

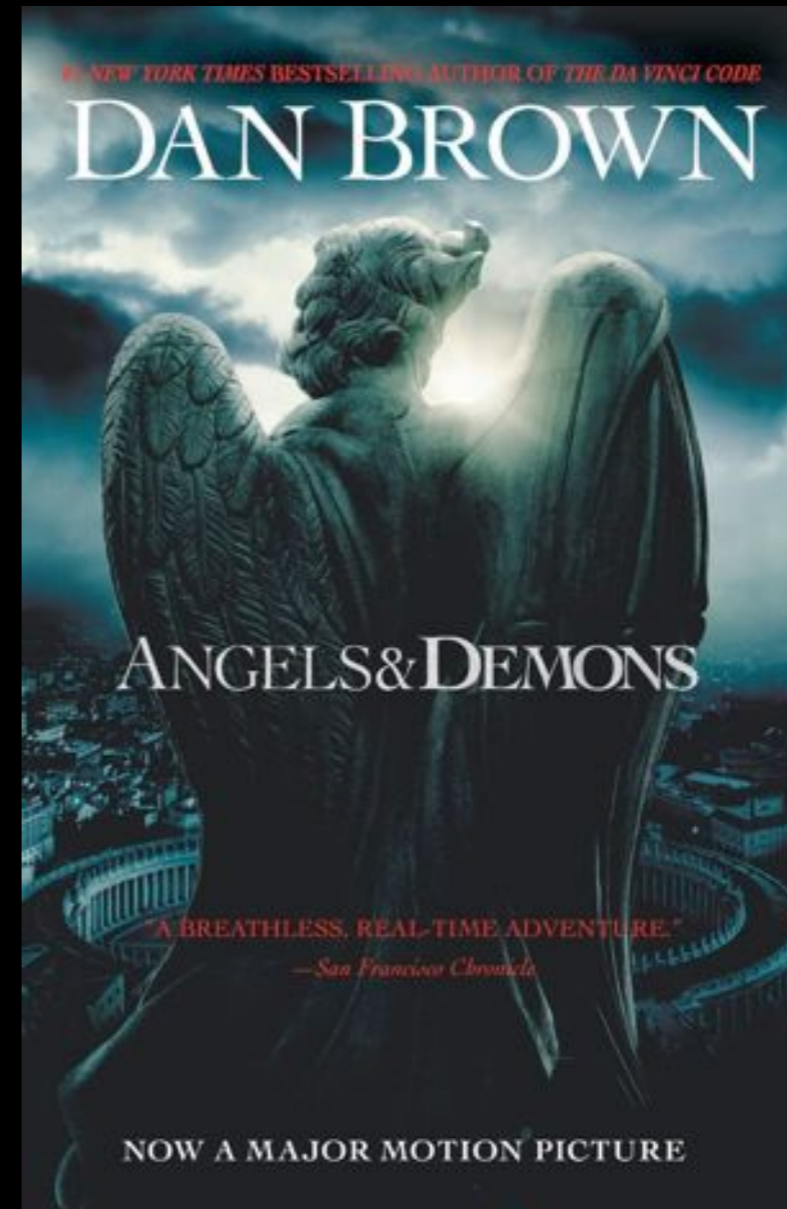
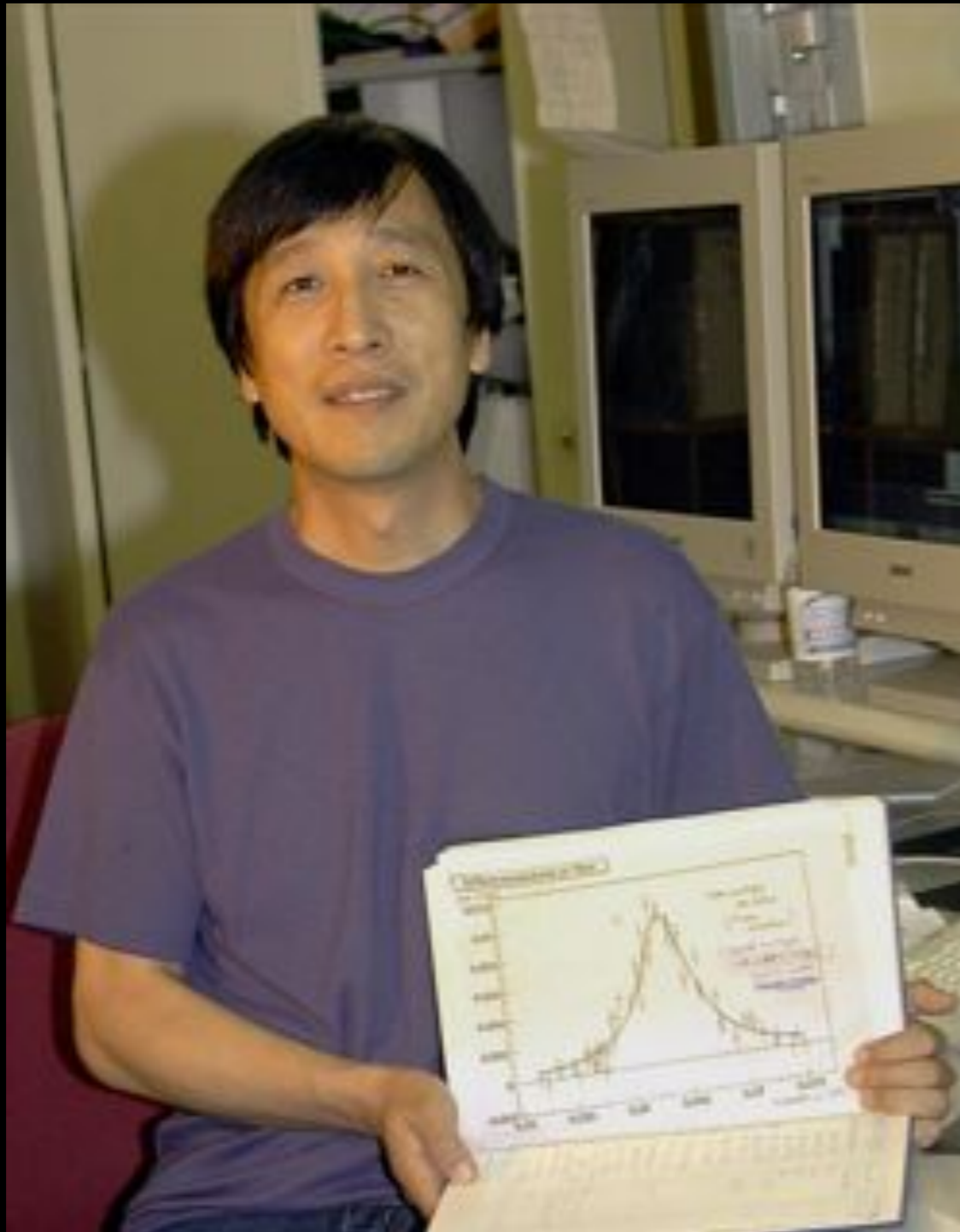
# Fukushima Dai-ichi Accident

- a personal recollection of a  
CERN "antimatter" physicist -

Ryugo Hayano, U. Tokyo & CERN

[ryugo.hayano@cern.ch](mailto:ryugo.hayano@cern.ch)

# “antimatter” at CERN Team leader since 1997





Where the WEB was born  
Higgs discovery  
LHC - powered by French nuclear energy



CERN is celebrating 60 years of science for peace in 2014

Bringing nations together through science

## Part 1

What happened at  
Fukushima Dai-ichi?

March 11, 2011

Earthquake

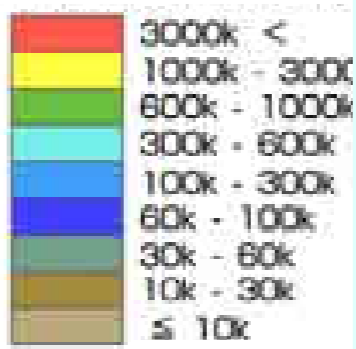


← Fukushima Daiichi

250km

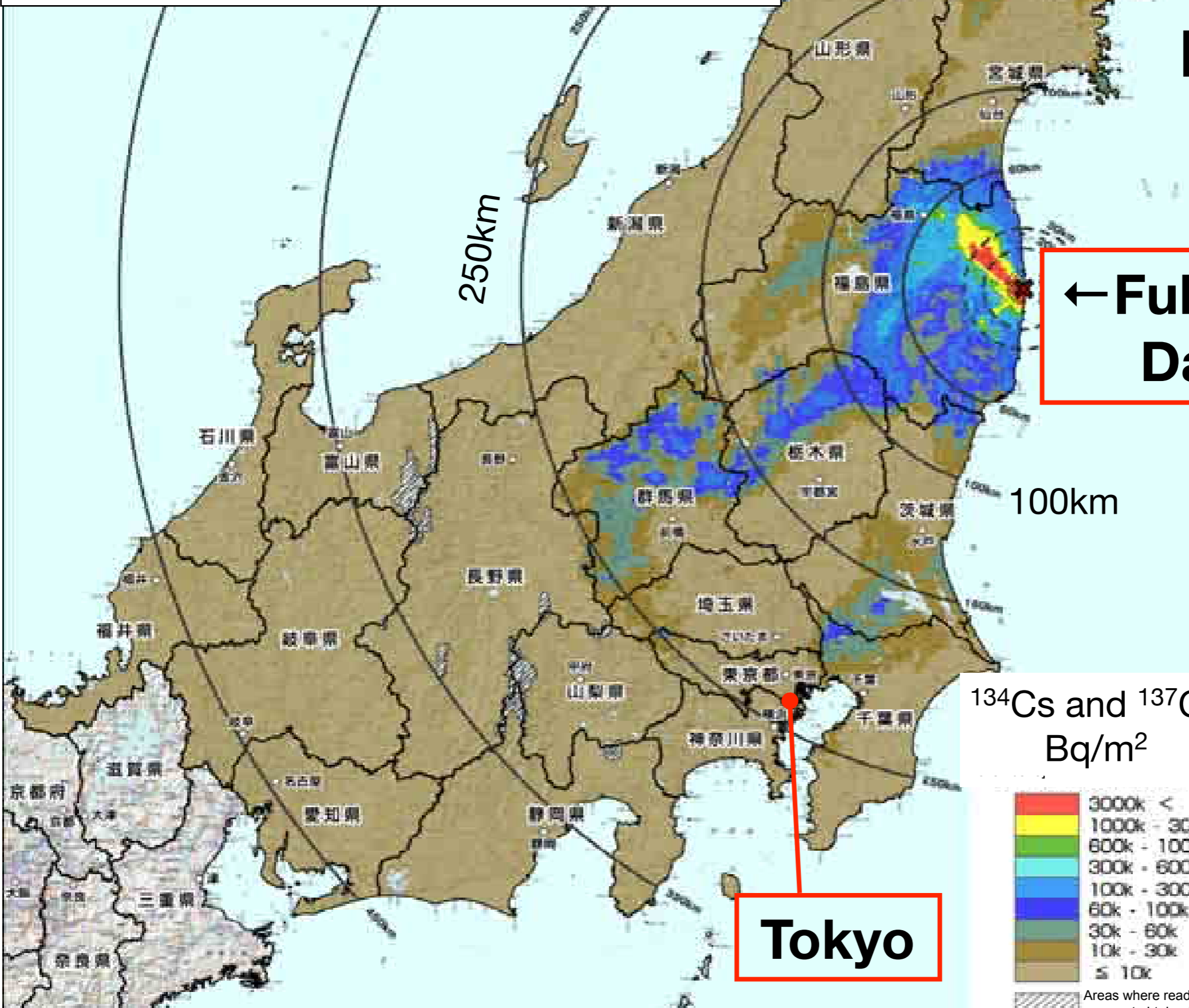
100km

<sup>134</sup>Cs and <sup>137</sup>Cs  
Bq/m<sup>2</sup>



Areas where readings were not obtained

Tokyo



# Nuclear Power Plants of TEPCO Fukushima Dai-ichi

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	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Electric output (10,000 kW)	46.0	78.4	78.4	78.4	78.4	110.0
Commissioning	1971	1974	1976	1977	1978	1979
Fuel assemblies	400	548	548	548	548	764
Number of control rods	97	137	137	137	137	185

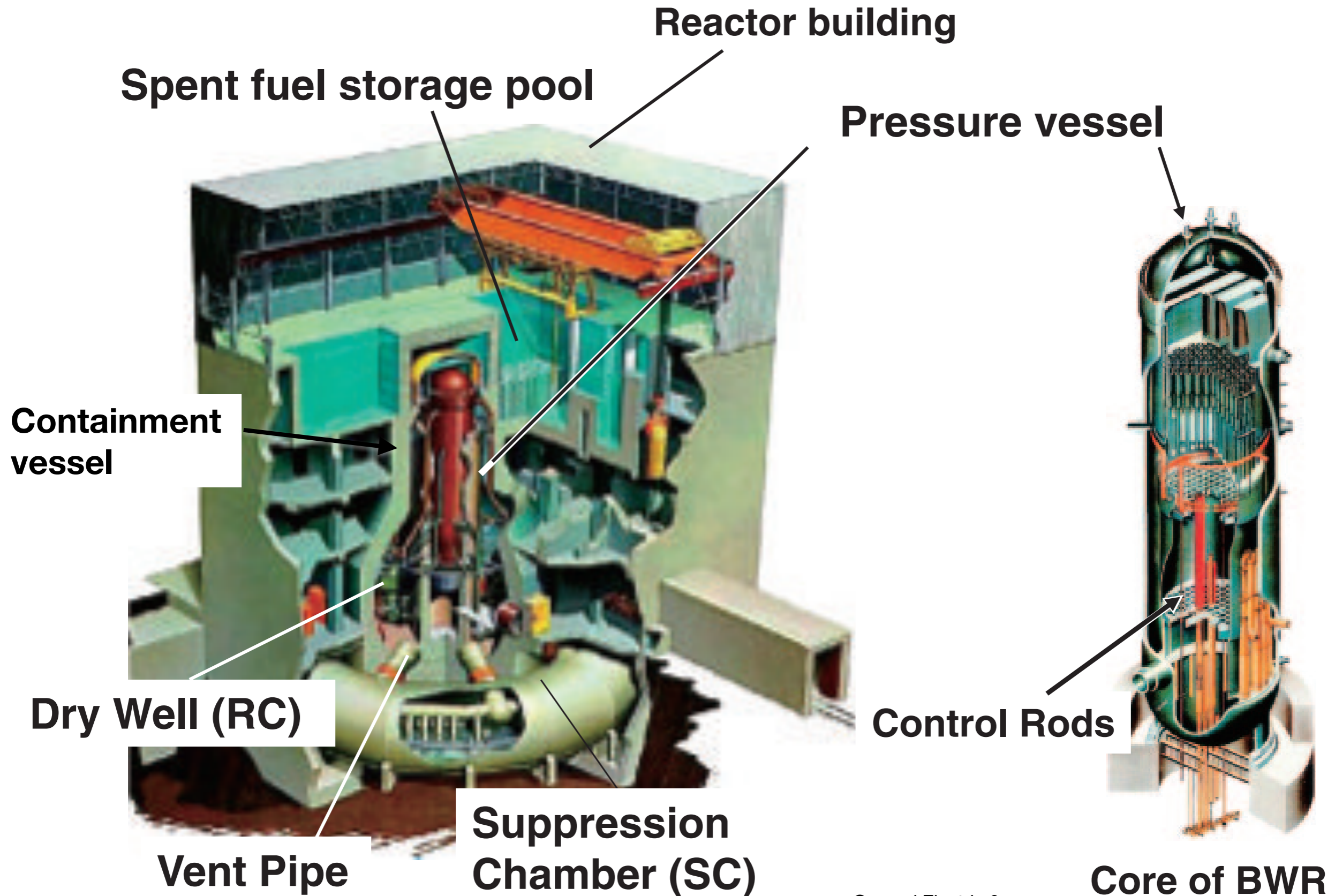
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# Nuclear Power Plants of TEPCO Fukushima Dai-ichi

