Investigating the Relative Biological Effectiveness of a Hydrogen Plasma Beam on Breast Cancer Cells

Kelly Donovan, Kate Huggler, Steve Hupcher, Susan Thomas, Robert O'Donnell, Stephen Padalino
State University of New York at Geneseo

Our Goal

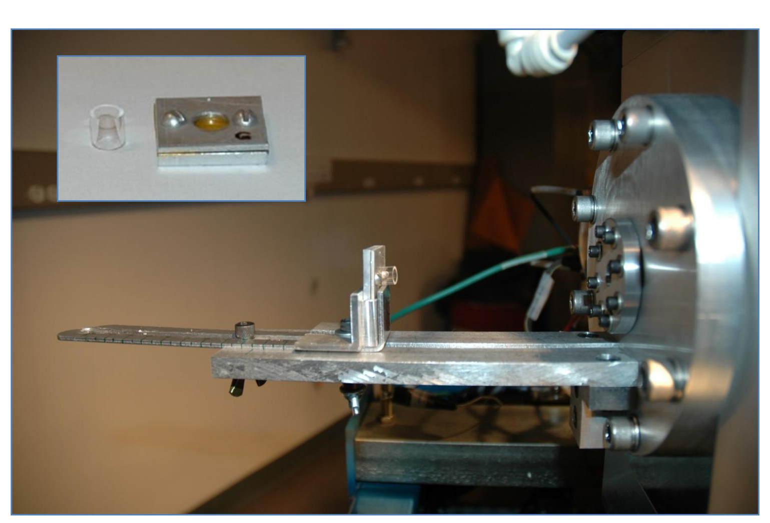
To develop a method for the irradiation of breast cancer cells with a 3 MeV proton beam produced by a NEC 5SDH Tandem Pelletron Accelerator. Which will;

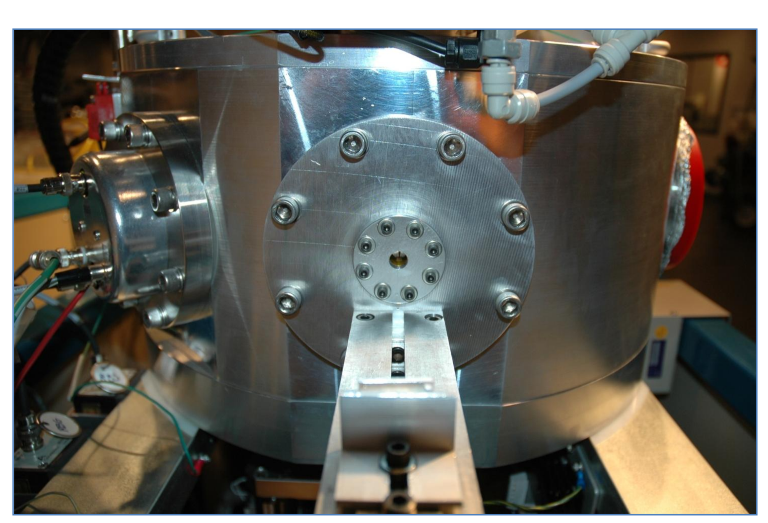
- Allow for the cells to remain in atmosphere during irradiation
- Utilize the unique energy deposition characteristics of a proton beam in cell cultures
- Allow for a range of radiation exposure times in an attempt to find an optimal dose.

