Target studies for radioisotope production using FFAGs

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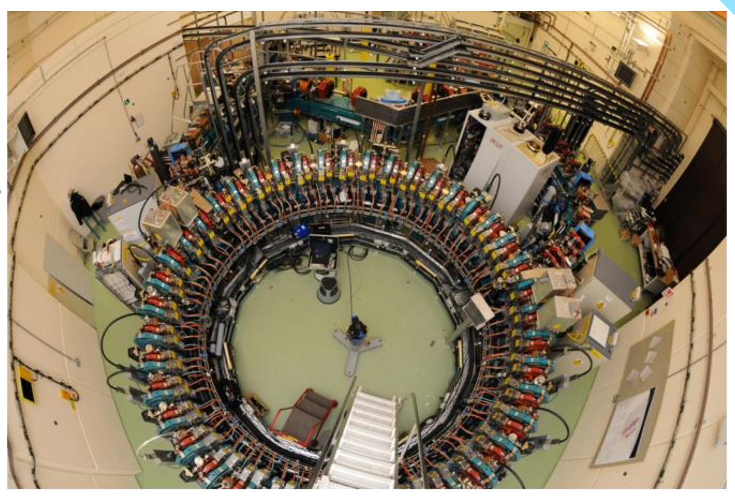
Introduction

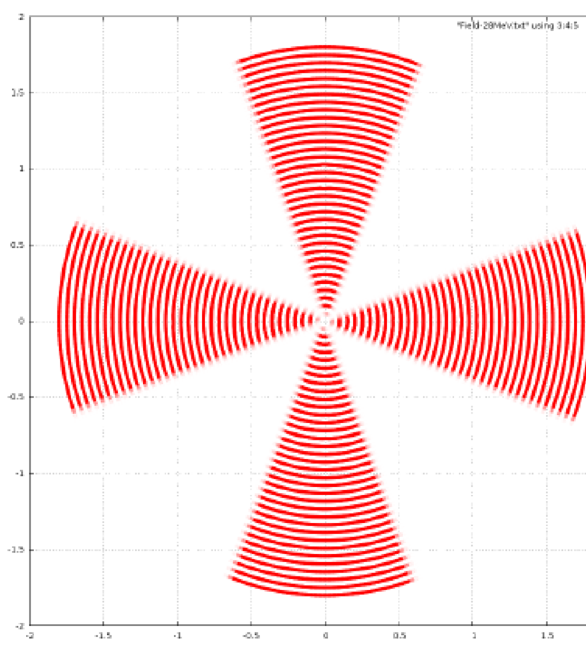
Radioisotopes have a wide array of applications in medicine and industry. For example in medicine radioisotopes can be used for imaging purposes (PET and SPECT), for the treatment of cancer in alpha therapy or for the sterilisation of medical equipment. Accelerator based production techniques can offer exciting possibilities in radioisotope production, especially in light of the ^{99m}Tc crisis, as has been identified by the UK STFC Healthcare Focus Group [1].
The construction of a 14 MeV fixed-field alternating gradient accelerator (FFAG) for the production of ^{99m}Tc is the main objective of this project. This builds on the success of EMMA and paves the way for a small, cheap, high current quick-to-build machine.
Target studies allow for efficient radionuclide production and is very important for accelerator design and construction. The positioning of the target (i.e. whether it is placed inside or outside the FFAG) will also affect the design (i.e. whether it is thick or thin). The optimisation in terms of target thickness and yield was performed with Talys, a software used for the simulation of nuclear reactions [2].



