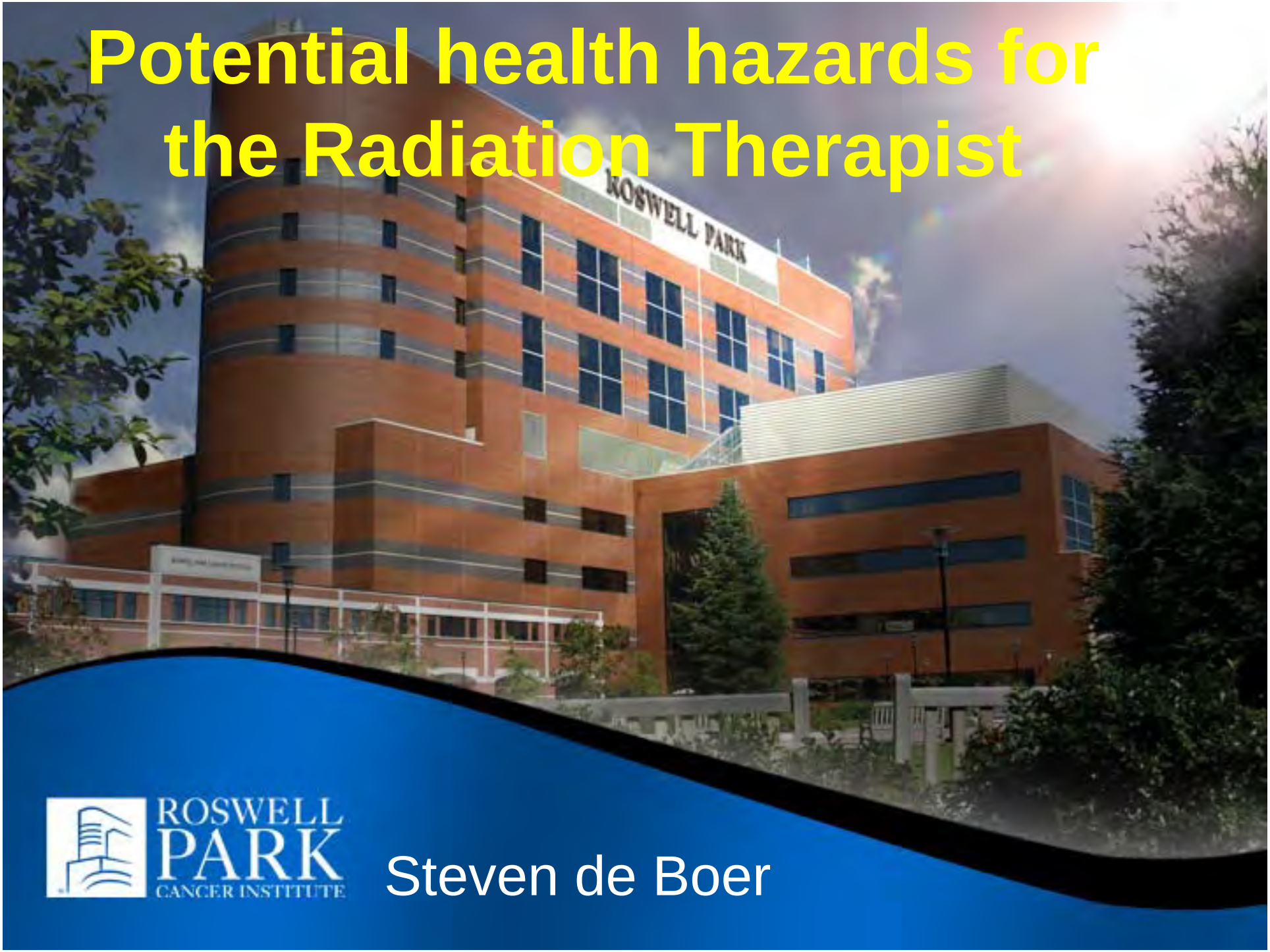
Potential health hazards for the Radiation Therapist



ROSWELL PARK CANCER INSTITUTE

Steven de Boer

Potential health hazards for the Radiation Therapist

Steven F. de Boer, M.Sc., FAAPM
Roswell Park Cancer Institute
September 9th, 2016
Niagara Falls, NY

Outline

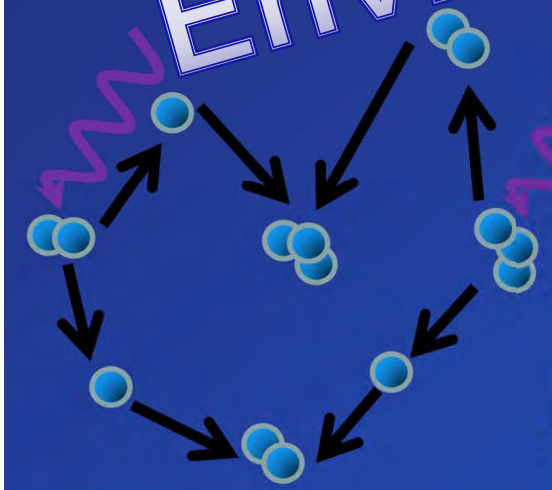
- Ozone
- Linear a ed
  radioact
- Neutron s linac vault
- SF_6

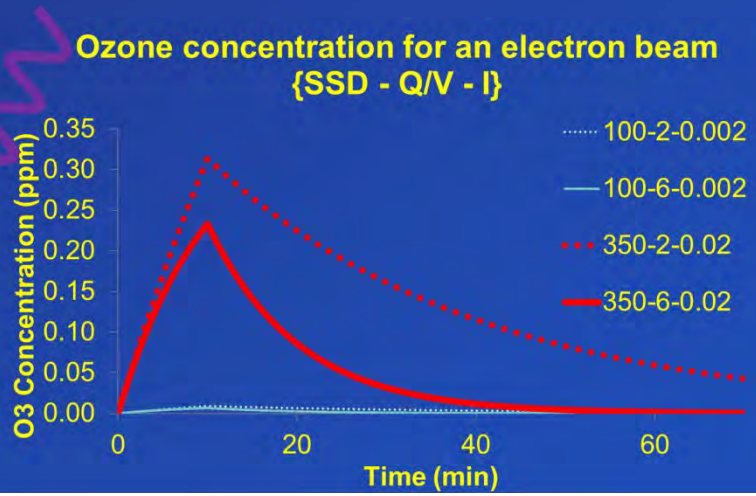
This is what you are instore for!

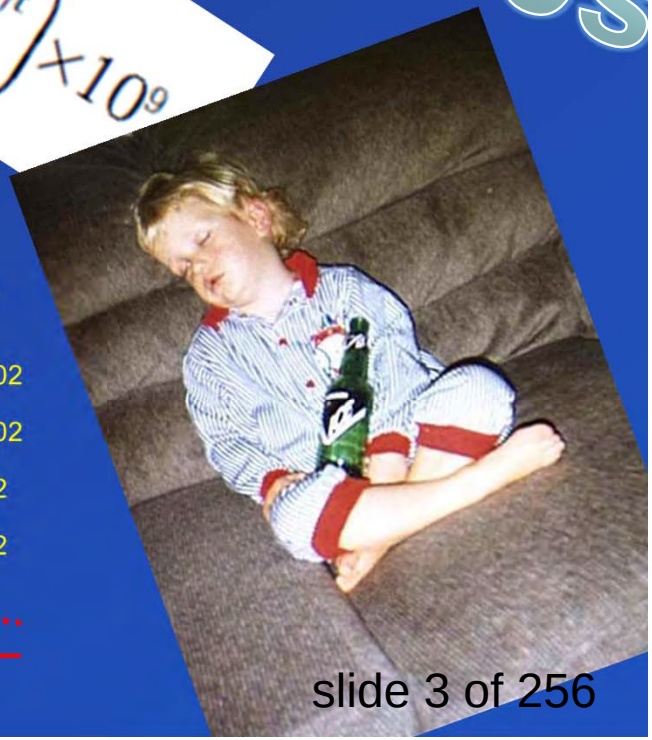
$$C = \frac{C_o GES_{col} Id}{NV(Q/V)} \times \left(1 - e^{-(Q/V)/I}\right) \times 10^9$$

Nuclear Physics

Environmental concerns







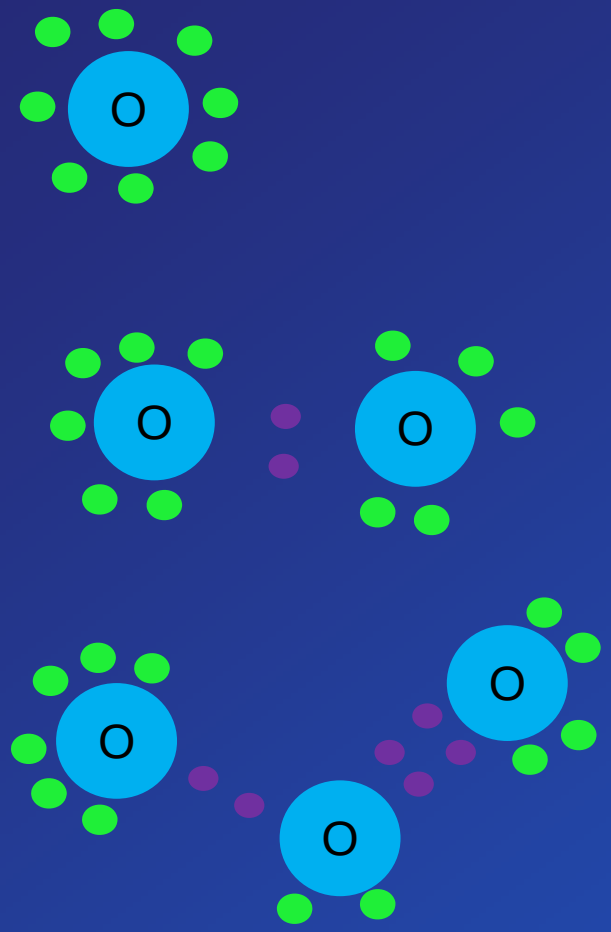
Who are you?

1. Radiation Therapist
2. Medical Dosimetrist
3. Medical Physicist
4. Physician
5. Other
6. Spy
7. Ninga
8. 6 and 7

Do you have concerns about occupational hazards?

1. Yes
2. No
3. My boss told me to say no
4. Not really, I have special powers

What is Ozone?



- Elemental oxygen
  - (8 electrons)
- Dioxygen, O_2
  - need to breath,
  - 21% of air
- Ozone, O_3
  - three oxygen atoms,
  - less stable than O_2,
  - strong oxidizer

Had you worried?

256 slides really?

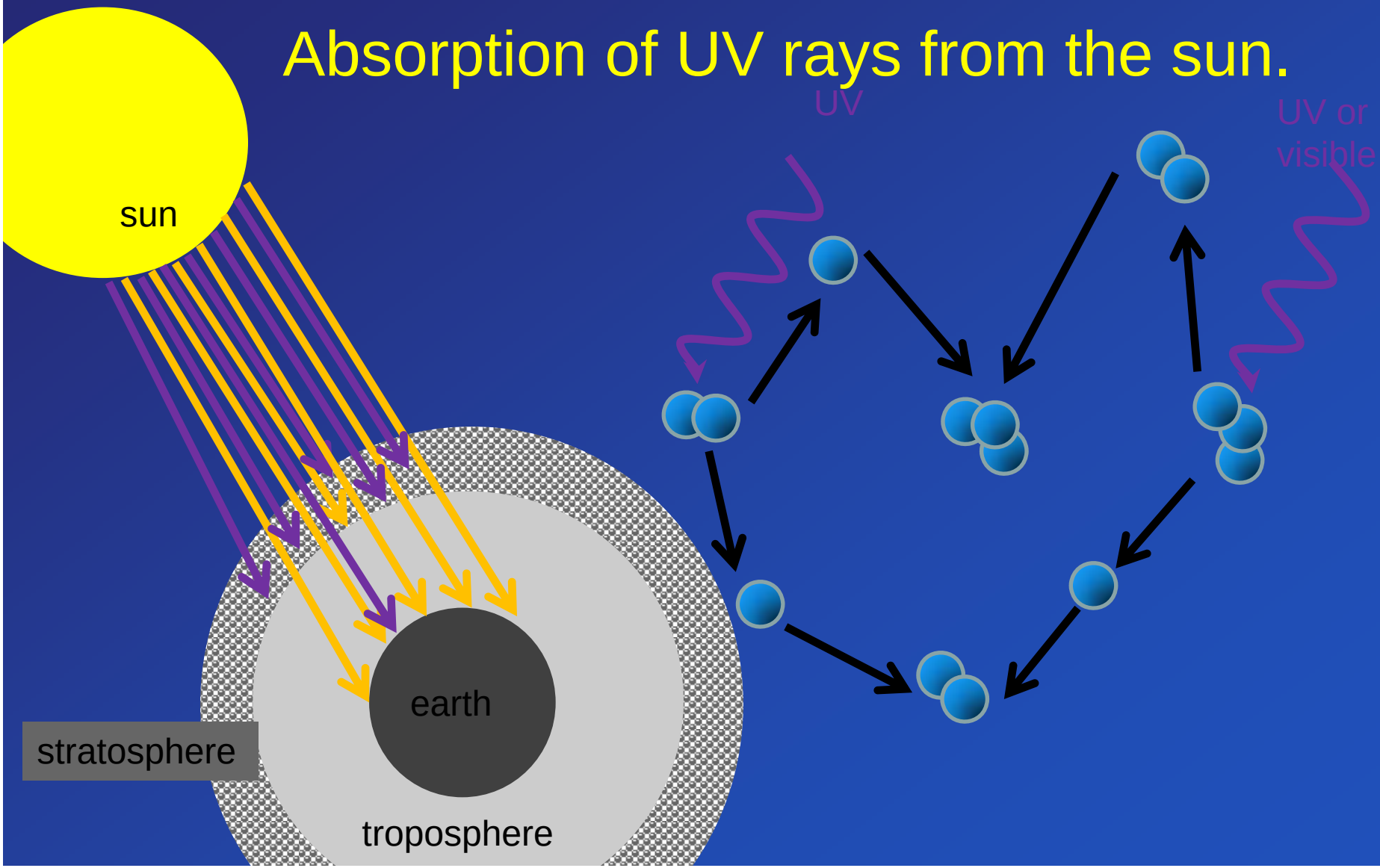
Ozone properties

Pale blue gas (condense into a violet black solid)
Pungent smell, chlorine smell,
Less stable than O_2
Powerful oxidant
Human detectable at 0.02 to 0.05 to 0.1 ppm
In stratosphere ozone is 2 to 8 ppm
More dense than air,
- Relative vapor density (air = 1): 1.6

Boiling point: -112°C
Melting point: -193°C

Ozone benefits

Absorption of UV rays from the sun.



