REDUCTION OF THE LONG-TERM TOXICITY OF NEPTUNIUM AND OTHER MINOR ACTINIDES BY NUCLEAR SPALLATION

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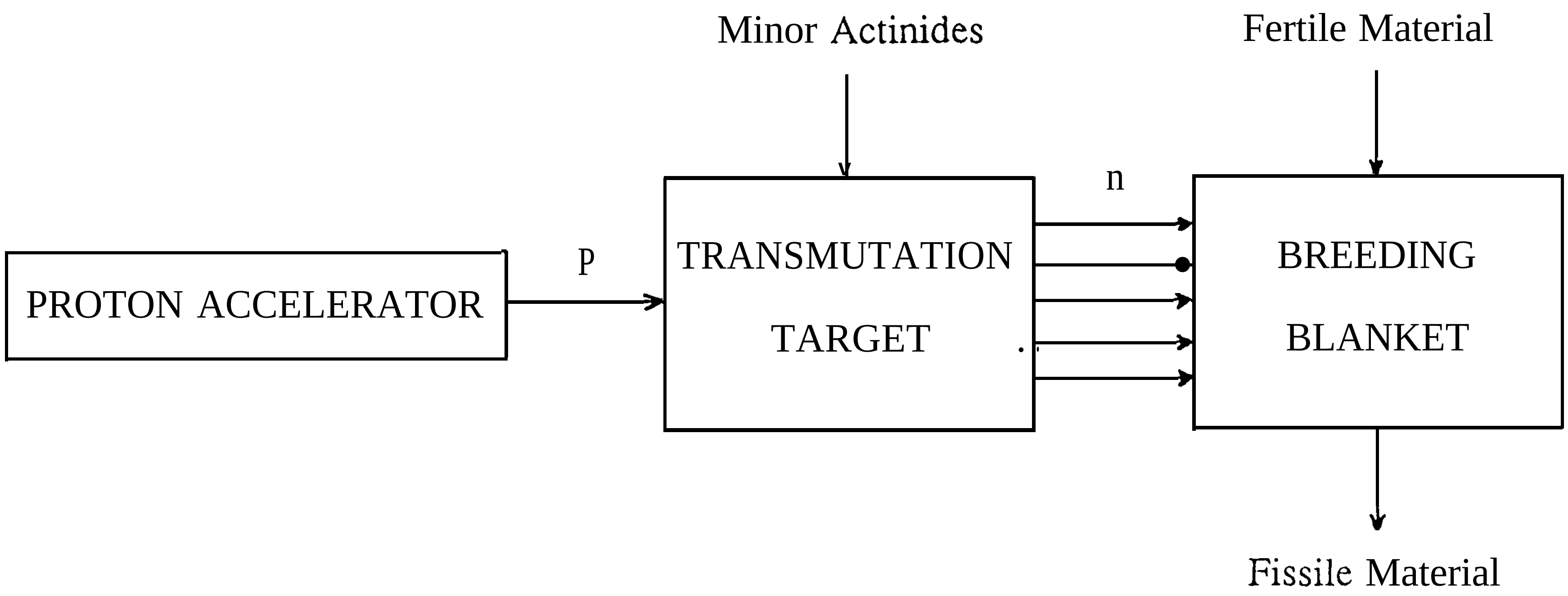
Aim of the study

- To examine the effectiveness of high-energy proton-induced reactions (spallation and fission) for reducing the long-term toxicity of Np-237 and other minor actinides
- To identify particular aspects of the overall process which work in favour of, or against, toxicity reduction

PSI-F4 / Advanced Systems/ **30.10.90** / PW



HIGH POWER ACCELERATOR DRIVEN TARGET-BLANKET SYSTEM

Basic advantages of the high-energy reactions

- *High fission probability*

  Fission probability is higher than for neutron-induced reactions at lower energies.

- *Tendency of the spallation reactions to directly reduce the atomic mass number of the bombarded nuclei*

  Neutron-induced capture reactions at lower energies lead to the build-up of new higher actinides.

Cases studied

- *Mass yield distribution in a thin iVp-237 target*

  Results may be compared with those from other calculations and thin foil experiments.

- *Mass yield distribution and toxicity of spallation and fission products produced in a quasi-infinite Np-237 target*

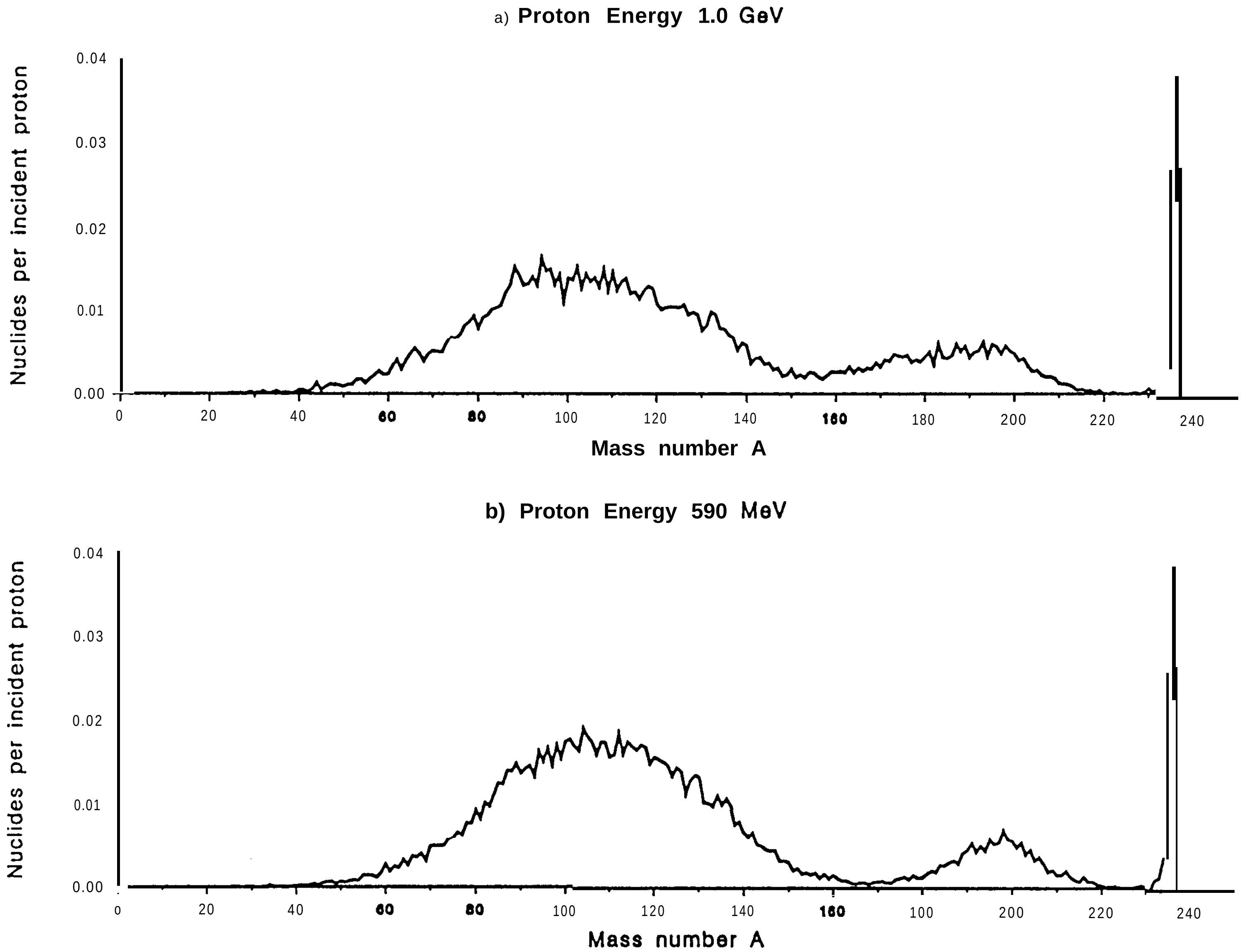
  System is physically unreal but will show the maximum contribution from the nucleon meson cascade.

