Endorsing Titanium-Scandium Radionuclide Generator for PET and Positronium Imaging

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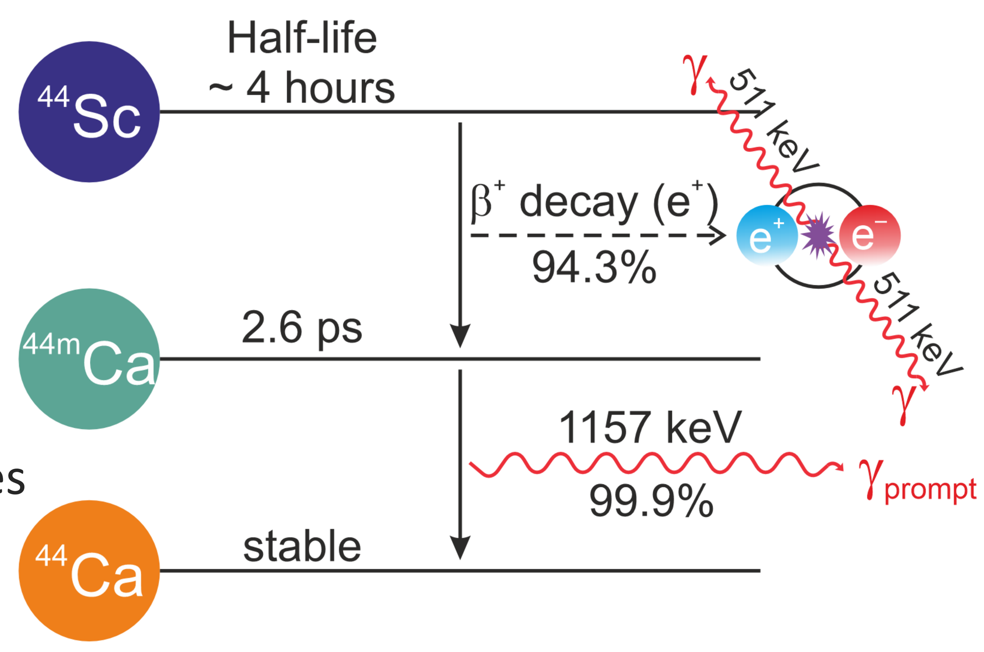
The development of positronium imaging is tightly linked to the availability of suitable radionuclides and robust radiochemistry platforms. Among the emerging candidates, ^{44}Sc has attracted significant interest due to its favourable physical properties, including a half-life of ~4 hours, a pure β^+ emission profile, and the additional prompt γ-emission that enables advanced triple-photon detection schemes. These characteristics make ^{44}Sc particularly promising for high-resolution imaging and novel quantitative methodologies.

However, routine clinical and preclinical implementation requires a practical, sustainable, and cost-efficient production route. Conventional supply based on cyclotron irradiation or ^{68}Ge/^{68}Ga generators is often limited by infrastructure, distribution logistics, and short half-lives. In this context, we propose a titanium-scandium radionuclide generator as a new solution. The concept is based on the production and long-term retention of a parent titanium isotope within a solid matrix, from which ^{44}Sc can be selectively eluted in a chemically pure form when needed.

Such a generator system could ensure an on-demand and decentralized source of ^{44}Sc, significantly simplifying the supply chain. Moreover, the titanium-scandium platform offers prospects for scalability, cost reduction, and compatibility with existing radiolabelling protocols. By providing reliable access to ^{44}Sc, this approach has the potential to accelerate the adoption of positronium imaging and extend its clinical impact.

Why Scandium?

- Ideal timescale for synthesis and imaging **($T_{1/2}$ ≈ 4 h)**
- **Pure β^+ emission** (94.3%) for PET and positronium studies
- **Prompt γ** (1157 keV, 99.9%) → precise timestamp and localisation of positronium formation
- Sc^{3+} chemistry similar to lanthanides → **highly stable complexes** with DOTA-type chelators

