Beyond

The Dirt

Beyond/Beneath Summer Series, Sudbury
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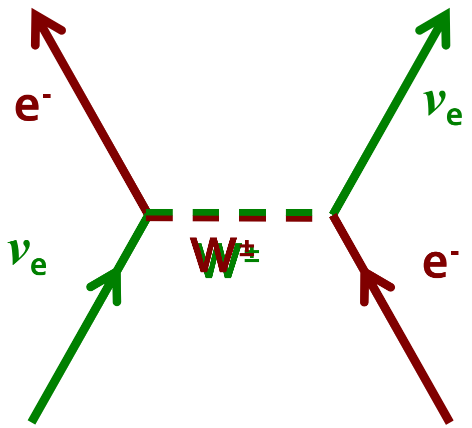
Signals

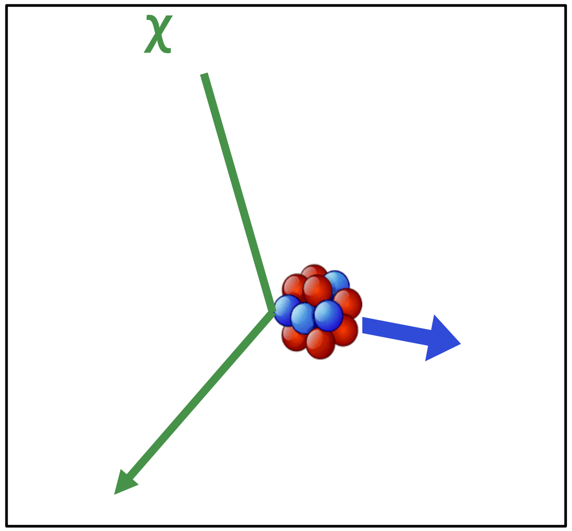
- Experiments at SNOLAB look for signals that are:
  - **Rare:** target sensitivities of one event per 10 tonnes of detector per year – or even less!
  - **Faint:** an event of interest creates a tiny signal.

    The optical signals detected by the SNO+ experiment have about the same intensity as a 100W light bulb in New York City, as viewed from Sudbury!
- The detectors must therefore be large, and extraordinarily sensitive!

What does an event look like?

- Typically, a particle of interest scatters from an electron or a nucleus, giving it some energy
- The recoiling nucleus or electron deposits that energy in the detector producing ionization, heat, and/or light, which is then detected
- Unfortunately, other processes can also produce charged particle recoils, and thus look similar to the signals of interest.





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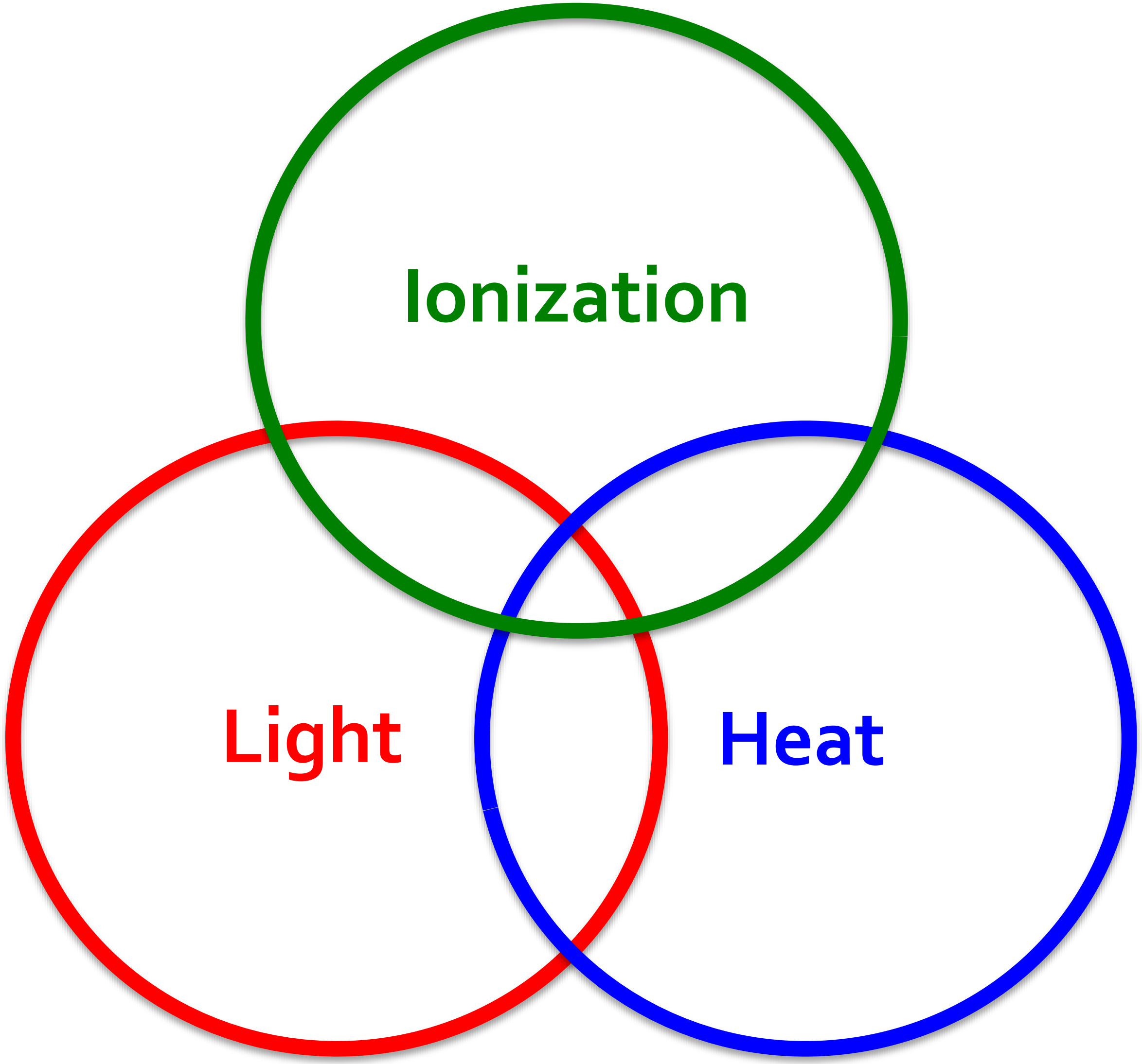
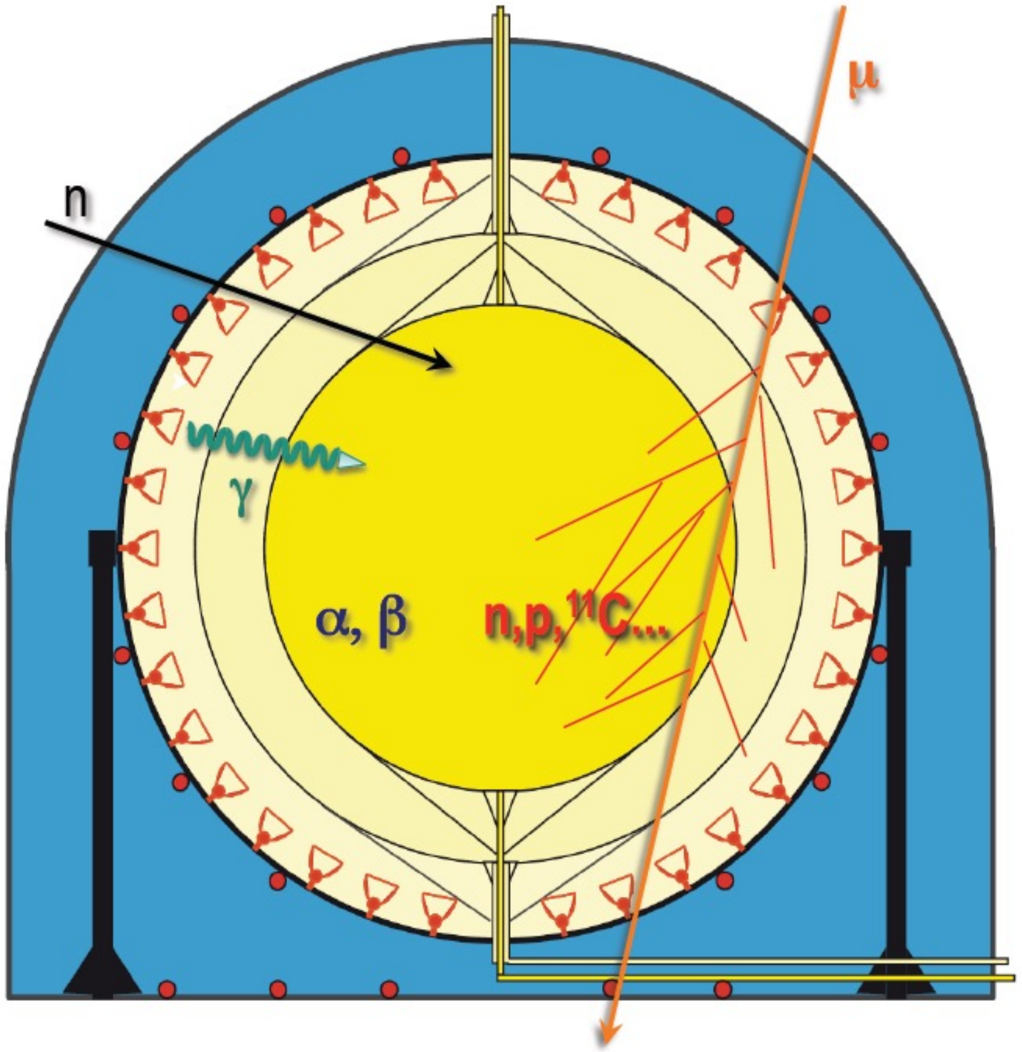


Background



Internal Radioactivity

^{238}U, ^{232}Th, etc.

