RADIATION SAFETY

Archamps - JUAS 2020

Science and Technology Facilities Council

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Safety Officer

ISIS Spallation Neutron&Muon Source

STFC-Rutherford Appleton Laboratory

Two accelerator facility examples

a. ALBA Synchrotron Light Source

3.0 GeV electron accelerator

b. ISIS Neutron Spallation Source

0.8 GeV proton accelerator

a. ALBA Synchrotron Light Source

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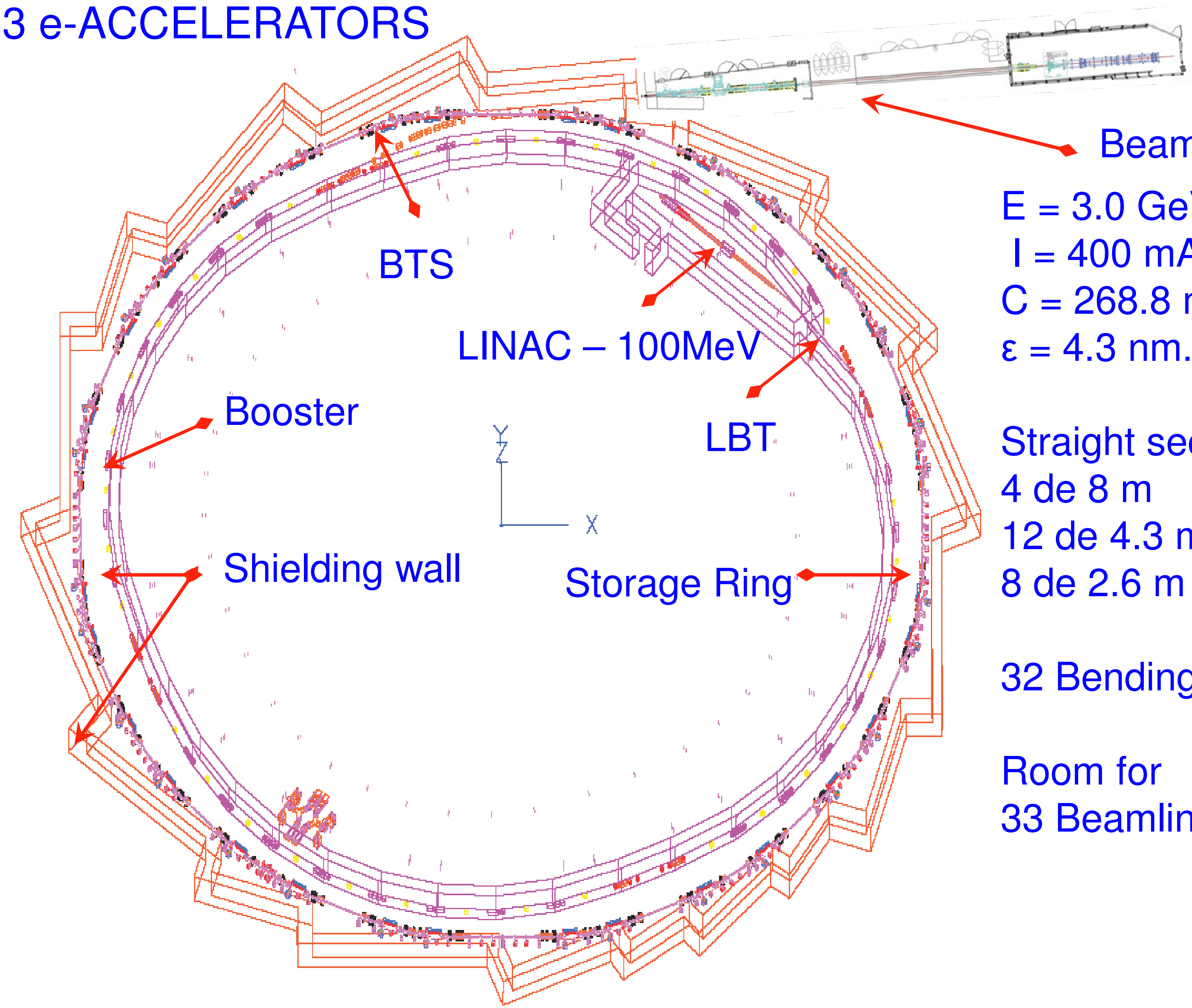
ALBA

