MACHINA, THE MOVABLE ACCELERATOR FOR CULTURAL HERITAGE IN-SITU NON-DESTRUCTIVE ANALYSIS

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Comitato Scientifico LABEC - Review del Laboratorio

31 May 2023, 10:45 → 1 Jun 2023, 15:00 Europe/Rome

139 (Edificio Fisica Sperimentale)

Leonardo - Codex Atlanticus

MACHINA

a joint INFN – CERN project

The idea: a **movable IBA system** for *in-situ* measurements, to be used at the

Opificio delle Pietre Dure in Florence (a world leader for art conservation)

A realistic compromise between a “perfect” and a “transportable” tool

for compositional diagnostics, to try and solve the problems of conservation

the challenge: maintain performances comparable to those of *standard* accelerators for the routine diagnostic measurements in the cultural heritage field with the following additional *heavy* constraints:

- **Low power consumption**
- **Low weight**
- **Compact (small form factor)**
- **Low radiation emission**
- **Low cost**
- **Transportable**

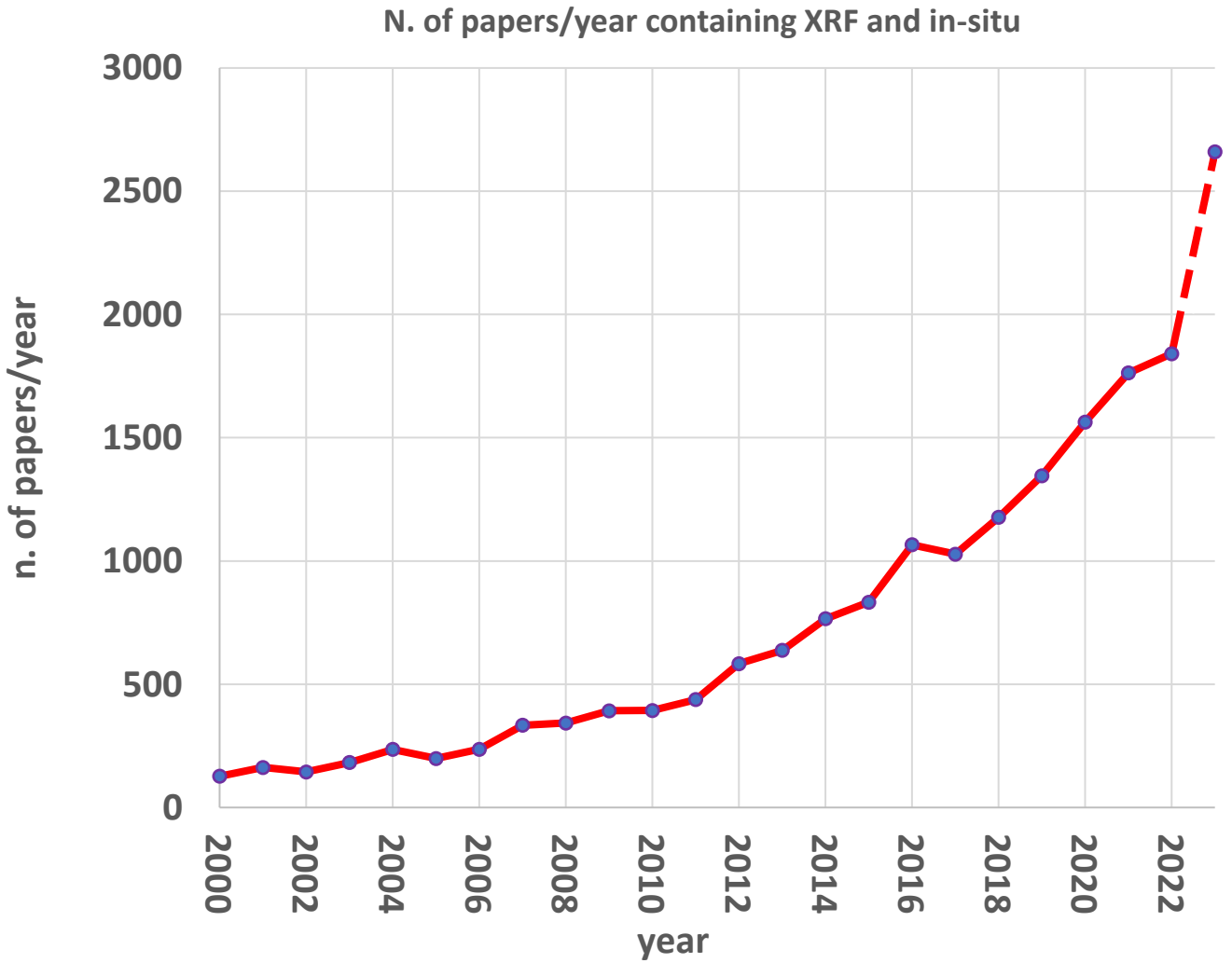
in-situ measurements has become increasingly widespread and common, with more and more fields of applications

ScienceDirect

Find articles with these terms

xrf and in situ

18,300 results



- 2024 (7)
- 2023 (1,108)
- 2022 (1,841)
- 2021 (1,763)
- 2020 (1,564)
- 2019 (1,346)
- 2018 (1,177)
- 2017 (1,028)
- 2016 (1,066)
- 2015 (833)
- 2014 (766)
- 2013 (638)
- 2012 (584)
- 2011 (438)
- 2010 (394)
- 2009 (393)
- 2008 (343)
- 2007 (334)
- 2006 (237)
- 2005 (199)
- 2004 (236)
- 2003 (183)
- 2002 (145)
- 2001 (163)
- 2000 (127)

INFN
Istituto Nazionale di Fisica Nucleare

a prophetic vision… IBA 2015

IAEA Panel on

IBT Roadmap

Aliz Simon

IAEA
Division of Physical and Chemical Sciences
Physics Section

The development of **smaller transportable accelerators** would open new fields, in particular in those applications, as cultural heritage, where the vast majority of the world cultural heritage is immovable. The impact of laboratory based analytical techniques could diminish in the future with the advent of more and more performing ED-XRF systems for elemental analysis of cultural heritage objects

Genesis of MACHINA and Timeline

- **May 2016 TT in Sassari:** first contact (CERN-INFN)
- **Aug 2016 Meeting in Florence and visit at OPD**
- **Feb 2017 1st technical meeting@CERN:** RFQ-PIXE proposal submission
- **Jun 2017 MACHINA proposal submission. RFQ-PIXE project approved**
- **Nov 2017 MACHINA project officially approved and funded (Fondo Integrativo Speciale per la Ricerca, FISR) 1.77 €**
- **Dec 2017 2nd technical meeting@LABEC**
- **Jan 2018 Technical kickoff. Data exchange, drawing production**
- **Feb 2018 Ignition! We start to spend money**
- **2018-19 INFN:** source, LEBT, HEBT, control system HD&SW
  CERN: accelerating cavities (RFQ) and RFQ PA
- **Aug 2020 CERN and INFN subsystems merged in one single system**
- **Sept 2021 RF-PA installed. Start conditioning**
- **May 2022 the first 2 MeV proton beam extracted in air**
- **→ now Multidetector Imaging and… waiting for the go!**

Istituto Nazionale di Fisica Nucleare

Rendiconti Lincei. Scienze Fisiche e Naturali
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RESEARCH PAPER

