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Accelerators at INFN-LNS

S.Gammino

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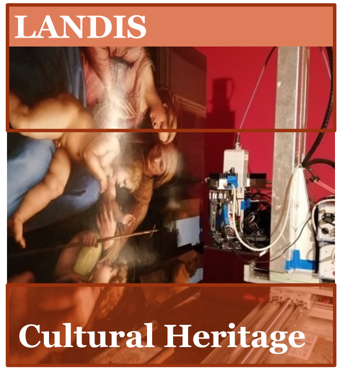
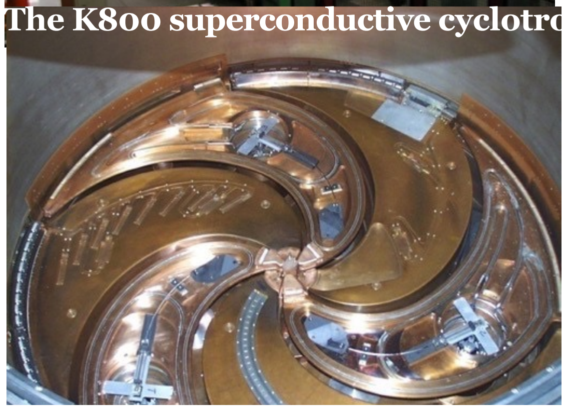
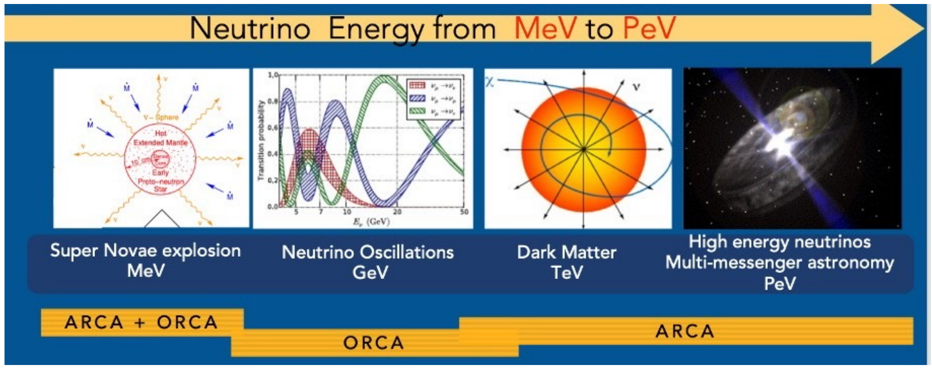
LNS past/present facilities

- Nuclear structure and dynamics
- Nuclear astrophysics
- Plasma physics
- Medical physics and biophysics
- Astro-particle physics
- Environmental physics
- Applications to cultural heritage







KM3NeT second phase is a research infrastructure housing the next generation neutrino telescopes. KM3NeT will open a new window on our Universe, but also contribute to the research of the properties of the elusive neutrino particles.

… and the (near) future

LNS upgrade of their facilities to keep the pace of research in nuclear physics at the international level. After the upgrade, the intensity and variety of beams will increase and new experimental setups will be made available to Users in 2023-24.

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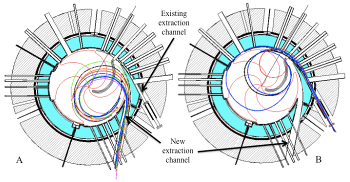
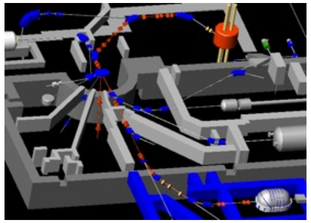
The POTLNS project aims at upgrading the LNS CS and beam lines to increase the the intensity by about 2 orders of magnitude for ion beams with mass number <= 40 and energies between 15 and 70 MeV/amu.



Extraction by stripping



Applications:

- In flight production of RIBs @ FRAISE
- High intensity beams for the study of $0\nu2\beta$ decay (NMEs)

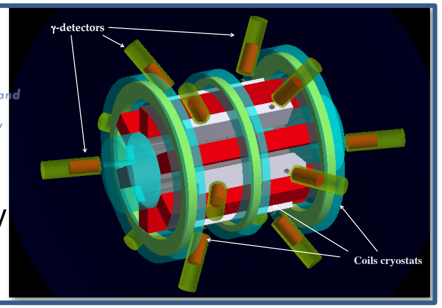
2020 Acceleration test of ions of interest for NUMEN/FRAISE

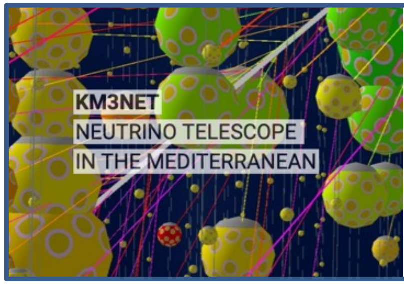
$^{18}O^{6+}$ @ 20 MeV
$^{18}O^{6+}$ @ 25 MeV
$^{18}O^{6+}$ @ 45 MeV
$^{18}O^{6+}$ @ 60 MeV

$^{40}Ar^{13+}$ @ 45MeV
$^{40}Ar^{13+}$ @ 60MeV

PANDORA aims at building an innovative magnetic plasma trap, for interdisciplinary and fundamental physics research, especially the study of β-decays under astrophysical conditions and opacities

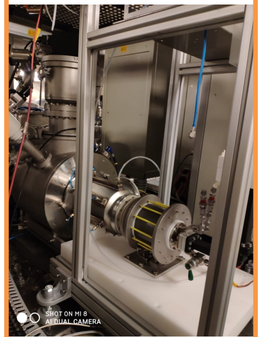
Plasmas for Astrophysics Nuclear Decay Observation and Radiation for Archaeometry





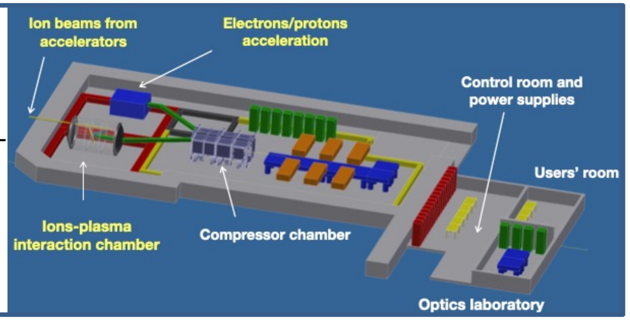
KM3NeT is a research infrastructure housing the next generation neutrino telescopes. KM3NeT will open a new window on our Universe, but also contribute to the research of the properties of the elusive neutrino particles.

NESTOR

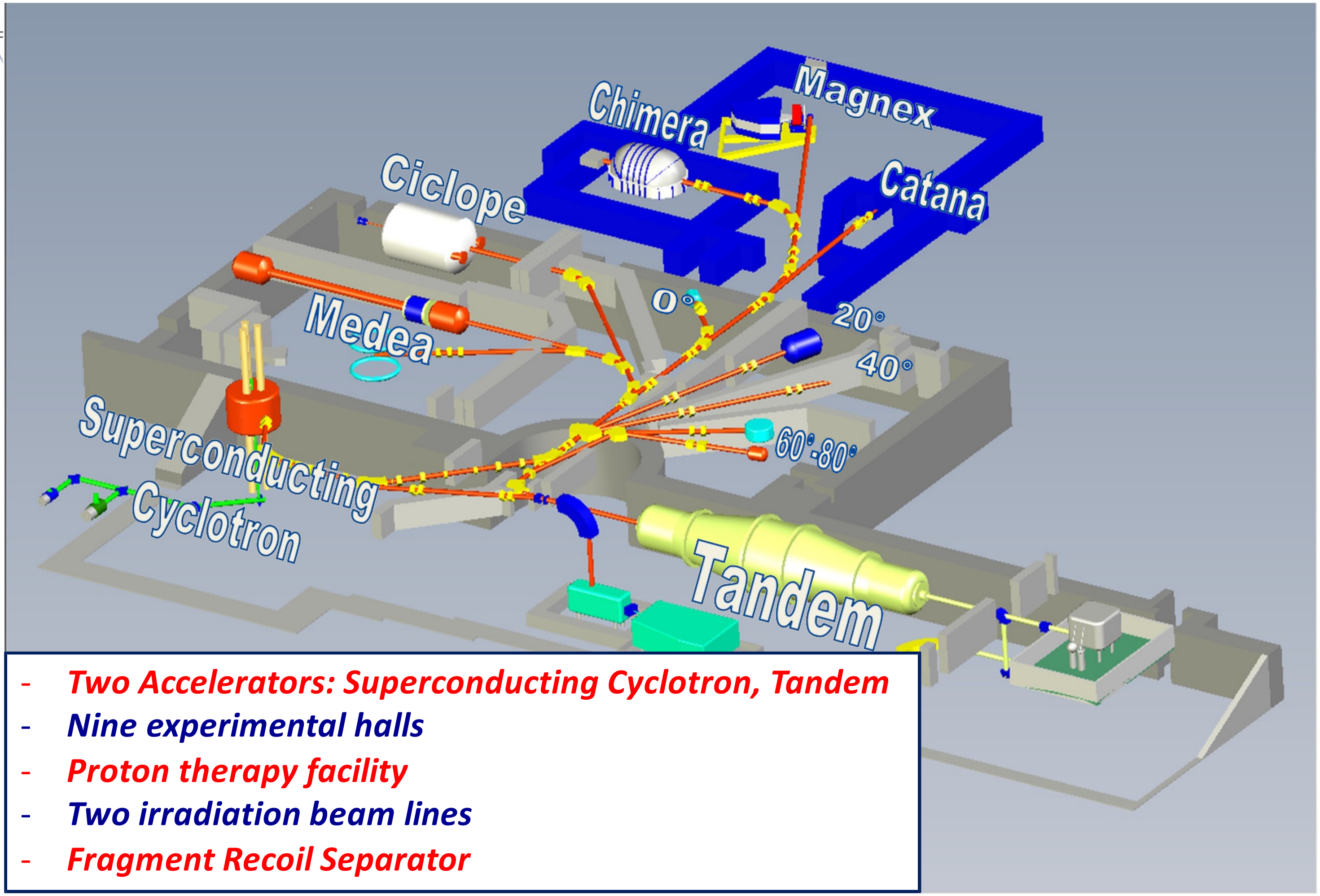


New beams of $^{4}He^{-}$ and $^{3}He^{-}$, H^{-}, $^{16\text{-}18}O^{-}$, $^{14}N^{-}$ … (hopefully ^{20}Ne…)

BCT define new therapeutic approaches for the treatment of breast carcinoma
I-LUCE particle acceleration by laser-matter interaction. Accelerated beams: electrons, protons, light ions
Energies: MeV/GeV in broad spectra
Intensities 10^9 - 10^{12}



Laboratori Nazionali del Sud: Layout



- *Two Accelerators: Superconducting Cyclotron, Tandem*
- *Nine experimental halls*
- *Proton therapy facility*
- *Two irradiation beam lines*
- *Fragment Recoil Separator*

LNS Accelerators

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Tandem

Superconducting Cyclotron

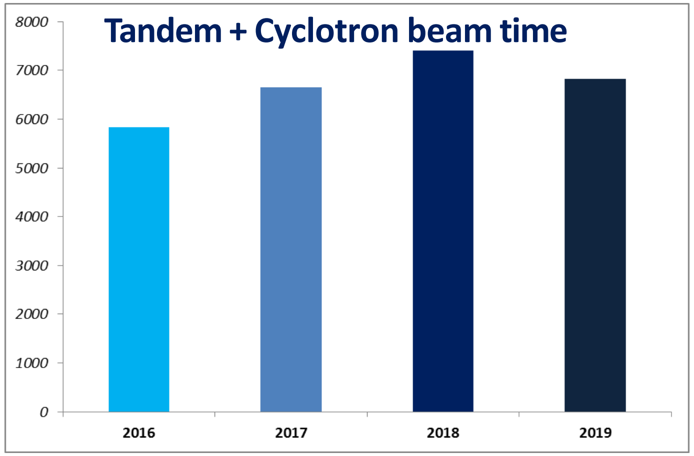
BTU=8 h

430 BTU circa per year delivered for each accelerator
(excluding beam time preparation)

35 - 40 experiments per year, including the proton therapy sessions

Beam time lost for failures:

- ***Tandem: < 2%***
- ***Cyclotron: < 4%***



2019

Superconducting Cyclotron yearly capability			
Total hours scheduled for operation	(hrs)		5830
Total hours scheduled for user-op	(hrs)		3945
Total hours realised for user-op	(hrs)		3850
Total down-time for user-op	(hrs)		100
Users Efficiency	(%)		98
Number of user groups	(n)		31
Total hours scheduled for Physics	(hrs)		1790
Total hours realised for Physics	(hrs)		1790
Total down-time for Physics	(hrs)		0
Efficiency for Physics	(%)		100
Number of physics groups	(n)		6
Tandem yearly capability			
Total hours scheduled for operation	(hrs)		4050
Total hours scheduled for user-op	(hrs)		2690
Total hours realised for user-op	(hrs)		2690
Total down-time for user-op	(hrs)		0
Users Efficiency	(%)		100
Number of user groups	(n)		11
Total hours scheduled for Physics	(hrs)		2150
Total hours realised for Physics	(hrs)		2150
Total down-time for Physics	(hrs)		0
Efficiency for Physics	(%)		100
Number of physics groups	(n)		7

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The Tandem Van De Graaff

Operating since 1983

Maximum High Voltage ≈ 13.5MV

Pelletron charging system

HV stability ≈ 10^{-4}

SF_6 insulating gas

Beams: from protons to gold (not noble gases, *YET*…)

Upgrade TANDEM automation and instrumentation

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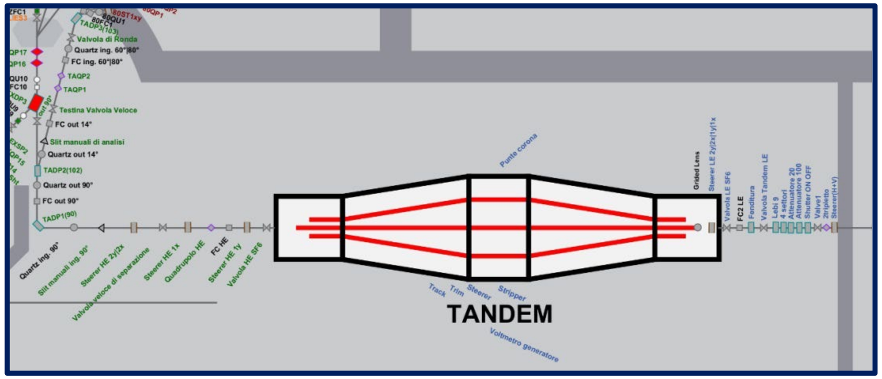
Replacement of obsolete instrumentation and renovation of installations

