A New Design of a Dressed Balloon Cavity With Superior Mechanical Properties

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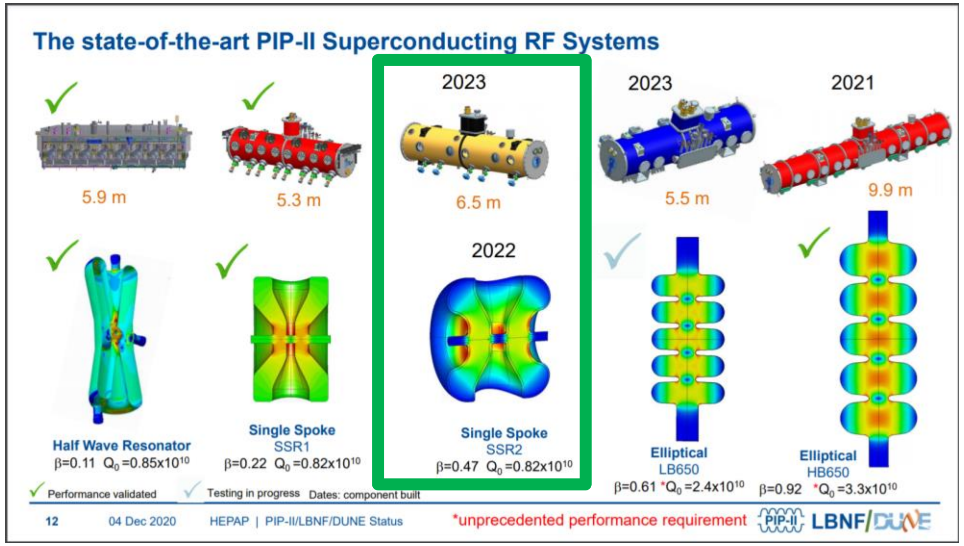
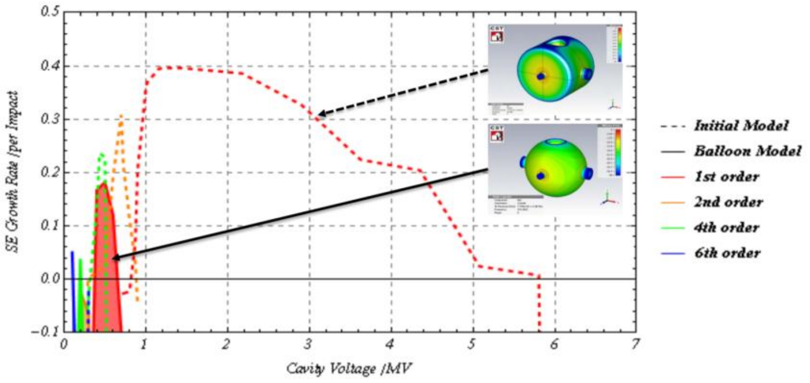
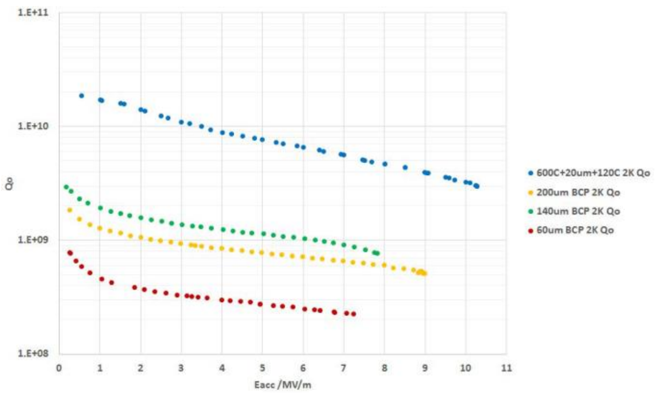
Motivation

