

# Positioning with Background Radioactivity

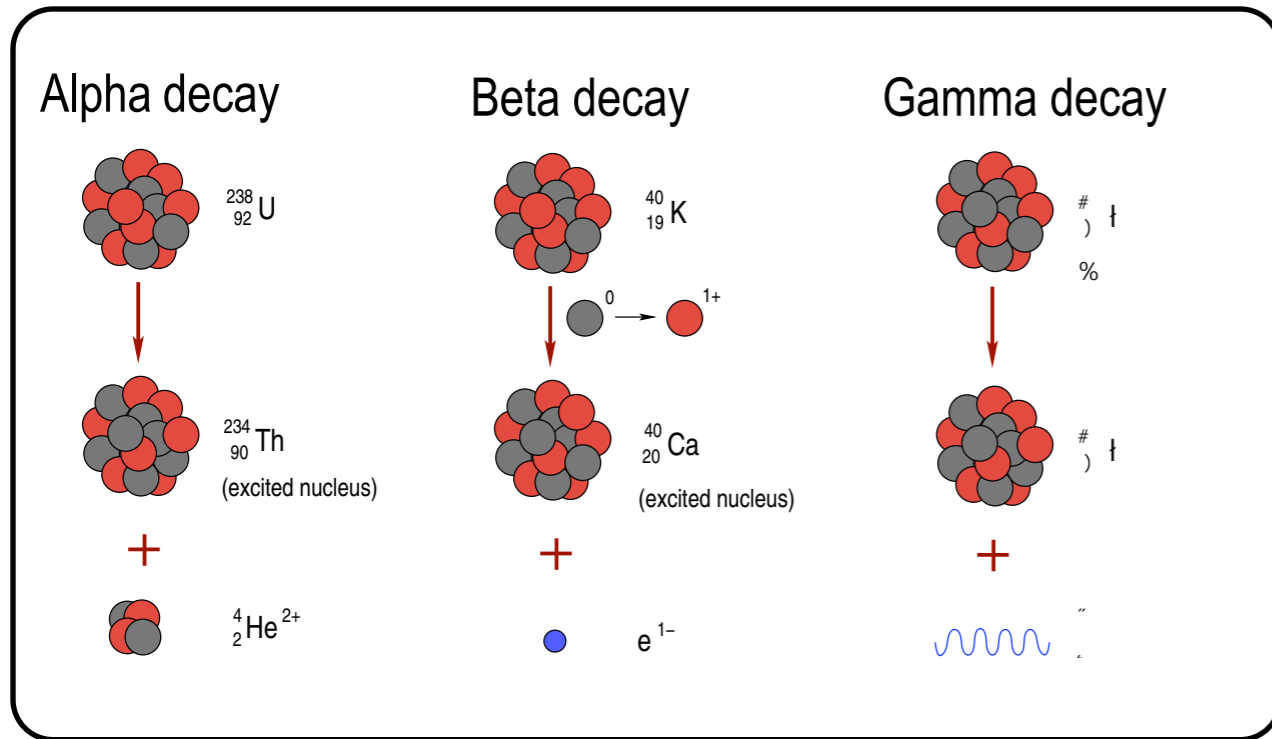
Doina Bucur and Mikkel Baun Kjaergaard

Oxford University, UK and  
Aarhus University, Denmark

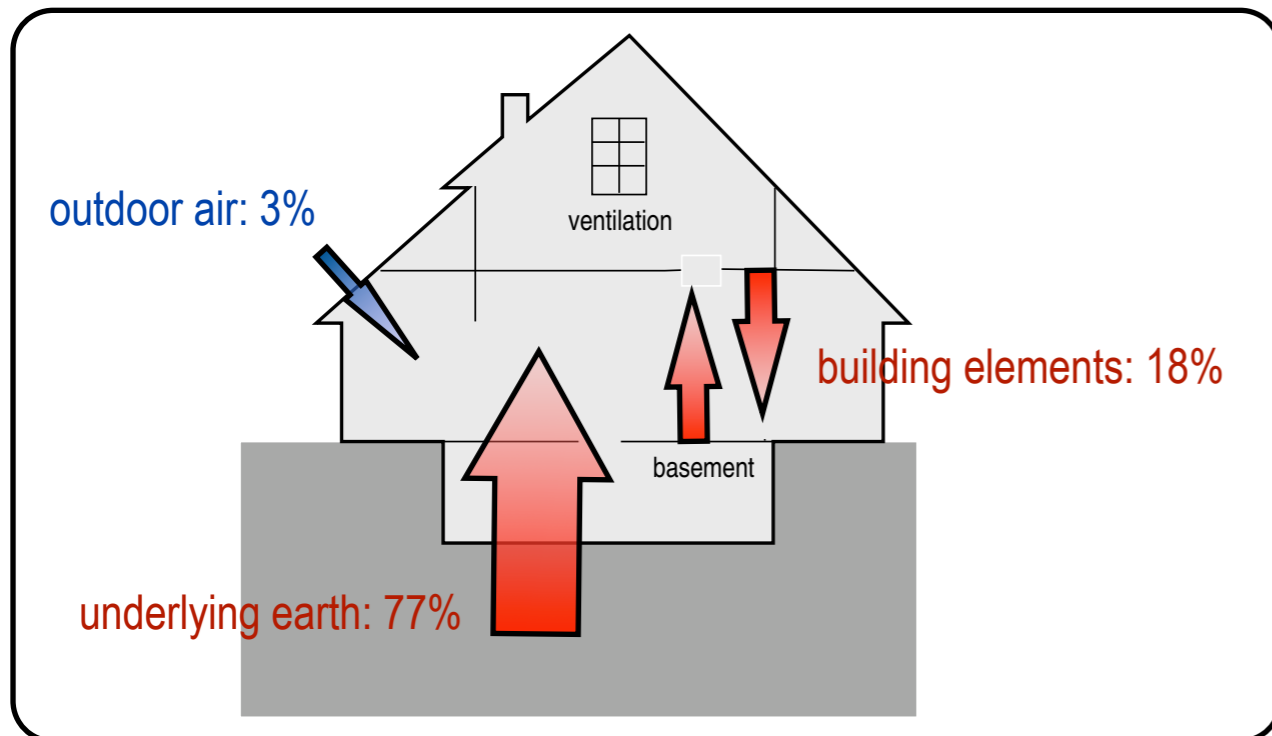
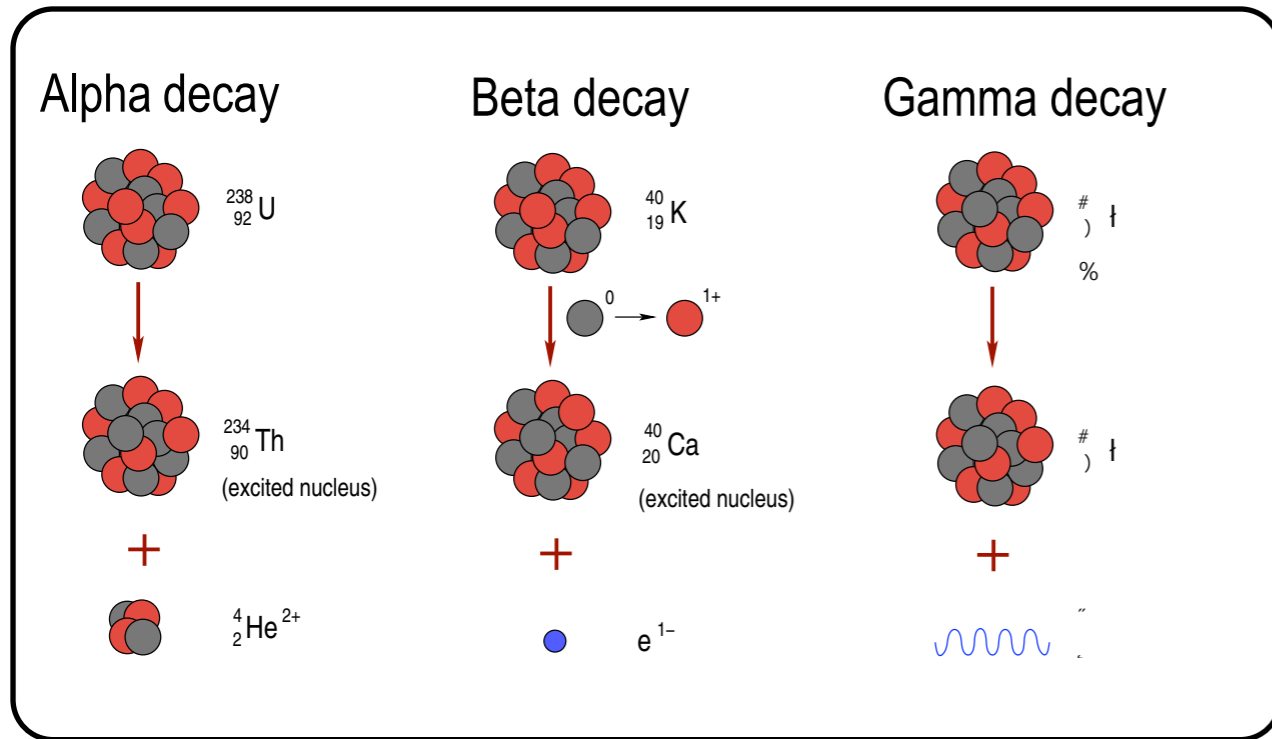
# Localization

