EM design for RAON SCL2 cavities

Hoechun Jung/ March 2nd, 2023

EM Performances

(CST code, Hexagonal, 3 symmetric planes, 4M meshes)

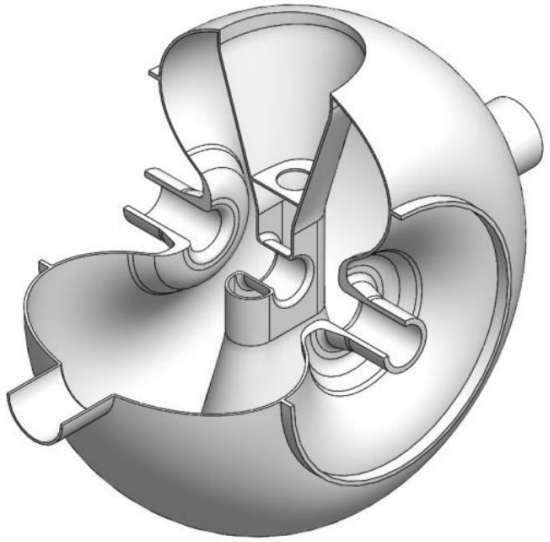
	QWR	HWR	SSR1	SSR2
Optimum β	0.047	0.12	0.3	0.51
$f\ [MHz]$	81.25	162.5	325	325
$L_{eff}(=\beta_o\lambda)[mm]$	173.5	221.5	276.9	470.8
$R/Q\ [\Omega]$	469	295	233	290
E_{peak}/E_{acc}	**5.7**	**5.2**	**4.1**	**3.7**
$B_{peak}/E_{acc}\ [mT/(MV/m)]$	**10.4**	**9.0**	**6.9**	**7.7**
Epeak	**34.8**	**34.3**	**34.9**	**32.2**
Bpeak	**63.4**	**59.4**	**58.7**	**67.0**
$E_{acc}\ [MV/m]$	6.1	6.6	8.5	8.7
$V_{acc}\ [MV]$	1.06	1.46	2.35	4.1
$Stored\ Energy\ [J]$	4.7	7.1	11.6	28.3
QRs	18.1	36.8	92.2	112.9

Limitation : Peak E-field < 35MV/m
Peak B-Field < 70mT

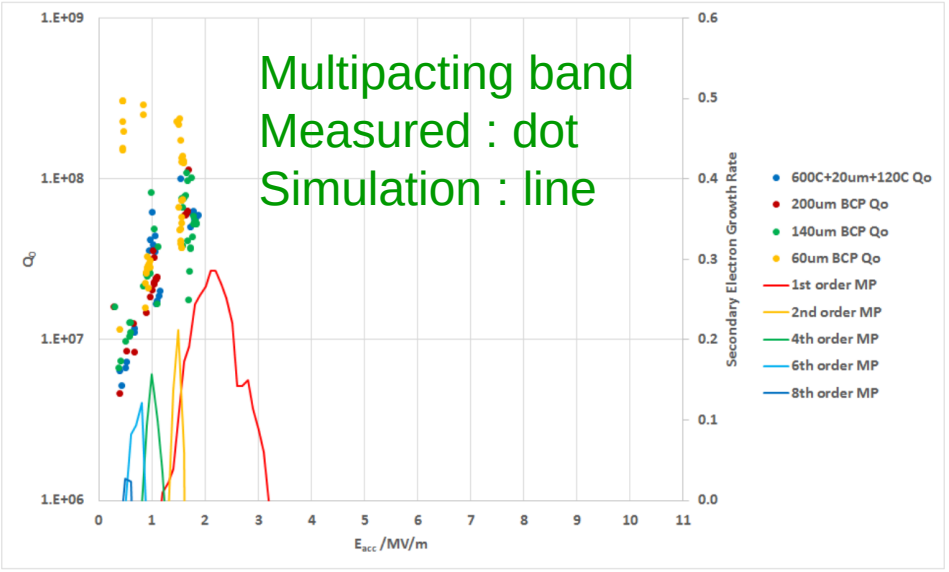
0.3 Beta Cavities

SSR1 Development with TRIUMF (Balloon Concept)

Design suggestion (2015. 07)

