WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

42nd Annual Meeting of the Health Physics Society of Japan, Okinawa, June 26-27, 2008

Using *In Vivo* Measurements and Urine Bioassay to Characterize the Absorption of Inhaled $^{241}AmO_2$ and Evaluate the Probability Distribution of Doses

Anthony C James[1], Timothy P Lynch[2], Alan Birchall[3], Matthew Puncher[3]

[1]U.S. Transuranium & Uranium Registries (USTUR), Washington State University ,
1845 Terminal Drive, Suite 201, Richland, WA 99354, USA
[2]Pacific Northwest National Laboratory (PNNL), In Vivo Monitoring Program,
PO Box 999, Richland, WA 99354, USA
[3]Health Protection Agency-Radiation Protection Division (HPA-RPD),
Chilton, Didcot, OXON, OX11 0RQ, UK

Work Supported Under USDOE Grant DE-FG06-92EH89181

USTUR Case 0855 – Acute $^{241}AmO_2$ Inhalation

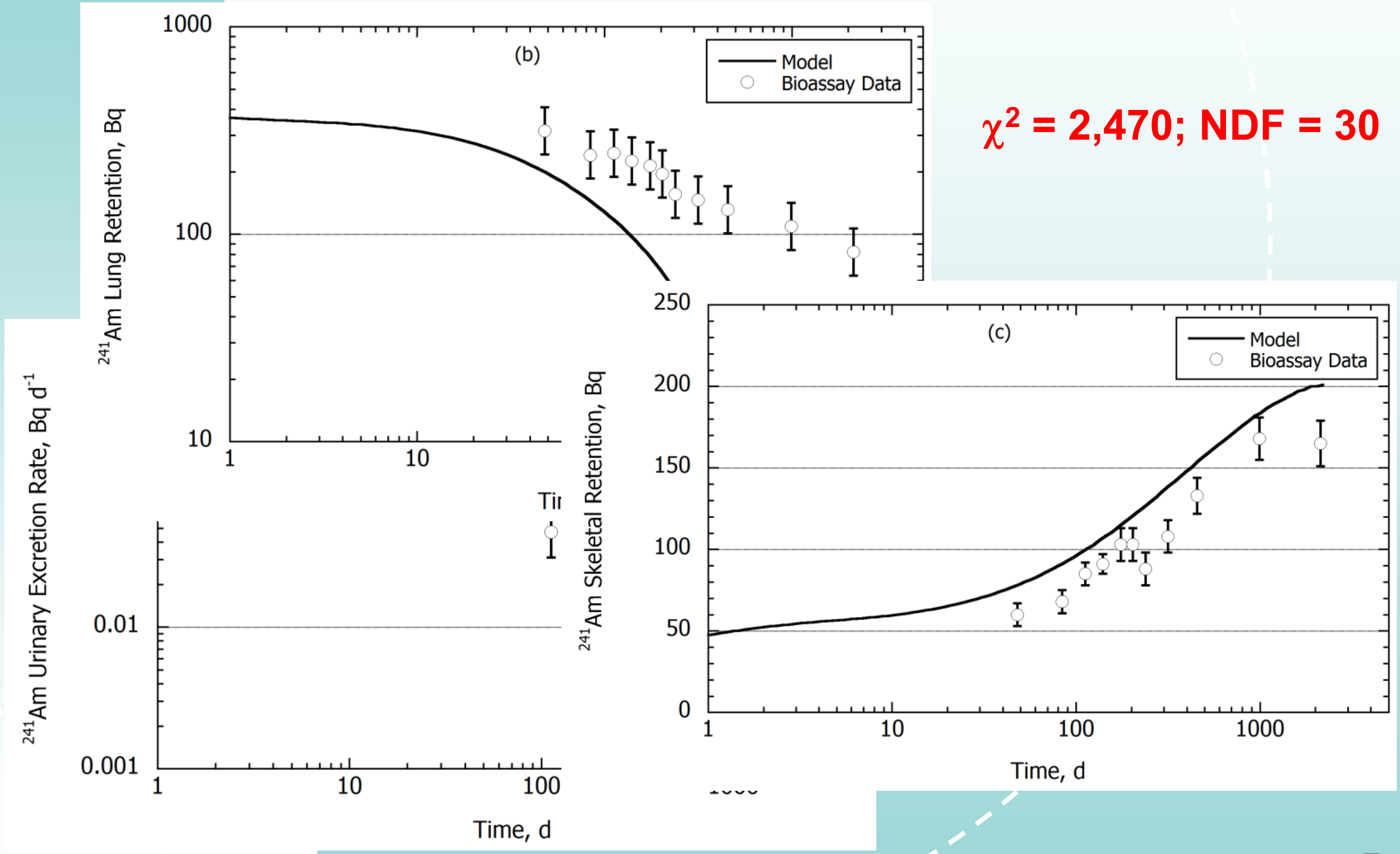
- 1996 : worker discovered α-contamination (> 1 kBq/100 cm^2) while examining old 370 MBq supposedly ‘sealed’ ^{241}Am source.
- 6 weeks later: the worker (healthy, 38-y-old non-smoker) voluntarily enrolled in USTUR – participate in long-term bioassay and external counting study.
- 2003: initial results of bioassay and external counting published (Kathren et al., Health Phys. 84:576-581; 2003).
- Results not consistent with either ICRP default absorption types ‘M’ or ‘S.’

