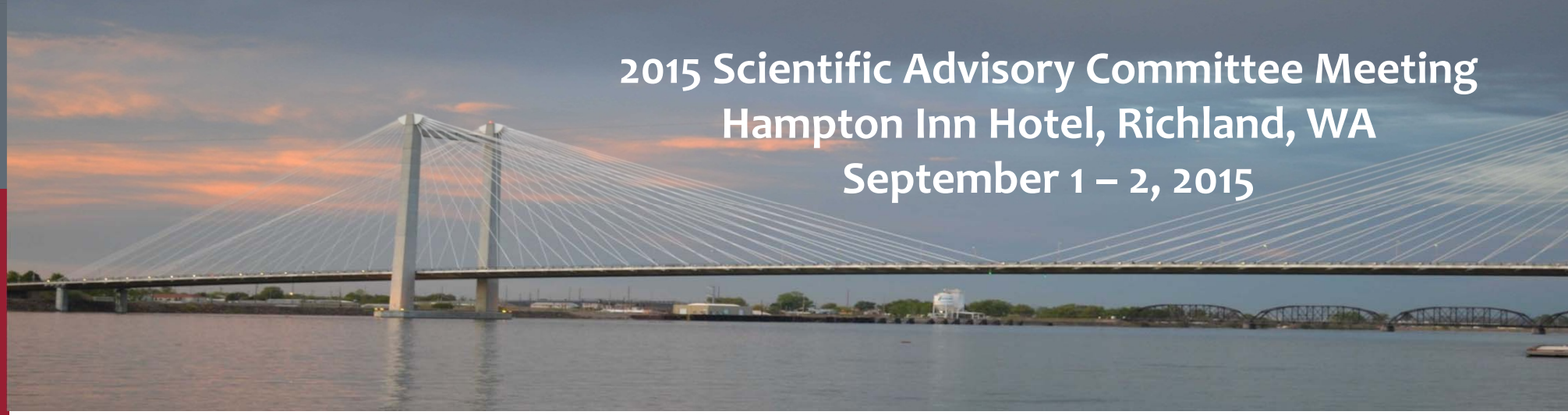

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USTUR Case 0837: Modeling Multiple Intakes

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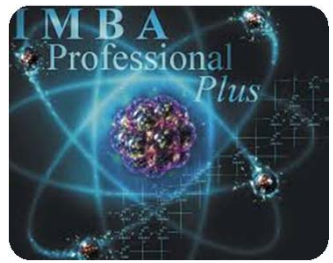
"Learning from Plutonium and Uranium Workers"

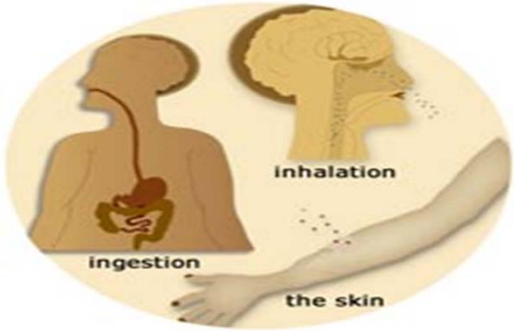
USTUR Mission

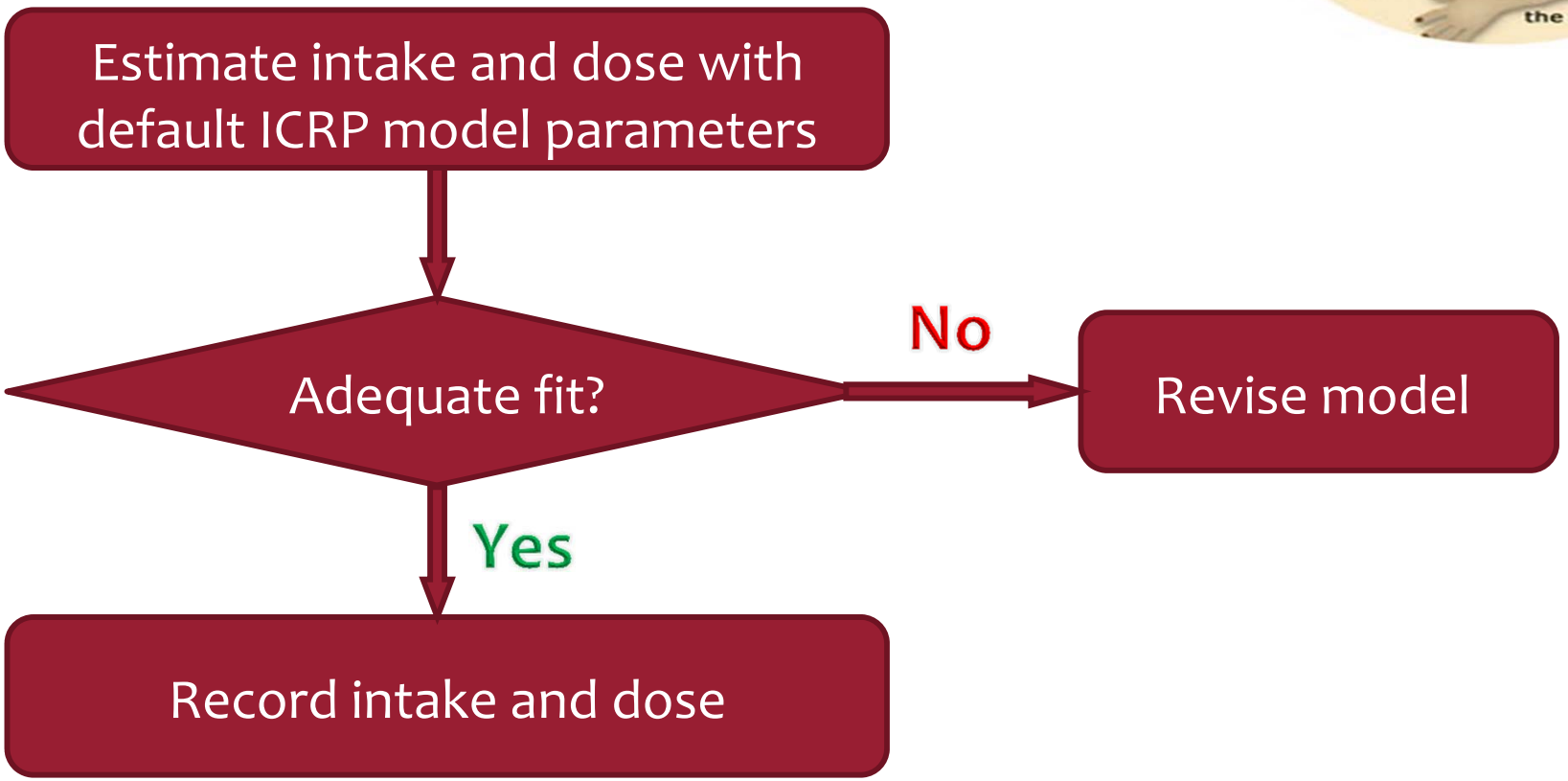
- Apply USTUR case study data to refine internal dose assessment methods as the bases for reliable epidemiological studies, risk projection, and credible standards for radiological protection

