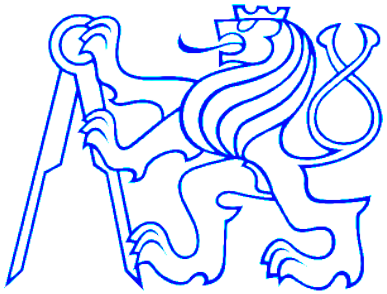
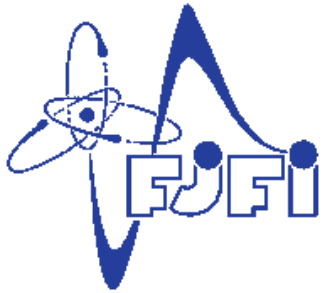
CZECH TECHNICAL UNIVERSITY IN PRAGUE

Faculty of Nuclear Sciences and Physical Engineering



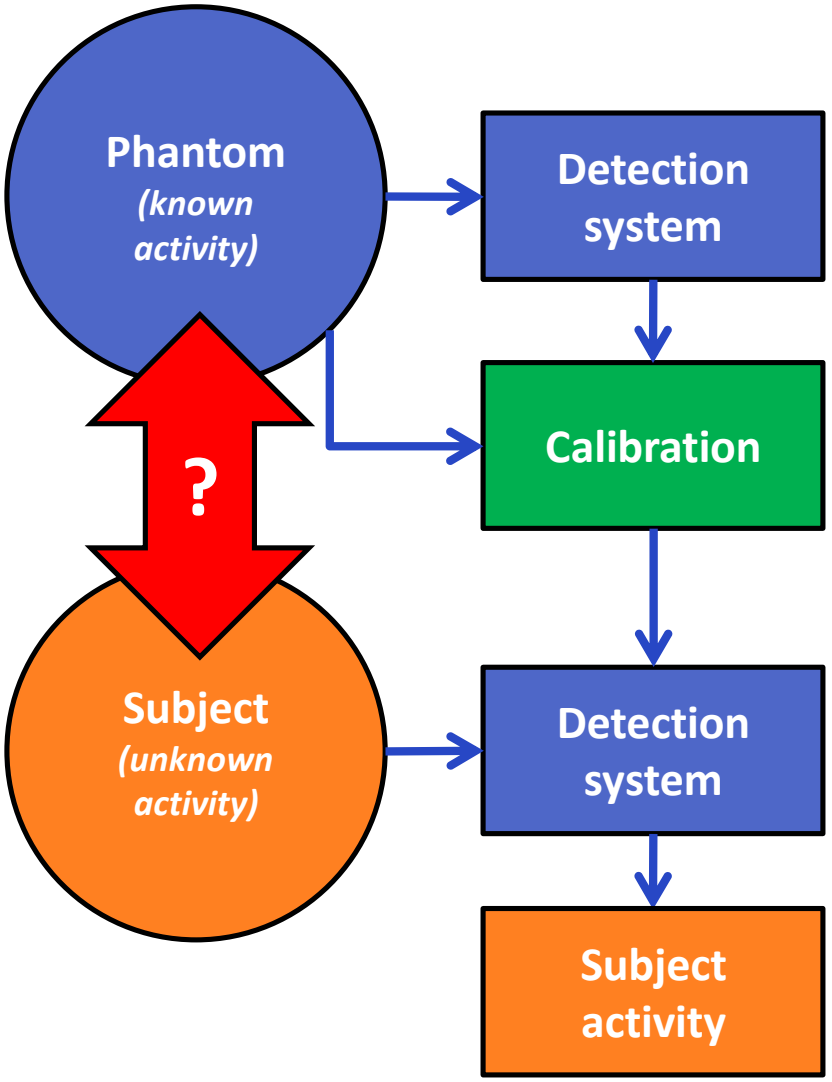


INFLUENCE OF HEAD SHAPE ON MEASURED ACTIVITY OF ACTINIDES

Tomas Vrba

General concept of in-vivo measurement in internal dosimetry

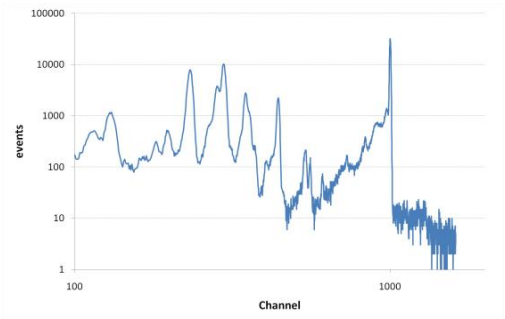
- advantages
  - non destructive
  - relatively fast
  - subject actual activity retention
- disadvantages
  - subject variability
  - activity distribution in subject
  - not applicable for all radionuclides



