The AISHa ion source for CNAO

L. Celona, G. Castro, F. Chines, S. Gammino, O. Leonardi, A. Massara, S. Passarello

Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud

V. Vercesi, A. Lanza, A. Kourkoumeli-Charalampidi, R.L. Ramos, C. Scagliotti, F. Vercellati

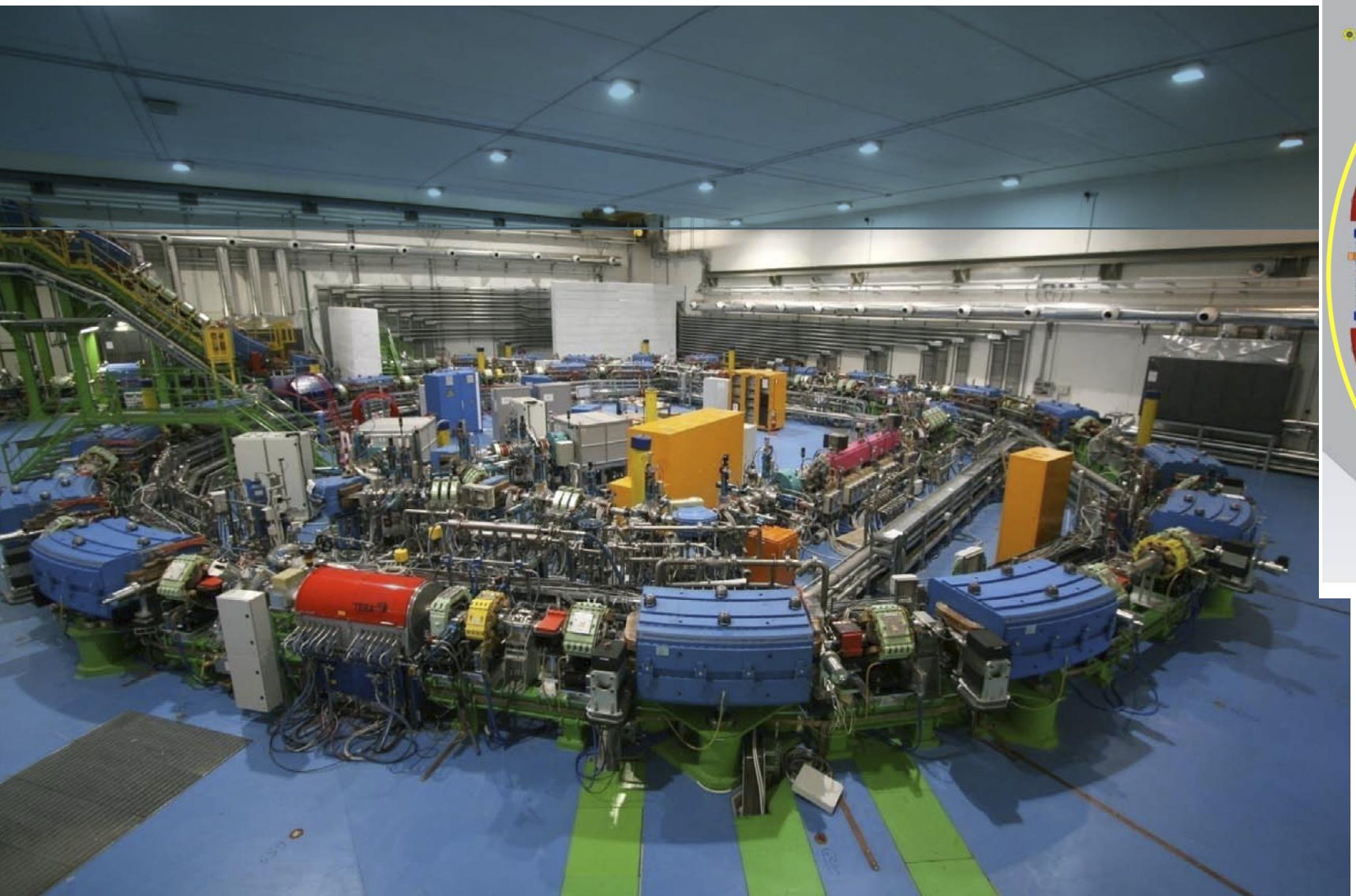
Pavia University and Istituto Nazionale di Fisica Nucleare

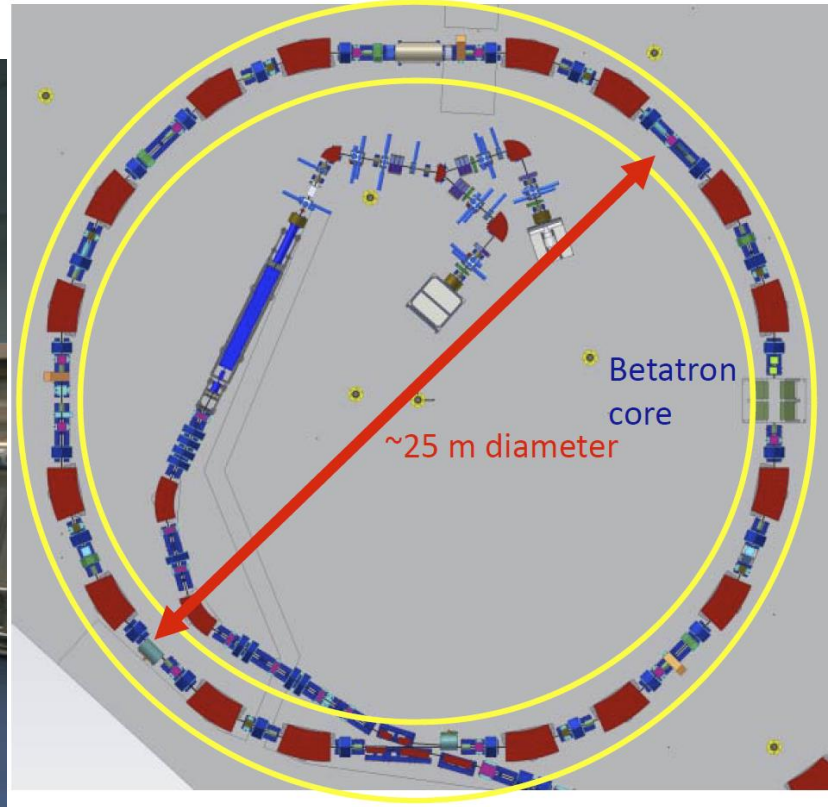
M. Pullia, L. Falbo, R. Monferrato, S. Sironi, G. Costanzo, C. Maugeri, F. Russo

CNAO Foundation – Pavia

International Conference on Ion Sources
(ICIS2021)

