Centrum pro výzkum toxických látek v prostředí

Lekce 9

ENV012

Chemická bezpečnost a hazardní materiály

Improved Personal Radiation Protection of Responders against Radioactive Sources

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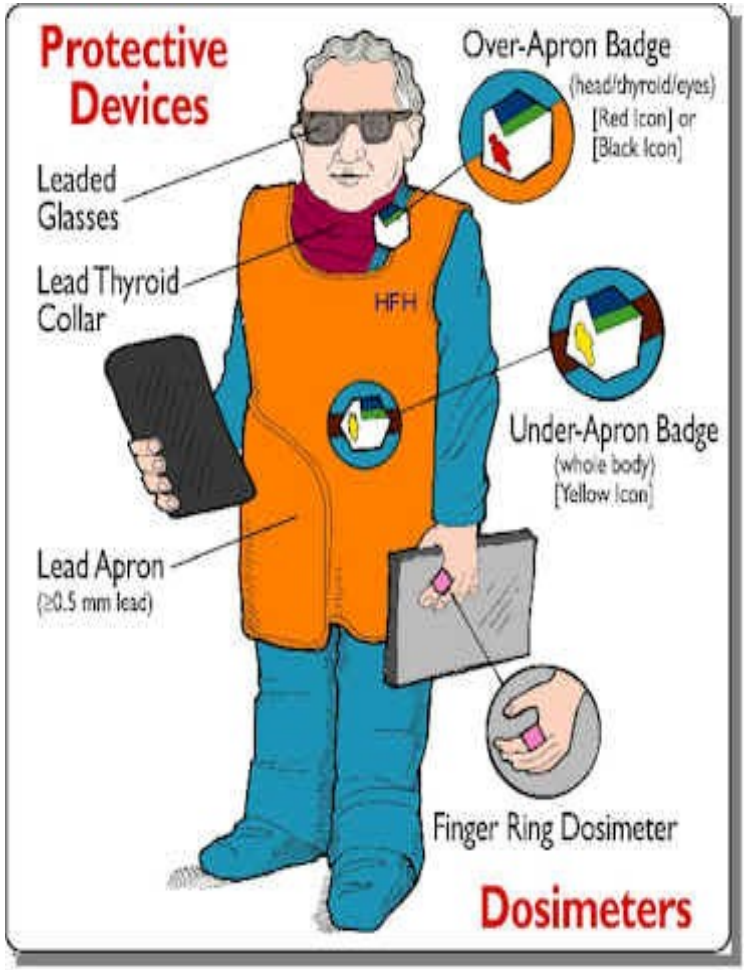
esf evropský sociální fond v ČR | EVROPSKÁ UNIE | MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY | OP Vzdělávání pro konkurenceschopnost | UNIVERSITAS MASARYKIANA BRUNENSIS

INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Příprava tohoto předmětu je spolufinancována Evropským sociálním fondem a státním rozpočtem České republiky

Radiation Safety

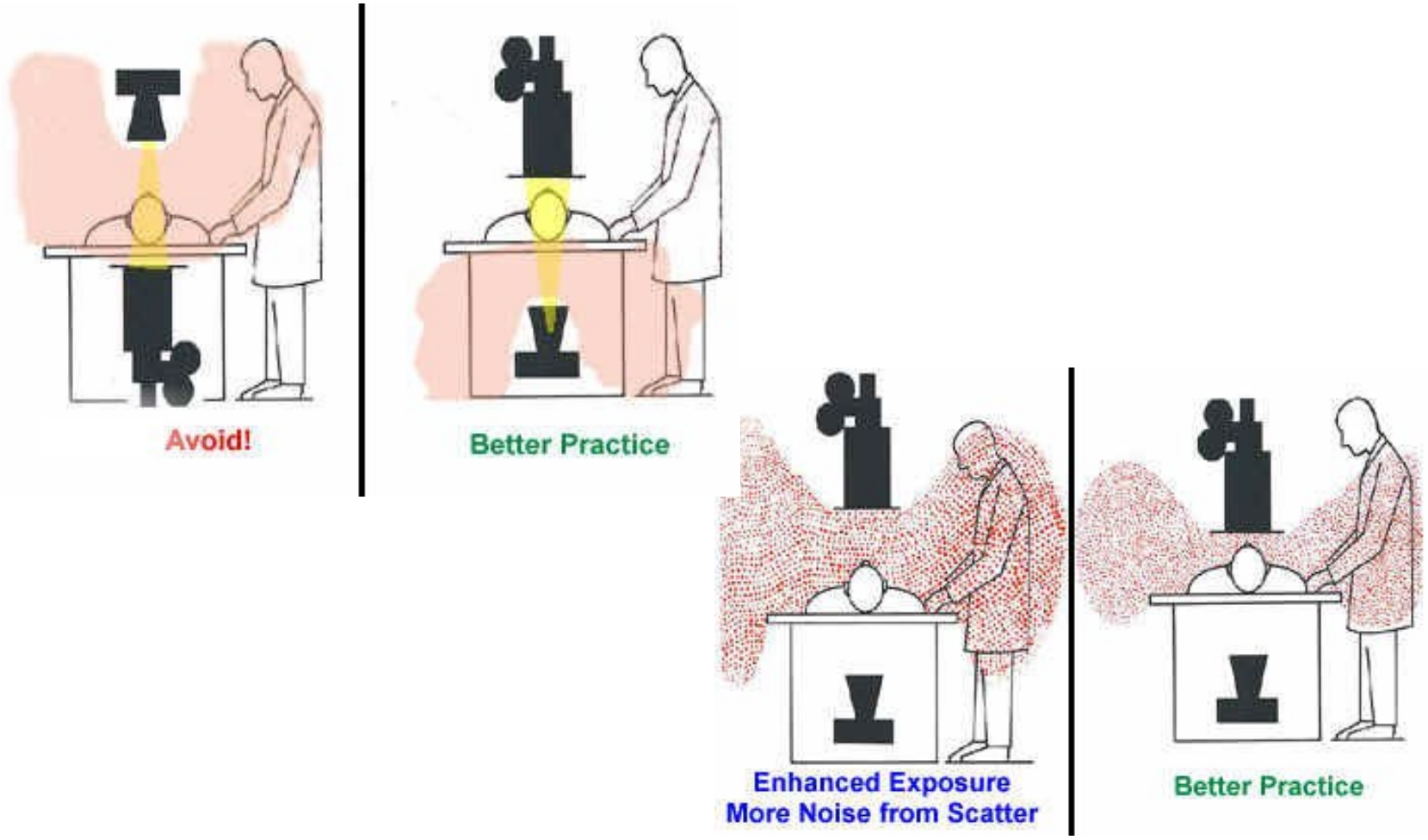


Courtesy of Sorenson, 2000

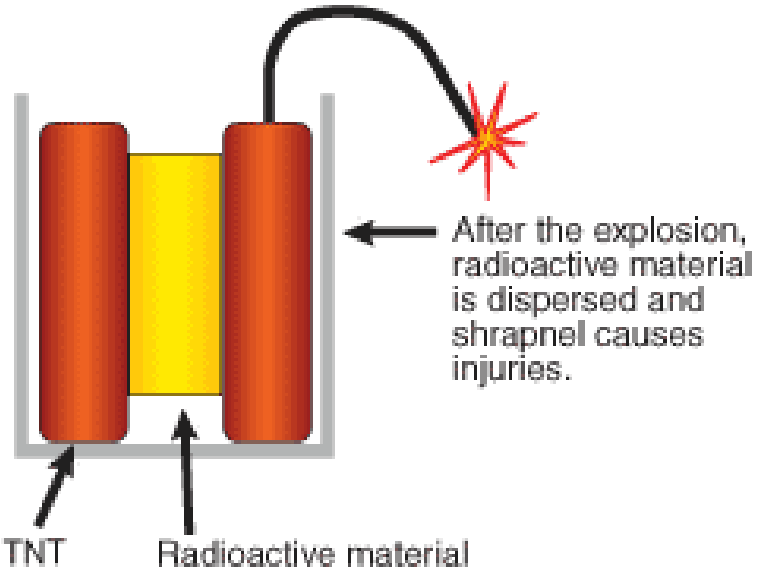
- Source of radiation (type/amount/energy)
- Dose Limits
- Time
- Distance
- Shielding
- Decontamination
- Dosimetry

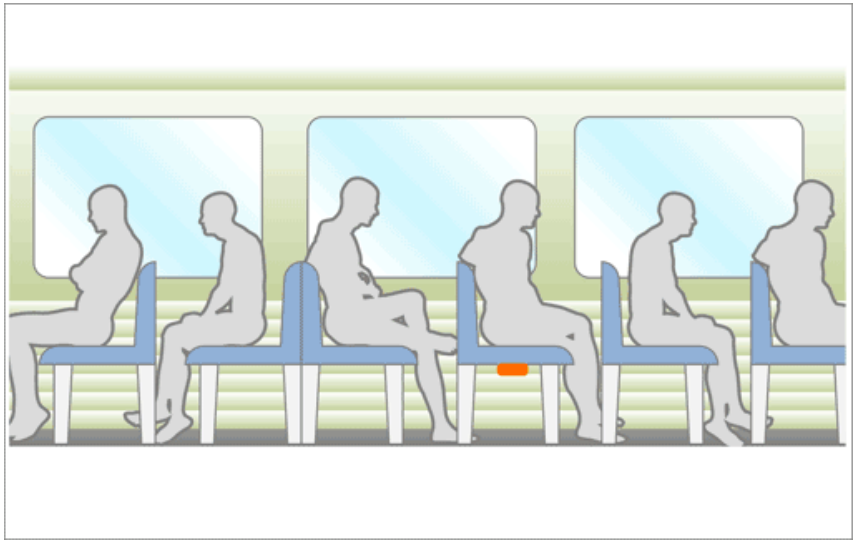
Radiography Technologies

Scattered Radiation Exposure



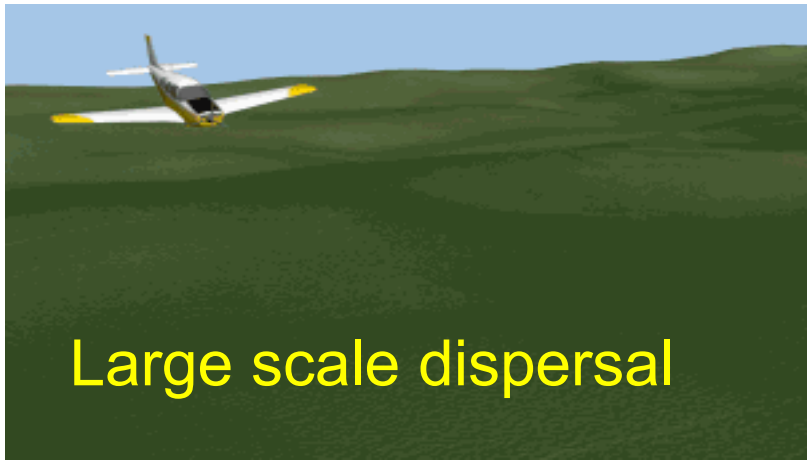
RDDs and REDs





Radiological Exposure Device
150 Ci of
Iridium-192 Source Under Seat

Cochabamba in Bolivia on 2002
Exposure of bus passengers
with ^{192}Ir (18Ci) from malfunction
defectoscopy device



Properties of Nine Key Radionuclides for RDDs

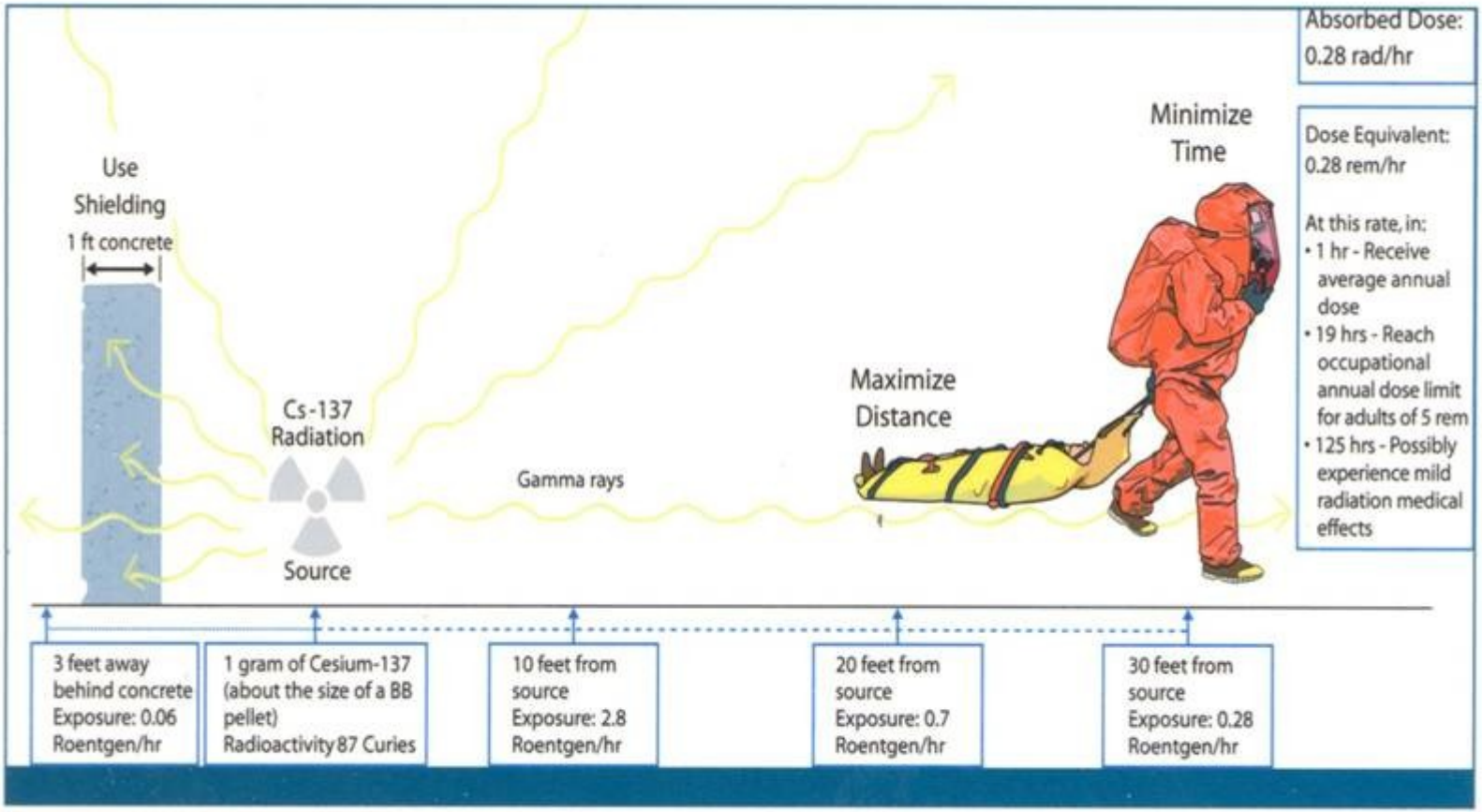
Isotope	Half Life [yrs]	Spec. Activ. [Ci/g]	Decay Mode	Alpha [MeV]	Beta [MeV]	Gamma [MeV]
Am-241	430	3,5	**α**	5,5	0,052	0,033
Cf-252	2,6	540	**α (n)**	5,9	0,0056	0,0012
Cs-137	30	88	**β**	-	**0,19;** 0,065	**0,60**
Co-60	5.3	1100	**β**	-	0,097	**2,5**
Ir-192	0,2/72d	9200	**β**	-	**0,22**	**0,82**
Pu-238	88	17	**α**	5,5	0,011	0,0018
Po-210	0,4/140d	4500	**α**	5,3	-	-
Ra-226	1600	1	**α**	4,8	0,0036	0,0067
Sr-90	29	140	**β**	-	**0,20; 0,94**	-

