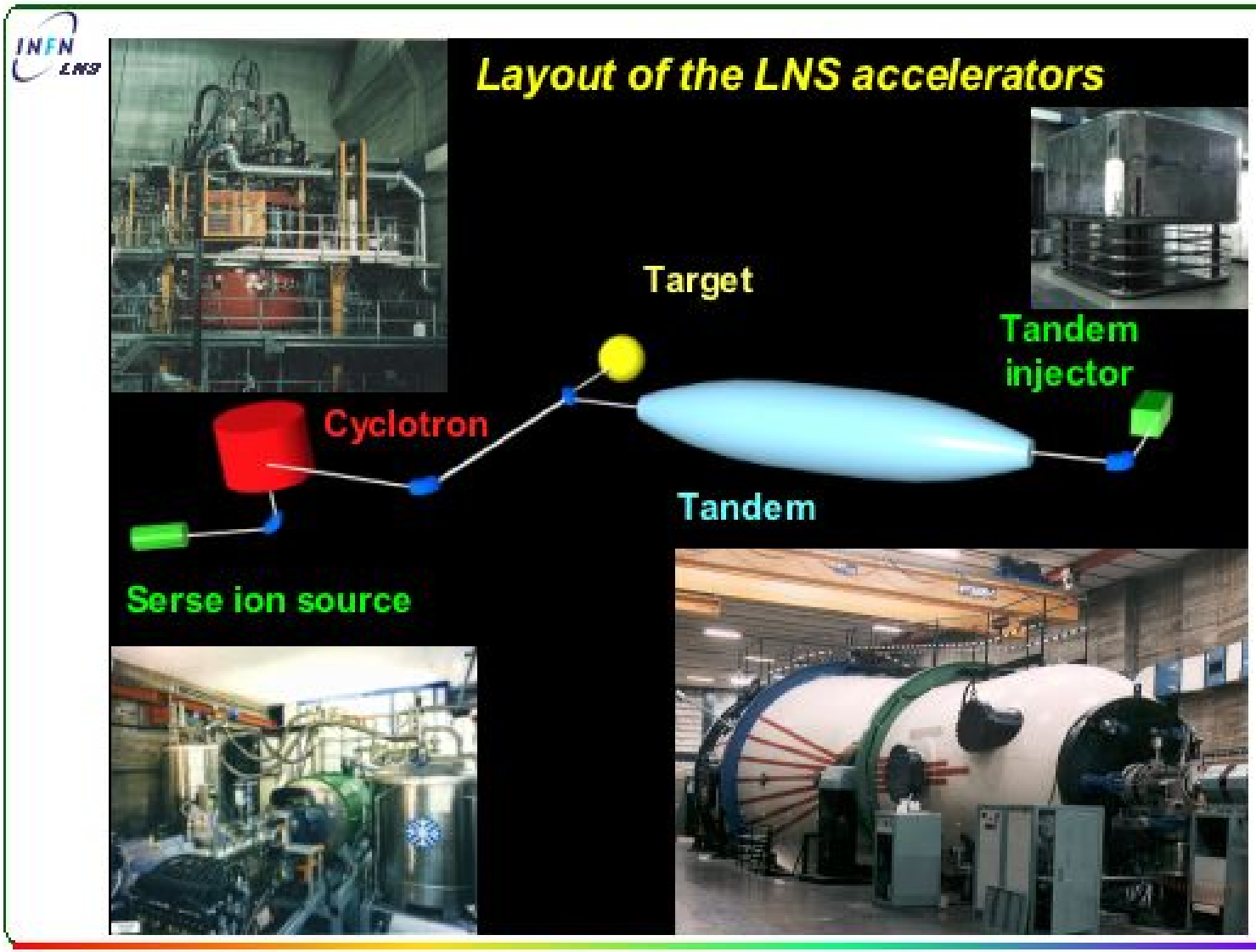
A short review of INFN irradiation facilities

