CNAO

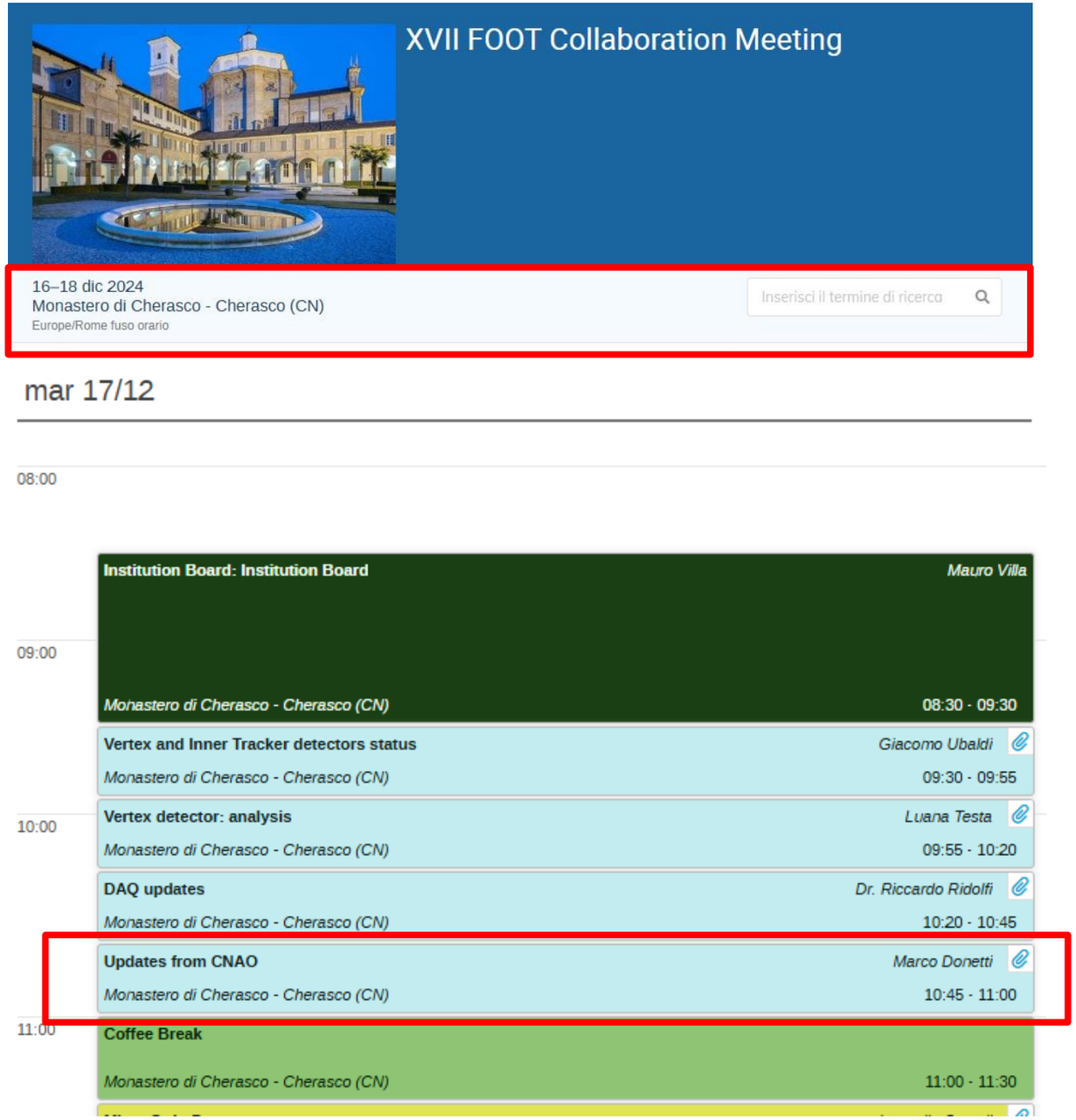
Centro Nazionale di Adroterapia Oncologica

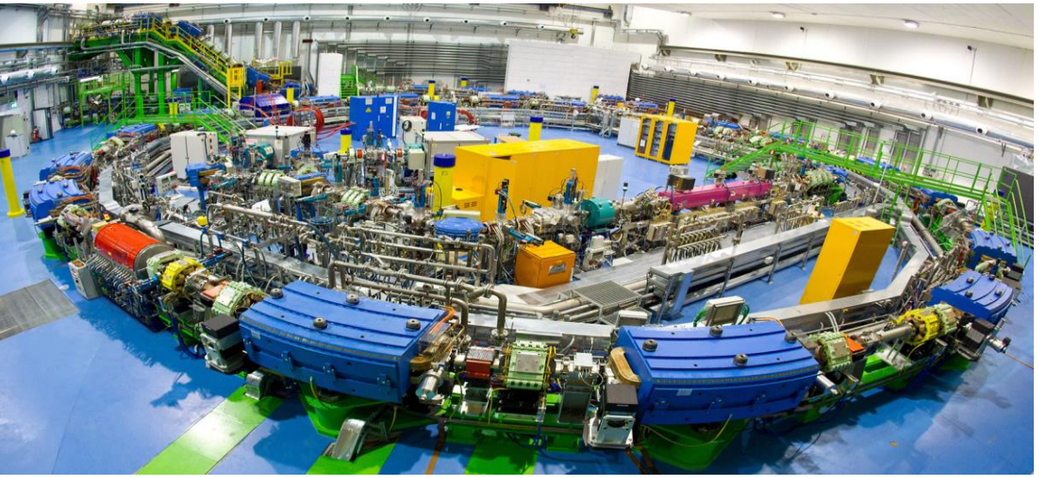
Activities at CNAO

A. Mereghetti, M. G. Pullia

Last Update

Last update on CNAO activities given by M. Donetti at the last FOOT General Meeting (Monastero di Cherasco, Dec 2024)





Outlook

- Introduction
- CNAO Expansion Project
- RFKO and Multi-Energy Extraction
- Third Source and He-Beams Commissioning