^{241}Am Bioassay Data Available for Case 0855

Date	Daily Urinary Excretion, mBq, Estimated from ^{241}Am Activity in Sampled Volume (L)*	Lung Activity, Bq	Skeletal Activity, Bq
02/10/1996	555 ± 37 (0.95)	-	-
03/20/1996	179 ± 5 (0.79)	315 ± 5	59 ± 10
04/25/1996	169 ± 4 (0.46)	241 ± 5	73 ± 6
05/23/1996	47 ± 2 (0.25)	246 ± 5	91 ± 8
06/20/1996	42 ± 2 (0.80)	226 ± 5	100 ± 23
07/25/1996	-	214 ± 5	105 ± 17
08/22/1996	27 ± 3 (0.35)	195 ± 4	104 ± 10
09/26/1996	-	156 ± 4	111 ± 6
12/12/1996	-	146 ± 4	121 ± 8
04/30/1997	-	131 ± 4	134 ± 13
05/01/1997	29 ± 1 (0.44)	-	-
10/16/1998	-	109 ± 3	154 ± 21
10/23/1998	11 ± 2 (0.70)	-	-
12/06/2001	-	82 ± 6	174 ± 30
01/23/2002	7 ± 1 (0.80)	-	-

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

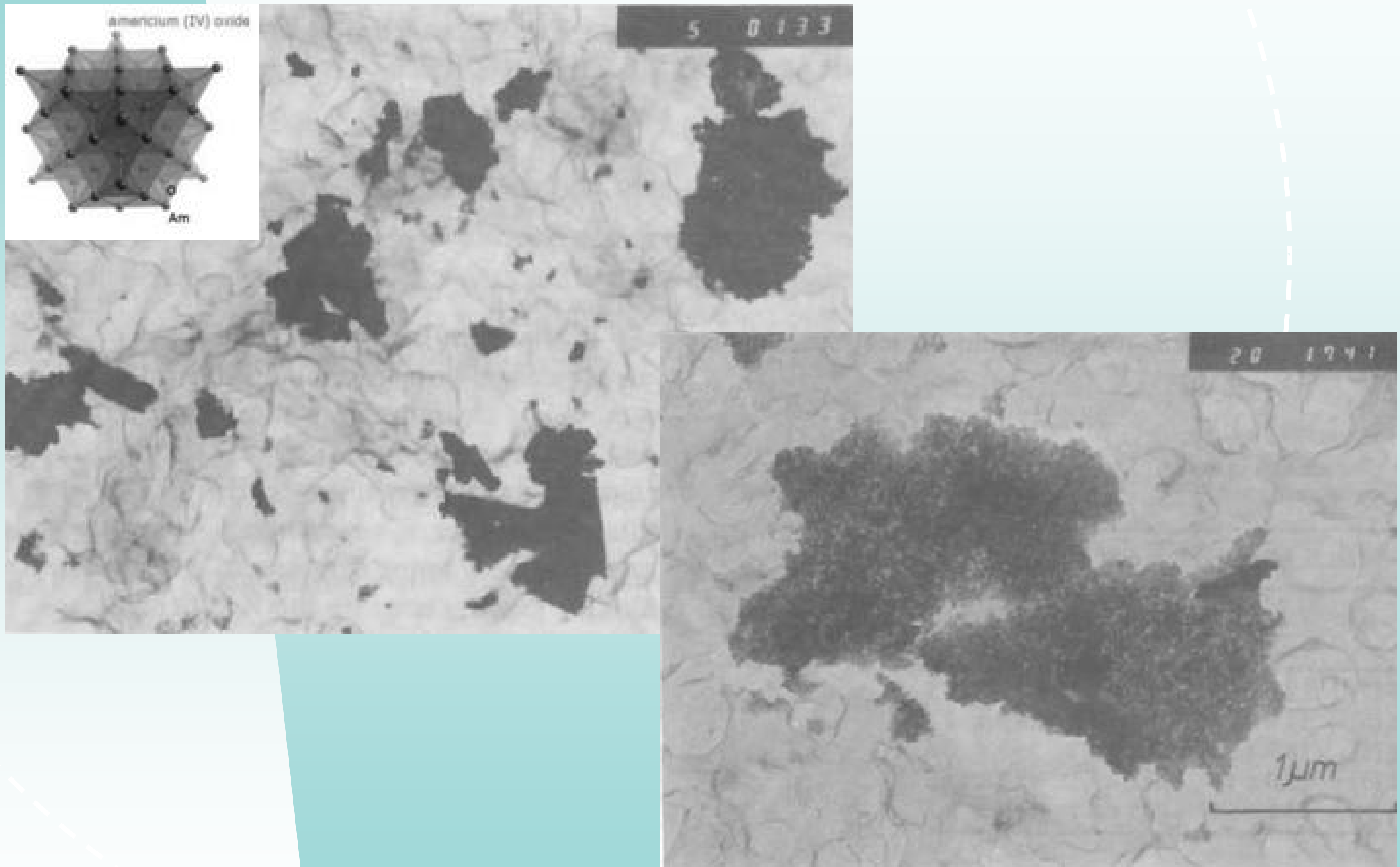
Bioassay Prediction for ICRP68 Type 'M' Material



