# KingCOBRA

## MC based Background Estimation

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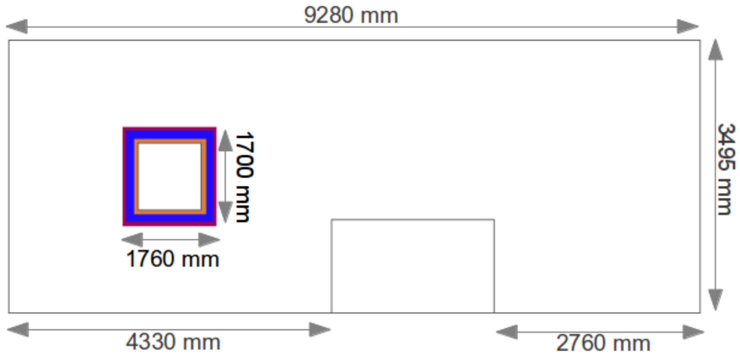
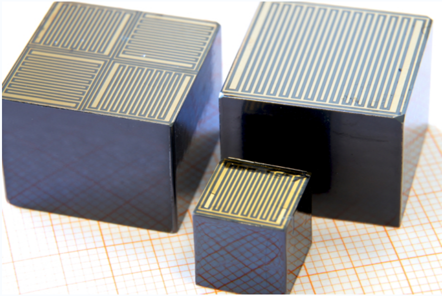
# Towards a large scale setup

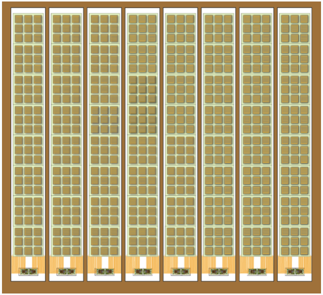
COBRA hut at LNGS:




- Developed shield: B5%PE (10 cm) – Lead (20 cm) – Copper (10 cm)
- $95.5 \times 90 \times 85\,\text{cm}^3$ are reserved for detectors

# Towards a large scale setup



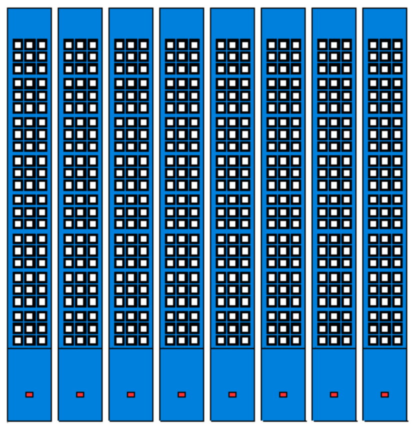


- Switch to larger detectors $2{\times}2{\times}1.5\,\mathrm{cm}^3$
  - Higher detection efficiency
  - Smaller surface to volume ratio

# Towards a large scale setup

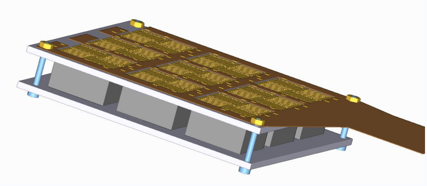
Inner structure:

- Size of detectors: $2 \times 2 \times 1.5\,\text{cm}^3$
- Number of detectors: $3 \times 3 \times 8 \times 8 \times 24 = 13824$
- Lacquer surrounding the detectors implemented
- Support structure (Delrin) implemented
- ASICs implemented

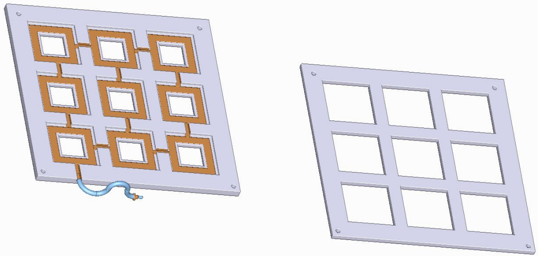


# Towards a large scale setup

- Complete holder:



- Bottom plate (left) and top plate (right):



# General

Goal:

- Calculate background rates for different setup parts and different background sources
- Determine upper limits of the corresponding activities

Simulation:

- Events ($\sim 10^6$) were generated for each setup part and source (intrinsic, surface, external)
- Simulation package: Geant4 9.6.p02

Measured activities:

- e.g. ILIAS database on radiopurity of materials: http://radiopurity.in2p3.fr/

# General

Calculation of the background rate:

$$B = \frac{N_{\text{ROI-SDE}}}{m \cdot \Delta E \cdot t}$$

$$\begin{aligned} m &= m_{det} \cdot N_{det} \cdot s \cdot a \\ &= 36\,\text{g} \cdot (3 \cdot 3 \cdot 8 \cdot 8 \cdot 24) \cdot 0.5 \cdot 0.9 \\ \text{ROI} &= 2.7 - 2.9\,\text{MeV} \\ \Delta E &= 200\,\text{keV} \\ N_{sim} &= 1.01 \cdot 10^6 \\ t &= \frac{N_{sim}}{A \cdot m_{mat}} \end{aligned}$$

$N_{\text{ROI-SDE}} \rightarrow$ Single detector events in the ROI

$m \rightarrow$ Mass of $^{116}$Cd

$N_{det} \rightarrow$ Simulated detectors

$s \rightarrow$ Ratio

$a \rightarrow$ Abundance

$\Delta E \rightarrow$ Energy resolution

$N_{sim} \rightarrow$ Simulated events

$A \rightarrow$ Activity per kg

$m_{mat} \rightarrow$ Mass of material (eg. Cu)

# Preliminary Result

PRELIMINARY!

$$\sim 15.697 \cdot 10^{-3} \, \frac{\text{events}}{\text{kg} \cdot \text{keV} \cdot \text{yr}}$$

**Considered setup parts:**

- Copper, lead
- Lacquer
- Holder
- Cathode
- ASICs

**Considered sources:**

- Decay chains, $^{40}$K, $^{137}$Cs, $^{190}$Pt, etc
- Fast neutrons, spontaneous fission neutrons
- Muons
- Cosmogenic radionuclei in CdZnTe

# Preliminary Result

PRELIMINARY!

$$\sim 15.697 \cdot 10^{-3} \, \frac{\text{events}}{\text{kg}\cdot\text{keV}\cdot\text{yr}}$$

Not applied:

- Lateral surface events cut
- Multi-side events within one detector
  - Further reduction of background rate possible

# Summary/Outlook

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- First results are promising!

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- Additional parts: HV supply, Kapton cable of anode readout
- Investigation of measured activities

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Thank you for your attention!

Backup–Slides

# Results: Copper & Lacquer (intrinsic)

| Source | Material Location | $A_m$ [mBq/kg] | $A_{rec}$ [mBq/kg] | B [1/kg/keV/yr] |
|---|---|---|---|---|
| $^{214}$Bi | Copper | $3 \cdot 10^{-3}$ | $10^{-2}$ | $2.5 \cdot 10^{-4}$ |
| $^{208}$Tl | Copper | 0.5–1 | $10^{-1}$ | $< 7.4 \cdot 10^{-4}$ |
| $^{214}$Bi | Lacquer | – | $10^{-1}$ | $(2.01 \pm 0.07) \cdot 10^{-5}$ |
| $^{214}$Po | Lacquer | – | $10^{-1}$ | $(1.45 \pm 0.02) \cdot 10^{-4}$ |
| $^{218}$Po | Lacquer | – | $10^{-1}$ | $(1.93 \pm 0.02) \cdot 10^{-4}$ |
| $^{220}$Rn | Lacquer | – | $10^{-1}$ | $(3.86 \pm 0.05) \cdot 10^{-4}$ |
| $^{216}$Po | Lacquer | – | $10^{-1}$ | $(3.54 \pm 0.04) \cdot 10^{-4}$ |
| $^{212}$Bi | Lacquer | – | $10^{-1}$ | $(3.42 \pm 0.07) \cdot 10^{-4}$ |
| $^{212}$Po | Lacquer | – | $10^{-1}$ | $(5.59 \pm 0.09) \cdot 10^{-4}$ |
| $^{208}$Tl | Lacquer | – | $10^{-1}$ | $(2.6 \pm 0.2) \cdot 10^{-5}$ |
| $^{235}$U | Lacquer | – | $< 10^3$ | $< 6.96 \cdot 10^{-6}$ |
| sum | | | | $< 3.022 \cdot 10^{-3}$ |

