The Proton Source for the European Spallation Source (PS-ESS): installation and commissioning at INFN-LNS

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Working group

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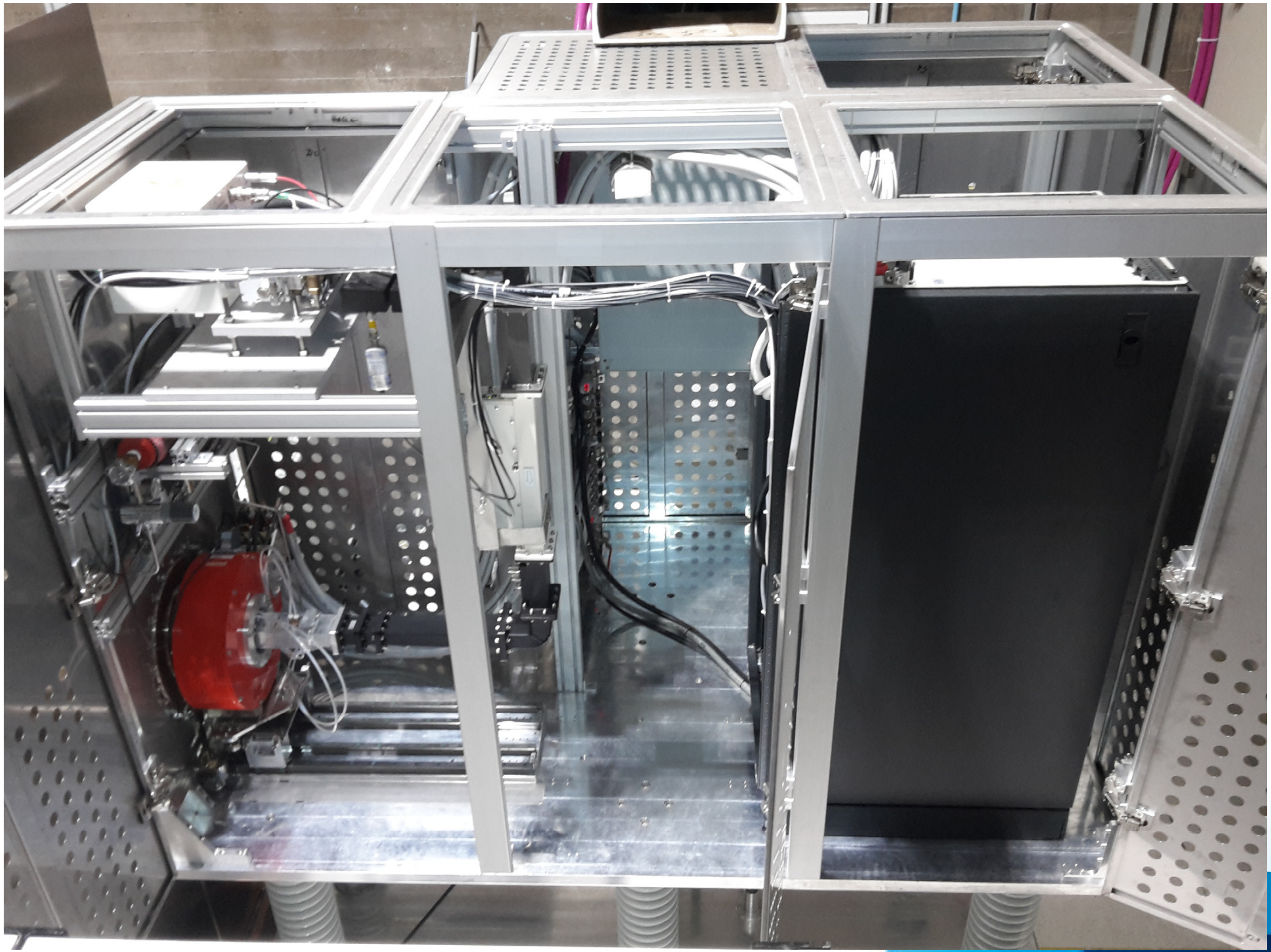
ESS groups: *Control System*, *Beam Diagnostics, Vacuum*, and *Beam Physics*

CEA (ESS subcontractor for Control System and Beam Diagnostics)

