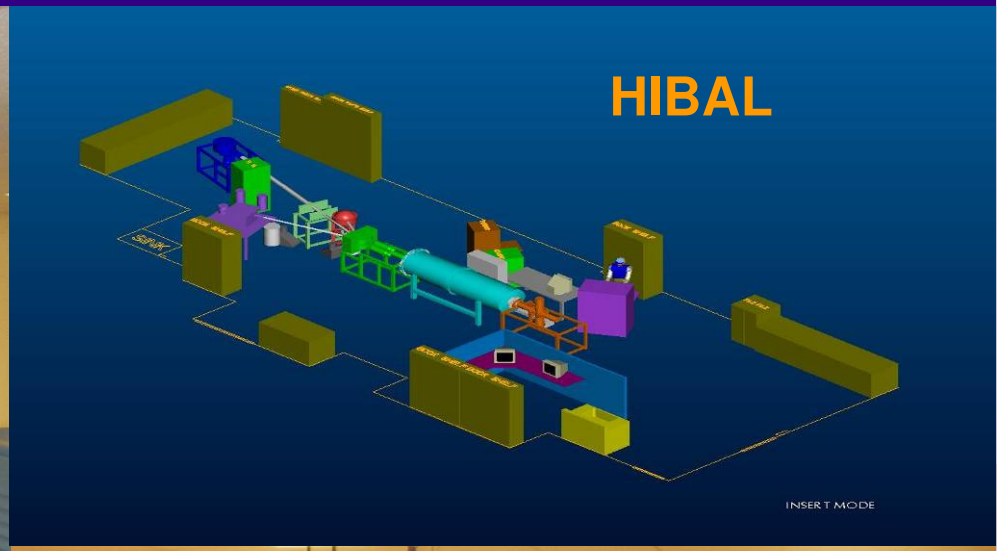
Particle Induced X-Ray Emission (PIXE)

Rutherford Backscattering (RBS)

Proton Elastic Scattering Analysis (PESA)

Ion Beam Induced Luminescence (IBIL)

