Borehole Muon Detector for 4D Density Tomography of Subsurface Reservoirs

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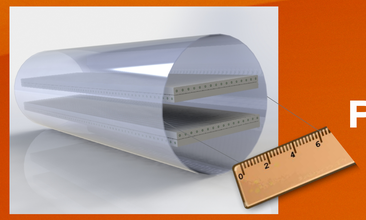

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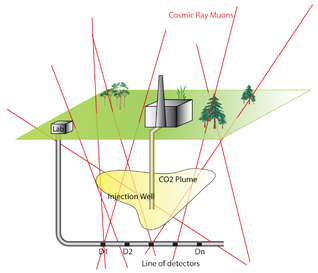
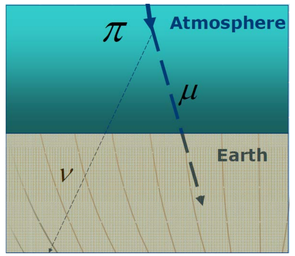
Objective



Develop miniaturized muon tracking detectors capable of fitting in standard boreholes to perform 4D density tomography of geological structures.

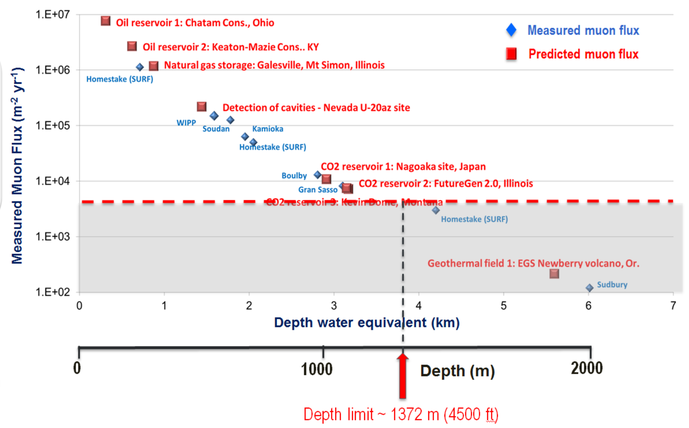
1 Cosmic Ray Muons

- Discovered in 1936
- Fundamental particles
- Similar to electrons, but much more massive
  - ~207 times an electron mass (105.7 MeV)
- Created when high energy cosmic rays interact with the atmosphere
  - Secondary cosmic rays are produced at approximately 15 km
  - Decay product of pions and kaons
  - Average energy is 6 GeV
- Muons lose about 2 MeV/g/cm^2
- Total surface muon flux = 5.26 10^9/m^2/yr

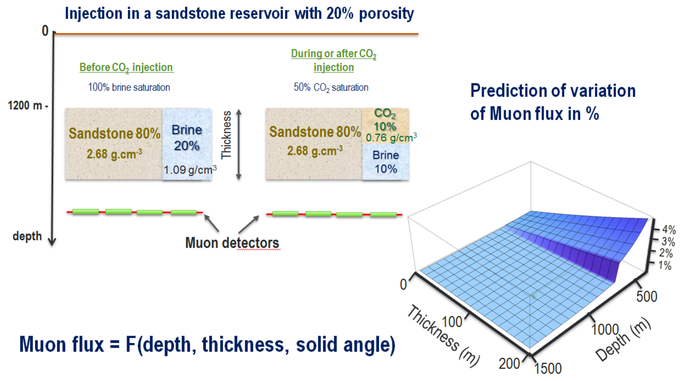


2 Predicted flux for some subsurface reservoirs

Rapid decrease of the Muon flux with depth : only 119 muons/m^2/yr at 2000 m.



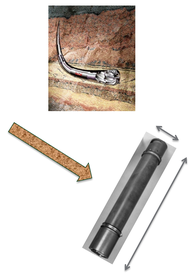
3 Example of a geological carbon storage site



Muon flux = F(depth, thickness, solid angle)

4 Detector Design: the challenge

LANL Mini Muon Tracker (MMT)



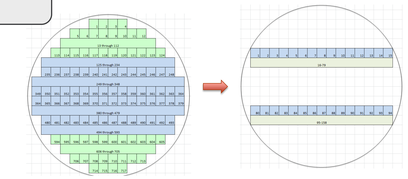
From a rack size detector….

…to a borehole detector.

- Miniaturization of the detector elements and of the electronics.
- Angular resolution is required, in both directions
- Goal: detect 1% change in density per year
- Diameter: 5.5” to 8”
- Detector components

5 Prototype design

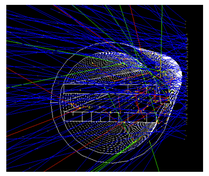
- plastic scintillator rods shielded
  - Easy to make angular measurements
  - Require photomultiplier tube
- optical fibers (Saint-Gobain BCF-922)
- PMT or light sensor (like Hamamatsu H8500C 64 pixels)



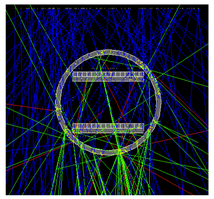
Simplified PNNL Borehole prototype

6 Simulation of Detector Performance

Using CERN code Geant4, an accurate simulation of the energy deposition on the rods as a function of incoming muon angle has been done. The effects of secondary particle generation and shielding of the thick (½ inch) stainless steel pipe in which the detector will be placed were also simulated.

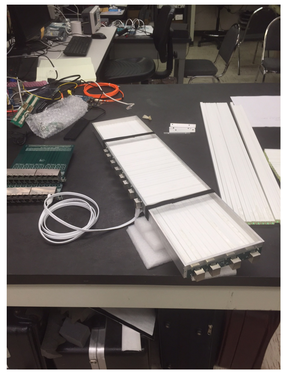


Muon tracks at 1500 meters water equivalent. Blue are muons, red are electrons, and green are gamma rays or other neutral particles.



With the full spectra at 1500 meters water equivalent, the angular errors are only 1-2 degrees and the detector will be able to successfully “bin” incoming muons by angle, increasing the detectors ability to resolve overburden density changes.

7 First working prototype!...



SUMMARY

- Deliver an operational borehole muon detector ready to be transferred to market.
- Demonstrate the feasibility of using an array of muon detectors, combined with gravity and seismic data, to map out subsurface density variations temporally and spatially.

  (new project in collaboration with LAN, LLNL, SNL, Univ. Utah, Univ. Hawaii and Paulsson, Inc.)
- Contribute towards achieving the goals of the New Subsurface Signals pillar of SubTER

U.S. DEPARTMENT OF ENERGY

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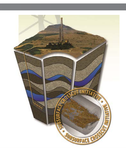

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