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Statistical error calculation for the proton dose distributions in a proton therapy facility

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Overview

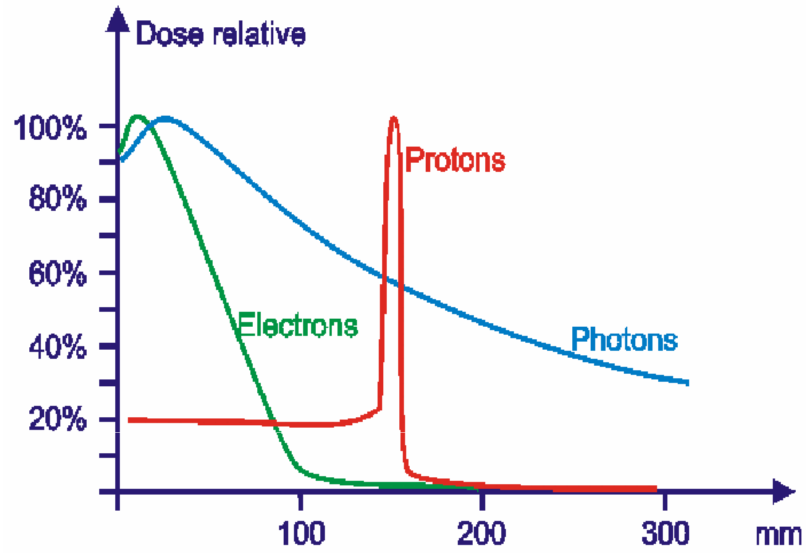
- Objectives
- Protontherapy concept
- Proton delivery techniques
- Simulation model description
- Results and discussion
- Perspective

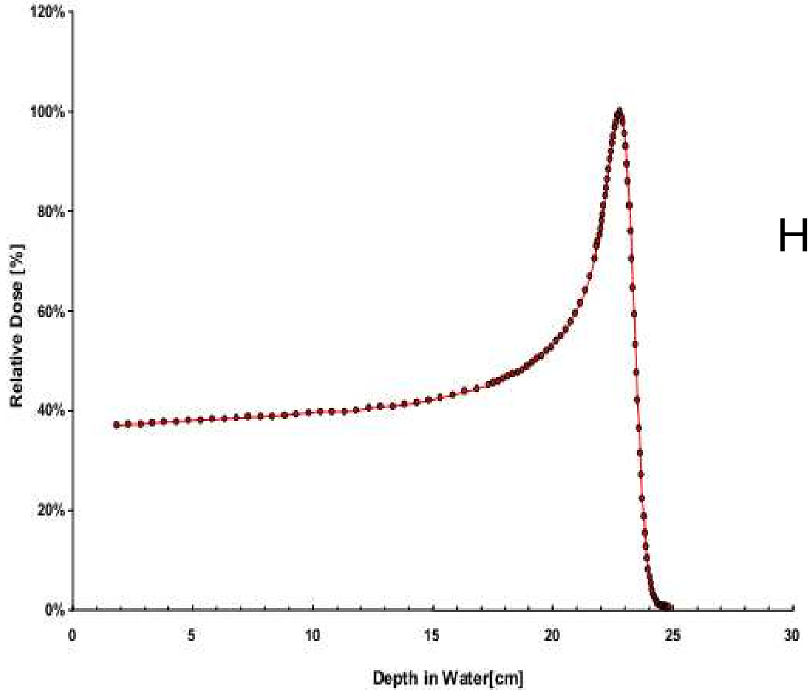
Objectives

- The aim of this work is to study the influence of Geant4 parameters on dose distribution for simulations of proton therapy.
  - Identification of different components contained in a proton therapy facility.
  - Using Geant4 simulation of a proton therapy system to calculate the proton dose distribution in depth.
  - Study of the statistical error of proton dose distribution in depth
  - (ICRU Dosimetry report) Comparison of the calculated error to the error recomended for a patient treatment in a proton therapy facility

Protontherapy concept

- Figure 1: depth–dose distributions for various particles in a water.





Highly localized dose distributions

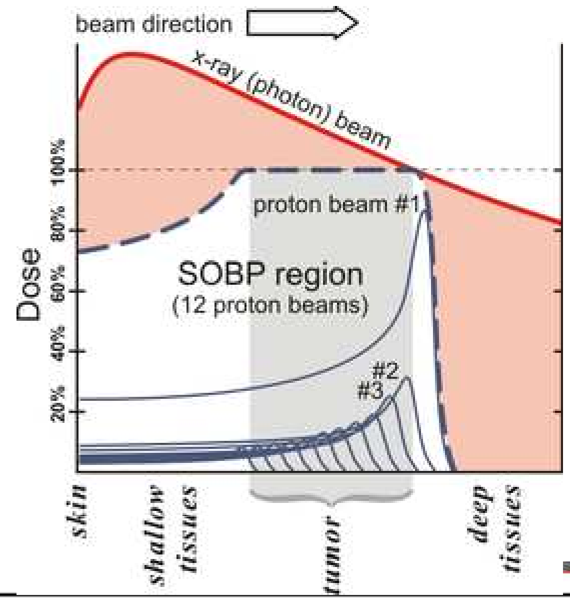
- Increased local control of tumors
- Can reduce dose at healthy tissues
- Maximize the effect at deeper tumor region

