EUCARD2/WP4:Applications
Medium Energy Accelerators/Accelerators for Medicine
Introduction

Hywel Owen

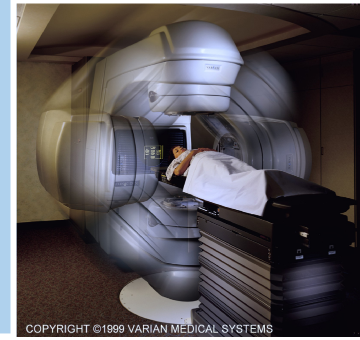
School of Physics and Astronomy, University of Manchester

&

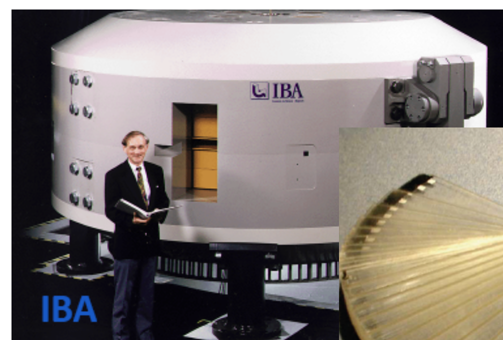
Cockcroft Institute for Accelerator Science and Technology

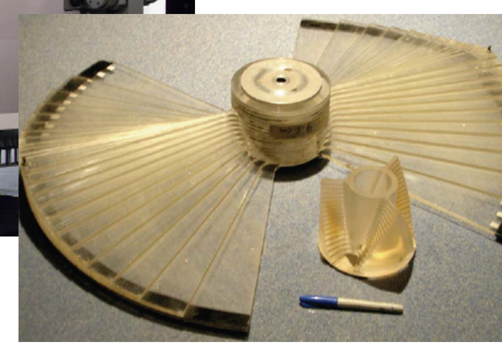
Area	Application	Beam	Energy	Number
Healthcare	Radiotherapy for cancer	X-ray Proton Carbon Neutron	<20 MeV 250 MeV 4800 MeV keV	>7500 32 4 UD
	PET isotopes and radioactive tracers	Proton	<100 MeV	>200
Energy production	Safer reactors & waste transmutation	Proton	~1 GeV	1 UD
	Fusion	Ions	Various	UD
Environment	Pollutants from chimneys	Electrons	0.8 MeV	UD
	Water treatment	Electrons	5 MeV	
Industrial	Cross-linking materials Medical sterilization Bio-fuels from non-edible starch	Electron Electron Electron	<10 MeV <10 MeV 1 MeV	1700
	Ion implantation	Ions	0.5 MeV	10000
	Elemental analysis	Ions	~1 MeV	100
Security	Cargo screening	Neutrons	<10 MeV	UD
		Protons	< 10 GeV	UD
		X-rays	MeV	UD
		Muons	~1 GeV	UD
Neutron spallation	Materials through interactions with nuclei	Protons	<2 GeV	5
Light sources	Materials through electron interactions	Electrons	Few GeV	60