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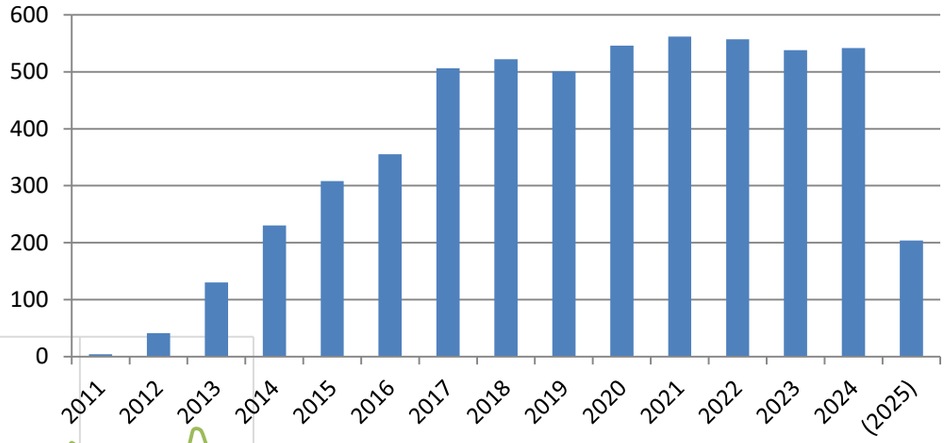
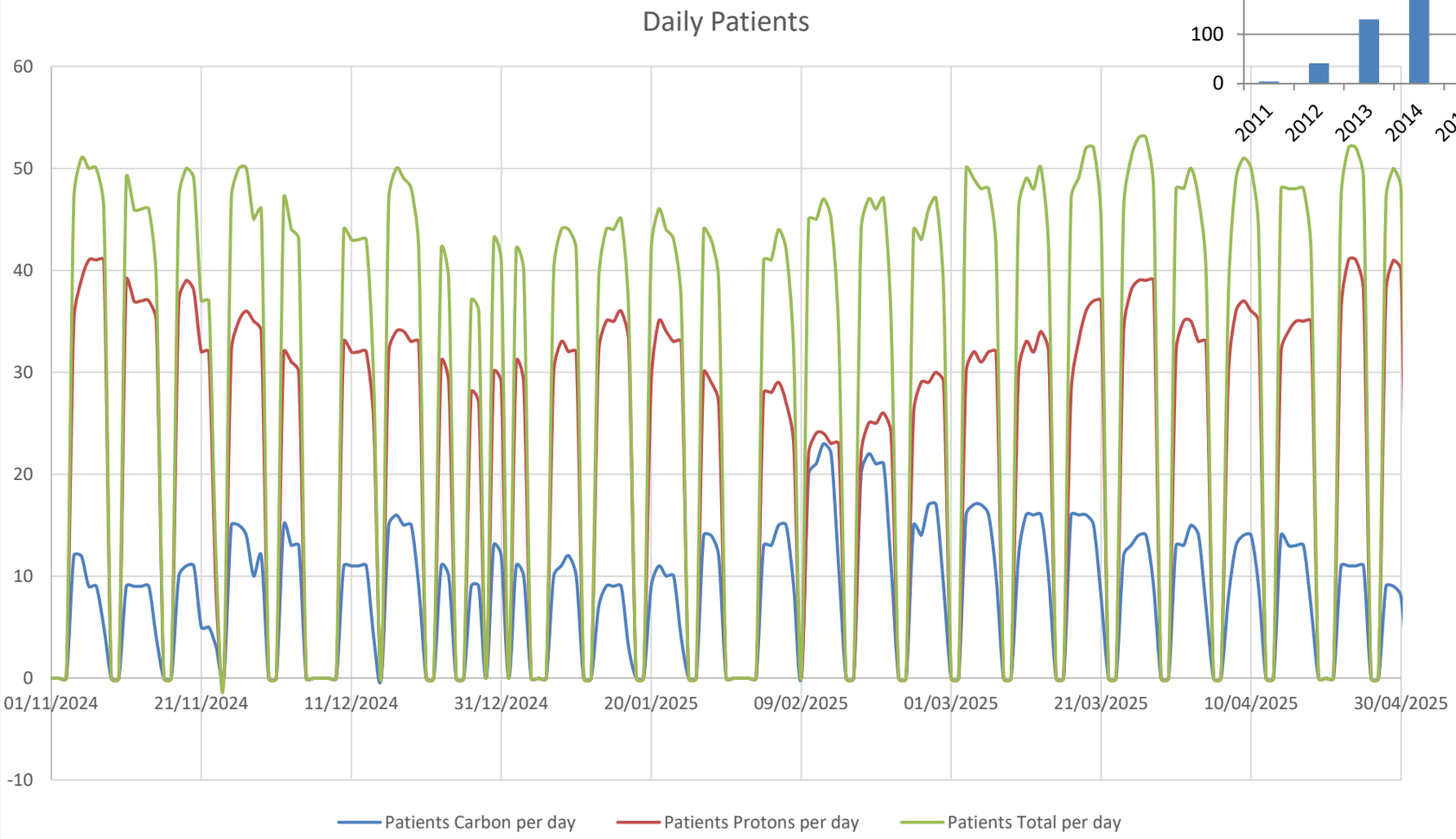
Daily patients





Courtesy of M. G. Pullia

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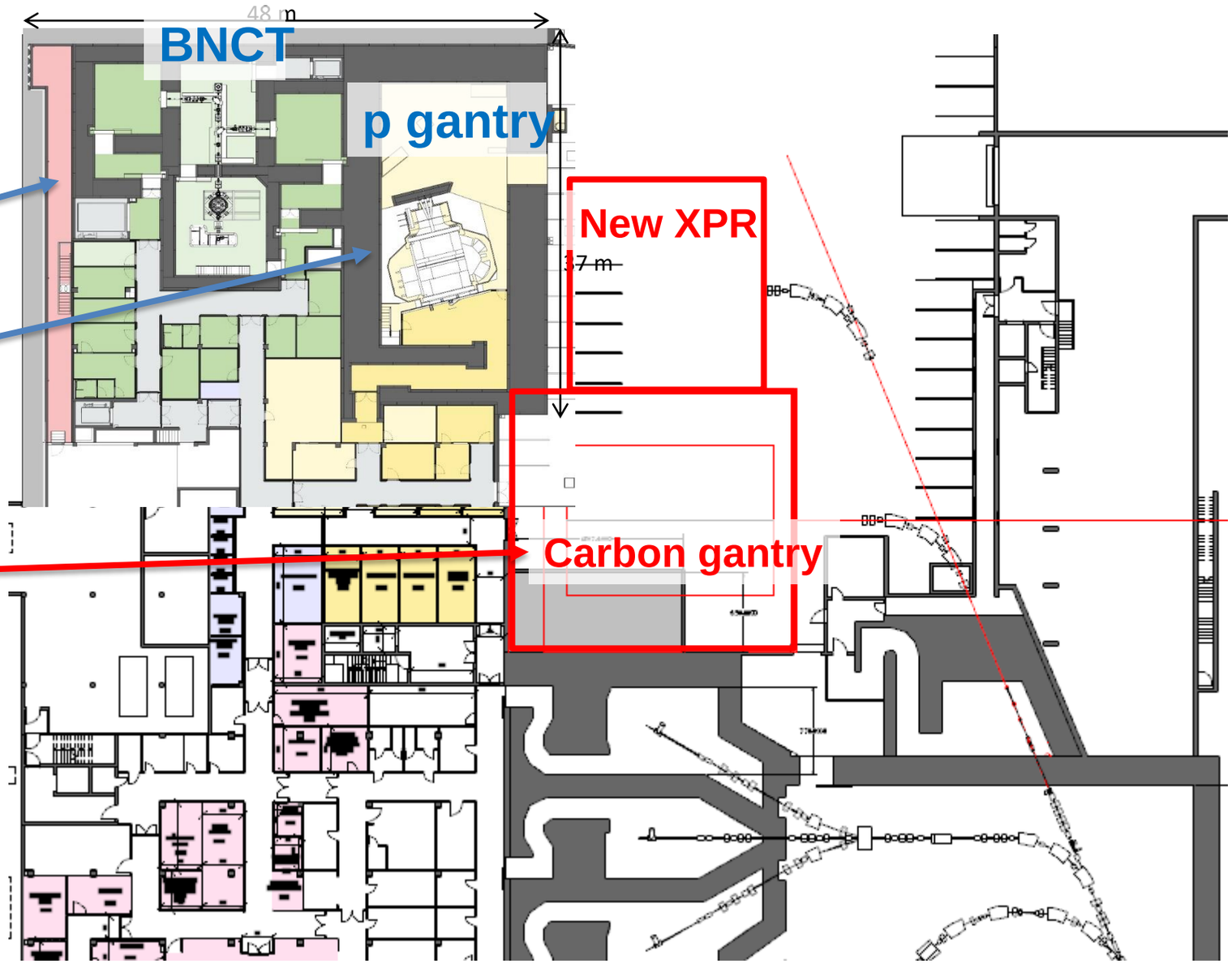
CNAO Expansion

