

# **Use of RIB facilities for producing isotopes for cancer treatment by DART**

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## ***DART in a nutshell***

- **DART (Diffusing Alpha-emitters Radiation Therapy):** a new concept in radiation therapy which may enable therapeutic tumor doses with negligible damage to nearby healthy tissue
- Comprises three elements:
  1. The use of **alpha particles** rather than photons or electrons
  2. Enhancement of the therapeutic range of alpha particles **from microns to millimeters**
  3. Utilization of the different properties of malignant and healthy tissues to ensure **minimal collateral damage**

# *Alpha particle essentials*

- Emitted by readily available isotopes
  - Densely ionizing (LET  $\approx$  100 keV/  $\mu$ m)
  - Range in tissue: 40 – 90  $\mu$ m
  - Possess all benefits of high-LET radiation:
    - Direct ionization of the DNA  $\rightarrow$  complex DNA lesions
    - Biological effect insensitive to hypoxia, dose rate, cell cycle
  - Single hit to the nucleus may induce cell death
  - Short range may guarantee sparing adjacent tissue
- ... **but also limits the use against solid tumors**

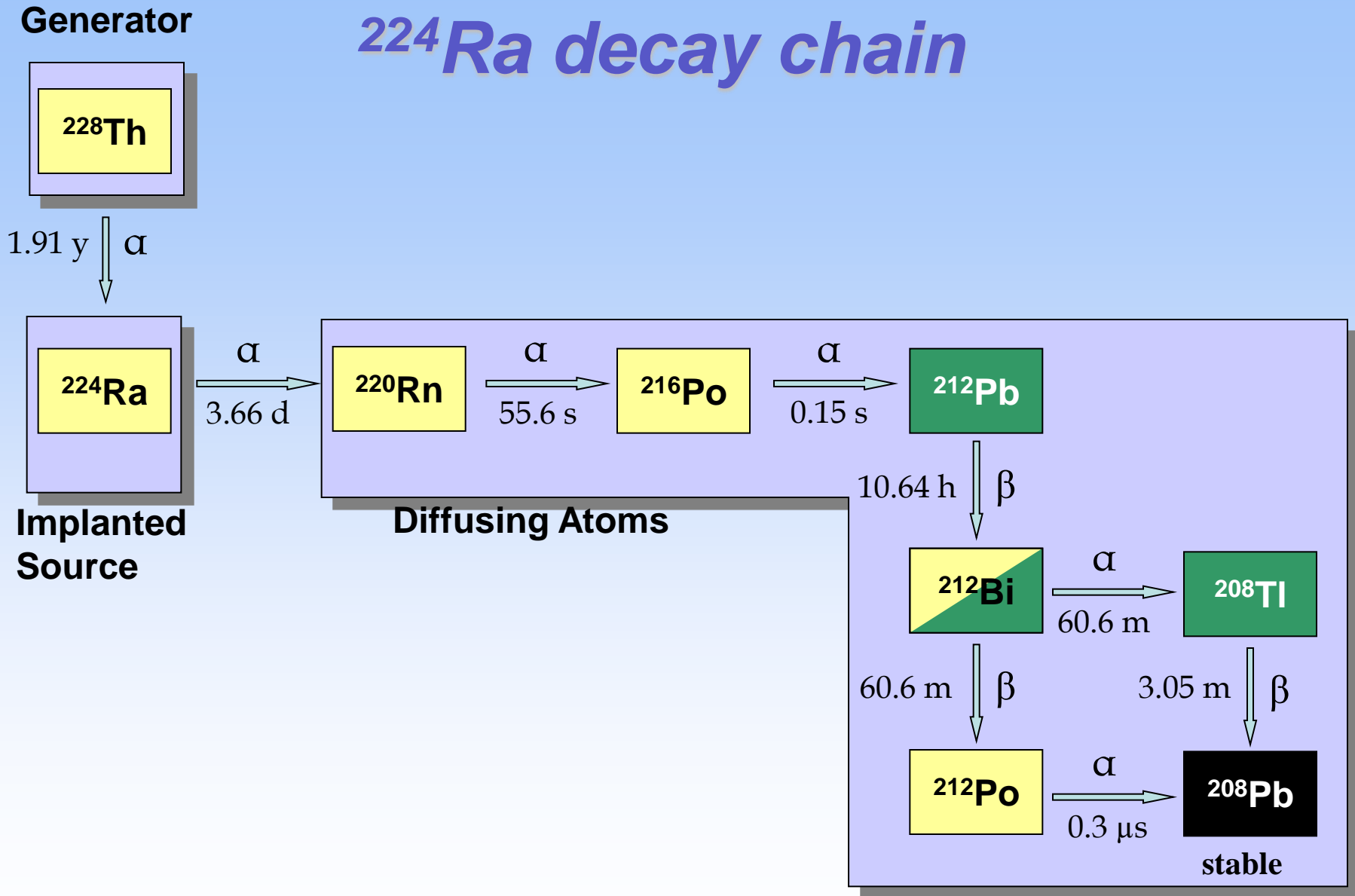
## *The idea*

- Rather than a source that emits alpha particles - **a source that emits alpha-emitting *atoms***
- The source is impregnated with small activities of  $^{224}\text{Ra}$
- When  $^{224}\text{Ra}$  decays its daughter atoms recoil out of the source ( $E_{\text{max}} \sim 100 \text{ keV}$ )
- The atoms disperse near the source, forming a cluster of alpha emissions **extending over several millimeters**