Cs-137 Incident in Goiania-Brazil on 1987

- The Caesium-137 teletherapy unit became totally insecure at an abandoned cancer clinic
- Soon afterward, a junkyard worker pried open the lead canister and discovered a pretty blue, glowing dust: radioactive CsCl of 93 grams.
- In the following days, scores of people were exposed to the substance - some parents painted their children with it and sold tickets to neighbors to watch them dance.
- As a result, 112,000 people had to be monitored. Of those, 249 were contaminated; 28 suffered radiation burns and 4 people died.
- More than 67 square kilometers was monitored, large areas had to be decontaminated and 3,500 cubic meters of radioactive waste was generated.
- For years afterward, the region was stigmatized and its economy devastated .

Fukushima´s Nuclear Power Plant

Response to Radiological Events



Minimizing radiation exposure

Courtesy RST Inc.

Decontamination Drill of Victim(s) Discrepancy of Theory and Reality

At least a dozen of shortfalls had been demonstrated

An example of the activity, where radiation shielding suits can be deployed, protecting also against Chem/Bio and splashes hazards

Decontamination Drill of Victim(s) Discrepancy of Theory and Reality

Decontamination Drill of Victim(s) Discrepancy of Theory and Reality

Israeli Radiation Drill on Radiation Contamination Control

Multi-trauma patient (contaminated) transferred directly into Emergency Care Room

Haifa Hospital

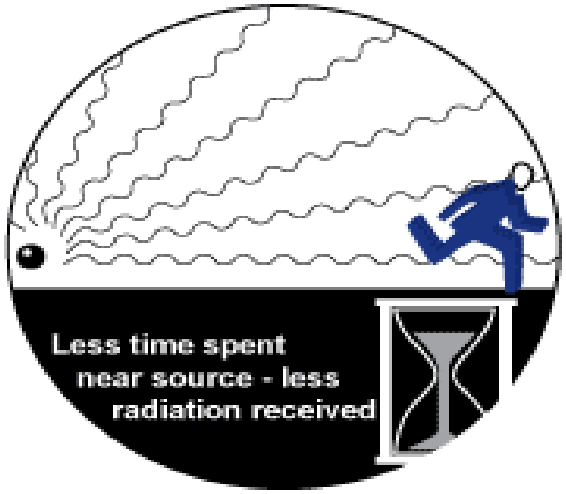
Ambulant and Non-ambulant Victim Decontamination Drill

Haifa Hospital

How to reduce radiation exposure of responders and victims ?

Three key concepts that apply to reduce exposure of all types of ionizing radiation

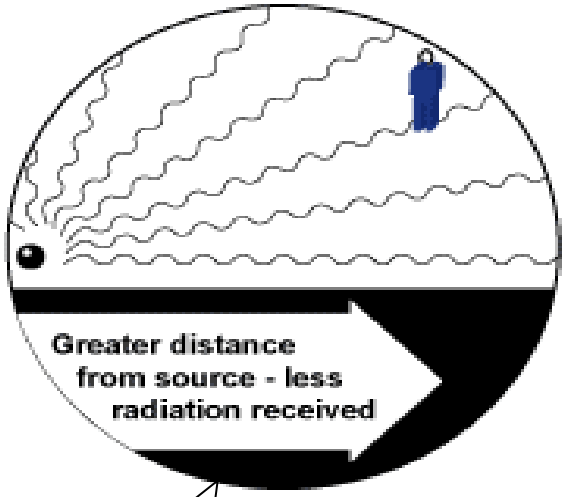
TIME



Dose = Dose Rate x Time

The radiation dose is directly proportional to the time spent in the radiation

DISTANCE

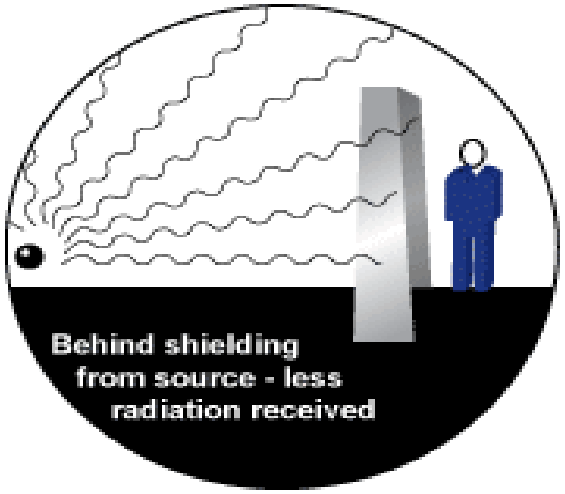


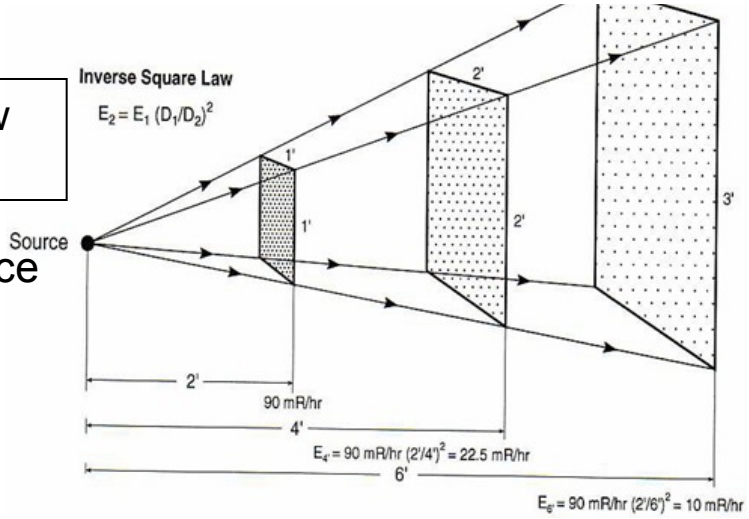
Inverse Square Law

$E_2 = E_1 [D_1 / D_2]^2$

Double the Distance
Quarter the
Exposure

SHIELDING

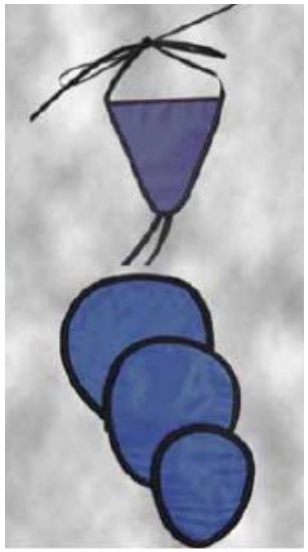




Personal Radiation Protection Apparel

Aprons, Skirts, Vests

Thyroid Shield



Reproductive organ shields

Glasses

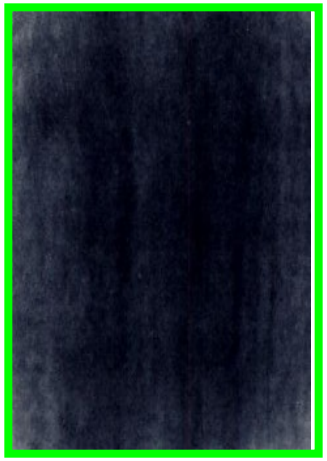
Gauntlets

Lead Apparel-Concerns

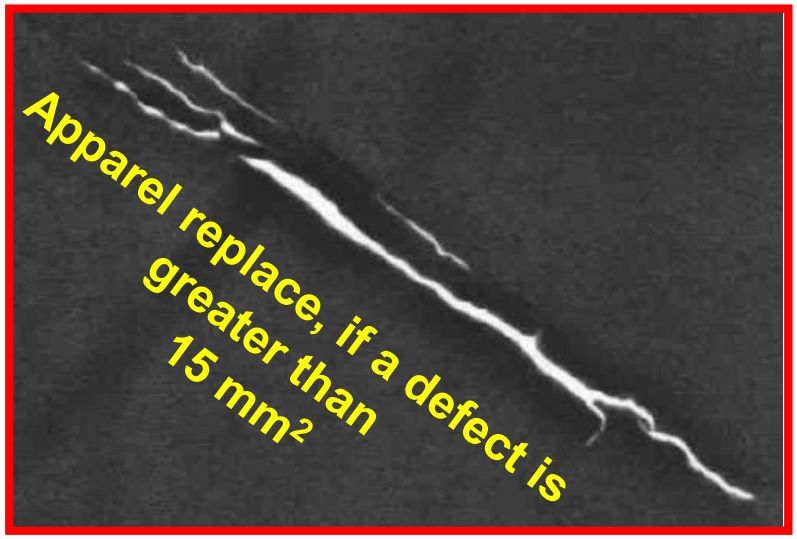
- Weight
- Embrittlement
- Mechanical sensitivity
- Microsized fillers
- Aging
- Attenuation limits
- Lead is toxic
- Disposal

Defects in Lead Protective Aprons

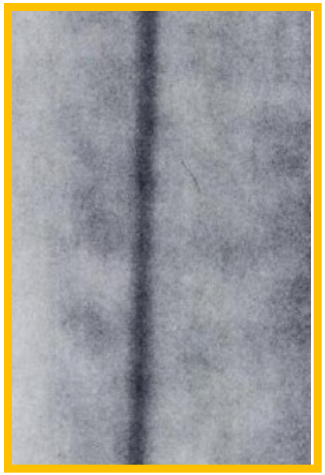
No defects



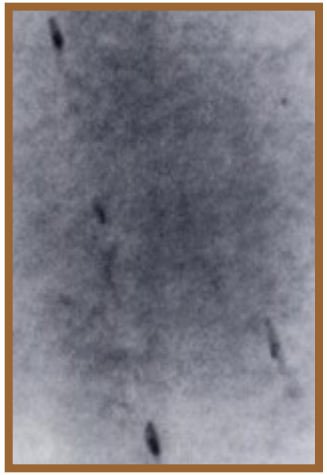
Bunching caused by folding



Low density strip defect



Peppering of small holes



Radiology 1982, 152; pp.217-218

Current CB(RN) PPEquipment

- All fabrics and skin block α-particles
- Inhaled or ingested α-particles are hazardous
- Provides Low Energy α and ß-particles protection only
- Impermeable PPEs are heat sinks and limit operations
- Protection against x and γ-rays is **„Zero“** and High Energy ß-particles is also negligible

Inadequate Radiation Protection of Responders

Tokaimura accident

Fukushima NPP

Zero rtg/γ,x-ray and limited β shielding

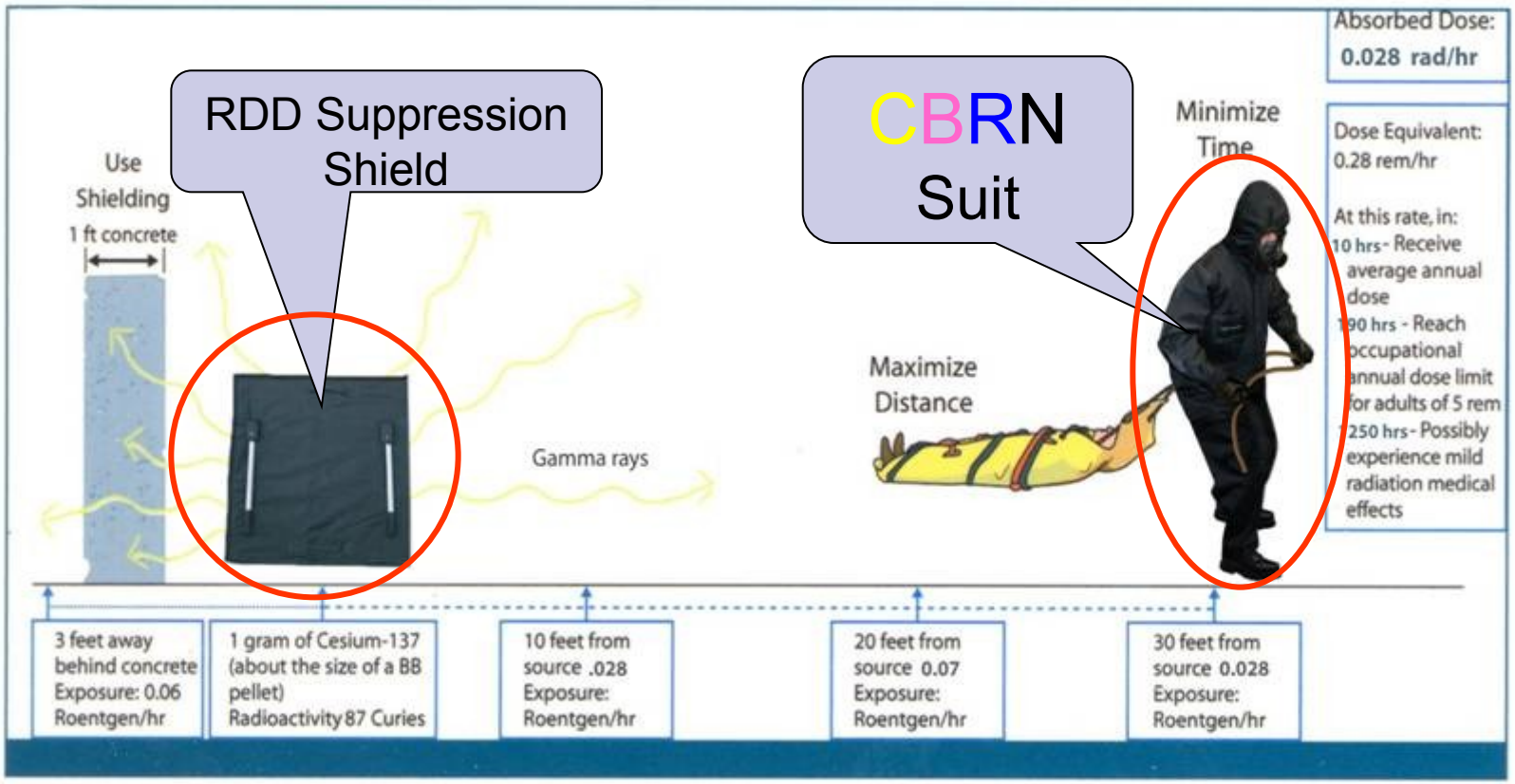
Controversies in radiation protection of citizens in radiation-hazards drill