CNAO Syncrotron room

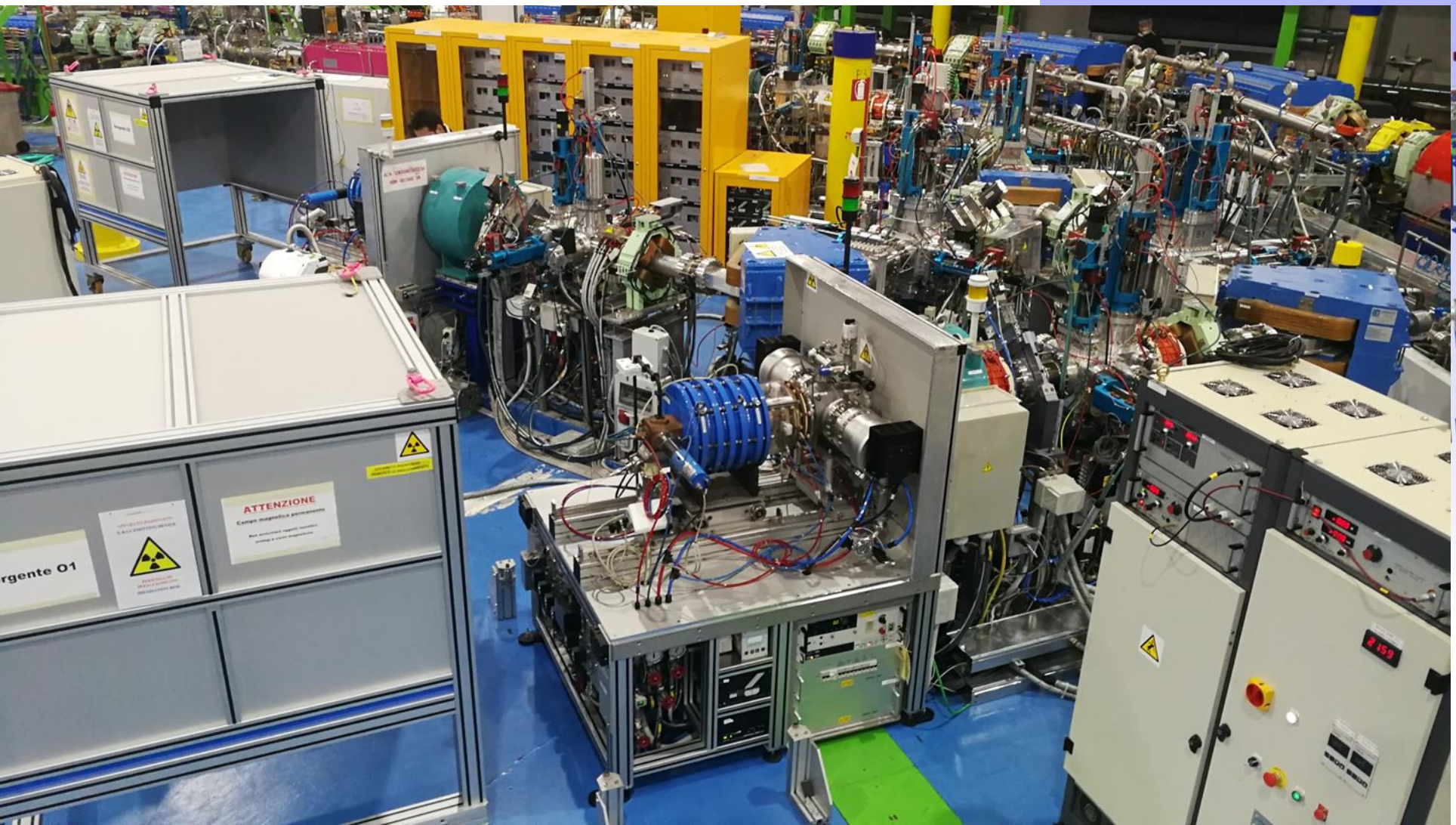


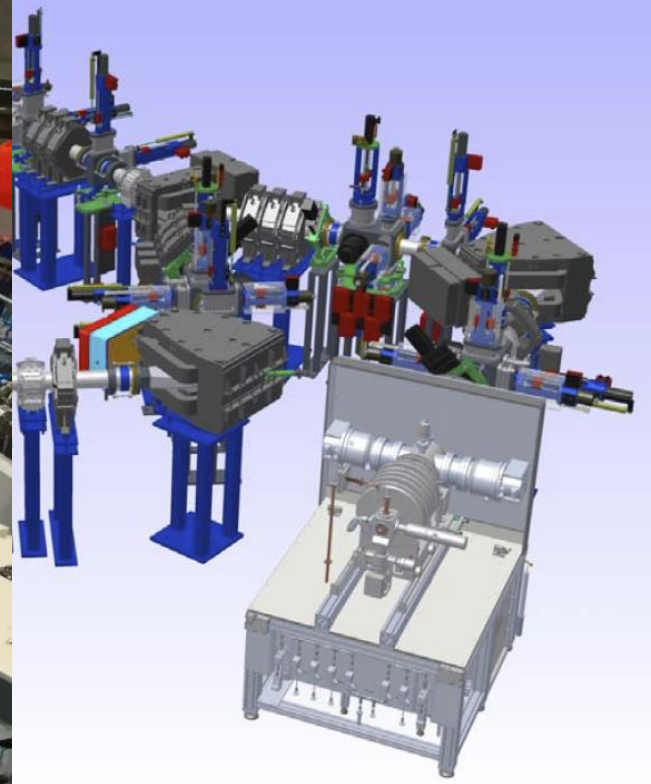


7-250 MeV (p)
7-400 A MeV (C)

I ~0.1-5 mA (p)
I ~ 0.03-1.5 mA (C)

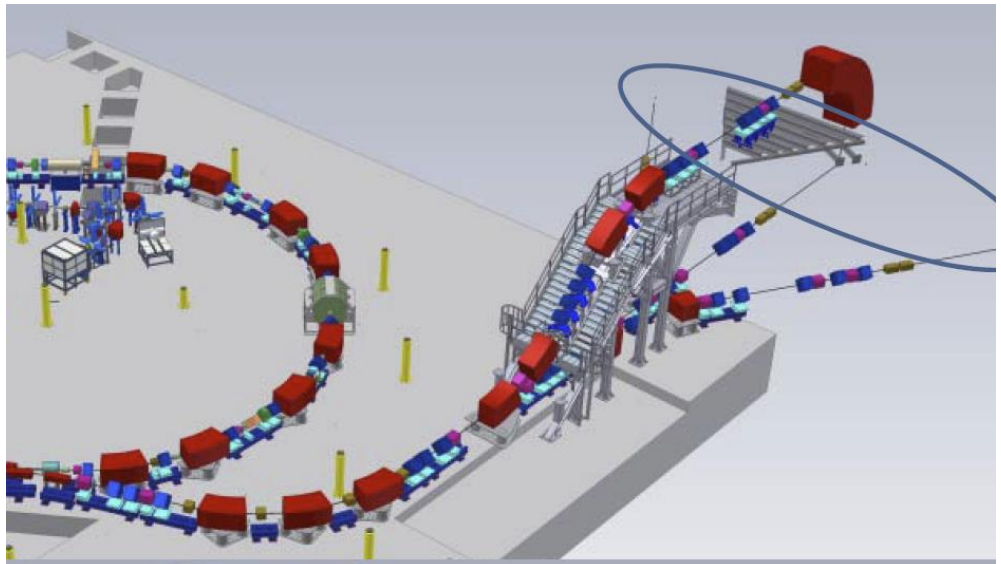
PK Supernanogun ion sources

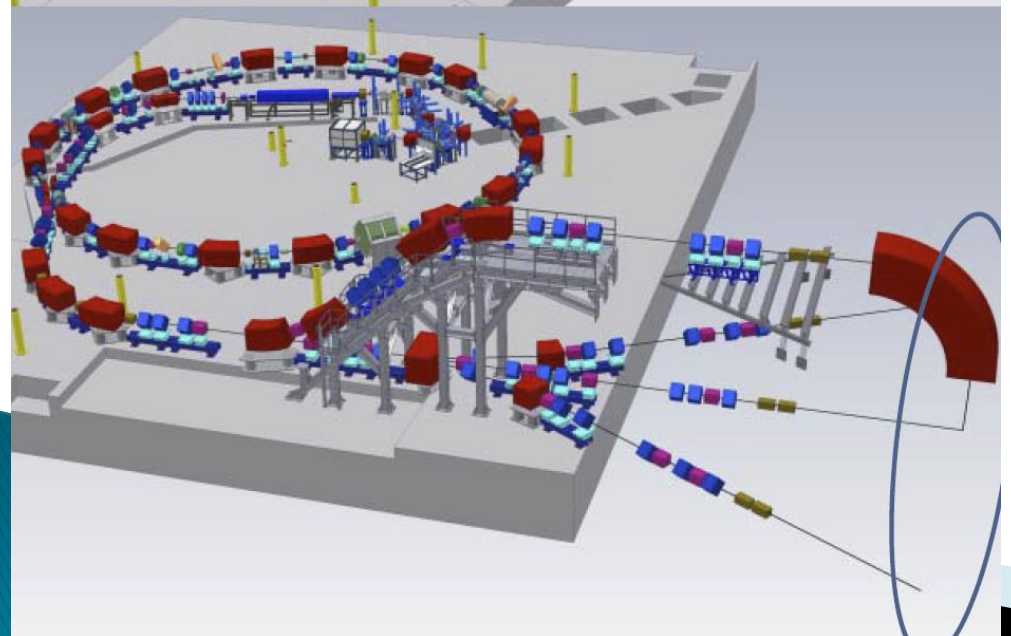




I ~ 0.5 mA (H3 +)
I ~ 0.15 mA (C4+)

