CLASSE 921 - General Radiation Safety Training

(for working near Radiation Producing Equipment [RPE])

Cornell University

Environmental Health and Safety

Radiation Safety Section

with Additions & Modifications by & for CLASSE

(last modified Mar 15, 2018)

Course Outline

- Training requirements
- Delegation of Authority / Responsibility
- Introduction to Radiation
- Units of Measure for Radiation
- Background radiation
- Biological Effects & Risks from Radiation
- Controlling Radiation Exposure (ALARA)
- Occupational Radiation Exposure Limits
- Radiation sources at CLASSE
- Special radiation safety issues at CLASSE
- Summary

General Radiation Safety Training Requirements

- **Initial training**
  - **Take this training & pass quiz before entering a controlled area**
    - **If you've taken "CLASSE 922 – RPE Training", you don't need this one**
- **Refresher training**
  - **Retake this CLASSE online training & pass quiz <u>EVERY YEAR</u>**
    - **If you refresh "CLASSE 922- RPE Training", you don't need this one**
- **Record of training**
  - **Check your training database entry: your job!**
    - **Regulators: "if it's not recorded, the training didn't happen!"**

Regulation of RPE

- NYS Dept of Health regulates RPE. It grants a broad license to Cornell, which agrees to regulate internally via Radiation Safety Committee (RSC), Radiation Safety Officer (RSO) & associated staff
- RSC & RSO grants “permits” to specific persons [Permit Holders (PH), senior research associate or above] for specific locations
- Permits include names of authorized “users” (operators)
- Permit applications must be approved by CLASSE Safety Committee before being sent to EH&S

RPE Authority Delegation

U.S.NRC
Protecting People and the Environment

STATE OF NEW YORK
DEPARTMENT OF HEALTH

CORNELL UNIVERSITY
FOUNDED A.D. 1865

Radiation Safety Committee

Report concerns about RPE safety to PH, CLASSE Safety Director, or RSO

RSO

Permit Holders

Operators

Introduction to Radiation

The term *radiation* is very broad and includes such things as radio waves, microwaves, visible light, gamma rays and x-rays. For the purpose of this training we are going to focus on ***Ionizing Radiation***.

What is Radiation?

In basic terms, it is simply the *movement of energy* from one place to another via an electromagnetic wave or a particle.

Types of *electromagnetic* radiation are:

- radio waves, visible light, ultraviolet light, x-ray, gamma

Particles constitute another form of radiation:

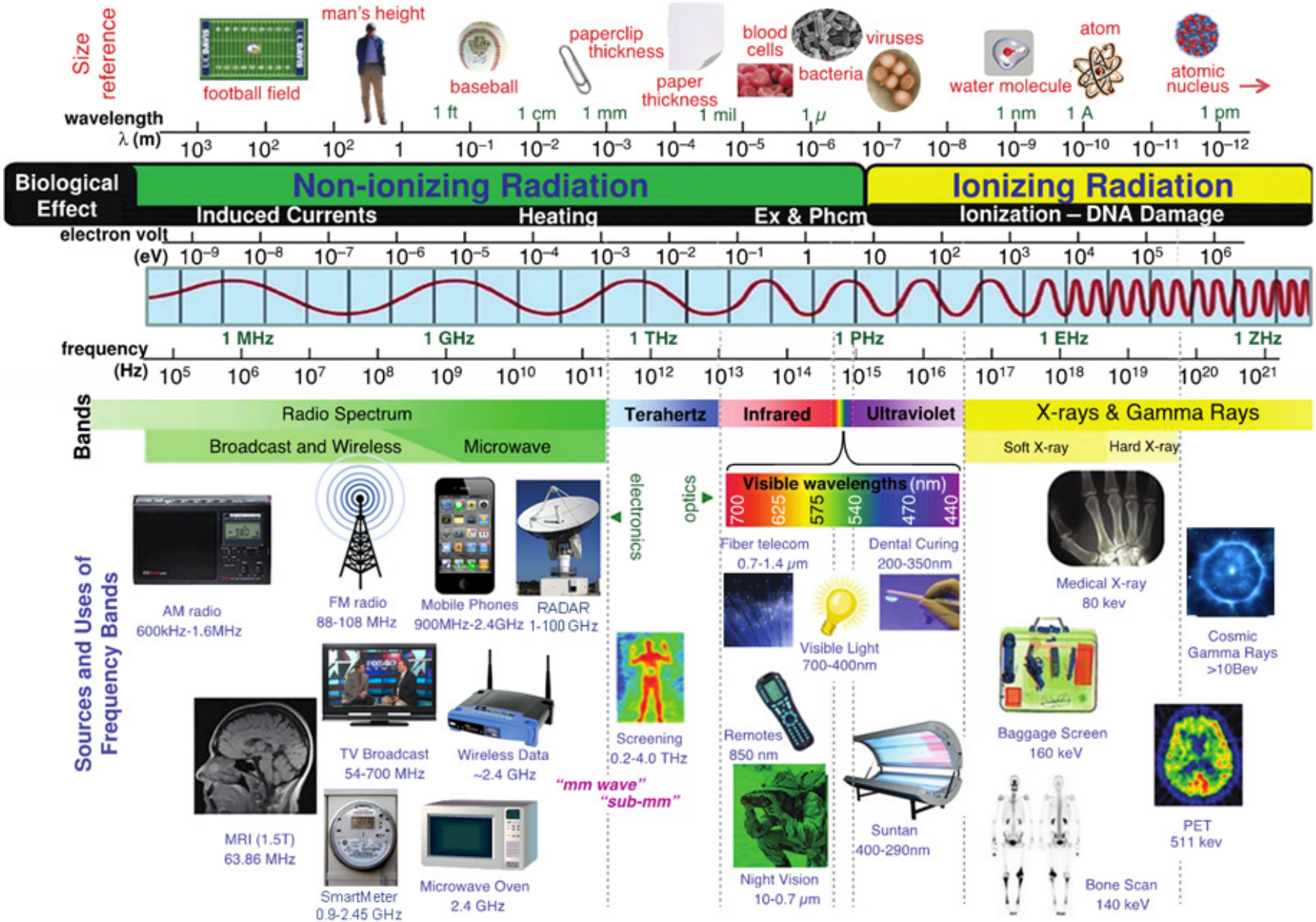
- alpha, beta, neutron, proton, cosmic rays

Ionizing Radiation

Ionizing Radiation is radiation with sufficient energy to remove electrons from atoms when it passes through material. Such atoms (molecules), after the removal of one or more electrons, have a net positive charge and are called **ions**. Ionization can occur in any material, including solids, liquids, gases, and living tissue.

Non-ionizing radiation: a type of radiant energy NOT capable of creating ions. Radiant energy, both visible and ultraviolet, and microwave radiation are examples of non-ionizing radiation.

ELECTROMAGNETIC RADIATION SPECTRUM



Units: Equivalent Radiation Dose

REM (originally for *Roentgen-Equivalent Man*, but more recently *Roentgen-Equivalent Mammal* or *Radiation-Equivalent Mammal*) is a unit used to derive a quantity called equivalent dose. This relates the absorbed dose in a human tissue to the effective biological damage of the radiation.

