Document Number	ESS-0036590
Date	Mar 18, 2016
Revision	1 (1)
State	Preliminary

Mechanical specifications for the ESS high energy wire scannerMechanical specifications for the ESS high energy wire scanner

This Document is describing the mechanical specification of the Wire Scanner (WS) actuator to be installed in the ESS linac for beam energies above 90 MeV. In total, 8 WS stations will be installed downstream the DTL section to the Target interface

1. INTRODUCTION

Wire scanners have been deployed successfully since decade in accelerator; they represent a conservative choice for beam profile measurement. Their principle is rather simple and consists of moving a wire across the beam while monitoring a signal proportional to the number of particles interacting with the beam, (see Fig. 1).

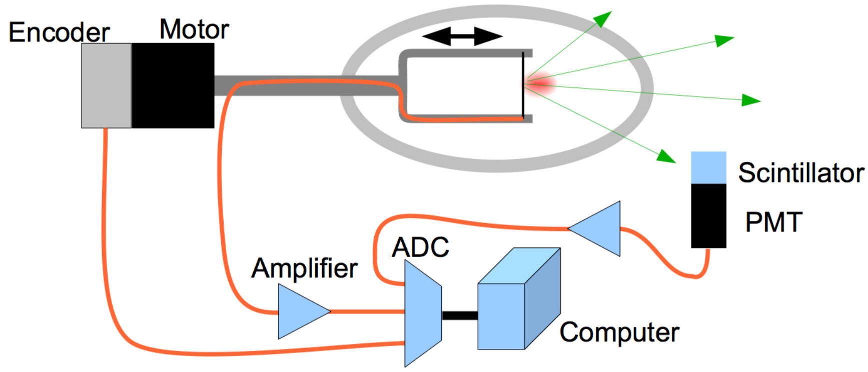

Figure 1 A thin wire is scanned through the particle beam while the secondary emission current, the signal from a calorimeter downstream, and the signal of the motor encoder are acquired simultaneously. Plotting either of the SEM or PMT signals against the encoder gives the beam profile.

The precision of the wire scanner is dominated by two aspects: the precision with which the wire is positioned and the precision of the acquired signal. The major problem in building a wire scanner is to design a solid and stable mechanical support for the wire and an accurate mechanism for the movement. Frequently some sort of encoder or resolver is used to read the position of the wire support (fork).

In the ESS linac[1] and in the transfer line to the target, a number of wire scanners will be installed at different locations. Due to the high power of the beam, the measurement can not be done during the production mode (2.86 ms, 62.5 mA, 14 Hz), the beam power has to reduced in order to preserve the wire integrity. Two beam modes will be dedicated to commissioning and specific beam studies where the insertion of interceptive devices are allowed:

– A slow tuning mode (i.e. 50 µs, up to 62.5 mA, 1 Hz).

---

[1] M. Eshraqi et al., "the ESS linac" THPME043, IPAC 2014, Dresden Germamy

– A fast tuning mode (i.e. 5 μs, up to 62.5 mA, 14 Hz).

At full duty cycle, non-invasive methods (NPM) are the primary choice for transverse profile measurements.

The current layout of the ESS linac is shown in Fig. 2, it can be separated in two sections, a first section composed with normal conducting cavities, a second one with superconducting cavities.

The warm linac will accelerate the beam up to 90 MeV, it consists on an Ion source, a Low Energy Beam Transport line (LEBT), a Radio Frequency Quadrupole (RFQ), a Medium Energy Beam Transport line (MEBT) and a Drift Tube Linac (DTL).
The cold section will be composed by different accelerating structures; the first ones are the Spokes cavities, followed by Elliptical cavities (Medium and High β). The High Energy Beam Transport line (HEBT) has the same periodicity than the elliptical section, and transport the beam to the target.

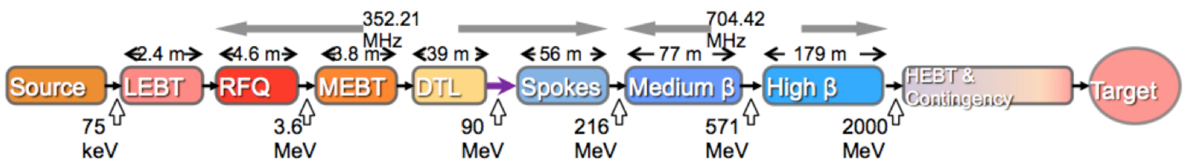

Figure 2 Current ESS baseline (2014)

In the spoke section 3 WS stations will be installed, 4 in the Elliptical (Medium and High β section) and 1 in the Accelerator to Target (A2T) section. The beam pipe aperture is slightly different for each section; nevertheless it is mandatory to have a single design for the actuator and the fork (note that the A2T WS might be an exception).

