# ILC HiGrade WP7
# Couplers R&D

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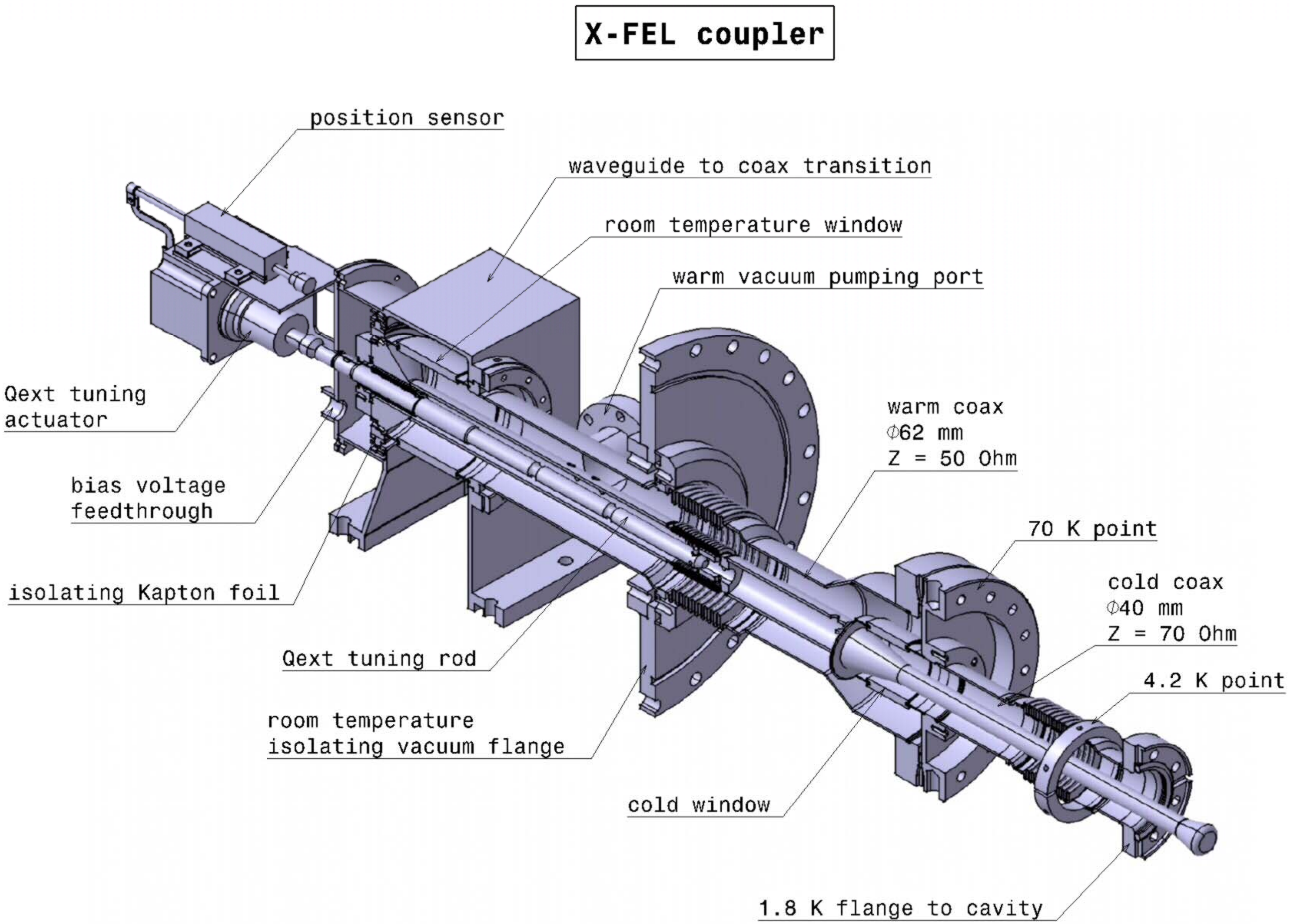
# Coupler Digest

- Accelerator component used to feed RF power (1 MW) into the superconducting cavity
- Conflicting requirements(must transmit MW of electrical power and at the same time, be thermally isolant (warm « head »-cold « feet »)) leads to a very complex mechanical object
  – Lesson learned : no industry can do it right the first time!
- A good design is in hand (TTF3) but still costly (30 k€ a piece for small quantities: would mean 600 M€ for the ILC linac!) and lenghty RF processing


X-FEL coupler
position sensor
waveguide to coax transition
room temperature window
warm vacuum pumping port
Qext tuning
actuator
bias voltage
feedthrough
warm coax
Φ62 mm
Z = 50 Ohm
70 K point
isolating Kapton foil
cold coax
Φ40 mm
Z = 70 Ohm
Qext tuning rod
4.2 K point
room temperature
isolating vacuum flange
cold window
1.8 K flange to cavity

