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Low Energy Medical Isotope Production

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Overview: Nuclear Medicine

- Cover the use of radioactive isotopes for diagnostic and therapy applications in medicine

- Scope of this presentation will be radio isotopes used for SPECT or PET imaging

- **SPECT** – Single Photon Emission Computed Tomography
  - *Uses a metastable γ-emitting isotope delivered to a specific region of interest.*
  - *Computer reconstruction of the recorded γ-rays to develop a map of the uptake area of the isotope.*

- **PET** – Positron Emission Tomography
  - *Same approach as SPECT only using a positron emitting isotope to produce secondary γ-rays which are detected for the reconstruction*

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Medical Isotope Crisis

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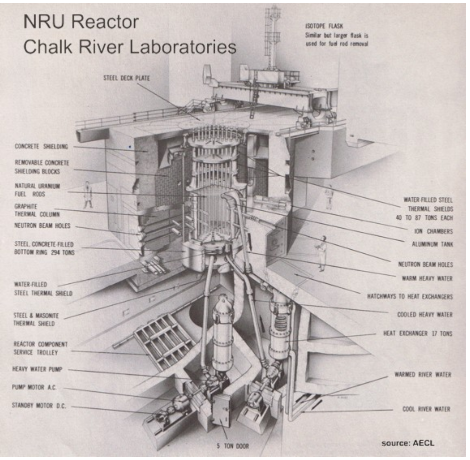
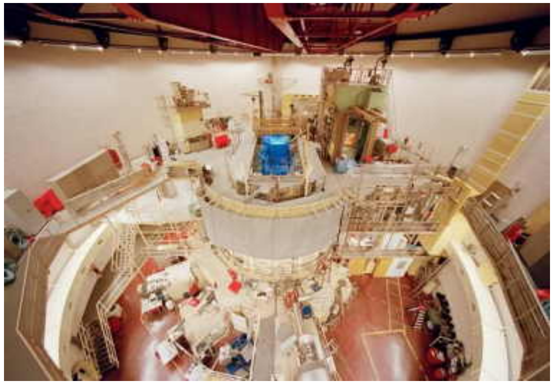
- 2010:
  - *long term shutdown of the principle isotope production reactors, Canadian NRU and Petten HFR*
  - *This caused a significant depletion in the ^{99m}Tc available for SPECT scans*
  - *~90% of procedures cancelled/postponed*

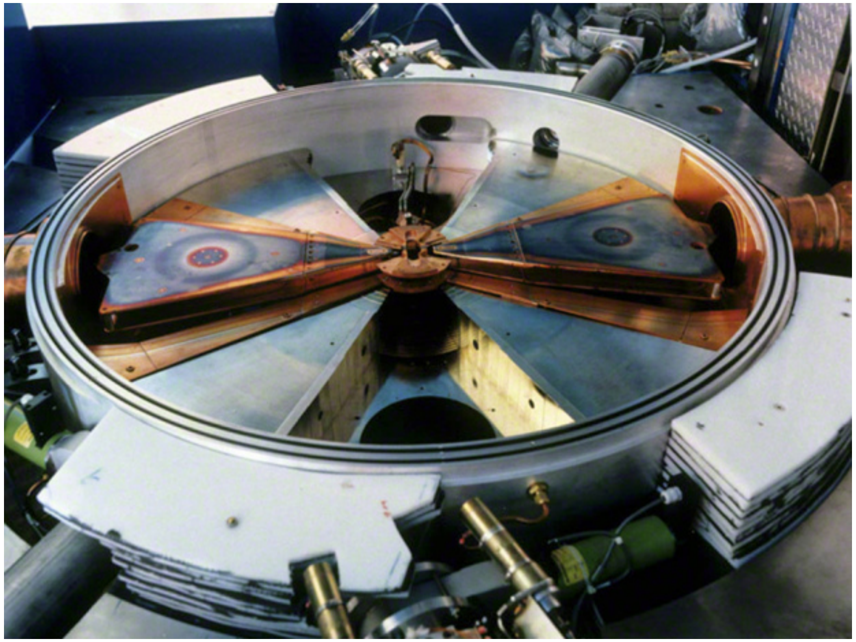


- These reactors are old and coming to the end of their life
  - *Shutdown 2016-2020.*
  - *There could be a similar world wide situation*



