

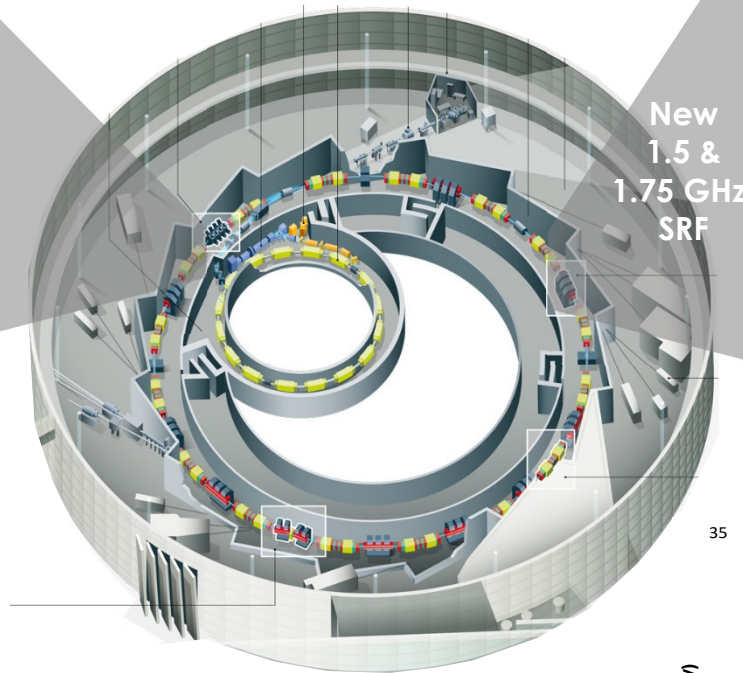
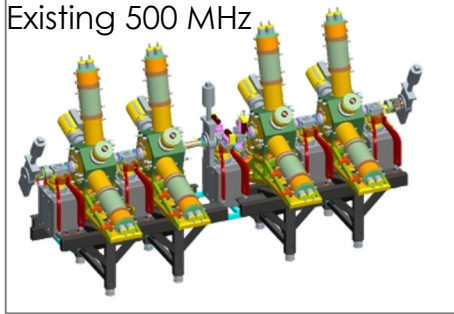
Development of RF couplers to power BESSY VSR

Emmy Sharples

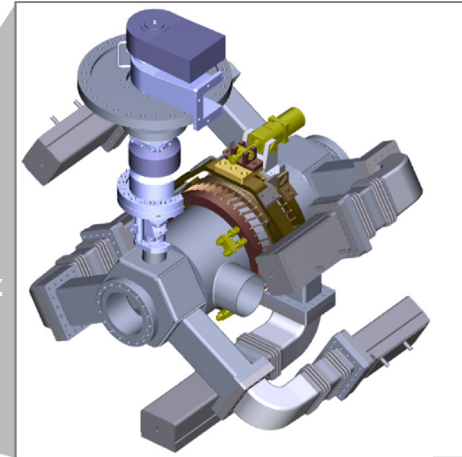
FG-ISRF, Helmholtz-Zentrum Berlin / BESSY II

- Upgrading the existing ring with complex SRF for new user applications
- Two-tone high-voltage CW SRF for innovative bunch-length manipulation

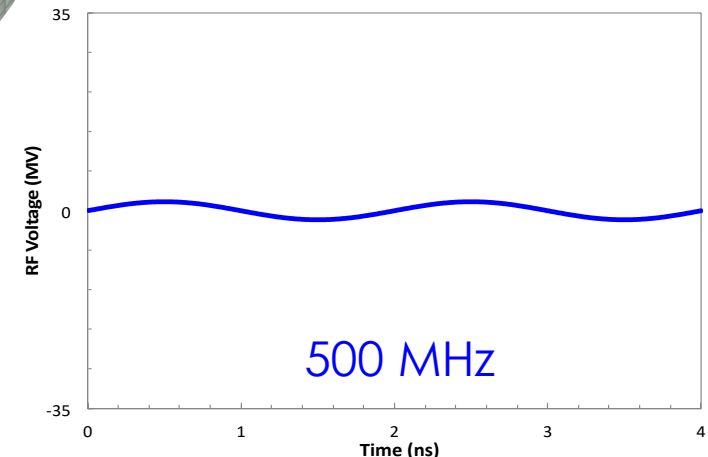
Existing 500 MHz



New
1.5 &
1.75 GHz
SRF

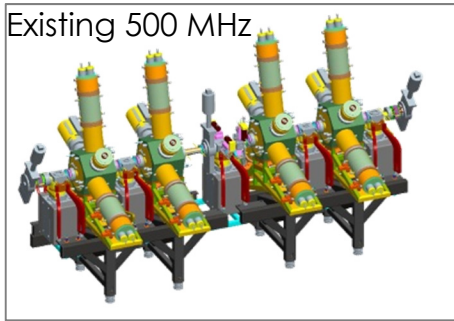


- Beating RF system provides two different buckets for **short** and **long** bunches spaced by 2 ns.

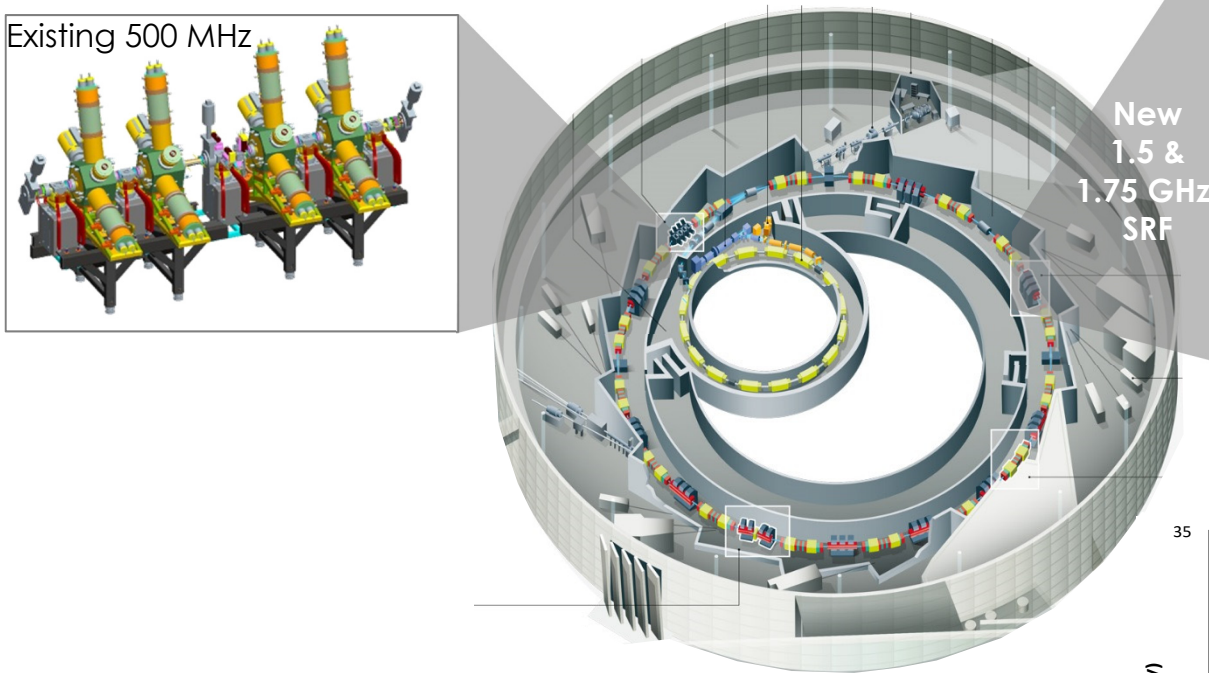
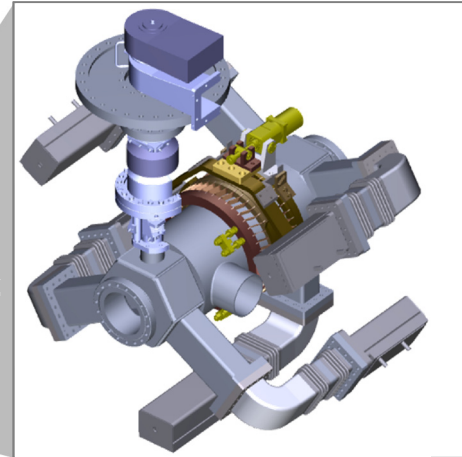


- Upgrading the existing ring with complex SRF for new user applications
- Two-tone high-voltage CW SRF for innovative bunch-length manipulation

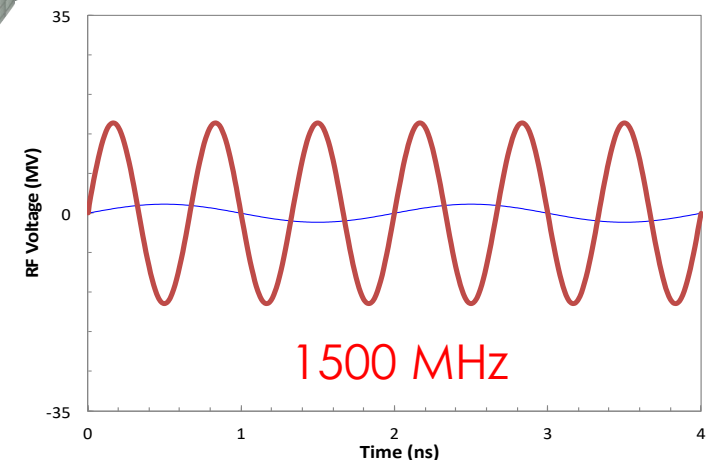
Existing 500 MHz



New
1.5 &
1.75 GHz
SRF

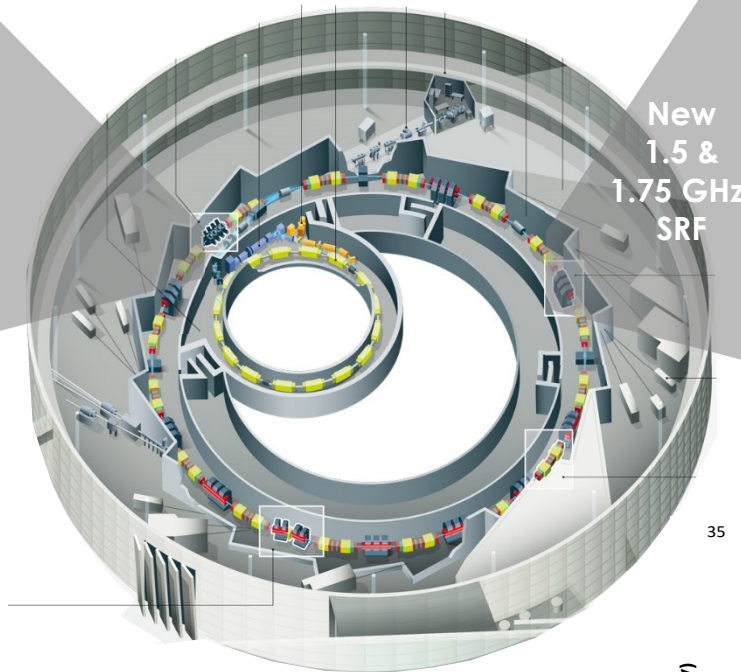
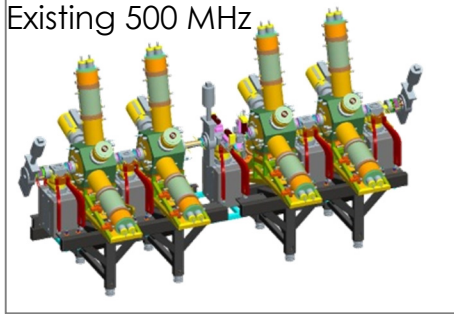


- Beating RF system provides two different buckets for **short** and **long** bunches spaced by 2 ns.