Ozone benefits

Sterilization

Ozone is the second most powerful sterilant in the world and can be used to destroy bacteria, viruses and odors

- fruits and vegetables & meat packing plants,
- water purification (drinking, pools, spas)
- manufacturing,
- medical,
- houses, cars, shoes

Ozone sterilization

- Ozone destroys contaminants such as odors, bacteria or viruses by oxidation
- Ozone reverts back to oxygen after it is used.
- Chemical half life is 30 to 50 minutes

ASTHMA, CHRONIC BRONCHITIS,

BRONCHITIC ASTHMA, HAY FEVER, and INFLUENZA.

The "Lancet."—"A convenient and valuable remedy."

Dr. Thorowgood.—"Pure spasmodic Asthma and Asthma due to Emphysema of the lungs with co-existent bronchitis alike appear to me to be materially relieved by the Ozone Paper."

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2s. 9d. and 4s. 6d. per Box, of all Chemists; or from the Proprietor for the amount in stamps or P.O.O. to any country within the Postal Union.

R. HUGGINS, Chemist, 199, Strand, LONDON.

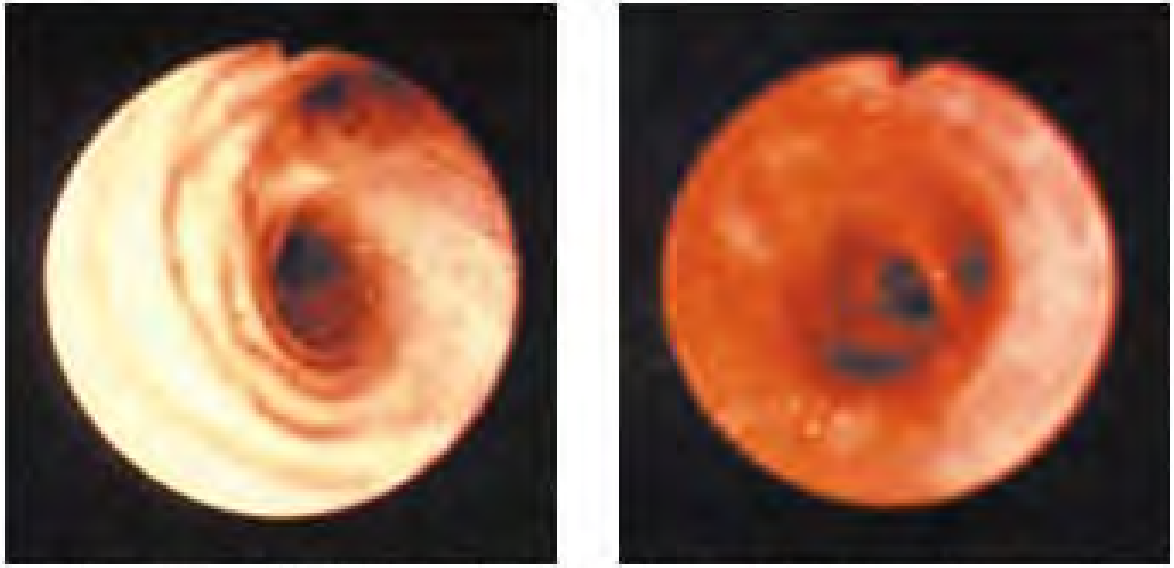

WARNING
OZONE
IN USE!

Ozone risks

- Hazardous at prolonged exposure to concentrations of 0.1 ppm[1-3]
- Damages mucous and respiratory tissues
- DNA breakage[4]
  - "at current permissible levels, it is more harmful than ionizing radiation"[4]

1 AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS, Threshold Limit Values of Airborne Contaminants and Physical Agents with Intended; Changes Adopted by ACGIH for 1971, ACGIH, Cincinnati, Ohio (1971).
2 OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION, Occupational Safety and Health Standards, US Department of Labor, Washington, DC, Federal Register 39 125 (1974) 23541.
3 IAEA Radiological Safety Aspects of the Operation of Electron Linear Accelerators, Vienna, 1979
4 Inhaled ozone as a mutagen: II. Effect on the frequency of chromosome aberrations observed in irradiated Chinese hamsters ; . Zelac [2], H.L. Cromroy, W.E. Bolch Jr., B.G. Dunavant, H.A. Bevis

Lung inflammation



**Ozone can inflame the lung's lining. These photos show a healthy lung air way (left)
and an inflamed lung air way (right).**

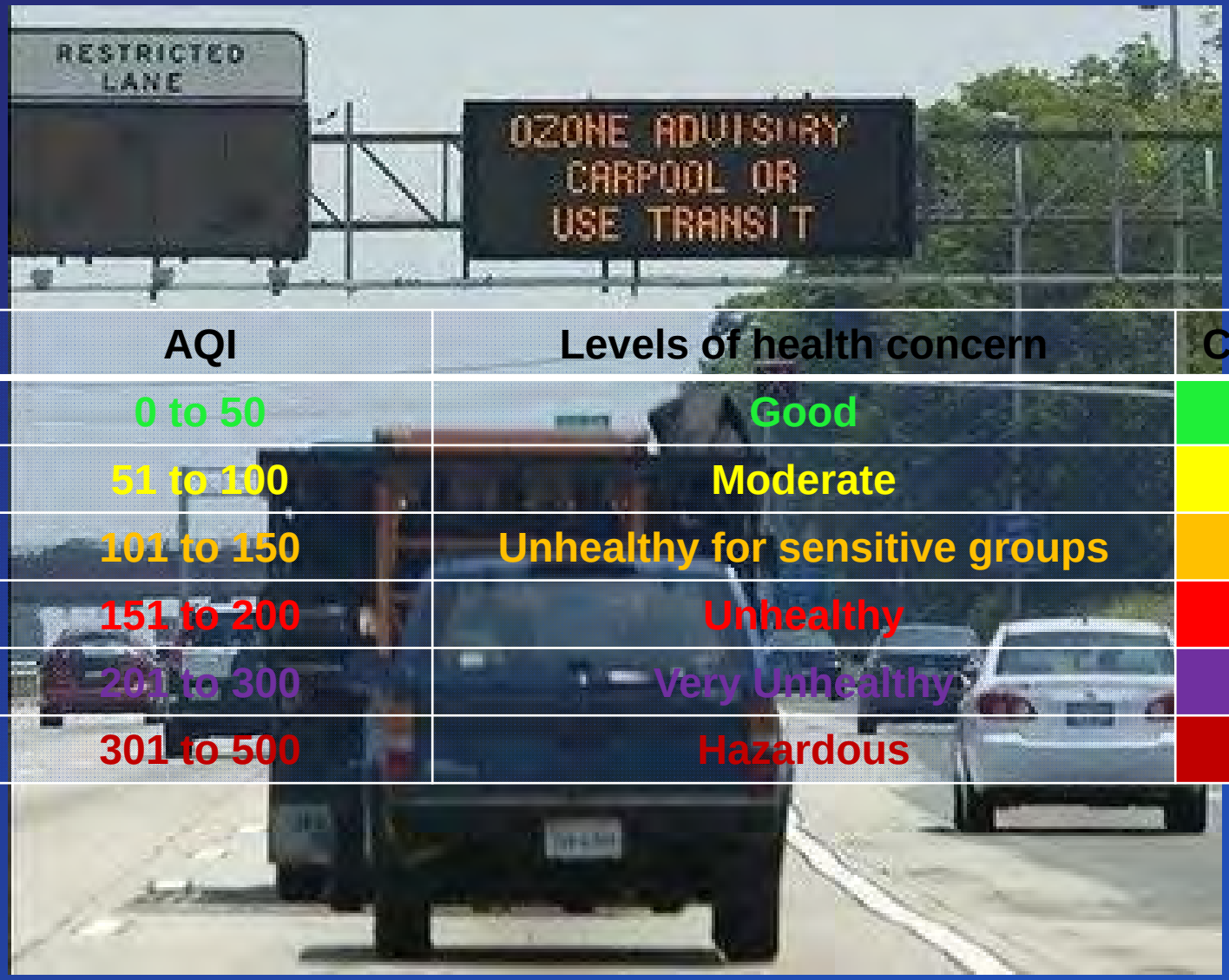
Ozone data sheet (MSDS)

Health Hazard Data		
Threshold Limit Value	The American Conference of Governmental Industrial Hygienists has set a threshold limit value for occupational exposure to ozone of 0.1 ppm as a time-weighted average over an 8-hour day. The short-term exposure limit is currently 0.3 ppm.	
Primary Route of Entry	Pulmonary system	
Effects of Single Overexposure	May cause irritation of the respiratory tract experienced as nasal discomfort, dryness, irritation of the throat, pain or congestion of the chest, difficult breathing or coughing. Irritation of the eyes, headache, nausea and drowsiness may also occur. Concentrations above 9 ppm have been found to result in pneumonia. Exposure to high concentrations could be fatal.	
Emergency First Aid		
Exposure	Symptom/Prevention	First Aid
Emergency Overview	Ensure adequate ventilation in the area where ozone is present	Remove from the presence of air containing ozone.
Inhalation	Irritating to respiratory system. Cough, headache, shortness of breath. Ventilation.	Remove from the presence of air containing ozone. Administer oxygen if necessary. If breathing is difficult or discomfort persists, obtain medical attention.

Disposal Information	
Waste Disposal	Ozone rapidly decomposes to form oxygen (O_2). Use an ozone destruct system to convert any unused ozone or off gas into oxygen prior to discharge.

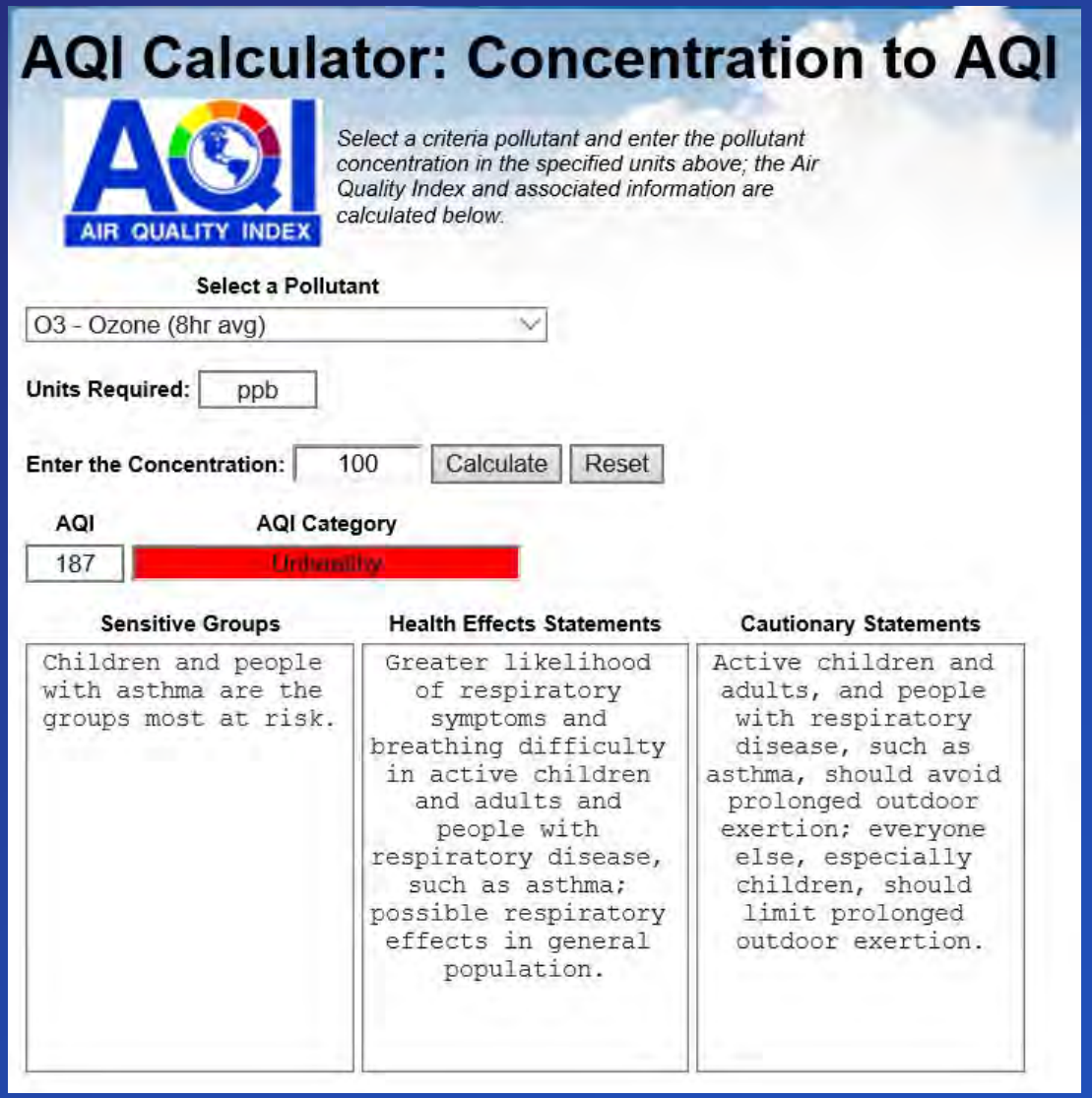
Waste Disposal	Ozone rapidly decomposes to form oxygen (O_2). Use an ozone destruct system to convert any unused ozone or off gas into oxygen prior to discharge.