Si.a.tel. (INFN & ESS control system subcontractor): S. Di Martino, P. Nicotra

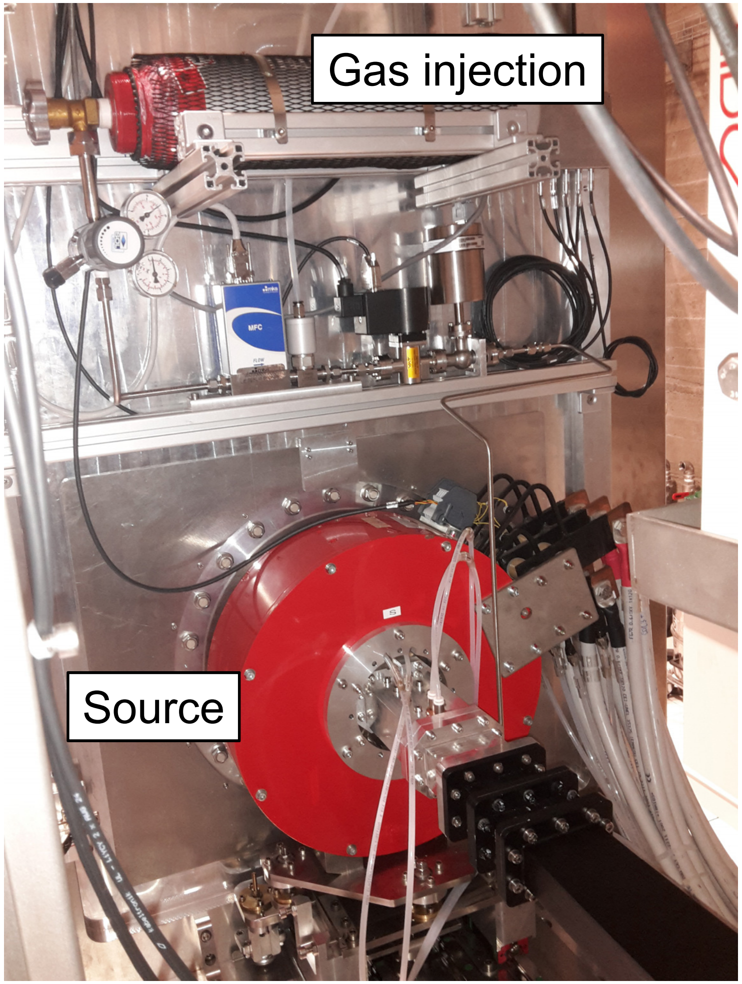
PS-ESS and LEBT
05/08/2016

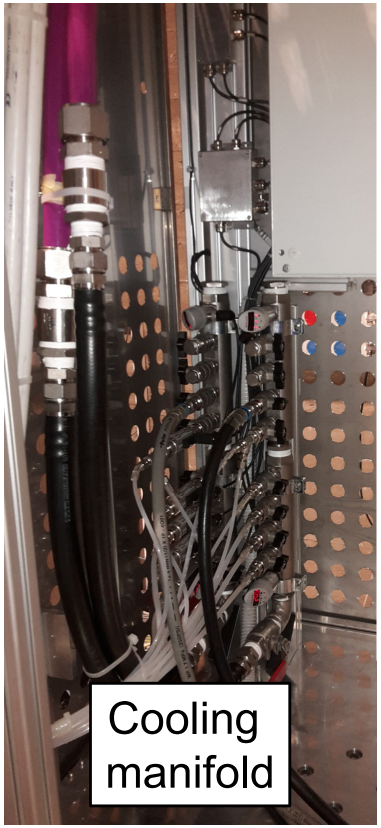
PS-ESS and LEBT
05/08/2016

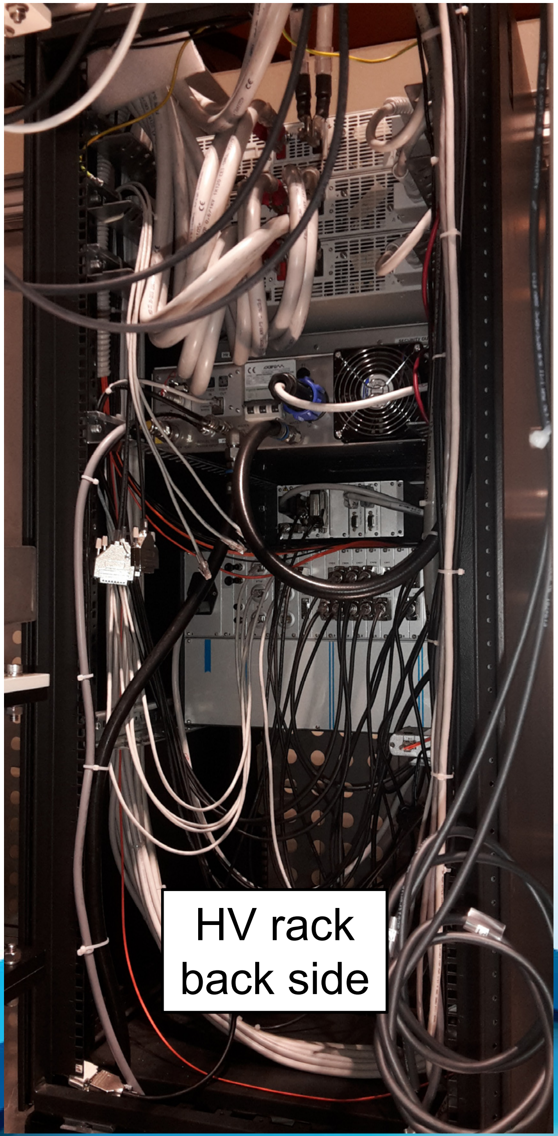


HV platform fully assembled and cabled
Control system will be installed in September

PS-ESS and LEBT
05/08/2016







PS-ESS and LEBT

05/08/2016

HV rack

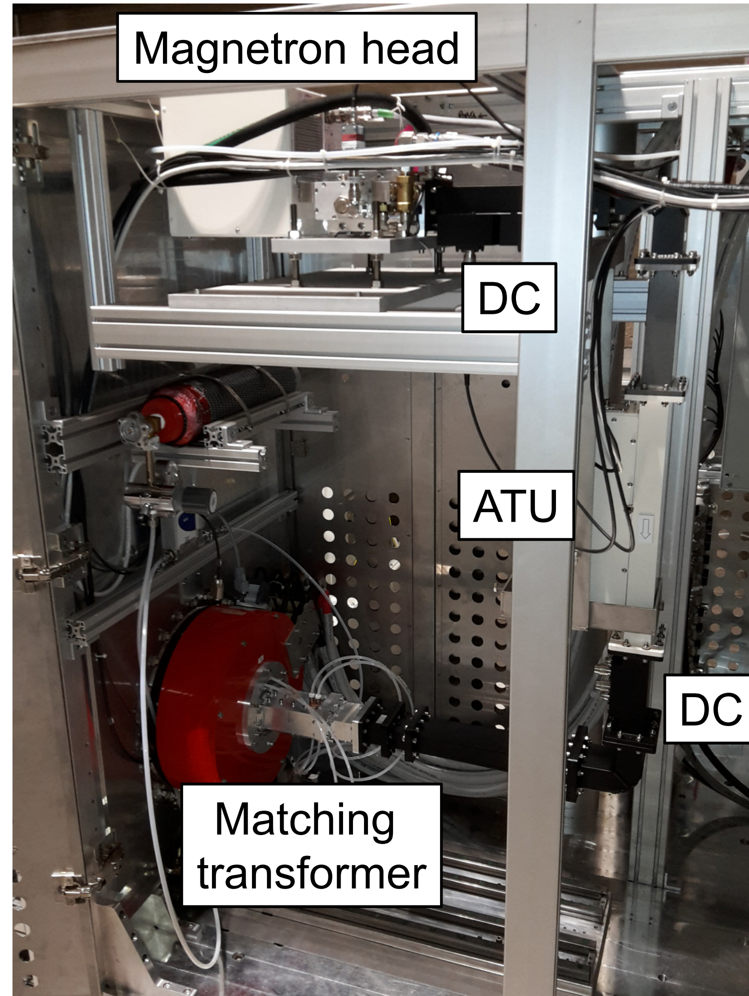
3 x power supplies for the magnetic system