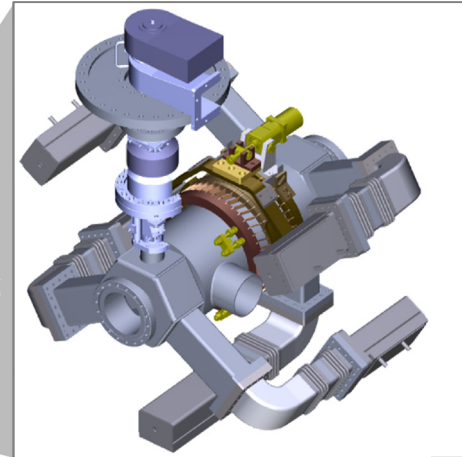


- Upgrading the existing ring with complex SRF for new user applications
- Two-tone high-voltage CW SRF for innovative bunch-length manipulation

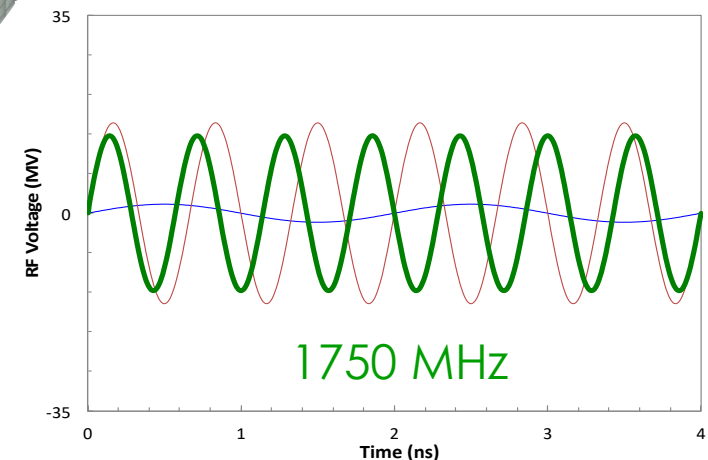
Existing 500 MHz



New
1.5 &
1.75 GHz
SRF

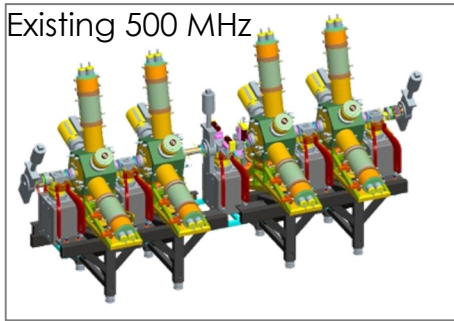


- Beating RF system provides two different buckets for **short** and **long** bunches spaced by 2 ns.

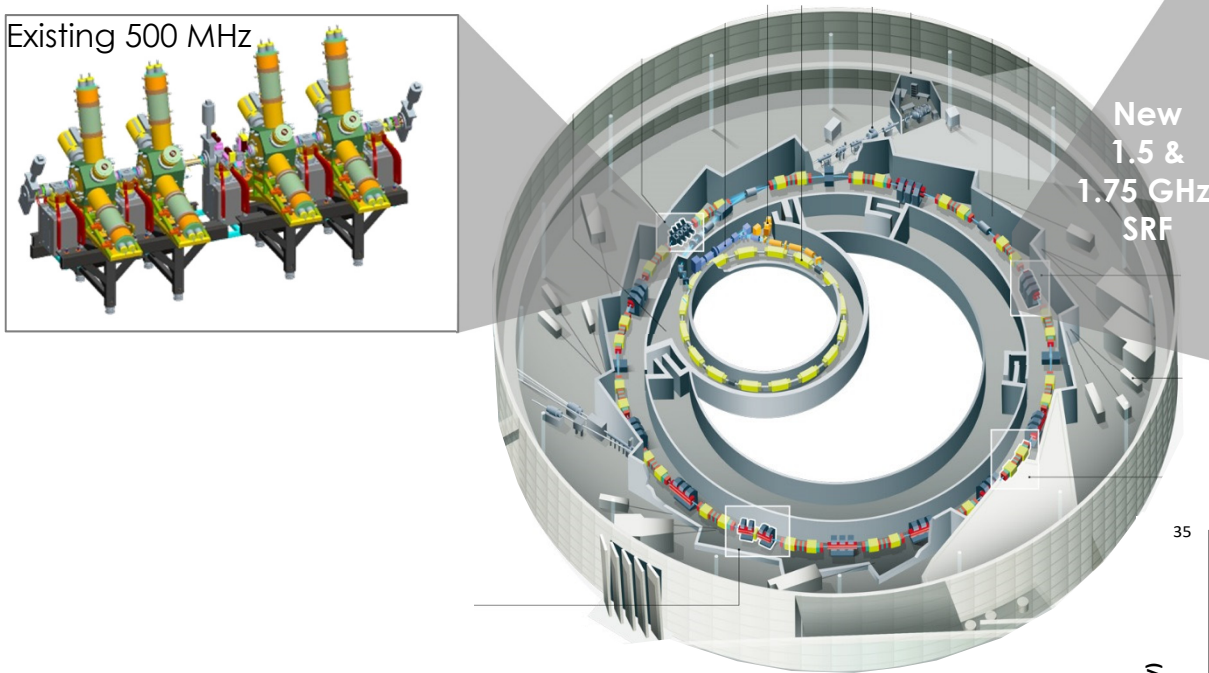
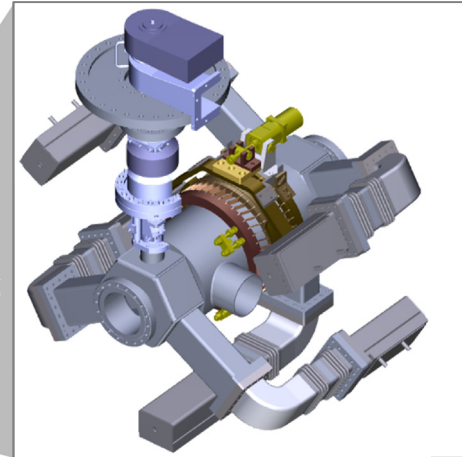


- Upgrading the existing ring with complex SRF for new user applications
- Two-tone high-voltage CW SRF for innovative bunch-length manipulation

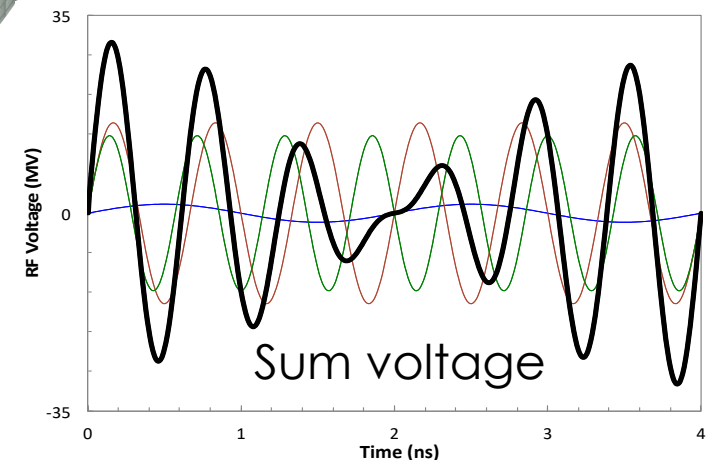
Existing 500 MHz



New
1.5 &
1.75 GHz
SRF

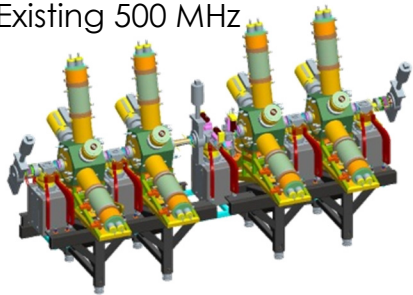


- Beating RF system provides two different buckets for **short** and **long** bunches spaced by 2 ns.

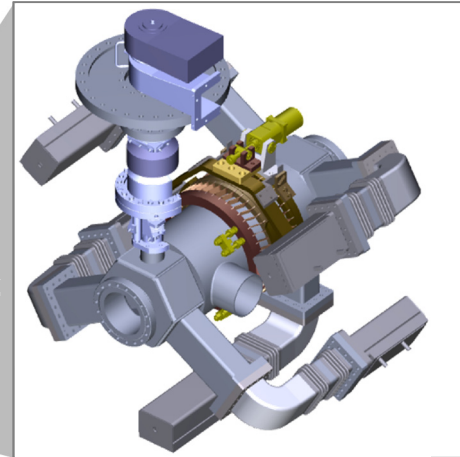


- Upgrading the existing ring with complex SRF for new user applications
- Two-tone high-voltage CW SRF for innovative bunch-length manipulation