# Results: Lacquer (surface)

| Source | Material / Location | $A_m$ [mBq/kg] | $A_{rec}$ [mBq/kg] | B [1/kg/keV/yr] |
|---|---|---|---|---|
| $^{214}$Bi | Lacquer sur | – | 1 | $(1.41 \pm 0.06) \cdot 10^{-4}$ |
| $^{214}$Po | Lacquer sur | – | 1 | $(7.5 \pm 0.1) \cdot 10^{-4}$ |
| $^{218}$Po | Lacquer sur | – | $10^{-1}$ | $(2.48 \pm 0.03) \cdot 10^{-4}$ |
| $^{220}$Rn | Lacquer sur | – | $10^{-1}$ | $(3.59 \pm 0.04) \cdot 10^{-4}$ |
| $^{216}$Po | Lacquer sur | – | $10^{-1}$ | $(2.39 \pm 0.03) \cdot 10^{-4}$ |
| $^{212}$Bi | Lacquer sur | – | 0.5 | $(4.15 \pm 0.07) \cdot 10^{-4}$ |
| $^{212}$Po | Lacquer sur | – | 0.5 | $(2.53 \pm 0.06) \cdot 10^{-4}$ |
| $^{208}$Tl | Lacquer sur | – | 0.5 | $(3.9 \pm 0.2) \cdot 10^{-5}$ |
| $^{235}$U | Lacquer sur | – | 3 | $(8.1 \pm 0.8) \cdot 10^{-5}$ |
| sum | | | | $\sim 2.525 \cdot 10^{-3}$ |

# Results: Delrin holder

| Probe | Activities (mBq kg$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | $^{238}$U | $^{232}$Th | $^{210}$Pb | $^{137}$Cs | $^{60}$Co | $^{40}$K |
| Sn granules | <7 | <8 | <1800 | <7 | <4 | <72 |
| Teflon powder | <9 | <11 | <70 | <10 | <9 | <108 |
| nylon screws | <14 | <14 | <70 | <13 | <7 | <139 |
| solenoid wire | <3 | <4 | <550 | <2 | <1 | <25 |
| Delrin | <10 | <12 | <91 | $21 \pm 5$ | <9 | <132 |
| OFHC Cu | <82 | <136 | $< 1.2 \times 10^4$ | <86 | <65 | <1200 |
| connector (280 g) | $314\pm5$ | $295\pm8$ | $600\pm15$ | $18\pm2$ | $24\pm2$ | $4600\pm90$ |
| Pb shielding | | | $(2 \pm 0.4) \times 10^5$ | | | |

Ref: ORPHEUS dark matter detector

# Results: Delrin holder (inside)

| Source | Material / Location | $A_m$ [mBq/kg] | $A_{rec}$ [mBq/kg] | B [1/kg/keV/yr] |
|---|---|---|---|---|
| $^{214}$Bi | Holder | $< 10$ | $10^{-2}$ | $(42 \pm 1) \cdot 10^{-5}$ |
| $^{214}$Po | Holder | $< 10$ | $10^{-2}$ | $(11.1 \pm 0.2) \cdot 10^{-4}$ |
| $^{218}$Po | Holder | $< 10$ | $10^{-3}$ | $(187 \pm 2) \cdot 10^{-6}$ |
| $^{220}$Rn | Holder | $< 12$ | $< 12$ | $(2.03 \pm 0.03) \cdot 10^{-4}$ |
| $^{216}$Po | Holder | $< 12$ | $< 12$ | $(1.97 \pm 0.03) \cdot 10^{-4}$ |
| $^{212}$Bi | Holder | $< 12$ | $< 12$ | $(7.7 \pm 0.2) \cdot 10^{-5}$ |
| $^{212}$Po | Holder | $< 12$ | $< 12$ | $(1.39 \pm 0.02) \cdot 10^{-4}$ |
| $^{208}$Tl | Holder | $< 12$ | $< 12$ | $(3.9 \pm 0.1) \cdot 10^{-5}$ |
| $^{235}$U | Holder | – | $10^{-1}$ | $(3.5 \pm 0.1) \cdot 10^{-4}$ |
| sum | | | | $\sim 2.722 \cdot 10^{-3}$ |

# Results: Delrin holder (surface)

| Source | Material / Location | $A_m$ [mBq/kg] | $A_{rec}$ [mBq/kg] | B [1/kg/keV/yr] |
|---|---|---|---|---|
| $^{222}$Rn | Holder sur | – | $< 10^{-2}$ | $(4.76 \pm 0.06) \cdot 10^{-4}$ |
| $^{210}$Po | Holder sur | $< 91$ | $< 10^{-3}$ | $(1.9 \pm 0.1) \cdot 10^{-3}$ |
| sum | | | | $< 2.376 \cdot 10^{-3}$ |

