ESS Vacuum System
A neutron facility

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Specialized Technical Service
Vacuum System Section Leader
European Spallation Source ERIC

Outline

- Neutron introduction,
- ESS Vacuum responsibilities,
- Vacuum Standardization, an Integrated Approach,
- ESS vacuum system Accelerator/Target/Instruments
- Vacuum Support.

Vacuum for what?

Why we need vacuum for a particle accelerator?

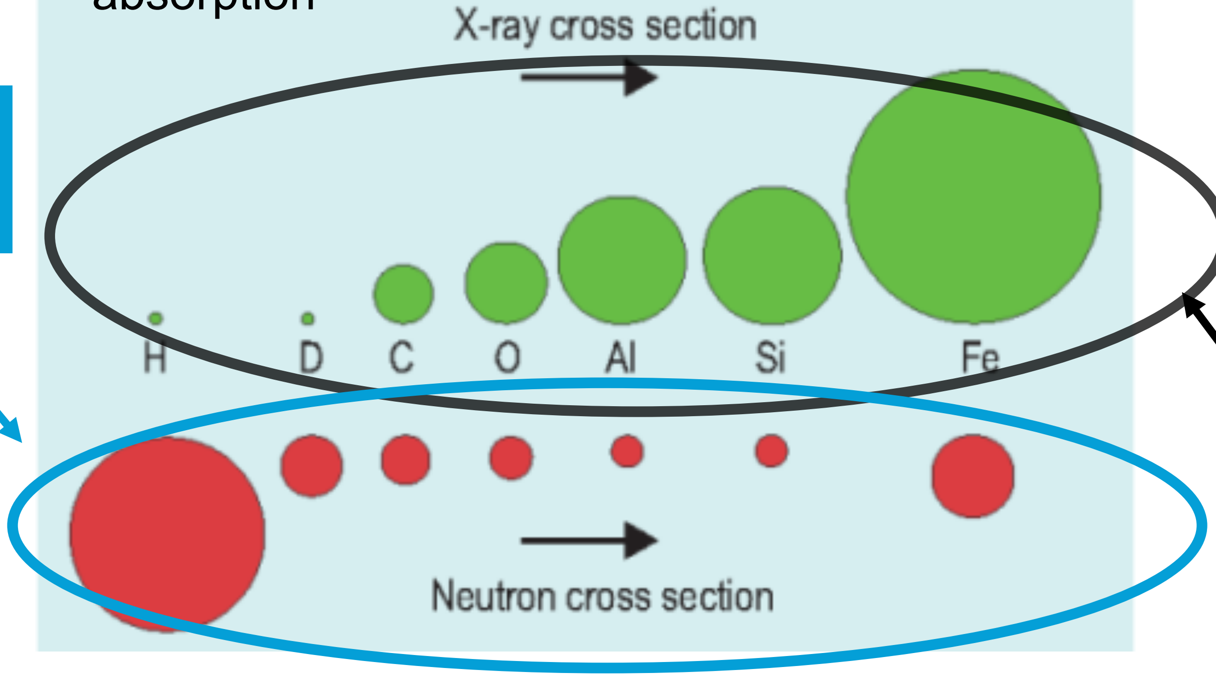
Why we need vacuum on a SRF LINAC?

Neutron Vision

Movie made by Neutron imaging and Activation Group, ICON Instrument. Paul Scherrer Institut, CH

Neutrons and Protons

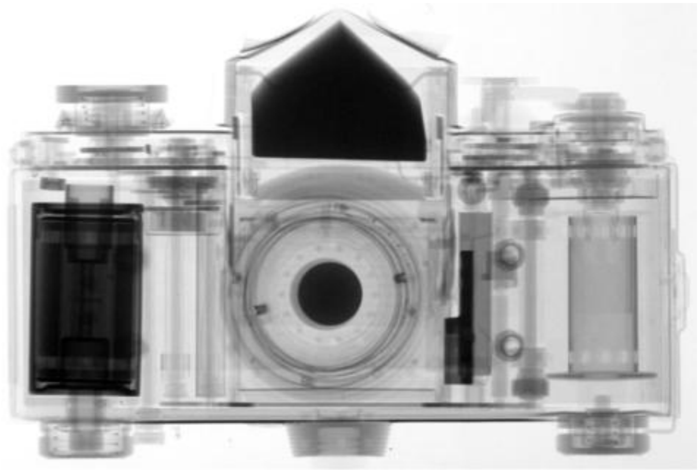
X-ray interacts with electrons in the atoms.
The heavier is the atom the larger is the absorption

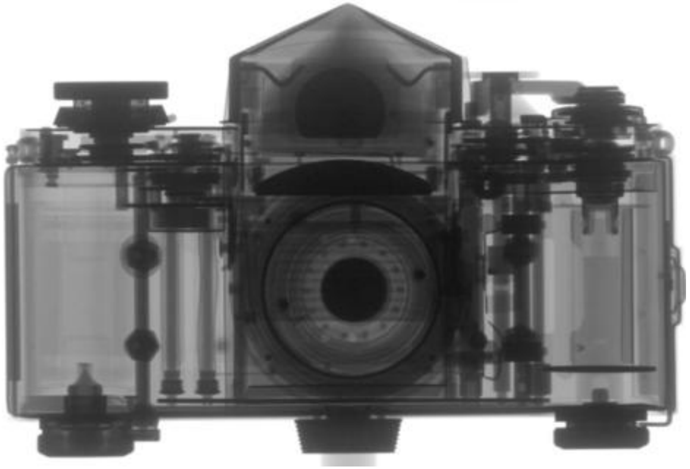


MAX IV

Neutrons interact with nucleus and have a very different absorption contrast.

Neutron images





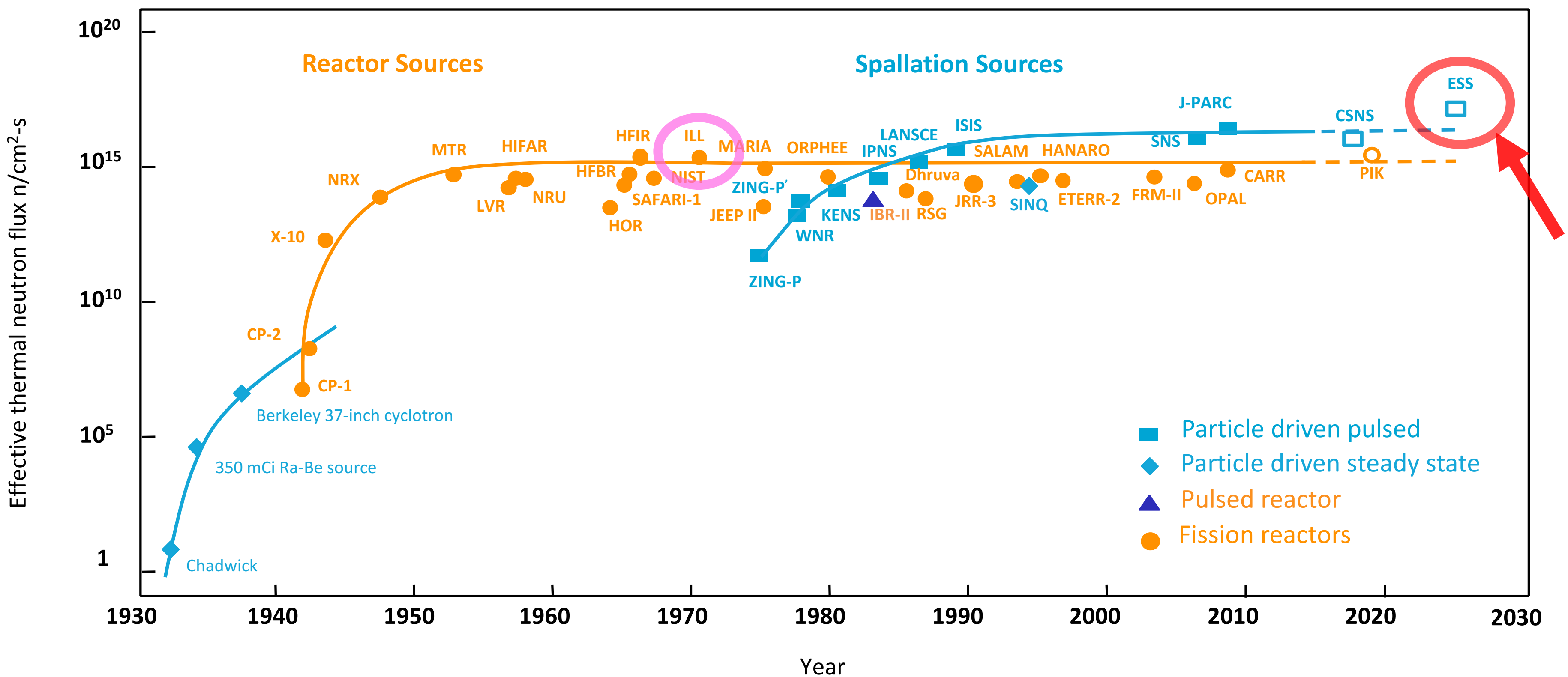
Radiograph of an analog camera: by neutrons (top) by X-rays (bottom). While X-rays are attenuated more effectively by heavier materials like metals, neutrons make it possible to image some light materials such as hydrogenous substances with high contrast: in the X-ray image, the metal parts of the photo apparatus are seen clearly, while the neutron radiograph shows details of the plastic parts.

by Neutron imaging and Activation Group
Paul Scherrer Institut, CH


Lightning
New materials
ESS
Solar energy
Food
Medicine
Tailor made materials
Pacemakers
Mobile phones
Cosmetics
Bio fuels
Implants
Transportation
Geo science

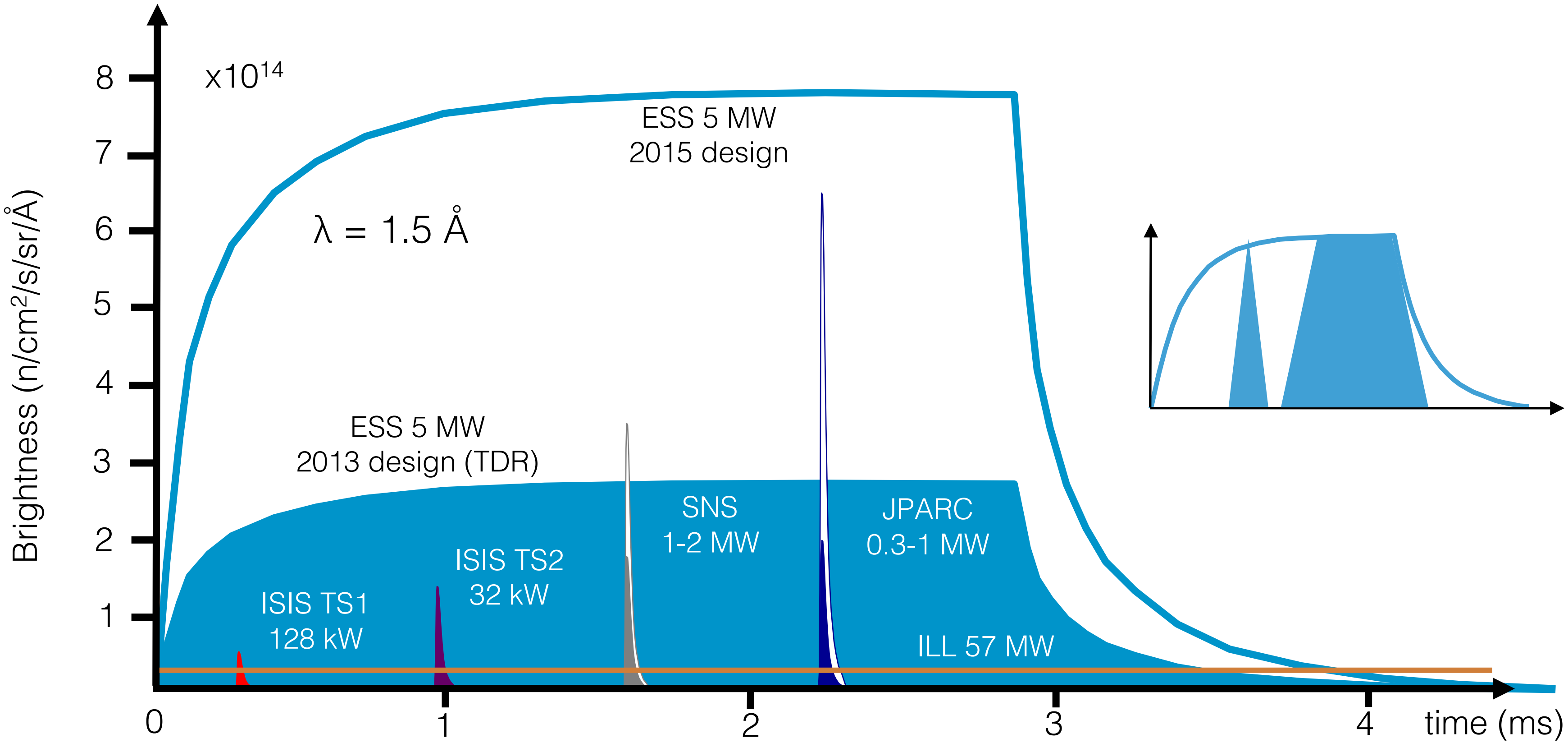
Neutrons facilities –
Reactors and particle accelerator driven

EUROPEAN SPALLATION SOURCE



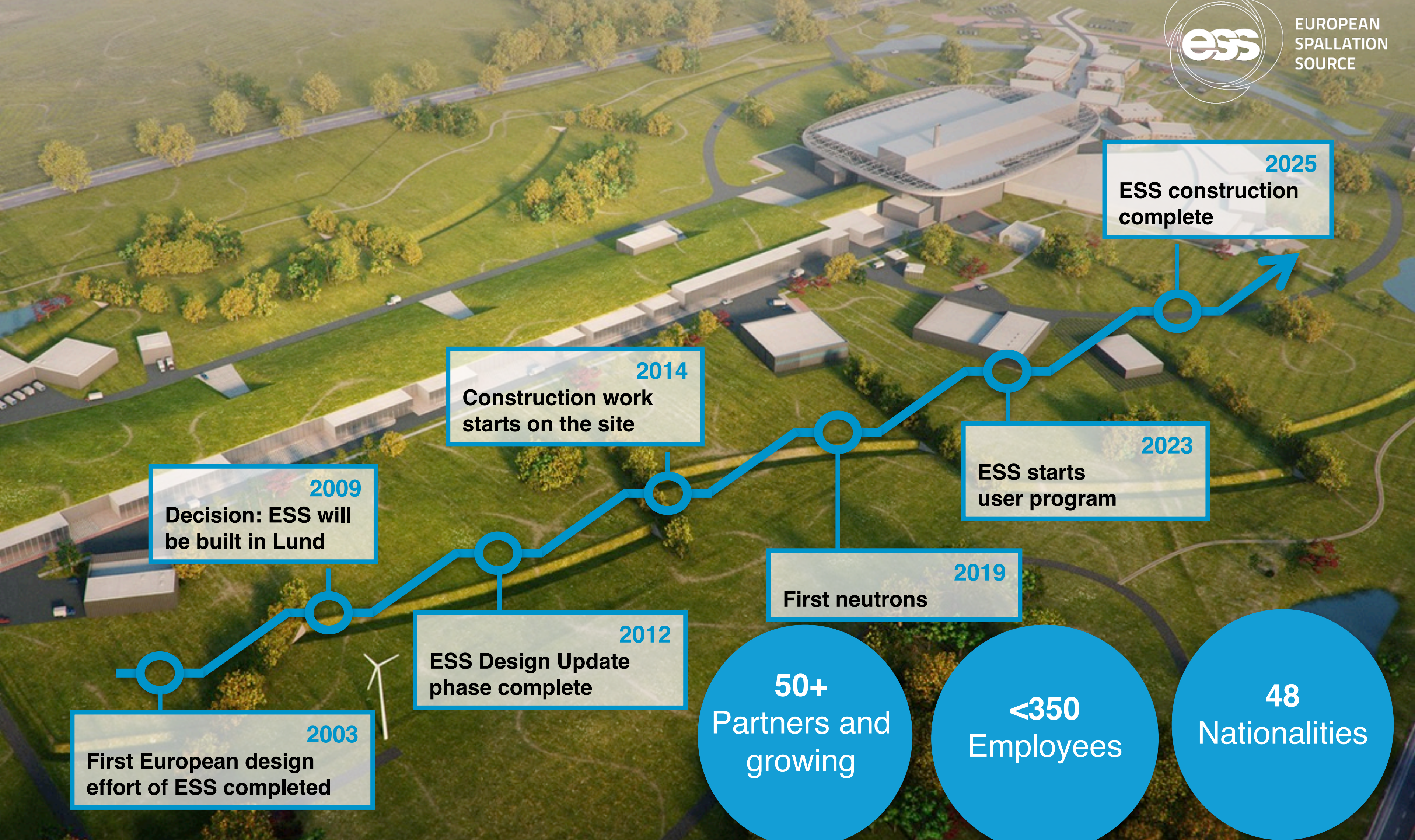
(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Academic Press, 1986)

