ACCELERATOR SURVEY AND ALIGNMENT AT THE ITALIAN NATIONAL CENTER FOR ONCOLOGICAL HADRONTHERAPY

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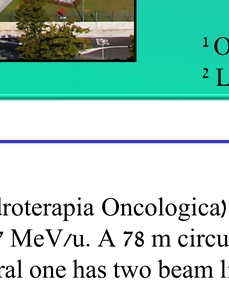
INTRODUCTION

The CNAO (Centro Nazionale Adroterapia Oncologica) is the first medical accelerator facility for deep hadrontherapy with C^{6+} and protons in Italy. Two Electron Cyclotron Resonance (ECR) ion sources produce a beam injected into a LINAC where it is accelerated at 7 MeV/u. A 78 m circumference synchrotron stores and accelerates carbon ions beam up to 400 MeV/u and protons up to 250 MeV. The beam extracted from the synchrotron can be delivered on four lines in three treatment rooms: the central one has two beam lines, one horizontal and one vertical; the laterals have an horizontal beam line each. The beam path from sources to patient, despite being compact with respect to similar accelerator complex, is rather long and many optical components contribute to the beam shaping. All these components need to be accurately aligned in a well defined position in order to accomplish their tasks. This poster shows the alignment method, the survey instruments and the software used for positioning both beam diagnostic devices and magnets.

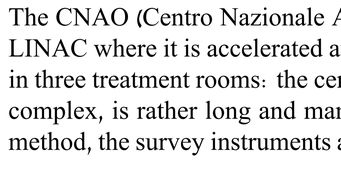
SURVEY INSTRUMENTS

➢ Laser tracker Leica LTD500

➢ Optical auto-level Leica NA2 equipped with plane parallel plate micrometer GPM3