THE 3 e-ACCELERATORS



E = 3.0 GeV
I = 400 mA
C = 268.8 m
ε = 4.3 nm.rad

Straight section:
4 de 8 m
12 de 4.3 m
8 de 2.6 m

32 Bending Magnets

Room for
33 Beamlines

b. ISIS Neutron & Muon Spallation Source

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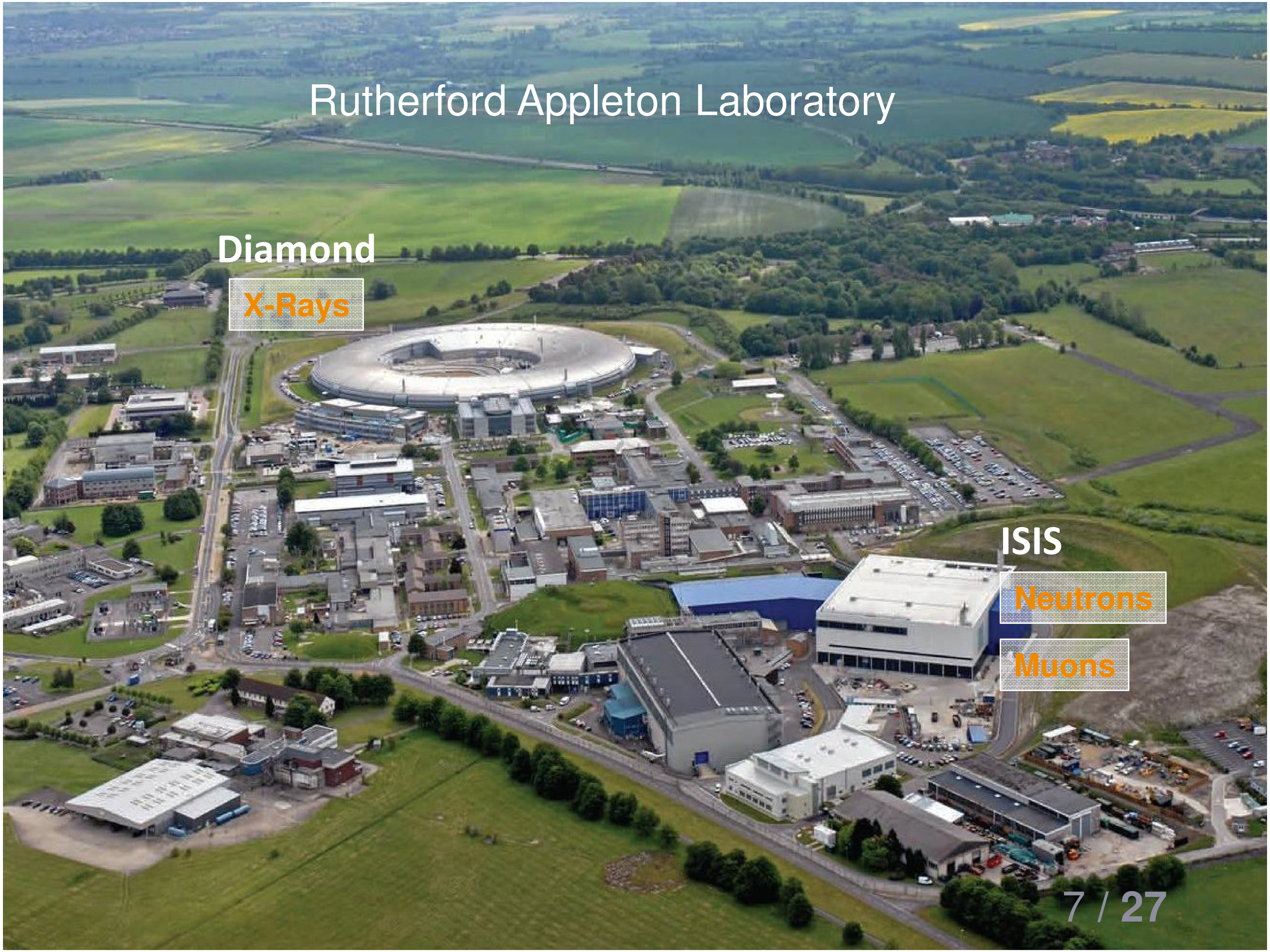
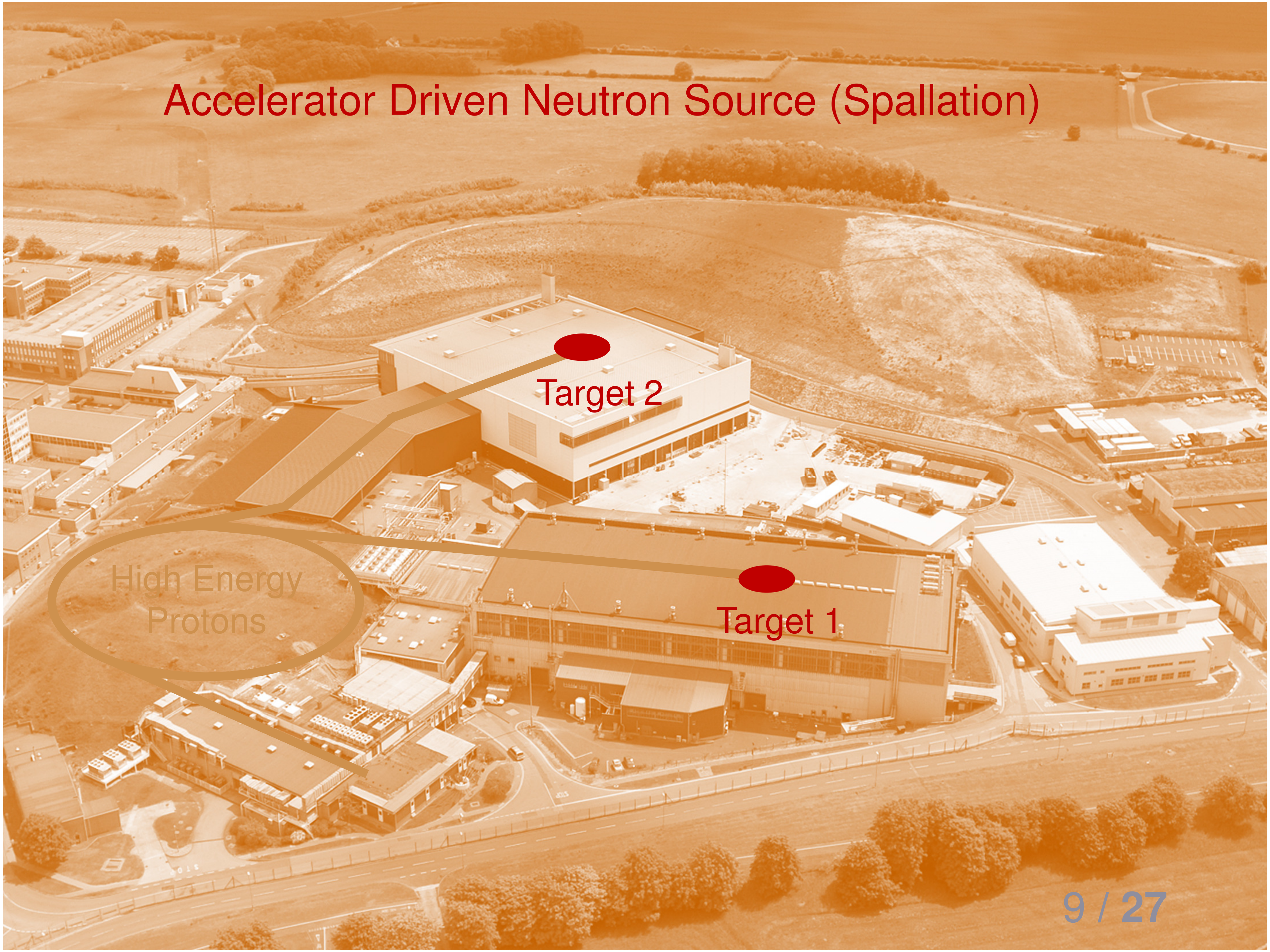
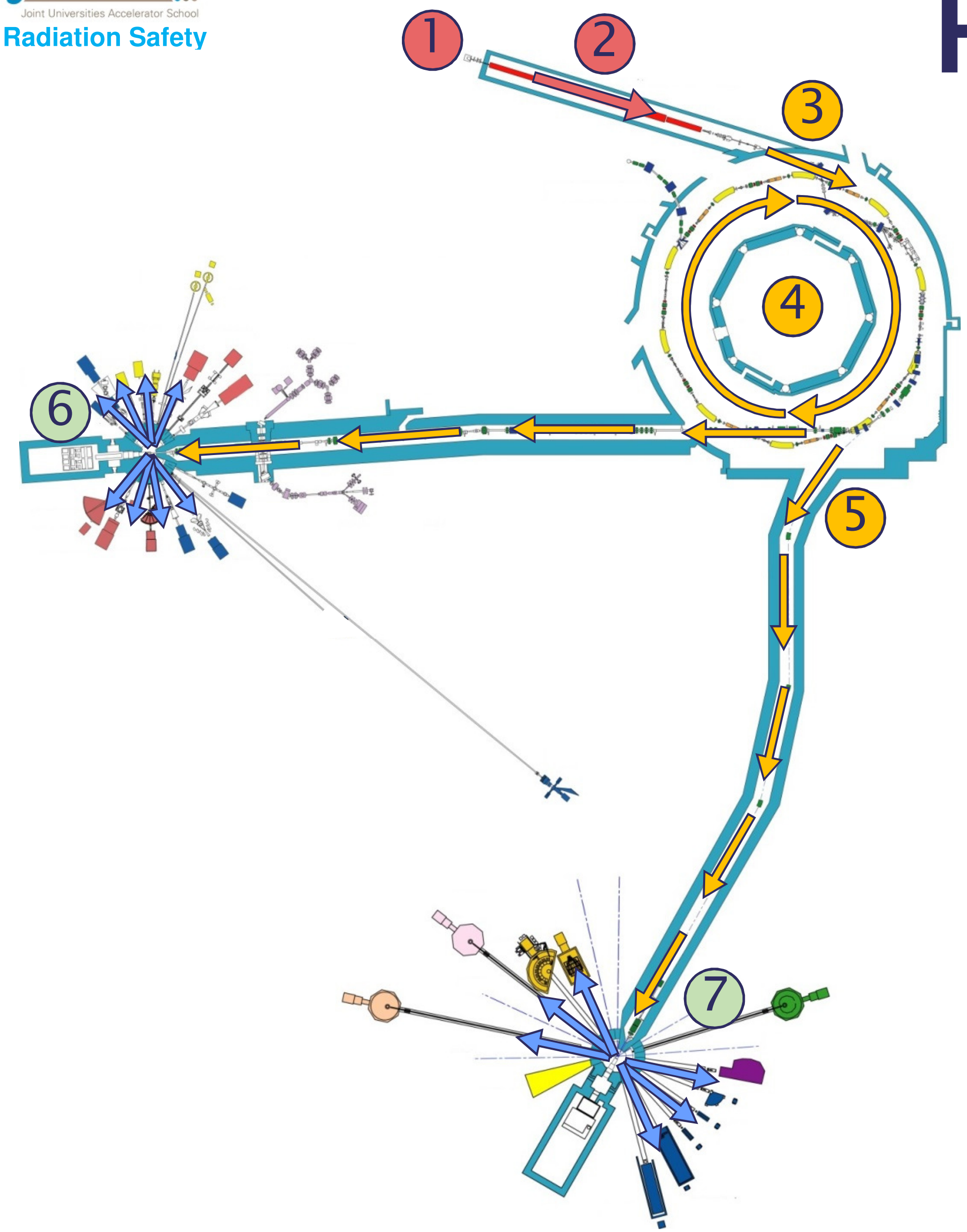

