SPECT/PET:
Shielding and Radiation Protection

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Disclosures

None
other than that
I do not know any good physics jokes

Learning Objectives

- Discuss the overall approach to nuclear medicine and hybrid PET/CT, SPECT/CT shielding and radiation protection problems
- Review the TG-108 approach to designing PET/CT facilities
- Outline difficulties encountered in practical nuclear medicine shielding design

Motivation for Attention to PET/NM Shielding

#HVL's	Lead Thickness Required mm (in, to next 1/16)	
	X-ray [1] (average primary for rad room)	PET[2]
1	0.044 (< 1/16)	5.3 (1/4)
2	0.103 (< 1/16)	9.9 (7/16)
4	0.278 (< 1/16)	19.0 (3/4)
8	0.718 (< 1/16)	32.5 (1 5/16)
10	1.366 (< 1/16)	46.0 (1 13/16)

Even a single half-value layer for PET is an expensive proposition!

1. NCRP 147: Structural Shielding Design for Medical X-Ray Imaging Facilities
2. Simpkin, 2004, developed for AAPM Task Group on PET Facility Shielding

In Diagnostic x-ray, we can apply the 3 models from NCRP 147 and find that 1/16" is (usually) the answer, with some to spare. We often calculate just the "closest" point.

Not true in PET. As we will see, it is true that normally we need 1-3 HVL's of shielding. We tend to put in just what we need, due to $$$.

Implication: At every protection point, we need to include all sources that can be contributing to the dose at that point (i.e. multiple injection rooms, scan rooms, etc.), because we do not have built in extra HVL's.

Overview: Shielding Guidance for NM/PET

- NCRP #147 (2004) addresses x-ray modalities and should be used for the CT component of SPECT/CT and PET/CT scanners
- NCRP Report #49 (1976) had guidance for isotopes in the context of brachytherapy and teletherapy sources (Cs-137, Au-198, Ir-192, Co-60, Radium)
- AAPM TG108 (2006) addressed PET and PET/CT Shielding Requirements
- Currently no up-to-date official shielding guidance for general diagnostic nuclear medicine

Typical Tasks We May Need to Address

- Hospital room for I-131 ablation patient
- PET/CT uptake room and scan bay in PET center
- SPECT/CT scan bay in NM department

The General Problem

Dose in Protected Location (per week) =

Dose from weekly isotopic workload in shielded location (all isotopes, all studies) +

Dose from weekly CT workload in shielded location (all studies)

and must be less than or equal the assigned protection limit; we hit this target by changing the barrier transmission, B, through adjustments to the barrier material and thickness

SPECIAL ISSUES FOR NM: Self-attenuation in patient, correct attenuation coefficients for isotopes.

Formal Approaches I

CT: NCRP 147

$$B = \frac{P}{T} \cdot \frac{d^2}{K^1 N}$$

Isotopes: Modified AAPM TG108

$$B = \frac{P}{T} \cdot \frac{d^2}{(\Gamma A_0 F_{tot} R_t t) N}$$

B = allowed fractional barrier transmission
P = assigned dose limitation goal per wk at protected location
T = occupancy factor (see NCRP 147, Table 4.1)
d = distance from source to protected location
N = number of patients per week

K^1 = average air KERMA per patient at 1 m for given workload

$\Gamma A_0 F_{tot} R_t t$ = average air KERMA per patient at 1 m for given isotopes, studies,

Formal Approaches I

NCRP 147

$$B = \frac{P}{T} \cdot \frac{d^2}{K^1 N}$$

Modified AAPM TG108

$$B = P \qquad d^2$$

Modification: air KERMA is used here (to match NCRP 147) instead of effective dose, E, as per AAPM TG108

B = allowed fraction

P = assigned dose limitatio

T = occupancy factor (see

d = distance from source to p

N = number of patients pe ek

K1 = average air KERMA per patient at 1 m for given workload

$\Gamma A_0 F_{tot} R_t t$ = average air KERMA per patient at 1 m for given isotope, study,

Formal Approaches II

$$B = \frac{P}{T} \cdot \frac{d^2}{(\Gamma A_0 F_{tot} R_t t) N}$$

Γ = specific dose or air KERMA rate constant for isotope

A_0 = injected activity

F_{tot} = combined physical decay and biological elimination of activity between injection and the time the patient enters the shielded location

R_t = dose reduction factor reflecting decay of isotope during stay in shielded location

t = time patient spends in shielded location

What about multiple sources?

Turn problem
on its head

$$K_{tot,prot} = \sum_i K_{i,prot} + K_{CT,prot}$$

Total KERMA (or dose) at protected location

Sum of isotopic contributions at protected location

CT contribution at protected location

$$K_{tot,prot} = T \cdot \frac{\sum_i B_{i}(x)(\Gamma A_0 F_{tot} R_t t)_i N_i + B_{CT}(x) K_{CT}^{1} N_{CT}}{d^2}$$

Adjust shield thickness, x, (thus changing B_{CT} and all B_i's) until $K_{tot,prot}$ is less than the protection goal.

Note assumption that d is the same for isotopes, CT.

Regulations and P, the Protection Limit

	Limitation per 10CFR20	**ALARA Action Limit**
Radiation Workers	50 mSv/yr (5000 mrem/yr)	5 mSv/yr 500 mrem/yr
Pregnant worker's fetus	5 mSv/term (500 mrem/term)	**P Targets** **controlled areas:** **100 µSv/wk or** **10 mrem/wk** **uncontrolled areas:** **20 µSv/wk or** **2 mrem/wk** **< 20 µSv in any hr**
Members of public	1 mSv/yr (100 mrem/yr)	
in any hour, not to exceed	.02 mSv (2 mrem)	

T, the Occupancy Factor

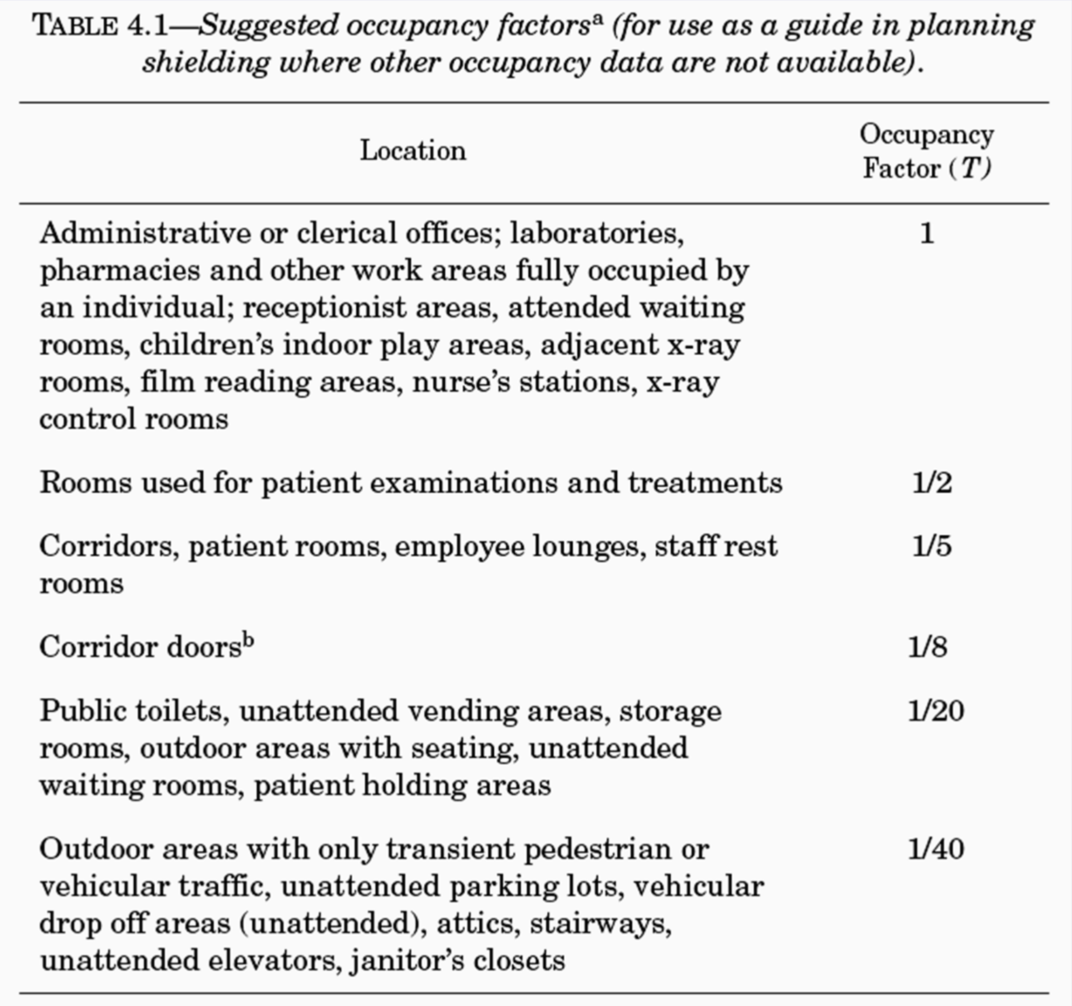


TABLE 4.1—*Suggested occupancy factors*[a] *(for use as a guide in planning shielding where other occupancy data are not available).*

Location	Occupancy Factor (*T*)
Administrative or clerical offices; laboratories, pharmacies and other work areas fully occupied by an individual; receptionist areas, attended waiting rooms, children's indoor play areas, adjacent x-ray rooms, film reading areas, nurse's stations, x-ray control rooms	1
Rooms used for patient examinations and treatments	1/2
Corridors, patient rooms, employee lounges, staff rest rooms	1/5
Corridor doors[b]	1/8
Public toilets, unattended vending areas, storage rooms, outdoor areas with seating, unattended waiting rooms, patient holding areas	1/20
Outdoor areas with only transient pedestrian or vehicular traffic, unattended parking lots, vehicular drop off areas (unattended), attics, stairways, unattended elevators, janitor's closets	1/40

Use occupancy factors from NCRP Report No.147, *Structural Shielding Design for Medical X-ray Imaging Facilities*, or other values chosen by the qualified expert (you!) as appropriate. Pay attention to the discussion that goes with this table in 147.

CT Component (NCRP 147)

NCRP 147 (Section 5.6 and, for B, Figs. A.2 and A.3)

$$B = \frac{P}{T} \cdot \frac{d^2}{K^1 N}$$

Total scattered air kerma at 1m for 1 week under expected workload (kVp, mAs, collimation, pitch, AEC, types of studies, number of patients)

Three ways of estimating K^1 from NCRP 147 :

1) CTDI (peripheral) and suggested scatter values per cm collimation

$$K^1 = \kappa*(L/p)*mAs*{}_{n}CTDI_{100}$$

$\kappa = 9 \times 10^{-5}$ cm^{-1}(head) or 3×10^{-4} cm^{-1} (body)
p=pitch, L= axial length of scan
mAs = mAs per rev*,**
${}_{n}CTDI_{100}$ = peripheral CTDI per mAs

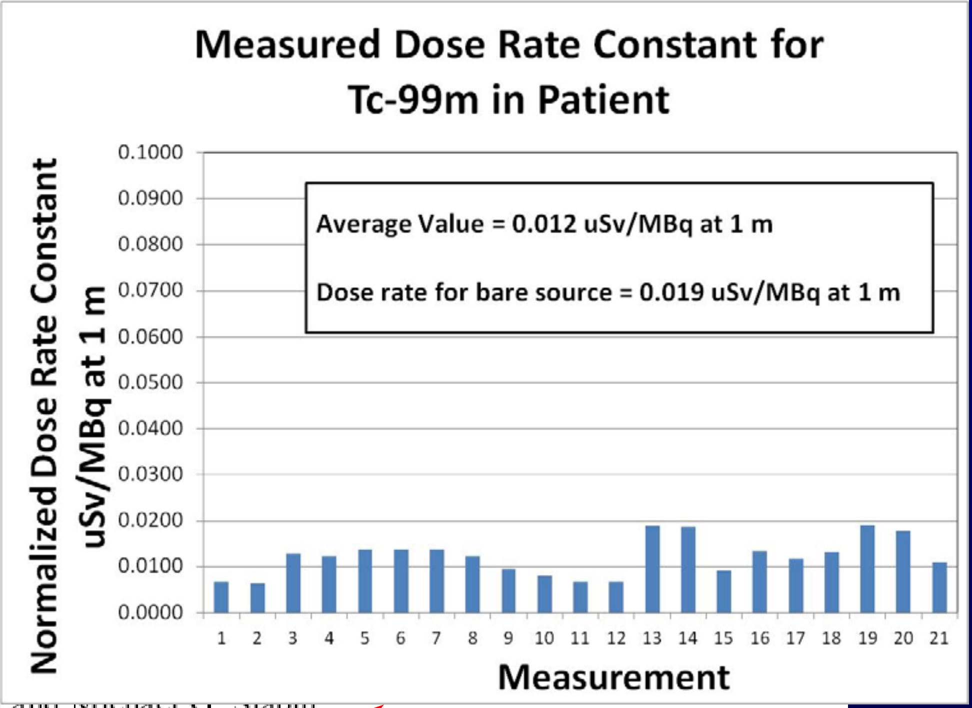
2) Isodose curves (allows correction for anisotropy)
3) DLP

$$K^1_{\text{(head)}} = \kappa_{\text{head}} * \text{DLP} \qquad K^1_{\text{(body)}} = \kappa_{\text{body}} * 1.2 * \text{DLP}$$

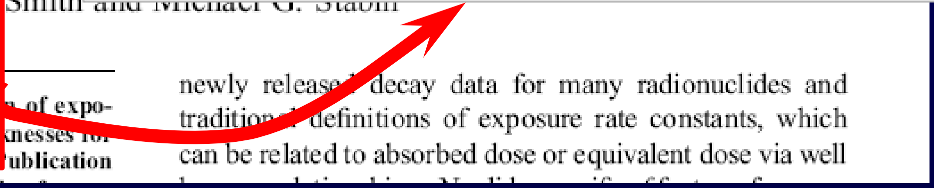
Γ for Nuclear Medicine: Not Simple

1) For bare sources, numerous compilations, including the recent "Exposure Rate Constants and Lead Shielding Values for over 1100 Radionuclides," DS Smith and MG Stabin, *Health Phys* 102(3):271-291, (2012).