# 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

EN 1.4435

EN 1.4429

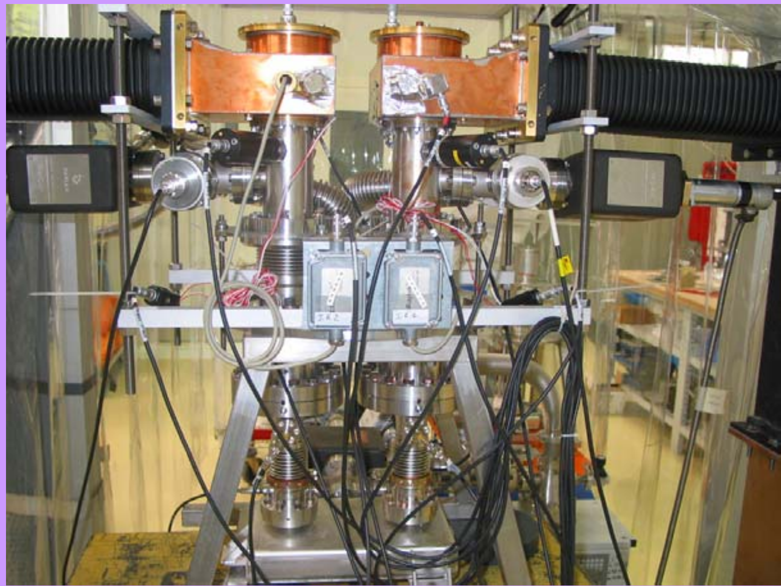
Special austenitic stainless steel

Cu plating: 10 < RRR < 100

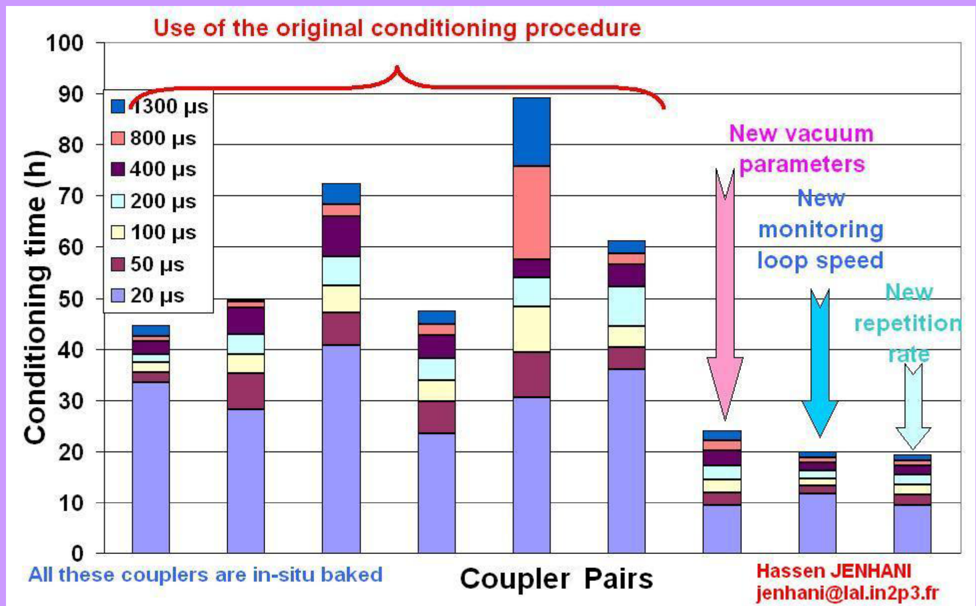
Motorized tuning

- + He leak rate < $10^{-11}$ Pa.m3/s
- + Careful Handling with gloves
- + Assembly in clean room
- + RF Conditioning

# Conditioning tests



TTF-III coupler test stand




Optimisation of the TTF-III conditioning procedure

**Further optimisation still possible:**

- ✓Less conditioning steps
- ✓New configuration : 2 coupler pairs conditioned at the same time (parallel or series)
- ✓Elimination of the coupler baking procedure (under vacuum) in the clean room

# WP7 in a nutshell

- Coupler cost and RF conditionning optimization
- Production and conditionning of 24 couplers
- Strong synergy with XFEL coupler production preparation
- 54 PM
- 1.4 M€ RTD budget
- 2 Deliverables : RF conditionning (M24), Couplers delivery (M36)

# Present R&D program

- Faster processing
  - RF sweeping strategy
  - 4 at a time (or more..)
- Integrate pumping to reduce processing time
- Minor design changes to reduce cost
- New geometries

# R&D 1

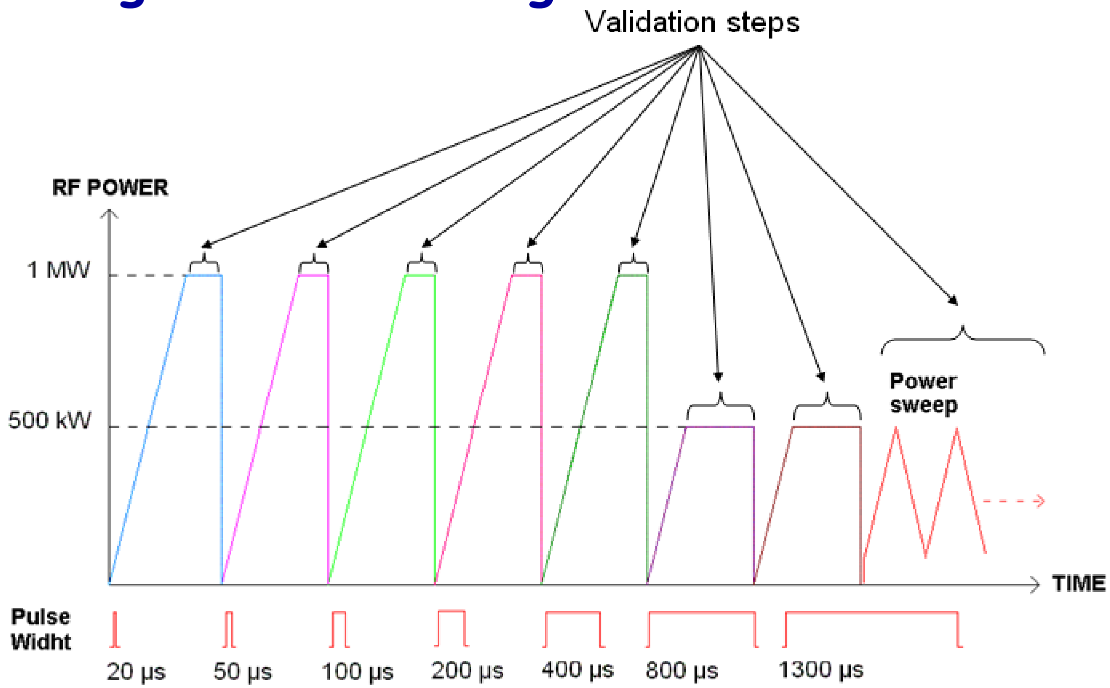
## Reduction of the Duration of the validation steps during RF conditioning

Validation steps duration:

(7 x 1h) + (10 x 1h) = **17 h**

Fixed maximum power duration

One sweep duration




## Proposal:

**Validation steps**

[5 min @ { 20 µs, 50 µs, 100 µs, 200 µs} + 30 min @ 400 µs]