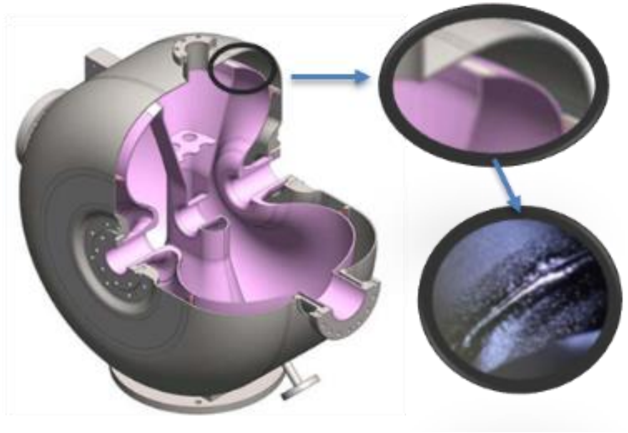
- Balloon Spoke cavity proposed almost a decade ago demonstrated superior multipactor suppression but unfortunately suffered from mid-field Q-slope.
- With this project we would like to demonstrate high Q0 performance for balloon cavity tailored down to PIP-II SSR2 needs as a reference point.
- SSR2 cavity design of PIP-II project at Fermilab is in the development stage.
- SSR2 section (35 cavities) consumes more than 25% of PIP-II cryogenic budget, having high Q0 will greatly benefit the whole linac.



Courtesy of: Chris Mossey, Fermilab Deputy Director For LBNF/DUNE
[Building for Discovery: PIP-II, LBNF, and DUNE.]



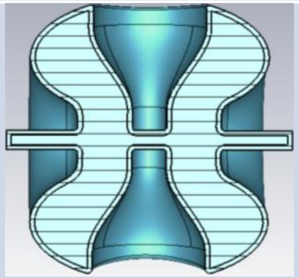
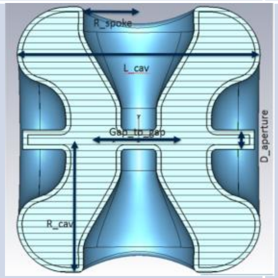
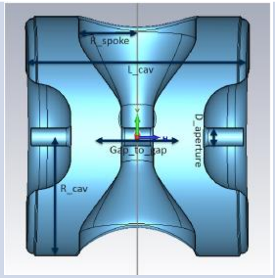




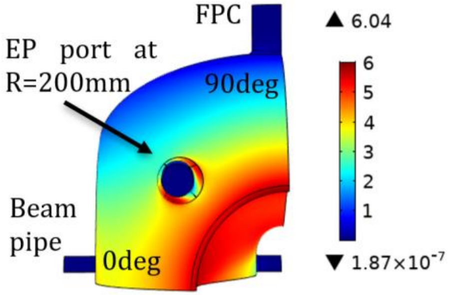
Courtesy of: Z.Yao, B.Laxdal, [Tesla Technology Collaboration meeting 2018].

Balloon cavity RF parameters compared with other cavities

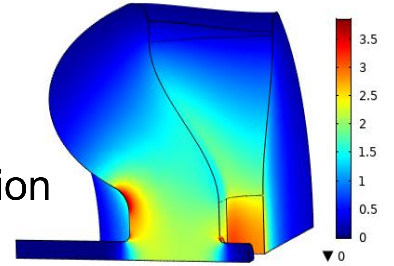
- Balloon cavity was optimized to satisfy PIP-II SSR2 requirements.
- 4 different spoke fillets were analyzed: from 5mm to 20mm.
- Electrodynamic parameters are comparable with current PIP-II design, but MP suppression is more efficient (see the next slide)
- Additional EP ports position were optimized to reduce filed enhancements
- EP port Radii R>200 has no effect on B_{pk} for 45deg configuration

Parameter	Balloon (10mm)	SSR2_V3.1 Current PIP-II	SSR2_V2.6 Previous PIP-II
Frequency [MHz]	325.02	325.0	325
Optimal beta	0.475	0.475	0.475
Effective length [m]	0.438	0.438	0.438
Epk/Eacc	**3.53**	**3.41**	**3.38**
Bpk/Eacc [mT/MV/m]	**5.92**	**6.78**	**5.93**
G [Ohm]	**115.7**	**115.18**	**115**
R/Q [Ohm]	**320.0**	**306**	**297**
Bpk at 5 MeV [mT]	68	77.6	67.7
			