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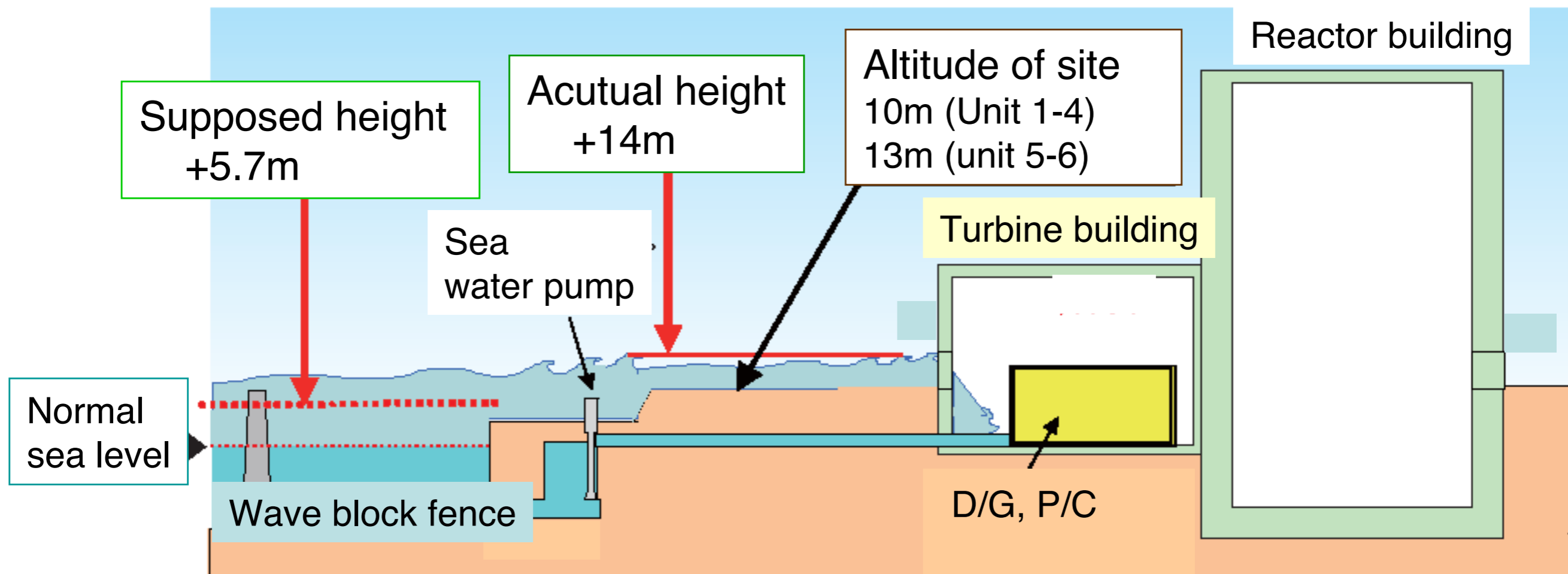
these three were operating on March 11, 2011

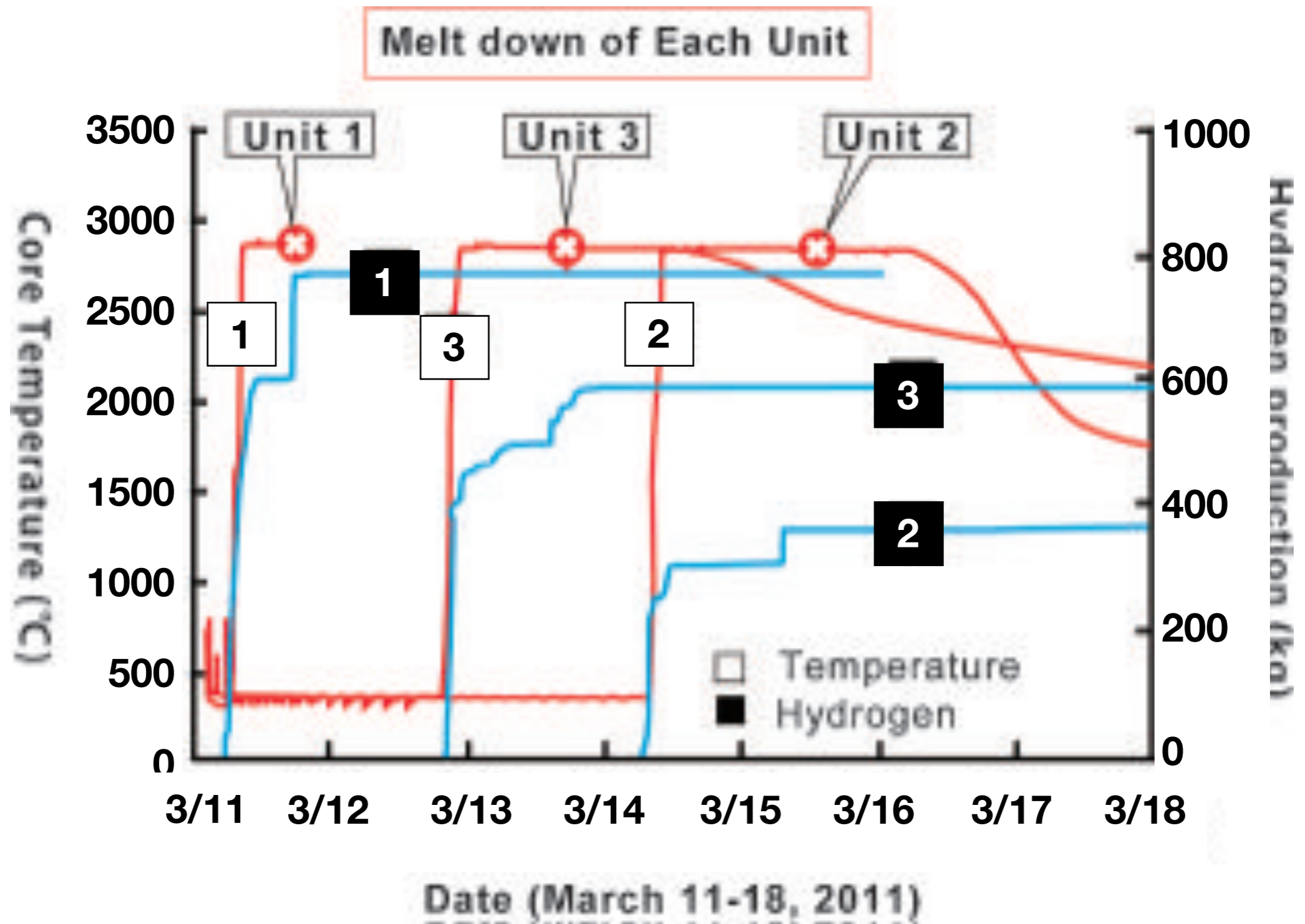
# BWR "Mark-1"





External power line destroyed by earthquake,  
Tsunami flooded all the diesel generators  
→ station blackout





# Fukushima soil : Cs - Sr - Pu

Cs

Sr

Pu

Maximum  
concentration

**10<sup>7</sup>**

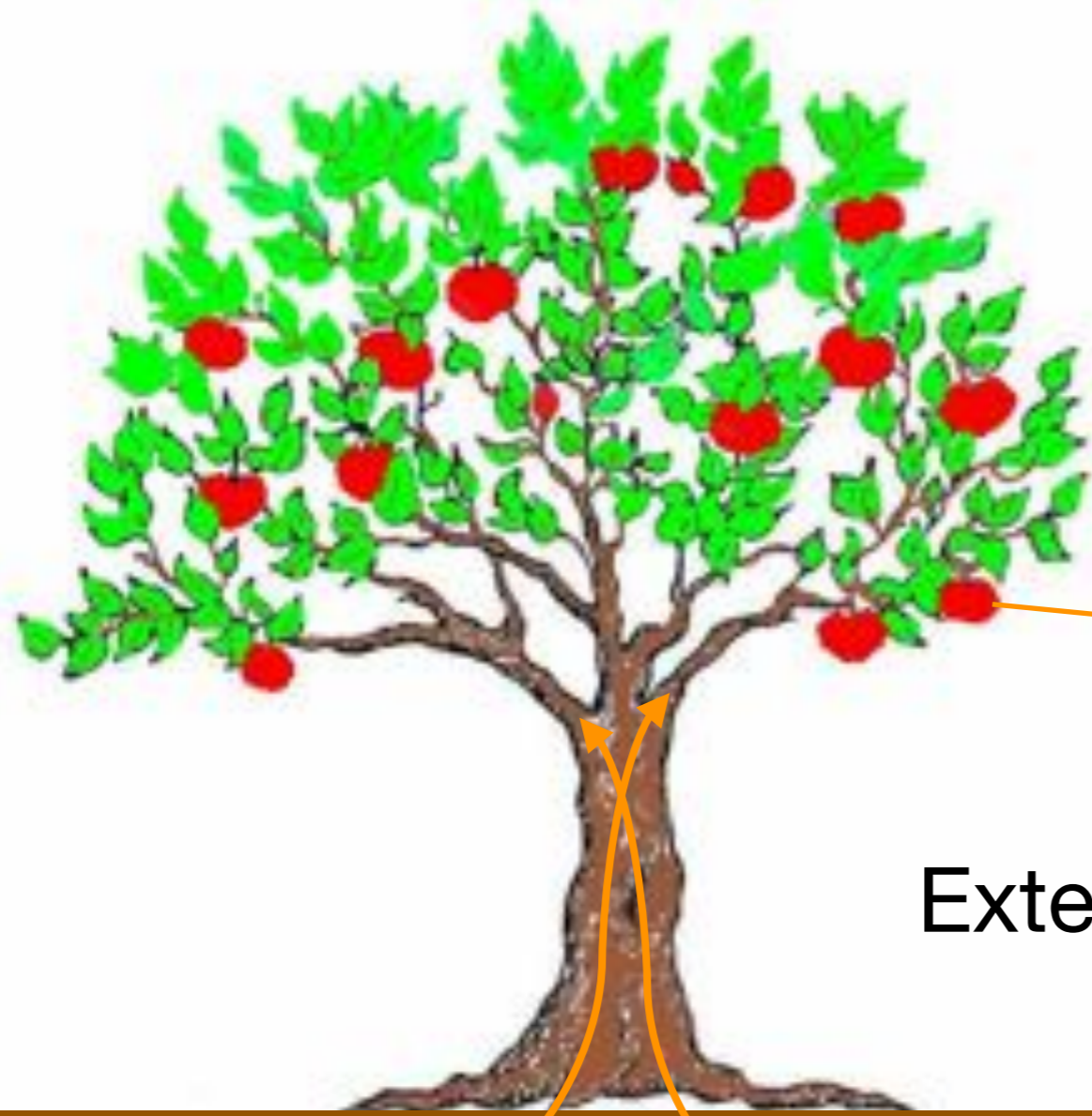
**10<sup>4</sup>**

**10**

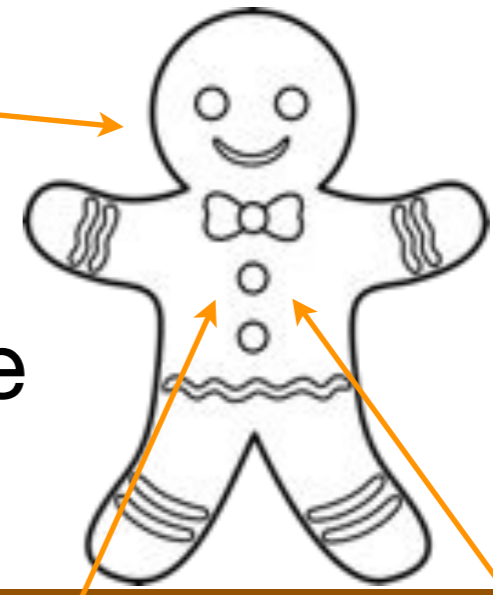
Bq/m<sup>2</sup>

Nuclides	Half life	max conc. *1 (Bq/m <sup>2</sup> )
Cs-134	2 y	1.4 × 10 <sup>7</sup>
Cs-137	30 y	1.5 × 10 <sup>7</sup>
I-131	8 d	5.5 × 10 <sup>4</sup>
Sr-89	50 d	2.2 × 10 <sup>4</sup>
Sr-90	29 y	5.7 × 10 <sup>3</sup>
Pu-238	88 y	4.0
Pu 239+240	2.4x10	15.0
Ag 110m	250d	8.3 × 10 <sup>4</sup>
Te 129m	34d	2.7 × 10 <sup>6</sup>

\*1 : 平成 23 年 6 月 14 日時点に



Internal exposure



External exposure

$^{134,137}\text{Cs}$

$^{134,137}\text{Cs}$



# Food, water, milk ...

**\*VERY strict\* regulatory criteria**

	provisional	April 1, 2012
[Bq/kg]	Old	New
Drink water	200	10
Milk	200	50
Vegetable, Rice, Meat, Fish, Others	500	100

The rest is NOT a review of the accident

but

about my personal involvement since 2011

(I will NOT discuss thyroid issues  
- being debated - )

## Part 2

Why am I here today?

## Part 2

Why am I here today?





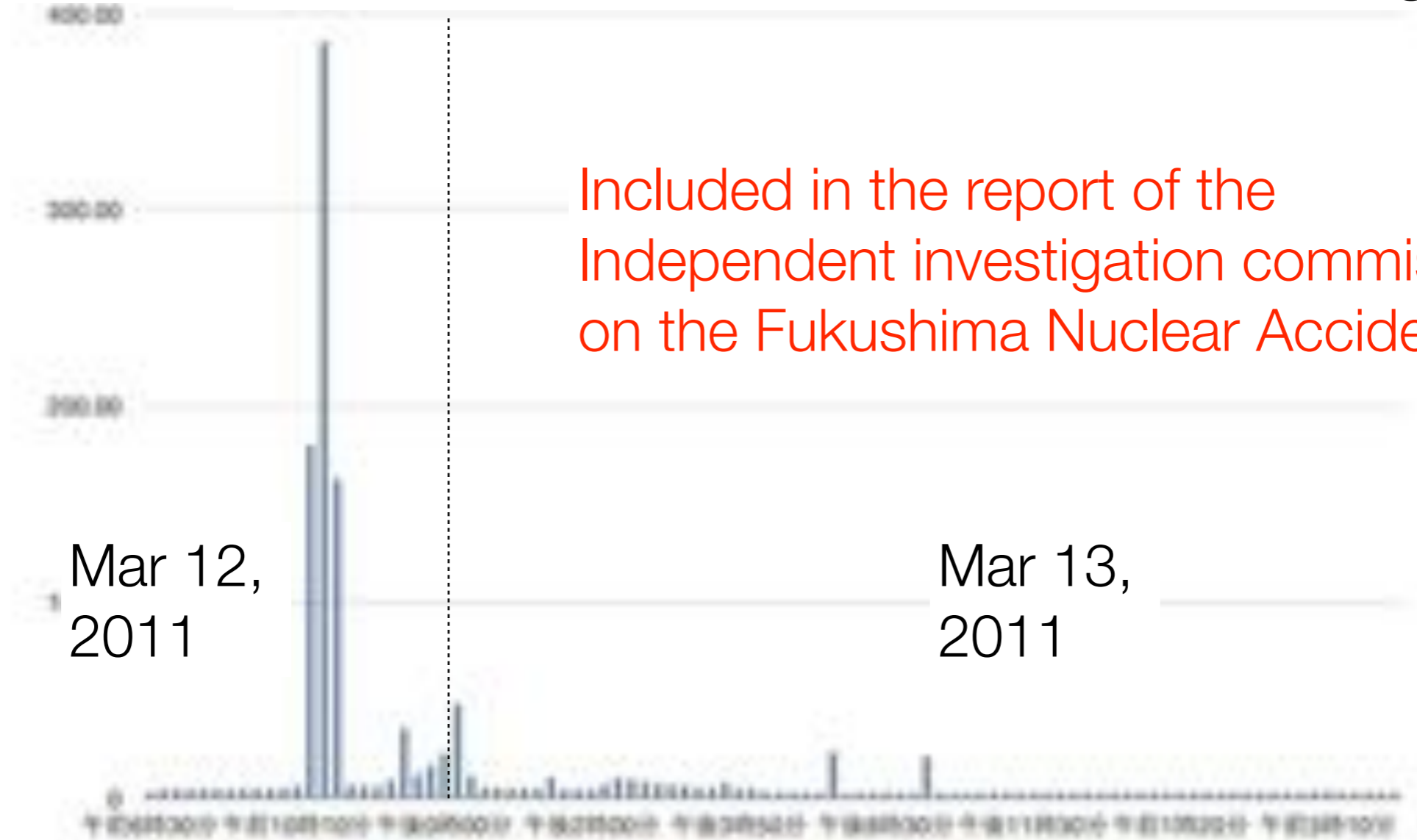
March 11, 2011, Tokyo University  
(was a physics department chair)