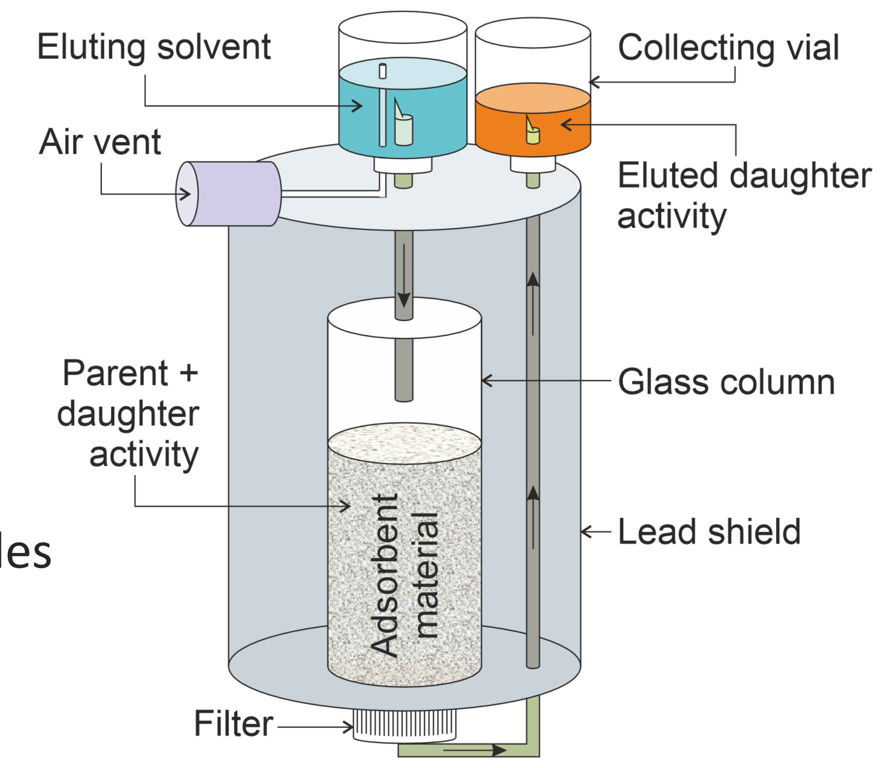


These features make ^{44}Sc a uniquely powerful radionuclide for advanced PET and positronium imaging

^{44}Ti/^{44}Sc Generator

- **Parent isotope (Ti)** fixed on adsorbent in a shielded glass column
- **^{44}Sc daughter** produced *in situ* by decay
- Selective **elution with solvent** releases pure ^{44}Sc into collecting vial
- Provides **on-demand supply** of ^{44}Sc without need for local cyclotron
- **Long-lived parent** (^{44}Ti, $T_{1/2}$ ≈ 60 years) → a single generator operates for decades

This simple, reusable system enables a sustainable and decentralised source of ^{44}Sc for PET and positronium imaging



