Underground Laboratories

or

Why do physiscists want to live like moles?

May 2019

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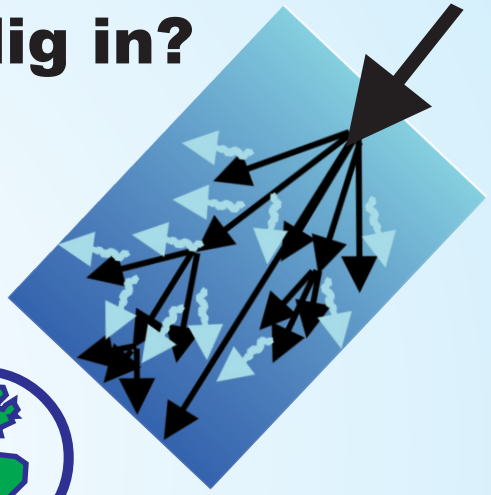
Underground Physics

- What kind of physics needs to dig in?
- Why does one have to go deep?



- Where can you find labs?

- What do experiments need?

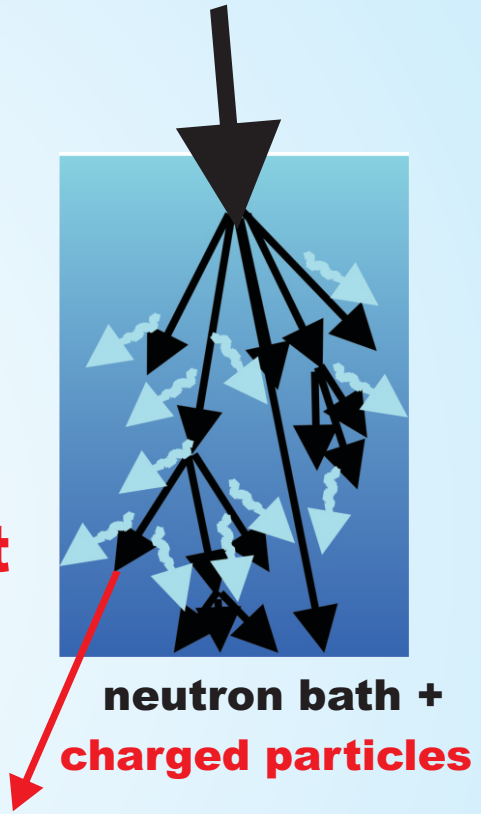
- How do experiments select a laboratory?

Rare Events

Experiments with few [no] events:

- **proton decay**
- **dark matter interactions**
- **neutrinoless double beta decay**

build a detector, hope and wait
– what counts is background



- **low energy neutrinophysics**

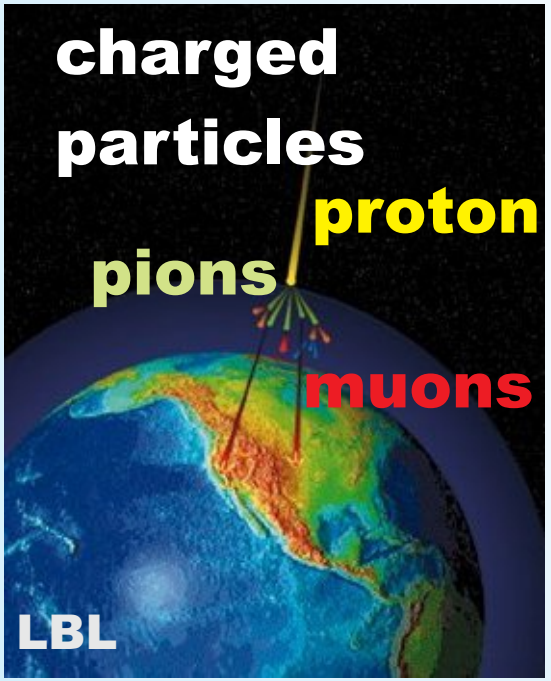
beams, reactors, sources like the sun

at least they have events - moderate depth

Muons

Why is a concrete bunker not good enough?