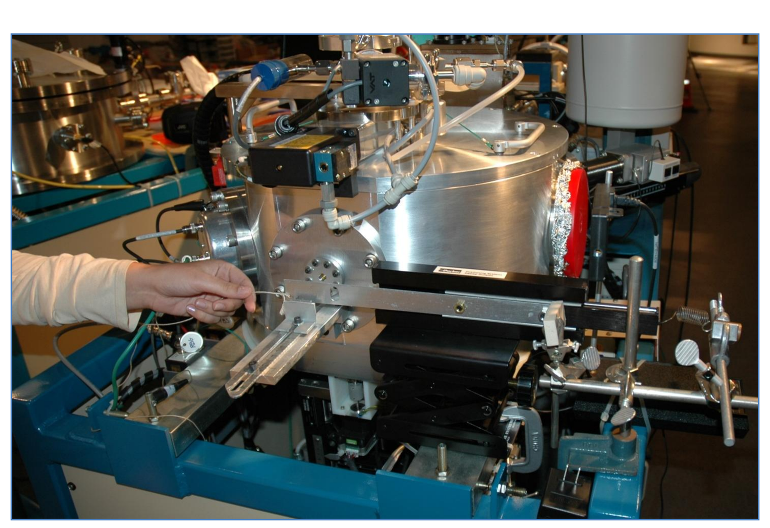
Experimental Setup

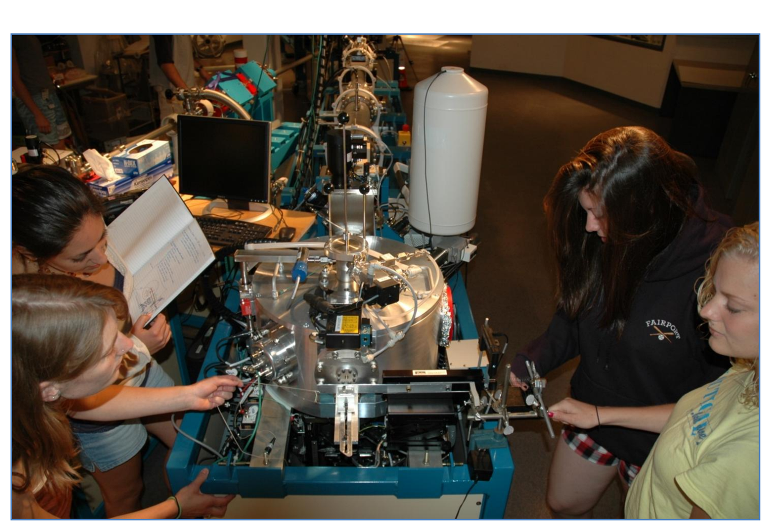
A 3 MeV proton beam is produced by a 1.7 MV Tandem Pelletron Accelerator. The beam then passes through an analyzing magnet, directing it through the 15 degree beam line to the end station where the cancer cells are exposed.

The beam exits the vacuum chamber through a 25 micron thick Kapton window and passes through 6 centimeters of air before striking the cancer cells.