2. MECHANICAL SPECIFICATION

Downstream the warm linac, the wire scanners will be installed in the Linac Warm Unit (LWU), the design of an elliptical LWU equipped with wire scanner an NPM is shown in Fig. 3.

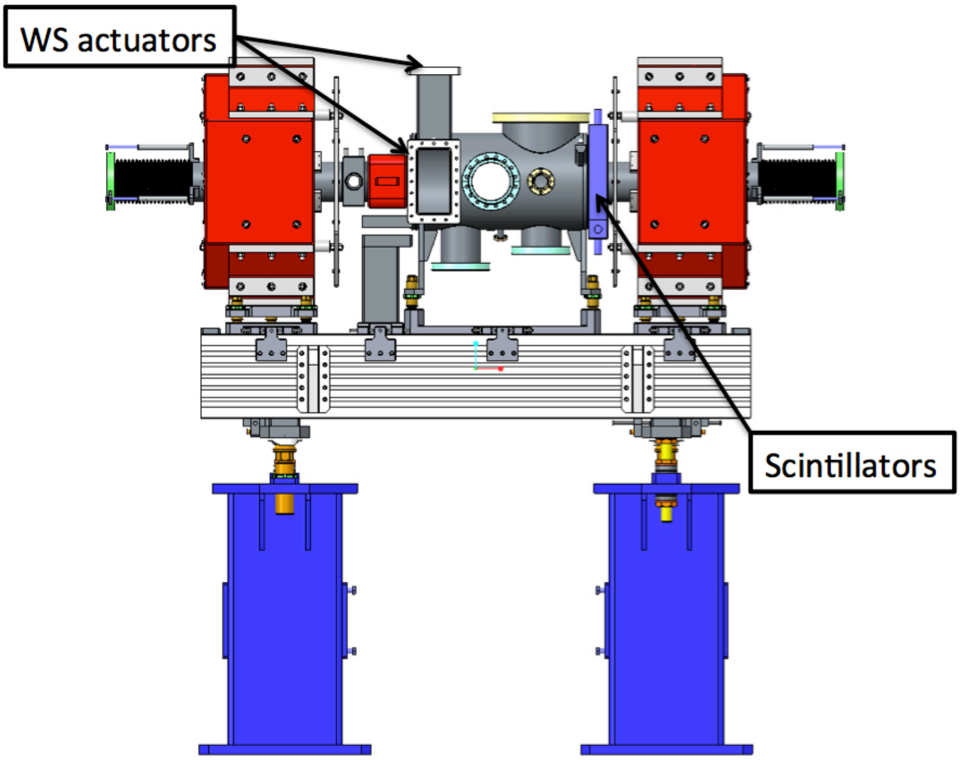

Figure 3 Design of a LWU in the elliptical section to be equipped with wire scanner and NPM (Courtesy of STFC Daresbury Laboratory).

In order to reduce mechanical complications, two separated actuators (one for sampling the horizontal plane and one for sampling the vertical plane) will be used.

2.1. Fork design

All wire scanners shall be equipped with a 40 µm tungsten wire [1] to withstand the beam power and provide enough signal . The aperture of the fork has to be at least equal to the beam pipe aperture (60 mm in the spoke section, 100 mm in the elliptical section). The wire shall intersect the actuator axis with an angle equal to 90± 0.1 degrees.

The electrical connections of the wire shall be able to withstand a bias polarization of the wire up to ± 100 Volts. The signal shall be read form both wire ends, this means to provide 2 feedthroughs per WS actuator mechanical assembly.

2.2. Actuator design

The wire scanner actuator must be designed to sample the beam transverse distributions for each beam position within the beam pipe acceptance (see section on geometric constraints).

As a consequence the full strokes of the actuator must cover 150 % of the beam pipe aperture in order to allow sufficient length to accelerate the wire to the nominal speed requested by the operator. In addition, the two wire scanner forks shall be shifted by few millimetres with respect to a reference plan to avoid collision.

The actuator shall allow the movement of the wire across the full beam pipe aperture at a constant speed and also to move the wire at a predefined position defined by the user. The maximum speed of the wire shall be 10 $mm.s^{-1}$, in order to allow a full scan of the beam pipe aperture in 10 seconds (in the Elliptical section), and down to 100 $\mu m.s^{-1}$.

