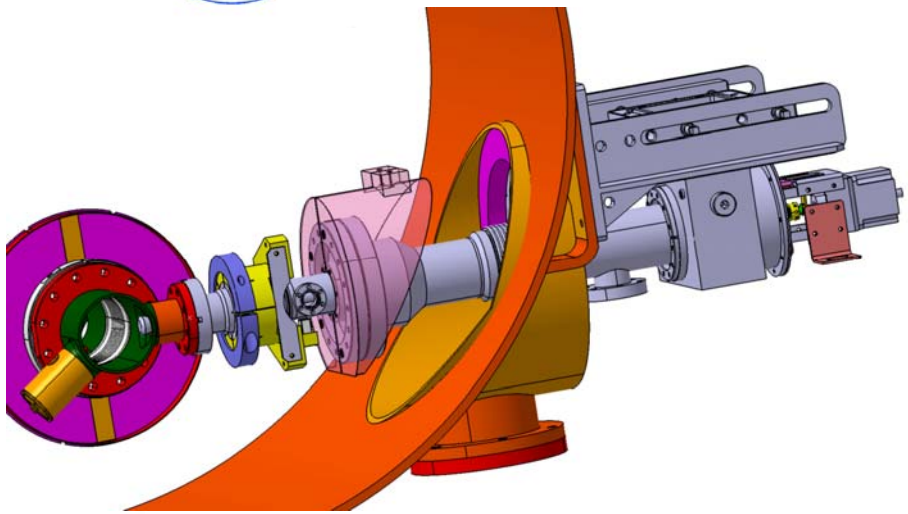
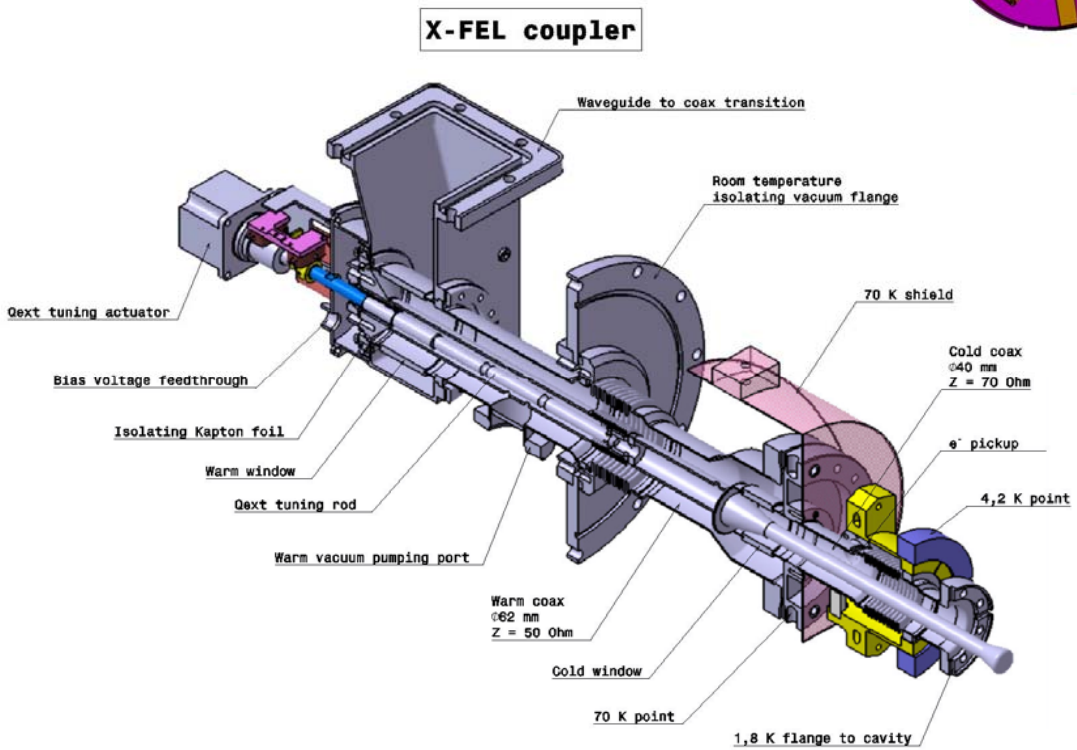
In the frame of the French contribution to **XFEL** project,

LAL is in charge of "in-kind" delivery of 832 input couplers



Input coupler on cryomodule



3 Main difficulties:

- Industrial production of coupler parts
- Assembly in clean room
- RF conditioning

Expertise required from industry in the couplers production

EB welding

Vacuum brazing

TiN coating th. ~ 10nm

Precise geometrical tolerances

Surface finish and cleanliness

TIG welding

Cu plating: 10 < RRR < 100

Motorized tuning

EN 1.4435

EN 1.4429

Special austenitic stainless steel

+ He leak rate < 10^{-10} Pa.m3/s
+ Careful Handling with gloves
+ Assembly in clean room
+ RF Conditioning

