LUNA-SHADES/STELLA

Background in underground experiments

Gran Sasso Hands On 2023

Francesca Passalacqua, Matteo Rossi

GRAN SASSO hands-on
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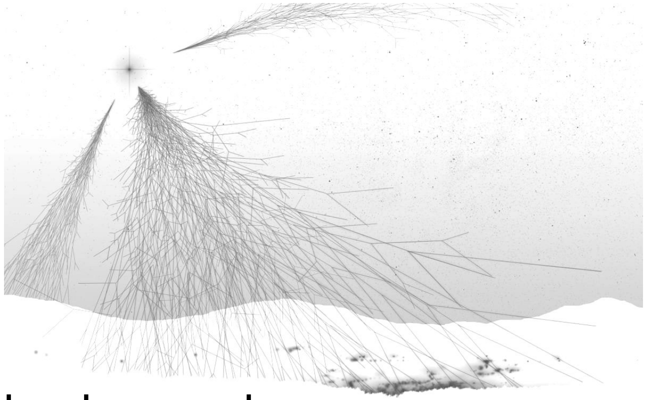
LUNA

Low Background @ LNGS

Rare processes measurement @ LNGS:

- neutrino experiments
- dark matter
- neutrinoless double beta decay

Rare processes → **deep underground** to reduce the background from cosmic rays



Experiments require:

- selection of **radio-pure materials**
- techniques for **shielding** against environmental backgrounds

➡ Main motivation for a Low Background Techniques Laboratory

1) STELLA

Sub**TE**rranean **L**ow **L**evel **A**ssay

- **Material screening**:

  measure α,β,γ background spectra to evaluate material radioactivity

- **γ** spectroscopy

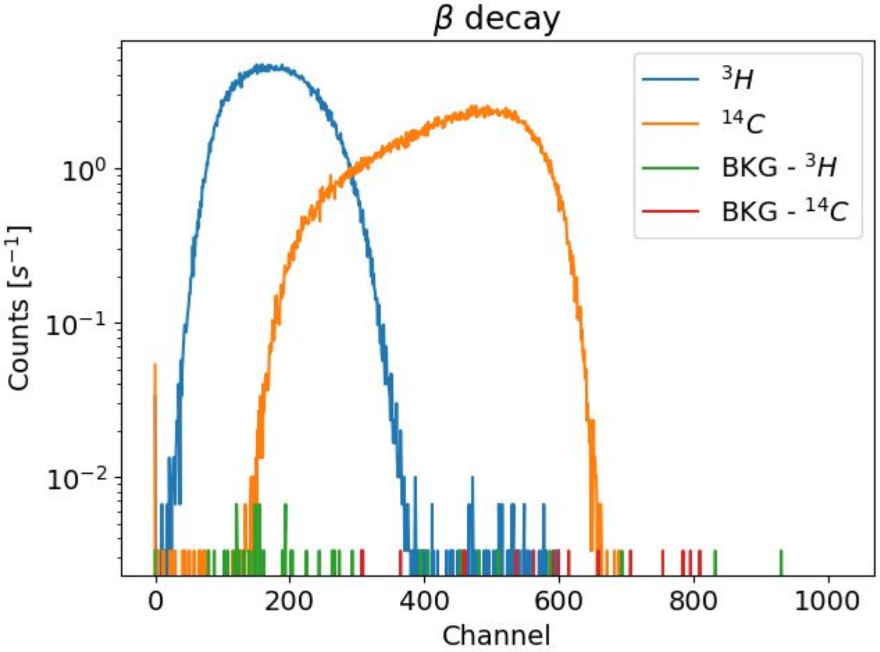
- Liquid scintillation counting (**α**,**β**) and **α** spectroscopy

1) STELLA

- **Liquid scintillation counting** using ^{14}C and ^{3}H samples
- glass bottle filled with liquid scintillator
- **β decay** (continuum spectrum) detected by **PMTs**

$$^{3}H \rightarrow {}^{3}He + e^{-} + \bar{\nu}$$

$$^{14}C \rightarrow {}^{14}N + e^{-} + \bar{\nu}$$



Background

The experiments require precise knowledge of:

- **External background**: flux of
  - gammas
  - neutrons
  - muons
- **Internal background** from the detector itself

Hands-On activity:

