

# **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

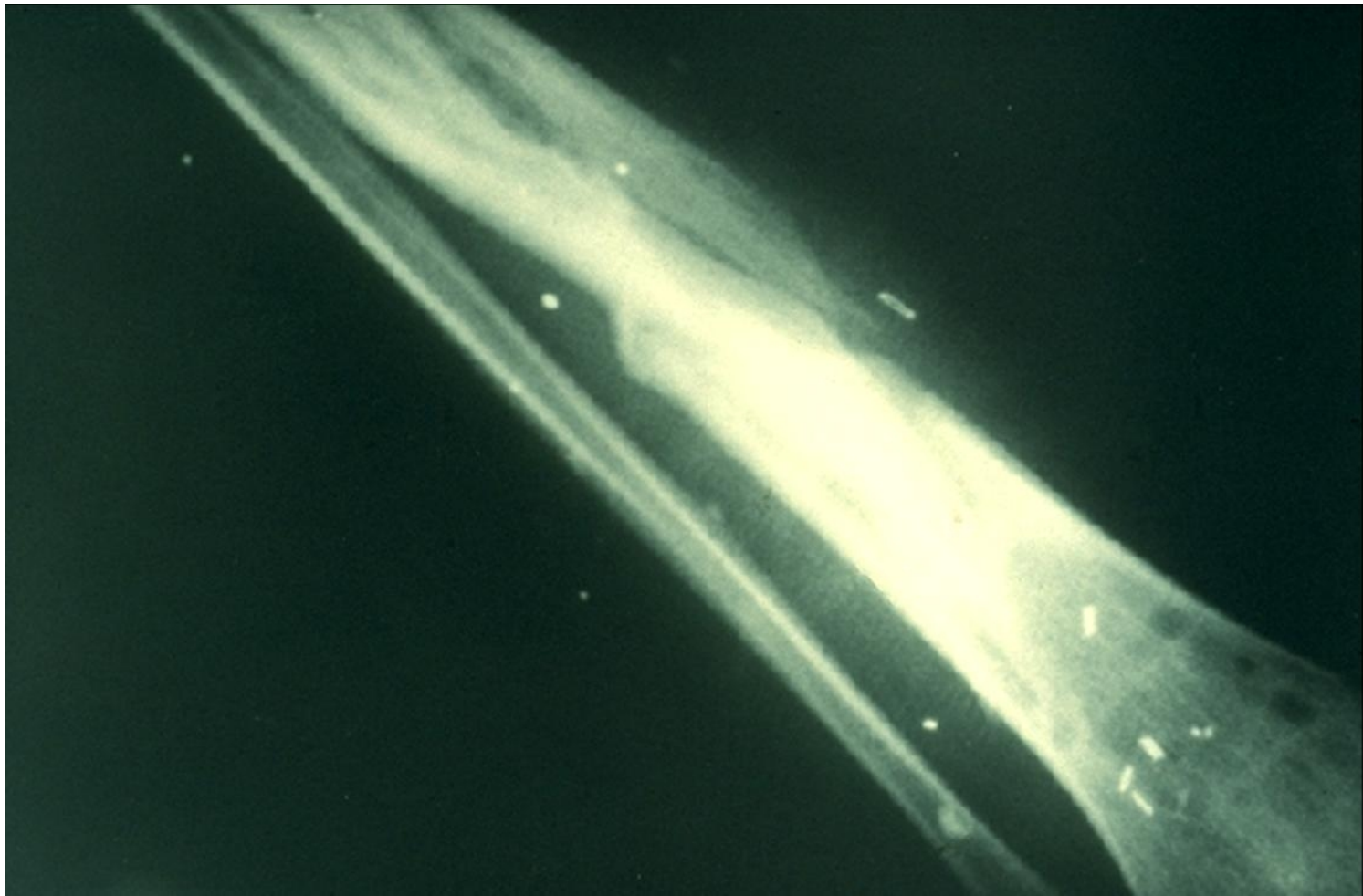
- Wounds relatively common in specialized plants in U.S.A. and Russia
  - 136 Pu wounds at Hanford by 1969
  - 429 Pu wounds at Rocky Flats Plant by 1967
  - 248 wounds at Mayak PA by 1994
- Relatively little reported biokinetic information on untreated workers in literature
- Can expect more wounds from decommissioning activities