INTERFACES OF POWER COUPLER WITH OTHER WP's

WP 1 – Waveguide
1.1 Waveguide flange, bolts and nuts
1.2 Kapton window

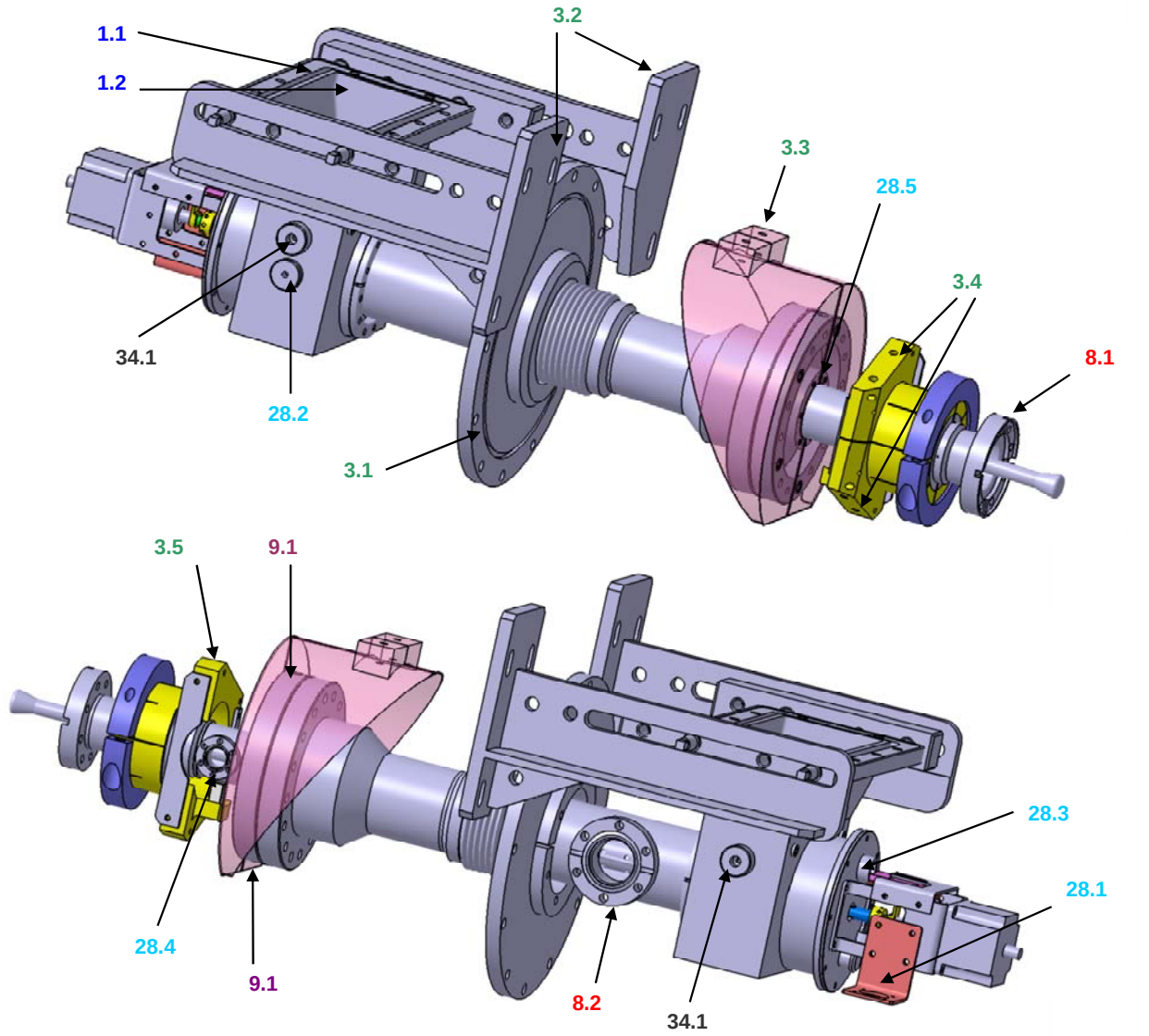
WP 3 – Cryomodule
3.1 Flange on vacuum vessel, gasket, bolts
3.2 Coupler supports (left & right), bolts
3.3 Connection of Cu braids from 80K thermal shield, bolts
3.4 Connection of Cu braids from 4K thermal shield, bolts
3.5 4 holes in 4K interface for assembly rods
3.6 Super insulation

WP 8 – Cavity & vacuum
8.1 Cavity flange, gasket, bolts & nuts
8.2 Coupler vacuum pumping port, gasket, bolts & nuts

WP 9 – Cavity string assembly
9.1 Two holes in big cold flange
9.2 Clamp for cold bellows