ESS Long-pulse performance

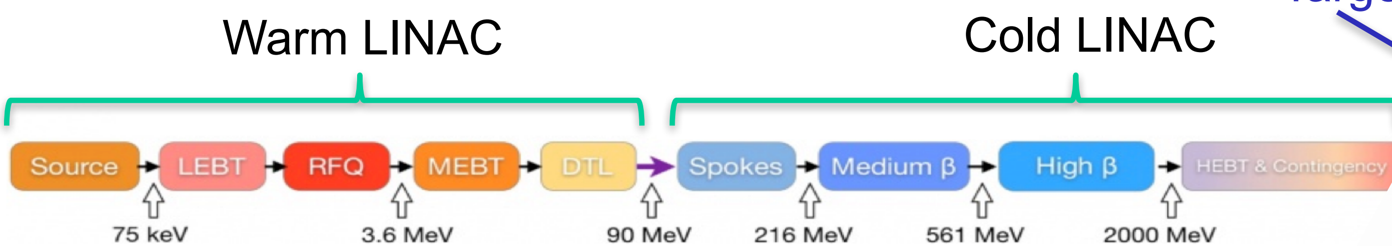


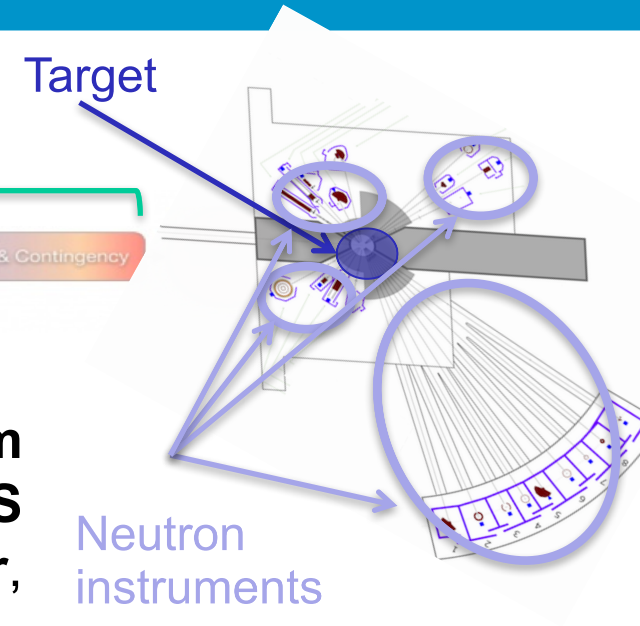
Road to realizing the world's leading facility for research using neutrons

EUROPEAN SPALLATION SOURCE



Introduction: ESS Vacuum system





The ESS organization charges the **ESS Vacuum** System team with the **responsibility for all ESS vacuum** systems including not only the **Accelerator**, but also **Neutron Instruments** and **Target**.

The main task of the team is to **support** the in kind contributions on the vacuum system and the **integrated vacuum design** of the ESS complex.

Vacuum Standardization
an Integrated Approach

EUROPEAN SPALLATION SOURCE

Working closely with our partners across the project, one of our primary goals was to **promote** the use of **common vacuum equipment and standards**. As a result a Vacuum Standardization meeting was held in February 2014 where equipment suitable for Standardization was agreed and reflected in the **ESS Vacuum Handbook**.

An important element of this **standardization** is the Vacuum Procurement Policy. The primary objective of the program is to develop a list of standard vacuum equipment through a **Vacuum Framework Agreement** (**VFA**) for use project wide to minimize project costs, reduce spares holdings, training and achieve other benefits of standardization. The **VFA** was made in conjunction with **UK** and **France**.

Description: ESS Vacuum Handbook Part 1
Document No 0.
Date 23 May 2014

1. INTRODUCTION

The European Spallation Source (ESS) is an accelerator-driven neutron spallation source. The linear accelerator (LINAC) of which is a critical component. The role of the accelerator is to create protons at the ion source, accelerates them to an appropriate energy, and steers them onto the target to create neutrons via the spallation process for use by a suite of research instruments.

2. SCOPE

The ESS Vacuum Handbook comprises four (4) parts:

ESS Vacuum Handbook Part 1 – General Requirements for the ESS Technical Vacuum Systems,

ESS Vacuum Handbook Part 2 – Vacuum Equipment Standardization,

ESS Vacuum Handbook Part 3 – Vacuum Design & Fabrication, and

ESS Vacuum Handbook Part 4 – Vacuum Test Manual

This Vacuum Handbook (VH) part 1 provides guidelines, and imposes requirements where necessary, for the definition of equipment and processes associated with the vacuum systems of the Accelerator, Target and Neutron Instruments. The VH is applicable to all vacuum components and systems exposed to a technical vacuum environment.

This VH, a level 2 requirement, is to ensure that consistent standards are employed throughout all the accelerator, target and neutron instrument vacuum systems and hardware.

This VH will be periodically updated throughout the life of the ESS project.

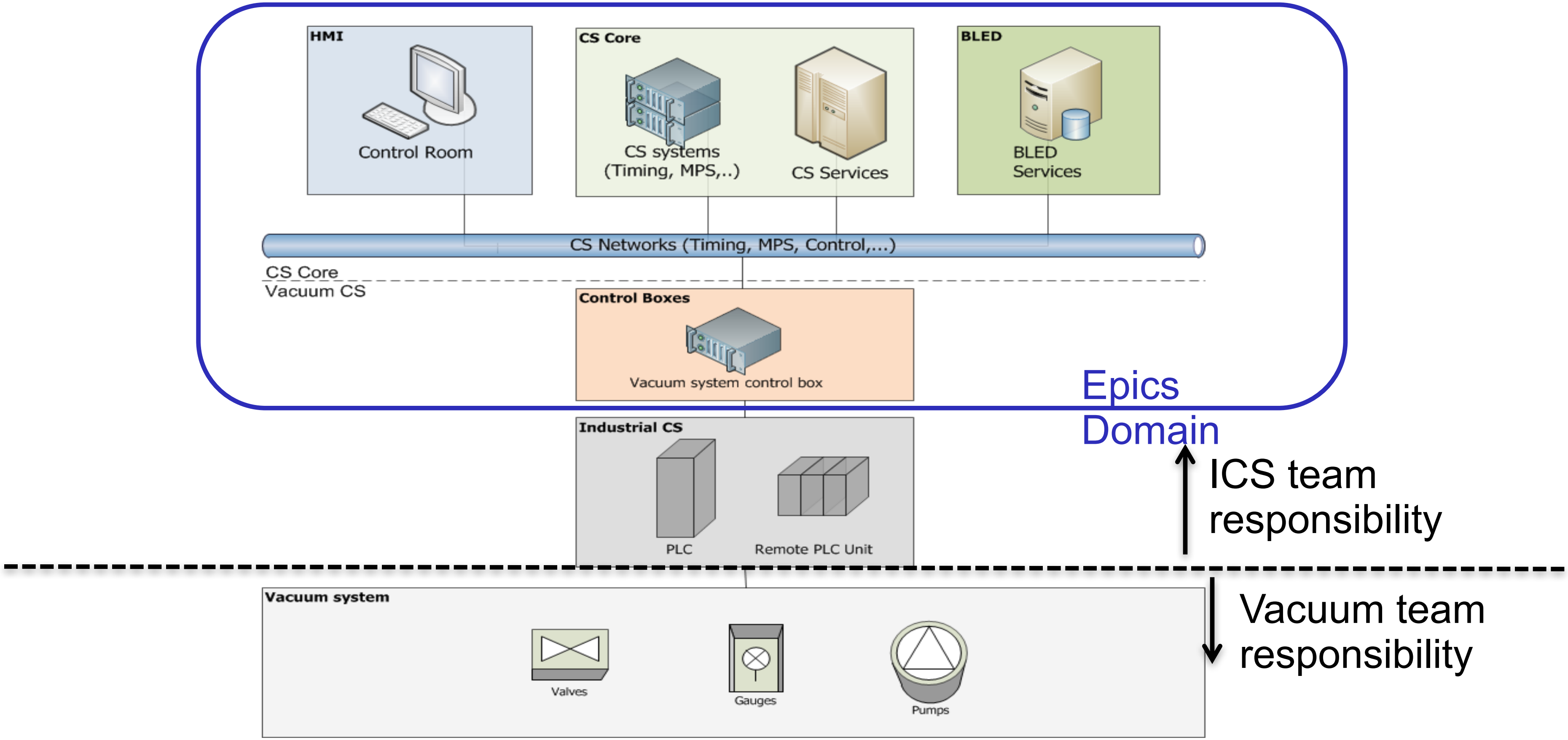
All queries or additional information concerning the contents of this handbook should be addressed to the ESS Vacuum Group Section Leader (VGL).

3. REPONSABILITIES

The ESS vacuum team has overall responsibility for all technical vacuum systems used on the Accelerator, Target and Neutron Scattering Instrument Systems and has

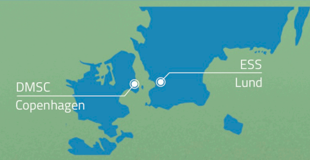
https://europeanspallationsource.se/vacuum

Vacuum Control System



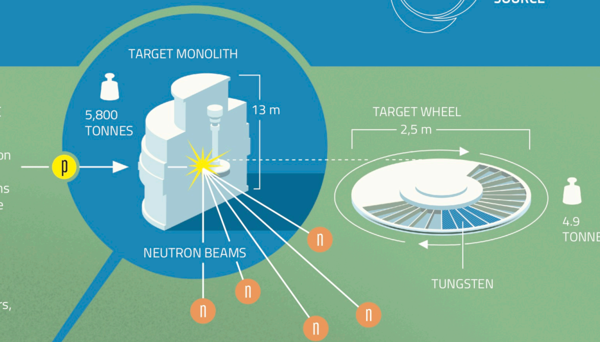
European Spallation Source

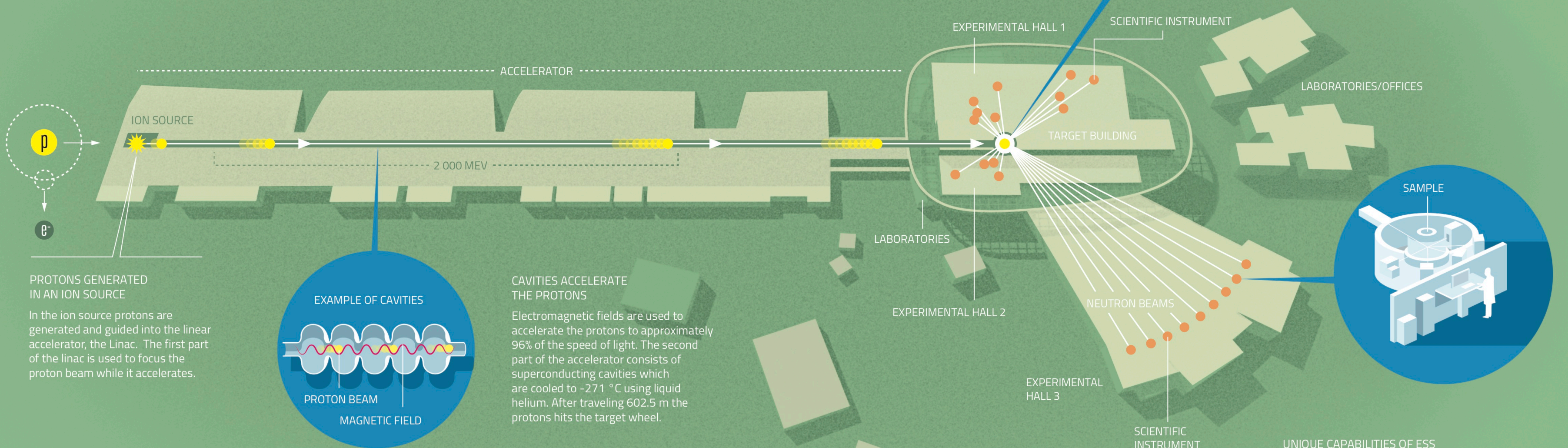
The European Spallation Source (ESS) is a multi-disciplinary research centre based on the world's most powerful neutron source. ESS will give scientists new possibilities in a broad range of research, from life science to engineering materials, from heritage conservation to magnetism. ESS is a pan-European project, with Sweden and Denmark serving as host countries. The main research facility is being built in Lund, Sweden, and the Data Management and Software Centre (DMSC) is located in Copenhagen, Denmark.



THE TARGET IS THE NEUTRON SOURCE

When the accelerated protons hit the rotating tungsten target wheel spallation occurs and neutrons are scattered from the tungsten nucleus. The more neutrons produced and collected in the target, the "brighter" the neutron source. The neutrons are directed through moderators and neutron guides to the scientific instruments where they are used for experiments. The Target monolith consists of the Target wheel, moderators, cooling systems and shielding and weighs approximately 5,800 tonnes.





PROTONS GENERATED IN AN ION SOURCE

In the ion source protons are generated and guided into the linear accelerator, the Linac. The first part of the linac is used to focus the proton beam while it accelerates.

CAVITIES ACCELERATE THE PROTONS

Electromagnetic fields are used to accelerate the protons to approximately 96% of the speed of light. The second part of the accelerator consists of superconducting cavities which are cooled to -271 °C using liquid helium. After traveling 602.5 m the protons hits the target wheel.

UNIQUE CAPABILITIES OF ESS

ESS will have 22 tailor-made instruments located in three experimental halls. Neutrons are excellent for probing materials on an atomic and molecular level – everything from motors and medicine, to plastics and proteins. The neutrons hit the sample and detectors register the neutron scattering, giving precise information about the material's structure and dynamics.

TOTAL BUILDING AREA 65 000 m²

The ESS facility will be approximately 650 metres in total length. The target building will be 125 metres long, and about 30 metres high. The 537-meter-long accelerator tunnel is built underground and will be covered with soil.

Concrete:	50 000 m³
Rebar:	6 000 tonnes
Pipes:	40 km
Cables:	2,000 km
Total volume:	400,000 m³

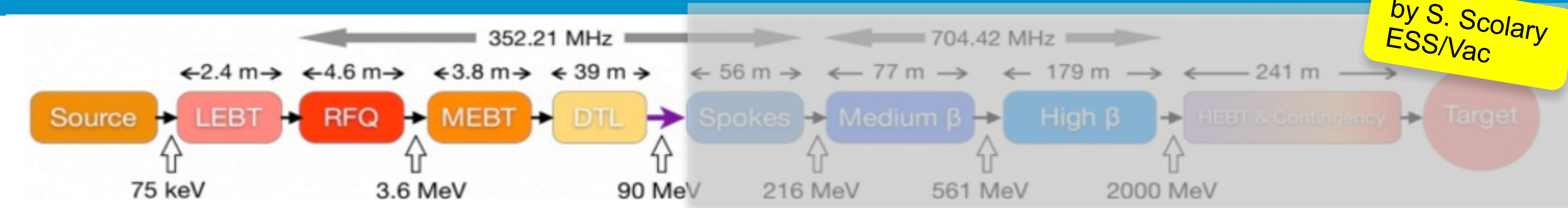
PILES TO AVOID MOVEMENTS

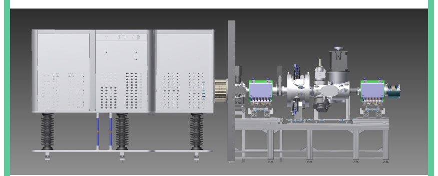
The heavy Target building and experimental halls are resting on a total of 6,400 piles of different types, in order to avoid unwanted movements in the structure.

Warm LINAC overview

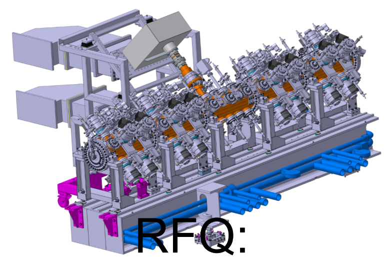
EUROPEAN SPALLATION SOURCE

by S. Scolary ESS/Vac

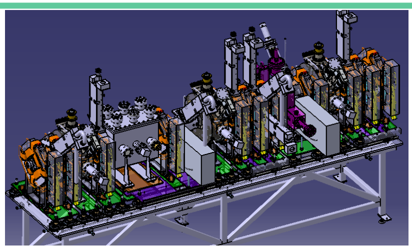




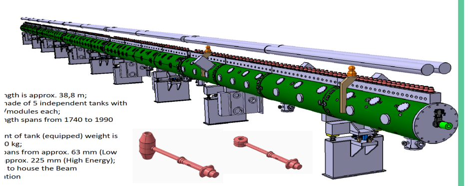
Source+LEBT:
- Designed at INFN Catania
- ESS reviews vacuum system, procedures and supplies Vacuum instrumentation.



