APPLICATION of PET IMAGING in LIGHT ION THERAPY

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AIMS

Development of an **integrated approach** that uses **PET** (Positron Emission Tomography) technology for

MONITORING of **RADIATION DOSE** delivered with therapeutic **ion** beams

Investigation of **TISSUE RESPONSE** to radiation

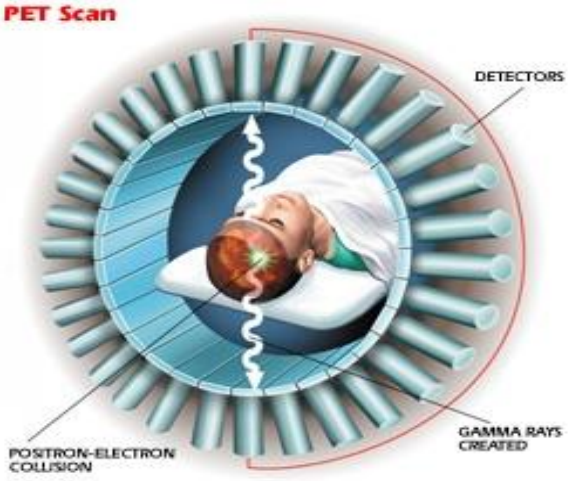
ADAPTATIVE RADIATION TREATMENT

Actual absorbed dose

Individual response features of each patient

BACKGROUND

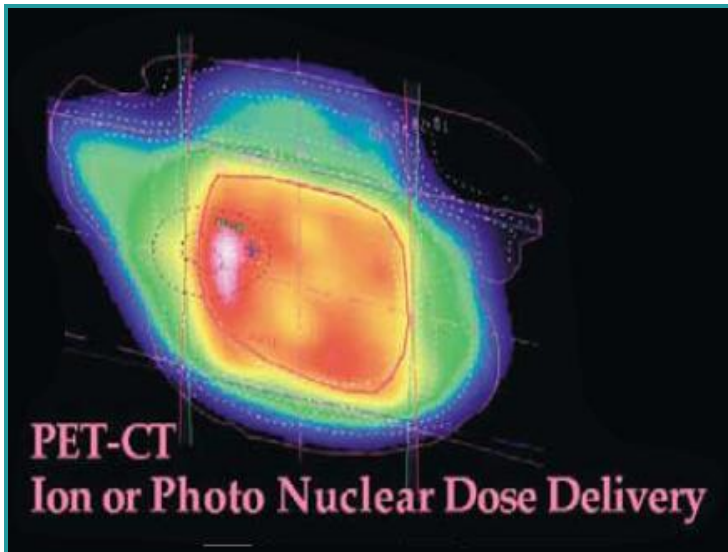
Positron emission tomography (**PET**) is a nuclear medicine imaging technique able to detect pairs of gamma rays in coincidence derived from the annihilation of a positron, emitted by a β^+ emitter isotope, with an electron of the body.



The β^+ emitters (^{11}C,^{13}N,^{15}O, ^{18}F) are usually brought into the body linked to a biologically active molecule in order to trace the functional and metabolic processes (FDG, FLT).

OR

They are produced through **nuclear** and **photonuclear reactions on ^{12}C, ^{14}N, ^{16}O in light ion** or **high energy photon facilities**.



(1) Accurate **monitoring** of the **absorbed dose delivered** to the tumor and normal tissues.

The method for **dose delivery verification** by **PET-CT imaging of photonuclear reaction** with **high energy photon beam** irradiation has already been tested at Karolinska Insitutet (*Janek et al, 2006*) with encouraging results for further developments for light ion therapy.

However

The **production of positron emitting isotopes in tissues** is usually **low** for imaging purpose.