# Results: ASICs

```
sample:          ASIC pieces from Gamma-Medica - Ideas (Norway) AS, COBRA
weight:          574.6 g
live time:               1178392 s
detector:                GeMPI2

radionuclide concentrations:

Th-232:
Ra-228:          < 1.9 mBq/kg           <==>     < 4.6 E-10 g/g
Th-228:          < 1.3 mBq/kg           <==>     < 3.1 E-10 g/g

U-238:
Ra-226           < 1.6 mBq/kg           <==>     < 1.3 E-10 g/g
Th-234           < 25 mBq/kg            <==>     < 2.0 E-9 g/g
Pa-234m          < 29 mBq/kg            <==>     < 2.3 E-9 g/g

U-235:           (1.5 +- 0.6) mBq/kg             <==>     (3 +- 1) E-9 g/g

K-40:            (16 +- 5) mBq/kg                <==>     (5 +- 2) E-7 g/g

Cs-137:          < 0.55 mBq/kg

Co-60:           < 0.13 mBq/kg          @ start of measurement, 09-APR-2013
```

Ref: M. Laubenstein

# Results: ASICs

| Source | Material / Location | $A_m$ [mBq/kg] | $A_{rec}$ [mBq/kg] | B [1/kg/keV/yr] |
|---|---|---|---|---|
| $^{214}$Bi | ASICs | $< 1.6$ | $10^{-1}$ | $< 3.08 \cdot 10^{-4}$ |
| $^{208}$Tl | ASICs | $< 1.3$ | $10^{-1}$ | $< 2.0 \cdot 10^{-4}$ |
| sum | | | | $\sim 0.508 \cdot 10^{-3}$ |

# Neutrons & Muons

| Source | Material Location | $A_m$ [mBq/kg] | $A_{rec}$ [mBq/kg] | B [1/kg/keV/yr] |
|---|---|---|---|---|
| muons | – | – | – | $< 1.7 \cdot 10^{-4}$ |
| fast neutrons | – | – | – | $< 1.98 \cdot 10^{-6}$ |
| SFN | Copper | $25 \cdot 10^{-6}$ | $25 \cdot 10^{-6}$ | $(2.9 \pm 0.2) \cdot 10^{-5}$ |
| SFN | Lacquer | $50 \cdot 10^{-6}$ | $50 \cdot 10^{-6}$ | $(3.3 \pm 0.2) \cdot 10^{-13}$ |
| SFN | ASIC | $12.5 \cdot 10^{-6}$ | $12.5 \cdot 10^{-6}$ | $(1.25 \pm 0.08) \cdot 10^{-7}$ |
| SFN | Holder | $12.5 \cdot 10^{-6}$ | $12.5 \cdot 10^{-6}$ | $(4.22 \pm 0.09) \cdot 10^{-10}$ |
| ($\alpha$,n) | TBA | TBA | TBA | TBA |
| sum | | | | $< 2.01 \cdot 10^{-4}$ |

# Results: Cosmogenic

## Background Rates

| Isotope | T1/2 | Activation rate | Saturation bkg. rate | 1y Activation no decay | Saturation +1y decay | 1y Activation + 1y decay |
|---|---|---|---|---|---|---|
| Na-22 | 2.6 y | 0.02 | 2E-6 | 4E-7 | 1E-6 | 3E-7 |
| Co-60 | 5.5 y | 0.05 | 2E-5 | 2E-6 | 1E-5 | 2E-6 |
| Y-88 | 107 d | 4.3 | 0.014 | 0.013 | 1.3E-3 | 1.2E-3 |
| Ag-110m | 250 d | 19.5 | 3.5E-3 | 2.2E-3 | 1.3E-3 | 8E-4 |
| K-42 | 33 y (mother) | 0.005 | 2E-4 | 3E-6 | 2E-4 | 3E-6 |
| Sc-44 | 63 y (mother) | 0.01 | 1E-5 | 1E-7 | 1E-5 | 1E-7 |
| Ga-68 | 271 d (mother) | 0.24 | 5E-5 | 3E-5 | 2E-5 | 1E-5 |
| Rb-82 | 26 d (mother) | 1.0 | 0.006 | 6.3E-3 | 3E-7 | 3E-7 |
| Rh-106 | 374 d (mother) | 1.1 | 0.004 | 2.1E-3 | 2.2E-3 | 1.1E-3 |
| Sb-126 | 100 ky (mother) | 1.3 | 8E-4 | 5E-9 | 8E-4 | 5E-9 |
| V-48 | 16 d | 0.06 | 8E-6 | 8E-6 | 1E-12 | 1E-12 |
| Co-56 | 77 d | 0.1 | 1E-4 | 1E-4 | 4E-6 | 4E-6 |
| Rb-84 | 33 d | 0.15 | - | - | - | - |
| Sb-124 | 60 d | 18.2 | 0.01 | 0.01 | 2E-4 | 2E-4 |
| Total | | | 0.0387 | 0.0333 | 6.8E-3 | 3.3E-3 |