THE NCRP WOUND MODEL: DEVELOPMENT AND APPLICATION

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Learning Objectives

- Describe the structure and use of the NCRP Wound Model
- Identify sources for wound model dose coefficients and retention factors

NEED FOR A WOUND MODEL

- **Wounds relatively common in specialized plants in U.S.A. and Russia**
  - **136 Pu wounds at Hanford by 1969**
  - **429 Pu wounds at Rocky Flats Plant by 1967**
  - **248 wounds at Mayak PA by 1994**

- **Relatively little reported biokinetic information on <u>untreated</u> workers in literature**

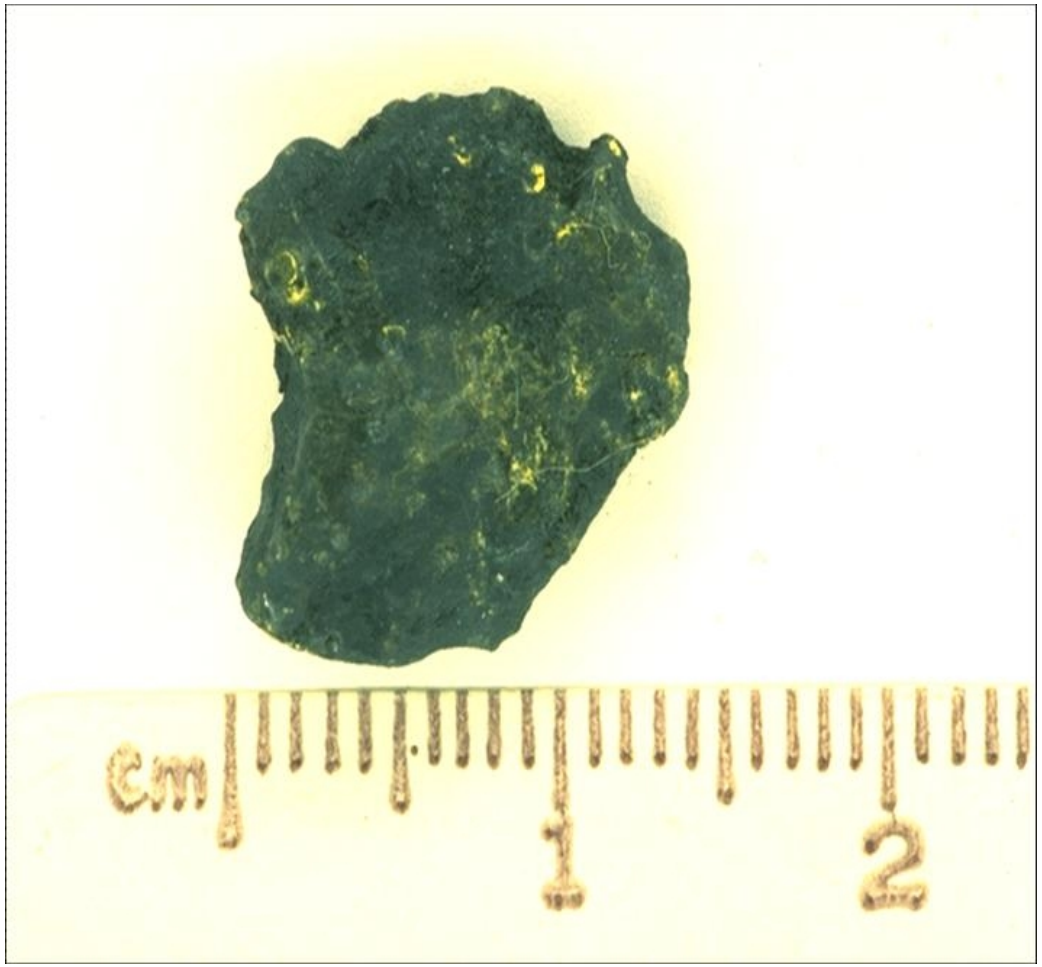
- **Can expect more wounds from decommissioning activities**

PERSIAN GULF WAR AND DU

- "Friendly Fire" incidents involving DU (depleted uranium) penetrators and armored vehicles
- 39 soldiers on long-term follow up for DU contamination (12 in high DU group)
- Questions about the dosimetry and risk from embedded DU fragments