External Radioactivity

gamma rays and neutrons from decays outside the detector

Cosmic Muons

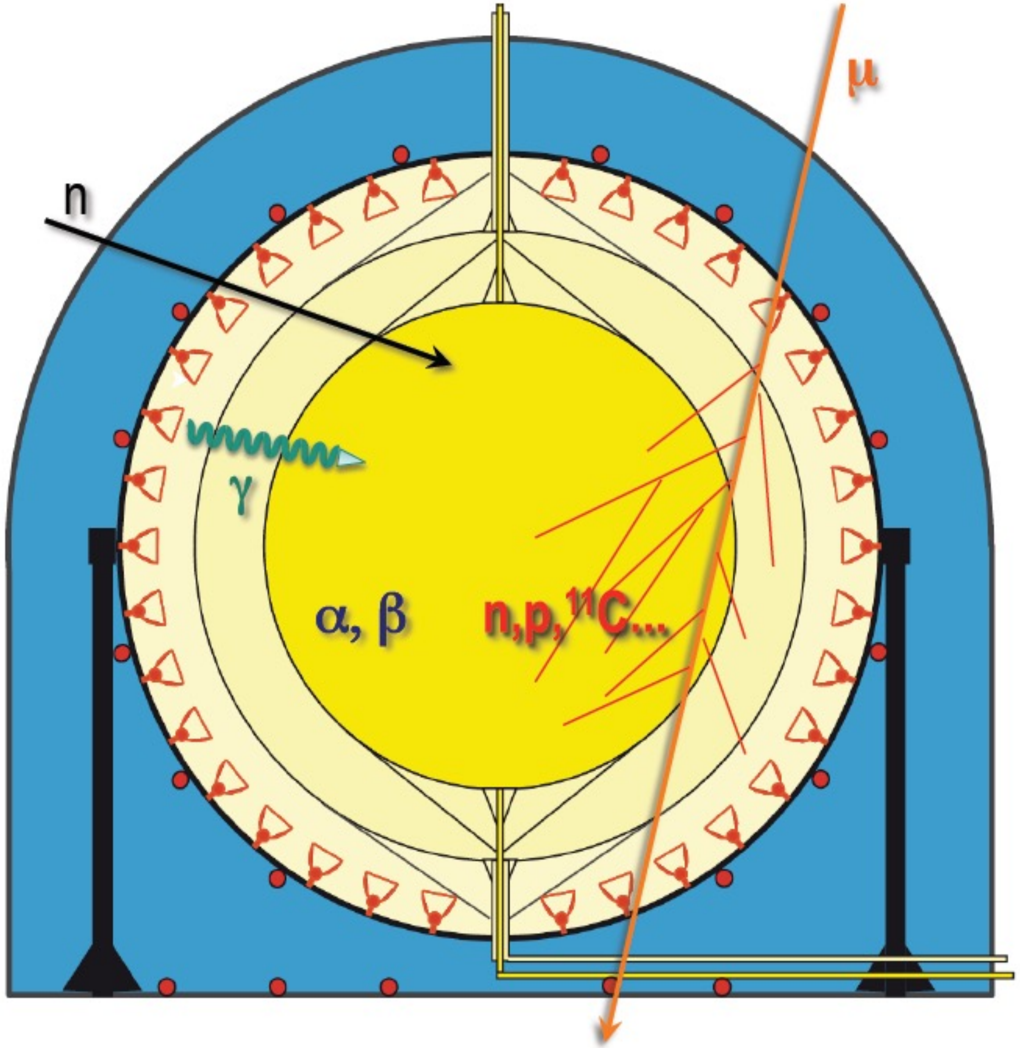
Pass through and near the detector, sometimes producing radiactive daughter particles

"Dirt" inside and outside the detector

Cosmic rays

Image: M. Wurm

Background



Signal: <1 ev/tonne-yr

Dust: ~7000 signals/mg-yr

Air: >300 signals/mL-yr

Fingerprint: ~10 signals/yr

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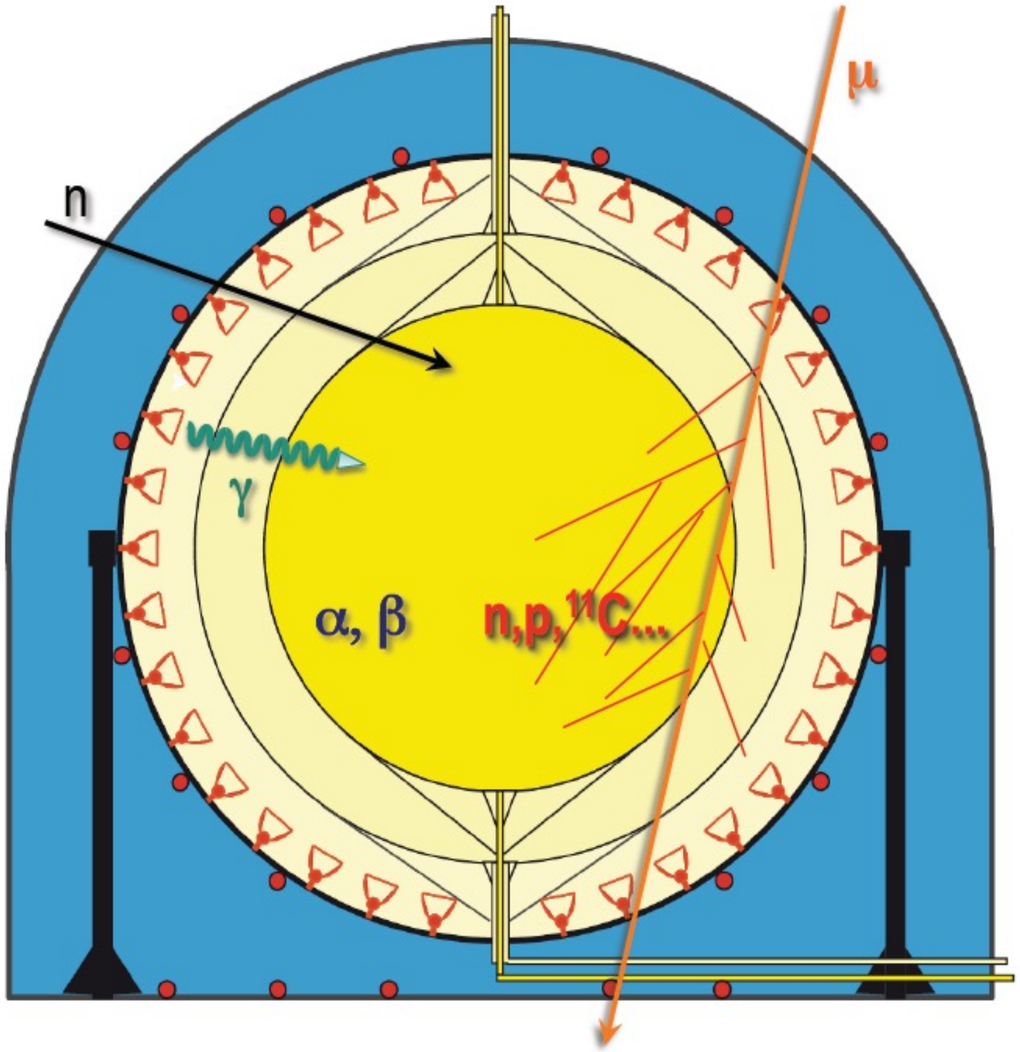
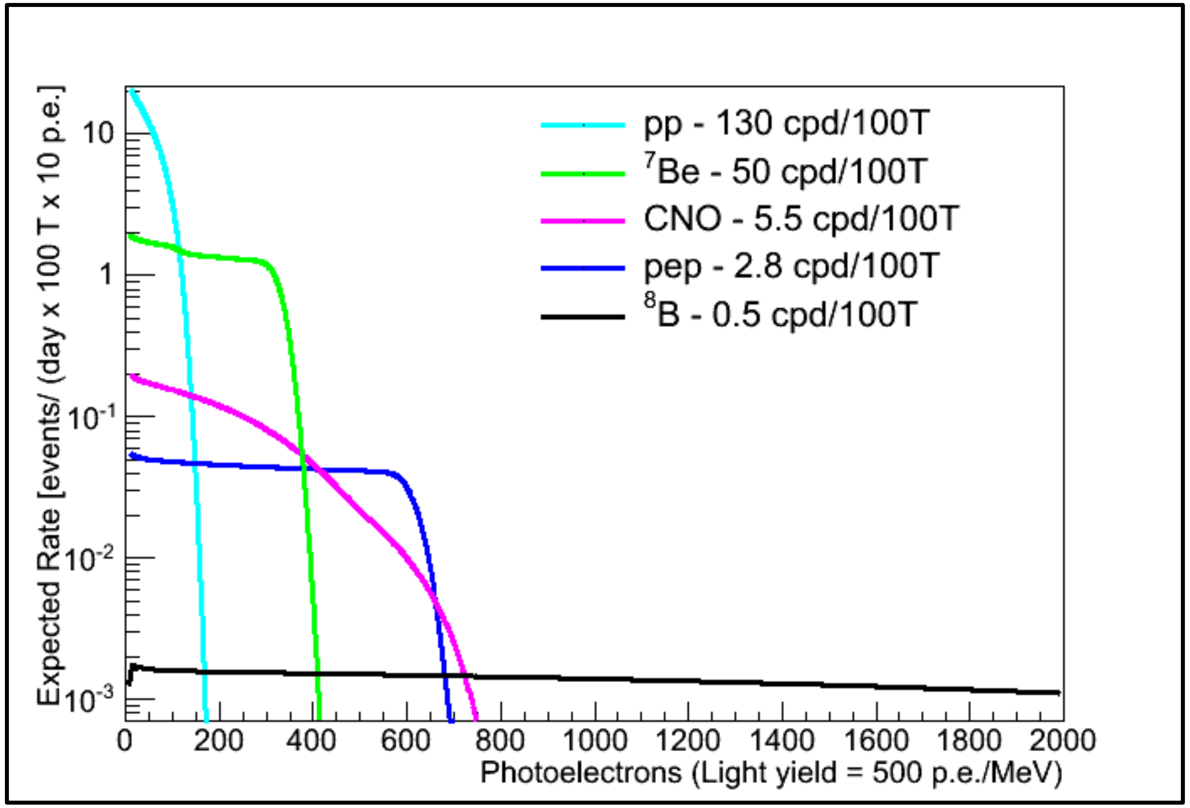