D. Bisello, University & INFN Padova

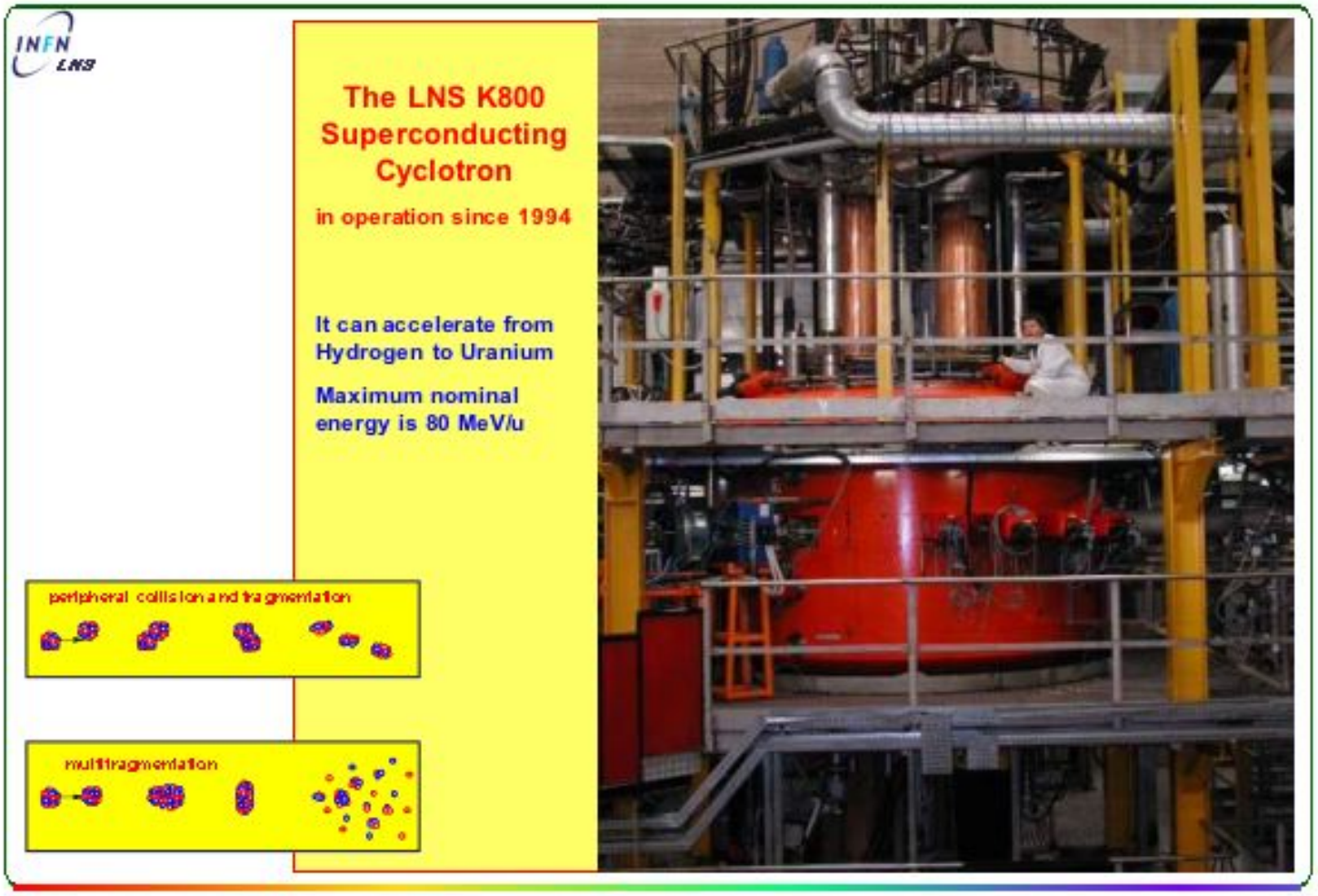
Only particle beams

- LNS
- LNF
- CNAO
- Trento hadroterapy center

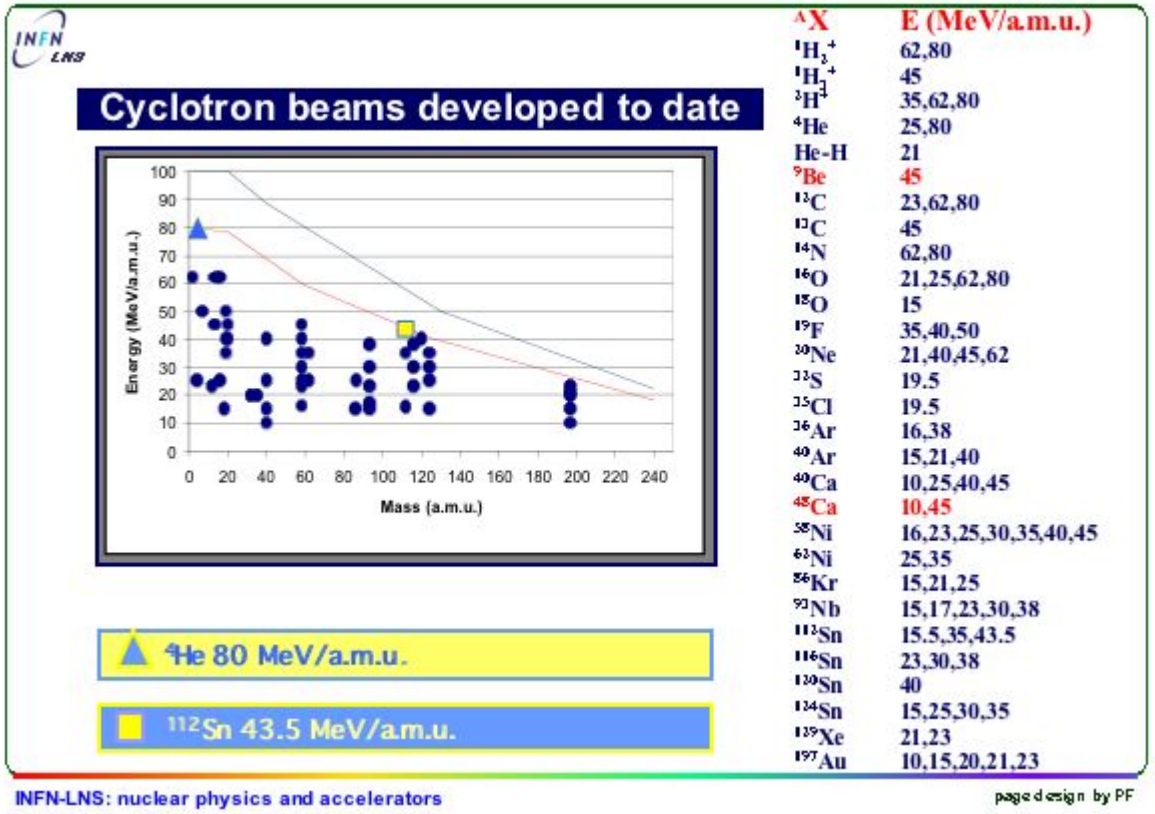
Laboratori Nazionali del Sud



The superconducting cyclotron



many new beams in addition to the Tandem ones



^{A}X	E (MeV/a.m.u.)
$^{1}H_{2}^{+}$	62,80
$^{1}H_{3}^{+}$	45
$^{3}H^{4}$	35,62,80
^{4}He	25,80
He-H	21
^{9}Be	45
^{12}C	23,62,80
^{12}C	45
^{14}N	62,80
^{16}O	21,25,62,80
^{18}O	15
^{19}F	35,40,50
^{20}Ne	21,40,45,62
^{32}S	19.5
^{35}Cl	19.5
^{36}Ar	16,38
^{40}Ar	15,21,40
^{40}Ca	10,25,40,45
^{48}Ca	10,45
^{58}Ni	16,23,25,30,35,40,45
^{62}Ni	25,35
^{86}Kr	15,21,25
^{93}Nb	15,17,23,30,38
^{112}Sn	15.5,35,43.5
^{116}Sn	23,30,38
^{120}Sn	40
^{124}Sn	15,25,30,35
^{129}Xe	21,23
^{197}Au	10,15,20,21,23

The irradiation facility

The LNS-IF site and the heavy ion dosimetry setup have been validated with an ESA audit on November 2009, exploiting a collaboration with MAPRAD. Two different dosimetry setups allow to study Single Event Effects (SEL, SEU, SEFI etc.) with 20 MeV/amu heavy ions, and Displacement Damage (non ionizing cumulative effects) with 62 MeV protons.

Both setups, located in a suitable hall along the 0-degree beam line, are placed in air just outside a thin cap on the beam pipe. They implement a motorized stepper with four degrees of freedom and position repeatability accuracy of 1 μm.

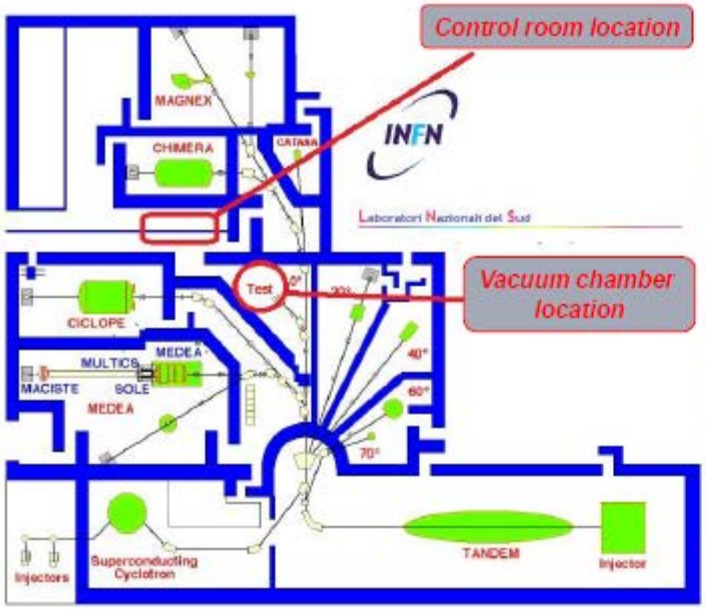
Ion	Energy [MeV]	Range in Si [μm]	Surface LET in Si [MeV cm^2 mg^{-1}]
Ne	28	>100	3.7
Ar	56	>100	13.13
K	80	>100	30.6
Xe	94	>100	52.9

The 0 degree experimental Hall

- Proton, carbon and other beams
- Relative and absolute dosimetry
- Radiation damage for aerospace applications
- Dosimetry and radiobiology irradiation in-air and also in the vacuum chamber
- Fast and easy positioning systems
- Not particular constrains from fixed elements

The "0 degree" irradiation chamber (in vacuum)

