Repeatable, non-destructive, spatially resolved measurements of carbon-in-soil

arpa·e — U.S. DEPARTMENT OF ENERGY

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Motivation

Carbon distribution in soil is intricately linked to soil health and fertility e.g. crop yields. In addition, soil is the largest storage pool of terrestrial carbon, hence offering the potential for mitigation of climate change by carbon sequestration on a large scale.

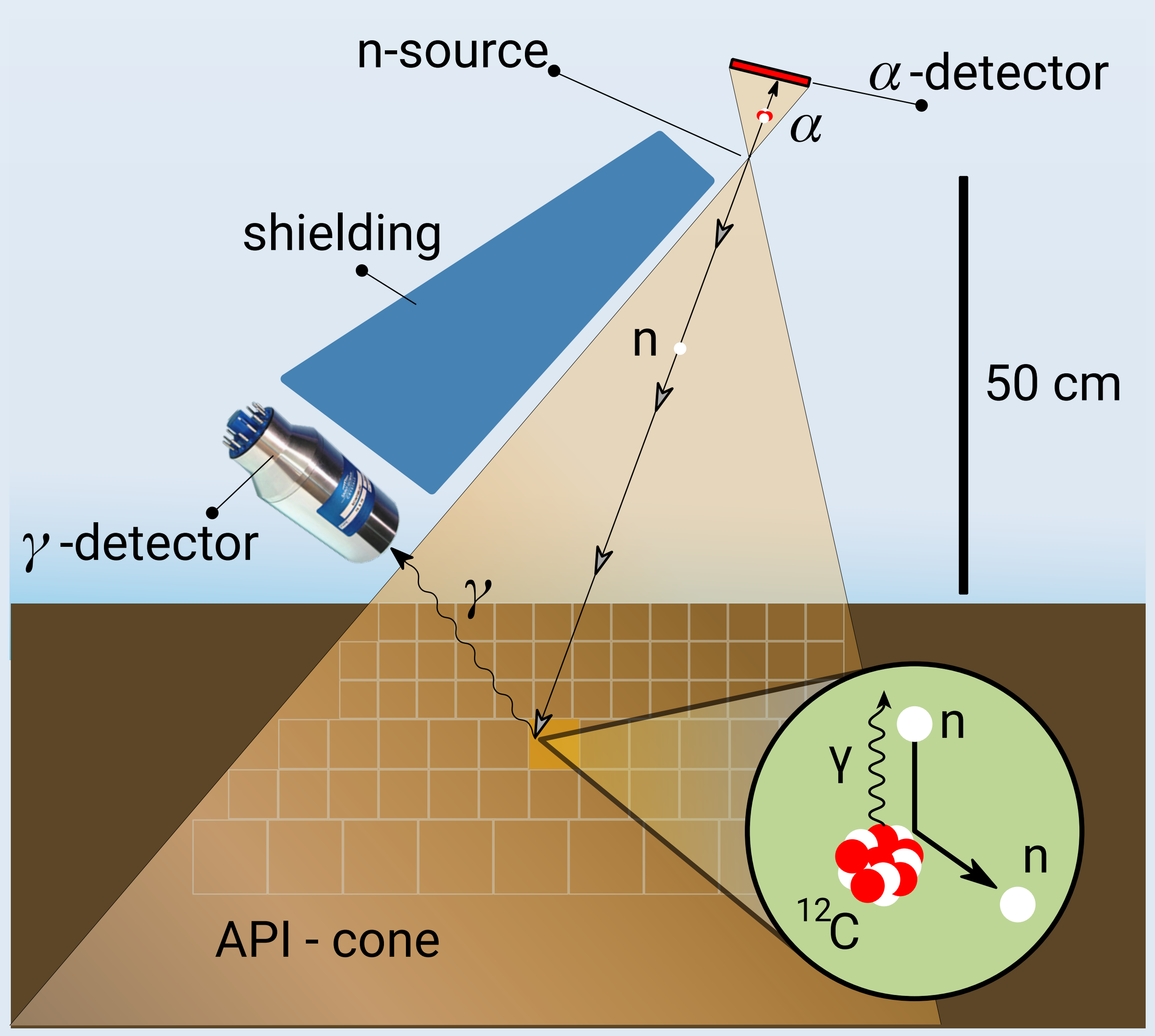
Goal: Develop a *non-destructive* method enabling 3D in situ *repeatable* measurements for soil carbon and other elements.

