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LABORATORI NAZIONALI DEL SUD

LNS Accelerator Division: status and perspectives

Luigi Celona

Seconda Giornata Acceleratori

Catania, March 02nd 2022

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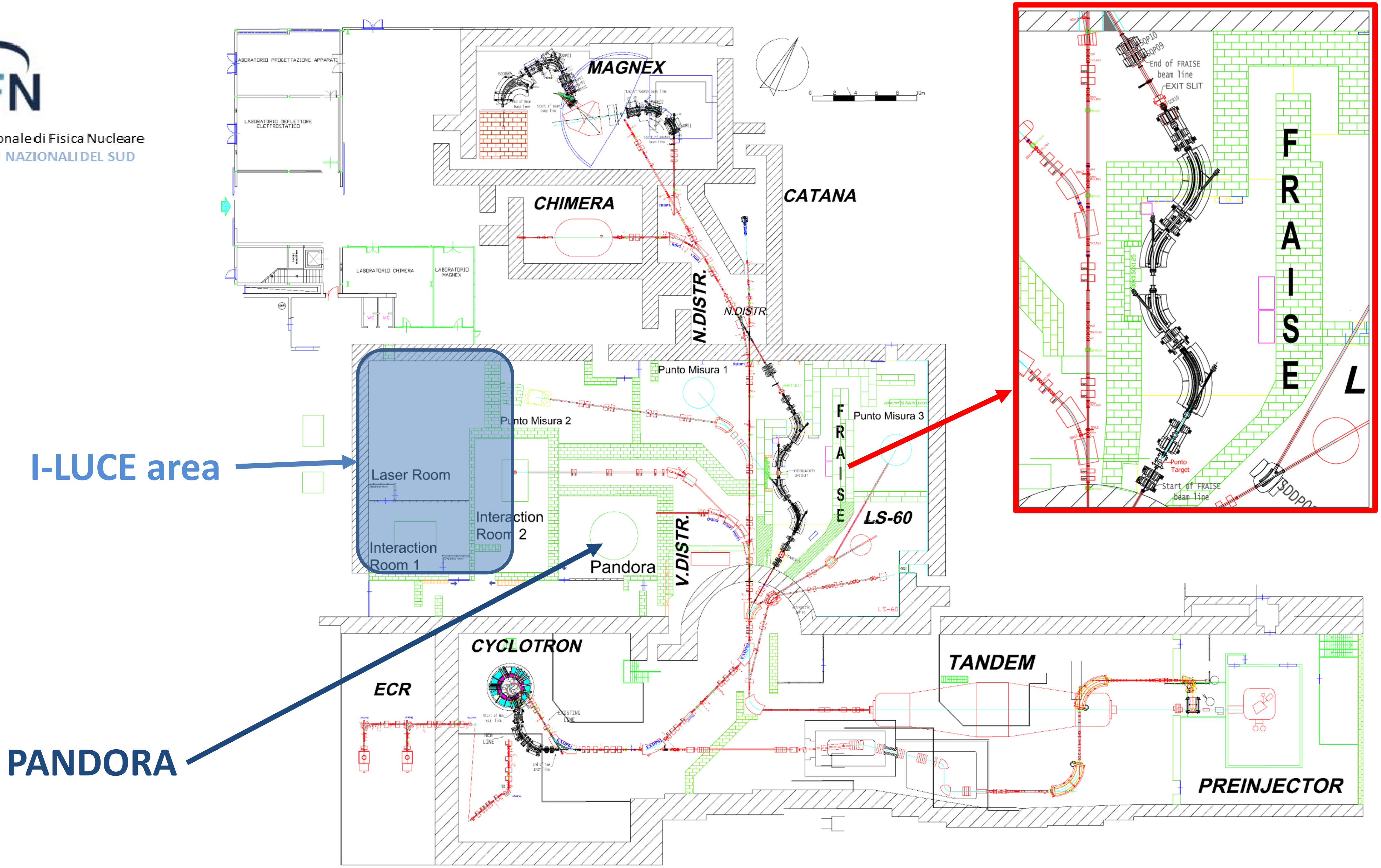

I-LUCE area

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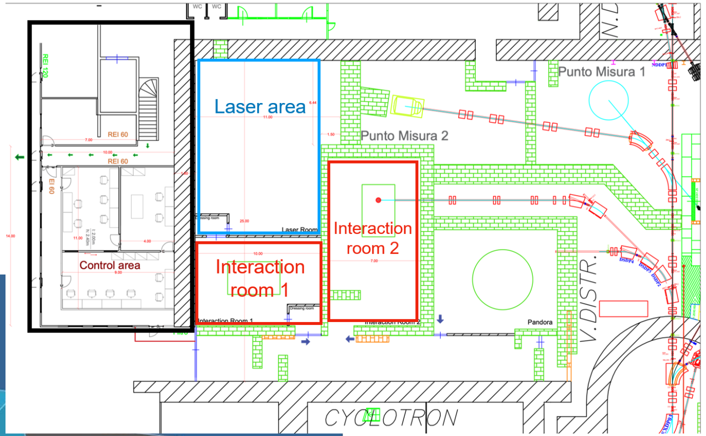

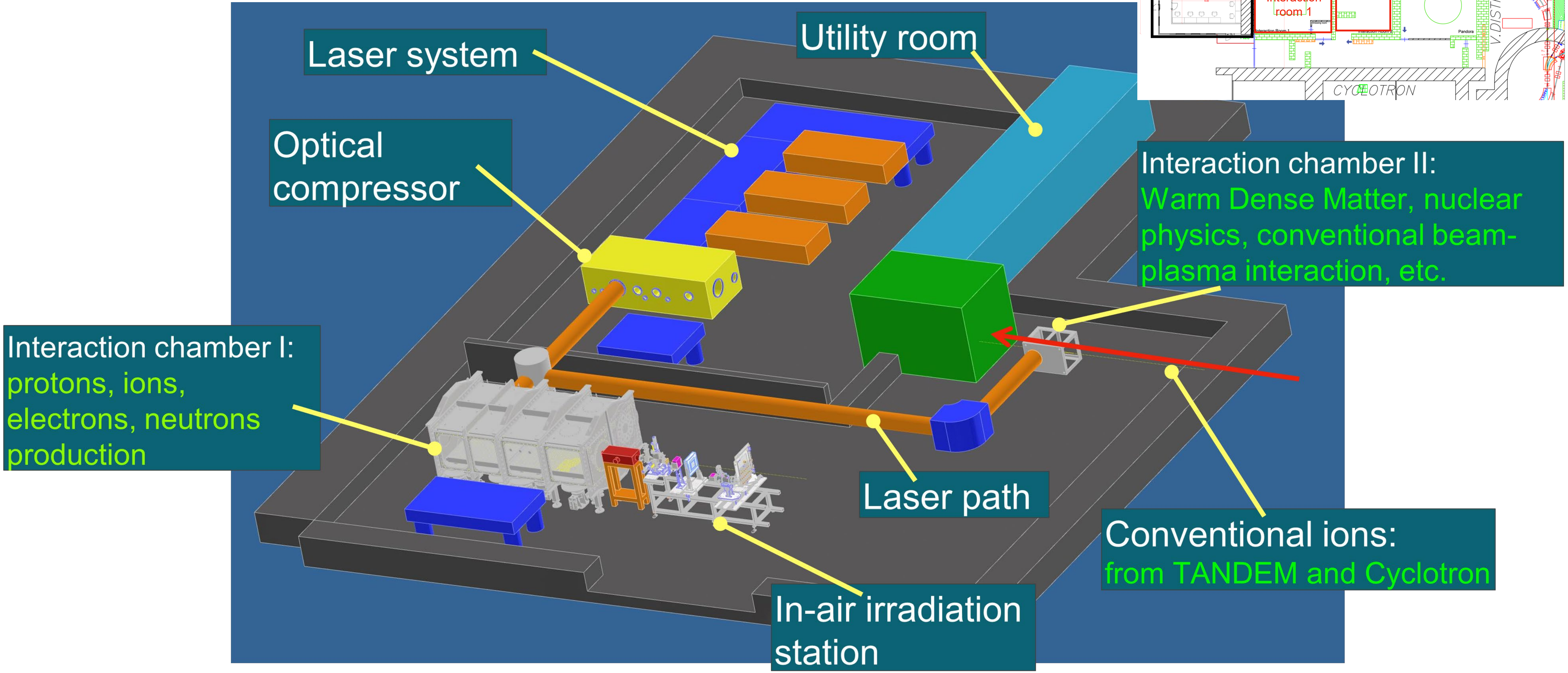

by P. Cirrone

PANDORA:Plasmas for Astrophysics, Nuclear Decays Observation and Radiation for Archeometry

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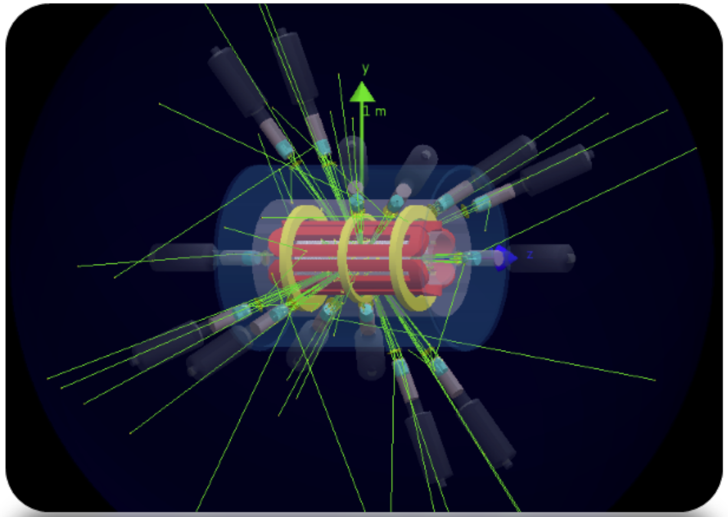
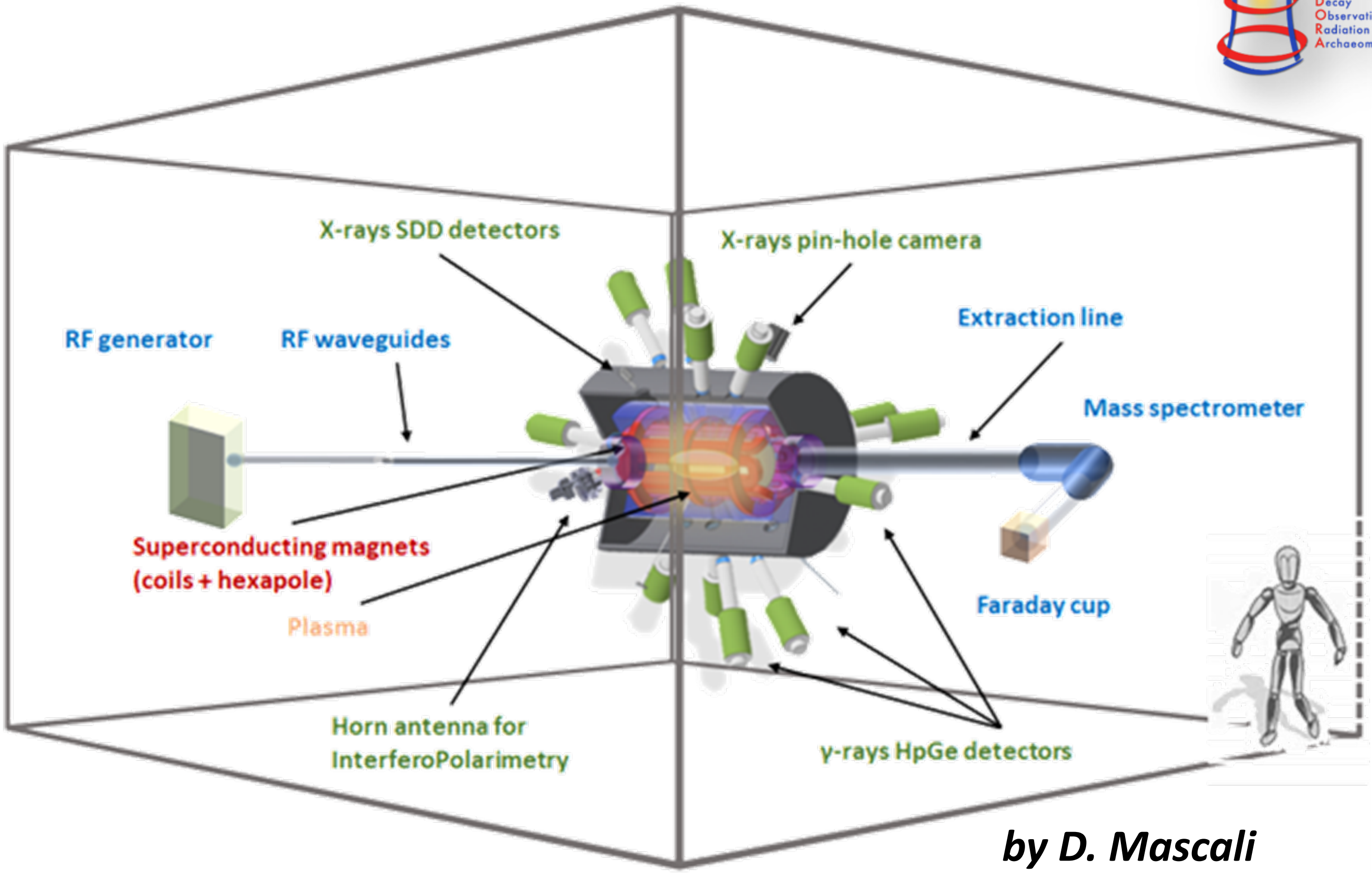
ECRIT – ECR Ion Trap for β-decay measurements in plasmas