RFQ:
- Designed at CEA
- ESS reviews vacuum system, procedures and supplies Vacuum instrumentation



MEBT:
- Designed at ESS Bilbao
- ESS reviews vacuum system, procedures, in-kind supplies Vacuum instrumentation



DTL:
-Designed at INFN Legnaro
- ESS reviews vacuum system, procedures and supplies Vacuum instrumentation

Warm LINAC: Ion Source (IS) + Low Energy Beam Transport (LEBT)

By Marletta, S. et all

Present design of P.S. and LEBT:

pumps, gauges and

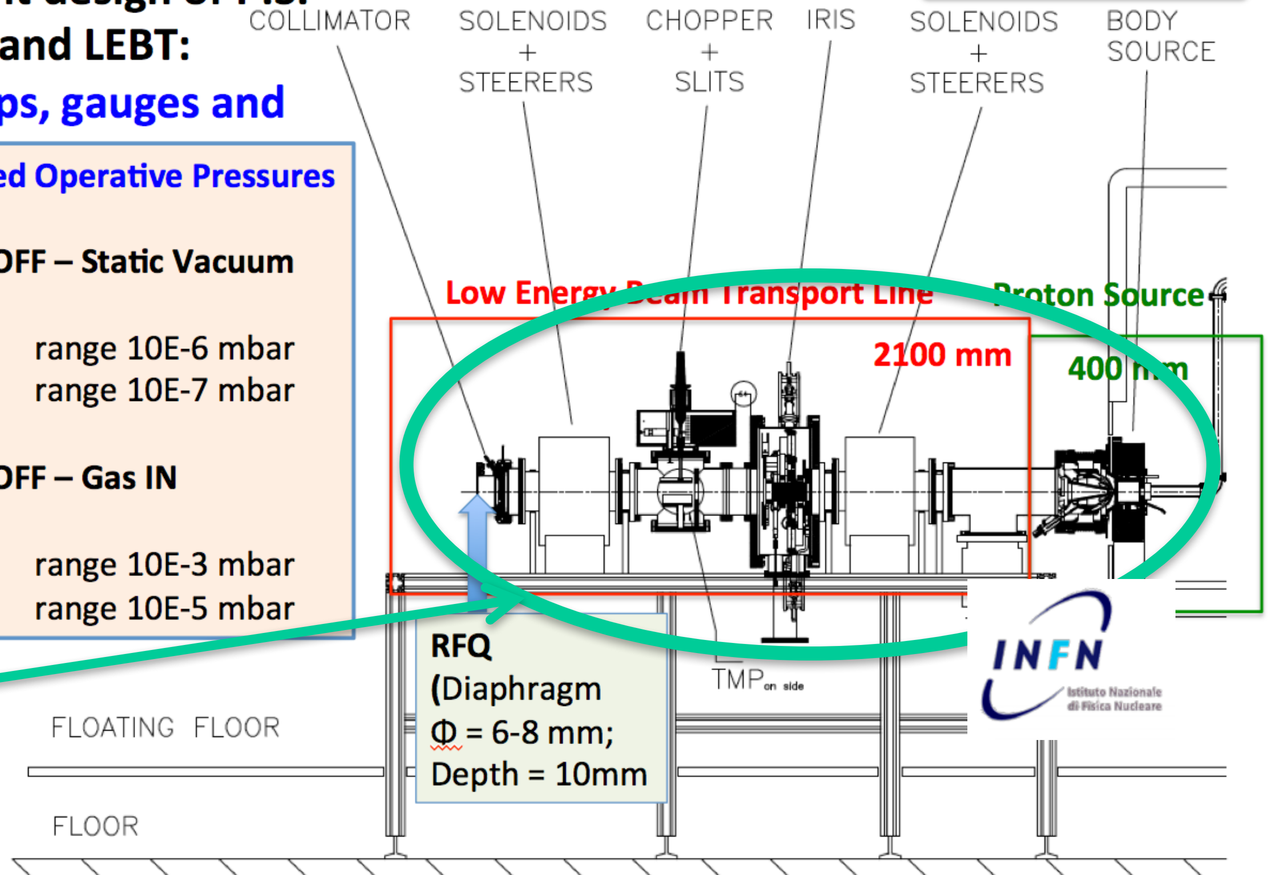
Expected Operative Pressures

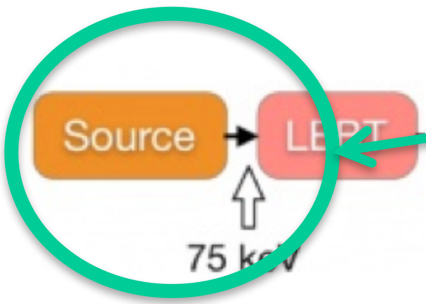
BEAM OFF – Static Vacuum

P.S.	range 10E-6 mbar
LEBT	range 10E-7 mbar

BEAM OFF – Gas IN

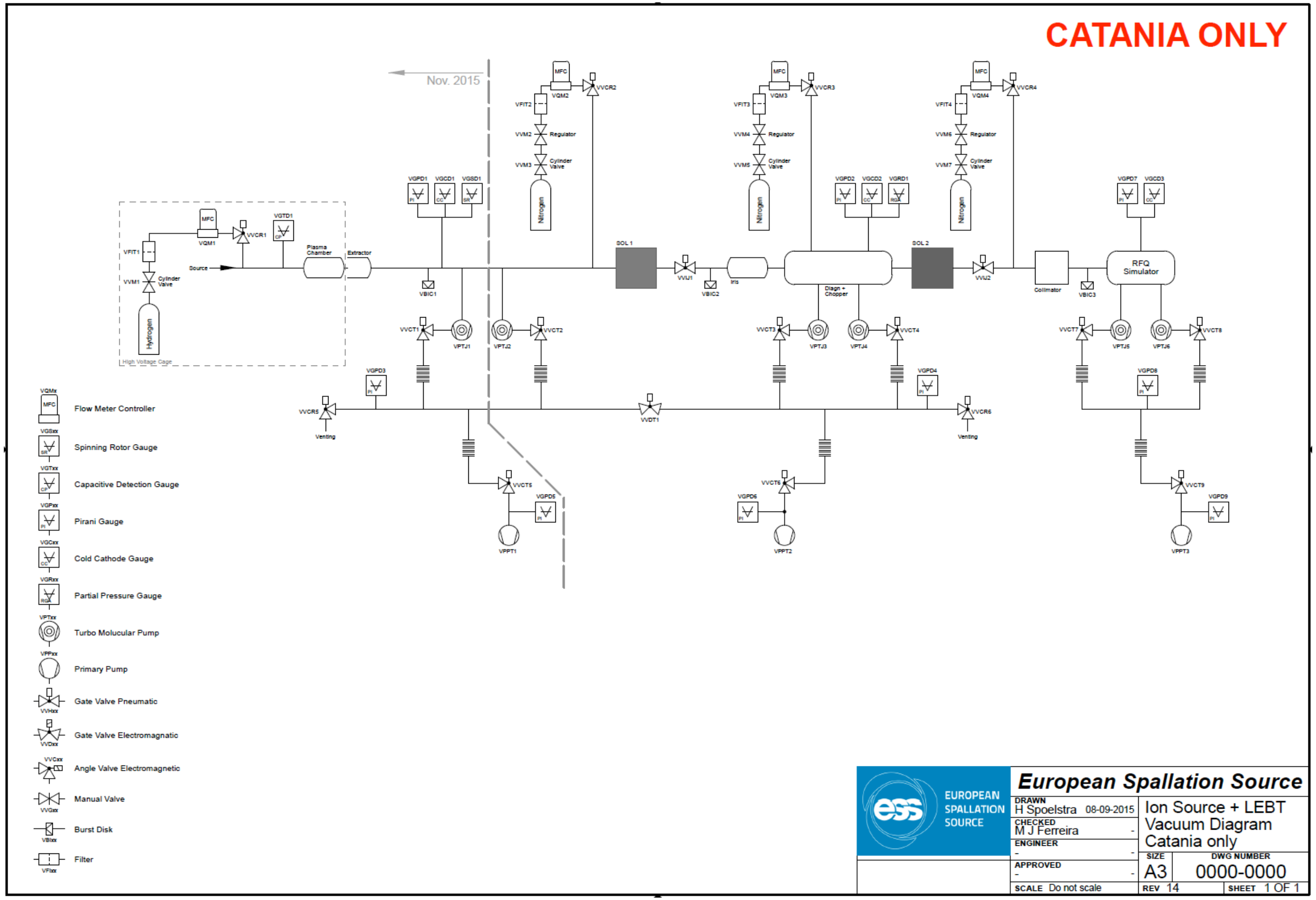
P.S.	range 10E-3 mbar
LEBT	range 10E-5 mbar





Warm LINAC: Ion Source (IS) + Low Energy Beam Transport (LEBT)

by H. Spoelstra ESS/Vac

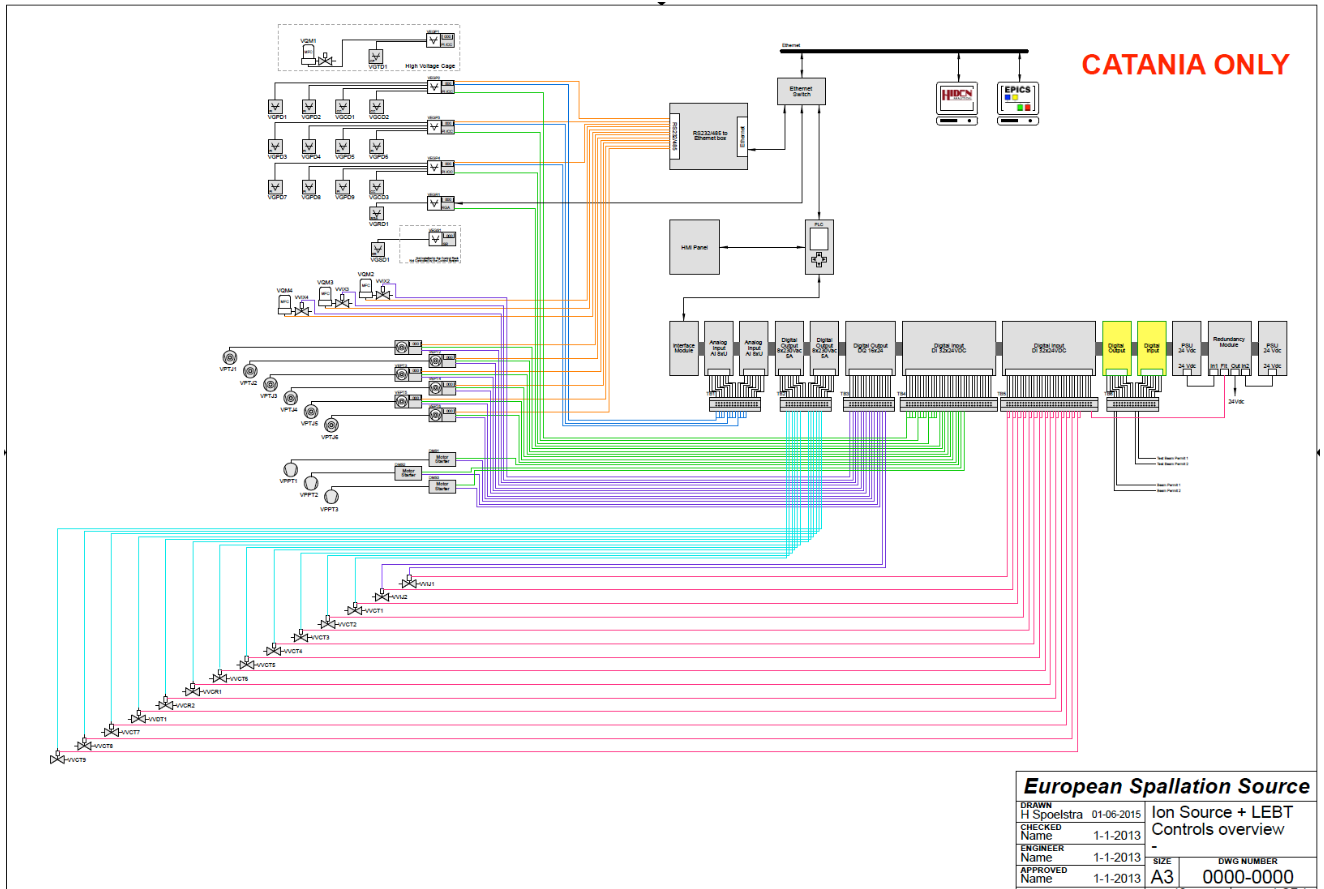


Vacuum diagram

Warm LINAC: Ion Source (IS) + Low Energy Beam Transport (LEBT)

EUROPEAN SPALLATION SOURCE

by H. Spoelstra ESS/Vac



Vacuum wiring diagram and logic (interlock system)

Vacuum WP is responsible to interface Vacuum Control and ICS (PSS and MPS).

Warm LINAC: Radio Frequency Quadrupole (RFQ)

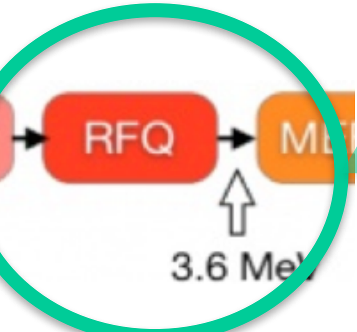
By Poton, A.

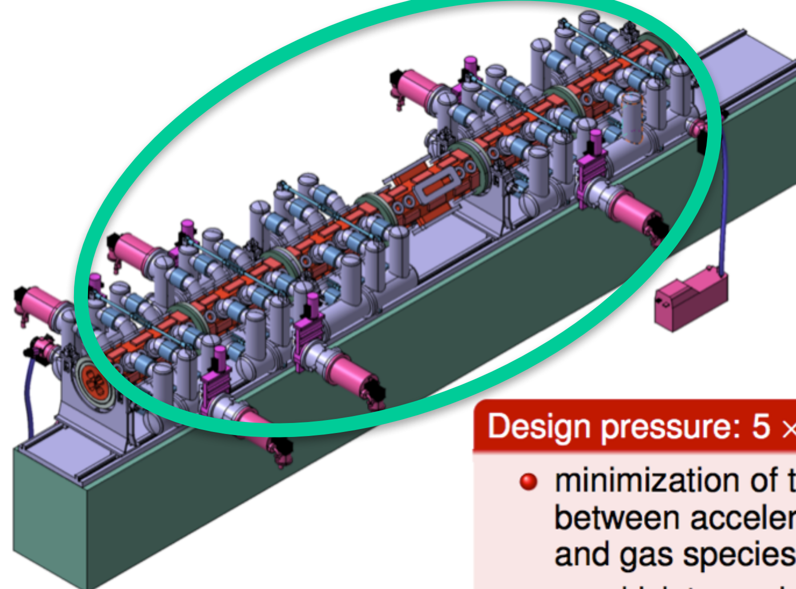
Pumps, gauges and valves

- 2 dry pumps (12.5 m^3/h)
- 6 cryo-pumps 200 L/s
- 2 sets of turbo-pumps 150 L/s
- 26 couples of gauges «Pirani - Penning»
- 14 valves
- 2 gauges Bayard-Alpert

Contributions

- gaz load from LEBT due to differential pressure
  - mainly H_2
  - other gas: *Kr*, *Ar* for SCC?
- out-gassing of copper
  - copper inner surface
  - RF loops due to RF
- desorption due to beam collision
  - depends on the history of the heat treatment
  - only the second half of the RFQ





Design pressure: 5×10^{-7} mbar

- minimization of the scattering between accelerated particles and gas species
  - high transmission
  - high quality beam
- minimization of the probability of discharge between surfaces

Warm LINAC: Radio Frequency Quadrupole (RFQ)

EUROPEAN SPALLATION SOURCE

by S. Scolary ESS/Vac

Vacuum components

- Rough vacuum system
- Turbomolecular pumps
- Gauges
- RGA

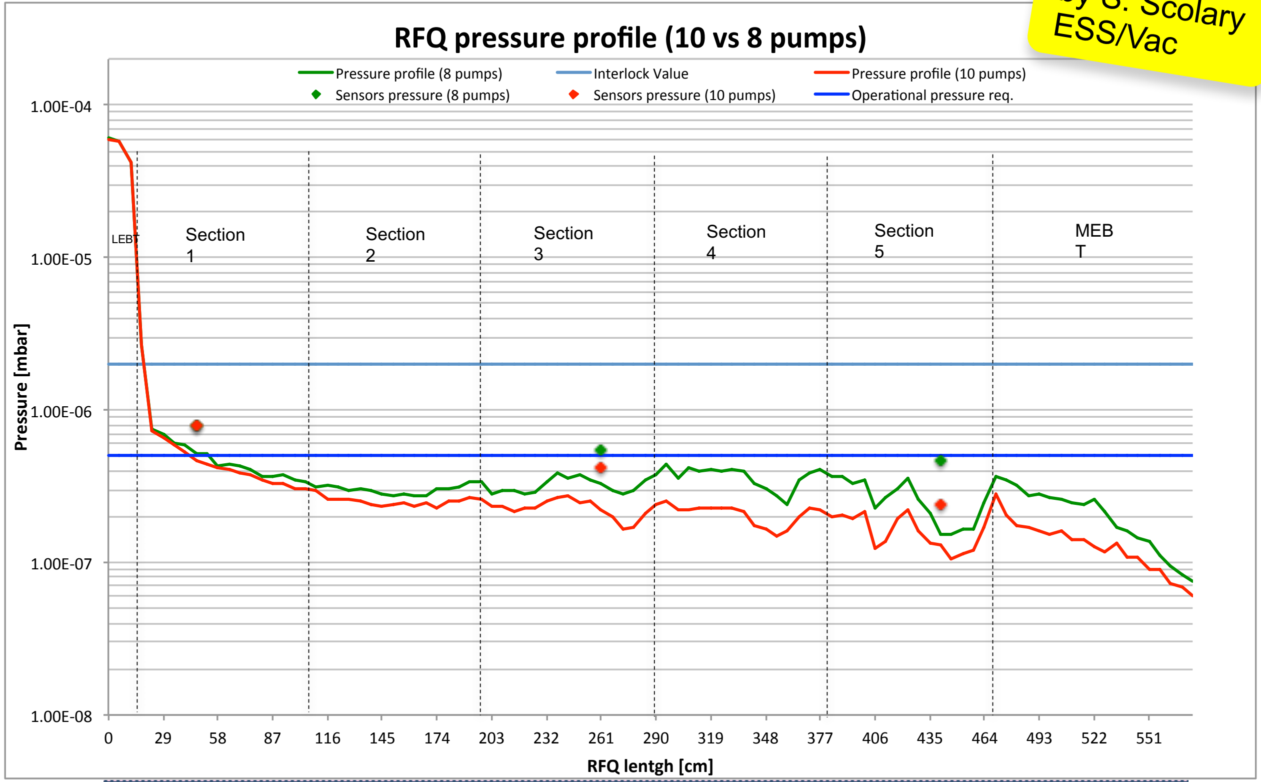
Outgassing and pumps:

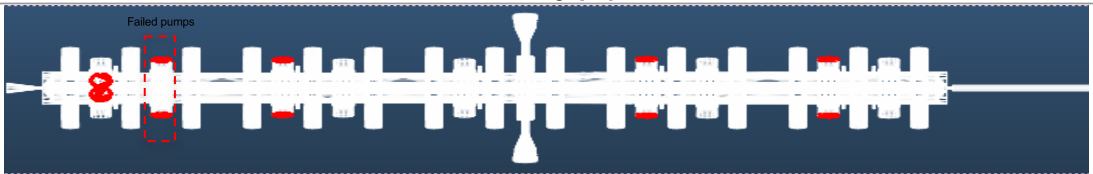
- OGR: 5E-10 mbar l/s/cm^2
- Gas: 50% H_2 and 50% N_2
- Pumping speed: 345 l/s (H_2) ; 340 l/s (N_2)

Interfaces:

- Upstream: LEBT collimator
  Gas in: 2E-05 mbar l/s
- Downstream: MEBT

  Gate valve on RFQ
- Implementation gate valves on TMPs ports TBD.