# PERSIAN GULF WAR AND DU

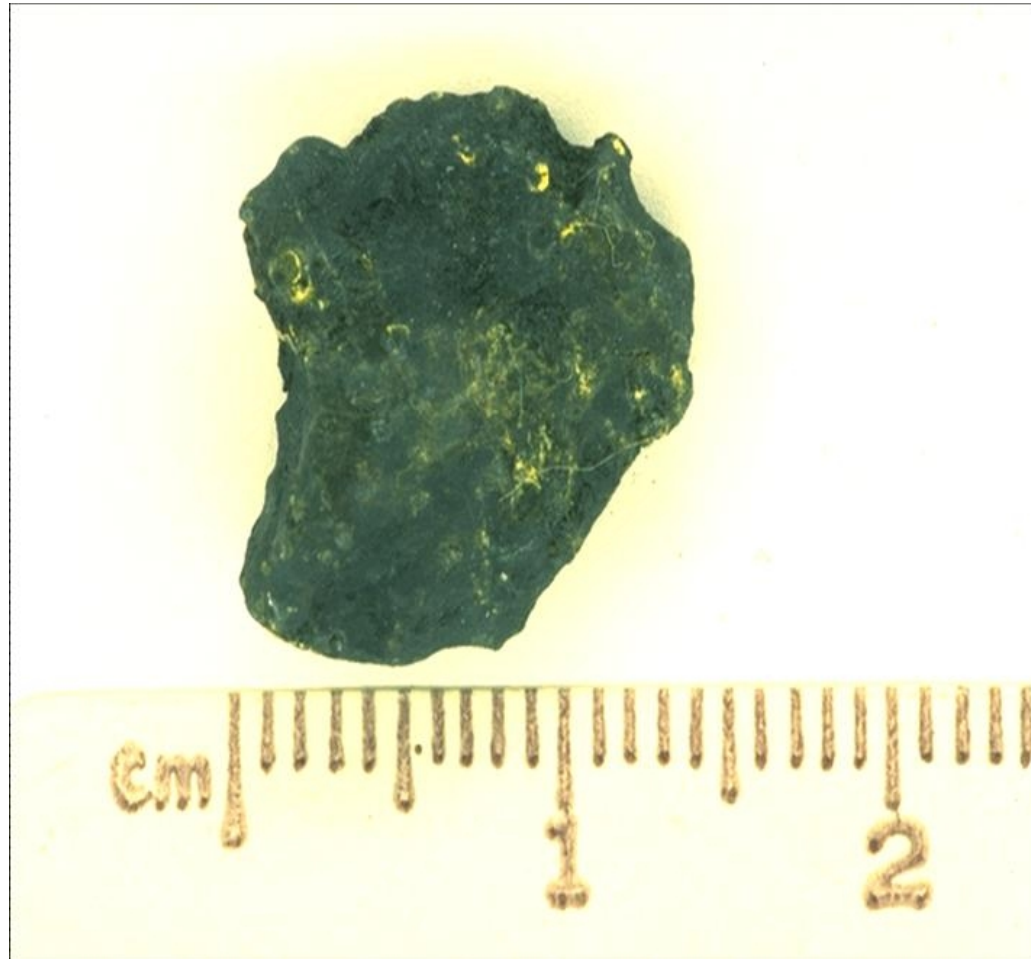


- **“Friendly Fire” incidents involving DU (depleted uranium) penetrators and armored vehicles**
- **39 soldiers on long-term follow up for DU contamination (12 in high DU group)**
- **Questions about the dosimetry and risk from embedded DU fragments**

# **RADIOGRAPH OF VETERAN WITH EMBEDDED DU FRAGMENTS**



# DU FRAGMENT REMOVED SURGICALLY



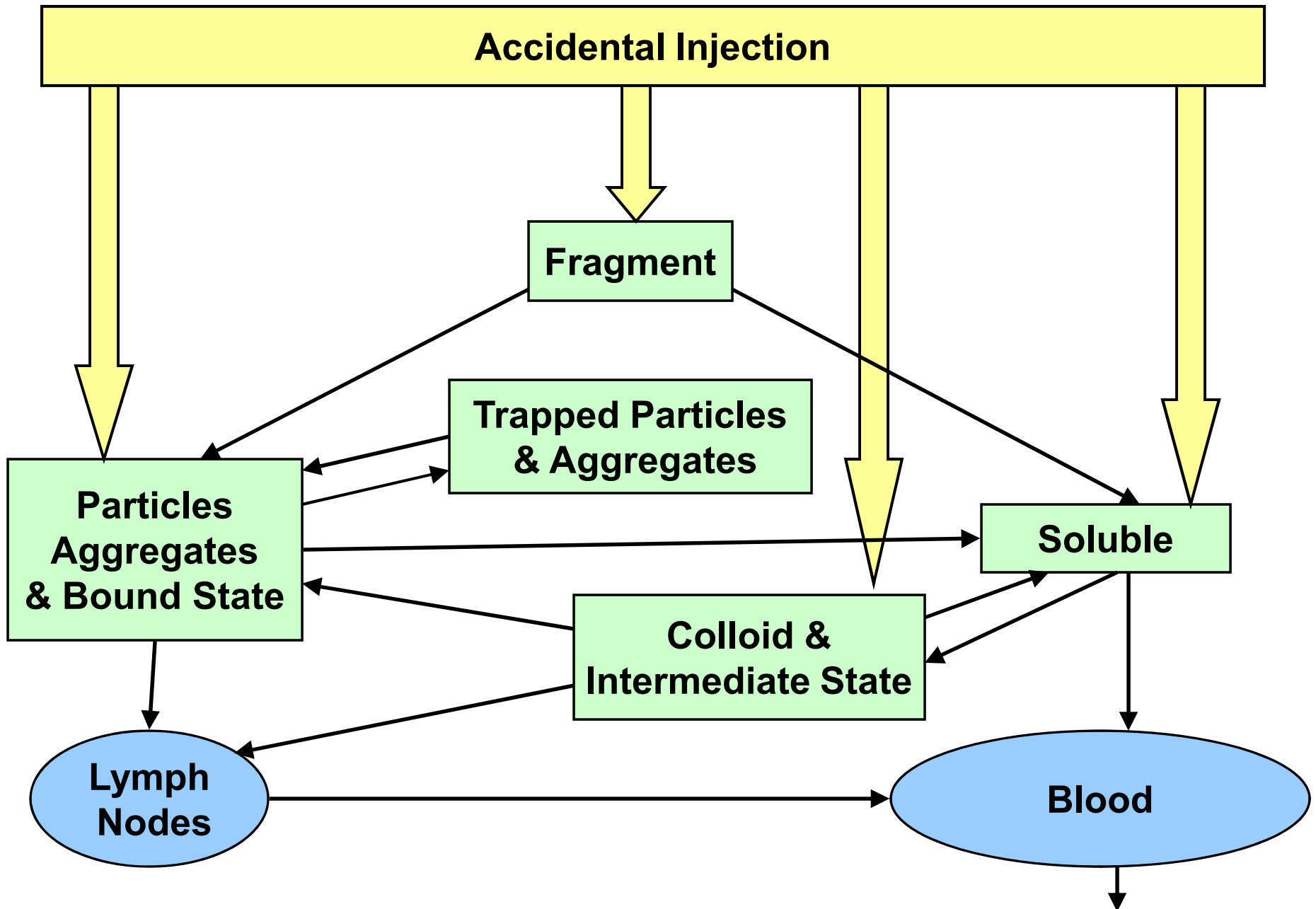
# STRATEGY FOR WOUND MODEL DESIGN

- 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
  - $1^- < 1^+ < 2^+ < 3^+ < 4^+$

