hochschule mannheim

SRIM and FLUKA Simulation for Target Design

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Why is good targetry relevant?

The number of cyclotrons for the production of radionuclides has increased steadily over the years.

Nevertheless, there is an increasing demand for radionuclides for

- diagnosis
- therapy and
- theragnostic pairs.

Many of these nuclides cannot be produced by the „medical" low energy cyclotrons.

They need to be produced in large quantities in central institutions.

Fundamental Activation Equation

$$A = \frac{m \cdot H \cdot N_A}{M_r} \cdot \; \sigma(E) \cdot \Phi \cdot \left(1 - \exp(-\lambda t_{irr})\right)$$

# of target atoms

reaction cross section

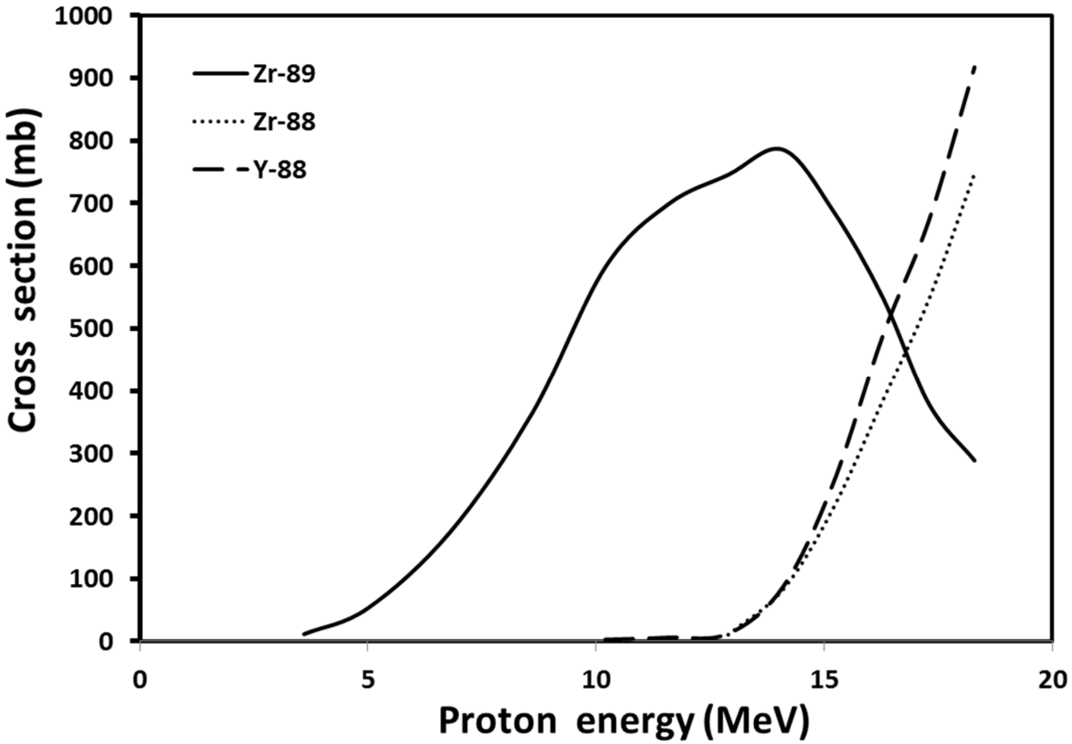
particle flux

saturation factor

- activity increases with **exponentially smaller increments.** Irradiations for up to 3 half-lives, only.
- cross section is energy-dependent, but constant for rxn.
- number of target atoms may be increased, but….
- particle flux is the only scalable parameter

Number of Target Atoms

The atomic stopping power reduces the projectile‘s energy.
Scanning over a region of the excitation function:



Adjusting Beam Energy by Degrader

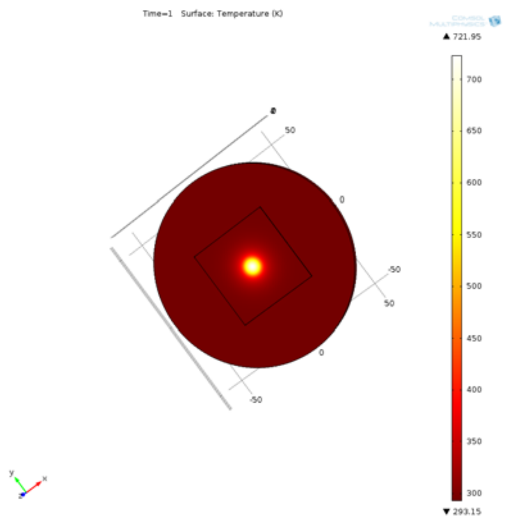
To match the required energy with that provided by the cyclotron a degrader foil is used

