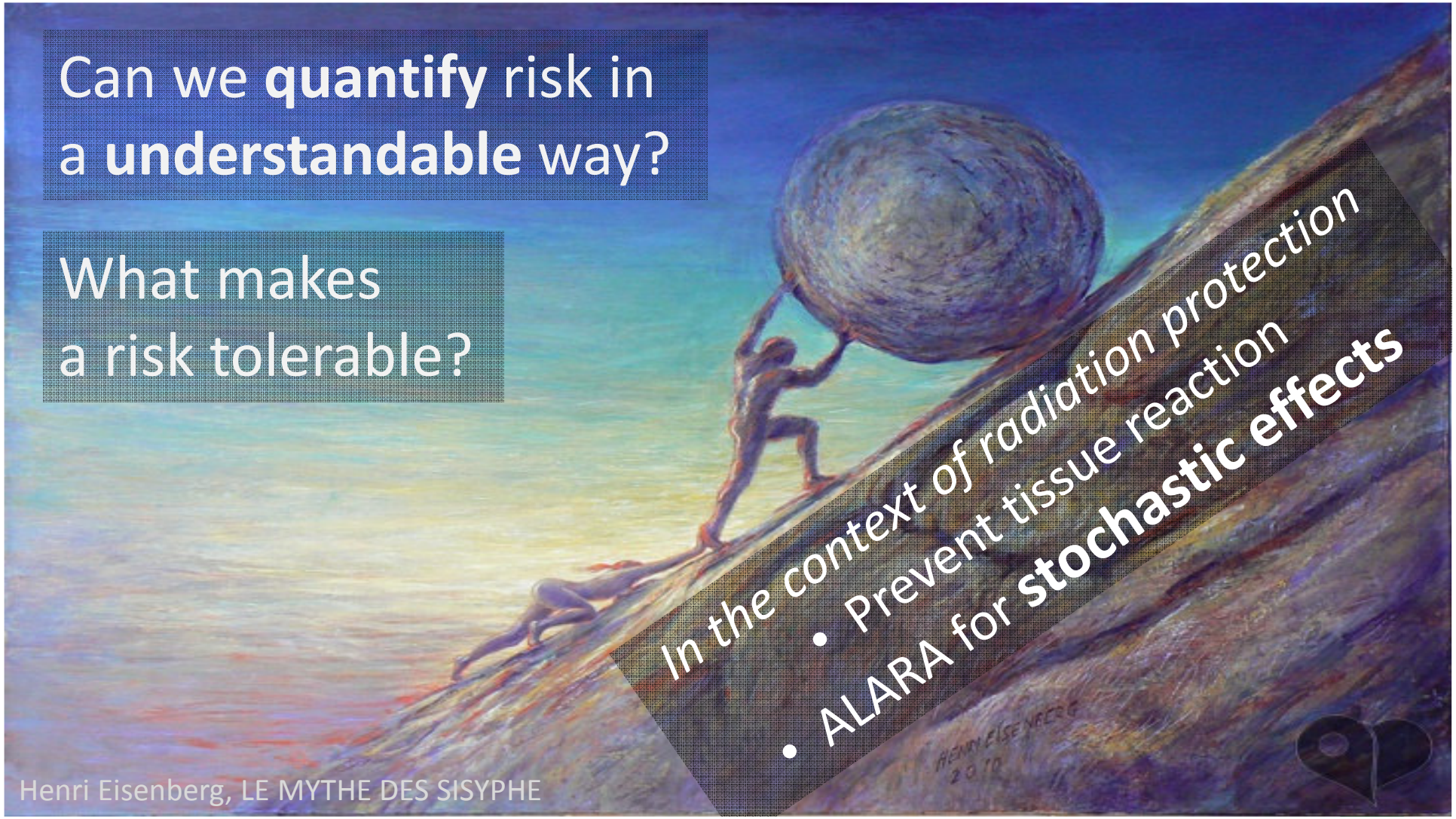
Quantification and tolerability of risk

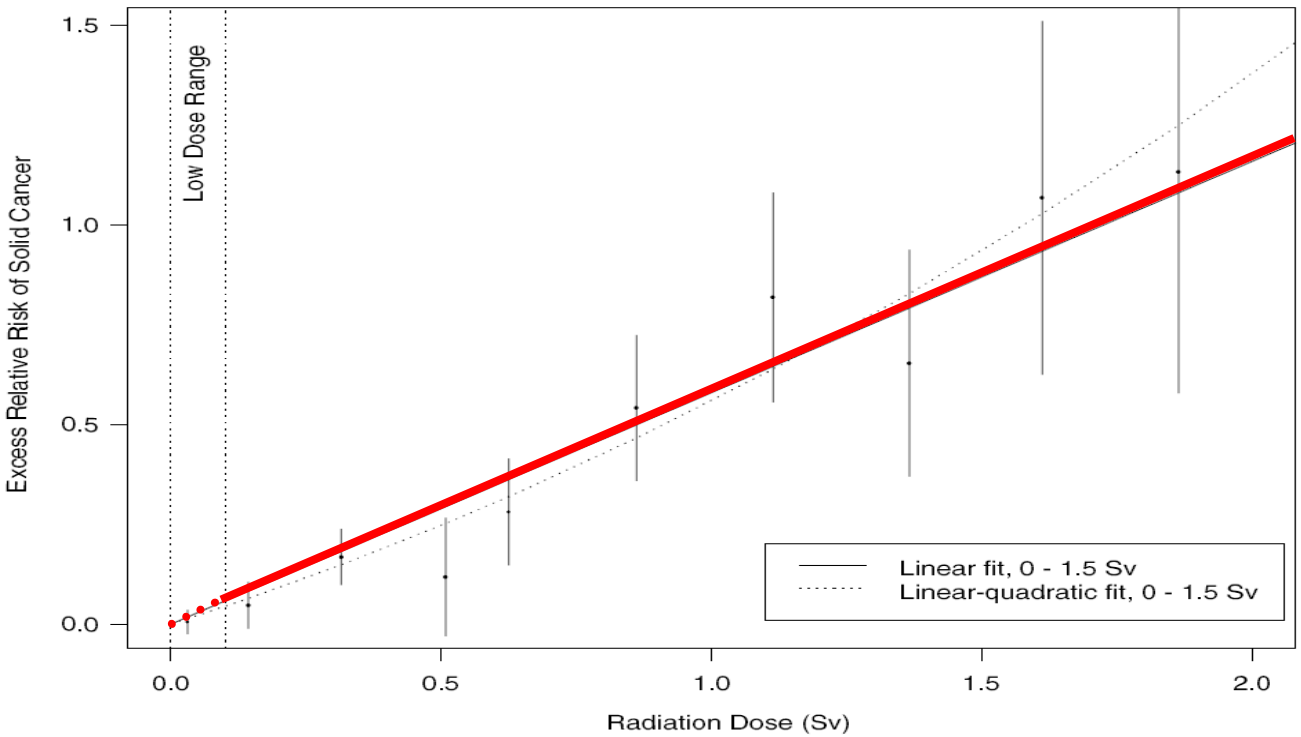
KSR Radiation Protection Workshop
Ethics and Justification of Radiation Protection
Bern, 7 April 2017

François Bochud

Federal Commission on Radiation Protection
Institute of Radiation physics
Lausanne University Hospital


