An overview of outer detectors

Teena Vallivilayil John

SNOLAB User Meeting 2026

LaurentianUniversity UniversitéLaurentienne

nEXO

Carleton University

Background in Rare-Event Searches

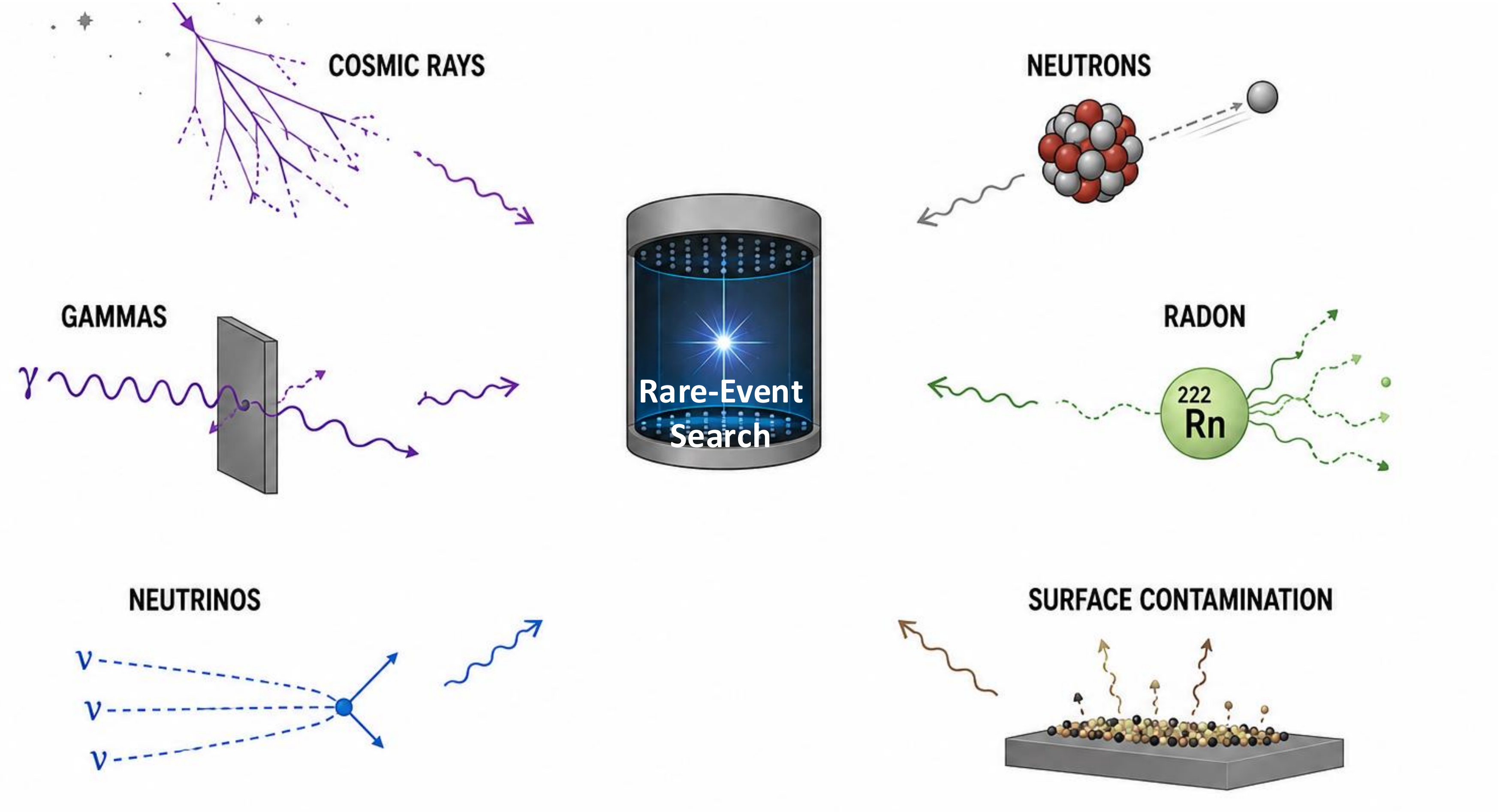
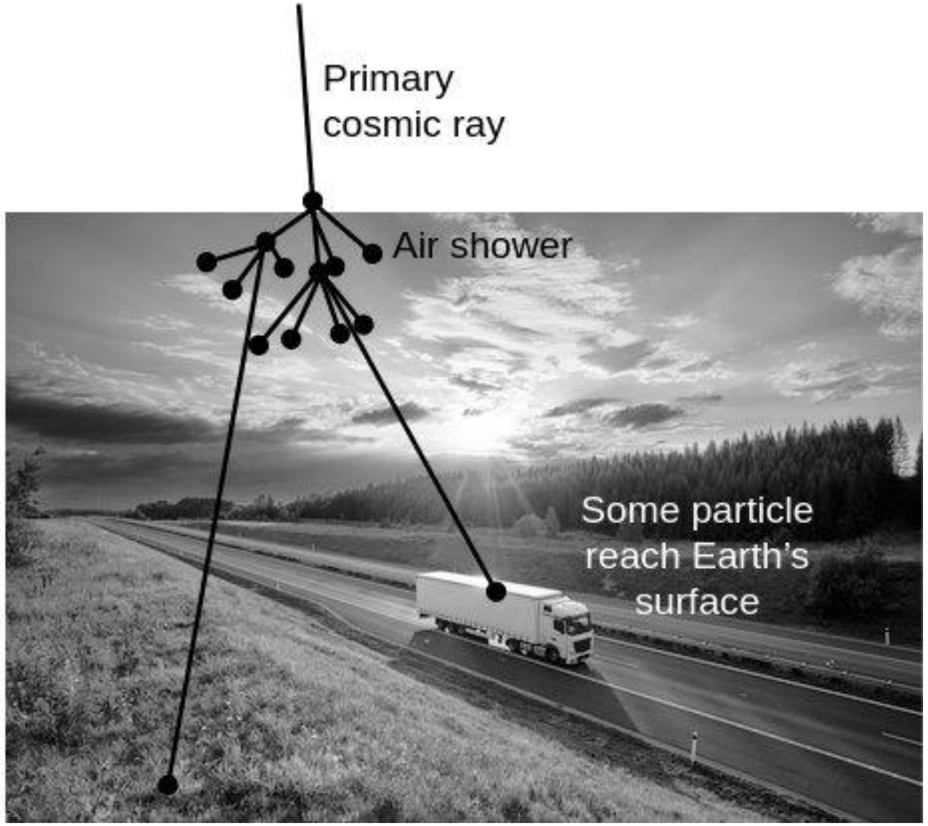


