Design of 325 MHz RF couplers for superconducting spoke resonators in MEHIPA-I

Sonal Sharma
Bhabha Atomic Research Centre
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Plan of talk

- Introduction
- Design of coupler
- RF simulation results of warm and cold part of coupler
- Thermal simulations and results
- Summary and acknowledgement
- 650 MHz RF couplers design

Introduction

- *RF coaxial couplers at frequency of 325 MHz are required to provide high RF power to the SSR cavities of MEHIPA-I project in BARC, India.*
- *Design and simulation of the coupler has been carried out in CST microwave studio.*
- *This design is based on the Fermilab coupler design.*
- *The MEHIPA-I coupler has been designed to work at power level of 50 kW at 325 MHz.*
- *Vacuum part (cold part) and warm part have been simulated separately*
- *Coupler RF- Thermal coupled simulations have been done using thermal solver of CST studio.*

MEHIPA-I (40 MeV, 10 mA accelerator)

Waveguide couplers

Coaxial couplers for cavities

NORMAL CONDUCTING SECTION

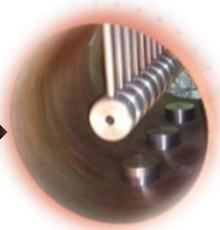
LEBT

50 keV Ion source

325 MHz, 3 MeV RFQ

MEBT

3 MeV



325 MHz, 3 MeV to 10 MeV DRIFT TUBE LINAC

HEBT

10 MeV

SC SPOKE CAVITIES

40 MeV

Technical Requirement for the design of RF coupler

- For MEHIPA1 SSR cavities, the highest power required is about 22 kW. So RF coupler has been designed to handle about 50kW power.
- This power requirement is higher than that of the Fermilab coupler at same frequency. So, the diameter, length, input line size, matching section etc. of the Fermilab coupler have been changed to meet the higher power requirements.

Design of the coupler

- This coupler has warm and cold part.
- It has a coaxial geometry and consists of single ceramic disk which acts as RF window.
- The input is 6-1/8 inch line.
- It uses air cooled inner antenna and has bellows on inner and outer conductor for flexibility.
- A copper disc in the inner conductor of cold part provides matching as well as protection to the window.

CST simulation of the coupler

- Full coupler CST model and its cut view is given in Fig 1.