Can we **quantify** risk in a **understandable** way?
What makes a risk tolerable?
In the context of radiation protection
• Prevent tissue reaction
• ALARA for **stochastic effects**
Henri Eisenberg, LE MYTHE DES SISYPHE

LNT: extrapolation to low-dose risk



Int.J.Radiat.Biol. 2004;80:327-37

healthy **survivor** effect

use of
absorbed dose

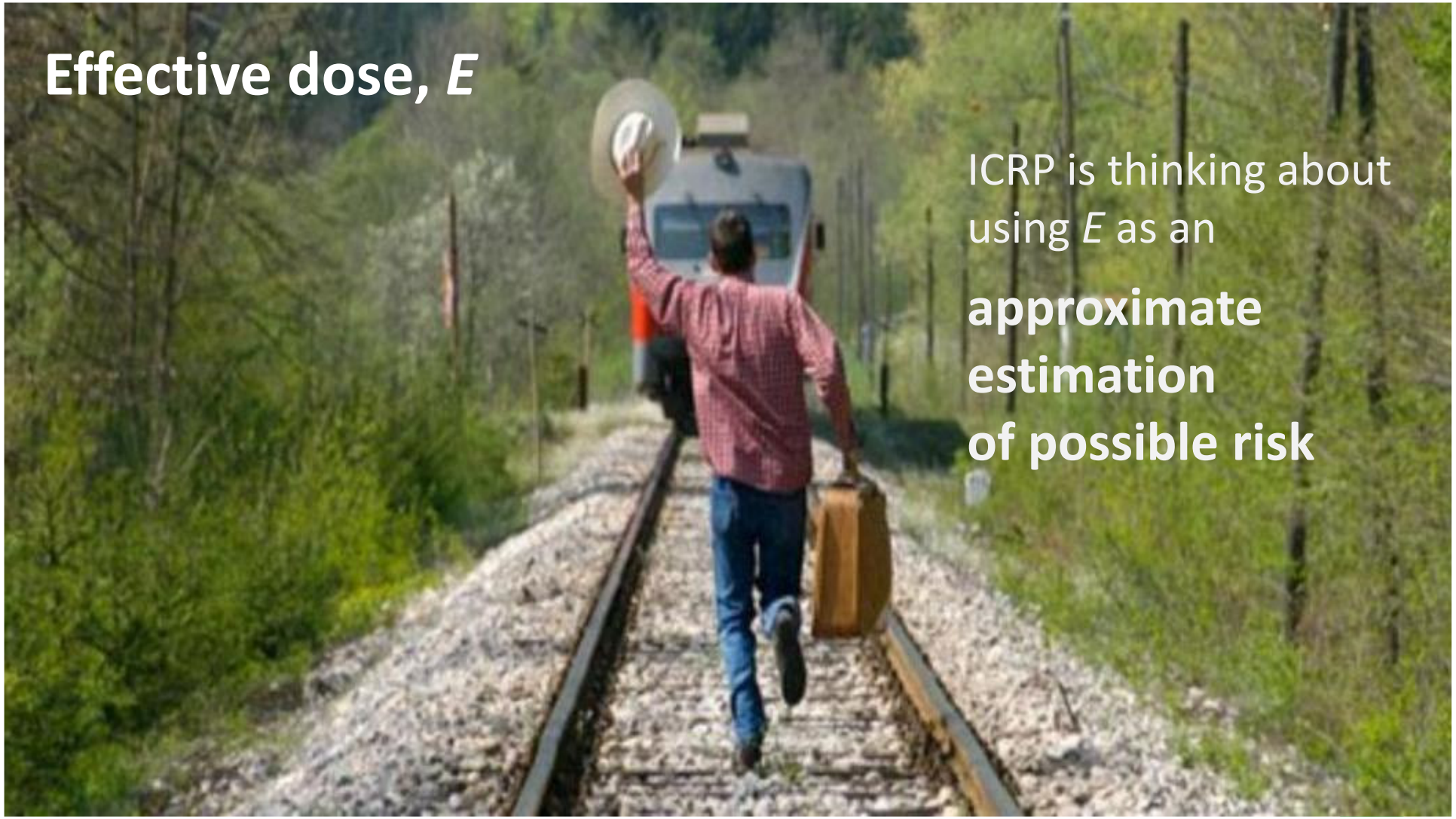
leukemia studies may have started **too late**

both study group and controls exposed to
internal radiations from **fallout**

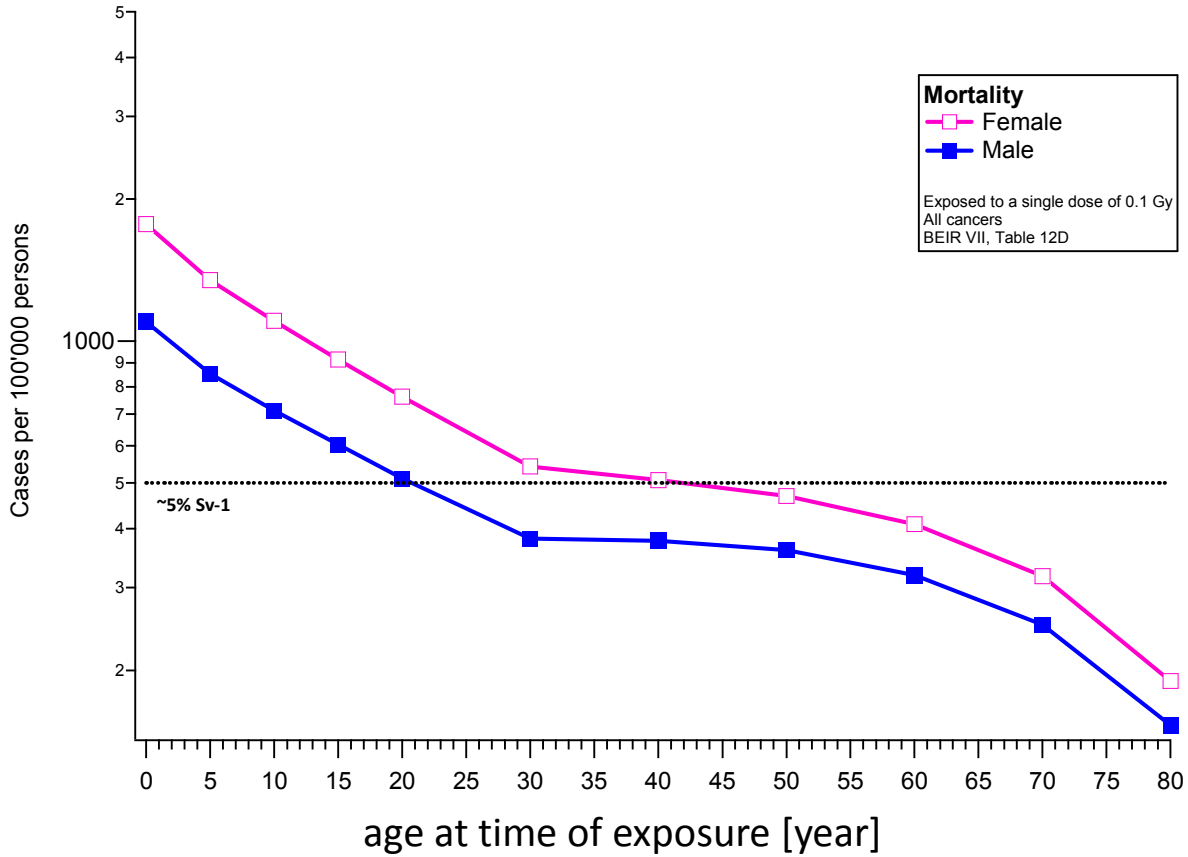
acute irradiation
external irradiation
high dose
based on **Japanese** population

several **extrapolations**

Many **uncertainties**
Do we need better than a **factor 2**?