Magnetic field distribution in 5mm balloon



Electric field distribution



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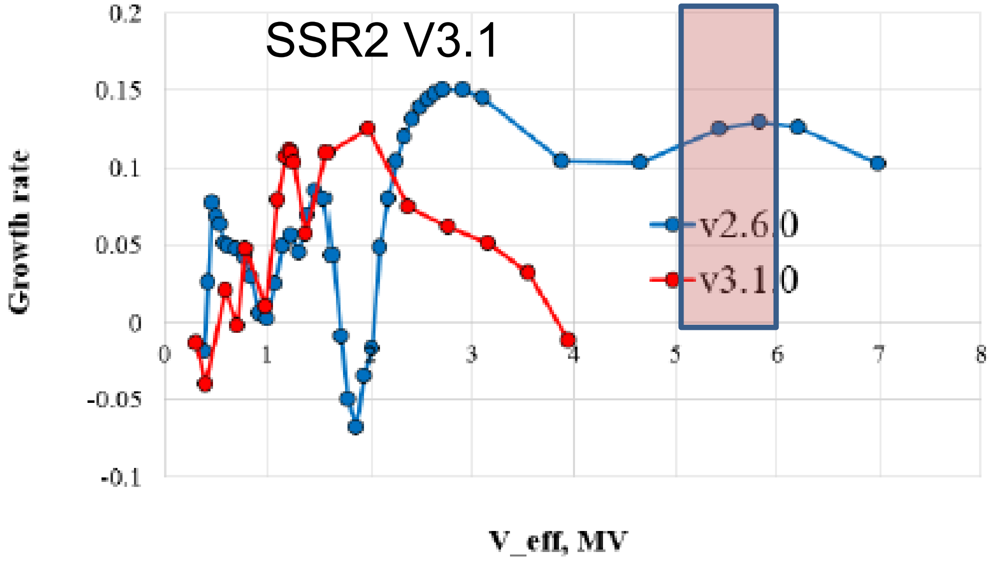
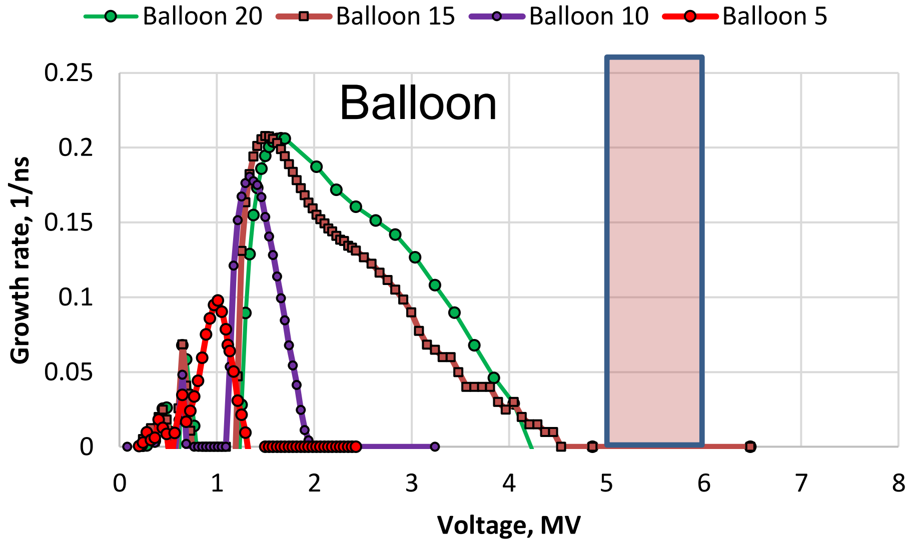
Multipactor (MP) performance

Courtesy of: P. Berrutti et al., "New Design of SSR2 Spoke Cavity for PIP II SRF Linac".

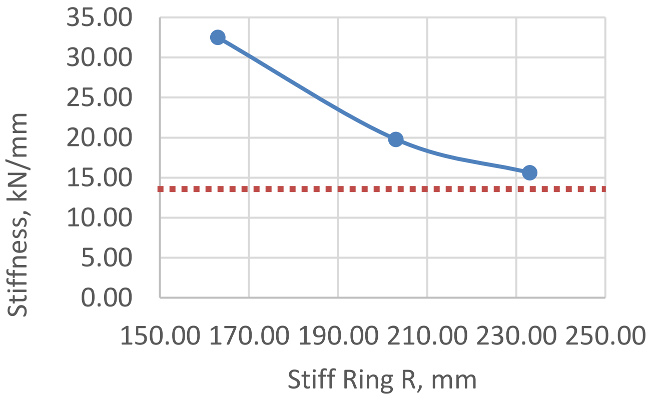
- SSR2 v2.6 has strong Multipactor at operating voltage (5MV), which was the main reason for the design change to V3.1.
- SSR2 v3.1 has pretty good MP suppression: no MP after 4MV.
- Balloon cavity MP suppression performance significantly depends on the spoke base fillet. Two main barriers are found around 1MV and at higher voltage depending on the fillet.
- 10mm spoke fillet configuration was chosen as a trade off between MP suppression and surface chemical treatment. This case provides significantly better MP suppression than SSR2 V3.1