1. Coverage
2. (In)Dependence

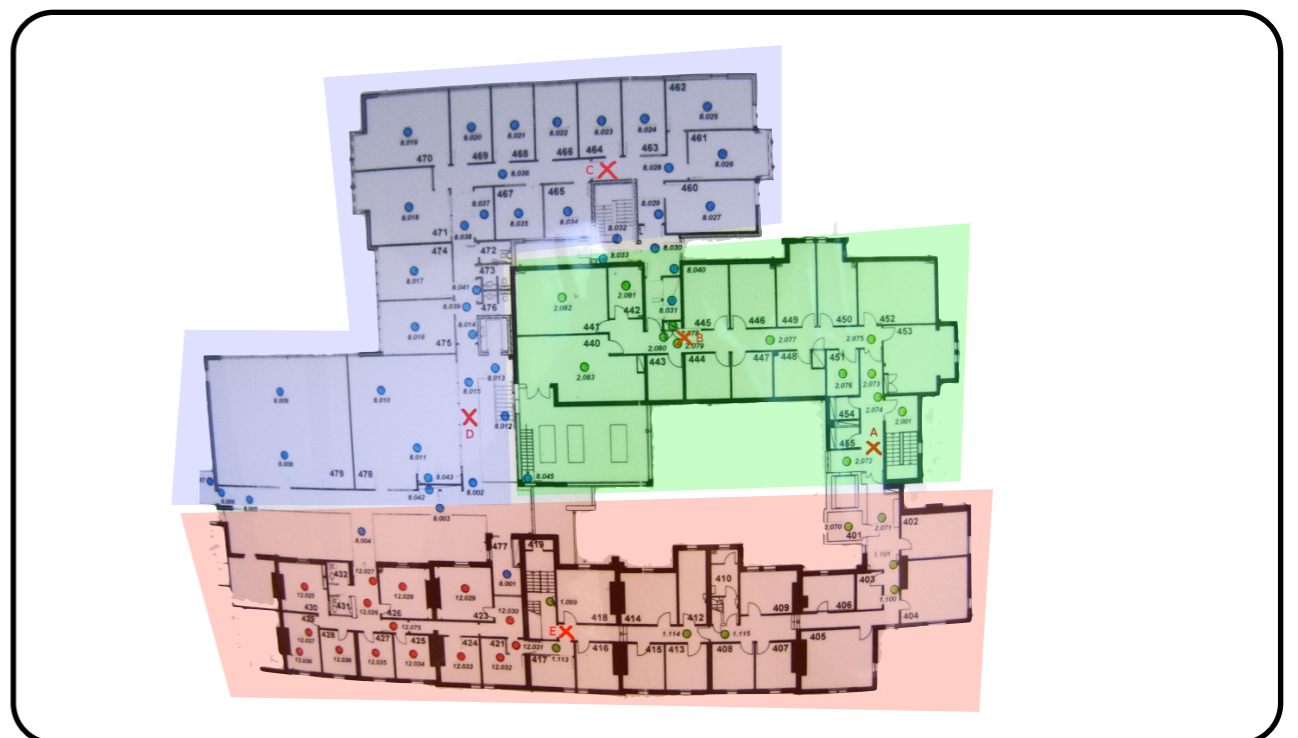
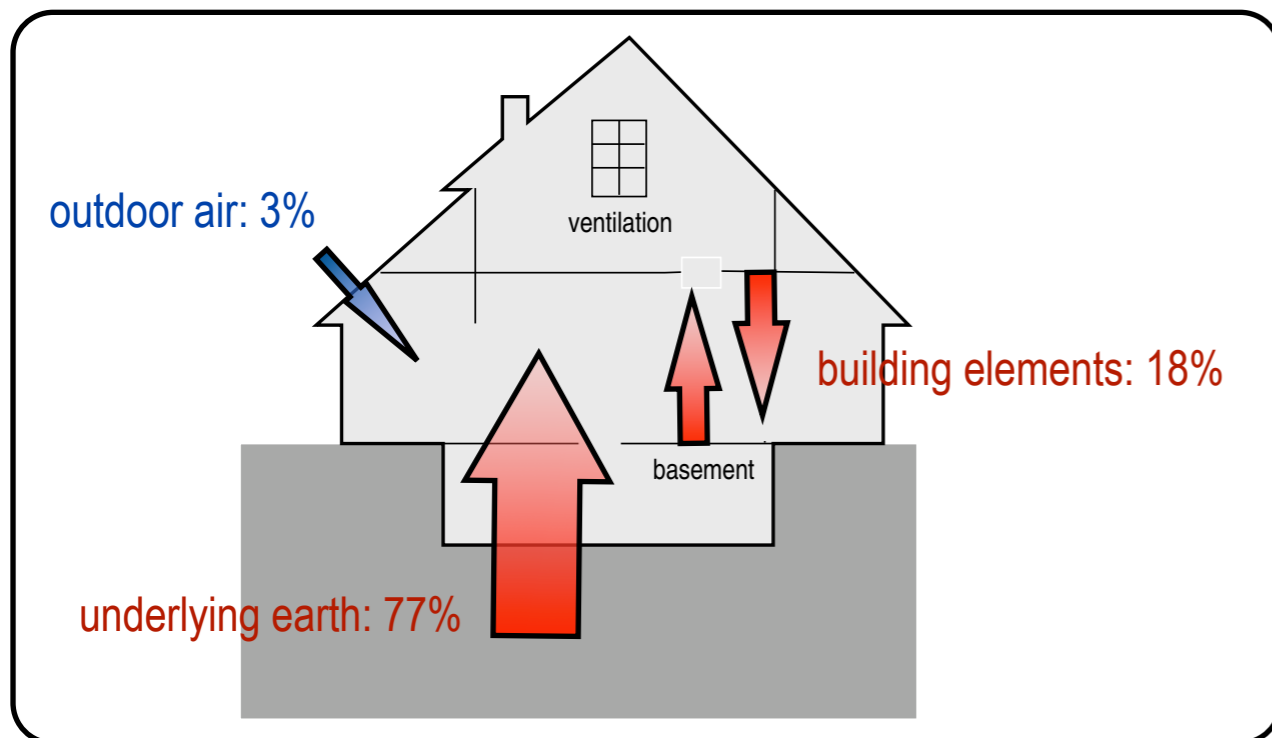
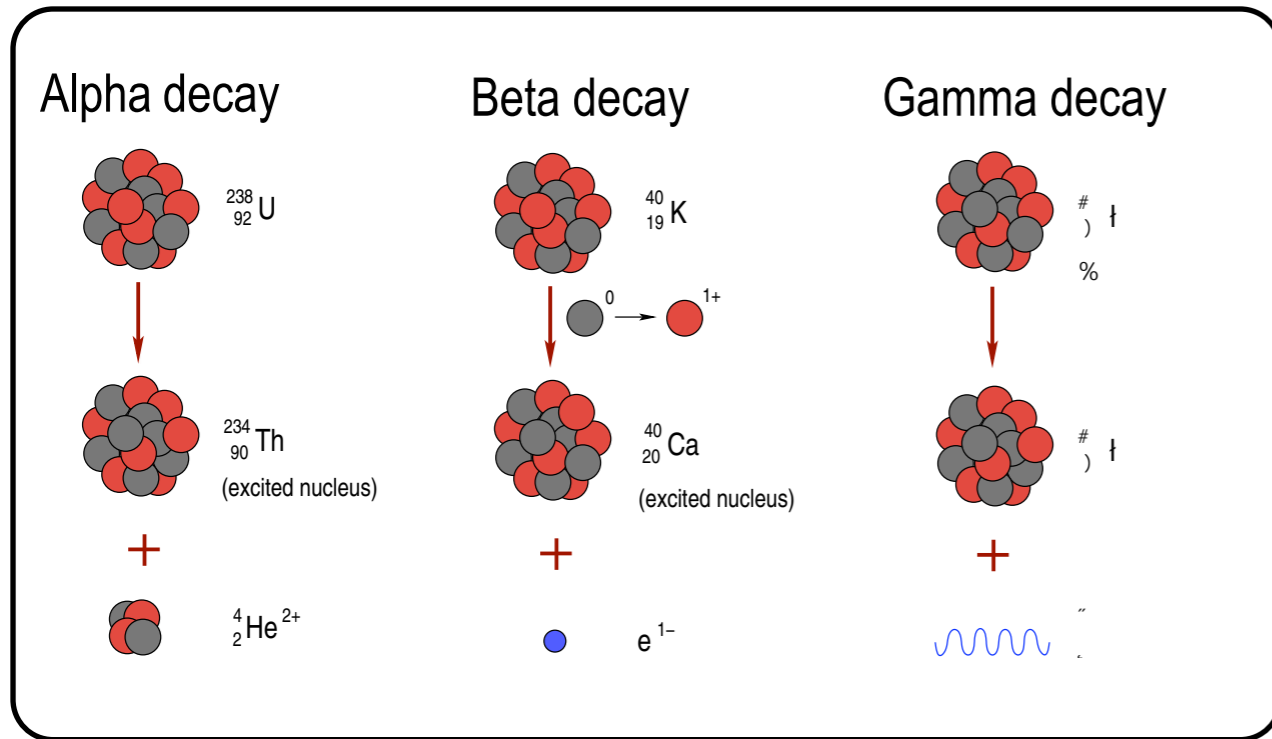
# To summarize:



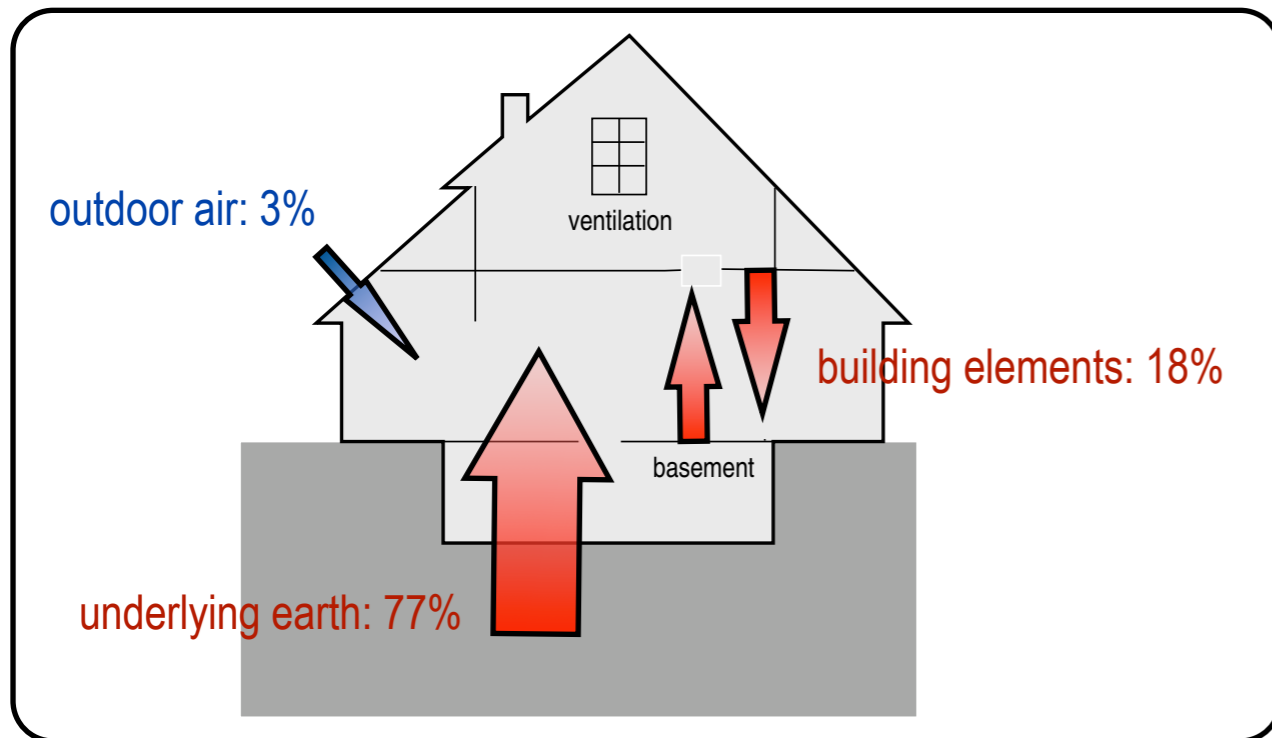
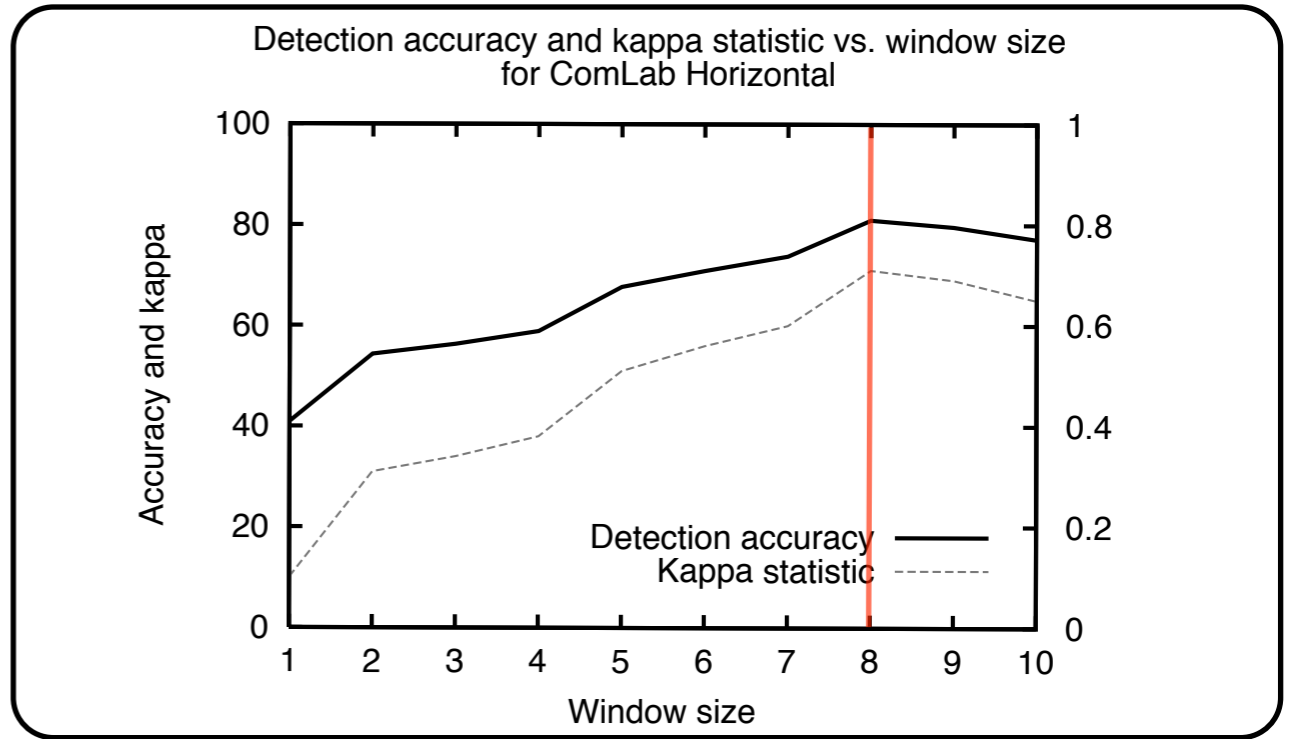
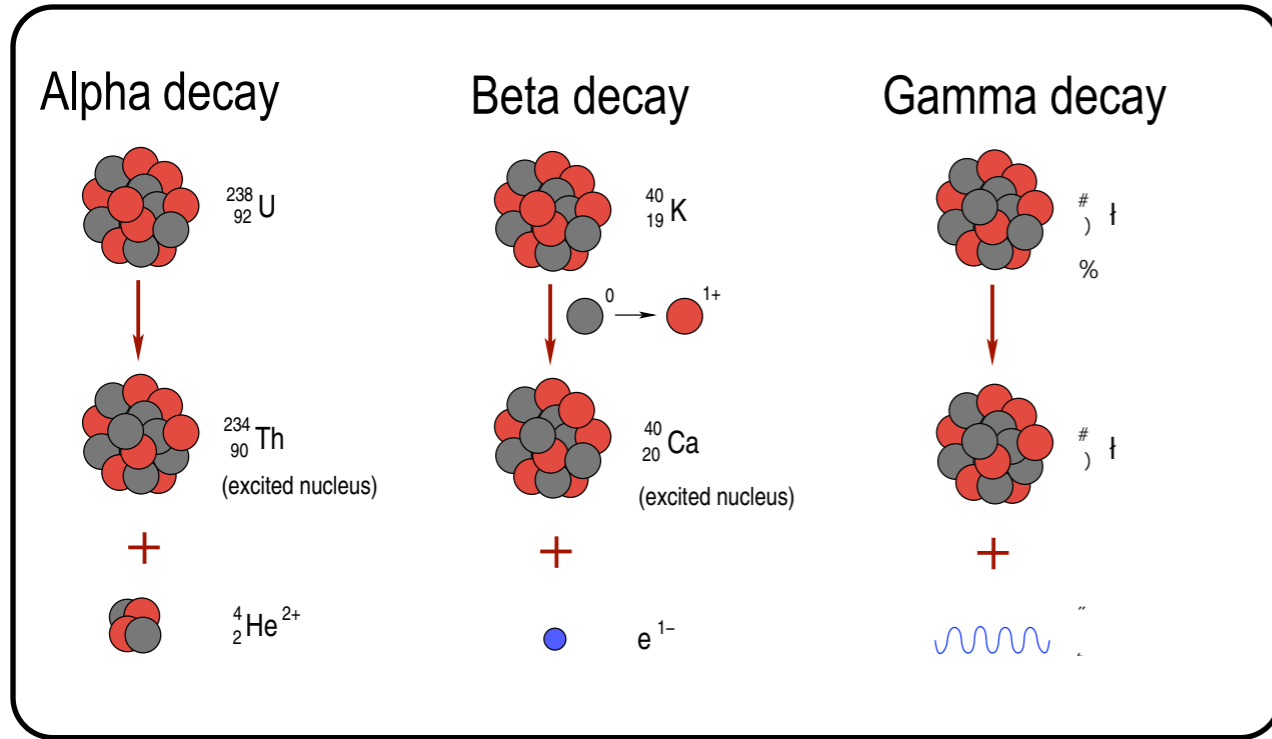
# To summarize:



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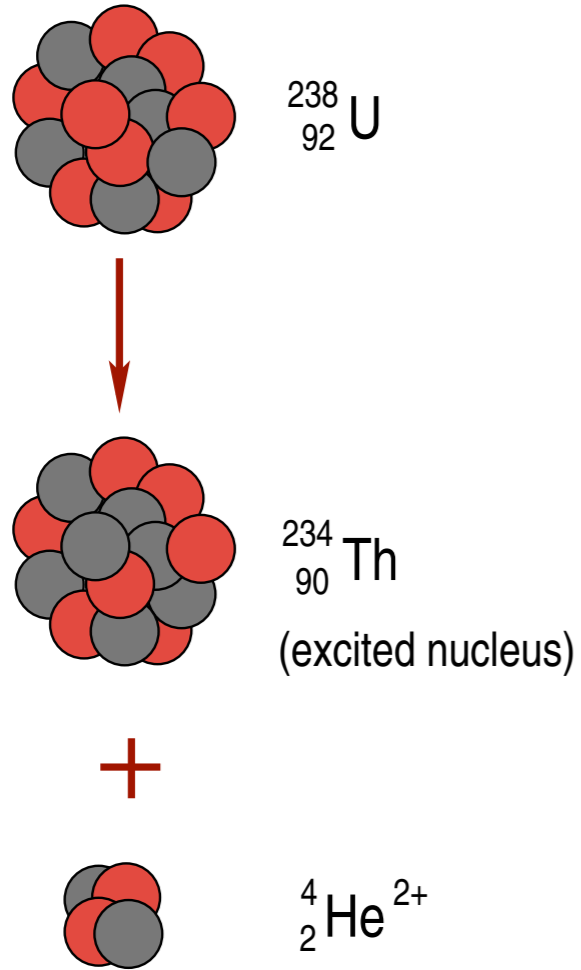