EMMA – the world's first non-scaling FFAG

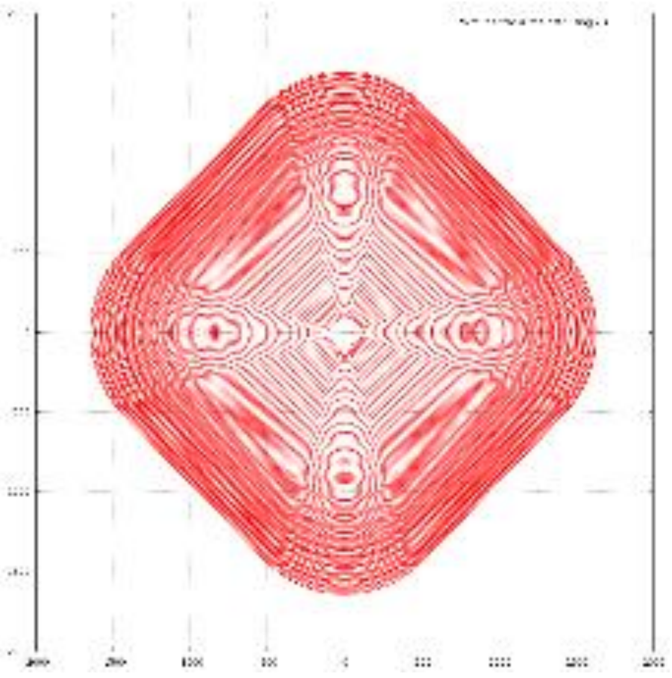
Initial design study

- Fixed magnetic field strengths
- Magnetic field strength map in the y direction for 28 MeV proton beam



Courtesy of D. Bruton

- Accelerate proton beams to more than 28 MeV with a fixed RF frequency
- Proton tracking in Opal: beam makes 28 MeV if RF ≥ 200 kv/turn
- Beam current capability of at least 2mA



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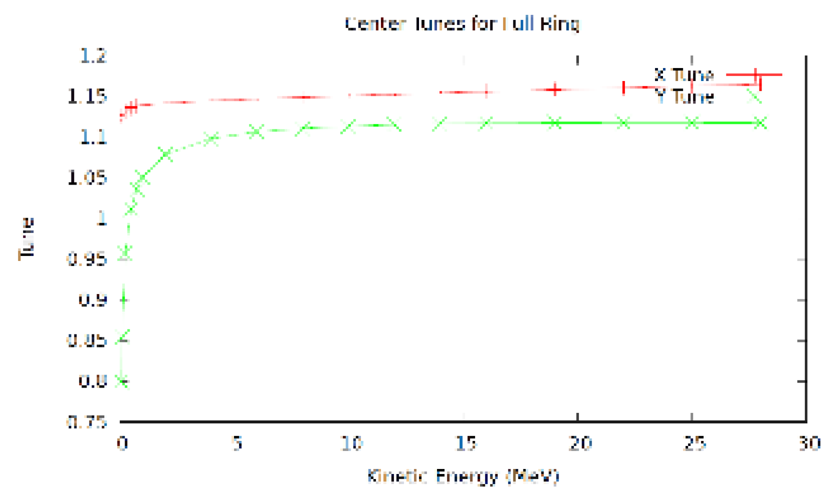
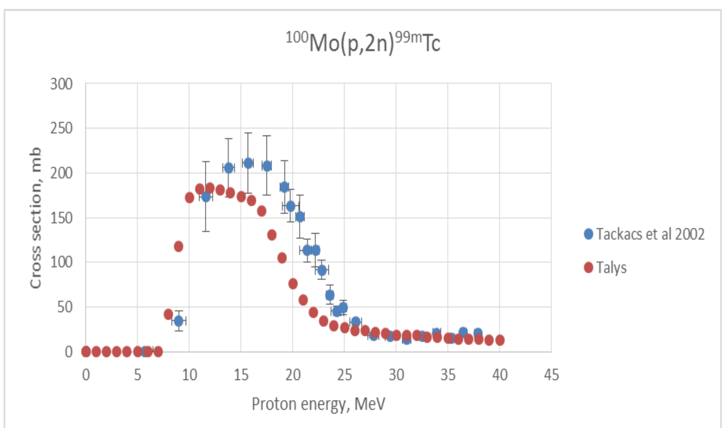


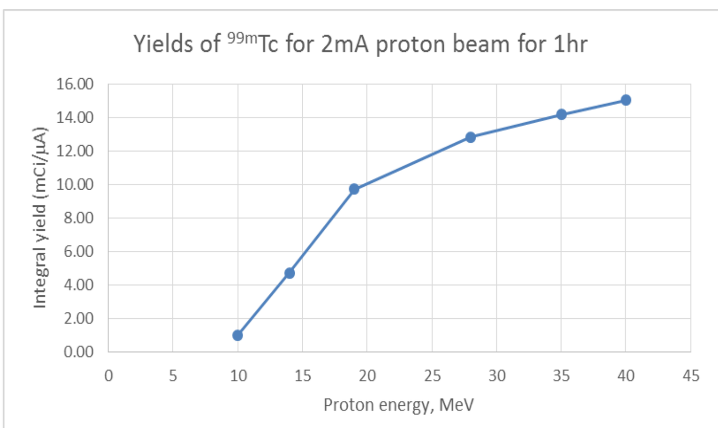
- Y tune goes through integer (i.e. 1)…an issue we are currently working on