MAIN GOAL: Make β–decay measurements in plasmas of astrophysical interest: many isotopes can change their lifetime of several order of magnitude when ionized!!



Isotope	$T_{1/2}$ (yr)	Eγ (keV)
^{176}Lu	3.78x10^{10}	88-400
^{134}Cs	2.06	>600
^{94}Nb	2.03x10^{4}	>700



by D. Mascali

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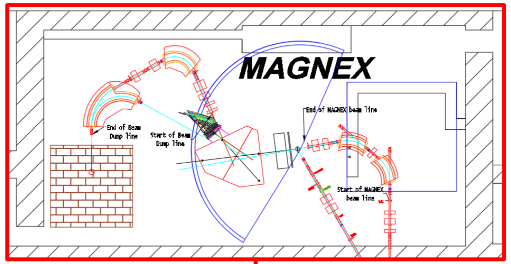
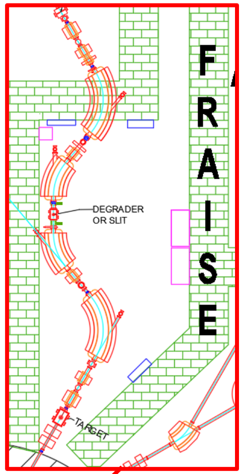
Status of accelerator rooms & beam lines

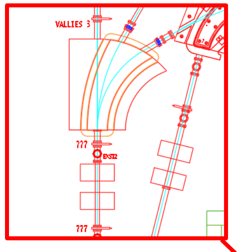
Magnex beam lines



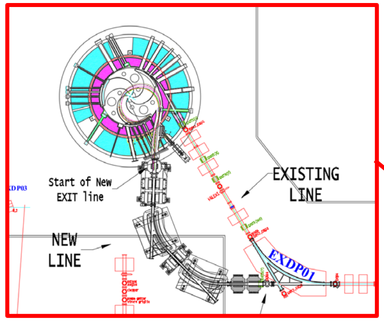
FRAISE Line

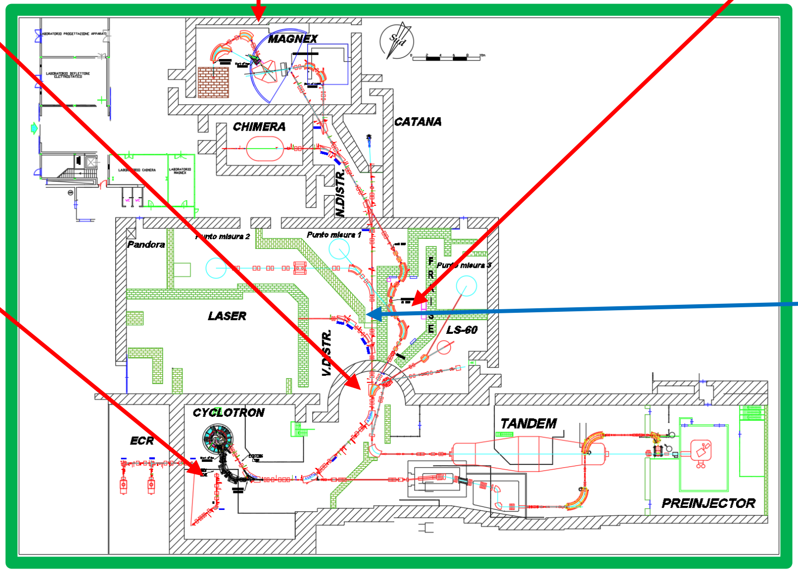


Switching magnet

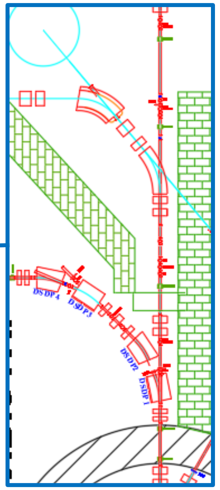


New Exit Line





Zero gradi



Attività esterne:

- Installazione ed allineamento delle linee di trasporto previste dal POTLNS;
- Installazione e collegamento dei nuovi power converter;
- Installazione del sistema da vuoto

Attività interne:

- Installazione ed allineamento linee di fascio smontate per upgrade schermature;
- Installazione linea di iniezione CS;
- Installazione canaline porta cavi e servizi;
- Ripristino dei collegamenti elettrici e servizi;
- Installazione nuova diagnostica e controlli;
- Restyling del sistema da vuoto attuale;
- Allineamento della linea di trasporto

TANDEM automation and instrumentation upgrading

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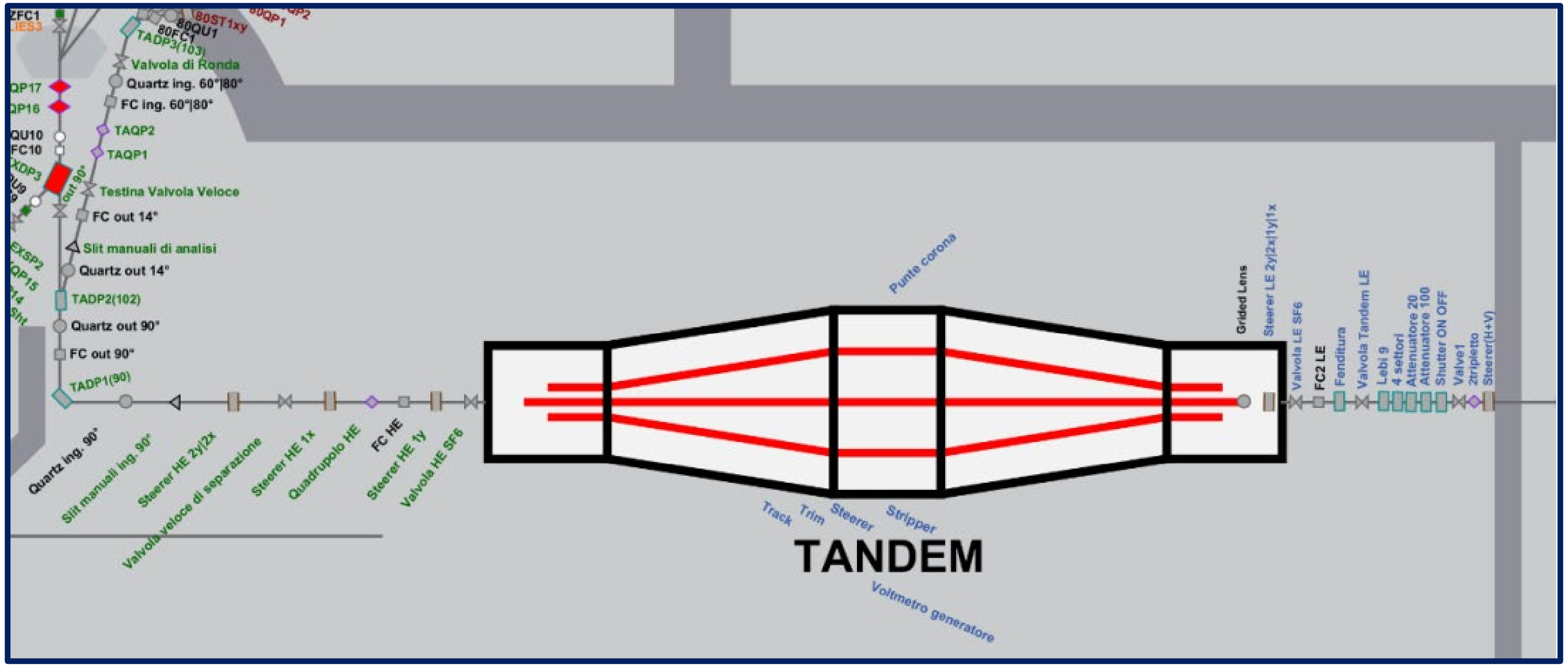

Implementation of a new software platform

Replacement of obsolete instrumentation

First Tandem beam delivered to 60° beamline expected for end of 2023

Pelletron extra maintenance and relative tests (NEC discussion ongoing)

Tandem vacuum system

Alignment check

Power converter change

Safety issues (RSPP prescriptions)

Tandem tests April-May’23

Switching magnet installation May’23

Electrical plant extra maintenance (compliance) June’23

SF6 plant extra maintenance (controls with redundancy of temperature and pressure gauges, alarm leak) July’23

Improved Diagnostics

Spectrometry of accelerated species

Consolle migration

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Tandem Beam Menu

- ^{1}H, ^{2}H
- ^{6}Li, ^{7}Li
- ^{9}Be, ^{10}Be
- ^{10}B, ^{11}B
- ^{12}C, ^{13}C
- ^{14}N
- ^{16}O, ^{17}O, ^{18}O
- ^{19}F
- ^{23}Na
- ^{24}Mg, ^{25}Mg
- ^{27}Al
- ^{28}Si, ^{29}Si
- ^{32}S, ^{34}S
- ^{35}Cl, ^{37}Cl
- ^{40}Ca
- ^{58}Ni, ^{60}Ni
- ^{63}Cu, ^{65}Cu
- ^{70}Ge
- ^{79}Br
- ^{93}Nb
- ^{116}Sn, ^{120}Sn
- ^{127}I
- ^{197}Au

Maximum High Voltage ≈ 13.5MV

Pelletron charging system

HV stability ≈ 10^{-4}

Noble gases development in progress

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Long half-life isotopes in batch-mode