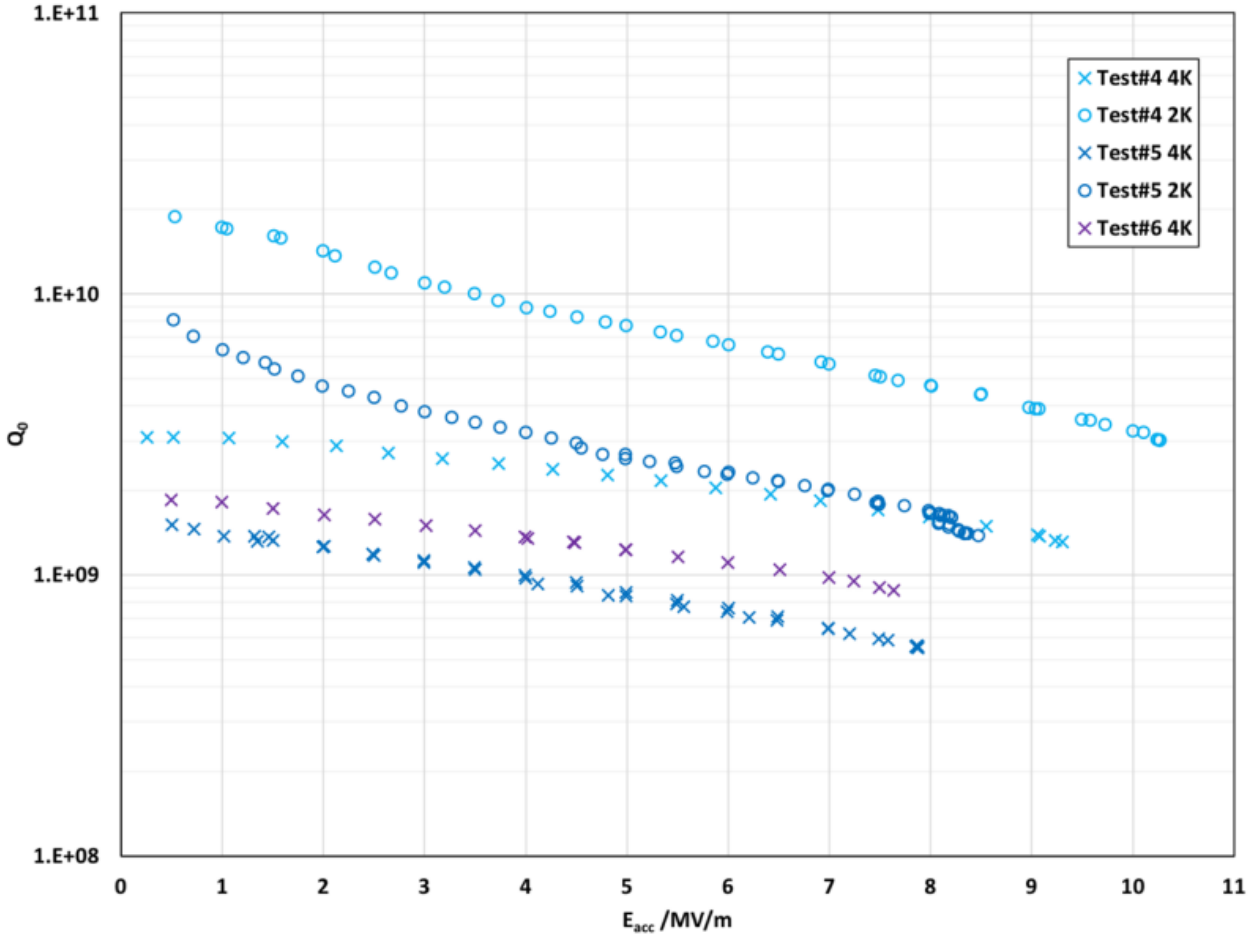


Test @ TRIUMF (Bare: 2018. 01, Jacketed: 2019.07)



- Cost effective design:
  Just 4 ports, minimized # of stiffeners,
  less fabrication process (forming, welding)
- Narrower multipacting band: < 4MV/m (Measured < 2MV/m)