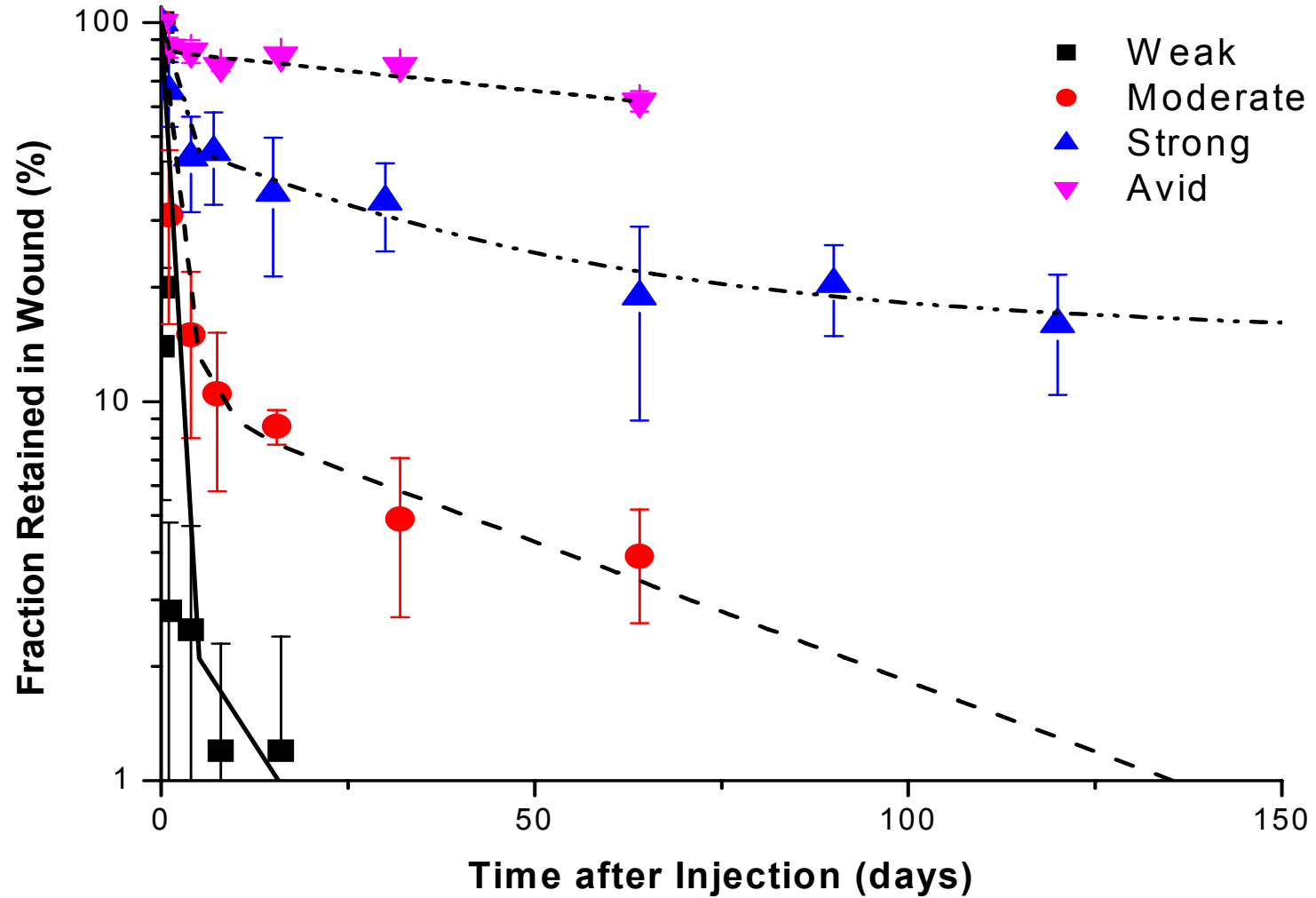
# CATEGORIES OF WOUND RETENTION FOR SOLUBLE RADIONUCLIDES

- **Weakly retained**
  - Simple anions (I), oxo- and chloro-anions (Sb, Tc, As, W, Sb)
  - Monovalent cations (Rb, Cs)
  - Divalent cations (Ca, Sr, Ba,  $\text{UO}_2^{2+}$ )
- **Moderately retained**
  - Chemical analogs of above
  - Ag, Ra, V, Te, Os, Pt

