FCC week 2015

23-27 March 2015
Marriott Georgetown Hotel

Superconducting RF: Novel Cavity Concepts & Cryomodules

Fundamental Power Coupler (FPC)

Eric Montesinos, CERN-RF

(inputs from all world wide FPC experts, great thanks to all of them !)

FCC FPC requirements

Requirements for the FCC FPC to date

- Less than 1 GHz (baseline 400 MHz)
- 100 MW CW SW
- ***300 FPC*** - 350 kW to ***1500 FPC*** - 80 kW

	Coupler	Frequency [MHz]	Average Power [kW]	Peak power [kW]	# in operation or in construction
Coaxial disk	SNS	805	78	2000	93
	JPARK	972	30	2200	23
	SPS	200	550	800	16
	KEKB	509	300	1420	8
	IHEP	500	150	270	2
	CEA-HIPPI-ESS	704	120	1200	120
	SPL	704	100	1000	4
	Crab Cavities	400	100	1000	4
WG	SPS	801	120	120	8
	Cornell	500	350	350	4
	LBNL	700	800	800	2
	Linac4	352	100	1000	30
Cylindrical	LEP († 1989-2000)	352	550	565	252
	LHC	400	550	575	16
	SPS († 1976-2000)	200	375	500	16
	New ESRF	352	300	300	4
	New APS	352	100	100	1
	New SOLEIL	352	200	300	4
Two windows	TTF III XFEL	1300	4.5	1100	600
	APT	700	1000	1000	2
	Cornell ERL	1300	75	75	2

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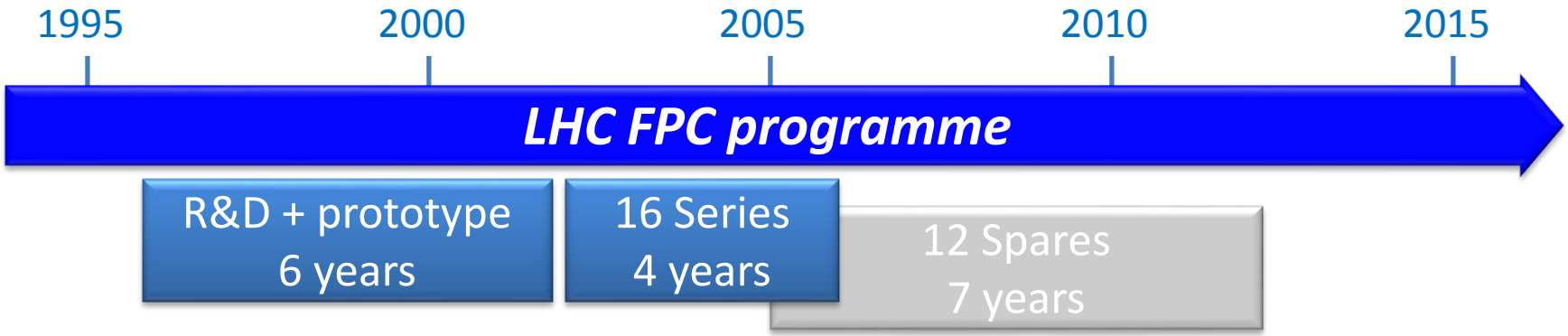
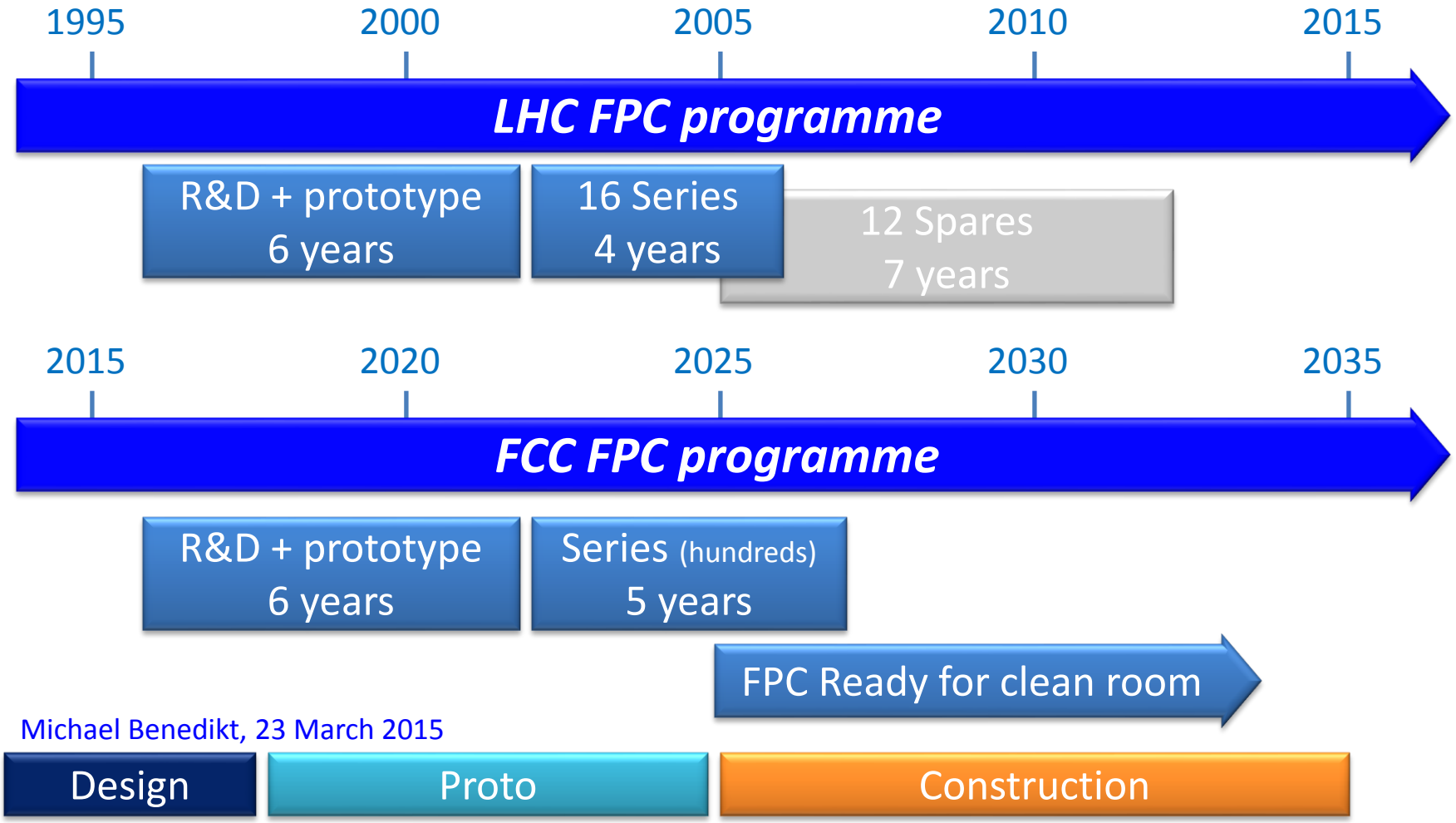
FCC FPC schedule



