Fundamental Power Coupler at CERN

WWFPC01, CERN, Geneva, 23-24 June 2015, Eric Montesinos, CERN-BE-RF

Outline

Past, present and future projects

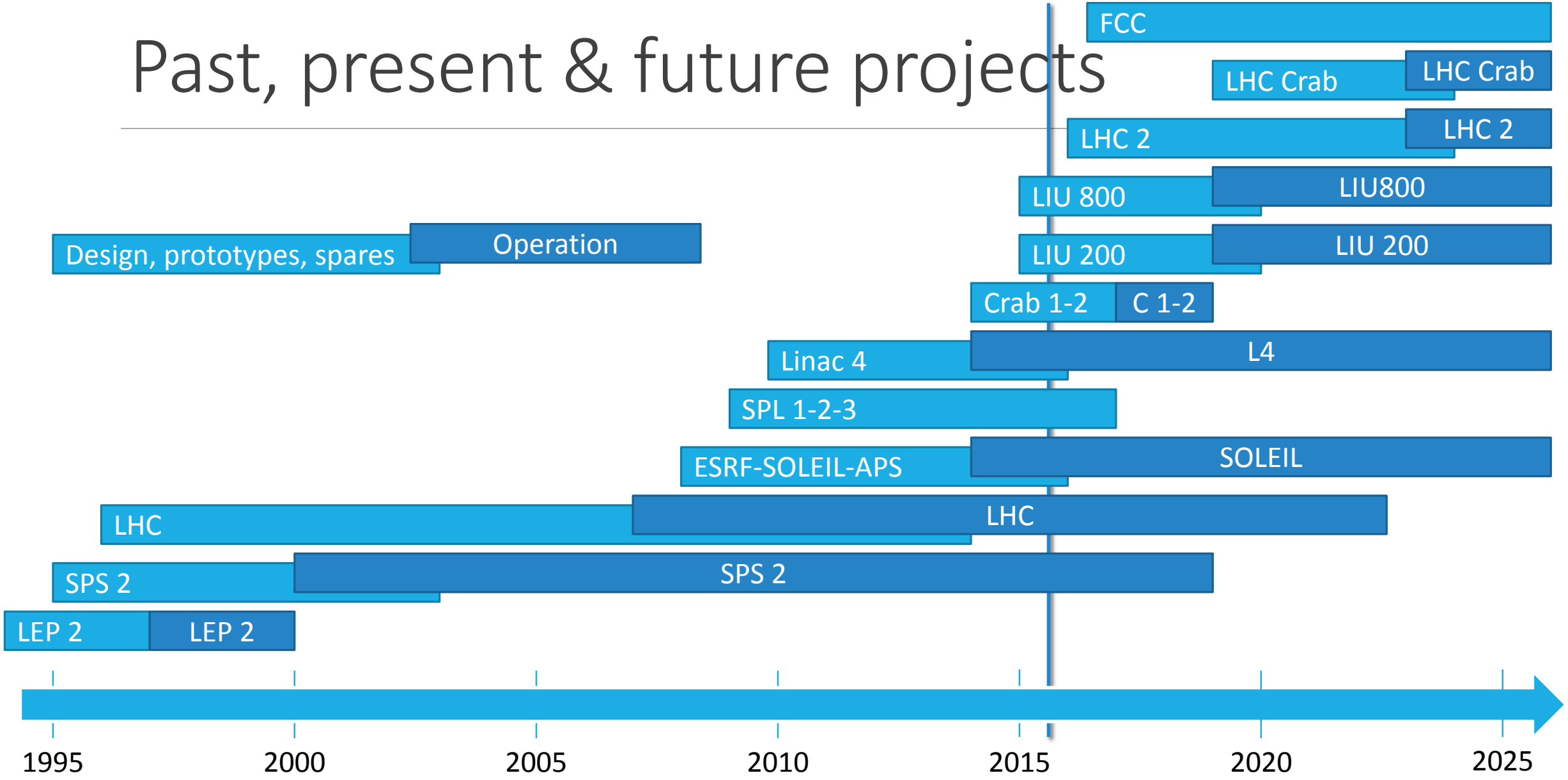
Windows for FPC at CERN

Statistics

Conditioning processes, test boxes, resonant rings

R&D programmes

Past, present & future projects



Frequency & Power levels

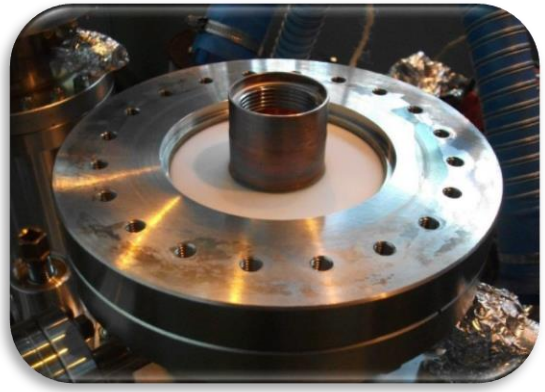
Coupler	Frequency [MHz]	Operation	TW [kW]	SW [kW]
LEP 2	352	CW	375	500
SPS 2	200	CW	500	-
LHC	400	CW	550	575
ESRF-SOLEIL-APS	352	CW	300	200
SPL 1-2-3	704	2 ms – 50 Hz	1000-1000-1500	600-1000-1500
Linac 4	352	2 ms – 1 Hz	-	1000
Design				
Crab	400	CW	100	100
LIU 200	200	CW	1000	-
LIU 800	800	CW	250	-
LHC 2	400	CW	600	600
LHC crab	400	CW	100	100

