High average power couplers

SPL possible designs

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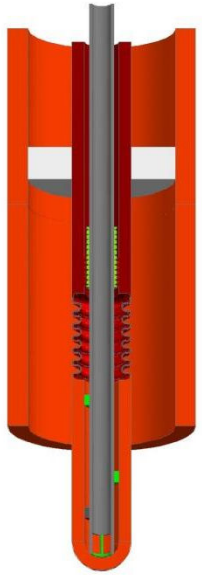
SPL requirements

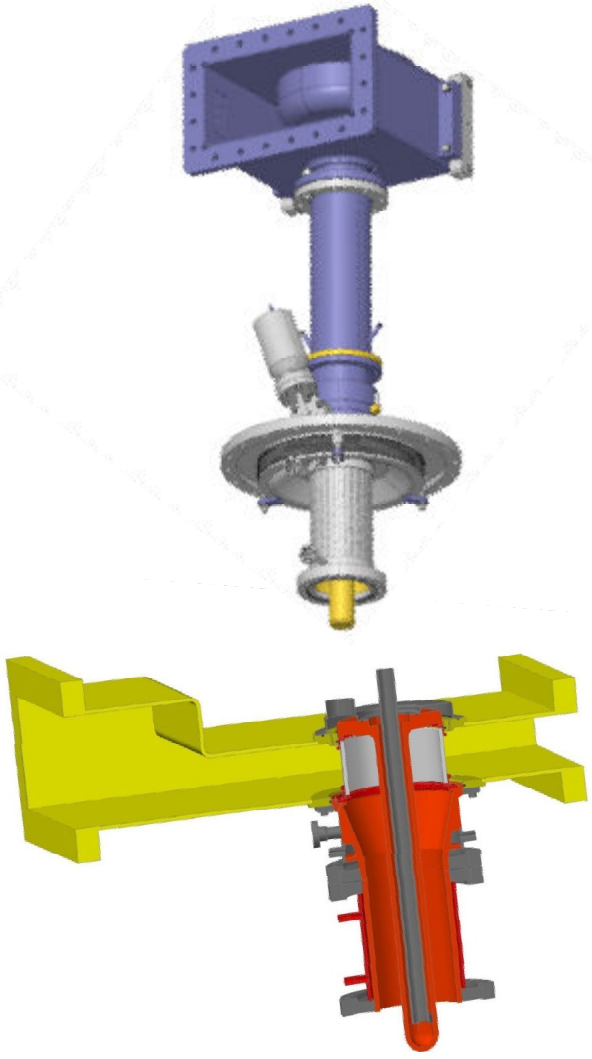
f_o	704.4 MHz
Low Power SPL	2.5 kW average 600 kW pulsed 0.4 + 1.2 + 0.4 = 2.0 ms 2 Hz (500 ms)
High Power SPL	100 kW average 1000 kW pulsed 0.4 + 1.2 + 0.4 = 2.0 ms 50 Hz (20 ms)
Cavity design gradient	19-25 MV/m
Q_{ext} of input coupler	$1 . 10^6$ for LP-SPL and HP-SPL
Input line Ø	100 / 43.5 mm = 50 Ω
Waveguides	WR 1150

Source : https://twiki.cern.ch/twiki/bin/view/SPL/SplWeb

Comparison basis

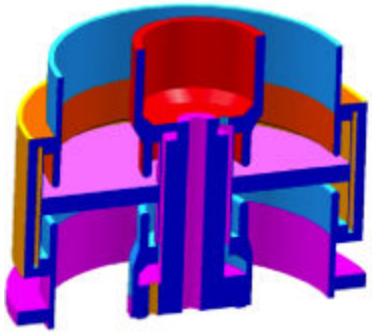
- Engineering points for super conducting power couplers:
  - RF power capability
  - Low heat load
  - Tuning capability (fixed coupling, adjustable coupling)
  - Contamination during beam vacuum part assembly
  - Easy installation
  - Integration with the cryomodule
  - Conditioning time
  - Easy operation
  - Cost

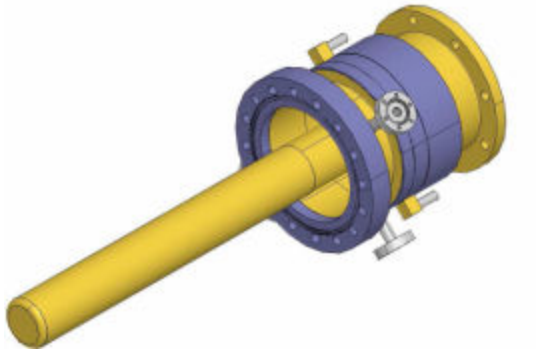


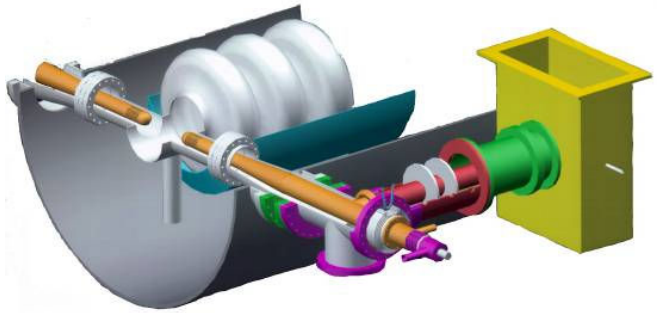


Coaxial Disk windows

Coupler	Frequency [MHz]	Average Power [kW]	Peak power [kW]	# in operation or constructed
APT	700	1000	1000	2
SPS	200	550	800	16
KEKB	509	300	1420	8
CEA-HIPPI	704	120	1200	2
IHEP	500	150	270	2
JPARK	972	30	2200	23
SNS	805	78	2000	93

