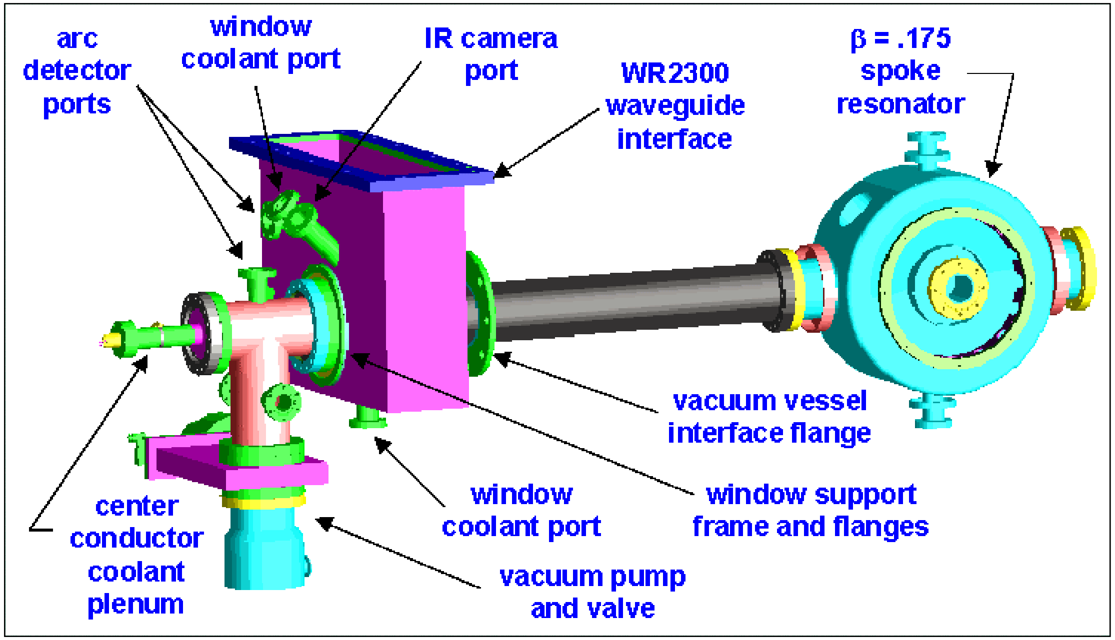
An Integrated Design for a β=0.175 Spoke Resonator and Associated Power Coupler



Frank Krawczyk, LANL
for the AAA Project
Presentation at EPAC 2002,
Paris, France on June 5, 2002

Introduction

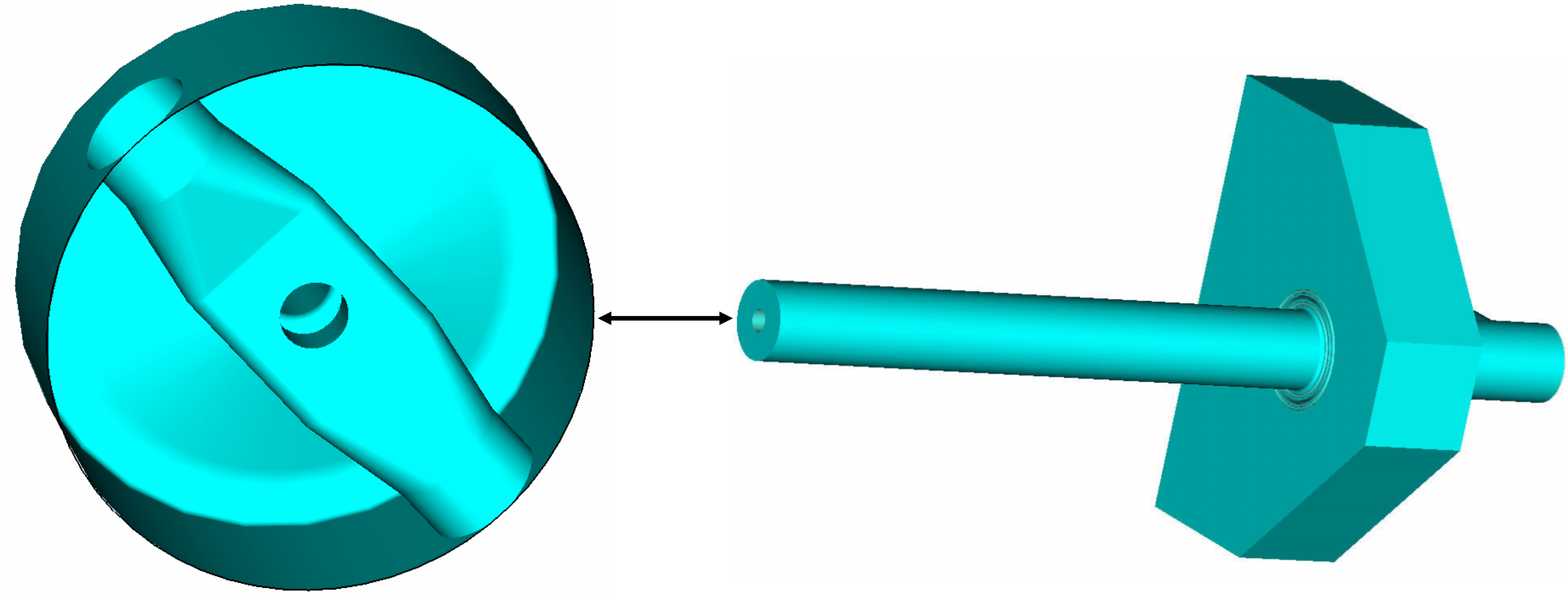
Acknowledgements: B. Rusnak, LLNL,
K. Shepard and M. Kelly, ANL,
G. Corniani, Zanon
C. Pagani's group at INFN-Milano

Structure: 2-gap spoke resonator at 350 MHz w/ power coupler (coaxial, 75 Ω)

- **Integration process**
- **Spoke cavity and coupler interface results**
- **Coupler results**
- **Other interface effects**
- **Construction and planned testing**

Design Integration: Standard Procedure

If minor perturbation occurs when cavity and coupler are interfaced, independent designs can be done.



If major perturbation occurs, e.g. significant volume change due to ports → interface must to be considered

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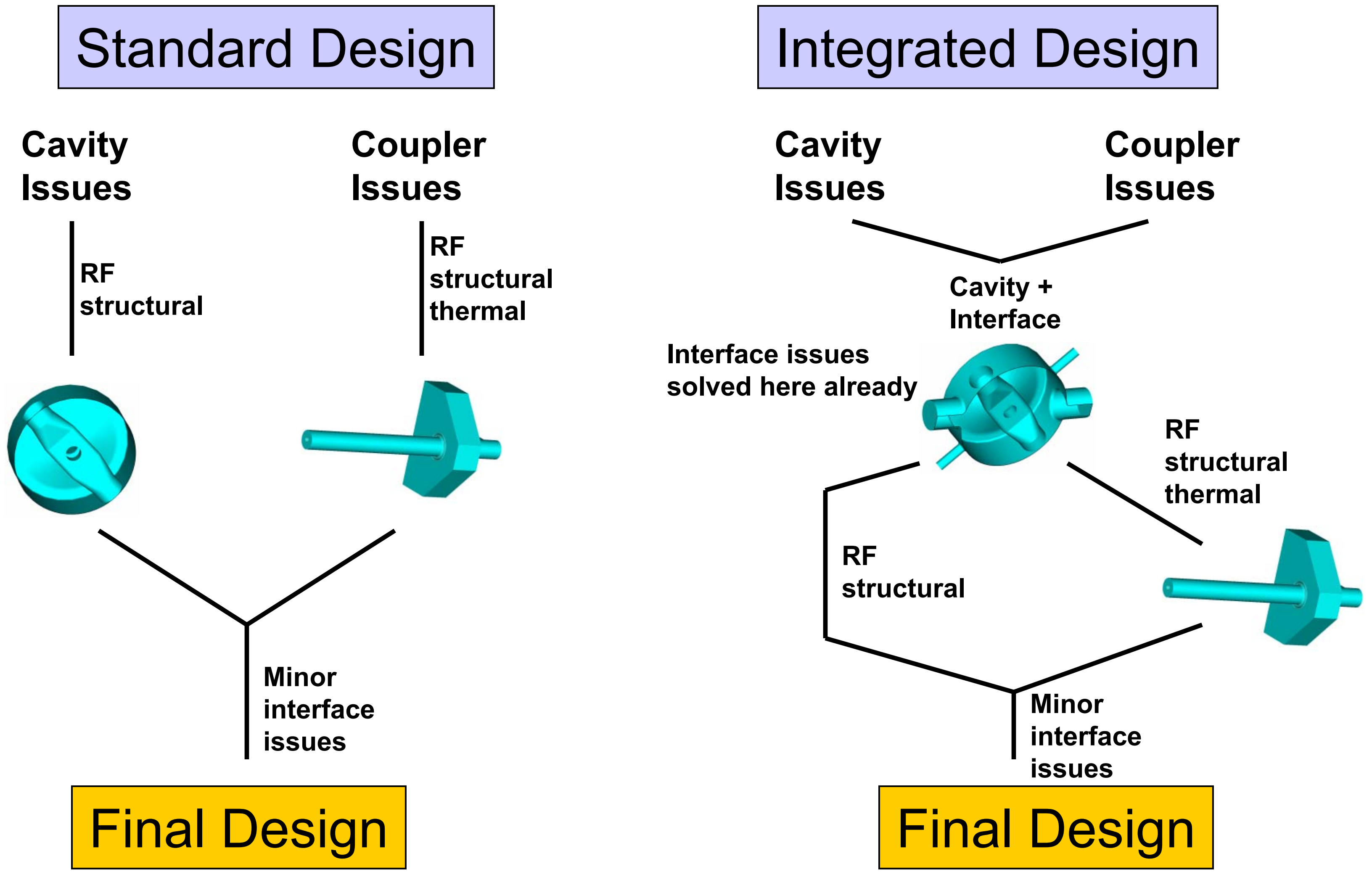
Design Integration: Overview