\+

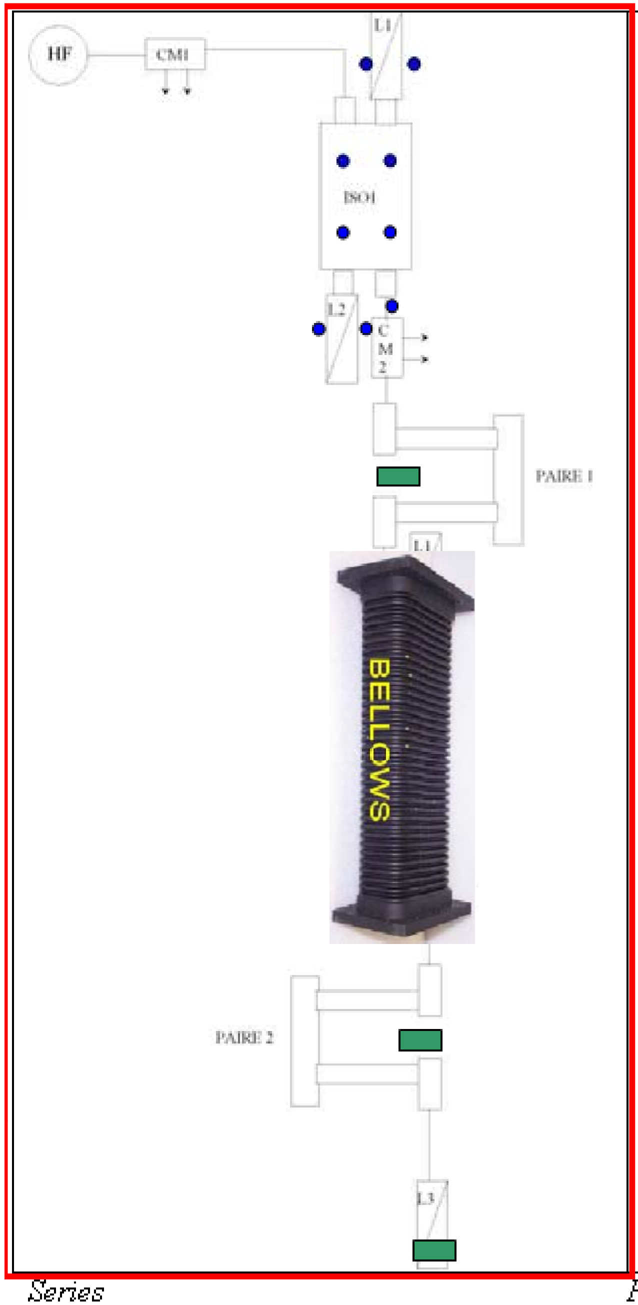
[5 min @ 800 µs + 30 min @ 1300 µs]

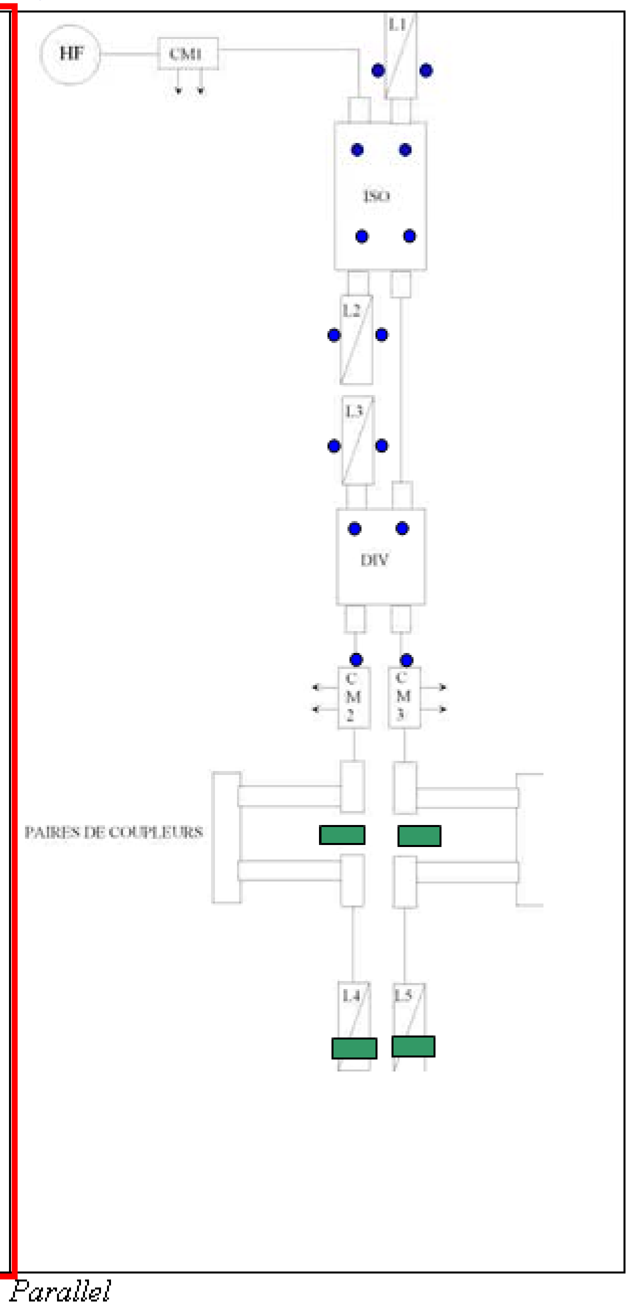
\+

3 x 1h (e.i. 3 sweeps only)