Existing 500 MHz

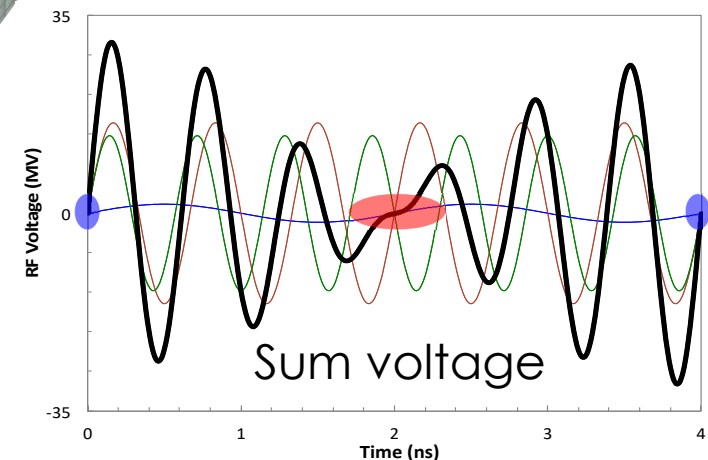


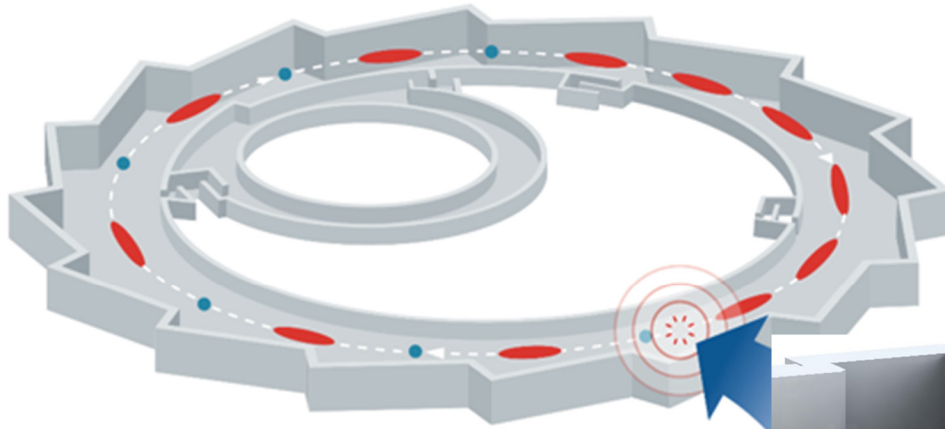
New
1.5 &
1.75 GHz
SRF



 **BESSY VSR**
Variable pulse length Storage Ring

- Beating RF system provides two different buckets for **short** and **long** bunches spaced by 2 ns.

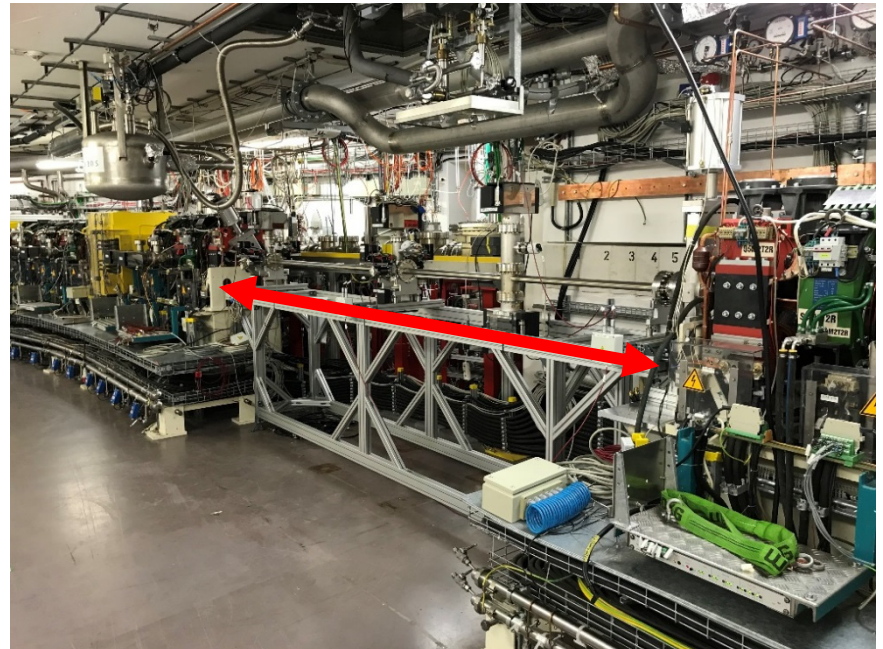
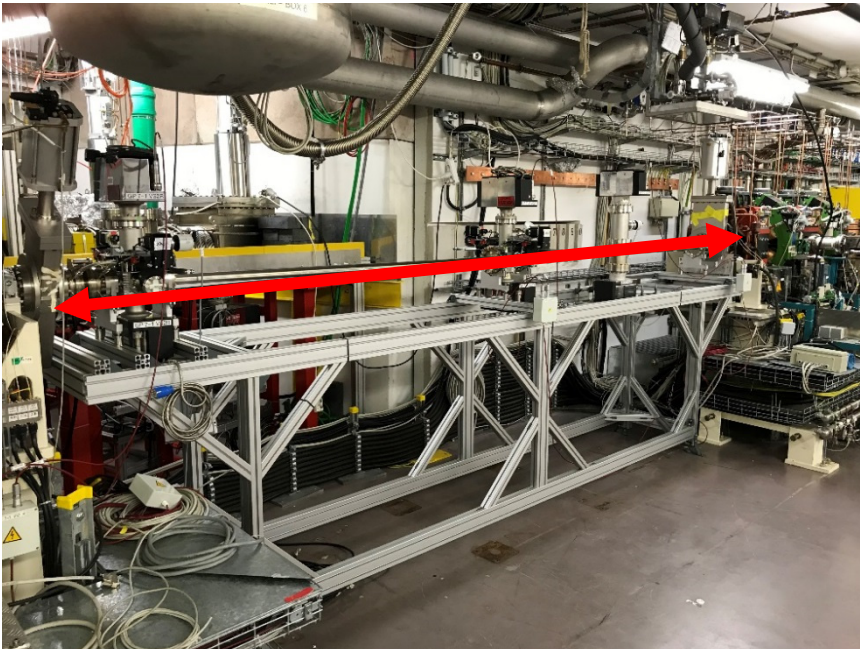
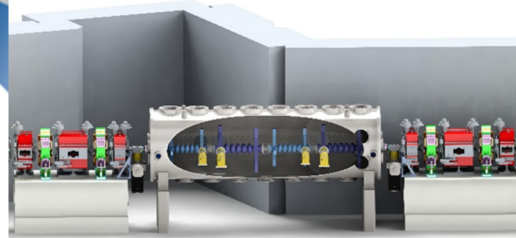


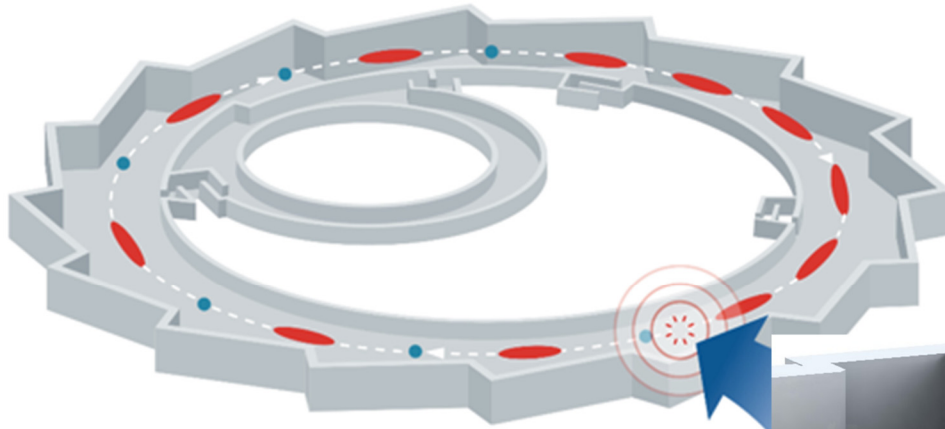


Located in a low beta straight to avoid high impedances

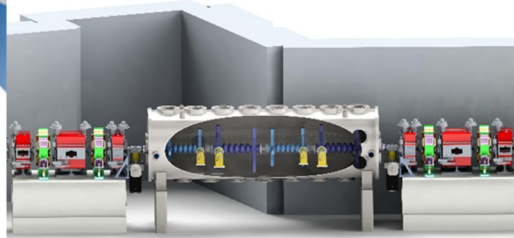
Constraints

- 4 m length constraint
- Vertical restrictions due to existing infrastructure
- Radiation protection wall



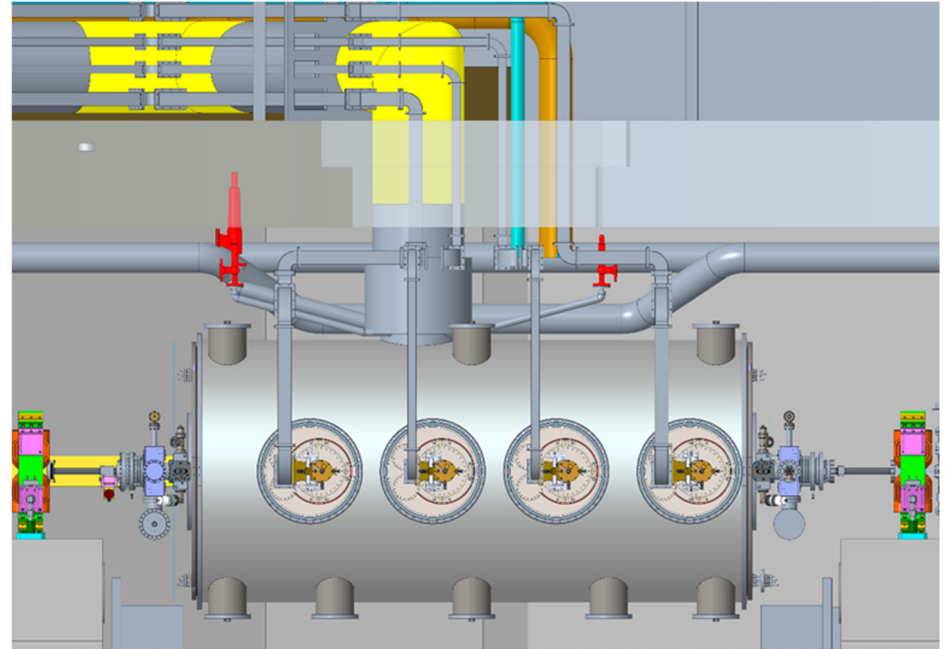
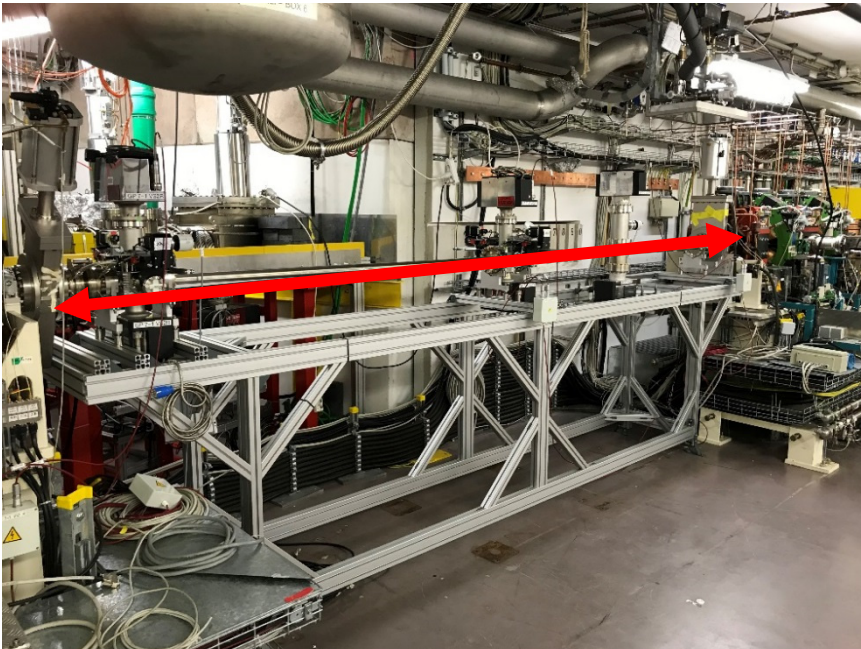