CNAO is carrying out a massive [expansion project](), with the addition of two new machines:

1. BNCT;
2. Single room proton-therapy machine, with gantry;

At the same time, we are designing a superconducting carbon-ion gantry, to be connected to the existing synchrotron;



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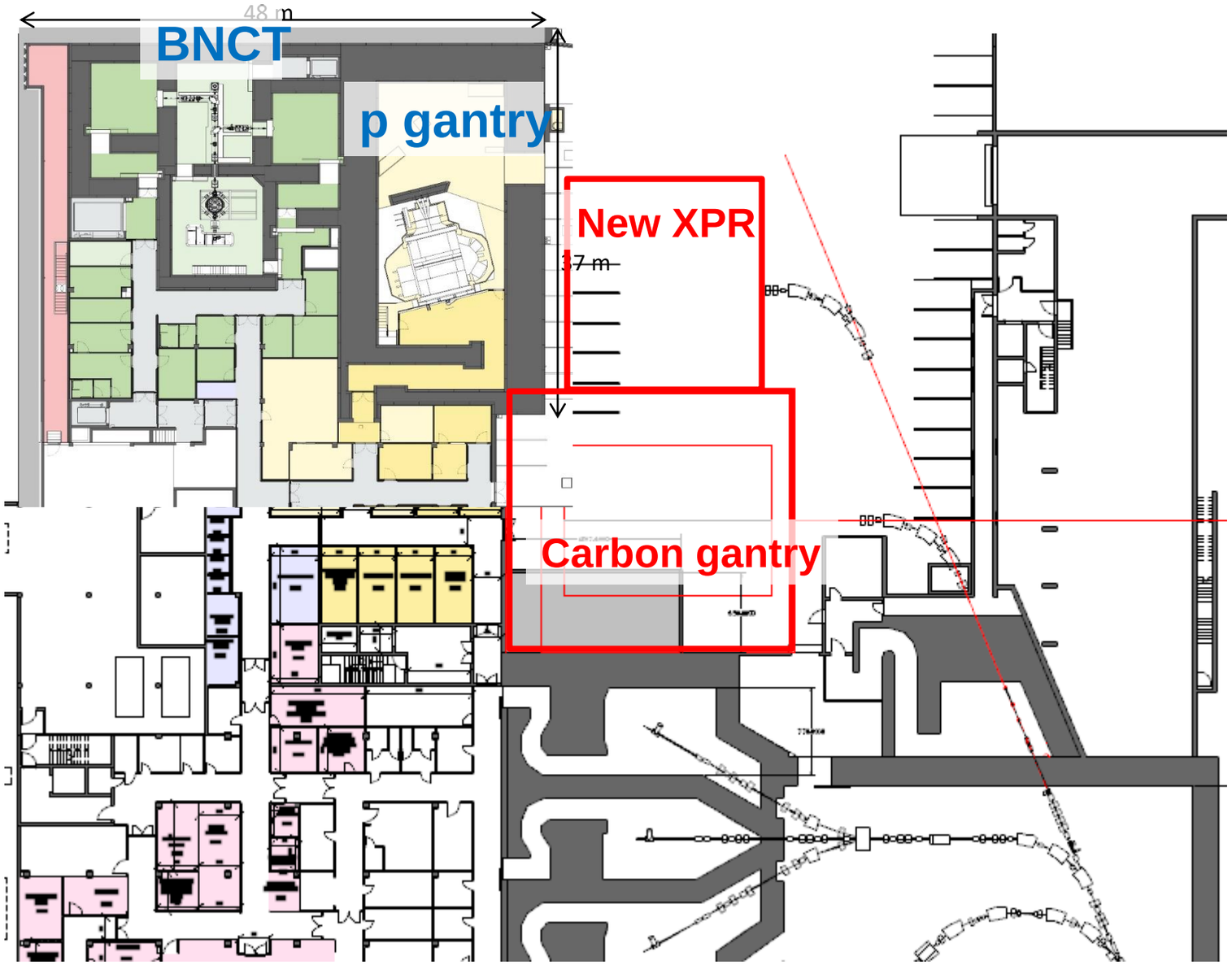
Construction Works

- Walls are practically completed.
- End of works is now scheduled on August 31st.
- Plants have been energized on September 9th, 2024; still to be tested properly (no load at the moment).

Courtesy of G. Venchi



Hitachi Installation

Almost complete

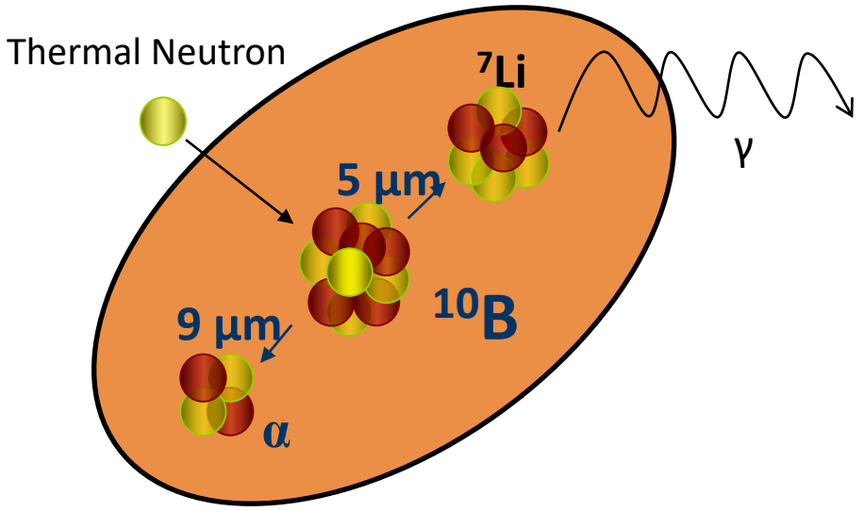
March 2025

Almost all magnets have been installed and aligned – vacuum chambers to be inter-connected;
Commissioning with beam optimistically starting in Sep 2025;

Boron Neutron Capture Therapy

Boron Neutron Capture Therapy (BNCT)

- The patient is given a ^{10}B-added drug, mainly methabolised by tumor cells;
- Under neutron irradiation, ^{10}B undergoes fission, yielding to two charged hadrons with very short range;
- Tumor volume irradiation is optimised not by means of a dose distribution system, but by the methabolism of the tumor (differential drug uptake);



Pavia was at the forefront of BNCT research activities in 2000s with the TAOrMINA project:

- 2 explanted livers drugged with ^{10}B irradiated at the LENA nuclear reactor in Pavia;
- Patients were terminally ill: one survived only for few days after re-implantation, the other one lived for almost 4 years!