= **4 h 25**

# R&D 2: RF conditioning configuration for two coupler pairs

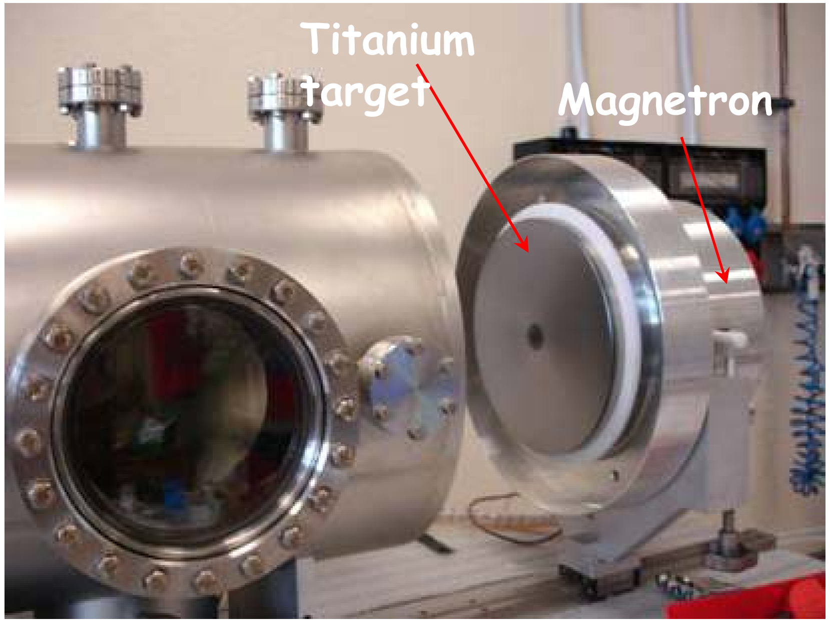


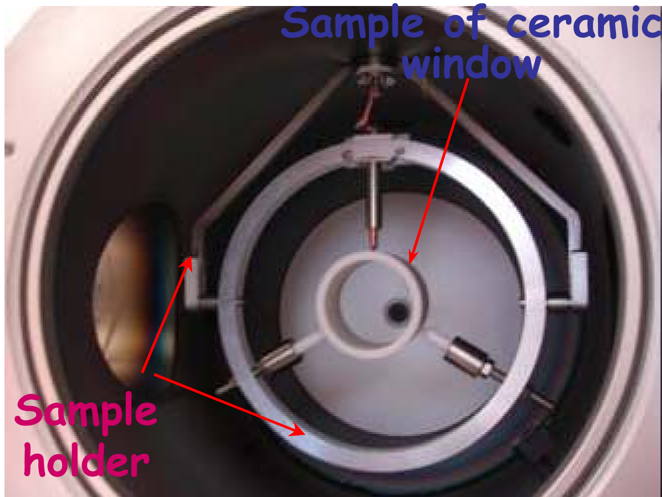



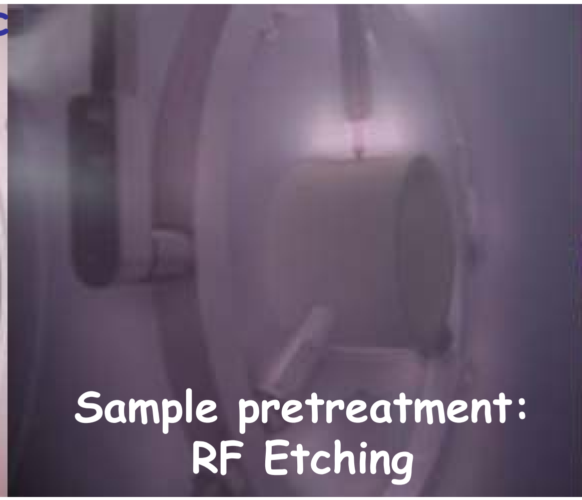

- Same conditioning procedure
- More RF materials
- More pumping arrangements
- More diagnostics
- More interlocks
- More inputs for the monitoring program

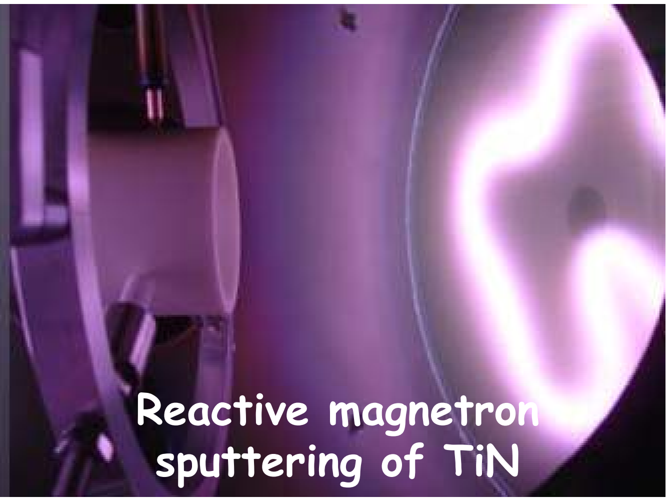
First Attempt with the simplest configuration: Series configuration without a use of a circulator between the two coupler pairs (W-D Moller suggestion in the XFEL Power Coupler Integration)

# R&D on coupler RF Windows: The sputtering machine at LAL

# R&D on coupler RF Windows: Study of TiN coating on ceramic windows

$TiN_x$ thick layer deposition (800 nm) on ceramic disk

⇩

TiN stoichiometry
(Samples analyzed by XRD and SIMS)

⇩

TiN thin layer deposition (10 to 20 nm) on ceramic disk using the same parameters

⇩

Optimal thickness will be determined by tg δ measurements and multipacting tests

⇩

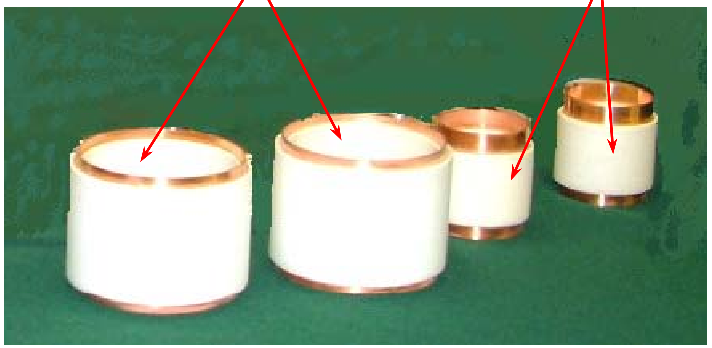
Deposition on cylindrical ceramic windows (internal and external surfaces)

**Samples : Ceramic windows ($97,6\%$ $Al_2O_3$)**

Disk planar window (Test Ceramic)

Warm windows
(Ø = 75 mm, h= 57 mm)

Cold windows
(Ø = 47 mm, h= 48 mm)



TTF-III coupler window types

# R&D on coupler RF Windows: TiN layer studies

**At LAL**

✓ Profilometer : surface roughness measurements (sample with & without TiN deposition layer)

✓ Scanning Electron Microscope + Energy Dispersive X-ray Spectrometer (SEM/EDX) : morphology, thickness estimation, cartography & the sample chemical composition.

