Carbon tracking for Climate Resilience

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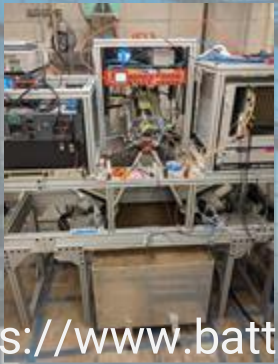

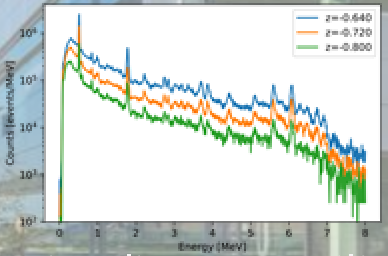

https://www.battelle.org/conferences/conference-on-innovations-in-climate-resilience

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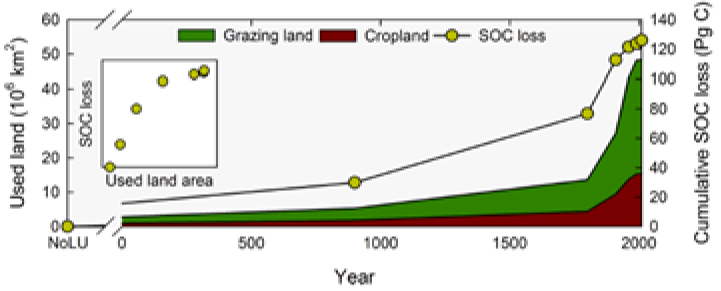
ACCELERATOR TECHNOLOGY & APPLIED PHYSICS DIVISION ATAP

Tracking Carbon in Soil — Motivation

- **Soil plays an important role in the global carbon cycle**
- **Carbon sequestration can help us to get to net zero carbon**

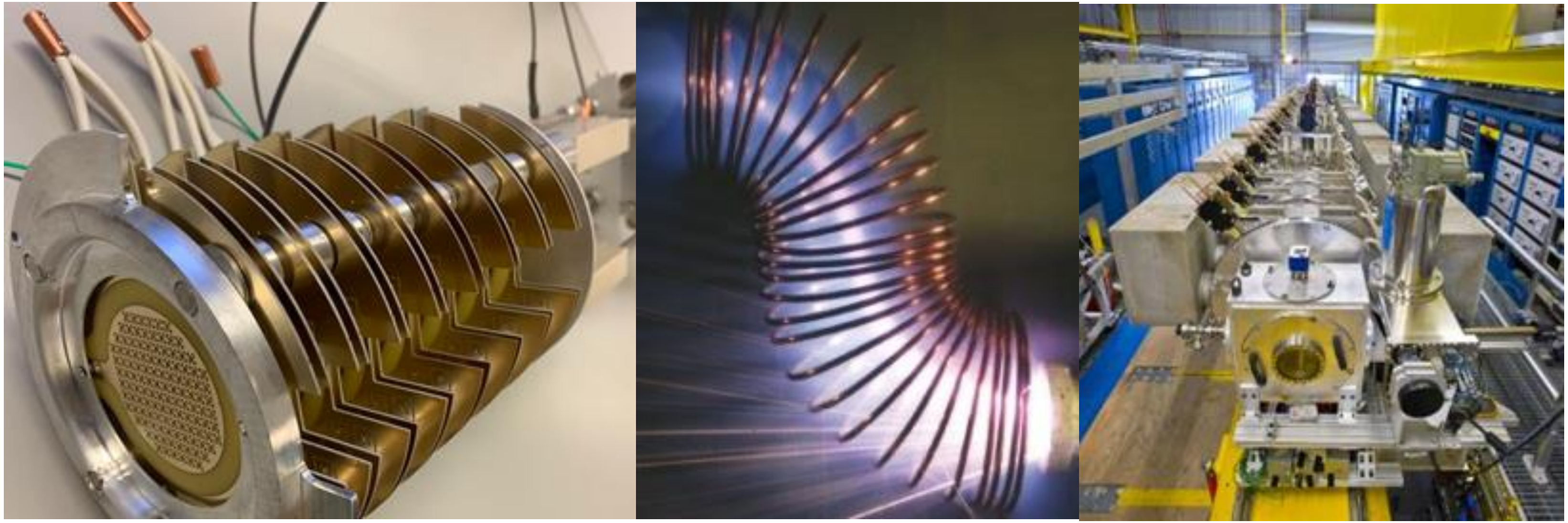
- 12000 years of land use has resulted in a 120 Pg loss of soil carbon (15% of the atmospheric carbon pool)
- Increasing soil organic carbon by 0.4% per year on agricultural soils globally could offset 20-35% of global emissions (Minasny et al. 2017)

Sanderman et al. 2017



Need: For a carbon economy we need to be able to quantify the amount of carbon in soil and carbon sequestered