# My first graph: Mar 13, 2011, 07:49



$\mu\text{Sv/h}$  Dose rate @ Fukushima Dai-ichi main gate



Included in the report of the Independent investigation commission on the Fukushima Nuclear Accident

# Ranked 7th among the most influential twitter accounts

No. of “follower”s, 3000 → 150,000 within a few days

- データの中でリツイートされた頻度が高いユーザーのトップ100:

<http://www.ci.ecei.tohoku.ac.jp/prj311/trend/rteduser/top100.html>

順位	ユーザ	被RT回数
1	@NHK_PR	630459
2	@nhk_seikatsu	304824
3	@Asahi_Shakai	279259
4	@nhk_news	209515
5	@nhk_HORIJUN	173995
6	@tsuda	165434
7	@hayano	145436
8	@nhk_kabun	127916
9	@earthquake_jp	114806
10	@tohokujishin	112592



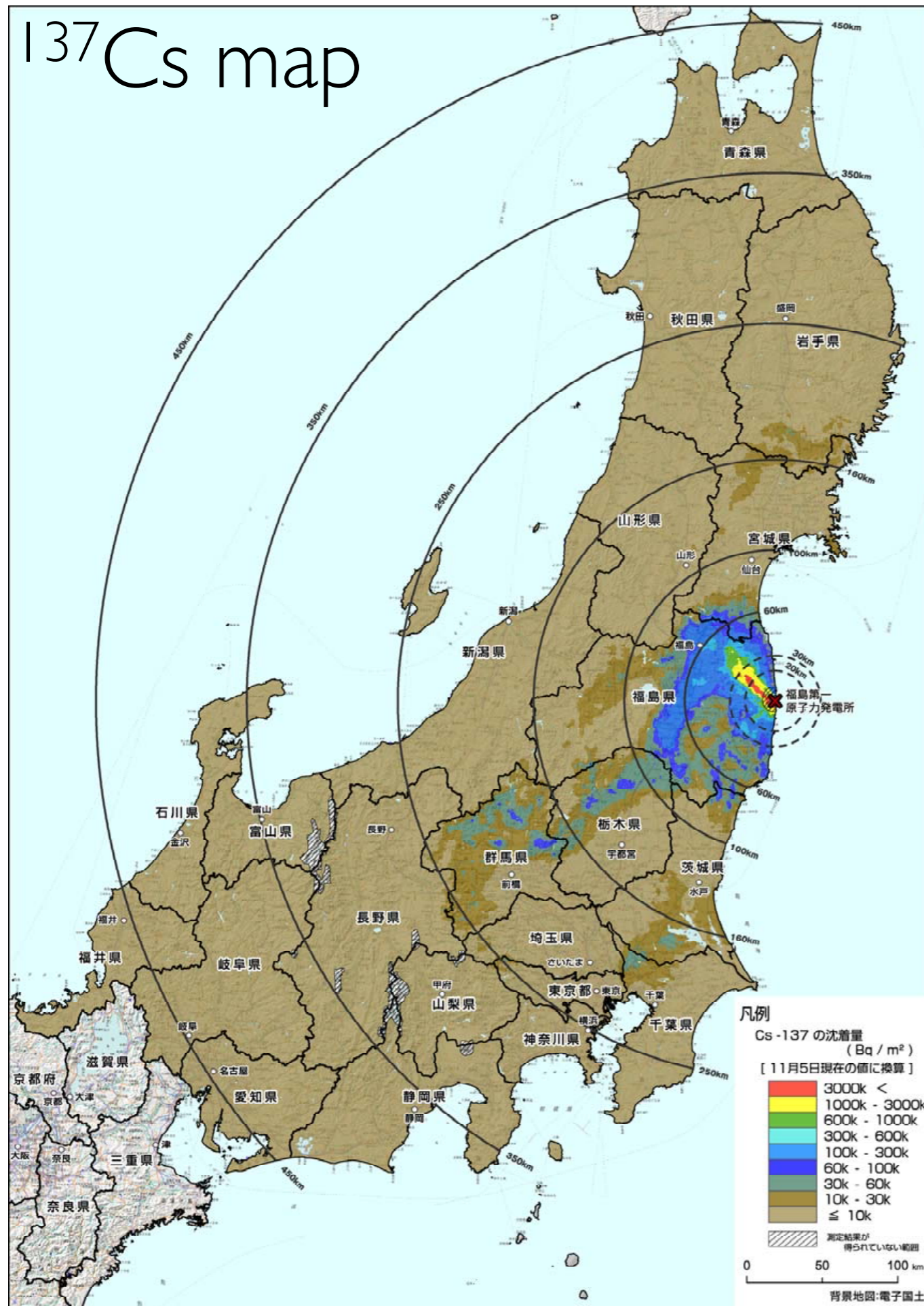
source, Tohoku Univ.

# Power of the social media

**twitter** 

is bi-directional

# $^{137}\text{Cs}$ map



Summer, 2011

contamination maps & various monitoring results became available -

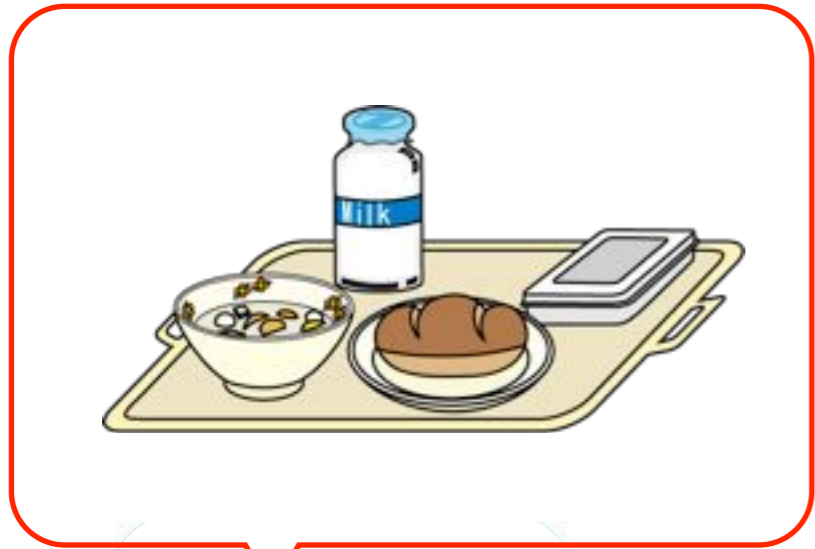
but

increasing number of tweets by worried mothers:

what about food safety?

what are OUR children eating?

# I proposed to measure school lunch, but was denied by the MEXT official



MEXT: What if radioactive cesium is  
“really” detected?

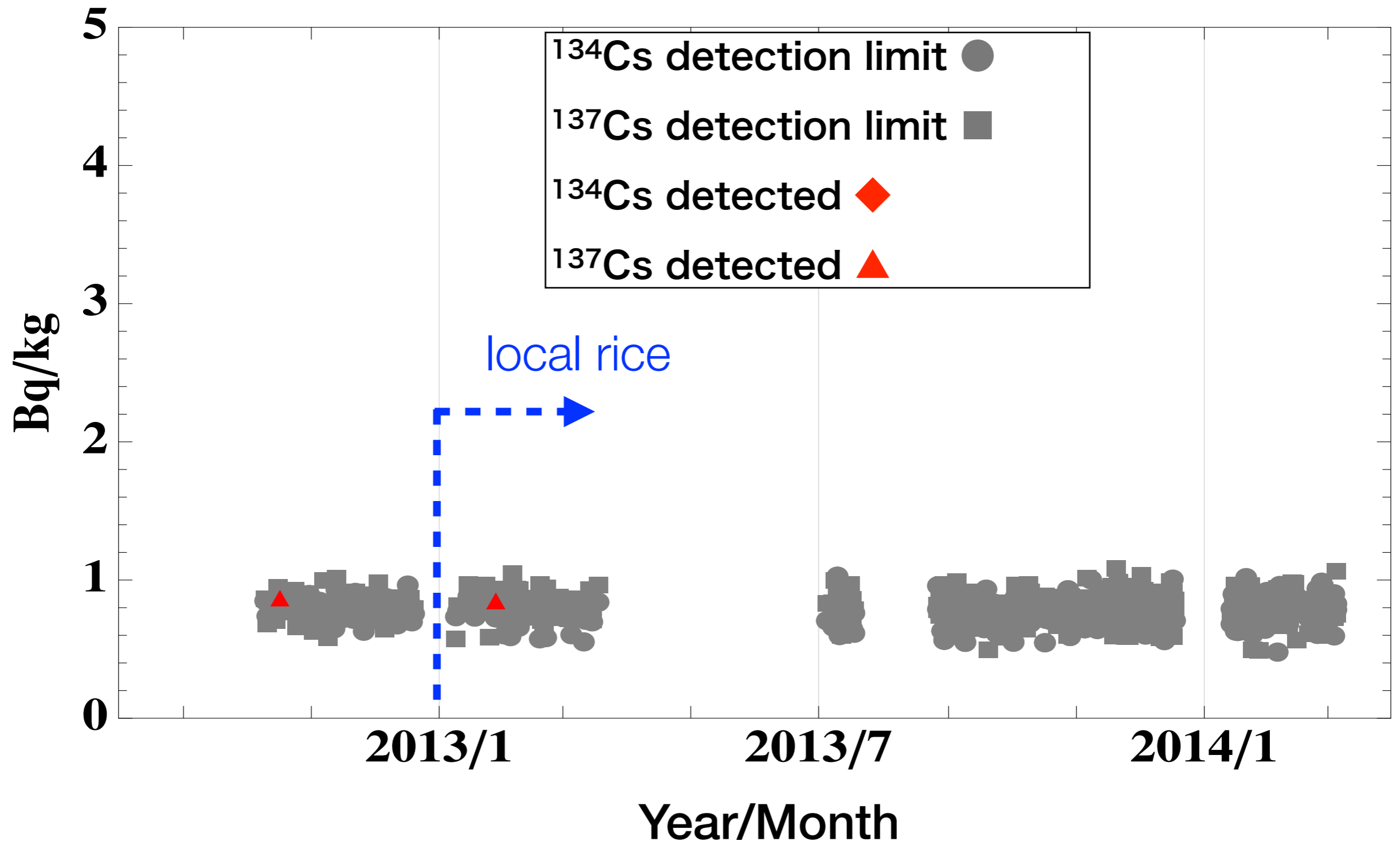
School teachers, school boards,  
etc., will not be able to cope with  
such situations



