## CLAIMS

1. A particle beam irradiation apparatus for charged particle cancer therapy of a tumor of a patient using a charged particle beam, comprising:

a synchrotron configured to accelerate the charged particle beam;

a respiration sensor configured to generate a respiration signal, the respiration signal monitoring a breathing cycle of the patient during use;

a rotatable platform configured to hold the patient, wherein said rotatable platform rotates through about three hundred sixty degrees during an irradiation period of the patient;

an injection system configured to inject protons into said synchrotron, wherein said injection system comprises:

a negative ion source configured to generate negative ions;

an ion beam focusing system configured to focus the negative ions along the a negative ion beam path inside a vacuum tube;

a tandem accelerator; and

a partial vacuum system,

wherein said synchrotron uses the respiration signal to deliver the charged particle beam to the tumor at a set point in the breathing cycle,

wherein said delivery of the charged particle beam at said set point of the breathing cycle occurs in greater than five rotation positions of said rotatable platform, and

wherein said tandem accelerator comprises a carbon foil in said negative ion beam path, wherein during use the negative ions that transmit through said carbon foil convert to protons along a proton beam path, wherein said carbon foil mechanically

couples to walls circumferentially surrounding the negative ion beam to yield a vacuum barrier between a negative ion beam side of said carbon foil and a proton beam side of said carbon foil.

2. The apparatus of Claim 1, wherein said respiration sensor comprises a force meter replaceably attached to the patient's chest.

3. The apparatus of Claim 1, wherein said respiration sensor comprises:

a first thermal resistor positioned proximate the patient's nose;

a second thermal resistor positioned both out of an exhalation path of the patient and in the same local room environment as said rotatable platform,

wherein said respiration signal is generated using differences between readings from said first thermal resistor and said second thermal resistor.

4. The apparatus of Claim 1, further comprising:

a display screen connected to an upper portion of said rotatable platform, said display screen displaying breath control commands to the patient.

5. The apparatus of Claim 4, wherein said respiration signal is used in generating said breath control commands and wherein said breath control commands comprise a visual countdown on said display screen to when the patient's breath is to be held.

6. The apparatus of Claim 1, wherein said delivery of said charged particle beam at said set point of said breathing cycle occurs in greater than twenty rotation positions of

said rotatable platform, wherein ingress energy of said charged particle beam is circumferentially distributed about the tumor.

7. The apparatus of Claim 6, wherein said delivery of said charged particle beam delivers none of said ingress energy to the patient's spinal cord or eye.

8. The apparatus of Claim 1, wherein said negative ion source comprises:

a high temperature plasma chamber;

a magnetic material within said high temperature plasma chamber, wherein said magnetic material provides a magnetic field barrier between said high temperature plasma chamber and a low temperature plasma region.

9. The apparatus of Claim 1, wherein said ion beam focusing system comprises:

a first electrode circumferentially surrounding said negative ion beam path; and

a second electrode partially obstructing said negative ion beam path with a conductive mesh,

wherein electric field lines run between said conductive mesh and said first electrode,

wherein said electric field lines focus said negative ions along said negative ion beam path.

10. The apparatus of Claim 1, wherein said partial vacuum system comprises:

a turbo molecular pump pumping air out of said vacuum tube into a holding volume;

a pressure sensor sensing a pressure in said holding volume;

a controller receiving said pressure from said pressure sensor, wherein said controller instructs an actuator to open a valve when said pressure crosses a threshold; and

a semi-continuously operating pump removing pressure from said holding volume, wherein said semi-continuously operating pump operates in coordination with said actuator opening and shutting said valve.

11. The apparatus of Claim 1, wherein said synchrotron comprises four turning sections, wherein each of said turning sections turns said charged particle beam about ninety degrees.

12. The apparatus of Claim 11, wherein each of said four turning sections comprises four main bending magnets.

13. The apparatus of Claim 12, wherein each of said main bending magnets comprises two beveled edges, wherein each of said two beveled edges focus said charged particle beam.

14. The apparatus of Claim 1, wherein said synchrotron comprises no quadrupole magnets about a circulating path of said charged particle beam in said synchrotron.

15. The apparatus of Claim 1, wherein said synchrotron comprises a circumference of less than sixty meters and at least thirty edge focusing surfaces, wherein an edge focusing surface comprises a beveled edge of a main bending magnet.

16. The apparatus of Claim 1, wherein said synchrotron comprises only four turning sections, wherein each turning section comprises at least four bending magnets, and wherein each bending magnet comprises at least one focusing edge.

17. The apparatus of Claim 1, wherein said synchrotron comprises:

exactly four turning sections; and

no quadrupoles about a circulating path of said charged particle beam in said synchrotron.