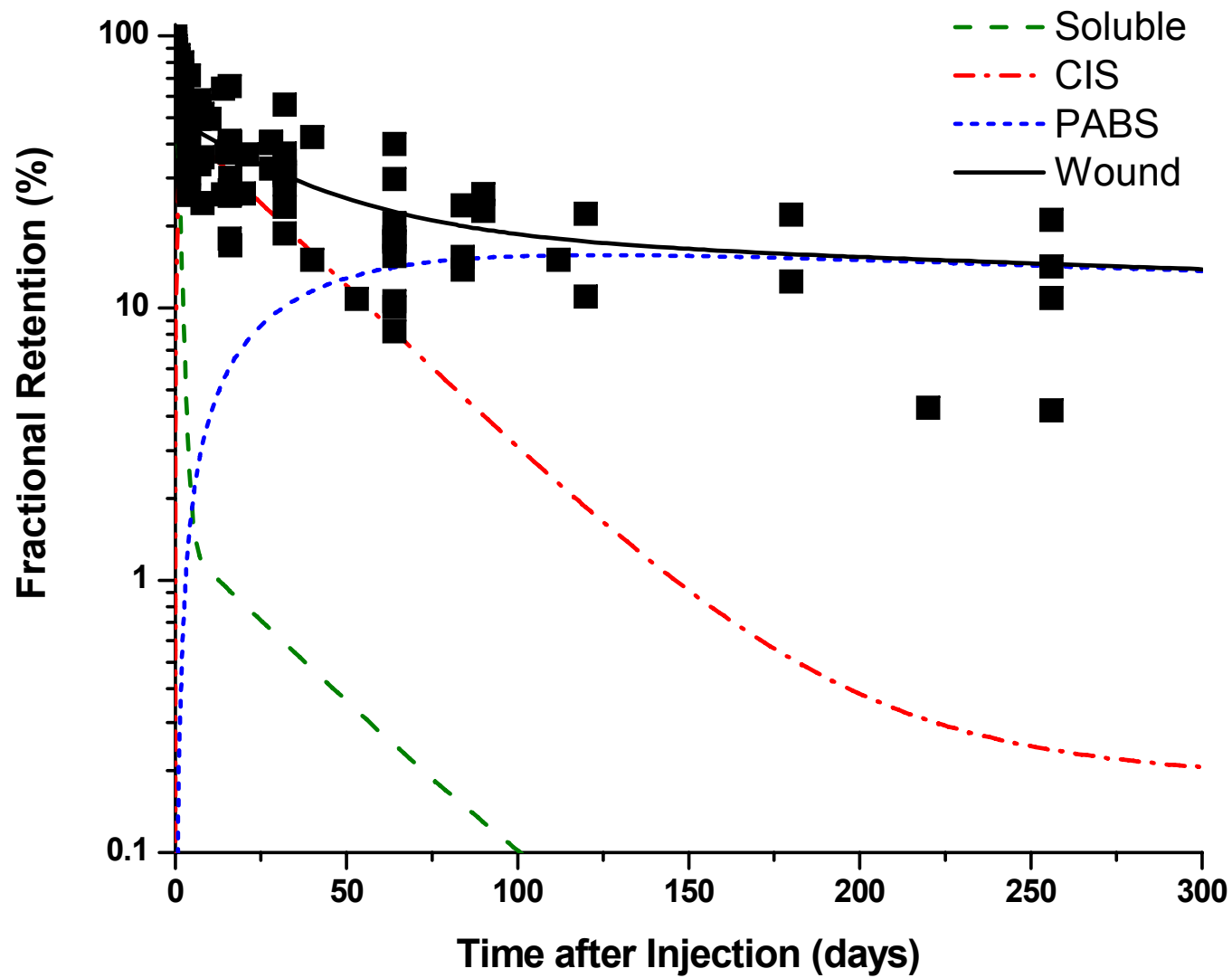
## CATEGORIES (continued)

