BRACHYTHERAPY PHYSICS & ISOTOPES RELEVENT TO PRACTICE

Thayalan Kuppusamy Ph.D.,

Consultant Medical Physicist

Dr.Kamakshi Memorial hospital,Chennai

Former Professor, Barnard Institute of Radiology & Oncology, Madras Medical College

kthayalan@gmail.com

CONTENTS

- Introduction
- Radio-nuclides
- Physical properties
- LDR/HDR Sources
- Design considerations
- Ir-192 vs Co-60 HDR source
- Summary

INTRODUCTION

- Brachytherapy is a short distance radiation treatment, by using radioisotopes
- Wwod brachytherapy is derived from Greek ‘brachio” means short
- Sources may be placed on or near the body surface with in natural cavities or implanted directly in to the tumor
- Radium-226 is the first brachy source (Marie Curie,1898)

INTRODUCTION-2

- AIM: To give localized high dose to the tumor with rapid fall off in the surrounding normal tissues
- Shapes dose distribution to the lesion- first conformational radiotherapy
- Dose restricted to the tumor site
- Sparing of normal tissue
- Radiobiological advantage of LDR

CLASSIFICATION OF BRACHY

- Treatment duration: Temporary, e.g Ir-192
  Permanent,e.g.I-125
- Dose rate : LDR :0.4-2 Gy per hour
  HDR :>12 Gy per hour
  MDR :2-12 Gy per hour
- Source loading: (i) Preloading
  (ii) After loading
  - Manual or Remote

AFTER LOADING SYSTEMS
ADVANDAGES vs DISADVANDAGES

- Reduced radiation dose
- Careful applicator position
- Check radiograph
- Avoidance of general anesthesia
- Optimization

- Sterilization of applicators
- No possibility for loss of source
- Reduction in patient discomfort
- Out patient treatment

- More expensive HDR devices

- Dedicated building & cost
- More fractions of treatment

- Potential late toxicity of large dose per fraction
- Regress quality assurance (QA)

RADIONUCLIDES

SUITABLE RADIONUCLIDES

- Gamma energy (0.2-0.4 MeV), avoid differential absorption by photoelectric process
- Beta energy: low, lesser sheathing
- Half life : Very low –permanent implant,

  High –Temporary implant, to avoid

  decay during treatment

SUITABLE RADIONUCLIDES-2

- No charged particle & gaseous product
- Material insoluble & nontoxic form
- High specific activity for miniature source
- Manufacture in different shapes & sizes (tubes, needles, sphere, wire)
- Cost: Cheaper

PHYSICAL PROPERTIES

Physical property	Relevance to Brachytherapy
Radiation emitted	Source geometry & Structure
Half life	Decides permanent or Temporary implant
Specific activity	Source size & Dose rate
Energy of emitted radiation	Dose distribution within tissue, Radiation protection issues
Density& Atomic Number	Radiographic visibility/localization, Isotropy/anisotropy of dose distribution

PHYSICAL CHARACTERISTICS

Source	Symbol	Z	A	Density, g/cm^3	Decay	Half life
Cesium	Cs	55	137	1.873	β^-	30.07 y
Cobalt	Co	27	60	8.9	β^-	5.27 y
Gold	Au	79	198	19.32	β^-	2.695 d
Iodine	I	53	125	4.93	EC	59.49 d
Iridium	Ir	77	192	22.42	β^- , EC	73.81 d
Palladium	Pd	46	103	12.02	EC	16.991 d
Radium	Ra	88	226	5.00	α	1600 y
Thulium	Tm	69	170	9.321	β^- , EC	128.6 d
Yetterbium	Yb	70	169	6.73	EC	32.015 d

PHYSICAL CHARACTERISTICS-2

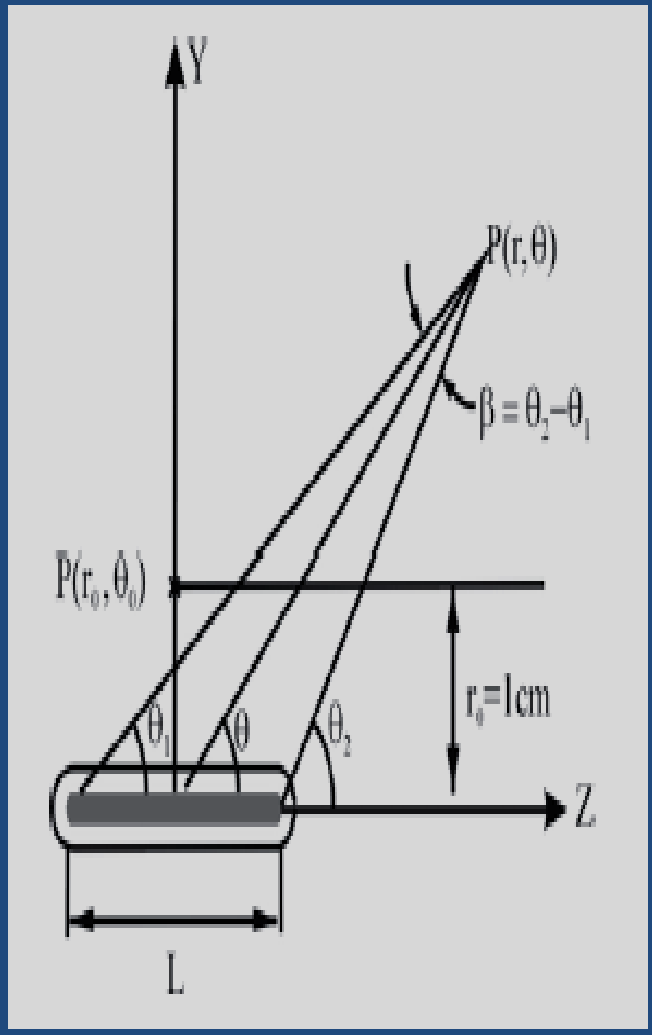
Source	Symbol	Mean γ energy (MeV)	HVL mm, Pb	Specific activity, GBq mg^{-1}	Γ_δ Gy h^{-1} MBq^{-1} m^2	Type of implant
Cesium	Cs	0.662	7.0	3.202	0.0771	Temporary
Cobalt	Co	1.253	12	41.91	0.3059	Temporary
Gold	Au	0.415	2.8	9055.12	0.0545	Permanent
Iodine	I	0.035	0.025	650.15	0.0348	Perm/Tem
Iridium	Ir	0.372	3	340.98	0.1091	Temporary
Palladium	Pd	0.137	0.008	2763.13	0.0361	Permanent
Radium	Ra	0.830	13	0.0366	---	Temporary
Thulium	Tm	0.084	0.17	221.07	0.00053	Temporary
Yetterbium	Yb	0.143	0.23	893.29	0.0431	Perm/Tem

AAPM TASK Group 43 (TG43) Formalism (1995)

The dose at a point P(r, θ) can be expressed as:

$$D(r,\theta) = S_k \Lambda t \frac{G(r,\theta)}{G(r_0,\theta_0)} g(r) F(r,\theta)$$

- where r is the radial distance
- θ is the polar angle
- S_k is the Air-kerma strength
- G (r, θ) is the geometry factor
- F (r, θ) is the anisotropy factor
- g(r) is the radial dose function



TG-43U1

- Originally air kerma strength is defined in vacuum
- Offered corrections for air attenuation
- Radial dose function is valid for point & line sources
- Data set for eight permanent seeds,

  I-125 (6) & Pd-103 (2)
- No change in dose rate constant, anisotropy factor, Ir-192 data set

WHY TG-43 FORMALISM?

- Earlier dosimetry based on apparent activity, mg equivalent of Ra, exposure rate constant, & tissue attenuation coefficient
- Did not account source-source differences: construction & encapsulation
- TG-43 depends on specific source design
- Source geometry, anisotropy, radial dose
- Water medium, experimental verification, Monte Carlo simulation
- Increased accuracy of clinical calculation

LDR /HDR SOURCES

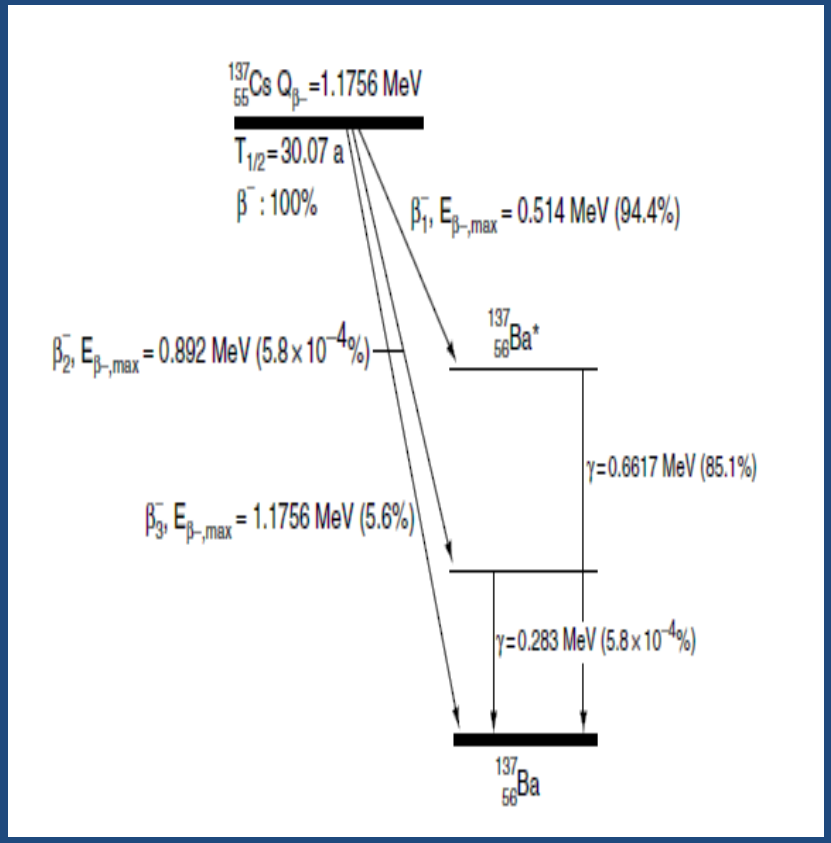
- LDR sources:
- Cesium-137,
- Iridium-192,
- Iodine-125,
- Palladium-103,
- Gold-198,
- Thulium-170