Implementation of a new software platform

- ^{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



Vacuum

Power converters

SF6 controls with redundancy of temperature and pressure gauges, alarm leak

Terminal Voltage

Spectrometry of accelerated species

Visual Diagnostics

Noble gases development in progress

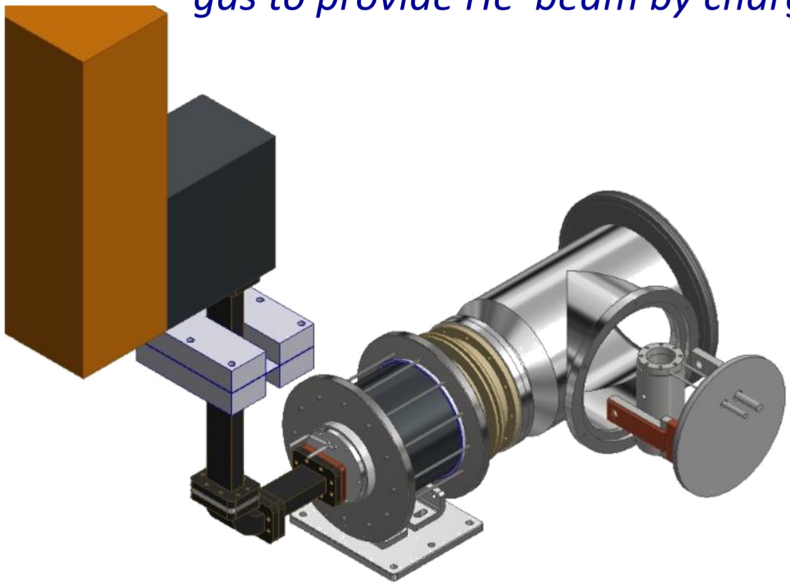
The software platform will be integrated into the existing one already realized and yet used for the cyclotron

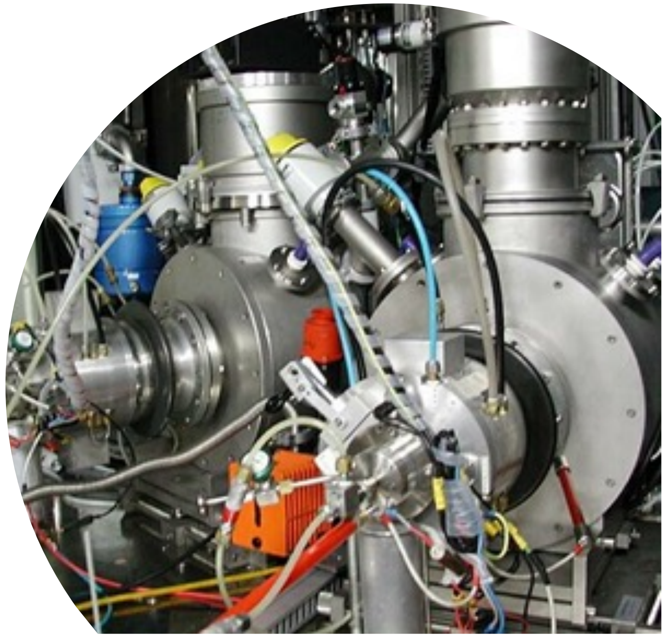
450 kV Tandem injection

Since November'22 extraordinary maintenance has been planned for all the subsystems present on the platform

In the early summer it is planned to restart with the full commissioning of the Nestor source for production of noble gas to provide He^- beam by charge exchange Li vapours

under study ^{22}Ne





Noble Elements Source for acceleraTORs (NESTOR)

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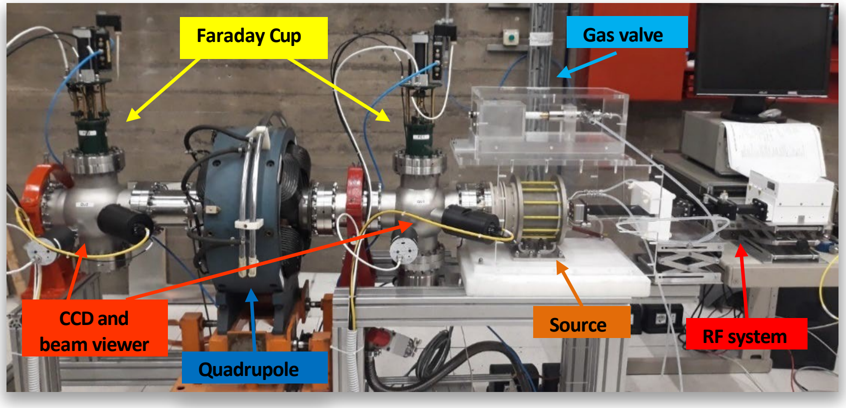
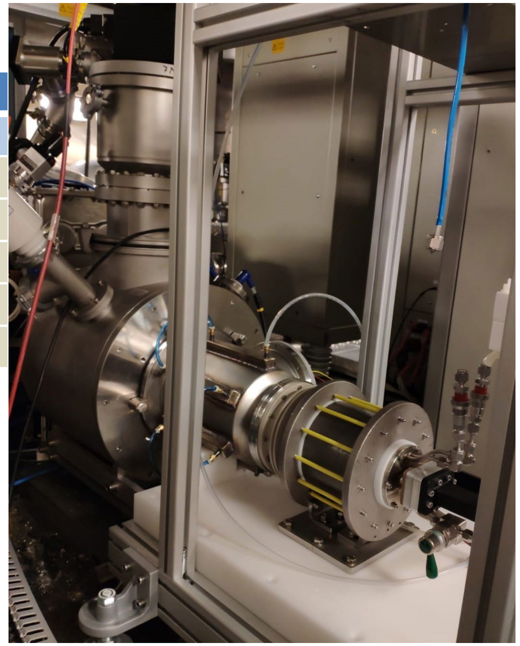
Current of positive beams [µA] (p=$4e^{-4}$ mbar)

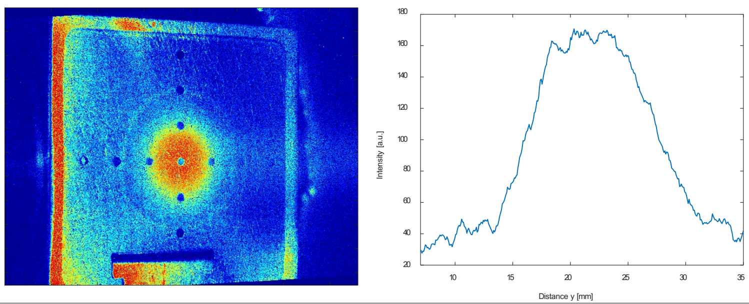


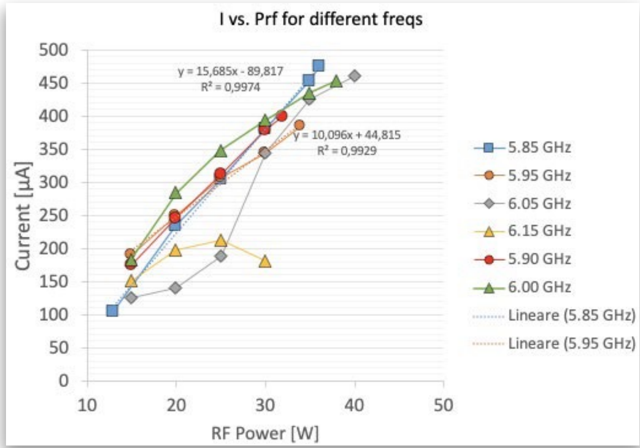
		Frequenza RF [GHz]					
		5.85	5.90	5.95	6.00	6.05	6.15
Potenza RF [W]	15	105	176	190	183	126	152
	20	235	245	250	284	140	198
	25	305	313	307	348	188	212
	30	382	379	344	394	344	182
	35	453	400	385	435	426	



NESTOR has been installed on the 450 kV platform for the production of noble gases negative ions for the Tandem Accelerator

Immagine e profilo del fascio (35 W, 6 GHz e $4EE^{-4}$ mbar)





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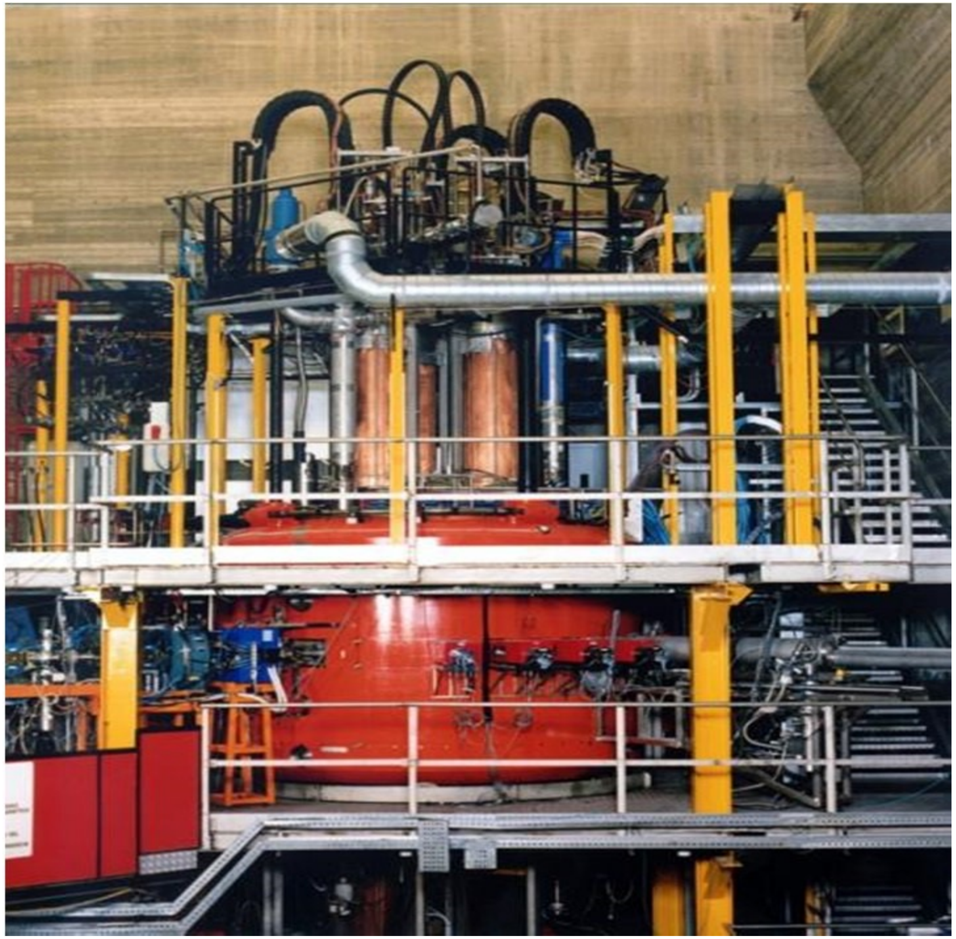
The Superconducting Cyclotron

Operating since 1994



Three sector compact accelerator

Energy range: 10 – 80 MeV/A

Beams: from protons to lead

- **E_{MAX} ~ 80 AMeV for lighter ions**
- **E_{MAX} ~ 25 AMeV for heavier ions (i.e. Au^{36+})**
- **Bending limit K_{bend} =800 - Focusing limit K_{foc}=200**
- **Pole radius: 90 cm**
- **Min-Max field: 2.2 - 4.8 T**
- **RF range: 15-48 MHz**
- **Axial Injection**
- **Two ECR ion sources: CAESAR and SERSE**
- **High Reliability**

Cyclotron Beams Menu

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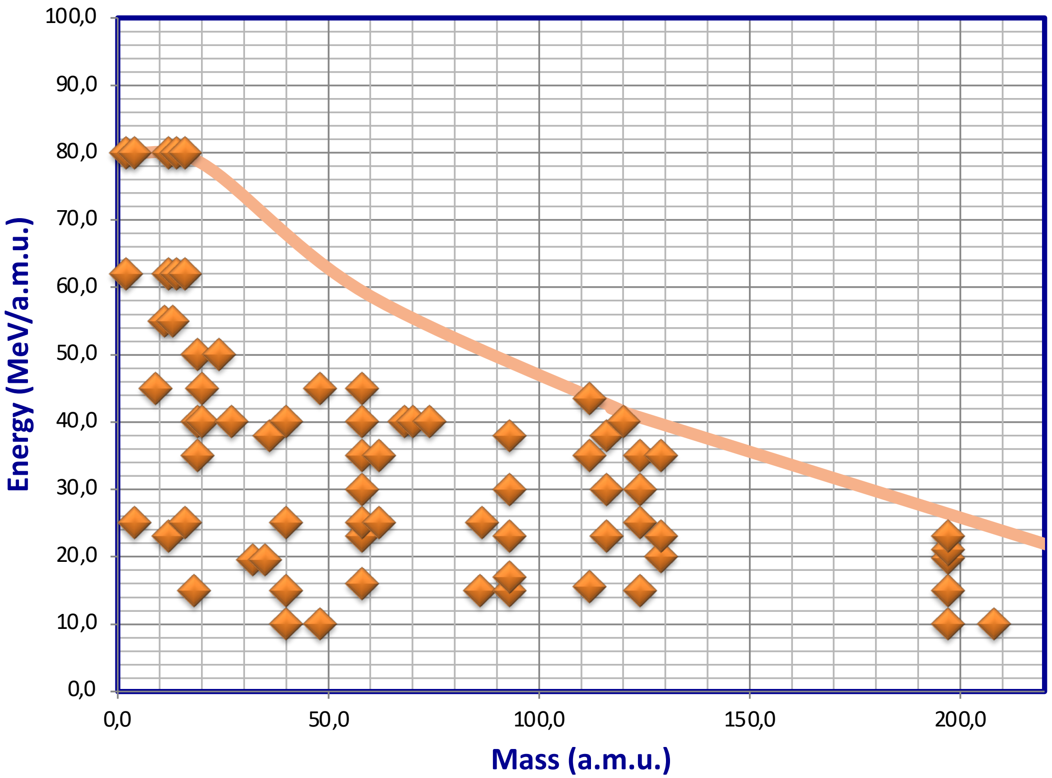


^{A}X	E (AMeV)
H_2^+	62,80
H_3^+	30,35,45
$^{2}D^+$	35,62,80
^{4}He	25,62,80
He-H	10, 21
^{9}Be	45
^{11}B	55
^{12}C	23,62,80
^{13}C	45,55
^{14}N	62,80
^{16}O	21,25,55,62,80
^{18}O	15,55
^{19}F	35,40,50
^{20}Ne	20,40,45,62
^{24}Mg	50
^{27}Al	40
^{36}Ar	16,38
^{40}Ar	15,20,40

^{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

		Tandem	Ciclotrone Superconduttore
1975			Presentazione idea concettuale di F.Resmini alla Cyclotron Conference di Zurich
1976		Nascita LNS	
1982-83		Installazione Tandem da 13 MV	Progetto (Sezione Milano)
1984		SOUP (start of user programme)	
1988		Progetto upgrade 16MV	Cool-down magnete
1990		Operativo a 16 MV, con trasmissione incrementata	Trasferimento ai LNS
1992			Criogenia operativa
1994			Fascio accelerato
1995			SOUP (start of user programme)
1995-99			Iniezione radiale
1998-99			Installazione sorgenti ECR e linea assiale
2000			Iniezione assiale
2006			EXCYT commissioning
2013		Pelletron update	
1984-2020		Users' programme	
1995-2020			Users' programme
23/06/20		Stop of users' programme	Stop of users' programme
Lug-Sett.2020			Beam tests per POTLNS