Rutherford Appleton Laboratory
Diamond
X-Rays
ISIS
Neutrons
Muons

Accelerator Driven Neutron Source (Spallation)

Accelerator Driven Neutron Source (Spallation)



How ISIS works



1. **Ion source:** produces negative H^- ions.
2. **Linear accelerator:** accelerates H^- ions to 37% speed of light.
3. **Alumina foil:** strips away electrons leaving protons.
4. **Synchrotron:** accelerates protons to 84% speed of light.
5. **Extracted proton beam**

6+7 **Tungsten targets:** neutrons are produced through spallation

INTRODUCTION

Historical examples

International organizations

Part A.

Dose magnitudes

Part B.

Radiation sources

Part C.

Radiation shielding

Part D.

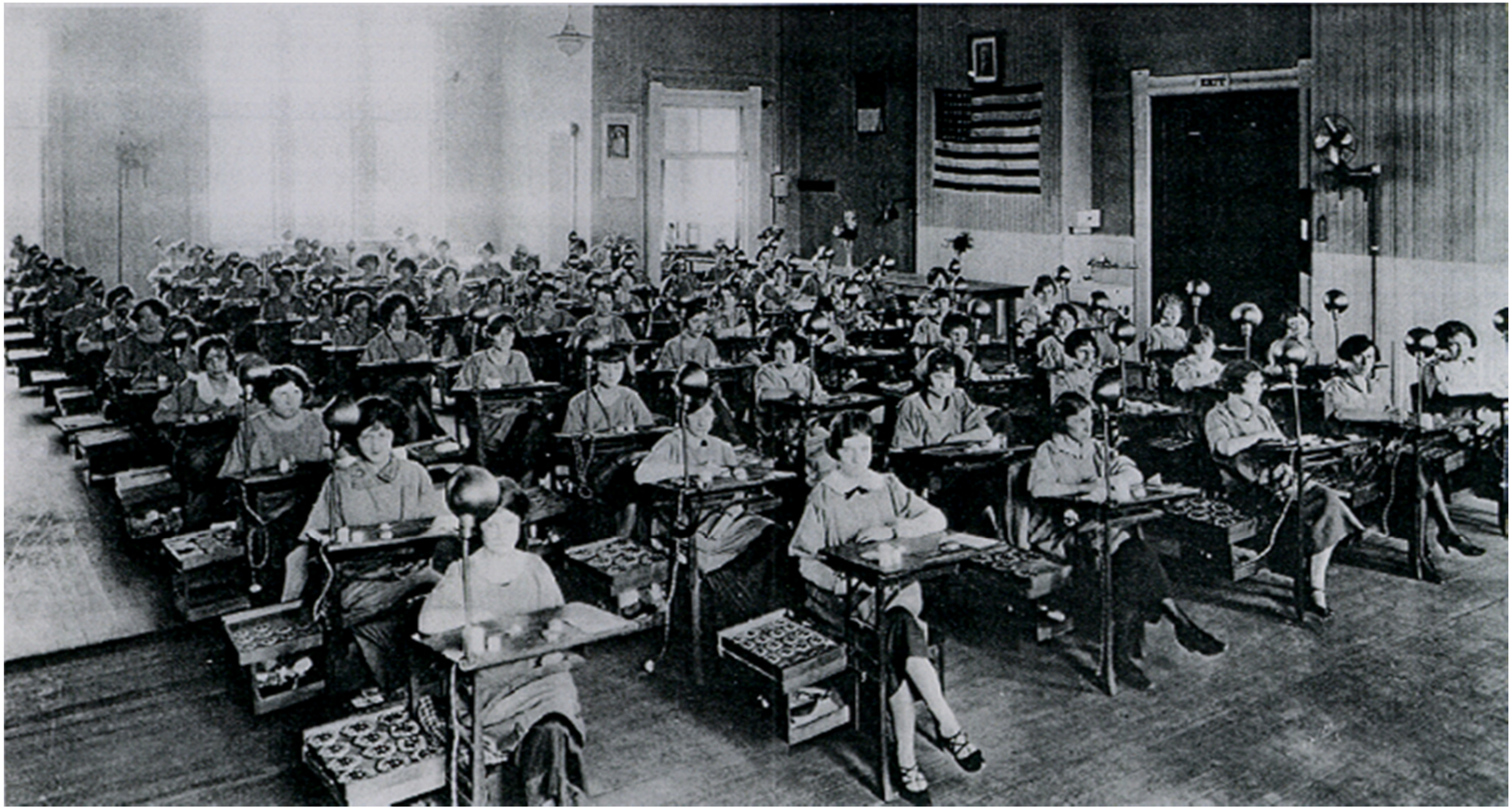
Radiation Safety Systems

Part E.

Radiation monitors

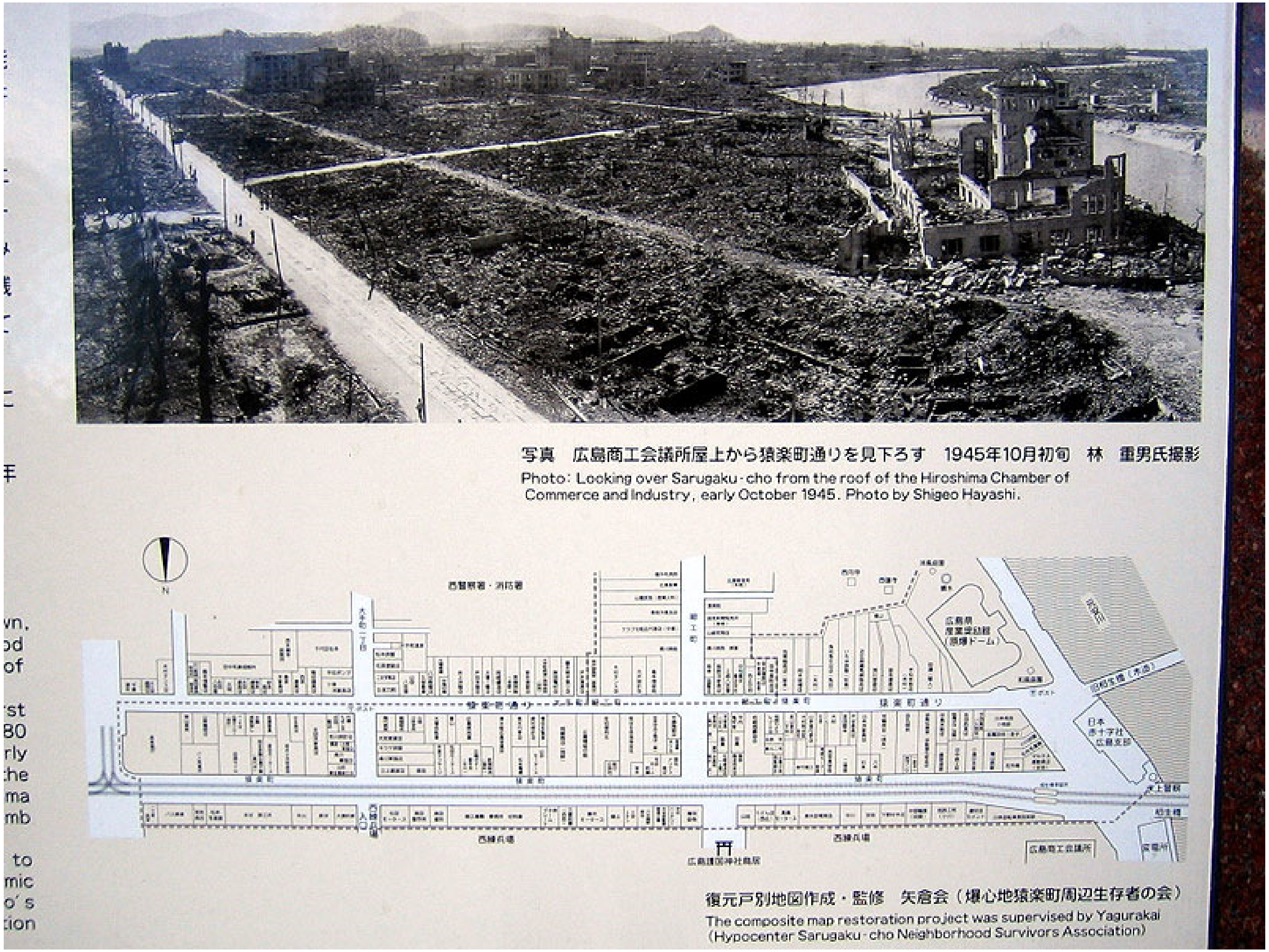
1. Historical examples
2. International organizations