Not all radiation has the same biological effect, even for the same amount of absorbed dose.

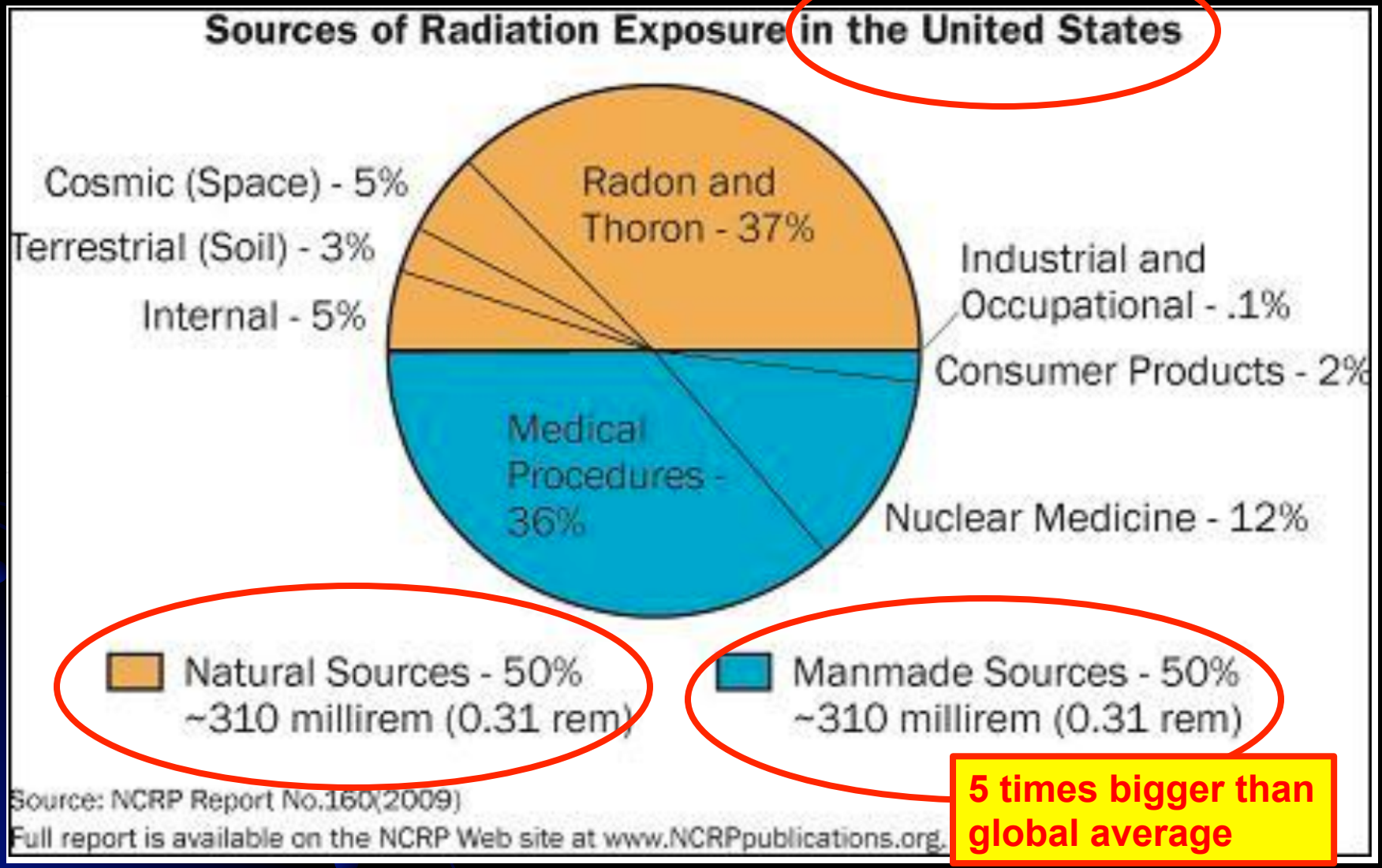
To determine **equivalent dose** (rem), you multiply absorbed dose (rad) by a quality factor (QF) that is unique to the type of incident radiation.

Energy	QF
Gamma, Beta and X-ray	1
Neutron	2 - 11
Alpha	20

Units for Dose & Dose Rate

- Equivalent dose is often expressed in *thousandths of a rem* or *mrem*. (*milli-rem*, usually lower case letters). Small doses are sometimes in *millionths of a rem*, or *µrem* (*micro-rem*). 0.05 mrem = 50 µrem; 1 mrem = 1000 µrem
- Dose rate is the "speed" of dose accumulation: dose per unit time; mrem/h
- Dose = Dose rate × exposure time

Sources of Radiation Exposure



Biological Effects of Radiation

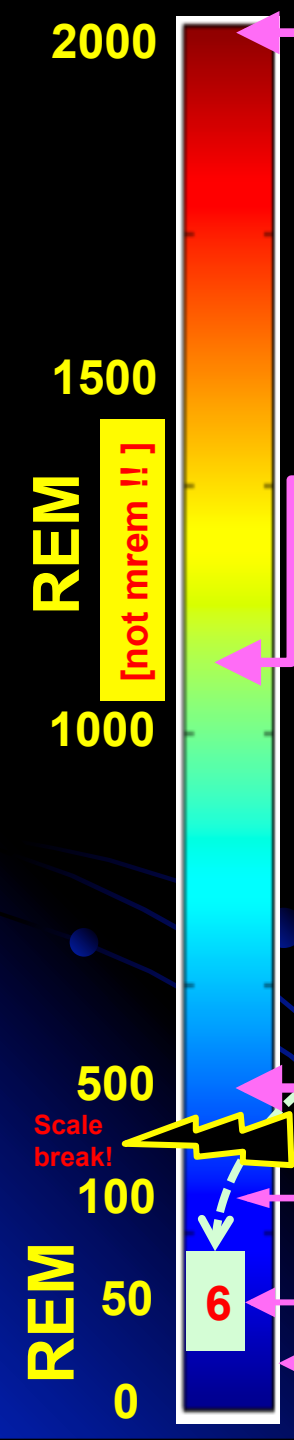
- **The short version –**
  - **Radiation causes ionization in tissue**
  - **Ionization – typically removal of orbital electrons**
  - **Ionization breaks molecular bonds**
  - **Broken molecules not usable and/or can participate in chemical reactions in cells**
  - **Buildup of broken molecules or reaction products can affect cell function**

Biological Effects of Radiation

- More damaging if high fraction of cells affected
  - Human embryo (1st 8 weeks after fertilization) most susceptible
  - Continuing heightened risk throughout pregnancy
  - Testes
  - Lens of the eye
  - Thyroid exposure, especially in children
  - See Handbook for radiation & pregnancy information
- Definitions
  - Somatic – affects person exposed
  - Genetic – affects future generations
  - Acute – over short time e.g. minutes
  - Chronic – over long period e.g. years

from the Greek, "somatikos": "of the body"

Acute (short term) exposure to major portion of body



2000+ rem: Almost immediate death

1100 rem: Lethal dose to 50% exposed (w/ bone marrow transplant)

500 rem: Lethal dose to 50% exposed (w/ medical care)

100 rem: Nausea in about half of those exposed ("radiation sickness"). Measureable & significant blood count changes.