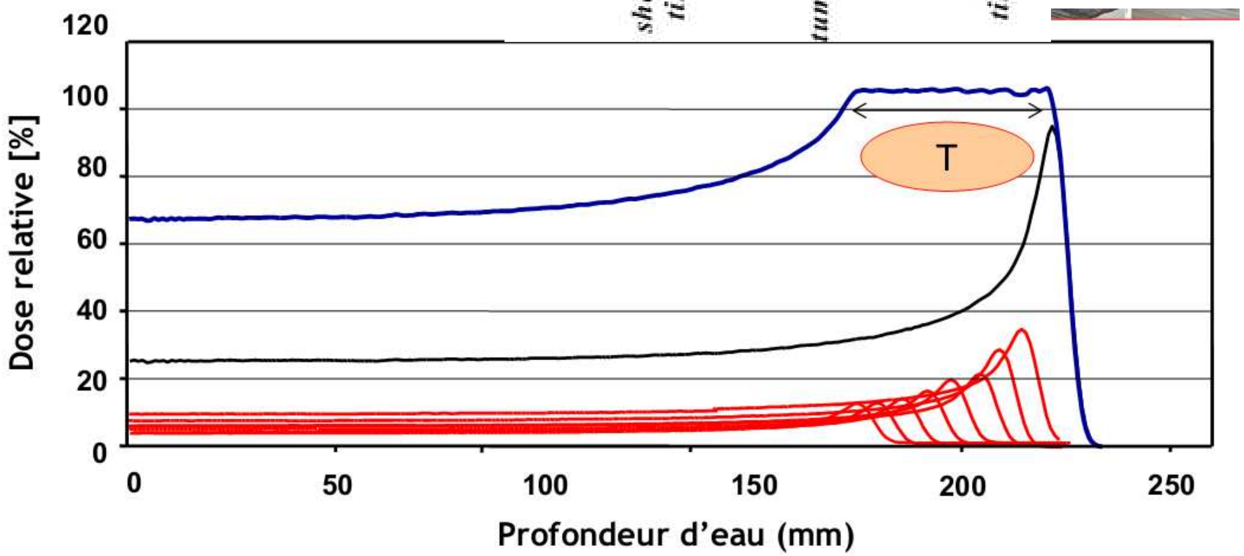
Protontherapy concept

- The concept is to use proton Bragg peak to cover the tumor volume

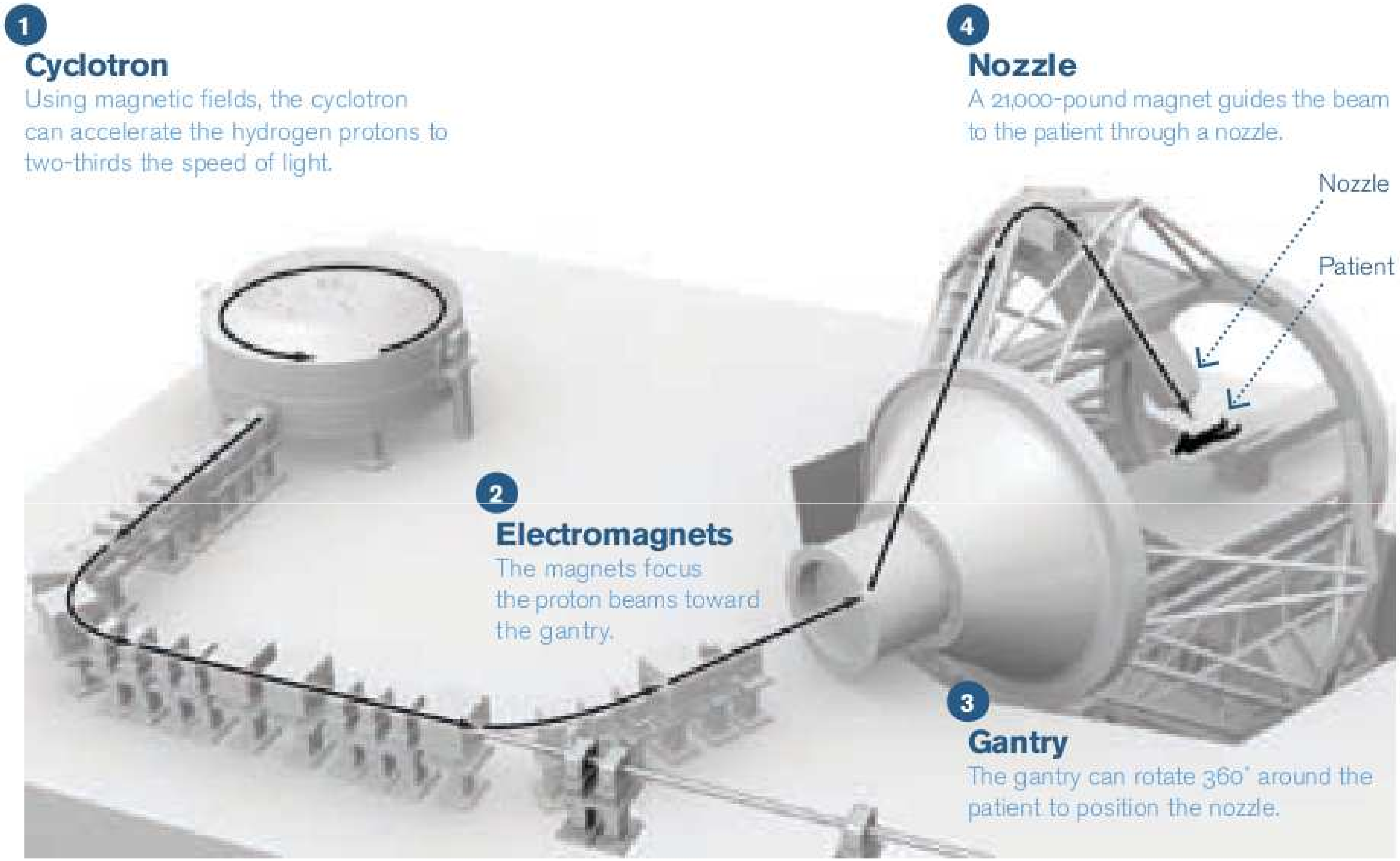
  - To spread out the Bragg Peak

  - To control the beam section.



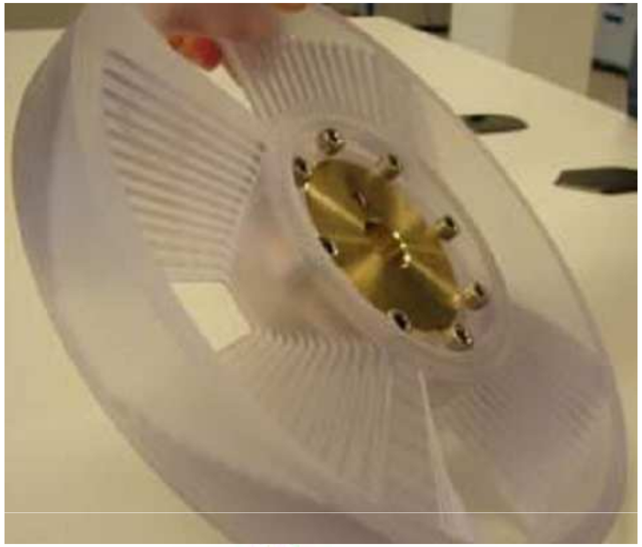