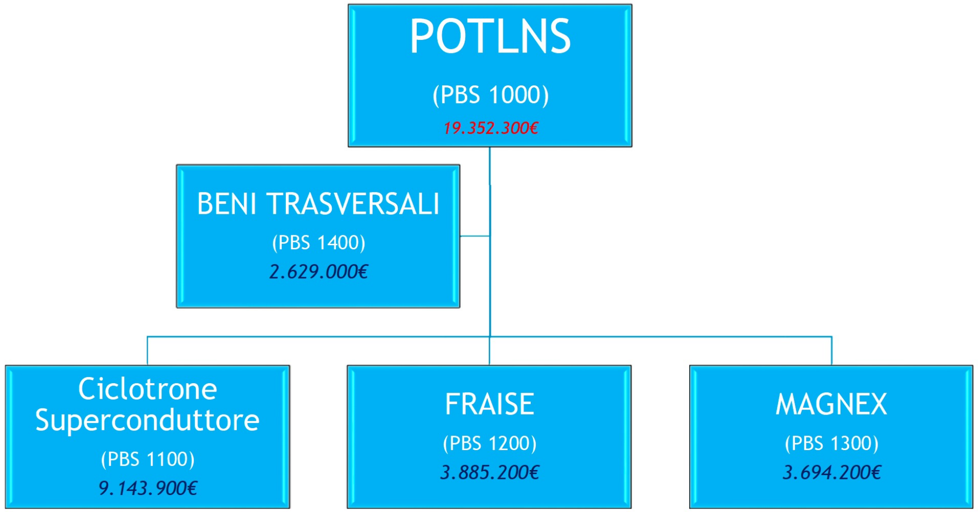
Superconducting Cyclotron upgrade within POTLNS

The project scientific goal is to increase the CS beam luminosity by two order of magnitude, in order to carry out new experiments investigating rare phenomena (e.g.: NUMEN, dealing with neutrinoless double beta decay nuclear elements matrix and all the activities related to FRAISE, the new fragment separator for the production of radioactive beams by fragmentation).

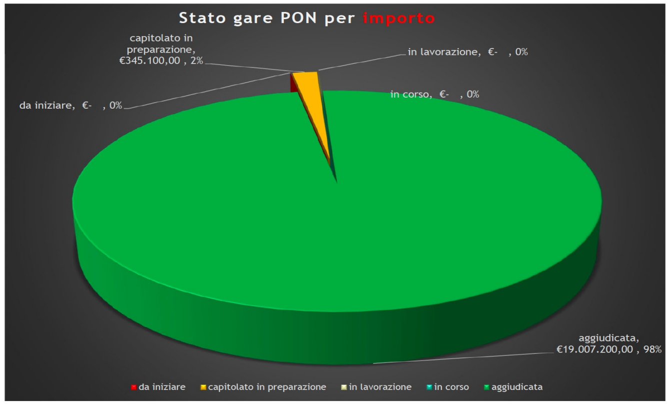
Additional reason: cryostat has been in operation for 30 years, and risks of failure were high.

Obsolescence of the infrastructures was also an issue. In fact, in addition to such action promoted by the Italian Ministry of Research, some funds have been made available by INFN budget in order to replace or improve ancillary equipments of the SC and of the beamlines.

General PBS adapted to the PON submission scheme



dashboard PON tenders status

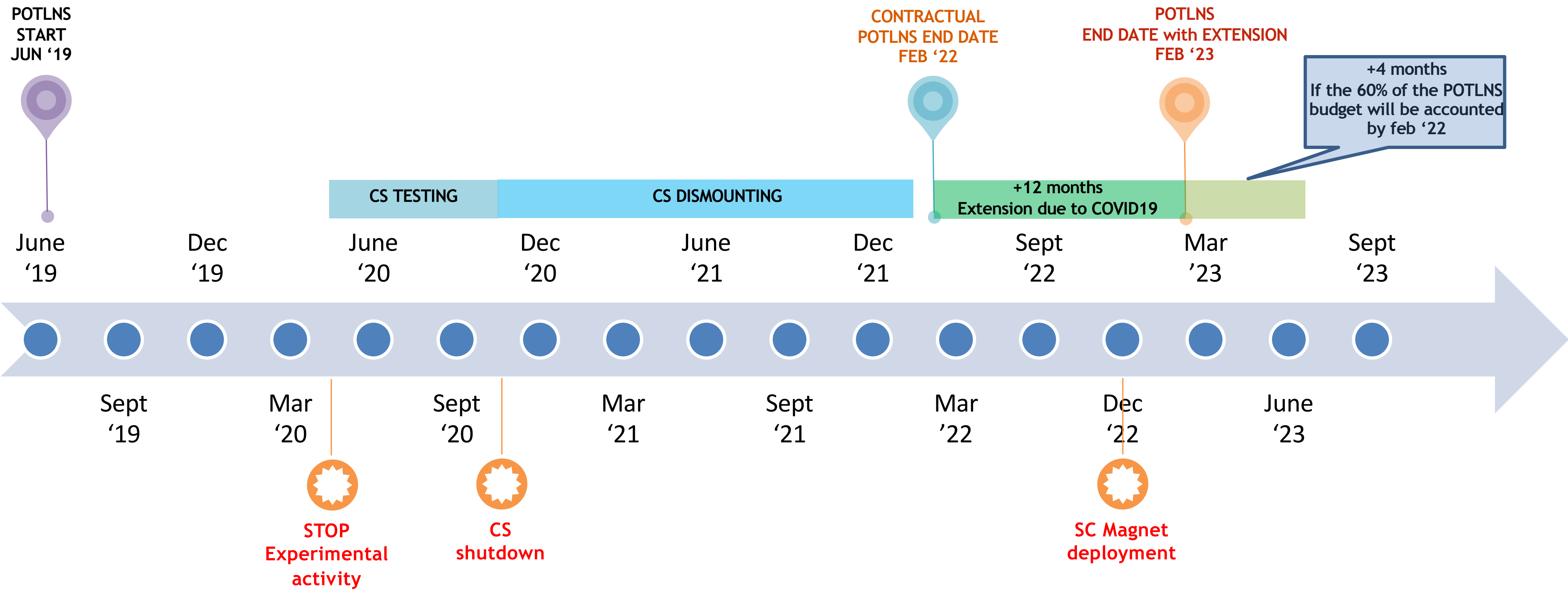


PON tenders status

Elenco beni approvati

Stato	Codice univoco del bene	Nome breve del bene	Costo ammissibile	data prevista di stipula contratto	data prevista di consegna
aggiudicata	PIR01_00005_3108	Magnete superconduttore (PBS 1101)	5.026.400,00 €	nov-19	lug-22
aggiudicata	PIR01_00005_18667	Liner (PBS 1102)	793.000,00 €	gen-21	gen-22
capitolato in preparazione	PIR01_00005_18750	DEE - coni (PBS 1103)	85.400,00 €	set-21	gen-22
capitolato in preparazione	PIR01_00005_85857	Canali magnetici (PBS 1104)	122.000,00 €		
capitolato in preparazione	PIR01_00005_85970	Movimentazioni (PBS 1105)	115.800,00 €	mar-21	dic-21
aggiudicata	PIR01_00005_86175	Stripper (PBS 1106)	1.067.500,00 €	lug-20	apr-22
aggiudicata	PIR01_00005_86337	Linea di estrazione (PBS 1107)	1.117.600,00 €	lug-20	nov-21
aggiudicata	PIR01_00005_102540	Convertitori TC (PBS 1108)	816.200,00 €	gen-21	set-21
aggiudicata	PIR01_00005_102731	Linea FRAISE (PBS 1201)	3.219.200,00 €	lug-20	nov-21
aggiudicata	PIR01_00005_102893	Schermature FRAISE (PBS 1202)	666.000,00 €	giu-21	feb-22
aggiudicata	PIR01_00005_103026	Linea MAGNEX (PBS 1301)	2.026.000,00 €	lug-20	nov-21
aggiudicata	PIR01_00005_103223	Schermature MAGNEX (PBS 1302)	1.127.300,00 €	giu-21	feb-22
aggiudicata	PIR01_00005_103274	Convertitori MAGNEX (PBS 1303)	519.000,00 €	gen-21	mag-22
capitolato in preparazione	PIR01_00005_103830	Pozzo di spegnimento (PBS 1304)	21.900,00 €		
aggiudicata	PIR01_00005_103933	Diagnostica (PBS 1401)	735.400,00 €	ago-21	mag-22
aggiudicata	PIR01_00005_112798	Impianto acqua (PBS 1402)	1.472.600,00 €	mar-21	lug-21
aggiudicata	PIR01_00005_113854	Monitor radiazioni (PBS 1403)	421.000,00 €	mar-21	dic-21

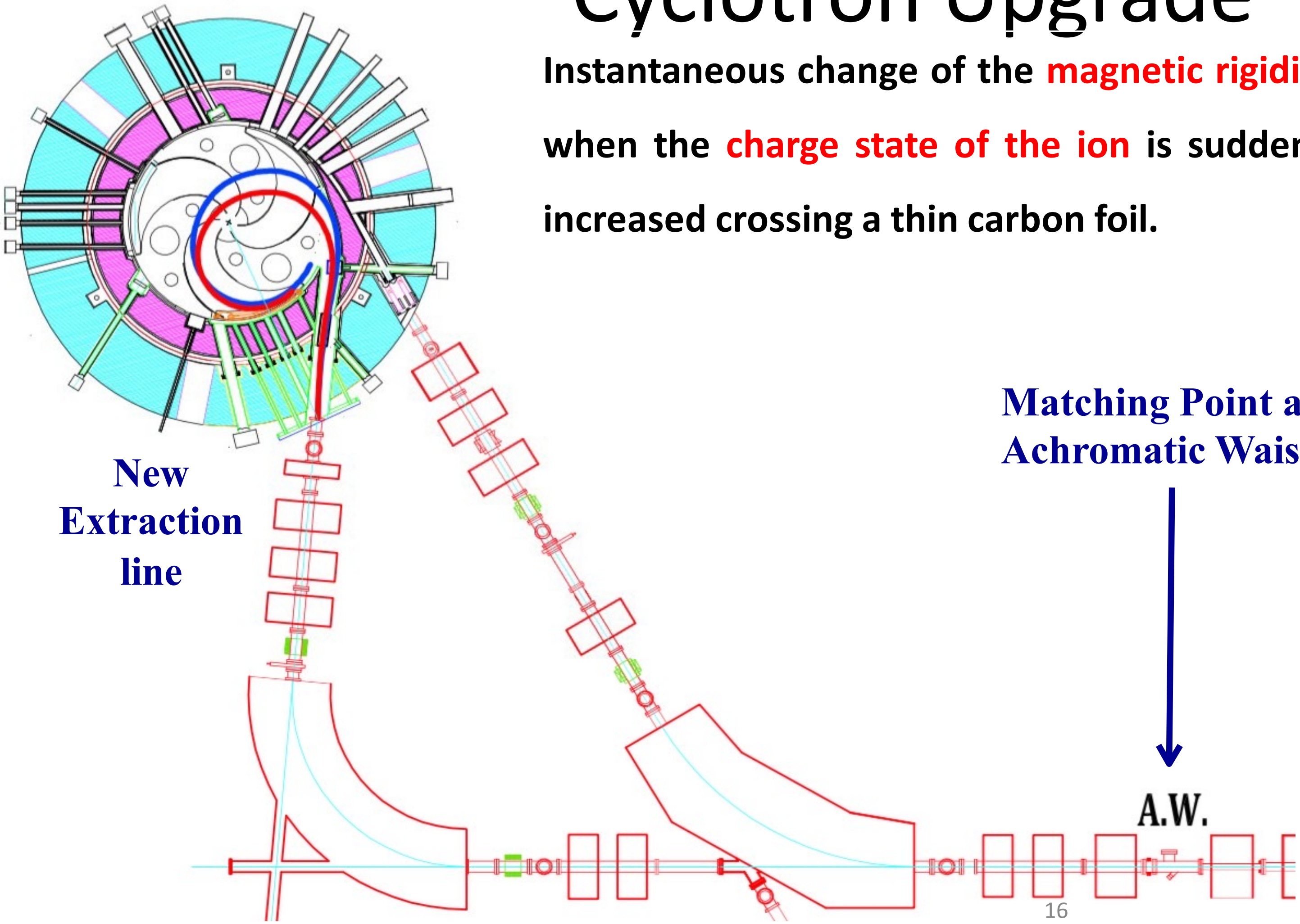
A significant upgrade of LNS has been funded in 2019 by a PON-FESR for boosting research infrastructures, having its own goals, time-schedule and deadlines.