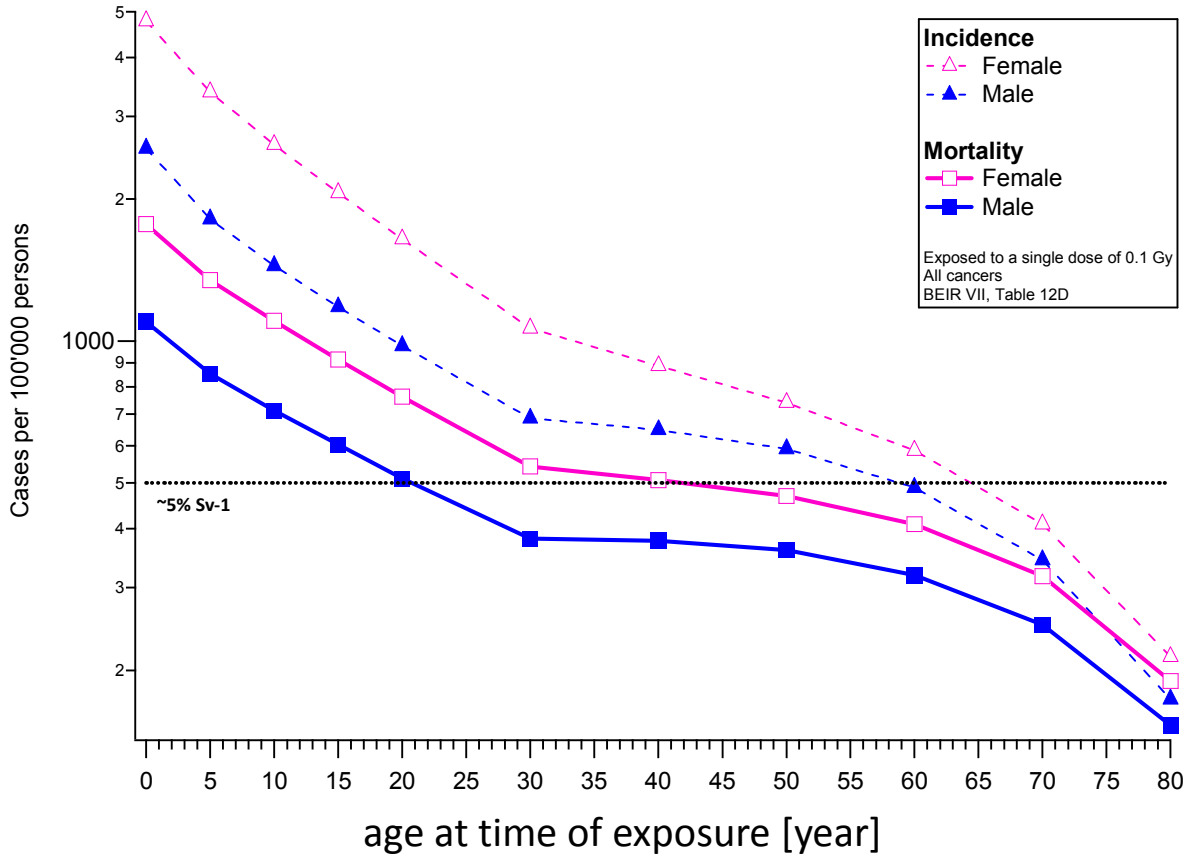

Effective dose, *E*
ICRP is thinking about using *E* as an
approximate estimation of possible risk

