A cryogenic detector for ^{222}Rn

^{222}Rn detection

The design...

Performance…

Conclusions

M. Wojcik[a], G. Zuzel[b]

[a] Institute of Physics, Jagellonian University, Cracow, Poland
[b] Max Planck Institute for Nuclear Physics, Heidelberg, Germany

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1. Selected detection techniques of ^{222}Rn

- Pre-concentration and counting using GALLEX/GNO low-level proportional counters
  - highly sensitive measurements of ^{222}Rn in nitrogen and argon (liquid nitrogen/liquid argon)
  - detection limit: ~0.5 µBq/m^3 **(Appl. Rad. Isot. 52 (2000) 691)**
- Electrostating chambers
  - high sensitive online ^{222}Rn monitoring (clean rooms, clean benches etc.)
  - detection limit 0.1 - 1 mBq/m^3 **(NIM A460 (2001) 272)**
- Scintillator Lucas cells
  - online ^{222}Rn monitoring (laboratories, air etc.)
  - insensitive to gas contaminations and easy to use detectors
  - detection limit: ~ 0.5 Bq/m^3 **(NIM A345 (1994) 351)**

2. The design of the cryogenic detector

^{222}Rn detection

The design...

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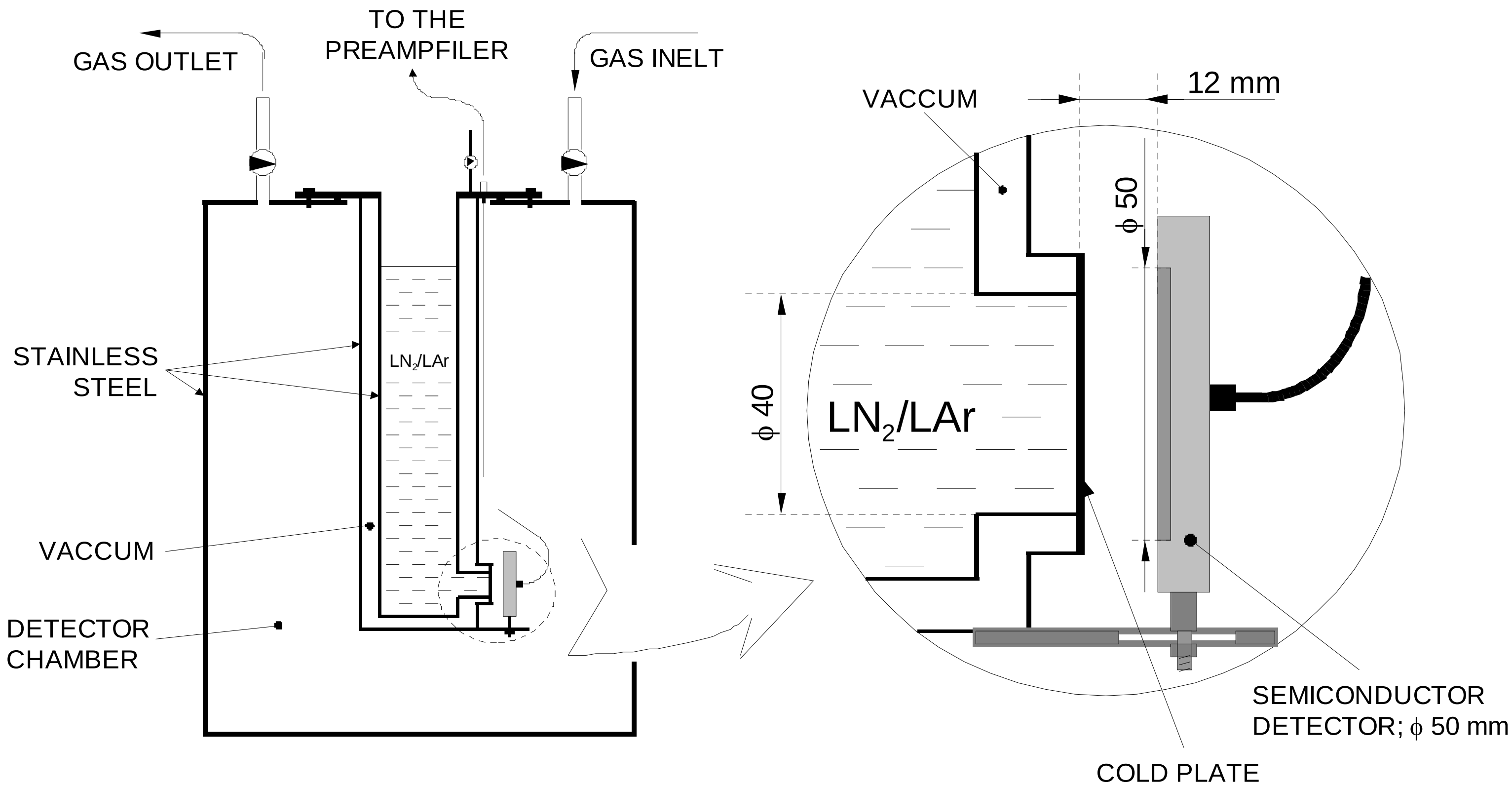