Multi flanged vacuum chamber
300 liters volume (diameter 60 cm, length 100 cm)
High level vacuum (below 10^{-5} mbar in two hours)
Distance to Control Room about 20 m



In vacuum irradiation setup

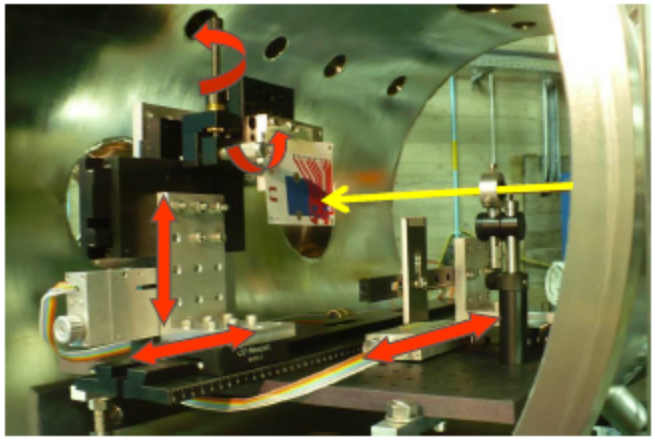
X-Y configuration linear stage actuators

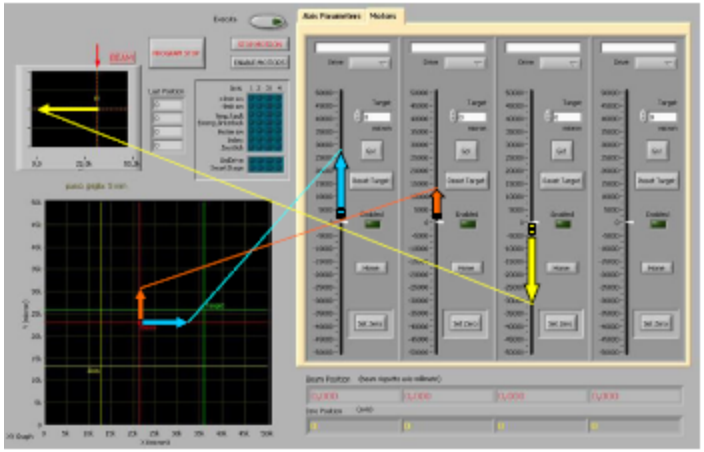
→ 50 nm encoder resolution

→ Available exposure area 40x40 mm²

θ_Y θ_Z manual rotation

Removable dosimetric apparatus

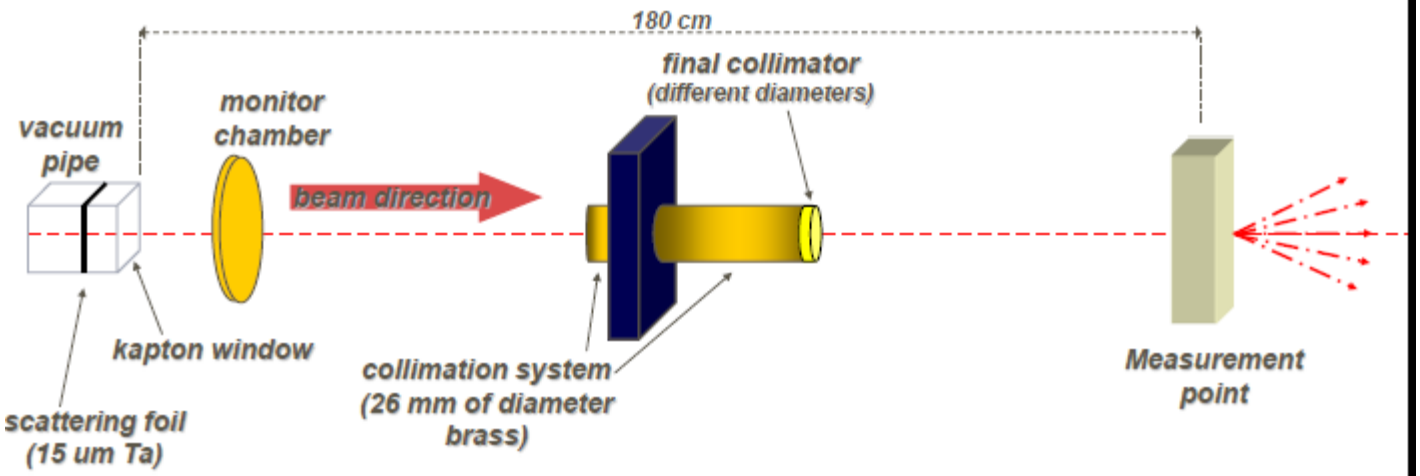




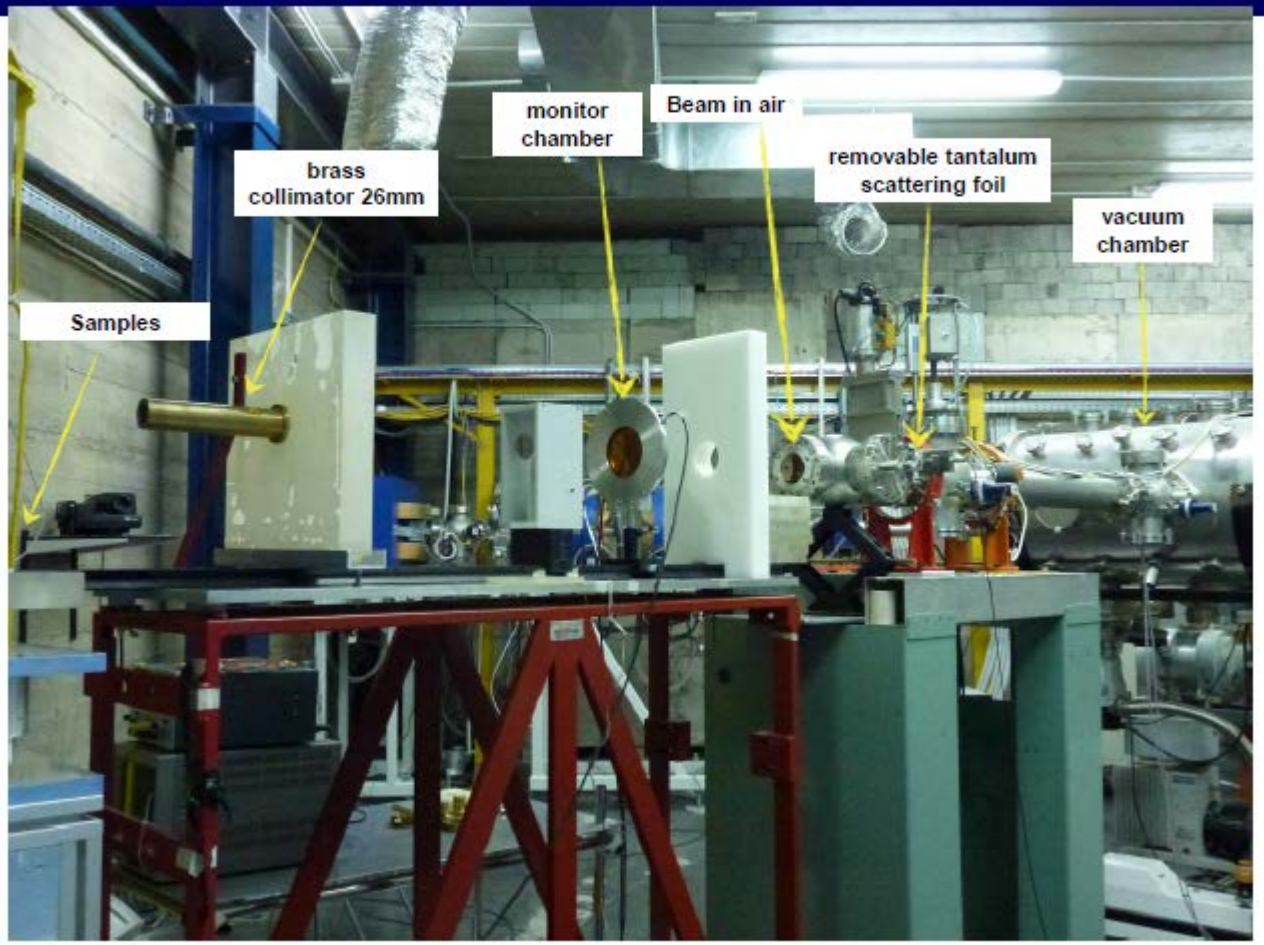
- *Exposure area view*
- *Absolute and relative coordinates*
- *Beam spot in respect to devices*
- *Irradiation point targeting*