Magnetron fast shutdown unit

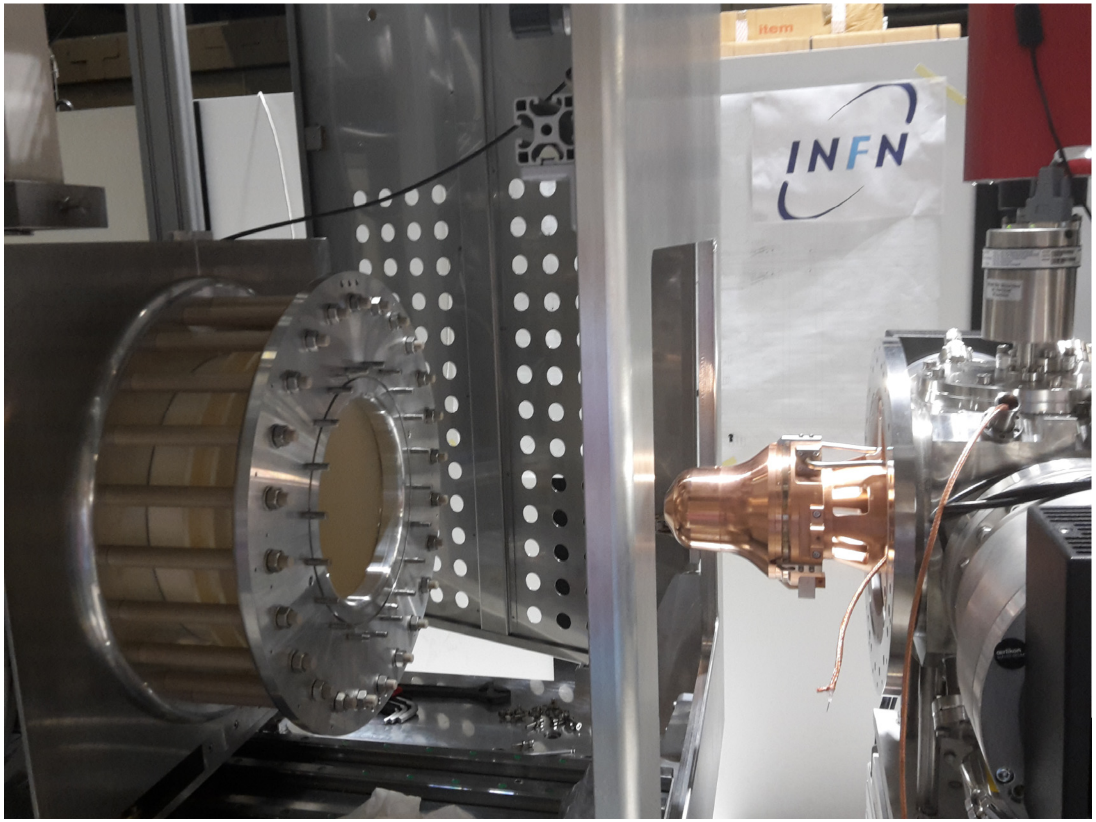
Magnetron

Vacuum controller unit

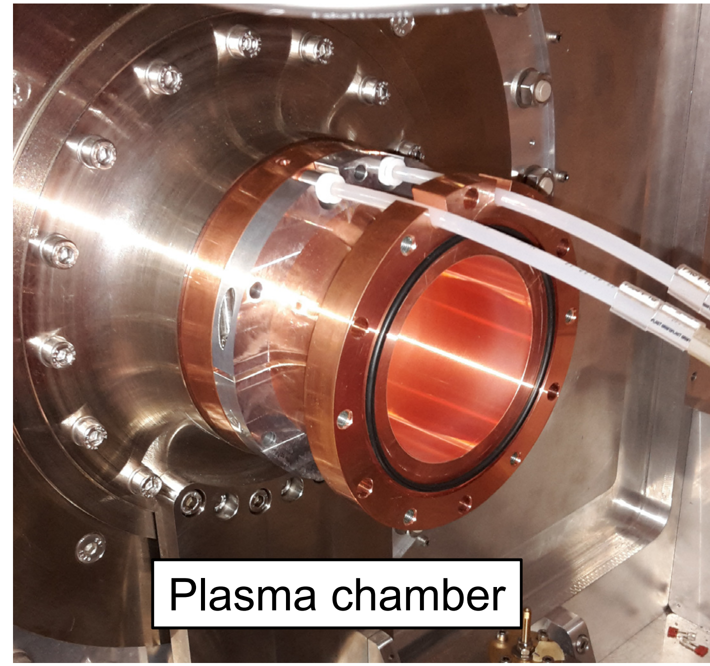
Shielded sub-rack for controls



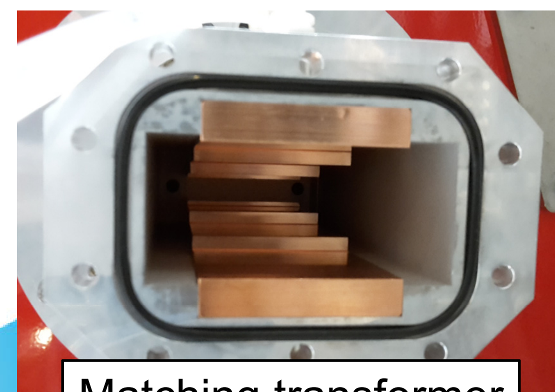
PS-ESS details



Design was optimized for easy and fast maintenance operation
(Poster WEPP15)

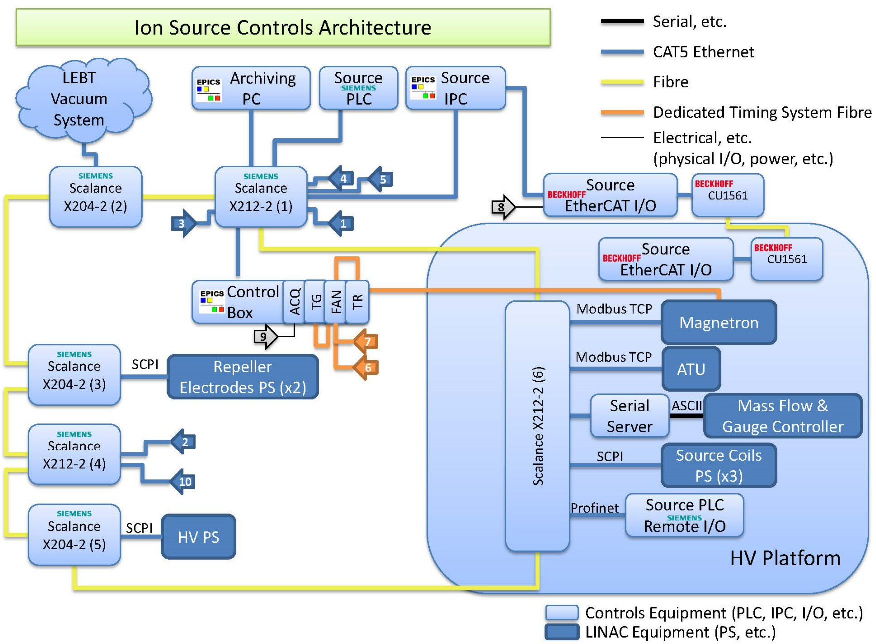


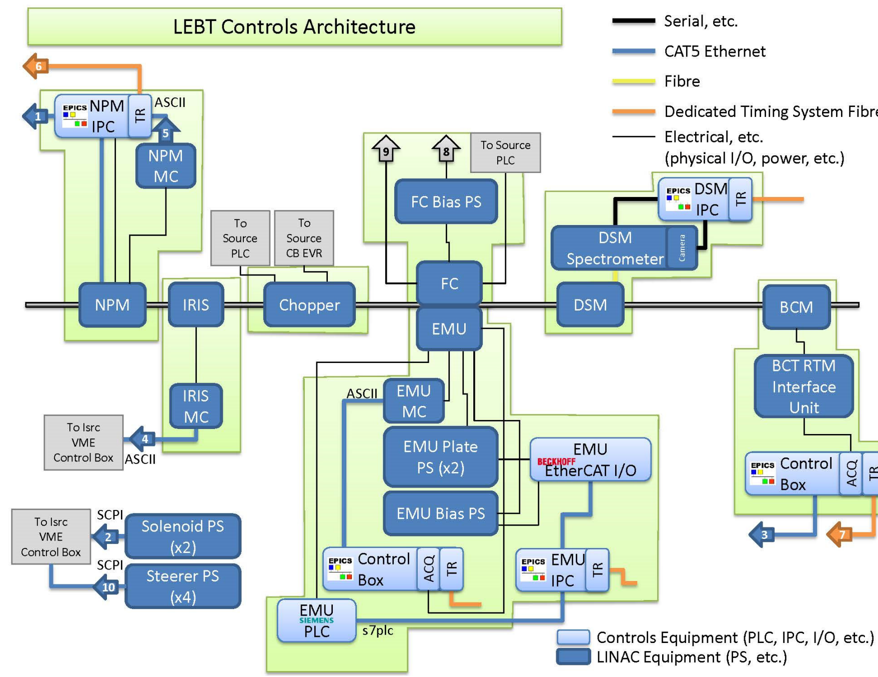
Plasma chamber



Matching transformer

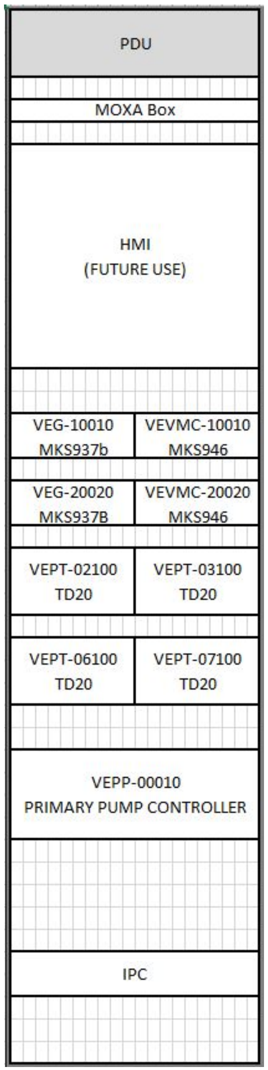
Control system



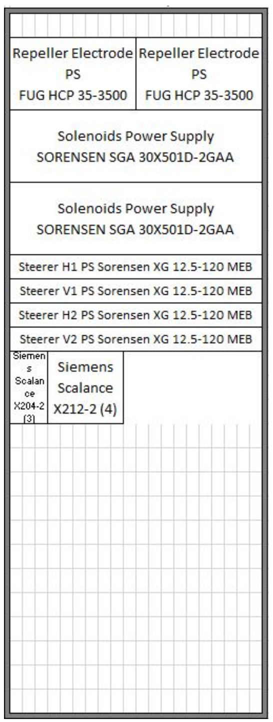


➢ Architecture	✓done
➢ PLC	✓done
➢ Ethercat I/O	✓done
➢ EMC protection	✓done
➢ Schematics	✓done
➢ Cabling at HV	✓done
➢ Cabling at ground	✓02/09/2016
➢ EPIC drivers	✓done
➢ GUI	✓In progress
➢ Software installation	✓30/09/2016