Ceramics

LHC cylindrical
400 MHz
500 kW
CW
TW + SW

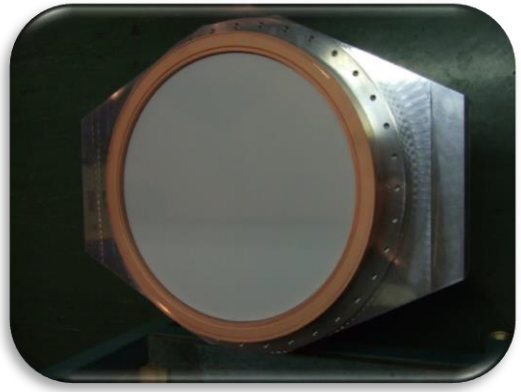
ESRF-SOLEIL-APS
352 MHz

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

Cylindrical windows

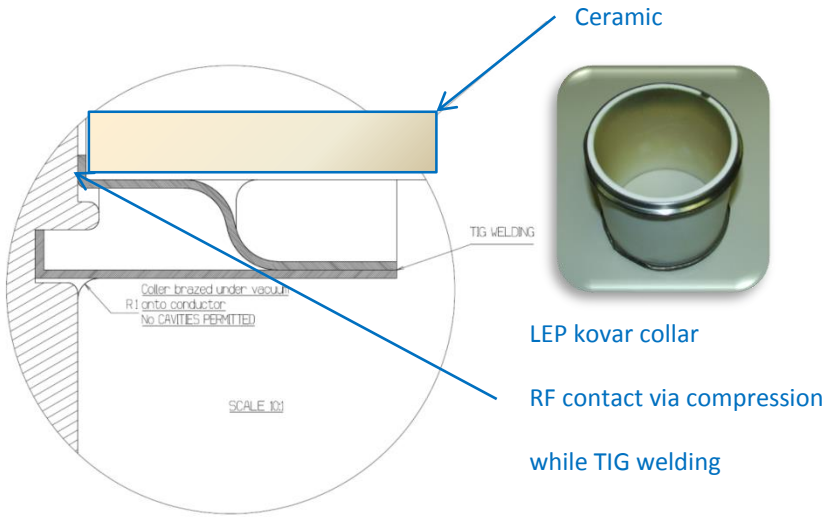
Initial design LEP 2

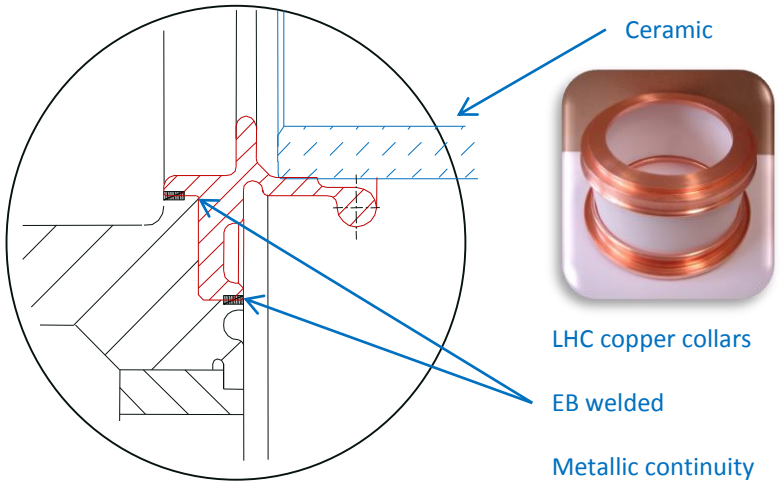
Brazing has been improved

- 2 mm copper collars instead of 0.5 mm kovar collars
- Less losses & better cooling

Electron Beam Welding

- More precise
- Perfect electrical continuity (no need of RF contacts)





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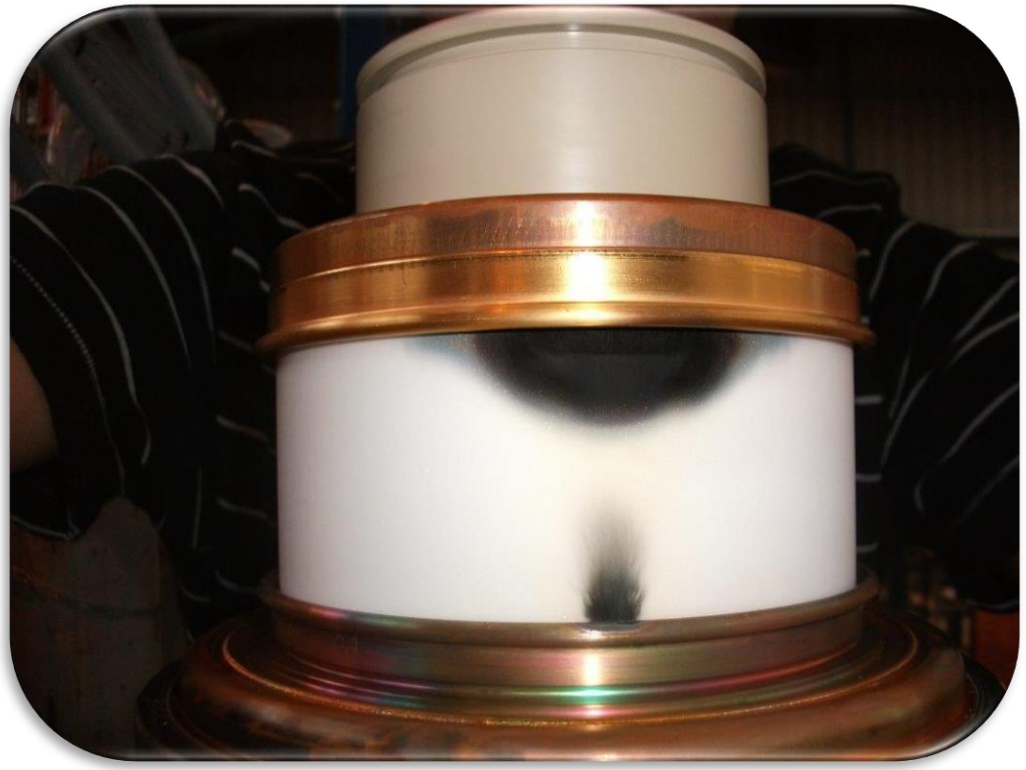
Cylindrical windows

Distance between rings limits the peak power due to surface flashover rating along the ceramic