- As yet no wide scale plan in place to maintain isotope supply

Solutions



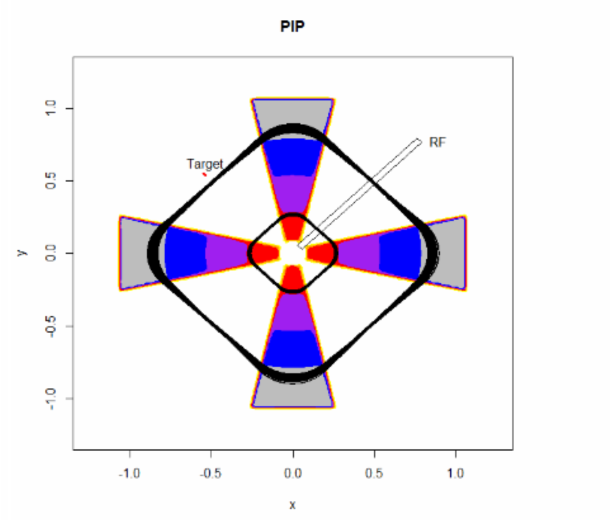
- Production of ^{99m}Tc is moving from reactor based systems to accelerator based routes
- Some of the initial development work has been performed by the Canadian associations TRIUMF and CLS
- CLS using electron linac
- TRIUMF using proton cyclotron ~20MeV
- We propose using a proton machine <10MeV to produce ^{99m}Tc and other replacement/supporting isotopes
- Low energy isotope production utilising the typically low threshold/high cross section (p,n) reaction while minimizing the contaminants produced

Low Energy Accelerators

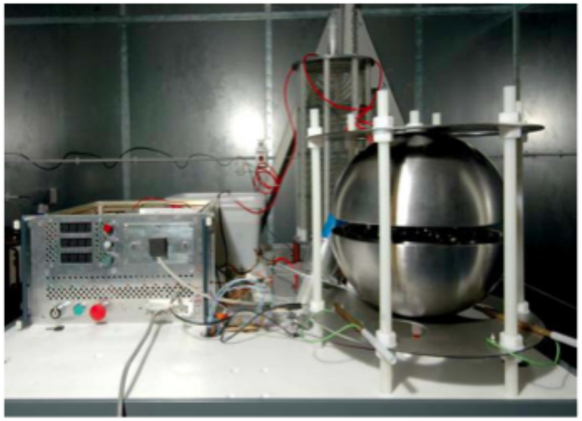
- Current medical cyclotrons >15MeV
- New machine requirements:
  - *<10MeV*
  - *CW/DC*
  - *high current*
  - *Small/compact*

- The size, lower potential backgrounds and simplicity lend these technologies to widespread use in hospitals getting the production of radioisotopes closer to point of delivery

1. ns-ffag – IIAA, Huddersfield



2.ONIAC – Siemens, RAL



Low Energy ^{99m}Tc Production

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- Several p and d driven reactions are available for both generator and direct production routes of ^{99m}Tc.
  - *However for the majority of these reactions the threshold is either too high or cross section too low to be viable.*

- There is one potentially promising reaction for low energy (<10MeV) ^{99m}Tc production

  ^{100}Mo (p,2n) ^{99m}Tc

- This is also the focus of the TRIUMF studies although at higher energies >20MeV

- Reaction cross section at <10MeV is low
  - *Implementation of a high current beam configuration could be used to increase the production rate*

An alternative to ^{99m}Tc:

^{113m}Indium

- Metastable isotope decays via 392keV γ-rays with half life 1.7hrs
- ^{99m}Tc replacement for brain and lung scans
- Currently produced mainly using the generator method:
  - *Parent isotope ^{113}Sn decaying into ^{113m}In*
- Using low energy methods there are two production routes available:
  - *Direct production via the reaction*