χ^2 = 2,470; NDF = 30

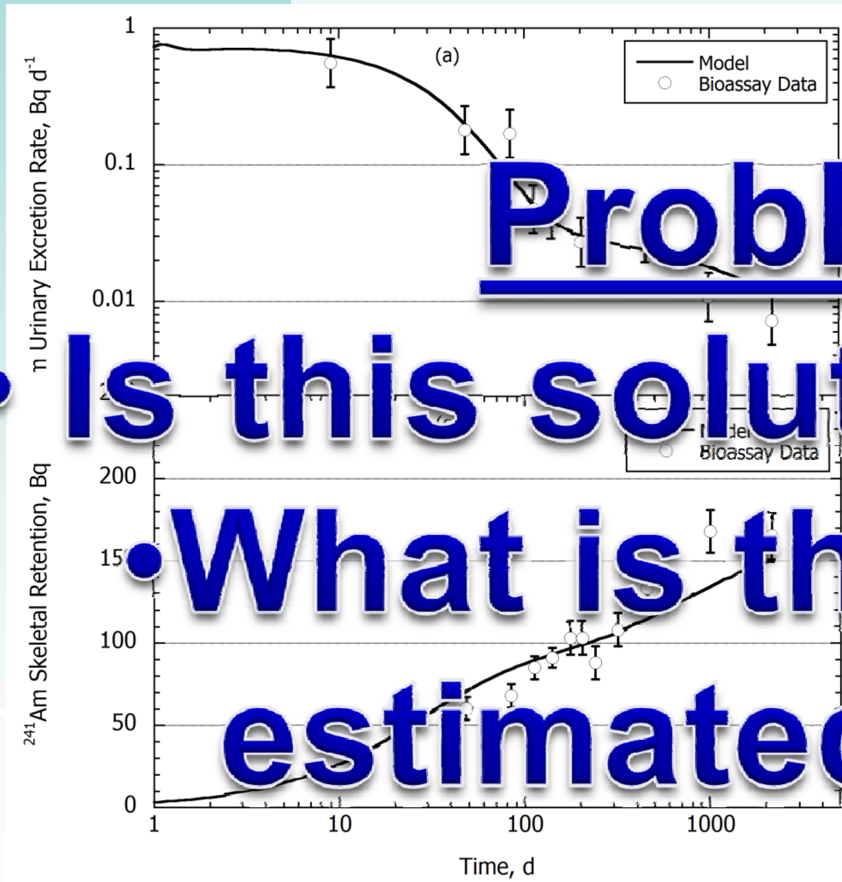
Washington State University
World Class. Face to Face.