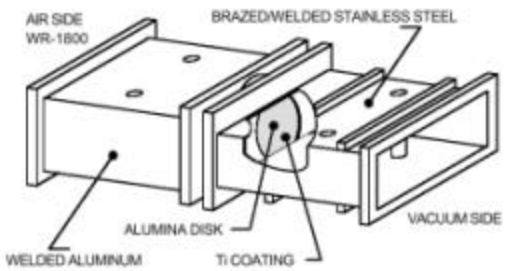


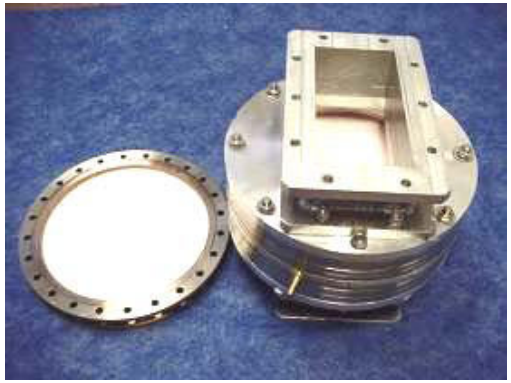


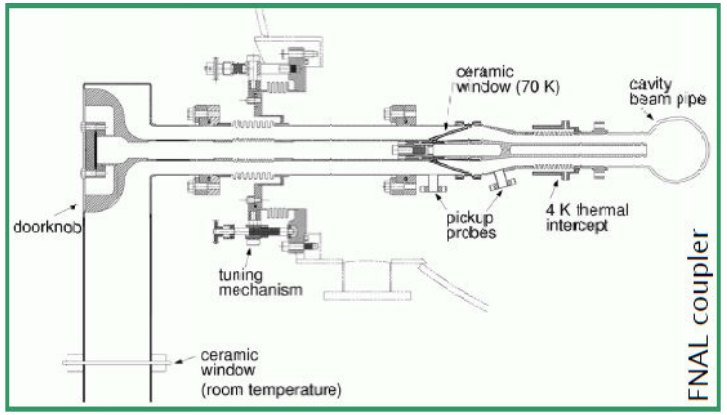


Waveguide windows

Coupler	Frequency [MHz]	Average Power [kW]	Peak power [kW]	# in operation or constructed
SPS	801	225	225 (more ?)	8
Cornell	500	350	350	4
FNAL / TTF II	1300	4.5	1000	32

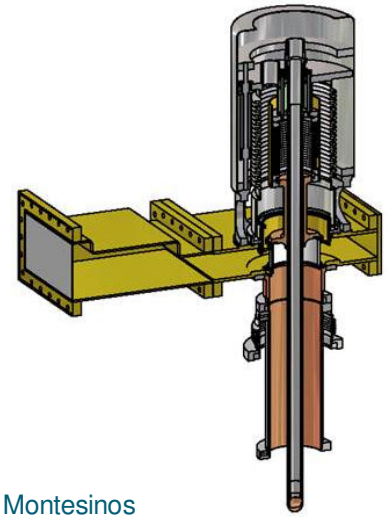


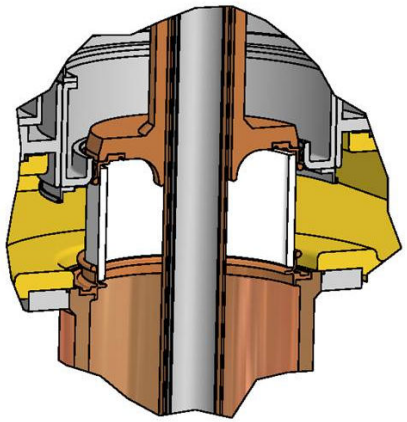


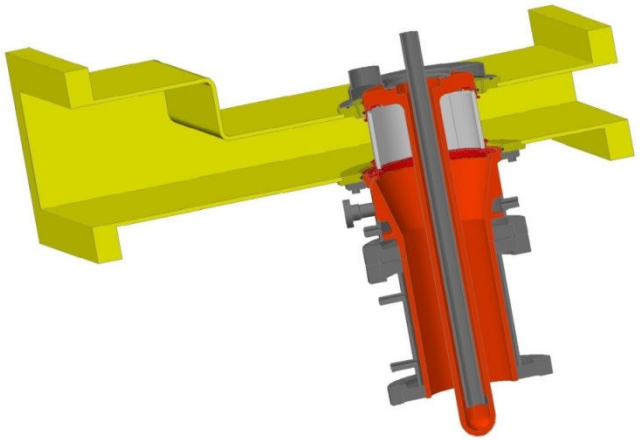


One cylindrical window

Coupler	Frequency [MHz]	Average Power [kW]	Peak power [kW]	# in operation or constructed
ESRF / Soleil	352	550 sw cw	Under construction	64
LHC	400	550 sw cw, (i.e 2200 tw cw)	i.e. 2200 tw cw	16
LEP	352	550 tw cw	565 tw cw	252
SPS (1976-2000)	200	375	500	16