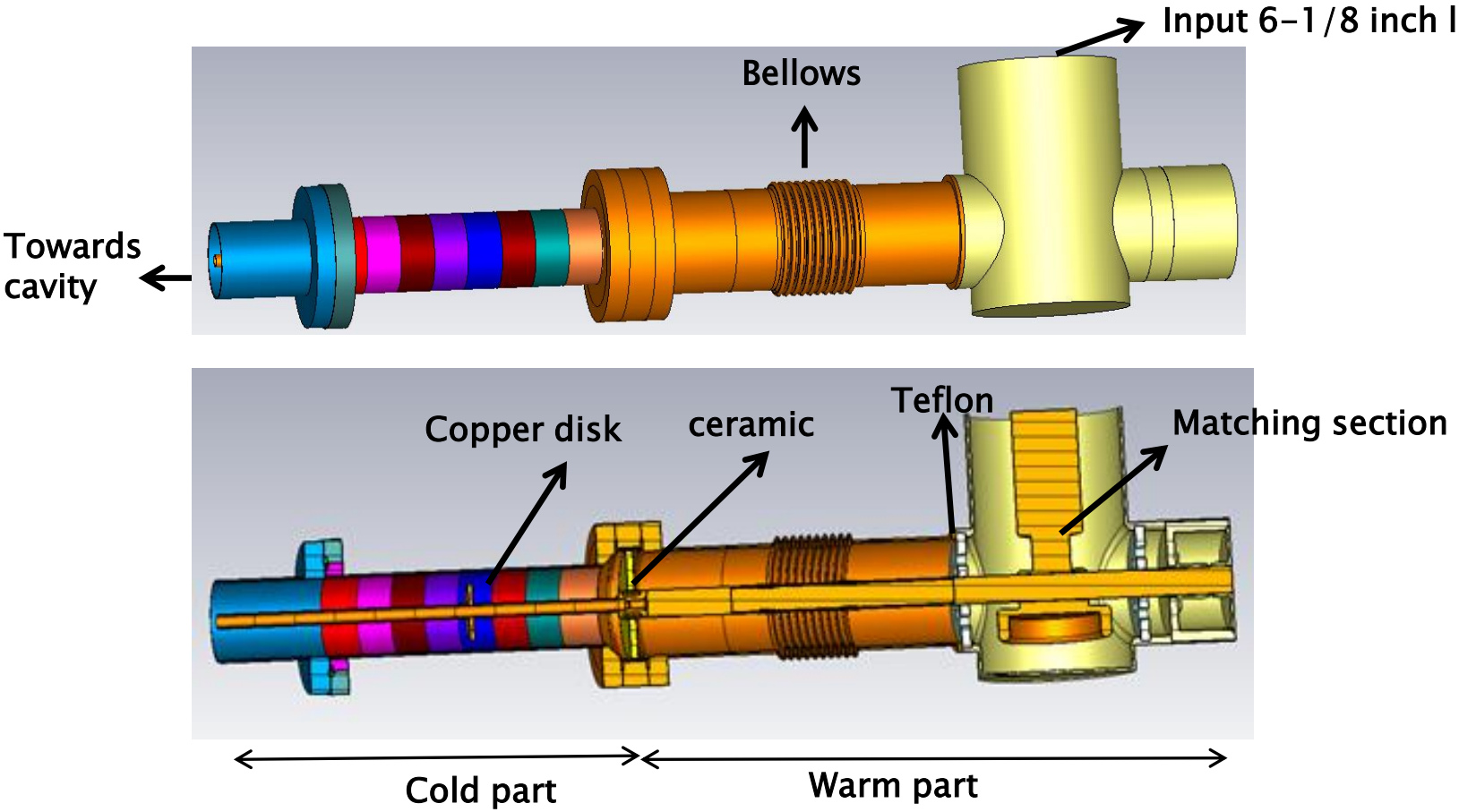


Fig 1

Cold/vacuum part coupler simulation

- Cold vacuum part is shown in fig 2.