Solar Neutrino Signals in Liquid Scintillator



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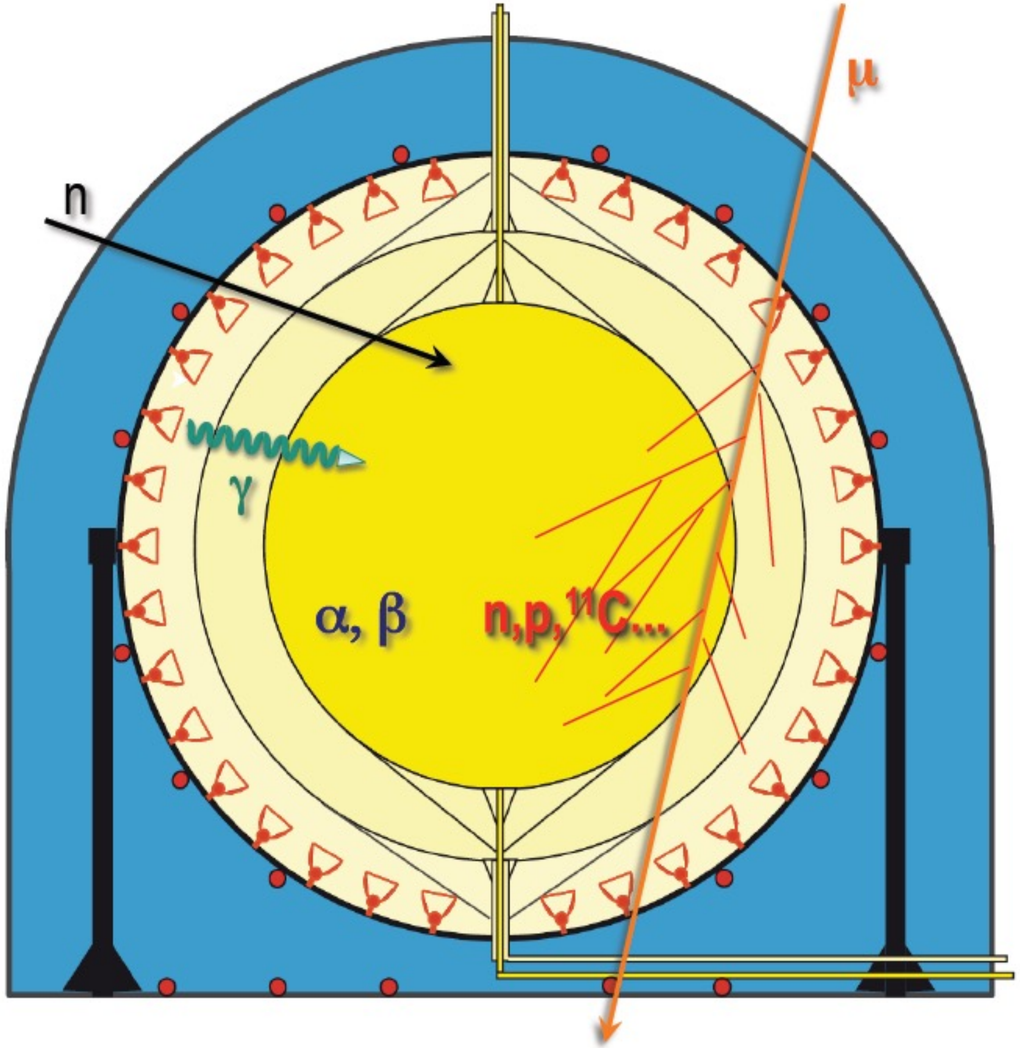

Solar Neutrino Signals in Liquid Scintillator

+ 10 Hand Prints

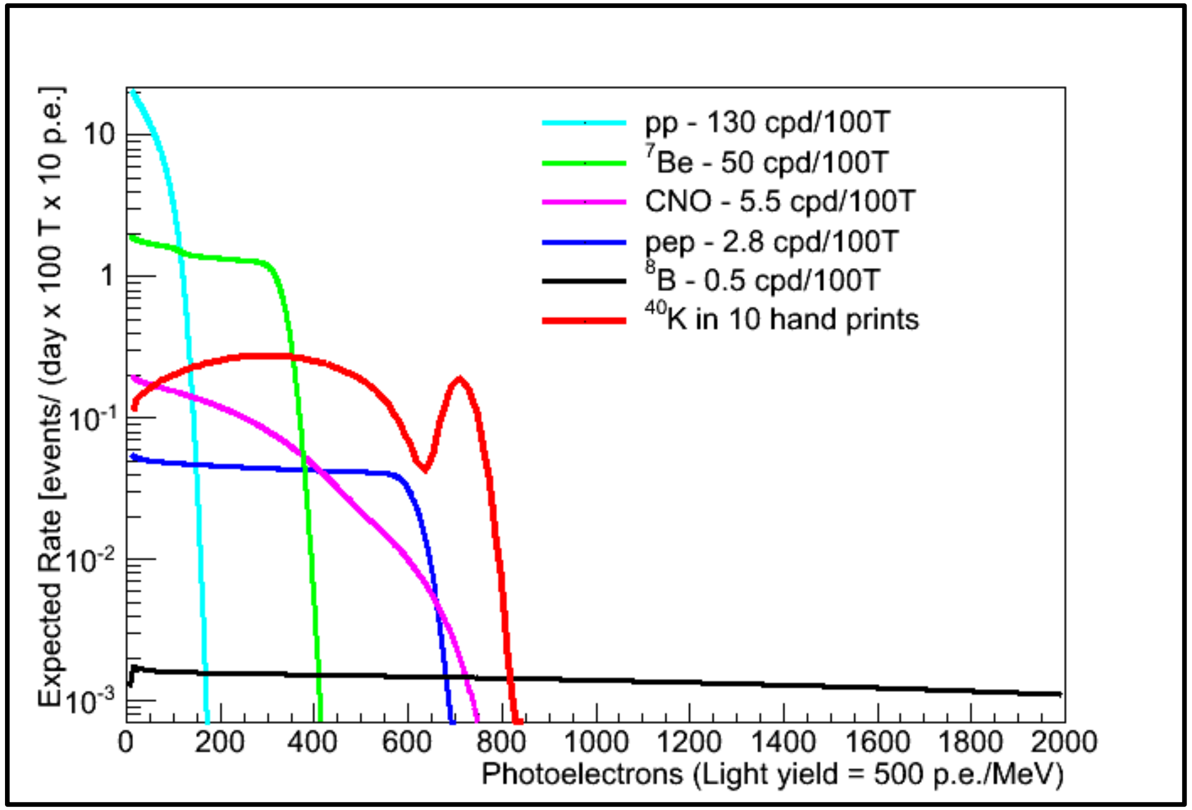

Image: M. Wurm

Cosmogenic Backgrounds: Depth

- The atmosphere is constantly bombarded by high energy particles from space
- Interactions in the atmosphere produce "showers" of secondary particles
- The particle showers eventually stop (in the air or in the earth.)
- Some particles (muons) are only slowly filtered by rock – deeper labs allow lower background