- *Mass yield distribution and toxicity of the spallation products produced in a quasi-infinite target consisting of a typical mixture of minor actinides from LWR spent fuel*

  Minor actinides recycling schemes
  a) without separation of newly generated U and Pu
  b) with separation of newly generated Pu
  c) with separation of newly generated U and Pu

Calculational methods

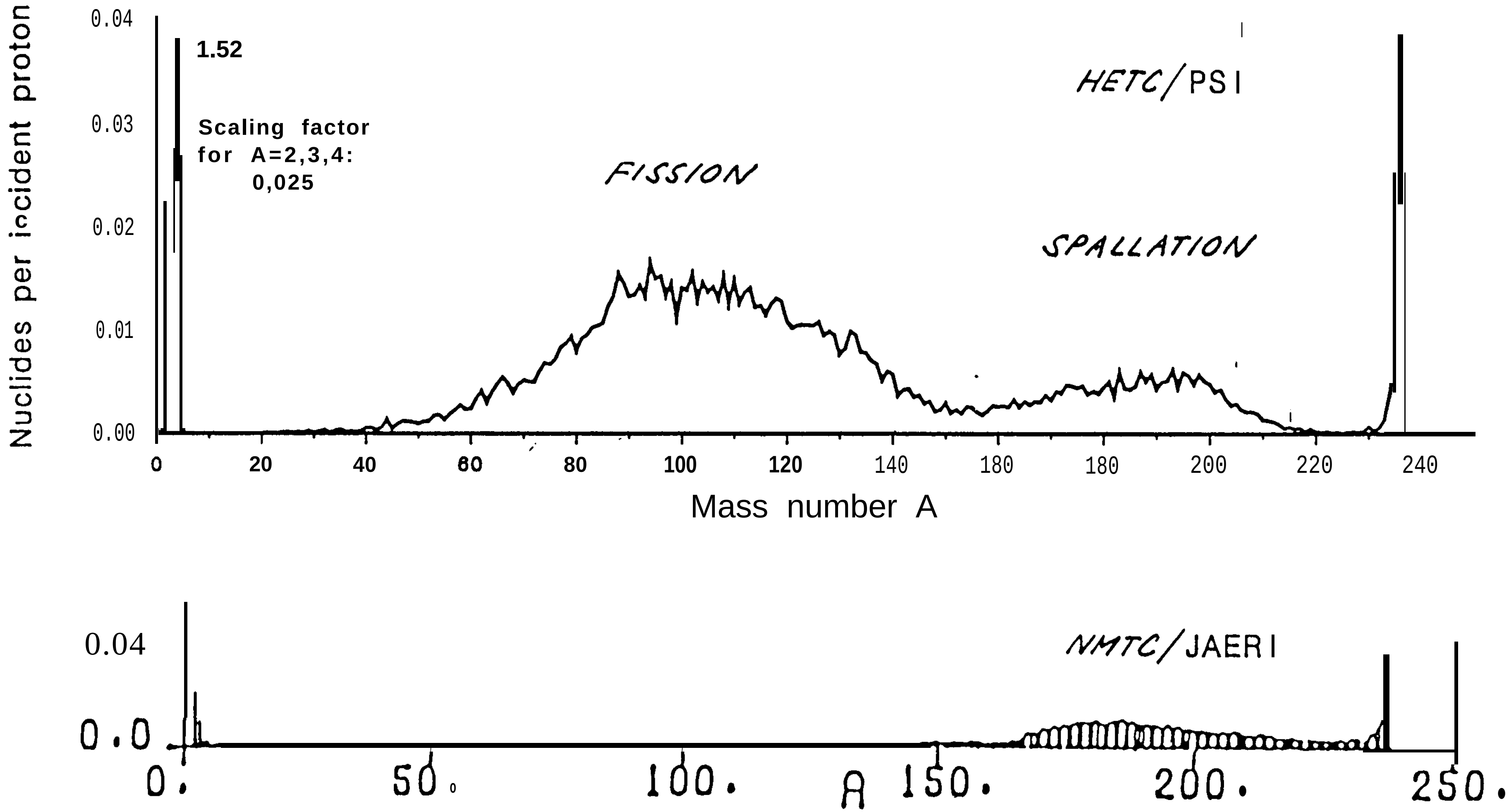
- The interactions of the nucleons and mesons with the target nuclei are calculated using the code package HETC.
- The PSI version of HETC includes a high-energy fission model.
- Neutron transport below 15 MeV is neglected.
- A chain-yield analysis of the transmutation products over a period of 10^7 years is performed.
- Dose conversion factors for ingestion are taken from ICRP-30.