FCC FPC schedule



FPC

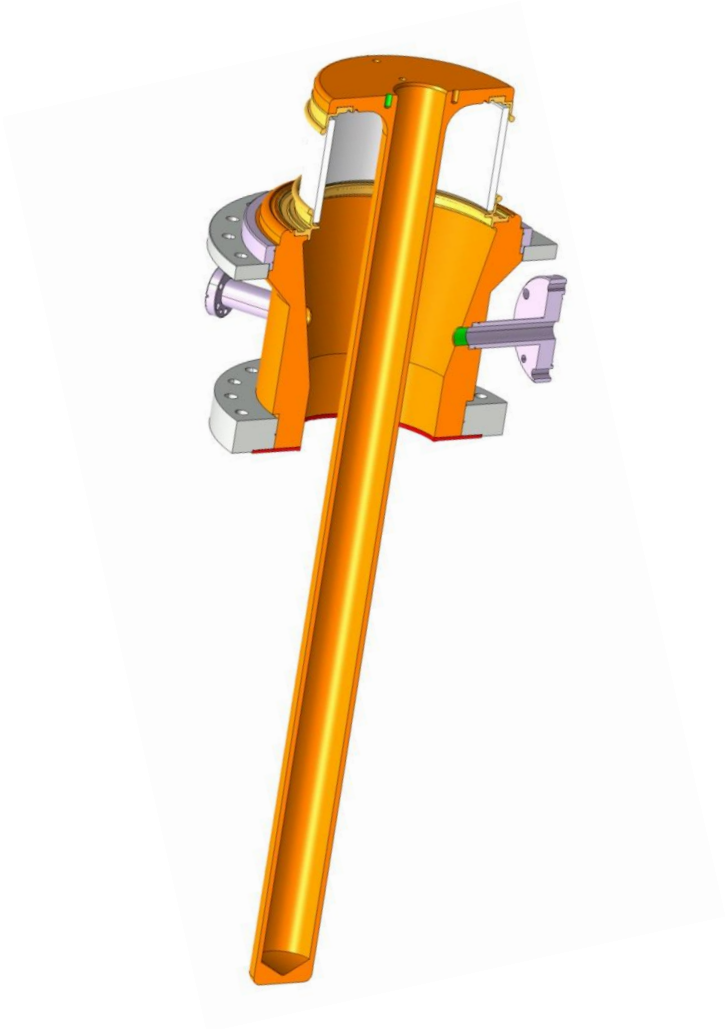
FPC is a specific RF transmission line

- Air side
- Vacuum side
- In between, there is a RF window

It has several additional features

- Coupling Element
- Double walled Tube
- DC Polarisation
- Variable coupling
- …

- = Optional



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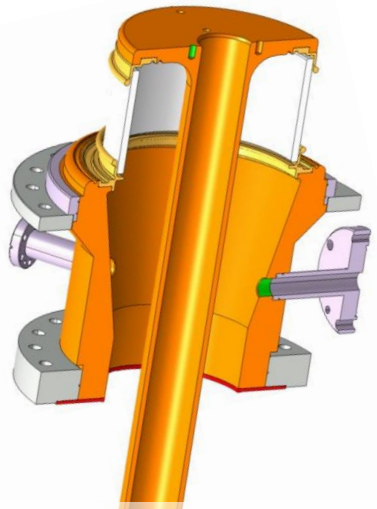
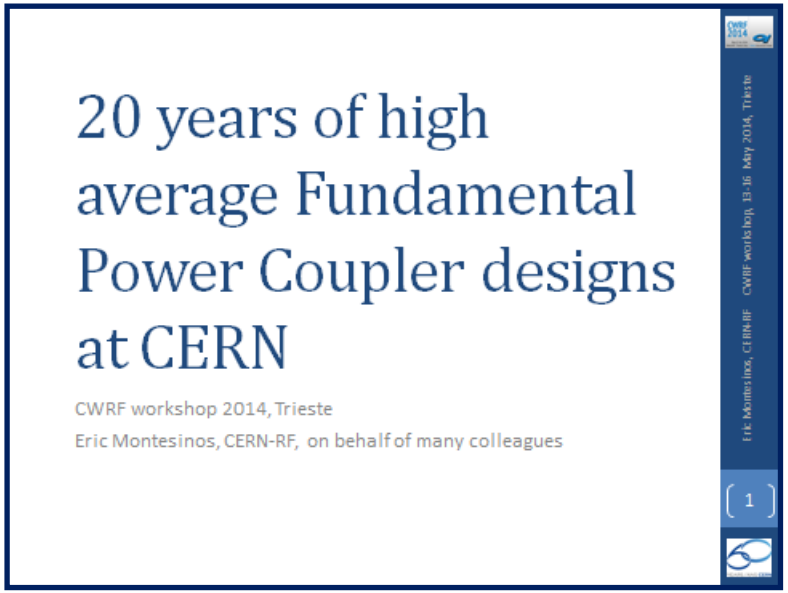


Goal of this talk
To list R&D topics that we should address for FCC FPC to be ready with a correct cost and in due time