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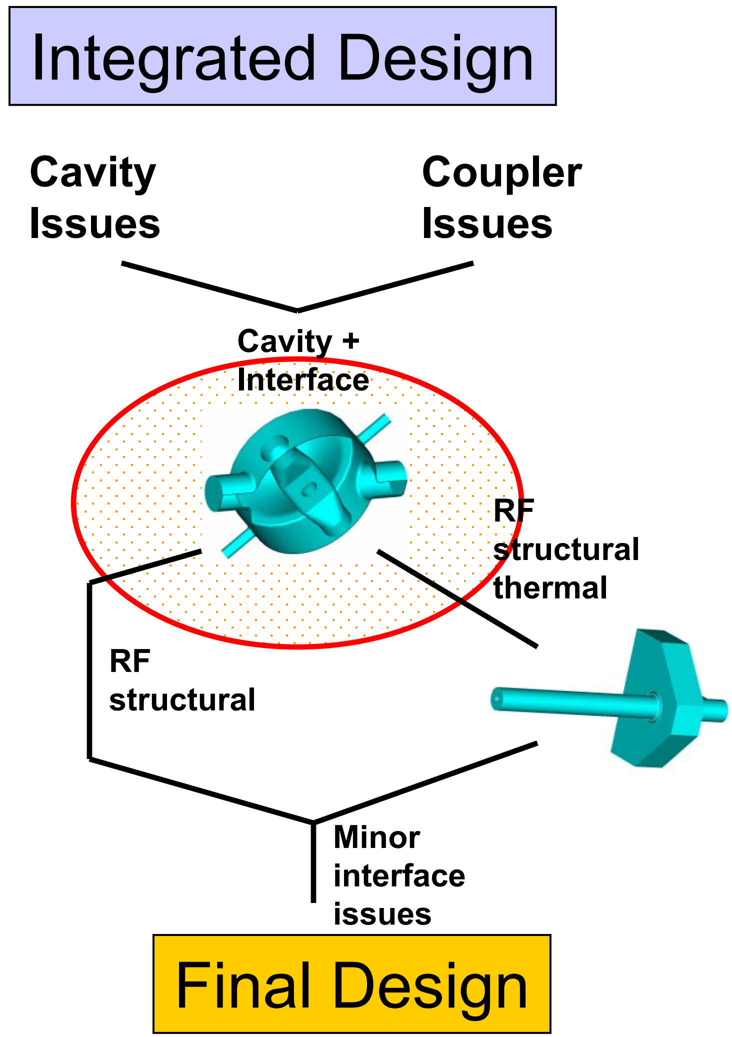
Design Integration: Where are we?



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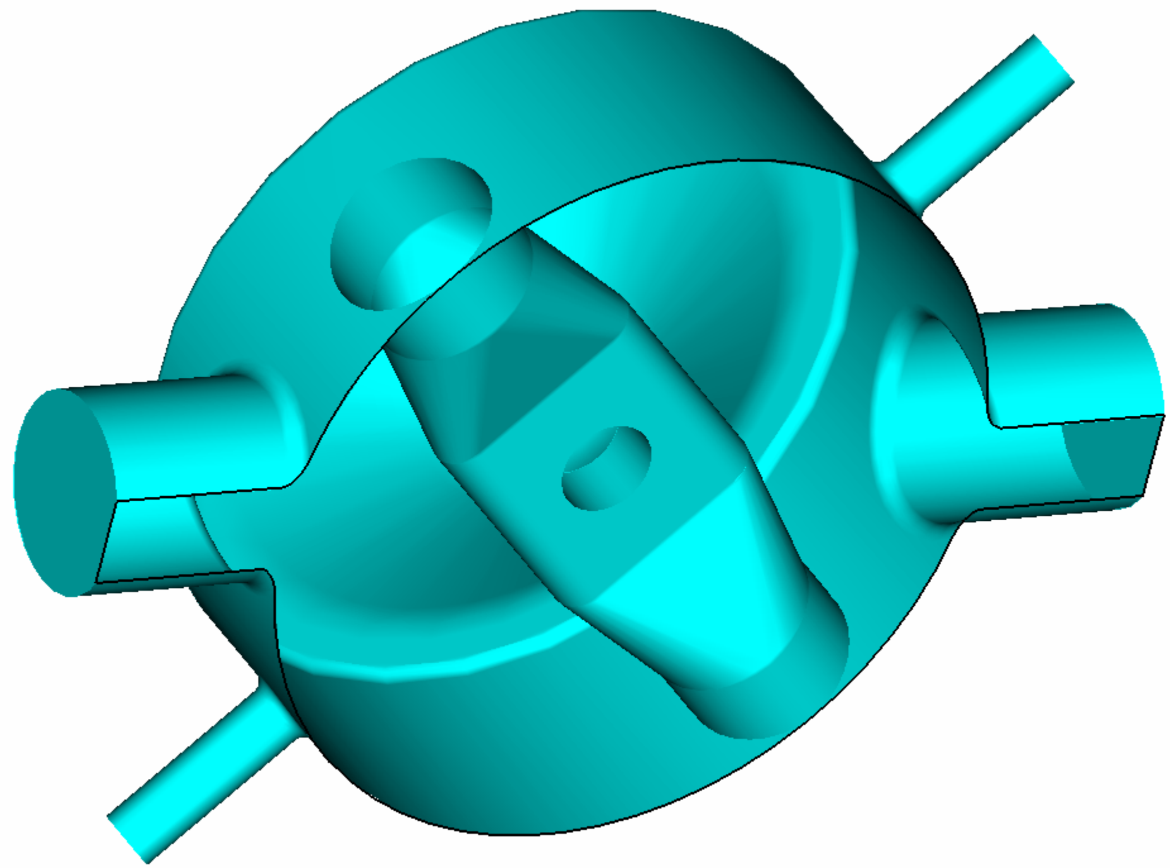
Design Integration: 1) Interface Consideration

Include ports as part of the initial cavity model.
This integrates the impact of the coupler interface into the solution already.