…from the painters of dials with fluorescence paints containing radium…



…and the appalling patients and doctors…

....Hiroshima and Nagasaki...



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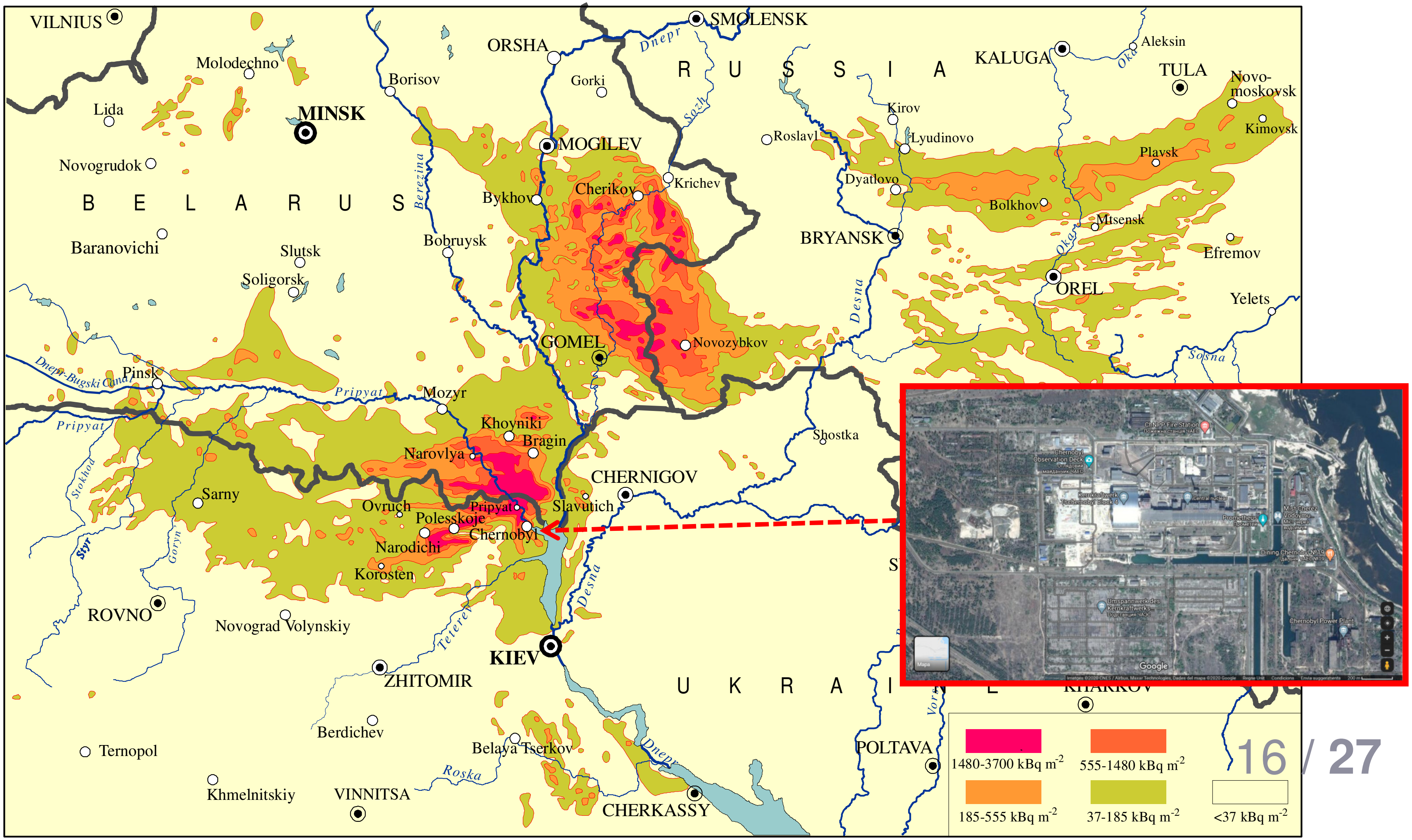
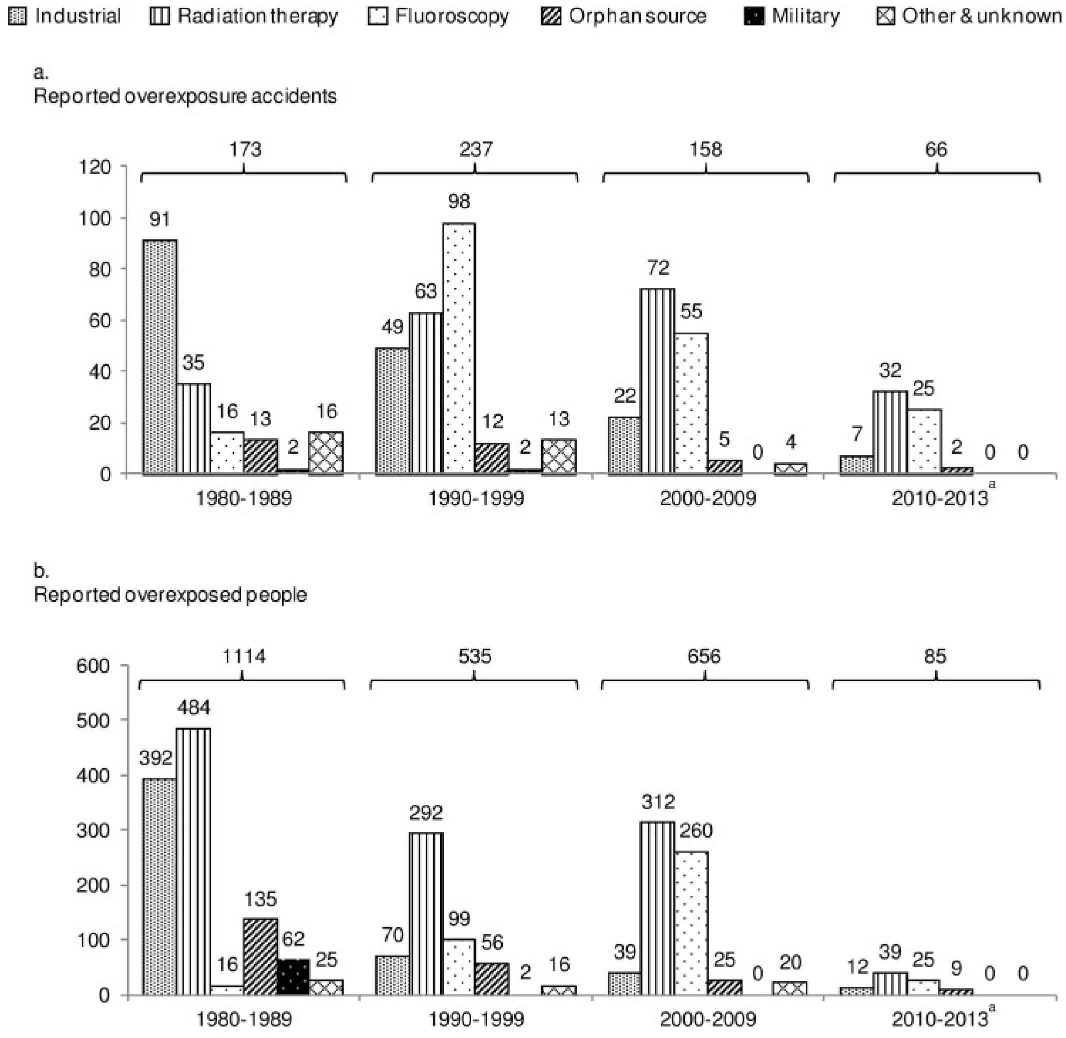
Joint Universities Accelerator School
Radiation Safety