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

## DEFAULT RETENTION GROUPS FOR SOLUBLE RADIONUCLIDES IN WOUNDS



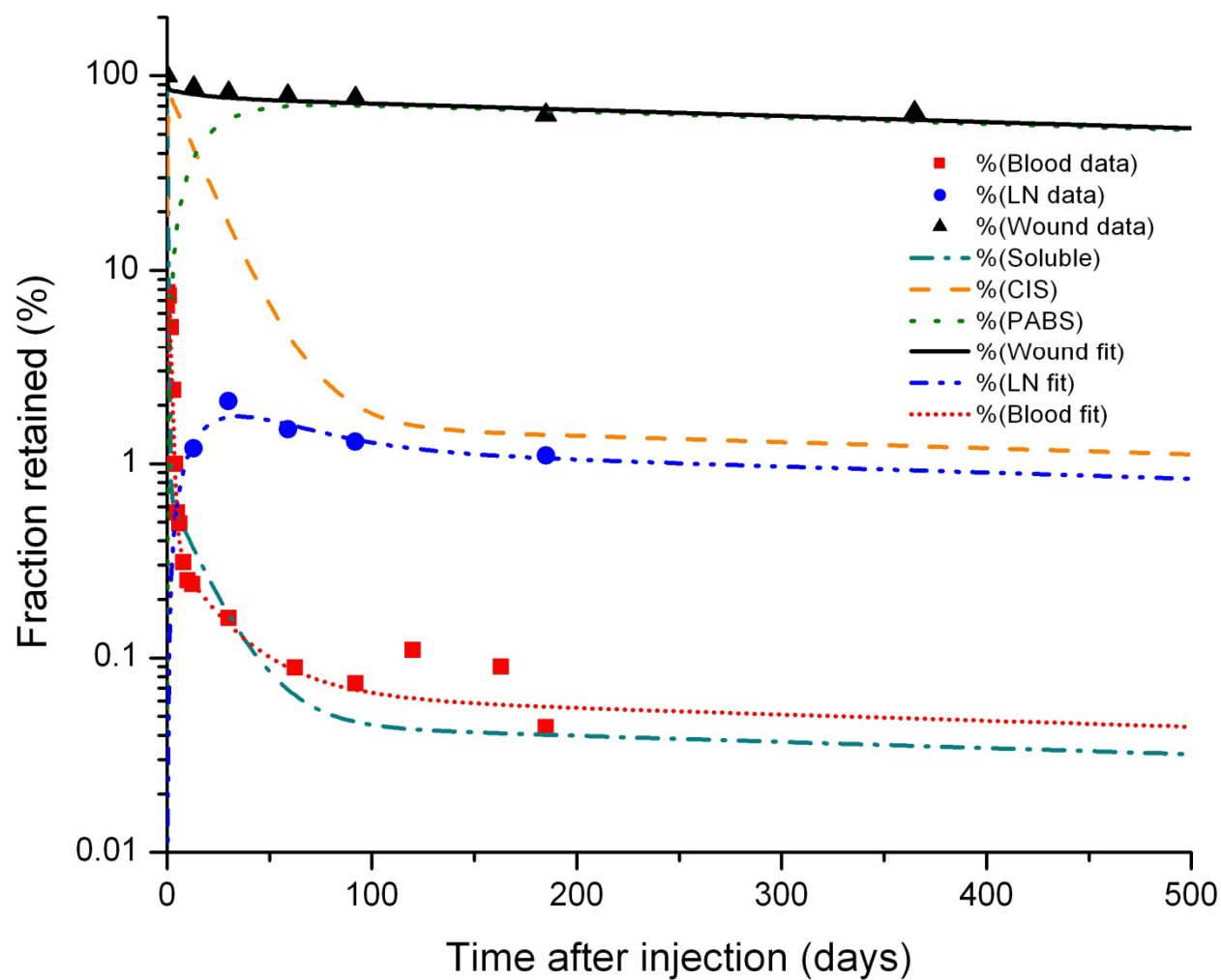
## COMPARTMENTAL MODEL OF STRONG DATA



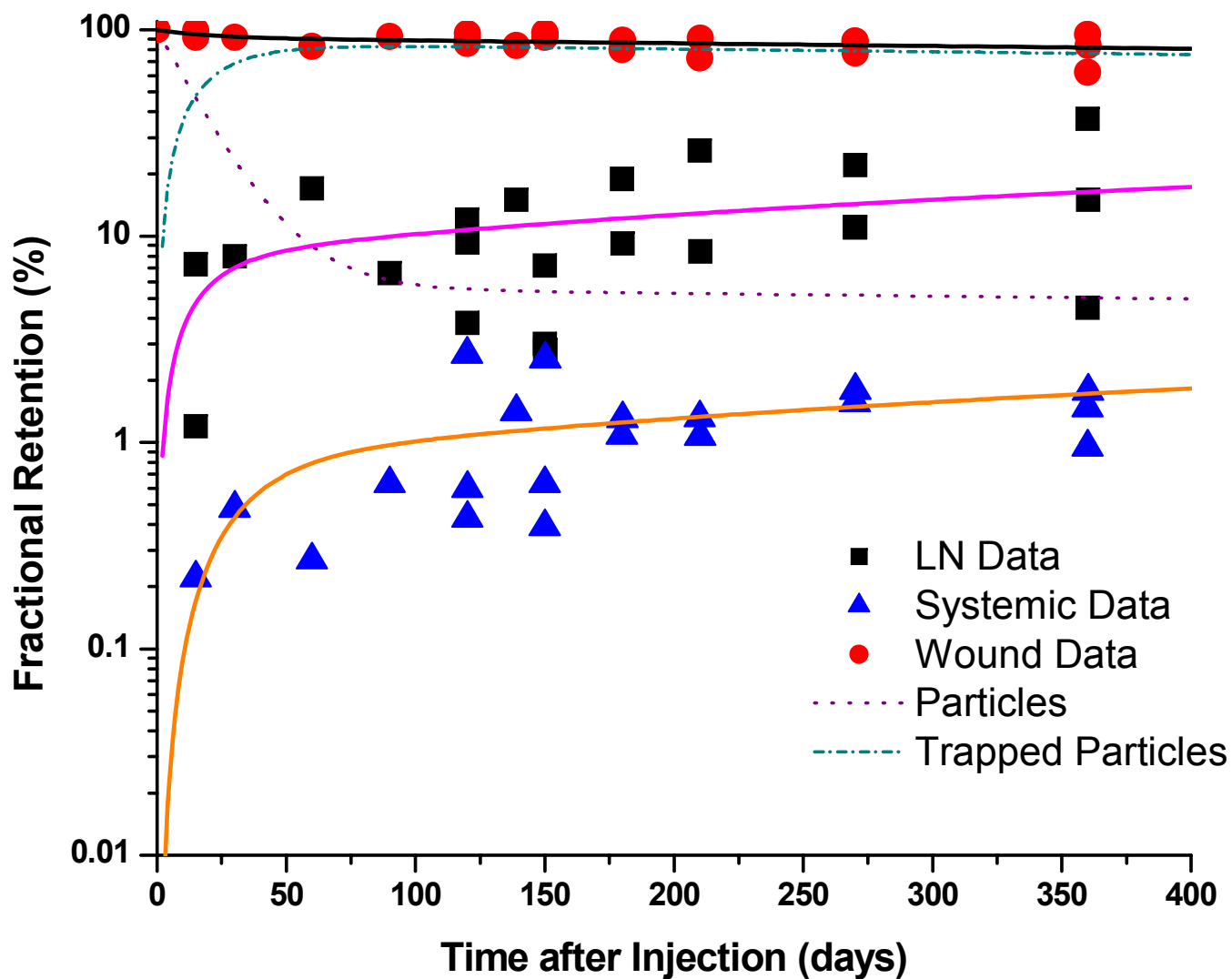
# BIOKINETICS OF RADIOACTIVE PARTICLES AND FRAGMENTS

- Few studies provide useful data for modeling
  - PuO<sub>2</sub> 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<sub>2</sub> in dogs (*Bistline 1973*)
  - Pu metal wire in rats and rabbits (*Lisco and Kisielewski 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)