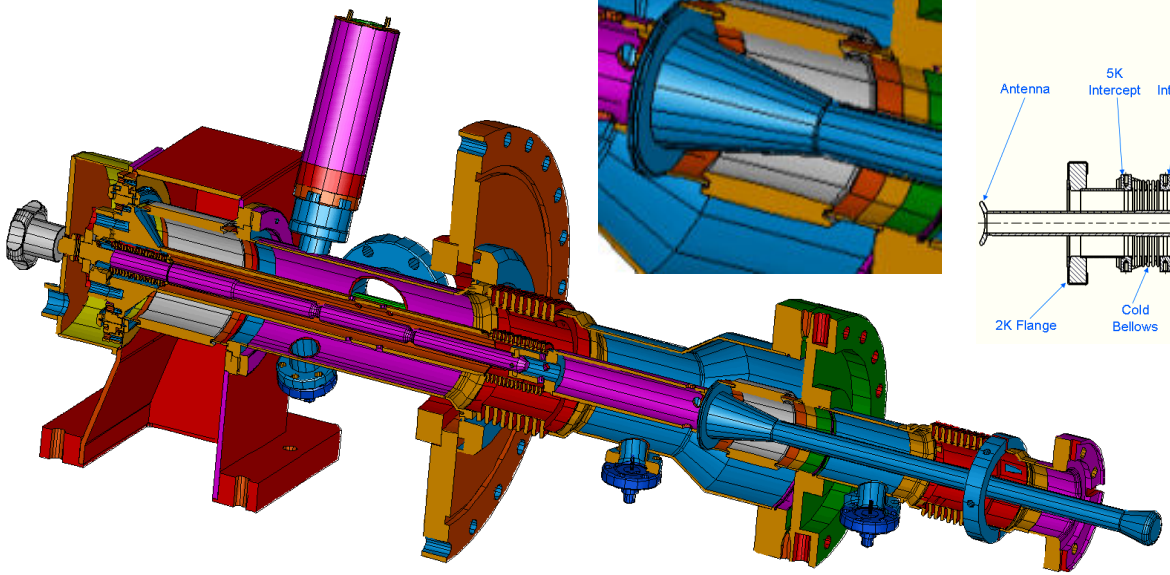


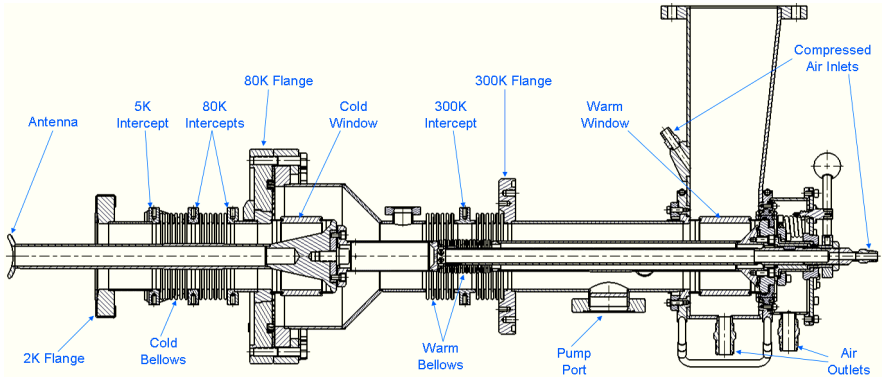




Two cylindrical windows

Coupler	Frequency [MHz]	Average Power [kW]	Peak power [kW]	# in operation or constructed
TTF family - XFEL	1300	4.5	1100	16 (+ 1064)
Cornell ERL	1300	75	75	2

