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Review of the A_1 and A_2 values: impact of all radiations on Q_A and Q_B

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Introduction

The A_1 and A_2 values of the Q System, described in the advisory material SSG-26, have been developed to provide maximum allowable contents in packages not designed to withstand accidents. Current values were determined in 1996 according to specific scenarios for five exposure pathways. Since then, the ICRP has published revised radiological data. In September 2013, an international group was created to discuss the improvement of calculation methods described in the Q system.

Within this framework, it has been decided to change the current deterministic and empiric method to a more accurate one, based on Monte-Carlo calculations. This evolution allows the working group to be more flexible and to get more accurate results, for instance by taking into account all particles created.

Hereafter are presented the changes in Q_A and Q_B assessments, and the impact on Q_A , Q_B and A_1 values.

Q_A

Method

	Current approach	New approach
Radiations	γ only	All radiations (β , γ , neutrons, positron, discrete electronic radiations)
Type of source	Point source	Point source
Distance from the source	1 meter	1 meter
Shielding	No shielding	Shielding: 0.5 mm of stainless steel (316L) (by consistency with Q_B)
Target	Whole body	Whole body
Calculation method	Air attenuation Exponential formula, with build-up	Air and shielding attenuation Monte-Carlo calculations
Dose coefficient	ICRP 51 : effective dose [1]	ICRP 116 : effective dose [2]

Results for some radionuclides

	Q_A (IRSN's proposal) (TBq)	Q_A (current) (TBq)	Relative deviation
Co-60	0.44	0.45	-2%
Cs-134	0.69	0.69	0%
Eu-154	0.88	0.90	-2%
Ir-192	1.37	1.30	5%
F-18	1.09	1.00	9%
Kr-85	333	480	-31%

Contribution of each source of emission : β , γ , neutrons, positrons, discrete electronic radiations

99 % of the total dose is due to gamma rays

Consistency between current and new values

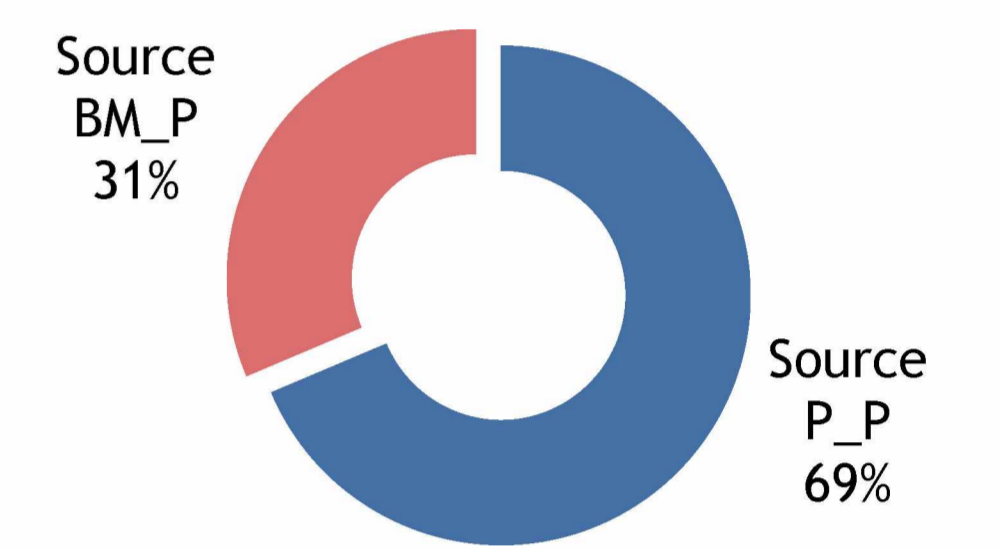
β^+ emissions properly taken into account with MC method :
 • 99.6 % of the total dose comes from gamma rays resulting from interactions between matter and positrons
 • 0.4 % of the total dose comes directly from electronics radiations (electrons/positrons).