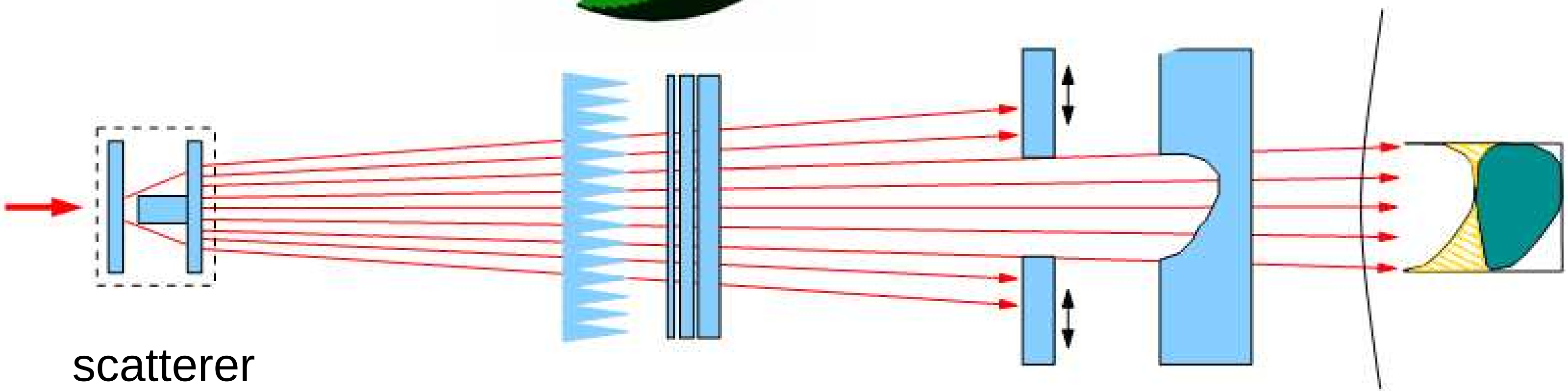
Proton delivery techniques



Beam-delivery techniques are categorized as passive or dynamic.
This categorization refers to the method used to spread out the beam laterally.
These beam-spreading devices are incorporated in the nozzle.