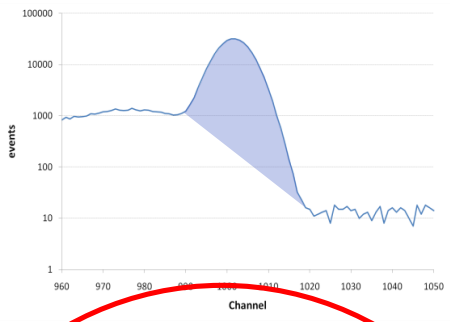
Actinides activity assessment – in vivo skull measurement

1. skull measurement

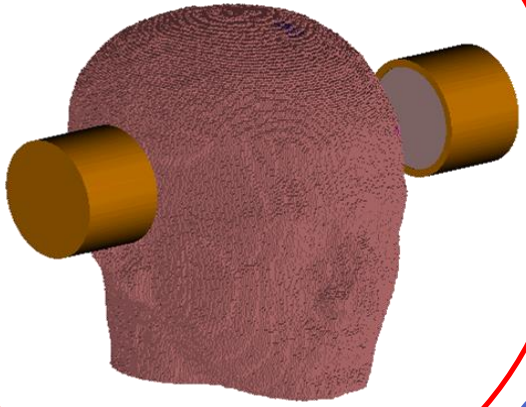
2. measured spectra



3. net-peak area



4. calibration & correction



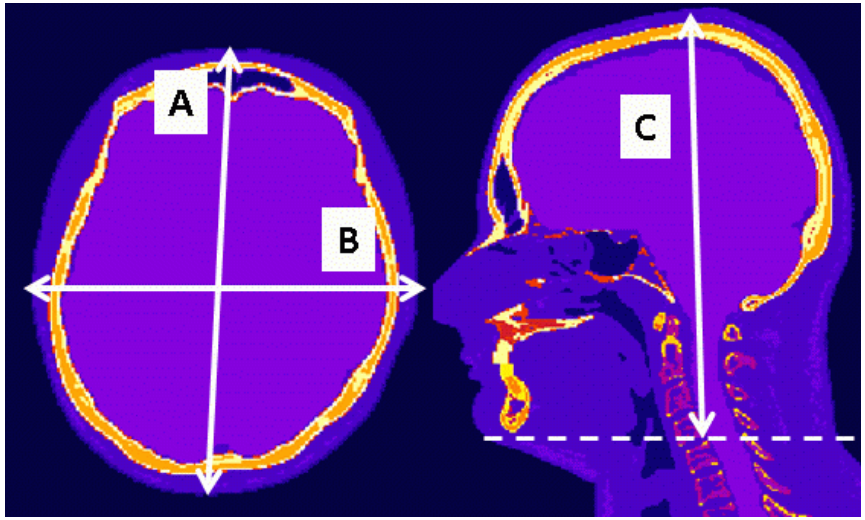
5. skull activity

6. skeleton activity

How skull size influence measurement ?

- strength of the effect deepens on detector(s) size and measurement geometry
- head mean radius R
  - measure of the head size

$$R = \frac{A + B + C}{6}$$



- difference in efficiency between minimal and maximal head size about factor 2
  - (Radiat Prot Dosimetry. 2007;127(1-4):201-4)

HEAD PHANTOMS FOR MC

Phantom	Voxel side (mm)			Diameters (cm)			R (cm)	number of voxels
	x	y	z	A	B	C		
ICRP female [1)]	1.78	1.78	4.84	20.47	14.86	21.30	9.44	715950
ICRP male [1)]	2.14	2.14	8.00	21.08	16.44	22.40	9.98	399156
Linda [2)]	1.00	1.00	1.00	18.70	16.00	21.70	9.40	11175868
Linda simple	2.00	2.00	2.00	18.70	16.00	21.70	9.40	1241550
CIPIC mean head	**Not applicable**			**19.96**	**14.49**	**21.46**	**9.31**	