Out of 167 radiation workers at Fukushima, just 6 got above 25 rem, & the maximum exposure was 68 rem. Several died from thyroid cancer & others remain at risk for thyroid cancer.

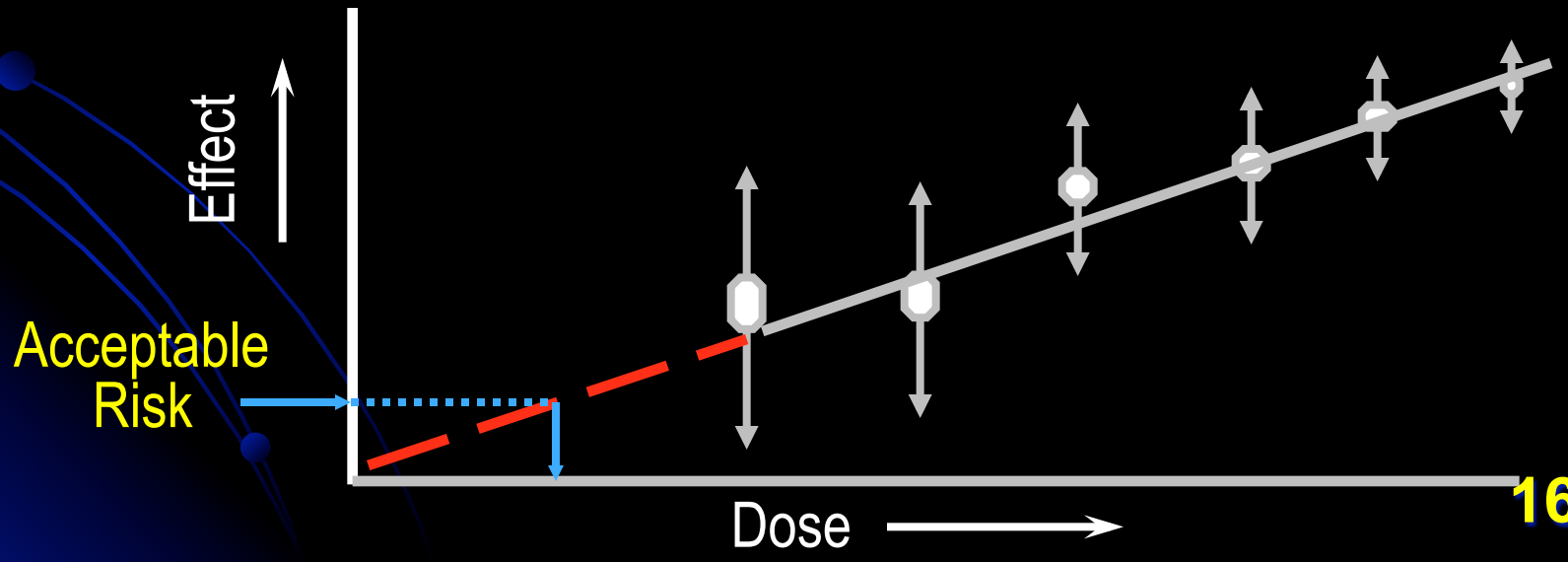
25-50 rem: Blood count changes become detectable

25 rem & below: No clinically detectable effects !

0.1 rem: Annual limit for exposure @ CLASSE

Long term effects of radiation exposure

- May not appear for many years
- Result from damage to genetic material – cancer
- Risk increases as dose increases
- At lower doses, there is larger statistical uncertainty
- Linear No-Threshold Hypothesis
  - Conservative model (i.e. assumes the worst at low exposures)
  - Assumes some risk of biological damage at any exposure
  - Difficult to prove or disprove due to other health effects



Models

- "We don't know exactly what the chances are of getting cancer from a low-level radiation dose, primarily because the few effects that may occur cannot be distinguished from normally occurring cancers."

NRC Regulatory Guide 8.29

- Linear No-Threshold model estimates that 47 years of 100 mrem per year occupational exposure will reduce lifespan by 5 days (the reality could be slightly more or no effect at all)

Radiation cancer risk

- Genetic risk < 1/3 of cancer risk
- Somatic cancer risk of more concern
- Cancer Incidence
  - National Research Council BEIR VII June 2006
    - 42% chance of contracting cancer in a lifetime from all causes
    - 0.3% incremental probability of contracting cancer due to 1 rem of exposure above background
- Cancer Death
  - American Cancer Society 2005
  - Approx 36% of incidence rate, averaged

ALARA Principles

As

Low

As

Reasonably

Achievable

Your Goal:

Keep your dose ALARA

What does ALARA mean?

- **Must keep doses below applicable absolute limits**
- **Must keep LOWER than limits as far as is practical**
- **"…it does not mean that each radiation exposure must be kept to an absolute minimum, but rather that "reasonable" efforts must be made to avert dose. In practice, ALARA includes planning tasks… so as to reduce dose to individual workers and the work group."**

NRC Regulatory Guide 8.29

CLASSE ALARA Limits

- More stringent than Cornell University
- 100 mrem per year (same as general public)
  - Under exceptional circumstances, there is a procedure to allow exposure up to 500 mrem in one year. See CLASSE-122 in our EDMS repository.
- In practice at CLASSE
  - 95% of those issued badges accumulate no measureable dose (<1 mrem/wear period)
  - 99.5% show < 25 mrem annual dose
  - No doses in excess of 100 mrem
  - If anyone's accumulated dose in a given badge-wear period is > 25 mrem
    - Work practices would be reviewed to verify if it is a real exposure & what could be done differently
    - That individual's work might be restricted to keep annual dose low