Image generated with ChatGPT

Cosmogenic Background

- Sources
  - Prompt Signals
  - Cosmogenic Activation
- Muon flux (sea level): 1 mu cm^{-2} min^{-1}
- Muon mean energy (sea level): 4 GeV

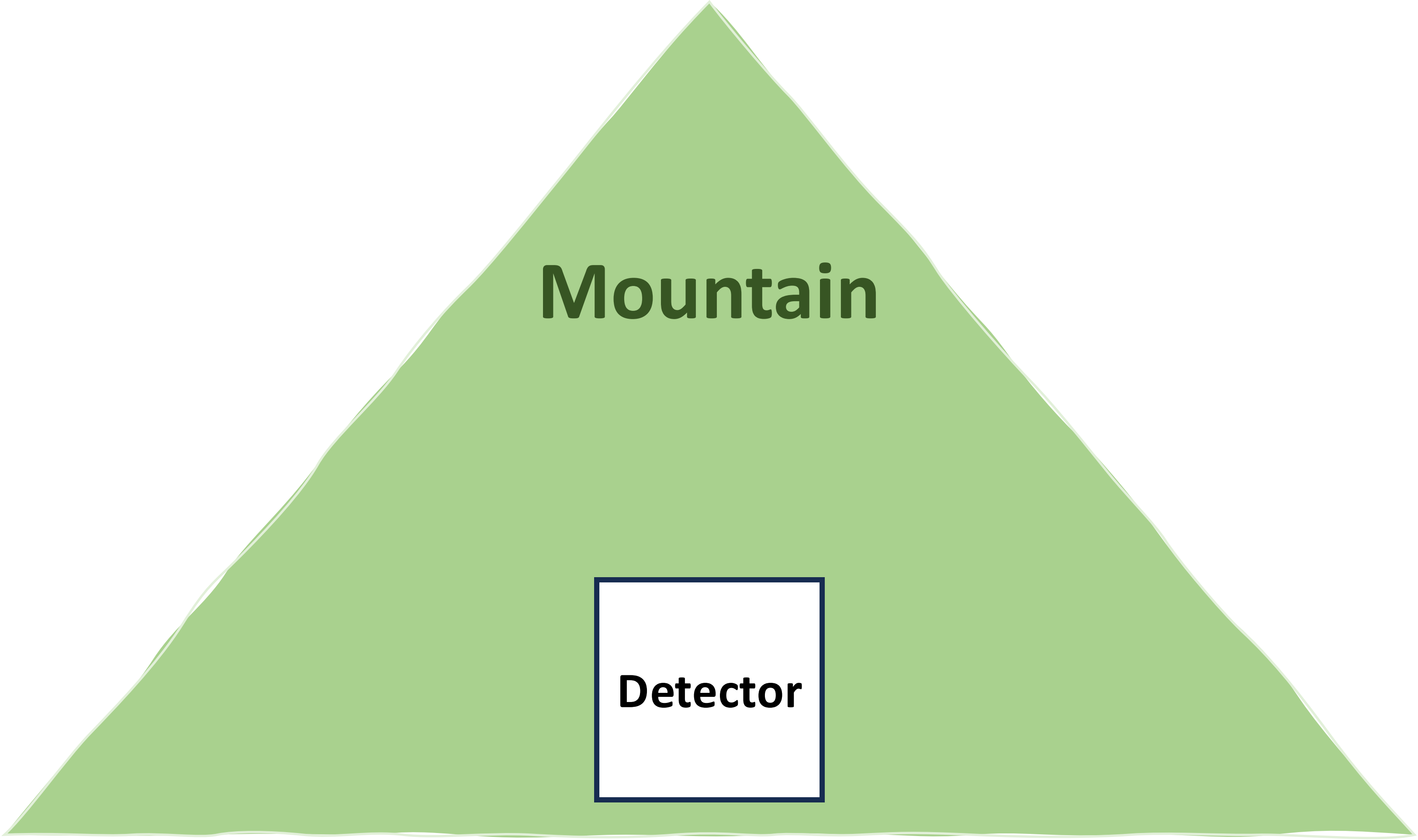


Cosmogenic Background

Mitigation Strategies

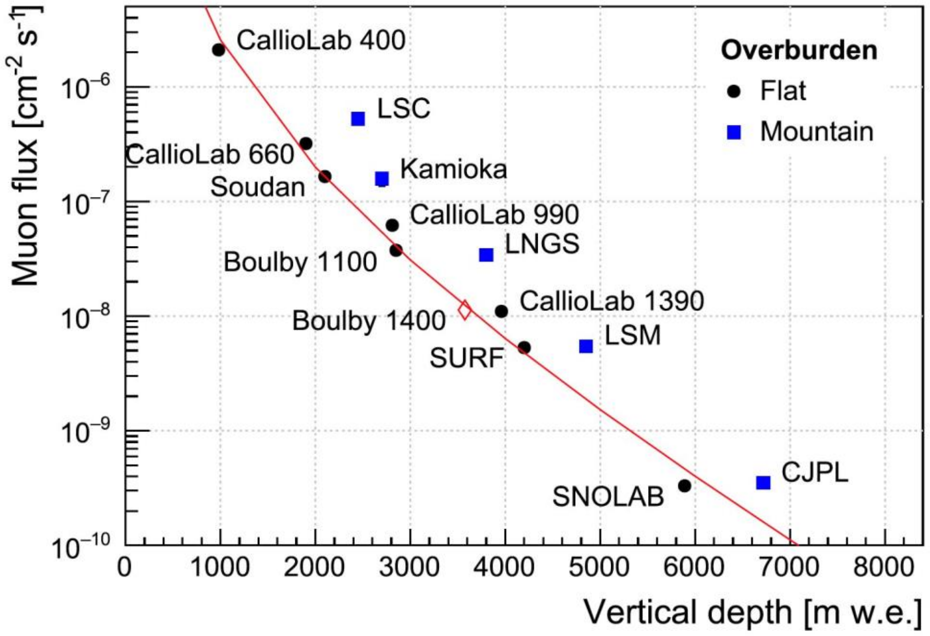
Background	Mitigation
Prompt Signals	Passive Shielding Active muon veto
Cosmogenic Activation	Efficient transportation and storage plans