AQI (air quality index)



AQI	Levels of health concern	Colors
0 to 50	Good	
51 to 100	Moderate	
101 to 150	Unhealthy for sensitive groups	
151 to 200	Unhealthy	
201 to 300	Very Unhealthy	
301 to 500	Hazardous	

Ozone and AQI



www.airnow.gov

Ozone production

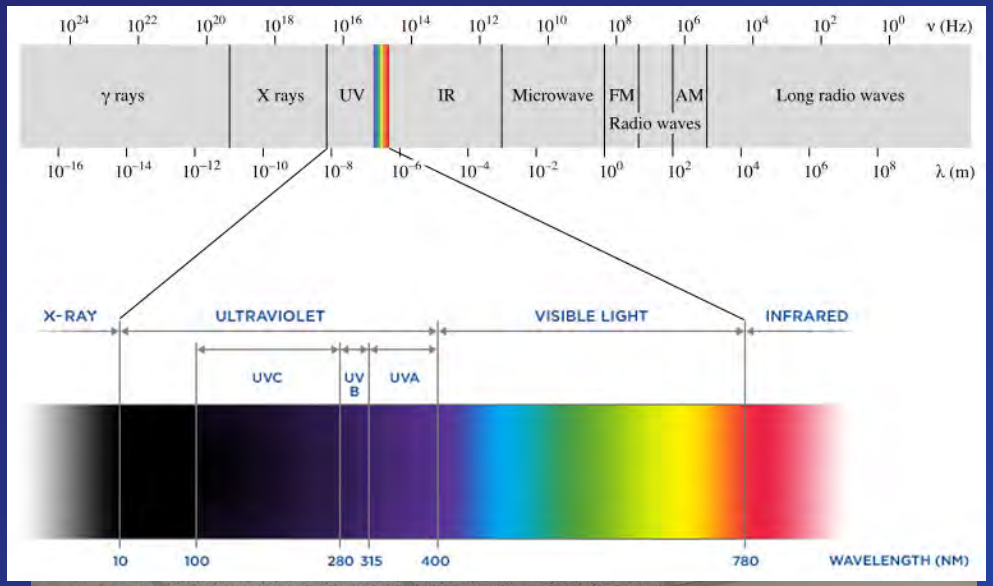
Air + energy = O

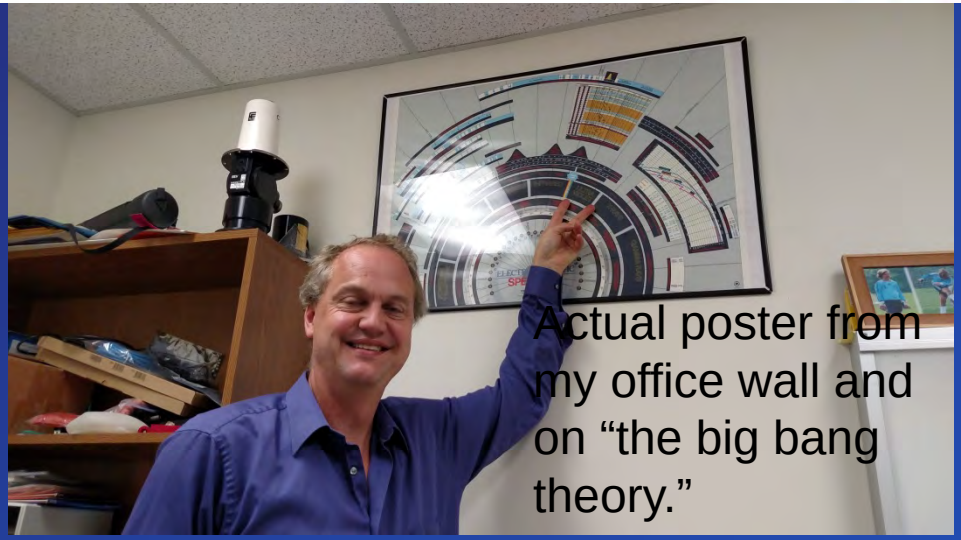
$O + O_2 = O_3$ (ozone)

Energy can be in different forms

- ultraviolet radiation
- corona discharge
- ionizing radiation

Ultraviolet radiation





Actual poster from my office wall and on “the big bang theory.”

First 35 images on google search for “ultraviolet”

Corona discharge

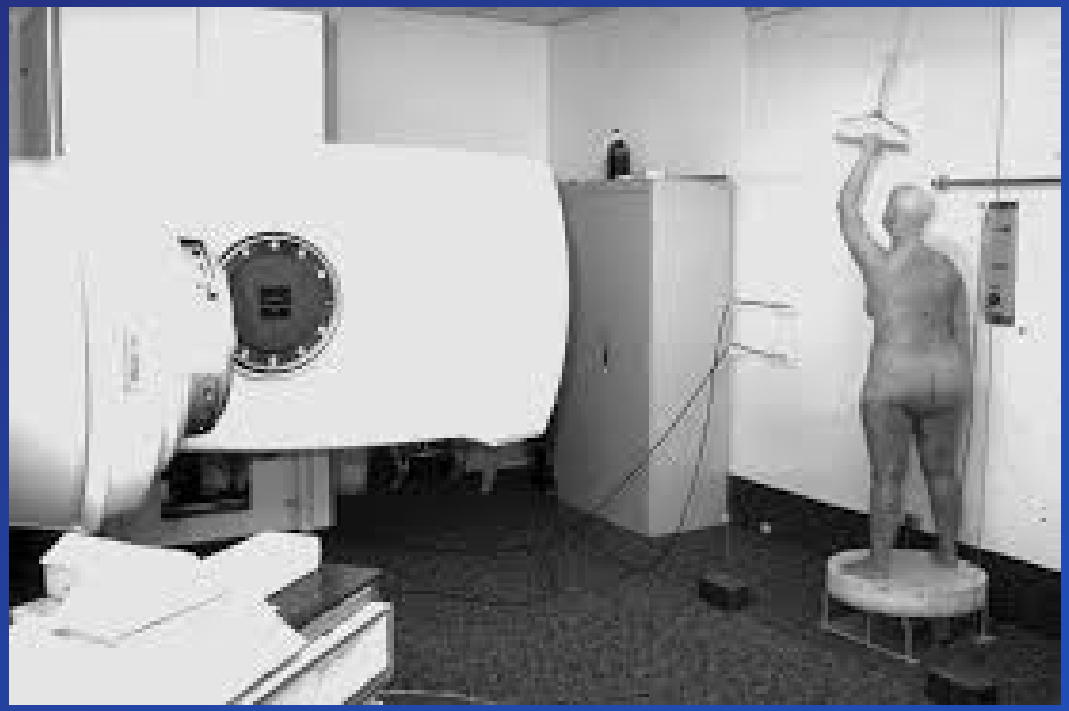
Wrong Corona

Two of my children →
(molson)

Ionizing radiation

Can be electrons or photons

Electron conversion is more efficient



IAEA textbook on radiotherapy

Ozone in linacs

- Electron beams are more efficient (than x-rays) at converting O_2 to O_3
- Yield increases with
  - Dose rate
  - Distance of beam in air
  - Area of beam
  - Length of time the beam is on
- These all increase in total skin electron irradiation (TSeI) treatments.
- SSD = 350 cm, DR = 2500 MU/min, time = 12min

Varian TSeI

- Nominal dose rate is 888 MU/min (at 1.6 m)
- Dose rate at 1m is then about 2500 MU/min
- Dose per MU is about 4 cGy/MU at isocenter (measured)
- Therefore dose rate at isocenter is 3552 cGy/min
- About 4 to 10 times conventional electron treatments

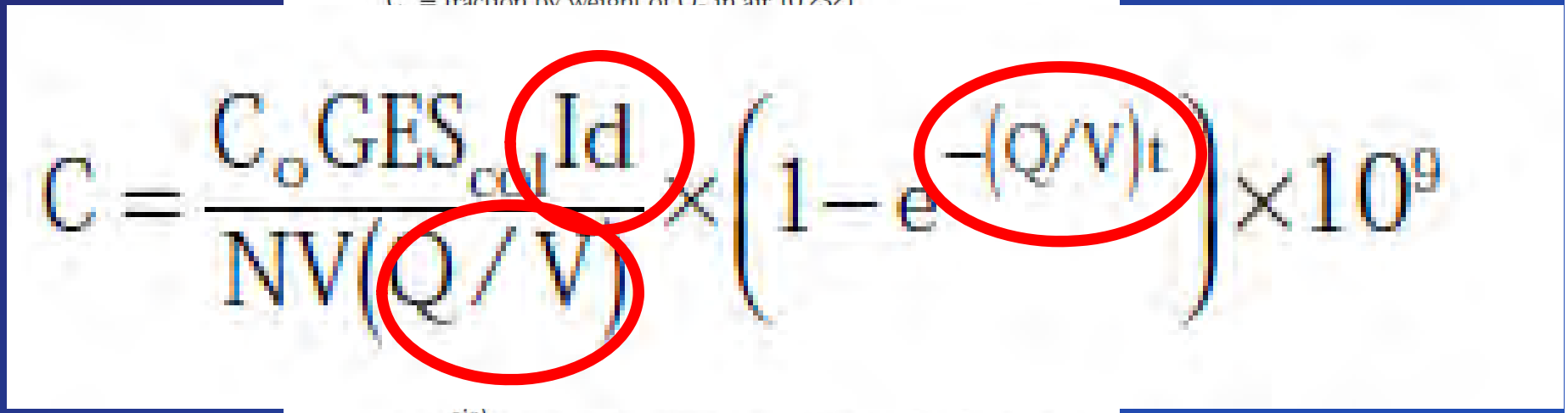
Roswell Park Cancer Institute experience
Similar to AAPM report 23, TOTAL SKIN ELECTRON THERAPY: TECHNIQUE AND DOSIMETRY, 1987

Ozone concentration in linear accelerators

$$C = \frac{C_o GES_{col} Id}{NV(Q/V)} \times \left(1 - e^{-(Q/V)t}\right) \times 10^9 \qquad (7\text{-}6)$$

where

C_o = fraction by weight of O_2 in air (0.232)



air)

V = room volume in liters

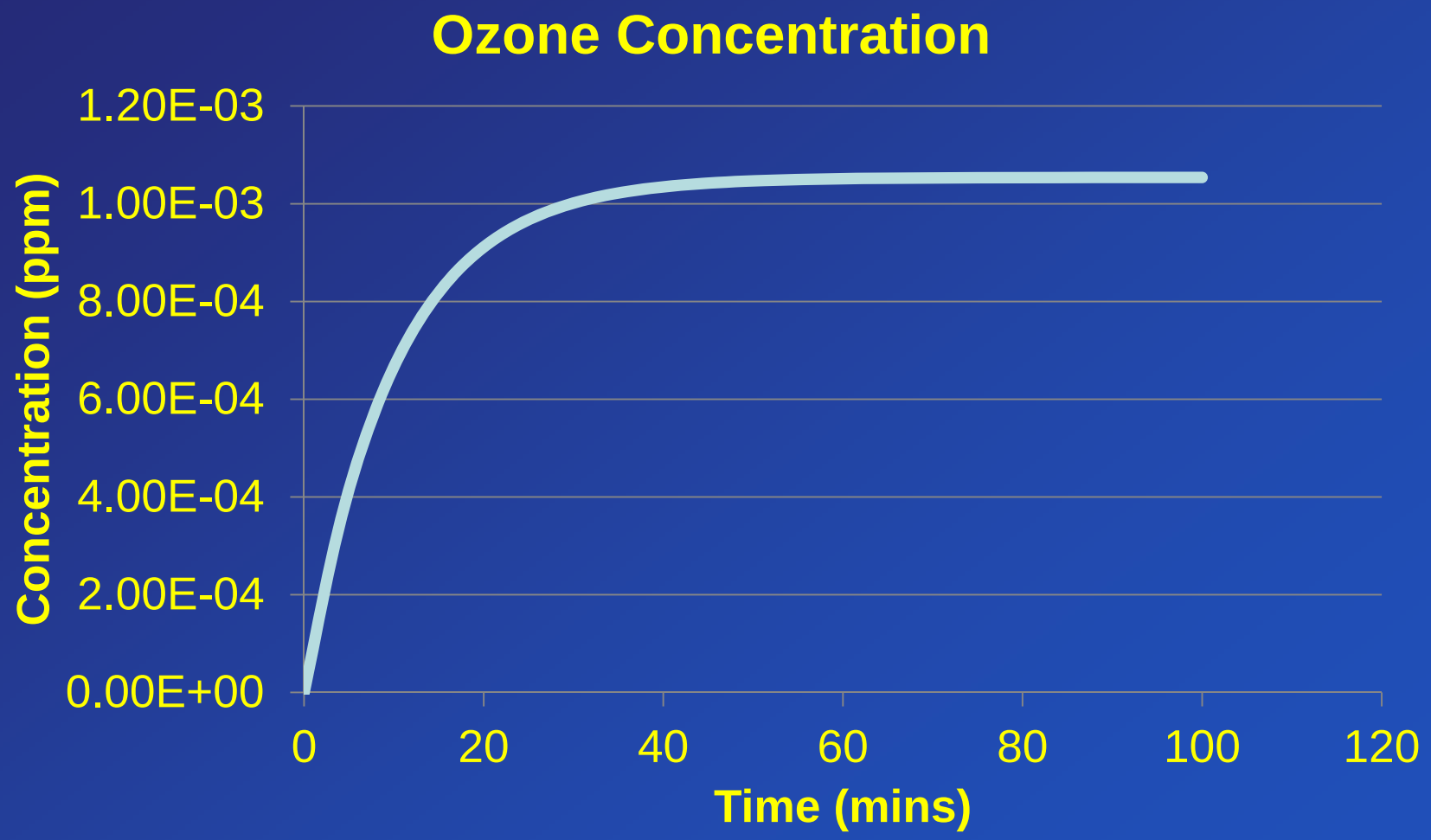
Q = room ventilation rate (liters s^{-1})

Q/V = number of room air changes per second

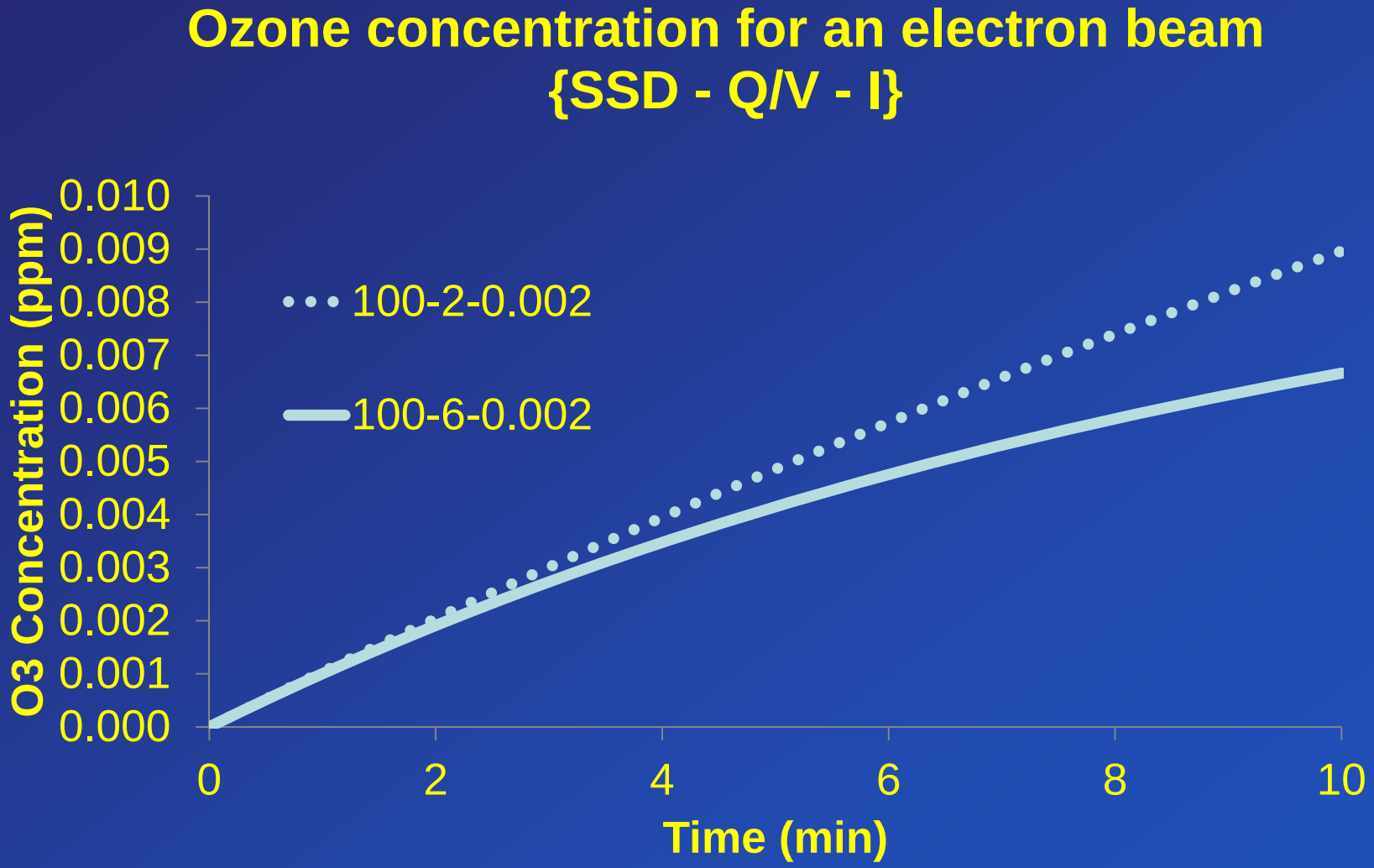
t = irradiation time(s).