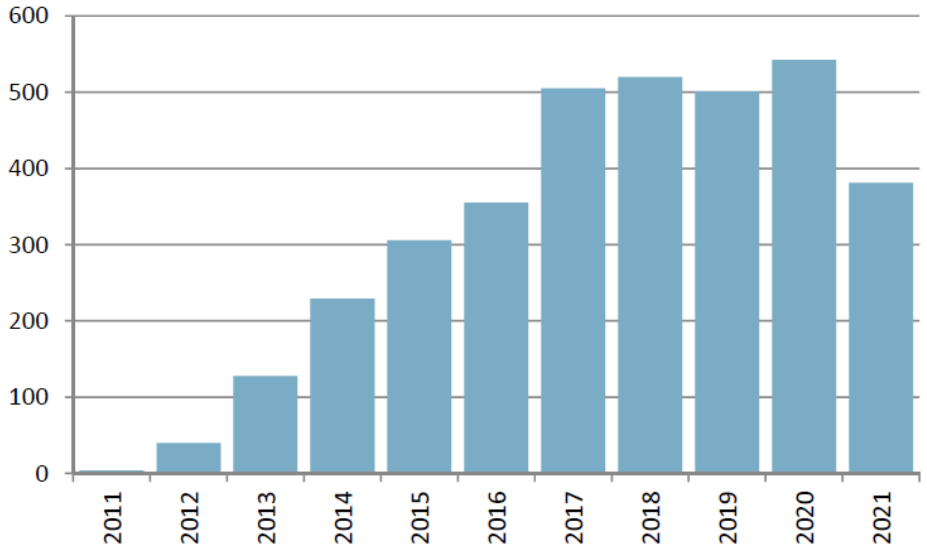
Treatment rooms





3 Treatment Rooms (2H, 1 H+V)

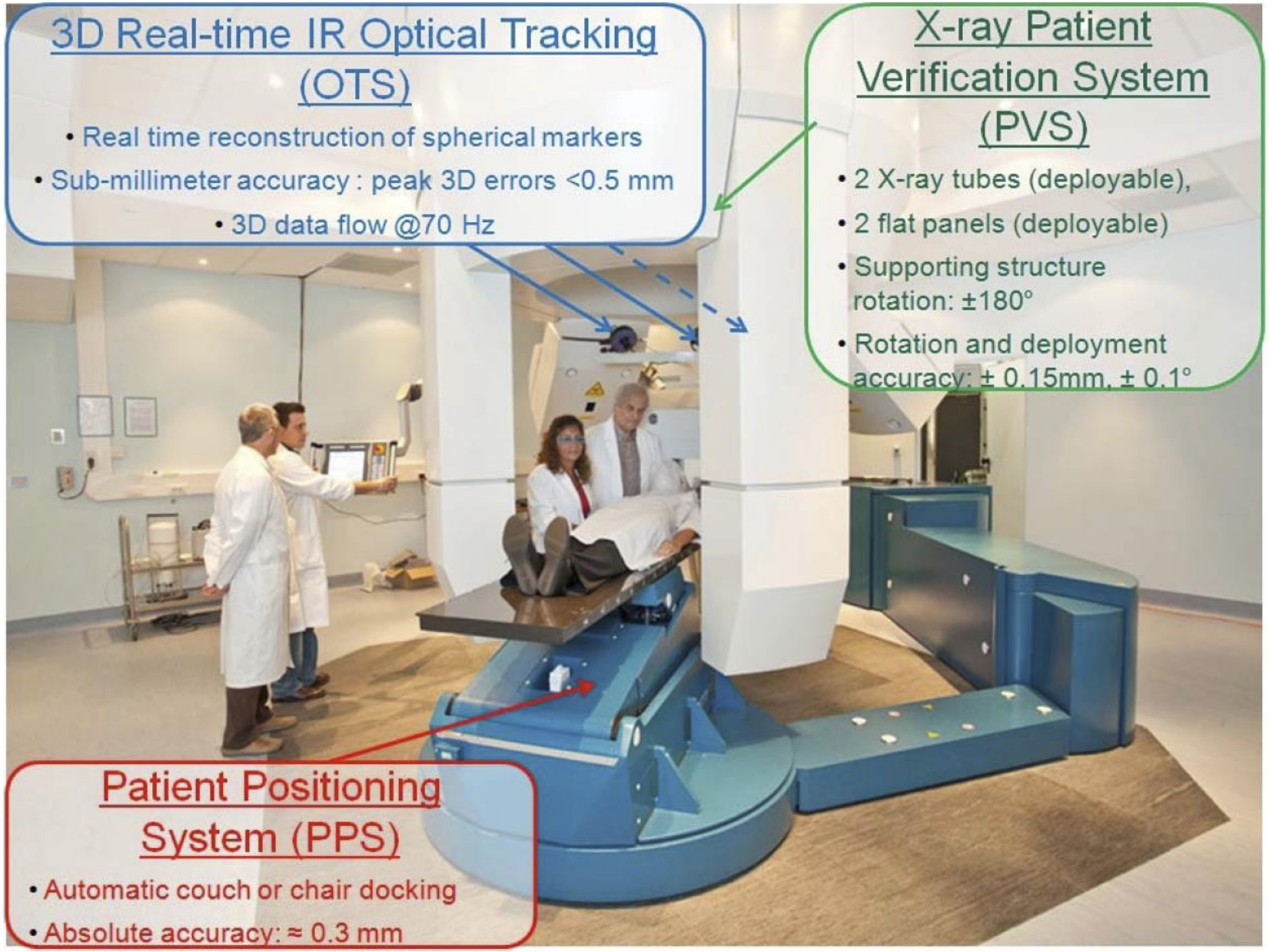
Protons: 60-250 MeV 10^{10} p/spill (~2nA)
Carbon: 120-400 AMeV 4 10^{8} C/spill (~0.4nA)