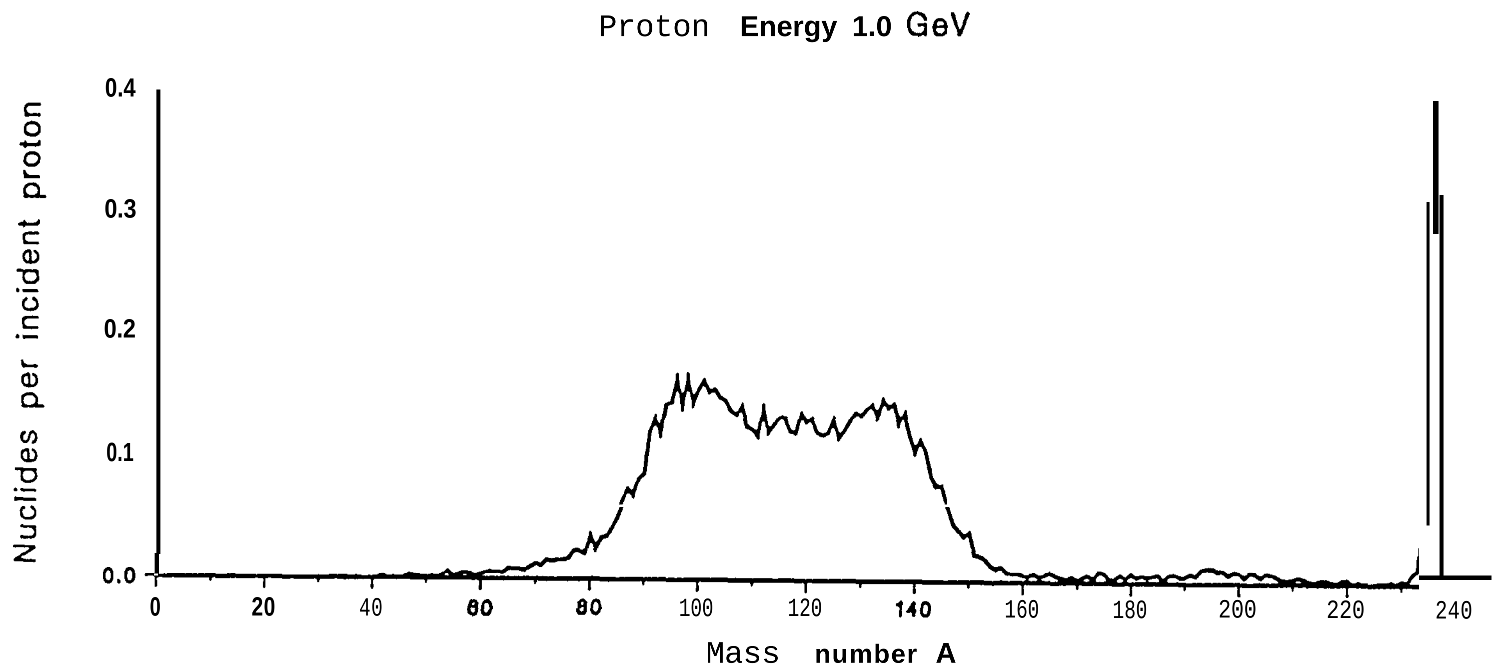


Mass yield distribution from bombardment of a thin Np-237 target

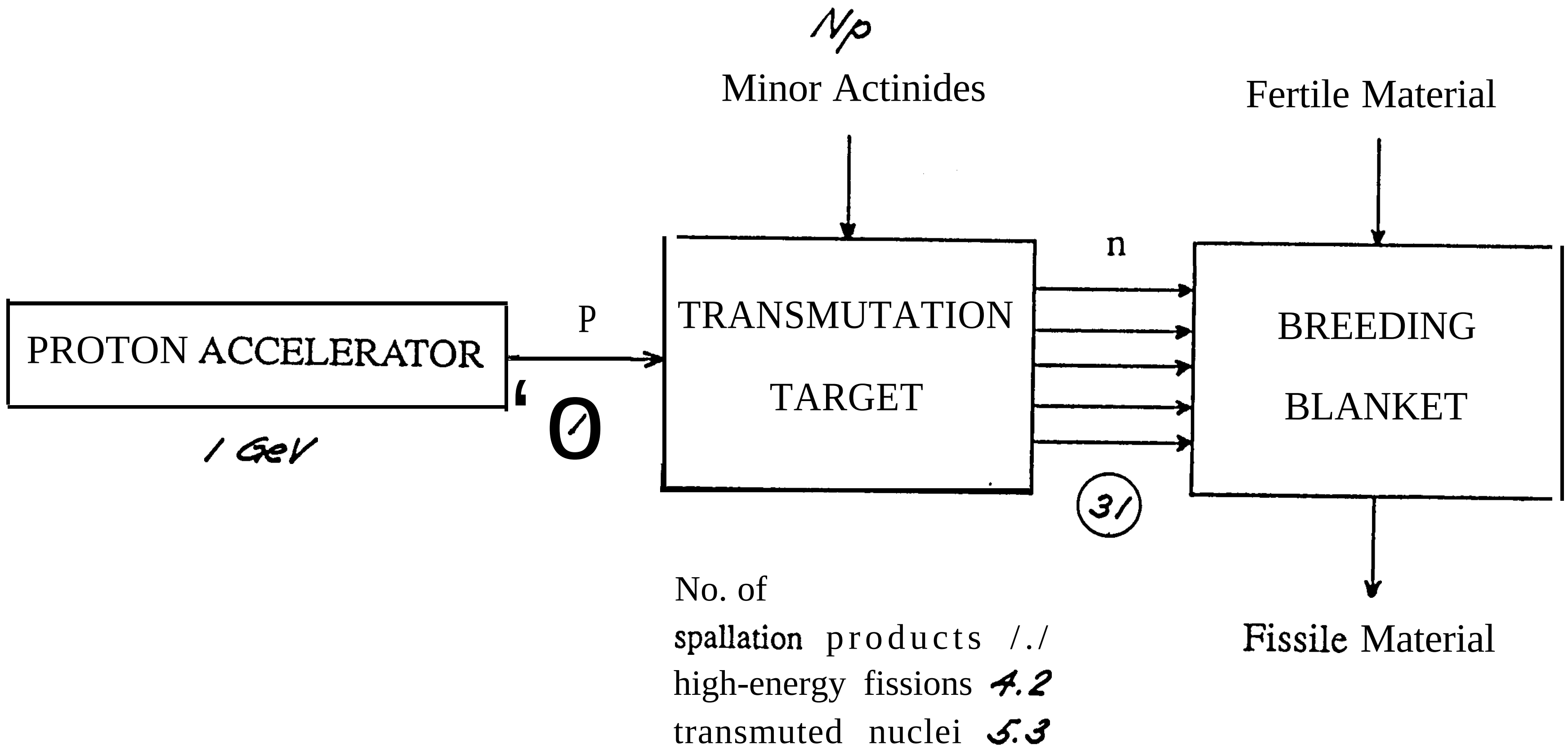
Np237

Proton Energy 1.0 GeV