↓ AIM:

Maximize the production of beta plus emitters

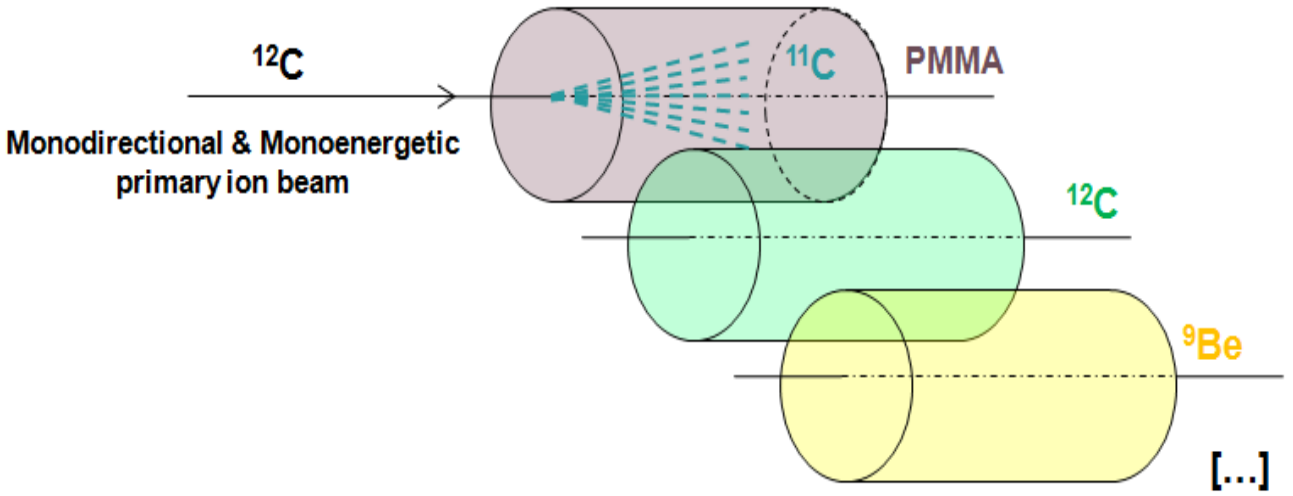
↓ HOW?

^{11}C therapeutic beams that allow a more accurate imaging of the Bragg Peak distribution than ^{12}C (*Brahme,NIRS,2009; Kempe, 2008*).