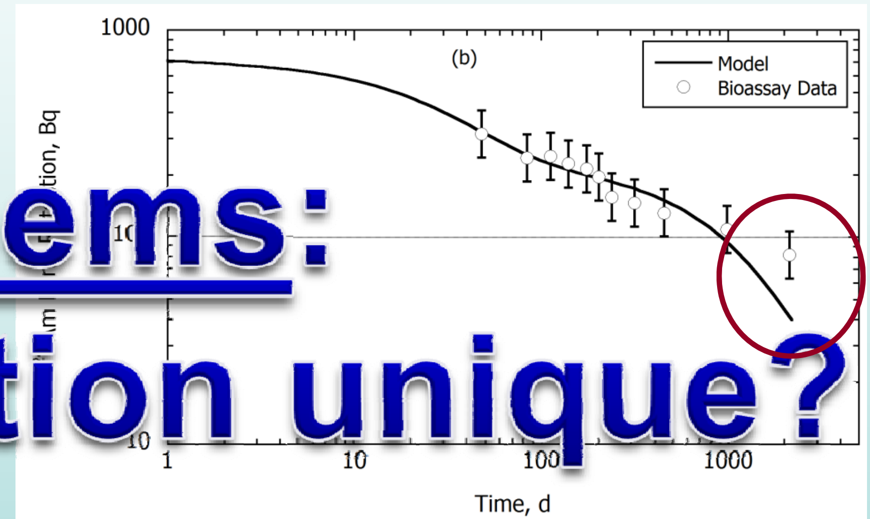
Nature of $^{241}AmO_2$ 'Dust' – 1970s NRPB Study



Maximum Likelihood Evaluation of $^{241}AmO_2$ Absorption Parameters (from Case 0855 Data)

- Manual (iterative) minimization of data χ^2 – using IMBA Professional Plus (IPP).





Problems:

- **Is this solution unique?**
- **What is the error on estimated doses?**

NDF = 30
$f_r = 0.45$
s_r
$s_s = 1$ 10^{-4} d^{-1}

E = 314 mSv; H_{BS} = 5,400 mSv

Washington State University
World Class. Face to Face.