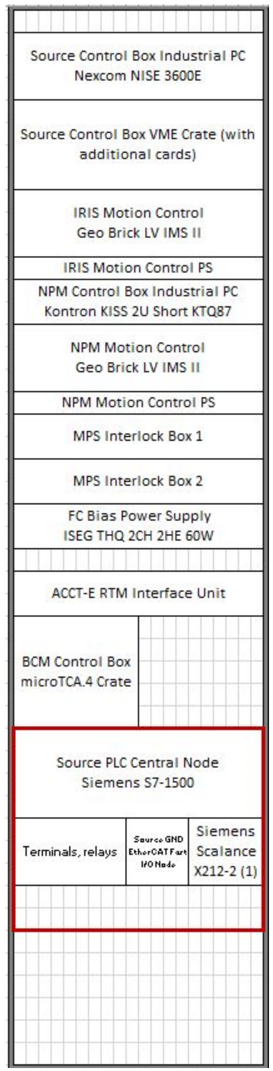
Racks layout



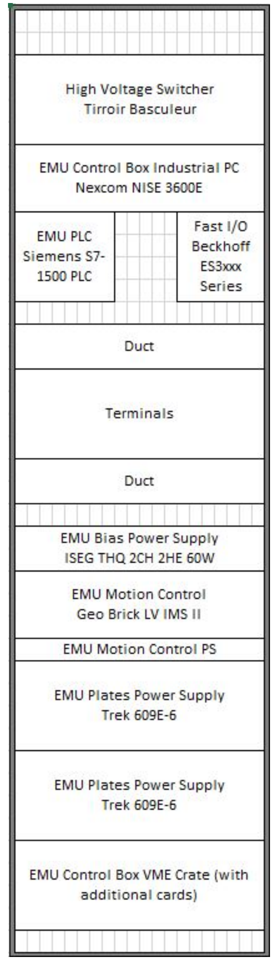
Vacuum



Power supplies



Diagnostics & Controls



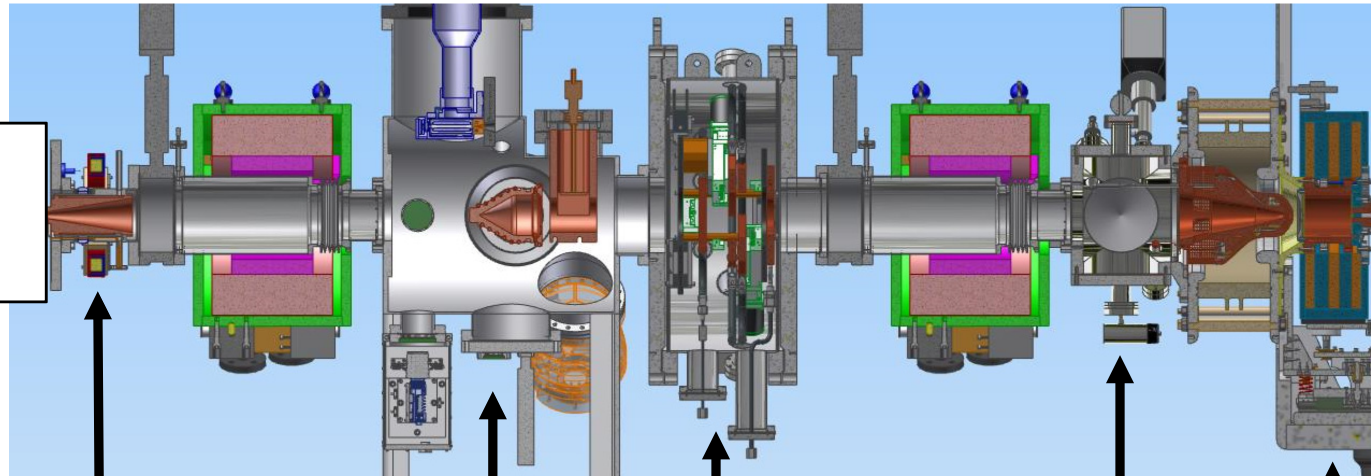
EMUs

Racks at ground are in the final position

EMUs rack will arrive 02/11/2016

Beam diagnostics

Diagnostics Tank



Current beam transformer

Vacuum gauges
Residual Gas Analyzer

Iris: beam density distribution vs Radius

High Voltage probe
Current probe
RF probes

Emittance Measurement Units (H+V)
Faraday Cup
Doppler shift measurement
Non invasive beam profile measurements (H+V)
Vacuum gauges

EUROPEAN SPALLATION SOURCE

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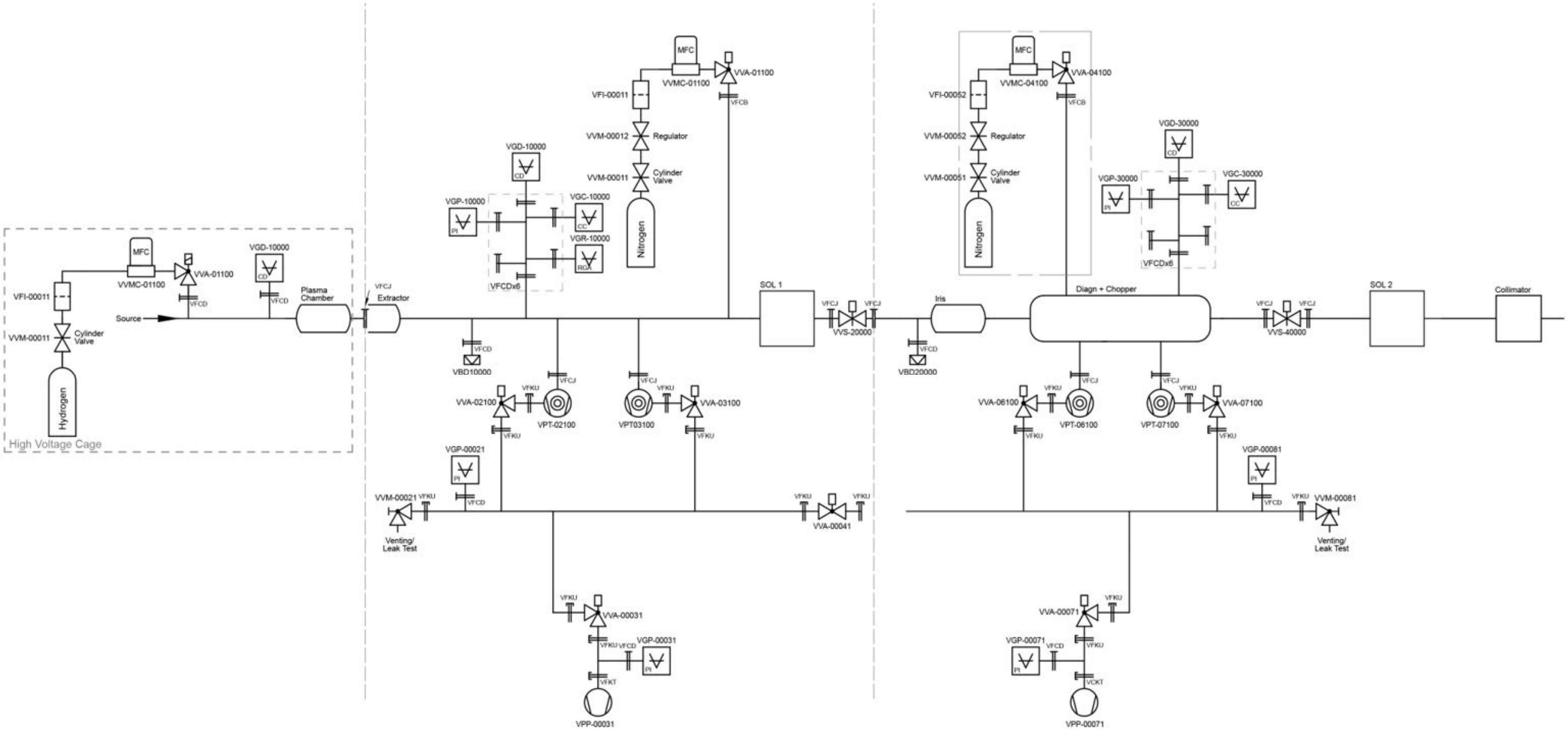
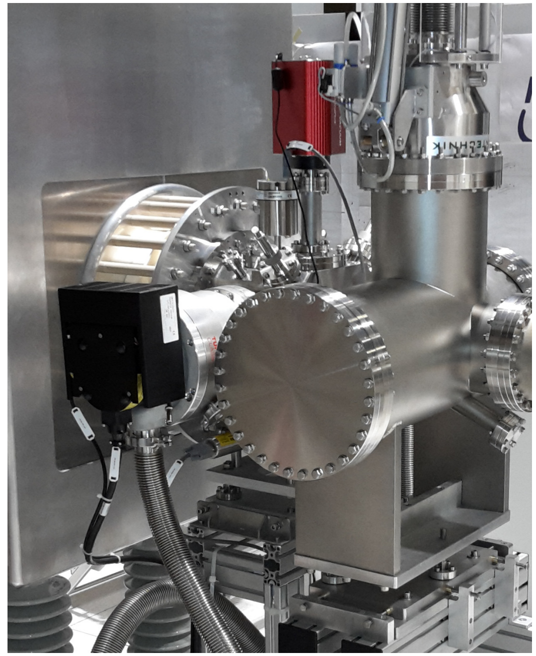
Vacuum layout