Non-comprehensive bibliography:

- Pinelli T. et al., TAOrMINA: from the first idea to the application to the human liver (2002)
- Zonta A. et al., La terapia per cattura neutronica (BNCT) dei tumori epatici diffusi: prima applicazione clinica (2003);
- Zonta A. et al., Clinical lessons from the first applications of BNCT on unresectable liver metastases (2006);
- Protti N., La Terapia per Cattura Neutronica con Boro (Boron Neutron Capture Therapy, BNCT) (2012)

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BNCT@CNAO

- There are still a number of open points:
  - Hydrogen management
  - SF6 management
  - Fire load / plastic content of the rooms
  - Structure of the BSA still evolving
  - Nuclear safety system
- These points are preventing the design of the plants to be completed
- We are also introducing modifications to allow the continuous infusion of the boron drug into the patient during irradiation.
- Still no installation plan available from TAE.

Courtesy of G. Venchi

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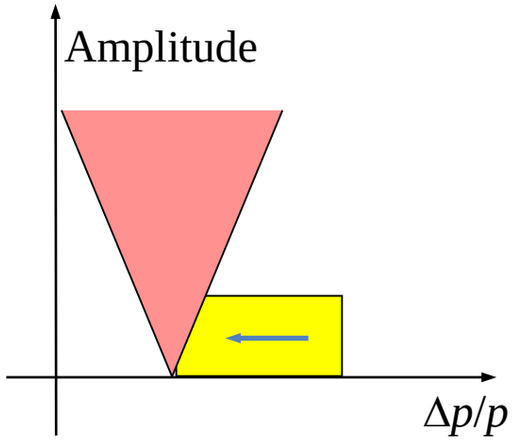
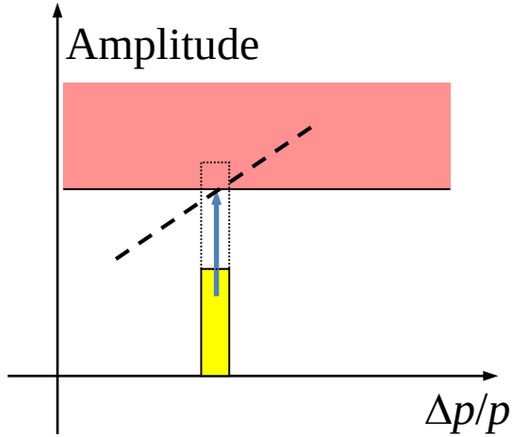
RFKO Extraction

Amplitude-momentum selection (Betatron core based extraction)



Currently used for Carbon ion beams
→ on-going migration to RF-KO;

RF-KO



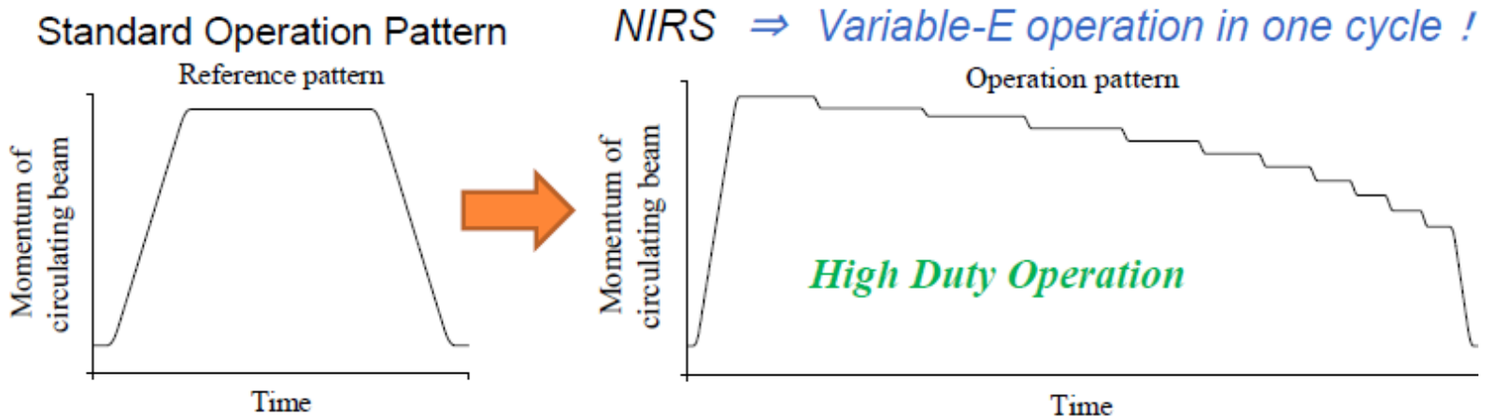
Currently used for proton beams

- Protons: clinically operational since 13th May 2024;
- Carbon ions:
  - We commissioned 4 intensities (8e7, 4e7, 1.6e7, 0.8e7 ions/s) in all the rooms.
  - Waiting for final commissioning by the Medical Physicists

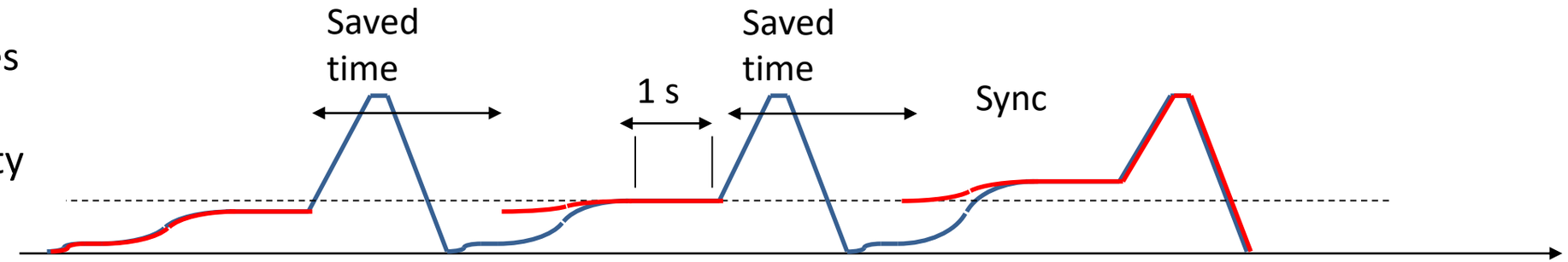
Multi-Energy Extraction

Use remaining beam after slice completion

Recent tests in machine (17-18 May 2025), to verify that the timing system correctly handles the information of beam intensity in machine;