high energy muons

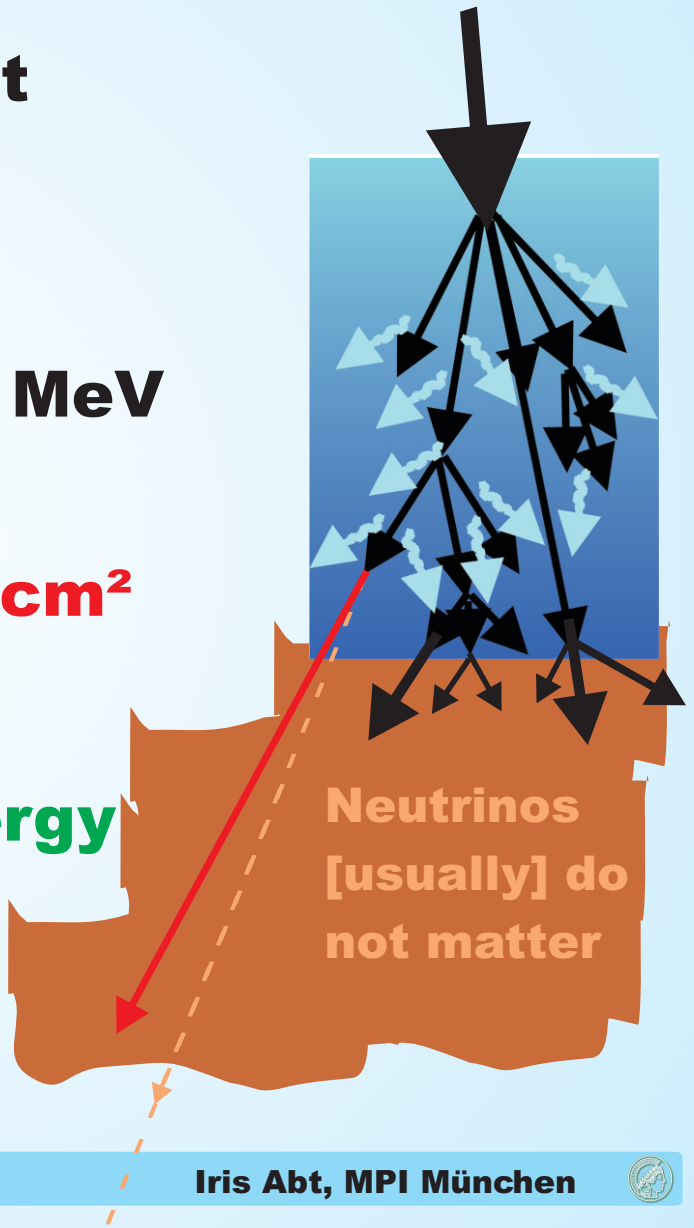


lose only 2 MeV per g/cm²

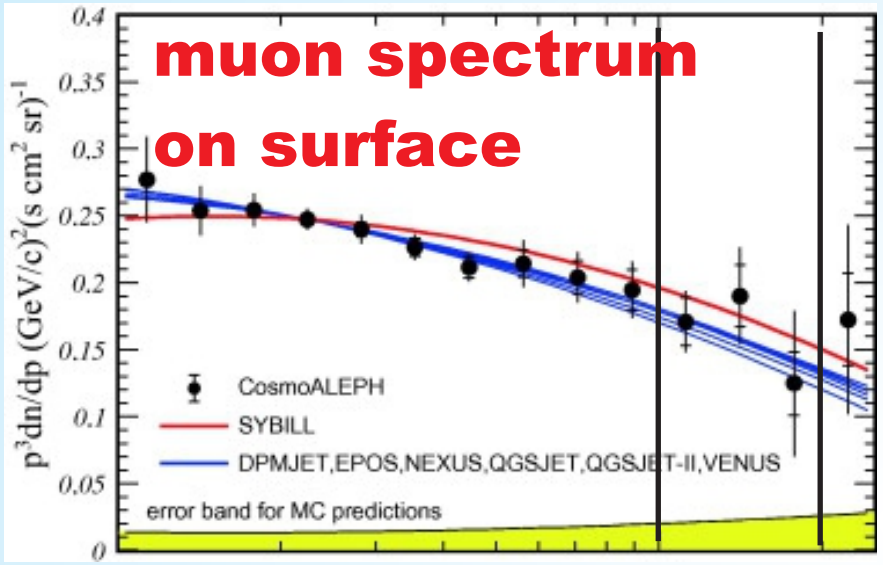
“rock”: 5 g/cm²

► 1GeV/m

average energy ≈ 4 GeV on surface



Spectra



CosmoAleph collaboration

