

# High Power Couplers for TESLA SL Cavities

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DESY

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# 1. Specification of the TESLA High Power Coupler

	<b>TTF</b>	<b>TESLA 9-cell / upgrade</b>	<b>TESLA superstructure / upgrade</b>
beam power incl. control margin	250 kW	250 kW / 500 kW	555 kW / 1110 kW
repetition rate	10 Hz	5 Hz	5 Hz
coupling	adjustable ( $10^6$ - $10^7$ )	fix ( $3 \cdot 10^6$ )	fix ( $2.5 \cdot 10^6$ )
cavity position during cool down	flexible (15 mm longitudinal)	fix point (1.5 mm longitudinal)	fix point (1.5 mm longitudinal)

# General Parameters

frequency	1.3 GHz
operation	pulsed: 500 $\mu$ sec risetime, 800 $\mu$ sec flat top with beam
power for High Power Processing in situ	1 MW at reduced pulse length ( 500 $\mu$ sec and repetition rate 1 Hz )
2 K heat load	0.06 W
4 K heat load	0.5 W
70 K heat load	6 W
diagnostic	sufficient for safe operation and monitoring

## 2. Design criteria for the TESLA Coupler

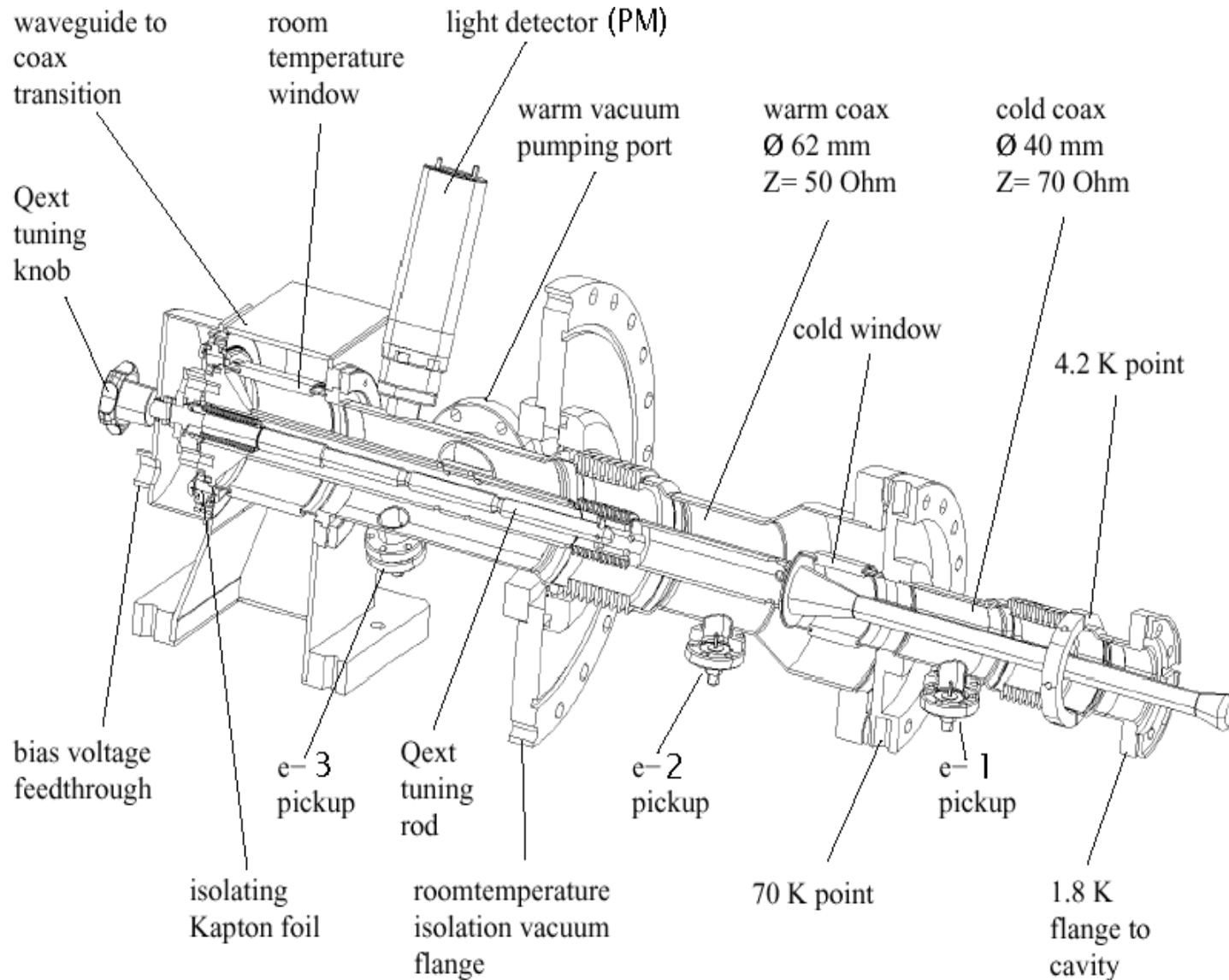
- coax is easy for:
  - variable coupling
  - fabrication
  - assembly
- two windows for:
  - clean assembly of the cavity
  - save operation
- cold coax:
  - at 70 Ohm, 40 mm diameter
- warm coax:
  - at 50 Ohm, 60 mm diameter
- bias on inner conductor:
  - suppress multipacting
- flexibility:
  - bellows in the warm and cold coax
- ceramics:
  - $\text{Al}_2\text{O}_3$  with TiN coating
- copper plating:
  - 10/30  $\mu\text{m}$  outer/inner coax
  - high thermal conductivity ( $\text{RRR} \geq 30$ )
  - high purity, Hydrogen free