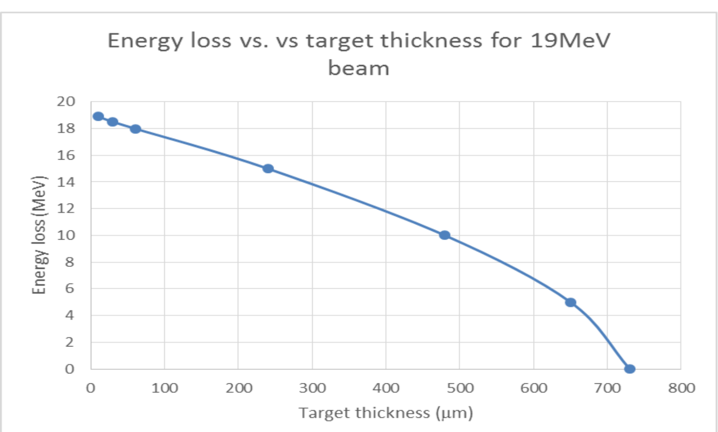
Production of radioisotopes – 2 examples

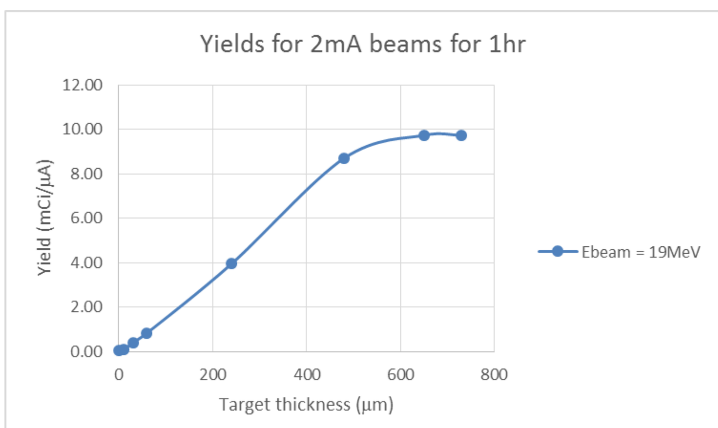
Technetium-99m

- Used as a radioactive tracer
- $T_{1/2}$ = 6 hrs
- CW operation to the 14/19 MeV required for ^{99m}Tc production.