- HDR sources:
- Iridium-192,
- Cobalt-60,
- Yetterbium-169

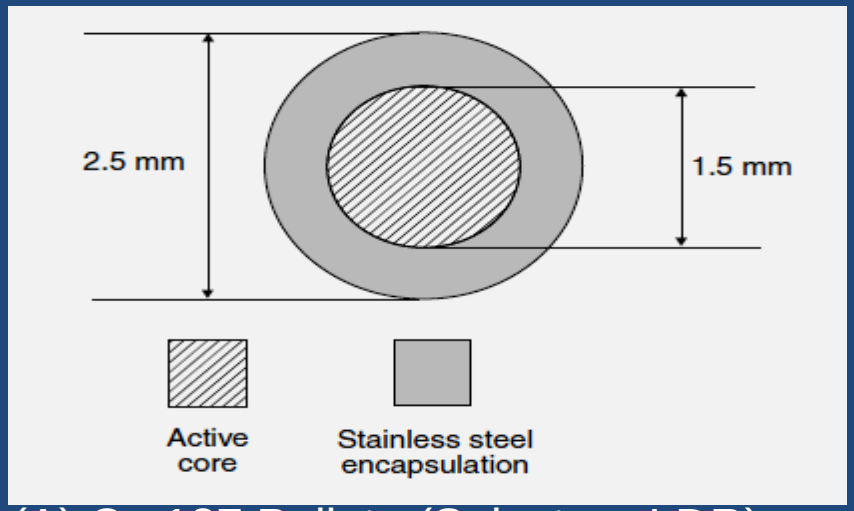
- PDR sources:Ir-192
- Beta sources:
- Sr-90, P-32
- Neutron sources:Cf-252

CESIUM-137

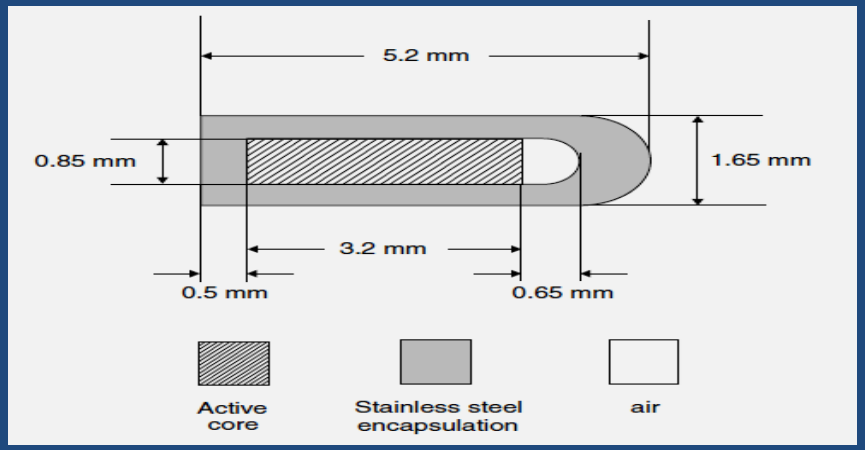
- Cs-137 decays via beta decay, half life 30 y, gamma energy 0.662 MeV
- Insoluble microspheres
- Activity correction: 2% per year
- Commonly LDR source in intracavitary applications
- Needle, tube and pellets
- Replaced Radium-226,due to its hazards



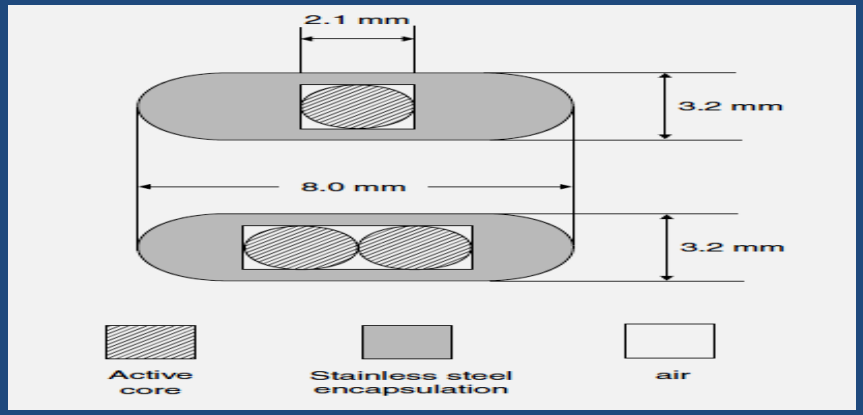
CESIUM-137..2



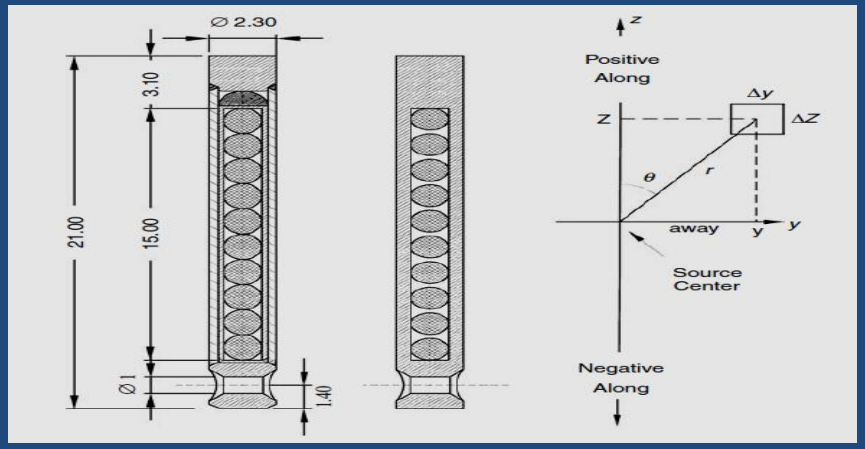
(A) Cs-137 Pellet (Selectron,LDR)



(B) Cs-137,Model CSM11, (CIS BIO international, France)



(C) Amersham (UK): CDC.K1-K3, Sphere, Manual /Remote AL

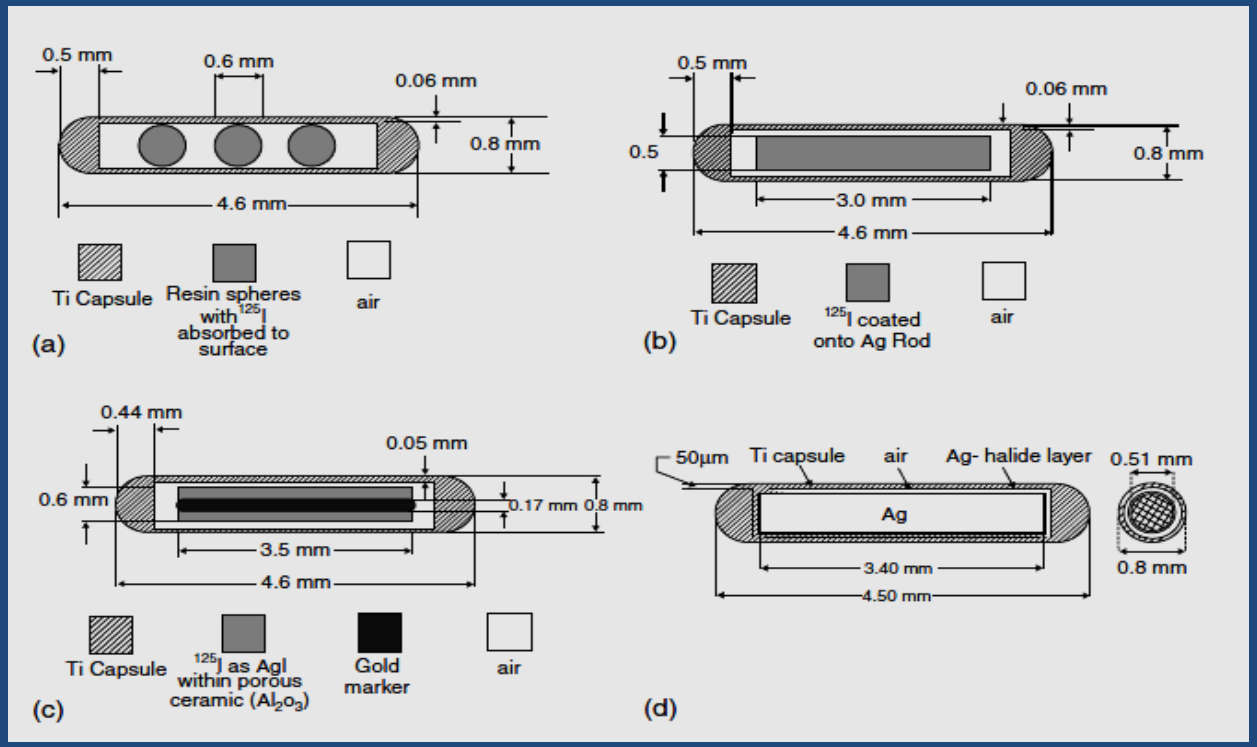


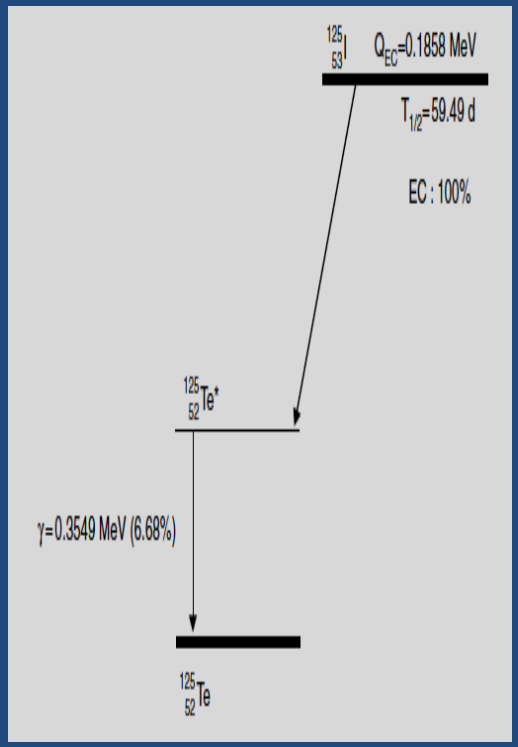
(D) Amersham (UK):CDCS-M

I-125 LDR SEEDS

- I-125, half life of 59.4 d, decays with emission of 35.5 keV gamma rays & X-rays of 31.7-27.2 keV
- Interaction with silver emits flourosecent characteristic X-rays: 22.1-25.2 keV (6711)
- Titanium shield absorbs electrons and photons up to 5 keV
- Available in the form of encapsulated seeds
- Dosimetry is much more complex
- Used in eye plaque (temporary) and prostate (Permanant)