E as an approximate estimation of possible risk



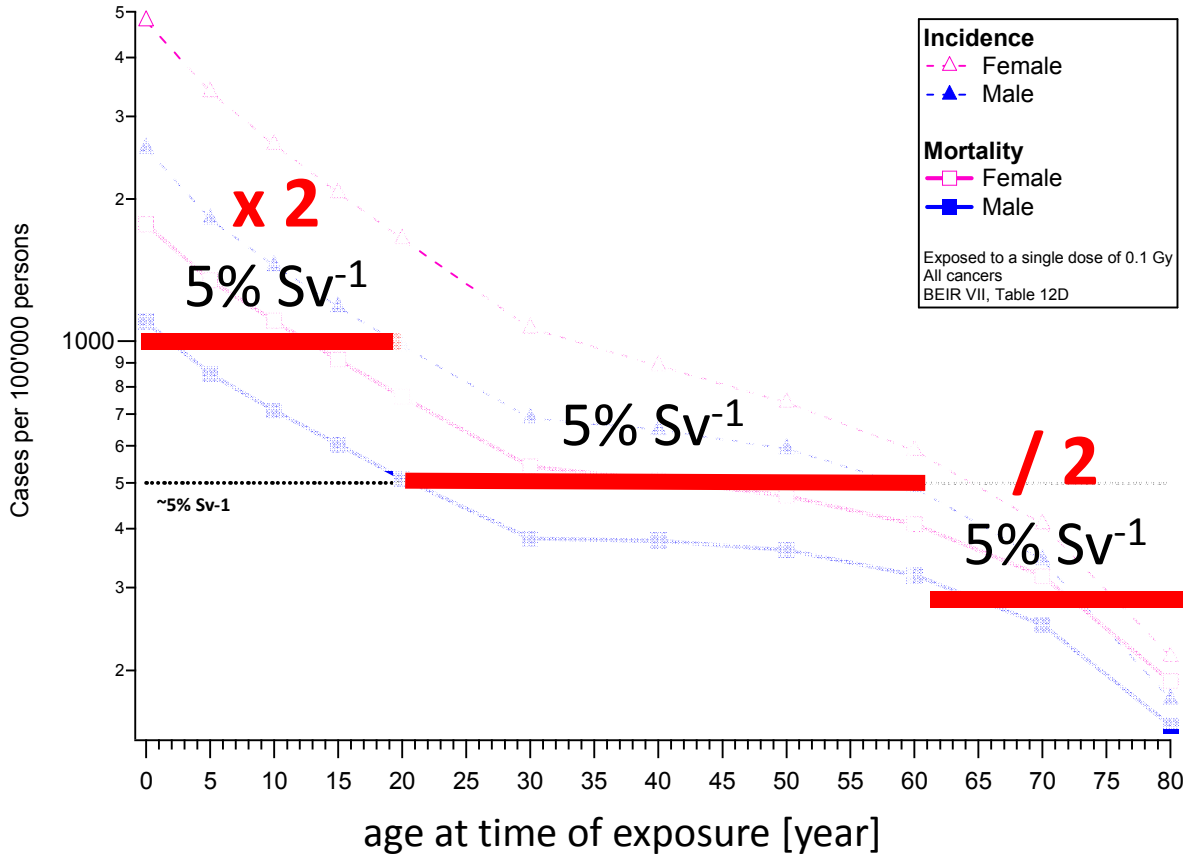
BEIR-7

E as an approximate estimation of possible risk



BEIR-7

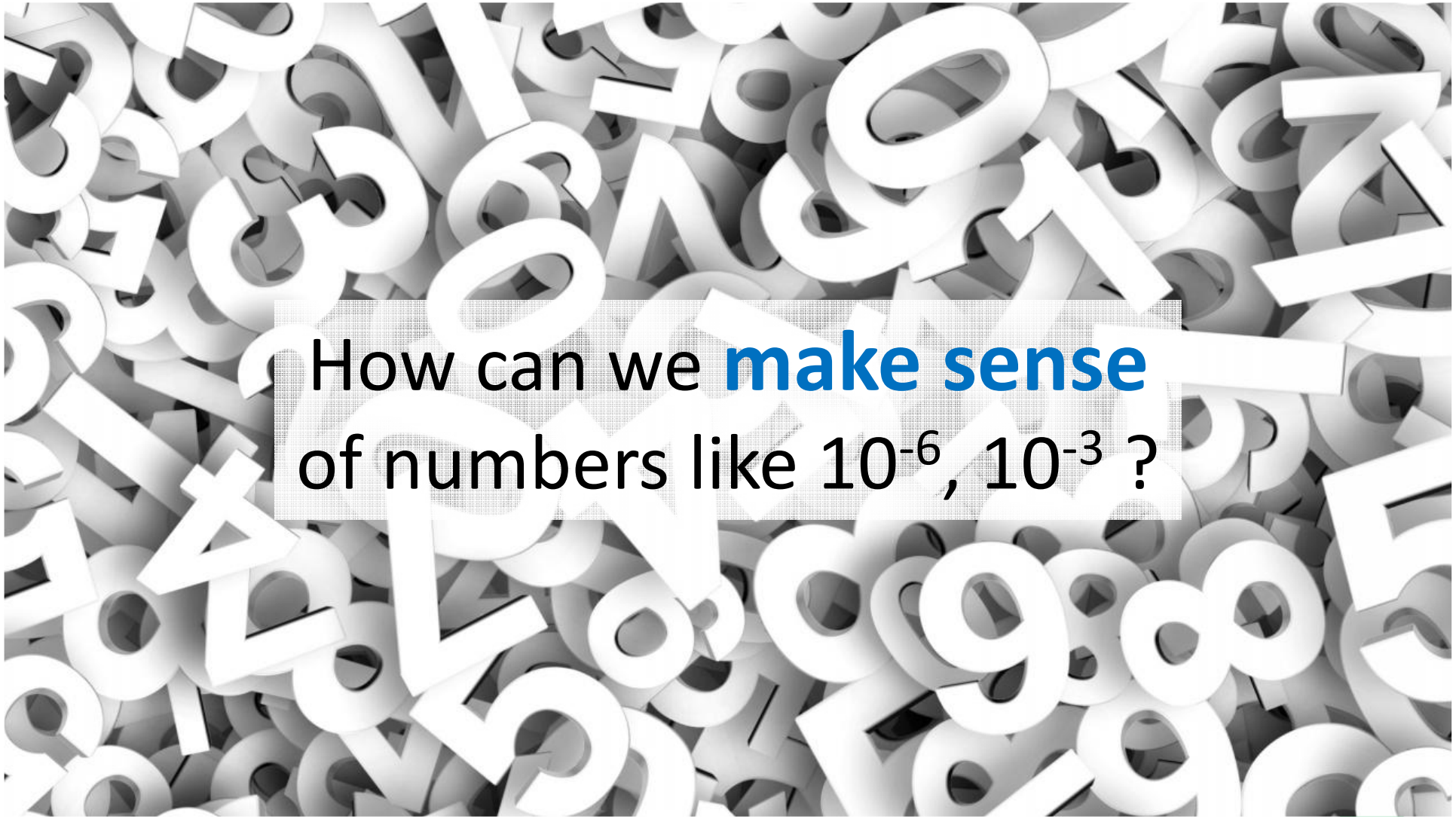
E as an approximate estimation of possible risk



BEIR-7

Limits are not borders between SAFE and DANGEROUS

Risk unacceptable
1 mSv/year approximately natural background (ICRP-103)
20 mSv/year risk of 10^{-3} (ICRP-103)
Limits are not borders between SAFE and DANGEROUS
Risk tolerable
http://www.denaligrizzlybear.com/



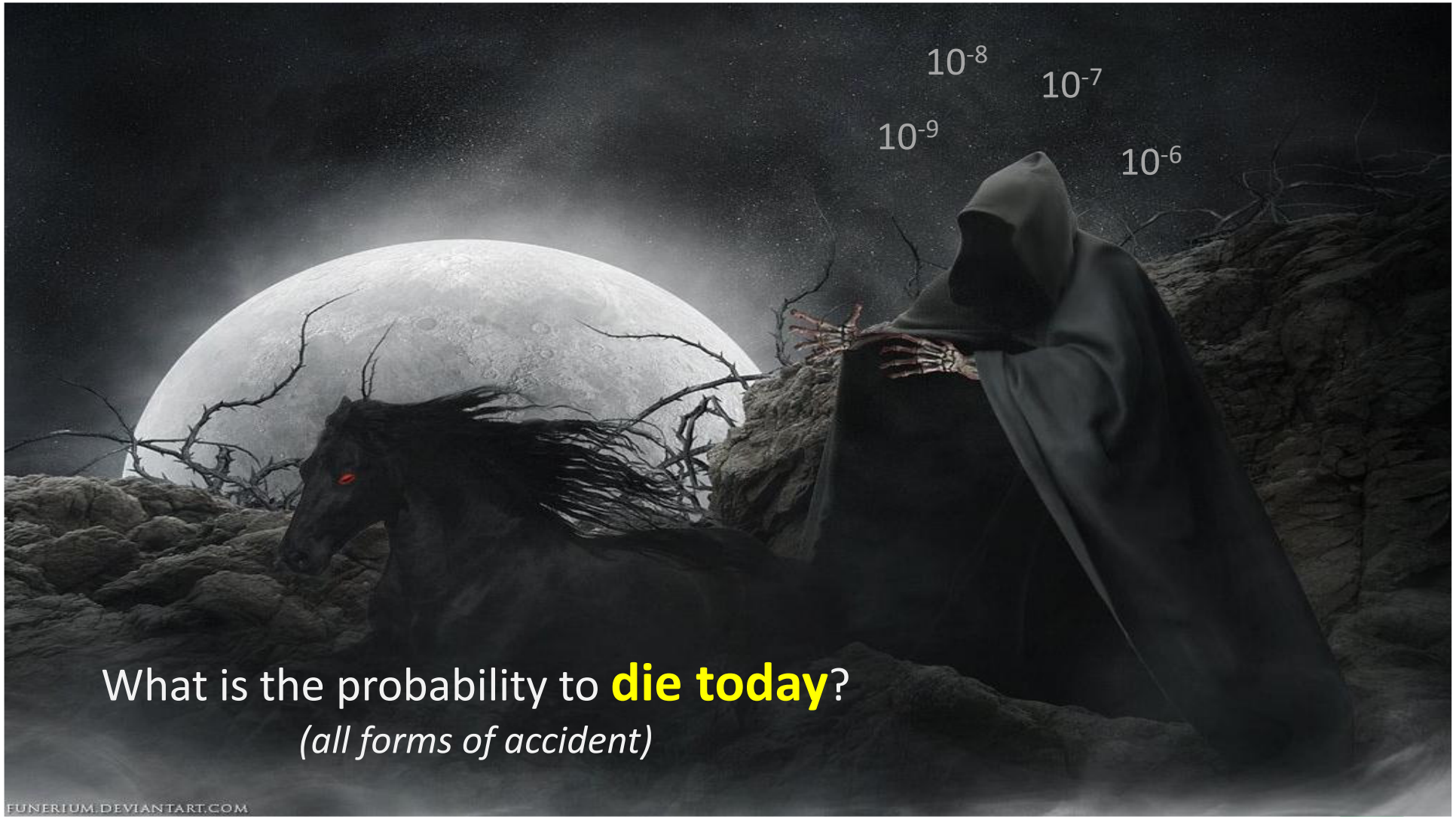
How can we **make sense** of numbers like 10^{-6}, 10^{-3} ?