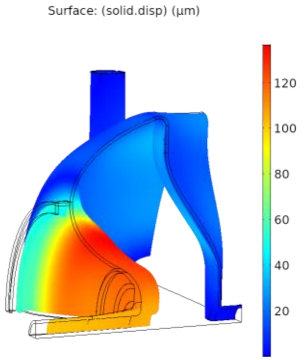




Bare cavity mechanical studies summary

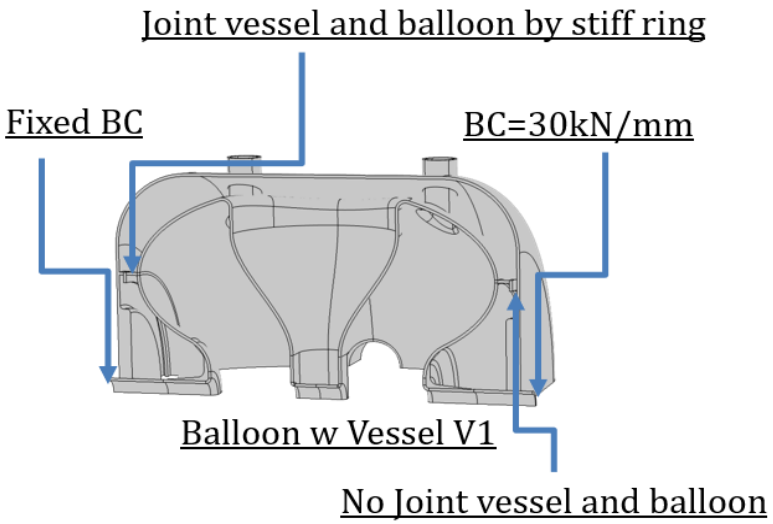
- Bare cavity satisfies almost all of the TRS.
- Cavity stiffness significantly depends on the side stiffening ring.
- To satisfy TRS, no ring should be used.
- dF/dP optimization can be carried out for the dressed cavity only.

