ESS ELLIPTICAL CRYOMODULE:
DESIGN PRINCIPLES AND ASSEMBLY

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With material provided by the ESS ECCTD team

PIP-II Cryomodule Design Advisory Meeting
Fermilab – October 2018
European Spallation Source (ESS) is under construction in the city of Lund, in southern Sweden. ESS will offer neutron beams of unparalleled brightness for cold neutrons, delivering more neutrons than the world’s most powerful reactor-based neutron sources today, and with higher peak intensity than any other spallation source.

ESS Cold Linac: a collaborative project.

- **Source** (75 keV)
- **LEBT**
- **RFQ**
- **MEBT**
- **DTL**
- **Spokes**
  - **Medium β** (216 MeV)
  - **High β** (571 MeV)
  - **Contingency** (2000 MeV)
- **Target**

**April 2018**

N. Bazin – PIP-II 650 MHz Cryomodule Design Advisory Meeting – October 2018
ELLIPTICAL CRYOMODULE MAIN FEATURES

- 704 MHz, 3.6 ms RF pulse at 14 Hz
- $E_{acc} = 16.7$ MV/m (MB) and 19.9 MV/m (HB) ($E_{peak} = 40/44$ MV/m)
- $Q_0 > 5 \times 10^9$ at 2 K
- Fundamental power coupler: 1.1 MW peak, 55 kW avg.
  - $Q_{ext} = 7.5 \times 10^5$
  - Coaxial type, single window, fixed coupling
- Mechanical slow tuner (600 kHz range, 1 Hz resolution)
- 1+1 Piezo fast tuner
- No HOM couplers

- Segmented design
- Spaceframe concept
- Similar design for medium and high beta cavities
Common design for medium and high beta cryomodules:

- Made sensible thanks to the small length difference between 6-cell medium and 5-cell high beta cavities
- Main components are identical: vacuum vessels, thermal shields, supports, spaceframes, alignment system …
- Only few elements differ: details in cryo piping, beam pipe bellows
- Same assembly tooling
ESS MEDIUM BETA ELLIPTICAL CAVITIES CRYOMODULE
ELLiptical Cryomodule

- 50K Thermal shield (aluminium)
- Trap door (CTS access)
- Hanging rods
- Positioning jacks (3 at 120°)
- Coupler
- Positioning optical devices
- Biphasic He pipe
- Vacuum vessel (stainless steel)
- Space frame (290K)
- Guide rail and wheel
- Door knob and RF wave guide
Spaceframe jacks adjustment

Port for alignment

Fiducial for alignment

Trap doors for tuning system maintenance

Stiffeners

Supports

One flat door at each extremity

Rail for spaceframe insertion

Port for instrumentation
Role of the spaceframe

- Supports the cavity string
- Key element for the alignment of the string → deformations along the assembly process shall be controlled

- Stays at room temperature → no deformation due to thermal shrinkage
- Made of aluminium
- Each cavity are attached to the spaceframe thanks to eight rods
- Preloading in the rods → no motion of the cavity in transverse direction during cool down (more details in Gilles’ presentation)
Axial position of each cavity is fixed during the assembly (use of temporary rods of temporary rods removed after the insertion of the cold mass inside the vacuum vessel)

- Plates fixed on the coupler flange and the vacuum vessel set the axial position but allow a vertical motion of the coupler (needed for the thermal contraction while cooling)
The aim of the device is to limit the load on the cavity flange while pumping and cooling (1 ton if nothing done).

A pre-stress is performed by means of 3 heavy load springs (3 x 172N/mm). A stop rod device (x3) avoids any force on the coupler flange during this operation.

The vacuum pressure is applied to the bellows flange (Dext 360mm)

Due to the cooling, the thermal shrinkage of the coupler (0,5mm) induces both the lifting of the lower parts of the RF line (coaxial line and door-knob) and a compression of the springs.
After insertion inside the vacuum vessel, the complete assembly is positioned by means of 3 mechanical jacks (2+1) located at the 2\textsuperscript{nd} and 7\textsuperscript{th} rings.

After positioning of the whole assembly, the spaceframe is blocked by means of 9 transversal jacks (2\textsuperscript{nd}, 5\textsuperscript{th} and 7\textsuperscript{th} rings) and fixed to the vacuum vessel using 4 brackets (3\textsuperscript{rd} and 5\textsuperscript{th} rings).
ALIGNMENT PHASES

PRELIMINARY SURVEY OF WORKING AREAS

DATA IMPORT AND STORING

CAVITY STRING ALIGNMENT

COLD MASS ALIGNMENT INTO VACUUM VESSEL

MODULE FINAL SURVEY AND DELIVERY

CAVITY STRING ALIGNMENT INTO SPACE FRAME

More details in Gilles’ presentation
ASSEMBLY PROCESS

Introduction and temporary hanging of the thermal shield inside the spaceframe

Introduction of the cavities assembly inside the spaceframe

Hanging of the rods to the spaceframe
Cross positioning of the cavities
Hanging of the thermal shield to the rods

USE OF RAILS SYSTEM (not shown)
Multi-layer insulation not shown

Introduction of the spaceframe inside the vacuum vessel (internal rail on the vessel, wheel on the spaceframe)

Positioning of the whole assembly inside the vacuum vessel by means of jacks
• First validation of assembly toolings and assembly procedures
• Integration until the vacuum vessel
- Performed in the ISO4 Saclay clean room
- Nitrogen venting during assembly process
- XFEL type aluminium gaskets
- Cavities pre-aligned
- Welding of the titanium diphasic line
- Assembly of the MLI, magnetic shields, cold tuners and cryogenic piping
• Adjustement of the tie rods to meet mechanical axis alignment specifications
INSERTION OF THE COLD MASS INSIDE THE VACUUM VESSEL
INSERTION OF THE COLD MASS INSIDE THE VACUUM VESSEL

- Jumper connection assembly
- Cryogenic connections at the cryomodule extremities
- Leak check of all the cryogenic circuits
- Closing the vacuum vessel
Experience has been acquired during the assembly of the medium cryomodule prototype by the ESS ECCTD team leading to some improvements of some parts and steps of the assembly process.

More experience will be acquired with the assembly of the series cryomodules and the testing of several cryomodules.

This experience will be very useful for the design of the PIP-II 650 MHz cryomodules if spaceframe is chosen.