^{10}Be ($T_{1/2}$ = 1.39×10^{6} y) *Tandem* beam has been produced in batch-mode, in collaboration with PSI (Zurich)

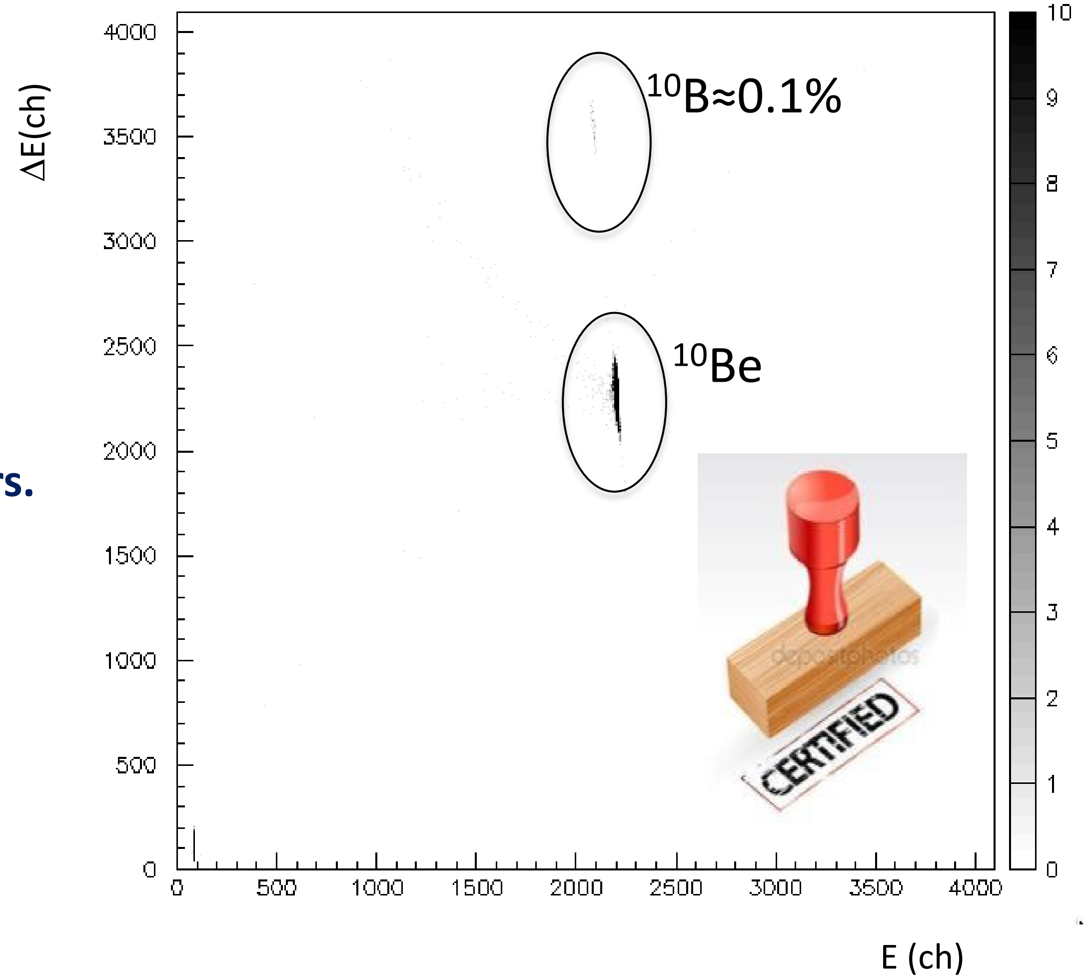
@ 47 MeV

I ≈10 nA for a few days

Contamination of ^{10}B≈ 0.1%

Batch-mode beam development is foreseen for the next years.

Next possible beam: ^{26}Al ($T_{1/2}$=7.17×10^{5} y)



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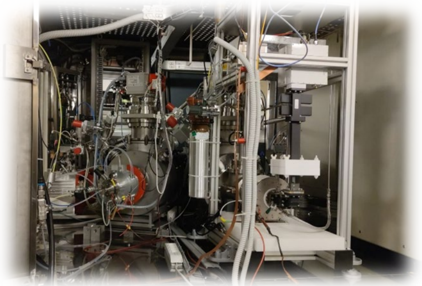
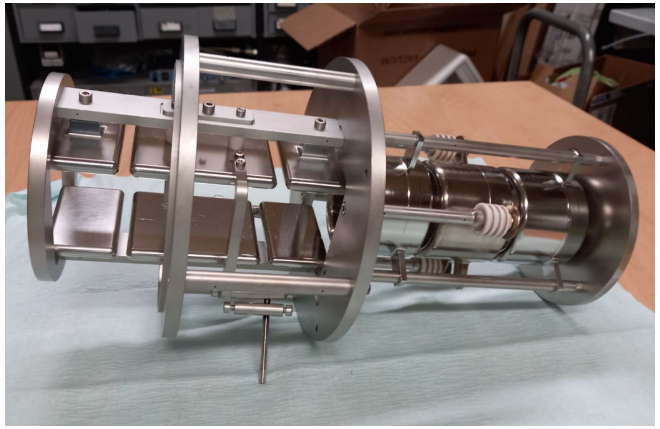
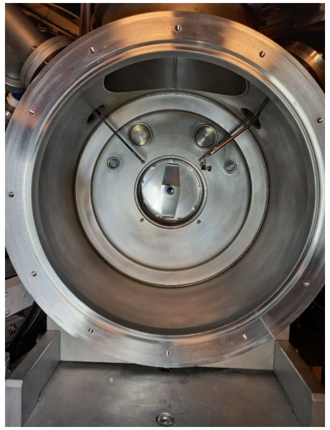
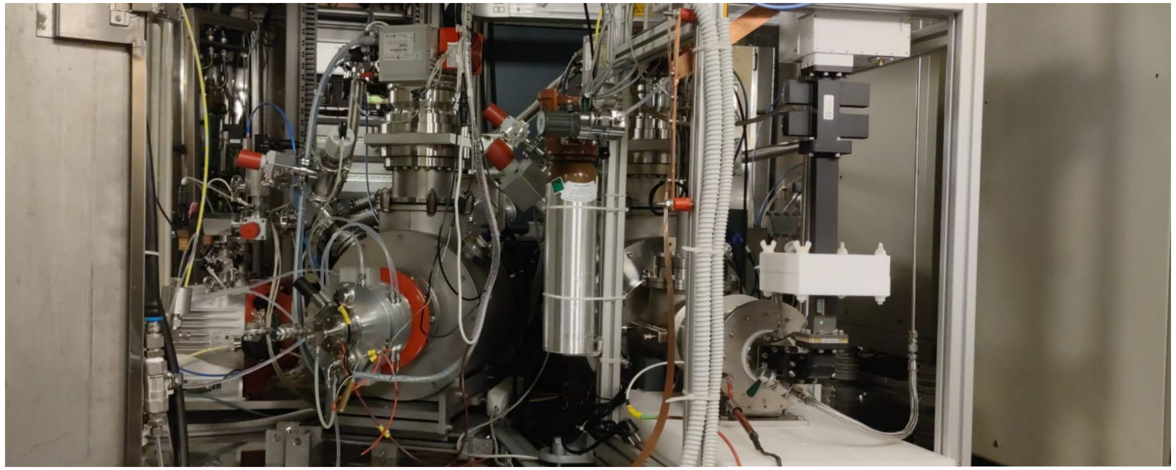
450kV PLATFORM-Sputter IS



Extraordinary maintenance was carried out for all the subsystems







Sputtering beam planned:

1. **Gold -> reference beam**
2. **Aluminium**
3. **Lithium** } from Li_2O+Ag
4. **Oxygen** } from Li_2O+Ag
5. **Magnesium** from Mg +H_2 or Mg+NH_3
6. **Carbon** from BN+ graphite or B_4C

Training and Skills transfer

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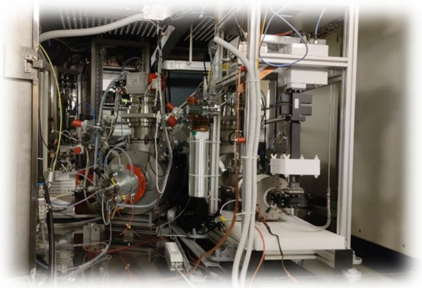
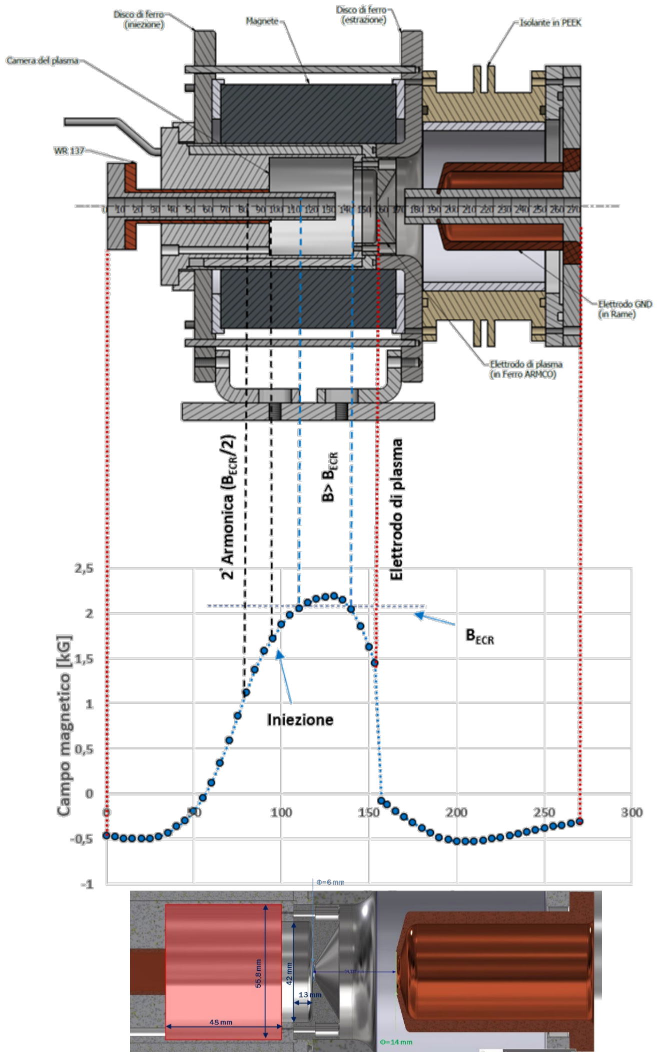
450kV PLATFORM-NESTOR





New characterization in progress:

- degradation of performance observed after almost one week of operation
- modification in progress

Planned operations:

- Positive He production and relative transport along the beam line in different conditions and operations
- Charge-exchange cell installation and test of production of negative ion beams in different conditions and operations.

Superconducting Cyclotron

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Operating 1994 - 2020

E_{MAX} ~ 80 AMeV for lighter ions

E_{MAX} ~ 25 AMeV for heavier ions (i.e. Au^{36+})

K_{bend} =800 - K_{foc}=200

Pole radius: 90 cm – Mag. field: 2.2 - 4.8 T

RF range: 15-48 MHz

Since 1999

Two ECR ion sources: CAESAR and SERSE

June 2020 last experiment, disassembly for the upgrading started in November.