Passive Shielding



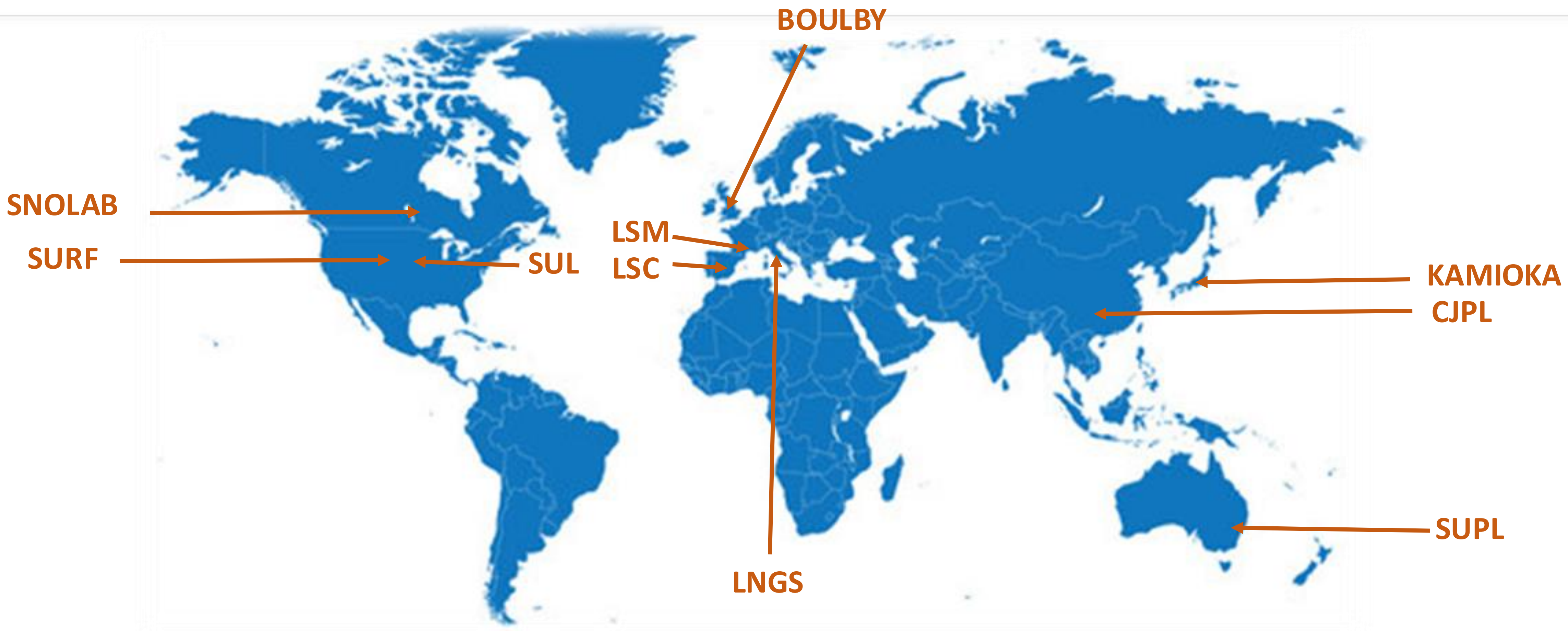
Deep Underground Laboratories

- Suppress muon flux by 5 to 6 orders of magnitude
- Selecting the optimal underground site involves the experiment's depth requirements.
- Depth is usually measured in meter water equivalent (m.w.e.)