Multi-hazard protection CBRN available now

- Demron PPE´s articles are the only protective gear available today providing complete multi-hazard protection
- Currently, most PP Ensemble only provided protection from chemical/biological agents and very limited radiological contamination, but no practical protection against nuclear and radiological threats, involving radiation sources with high energy penetration rays

- This is because the standards, which had been set to address the major chemical and biological threats of the past, had not been updated to address new emerging threats

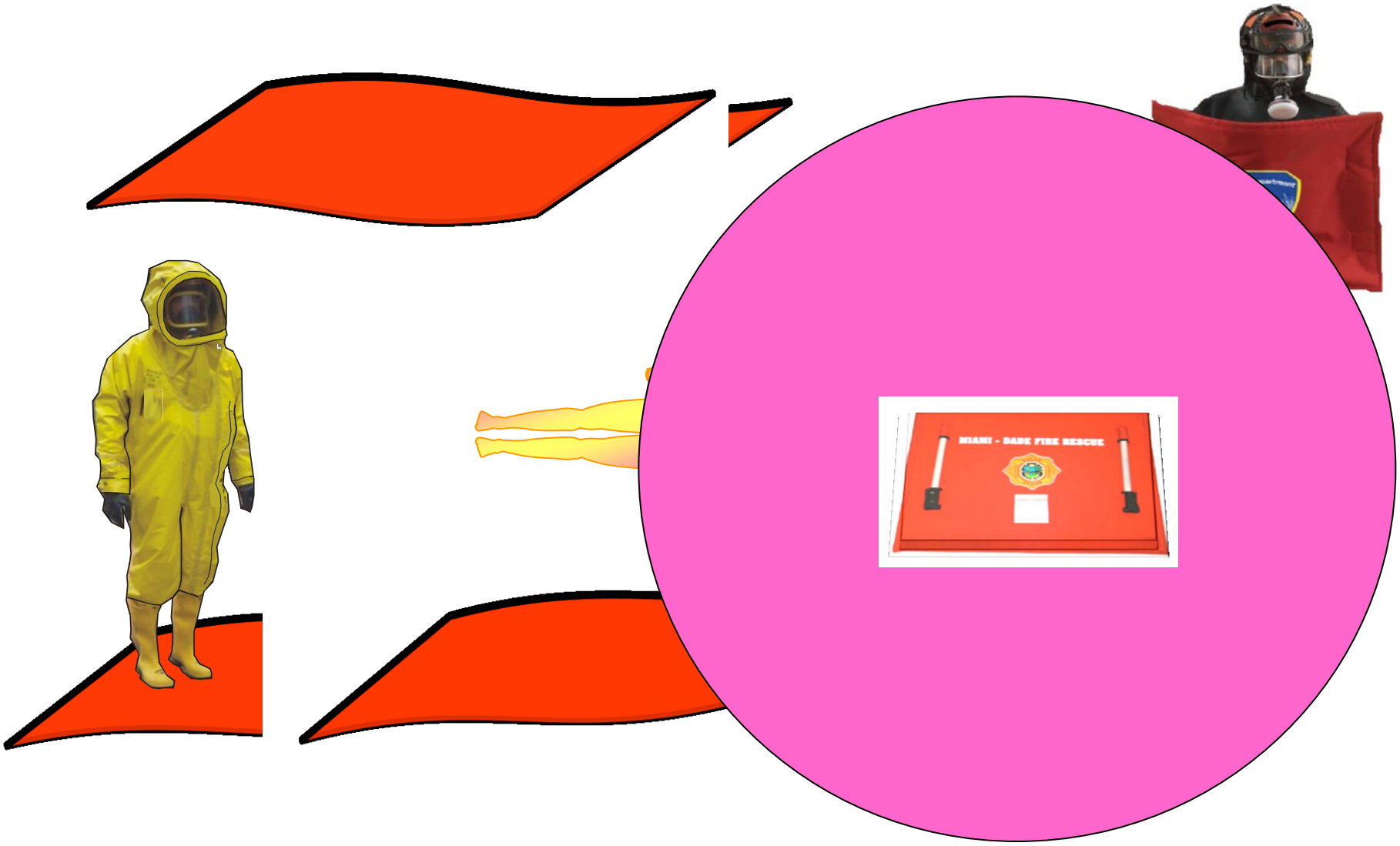
Improving Radiation Safety through Protection



Minimizing radiation exposure

Courtesy RST Inc.

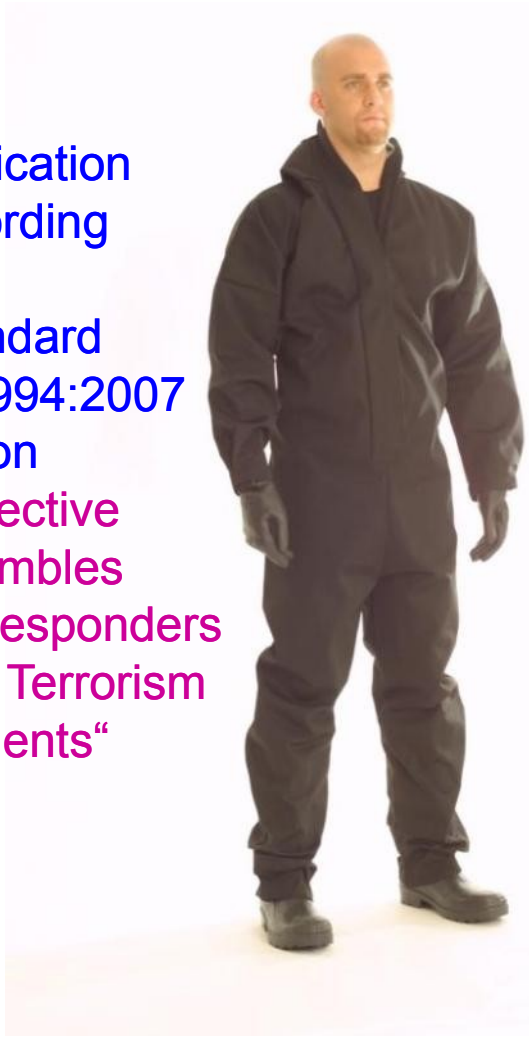
Some applications of shielding



Radiation CBRN Shielding Suits-Class 2

Certification according

Standard NFPA 1994:2007 on „Protective Ensembles for First Responders to CBRN Terrorism Incidents“



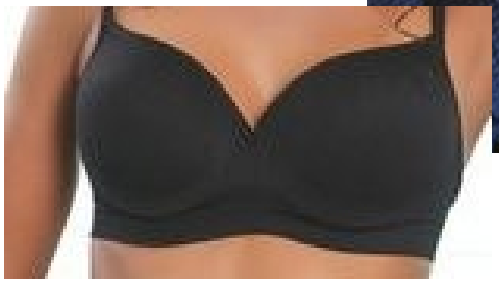
Complementary shielding with Torso Vest

Thyroid Shielding Collar

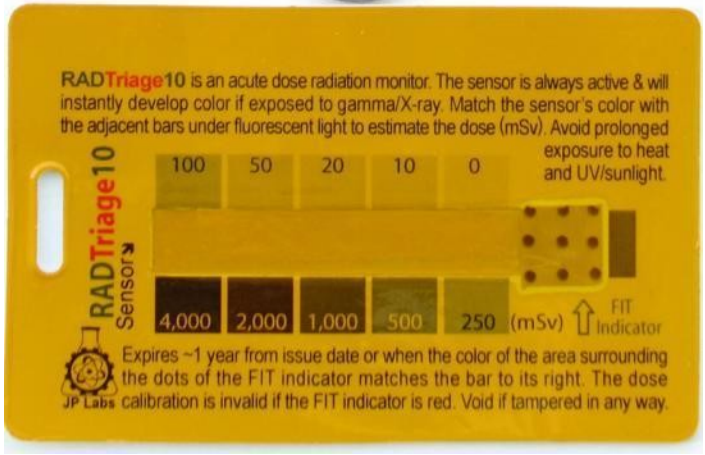
Radiation Suppression and Ballistic Blanket

Radiation-shielding **surgical mask**

- The disposable nonwoven Demron-M **surgical mask** has a non-breathable area to cover the bridge of the nose and cheeks, and a breathable protective construction below the nose.
- Shielding **bra** for female in radiology/surgery departments and/or for stewardess in aircrafts.

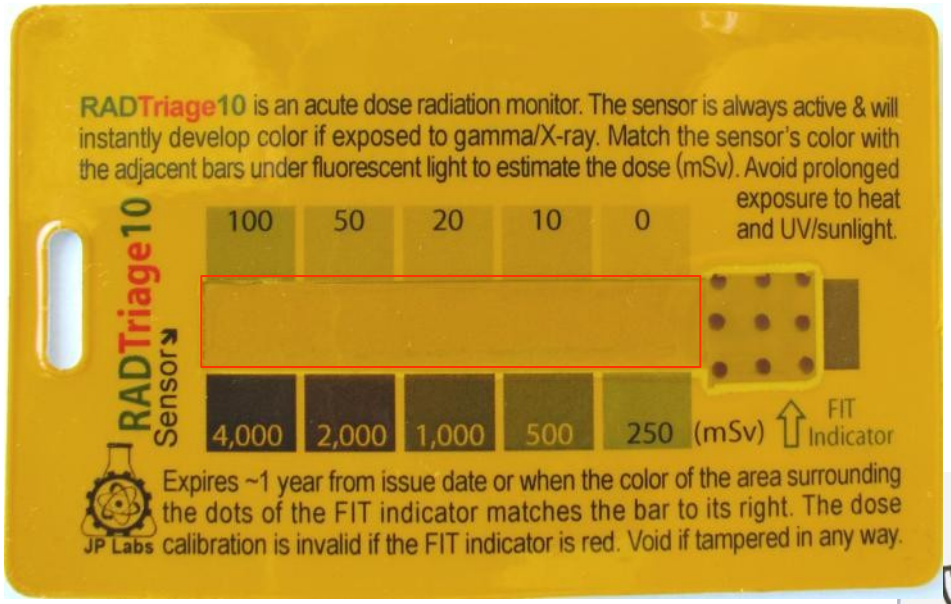


Personal Dosimeter RAD Triage



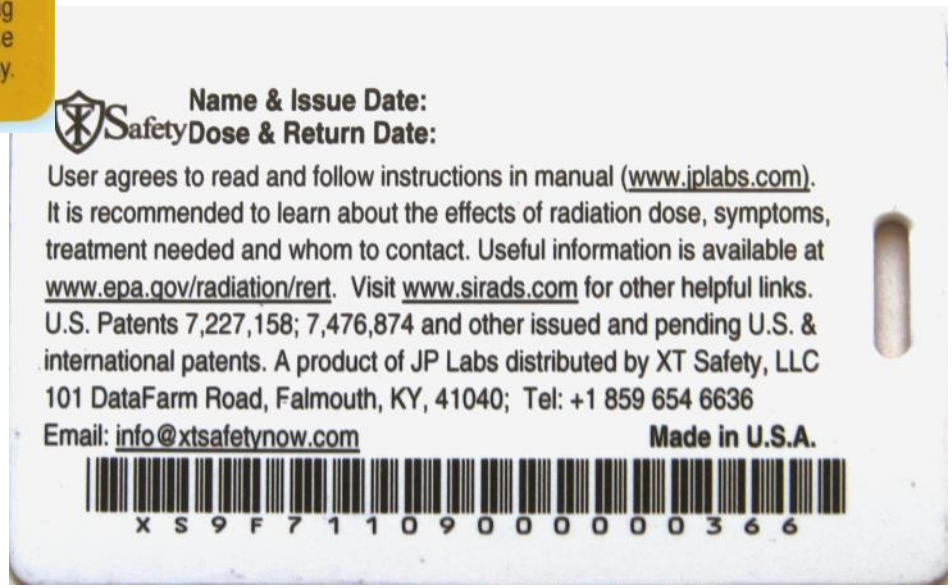
Next version will be
Thermo-Luminescence Detector
with **„flip-out“ microchips**
starting at 0,05 mSv

Personal Dosimeter RAD Triage



Self-Indicating Radiation Alert Dosimeter (SIRAD)
Dose Radiation range
10 mSv-4000-10000 mSv

Color change of the sensor responds to gamma/X-ray (energy higher than 30 KeV) and high energy (e.g., above 0.5 MeV) electrons/beta particles



Nano-composite shielding material
Test results

Gamma and X-rays Attenuation

- Gamma (γ) and X-rays radiation consists of highly energetic photons with high frequency. They can be stopped by a sufficiently thick layer of material with high atomic number "Z", such as Lead (Pb-82) or depleted Uranium (U-92).