Radiation Badges

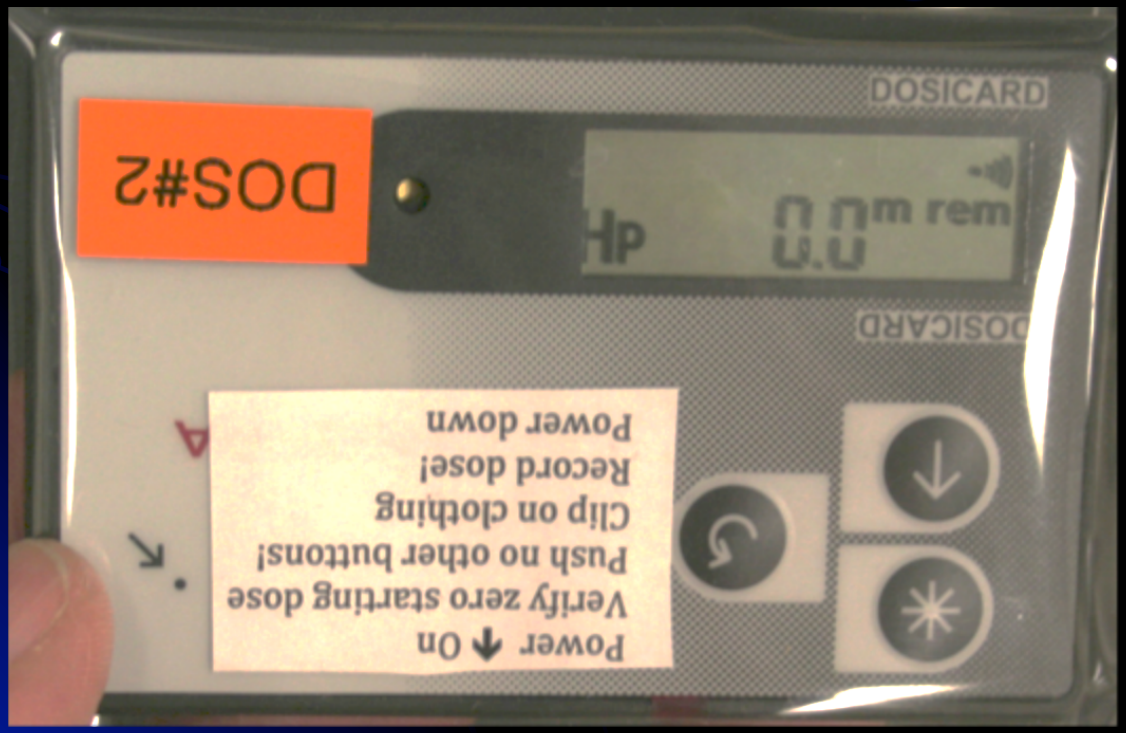
- Measures radiation dose (up to 1 million mrem)
- Wear in controlled areas between waist & neck, outside clothing
- If lost, exposed to medical scan or radiological injection, worn on an airplane trip, or left in a radiation area:
  - FILE ONLINE BADGE MISHAP FORM
- 3 month wear period (staff); 1 month (visitors & CHESS users)

Radiation Badges (cont'd)

- Badge sent back to vendor (Landauer) where
  - Its reading is taken
  - Compared to "control" badges which stayed on rack
  - Background radiation is subtracted
  - Occupational dose recorded in their database & transmitted to CLASSE Radiation Safety Specialist & Cornell EH&S database
  - CLASSE checks readings for anomalous values; investigates if needed
- Your lifetime dose history available from EH&S
  - See EH&S website or Safety Handbook for link

Dosimeters

- Measures radiation dose IN REAL TIME!
  - Neither is sensitive to neutrons
- Must sign out & back in, recording reading in log
- Analog (peer into end to read out) or digital
  - Dosiman always starts at zero; analog doesn't, so record it!
- Wear on outside of clothing, between neck and waist



Classifications of areas: dose limits

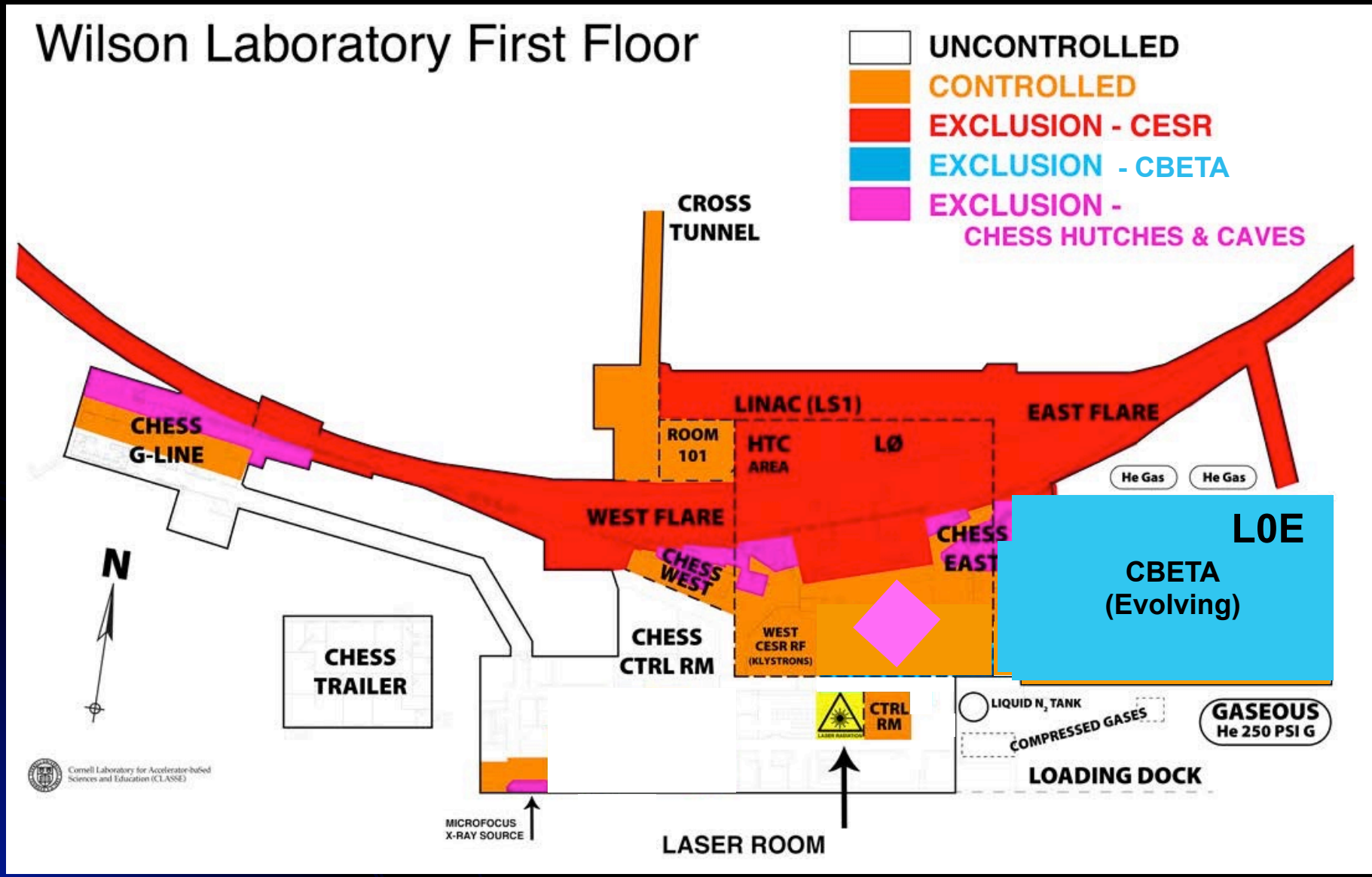
AREA	DOSE	COMMENTS
Non-controlled	Less than 2 mrem in 1 hr & 100 mrem in 1 yr*	Safe for general public
Controlled	Potential exists for more than 2 mrem in 1 hr or 100 mrem in 1 yr*	Active monitoring trips off RPE at 2 mrem / h within seconds, preventing any significant dose to anyone
Radiation Area	More than 5 mrem / h at 30 cm from any source	Signage & rope off area at distance for < 2 mrem / h
High Radiation Area	More than 100 mrem / h at 30 cm from any source	Signage & rope off area at distance for <2 mrem / h
Exclusion	**No limit (when RPE ON)**	Personnel are not permitted inside the area during RPE operation due to high potential dose rates

* Annual dose implies a potential dose during 52 consecutive workweeks.