Radiotherapy Statistics for UK

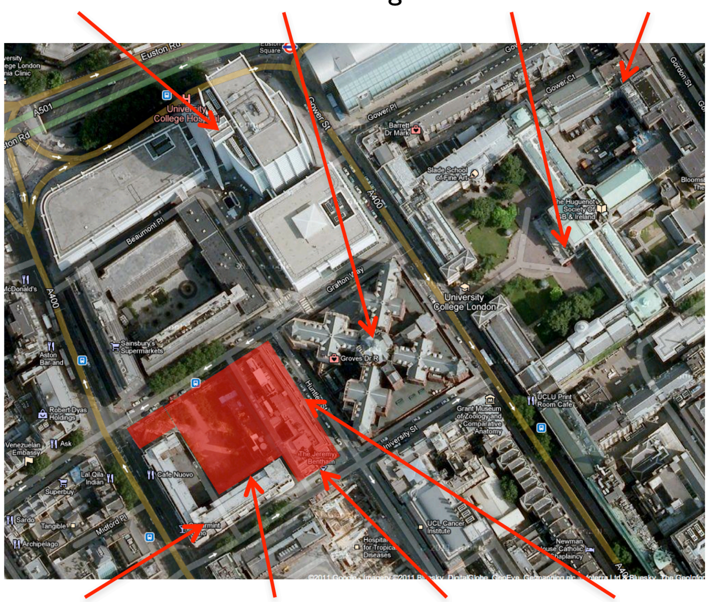


- 'Radiotherapy Services in England 2012', DoH
  - 130,000 treatments, most common age around 60 yrs
  - 2.5 million attendances
  - More than half of attendances are breast/prostate
- X-rays
  - 265 linacs in clinical use
  - Almost all machines IMRT-enabled, 50% IGRT (Image-Guided)
  - Each machine does >7000 'attendances'
  - 147 more linacs required due to increasing demand
- Protons
  - 1 centre (Clatterbridge)
- Cancer care
  - 40% curative treatments utilise radiotherapy
  - 16% cured by radiotherapy alone





Proton Therapy Siting



- The primary focus in the UK: development of proton therapy accelerators
- 2 New UK Centres for Proton Therapy
  - Christie Hospital (Manchester)
  - UCL Hospital (London)
  - Choice made on basis of oncology expertise, critical size, and location cf. patient load
    'The facility should go where the patients are and where the clinical strength is' – Stuart Green, UHB

Compressed sites + throughput + cost = compact gantries, low cost machines

Some provocative statements

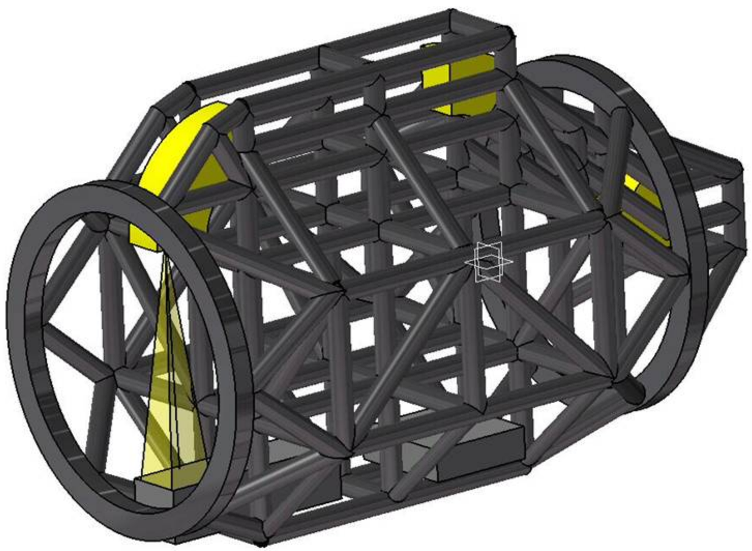
- Much applied accelerator technology is old, therefore unexciting
  - We should not work in established technology, e.g. linacs
  - We should work on either:
  - Near-term big improvements to emerging technology
    - e.g. better proton/carbon machines, e.g. FFAGs, RCS
  - Longer-term technology shifts
    - E.g. plasma, dielectric, metamaterials
- New entrants to market must provide product which is significantly better, not just equally capable
  - Size matters!!!
- Industry is more concerned at providing equipment with lower cost (including for example, rather than with greater capability, unless customer demands it
  - Example: proton therapy
- Networking seen as very important in catalysing technology transfer

My view of priority areas where we can contribute

- Monte Carlo e.g. GEANT4
  - Coupling to beam transport, BDSIM
  - Faster calculations
  - Better nuclear models
  - Better beam models in treatment planning
- Imaging technologies/diagnostics
  - Proton tomography
  - Secondary particle imaging
  - Use of silicon detector tech.
- Gantry design
  - Superconducting dipoles
  - FFAG gantries
  - Spot scanning
  - Test stand?
- Rapid-varying energy (size crucial)
  - FFAG
  - Rapid-cycling synchrotron
  - Cyclinac
- Compact technologies
  - Dielectric wall accelerators
  - Metamaterials
  - Plasma
  - Gradient is crucial
- Radiobiology
  - European facility essential
- Use of other particles
  - Helium?