2) For patient as a source, the situation is more uncertain!!!



Measurements reflecting different times post injection, disease states, projection, etc.
Corrected for decay and activity
Collected from NCRP 105, NCRP 124, White et al. Clinical PET 3(3), 127-129 (2000), Greaves and Tindale, Nuc. Med. Commun. 20 179-187 (1999).



TAN

R 1,1

Smith and Michael G. Stabin

of expo-
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ublication

newly released decay data for many radionuclides and traditional definitions of exposure rate constants, which can be related to absorbed dose or equivalent dose via well

Γ for Nuclear Medicine: Not Simple

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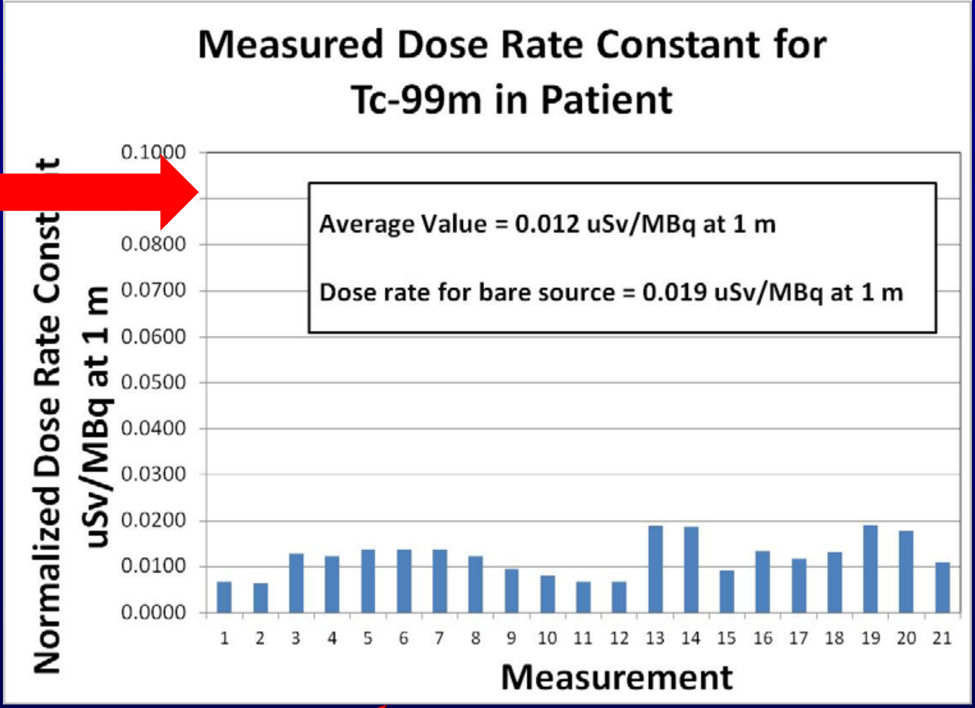
Meas times post injection, disease states, projection, etc. Corrected for decay and activity Collected from NCRP 105, NCRP 124, White et al. Clinical PET 3(3), 127-129 (2000), Greaves and Tindale, Nuc. Med. Commun. 20 179-187 (1999).

Aside:
For F-18 PET, the patient as a source is about 0.093 uSv/hr-MBq at 1 m.

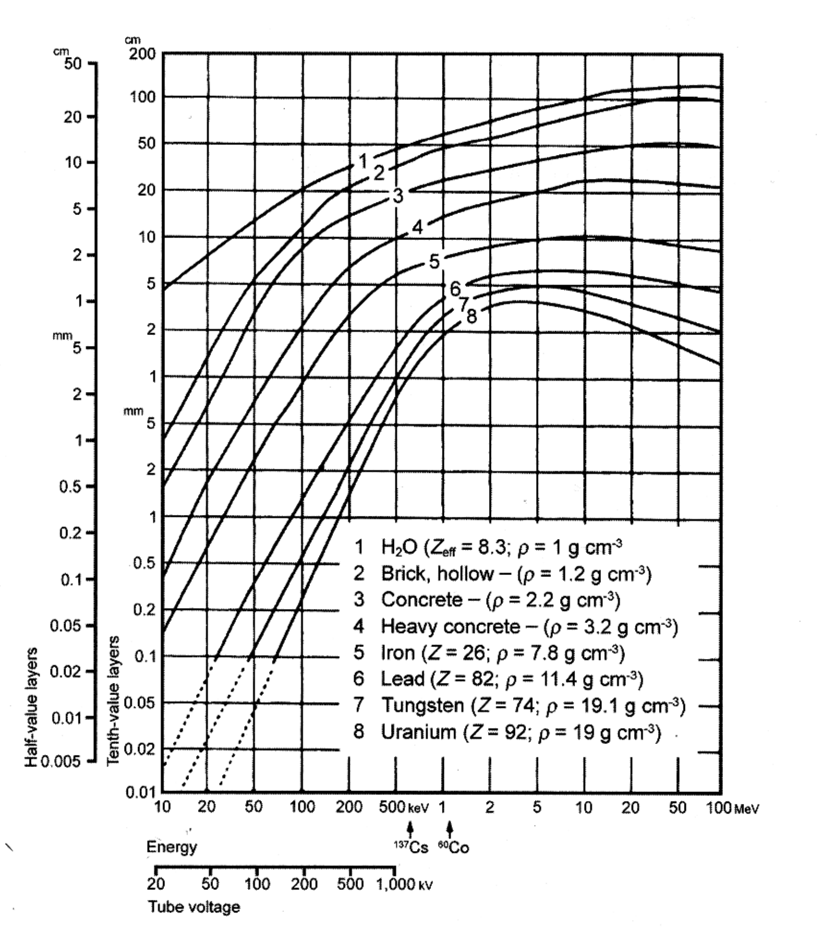
2) For patient as a source, the situation is more uncertain!!!



Barrier Transmission B for NM

- As in all shielding problems, must use broad-beam attenuation coefficients.
- NCRP 49 has values for Pb, Fe, concrete, but only for a few isotopes (Cs-137, Au-198, Ir-192,Co-60).
- For lead, the recent Smith and Stabin paper (previous slide) is very useful.
- For other materials, data is limited and must resort to attenuation coefficient tables and build-up tables for each gamma energy

Finding the Transmission Data



Wachsmann and Drexler in NCRP 151

Wachsmann and Drexler curves (1975), found in NCRP 151.

Various sources for buildup factors at energy E and thickness x:

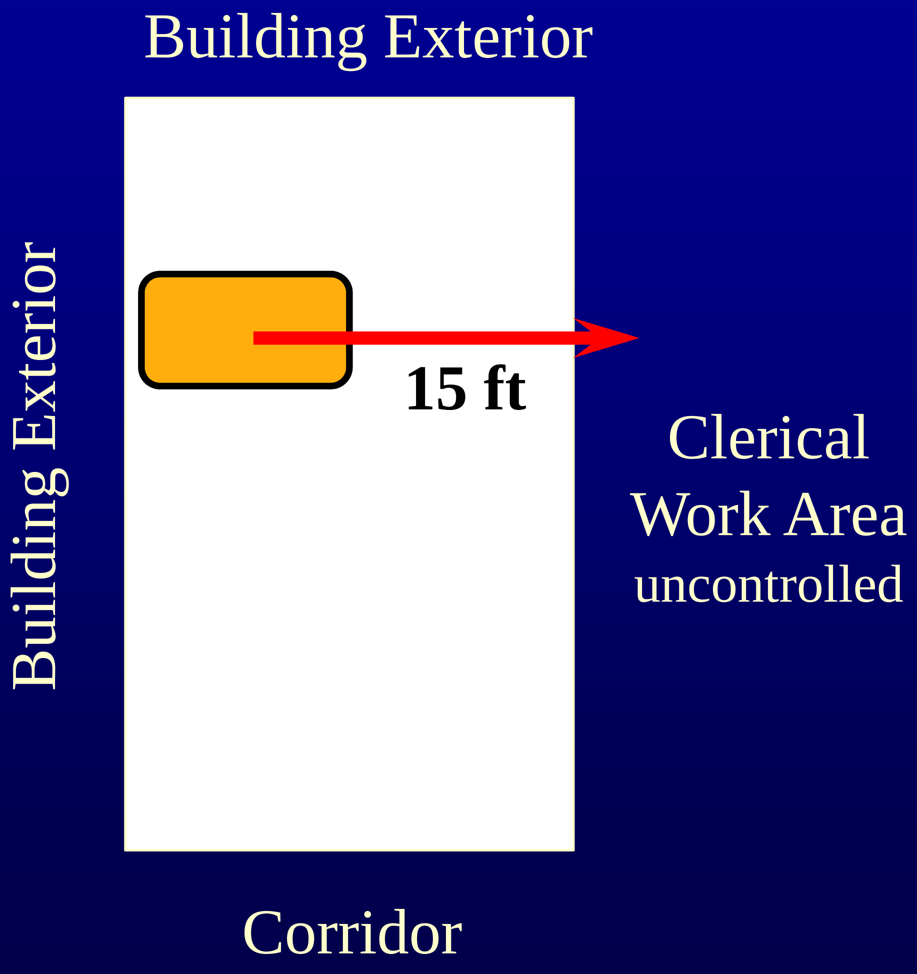
$$B = X/X_0 = BU(E,x) * e^{-ux}$$

Watch out for build-up factors -- some are for realistic shielding configurations (Kharrati for Pb), but conventional BU is for infinite media (which will show backscatter!) (Shimizu, ANS 6.4.3)

Shielding Example: I-131 Hospitalization

A thyroid cancer ablation patient must be held for approximately 24-48 hours after treatment with 150 mCi I-131 to meet release criteria (1 cases/wk). Is shielding required for the work area?

Look at how modeling of effective half-life affects requirement.



I-131 Example Setup

$$B = \frac{P}{T} \cdot \frac{d^2}{(\Gamma A_0 F_{tot} R_t t) N}$$

Half-life of I-131 is 8.04 d; NUREG 1556 indicates that for first 8 hours, should use physical half-life without correction for biological elimination.

Γ = 0.052 (uGy/hr)/MBq at 1 m (Smith and Stabin value, converted to air kerma rate)

P = 20 uSv (uncontrolled)

T = 1 (as far as we know)

d = 15 ft

N = 1 per week

A_0 = 150 mCi

t = 8 hours (shift length for protected personnel, assume treatment started at beginning of shift)

F_{tot} = 1 (no appreciable decay before entering room)

R_t = 0.984 (no appreciable decay during the shift)

I-131 Example Results

Two Bs or not two Bs,
that is your choice.

$$B = \frac{P}{T} \cdot \frac{d^2}{(\Gamma A_0 F_{tot} R_t t) N}$$

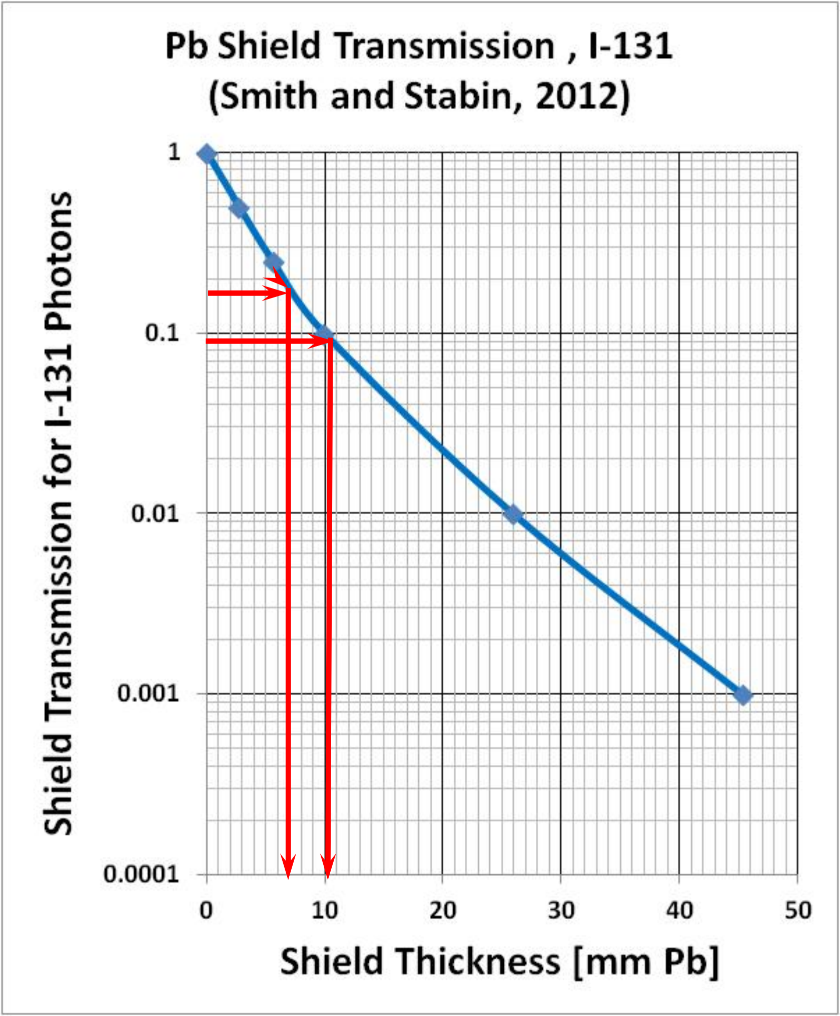
NUREG 1556 I-131 two compartment washout model allows 95% of retained I-131 to be assigned T_{eff} = 0.32 day and the other 5% to be assigned T_{eff} = 7.3 day after the initial 8 hours post treatment

1) Check for initial air kerma rate at the unshielded location. It is 14 uGy/hr (1.4 mrad/hr), less than 20 uSv in any one hour limit

2) Assuming the patient is released before the shift comes back on duty, B = 0.184 to protect to 20 uSv/wk.