UK Public Health England's (PHE) IMBA Professional Plus is applied to assess actinide intakes in individual USTUR cases



Internal Dose Assessment





J.W.Marsh, M.R.Bailey, A.Birchall. A Step-by-step Procedure to Aid the Assessment of Intake and Doses from Measurement Data. *Radiat Prot Dosim* 2005; 114(4): 491-508

USTUR Case 0837

- *Employment at NDF*: 20 y
- *Major work type*: Pu recovery and metal reprocessing
- *Exposure*: Multiple inhalations
- *Donation type*: Partial-Body
- *Cause of death*: Heart disease
- *Age*: 84 y

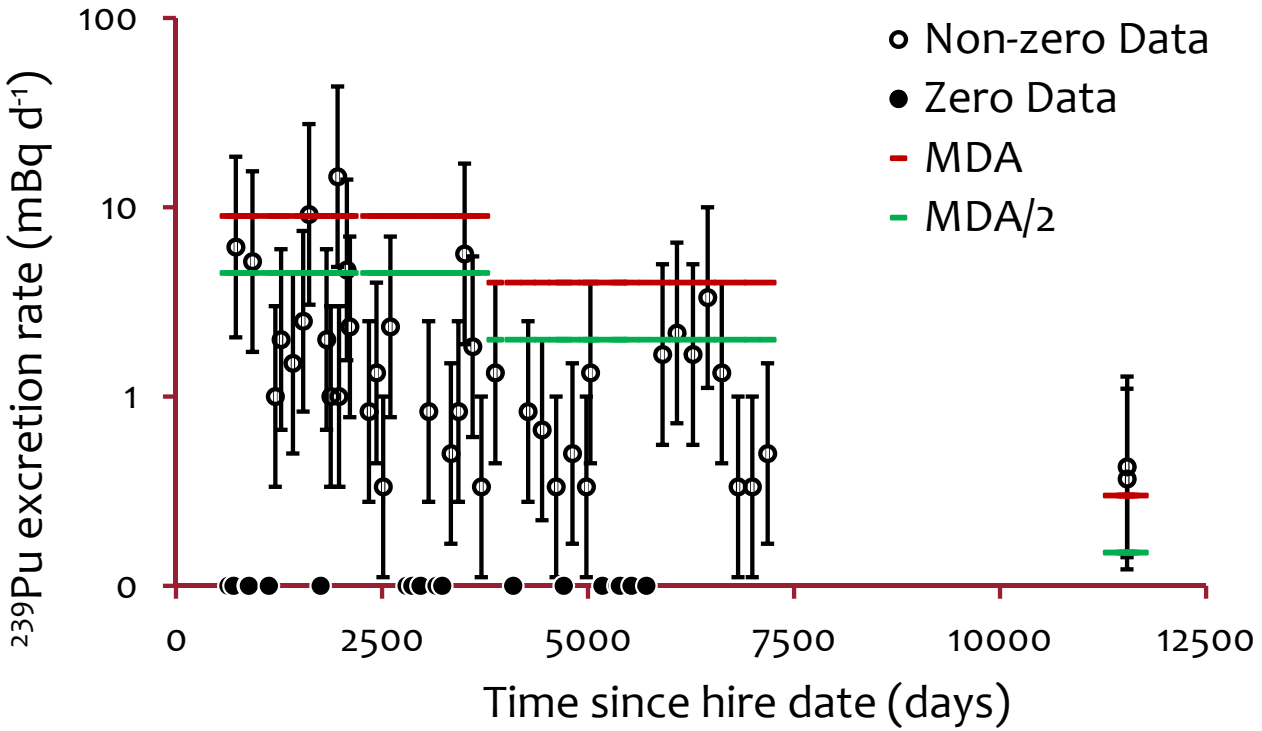
Exposure History

- Six recorded skin contamination incidents
- Only two of these resulted in positive urine bioassay
  - ✓ Day 725†: 2,000 cpm in mouth and on face
  - ✓ Day 1,954†: 10,000 cpm on hand; no respiratory protection
- Suspected inhalation based on positive lung count
  - ✓ Day 2,761†: no exposure incident reported
  - ✓ Worksite personnel assumed 1,000 ppm ^{241}Am in Pu mixture