1. **γ** background → LUNA 400 kV
2. **neutron** background → LUNA MV

LUNA 400 kV

Laboratory for **U**nderground **N**uclear **A**strophysics

- 400 kV accelerator → beams of **protons** and **helium**
- both **solid** and **gaseous** targets
- Investigate **nuclear fusion reactions** in stars

Low cross-sections → Low background needed

LUNA 400 kV

- Nuclear reactions between beam and target emit **photons**, detected by High Purity Germanium detectors (**HPGe**)

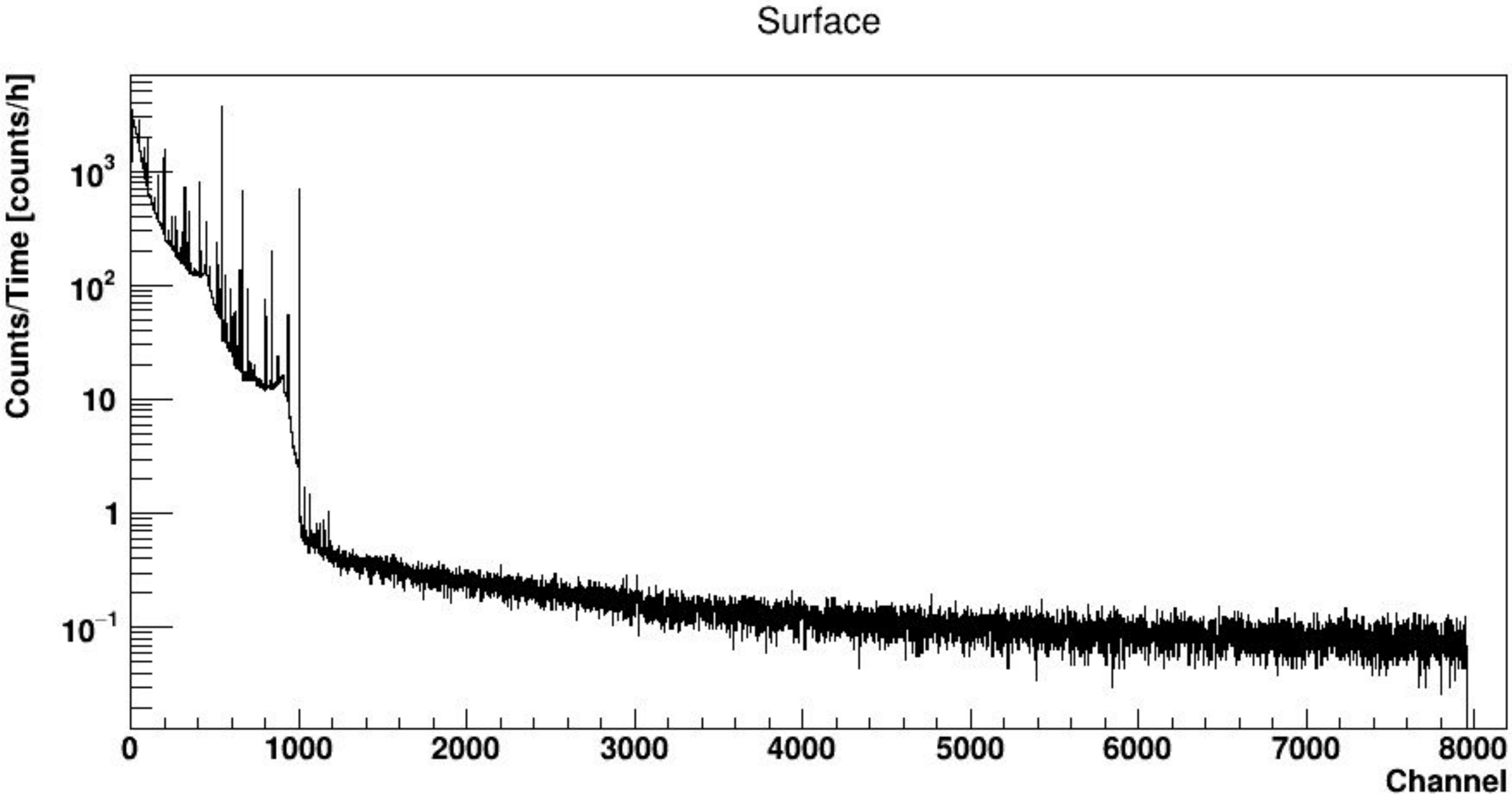
- Energy deposit in semiconductor detectors → E-H pairs → current signal