More than 3500 patients treated

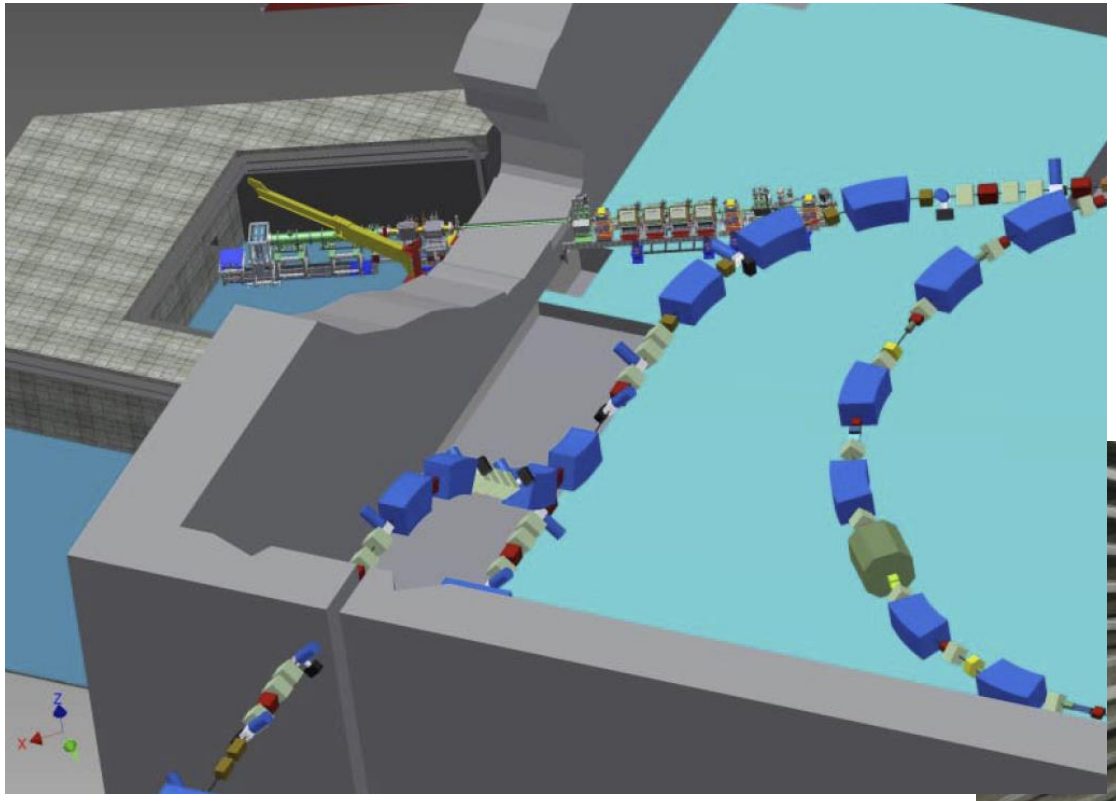
Carbon/Protons=60/40

Treatment rooms



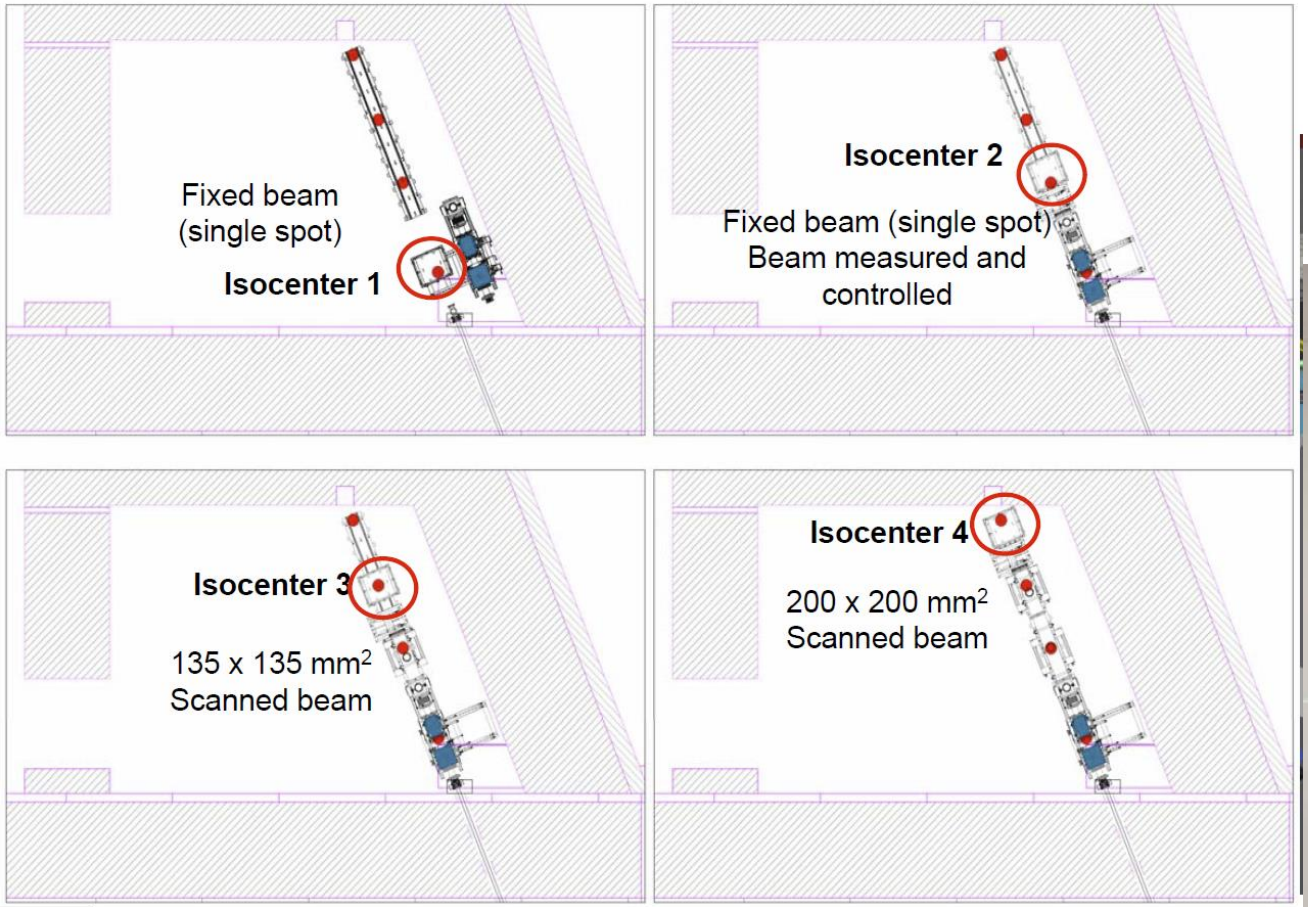
Courtesy of M. Pullia

Beam line for R&D activities

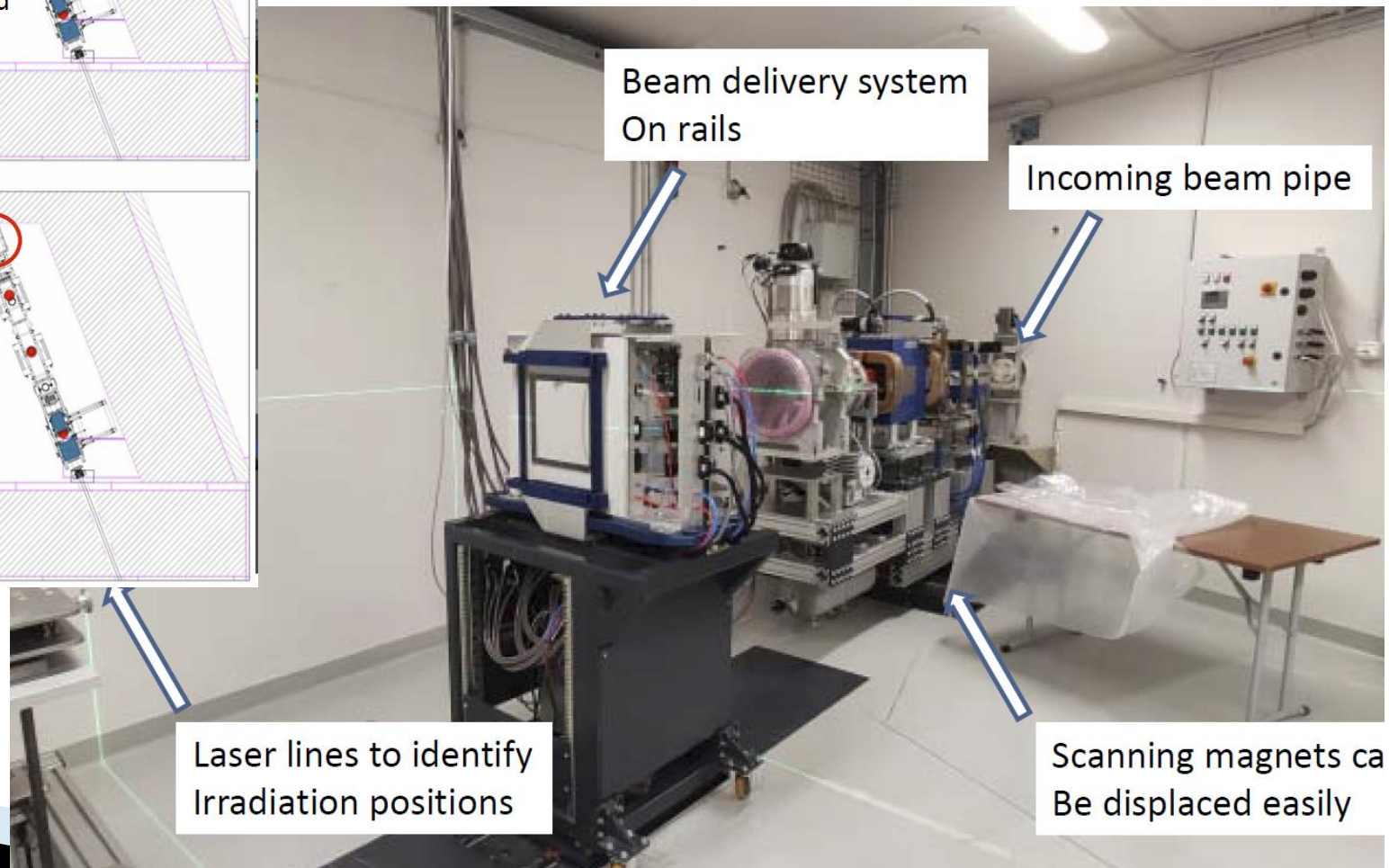


Unique possibility to perform activities ranging from clinical to radiobiological research.
A dedicated experimental irradiation room is available in time slots not impacting on patient treatments, but specifically devoted to research purposes.