PCB alignment and removal from beam line

Scheme of the beam line (in air)

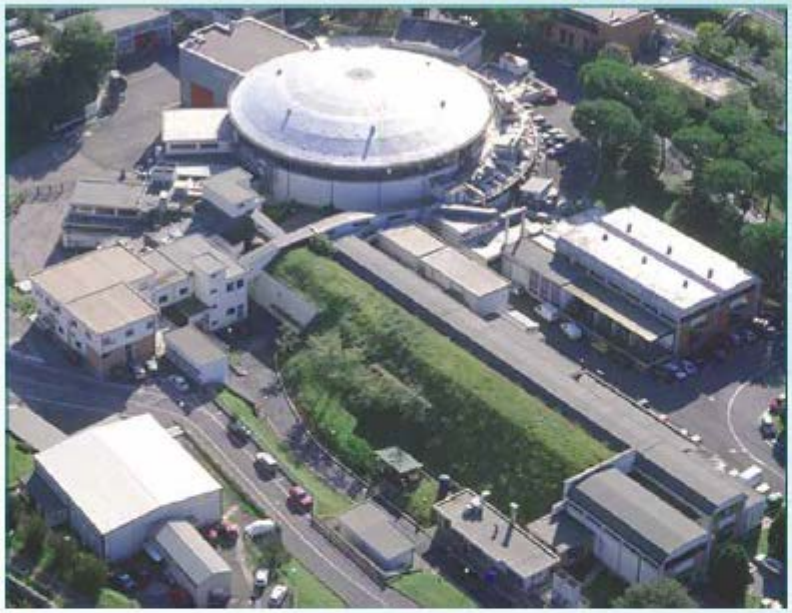


The 0 degree experimental Hall



The 0 degree experimental Hall

DAΦNE BTF



Linac ad **alta corrente**:

- 1 – 500 mA e^- 100 mA e^+,
- Impulsi da 1 oppure 10 ns
- Corrente minima ~ 1 mA ~ 10^7 particles

La **BTF** è una facility che può **estrarre** il fascio di e^-/e^+ dal Linac; è parte integrante del complesso del *collider* DAFNE dei Laboratori di Frascati

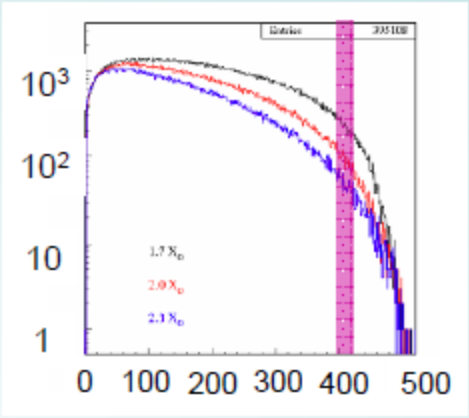
Attenuando il fascio primario è possibile:

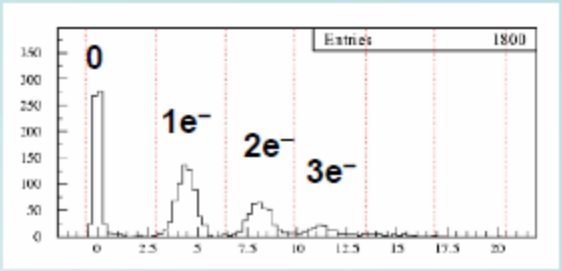
- ottenere il regime di **particella singola**, ideale per test di rivelatori
- modulare l'**intensità** del fascio
- modulare l'**energia** del fascio

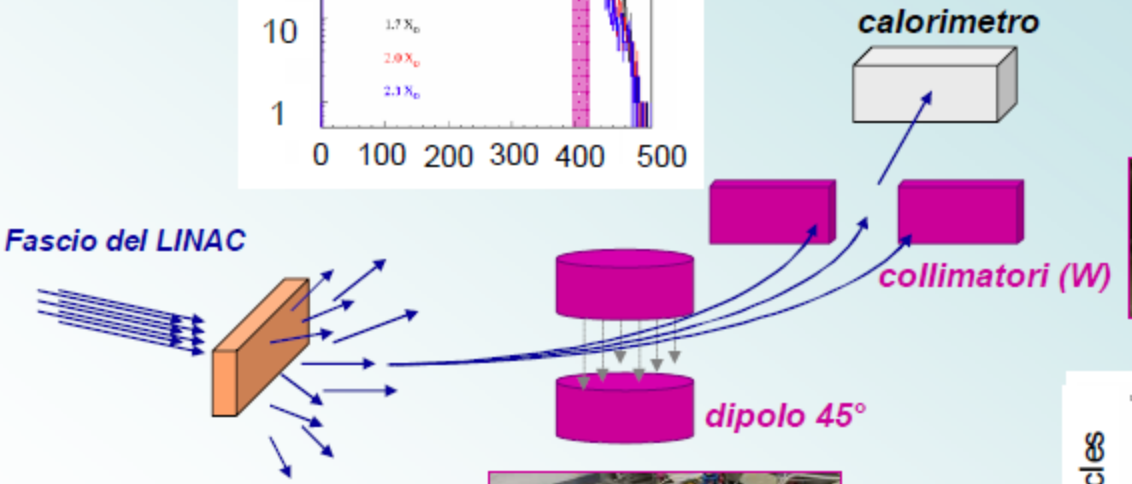
INFN
Istituto Nazionale di Fisica Nucleare

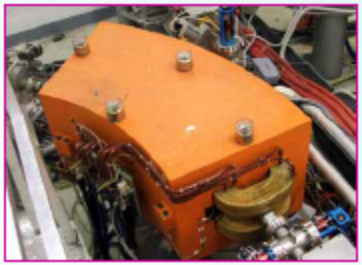
BTF
SLTB04
SLTB03
misura p
selezione p
DHSTS01
to BTF hall
DHSTB101
to accumulator
from Linac
DHSTP001
target
SLTB01
SLTB02
TARGET
DHTB001