RADIOGRAPH OF VETERAN WITH EMBEDDED DU FRAGMENTS

DU FRAGMENT REMOVED SURGICALLY



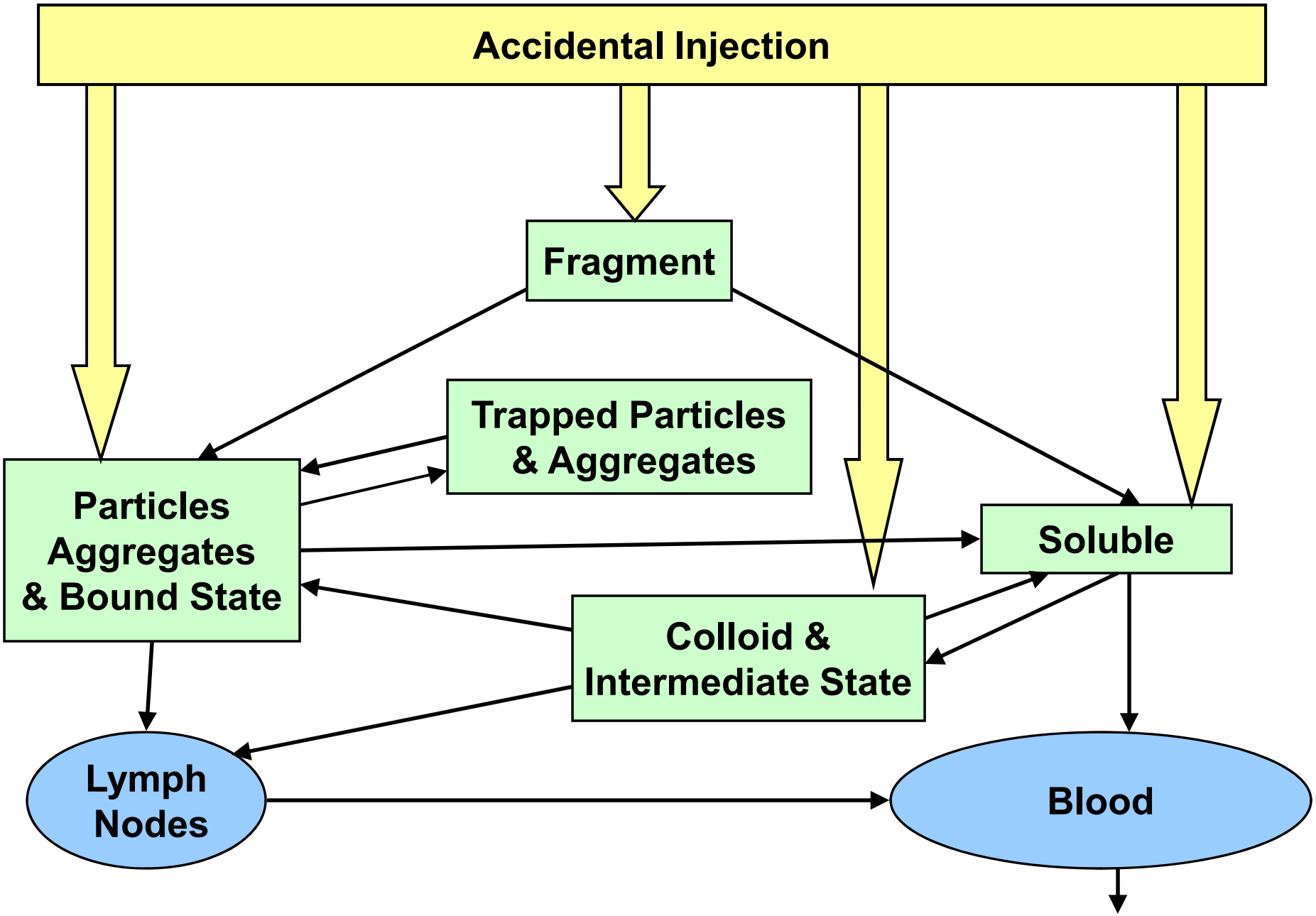
STRATEGY FOR WOUND MODEL DESIGN

- Scientifically and mechanistically based
- Can extrapolate to elements without data
- Can couple to systemic models for bioassay
- Pragmatic and easy to implement

DESIGN BASIS

- Source characteristics
  - Physical
  - Chemical
- Wound characteristics
  - Foreign body reaction

THE NCRP WOUND MODEL



DEVELOPMENT OF DEFAULT CATEGORIES FOR SOLUBLE RADIONUCLIDES IN WOUNDS

- **Data from 48 radionuclides injected as initially soluble radionuclides (mostly from studies at Crocker Labs, now LBNL)**

- **Retention classified according to chemical properties**
  - **Tendency for hydrolysis**
  - **Relationship with solubility product K_{sp} (depends on chemical, pH, concentration/mass)**

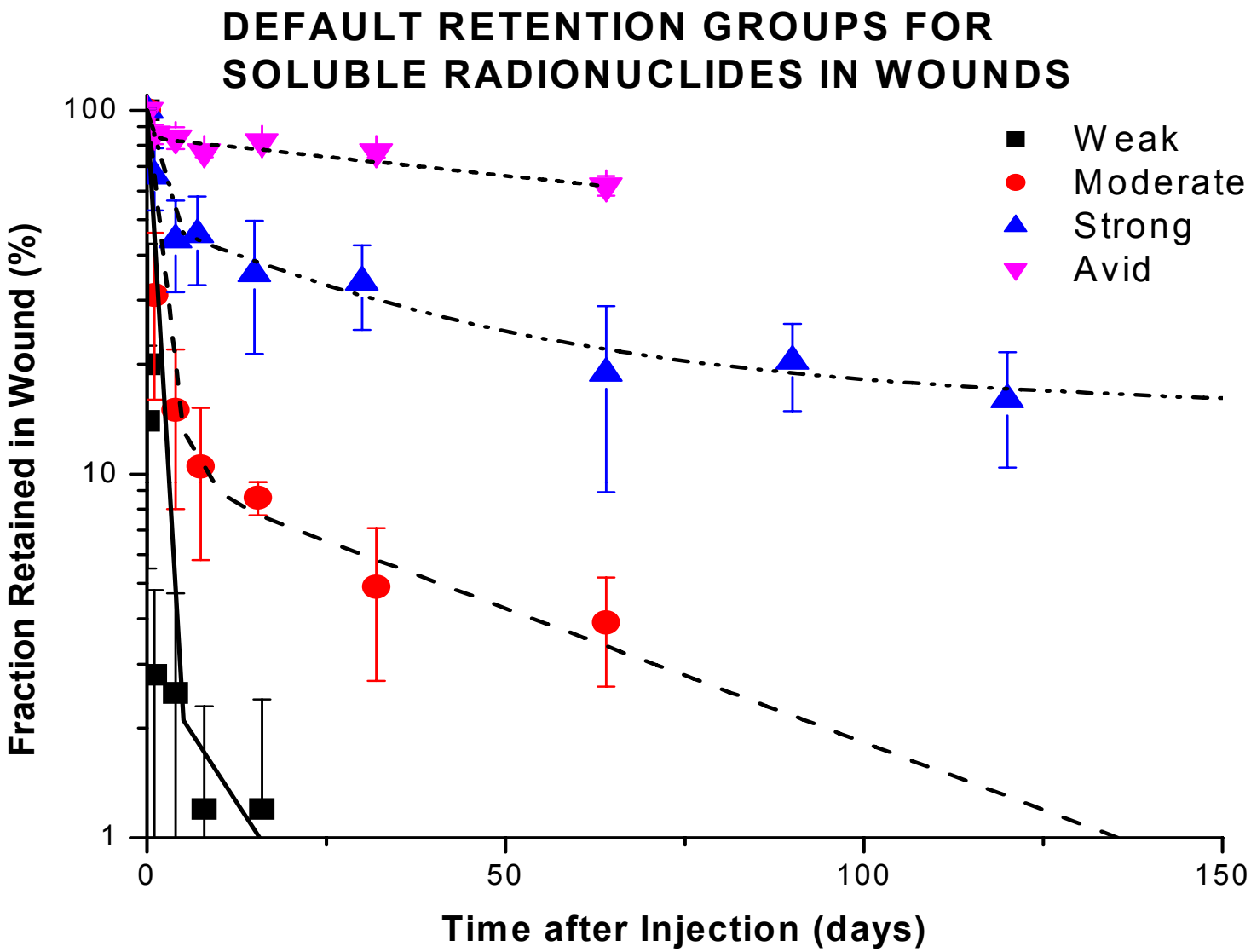
- **In general, retention roughly proportional to hydrolysis potential**
  - **$1^- < 1^+ < 2^+ < 3^+ < 4^+$**