Lead passive shielding to decrease environmental background
Secondary radiation usually created in the shielding itself is reduced due to the lower cosmic muonic component

+

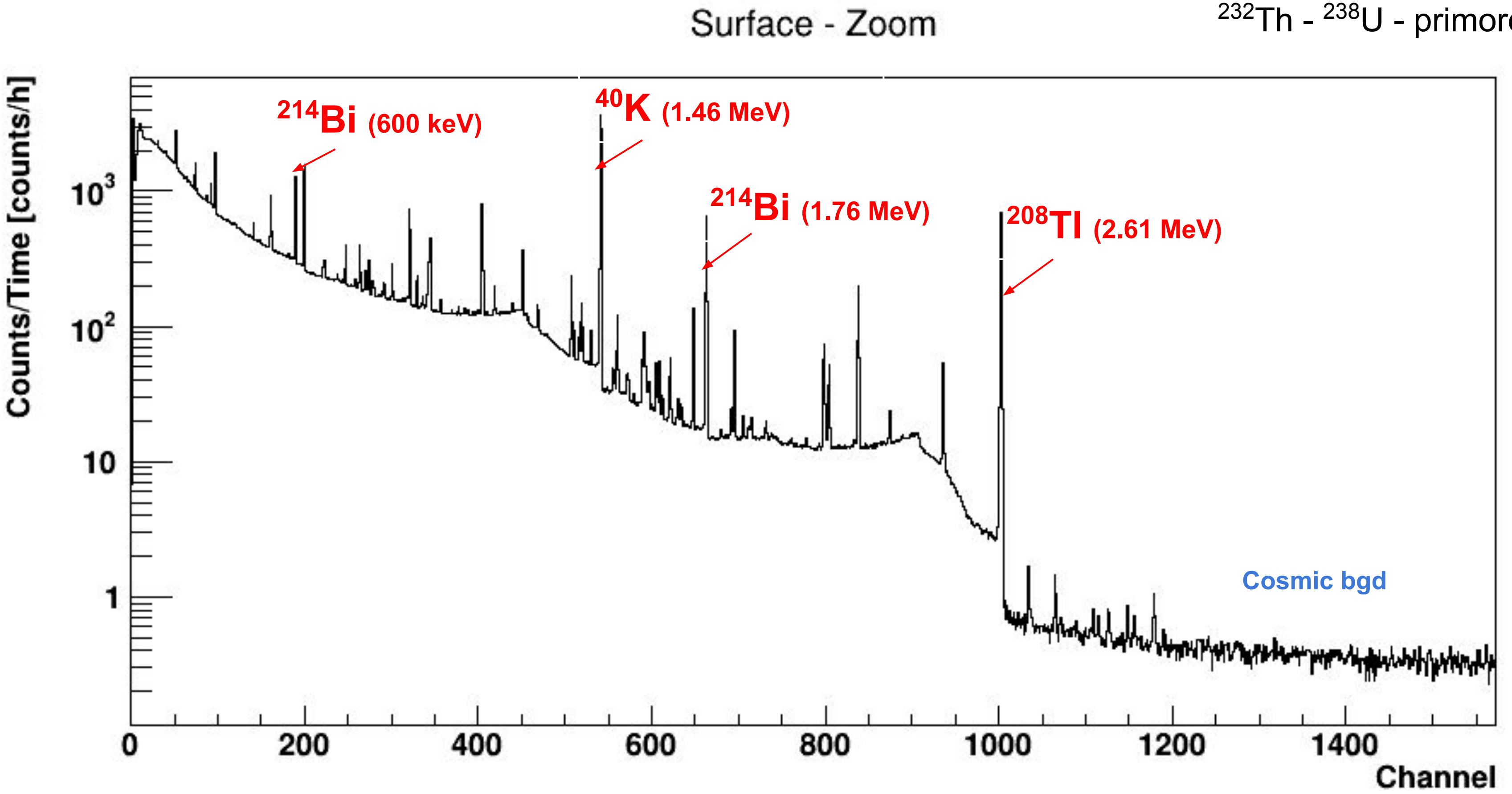
Copper close to the detectors to further reduce it (*e.g.* Bremsstrahlung of electrons interacting in Lead since high Z)