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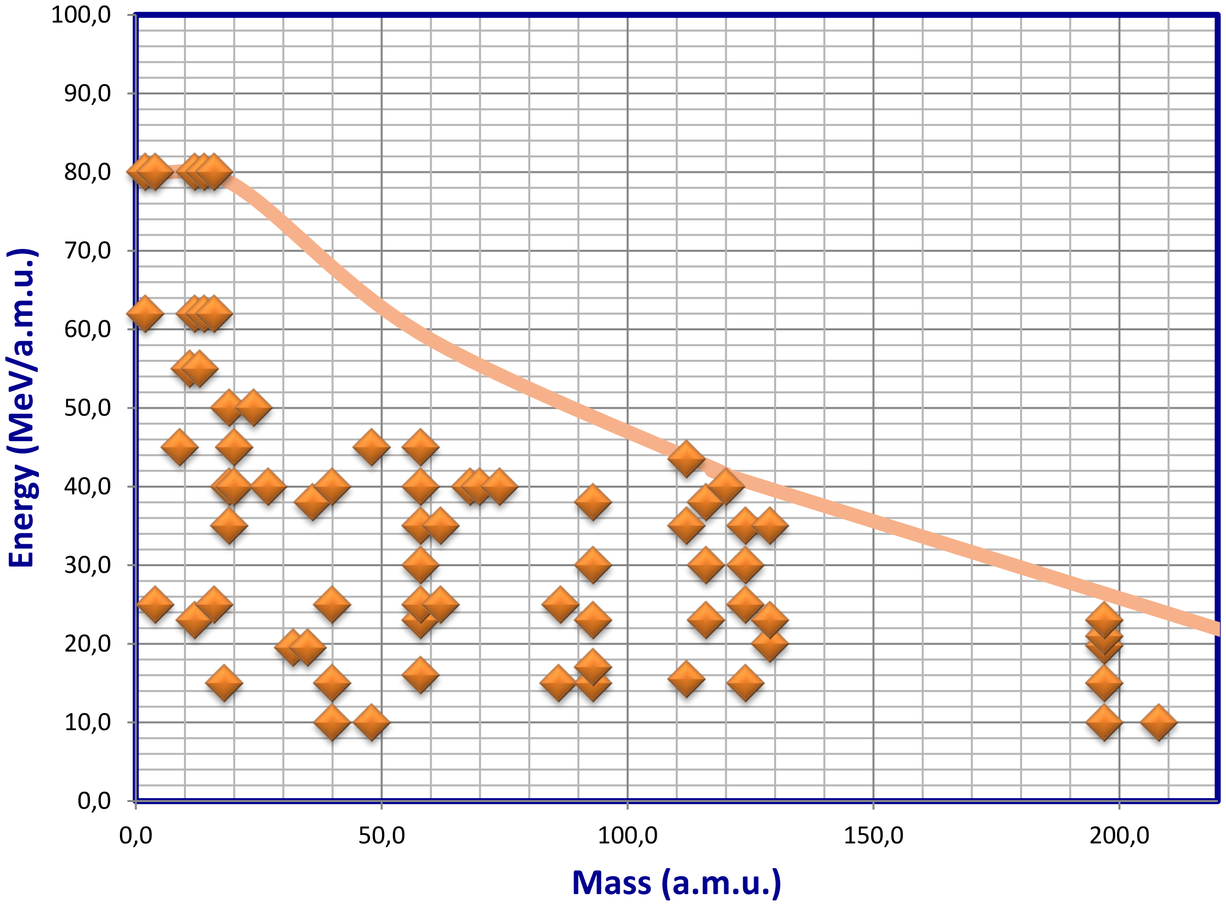
Cyclotron Beams Menu



^{A}X	E (AMeV)
H_2^+	62,80
H_3^+	30,35,45
$^{2}D^+$	35,62,80
^{4}He	25,62,80
He-H	10, 21
^{9}Be	45
^{11}B	55
^{12}C	23,62,80
^{13}C	45,55
^{14}N	62,80
^{16}O	21,25,55,62,80
^{18}O	15,55
^{19}F	35,40,50
^{20}Ne	20,40,45,62
^{24}Mg	50
^{27}Al	40
^{36}Ar	16,38
^{40}Ar	15,20,40

^{A}X	E (AMeV)
^{40}Ca	10,25,40,45
^{42,48}Ca	10,45
^{58}Ni ,45	16,23,25,30,35,40
^{62,64}Ni	25,35
^{68,70}Zn	40
^{74}Ge	40
^{78,86}Kr	10
^{84}Kr	10,15,20,25
^{93}Nb	15,17,23,30,38
^{107}Ag	40
^{112}Sn	15.5,35,43.5
^{116}Sn	23,30,38
^{124}Sn	15,25,30,35
^{129}Xe	20,21,23,35
^{197}Au	10,15,20,21,23
^{208}Pb	10

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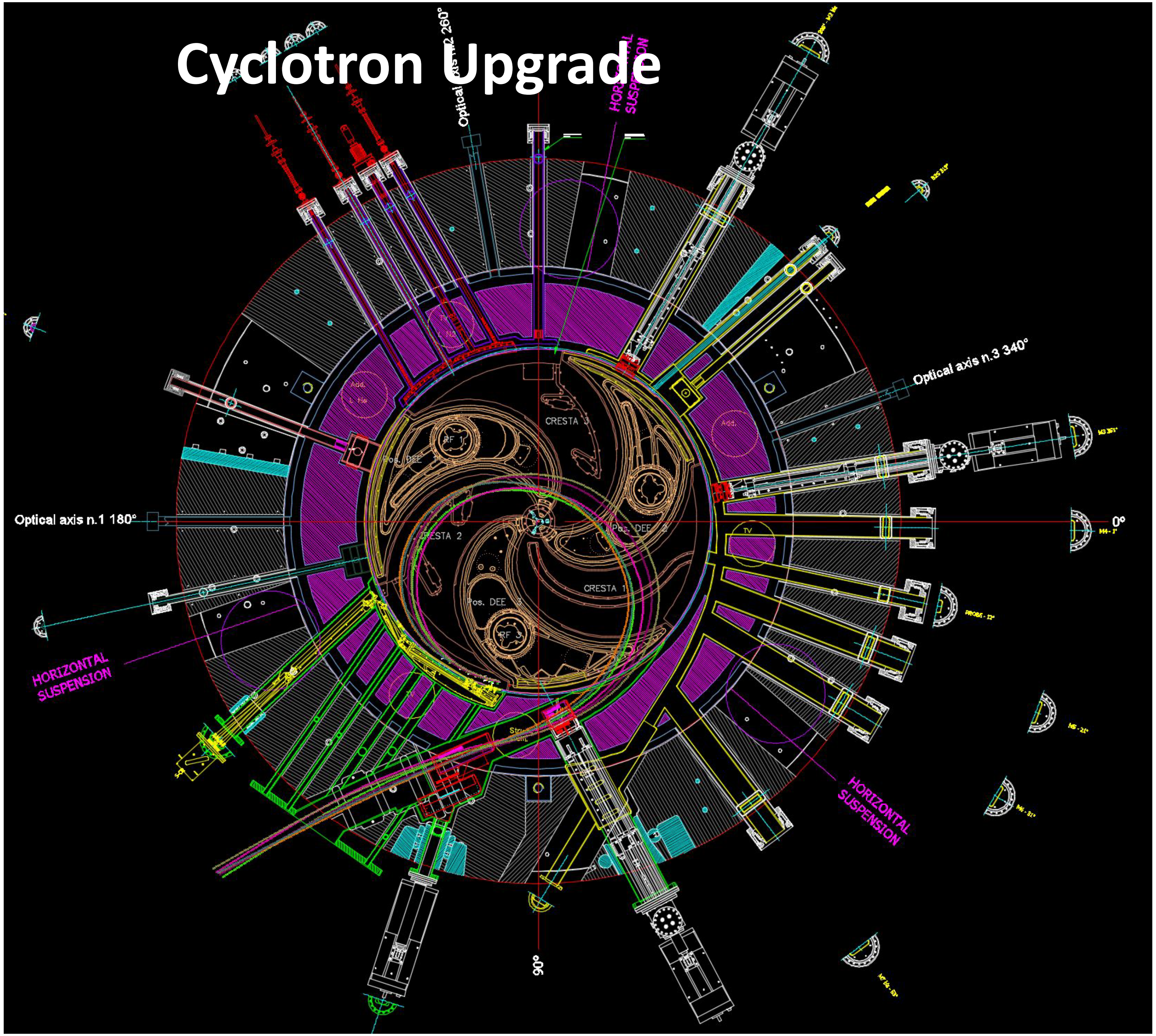
Cyclotron Upgrade



New Extraction line by stripping

Instantaneous change of the magnetic rigidity, when the charge state of the ion is suddenly increased crossing a thin carbon foil

Beam extraction by stripping
Efficiency >99%

Extraction by electrostatic deflection

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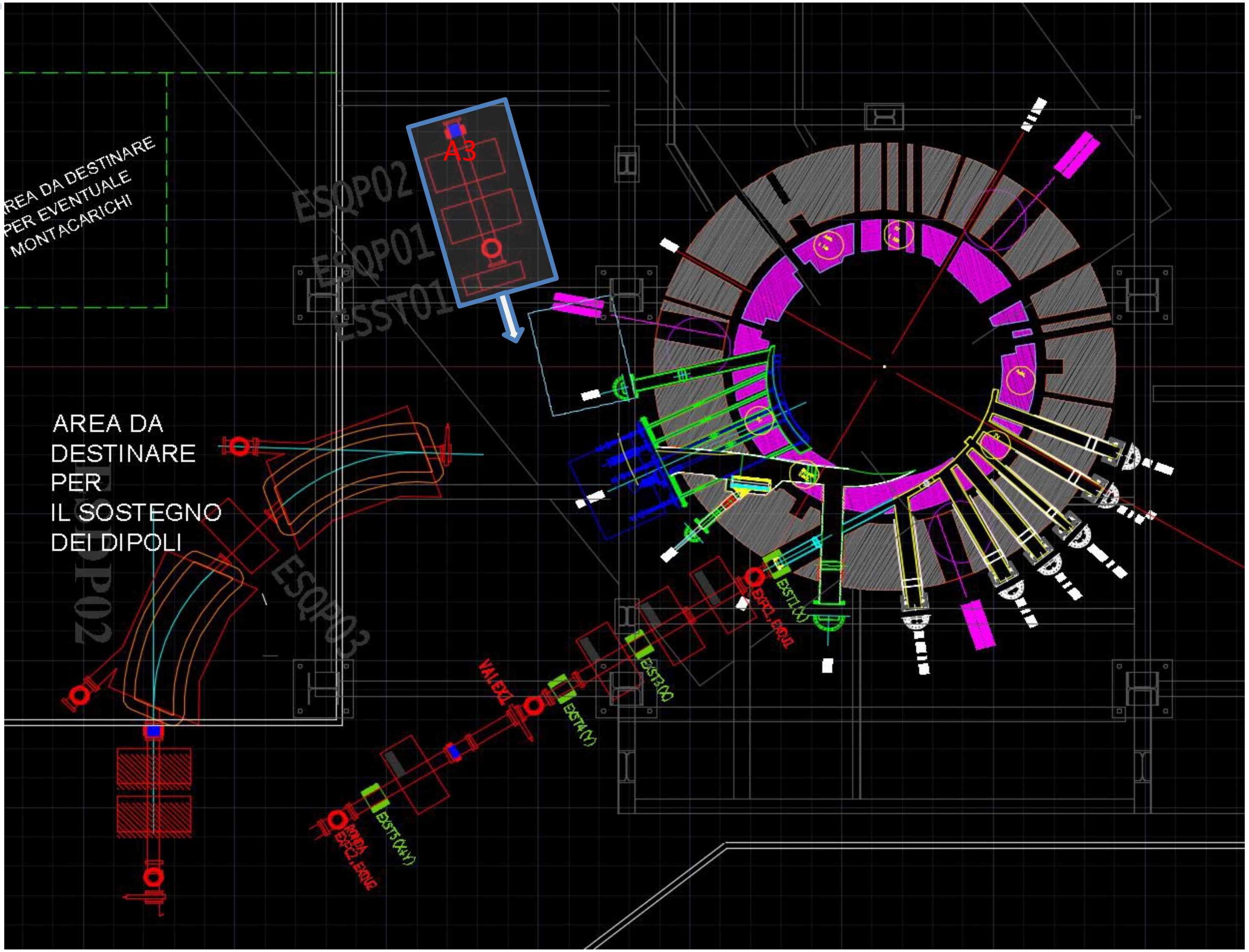
Extraction by electrostatic deflection



