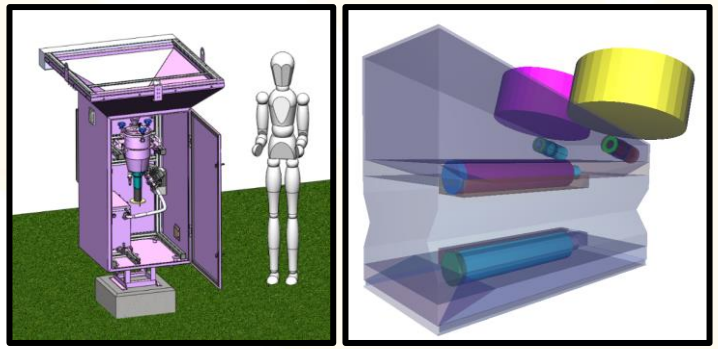
Development of the new tools for monitoring of ambient dose equivalent and rain water contamination



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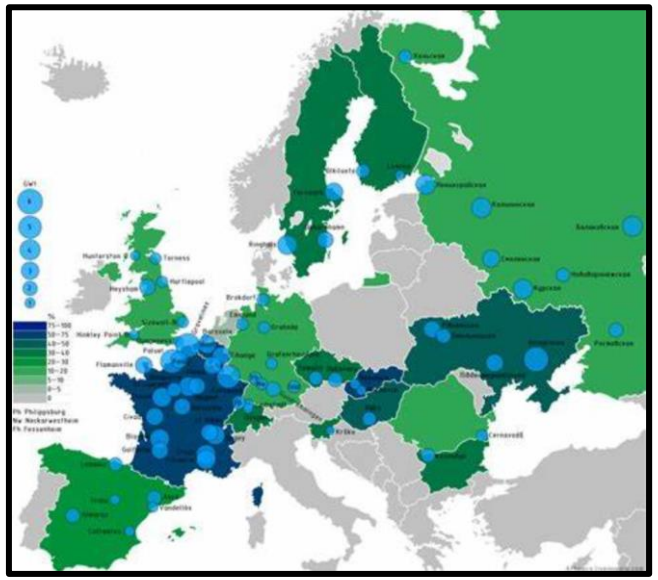
ARPS2023
EXPANDING THE SCOPE OF RADIATION PROTECTION

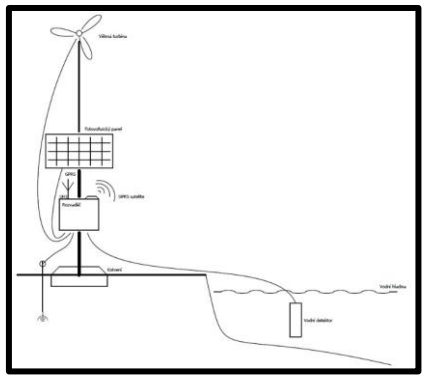
SÚRO

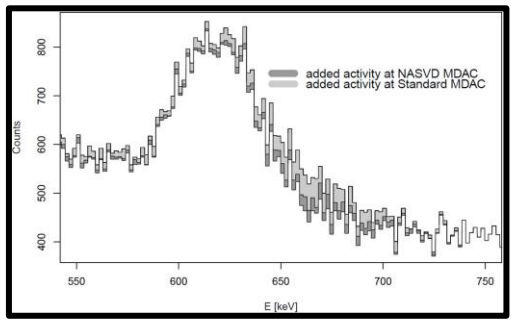


Emergency preparedness

- 171 nuclear power plant units in Europe
- emergency preparedness system trends to use of new-generation monitoring systems
- continuous, on-line, autonomous monitoring systems making decision-making process easier