Approach

Use isotopic response to neutron irradiation to measure carbon distribution in soil:

- Neutrons excite isotopes which emit characteristic gamma rays
- Associated Particle Imaging (API) combined with time-of-flight analysis enables correlation of measured gamma ray with nucleus location in soil
- Position and timing information from API allows imaging of carbon in a region of 50 cm × 50 cm × 30 cm with a few centimeters resolution
- Measured gamma rates reflect carbon concentration
- Neutron source: Adelphi DT108-API neutron generator

Estimated measurement time for (0.2—1.0 ± 0.1)% C concentration: 10 min for commercial product (using multiple detectors)



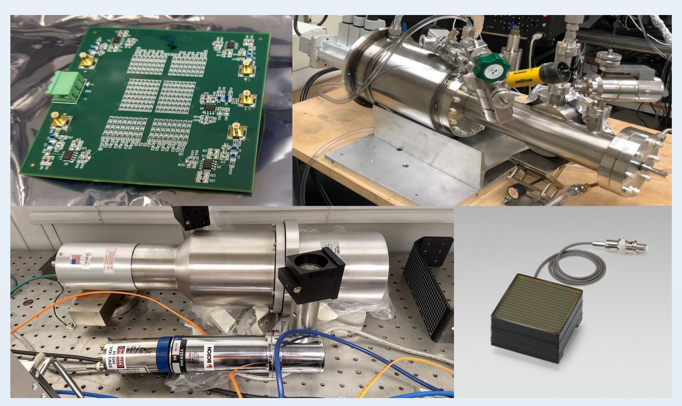
Applications

- Quantify improvement of soil health
- Quantify carbon sequestration in agriculture
- Possibility for volumetric water measurement
- Possibility for bulk density measurement

Current status

A prototype instrument has been built and we are currently optimizing performance in a laboratory setting. First soil samples have been measured and we are in the process of benchmarking the instrument with simulations and soil samples of known composition.

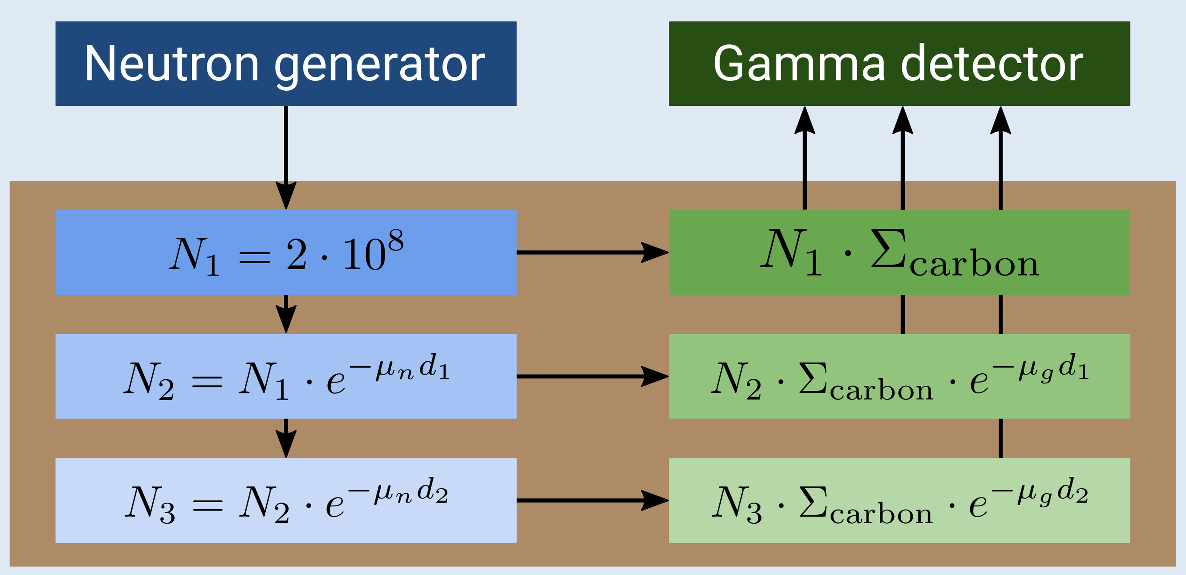
Hardware



The system consists of a microwave-driven neutron generator, two gamma detectors (LaBr and NaI), a pixelated alpha detector and a digital data acquisition unit.