Hope College Ion Beam Analysis Lab

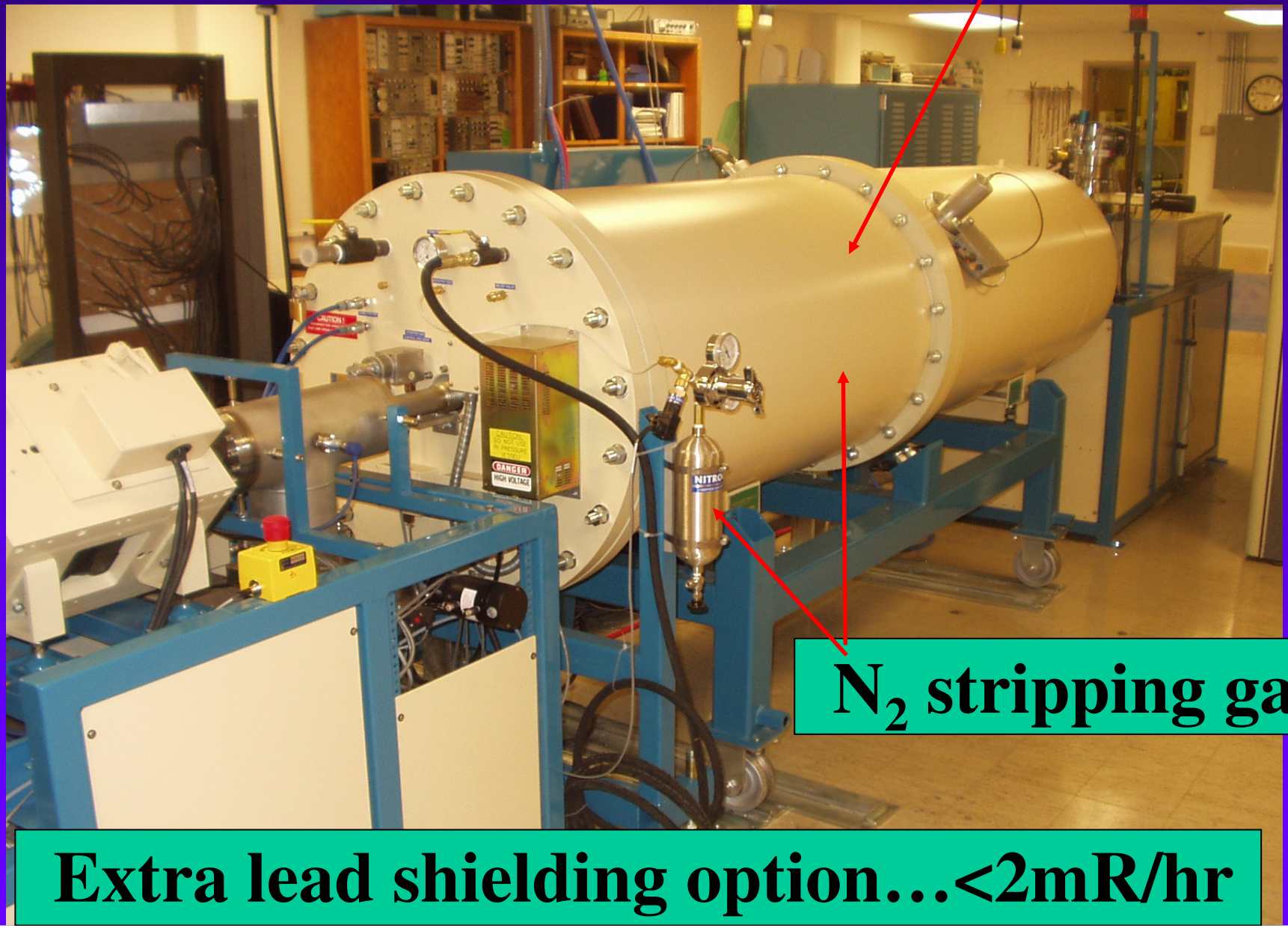


"Standard" Alphatross Ion Source

Rb charge exchange: H^- or He^-

H^+ or He^+ available

Pelletron Tank: +1.7MV



N_2 stripping gas

Extra lead shielding option…<2mR/hr

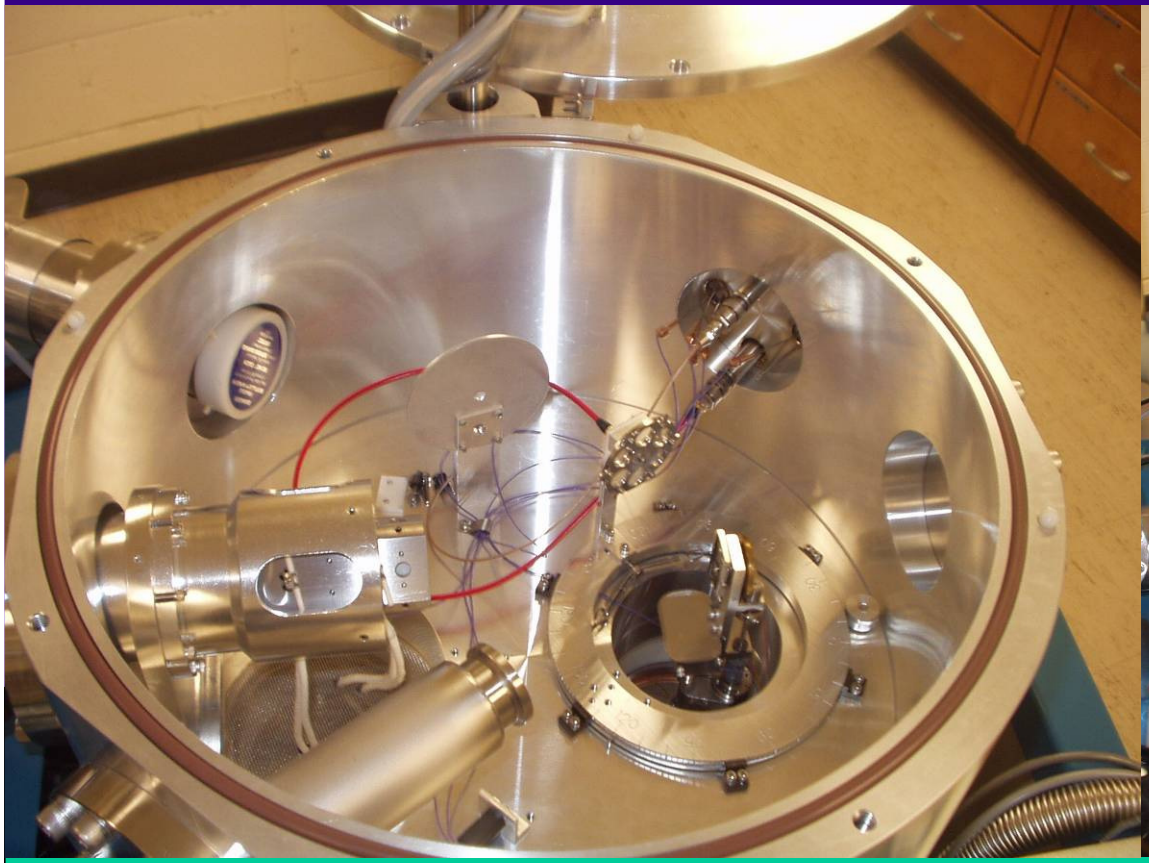
HE Focusing & Analyzing

Full energy:

3.4 MeV H^+

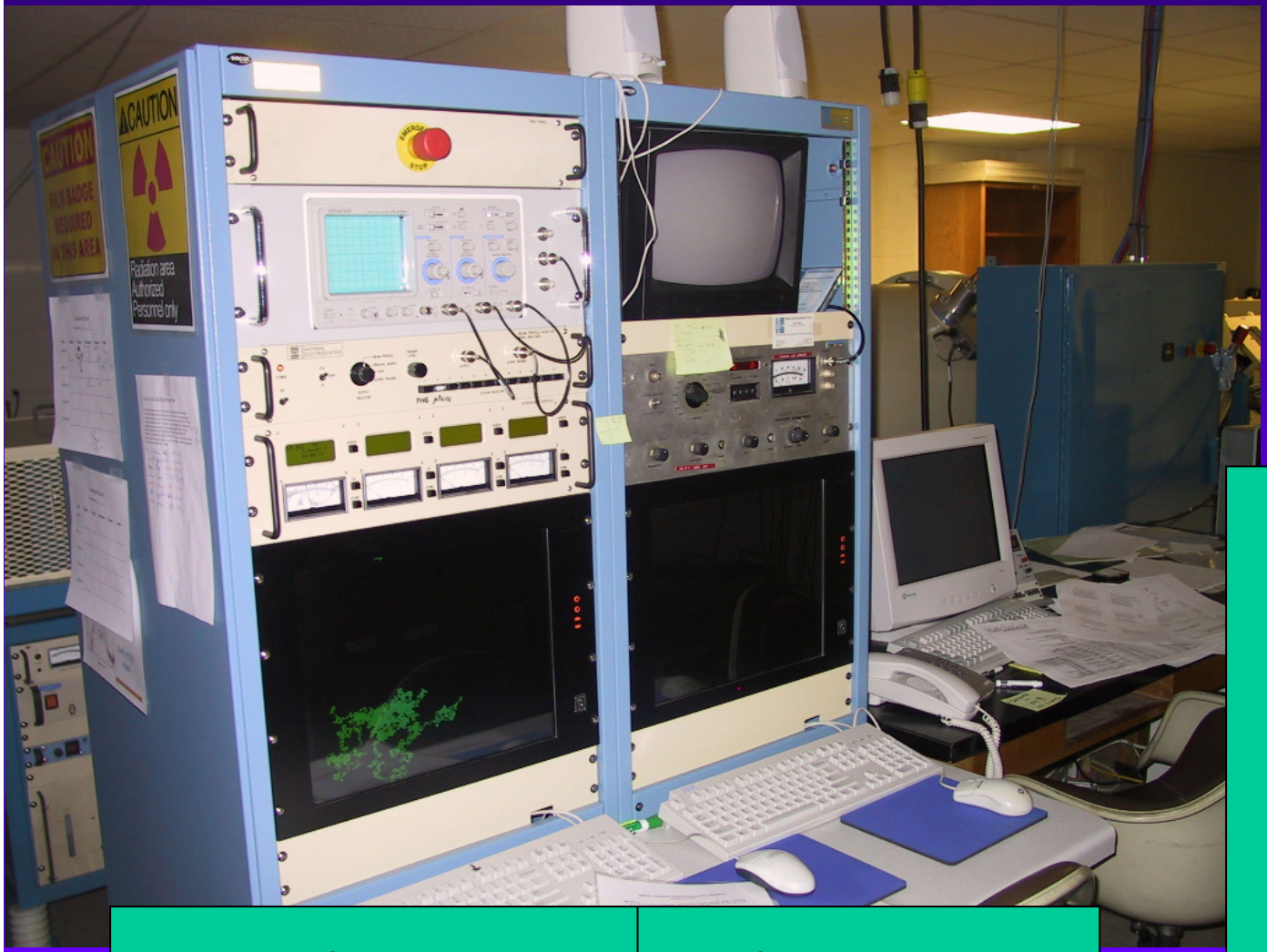
5.1 MeV He^{2+}

Endstations & Microprobe



5-axis goniometer, CCD camera, sample vacuum interlock, separate control console

Control Consoles



Linux
AccelNET

Windows
RC43

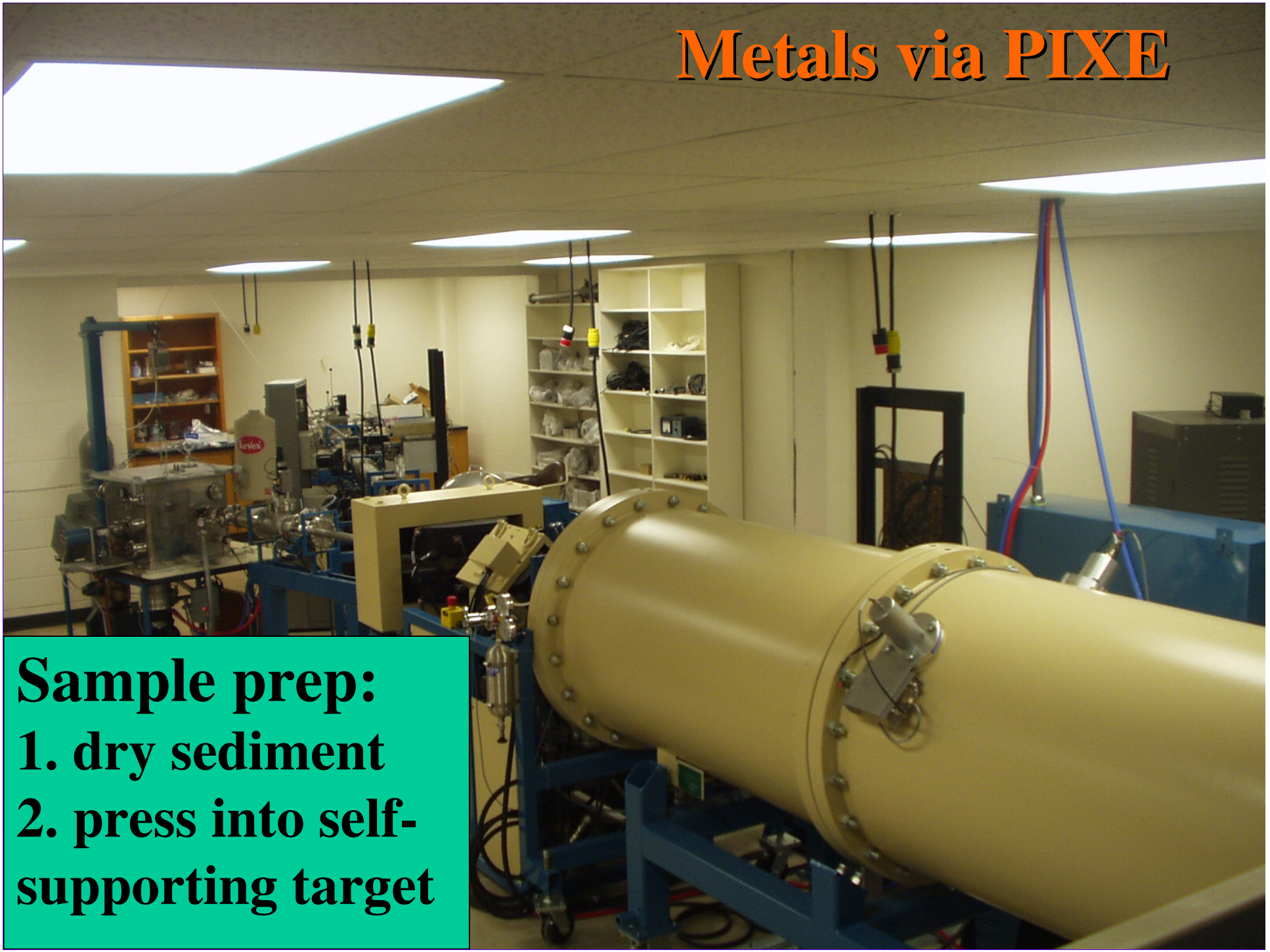
Windows

CAMAC/
FPGA
DAQ
control

Trace Metal Analysis of Sediment...

Metals via ICP

Metals via PIXE

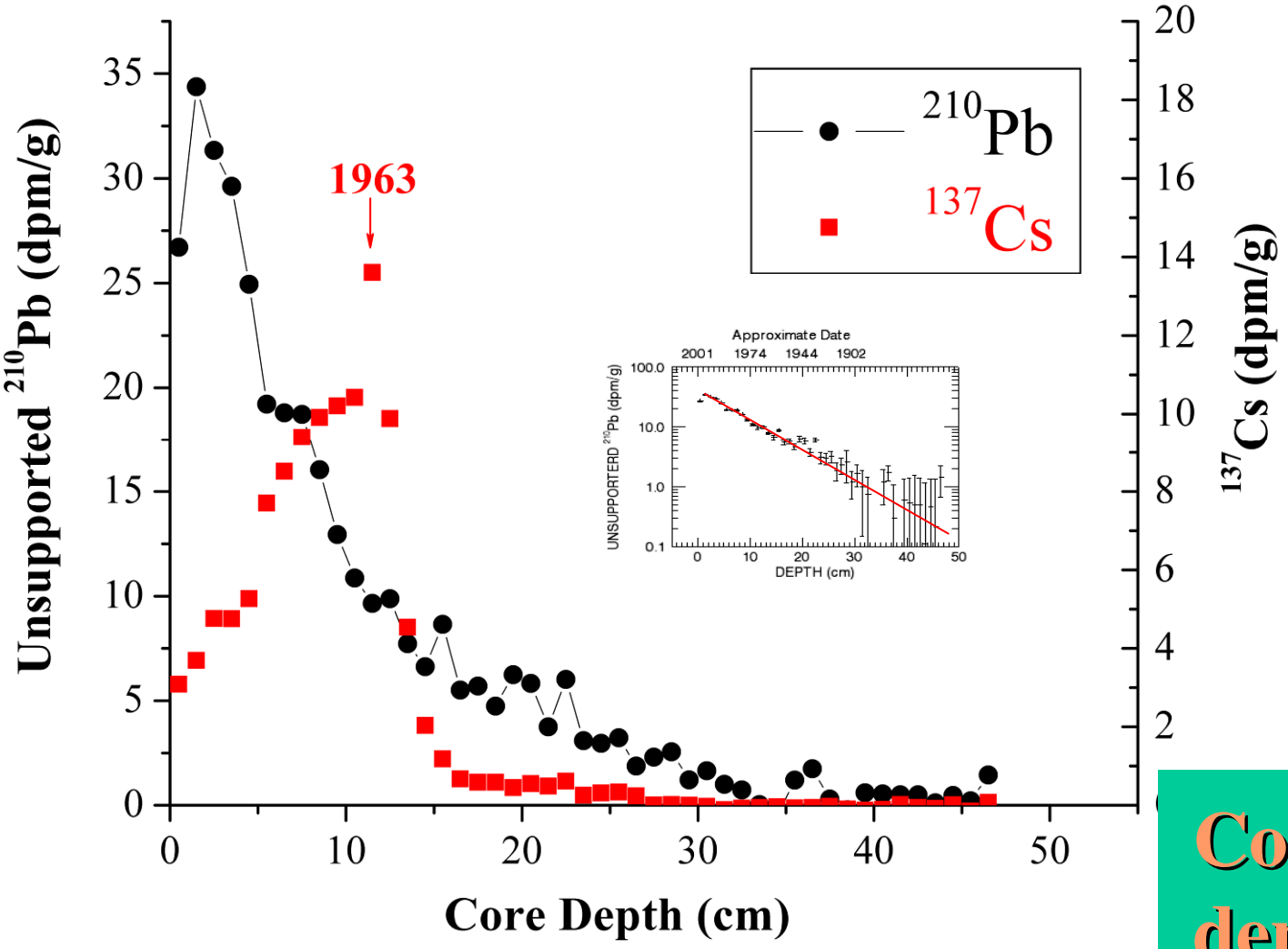


Sample prep:

1. dry sediment

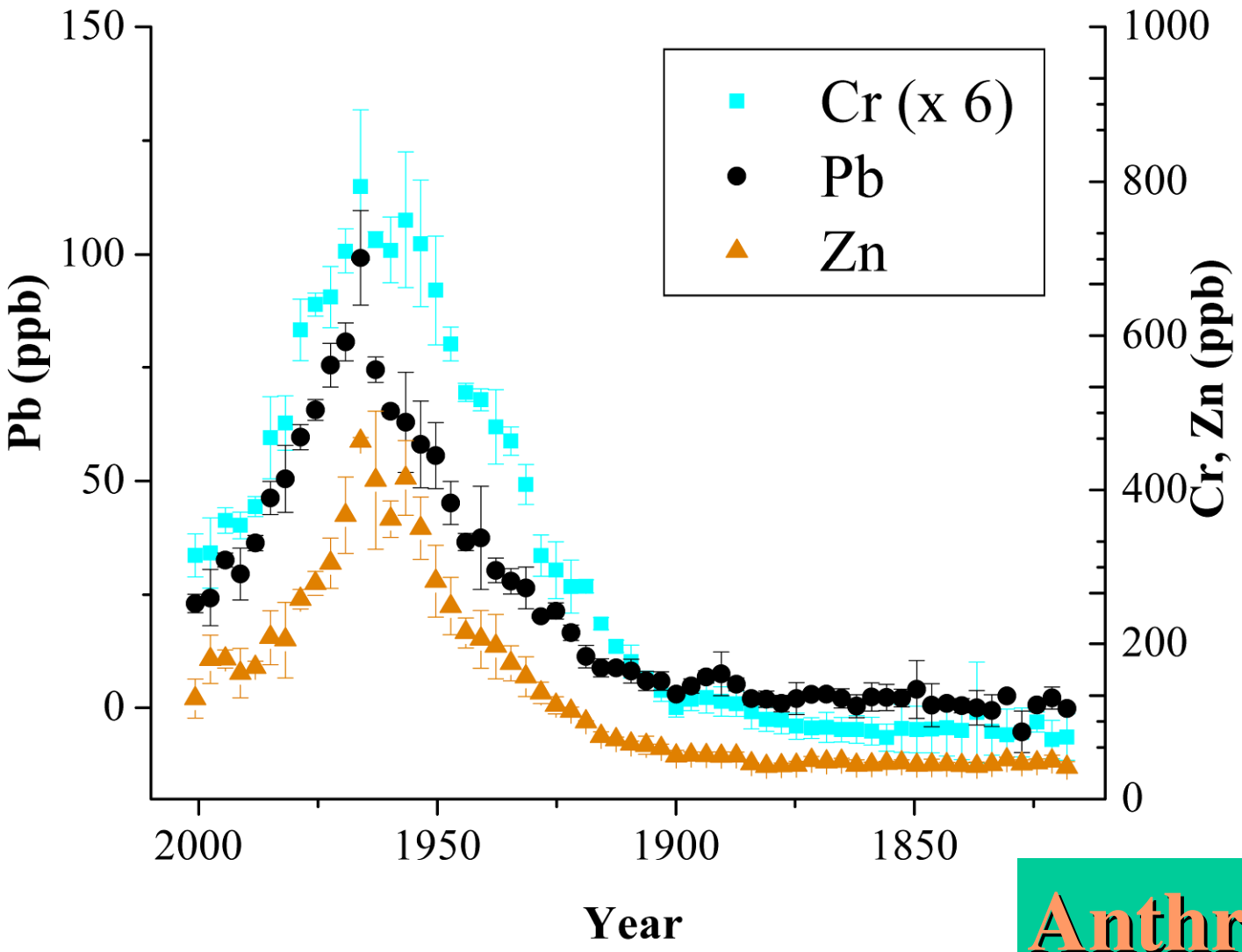
2. press into self-supporting target

Radiodating Lake Cores



Convert core depth to year

Sediment Chemistry

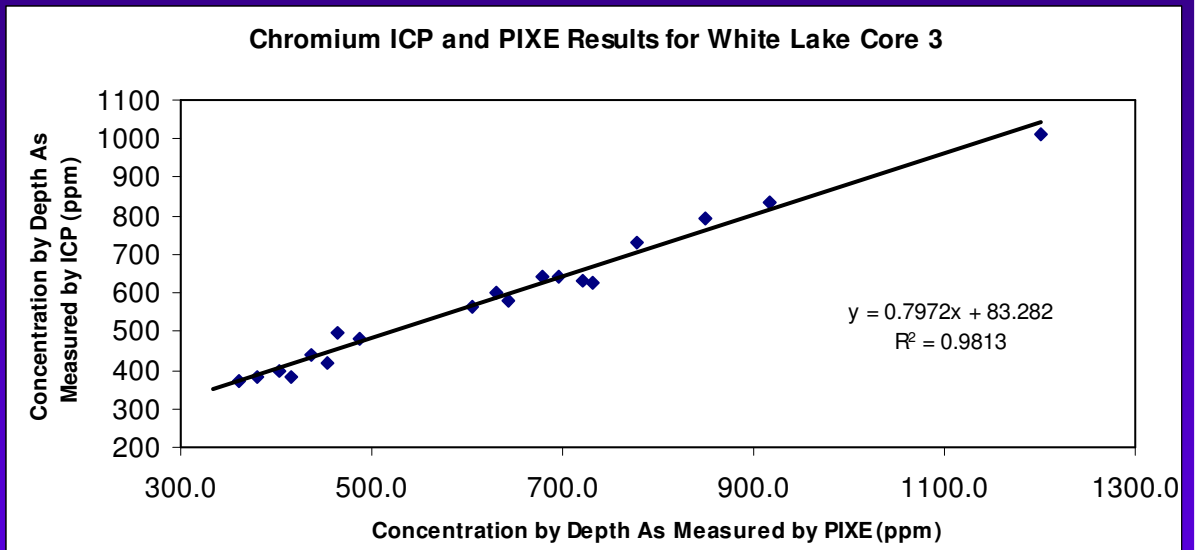


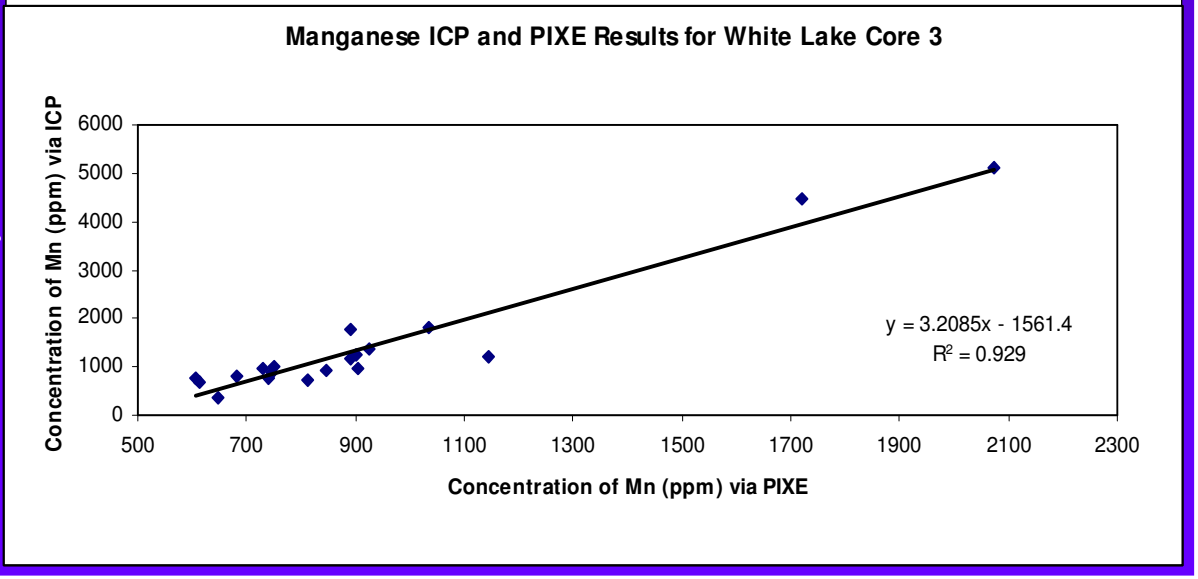
Anthropogenic

ICP vs. PIXE

- **White Lake Sediment Core**
  - **Quantitative, reproducible, non-destructive**
  - **Faster by a factor of ~3!**