Areas at CLASSE

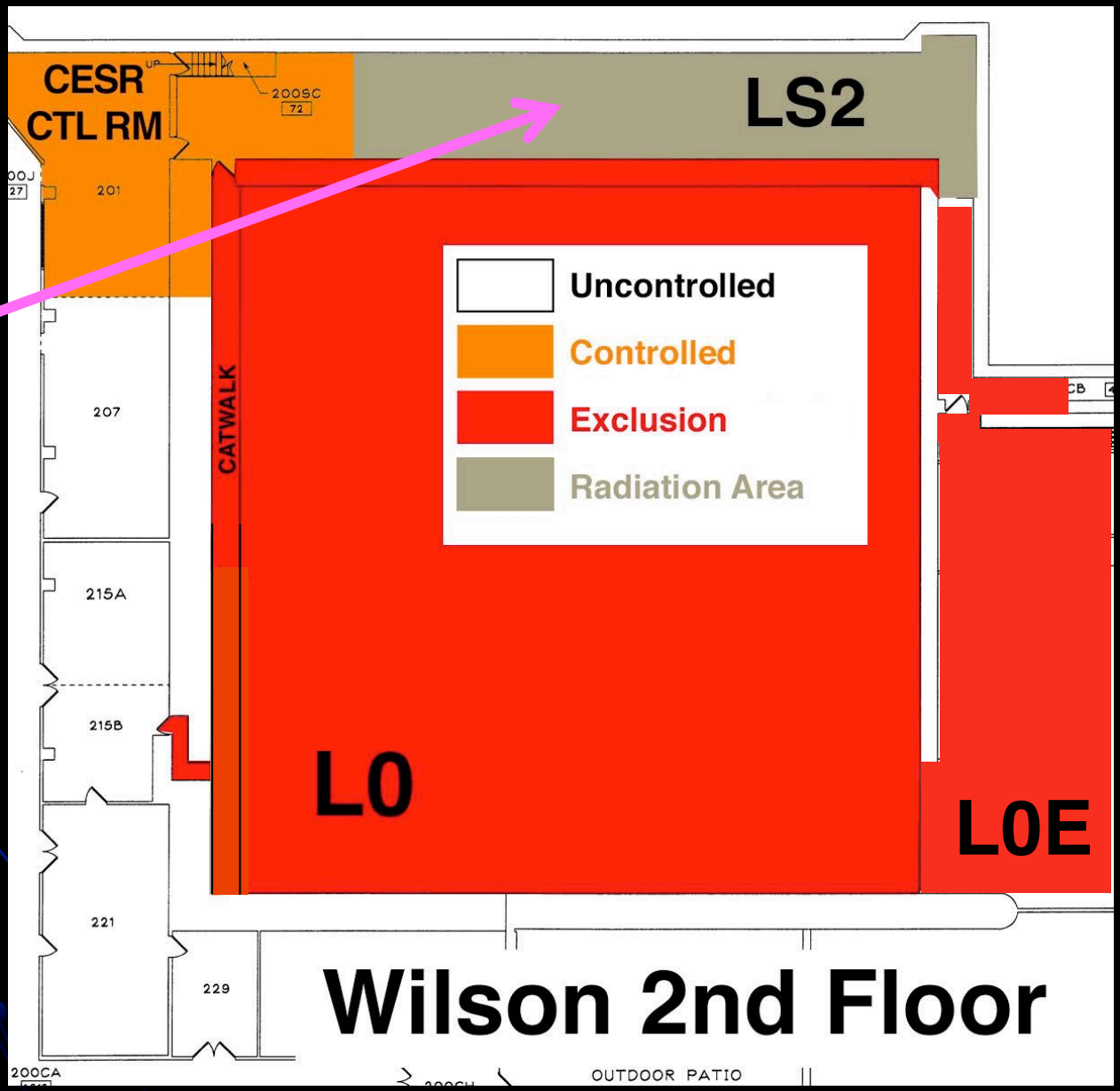
- Newman
  - Most spaces are uncontrolled
  - B24 (Gun Lab) is an exclusion area
  - SRF pits are exclusion areas
- Wilson
  - Uncontrolled
    - Offices, modules, stockrooms, loading dock
  - Controlled
    - CESR & ERL control rooms, all CHESS hutches & caves
    - L0, L0E, CESR Tunnel, LS1, LS2, Rm 180, Cross-tunnel
  - Exclusion
    - CESR Tunnel, L0 catwalk, LS1, part of Rm 180
    - All CHESS hutches & caves
    - Areas in L0 inside CESR or ERL shielding blocks