Beam extraction by stripping: **Efficiency >99%**

Cyclotron Upgrade

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



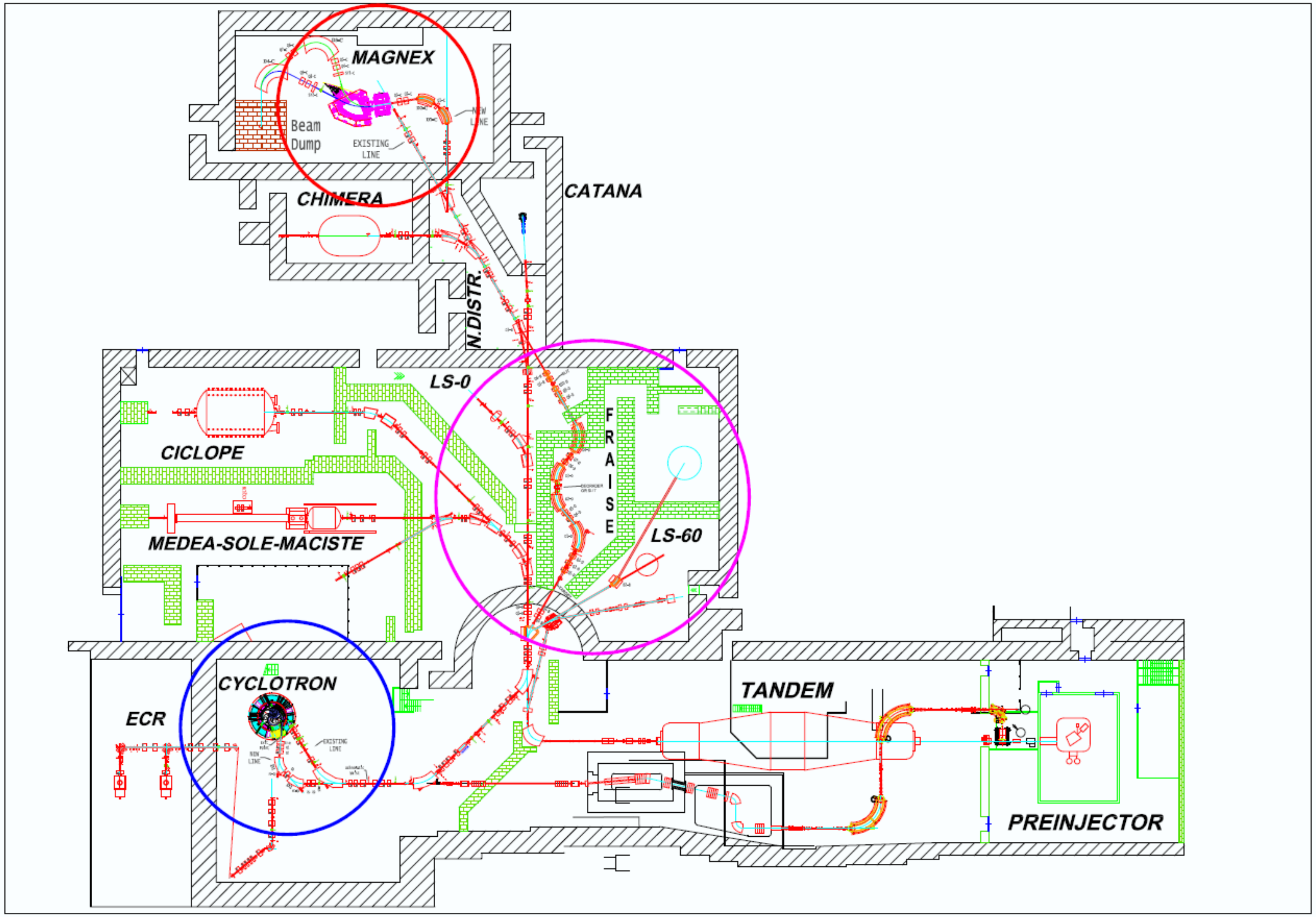
Cyclotron Upgrade

Ion	Energy	Isource	Iextr	Iextr	Pextr
	MeV/u	eμA	eμA	pps	watt
^{12}C	30	200	45	$4.7 \cdot 10^{13}$	2700
^{12}C	45	400	90	$9.4 \cdot 10^{13}$	8100
^{12}C	60	400	90	$9.4 \cdot 10^{13}$	10800
^{18}O	20	400	80	$6.2 \cdot 10^{13}$	3600
^{18}O	29	400	80	$6.2 \cdot 10^{13}$	5220
^{18}O	45	400	80	$6.2 \cdot 10^{13}$	8100
^{18}O	60	400	80	$6.2 \cdot 10^{13}$	10800
^{18}O	70	200	34	$2.7 \cdot 10^{13}$	5400
^{20}Ne	28	400	85	$5.3 \cdot 10^{13}$	4800
^{20}Ne	70	400	85	$5.3 \cdot 10^{13}$	10280
^{40}Ar	60	400	77	$2.7 \cdot 10^{13}$	10280

Areas involved in the project

To increase the beam luminosity the Superconductive main magnets with the cryostat and the liner of the CS, the beamlines, the shielding, the power supplies and cooling plant of the LNS shall be rebuilt.

A number of ancillaries, the iron of the cyclotron are modified, mechanical matching is an issue.



POTLNS Master Schedule

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Dismantled:

- AISHA
- KM3NET
- ESS

Dismantled:

- 0 GRADI
- VECCHIA DISTRIBUZIONE
- MAGNEX

POTLNS
END DATE with
EXTENSION

FEB 2023

Beam lines dismantling and removal

Dec19 Feb20 Apr20 Jun20 Aug20 Oct20 Dec20 Feb21 Apr21 Jun21 Aug21 Oct21 Dec21 Feb22 Apr22 Jun22 Aug22 Oct22 Dec22 Feb23

Dismantling
tunnel
(PBS 1602)

Preparatory works

Dismantled:

- 20 gradi
- 40 gradi

Legenda	
	LNS Personnel
	External company

Dismounting underground tunnels and preliminary construction works -> building of basement for new shielding walls

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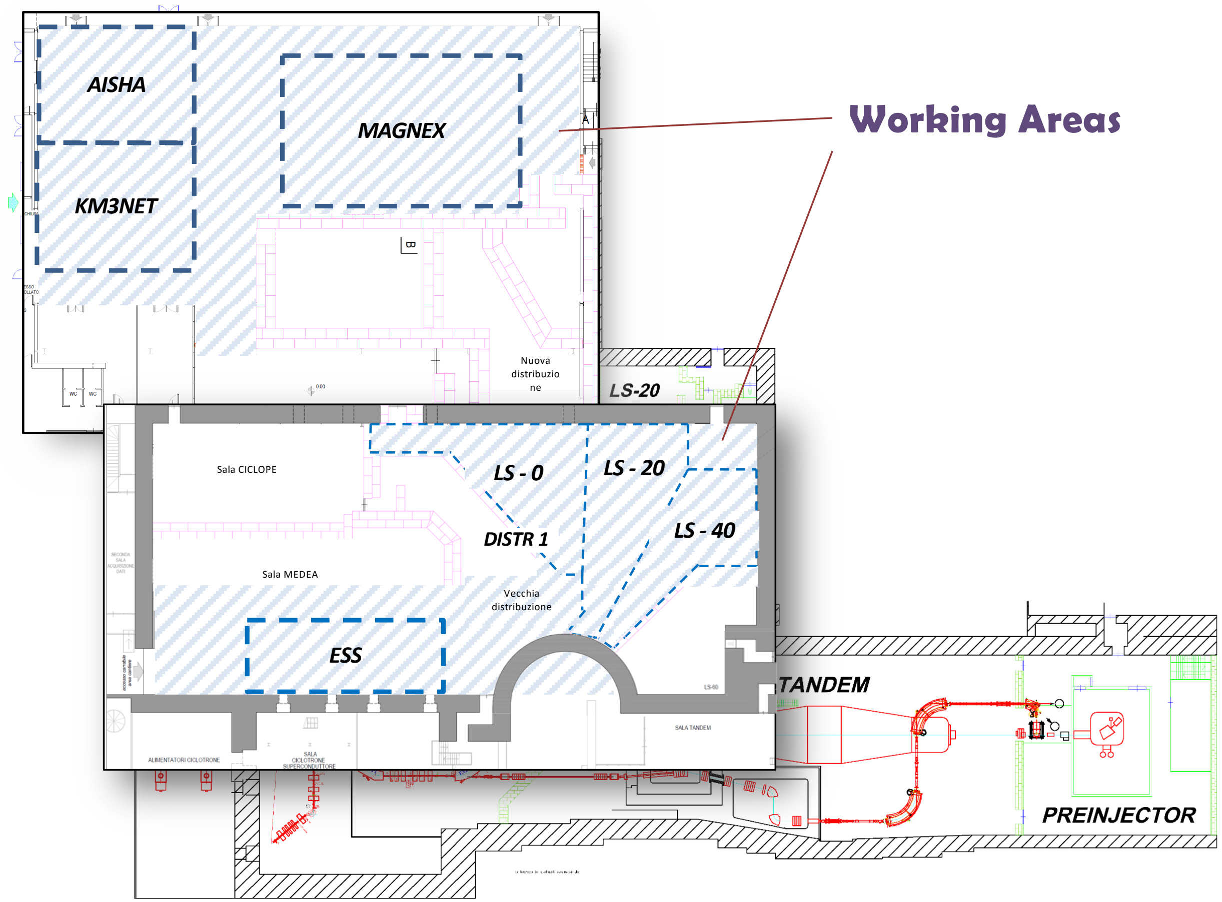


The infrastructural tasks have begun

MAGNEX shielding removed and placement of «sarcofago»

Same for MEDEA, to be removed afterwards

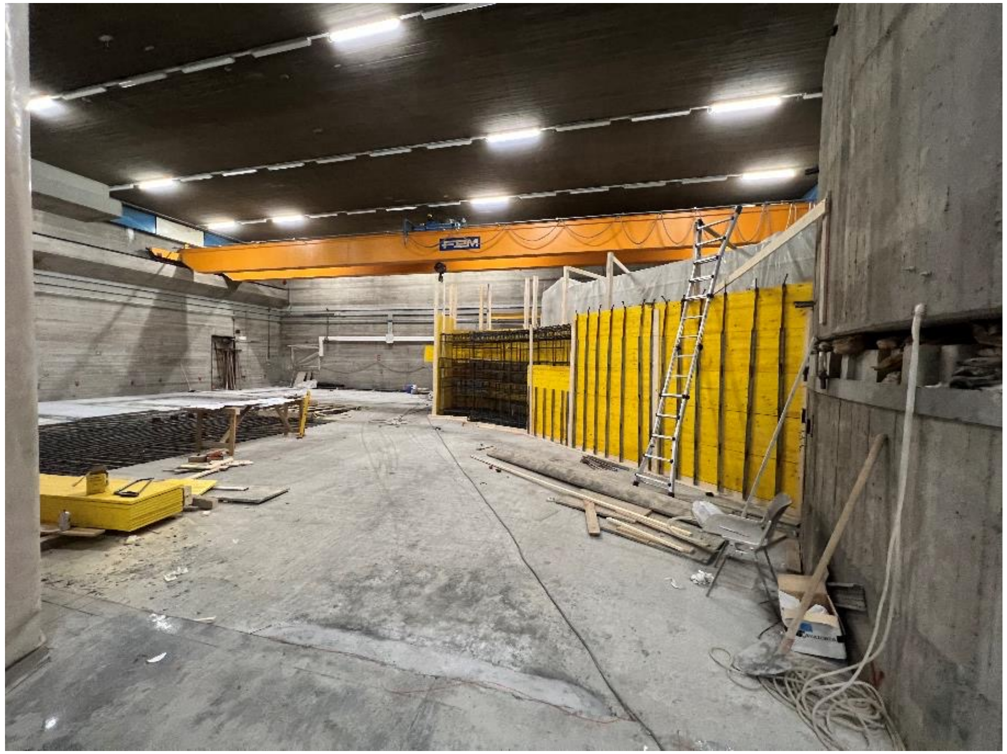
And completed

Infrastructural sub projects were about on time, not a bottle neck for the main project

Began

FRAISE radiation shielding installation

And completed



101/2020 obliged to reconsider some tasks, though the radioprotection regulations are not significantly different, as they were already a challenge…

Began

MAGNEX radiation shielding installation

And completed

Began

And completed

The same for other infrastructural sub project

POTLNS Master Schedule

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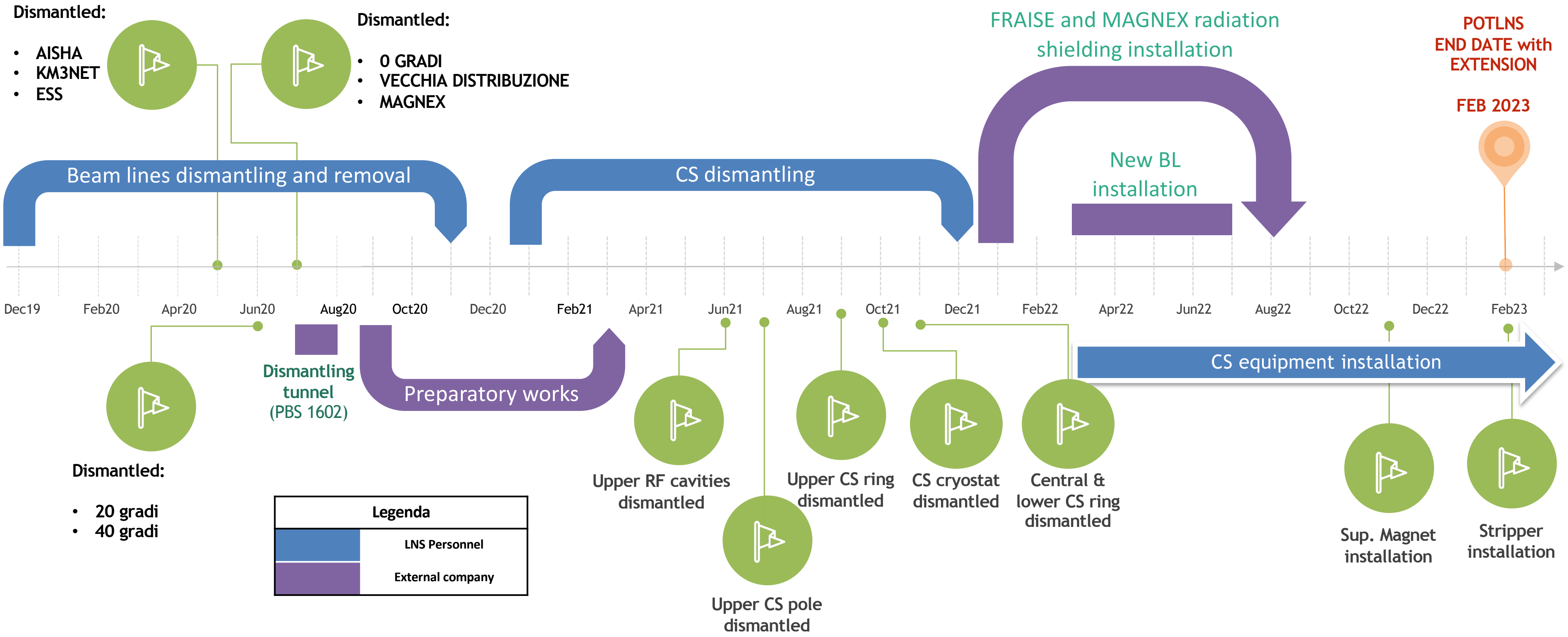

POTLNS Master Schedule

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POTLNS END DATE with EXTENSION

FEB 2023

Dismantled:

- AISHA
- KM3NET
- ESS

Dismantled:

- 0 GRADI
- VECCHIA DISTRIBUZIONE
- MAGNEX

Beam lines dismantling and removal

CS dismantling

Dec19 Feb20 Apr20 Jun20 Aug20 Oct20 Dec20 Feb21 Apr21 Jun21 Aug21 Oct21 Dec21 Feb22 Apr22 Jun22 Aug22 Oct22 Dec22 Feb23

Dismantled:

- 20 gradi
- 40 gradi

Dismantling tunnel
(PBS 1602)