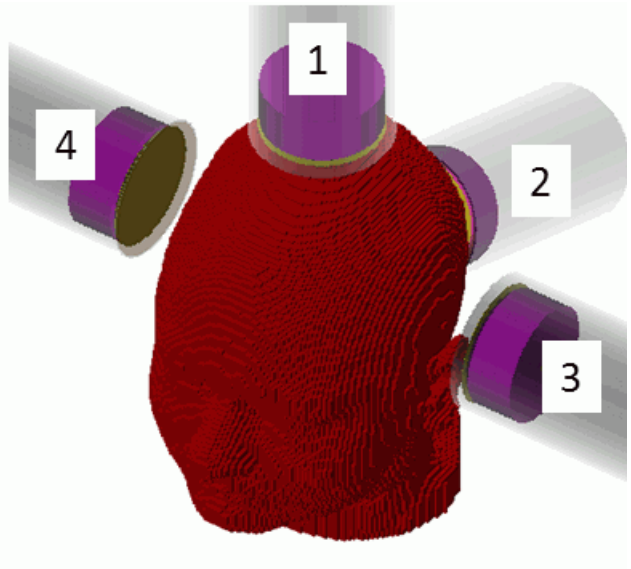
1) ICRP reference phantom models (ICRP Recommendation 110)
2) woman head phantom (Radiat Prot Dosimetry. 2007;127(1-4):201-4.)

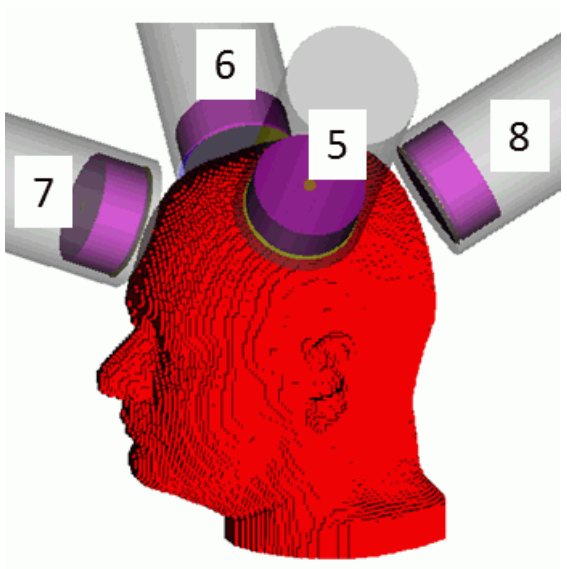
TYPICAL DETECTORS

- High Purity Germanium (HPGe)
  - different sizes (up to 8 cm in diameter)

Detector property	Canberra (GL3825R)	Ortec (LX-70450-30CW)	detector at NRPI
diameter (mm)	70	70	69.8
depth (mm)	25	30	30.5
window thickness (mm)	0.6	0.6	0.6
FWHM @ 5.9 keV (eV)	475	450	n/a
FWHM @ 122 keV (eV)	750	725	730
crystal to window (mm)	5	4	4

Detector positions





Position no.	distance to head (cm)	description
1	1	above skull circa 1-2 cm posteriorly from Bergma
2	1	pointing bottom part of occipital bone
3	3	left temporal bone
4	3	right temporal bone
5	1	between frontal and left parietal bone , angle 52°
6	1	between frontal and right parietal bone, angle -52°
7	1	median part of the frontal bone
8	1	between parietal bones above occipital bone