# To summarize:



# Radioactivity

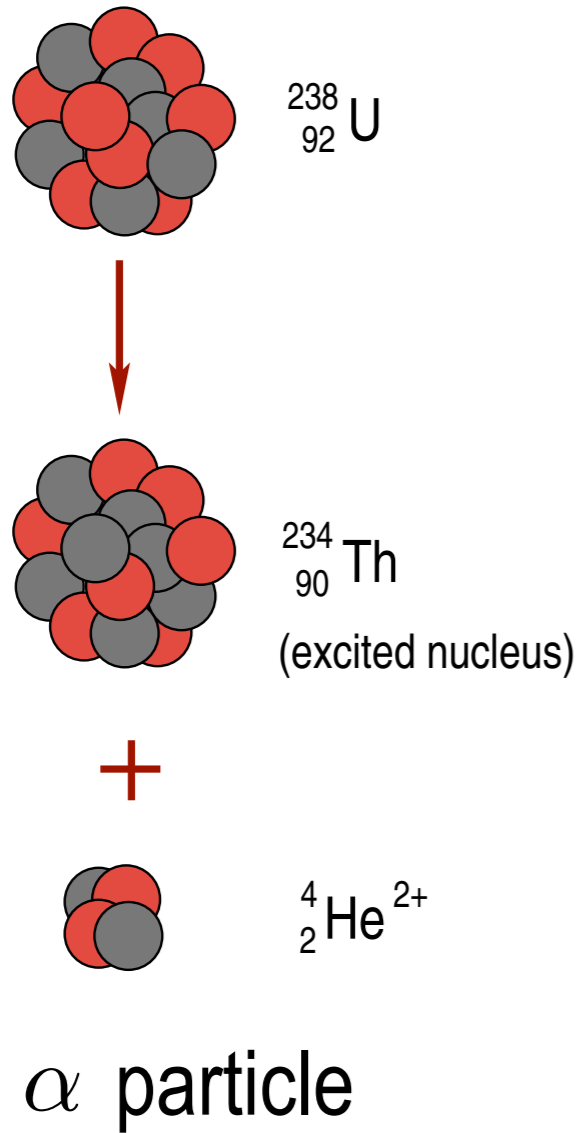
## Alpha decay



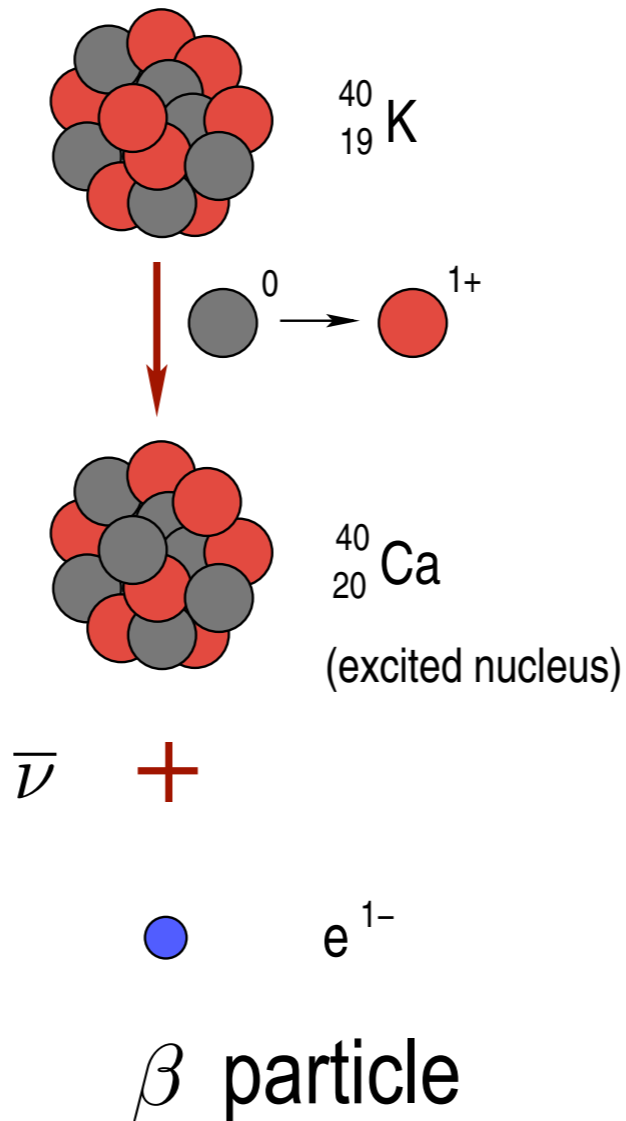
$\alpha$  particle

# Radioactivity

## Alpha decay

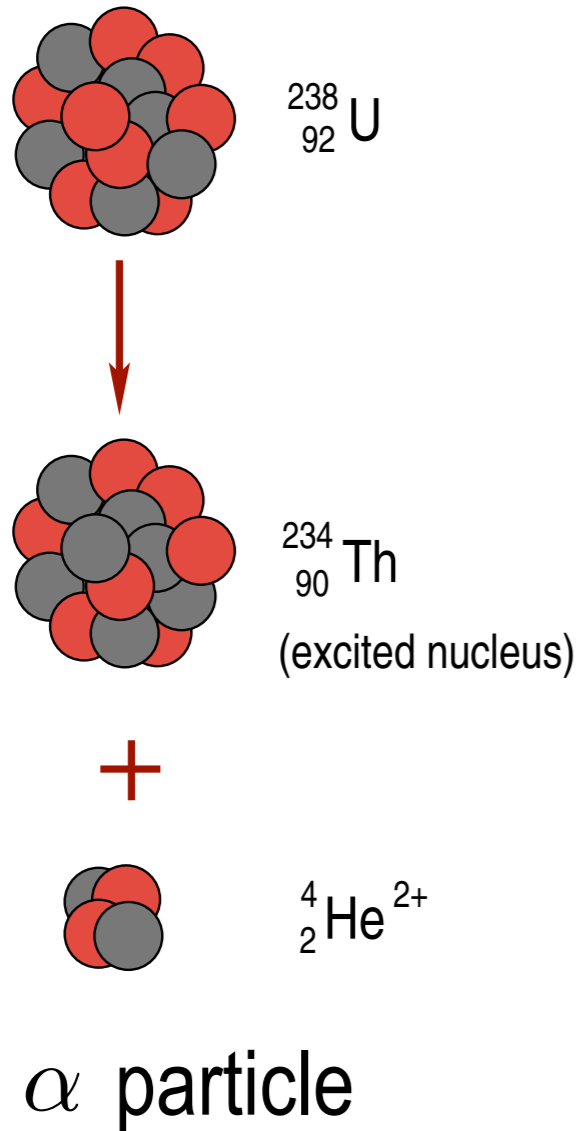


## Beta decay

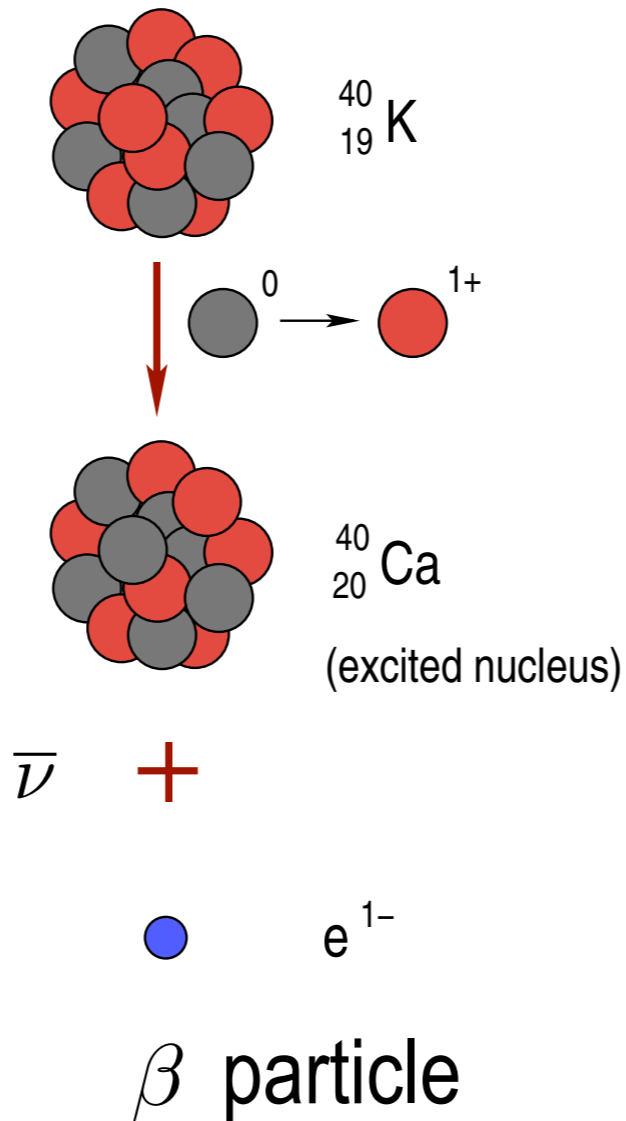


# Radioactivity

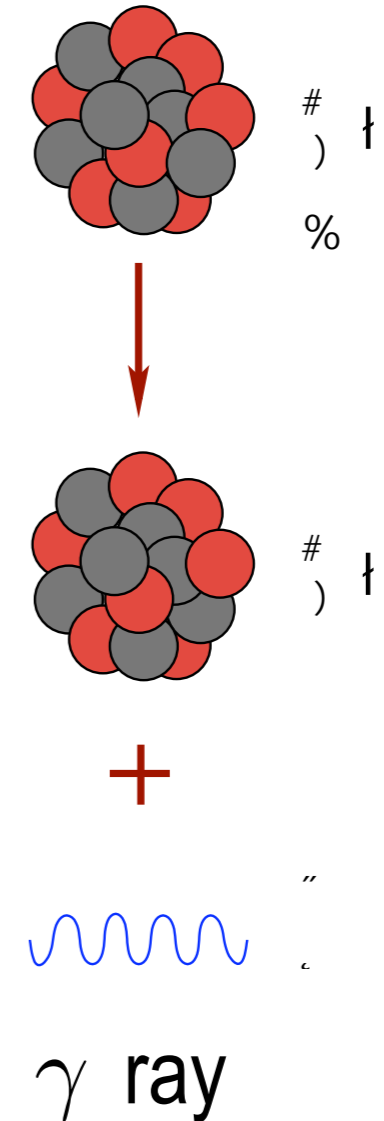
## Alpha decay



## Beta decay

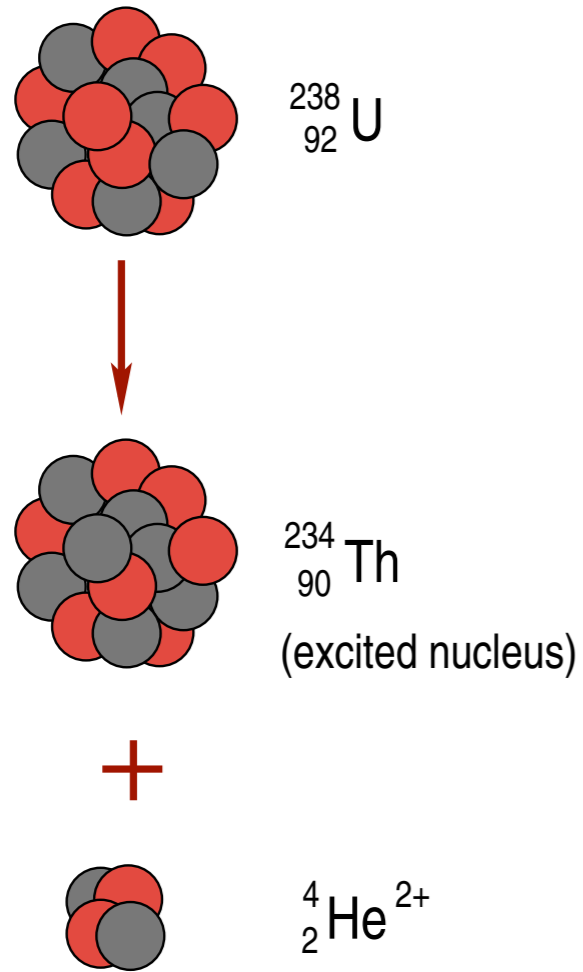


## Gamma decay



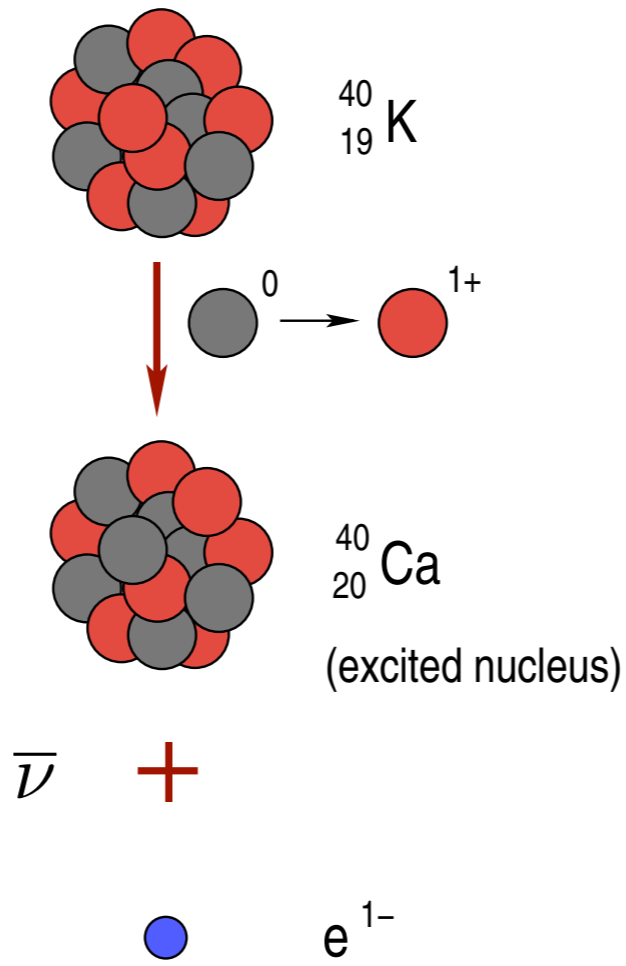
# Radioactivity

## Alpha decay



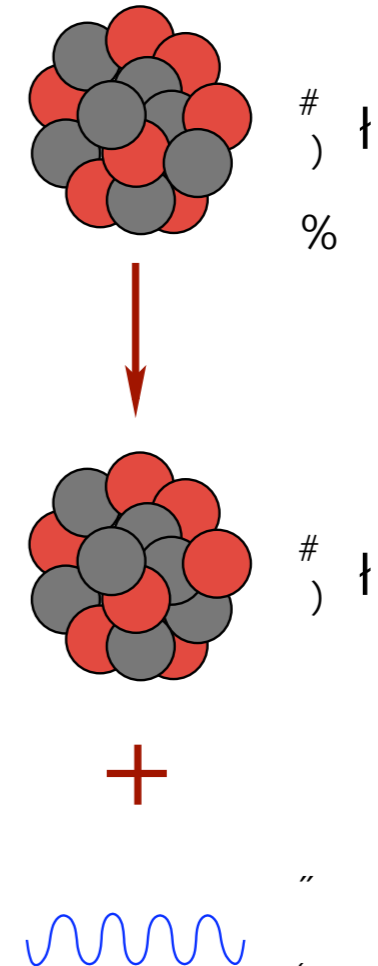
$\alpha$  particle