Preparatory works

Upper RF cavities dismantled

Upper CS pole dismantled

Upper CS ring dismantled

CS cryostat dismantled

Central & lower CS ring dismantled

Legenda	
	LNS Personnel
	External company


ACCESSO REGOLAMENTATO
MAGNETE ACCESO
RADIO FREQUENZA


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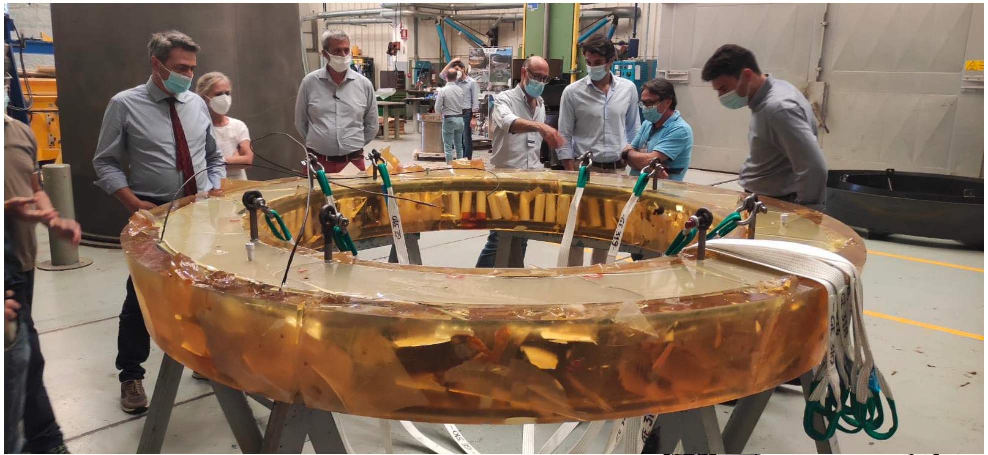

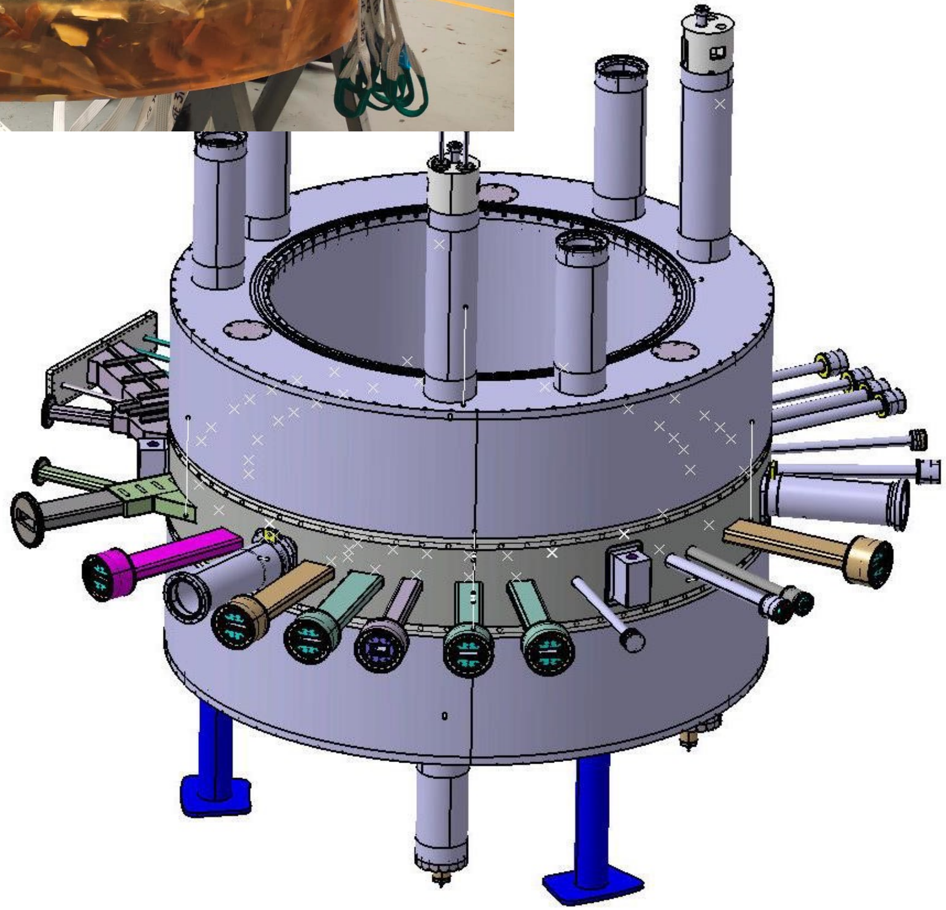

New spectrometer for projectile fragmentation

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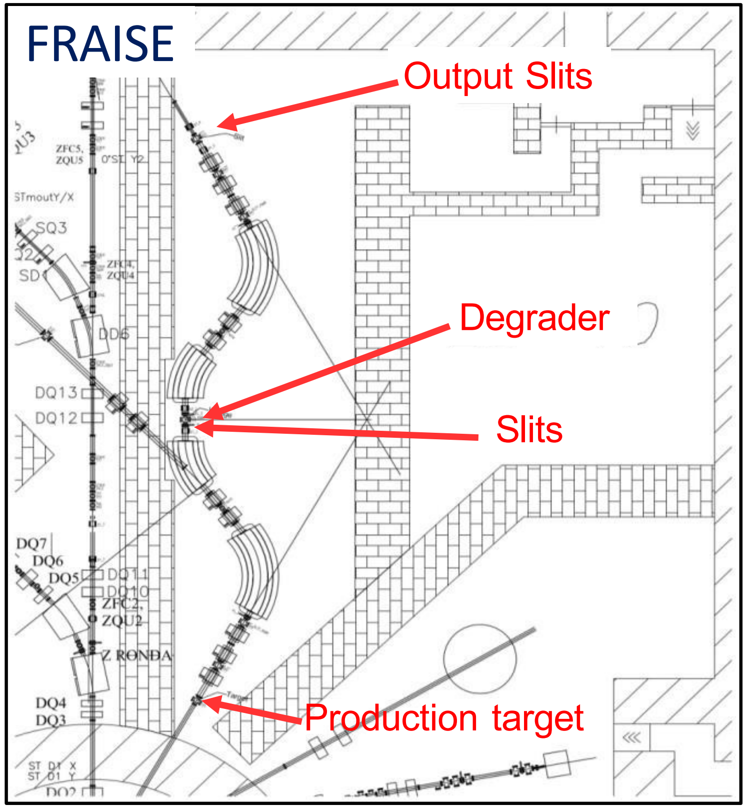

Foreseen intensities

BEAM	primary beam / energy (AMeV)	thick wedge	YIELD new separator (kHz)	purity %
14Be	18O/55	0	2,6	2
14Be	18O/55	1000	2,2	70
13N	16O/40	600	1230	54
14O	16O/40	600	807	36
18Ne	20Ne/60	0	16700	16
18Ne	20Ne/60	1000	3120	47
17F	20Ne/60	1000	3300	49
34Si	36S/40	500	980	81
38S	40Ar/40	300	1840	66
34Ar	36Ar/50	0	2800	4
34Ar	36Ar/50	500	426	12
68Ni	70Zn/40	200	490	50

ECR ion sources

High Intensity operation with the upgraded CS and HCI production REQUIRE SERSE or a similar class ECRIS.

SERSE (1997)
High B mode – Highly charged ions

Refurbishment of some subsystems carried out in previous years (controls, gas box, insulated rack), ***BUT*** serious cryogenic problem arose during last operations and a few weeks ago identified.

Cost-benefit analysis under way to decide how to proceed

CAESAR (1999)

The source, although totally unsuitable to support the high intensities desired with the new CS, *can continue to provide the less critical beams in the first operational years*.

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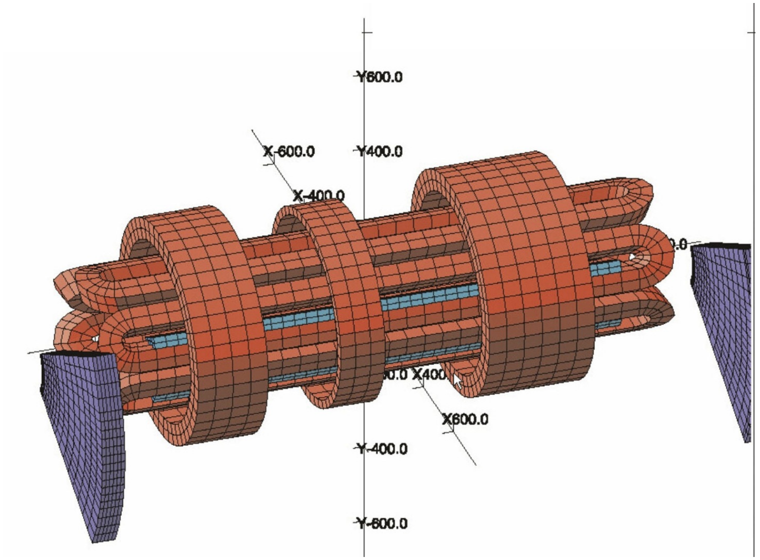
New ECRIS for the upgraded CS- Option 1: SC-AISHa

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.

However the permanent magnet hexapole may be replaced by a superconducting structure with a minor changes on the solenoid coils for axial confinement (may be decreased to 3). Increase of extraction voltage is also mandatory.

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	60 kV (max)
Chamber diameter / length	Ø 130 mm / 600 mm
LHe	Free
Warm bore diameter	140 mm
Source weight	2100 kg



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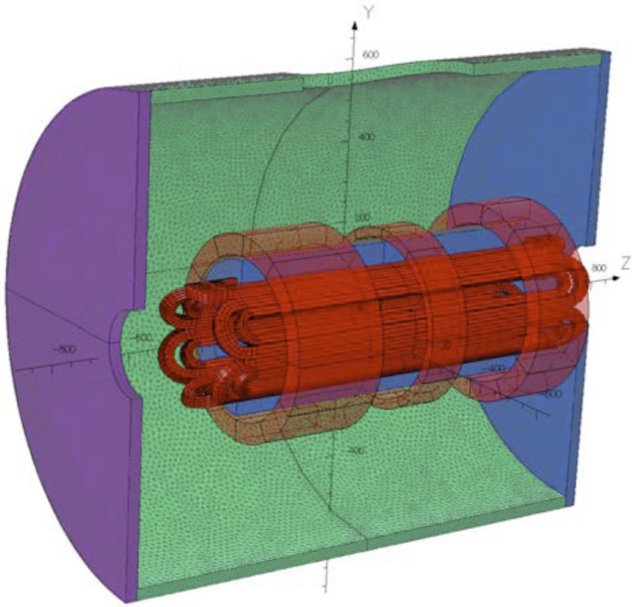
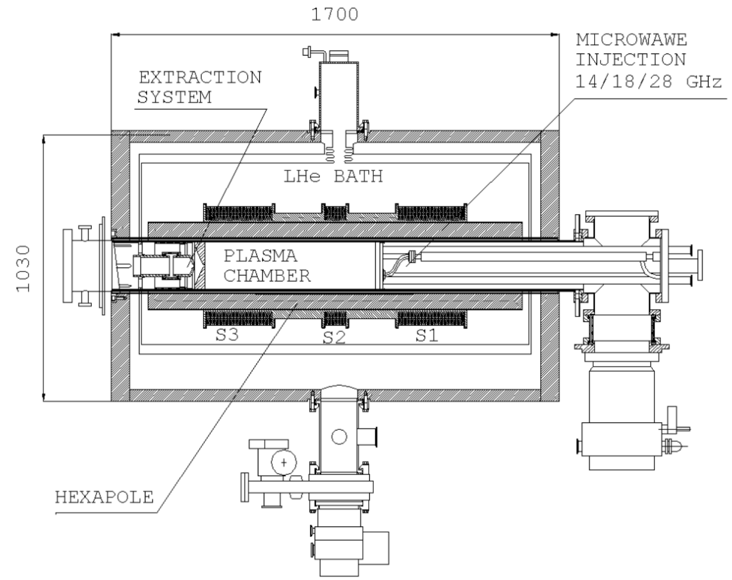
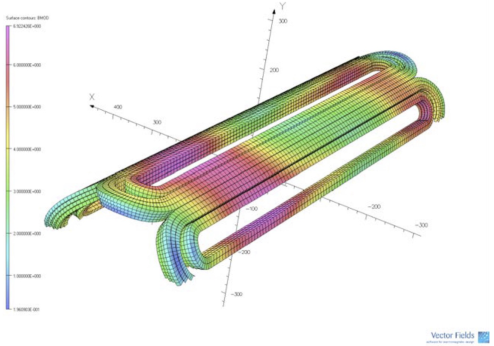
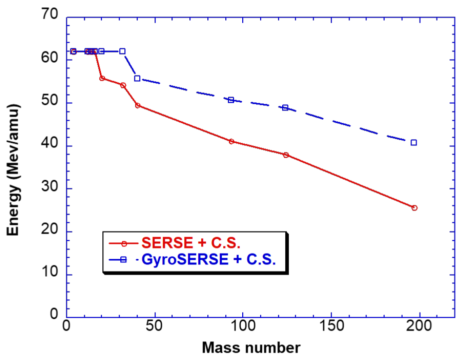
New ECRIS for the upgraded CS- Option 2: GyroSERSE

Operating frequency	**Up to 45 GHz**
Maximum rf power	20 kW
B_{max} (injection side)	**4.5 T**
B_{min}	0.5 T
B_{max} (extraction side)	3.5 T
B_{rad} (at chamber wall)	**2.7 T**
Cryostat length	1700 mm
Hexapole inner diameter	216 mm
Length of the chamber	650 mm
ϕ chamber	180 mm
Extraction voltage	60 kV









Coil	Current [A]	B_z on axis [T]	Br at R=90mm [T]	|B| at Coil [T]	Margin to Quench [%]
Sextupole	286.54	-	2.69	6.79	19
Extraction Solenoid	104.71	3.2	-	6.0	29.2
Injection Solenoid	104.66	4.49	-	6.6	23.5
Middle Solenoid	112.49	0.492	-	4.0	49.3

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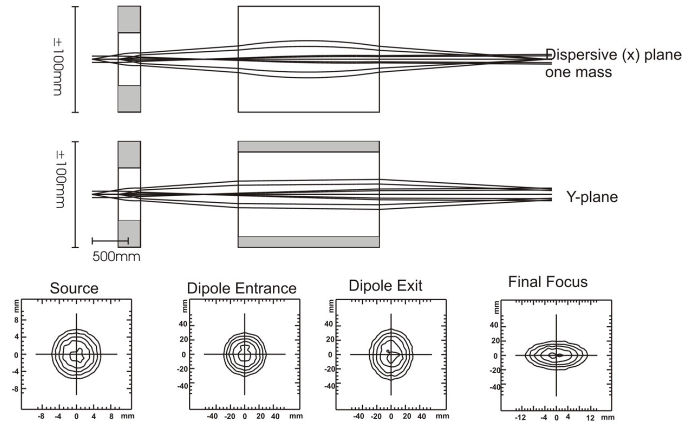
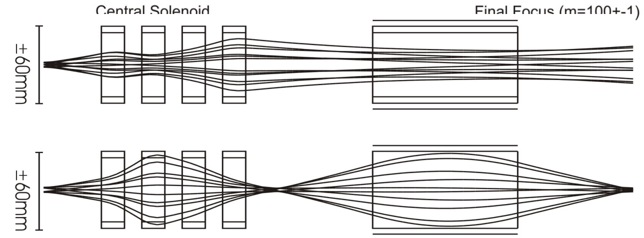
Ion source analysis beam line

Two options have been studied for the SC-AISHA or MS-ECRIS analysis beamline :

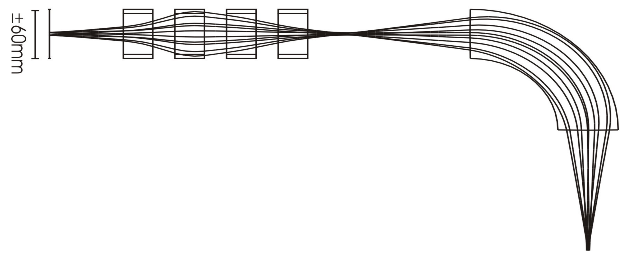
a) a 90° dipole magnet with a bending radius of 1200 mm (mass resolution better than 100). The dipole gap is ±80 mm. The entrance and exit field boundaries of the dipole are inclined by 26° in order to be double focussing. The needed solenoid strength is 0.3 T. Similar results may be achieved decreasing the bending radius to 700 mm. In this case the needed solenoid strength is 0.62 T.



b) a quadrupole quadruplet to obtain a relatively narrow beam and a smaller 90° dipole magnet (ρ=800 mm without any inclined field boundaries and higher order correctors) with a mass resolving power better than 120. The advantage of this system is, that it provides astigmatic focusing. The length of the magnetic quadrupoles is 200mm, the radius is 50mm and their separation is 50mm.



