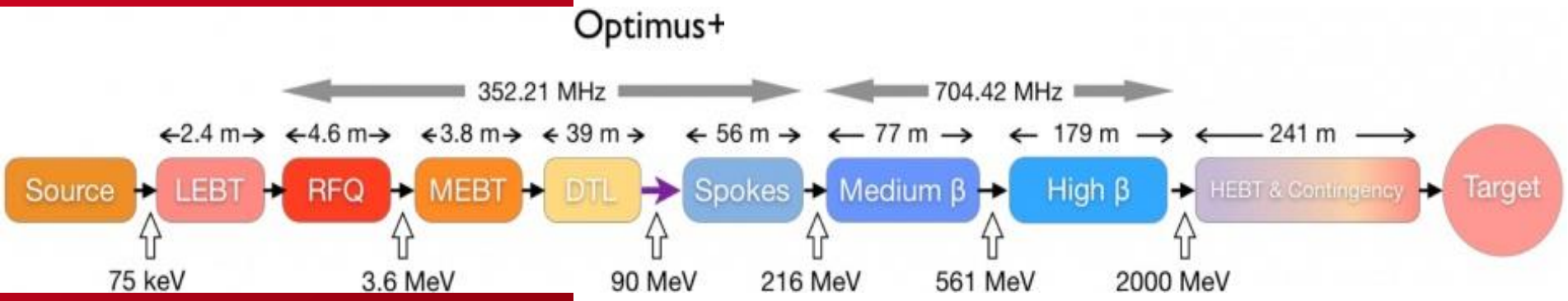
DE LA RECHERCHE À L'INDUSTRIE

CEA – Saclay

EUROPEAN SPALLATION SOURCE

RFQ



CONTENTS

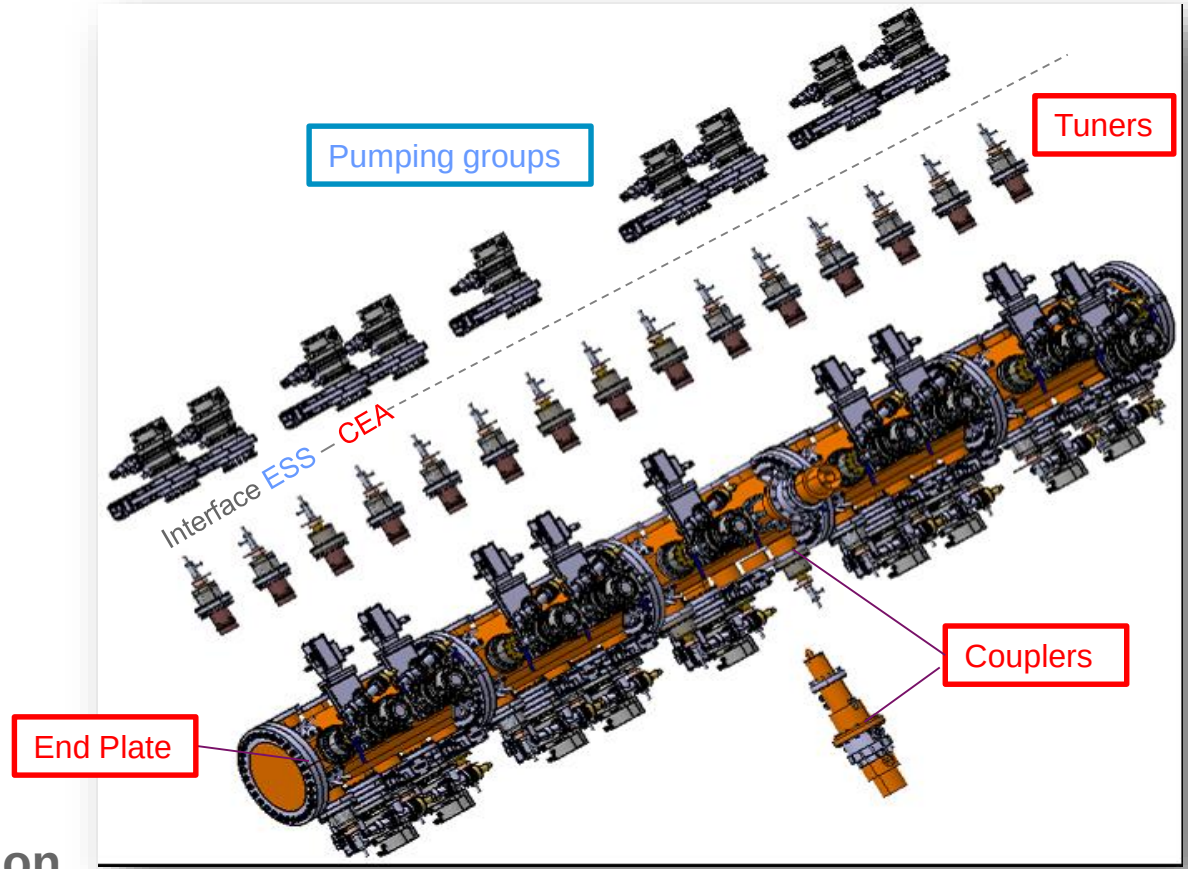
CEA – Saclay

EUROPEAN SPALLATION SOURCE

DELIVERABLES AND SCHEDULE

ESS RFQ – CEA DELIVERABLES

- **RFQ** including support for the tunnel, ready for conditioning phase
- **Tuners**
- **RF coupling loops**
- **Pickups**
- **In/out end-plates**
- **Cooling system**
  - SKID
  - Water manifolds
- Part of the **RF distribution**
  - Waveguides, load, magic Tees, transitions et bidirectional couplers



ESS RFQ DELIVERABLES

CEA ESSI is in charge of RFQ delivery, including

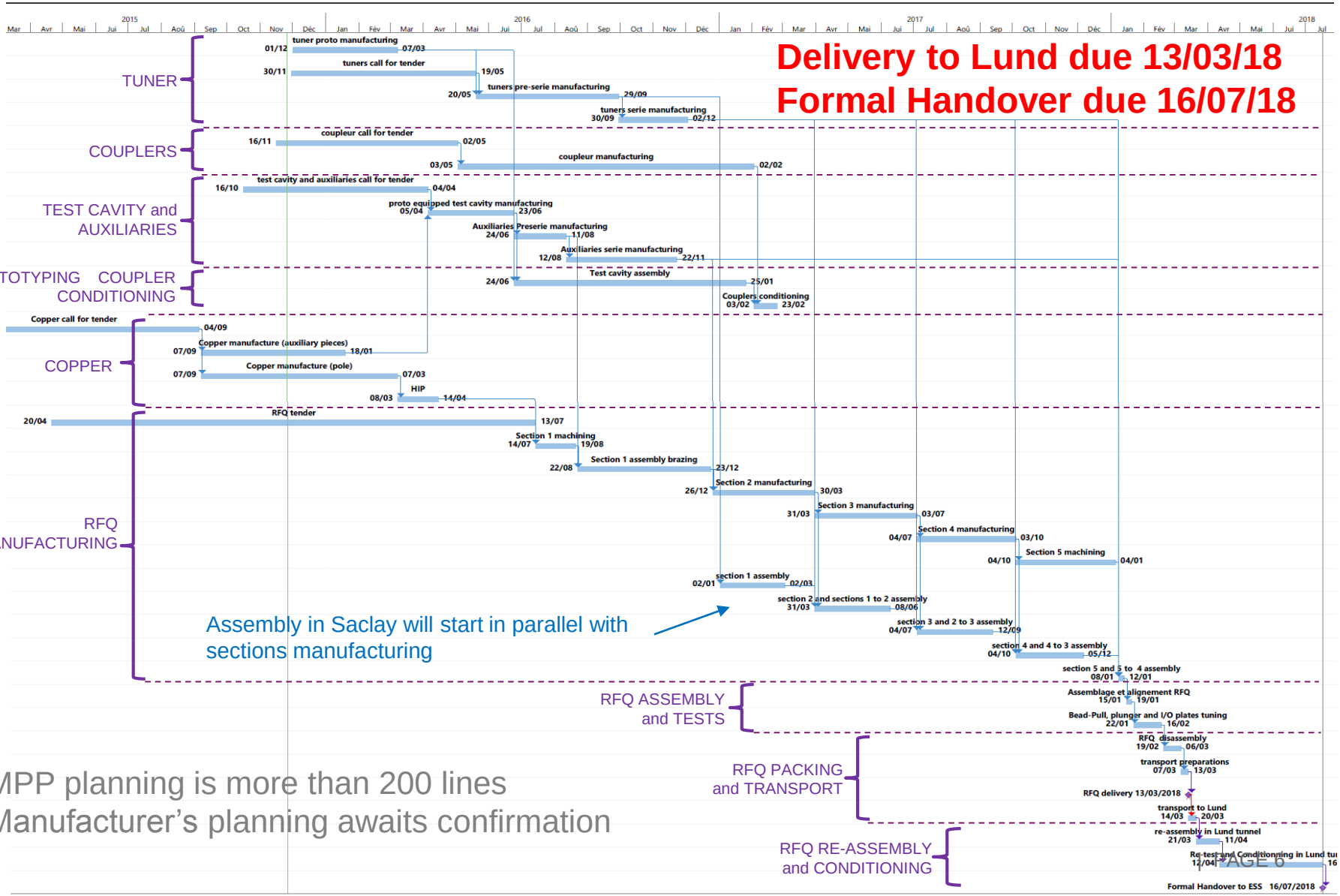
- Preliminary validation of assembly, at Saclay
- Packaging of individual RFQ sections, ready for transportation
- Assembly on site, ready for conditioning