WP 28 – Control system
28.1 Connector for motor, end switches, PT100
28.2 Arc detector
28.3 HV connector
28.4 e- pickup
28.5 2 sensors PT100 in 80K zone

WP 34 – Utilities
34.1 Two N2 cooling ports
34.2 Environmental conditions: T, P, H, radiations



1 - LAL conducted industrialization studies to clarify the mass production of couplers

Award of 3 contracts in March 06: ACCEL, e2v, TOSHIBA

System Design Review:

- functional analysis

SDR →

Preliminary Design Review:

- feasibility of the manufacturing processes
- samples for parts and joining

PDR →

Critical Design Review:

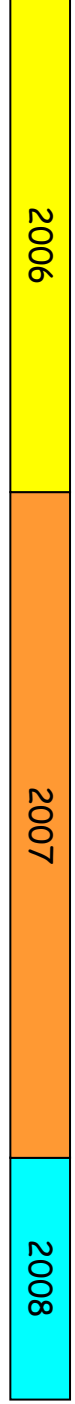
- detailed drawings
- organization of the mass production
- risks analysis
- samples of Cu plating and TiN coating

CDR →

Final Project Review:

- deliver 2 prototypes
- volume manufacturing plan
- costs estimate for XFEL couplers

FPR →



2 full days for each review at each contractor

Prototypes: what will be done at LAL

1. Analysis of documents
   - Shipping documents
   - Shock data (if any)
   - Material certificates
   - Production data book

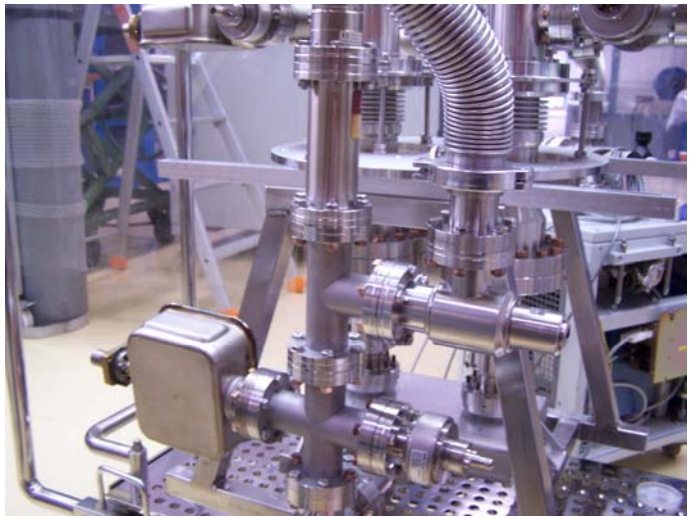
2. Visual inspection:
   - Examination of shipping container and packing
   - How couplers are mounted on test stand
   - External aspect of couplers, cleanliness, finger prints
   - Identification numbers
   - Inspection of transmission rod, WG interface box, motorized tuning
   - Remove test support from shipping container
   - Install on special clean room cart

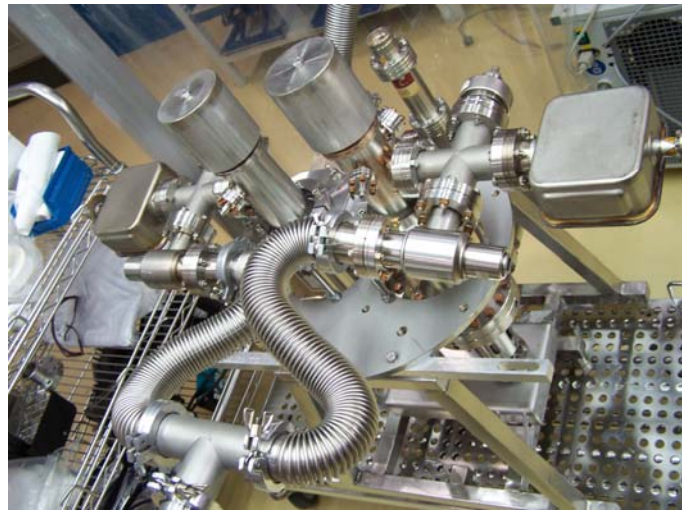
3. Bring test stand in clean room:
   - Air shower
   - In ISO 6: wipe with alcohol-soaked cloth all external surfaces
   - In ISO 4:
     - Connect pumping accessories to the 2 warm ports
     - Connect pumping accessories to the cold valve
     - Connect successively each of the 3 ports to external vacuum pump and proceed with He leak test, then close valves on vacuum
   - Exit clean room

Prototypes: what will be done at LAL

4. Outside clean room:

- Install test support in baking oven
- connect warm side & cold side to 2 turbo pumps
- Start turbo pumps, wait 10 min → ~ 10^{-5} mbar
- Open the 2 valves
- Vacuum pump until 10^{-7} to 10^{-8} mbar