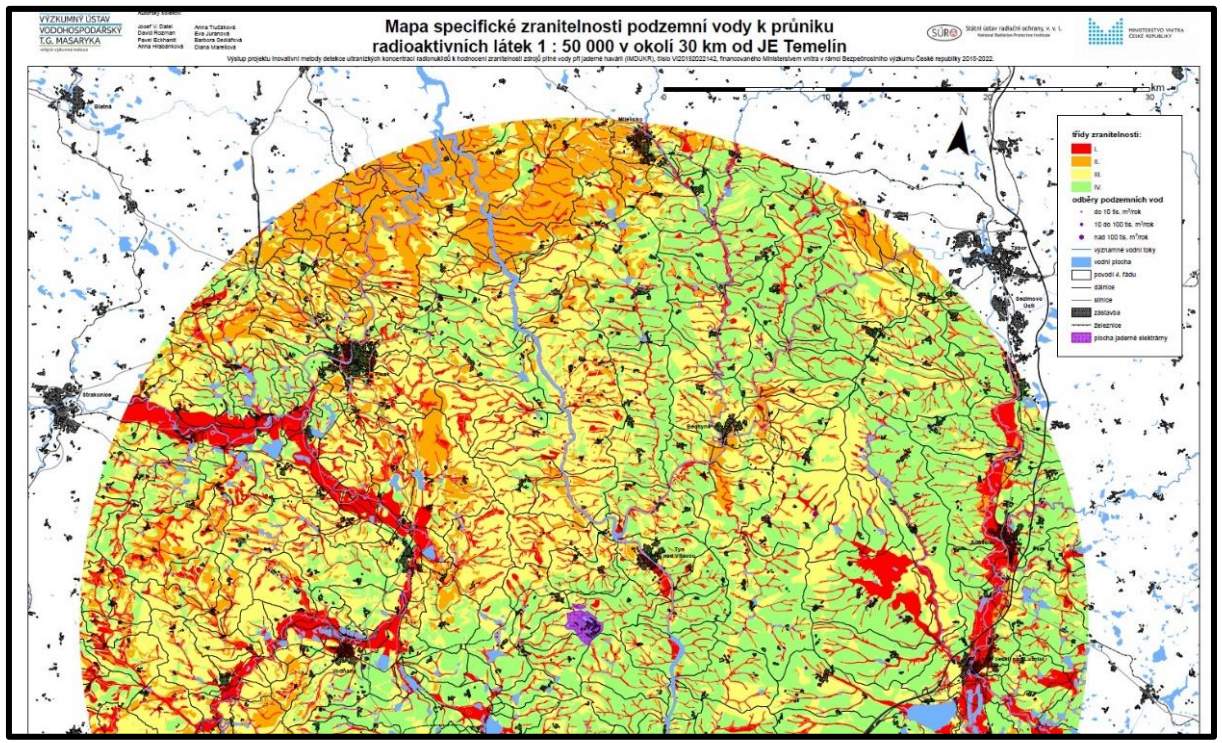
SPERA Conference 2018





SPERA 2022

Map of the specific vulnerability of aquifers



Endeavour of replacing conventional monitoring means (far future) or at least to bring additional information supporting run of the simulations of contamination dissipation (now)

RENOGEM research project funded by the Ministry of the interior of the Czech Republic

Objectives:

- ***„Using the new type scintillation crystals (CsI(Tl), GAGG+, YaG:Ce and YaP:Ce) and modern electronic components (SiPM and MCA), probes for gamma activity measurements will be assembled. These will be used as a detection unit in the facilities for emergency gamma spectrometric detection of radioactive contamination in surface water, rain water and in the air and subsequently used to construct of the monitoring network in the target environment"***

- **1) rainwater collector with continuous Gamma activity detection**
- **2) Gamma dose rate monitor distinguishing contribution from radionuclides in air and in surface contamination**

Determination of rainwater contamination

Present way of rainwater measurements:

- **SENYA Pirkko sampler separating rainwater and atmospheric fallout, chemical concentration and HPGe lab analysis**
- **normal monitoring – sampling period = 1 month**
- **emergency monitoring – sampling period shortened = 1 day to 1 week (Fukushima event.)**

Recent attempt to build automatic rainwater sampler (2013):

- **enhanced time resolution**
- **limited volume capacity of sampling bottles during strong rain**
- **reliability of valves was limited**