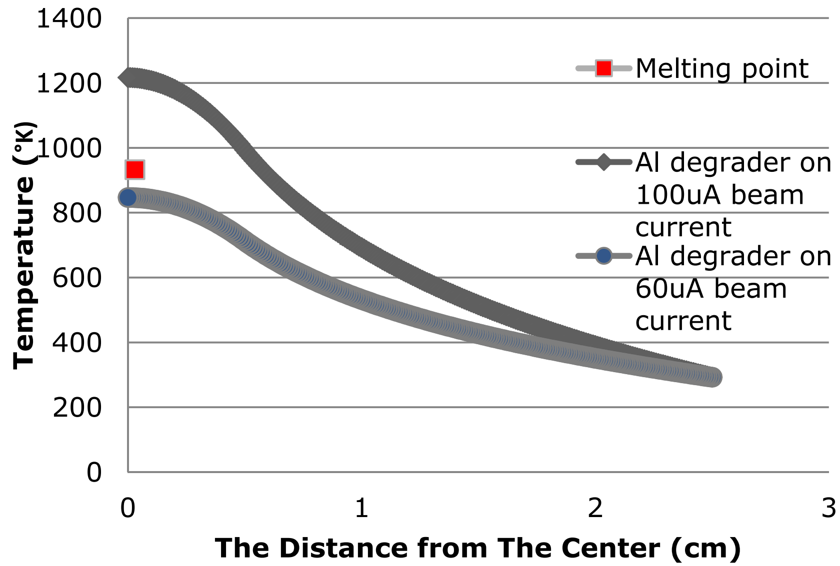
Problem: Heat Dissipation

Nuclear reactions are rare events so most energy is lost in degradation

5 MV * 100µA = 500 W

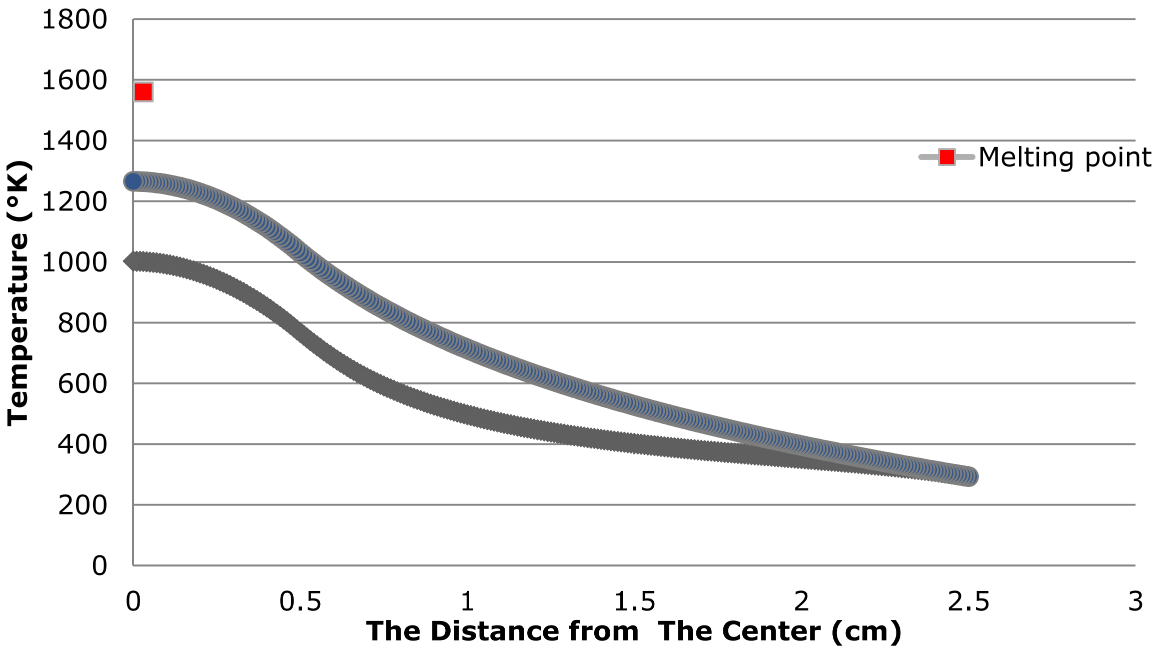
Focussed on a spot of a few cm^2





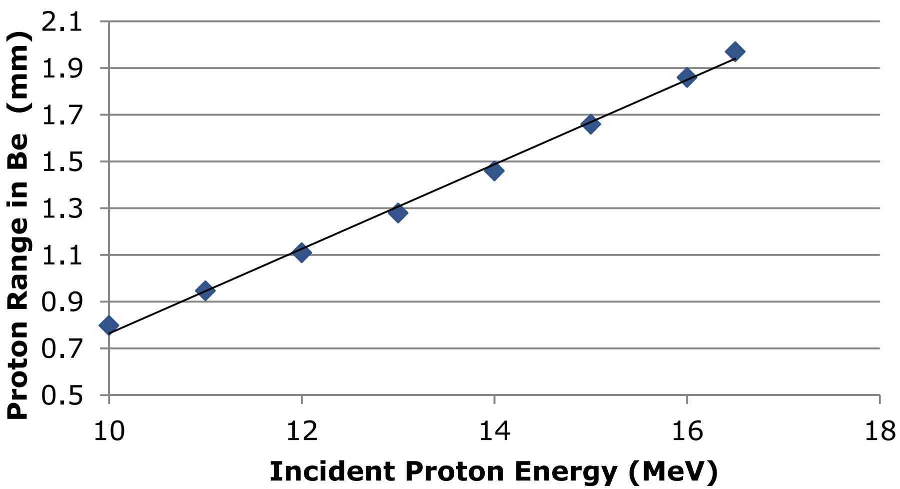
Degrader

Be is better suitable as degrader

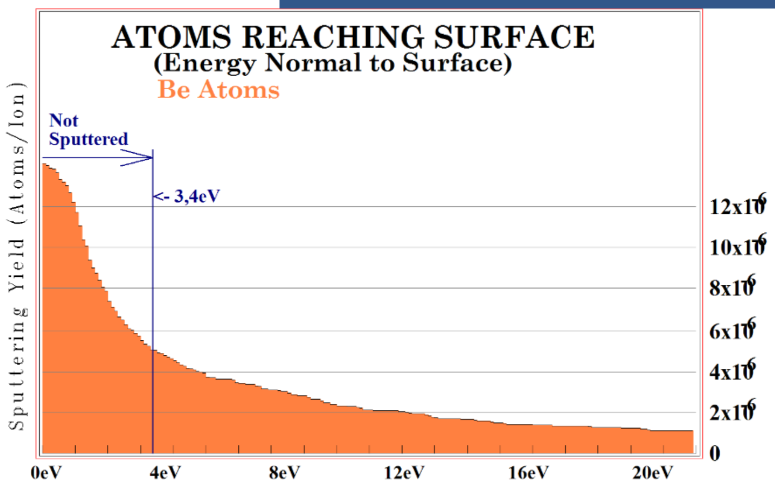


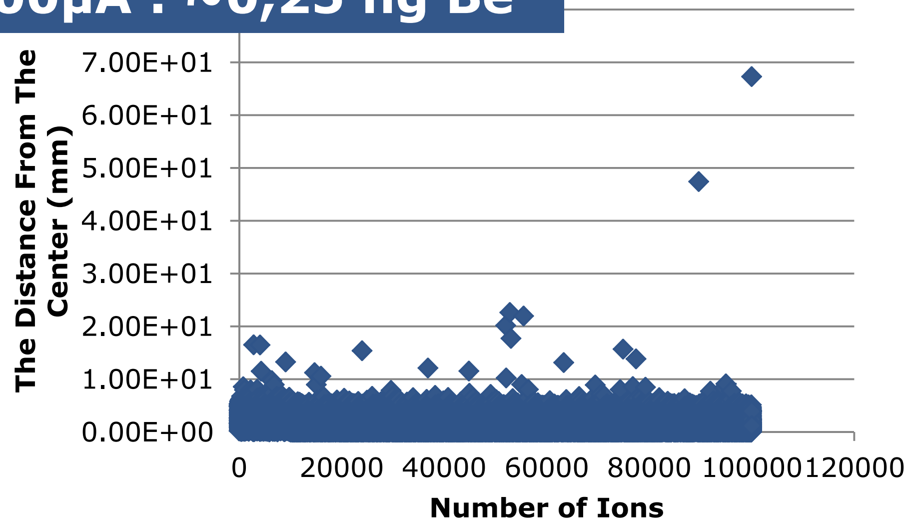
…but it is highly toxic

Degrader Development with SRIM