† Days since hire

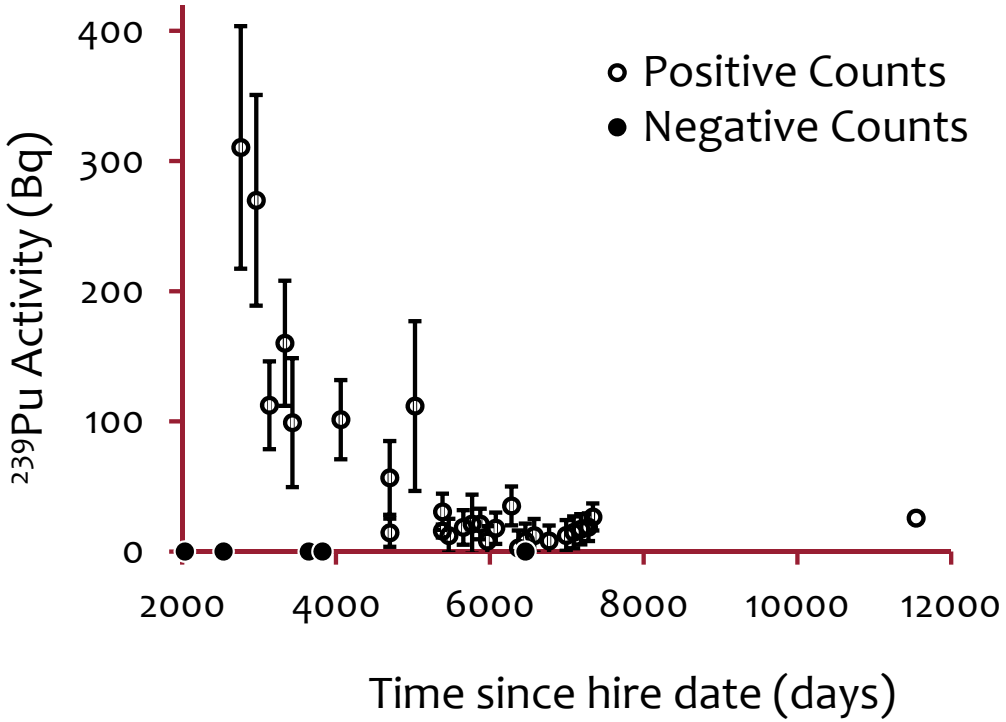
In-Vitro Bioassay: Urine

- 57 Pu measurements
  - ✓ 2 samples: > MDA
  - ✓ 8 samples: > MDA/2 (assumed to be LOD)
- 2 follow-up samples: > MDA



In-Vivo Bioassay: Lungs

- 40 in-vivo lung measurements
  - ✓ 59.5-keV gamma photons from ^{241}Am
  - ✓ 30 results with positive counts
  - ✓ In-growth of ^{241}Am from ^{241}Pu taken into account
  - ✓ Data adjusted for calibration discontinuities



Worksite Estimate of Pu Deposition

Burden	Activity, Bq (nCi)	
	Estimate	Permissible Amount
Systemic	111 (3.0)	1,480 (40)
Lungs	33 (0.9)	592 (16)

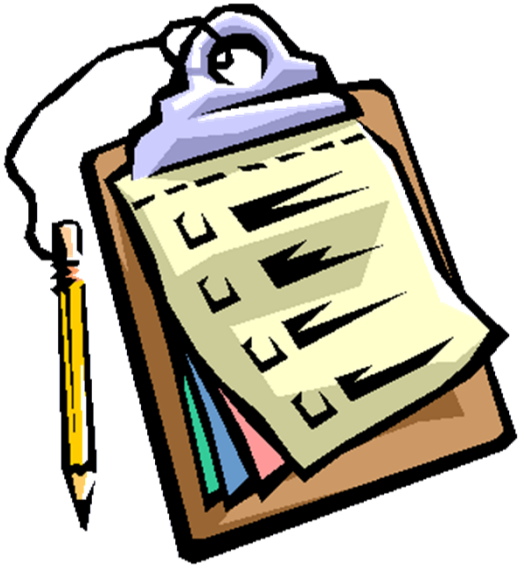
Autopsy Tissue Analysis

- Measurement method: alpha spectrometry

Tissue	Sample mass (g)	Concentration (Bq kg^{-1})	Organ content (Bq)
Lungs	490.10	16.3 ± 0.3	21.6
Thoracic Lymph Nodes	6.59	74.0 ± 4.0	1.1
Liver	574.50	5.4 ± 0.1	7.5
Kidneys	101.89	0.064 ± 0.009	0.015
Skeleton (5 samples)	250.02	0.9 ± 0.1	9.3[a]

[a] Based on total skeletal weight (9.85 kg) predicted from height (1.73 m) (ICRP 2002)

Observations

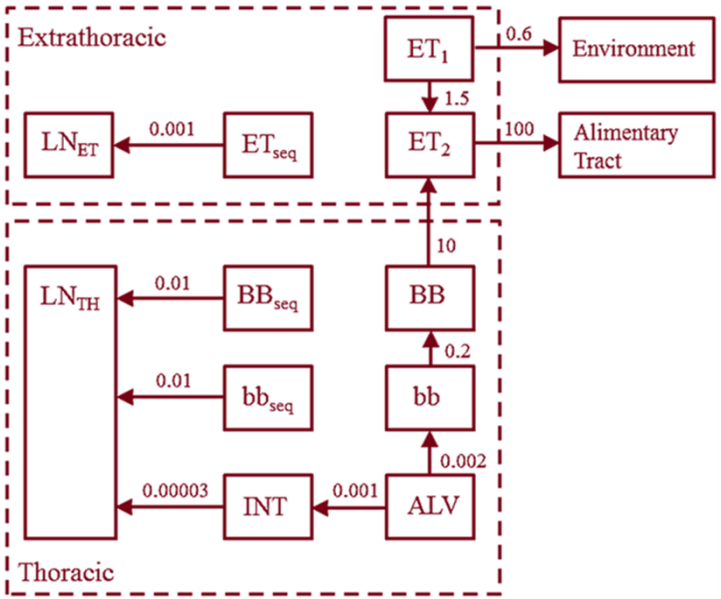


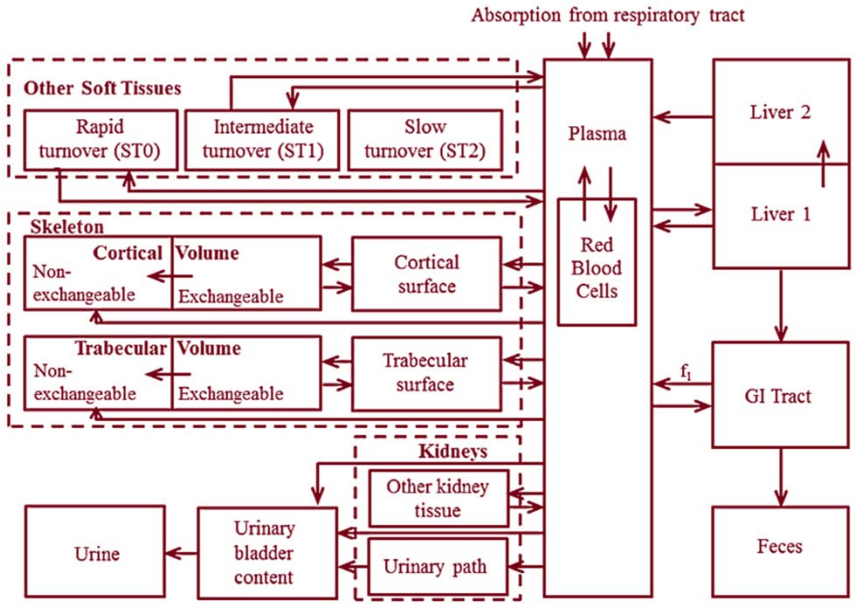
- LN_{TH}/Lung concentration ratio: 4.5
  - ✓ Between 1 (type M) and 19 (type S)
  - ✓ More soluble Pu compounds ?
- Liver/Lung activity ratio: 0.3
  - ✓ < 1.6
  - ✓ Insoluble Pu compounds ?

