

The Representative Point Method for Efficiency Calibration of Germanium Detectors

- ▶ Department of Radiation Protection
Japan Atomic Energy Agency

Jun Saegusa

1. Methods for efficiency calibration

(1) Measurement of standard volume source



- ▶ Complicated procedures in manufacturing
- ▶ Frequent manufacturing of standard volume sources



Increase of radioactive waste

(2) Monte Carlo simulation (MC)

- ▶ Parameterisation of geometry is necessary



Ineffective region in Ge crystal

- ▶ Traceability not assured

2. What is the RP method ?

2.1 General concept

Efficiency calibration method combines
"MC" and "Point Source Calibration"

Representative Point (RP)

A position which gives
approximately the same
efficiency curve as a
volume sample

Reduce volume to a single point



*Calibration with a **standard point source** at the RP*

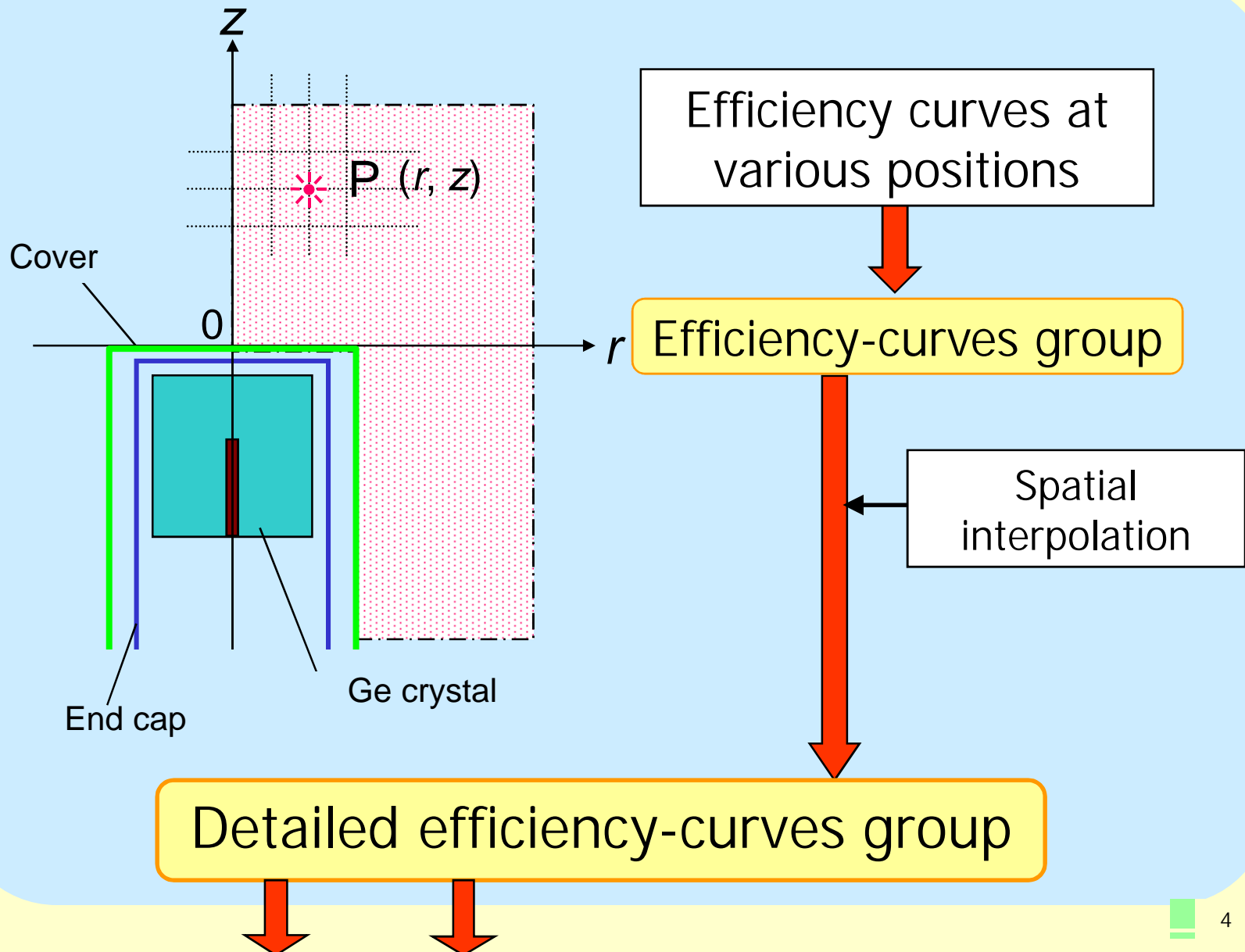


Correction of self-absorption effect

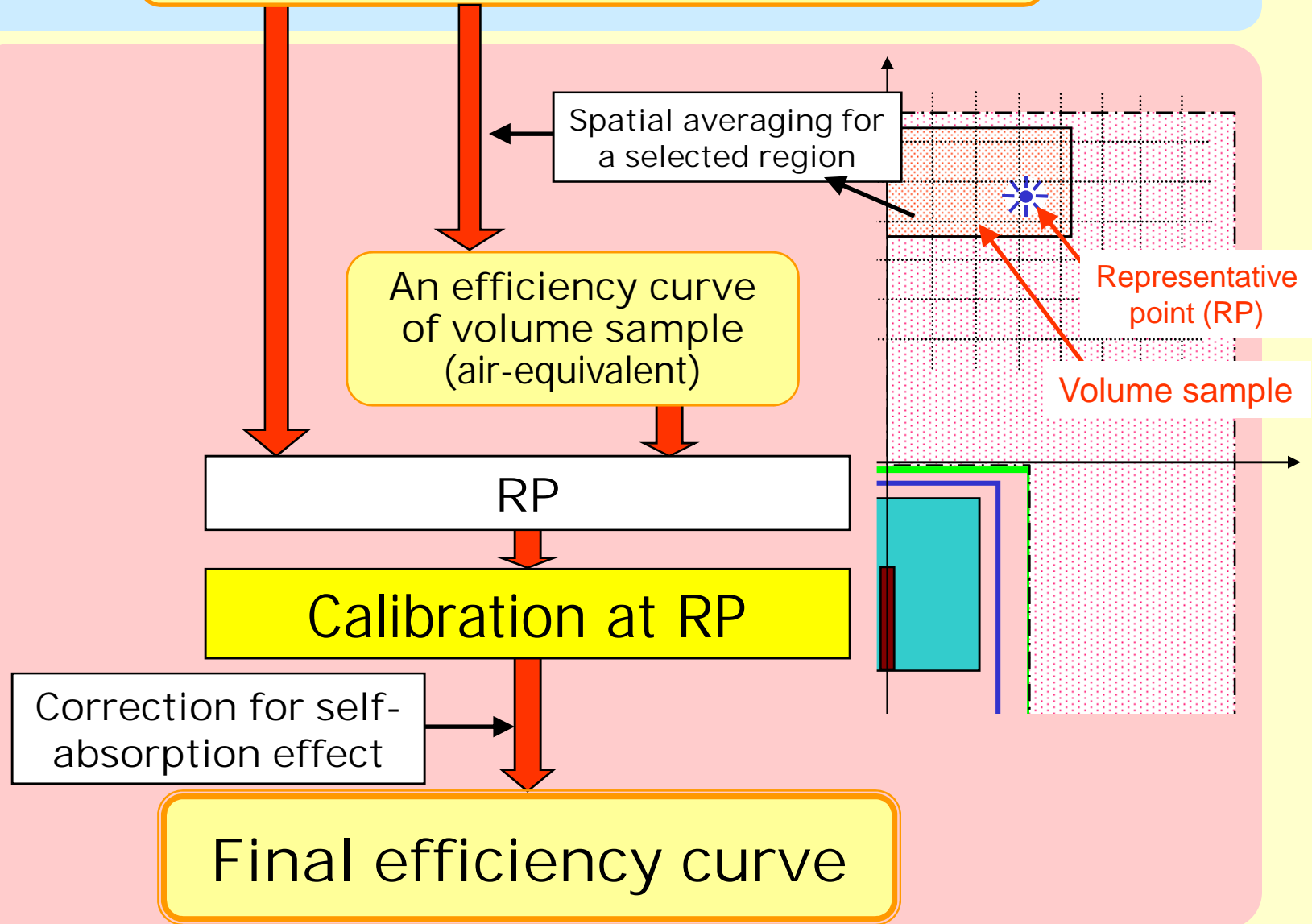


Efficiency curve

2.2 Procedure of the RP method



Detailed efficiency-curves group



2.3 How to find the RP

Parameter t

$$t = \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{P_{E_i} - V_{E_i}}{V_{E_i}} \right)^2} \times 100 (\%)$$

P_{E_i} : Efficiency at each point

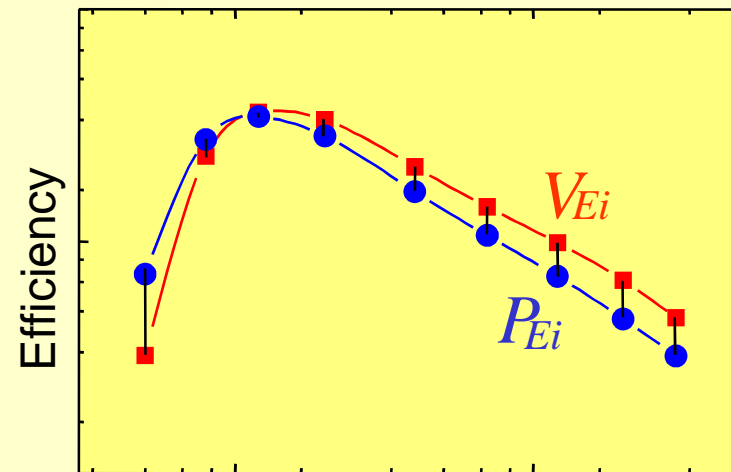
V_{E_i} : Efficiency of volume sample (air-equiv.)