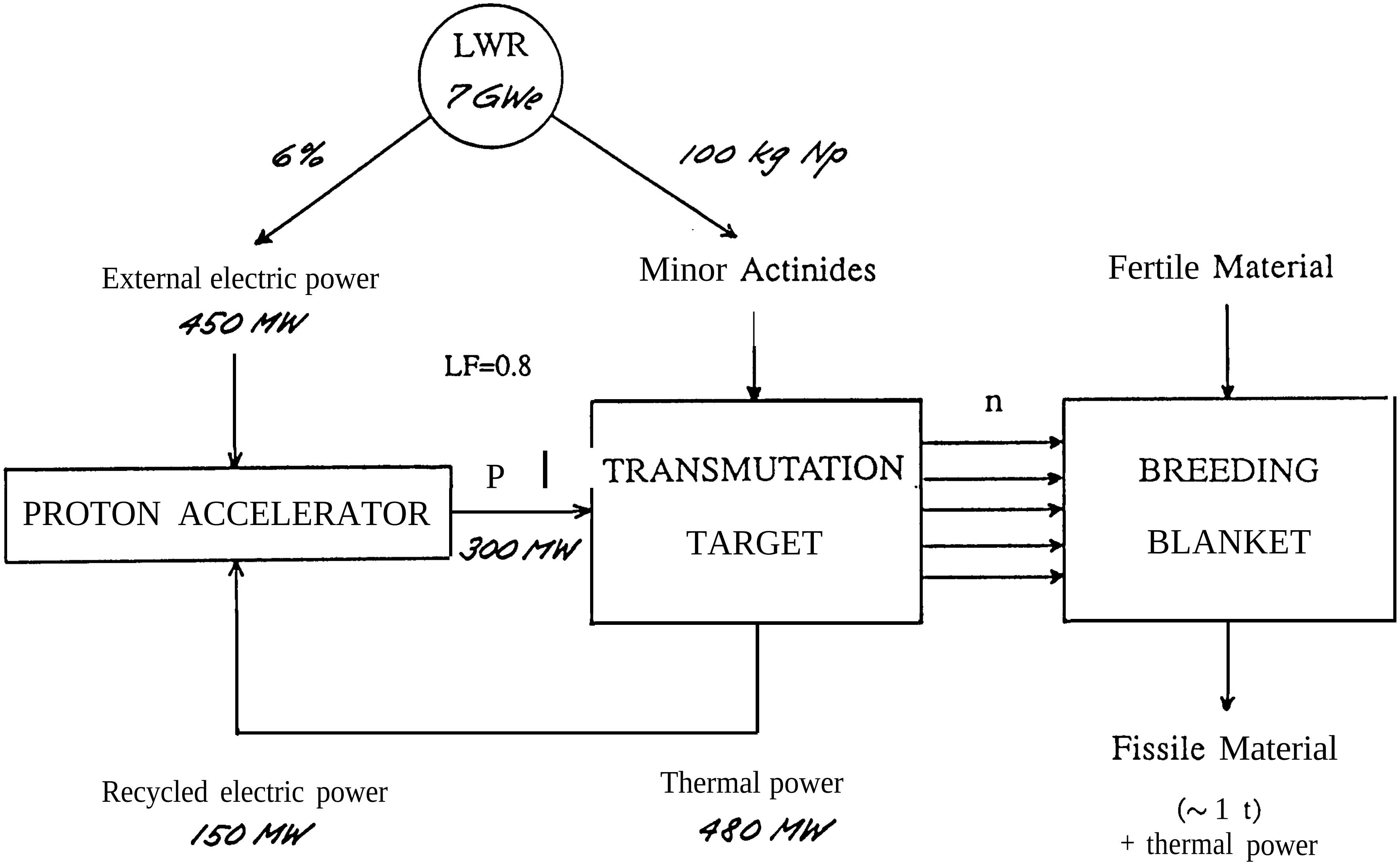




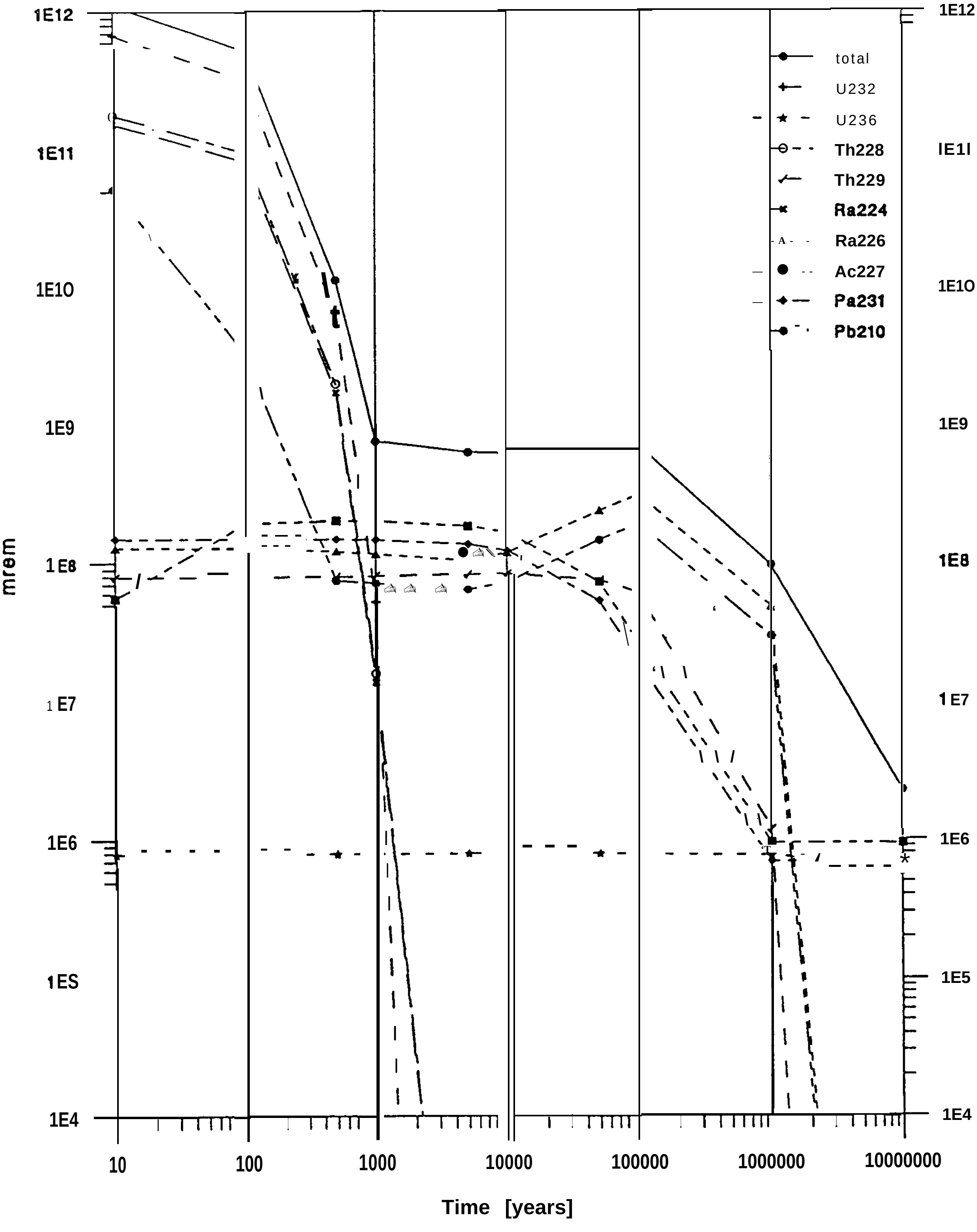
Mass yield distribution from bombardment of a quasi-infinite Np-237 target