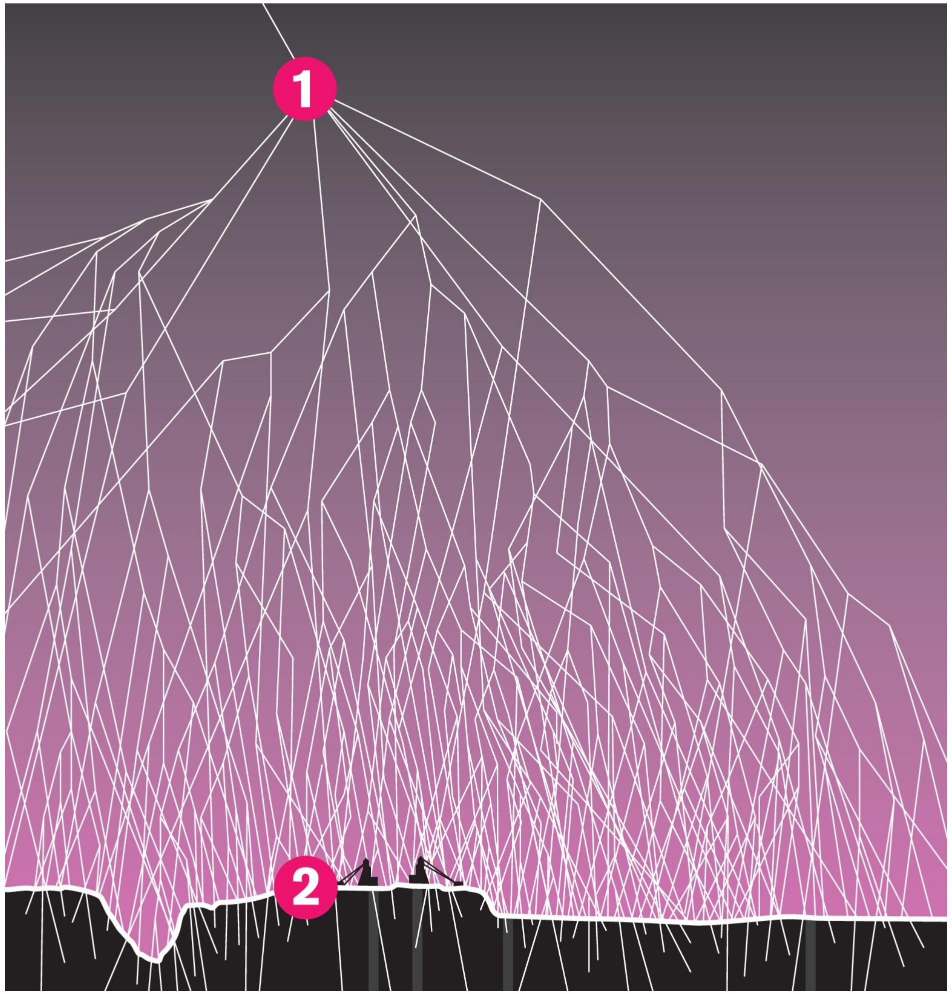

Image by Sanford Laboratory, www.symmetrymagazine.org

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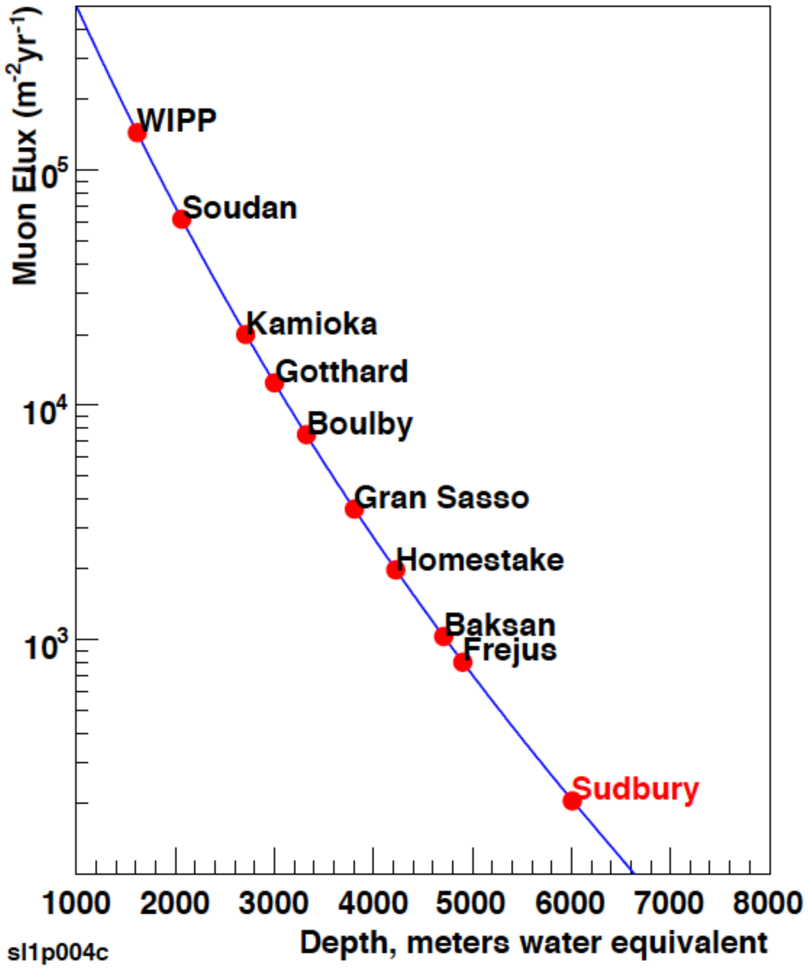

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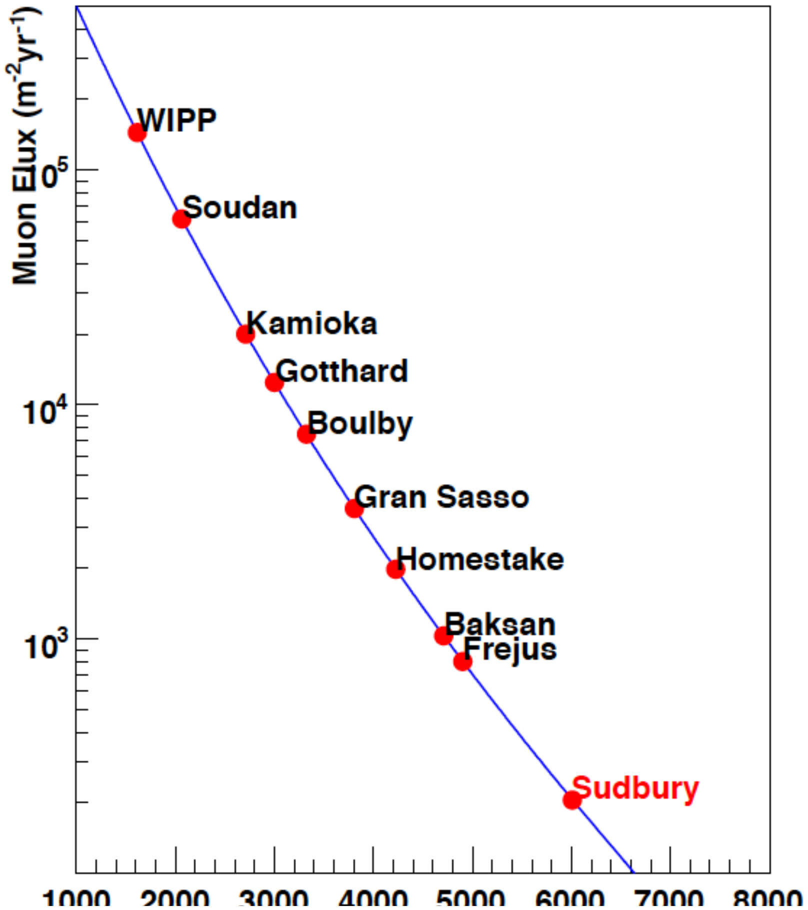
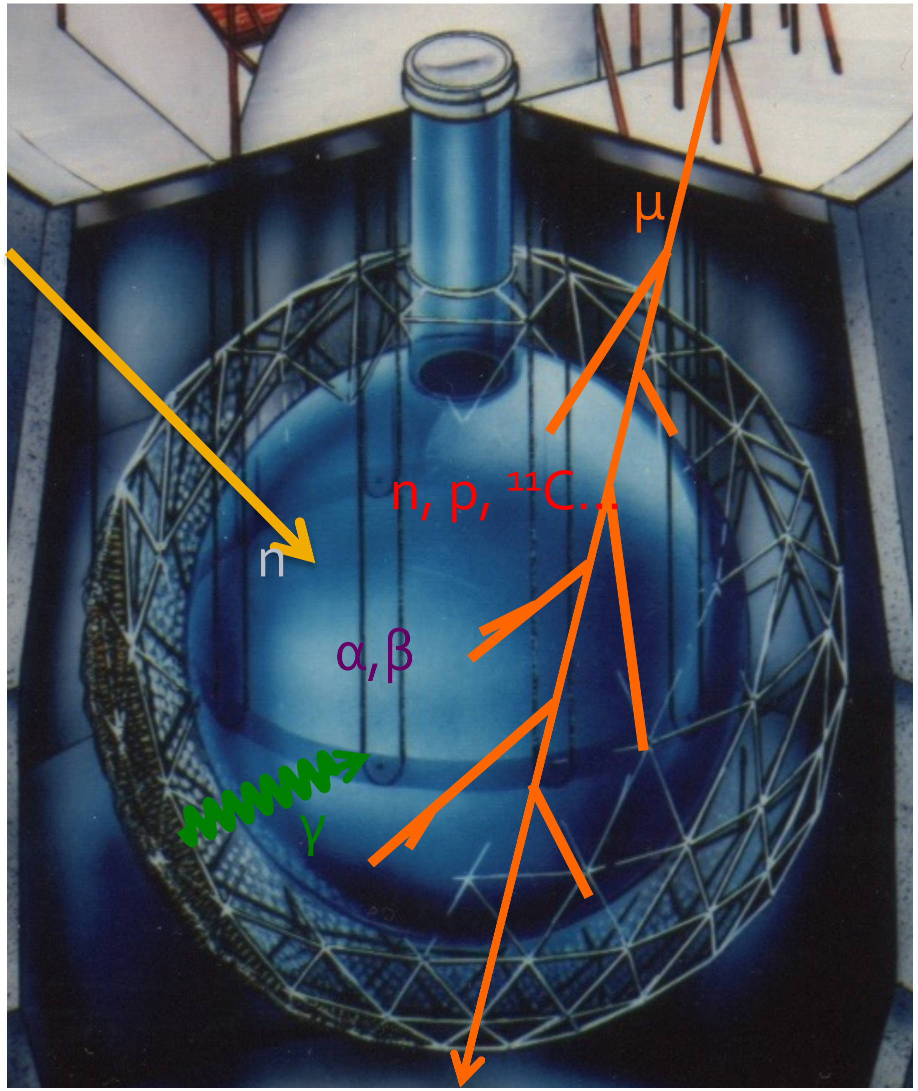


SNOLAB & CJPL (in China) have the world's lowest muon backgrounds.