V. Pěč et al. Eur. Phys. J. C 84, 481

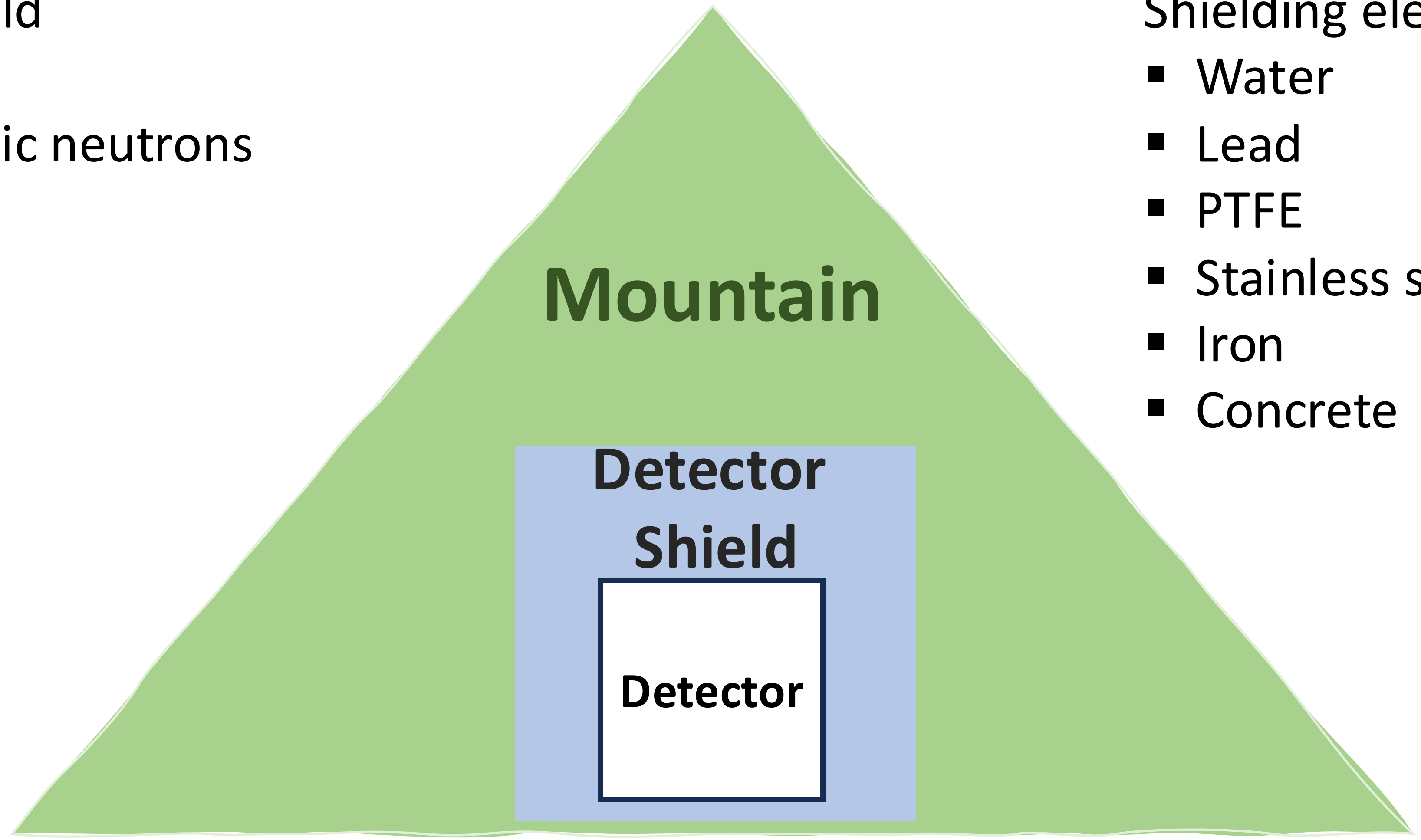
Deep Underground Laboratories



Passive Shielding

Passive shield

- Gammas
- Radiogenic neutrons

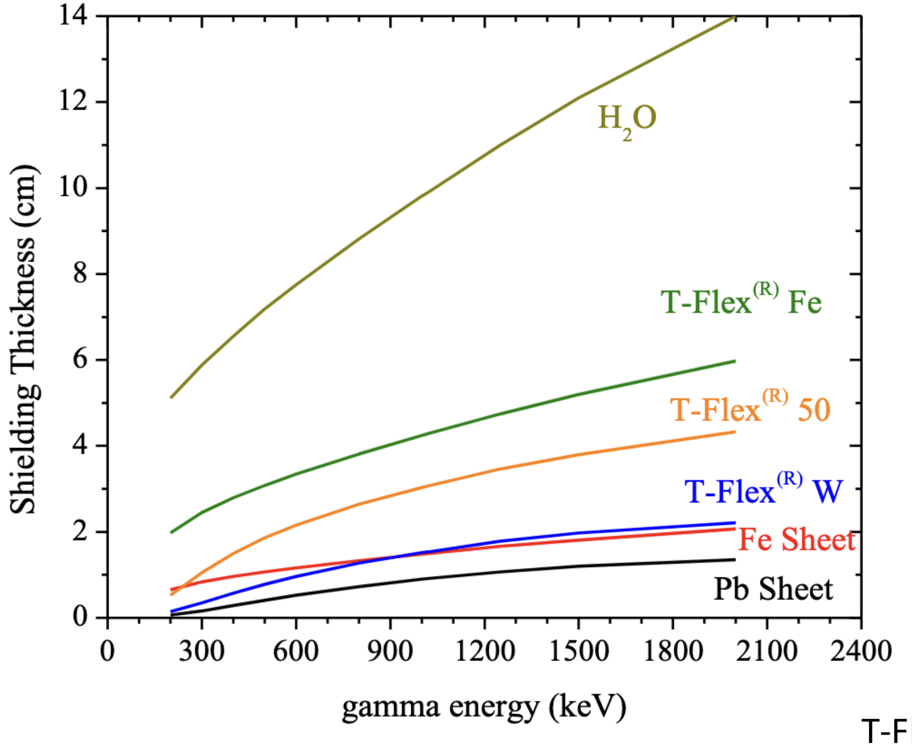


Shielding elements for gammas

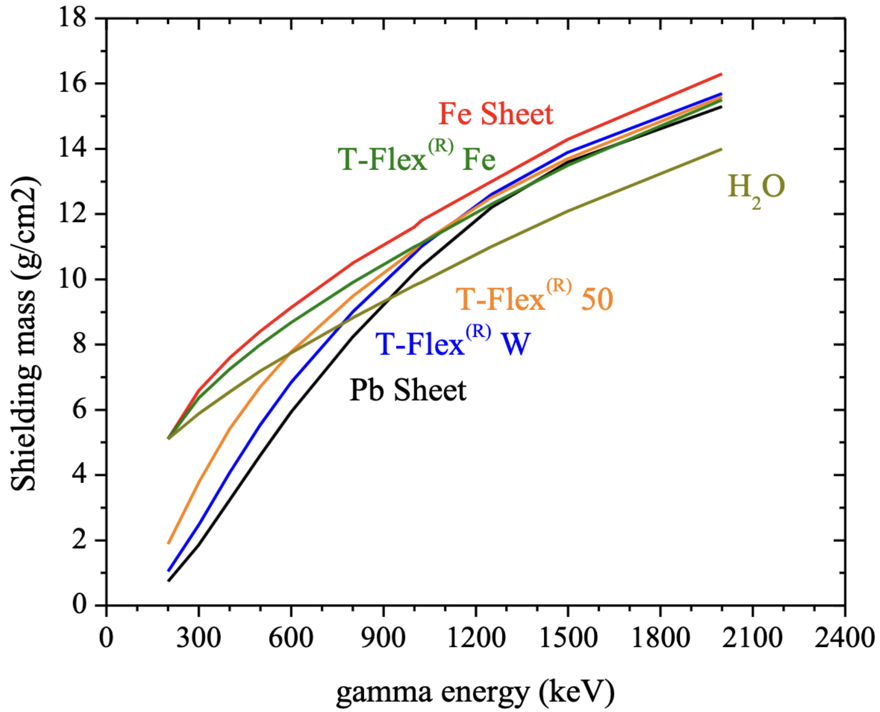
- Water
- Lead
- PTFE
- Stainless steel
- Iron
- Concrete