These ceramics are part of the matching system, reduces the RF peak power limit

End of a cycle… except if we again have to go to variable couplers



SPL couplers
TW 1000 kW were ok
SW 600 kW were arcing

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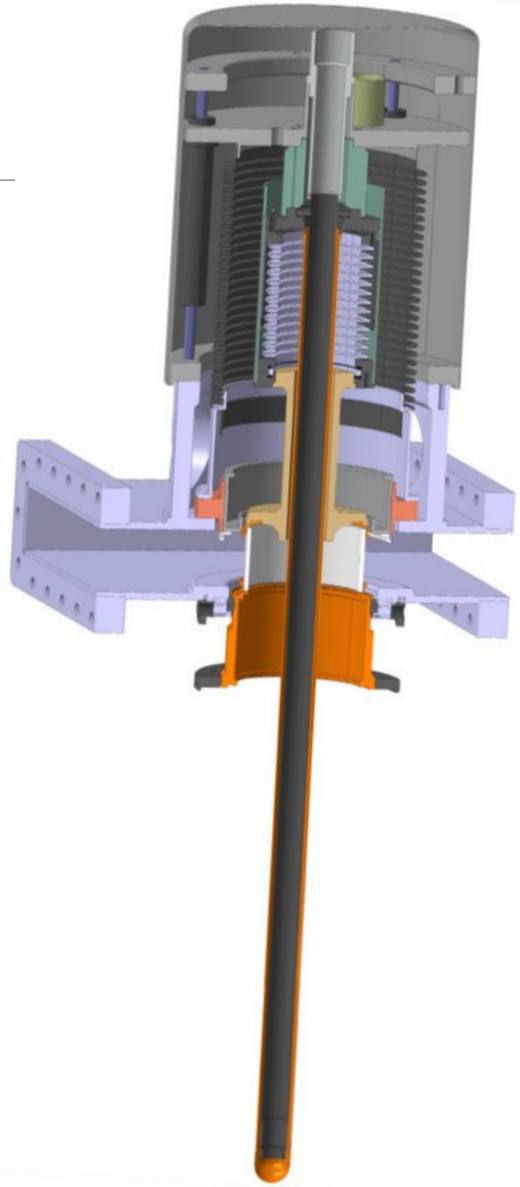
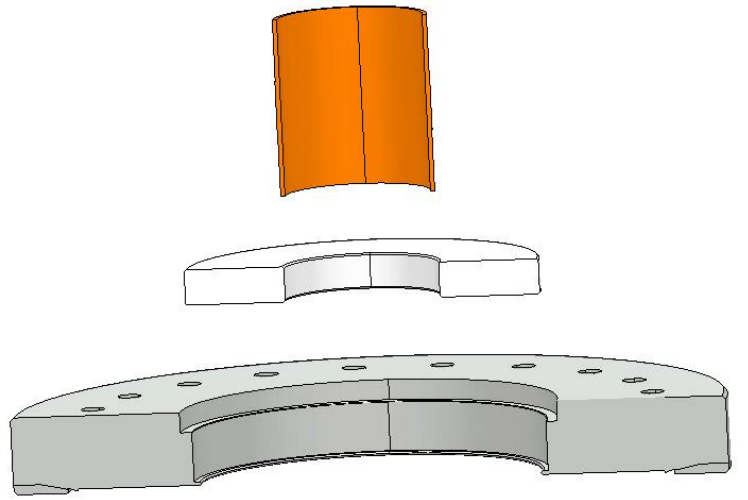


Coaxial disk windows

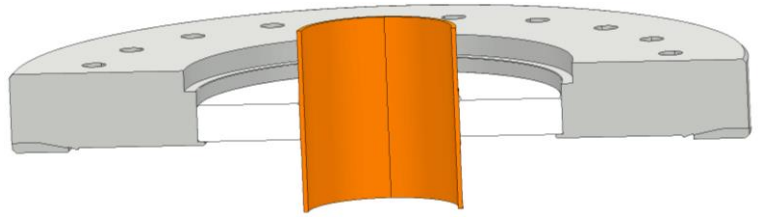
Easier to manufacture

- Titanium external flange
- Ceramic coaxial disk (quite thick to be robust even if with few losses)
- Copper inner tube
- Easier TiOx sputtering
- EBW on the inner copper tube side
- Standard vacuum seals on the Titanium flange outer side



Simple design used as a new baseline for several project

‘Cyclotronic’ air cooling



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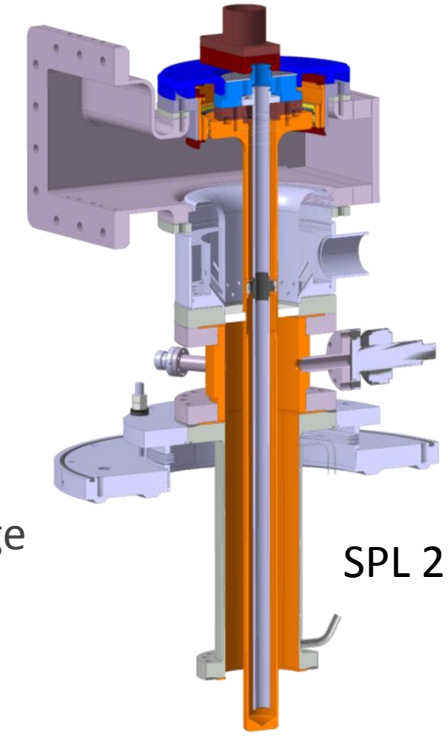
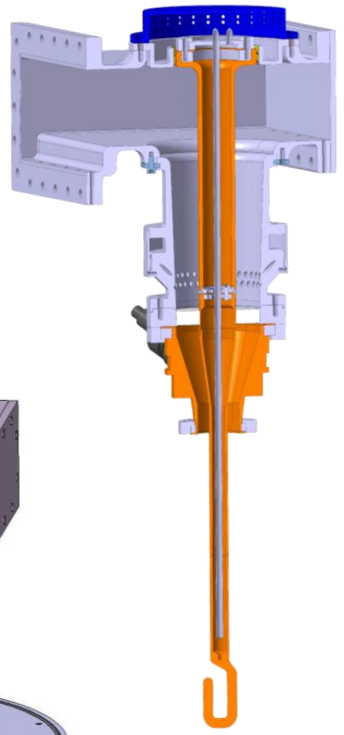
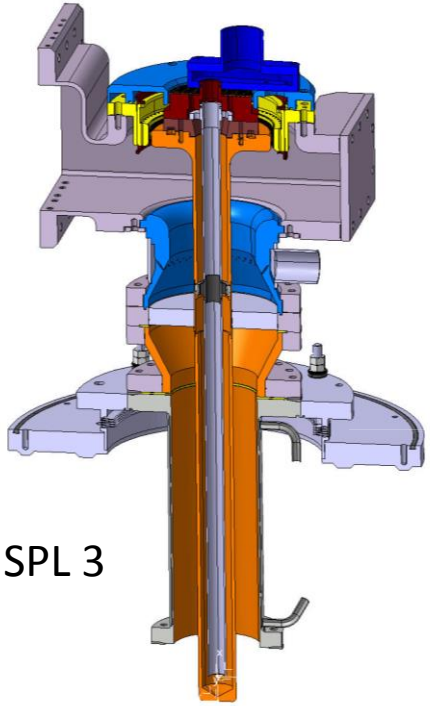


