Sources and Delivery Systems I: Radionuclides

Ravinder Nath, Ph.D.
Yale University

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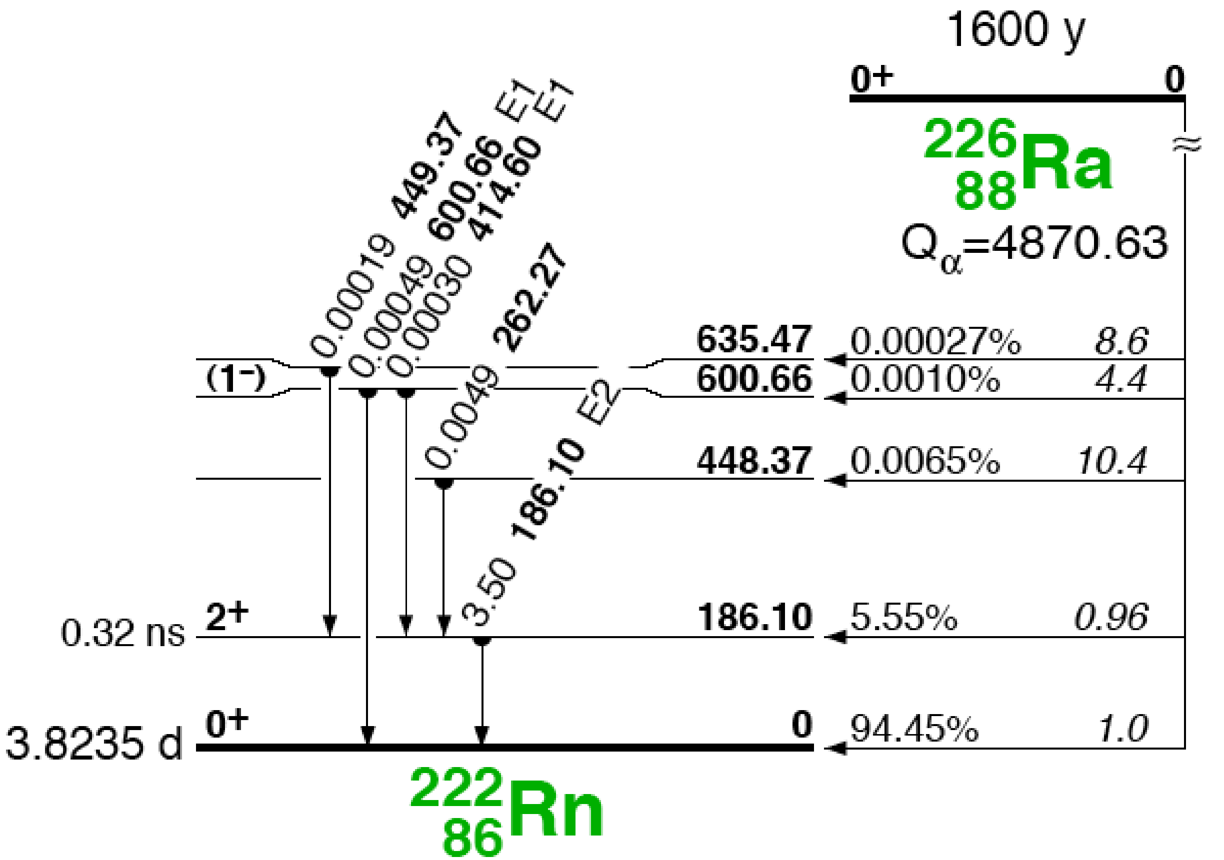
Outline

- Photon-Emitting Radionuclides Used in Brachytherapy
- Beta-Emitting Radionuclides Used in Brachytherapy
- Neutron-Emitting Radionuclides Used in Brachytherapy

Photon-Emitting Radionuclides Used in Brachytherapy

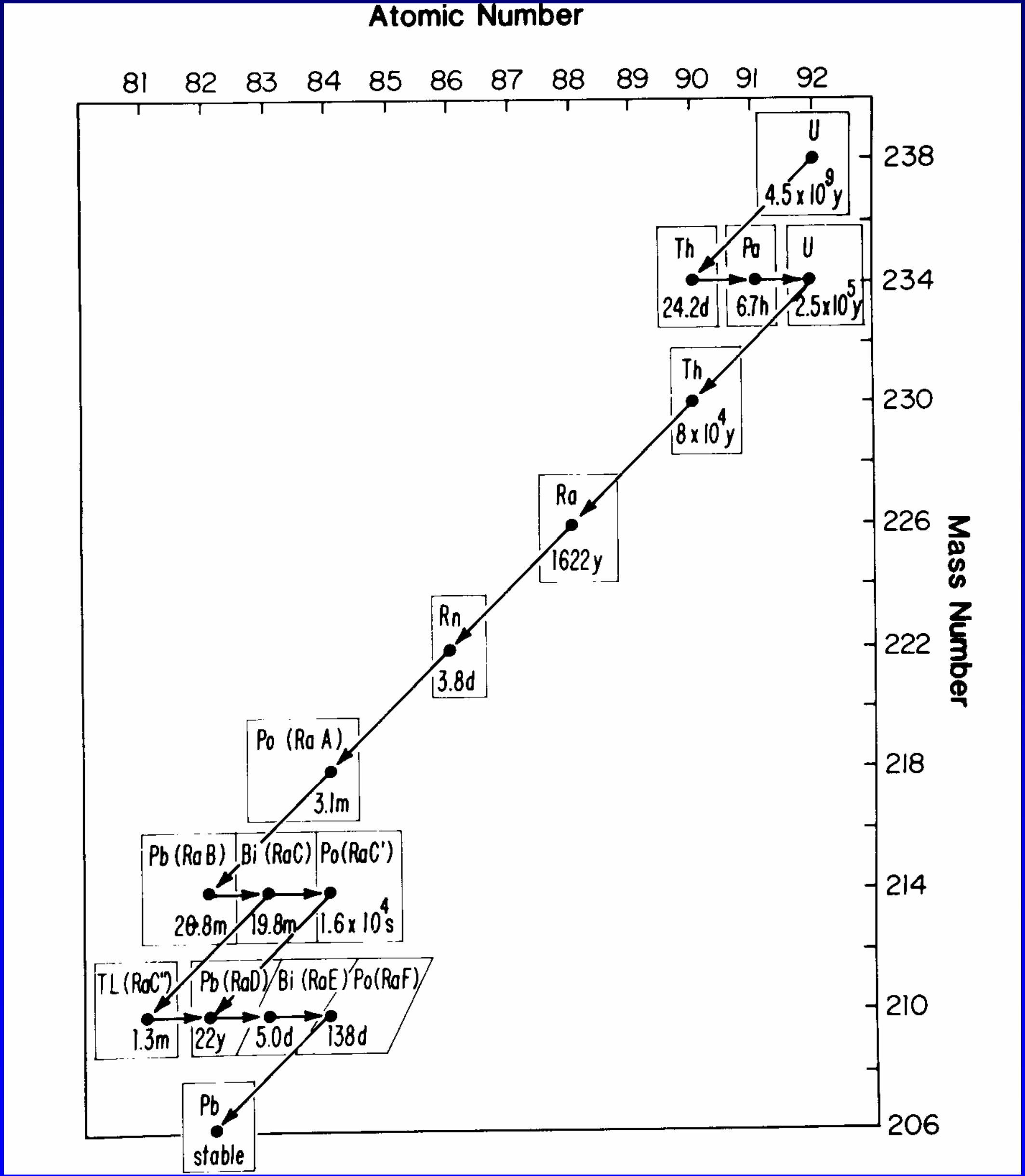
– Cesium-137
– Iridium-192
– Radium-226
– Gold-192
– Iodine-125
– Pd-103