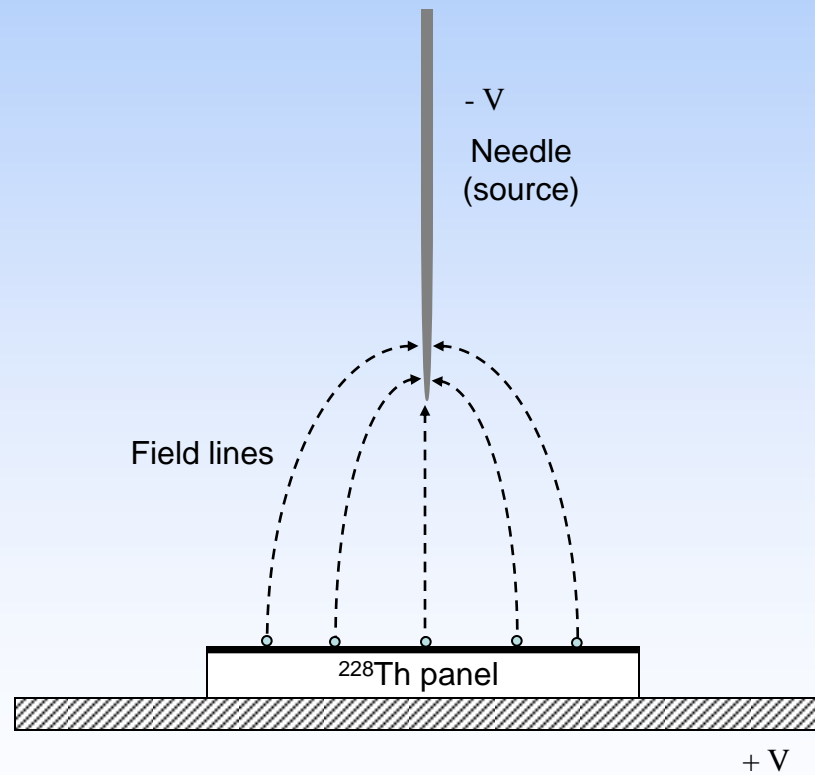


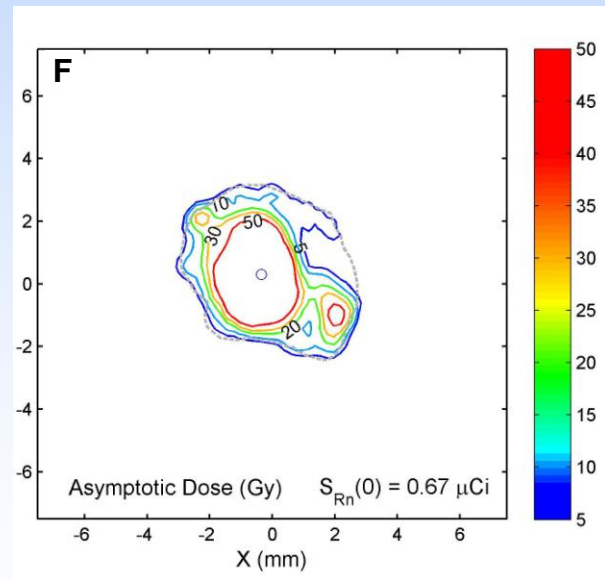
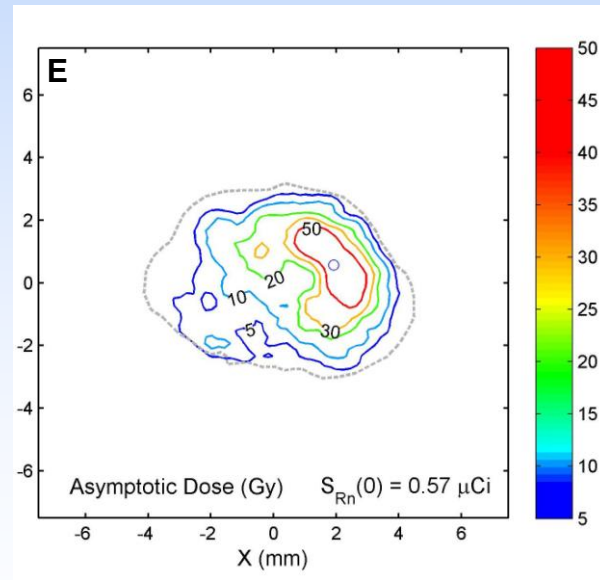
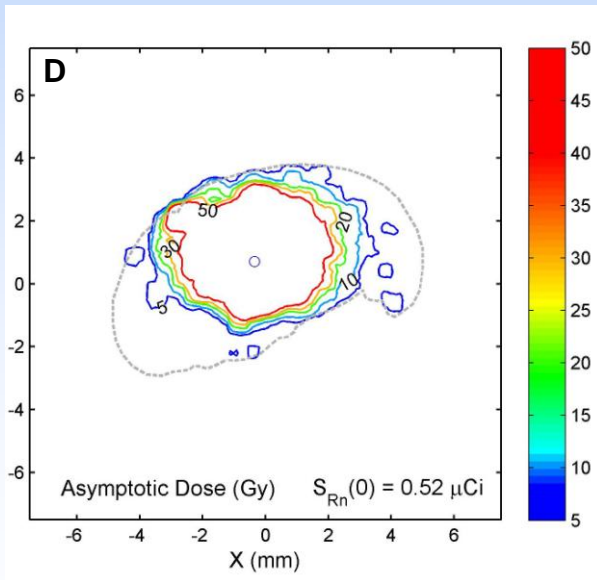