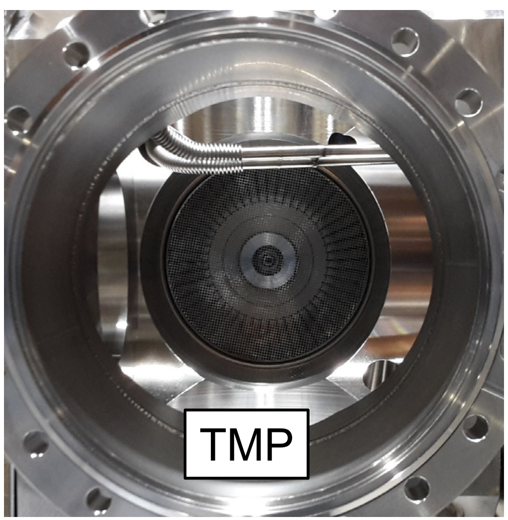


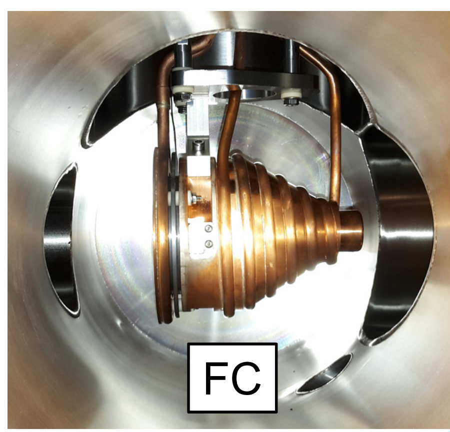
2 x Primary pumps	6 x Pirani gauges
4 x Turbo molecular pumps	2 x Cold cathode gauges
3 x Mass flow controllers	3 x Capacitive gauges
Hydrogen bottle for the source	2 x Burst disck
Nitrogen bottle for the LEBT	2 x Gate valves in the beam pipe
Residual Gas Analyzer	

LEBT ready for beam commissioning phase 1 & 2

- Extraction system
- Insulating column
- Extraction cooling
- 2 x TMP
- Gauges
- RGA
- FC
- Beam stop
- Valves
- Primary pump