Detector : ORTEC ULTRA™ diode, 50 mm diameter

Cold plate : 40 mm diameter, 12 mm distance from the diode

Cooling : Liquid nitrogen

Volume : 65 L

Material : Electropolished stainless steel

^{222}Rn detection

The design...

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3. Performance of the cryogenic detector

3.1 Background

- ORTEC diode (impurities + cosmic rays)

$$A_D = (0.93 \pm 0.31) \text{ cpd}$$

- Emanation of ^{222}Rn (detector components, welds etc.)

$$A_E = (23.6 \pm 3.5) \text{ cpd}$$

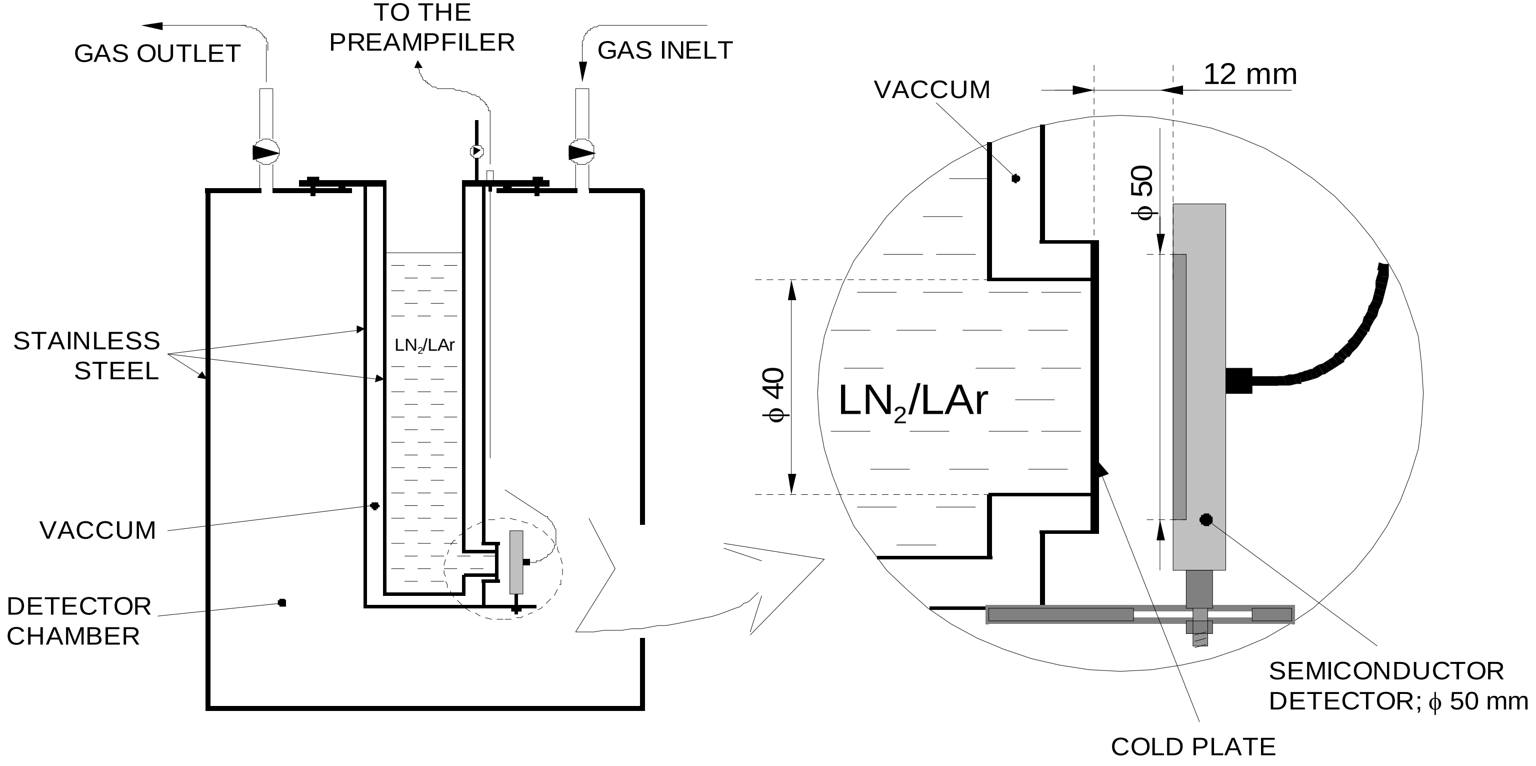
- Total

$$\boldsymbol{A_B = (24.5 \pm 3.5) \text{ cpd}}$$

3. Performance of the cryogenic detector

3.1 Background – ^{222}Rn daughters deposition

- ^{222}Rn detection
- The design...
- Performance…
- Conclusions

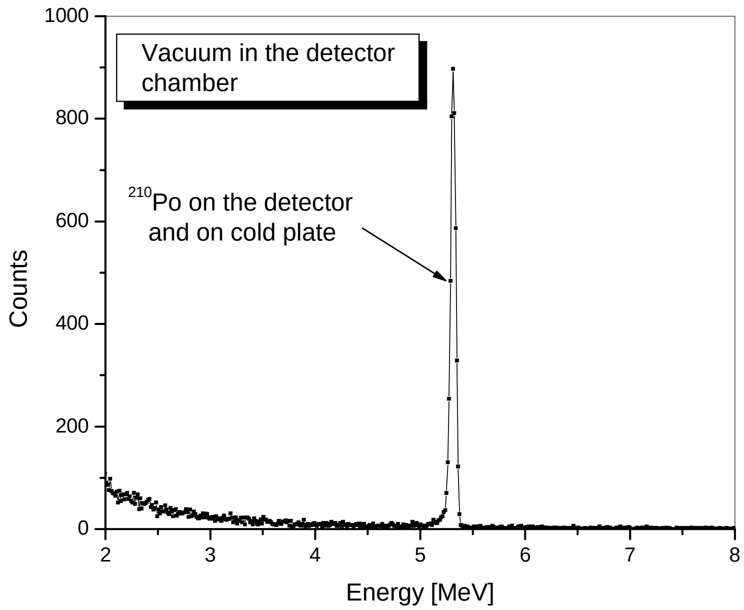


3. Performance of the cryogenic detector

3.1 Background after many test with high ^{222}Rn activities

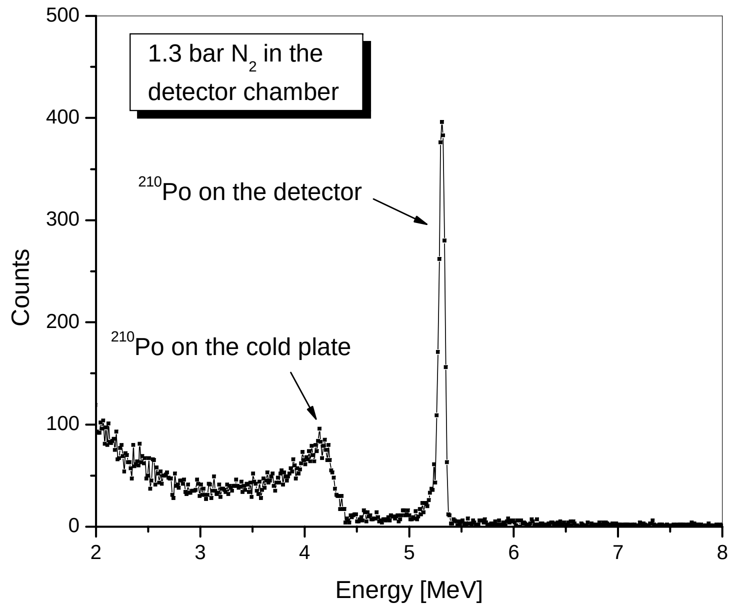
- ^{222}Rn detection
- The design...
- Performance…
- Conclusions