Passive Shielding Element Thickness

Shielding Thickness(for 50% gamma attenuation) vs Gamma Energy



Shielding Mass (for 50% gamma attenuation) vs Gamma Energy

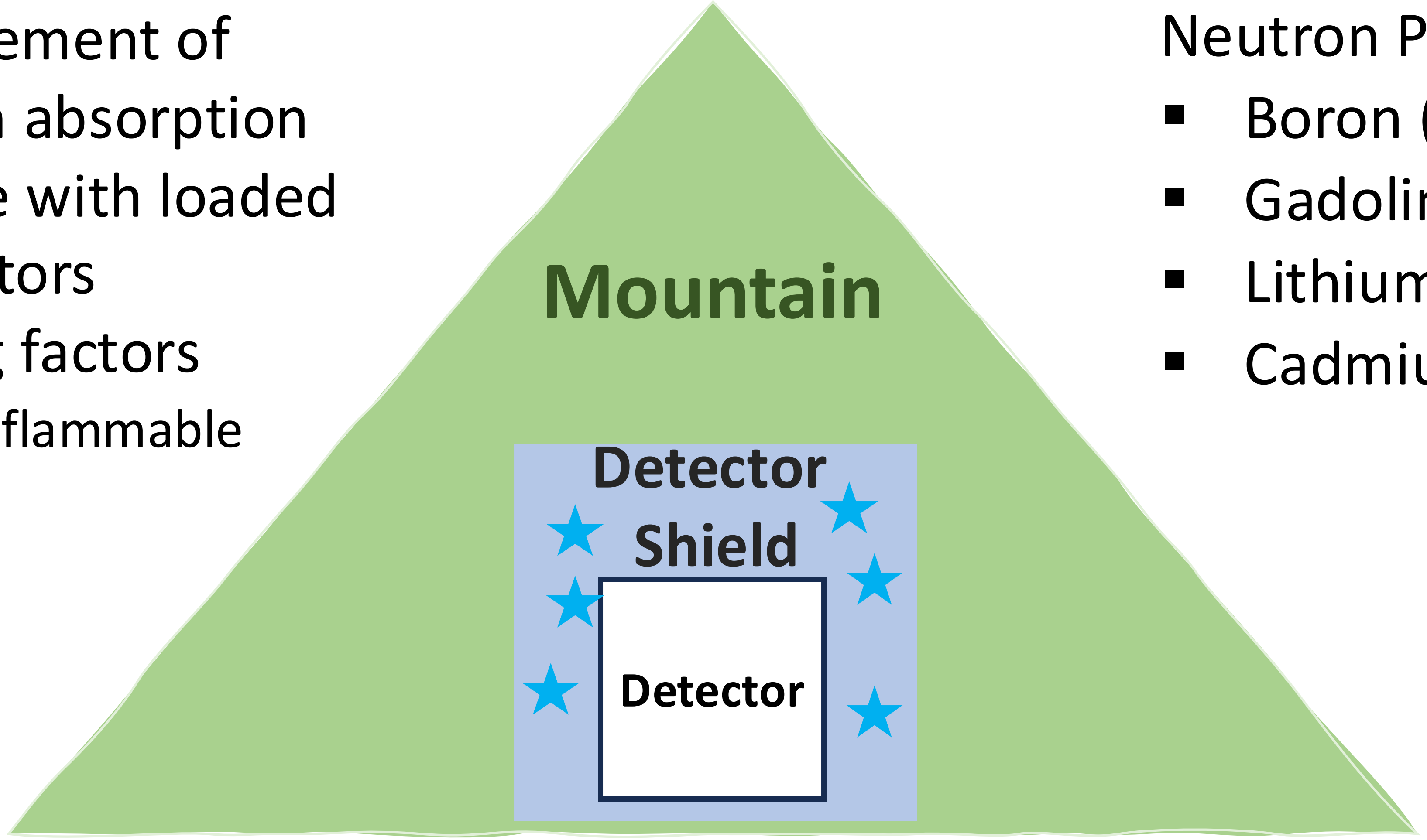


T-Flex® W :Tungsten suspended in polymer (88% by mass W)
T-Flex® Fe :Iron suspended in polymer (69% by mass Fe)
T-Flex® 50: Blend of tungsten and iron suspended in polymer (39% W and 39% Fe by mass)

McAlister

Passive Shielding

- Enhancement of neutron absorption possible with loaded scintillators
- Limiting factors
  - Highly flammable
  - Toxic