Kr-85 source rays:

- low gamma emission rate: 0.5% of ~ 500 keV gamma/nuclear transformation
- 100 % of beta emission/nuclear transformation (average energy: ~ 250 keV)

Contribution of each radiation for ^{85}Kr case :

- SourceP_P: photon dose due to photon emission, i.e. primary photon
- SourceBM_P: photon dose due to beta minus emission (interaction ray- matter)



Q_B

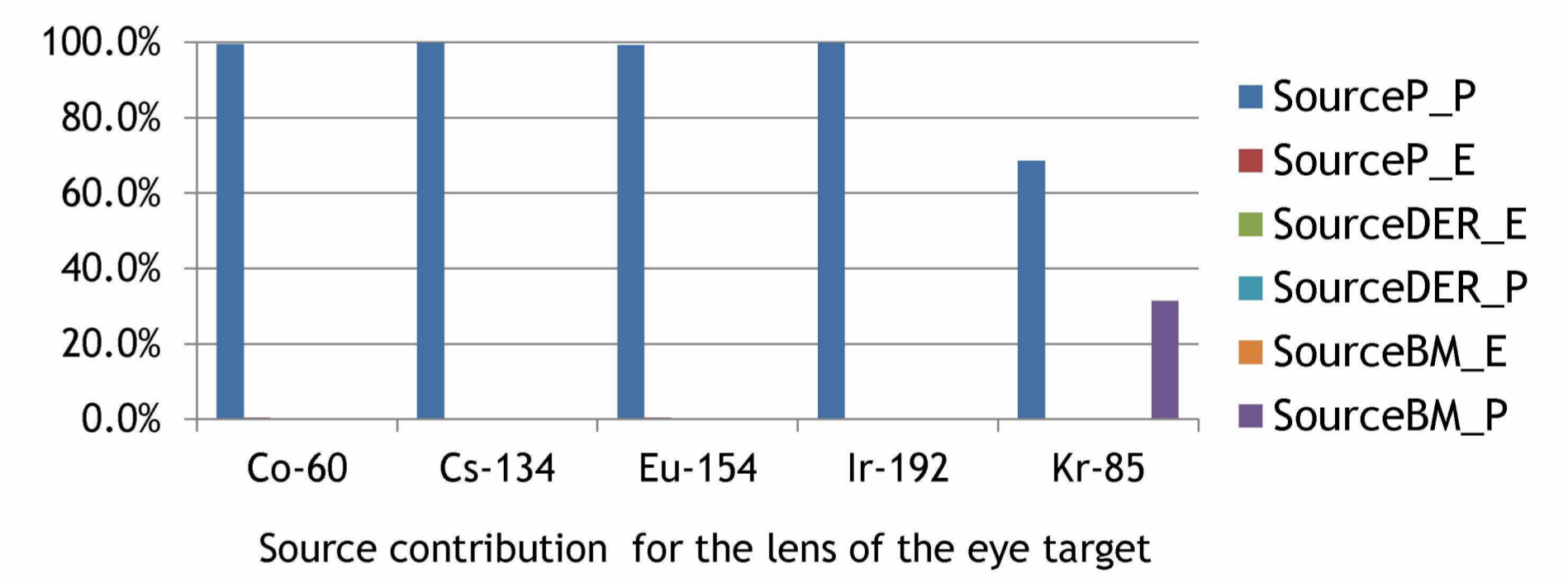
Method

	Current approach	New approach
Radiations	β only	All radiations (β , γ , neutrons, positron, discrete electronic radiation)
Type of source	Point source	Point source
Distance from the source	1 meter	1 meter
Shielding	Remnant shielding (150 mg/cm ²)	Remnant shielding: 0.5 mm of stainless steel (316L)
Target	Skin	Skin Lens of the eye
Calculation method	Shielding: cf. fig. 1 below Empirical formula	Air and shielding attenuation Monte-Carlo calculations (fig. 2)
Dose coefficient	Cross & al. skin dose coefficients [3] [4]	ICRP 116 skin dose coefficients IRSN skin dose coefficients for photons and neutrons [5]