Passive beam-delivery techniques





scatterer

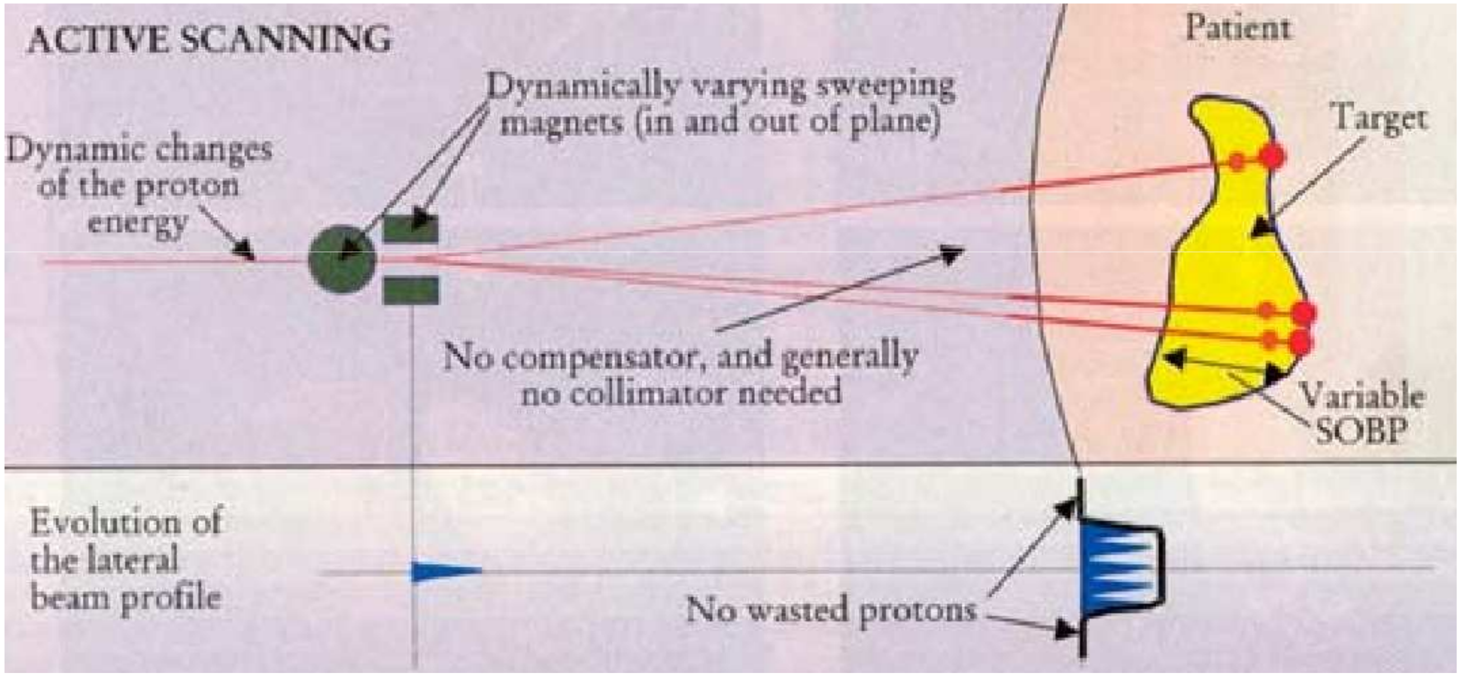
modulator

MLC

compensator

Dynamic beam-delivery techniques

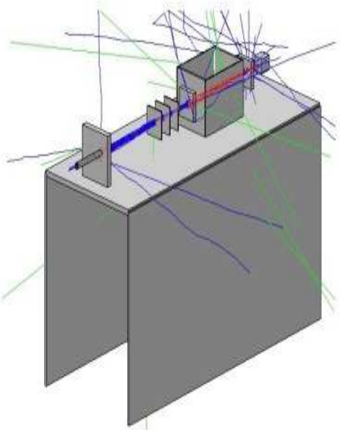
- Method to achieve a desired dose distribution by magnetically moving the beam across the target.
- Dynamically changing the energy of the beam and, consequently, the depth of penetration.



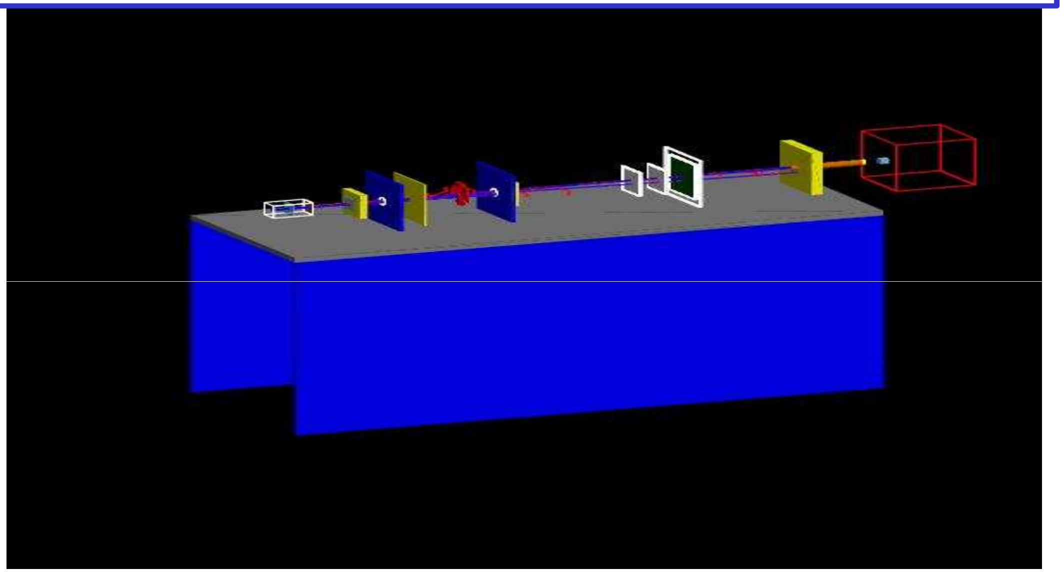
Simulation model description

- Tools
  - Geant4 -4.9.6
  - *Monte carlo method*
  - *Toolkit for the simulation of the particles passage through matter*
  - ROOT-5.26
  -
  - *IFIC Grid Infrastructure for calculation*

Model description



The simulation represents the treatment room for proton therapy, installed at the LNS-INFN facility in Catania, for eye tumor treatment with protons at 62 MeV.