McGinley; Shielding …

Ozone concentration over time

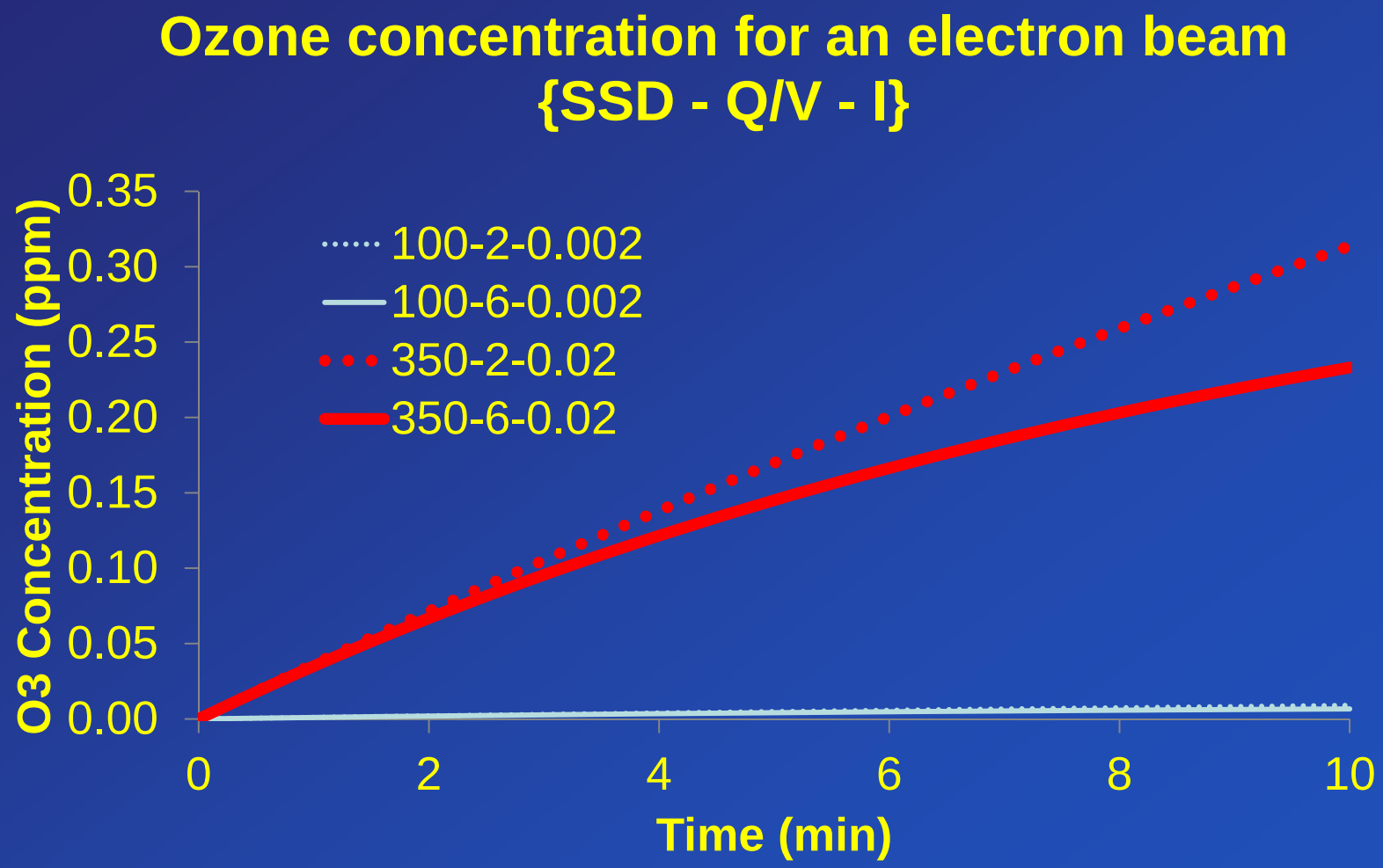


Ozone concentration overtime

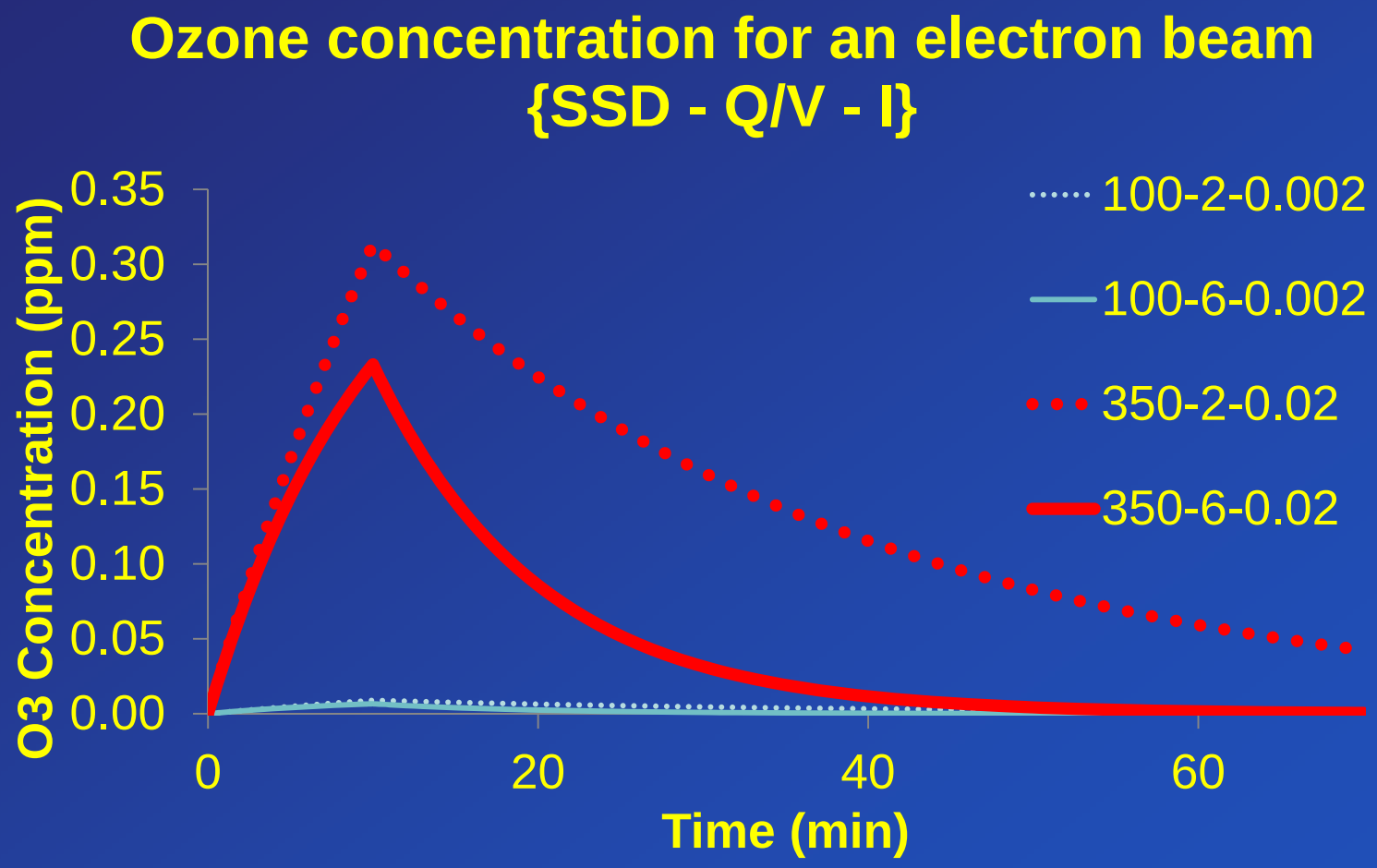


Recall MPC = 0.1 ppm

Ozone concentration over time (TSeI)



Ozone Concentration after 10 minute exposure



Ozone filters

Activated carbon filters can be very effective

not indefinitely because chemical reactions of ozone and carbon change the carbon.

Initial efficiencies of the 1.27-cm thick flat samples varied from **4.6 to 98.3%.**

Consequently, removal efficiency decreased with use.

Ozone detectors

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Departments | Browsing History | Steven's Amazon.com | Today's Deals | Gift Cards & Registry | Sell | Help | Hello, Steven Your Account | Prime | Lists

Showing results for "ozone monitor" — Sort by: Relevance

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Avg. Customer Review
- ★★★★☆ & Up
- ★★★☆☆ & Up
- ★★☆☆☆ & Up
- ★☆☆☆☆ & Up

International Shipping
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Condition
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Eco Sensors EZ-1X Ozone Monitor, continuous duty
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$425.99

More Buying Choices
$419.00 new (2 offers)

★★★★★ ▾ 3

FREE Shipping on eligible orders

Product Features
Gas: *Ozone* Model: EZ-1X Product Type: Single Gas *Monitors*/Detectors

Industrial & Scientific: See all 66 items

American Marine Pinpoint ORP Monitor
by Pinpoint

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Product Features
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Industrial & Scientific: See all 66 items

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Tools & Home Improvement: See all 18 items

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by Carolina

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★★★★★ ▾ 3

Industrial & Scientific: See all 66 items

Eco Sensors A-21ZX Ozone Monitor, digital
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$797.00

More Buying Choices
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FREE Shipping on eligible orders

Product Features
Gas: *Ozone* Model: A-21ZX Product Type: Single Gas *Monitors*/Detectors

What can be done to minimize your exposure to ozone in the radiation therapy clinic

1. Have adequate ventilation.
2. Wait a few minutes after treating a TSeI before entering the room.
3. Ask Larry to treat the total skin patient for you.
4. Be tall!
5. All of the above (unless you are Larry).

Radioactivity in the linac vault

subtleties

"When the beam is off or the door is open there is no radiation in the room"

"When the beam is off or the door is open there is no radiation **being produced** in the room"

Why Radiation Therapists don't want Medical Physicists at the machine

Patient: *"I won't glow from my treatment will I?"*

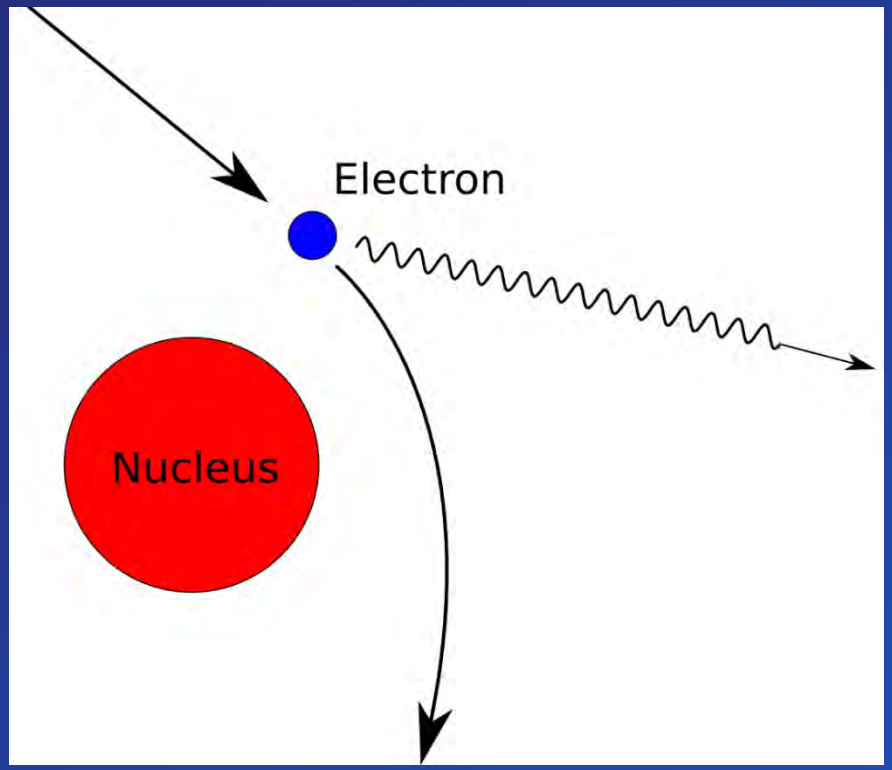
Therapist: *"No, of course not."*

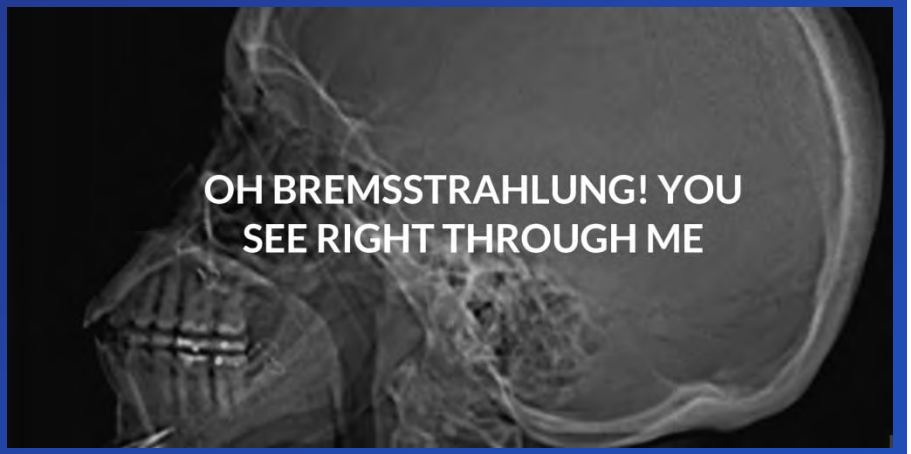
Physicist: *"Well actually….."*

[Therapist kicks Physicist in shin]