Optimal production of ^{11}C for improved light ion therapy

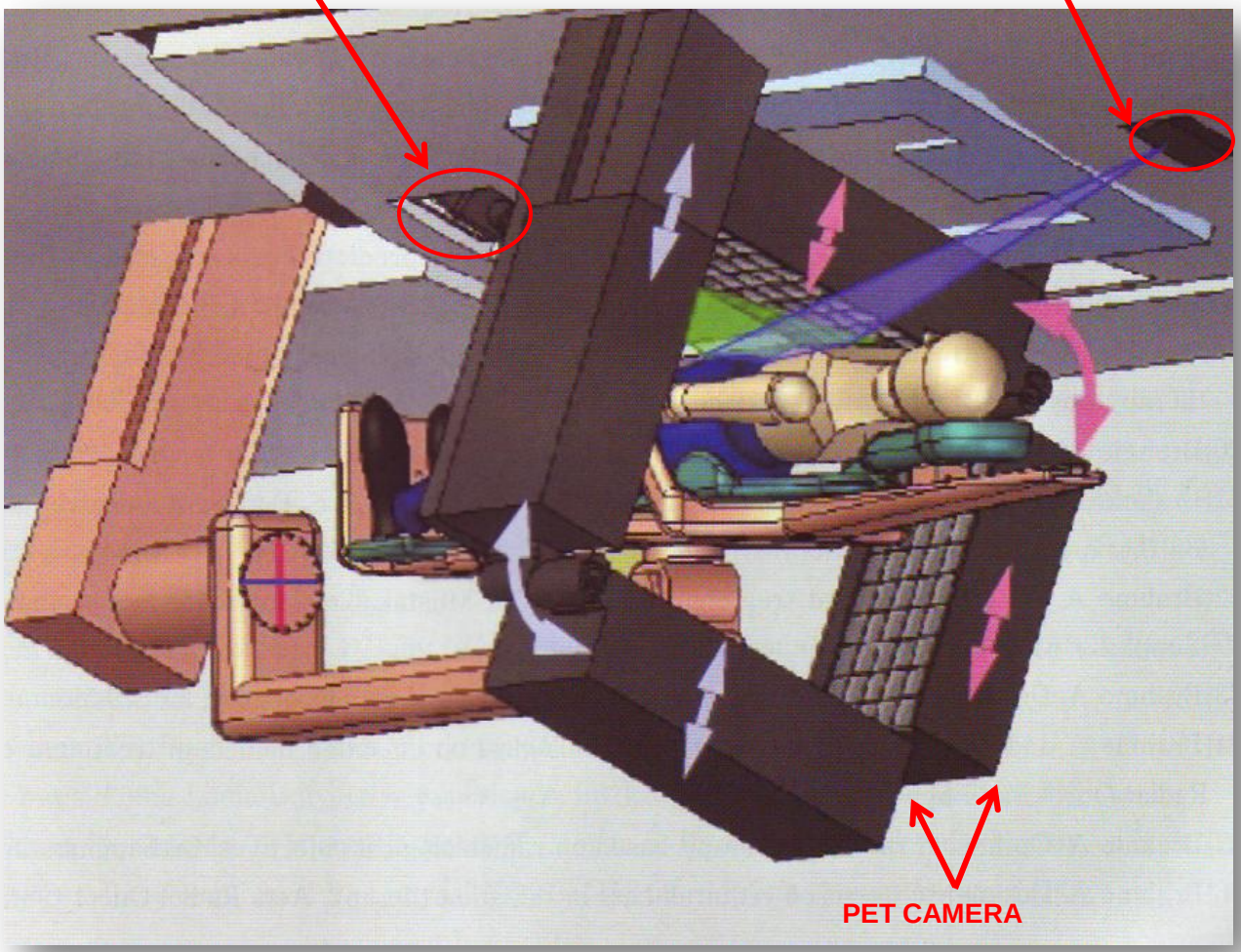
The choice of the target material

The Monte Carlo Code SHIELD-HIT could be used for the evaluation of the production of ^{11}C in ^{12}C light ion beams allowing the investigation of the optimal choice of target material for maximising the production of positron emitting isotopes that could be used for monitoring the absorbed dose.



The production of ^{11}C will be evaluated by scoring the particle fluence and track lengths differential in energy in 0.1 cm thick slices in the phantom.

