Understanding Proton Beam Therapy

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Outline

• Proton Therapy why now?
• Science underpinning protons
• What we did at Surrey
• What are doing in Manchester
So what is proton beam therapy
What is the most effective cure for cancer?

Patients cured by the major cancer treatment modalities

- Radiotherapy: 40%
- Surgery: 49%
- Chemotherapy: 11%
  - alone
  - with surgery
  - with radiotherapy

Reference
Cancer Services Collaborative 2002
www.nhs.uk/npat
Radiotherapy wish list

- Conform radiation to tumour
- Maximum damage to tumour
- Minimum damage to surrounding healthy tissue
The Bragg Peak

![Bragg Peak Diagram]

*Effective Relative Dose* for different types of radiation (Photon, Carbon, Protons). The diagram shows the depth in tissue (cm) with prescribed dose in tumor, indicating the Bragg peak effect.
Advances in Radiotherapy

- Development constrained by
  - Imaging
  - Computing

- Full potential only realised from ≈ 1990s
- Since then things have advanced very rapidly
Advances in Imaging

1970s  1980s  2003  2010
Interaction of radiation with cells

Consequences for the cell:

- **repair**
- **viable cell**
- **mis-repair**
- **not repaired**
- **cancer**
- **mutation**
- **cell death**
Proton/ Hadron therapy

- Understanding how ion beams interact with living cells
- Through direct interaction with DNA
- Non targeted effects
Measuring radiobiological effect

• So how do we study the effects of radiation on biological systems

• Typically, radiobiological effect is measured by irradiating and analysing cell populations.
**Rationale for broadfield and microbeams**

**Average** of one particle per cell

- ‘Broad-field’ irradiation
- Microbeam irradiation

**Exactly** one particle per cell

- For charged particles, delivering an average of one particle per cell
  - ≡ 37% receive no particles,
  - ≡ 37% receive 1 particle
  - ≡ 26% >1
Applications of Microbeams

Every cell

Single cell

Sub-cellular region
What do we need to build a microbeam?

- Biological model system
- Microscopy imaging system
- Beam Line
- Accelerator
- Software

PATIENCE

PEOPLE

MONEY

And.......
And a building to house it
We need to see what we are irradiating

- Detector
- Microscope/detector
- CCD camera
- Stage
- Computer control
- Particle microbeam
- Shutter
- Cell finding
- Cell positioning

(Flowchart showing the connection between the components.)
OPTICAL DETECTION END-STATION

- environment control
- objectives
- wide throat stage
- focus
- widefield trans-illumination
- beam focusing and scanning
What can we use it for?

- Radiation and cytotoxic drugs or nanoparticles
- Non-targetted effects
- Genomics & sub-cellular targeting
- Environmental control
- DNA repair kinetics
- Modelling effects of radiotherapy
PBT Centre: Designated Research Space
Proton Therapy in Manchester

Proton Therapy

Christie

University

Manchester Cancer Research Centre
Proton Therapy Research Pipeline

- Basic Research
- Pre-clinical Research
- Translational Research
- Clinical trials
- Patient Benefit

Underlying basic research; physics, biology, chemistry
Proton Therapy Research Pipeline

- **Basic research**
- **Pre-clinical research**
- **Translational research**
- **Clinical Trials**
- **Patient benefit**

Application of basic research to address PBT research questions
Proton Therapy Research Pipeline

- Basic Research
- Pre-clinical Research
- Translational Research
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Application of basic and preclinical research to address real clinical issues
Proton Therapy Research Pipeline

- Basic Research
- Pre-clinical research
- Translational research
- Clinical trials
- Patient benefit
Proton Therapy Research Pipeline

- **Basic research**
  - Underlying basic research; physics, biology, chemistry (TRL 1-2)
- **Pre-clinical research**
  - Application of basic research to address PBT research questions (TRL 2-4)
- **Translational research**
  - Application of basic and preclinical research to address real clinical issues (TRL 4-6)
- **Clinical trials**
  - Clinical trials (TRL 5-9)
- **Patient benefit**
  - Patient benefit and quality of life
Research

Clinical trials

Proton therapy

In Manchester

Pre-clinical radiobiology
Pre-clinical radiotherapy
Clinical trials
Translational technical radiotherapy
Clinical Oncology and translational research
Translational radiobiology
Data analysis, big data, data theragnostics
Multi-scale Mathematical modelling

The Christie NHS Foundation Trust
Designated research room
Scope of research room
Use of the research room

- Research pipeline
- Technical developments of Proton Therapy required
- Radiobiology research
- Accelerator and imaging development
- Complement clinical research
- National Service – one of two centres in the UK

Potential lost opportunity that can not be revisited
Ability to deliver high quality research