Radium-226



1600 year

Alpha decay to radon-222



Radium-226

Uranium Series

Sixth member

Alpha decay to Radon-222

49 photons

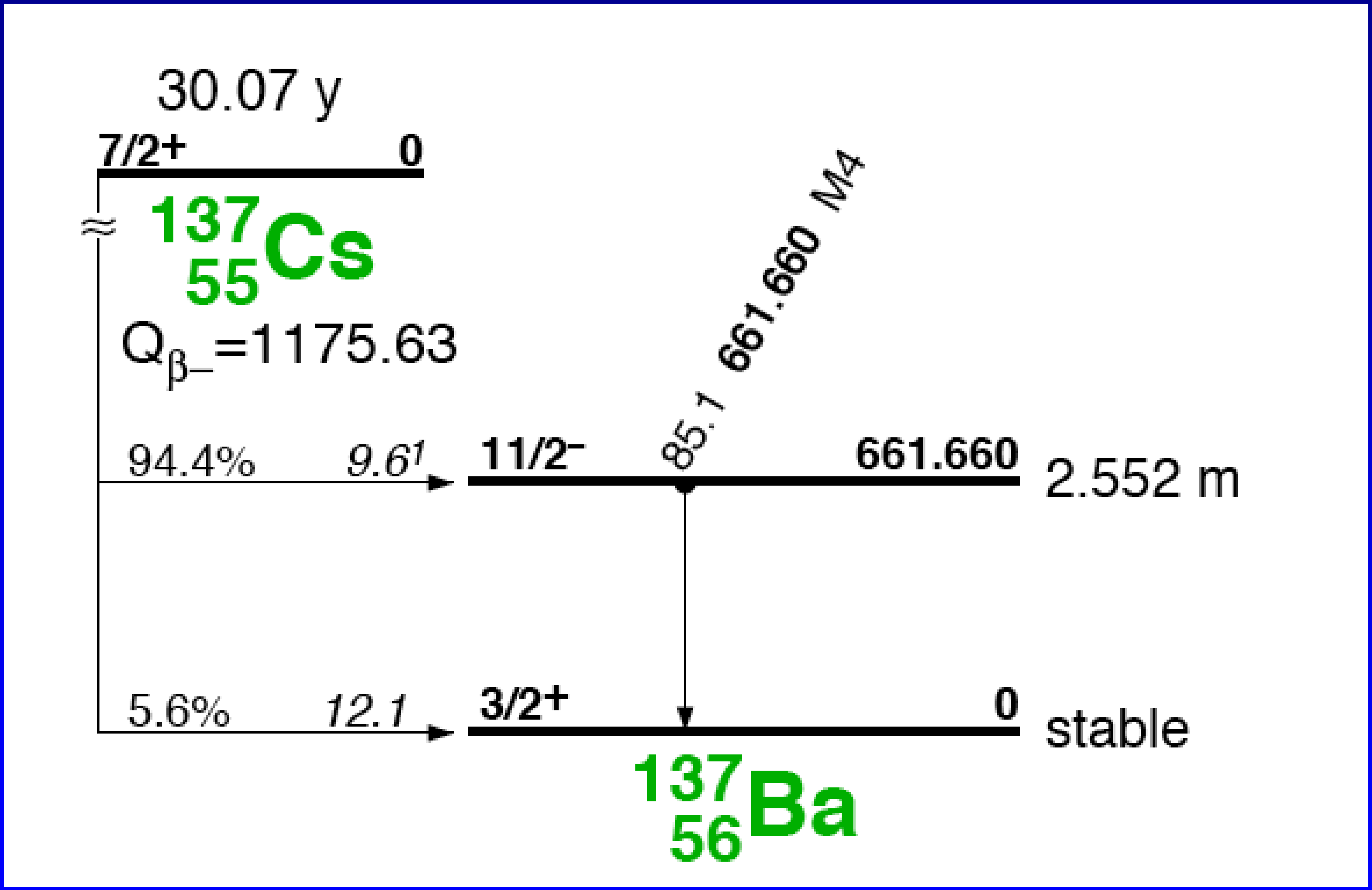
0.184 to 2.45 MeV

Average 0.83 MeV

HVL 14 mm Pb

0.5 mm Pt encapsulation

Cesium-137



30 year

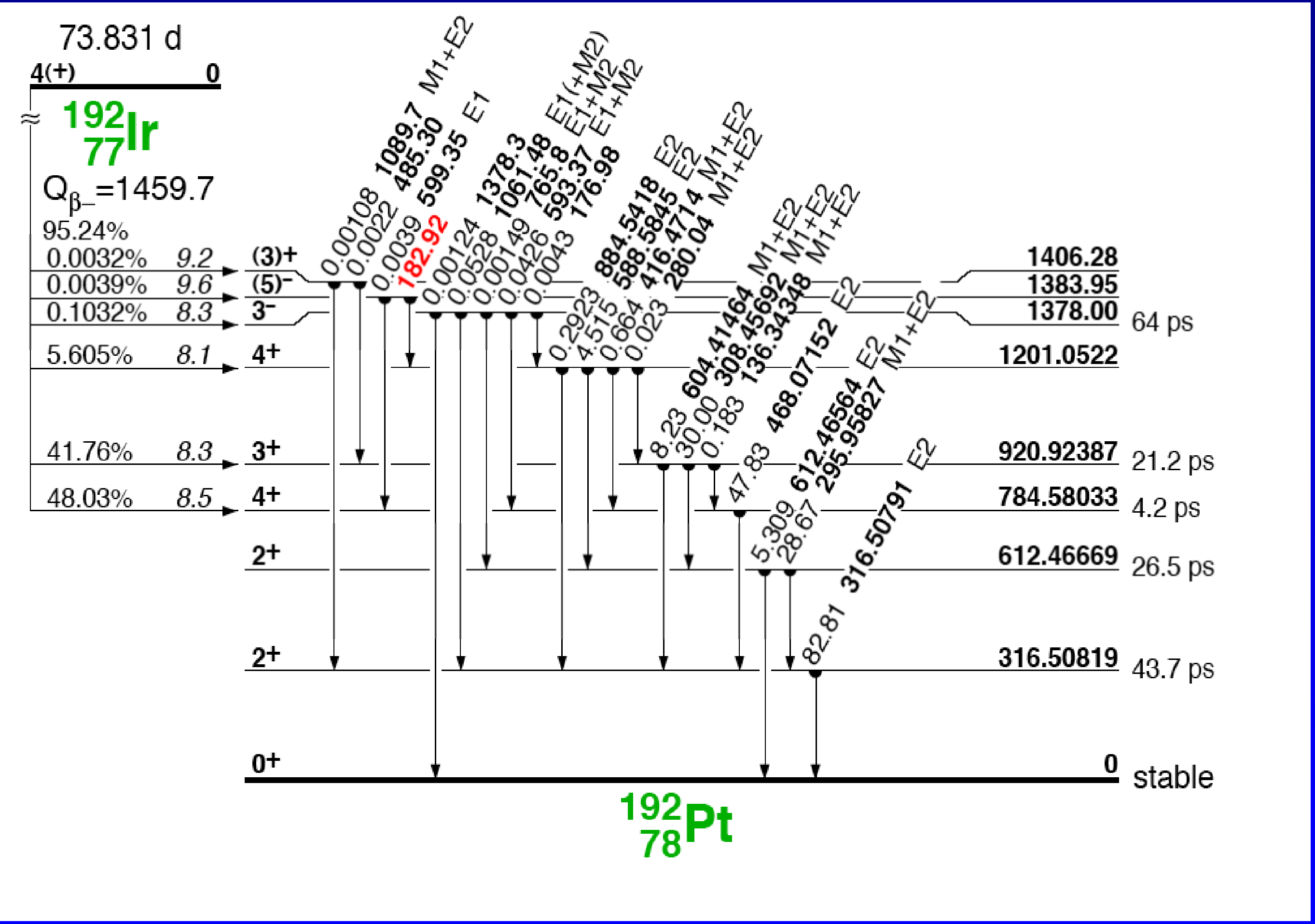
Beta decay to Ba-137m

662 keV photons

Cesium-137

- Bye-product of nuclear fission
- Half life 30 years
- 662 keV photons
- HVL 5.5 mm Pb
- Stainless steel encapsulation
- Less shielding compared to radium-226
- Need to adjust activity due to decay
- Typically needs replacement after 7 years

Iridium-192



74 days

Beta decay to Excited states of Pt-192 and electron capture to Os-192