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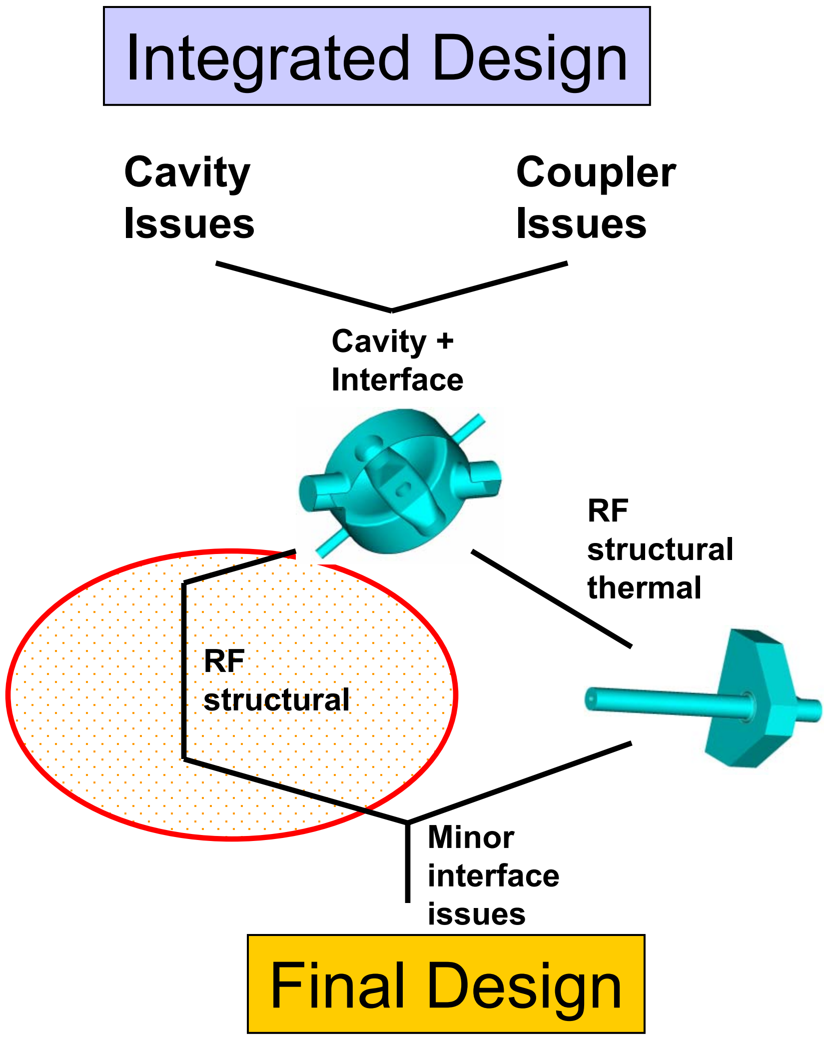
Design Integration: Where are we?



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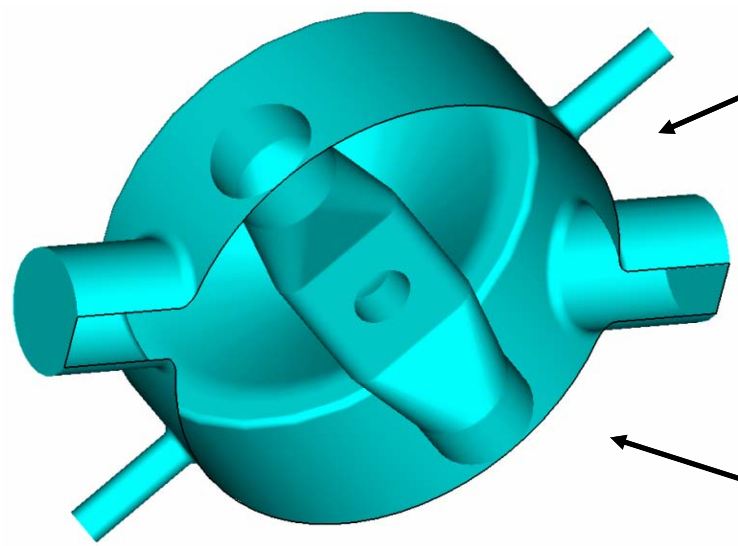
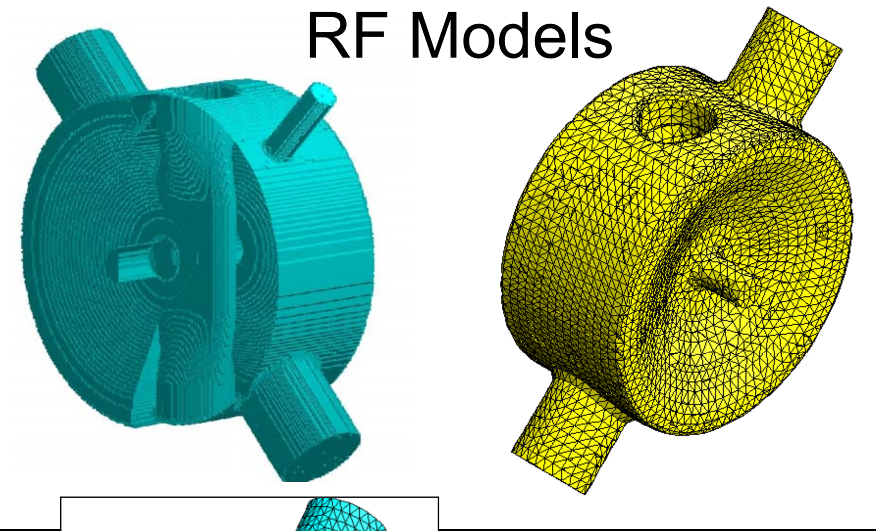
Design Integration: 2a) RF and Structural Design

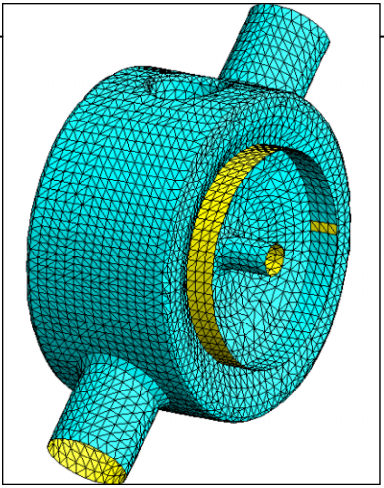
Quality Assurance

Common CAD Model



RF Models

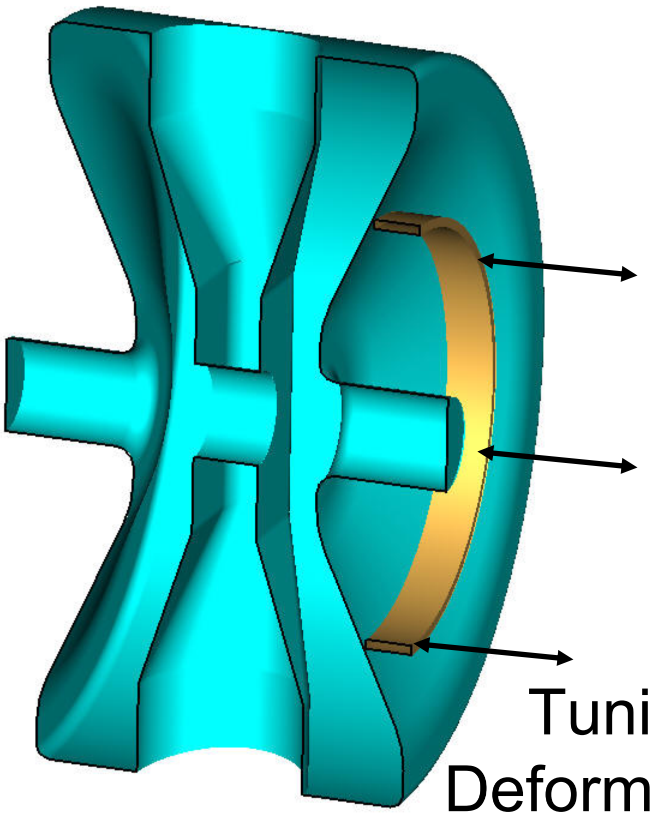




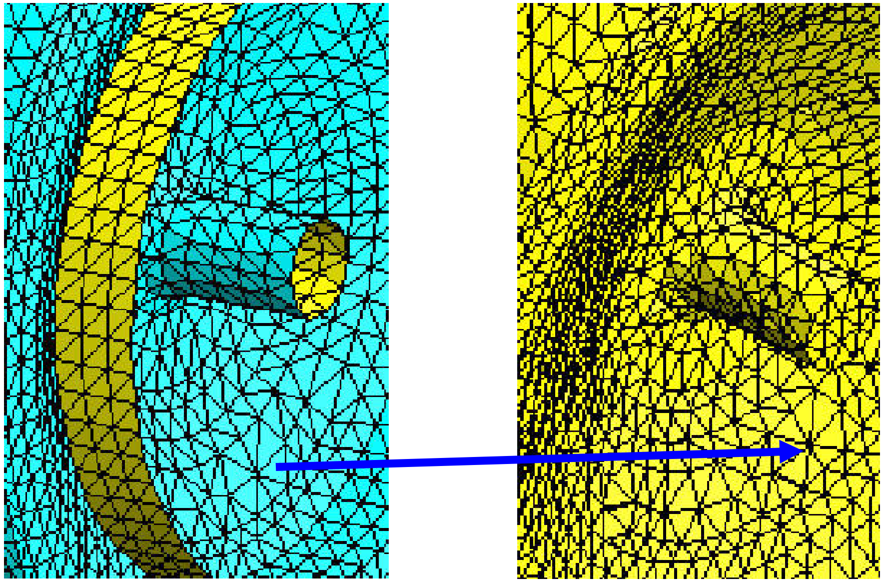
Structural Shell Model

Design Integration: 2b) RF and Structural Design

RF effects of deformations:
Tuning Sensitivity/ Forces



Tuning
Deformations



Shell Mesh ⟷ Volume Mesh

Common nodes allow recalculation
of RF-case without re-meshing
(reduces discretization error)