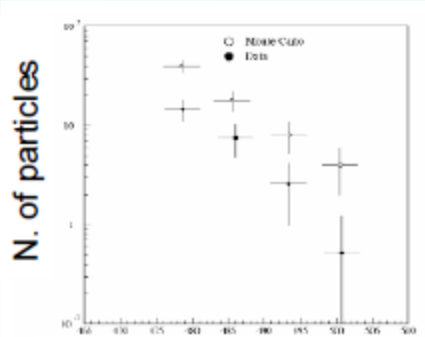
Fascio secondario





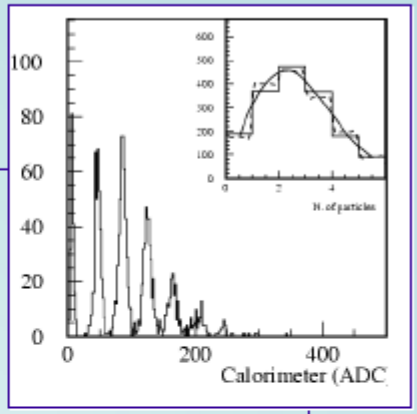






Caratteristiche del fascio

Fascio di **positroni** o **elettroni**, con una intensità modulabile grazie alla **dispersione in energia** introdotta dal bersaglio, selezionando l'energia e tramite dei **collimatori,** fino ad otterene il regime di **singola particella** per impulso

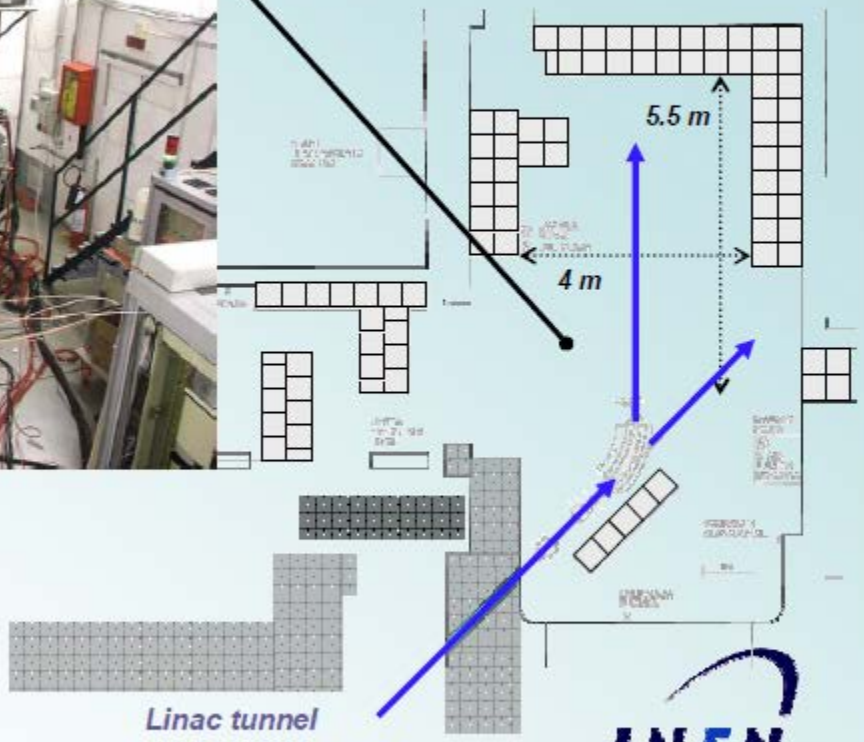


Number *(particles/pulse)*	*1÷10⁵*	*1÷10¹⁰*
Energy *(MeV)*	*25-500*	*25÷750*
Repetition rate *(Hz)*	*20-50*	*50*
Pulse Duration *(ns)*	*10*	*1 or 10*
p resolution	*1%*	
Spot size *(mm)*	$\sigma_{x,y} \approx 2\times2$ *(single particle) up to* 10×10 *(high multiplicity)*	
Divergence *(mmrad)*	$\sigma'_{x,y} \approx 2$ *(single particle) up to 10 (high multiplicity)*	

Multi-purpose facility:

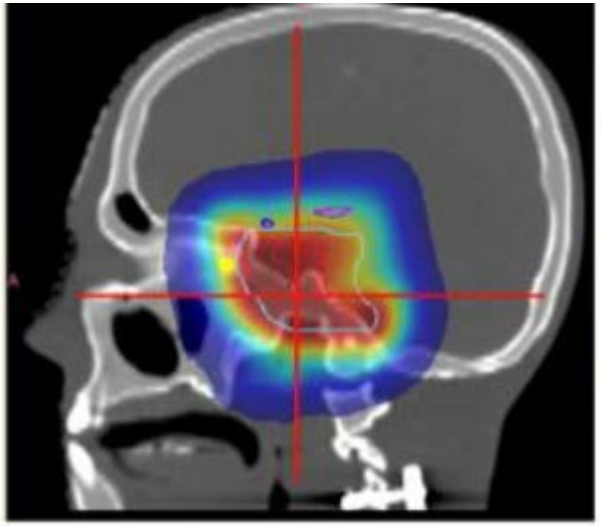
- **Detector calibration and setup**
- **Calorimetry**
- **High multiplicity efficiency**
- **Detectors aging and efficiency**
- **Beam diagnostics**

Infrastruttura



Future irradiation facilities at the hadrotherapy centers

Usually they do that but…..



Design of the CNAO experimental room

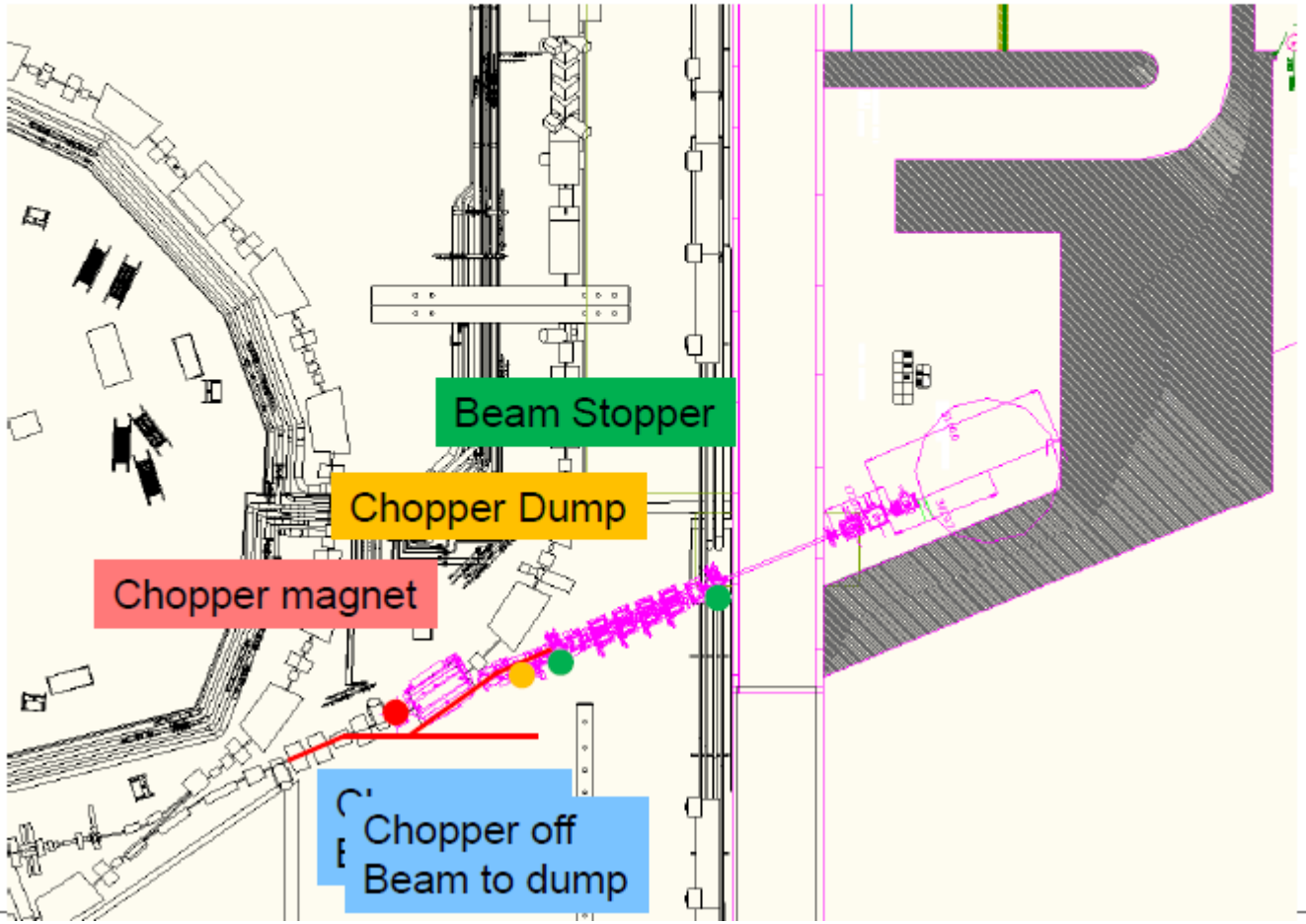
M. Pullia[1], C. Sanelli[2]