Some SC Gantry Pictures

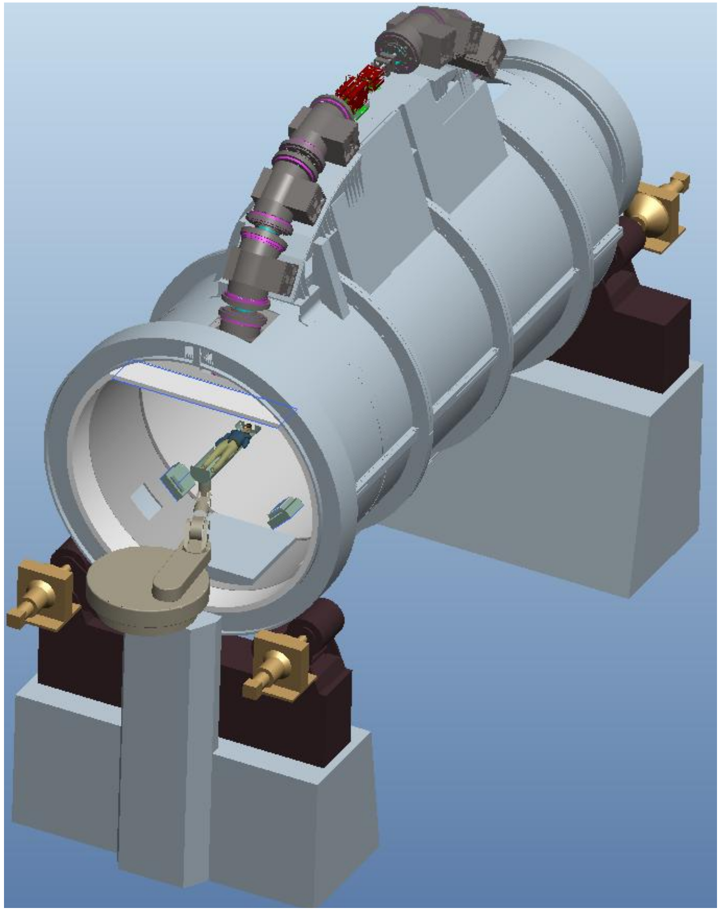
(both Pavlovic optics)