p ~ 0 mbar



$A_D = (174 \pm 6)$ cpd

p = 1300 mbar

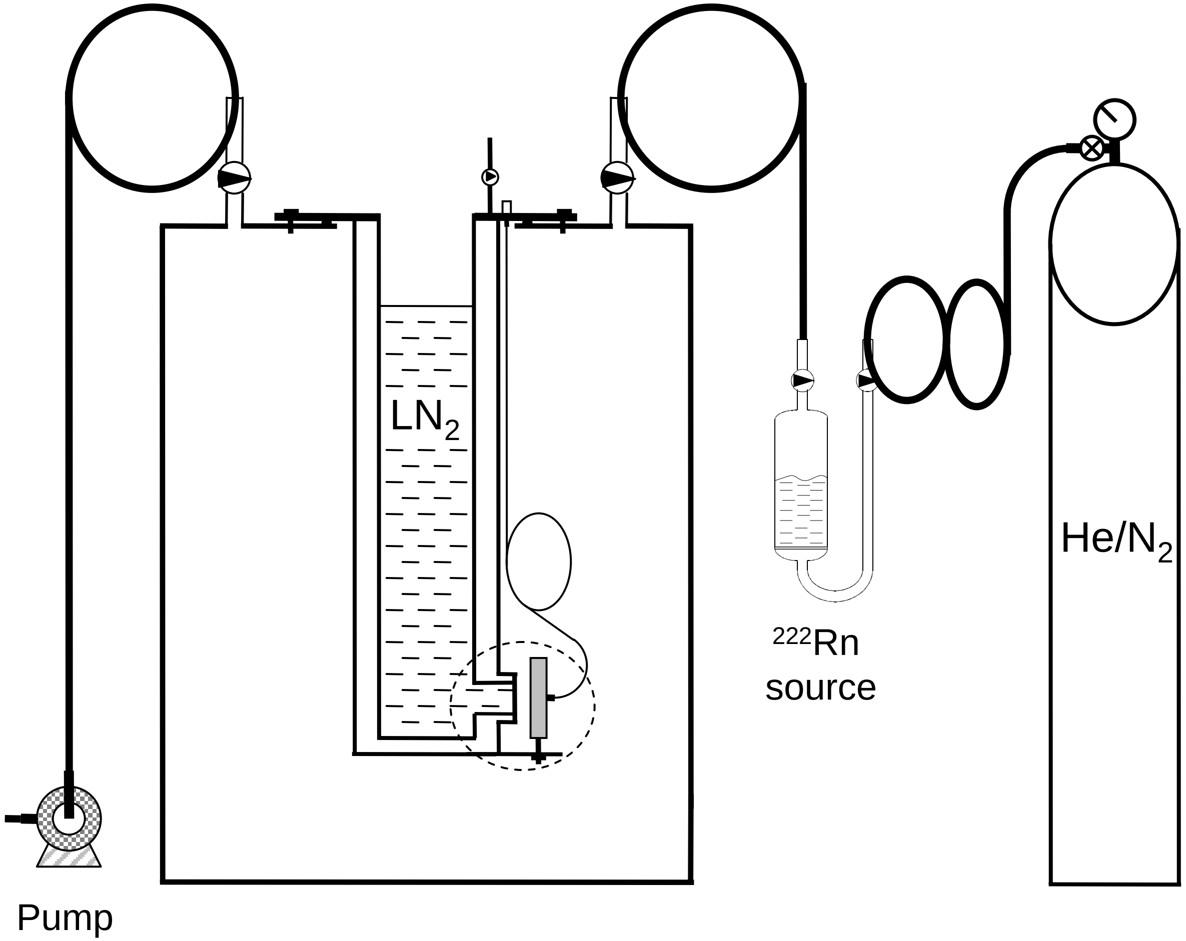


$A_D = (57.6 \pm 2.6)$ cpd

~1/3 of the ^{210}Po is deposited on the detector:
sputtering + low temperature collection

3. Performance of the cryogenic detector

3.2 Absolute detection efficiency at low pressure (~ 2 mbar)



3. Performance of the cryogenic detector

3.2 Absolute detection efficiency at low pressure (~ 2 mbar)

- Nitrogen as a carrier gas

$$\varepsilon_N = (31.2 \pm 0.9)\ \%$$

- Helium as a carrier gas

$$\varepsilon_{He} = (31.7 \pm 0.9)\ \%$$

- Average value

$$\boldsymbol{\varepsilon = (31.5 \pm 0.6)\ \%}$$

3. Performance of the cryogenic detector

3.3 Minimum Detectable Activity (MDA)

^{222}Rn detection

The design...