  - Photoelectric Effect of attenuation coefficient μ is proportional to atomic number "Z"

$$\mu = f Z^3$$

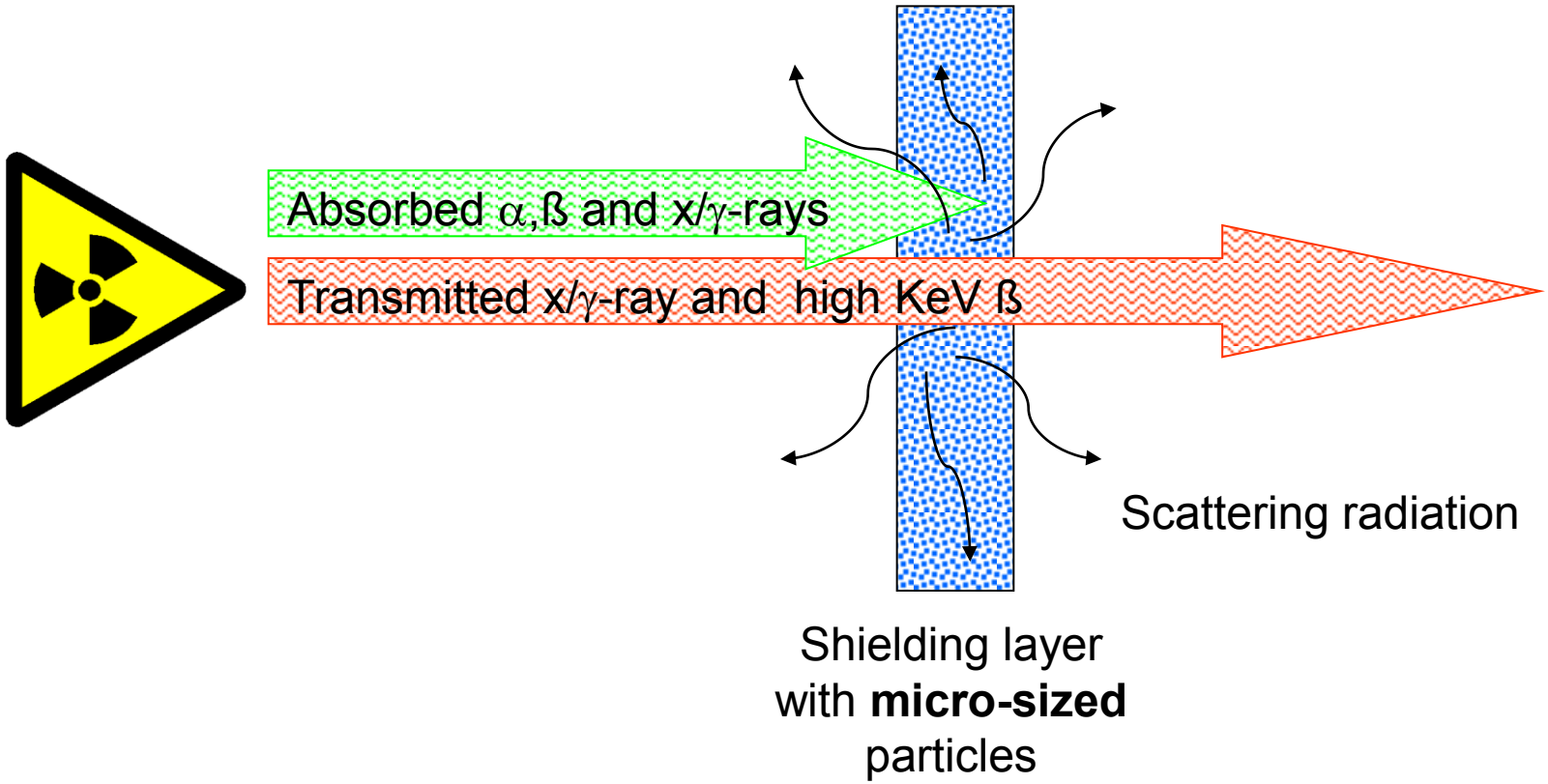
  - **E.g. Pb aprons (Z = 82) absorbs γ and X-rays ~ 1,000 more rather than soft tissue with approx. Z ~ 8**

Elements incorporated into some commercial radiation-shielding garment materials

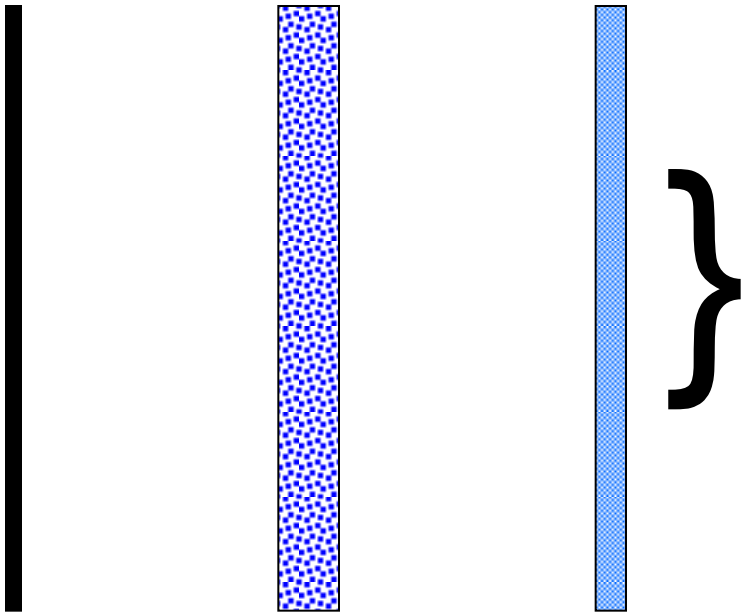
ELEMENT	ATOMIC NO.	Density (g/cm^3)	K absorption edge (keV)
Cadmium (Cd)	48	8.65	26.7
Indium (In)	49	7.31	27.9
Tin (Sn)	50	7.30	29.2
Antimony (Sb)	51	6.69	30.5
Cesium (Cs)	55	1.87	36.0
Barium (Ba)	56	3.5	37.4
Cerium (Ce)	58	6.66	40.4
Gadolinium (Gd)	64	7.90	50.2
Tungsten (W)	74	19.3	69.5
Lead (Pb)	82	11.36	88.0
Bismuth (Bi)	83	9.75	90.5

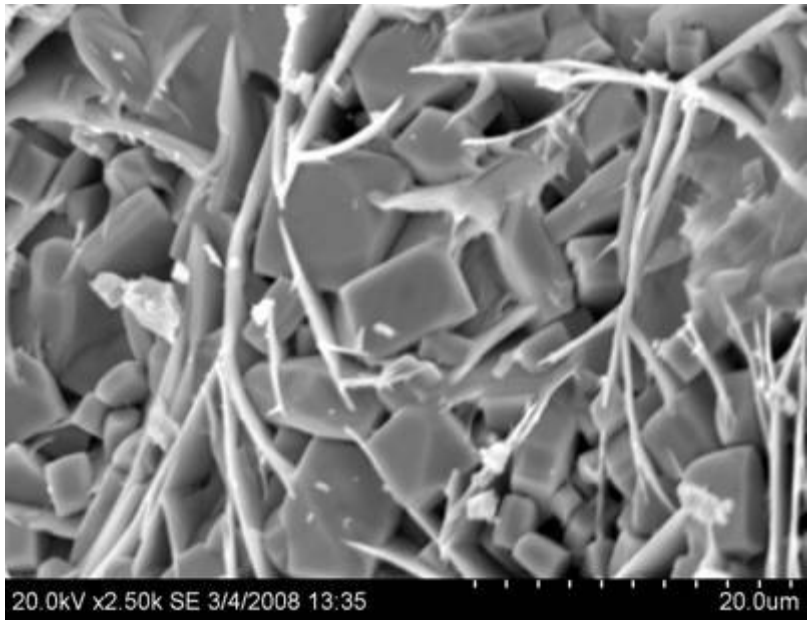
McCaffrey *et al.:*Med. Phys. 34 ,(2) February 2007