2) Gamma background spectra comparison - **surface**



2) Gamma background spectra comparison - **surface**

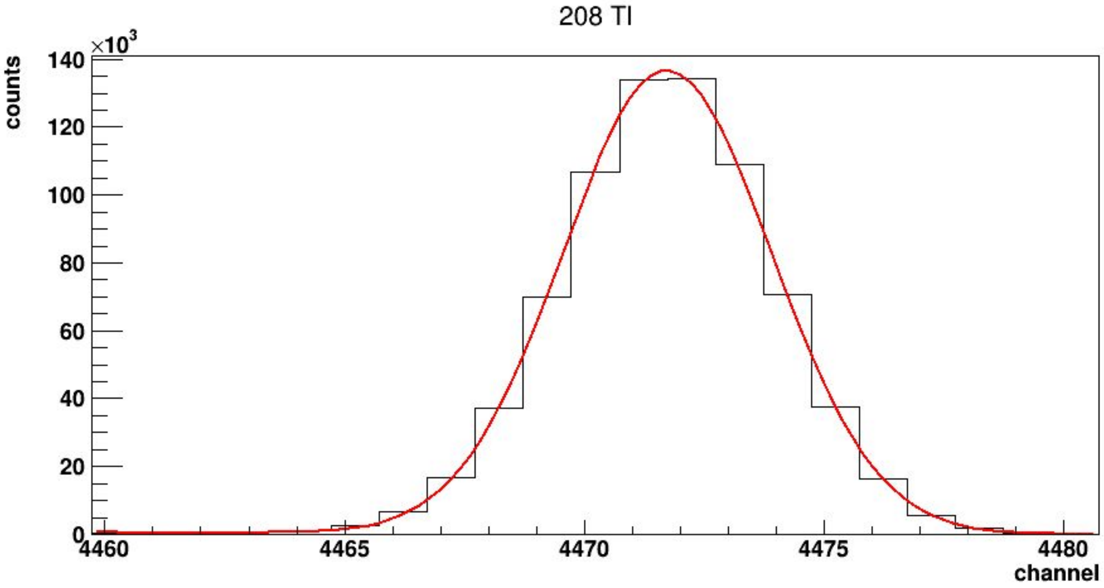
^{232}Th - ^{238}U - primordial



2) Gamma background spectra comparison - **surface**

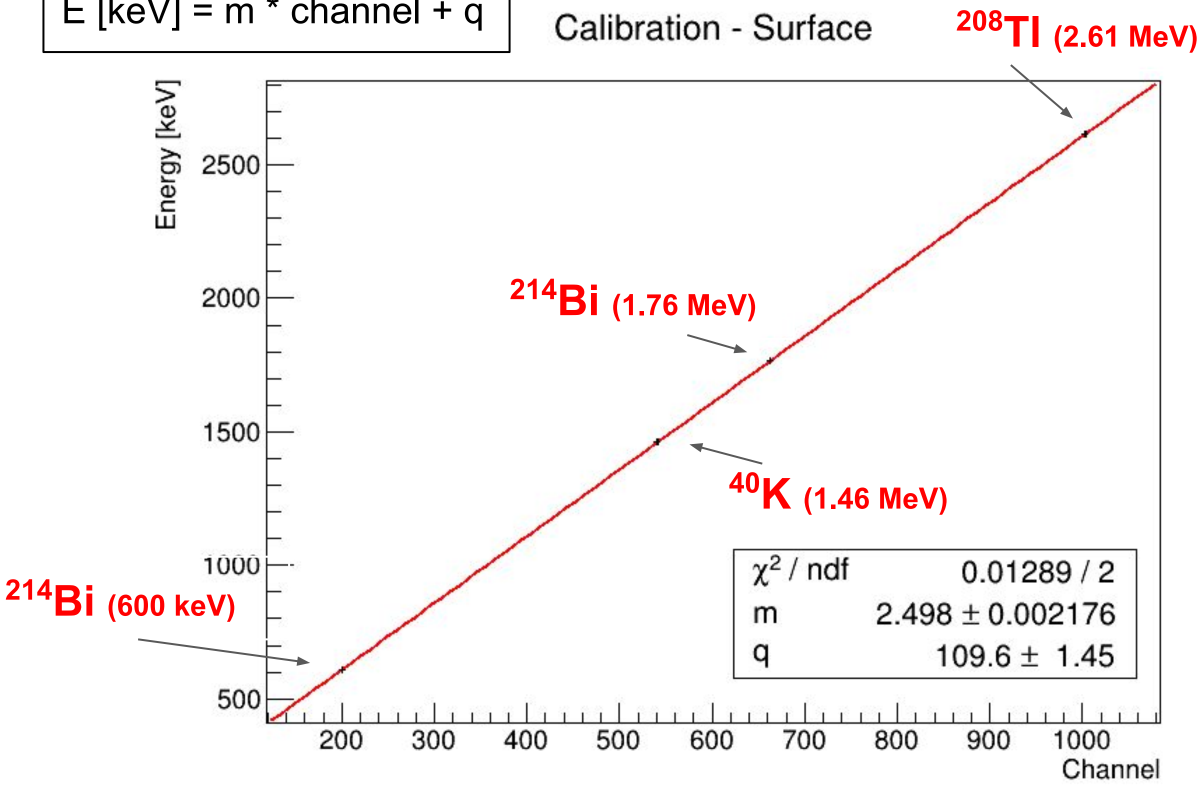
^{208}Tl 2614 keV gamma decay from ^{232}Th radioactive decay chain