A part of the GEANT4 Hadrontherapy advanced example

- Allowed to the user to simulate a complete proton therapy beam line
- The possibility to test its elements and to generate all the dose distribution curves of the involved beams.

http://g4advancedexamples.lngs.infn.it/Examples/hadrontherapy

Model description

The main elements are:

The SCATTERING SYSTEM

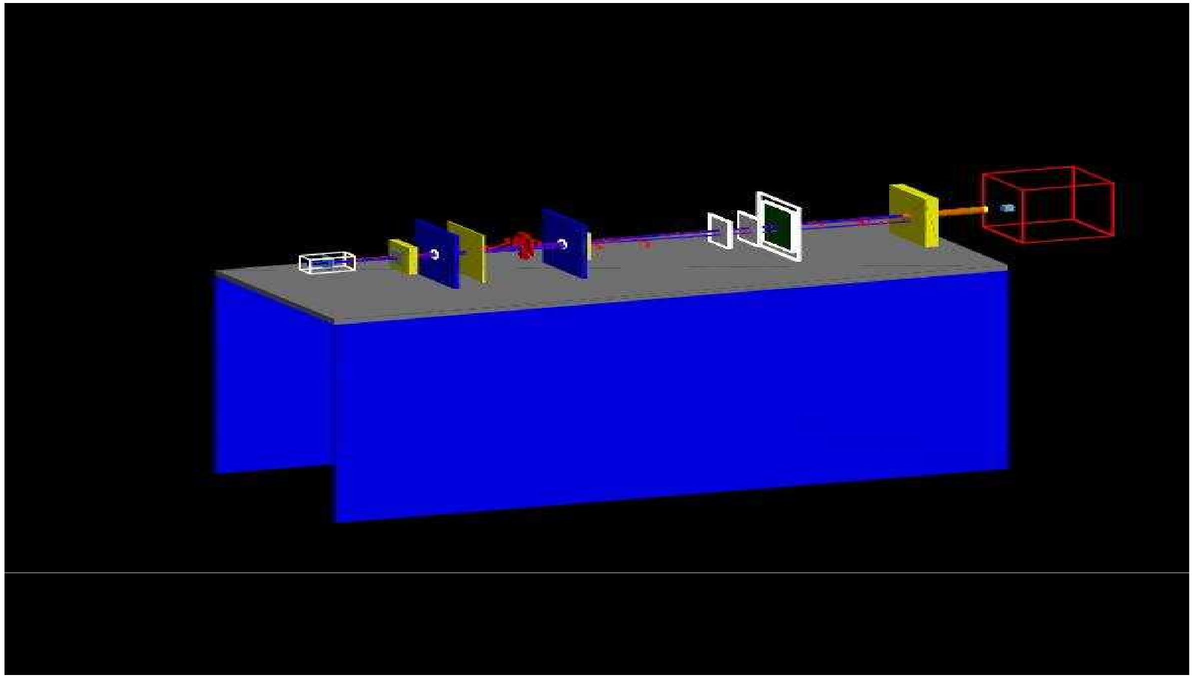
The COLLIMATORS

The RANGE SHIFTERS

The MODULATOR WHEEL

The MONITOR CHAMBERS

The PATIENT COLLIMATOR:



Hadrontherapy distribution contain different sub-folders:

\src: where source .cc files are stored
\include: where header .hh files are stored
\macro: where a set of ready-to-use macro files are provided
\experimentalData: a set of reference (experimental and analytical) data are stored.
\SimulationOutputs: when one of the .mac file contained in the macro folder is used.
\RootScripts: permit to user to compare directly results from the simulation with reference data provided inside the experimental Data folder.

DETECTOR

changePhantom/position 20. 0. 0. cm
/changePhantom/update/changePhantom/size 40 40 40 cm
/changePhantom/position 20 0 0 cm
/changeDetector/size 4 4 4 cm#
/changeDetector/voxelSize 100 um 40 cm 40 cm
changeDetector/displacement 0 18 18 cm
/control/alias initialValue 0/control/alias
 finalValue 359/control/alias   stepSize 1
/gun/particle proton/beam/energy/meanEnergy 62 MeV
/beam/energy/sigmaEnergy 400 keV
/beam/position/Xposition -2700 mm
/physic/setCuts 1 mm
/Step/waterPhantomStepMax 0.005 mm