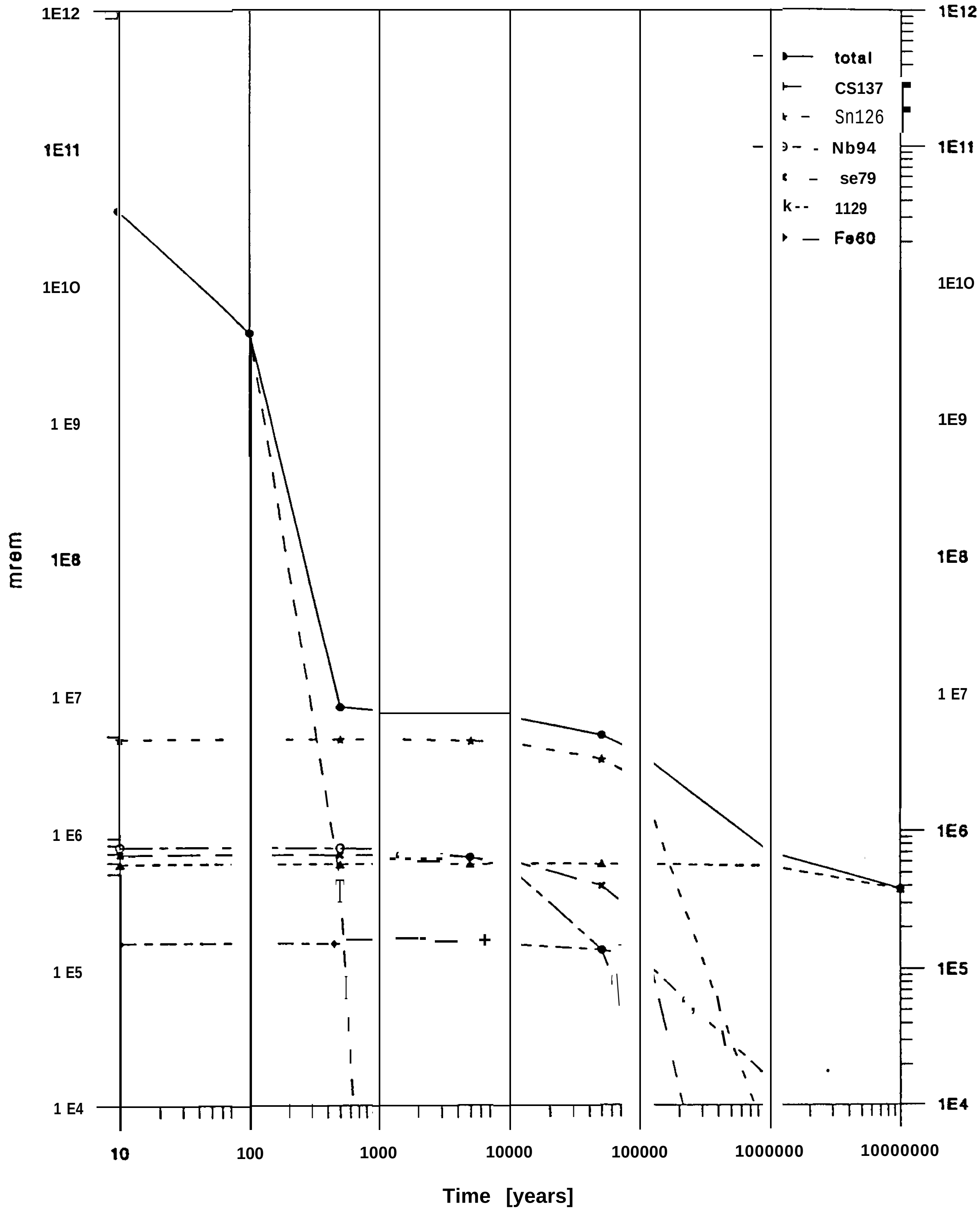
TRANSMUTATION EFFICIENCY



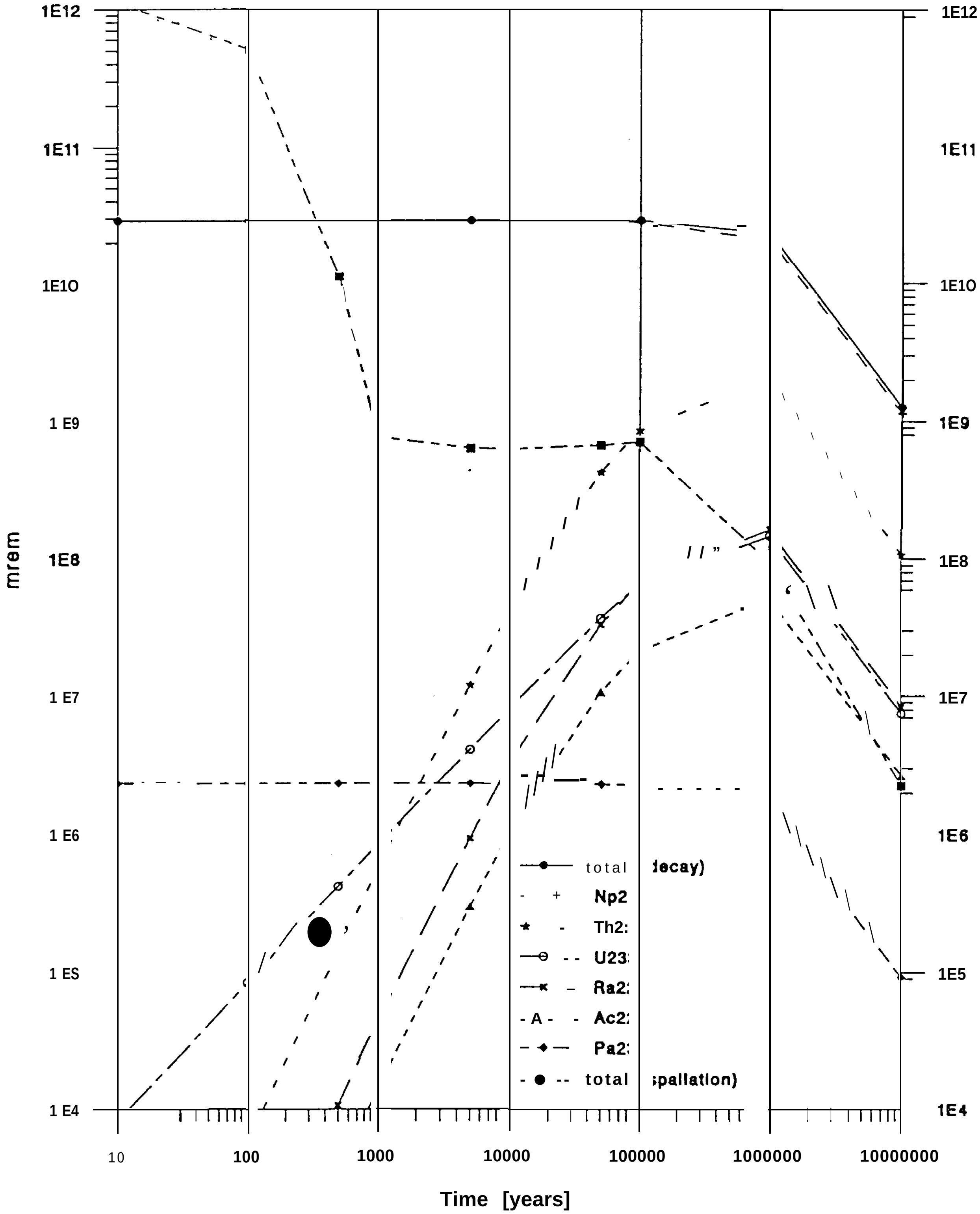
ENERGY BALANCE



Long-term toxicity of Np-237 spallation products