Hard stops shall be implemented in the design and shall act as mechanical precautions in the case that the actuator does not stop when the limit switches are engaged. These hard stops mainly protect the fork from over travel into the beam line. Additionally, it protects the bellows from over extending or over compressing which may cause tearing and leaks.

2.3. Interface with vacuum chamber

The connection of the WS actuator to the vacuum chamber shall be done with a rectangular conflate flange with a clear aperture equal to 165x82 mm^2. The distance from the flange surface to the theoretical beam axis shall be equal to 300 mm.

The flanges foreseen to connect we wire scanner actuator flanges shall not deviate from an angle larger than ±0.2 degree compared to the reference beam axis in the 3 directions [2]. The total defect due to Machining and positioning of the wire scanner flange tolerances shall not exceed 0.5 mm.

Alignment of the vacuum chamber is not considered in this note.

3. MOTORISATION AND ACTUATION SPECIFICATIONS

The knowledge of the absolute position of the wire with respect to the beam reference axis is not mandatory for beam profile measurement; the “zeros” of each profile distribution can be retrieved with the Beam Position Monitor system (BPM) during operation.

The overall accuracy on the transverse profile reconstruction depends on the knowledge of the transverse positions of the wire with respect to each other; it is mandatory that the wire movement system provides a high precision step by step positioning of the device. The

[2] This applies both to roll and to pitch of the flange.

repeatability of the wire position shall be better than ± 25 μm, a resolver/encoder shall provide this information to the motion control system.

A metrology campaign is mandatory to calibrate the motion controller for easier operation of the wire scanner system. The conversion motor step/millimeter has to be measured and the geometrical center of the chamber has to be converted in number of steps for both wires. These information have to be communicated to the relevant stakeholder and implemented in the motion controller software.

Electrical end switches are necessary to set the wire travel limits and to reset the wire zero position. At the end switches positions the wire shall not be in the beam pipe aperture. It is mandatory to install 2 limit switches at both ends position, one will be use for motion control purposes, and the other one will be connected directly to the Machine Protection System (MPS). “Dry contact” end switches are preferred.

The wire position measurement must be part of an interlock system that forbids the movement of the horizontal (vertical) wire form the parking position when the vertical (horizontal) wire is not in its parking position.

All the component of the motion (including motor, end switches, encoder…) shall be installed outside vacuum. The stepper motor shall be compliant with the NEMA standard and equipped with an electromagnetic brake.

All the components shall be compliant with the ESS standards, a list of standard solutions for motion control component are summarized in [2].

4. INTERFACES WITH ACQUISITION ELECTRONIC

Due to the low intensity signal, the connection of the wire to the acquisition system shall be deigned carefully, in particular the signal cable and the grounding of them. The concept of the Analog Front End (AFE) designed by Elettra Sincrotrone Trieste is shown in Fig. 4 [3], a particular attention has been paid to solve the grounding issues and the mechanical design of the WS shall reflect this.

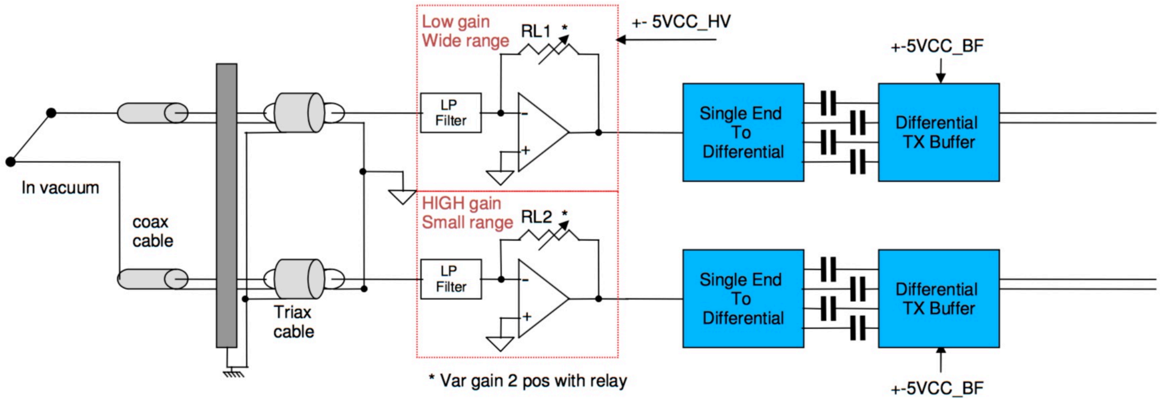

Figure 4 Simplified Block Diagram for AFE (courtesy of R. De Monte et al. Elettra)

Tri-axial electrical components are mandatory for detecting low level electrical currents or voltage signals. An example of a TRIAX vacuum feed-through mounted on a CF16 flange is shown in Fig. 5.