Atomic Physics 101

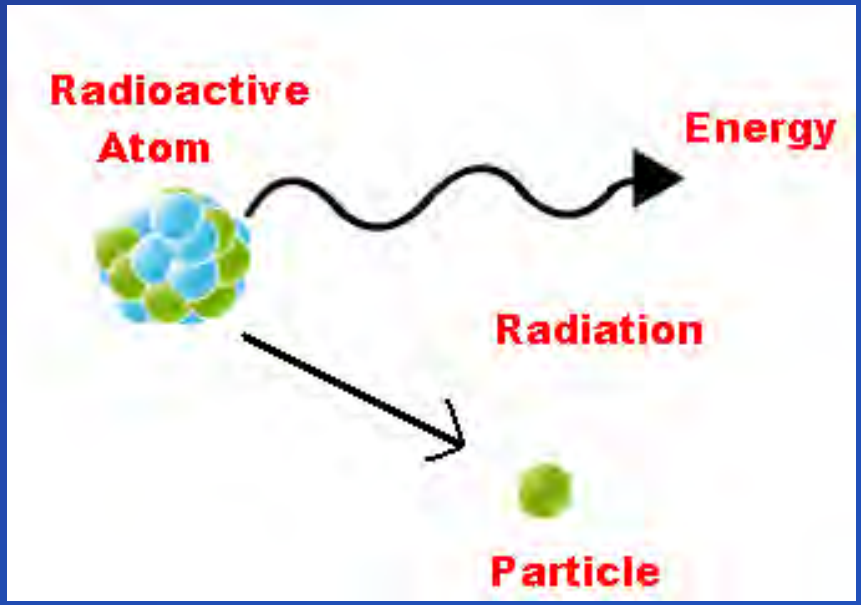
bremsstrahlung





Nuclear Physics 101

- The nucleus of an atom is composed of neutrons and protons.
- If the ratio of neutrons to protons is not optimal the isotope will change to a more stable state
- energy is released,
- radioactivity



Nuclear Physics 201

Activation: To induce radioactivity

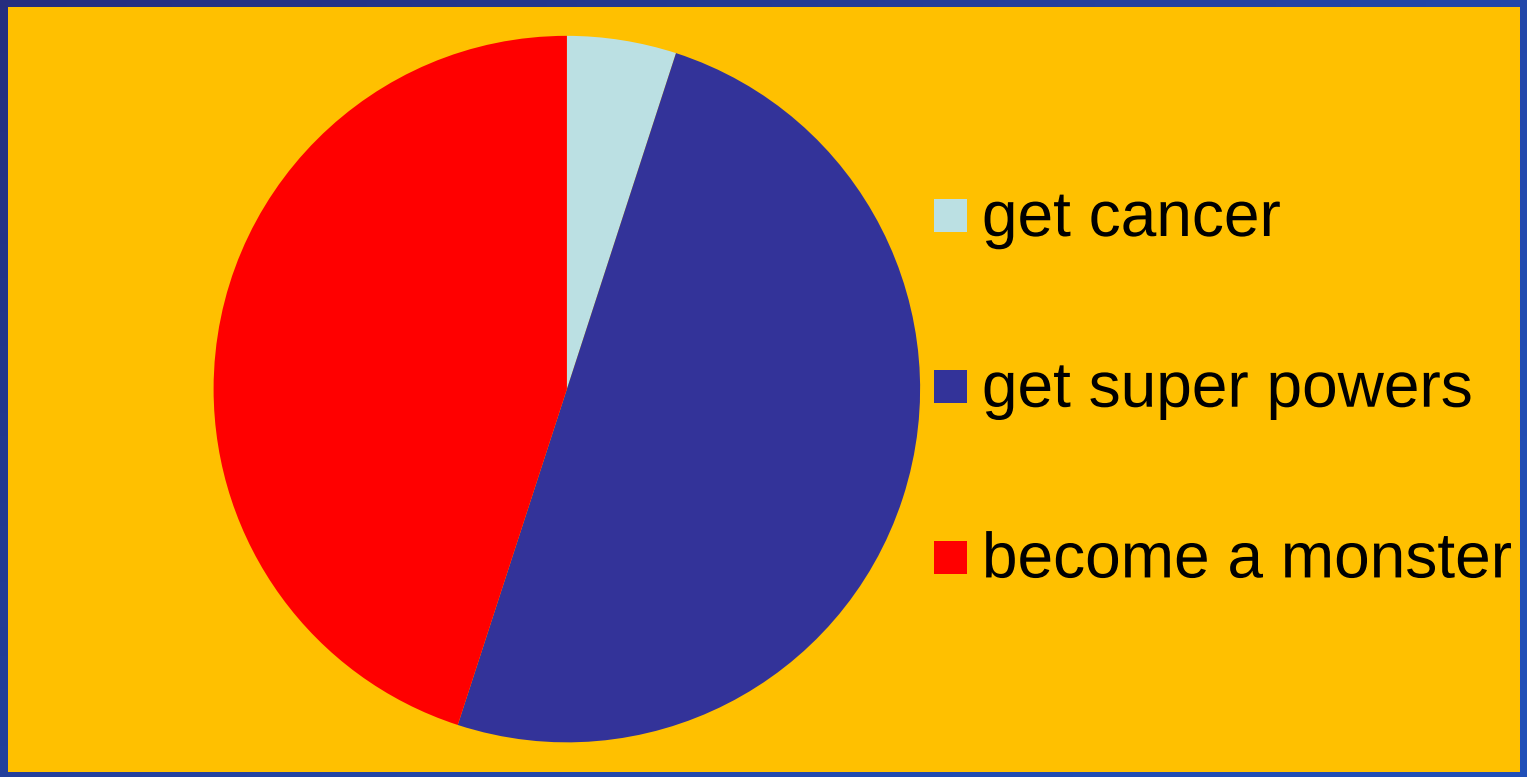
Energy imparted to nucleus can activate it (neutrons, x-rays, γ rays, electrons …)

Example:

$^{59}Co + n \rightarrow {}^{60}Co \rightarrow {}^{60}Ni + e^{-} + \nu_e + \gamma$ rays

Radiobiology 101

What is the effect of radiation on the healthy human body?



Marvel Comics 1973

Activation in high-energy accelerator treatment rooms arises from

- primarily the accelerator itself and its components,
- to a lesser extent from the walls, floor, and ceiling,
- minimally from the patient and from the air in the room.

Dose to radiation therapists from activation at high-energy accelerators used for conventional and intensity-modulated radiation therapy

J. Alan Rawlinson[a)]
Cancer Care Ontario, and Department of Medical Biophysics, University of Toronto, Toronto, Ontario M5G 2M9, Canada

Mohammad K. Islam
Radiation Physics, Princess Margaret Hospital, and Department of Radiation Oncology, University of Toronto, Toronto, Ontario M5G 2M9, Canada

Duncan M. Galbraith
Radiation Physics, Princess Margaret Hospital, 610 University Avenue, Toronto, Ontario M5G 2M9, Canada

(Received 23 October 2001; accepted for publication 14 January 2002; published 21 March 2002)

^{28}Al - treatment couch

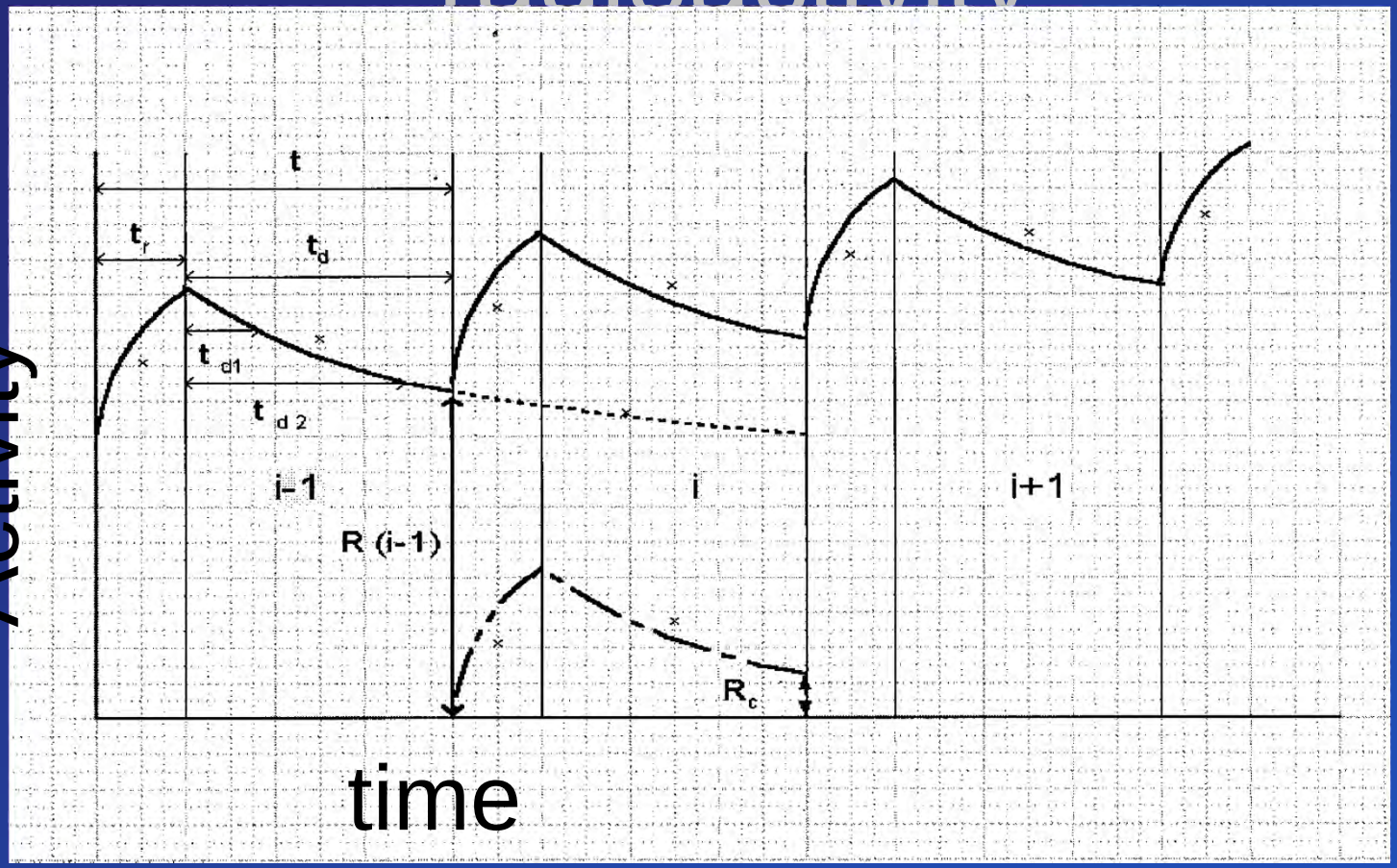
^{122}Sb lead shielding in linac head

^{56}Mn and ^{24}Na not identified

TABLE I. Principal radioisotopes identified at 1 m lateral to isocenter of Varian Clinac 21EX Linear Accelerator.

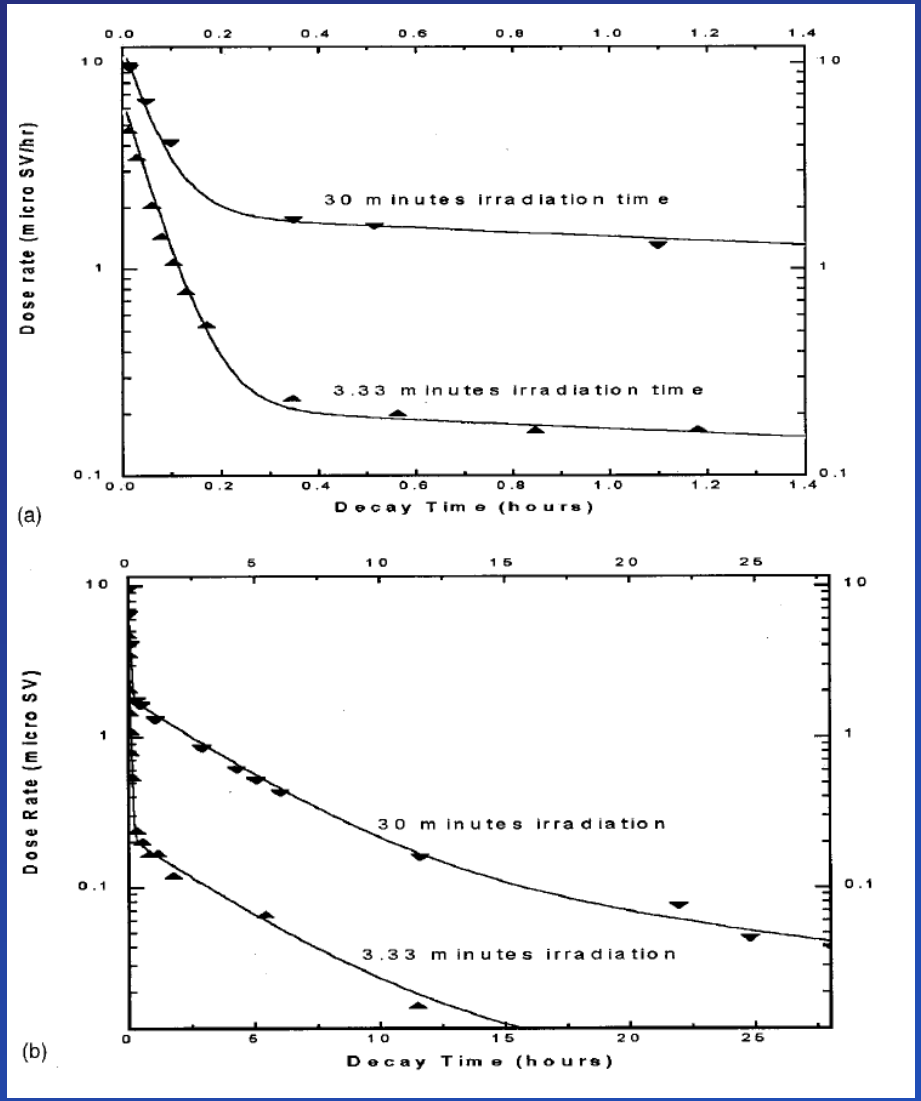
Nuclide	Half-life	Probable nuclear reaction	Decay mode	Principal gamma Energies (keV)
^{28}Al	2.3 m	^{27}Al(n, γ)^{28}Al	β^-, γ	1780
^{56}Mn	2.6 h	^{55}Mn(n, γ)^{56}Mn	β^-, γ	847, 1811, 2113
^{24}Na	15 h	^{23}Na(n, γ)^{24}Na	β^-, γ	1369, 2754
^{122}Sb	2.8 d	^{121}Sb(n, γ)^{122}Sb	β^-, β^+, γ	511, 564

Buildup and decay of radioactivity



"These machines had each been operated for 5 years with an average annual high-energy workload"

Dose rate beside linac table after beam off



Activation doses for different treatment regimes

Annual dose 1.6 to 13.4 mSv

TABLE II. Activation doses for different treatment regimes.