Located in a low beta straight to avoid high impedances

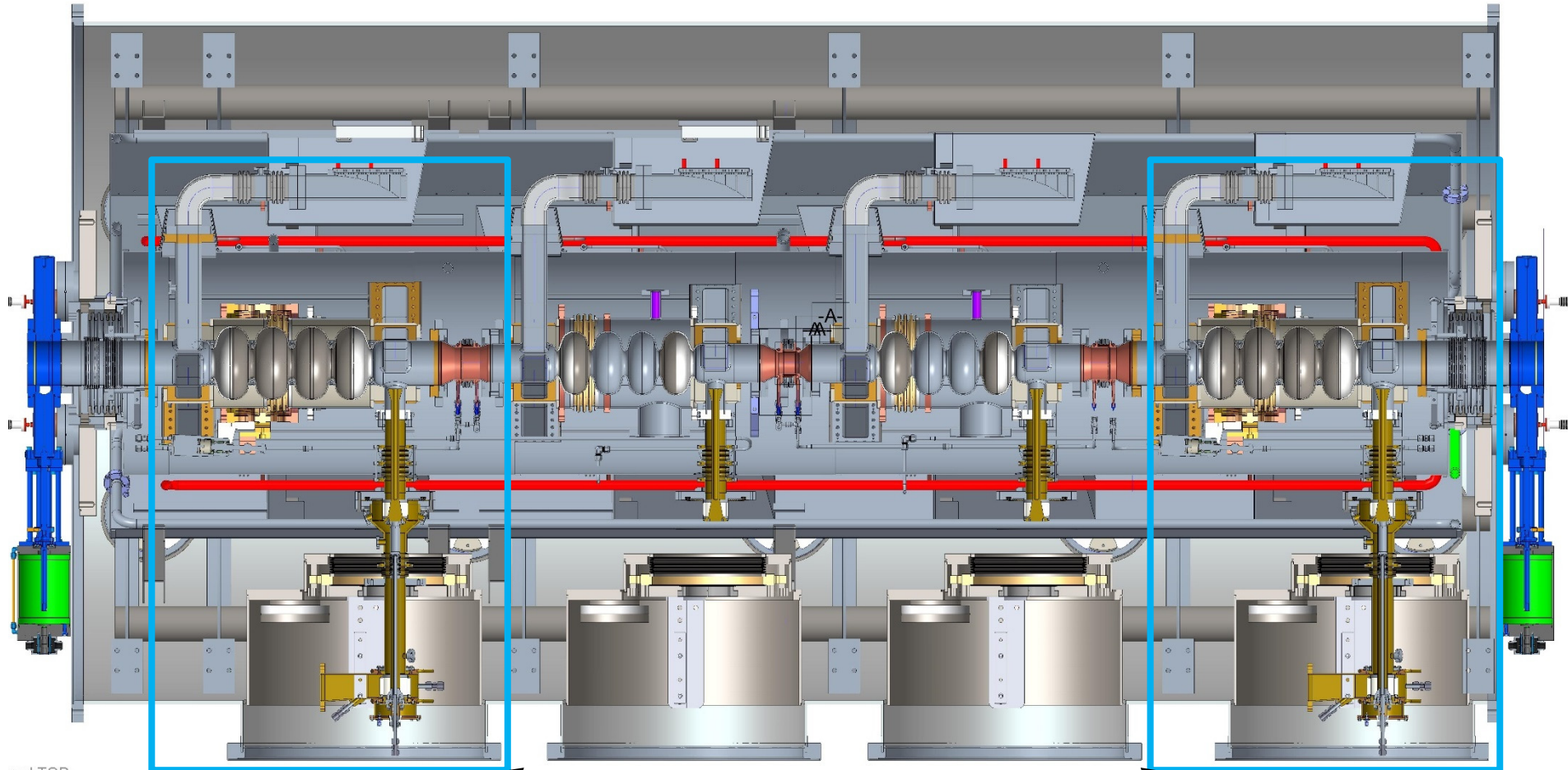


Constraints

- 4 m length constraint
- Vertical restrictions due to existing infrastructure
- Radiation protection wall

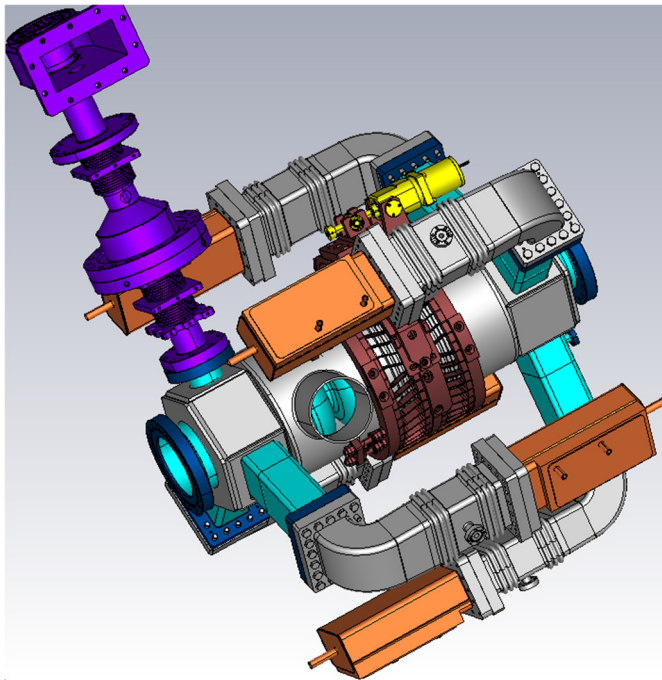


A top down view of the BESSY VSR module showing all cold string elements and shielding



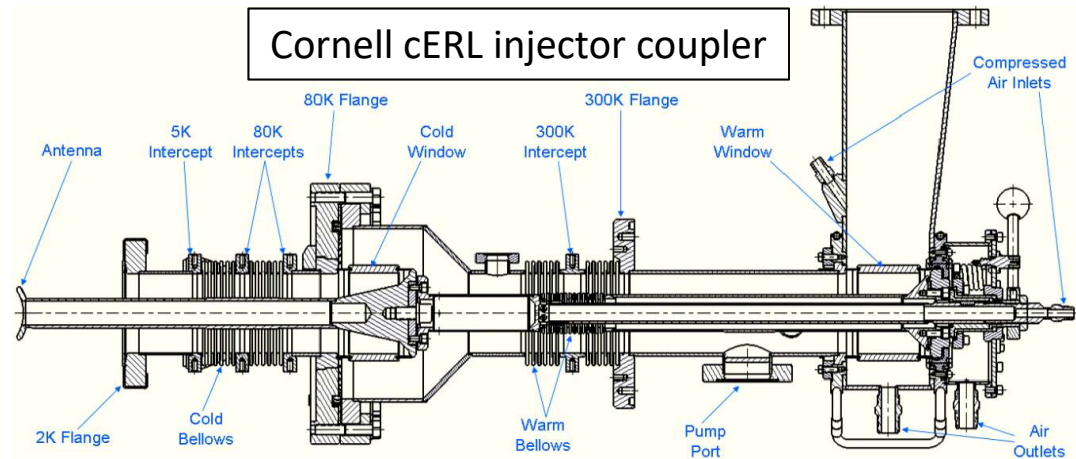
1.5 GHz cavities and couplers

Parameter	Value
Central Frequency (f_c)	1.498 GHz
Power level	16 kW CW
Q_{ext} range	6×10^6 to 6×10^7
Q_{loaded}	5×10^7
S_{11} @ f_c	≤ -30 dB
S_{11} @ $f_c \pm 5$ MHz	≤ -20 dB



Fundamental Design

Adjustable coaxial coupler based on Cornell cERL injector coupler: Lower coupling level and lower power but higher frequency