PHANTOM SHAPE MODIFICATION

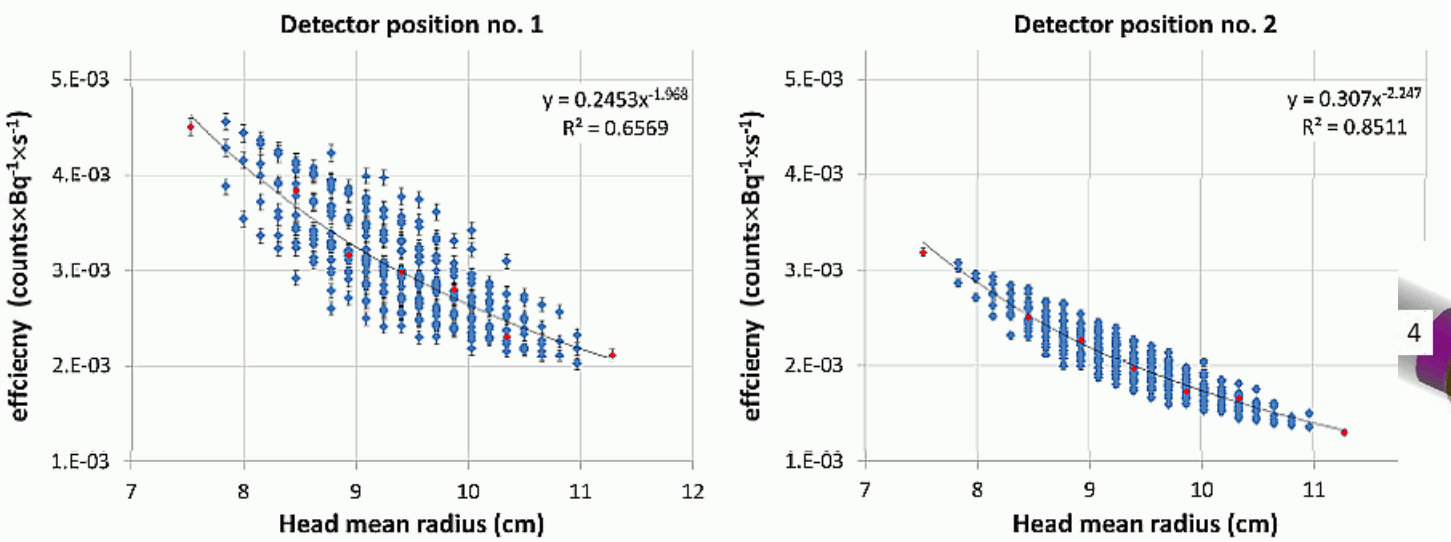
- phantom split to the bone, air, soft tissue subsets
- resizing of three subsets
  - uncorrelated in all three dimensions
  - discrete steps (0.8 - 0.9 - 0.95 - 1 - 1.05 - 1.1 - 1.2)
  - covers ~ 95% percentile of the human skull sizes
  - thickness of the covering tissue kept constant

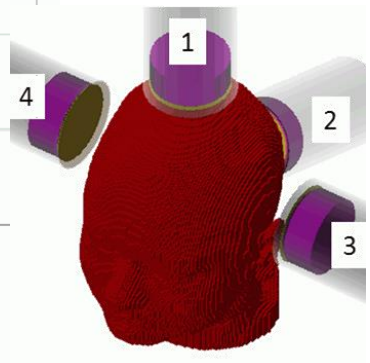
- merging importance (bone > air > soft tissue)
- detector positions adjusted to the new head dimensions