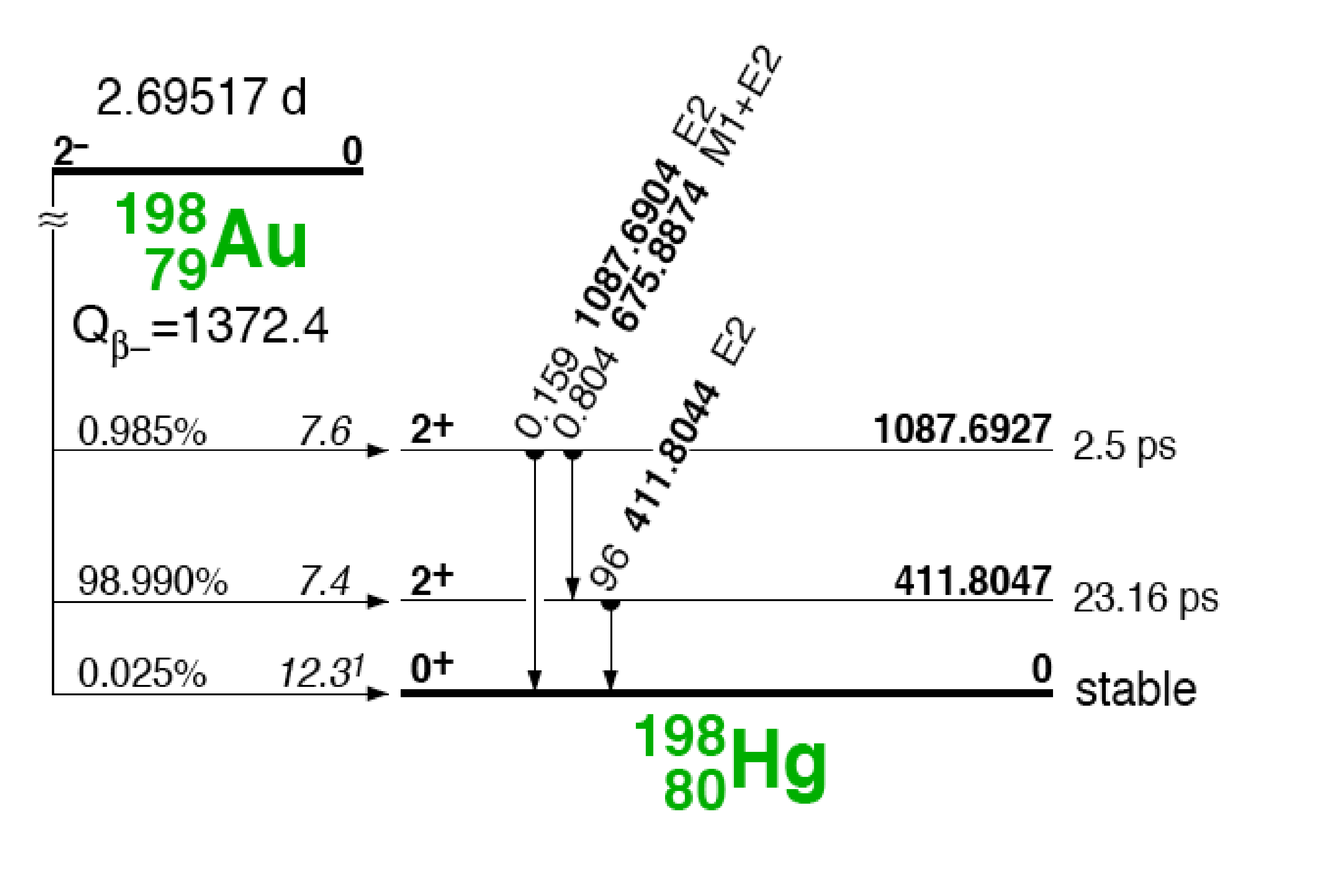
Complex energy spectrum

Average 0.38 MeV

Iridium-192

- Produced neutron activation in a reactor
- Small tubes or wires
- High specific activity
- High activity small sources for HDR
- Temporary brachytherapy applications
- HVL 2.5 mm Pb
- Widely used in multiple applications

Gold-198



2.7 days

Beta decays to Hg-198

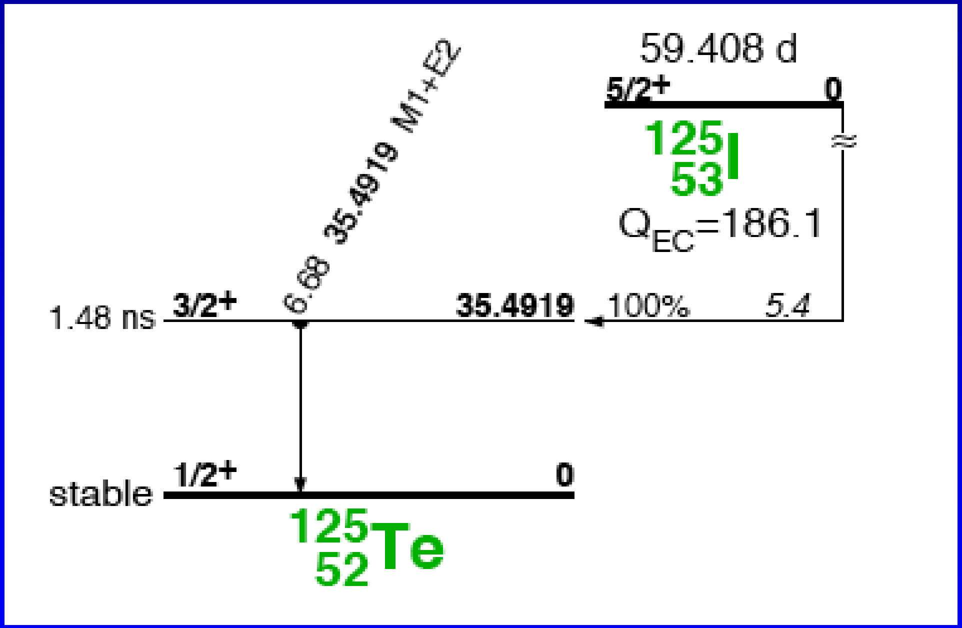
0.412 MeV photons

Nearly monoenergetic

Gold-198

- Produced by neutron activation in a reactor
- Typically 0.1 mm Pt encapsulation
- Small seeds or gold “grains”
- Suitable for permanent implants
- Not commonly used in US
- HVL 2.5 mm Pb

