GEODATING RECAP

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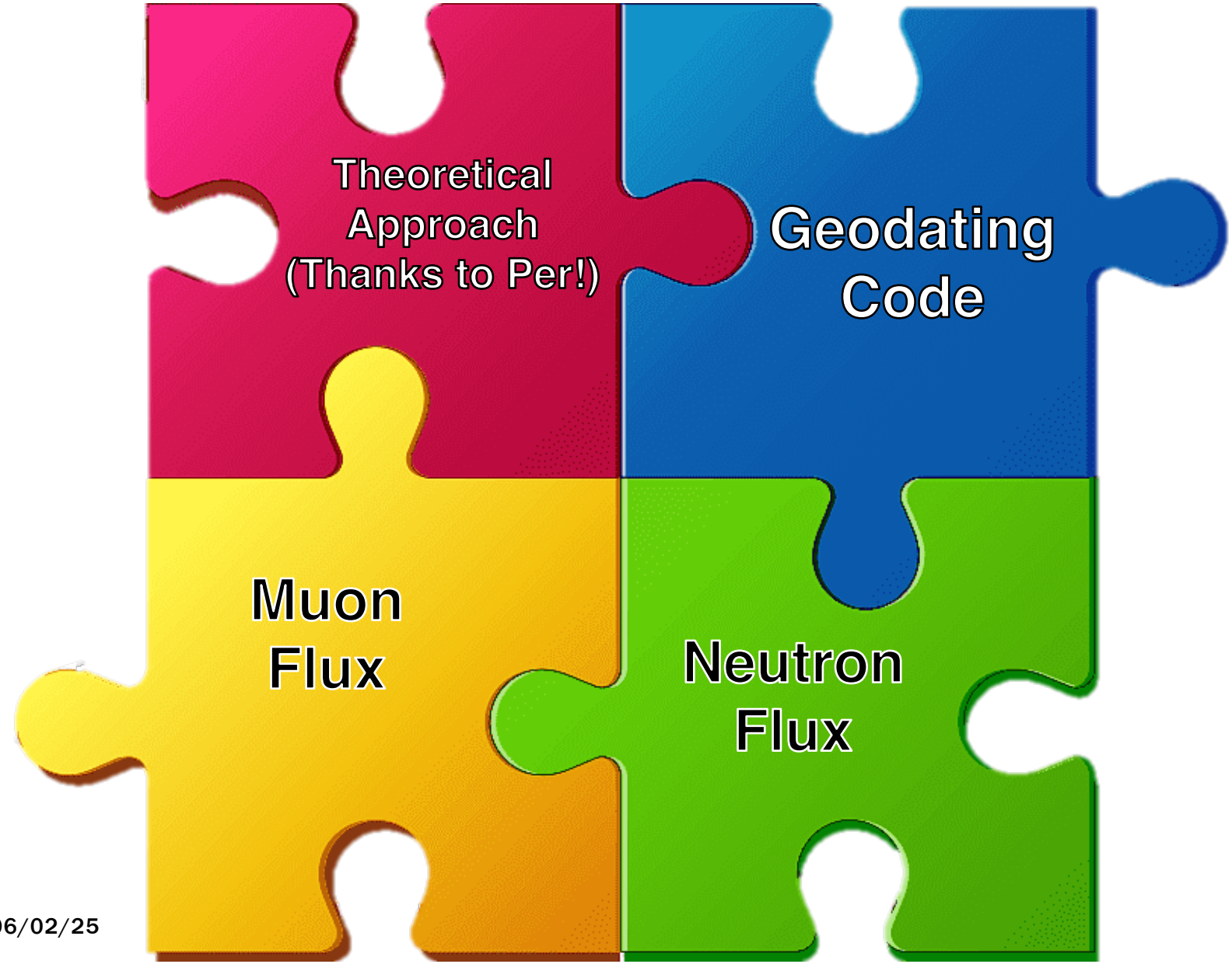
The Geodating Puzzle



Quick Remind

Simple Burial dating

- No post-burial production
- 2 Hypothesis:
  - Constant Exposure
  - Steady Erosion
- Parameter of Interest: Production Rate (P_{10}, P_{26}) at the **surface**

Min/Max method

- Post burial production
- 2 Ingredients:
  - Min: Simple Burial Method
  - Max: highest post burial production (steady erosion hypothesis to calculate R_{inh})
- Parameter of Interest: Production Rate (P_{10}, P_{26}) at the **sample depth**