$$^{113}Cd\ (p,n)\ ^{113m}In$$

  - *Generator production via the reaction*

$$^{113}In\ (p,n)\ ^{113}Sn_{T1/2=118days} \rightarrow\ ^{113m}In$$

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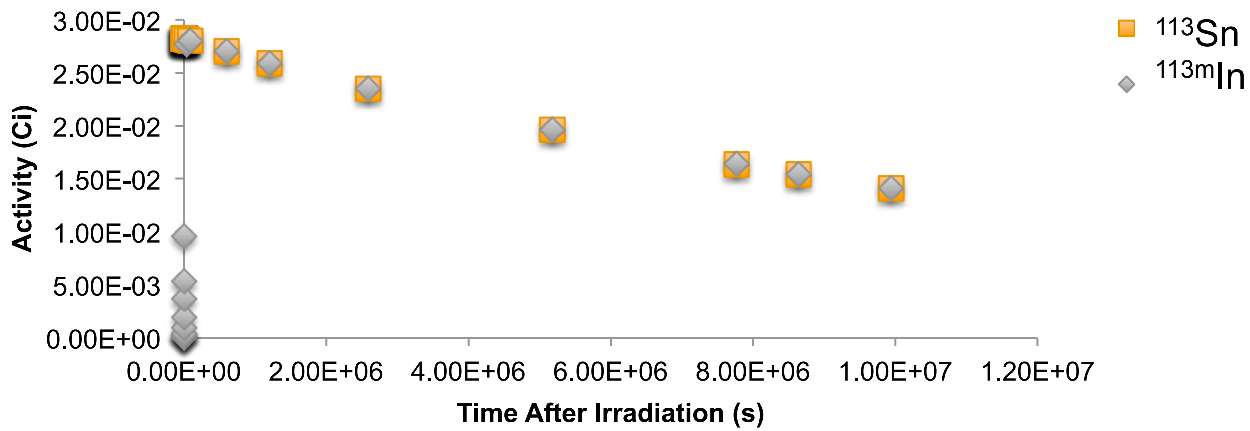
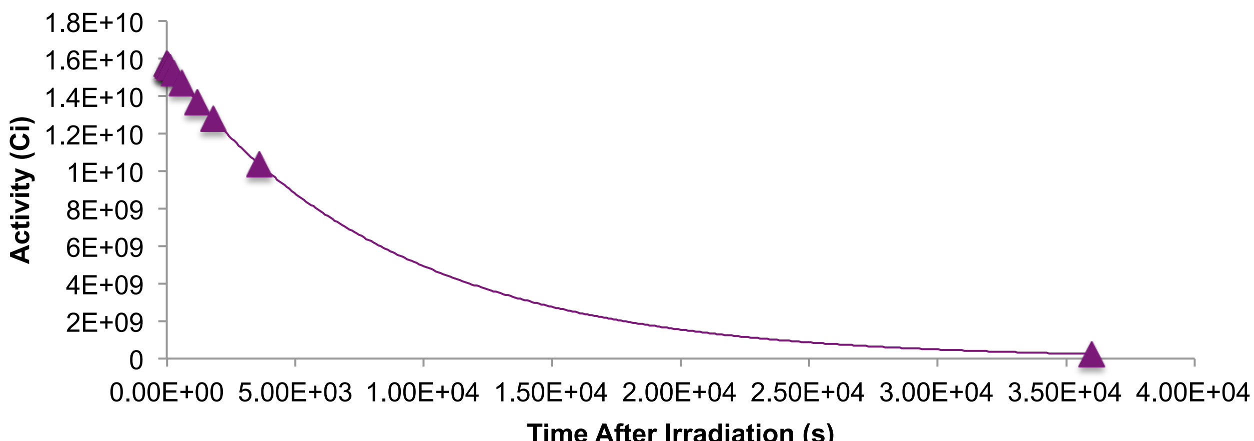
Simulation Activity

- Simulation results from a new GEANT4 model for low energy proton interactions to explore target designs and feasibility of low energy isotope production

Activity Generator production $^{113}In(p,n)$ ^{113}Sn-^{113m}In



Direct ^{113m}In production $^{113}Cd(p,n)^{113m}In$



^{87m}Strontium

- Metastable isotope decays via 388keV,γ-rays with half life 2.8hrs
- ^{87m}Sr is used in skeletal SPECT imaging for diagnosis of diseases such as osteoporosis
- Proton and α > 20 MeV currently used to make ^{87}Y, the ^{87m}Sr generator.
- Low energy production is possible for both direct and generator methods:
  - *Direct production*

$$^{87}\text{Rb (p,n) }^{87m}\text{Sr}$$

  - *Generator production*

$$^{87}\text{Sr (p,n) }^{87}\text{Y} \xrightarrow[T_{1/2}=79.8\text{hrs}]{} {}^{87m}\text{Sr}$$