## Beta decay



$\beta$  particle

## Gamma decay



$\gamma$  ray



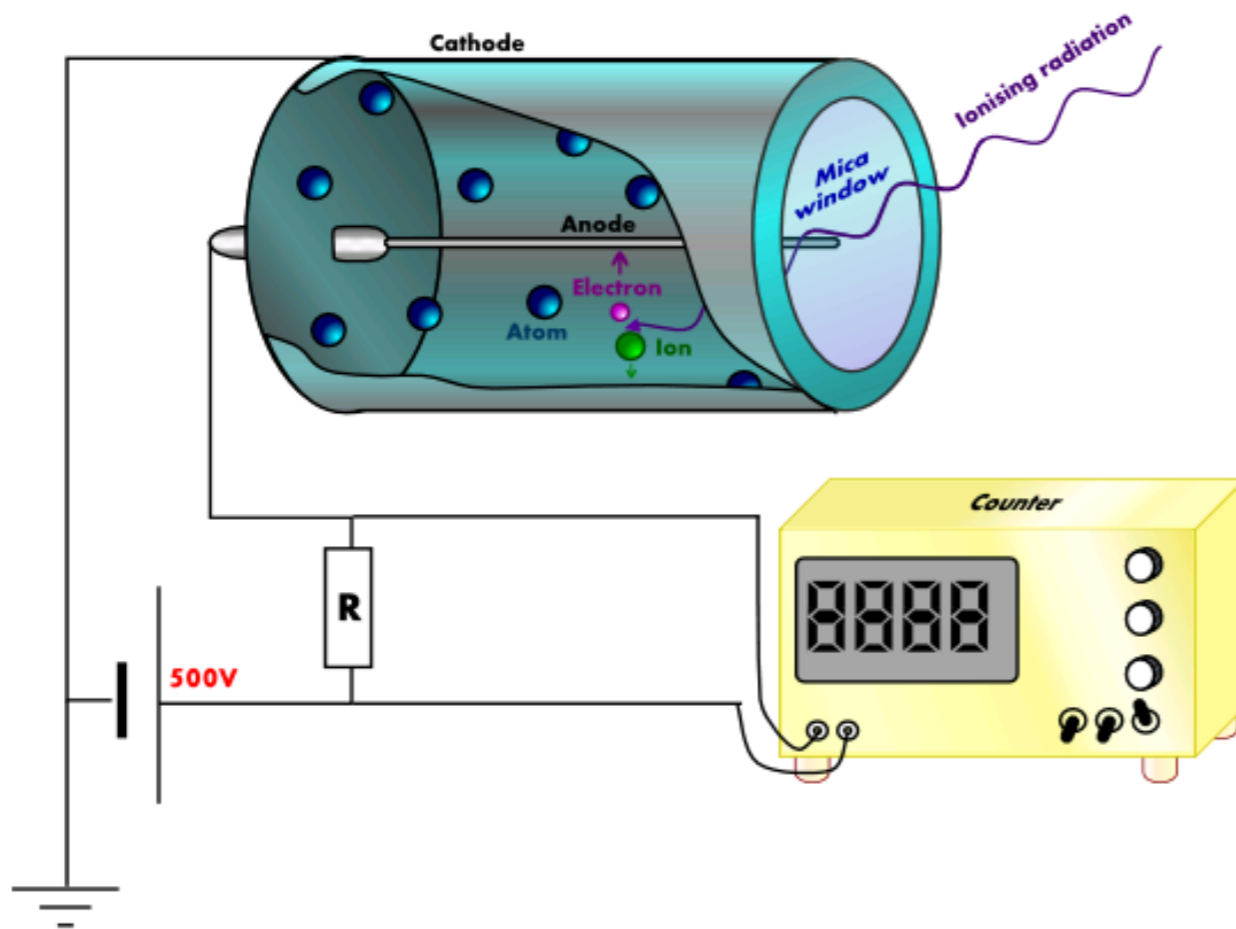
energy  
range  
detectability

# Sensing radioactivity

- Radiation **detectors** vs. radiation **counters**
- Gaseous ionization detectors: **Geiger-Mueller** counters

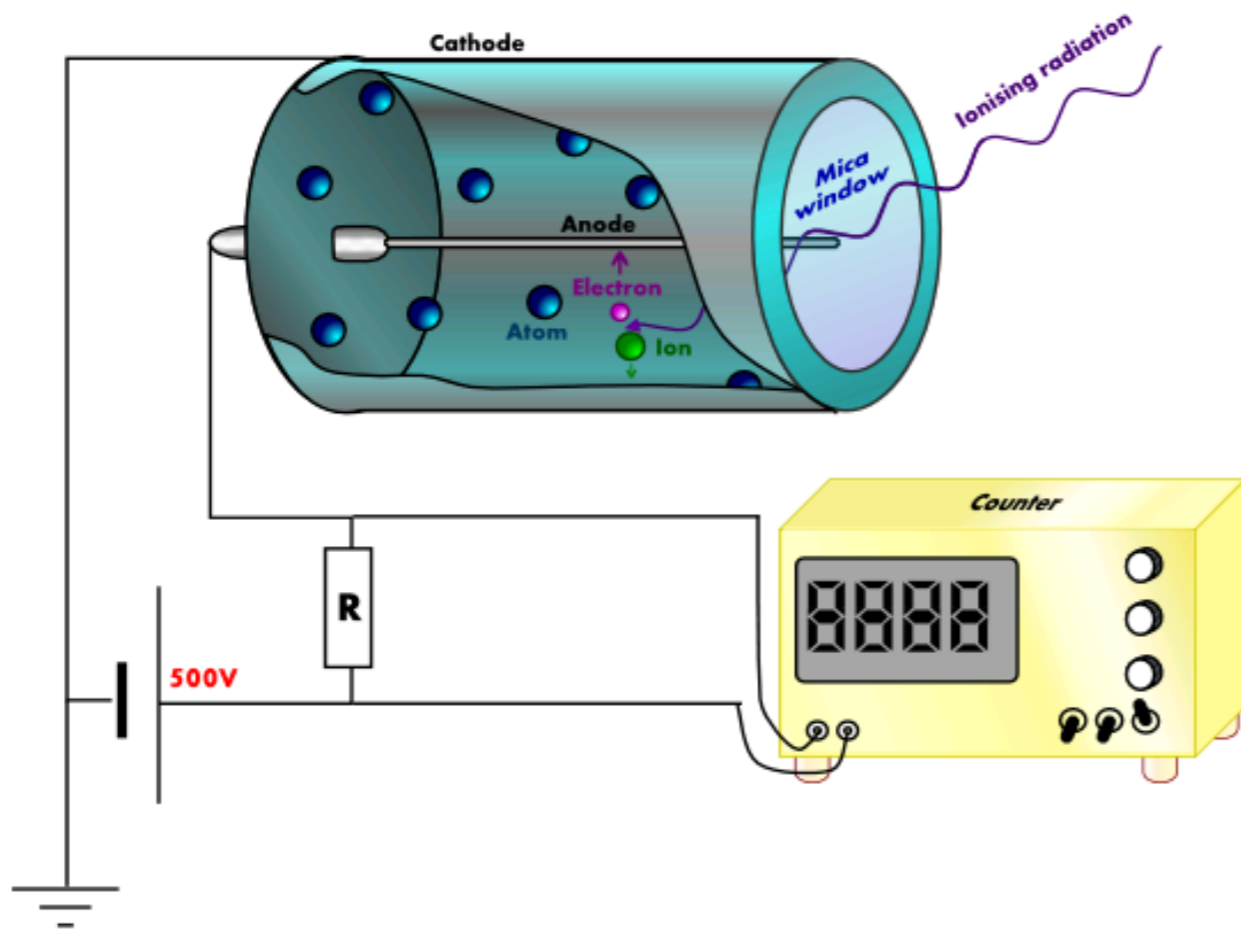
# Sensing radioactivity

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# Sensing radioactivity

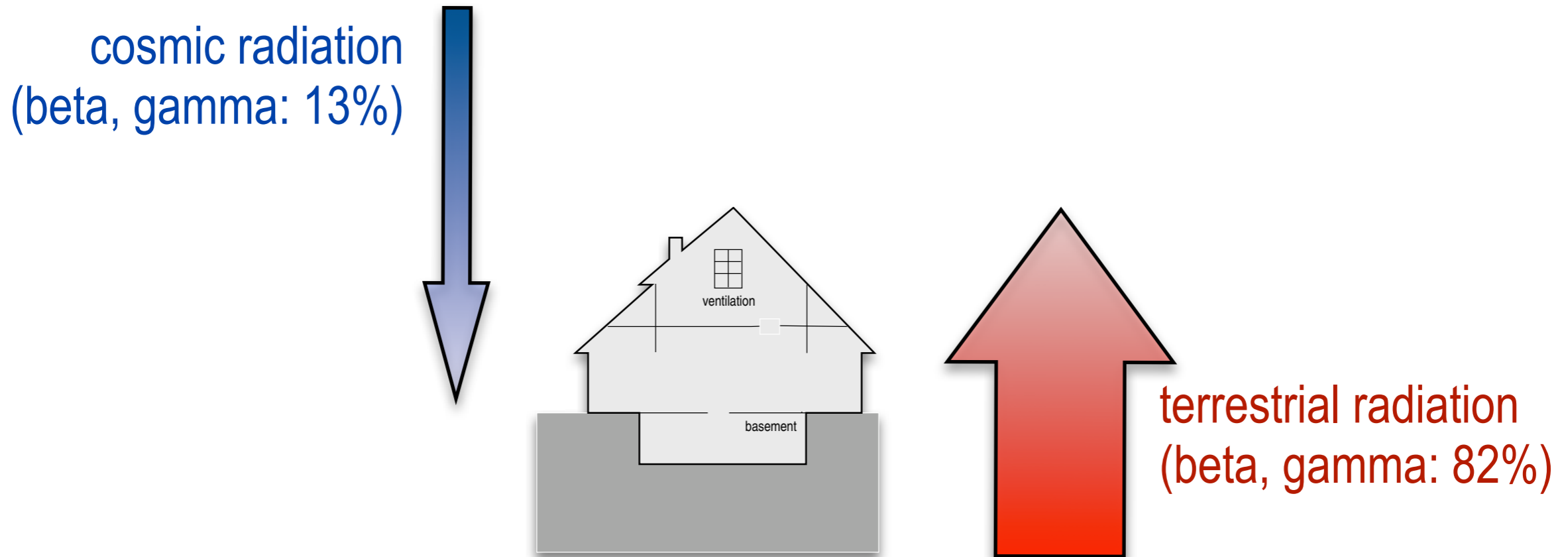
- Radiation **detectors** vs. radiation **counters**
- Gaseous ionization detectors: **Geiger-Mueller** counters