Treatment regime		Weekly dose (μSv/week) ^{28}Al	^{56}Mn	^{24}Na	Long-lived	Total	Annual dose (mSv/yr)
Conventional radiation therapy	Benchmark	26.2	23.2	5.9	5.6	60.9	3.2
	Four field	21.6	22.2	5.8	5.6	55.2	2.9
	Mixed energies	13.0 H	6.2 H	1.5 H	1.4 H	30.8	1.6
		0.1 L	5.7 L	1.5 L	1.4 L		
	Benchmark with QA	27.9	31.4	7.9	7.2	74.2	3.9
Intensity-modulated radiation therapy	Current IMRT	6.1	17.1	4.3	4.0	31.5	1.6
	High efficiency IMRT	50.5	59.9	15.1	14.4	139.9	7.3
	Future IMRT	108.3	99.7	25.1	24.0	257.1	13.4

Radiation Therapist exposure in extreme conditions

radiation worker limit exposure limit

USA = 50 mSv Europe 20 mSv

"However, under extreme conditions of IMRT operation, i.e.,

- *all fractions at 18 MV,*
- *large MU per fraction,*
- *short treatment delivery times,*
- *short patient setup times,*
- *maximum treatment room occupancy,*

the activation dose would reach about 17 mSv/y, a value which is close to internationally recommended occupational dose limits" – Rawlinson, Islam, Galbraith

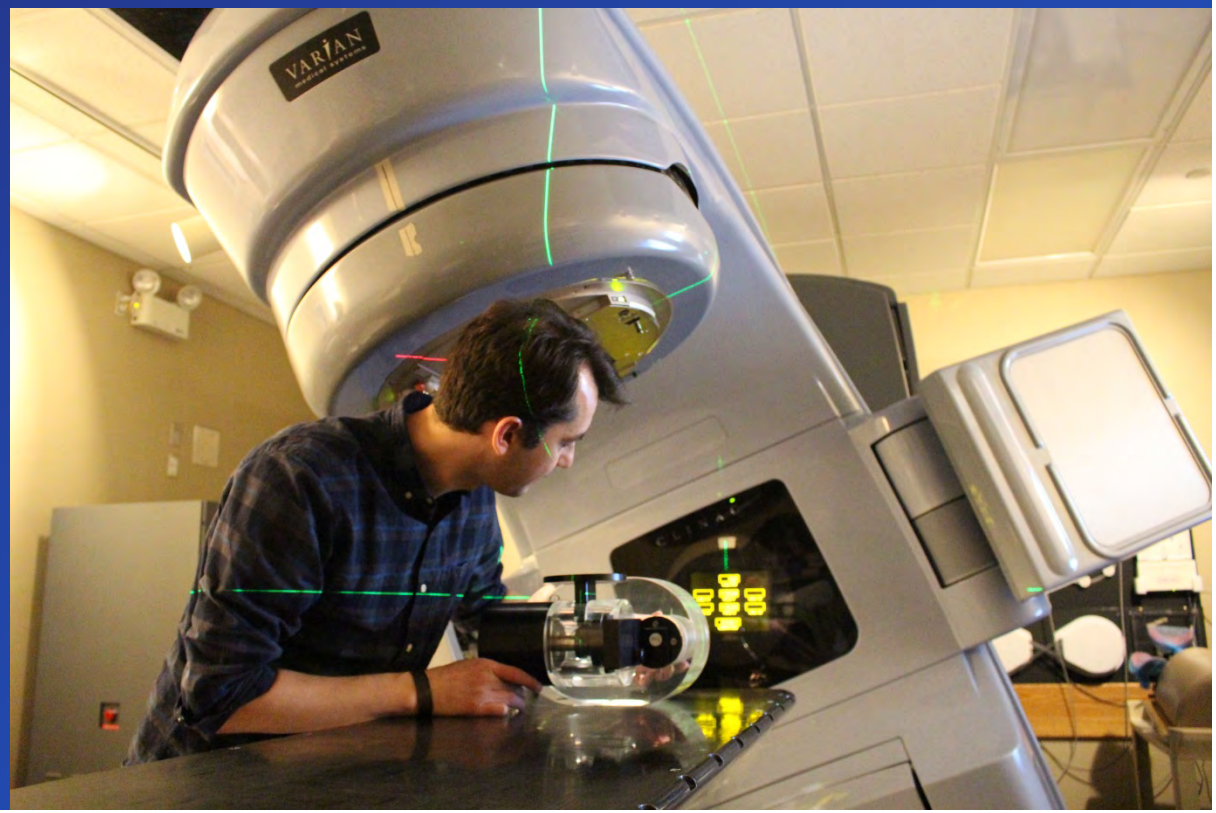
“These numbers show that activation dose is not negligible and suggest that, at least in conservatively shielded facilities, the therapist receives a greater occupational dose from activation than from radiation transmitted through the shielding barriers.”

Recommendations

Avoid using >10 MV for IMRT

Treat 18 MV at the end of the day (sorry physics)

Have you ever wondered why physicists have bald spots?



Radionuclides Created in High Energy Linear Accelerators by Nuclear Activation Processes

Accelerator Component	Observed Contact Dose Rate (μSv/h)
flattening filter	70
Target	36
primary collimator	11
upper jaw	50
lower jaw	30

50 mSv/ 50 μSv = 1/1000

Table 1: Isotopes Identified on Varian High Energy Accelerators

Isotope	Decay Mode	Half-life		Photon Energy (keV)
Na 24	**e^-**	**15**	**h**	**1369**
Al 28	**e^-**	**2.24**	**min**	**1779**
Cr 51	EC	27.7	d	320
Mn 54	e^+	312.3	d	835
Mn 56	**e^-**	**2.58**	**h**	**847, 1811**
Co 57	e^+	271.8	d	122
Co 58	e^+	70.9	d	811
Co 60	e^-	5.27	y	1173, 1333
Ni 57	e^+	35.6	h	1378
Cu 62	**e^+**	**9.7**	**min**	**(511)**
Cu 64	e^-, e^+	12.7	h	1346
Zn 65	e^+	244.3	d	1116
Br 82	e^-	35.3	h	619, 777
Sb 122	**e^-, e^+**	**2.72**	**d**	**1141**
Sb 124	e^-	60.2	d	603
W 181	EC	121.2	d	(57)
W 187	**e^-**	**23.8**	**h**	**480, 686**
Au 196	e^-, e^+	6.18	d	356
Potential activation products				

Varian CTB GE-924: Radionuclides Created in High Energy Linear Accelerators by Nuclear Activation Processes

VARIAN
medical systems

TECHNICAL ADVISORY

Subject:	***Potential Increase in Ambient Dose after Extended High Energy Use***
Commercial Name of Affected Product:	***TrueBeam® RadioTherapy Delivery System***
Affected Version(s) / Lot(s):	**TrueBeam® versions 1.6, 2.0 and 2.5**
Reference / FSCA Identifier:	**CP-20951**
Date of Notification:	***2015-07-17***
Type of Action:	**Notification and Correction**

Description of Problem

Varian recently received a report of an increase in ambient dose measurement due to target activation after extended operation in high energy mode. Only TrueBeam® RadioTherapy Delivery Systems versions 1.6, 2.0 and 2.5 with 18MV [23MV-BJR17] and 20MV [25 MV-BJR17] energies are affected. Measurements of ambient exposure simulating treatment activites consisting of repeated 4 Gy irradiations separated by 10 minutes over a 4 hour period exceeded Varian's specification. The ambient dose measurements taken at 1 meter below the collimator face were less than 100 µSv/h.

This issue does not impact patient safety or treatment delivery. Varian has not received a report of any person receiving excess radiation exposure due to this issue.

- Edge, UNIQUE and TrueBeam version 1.5 linac devices are not affected because the energies available are lower than 18MV.
- C-Series linac devices are not affected because the target is shielded by the flattening filter.

18 MV x-rays

- Creation of ^{62}Cu (half life 9.7 min)
- The filter carousel moves to the field light position (moving the flattening filter out of the path)
- The activated source is no longer “shielded” by the flattening filter.
- Increase ambient dose rate in the region directly below the field aperture

trueBEAM carousel

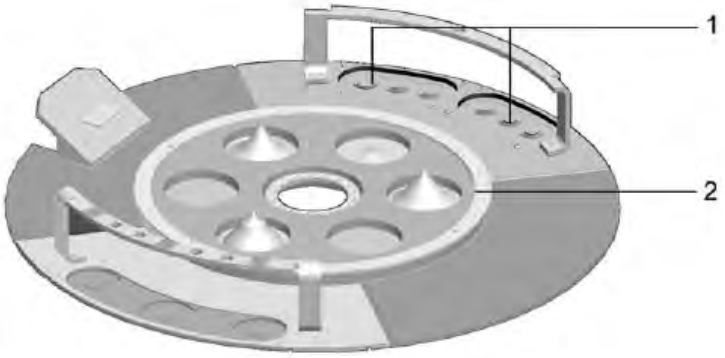


Figure 20 Foils (1) and Filters (2)

Carousel Y-Stage

The BGM-POS node positions the carousel Y-stage axis, providing longitudinal motion for the carousel. The Y-stage axis drive (see below) moves the target out of the way when electron mode energies are used; positions foils and filters; and adjusts the field light mirror for proper focus.

Figure 21 Y-stage Axis

Carousel Ion Chamber

Located at the end of the carousel closest to the collimator, the ion chamber (see the following figure) is intercepts the radiation beam after it has passed through the X-ray filter or electron foil. The BGM-POS subnode positions the ion chamber into the path of the beam.

The ion chamber monitors the radiation treatment beam to provide feedback to the BGM controller on actual dose rate, symmetry, and flatness.

Based on spatial distribution, the BGM generates corrective signals for radial and transverse angle and position steering servo systems.

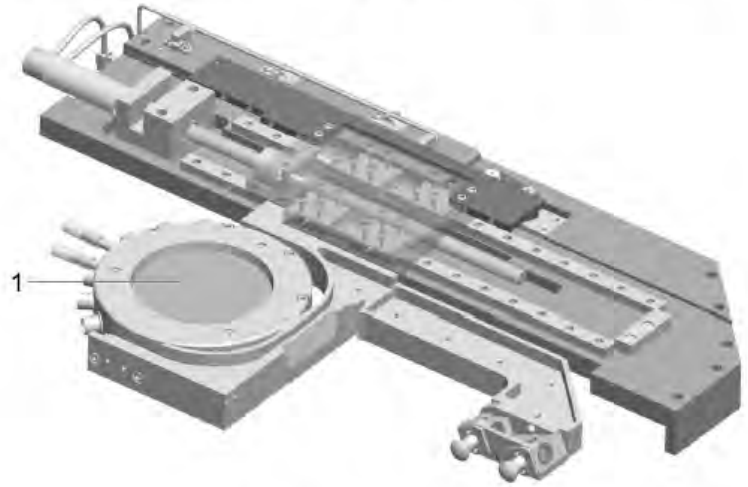
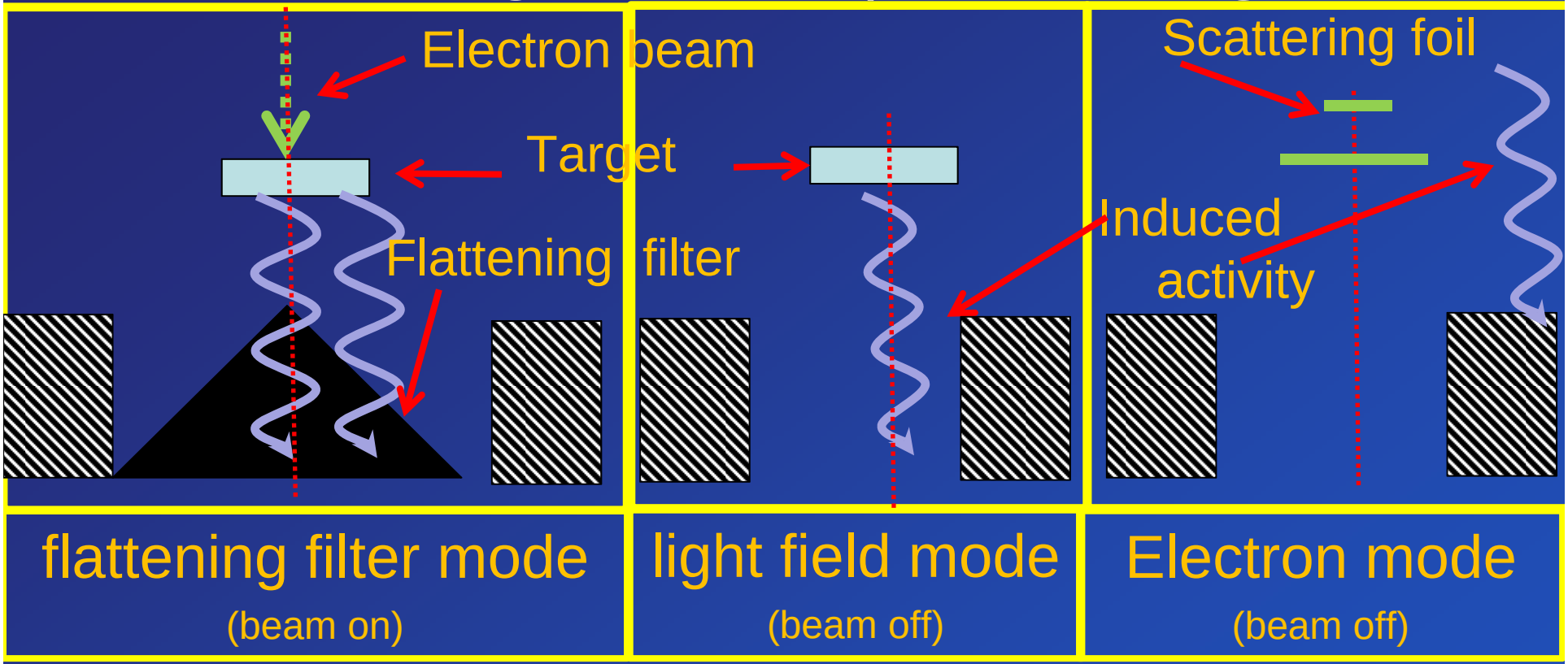


Figure 22 Ion Chamber Axis (1)

Varian trueBEAM technical reference guide part 1 version 2.5

The flattening filter therapist shielding effect



- Measurements of ambient dose 1 meter below the collimator face due to target activation was less than 100 µSv/h.
- below annual radiation exposure limits
  - 50 mSv per year (USA) 20 mSv (Europe).