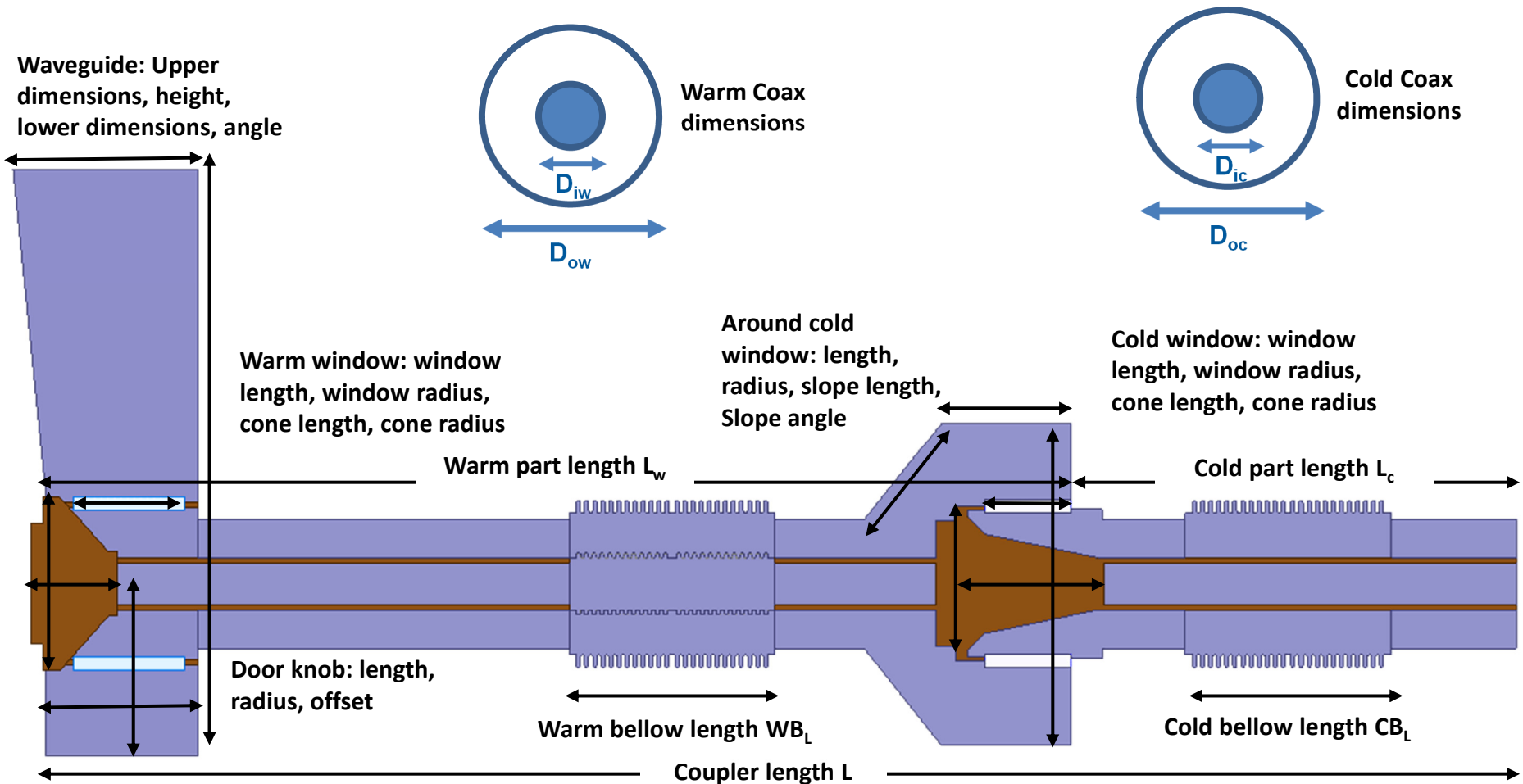


Unique challenges of VSR

- Installation into an existing machine with 20 years operation: Space constraints, Higher order mode propagation, installation constraints.
- Heating challenges: high power, high fields, small scale
- Mechanical challenges: 1.5 GHz means smaller scales
- High gradients and SRF: Field emission and multipacting must be avoided, cleanliness of cavity vacuum

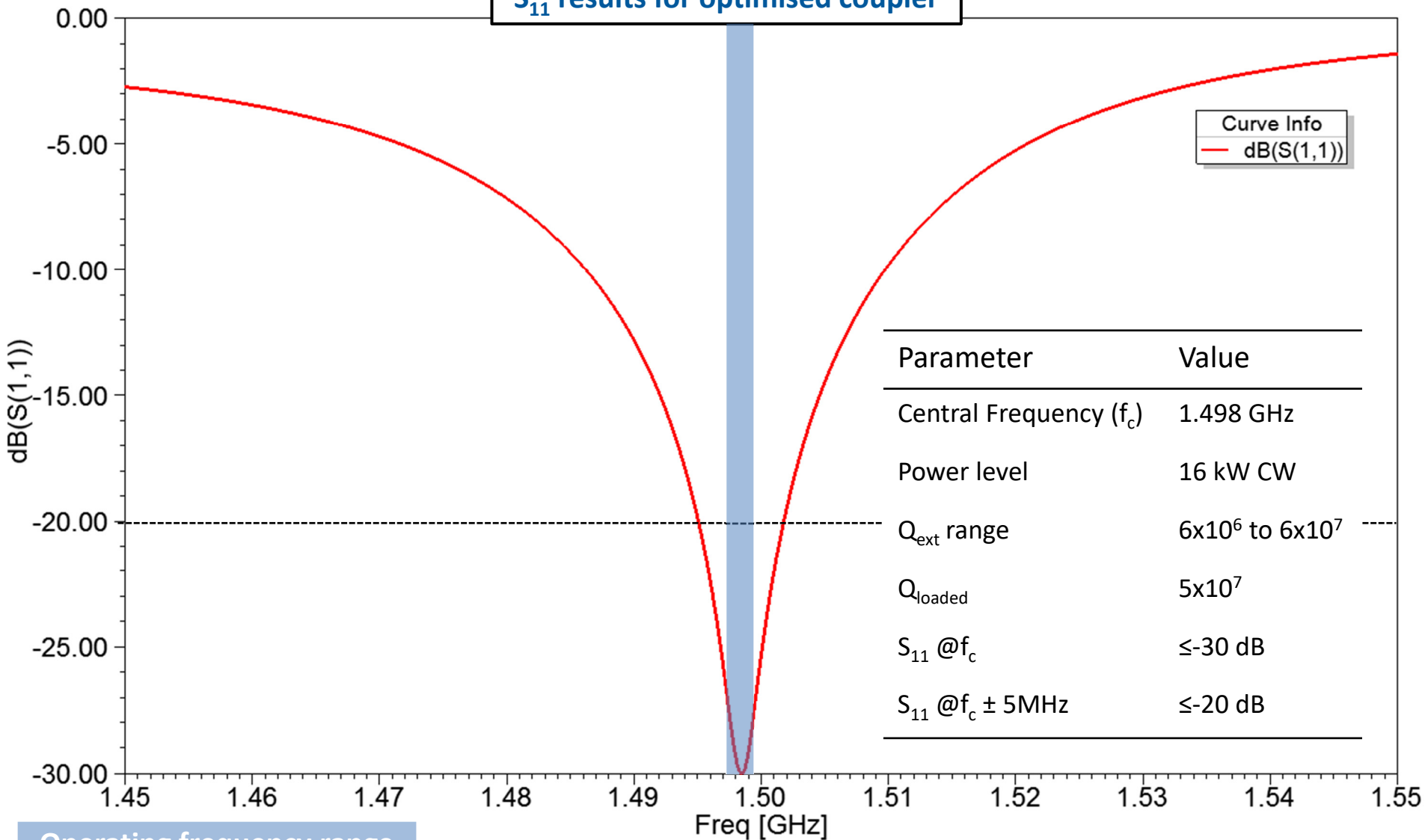
Step 1: Initial RF design:

11

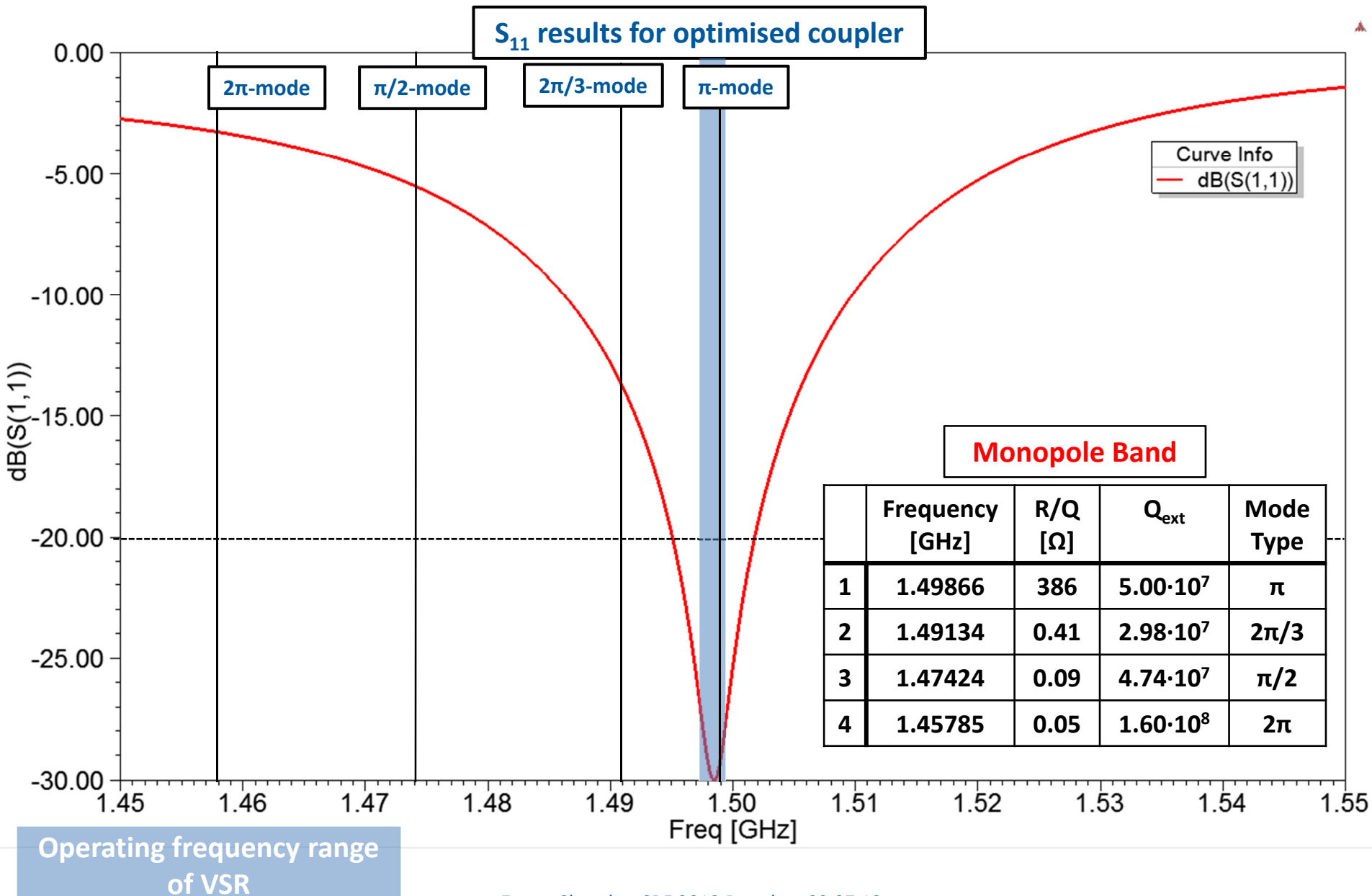


Highly iterative method in which the complexity of the design is increased with each step until this “simplified” model is ready to be translated into a mechanical model