CEA ESSI is in charge of conditioning operations at Lund

ESS deliverables to CEA :

- Vacuum system and its control system
- RFQ control system
- Adequate environment and RF system
- Part of RF distribution
- Piping between SKID and RFQ
- Inputs for the external interfaces
- Transportation based on requirements provided by CEA
- Start of the vacuum system

TIME SCHEDULE

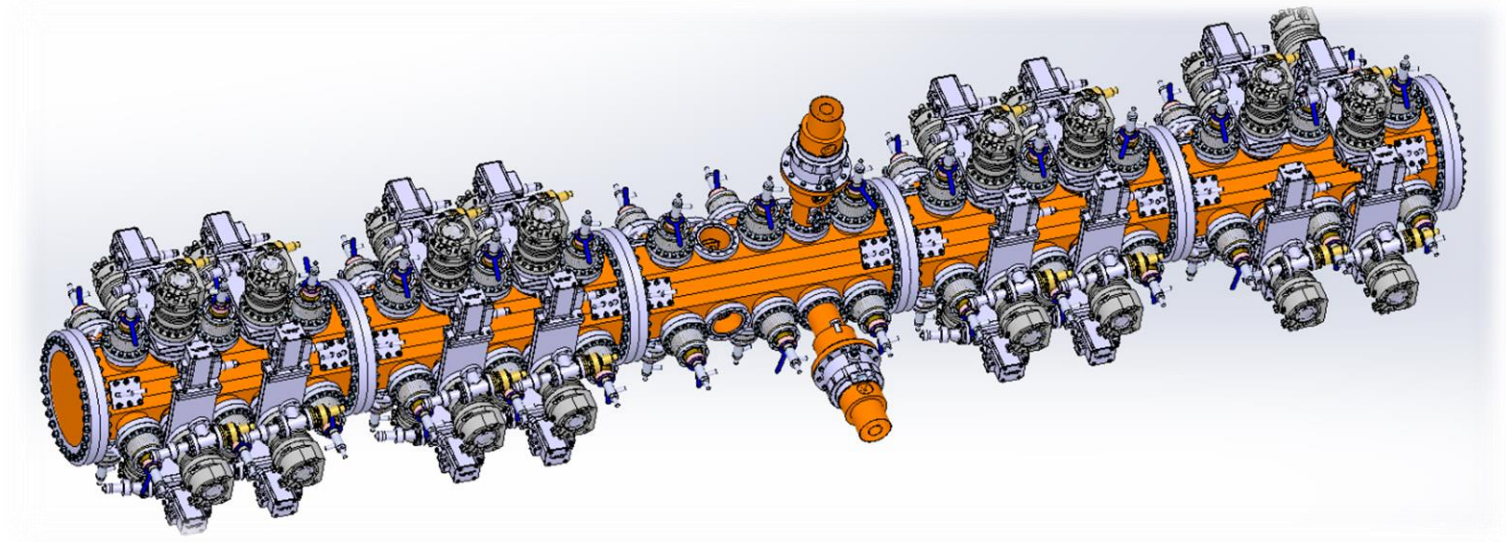


MPP planning is more than 200 lines
Manufacturer's planning awaits confirmation

EUROPEAN
SPALLATION
SOURCE

RFQ OVERVIEW

PHYSICAL DESCRIPTION



Requirements:

Accelerate 70 mA of protons from 75 keV to 3.6 MeV

Frequency 352.21 MHz

Pulsed operation at 4% dc

Transmission > 90%

Beam quality: $\Delta\varepsilon_{trans}$ = < 5%, ε_{long} < 0.15 π.deg.MeV

Limitations: K_p < 1.9, P_{RF} < 1.6 MW

Design features:

RFQ realized in 5 sections (L = 0.92 m); total length = 4.58 m

CuC2 copper and stainless flanges

38 vacuum ports (2×4 in S1-S2-S4-S5)

60 adjustable slug tuners (3×4 in S1-S2-S3-S4-S5), 80 mm dia.

8 end-tuning rods (4 per end plate)

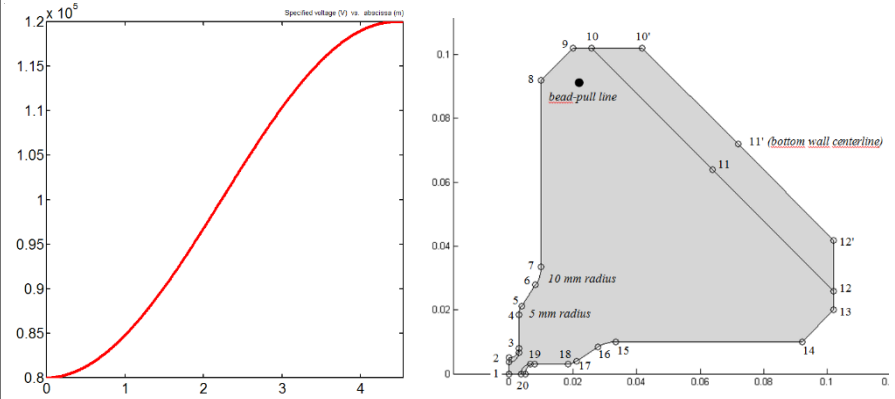
8 10mm-diameter cooling channels per section (variable length)

2 power coupling loops (S3)

20 pickups for voltage profile reconstruction

MAIN RF PARAMETERS

Variable position of quadrant bottom wall, to achieve a variable voltage profile



Naturally stable with chosen length to wavelength ratio:

Eigen-modes closer to accelerating mode:

Q_1 at +1.65 MHz, D_2 at –5.25 MHz, D_3 at +2.67 MHz,

to be compared to

Δf_{3dB} = 0.103 MHz (theoretical design, all tuners recessed)

Δf_{3dB} = 0.186 MHz (max copper losses, all tuners in)

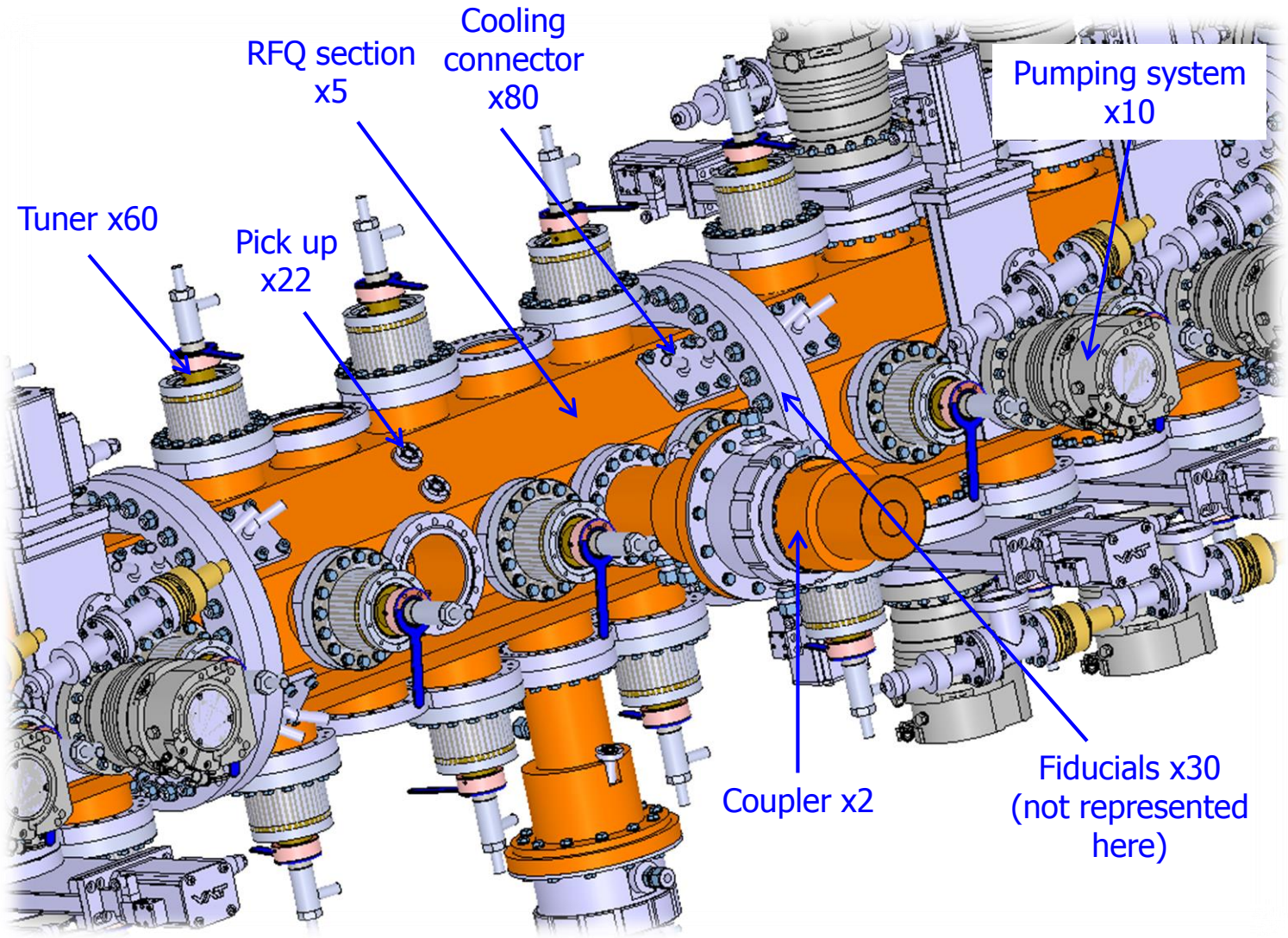
Error analysis:

- compensation of construction errors:
  - sixty 80 mm dia. slugs, 60 mm tuning range
- stability under operation:
  - water flow alternated from one section to the next
  - optimized position of channels
  - voltage variation < 0.1% for a freely expanding RFQ
  - 20 voltage monitoring pickups

Two RF power-coupling loops

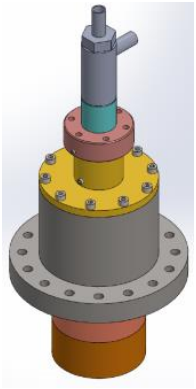
P_{Cu}	713 kW	→	1375 kW
Q_0	7891	→	4092
Q_L	3408	→	1891
β	1.316	→	1.164
Γ_0	–17.3 dB	→	–22.4 dB

RFQ PARTS


RFQ section
x5
Cooling
connector
x80
Pumping system
x10
Tuner x60
Pick up
x22
Coupler x2
Fiducials x30
(not represented
here)

SLUG TUNERS

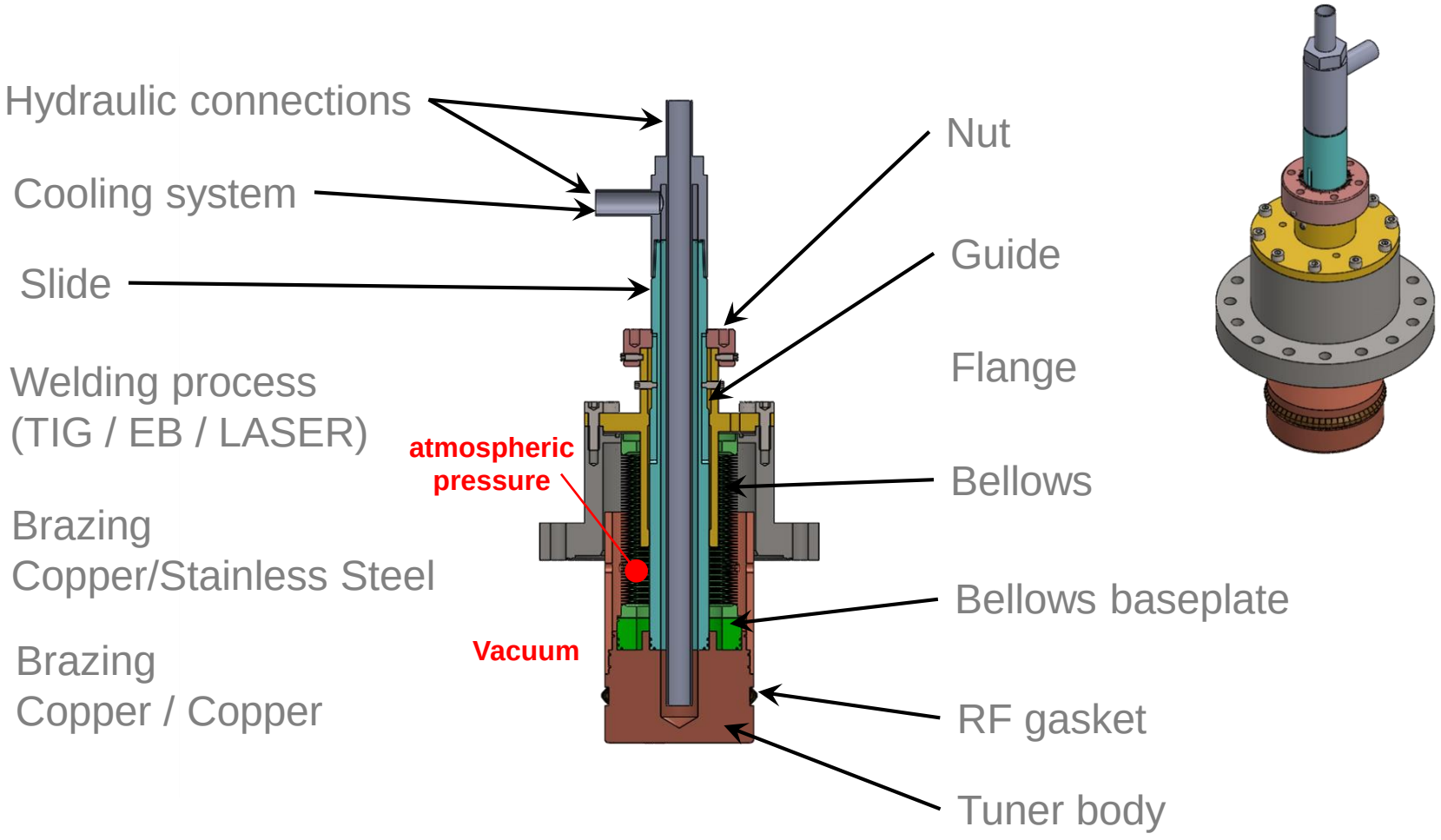
IPHI → ESS



- Adjustable slugs used for RF tuning
- All operational copper tuners share the same length
- Correct position is achieved with machined shims
- Drawbacks:
  - adjustable and operational slugs are not strictly electrically identical
  - machining delay between adjustment and operation
  - no possible readjustment (after vacuum test, for example)

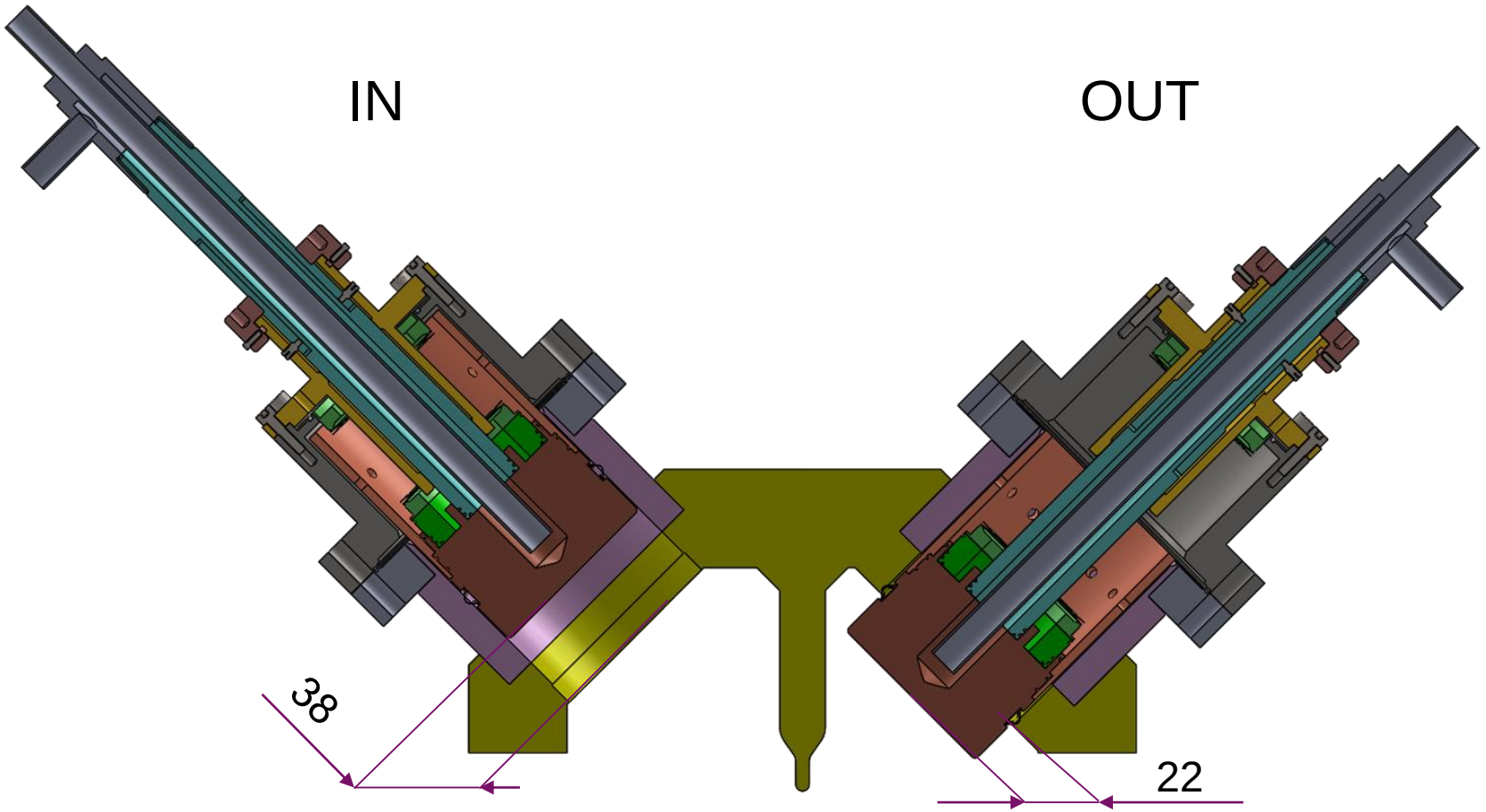
- Adjustable tuners used for tuning and operation
- Same electrical properties during adjustment and operation
- Definitive position just after adjustment
- No delay for machining between adjustment and final position
- Adjustment possible in operation or after a transport