MACHINA, the Movable Accelerator for Cultural Heritage In-situ Non-destructive Analysis: project overview

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The CERN PIXE-RFQ, a transportable proton accelerator for the machina project

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Main features of MACHINA

Source, LEBT and HEBT:

1.5 m x 1 m, 1 kW, 400 kg

2 HF-RFQ cavities:

1 m x 0.4 m, 100 kg mass

Accelerator system:

500 kg, 2.5 m x 1 m, <1 kW

Ancillaries:

RFQ Power supplies*:*

Now: 860 kg, 2.5 m x 1 m, 14 kW,

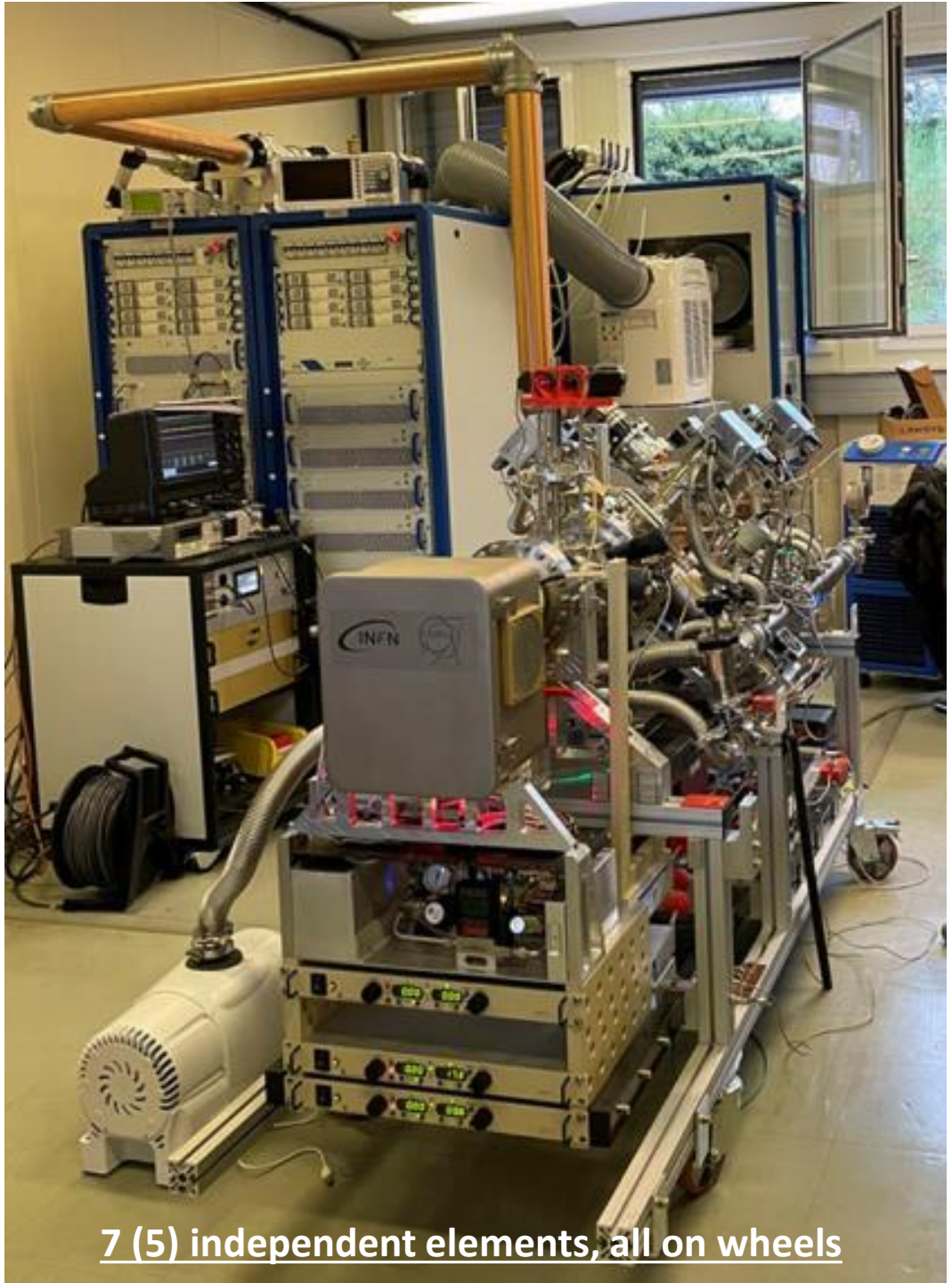
Next gen: 500 kg, 0.6 m x 0.6 m, 7-8 kW

As a whole, now:

Mass ~1300 kg ,

Power ~15 kW,

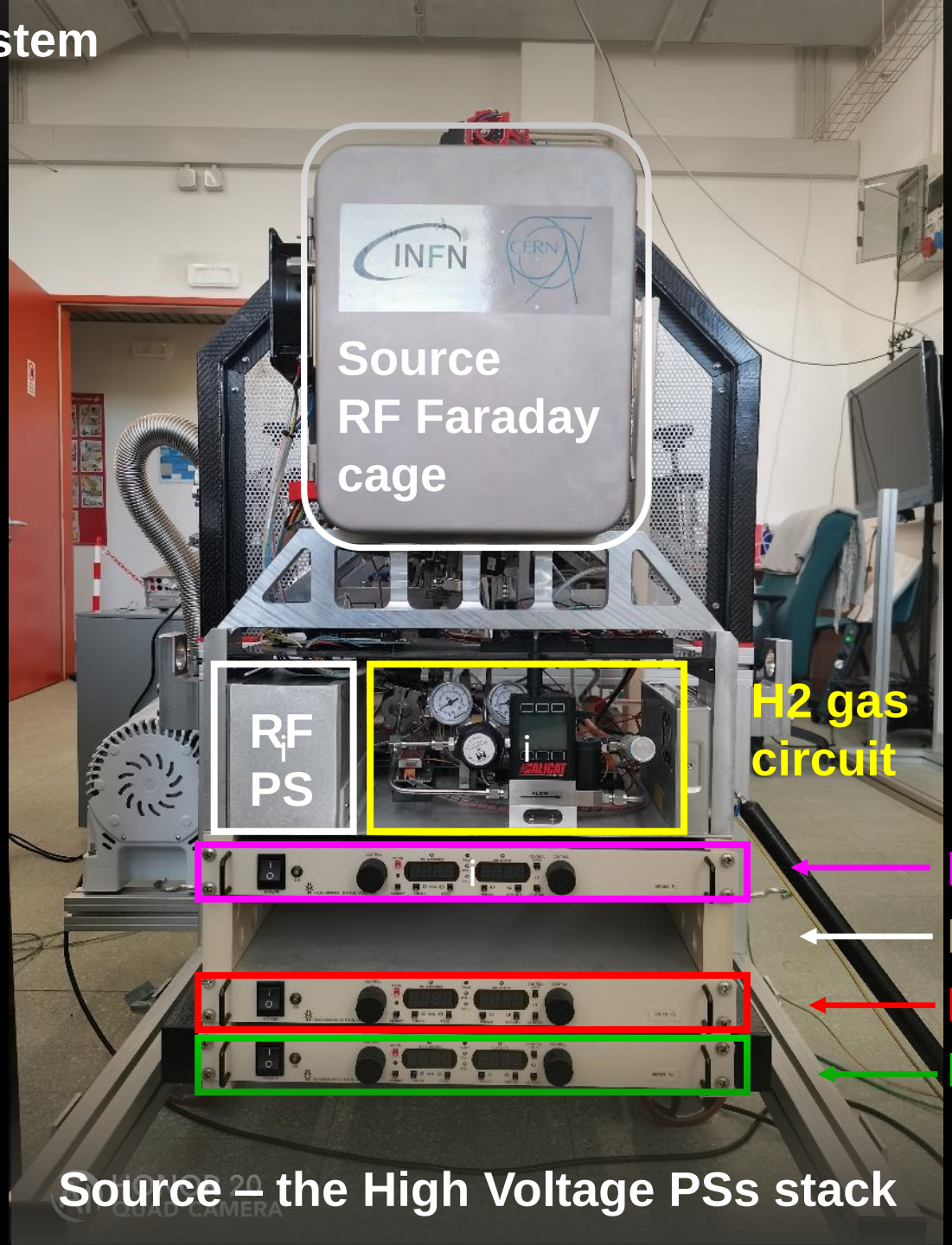
Footprint < 10 m²



7 (5) independent elements, all on wheels

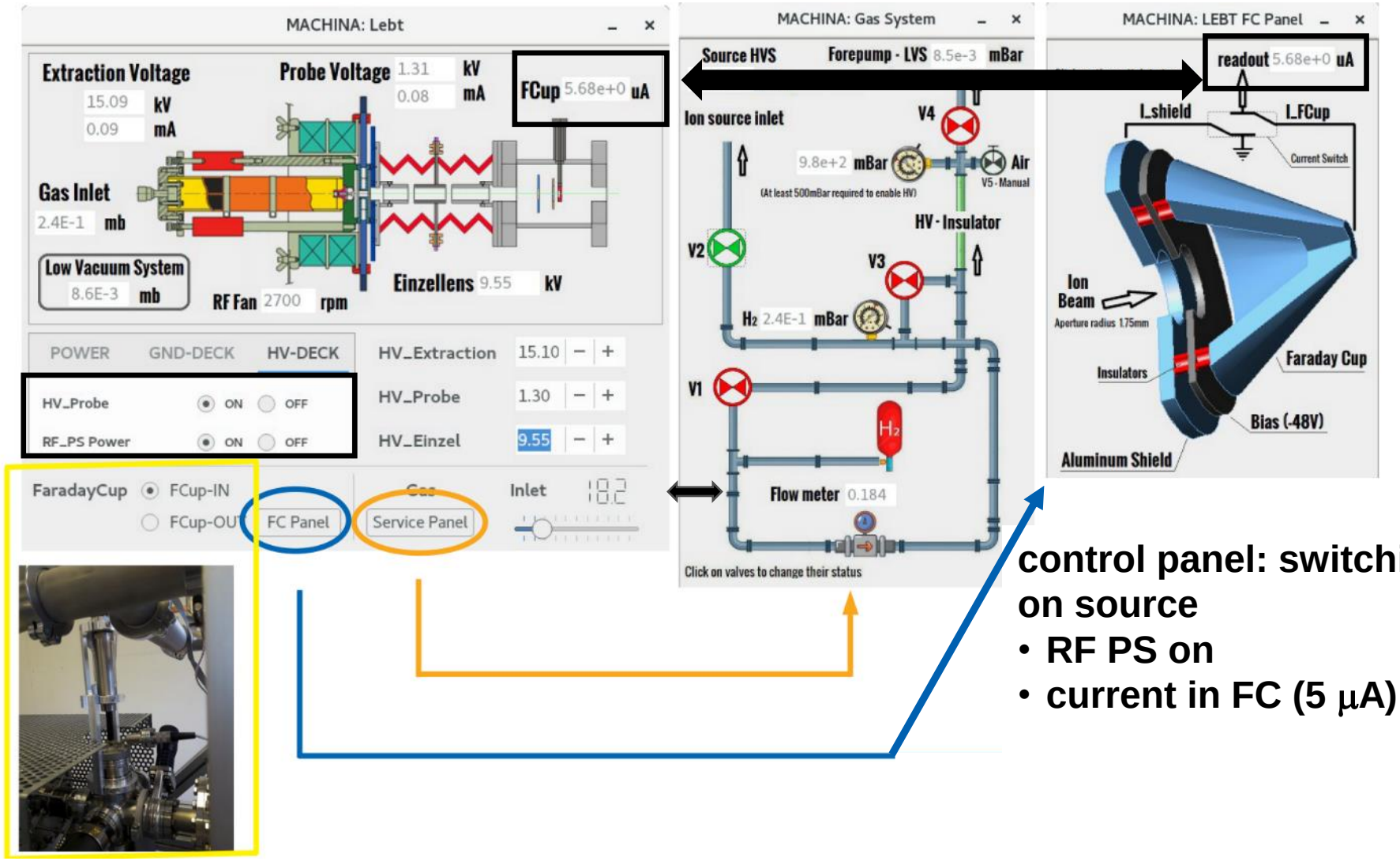
Source – the whole system

Source – the High Voltage security cage



Source – the High Voltage PSs stack

LEBT