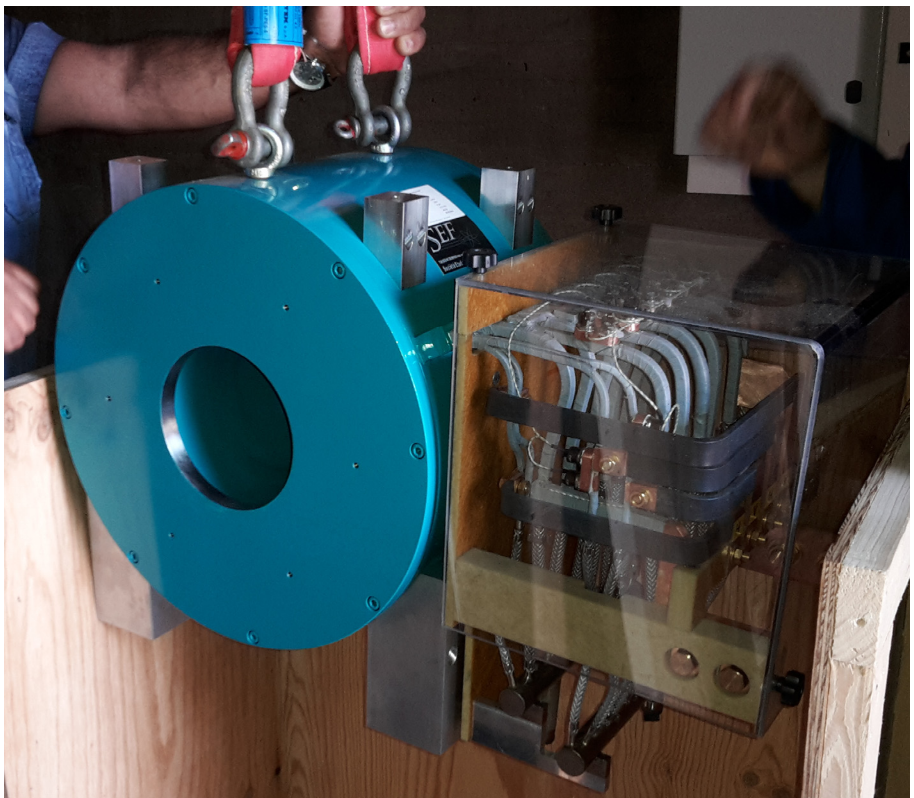




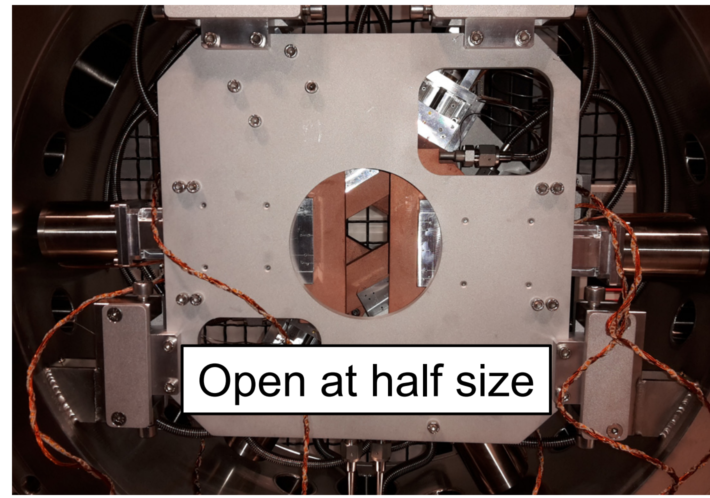


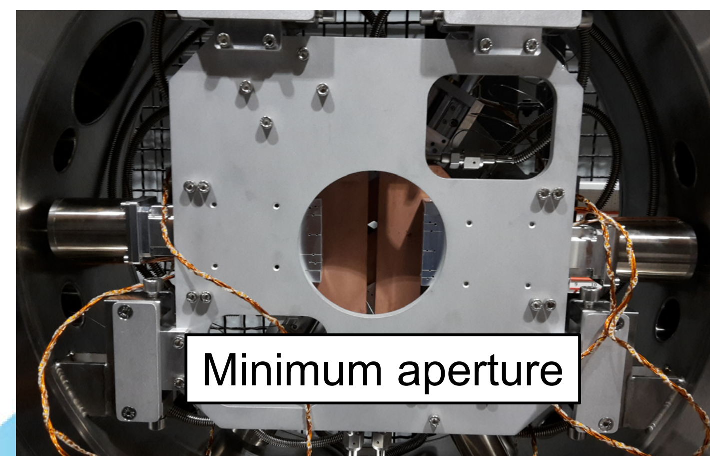
Preparation for next commissioning phases

Two LEBT solenoids with integrated steerers were delivered



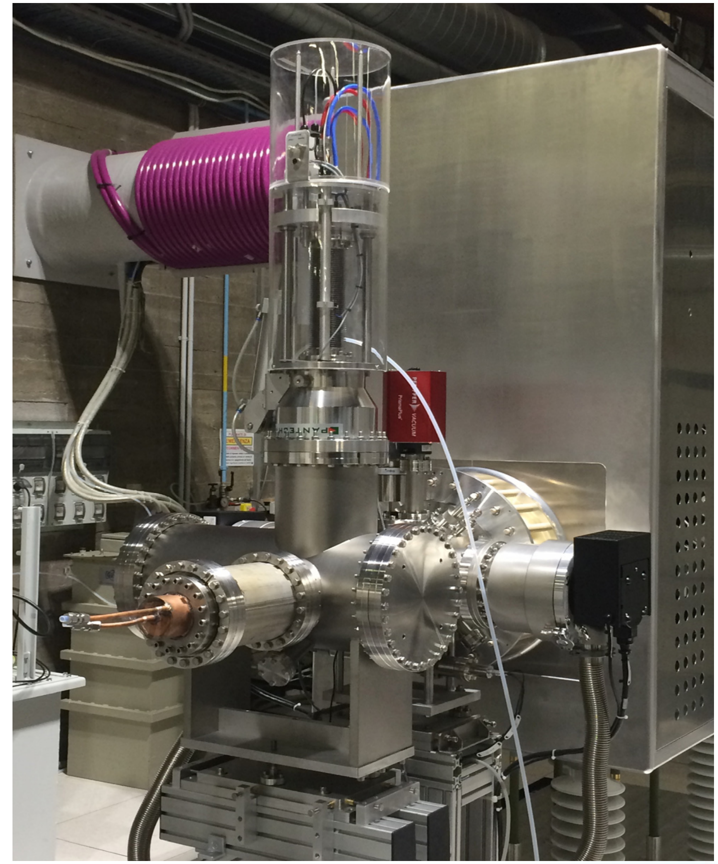
Iris mechanics, motors and controls are almost ready





Phase 1: IS with FC and DSM
Phase 2: Phase 1 + EMU

Beam performance	Value	Measurement device
Maximum beam current	> 90 mA	FC
Nominal proton beam current	74 mA	FC
Pulse length	3 ms	
Pulse length maximum	6 ms	
Flat top stability	±2 %	
Pulse to pulse stability	±3.5 %	
Repetition rate	14 Hz	
Repetition rate range	1-14 Hz, 1 Hz step	
Pulse length range	1 ms - 3 ms	
Recovery after 5 s downtime	1 pulse	
Proton fraction	> 75 %	DSM
Beam energy	75 keV	HV power converter
Beam energy fluctuation	± 0.01 keV	
Energy adjustment range	± 5 keV	
Energy adjustment precision	± 100 eV	
Transverse emittance (99 %) at IS-LEBT lattice interface	1.8 µm	EMU
Beam divergence (99 %) at IS-LEBT lattice interface	80 mrad	
Beam alignment at solenoid 1	±0.5 mm	
Beam center offset at IS-LEBT lattice interface	±0.1 mm	
Beam angle offset at IS-LEBT lattice interface	±1 mrad	

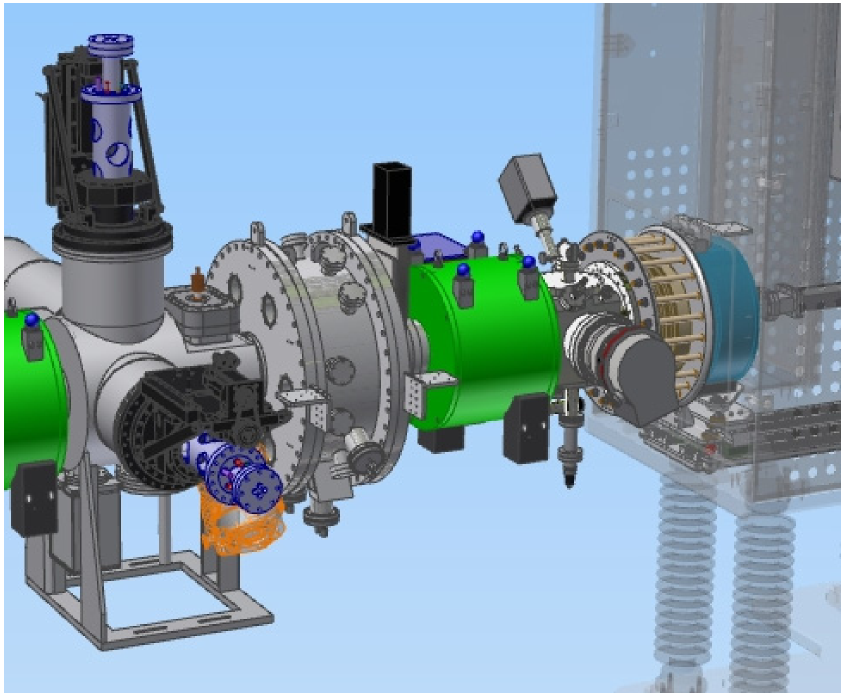


Study of different parameters:

- Insulating/conductive plasma walls
- Magnetic configuration
- Extraction geometry
- Gas injection
- Pressure

Phase 3: beam characterization after the first solenoid

Beam performance	Value	Measurement device
Beam current range	7-74 mA	Faraday cup
Beam current range step size	2 mA	
Beam current precision	±1 mA	
Orbit control with respect to beam axis	±0.5 mm	NPM
Transverse emittance	–	EMU
Beam center offset	–	
Beam angle offset	–	