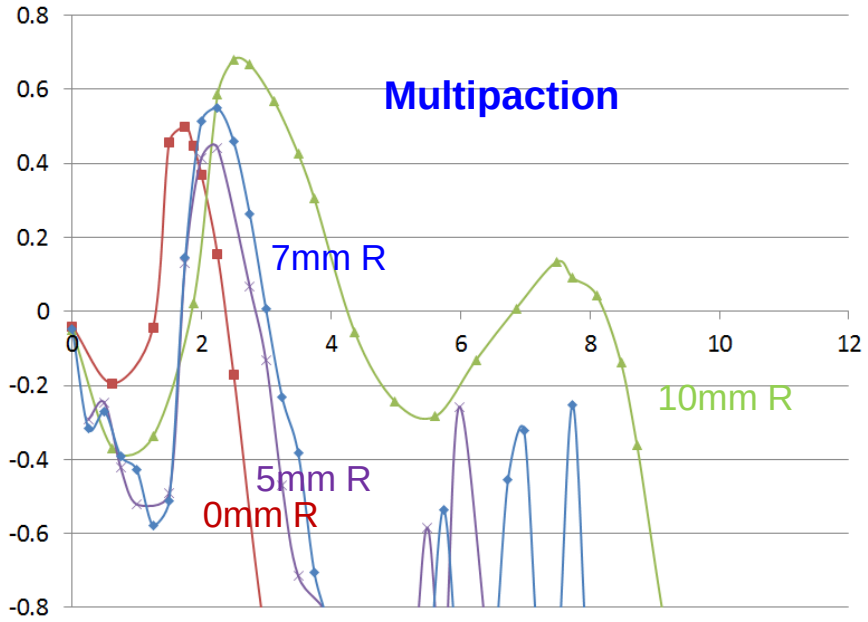
SSR1 Development with TRIUMF (Balloon Concept)



- Thermal quench? contaminants or poor etching
  → suggest use rounding between spoke and shell(by reviewer, 2018.02)

RF Shape modification for SSR1

2018. 03.

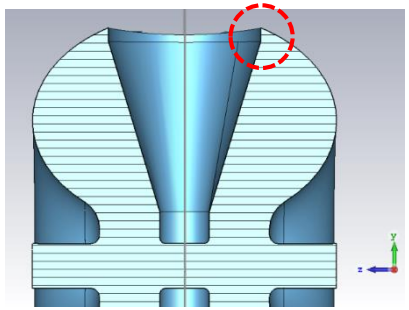


EM Properties

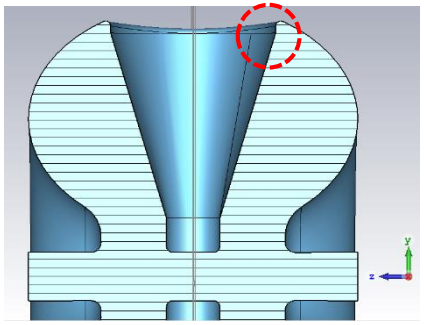
	TRIUMF Original	5mm R	7mm R	10mm R
$R/Q\ [\Omega]$	**235**	**234**	**232**	**232**
E_{peak}/E_{acc}	**4.12**	**4.12**	**4.12**	**4.11**
B_{peak}/E_{acc} $[mT/(MV/m)]$	**6.93**	**6.93**	**6.78**	**6.78**
$E_{peak}\ [MV/m]$	**35**	**35**	**35**	**35**
$E_{acc}\ [MV/m]$	**8.5**	**8.5**	**8.5**	**8.5**
$V_{acc}\ [MV]$	**2.35**	**2.35**	**2.35**	**2.35**

RF Shape modification for better surface treatments
→ <7mm Rounding w/o multipacting enhancement

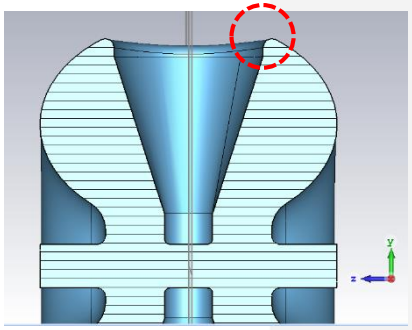
Original (0 mm Rounding)