Shielding through Pb composite



Pb-equivalent shielding fabrics





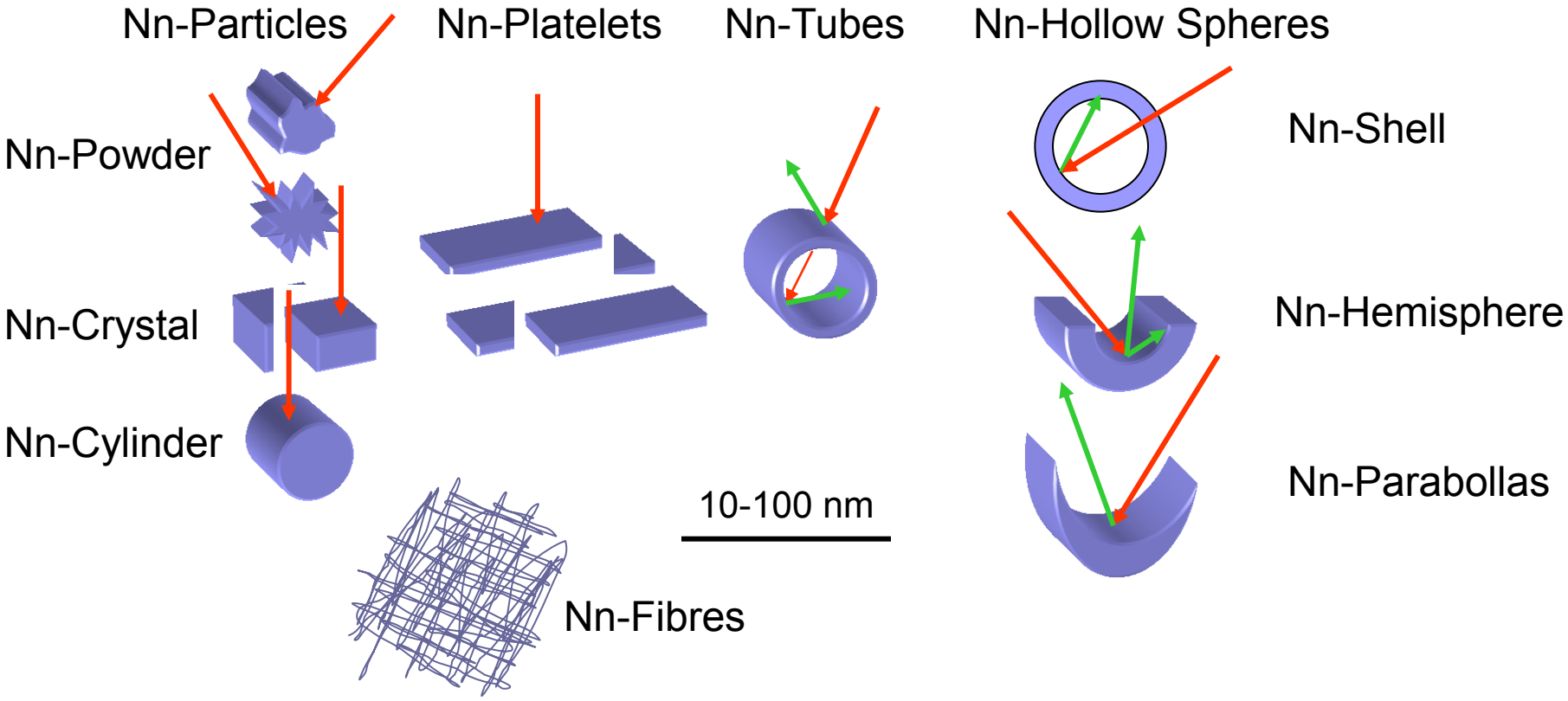
Pb Sheet 0,25; 0,35; 0,5; 0,75; 1,0 mm

Pb/PbO micro-sized in vinyl or butyl rubber composite

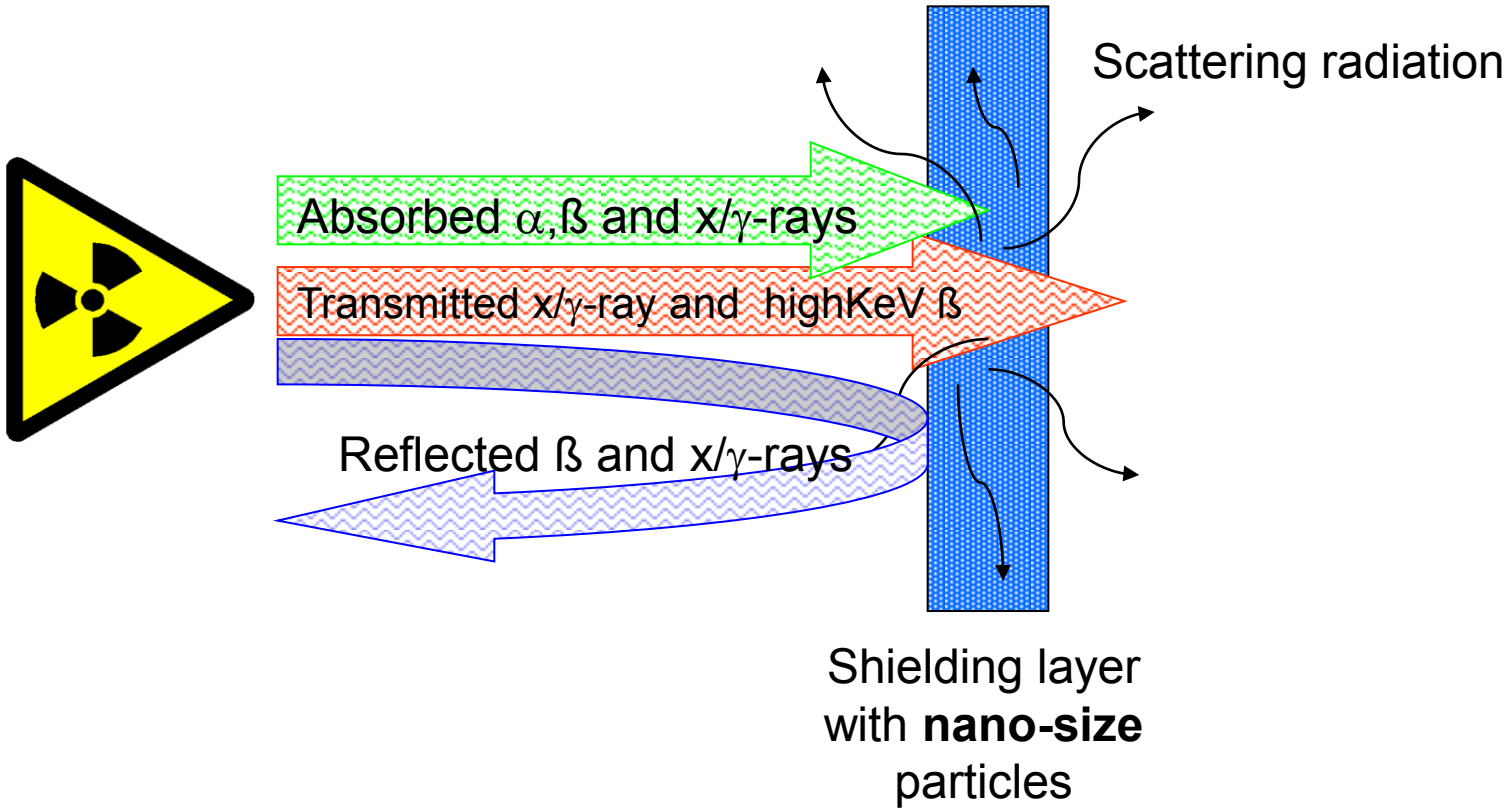
Nano-particle composite

Absorption and deflection of Rays on nano-particles

- Different shape of nano-particles

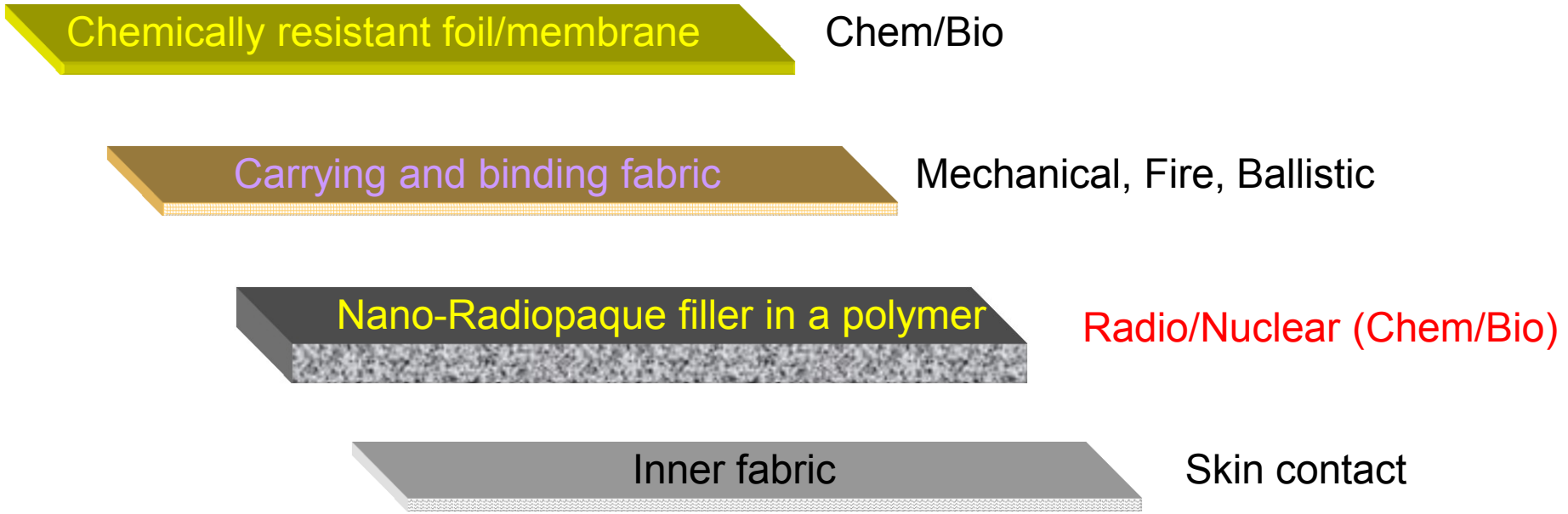


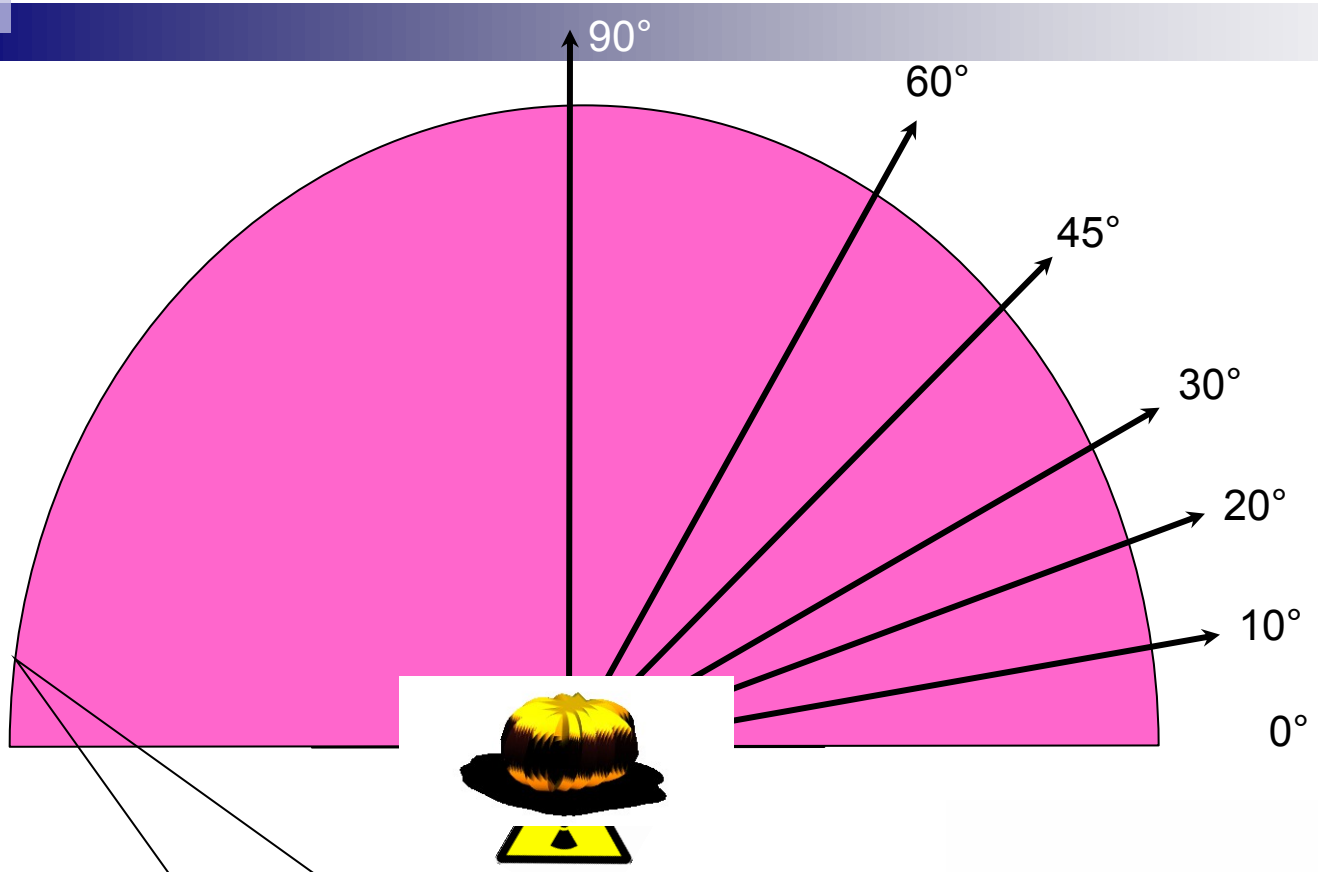
Shielding composite with nano-particles

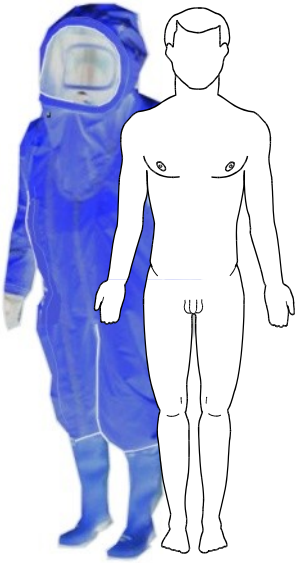


Multiple Hazard Protection Composite Material

Polymer with radiopaque fillers is sandwiched between layers of fabric and/or foils/membranes