3) If a second personnel exposure (shift starting 24 hr after treatment) can occur, then B must be decreased to B =0.096 if only physical decay is considered. If NUREG 1556 washout model is used, B would be decreased to B= 0.154 [either approach done by calculating total kerma, then B]

Getting the Shield Thickness

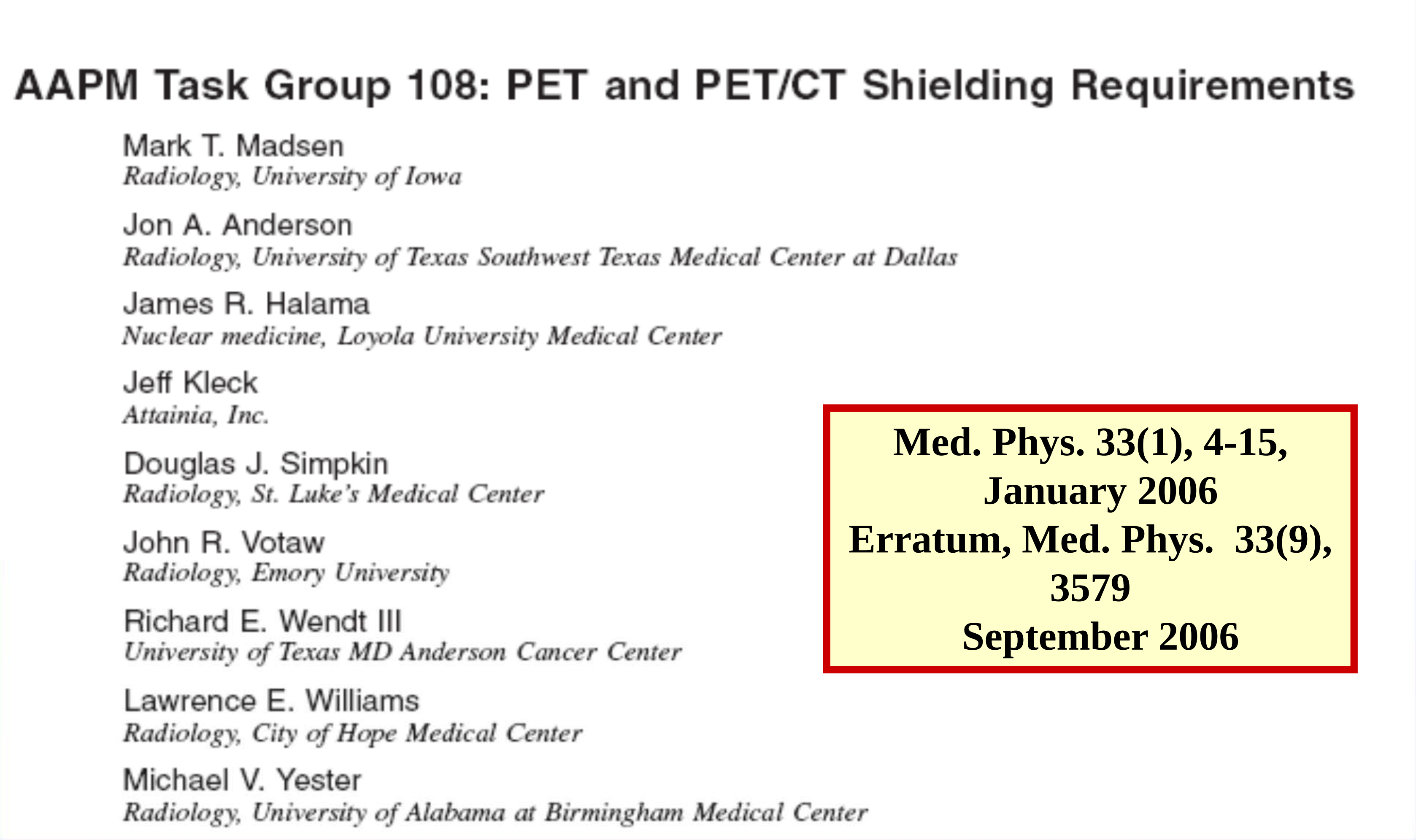


B = 0.184 => x = 7.04 mm Pb
= 5/16" Pb
(single day scenario)

B = 0.153 => x = 7.92 mm Pb
= 5/16" Pb
(two day with washout)

B = 0.096 => x = 10.2 mm Pb
= 7/16" Pb
(two day, no addn'l washout)

PET Shielding in More Detail



AAPM Task Group 108: PET and PET/CT Shielding Requirements

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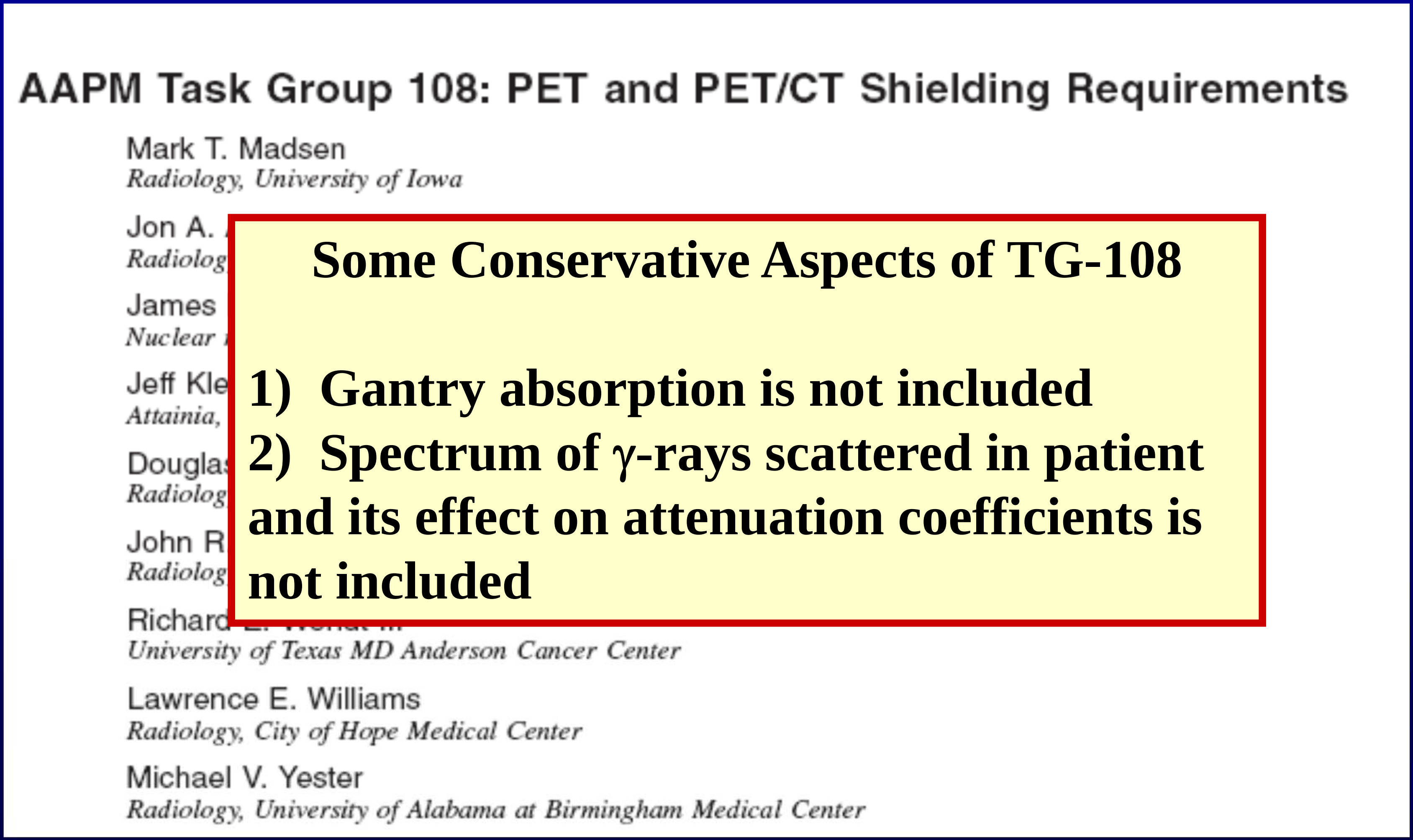
Med. Phys. 33(1), 4-15, January 2006
Erratum, Med. Phys. 33(9), 3579
September 2006

PET Shielding: AAPM TG-108 Approach



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Some Conservative Aspects of TG-108

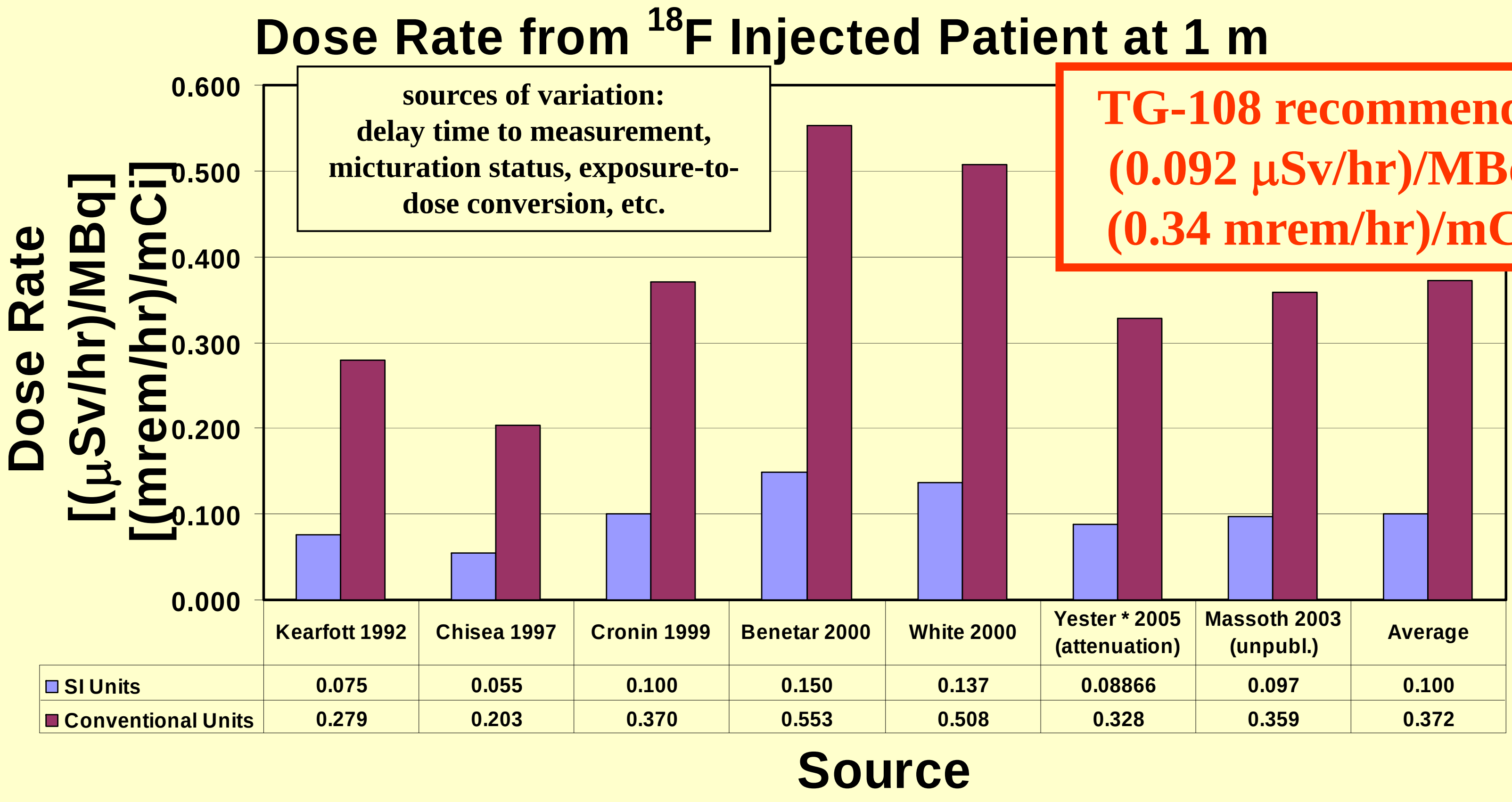
1) **Gantry absorption is not included**
2) **Spectrum of γ-rays scattered in patient and its effect on attenuation coefficients is not included**