CEA/IBA
3.3 T for 425 MeV/u
150 t structure
210 t total

13.5 m x 4 m

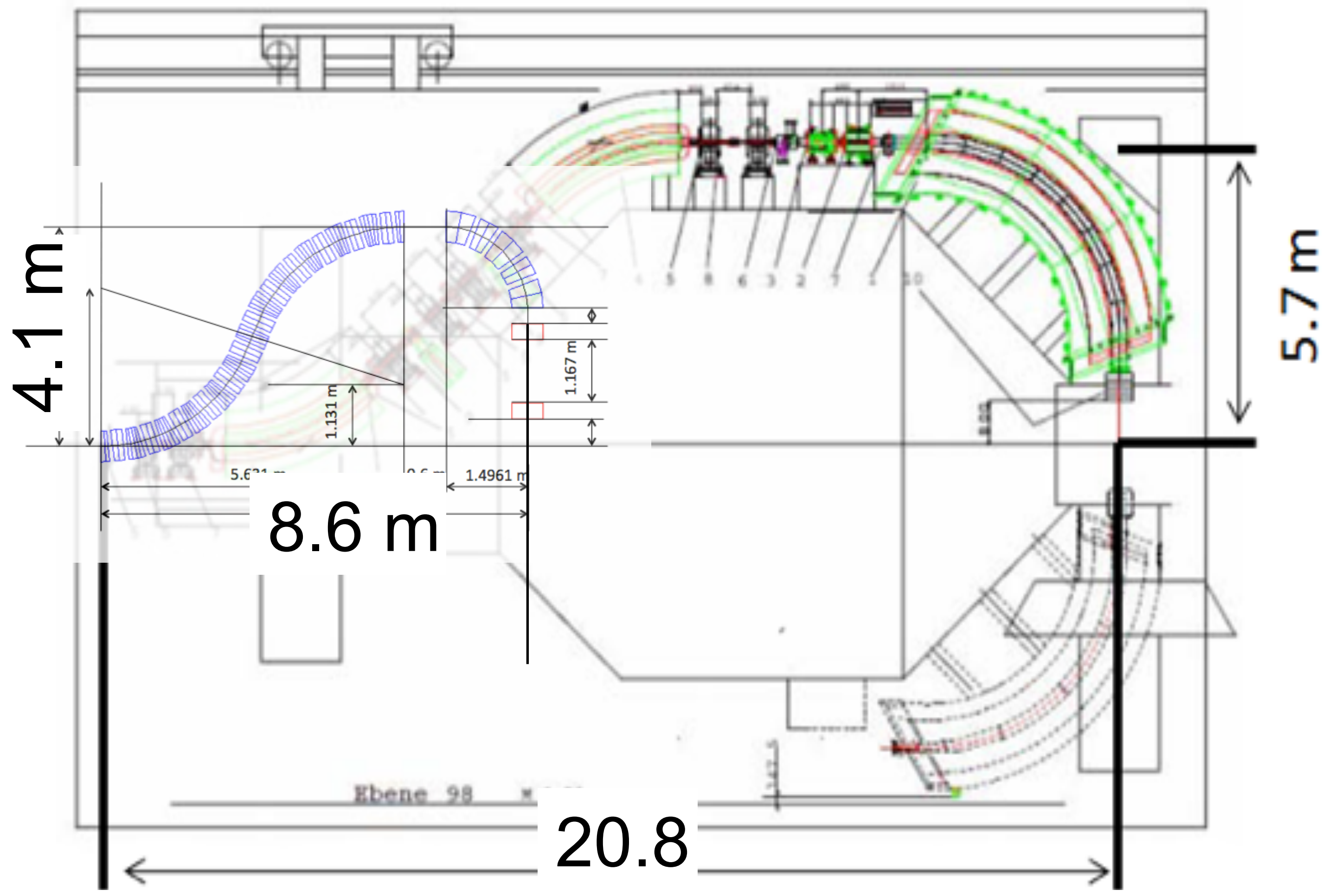
1mm deformation
1cm isocentre stability



NIRS (Japan)
3.0 T for 430 MeV/u
200 t total

13 m x 5.5 m

FFAG Gantries (Trbojevic, BNL)