n : Number of energy points

* Simplified expression for this presentation

The RP

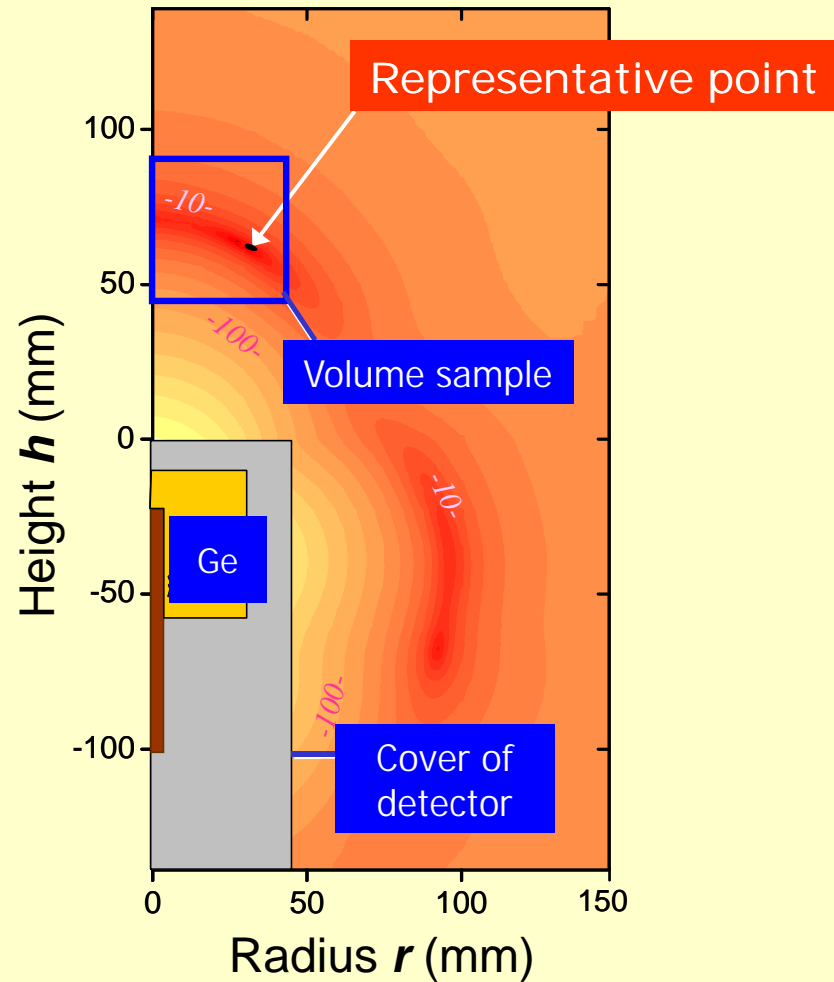
A position which gives
the smallest t



Photon energy (keV)