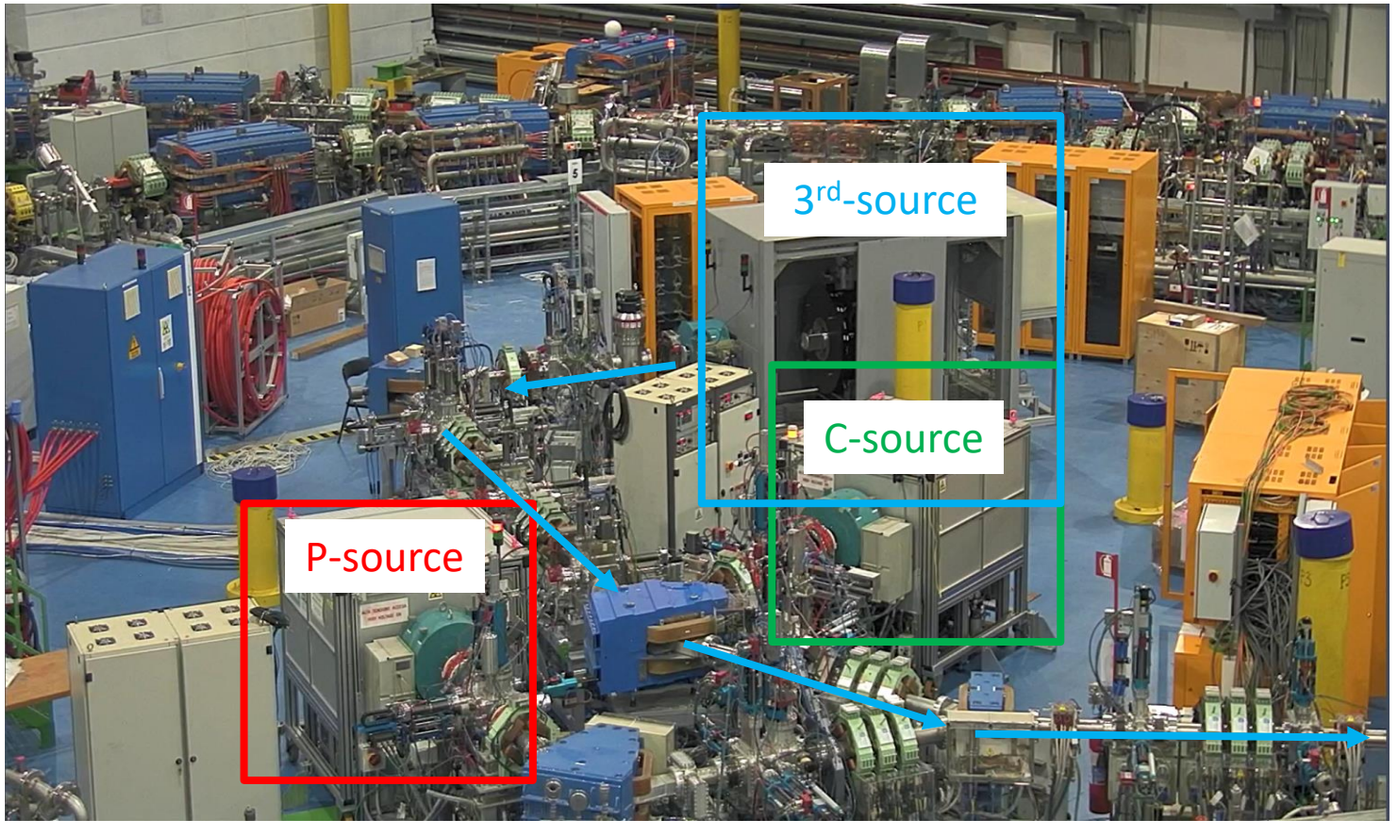
(Courtesy K. Noda – CAS Medical)



Third Source

- Third source: AISHA2, by LNS;
- Installed in 2022, we had to wait for the new RP legal allowance (July 2024) to turn it on;
- New species available, candidates for both clincial applications and non-clinical research activities;

species	A	Q source
C	12	4
O	16	6
Fe	56	19
Li	7	3
He	4	2



Third Source: Helium Commissioning

2024-09-29: commissioning started;

2024-11-14: He arrived at RFQ entrance;

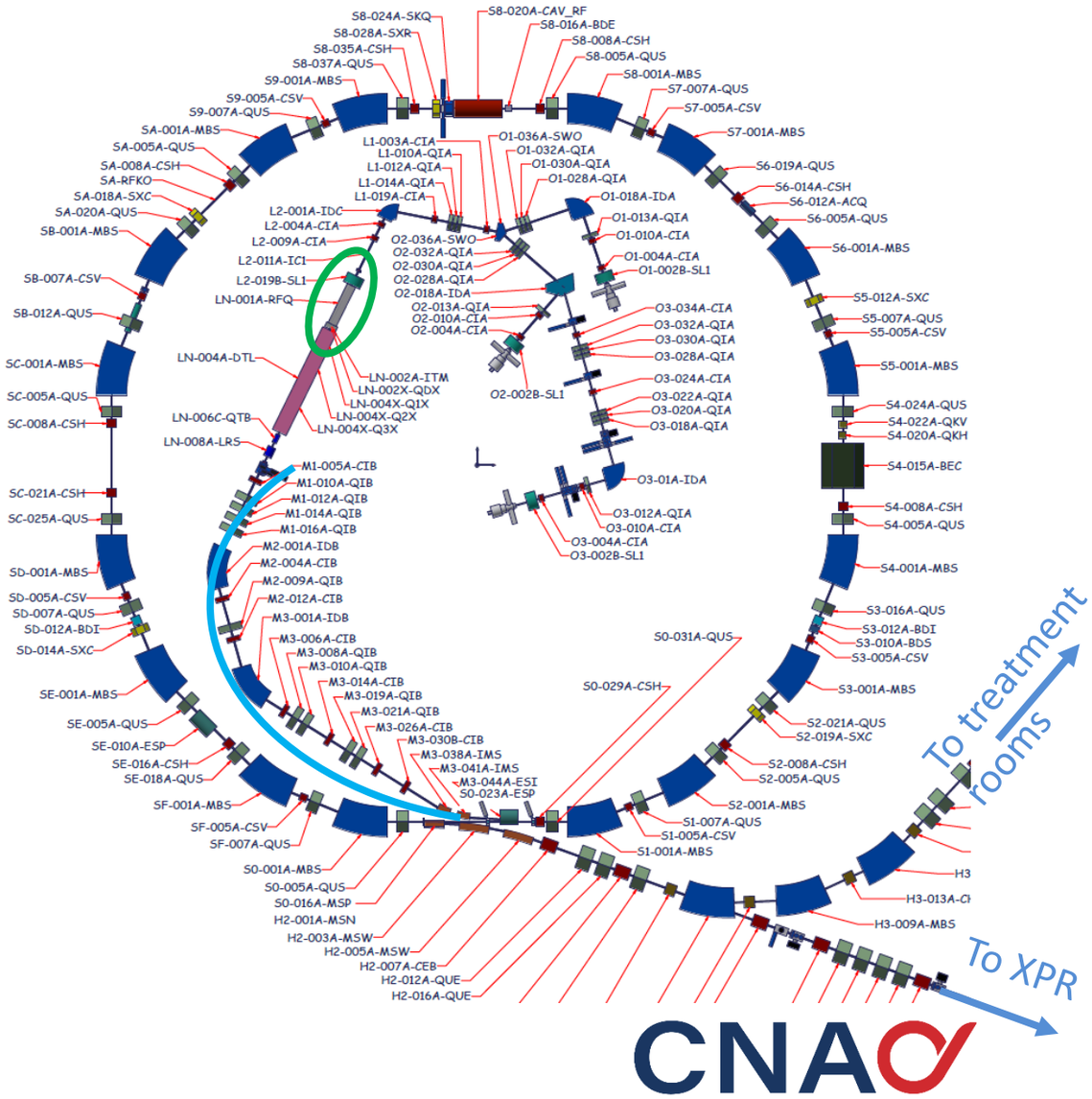
2024-12-15: He through the LINAC;

2024-12-21.22: MEBT commissioning;

(two weeks stop due to a failure of a turbo vacuum pump)

2025-01-25: injection into synchro and acceleration up to 227 MeV/u (i.e. 320 mm WET);

2025-02-15: He beam in treatment room 1;



Third Source: Helium Beam to Treatment Room (2025-02-15)!