SPL 2

SPS Crab x2

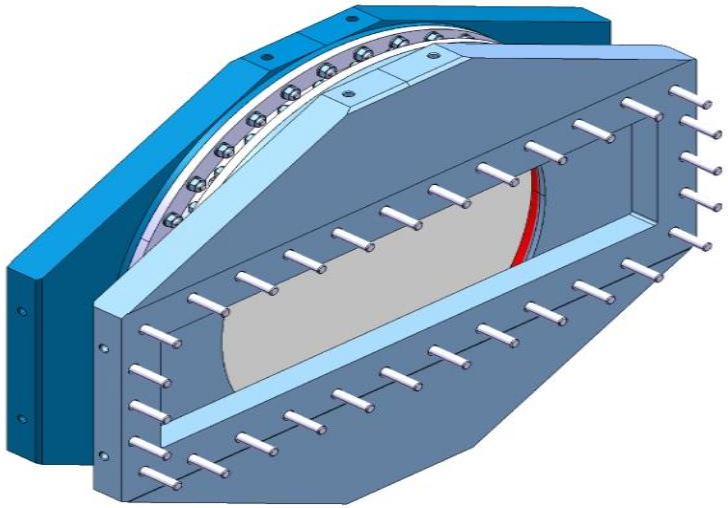


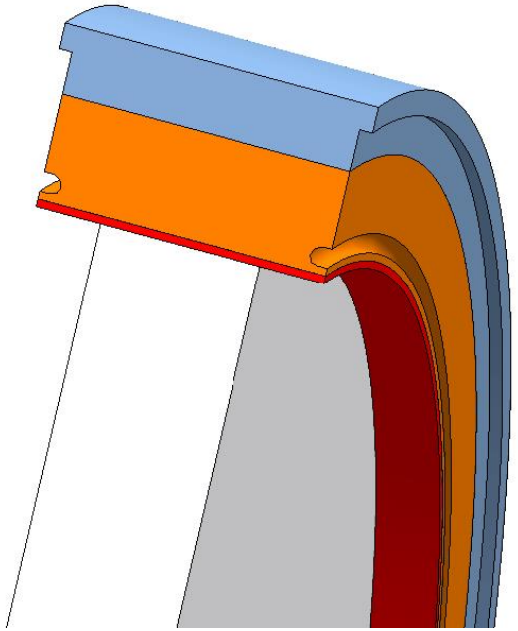


SPL 3

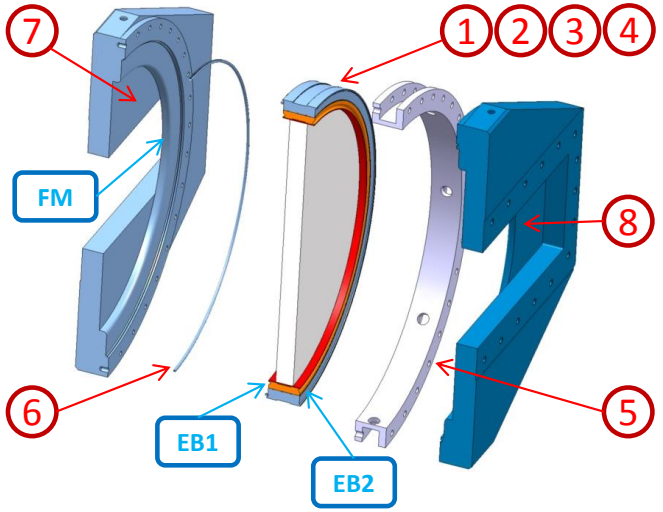
Disk windows

Robust and compact (in length) design
- 12 kg ceramic
- 400 mm diameter
- 25 mm thickness





As simple as possible
- 1-2-3-4 : Ceramic assembly
- 5 : spacer
- 6 : Helicoflex seal
- 7-8 : Stainless Steel flanges



Massive stainless Steel flanges, not copper plated

More difficult design than it looks like because of the two shapes: cylindrical and rectangular, with integrated screws

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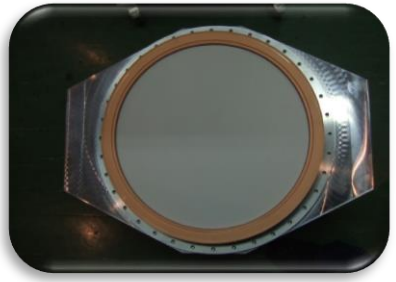

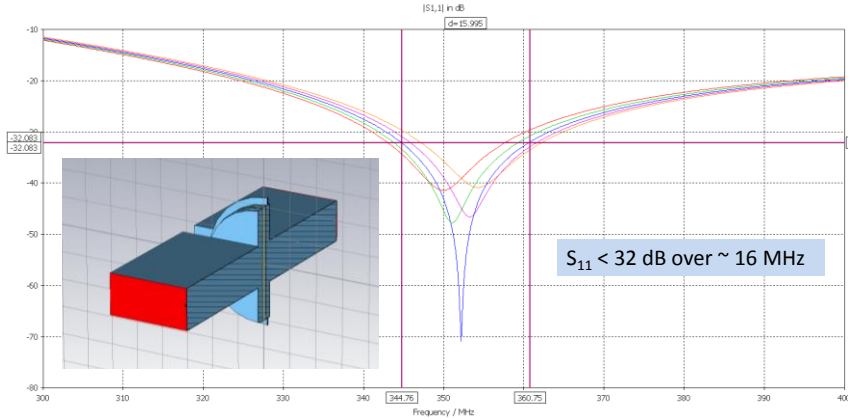

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Ceramics

Whatever the shapes, all our ceramics are specified regarding the same Technical Specification since 1996, 'RF Windows for the LHC'

http://cds.cern.ch/record/91419?ln=fr

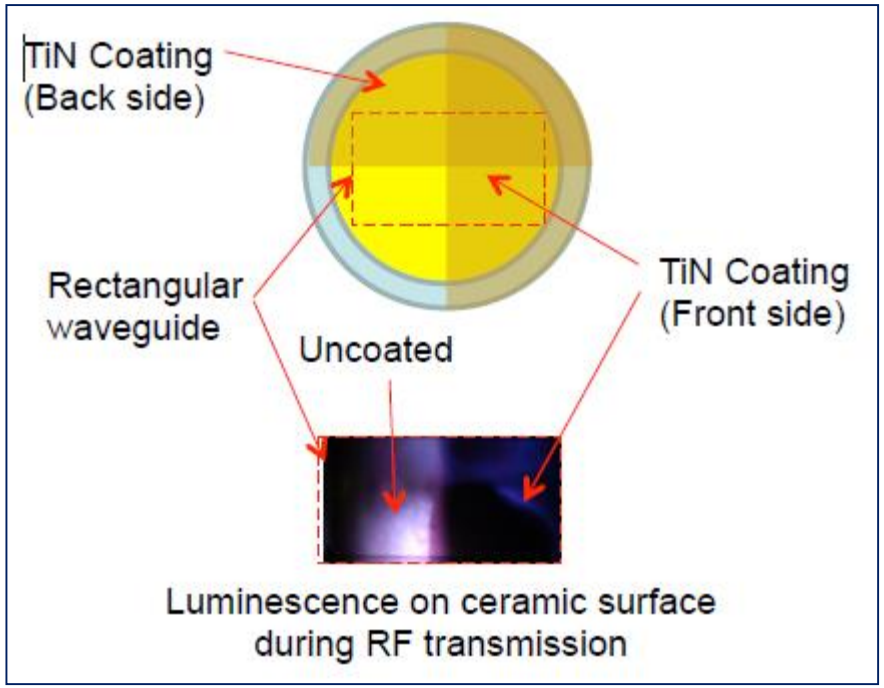
They are all Al_2O_3 minimum 99.5 % purity, with MoMn metallization with Ni diffused to a depth of between 5 – 10 µm