5mm Rounding



10mm Rounding



Frequency Tracking for SSR1

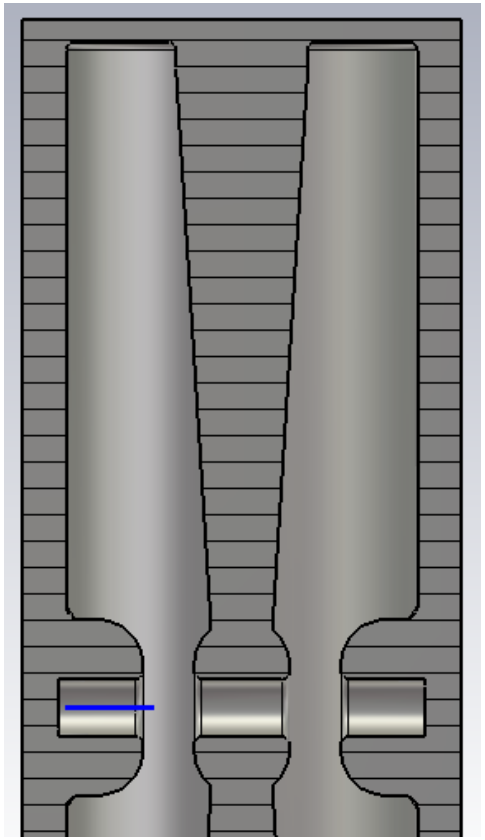
2019. 09.

Process	Estimated Frequency (MHz)
Operating	325
Jacketed cavity(2K), Tuner positioning	325.1
Bare cavity(2K), Jacketing	325.1
Evacuation &Cool down(300K → 2K) with STS tuner/Jig	324.818
BCP (150um)	324.803
Welding shrinkage	324.857
W/O 5mm round clamp-up	324.663

HWR Modification with Balloon Concept

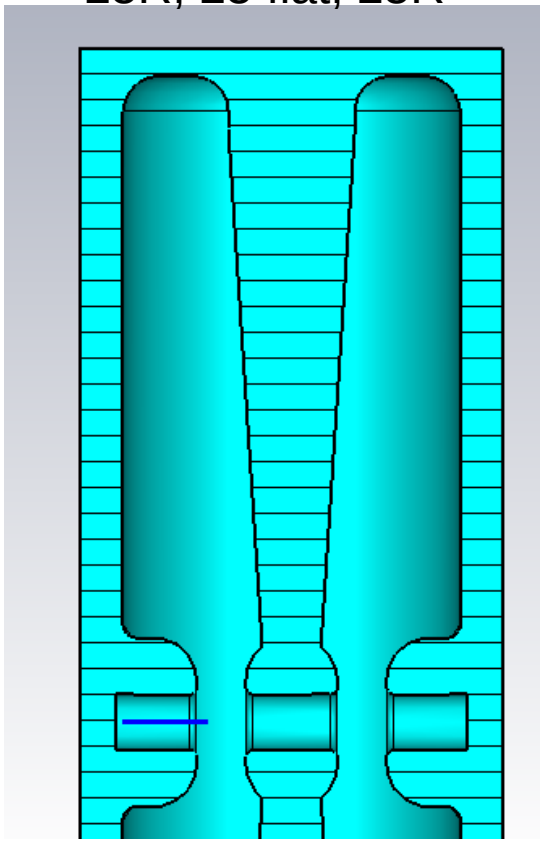
2015. 10.