Third Source: Helium Commissioning (II)

2024-09-29: commissioning started;

2024-11-14: He arrived at RFQ entrance;

2024-12-15: He through the LINAC;

2024-12-21.22: MEBT commissioning;

(two weeks stop due to a failure of a turbo vacuum pump)

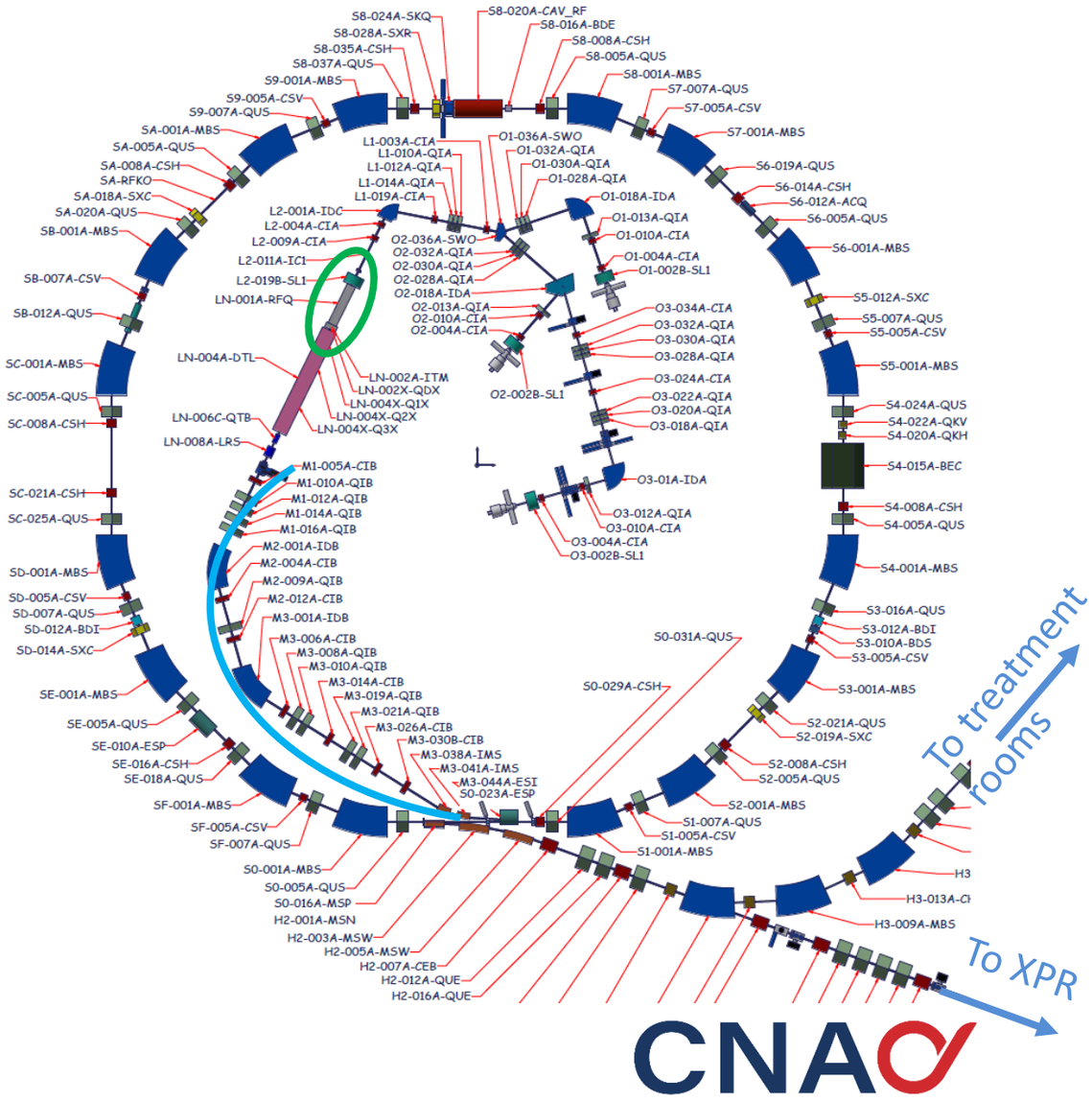
2025-01-25: injection into synchro and acceleration up to 227 MeV/u (i.e. 320 mm WET);

2025-02-15: He beam in treatment room 1;

2025-03: 1 month stop due to a fault;

2025-04: LEBT optics re-optimisation (to recover from fault) and optimisation of beam at ISO;

2025-05-06: new stop due to discharges (still to be solved);



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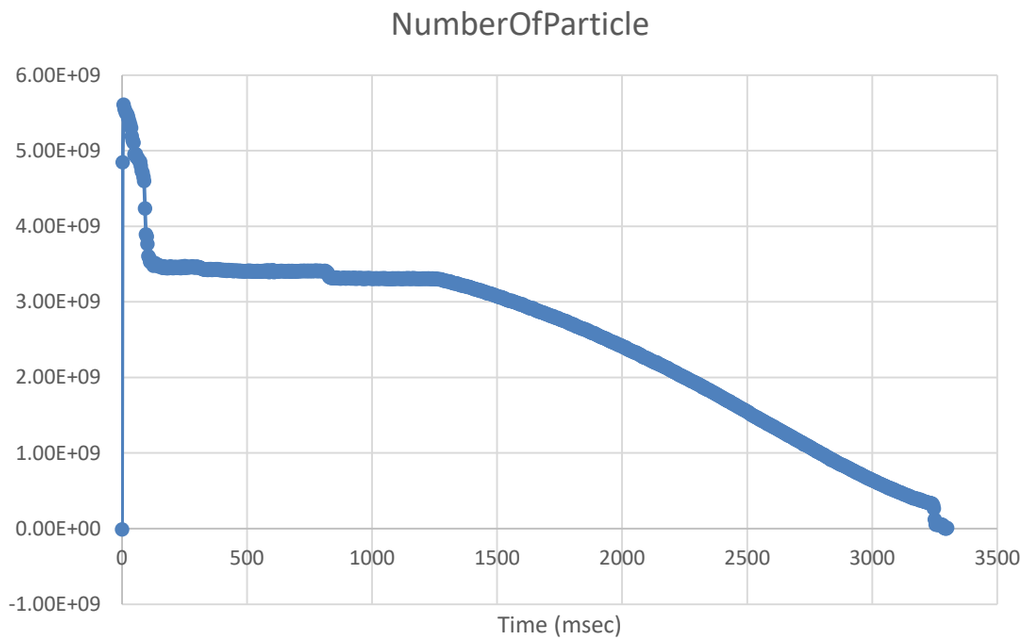
Third Source: Helium Commissioning (III)