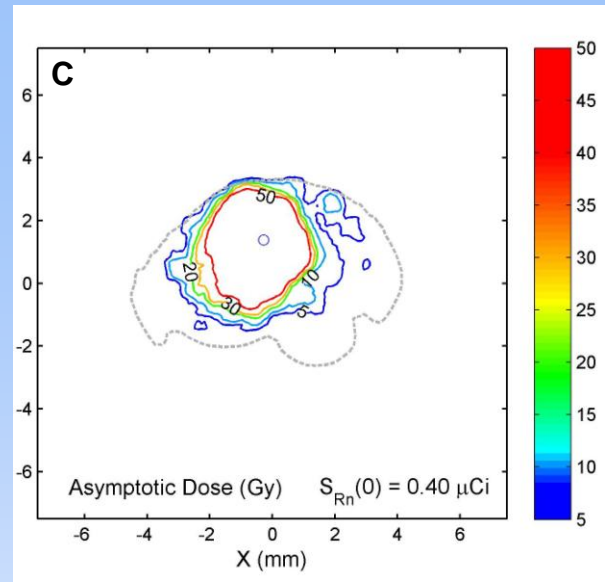
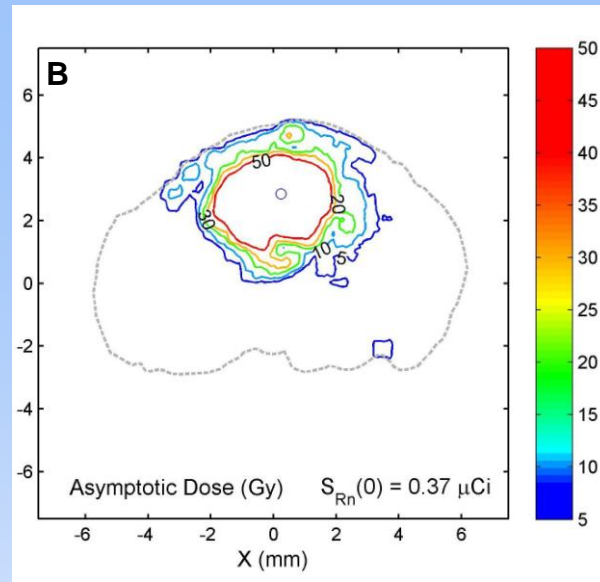
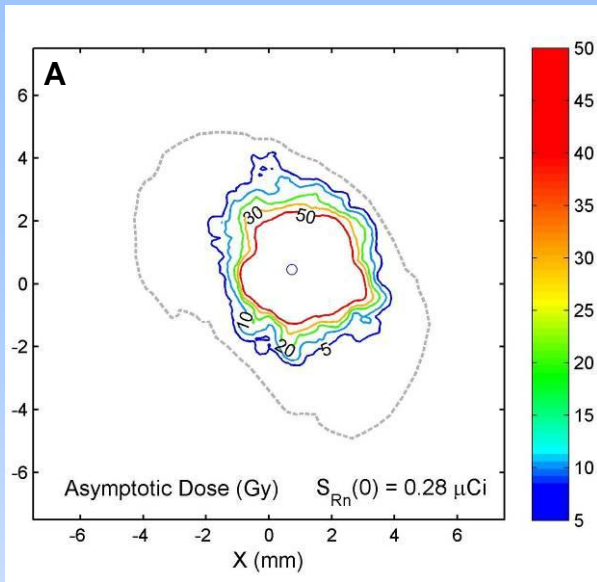
DART Seed