Iodine-125



59.4 days

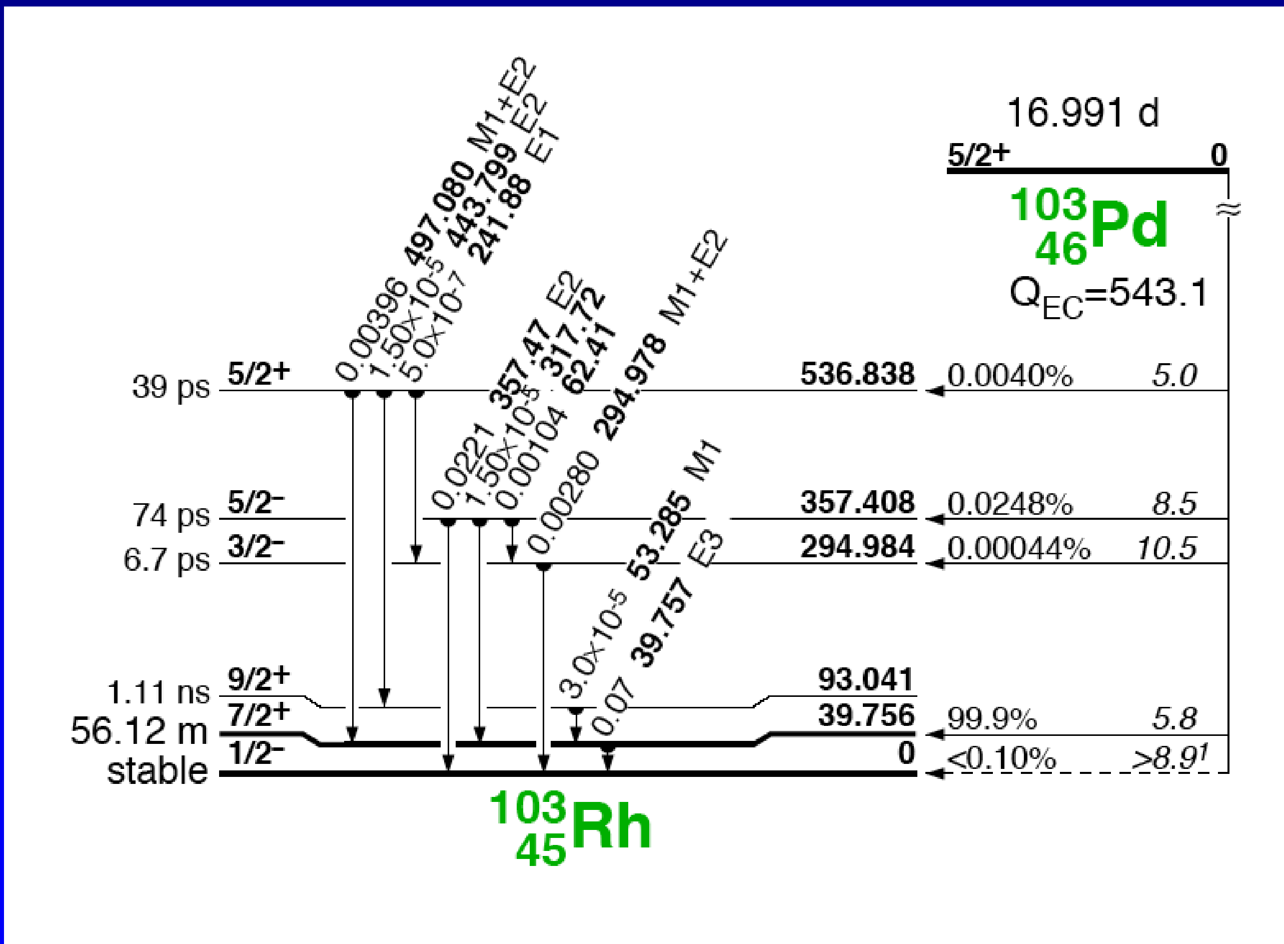
Electron capture to excited state of Te-125 followed by characteristic x-ray emission

Average 0.028 MeV

Iodine-125

- Produced in a nuclear reactor
- Widely used for permanent implants
- HVL 0.025 mm Pb
- Wide range of activities available
- Numerous models available

Palladium-103



17 days

Decays by electron capture to excited states of Rh-103 followed by characteristic x-ray emission