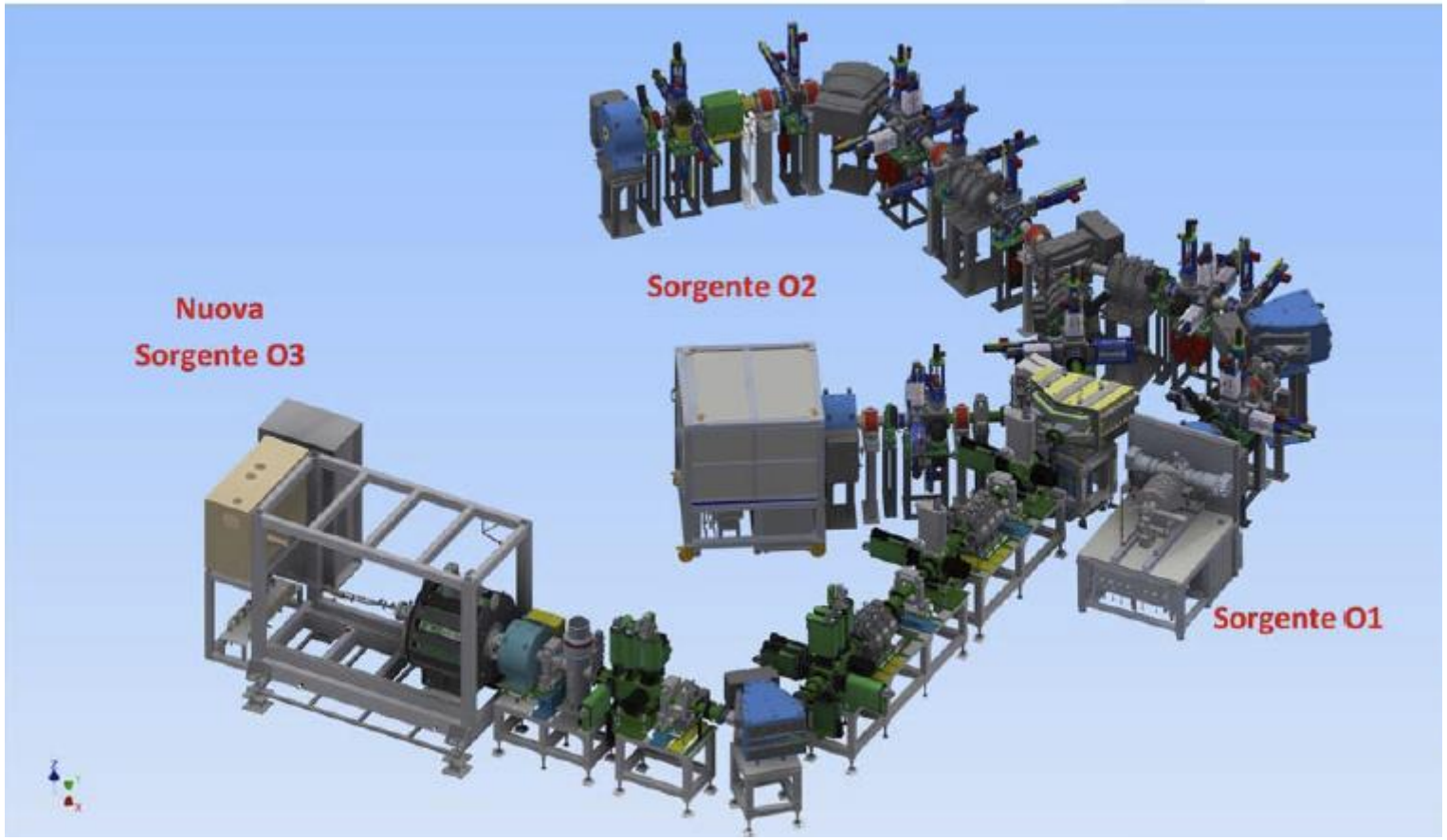
Experimental room



Easily reconfigurable!



INSpIRIT



Revamping of critical components in order to speed some normal machine operations:

- Revamping of critical components to increase machine reliability
- Upgrade of the radiobiology laboratory
- **AISHa source** for **Helium, Lithium, Oxygen and Iron** for new clinical protocols (He, O, Li) and biological/material experiments for space radiation research.

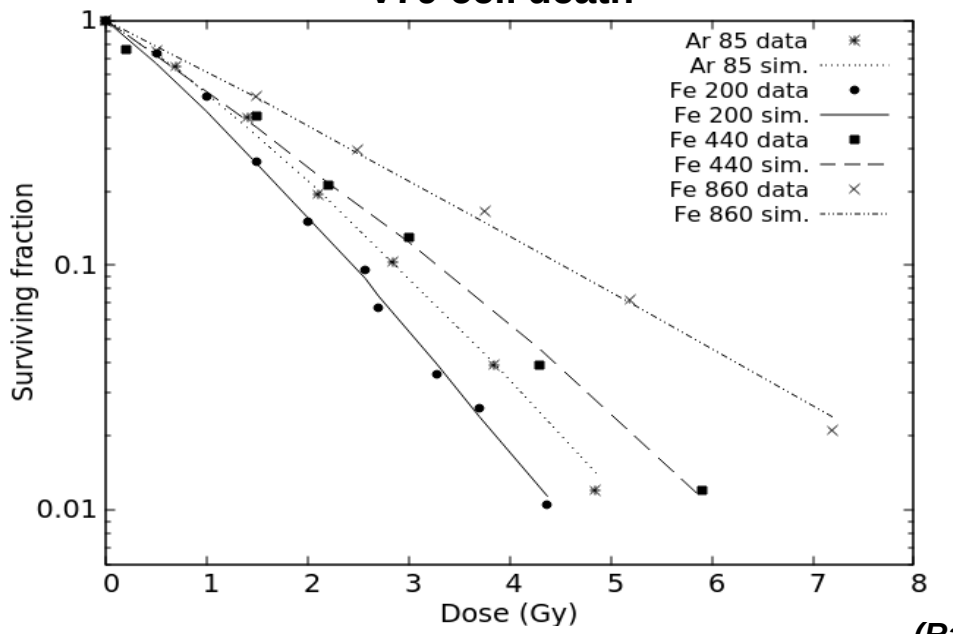
UNIONE EUROPEA
Fondo europeo di sviluppo regionale
Regione Lombardia
fesr
POR FESR 2014-2020 / INNOVAZIONE E COMPETITIVITÀ

Space radiation research

Extension of the BIANCA biophysical model up to Fe-ions and applications for space radiation research

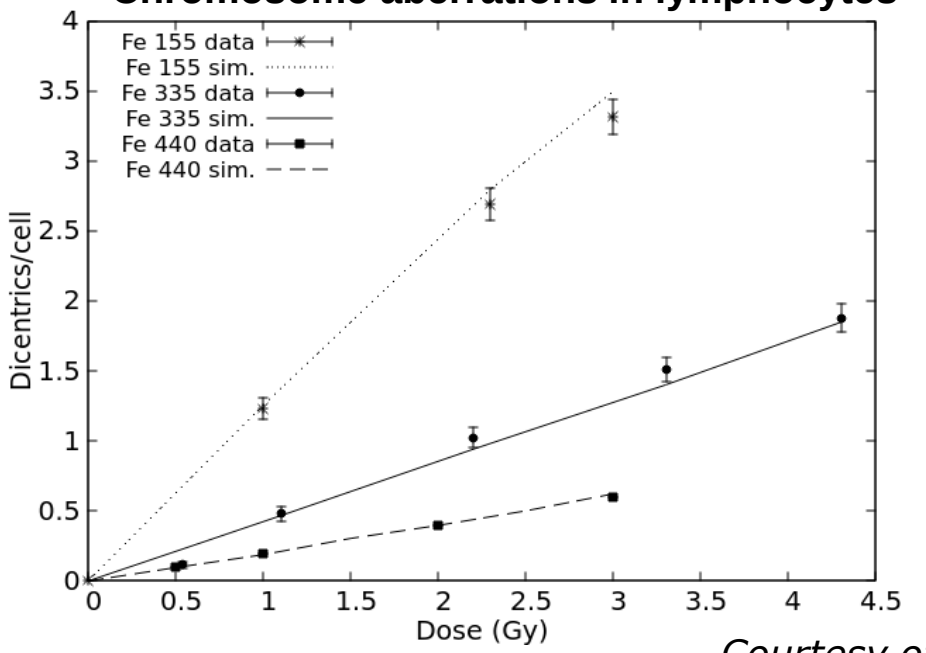
- *BIANCA simulations vs experimental data for monochromatic ion beams.*

V79 cell death



(Ramos et al., submitted)

Chromosome aberrations in lymphocytes



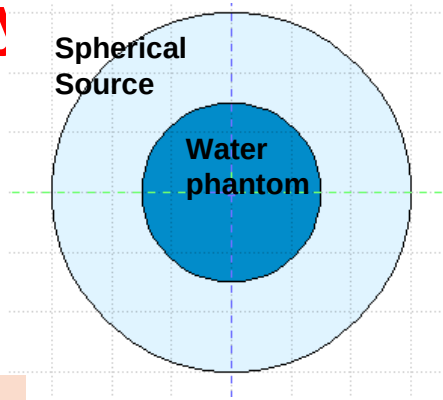
Courtesy of V. Vercesi

Radiobiological databases predicting cell death and chromosome damage as a function of dose and energy already created from Z=1 to Z=26