Calibration = find relation between channel and energy



2) Gamma background spectra comparison - **surface**

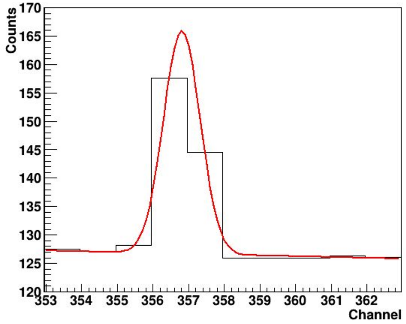
E [keV] = m * channel + q



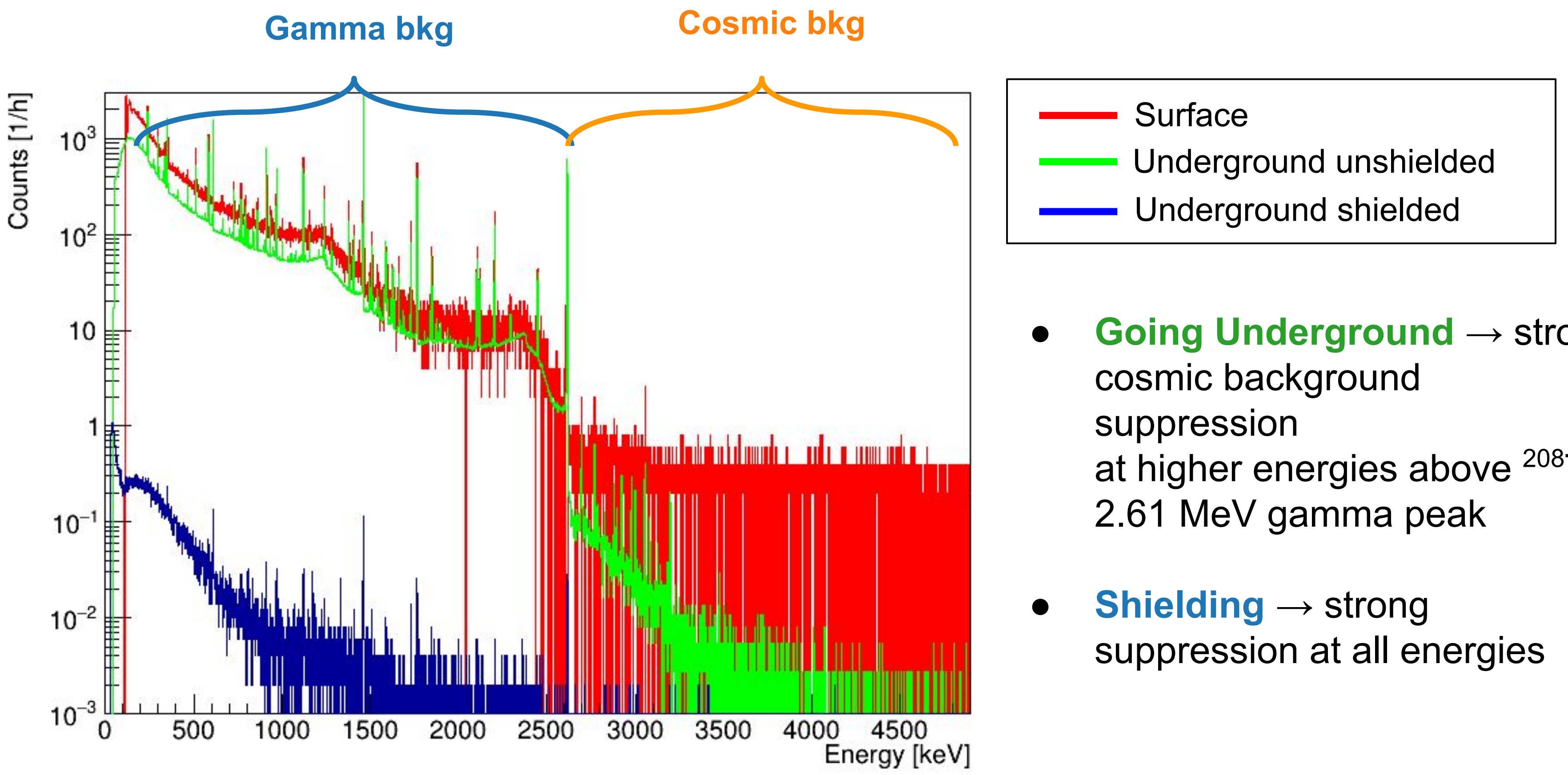
Less resolution

→ worse fit based only on few bins

→ half bin error hardcoded



2) Gamma background spectra comparison



- **Going Underground** → strong cosmic background suppression at higher energies above ^{208}Tl 2.61 MeV gamma peak

- **Shielding** → strong suppression at all energies

3) LUNA MV

- LUNA 400 kV upgrade: 3.5 MV accelerator for beams of **protons**, **Helium** and **Carbon,** both for solid and gaseous targets

- Study the key reactions of Helium and Carbon burning, and the ***neutron-source reactions***, which produce neutrons to create elements heavier than Iron