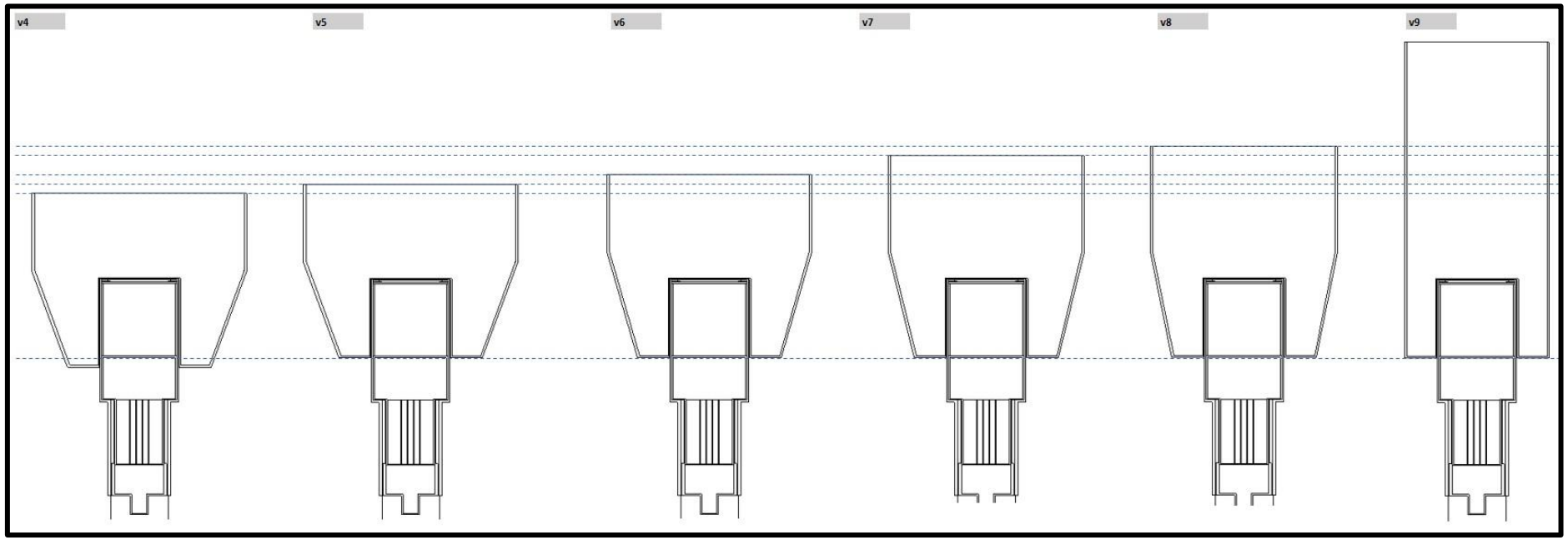
Rainwater collector – a novel structure

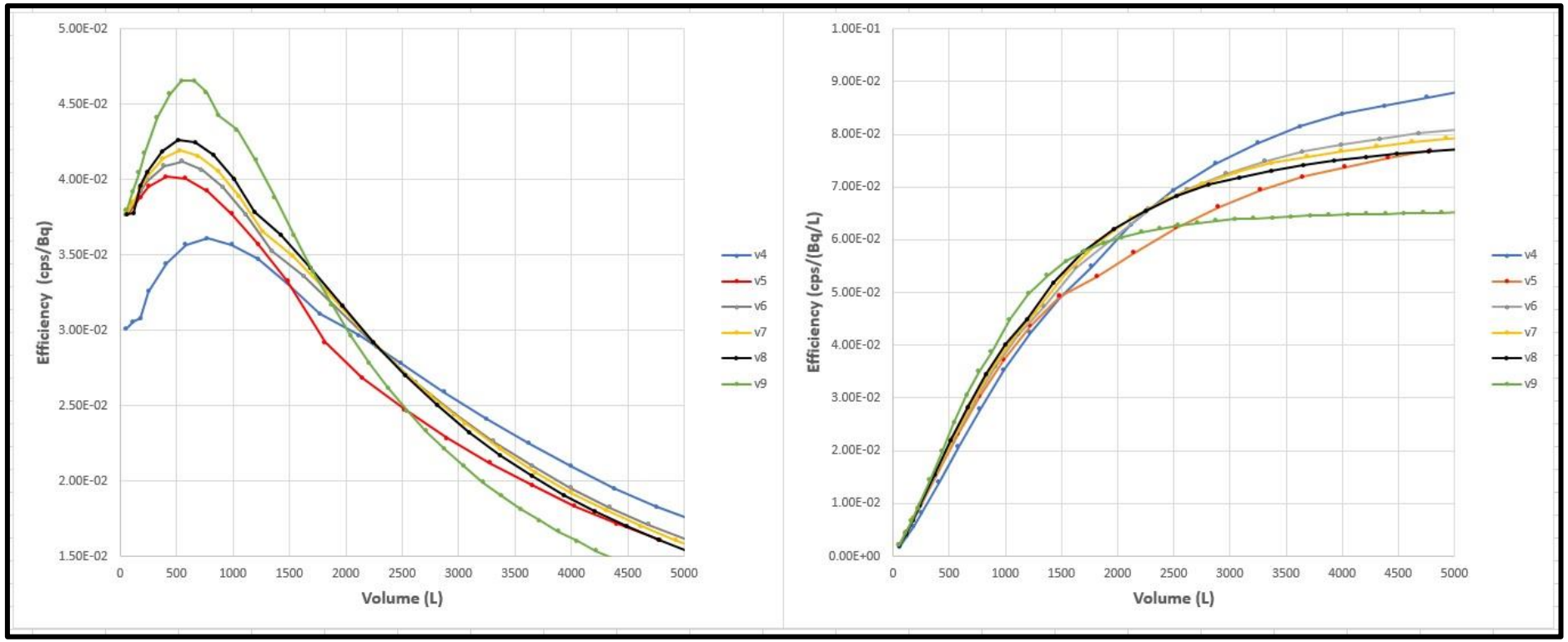
Requirements:

- **semi-continuous measurements using flow-through Marinelli beaker and 3-inch NaI(Tl)**
- **modular rate of the sample throughput**
- **Sample residence time is controlled due to rain intensity and contamination probability**
- **„maintenance – free" water sample distribution system – gravitation propulsion, clogging-resistant valve and insoluble particles elimination**
- **Temperature stabilization due to detection stability**

Marinelli beaker shape optimization:

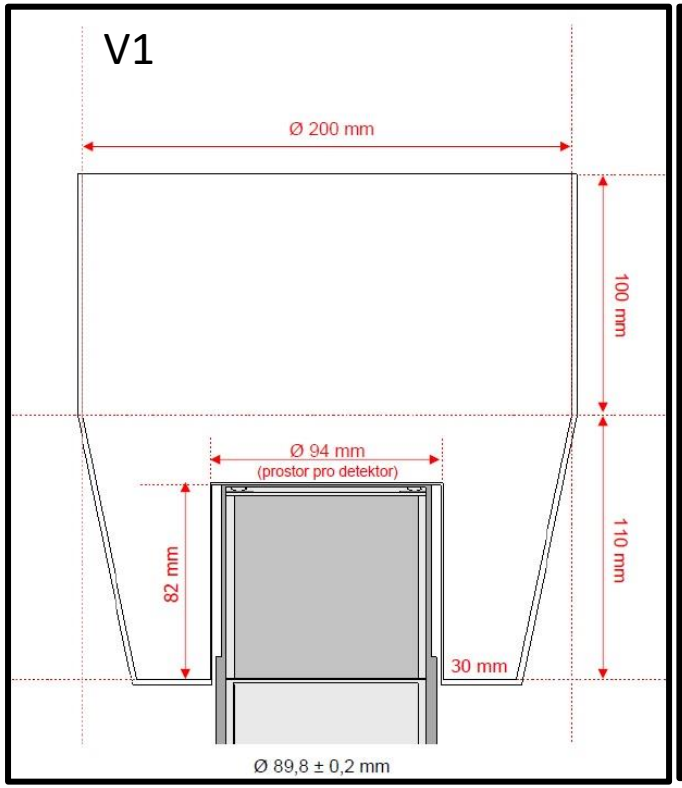
- **Chasing for the best geometry enabling high efficiency of low-volume measurements (~100mL) as well as reasonable efficiency of high volume measurements (~ 5L)**
- **Monte Carlo mathematical simulations – Cs-137 absolute and relative detection efficiency**
- **Competition between shapes advantageous for routine (wide, blunt) and emergency (narrow, sharp) measurements**