A total space charge of 1 mA has been considered.



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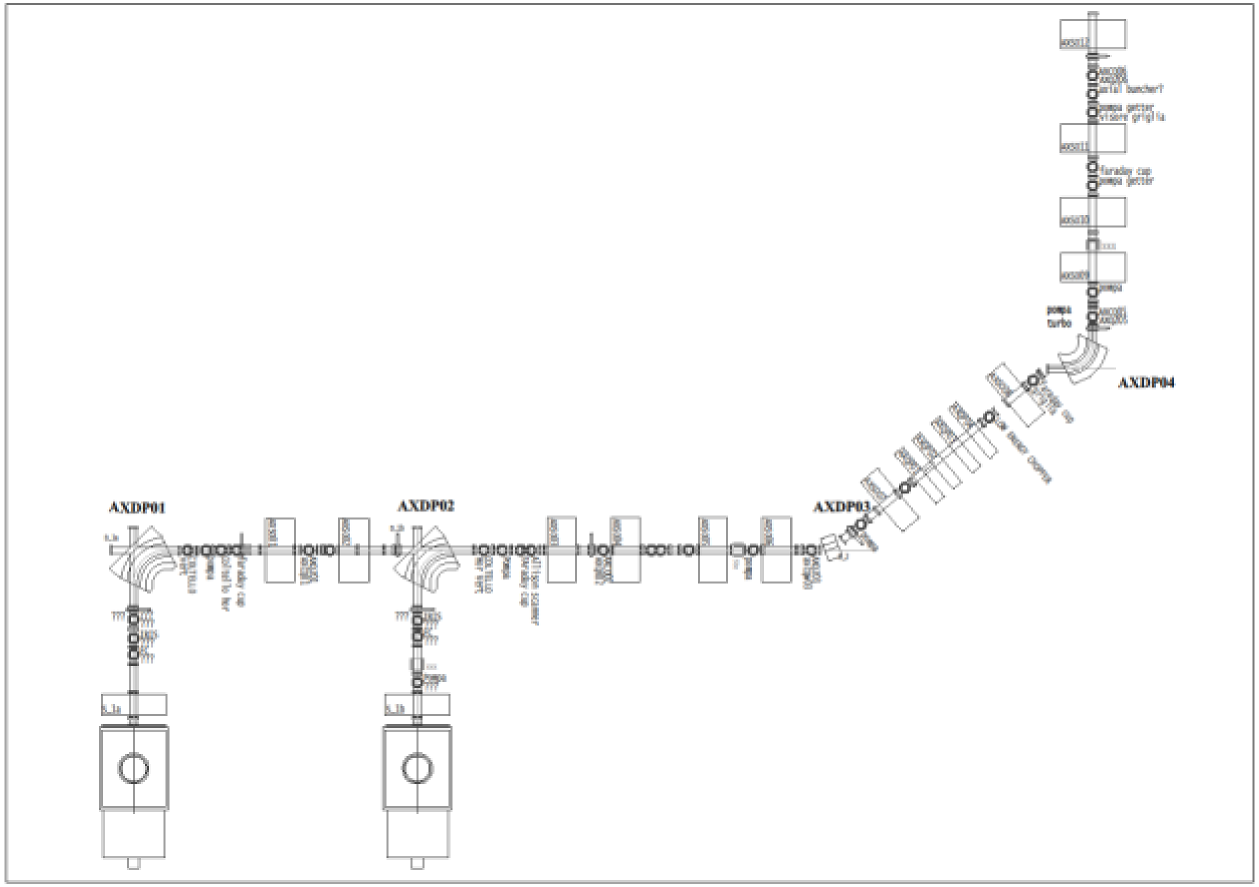
New axial beam injection line: ECRISs – CS matching optimization



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

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

Insertion of a Low Energy Chopper as mitigation device for MPS and beam intensity tuning.

Renewal of the two axial bunchers

Modification in beam diagnostics

Refurbishment vacuum system and controls

The new Control System Architecture

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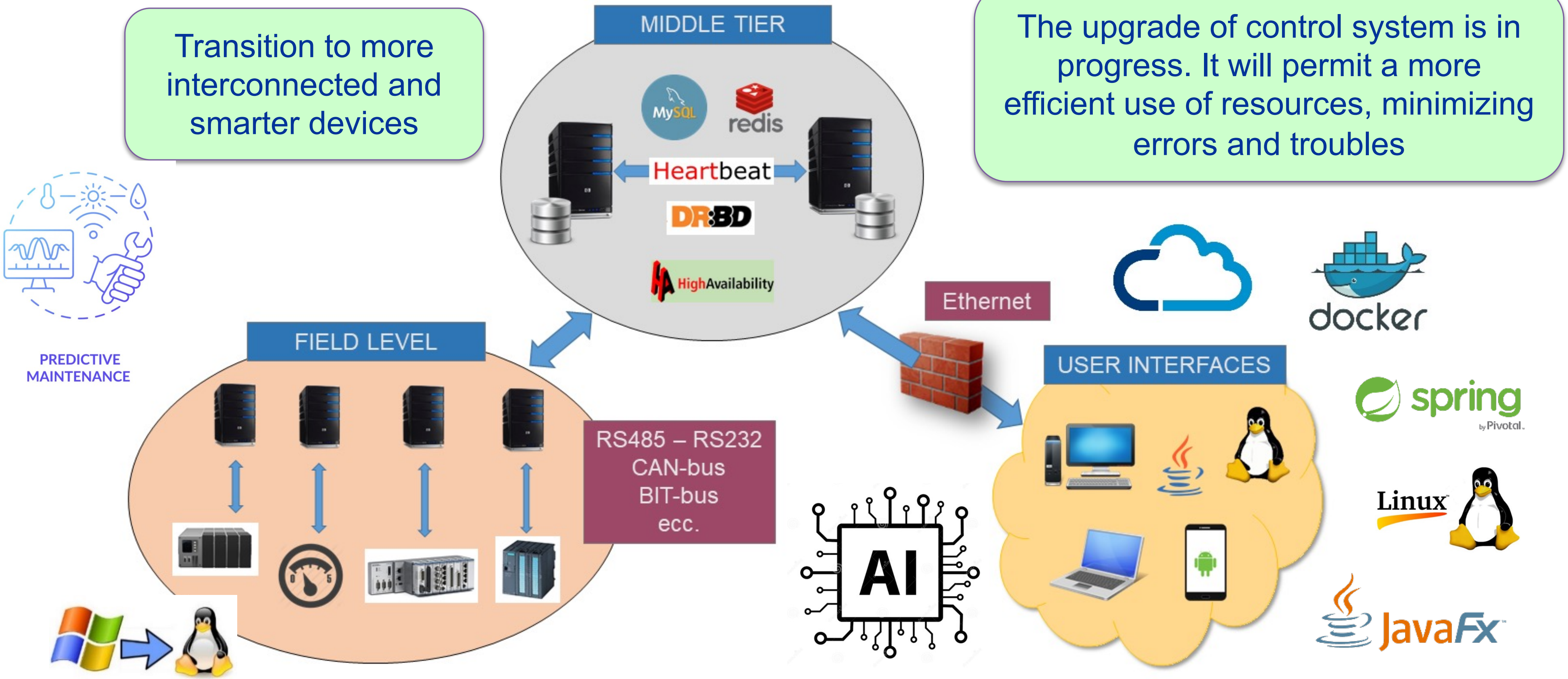
Transition to more interconnected and smarter devices

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



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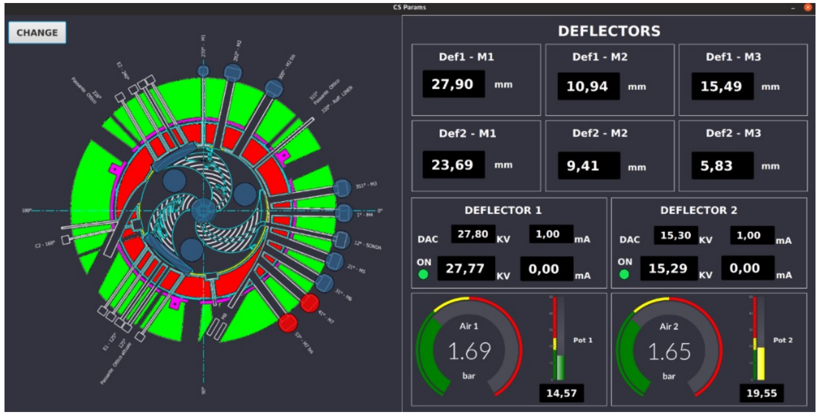
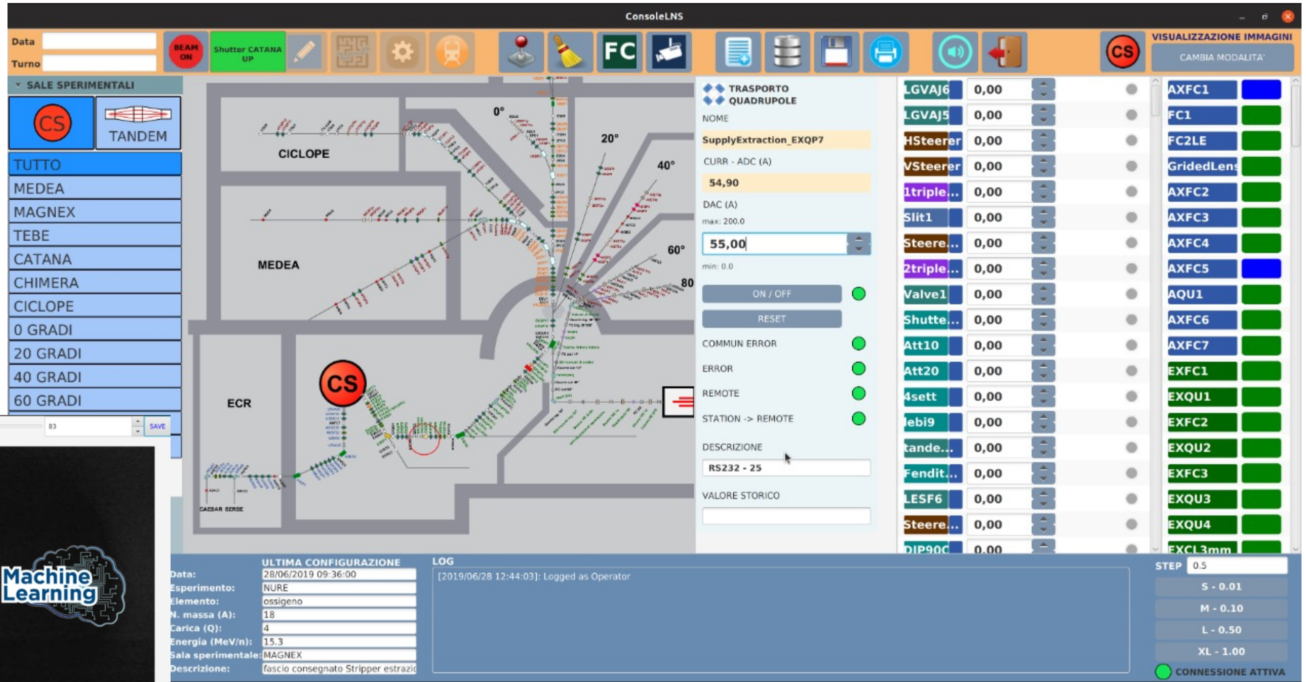
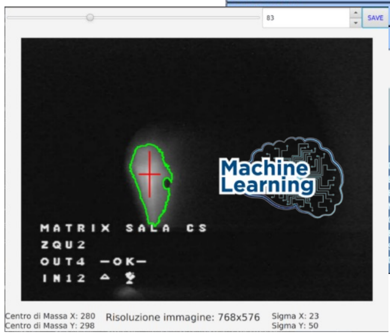
Beam Auto Tuning with AI tools

Speed up of the beam tuning with Artificial intelligence





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



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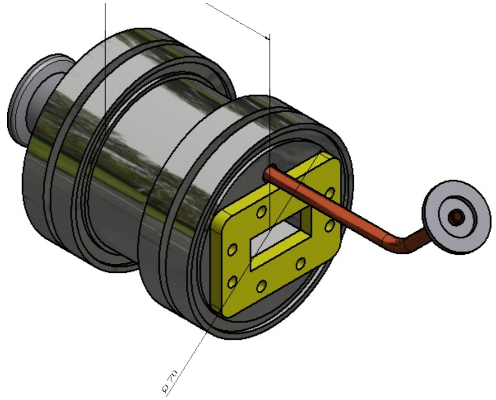
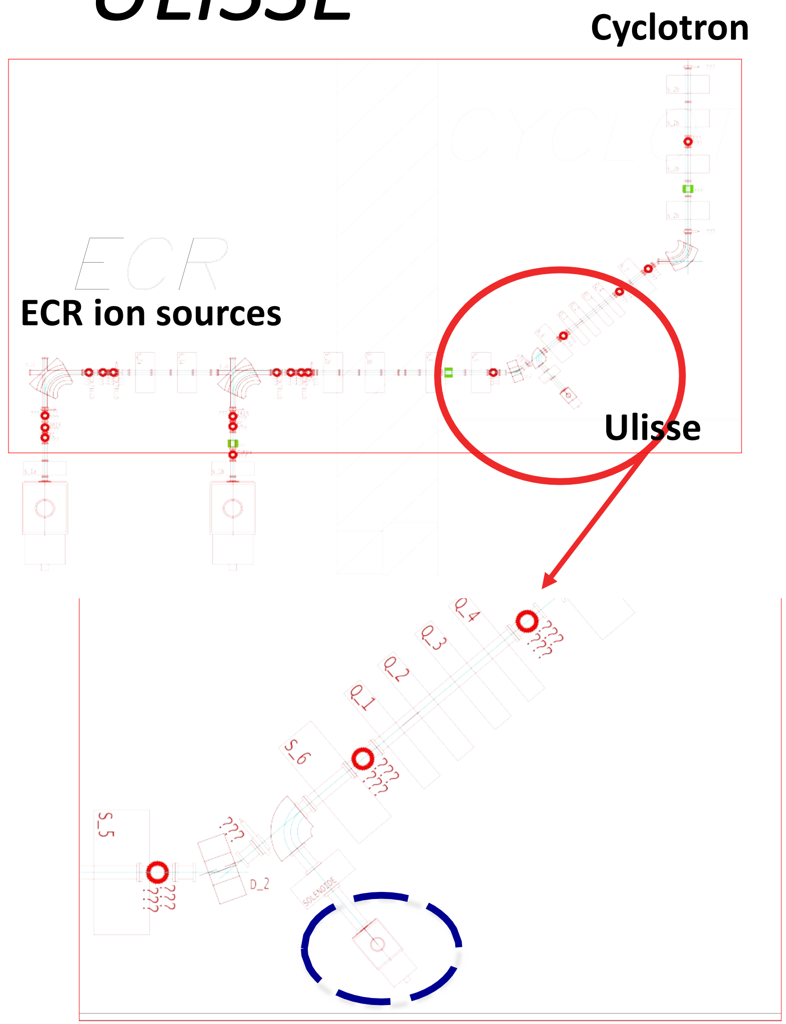
ULISSE

ULISSE is a new compact proton source devoted to all protontheraphy CATANA sessions and to all experiments envisaging protons, H2+ or deutons.