FCC FPC

Complementary to this talk

https://indico.cern.ch/event/196164/
http://indico.cern.ch/event/196164/contribution/45/material/slides/7.pptx



https://indico.cern.ch/event/276274/
https://indico.cern.ch/event/276274/session/5/contribution/35

FPC Window (1/2)

The window is the key item of the FPC
The whole accelerator reliability will depend on its design

Fail safe design

Largely depends on the cryomodule design and cryomdodule integration

- Disk, Coaxial disk, Cylindrical, could be any other shapes

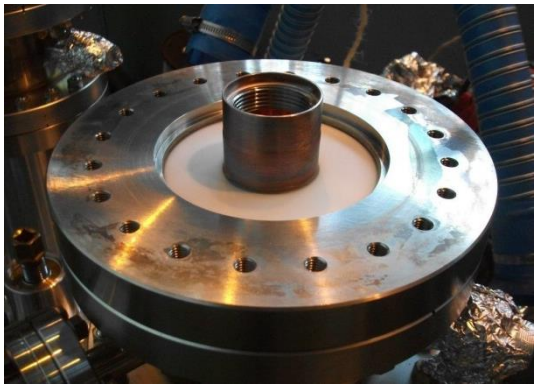
Maximum Power

- With less than 1 GHz, TW & SW all phases limits are probably (frequency dependant) 1 MW peak for few ms, 500 kW CW
- Lower power is only slightly easier and slightly less expensive

LHC cylindrical
400 MHz
500 kW
CW
TW + SW

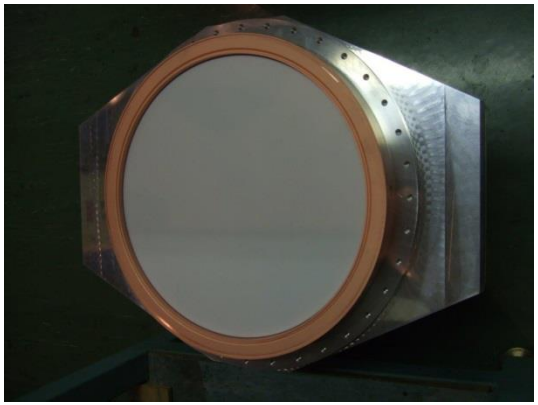
ESRF-SOLEIL-APS
352 MHz

SPL
704 MHz

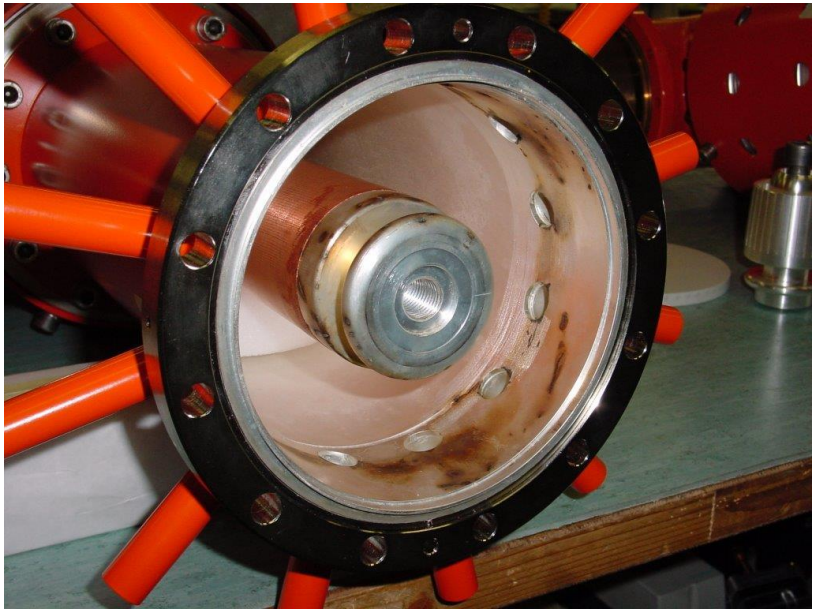


SPL coaxial disk
704 MHz
1000 kW
2 ms – 50 Hz
TW + SW

Crab Cavities
400 MHz



Linac 4 disk
352 MHz
1000 kW
1ms – 2Hz
TW + SW



1998 SPS couplers during design phase
Operating at 200 MHz
800 kW TW ok
Arcing at almost 500 kW SW due to sharp edges at the air exhausts

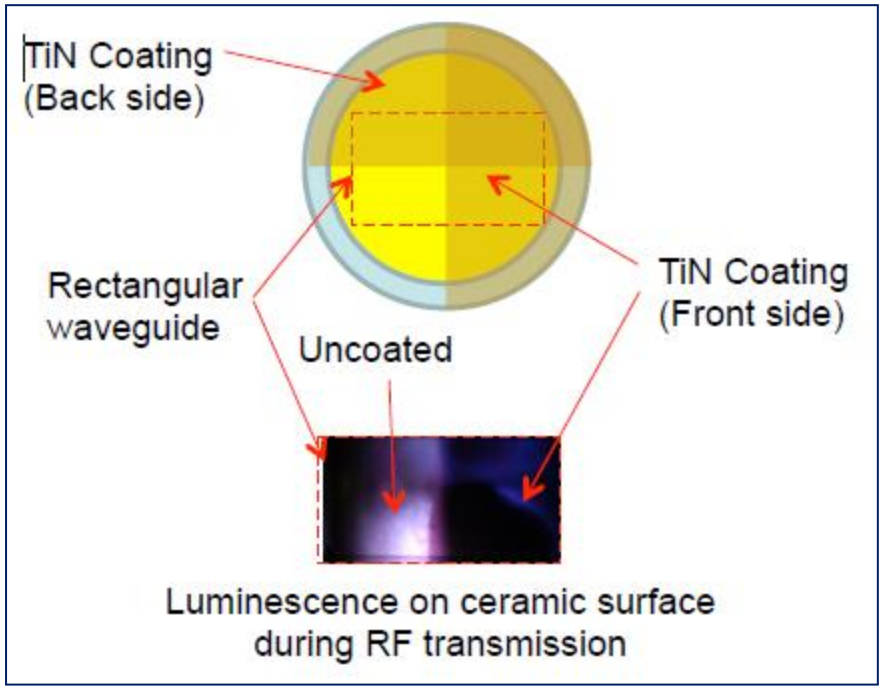
FPC Window (2/2)