# DU METAL FRAGMENTS IMPLANTED IN RAT MUSCLE



A



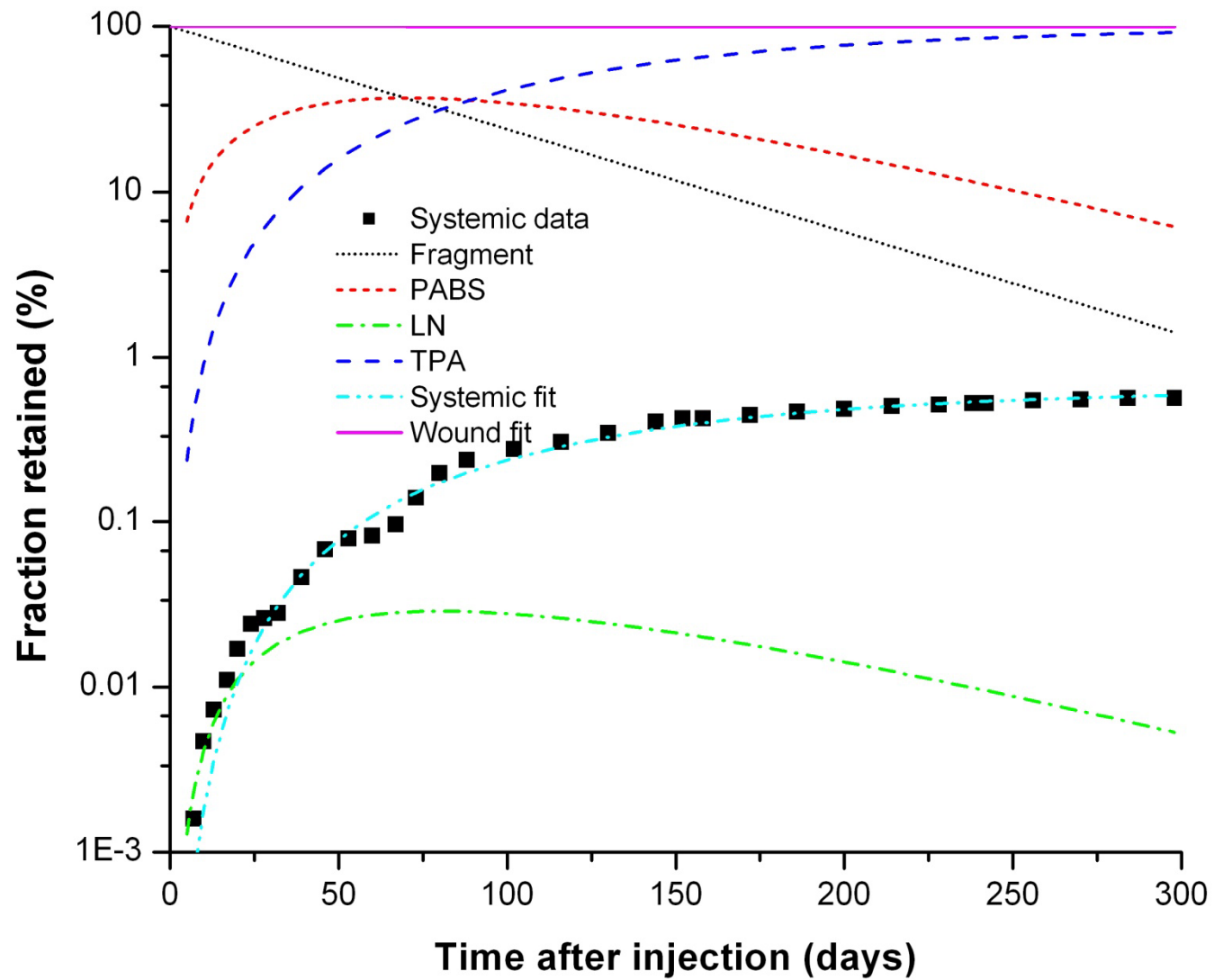
B



C

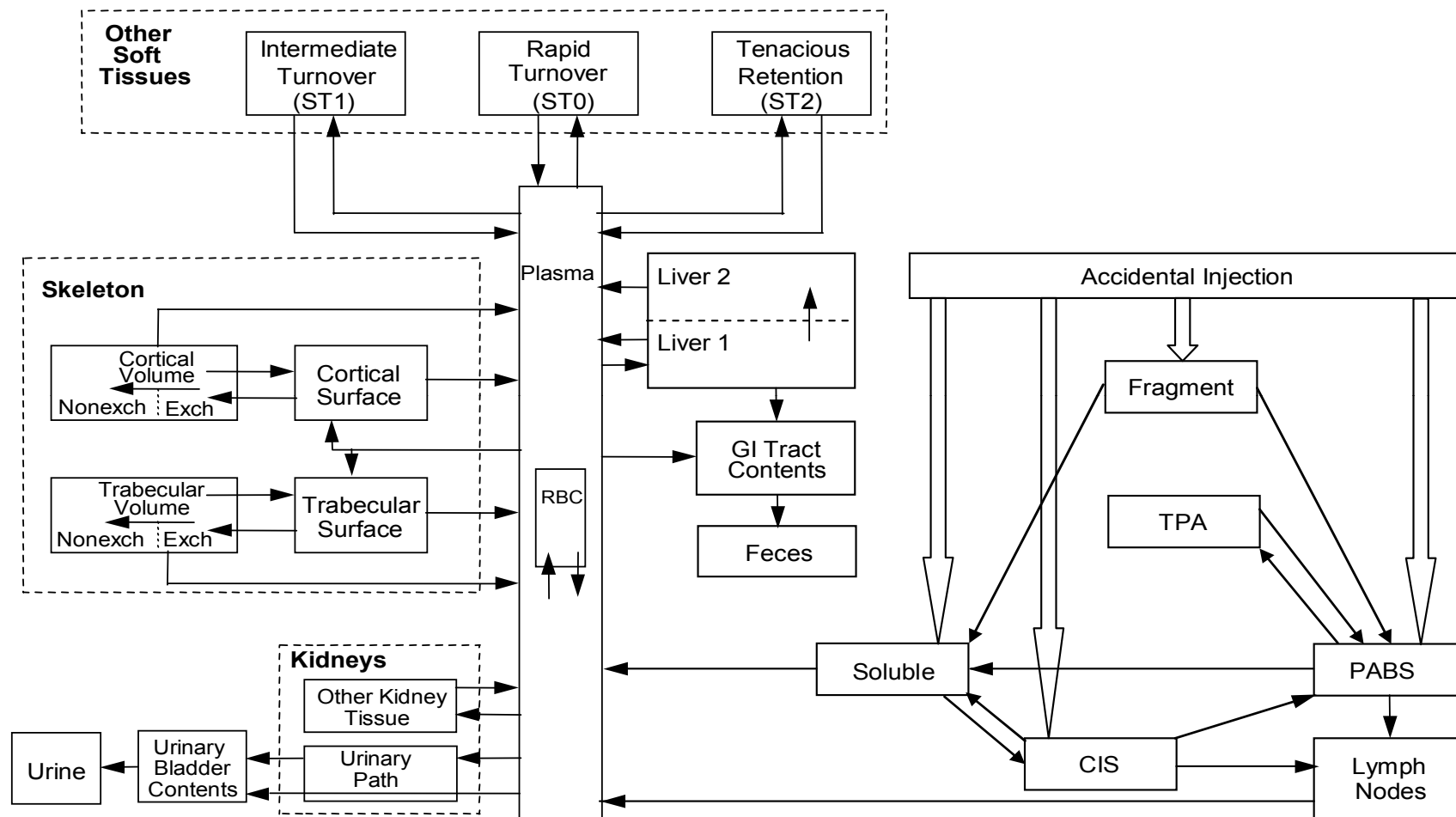
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# DU METAL IN RATS