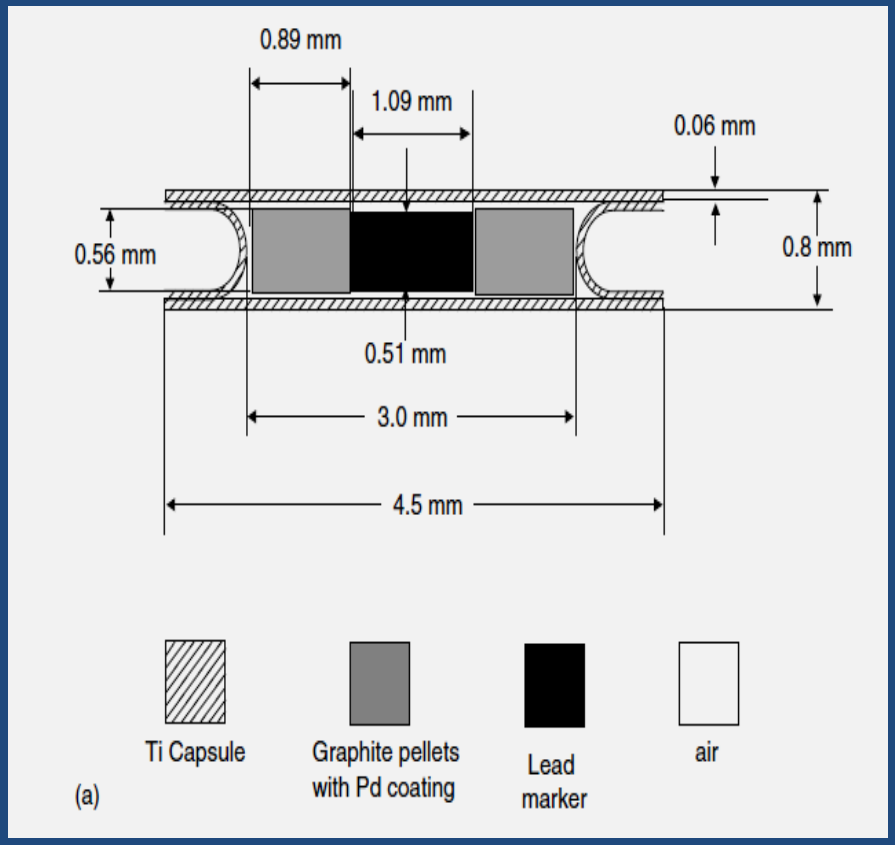
I-125 LDR SEEDS..2

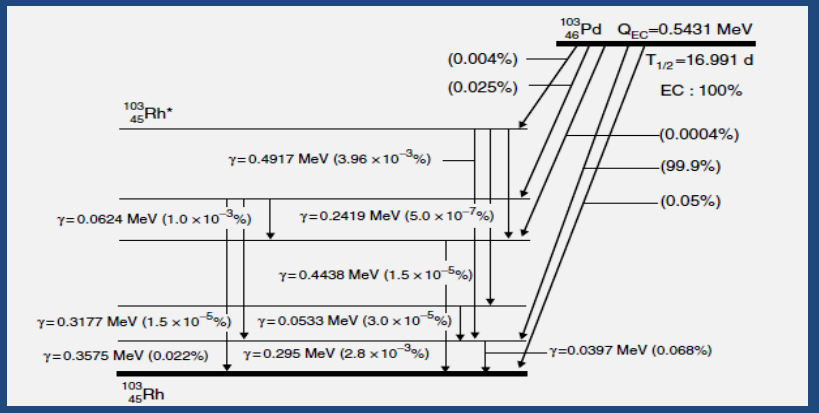


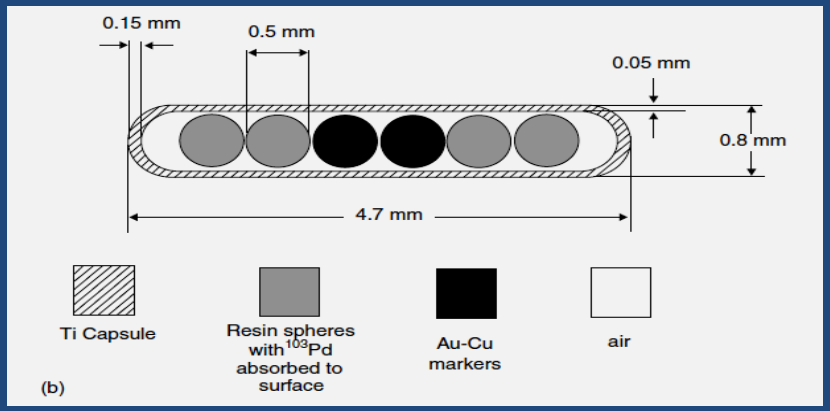


Cross-sectional drawings of the four ^{125}I LDR seed sources.[13] (a) Amersham model 6702,[13] (b) Amersham model 6711 OncoSeed,[13] (c) BEBIG Symmetra I25.S06,[13] and (d) Nucletron select Seed model 130.002.[82]

Pd-103 SEEDS





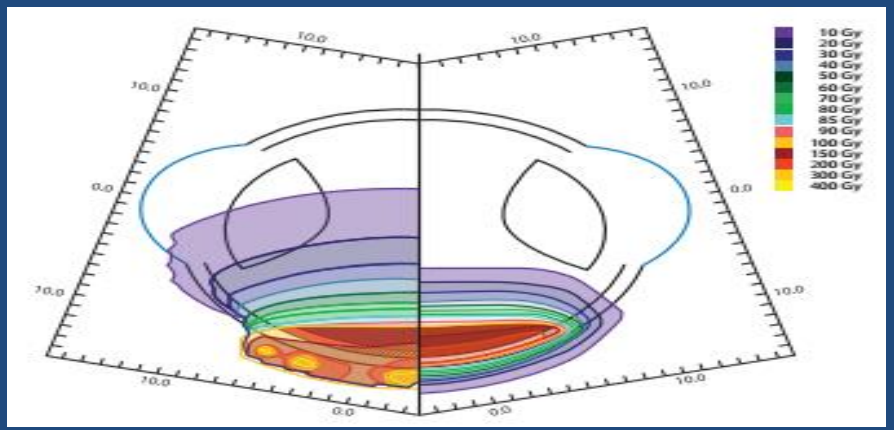


Cross-sectional drawings of the ^{103}Pd LDR seed sources considered in the TG-43 U1 report.[13] (a) Theragenics TheraSeed model 200, and (b) North American Scientific model MED3633.

RU-106 vs I-125

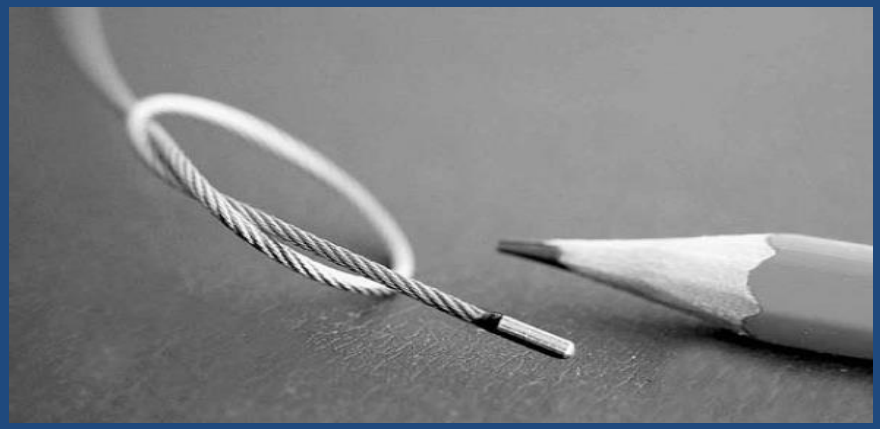
Ru 106	I 125
Uniform Dose Distribution throughout the plaque	Based on the seed placement and planning
Half life 374 days	Half Life 60 days
Shielded and Ru106 embedded in a thin foil sandwiched	Individual seeds
Handling as a one single piece and sterilization is very easy	Handling individual seeds and pasting and removal is not very easy , Sterilization is difficult.
Recommended for the tumor up to 6mm	Useful for the tumor >6mm
Useful life upto 1 year	Useful life only up to 2 months.
Calibration of the single plaque has certificate	Individual calibration is needed.