Germanium detector

# Proposed to MEXT vice minister Funded by MEXT, 2012 & 2013

## Fukushima city school lunch



# Power of the social media - 2

**twitter** 

connects people



Doctors having difficulties with  
“whole body counting” found me on twitter

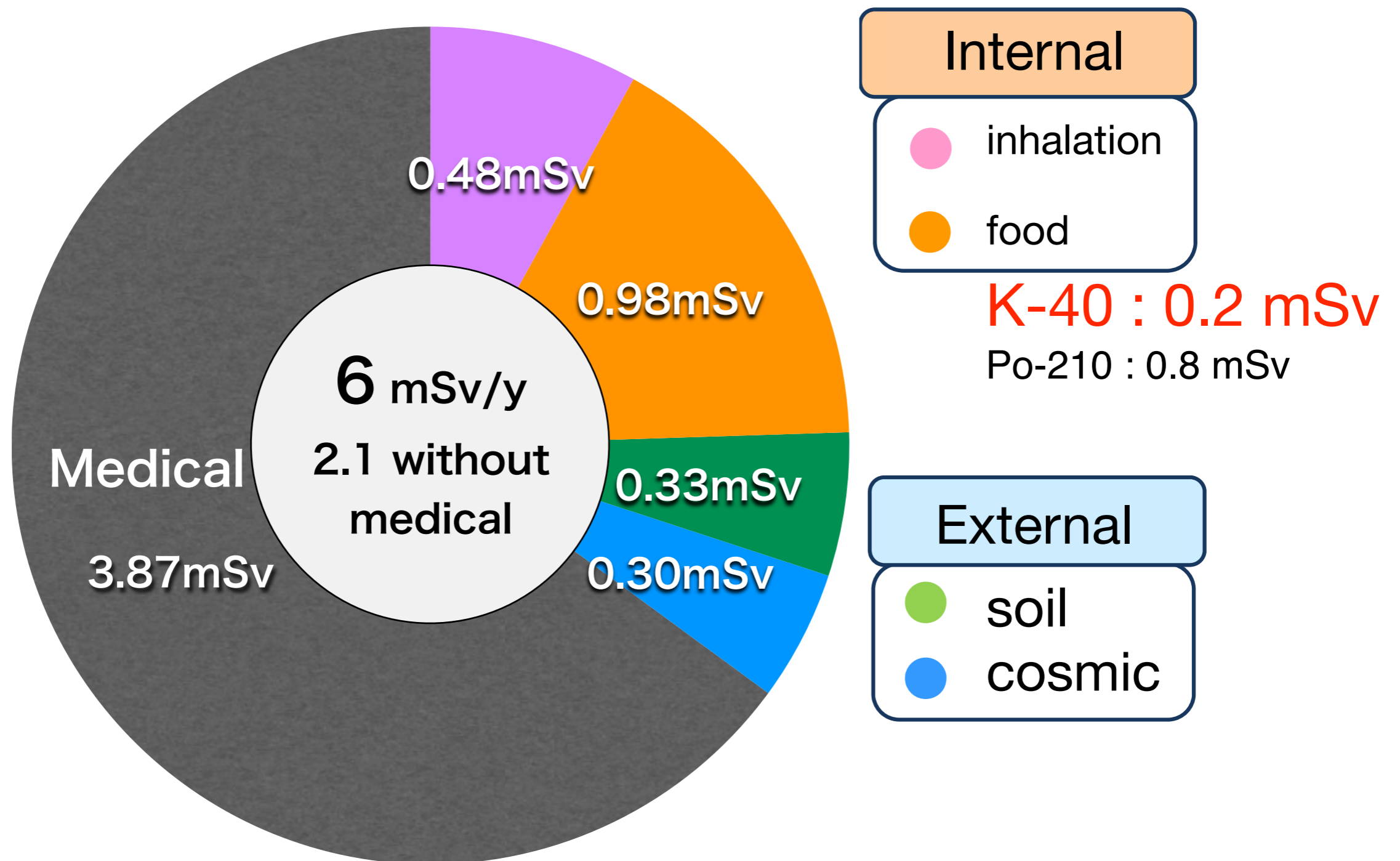


## Part 3

# Internal Exposure in Fukushima (daily ingestion of radiocesium)



# Average dose of Japanese (before the accident)



# WBC

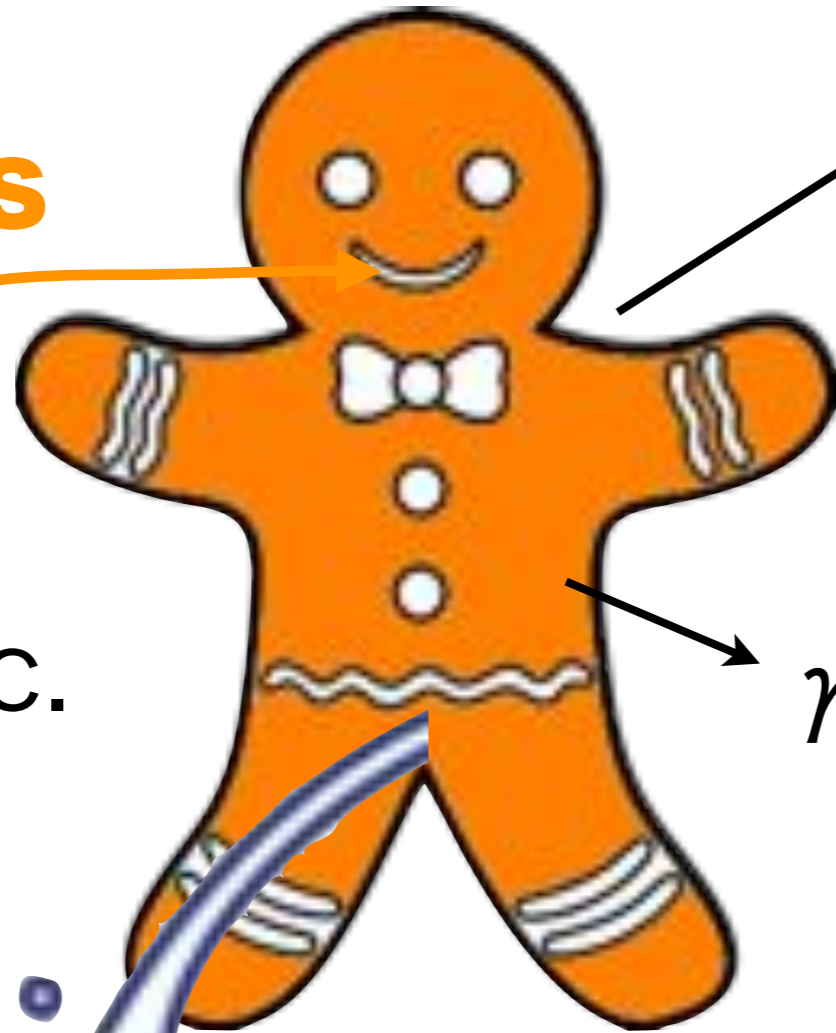
2~3Bq/day  
0.02mSv/year

**Cs**

$\gamma$ -ray

$\gamma$ -ray

urine

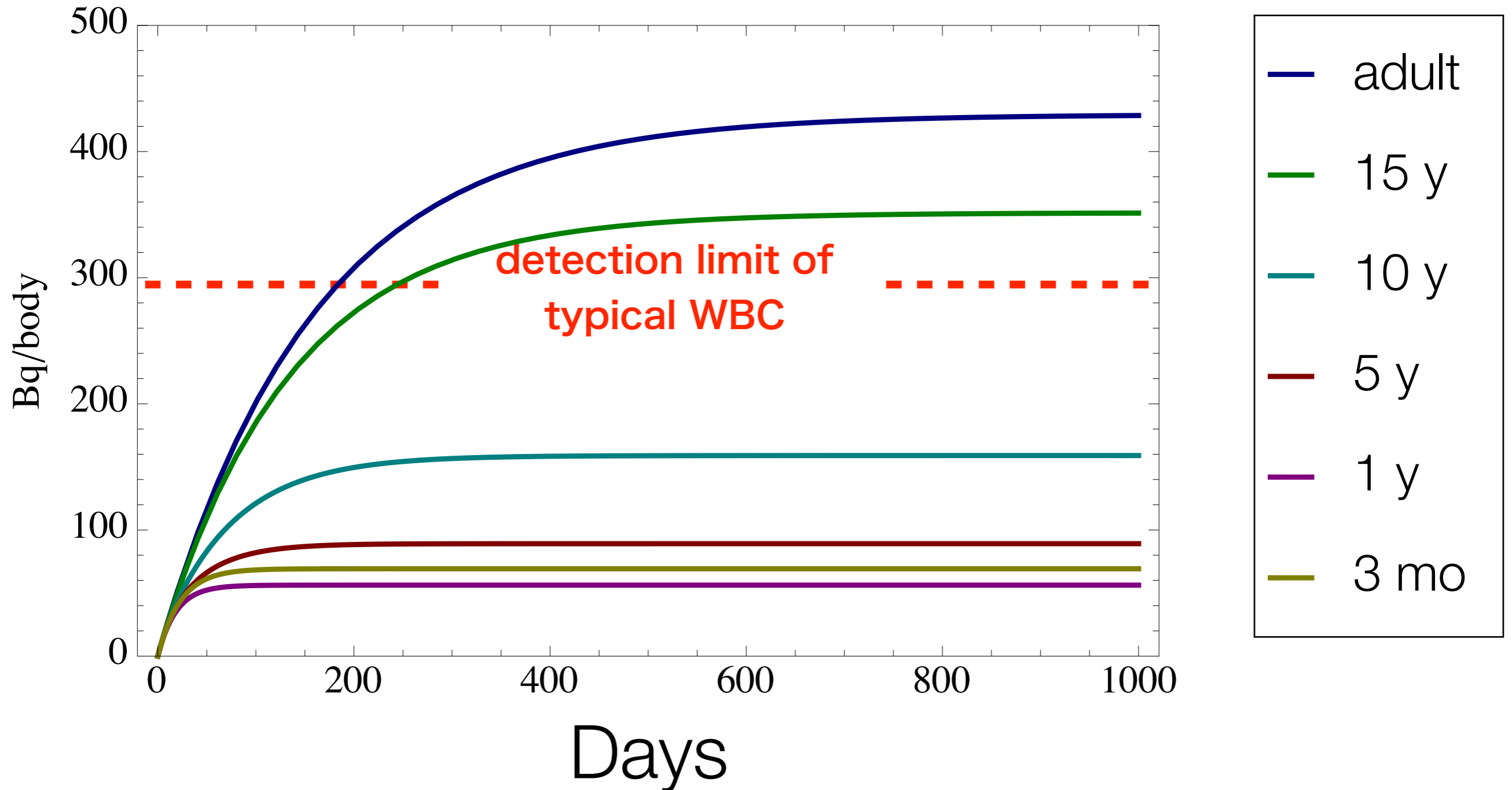


Lunch test etc.

1~2Bq/day



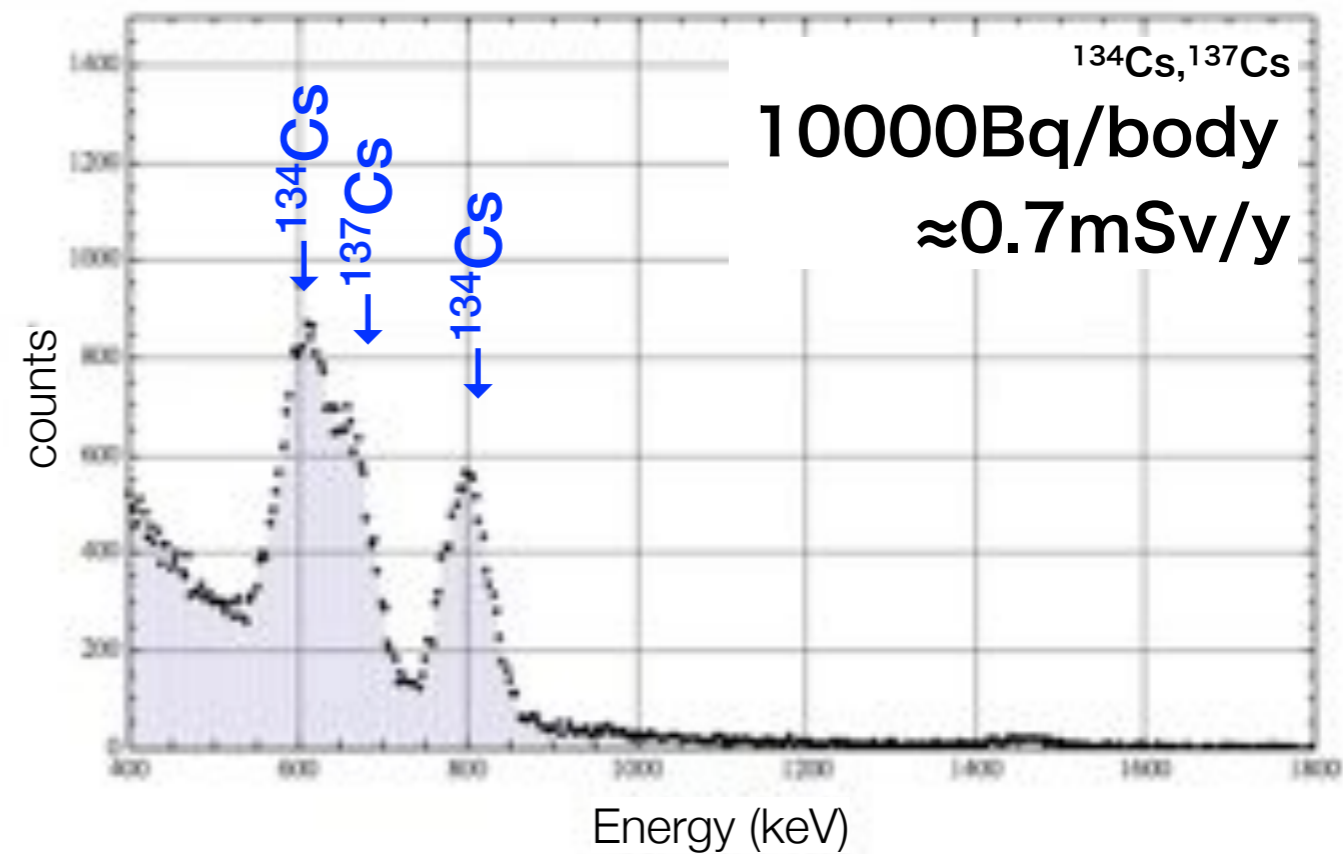
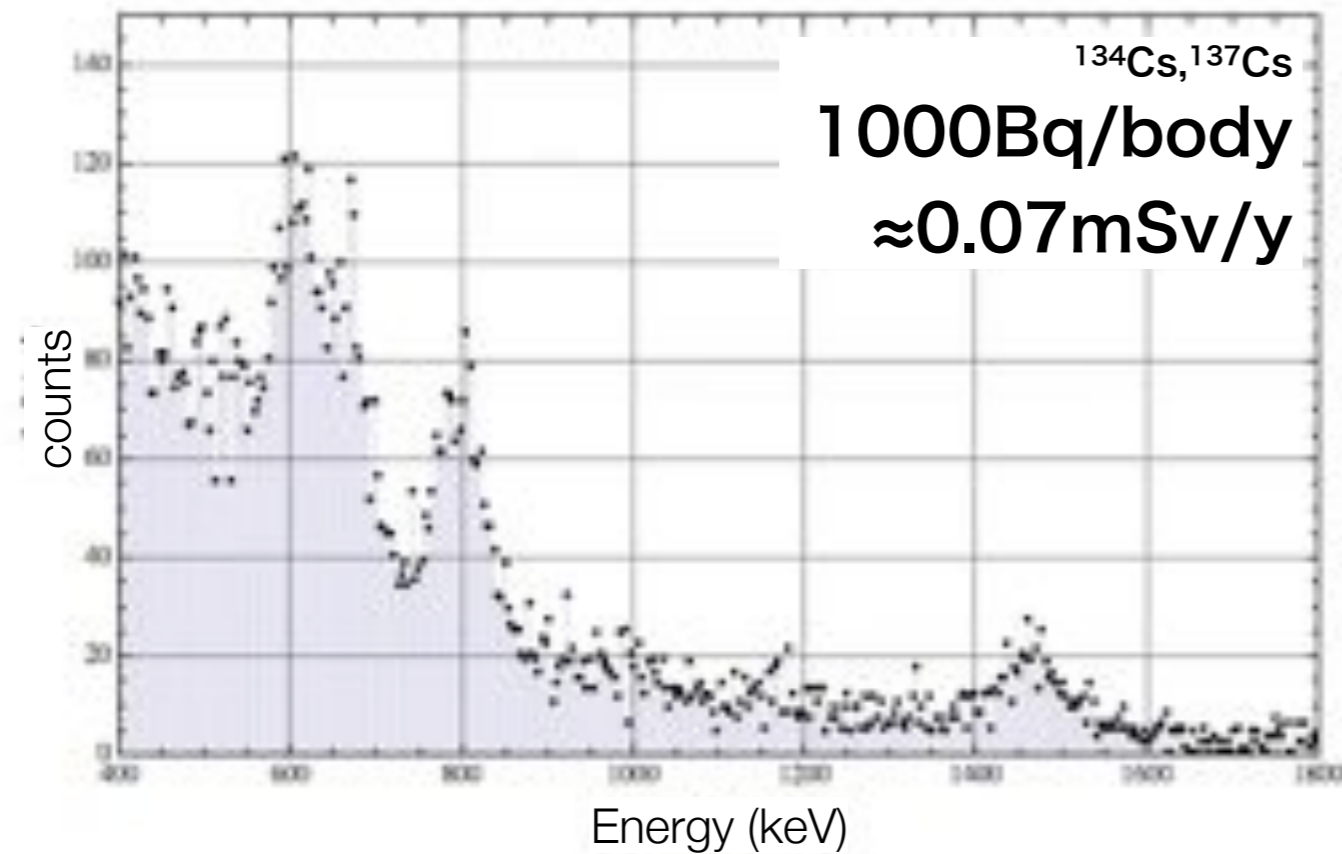
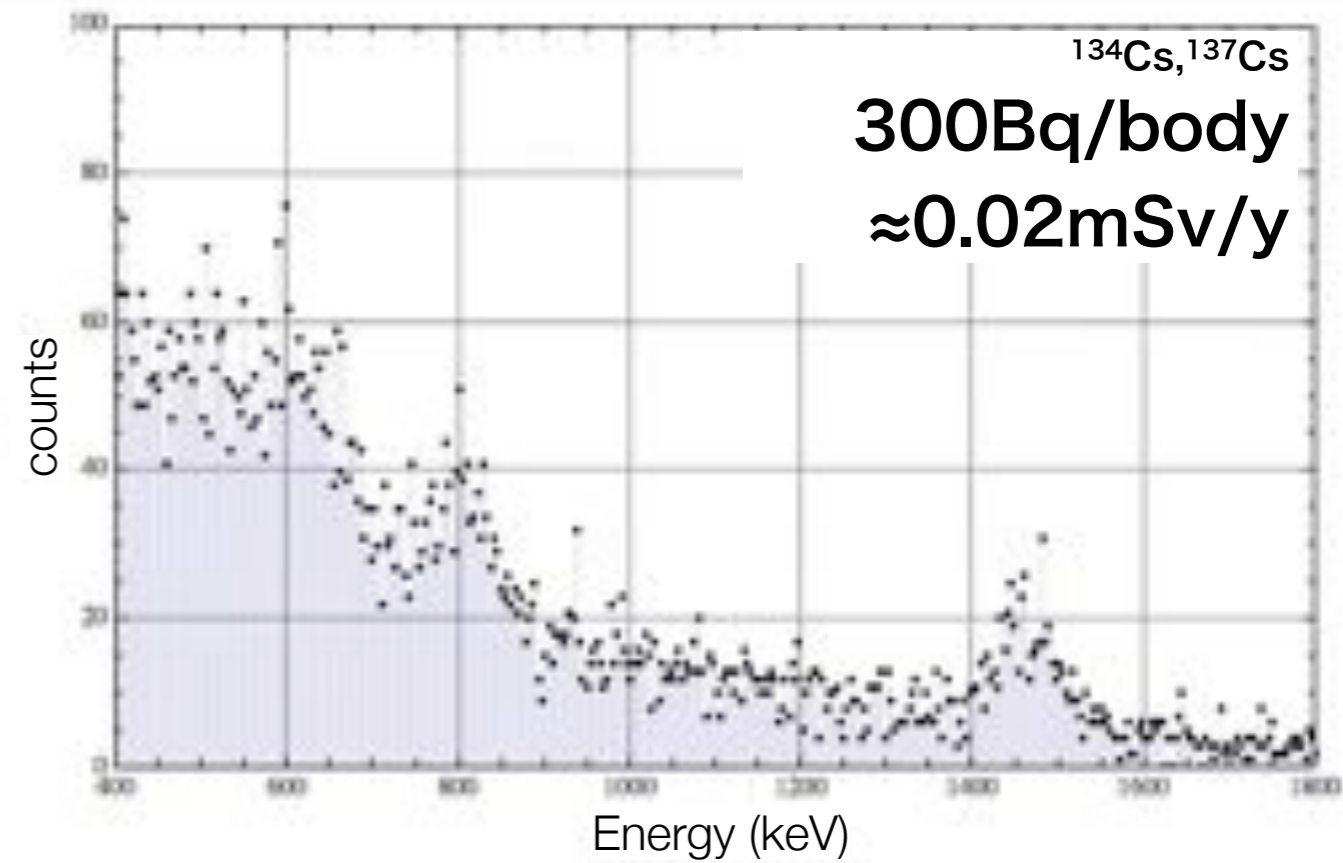
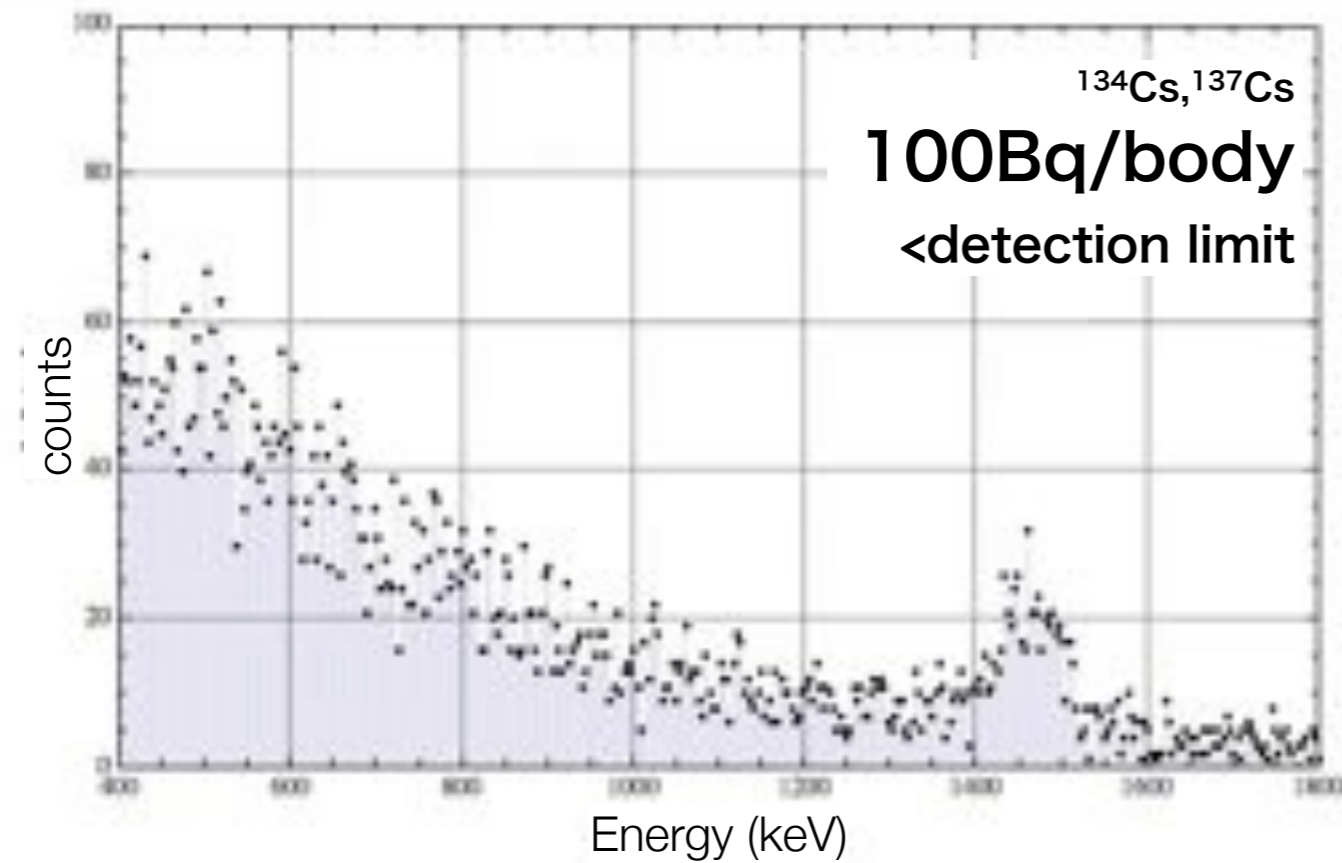
# Amount of $^{137}\text{Cs}$ in body (constantly eat 3 Bq everyday)