Loss during 1 h @ 100µA : ~0,25 ng Be





Target

The same issue also apply to targets
A large variety of materials is available:

- metal foils and powders
- oxides
- salts
- solutions
- gases

To predict the yield FLUKA is used.
Quality of the predictions?

Check by „predicting“ literature data.

Comparison of FLUKA with Literature

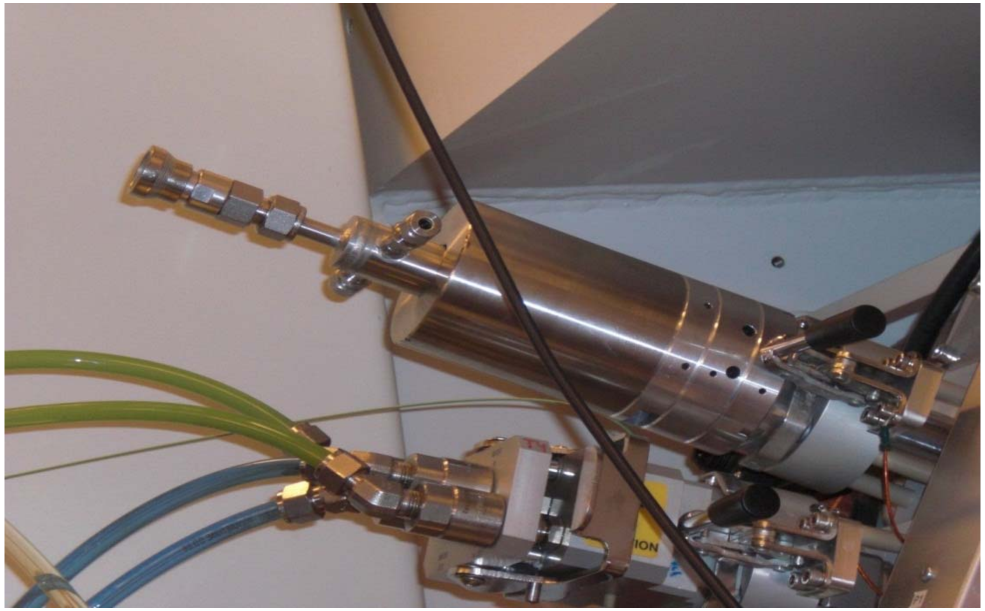
Compare literature data for $^{89}Y(p,n)^{89}Zr$ with FLUKA models

Source	Energy Range /MeV	Ratio Y_{SE}/Y_{exp}	
Wooten [1]	14.7 -> 8	1.00	Foil
Siikanen [2]	12.8 -> 4	1.04	Foil
Link [3]	10.7 -> 4	1.10	Foil
Infantino [4]	13 -> 10	2.6	Degraded from 17.4
Sadeghi [5]	15 ->	1.01	Oxide
Infantino [6]	12.6 ->	1.09	Foil
Queern [7]	12.5 ->	1.66	Degraded from 17.8
Yu Tang [8]	14 ->	0.68	Foil

Cooling Systems: Study with COMSOL

Behind the target the proton beam is stopped completely $\Rightarrow$ Good thermal contact between target and backing

Efficient cooling required to remove a few kW.