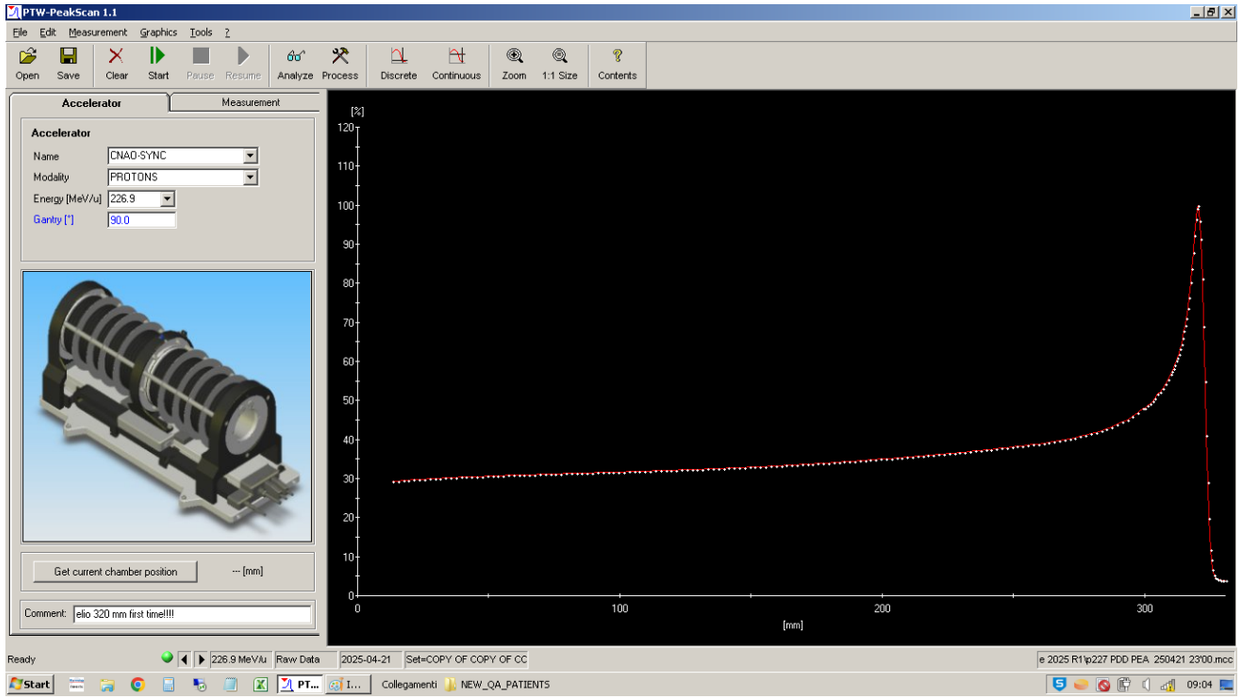
The first acceleration at 320mm .



	Pre Fault	Post Fault
Inj Part	6.50E+09	3.00E+09
Acc part	3.90E+09	1.50E+09
% Acc	60	50

Courtesy of L. Falbo et al.

Measured Depth=320.5mm



Courtesy of CNAO Med. Phys. Unit

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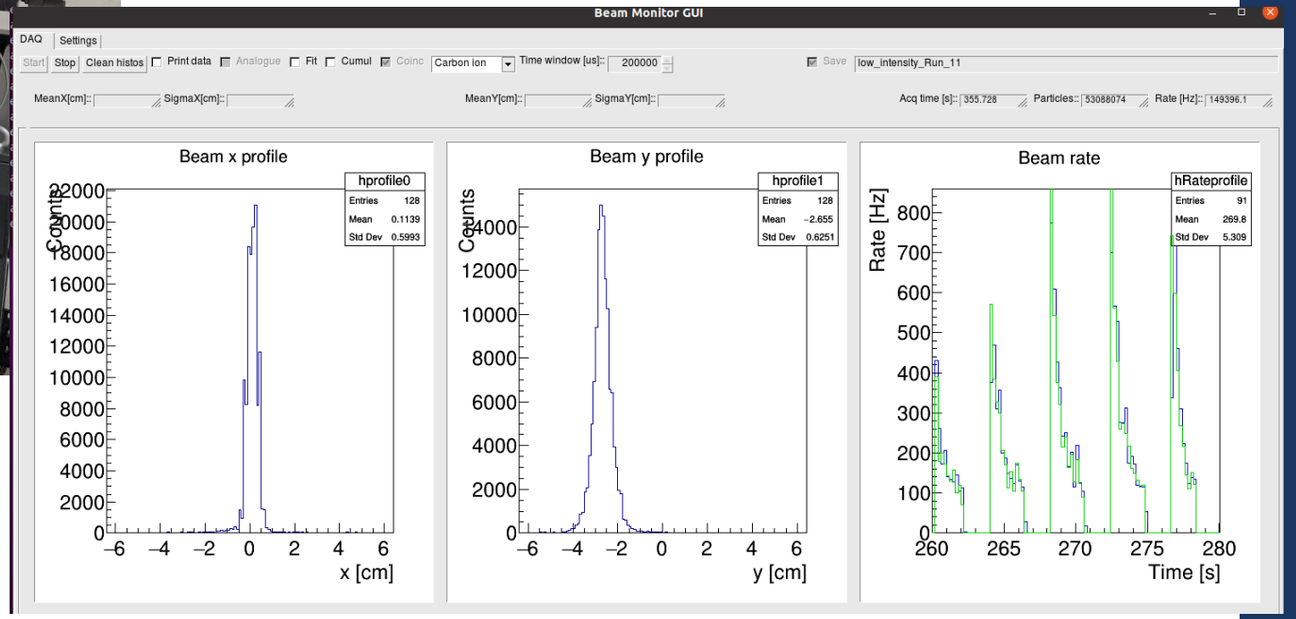
LENTO (Low intEnsity beam moNiTOr)

- For monitoring intensity and position of low intensity beams in the experimental room @ CNAO
- Scintillating fiber-based detector;
- Two orthogonally oriented fiber planes read-out by SiPMs;
- The whole active area of the detector is 12.8 x 12.8 cm^2.