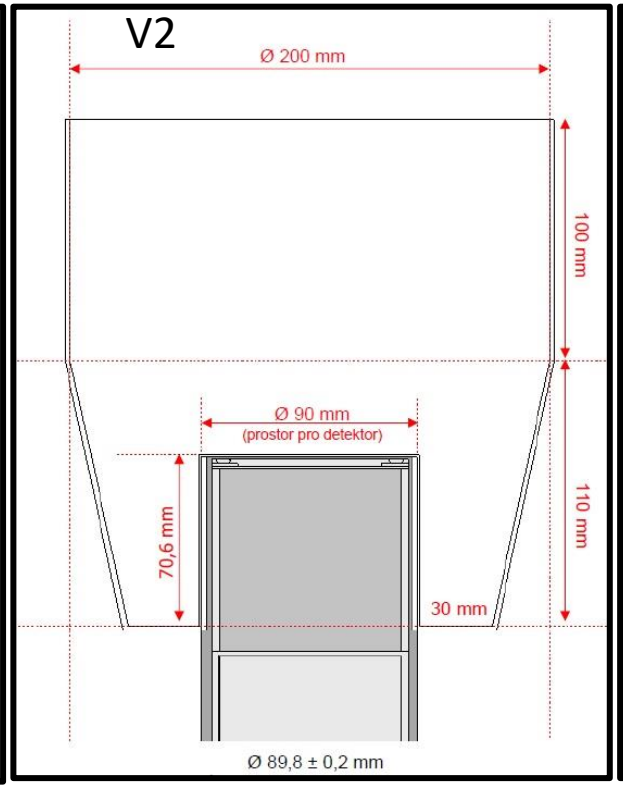

v4
v5
v6
v7
v8
v9

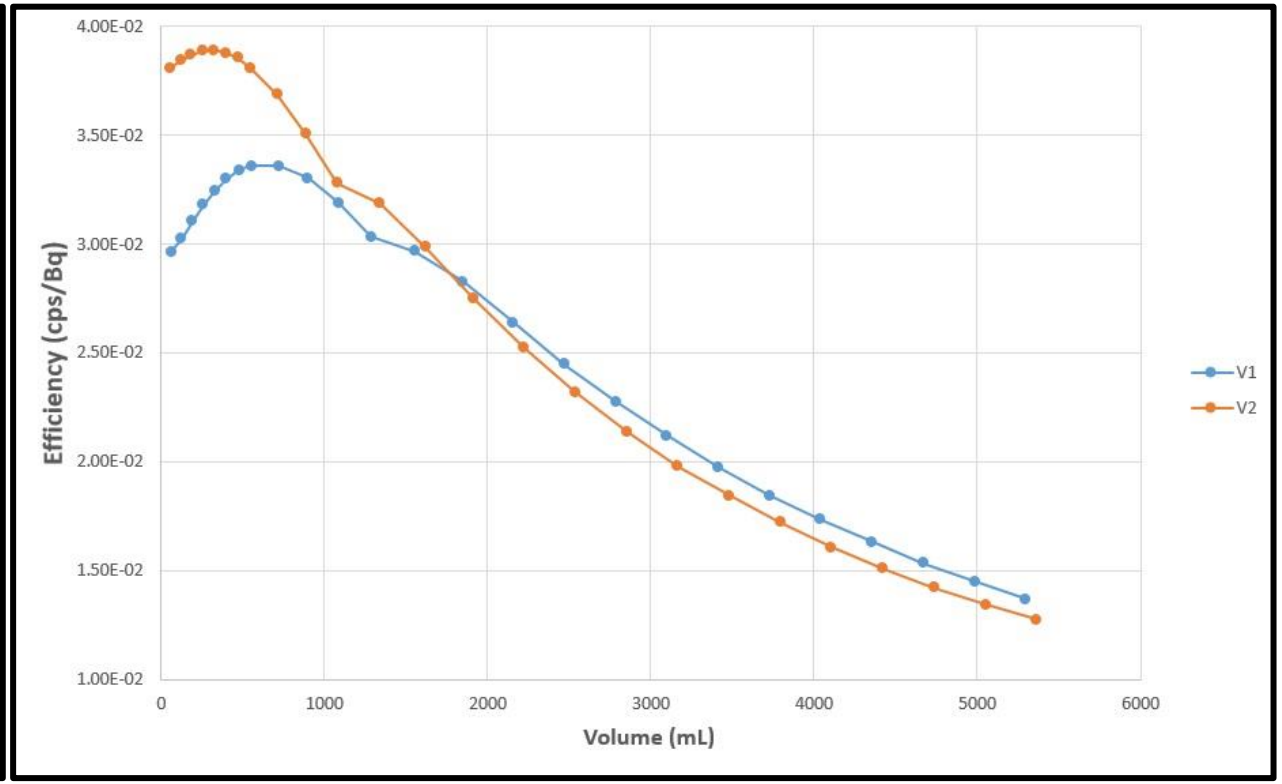

Efficiency (cps/Bq)
5.00E-02
4.50E-02
4.00E-02
3.50E-02
3.00E-02
2.50E-02
2.00E-02
1.50E-02
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Volume (L)
v4
v5
v6
v7
v8
v9
Efficiency (cps/(Bq/L)
1.00E-01
9.00E-02
8.00E-02
7.00E-02
6.00E-02
5.00E-02
4.00E-02
3.00E-02
2.00E-02
1.00E-02
0.00E+00
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Volume (L)
v4
v5
v6
v7
v8
v9

Marinelli beaker shape optimization

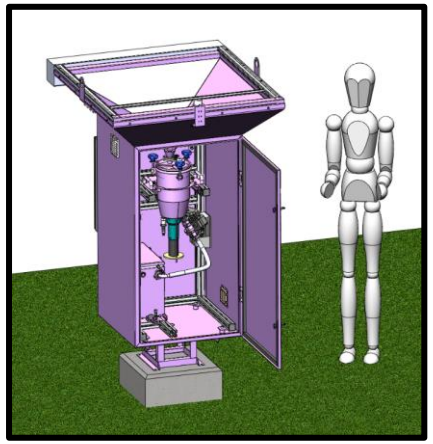
- realistic simulation: real detector shape including surface rubbing and construction material of a beaker
- V2 - shape and position are adjusted to probe cladding