1st Floor Wilson Areas



2nd Floor Wilson Areas

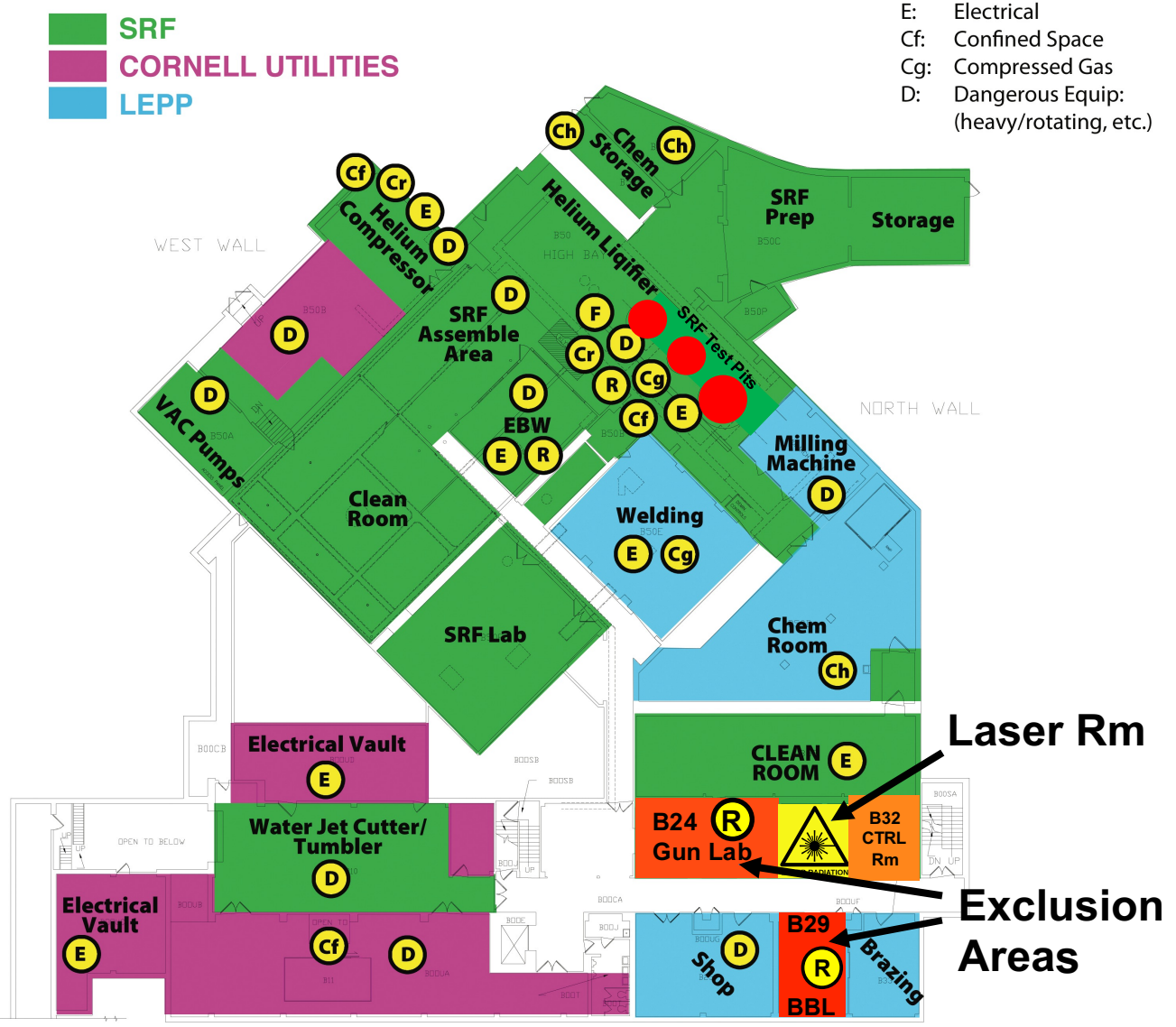
LS2 gated off as a Radiation Area (perimeter violation causes gun to trip)



Newman Basement

Newman Laboratory Basement

F: Fall
Ch: Chemicals
R: Radiation
Cr: Cryogens
E: Electrical
Cf: Confined Space
Cg: Compressed Gas
D: Dangerous Equip: (heavy/rotating, etc.)



Minimizing Dose: ALARA Principles

Time Exposure = Exposure Rate X Time. Exposure to radiation is at a rate. This means that the longer you are exposed to radiation the higher your total exposure is. By reducing time being exposed you reduce your total exposure.

Distance Radiation dose decreases the further away you are from the source. Radiation exposure decreases by the inverse square law. This means if you double the distance from the radiation source, your exposure is ¼ of what it was at the closer point.

Shielding Radiation can be attenuated or stopped by the use of a barrier or shielding. The amount of radiation penetrating the barrier depends on the density and thickness of the material and the energy type of the radiation.

Ionizing Radiation at CLASSE

- Large accelerators: initial e^+ & e^-; later, gammas & neutrons
  - Linac injector to the synchrotron; CESR; ERL injector
- Bending magnets & undulators: x-rays
  - X-rays emitted when $e^{\pm}$ path is bent (i.e. it accelerates) (~keV)
  - Some is intentionally directed into CHESS beamlines
- Bremsstrahlung photons: gammas
  - Beam electrons interact with nuclei of residual gas inside vacuum chamber, emitting energetic photons
  - Much higher energy than x-rays; up to incident $e^{\pm}$ energy

Ionizing Radiation at CLASSE

- Field emission in electron guns, electrostatic separators, & SRF cavities: electrons
  - High fields liberate electrons from surfaces, which accelerate
- Stand-alone, plug-in x-ray generators: x-rays
  - Used for teaching (xPloration Station); calibration in CHESS hutches; useful research
- Radioactivity caused by activation from intense beam exposure (e.g. at the e^+ converter)
  - Remains even after RPE is turned off

Signs

- Check status boards
- Watch for signs, chalkboards, gates, ropes, chains at the few places where high radiation levels may be present
  - Do not approach such an area!

Signs

Activated material ?

- Never remove anything you didn't bring in out of an exclusion area (tunnel, ERL) [that has been exposed to >6 MeV electrons] without a survey showing less than **50 µrem / h on contact (0.05 mrem / h)**
  - **Survey it yourself if you have had meter training**
  - **If you don't survey it yourself:**
    - **Leave inside exclusion area labeled as**

      "Needs Radiation Survey"

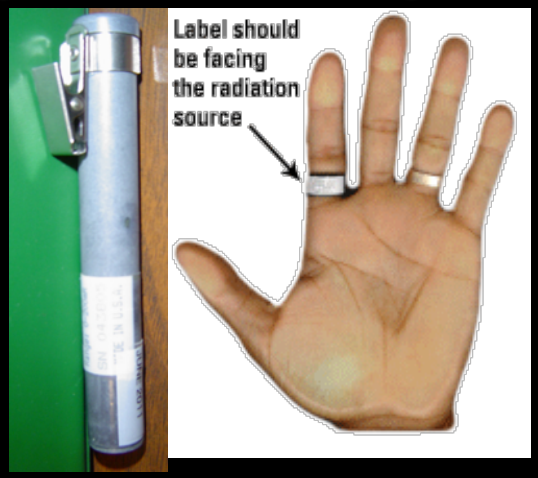
      and contact Radiation Safety Technician (RST) (Stilwell) (Widger)
    - **If RST not available, contact Radiation Safety Specialist (RSS)**
- **Note: Any object > 0.05 mrem / h on contact cannot leave the building without EH&S approval**

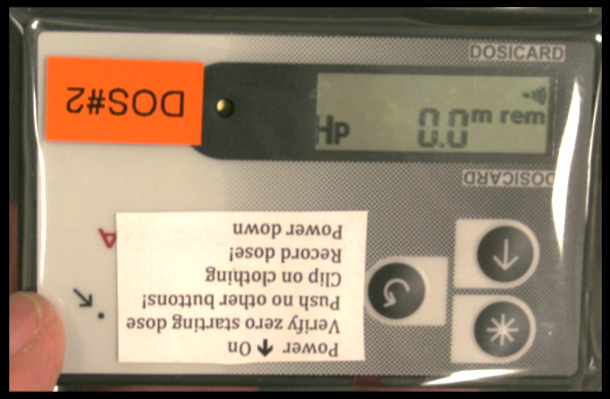
Activated material?