…the effects of the Chernobyl accident (26th April 1986) …



Reported Radiation Overexposure Accidents Worldwide, 1980-2013: A Systematic Review
K. Coeytaux, E. Bey, D. Christensen,ES. Glassman,B. Murdock and C. Doucet



[a] Partial decade

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4366065/

Chernobyl - 1986
- The No. 4 light water graphite moderated reactor
- A lethal dose is ~5 Gy over 5 hours, unprotected workers received **fatal doses in less than a minute**.

Fukushima - 2011
- Four reactors were written off due to damage in the accident
- High radioactive releases **over days 4 to 6, eventually a total of some 940 PBq**

Uranium fission reaction – Fission reactors

$$ {}^{1}_{0}n + {}^{235}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n + 202.5\ \text{MeV} $$

202.5 MeV = 3.24×10^{-11} J/atom

235 g ${}^{235}_{92}U$:

(6.023×10^{23}) atoms x (3.24×10^{-11}) J/atom = 2×10^{13} J

Mass in a Fission reactors

A critical mass is the smallest amount of fissile material needed for a sustained nuclear chain reaction (For U235 is **52 kg**).

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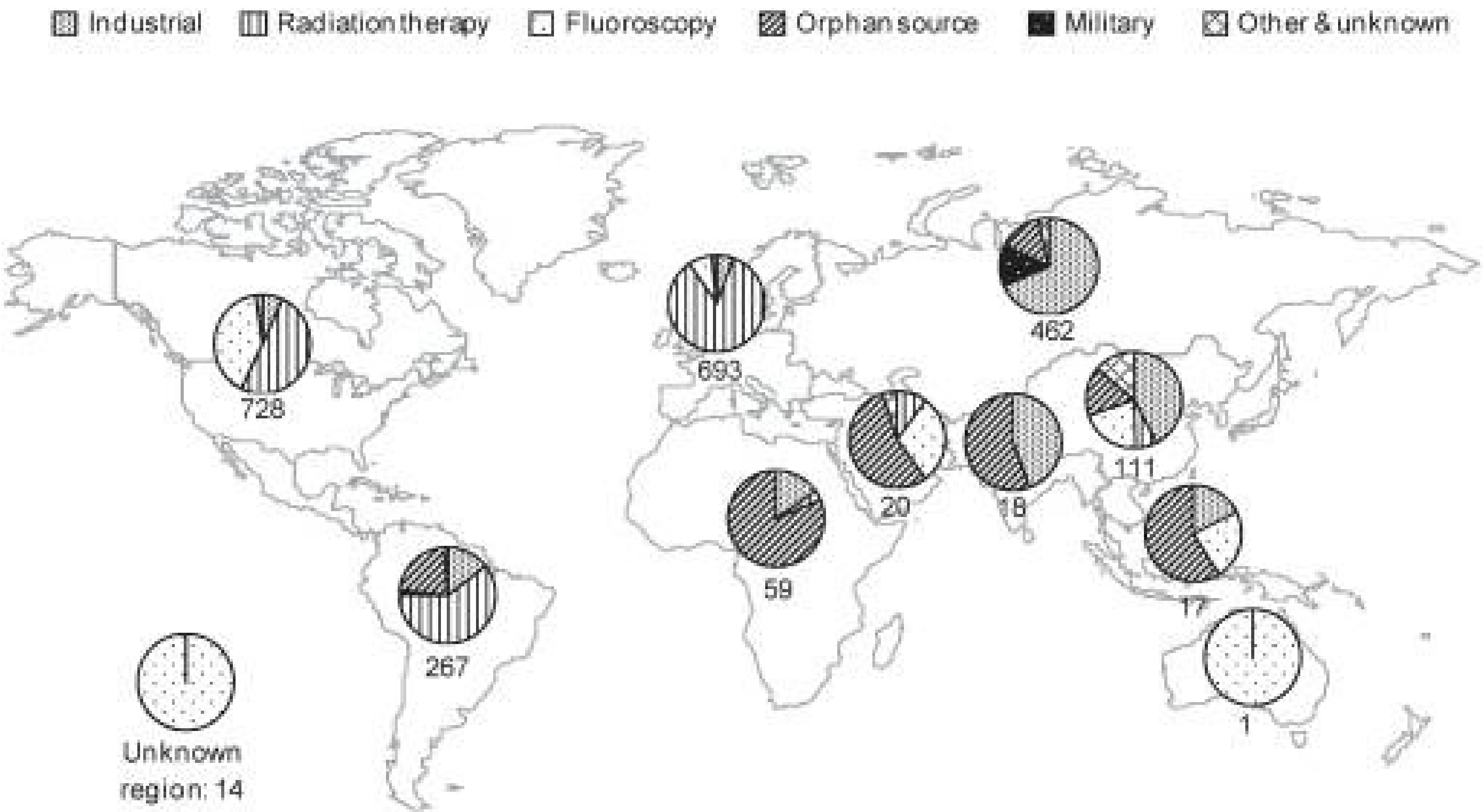