# Multipacting as a Design Criteria

in order to avoid multipacting during conditioning and operating one has to:

- choose the right coaxial line diameter (MP level moves up with the 4<sup>th</sup> power)
- the right impedance (MP level moves up linear)
- lower the secondary electron emission coefficient on the surfaces (especially the ceramic)
- add a bias voltage to the inner conductor to suppress multipacting

# 3. TESLA Coupler TTF 3



# 4. Power Couplers in use at TTF-FEL

Coupler type		FNAL	TTF II	TTF III
cold part	window	conical	cyl.	cyl.
	coax diameter, mm	40	40	40
	Impedance, Ohm	50	70	70
warm part	window	flat, WG	flat, WG	cyl.
	coax diameter, mm	60	60	60
	Impedance, Ohm	50	50	50
coupling		adjustable	adjustable	adjustable
bias		no	yes	yes
TiN coating		FermiLab	FermiLab	DESY
test stand TW	2Hz / 500 $\mu$ s	1MW	2MW	1MW
	2Hz / 1.3ms	1MW	1.8MW	1MW
	cold test done	yes	no	no
hor. test SW	2Hz / <500 $\mu$ s	1MW	1MW	1MW (HPP)
	10Hz / 1.3ms	33MV/m	35MV/m	35MV/m (600 kW)
	cold test done	yes	yes	yes
fabricated total		16	20	62
tested		16	20	24
used in TTF modules		12	19	11
assembled to		Mod.1*, 2	Mod.1*, 3*, 4	Mod.5 (6, 7, 8) SS
operated		1997-2004	1998-2004	2001-2004
		100000 hr*coupler	130000 hr*coupler	35000 hr*coupler

## 5. Tests at 35 MV/m

- Long run test of EP cavities in the horizontal cryostat
  - o This test includes all auxiliaries like power coupler, HOM coupler, tuner, piezo...
  - o Gradient: 35 MV/m
  - o Max forward power: 600 kW
  - o RF on time 2400 hs
  - o No breakdowns in the coupler
- High gradient test with beam (in module ACC1)
  - o Gradient: 35 MV/m
  - o Gradient calibration with beam



# 6. Industrial Study of the TTF 3 Coupler for X-FEL (Collaboration between LAL & DESY)

Publication of the call for candidacy was on February 15<sup>th</sup> 2005, study will finish February 2007 with delivery of two prototypes. Three companies will be involved.