# *$^{224}\text{Ra}$ decay chain*



# Source preparation electrostatic collection of $^{224}\text{Ra}$





All:  $^{212}\text{Pb}$  autoradiography of murine squamous cell carcinoma (SQ2)



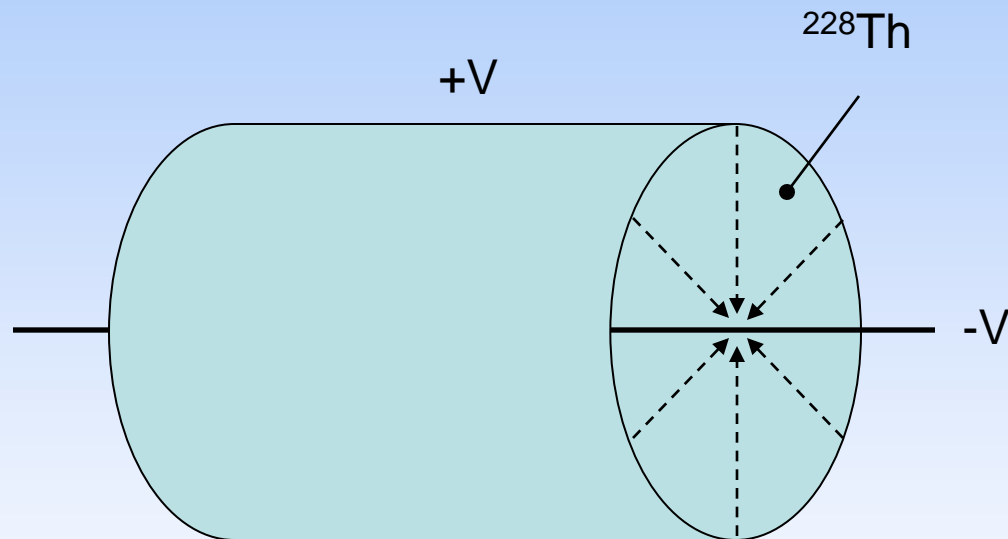
Mouse treated with a placebo source