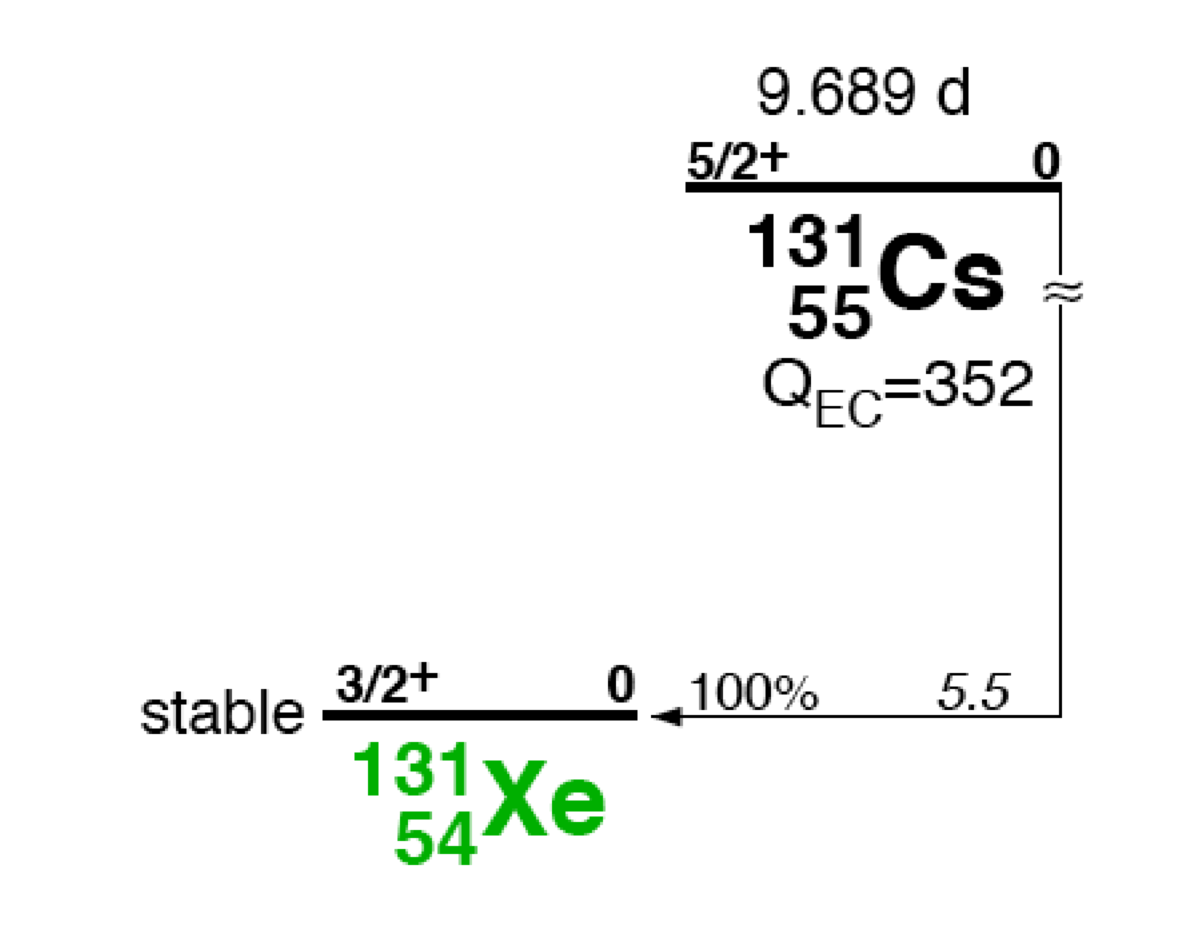
20-23 keV photons

Average 21 keV

Palladium-103

- Can be produced in a nuclear reactor or in a cyclotron by proton bombardment
- Widely used for permanent implants
- Wide range of activities available
- Various models available
- HVL 0.004 Pb

Cesium-131



10 days

Decays by electron capture to Xe-131 followed by characteristic x-ray emission

4-34 keV photons

Average 30 keV

Dose Rate Constant of a Cesium-131 Interstitial Brachytherapy Seed Measured by Thermoluminescent Dosimetry and Gamma-ray Spectroscopy

Zhe Chen, Ph.D., Paul Bongiorni, M.S.,

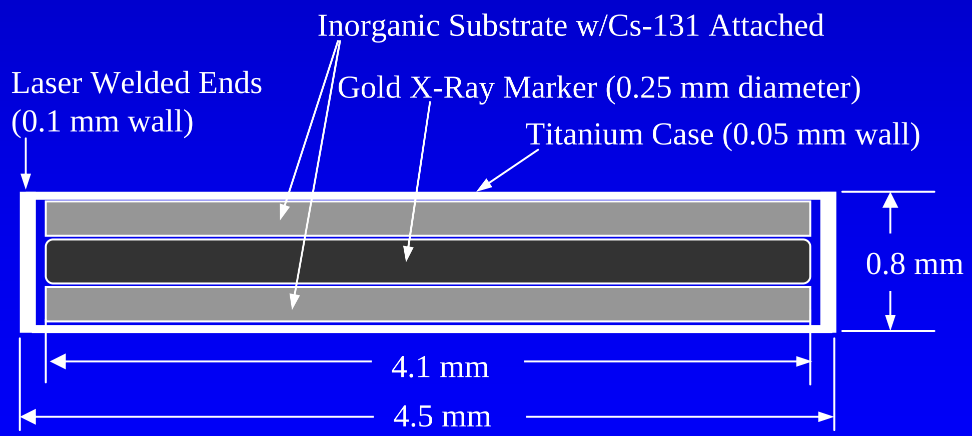
and Ravinder Nath, Ph.D.

Yale University School of Medicine

Introduction

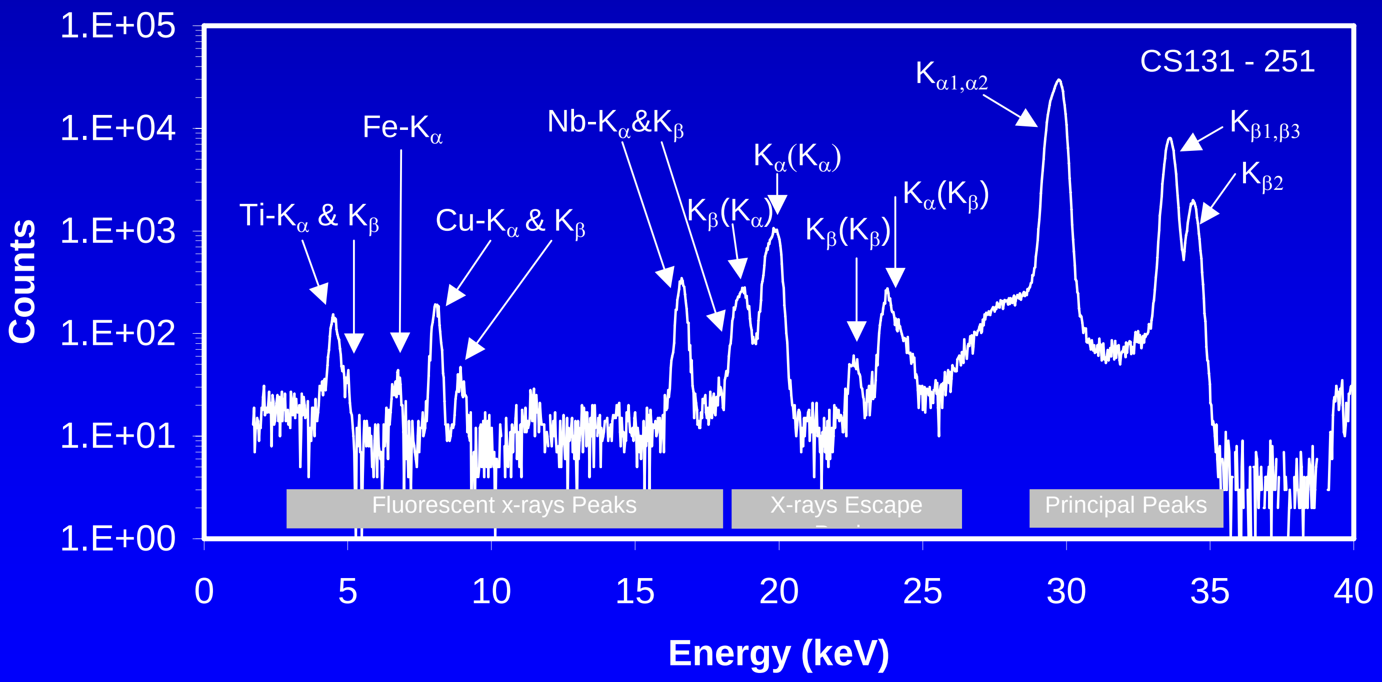
- A new low-energy interstitial brachytherapy seeds containing ^{131}Cs (model CS-1) has been introduced by IsoRay Medical Inc.