External Backgrounds: Graded Shielding



- Surround the sensitive region of the detector with "onion layers" of sequentially cleaner material
  - Block backgrounds from the outer layers while minimizing the background sent to the inner layers
  - The required shielding is often much larger than the detector itself!

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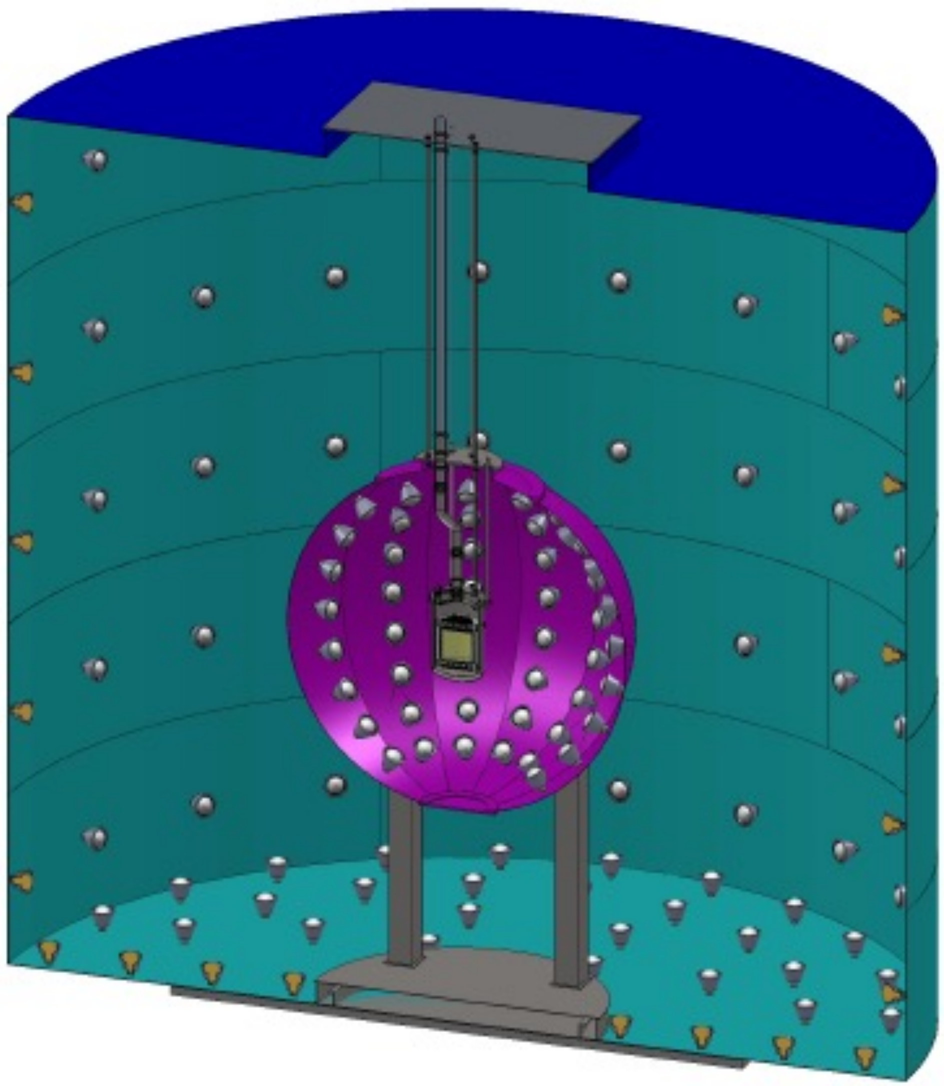

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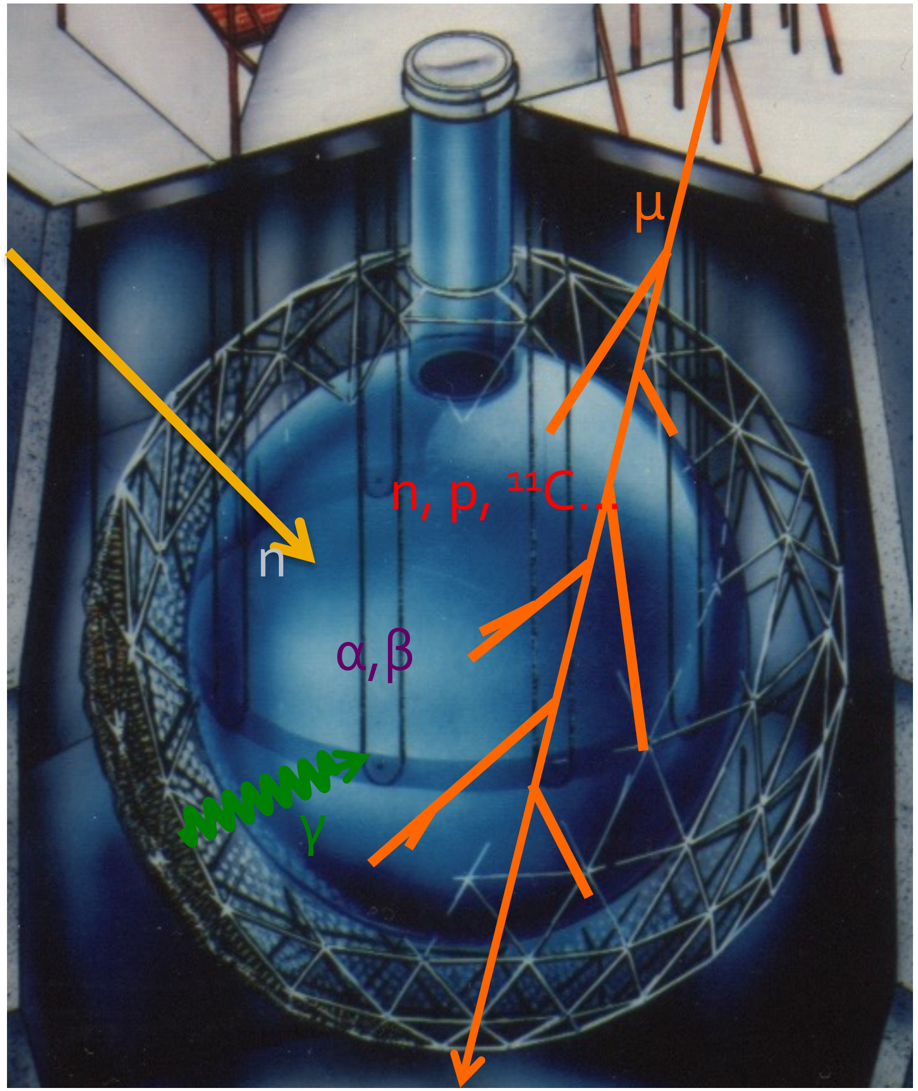
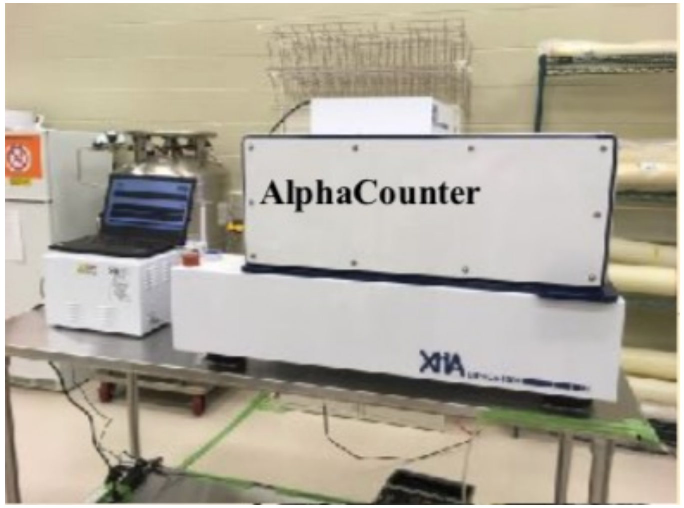
Internal Backgrounds: Ultrapure materials



- Backgrounds from within the detector itself can't be shielded, so detector components must contain very low levels of background radioisotopes
  - Required activities are often millions of times lower than in "regular clean" material
  - Many different ways to achieve this….