## Goals:

- minimize risks related to project:
  - all technical issues will be solved
  - development plan ready
- minimize financial risks:
  - precise estimation of cost in series
  - assurance that the chosen contractors will succeed
- gain time on manufacturing contract: all studies are done









## Principle of “Definition contract for industrialisation studies”




- Essentially intellectual work:
  - Define all manufacturing processes
  - Risk analysis (process, logistics)
  - Determine cost in series and justify
- Produce validation models and 2 prototypes

### Particularities

- 3 contracts will be awarded on the same subject
- these contracts will run simultaneously during 21 months
- evaluation of performance will be continuous ( formal reviews are key points)
- 2 teams will be selected after final evaluation
- contracts for manufacturing 2 series of 500 XFEL couplers will be awarded without new call for tenders
- the 2 contracts may be awarded to a single company

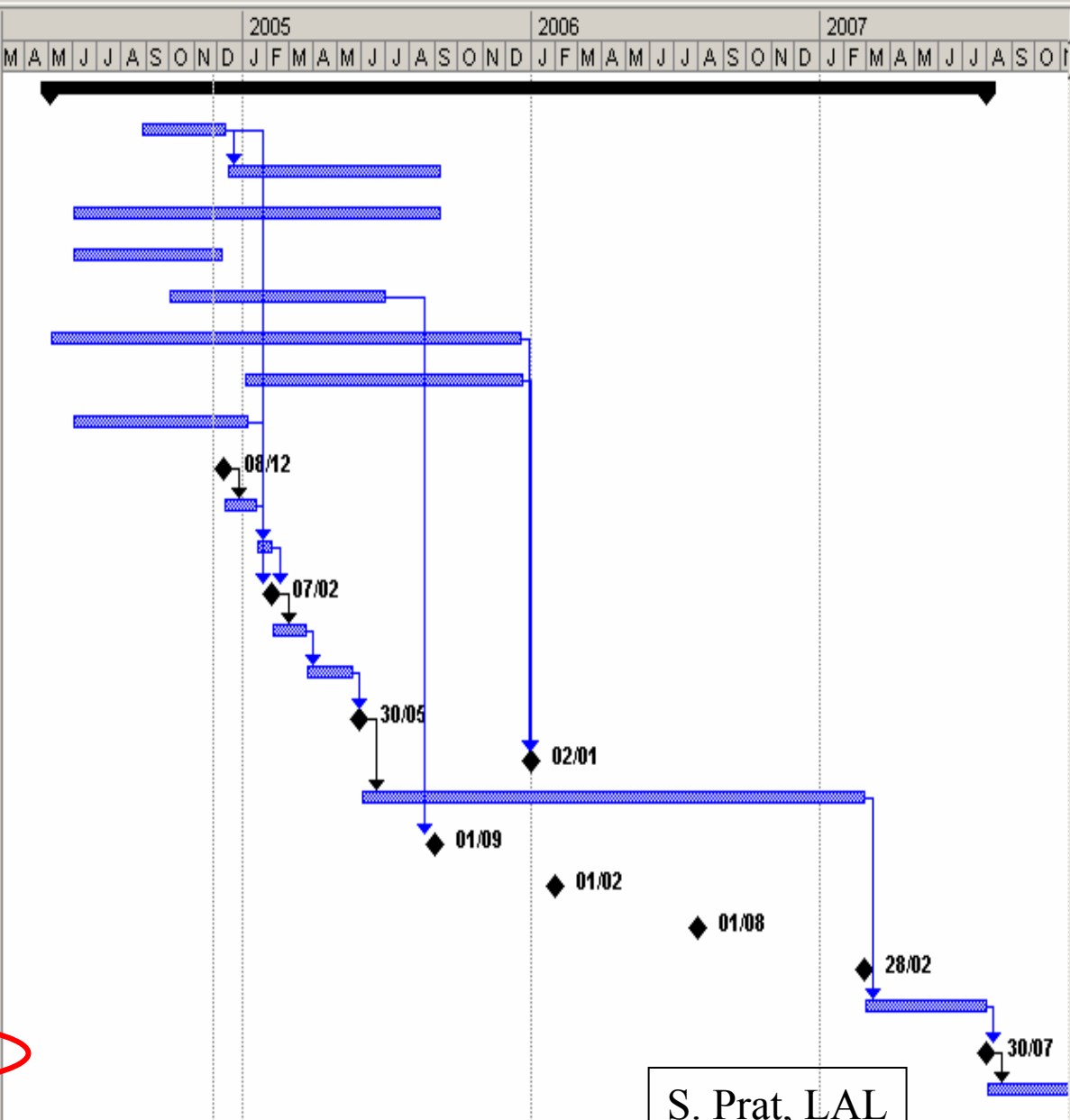
## Status of additional work

- Study of geometrical tolerances (RF studies) 
- Thermal studies (analytical + FEA) 
- RF studies of capacitor 
- Control electronics 
- Conditioning studies 
- EDMS 
- TiN coating technology 
- Interfaces definition with:  
WP3, WP8, WP9, WP19, WP28, WP29, WP33,  
WP34, WP36 

-  Completed