➢ Total station Leica TDA5005



➢ Micro-alignment telescope Taylor-Hobson

ALIGNMENT NETWORK

➢ SYNC alignment network survey

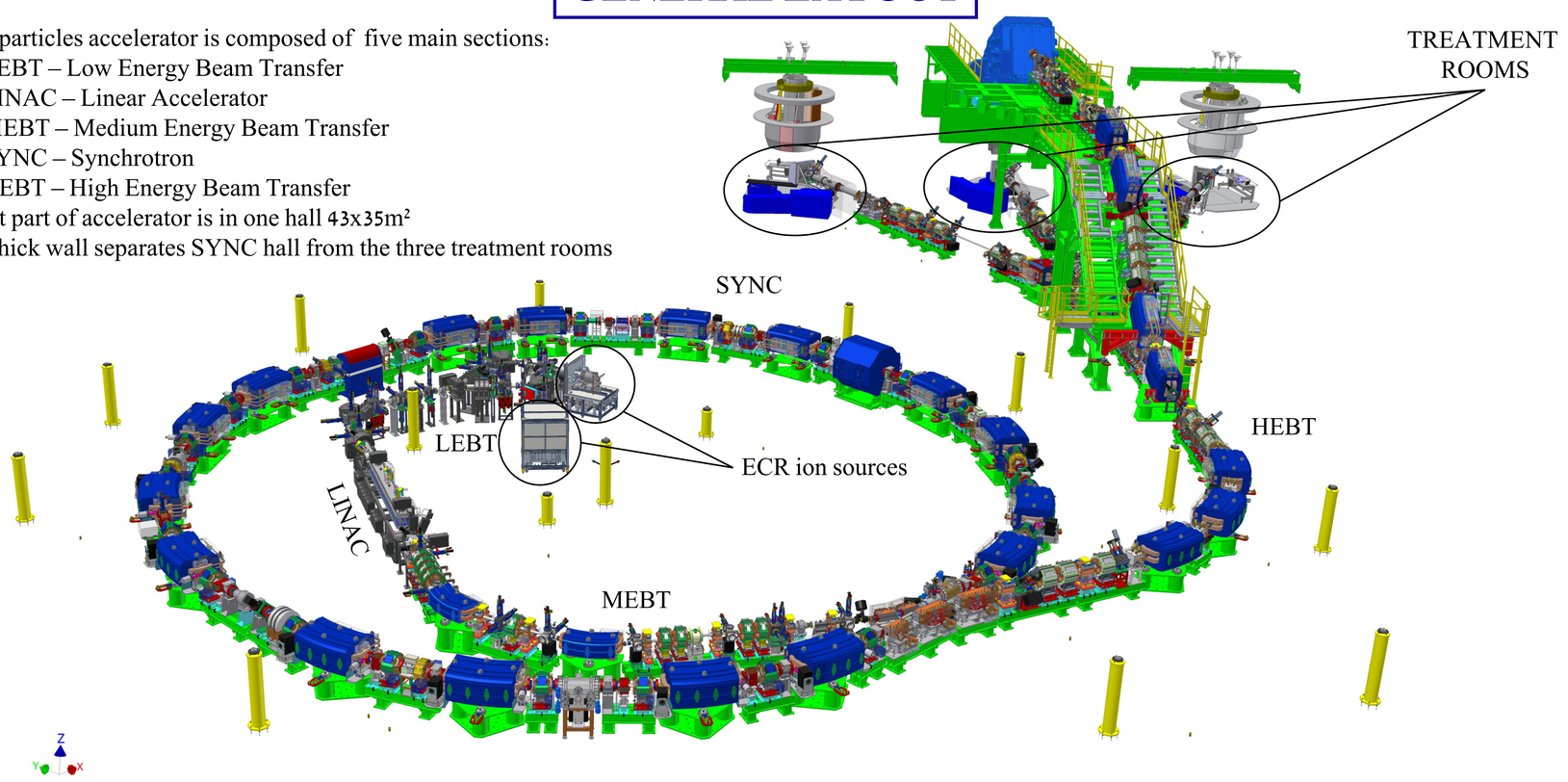
- 15 pillars with adjustable plates
- 20 ground sockets
- 18 magnetic wall sockets

- 11 laser tracker stations
- 135 points measured
- Axyz bundle adjustment
  total RMS 60 μm
  Max. ponting error exceeded 0.25 mm

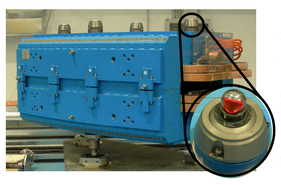
GENERAL LAYOUT

➢ The particles accelerator is composed of five main sections:
- LEBT – Low Energy Beam Transfer
- LINAC – Linear Accelerator
- MEBT – Medium Energy Beam Transfer
- SYNC – Synchrotron
- HEBT – High Energy Beam Transfer

➢ Most part of accelerator is in one hall 43x35m²
➢ 2m thick wall separates SYNC hall from the three treatment rooms



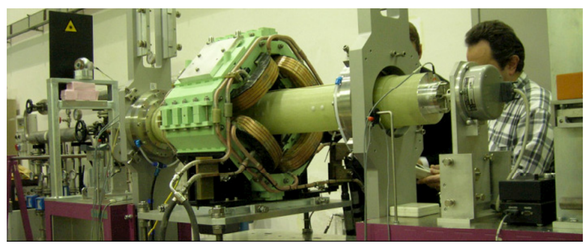
DIPOLES



➢ 16 SYNC dipoles each one equipped with 4 CERN socket-type fiducials and positioned along straight line. They can be used as holders for theodolite tribrach with auto-centering pin.