~~Isochron dating~~

Ref: https://agenda.infn.it/event/42364/

Quick Remind

Simple Burial dating

- No post-burial production
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  - Steady Erosion
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→ Neutron Flux

Connection between Muon/Neutron Flux and the Production Rate

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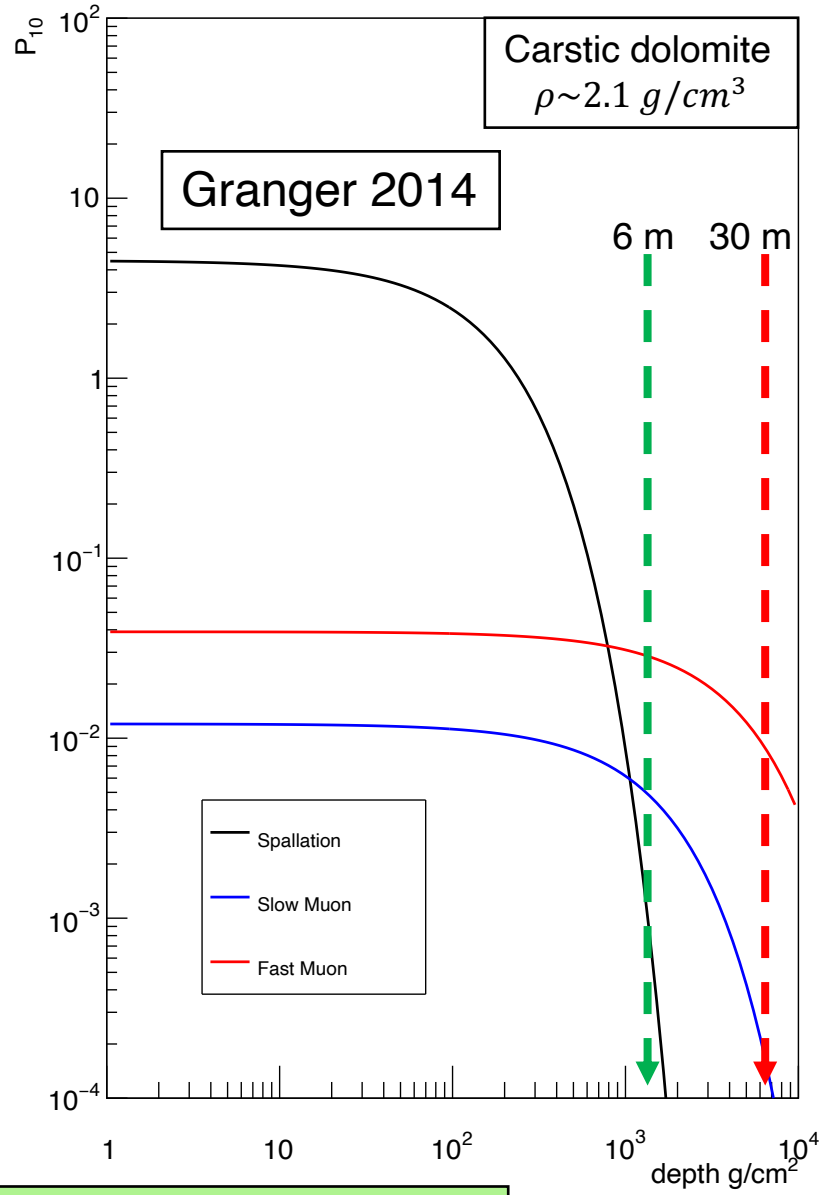
→ Muon Flux

Berilium Production Rate



Similar behavior for P_{26}

Quick Remind: Muons

P - "fast" muon

- Muon Flux: $\frac{2\pi}{n(h)+1} \cdot \Phi_V(h)$
- Mean Energy of muons at a given depth $(\overline{E'(h)})$
- Cross Section at mean energy:

$$\sigma(E) = \sigma_0 \cdot E^{\alpha}$$

- Number of atoms per gram in SiO_2: $N_a/(28+2*16)$[for Al]; $2*N_a/(28+2*16)$[for Be]
- Ref: https://agenda.infn.it/event/42981/

P - muon capture

- Stopping Rate:

$$R_{\mu^-}(h) = \frac{d}{dh}\left(\frac{2\pi}{n(h)+1} \cdot \Phi_V(h) \cdot f_{\mu^-}\right)$$