SLUG TUNER CURRENT DESIGN



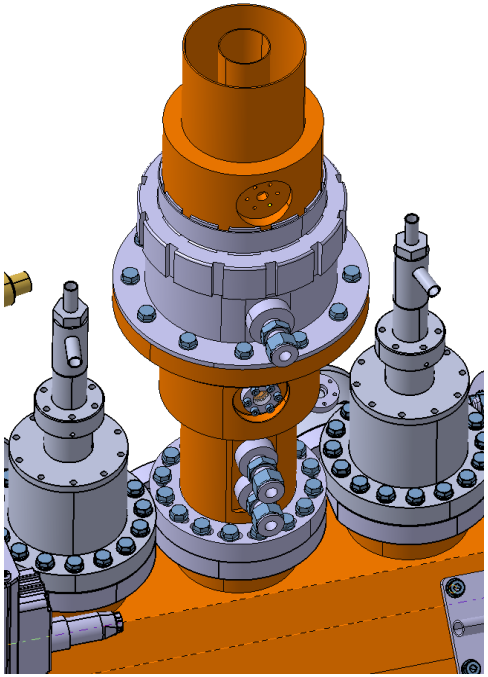
SLUG TUNER POSITION RANGE

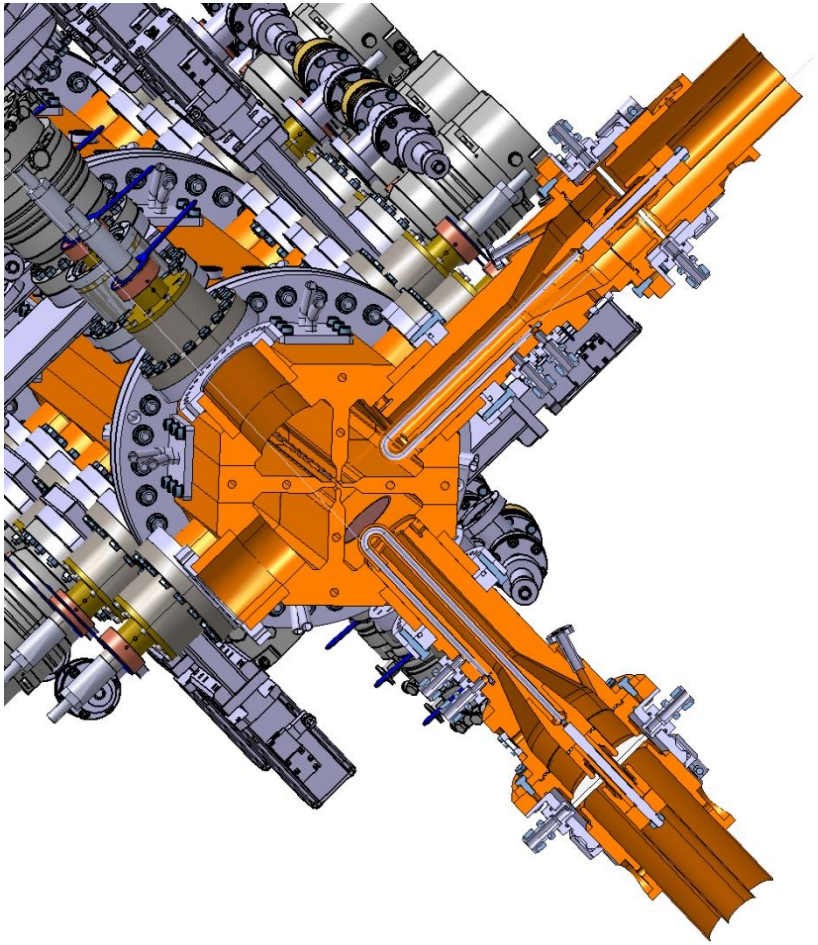
Position range = 60mm



RF COUPLER DESIGN

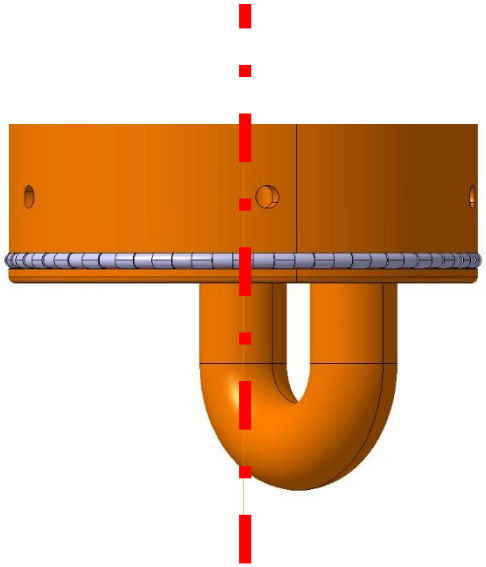
- 2 coupling loops and 2 slug tuners in Sect. 3
- couplers include cooling, vacuum window, gauges, ...
- voltage tuning is performed with dummy parts in place of loops and slugs. Then loops are inserted, and slug are adjusted to compensate induced voltage error.

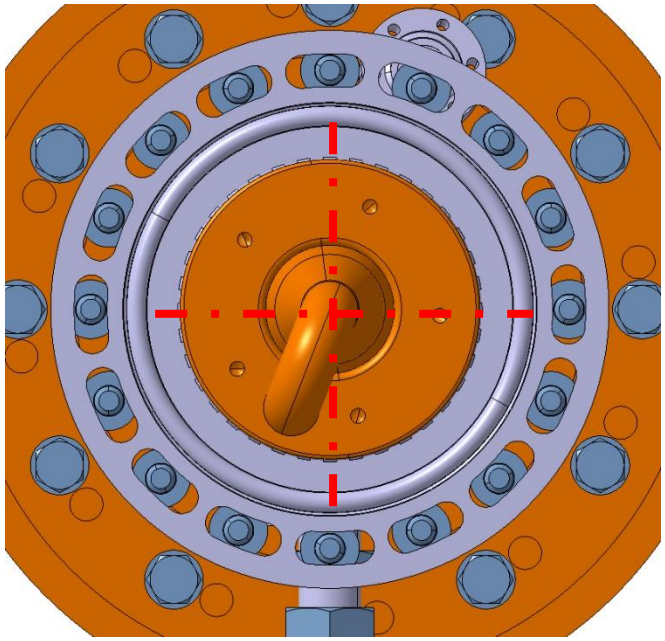




RF COUPLER TUNING

- Coupling performed by rotating the coupler arround its rotation axis
- Specific flange allowing rotation without systematically removing the screws
- Vacuum thightness obtained with adequate O-rings