(1 GeV protons, quasi-infinite target)

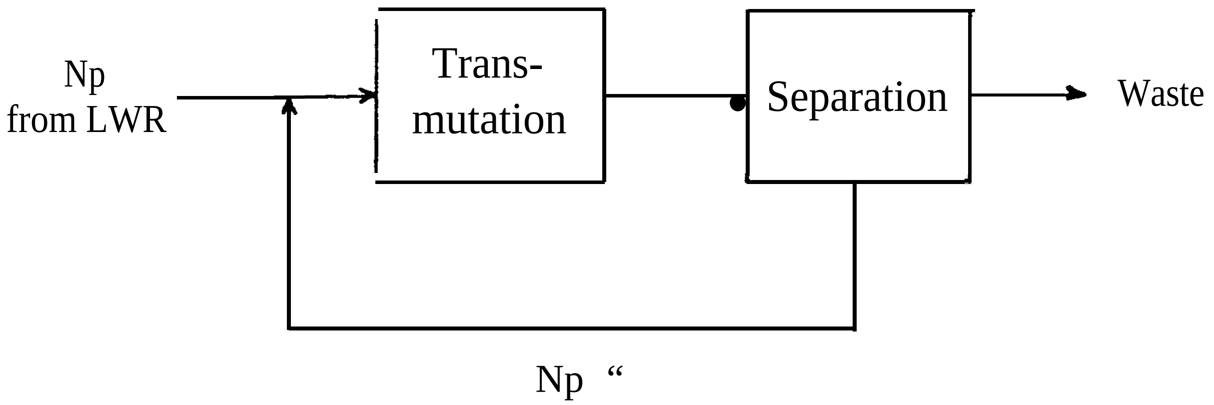


Long-term toxicity of Np-237 fission products
(1 GeV protons, quasi-infinite target)