[1]CNAO, [2]INFN

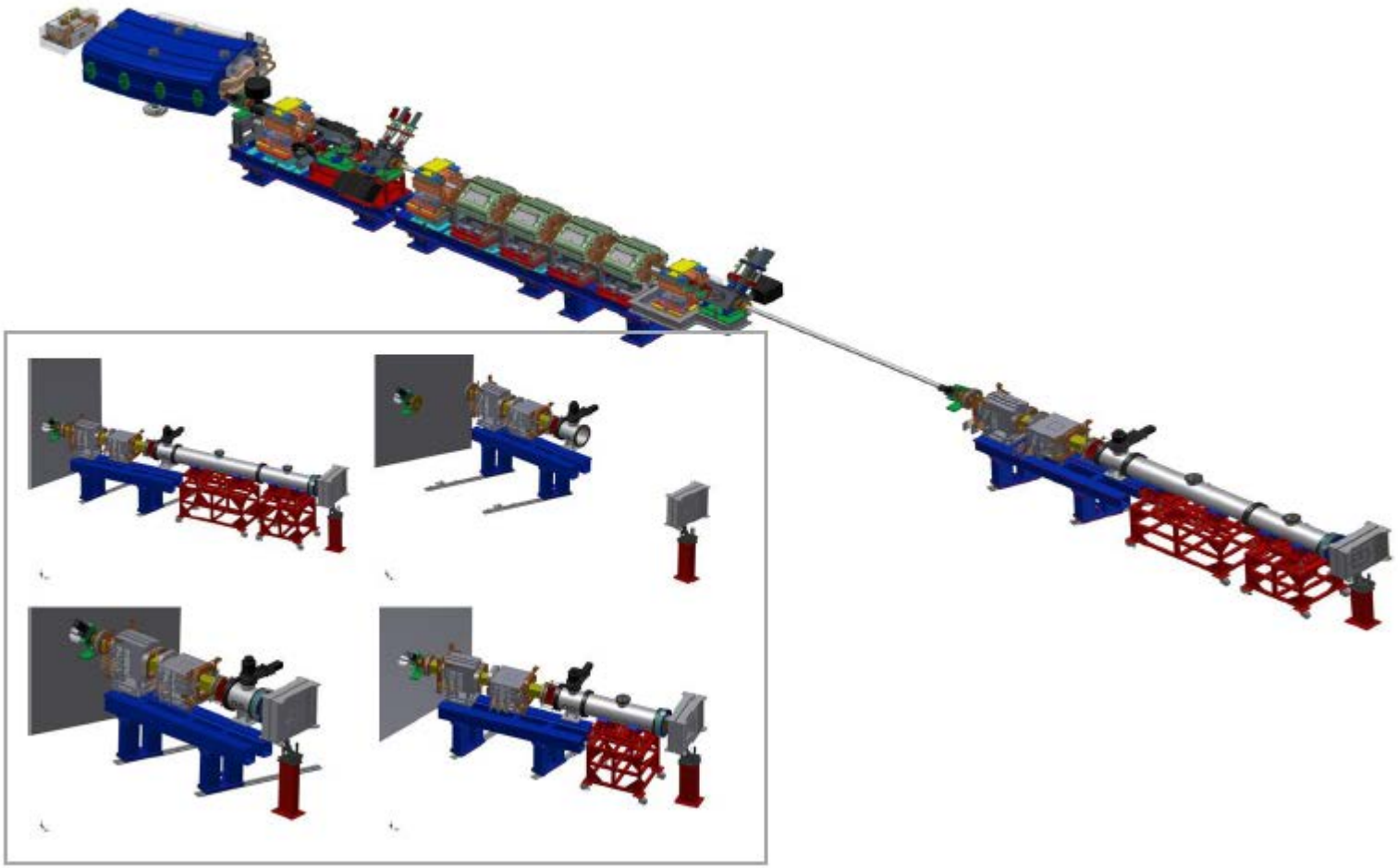
Pavia, September 9th, 2014

- **Design carried out by a CNAO-INFN collaboration in the framework of the "Accordi attuativi 2009" and "Accordi attuativi 2013"**
- **Final design completed in April 2014**
- **Functional specifications defined with a survey**
- **Construction foreseen in subsequent phases:**
  - initially only the HEBT will be constructed and
  - in a second phase, when the funding will be available, also a third source and its LEBT will be built.