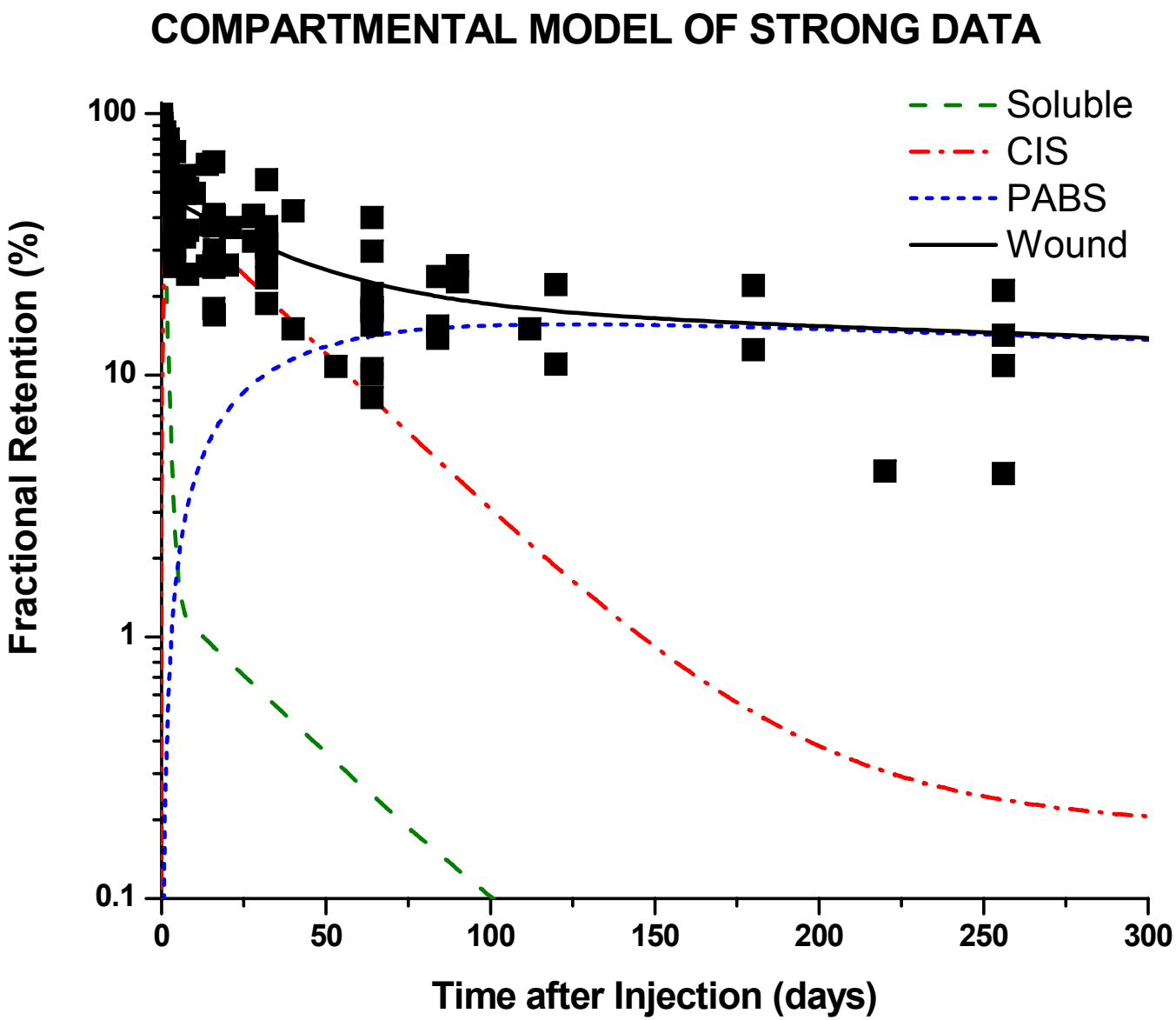
CATEGORIES OF WOUND RETENTION FOR SOLUBLE RADIONUCLIDES

- **Weakly retained**
  - Simple anions (I), oxo- and chloro-anions (Sb, Tc, As, W, Sb)
  - Monovalent cations (Rb, Cs)
  - Divalent cations (Ca, Sr, Ba, UO_2^{2+})
- **Moderately retained**
  - Chemical analogs of above
  - Ag, Ra, V, Te, Os, Pt

CATEGORIES (continued)

- **Strongly retained**
  - Trivalent cations (Y, La, Ga, In, Cr, Nb)
  - Trivalent lanthanides
  - Ac, Pu (small masses < 0.2 μg), Am, Cm
  - Be, Po
- **Avidly retained**
  - Tetravalent cations (Zr, Sn, Th, Pu > 10 μg)
  - Pentavalent Pa