Whatever the coupler and the frequency, vacuum side is Titanium sputtered in house and at CERN we only have TiOx sputtering

Ceramics

R&D Program launched in collaboration with KEK to test a new Kyocera ceramic that would not need any sputtering process

Comparison will be made with ‘traditional’ ceramic in order to validate the results



New Kyocera alumina
Test at KEK

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

Statistics

Coupler	Number	Lifetime [years]	Number of fault	Machine stop
LEP 2	288	5	2	0
LHC	16	7	0	0
SPS 200 – 1	16	24	2	2 x 3 days
SPS 200 – 2	16	14	0	0
SPS 800	8	35	0	0

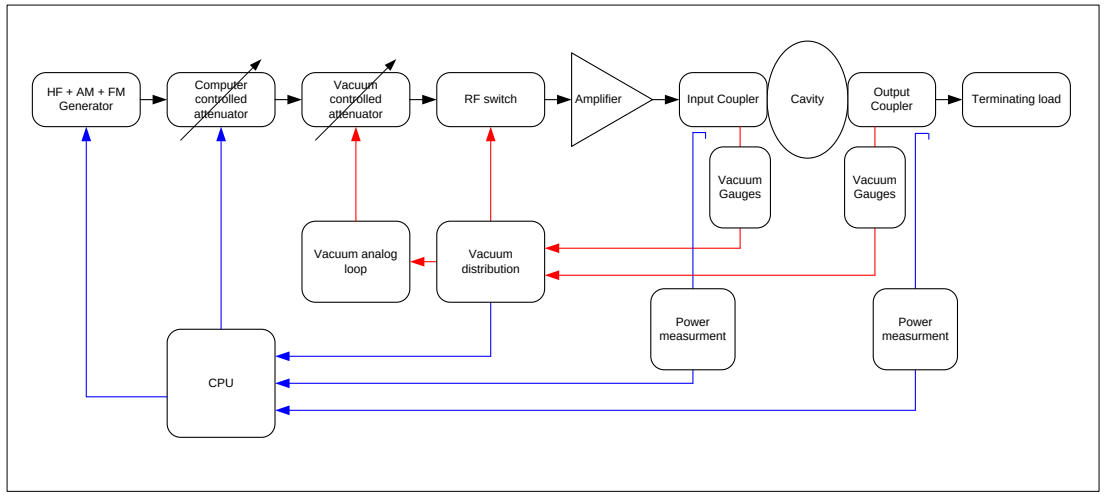
LEP 2 couplers fault were small cracks in the ceramic, not detected during operation, only lowering the performance of the cavities

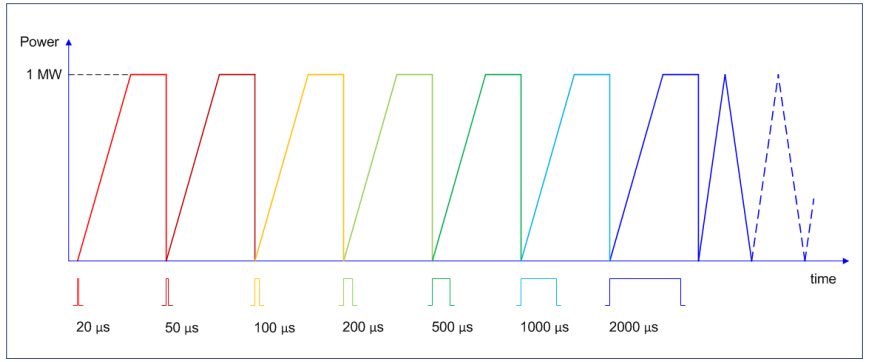
LEP 2 & LHC results with the DC polarisation always ON ! (mandatory with LHC couplers)

Conditioning process

Since 1998 at CERN, pulse mode conditioning process under vacuum loop control

- A first direct vacuum loop (red) ensures RF is never applied if pressure exceeds 5.0 x 10-7 mbar
- This interlock vacuum threshold is to protect the couplers, but also to have an as short as possible conditioning time
- The settings are adjusted to have minimum attenuation under 1.0 x 10-8 mbar and maximum attenuation over 2.5 x 10-7 mbar (~40 dB dynamic range with the attenuator)