- Bring a survey meter or ask RST for a survey !
- If level > 2 mrem / h: special work procedures!
  - Supervisor approval of workplan
  - RSS can provide assistance

Activated Material (cont'd)

- Bring a survey meter!
- Wear your badge
- Sign out a dosimeter
- Ring badges may be appropriate
- Safety glasses: protect eyes from β's
- Gloves
- Wash up before eating or leaving bldg



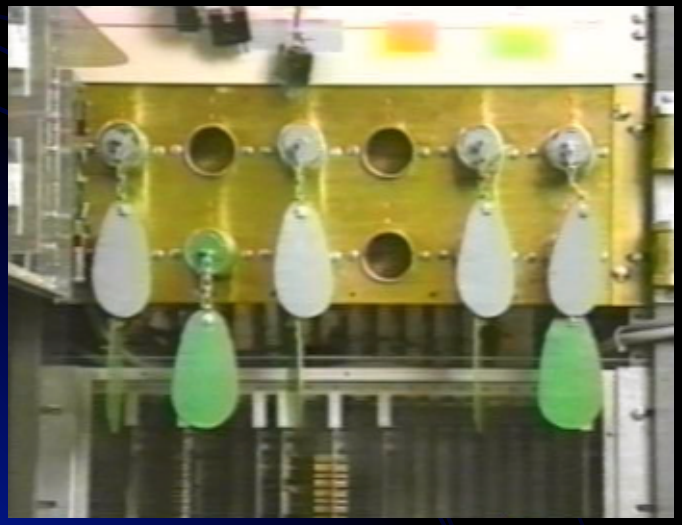


Activated Material (cont'd)

- Positron converter cave (part of linac in LS1)
  - Tungsten disk gets inserted into e^- beam to make e^+
  - Residual radiation near (unshielded) converter may be > 500 mrem / h !
- No entry without
  - A need
  - Supervisor approval for non-exempts
  - Dosimeter & safety glasses

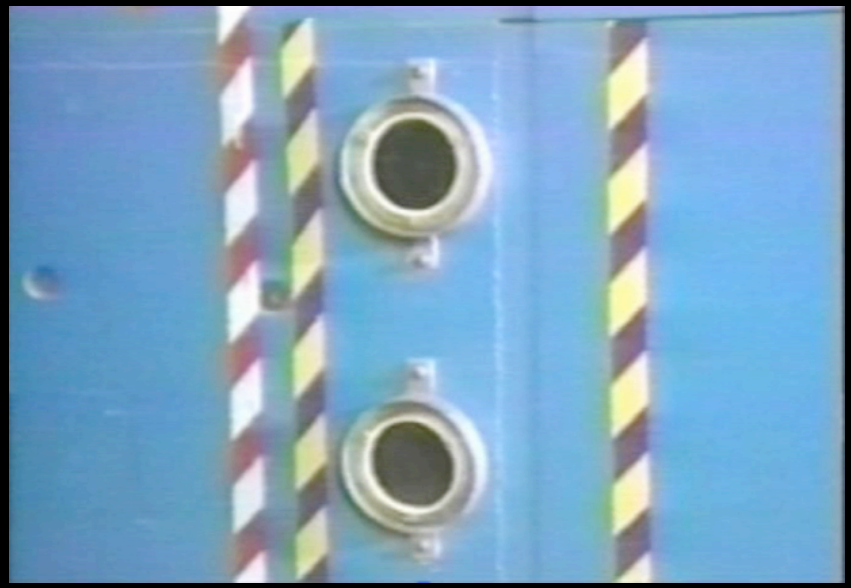
Key / Light Beam Interlocks

- Possessing an interlock key protects **you** when you're in an exclusion area
- Different color keys for different areas: ask operator !
- Electronic circuits disable the machine until all the keys are in the storage box



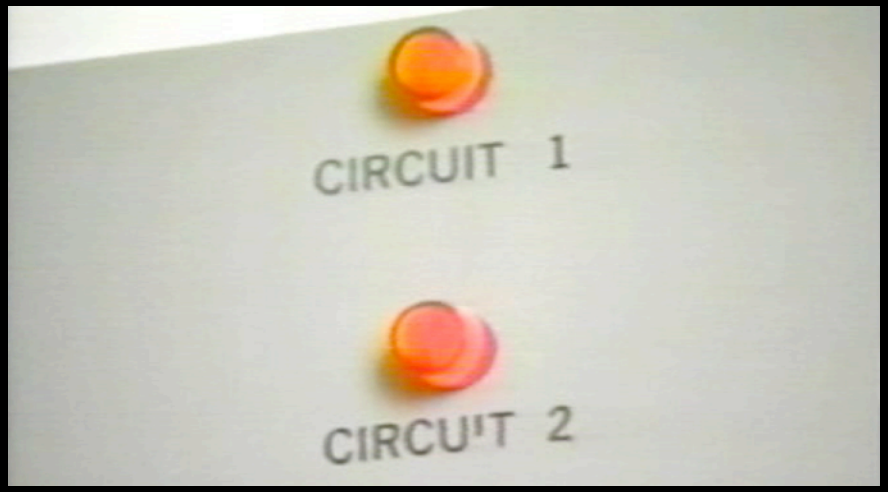
Key / Light Beam Interlocks

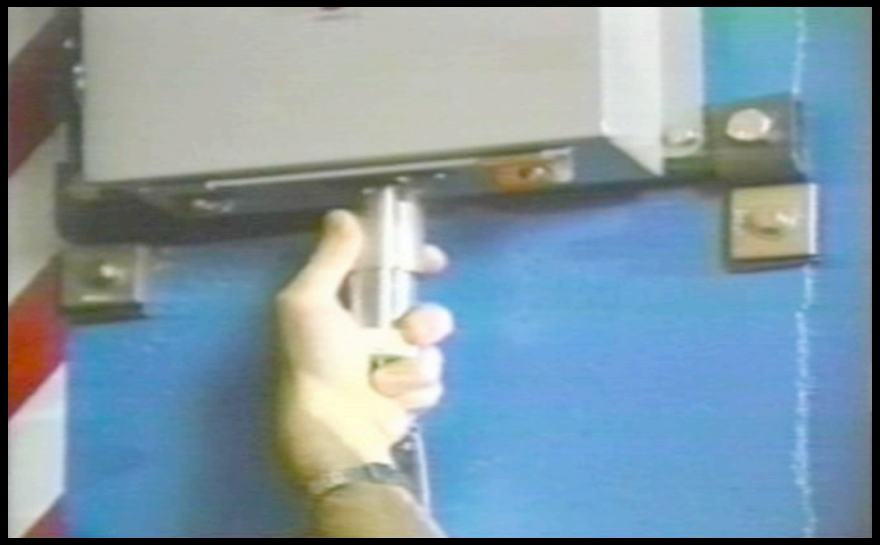
- Stop before wall & floor stripes
- Insert key, being careful not to block light beam



Key / Light Beam Interlocks

- Verify both circuit lights come on
- Exert upward pressure as you pass through
- After you are past wall & floor stripes, remove key, again not blocking light beam





Key / Light Beam Interlocks

- One key / person
- Do not bypass interlocks for someone else
  - Exception: if necessary to facilitate transport of materials; confirm that other person has proper key !
- Never leave the lab with the key because it will prevent the re-powering of the accelerator !
- Interlocks must always be reset manually, never automatically