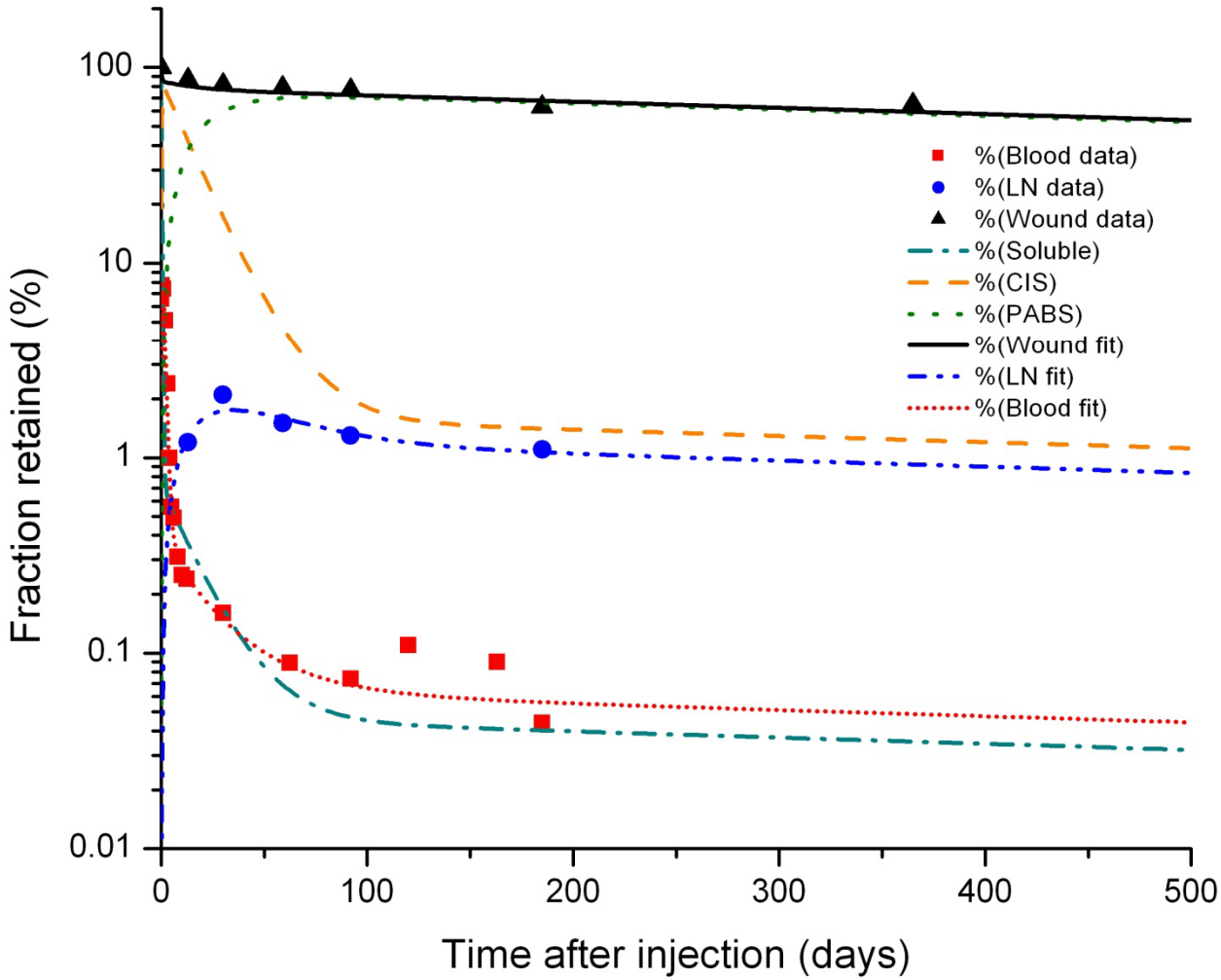

DEFAULT RETENTION GROUPS FOR
SOLUBLE RADIONUCLIDES IN WOUNDS
Weak
Moderate
Strong
Avid
Fraction Retained in Wound (%)
100
10
1
0
50
100
150
Time after Injection (days)

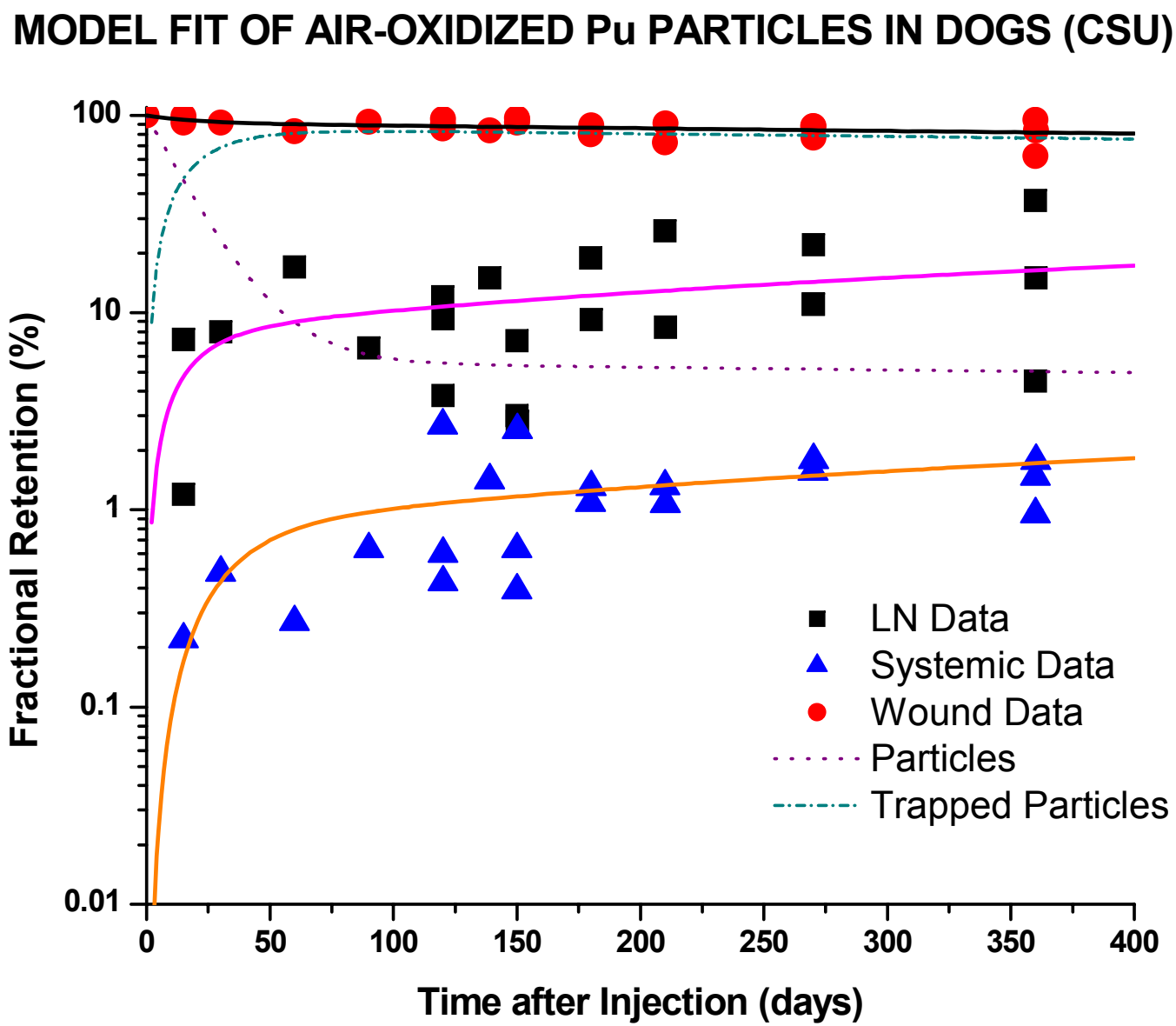

COMPARTMENTAL MODEL OF STRONG DATA
Soluble
CIS
PABS
Wound
Fractional Retention (%)
100
10
1
0.1
0
50
100
150
200
250
300
Time after Injection (days)