Dose Rate Constants Listed by TG108

^{18}F Rate Constants	SI Units		Conventional Units	
Exposure Rate Constant	15.5	(μR/hr) m^2/MBq	0.5735	(mR/hr) m^2/mCi
Air Kerma Rate Constant	0.134	(μSv/hr) m^2/MBq	0.4958	(mrem/hr) m^2/mCi
Effective Dose Equivalent (ANS-1991)	0.143	(μSv/hr) m^2/MBq	0.5291	(mrem/hr) m^2/mCi
Tissue Dose Constant	0.148	(μSv/hr) m^2/MBq	0.5476	(mrem/hr) m^2/mCi
Deep Dose Equivalent (ANS-1977)	0.183	(μSv/hr) m^2		
Maximum Dose (ANS-1977)	0.188	(μSv/hr) m^2		

TG-108 recommends
0.143 (μSv/hr)/MBq
0.53 (mrem/hr)/mCi
for F-18 bare source

The F^{18} Injected Patient as a Source



	Kearfott 1992	Chisea 1997	Cronin 1999	Benetar 2000	White 2000	Yester * 2005 (attenuation)	Massoth 2003 (unpubl.)	Average
🟦 SI Units	0.075	0.055	0.100	0.150	0.137	0.08866	0.097	0.100
🟥 Conventional Units	0.279	0.203	0.370	0.553	0.508	0.328	0.359	0.372

sources of variation:
delay time to measurement,
micturation status, exposure-to-
dose conversion, etc.

TG-108 recommends
(0.092 μSv/hr)/MBq
(0.34 mrem/hr)/mCi

about 20% of dose will be in bladder after 1-2 hours;TG108 uses 15%

Simplified TG108 Formalism

B, the required barrier transmission factor, can be calculated as

Uptake Room:

$$B = \frac{10.9 * P[\mu Sv] * d[m]^2}{T * N_w * (A_0[MBq] * t_U[hr] * R_{tU})}$$

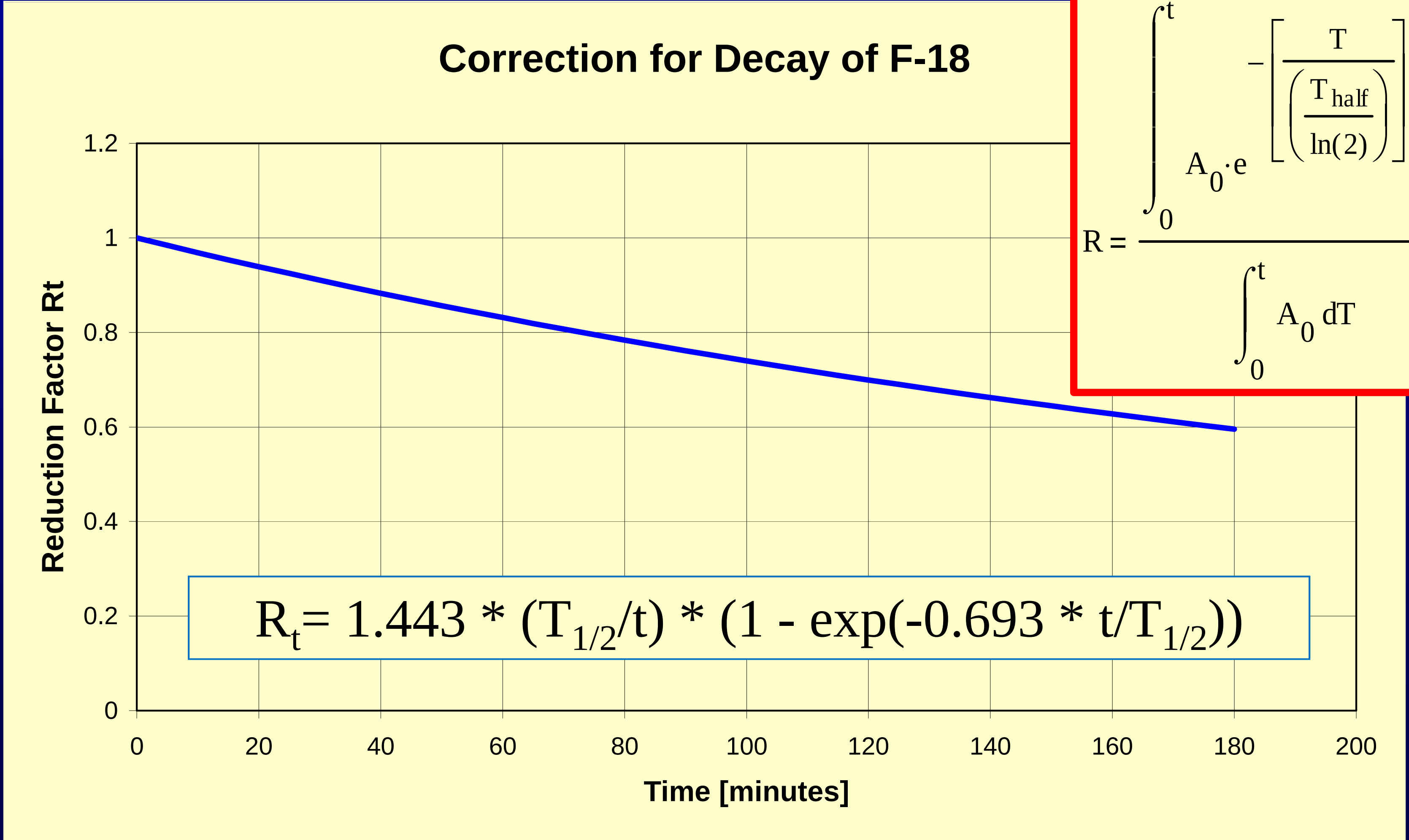
10.9 is $1/\Gamma$ in $(hr/\mu Sv)(MBq/m^2)$;
F_{tot} = 1 (no physical decay prior to injection, no elimination)
R_{tU} = reduction factor for uptake time t_U

Scan Bay:

$$B = \frac{12.8 * P[\mu Sv] * d[m]^2}{T * N_w * (A_0[MBq] * F_U * t_I[hr] * R_{tI})}$$

12.8 includes Γ and the effects of voiding 15% of injected activity before scan
$F_U = \exp(-0.693 t_U / T_{1/2})$, the physical decay of the isotope before the scan

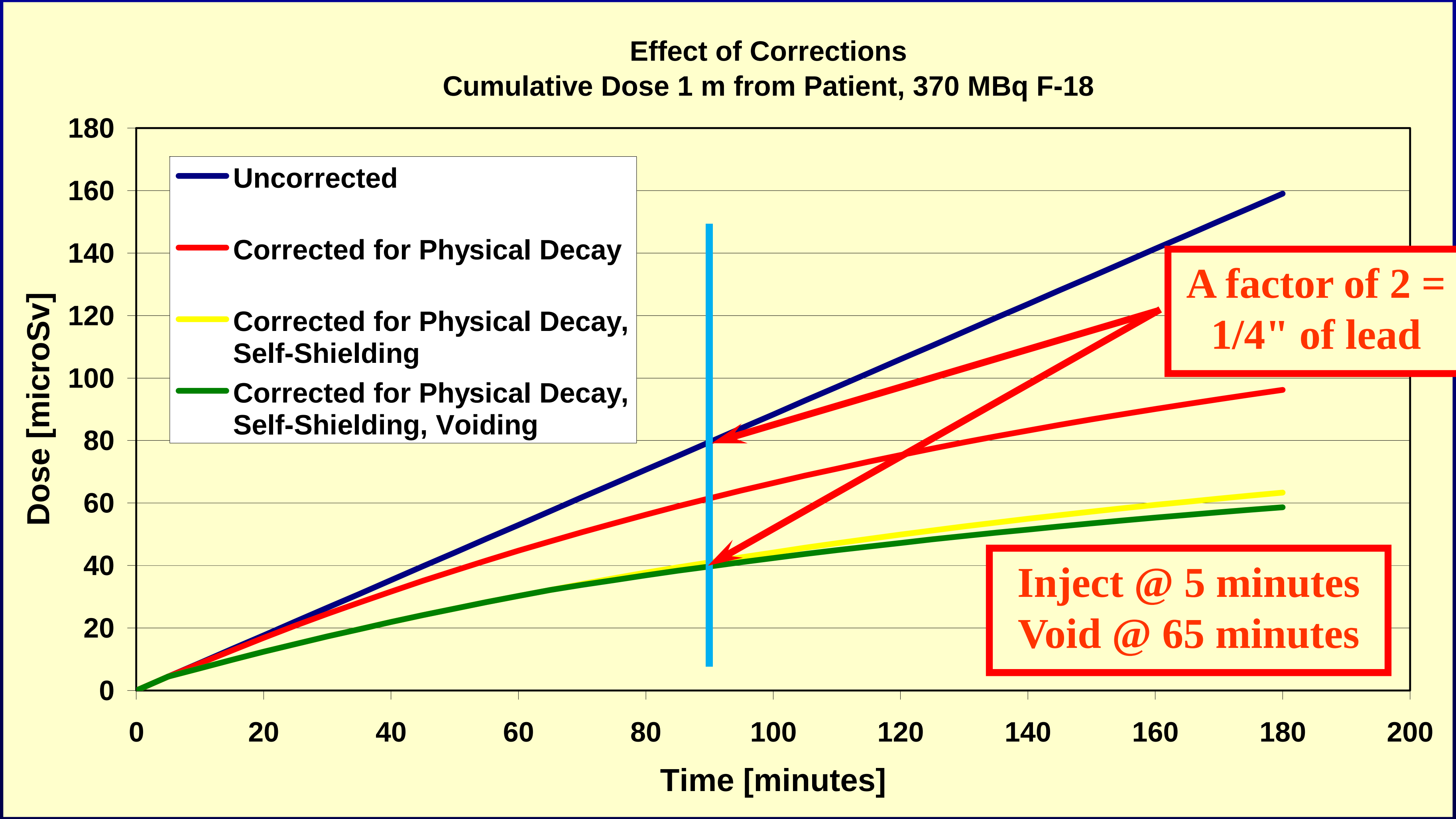
R_t for PET: Significant Correction for Decay



$$R = \frac{\int_0^t A_0 \cdot e^{-\left[\frac{T}{\left(\frac{T_{half}}{\ln(2)}\right)}\right]} dT}{\int_0^t A_0 \, dT}$$

$$R_t = 1.443 * (T_{1/2}/t) * (1 - \exp(-0.693 * t/T_{1/2}))$$

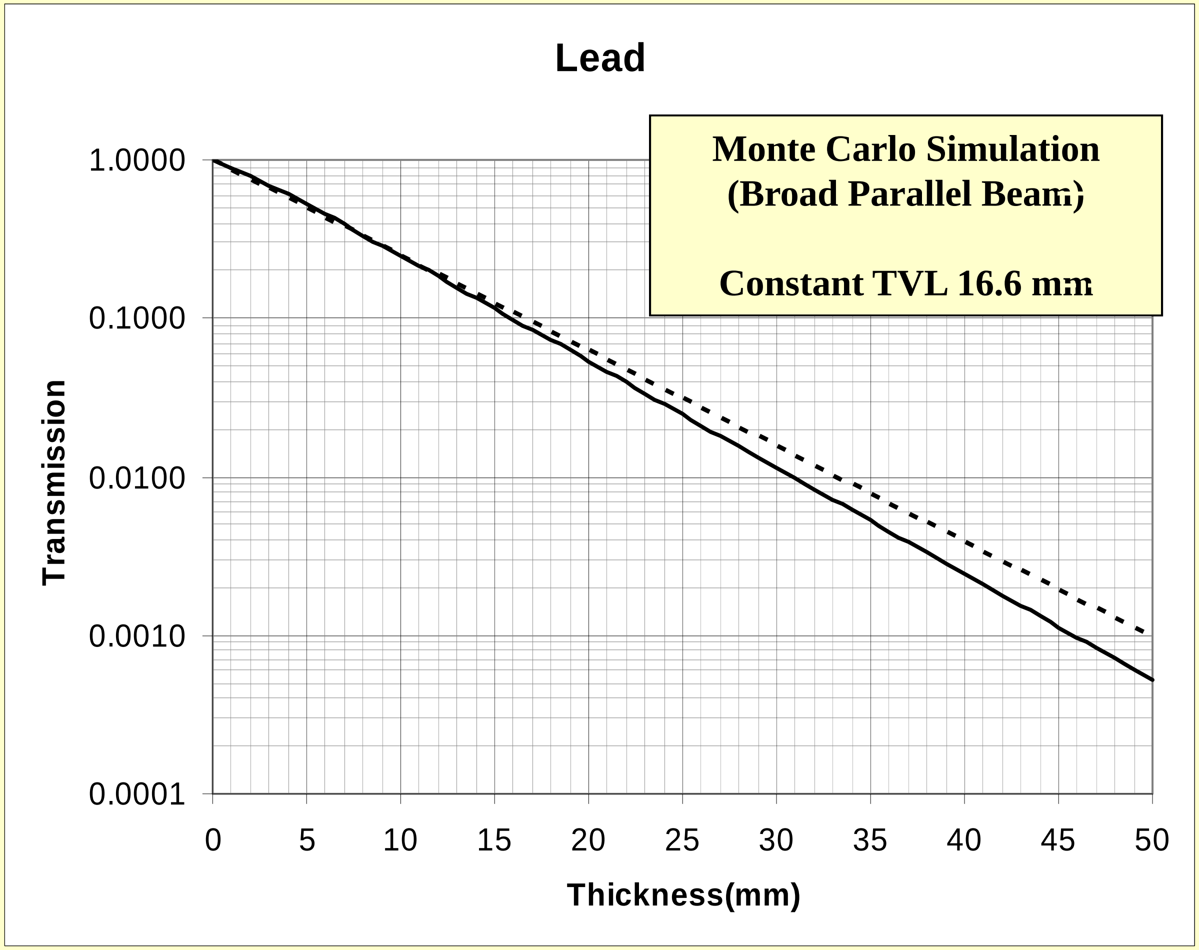
NET Effect of Decay, Self-Shielding, Voiding