Space radiation research

Evaluation of biological damage by Galactic Cosmic Ray

example of calculation using FLUKA + BIANCA



- ***Spherical water phantom (radius 15 cm) included in a spherical, isotropic source (radius 32 cm).***
- ***The simulations were repeated for a source consisting of 1 GeV protons, 1 GeV/u He-ions, 1 GeV/u C-ions, or 1 GeV/u Fe-ions.***

$$RBE = \frac{\text{photon dose}}{\text{Ion dose}}$$

to obtain the same biological damage

			Travel to Mars	
Ion	RBE_{dic}	Dose(Gy)*RBE_{dic}	RBE_{surv}	Dose (Gy)*RBE_{surv}
^{1}H (0.20 Gy)	1.56	0.31	1.48	0.30
^{4}He (0.10 Gy)	2.56	0.26	1.40	0.14
^{12}C (0.15 Gy)	2.82	0.42	1.76	0.26
^{56}Fe (0.05 Gy)	14.52	0.73	7.37	0.37

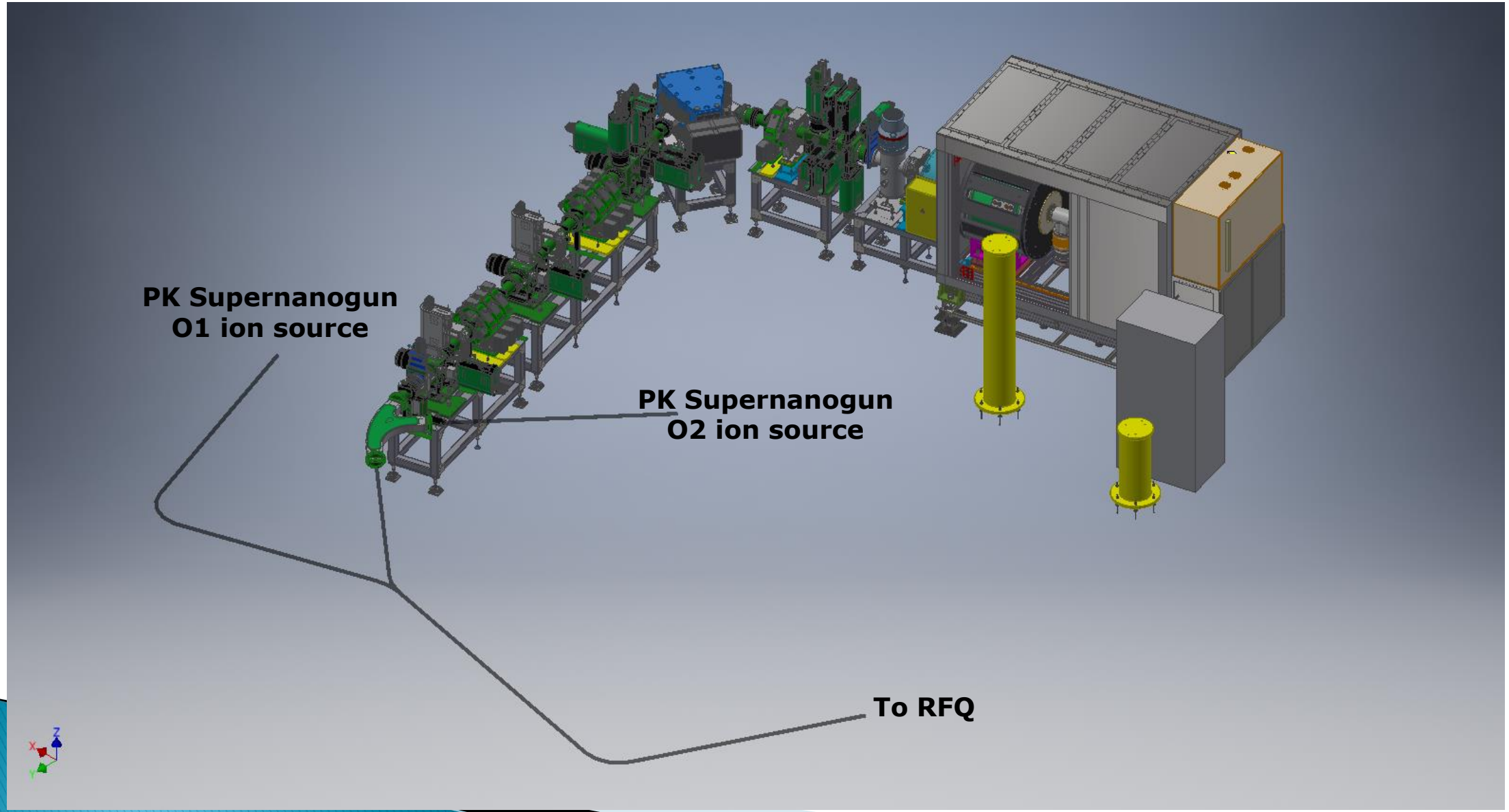
(Ramos et al., submitted)

Courtesy of V. Vercesi

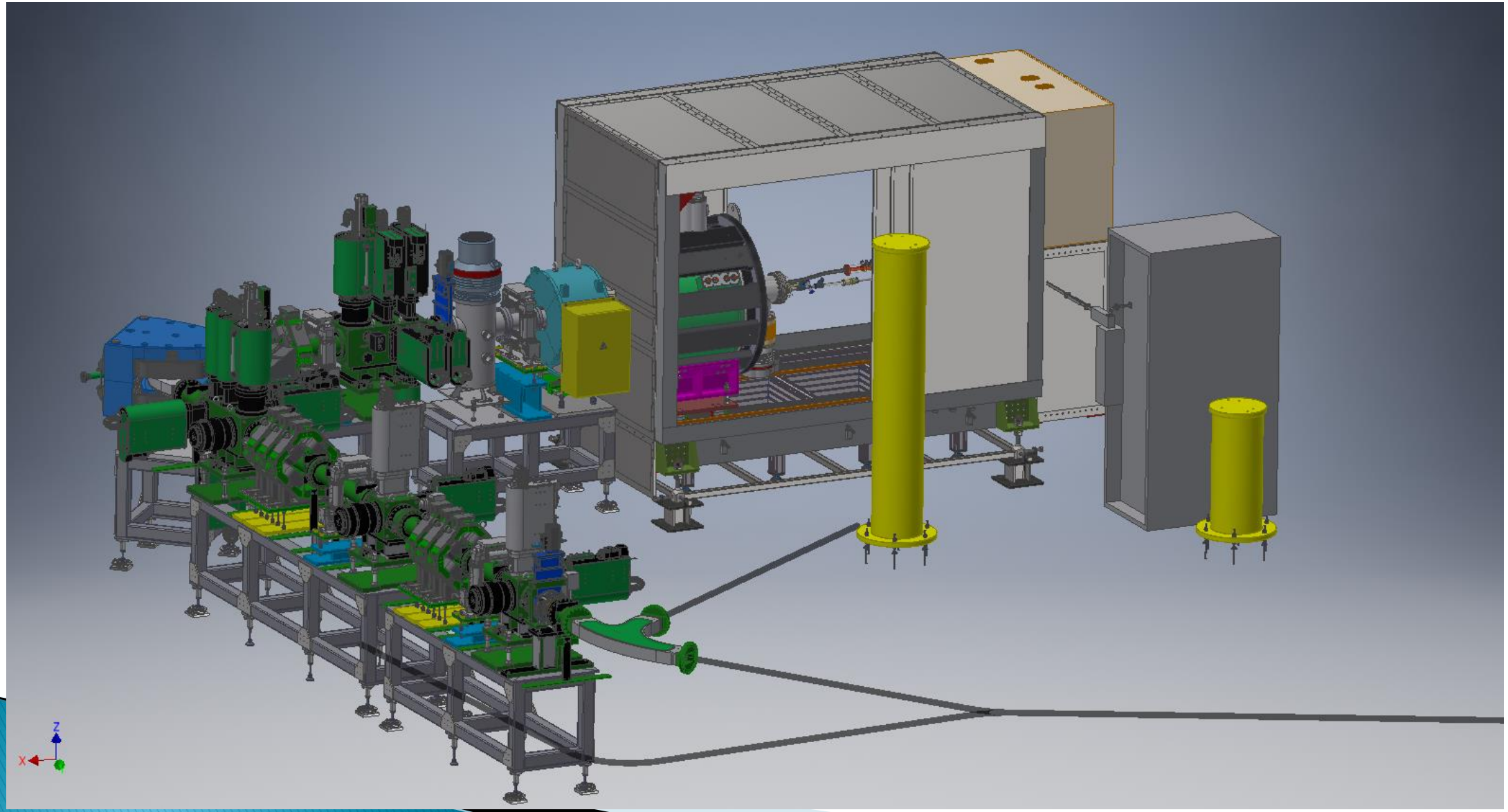
PERMANENT DAMAGE

More simulations, considering the full GCR spectrum and/or an anthropomorphic phantom, included in a shielding structure, will be object of future studies.