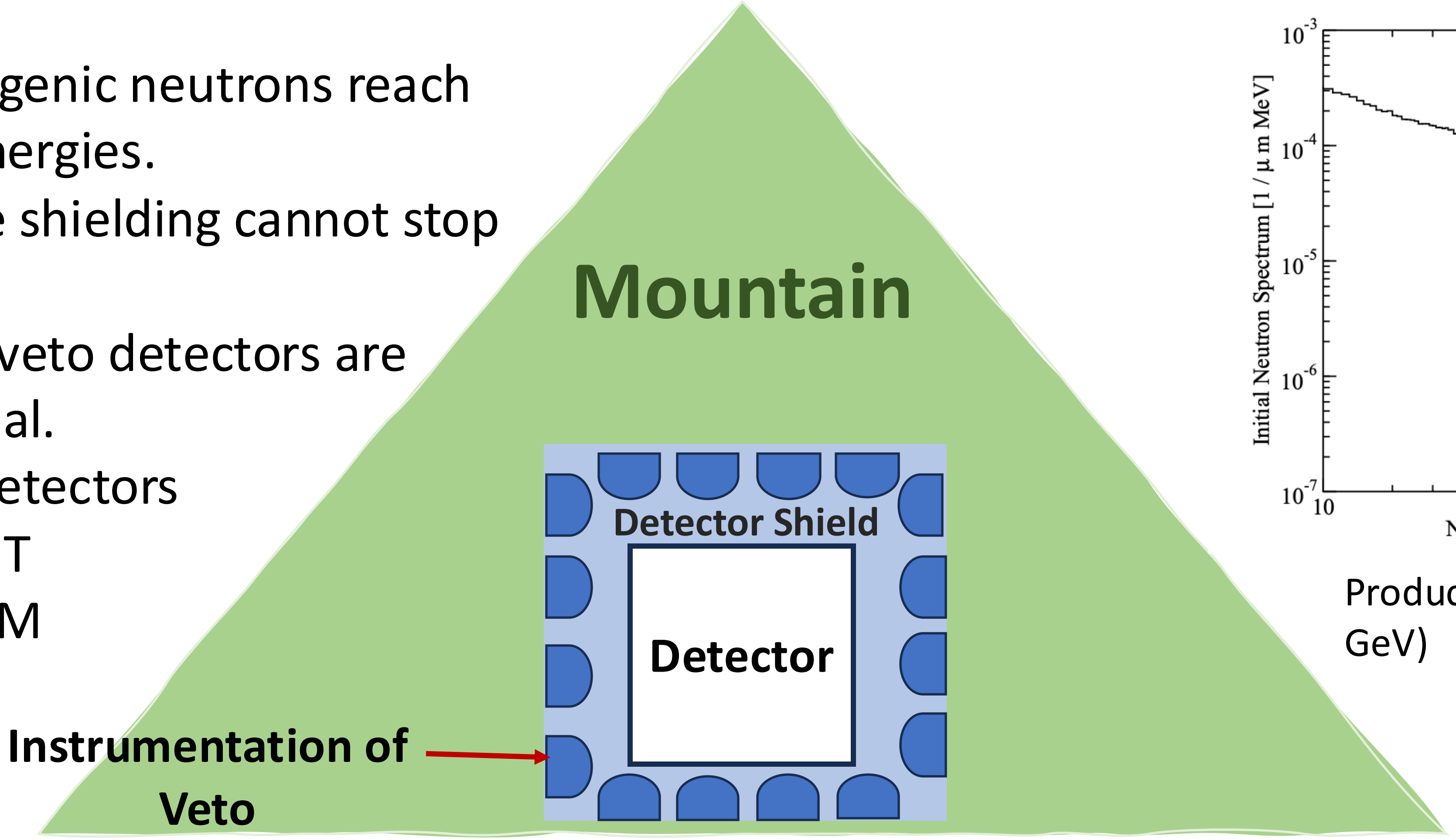


Neutron Poisons

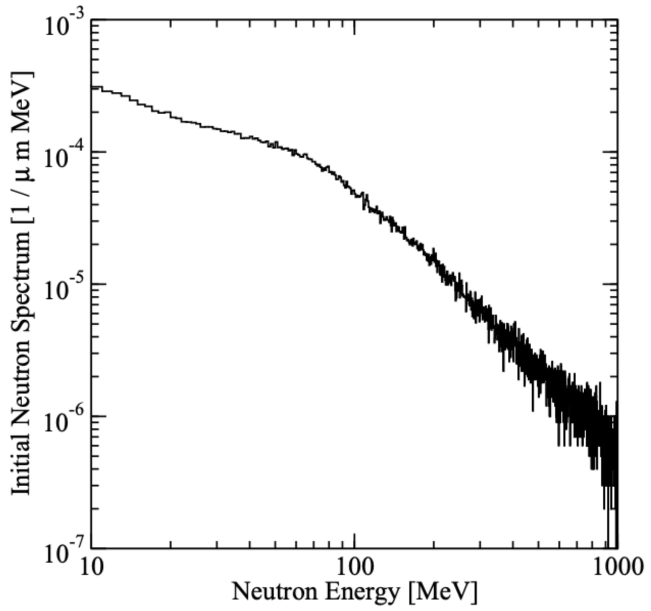
- Boron (^{10}B)
- Gadolinium (^{157}Gd)
- Lithium (^{6}Li)
- Cadmium (^{113}Cd)

Active Veto

- Cosmogenic neutrons reach GeV energies.
- Passive shielding cannot stop them.
- Active veto detectors are essential.
- Light detectors
  - PMT
  - SiPM



Cosmogenic neutron energy spectrum

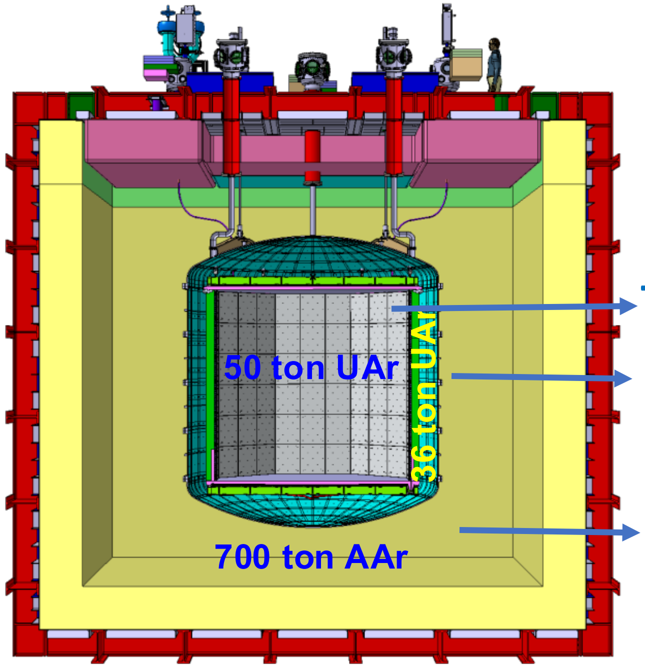


Produced by muon (285 GeV)

Spectrum

Scintillation Detector

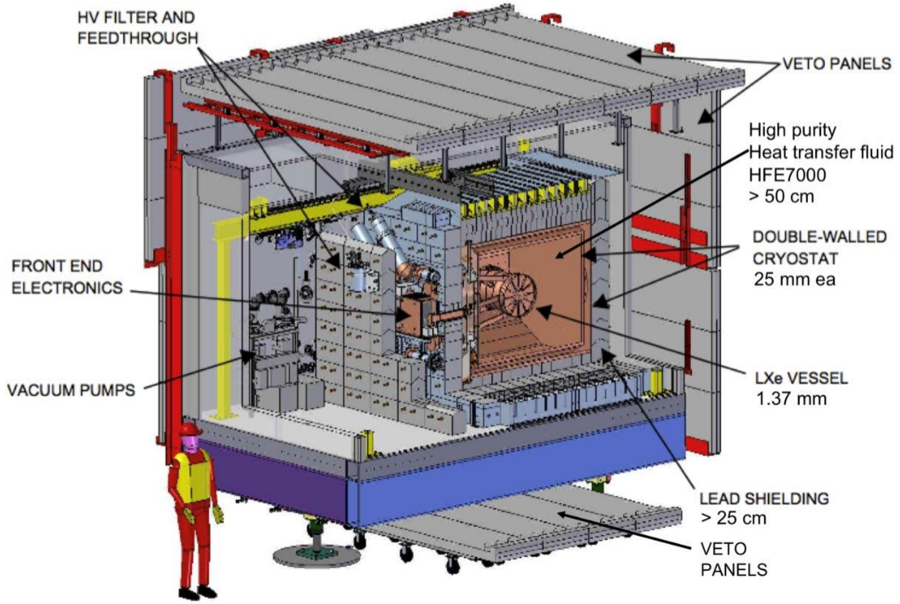
Schematic diagram of DS-20k



IV : Vetoes radiogenic neutrons and γ

OV : Tags cosmogenic muons and neutrons.