Simulation Activity

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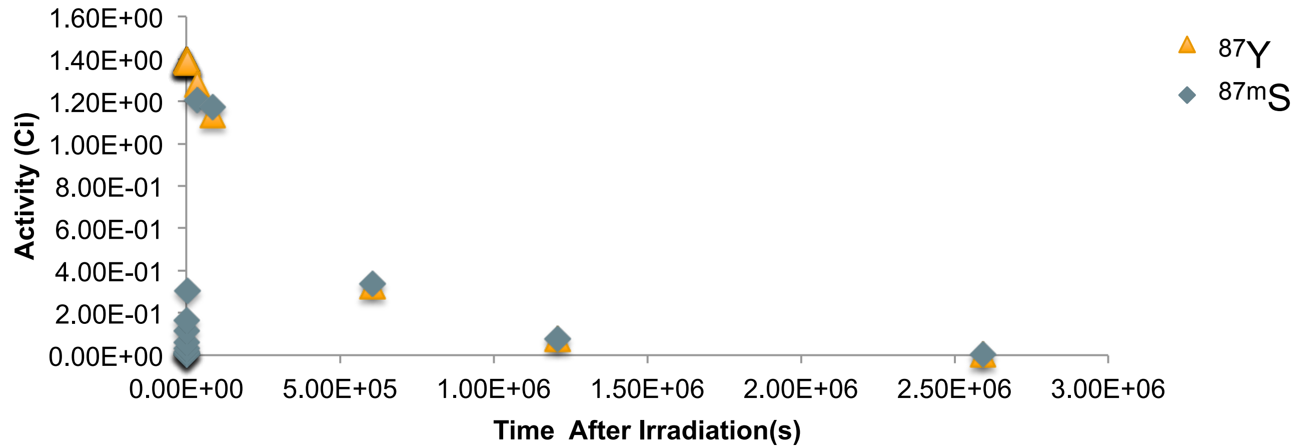
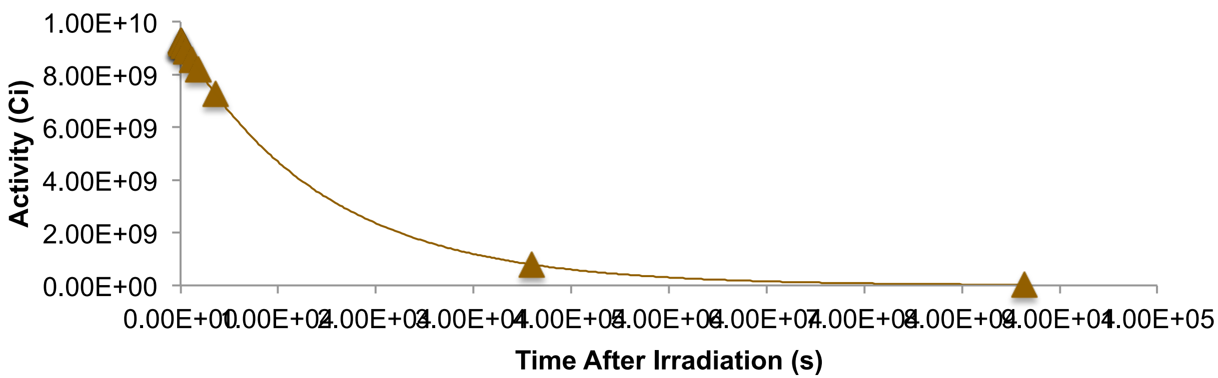
^{87m}Sr Generator Production $^{87}Sr(p,n)^{87}Y$-^{87}Sr



Direct ^{87m}Sr production $^{87}Rb(p,n)^{87m}Sr$



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Conclusions

- It is possible to produce ^{99m}Tc using a direct reaction using a proton driven reaction below 10MeV
  - *Yields obtained from such a reaction are low but could be offset by high currents*

- Direct proton production routes for the production of both ^{113m}In and ^{87m}Sr have been demonstrated
  - *These routes are possible at relatively low proton energies and that higher activities can be achieved.*
  - *This represents a significant advantage over conventional production methods*

- Results from this study have demonstrated the potential of low energy proton machines as a source for medical grade radioisotopes

Further proposed work

- Following on from this successful simulations study, further work will be carried out to:
  1. *Optimisation of these target designs for the potential of isotope production*
  2. *Initiate a broader investigation of as yet unused isotopes that may have the potential for use in either SPECT or PET imaging techniques*
  3. *Identification of the best methods of producing said isotopes*

Acknowledgements

University of Huddersfield
- Prof R. Cywinski
- Prof R. Barlow
- Prof R. Edgecock
- Dr C. & A. Bungau

Siemens
- Prof O Heid
- Prof P. Beasley

- Project funding EP- SRC/Siemens CASE studentship.