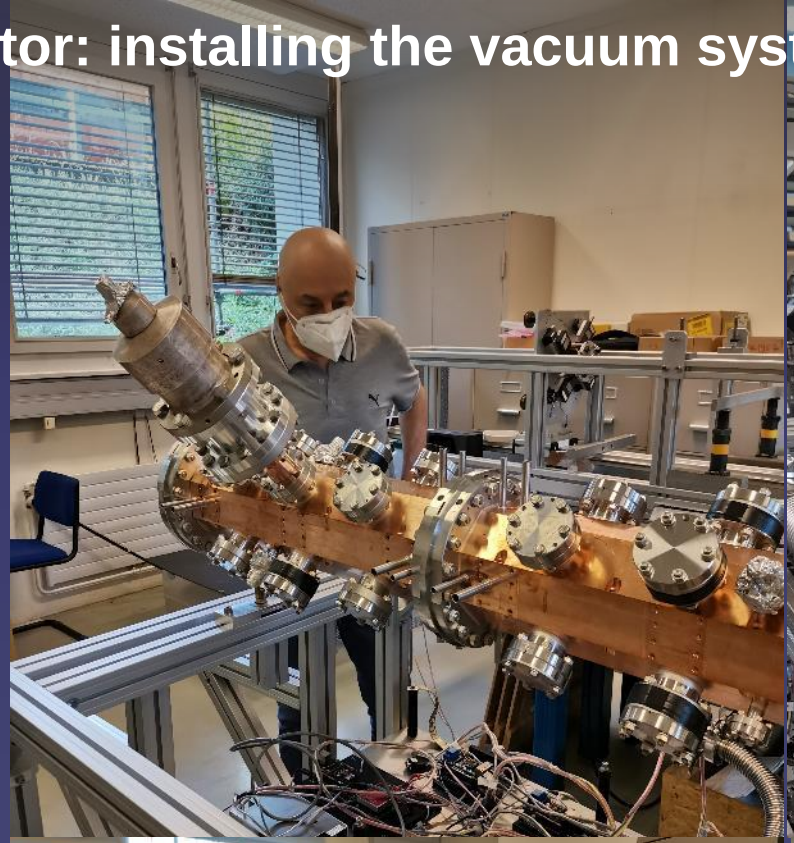


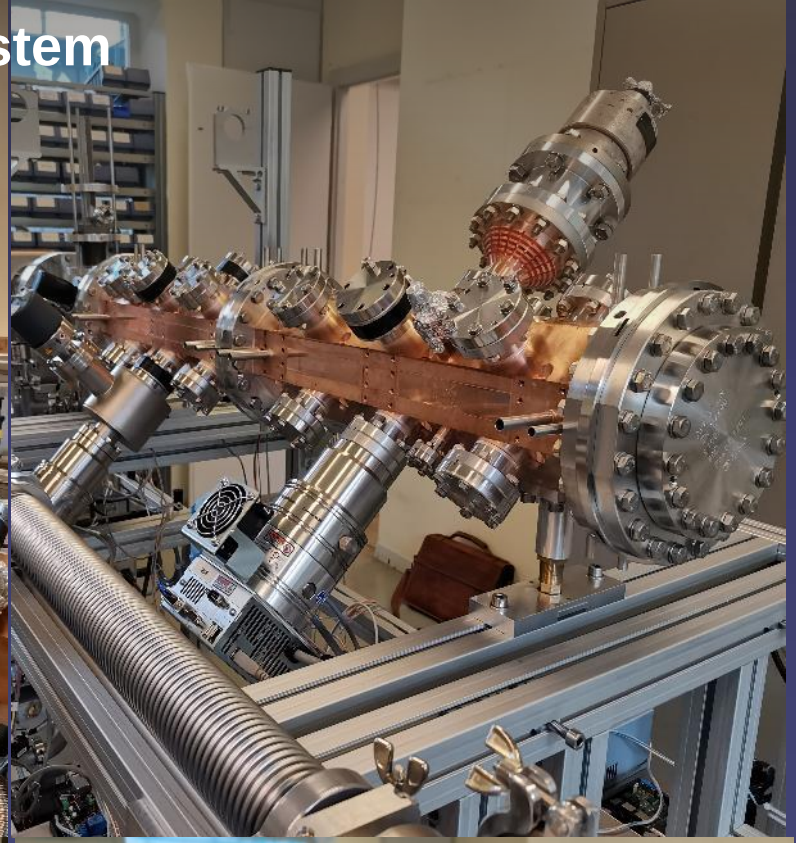
control panel: switching on source

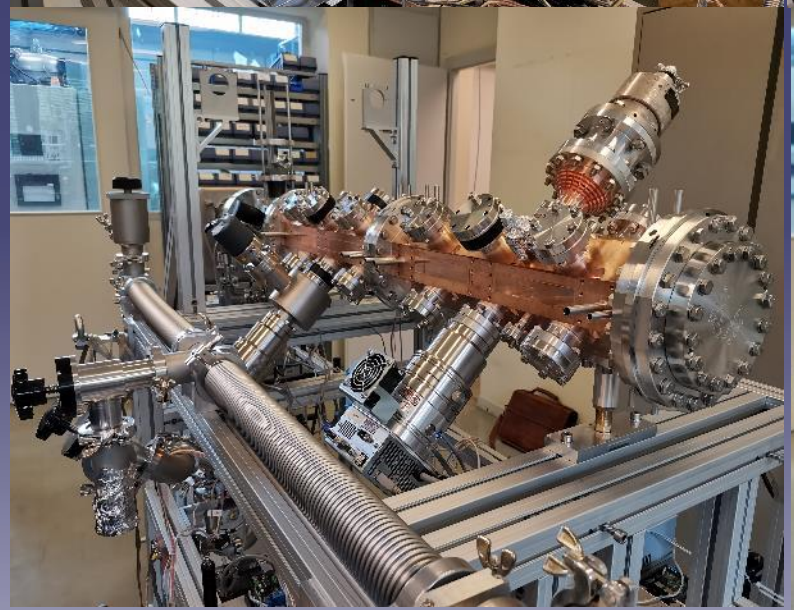
- **RF PS on**
- **current in FC (5 μA)**

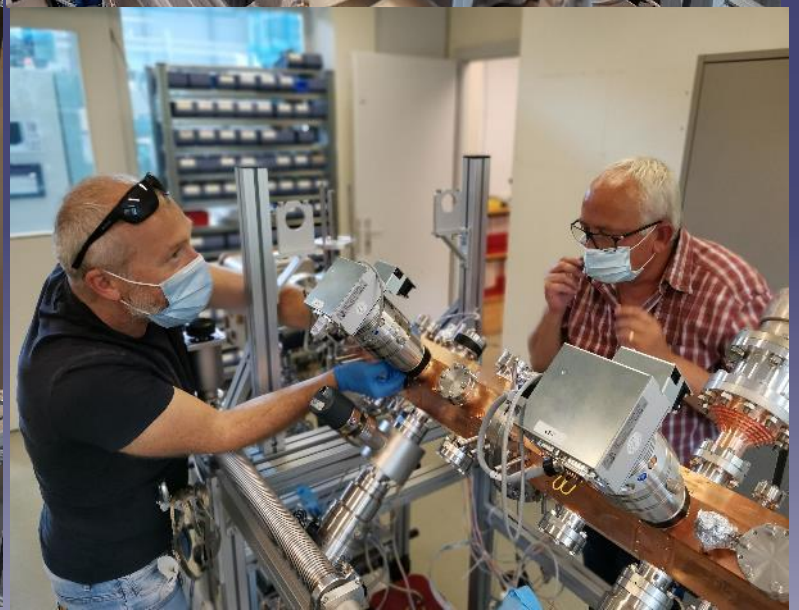
LEBT: source gas and current measurement with the source switched on