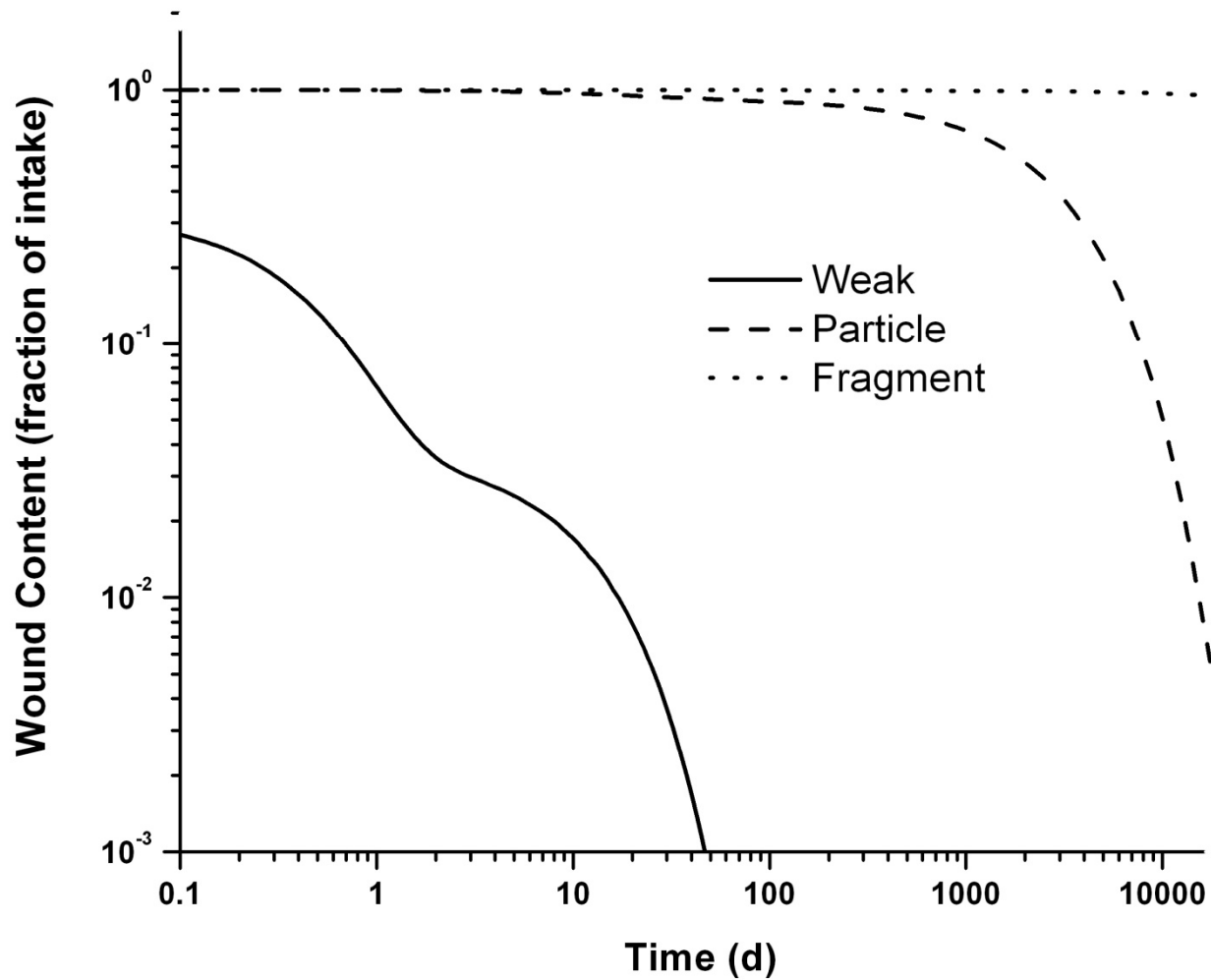


# **APPLICATION OF WOUND MODEL TO BIOASSAY INTERPRETATION**

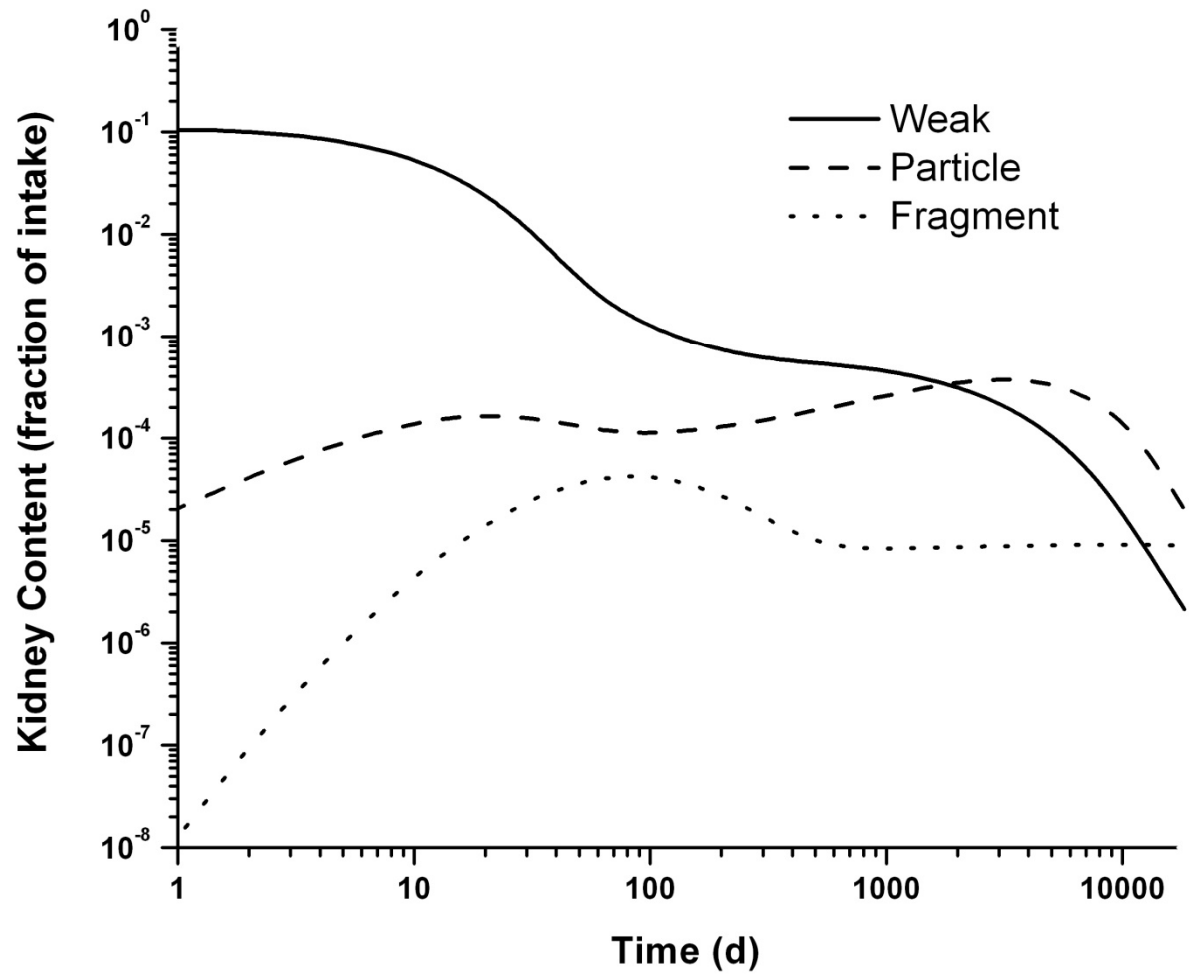
- **Select  $^{238}\text{U}$  and three relevant default categories**