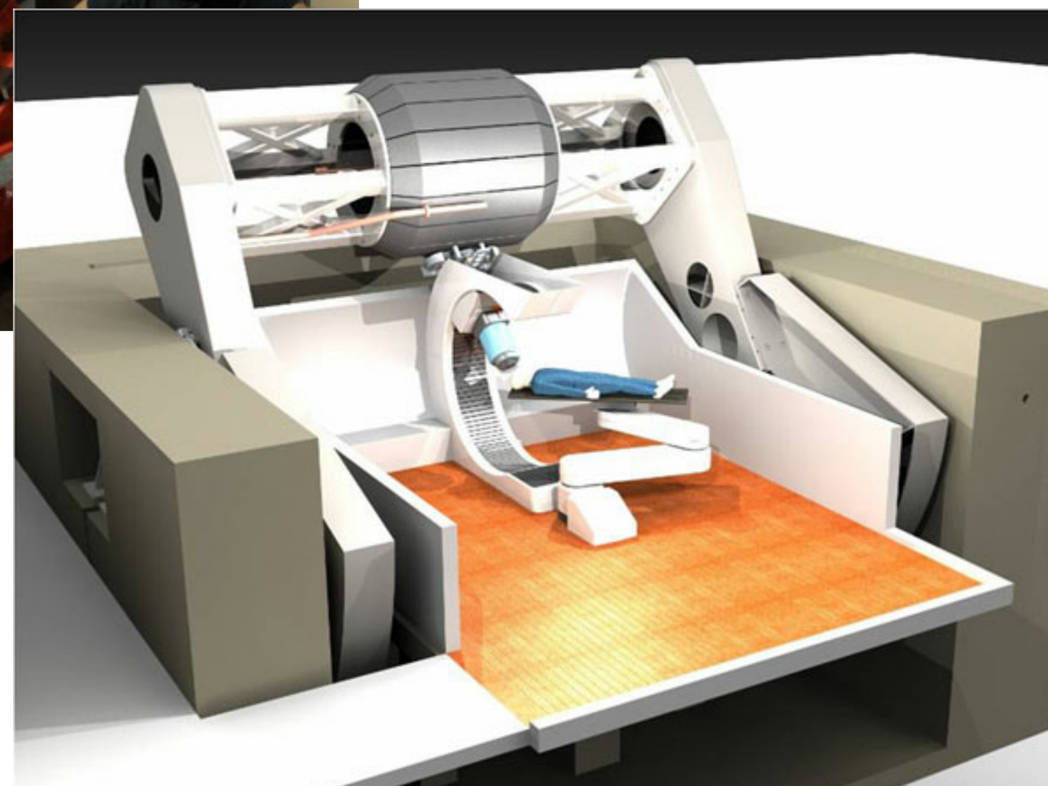


Carbon E_k=400 MeV/u → Bρ = 6.35 Tm ($\theta = Bl/B\rho$)

Warm iron magnets: B=1.6 T then ρ ~ 4.0 m

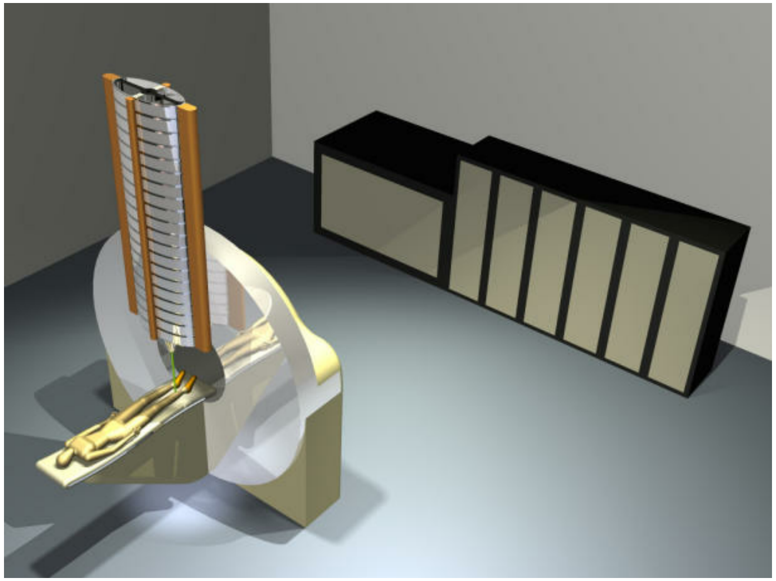
Superconducting magnets B=3.2 T then ρ ~ 2.0 m

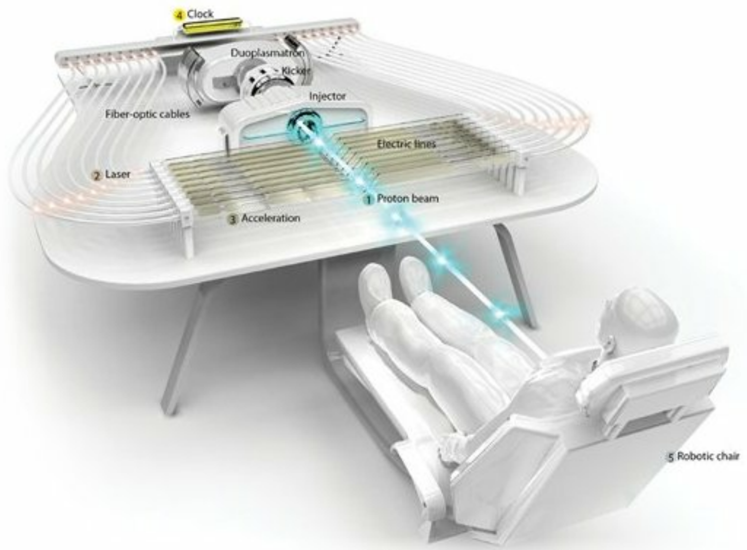
Put the cyclotron on the gantry?