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Design Integration: Benchmark

Argonne National Lab (ANL) Cavity Used for Benchmark

	Measured	Cosmos/Micav	Error
f_0	339.699 MHz	338.821 MHz	-0.26%
df/dz	9.356 MHz/in	11.32 MHz/in	21%
stiffness	34.36 lb/mil	44.4 lb/mil	29%
df/force	0.272 kHz/lb	0.255 kHz/lb	-6.35%

Common nodes concept does allow calculation of volume changes.

→

A "3D-Slater" theorem calculation could be implemented. This would give a more accurate prediction of the tuning sensitivity

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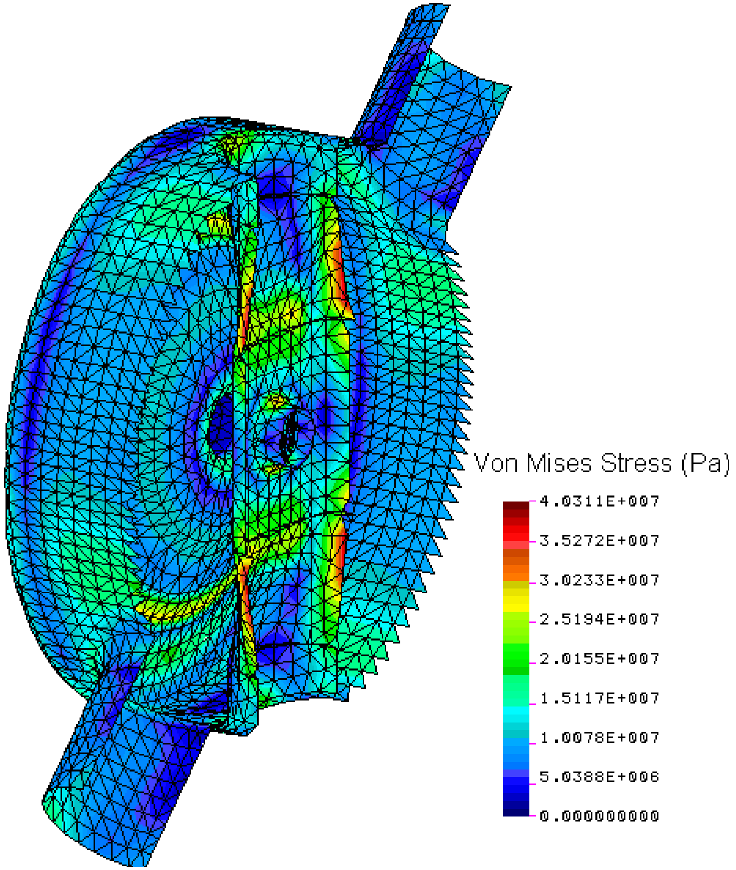
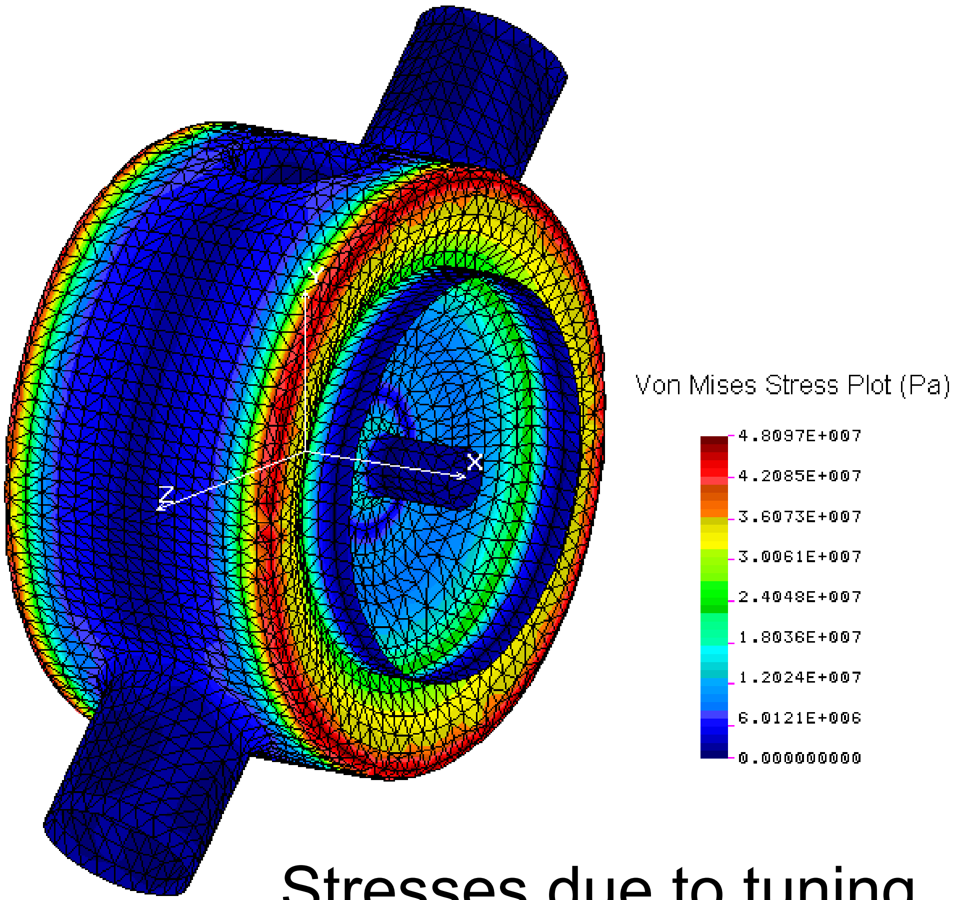
Spoke Cavity: Structural Results