- Hosted in a **concrete infrastructure**, 80 cm thick

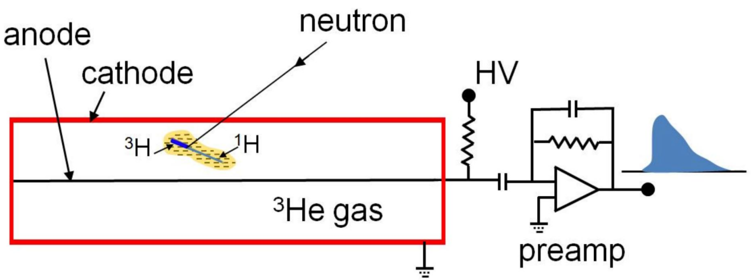
- Study **neutrons** produced in scattering events allows to find the reaction cross-section

3) Neutron background spectra measurement

- **nuclear fusion reactions** in stars also produce neutrons via **(α,n)** reactions
- Use the same detectors that will study the beam to measure **natural neutron background**
- ^{3}He proportional counters to measure **thermal** neutron background:

$n + {}^{3}He \rightarrow p + {}^{3}H$ **Q=764 keV** E_p = 573 keV, E_{3H} =191 keV

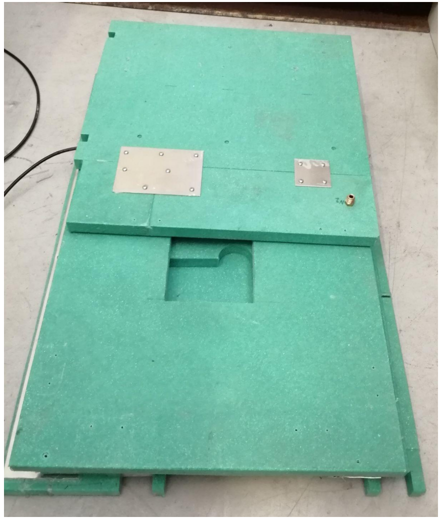
→ **ionisation and excitation** of ^{3}He by p and ^{3}H → **charge signal** proportional to the deposited energy