Accelerator: installing the vacuum system





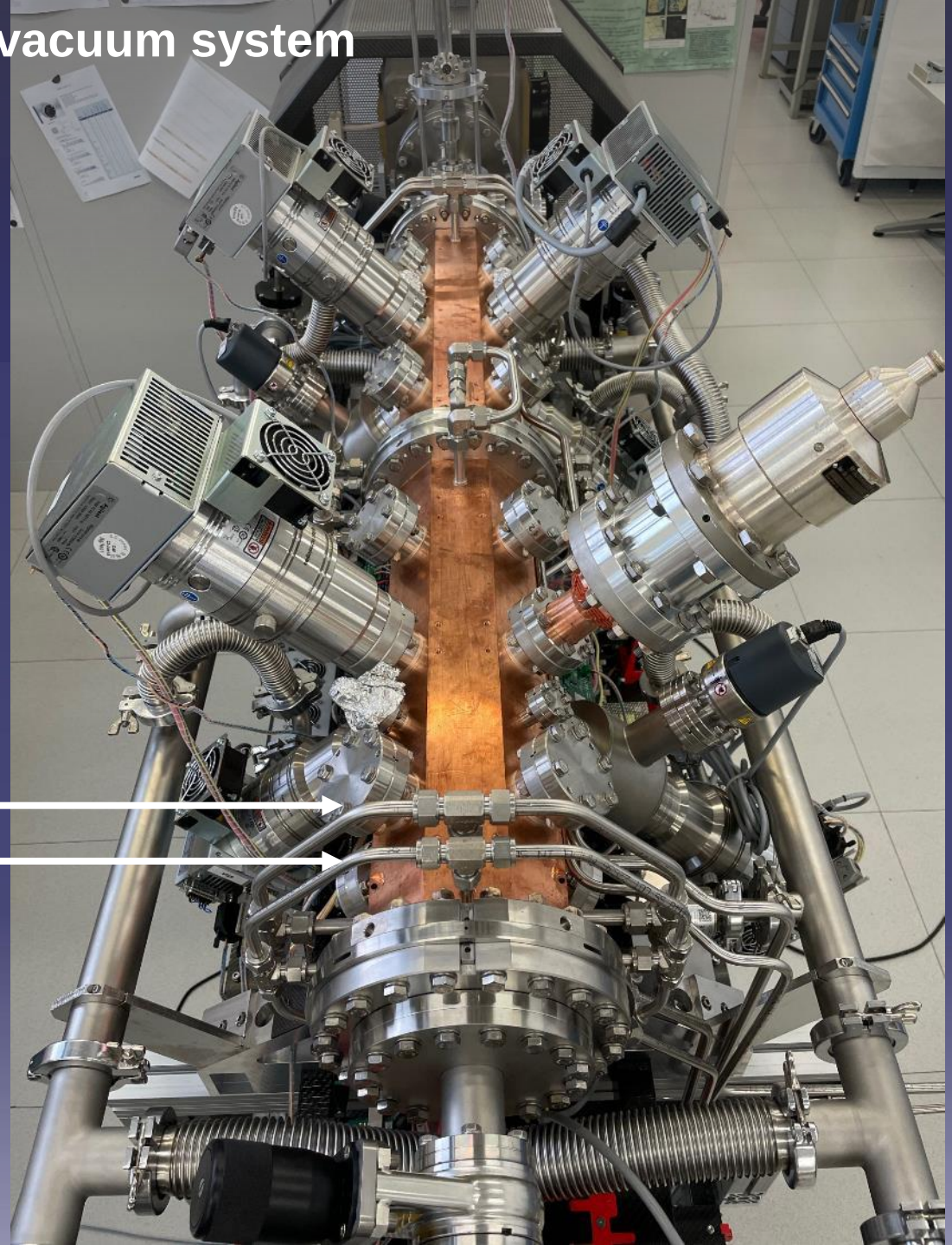




Accelerator: installing the vacuum system

The vacuum system installed
High vacuum
Low vacuum
Pressure gauges
Control system