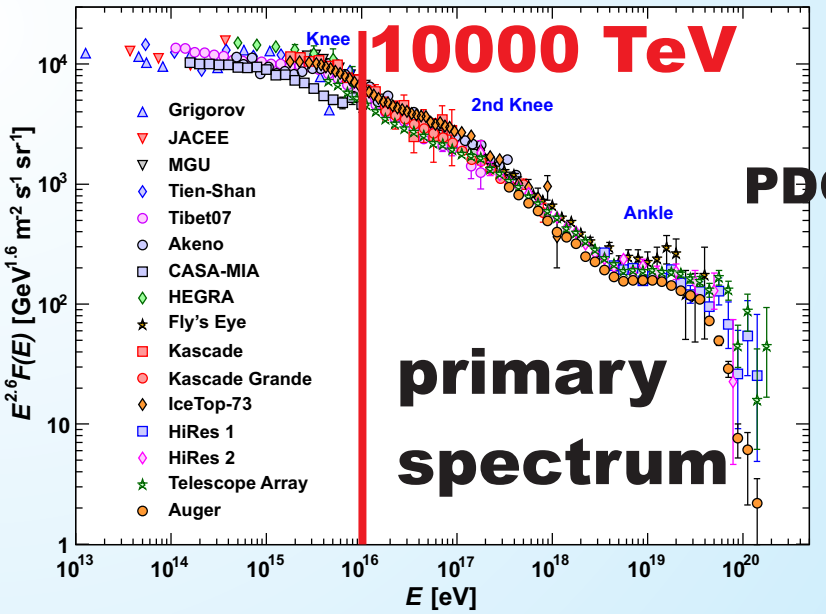
Astropartical Physics, 49, 2014,1-5

Muons can take their share. Certainly, they can have > 100 TeV.

1TeV lets a muon travel through 1km of rock.

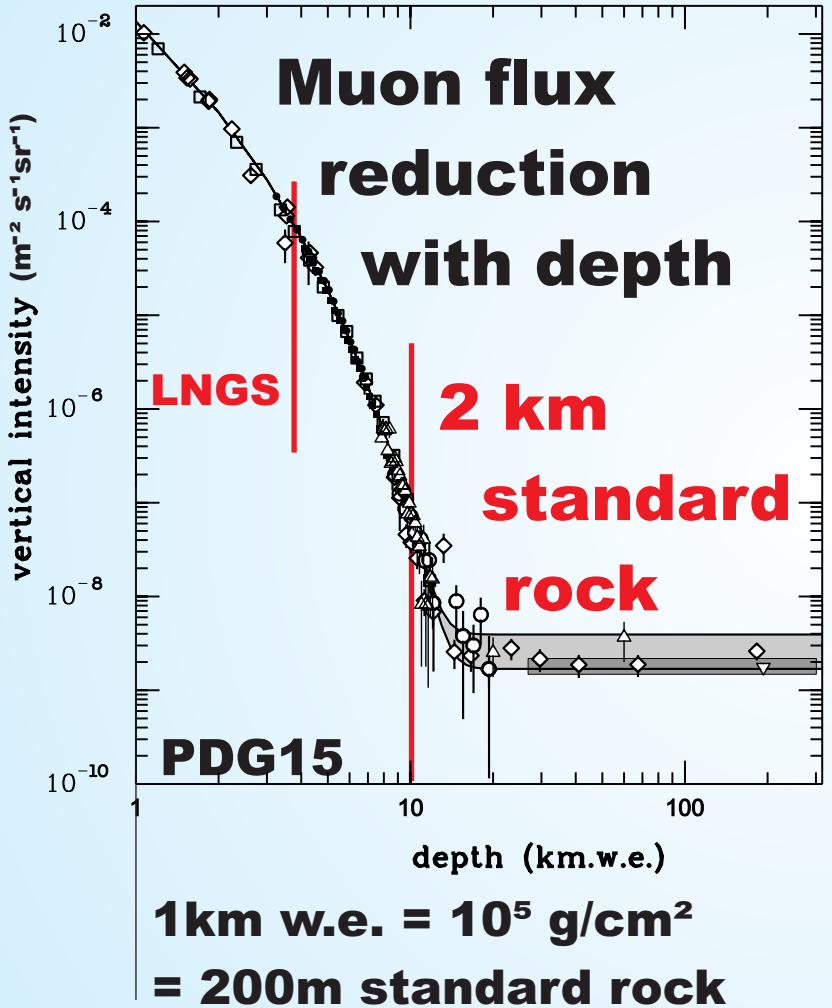
2 TeV ....