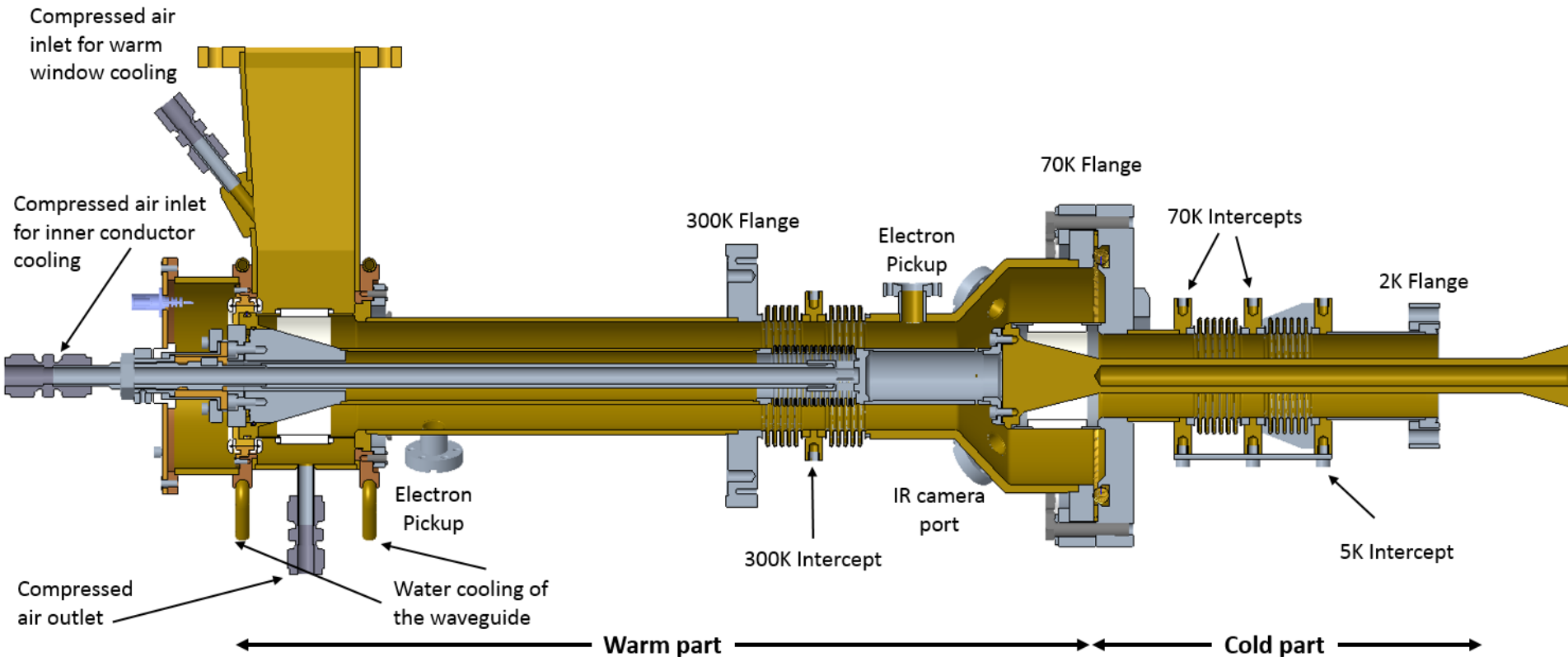
S_{11} results for optimised coupler



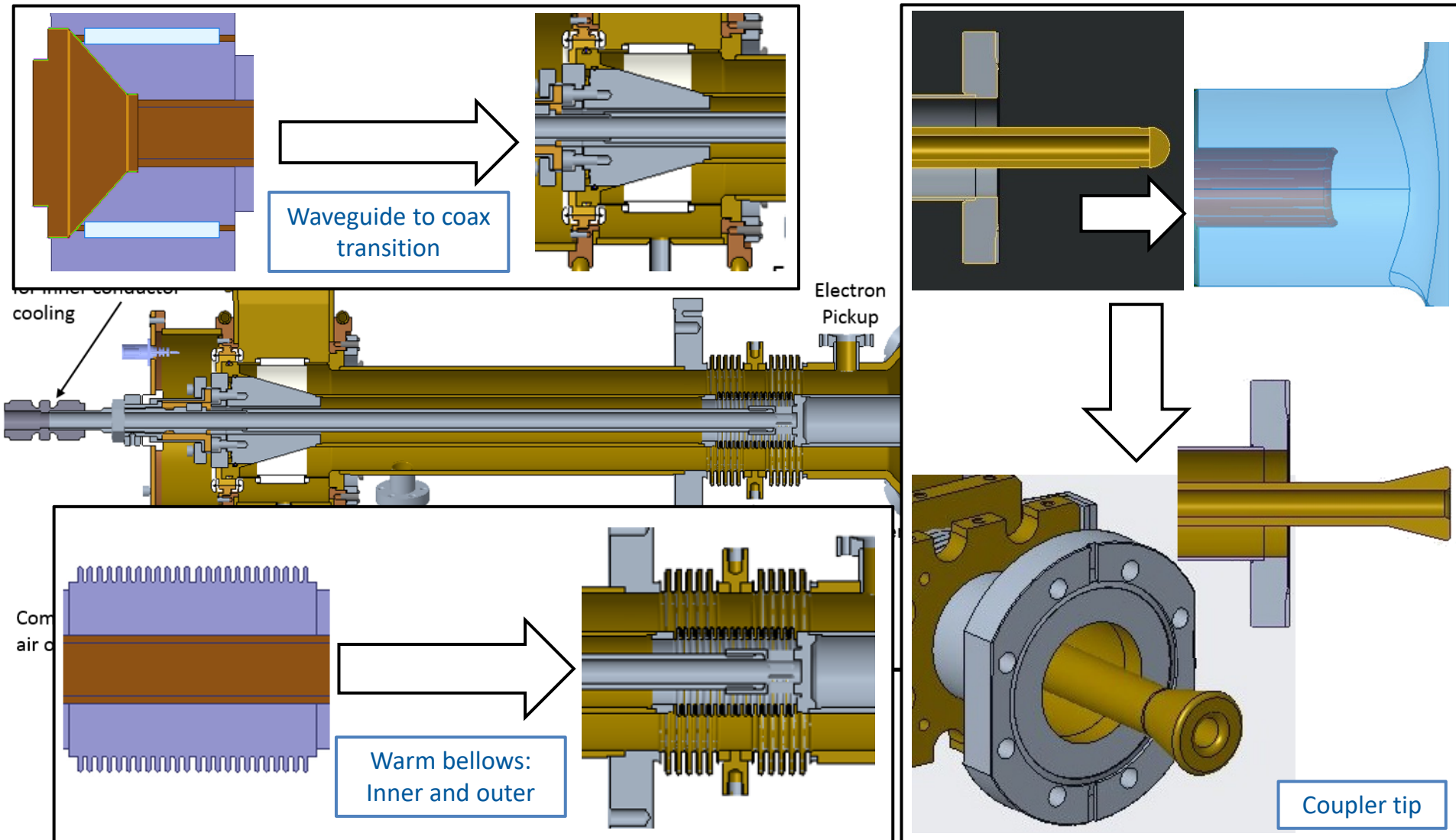
Operating frequency range
of VSR



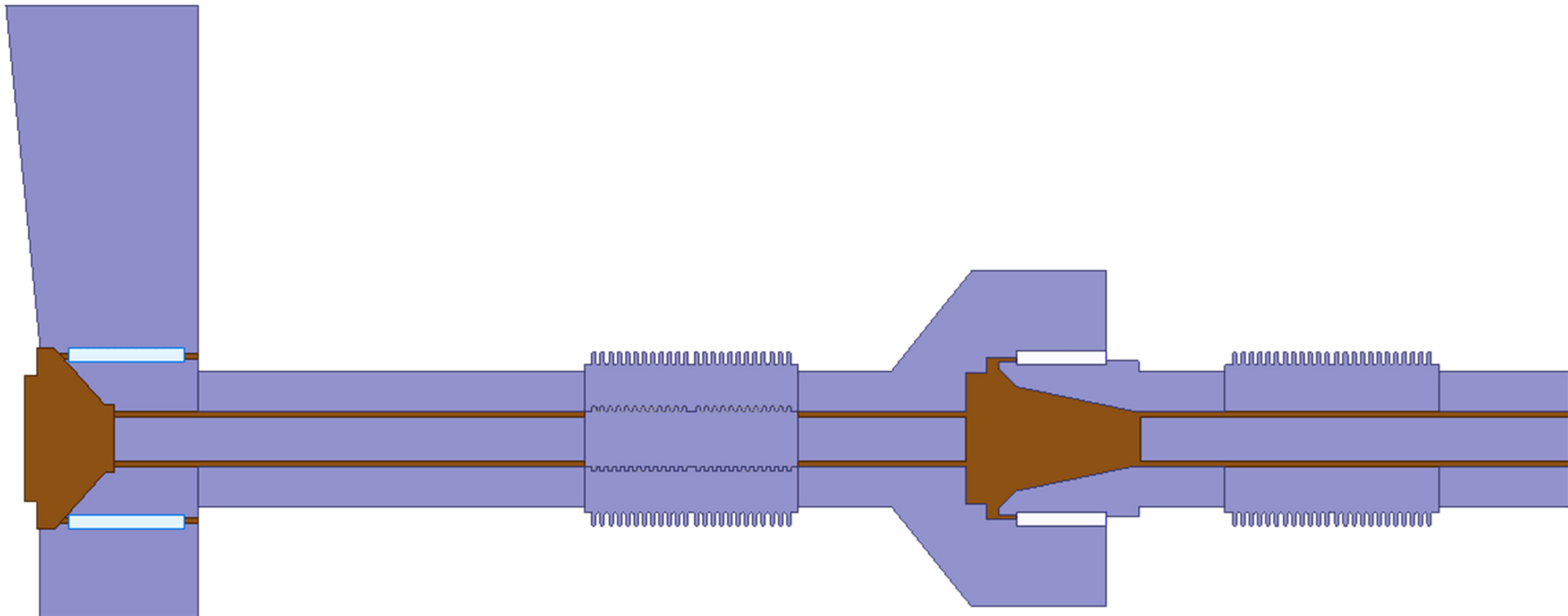
Final mechanical design of the 1.5 GHz coupler for BESSY VSR