Warm LINAC: Radio Frequency Quadrupole (RFQ) status

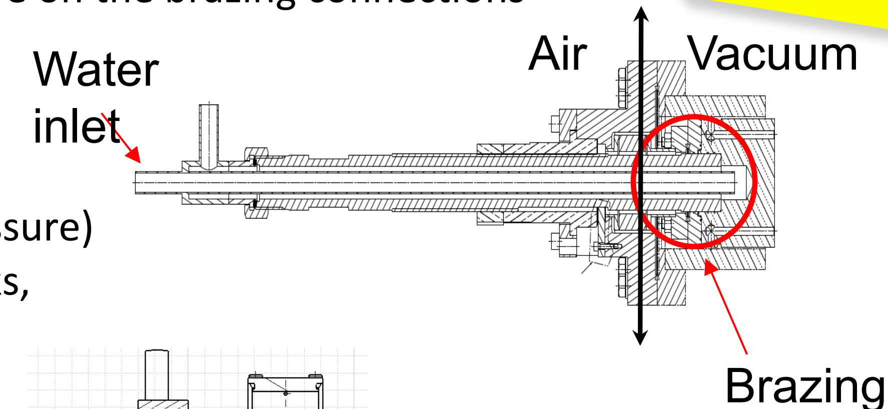
EUROPEAN SPALLATION SOURCE

by S. Scolary ESS/Vac

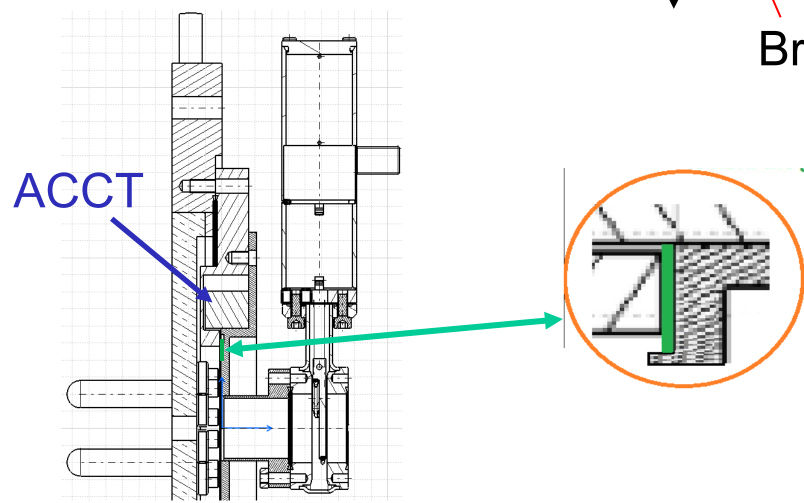
- **TUNERS**: Definition on He leak check procedure on the brazing connections (lessons learned from SNS and SLAC).

  ESS requirements (ESS VHB):

  - Hydrostatic test (x1.5 maximum design pressure)
  - Baking to remove water from possible cracks,
  - Leak check

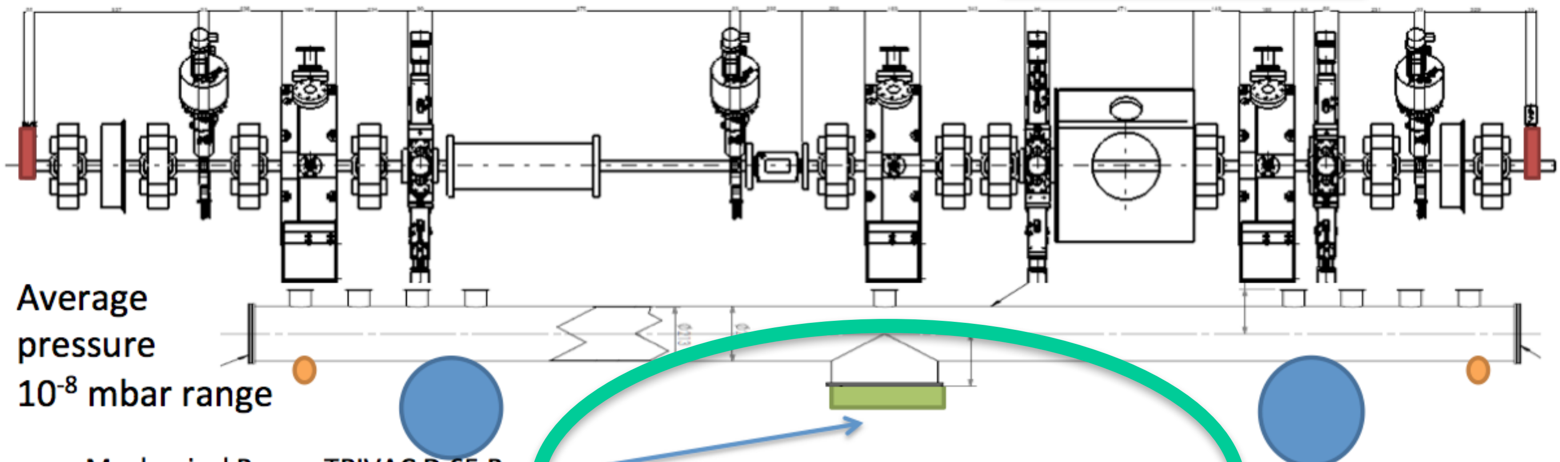


- **ACCT brake at RFQ exit plate**.
  - ESS proposal of a flat gasket accepted
  - Test to evaluate the required closing force to be executed envisaged at ESS



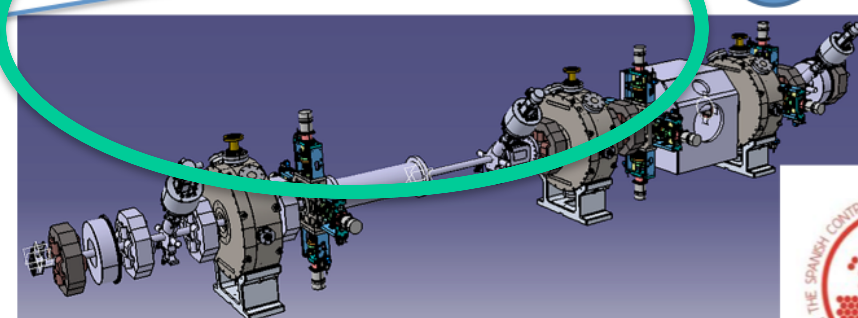
Warm LINAC: Medium Energy Beam Transport (MEBT)

By Zugazaga, A. et all



Average pressure
10^{-8} mbar range

Mechanical Pump: TRIVAC D 65 B
Turbo Pump: HiPace 700
Ion Pumps: NexTorr D300-5
VAT Mini UHV Gate Valve 01032-CE44
VAT UHV gate valve 10844-CE44
PKR 251 / ITR 90

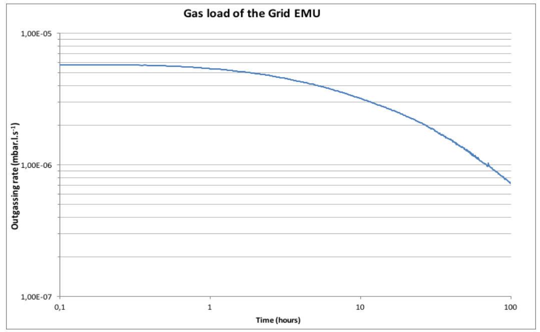


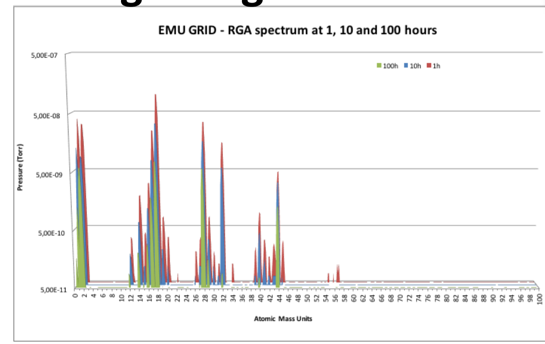
Warm LINAC: Medium Energy Beam Transport (MEBT)

by S. Scolary
ESS/Vac

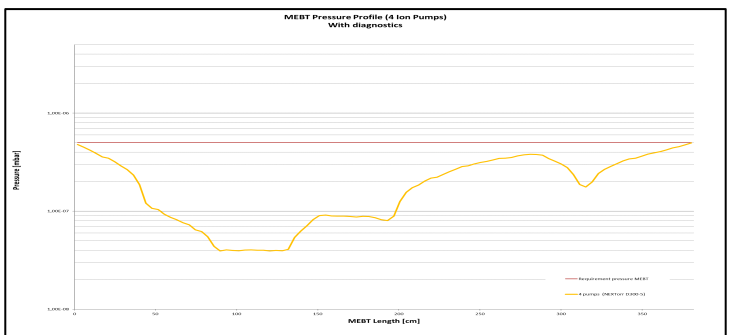
ESS ERIC provides testing capabilities for outgassing.

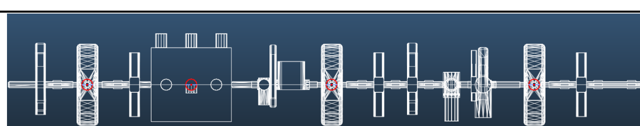
- Test performed:
  - Black coating
  - Graphite
  - EMU grid
  - EPDM





ESS Bilbao responsible for vacuum design and MolFlow simulations.





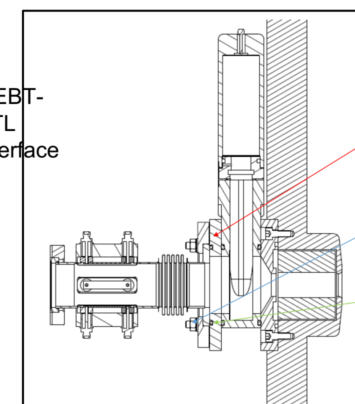
Vacuum components:

- Pump-down system
- NEG pumps
- Gauges

Interfaces:

- Upstream: RFQ (valve sits on RFQ
- Downstream: DTL (valve sits on DTL and it's an insertable valve)

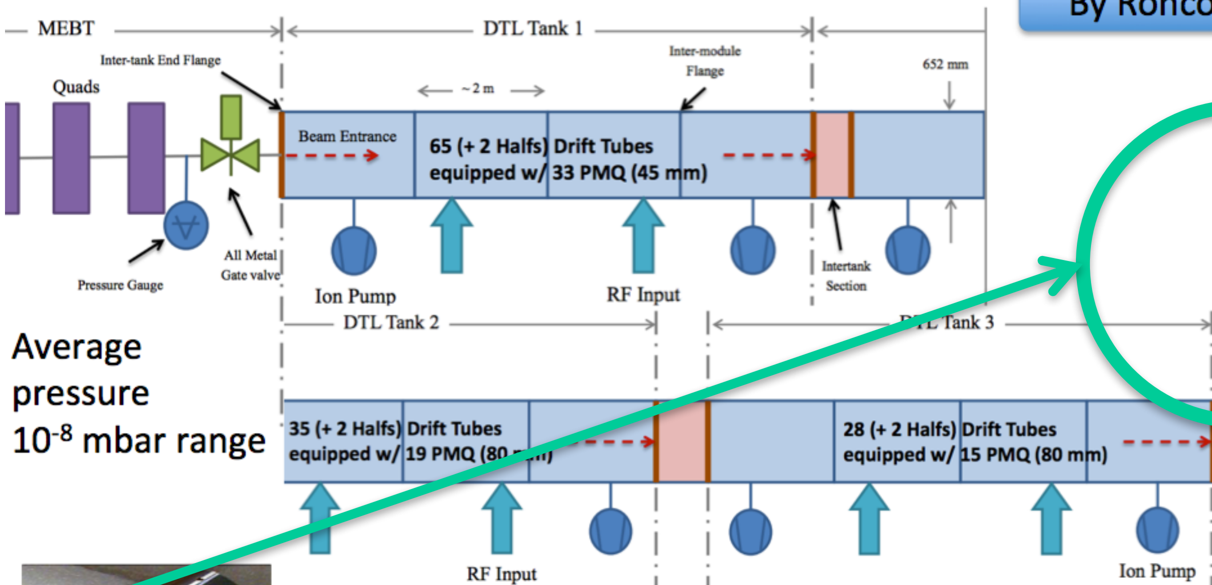
MEBT-DTL interface



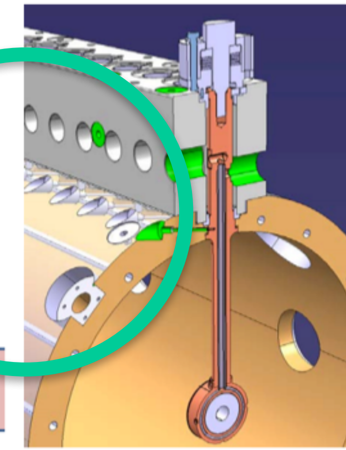
Warm LINAC: Drift Tube LINAC (DTL)

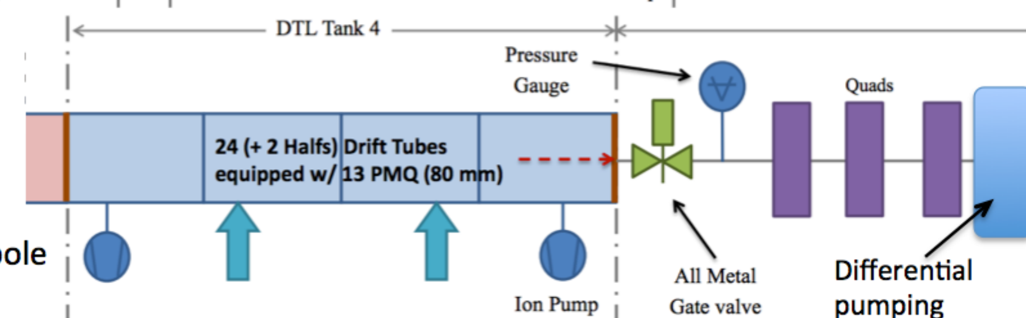
EUROPEAN SPALLATION SOURCE

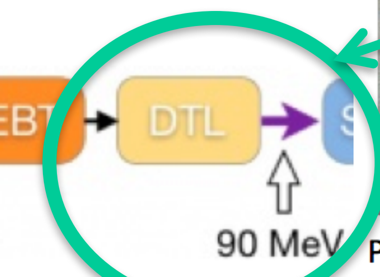
By Roncolato, C.