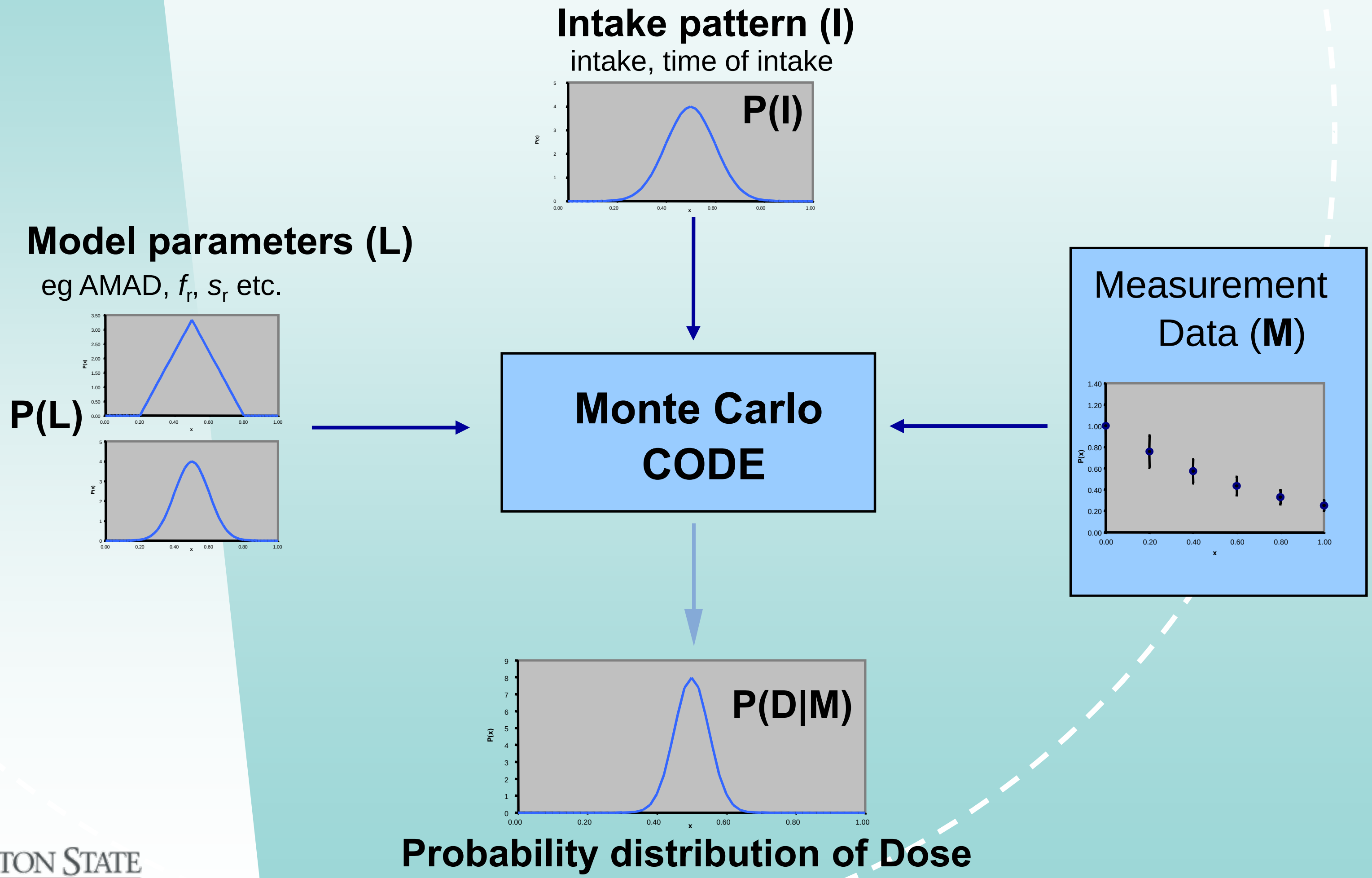
Objectives of This Study

- Use **Bayesian inference** to evaluate posterior **probability distributions** of ***Effective Dose, E,*** and ***Committed Equivalent Dose to Bone Surfaces, H_{BS}*** (i.e., the quantities of regulatory interest) ***directly from bioassay data***.
- **Assume *no explicit knowledge* of clearance rates from the lungs:**
  - **Unknown 'absorption' rates (for $^{241}AmO_2$)**
  - **Unknown 'particle transport' rates (for individual)**

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Overview of Bayesian Calculation: WEighted Likelihood MOnte Carlo Sampling (WELMOS)

Puncher & Birchall (in press)



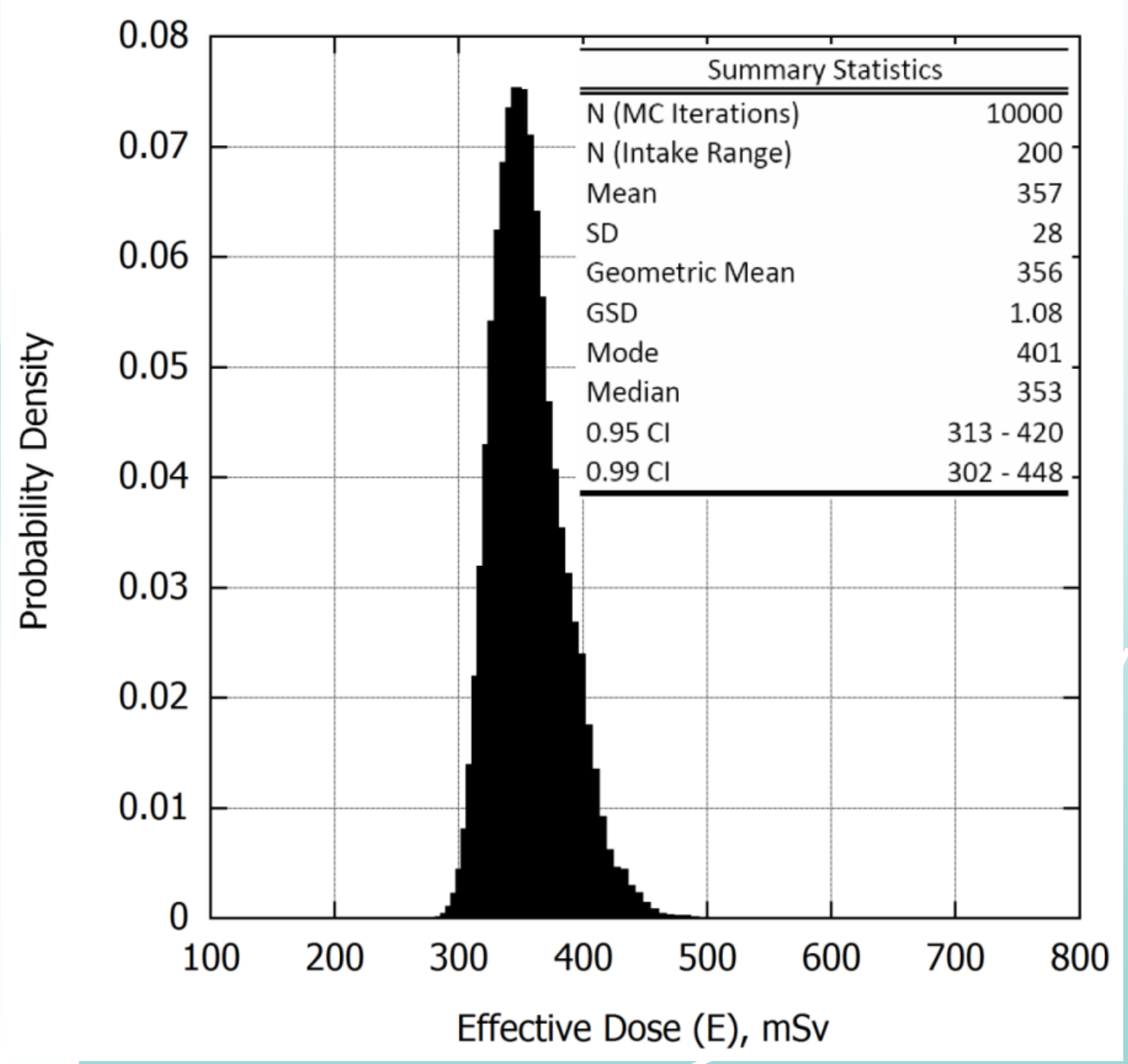
WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Bayesian Priors Used to Analyze Bioassay Data