Schematic diagram of EXO-200



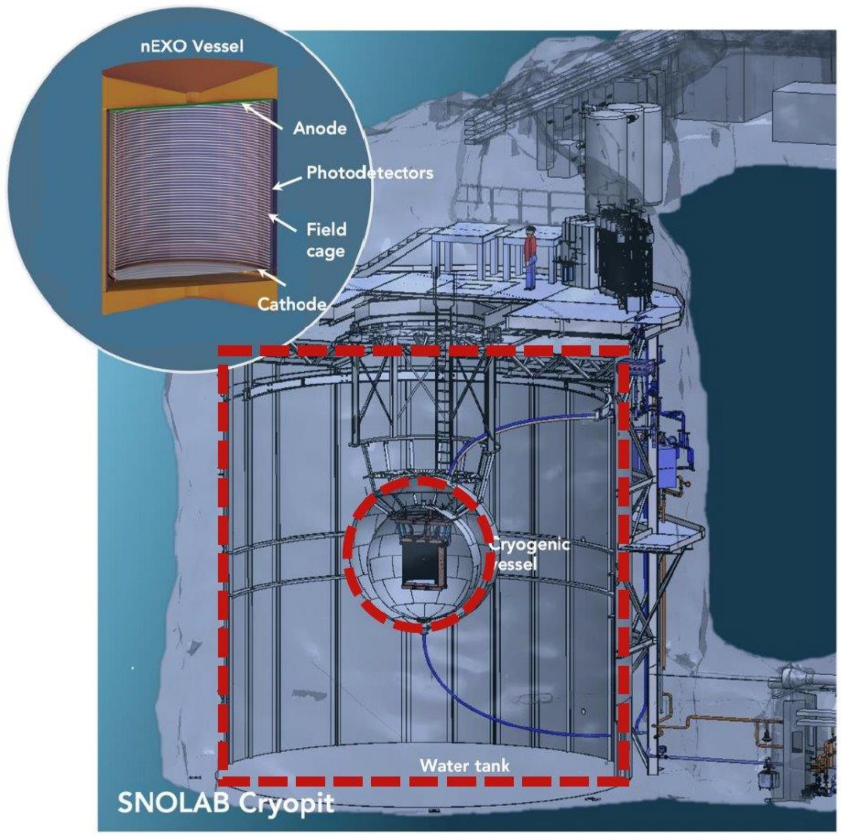
Scintillation panels around the detector.

Segmentation allows more channels

Expensive for large volumes

Cherenkov Detector

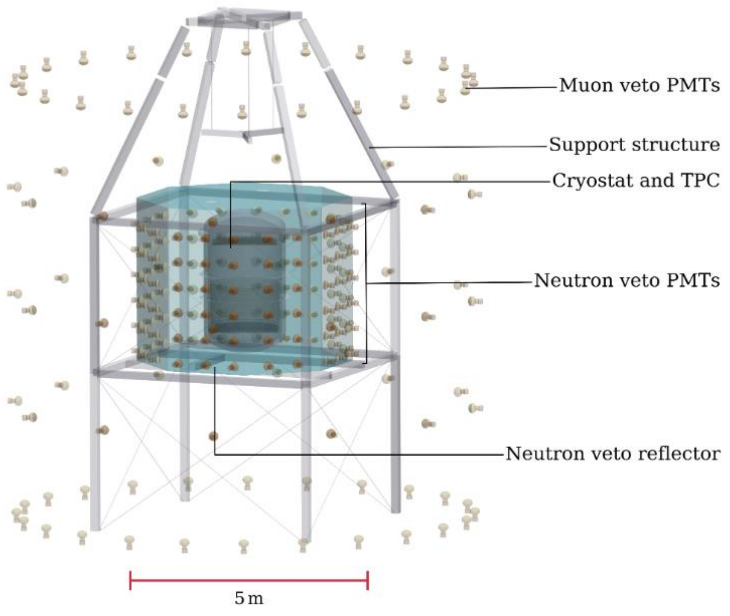
- Water tank instrumented with PMTs
- Cost competitive
- Keep the radon concentration in water less than 10 mBq/m^3
- Reflective surface helps to reduce the number of PMTs
- Limiting factors
  - Reduced light yield
  - Need a higher energy threshold
  - Biological growth can influence the water transparency and light scattering.