5. In situ baking:

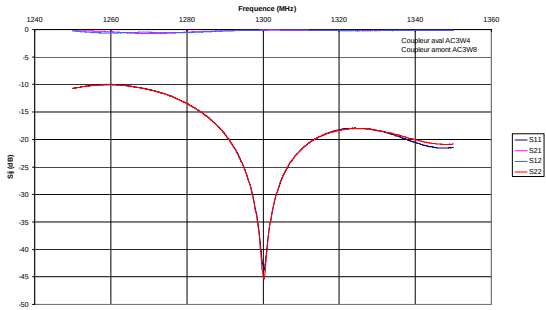
- Ramp up to 130°C in 1 day
- Bake at 130°C during 3 days
- Ramp down to ambiant 0.5 day
- Connect and start: 3 vacuum gages, 3 ion pumps, RGA on cold side
- Close valves and remove turbo pumps
- Exit baking oven

Prototypes: what will be done at LAL

6. Mount WG interface boxes and capacitors

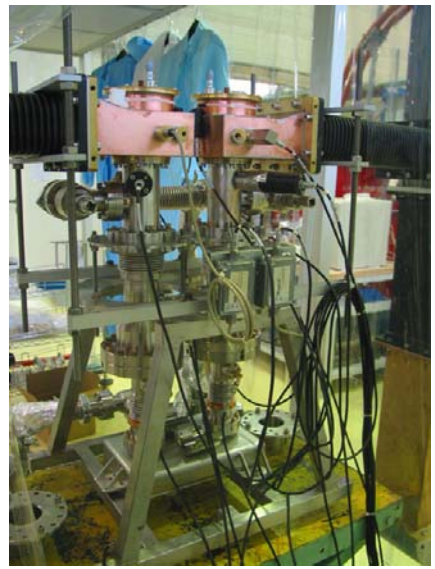
7. Mount motorized transmissions
   - Operational check

8. RF tuning:
   - Connect coaxial transition adapters on input and output waveguides
   - Connect pulse generator
   - Tune both couplers to optimum frequencies
   - Dismount transition adapters



9. Connect couplers to waveguide and to end load
   - Connect diagnostics to interlock electronics

10. Start conditioning process
    - Record vacuum gauges & electronic activity versus time, RGA
    - Ramp up RF power for each pulse length → record duration



Prototypes: what will be done at LAL

11. Disconnect from waveguide

12. Disconnect from pumps, dismount pumping adapters

13. Dismount motorized transmissions & interface boxes
    - Visual inspection, record on inspection table

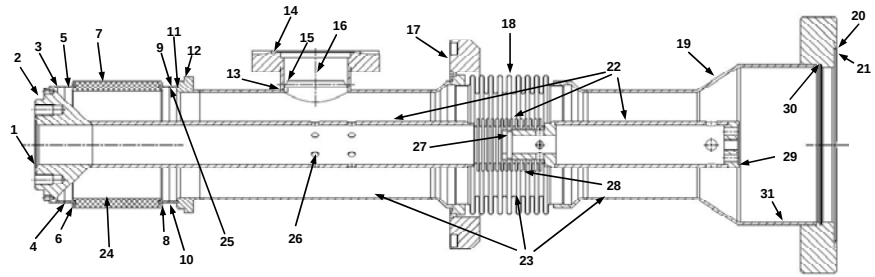
14. Dismount 2 warm assemblies from test stand
    - Visual inspection, record on inspection table
    - Control of some critical dimensions
    - Control of angular alignment
    - Measurement of rugosity on Cu coated surface

15. Dismount 2 cold assemblies from test stand
    - Visual inspection, record on inspection table
    - Control of some critical dimensions
    - Control of angular alignment
    - Measurement of rugosity on Cu coated surface

Visual inspection of warm and cold assemblies

Outside

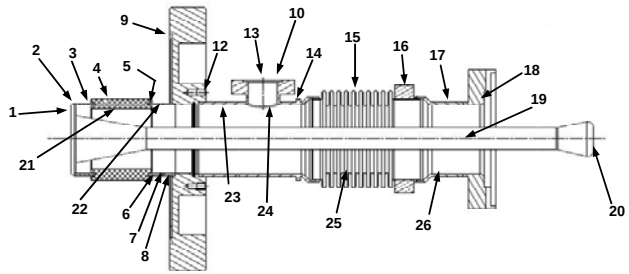
- identification
- conformance of geometry
- cleanliness
- surface finish
- ceramic aspect (absence of scratches, broken edge, stain)
- brazes aspect (good filling, no spill)
- welds aspect (absence of holes, corrosion)
- centering
- bellows (no excessive deformation, no dents)
- CF flanges (no damage)
- edges (good chamfers or rounded edges, sharp edge when needed)