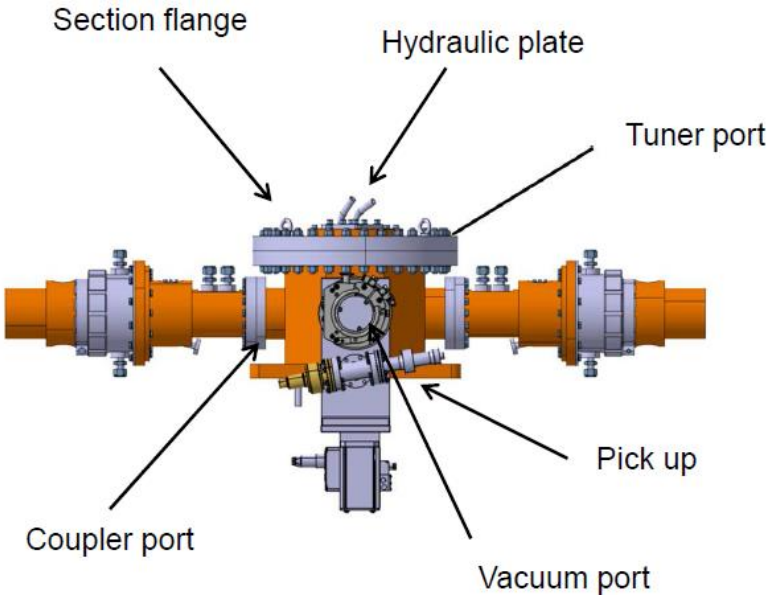


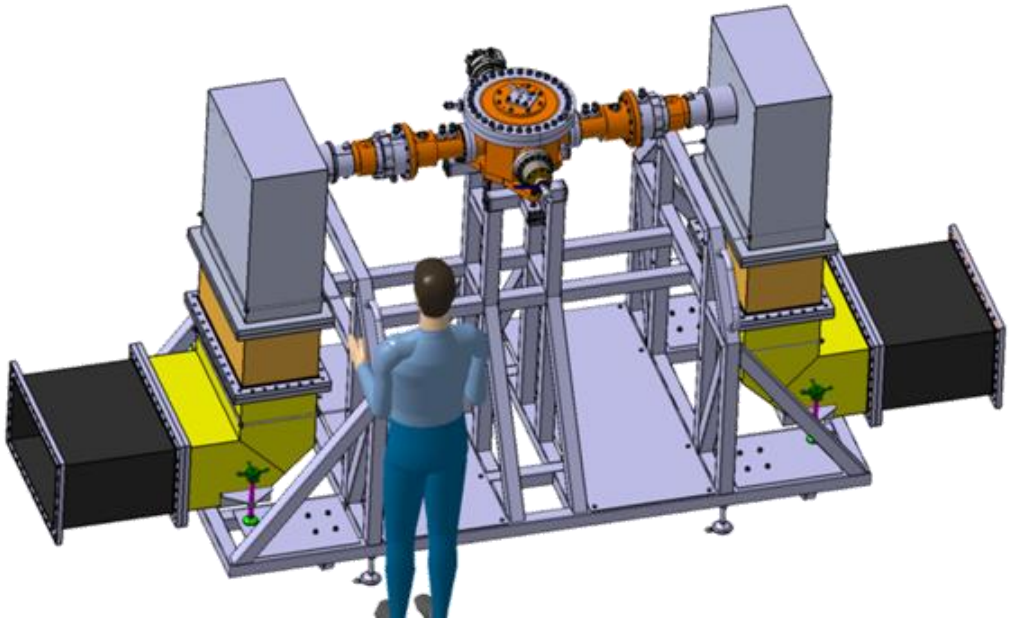


RF COUPLER TEST BENCH

Three simultaneous goals:

- RF coupler conditionning
- Brazing process validation
- RFQ interfaces validation





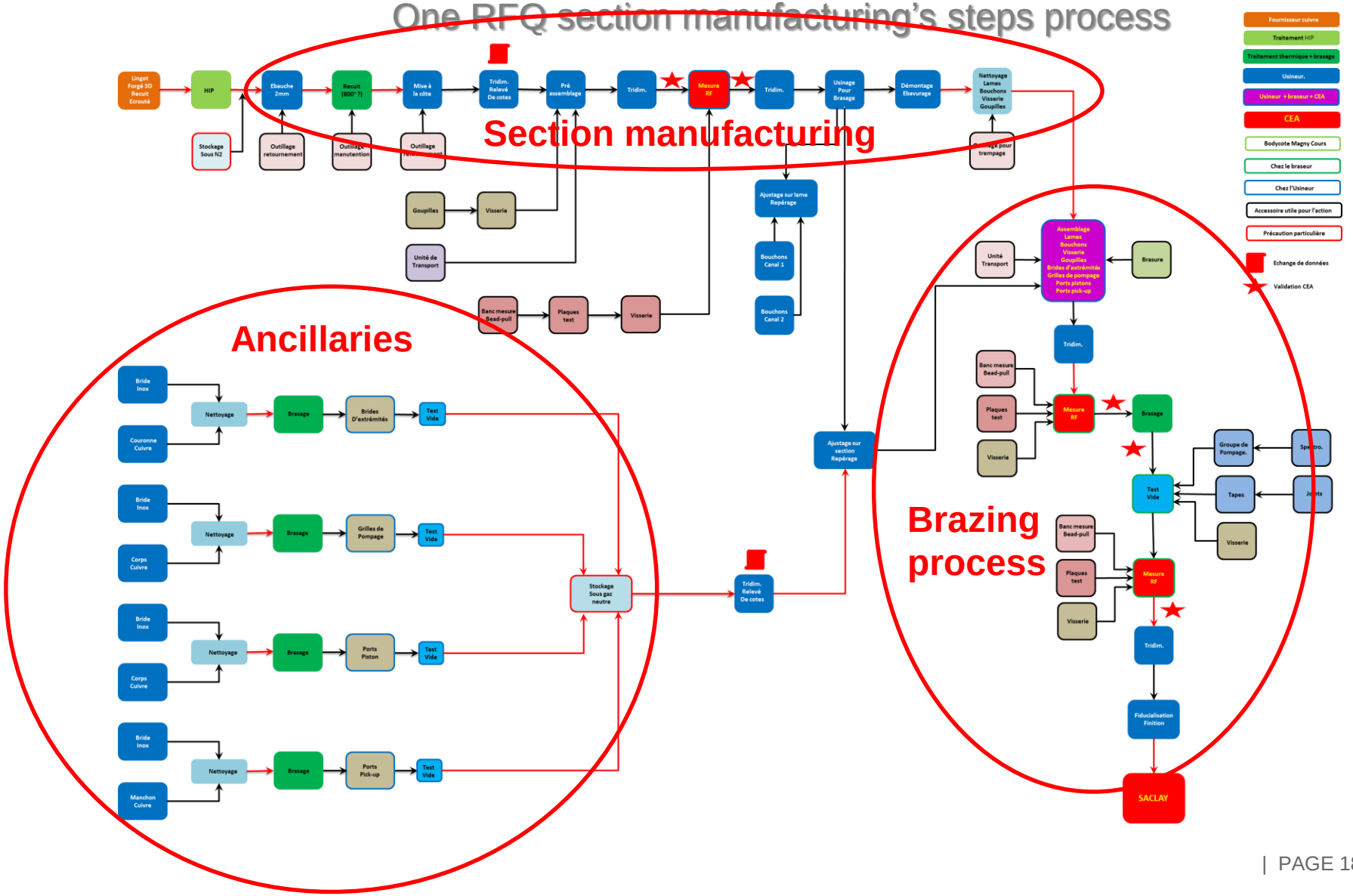
CEA – Saclay

EUROPEAN SPALLATION SOURCE

MANUFACTURING

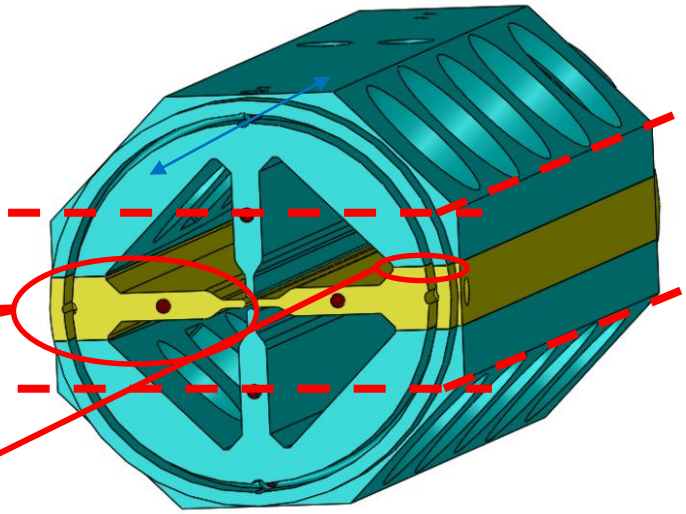
MANUFACTURING FLOW CHART

One RFQ section manufacturing's steps process

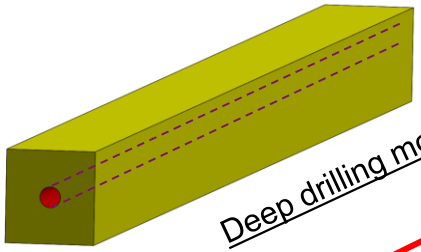


Manufacturer and process validation

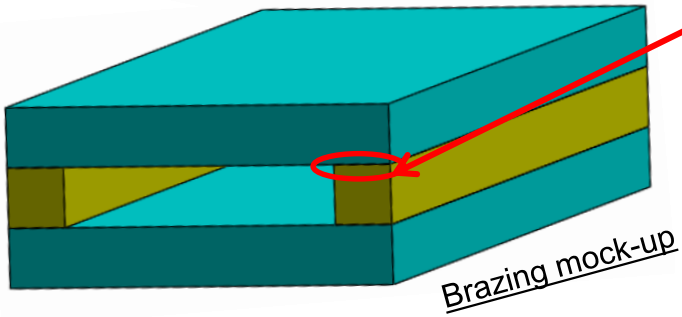
2 major technical phases to be tested in parallel