-  In progress
-  Not started

# Time schedule (now shifted by 2 month)

Nom de la tâche	Début	Fin
1 <b>Industrialisation phase</b>	<b>03/05/04</b>	<b>30/07/07</b>
2 Drawings preparation	27/08/04	10/12/04
3 Drawings update	13/12/04	08/09/05
4 Thermal studies	01/06/04	08/09/05
5 HF analysis (tolerances studies)	01/06/04	06/12/04
6 Studies of motorized tuning and control	01/10/04	30/06/05
7 Coupler conditioning studies	03/05/04	19/12/05
8 TiN coating technology development ?	03/01/05	21/12/05
9 Call for tenders preparation	01/06/04	07/01/05
10 Notification for tenders	08/12/04	08/12/04
11 Time for receipt of candidacy	08/12/04	17/01/05
12 Selection of candidates	18/01/05	07/02/05
13 Tender documents are sent	07/02/05	07/02/05
14 Time for receipt of tenders	08/02/05	21/03/05
15 Tenders analysis	22/03/05	19/05/05
16 Award of definition contracts (2 or 3)	30/05/05	30/05/05
17 Technology transfer to industry	02/01/06	02/01/06
18 Progress of 3 definition contracts	01/06/05	27/02/07
19 System Design Review	01/09/05	01/09/05
20 Preliminary Design Review	01/02/06	01/02/06
21 Critical Design Review	01/08/06	01/08/06
22 Delivery of prototypes	28/02/07	28/02/07
23 Analysis of results	28/02/07	30/07/07
24 <b>Award of manufacturing contract(s)</b>	<b>30/07/07</b>	<b>30/07/07</b>
25 <b>1000 couplers manufacturing phase</b>	<b>31/07/07</b>	<b>14/02/11</b>