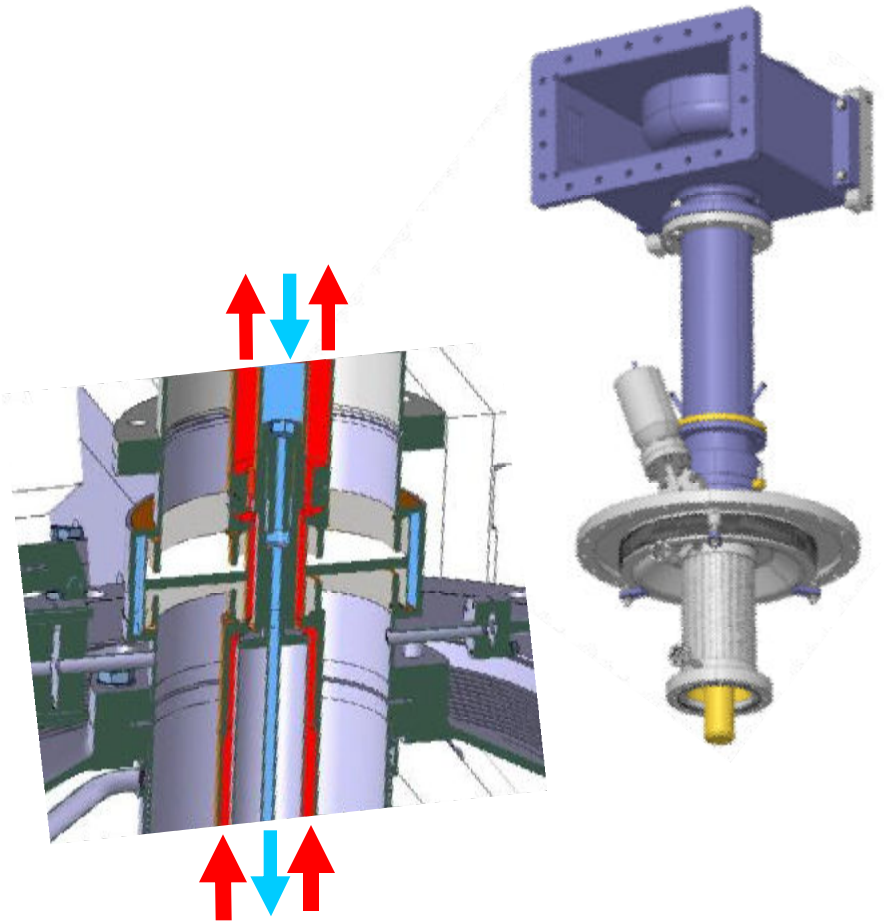




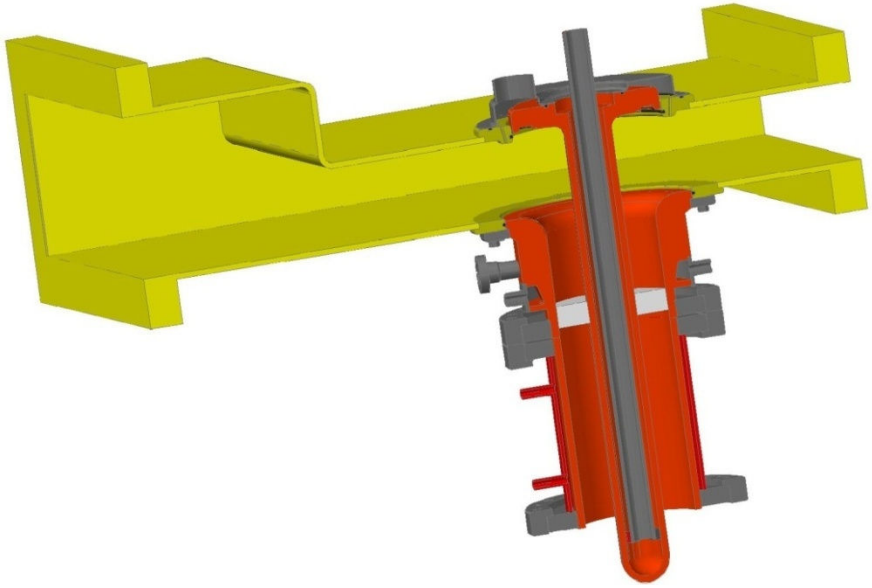
Cold window (beam vacuum / coupler vacuum) is difficult to cool down enough for high average power coupler

CEA Saclay - Coaxial disk window Baseline project

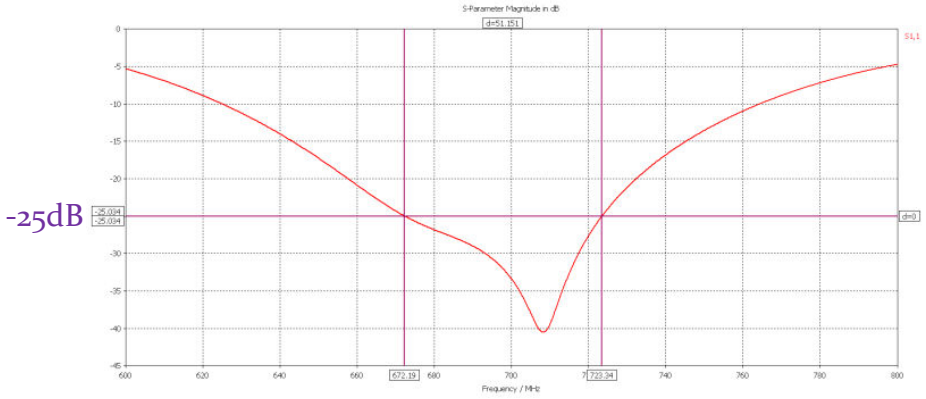
- Design based on a coaxial disk ceramic window as in operation at KEKB and SNS, modified for 704 MHz
- Advantages
  - High power capability, ***tested*** :
    - Up to 1 MW with 2 ms / 50 Hz on warm test cavity
    - Tests ongoing on cold cavity
  - Possible DC HV biasing
  - Commercial window
- Difficulties
  - Window with water cooled antenna, needs an accurate mounting
  - No air cooling to relax mounting (too small pipes)
- Modification of double walled tube for cryomodule compatibility