✓ Dielectric characterization: RF losses measurements using a cavity resonator (tg δ).

✓ Multipacting measurements: DESY design multipacting resonator (under study : new RF coupling and vacuum pumping port)

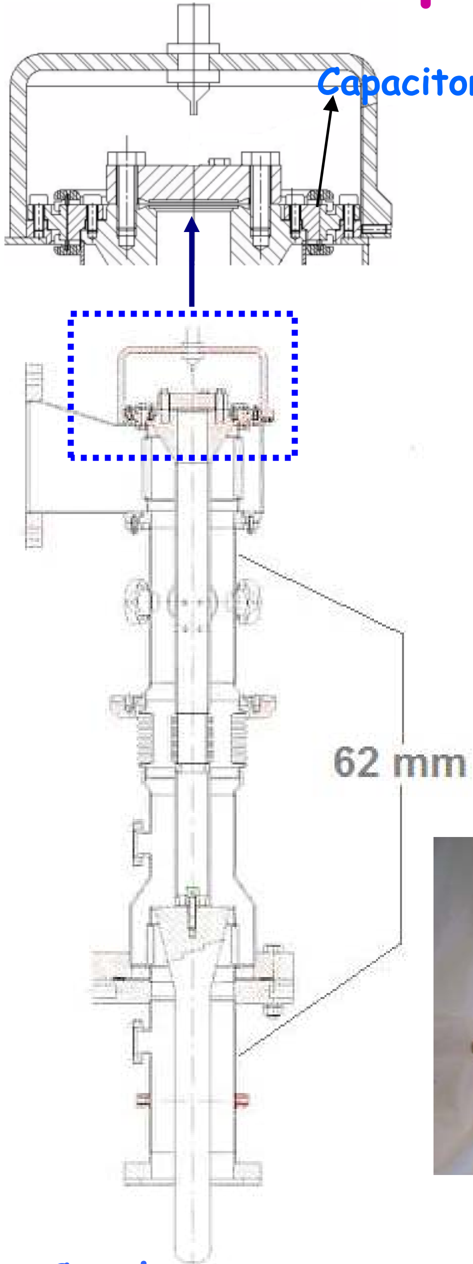
✓ Diffractometer (already ordered): thickness estimation of the deposit layer & stoichiometry determination.

**Outside:**

✓ RBS & SIMS : Elementary analysis of the deposed TiN (surface and bulk).

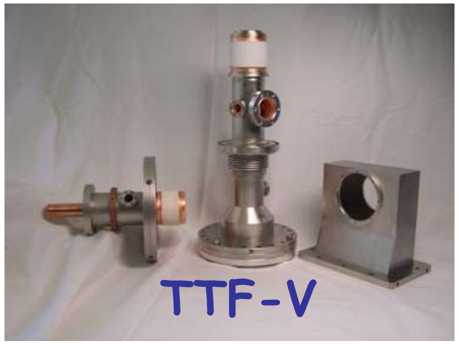
- All the different parts of the NEG couplers are ready for low level anf HF tests.

# R&D on coupler prototypes: TTFV & TW60

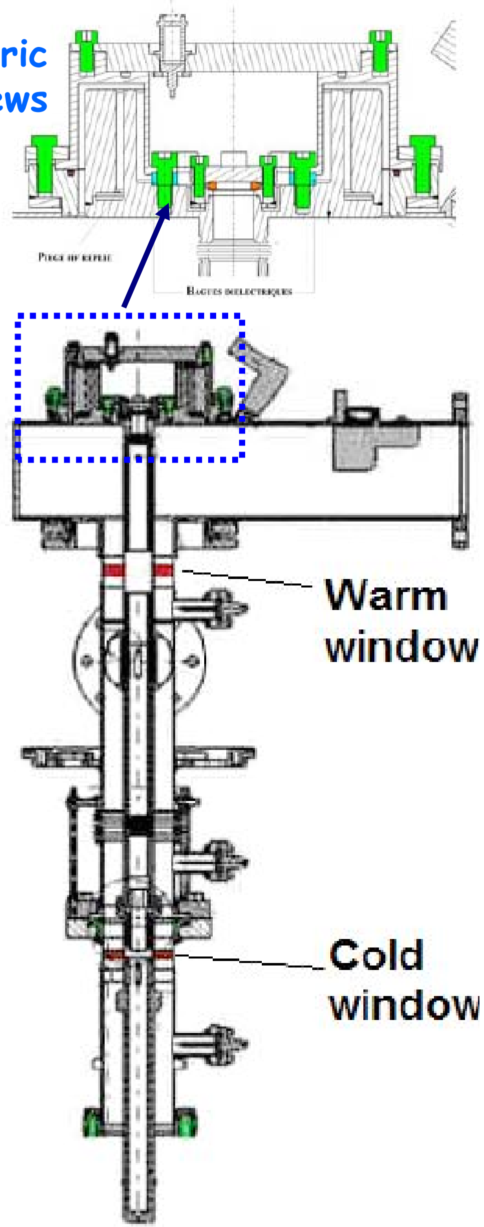



Coupler prototype TTF-V

Spare plan : September => KEK
And test of both prototypes.
In the framework of the LIA
French-Japanese collaboration