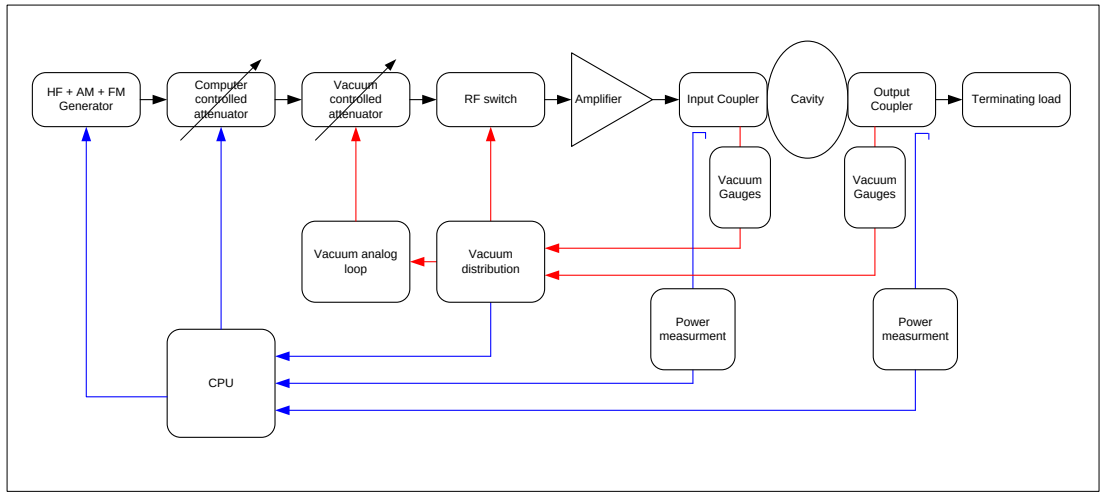


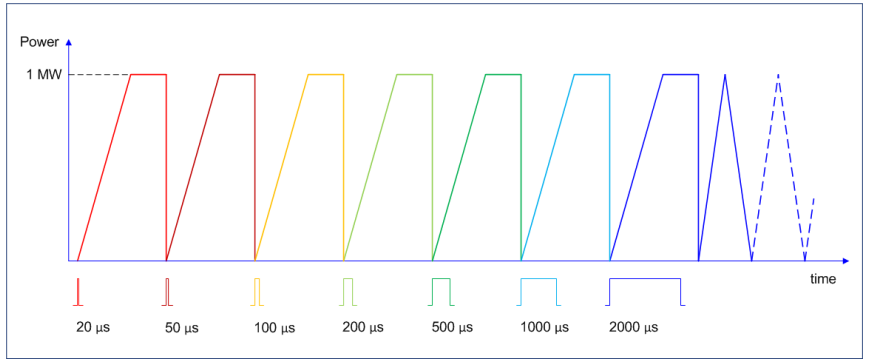


Conditioning process

Since 1998 at CERN, pulse mode conditioning process under vacuum loop control

- A second vacuum loop (blue), cpu controlled, executes the automated process
- Always starts, under vacuum control, with very short pulses of 20 µs every 20 ms
- Power level is increased using short pulses up to full power passing slowly through all power levels to avoid “de-conditioning”
- Same procedure repeated for initially short then longer and longer pulses up to the maximum length





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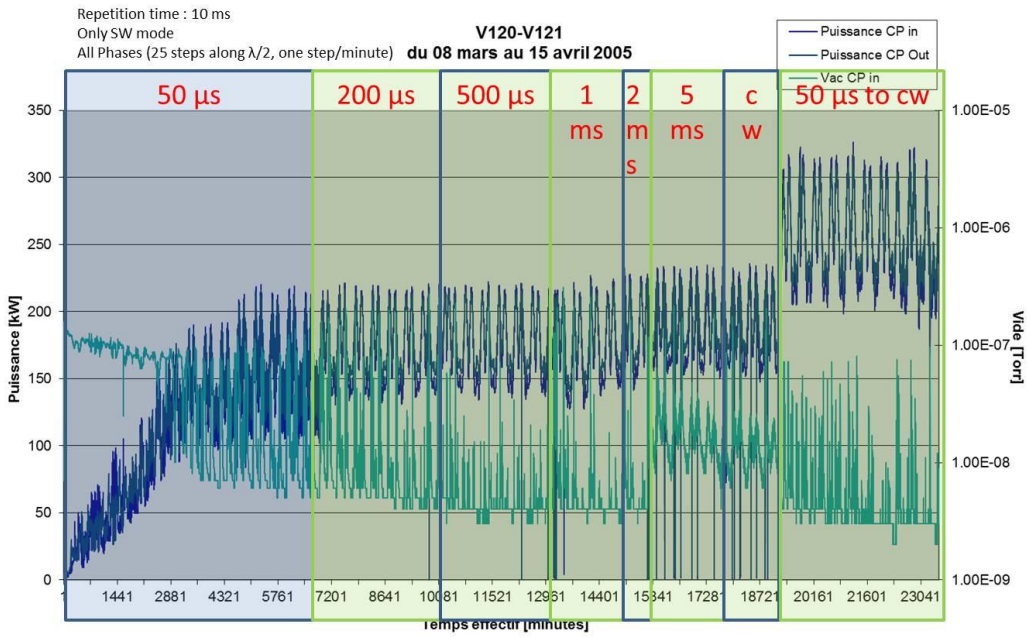
Conditioning process

Safe but very slow process

More than 40 pairs have been processed

Ok for prototyping, but not for large series production



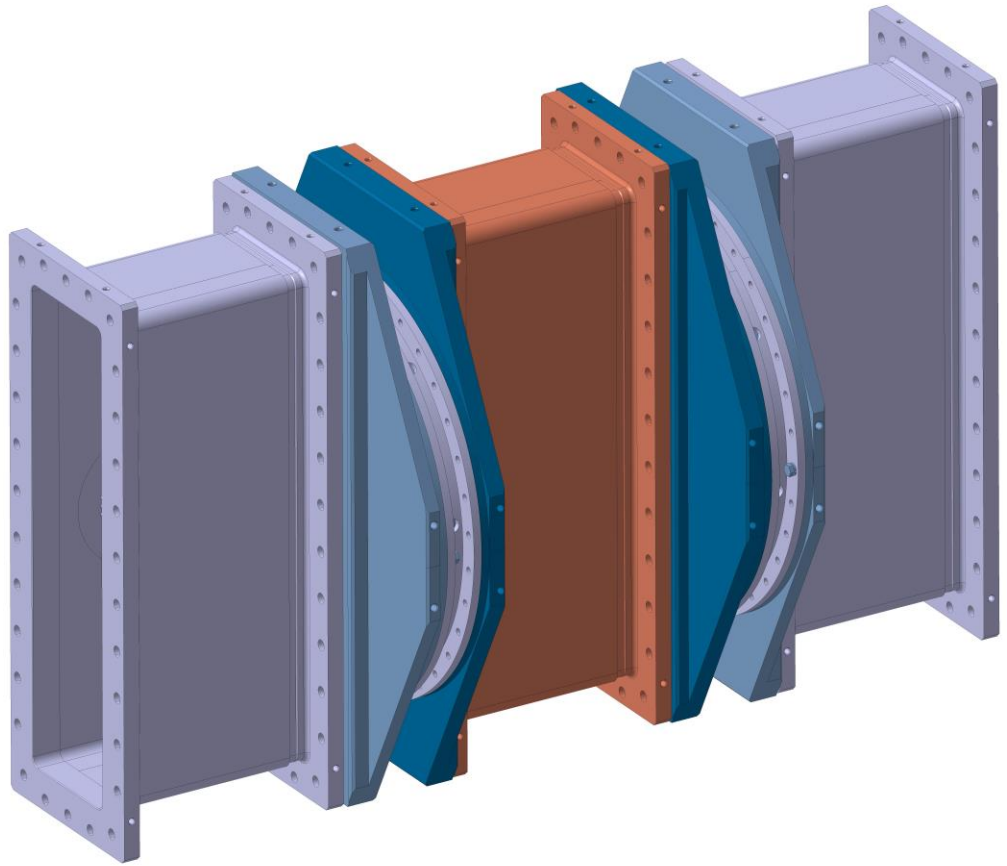
LHC coupler processing: 6 weeks 24/7 for two couplers

Test boxes

A way to speed up the process, several test boxes in series

Example of Linac 4 windows processing

- 50 – 100 – 200 – 600 µs / 2 Hz
- 16 phase steps
- 1 MW @ 352 MHz
- 5 weeks 7/24 with 1 test box
- 6 weeks 7/24 with 2 test boxes