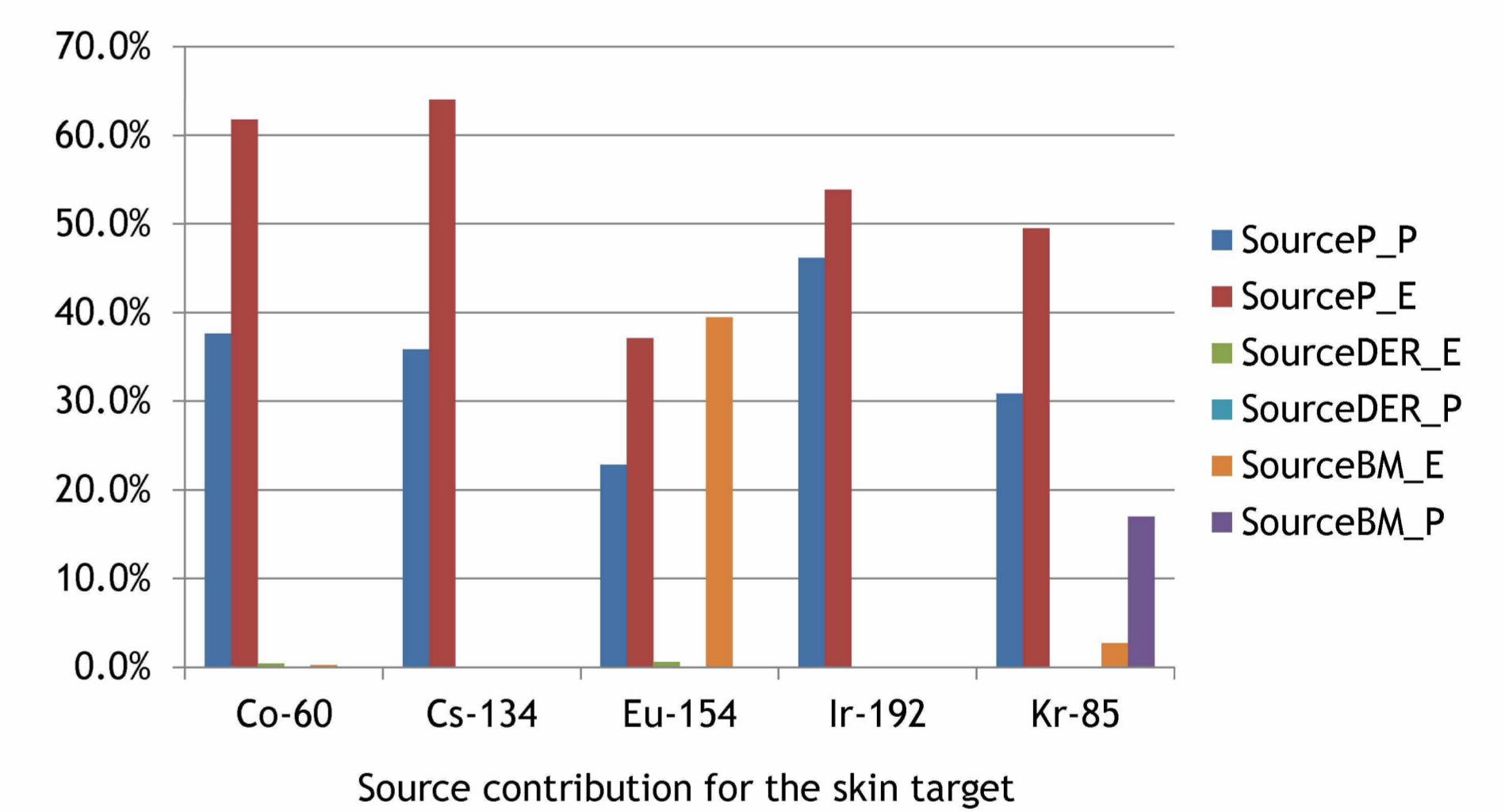
Results for some radionuclides

Nuclide	$Q_{B,skin}$ (IRSN's proposal) (TBq)	$Q_{B,eye}$ (IRSN's proposal) (TBq)	Q_B (Current) (TBq)
Co-60	2.6	1.1	730
Cs-134	3	1.7	3.6
Eu-154	2.6	2.2	1.6
F-18	4.5	2.6	28
Ir-192	6	3.4	46

Contribution of each source of emission: β , γ , neutrons, positrons, discrete electronic radiations



For the lens of the eye, almost all of the dose comes from the primary photons (SourceP_P)



Except for ^{18}F , over 80% of the dose comes from photon source (SourceP) :