Sensitive to: beta, gamma rays  
Manufacturer: Impo Electronic

# Natural radioactivity

- Worldwide exposure to radioactivity

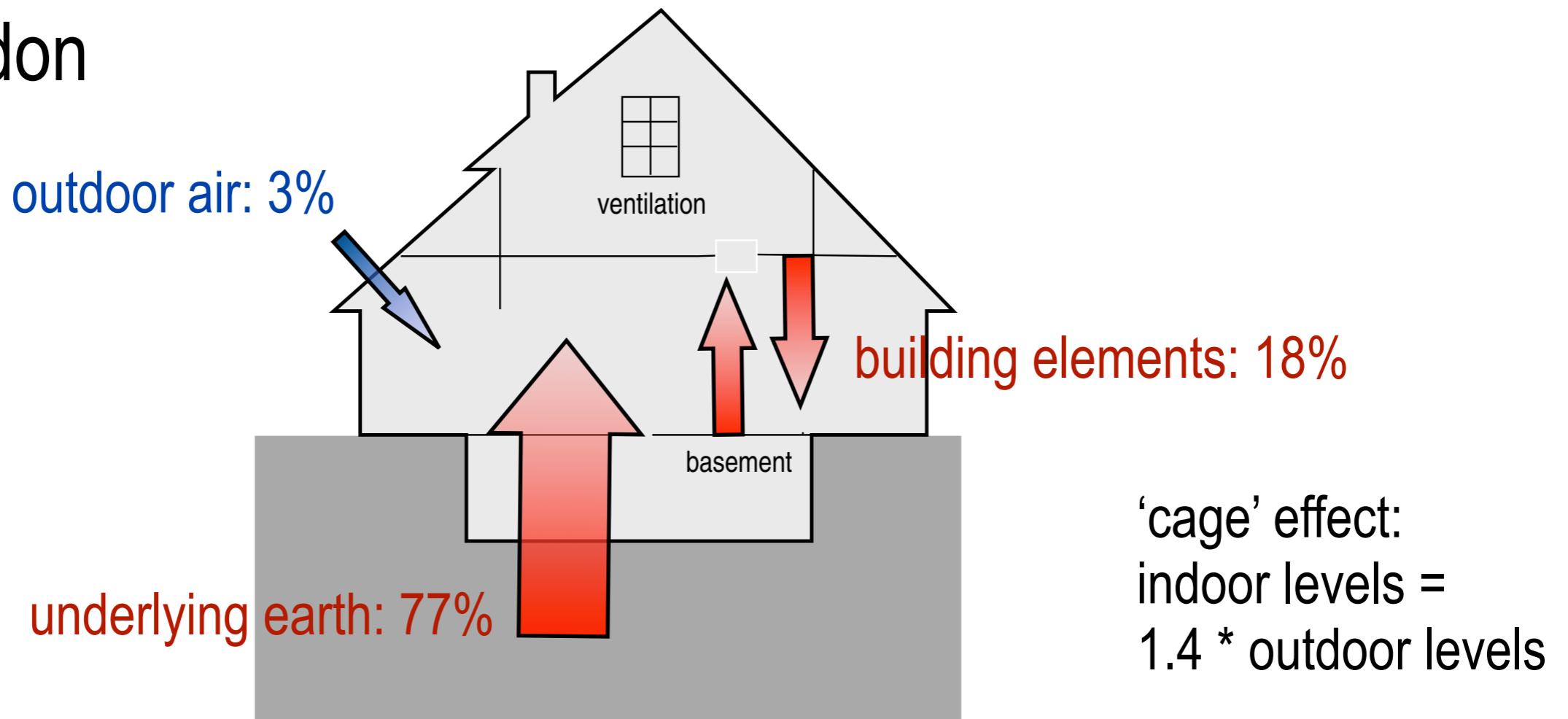


| Source of radiation  | Percentage |
|--|------------|
| Cosmic radiation total   | 18.48      |
| (beta, gamma)  | 13.74      |
| Terrestrial radiation total  | 82.46      |
| soil, building materials: $^{238}\text{U}$ , $^{232}\text{Th}$ (alpha), $^{40}\text{K}$ (beta) | 22.74      |
| air: radon $^{222}\text{Rn}$ , thoron $^{220}\text{Rn}$ (alpha)                                | 59.24      |

[From UNSCEAR (United Nations Committee on the Effects of Atomic Radiation)]

# Indoor geometry of sources

## ■ Radon



| Source of radon   | Mechanism    | Rate ( $Bq/m^3h$ ) and percentage |              |
|-------------------|--------------|-----------------------------------|--------------|
|                   |              | Masonry house                     | Wooden house |
| Building elements | Diffusion    | 16 (18)                           | 2 (3)        |
| Walls and ceiling |              |                                   |              |
| Subjacent earth   |              |                                   |              |
| Through gaps      | Advection    | 66 (73)                           | 60 (86)      |
| Through slab      | Diffusion    | 4 (4)                             | 4 (6)        |
| Outdoor air       | Infiltration | 3 (3)                             | 3 (4)        |
| Water supply      | De-emanation | 1 (1)                             | 1 (1)        |
| Total             |              | 90 (100)                          | 70 (100)     |

[From UNSCEAR]

# Fingerprinting

- Prerecorded database of readings at all locations
- Client's reading compared to database
- Probabilistic answer