A factor of 2 = 1/4" of lead

Inject @ 5 minutes
Void @ 65 minutes

Barrier Transmission to Barrier Thickness



Monte Carlo calculations by Douglas Simpkin (2004)

$$x(B) := \frac{1}{\alpha\cdot\gamma}\cdot\ln\left[\frac{\left(B^{-\gamma}+\frac{\beta}{\alpha}\right)}{1+\frac{\beta}{\alpha}}\right]$$

Curves and fitting parameters for iron and concrete are also found in the report

Fitting Parameters are Provided for B,x

For PET
(511 keV)

Archer Parameters

	α [cm^{-1}]	β [cm^{-1}]	γ
Lead	**1.543**	**-0.4408**	**2.136**
Concrete	**0.1539**	**-0.1161**	**2.0752**
Iron	**0.5704**	**-0.3063**	**0.6326**

$$B(x) = \left[\left(1+\frac{\beta}{\alpha}\right)\cdot e^{\alpha\cdot\gamma\cdot x}-\frac{\beta}{\alpha}\right]^{\frac{-1}{\gamma}}$$

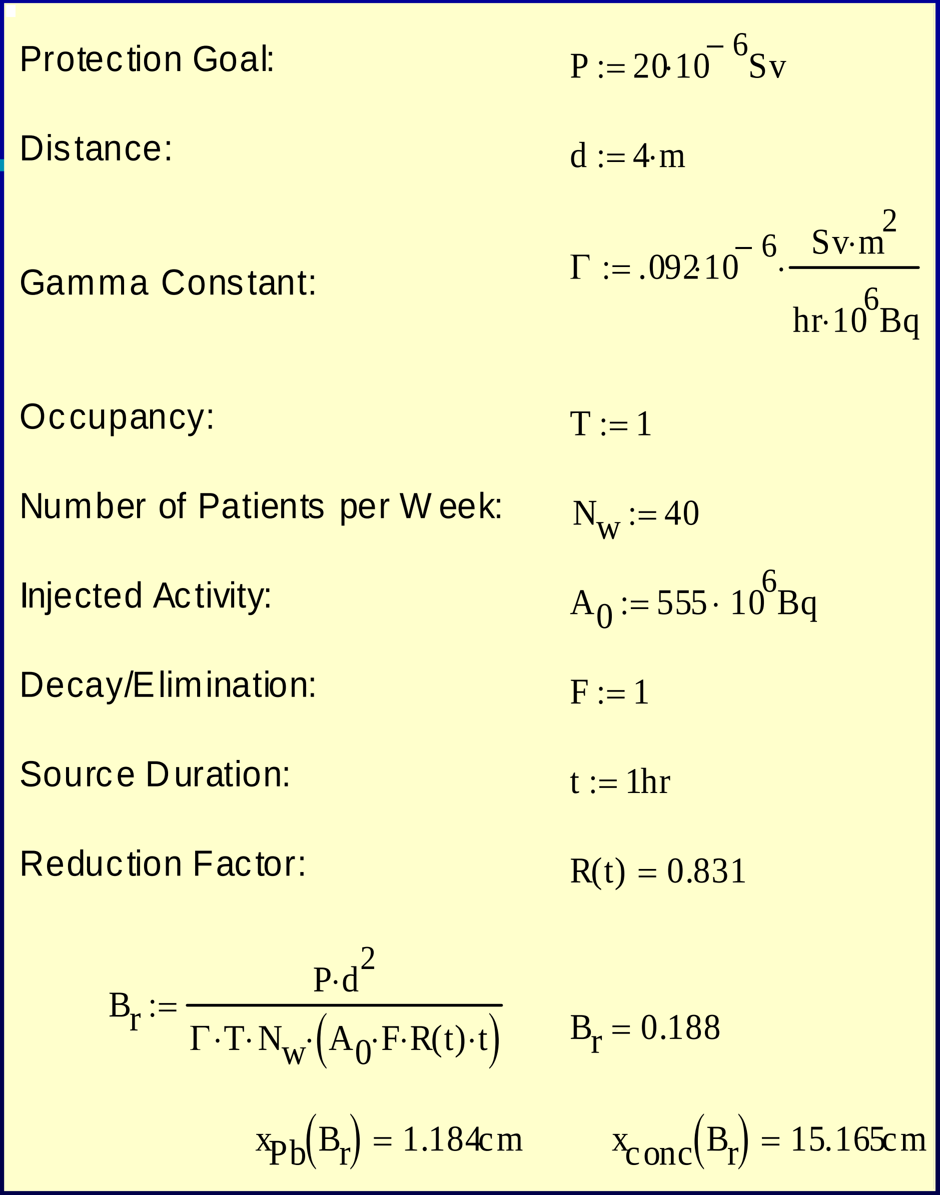
$$x(B) = \frac{1}{\alpha\cdot\gamma}\cdot\ln\left[\frac{\left(B^{-\gamma}+\frac{\beta}{\alpha}\right)}{1+\frac{\beta}{\alpha}}\right]$$

An Uptake Room

An uncontrolled area with 100% occupancy is 4m from the patient. 40 patients a week are injected in this room with 555 MBq (15 mCi) of FDG and held for a 1hr uptake time.

How much shielding is needed?

Ans: 1.2 cm of Pb or 15.2 cm of concrete



Protection Goal:	$P := 20 \cdot 10^{-6} \mathrm{Sv}$
Distance:	$d := 4 \cdot \mathrm{m}$
Gamma Constant:	$\Gamma := .092 \cdot 10^{-6} \cdot \frac{\mathrm{Sv} \cdot \mathrm{m}^2}{\mathrm{hr} \cdot 10^6 \mathrm{Bq}}$
Occupancy:	$T := 1$
Number of Patients per Week:	$N_W := 40$
Injected Activity:	$A_0 := 555 \cdot 10^6 \mathrm{Bq}$
Decay/Elimination:	$F := 1$
Source Duration:	$t := 1\mathrm{hr}$
Reduction Factor:	$R(t) = 0.831$

$$B_r := \frac{P \cdot d^2}{\Gamma \cdot T \cdot N_W \cdot \left(A_0 \cdot F \cdot R(t) \cdot t\right)} \qquad B_r = 0.188$$

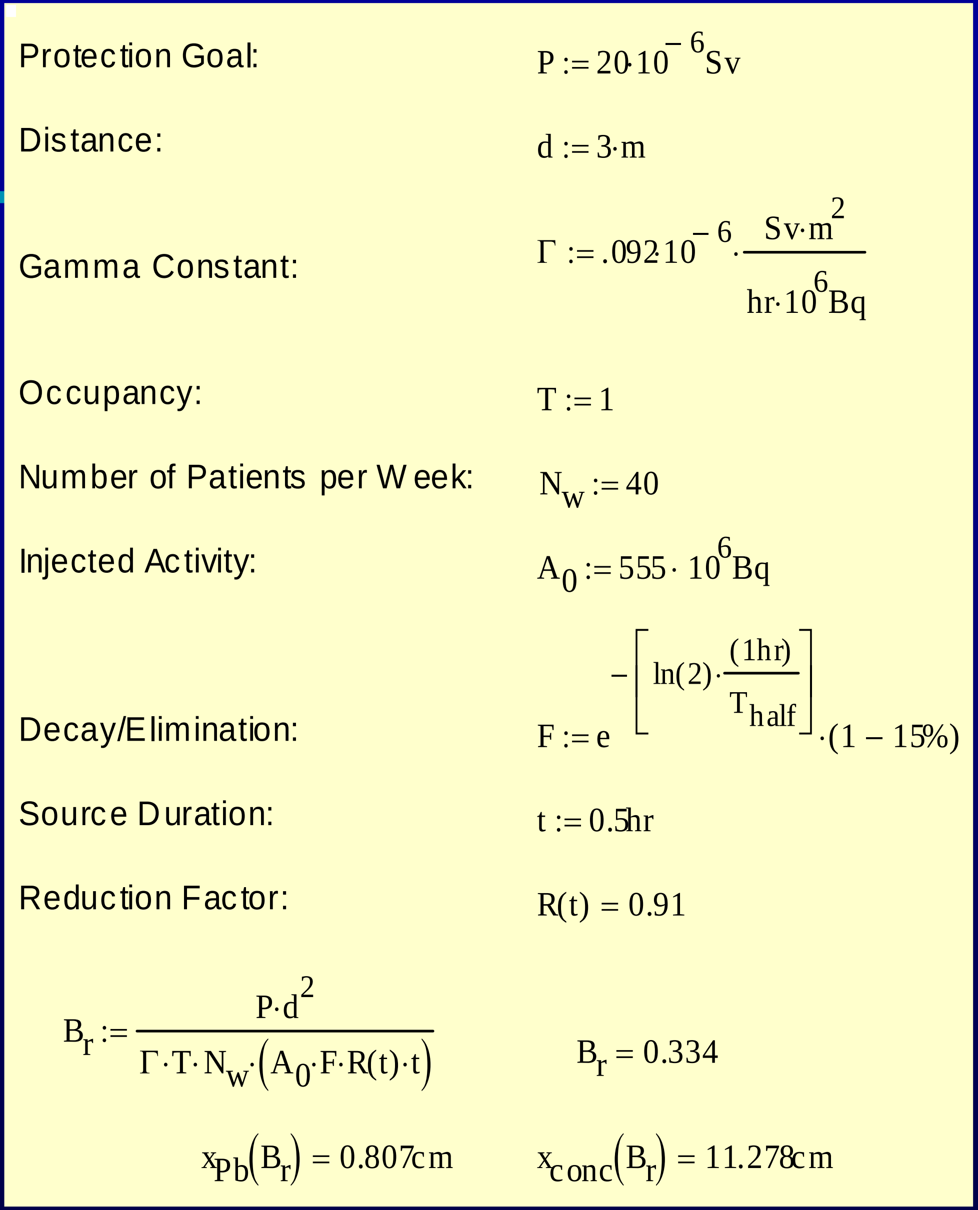
$$x_{Pb}(B_r) = 1.184\mathrm{cm} \qquad x_{conc}(B_r) = 15.165\mathrm{cm}$$

A Scan Bay

An uncontrolled area with 100% occupancy is 3m from the patient. 40 pts/week, 555 MBq (15 mCi) FDG/pt, 1hr uptake time. Patients void (15% of the dose) at 1 hr. 30 minutes in scan bay.

How much shielding ?