Parameter	Range	Distribution
Rapidly absorbed fraction, f_r	0 – 1	Uniform
Rapid absorption rate, s_r (d^{-1})	0.01 – 100	Log-uniform
Slow absorption rate, s_s (d^{-1})	1×10^{-7} – 0.01	Log-uniform
Particle transport rate factor, K_{PT}	Median = 1, σ_g = 1.7	Lognormal

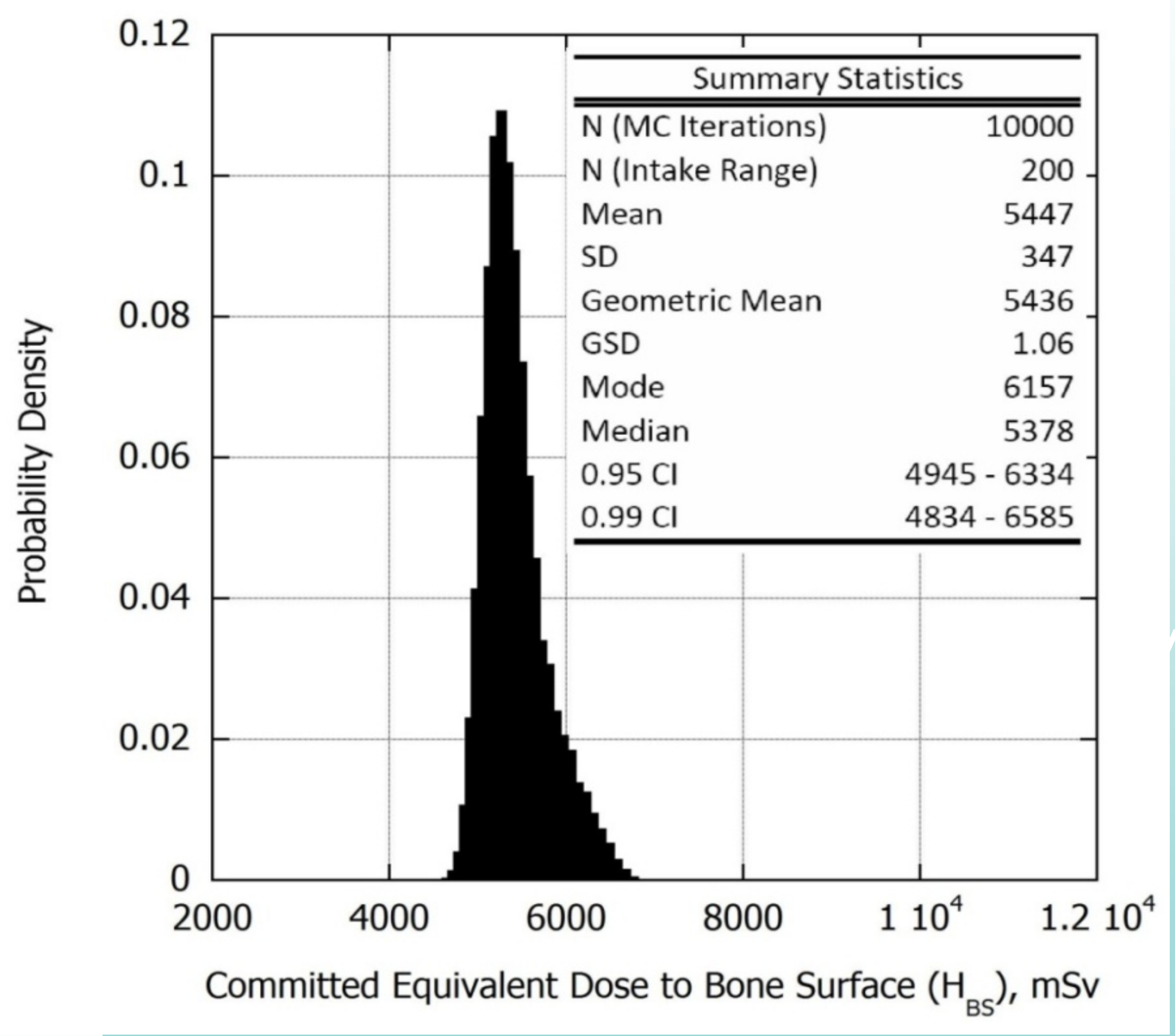
Washington State University
World Class. Face to Face.