- The design has been optimized to get perfect matching at input.

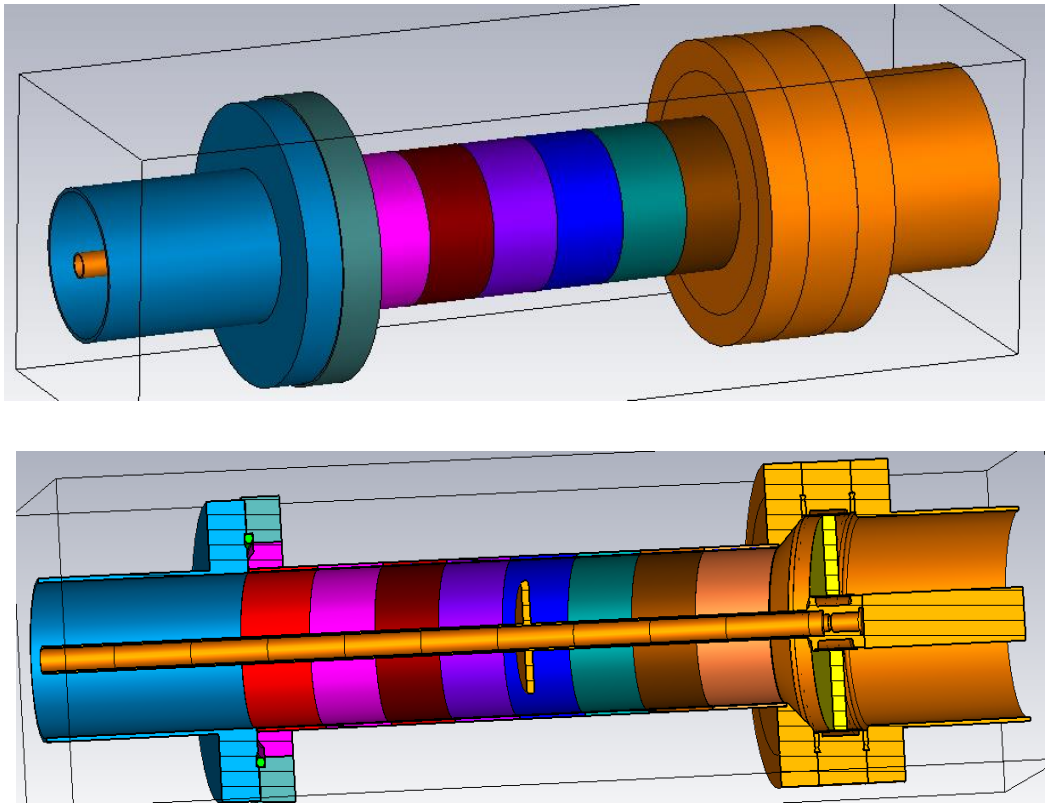
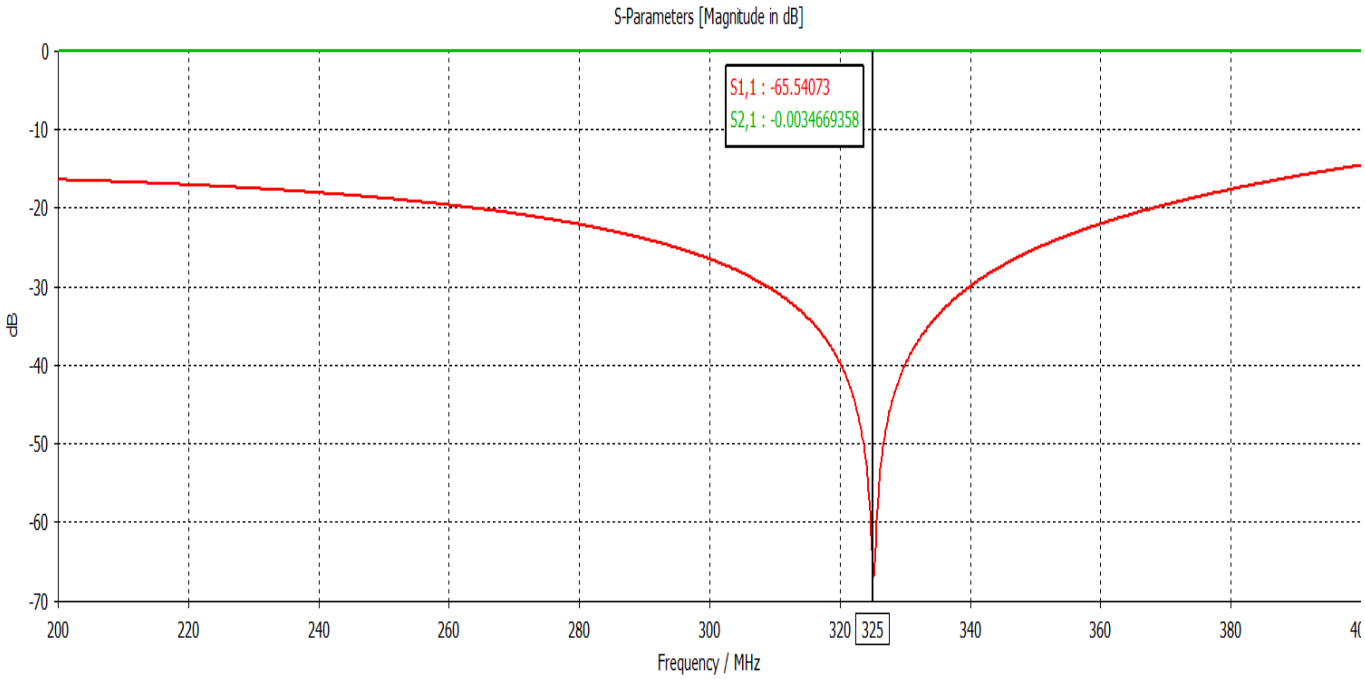