What is the usual threshold between **low/high LET**?

1.602 nJ/m
3.83×10^{-10} cal/m
10 keV/µm

Which **nuclide** is **decaying** the fastest?

nuclide 1	$\lambda = 0.1315\ y^{-1}$	^{60}**Co**	T = 5.27 y
nuclide 2	$\lambda = 0.1155\ h^{-1}$	^{99m}**Tc**	T = 6 h


10^{-8}
10^{-7}
10^{-9}
10^{-6}
What is the probability to **die today**?
(all forms of accident)
FUNERIUM.DEVIANTART.COM

Number of deaths in Switzerland *(2013)*

Cause de décès	Nombre de décès 2013		Taux de mortalité 2013	
	Hommes	Femmes	Hommes	Femmes
Toutes les causes de décès	31257	33704	555.0	371.0
Maladies infectieuses	352	415	6.4	4.8
Tumeurs malignes	9200	7475	167.0	107.0
Gros intestin	584	583	10.3	7.4
Poumons	1960	1208	36.5	19.4
Sein	5	1329	0.1	20.0
Diabète sucré	615	700	10.6	6.8
Démence	1797	4110	28.5	34.5
Appareil circulatoire	9719	11793	164.0	109.0
Cardiopathies, toutes formes	7663	8984	130.0	81.3
Cardiopathies ischémiques	4097	3628	69.9	33.4
Maladies cérébro-vasculaires	1465	2238	24.3	21.5
Appareil respiratoire, toute formes	2167	1949	36.4	20.4
Cirrhose du foie alcoolique	319	121	6.5	2.3
Accidents et morts violentes	2177	1642	44.0	21.0
Accidents, toutes formes	1312	1285	25.3	13.7
Suicides	786	284	16.9	6.0

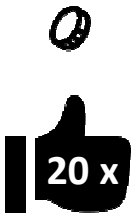
1312 + 1285
= **2597** people

$$\frac{2597}{8 \cdot 10^{6} \cdot 365} = 0.89 \cdot 10^{-6}$$

deaths per day
per inhabitant

http://www.bfs.admin.ch/bfs/portal/fr/index/themen/14/02/04/key/01.html#parsys_84305

The probability to die from an accident in the general population is about **10^{-6}** per day



10^{-6} is **1 MicroMort**

10^{-3} (**20 mSv/y**) = 1000 MicroMort/y

In radiation protection,
3 MicroMort/day is **unacceptable**

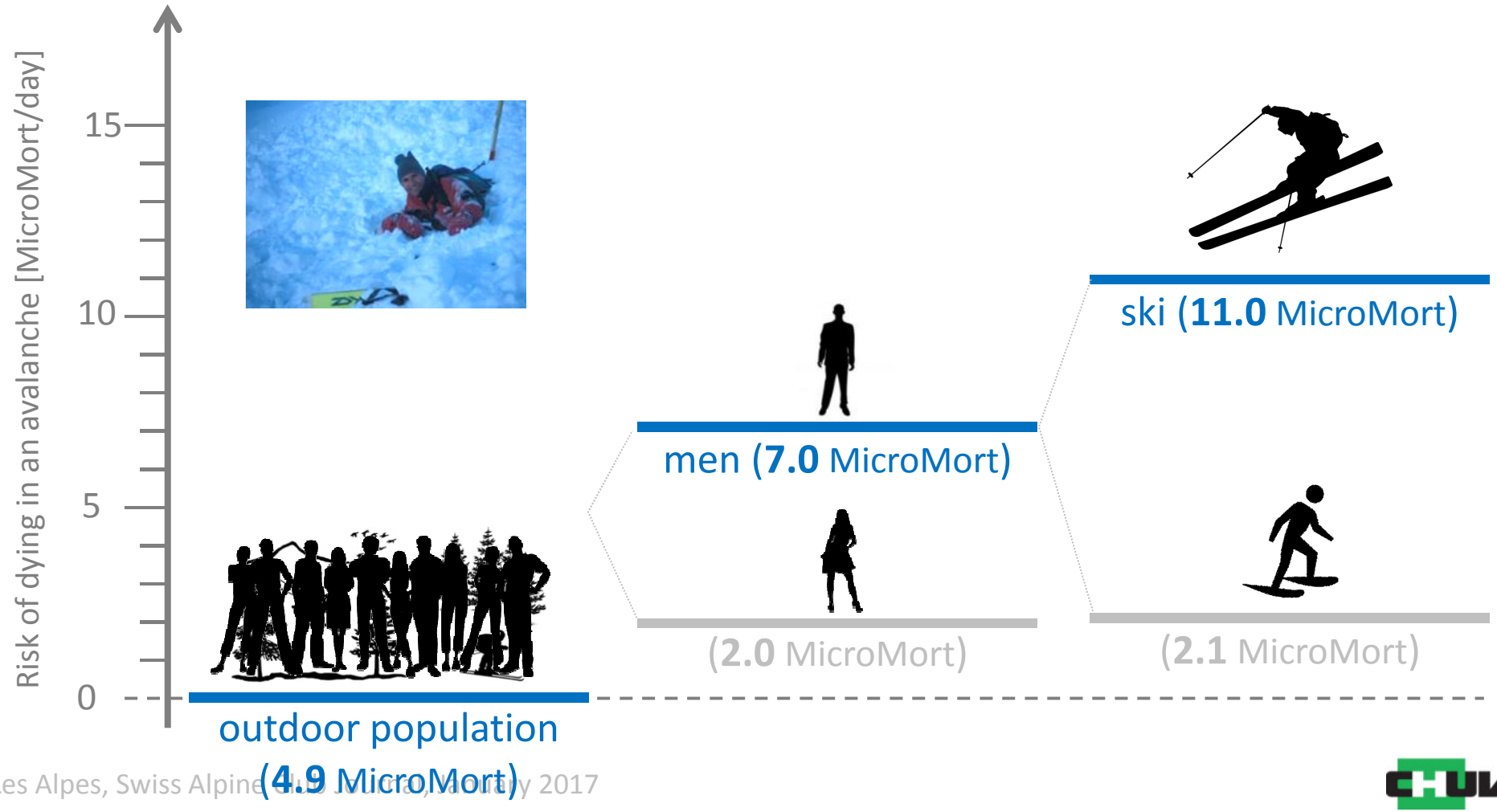
R.A. Howard, Intl. J. of Technology Assessment in Health Care, 1989, 5, 357-370

Which **risk** do I **tolerate** when I climb
during the winter season?