- Physical characteristics



Results – Spectrum

A. Typical measured photon energy spectrum for a Cs-131 seed



Results – Relative Spectrum

B. Measured average relative photon energy spectrum for the Cs-131 seeds

Energy (keV)	Radiation Source	Relative Intensity	
		Bare ^{131}Cs	^{131}Cs seed
4.1	^{131}Cs – L	0.143	0.0
16.6	Fluorescent (Nb - K_{α})	-	0.007 ± 0.0003
18.7	Fluorescent (Nb - K_{β})	-	0.001 ± 0.00006
29.7	^{131}Cs – K_{α}	1.000	1.000
33.6	^{131}Cs – $K_{\beta1, \beta3}$	0.178	0.201 ± 0.0007
34.4	^{131}Cs – $K_{\beta2}$	0.035	0.050 ± 0.0003

(Standard deviation represents deviations among the eight seeds)

Monte Carlo Simulations and experimental determinations complement each other, neither alone is sufficient for characterization of a new brachytherapy source

Results – Dose Rate Constant

C. Dose rate constant determined by TLD dosimetry:

1.058 ± 0.099 $cGyh^{-1}U^{-1}$

D. Dose rate constant determined by the gamma-ray spectroscopy technique:

1.066 ± 0.064 $cGyh^{-1}U^{-1}$

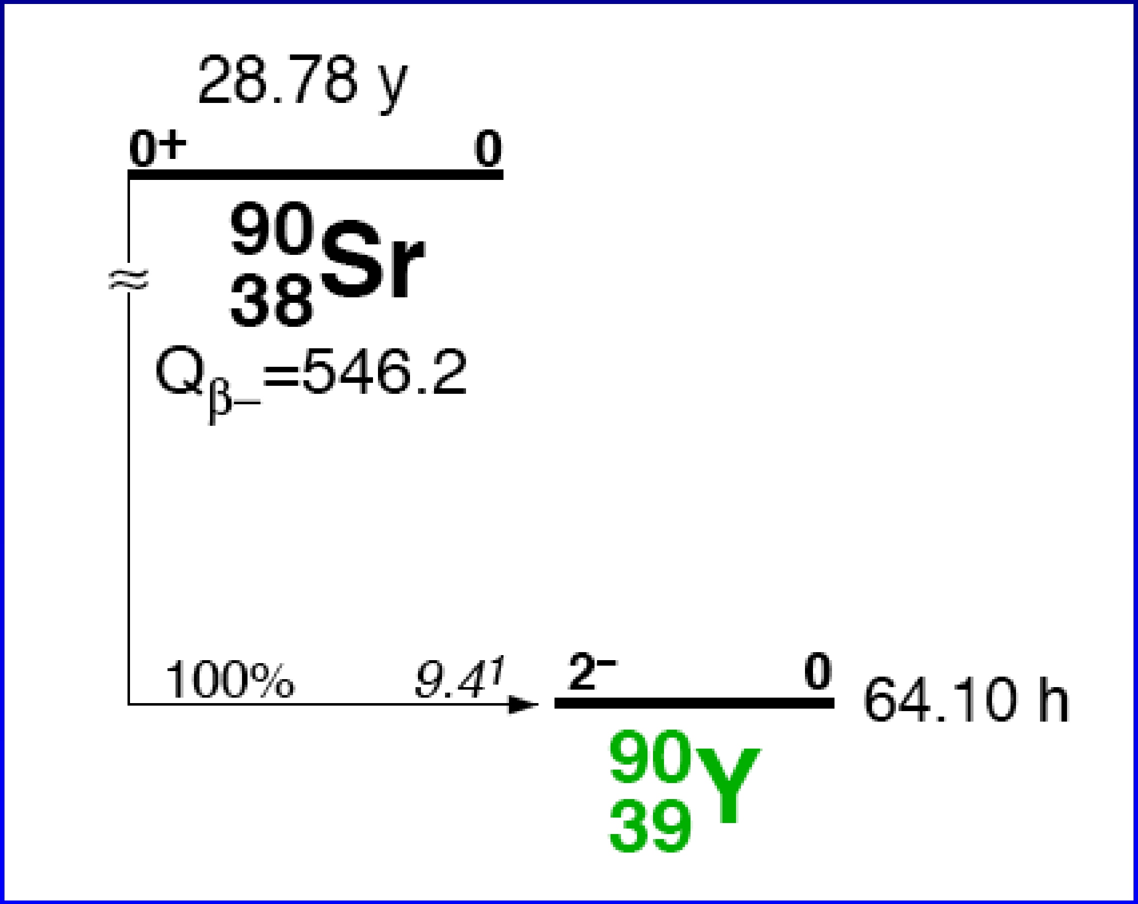
$\Rightarrow$ **Approximately 15% greater than a previously measured value of**