J. M. Lunderberg et al.
NIM B266 (2008) 4782-4787



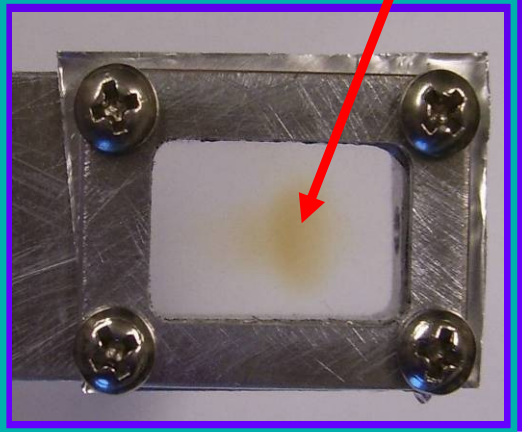


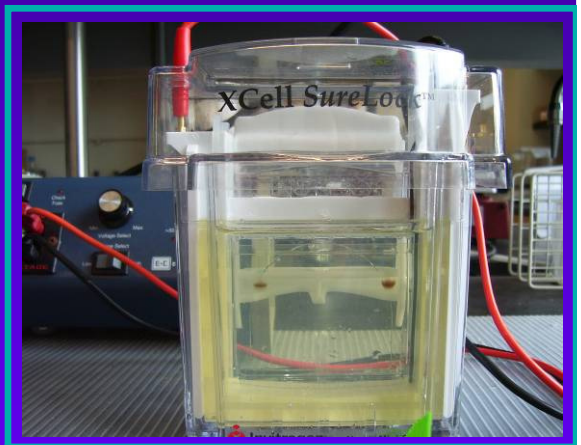
Gel Thickness Determination

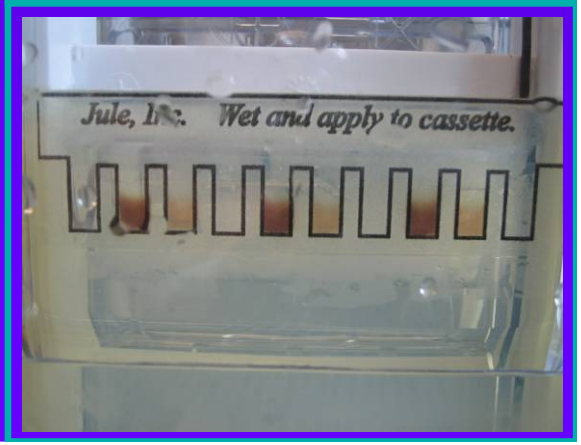
Proton Elastic Scattering Analysis (PESA)

- **ΔE is directly proportional to Δx**
- **SIMNRA allows us to relate energy loss to atoms/cm^2**