Interlocks (cont'd)

- If you try to enter an exclusion area when interlocks are active (i.e. when radiation inside is possible) without a key, you will trip the interlocks, disabling Radiation Producing Equipment (RPE)
- Accessing a CHESS hutch requires beam stops to be in the dropped position

Active Radiation Monitors

Active radiation monitors outside exclusion areas will turn off RPE (i.e. CESR or ERL) if radiation exceeds 2 mrem / h within a few seconds; **by the time you hear an alarm or see a flashing light, there is no potential hazard anymore**

Gamma probe

Neutron probe

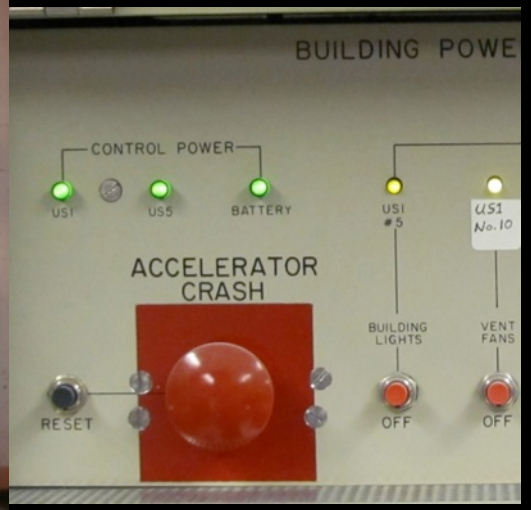
Search & Secure

- Prior to Linac/CESR turn-on
  - Announcements on PA
  - Interlocks set, if not already
  - CESR Operator searches entire area
    - Supervisor sometimes hides in exclusion area in order to test thoroughness of the search
- CHESS: In order to open the beamstops, user/operator must view the entire hutch and then press the search button(s), which provides a 30 second time window in which to secure the hutch.

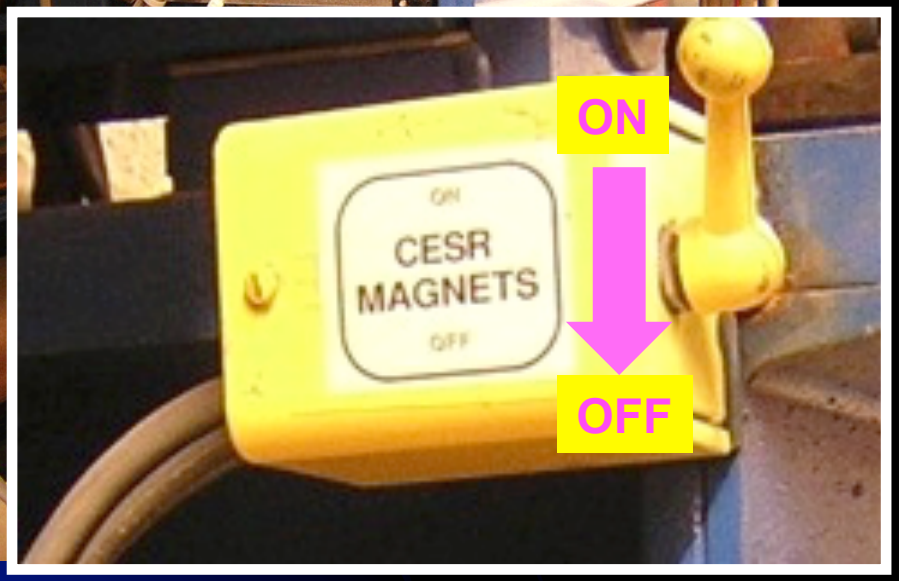
Emergency Shutoffs

- **Never hesitate if worried:**
  - **If trapped in a CHESS hutch, push ➔**
  - **If trapped in CESR tunnel, pull cord ➘**

- **Accelerator crash buttons➘**



Emergency Shutoffs



- If crash cord in CESR tunnel is inaccessible, beam will also be disabled by turning Magnet Safety Switch to the OFF position

Newman SRF Testing

- If anything is suspected to be wrong with the Newman SRF testing in the pits or movement of the 90-ton block, press ➔

Fig. 10 Emergency shut off button for RF and shielding block

Pregnant Workers (1)

CLASSE will provide *confidential* counseling and services upon request by any worker who is pregnant, or thinks she may be pregnant, and is concerned about exposure to radiation. The CLASSE Safety Director and/or the CHESS Safety Officer will generally provide these services, although, with advance notice, counseling by a qualified *female* staff member of University Environmental Health and Safety can be arranged.

Optional counseling and services for pregnant workers

From CLASSE Safety Handbook

See next slide

Pregnant Workers (2)

Topics for discussion and services include:

1. Potential effects of radiation on a developing fetus.
2. Badging requirements and dose limits from section 8.3 of the University Radiation Safety Manual.
3. Historical radiation dose rates for relevant area badges and surveys, and typical personal badge readings for those sharing the individual's work area.
4. Location and operation of radiation monitoring and accelerator interlocks in the individual's work area.
5. Radiation survey of the individual's work area.
6. Issuance of a dosimeter that will provide real-time readings for the individual's use.
7. Instruction on use of a survey meter for real-time monitoring.
8. The choice that a badgeholder has, at her discretion, to *declare* a pregnancy, which, if made, *requires* issuance of a *fetal badge set*.
9. Whether or not a pregnancy is declared, a *fetal badge set* can be supplied if requested by the badgeholder with sufficient advance notice. This set consists of a control badge (which should not be worn), a whole-body badge (which should be worn between the neck and waist), and a fetal monitoring badge (which is placed over the abdomen, and, when not worn, stored with the control badge). If confidentiality is desired, the fetal monitoring badge may be worn underneath clothing, and when not worn, the control and fetal badges should be stored separately from other badges.
10. All counseling and services are confidential. Identifying information will be limited to the few staff members with a need to know. The name of anyone receiving such services will not be posted in any widely accessible written or electronic logs.

Summary

- Ionizing radiation can cause biological damage above certain levels of exposure
- Multiple, redundant controls, policies, & procedures are in place to restrict possible exposures to CLASSE personnel & public to below ALARA limits
- Each worker has responsibilities to follow procedures, be aware of signs and restricted areas, report RPE safety concerns, & to follow ALARA guidelines to avoid hazardous or unnecessary exposure
- Permit Holders & Operators are responsible for safe operation of RPE under their control, & for following all requirements of the RPE permit & NYS regulations

Summary (continued)

- **Resources:**
  - Cornell Radiation Safety Manual (online @ EH&S)
  - Permit Applications & Permits (stored in CLASSE EDMS)
  - CLASSE Safety Handbook Radiation Safety & Who's Who
  - Procedures stored in respective control rooms
  - CLASSE-122 ALARA Policy (in EDMS)
- **Refresh training annually**
- **Questions/concerns:**
  - Permit Holders
  - Safety Director
  - RSO & EH&S (255-8200)