Eckert & Ziegler



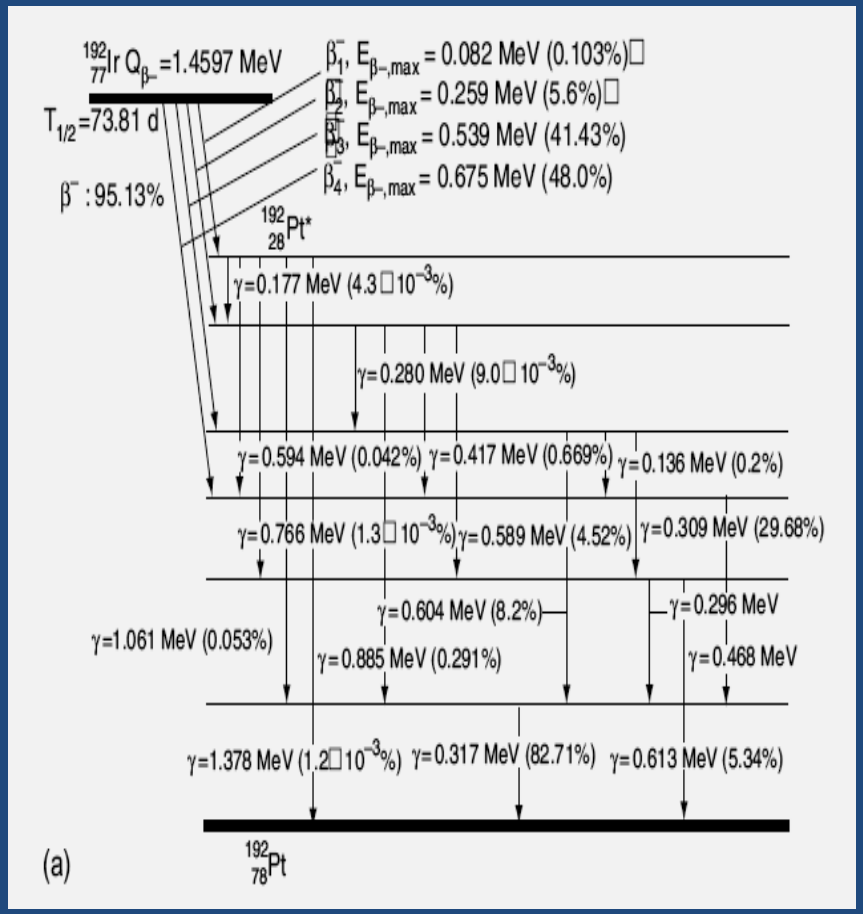
HDR SOURCES

^{192}I SOURCE & PETTEN REACTOR, Netherland

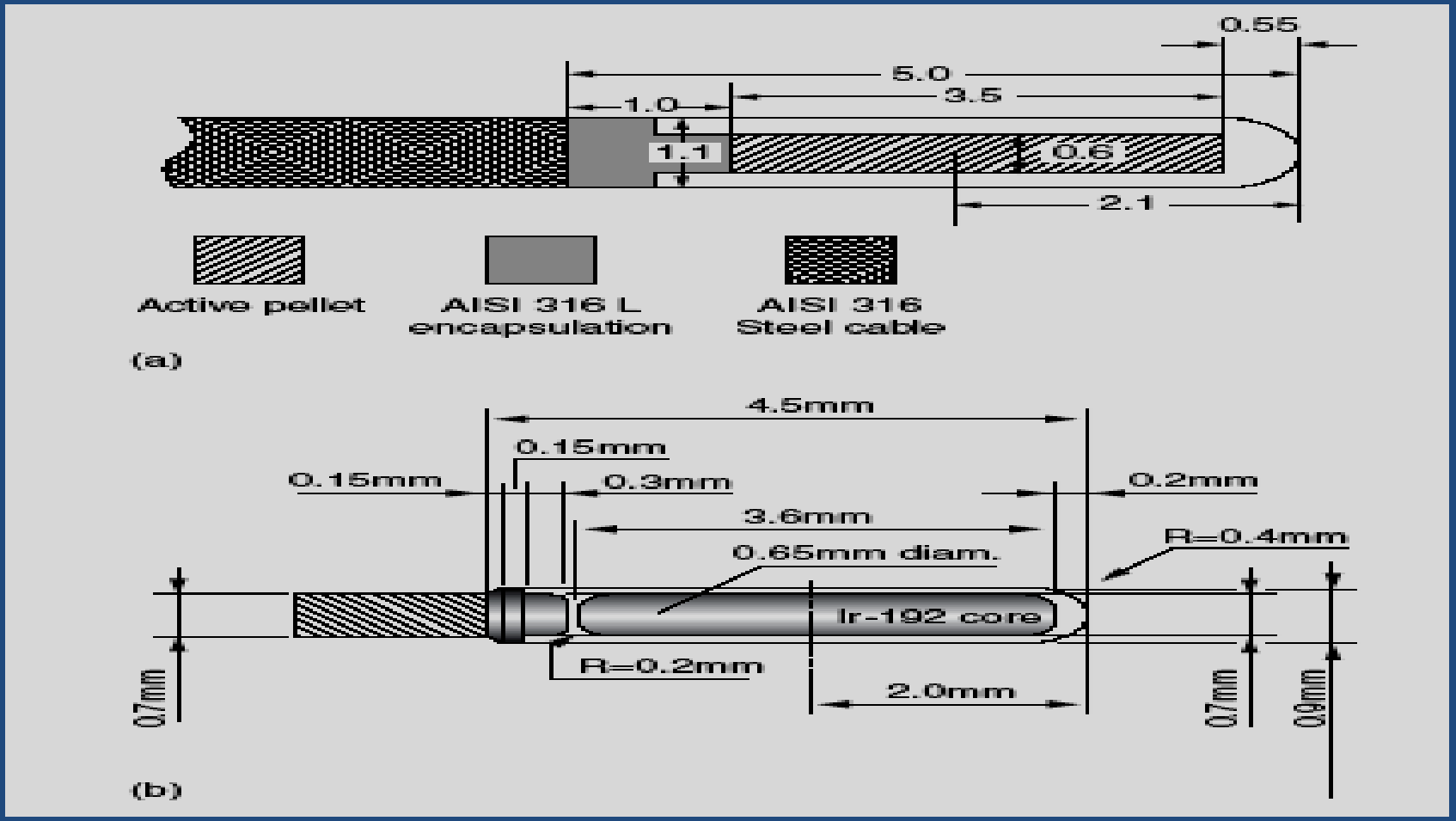


Ir-192 SOURCE

- Ir-192, half life 73.83 days
- Average gamma energy 0.380 MeV
- High specific activity, 450 Ci/g
- Seeds, pellet and strands of nylon ribbon
- HDR source, 10 Ci, source replacement 3-4 months
- Wipe test, to find crack & avoid contaminations