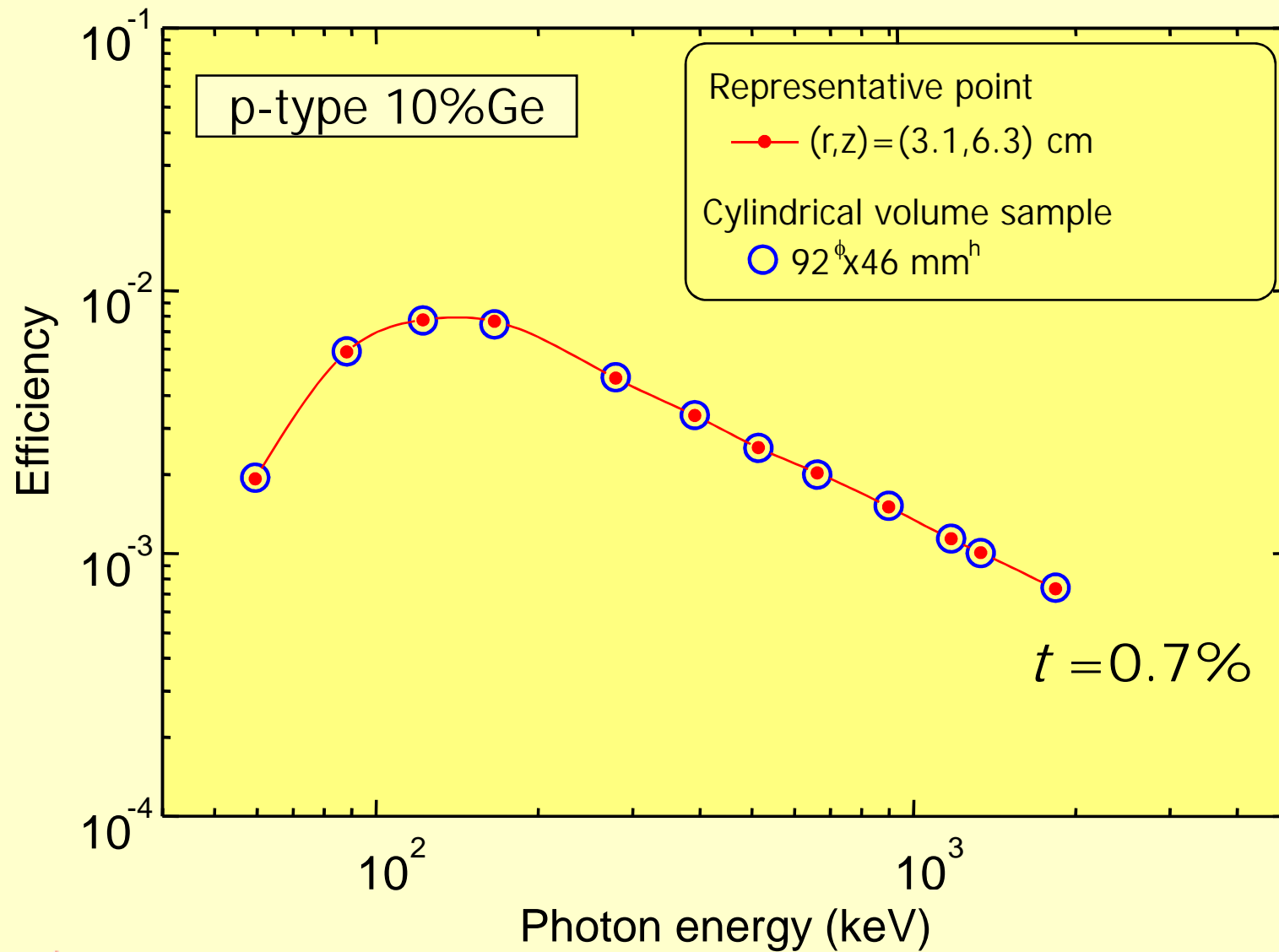
Comparison of two efficiency curves

2.4 Distribution of parameter t

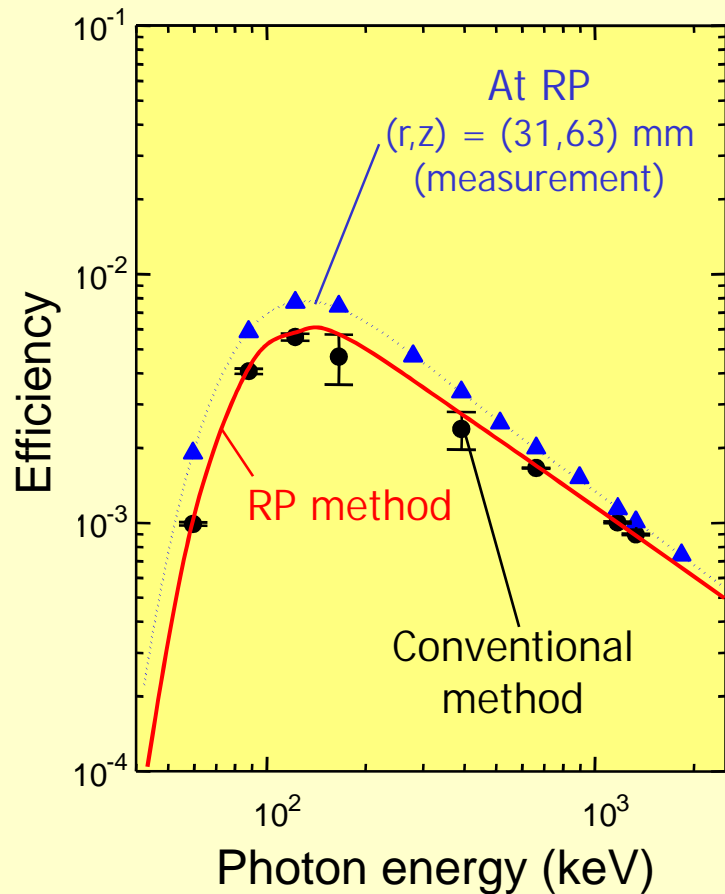


Contour map of parameter t around a detector

2.5 Efficiency curve of the volume sample and that at RP



2.6 Correction of self-absorption effect



Cement standard source
(92 mm in dia., 46 mm in height)

Self-absorption correction
factor (obtained by MC)

Corrected efficiency =

$$\text{Efficiency at the RP} \times \frac{\text{Efficiency with material}}{\text{Efficiency without material}}$$

By Measurement

≈ efficiency of volume
sample (air-equiv.)

3. How to apply the RP method ?

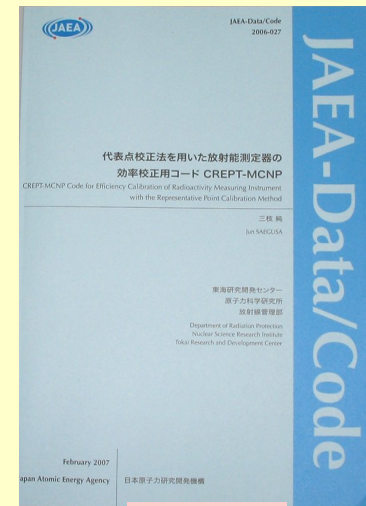
3.1 Features of CREPT-MCNP*

System

- ▶ Microsoft Windows 2000, XP
- ▶ Graphical User Interface (GUI)
- ▶ MCNP-4 or -5