5R, 65 flat, 5R



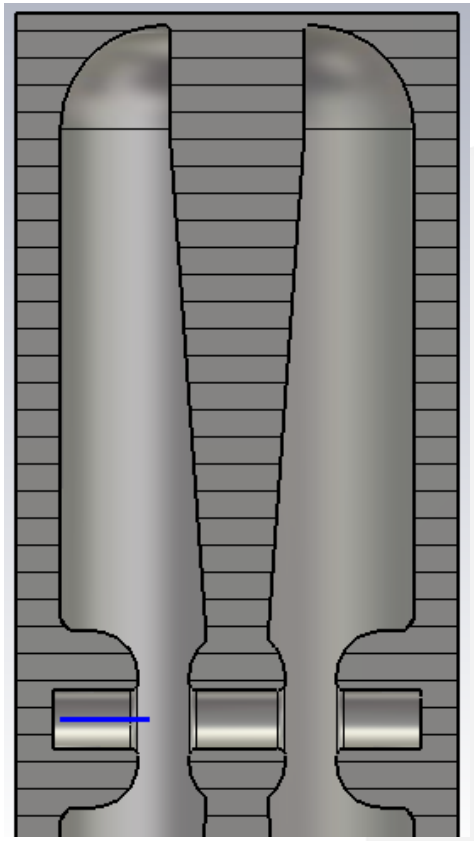
Flat top

25R, 25 flat, 25R



1st HWR

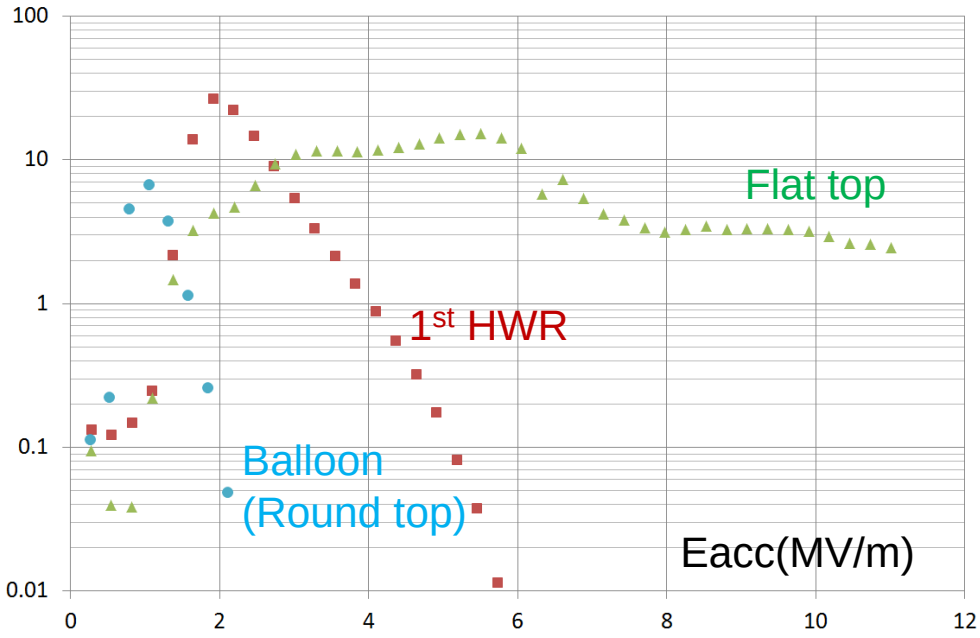
70R, 5R



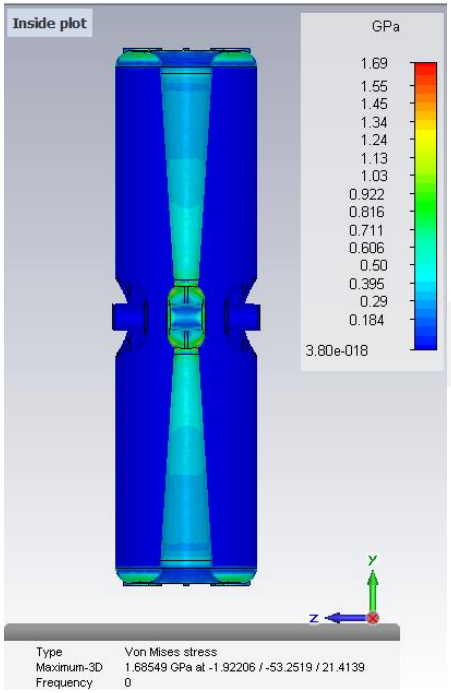
Balloon(Round top)

Merits of Balloon Concept HWR

MP Factor

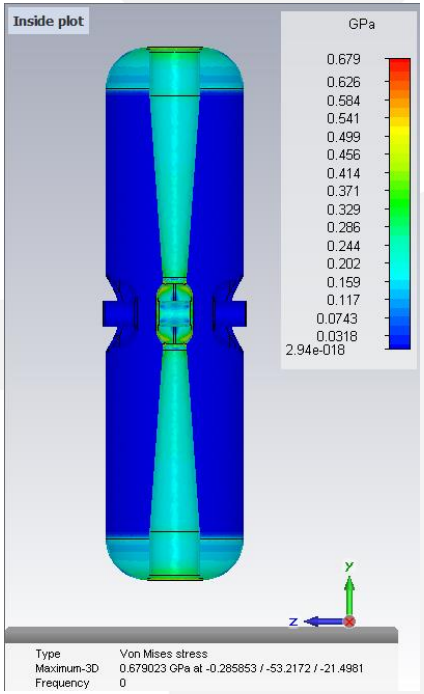


1st HWR



1.69GPa/100Bar

Balloon HWR



0.679GPa/100Bar

- Narrower multipacting band
- Higher stiffness(lower mechanical stress)