Mouse treated with a 800 nCi source



# Source preparation (future plant)



Typical dimensions:  $L=100$  cm,  $R=3$  cm

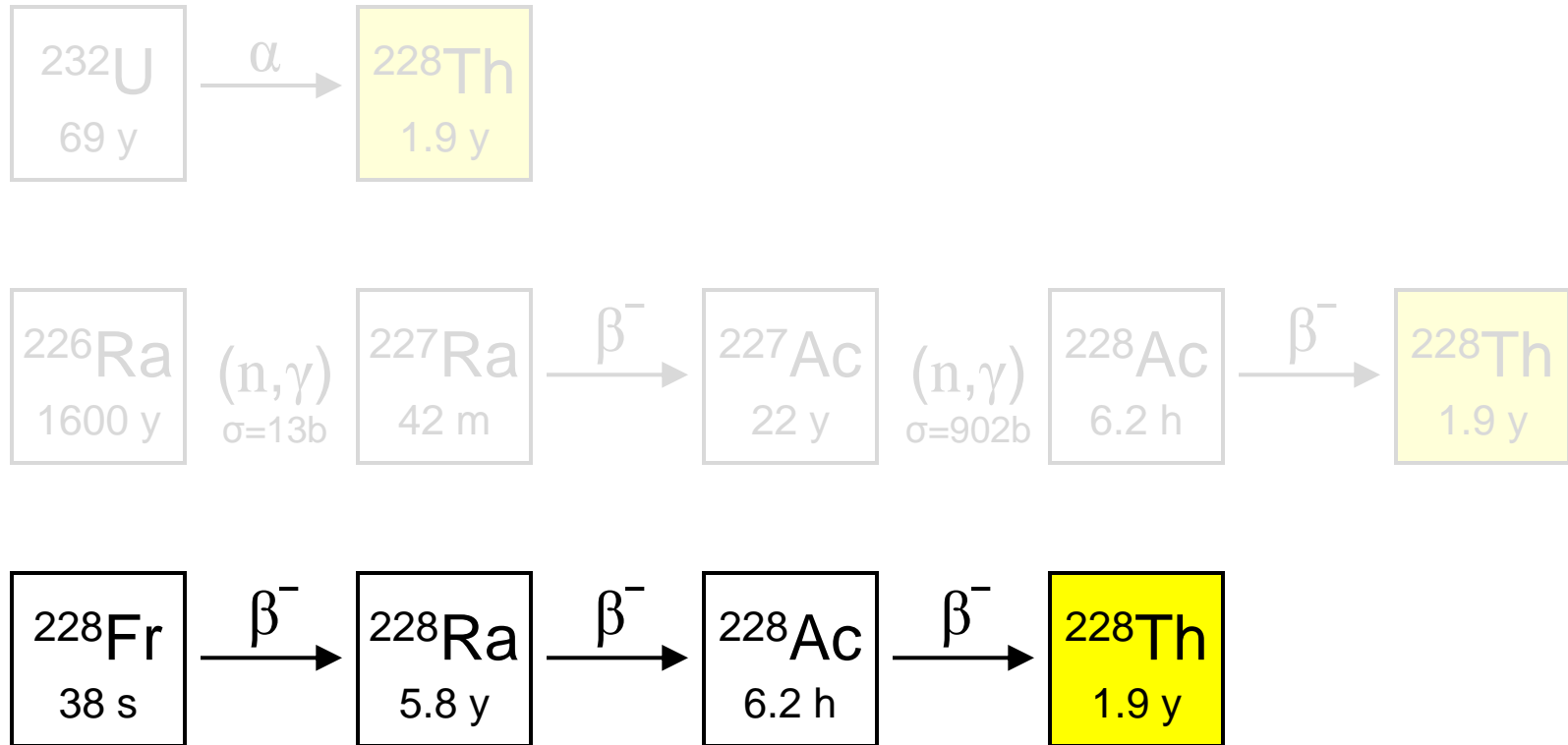
Typical  $^{228}\text{Th}$  activity:  $10 \mu\text{Ci}/\text{cm}^2$