BIOKINETICS OF RADIOACTIVE PARTICLES AND FRAGMENTS

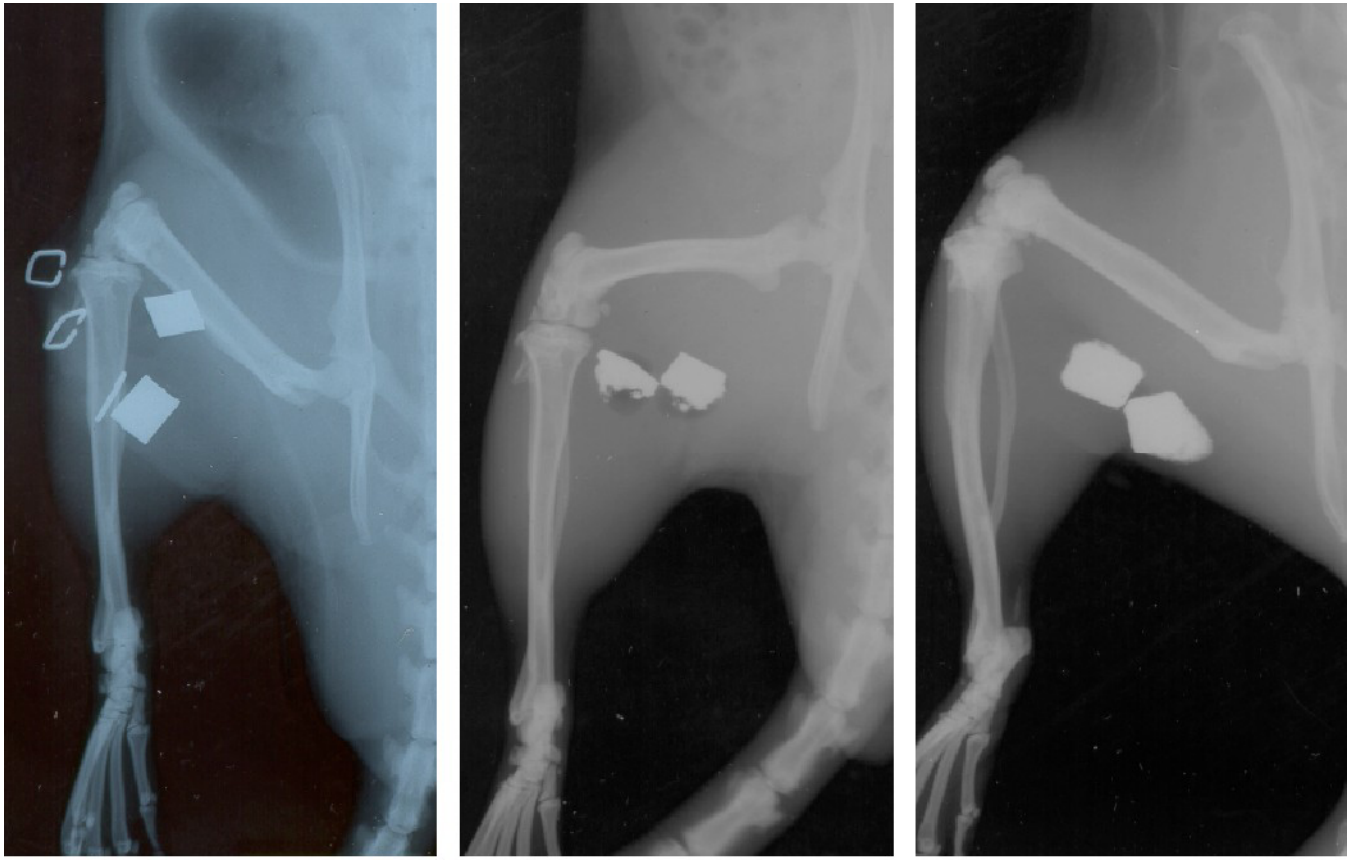
- **Few studies provide useful data for modeling**
  - **PuO_2 particles in rats (*Harrison et al. 1978)***
    - **Avid retention - 97% at 28 d**
  - **Polymeric Pu in rats and mice (*Brues et al. 1965*)**
    - **Avid retention – 80% at 6 mo**
  - **PuO_2 in dogs (*Bistline 1973*)**
  - **Pu metal wire in rats and rabbits (*Lisco and Kisieleski 1953*)**
    - **Wire rapidly disintegrated into fragments**
    - **Accompanied by significant tissue reaction**
  - **DU fragments in rats (*Hahn et al. 2001*)**
    - **Fragments corroded and disintegrated with time**

RETENTION OF COLLOIDAL Pu NITRATE IN DOGS (data from Bistline 1973)