J.Warner, L.Ellsworth, M.Rycenga, L.Kiessel

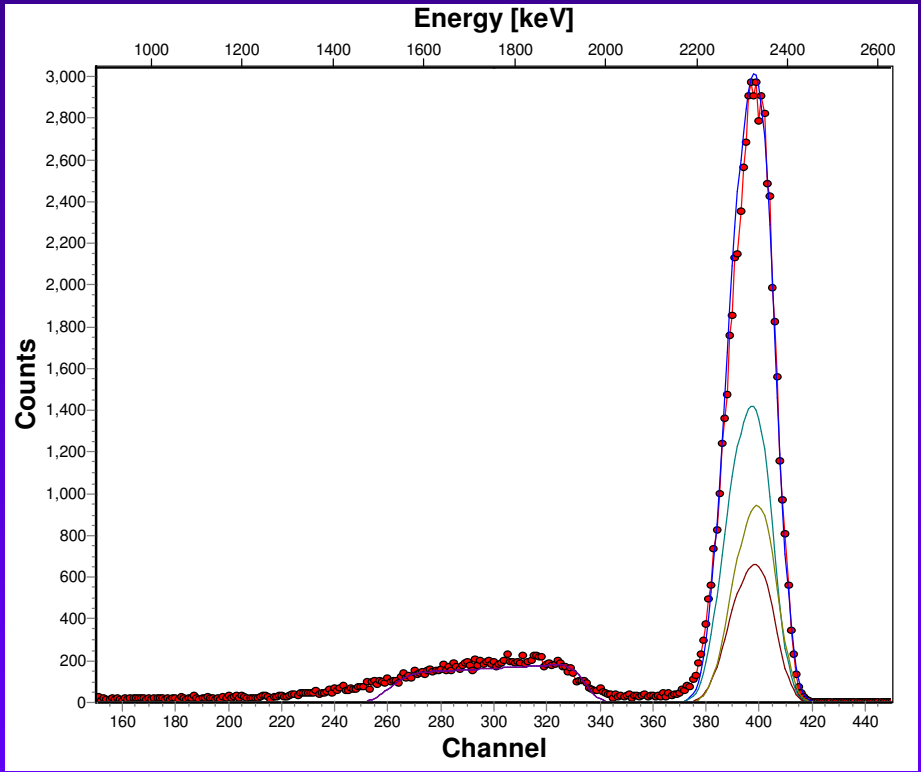


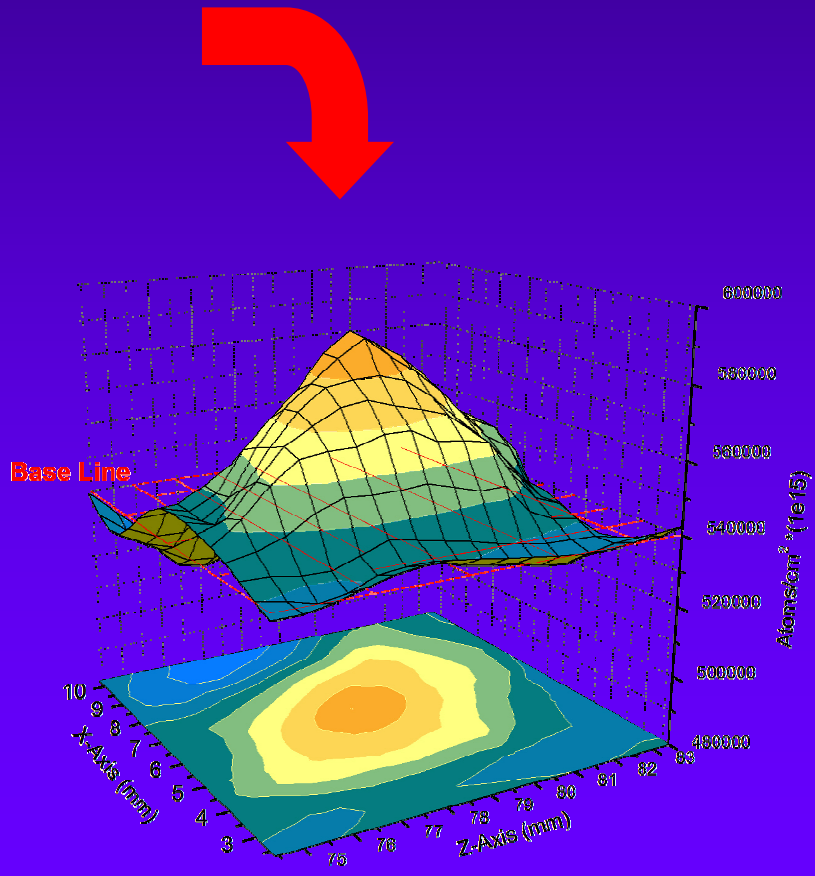




PESA Analysis

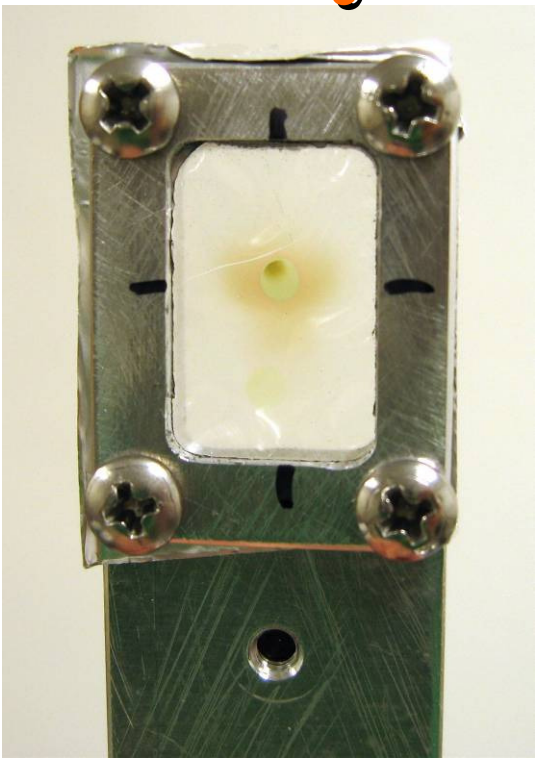
SIMNRA Analysis



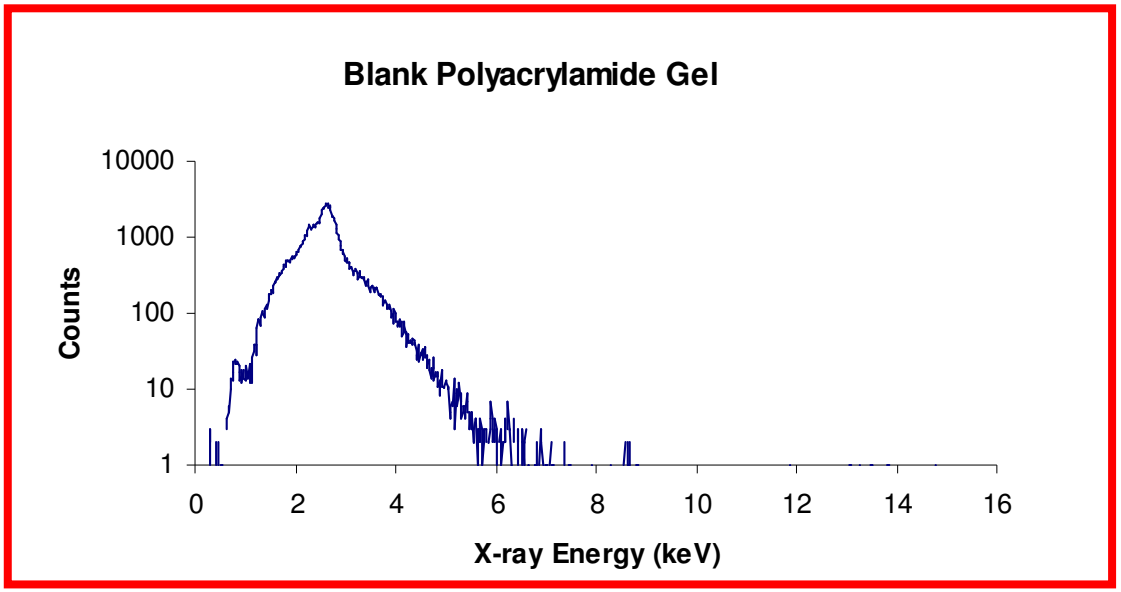


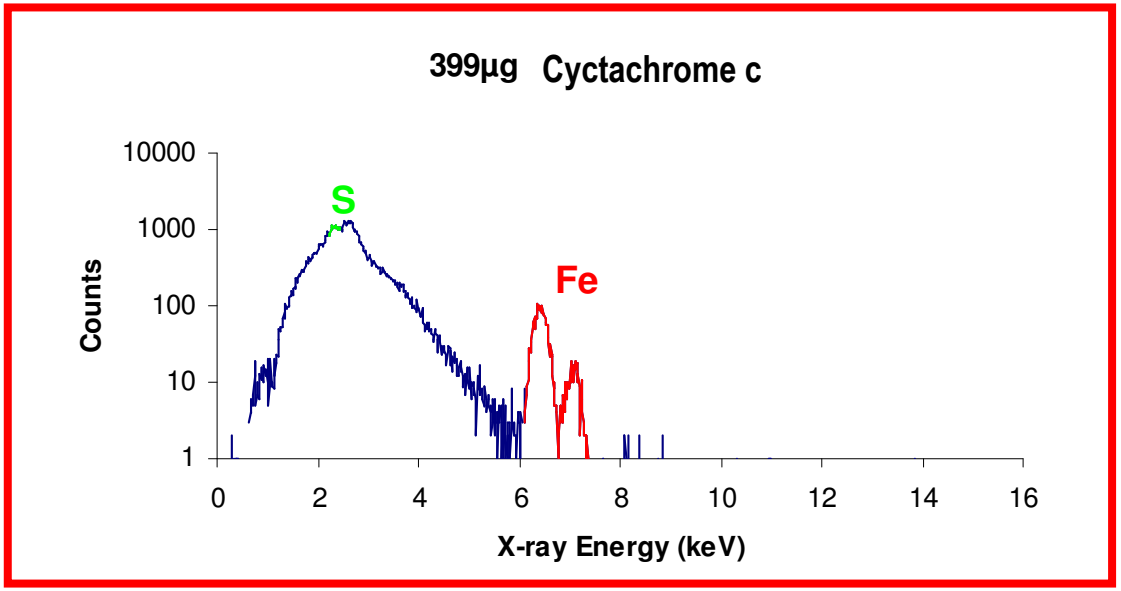
SIMNRA by Matej Mayer
http://www.rzg.mpg.de/~mam/index.html

PIXE Analysis

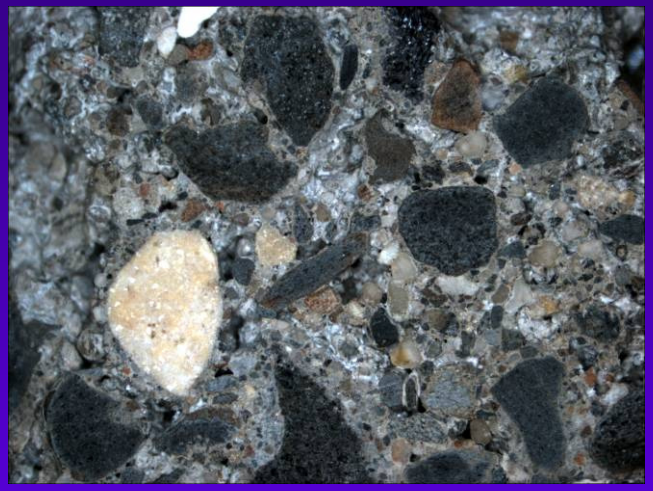


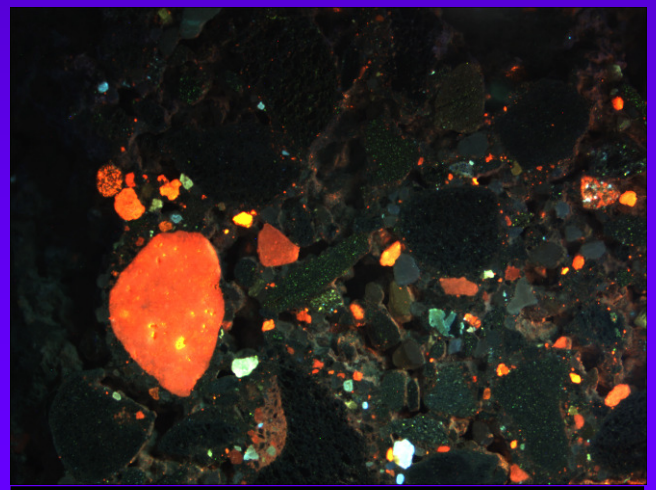
J. D. Warner et al.
NIM B (2009)
submitted