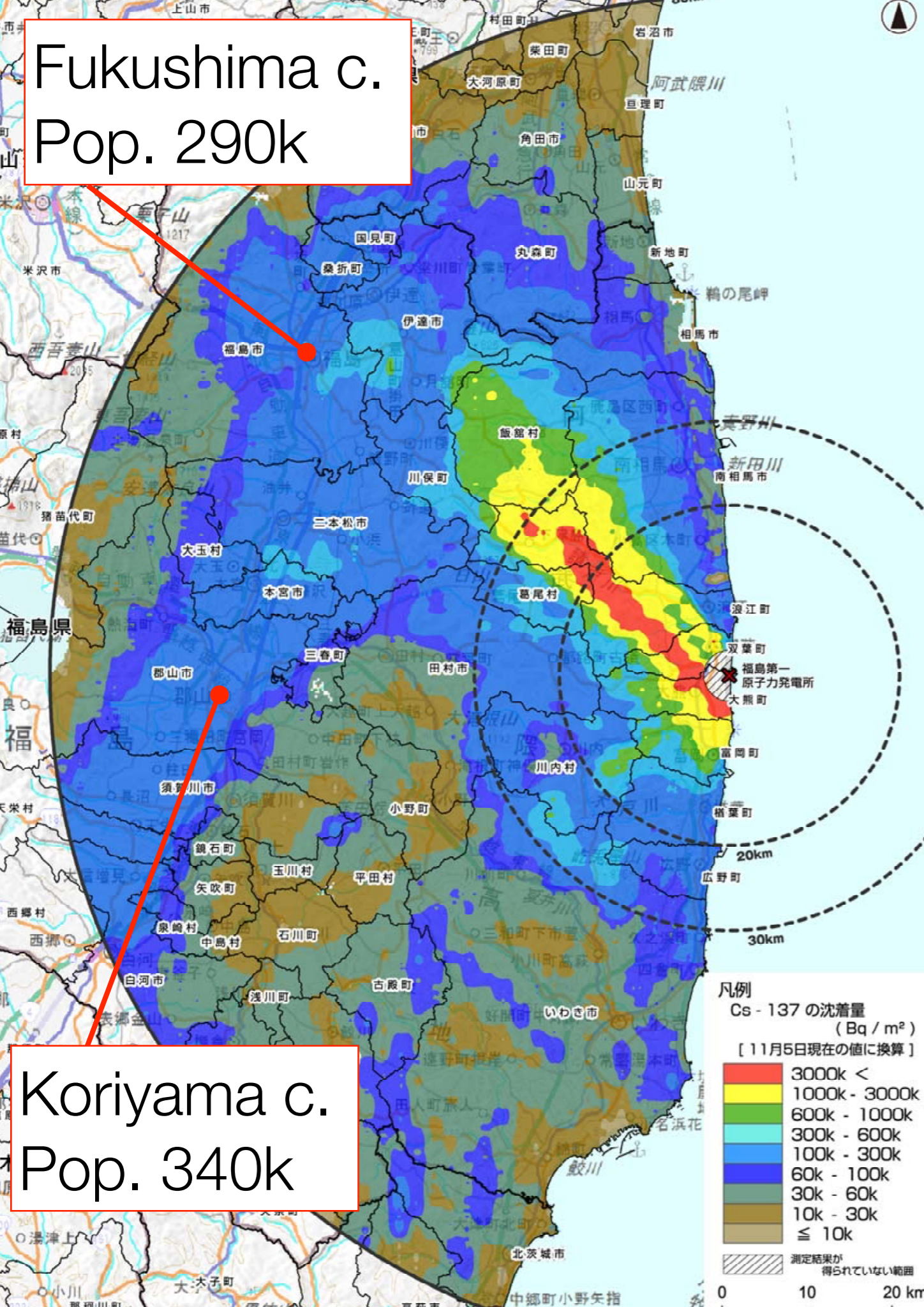
	<b>K-40</b>	<b>Cs-137</b>
	This we cannot avoid	This we can avoid
<b>Annual dose (mSv/y)</b>	0.2	1 (for example)
<b>Intake per year (Bq)</b>	20,000	70,000
<b>Amount in the body (Bq)</b>	4,000	27,000
<b>Concentration (Bq/kg)</b>	55	400

These are for adults  
All numbers are approximate

# WBC spectra (simulations based on actual data)



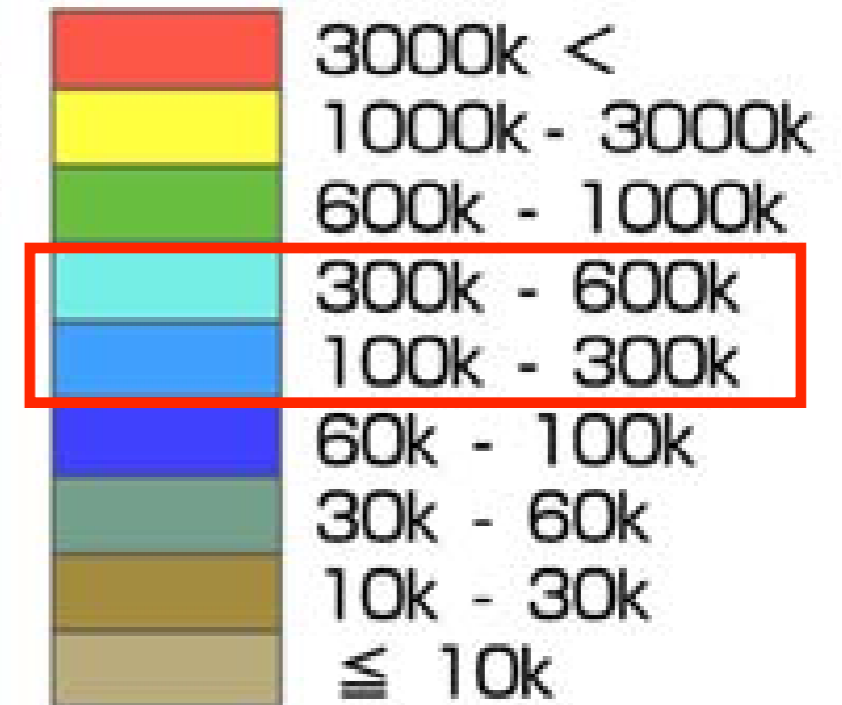
Fukushima c.  
Pop. 290k



# Chernobyl studies infer:

100kBq/m<sup>2</sup> of <sup>137</sup>Cs on soil  
→ internal exposure 2 mSv/y

<sup>137</sup>Cs deposition  
Bq/m<sup>2</sup>  
(2011/11/5)



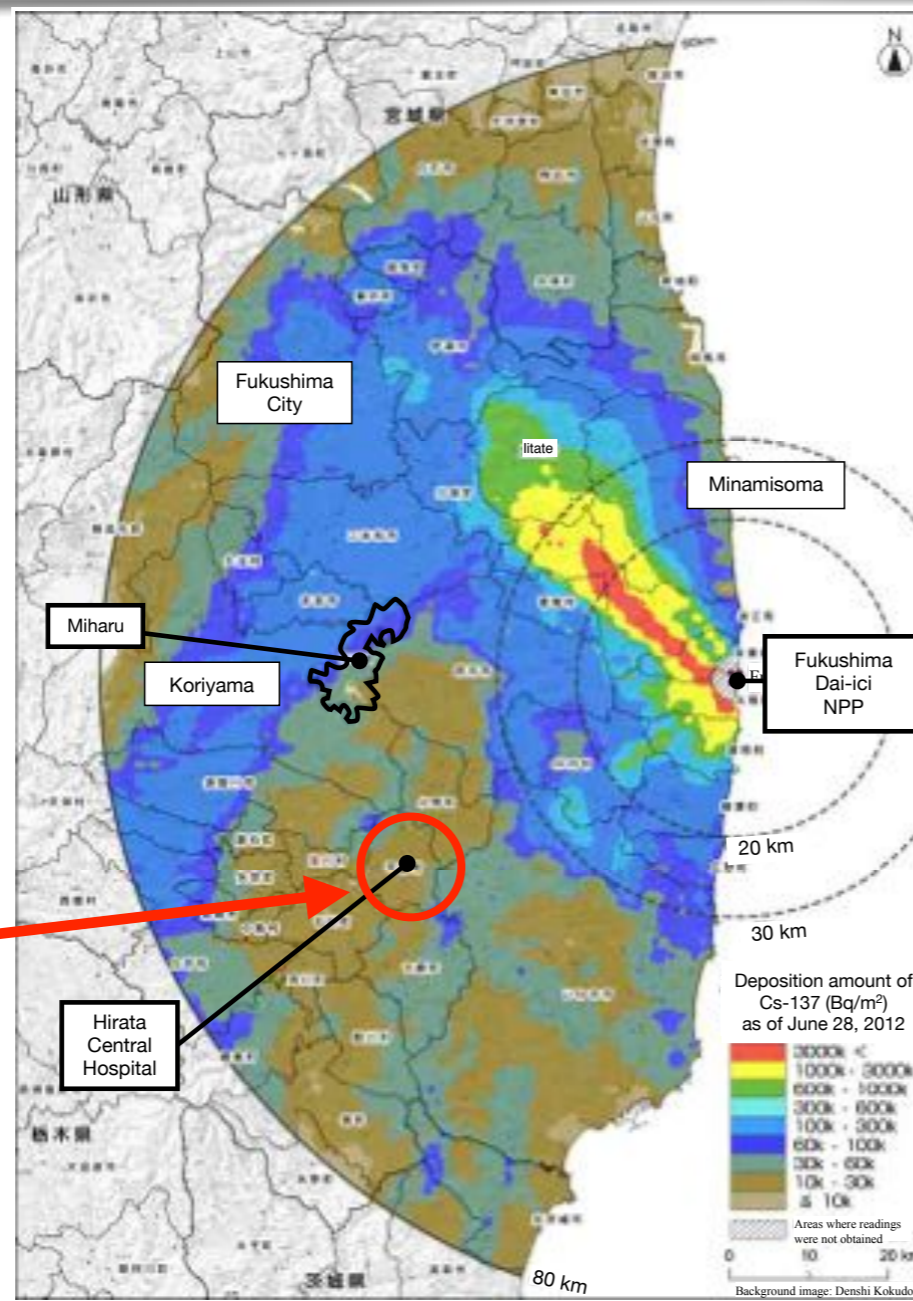
Koriyama c.  
Pop. 340k



# my first medical paper

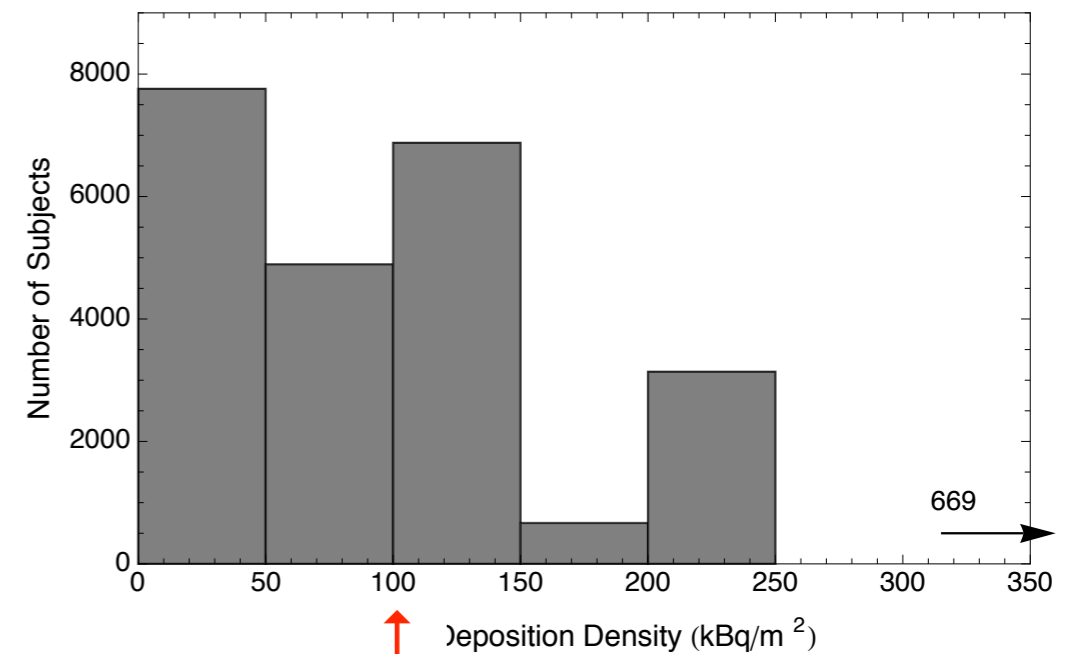
## Internal radiocesium contamination of adults and children in Fukushima 7 to 20 months after the Fukushima NPP accident as measured by extensive whole-body-counter surveys

By Ryugo S. HAYANO,<sup>\*1,†</sup> Masaharu TSUBOKURA,<sup>\*2</sup> Makoto MIYAZAKI,<sup>\*3</sup>  
Hideo SATOU,<sup>\*4</sup> Katsumi SATO,<sup>\*4</sup> Shin MASAKI<sup>\*4</sup> and Yu SAKUMA<sup>\*4</sup>