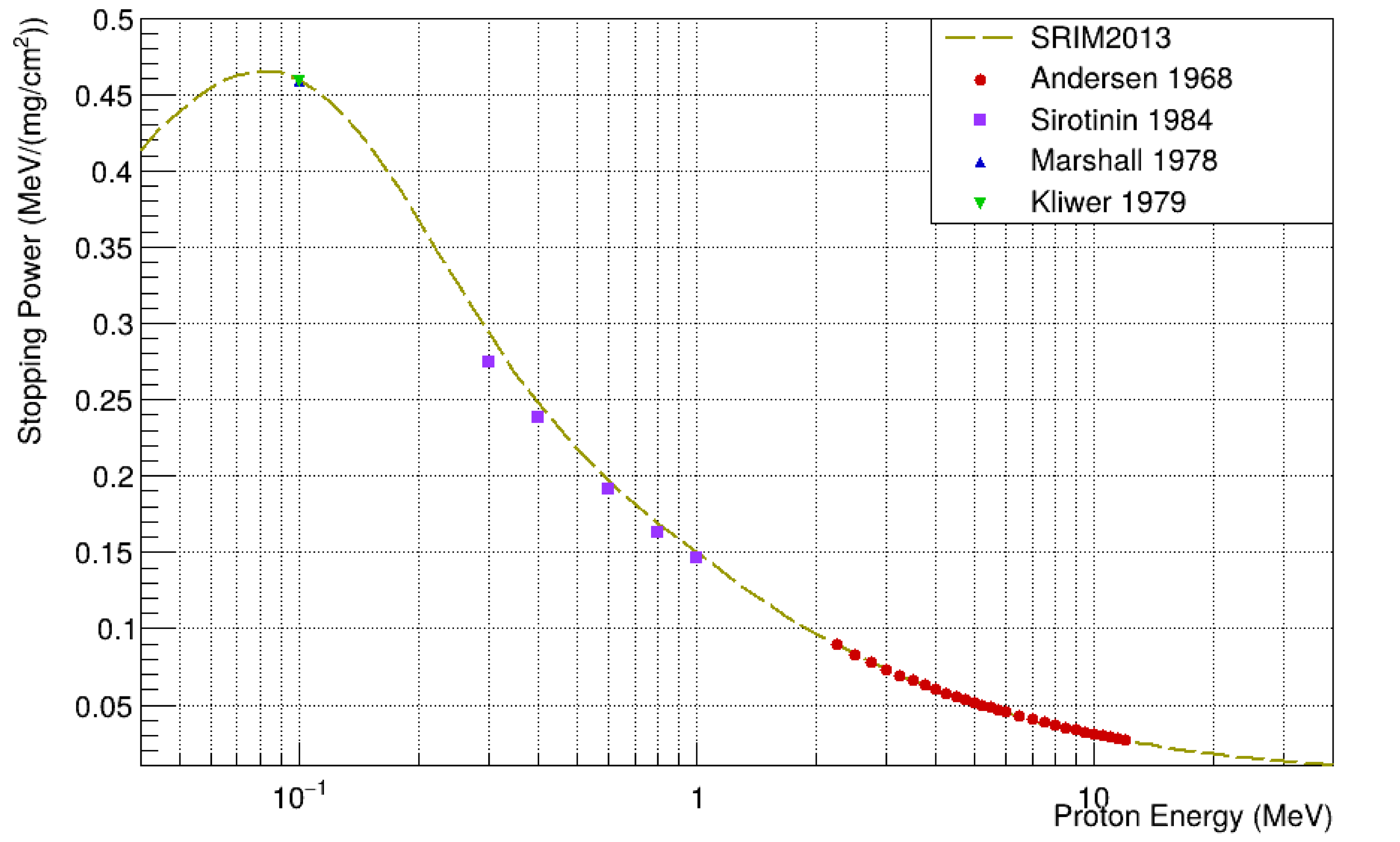
Production of ^{44}Ti

- The **^{45}Sc(p,2n)^{44}Ti** reaction provides the **highest cross section σ (~40 mb)** in an energy window (20-25 MeV) and is considered the **most efficient route**.
- **^{45}Sc(d,3n)^{44}Ti** requires higher energies (40-50 MeV) and gives lower σ (~20 mb).
- **^{44}Ca(α,4n)^{44}Ti** needs enriched targets and α beams >40 MeV, with σ below 20 mb (modelled).

	^{45}Sc(p,2n)^{44}Ti	^{45}Sc(d,3n)^{44}Ti	^{44}Ca(α,4n)^{44}Ti
Threshold	12.7 MeV	21 MeV	> 30 MeV
σ_{max}	40 mb	21 mb	≲ 20 mb
Optimal energy range	20-25 MeV	40-50 MeV	45-55 MeV

Stopping Power

Stopping power of protons in scandium determines their energy loss inside the target and thus defines the optimal scandium target thickness for efficient ^{44}Ti production.