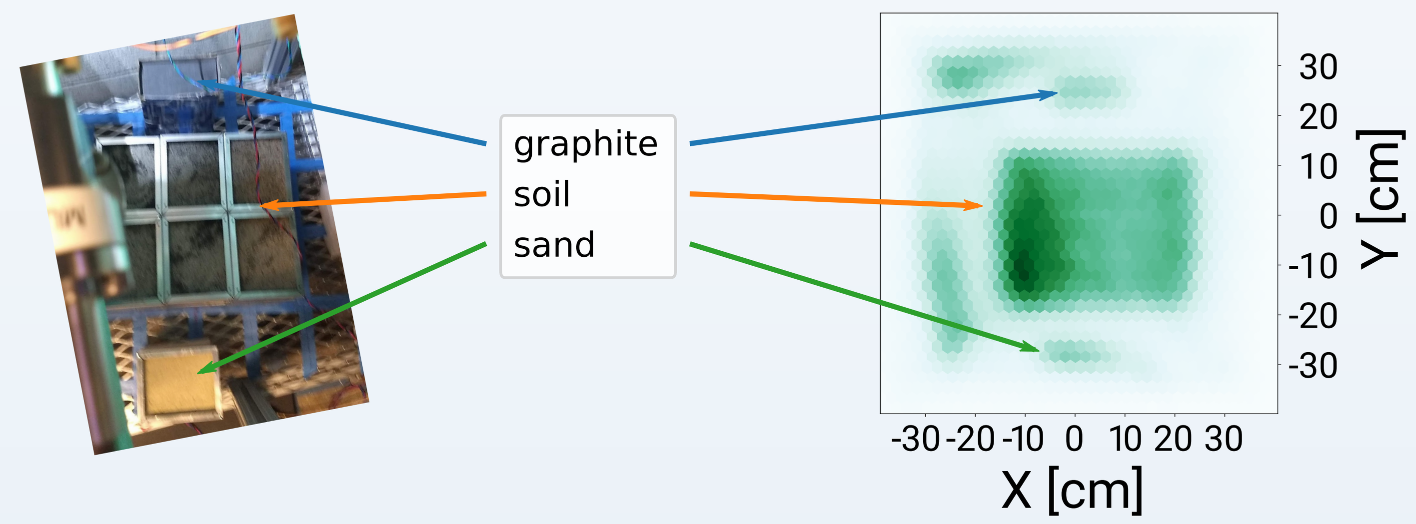
Density reconstruction

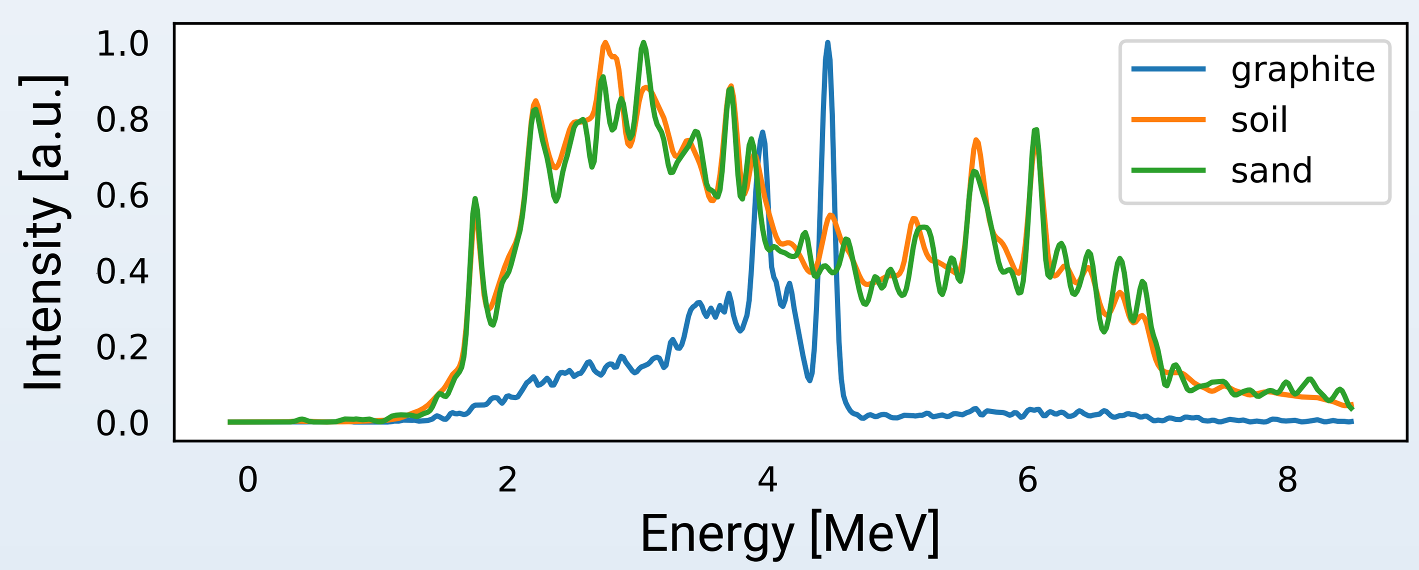
In order to calculate the carbon density, the neutron flux at each voxel, gamma attenuation, and effective detector efficiency (including geometric factors) are taken into account. We developed a simplified algorithm that applies to a wide varriety of soil.



Latest results

Experiments with pre-mixed soils show a position resolution of several centimeters. The carbon-12 gamma line at 4.4 MeV can be clearly seen in a graphite sample and also in the comparison between sand and soil samples.





Field tests

Field tests are planned for the final year of the project (2020). These will be performed at three different locations where the soil composition is well-known in order to benchmark the capabilities of our instrument.

Conclusion

We are developing a new type of instrument to measure carbon-in-soil distributions. Our goal is to de-risk the major hurdles towards its commercialization.

We are looking for feedback from potential users, companies, and investors and are interested in other use cases for this instrument (e.g. co-variance between carbon and other elements).

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