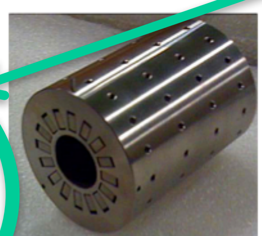


Average pressure 10^{-8} mbar range









PMQ = Permanent Magnets Quadrupole

In vacuum, Sm_2Co_{17} magnets

Warm LINAC: Drift Tube LINAC (DTL)

EUROPEAN SPALLATION SOURCE

by S. Scolary
ESS/Vac

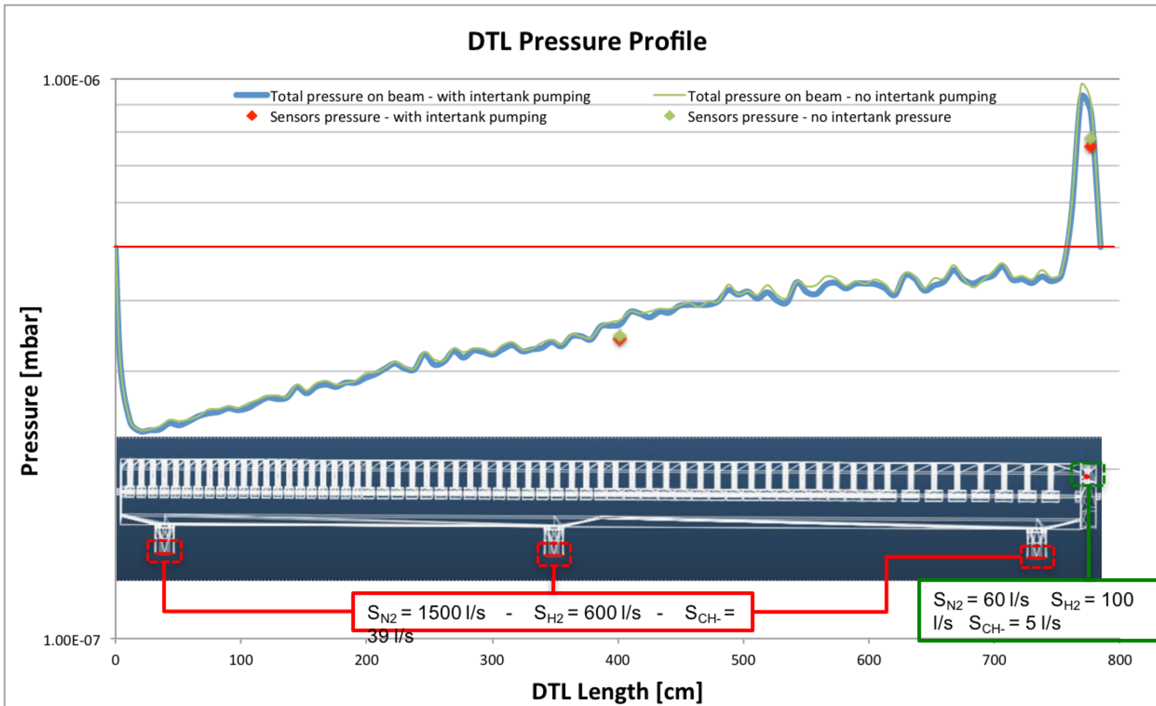
Outgassing tests and Molflow simulations carried out at ESS.
Critical tested components: PMQs and ACCT

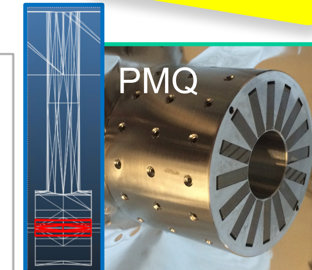
Vacuum components per tank:

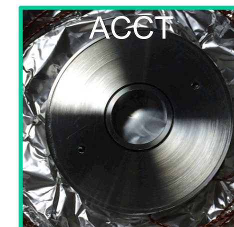
- Pump-down system (carts)
- NEG pumps (both in the tank and the inter-tank)
- Gauges

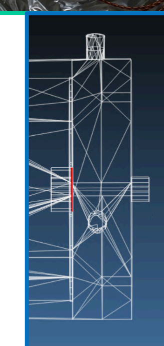
Interfaces:

- Upstream: MEBT (insertable gate valve on DTL)
- Downstream: LEDP (All metal gate valve on DTL intertank)







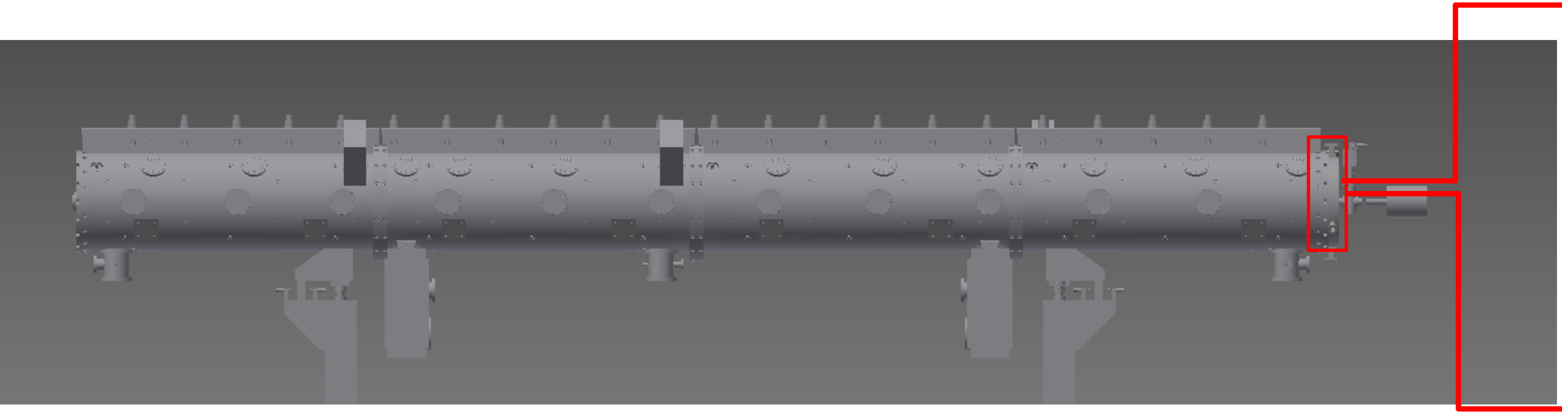


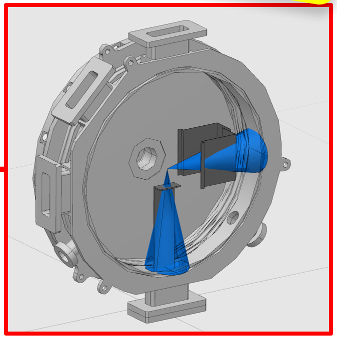
Due to high gas load of epoxy insulation, a pre-installation outgassing process is necessary.

Warm LINAC: Drift Tube LINAC (DTL)

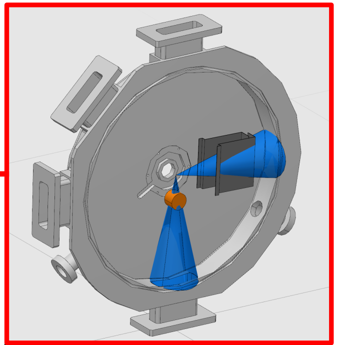
by S. Scolary
ESS/Vac

- Black coating for NPM in the DTL inter-tanks: two different solutions depending on installation schedule of Faraday cup.





Before FC installation



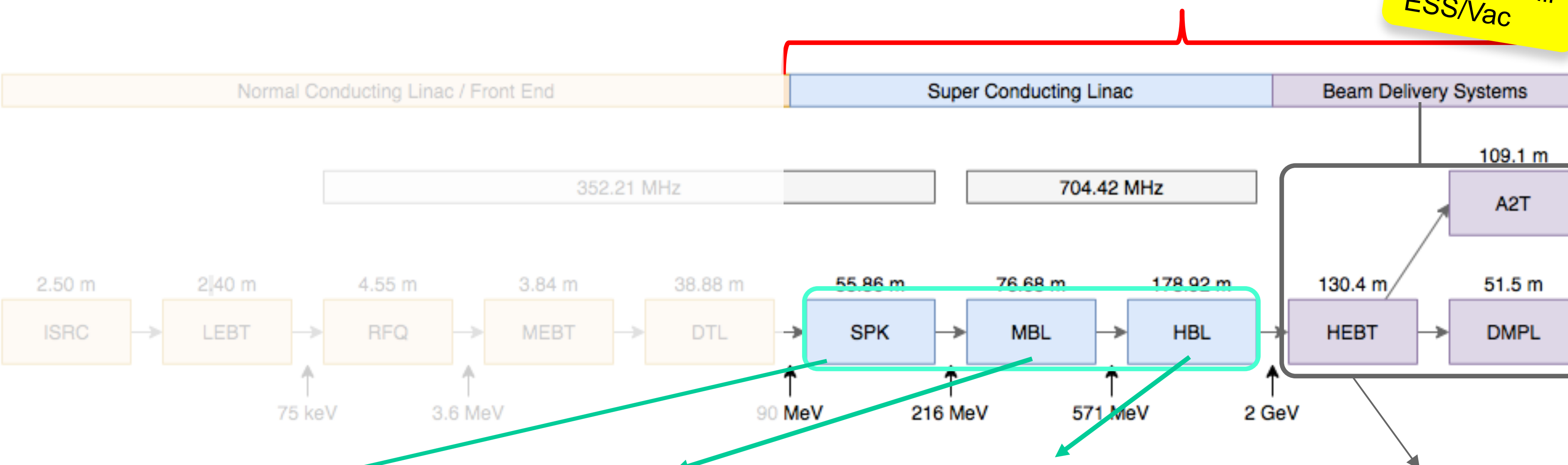
After FC installation

- Leak check procedure for the water cooled stems.

Cold LINAC

EUROPEAN SPALLATION SOURCE

by F. Ravelli ESS/Vac

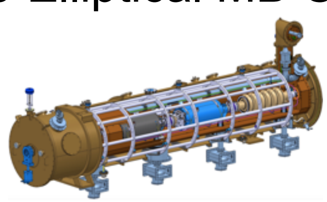


13 Spoke CM's

Low Energy DP WU

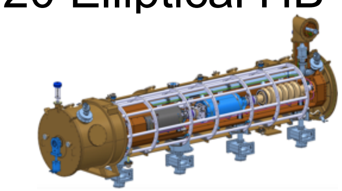
12 Spokes LWU's

9 Elliptical MB CM's



9 Elliptical Medium β LWU's

20 Elliptical HB CM's



20 Elliptical High β LWU's

High Energy DP WU

15 Elliptical WU's in HEBT

6 in DogLeg

3 WU's in A2T

3 WU's in DMPL

Cold LINAC: Low Energy Differential Pump (LEDP)

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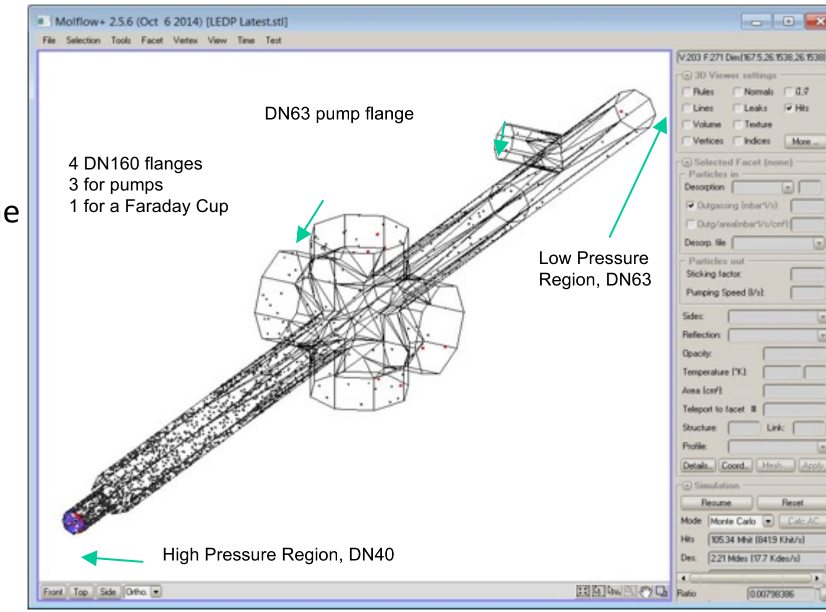
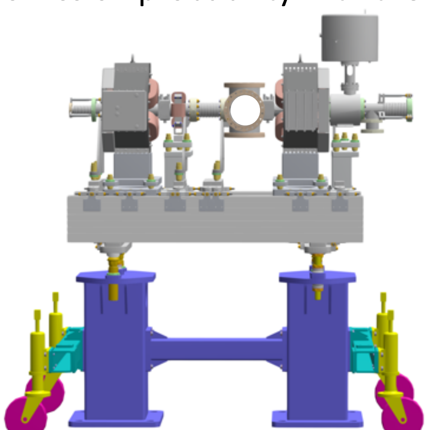
by F. Ravelli
ESS/Vac

Requirement of the differential pumping sections:

- HPR pressure / LPR pressure = 100 to protect superconducting RF cavity
- Molflow+ simulation with the following parameter set:
  - HPR facet desorption = 1
  - HPR facet sticking coefficient S = 1
  - LPR sticking coefficient S = 1
  - All simulations were run for mass 28
  - The pressure ratio is calculated as the ratio between the adsorbed particles on LPR facet and the total desorbed particles

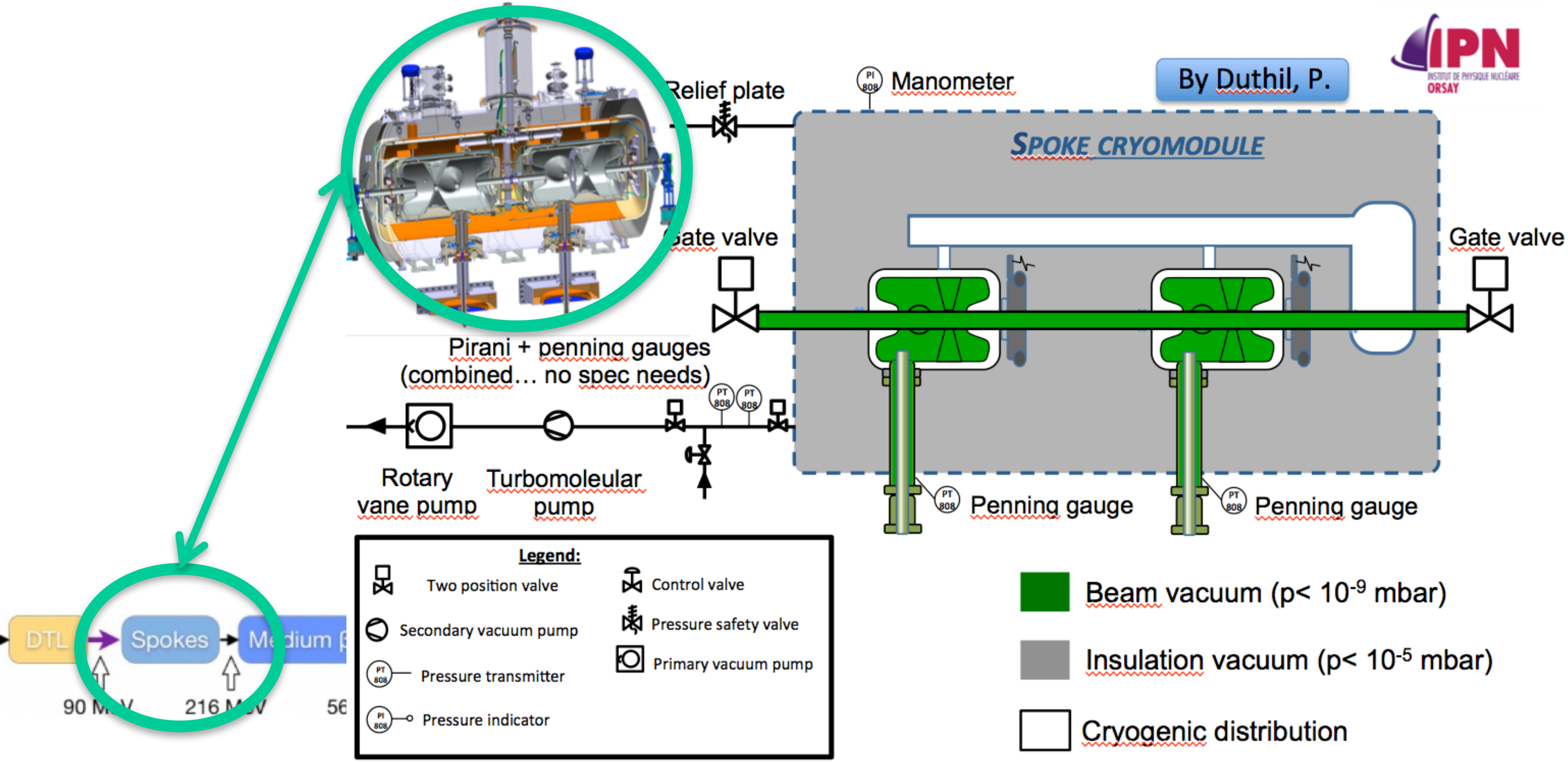
<u>Simulation result</u>: a 100:1 ratio across the section requires approximately 2000 l/s (N_2), transmission probability with the parameters listed is 0.008