# Results: floor detection

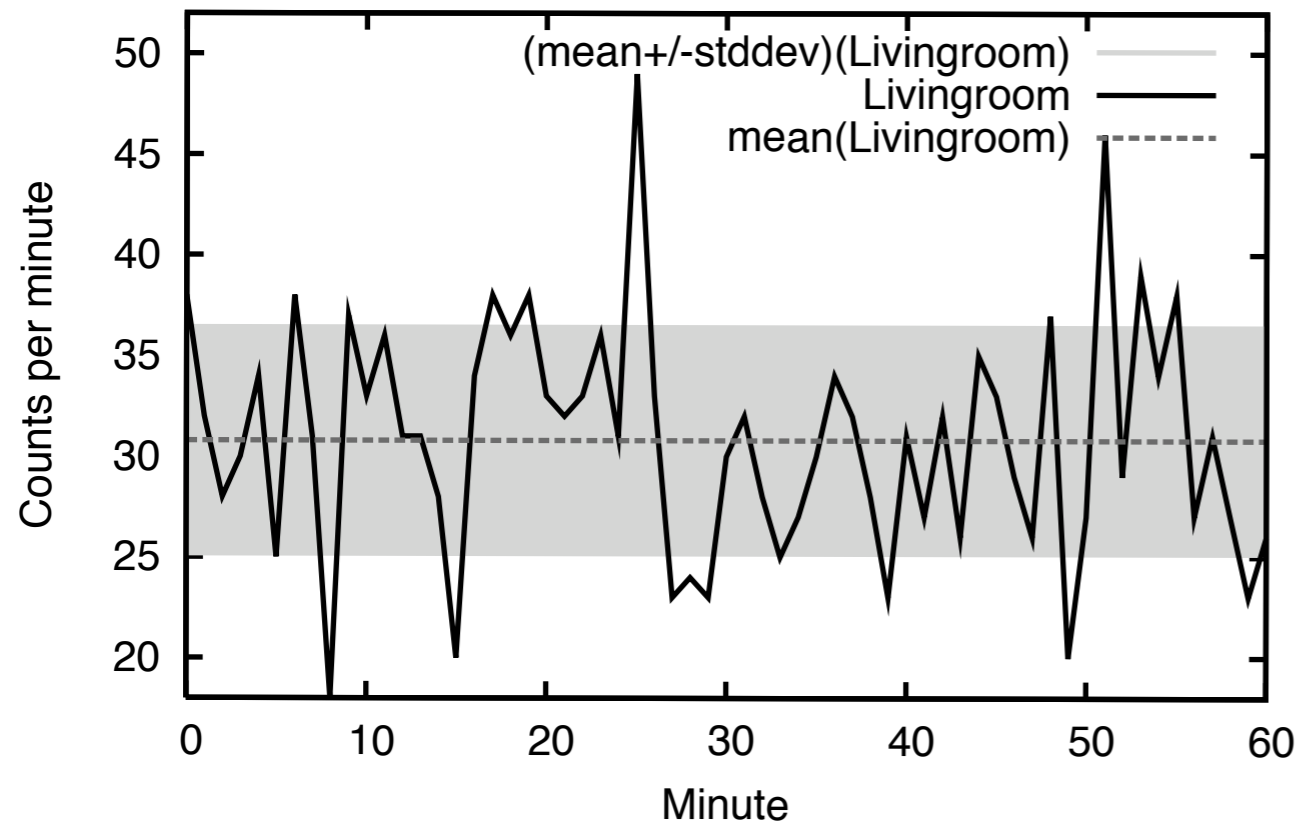
# Results: floor detection



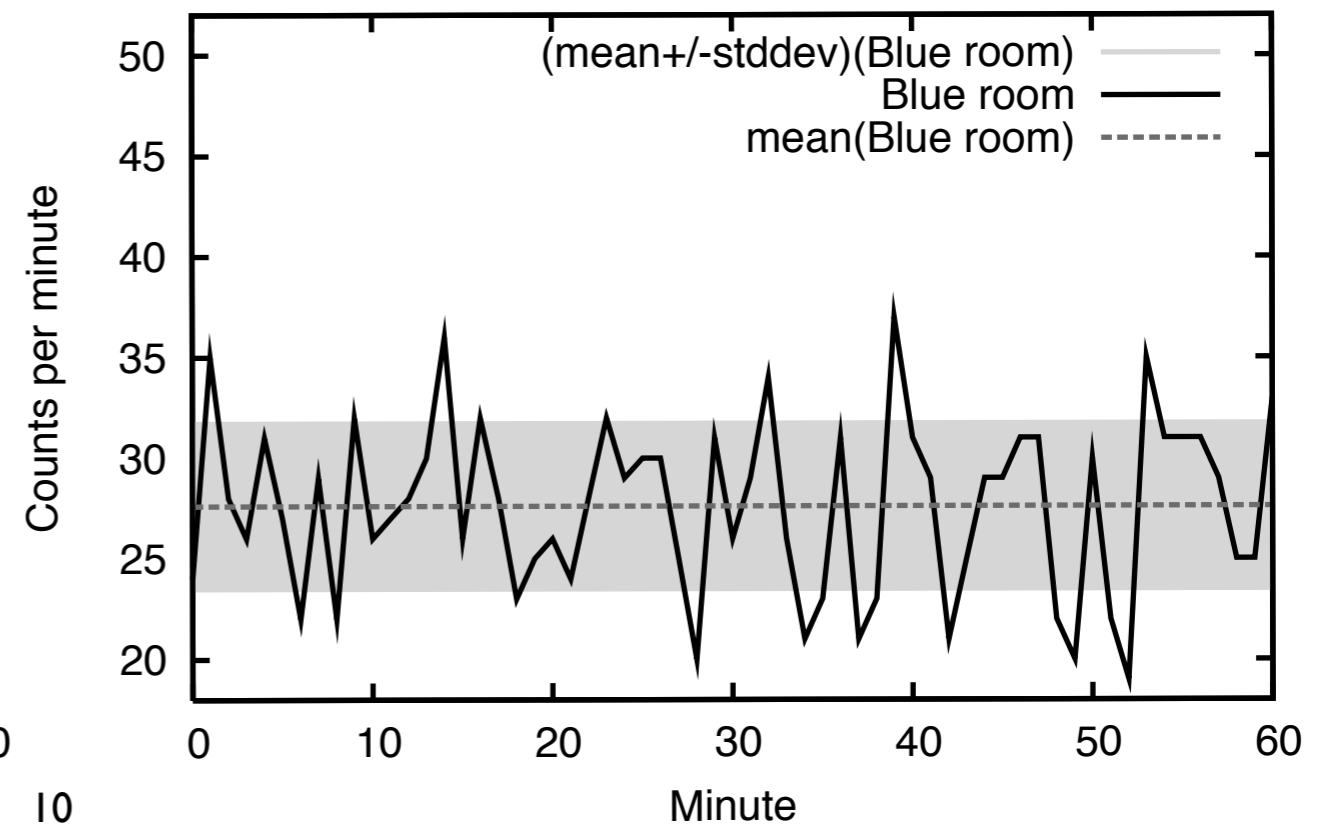
# Results: floor detection



Egaa, Level 0, Livingroom



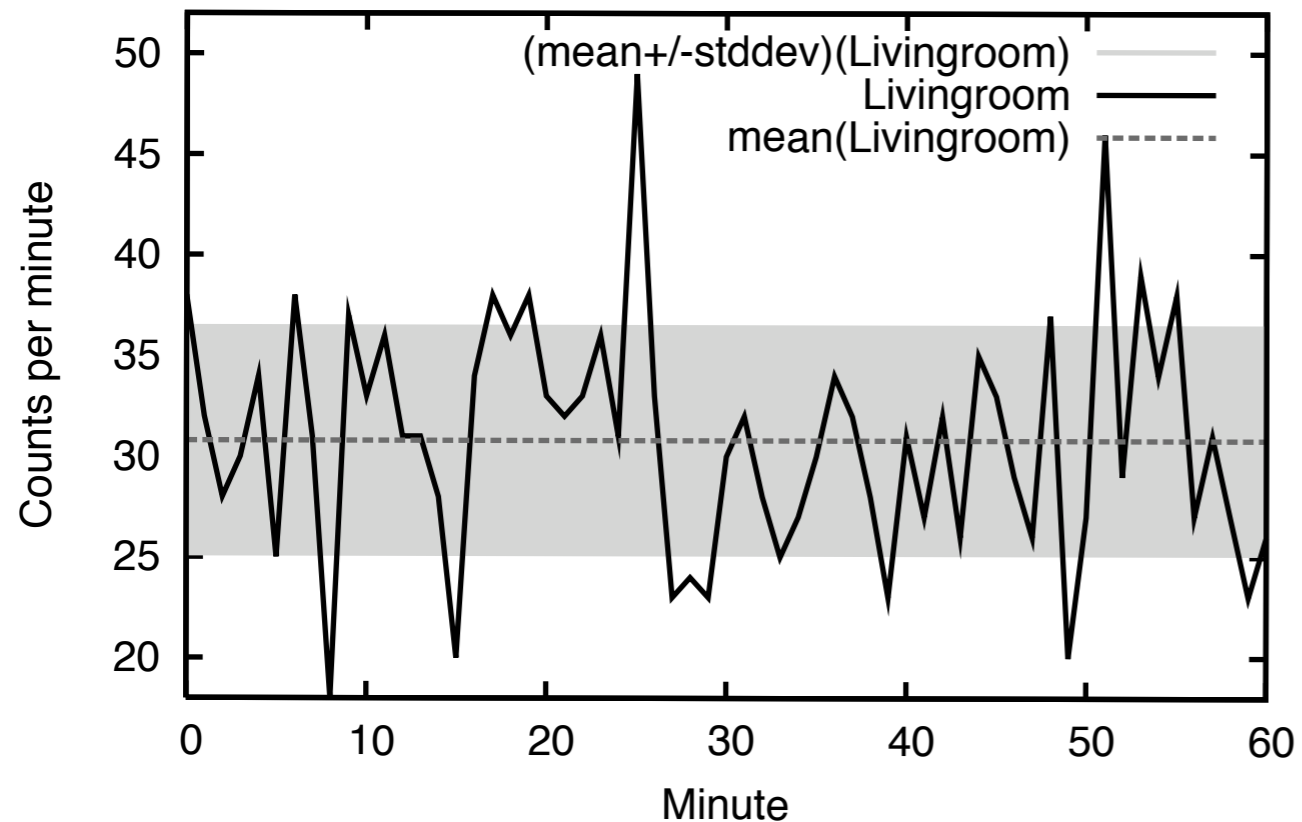
Egaa, Level 1, Blue Room



# Results: floor detection



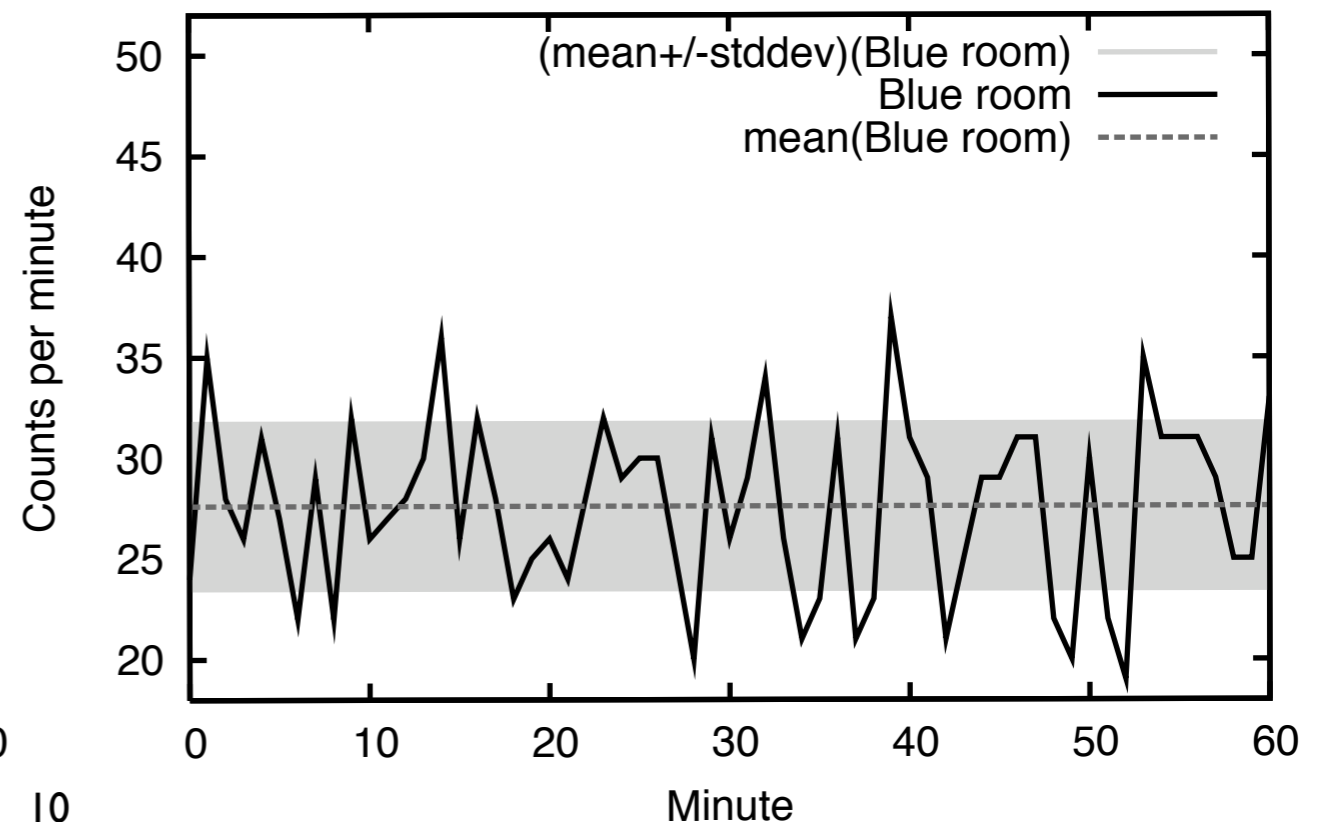
Egaa, Level 0, Livingroom



- upper floor: 10% decrease in mean, 25% decrease in standard deviation
- machine learning: 72% floor identification

(5 x 1 minute counts at client, 60 x 1-minute fingerprints)