Materials

- Al2O3 + (TiOx or TINx) sputtering on vacuum side against multipacting
- Other ceramic without treatment having intrinsically better SEY against multipacting
- Could be other materials

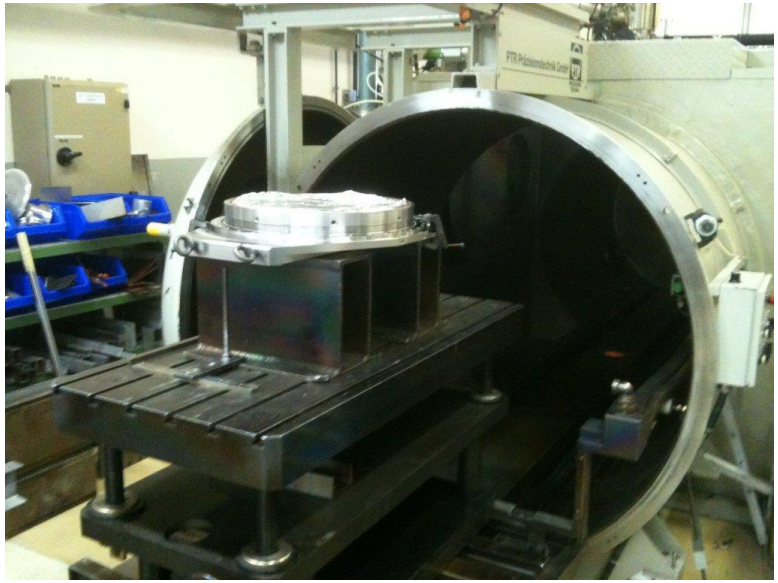
Brazing, welding

- Copper (+ EBW provides RF continuity without RF contacts), Titanium, Kovar©, Stainless steel, …



New Kyocera alumina
Test at KEK

(K. Iwamoto, KYOCERA Corporation)
(S. Michizono, A. Yamamoto, High Energy Accelerator Research Organization)



Large devices EBW at CERN
Linac4 window
600 mm x 400 mm x 60 mm
Copper/Copper

Variable Q_{ext}

Major additional difficulty due to Q_{ext} excursion

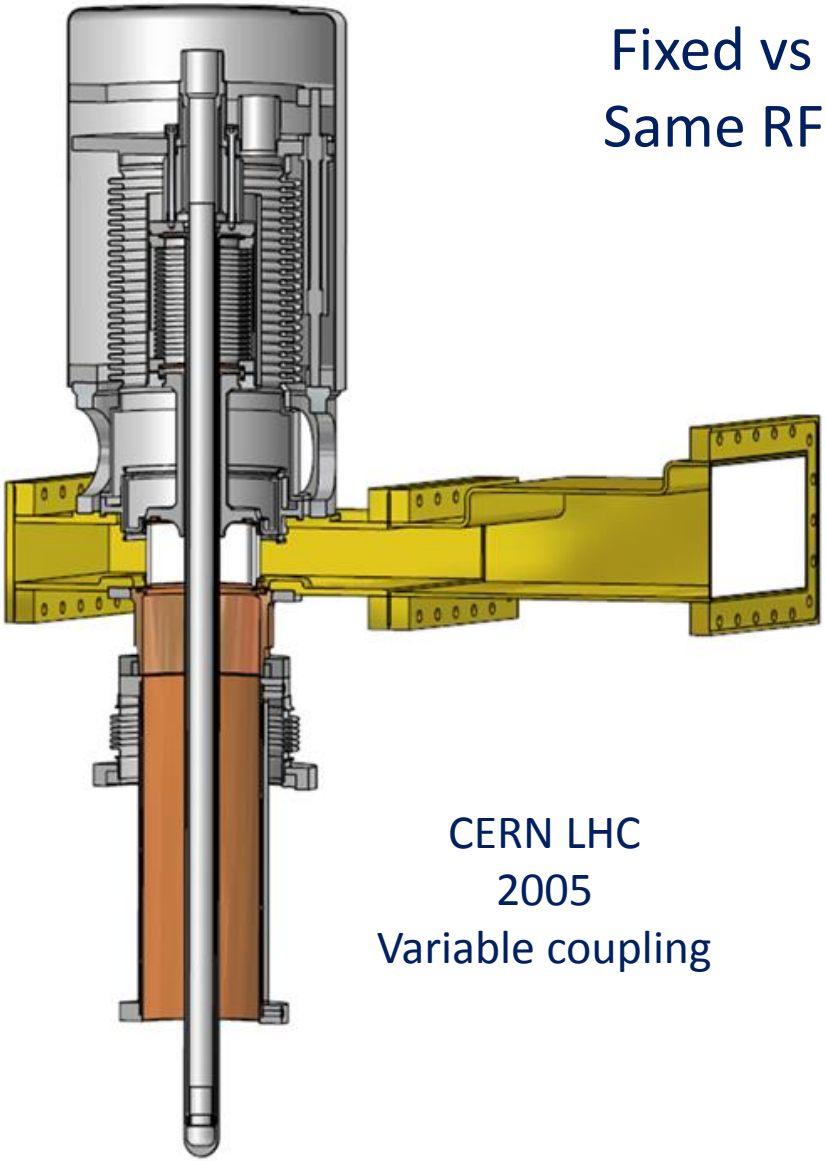
Main cost driver

- Everything is more complicated: design, drawings, construction, test, integration, operation, maintenance,… everything !
- Can drive cost ***from 1 (fixed coupling) to minimum 2 (variable coupling), and even more !***