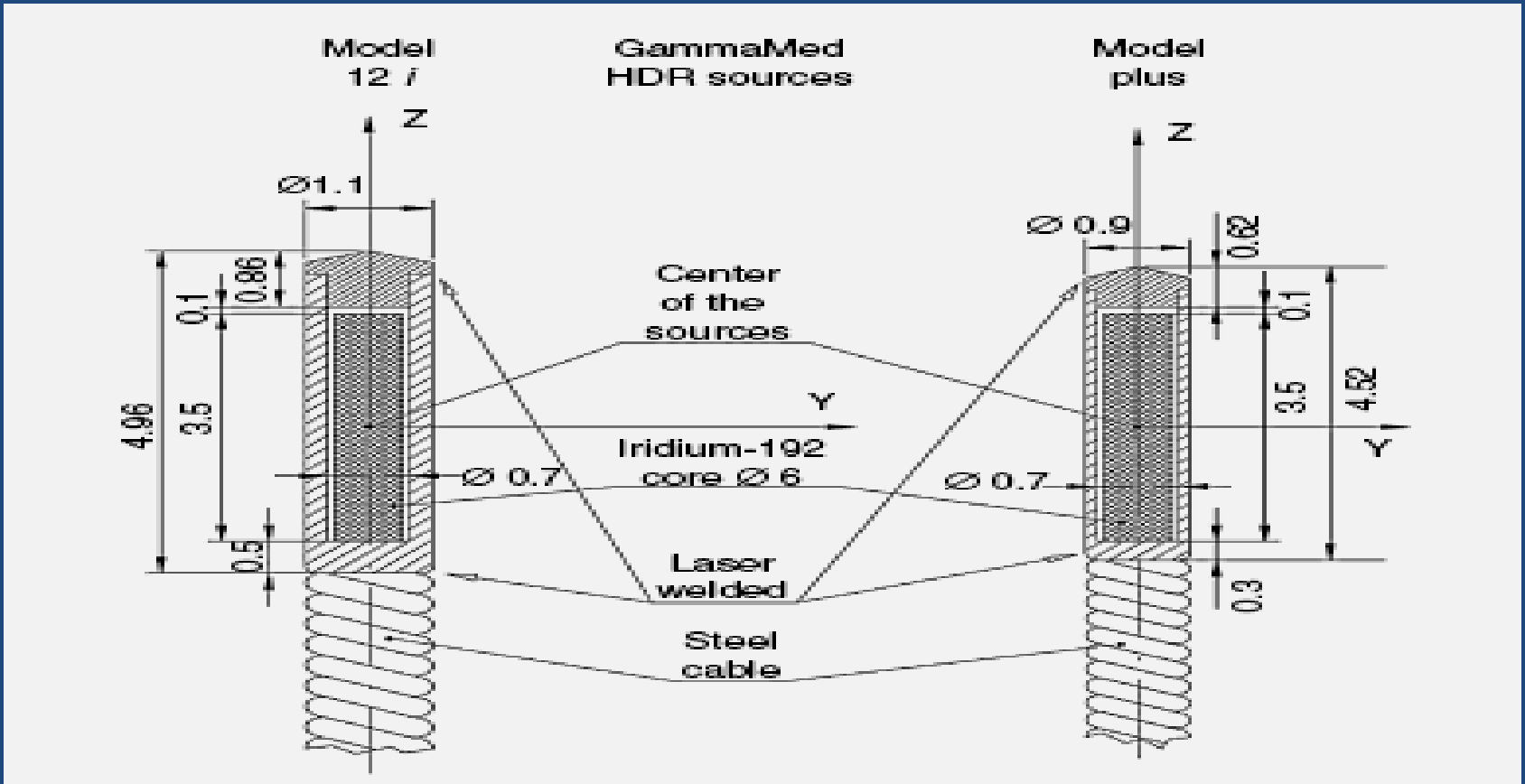


MICROSELECTRON HDR



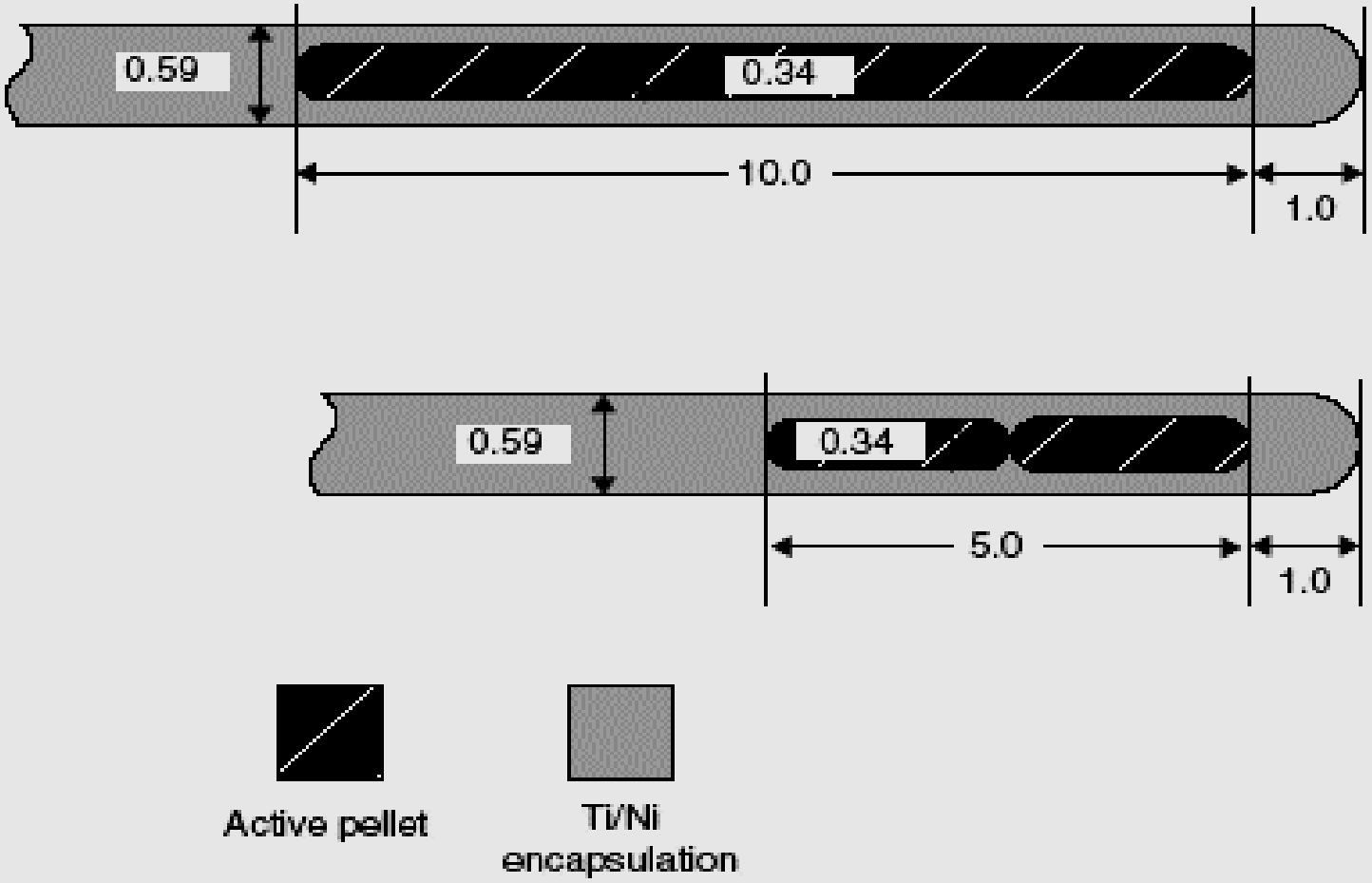
(A) Old Classic design, (B) New design

GammaMed HDR:Ir-192



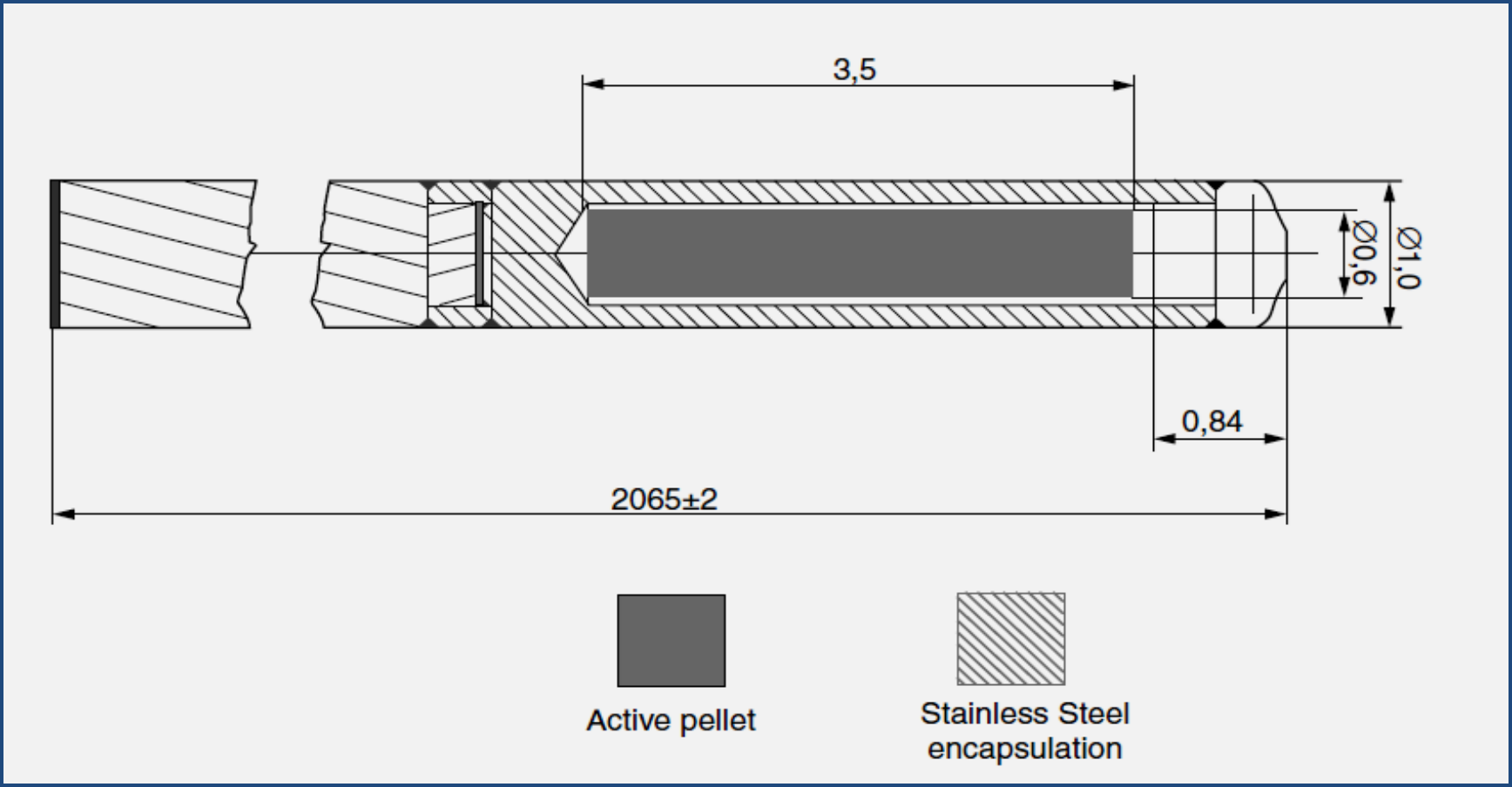
(A) GammaMed 12i, GammaMed plus, Varian oncology systems, Palo,Alta,USA

VARISOURCE HDR



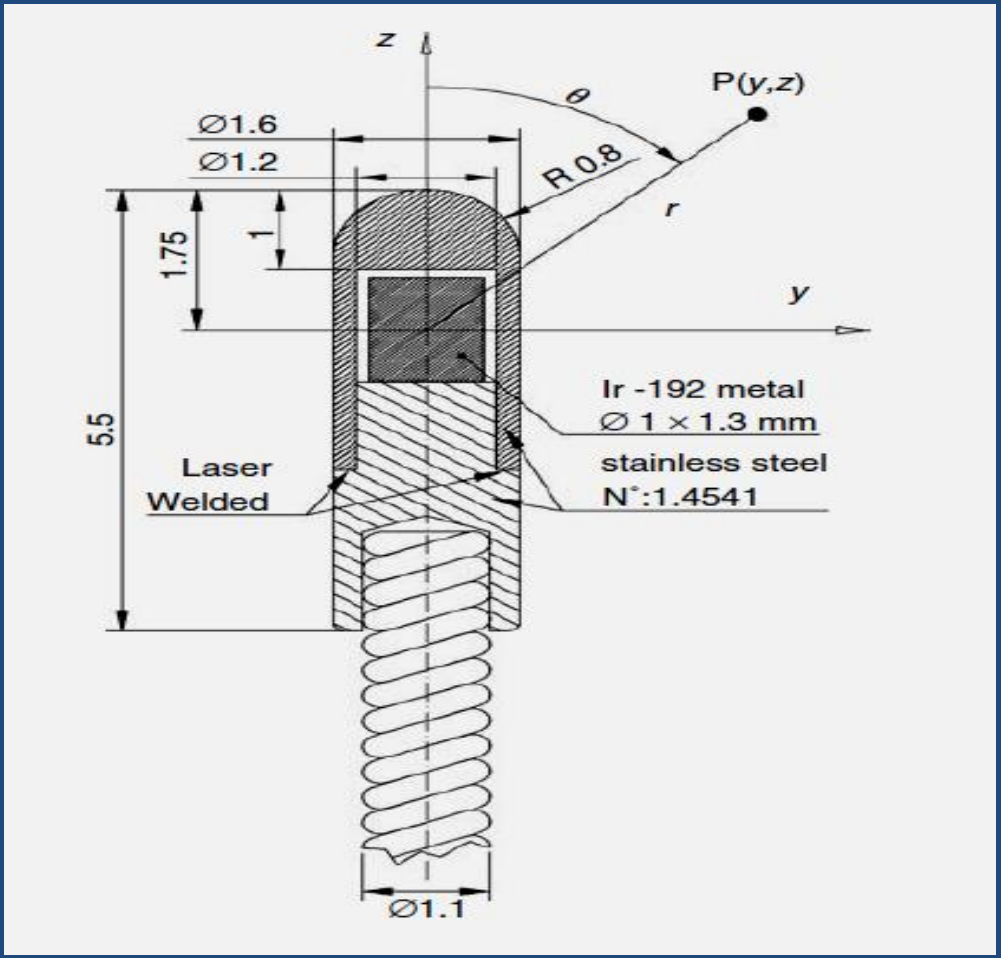
Varian oncology systems,Palo,Alta,USA,Old & New design

MULTISOURCE HDR



^{192}Ir source type GI192M11 design by BEBIG used in the MultiSource HDR afterloader

BUCHLER HDR,Ir-192 SOURCE
(Amersham)