➢ Mechanical fiducialisation by means of LTD500

QUADRUPOLES AND SEXTUPOLES

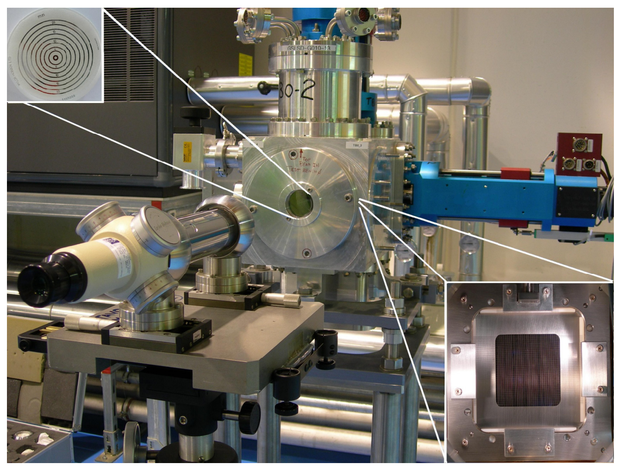


➢ 24 SYNC quadrupoles and 5 sextupoles.
➢ 37 HEBT quadrupoles.
➢ Magnetic measurements by means of Danfysik rotating coil bench.
➢ Mechanical measurements by means of LTD500 using customized tools: alignment table with micrometric measuring slides and Taylor-Hobson spheres.

ALIGNMENT JOB

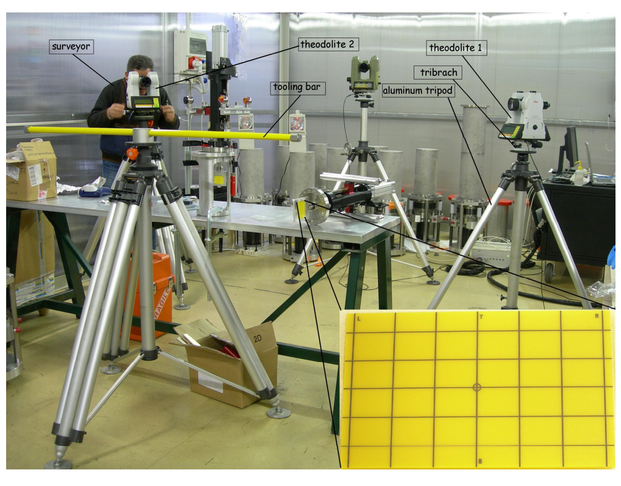
➢ For most part of magnets and diagnostic each component has its own regulation table; levelling screws, indipendent of horizontal regulation ones, make the alignment job easy and flexible.
➢ Stiffness of straight lines is guaranteed by girders.
➢ Same network references used for alignment of all components which belong to the same straight accelerator sector.
➢ Update network coordinates each time best-fit of some points exceeds 0.1mm respect to previous set of coordinates.
➢ Installation and alignment activities performed in three and half years.

PROFILE GRID



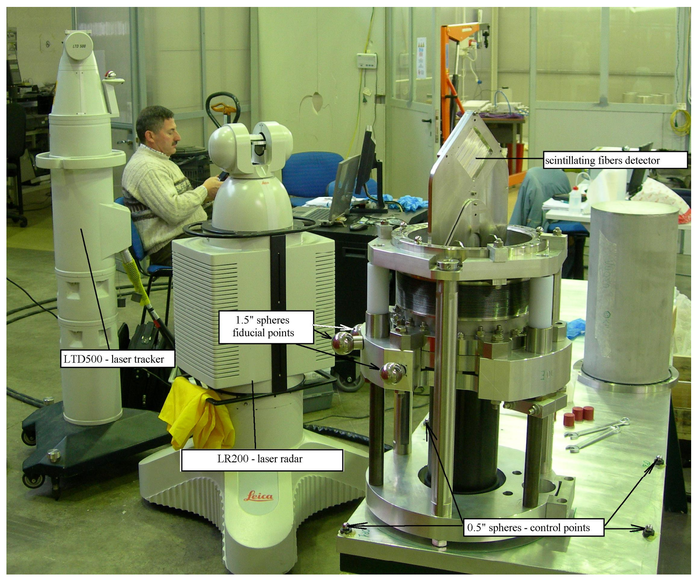
➢ A profile grid is aimed to measure beam transversal profile in both horizontal and vertical planes. Grid monitor consists in a given number of thin wires, arranged as a harp and is used in the LEBT and MEBT lines where the beam is pulsed. The detector is mounted on a pneumatic actuator and the whole device is inserted into a vacuum tank. The qualification purpose is to know exactly where the centre of the grid respect to the nominal beam-line is.
➢ A micro-alignment telescope of Taylor-Hobson is positioned along the tank beam-line which is the virtual line passing through the centre dots of two glass targets at the tank's entrance and exit. A very precise alignment is possible using levelling screws of tank and measuring slides of the telescope table. After the telescope crossline is perfectly coincident with the centre dots, the detector is moved and the offset checked. A customized mask, applied on the detector frame, locates the square of wires at the centre. Fine regulations screws on the actuator's frame can finally align this square with the telescope crossline. Fiducials on the tank are finally measured respect to the telescope cylinder and glass targets, by means of laser tracker. The overall accuracy obtained is 0.1 mm, which is the same order of magnitude of wire's diameter.