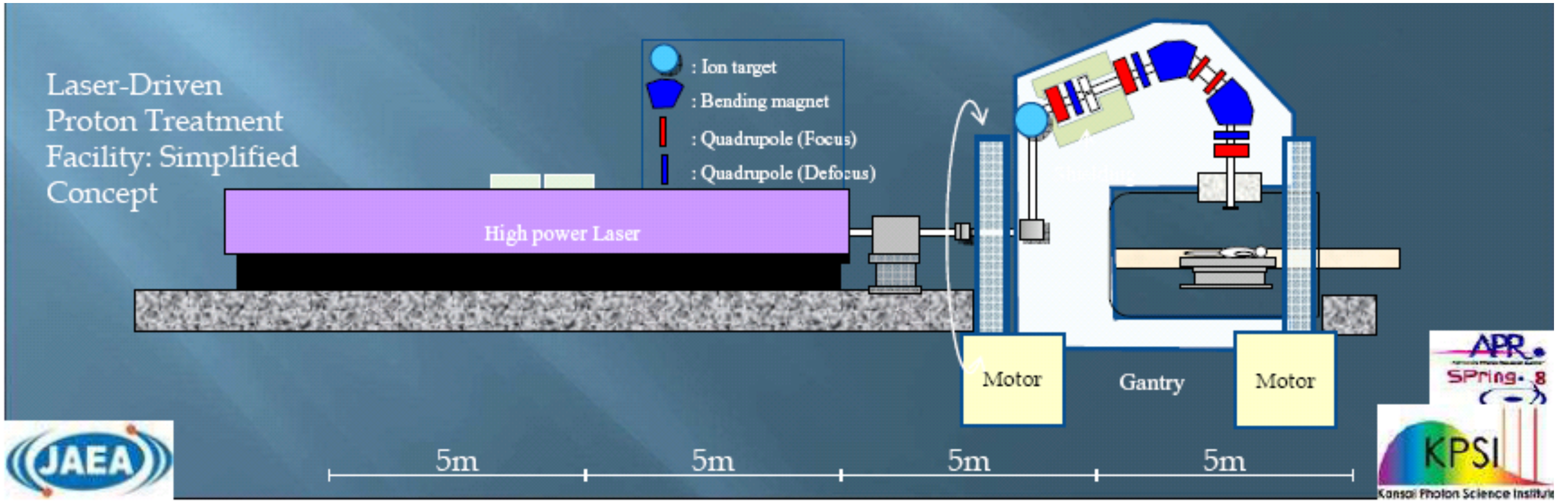


The required size of new technology

Gradient + quality + clean







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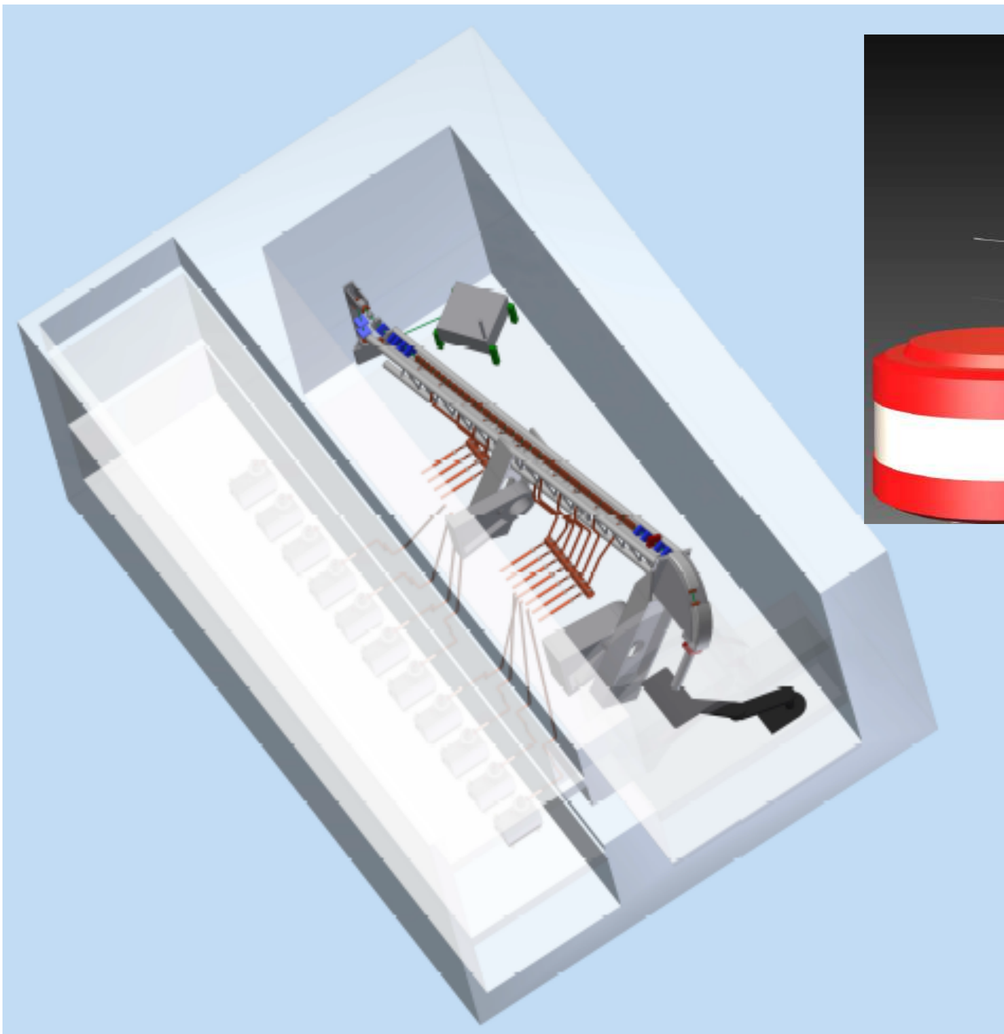

