HollandPTC
Protonen Therapie Centrum

Various Other Proton Therapy Projects

1. A novel method for image reconstruction (MEP)
2. Breathing uncertainties in proton therapy (BEP)

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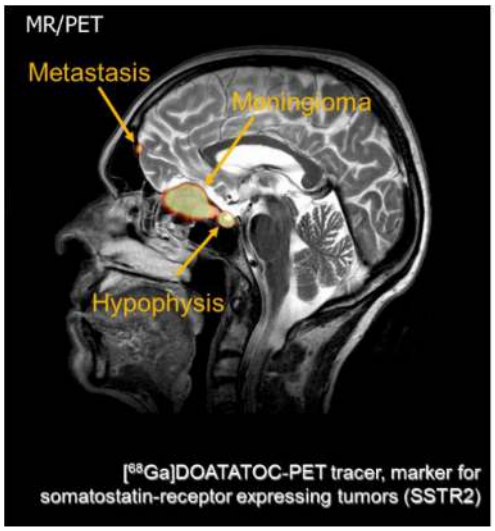
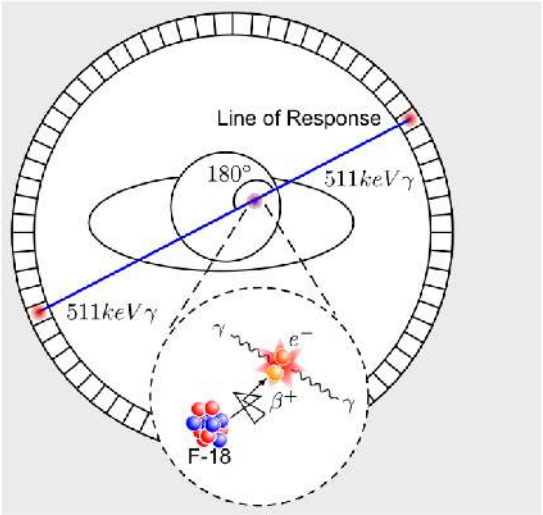
1.A novel method for image reconstruction (MEP)

In vivo molecular imaging is a discipline at the intersection of molecular biology and medical imaging, It is based on the use of biomarkers to probe molecular targets or pathways in living organisms without perturbing them. Imaging of biomarkers radiolabeled with isotopes that decay by positron emission, using positron emission tomography (PET), provides the best spatial resolution, molecular sensitivity (~10^6 times better than fMRI) and quantitative accuracy available today. PET is based on the detection of the pairs of gamma rays created in the annihilation of positrons with electrons.





PET image reconstruction is practically based on first calculating the 'system matrix' that describes how each single voxel affects the detector response. This makes the problem discrete and can be done by a Monte Carlo code, taking as input the patient geometry and tissue properties (scattering, attenuation). This data, together with the actually measured response, is then used to reconstruct the source (i.e., the radiotracer concentration) in the body through a discrete optimization algorithm. Such iterative reconstruction algorithms are very time-consuming and may take up to several hours to complete.