0.915 ± 0.020 $cGyh^{-1}U^{-1}$

Beta-Emitting Radionuclides Used in Brachytherapy

- Strontium-90
- Phosphorus-32
- Ytrium-90

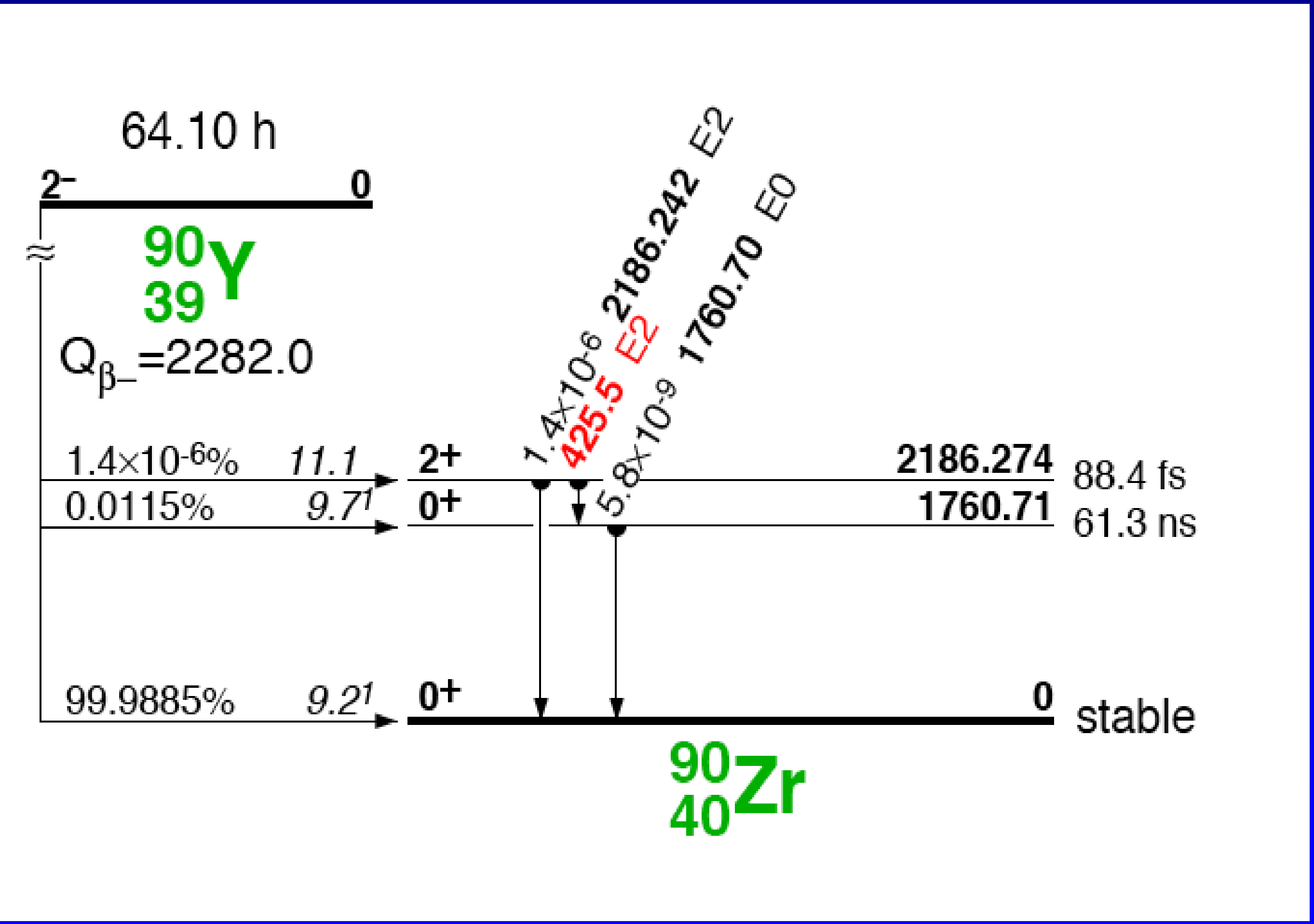
Strontium-90



29 year

Beta decay to Y-90 and Y-90m with a maximum energy of about 0.5 MeV

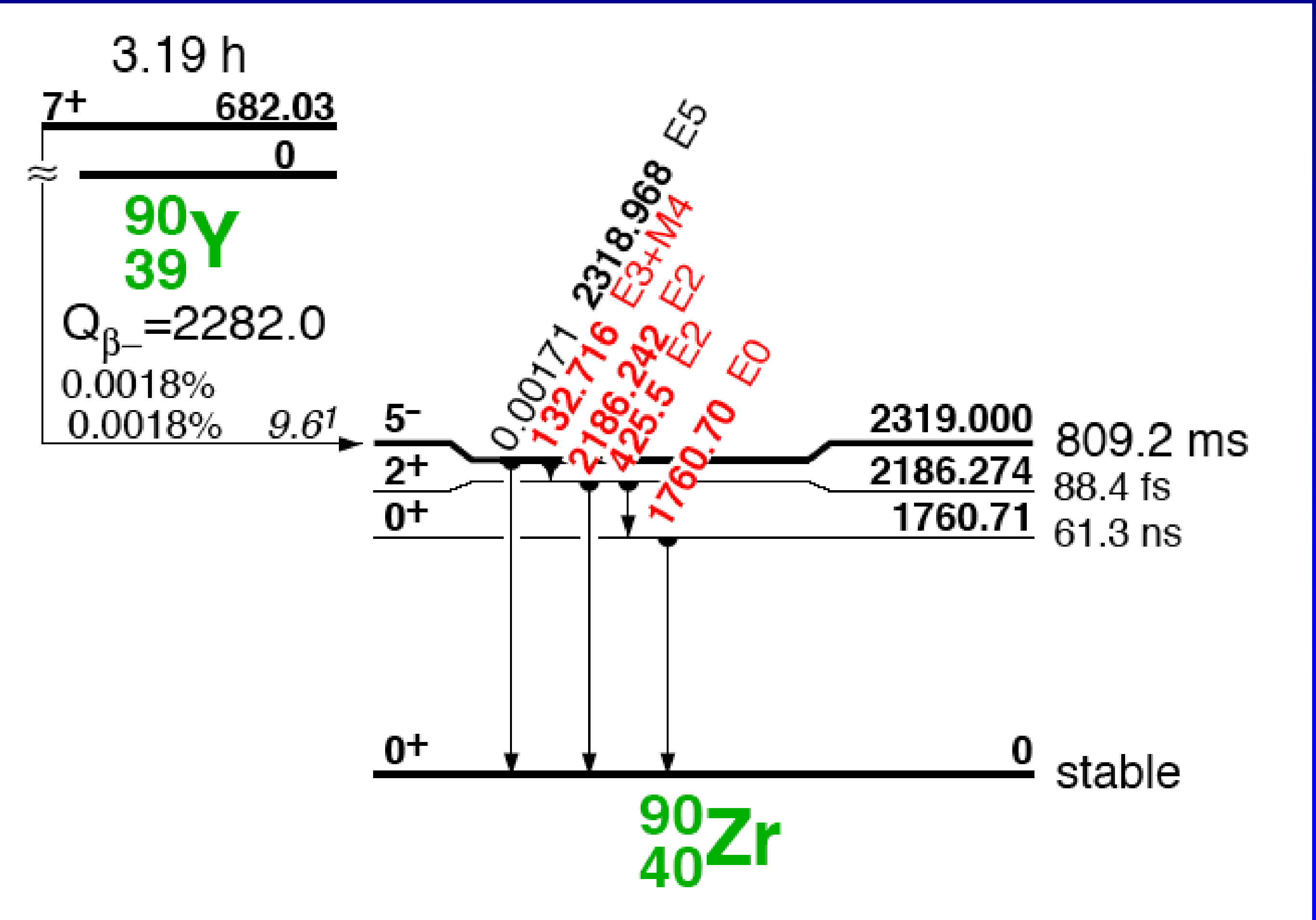
Ytrium-90



64 hours

Beta decay with a maximum energy of 2.27 MeV

Ytrium-90m



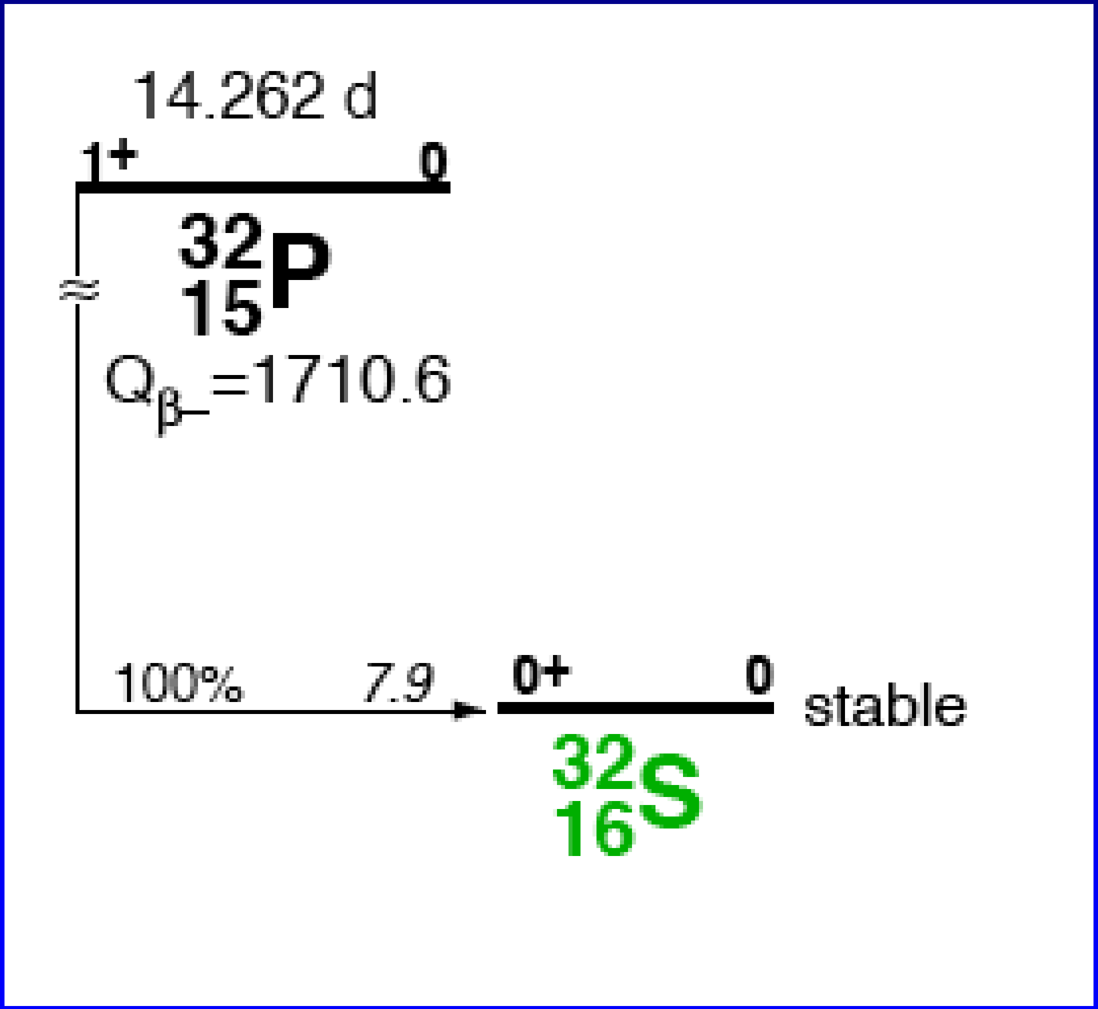
3 hours

Beta decay with a maximum energy of 2.28 MeV

Strontium-90

- Bye product of nuclear fission
- Therapeutic radiation is primarily from 2.27 MeV betas from Y-90
- Suitable for treatment of superficial lesions, ocular lesions and coronary vessels
- Limited depth of penetration

Phosphorus-32



14 days

Beta decay to S-32 with a maximum energy of 1.7 MeV

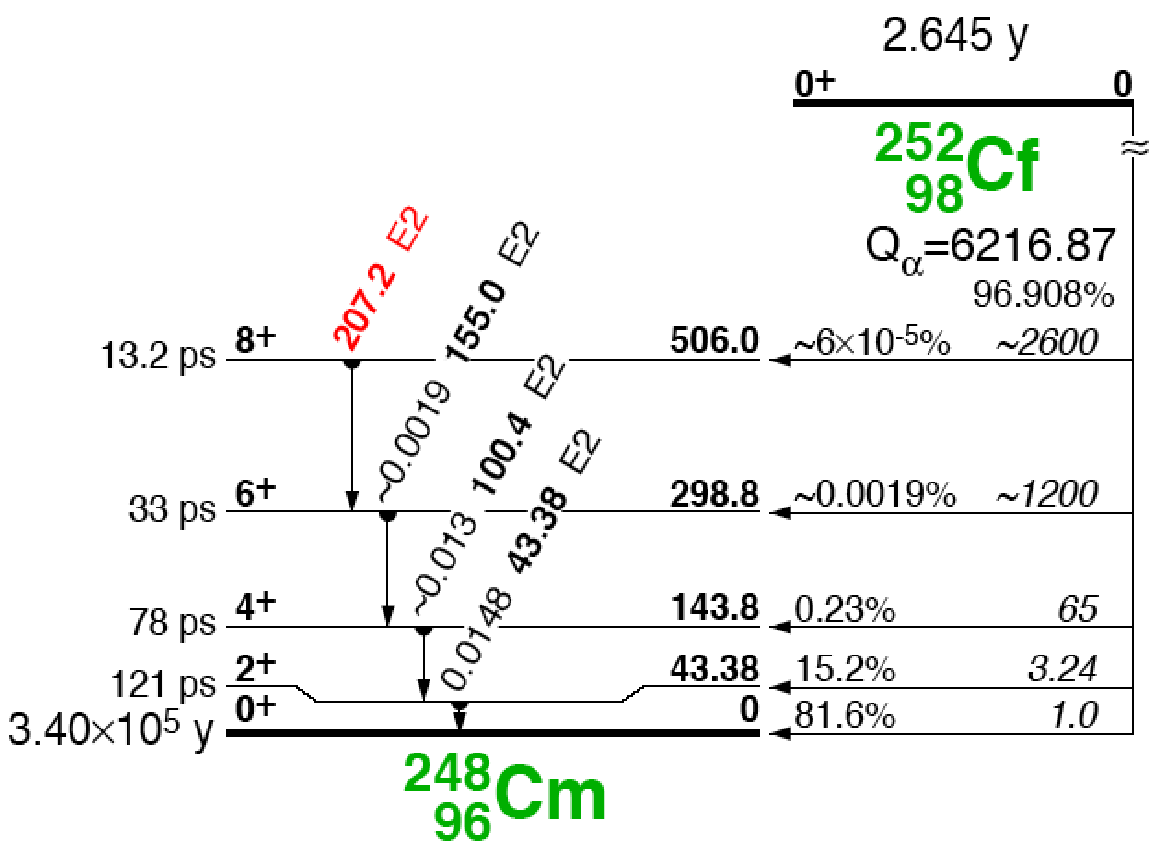
Phosphorus-32

- Pure beta emitter
- Often used as a liquid in a balloon
- Used as wire in an intravascular brachytherapy delivery system
- Even more limited depth of penetration compared to Sr-90

Neutron-Emitting Radionuclides Used in Brachytherapy

Californium-252

Californium-252



2.6 years

Alpha decay (97%)

Fission (3%)

Fission neutrons