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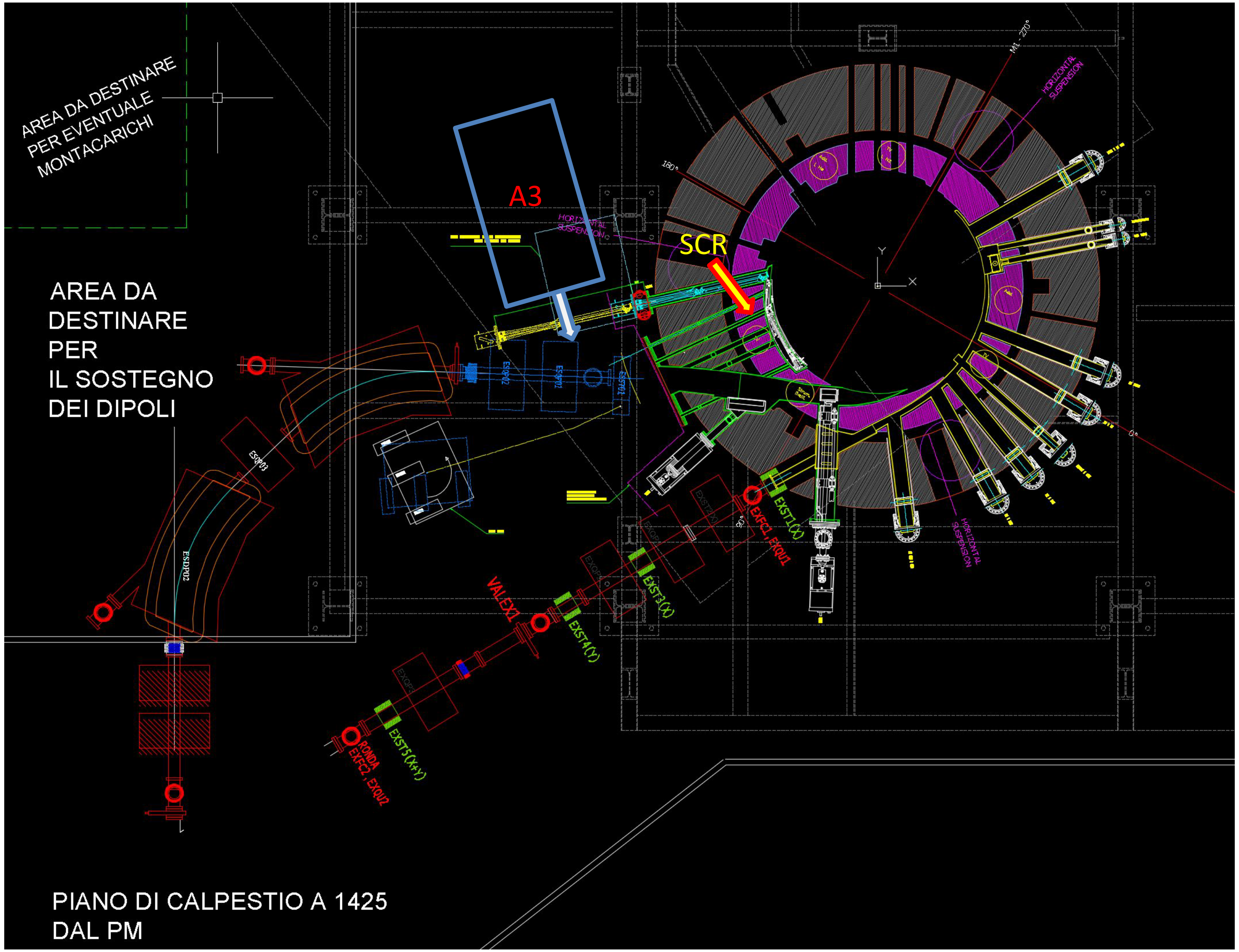
Extraction by stripping



From ED → Stripping:

- Rimuovere il Def E1 dall'interno del CS
- Rimuovere la piastra unica con motori e slitte
- Rimuovere le aste di collegamento al Def E1

- Montare lo Stripper all'interno del CS
- Inserire il complessivo della trasmissione
- Assemblare il complessivo quadrupoli e Steerer (in azzurro) dislocato preventivamente nell'area A3

Durante il funzionamento del CS con estrazione per Stripping, non è prevista la rimozione del deflettore E2

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Cyclotron Upgrade: expected currents by stripping

Ion	q	Energy	Isource	Iacc	I extract	rate
		MeV/u	eμA	eμA	eμA	pps
12C	4	18	400	60	90.0 (6+)	9.5E+13
12C	4	30	200	30	45.0 (6+)	4.7E+13
12C	4	45	400	60	90.0 (6+)	9.5E+13
12C	4	60	400	60	90.0 (6+)	9.5E+13
18O	6	20	400	60	80.0 (8+)	6.3E+13
18O	6	29	400	60	80.0 (8+)	6.3E+13
18O	6	45	400	60	80.0 (8+)	6.3E+13
18O	6	60	400	60	80.0 (8+)	6.3E+13
18O	7	70	200	30	34.3 (8+)	2.7E+13
20Ne	4	15	600	90	225.0 (10+)	1.4E+14
20Ne	7	28	400	60	85.7 (10+)	5.4E+13
20Ne	7	60	400	60	85.7 (10+)	5.4E+13
40Ar	14	60	400	60	77.1 (14+)	1.0E+13

18O @ 20 MeV will be the beam used to commissioning of the machine:

- The power is not too high and it could mitigate eventually activation issues during the commissioning phase.
- During the commissioning of the machine the beam intensity will be increased step by step adjusting the duty cycle of the CHOPPER.
- Diagnostics improved to monitor the beam losses permitting a better optimization of the tuning.

Beam dynamics simulations.
Warm coil qualification will permit to refine the studies.

in progress

- Magnetic measurement on «Alfa 2» (superior coil)
  Decrease of Bz component at the current feedthroughs, probably due to a non-uniform density of windings at that area for construction reasons.
- Magnetic measurement on «Alfa 1» (bottom coil) just started

preliminirary

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Upgrade of CS & Tandem ancillaries

Vacuum	Improvement of the entire vacuum system is in progress (acceleraton chamber, liner), splitted-cryo not anymore supported, Trim coils. New Vacuum system for TANDEM and the related beam lines.
Cryogenics	Revamping HELIAL 4011, P&I and control system maintenance and ugrading in progress
RF	Refurbishment of the entire LLRF and development of Labview control software , HLRF (MV transformers and MV cables replacement, Three Phase Power Controller replacement, BBC refurbishment, new configuration with 3x80 kW dummy load BIRD 7092), Pulsing systems, Extraordinary maintenance of CS cavities.
Diagnostics	New non-interceptive diagnostics along old and new beam lines; visual diagnostics.
Power converters	Power converters for new beam lines: Extraction, Fraise, Magnex. New power converters for TANDEM and related beam lines.

The new Control System Architecture

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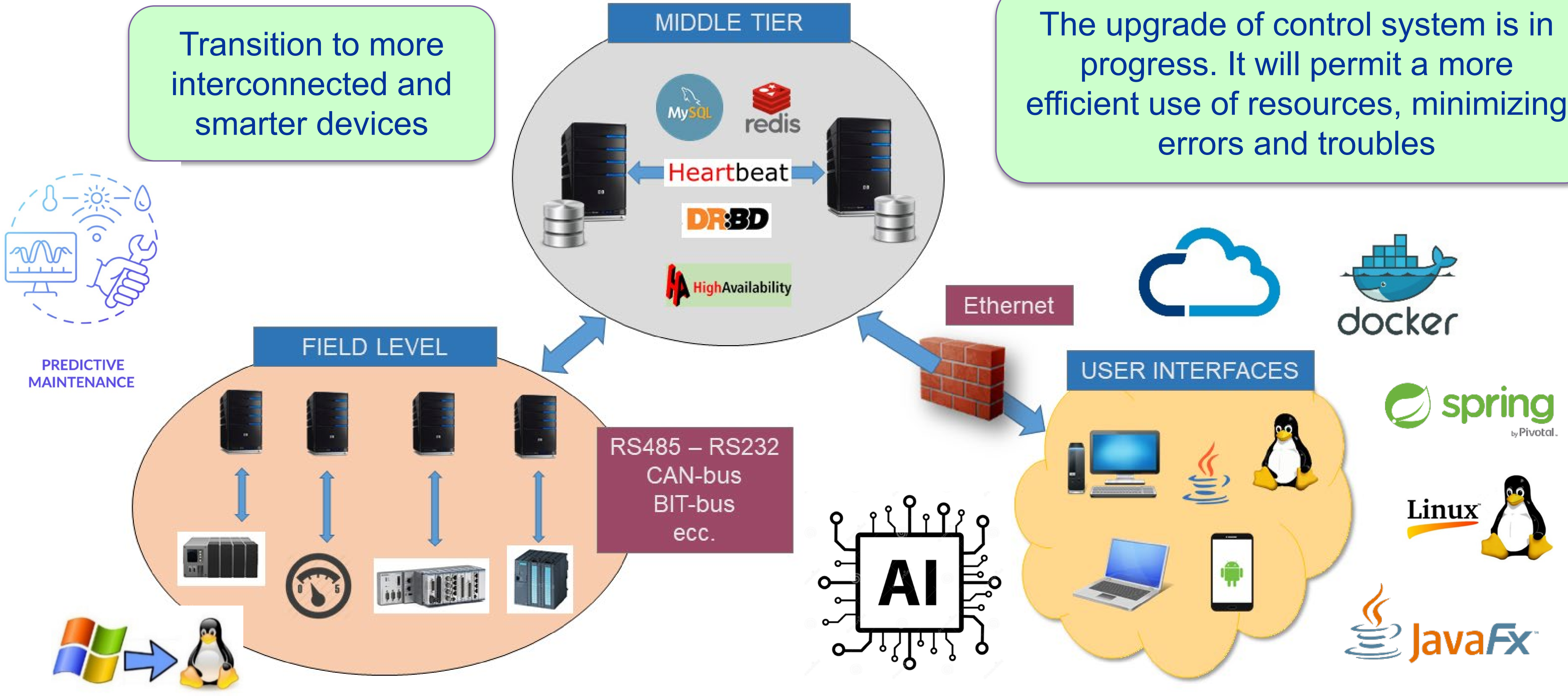
Transition to more interconnected and smarter devices

The upgrade of control system is in progress. It will permit a more efficient use of resources, minimizing errors and troubles



