RF-Design of the AAA β=0.175 Spoke Resonator

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LANL

Workshop on the Advanced Design of Spoke Resonators

Los Alamos, NM, USA
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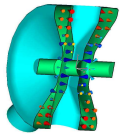
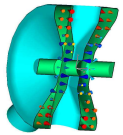


Introduction

- Presentation covers a low-β spoke resonator with:
  - 2 gaps, β=0.175, 350 MHz, integrated ports for high current operation

- The following issues will be covered:
  - Simulation tools -RF Design-
  - Design strategy
  - Integration of RF and mechanical design
  - Other conventions
- Results will be presented for
  - Cavity geometry
  - RF parameters of the cavity
  - RF-Interaction with the coupler
  - Thermal issues of the coupler/cavity interface



Simulation Tools -RF Design-

<table>
<tr><th>MAFIA</th><th>MWS</th><th>MICAV</th></tr>
<tr><td>Known reliability</td><td colspan="2">Fairly new</td></tr>
<tr><td>Extensive post-processing</td><td>Post-processing by user written VBA</td><td>Post-processing by external user programs</td></tr>
<tr><td colspan="3">Geometry import from CAD</td></tr>
<tr><td>Poor surface representation
(requires fine meshes)
slow</td><td colspan="2">Accurate surface representation
(requires moderate meshes)
fast</td></tr>
<tr><td>Manual mesh improvements give good results</td><td>Overall very efficient tool.
Modeling difficulties for complex geometry,
Inaccurate peak surface fields.</td><td>RF models compatible with mechanical (COSMOS/M) models
Limited experience with quality of results</td></tr>
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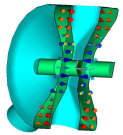
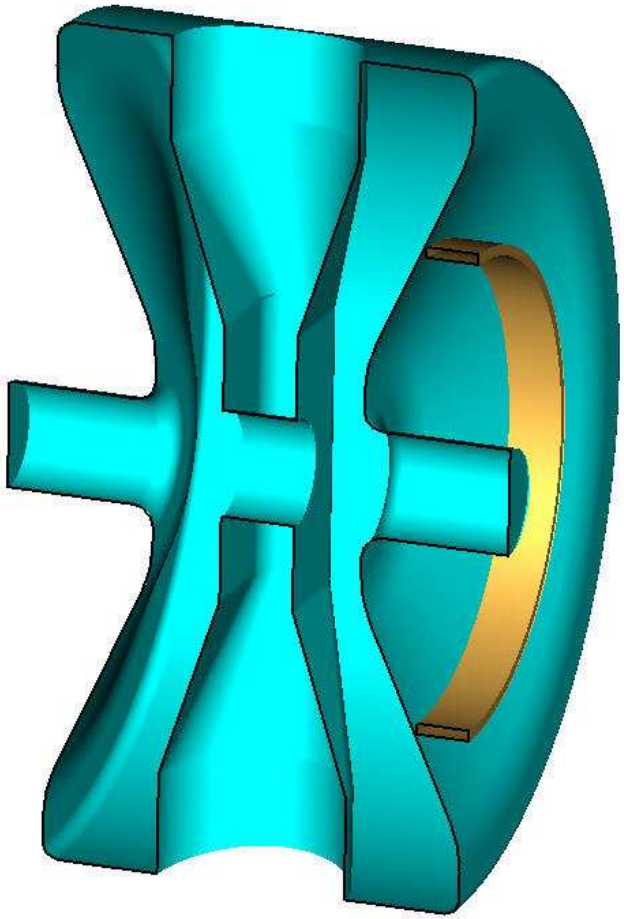
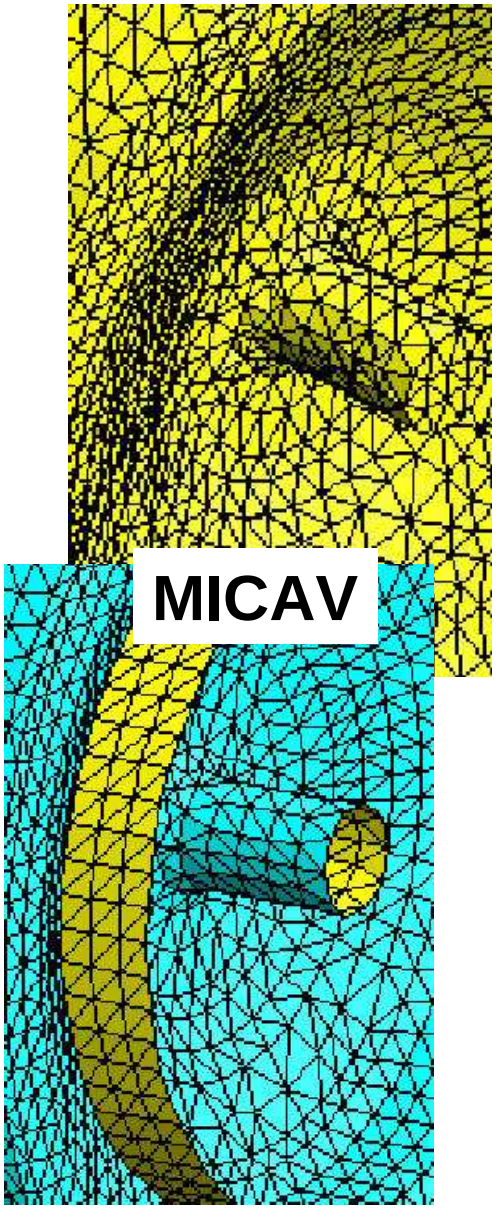