BEBIG Co-60 SOURCE

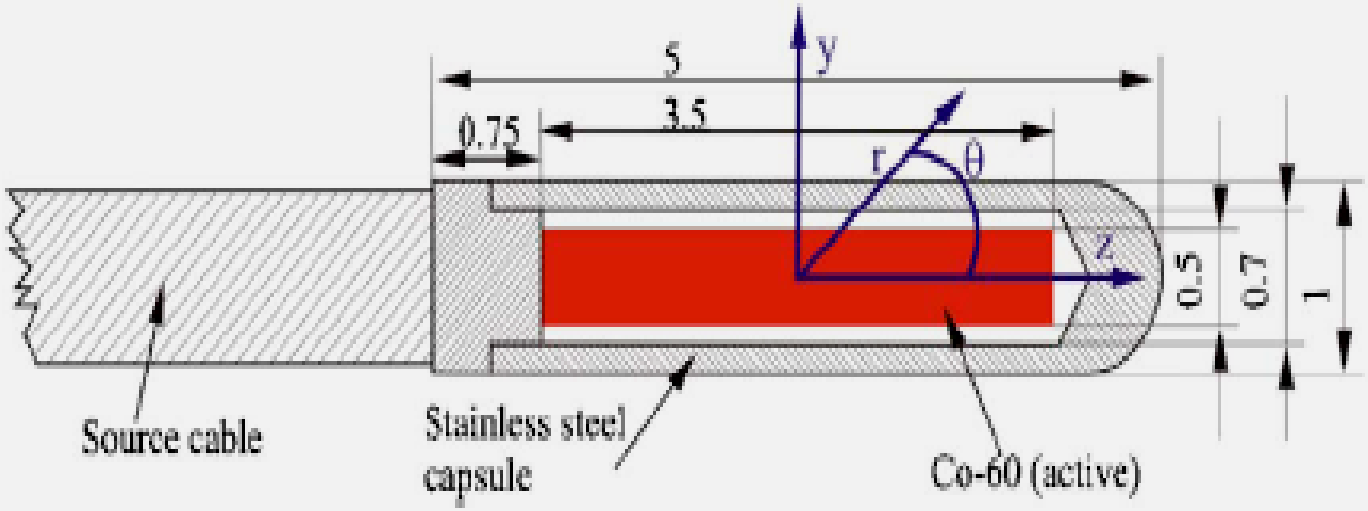
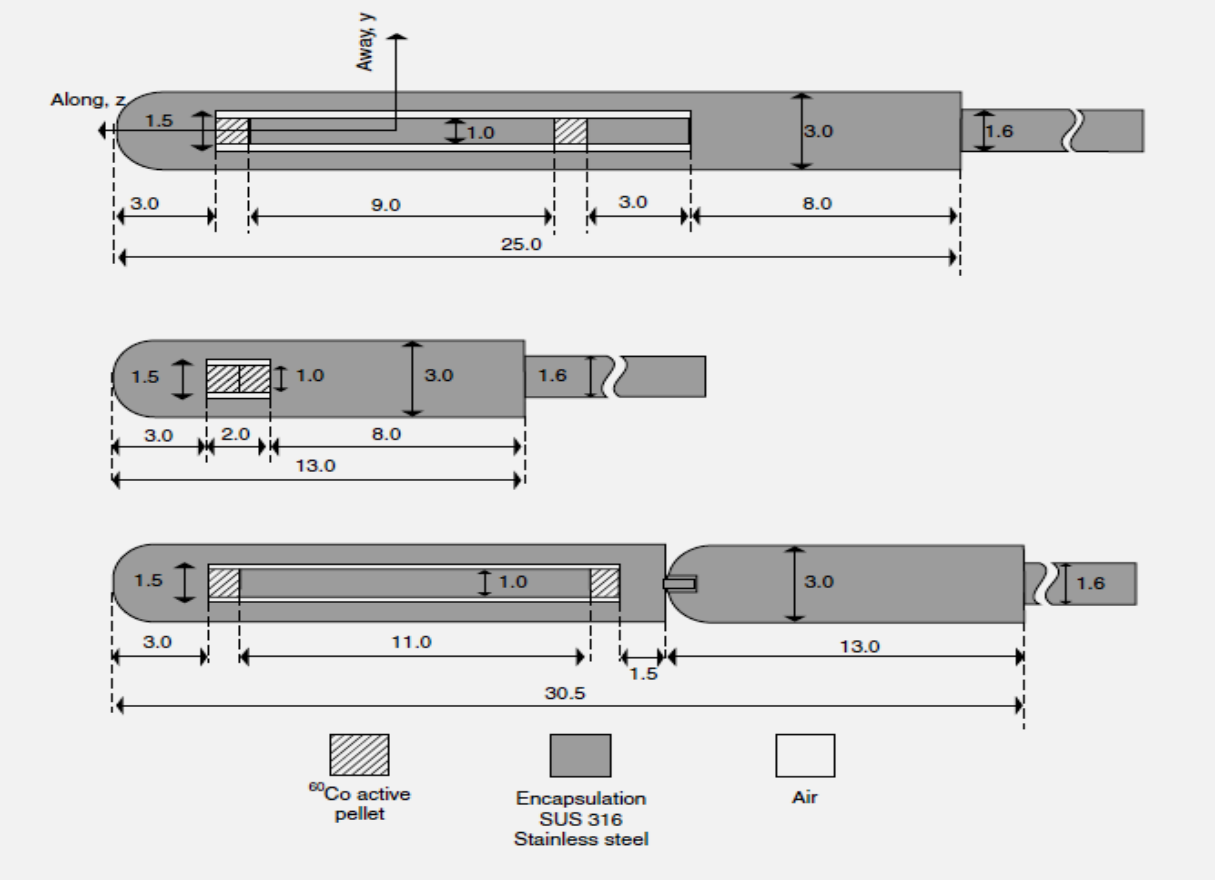
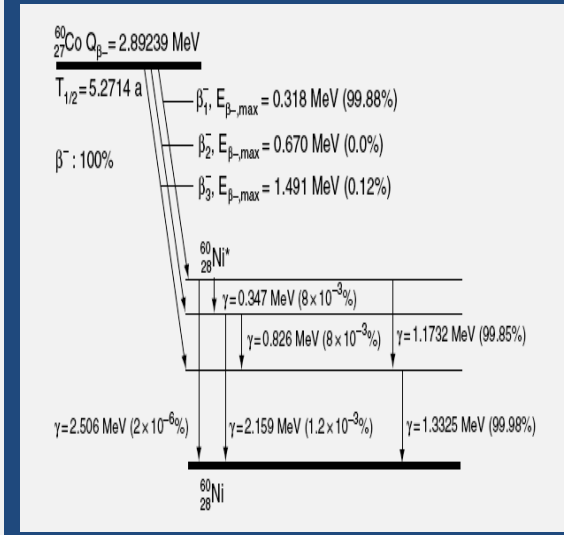


FIG. 1. Schematic view of the ^{60}Co source (model Co0.A86). The coordinate axes used in this study are also shown with their origin situated in the geometric center of the active volume. Dimensions are in millimeters.

RALSTON HDR Co-60

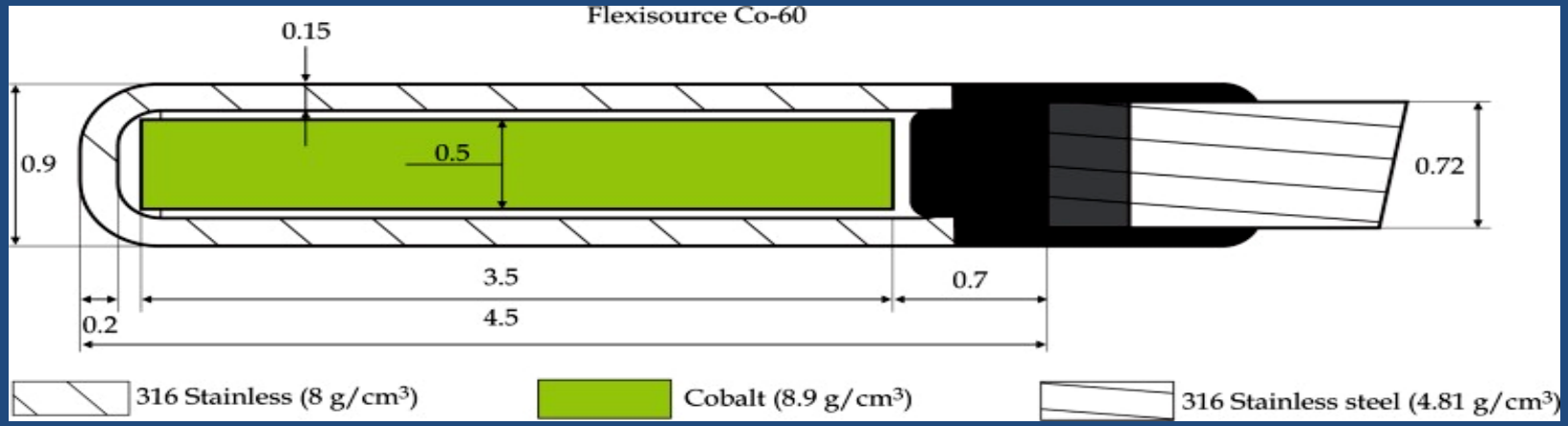




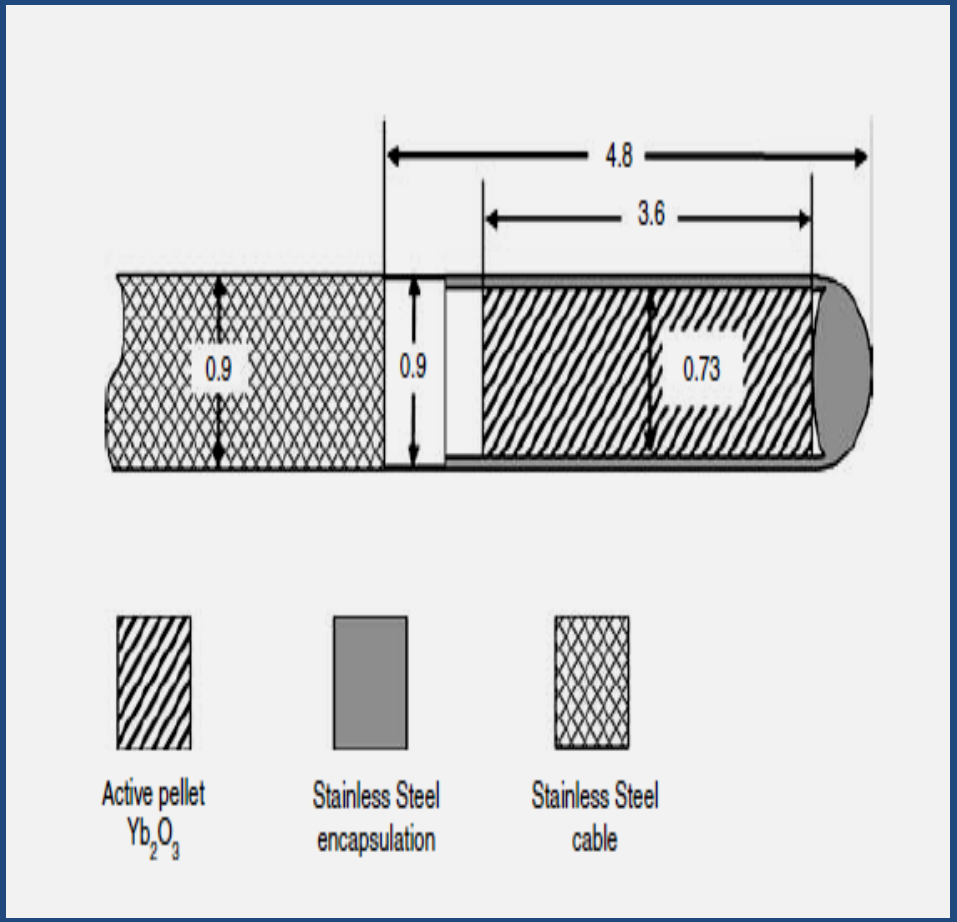
Schematic diagrams of the three ^{60}Co source types, type 1, type 2, and type 3, used with the Ralston remote afterloader (Shimadzu Corporation, Japan) showing geometries and materials.