Fig 2

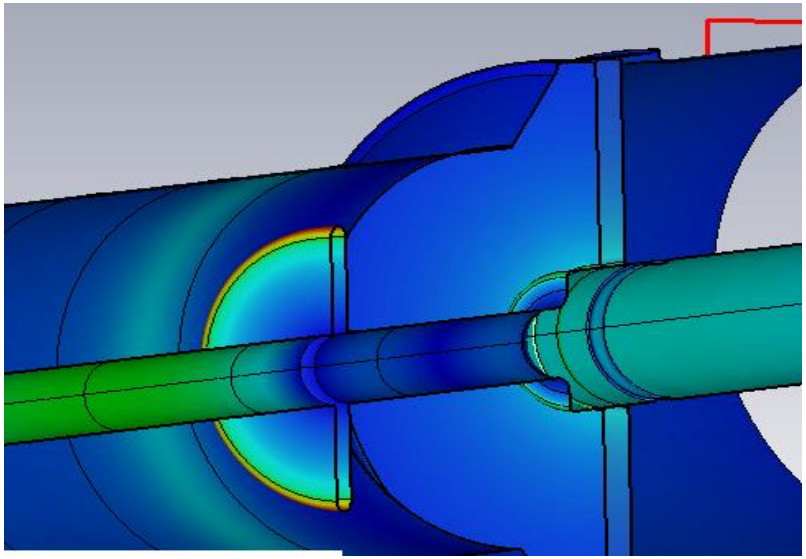
S-parameters of cold part of coupler



s-parameters for the cold part of coupler

Max E field in vacuum

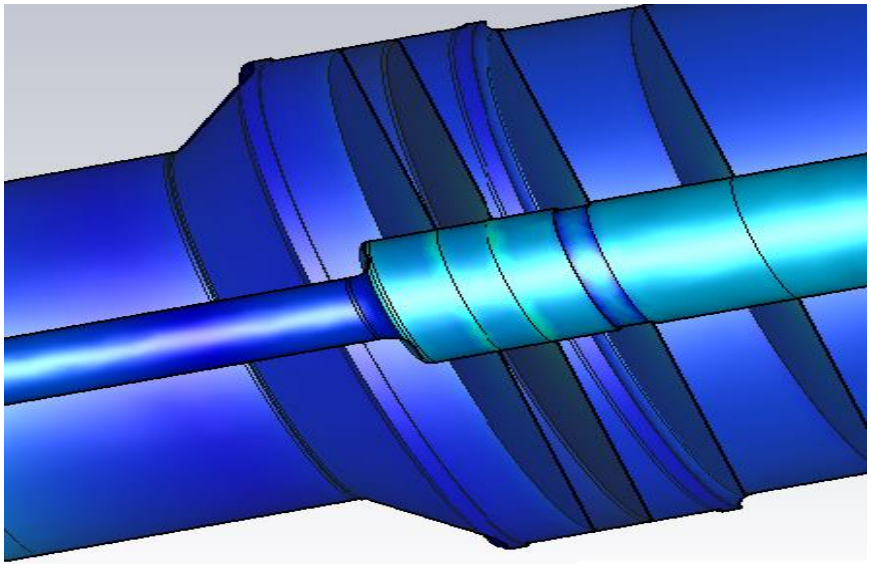
- Maximum RF electric filed in vacuum is at edge of antenna disk. Max. of electric field for 50 kW full reflection (worst phase) is 1.577e6 V/m (15.7kV/cm).(For 0.5 W input Emax is 4989 V/m)



- Max. electric field of 5kV bias is ~ 11.7kV/cm.
- Total max. electrical filed, RF + bias ~ 27.4kV/cm.

Max E field in air side

- Maximum is located in ceramic-copper area.
- Maximum is ~ **7.8kV/cm** for **50kW full reflection (2471V/m for 0.5W)**

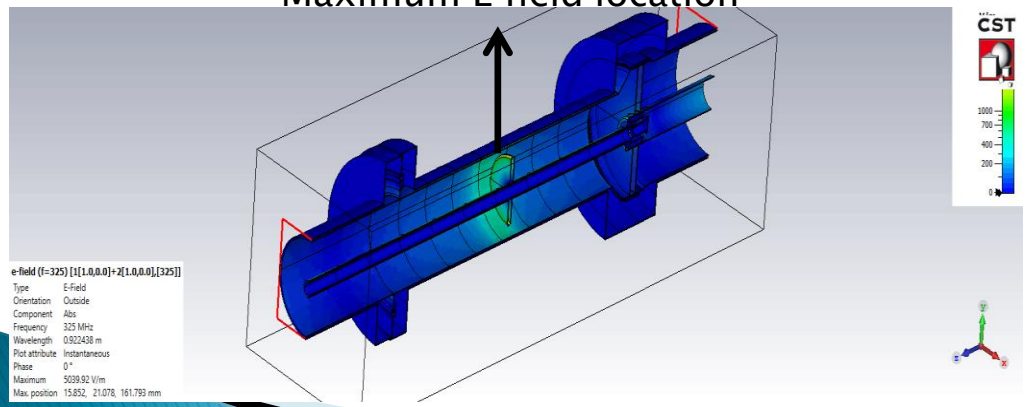


Maximum RF field for different reflection phases

Table 1

S no	Output port phases	Max Electric field for input 0.5W (V/m)
1.	matched	2633
2.	Full reflection 0 degree	4727
3.	Full reflection 90 degree	2471
4.	Full reflection 180 degree	2329
5.	Full reflection 270 degree	4989

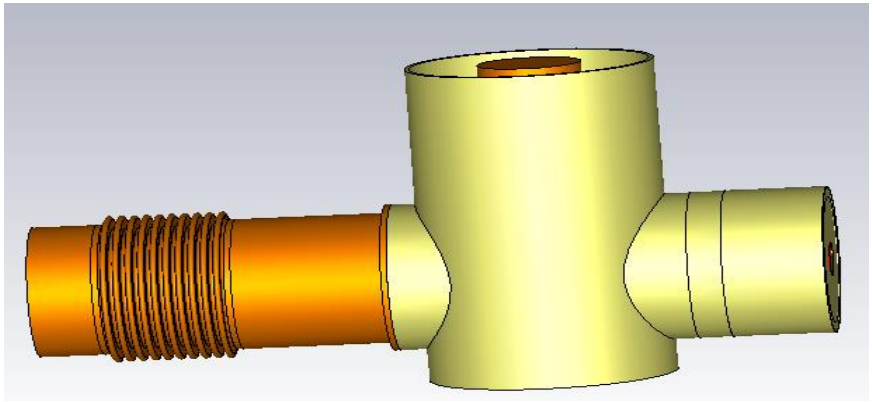
Maximum E field location



- Maximum field values for different phases is given in table 1.
- Maximum RF field for full reflection has been obtained at 270 degree phase of output port. The location of this Maximum RF electric filed in cold vacuum part is at the edge of antenna disk as shown in the figure.
- For 50 kW this comes out to be about 15.77 kV/cm.
- When 5 kV HV is applied at the inner conductor antenna for multipacting suppression the field obtained is about 11.7 kV/cm. So total maximum RF field is 27.4 kV/cm in vacuum.