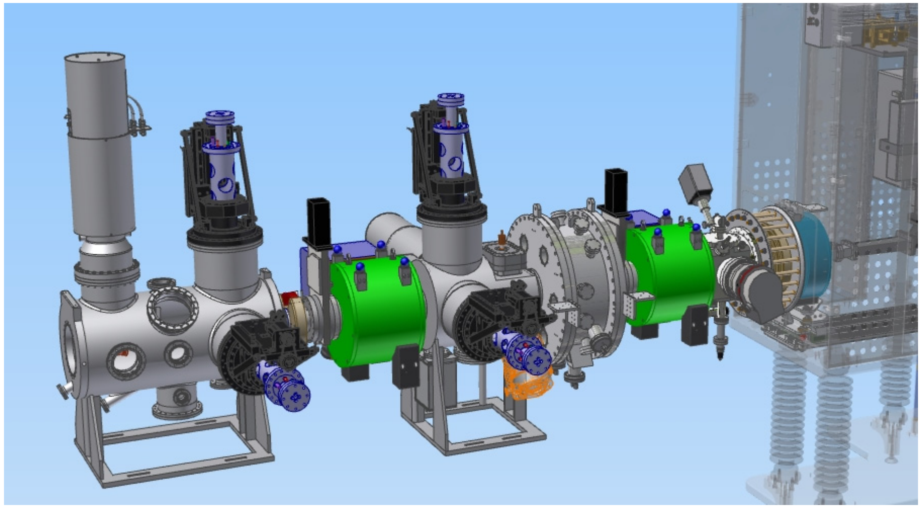


Study of different parameters:

- Addition LEBT gas injection
- LEBT pressure
- Solenoids configuration
- Repelling electrodes voltage

Phase 4: beam characterization at the LEBT-RFQ lattice interface

Beam performance	Value	Measurement device
Nominal beam current	74 mA	ACCT / Faraday cup
Beam current transmission	95 %	
Pulse length	2.86 ms	
Maximum pulse length	2.88 ms	
Pulse length range	0.005-2.88 ms	
Single pulse production	–	
Transmission of transient	>1 %	
Transverse emittance (norm, rms) at LEBT-RFQ lattice interface	0.25 µm	EMU
Transverse emittance (99 %) at LEBT-RFQ lattice interface	2.25 µm	
Beam alignment at LEBT-RFQ lattice interface	±0.1 mm	
Transverse twiss α at LEBT-RFQ lattice interface	1.02 ± 20 %	
Transverse twiss β at LEBT-RFQ lattice interface	0.11 mm ± 10 %	



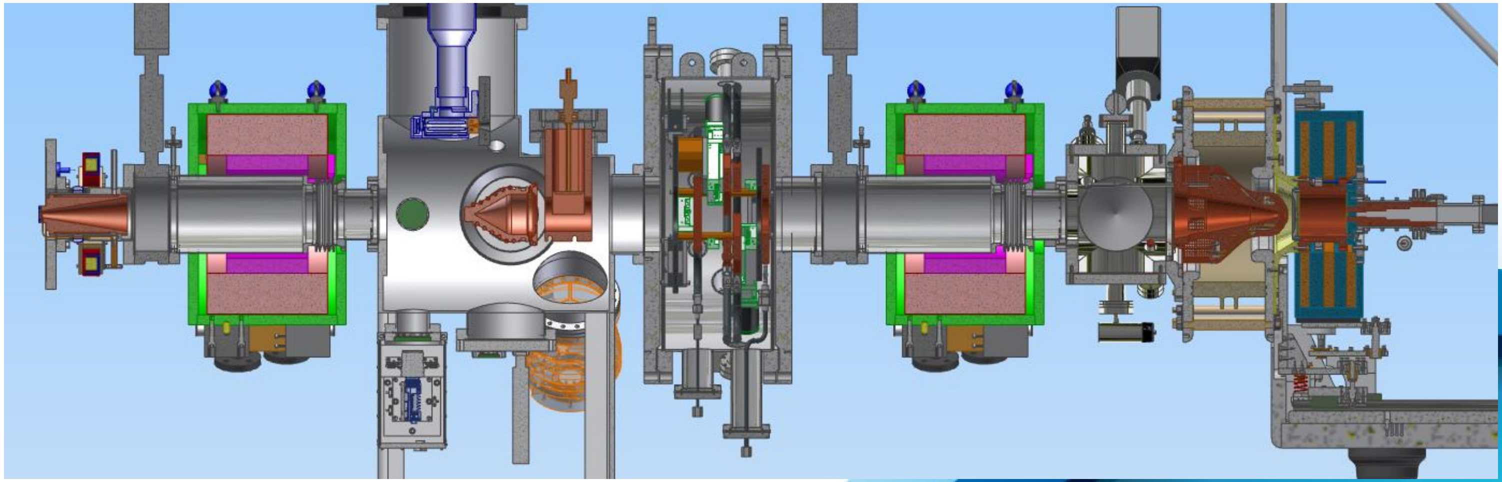
Study of different parameters:

- Addition LEBT gas injection
- LEBT pressure
- Chopper voltage and rise/fall time speed
- Solenoids configuration
- Repelling electrodes voltage

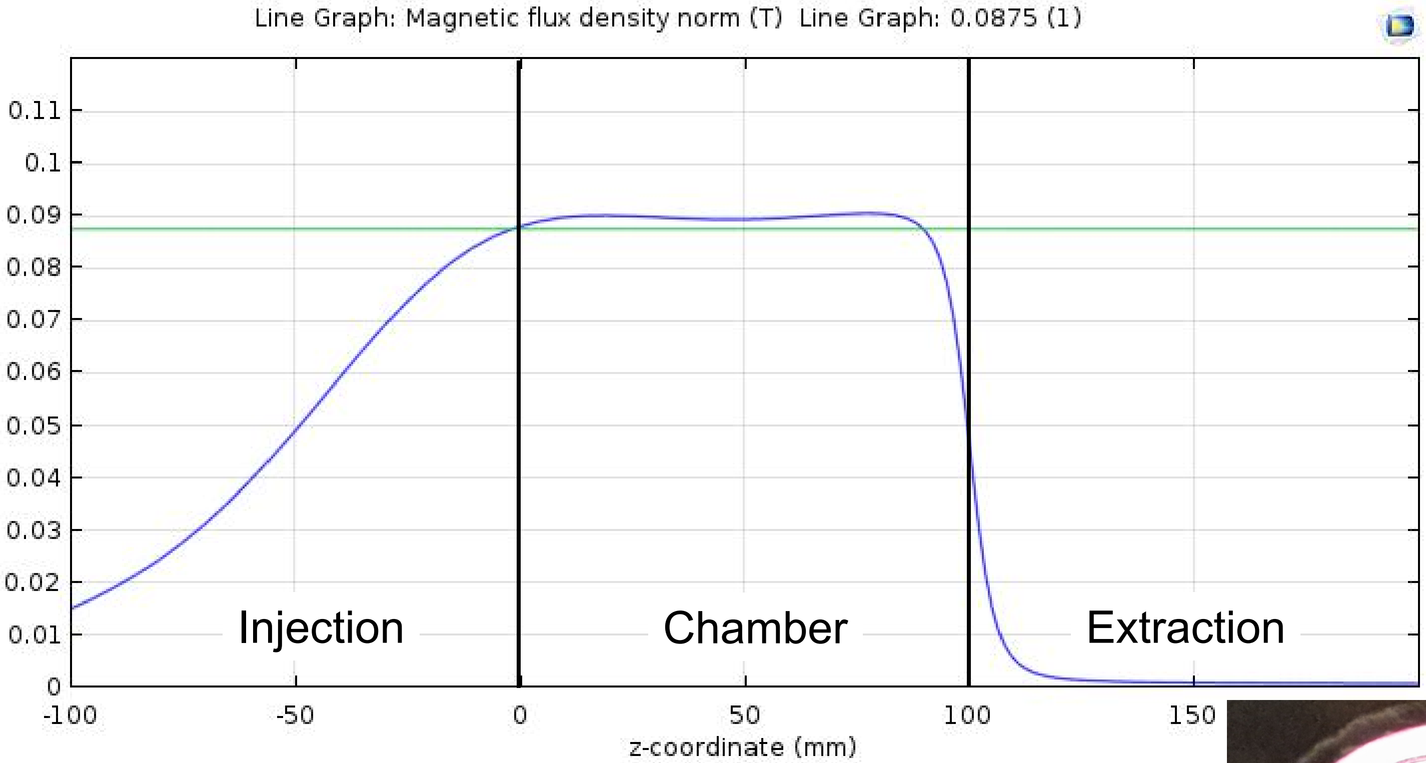
Phase 5: long duration tests (to be completed after RFI)

Consists of several tests:

- study the long-term reliability of the ion source and define which parts get degraded over time,
- study the current range that can be produced by the ion source (6-74 mA, ISrc.SyR-13),
- analyze potential beam trips to evaluate and prevent downtime,
- define a sequence for an automatic start-up of the ion source,
- simulate the time needed to restart the ion source after shut down (16 hours, ISrc.SyR-14),
- simulate the time needed to restart the ion source after maintenance, such as replacing the boron nitride disks (32 hours, ISrc.SyR-15),
- ensure that the different beam requirements can be satisfied at the same time (ISrc.SyR-22, LEBT.SyR-20),
- improve the design (for example of the extraction system) and ion source and LEBT settings to ensure that the requirements settled are satisfied.