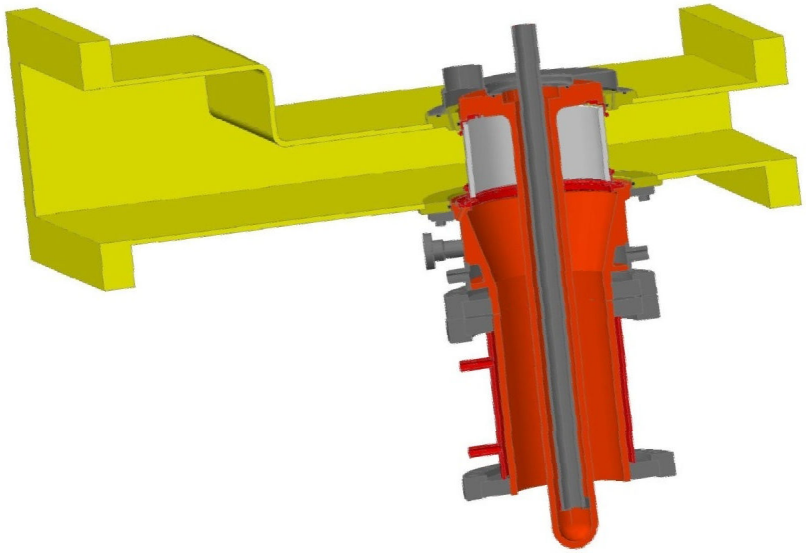
CERN – TWC 200MHz based Coaxial disk window



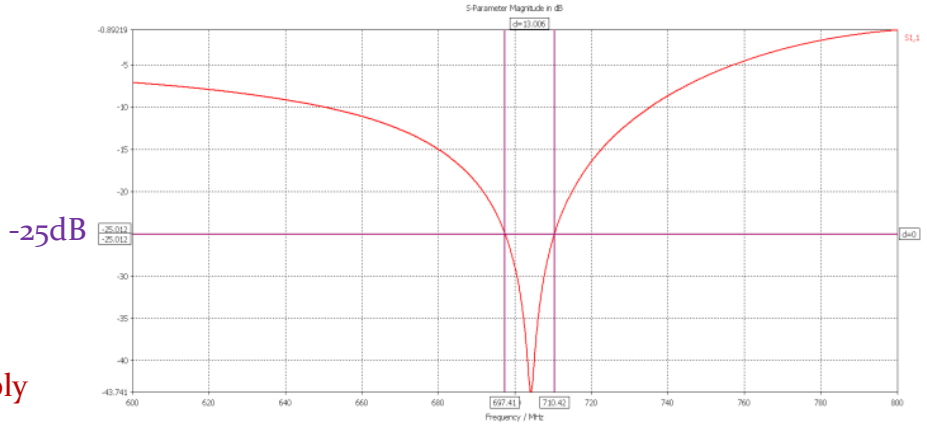
- Design based on a coaxial disk ceramic window as in operation on the CERN SPS TWC 200 MHz
- Advantages
  - High power capability
  - Very easy to cool down the antenna (air cooling)
  - Plain copper body water cooled
  - Upper part of the antenna with sliding contacts, easy mounting
  - Possible DC HV biasing
- Difficulties
  - Ceramic is part of the matching system
  - Position of the ceramic for cryomodule assembly



CERN - LHC based
One cylindrical window

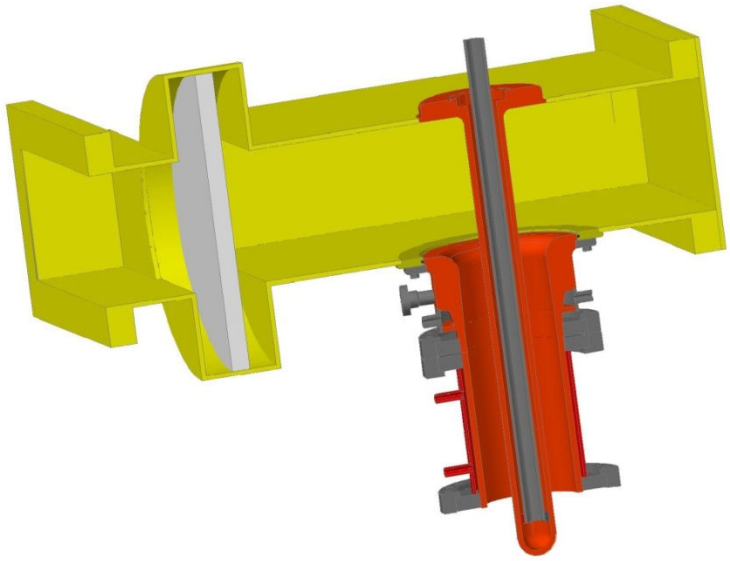


- Design based on the same cylindrical window as used with LHC couplers
- A new version is under construction for ESRF and Soleil (352 MHz, warm cavity)
- Advantages
  - High power capability, LHC proven
  - Very easy to cool down the antenna (air cooling)
  - Upper part of the antenna with sliding contacts
  - Possible DC HV biasing
  - Ceramic air cooled with its own air cooling
  - Plain copper body water cooled
  - Easy to assemble
  - Less expensive version of coupler
- Difficulties
  - Ceramic is part of the matching system
  - Position of the ceramic for cryomodule assembly