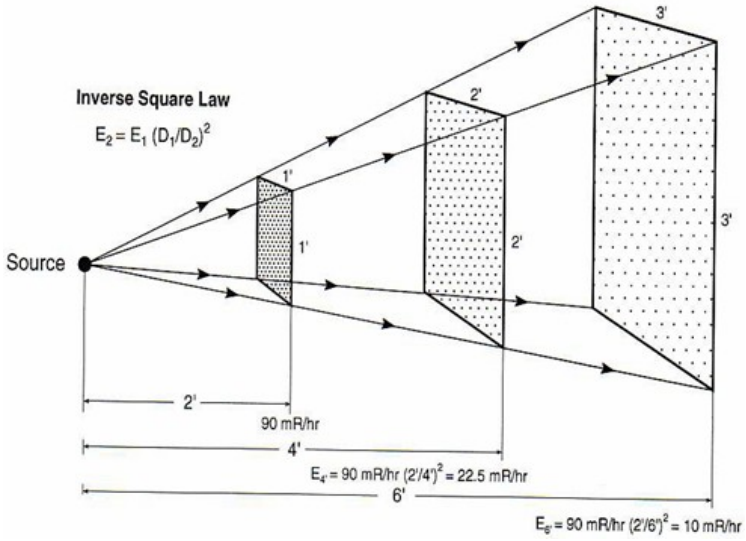


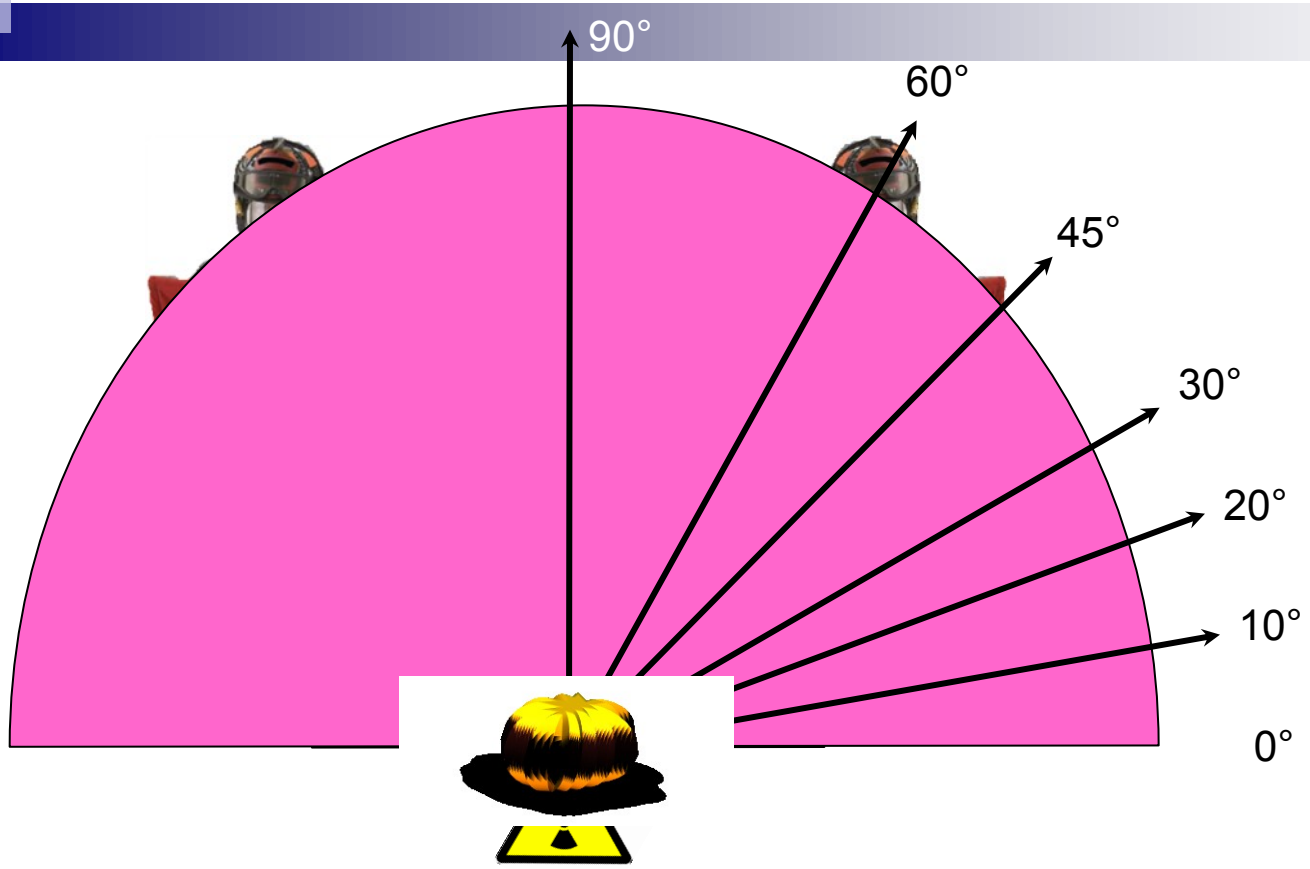


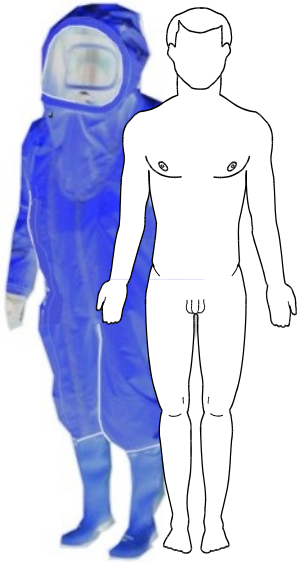
Inverse Square Law

$E_2 = E_1 [D_1 / D_2]^2$

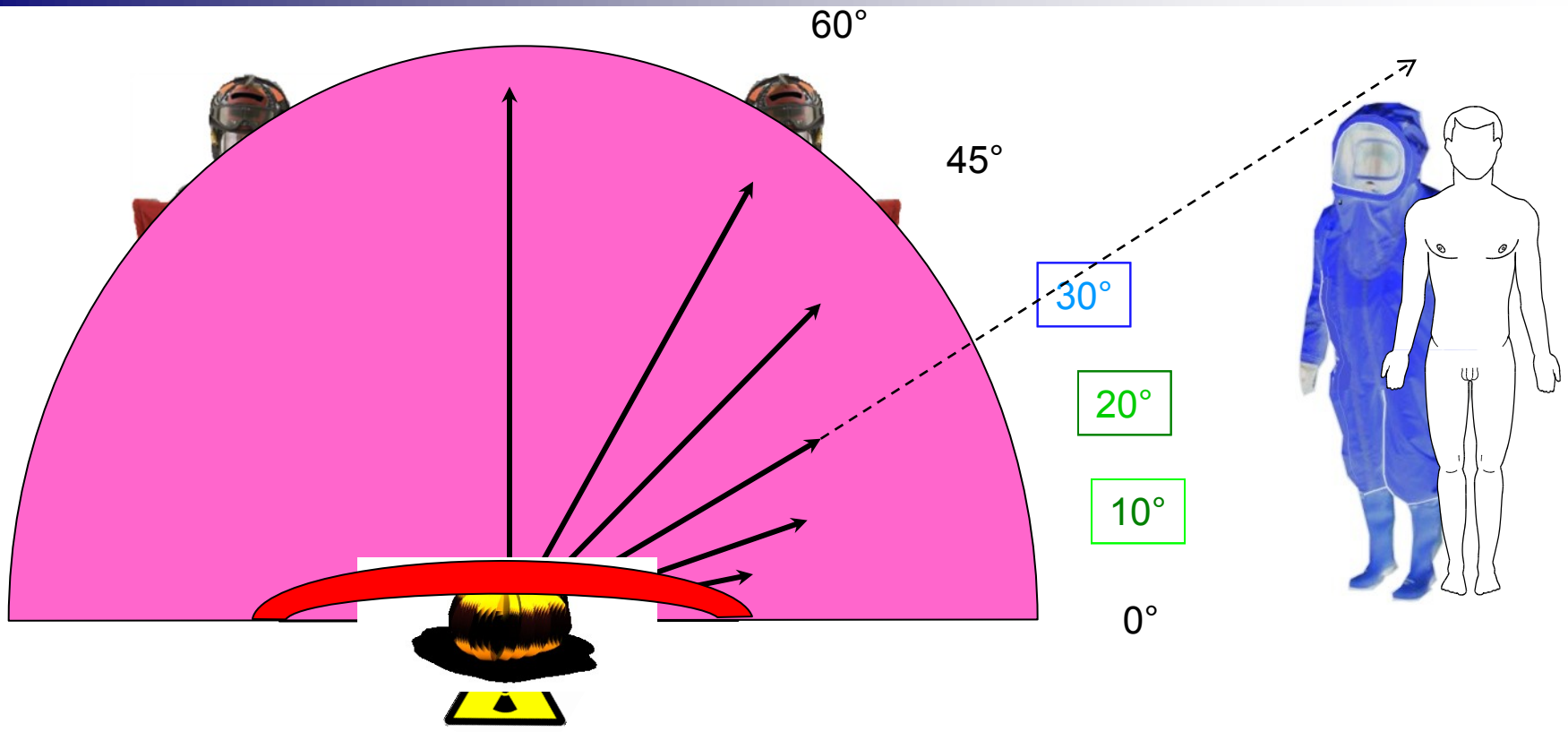
Double the Distance
Quarter the Exposure



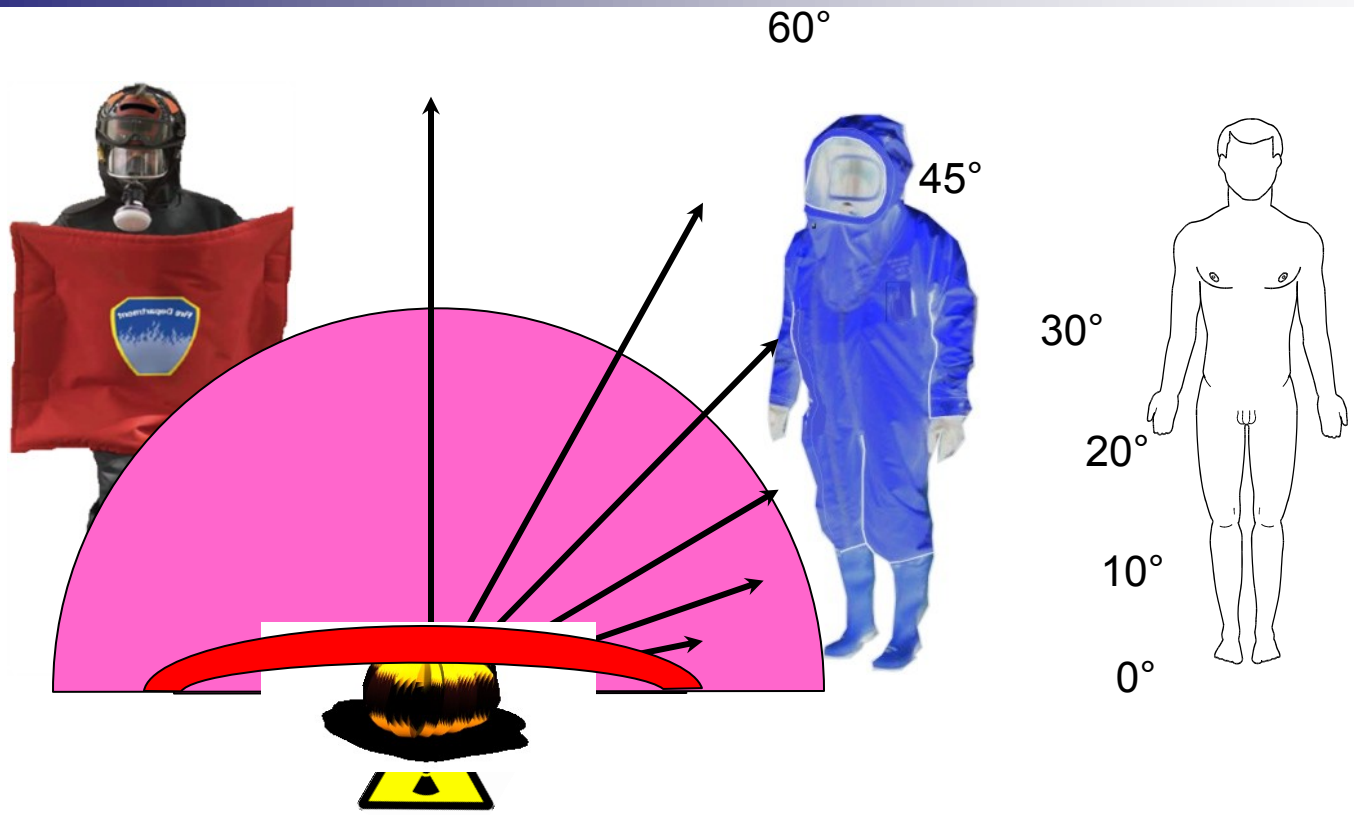




Radiation shielding suits and
radiation suppression and ballistic blankets
allows significant reduction of radiation exposure
during approaching to radiation source



Cover of radiation source with
Radiation suppression and ballistic blankets
reduce radiation exposure and mechanical hazards of potential explosion
Low angles of approach, in the range 10°-30°
are especially desired



Cover of radiation source with
Radiation suppression and ballistic blankets
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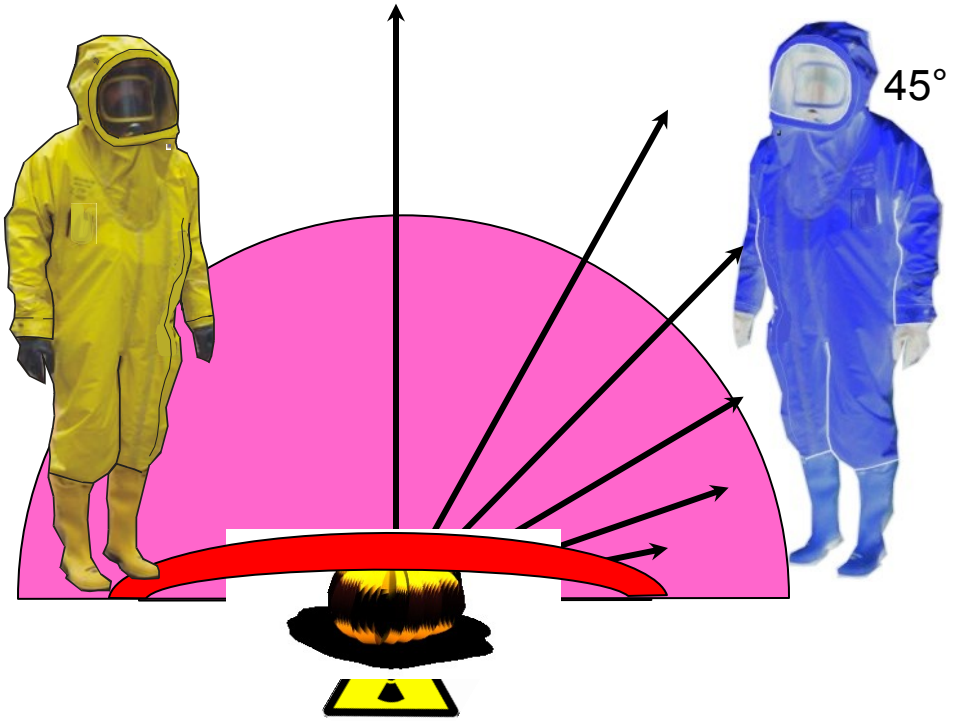
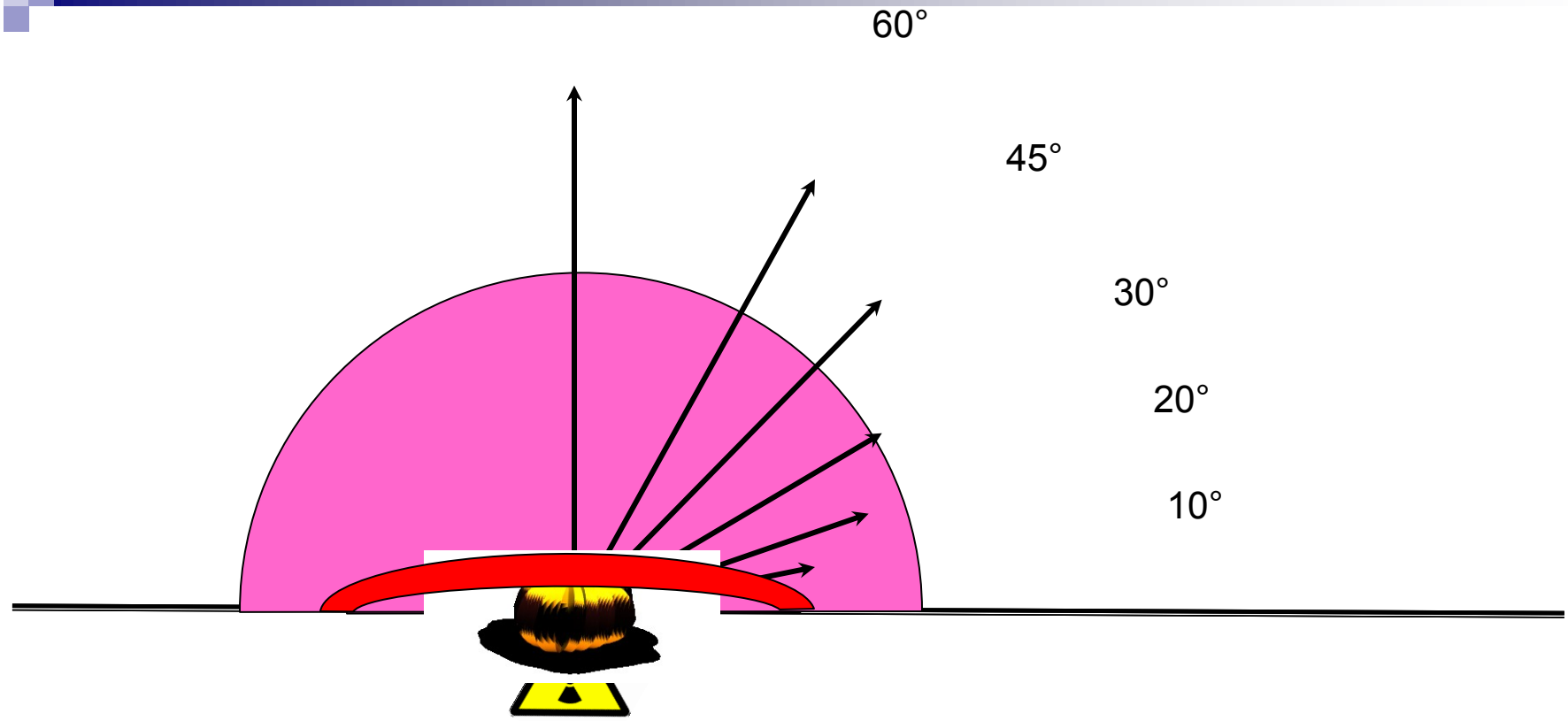
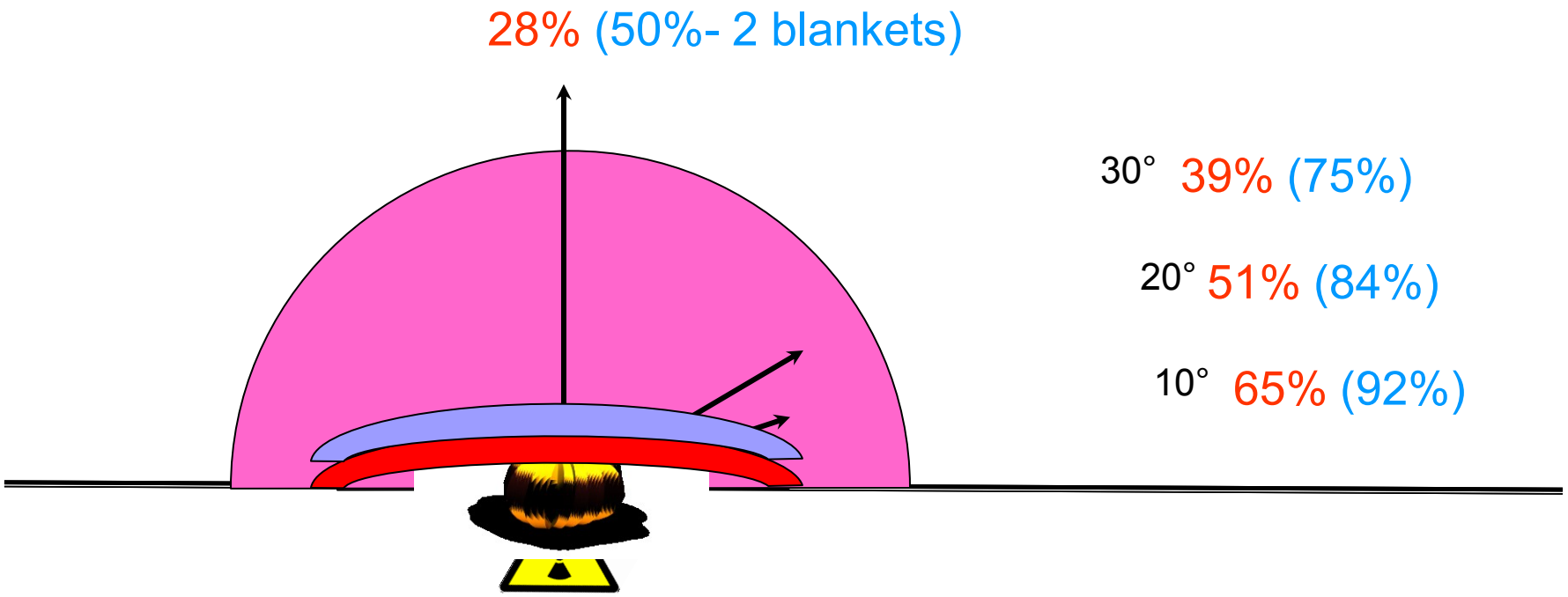