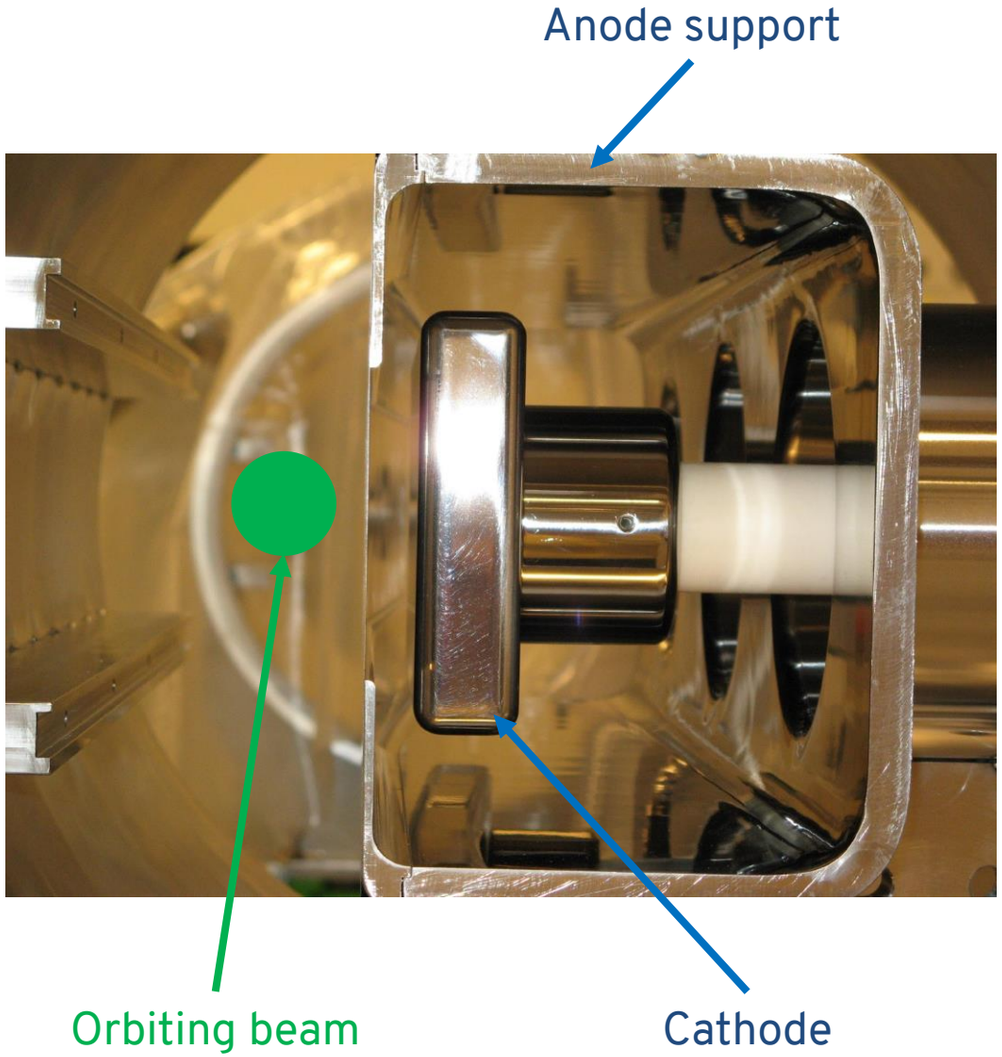
2025-05-24.25: First data taking with LENTO as part of the DDS monitor system at the NZL;

→ Still quite some work for a smooth system!



ESE2

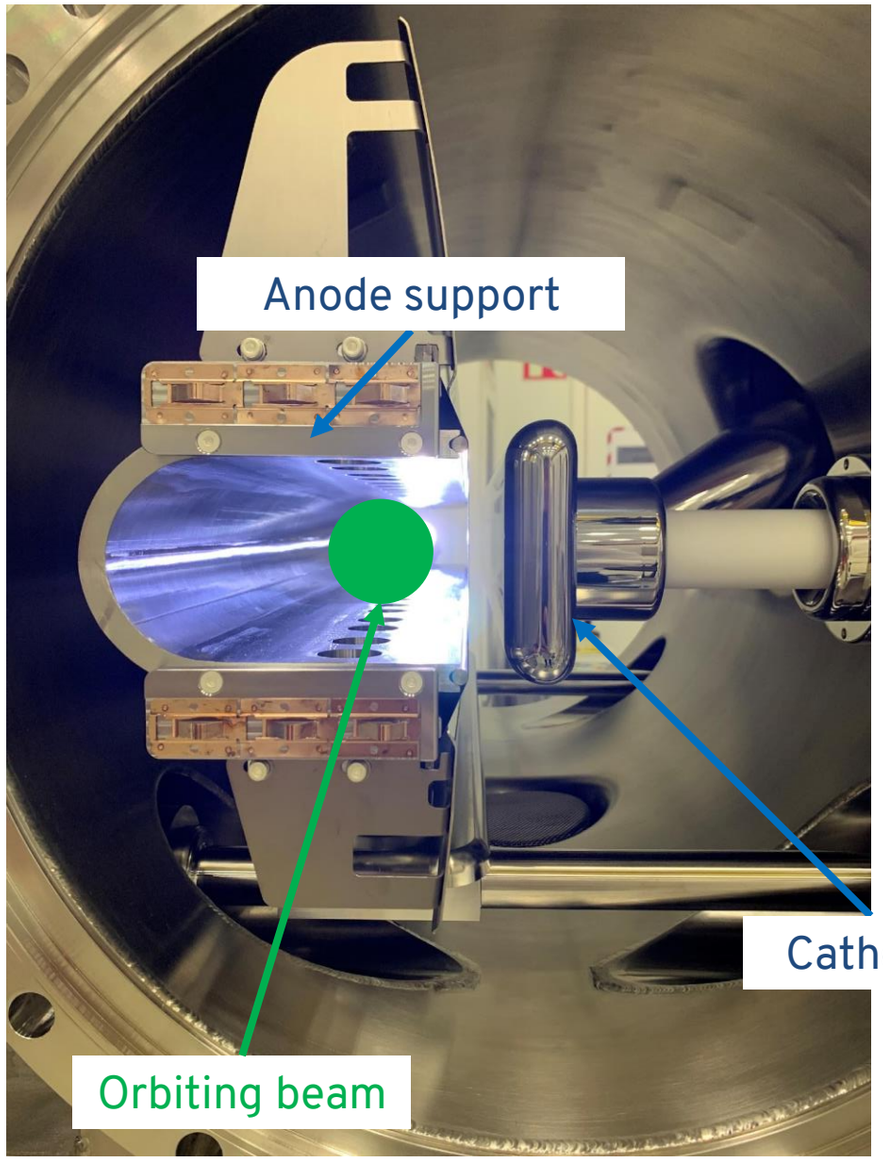
- The Electrostatic Septum (ESE) is an essential device in slow-extraction from a Synchrotron (as done in CNAO);
- The present CNAO septum (ESE1) was manufactured in 2008 in industry following a CERN design;
- A few flaws were discovered after installation:
  - The beam acceptance is reduced since the exit extrusion is not centred on the beam line, i.e. 20mm too close to the orbiting beam.
  - Consequently, the cathode and anode displacement range is compromised w.r.t. original requirement.
  - Although the nominal voltage is 70 kV, the HV feedthrough limitation of 100 kV, limited HV conditioning.
  - Furthermore, the cathode-inside-anode-support layout complicates conditioning as well.
  - The anode/cathode displacement system doesn't function remotely in operation.



Courtesy of J. Borburgh

ESE2 (II)

- **In 2020 a collaboration was launched between CERN and CNAO to design a new ESE (ESE2):**
  - To mitigate the shortcomings by design;
  - To take advantage of the latest developments in the field;
  - To upgrade the device to make it suitable for future operational parameters.
- **ESE2 arrived at CNAO late march 2025;**
  - Alignment qualification;
  - Vacuum conditioning;
  - Ready to move to synchrotron hall this Thursday/Friday;
  - Installation in synchrotron foreseen this Nov;



Further Info

New beams....

- He^{2+} beam at linac ✓
- He^{2+} ready by 2025 end
- O^{8+} in 2026
- In 2025 only p and C^{6+} beams availables ✓

M. Donetti, last FOOT General Meeting

Shifts ✓

- In 2025 quite large increase of shifts number
- Most of them dedicated to radiobiology and 'internal' research
- Number of 'external' shifts confirmed
- FOOT more than welcome

+ shifts for the second semester of 2025 should be circulated internally shortly

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CONTATTI

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PER COMBATTERE I TUMORI PIÙ DIFFICILI

Grazie per l'attenzione

Stage 1

Inserire descrizione

Stage 2

Inserire descrizione

Stage 3

Inserire descrizione