Mixture !!!

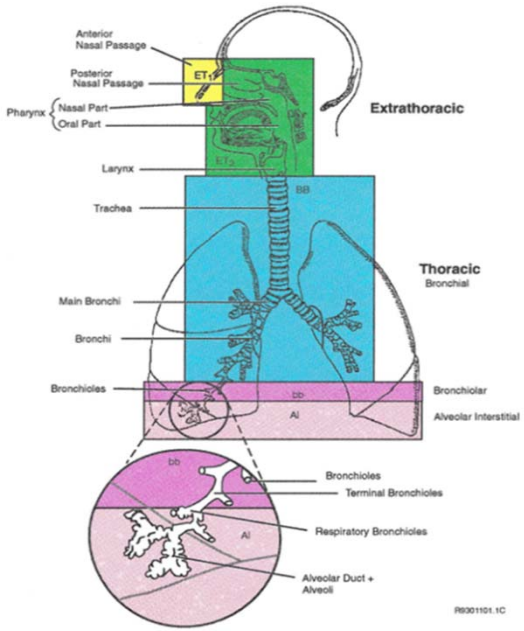
Data Analysis Method

- Data: urinalyses, lung counts, organ contents
- Method: maximum likelihood fitting
- Models used
  - ✓ ICRP 130 OIR: revised HRTM
  - ✓ ICRP 67 Pu systemic model





Using ICRP Defaults (1)



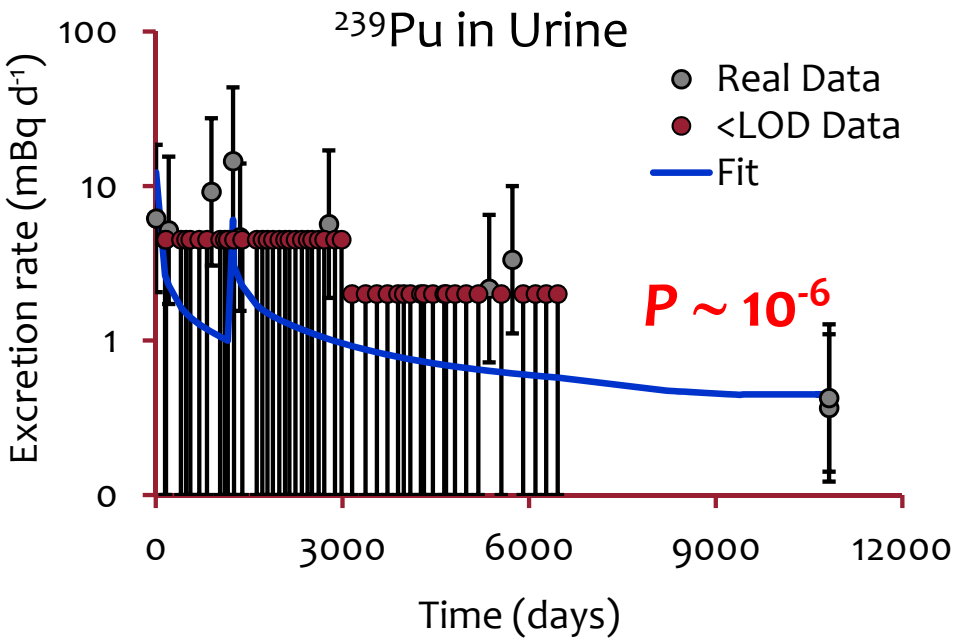
- Particle size: 5 μm AMAD
- ICRP 130 default particle transport
- Absorption Type M
- Exposure scenario: multiple inhalation intakes
  - ✓ *IR1*: Day 1
  - ✓ *IR2*: Day 1,236

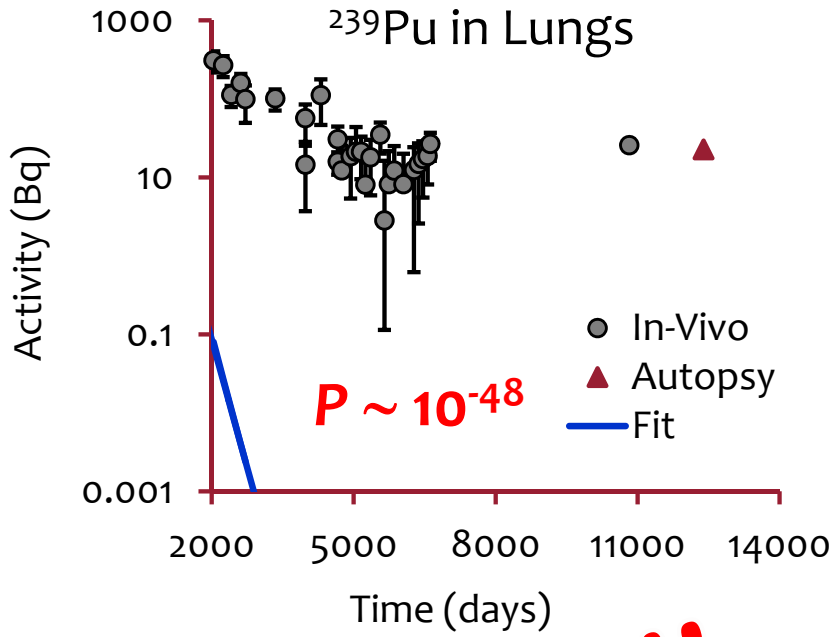
  } Reported Contamination

  - ✓ *IR3*: Day 2,043 ⟵ Suspected Inhalation

Using ICRP Defaults (2)