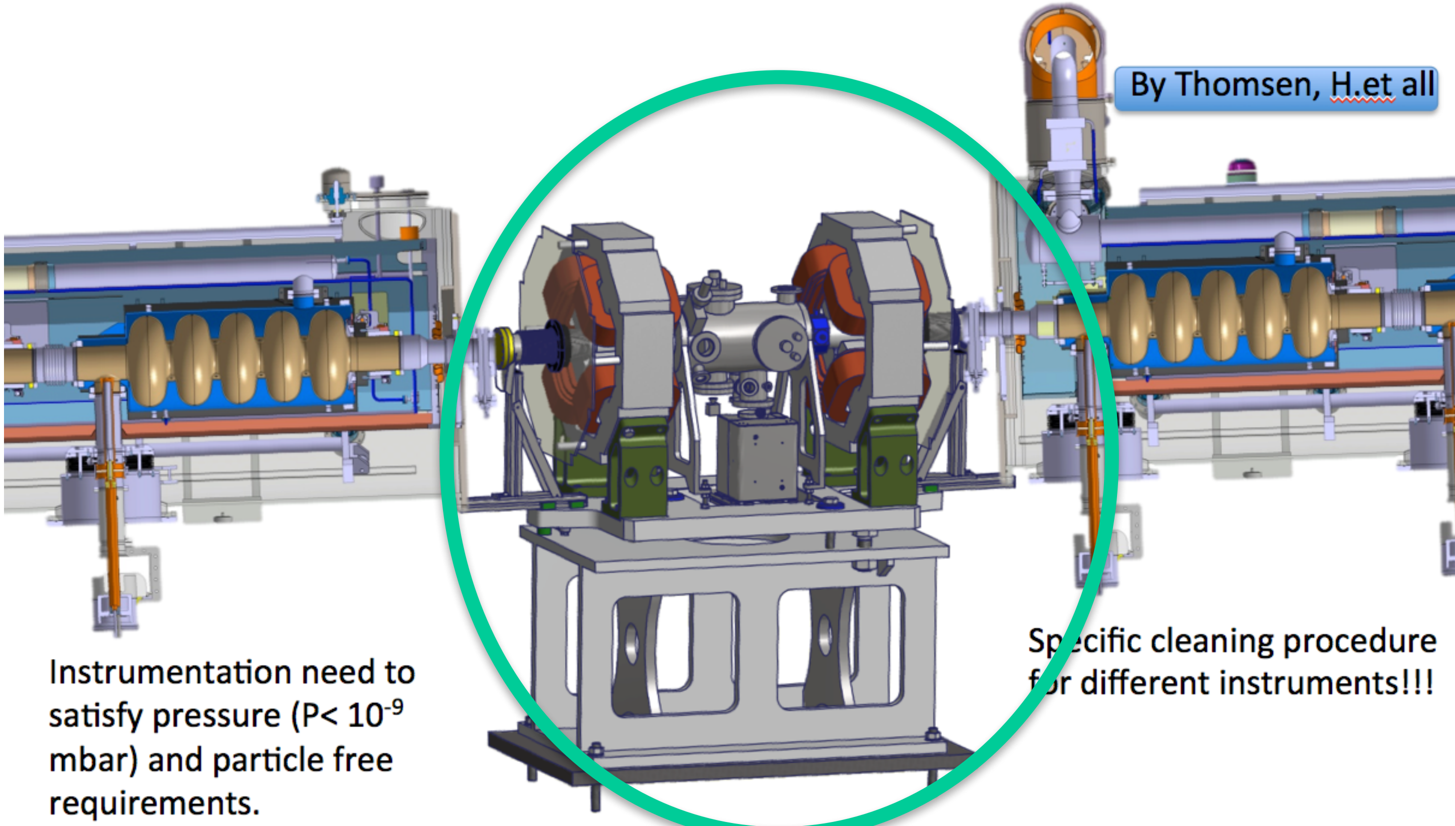


LEDP, approximately 2m long

Cold LINAC: Spoke cryo module



Cold LINAC: LINAC Warm Unit (LWU)



Instrumentation need to satisfy pressure (P< 10^{-9} mbar) and particle free requirements.

Specific cleaning procedure for different instruments!!!

Two families: 13 x Spoke LWU (SWU) & 51 x Elliptical LWU (EWU)

Cold LINAC: LINAC Warm Unit (LWU)

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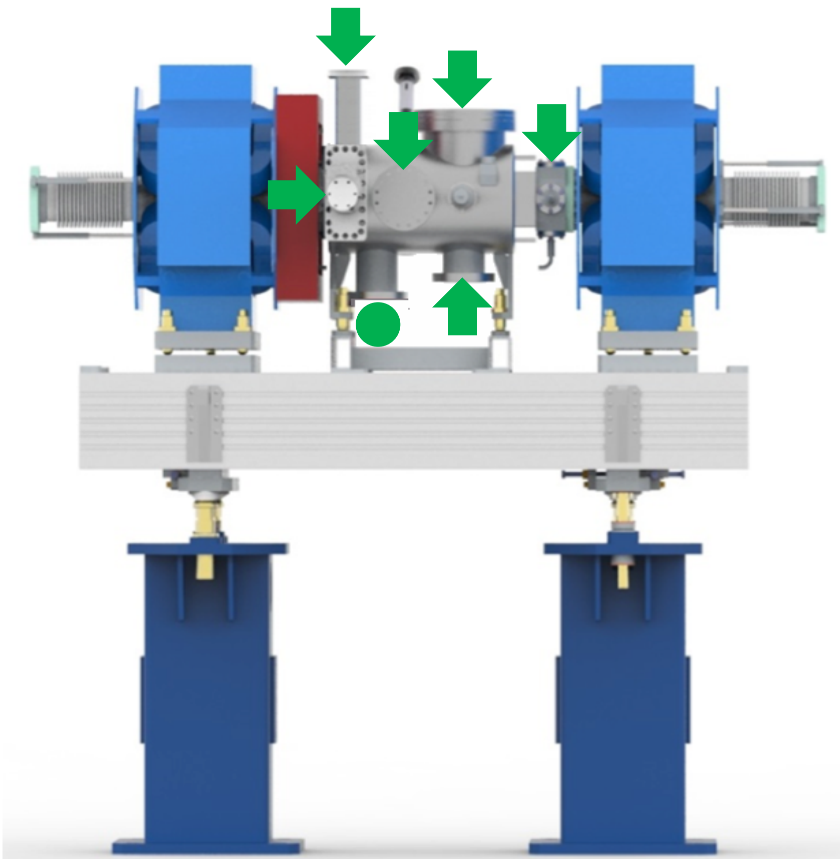


LWU's provide vacuum continuations between cryo-modules and host beam diagnostic and magnets. Designed, built and processed for UHV and particle free operation (base pressure 5*10^{-9} mbar, without beam).

Equipped with **DN100 flange** for UHV pump, DN40 manual valve, Pirani and cold cathode, burst disk.

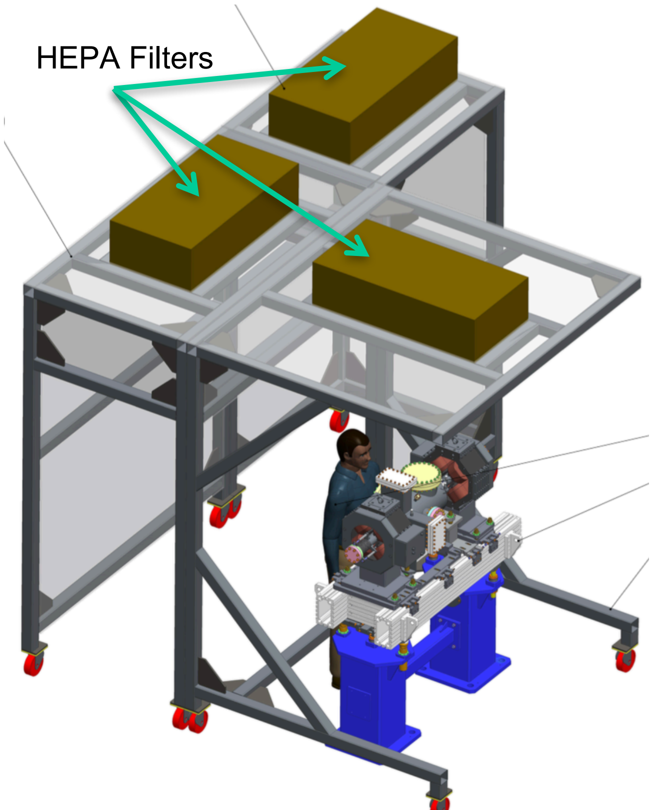
LWU's integrate **quadrupoles** and **correctors.**

Various **flanges** dedicated to diagnostics (e.g. Wire Scanners, BPM, BCM, Faraday Cup, Bunch Shape Monitor).

Adjustment **fixtures** for the alignment of the girder, the chamber and the quadrupoles.

Cold LINAC: LWU installation with portable clean room

by F. Ravelli ESS/Vac

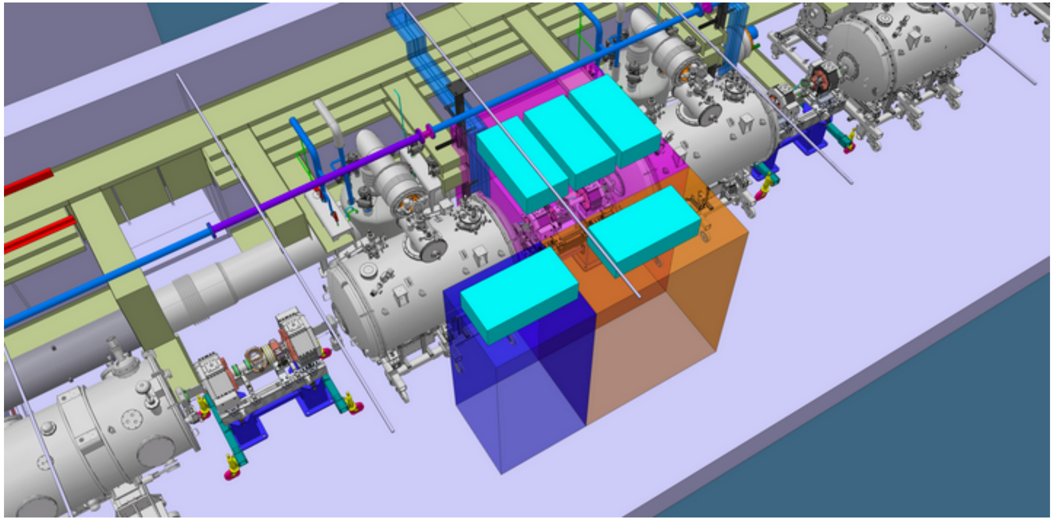


Soft-walls are not showed

Installation of LWU to the cryo-modules require a **particle free environment**; portable modular clean rooms are designed by STFC/Daresbury for in-tunnel installation.

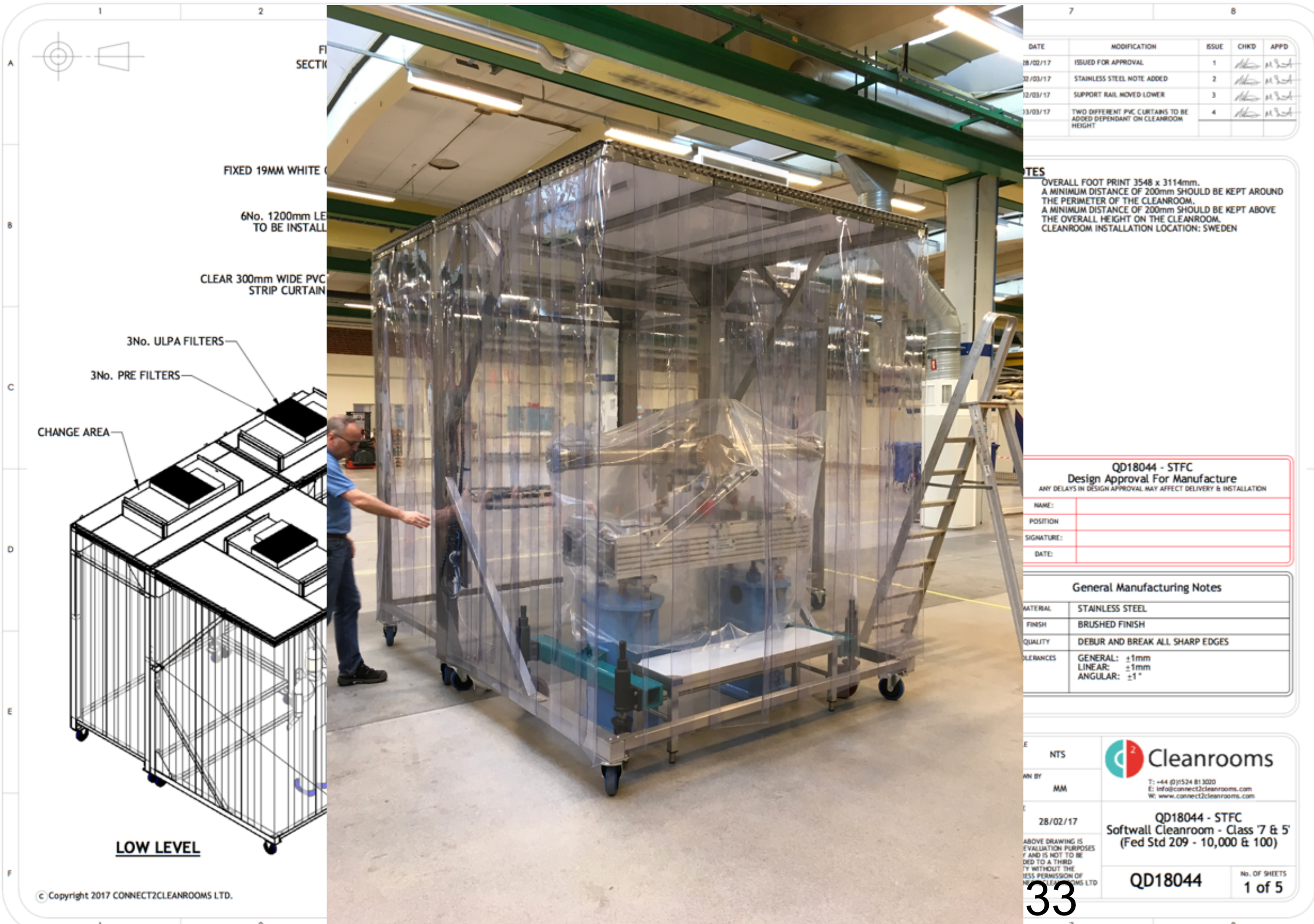
Three independent units with specific functions: gowning room, stock room for tools and components and working unit (ISO class 5 standard).

Prototype version installed at RATS for testing



Cold LINAC: Mobile Clean room

by F. Ravelli
ESS/Vac



Cold LINAC: LINAC Warm Unit (LWU)

EUROPEAN SPALLATION SOURCE

by F. Ravelli ESS/Vac

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Home / News / Daresbury engineers help to unlock the secrets of materials at the atomic level

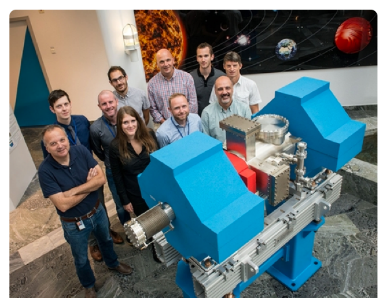
Daresbury engineers help to unlock the secrets of materials at the atomic level

15 September 2016: UK engineers from Daresbury, Cheshire, have this week delivered a key piece of prototype equipment to one of the world's most ambitious scientific experiments, currently being constructed in Sweden.

STFC teams are playing a key role in the design and development of the €1.84 billion European Spallation Source (ESS).

Once complete, it will be the world's most powerful neutron source dedicated to generating neutrons to help us look deep inside the materials from which our world is made.