Internal Backgrounds: Ultrapure materials

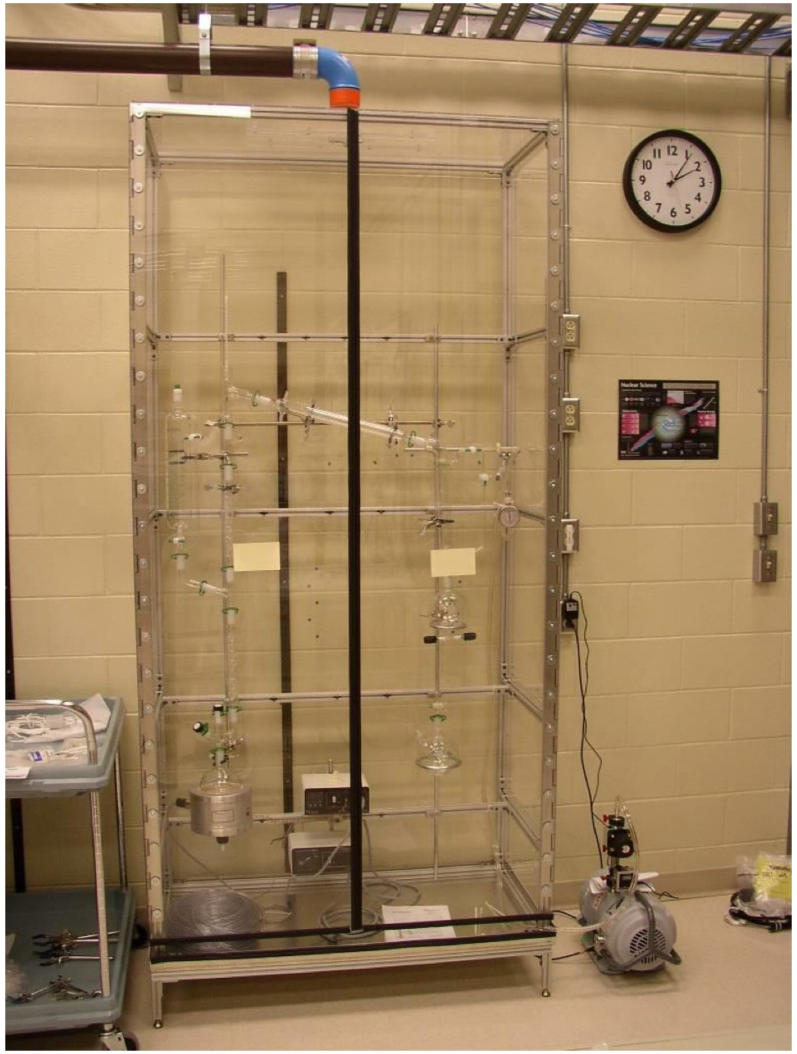
- Materials screening
  - Selecting materials with low backgrounds
  - SNOLAB: ICP-MS, Germanium Detectors, XIA surface counting, Rn emanation measurements, water assays, etc



Selection examples: Cu vs Al, Doe Run lead, virgin vs. recycled material, ziplock bags

Internal Backgrounds: Ultrapure materials

- Purifying materials
  - Liquids: Distillation, filtration, reverse osmosis, ion exchange
  - Solids: recrystallization, zone refining
  - Surfaces: etching,sanding, leaching
  - Etc, etc



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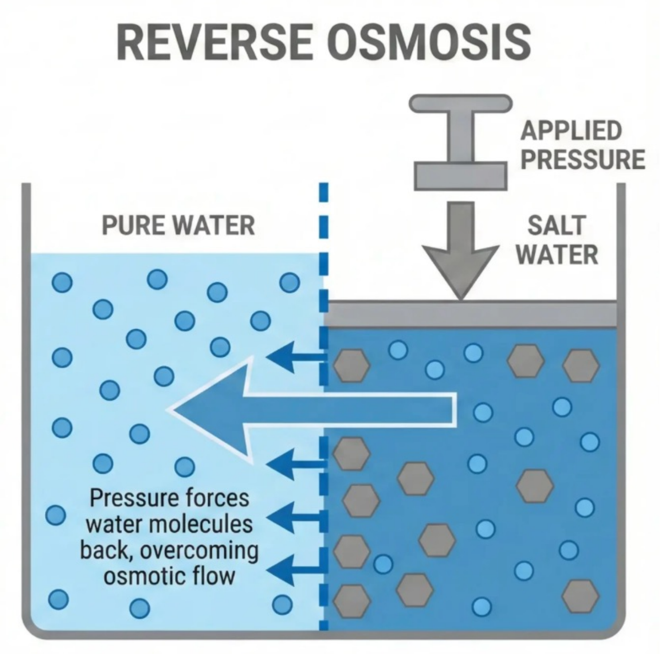

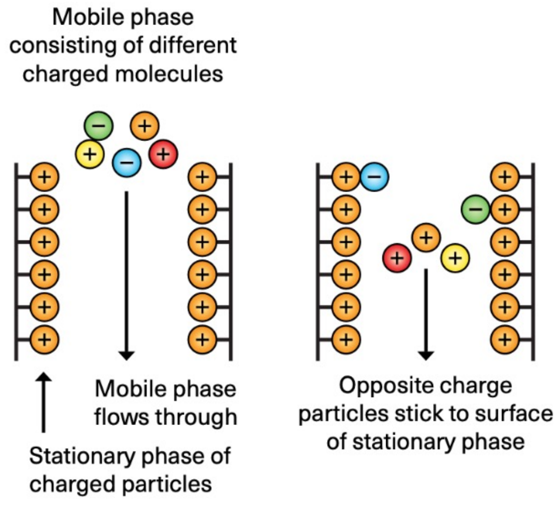

Images: abbviecontractmfg.com, stark-water.com

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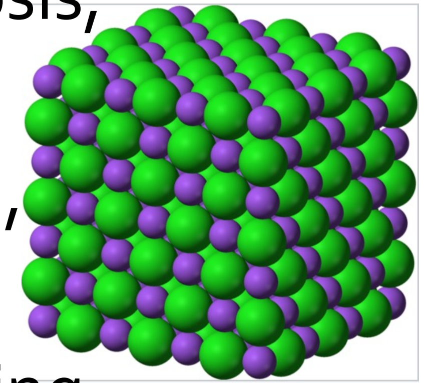
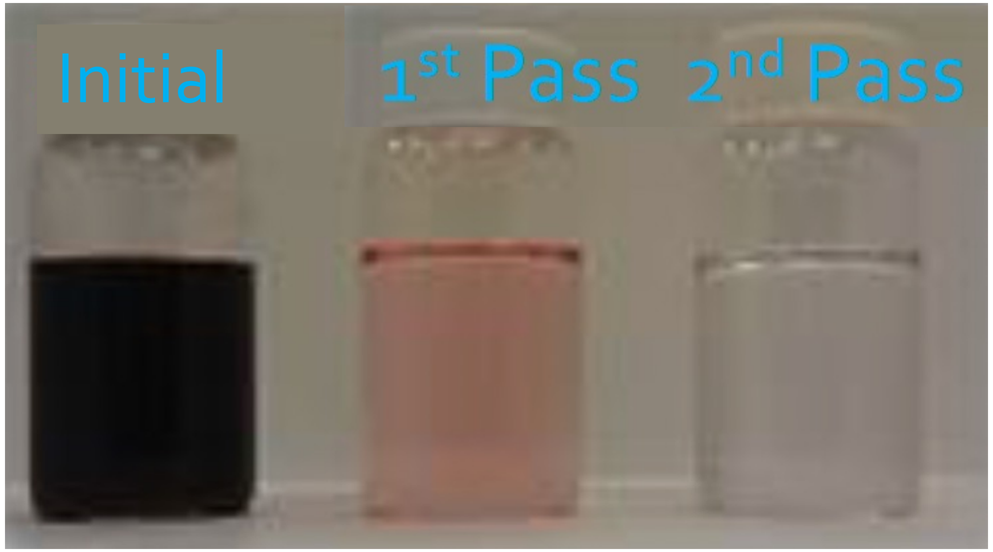