Main Features

- ▶ Calculation of **efficiency curves group**
- ▶ **Representative point search**
- ▶ Calculation of **self-absorption correction factor**



Manual

* Calibration code for the Representative Point calibration method with MCNP

3.2 Geometry modelling

CREPT code for efficiency calibration of radioactivity measuring instrument with the rep

File(F) Data(D) Calculation(C) Calculation results(O) Window(W) Help(H)

detector window for data originationnGe3.csv *

New Open file Overwrite Save as Close Show text file Display cross section

Default: ge_TypeN

Parameter	Value
1 Length of end cap [cm]	11
2 Distance from upper surface of detector case to upper surface of Ge crystal [cm]	0.45
3 Length of Ge crystal [cm]	7.98
4 Distance from upper surface of Ge crystal to tip of contact pin [cm]	2.66
5 Length of mount-cup [cm]	9.68
6 Thickness of dead layer [cm]	0.00003
7 Thickness of end cap (cylinder tube) [cm]	0.1
8 Gap between end cap and protector [cm]	0.03
9 Thickness of protector (radial) [cm]	0.2
10 Thickness of end cap (top) [cm]	0.05
11 Thickness of protector (top) [cm]	0.1
12 Thickness of mount-cup [cm]	0.1
13 Outer radius of Ge crystal [cm]	2.92
14 Outer radius of end cap [cm]	3.5
15 Material of Ge crystal (incl. dead layer)	germanium
16 Material of mount-cup	copper
17 Material of end cap (cylinder tube)	magnesium
18 Material of end cap (top)	beryllium
19 Filling material between end cap and protector [cm]	air
20 Material of protector	PMMA