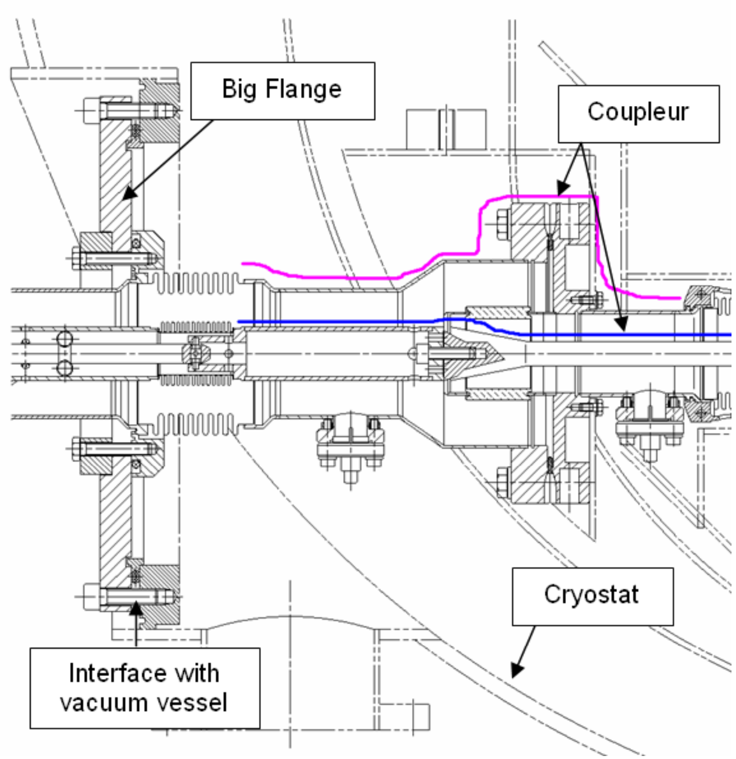



Coupler prototype TW60

# Industrialization; Cost reduction
# Example: big flange on vacuum vessel

Big flange for TTF3: 12mm thick plate, 3.8 kg

Results of industrial studies show that this flange is the most expensive machined part of the coupler !




Study done by Sandry Wallon (LAL)

FE analysis shows that a 6 mm stainless steel plate can do the job with a safety factor of 3:

Stress: $\sigma_{VMmax}$ = 90 Mpa
Displacement: $\Delta x$ = 0.1 mm

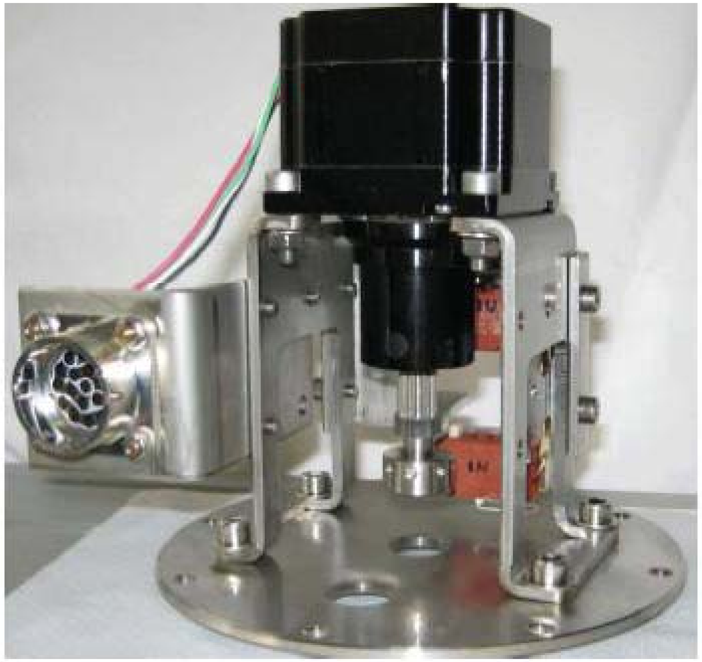
} for $\Delta P$ = 1 bar

Able to withstand $\Delta P$ = 3 bar

→ This helps to decrease the amount of raw material, and coupler cost !

# Some examples of cost reduction thru industrial redesign

Example of systems engineering result



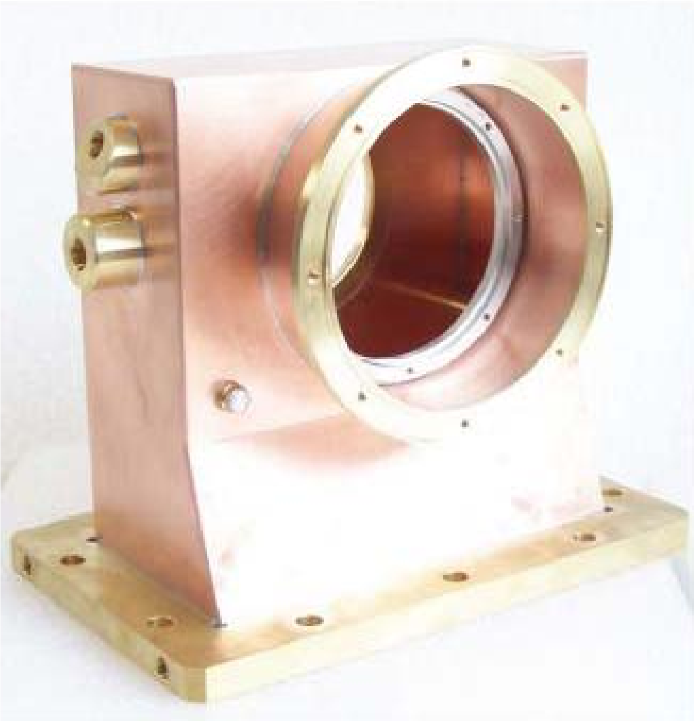
Prototype design

Industrial design

Design to minimize assembly time

(original design: counter flanges + 14 screws

Waveguide to coax interface part



Copper + stainless steel + brass: 13 parts
brazed and soldered

Al alloy: 1 single part
- Prototypes: machined from single block
- Mass production: casting + final machining

## Cost reduction was one of the main objectives :

Phase 1: **functional analysis of existing design**

Functions & requirements for each sub-assembly, each part
Analysis of requirements for each interface
Functionality of global breakdown:

- analyze limits of each sub-assembly
- what are the purposes of this design ?