- Absorption Type M assumed for all intakes
  - ✓ $f_r = 0.2$; $s_r = 3\ d^{-1}$; $s_s = 0.005\ d^{-1}$





$P_{liver} = 0.50$

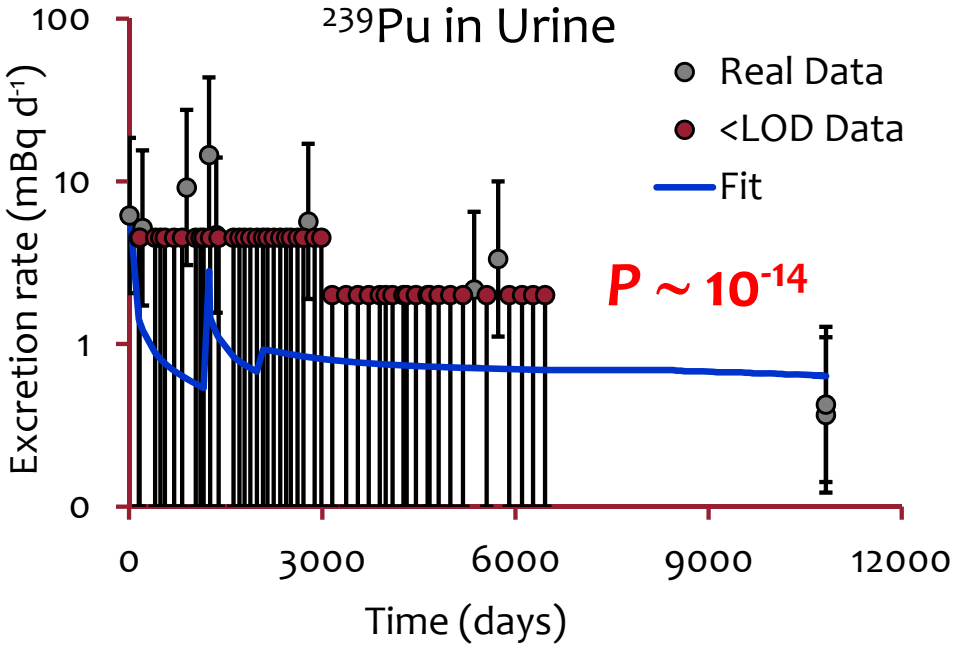
$P_{skel} = 0.45$

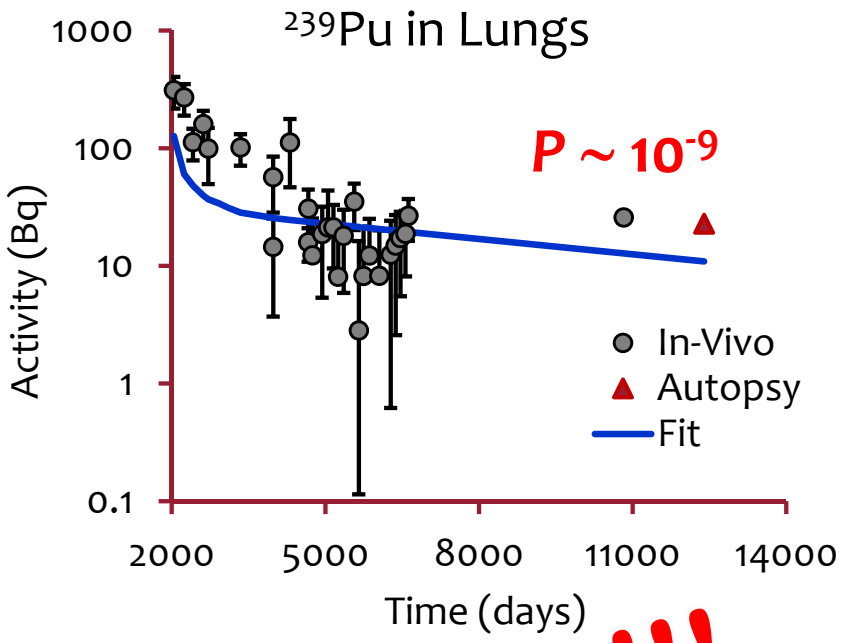
$P_{total} \sim 10^{-53}$

Poor Fit !!!

Revising the Assumptions

- Absorption Type S assumed for suspected intake
  - ✓ $f_r = 0.01$; $s_r = 3\ d^{-1}$; $s_s = 0.0001\ d^{-1}$





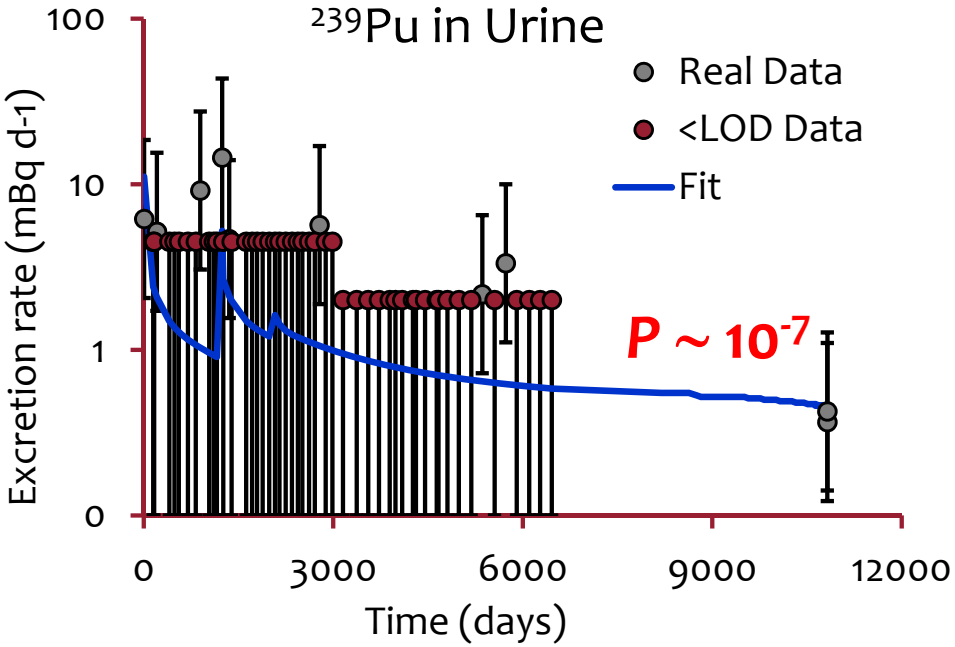
$P_{liver} = 0.002$ $P_{total} \sim 10^{-23}$