### soil contamination level of the subjects

Number of Fukushima subjects (n=24004) vs Deposition density



↑ 100kBq/m<sup>2</sup>

# $^{137}\text{Cs}$ concentration (Bq/kg) after March 2012

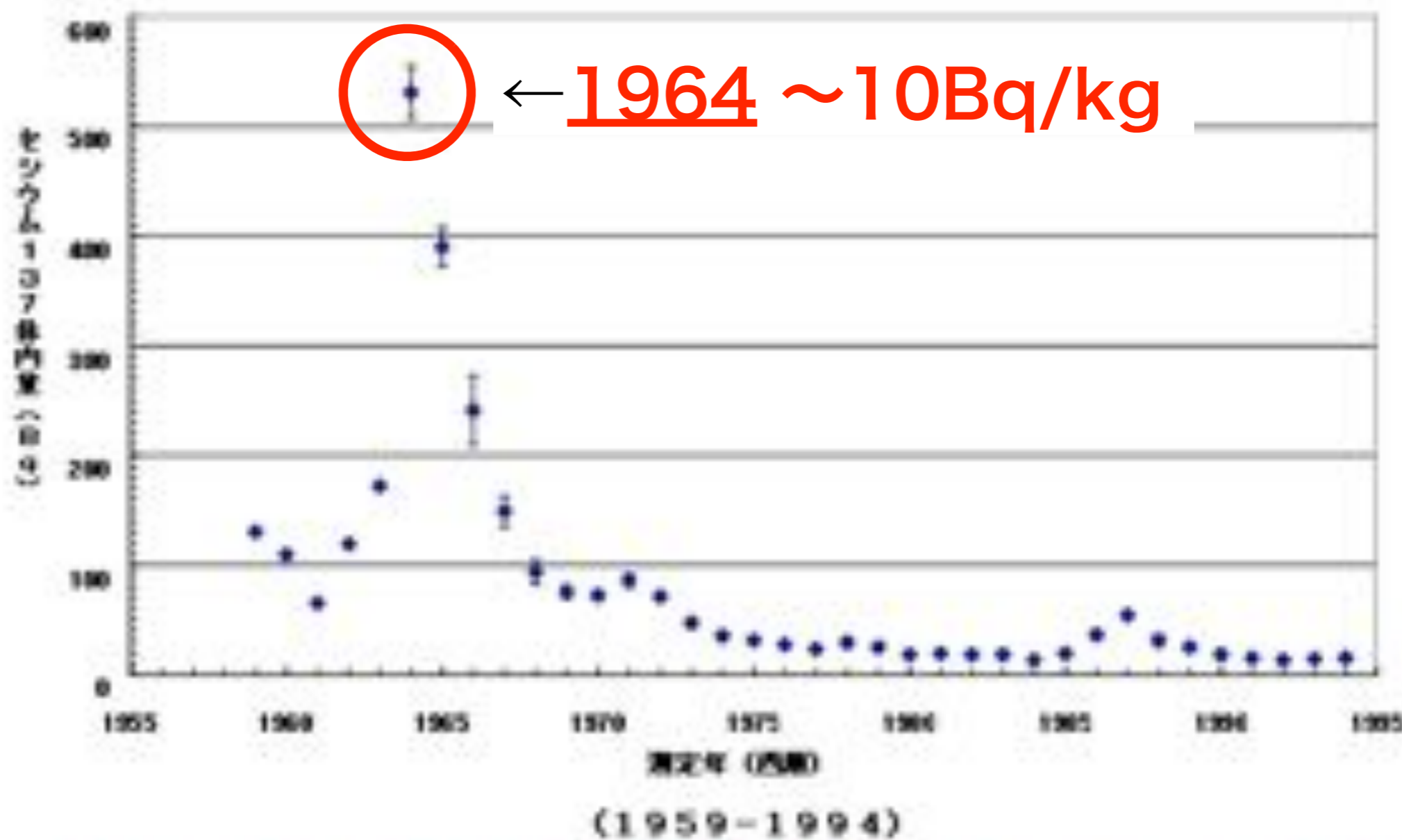
99% (children 100%) were below the detection limit

↓  
↑  
10Bq/kg

≈1mSv/y  
including  $^{134}\text{Cs}$

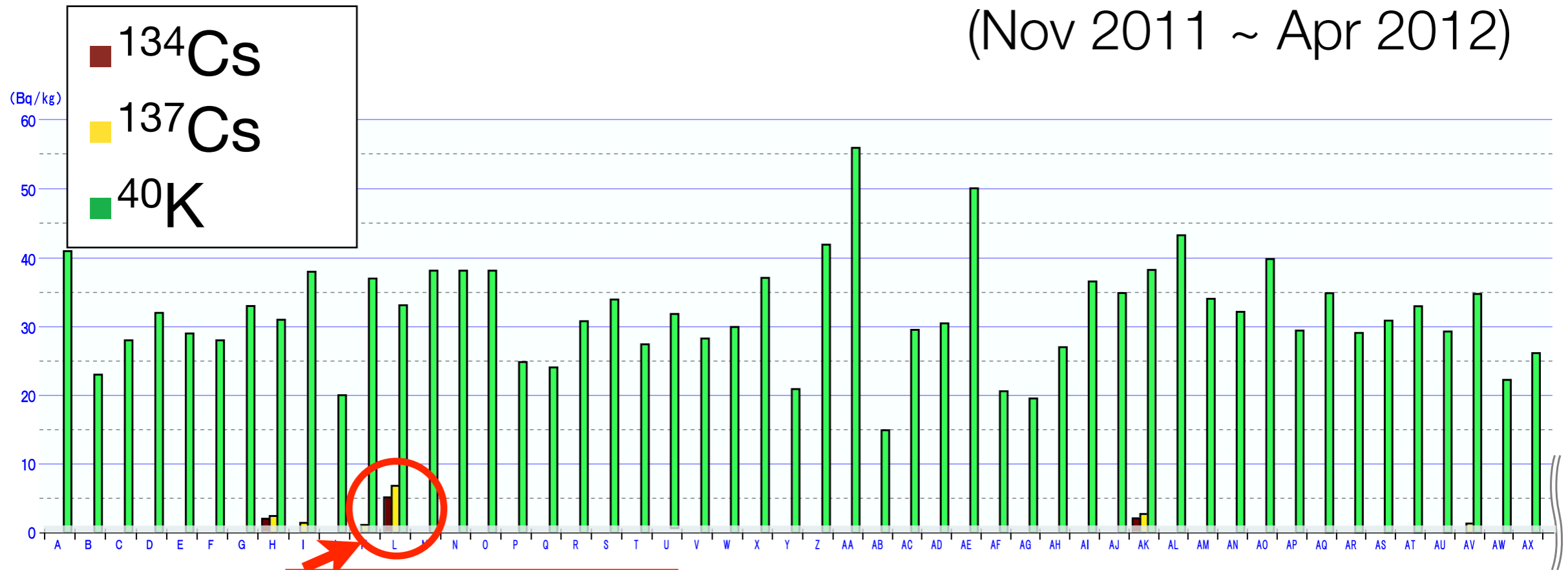


# $^{137}\text{Cs}$ in Japanese adult male, 1959-1994

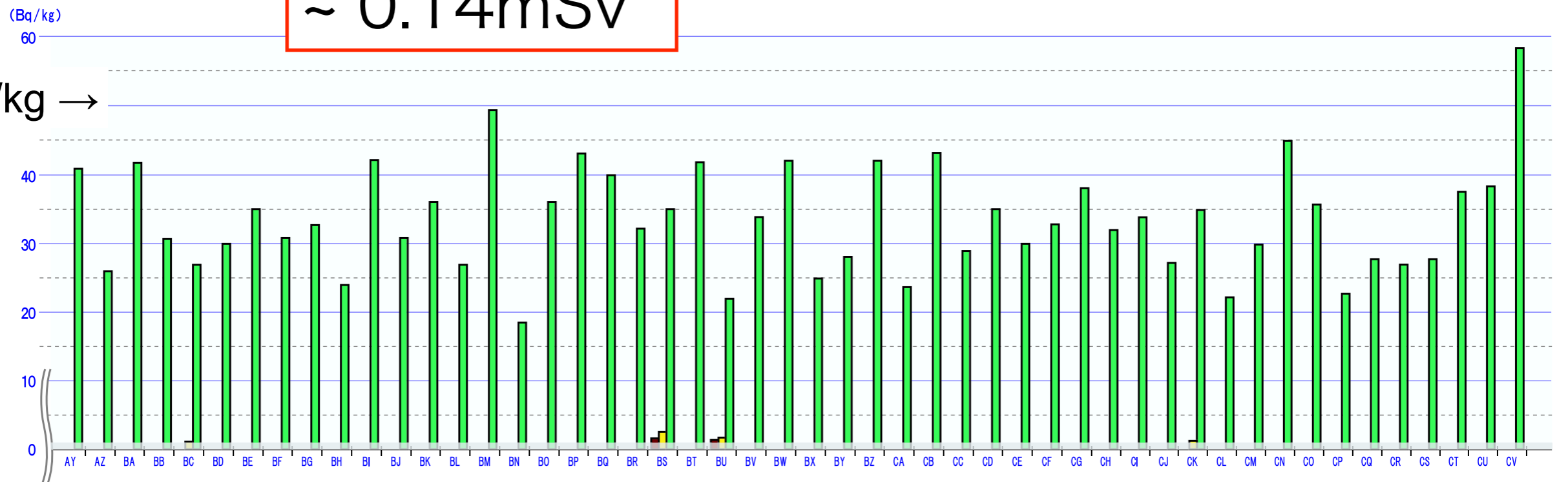


# K and Cs in food served (100 families)

(Nov 2011 ~ Apr 2012)



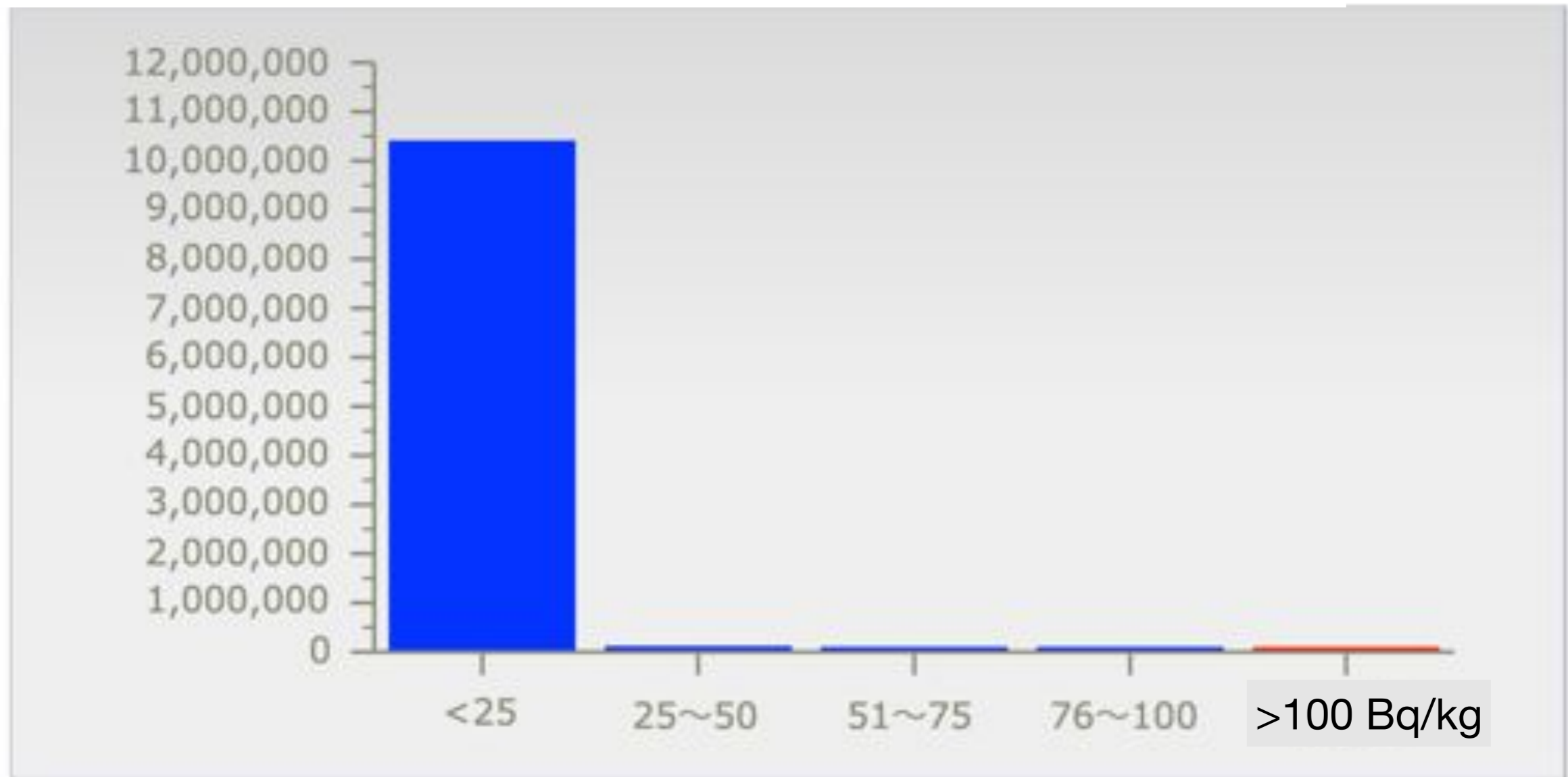
~ 0.14mSv



Why?

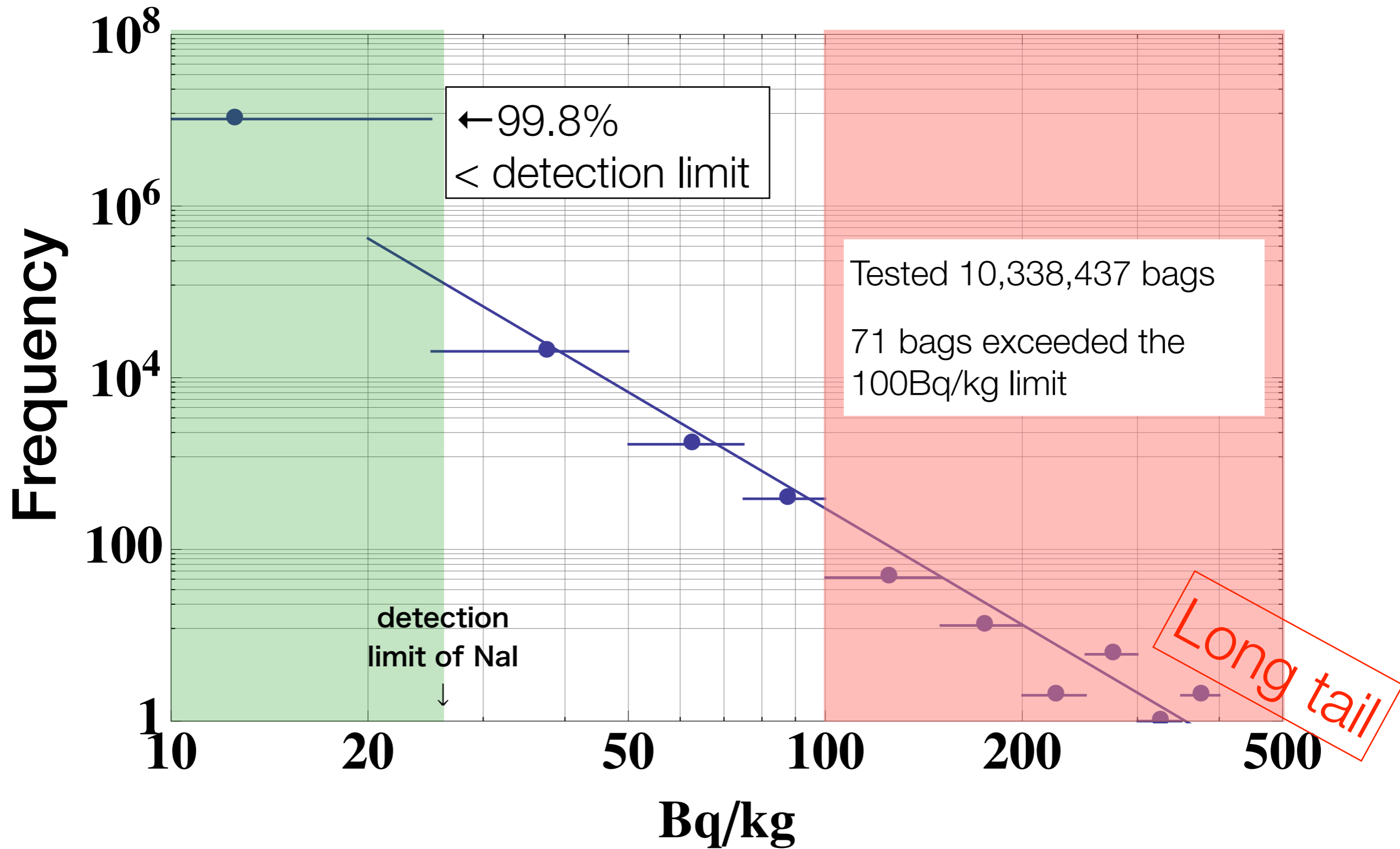
# Every bag (30kg each) of brown-rice harvested in Fukushima in 2012 tested for radiocesium