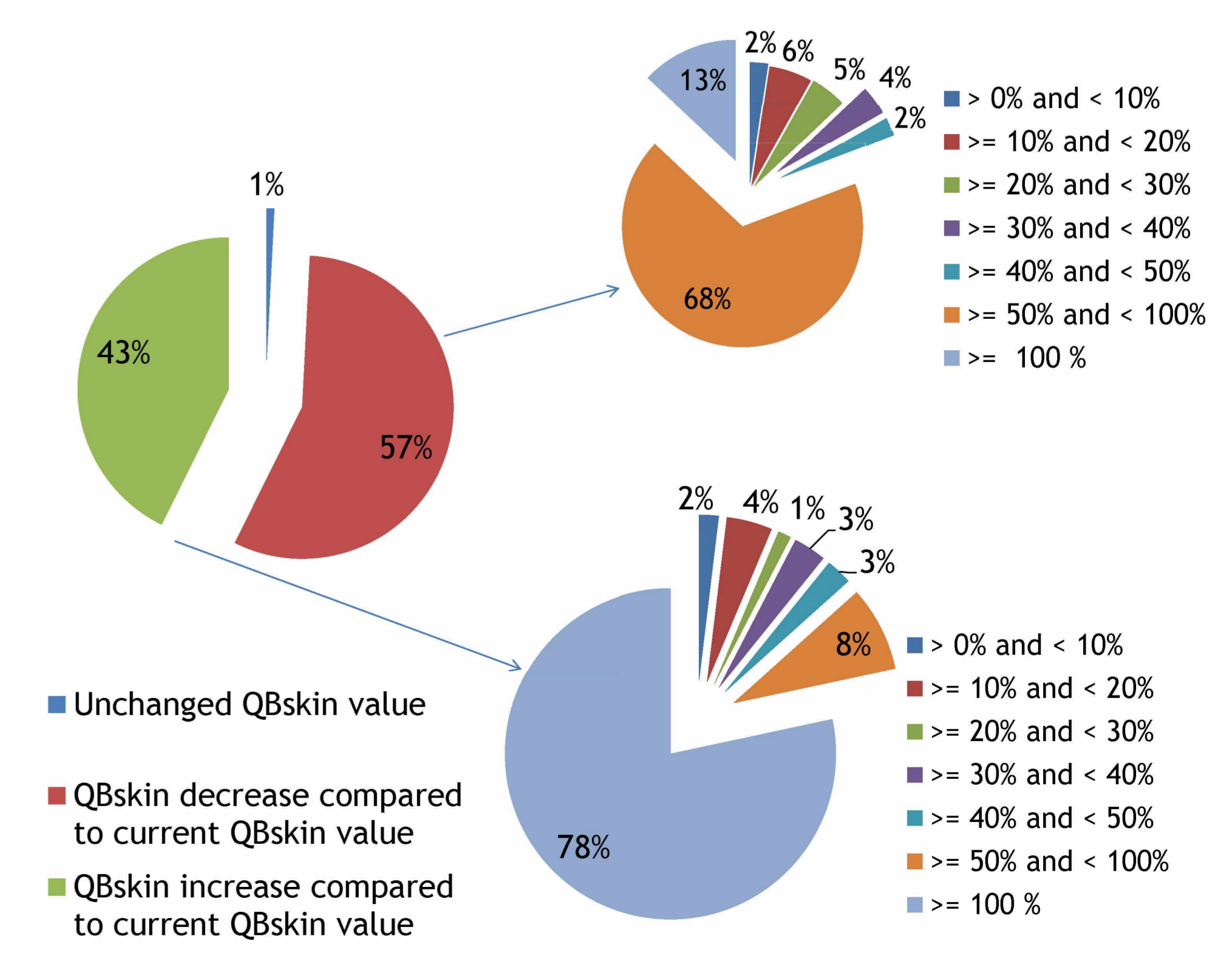
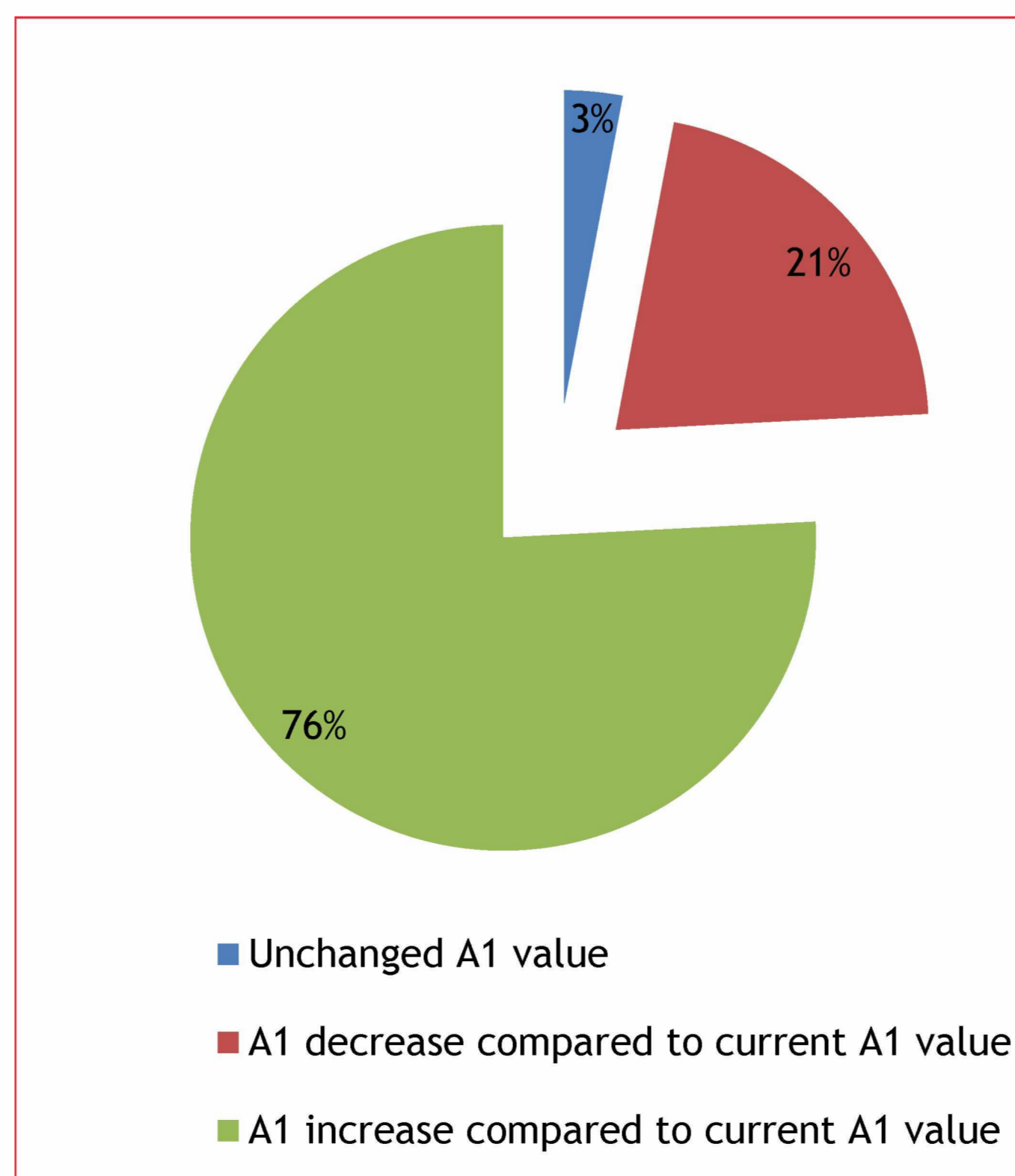
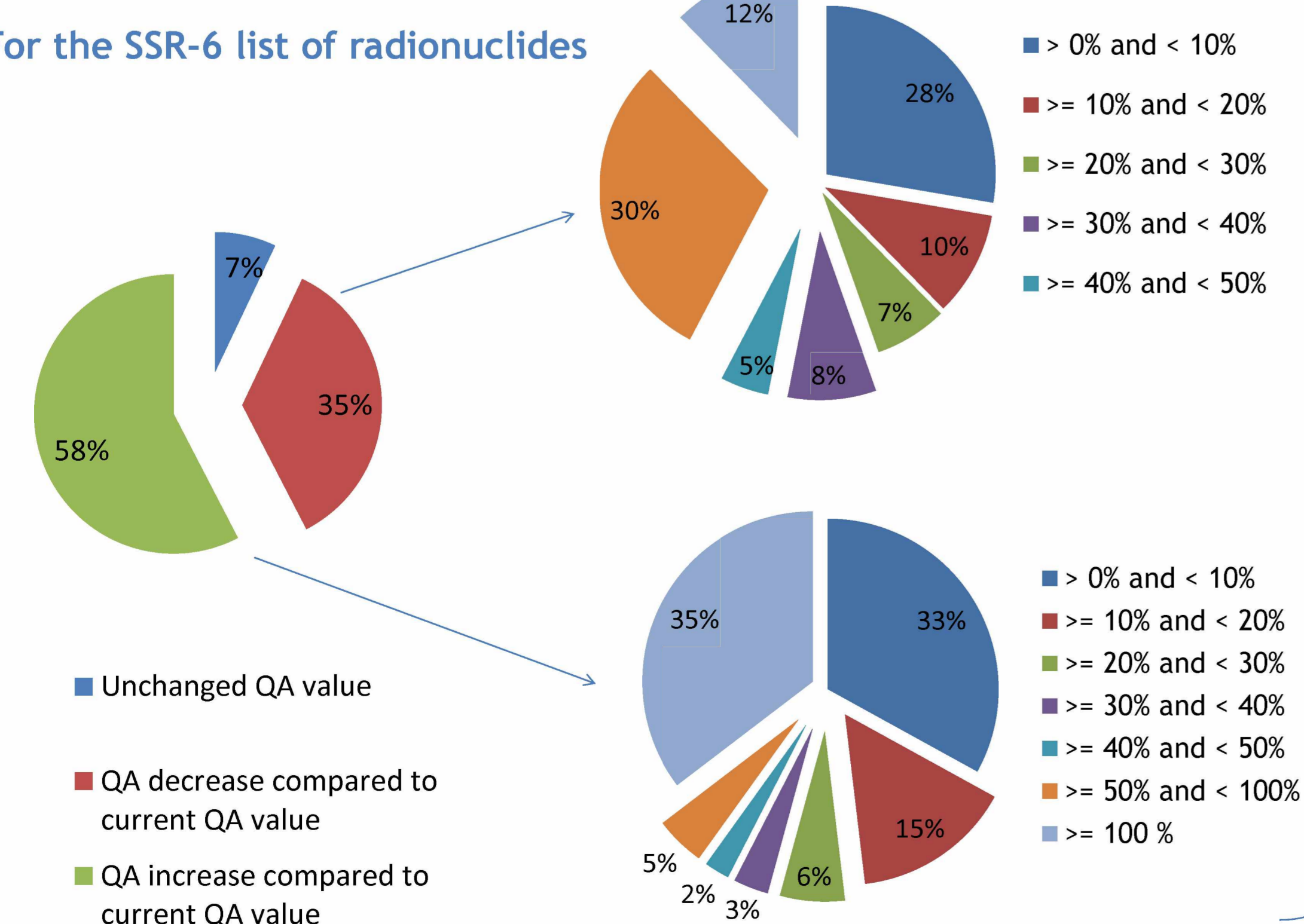
- almost half is due to photons (i.e. primary particles, SourceP_P)
- the other part to electrons (i.e. secondary particles, SourceP_E)