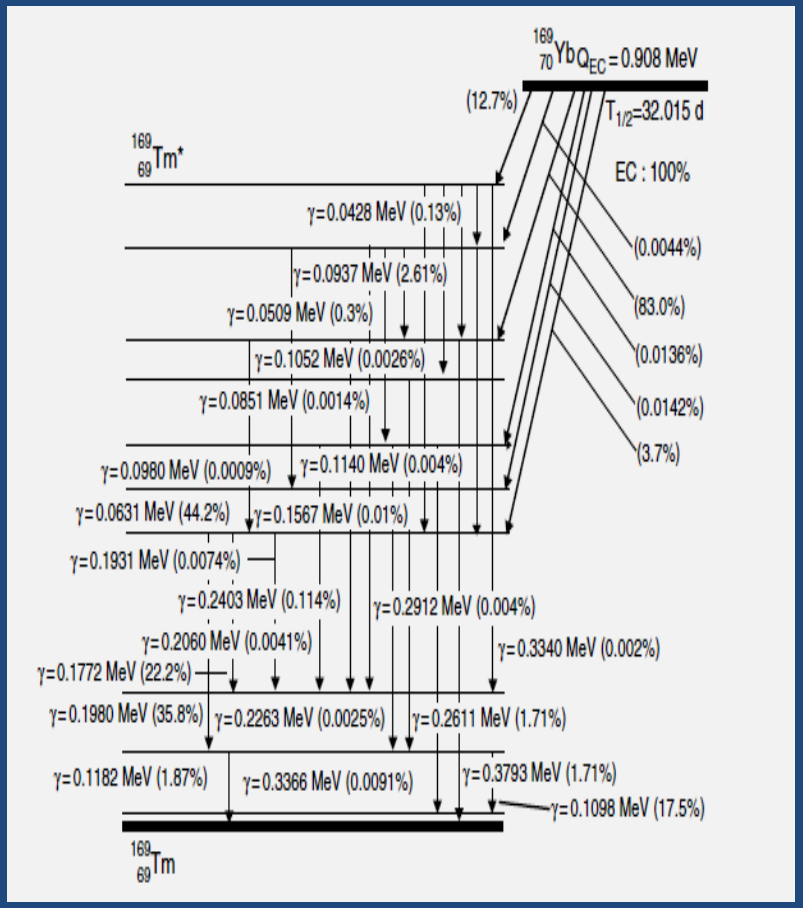
FLEXI SOURCE:Co-60

- Source: 3.5 mm long, 0.5 mm diameter
- Stainless Steel Capsule outer dia 0.9 mm
- Last 150 mm of cable is highly flexible
  - multi-strand cable 7x7, 0.72 mm,
- Stiff drive cable
  - multi-strand cable



YETTERBIUM-169





Model: HDR4140

HDR SOURCE DETAILS

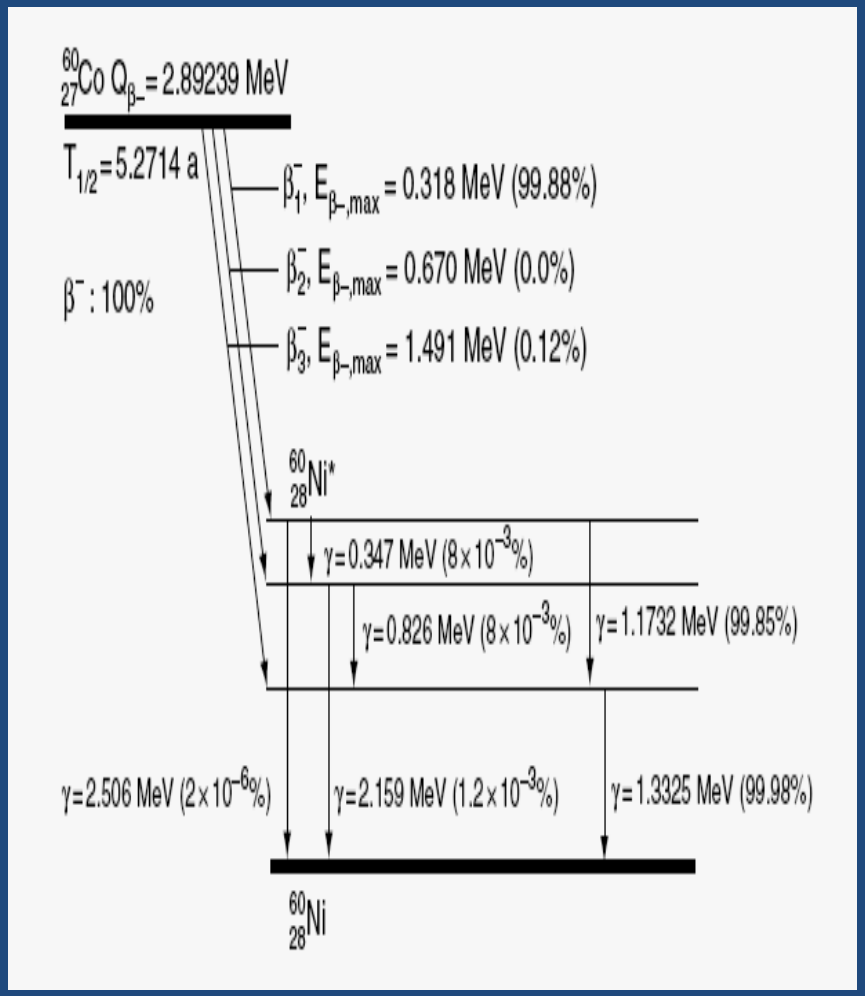
Parameter (mm)	μSelectron ^{192}Ir		Gammamed ^{192}Ir		Varisource ^{192}Ir		Multisource		Flexitron
	Old	New	12i	Plus	Old	New	^{192}Ir	^{60}Co	^{192}Ir
Active length	3.5	3.6	3.5	3.5	10.0	5.0	3.5	3.5	3.5
Active diameter	0.6	0.65	0.6	0.6	0.35	0.34	0.6	0.6	0.6
Total length	5.0	4.5	4.96	4.52	11.0	6.0	4.9	4.9	4.6
Capsule diameter	1.1	0.9	1.1	0.9	0.61	0.59	1.0	1.0	0.85
Capsule wall	0.25	0.125	0.2	0.1	0.13	0.125	0.2	0.2	0.125
End cap length	0.55	0.40	0.86	0.62	1.00	0.30	0.90	0.90	0.65
Activity (max), Ci	10.0	10.0	10.0	10.0	10.0	10.0	10.0	2.0	10.0

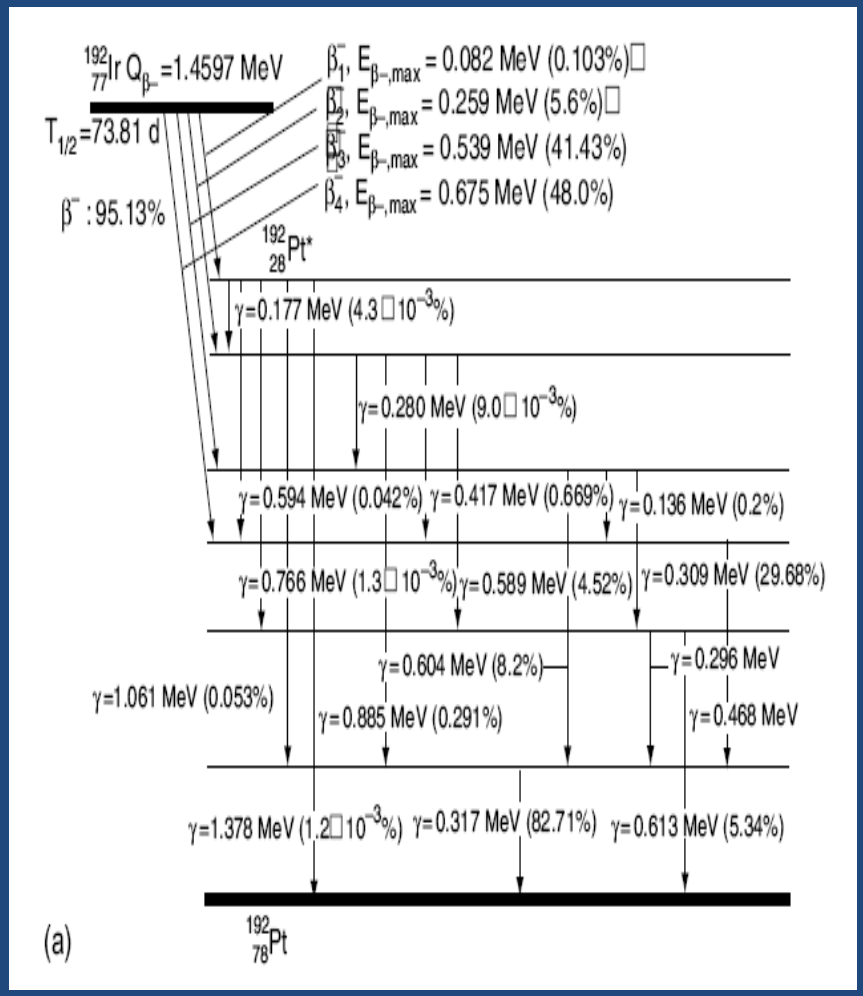
PHYSICAL PROPERTIES OF HDR SOURCES

Radio-nuclide	$T_{1/2}$	Energy (MeV)		Γ_x Rcm²/h/mCi	Γ_k μGym²/h/MBq	HVL (mm) Water	HVL (mm) Lead
		Gamma	Beta				
^{60}Co	5.26 y	1.25	0.31	13.07	0.308	108	11.0
^{192}Ir	73.8 d	0.38	0.67	4.69	0.111	63	2.5