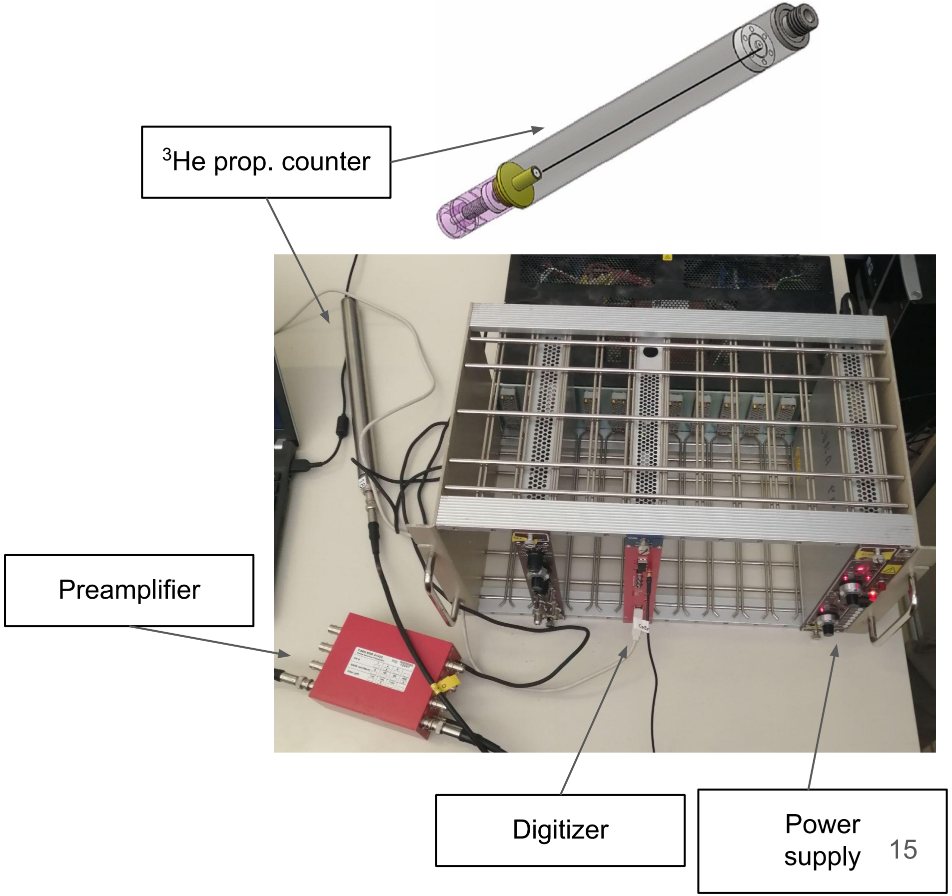


3) Neutron background spectra measurement

- Need to shield LUNA MV detector from background neutrons

  → ***borated-polyethylene*** shield around the proportional counter to **slow down** and **capture** n