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$$A_0(0)_{min} = \frac{\lambda e^{\lambda t_s}\left(1+\sqrt{1+4\left(\Delta t^2 \sigma_{A_B}^2 + \Delta t A_B\right)\left(\delta^2-\delta_\varepsilon^2\right)}\right)}{2\varepsilon\left(1-e^{-\lambda \Delta t}\right)\left(\delta^2-\delta_\varepsilon^2\right)}$$

A_B – background (total)

σ_{AB} – standard deviation of A_B

ε – total detection efficiency

δ_ε – standard deviation of ε

δ – assumed measurement accuracy

t_s – time between ^{222}Rn filling and measurement start

Δt – measurement time

λ – ^{222}Rn decay constant

3. Performance of the cryogenic detector

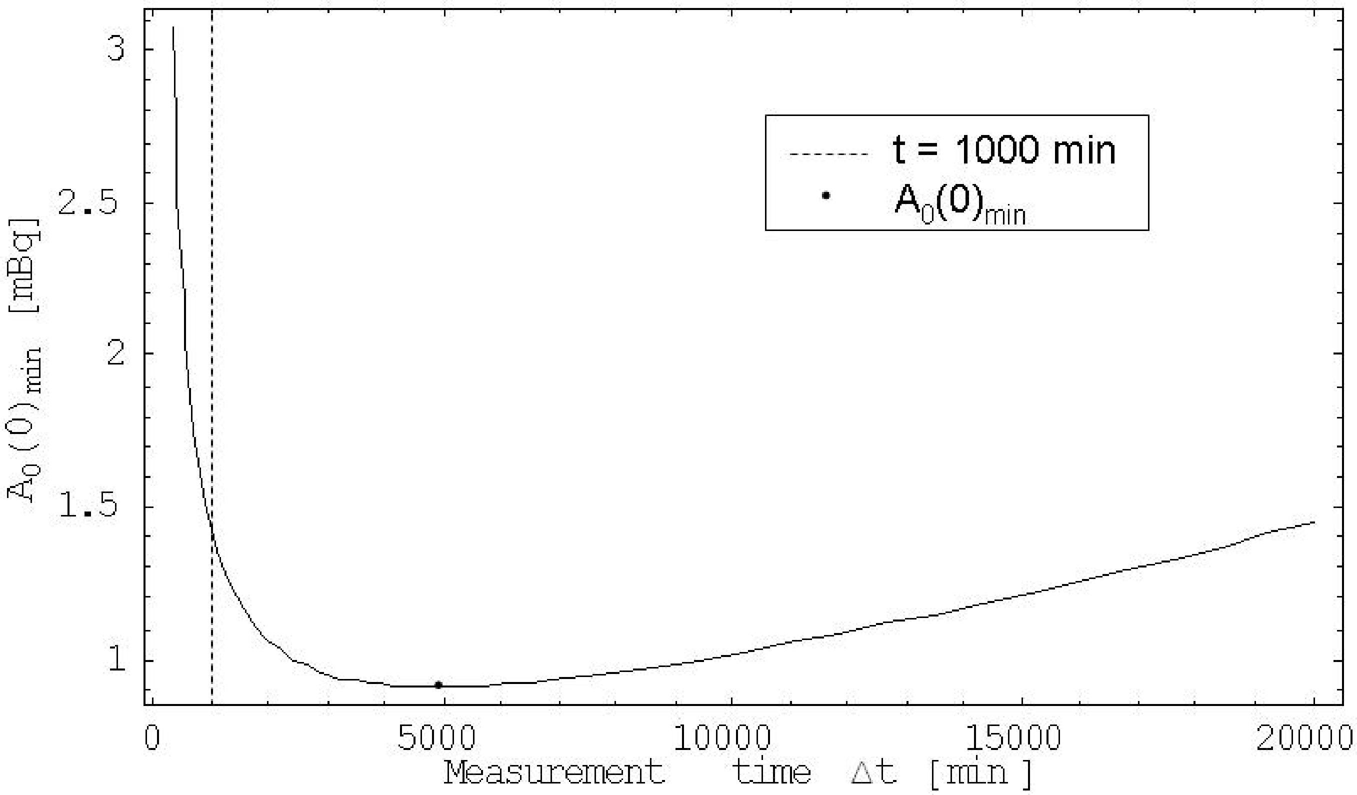
3.3 Minimum Detectable Activity (MDA) - continued

^{222}Rn detection

The design...