cosmic rays



PDG15

Muon Flux Reduction



1km w.e. = 10^5 g/cm²
= 200m standard rock

Surface:

1 μ/cm²/minute

≈ 53 10^8 μ/m²/year

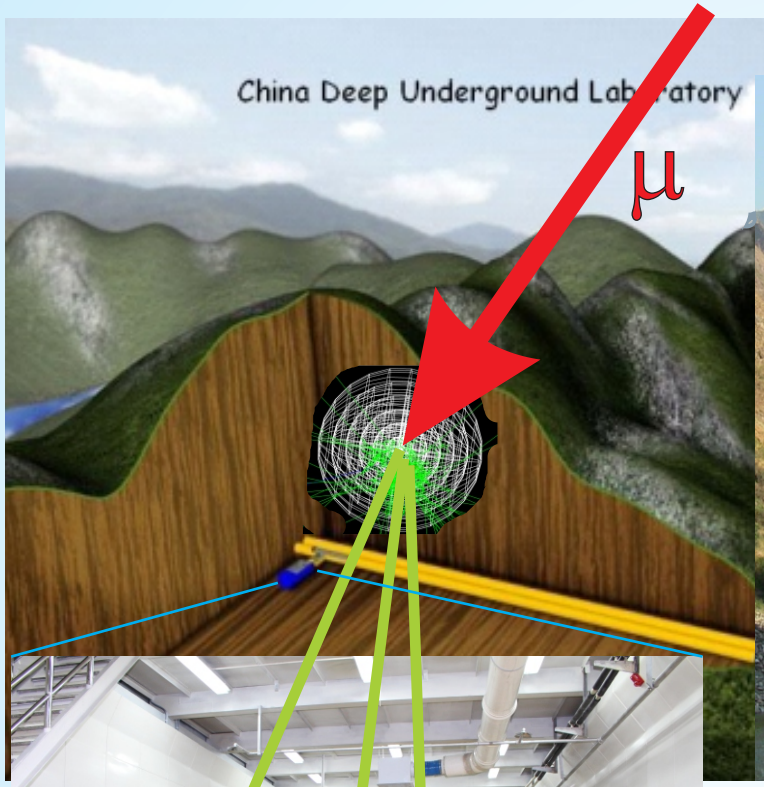
There is no mountain made of standard rock.

LNGS: 10^4 μ/m²/year

Record:

CJPL 2400m marble
= 7500 m w.e.
60 μ/m²/year
reduction by 10^8

What do muons do?