Ans: 0.8 cm of Pb or 11.3 cm of concrete



Protection Goal:	$P := 20\cdot 10^{-6}\,Sv$
Distance:	$d := 3\cdot m$
Gamma Constant:	$\Gamma := .092\cdot 10^{-6}\cdot\frac{Sv\cdot m^2}{hr\cdot 10^6 Bq}$
Occupancy:	$T := 1$
Number of Patients per Week:	$N_w := 40$
Injected Activity:	$A_0 := 555\cdot 10^6 Bq$
Decay/Elimination:	$F := e^{-\left[\ln(2)\cdot\frac{(1hr)}{T_{half}}\right]}\cdot(1-15\%)$
Source Duration:	$t := 0.5hr$
Reduction Factor:	$R(t) = 0.91$

$$B_r := \frac{P\cdot d^2}{\Gamma\cdot T\cdot N_w\cdot\left(A_0\cdot F\cdot R(t)\cdot t\right)} \qquad B_r = 0.334$$

$$x_{Pb}(B_r) = 0.807cm \qquad x_{conc}(B_r) = 11.278cm$$

Site Evaluation for PET Shielding

Uses of adjacent spaces (including above and below) and occupancy factors for them

 # patients/week
isotopes to be used, activity/pt
types of PET studies to be performed (brains, WB, cardiac)
uptake time and scan time for this equipment/study/center

dose delivery schedule (once a day?, multiples?); maximum activity on hand

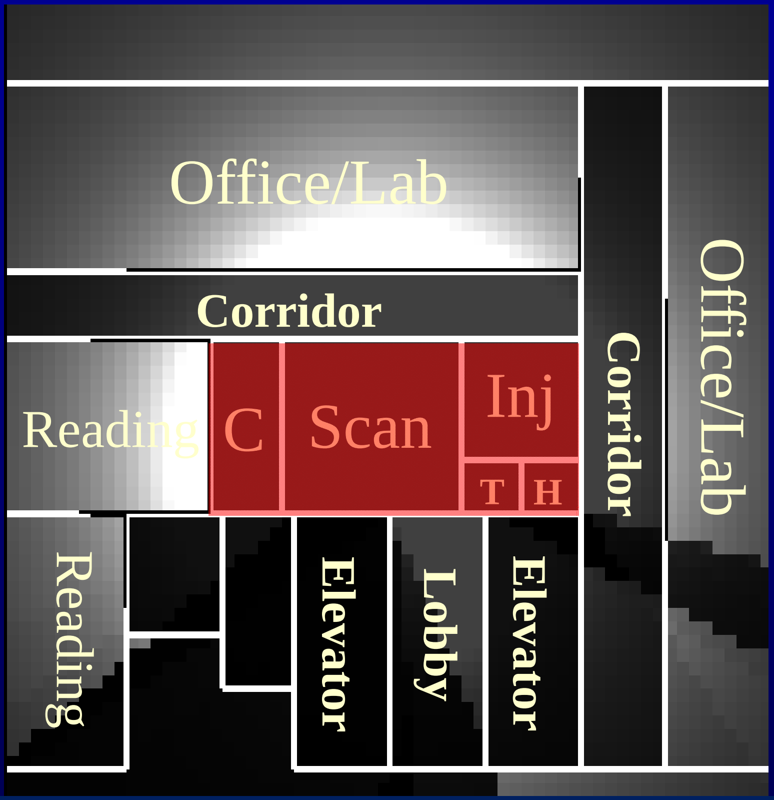
CT technique factors (kVp, mAs/scan [depends of # beds])
 # scans per patient (additional diagnostic scans?)
amount of "non-PET" CT workload expected

General Suggestions

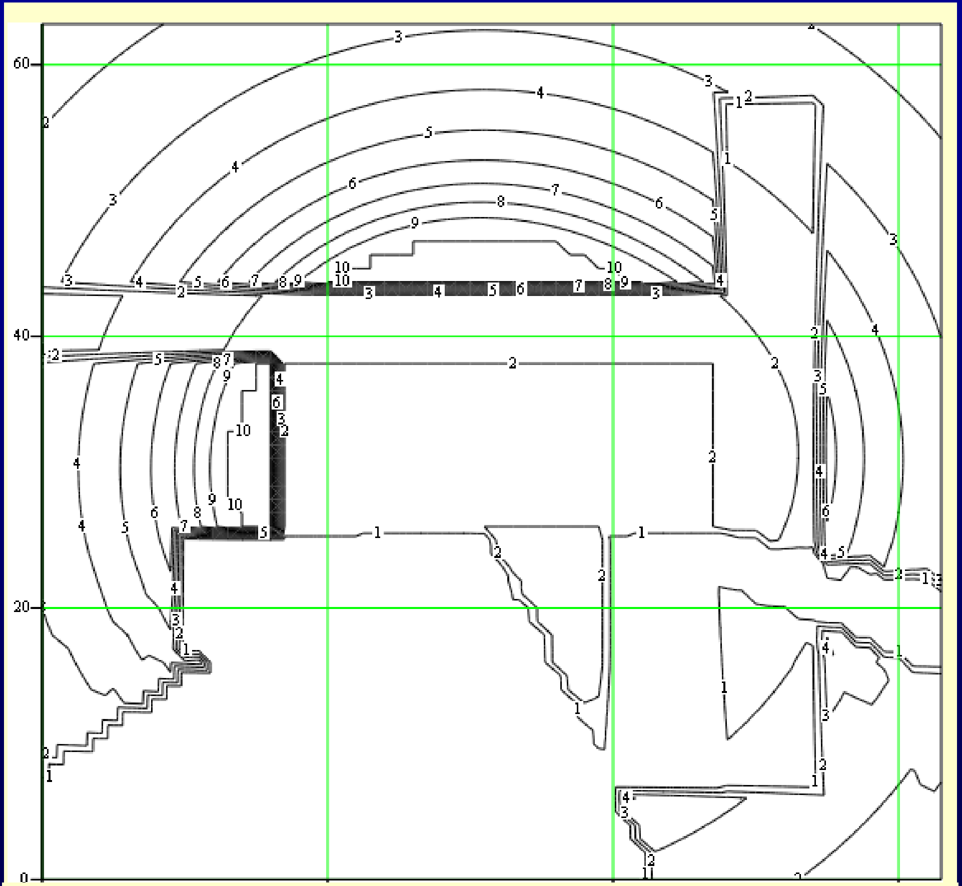
- At each point, include all principal sources
  - Patient in uptake room
  - Patient in scanner bay
  - Patient in hot toilet
- Spread the lead (multiple thin vs single thick)
- Avoid doors with more than 1/8" Pb
- Planning beforehand to separate hot areas (patient uptake rooms) from uncontrolled areas will pay off!

  (Pasciak and Jones -- this month's Med Phys. looks at optimization routines for PET shielding)

Example: Grid Calculation Before Shielding

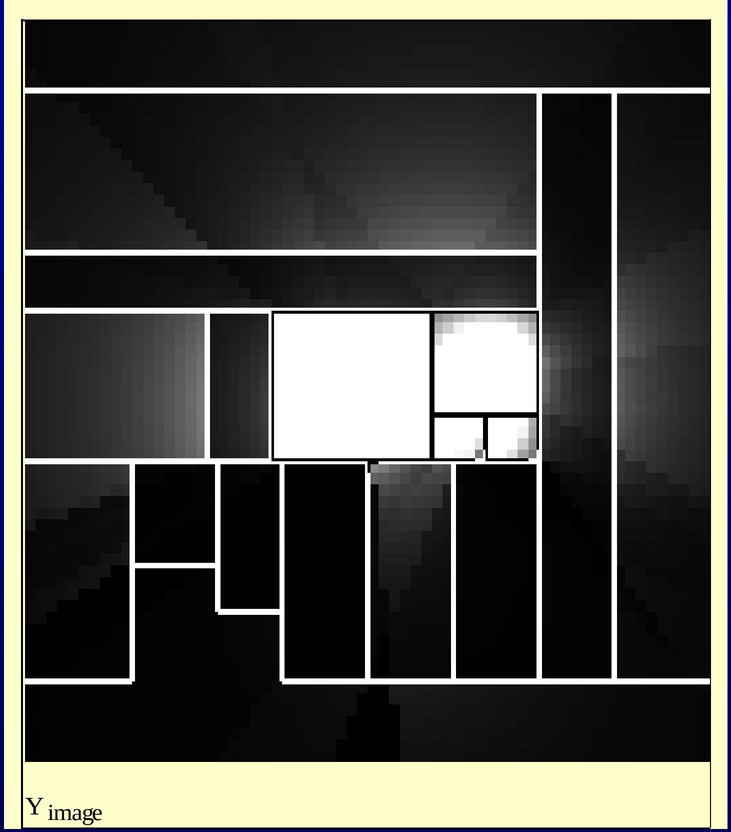


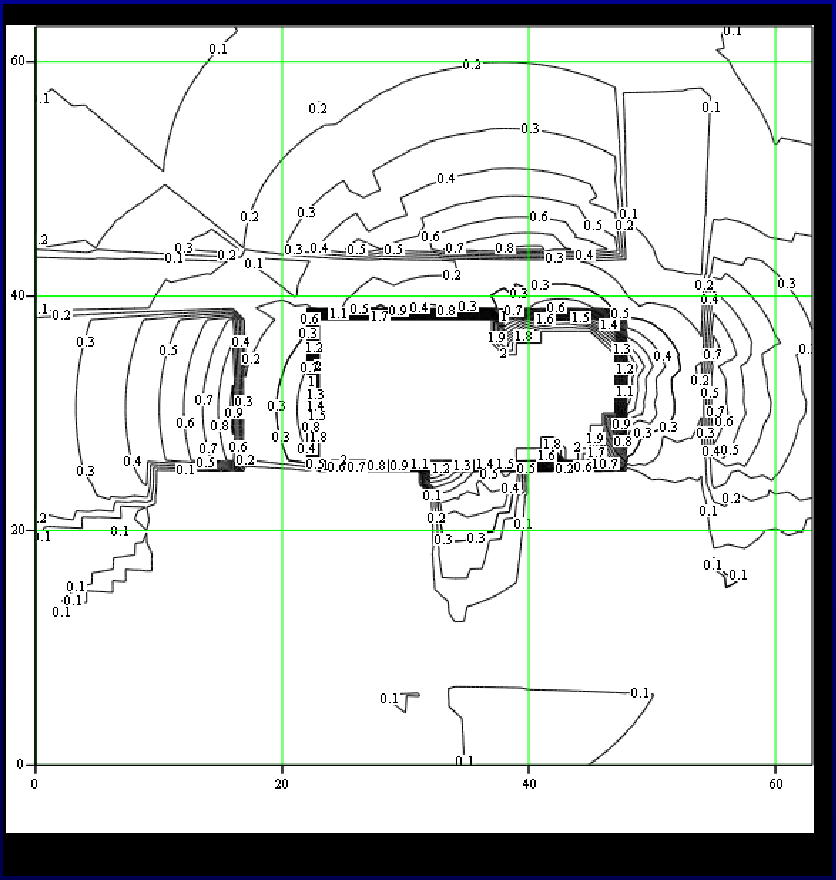
Sources: Injection room, HL, HWC, Scanner, CT, Cal Source 4 pts/day, 1 hr in uptake, 2 hrs in scan room



Ratio of calculated dose to target dose, adjusted for occupancy

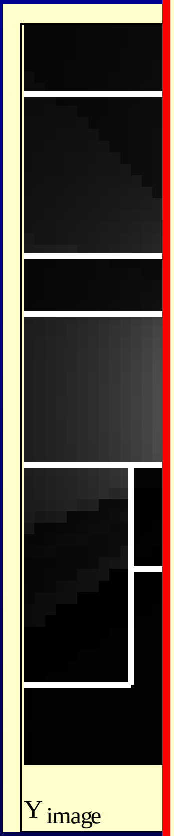
Example Grid Calculation, After Shielding





No shielding in walls in excess of 5/16" Pb; did require ceiling, floor shielding. Was not necessary to run "box" to ceiling.

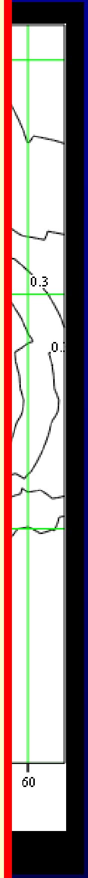
Example Grid Calculation, After Shielding



OOPS's happen with complicated schemes: Both floor and ceiling needed lead, installed as lead sheet bonded to plywood panels and held in brackets fastened to structural web, but different thickness for ceiling, floor.