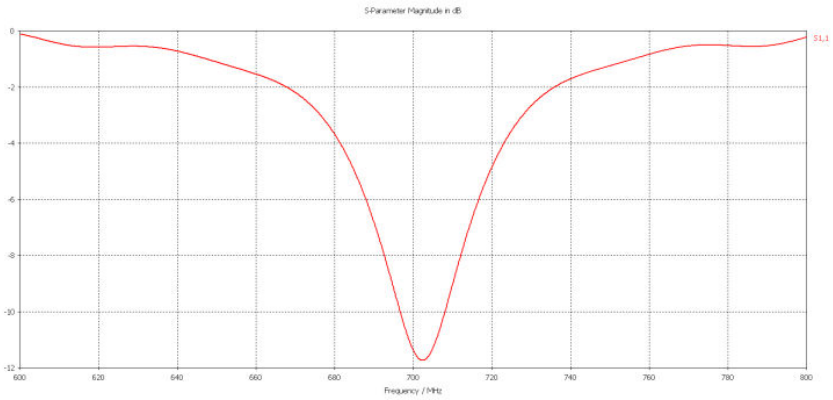


BW 17 MHz

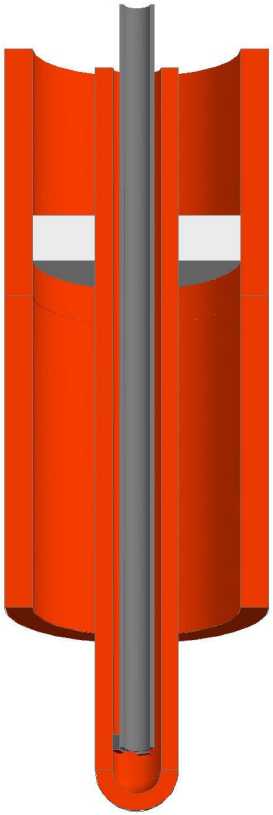
CERN – TWC 800MHz based Waveguide window



- Design based on a waveguide disk window as in operation on the CERN SPS TWC 800 MHz couplers
- Advantages
  - Very simple antenna system
  - Mechanically very robust
- Difficulties
  - Not known brazing process at CERN
  - Difficult DC HV biasing
  - Larger vacuum volume to pump
  - Power limit
  - Very difficult position of the ceramic for cryomodule assembly

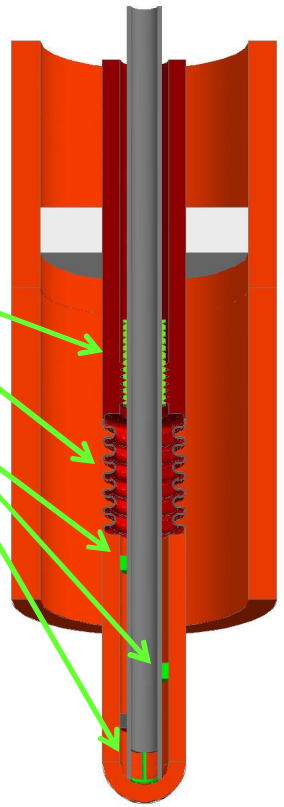


Fixed versus Adjustable coupler



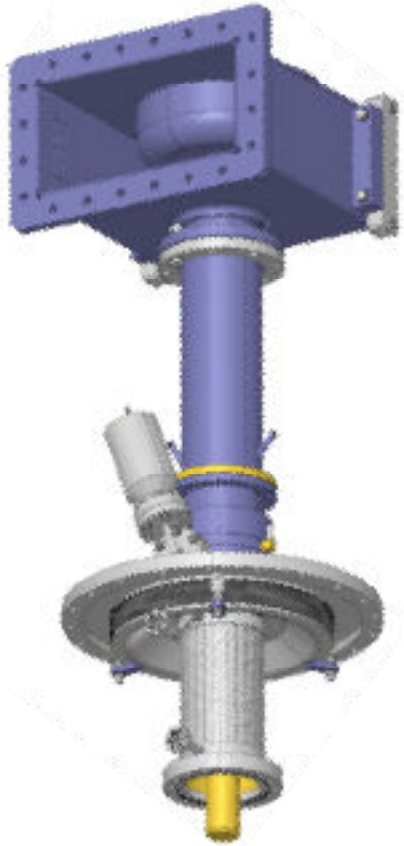
Disk window - fixed coupler

- An adjustable coupler is not a variable coupler (only few mm of fine coarse)
- However, in addition to the already complex line :
  - Moving system not stressing the ceramic
  - Below, more EB welding
  - Alignment system to keep the bottom part of the antenna at the right place under the below
- This will :
  - increase the complexity
  - Increase the number of mechanical operations
  - Increase the risk of pollution of the coupler
  - Increase the risk of vacuum leak
  - Subsequently increase the total price