Length and position settings

Material settings

Derived MCNP input file

```

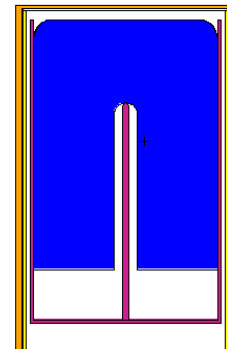
7 3 -1.74000E+00 18 -19 11 -3
   imp:p 1.000 imp:e 1.000
8 4 -1.85000E+00 3 -2 -19
   imp:p 1.000 imp:e 1.000
9 5 -1.20490E-03 11 -2 19 -20
   imp:p 1.000 imp:e 1.000
10 6 -1.19000E+00 (2 -1 -20):(11 -1 20 -21)
    imp:p 1.000 imp:e 1.000

c
c *****
c ** surface card for geometry **
c *****
c
1 PZ 0
2 PZ -0.1
3 PZ -0.15
4 PZ -0.45
5 PZ -0.45003
6 PZ -1.05
7 PZ -3.485
8 PZ -8.43
9 PZ -10.03
10 PZ -10.13
11 PZ -11
12 CZ 0.1
13 CZ 0.375
14 CZ 2.32
15 CZ 2.91997
16 CZ 2.92
17 CZ 3.02
18 CZ 3.17
19 CZ 3.27
20 CZ 3.3
21 CZ 3.5
22 KZ -3.11 1 -1
23 SZ -3.485 0.375
24 TZ 0 0 -1.05 2.32 0.59997 0.59997
25 TZ 0 0 -1.05 2.32 0.6 0.6

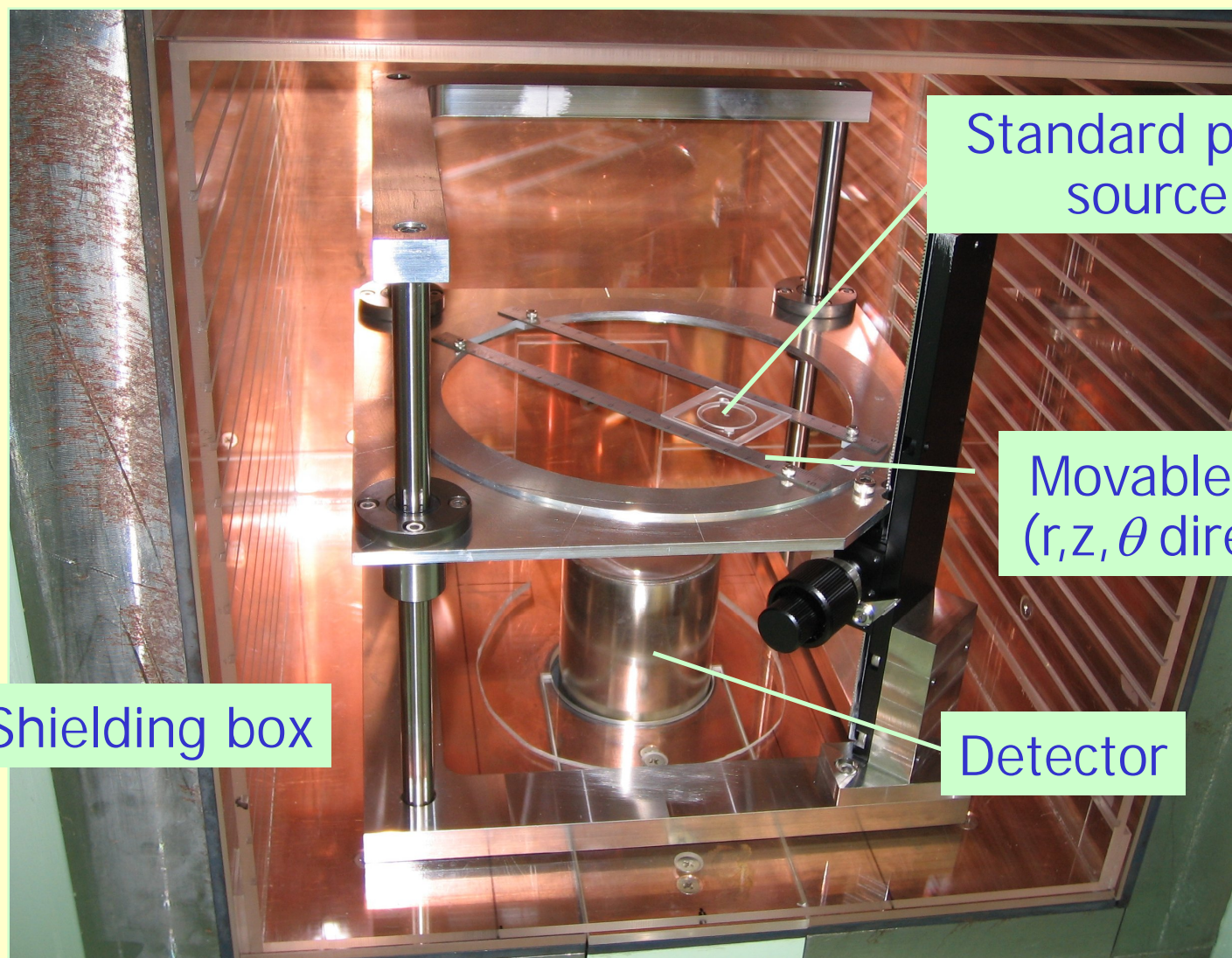
c
c *****
c ** material cards **
c *****
c
---- no. 1 material: copper
m1 29000 -1.000000E+00
c
---- no. 2 material: germanium

```

Geometric representation



3.3 An apparatus for positioning a point source at RP



Standard point source

Movable stage
(r, z, θ direction)

Shielding box

Detector

4. Summary

Merits of RP Method

- (1) Expansion in applicable volume samples
- (2) Reduction of radioactive waste, costs
- (3) Easy efficiency calibration

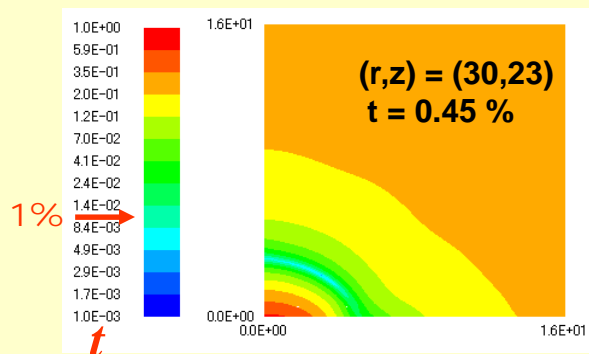
CREPT-MCNP

- (1) A GUI based code for the RP method
- (2) Registered in JAEA Software Library, PRODAS