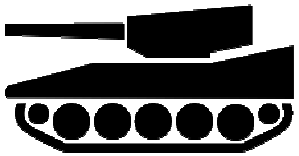
20-30 deaths per year in Switzerland
8 million inhabitants

$$\text{risk} = \frac{30}{365 \times 8'000'000} = 0.01 \times 10^{-6}$$

0.01 MicroMort/day


Risk of dying in an avalanche [MicroMort/day]
15
10
5
0
ski (11.0 MicroMort)
men (7.0 MicroMort)
(2.0 MicroMort)
(2.1 MicroMort)
outdoor population
(4.9 MicroMort)

MicroMort is useful for events with **immediate** effect



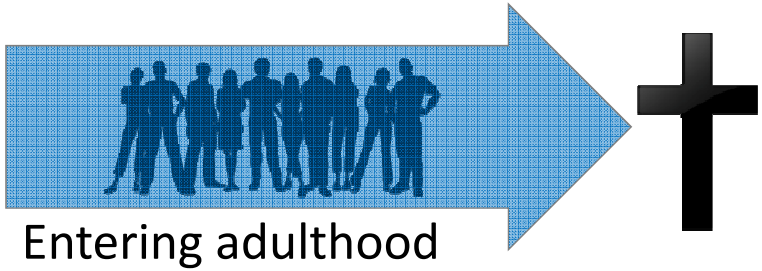
It allows us to **evaluate now**
a risk that could (or not) **materialize now**

not adequate
for **stochastic risk**

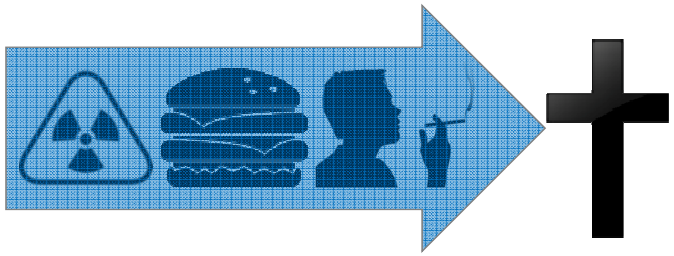
For **delayed risks**, we need to project ourselves into the future

*(and there is **no reset button**, once the risk has been taken)*

30 minutes = **1 MicroLife**



Entering adulthood
1 million half-hours to use



M. Blastland and D. Spiegelhalter, The Norm Chronicles, Stories and Numbers About Danger, Profile Books, 2013

Long-term risk

can be understood **now**
as changing
the pace of time

doing a **20 min exercise gives** you **2** additional **MicroLives**
(at the end of the day, you actually used 46 MicroLives)

smoking **15-24 cigarettes uses 10** additional **MicroLives**
(at the end of the day, you actually used 58 MicroLives)

https://en.wikipedia.org/wiki/Microlife

Exposure	E [mSv]	Average loss in life expectancy	MicroLives
Annual occupational limit	20	7 days	400
Whole body CT scan	10	3 days	150
Fukushima prefecture	1 – 10	10h – 3d	20 - 150
Fukushima Town Hall in the two weeks following accident	0.1	1 h	2
Flight from London to New-York	0.07	37 min	1
Chest X-ray	0.02	11 min	0.5

M. Blastland and D. Spiegelhalter, The Norm Chronicles, Stories and Numbers About Danger, Profile Books, 2013

Summary of the

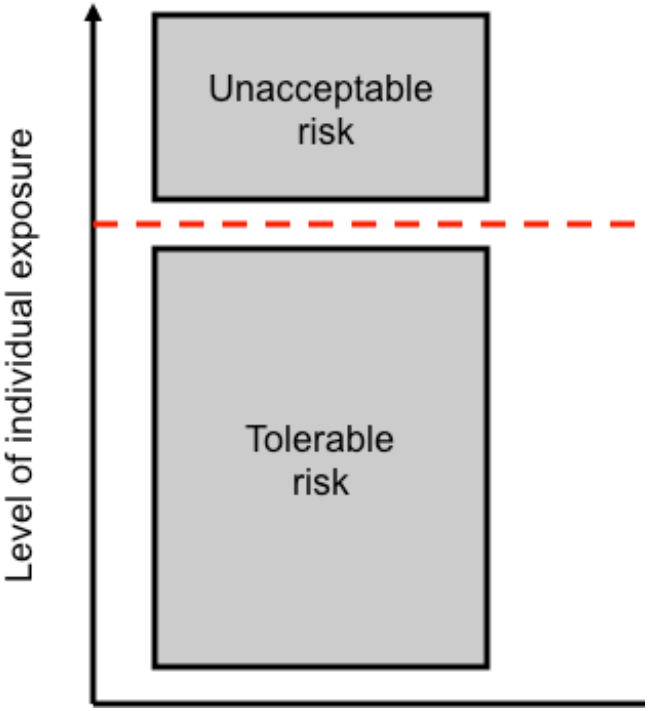
numerical

rational **risk**

Ratio *(e.g. 10^{-5})*	nobody has any cue *(what is riskier 10^{-4} or 10^{-5}?)*	effect **now**
MicroMort	10^{-6} linked to one "normal day" scale intuitive and easy to grasp	
Natural background	most people don't even know about natural radiation	effect **delayed**
MicroLife	put radiation risk into "normal life" scale intuitive and easy to grasp drawback: *if I die, I lose more than a few MicroLives**	

** NB: this is the same for all other decisions that we make in our lives*

The **numerical understanding** of the risk is only a (small) part of what defines tolerability



Beneficence
exposure must bring **benefit**

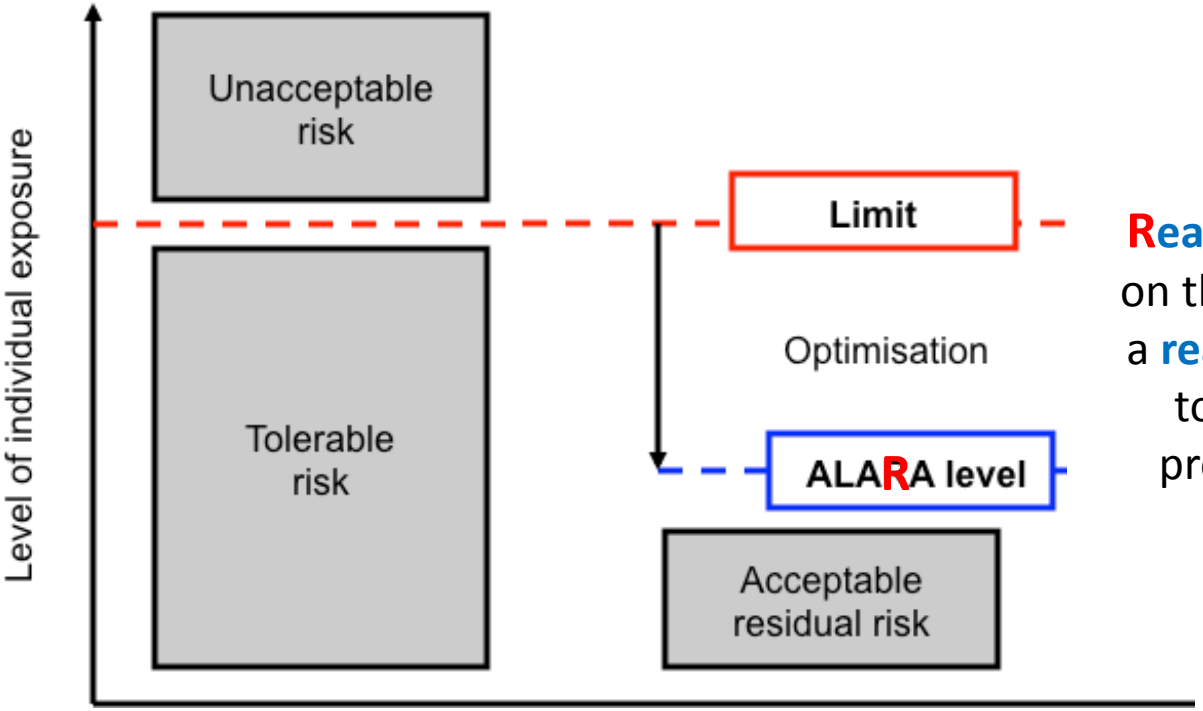
Prudence
risk is supposed to be proportional to the dose (**LNT** hypothesis)