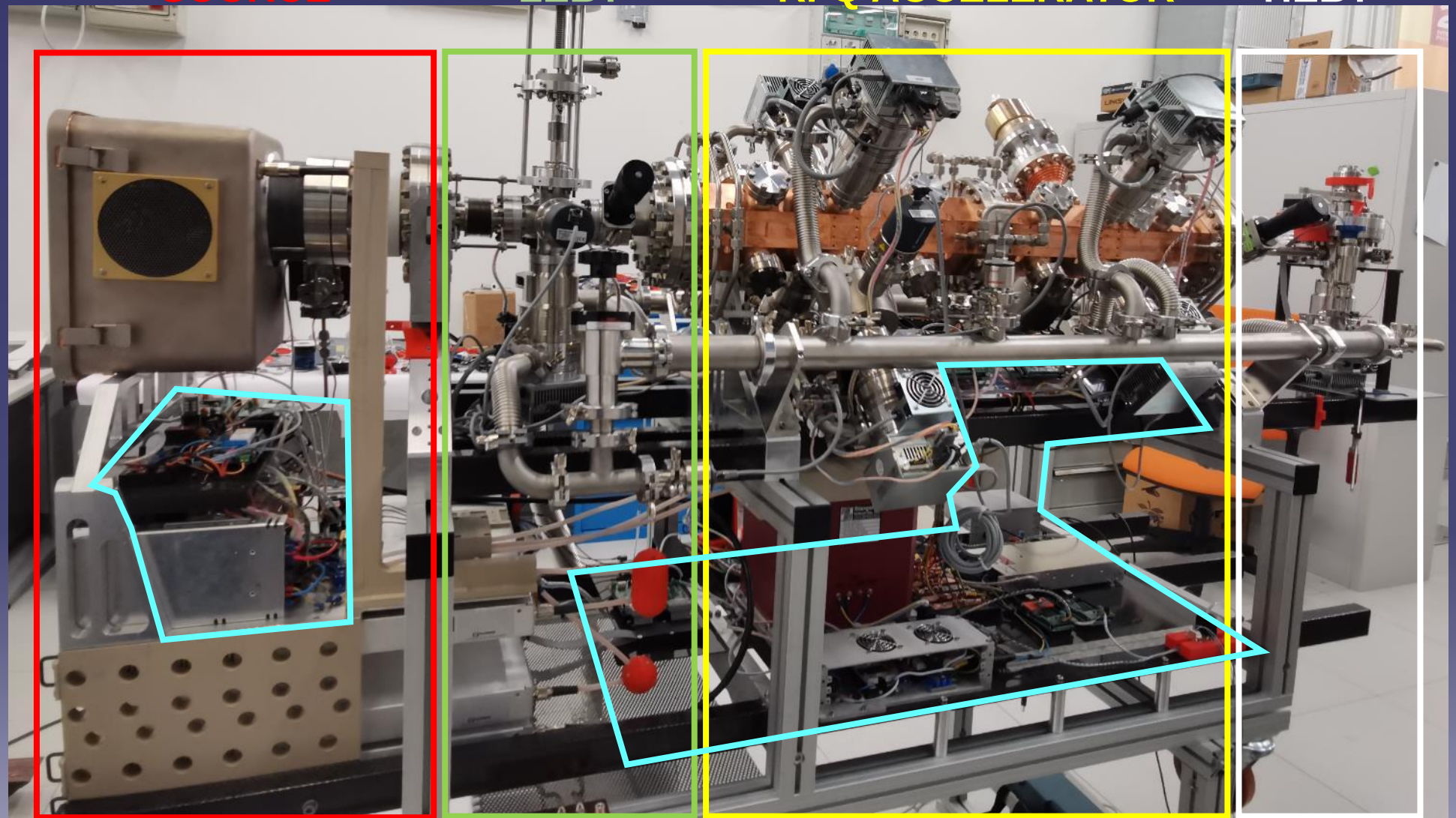
the water ducts
for the RFQ cooling



Accelerator: the whole system

CONTROL ELECTRONICS

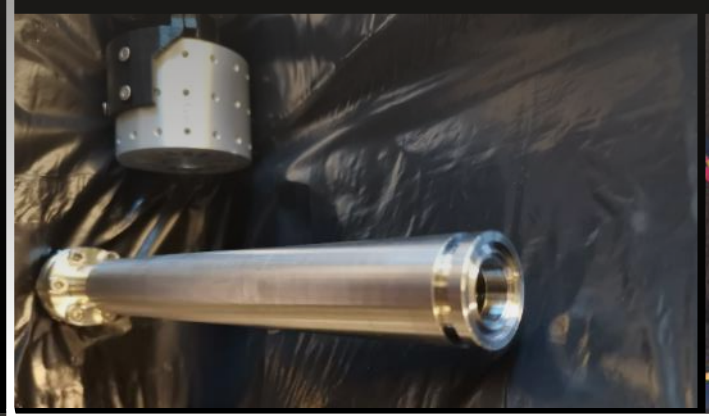
SOURCE LEBT RFQ ACCELERATOR HEBT

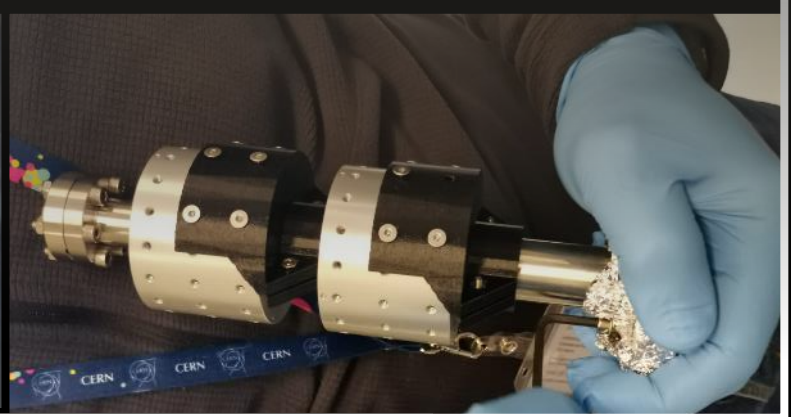


Accelerator: the whole system

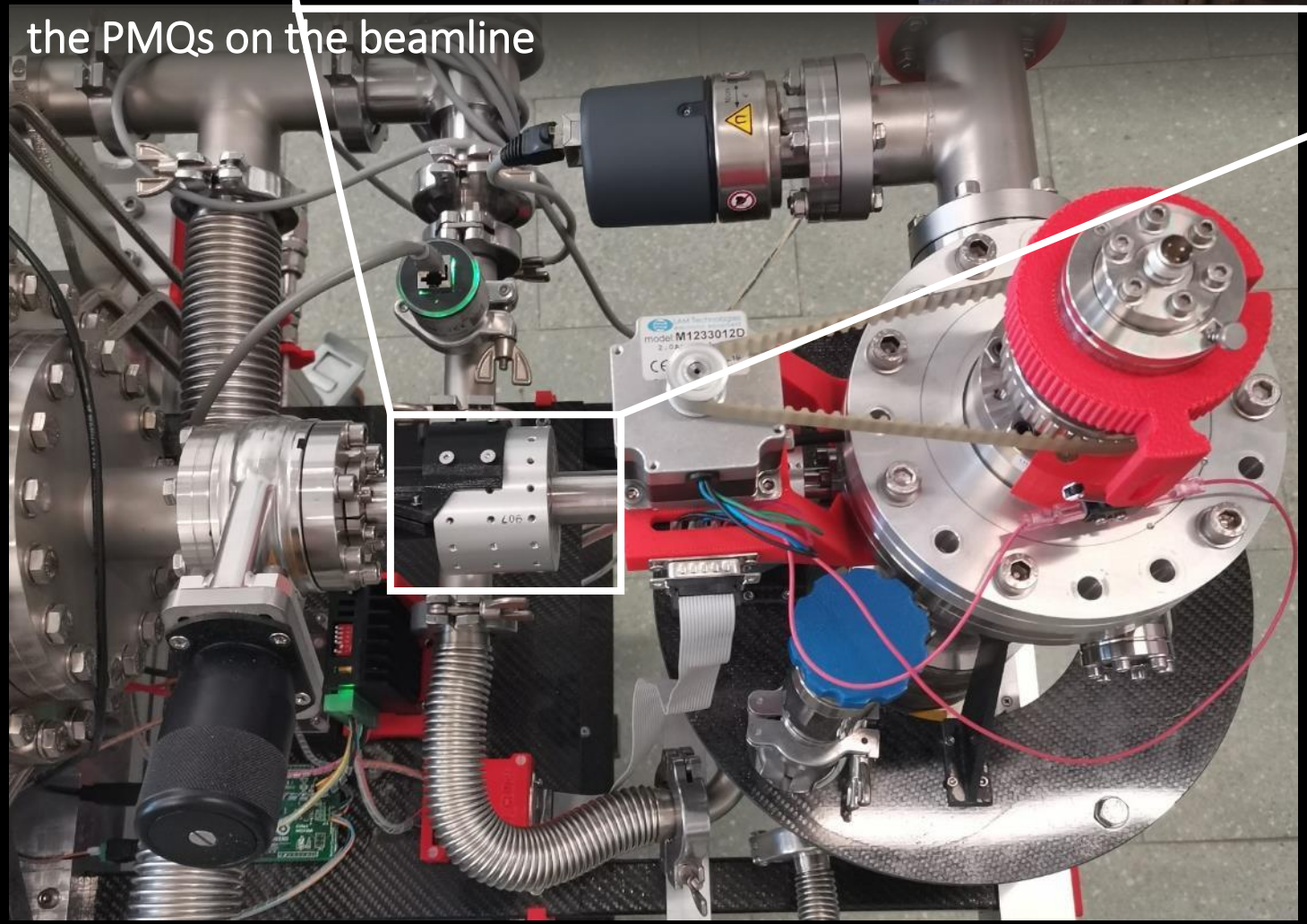
RFQ power apmplifiers and their chiller

HEBT



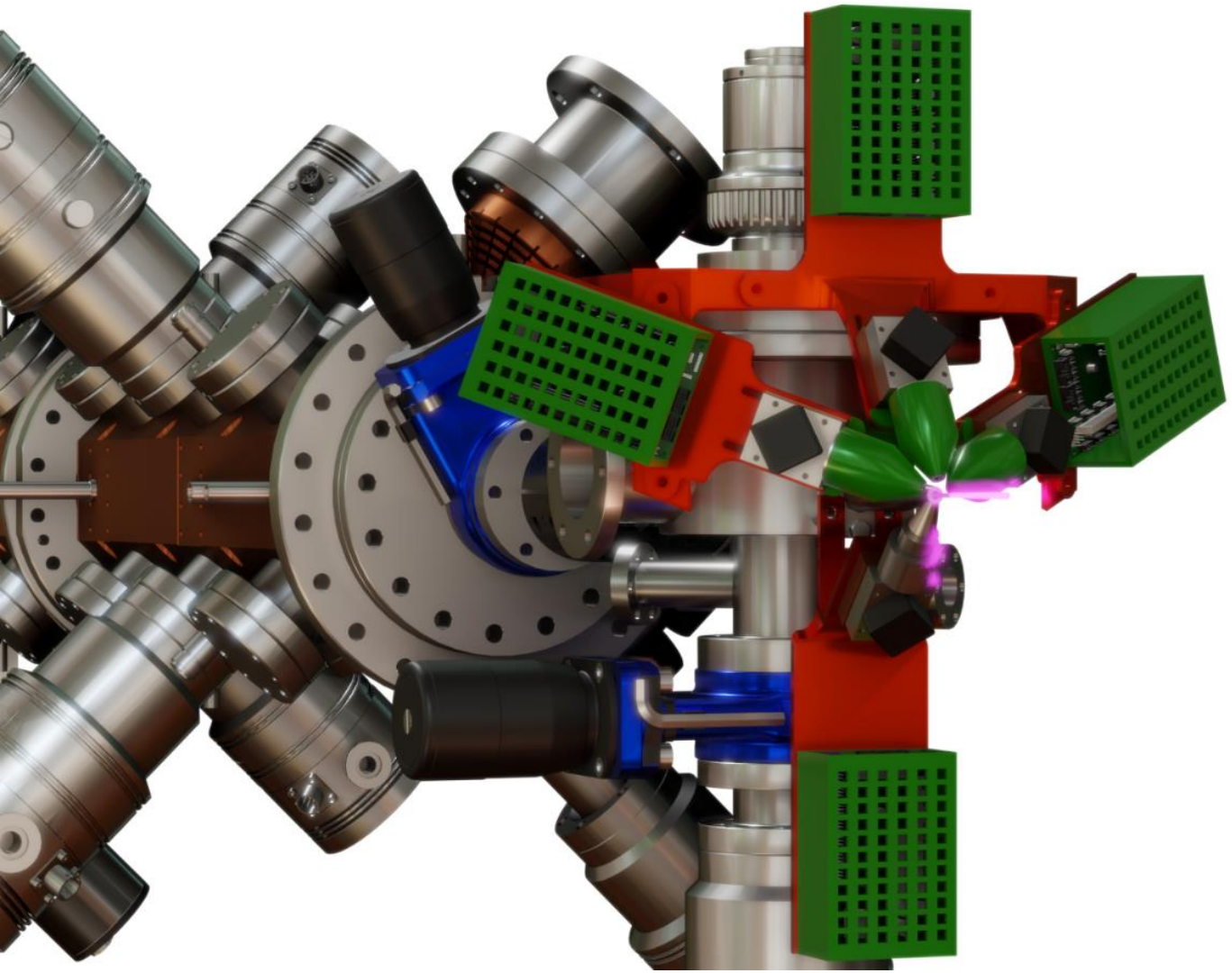


the PMQs on the beamline



500 nm Si3N4 window on the exit nozzle

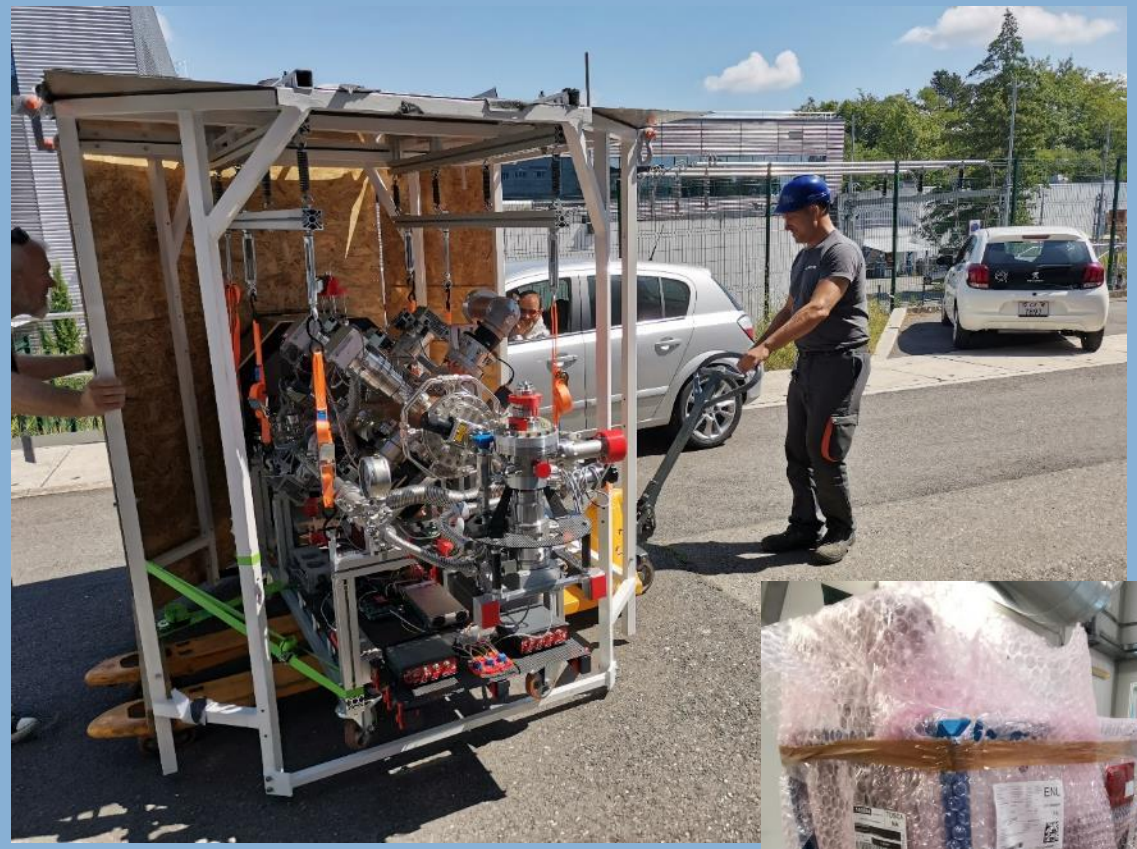
HEBT



Detection set-up