Beam Auto Tuning with AI tools

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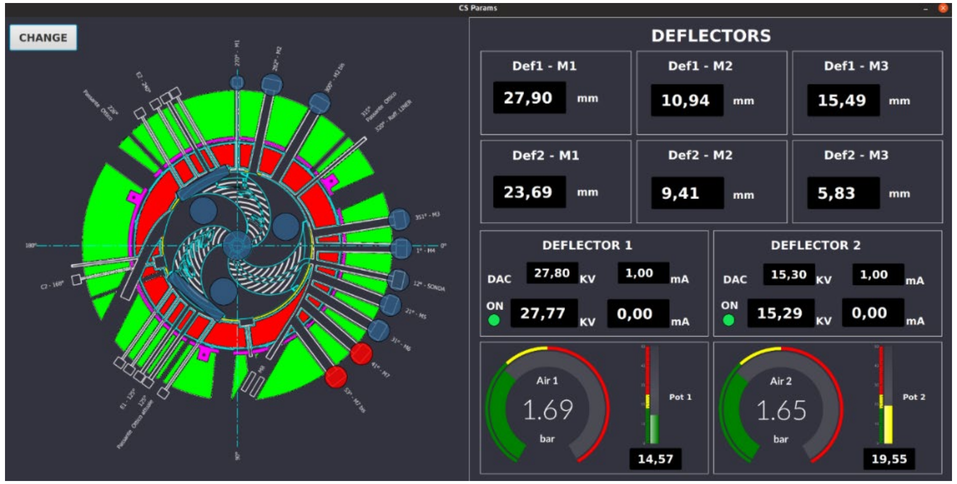
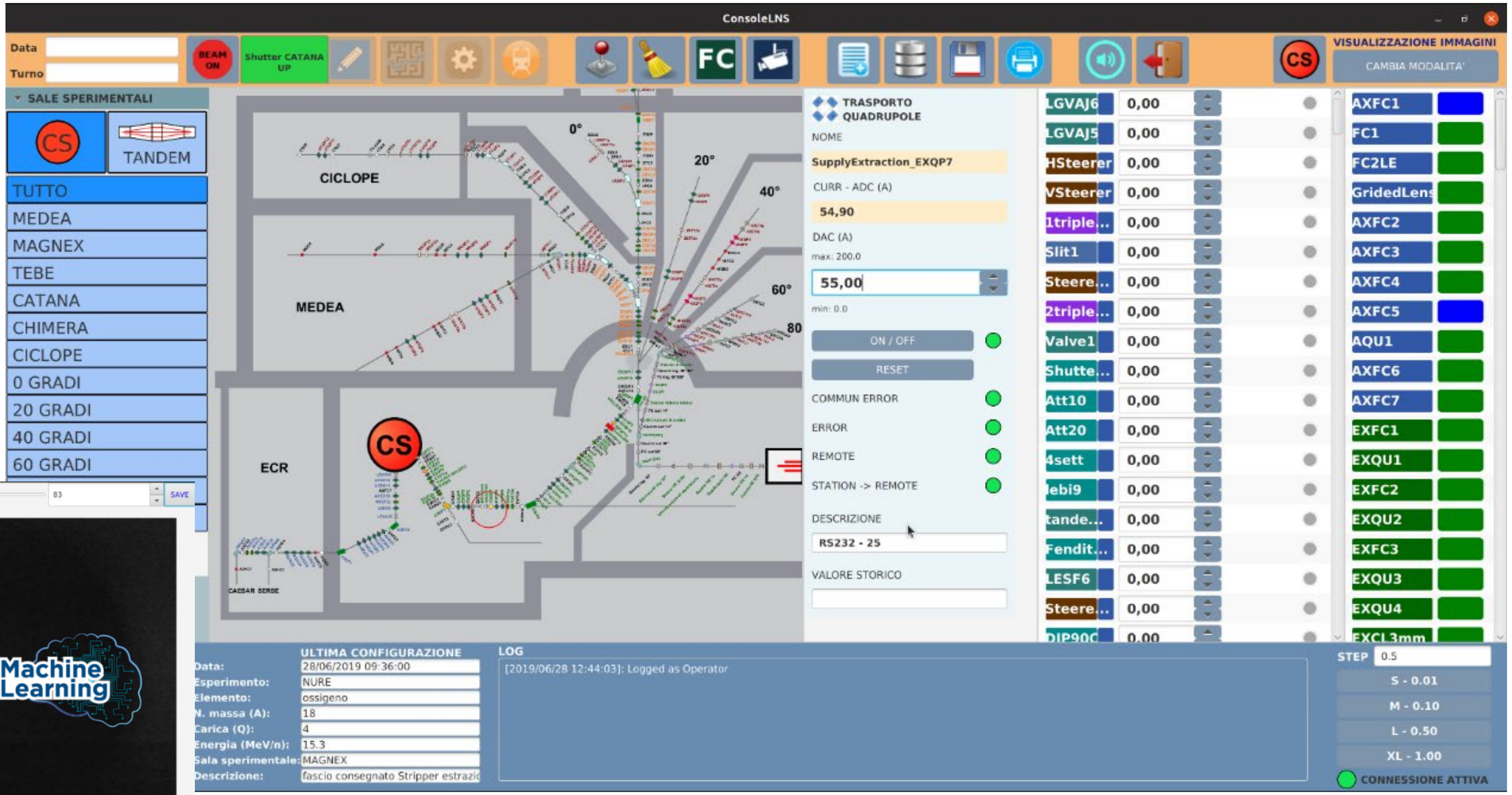
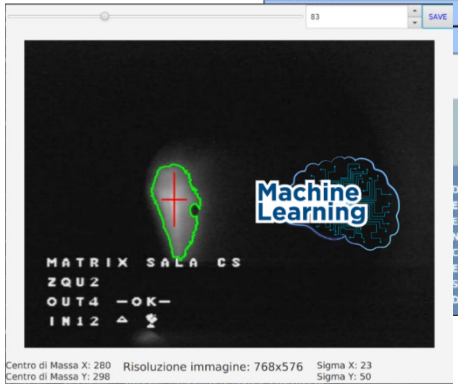


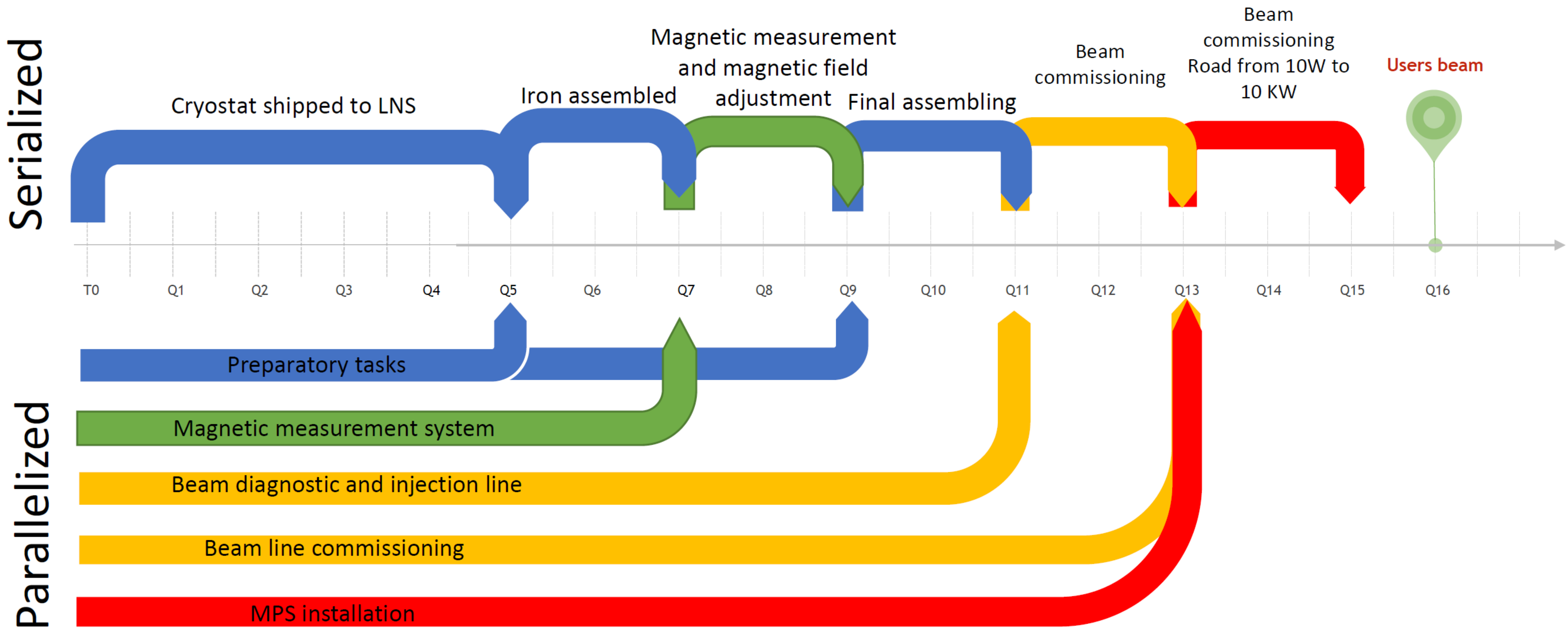
Speed up of the beam tuning with Artificial intelligence



Real-time messages and alarms received automatically by field devices to improve safety



CS masterplan



by M. Musumeci

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Masterplan

PREPARATORY PHASE

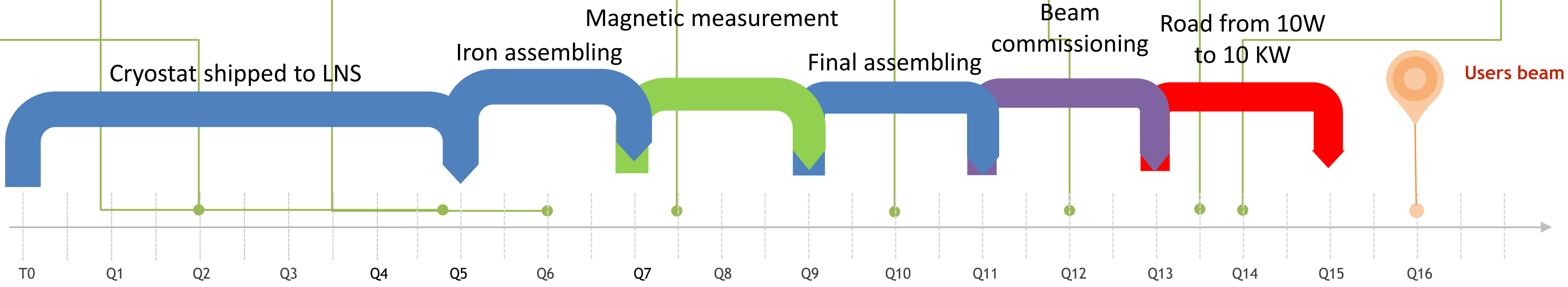
- Iron Cleaning
- Cavity Maintenance
- Liner installation
- Trim coils Maintenance
- Liner + Dees
- Stripper
- Magnetic channels
- Power converters
- Beam lines
- Services restyling

- **Mapping at different coils current**
- **Harmonic study**
- **Coils position adjustment**

- RF System
- Stripping system
- Beam probe
- dismantled

- Deflecting method
- Stripping method
- **Beam characterization**

- **Low power**
- **Medium power**
- **High power**



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ECR ion sources

SERSE (1997)
High B mode operation– HCI production (e.g.: 80 μA of Xe^{27+})

CAESAR (1999)