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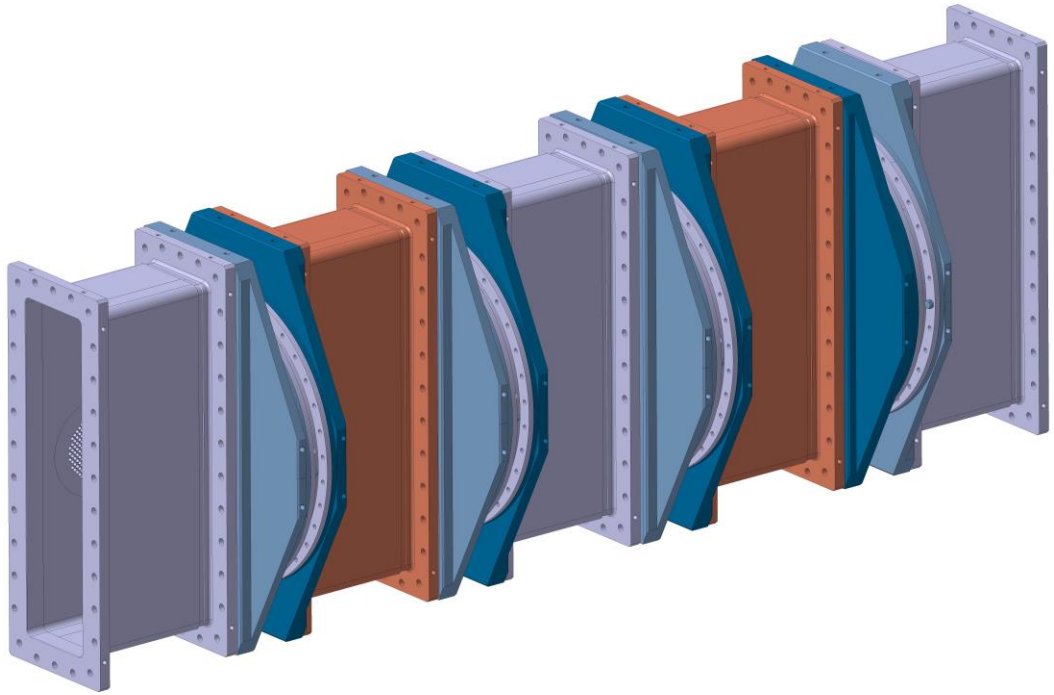


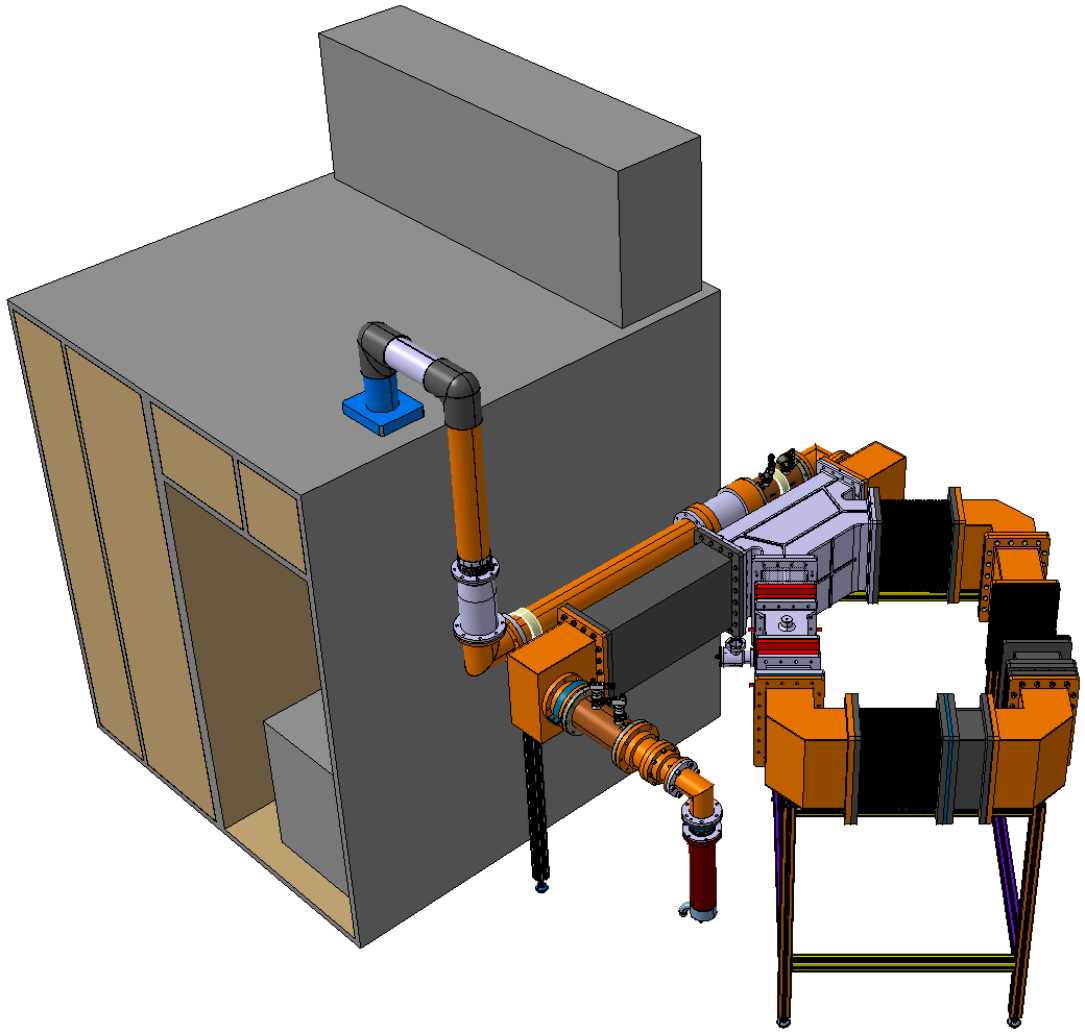
Resonant ring(s)

A way under study to minimize cost is the resonant ring solution

Three options are under study

- One ring with one coupler (to re-start with something)
- One ring with several pairs of couplers
- A double resonant ring

