Experimental evaluation of algorithms of collimated detectors using point source Cs-137 and Tc-99

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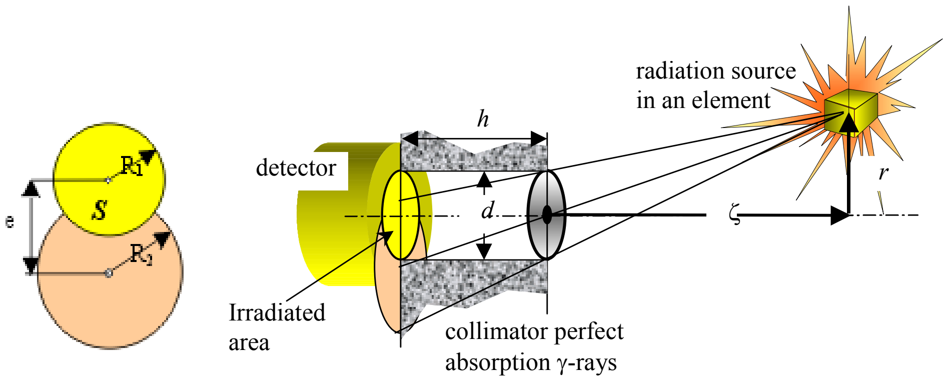
The two following algorithms suggested for evaluation of actual or numerical (CFD) experiments with collimated detectors were presented at conference ChISA 2000 by Zitny et al. Aim of this article is experimental assessment of these algorithms using point source measurement.

Collimation – simplified algorithms

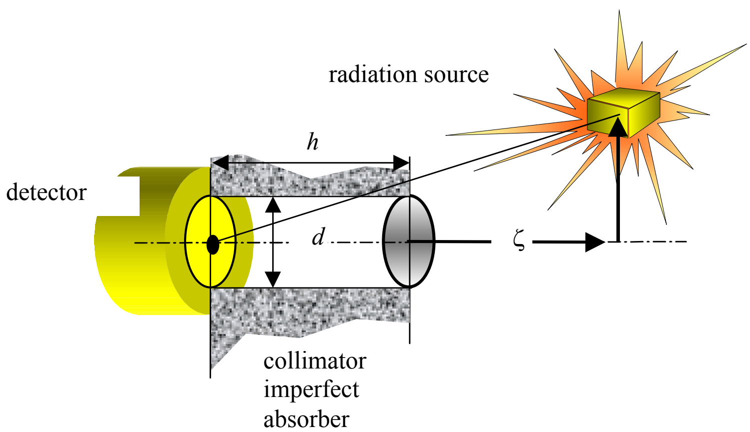
2. Compton scattering neglected
3. Perfect absorption/slim collimators

A) View factor method ("soft" radiation)



$$c_d(t) \approx J = \int_0^{\infty} \int_0^{\zeta d/h} \int_0^{2\pi} e^{-\int_0^{\sqrt{r^2+\zeta^2}} \rho\mu dl} \frac{S\zeta r}{4\pi(r^2+\zeta^2)^{3/2}} c(t, r\cos\varphi, r\sin\varphi, \zeta)\, d\varphi \cdot dr \cdot d\zeta$$

B) Single ray method ("hard" radiation)