Recommended User Action

- Close the jaws after high energy photon treatments are complete.
- Select and mode-up an electron treatment field after treatment is complete.
- Wait at least 10 minutes after the beam has been stopped, before working underneath the target (e.g. setting up QA equipment and phantoms).
- DO NOT use "Mimic Treatment Room Light Field" when in service mode.
- Minimize the time you spend in the proximity of the beam aperture.

Personnel exposure is more of a concern with a trueBEAM than a trilogy linac because the trueBEAM

1. has an FFF mode
2. has higher dose rates
3. retracts the flattening filter when the door is opened
4. has the awesome accent lighting

Review Paper

POTENTIAL HAZARD DUE TO INDUCED RADIOACTIVITY SECONDARY TO RADIOTHERAPY: THE REPORT OF TASK GROUP 136 OF THE AMERICAN ASSOCIATION OF PHYSICISTS IN MEDICINE

Bruce Thomadsen,* Ravinder Nath,† Fred B. Bateman,‡ Jonathan Farr,§ Cal Glisson,**
Mohammad K. Islam,†† Terry LaFrance,‡‡ Mary E. Moore,§§ X. George Xu,***
and Mark Yudelev†††

Radionuclides produced by photon activation in linear accelerators

Maximum half life = 5.27 y (^{60}Co)

Minimum activation energy

= 7.67 to 8.39 MeV (^{184}Re,^{197}Au,^{203}Pb)

Maximum gamma energy = 2.754 MeV (^{24}Na)

^{59}Fe	β^-	44.5 d	^{58}Co(n, p)^{59}Fe	1099, 1292	—
^{57}Co	β^+	271.8 d	^{59}Co(γ, $2n$)^{57}Co	122, 136	19.3
			^{58}Ni(γ, p)^{57}Co		8.17
^{58}Co	β^+ EC	70.78 d	^{59}Co(γ, n)^{58}Co	811, 864, 1675	10.45
			^{60}Ni(γ, np)^{58}Co		19.99
^{60}Co	β^-	5.3 a	^{61}Ni(γ, p)^{60}Co	1173, 1333	9.86
			^{59}Co(n, γ)^{60}Co		
^{57}Ni	β^+ EC	35.6 h	^{58}Ni(γ, n)^{57}Ni	127, 1378, 1920	12.22
^{62}Cu	β^+ EC	9.74 m	^{63}Cu(γ, n)^{62}Cu	876, 1173	10.85
			^{64}Zn(γ, np)^{62}Cu		18.57
^{64}Cu	EC β^- β^+	12.7 h	^{65}Cu(γ, n)^{64}Cu	1346	9.91
^{63}Zn	EC β^+	38.4 m	^{64}Zn(γ, n)^{63}Zn	670, 962, 1412	11.86
^{65}Zn	β^+	244.3 d	^{66}Zn(γ, n)^{65}Zn	1116	11.06
^{82}Br	β^-	35.34 h	^{81}Br(n, γ)^{82}Br	554, 619, 777	—
^{99}Mo	β^+	66.0 h	^{100}Mo(γ, n)^{99}Mo	181, 739, 778	8.29
^{120}Sb	β^+ EC	15.9 m	^{121}Sb(γ, n)^{120}Sb	703, 989, 1172	9.24
^{122}Sb	β^- β^+,EC	2.7 d	^{121}Sb(n, γ)^{122}Sb	564, 693, 1257	—
^{124}Sb	β^-	60.3 d	^{123}Sb(n, γ)^{124}Sb	603, 723, 1691	—
^{184}Re	β^+	38.0 d	^{185}Re(γ, n)^{184}Re	111, 792, 903	7.67
^{187}W	β^-	23.72 h	^{186}W(n, γ)^{187}W	134, 479, 686	—
^{196}Au	β^+	6.2 d	^{197}Au(γ, n)^{196}Au	333, 356, 426	8.07
^{203}Pb	β^+	51.9 h	^{204}Pb(γ, n)^{203}Pb	279, 401, 681	8.39

Recommendations

- Use lower beam energy
- Avoid material with high activation cross sections
- Restrict high energy for the end of the day
- Delay room entry
- Minimize wedge and compensator use
- Close the collimators following high energy deliveries
- Move couch and gantry from outside the room when possible
- Assign pregnant staff to low energy machines
- Use survey meter before service work
- Assess brass and copper buildup caps

Absorbed dose to technicians due to induced activity in linear accelerators for radiation therapy

A Almen, L Ahlgren and S Mattsson

PMB 1991

“The total annual absorbed dose to the trunk and to the hands have been estimated to be 2 mGy, of which the induced activity contributes one-third (0.7 mGy).”

Air activation (γ,n)

Element	Threshold Energy (MeV)	Result	Half life (s)	Emission	Energy (MeV)
^{14}N	10.5	^{13}N +n	600	β	1.19
^{16}O	15.7	^{15}O + n	122	β	1.73

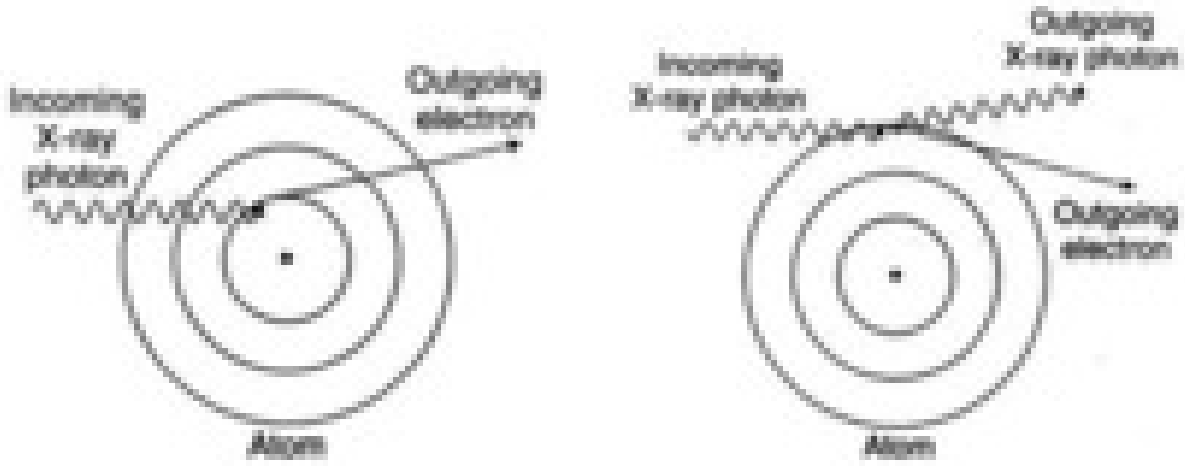
1% or less of the maximum permissible concentrations

Air activation produced by high-energy medical accelerators, McGinley, Patton; White, Thomas, MedPhys 1983

Neutrons and the door less vault

X-rays

Lead is a good x-ray attenuator because it has high atomic number (lots of electrons)