Purification of telluric acid by recrystallization

$$Te(OH)_6 \rightleftharpoons Te(OH)_5O^- + H^+$$

solid

Liquid/solution



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Zone refinement of Ge

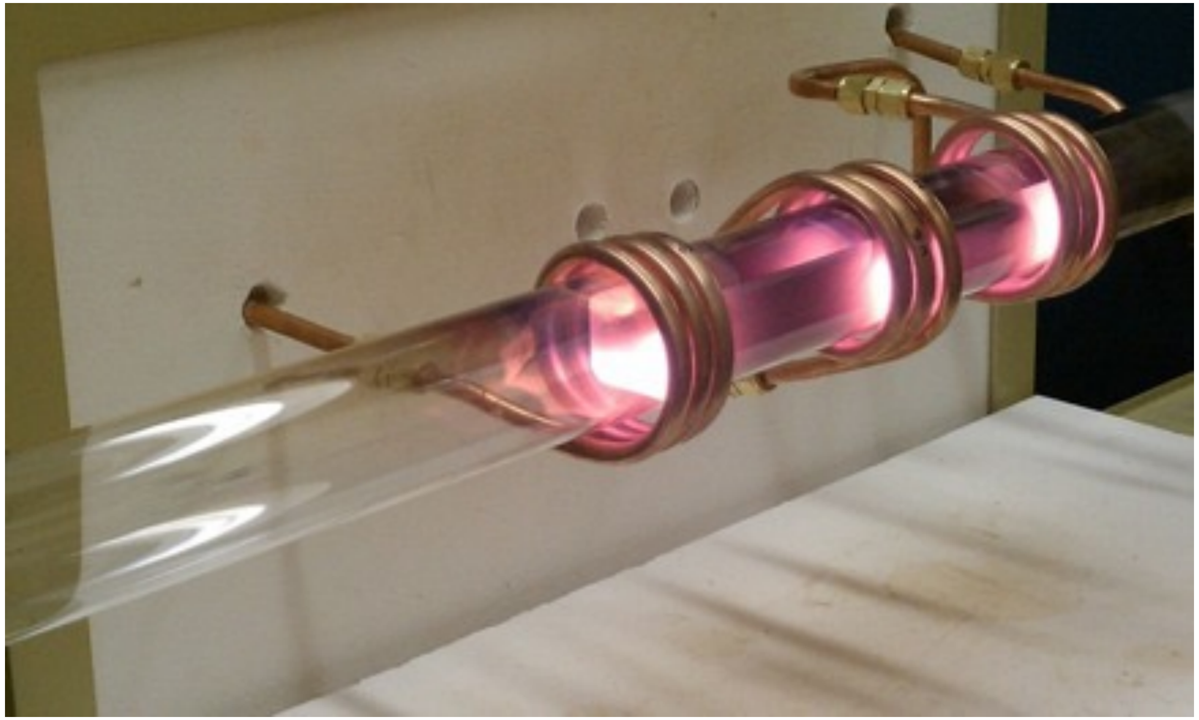

Image: Ryan Martin

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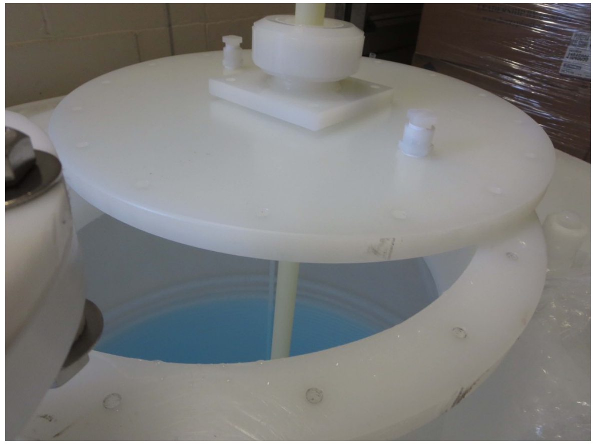


Results from ICP-MS assay of leachate (ppt)

	Soak 1	Soak 2	Soak 3
Ca	2700	380	<20
Fe	5600	220	17

Internal Backgrounds: Ultrapure materials

- Synthesizing clean material
  - Electroformed copper, CVD nickel

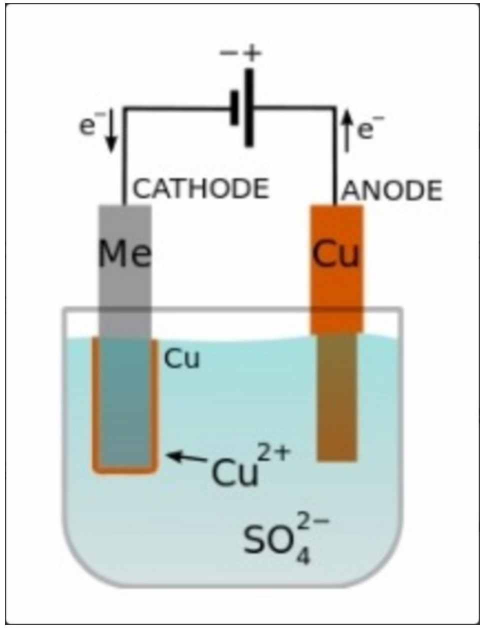
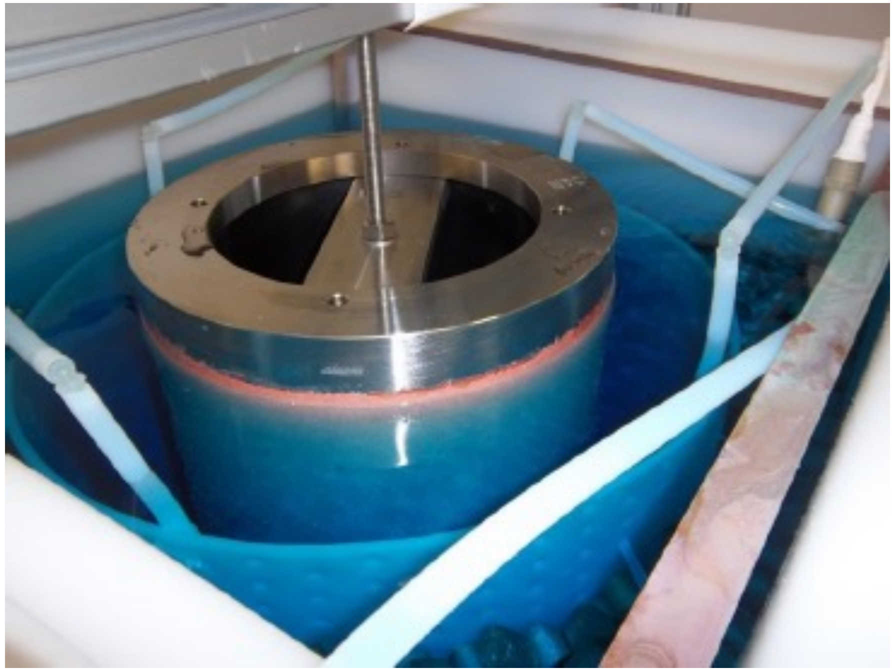


Image: precisioneforming.com



Copper electroforming

Nickel Carbonyl

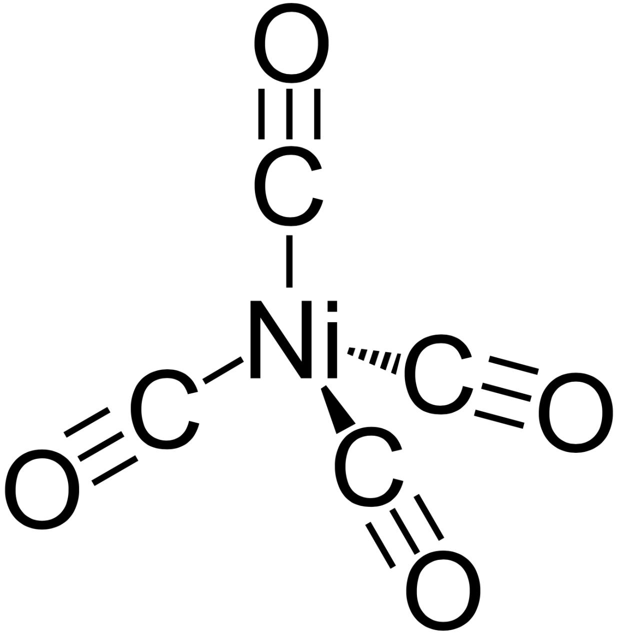
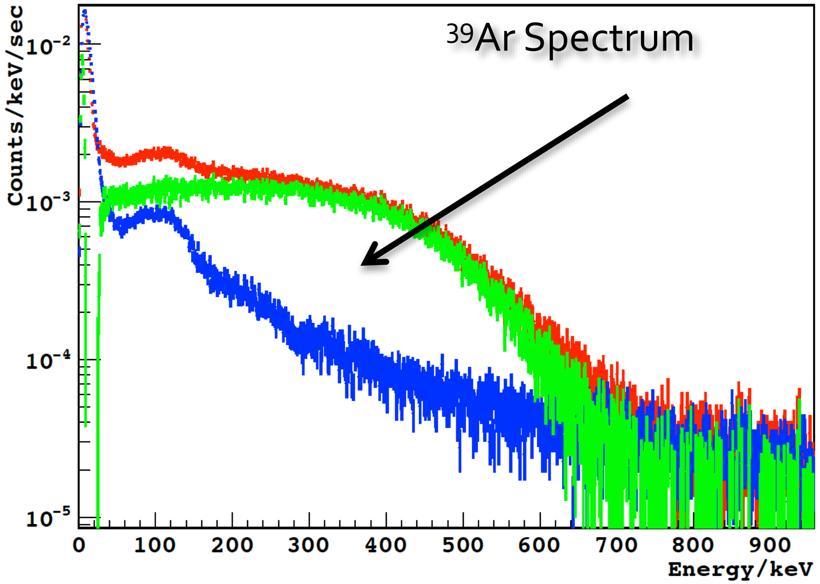


Image: wikipedia

Internal Backgrounds: Ultrapure materials

- Sourcing cosmogenically protected material
  - Archeological lead, petrochemical carbon, underground argon

Image: medium.com, STFC



Internal Backgrounds: Cleanliness

- To obtain and maintain ultrapure materials, great care must be taken to prevent them from getting re-contaminated
  - Clean rooms
  - Clean handling
  - Air exclusion/Rn-reduced air
  - Underground storage/handling

