

Canada's national laboratory for particle and nuclear physics and accelerator-based science

DESIGN AND FABRICATION OF BALLOON SINGLE SPOKE RESONATOR

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- Balloon Concept
- RISP SSR1 Cavity
- Cavity Fabrication
- Frequency Control (RF Stack-up)
- Summary





BALLOON VARIANT





MULTIPACTING IN SPOKE CAVITIES



325MHz beta=0.22 SSR1 L. Ristori, TTC2016







MULTIPACTING IN SPOKE CAVITIES





325MHz beta=0.22 SSR1 L. Ristori, TTC2016



Pillbox









MULTIPACTING IN SPOKE CAVITIES





Spoke Cavity

























Z.YAO, Balloon Single Spoke Resonator, SRF2017, China



RISP SSR1 CAVITY



TRIUMF

RISP SSR1 CAVITY





• TRIUMF designed, is fabricating, processing, and testing 2 balloon variant prototype cavities of RISP SSR1.

RISP SSR1 Specifications				
Operating frequency	325 MHz			
Geometry β	γβ 0.30			
Operating temperature	2K			
Q ₀	>5X10 ⁹			
Epeak	35 MV/m			
V _{acc}	>2.5 MV			
df/dp	<10 Hz/mbar			
Frequency tuning range	±100 kHz			
Q _{ext}	8X10 ⁶			
RF bandwidth	40 Hz			
Beam aperture	50 mm			
Pressure envelop at 300K	2 bar			
Pressure envelop at 2K	5 bar			





E-Field



Design Parameters				
Frequency	325 MHz			
Geometry β	0.30			
Geometry factor	93 Ω			
R/Q	233 Ω			
E _{peak} /E _{acc}	3.84			
B_{peak}/E_{acc}	6.07 mT/(Mv/m)			
Operational Parameters				
E _{peak}	ak 35MV/m			
E _{acc}	9.11MV/m			
V _{acc}	2.52MV			
B _{peak}	55.3mT			
U	13.4J			



RF DESIGN AND MULTIPACTING





MECHANICAL DESIGN

- Comply ASME guidelines based on the knowledge of the material properties and FEA analysis
 - To reduce peak stress under external pressure load.
 - Add spoke reinforce plates and stiffener rings
 - Bulk beam tube with iris
 - Need balance with thermal feedback effect
- To minimize pressure sensitivity
 - Asymmetric ring stiffeners (attached to jacket on one side)
 - End shell geometry of helium jacket



Parameters	Beam Tube	Value	
df/dp /Uz/mbar	free	-1.6	
ul/up /nz/mbai	fixed	+1.5	
LFD /Hz/(MV/m) ²	free	-8.7	
	fixed	-1.4	
Tuning consitivity		467 kHz/mm	
		32.7 kHz/kN	



ENGINEERING DESIGN



Shell subcomponent Spoke subcomponent



CAVITY FABRICATION





SPOKE FORMING

- Forming die was developed at TRIUMF.
- Deep drawing was tested in copper before moving to Nb.
 - Die shape was good. No modification is required.
 - Blank sheet was optimized.
- Niobium half spokes were then punched and machined.





HALF SPOKE INSPECTION



- Dimensions are on size.
- No significant material thinning.





After polishing



Salted water soak







SHELL SPINNING

- Nb hemisphere was spun as a trial.
- 2-steps spinning for shell.
 - Spun nose cone
 - Spun outer shell
- Two Cu shells spun then move to Nb shells.













• Significant thinning was noticed on both Cu and Nb spun shells





• Significant thinning was noticed on both Cu and Nb spun shells





- Mechanical polishing was done at vendor
- Salted water (X2)
- Nitric acid brush (X2)
- Ultrasound
- 10um BCP both sides
- Salted water
- Ultrasound

Rust spots





Post-BCP salted water soak

July 20, 2017



OTHER PARTS

Collar forming











Nb-Cu TIG welding





RF tubes Beam tubes SS flanges



Nb-SS Brazeing Follow recipe from CERN, ATLAS and FNAL. [1] J.P. Bacher, CERN/EF/RF 87-7. [2] J.D. Fuerst, TUP11, SRF2003. [3] L. Ristori, WEPPC058, IPAC2012.



EB WELDING



Z.YAO, Balloon Single Spoke Resonator, SRF2017, China



FREQUENCY CONTROL





FREQUENCY CONTROL

Conventional

Balloon











PRE-MEASUREMENT





- Key dimensions
 - Accelerating gaps
 - 68.29±0.04mm
 - Nom. 67.5mm
 - Draft tube length
 - 54.38±0.10mm
 - Nom. 55mm

 Nose cones depth

- 74.90±0.01mm
- Nom. 75mm

FREQUENCY MEASUREMENT



	Conditions	Target Freq. /MHz	Freq. Shift /MHz
Operational	2К	325.000	-
	Pre-tune	N/A	±100kHz
Jacketed Cavity	2К	325.000	-
	R.T. and atm.	324.683	-213kHz-104kHz
	Pre 30µm etch	324.723	+40kHz
	Tuning	324.723	As needed
	Weld Jacket	N/A	±160kHz* (PAVAC)
Bare Cavity	4K/2K w/ support	325.293	+466kHz+104kHz
	R.T. and atm.	324.723	-
	Tuning	324.723	As needed
	Pre 150µm etch	324.921	+198kHz
	Tuning	324.921	As needed
Weld	Final weld	-	-
	Collar weld	-	±72kHz/mm*
	RF Tubes weld		_
	Equator weld shrinkage	324.974	+88x0.6*=+53kHz

Target frequency 324.974MHz±100kHz

1st stack-up 325.041MHz

@ S_{21} -75dB and $Q_L(Q_0)$ 3000.



- Balloon variant was proposed to mitigate multipacting around operational field level.
- Cavity geometry was optimized to high R/Q and G, and high V_{acc} @ 35MV/m E_{peak} with reasonable B_{peak}.
- Mechanical design complies ASME guidelines and minimizes pressure sensitivity for CW operation.
- Fabrication techniques on this prototype cavity were developed at TRIUMF, that extends TRIUMF's capability on cavity production.
- RSIP SSR1 cavities are under fabrication and currently in welding stage for #1 and RF stack-up stage for #2.
- Final EB welding soon, cavity processing and cold tests in August 2017.





- RISP
- Chris Compton, John Popielarski (FRIB)
- Waldemar Singer (DESY)
- Ralf Edinger
- TRIUMF machine shop, Vector Aerospace, AMS Industries ltd., ROARK





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Thank you! Merci!

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