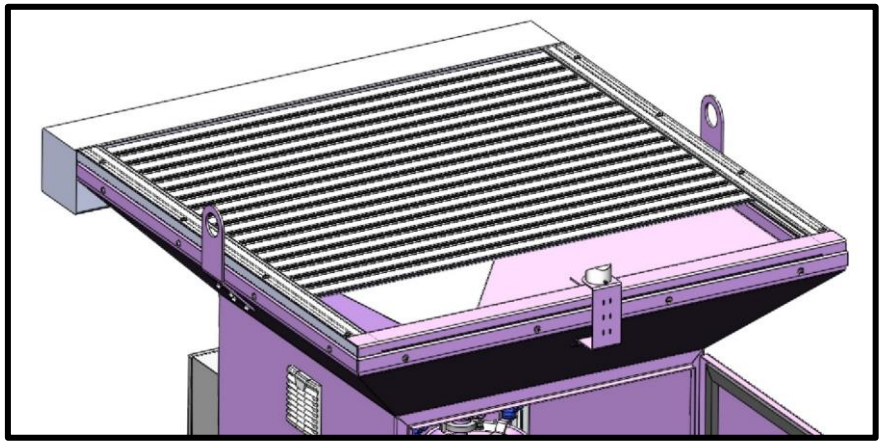






Rainwater collector – technical proposal



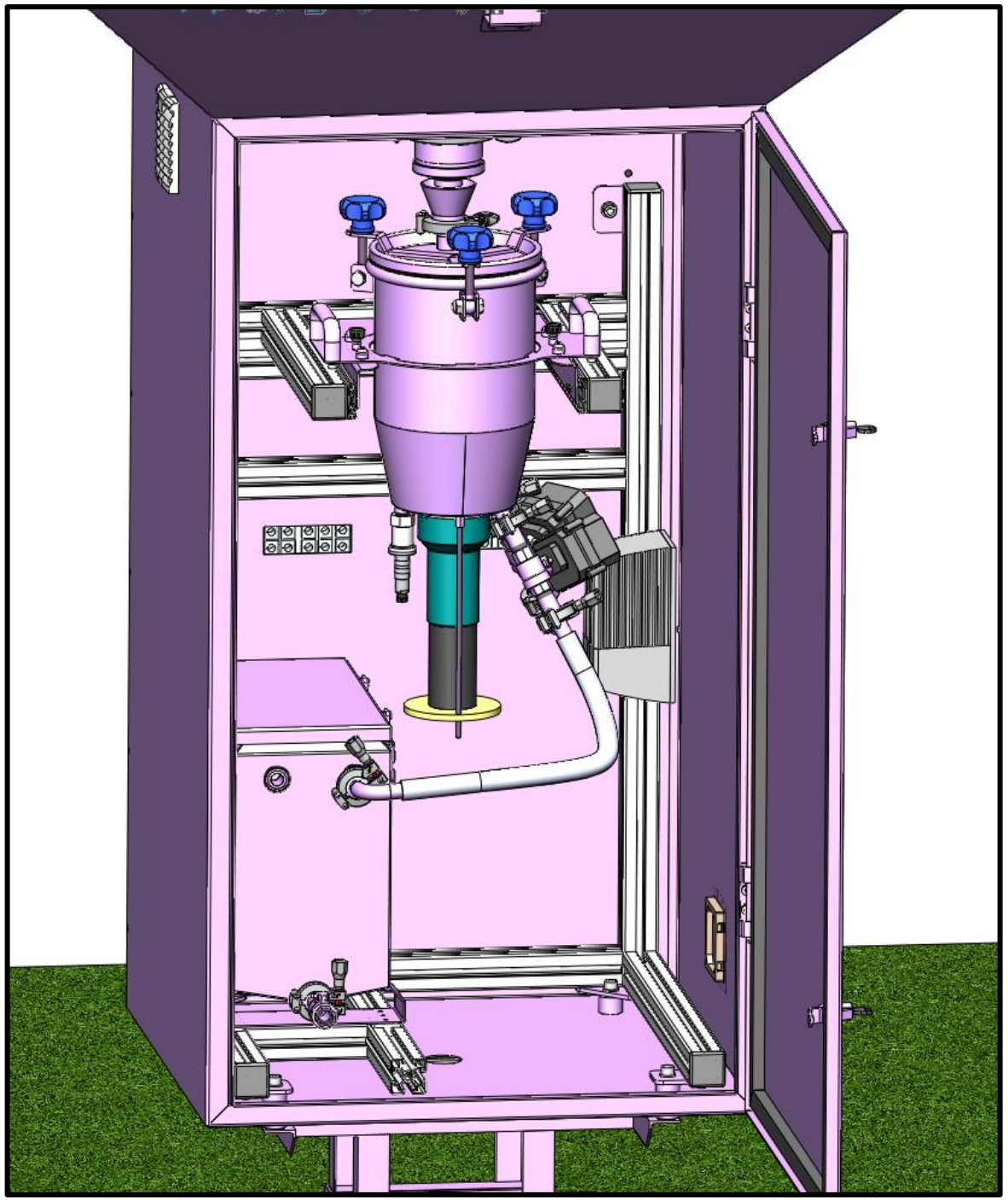


technical properties:

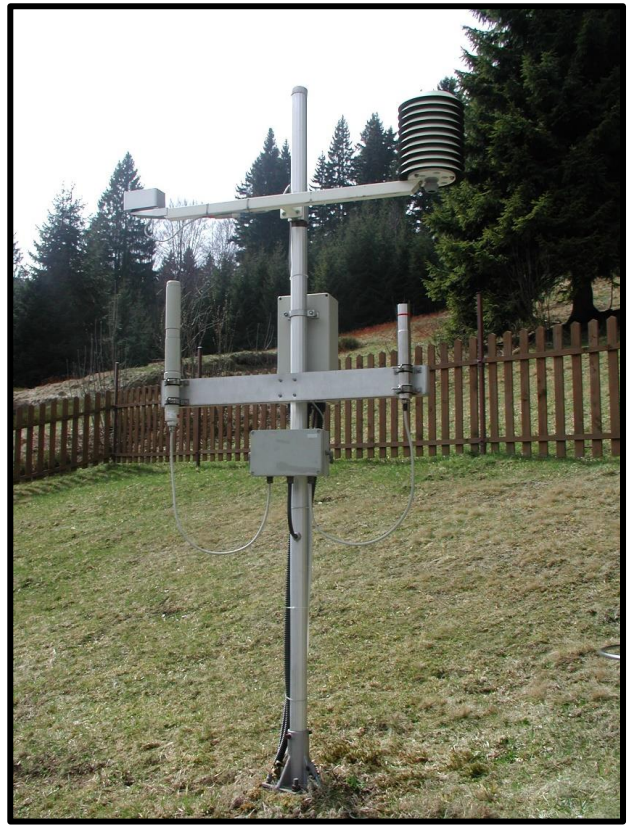
- **funnel-shaped collector with an area of 1m^2**
- **rain intensity sensor – blinder control**
- **exchangeable solid particle filter**
- **through-flow Marinelli beaker (stainless steel sheet, 5.3L volume)**
- **water level sensor (pressure)**
- **water surface and flow speed controlled by reduction valve (data from sensors of water level and rain intensity)**
- **inner temperature stabilisation (heater, vent), (~15 to 35 °C)**
- **20L end-point collector with a spillway**
- **every step controlled by SW tool**

expected benefits:

- **full-time coverage**
- **versatility of sample volume and time of measurements**



Gamma dose rate monitor



present way of Gamma dose rate measurements:

- **Early Warning Network built after Chornobyl accident**
- **5,000 station in Europe, continuous H*(10) determination**
- **ordinary station: 2 different size Geiger-Muller detectors to cover wider dose rate range (H*(10) ambient dose equivalent 20 nSv - 5 Sv per hour)**
- **in NPP local networks some of the detectors are shielded using Pb-tube to eliminate ~99% of terrestrial contribution**
- **several scintillation detectors bringing additional qualitative information**
- **literary sources report 2-detector system distinguishing photons from the air and from the ground (Casanovas et al., 2014)**

Validation by a real emergency leak:

- **~40 years of experiences, lack of experimental data**
- **real leaks were accessed mostly by aerosol samplers due to higher sensitivity**
- **even if activity increase is detected, the output can be misleading (response is not characteristic for particular contamination distribution)**