Posterior Probability Distribution of Effective Dose



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Posterior Probability Distribution of Bone Surface Dose



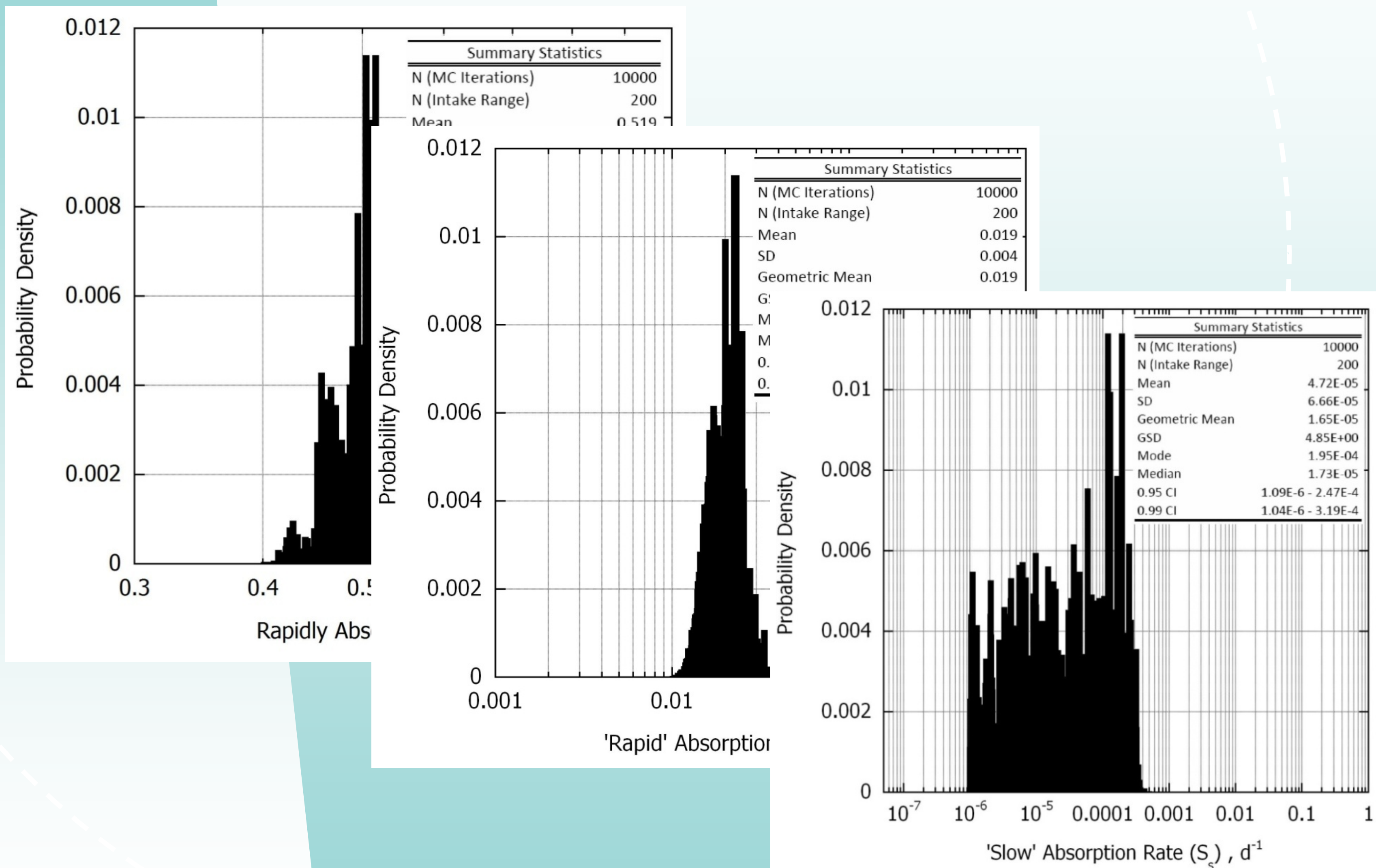
WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Joint Evaluation of Uncertainty in ICRP66 Clearance Model Parameters - for $^{241}AmO_2$ and Particle Transport

- Monte Carlo simulation (10,000 iterations) covers whole range of possible values of clearance model parameters
- Store results for each iteration
- Integrate joint probability distribution of all these parameters over parameter of interest
- Evaluate posterior probability distribution of each clearance parameter in turn