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UNSCEAR: United Nations Scientific Committee on the Effects of Atomic Radiation

- Sources, effects and risks of ionizing radiation (2017)
- Hereditary effects of radiation (2001)

http://www.unscear.org/

IAEA: International Atomic Energy Agency

http://www.iaea.org/

ICRP: International Commission on Radiological Protection.

- Publication 103: "The 2007 Recommendations of the International Commission on Radiological Protection"

http://www.icrp.org/

ELSEVIER

ICRP Publication 103

Annals of the ICRP

The 2007 Recommendations of the International Commission on Radiological Protection

ICRP Publication 103

Approved by the Commission in March 2007

Keywords: Justification; Optimisation; Dose limits; Constraints; Reference Levels

(n) The Commission now recognises three types of exposure situations which replace the previous categorisation into practices and interventions. These three exposure situations are intended to cover the entire range of exposure situations. The three situations are:

- *Planned exposure* situations, which are situations involving the planned introduction and operation of sources. (This type of exposure situation includes situations that were previously categorised as practices.)
- *Emergency exposure* situations, which are unexpected situations such as those that may occur during the operation of a planned situation, or from a malicious act, requiring urgent attention.
- *Existing exposure* situations, which are exposure situations that already exist when a decision on control has to be taken, such as those caused by natural background radiation.

(o) The three key principles of radiological protection are retained in the revised Recommendations. The principles of *justification* and *optimisation* apply in all three exposure situations whereas the principle of *application of dose limits* applies only for doses expected to be incurred with certainty as a result of planned exposure situations. These principles are defined as follows:

- *The Principle of Justification*: Any decision that alters the radiation exposure situation should do more good than harm.
- *The Principle of Optimisation of Protection*: The likelihood of incurring exposure, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors. → **ALARA** principle
- *The Principle of Application of Dose Limits*: The total dose to any individual from regulated sources in planned exposure situations other than medical exposure of patients should not exceed the appropriate limits specified by the Commission.

The Commission continues to distinguish amongst three categories of exposure: occupational exposures, public exposures, and medical exposures of patients (and comforters, carers, and volunteers in research). If a female worker has declared that she is pregnant, additional controls have to be considered in order to attain a level of protection for the embryo/fetus broadly similar to that provided for members of the public.

Hazard & Risk

From Wikipedia *(http://en.wikipedia.org/wiki/Ionizing_radiation):*
"***Ionising radiation*** is radiation that carries **enough energy to liberate electrons from atoms or molecules**, thereby ionizing them. Ionising radiation is composed of energetic subatomic particles, ions or atoms **moving at relativistic speeds, and electromagnetic waves on the high-energy** end of the electromagnetic spectrum."

HAZARD:

1. Exposure or vulnerability to injury, loss, evil, etc
2. A thing likely to cause injury, etc

RISK:

1. The possibility of incurring misfortune or loss;

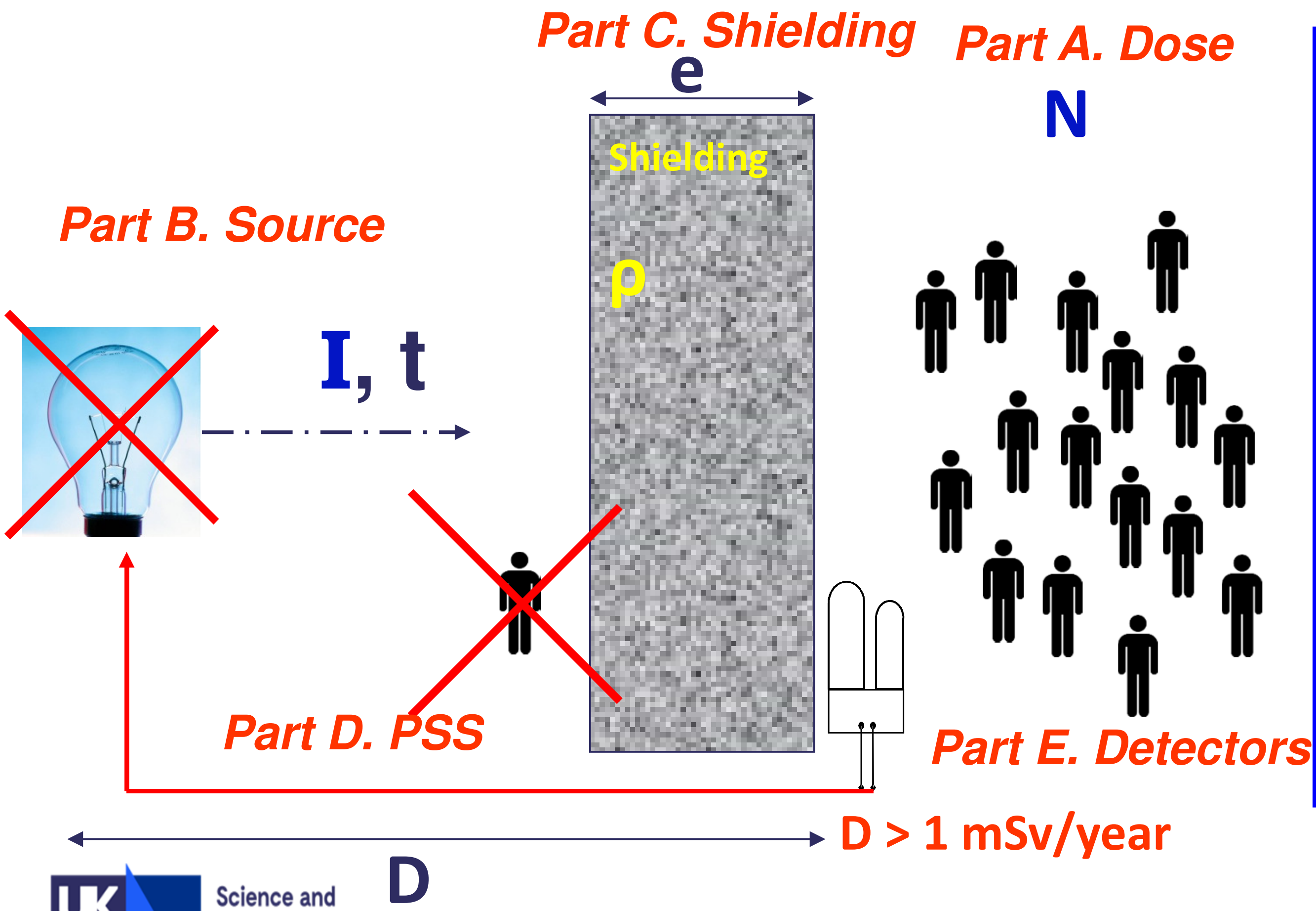

Ionisation Radiation Hazard symbol

Control Measures - The right priorities (5)

1. Elimination
2. Substitution
3. Engineering Controls
4. Administrative Controls
5. Personal Protection Clothes and Equipment (PPE)

Radiation Safety

The Risk Assessment
ALARA principle:
As **L**ow **A**s **R**easonably **A**chievable



I Source Intensity

N Number of exposed workers

Distance **D**

Time **t**

Shielding
- **e** Thickness
- **ρ** Density / Composition

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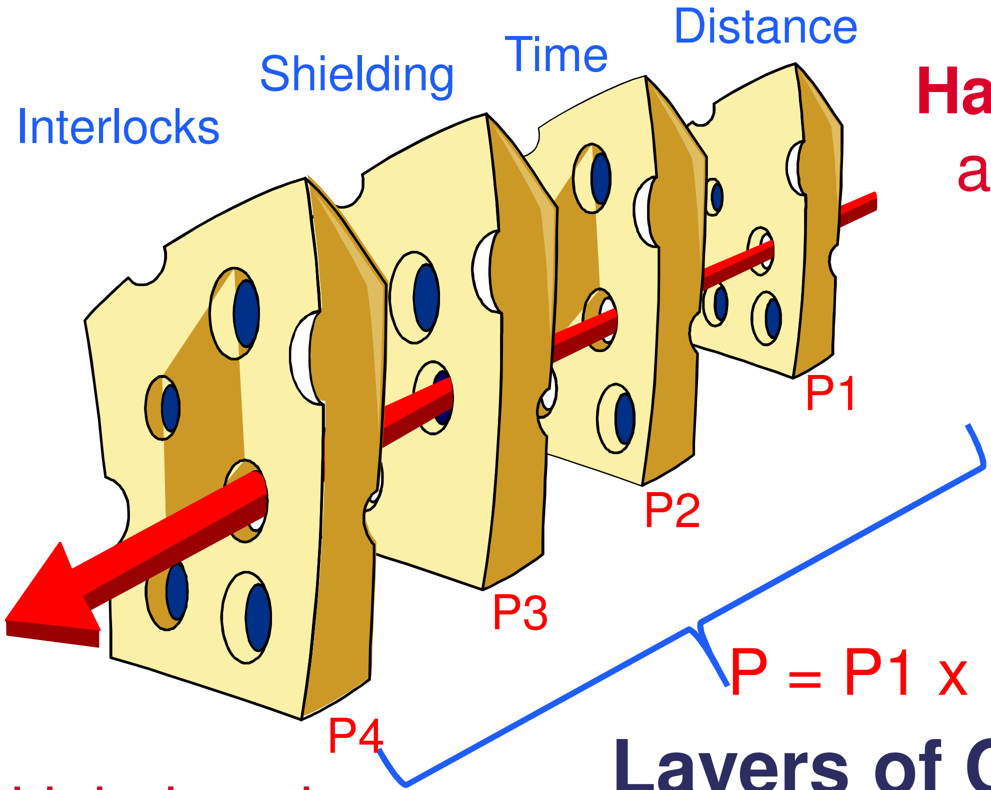
Swiss cheese model



Hazards from any source

P = P1 x P2 x P3 x P4

Layers of Control: to reduce the **RISK** (harm x likelihood)

Losses: personal injuries, time, reputation, equipment damage.

… **<u>towards ALARA solution</u>**

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