We are developing Applied Physics tools for applications in Climate and Energy



https://atap.lbl.gov/
https://fs-ibt.lbl.gov

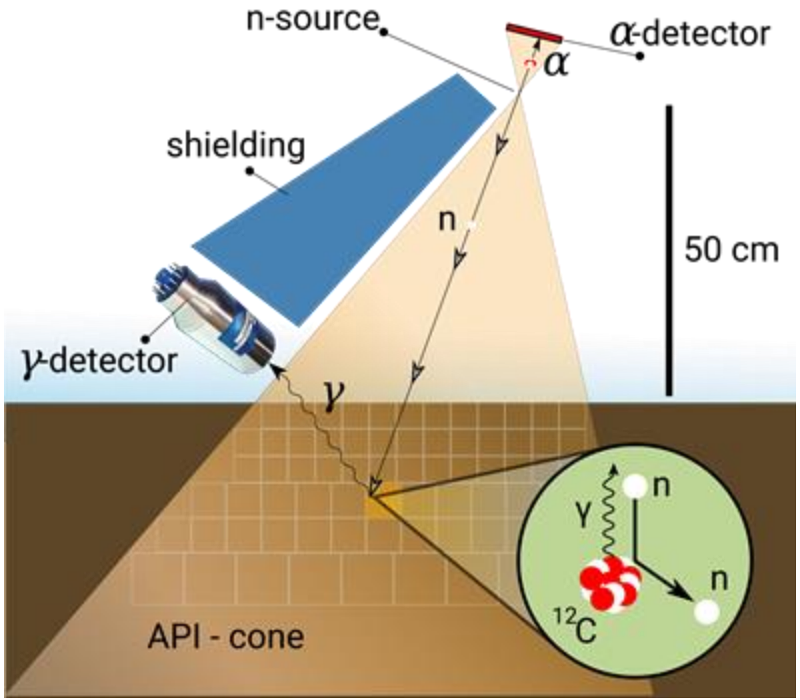
We are developing an instrument to quantify and image carbon in soil

Current methods of measuring soil carbon cannot track small changes over time and do not scale to large areas

- **Our non-destructive** method enables *in situ* **repeatable** measurements
- 3D carbon distributions with a resolution of ~5 cm down to a depth of ~30 cm
- **Field-portable** system
- Measurement times of several minutes (for a commercial system)

Utilize isotope-specific response to fast neutrons to measure carbon distribution in soil

D+T → n (14 MeV) + α (2.5 MeV)



- Fast neutrons excite isotopes by inelastic scattering leading to emission of characteristic gamma rays of isotope-specific energies
- Associated Particle Imaging (API) combined with time-of-flight analysis enables correlation of measured gamma ray with nucleus location in the soil
- Measured gamma rates map to carbon concentrations
- 50 cm × 50 cm × 30 cm(depth)
- 1-10 minutes measurement time for a commercial system operating at full neutron rate

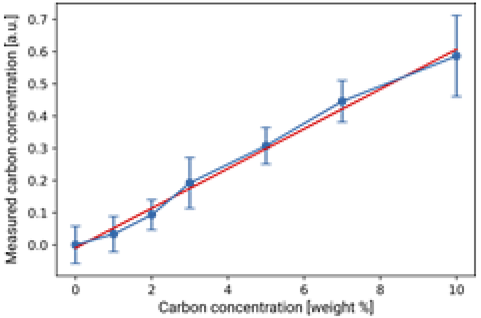
A. M. Unzueta, et al., Rev. Sci. Instrum. 92, 063305 (2021)

https://doi.org/10.1063/5.0030499

API Status and outlook

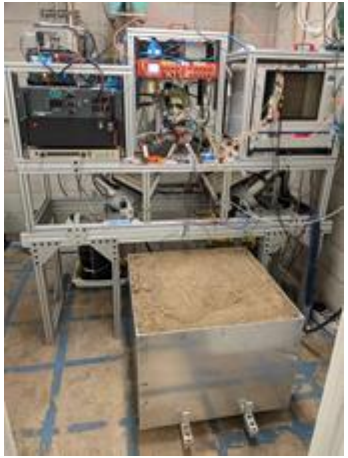
Status:

- We have built a prototype API instrument with centimeter resolution operating at lower neutron rate
- Have shown linear response to carbon concentration
- Lab-based soil experiments in progress



Opportunity:

- Let's develop a measurement technology that can enable a quantitative carbon economy in agriculture
- We can leverage Berkeley Lab's strength in beams and plasmas and in instrument development

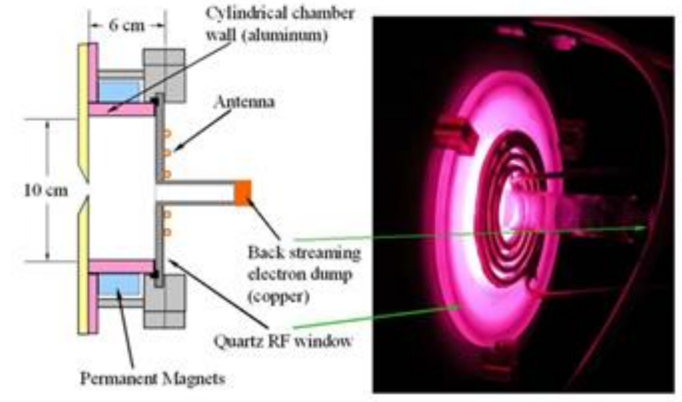


We have received positive feedback from industry & earth science researchers

The next important demonstration is to benchmark our instrument in a field setting