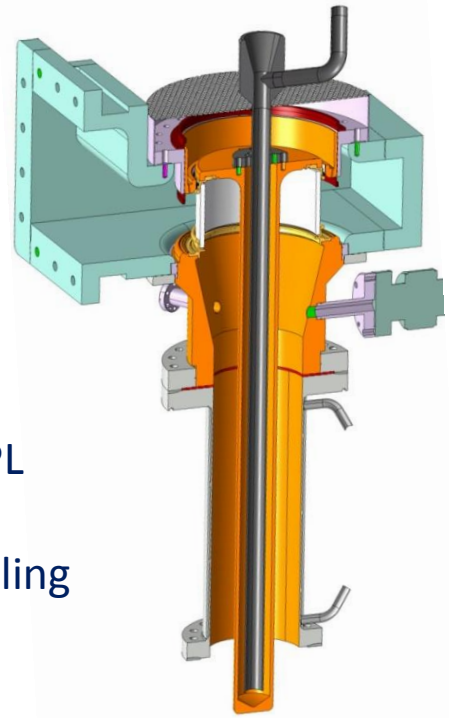
Efficiency

- S_{11} & S_{21} variations inducing loss of efficiency
- Better match to beam providing gain of efficiency

Fixed vs Variable
Same RF window

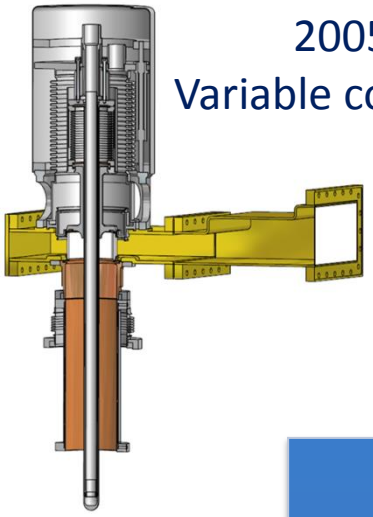


CERN LHC
2005
Variable coupling



CERN SPL
2013
Fixed coupling

CERN LHC
2005
Variable coupling



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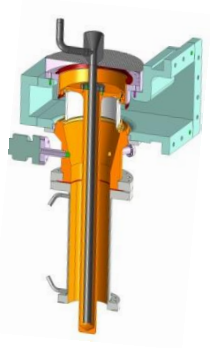


Fixed vs Variable
Same RF window

LHC Variable		SPL Fixed
185	Drawings	45
160	Main items	40
350	All devices	150
$$$	Cost	$

Double walled Tube (DT)

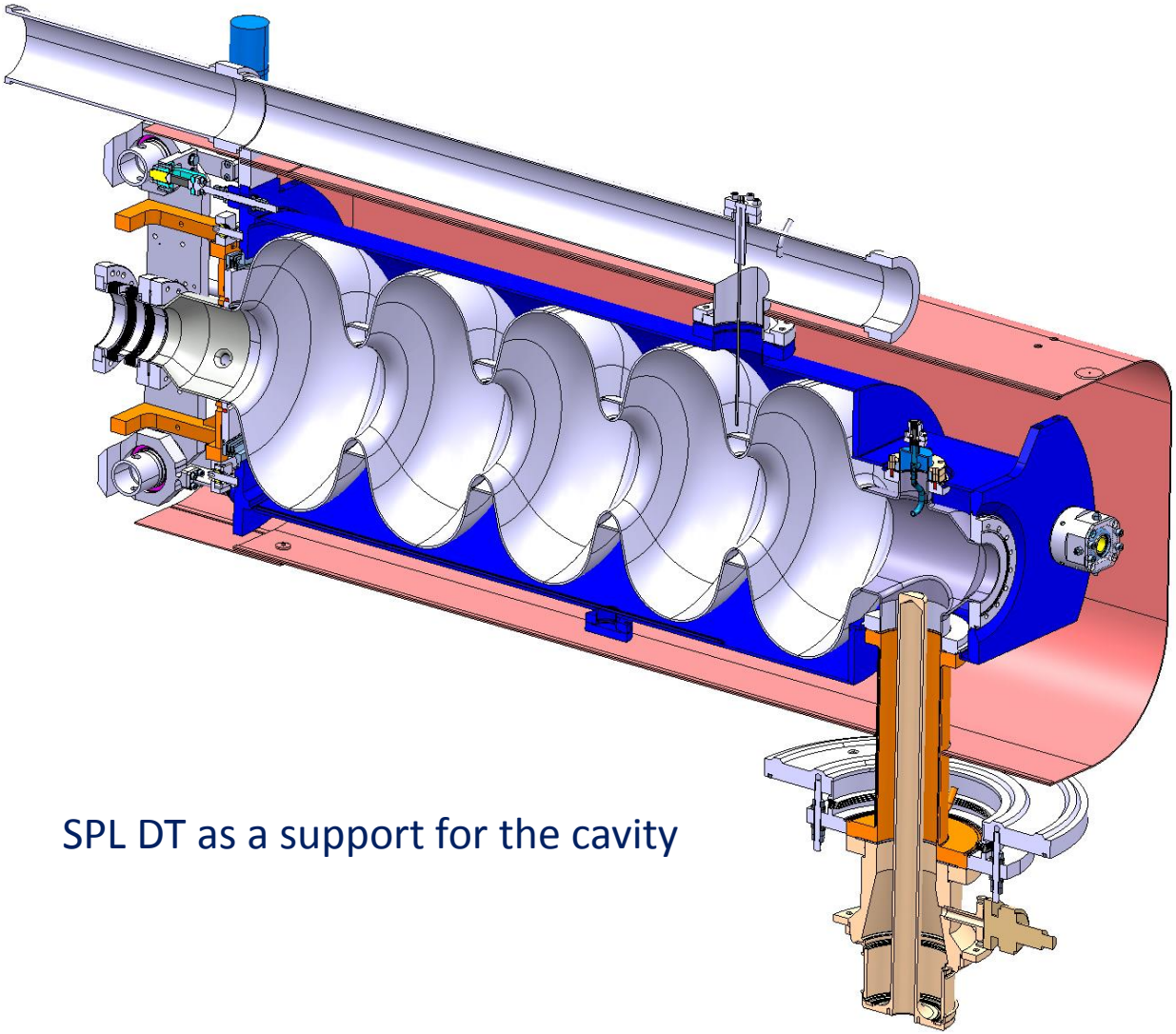
DT makes the transition from cold to warm

- From FPC point of view DT is a simple thin copper tube
- Skin depth effect vs frequency