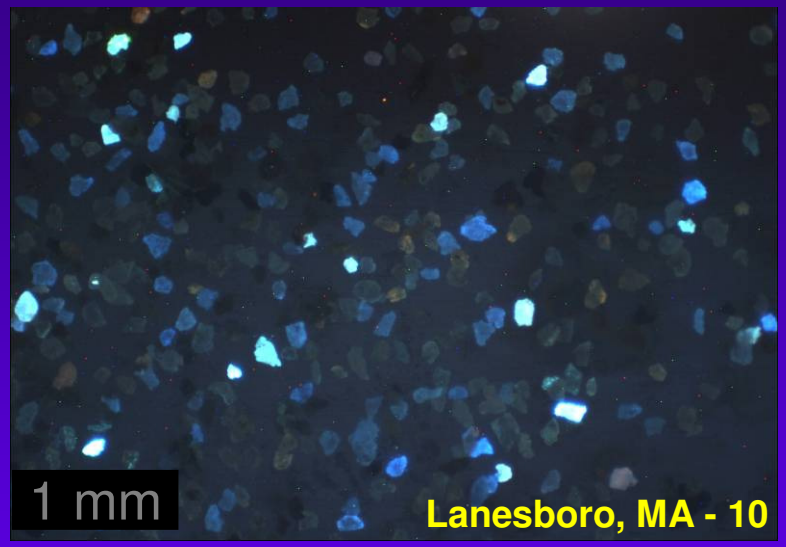


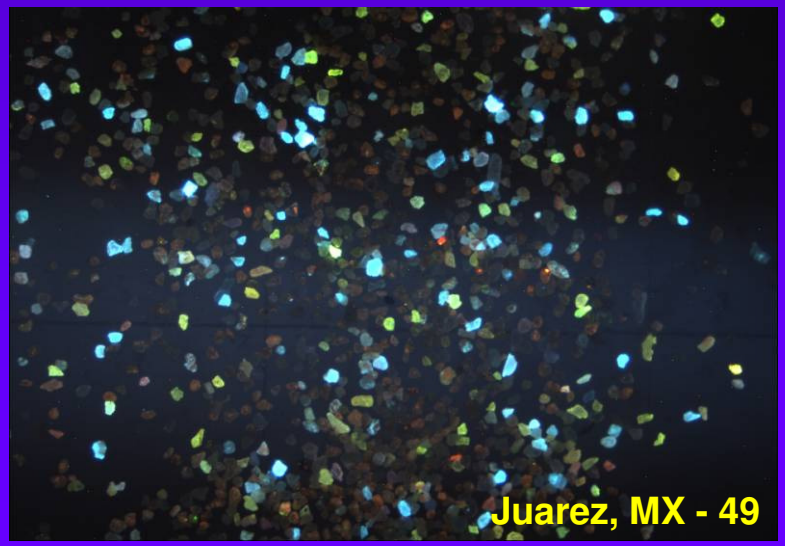
CL System for Forensic Geology

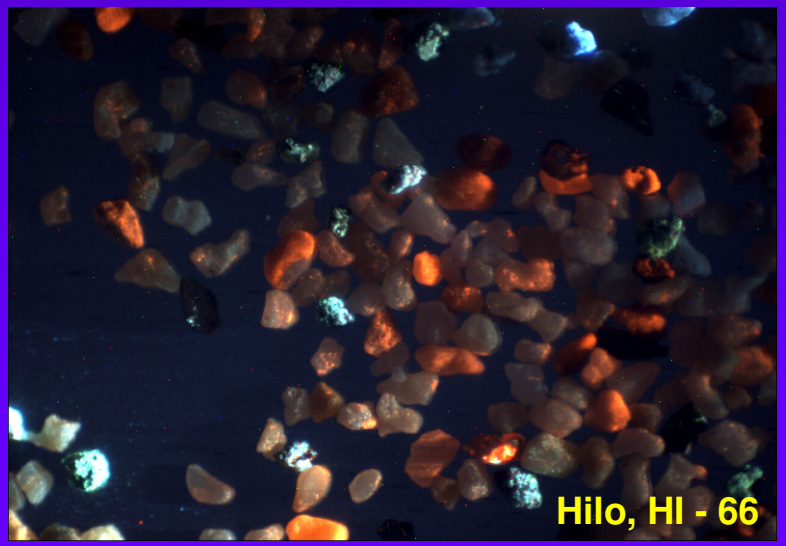




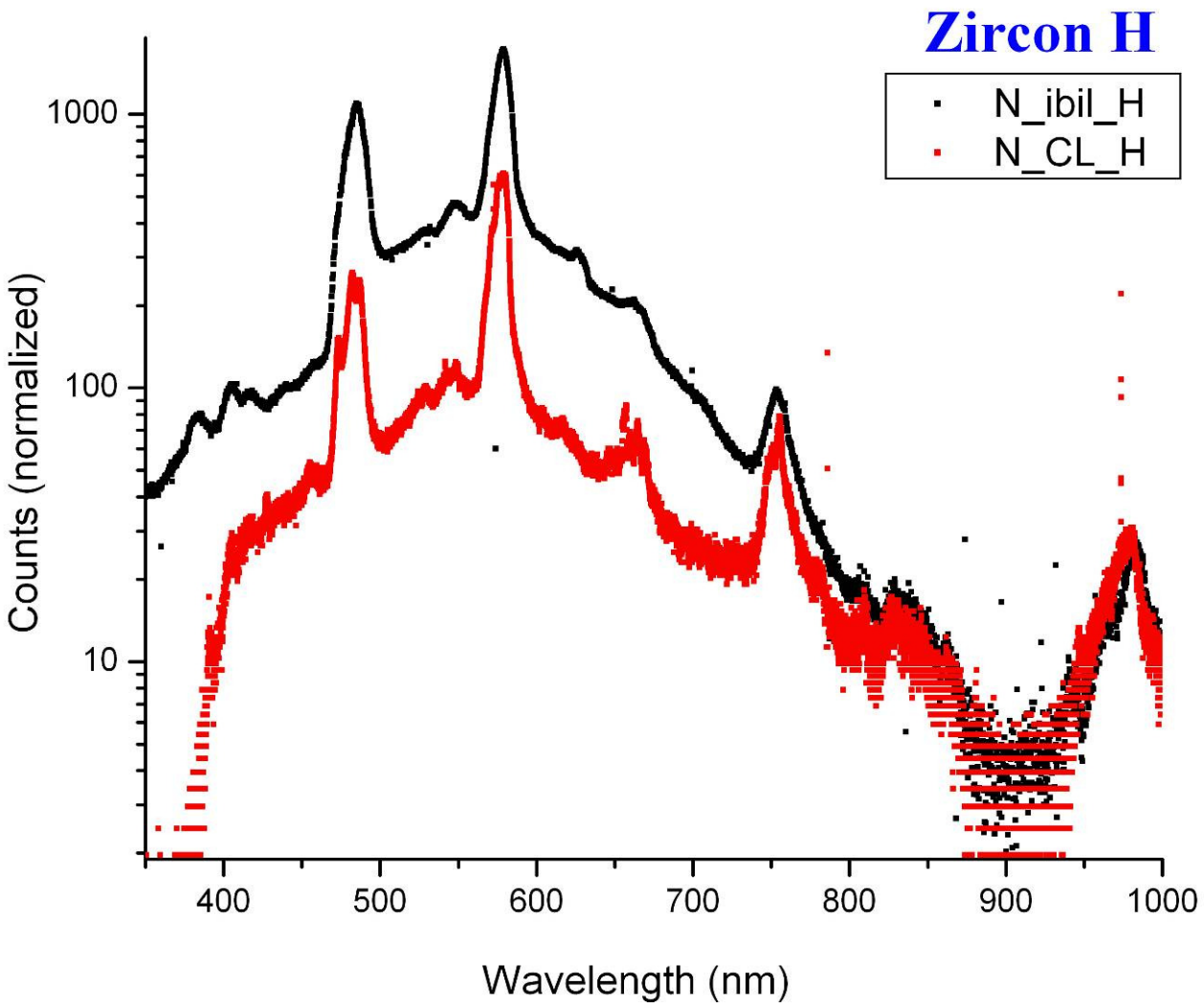
Soil Analysis



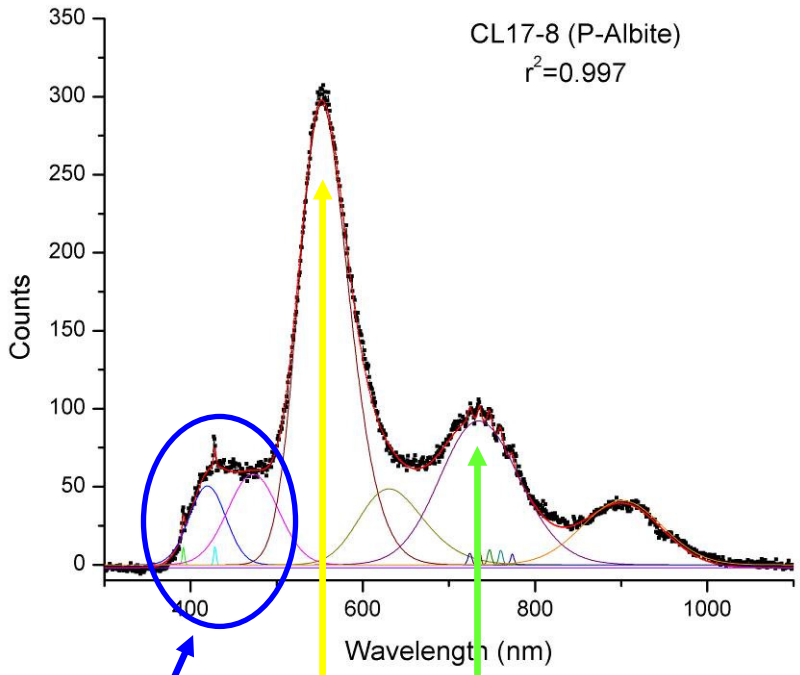




Ion Beam Induced Luminescence



Another Example: Feldspars



Mn2+

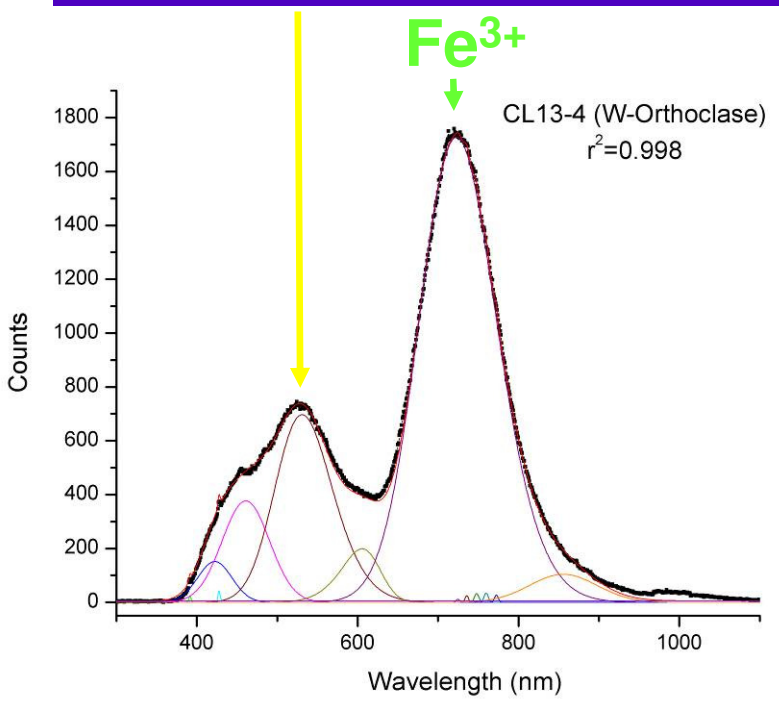
Fe3+

Lattice defects?

CL peaks of known origin, mostly…