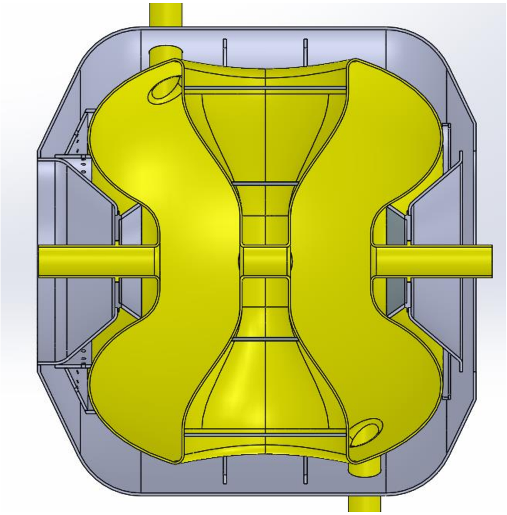


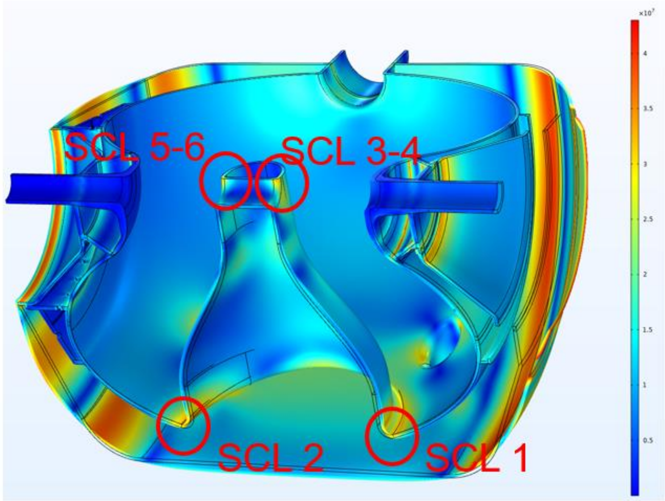


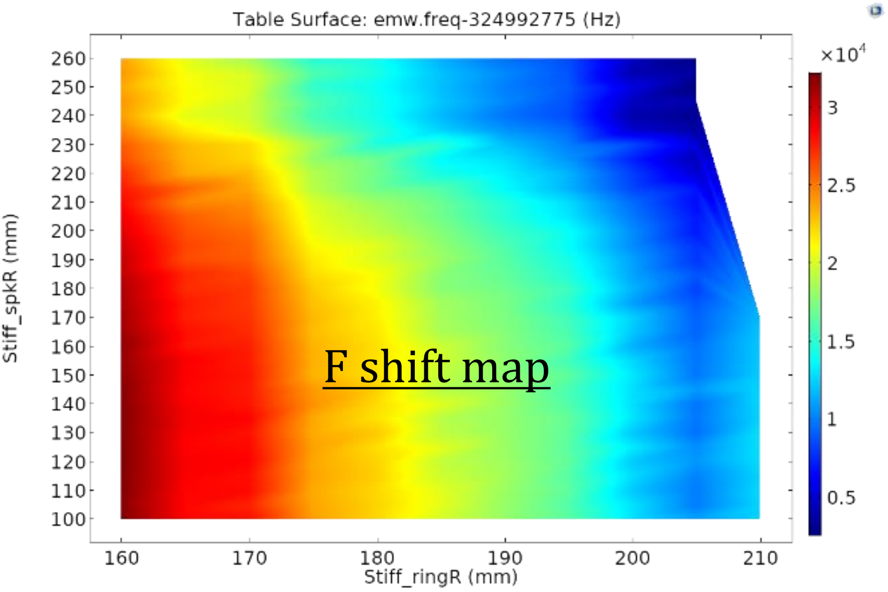
Mechanical design requirements	TRS	**Bare Balloon**
Stiffening ring R, mm	--	NA/160
Longitudinal stiffness at room temperature, kN/mm	<16	14.3/32
Operating frequency tuning sensitivity, kHz/mm	>250	538
MAWP of jacketed cavity RT/2K, bar	2/4	NA
Inelastic tuning, kHz	>500	1028
LFD	<4	?/3.2
Cool down F0 shift, kHz	NA	464
Leak check F0 shift, Pressure/Epsilon/Total, kHz	NA	+81/-62/+19
Leak check Stresses, MPa	43	30
~~Sensitivity to LHe pressure fluctuations of dressed cavity, Hz/mbar~~	~~<25~~	