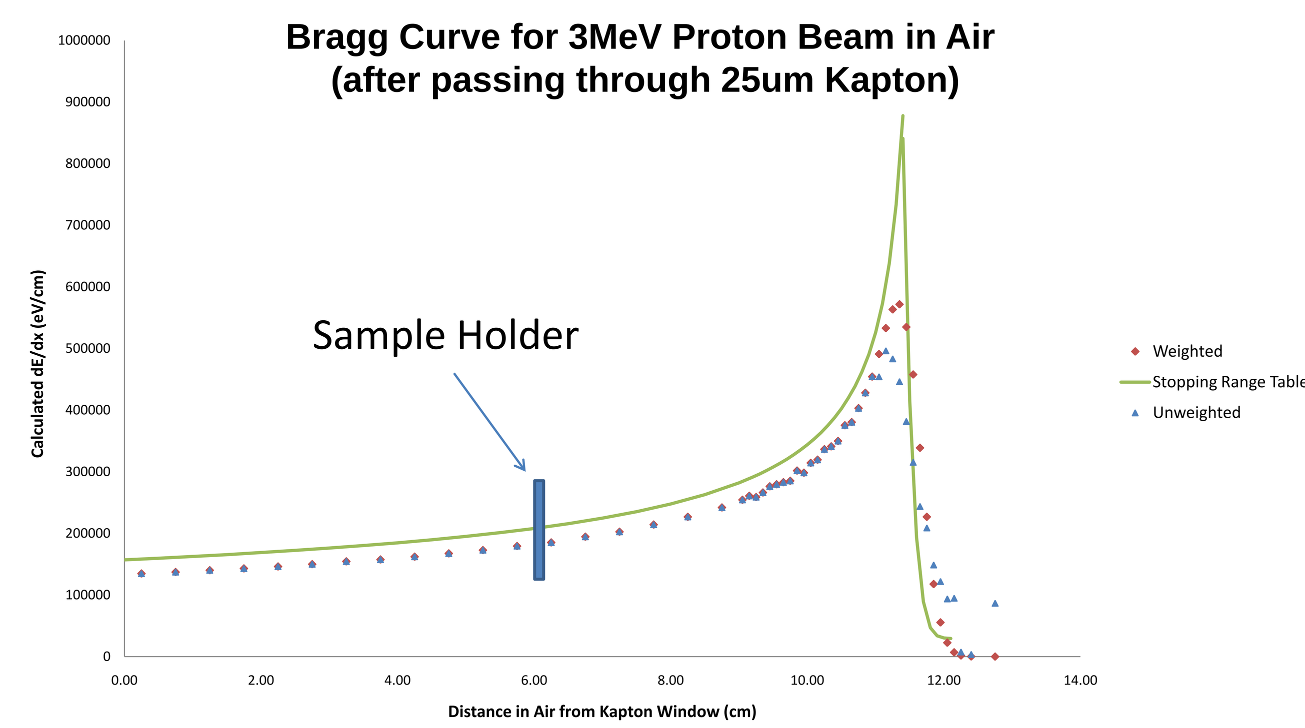






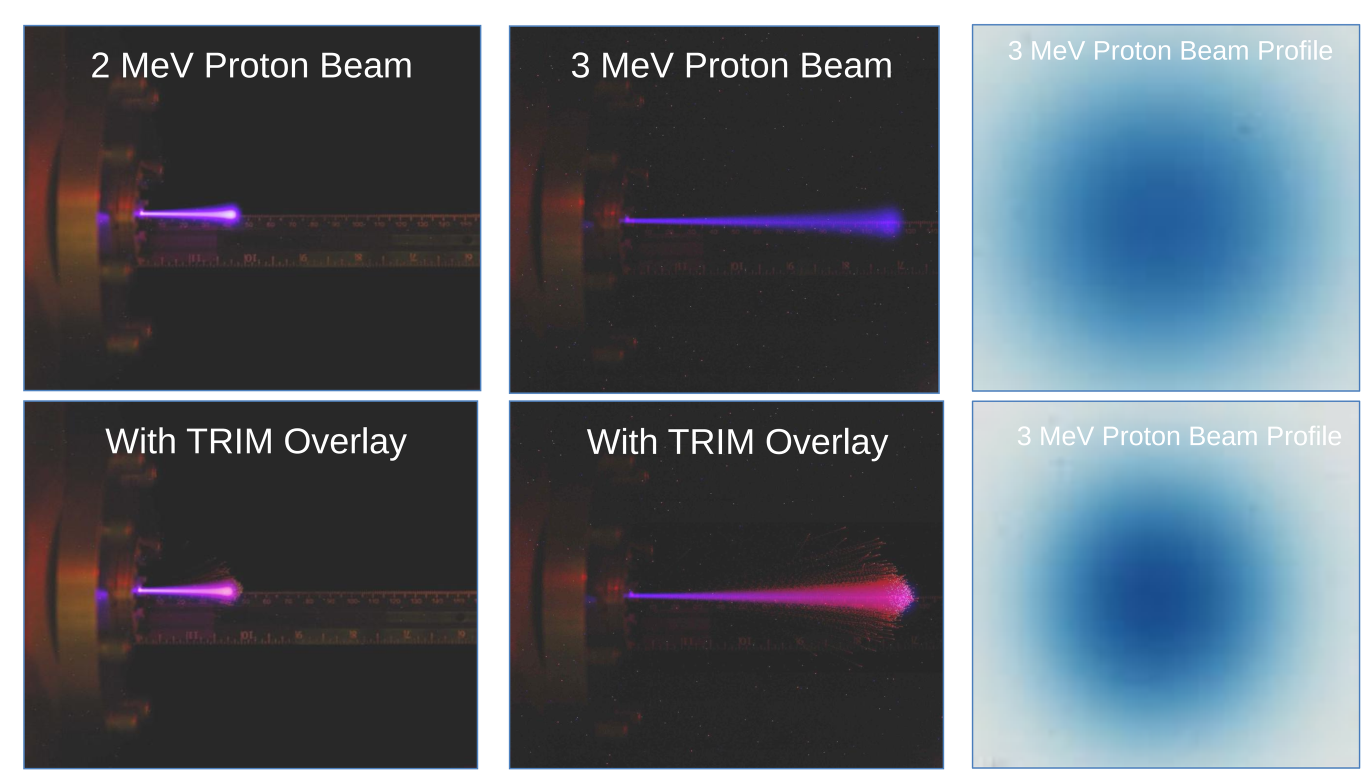
Proton Beam in Air

Proton beams are ideal for radiation therapy because they deposit the majority of their energy in a localized area smaller than the dimensions of most tumors. The energy deposition per unit length as function of distance is described by Bragg curve.