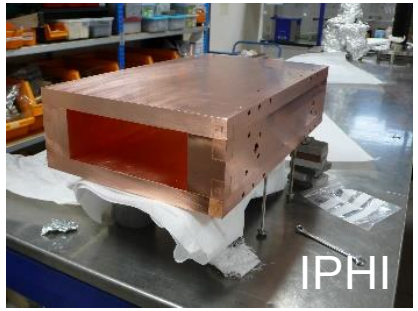


- **Step1**
  - *Qualification of deep drilling and machining technic*
  - *Validation of process and manufacturer capacity with his equipment*
  - *Ultrasound test and tridim measurement*



- **Step 2**
  - *Qualification of vertical brazing process*
  - *Validation of manufacturer brazing process*
  - *Tridim measurement and leak test*



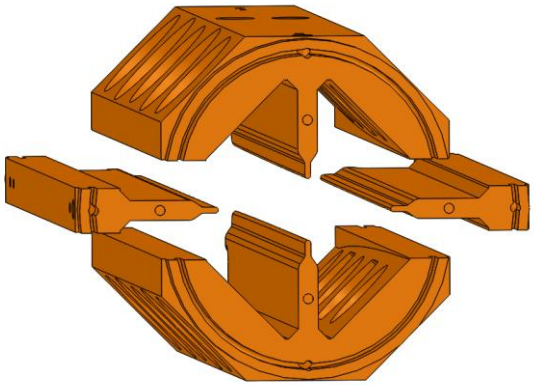


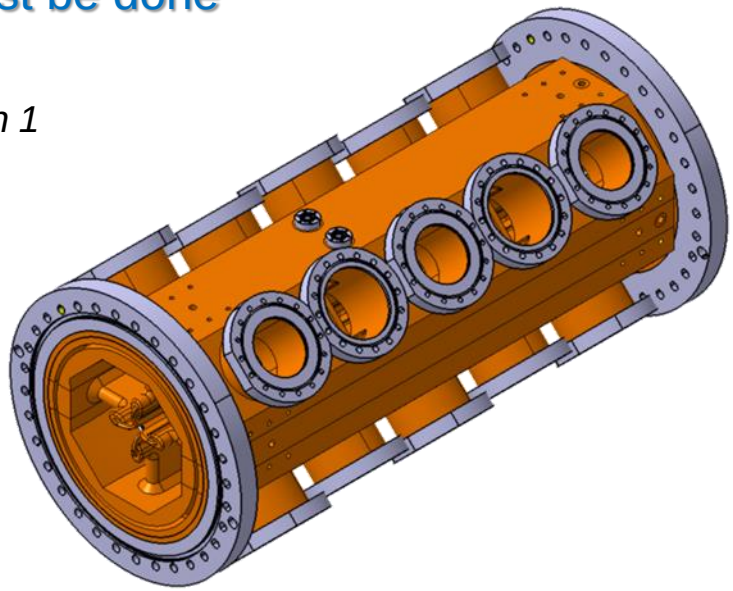
→ Schedule and process adaptation to reach the ESS schedule

SECTION MANUFACTURING

To start the third step, the steps 1 and 2 must be done

- **Step 3**
  - *Qualification of a total section manufacturing : Section 1*
  - *Leak test, tridim and RF measurement*





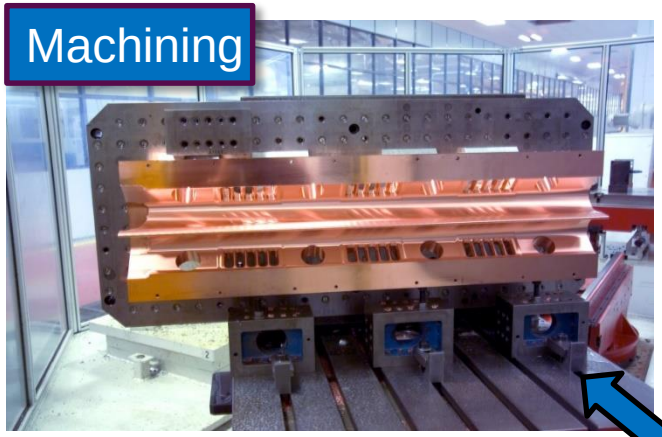
To start the series production, the step 3 must be validated

- Series production
  - *Sections manufacturing : process adaptation with industrial*
  - *Following process to optimize the time*
  - *Leak test, tridim and RF measurement*

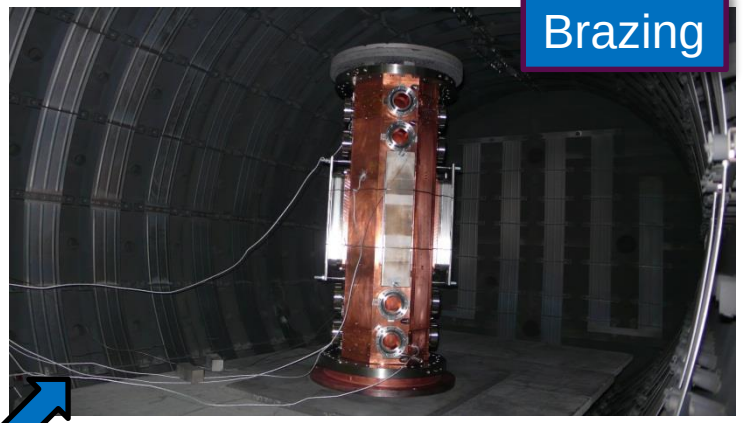
- Development plan and validation test according to the qualification phase

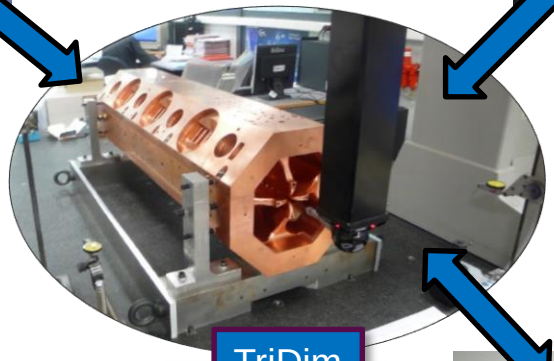
SECTION MANUFACTURING

Machining



Brazing





TriDim

Vacuum leak test validation

RF validation

ANCILLARIES

IPHI → ESS

Tuner ports : *stainless steel with copper coating inside and nickel coating outside*

Section flanges: *stainless steel with nickel coating*

Vacuum port grids: *machined directly on the vane*

➢Technological problem to braze the stainless steel on the copper module

➢copper to copper and stainless steel to copper brazing in 1 step

Avoid machining of vacuum port grids in vanes: *vacuum port position is adjusted to electrically neutral position*

Two brazing steps:

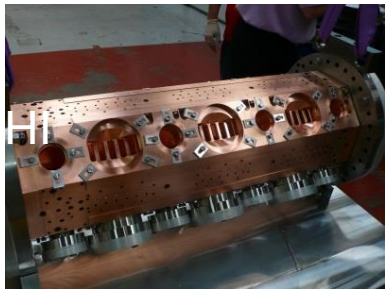
stainless steel to copper for ancillaries

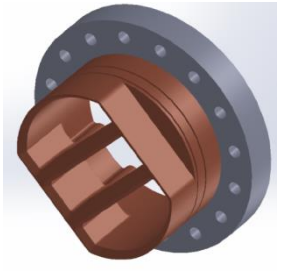
copper to copper for module + ancillaries