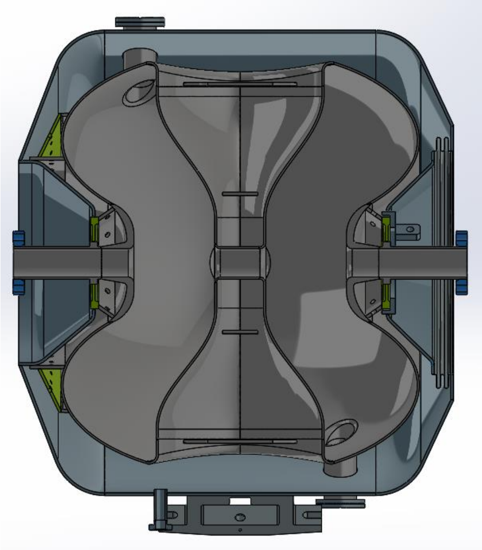
Helium Vessel design studies

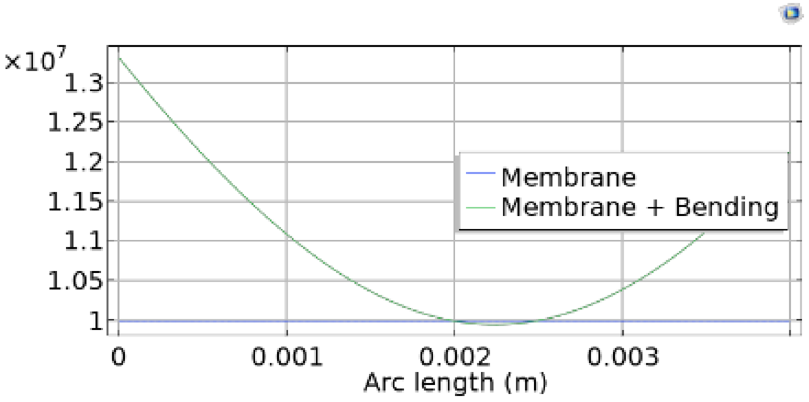






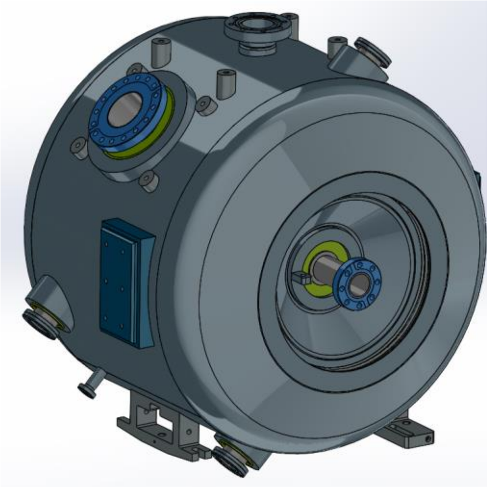


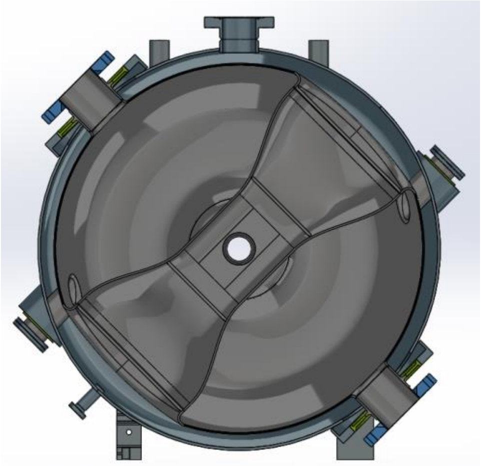


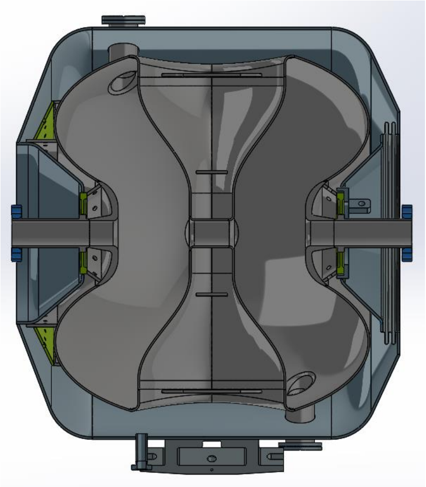


Mechanical Properties Summary

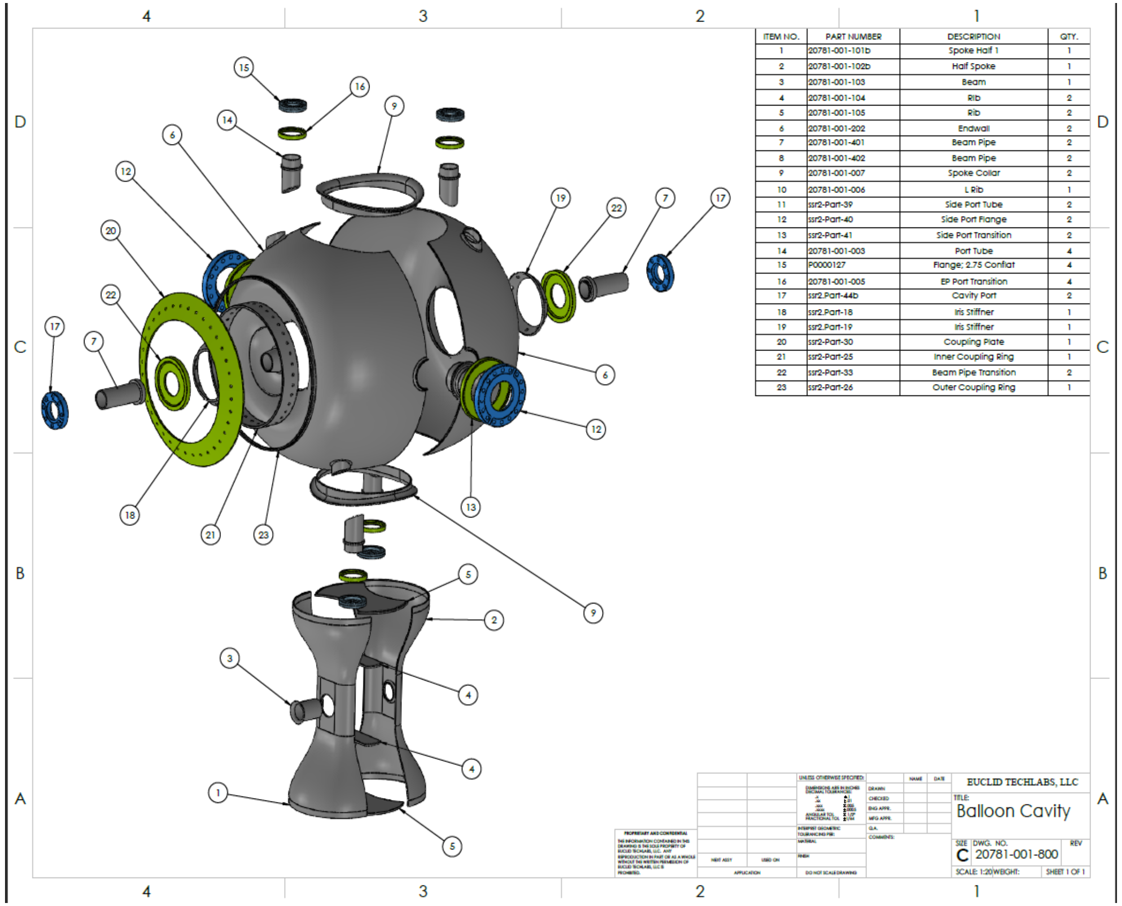
Mechanical design requirements	PIP-II SSR2 TRS	V1.0 bare	V2.1 Dressed	SSR2 V3.1
Longitudinal stiffness at room temperature, kN/mm	**<16**	14.3	16.5	14.95
Operating frequency tuning sensitivity, kHz/mm	**>250**	538	292	308
MAWP of jacketed cavity RT/2K, bar	**2/4**	NA	OK	OK
Inelastic tuning, kHz	**>500**	1028	990	--
LFD	**<4**	3.2	3.0	4.73
Sensitivity to LHe pressure fluctuations of dressed cavity, Hz/mbar	**<25**	NA	0	0