Results and discussion

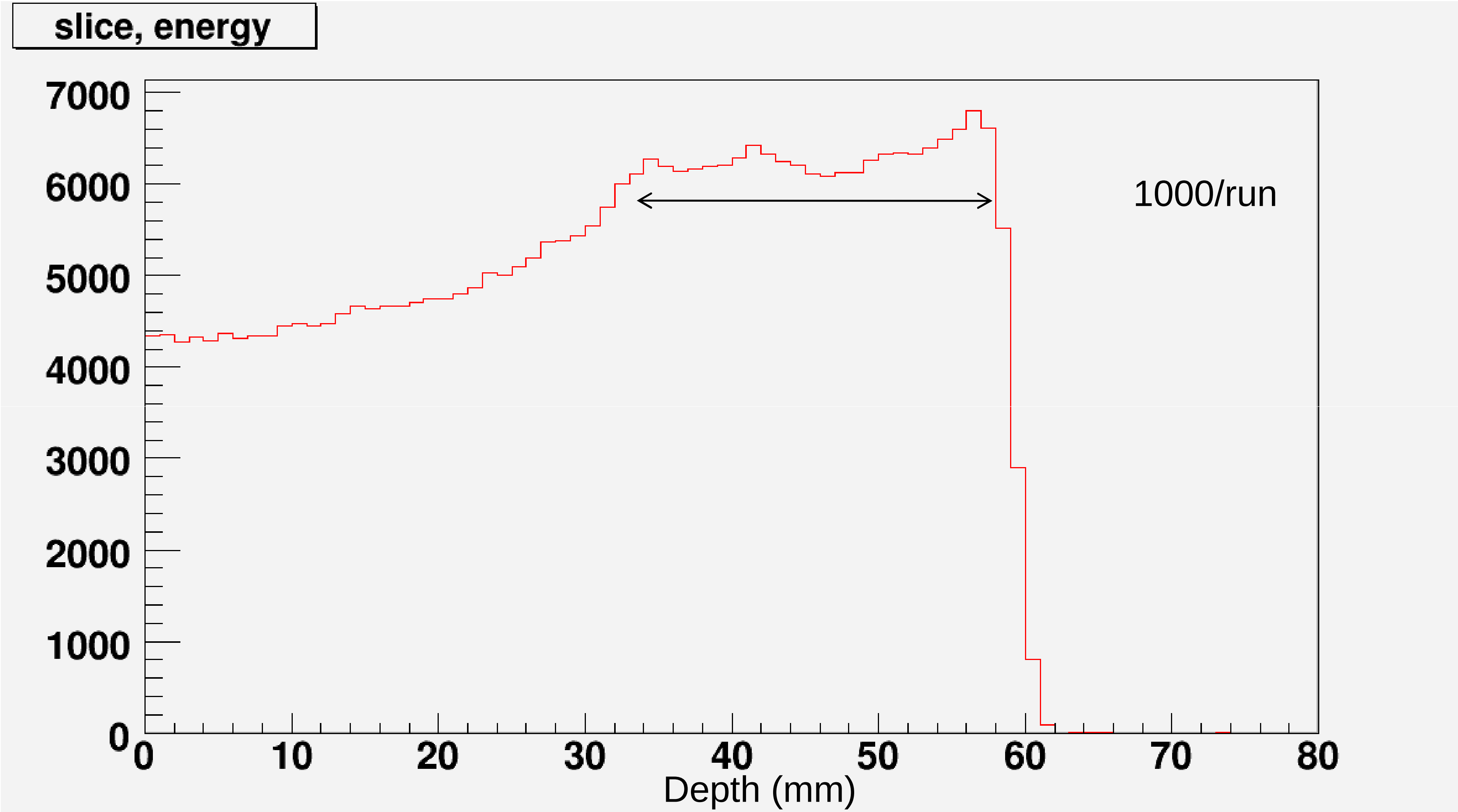


Figure 1: SBOP using all components for proton beam energy E=62 with modulator rotation.