SIMULATIONS

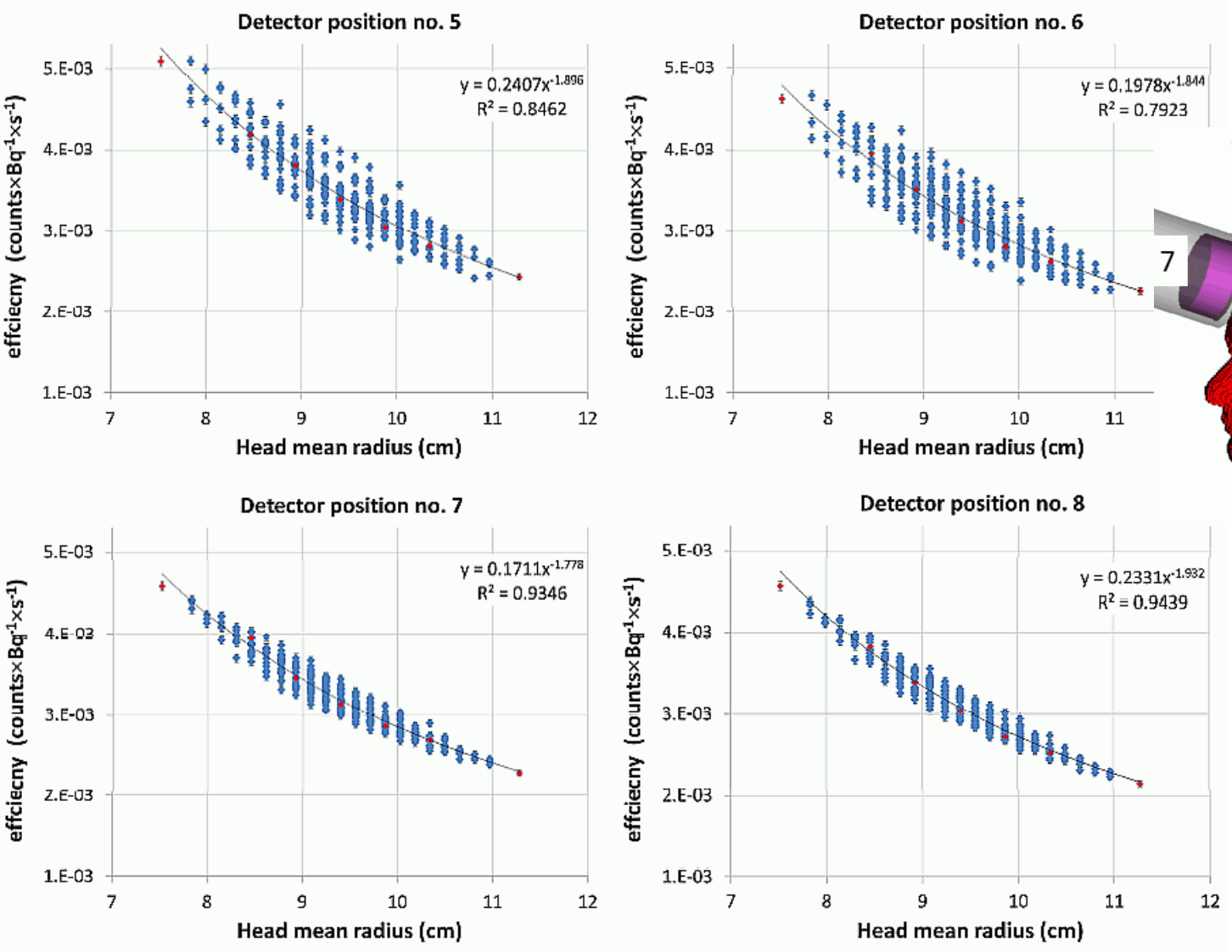
- MCNPX 2.6, default transport parameters, no GEB
- only photons with E = 59.54 keV (^{241}Am)
- homogenous distribution in bone volume
- tally F8 from 55 to 65 keV with 0.5 keV bins
- energy cut-off for non detector cells (ELPT) at 57 keV
  - speedup calculations about factor 2
  - does not affect tally results
- statistical relative standard deviation @ 59.54 bin < 0.75 %
- 686 simulations

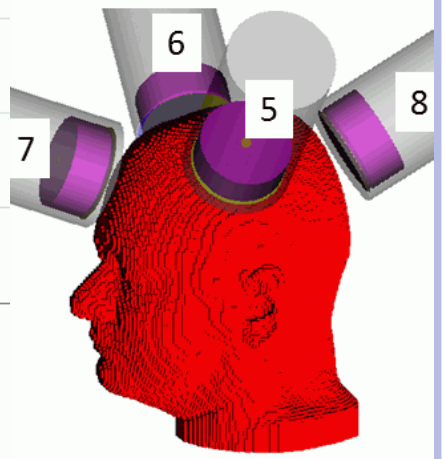
RESULTS I.


Detector position no. 1
y = 0.2453x^-1.968
R² = 0.6569
effciecny (counts×Bq⁻¹×s⁻¹)
Head mean radius (cm)
Detector position no. 2
y = 0.307x^-2.247
R² = 0.8511
effciecny (counts×Bq⁻¹×s⁻¹)
Head mean radius (cm)
Detector position no. 3
y = 0.1335x^-1.859
R² = 0.6517
effciecny (counts×Bq⁻¹×s⁻¹)
Head mean radius (cm)
Detector position no. 4
y = 0.1181x^-1.814
R² = 0.6286
effciecny (counts×Bq⁻¹×s⁻¹)
Head mean radius (cm)