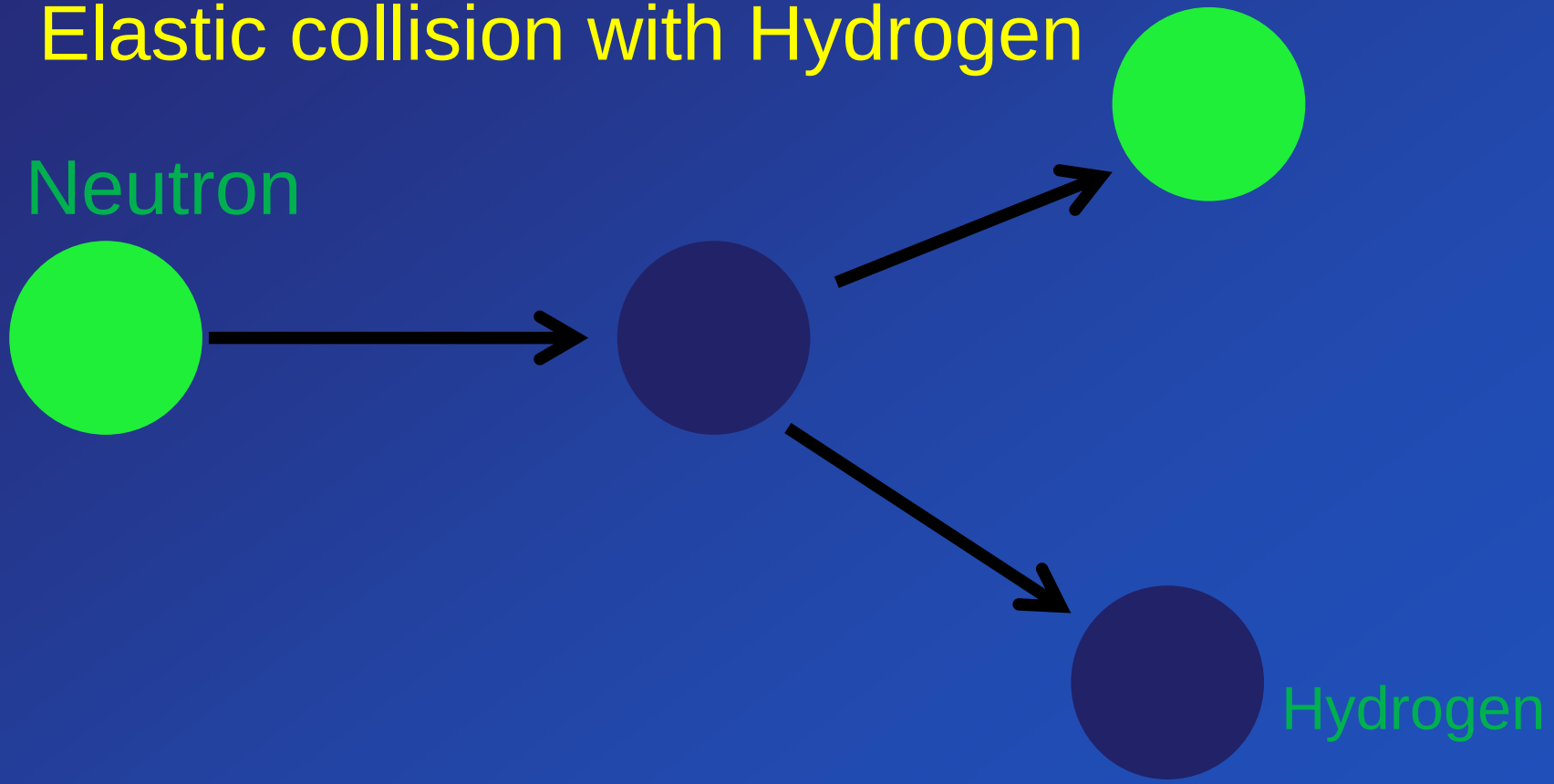


Photoelectric effect + Compton scattering = X-ray attenuation

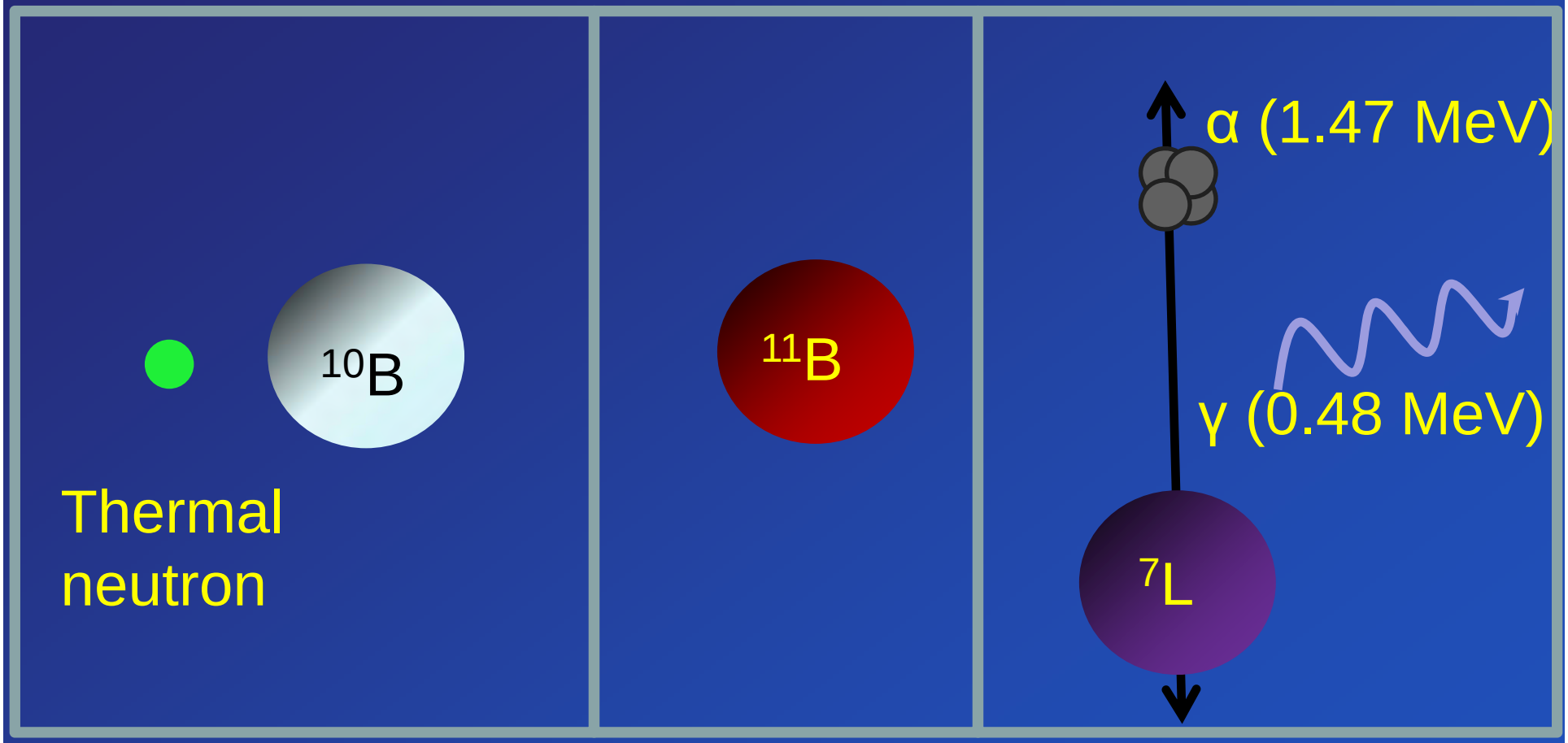
Neutrons

No charge means no coulomb interactions

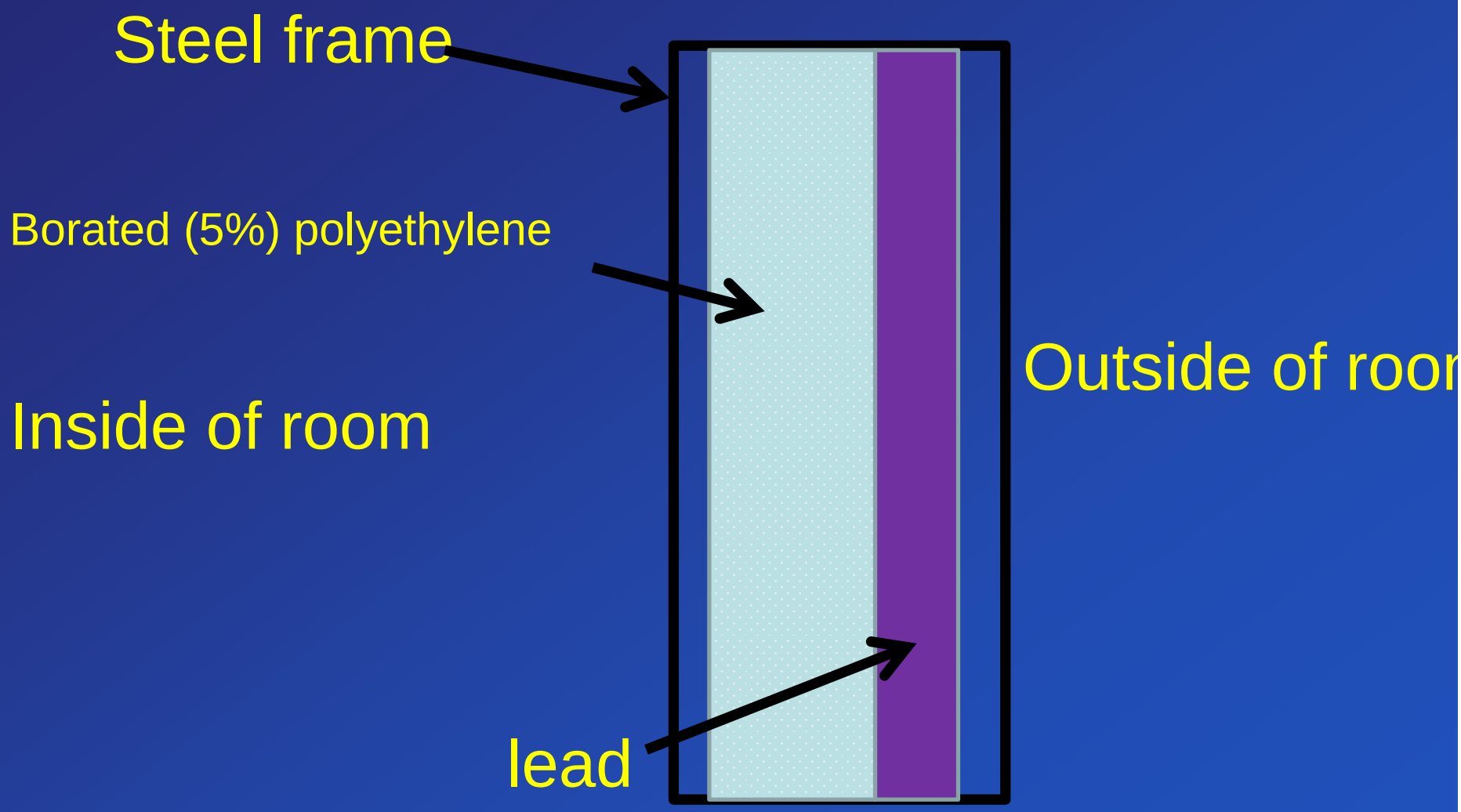
Elastic collision with Hydrogen



Thermal interaction with Boron



Neutron shielding door



Neutron door

Why doorless

Increase patient throughput 5 to 7%

Preferred by therapists

Expense

Physical safety concerns

Doorless vault design

- Limit 5 mSv / year for 16 MV beam
- Normal vault footprint
- Borated polyethylene at various points

- Result was 0.2 to 2 mSv / year

SU-FF-T-176: A Shielding Design for a High-Energy Doorless Accelerator Vault; T Bichay, J Meadows and C Chen

Med. Phys. 32, 1990 (2005); http://dx.doi.org/10.1118/1.1997847

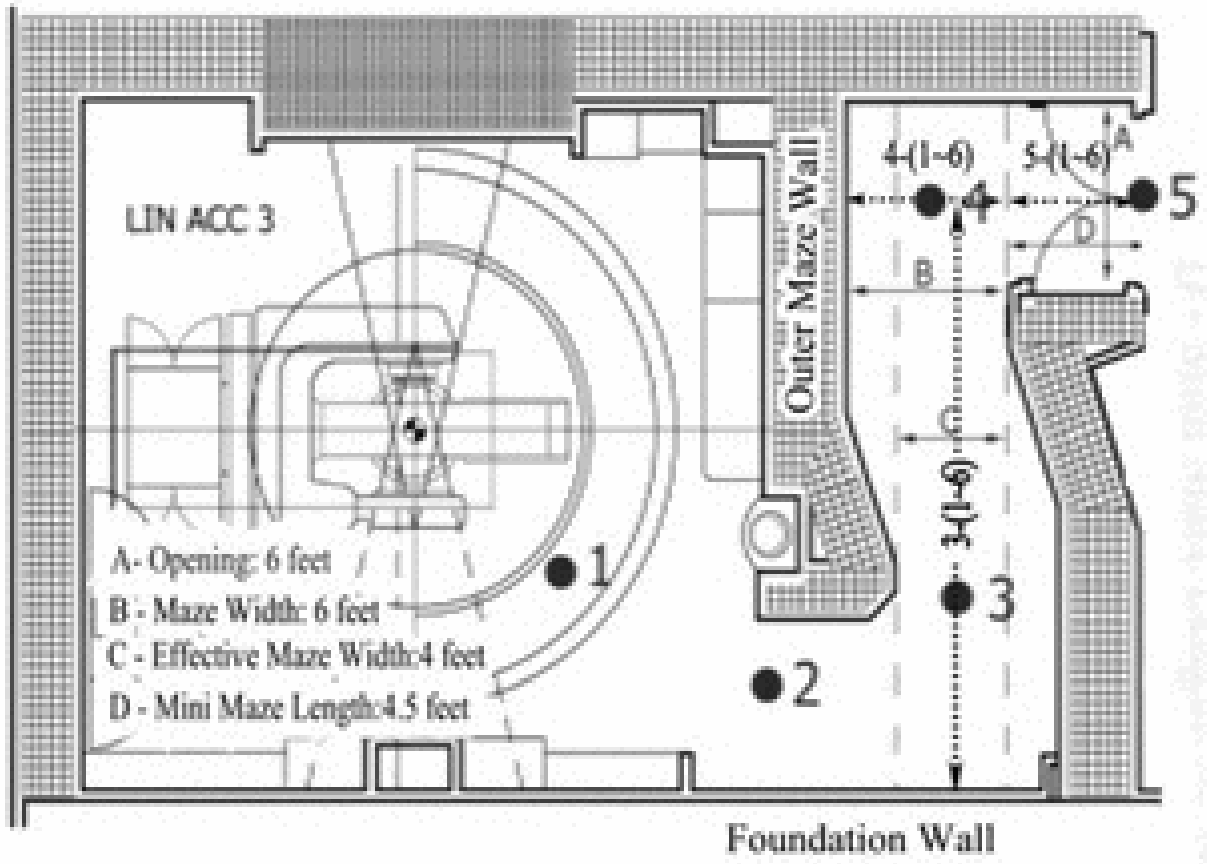


Figure 1: Schematic of the doorless vault and various measurement points.


SF_6

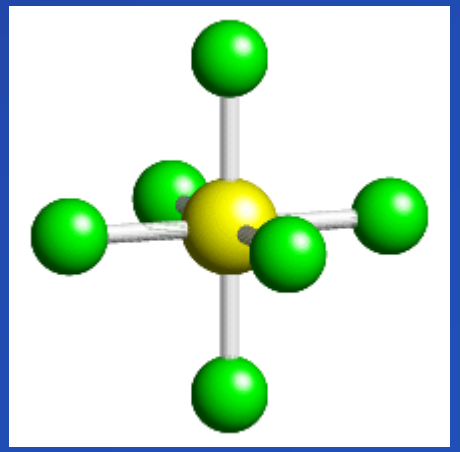
What is Sulphur hexafluoride (SF_6)?

Inert gas

Colorless, odorless, non flammable

Non toxic

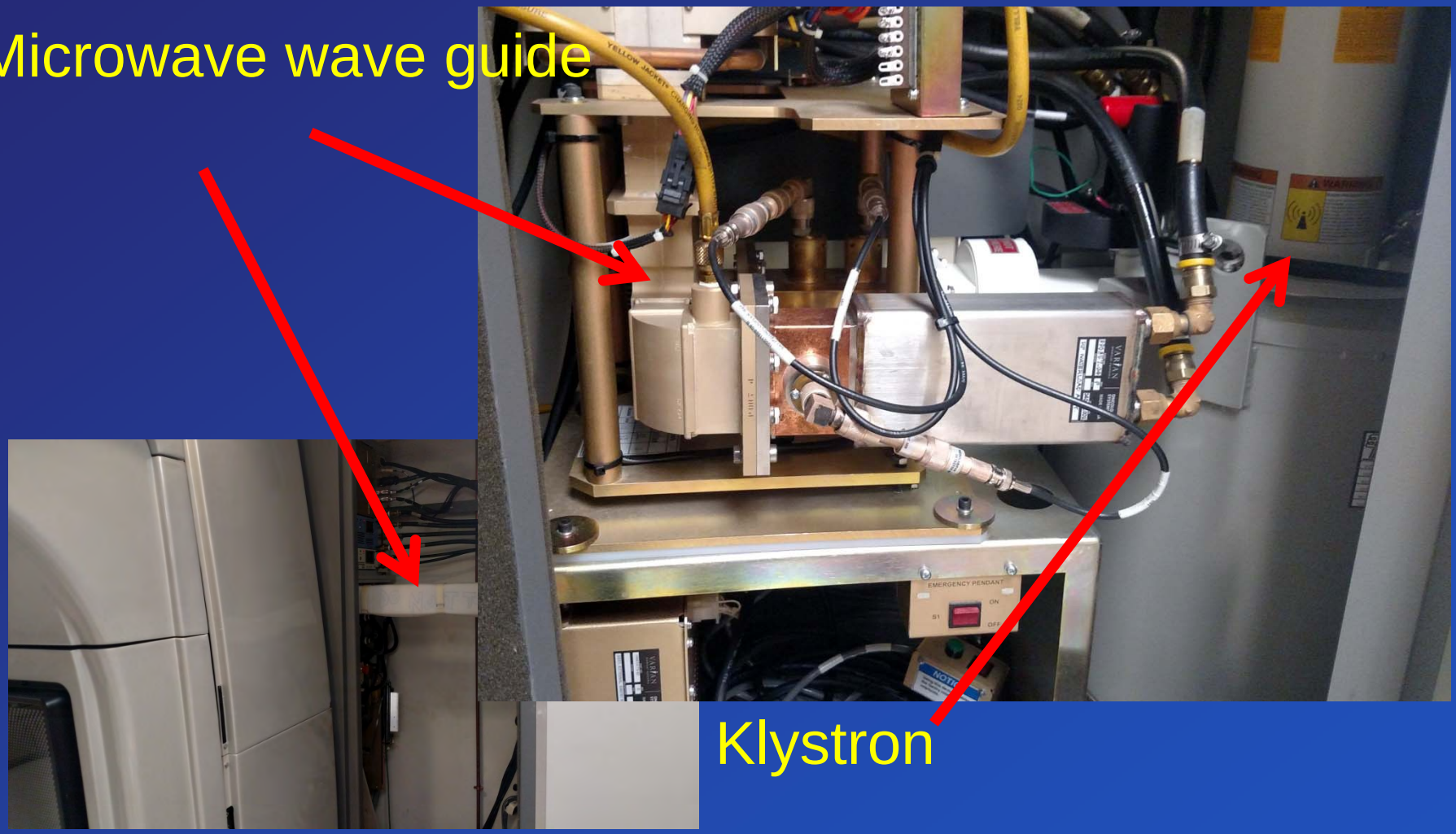
Heavier than air



Why do we need SF6 in linear accelerators

- SF6 is commonly used as a high voltage dielectric (an insulator that prevent discharge)
- In linacs it confines and transmits the RF (radio frequency) energy from the klystron to the accelerating waveguide

Varian Silhoutte



What is the potential risk of SF6

The main health hazard associated with releases of this gas is asphyxiation, by displacement of oxygen.

- headaches,
- ringing in ears
- dizziness
- drowsiness
- unconsciousness
- nausea,
- vomiting
- depression of all the senses.
- death may occur, due to the displacement of oxygen

The liquefied gas will rapidly boil at standard temperatures and pressures.

Sulfur hexafluoride has an anesthetic potency slightly lower than nitrous oxide.

Medical treatment

RESCUERS

Self-Contained Breathing Apparatus should be worn.

Remove victim to fresh air, as quickly as possible.

If not breathing, give artificial respiration

If breathing is difficult, give oxygen

SKIN EXPOSURE:

Immediately begin decontamination with running water.

Minimum flushing is for 15 minutes.

EYE EXPOSURE

Open victim's eyes while under gentle running water.

Use sufficient force to open eyelids.

Have victim "roll" eyes.

Minimum flushing is for 15 minutes.

The SF6 defence

Medical Treatment

“Stand on your head and breath deeply!”

– Rick Hoffmeister, Linac engineer,

Democratic Youtube

1

Mythbusters Adam Savage Helium and Sulfur Hexafluoride

2

Neil Patrick Harris and Kelly Ripa inhale sulfur hexafluoride

3

Sulfur Hexafluoride vs GIRL (Anna Spitz) with Explanation

4

Jennifer Lawrence Plays Balloon Roulette

I just have to say…3 out of 4 youtube videos are wrong

Speed of sound = $\sqrt{\frac{\kappa_s}{\rho}}$

Conclusion

Your odds of dying in a car accident in your lifetime are 1 in 606

Work from home!

Thank You!

https://www.youtube.com/watch?v=IPLYfC4o3vE

https://www.youtube.com/watch?v=Kvr9LFzOo50

https://www.youtube.com/watch?v=yDFgytoiGUw

https://youtu.be/oNMGZQVkNQY