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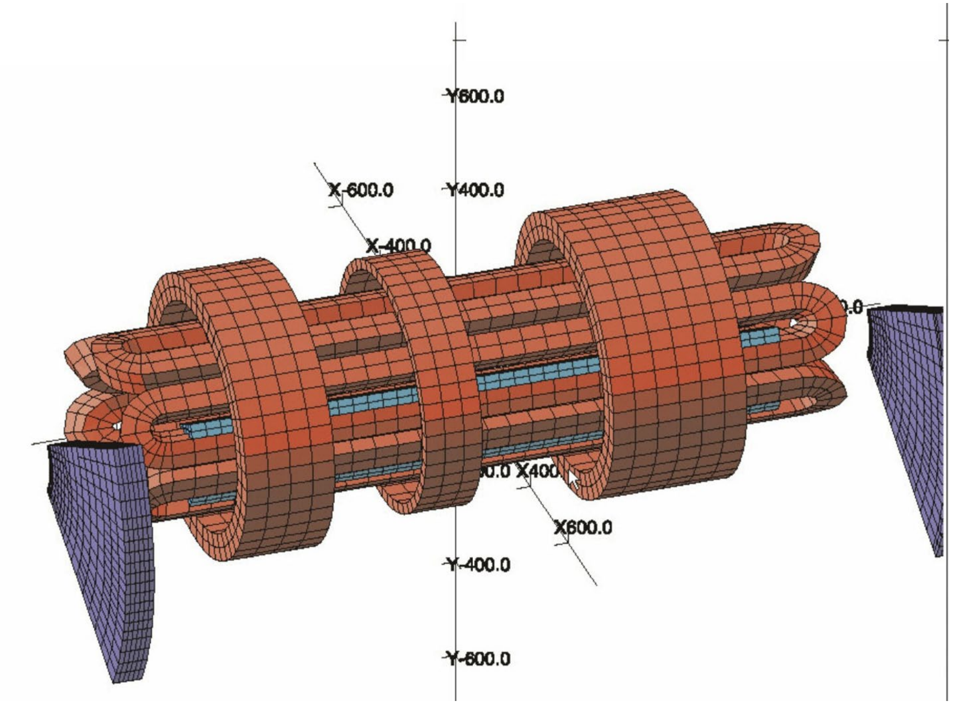
SC-AISHa: a new ion source for INFN-LNS

- The AISHa ion source has been expressly conceived and realized for actual and future hadrontherapy facility (e.g.:HITRI+). It has a strong limitation on a radial field (1.28T instead of 1.55T of SERSE) affecting HCI production.
- A fully superconducting version has been conceived to overcome such limitation.

Radial field	1.9 T
Axial field	3.5 T - 0.5 T – 2.2 T
Operating frequencies	24 GHz – 18 GHz
Operating power	5 + 5 kW (max)
Extraction voltage	50 kV (max)
Chamber diameter / length	Ø 130 mm / 500 mm
LHe	Free
Warm bore diameter	140 mm
Source weight	2100 kg



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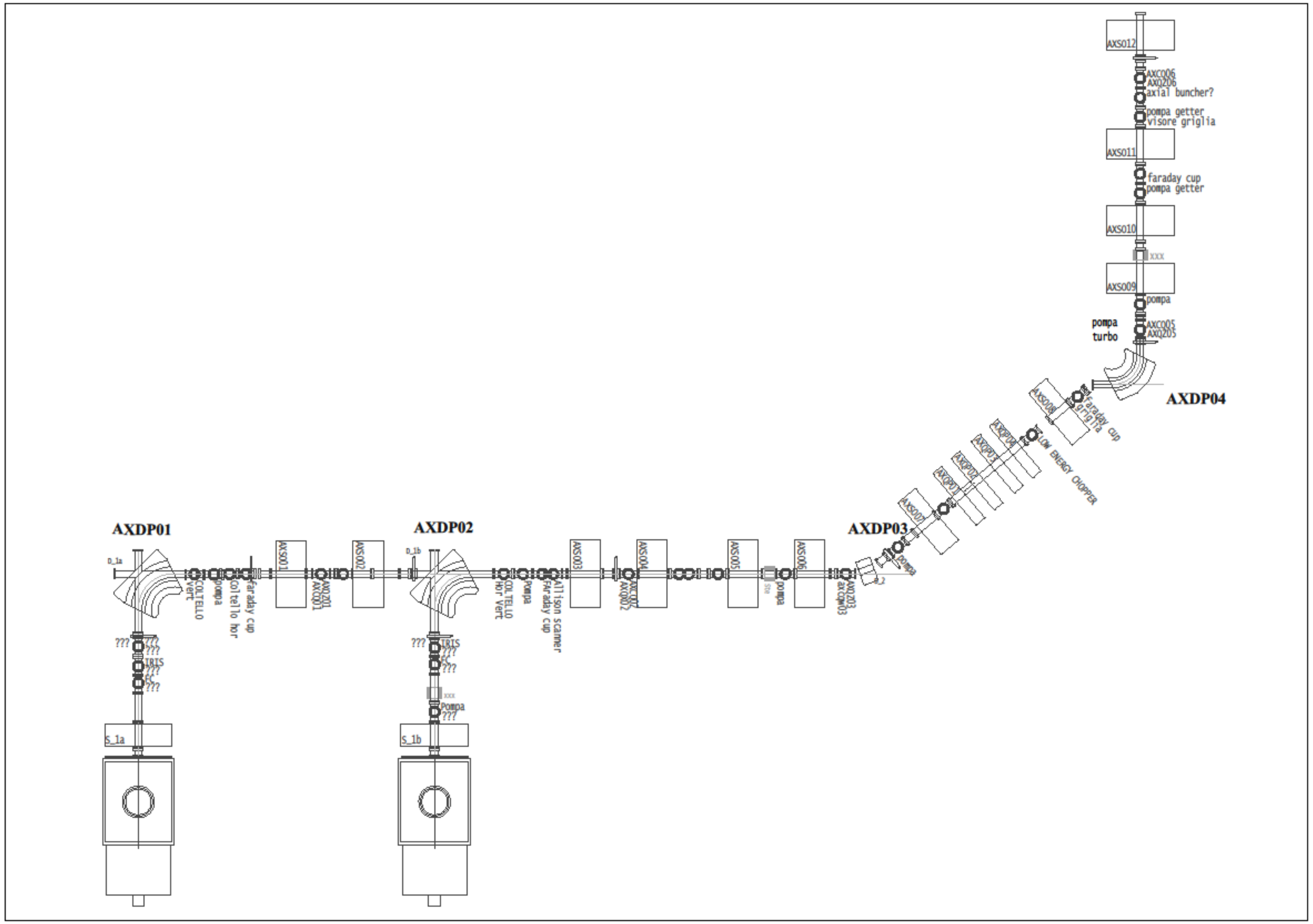
Axial injection beam line



Designed in late 90's to permit selection and transport of low currents of highly charged ions.

Review to adapt it for the transport with a good efficiency of high currents.

Insertion of a Low Energy Chopper as mitigation device for MPS.

Renewal of the two axial bunchers

Modification in beam diagnostics

Refurbishment vacuum sysytem and controls

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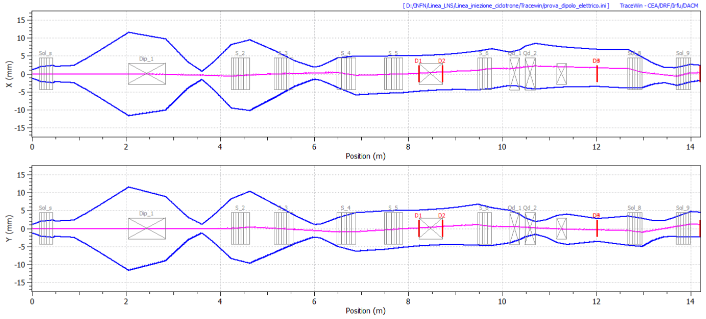
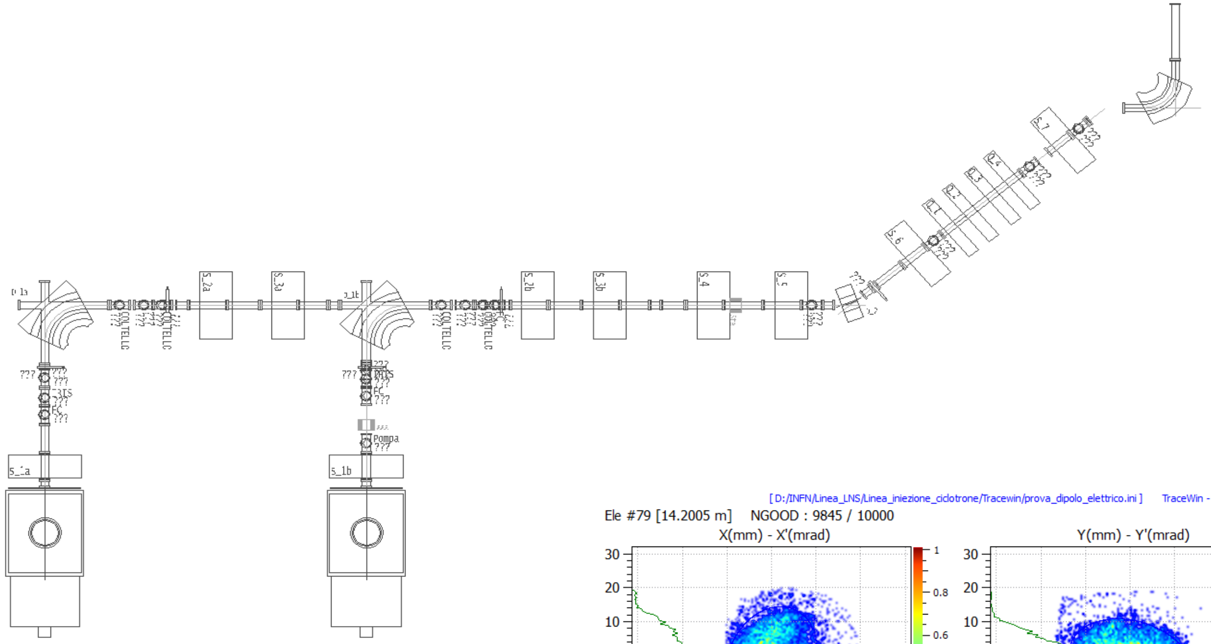
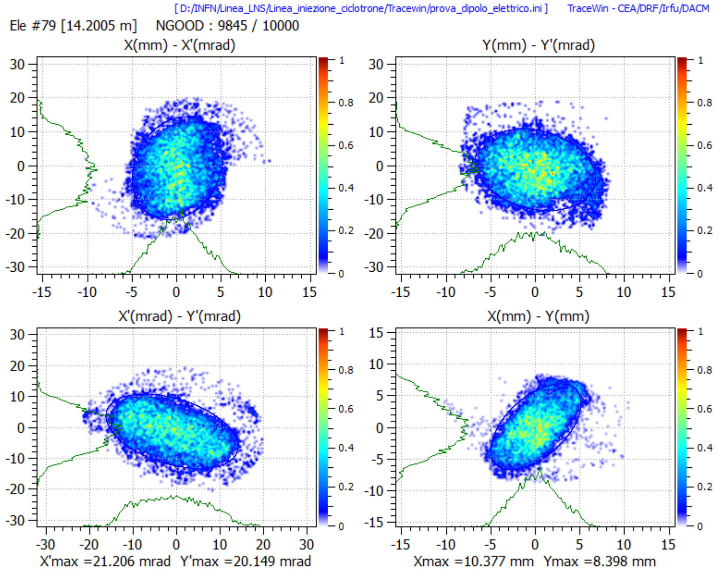
Axial injection beam line