TV-SCREEN



➢ Two monitors, consisting of a luminescent screen read-out by a radiation-hard camera, are installed in the synchrotron injection/extraction vacuum chamber to measure transverse size and position of the beam injected into the SYNC ring and after the first turn. Screens are made up of zirconia material. On each screen, which is driven by pneumatic actuator, a mask is engraved to give the user reference points to reconstruct beam position.
➢ The qualification job consists on relating the screen geometry to 6 fiducial points for both monitor. The solution adopted is a Theodolite Measurement System (TMS): two motorized theodolites Leica TM5100A, a carbon fiber tooling bar and the software Axyz. The points to be collimated on the screens are the interception between horizontal and vertical serigraphy lines.
The total RMS is 10 μm.

SCINTILLATING FIBER HARPS



➢ A Scintillating Fiber Harp (SFH) is the profile and low-bandwidth intensity beam monitor designed by Laboratoire Leprince-Ringuet (LLR-Paris) and installed along HEBT lines. The detector consists of 128 scintillating fibers in the horizontal plane and 128 in the vertical plane, covering an area of 64x64 mm². The signal of the fibers is acquired through a CCD firewire camera. Detector and camera are mounted on a frame equipped with a pneumatic actuator.

➢ The LR200 laser radar, the first non-contact measurement device to combine radar, laser and 3D software technologies with an accuracy up to 20 μm, has been the solution adopted for qualification of 24 SFH detectors. The instrument can scan all types of surface through a cloud of points. In the specific case is sufficient to scan 2 precise circular holes ϕ4 mm, the frame plane on which fibers are mounted and 6 spheres 1.5". All data are acquired and analyzed by Spatial Analyzer (New River kinematics)

PICKUPS

➢ 20 capacitive pickup detectors for SYNC: 9 for vertical plane and 11 for horizontal one. Pickup detectors measure the beam centre of mass transverse position in a not-interceptive way. A pick up detector is a metallic box divided in two halves and inserted into a metallic body which is grounded. The capacitive coupling between body and the electrodes determines the signal generation when the particles bunch passes through the detector.
➢ The qualification job is divided into two phases: measuring the electrodes mechanical centre first and the electrical centre after.
Each pick-up was measured through a Coordinate Measurement Machine (CMM). On each pick-up a survey table, consisting of two orthogonal planes, is screwed on a reference plate and can be repositioned using two precision pins.
➢ For the electrical centre measurements, a metallic wire, connected to encoders, was stretched along the longitudinal direction and moved in transversal directions. Injecting a sinusoidal signal into the wire a signal is induced on the pick-up electrodes.

CONCLUSIONS

Installation and alignment of all components are complete. Presently accelerator commissioning is ongoing and protons beam stored in SYNC. Future activities on alignment network monitoring and, eventually, smooth alignment corrections are foreseen during accelerator shut down periods.