Summary of the technical specification of the Cryogenic Stopping Cell of the Super-FRS

Deliverable

- The contractor shall deliver the complete CSC assembly consisting of:
- Integrated nested aluminum vacuum chamber system (cold chamber inside warm chamber)
- Removable titanium beam window assemblies on both ends (cold and warm sides) (4 units assembled and 8 units spare)
- Complete sealing system for all main flanges (20 spares for cold flanges, 10 spares for warm flange)
- Top flange assemblies including all media and electrical feedthrough interfaces
- Internal suspension system for the cold chamber
- External structural support frame
- Integrated lifting and transport interfaces
- Pressure protection components (if required by PED assessment)
- All mechanical fastening and sealing hardware
- Interfaces for maintenance lifting table

Mandatory Qualifications of the Contractor

- Proven experience with structural simulations in accordance with AD2000 or EN 13445, including acceptance by a notified body (third-party certification) for components exceeding 3 meters in length.
- Demonstrated experience in ultra high vacuum (UHV) applications, including the design and fabrication of custom-made metal flanges with lengths of at least 3 meters.
- Demonstrated experience in high-vacuum applications and cryogenic systems.
- Proven experience in the design, welding, and machining of aluminum vacuum chambers with lengths exceeding 3 meters.

Summary of requirements

System Overview

The CSC is a large-scale cryogenic vacuum system designed to thermalize high-energy ion beams. The system operates at cryogenic temperature (70–130 K) and pressure of 300 mbar of helium gas. In idle it stays under ultra-high vacuum. The system consists of nested rectangular aluminum vacuum chambers with integrated beam windows, suspension, and support frame.

Contractors are expected to:

- Propose and implement technically viable manufacturing and sealing solutions.
- Demonstrate compliance with mechanical, vacuum, and thermal requirements.

This is not a build-to-print project. The contractor is fully responsible for:

- Design and engineering (3D model, mechanical calculations, thermal calculations, and detailed engineering drawings)
- Production planning and project management
- Manufacturing and fabrication
- Quality assurance (inspection and test plan, handling instructions, risk assessment)
- Testing (vacuum testing and mechanical survey)
- Packaging and shipping

Key technical challenges:

- Large rectangular aluminum vacuum chambers with cryogenic operation at 70 K
- Leak-tight sealing over ~6 m perimeter under repeated thermal cycling (70-380 K)
- Combined requirements of UHV performance, flexibility of maintenance and mechanical rigidity

Overall constraints

GSI will provide a conceptual CAD model, and the definition of all required interfaces. The general information necessary for cost estimation is provided below.

- Total mass of the system excluding lifting table: <3 tons
- Maximum footprint (including frame): length < 2.9 m, width ~1.3 m
- System must be transportable without the crane through restricted paths (elevators / labyrinths)
- UHV performance
- Bake-out capability (up to 380 K)

Rectangular vacuum chambers: specifications and materials

Cold chambers:

- The dimensions envelope is ~2500 x 900 x 600 mm.
- Material: Aluminum, preferred alloy is 6061-T6.
- Operating conditions: maximum allowable pressure 1050 mbar (absolute), from room temperature to 70 K

Warm chamber:

- The dimensions envelope is ~2500 x 1000 x 800 mm.
- Material: Aluminum (same as for cold chambers).
- Operating conditions: maximum allowable pressure 1050 mbar (absolute), room temperature

Beam windows. Both chambers require removable beam windows on both ends. A beam window is a titanium foil (~ 400 x 150 mm) with thickness of ~100 micrometers welded onto a flange.

Regulatory Compliance and PED Assessment

The contractor shall perform a formal assessment of PED applicability and classification. Where required, the contractor shall ensure full compliance, including CE marking, notified body involvement, and implementation of appropriate pressure protection measures.

Flanges and sealing solution

Machining tolerances and surface roughness requirements will be driven by vacuum sealing and cryogenic contraction considerations. Contractors are expected to propose achievable tolerances consistent with the sealing solution.

- Sealing and Vacuum Integrity Requirements
  - The sealing solution shall ensure an integral helium leak rate of $\leq 1 \times 10^{-9}$ mbar·L/s, measured at room temperature using a calibrated helium mass spectrometer leak detector.
  - Leak testing shall be performed after final assembly and after any thermal cycling.
  - For cold chambers, vacuum integrity shall be maintained at 70 K and during thermal cycling between operating temperature and bake-out temperature.
  - All sealing materials shall withstand repeated thermal cycling up to 400 K (~100°C) for bake-out and cleaning without degradation.
- Mechanical and Thermal Compatibility
  - The sealing solution shall be suitable for large rectangular flanges with sealing perimeters of approximately 6 m.
  - Seals shall be compatible with aluminum or bimetallic flanges, considering thermal contraction and surface hardness.
  - The design shall preferably allow direct flange-to-flange contact to ensure efficient conductive cooling from the top flange to the chamber body.
  - Seals shall be replaceable or resealable in a restricted-access environment.
- Interfaces
  - All media and electrical connections shall be routed through the top flanges of the warm and cold chambers to facilitate maintenance.

Support structures and frame

Suspension system:

The cold chamber is suspended from the top flange of the warm chamber. The suspension system must minimize heat input while maintaining structural integrity. This system is designed to be rigid, however, motion within a few millimeters is tolerable.

Frame:

- The frame must support a total estimated mass of 5 tons.
- The frame must allow for the dismounting of feet to facilitate transport through restricted paths (e.g. elevators).
- The complete system including the frame must be <2.9 m (L) x ~1.3 m (W). The height must ensure that the beam axis is at the height of 2 m.

Maintenance equipment (Lifting table)

A scissor-style lifting table is used to lower and raise the vacuum chamber bodies for maintenance. It is also used for transporting the complete assembled CSC through restricted paths (elevators/labyrinths).

- The table must support a total estimated mass of 5 tons.
- Connection/lifting points must be integrated into the design of the vacuum chambers and frames