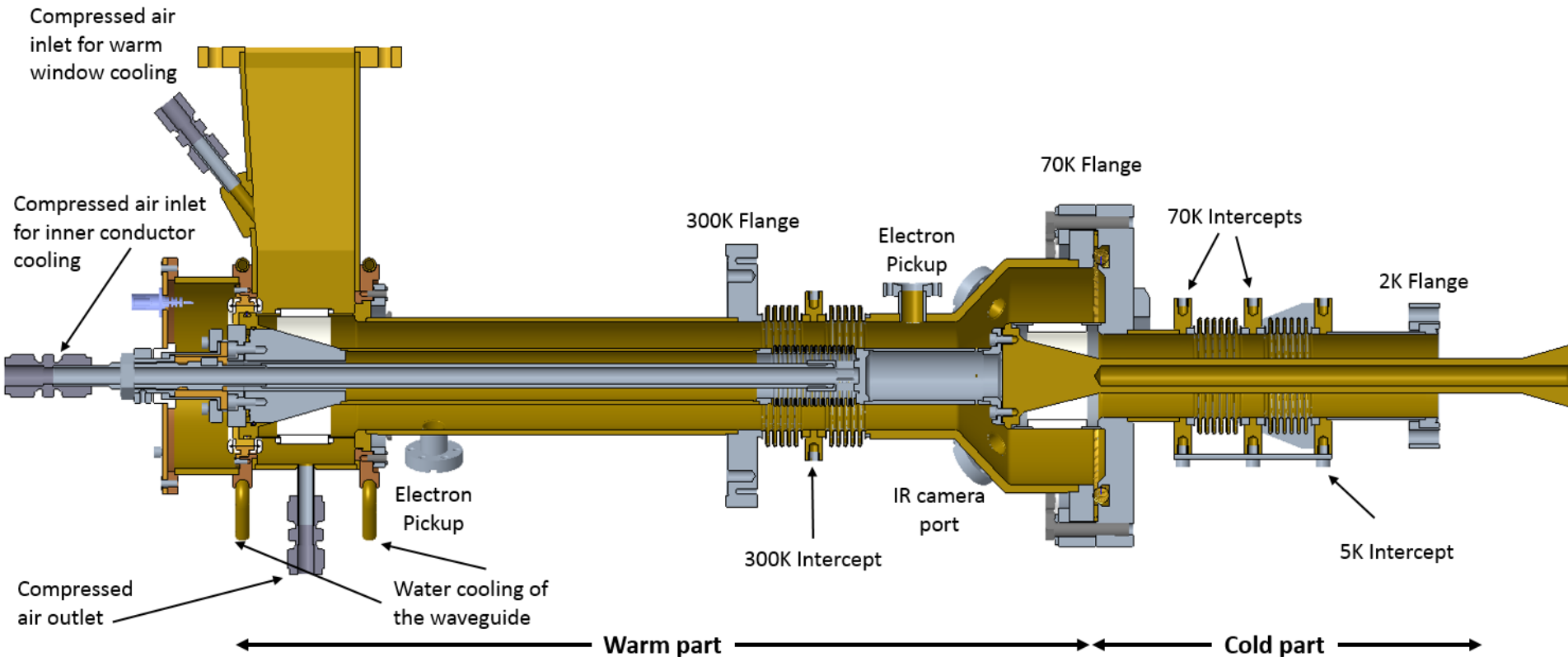
Final mechanical design of the 1.5 GHz coupler for BESSY VSR

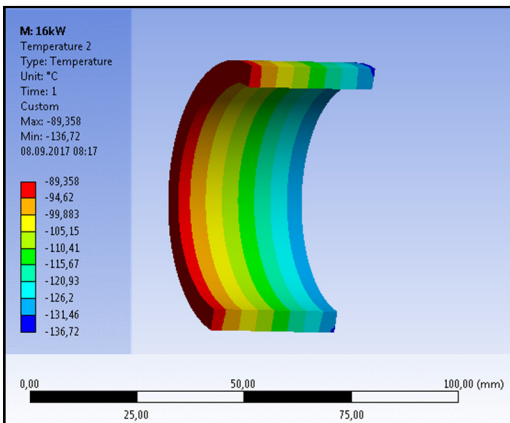


Final mechanical design of the 1.5 GHz coupler for BESSY VSR



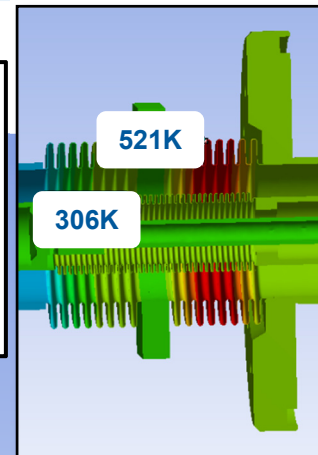
Final mechanical design of the 1.5 GHz coupler for BESSY VSR



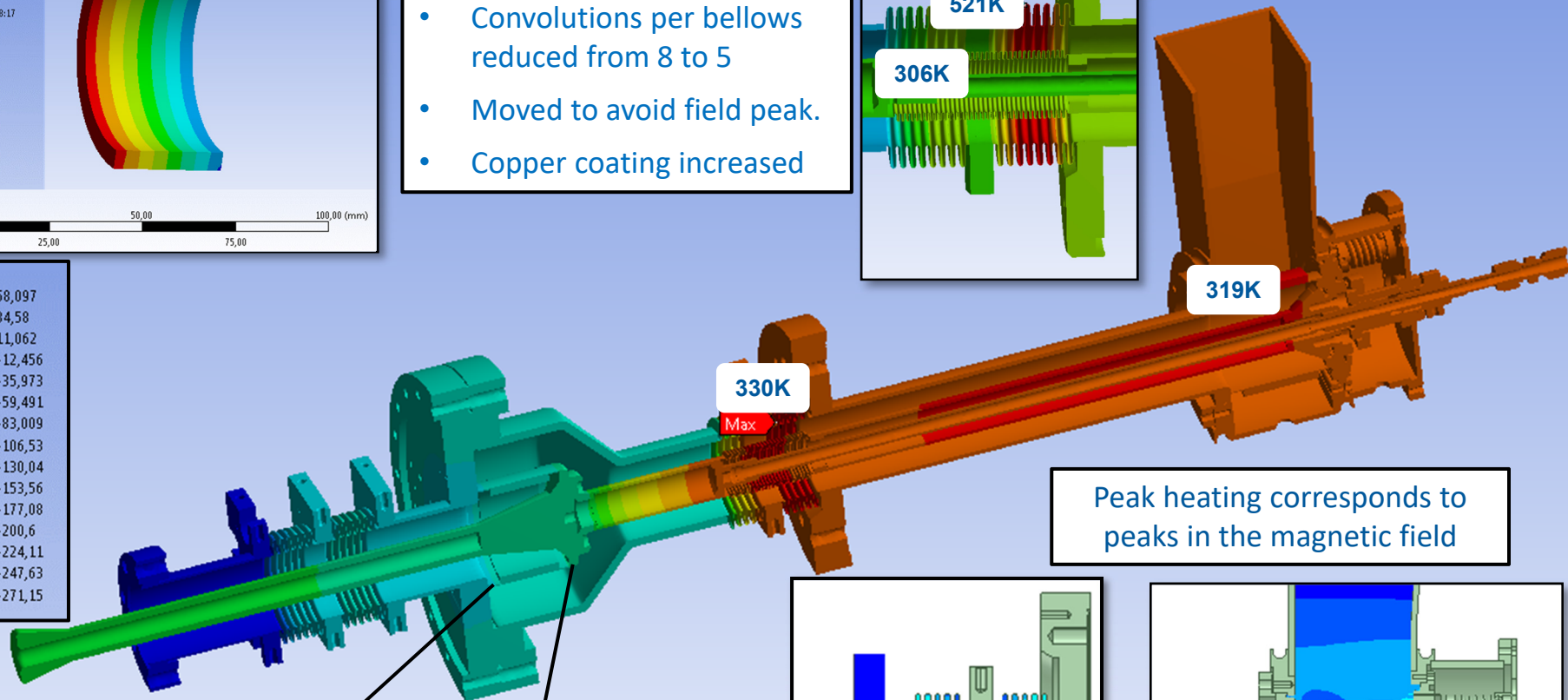
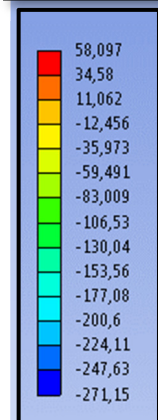


Bellows temp reduction ~190K

- Convolutions per bellows reduced from 8 to 5
- Moved to avoid field peak.
- Copper coating increased

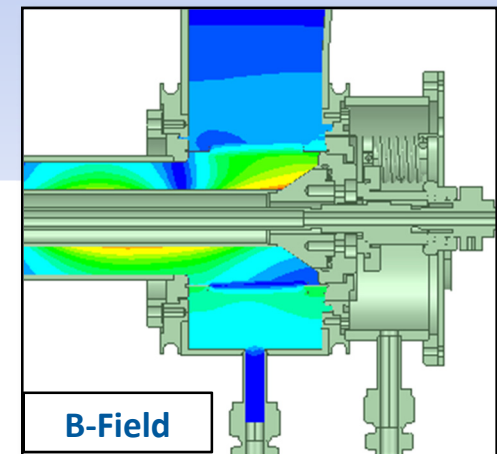
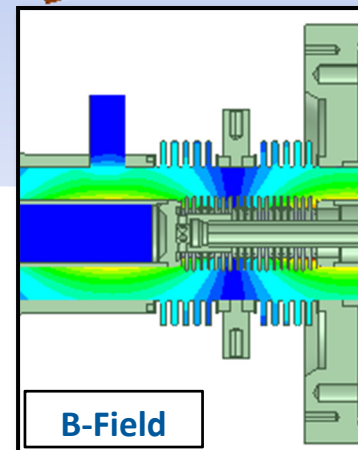
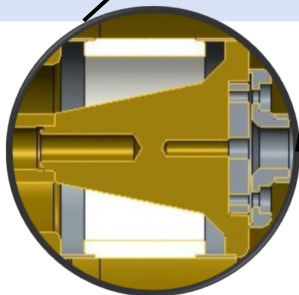


Thermal analysis by Marc Dirsat



Peak heating corresponds to peaks in the magnetic field

New design resulted in 60% less thermal stress on the window



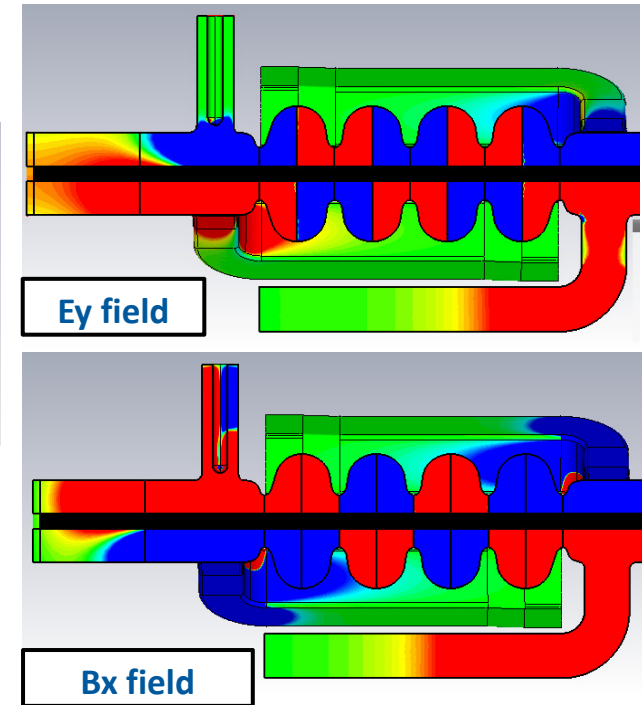
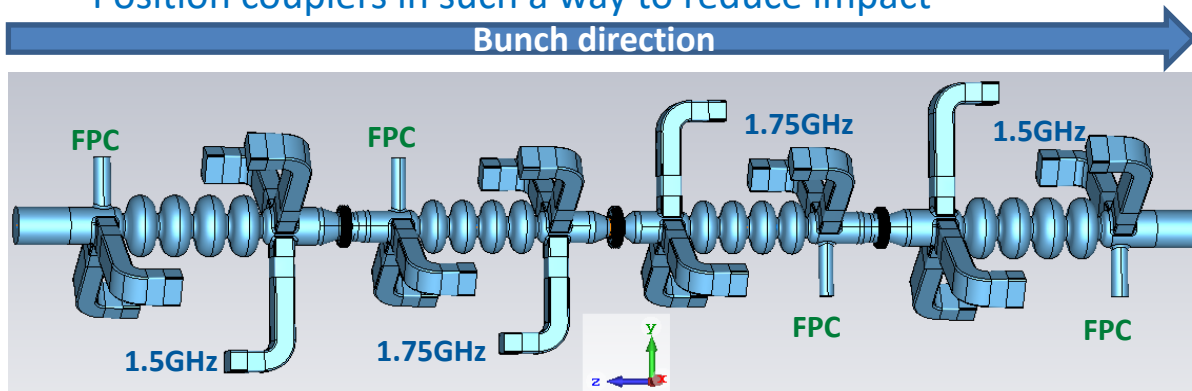
Coupler kicks

19

Disruptions in the cavity electromagnetic field and hence the beam as a result of the coupler.