Phase 2: **systems engineering**

- reduce number of parts
- reduce number of junctions
- reduce number of different junctions, types of junctions

Phase 3: **design for manufacturability**

analysis of manufacturing method for each part:

- prefer deformation process instead of material removal process
- optimize design of parts connected to interfaces (functional analysis results)

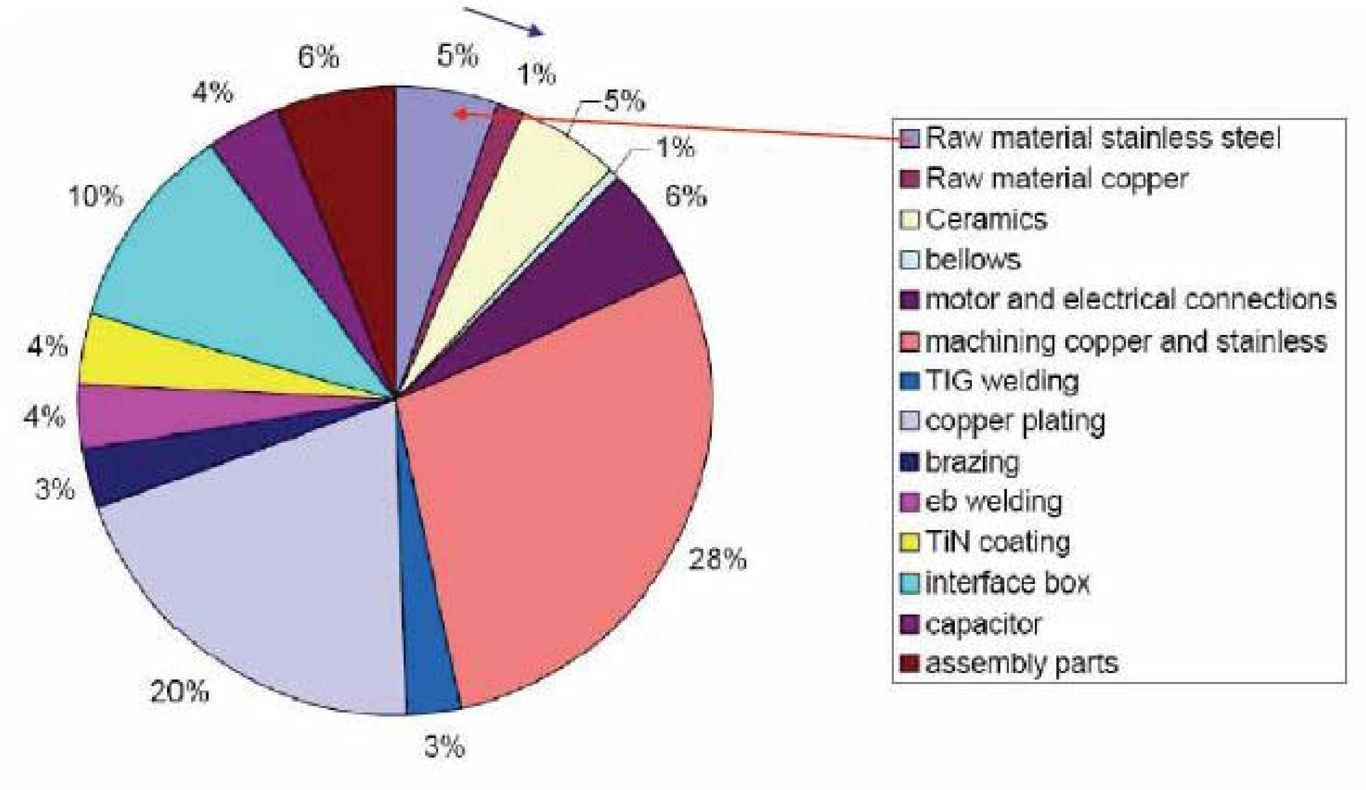
Phase 4: **lean manufacturing methods**

- optimise the design in terms of functions
- analyse bar chart of components costs:
  concentrate efforts of cost reduction on most expensive components
- think about production with less of everything:
  . less human resources, less specific competences
  . less manufacturing equipments and space
  . less raw material, less tooling & jigs
  . less stock, less spares, less energy, less waste

Phase 5: **analysis of final assembly**

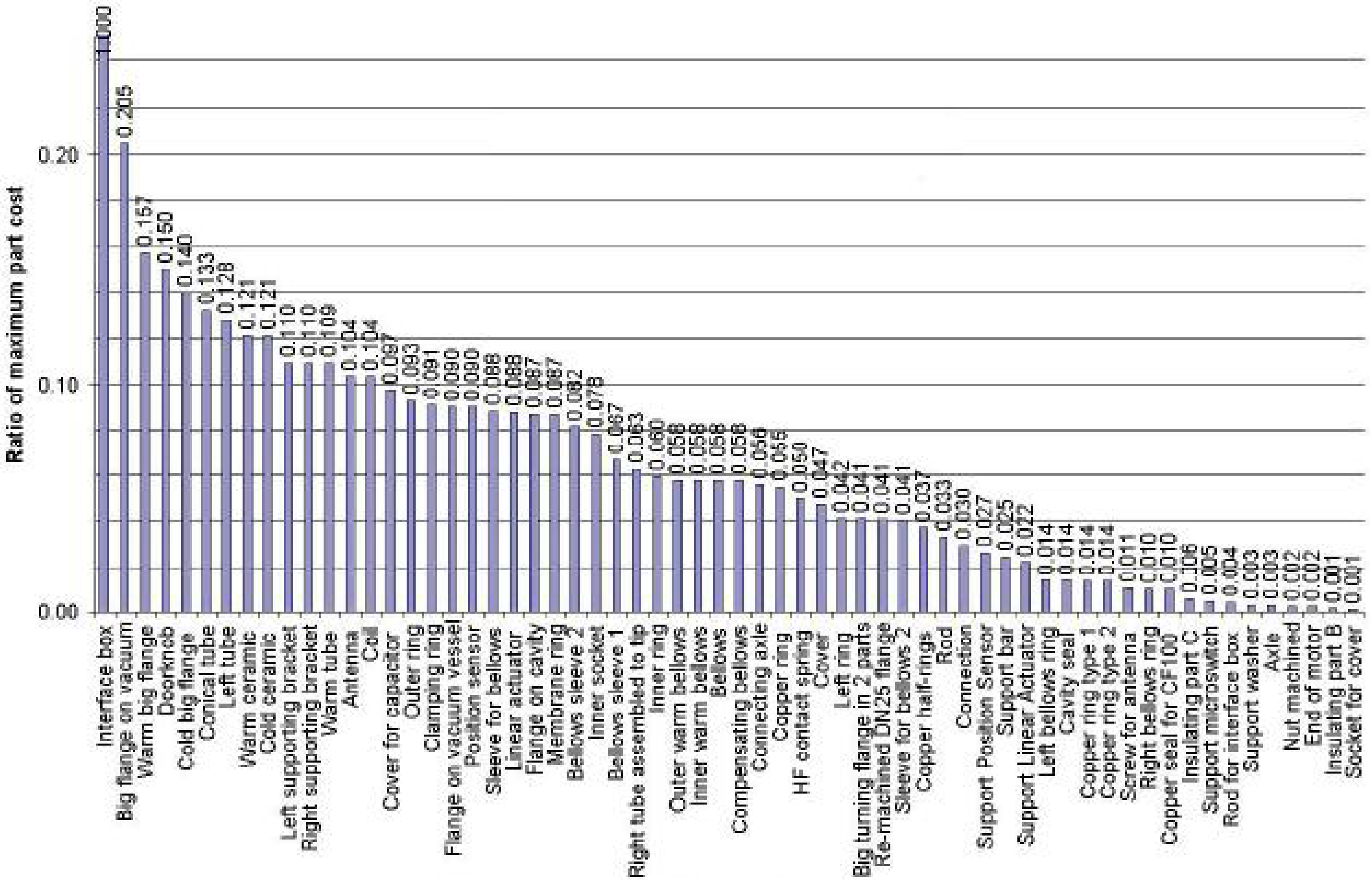
- decompose assembly operations in successive sequences
- what are the consequences of assembly on each component ?
- what parts could be simplified ?
- how to save manpower and assembly time ?