Error calculation with simulation using all components

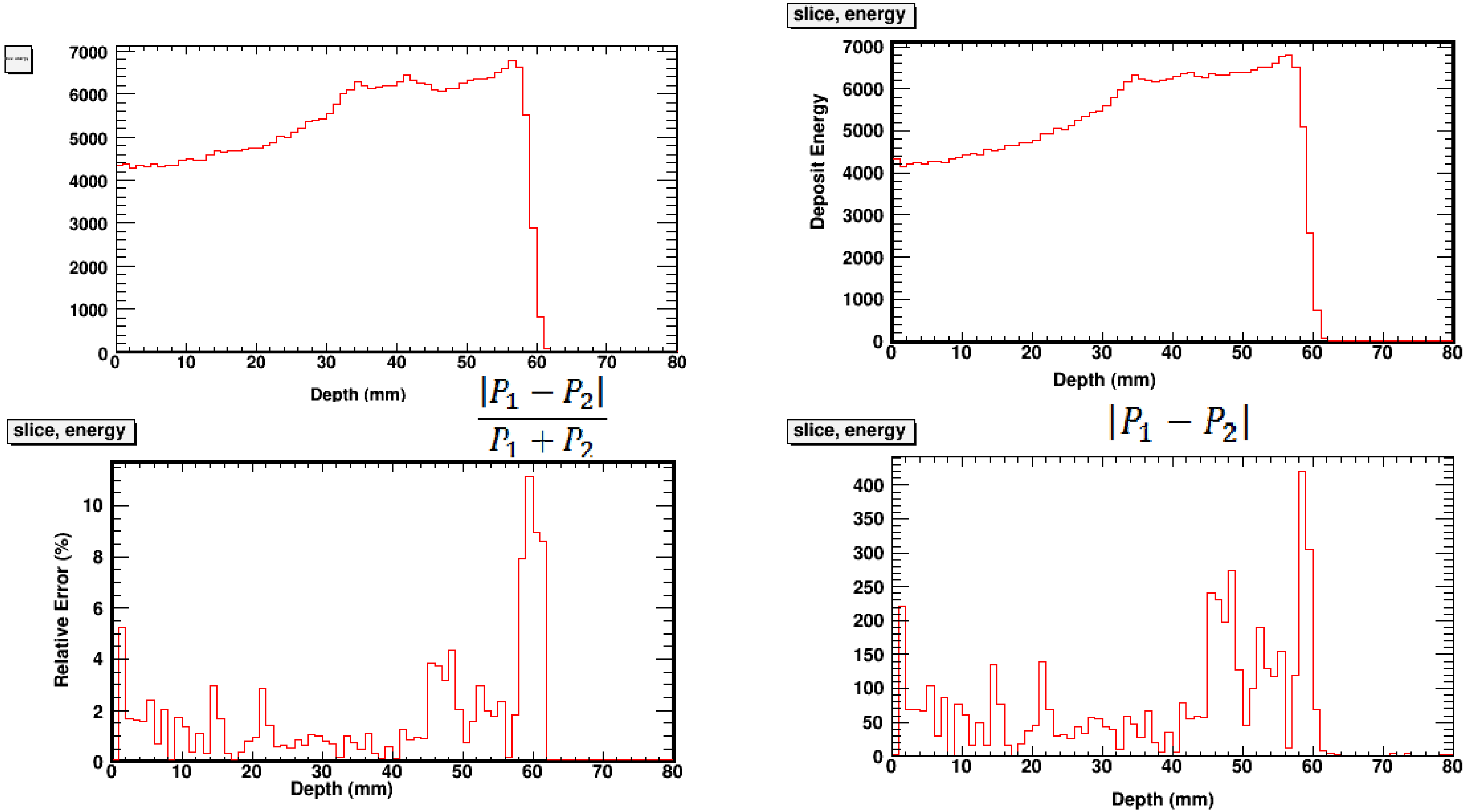
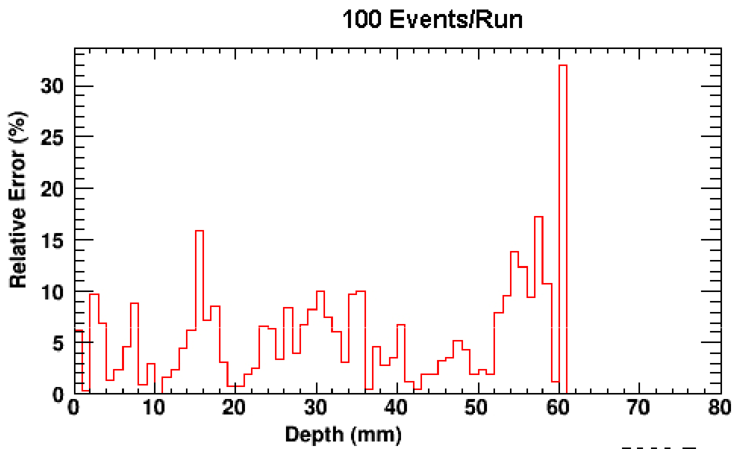
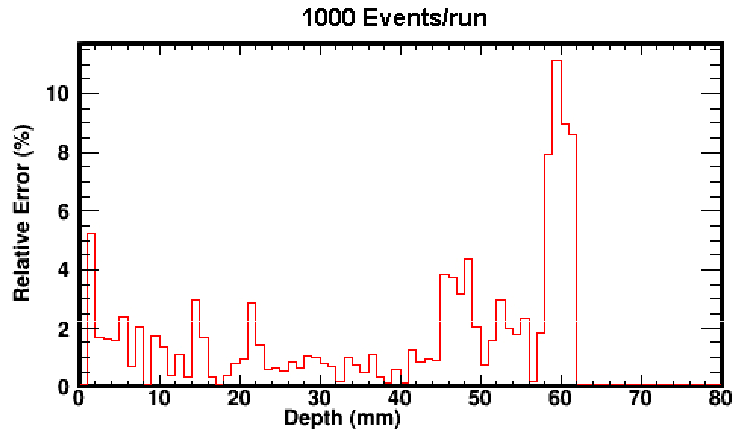
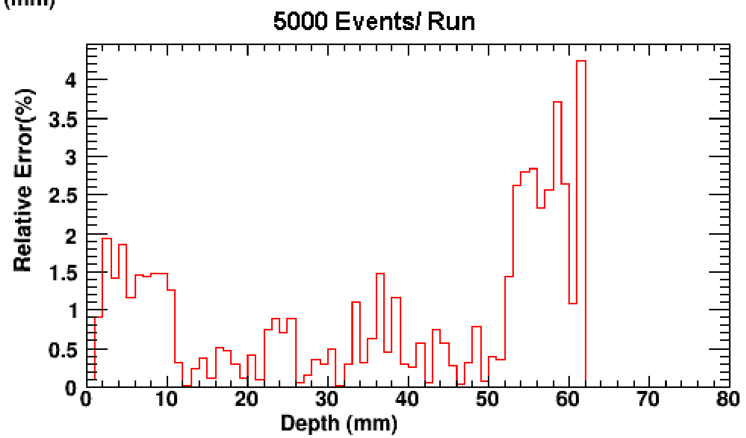