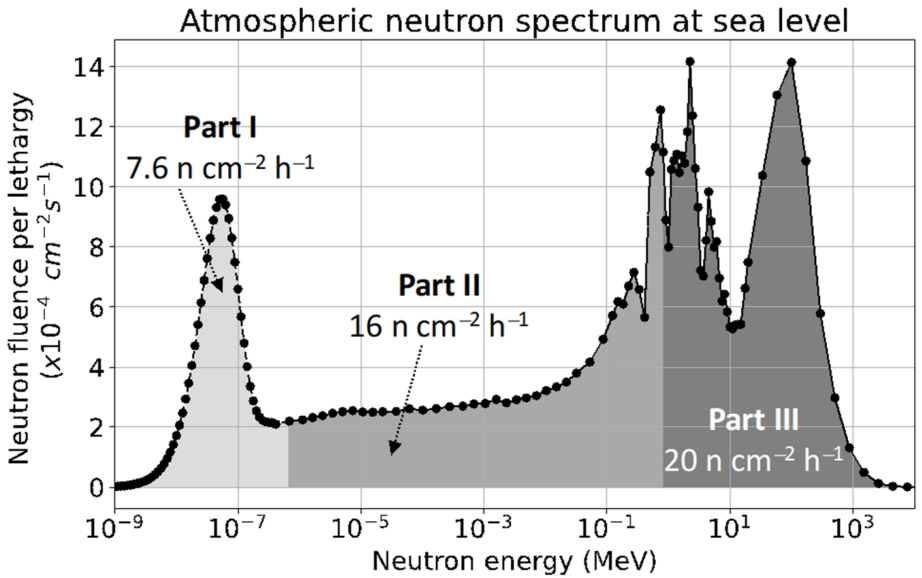
- 3 factors: f_c, f_D, f^*
- Find the right point on the "standard" parametrization of the flux to take the derivative
- Ref: https://agenda.infn.it/event/43383/

Quick Remind: Neutron

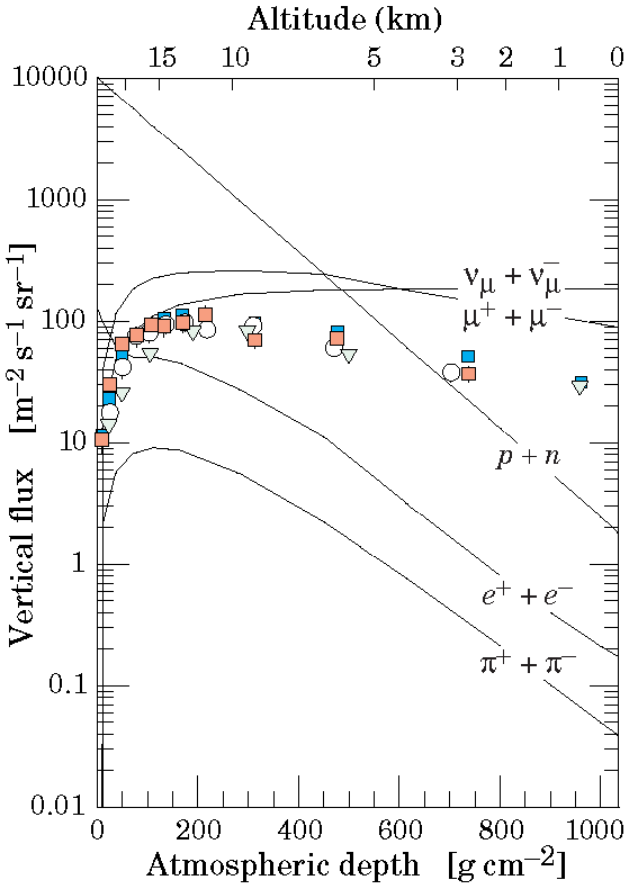
- P-value for spallation:

  flux(neutrons)*cross section*Target nuclei
- E.g. P_{26} (spallation) = 21 atoms/g*y [calculation];

  P_{26} = 30.6 atoms/g*y [literature]
- Thermal part: negligible contribution
- https://agenda.infn.it/event/44144/



- Estimation of the intermediate region
- Proton contribution



" At sea level, about 1/3 of the nucleons in the vertical direction are neutrons (up from about 10% at the top of the atmosphere as the n/p ratio approaches equilibrium). The integral intensity of vertical protons above 1 GeV/c at sea level is ablout 0.9 m-2s-1sr-1 [68,80]. " (PDG (rev. 2022))