Inspection points on warm assembly

Inside

- cleanliness
- end of inner conductor (sharp edge)
- inner bellows (no excessive deformation, no dents)
- pumping holes (rounded edges)
- RF surface finish (roughness value, absence of scratches, stains)
- Ceramic aspect (absence of scratches, broken edge, stain)
- joints aspect (full penetration, smoothness, no peaks)
- Cu coating aspect (smoothness, color, coating limit, no flakes, stains, corrosion)
- rounded edges (for RF needs)



Inspection points on cold assembly

Visual inspection of other assemblies

Push rod assembly

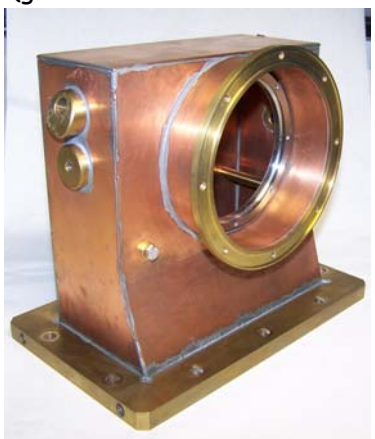
- conformance of geometry
- cleanliness
- surface finish
- welds aspect (absence of holes, corrosion)
- centering
- bellows (no excessive deformation, no dents)
- CF flange (no damage)
- HF contact springs
- end axle
- edges (good chamfers or rounded edges)

Capacitor

- Quality of assembly
- cleanliness
- Peek covers (machining quality, gluing to Kapton film)
- Outer & inner ring
- Test record

WG interface box

- identification
- conformance of geometry
- cleanliness
- surface finish (absence of scratches, broken edges, corrosion)
- edges (good chamfers or rounded edges)



Tuning actuator

- identification
- conformance of geometry
- conformance of components
- cleanliness
- fixtures

→ Final rating of the prototypes

This evaluation form is a systematic method of evaluation of the quality of a pair of input couplers.

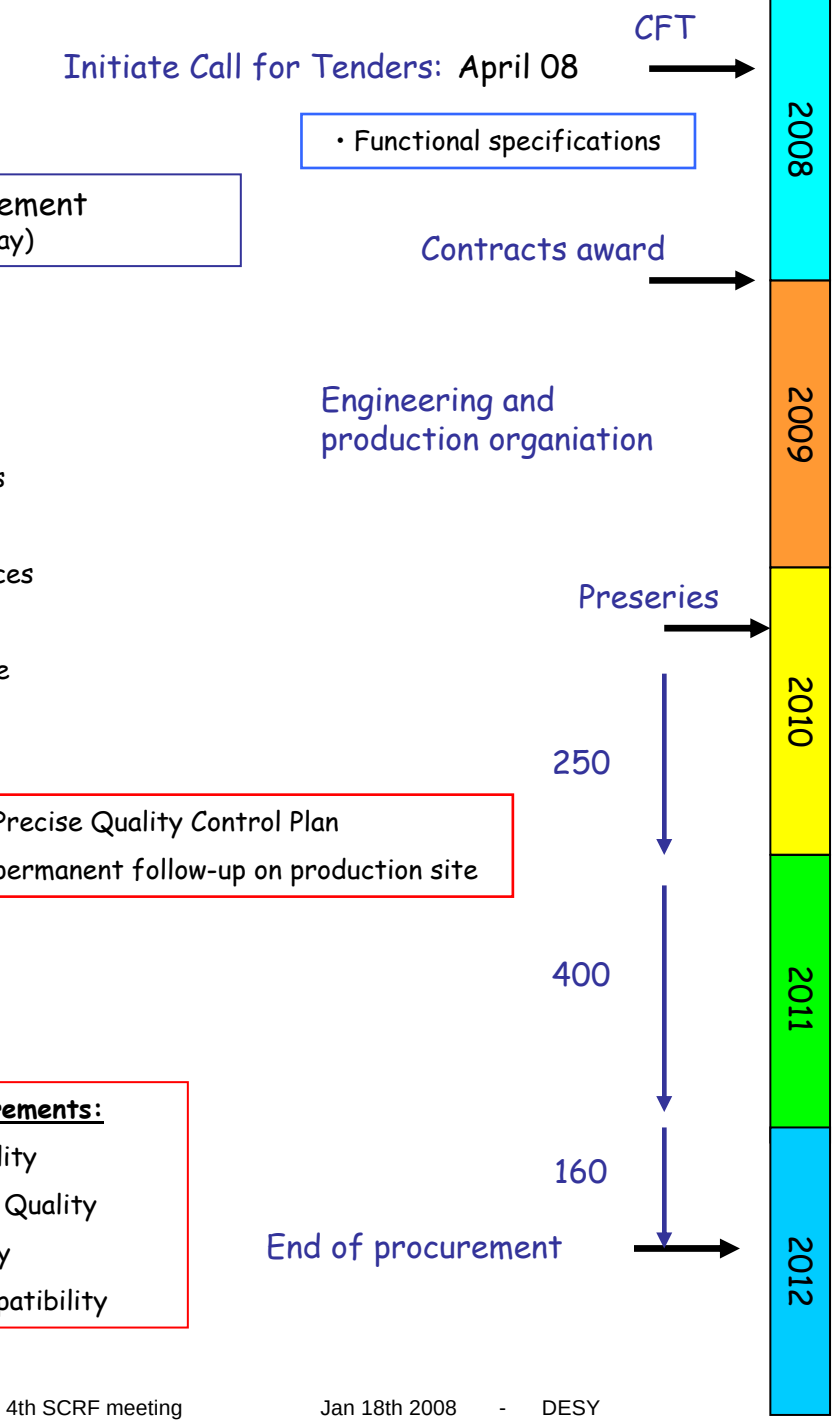
Every listed detail must be inspected and rated with penalty points as follows:

- satisfactory: 0 point
- small defect, no consequence on performance: 1 point
- big defect with consequence on performance: 2 points
- big defect with consequence on operation: 3 points

The final result is the sum of all penalty points

Pt N°	Detail to inspect	Good	Small defect	Big defect	Description	Points
	External aspect, surface quality, cleanliness					
	Identification: where, type, quality					
1	Knife edge quality					
2	Quality of contact to capacitor, fixation					
3	Braze joint quality					
4	Joint quality if any, regularity, smoothness					
5	Cu rings: centering, shape, smoothness					
6	Braze: regularity, smoothness, centering, metallization					
7	Ceramic: color, stains, no chips					
8	...					
9	.....					

Schedule for XFEL couplers procurement
6 months ahead of linac schedule (today)



Requirements:

- Certified materials
- Industrial processes
- Written procedures
- Standard competences
- Qualified operators
- Adequate means size
- Optimized costs

- Precise Quality Control Plan
- permanent follow-up on production site

End requirements:

- Traceability
- Constant Quality
- Reliability
- Plug-compatibility

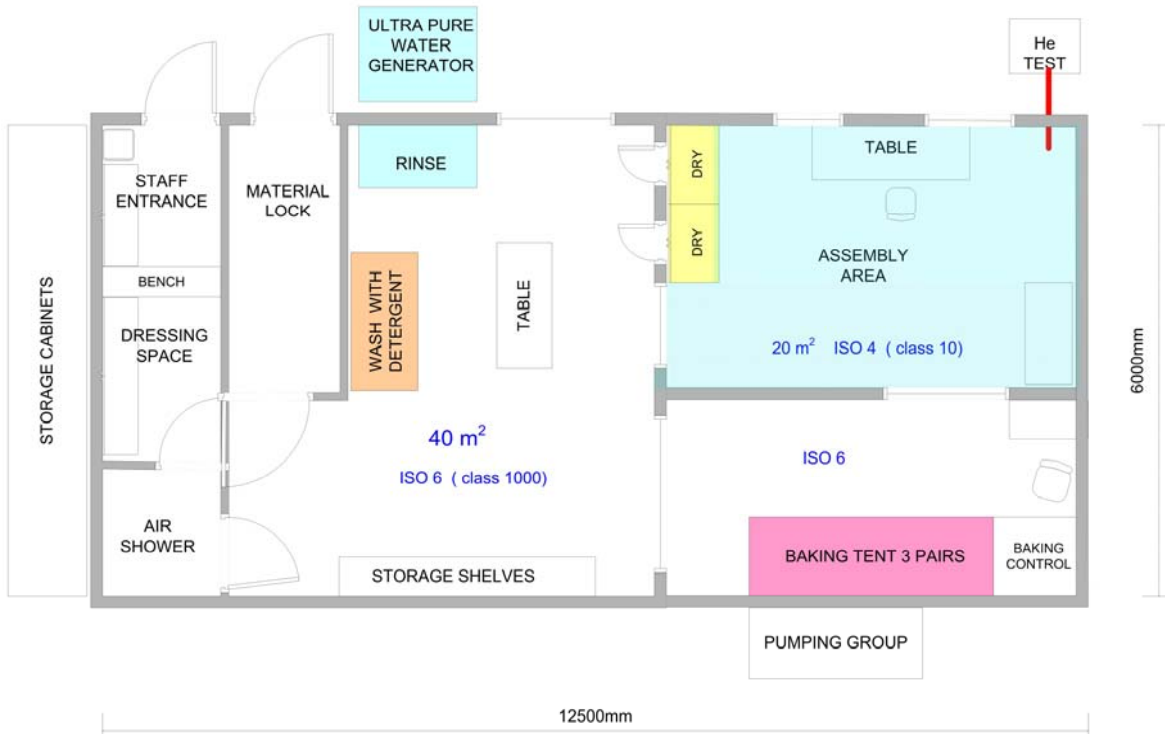
2 - LAL has gained experience in Assembly and Conditioning

Test station at LAL, sized for 50 couplers /year:

- clean room with 2 zones:
  - class 1000: wash and rinse
  - classe 10: dry, bake, assemble
- RF Modulator and 5 MW Klystron

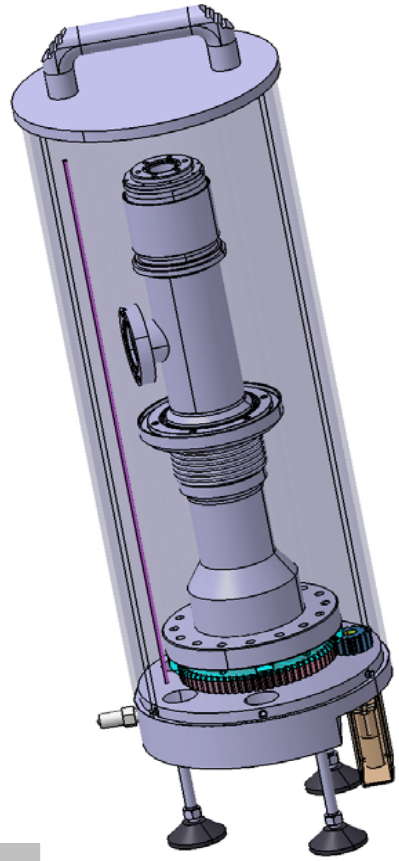
Project of Clean room layout for 200 couplers / year

(at industry location)



Special clean room equipment

Cleaning with detergent in US bath



Rinsing tank

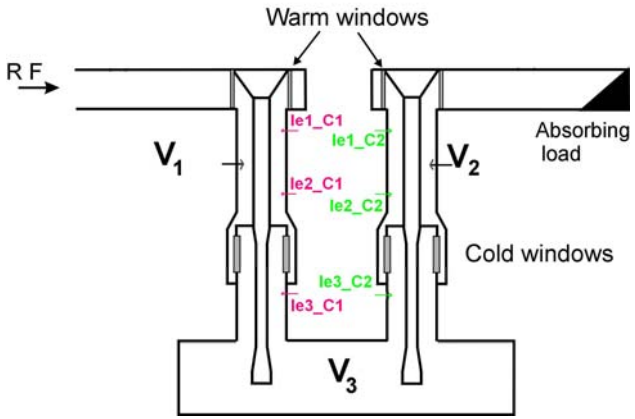
(LAL design)

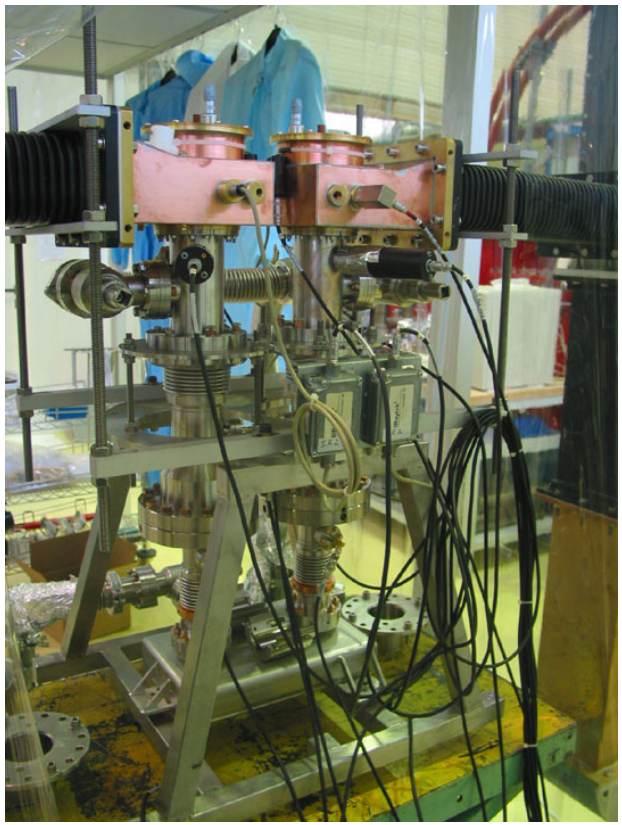
Industrial washing / drying machine

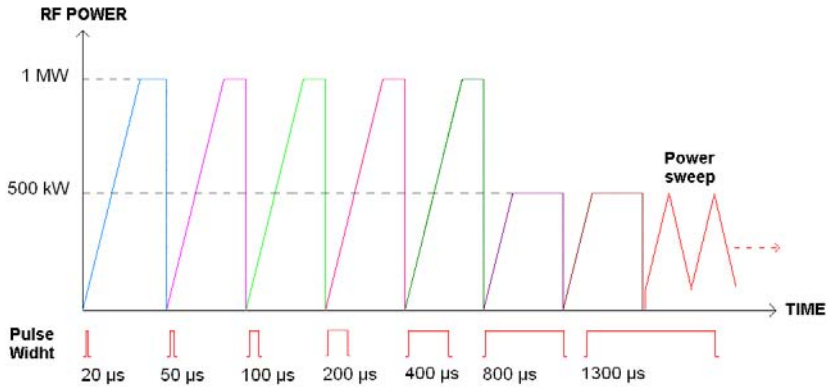
(Used at DESY for cleaning of UHV parts)