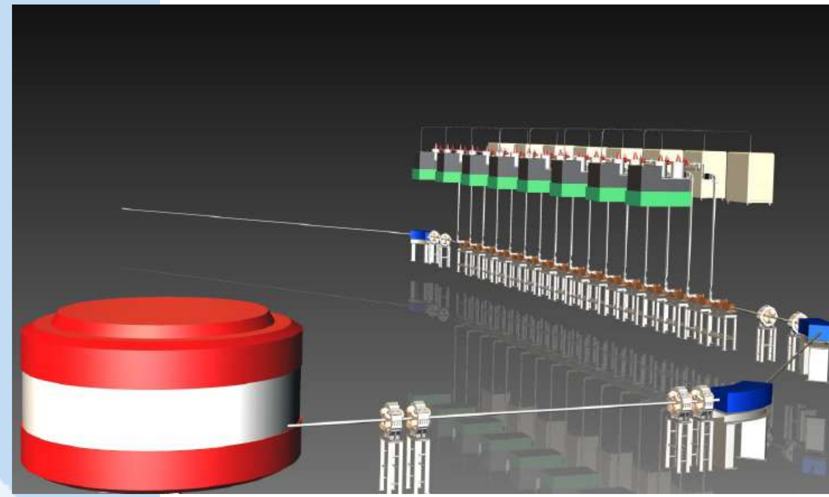

Radioisotope Production – 1 Page Summary

- Can divide isotope needs into 4 groups:

1. Technetium-99m (SPECT)
   - Reactor-based supply (235U(n,f))
   - Ongoing supply threat
   - New European reactor best option, but expensive
   - Accelerator-based methods possible, but limited activity
   - Use of FETS/other test stands? (Direct 100Mo(p,2n)
   - Use of Laser-proton acceleration
   - Electron linacs? (100Mo(g,n)

- 2x STFC/CI workshops held, 2011 and 2012
- National UK isotope working group established
  - Reviewing options
  - No central facility development, commercial only!

2. Conventional PET/SPECT isotopes (18F, 82Rb, I-123, 201Tl, 111In)
   - Currently met by domestic cyclotrons (c. 18 MeV)
   - Some interest in compact cyclotrons (c. 9 MeV) (STFC workshop)
   - Perhaps development of compact FFAGs?

3. Brachytherapy/radionuclidic therapy isotopes
   - I-131, Ir-192, Pd-103 from cyclotrons
   - Lots of research/clinical interest in alpha-only emitters
     - e.g. Radium-223 Chloride
   - Relatively unexplored by accelerator community

4. Exotic imaging/therapy isotopes
   - 61Cu, 62Cu, Tc94m, Mn52m, In110, etc.
   - Number of isotopes already sold, e.g. AAA spinout from CERN/Rubbia