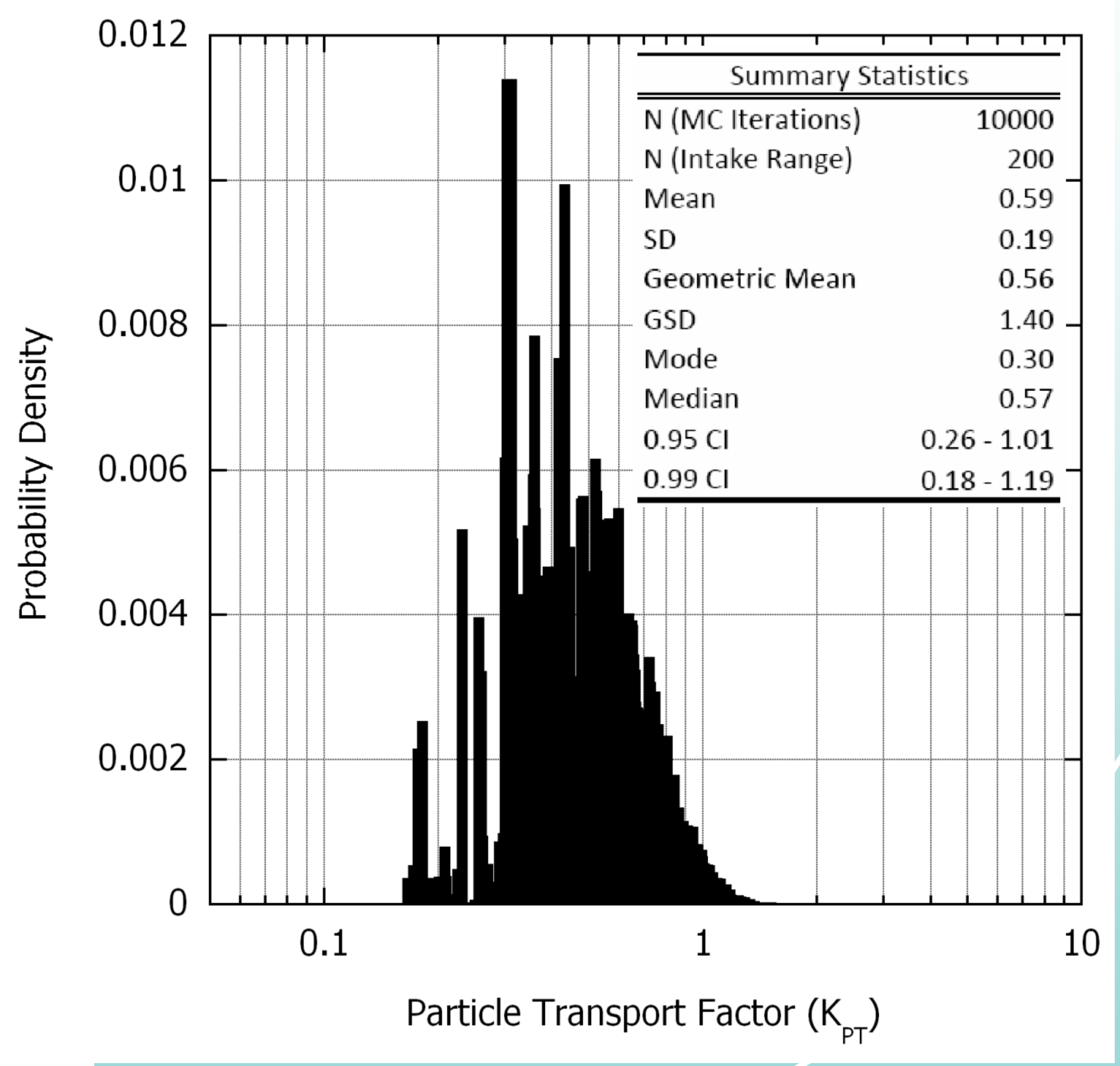
Washington State University
World Class. Face to Face.

Posterior Probability Distributions of Absorption Parameters



WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Posterior Probability Distribution of Particle Transport



WASHINGTON STATE UNIVERSITY

World Class. Face to Face.

Applications

- Clearance parameter probability distributions are **NOT** used to estimate doses for this individual
- Nevertheless they provide valuable **NEW** information (on absorption parameter values for inhaled $^{241}AmO_2$) which might be useful for **other individuals** exposed to this material, e.g., with **sparser bioassay data**
- Probability distribution of particle transport rates **ONLY** applicable to **this individual**

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Disclaimer: "This presentation was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."