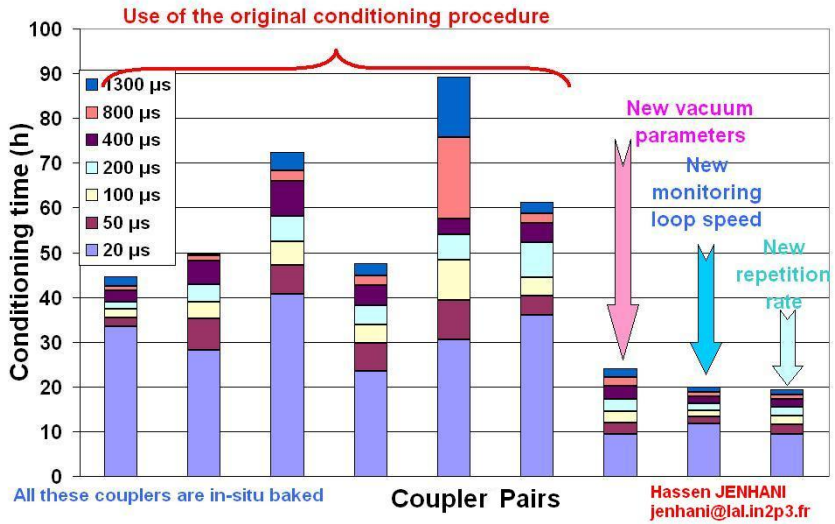
Bake out tent

3 - LAL has been working several years to optimize the RF conditioning time









Now: Total duration for conditioning + tests → 40h / pair if OK

Scenario for couplers production – WP5 of XFEL project

Principles:

- 2 industrial contracts: each for 416 couplers + (n/2) spares
- Production and assembly in specific clean room at each industry
- Responsibility of industry includes RF conditioning
- RF conditioning: 1 single station at LAL

Limit of responsibility for industry

Ind 1 → Ind 1

Ind 2 → Ind 2

Manufacturing

at LAL

Conditioning station

DAPNIA (Saclay)

Cryomodules assembly

Clean rooms operations:
- wash
- rinse
- dry
- assemble
- vacuum pumping
- bake
- He leak test

- 1.3 GHz tuning
- RF conditioning
- acceptance tests
- dismount in clean room
- pack (double bag)
- store

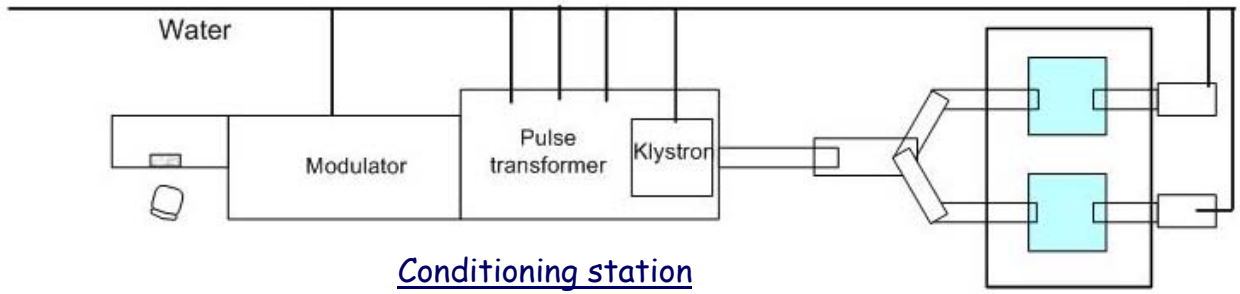
Cold part: WP9 (cavity string assembly)

Warm part: WP3 (Cryomodules assembly)

Different phases in couplers production & assembly

Phase	Actor	Control	Where
Couplers fabrication	Industries	LAL Inspector on site	2 industrial locations
Operations in clean room: Washing, rinsing, drying, baking, He test		LAL Inspector on site	2 industrial locations
RF Conditioning & reception tests		LAL	LAL
Dismount from test stand Pack in 2 envelopes		LAL	LAL
Storage until needed	LAL		LAL
Transport to cryomodule assembly location	LAL		SACLAY
Assemble to cavities and to cryomodules	X	DAPNIA	SACLAY

Necessary infrastructure at LAL for XFEL couplers



Conditioning station

40 m² Clean room for:

- dismounting warm & cold parts from test stand
- packing in double bags filled with N2
- treatment of couplers which failed conditioning

Storage space:

- shelves for 200 couplers
- prepare to deliver batches to SACLAY