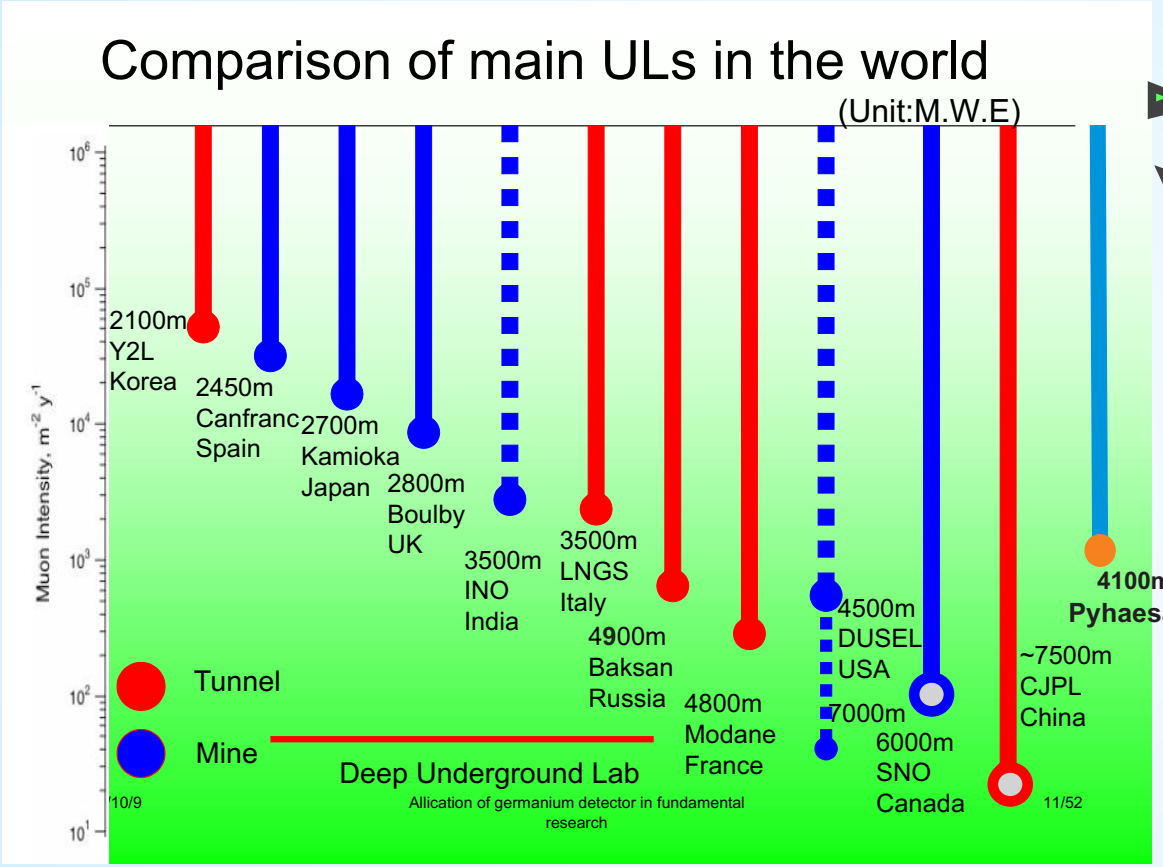


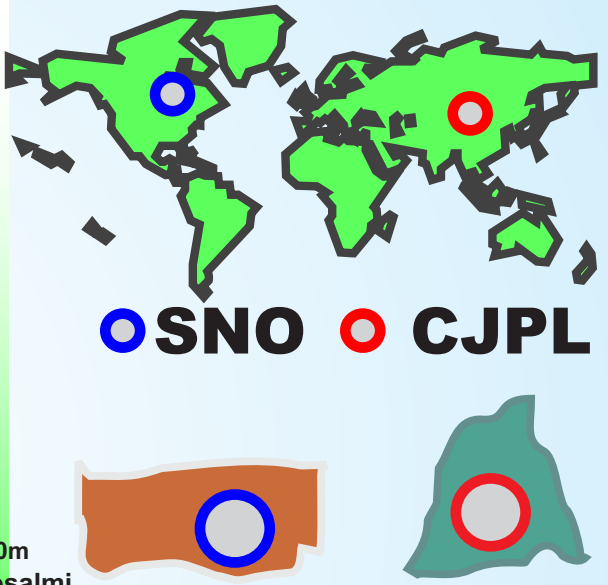
Muons interact in the rock around the laboratory and create showers with neutrons.