Warm part coupler simulation

- Warm air part and its cut view is shown in fig 3.
- The input is 6-1/8 inch line.
- Matching section is designed to minimize the reflection at input.



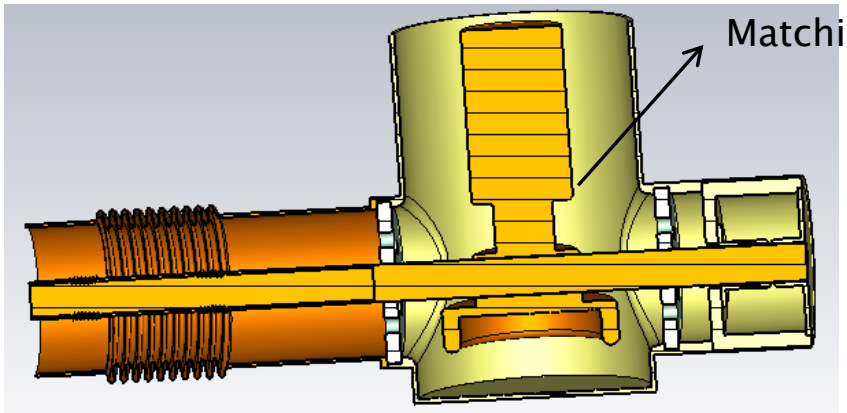
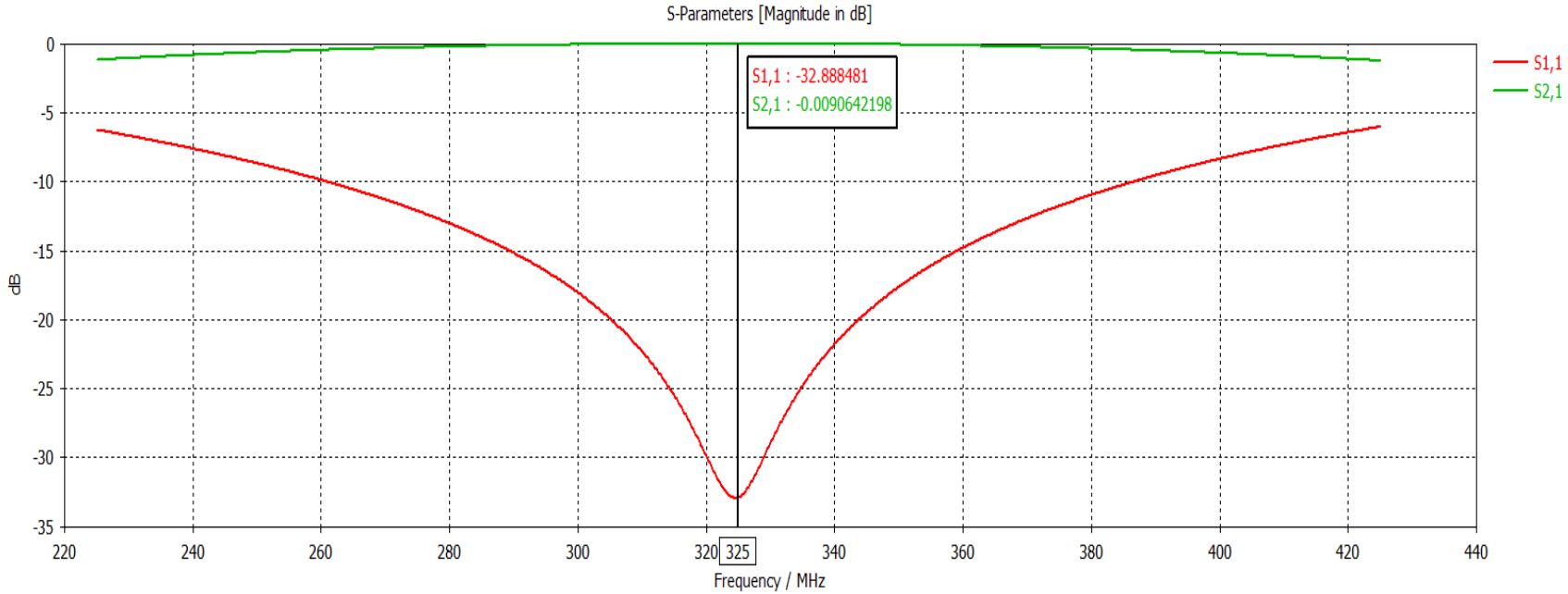