→No copper coating inside

→No nickel coating outside

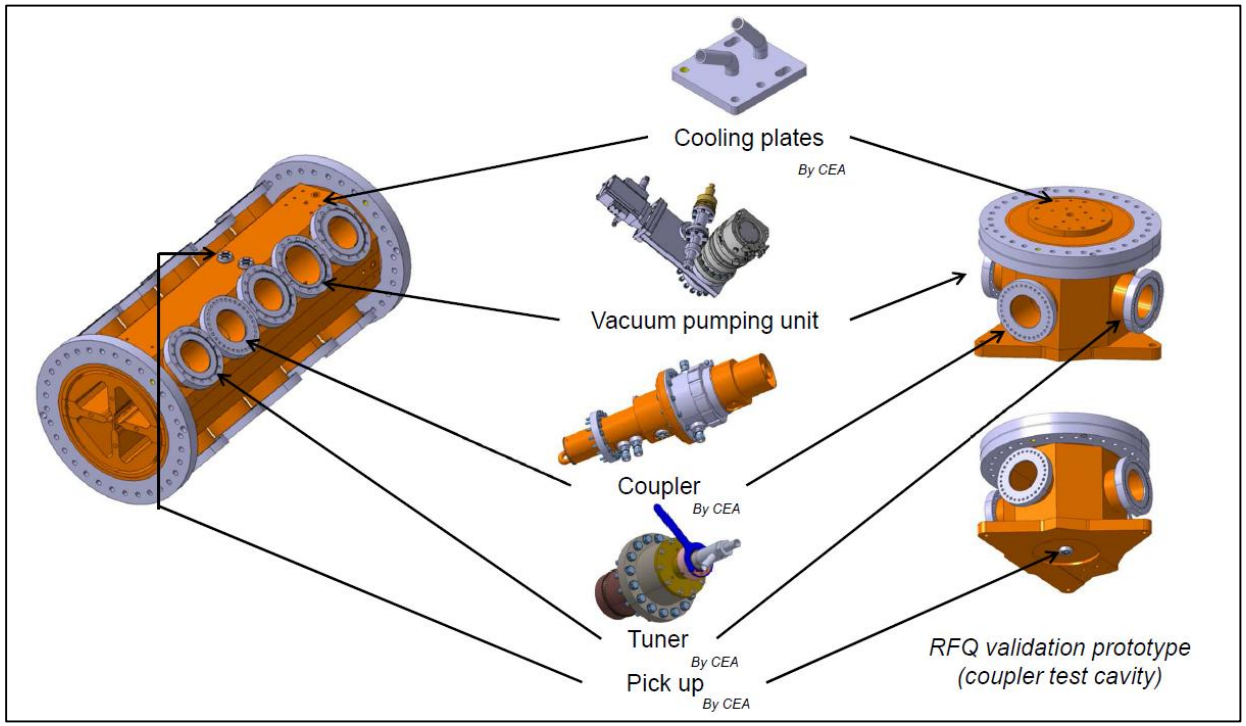
Final machining adjustment for brazing on copper

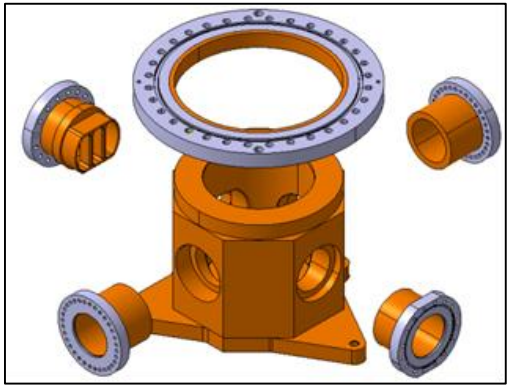




ANCILLARIES PROCUREMENT : TEST CAVITY

- Mock-up validation of brazing process of ancillaries on a copper cavity:
  section flange, tuner port, coupler port, vacuum port grid, pick up port
- Validation with leak test and tridim measurements





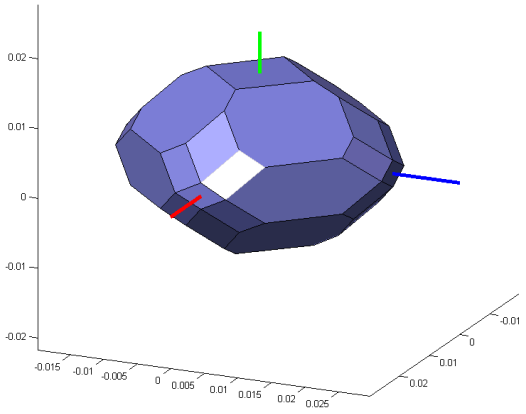
SECTION MANUFACTURING: RF VALIDATION

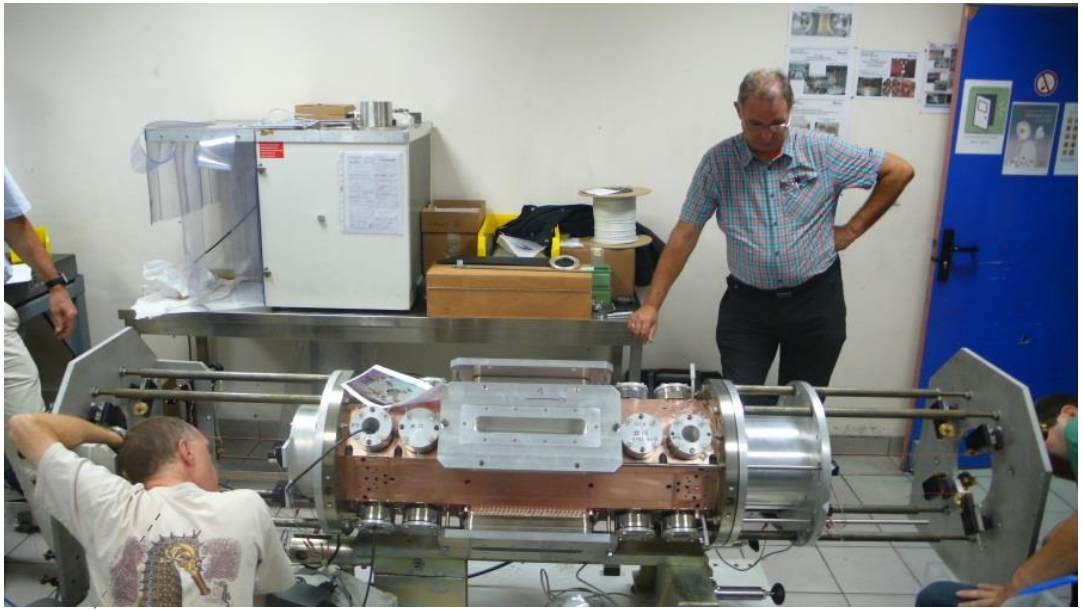
RF measurements are performed at three steps:

1. after electrode assembly
2. just before brazing; vacuum ports position is adjusted there
3. just after brazing

All errors are interpreted in terms of inter-vane capacitance errors, and compared to the specified capacitance error polyhedron.

(±1.55% along the C_{QQ} axis, ±2.35% along the C_{SQ} and C_{TQ} axes)