Cover of radiation source with
Radiation suppression and ballistic blankets
allows operations with less shielding protective ensemble

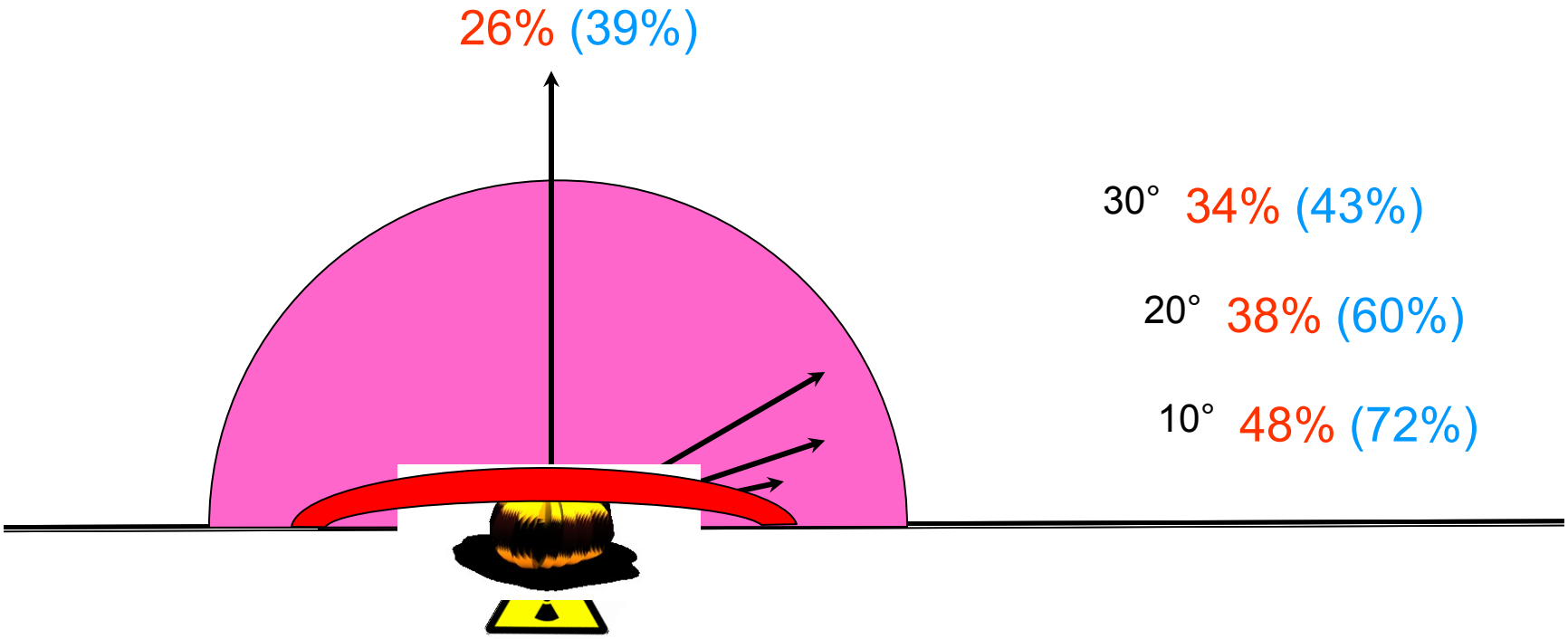


Radiation suppression blanket attenuation factors change with angle, corresponds to thickness of blanket traversed by the radiation



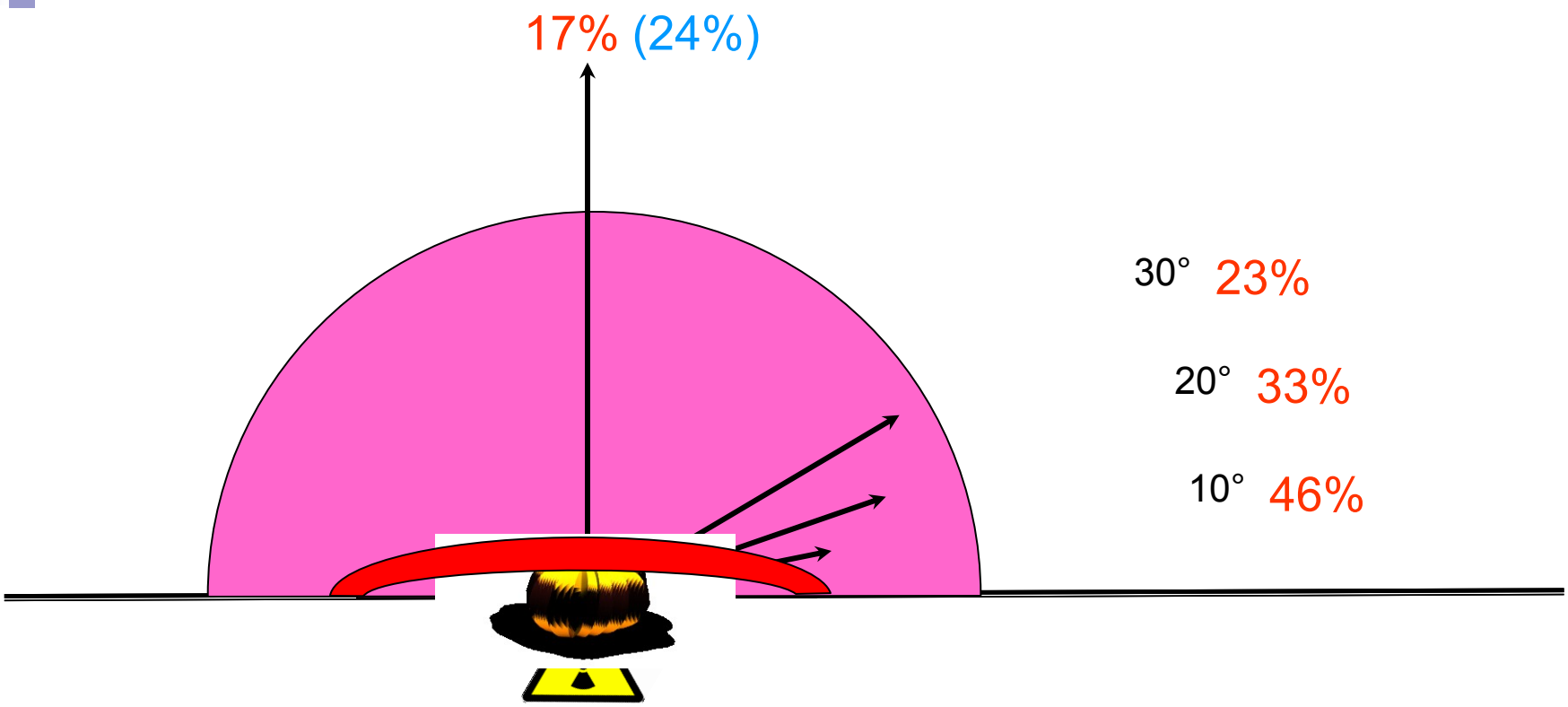
Cs-137 Point gamma-ray source
14 mCi, 662 keV
Attenuation factor at 100 cm from the source

Ref.: Battelle, Radiation & Health Technology



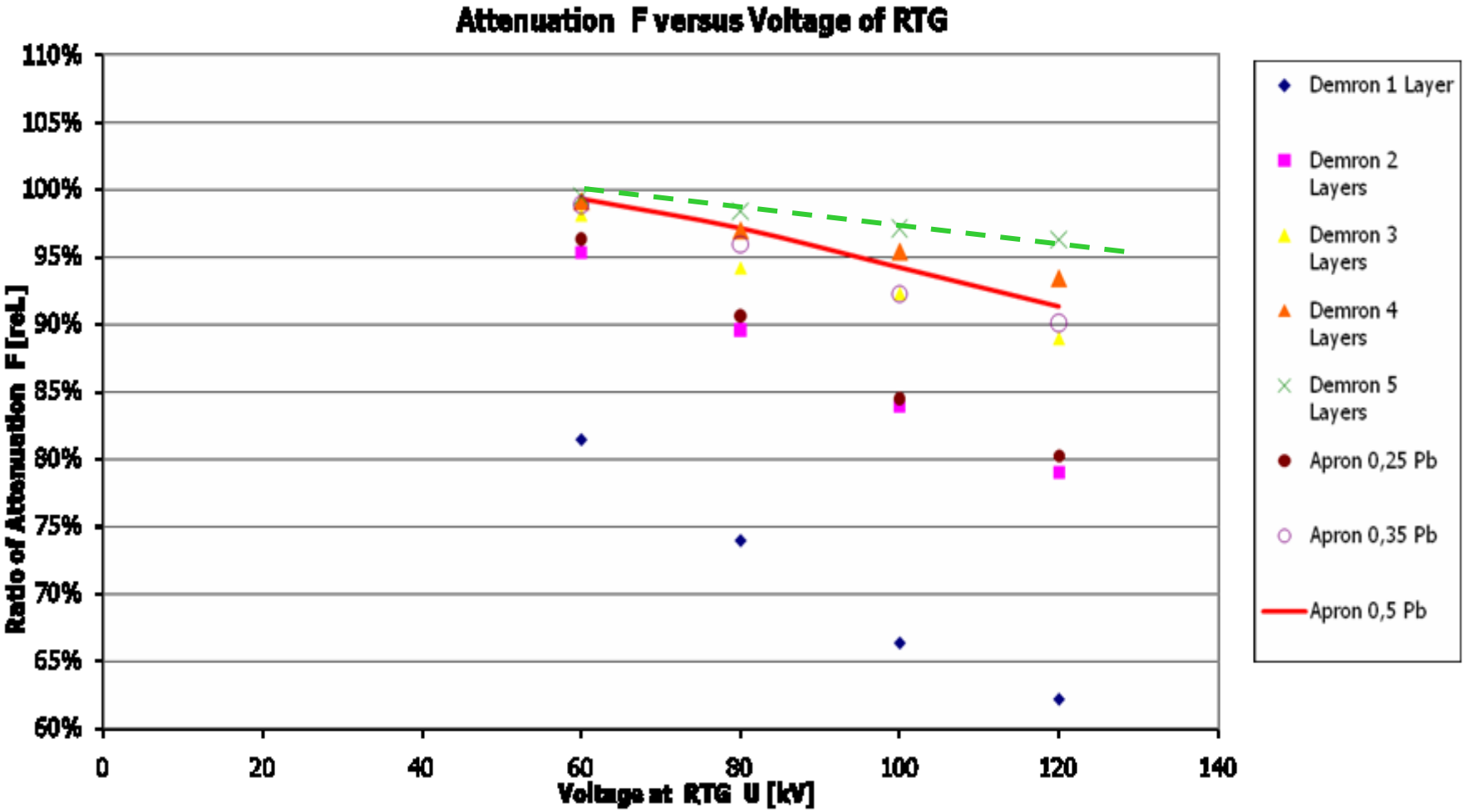
Ra-226 Point gamma-ray source,
1,7 Ci, 186-610 keV
Attenuation factor at 100 cm from the source