Performance…

Conclusions



$A_B = (24.5 \pm 3.5)$ cpd
$\varepsilon = (31.5 \pm 0.9)$ %
$t_s = 1.5$ h
$\delta = 30$ %

$\Rightarrow$ **A_{min} = 0.8 mBq (12 mBq/m^3)**

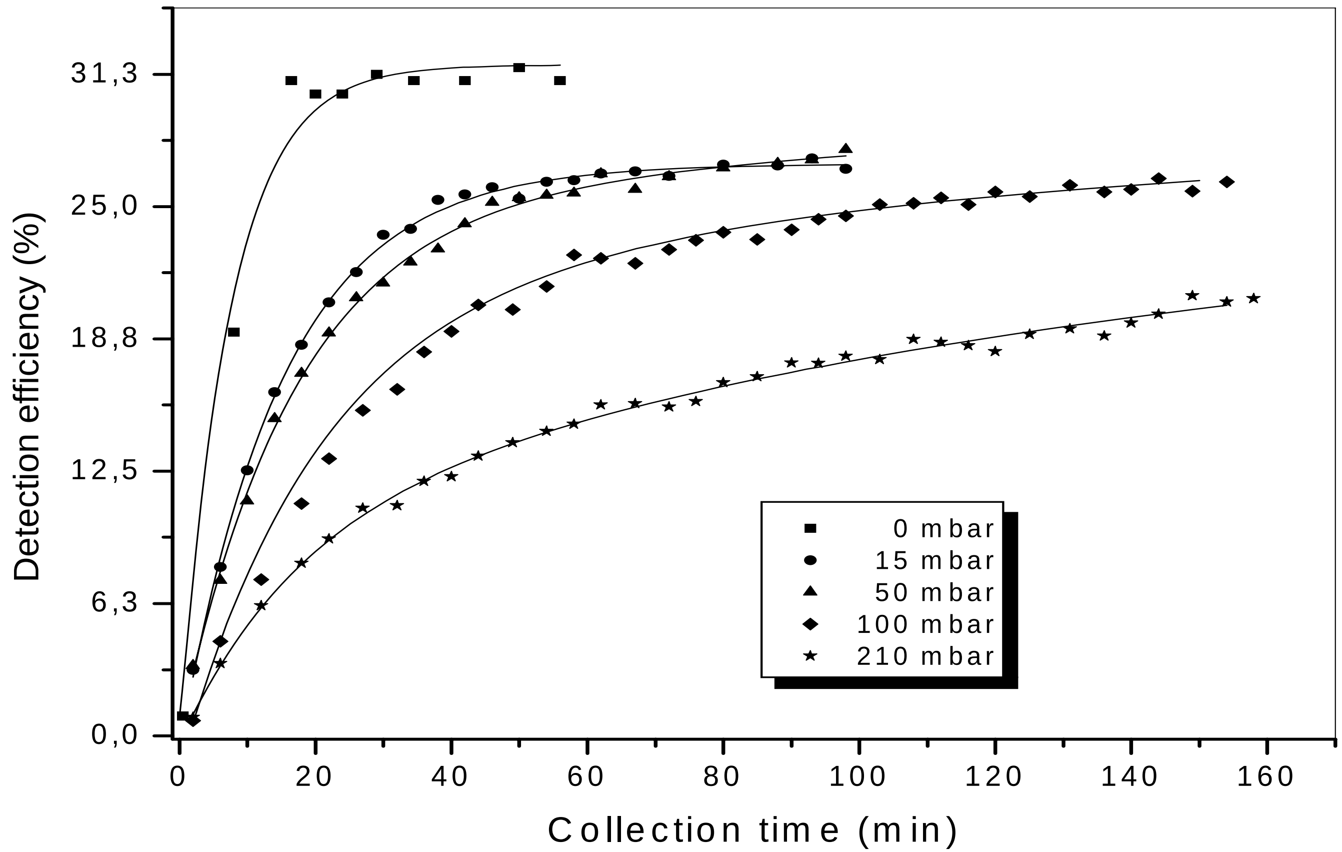
$\Rightarrow$ **A_{1000} = 1.3 mBq (21 mBq/m^3)**