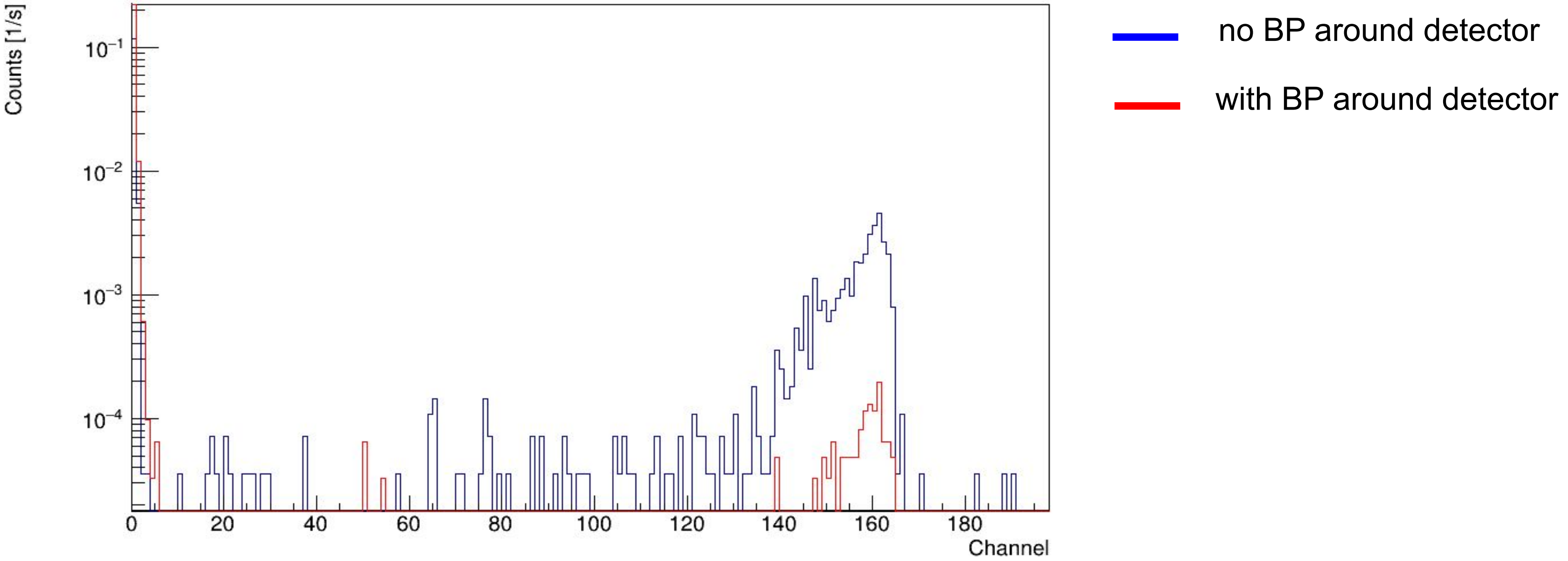




3) Neutron background spectra measurement

- Effect of borated-polyethylene (BP) on surface neutron background

^{3}He counter neutron surface spectra



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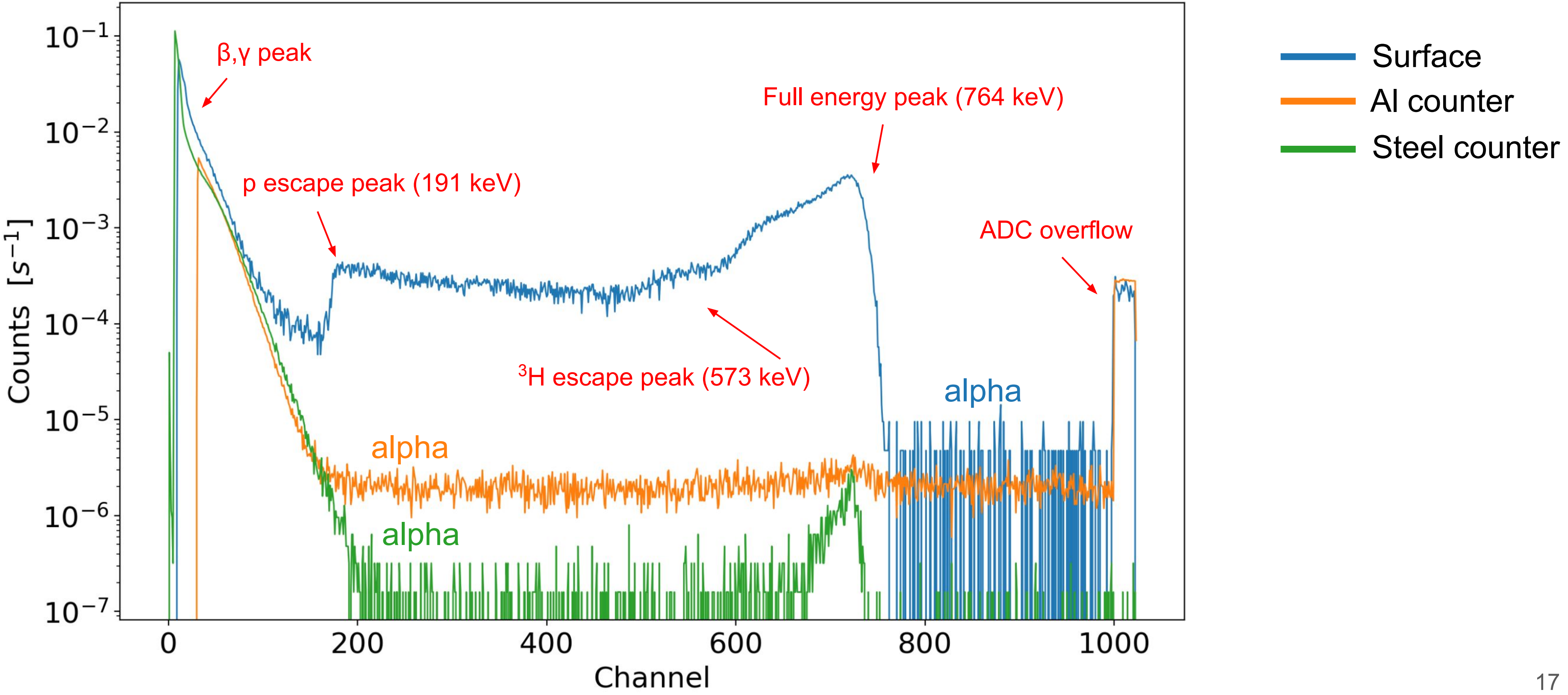

CONCLUSIONS

Going underground is really useful :)