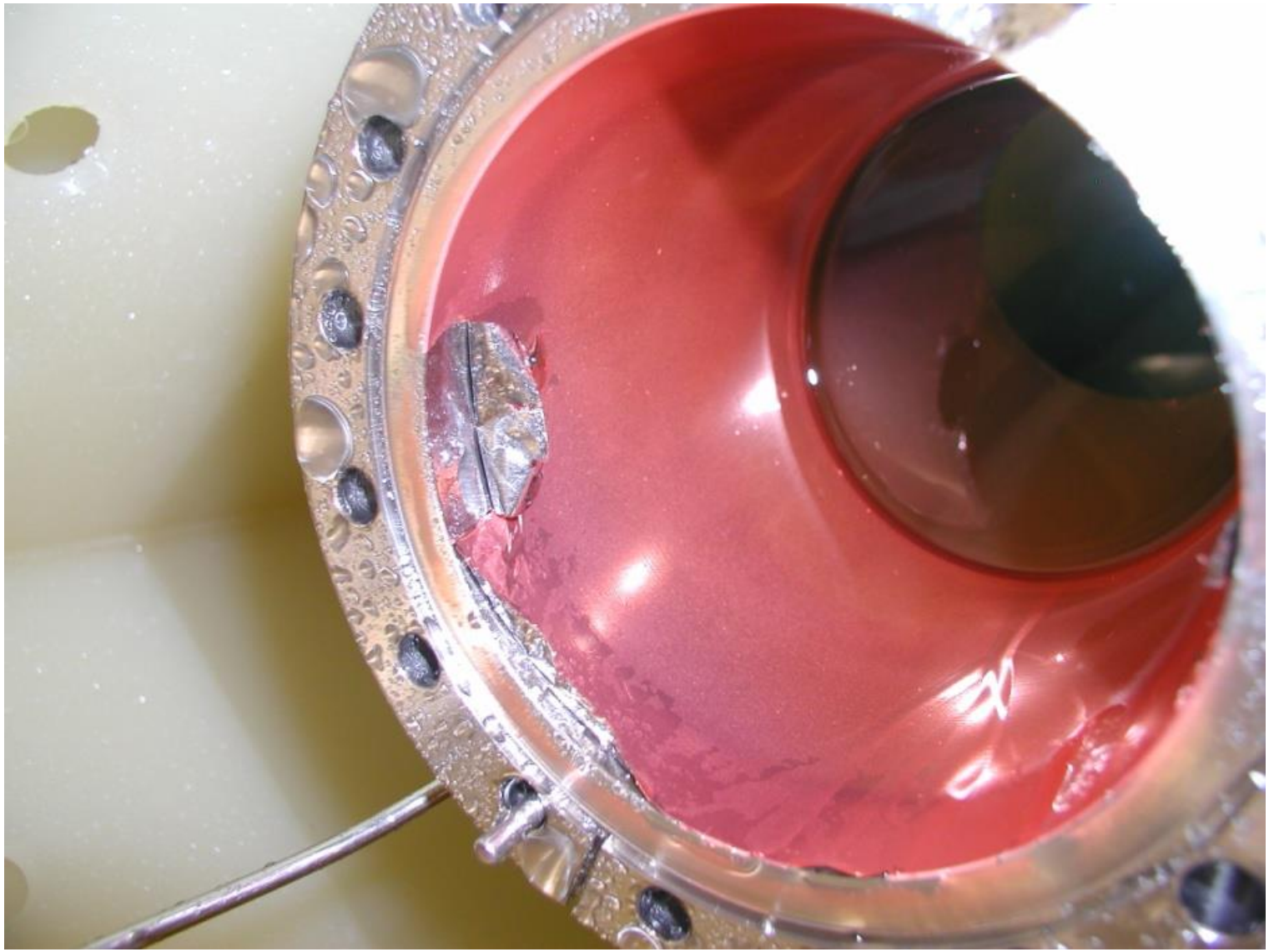
DT could be a support for the cavity

DT ***copper coating has always been a difficulty***

- ***Cost & schedule***



SPL DT as a support for the cavity



SPL Double walled Tube, copper coating peeling

Cooling

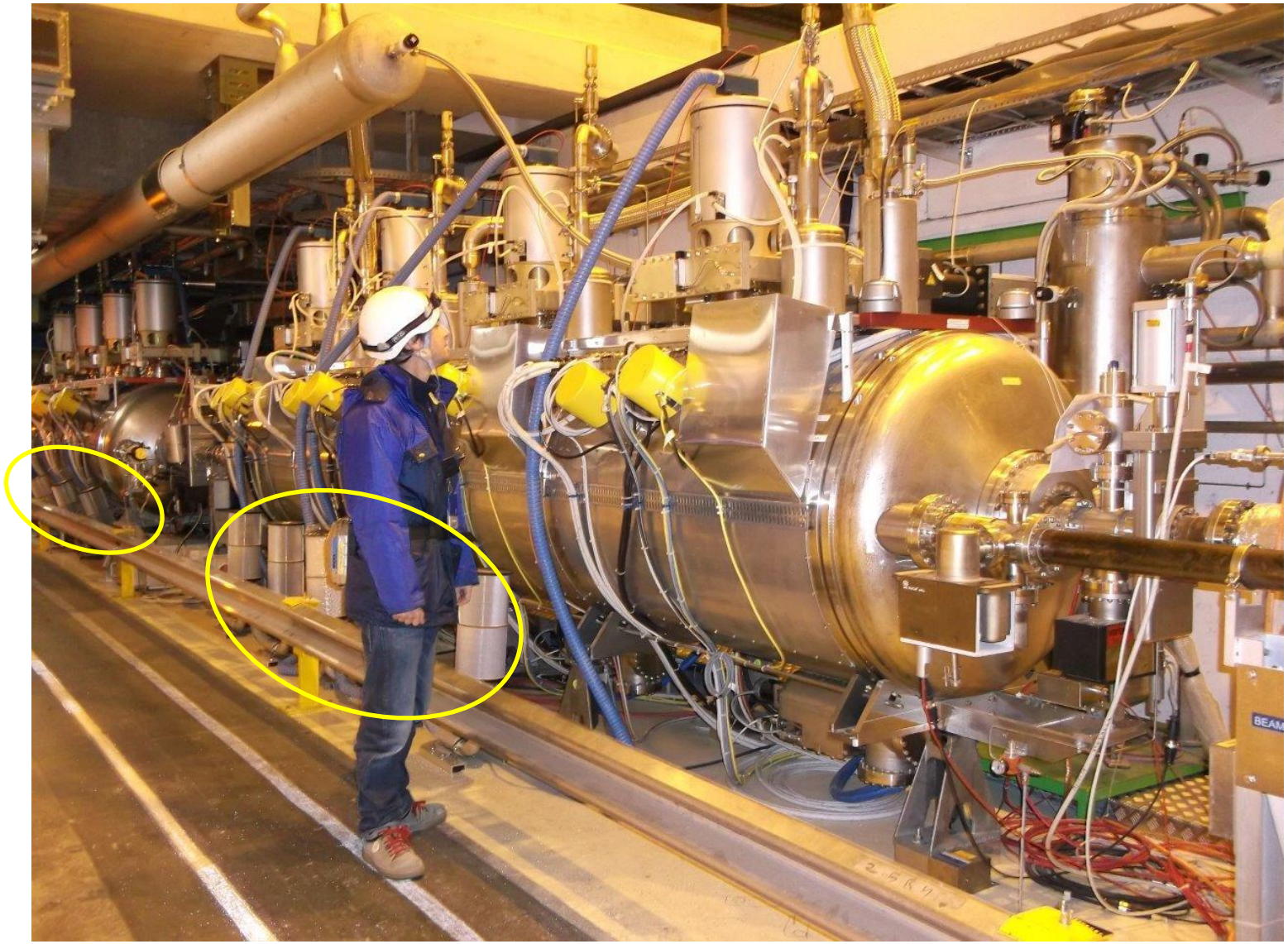
***Air cooled only** (specific rule at CERN)*