Figure 5 CF16 flange with Triaxial feedthrough with both connectors (LEMO) on vacuum and air side

In order to facilitate the cable installation and to have a clear interface between the different partners involve on the WS design, a standardized patch panel for the WS application is proposed by ESS (see Fig. 6). The proposed model assumed that all the cable of both actuator of a WS station would be aggregated to a single patch panel, with the AFE install on the panel. The design can be modified to meet the space constraints or other design parameters; one other option is to install a simpler patch panel (red box on the figure) on the actuator itself.

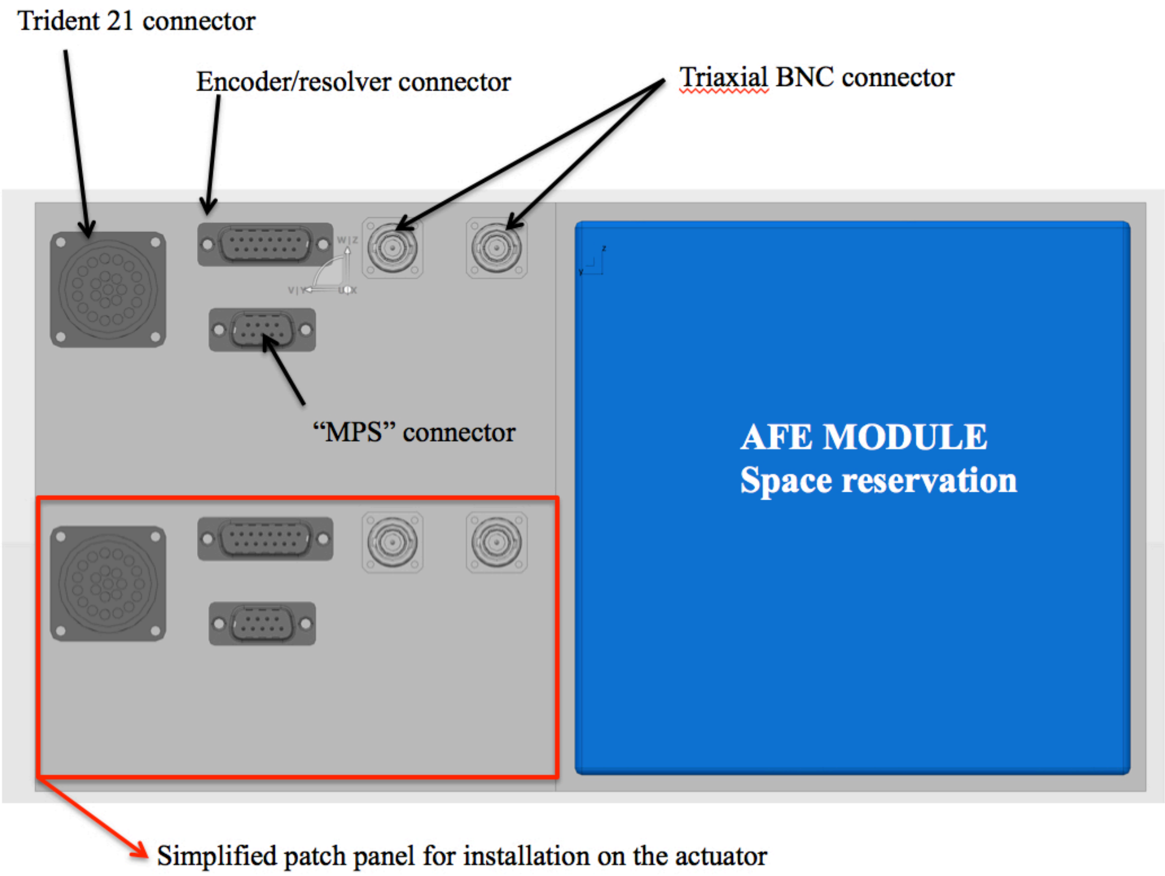

Figure 6 Preliminary concept of the WS patch panel for an installation on the LWU. The blue square represents the space allocation of the AFE module, the red box is showing the minimum connectors suit for a single WS actuator.

The connectors on the patch panel define the interfaces. Note that at this preliminary stage of the design the panel dimension and the exact position of the connectors might change. The final design shall be done according to the final position of the AFE, the position shall be chosen in order to prevent to high radiation damage of the electronic, ESS ERIC shall provide this information to the relevant partners.