Experimental results

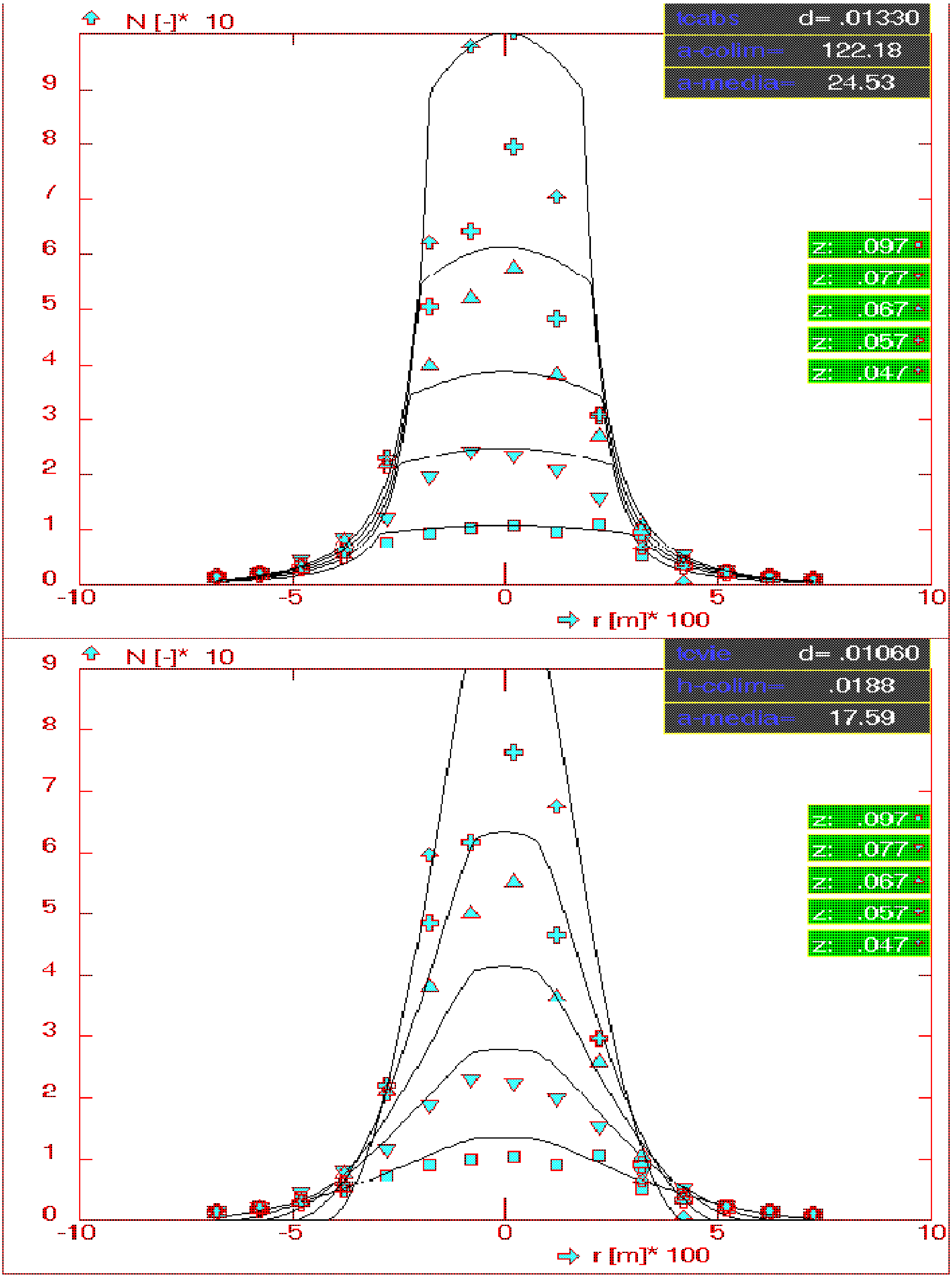
Experiments were performed with point sources
Cesium-137 high energy (t1/2=30 years, 0.511 MeV)
Technetium-99 low energy (t1/2=6 hours, 0.14 MeV)

Attenuation factors in water are a=15.5 [1/m] for Technetium and a=9 [1/m] for Cesium, according to tables.