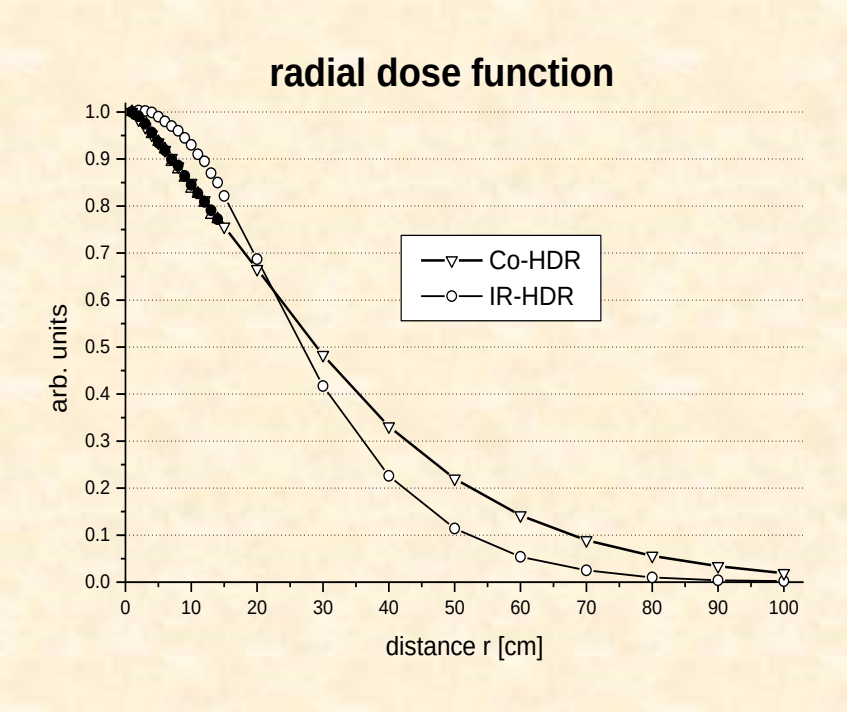
y = year, d = days

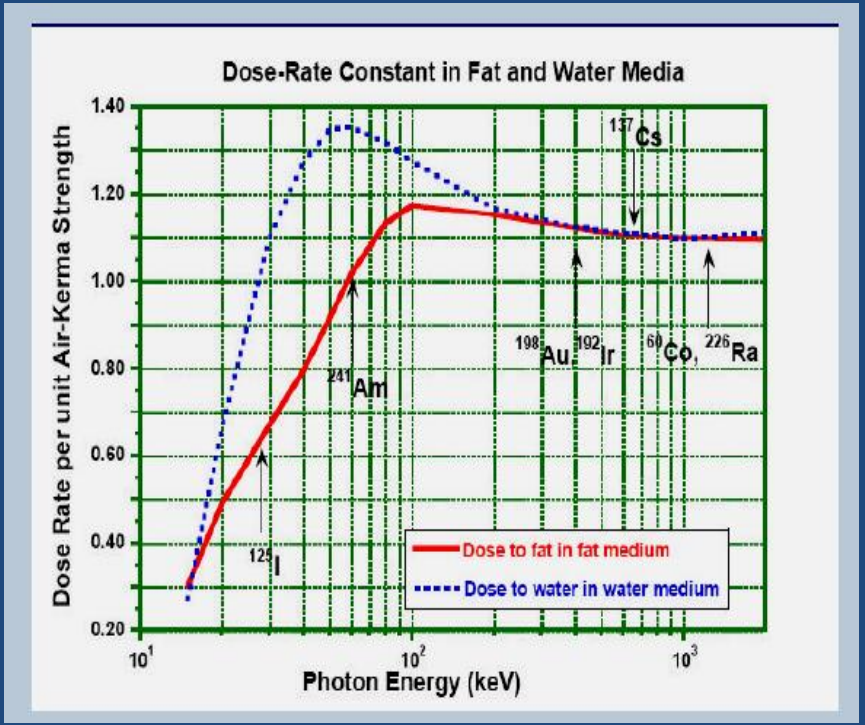
DECAY SCHEME OF ^{60}Co & ^{192}Ir





Ir -192 vs Co-60 HDR SOURCE





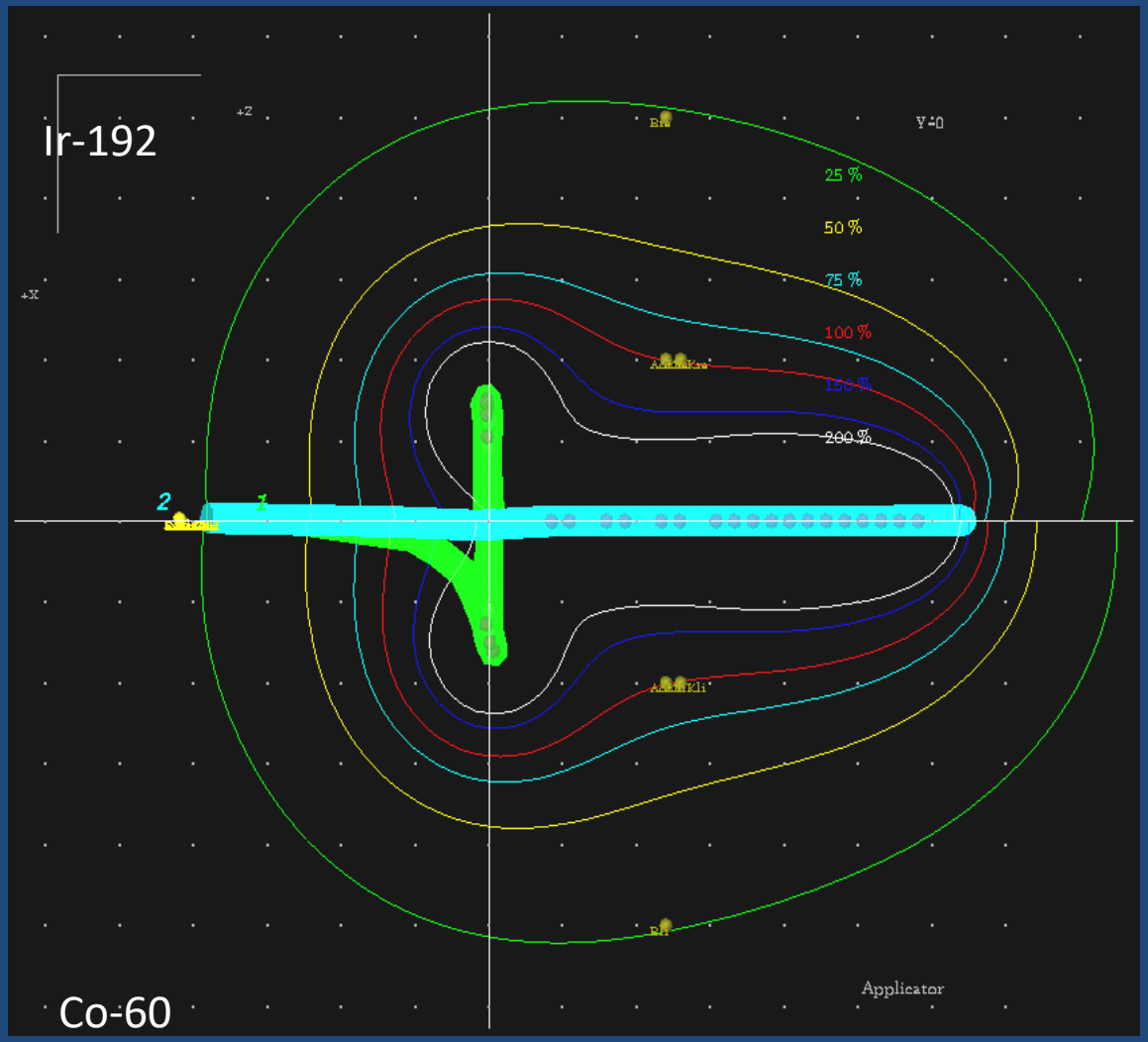
Strahlentherapie und Onkologie

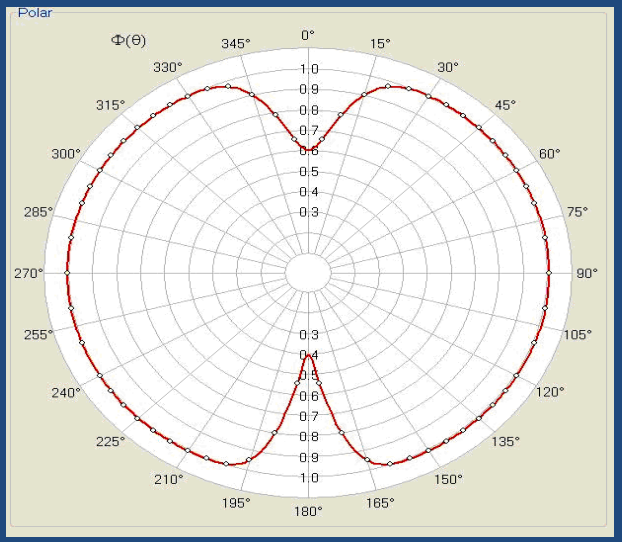
Current Discussion

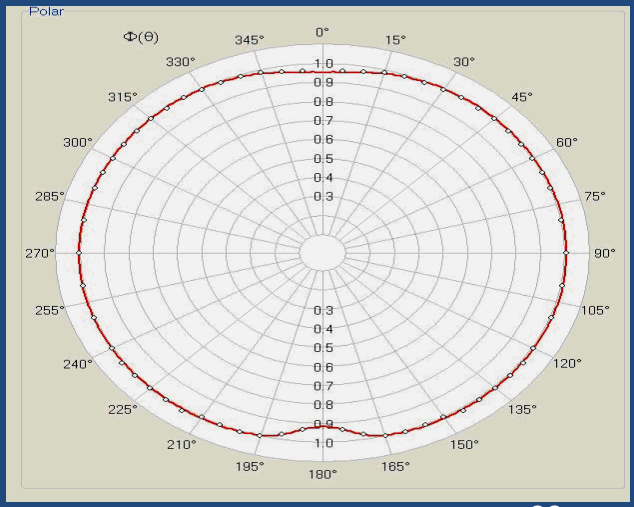
Comparison of ^{60}Cobalt and ^{192}Iridium Sources in High Dose Rate Afterloading Brachytherapy

Jürgen Richter, Kurt Baier, Michael Flentje[1]

Ir-192 vs Co-60 HDR SOURCE







DOSE RATE CONSTANT

Source type	Reference	Dose rate constant, Λ $cGy.h^{-1}.U^{-1}$
Nucletron HDR Classic1.1 mm	Williamson (1995)	$1.115 \pm 0.5\%$
Nucletron HDR New 0.9 mm	Daskalov (2000)	$1.108 \pm 0.13\%$
Varisource HDR classic,0 mm L	Wang & Sloboda (1998)	$1.044 \pm 0.2\%$
Varisource HDR New, 5mm L	Angelopoulos (2000)	$1.101 \pm 0.5\%$
Buchler HDR,1.6 mm	Balleater (2001a)	$1.115 \pm 0.3\%$
Gamma Med 12i HDR,1.1 mm	Ballester (2001b)	$1.118 \pm 0.3\%$
GammaMed Plus HDR,0.9 mm	Ballester (2001c)	$1.118 \pm 0.3\%$

HDR SYSTEMS

Elekta: Ir-92 or Co-60

MicroselectronHDR

Flexitron

Varian: Ir-192

Varisource

GammaMed

BEBIG
Ir-192
or
Co-60

BRIT:
India
Ir-192
Yet to be
released

SUMMARY

- Numerous radionuclides are commercially proposed, few are abandoned
- Cobalt-60, Iridium-192, ytterbium-169 are HDR sources
- Cesium-137, Iridium-192, are the LDR sources.
- Though I-125 is a popular LDR seed, substitutes like Pd-103,Ru-106,Au-198 & Cs-131 are also in race.
- Pd-103 has radibiological advantage: short half life, higher seed activity, higher absorbed dose rate

THANK YOU