First plasma
15/06/2016



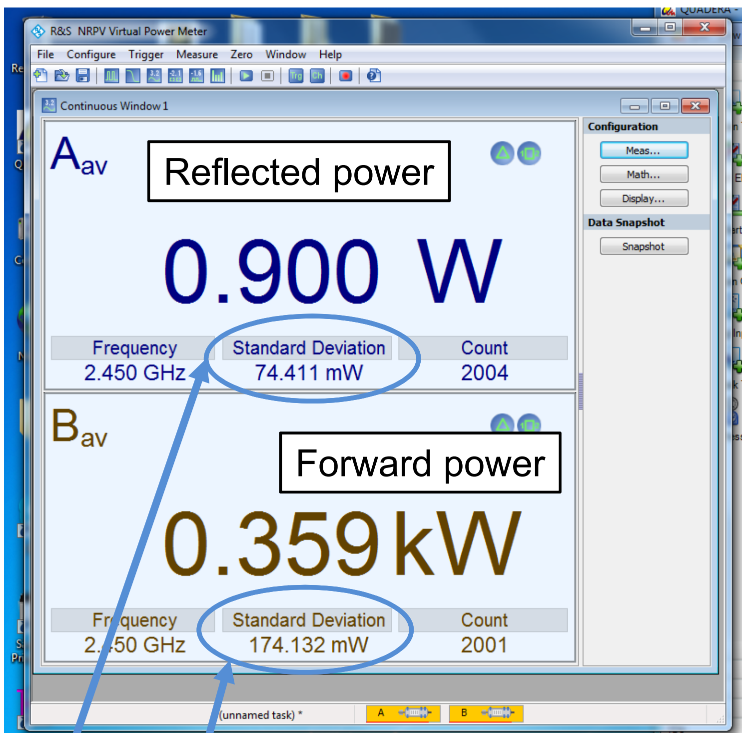
H_2 flow 0.7 sccm	RF power up to 380 W

LEBT background pressure $1.8 \cdot 10^{-6}$ mbar

LEBT pressure $8.9 \cdot 10^{-6}$ mbar with plasma

Measurement of RF power to plasma matching

Software interface of the two RF probes

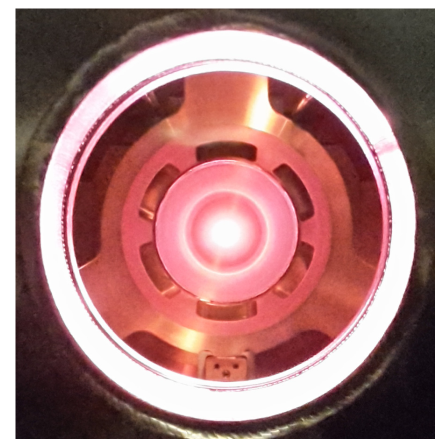


Standard Deviation

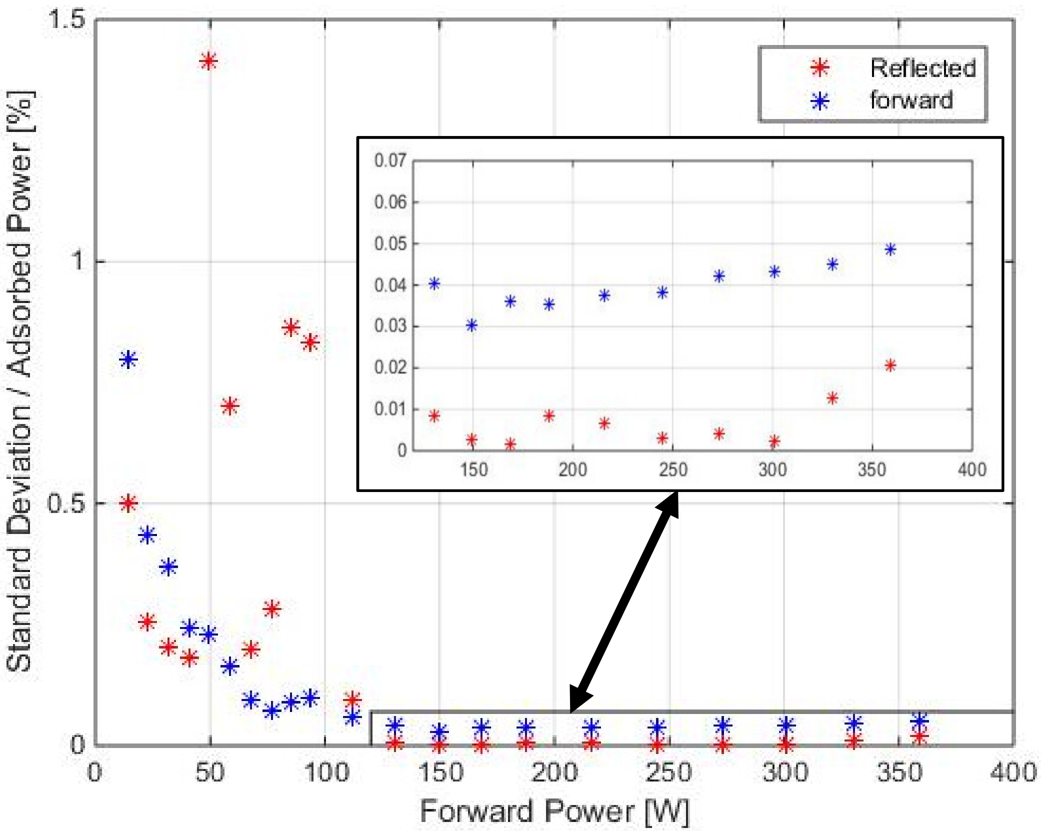
RF probes

Directional couplers

First plasma 15/06/2016



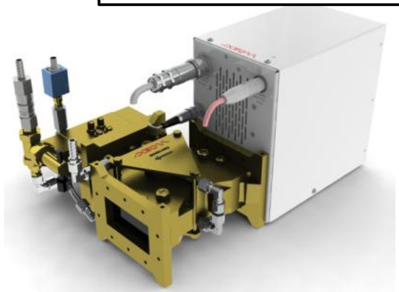
Extremely high stability of adsorbed RF power



Plasma stability is not enough to predict that beam stability will be in the required range of ± 2%, but it is a good starting point to be optimistic.

Magnetron power supply

Magnetron head



Frequency	2450 MHz ± 25 MHz
Output power	2 kW with 10 W step
Power stability	1 %
Ripple	< 1 % RMS

Conclusion

PS-ESS and LEBT:

- The source is fully assembled
- The LEBT for the first two commissioning phases is ready
- The cabling is almost finished
- The software will be installed in September
- Commissioning plan is defined
- Plasma conditioning started
- Excellent RF to plasma coupling and stability was observed