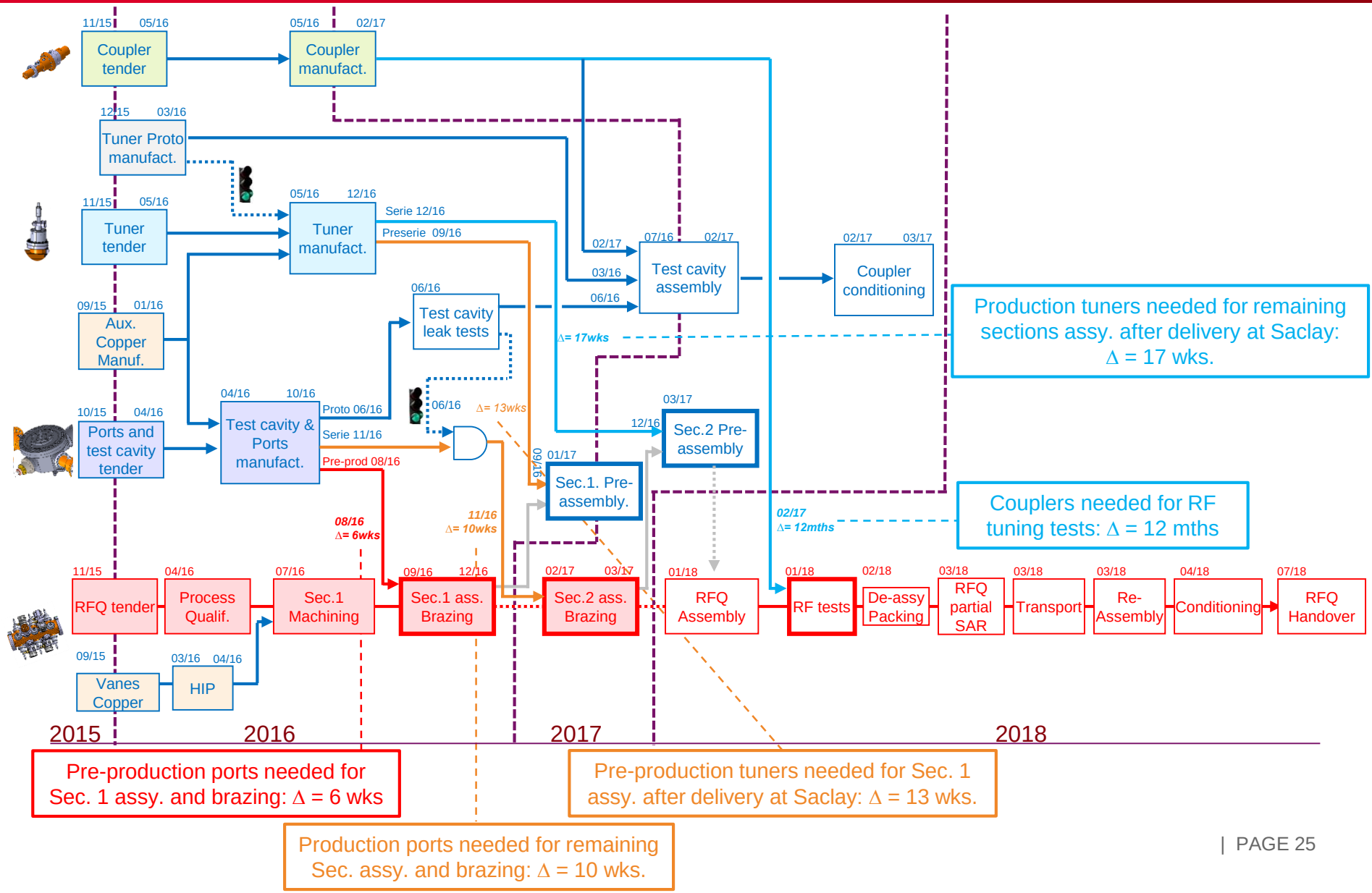




I am here

Linac4 example

TENDERS PLANNING CONNECTIONS

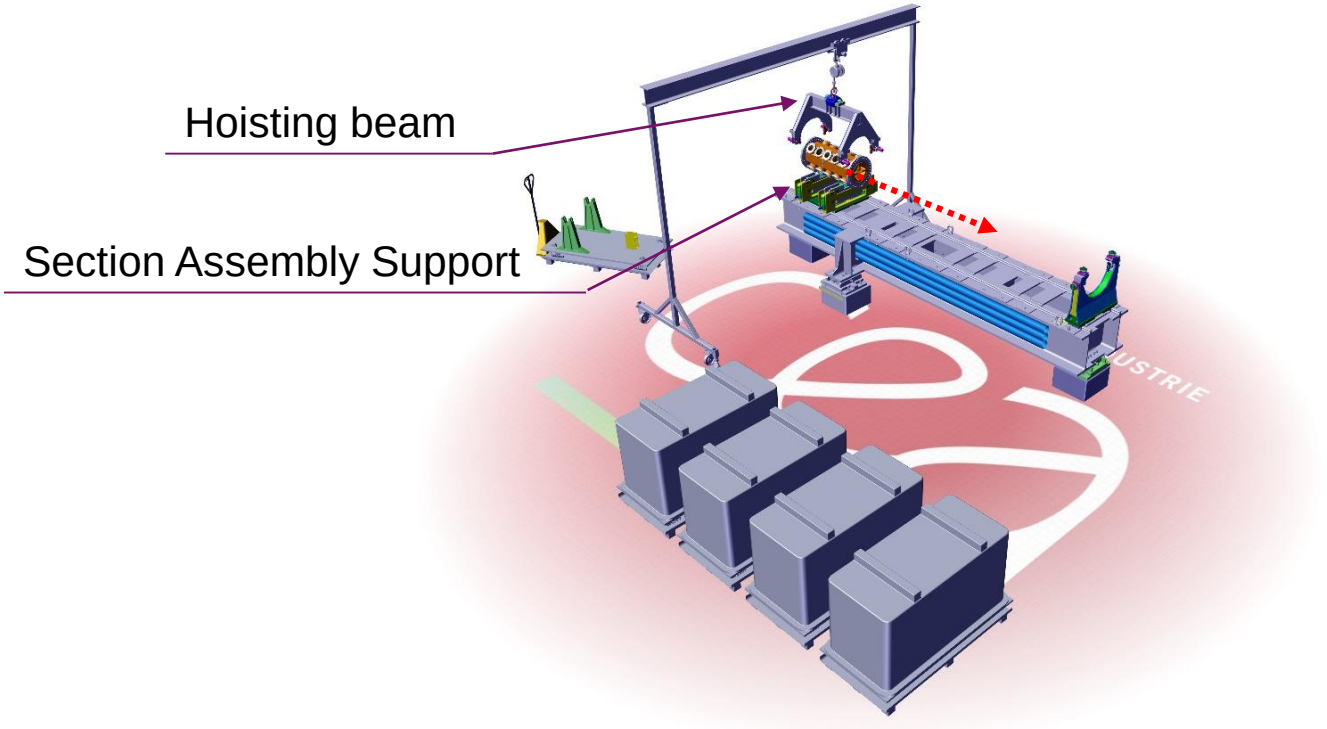


CEA - Saclay

EUROPEAN SPALLATION SOURCE

RFQ ASSEMBLY

RFQ ASSEMBLY: AT CEA



Section 1 is put in place on the Section Assembly Support sliding on the RFQ chassis.

The hoisting beam is removed; the section is moved to the first section support.

These operations are repeated for sections 2 to 5; then elements like pumps, tuner, coupling loops, etc. can be mounted.

Vacuum and RF tests are performed.

RFQ ASSEMBLY: AT ESS

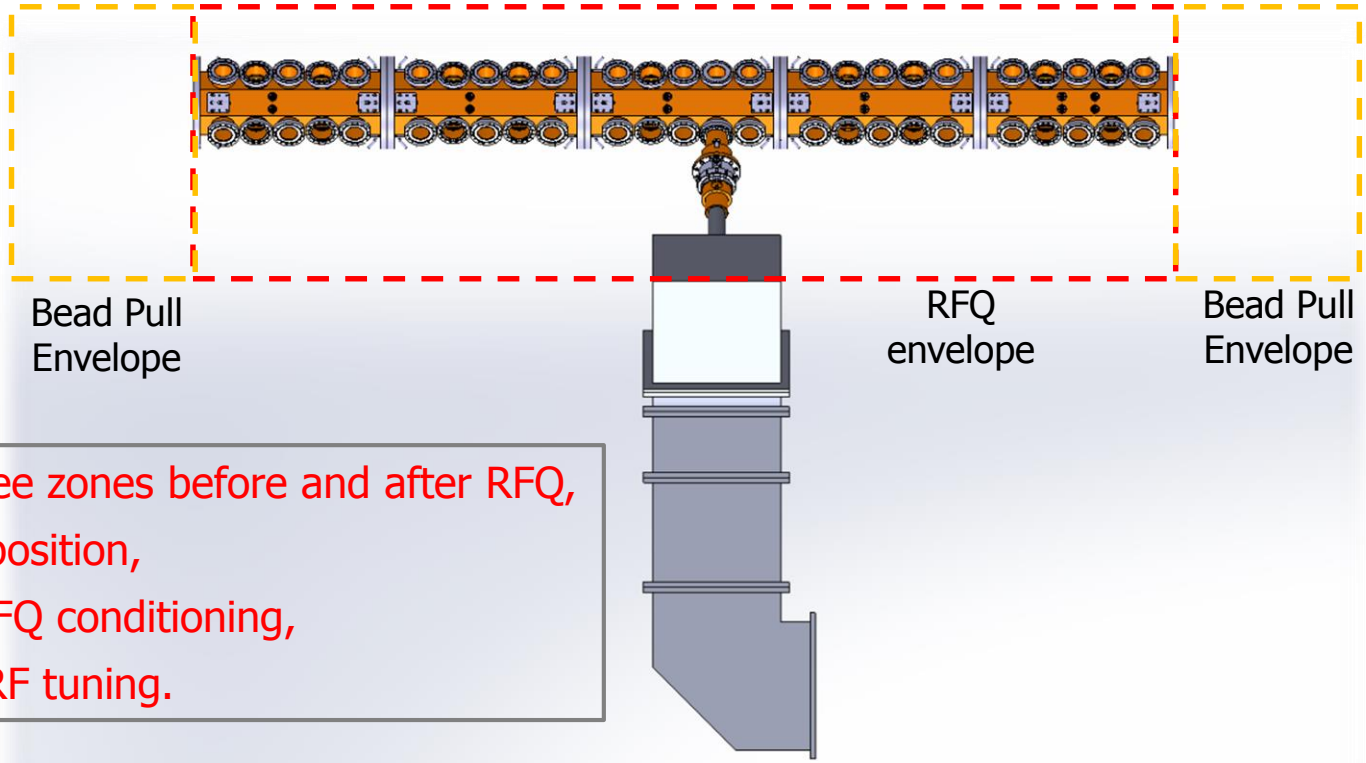
The RFQ chassis is adjusted to its final position and then definitely fasten to the ground.

RFQ sections are assembled on chassis.

Pumps, tuners, couplers, etc. are mounted.

The gantry-crane is removed when the installation process is completed.

Final RF tuning (voltage, frequency and partial coupling coefficients) is performed.



CEA needs 1m free zones before and after RFQ,
at the final RFQ position,
just before the RFQ conditioning,
to perform final RF tuning.

ACCELERATOR BUILDING INTEGRATION

Elements at 1 meter of RFQ input and output plates or closer can be mounted after final RF tuning operations.