Proton energy loss and beam straggling through Kapton and air were determined theoretically using TRIM tables and SRIM calculations. These were confirmed by calibration experiments using time exposure photography and Radiochromic Film.

Projection of Beam into Air



Calculating Radiation Dose

- Calculate (mass)/(Surface Area of cell sample):
  σ = (Density) x (thickness) = 1.09×10^{-12}g/μm
- Calculate beam spot area:
  $A_b = \pi r^2 = 3.14\times10^6 \mu m^2$
- Calculate flux

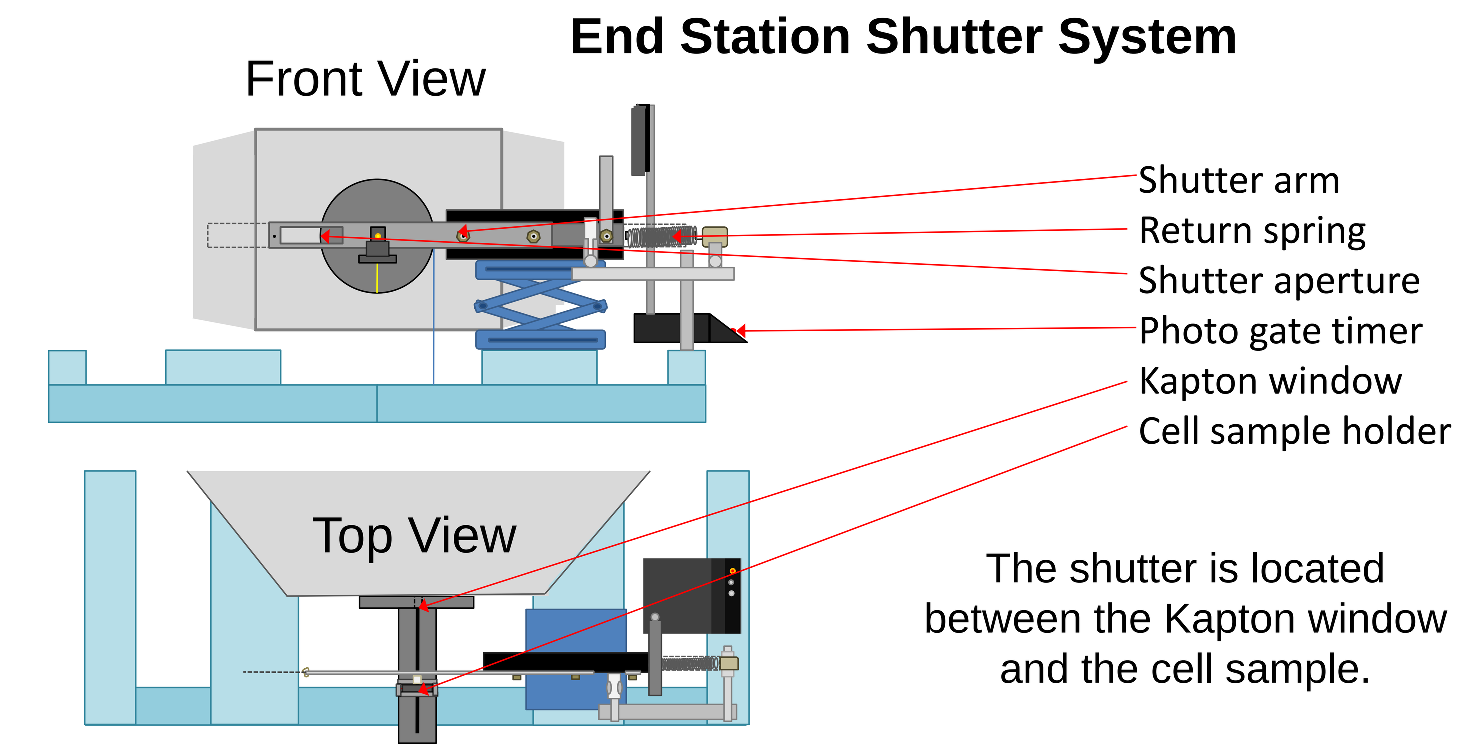
Flux = [(#protons)/(time)]/(Area of beam spot)
  Flux = $[I/(1.602\times10^{-19}C)]/A_b$
- Determine E_{lost} in cell medium:
  Differential TRIM calculations
- Calculate dose per second:

$[(flux)x(E_{lost})]/\sigma = \{[(proton/s)/\mu m^2]x(J)\}/[g/\mu m^2]$ = proton/s (Gy)
  dose/s = $(\{[I/(1.602\times10^{-19}C)]/A_b\}/\sigma)xE_{lost}$

Assumptions:
Cell thickness ~1μm
Beam radius ~1000μm
Beam spot intensity ~ Uniform

Controlling Radiation Dose

- The beam current in air for each exposure is measured using a hand held faraday cup
-An End Station Shutter System is used to control the radiation exposure time
-The dose is confirmed using Radiochromic Film

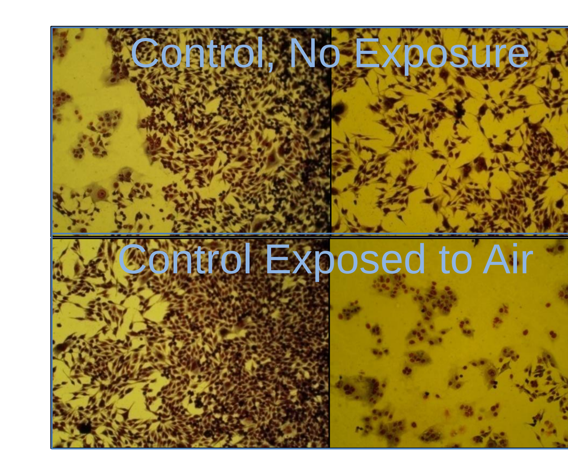


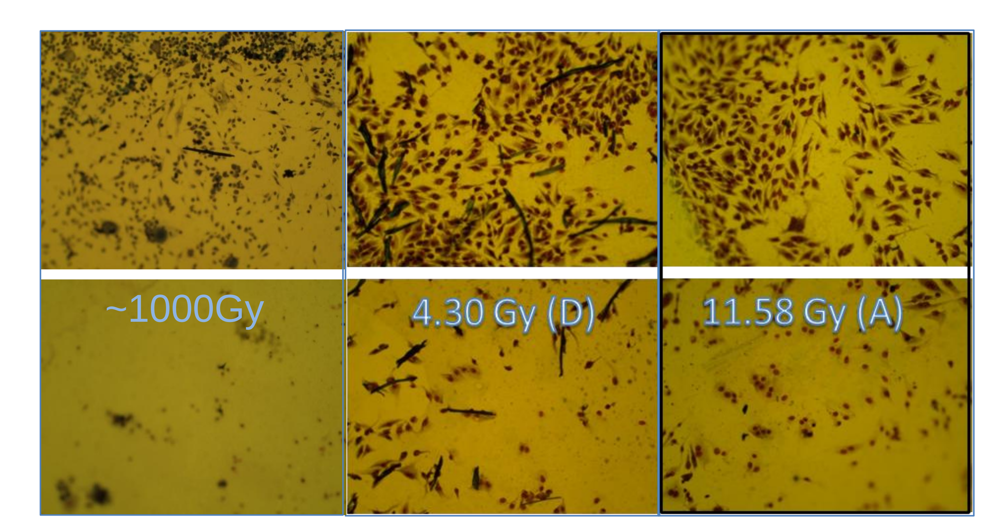
The shutter is located between the Kapton window and the cell sample.

Experimental Results

Several experimental trials have been performed in which breast cancer cells were irradiated at various doses. The radiation effect was analyzed by determining the change in cell density per unit area in each cell sample. Photographic images of various cell samples seen in the phase contrast microscope are shown below,

Air exposure has a negative effect on cell density





High doses of radiation have a clear effect on cell survival Slight differences in dose levels do not result in a clear relationship with cell survival.

Future Plans

- Improved dose Calibration using an RCF Dosimeter and an external precision faraday cup to more accurately measure energy deposition and beam spot uniformity at the irradiation site
-Design and construct new sample holders for production runs
-Minimize air exposure of the cell samples caused by the removal of the cell supernatant during irradiation
-Optimal Drug/Radiation combination