Mass Production with Balloon shape

1st HWR Balloon(Round top) HWR

- 106 Balloon HWRs are fabricated
- 106 Balloon HWRs have passed the qualification (100% yield rate)
- More than 90% test success rate
  (51 success at 56 times tests with proper test couplers)

Plan B for 0.3beta Cavity

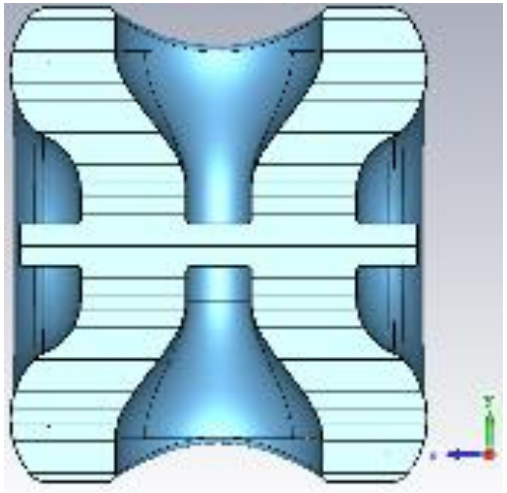
Parameter	Unit	SSR1	PAL HWR	KOMAC HWR
Frequency	MHz	325	325	325
Optimum beta	-	0.3	0.3	0.3
L_{eff}	m	0.277	0.277	0.277
V_{acc} ($@\beta_{opt}$)	MV	2.4	1.94	2.1
E_{acc} ($@\beta_{opt}$)	MV/m	8.66	7.02	7.5
E_{pk}	MV/m	35	35	35
B_{pk}	mT	58	60.8	68.8
E_{pk}/E_{acc}	-	4.04	4.98	4.64
B_{pk}/E_{acc}	mT/(MV/m)	6.70	8.65	9.12
R/Q ($@\beta_{opt}$)	ohm	230	238.3	205
Q_0 ($@R_s$ = 20 nΩ)	-	-	-	4.0E9
Beam aperture	mm	50	50	50
Cavity inner diameter	m	-	0.3	0.3

- Alternative HWRs couldn't match the accelerating voltage requirement

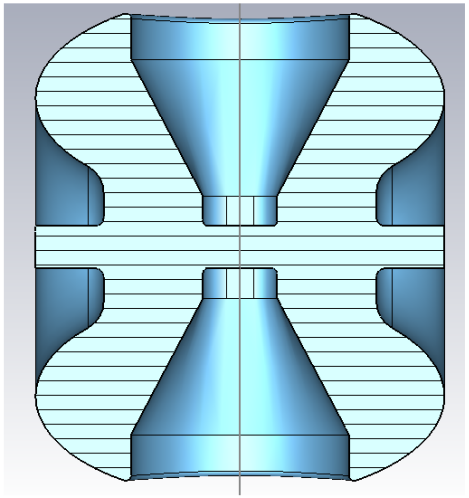
0.51 Beta Cavities

0.51 beta SSR Cavities

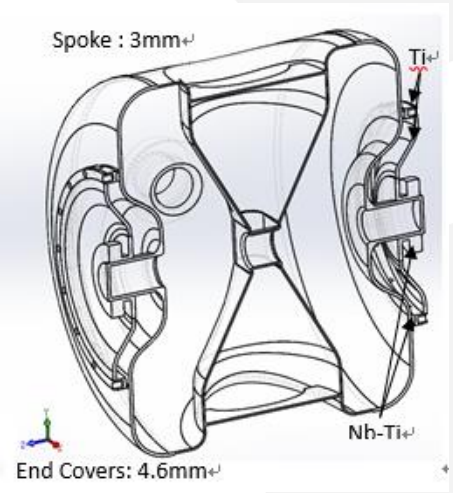
1st SSR2 (with Fermi lab)



2nd SSR2 (Balloon type)