Ways to mitigate coupler kicks;

- Design the tip to reduce interaction
- Use coupler pairs or a compensating so disruption is symmetric
- Position couplers in such a way to reduce impact



Coupler kicks

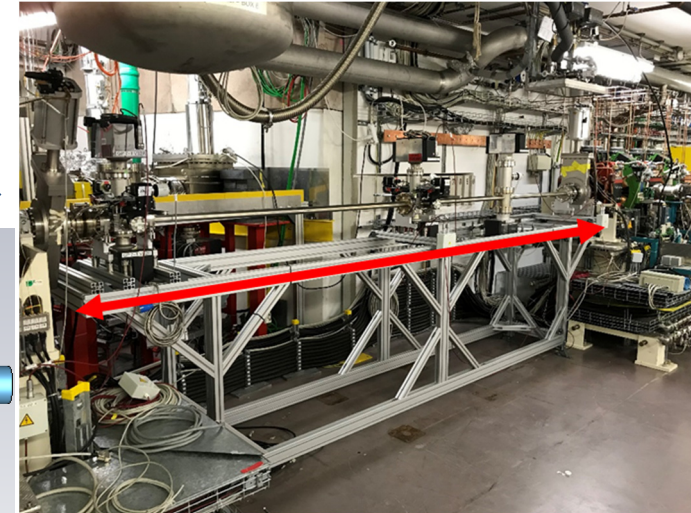
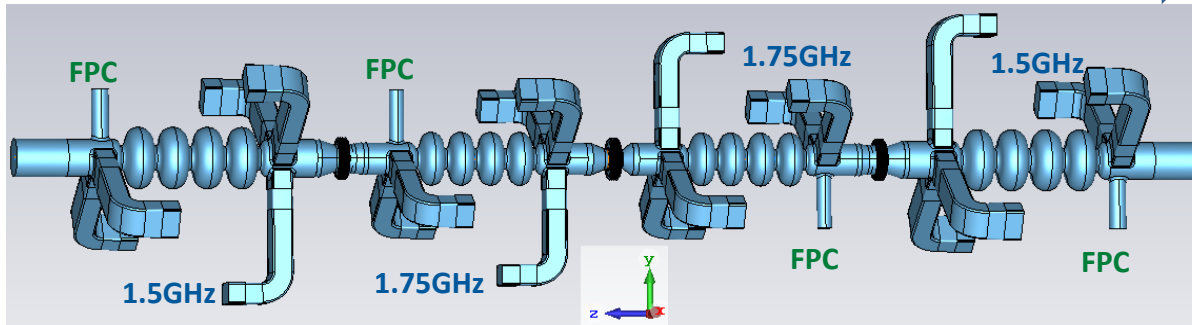
20

Disruptions in the cavity electromagnetic field and hence the beam as a result of the coupler.

Ways to mitigate coupler kicks;

- Design the tip to reduce interaction
- Use coupler pairs or a compensating so disruption is symmetric
- Position couplers in such a way to reduce impact

Bunch direction



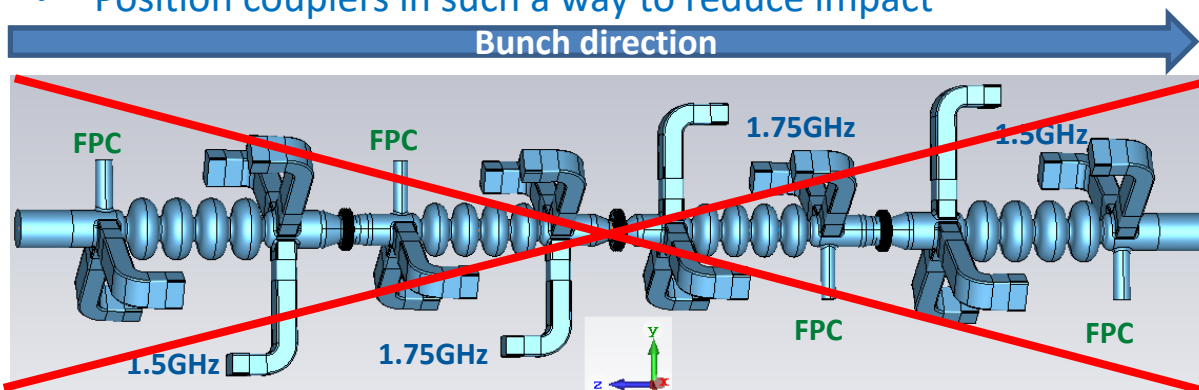
Coupler kicks

21

Disruptions in the cavity electromagnetic field and hence the beam as a result of the coupler.

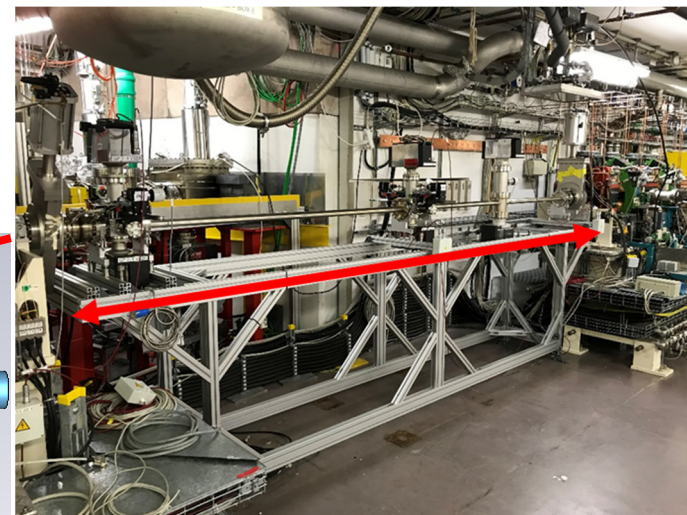
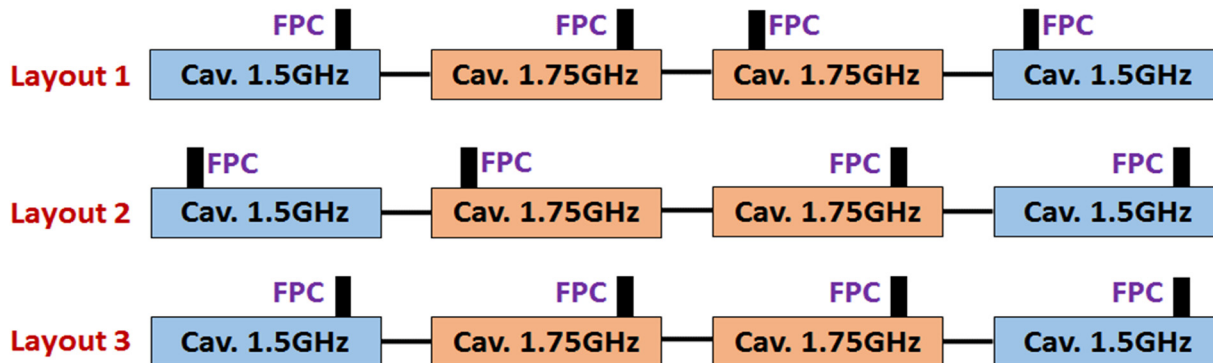
Ways to mitigate coupler kicks;

- Design the tip to reduce interaction
- Use coupler pairs or a compensating so disruption is symmetric
- Position couplers in such a way to reduce impact



Space constraints limit coupler position to all on the one side.

Different FPC positions of the 4-cell cavity arrangement in SRF module



Cavity	Port	HOM Power [W]		
		Layout 1	Layout 2	Layout 3
1.5 GHz	FPC	25	28	61
	WGS	674	721	650
1.75 GHz	FPC	66	67	73
	WGS	1185	117	1188
1.75 GHz	FPC	107	72	114
	WGS	1190	1215	1185
1.5 GHz	FPC	59	25	74
	WGS	654	694	649
Beam pipes		593	680	520
Total		4534	4693	4515

- The design for the 1.5 GHz BESSY VSR coupler for 16 kW complete.
- A complex mechanical design is required to deal with the unique challenges of VSR.

- Further complexity is expected with the design for the 1.75 GHz coupler
- Installation into an existing machine creates unique challenges of the physics, the mechanics and the installation.



Thank you for your attention

Any Questions?

Acknowledgements:

Adolfo Velez
Jens Knobloch
Andranik Tsakanian
Steffen Schendler
Marc Dirsat

Zeljko Muza
Volker Dürr
Wolf Dietrich-Moeller
Axel Neumann
Members of the WWFPC network

Procurement

- Procuring:
 - 2 diagnostic prototype + 2 spare warm outers. (For both frequencies.)
 - 4 Series couplers (For both Frequencies)
 - Total number to procure: 12 couplers
- Tender opened May 2019
- Company selection for bidding opened June 17th
- Bids in on July 21st
- Contract Awarded Sept 2019

On going

- Multipacting studies on the 1.5 GHz coupler design.
- Testing plan development
 - RF design: complete
 - Mechanical design: awaiting an engineer
 - Testing schedule/ Methods to be finalised
- Finalisation of 1.5 GHz drawings
- Procurement of sample ceramics for testing

To do

- Design of the 1.75 GHz coupler: Mechanical seen as key challenge.

May 2019
Tender open

Sept 2019
Contract
awarded

March 2021
1st 1.5 GHz
prototypes

Feb 2022
1.5 GHz
series

Dec 2022
1.75 GHz
Prototypes

Dec 2023
1.75 GHz
series