Stresses due to external vacuum load



Stresses due to tuning deformation

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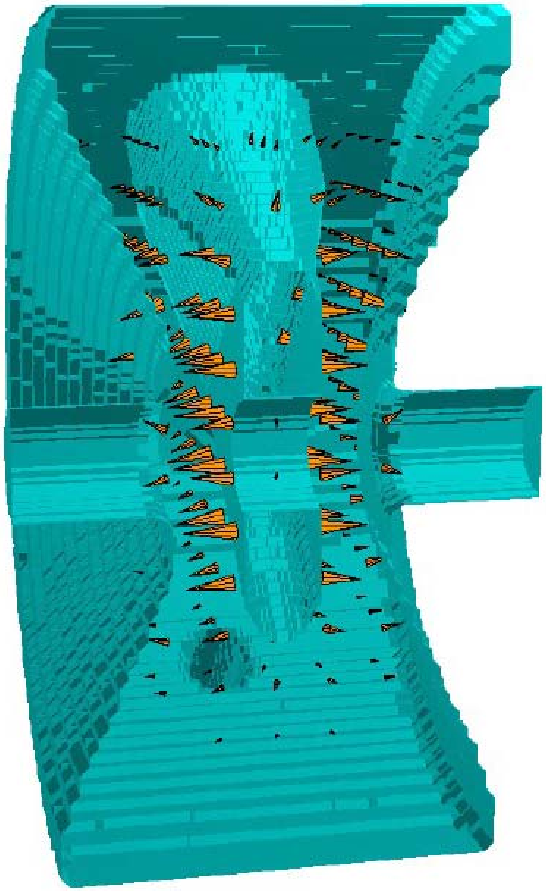
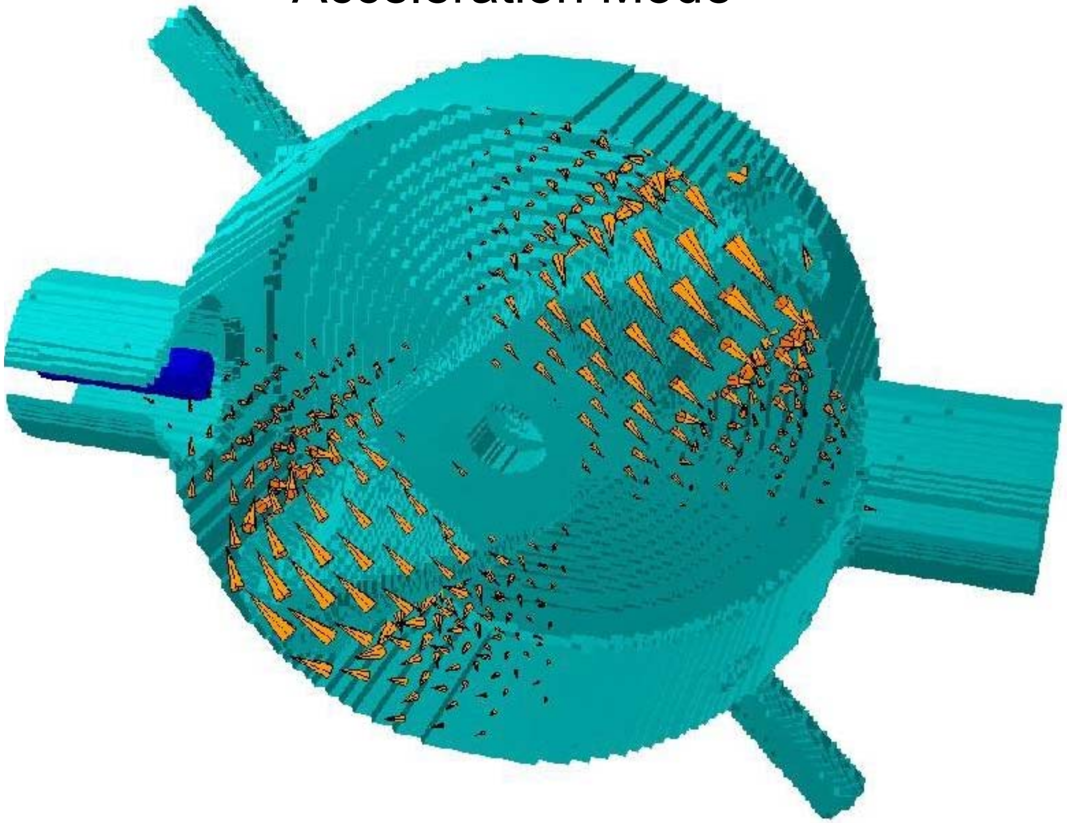
Spoke Cavity: RF Results

Electric Field of Acceleration Mode



Magnetic Field of Acceleration Mode



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Spoke Cavity: Data

RF Data

Q_0 (4 K)	1.05E+09 (for 61 nΩ)
T (β_g)	0.7765 (β_g=0.175)
T_{max}(β)	0.8063 (@ β=0.21)
G	64.1 Ω
E_{pk}/E_0T	2.82
H_{pk}/E_0T	73.8 G/MV/m
P_{cav} (4 K)	4.63 W @ 7.5 MV/m
R/Q	124 Ω

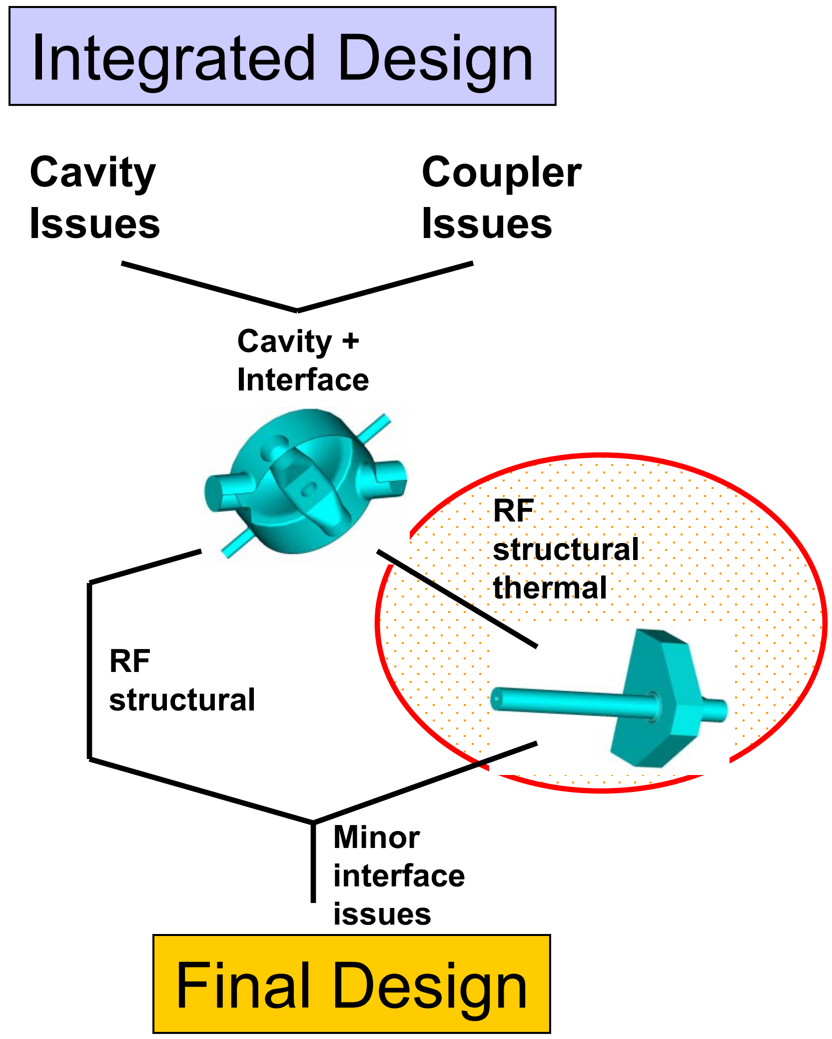
Effects of 2 atm external differential load

Ring - diameter	**Reaction-force [lbs]**	**Von Mises Stress [psi]**	**Δf [kHz]**
28 cm	3875	5172	-94.98
26 cm	3776	5177	-87.96
24 cm	3743	5181	-74.94

Tuning sensitivities

Ring Dia-meter [cm]	**Boundary Condition**	**Tuning Sensitivity**	
		kHz/lbs	kHz/mil
28	Moving	- 0.3542	-45.148
28	Fixed	- 0.3108	-25.845
26	Moving	- 0.3914	-45.404
26	Fixed	- 0.3504	-25.664
24	Moving	- 0.4012	-46.076
24	Fixed	- 0.3490	-25.370

Design Integration: Where are we?



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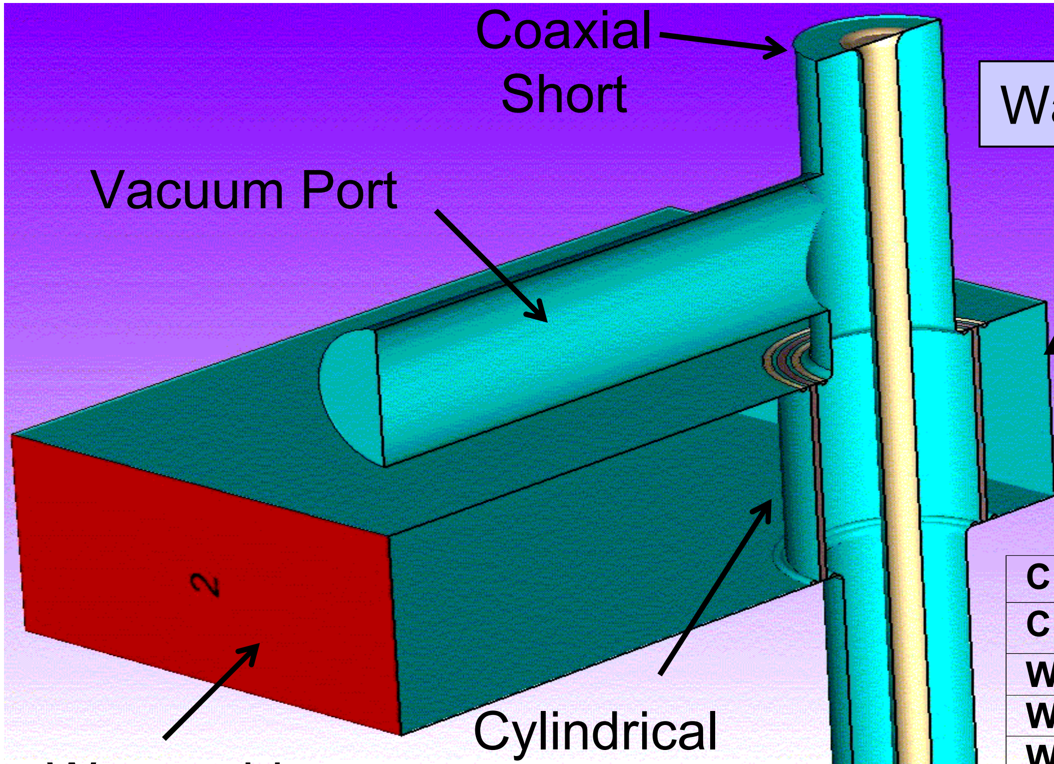
Power Coupler: Concept