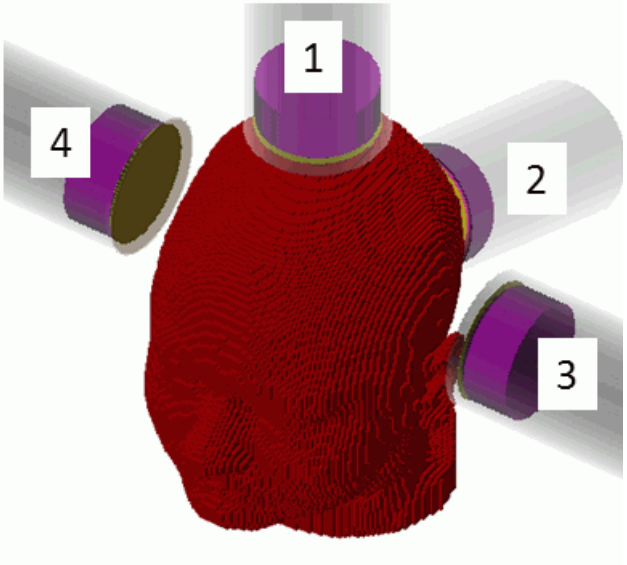

1
2
3
4

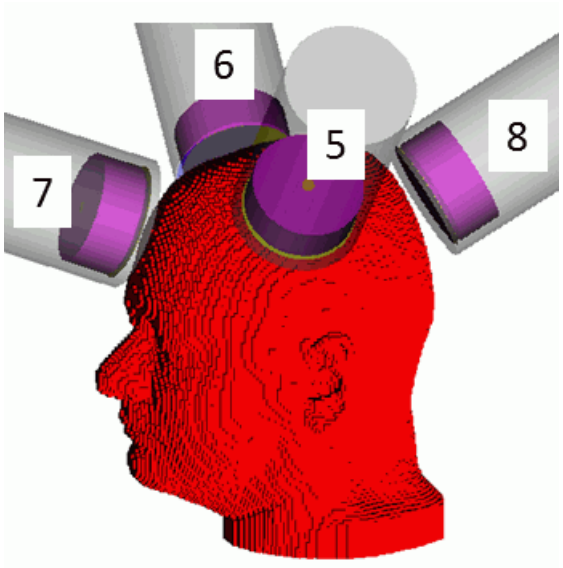
RESULTS II.


Detector position no. 5
y = 0.2407x^-1.896
R² = 0.8462
efficiency (counts×Bq⁻¹×s⁻¹)
Head mean radius (cm)
Detector position no. 6
y = 0.1978x^-1.844
R² = 0.7923
efficiency (counts×Bq⁻¹×s⁻¹)
Head mean radius (cm)
Detector position no. 7
y = 0.1711x^-1.778
R² = 0.9346
efficiency (counts×Bq⁻¹×s⁻¹)
Head mean radius (cm)
Detector position no. 8
y = 0.2331x^-1.932
R² = 0.9439
efficiency (counts×Bq⁻¹×s⁻¹)
Head mean radius (cm)


6
5
8
7

RESULTS SUMMARY





Parameter	Detector position							
	1	2	3	4	5	6	7	8
Minimal efficiency[a]	2.0E-03	1.3E-03	1.5E-03	1.5E-03	2.4E-03	2.3E-03	2.3E-03	2.1E-03
Maximal efficiency[a]	4.6E-03	3.2E-03	3.1E-03	3.0E-03	5.1E-03	4.7E-03	4.6E-03	4.6E-03
Relative standard deviation due to head shape (%)	10.5	7.0	10.1	10.2	6.0	7.0	3.5	3.5

[a] efficiency in counts×Bq^{-1}×s^{-1}

Conclusion and prospect

- estimated uncertainty of detection efficiency due to head shape between 3.5 – 10.5 %
  - less sensitive positions is for median part of the frontal bone and between parietal bones above occipital bone
  - comparable with detector positioning error (~ 12%)
- limitations of presented results
  - uncorrelated head dimensions
    - there is significant correlation between A and B
  - voxel resizing inaccuracy (sub-voxel changes)
- prospect and possible improvement
  - introduce sampling distribution for A, B, C with correlation
  - use NURB phantoms or original Linda phantom
  - integrate it to the total uncertainty of the measurement

THANK YOU FOR YOUR ATTENTION.

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BONUS – SKULL PHANTOM COMPARISON