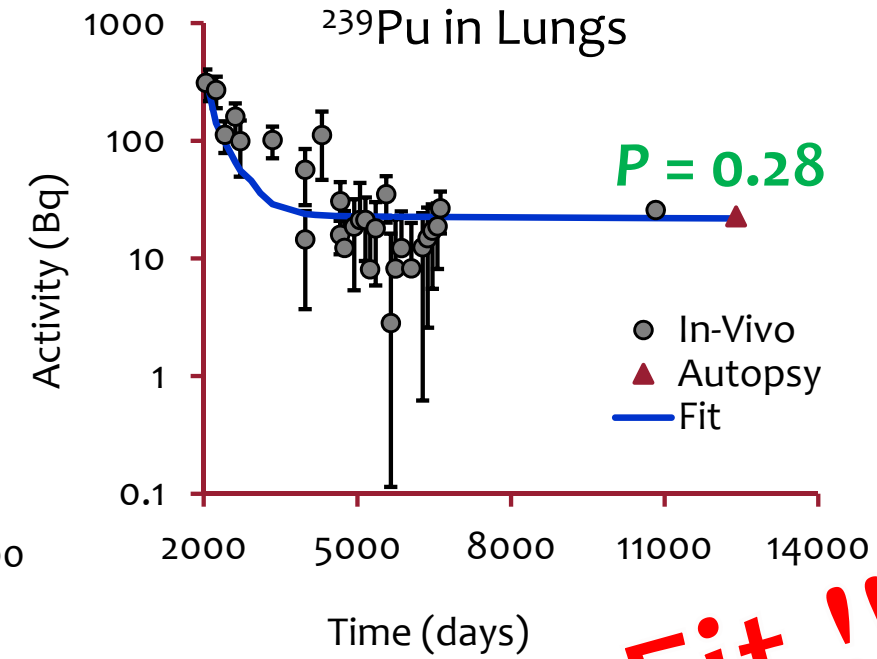
$P_{skel} = 0.26$

Poor Fit !!!

Revising the Model

- Revised HRTM parameters for suspected intake
  - ✓ Absorption: f_r = 0.01; s_r= 1 d^{-1}; s_s = 5×10^{-6} d^{-1}
  - ✓ Particle Transport: *Alv / Int* = 0.9 / 0.1 (*vs* default 0.63 / 0.37)





P_{liver} = 0.39

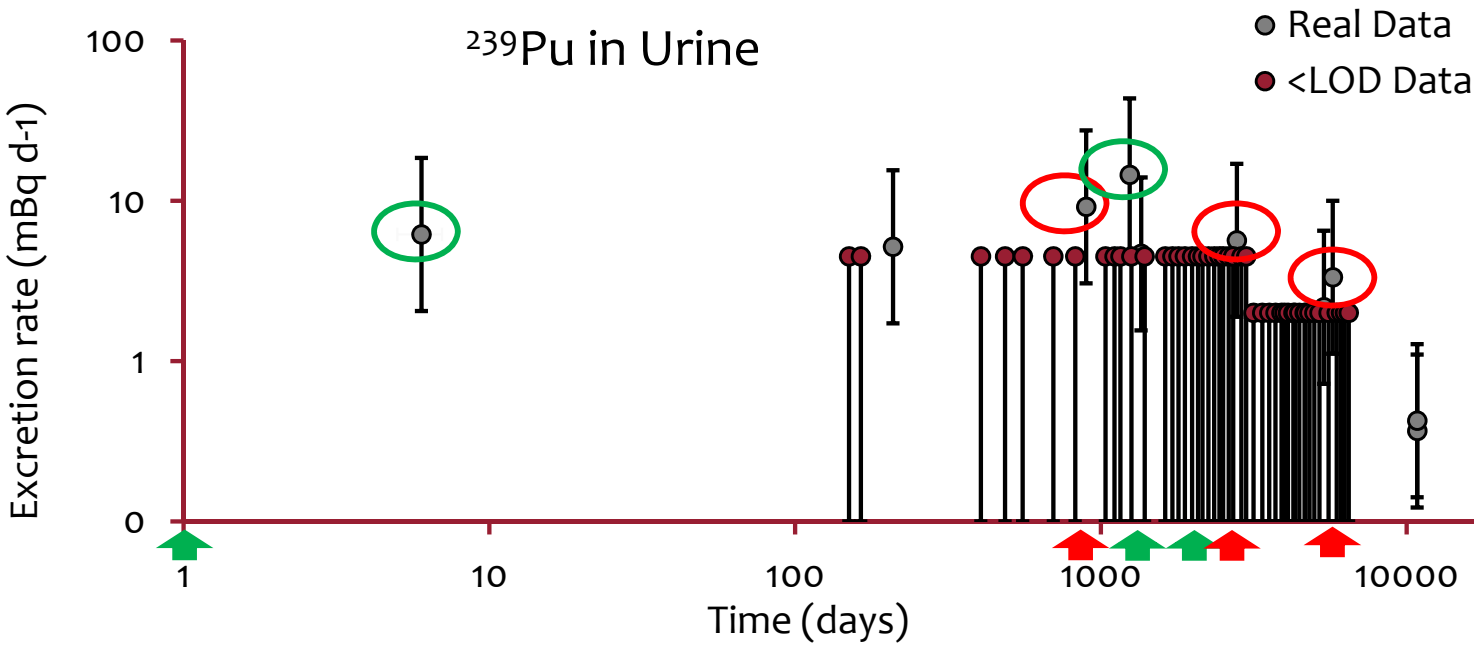
P_{skel} = 0.44

$P_{total} \sim 10^{-5}$

Still Poor Fit !!!