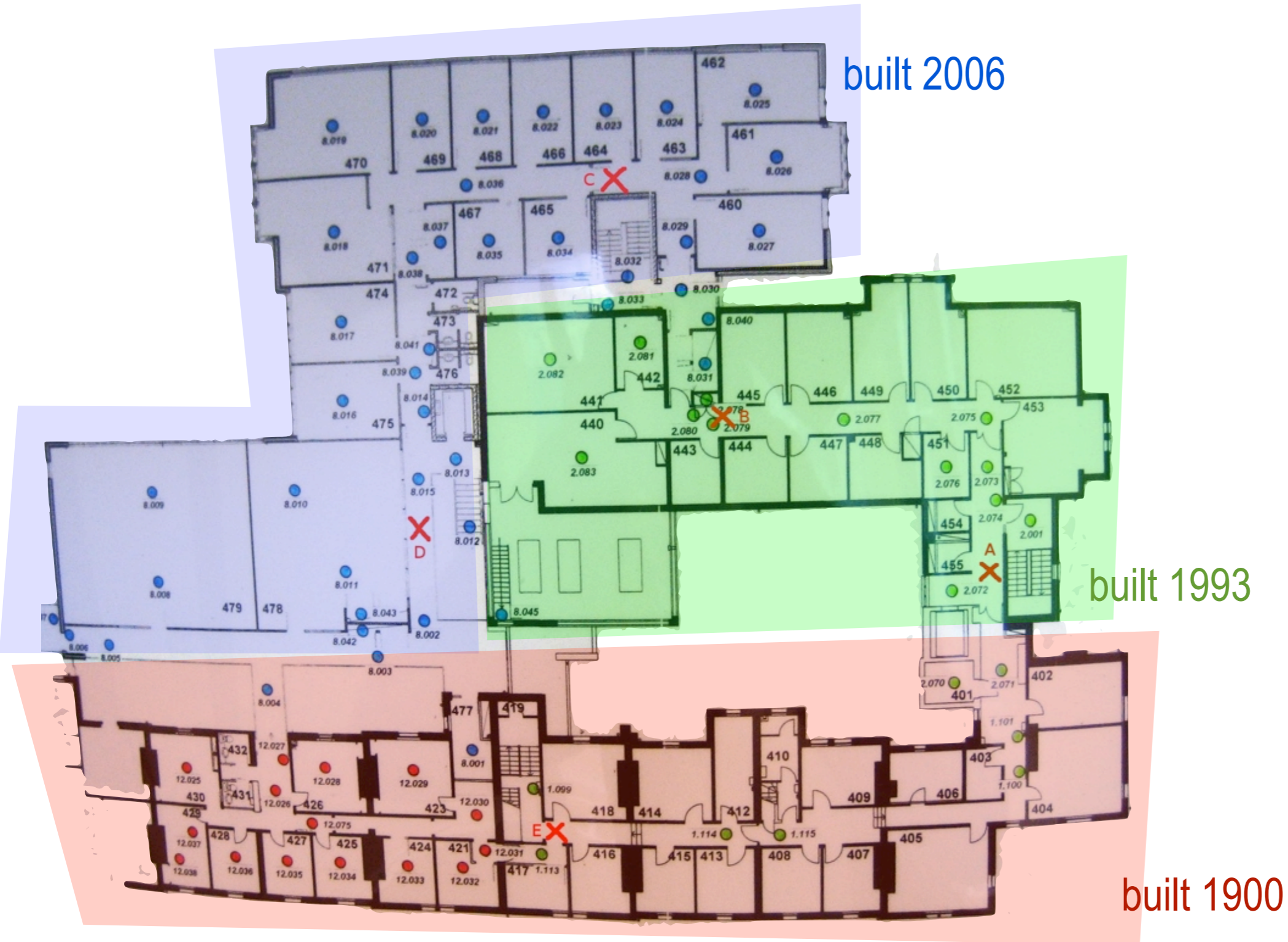
Egaa, Level 1, Blue Room



# Results: wing detection



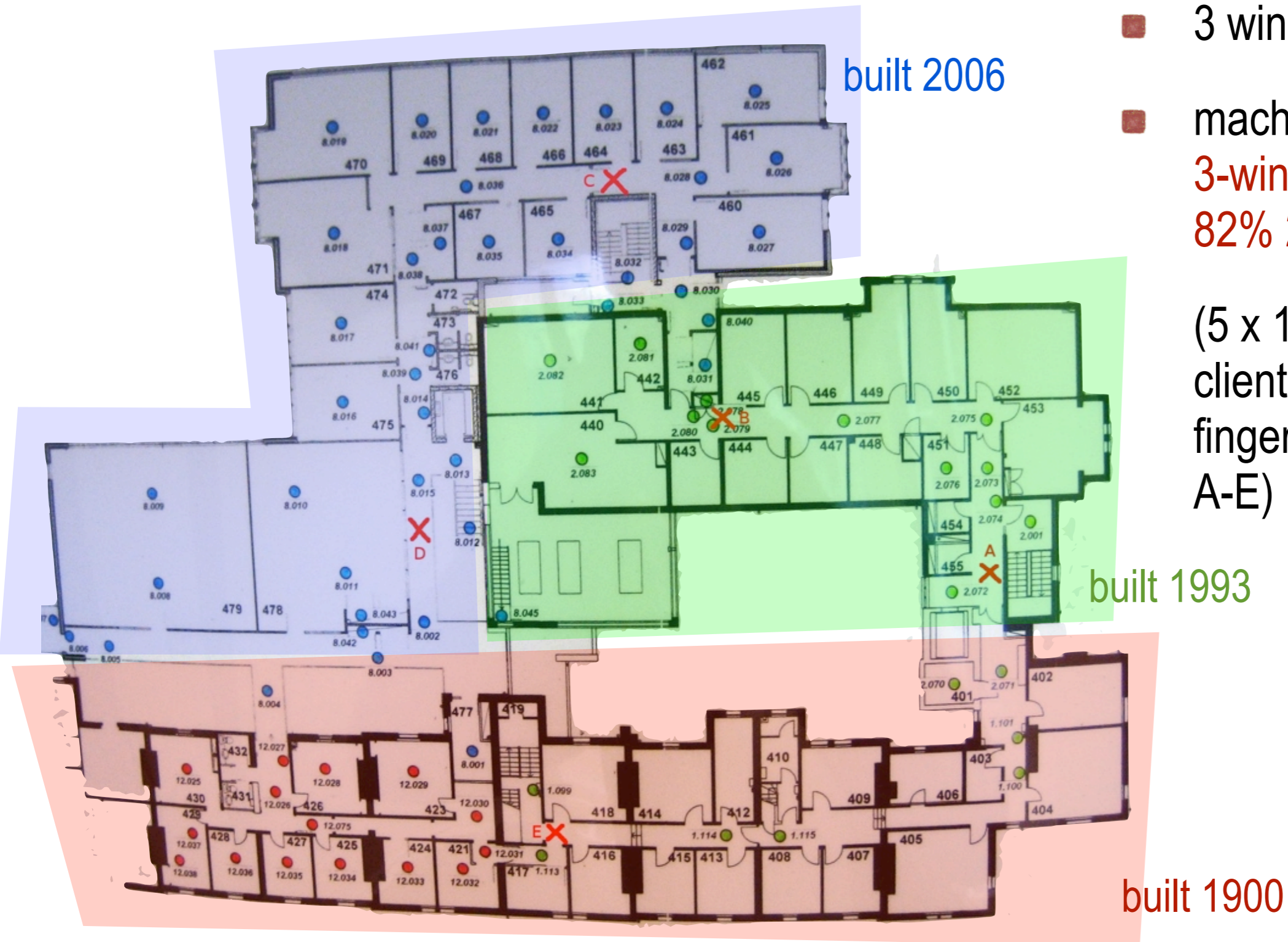
# Results: wing detection



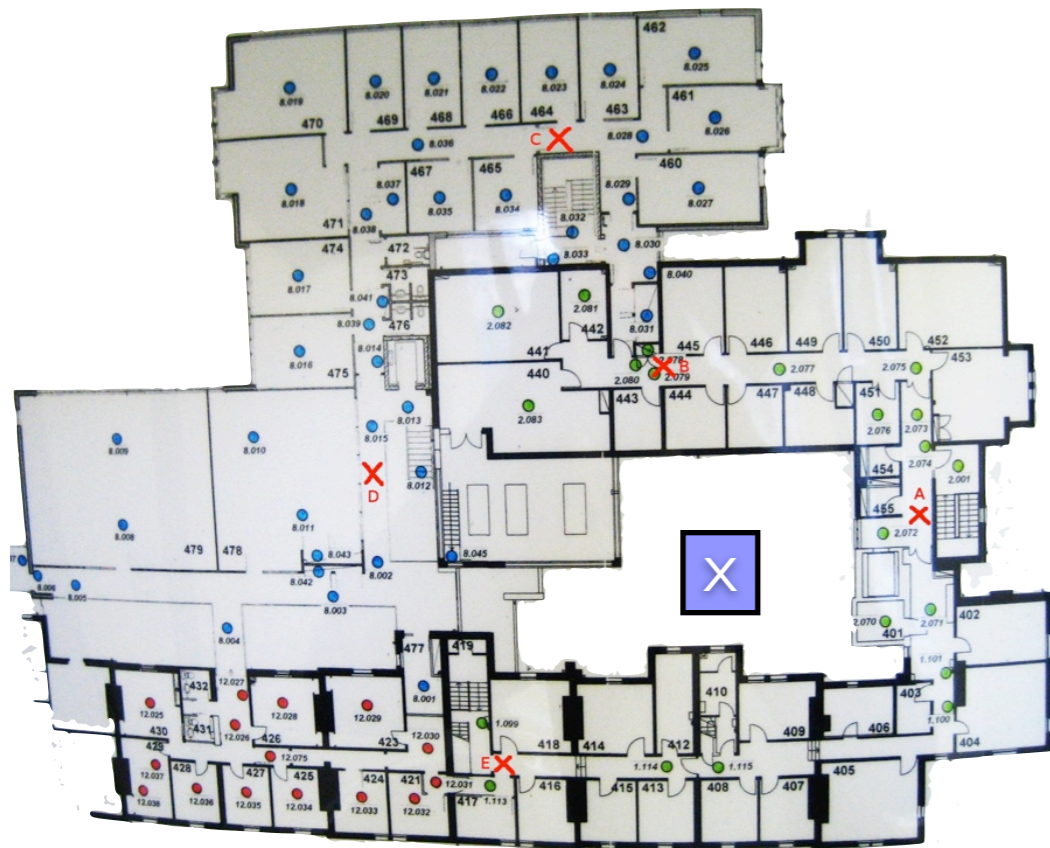
# Results: wing detection

- 3 wings
- machine learning: 68%  
3-wing detection and  
82% 2-wing detection

(5 x 1 minute counts at client, 20 x 1-minute fingerprints at marks A-E)



# Results: Indoors-vs.-outdoors

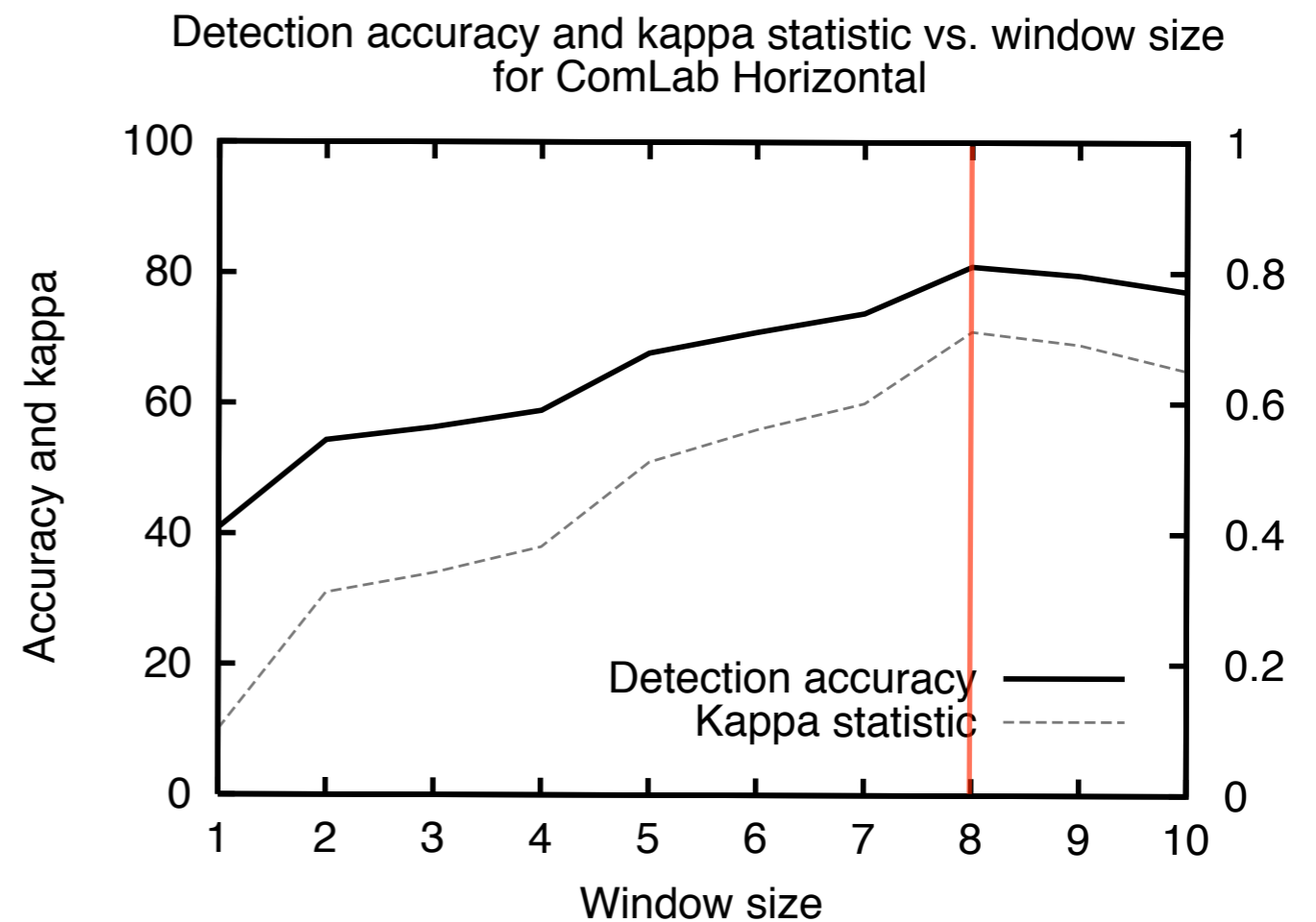


- X/Y versus A-E (on five floors)
- machine learning: **92% indoors-vs.-outdoors detection**

(5 x 1 minute counts at client, 20 x 1-minute fingerprints at all marks)

# Sensitivity of algorithm

- **Sensitivity:** how accuracy varies with the number of counts at client  
(default: 5 x 1-minute counts)
- Max. accuracy for 8 minutes of readings at client



# Summary and conclusions

- Floor, wing and indoor-vs.-outdoor detection
- **Accuracy** varies greatly with building
- Miniaturized radiation sensors commercially available [16]
  
- **Stability of signal** over long time unproven
- Not surveyed: sky scrapers
- Potentially interesting: indoor **activity recognition**

Thank You