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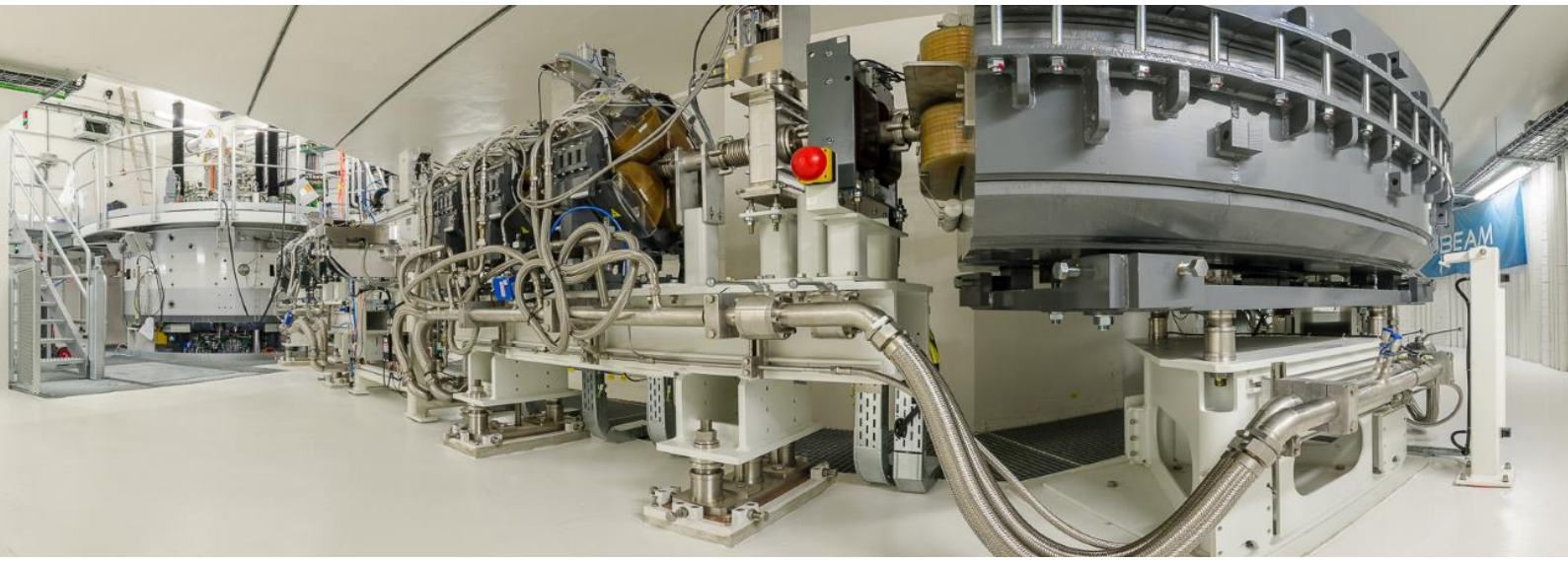

Here we will investigate a completely new idea for source reconstruction. In this method we view the reconstruction as a continuous pde-constrained optimization problem that can be formulated precisely in terms of the radiation equations (the linear Boltzmann equation) describing the particle behavior from source to detector. This bypasses the necessity of the system matrix completely: after numerical solution of the set Karush-Kuhn-Tucker (KKT) optimization equations, the optimal source distribution is known. It is expected that this can be done in much less time than previously possible.

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2.Breathing uncertainties in proton therapy (BEP)

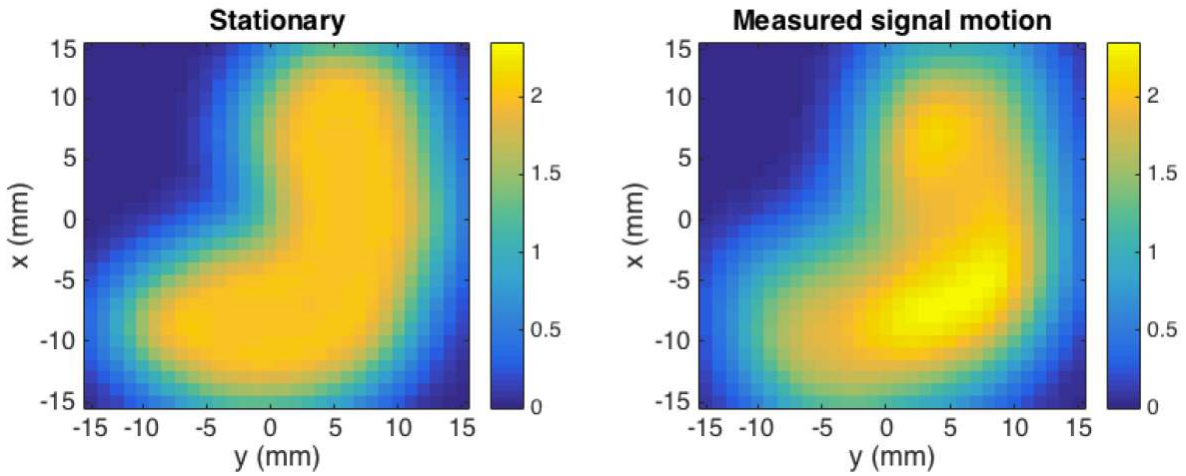

Figure 1 - Difference between the planned (left) and the interplay (right) dose distribution in a 2 dimensional tumor. The interplay clearly causes hot and cold spots in the tumor, compromising dose coverage.