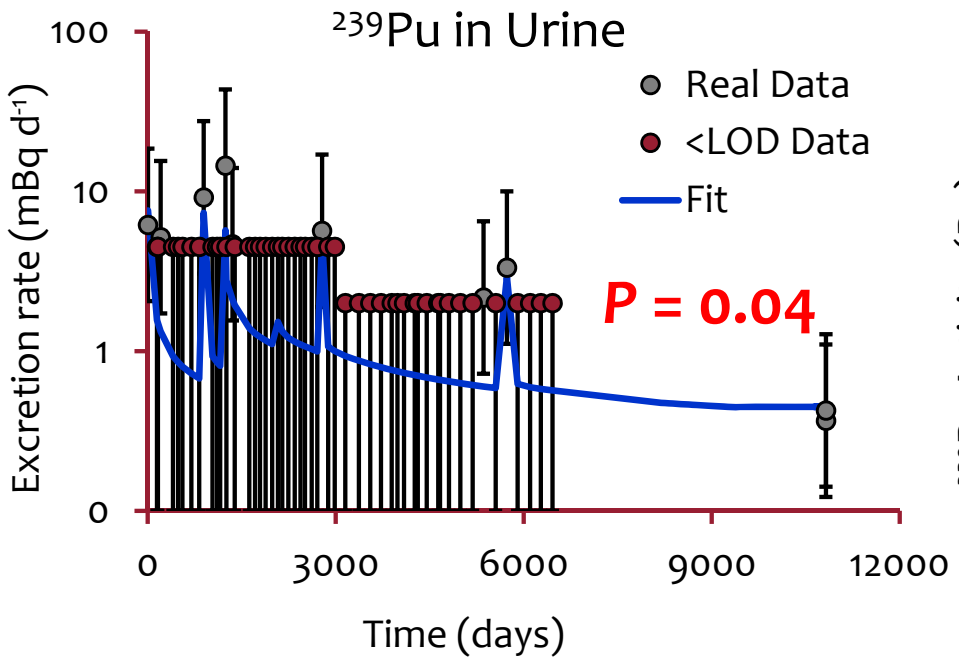
Accounting for Missed Intakes

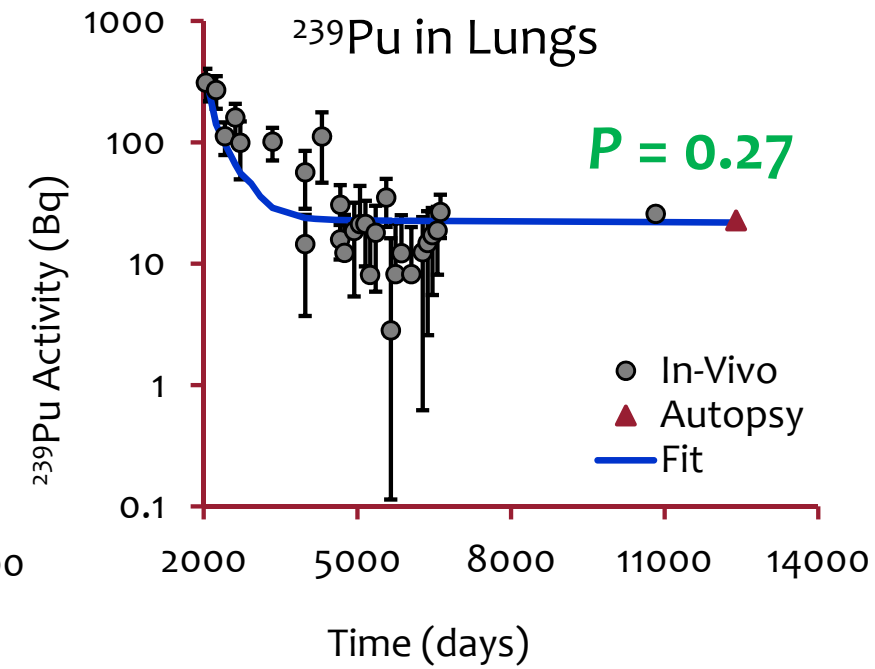
- Added three hypothetical intakes to fit urine data
  - ✓ IR1: Day 1 Reported
  - ✓ IR2: Day 893 Hypothetical
  - ✓ IR3: Day 1,236 Reported
  - ✓ IR4: Day 2,043 Suspected
  - ✓ IR5: Day 2,782 Hypothetical
  - ✓ IR6: Day 5,731 Hypothetical