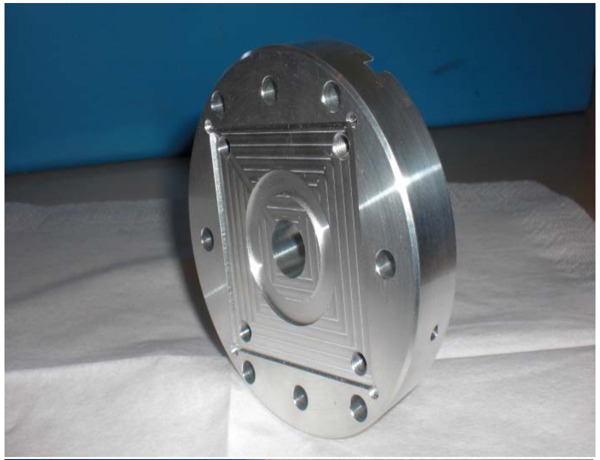


But there is more…

Technical Realisation

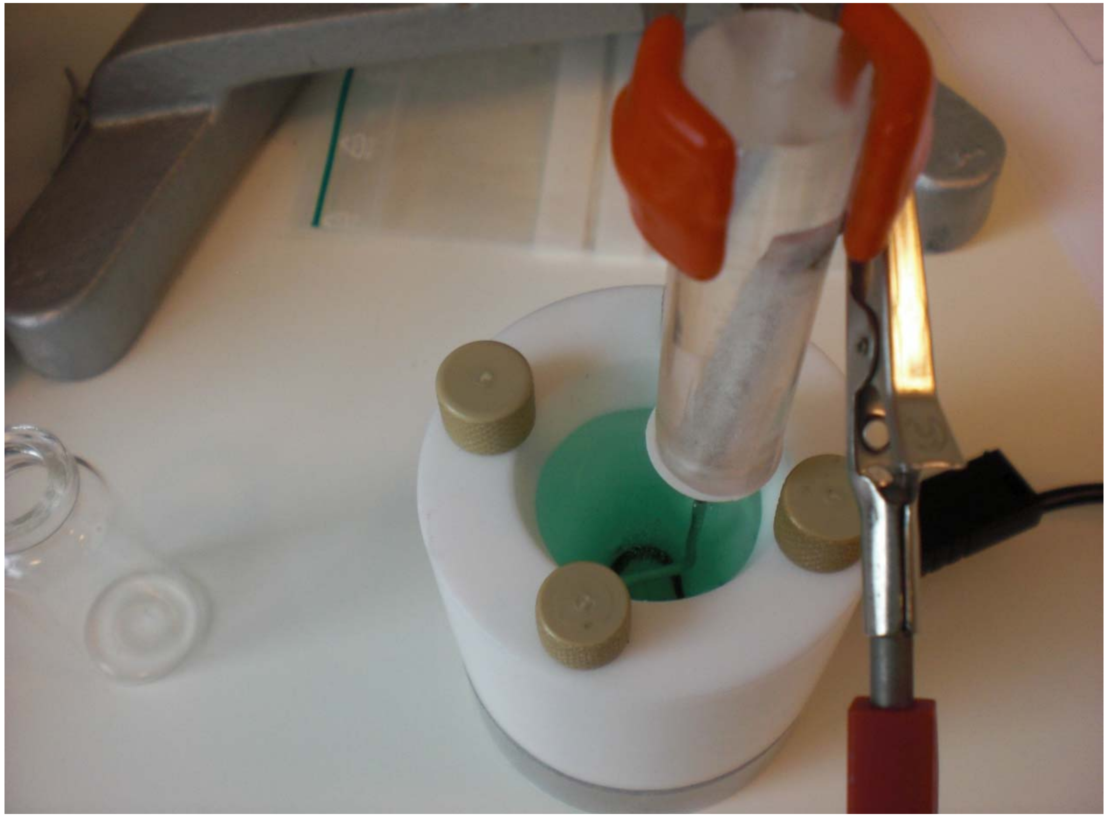
Vacuum flange

target changer



Electrolytic Deposition of Target Layer

Preparation of the target: electrolysis of Ni-solution (>95% enriched ^{64}Ni) on silver disc
3.2 V & 5-8 mA for 1- 4 days -> < 50 mg



Goal

All these (and more) aspects need to be considered on the way to achieve

High Performance Targetry

- high high beam currents (several 100 µA)
- high yields
- high radionuclidic purity
- good chemical behavior for labeling

Thank you for your attention !

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