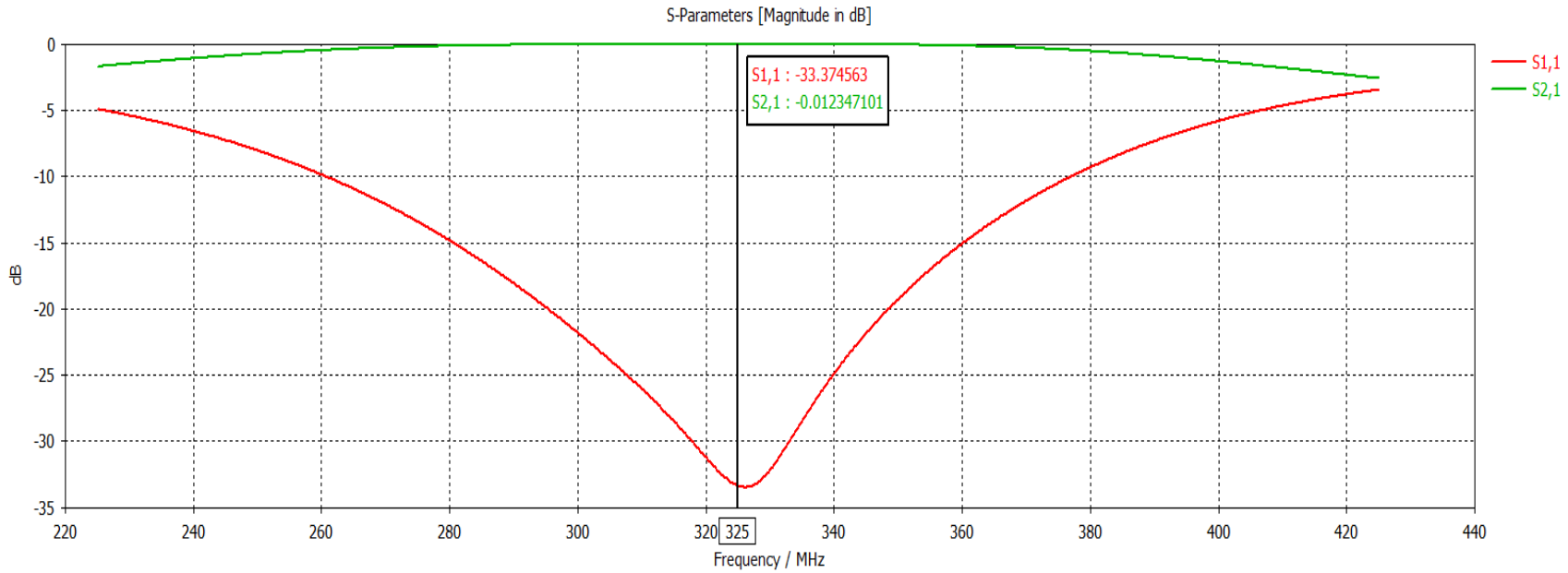
Fig 3

S-parameters of warm part of coupler



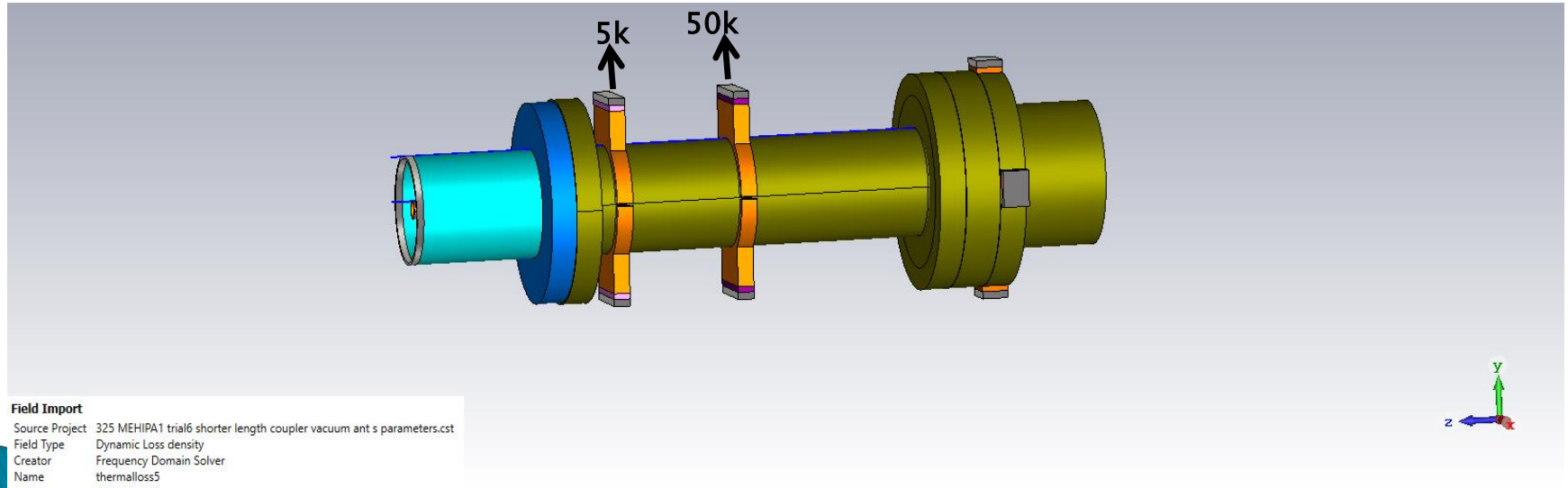
S-parameters of the full coupler

- Full coupler s parameters are shown below.
- Matching of better than 33 dB has been obtained at 325 MHz.



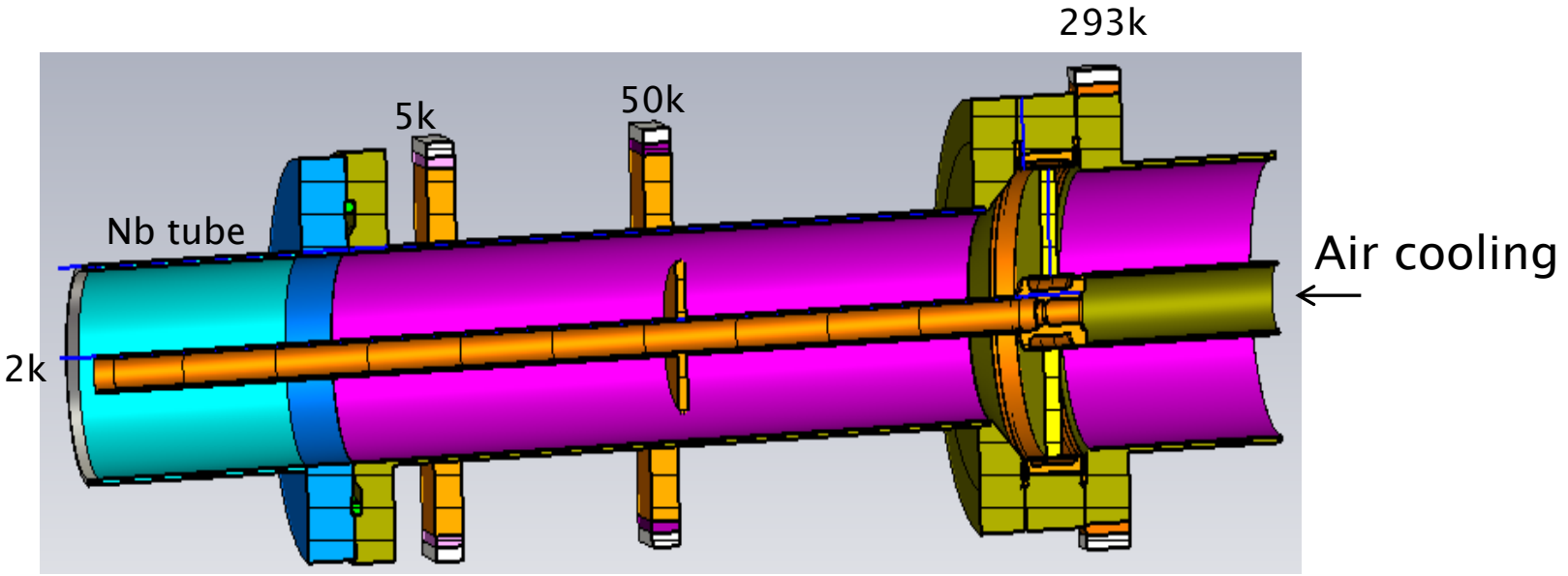
Thermal simulations of the coupler

- Thermal simulation has been coupled with RF simulations to obtain the temperature profile and heat flow values.
- Specially cold part thermal simulation is important to know the cryogenic load.
- Two intercepts at 5k and 50k are used to cool outer conductor. Inner conductor is air cooled.
- Cold part thermal model is shown below