3. Performance of the cryogenic detector

3.4 Detection efficiency at higher pressures

- ^{222}Rn detection
- The design...
- Performance…
- Conclusions

Nitrogen as a carrier gas

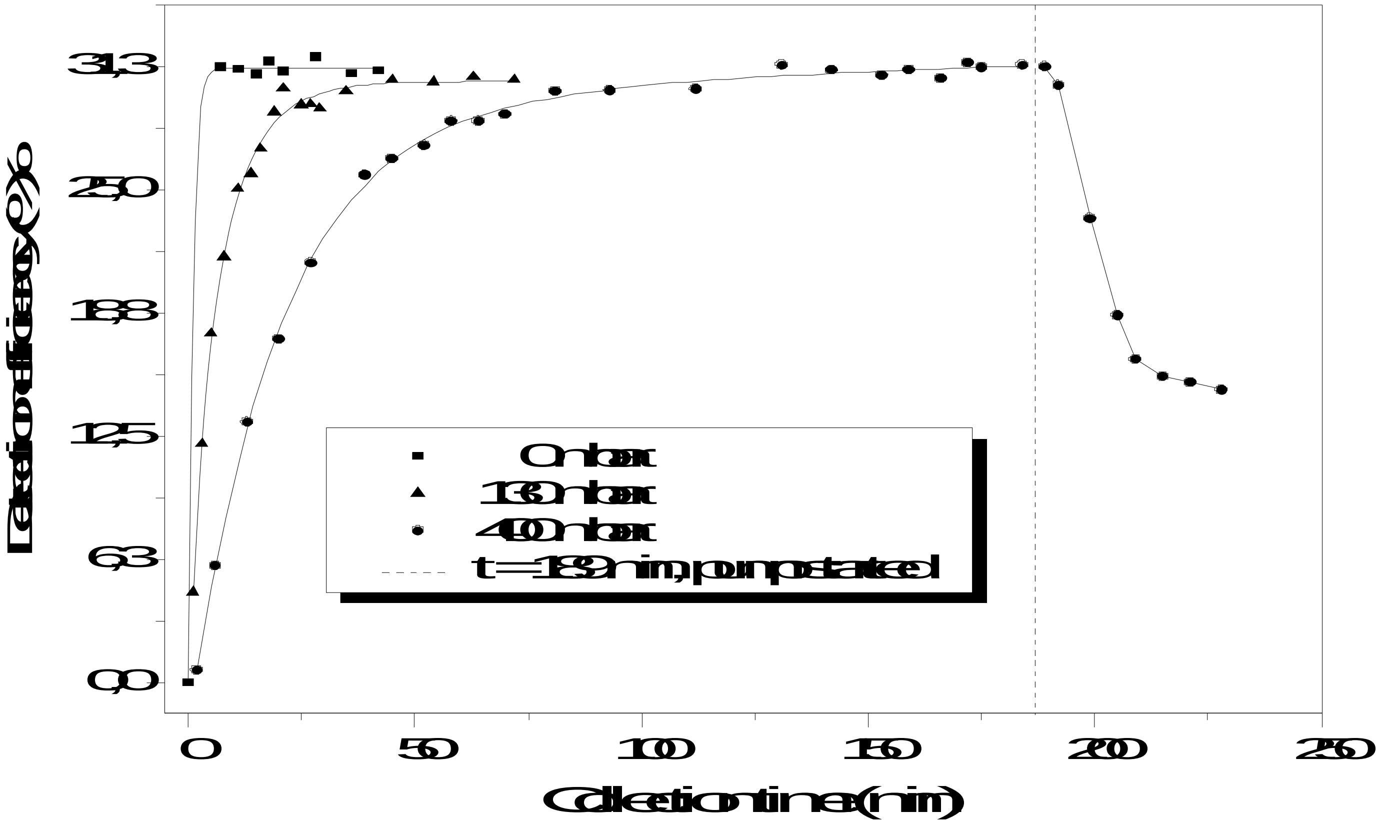


3. Performance of the cryogenic detector

3.4 Detection efficiency at higher pressures - continued

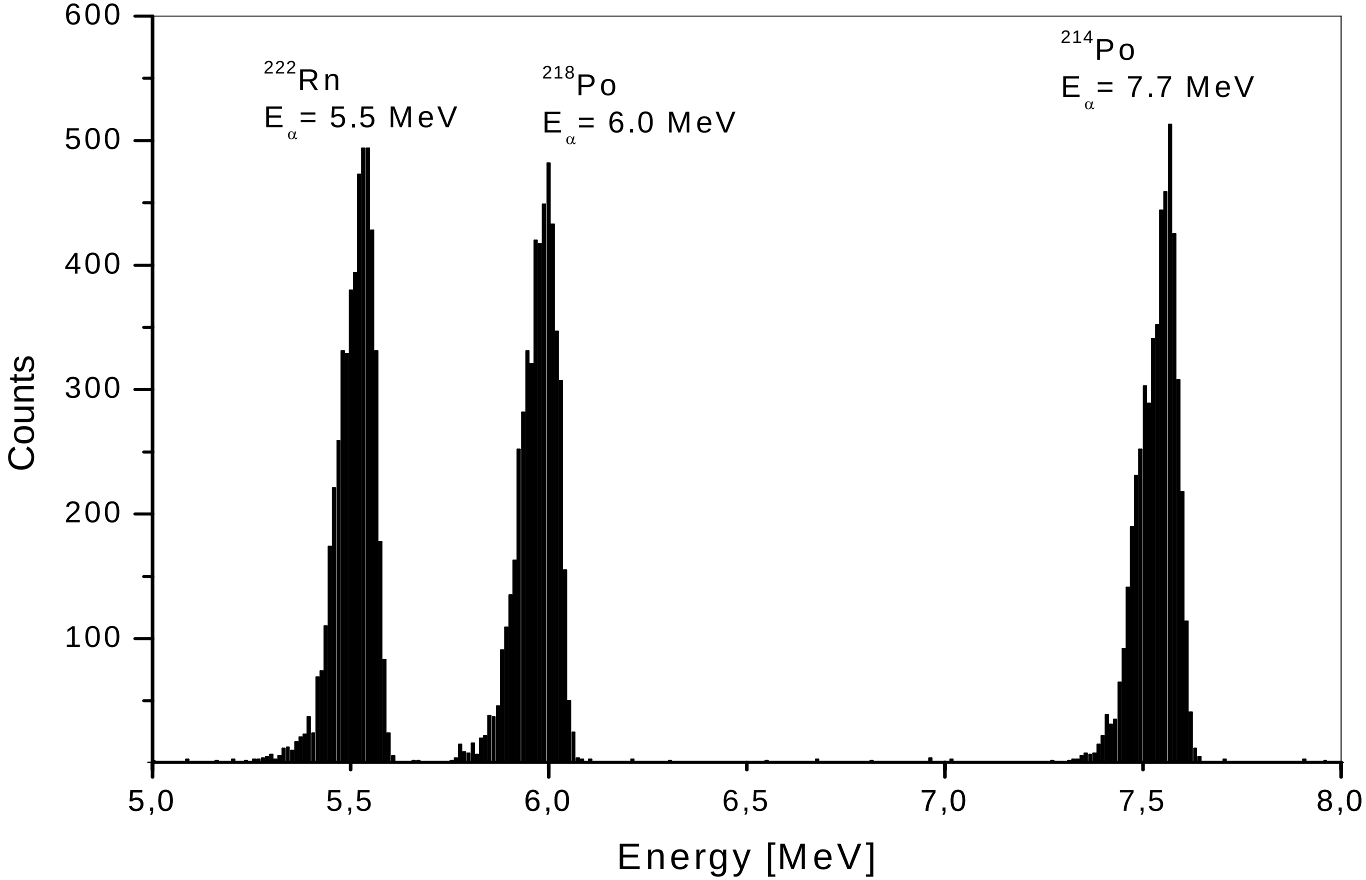
- ^{222}Rn detection
- The design...
- Performance…
- Conclusions

Helium as a carrier gas



3. Performance of the cryogenic detector

3.5 Energy spectrum



Energy resolution for ^{222}Rn: 105 keV (FWHM)

^{222}Rn detection
The design...
Performance…
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4. Conclusions

- The prototype of the cryogenic detector works as expected
- Reached sensitivity is acceptable (12 mBq/m^3) however the goal for a target detector is $\leq$ 1 mBq/m^3
- Improvement possibilities:

  - background reduction
    → careful construction and selection of materials
    → use of an ultra-low background alpha detector
  - increase of the detection efficiency
    → use of an alpha detector able to work at LN_2 temperature (smaller distances between the diode and the cold plate possible)
    → use of liquid argon for cooling (higher ^{222}Rn collection efficiency for N_2)
  - increase of the active volume of the detector up to 1 m^3
- Cryogenic detector has a possibility to measure others Rn isotopes (^{219}Rn/^{220}Rn)
- Rn emanation tests from solids can also be performed