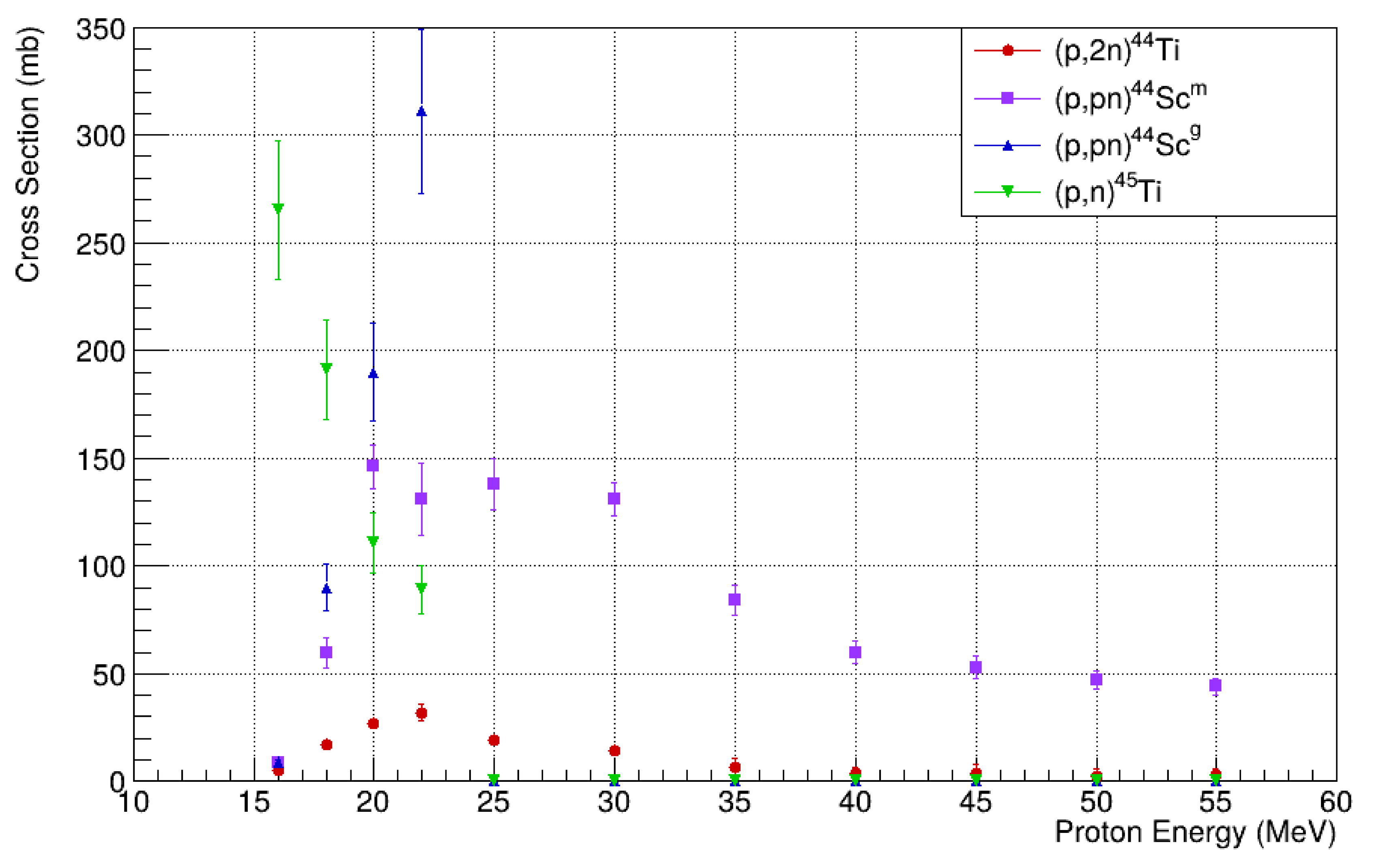
Target thickness can be estimated from SRIM stopping powers by integrating energy loss of protons in scandium. The calculation links the required ΔE to an equivalent material depth ($\rho_{Sc} = 2.99\ \mathrm{g/cm^2}$).

$$t_{mm} = \frac{10}{\rho}\int_{E_{out}}^{E_{in}} \frac{dE}{S_e(E)} \approx \frac{10}{\rho}\sum_i \frac{\Delta E_i}{S_e(E_i)}$$

ΔE (MeV)	t (mm)
2	~0.37
5	~0.84
7	~1.17
10	~1.67

^{45}Sc(p,x) excitation functions

Excitation functions for ^{45}Sc(p,x) show that the ^{45}Sc(p,2n)^{44}Ti channel peaks at ~20-25 MeV, providing the most efficient production window, while competing (p,pn) and (p,n) channels generate contaminant scandium and titanium isotopes.



Conclusions

The ^{45}Sc(p,2n)^{44}Ti reaction at **20-25 MeV** provides the most efficient ^{44}Ti production route. SRIM-based stopping power analysis defines optimal Sc target thickness of **~0.4-1.7 mm**. These results support practical design of ^{44}Ti/^{44}Sc generators for PET.

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