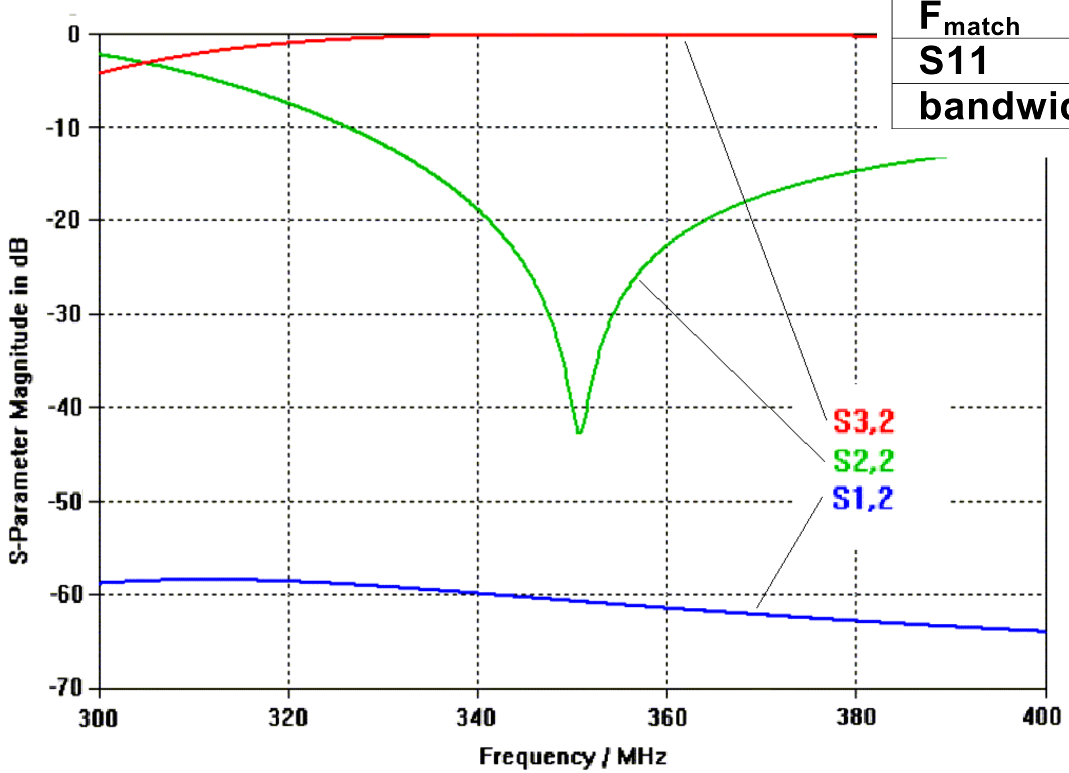
Warm part of the coupler

Coax diameter	103 mm
Coax impedance	75 Ω
Waveguide	WR3200
Window-type	cylindrical
Window-material	95% pure ($\varepsilon = 9.1$, $\tan\delta = 0.0027$)
Window OD	139.7 mm
Thickness	4.8 mm
Transition	½-height waveguide to $\lambda/4$ stub

Power Coupler: RF Results

Coax short	305.5 mm to window center
Waveguide short	130 mm to window center
Vacuum port	140 mm to waveguide top
Coax-length	1196.7 mm from short to tip
Pump flange	450 mm to coax center
Orientation	45 degrees from spoke
F_{match}	350.1 MHz
S11	-45 dB
bandwidth	± 11 (3) MHz at -20 (30) dB

S-parameters



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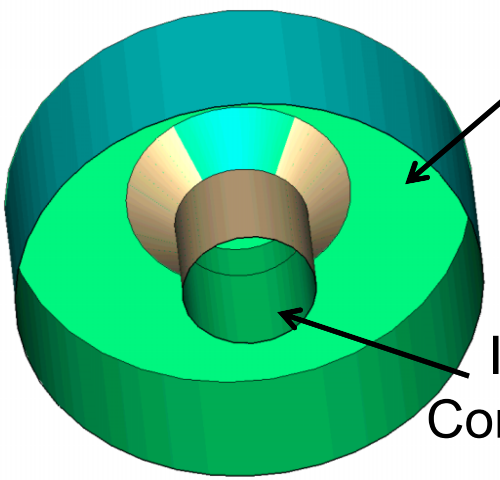
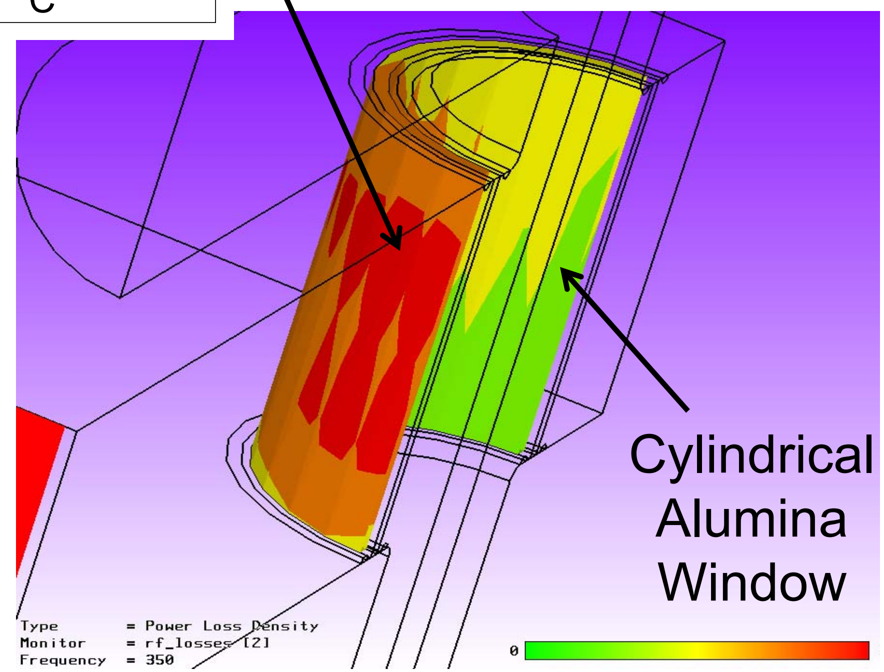
Power Coupler: Thermal/Structural Evaluation

Beam Current **Transmitted Power**	**13.3 mA** **8.5 kW**	**20 mA** **12.8 kW**	**100 mA** **63.6 kW**
Coax-center, Straight Coax	3.6 W	5.135 W	26.90 W
Coax-center, Actual Coupler	3.94 W	5.93 W	29.48 W
Coax Short	113 mW	170 mW	843 mW
Waveguide Short	116 mW	174 mW	865 mW
Window Ceramic	6.6 W	9.9 W	49.4 W
Peak Loss in Window [W/cm^3]	0.04	0.06	0.27
Peak Temperature on Window	< 47^o C		
dT$_{max}$ across Window	2^o - 22^o C		