Fitting Postulated Intake Scenario

- Absorption Type M assumed for missed intakes



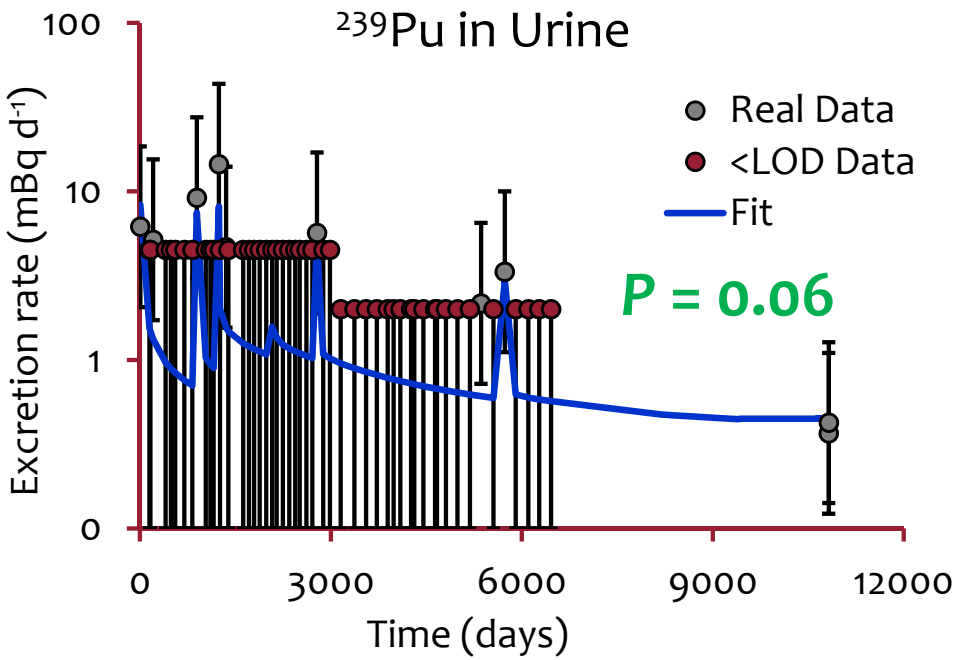


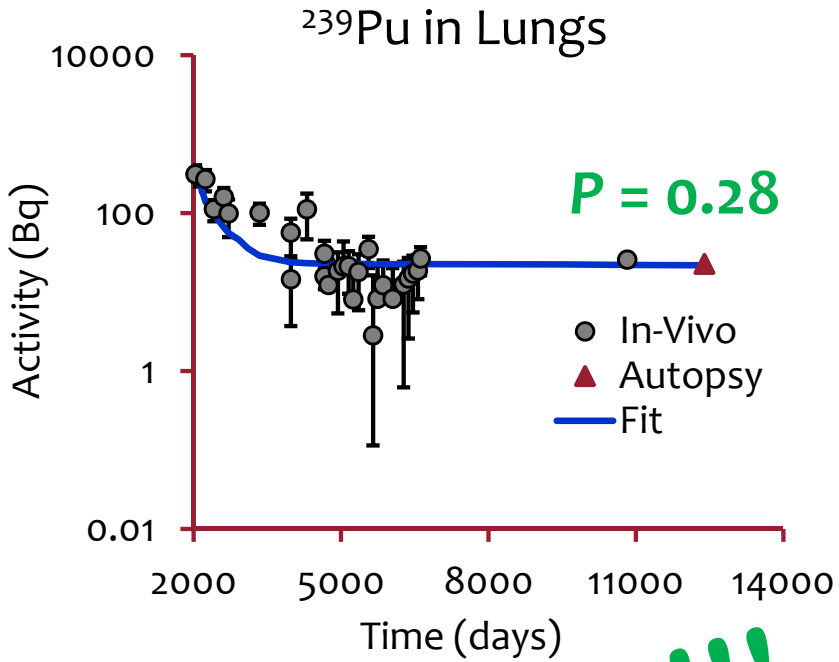
$P_{liver} = 0.75$ $P_{total} = 0.07$

$P_{skel} = 0.57$

Optimizing the Fit

- Revised absorption parameters for second real intake
  - ✓ Absorption: $f_r = 0.3$; $s_r = 0.5\ d^{-1}$; $s_s = 0.0012\ d^{-1}$





$P_{liver} = 0.78$ $P_{total} = 0.09$

$P_{skel} = 0.58$

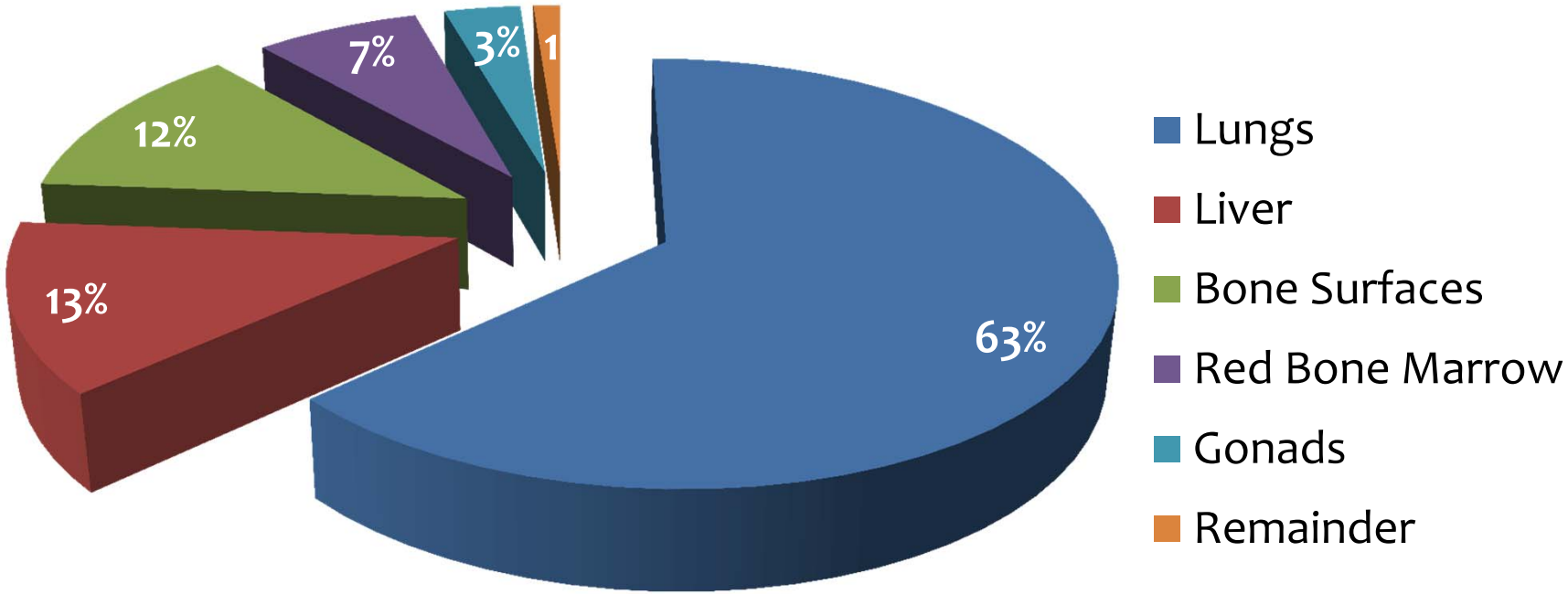
Good Fit !!!

Recording Intake

Intake Regime	Year	Intake (Bq)	% of Total Intake
IR1 Reported	1969	324	6.6
IR2 Hypothetical	1972	74	1.5
IR3 Reported	1973	251	5.1
IR4 Suspected	1975	4,202	85.7
IR5 Hypothetical	1977	34	0.7
IR6 Hypothetical	1985	20	0.4
Total		4,905	

Calculating Dose

Total Committed Effective Dose: 50.2 mSv



Conclusions

- USTUR Donor 0837 was involved in multiple inhalation incidents with only three of them deemed significant based on bioassay monitoring data
- IMBA Professional Plus was used to fit bioassay and autopsy data and estimate intake and tissue doses
- Revising the default ICRP model assumptions and adding hypothetical intake regimes were necessary to obtain a credible fit to the data
- 86% of internal contamination appears to have resulted from a major inhalation intake of highly insoluble Pu material
- Total committed effective dose was estimated to be ~ 50 mSv with 63% contributed by lungs

Thank you!