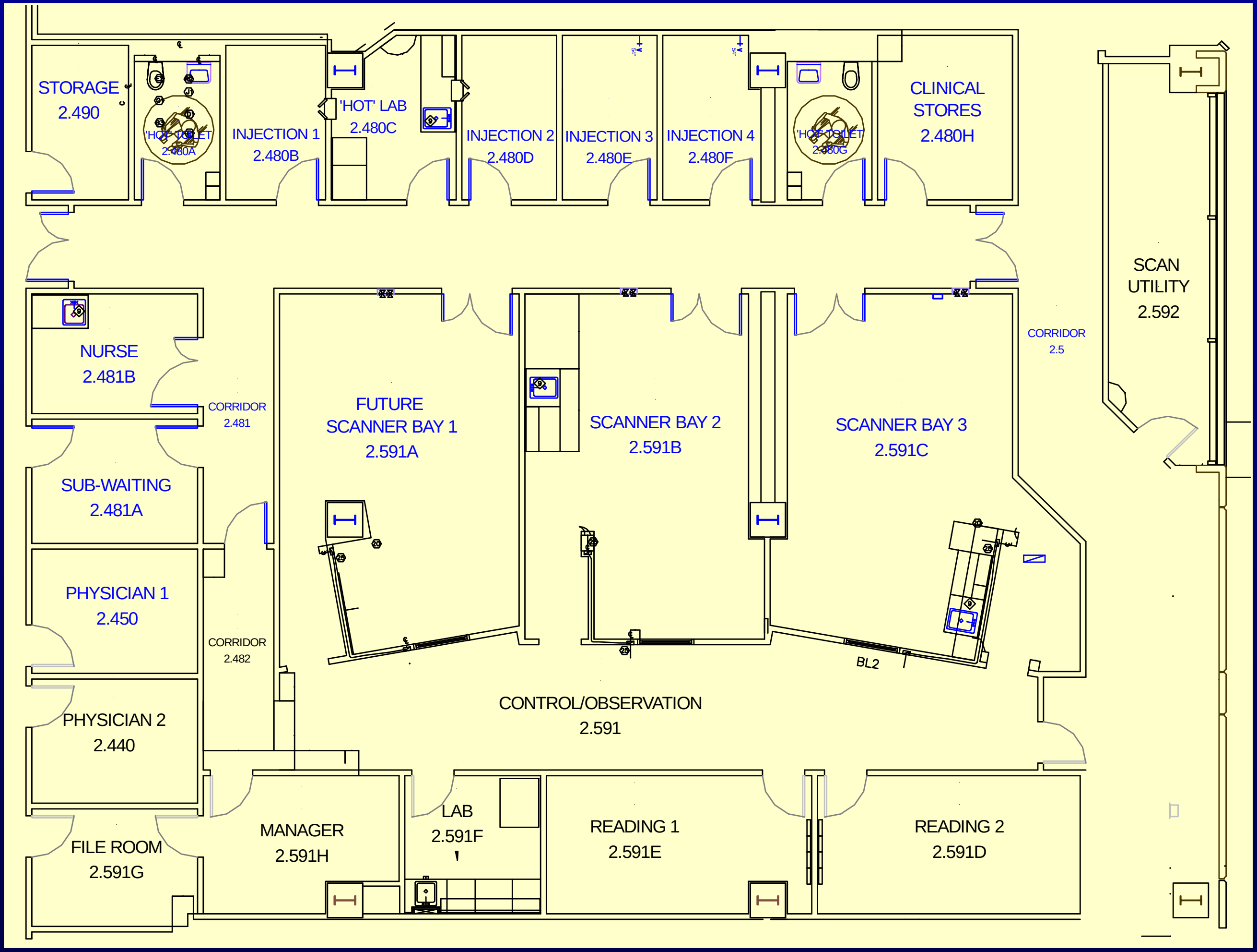
The contractor switched them in spite of drawings and well-labeled pallets; did not call for inspection until after ductwork, electricals in.

A very skinny construction worker was needed for the fix



No shielding in walls in excess of 5/16" Pb, did require ceiling, floor shielding. Was not necessary to run "box" to ceiling.

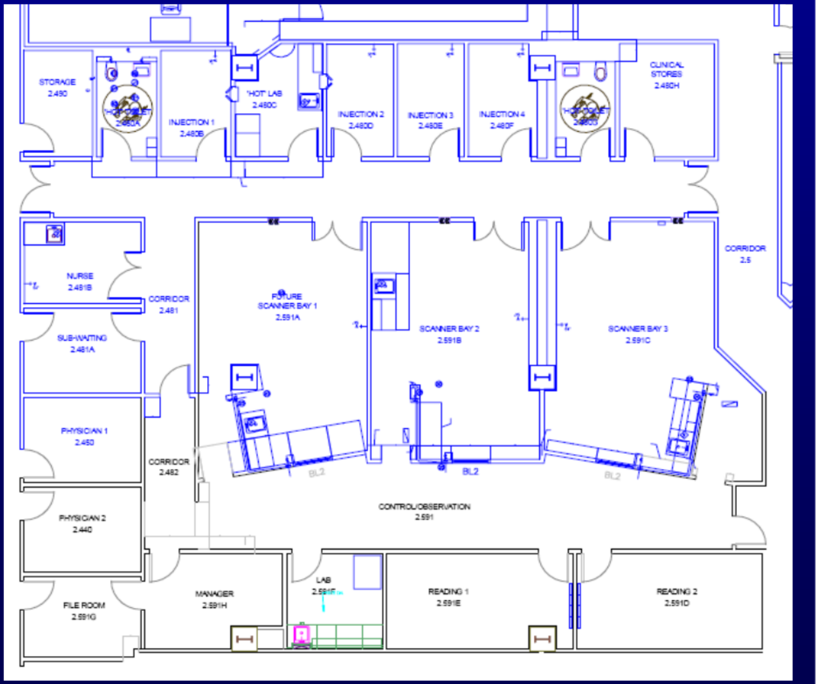
University Medical Center PET Facility



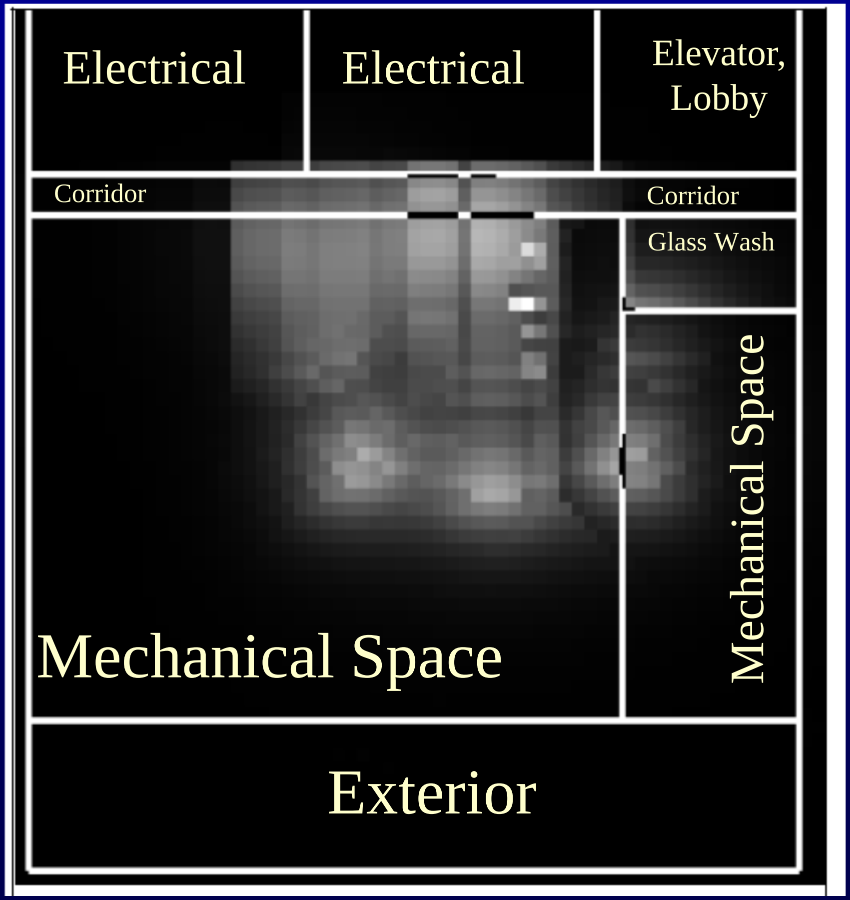
3 Bays, 4 Uptake Rooms. Overall design: No lead in excess of 3/8". Shell space beyond north wall of injection rooms, hot lab shielded with 16" of dry-laid, full-density concrete block

Considerations Above and Below

Duct penetrations in ceiling required separate shielding.



Floor Plan

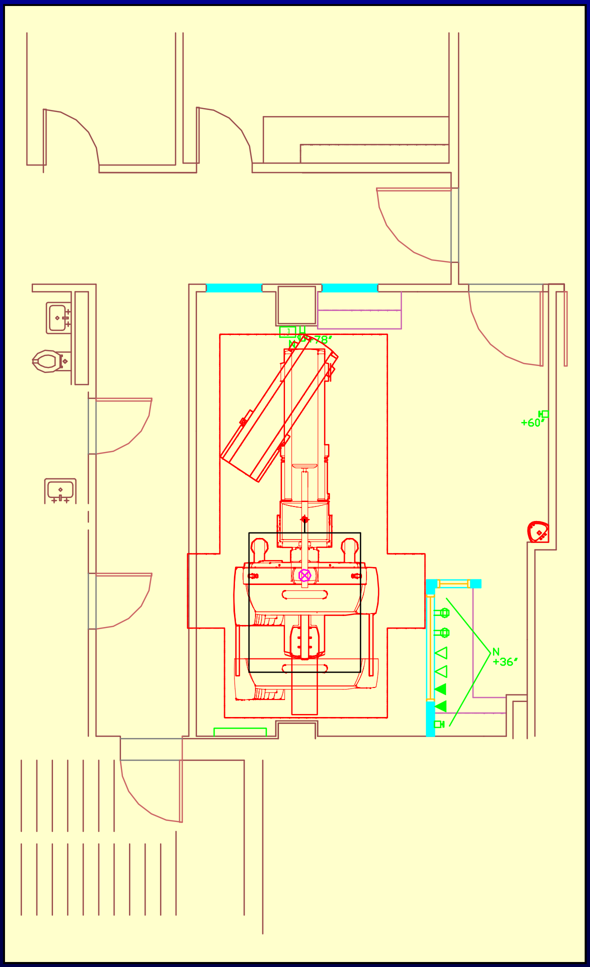


Relative Dose Map on Floor Above

Shielding for SPECT/CT

- Need to know workload (patients per week, isotopes used, activities per patient, CT techniques and usage, etc.)
- CT will often be the main determinant for shielding, but presence of isotope load may require more lead than CT calculation shows.
- Calculating barrier transmission for other materials than Pb may present problems; may be useful to make very conservative assumptions
- Uncontrolled spaces above and below may require attention

An Example SPECT/CT



8 pts/day

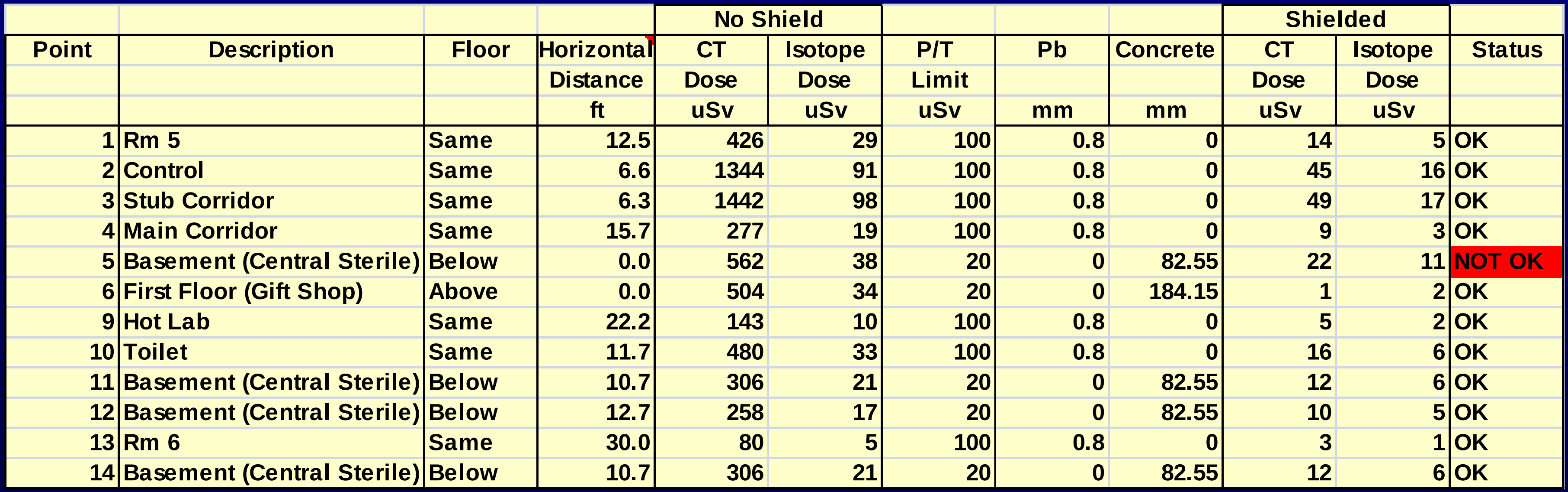
- 4 MDP (27 mCi Tc-99m)
- 2 renal (16 mCi Tc-99m)
- 1 Octreotide (6 mCi In-111)
- 1 Ga-67 (10 mCi);