Goals:
1. Input for thermal
2. Critical spots
3. Cooling needs

Inner conductor cooling: GHe
Window cooling: dry air





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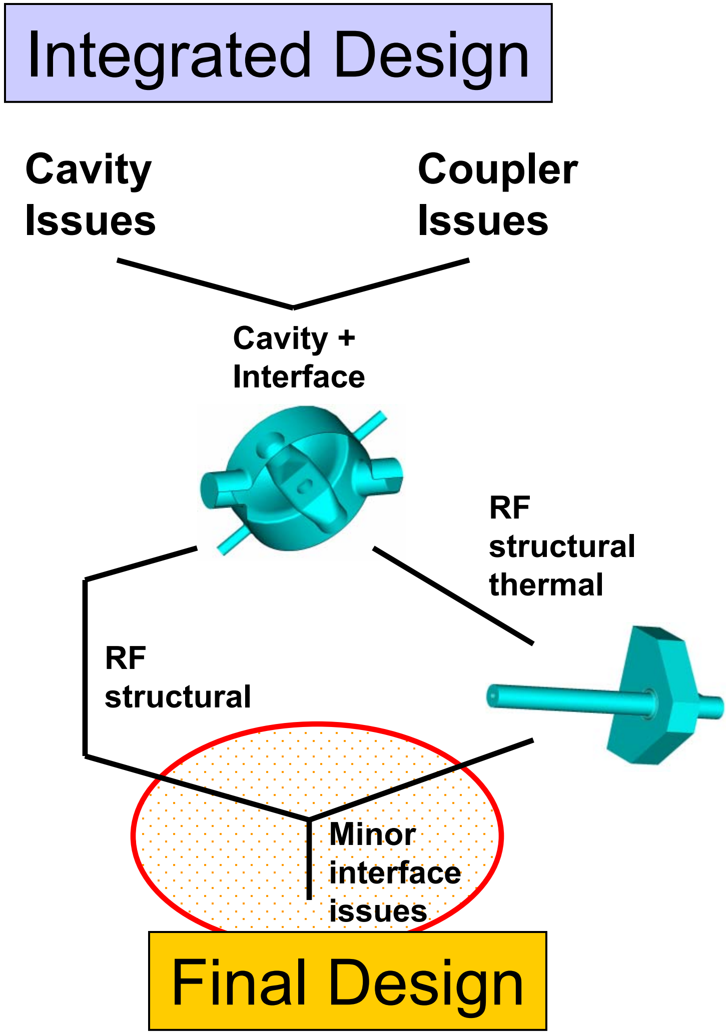
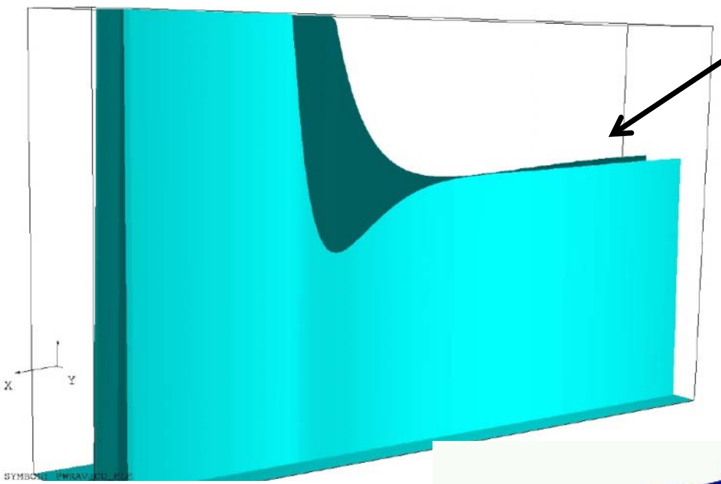
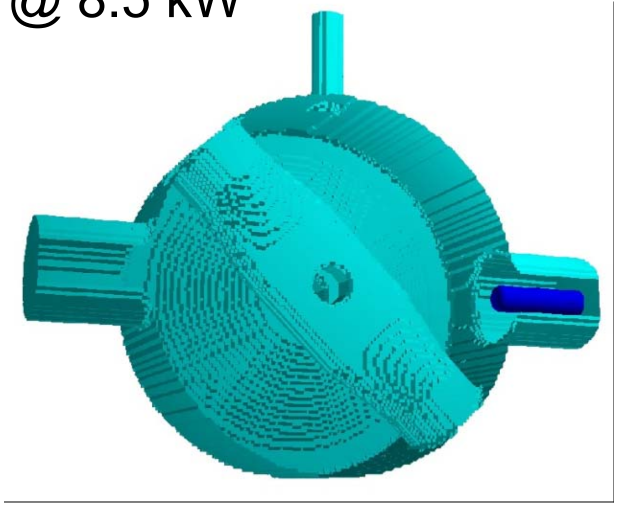
Design Integration: Where are we?

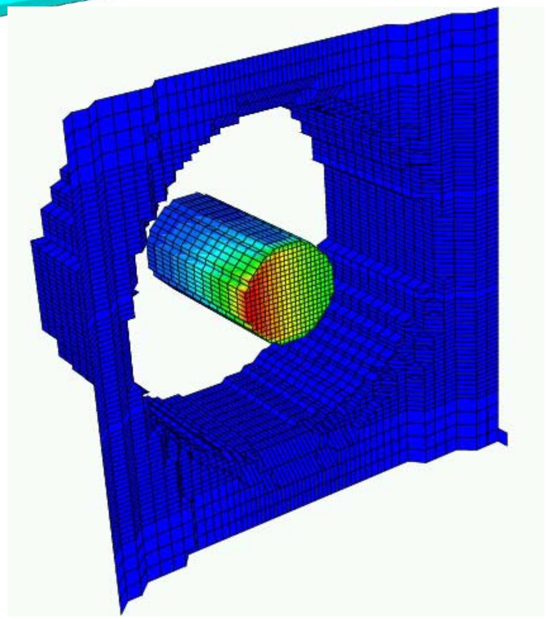


Design Integration: 3a) TW Properties at Interface

6.5 mW/cm² @ 8.5 kW







Losses @ 8.5 kW

p_{tip_max}	4.82 W/cm^2
P_{tip_total}	25.2 W
T_{tip}	52^o C
$P_{thermal}$	0.5 W

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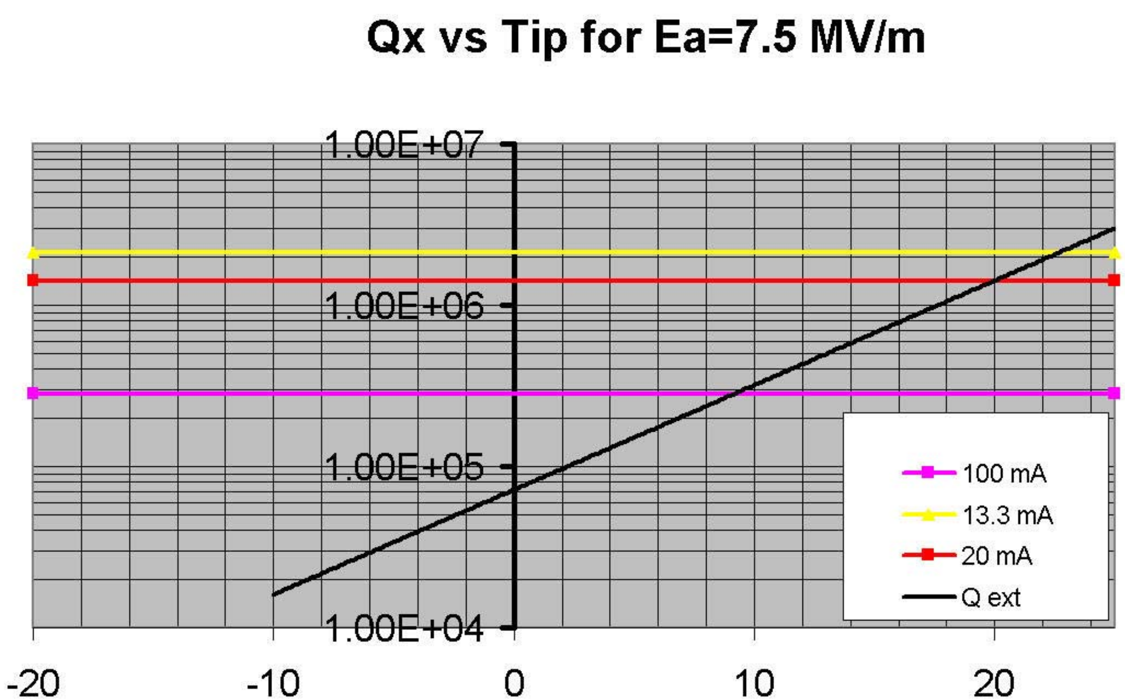
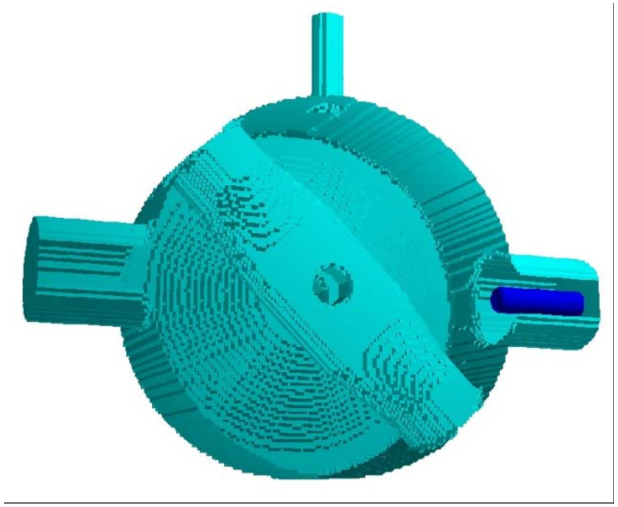
Design Integration: 3b) Coupling Evaluation