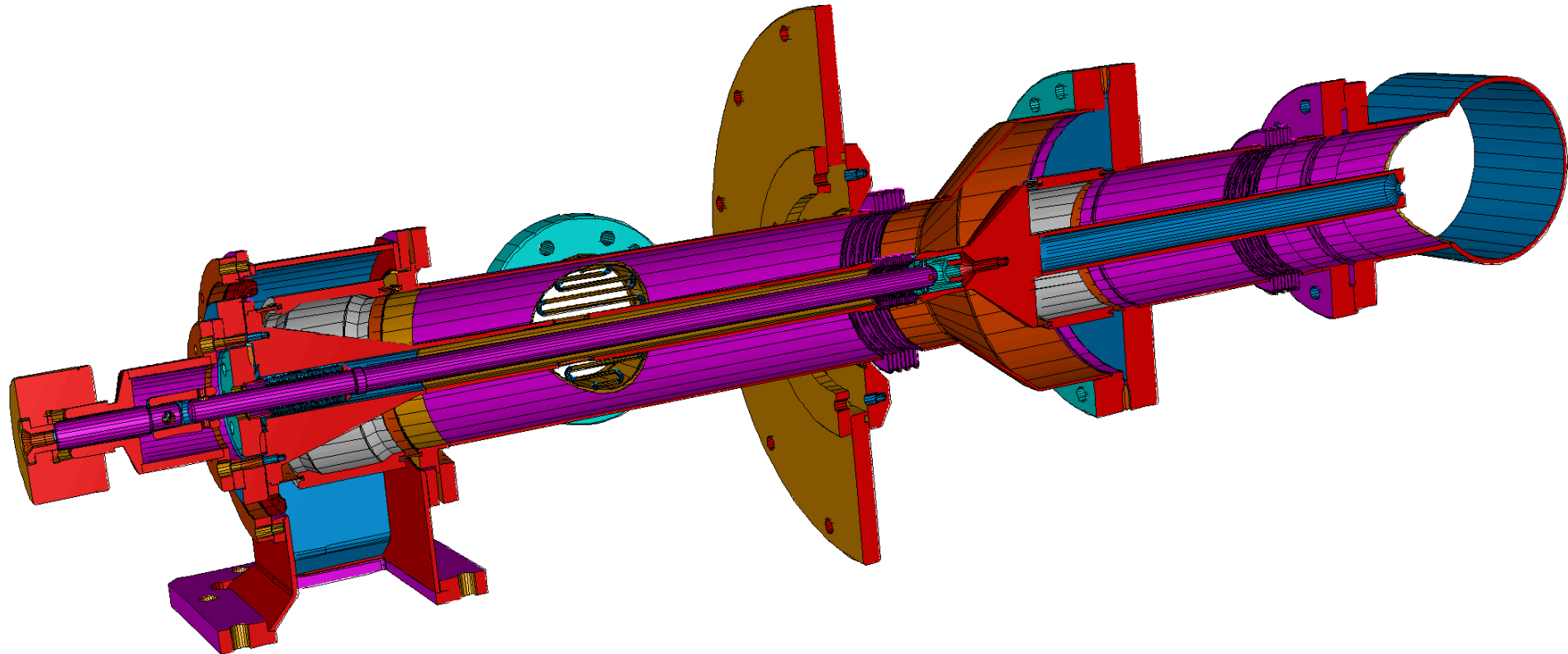


## 7. Other Developments

- Coupler design with 80 mm coax diameter (foreseen for the 4 x 7 cell superstructure) was designed at DESY, build and tested at LAL, Orsay
- DESY RF design for a 60 mm coax diameter is finished for the 2 x 9 cell super structure
- LAL design of 60 mm coax diameter and disc windows is under construction
- In collaboration with AMAC a 80 mm coax coupler with disc windows is designed, fabricated and tested
- Simplification of the diagnostic
- CW tests at Elbe Rossendorf and Bessy Berlin up to 4.5 kW
- New collaboration with KEK well on the way