Schematic diagram of nEXO

Two Veto Detectors

XenonnT

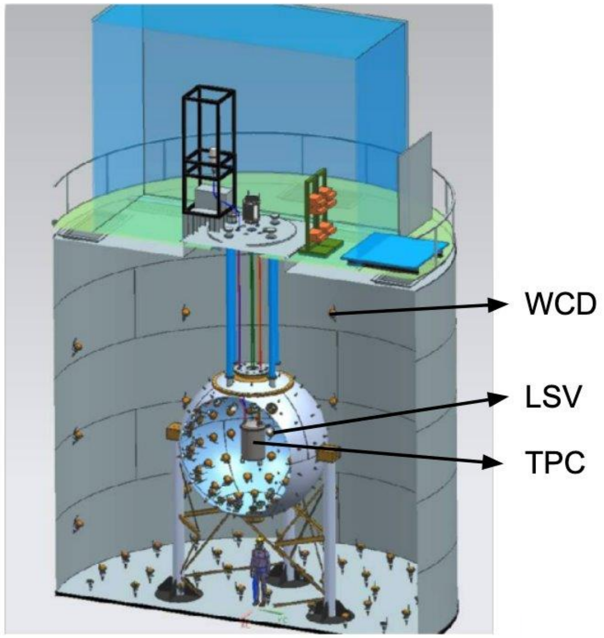


Muon Veto: Water Cherenkov Detector

Muon tagging efficiency : 99.5%

Neutron Veto : Gd-doped water Cherenkov detector

DarkSide-50

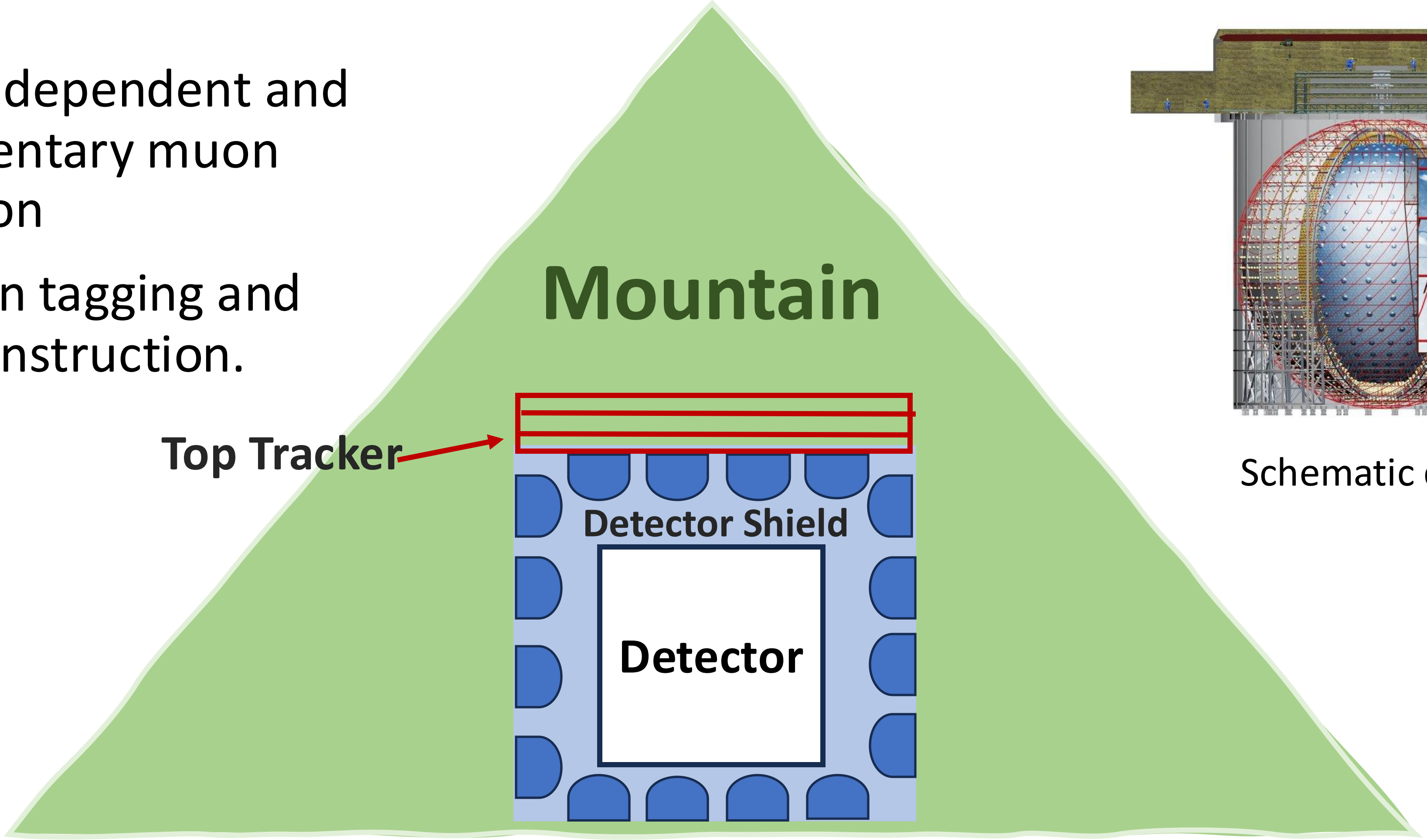


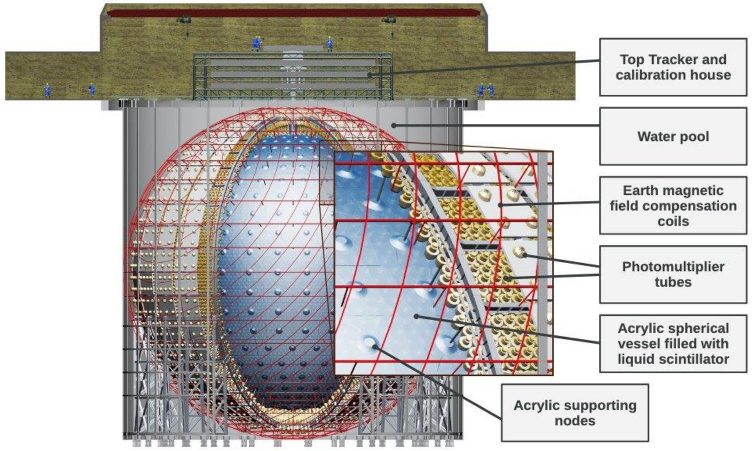
Neutron Veto : Boron-loaded liquid scintillator

Muon Veto: Water Cherenkov Detector

Top Tracker

- Provide independent and complementary muon information
- Help muon tagging and track reconstruction.

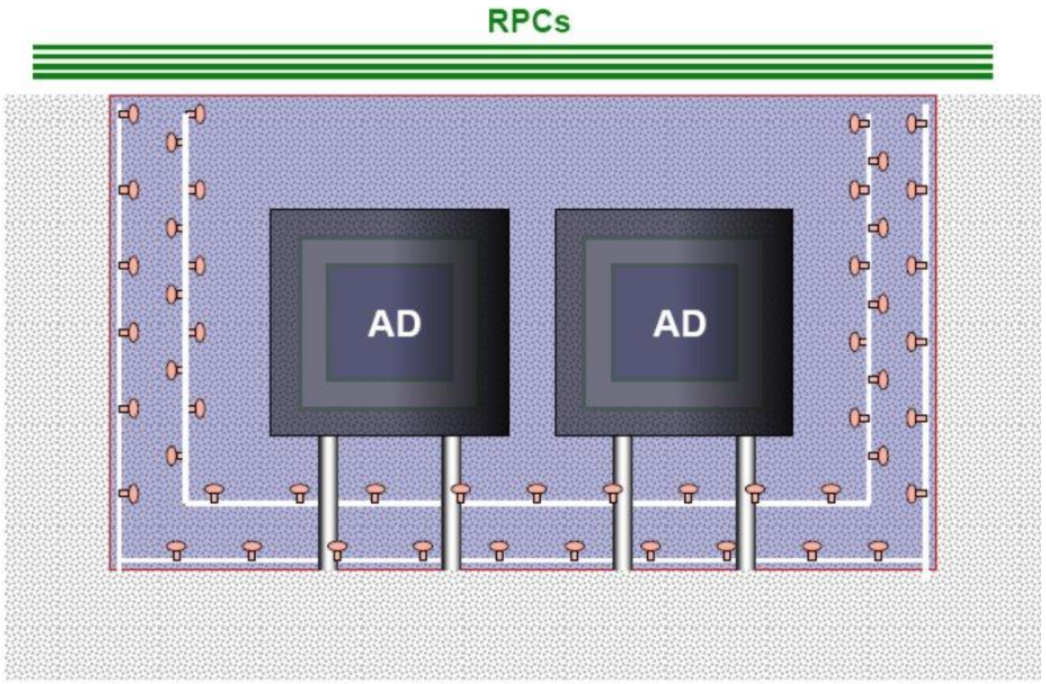




Schematic diagram of JUNO

Resistive Plate Chamber

- Gaseous particle detectors
- Daya Bay used RPCs as veto detectors.
- Water pools miss short-track muons.
- RPCs provide muon directionality.
- Combined muon veto efficiency ≥ 99.5%.
- Limiting factors
    - Needs high voltage and careful gas handling.
    - Sensitive to temperature, humidity, and gas purity.
    - Prone to aging over long term operation.



Schematic diagram of DayaBay

Summary

- Underground labs reduce cosmogenic backgrounds by 5–6 orders of magnitude.
- Water Cherenkov detectors offer flexible design options for the central detector's size and shape.
- Scintillator detectors deliver higher light yield for improved signal detection.
- Resistive plate chamber, or top trackers along with water Cherenkov can improve the muon detection efficiency
- Efficient transportation and storage plans

Thank you for your attention