Goal: 1. Tip position
2. Frequency

I [mA]	Q_x	Δf [kHz]	z [mm]
13.3	2.13E+6	reference	23
20.0	1.42E+6	-200	20
100.0	2.83E+6	-970	9

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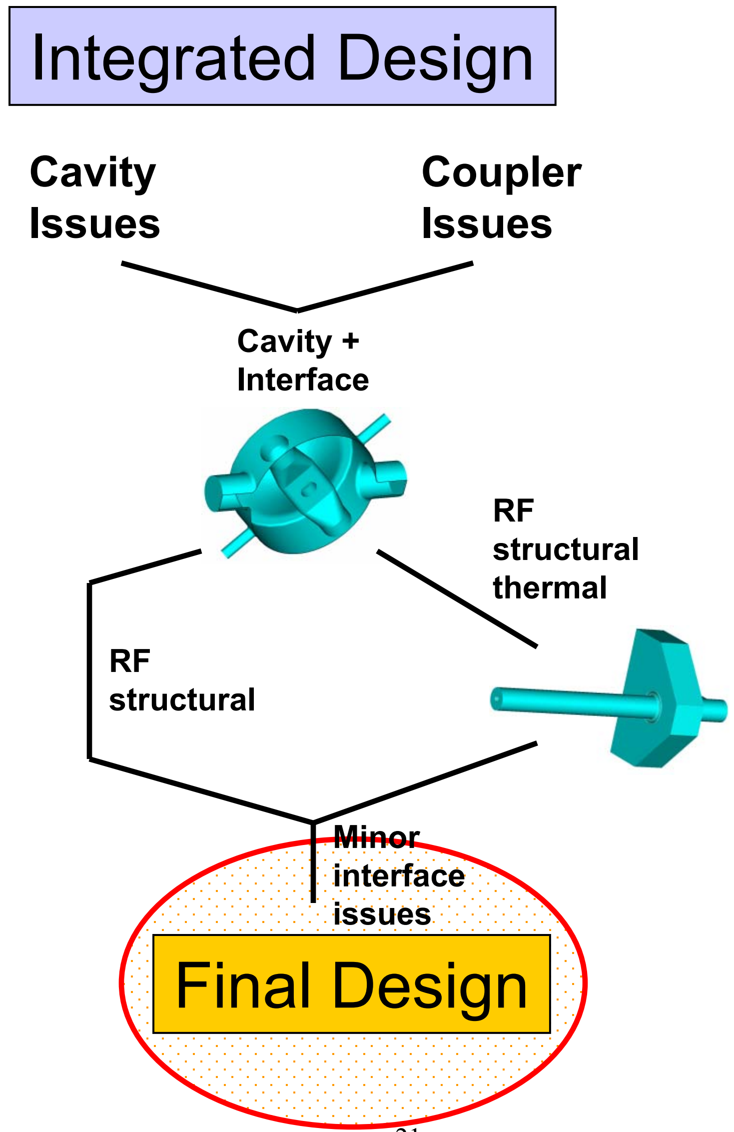
Design Integration: Where are we?



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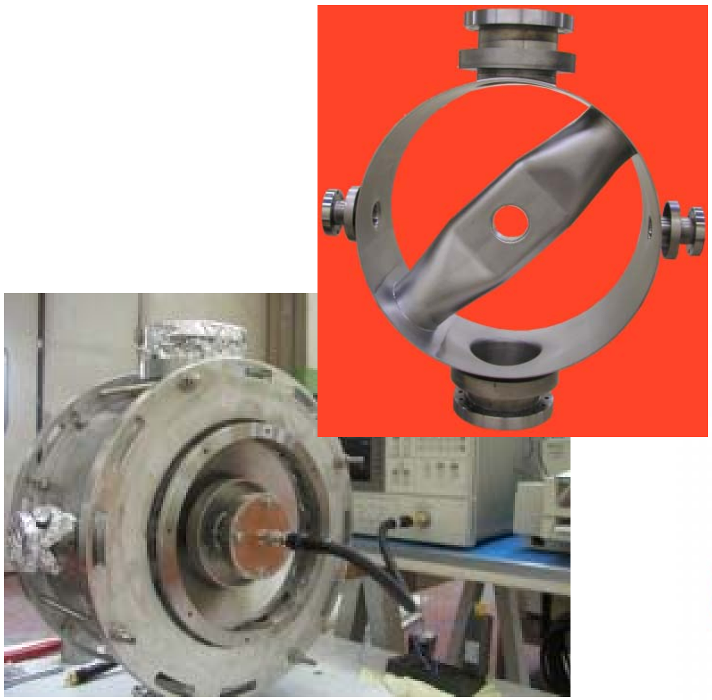
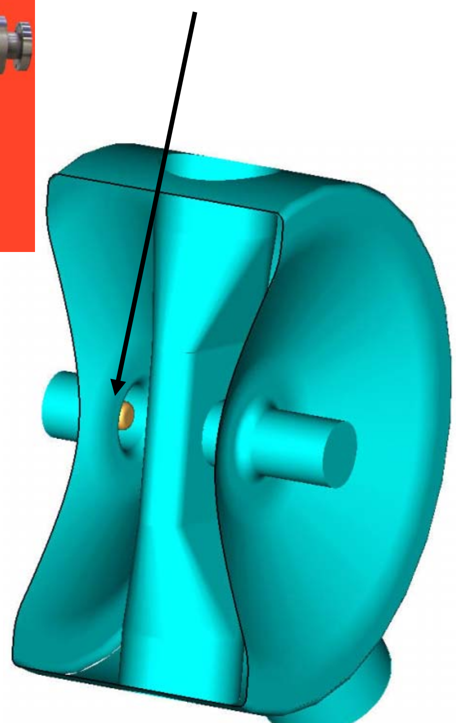
Cryogenic Cavity Test, Interface Verification

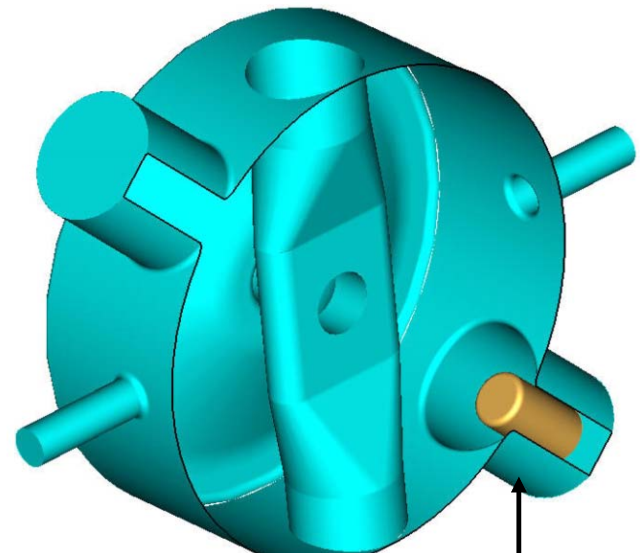
- Spoke Cavity is built by ZANON w/ INFN Milan,
- Coupler production pending
- Vertical test will use 2 coupler for $Q_x(z)$, df(z), Q_0



Cavity ready 2nd week of June, 2002

Fixed probe in low B-field





variable probe in high B-field

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Summary

- Tools and strategies for an integrated cavity/coupler design have been presented.
- The integrated design of the spoke cavity and associated power coupler was presented.
- Single steps have been benchmarked.
- A good understanding of the system has been achieved.
- Verification under cryogenic conditions will happen within a few months.