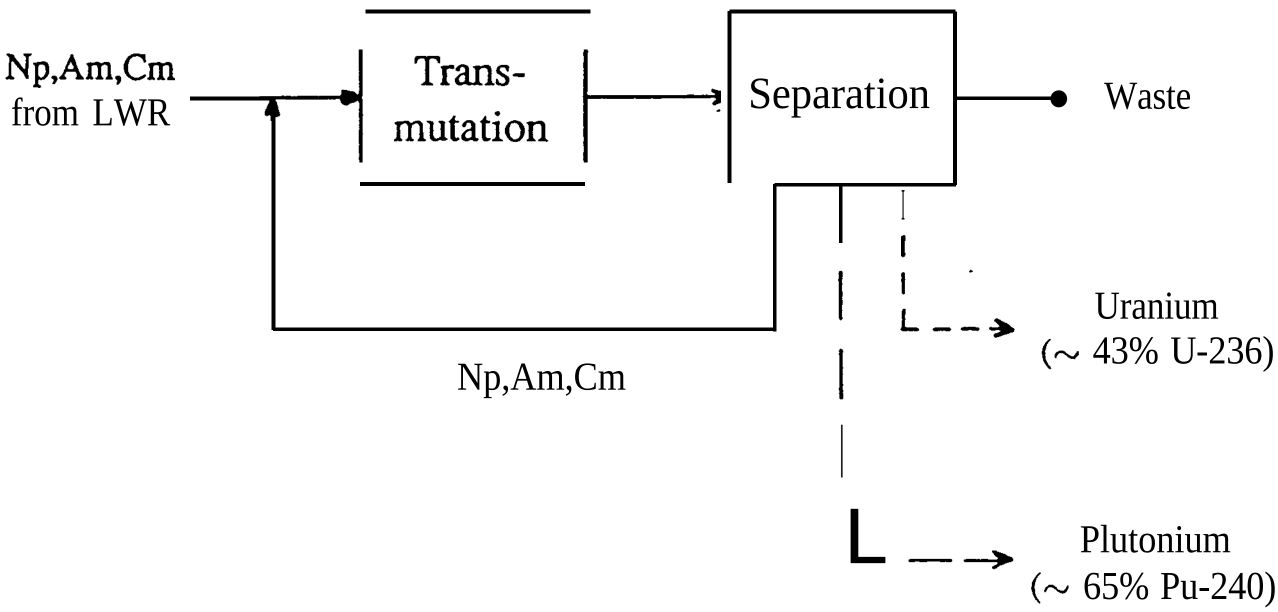


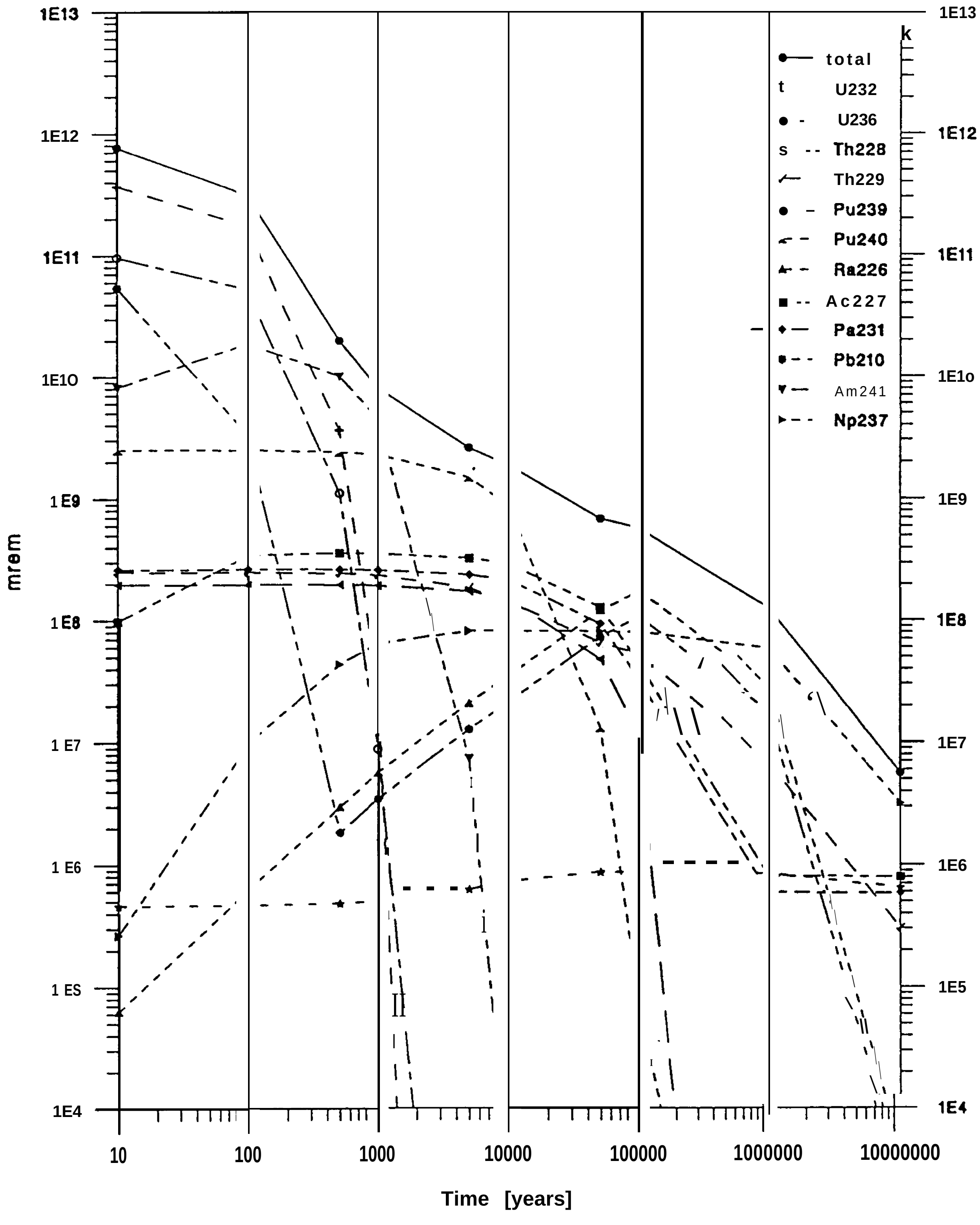
Long-term toxicity from direct Np-237 decay