Manufacturing cost breakdown for materials and processes
(XFEL)



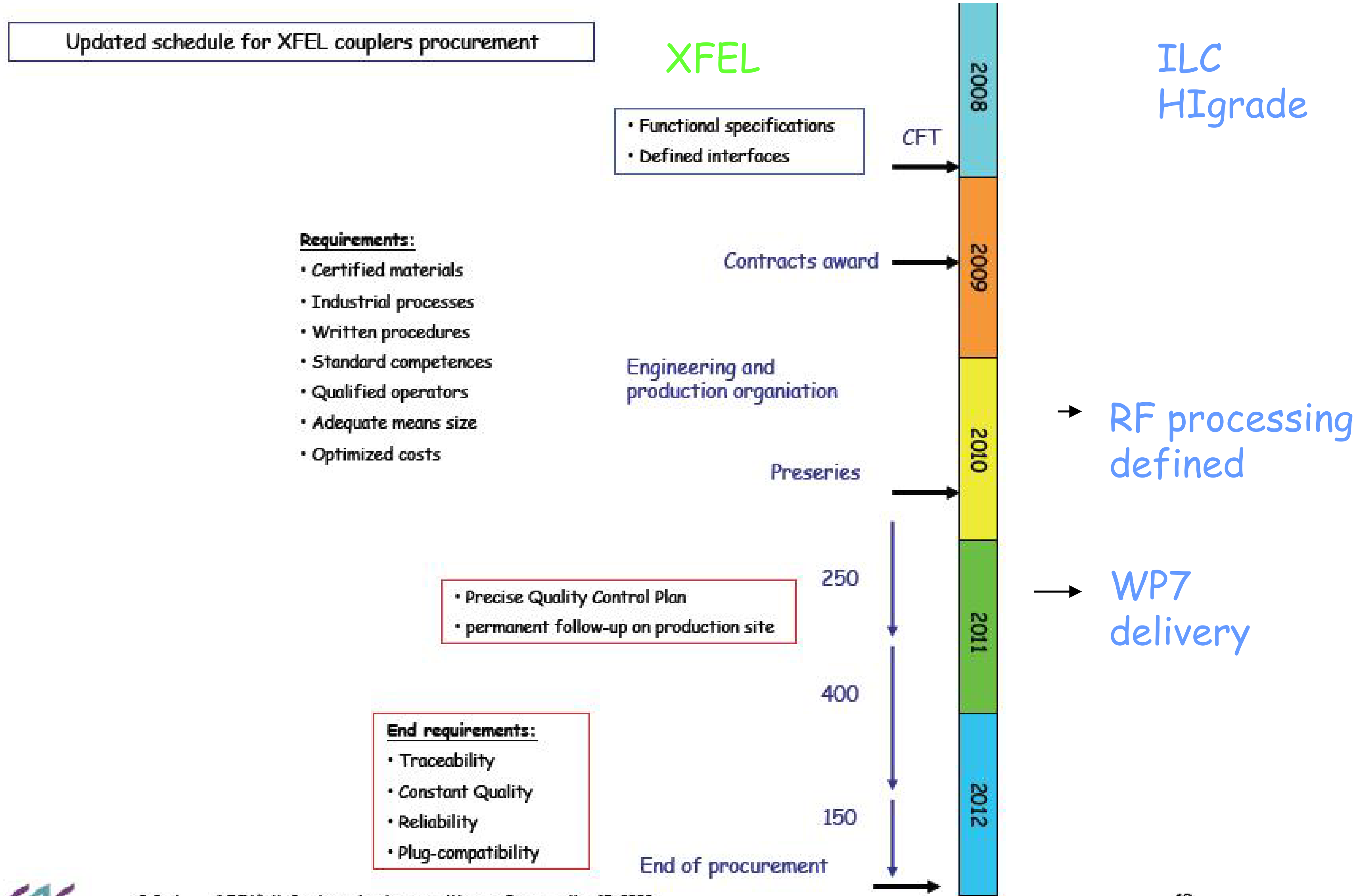

Total raw material cost ~ 20 %

## Bar chart for each part




This is the basis for future round of cost reduction: → concentrate efforts on expensive items

# Schedule synergy with XFEL



# Conclusion

- ILC HiGrade coupler program very important for ILC : cost and RF processing have to be reduced
- Strong synergy with XFEL program at LAL
- Intense R&D program presently on going on several fronts
- ILC HiGrade off to a good start!