With powerful neutron beams that are a hundred times brighter than at any other facility in the world, it will help us to unlock the secrets of materials at the atomic level. Situated in Lund,



Group photo of the teams from STFC and the ESS Vacuum Section

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January 9, 2017
Black holes hide in our cosmic backyard

January 6, 2017
Update on Neutron Strategic Review

December 31, 2016
New Year Honour for STFC's Sue Carter

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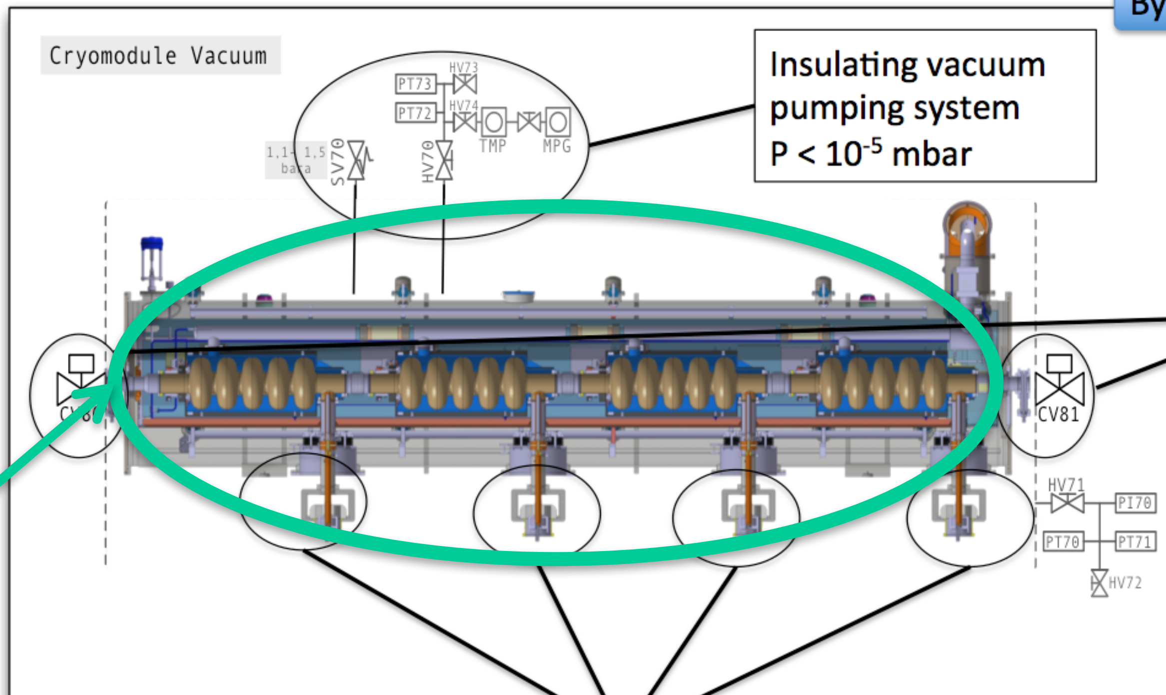
October 2016 –

rototypes (1st
ite 2nd prototype
picture)
procedure for

ction floor

Cold LINAC: Elliptical cavity (medium/high Beta)

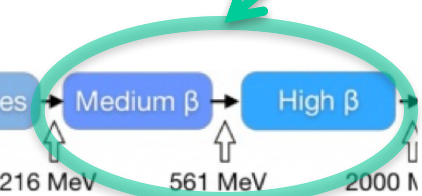
By Bosland, P. et all



Insulating vacuum pumping system
P < 10^{-5} mbar

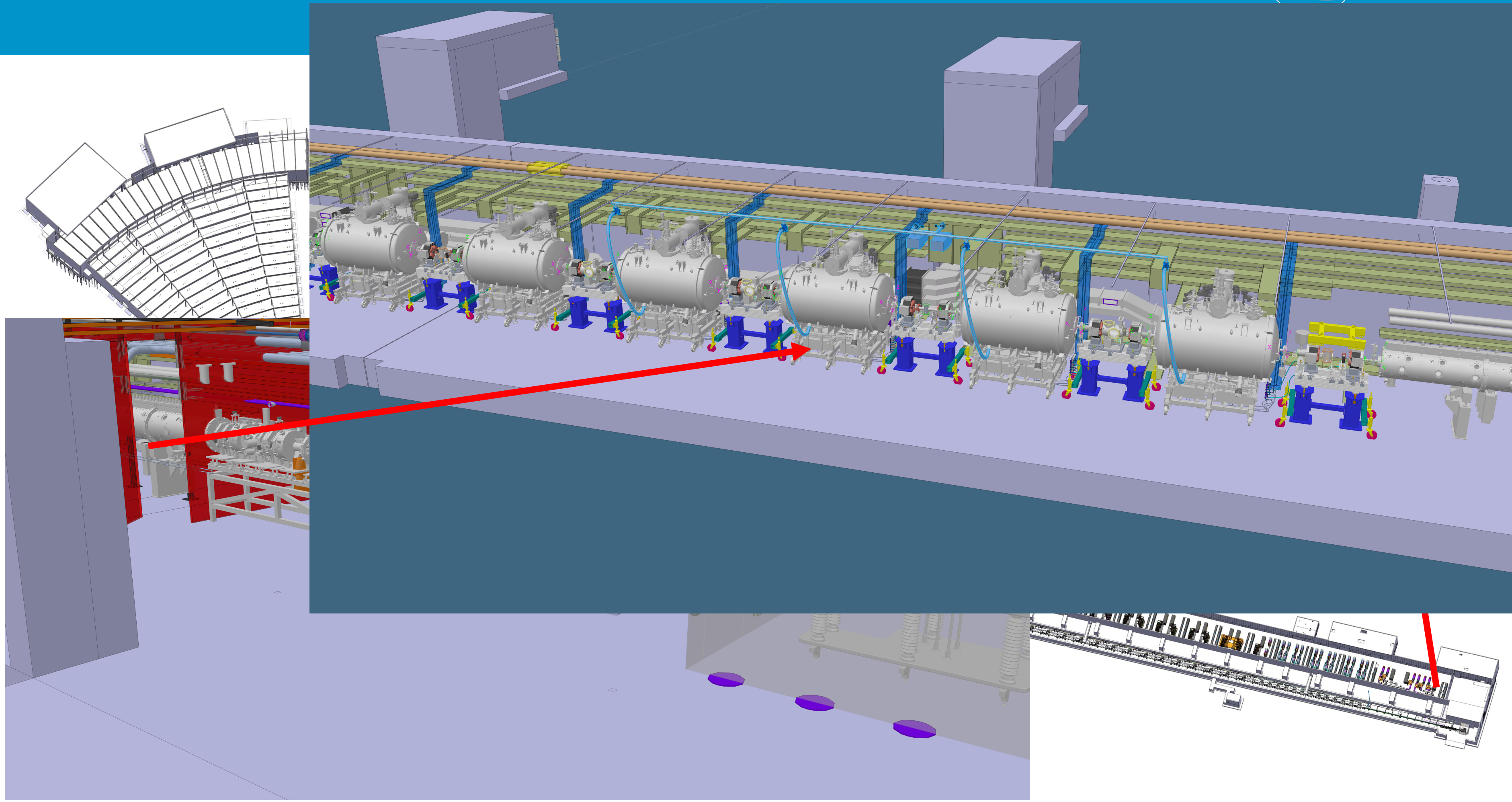
Cavity string pumping through the gate valves.
Particle free operation to connect components.
P< 1 x10^{-9} mbar

4 gauges for coupler protection and cavity vacuum monitoring



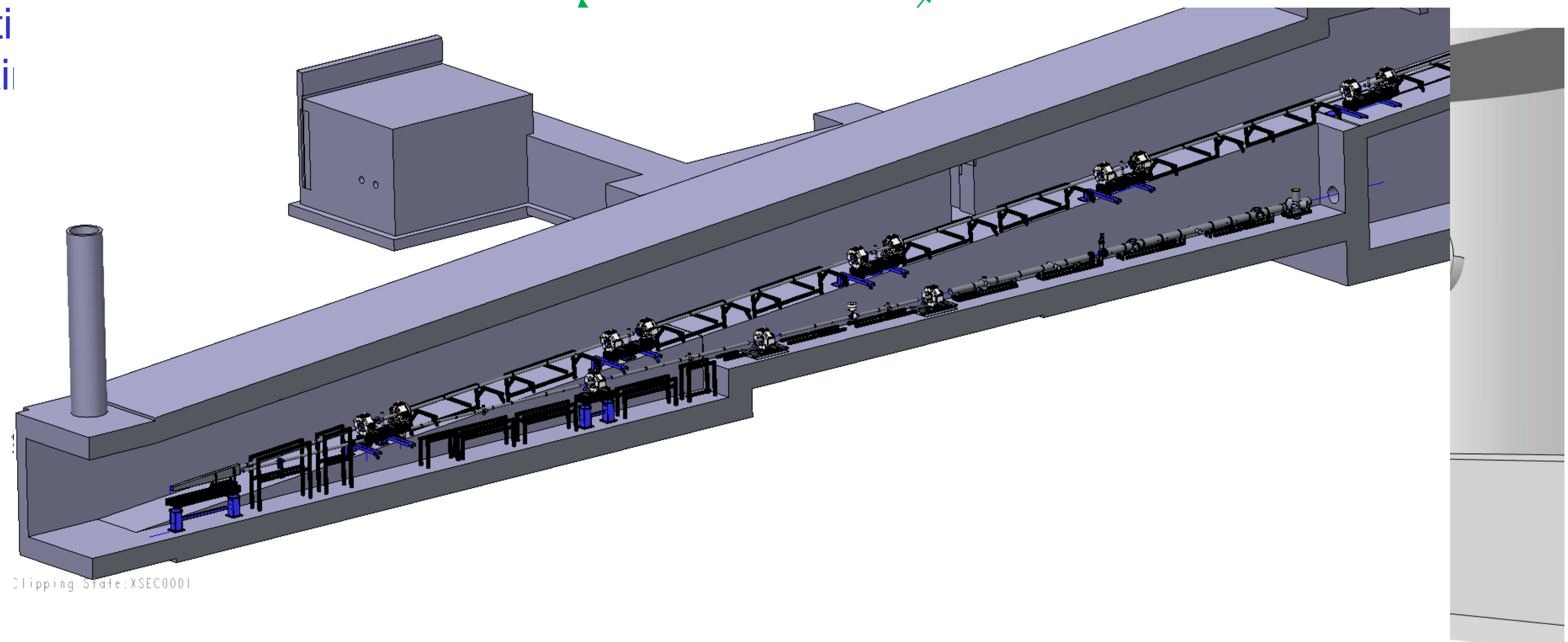
ESS Accelerator

EUROPEAN SPALLATION SOURCE



Cold LINAC: HEBT, DogLeg and A2T

EUROPEAN SPALLATION SOURCE



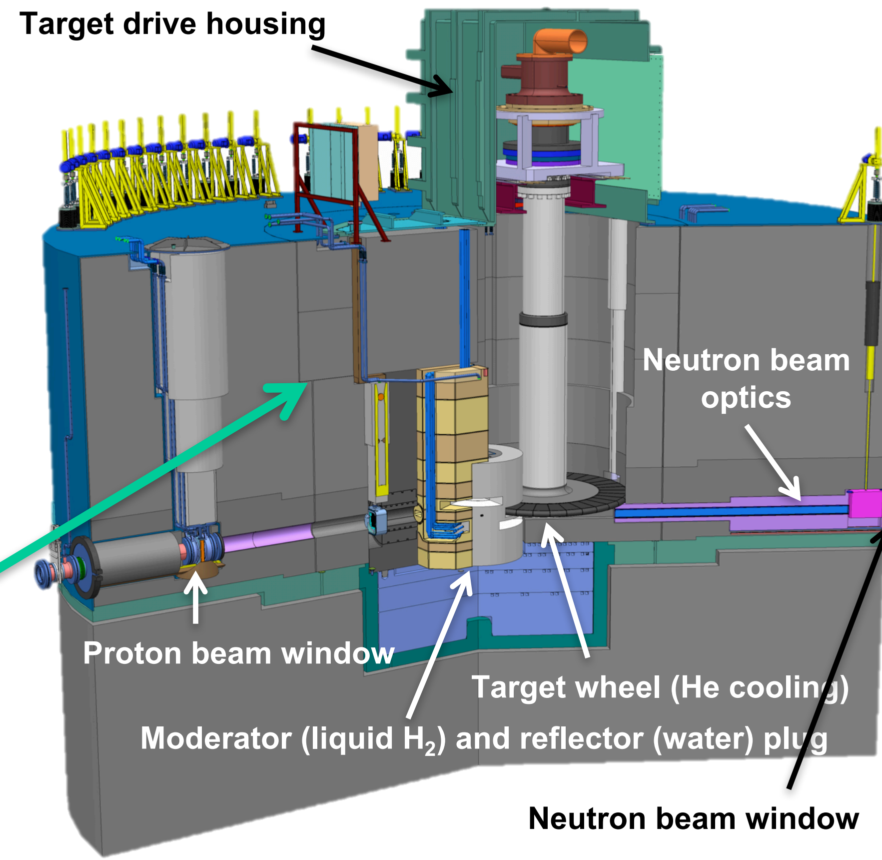
Pressure requirement for (HEBT) < 10^{-4} Pa is sufficient from proton-beam interaction.

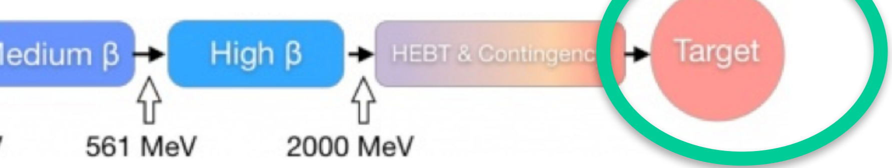
TARGET: monolith vessel

EUROPEAN SPALLATION SOURCE

The **baseline** design for the **monolith vessel** includes operation from **1 atmosphere He**, **1 mbar pressure (air or He)** all with Proton Beam Window (PBW) or **high vacuum** without PBW. The vacuum system can provides capabilities to reach rough vacuum for purging and purge, rough pressure solution or high vacuum. The purging system must be able to handle both He and H2 as media in the system.

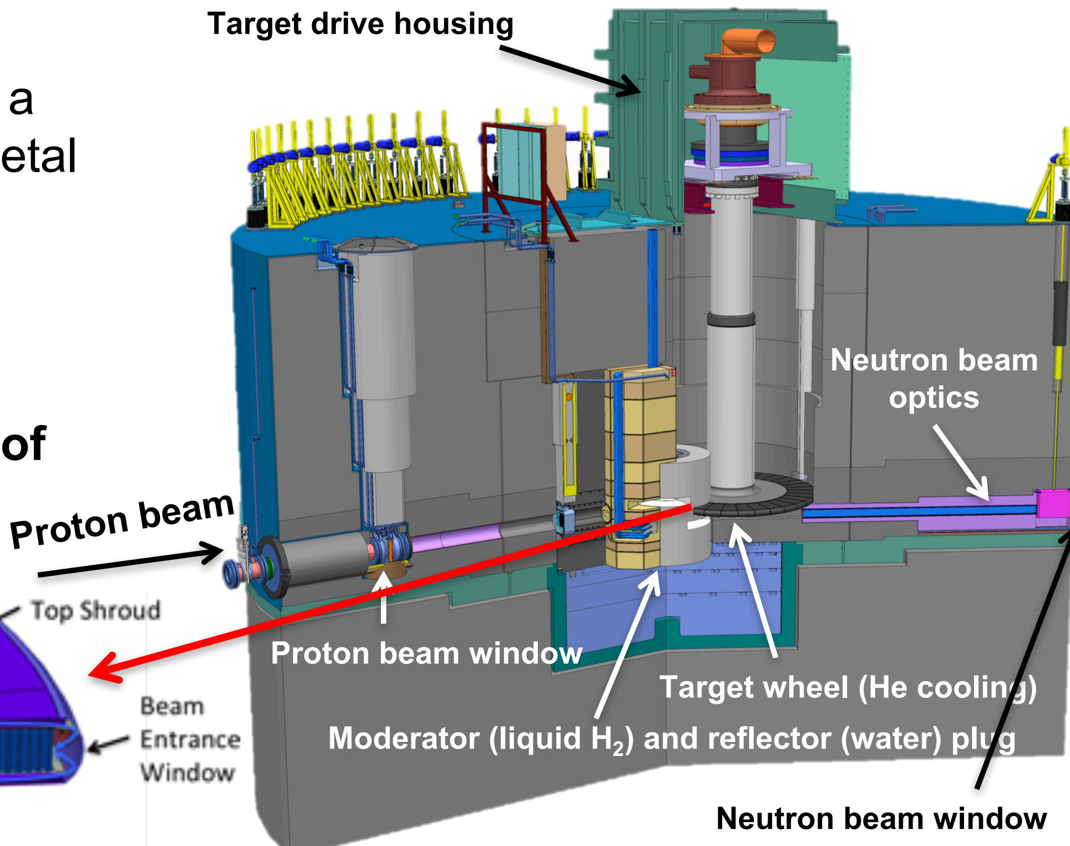
The vacuum for thermal insulation (moderator and target wheel) will be an active vacuum that will handle both the cryostat vacuum and the piping adjacent to the system. This vacuum might be contaminated by H_2O, H_2 and He .