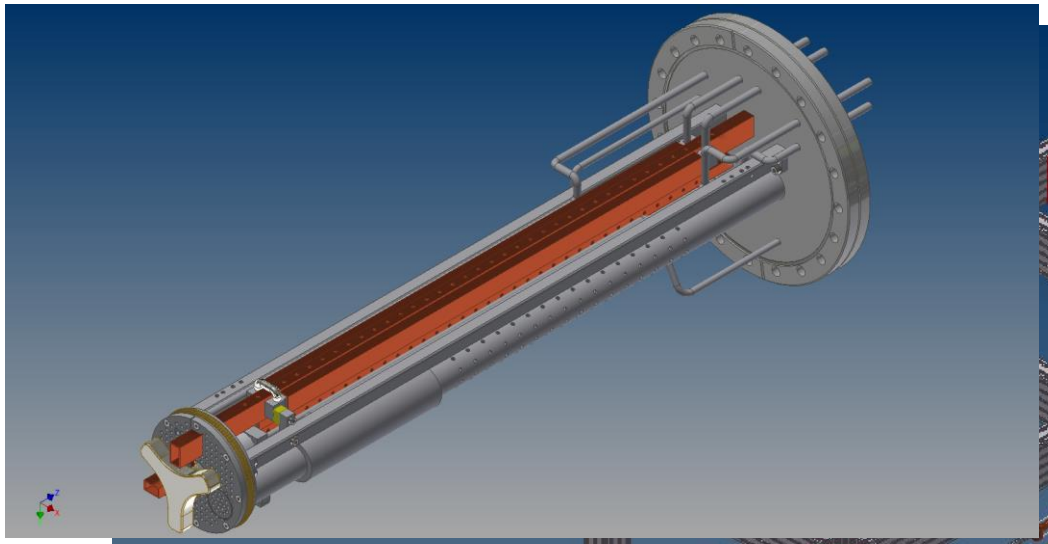
AISHa integration@CNAO



AISHa integration@CNAO



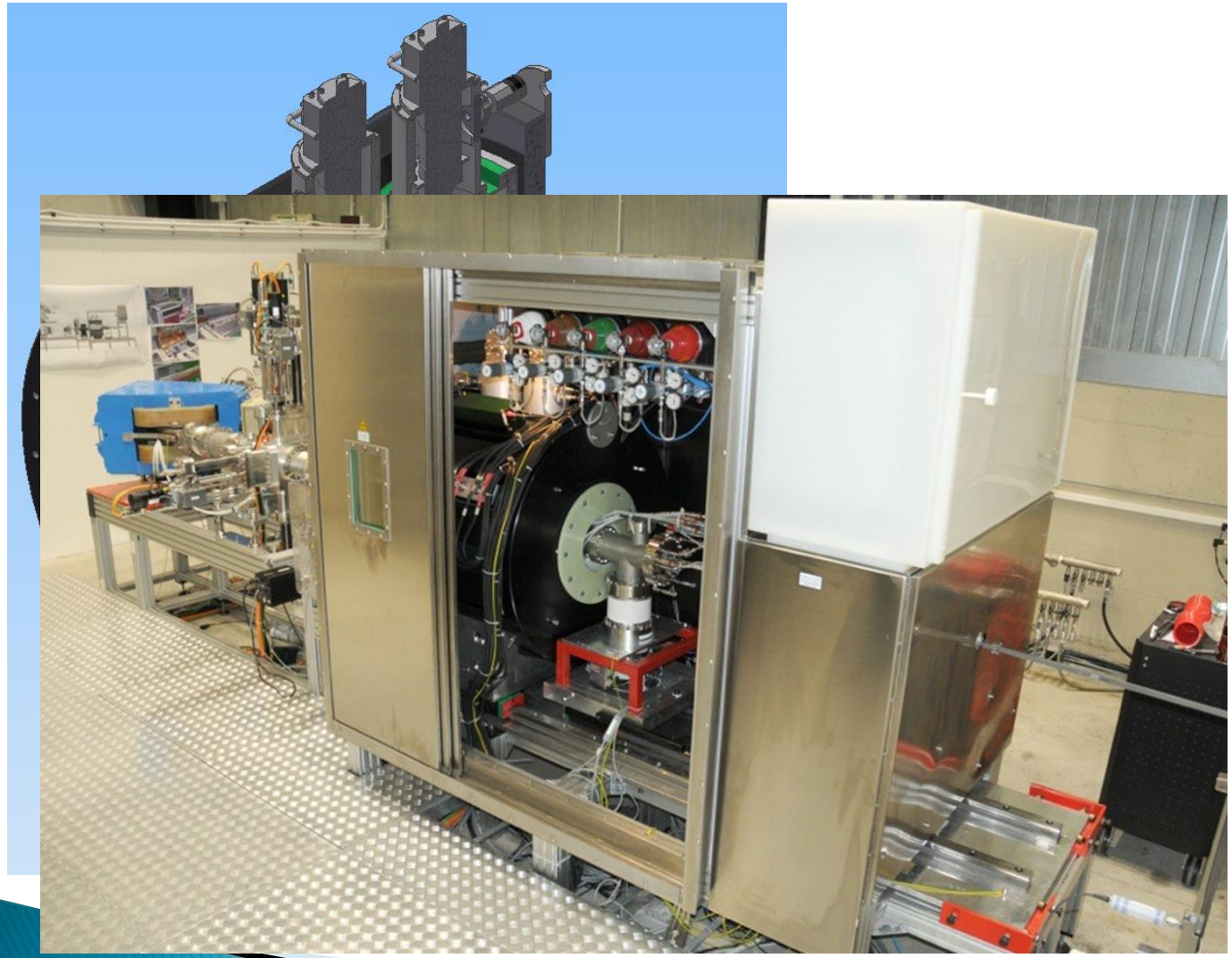
AISHa integration@CNAO



AISHa integration@CNAO

AISHA

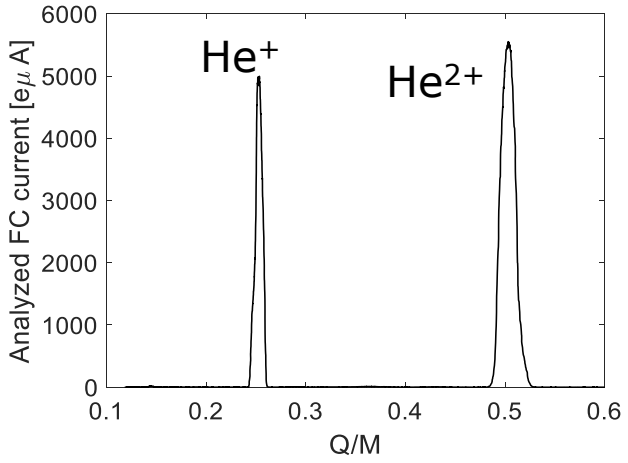
Advanced Ion Source for HAdrontherapy

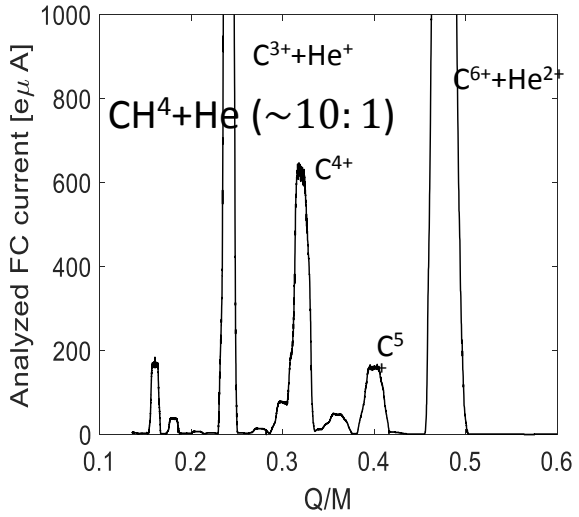


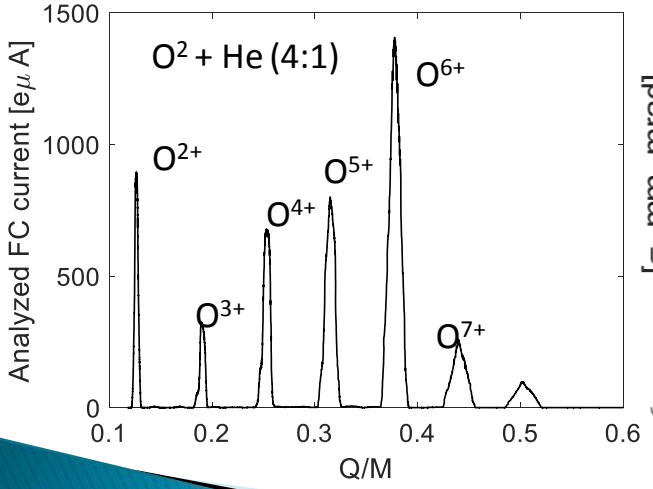
- *low space occupation and minimization of electrical consumption*
- *high stability and high reproducibility*
- *highly charged ion beams with low ripple*
- *low maintenance time*

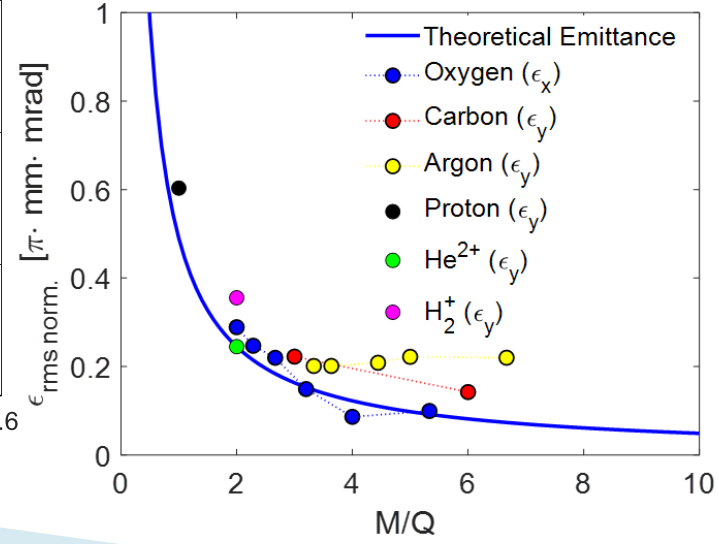
Radial field	1.3 T
Axial field	2.7 T - 0.4 T - 1.6 T
Operating frequencies	18 GHz – 21 GHz
Operating power	1.5 + 1.5 kW (max)
Extraction voltage	40 kV (max)
Chamber diameter / length	Ø 92 mm / 360 mm
LHe	Free
Warm bore diameter	274 mm
Source weight	1400 kg

AISHa performances @INFN-LNS (17.3-18.4 GHz – 1.5 kW max)





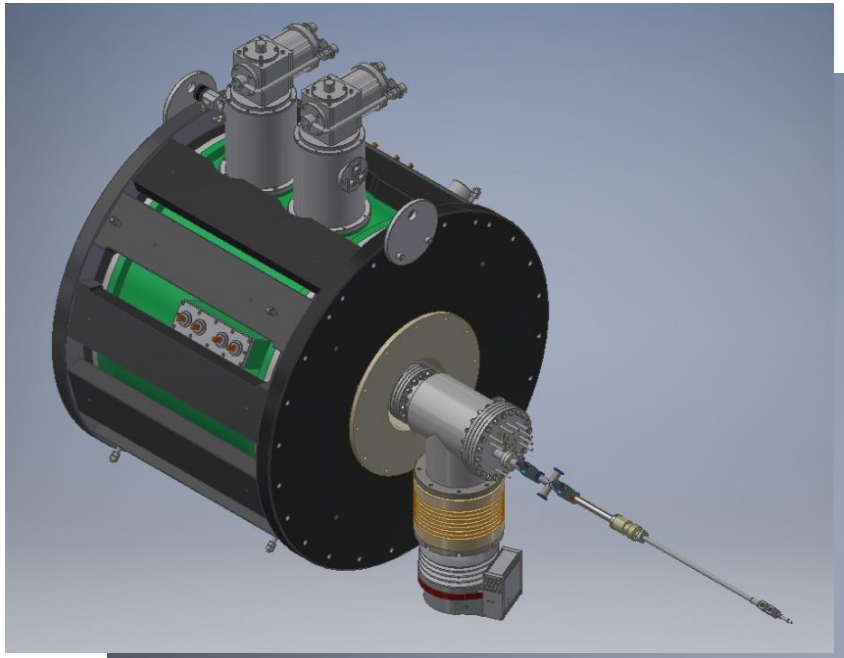




Charge state	Beam intensity [eμA]	$\varepsilon_{rms.norm}$ $[\pi \cdot mm \cdot mrad]$
$^{16}O^{6+}$	1400	0.2198
$^{16}O^{6+}$	225	0.115
$^{16}O^{7+}$	350	0.247
$^{12}C^{4+}$	650	0.272
$^{12}C^{4+}$	150	0.222
$^{12}C^{5+}$	165	---
$^{40}Ar^{11+}$	155	0.201
$^{40}Ar^{12+}$	140	0.201
He^{2+}	5400	0.418
He^{2+}	700	0.245

News: 21 GHz just delivered!

Fe beam development



Adaptation of GSI STO oven to AISHa for PANDORA to test long term production of 176Lu