The preliminary list of connectors and signal type on the simplified patch panel is:

- A trident 21 connector for:
  - ✓ Motor power
  - ✓ Limit switch for the motion controller

  - ✓ Brake control
- 2 triaxial BNC connector:
  - ✓ For SEM signal readout from both end of the wire.
- A 15 pin D type connector
  - ✓ For resolver/encoder control. For preliminary design, it is assumed to use the same linear optical encoder as the MEBT WS (RENISHAW LM10 type)
- A sub-D type connector to be defined
  - ✓ For the connection to the MPS

5. VACUUM REQUIREMENTS

All material used for the wire scanner fabrication shall be compliant with the ESS vacuum group specifications [4]

In particular, the ESS vacuum group shall approve all the material used for the wire scanner fabrication. A list of approved material can be found in the ESS Vacuum handbook “General Requirements for the ESS Technical Vacuum System”. All materials not approved for use in vacuum per ESS Vacuum Handbook are to be submitted to the ESS Vacuum Team for approval. No non-metallic materials are not to be used unless tested and approved by the ESS Vacuum Team. Materials used shall be non-particle generating.

ISO bakable knife-edge flanges (rectangular Conflat style - CF) are the preferred type for high vacuum and UHV applications. Metal seals shall be OHFC copper.

For wire scanner installed in the Spokes and Elliptical section, the vacuum part of the system has to be compliant with the standard ISO2/3 for clean room.

All parts have to be cleaned and prepared in accordance with the requirements of the ESS Vacuum Handbook and particle free (ISO 3 or better). Packaging for shipment should reflect this requirement.

6. GEOMETRIC CONSTRAINTS-SUMMARY

The following figure summarized the geometric constraints for the wire scanner actuator.

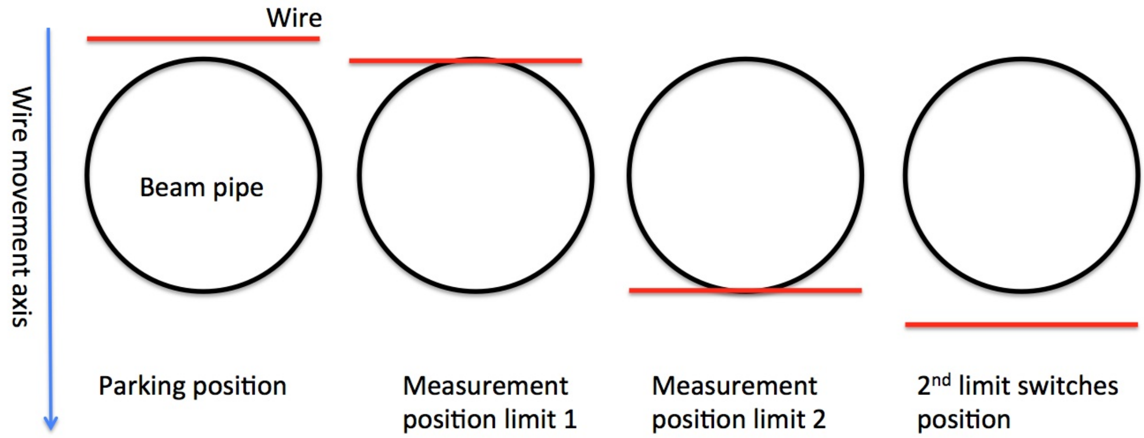

Figure 7 Wire scanner actuator geometric constraints.

The relevant parameters for the wire scanner design are summarized in Tab.1.

	Spoke	Elliptical	A2T
Maximum speed [mm.s-1]	10	10	10
Minimum stroke [mm]	150	150	150
Position repeatability [µm]	< ±25	< ±25	< ±25
Fork aperture [mm]	>100	>100	>100
Wire material	Tungsten	Tungsten	Tungsten
Compilant with ISO2/3 clean room	yes	yes	no

Table 1 Parameters relevant for wire scanner mechanical design

7. REFERENCE

[1] B. Cheymol, "ESS wire scanner conceptual design", ESS note ESS-0020237
[2] "Motion control components standard for ESS applications" ESS-0037290
[3] M. Ferianis, S. Cleva R. De Monte and S. Grulja "Document package for the WS Preliminary Design Review" ESS-0064476
[4] "ESS Vacuum Handbook", Part 1-4, ESS-0012894, ESS-0012895, ESS-0012896, ESS-0012897