Total 10,338,437 bags

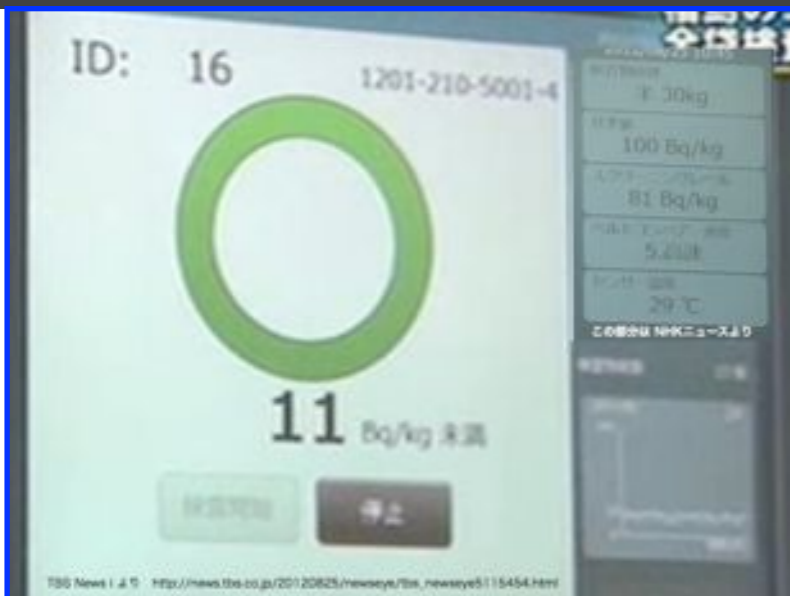


<https://fukumegu.org/ok/kome/>

# Same data in log-log plot



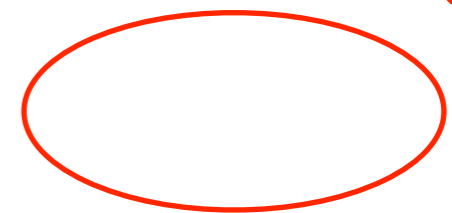
# How the rice bags are measured



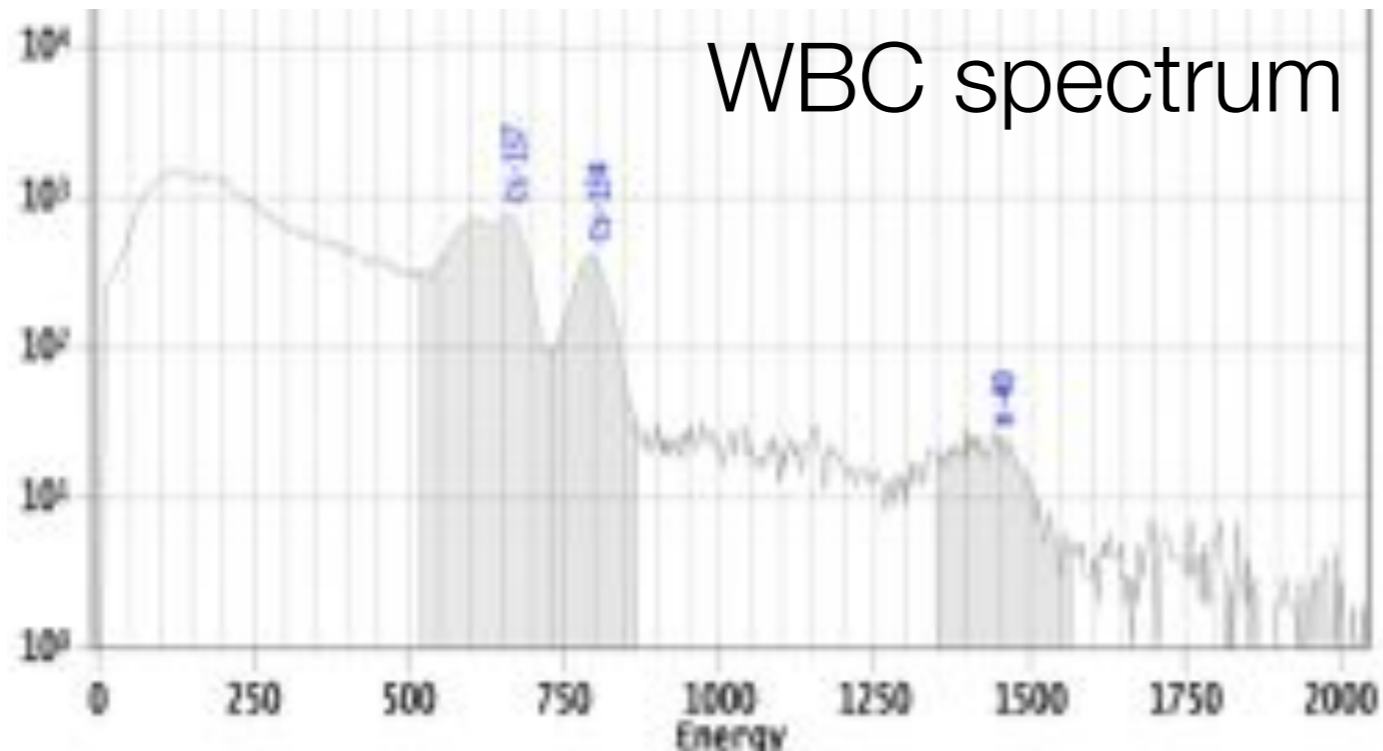


But there is a “long tail” - exceptionally high people

$\approx 1 \text{ mSv/y}$   
including  $^{134}\text{Cs}$



70-male, 20,000Bq/body, 0.8mSv/y  
140,000 Bq/kg mushroom was found in his pantry

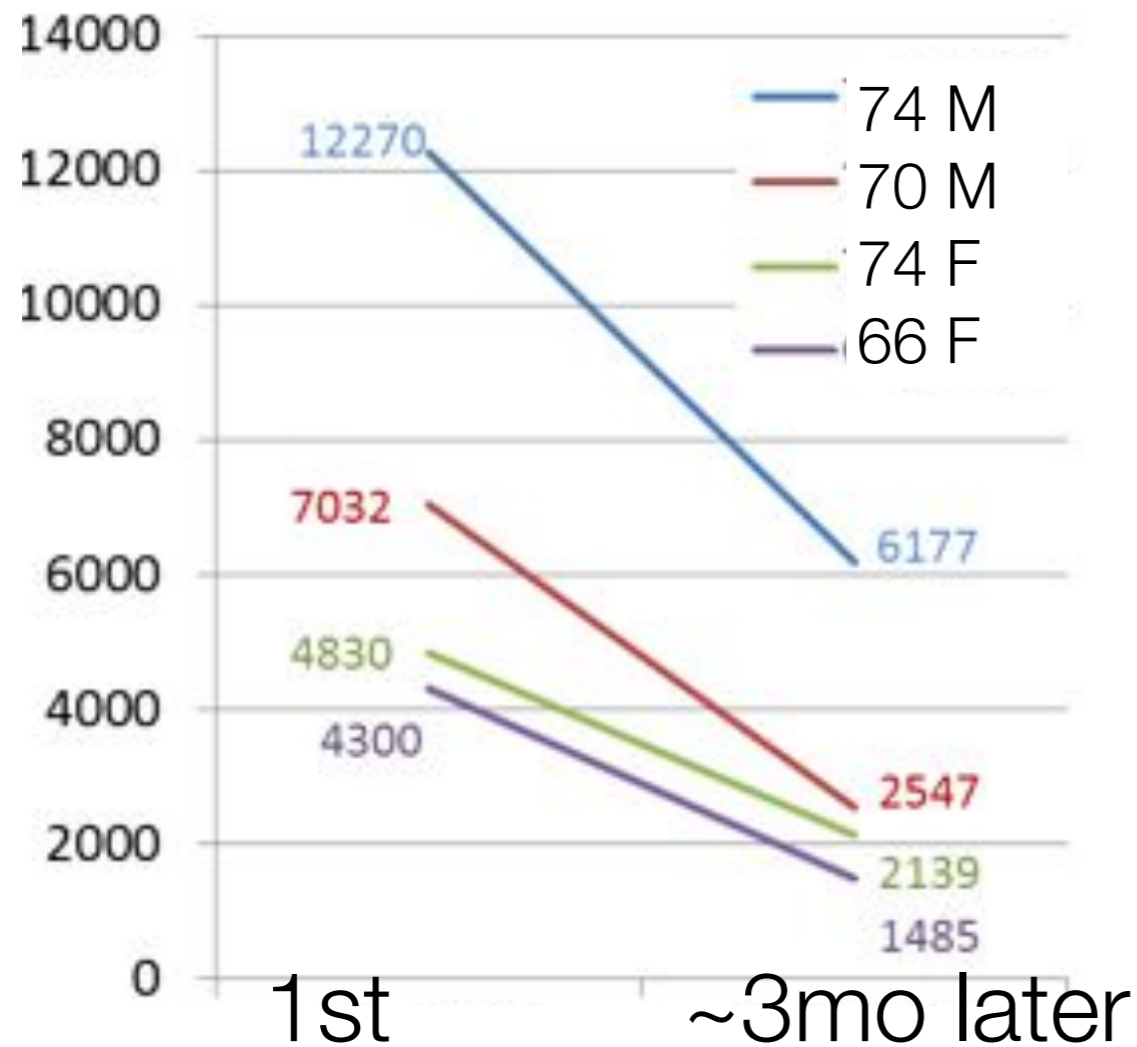


Shiitake mushroom

Wild boar, wild mushrooms, ...,  
not from markets  
not tested for radiocesium  
consumed regularly

# Such people are rare (~ 0.01%)

Age	Sex	Resident of	First measurement	$^{137}\text{Cs}$ (Bq/body)	$^{137}\text{Cs}$ (Bq/kg)
74	M	Nihonmatsu	2012.8	12,270	183.7
70	M	Kawamata	2012.7	7,032	111.6
74	F	Nihonmatsu	2012.8	4,830	69.4
66	F	Kawamata	2012.7	4,300	69.6