Hall for magnetic measurements and source assembly at INFN - Pavia

Oct.21 Magnetic measurements.

Nov.21-Jan.22 Assembly of supports and ancillary equipment.

Feb.22 Test of electronics and CC debugging.

Mar.22 Source disassembly in macro-parts, transportation to CNAO, integration with the syncrotron ring.

Apr.22 Start commissioning with O, He and C beams, test acceleration through the syncrotron.

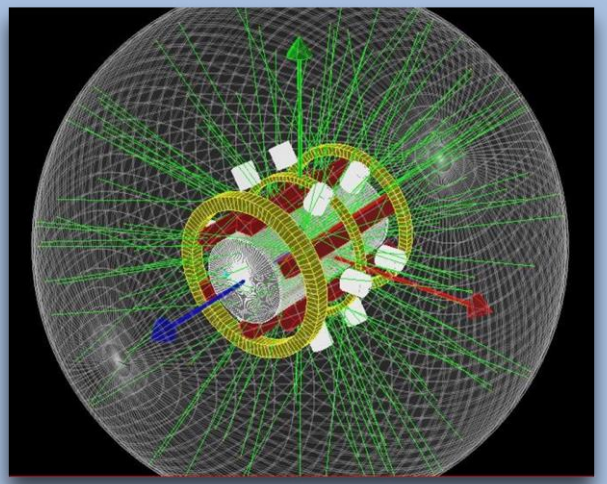
Operation planned, in the meanwhile, at the AISHa site @INFN-LNS: restart operation in the new room, new diagnostics and OES setup, double frequency operation, Fe beam development

Conclusion&Perspectives

PANDORA

Competitive dialogue for the construction of the fully superconducting magnetic trap just published on-line

Prequalification phase open up to October 25th



https://servizi-dac.dsi.infn.it/index.php/gestioneavvisi/dettaglioAvviso/2151819/0/2

- Fe beam development in collaboration with GSI and in the framework of PANDORA developments for the production of ^{176}Lu.


ALSHa
Beam Emittance
40.00
-40.00
-15.00
-9.00
-3.00
3.00
9.00
15.00
Ver [mm]
Ver [mm]
1.00
0.50
-0.01
ROW
60
AUTOSCALE
Clear
OPEN
85.0
File/Dir
A: 41.5238 K
B: 41.3278 K
C1: 2.9578 K
D1: 3.0920 K
C2: 3.0760 K
D2: 3.4275 K
C3: 3.0959 K
D3: 3.5200 K
C4: 3.1430 K
D4: 51.4090 K
C5: 3.1920 K
D5: 56.4509 K
Thanks for your attention!