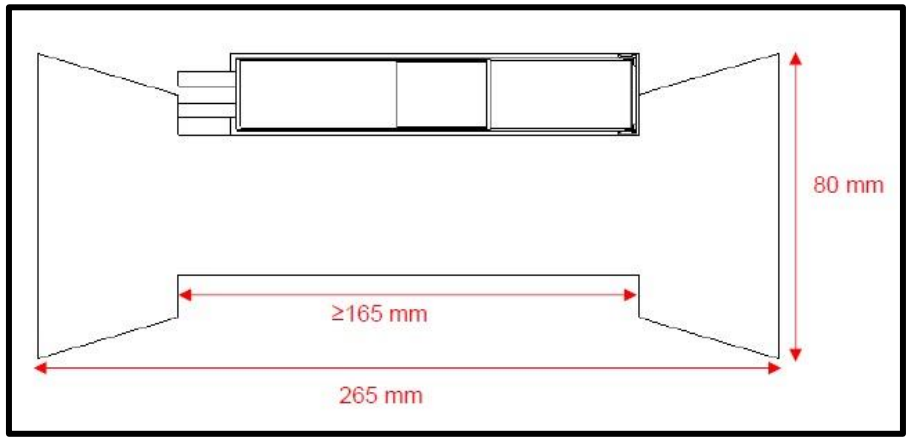
Gamma dose rate monitor – a novel structure

Objectives: to supplement present system by additional information

- **signal conversion to H*(10) is not the goal**
- **double detector device assembled from 3-inch NaI(Tl) detectors and Pb-shielding**
- **enhanced sensitivity**
- **spectrometric information**
- **distinguish distribution of contamination**

Monte Carlo mathematical simulations

- **Monte Carlo mathematical simulations**
- **definition of ideal shielding parameters for determination of terrestrial and airborne contamination**
- **>99% reduction of terrestrial or airborne contribution (E_{max} 2614 keV, ^{208}Tl)**
- **many scenarios of contamination distribution → even this spectrometric response from shielded half-space can be misleading**



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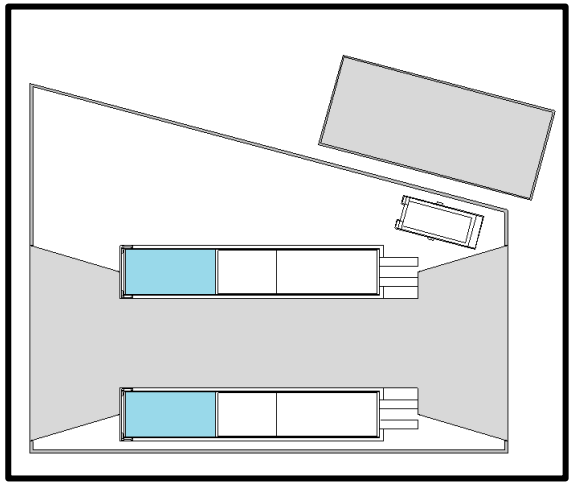
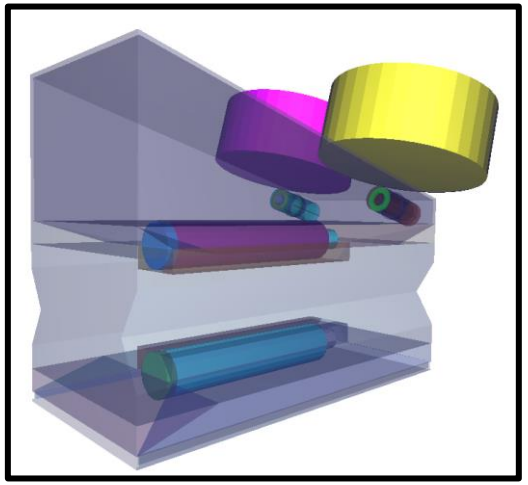
→ monitoring assembly designed to enable identification of the contamination distribution

- **2 NaI(Tl) detectors for measurements of airborne and terrestrial contamination**
- **2 GM probes as „sensor of surface contamination distribution"**
- **1. GM probe is in shade of shielding (detection of surface contamination)**
- **2. GM probe is in shade of „fake shielding" (detection of reduced surface contamination + cloud)**





- **output of GM can indicate how likely photons come from the cloud or from surface**
- **the bigger is difference in response between of 1. and 2. GM, the higher is probability that photons come from the cloud**
- **Monte Carlo mathematical simulations using a realistic scenario demonstrates that such „sensor" theoretically can work**
- only experimental measurements in an unstable background will show whether it really works

Conclusion

- **both devices are under construction**
- **1/2024 - launch of experimental measurements**
- **4/2025 – installation at monitoring sites**

Acknowledgement

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