Average neutron energy 2.15 MeV

Average photon energy 0.8 MeV

Californium-252

- Pt-Ir encapsulation
- Small tube sources available
- Limited use only
- Temporary intracavitary brachytherapy
- Difficult to shield the OR
- Risk of neutron-induced carcinogenesis

Some of the Possible Radionuclides For Intravascular Brachytherapy

Radionuclide	Emission	Maximum Energy (keV)	Average Energy (keV)	Half-Life	Delivery System
^{32}P	Beta	1710	695	14.28 days	C,S,L
^{90}Y	Bet a	2282	934	2.671 days	C,S,L
^{90}Sr	Beta	546	196	28.5 years	C
^{192}Ir	Gamma	612	370	73.831 days	C
^{103}Pd	X-ray	23	21	16.97 days	S
^{125}I	X-ray	35	28	60.14 days	S
^{48}V	Positron	696	144	15.976 days	S
^{106}Rh	Beta	923	307	2.17 hours	L
^{188}Re	Beta	2120	756	16.98 hours	L

Summary

Radionuclide	Half-life	Principal or mean energies from encapsulated sources, MeV*		
		Photon	Beta	Neutron
Radium-226	1622 y	0.830		
Cesium-137	30 y	0.662		
Iridium-192	74 d	0.380		
Gold-190	2.7 d	0.412		
Iodine-125	60 d	0.028		
Palladium-103	17 d	0.021		
Strontium-90	29 y		0.50	
Ytterbium-90	64 h		2.27	
Phosphorus-32	14 d		1.71	
Californium-252	2.65 y			2.15

* These are nominal values assuming typical encapsulation for sources.