Justice
risk must be **comparable with other** accepted activities

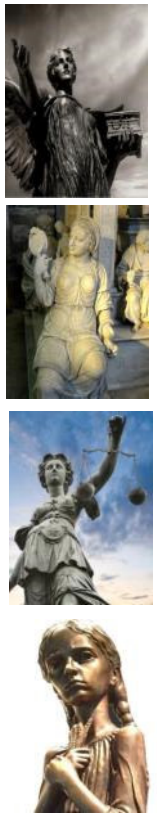
Dignity
autonomy must be respected & stakeholders have more knowledge than we like to admit (**co-expertise**)

T. Schneider, J. Lochard, L. Vaillant, ICRP Symposium, Seoul, October 2015

Tolerable does not mean **acceptable**



Reasonableness relies on the development of a **reasoning** accessible to **others** and the promotion of a **fair** cooperation



T. Schneider, J. Lochard, L. Vaillant, ICRP Symposium, Seoul, October 2015

Conclusion

- **Tolerability** / **acceptability**
  - are **subjective** concepts that cannot be reduced only to a **single number**
  - Quantification has to be **understandable** by lay people
    - **10^{-6}** or 10 times **natural background** **do not qualify**
    - **MicroMort** **ok** for immediate effect *(tissue reactions)*
    - **MicroLife** **ok** for delayed effect *(stochastic effects)*
- **Ethics** can provide a framework to ask the **good questions**
- We have to consider the **stakeholders** as **co-experts**

86'611 persons within 10 km of epicenter
(Hiroshima + Nagasaki)

$$D = D_\gamma + 10\, D_n$$

- D < 5 mGy
- 5 mGy < D < 0.1 Gy
- 0.1 Gy < D < 0.5 Gy
- 0.5 Gy < D < 1.0 Gy
- D > 1 mGy
- unknown dose