- 2 x 50 mm2 SDD for PIXE
- 1 x CdTe 25 mm2 area, 1 mm thick, or high energy PIXE - low energy PIGE)
- 1 x 50 mm2 SDD x current (below the beam, upside looking)

Transportabilty



The whole system proved its transportability.
The accelerator system has been moved back and forth from the INFN-LABEC in Florence and CERN in Geneva many times, once including also the PSs

Transport needs:

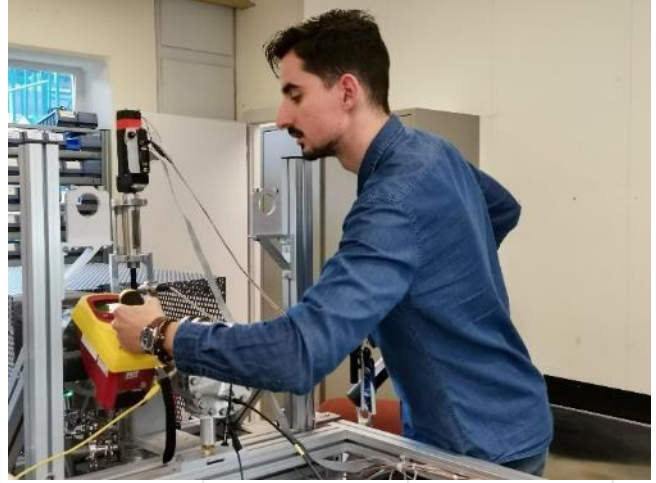
- 2 small trucks/van (1 for the accelerator and 1 for the PSs), easier than using 1 big lorry
- half a day for packing