for any part in direct view to beam vacuum in case of failure

- Brazing
- Electron Beam Welding
- Freezing of coolant problem

Side effect requirements

- Not a single water hammer effect allowed to the ceramic
- Clean air system as high E-field area
- Individual local pump or local blower close to the FPC
- Thermal losses added into the accelerator
  (could be up to hundreds of kW losses in the tunnel)



LHC cryomodule with individual 1 kW blower per coupler

Cleanliness

Key topic (specially large series production)

High gradient & clean room

- Clean room class vs gradient
- Specific cleaning tools and processes, to be though for large series production
- Trained specialists
- Cost of infrastructure can deeply impact the FPC costs
- Schedule impacted by the size and availability of the infrastructure

Handling and storage of sensitive items

- No degradation of clean & sensitive items
- Duration of storage

DESY clean room

SPL special transport frame

DESY coupler, metalic storage cabinet

FPC test benches (1/2)

Often neglected even if a so important topic

Minimum 2 test benches during R&D phase

- Including design and construction of the test box
- Designed for both TW and SW all phases

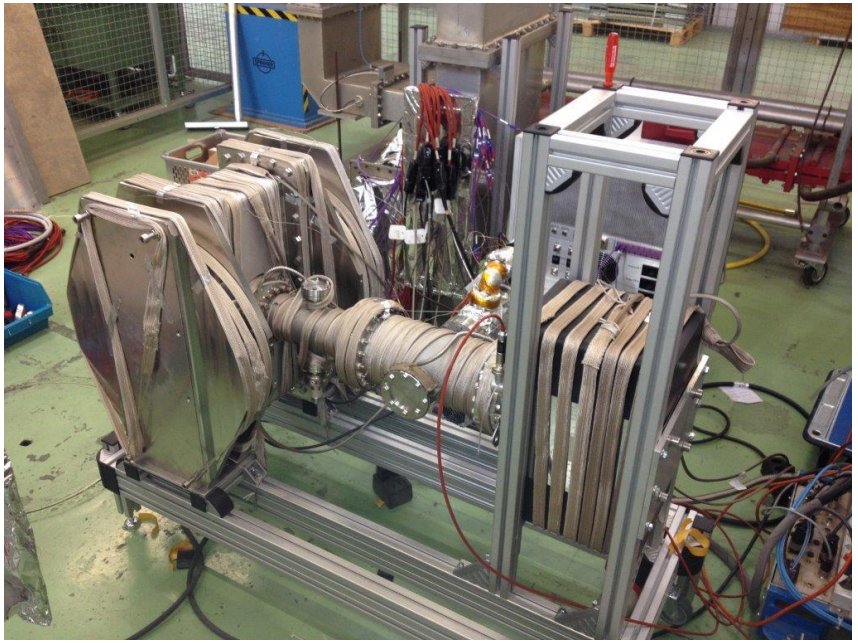
Define required diagnostics

- Quite a lot for the R&D phase
- Minimize the ones needed for machine operation

Prepare and define quick & safe RF conditioning processes for large series

- Bake out
- Pulsed mode - power ramping – outgassing limits

LHC test cavity