- **Couple wound model to ICRP 69 systemic biokinetic model**
- **Solve using AIDE dose assessment software (v.4; Bertelli)**



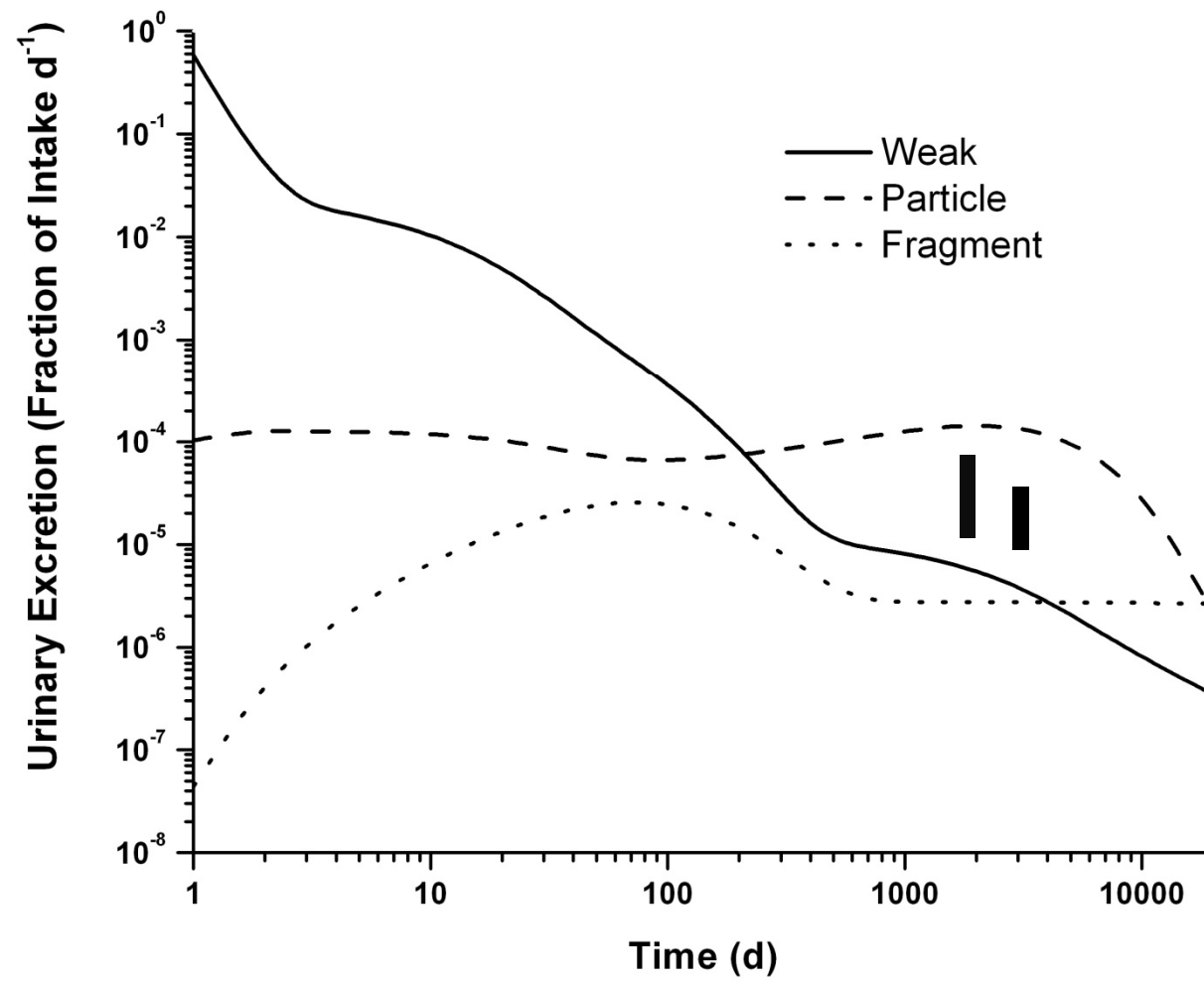
# U RETENTION IN WOUND SITE



# 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>**