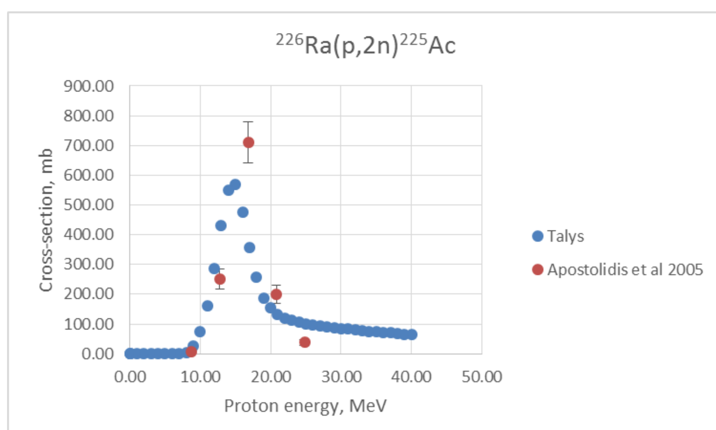


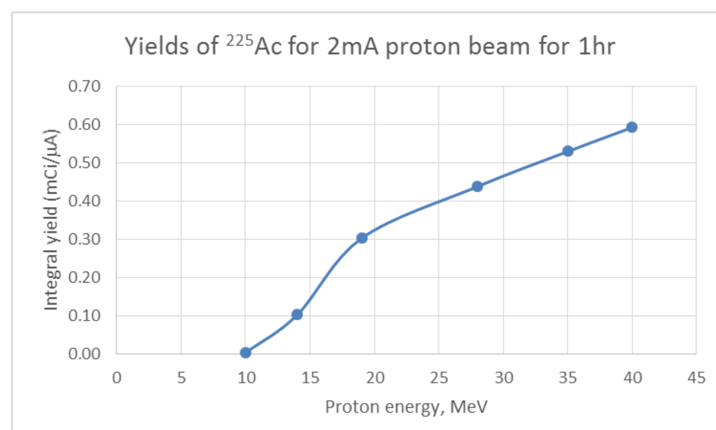


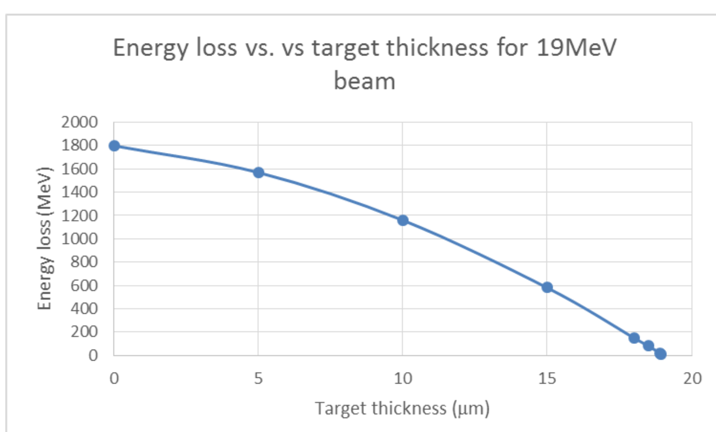
- For a 19MeV beam and a target of thickness 10 μm, the produced heat in the target would be 0.2 kW

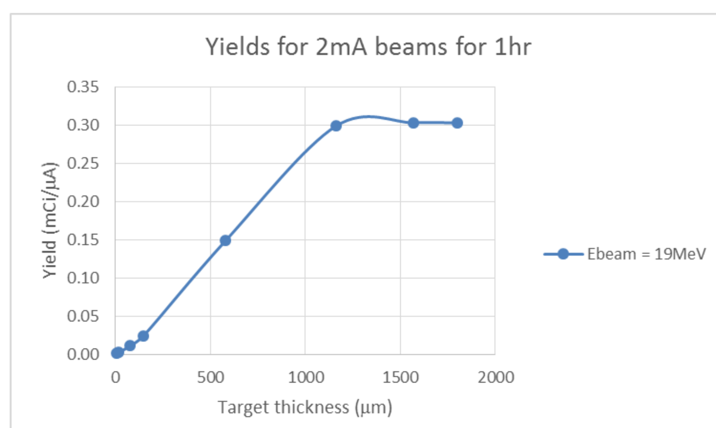
Actinium-225

- Used in radiotherapy
- Alpha emitter, has short range in soft tissue and is limited to only a few cell diameters
- For targeting micro-metastatic disease and single tumour cells









Target design options & future steps

Internal target

- Large acceptance means it's possible to use a thin internal target
- Recirculate the same beam many times through the target
- ERIT, FFAG at KEK achieved 1000 turns with an internal target
- 10 μm ^{100}Mo target needs 126 turns to produce the same yield as thick target
- Heating is approx. 50% less
- More turns reduces beam current requirement

External target

- Charge exchange extraction causes larger than ideal losses
- Does not work for α
- Separation between magnets in FFAG large
- Separation between last two orbits approx. 3mm

The future

- Need to study issues surrounding target cooling. Cooling of an internal target would be more difficult

The future cont'd

- Need to study beam extraction methods for external target and whether separation between orbits allows for extraction
- Need to study other radioisotopes e.g. Terbium and Astatine and obtain yield plots as a function of energy.

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[1] STFC CLASP Guidance Notes
[2] Koning, A., Hilaire, S., Goriely. S., Talys 1.6 User manual. 2013.
[3] Takács, S., et al. (2003). Evaluation of proton induced reactions on ^{100}Mo : New cross sections for production of ^{99m}Tc and ^{99}Mo, *Journal of Radioanalytical and Nuclear Chemistry, 257*(1), 195–201.
[4] Apostolidis, C., et al. (2005). Cyclotron production of Ac-225 for targeted alpha therapy. *Applied Radiation and Isotopes*, *62*(3), 383–7.