Linac4 test bench under baking

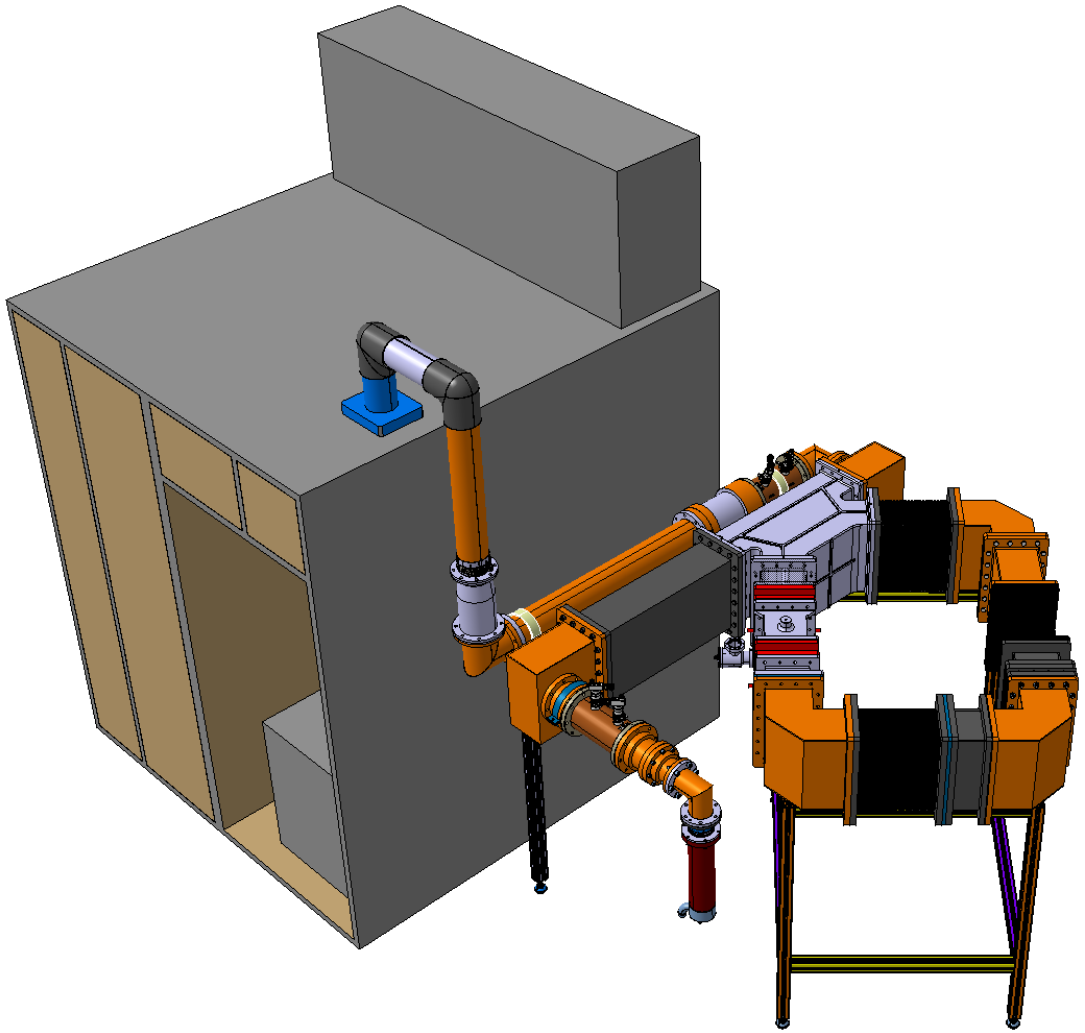
FPC test benches (2/2)

One destructive programme to check limits

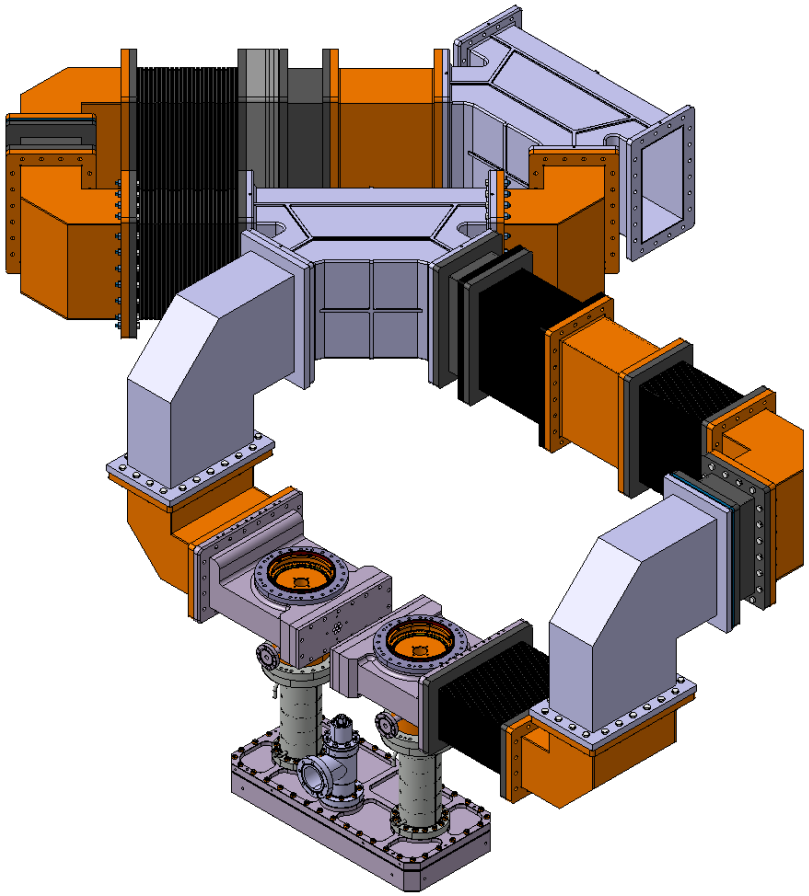
- Maximum Power
- Maximum vacuum pressure
- Cooling system
- Materials

Minimum number of test benches during production phase depends on

- Total quantity of couplers to be produced
- Production schedule
- Cost of test benches (promising resonant rings R&D)



800 MHz resonant ring
to test SPS RF windows
up to 600 kW with a 60 kW IOT



Latest idea
704 MHz double resonant ring
to test SPL FPC
up to 8000 kW with a 80 kW IOT

FCC Challenges

How to produce at low cost AND with high quality ?

Launch several R&D programmes

- FPC will deeply impact cryomodule design
- FPC design will deeply be impacted by cryomodule design (can cost a lot !)

All listed topics to be studied in detail to minimize cost and schedule impact, always taking into account large series production phase

World Wide Programme

Quite a lot of R&D to be addressed
(not all listed today, the list is too long…)

Setting up a World Wide community sharing R&D and results

- CERN, KEK, DESY, CEA, SLAC, ORNL, BNL, …
- First meeting at CERN in June 2015 to list all ideas to be addressed
- Yearly specific dedicated FPC workshop/meeting between experts
- ***Definition and distribution of 'individual tasks' and global sharing of results***

WWFPCTS★ Ready to go !

★ World Wide Fundamental Power Coupler Task Force ™

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