Only TW test, to be compare to SW



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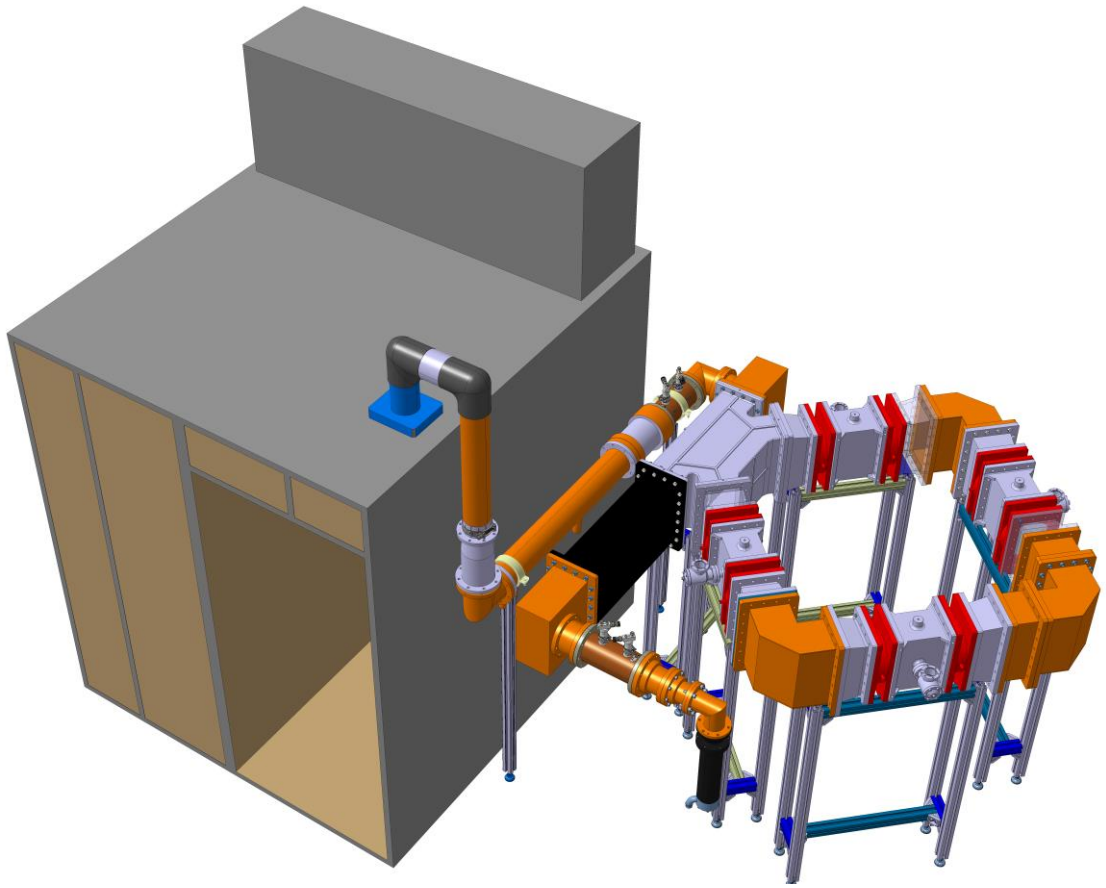

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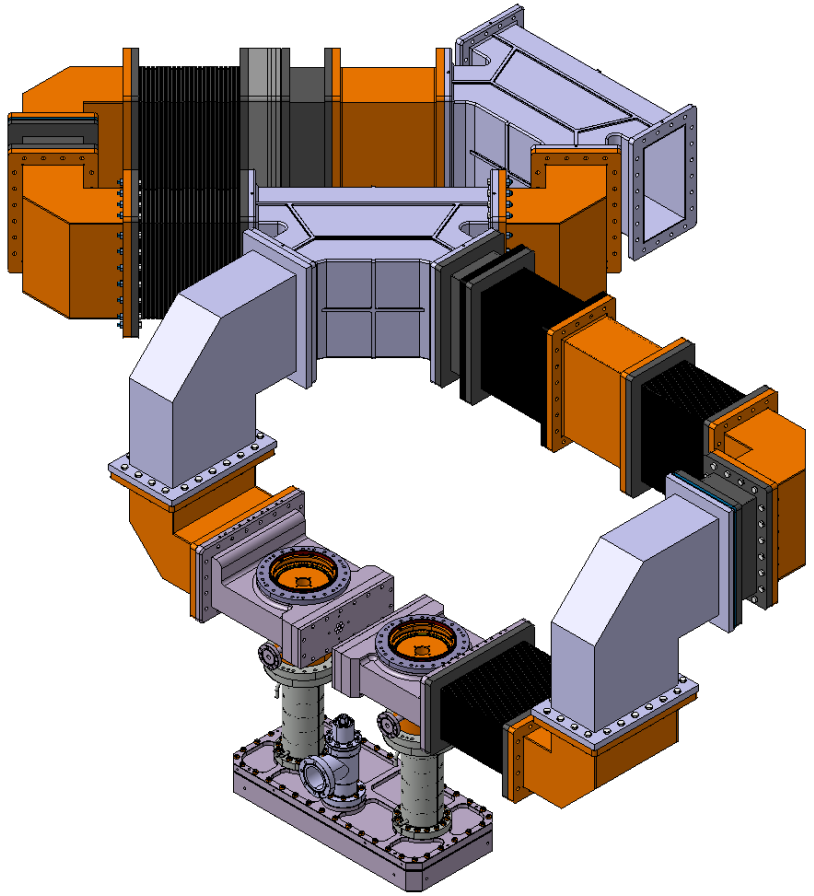


3D printing

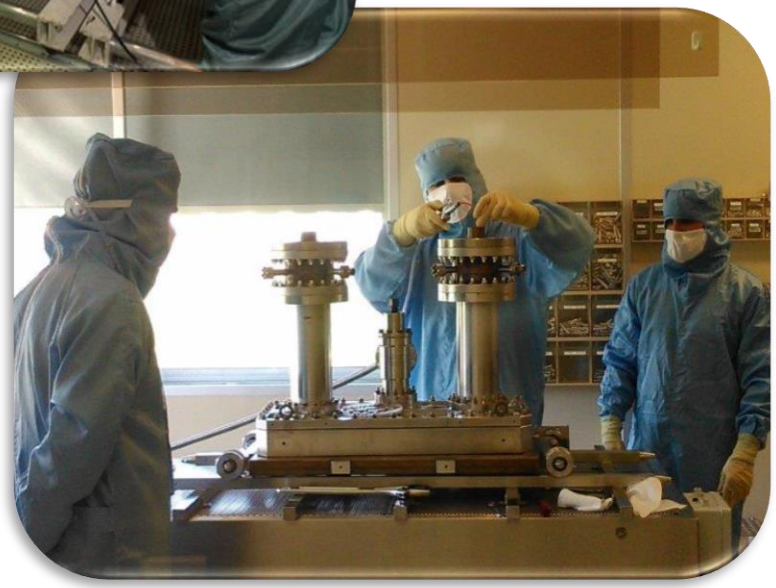
Initially used for mechanical qualification

R&D programme with Grenoble INP for an all in one metallic and plastic printing, including cooling channels

Clean room assembly

Cern restarted its SRF programme

From next year we will assemble couplers in-house for SPL project



Next steps

Several FPC projects are in the pipeline

LIU 200	already started
LIU 800	already started
LHC 2	from 2016
LHC Crab	from 2017
FCC	from 2016

for which your help and your advice will be very welcomed

Thank you very much