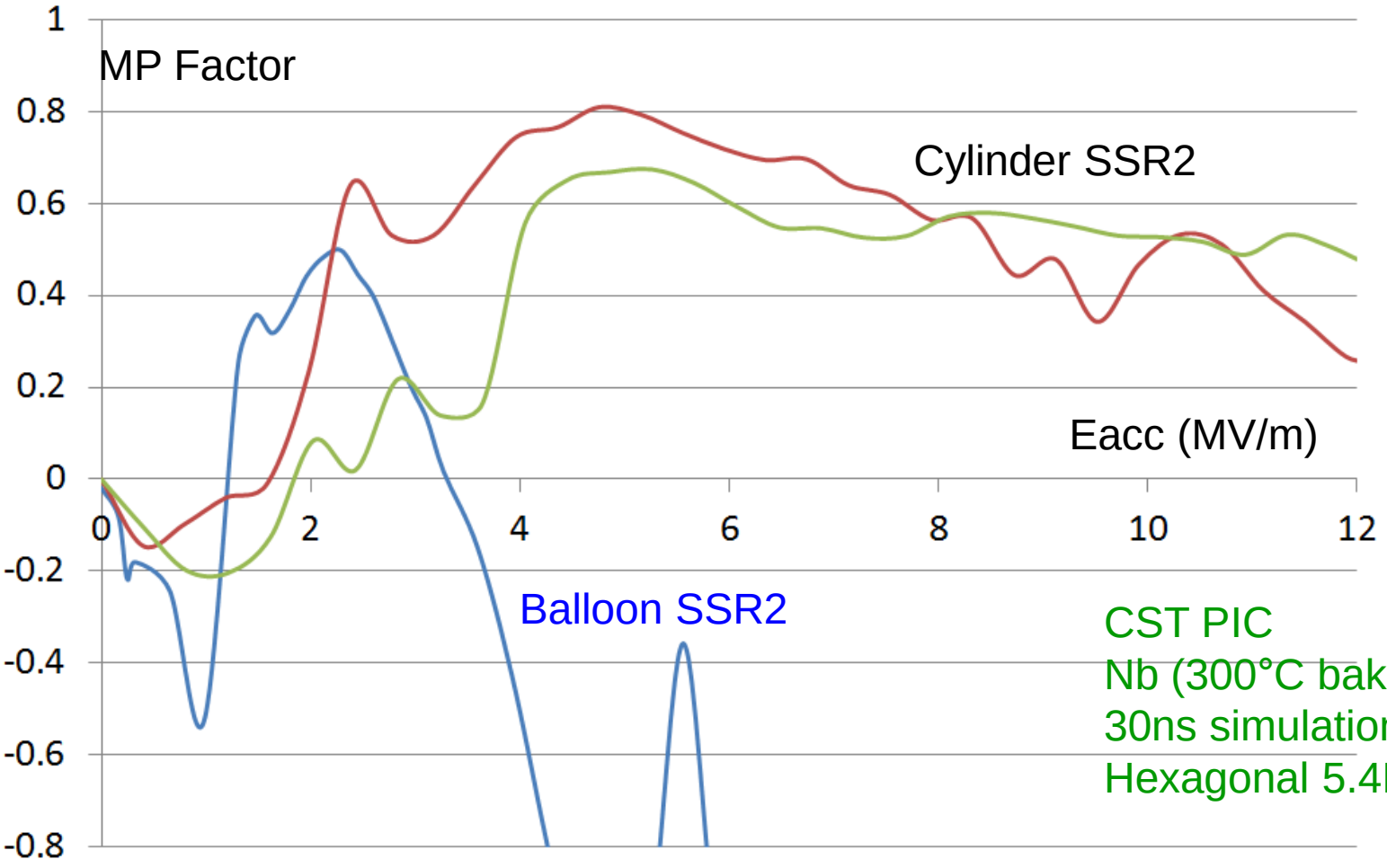
Plan B (with IHEP, China)



	1st SSR2	Balloon SSR2	IHEP SSR2
Optimum β	0.51	0.51	0.51
f $[MHz]$	325	325	325
E_{peak}/E_{acc}	4	3.7	4.1
B_{peak}/E_{acc} $[mT/(MV/m)]$	8	7.7	**9.8**
B_{peak} [mT] @ 4.1 MV	69.6	67	**83.3**

- The maximum B-field of IHEP SSR2 is higher than the limit(70mT)

MP Prediction for Balloon SSR2



CST PIC
Nb (300°C baked)
30ns simulation time
Hexagonal 5.4M meshes

- Multipacting band of Balloon SSR2 is far from the operating gradient(8.7MV/m)

Thank you!