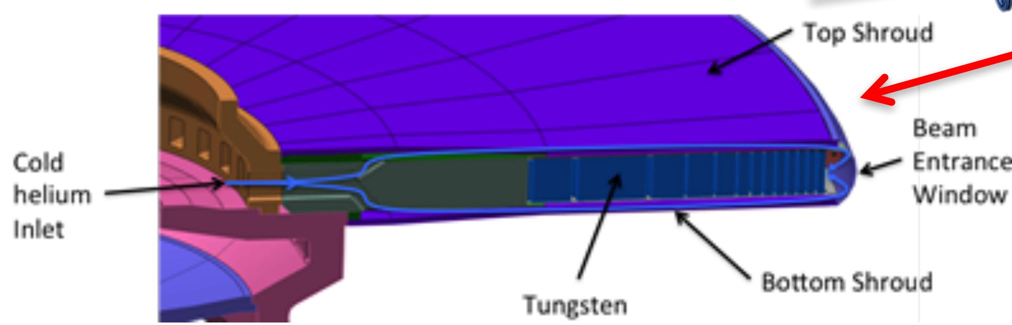




TARGET: neutron production

Spallation is the process for **producing neutrons** by means of a particle accelerator and a heavy metal target. **Protons** derived from hydrogen gas are drawn through a linear accelerator to a velocity just below the speed of light, at which point they **collide with the nuclei of the target metal**, tungsten





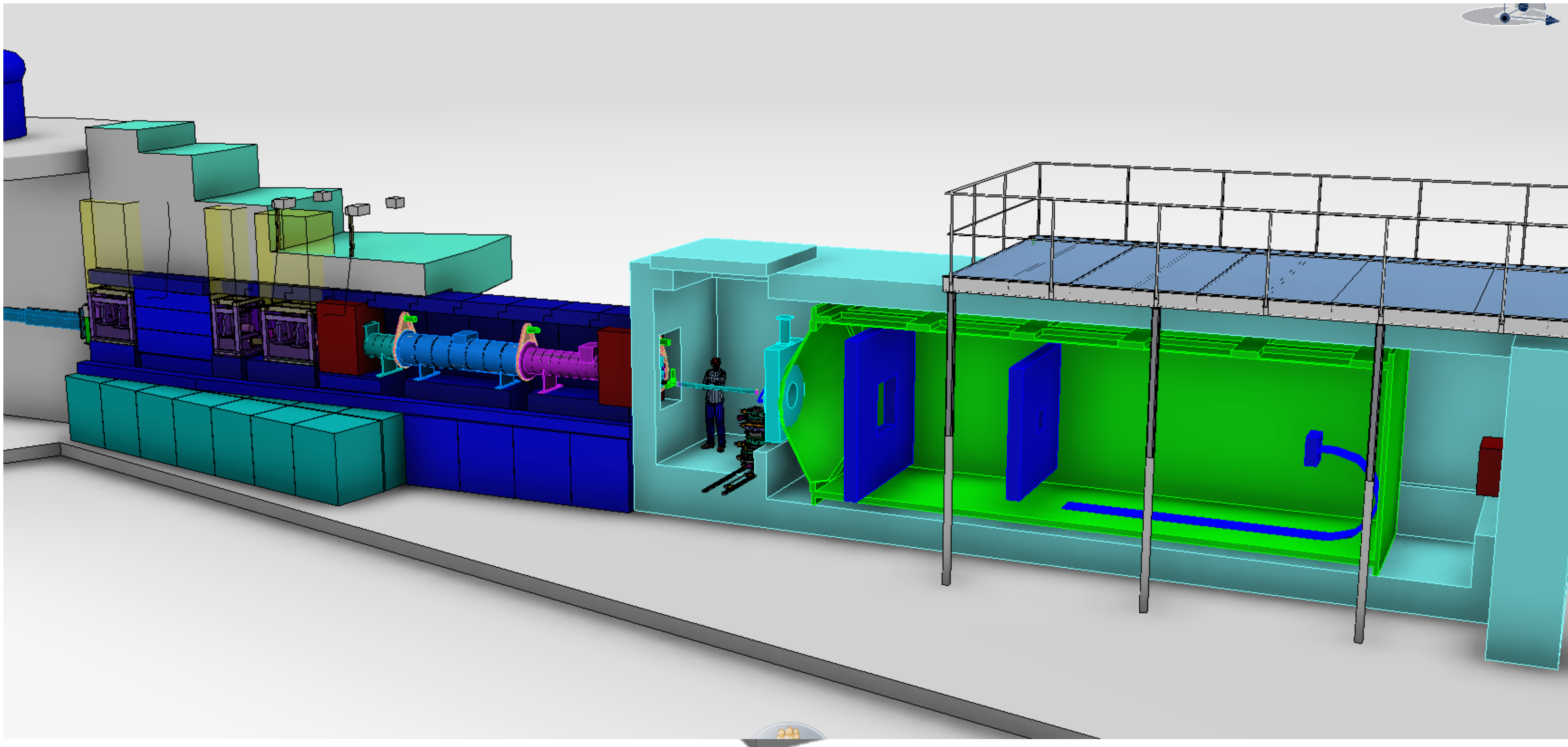
Neutron Scattering Science (NSS): vacuum integrated approach

EUROPEAN SPALLATION SOURCE

Neutron Instrument scheduling

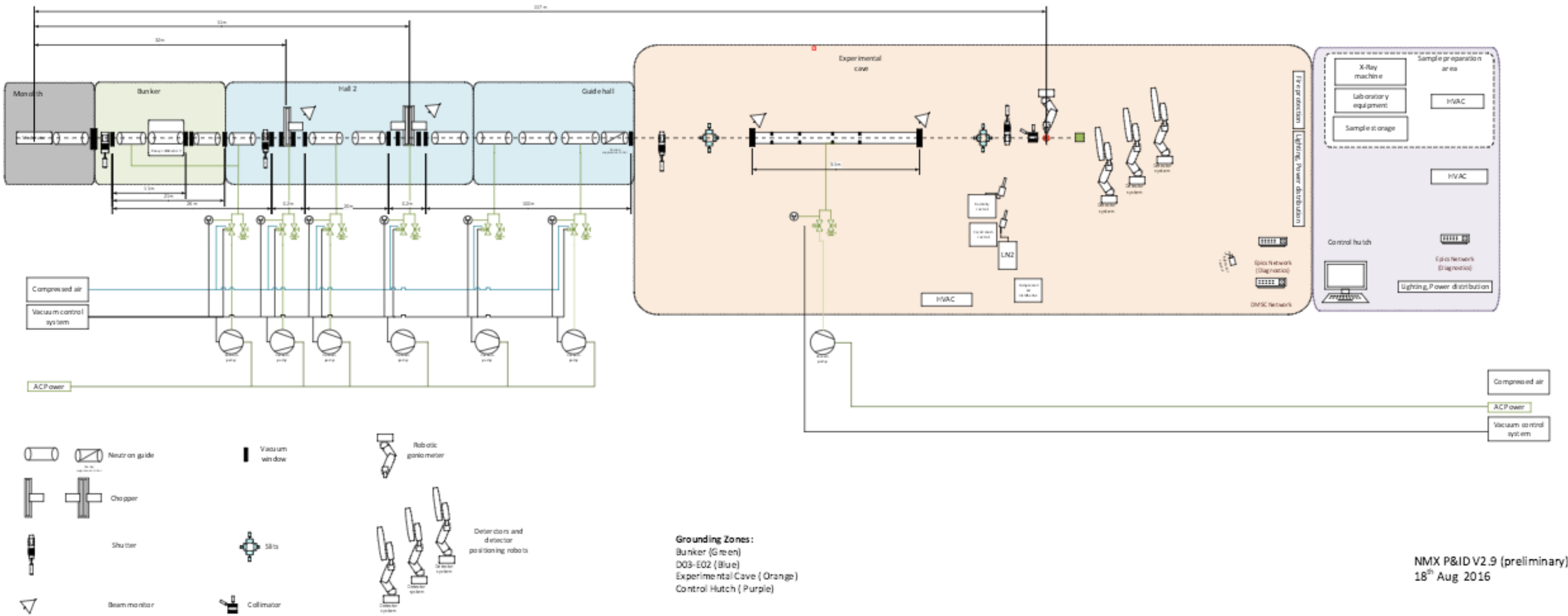
NBI name	Cost Book Value/Target [kEuro] / Construction	Phase 1 - Preliminary Eng. Design	Duration [Days]	Phase 2 - Detailed Eng. Desing	Duration [Days]	Phase 3 - Procurement & Manufacturing	Duration [Days]	Phase 4 - Installation & Integration	Duration [Days]	Phase 5 - Hot Commissioning	Duration [Days]	Phase 6 - Operation	Duration [Days]
Neutron Bunker	14500	12-Sep-15	366	12-Sep-16	306	15-Jul-17	396	15-Aug-18	525	22-Jan-20	60	22-Mar-20	3967
Test Beamline	0	1-Aug-16	273	1-May-17	275	31-Jan-18	276	3-Nov-18	250	11-Jul-19	120	8-Nov-19	4102
LOKI (N7)	12200	1-Mar-14	730	29-Feb-16	445	19-May-17	1137	29-Jun-20	389	23-Jul-21	336	24-Jun-22	3143
NMX (W1)	11700	1-Apr-14	720	21-Mar-16	366	22-Mar-17	942	20-Oct-19	900	7-Apr-22	700	7-Mar-24	2521
ODIN (S2)	9000	1-Apr-14	1017	12-Jan-17	365	12-Jan-18	730	12-Jan-20	642	15-Oct-21	365	15-Oct-22	3030
BEER (W2)	12000	1-Apr-16	296	22-Jan-17	365	22-Jan-18	730	22-Jan-20	670	22-Nov-21	365	22-Nov-22	2992
SKADI (E8)	12000	1-Apr-16	200	18-Oct-16	365	18-Oct-17	939	14-May-20	1145	3-Jul-23	365	2-Jul-24	2404
DREAM (S4)	12000	1-Apr-16	292	18-Jan-17	365	18-Jan-18	782	10-Mar-20	500	23-Jul-21	365	23-Jul-22	3114
ESTIA (E1)	9000	1-Jul-15	450	23-Sep-16	365	23-Sep-17	813	15-Dec-19	770	23-Jan-22	365	23-Jan-23	2930
C-SPEC (W3)	15000	1-Apr-16	300	26-Jan-17	365	26-Jan-18	800	5-Apr-20	831	15-Jul-22	365	15-Jul-23	2757
HEIMDAL (W8)	12000	1-Apr-16	350	17-Mar-17	455	15-Jun-18	900	1-Dec-20	1000	28-Aug-23	457	27-Nov-24	2256
BIFROST (W4)	12000	1-Apr-16	291	17-Jan-17	455	17-Apr-18	930	2-Nov-20	640	4-Aug-22	365	4-Aug-23	2737
T-REX (W7)	15000	1-Jun-16	365	1-Jun-17	455	30-Aug-18	1095	29-Aug-21	740	8-Sep-23	487	7-Jan-25	2215

NSS: Instruments

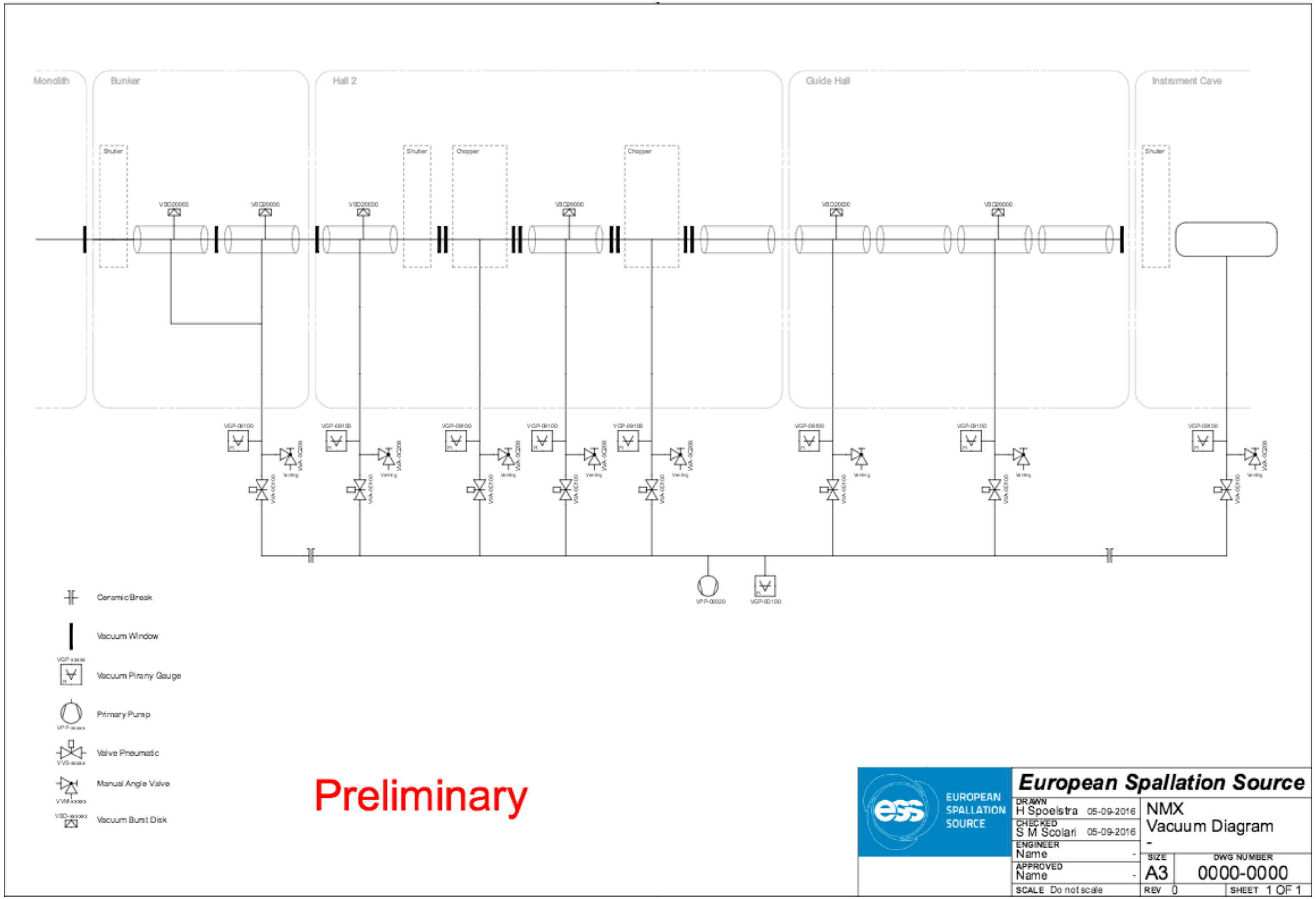


NSS: NMX instrument control diagram

EUROPEAN SPALLATION SOURCE



NSS: NMX instrument vacuum diagram

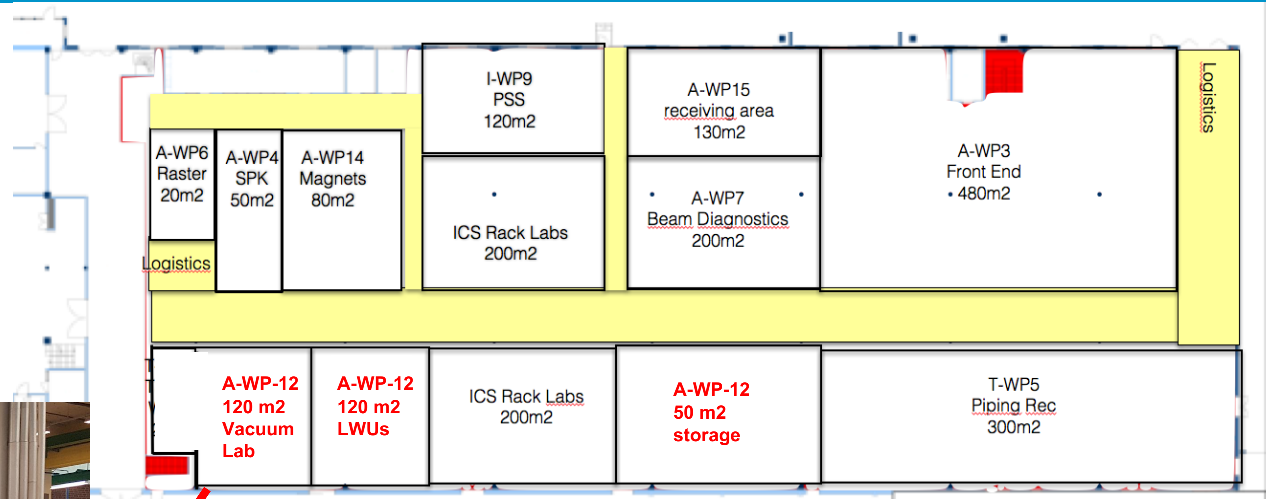


Vacuum support: RATS Receiving/Acceptance test/Storage

EUROPEAN SPALLATION SOURCE

Vacuum in RATS

- Clean room for assembling and testing components,
- Acceptance are for LWUs,
- Assembling area for vacuum chambers,



Clean room Class 5

- Assembling area for Vacuum racks (share with ICS),
- Testing area for portable cleaning rooms,
- Assembling area for LWU Beam Instrumentation,

Vacuum support: Vacuum Laboratory

EUROPEAN SPALLATION SOURCE

Vacuum Integration Test Facility (VITF)

This facility will provide the capability for seamless integration of all vacuum systems used on the accelerator, target and neutron instruments with the ICS (ESS Integrated Control System).

Outgassing Test Facility (MTF)

This facility is designed to support the selection and approval of materials for use in vacuum environment in accordance with the requirements of the ESS Vacuum Handbook. Ex: selection of vacuum compatible cabling, to minimize the contamination of vacuum spaces.

Gauge Calibration Facility (GCF)

The GCF will be used to confirm the operation and calibration of all vacuum gauges and RGAs prior to installation, with calibration performed against a secondary standard.

Vacuum for what?

Why we need vacuum for a particle accelerator?

Why we need vacuum on a SRF LINAC?

Thank you!

Tack!

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Neutron Vision

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