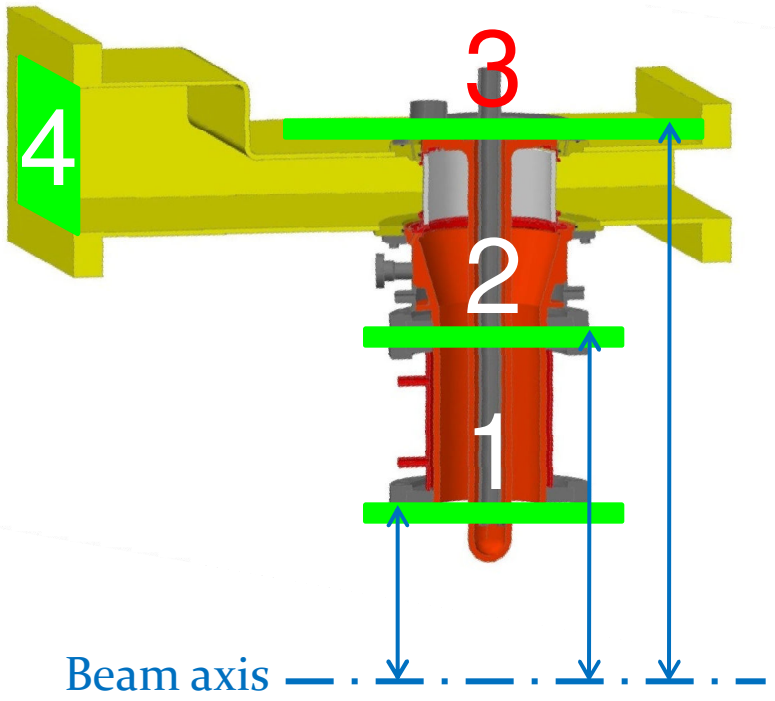
Disk window - adjustable coupler

Proposed design



- For mechanical reasons:
  - Better to have the coupler mounted vertically, above or below the cavity
  - Less stress to the antenna
- Due to the high average power:
  - Only one ceramic, difficult to cool down a beam vacuum / coupler vacuum ceramic
  - Connected with a double walled tube to ensure the thermal transition

Interfaces



- Interfaces will have to be decided as soon as possible :

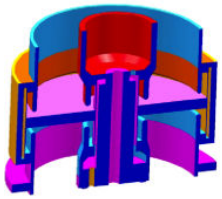
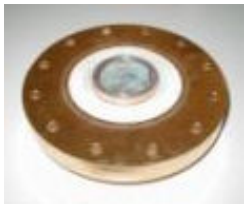
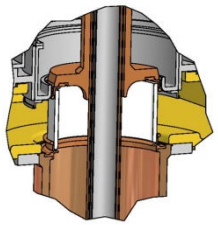
1/ Cavity flange, lower part of the double walled tube, the fix point of the power coupler

2/ Cryostat flange, upper part of the double walled tube (cavity isolation vacuum)

3/ Total height of the coupler for cryomodule integration

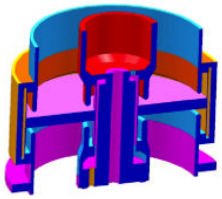
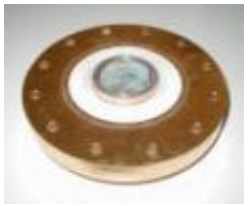
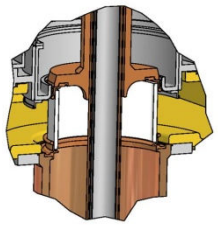
4/ Waveguide flange, will impact on the wave guide distribution, and the needed supporting tools of the coupler

Couplers comparison


Parameter	CAE Saclay 704 MHz	SPS 200 MHz based	LHC 400 MHz based	SPS 800 MHz based
Ceramic	Coaxial Disk (water cooled)	Coaxial Disk (air cooled)	One cylindrical plain copper	Waveguide Disk
Max Peak Power	1200	1200	2200	250 ?
Max Average Power	120	550	550	250
Easy integration with cryomodule	yes	yes - no	difficult	very difficult
Easy DC-HV biasing	yes	yes	yes	no
Adjustable	difficult	yes	yes	yes
Exists and tested !	**YES**	no	no	no

Cost estimate (fixed coupler only)