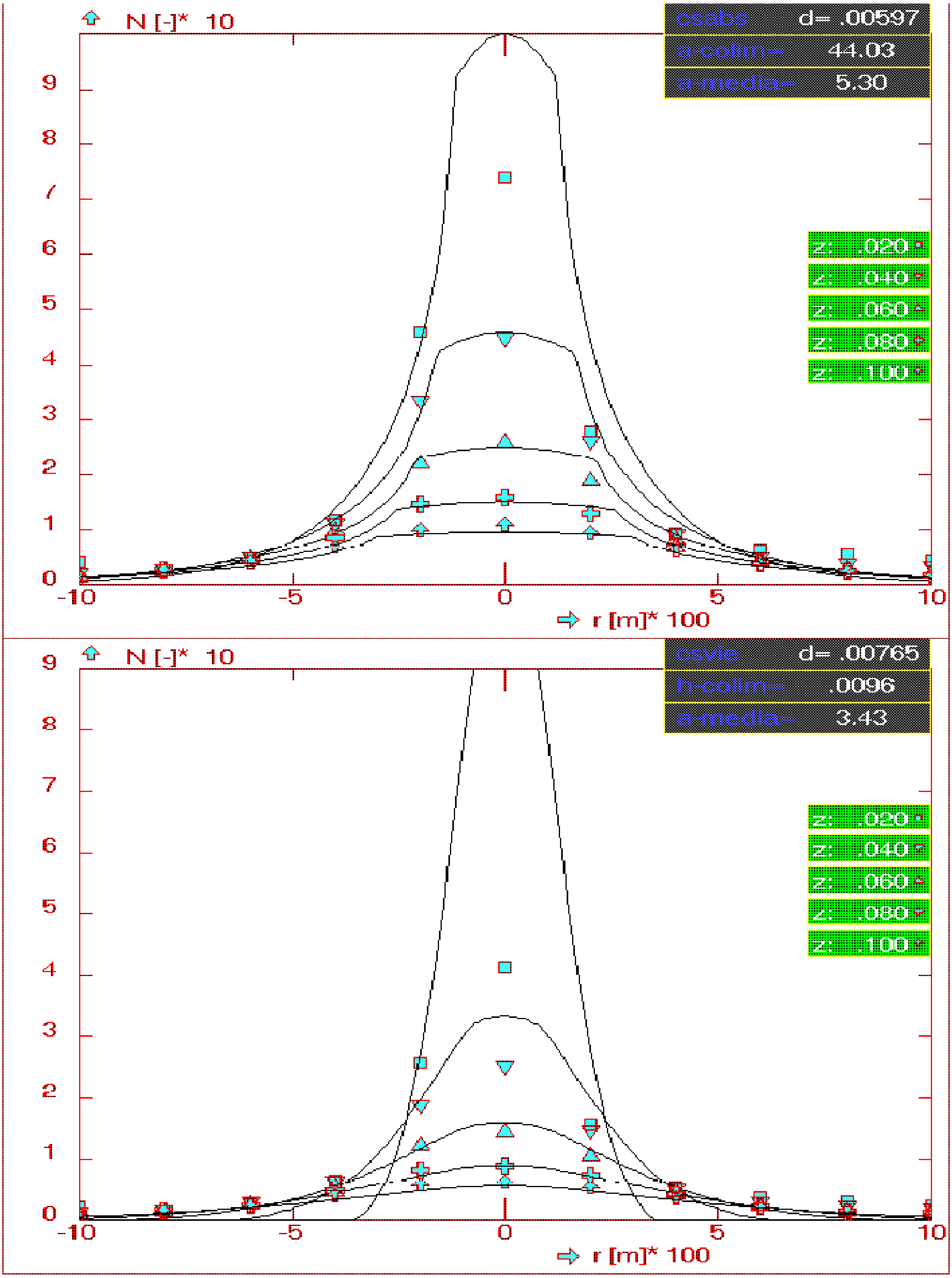
Experimental setup used in measurement with Cesium is shown in the following photograph. A similar arrangement was used for Technetium, only the positioning of point source had been improved (milling machine). Standard detectors NaI and counters were used.

Robotron 20046

Measured data points (after corrections for decay and background subraction) has been compared with prediction of previous models



Technetium – single ray method (above), view factor method (below).



Cesium– single ray method (above), view factor method (below).

Results are summarized in the following table

File	Mean deviation	Normalis. factor	h-effective thickness of collimator [m]	Effective attenuation of media [1/m]
csvie	0.0076	0.41	0.0096	3.4
tcvie	0.0106	0.96	0.0188	17.6
			Effective attenuation of collimator [1/m]	(compare 9 for Cs and 15.5 for Tc)
csabs	0.0060	0.74	44	5.3
tcabs	0.0133	0.99	122	24.5

Results confirm working hypothesis, that the view factor method is more suitable for soft radiotracers, while the single ray method is better for hard radiation.

In our case, the error of measurement is always higher using technetium (probably due to higher noise corresponding to low activity of source). However if we compare quality of approximation for cesium we find that deviation of view factor prediction (0.0076) is higher and worse than the single ray prediction (0.0060). In the case of softer radiation (technetium) the situation is reversed and view factor method is better (deviation 0.0106) than the one ray prediction (higher deviation 0.0133).

The both algorithms were applied for comparison with experimental data with parameters identified by regression – optimized parameters are effective thickness of collimator, attenuation in material of collimator and media. It is seen that the effective thickness of collimator (approx. 1 cm for cesium and 2 cm for technetium) is lower than the nominal thickness 3 cm and this is logical – lower thickness artificially increases the view angle and thus compensates the negative effect of imperfect absorption of radiation in collimator.

So that the proposed methods could be applied in praxis, the values of effective geometry of collimator and/or effective attenuation coefficients must be known in advance. These values can be derived from actual geometry and material of collimator and from energy of radiation. For example the effective thickness can be calculated using simple (and quite empirical) correlation

$$H_{eff} = H \exp(-E / E_o)$$

where H is nominal thickness of collimator and E is energy of radiation (in MeV), E_0=0.41.