Figure 2: the error |P1-P2| and the relative error calculated for all components simulations (1000 events per run)**.**

Error calculation with simulation in different number of events







Error calculation with simulation using Two components

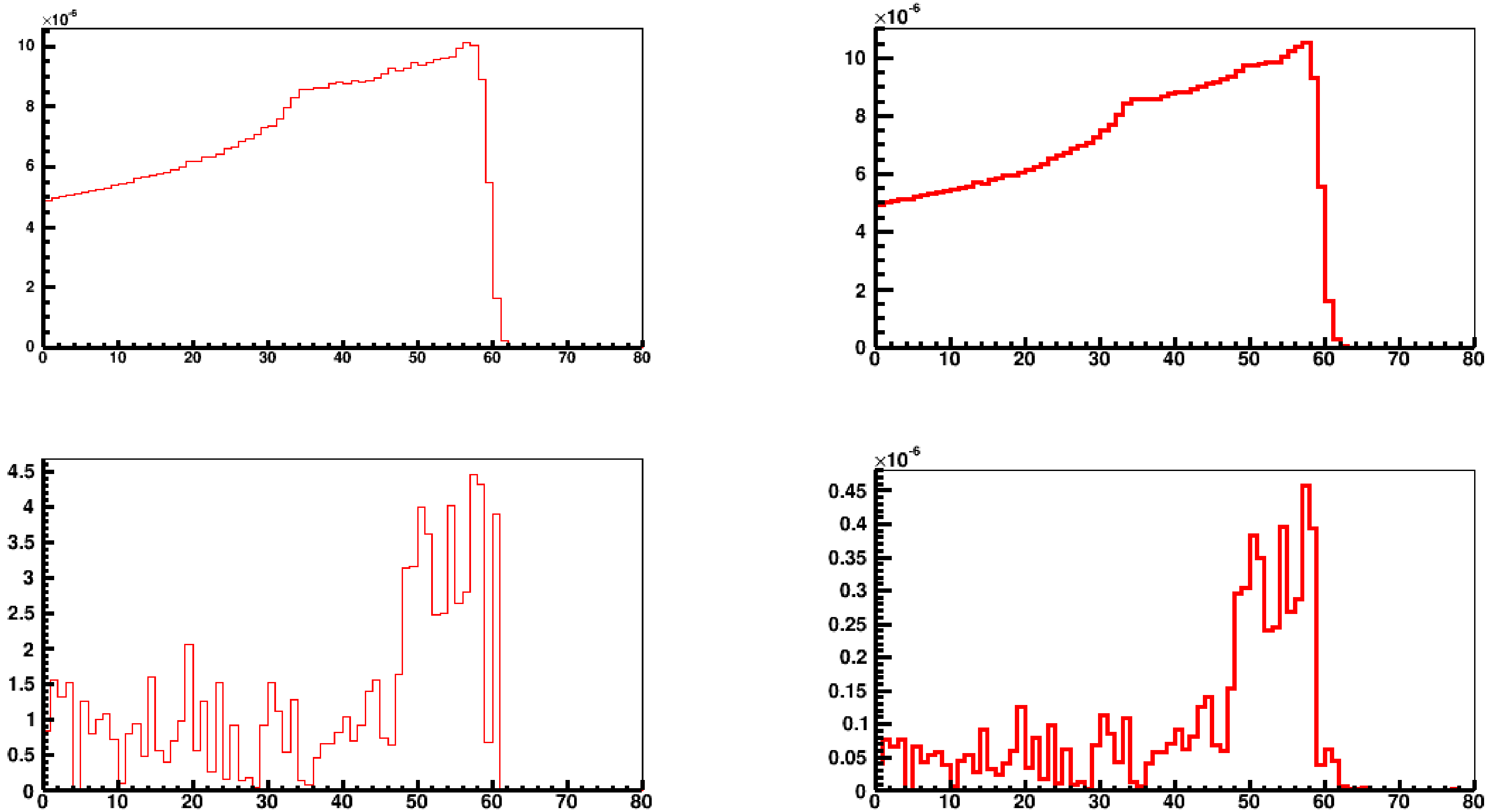


Figure 2: the error |P1-P2| and the relative error calculated for all components simulations (100 events per run**).**

Perspective

- follow this work .
- Study the impact in to the error of:
  - the components of the delivery system.
  - The Geant4 parametre (setcut, stepMax, physicslist)
  - (ICRU Dosimetry report) Comparison of the calculated error to the error recomended for a patient treatment in a proton therapy facility