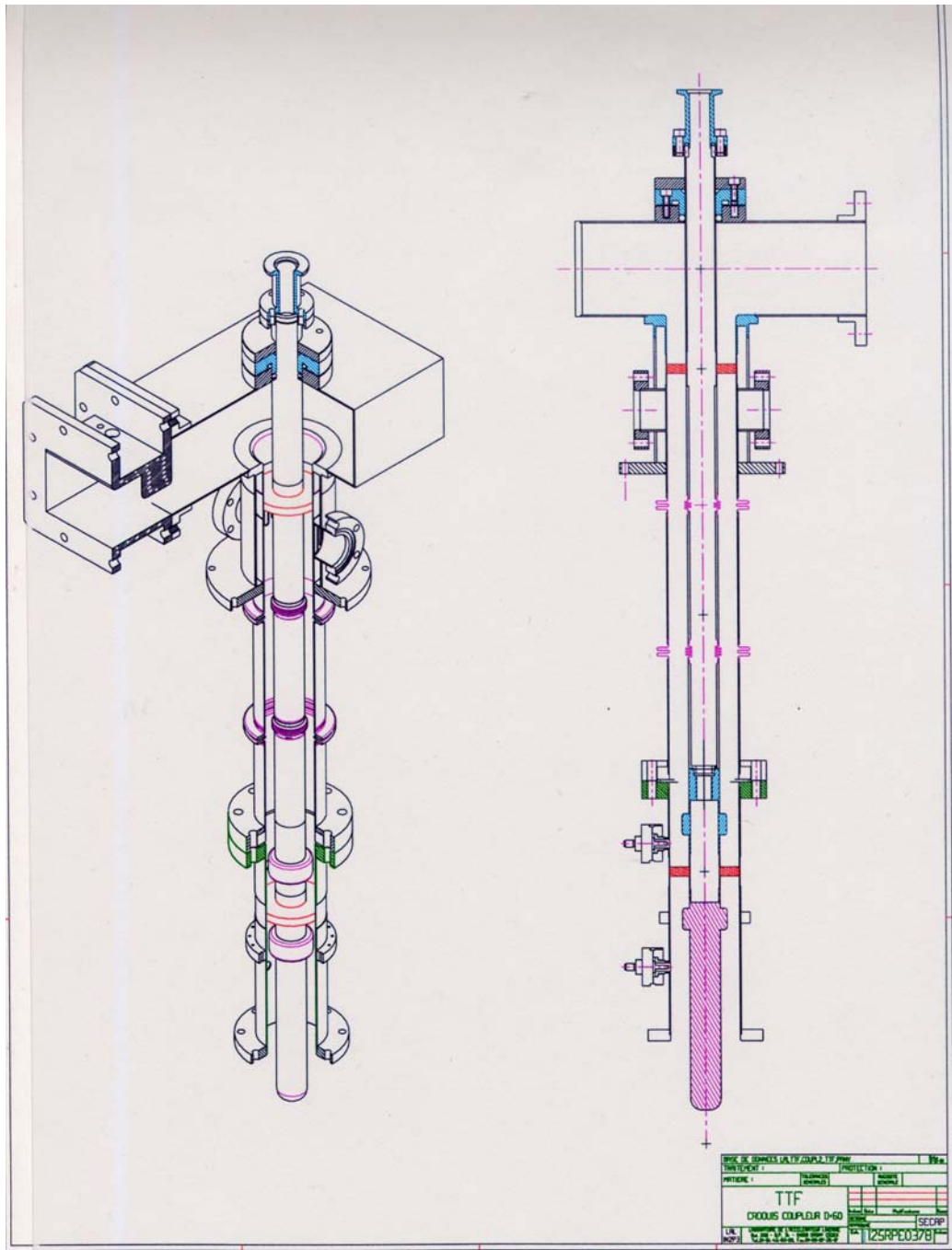
# TTF 4 coupler

- 80 mm coax
- Foreseen for the 4 x 7 cell superstructure
- Two prototypes build & tested at LAL



# LAL Design

- Coax 60 mm
- Disc windows
- Under construction



# AMAC - DESY Collaboration

- 80 mm coax
- Two prototypes fabricated and under test



# Conclusion

- 62 TTF 3 couplers are fabricated
- 24 are tested
- 11 TTF 3 couplers are under operation in TTF
- Several tests at  $E_{acc} \geq 35$  MV/m done
- One test at 35 MV/m over 2400 hrs
  - No breakdowns in the coupler
- Industrial study for the X-FEL is started
- Coupler developments for higher power (bigger coax diameter) is under way