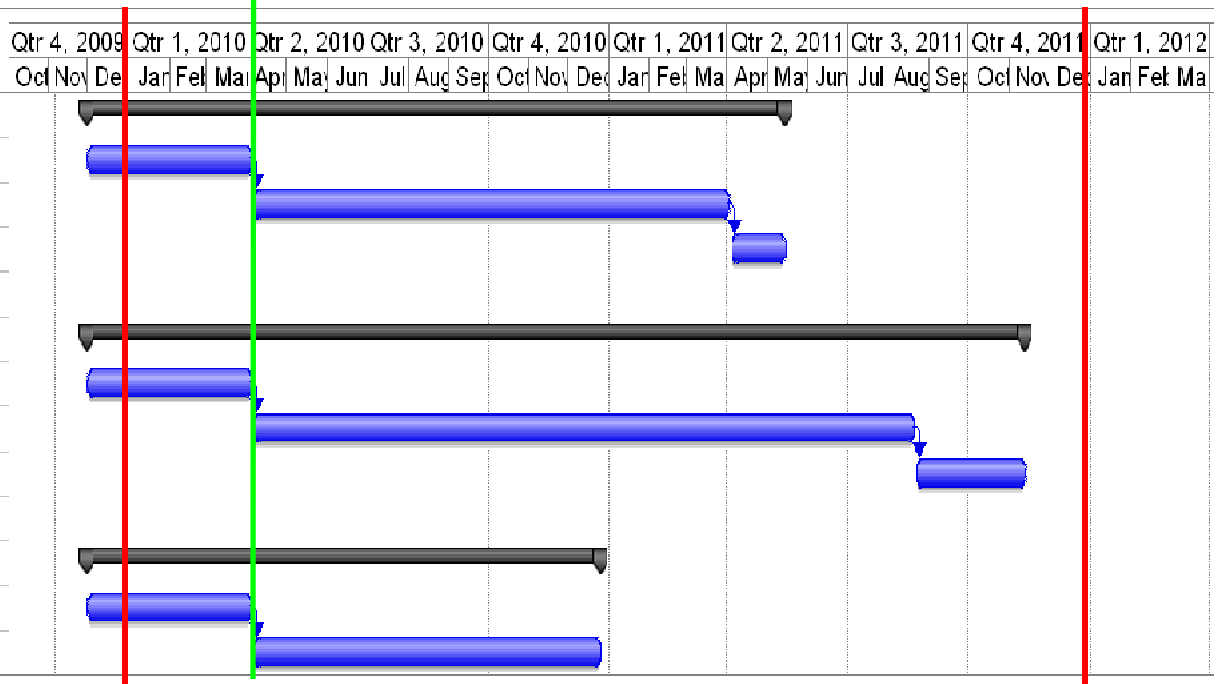





All in kCHF	CAE Saclay 704 MHz	SPS 200 MHz Based	LHC 400 MHz Based	SPS 800 MHz Based
Window only	50	20	10	15
Design	10	10	10	10
Coupler (unit price)	90	70	60	65
4 Warm test cavities	150			
Total 8 (+2 ceramics)	**980**	**800**	**720**	**720**

Draft time table

Coupler design review
March 2010

ID	Task Name
1	SPL CEA Saclay couplers
2	Design modification for SPL cryomodule
3	Construction and assembly
4	Tests on warm cavity
5	
6	SPL Other designs
7	Design
8	Construction and assembly of chosen designs
9	Tests on warm cavity
10	
11	Warm tests cavities
12	Design
13	Construction and assembly



Interfaces definition
for end 2009

8 couplers fully RF conditioned
for beginning 2012

Conclusion

- One window coupler (for high average power)
- Vertical position (preferably above)
- Double walled tube
- Design(s) ended march 2010 :
  - Fixed or adjustable coupler
  - Interfaces with cryomodule
  - Chosen design(s)
- Would help to define the best solution for large series of 250 HP-SPL couplers enabling us to define:
  - Power capability
  - Easy construction and assembly for large series
  - Integration with cryomodule and waveguide lines
  - Reliability
  - True series cost

Thank you for your attention

Coupler review

- http://www.jlab.org/div_dept/admin/publications/papers/02/ACT02-12.pdf
- http://www.lns.cornell.edu/public/SRF/2002/SRF021105-09/SRF021105-09.pdf
- http://accelconf.web.cern.ch/AccelConf/e02/TALKS/TUXGB002.pdf
- http://hal.archives-ouvertes.fr/docs/00/18/93/23/PDF/in2p3-00189323.pdf
- http://srf2003.desy.de/talks/Rusnak/Rusnak.pdf
- http://www.astec.ac.uk/ERL07/Presentations/Wednesday_Presentations/WG3/Wednesday/BEARD_ERL_WORKSHOP_COUPLERS_TALK_v3.pdf
- http://accelconf.web.cern.ch/accelconf/srf2007/PAPERS/WE305.pdf
- http://srf.desy.de/fap/paper/ThP34.pdf
- http://hal.archives-ouvertes.fr/docs/00/07/74/45/PDF/LALRT06-03.pdf
- http://indico.cern.ch/getFile.py/access?contribId=34&sessionId=75&resId=2&materialId=slides&confId=44821

Waveguide windows

Rossendorf / ELBE	http://accelconf.web.cern.ch/AccelConf/srf2007/PAPERS/WEP81.pdf
Cornell / CERS	http://laacg1.lanl.gov/rfsc99/rfsc99_web/THA/tha006.pdf

Coaxial Disk windows

Los Alamos / APT	http://accelconf.web.cern.ch/accelconf/l00/papers/THD16.pdf http://www-linac.kek.jp/~suwada/ERLSC/F/MOP133.pdf
KEKB	http://accelconf.web.cern.ch/accelconf/e00/PAPERS/THP1A11.pdf http://srf2009.bessy.de/papers/tuppo022.pdf http://accelconf.web.cern.ch/AccelConf/srf2007/PAPERS/TUP60.pdf
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SNS	http://www.ornl.gov/~webworks/cppr/y2001/pres/111126.pdf http://epaper.kek.jp/l02/PAPERS/TH455.PDF http://accelconf.web.cern.ch/AccelConf/e02/PAPERS/THPDO016.pdf http://tdserver1.fnal.gov/8gevlinacpapers/RF_Couplers/SNS_Coupler_Prototype_ACT01-14.pdf http://tdserver1.fnal.gov/8gevlinacpapers/RF_Couplers/SNS_RF_Coupler_Processing_Stand_ACT01-08.pdf

Two cylindrical windows

DESY / TTF family	http://hal.archives-ouvertes.fr/docs/00/07/74/31/PDF/LALRT0602.pdf http://tdserver1.fnal.gov/8gevlinacpapers/Cavities/TESLA%20Cavity/RF%20Coupler/DKostin_Coupler%20DevelopmentPT001.pdf http://ilcagenda.linearcollider.org/getFile.py/access?contribId=51t8&resId=0&materialId=0&confId=desya052 http://www.cpii.com/docs/related/21/Power%20Couplers%20for%20the%20ILC.pdf
ERL	http://www-linac.kek.jp/~suwada/ERLSC/F/Input_coupler_for_ERL_injector.pdf http://www.springerlink.com/content/14138622h45138n1/ http://accelconf.web.cern.ch/AccelConf/srf2007/PAPERS/WEP26.pdf

One cylindrical windows

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