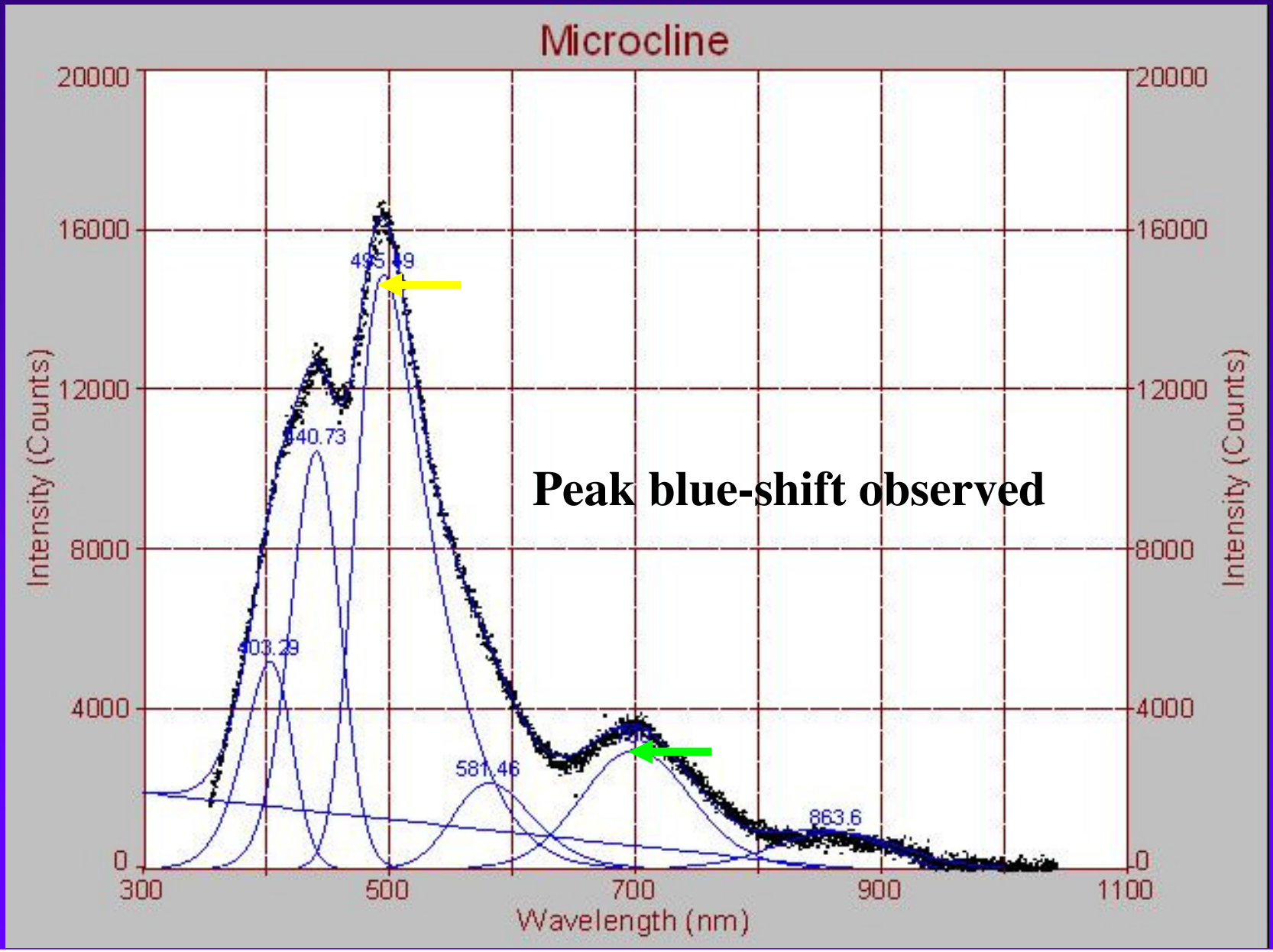
Mn2+

Fe3+



PeakFit 4.0©

Similar Spectra: Feldspar IBIL



Conclusions

- It is not only possible to integrate research and education – it attracts students
- New instrumentation and connectivity allow new collaborative approaches
- Undergraduates can contribute
- Interdisciplinary and non-proliferative

Acknowledgements

NSF – MRI 0319523 & RUI 0651627

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