XPR Chopper


Beam Stopper
Chopper Dump
Chopper magnet
Chopper off
Beam to dump

Multiple isocenter setup



Additional ions

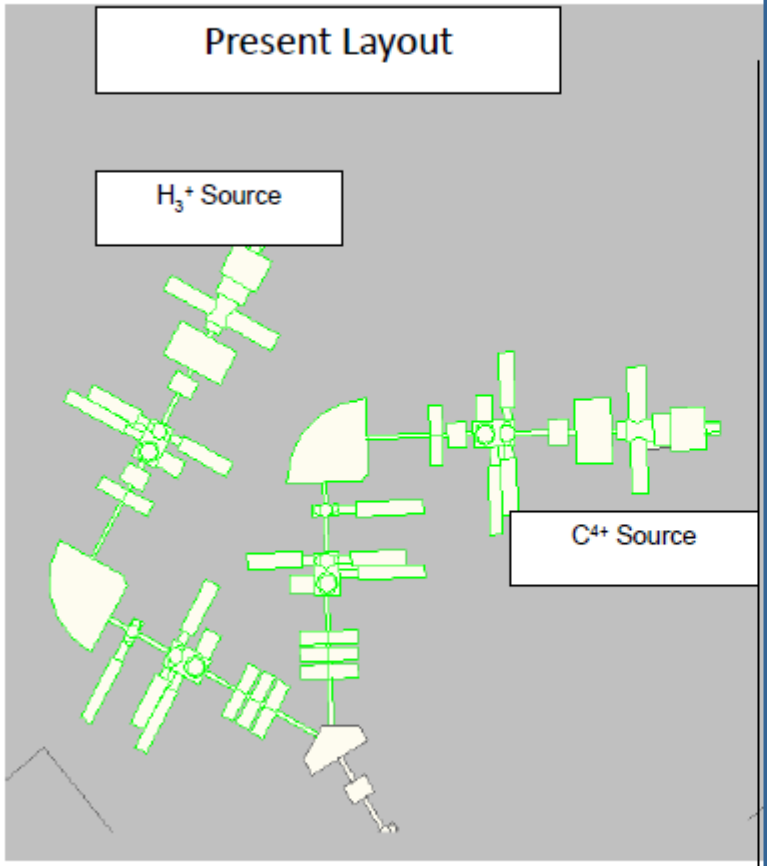
First stage

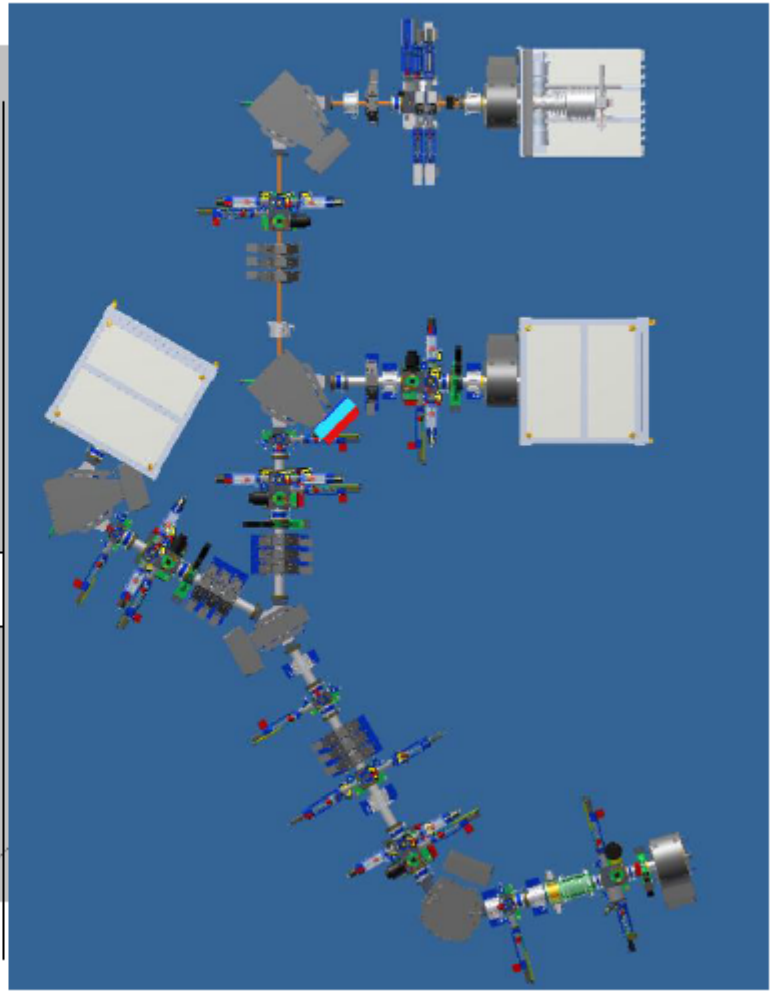
	H	He	Li	C	O
Z	1	2	3	6	8
I (p/s)	1.00E+10	2.50E+09	1.11E+09	2.78E+08	1.56E+08
K (MeV/u)	250	261.4	253	400	400

Second stage

	H	He	Li	Be	B	C	N	O
Z	1	2	3	4	5	6	7	8
I (p/s)	1.00E+10	2.50E+09	1.11E+09	6.25E+08	4.00E+08	2.78E+08	2.04E+08	1.56E+08
K (MeV/u)	330	400	400	400	400	400	400	400

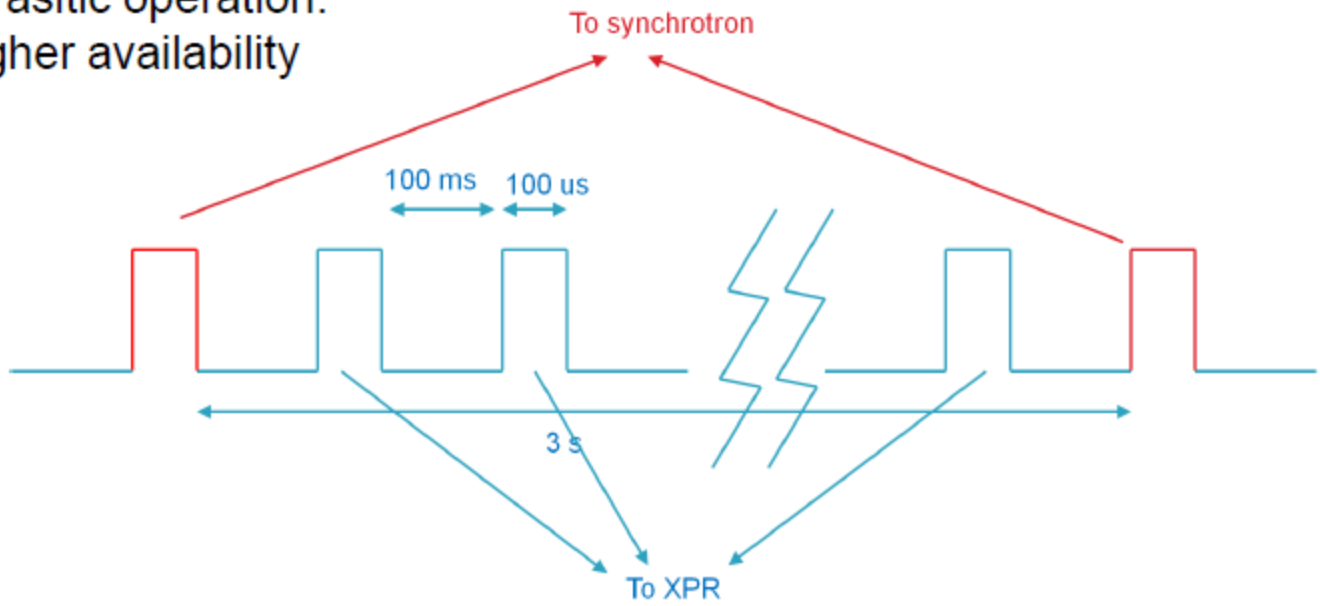
Third source and LEBT



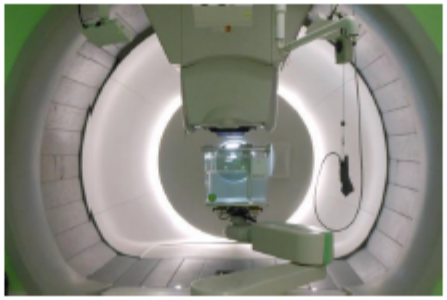


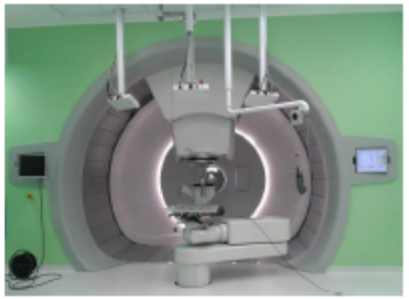
Maybe in future, 7 MeV Beam?