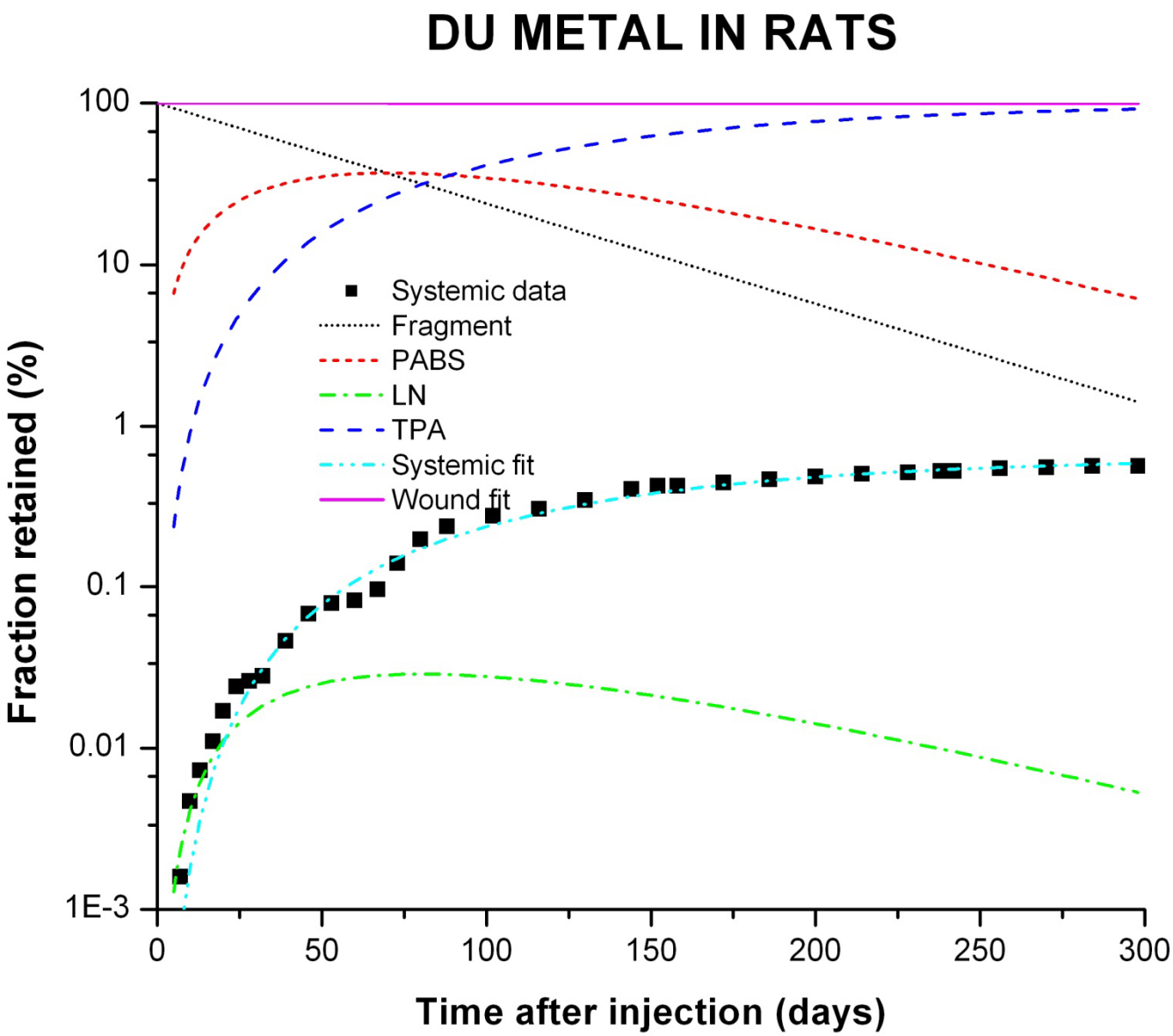

MODEL FIT OF AIR-OXIDIZED Pu PARTICLES IN DOGS (CSU)
Fractional Retention (%)
100
10
1
0.1
0.01
0
50
100
150
200
250
300
350
400
Time after Injection (days)
LN Data
Systemic Data
Wound Data
Particles
Trapped Particles