It is important to underline that the photon source contribution is not considered in the current Q_B values and tend to legitimate the new WG's philosophy.

For the SSR-6 list of radionuclides, new calculations show that dose to the skin is always limiting

Conclusions & outlooks

For the SSR-6 list of radionuclides



[1] ICRP, Data for Use in Protection against External Radiation. ICRP Publication 51. Ann. ICRP 17 (2-3), 1987

[2] ICRP, Conversion Coefficients for Radiological Protection Quantities for External Radiation Exposures. ICRP Publication 116, Ann. ICRP 40(2-5), 2010

[3] CROSS, W.G., ING, H., FREEDMAN, N.O., WONG, P.J., Table of beta-ray dose distributions in an infinite water medium, Health Phys. 63, 1992

[4] CROSS, W.G., ING, H., FREEDMAN, N.O., MAINVILLE, J., Tables of Beta-Ray Dose Distributions in Water, Air, and Other Media, Rep. AECL-7617, Atomic Energy of Canada Ltd, Chalk River, ON, 1982.

[5] J. Bez, S. Thomas, B. Louis : Review of the A_1 and A_2 values: an overview of the new calculation method, Paper No. 1403, Packaging and Transportation of Radioactive Materials Proceedings of the PATRAM 2019 symposium, New Orleans, LA, USA, 2019