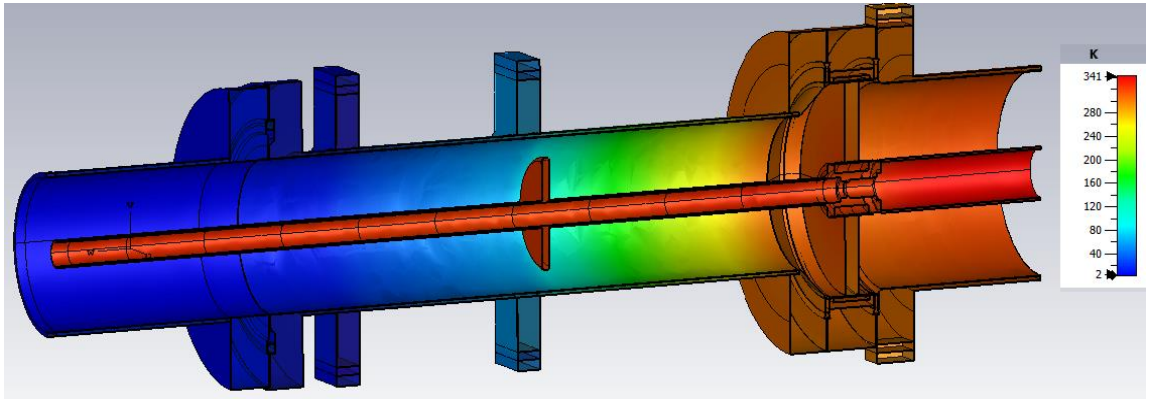
Cold part thermal model of the coupler

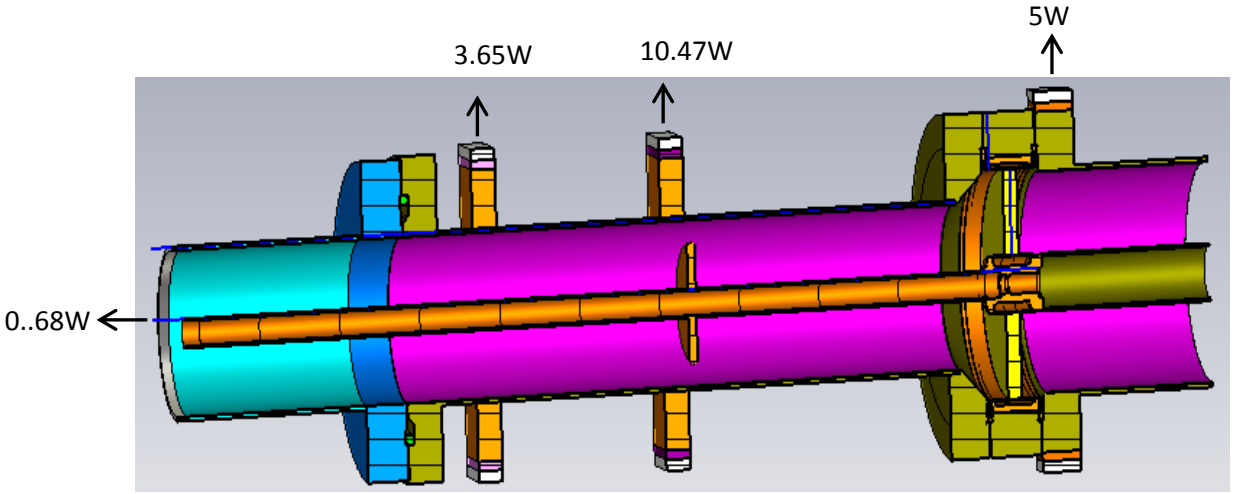
Configuration of vacuum part of coupler for thermal simulations



Air flow has been taken as 5 gps

Heat load for worst case full reflection





Heat loads for different phases of reflection

- Maximum temperature and heat flow values for different phases are given in table 2.
- Max temperature for worst phase full reflection is T= 341 K. Maximum heat flow towards cavity is 0.68 W.
- Maximum temperature at ceramic disc is about 317k .

Table 2

Power and reflection	2K, W	5K, W	50K, W	293 K, W	Tmax K
50 kW, full reflection, 0, 270 degree	0.68	3.65	10.47	5.06	341
50 kW, full reflection 90 degree	0.24	2.45	12.56	6.66	335
50 kW, full reflection 180 degree	0.2	2	12	8.2	345

Summary and acknowledgement

- Full design of MEHIPA1 couplers is under progress.
- RF simulations of full coupler has been done and results are satisfactory .
- Thermal simulations of the cold part has been done. Temperature profiles and heat load have been analysed for full reflection cases.
- Thermal simulations of the warm part is under progress.
- We would like to thank MR Nikolay Solyak and Mr Sergey Kazakov of Fermilab for their support and useful discussions.

Design of 150 kW, 650 MHz RF couplers

- The design will be based on the 650 coupler design of Fermilab.
- The input side will be waveguide WR1150
- The power requirement is high. We need to make changes so as to reduce the cryogenic heat load and also to reduce the maximum temperature at the ceramic window.
- Suggestions on the design changes to achieve the above goals are welcome.


Thank
You