Frequency: 5.85-6.425 GHz
Power: 40W
Amplifier type: Solid State
Plasma Chamber length: 70 mm
Plasma Chamber radius: 70 mm
Magnetic field: 0.2 T (around)

Optimization of the matching Ion Source – Cyclotron

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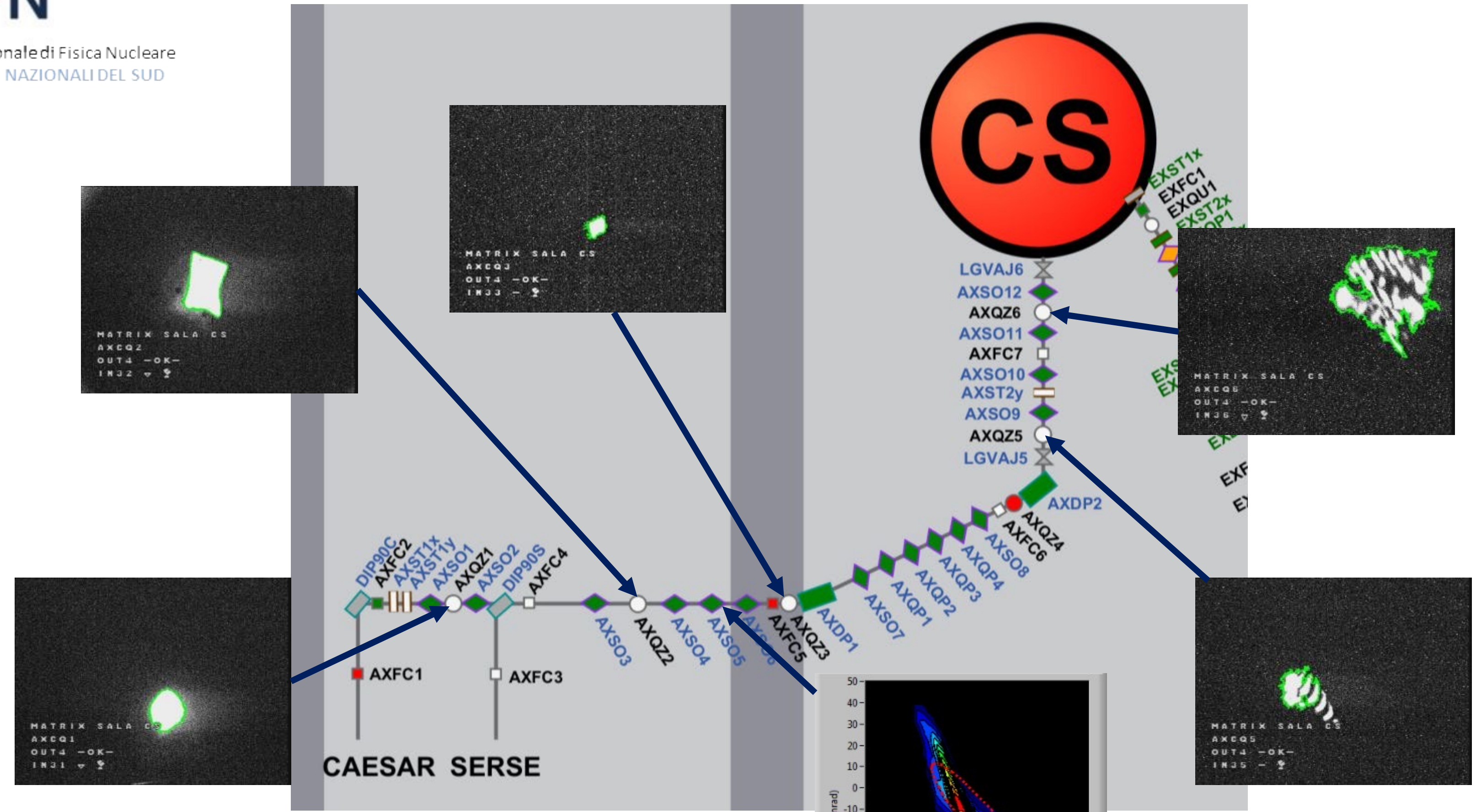
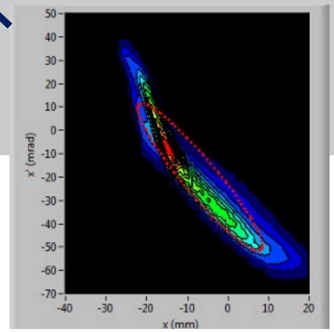


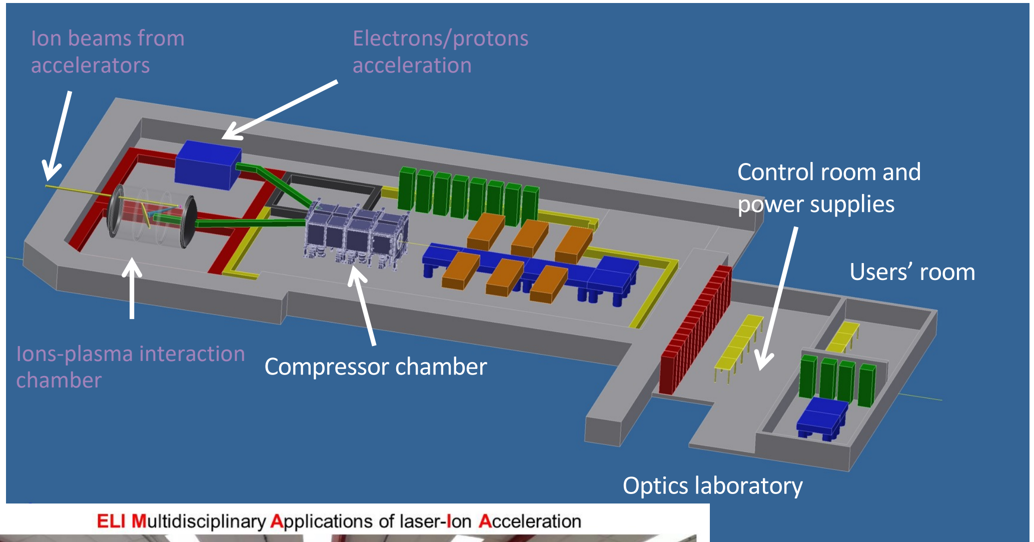


Beam Image and Emittance to optimize the beam injection in the Cyclotron

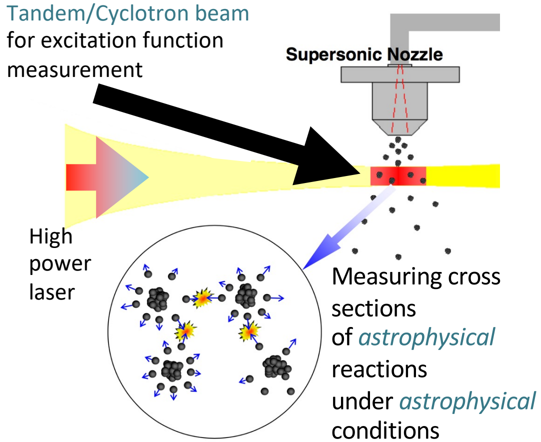
I-LUCE: INFN Laser indUced aCcEleration facility

0.2 PW, < 30 fs, > 1Hz Ti:Sapphire, 800 nm laser system

Ion accelerations and applications



Nuclear physics and astrophysics



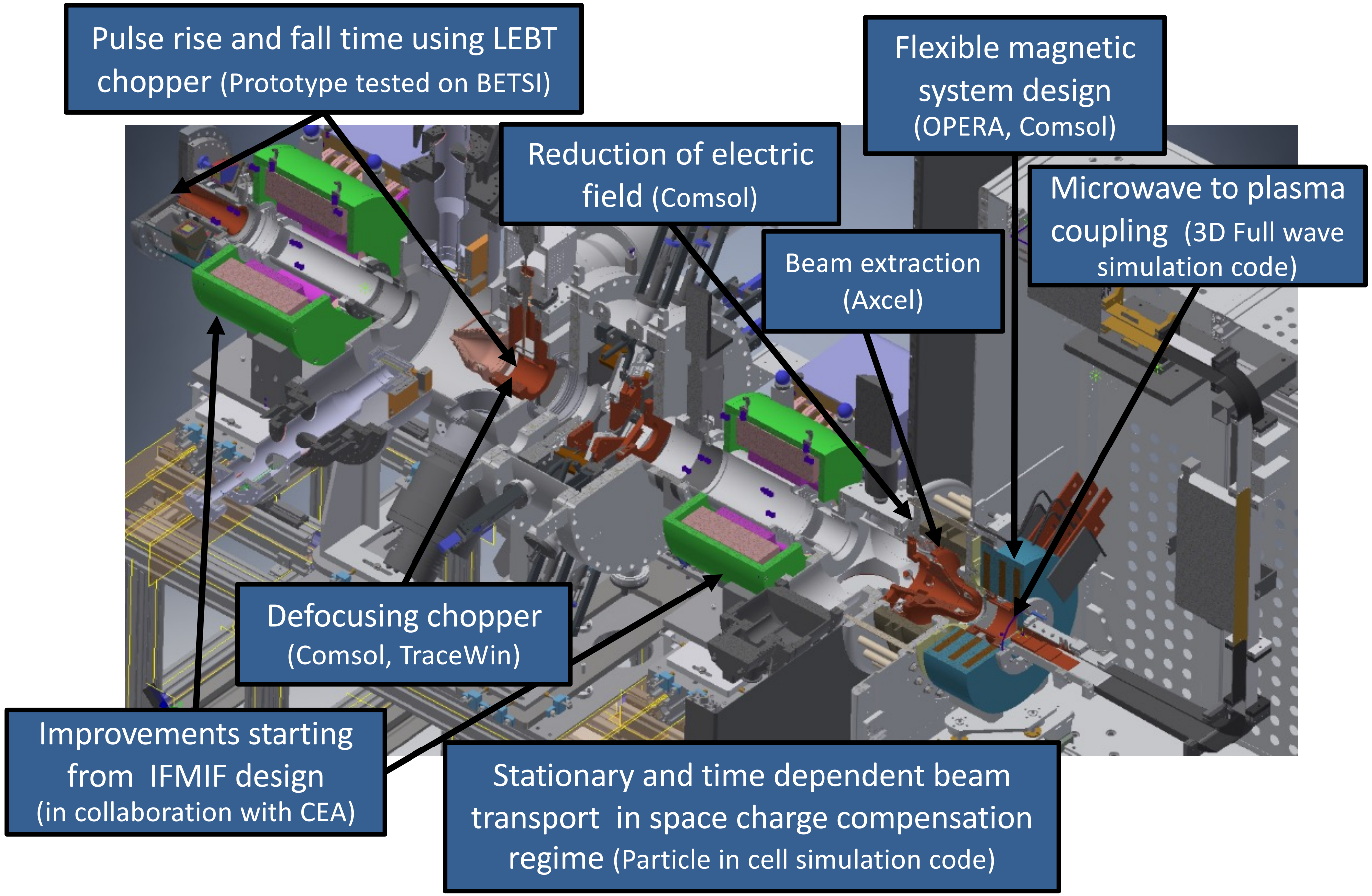
ELI Multidisciplinary Applications of laser-Ion Acceleration

- Installed in July 2018
- Commissioning will start in September 2020 (INFN-LNS and Queen’s University resp.)
- Laser-driven proton (up to 300 MeV) - ion (up to 70 AMeV) beam lines for interdisciplinary applications
- First world open Users’ beam line for studies with laser-accelerated ion beams

Long list of INFN funded projects: ECLISSE since 1997 in collaboration with CAS Prague and IPPLM Warsaw, then PLATONE, PLAIA, LIANA, LILIA, ELIMED, L3IA, LPA2 with ELI Beamlines

BERKELEY LAB Technical University of Munich TUM eli beamlines QUEEN'S UNIVERSITY BELFAST

ESS high intensity proton source



2011	Strat of the design at LNS
2015	Start of the construction at LNS
25/05/2017	ESS visit for requirement verification
12/09/2017	ESS visit for requirement verification
17/11/2017	End of the commissioning at LNS
01/02/2018	Delivered and assembled in Lund

ESS high intensity proton source

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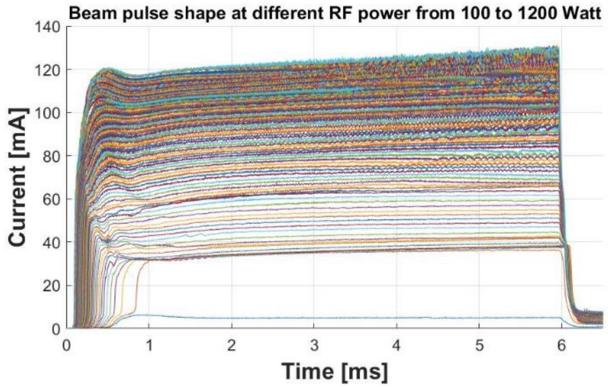
PS-ESS was fully commissioned at LNS
and performance were validated by ESS personnel