► **background**

Neutrons deposit energy or create meta-stable elements which much later decay.

Laboratories





depth records

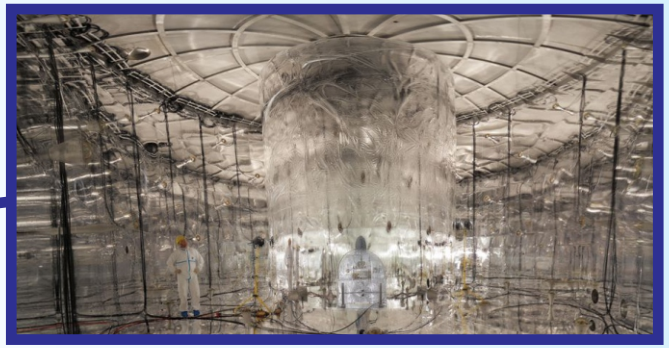
mine **tunnel**

Depth is important, but so are overburden and access.

Muon Vetos

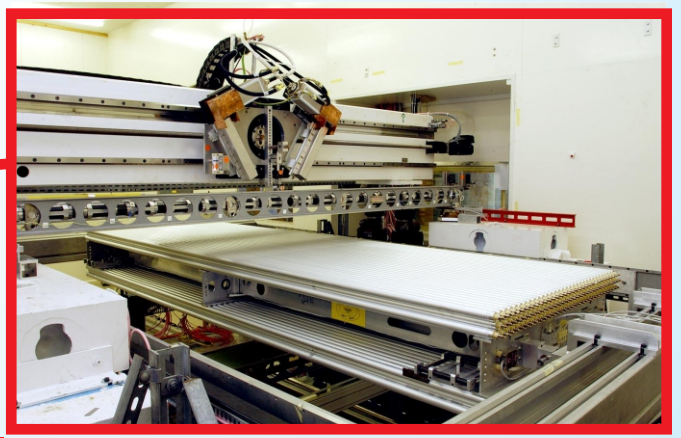
Space availability is also an important issue.

Depth controls the muon flux, space opens possibilities to monitor muons.



A water tank only reports muons traversing the experiment.

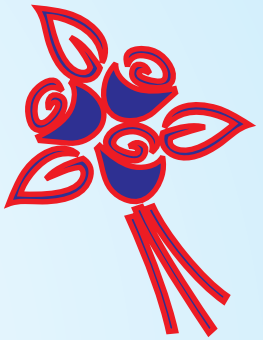
Muon chambers mounted on the walls would monitor all muons and intruding showers.



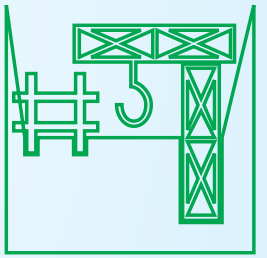
Laboratory Selection

Depth and space are primary parameters.

But there is more:



- **Availability [willingness/ability to host]**
- **Access [shaft or tunnel][cage or truck]**
  - **maximum package size, booking time**
- **power (availability, cost)**
- **clean room conditions**
- **radioactivity of surrounding rock**



- **infrastructure (fork lifts, [demineralised] water, gases, LN, LAr.....plus ventilation)**
- **rules (welding, studding, soldering)**

Laboratory Selection

Depth and **space** are primary parameters.

But there is more:

- **Logistics**
  - How to get there (car, bus, ...)
  - Where to stay and how to book (hotels, ...)
  - How to schedule work (contact, internet, ...)
  - How to order things (contact, internet, ...)
- **Safety (officer, team, rules, ...)**
- **Involvement of lab**
  - Support team ([cryo-] technicians], work-shops, ...)
- **Security**

And in the end it is politics.
That is the unfortunate truth.

Summary

- Underground Laboratories are needed for rare event physics.
- On the surface, cosmic rays create a bath of neutrons and charged particles.
- Below 10 m w.e., muon are what counts.
- Muons interact and produce particle showers which contain neutrons.
- Neutrons can cause background events.
- To avoid neutrons, the experiments go deep to reduce the muon flux.
- Space and infrastructure also count.