DU METAL FRAGMENTS IMPLANTED IN RAT MUSCLE



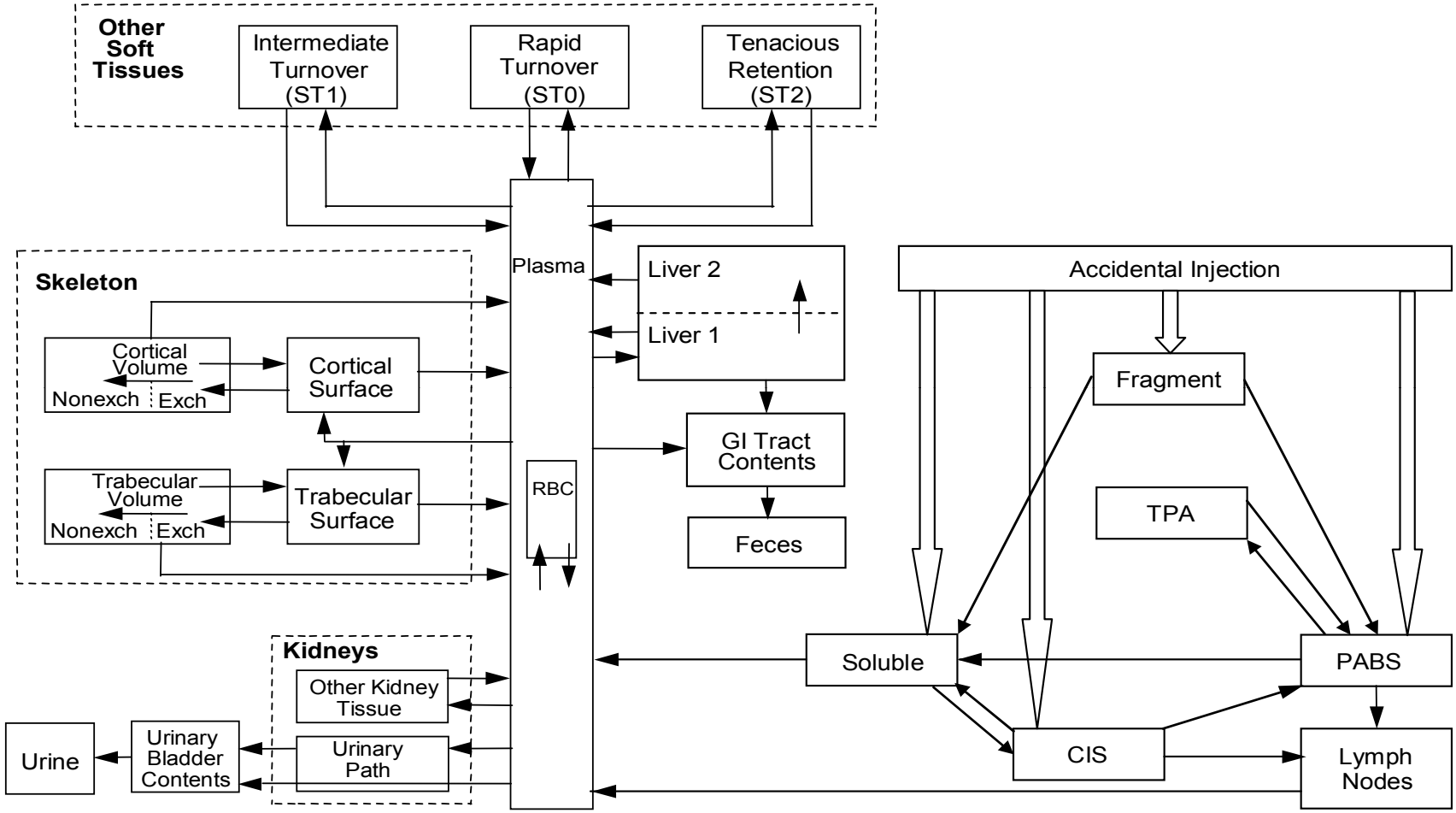
A B C

4530-2

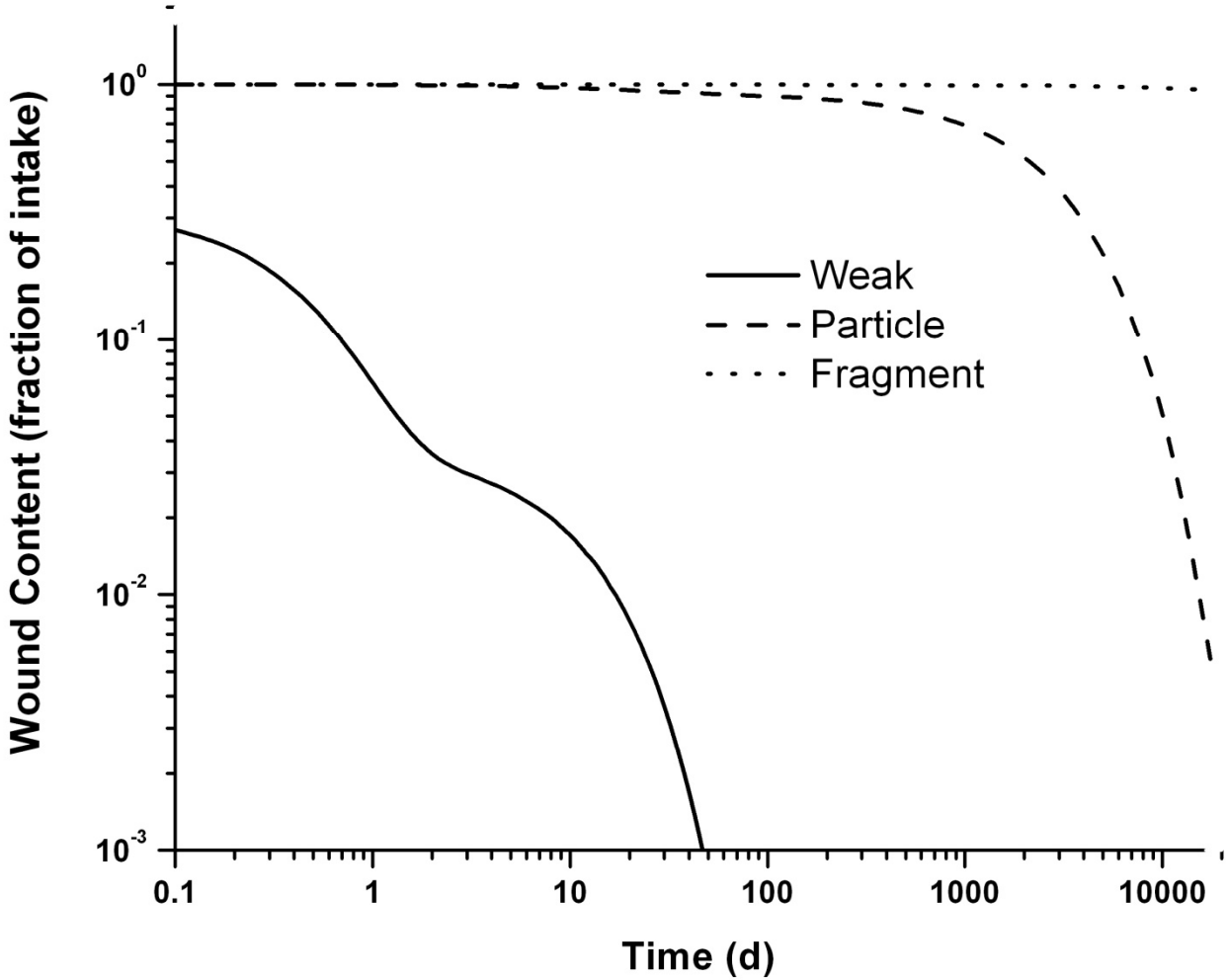

DU METAL IN RATS
Fraction retained (%)
100
10
1
0.1
0.01
1E-3
0
50
100
150
200
250
300
Time after injection (days)
Systemic data
Fragment
PABS
LN
TPA
Systemic fit
Wound fit

APPLICATION OF WOUND MODEL TO BIOASSAY INTERPRETATION

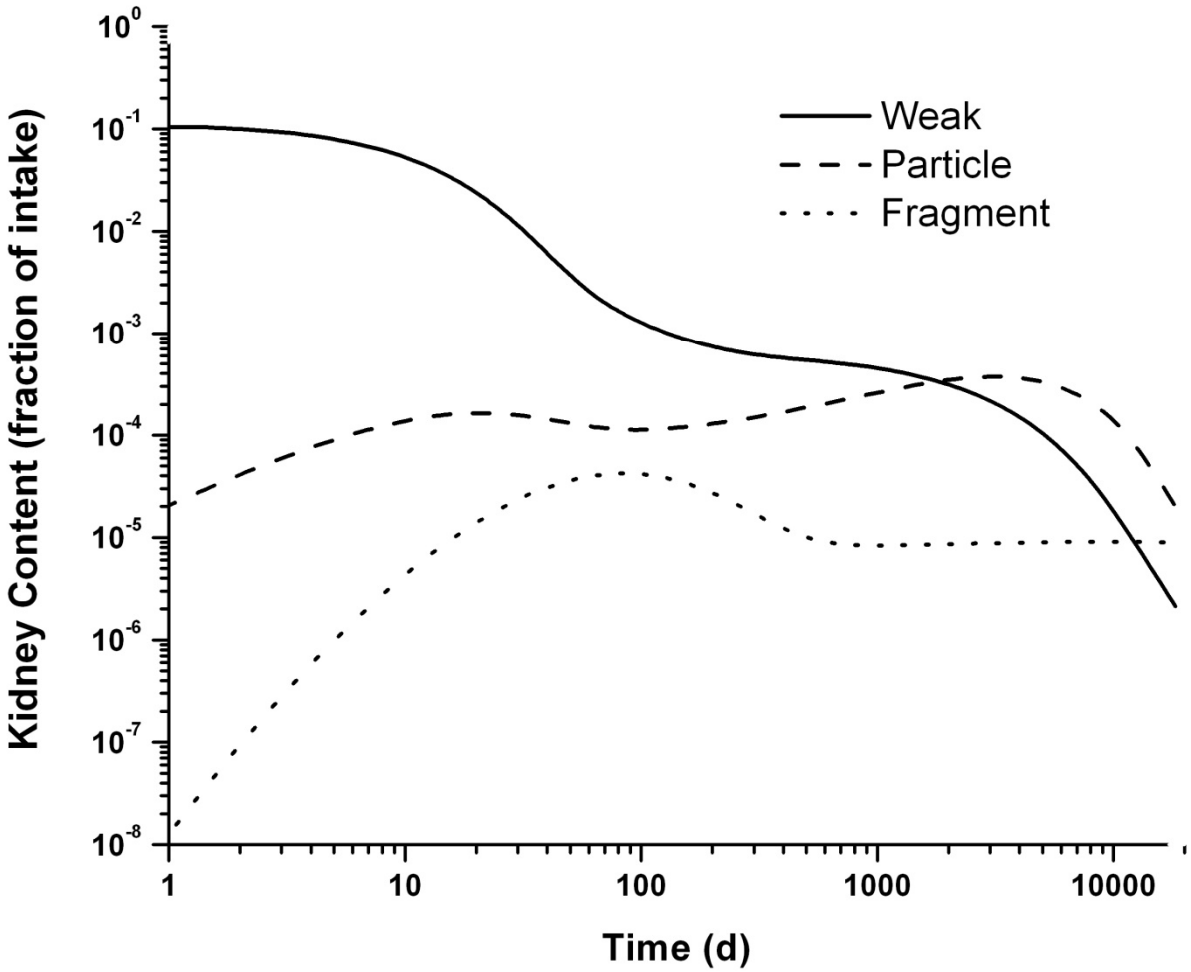
- Select ^{238}U and three relevant default categories
- Couple wound model to ICRP 69 systemic biokinetic model
- Solve using AIDE dose assessment software (v.4; Bertelli)