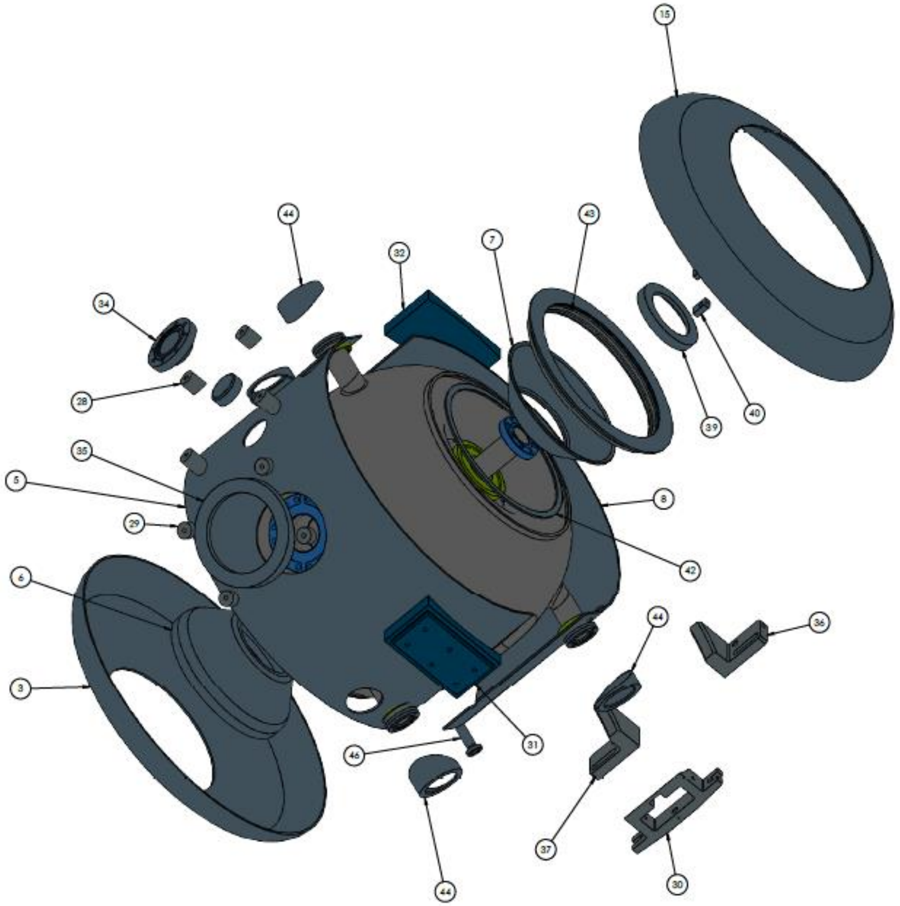


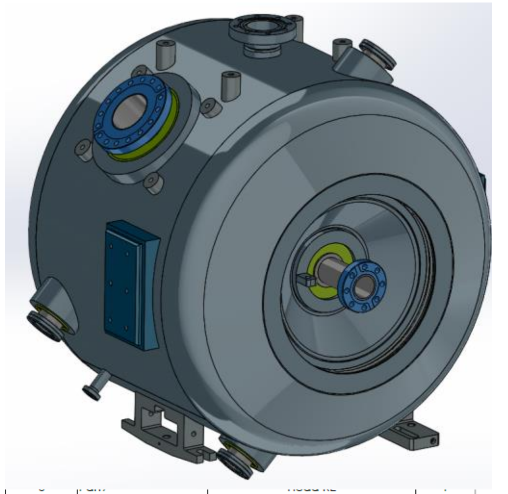


Assembly drawing of Balloon 10EP w SSR2 HV



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	20781-001-101b	Spoke Half 1	1
2	20781-001-102b	Half Spoke	1
3	20781-001-103	Beam	1
4	20781-001-104	Rib	2
5	20781-001-105	Rib	2
6	20781-001-202	Endwall	2
7	20781-001-401	Beam Pipe	2
8	20781-001-402	Beam Pipe	2
9	20781-001-007	Spoke Collar	2
10	20781-001-006	L Rib	1
11	ssr2-Part-39	Side Port Tube	2
12	ssr2-Part-40	Side Port Flange	2
13	ssr2-Part-41	Side Port Transition	2
14	20781-001-003	Port Tube	4
15	P0000127	Flange; 2.75 Conflat	4
16	20781-001-005	EP Port Transition	4
17	ssr2.Part-44b	Cavity Port	2
18	ssr2.Part-18	Iris Stiffner	1
19	ssr2.Part-19	Iris Stiffner	1
20	ssr2-Part-30	Coupling Plate	1
21	ssr2-Part-25	Inner Coupling Ring	1
22	ssr2-Part-33	Beam Pipe Transition	2
23	ssr2-Part-26	Outer Coupling Ring	1





5	Part12	Shell Bottom	1
6	ssr2-Part-11	Cone RE	1
7	ssr2-Part-10	Cone BE	1
8	Part11	Shell Top	1
9	20781-001-103	Foot Coupler Side, BE	1
15	Part8	Head BE	1
17	20781-001-003	Port Tube	4
18	P0000127	Flange; 2.75 Conflat	4
20	ssr2.Part-44b	Cavity Port	2
28	ssr2-Part-3	Lug	4
29	ssr2-Part-4	Lug	4
30	ssr2-Part-5	Foot WU/CD Side	1
31	ssr2-Part-6	Tuner Support	1
32	ssr2-Part-7	Tuner Support	1
33	ssr2-Part-8	Two-Phase Tube	1
34	ssr2-Part-9	Flange	1
35	ssr2-Part-12	Side Port Adapter	2
36	ssr2-Part-15	Foot Coupler Side, BE	1
37	ssr2-Part-18	Foot Coupler Side, RE	1
39	ssr2-Part-1	Tuning Ring	1
40	ssr2-Part-2	Tuning Pad	2
42	ssr2-Part-22	Tuning Ring	1
43	ssr2-Part-21	Cavity Bellows Sub-Assy	1
44	ssr2-Part-45	EP Port Adapter	4
45	ssr2-Part-16	WU/CD Port Flange	1
46	ssr2-Part-20	WU/CD Port	1

Thank you for your attention!