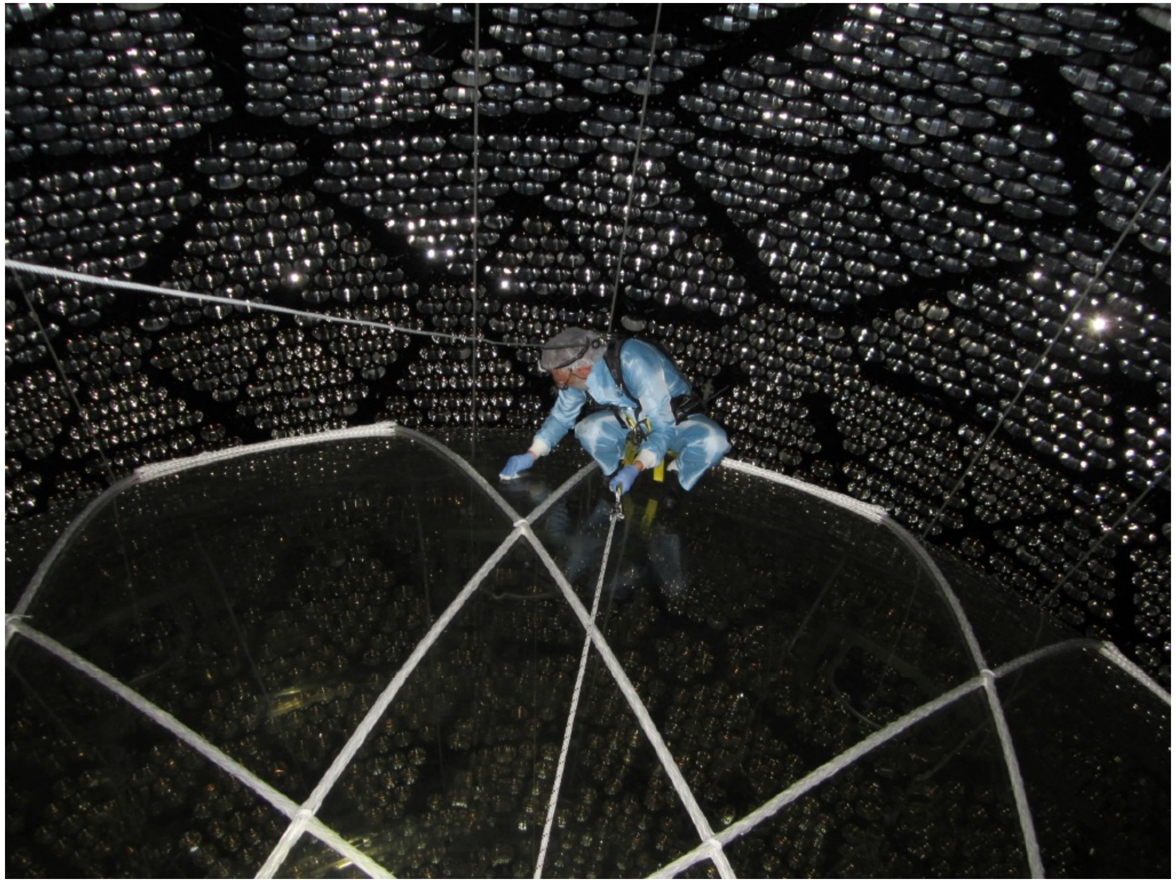
Internal Backgrounds: Cleanliness

SNOLAB experimental area is a clean room

Constant cleaning is required....

Internal Backgrounds: Cleanliness

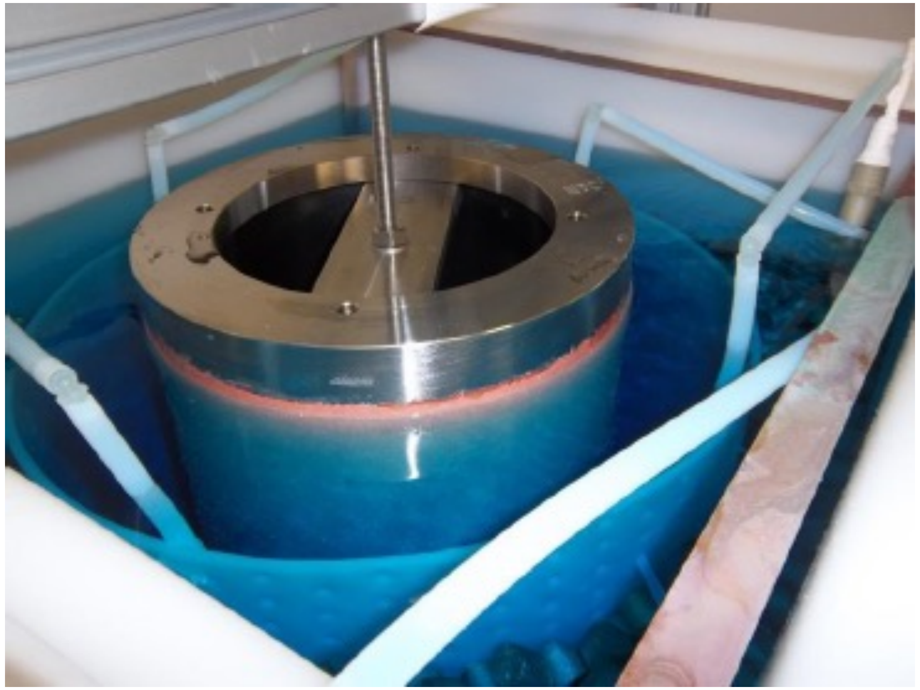
SNOLAB experimental area is a clean room



Constant cleaning is required… even of the experiments!

Internal Backgrounds: Cleanliness

Underground electroforming.



Underground machining

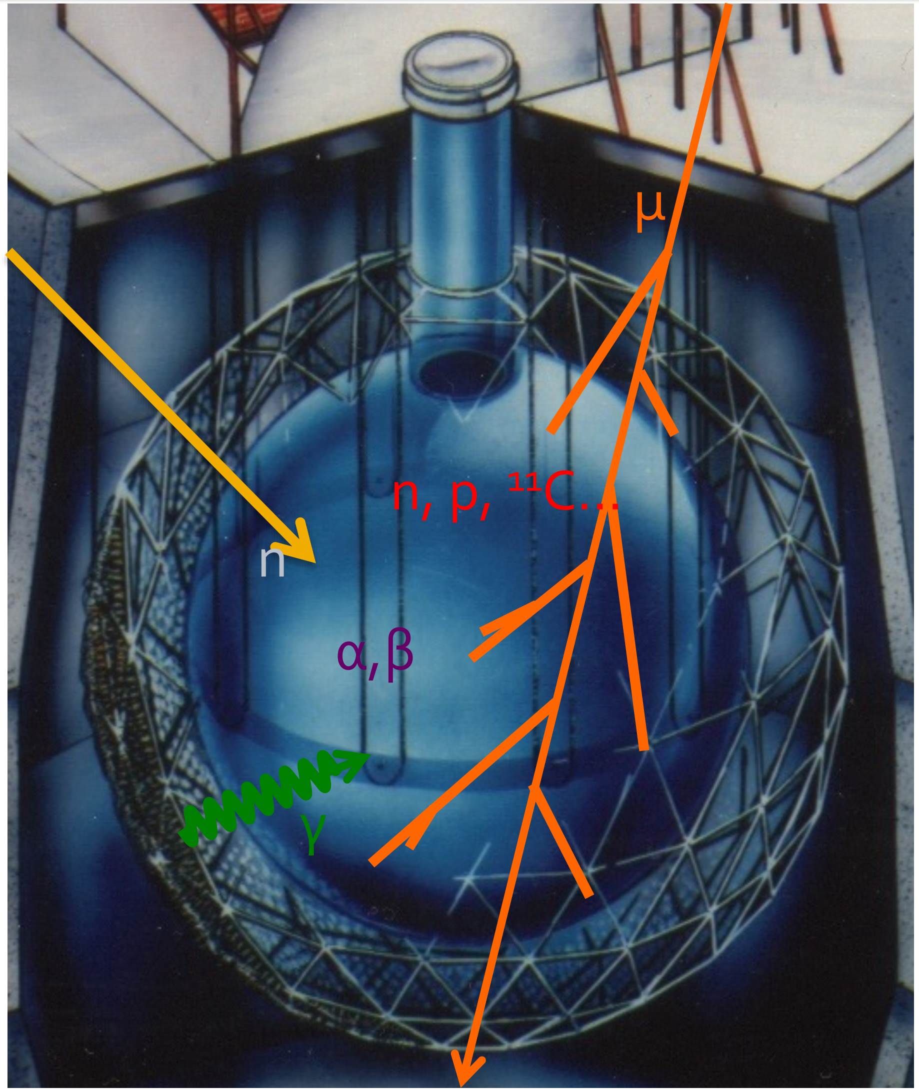
Images: Ryan Martin, Sanford Lab

Internal Backgrounds: Cleanliness

Assembly inside a glovebox inside an underground clean room – the components never "touch" air.

Images: Ryan Martin, Sanford Lab

Summary



The extraordinarily sensitive detectors needed for rare event searches are susceptible to background from a variety of sources. We mitigate these backgrounds by locating our experiments underground, shielding them carefully, and going to great lengths to achieve and maintain very high levels of material purity.