$^{12}C^{4+}$ @ 10 AkeV

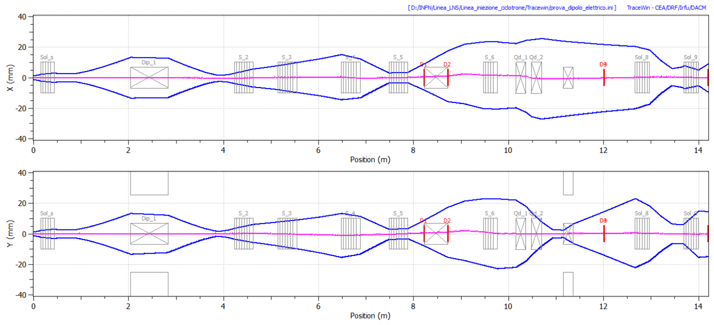
I=0 mA



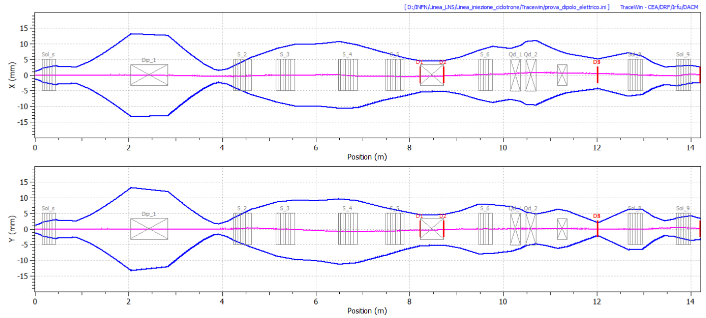




I=0.5emA-Not optimized



optimized



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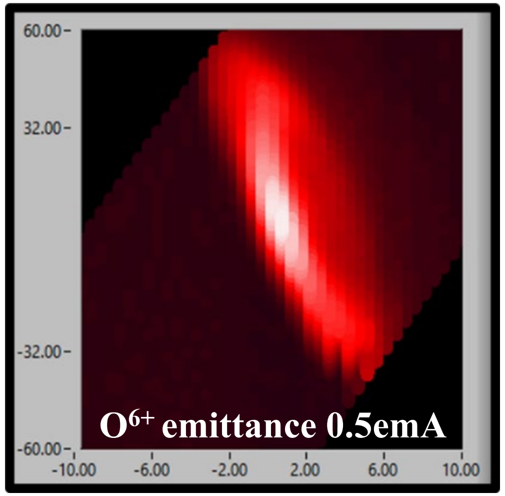
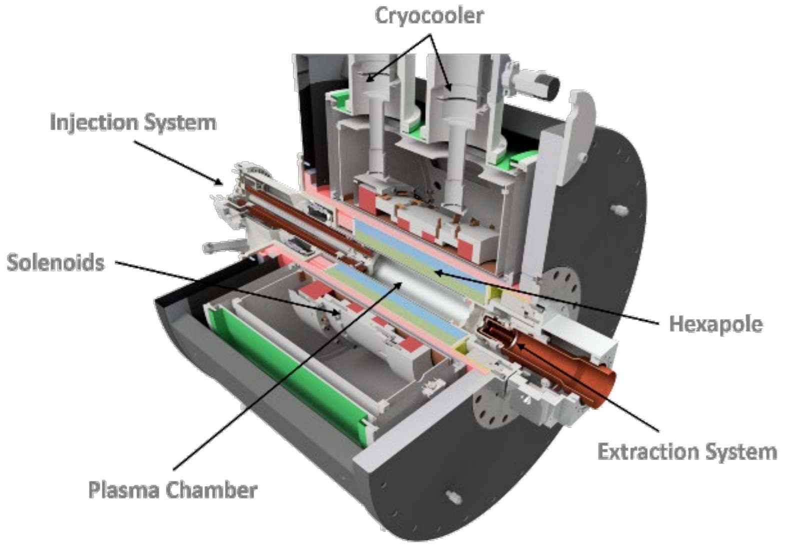
AISHa: a testbench for INFN-LNS

AISHa source has been moved to a new room being in conflict with the civil works of CS upgrading.

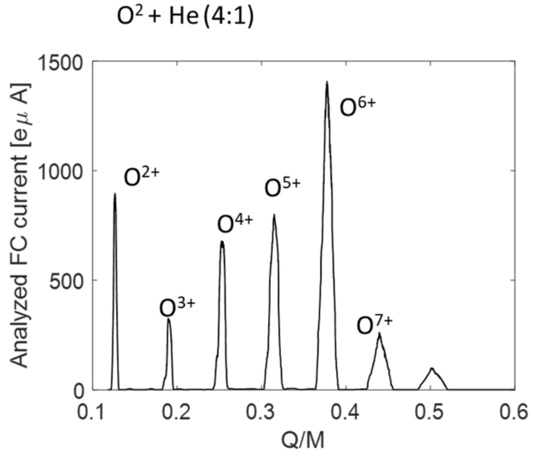
Installation of crane and services needed to operate is expected for June'23 and restart of operation is planned for October'23

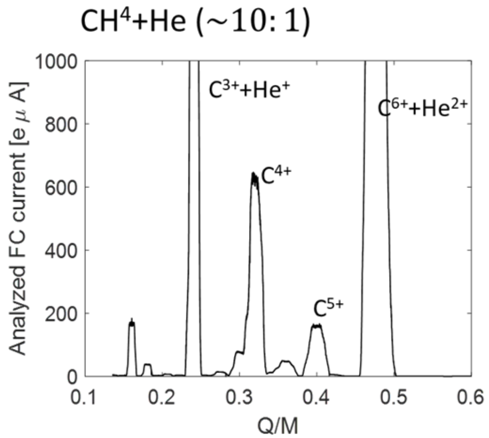


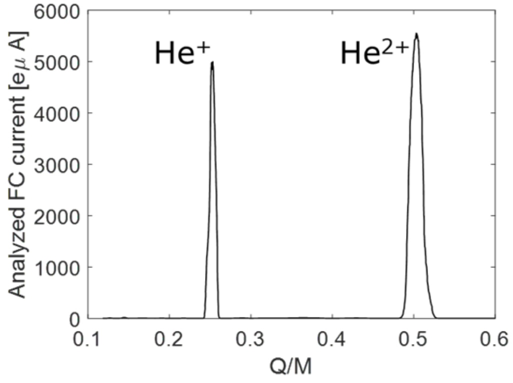


R&D activities →IONS

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







AISHa@CNAO (IRPT, INSPIRIT)

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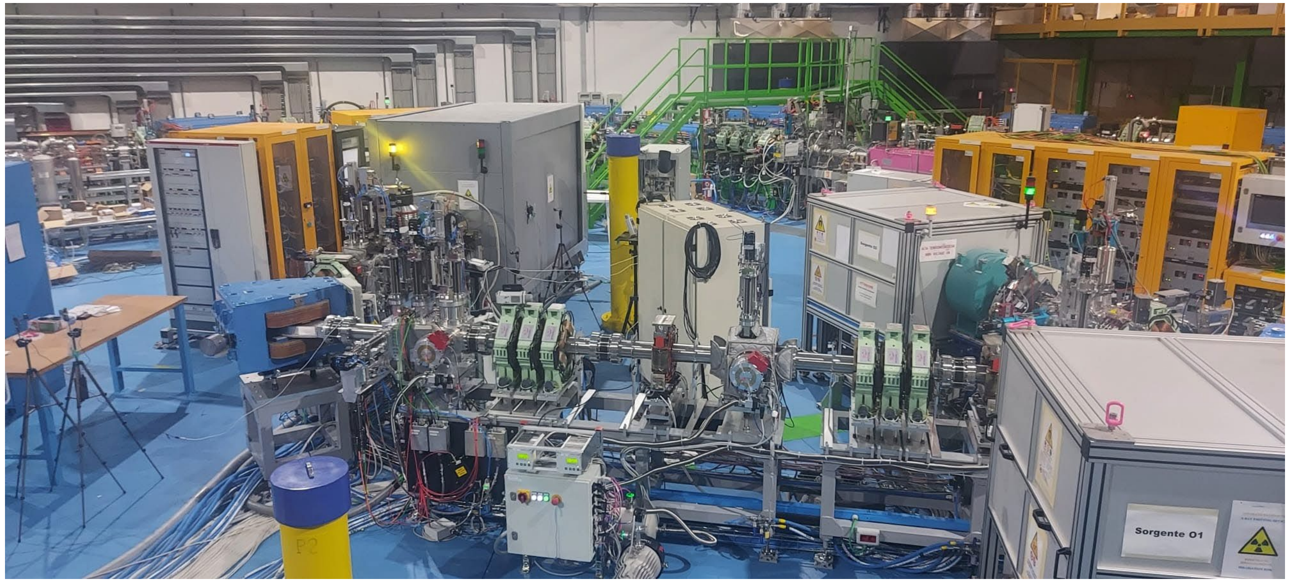
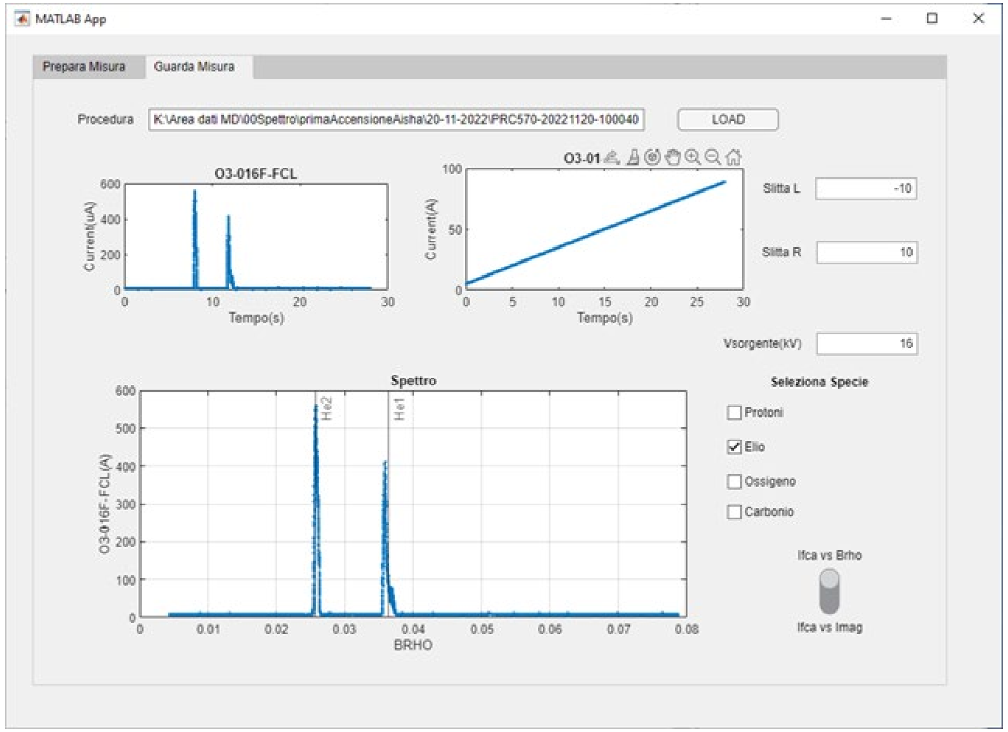
CNAO





Ion	AISHa Performances [uA]	Requirement CNAO [uA]
C^{4+}	520	110
O^{6+}	1200	64
He^{2+}	5400	344
Li^{3+}	To be developed	230
Fe^{19+}	To be developed	175

First beam produced on 19/11/22 (He@16kV).

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Thanks for your kind attention!