Neptunium Recycling Scheme

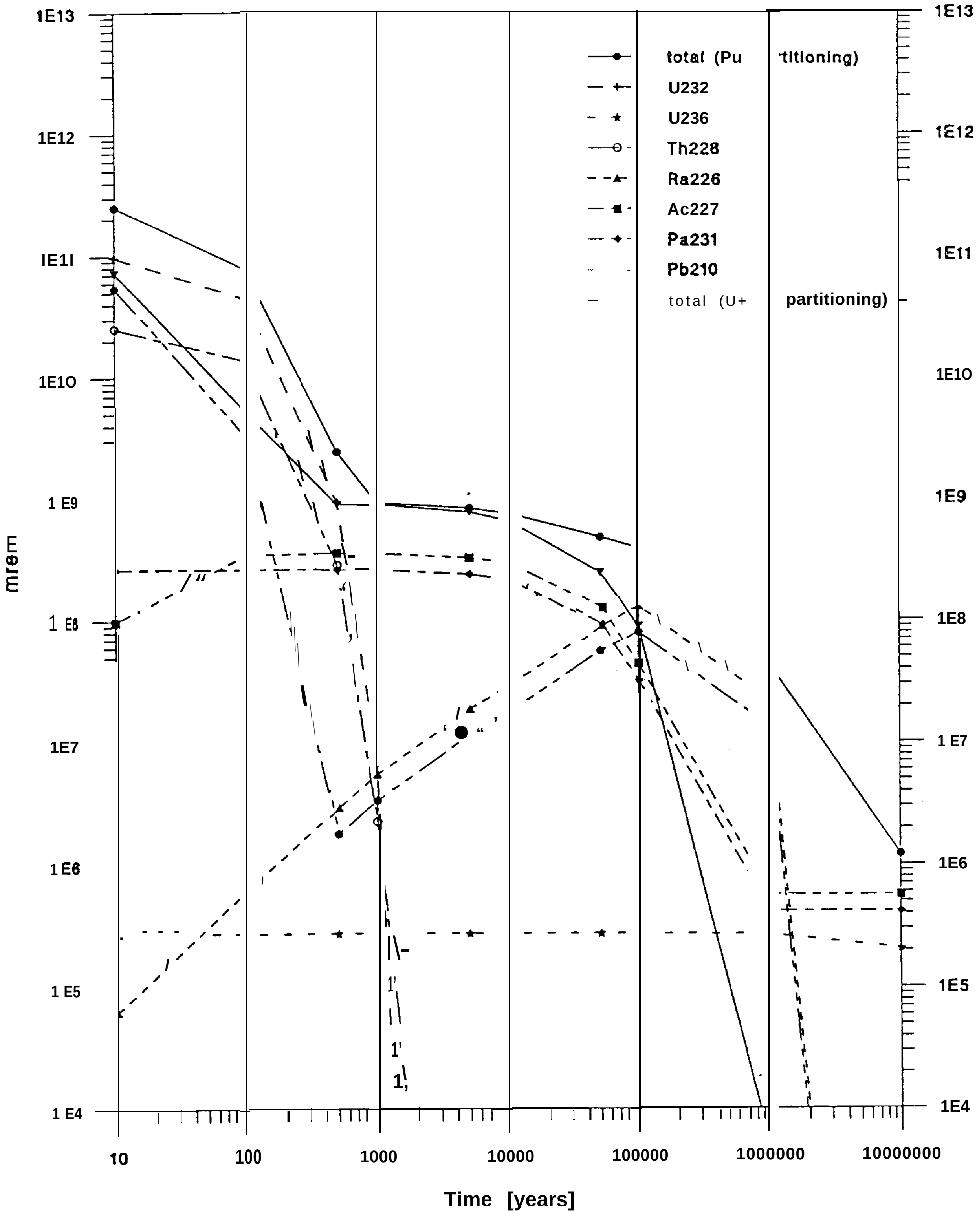


Minor Actinide Recycling Schemes

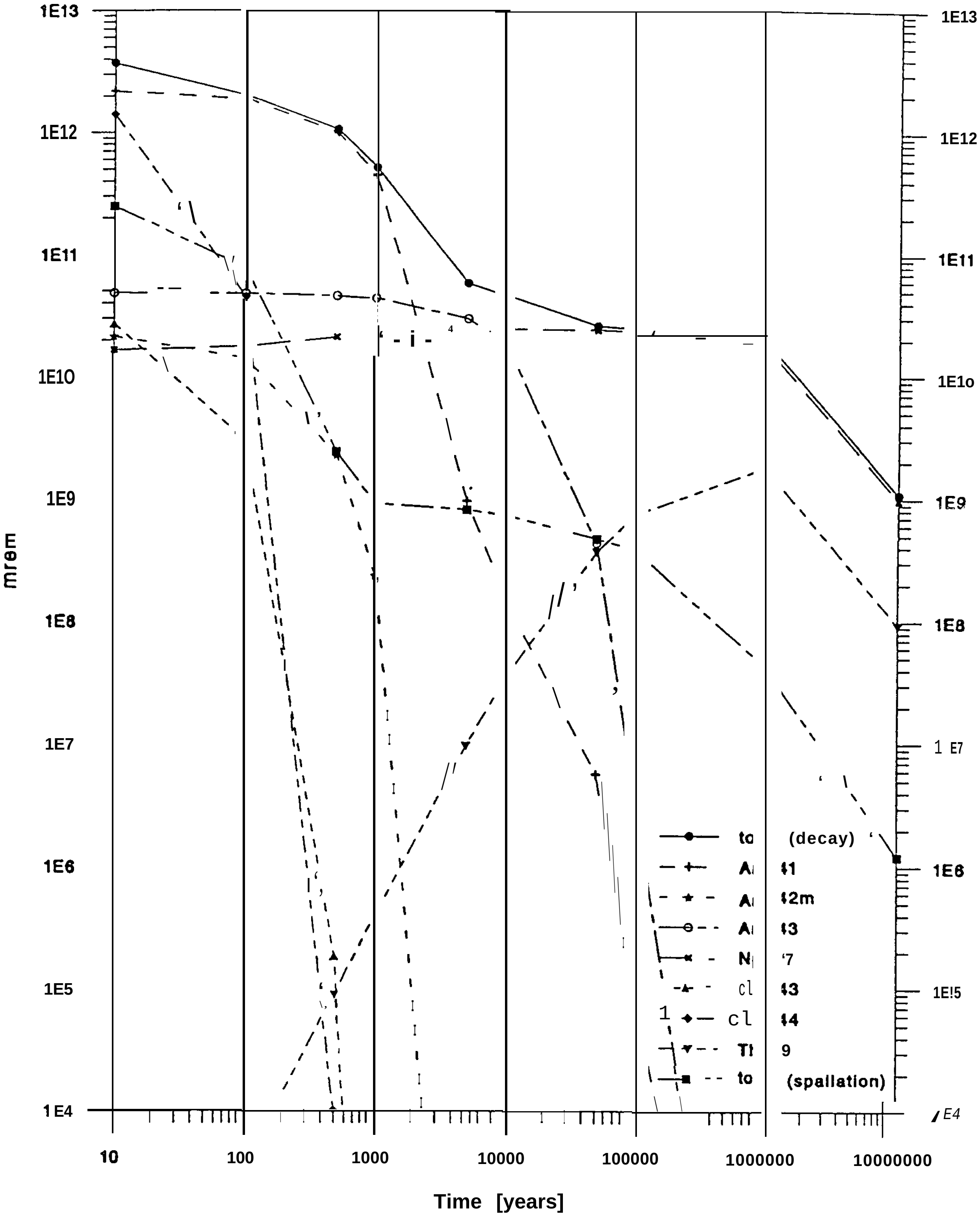




Long-term toxicity of the remaining spallation products for a minor actinide recycling scheme without major actinide partitioning



Long-term toxicity of the remaining spallation products for a minor actinide recycling scheme with additional plutonium partitioning



Long-term toxicity of the original minor actinide mixture
and its decay products

Conclusions

- The basic potential of high-energy proton-induced reactions for reducing the long-term toxicity of minor actinides is confirmed.
- The energy multiplication factor for a pure spallation target is only about 1.6 but may be acceptable, if the facility is also used for other purposes.
- The long-term toxicity is dominated by spallation products.
- For pure Np, the toxicity reduction factor increases from 40 to more than 500 in the time period from 10^3 to -2.107 years.
- For a MA mixture, the toxicity reduction factor is at least 60 and reaches a maximum of 900 around 10^7 years, if Pu is separated from the transmutation products.
- Beyond 10^7 years, the remaining toxicity of the transmutation products is about the same as that of an equal amount of pure U_3O_8.
- The theoretically achievable toxicity reduction depends on the high-energy fission model.