Catalytic plasma-assisted conversion of CO_2 and plastic waste to value-added products

- Plasma provide energetic particles (electrons and ions), free radicals, atoms or molecules in vibrational excited states.
- Plasma catalysis allows thermodynamically difficult reactions to precede at ambient pressure and temperature.
- Plasma processing of CO_2 and of plastic waste products can be high throughput - but plasma can also be lossy
- We can design plasma confinement conditions to maximize vibrational excitation efficiency, boosting process efficiency.



- Approach:
  - *in situ* and *operando* surface characterization
  - Modeling and plasma simulations
  - Quantify plasma - catalytic dynamics for rational design of specific catalysts

Q. Ji et al, Review of Scientific Instruments 81, 02B312 (2010); https://doi.org/10.1063/1.3267832

Outlook – Applied Physics tools for Climate Resiliance

- Applied physics tools with beams and plasmas enable new techniques and approaches in support of Climate Resiliance
- We are developing a new technique to measure and image carbon in soil non-destructively
- Plasma-catalysis has great potential for high throughput CO_2 conversion and plastic waste processing

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https://carbonnegative.lbl.gov/

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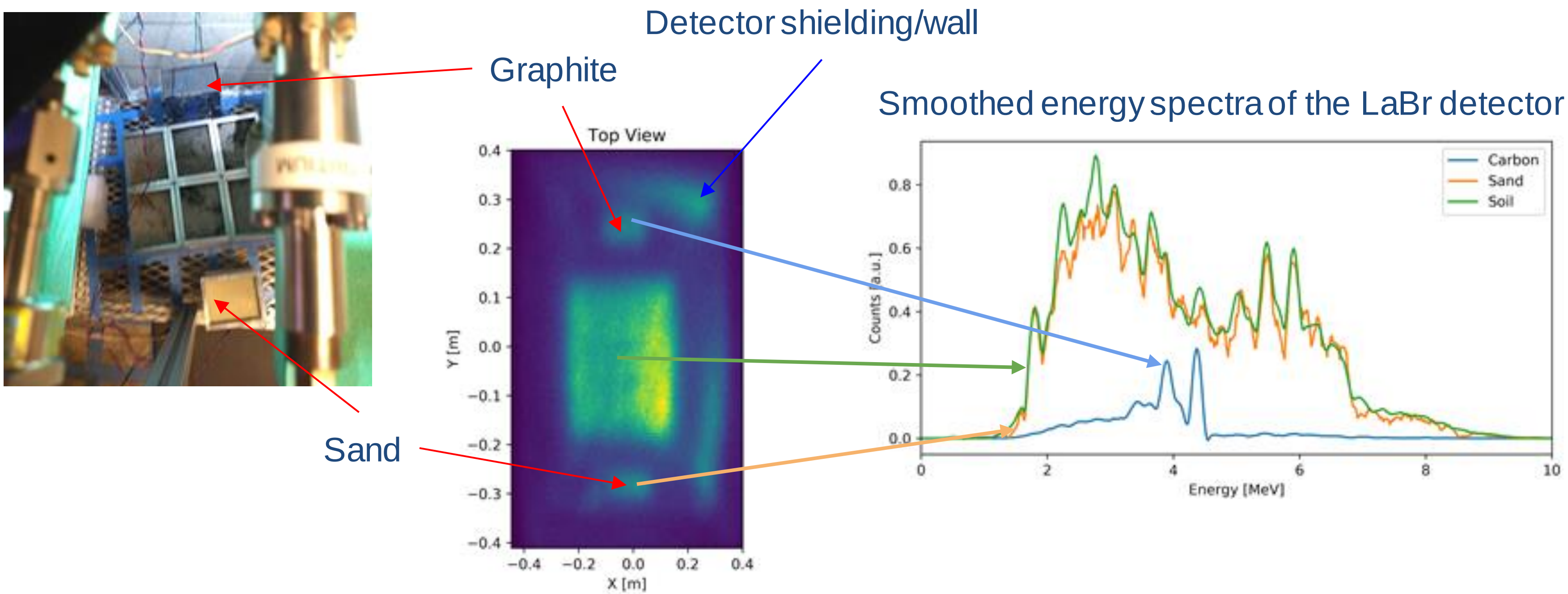
Extra Slides

API results using pre-mixed soil sample provide high spatial resolution



Here, we use a mixture of sand and worm casting to generate a soil proxy with varying carbon content (here 4%).

XY resolution on the order of 4 cm.
Z resolution on the order of 7 cm.