Ref.: Battelle, Radiation & Health Technology

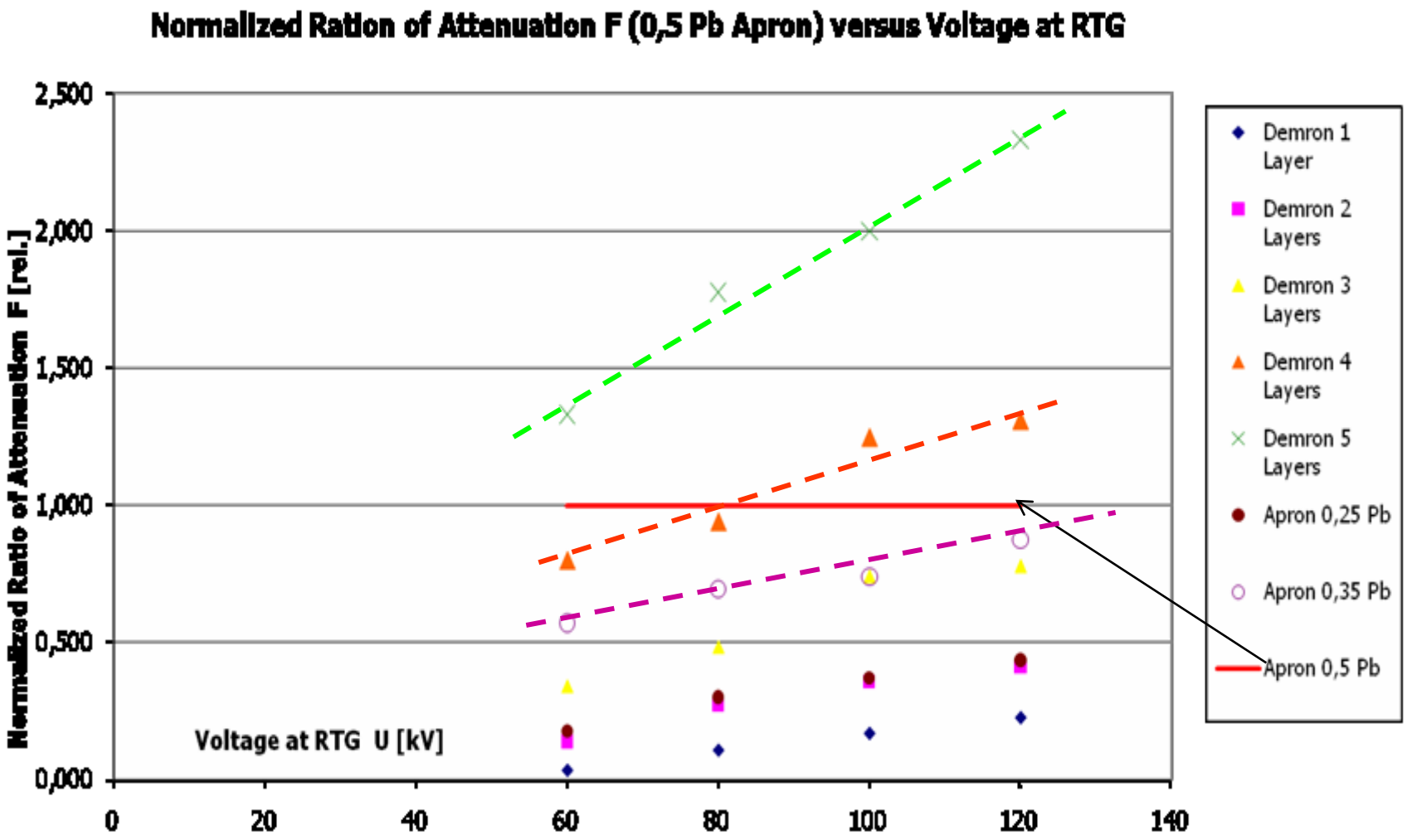


Co-60 Point gamma-ray source,
320 μCi, 1250 keV
Attenuation factor at 100 cm from the source

Ref.: Battelle, Radiation & Health Technology

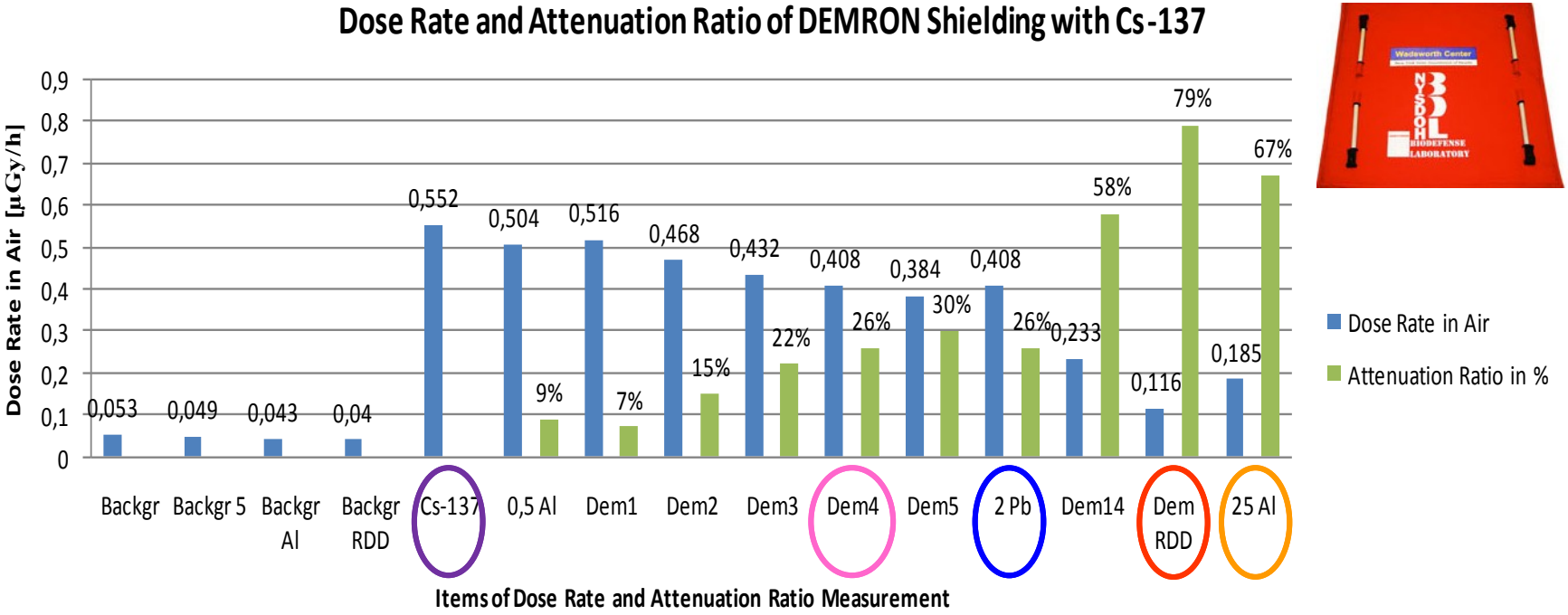


Courtesy VF a.s. Černá Hora



Courtesy VF a.s. Černá Hora

Cs-137 (β)512 keV and (γ)662 keV



- During the measurement background dose rate fluctuated between 0,04-0,05 µGy/h and Cs-137 source gave dose rate of 0,552 µGy/h. Folding of DEMRON layers provide synergy effect in increasing of attenuation rate. 4 layers of DEMRON are surprisingly equivalent to 2 mm of Pb. Sample of multiply DEMRON layers as RDD shield provide effective attenuation of 79% against Cs-137 source.

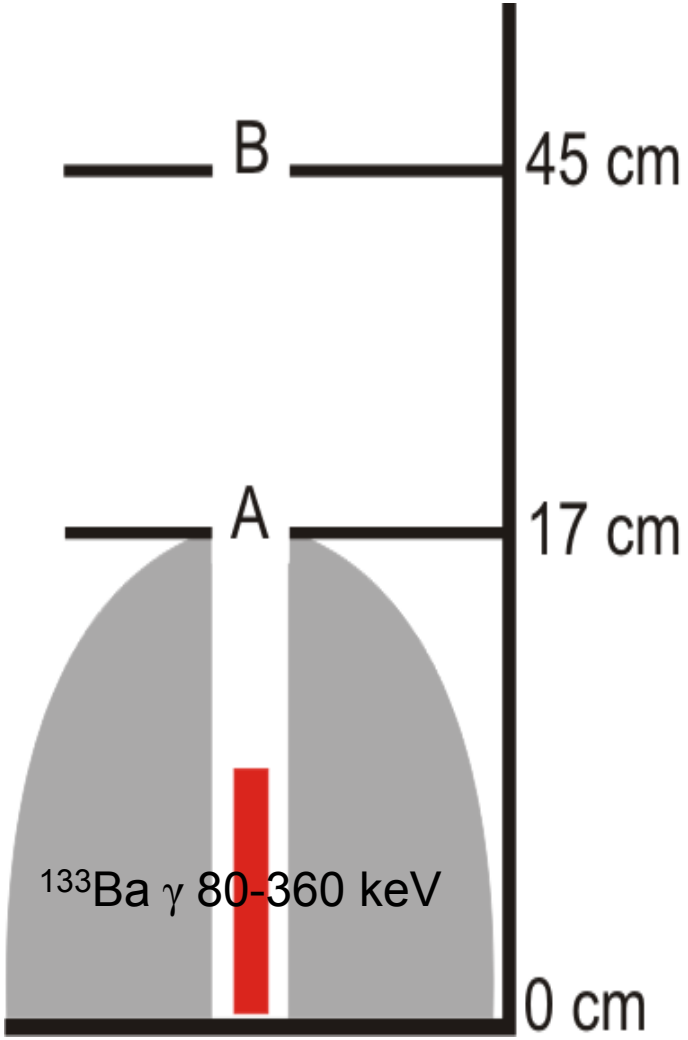
Courtesy VF a.s. Černá Hora

Shielding measurement in A or B geometry position with ^{133}Ba

DEMRON ®
Shielding layers
ρ **0,2** g.cm^{-2}
2,7 g.cm^{-3}

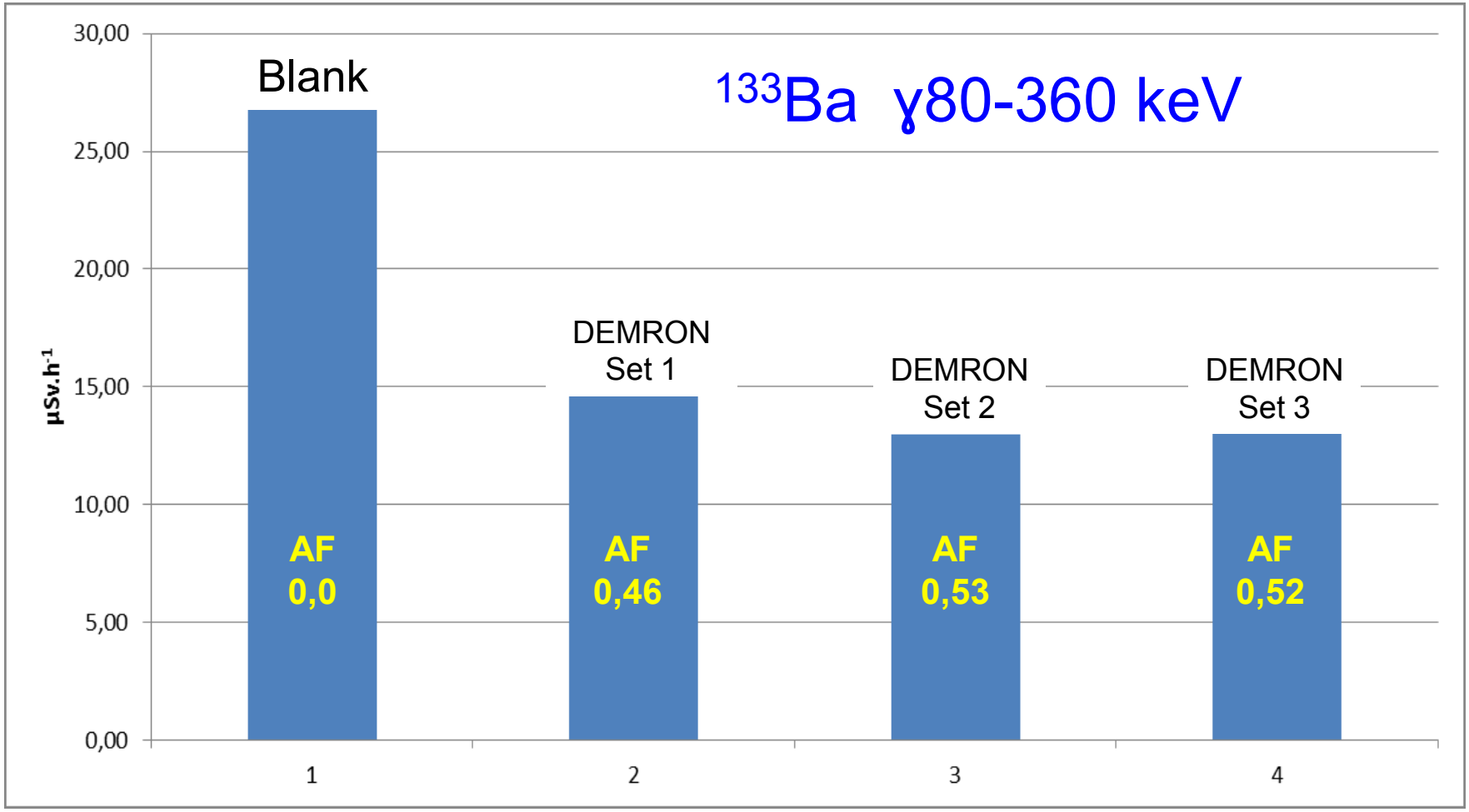
DIS-1 dosimetr
or
EXPLORANIUM GR-135
detector

Dos



Courtesy by P. Otáhal, M. Kozlovská, I. Burian;
SUJCHBO, Project VF20112015013

Attenuation Factor of DEMRON layers (A geometry)



Courtesy by P. Otáhal, M. Kozlovská, I. Burian;
SUJCHBO, Project VF20112015013

Cleanup operations in Fukushima with Demron Shielding Suits

- Mr. Kevin Wang, president with PowerPlus Cleaning Solutions, who is leading the radiation cleanup efforts in Japan stated:
- *"We have tested and measured the protection Demron provides, and Demron is the only gear that we trust one hundred percent to protect our team and equipment for the cleanup process in Japan.*
- *Our equipment has registered dangerous radiation levels in zones that Japanese officials had determined were 'clean.' Radiation levels are dangerously high at this point, and without Demron, we would not be able to calibrate our equipment, take accurate readings of radiation levels or safely perform our work.*
- *After comparing Demron with other gear available today, it's clear that Demron is the absolute best and only choice because it is the only gear that provides the necessary radiation protection. It's also flexible, lightweight and adaptable for multiple uses. We stand by Demron."*

Demron™ -RST

Dr. Ronald DeMeo has been manufacturing Demron products to military and rescue staff around the globe for several years, but he invented the fabric for medical personal. After using a continuous X-ray machine with his patients, he saw sunburn-like skin damage on his arms and hands. And he also saw many colleagues in his field afflicted with different types of skin cancers.

More than 200 full-body nuclear radiation protection suits manufactured in Medley have been donated to aid power plant workers and rescue teams in Japan, and the company, Radiation Shield Technologies, is working full-time to keep up with orders from companies in Japan.

*"We have distributors and have folks that we work with in Asia, and it prompted me to say**, 'We have to just get suits over there as quickly as possible,' and the fastest way to do that is simply to donate them**," said RST CEO Dr. Ronald DeMeo*.

Thank you for your Attention

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