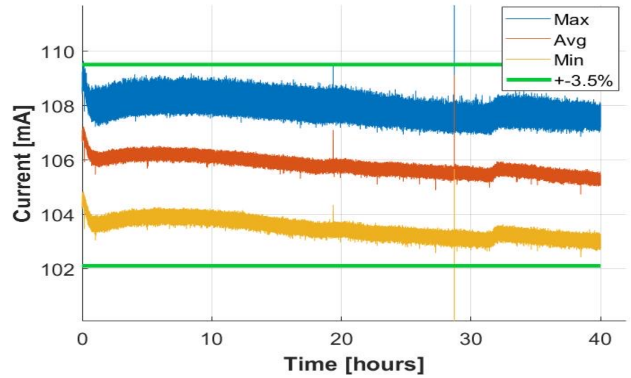
Requirement	Value	Measurement done for configurations that satisfy the ESS stability requirements	Comments
Total beam current	>90 mA	40 - 140 mA	✓
Nominal proton beam current	74 mA	40 - 105 mA	✓
Proton beam current range	67-74 mA	40 - 105 mA	✓
Proton fraction	>75%	Up to 85%	✓
Pulse length	6 ms	6 ms	✓
Pulse flat top	3 ms	3 ms	✓
Flat top stability	±2 %	< ±2 % up to 1.5%	✓
Pulse to pulse stability	±3.5 %	< ±3.5 % up to 3%	✓
Repetition rate	14 Hz	14 Hz	✓
Beam energy	75±5 keV	75 keV	✓
Energy adjustment	±0.01 keV	±0.01 keV	✓
Transverse emittance (99%)	1.8 pi.mm.mrad	1.06 pi.mm.mrad @ 82 mA	✓
Beam divergence (99%)	<80 mrad	50 mrad @ 82 mA	✓
Start-up after source maintenance	32 hours	32 hours	✓

Second source with second part of the commissioning was not needed

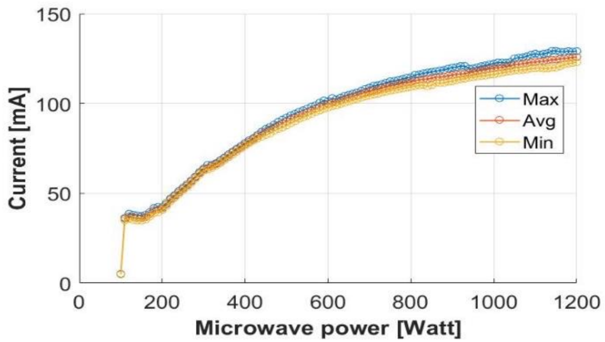
Intra-pulse stability < ±2%

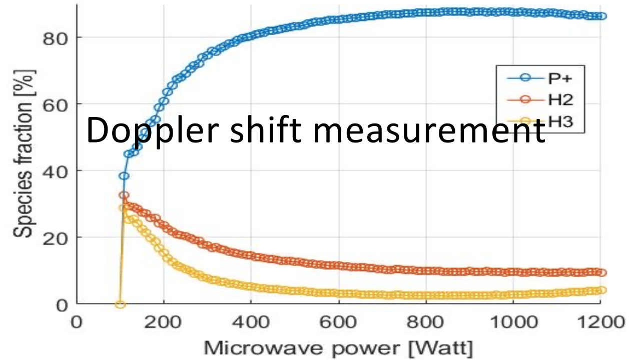


Pulse to pulse stability < ± 3.5%



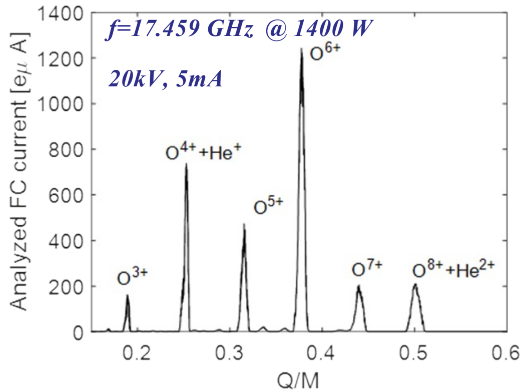
Minimum proton current range 67-74 mA

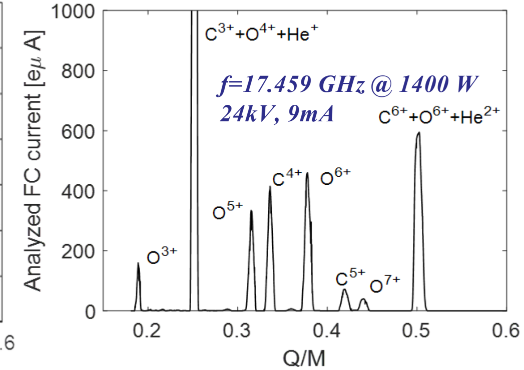




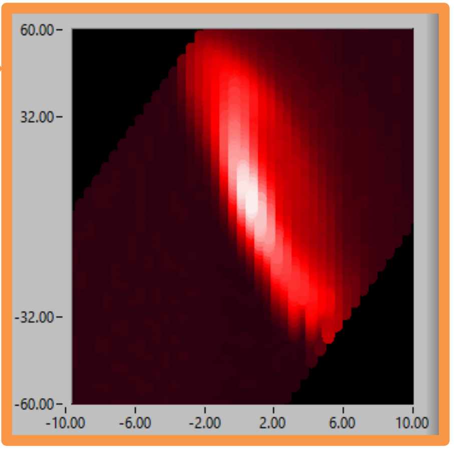
Advanced Ion Source for Hadrontherapy

AISHA is a hybrid ECRIS meeting the **needs of the installation in hospital** environments: the radial confining field is obtained by means of a permanent magnet hexapole, while the axial field is obtained with a **Helium-free superconducting system.**





O6+ emit. (60π geom – 0.1π norm.) 0.5emA – Extraction 20 kV – 17.376 GHz – 500W



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
Extraction voltage	40 kV
Chamber diameter / length	Ø 92 mm / 360 mm

Activities in 2022

Recommissioning after improvements
Beam emittance measurements (O, He, C, Ar)
New setup for CNAO.

INSPIRIT expected beams

Carbon 24 kV (4+)
Oxygen 21.33 kV (6+);
Helium 16.01 kV;
Iron 23.55 kV;
Lithium 18.71 kV;

AISHa @ CNAO

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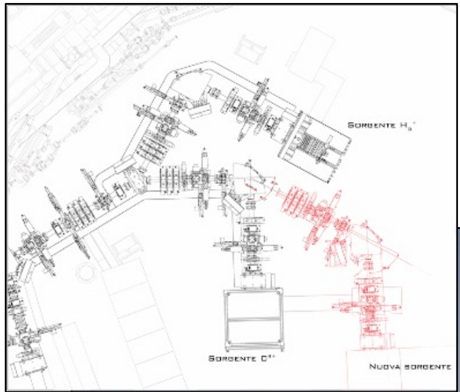
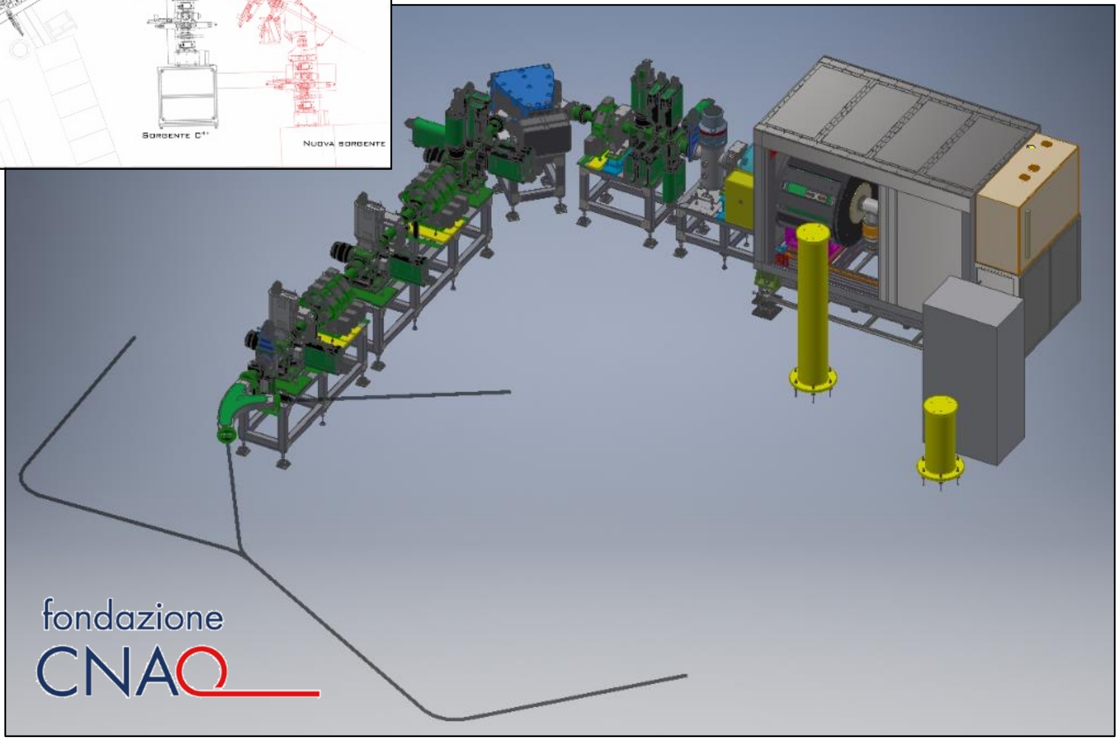


INSpiRIT

INnovative accelerator facility with **S**ources **I**ons for **R**esearch and radiation hardness studies with **I**ndus**T**rial and clinical applications



Helium, Lithium, Oxygen and Iron for new clinical protocols and biological/material experiments for space radiation research

Source and ancillary equipment are being preassembled in INFN-PV.

Commissioning is planned to start in Q4-2022 and will envisage night shifts

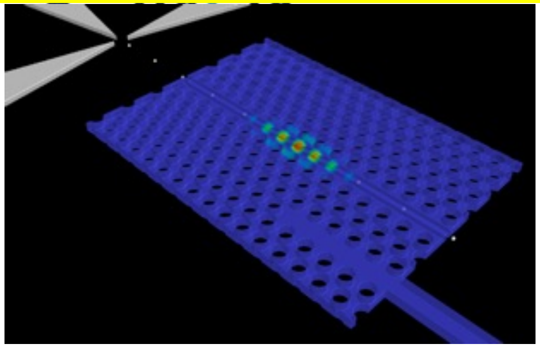
Conclusions

The end of the phase supported by the PON, aiming at procurement and tenders, set a Start of User Programme (SOUP) at the end of Q2-2023 for the Tandem and in Q4-2023 for the Superconducting Cyclotron (CS).

A number of improvements to the accelerators and to ancillaries will continue during the next months and also the R&D activities will be boosted by the end of infrastructural works that will permit to operate more or less as in the past years, that has been not the case in 2021.

For sake of brevity I am not describing the Accelerator R&D activities, most of them in CSN5: HSMDIS, IONS, MICRON, etc but also Muon Collider, DTT, Life Sciences, etc. Some of these activities will be described in other talks (Mascali, Cuttone, Cirrone), others are in so early stage that may be the subject of future INFN-A workshops.

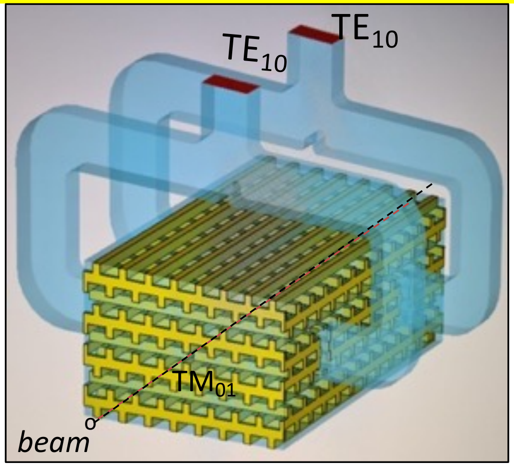
Photonic Crystal (PhC)-based Dielectric Laser Accelerator (DLA)



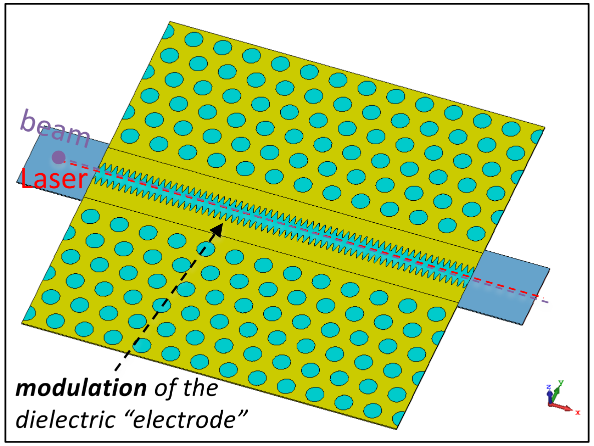
*DLA **high-Q photonic-crystal cavity***
[courtesy of C2N]

LoI Core Ideas:

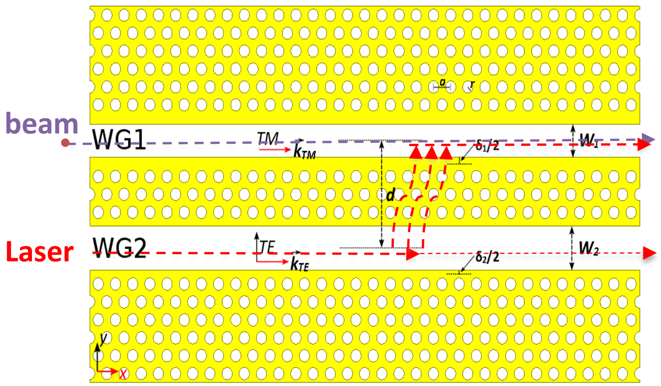
- **Hollow-core waveguides** for high power handling
- **High interaction impedance** Z_c and accelerating gradient
- **Continuous wave** (CW) laser operation (1-5 µm)
- **Collinear** co-propagating laser and beam
- Sub-wavelength features for **sub-relativistic particles**
- Integrated **nano-proton-source** for **proton-DLA**



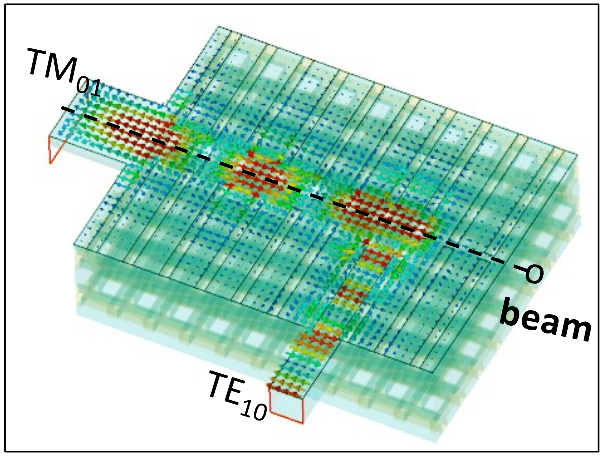
*3D Silicon **Woodpile mode launcher***



*RFQ-like 2D **Longitudinal PBG***
*for tabletop **proton-DLA***



***2D** longitudinal Photonic Crystal*
Directional Coupler



3D woodpile mode converter side-coupler

Handle with care

Turnover of researchers

Turnover of technicians with “multiple” expertise

<u>Cherrypicking by other Labs, or other fields, is a nightmare (accelerators’ people are success oriented, so highly appreciated everywhere)</u>

Question: why a student should look to accelerator physics, less appealing with respect to other branches, that are well paved to become a Nobel laureate?