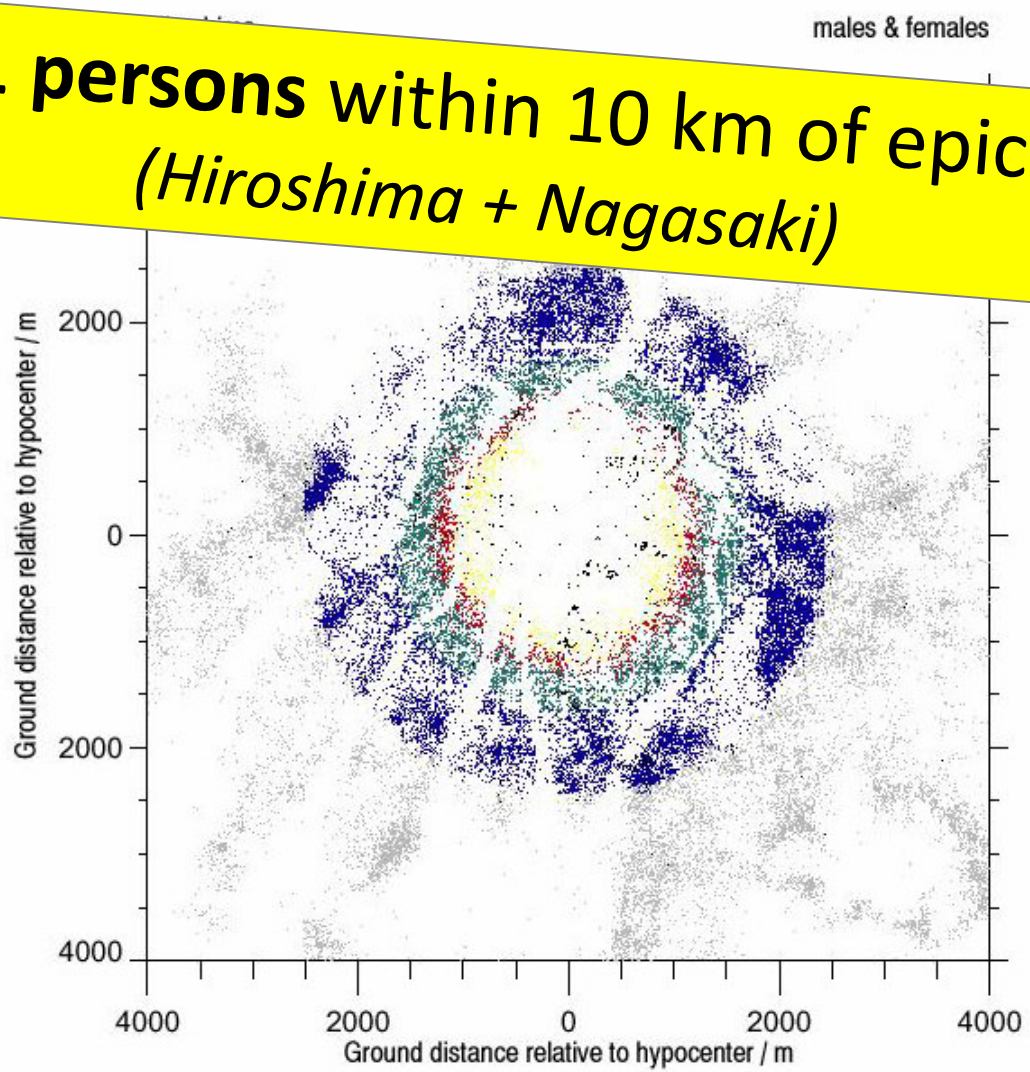
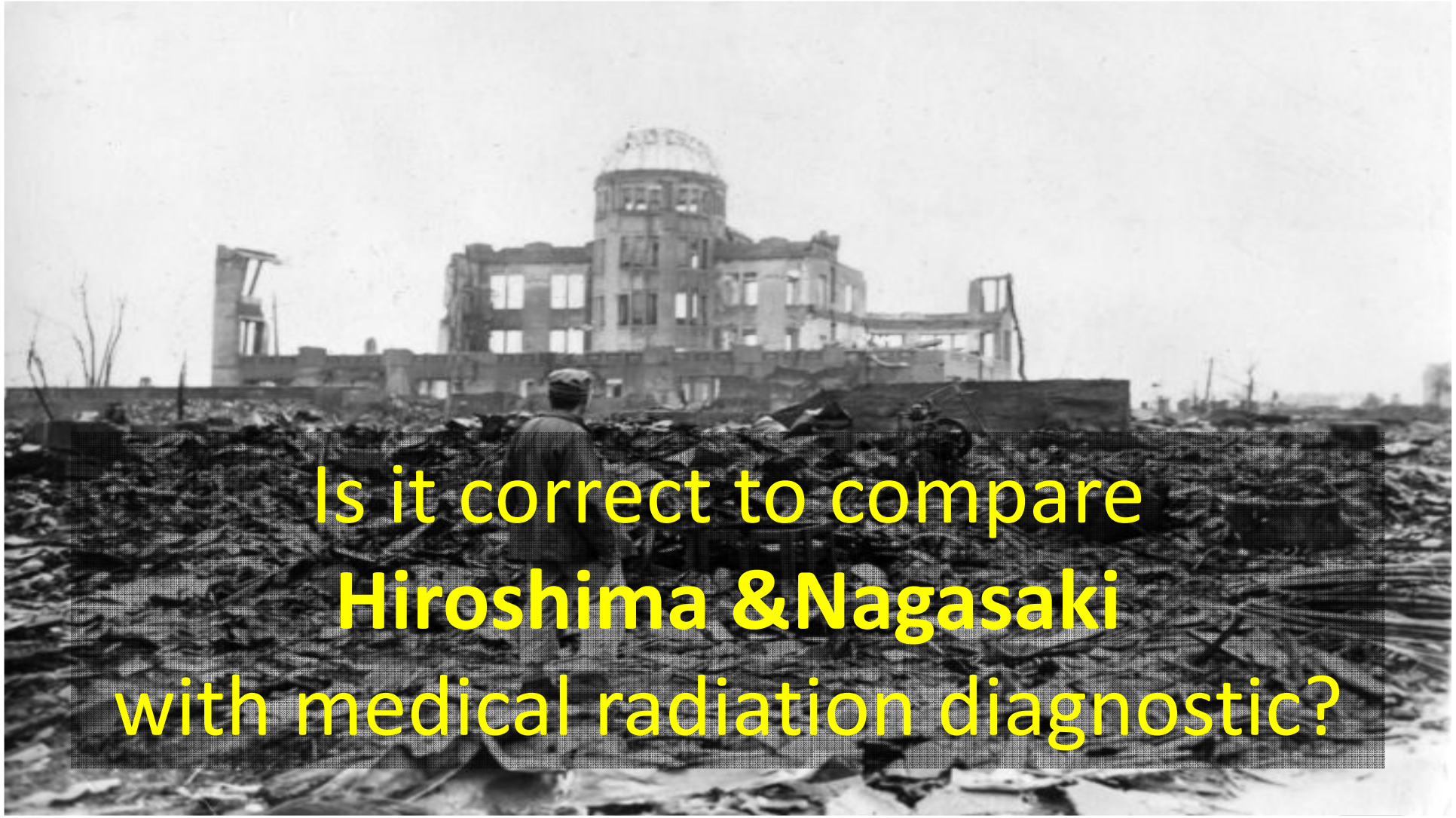
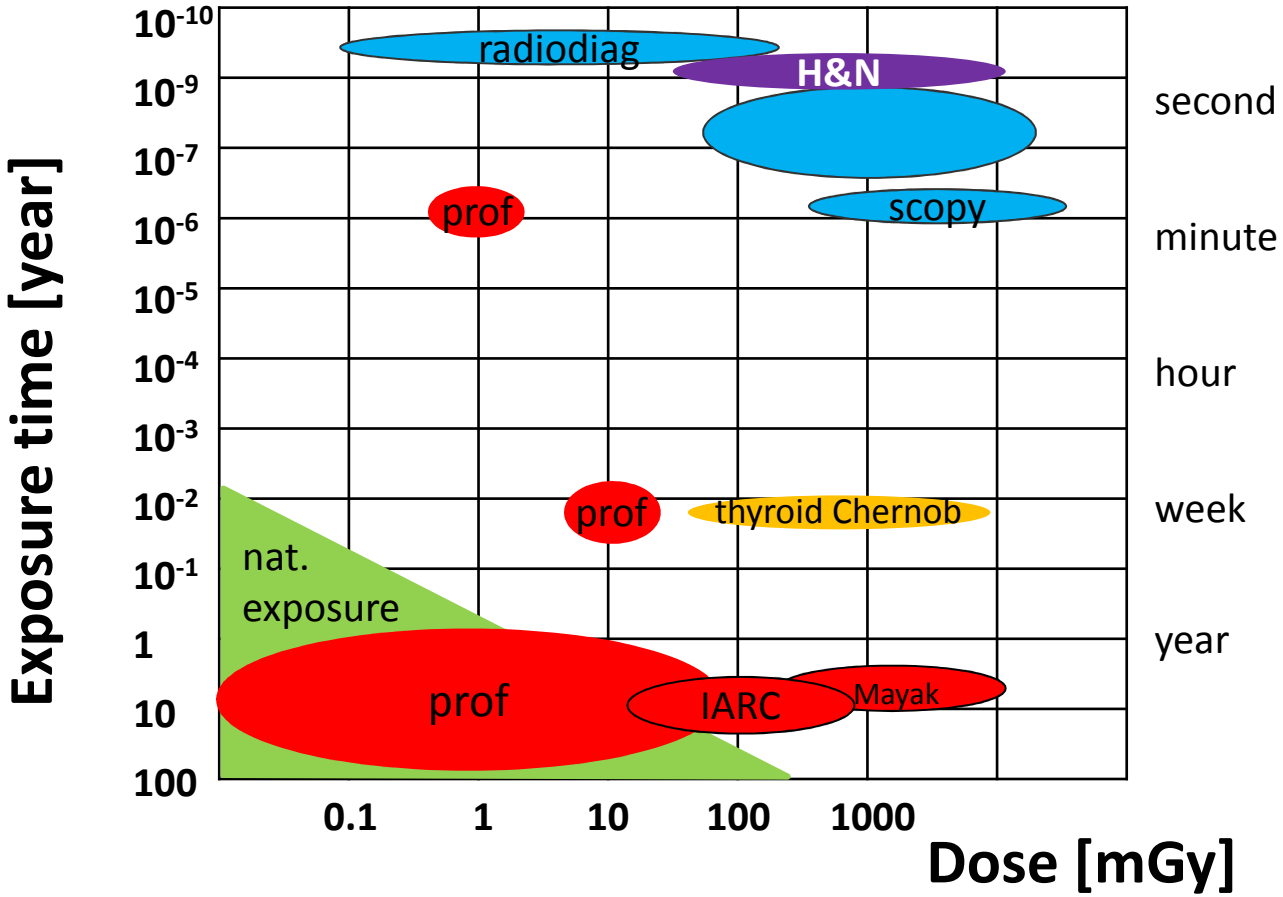


Figure: Linda Walsh, KSR 23.03.2017



Is it correct to compare
Hiroshima &Nagasaki
with medical radiation diagnostic?


Exposure time [year]
10-10
10-9
10-7
10-6
10-5
10-4
10-3
10-2
10-1
1
10
100
radiodiag
H&N
prof
scopy
prof
thyroid Chernob
nat.
exposure
prof
IARC
Mayak
0.1
1
10
100
1000
Dose [mGy]
second
minute
hour
week
year