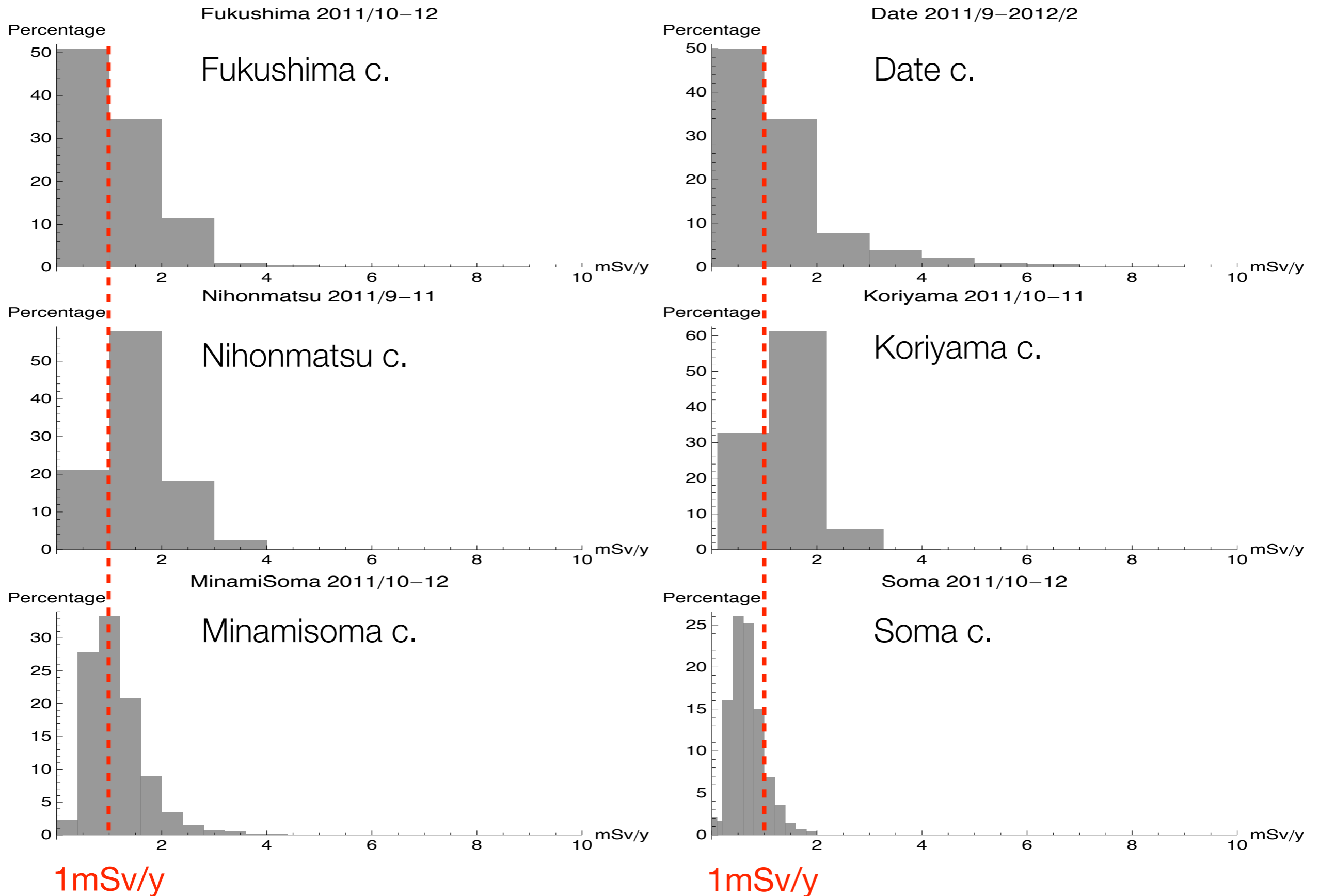


← after receiving advice, the Cs concentration decreased as expected

# External Exposure



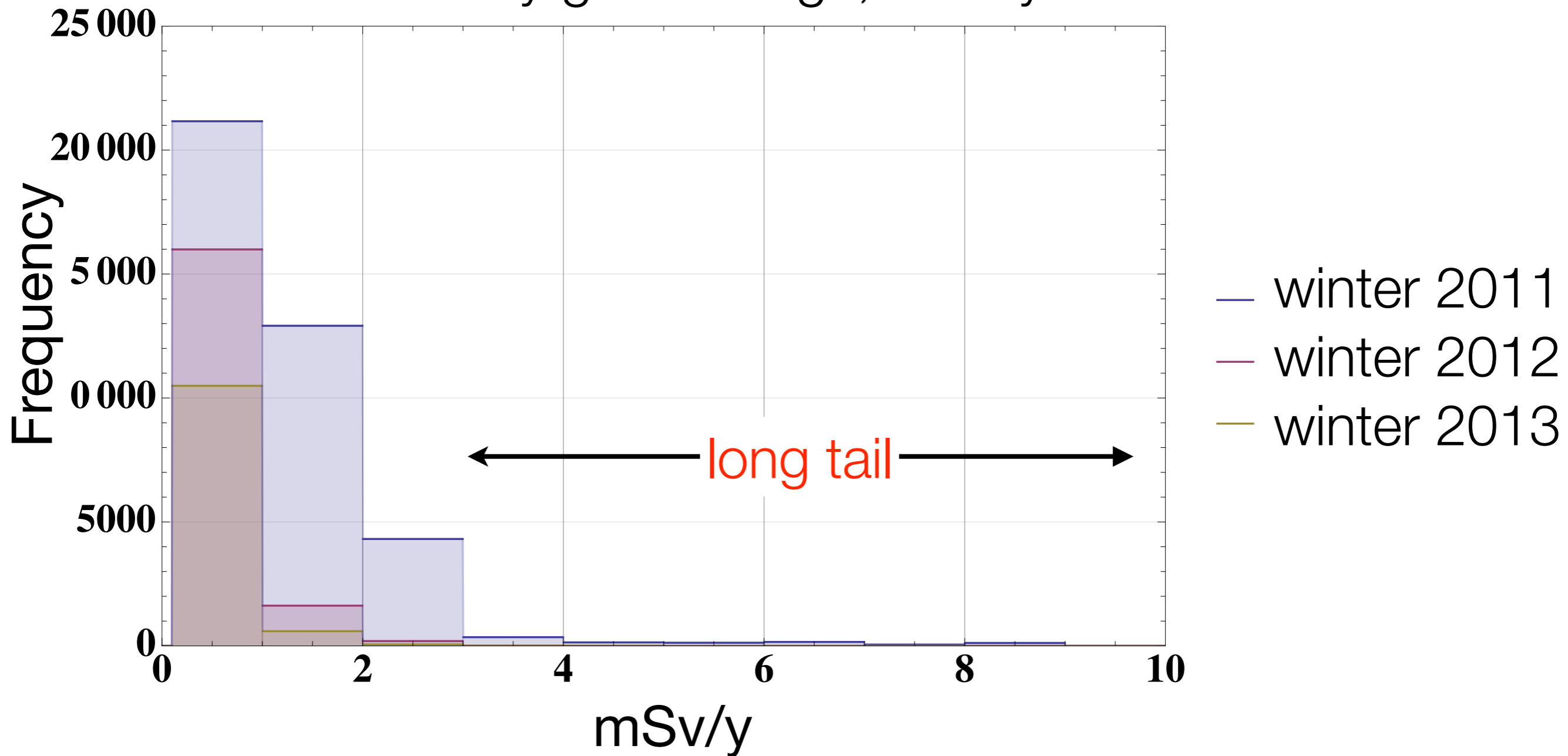
# “Glass badge” results, winter 2011



2~3 mo. results extrapolated to 1 year

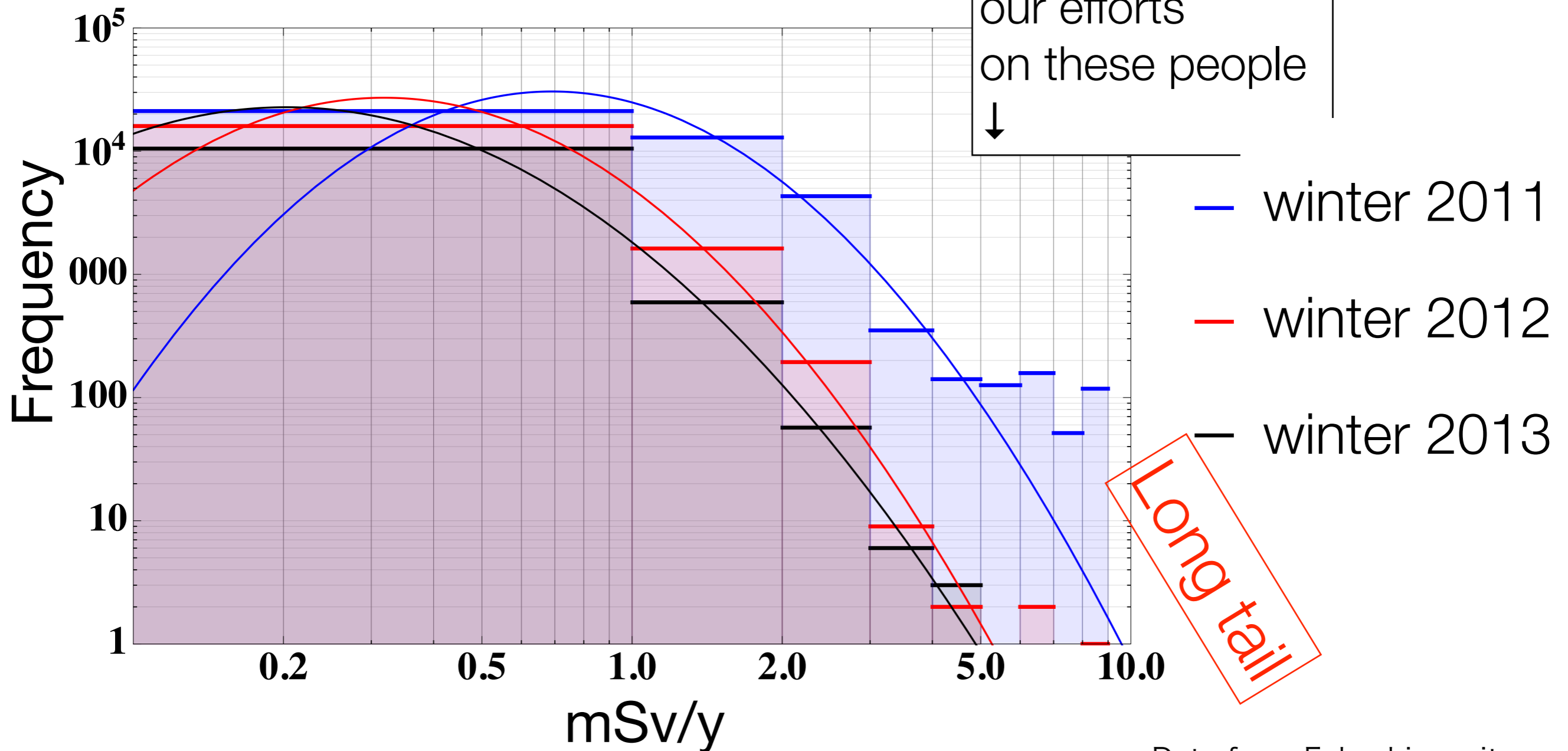
# Long tail of “glass badge” data

Fukushima city glass badge, 6-15 years



# Fukushima city glass badge data in log-log

Fukushima city glass badge



We must focus our efforts on these people  
↓

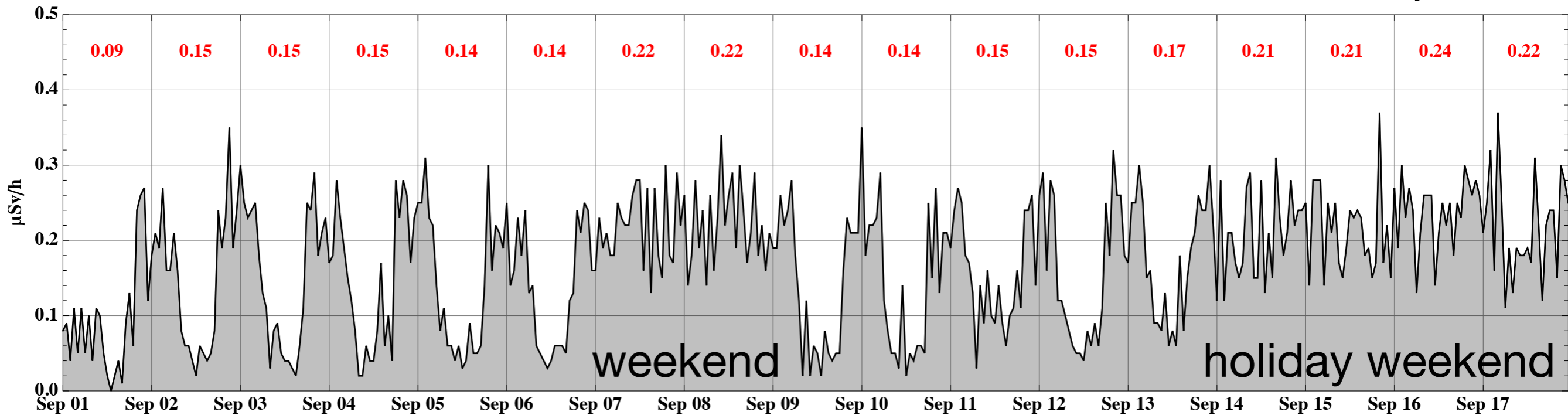
- winter 2011
- winter 2012
- winter 2013

Long tail

# Personal dosimeter with 1-hour integrated-dose readout



a Fukushima city resident





the key is to share the data with each individual

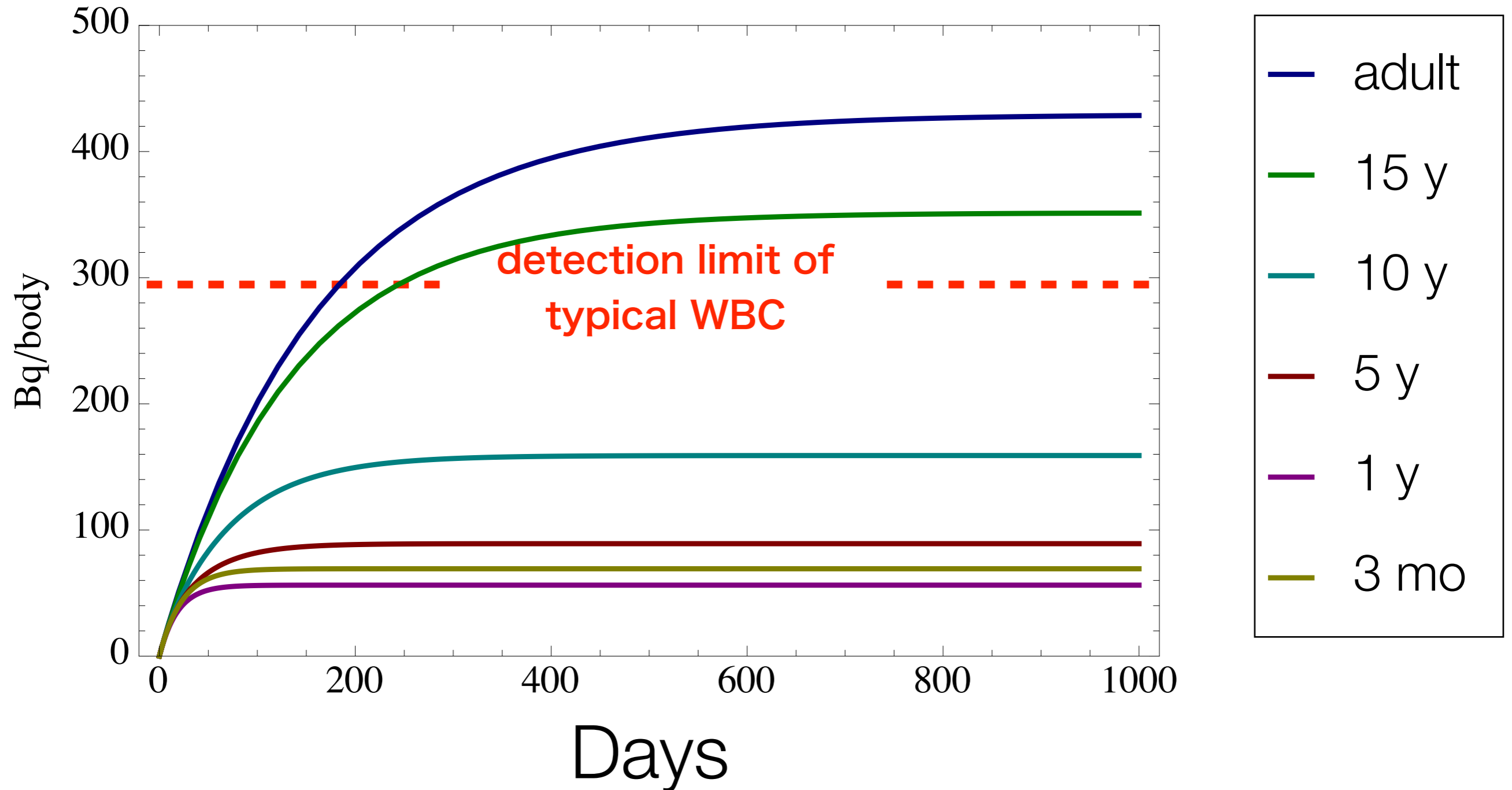


## Summary

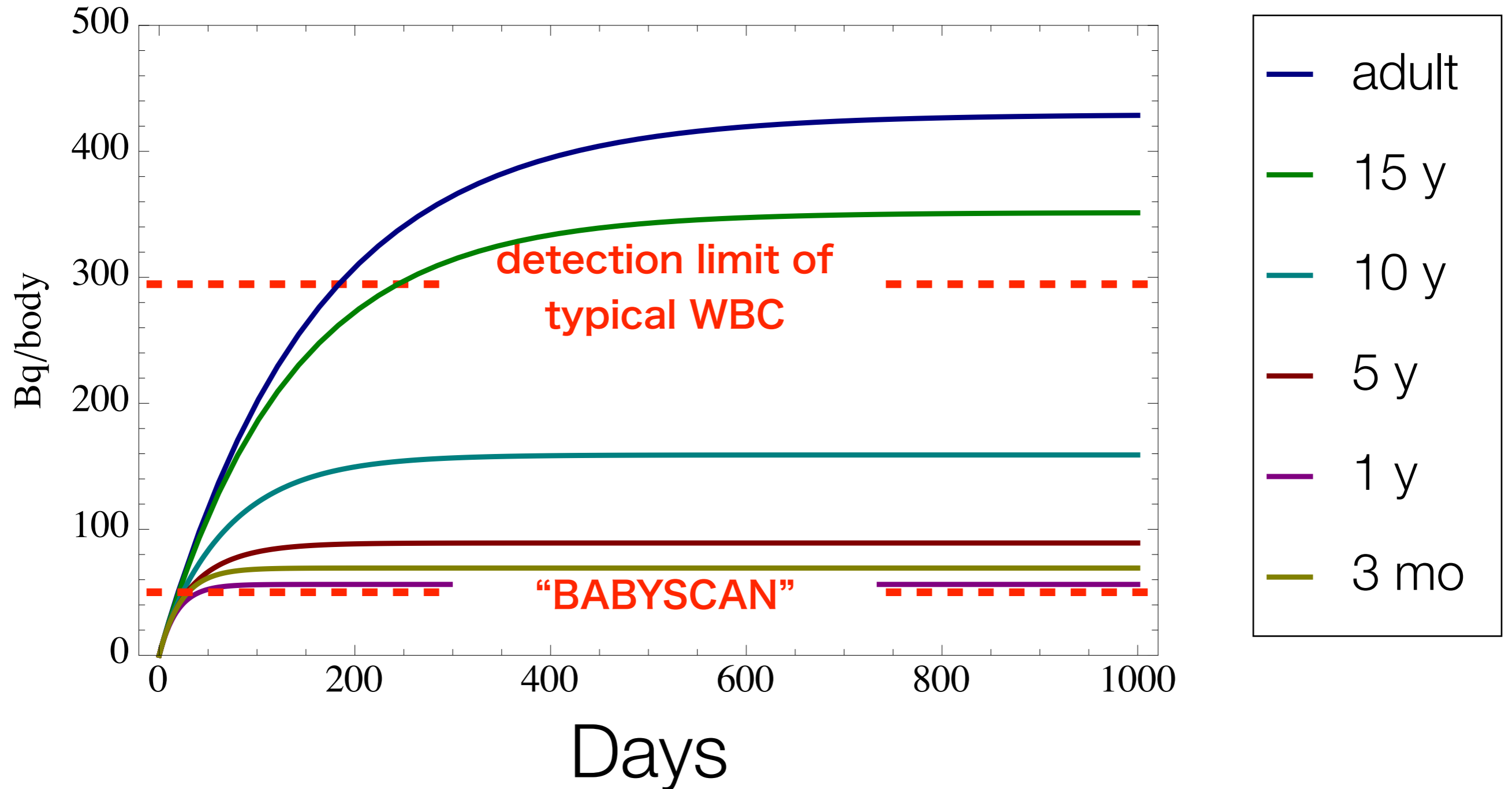
What have we learned?

1. Essential to measure internal+external dose for each individual
2. Dose (internal+external): MUCH lower than initially feared
3. But there is a “long tail”
  1. Looking at the “average” is insufficient
  2. Important to find the people in the “tail”, explain, consult, devise effective measures to reduce their dose
4. Importance of face-to-face communication (dialogue)
5. Radiation is NOT the only problem -  
Many more psycho-social problems

Scientifically, it is sufficient to measure parents but mothers want to have their babies measured



Scientifically, it is sufficient to measure parents but mothers want to have their babies measured



So I made this device, “BABYSCAN”  
world’s first WBC dedicated for small children