Other Soft Tissues
Intermediate Turnover (ST1)
Rapid Turnover (ST0)
Tenacious Retention (ST2)
Plasma
Skeleton
Cortical Volume
Nonexch
Exch
Cortical Surface
Trabecular Volume
Nonexch
Exch
Trabecular Surface
RBC
Liver 2
Liver 1
GI Tract Contents
Feces
Accidental Injection
Fragment
TPA
Soluble
PABS
CIS
Lymph Nodes
Kidneys
Other Kidney Tissue
Urinary Path
Urinary Bladder Contents
Urine

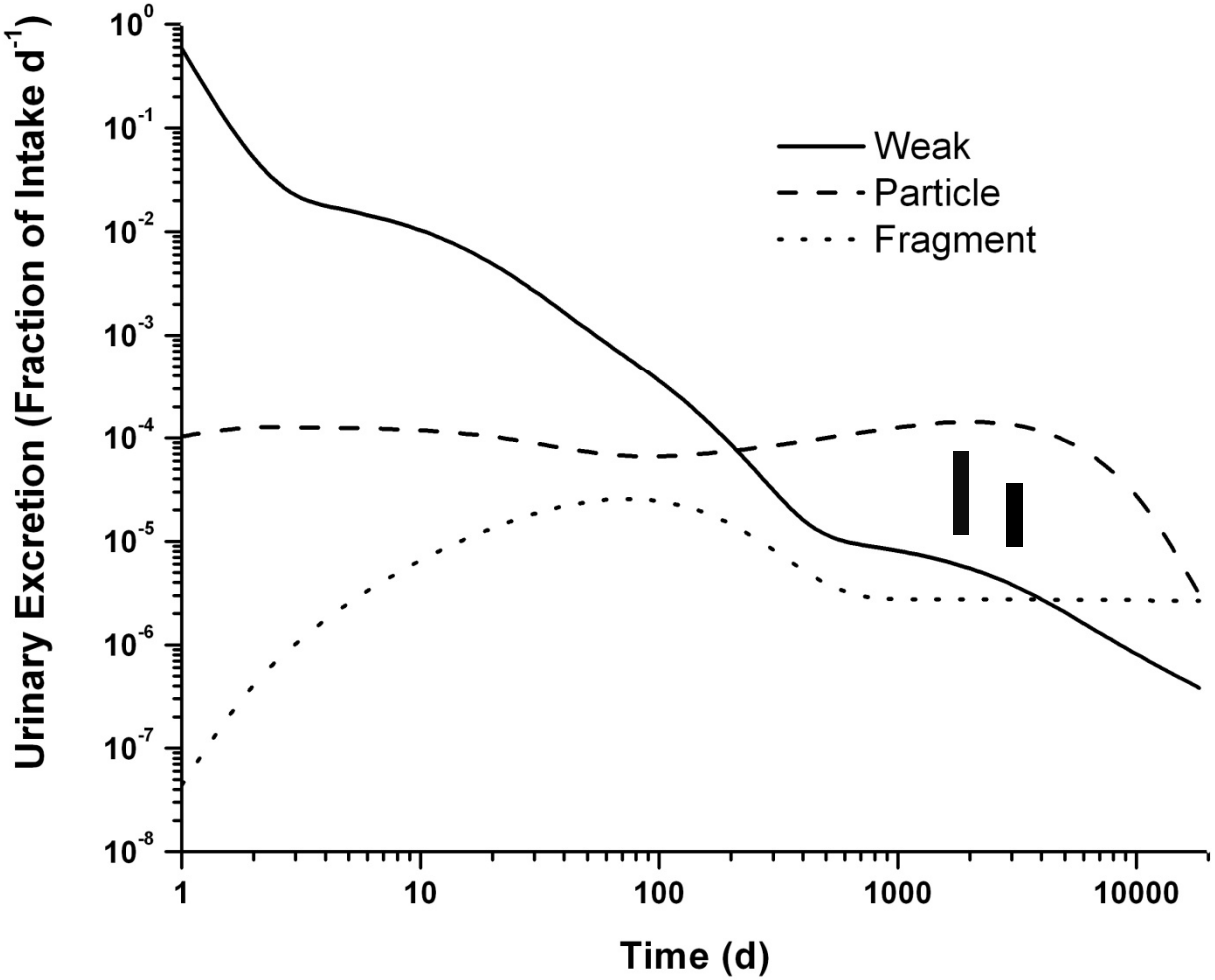
U RETENTION IN WOUND SITE



U RETENTION IN KIDNEY



U EXCRETION IN URINE



SUMMARY AND CONCLUSIONS

- Wound model describes radionuclide behavior for:
  - Range of physical and chemical forms
  - Large number (48) of solubles
  - Fewer (4) insolubles
- Sound scientific basis in chemistry and biology
- Easy to use for bioassay interpretation
- Model proposed by INDOS/DOCAL for implementation in ICRP revision of occupation guidance on radiation protection from intakes of radionuclides
- Model report published as NCRP report 156 (2006)

Follow-on Tasks

- The Radiation Emergency Assistance Center/Training Site (REAC/TS) at ORISE has coupled the NCRP wound model to the ICRP biokinetic models for other elements to generate dose coefficients and intake retention/excretion factors
- Data for 38 selected radionuclides were published in the May 2011 issue of Health Physics journal (Toohey et al., Health Phys. 100(5), 508-514, 2011.)
- Complete data tables are available on line at http://orise.orau.gov/reacts/resources/retention-intake-publication.aspx