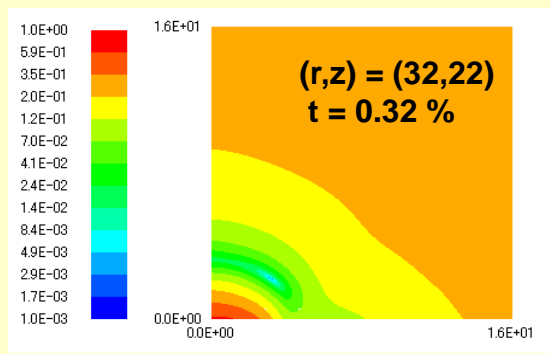
Appendix "Position of RP" and "Dead layer thickness"

p-type HPGe with different dead layer thickness

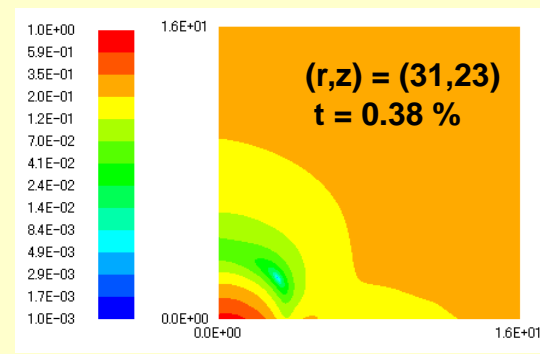
(Sample: 92 mm in dia. x 46 mm in height)



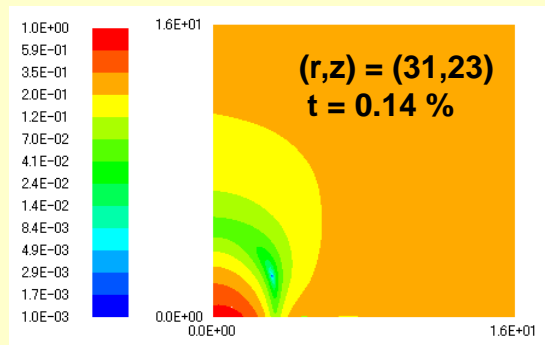
(a) Dead Layer **0 mm**



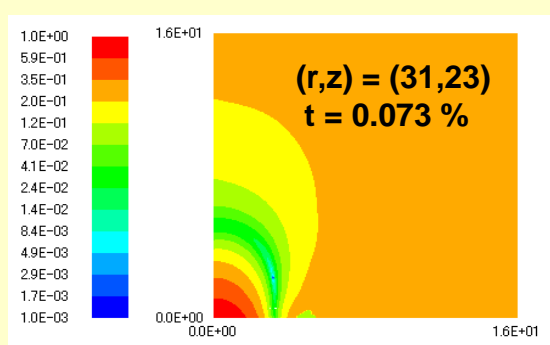
(b) Dead Layer **0.9 mm**
(Best estimate)



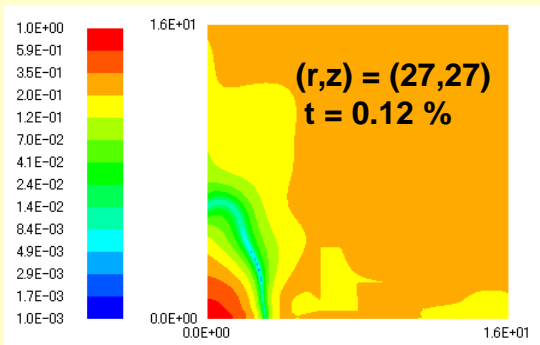
(c) Dead Layer **1.8 mm**



(d) Dead Layer **2.7 mm**



(e) Dead Layer **3.6 mm**



(f) Dead Layer **5.4 mm**

The RP is very stable !