Each unit produces  $\sim 2000$  treatments/year

# *Design criteria for $^{228}\text{Th}$ generators*

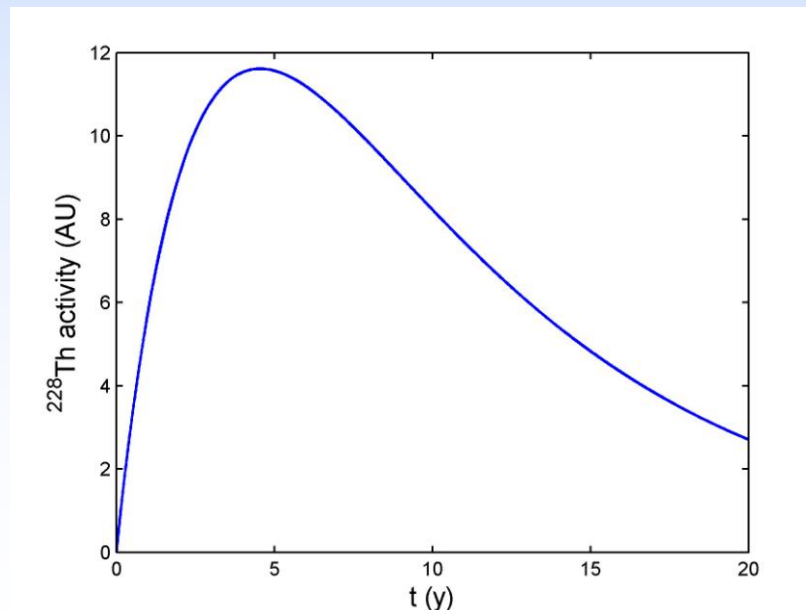
- $^{228}\text{Th}$  activity  $\sim 10 \mu\text{Ci}/\text{cm}^2$
- $^{224}\text{Ra}$  desorption probability  $\sim 40\%$
- No knock-out of  $^{228}\text{Th}$  atoms
- Safe, low-cost production
- Long operational lifetime

# $^{228}\text{Th}$ Production Schemes



# *$^{228}\text{Fr}$ scheme - quantitative aspects*

- Typical DART treatment  $\sim 100 \mu\text{Ci } ^{224}\text{Ra}$  ( $1.7 \cdot 10^{12}$  atoms)  
→  $^{228}\text{Th}$  atoms per treatment  $\sim 10^{13}$
- Assuming  $^{228}\text{Fr}$  production rate of  $10^{12}$  atoms/s:
  - ~10 seconds per treatment
  - ~200 seconds per  $\text{cm}^2$  of generator



# *Design criteria for $^{228}\text{Th}$ generators - RIB*

- $^{228}\text{Th}$  activity  $\sim 10 \mu\text{Ci}/\text{cm}^2$  ✓
- $^{224}\text{Ra}$  desorption probability  $\sim 40\%$  ✓
- No knock-out of  $^{228}\text{Th}$  atoms ✓
- Safe, low-cost production ✓
- Long operational lifetime ✓