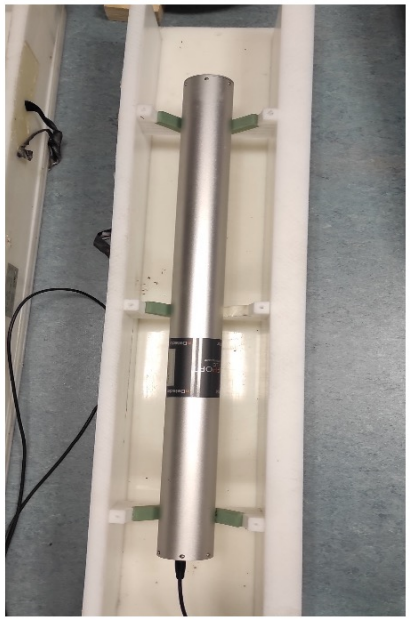
Neutron Flux + Production Rate

PoliMi Detector:

- Proper moderating material to count neutron over a certain energy
- Easily shipping without shielding
- Need efficiency calibration
- No energy information, only counts
- https://agenda.infn.it/event/44144/

iThemba LAB:

- Bonner Sphere (not calibrated yet)
- Shielding for the PoliMi detector



n_TOF:

- Direct measurement of the neutron production rate: irradiation of a rock sample
- Measurement of the ^{10}Be and ^{26}Al before and after irradiation
- Measurement of the ^{26}Al concentration in loco
- Knowledge of the flux that irradiate the target

+

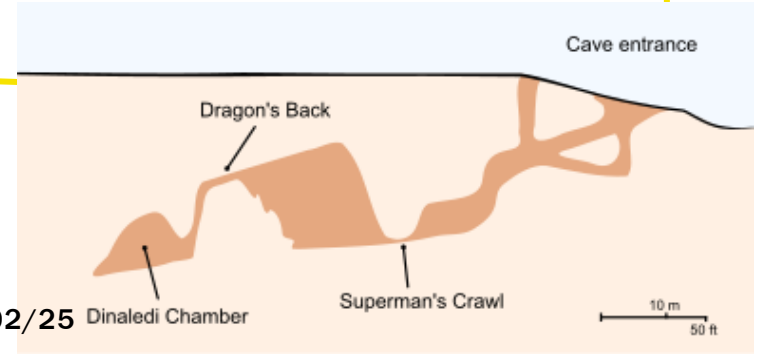
Isotopes Concentration Measurements (AMS)

Next Steps…

- Contribution of the intermediate part of the neutron spectrum
- Contribution of the proton flux to isotope production

- Develop a code to calculate the age of the rock starting from the experimental values we want to measure.
- Simulations to evaluate uncertanties on the geodating measurements

- Muon flux measured during proof of concept can be used to correct the P-value?
- Is it necessary to measure the energy spectrum of muons inside the cave?
- Should the muon flux also be measured inside the Dinaledi Chamber?



- Could a direct measurement of the production rate be useful?

  ⟶ Proposal to n_TOF (very soon)
- Is it possible to measure the neutron flux and spectrum with the W-PIE neutron spectrometer?
- Time table for neutron flux measurement

…Proposal for Muon

IMPROVEMENT of the P-value

- First Step:
  - Measurements of the directional Muon Flux (PoC)
  - Introduce the experimental data inside the calculation of the sample age.
- Second Step:
  - Measurement of the muon Spectrum
  - How accurate are the values of σ_0 and α? And in a second phase, could conducting a study on these values improve the measurement?

$$P_{fast\ \mu} = \beta(h) \cdot \Phi \cdot \sigma_0 \cdot \bar{E} \cdot \alpha \cdot N_{target\ nuclei}$$

$$P_{muon\ capture} = R_{\mu^-} \cdot f_C \cdot f_D \cdot f^*$$

Factors that we take from literature (see Per's slides)

...Proposal for Neutron

DIRECT measurement of the P-value:

1. Irradiation of representative sample
2. Irradiation of a non-representative sample

} n_TOF

3. Measurement of the neutron flux in loco with scintillating detector
4. (Measurement of the neutron flux in loco with Bonner Spheres)
5. Evaluation of uncertainties and systematics on the measurements

TO DO LIST:

- Define and write a proposal to use the neutron beam at n_TOF (1-2)
- Establish contact with an AMS laboratory(1-2)
- Building shielding for the neutron detector (3)
- Calibration of the neutron detector (3)
- Are Bonner Spheres avalilable? Which is the hypothetical time scale for the calibration? (4)
- Theoretical study on the contribution of protons and the intermediate spectrum of neutrons
- Developing simulations (5)