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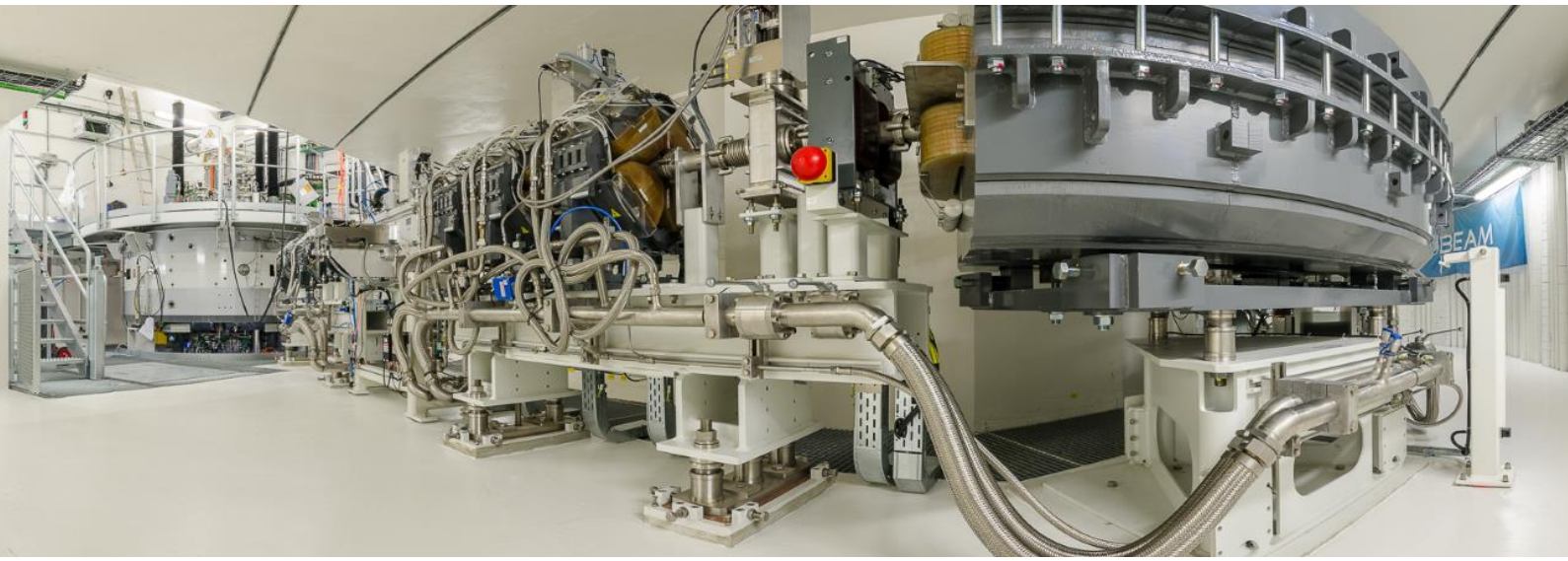

The current state-of-the-art in radiotherapy is Intensity Modulated Proton Therapy (IMPT), where high energy proton beams are directed at the patient from different beam directions with varying intensities, to achieve as conformal dose distributions as possible, ensuring treatment success without overdosing healthy tissues. During the delivery of such treatments so-called pencil beams are used, which can deliver high dose to very small spots (e.g. a sphere with roughly 5 mm diameter). Since most tumors are much bigger than this, the proton beams have to be “spread”.

This “spreading” is done using scanning, where magnetic fields steer pencil beams from spot to spot, covering the tumor in a layer-by-layer fashion (much like older printers going from left to right, line by line).

The proton machine naturally needs time to switch between spots, and especially to switch between layers. This time is comparable to the typical period of breathing, which causes a so-called interplay effect. This interplay can degrade the dose distribution in the patient, since the organ in reality can be in a different position than in the planning CT, making the spot deliver its dose at the wrong location. To correctly evaluate the dose the patient receives, the breathing has to be taken into account and the “interplay dose” needs to be calculated. For this, the breathing pattern needs to be known, however this can only be measured prior to the treatment, and can be different from the actual pattern during the treatment.

This project focuses on the effects of these uncertainties in the breathing pattern on the dose distribution, and on how accurately the breathing signal needs to be known for accurately predicting the resulting interplay dose distribution.

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