4 studies w CT,

- 150 mAs
- 130 kVp
- p = 1
- 66 cm length

Shielding for SPECT/CT

Spreadsheet calculates distances, attenuations, doses

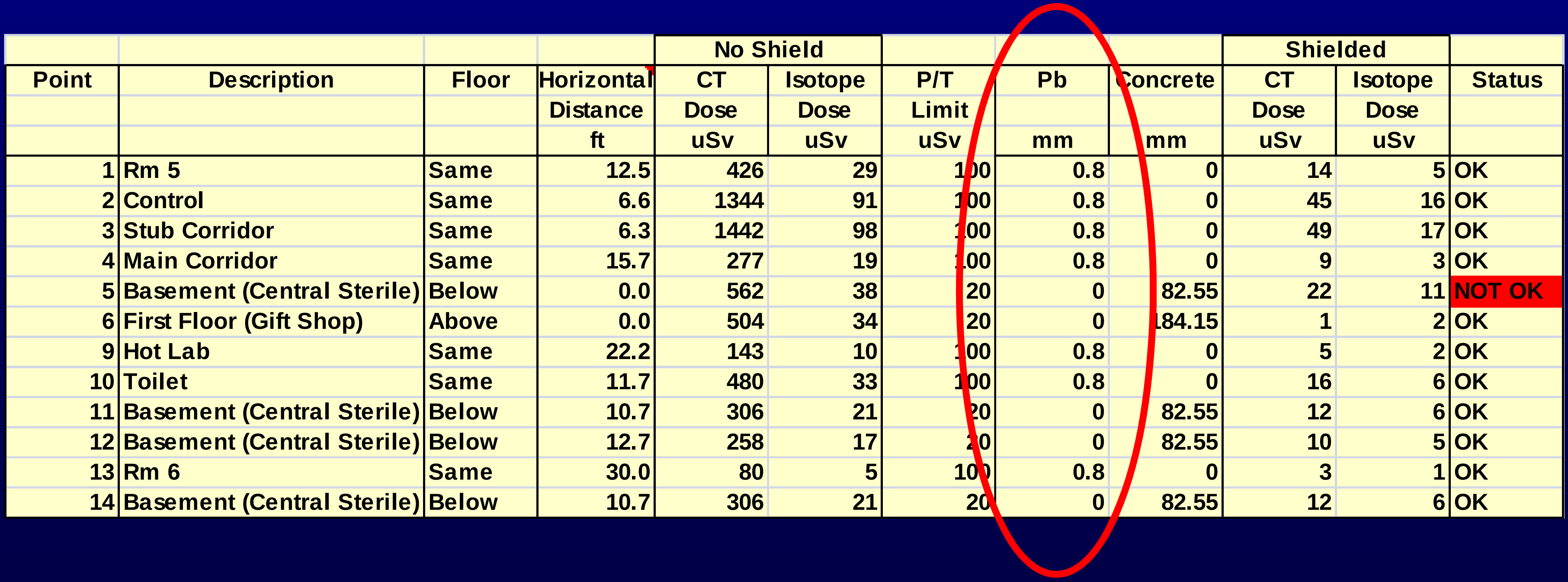


				No Shield					Shielded		
Point	Description	Floor	Horizontal Distance ft	CT Dose uSv	Isotope Dose uSv	P/T Limit uSv	Pb mm	Concrete mm	CT Dose uSv	Isotope Dose uSv	Status
1	Rm 5	Same	12.5	426	29	100	0.8	0	14	5	OK
2	Control	Same	6.6	1344	91	100	0.8	0	45	16	OK
3	Stub Corridor	Same	6.3	1442	98	100	0.8	0	49	17	OK
4	Main Corridor	Same	15.7	277	19	100	0.8	0	9	3	OK
5	Basement (Central Sterile)	Below	0.0	562	38	20	0	82.55	22	11	NOT OK
6	First Floor (Gift Shop)	Above	0.0	504	34	20	0	184.15	1	2	OK
9	Hot Lab	Same	22.2	143	10	100	0.8	0	5	2	OK
10	Toilet	Same	11.7	480	33	100	0.8	0	16	6	OK
11	Basement (Central Sterile)	Below	10.7	306	21	20	0	82.55	12	6	OK
12	Basement (Central Sterile)	Below	12.7	258	17	20	0	82.55	10	5	OK
13	Rm 6	Same	30.0	80	5	100	0.8	0	3	1	OK
14	Basement (Central Sterile)	Below	10.7	306	21	20	0	82.55	12	6	OK

Shielding for SPECT/CT

8 pts/day (4 MDP (27 mCi Tc-99m), 2 renal (16 mCi Tc-99m), 1 Octreotide (6 mCi In-111), 1 Ga-67 (10 mCi); 4 studies w CT, 150 mAs, 130 kVp, 66 cm length

Spreadsheet calculates distances, attenuations, doses



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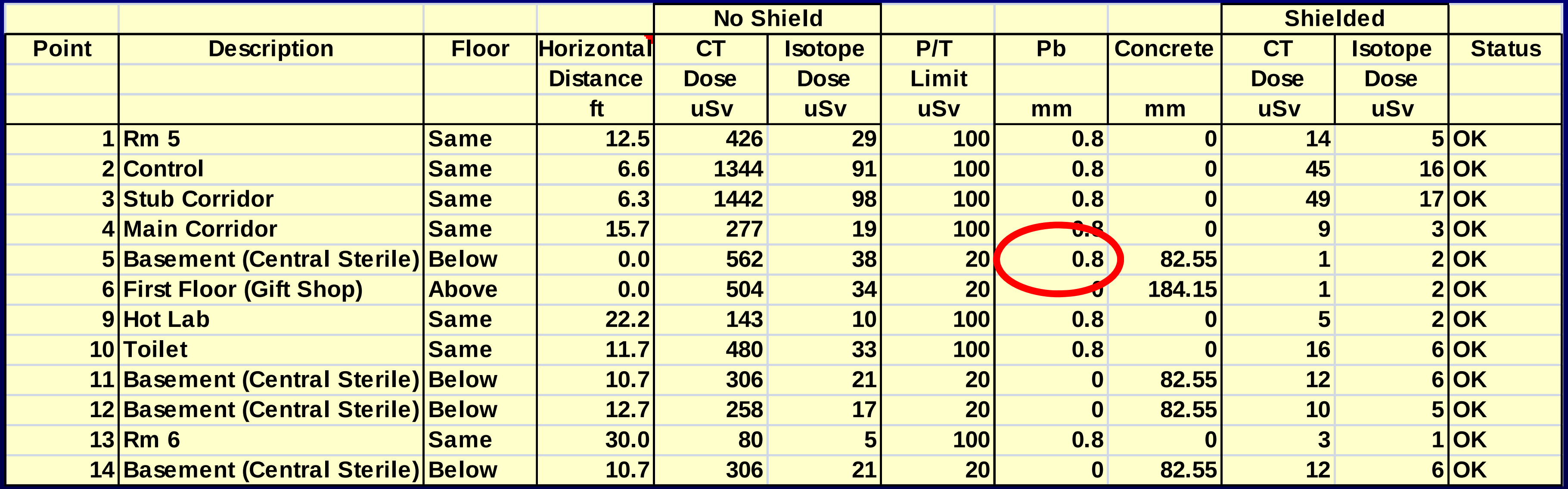
Shielding for SPECT/CT

8 pts/day (4 MDP (27 mCi Tc-99m), 2 renal (16 mCi Tc-99m), 1 Octreotide (6 mCi In-111), 1 Ga-67 (10 mCi); 4 studies w CT, 150 mAs, 130 kVp, 66 cm length

1/32 Pb in walls is adequate; needed some in the floor, too



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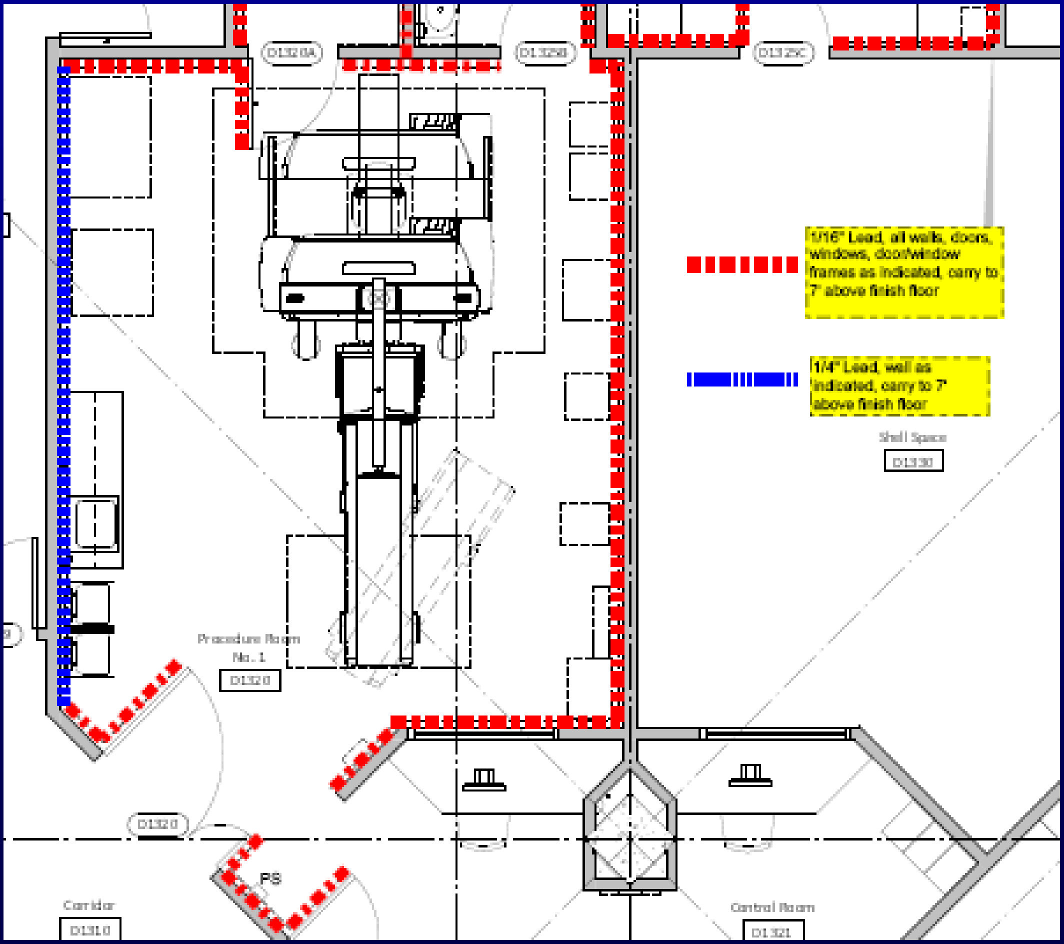
Some Other Things to Consider



If PET and SPECT a both present in a facility, additional shielding may be necessary to suppress noise from the PET isotopes entering the NM camera.

In Parting, Some of the Problems

1) Patient as source for NM: much of the data is 10-40 years old and is inconsistent.
2) Broad beam attenuation coefficients for concrete, other materials, are not available in an accessible form for many users.
3) Watch out for build-up factors: not all are the same!
3) Layered shielding materials (say lead followed by concrete) present problems
4) Some new PET isotopes (Y-86, Zr-89, I-124) may have larger values of TVL (about twice!) than conventional PET isotoptes; some have higher exposure rate constants: may have implications for some scan suites.

People will do the Darnedest Things

In spite of the best planning and design, things on the ground may fail to live up to your expectations. Leaded wallboard mounted upside down!

Acknowlegements

- **Michael Viguet, CNMT**
- **Alice Griego-Garcia, CNMT**
- **George Jacob, CNMT**
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- **William Erdman, MD**
- **Richard Massoth, PhD**
- **Larry Windedahl**
- **Doug Simpkin, PhD**
- **Mark Madsen, PhD**

The End

Useful Resources

- **The x-ray part and general shielding design information:**
  NCRP Report No. 147, *Structural Shielding Design for Medical X-ray Imaging Facilities* (2004)
- **Still useful:**
  NCRP Report No. 49, *Structural Shielding Design and Evaluation for Medical Use of X-rays and Gamma Rays of Energies up to 10 MeV* (1976)
- **Also useful, for information in appendices**
  NCRP Report No. 151, *Structural Shielding Design and Evaluation for Megavoltage X- and Gamma-Ray Radiotherapy Facilities*
- **For information on radioactive patients:**

  NCRP Report No. 105, *Radiation Protection for Medical and Allied Health Personnel* (1989) and NCRP Report No. 124, *Sources and Magnitude of Occupational and Public Exposures from Nuclear Medicine Procedures.*

Useful Resources

- **Madsen MT, et al., *AAPM Task Group 108: PET and PET/CT Shielding Requirements*, Med. Phys. 33(1) 4-15 (2006)**
- **Smith DS and Stabin MG, *Exposure Rate Constants and Lead Shielding Values for over 1100 Radionuclides*, Health Phys. 102(3) 271-291 (2012)**
- **Shimizu A, et. al., *Calculation of Gamma-ray Buildup Factors up to Depths of 100 mfp by the Method of Invariant Embedding (III)*, J. Nucl. Sci. and Tech. 41(4) 413-424 (2004)**
- **Kharrati H, et. al. *Monte Carlo Simulation of X-ray Buildup factors of Lead and Its Applications in Shielding of Diagnostic X-ray Facilities*, Med. Phys 34(4) 1398-1404 (2007)**
- **Greaves CD and Tindale WB, *Dose Rate Measurements from Radiopharmaceuticals: Implications for Nuclear Medicine Staff and for Children with Radioactive Parents*, Nuc. Med. Commun. 20 179-187 (1999)**

Useful Resources

- **Holland JP, et al., *Unconventional Nuclides for Radiopharmacuticals*, Mol Imaging 9(1) 1-20 (2010)**
- **Zeff BW and Yester MV, *Patient Self-attenuation and Technologist Dose in Postiron Emission Tomography* , Med. Phys 32(4) 861-865 (2005)**
- **Kirn FS, et al., *The Attenuation of Gamma Rays at Oblique Incidence*, Radiology 63 94-103 (1954)**
- **Zanzonico P, et al., Operational Radiation Safety for PET-CT, SPECT-CT, and Cyclotron Facilities, Health Phys. 95(5) 554-570 (2008)**
- **Pasciak AS and Jones AK, PShield: An exact three-dimensional numerical solution for determining optimal shielding designs for PET/CT facilities, Med. Phys. 39(6) 3060-3069 (2012)**