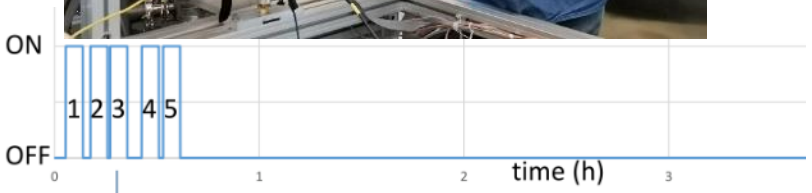
Transportabilty

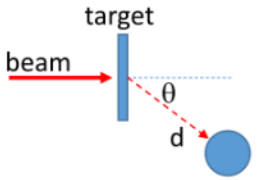
Radio safety

MACHINA is intrinsically safe as radiation protection is concerned

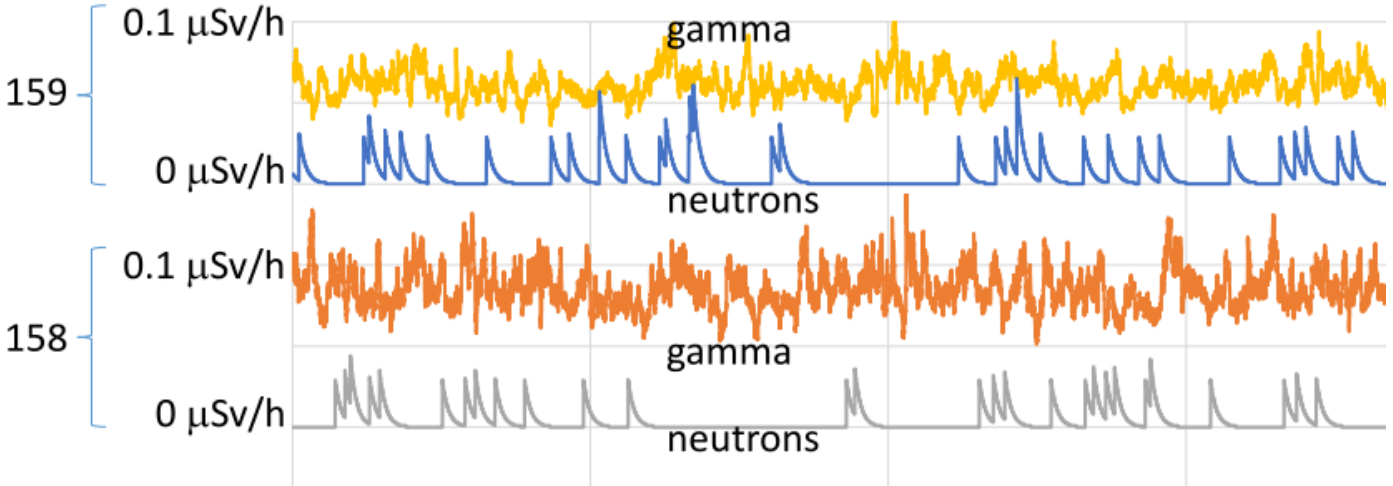
- Source+LEBT: X-rays (E<20keV) absorbed in the walls
- Accelerator: lost particle energy < 200 keV.
- Beam energy < 2 MeV neutrons negligible, even on copper (E_{th} ($^{65}Cu(p,n)^{65}Zn$) = 2.17 MeV)
- HEBT and extracted beam:
  2 MeV, @ 100-300 pA on PLA, Al, Fe, Cu:
  no difference in the e.m. and neutrons dose rates from background
  (50-100 nSv/h for e.m. radiation and < 100 nSv/h for neutrons)
- but still waiting for the go!







RUN	Target	Angle	current
1	Fe	50°	0.17 nA
2	Cu	50°	0.17 nA
3	Air	50°	0.19 nA
4	Fe	0°	0.23 nA
5	Air	0°	0.34 nA

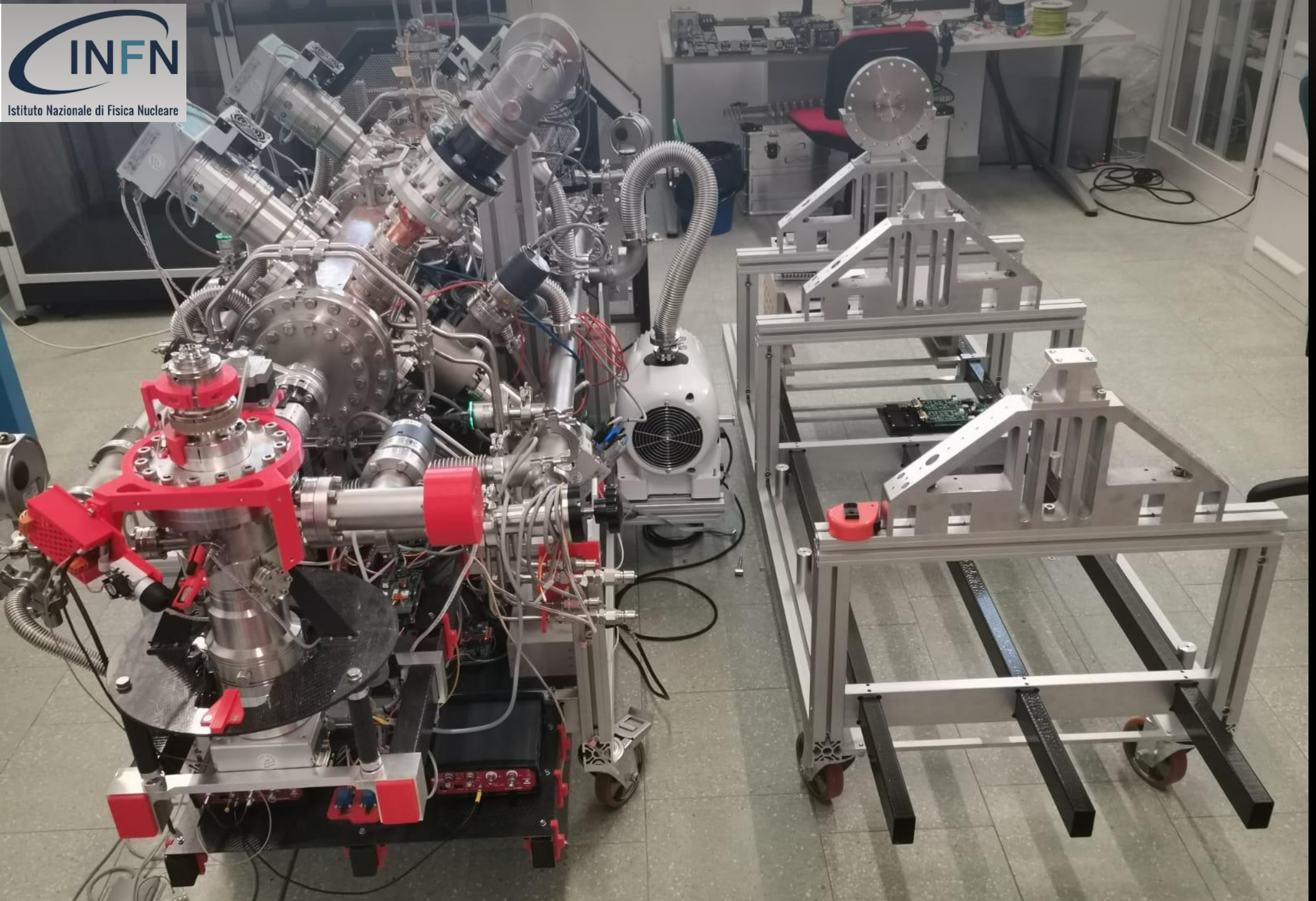


Beam

First extracted beam

Beam

First extracted beam and focussing
~ 100 pA, ~ 0.5 mm diameter



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MACHINA2 is coming!

GSSI will invest about 2 M€ for MACHINA2

new students!

many
thanks
for your
attention!