Gamma-Ray Spectroscopy in the HERA Tunnel

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1 COBRA Experiment

2 HERA Tunnel

3 Summary and Outlook
Cadmium Zinc Telluride 0-Neutrino Double-Beta Research Apparatus

- Cadmium Zinc Telluride is a semiconductor used as detector
- 9 isotopes with double beta decay, especially Cd-116
- source = detector
- neutrinoless double beta decay
  - is possible if neutrinos are majorana particles
    - neutrinos and anti neutrinos are identically and have mass
  - expected half-life is very high: $> 10^{26}$ years
Mass Chain: Cd-116

mass chain
mass number: 116

Pd → Ag
β⁻

Cd → In → Sn → Sb → Te
β⁻
β⁺

Q = 2809 keV
Sensitivity

Detection Limit

\[ T_{1/2}^{0\nu} = a \cdot \epsilon \cdot \sqrt{\frac{M \cdot t}{B \cdot \Delta E}} \]

- \( a \): enrichment
- \( \epsilon \): efficiency
- \( M \): detector mass
- \( t \): measurement time
- \( \Delta E \): energy resolution
- \( B \): background rate

Goal: \( B < 0.001 \) counts \( \frac{keV \cdot kg \cdot year}{\text{keV} \cdot kg \cdot \text{year}} \)
Natural Background in Region of Interest

Gamma-Ray Spectroscopy in the HERA Tunnel

- Ge
- Bi
- Xe
- Te
- Cd
- Bi
Gamma-Ray Spectroscopy in the HERA Tunnel
• 16 m sand and 10 m silty sand
• sand and silt are mostly quartz (SiO$_2$)
  • density: 2.65 g/cm$^3$
  • 50% porosities
  • grain size of silt is (0.002 - 0.063) mm and sand (0.063 - 2) mm

→ ~ 41 meters of water equivalent (mwe)
Setup

- Ortec GEM Profile Series HPGe Coaxial Detector (GEM30P4-76-S)
- detector mass: 0.8207 kg
- electrically cooled with Ortec X-Cooler II
- Canberra Spectroscopy Amplifier Model 2020 at $0.6 \times 30$ gain and 4 $\mu$s shaping time
- ORTEC Model 659 5 kV Detector Bias Supply at 4.8 kV
- CAEN 8k Multi-Channel Analyzer Model NIM N957
- peak-to-compton ratio, $^{60}$Co: 55
- resolution (FWHM) at 1.33 MeV, $^{60}$Co: $(1.95 \pm 0.05)$ keV
Gamma-Ray Spectroscopy in the HERA Tunnel
Myon-Veto with Scintillators

\[
\phi_{\text{max}} \int_{0}^{\pi/2} \cos^2 \varphi \, d\varphi \approx 40\% \\
\int_{0}^{\pi/2} \cos^2 \varphi \, d\varphi
\]

Detektor

\(\phi_{\text{max}} = 21.8^\circ\)
Spectra up to 30 MeV

- Laboratory with lead and flushing
- "- with lead, veto and flushing
- HERA tunnel with lead
- "- with lead and veto

Energy [keV]

Counts/keV/kg/day

40K, 208Tl
Spectra up to 3 MeV

- $^{137}$Cs
- $^{40}$K
- $^{214}$Bi
- $^{208}$Tl
## Integral Count Rate

<table>
<thead>
<tr>
<th>location</th>
<th>[counts/kg/s] (0.04 - 2.7) MeV</th>
<th>[counts/kg/keV/day] (2.7 - 3) MeV</th>
<th>[counts/kg/keV/day] (3 - 8.5) MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>laboratory</td>
<td>124 ± 0.01</td>
<td>5.19 ± 0.04</td>
<td>—</td>
</tr>
<tr>
<td>lead and flushing</td>
<td>—</td>
<td>—</td>
<td>1.52 ± 0.01</td>
</tr>
<tr>
<td>lead, veto and flushing</td>
<td>0.986 ± 0.001</td>
<td>1.79 ± 0.03</td>
<td>0.88 ± 0.01</td>
</tr>
<tr>
<td>tunnel</td>
<td>159 ± 0.01</td>
<td>1.11 ± 0.02</td>
<td>—</td>
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<tr>
<td>lead</td>
<td>1.1 ± 0.01</td>
<td>0.48 ± 0.01</td>
<td>0.153 ± 0.001</td>
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<tr>
<td>and veto</td>
<td>1.078 ± 0.002</td>
<td>0.27 ± 0.02</td>
<td>0.097 ± 0.001</td>
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<tr>
<td>DLB with veto</td>
<td>0.071</td>
<td>0.025</td>
<td>—</td>
</tr>
<tr>
<td>15 mwe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Felsenkeller without Veto</td>
<td>0.034</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>110 mwe</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary

- the Hera tunnel offers a coverage of 40 mwe
- 10% more integral activity up to 3 MeV in comparison to laboratory
  - basically due to 50% more of thorium decay chain
- no more radon in comparison with the laboratory

Outlook

- the HERA tunnel offers possibility to
  - supporting material screening
  - storage of materials
Thanks for your attention!