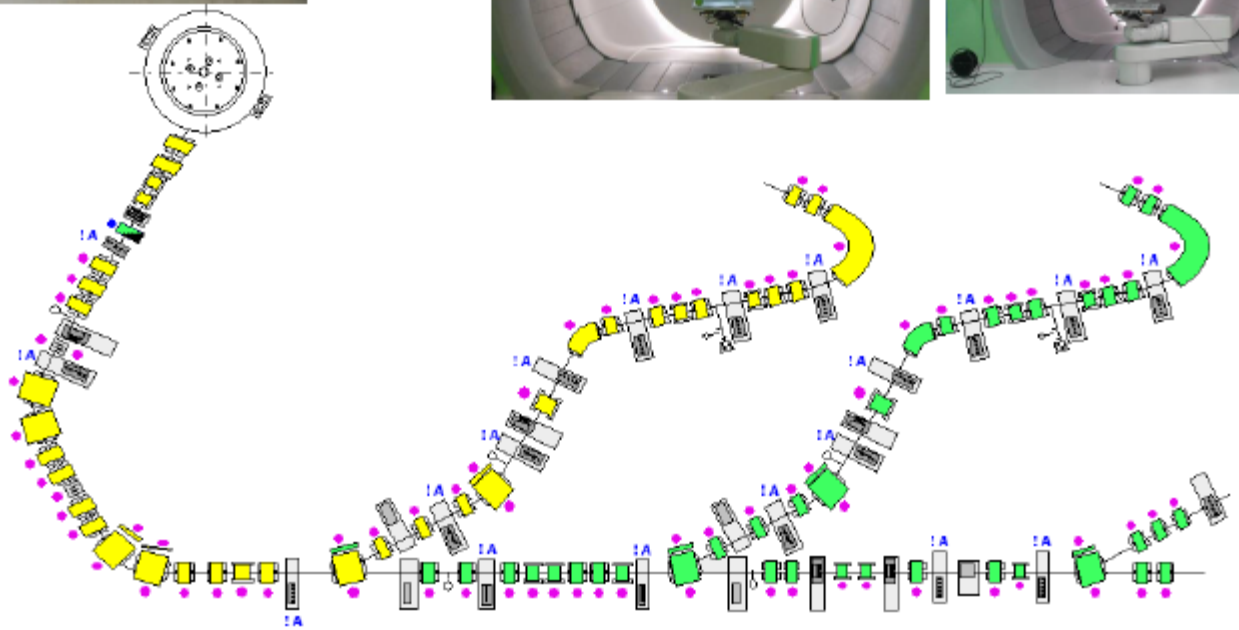
Use LINAC beam in parasitic operation. Higher availability

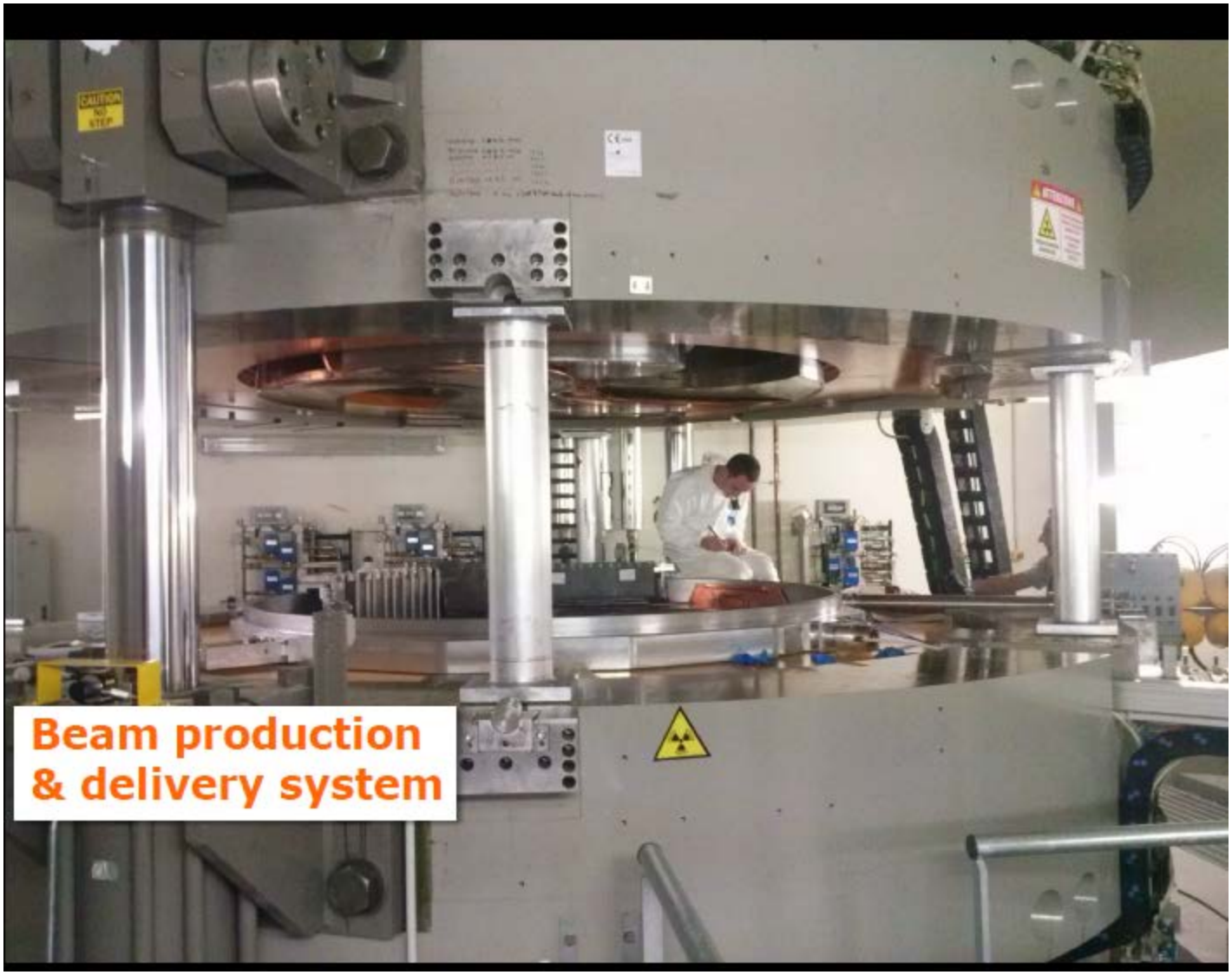


The Trento center








Beam production
& delivery system

Beam Production

Isochronous cyclotron
235 MeV max proton energy
300nA beam current
Typical efficiency:55%

Conventional magnet coil:1.7-2.2T (fixed field)
RF frequency: 106 MHz (fixed frequency)

Approx weight: 220 tons
Diameter: 4.3m

Conclusions

- The INFN labs (+ HTC) cover a large part of the LET/range needed for SEE studies
- Many centers provide gamma and/or X-rays
- Neutrons are available at the LENA reactor (PV) and at the ENEA facilities at Casaccia.

- Thanks to the many persons that helped me in collecting these data