Illustration of the new light ion excentric gantry

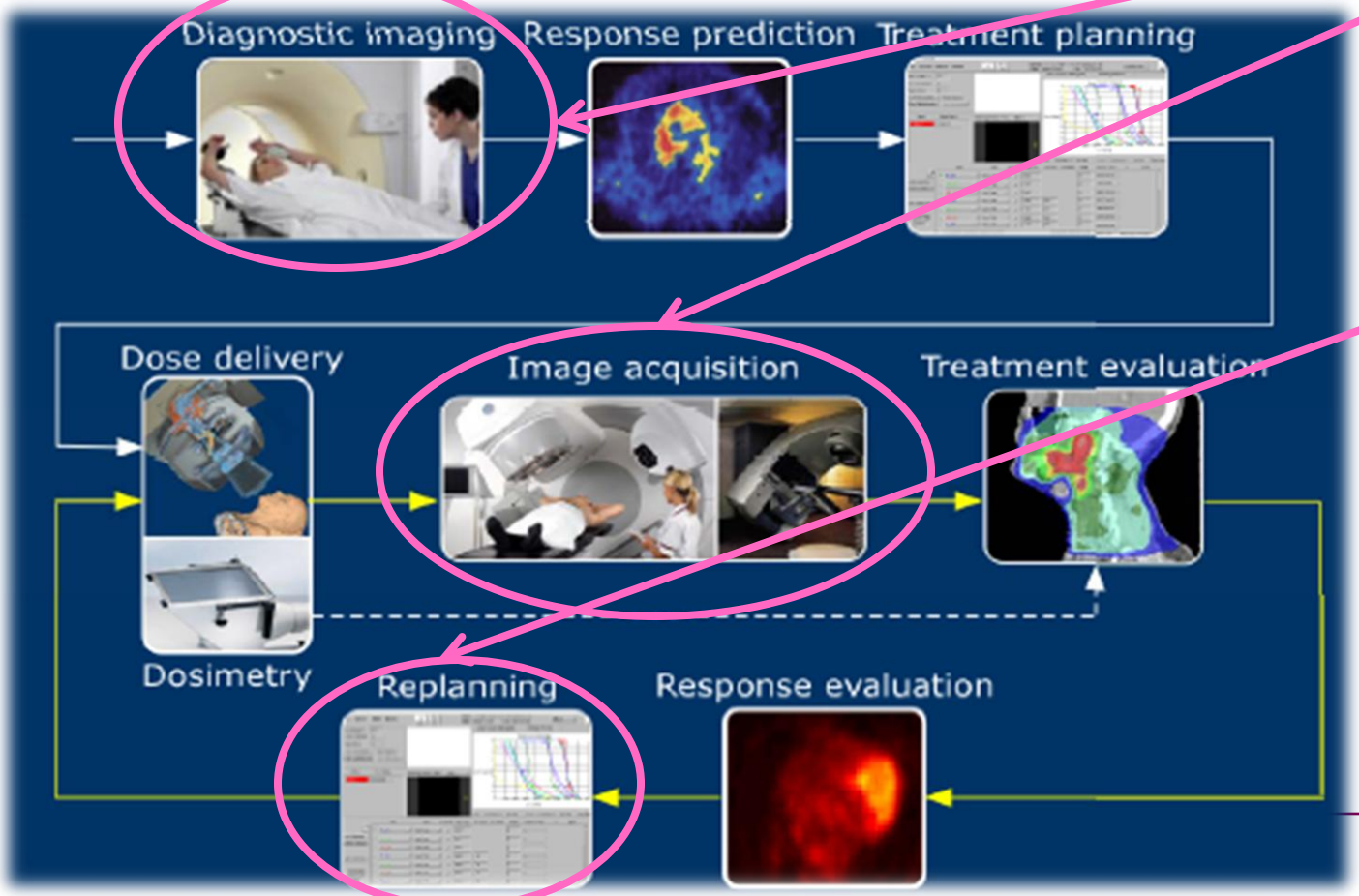


[A. Brahme, Potential developments of light ion therapy: The ultimate conformal tretment modality; Radiological Sciences, 1st NIRS International Open Laboratory Workshop on Innovation in the Radiation Therapy, 2009.02, vol.52, p:8-31.]

A design for integrating the equipment required for dose delivery imaging in a new light ion excentric gantry (6m in diameter) allowing the use in 4 different treatment rooms has been proposed (*Svensson et al, 2004*).

(2) **Determination** of the **radiation responsiveness** and **tumor cell density**.

It is possible **to quantify** both **the tumor responsiveness to therapy** and **the rate of loss of functional tumor cells** by **imaging the tumor twice** during the early course of therapy with fluorodeoxyglucose (FDG) or fluorotymidine (FLT) with a PET-CT (*Brahme; 2003,2005*).



A **new optimised treatment plan** overcoming the **estimated radiation resistance** could be designed and used for the remainder of the treatment.

The new plan could be **physically optimised** using the **calculated dose distribution as physical objective**.

An even better alternative could be to use:
- **Tumor cell density data extracted from the PET image**
- **Estimated effective radiation resistance**

for a **biological effective dose delivery optimization.**

The **BioArt** (**Biologically Optimized 3D in vivo predictive assay-based radiation therapy**)**:**
- Not just a correction for the potentially misplaced dose delivery

but

- An integral correction if part of the tumor, which is more **radiation resistant**, has been missed during the early treatments
- or even if the **biological response parameters** of the tumour used during treatment planning were inaccurate.

The BioArt approach has the potential to remove all uncertainties in the whole treatment planning process and represents a quantum leap in radiation therapy development.

Materials & Methods

1. The **Monte Carlo Code SHIELD-HIT** will be used to simulate and investigate the **production of β^+ emitters** in different materials irradiated by light ion beams.

2. The **new light ion excentric gantry design** could be further improved taking into account the results obtained in the first part of the project.

3. The **tumor responsiveness** will be studied using radiobiological models and a workstation for treatment planning developed by RaySearch Laboratories AB, Stockholm in collaboration with Prof. Anders Brahme.

4. The **BIOART approach** will be further developed for **ion therapy** and will be applied on **clinical data** already available at Prof. Anders Brahme.

SIGNIFICANCE

This project will contribute **to transform the current radiation therapy** into an exact science where the complication-free tumour cure can be **truly optimised** by looking at the **dose distribution delivered** or the **resultant treatment effect on the tumor cells**.

Therefore the overall strategy of the work plan for this project aims at **the integration of the proposed method**, **instrument** and **imaging system** into a **complete biologically optimised treatment strategy**.