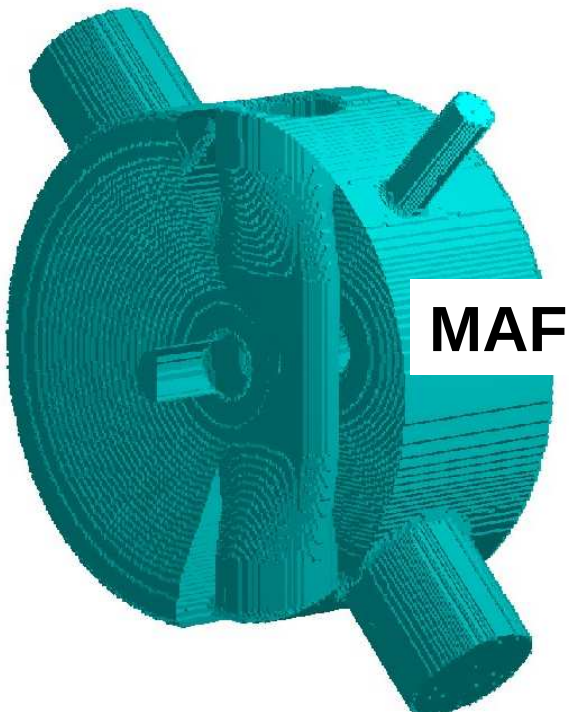
Simulation Tools

CAD

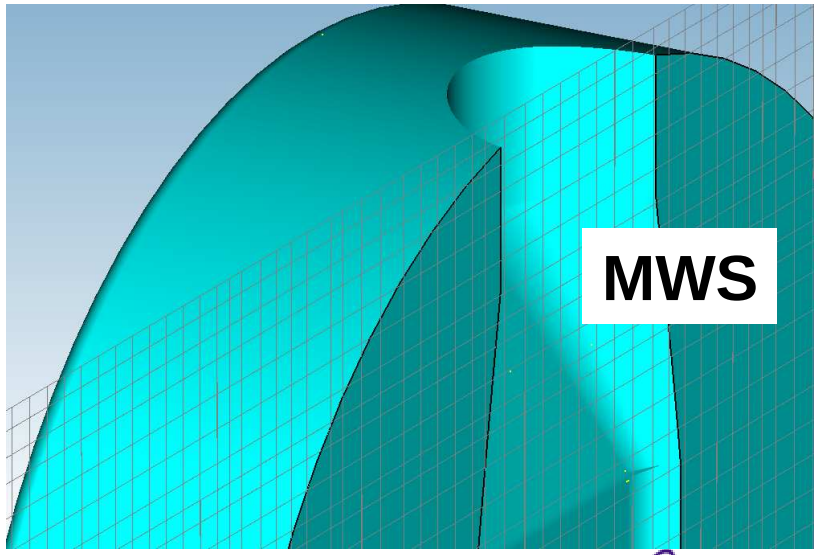




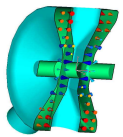
MICAV



MAFIA



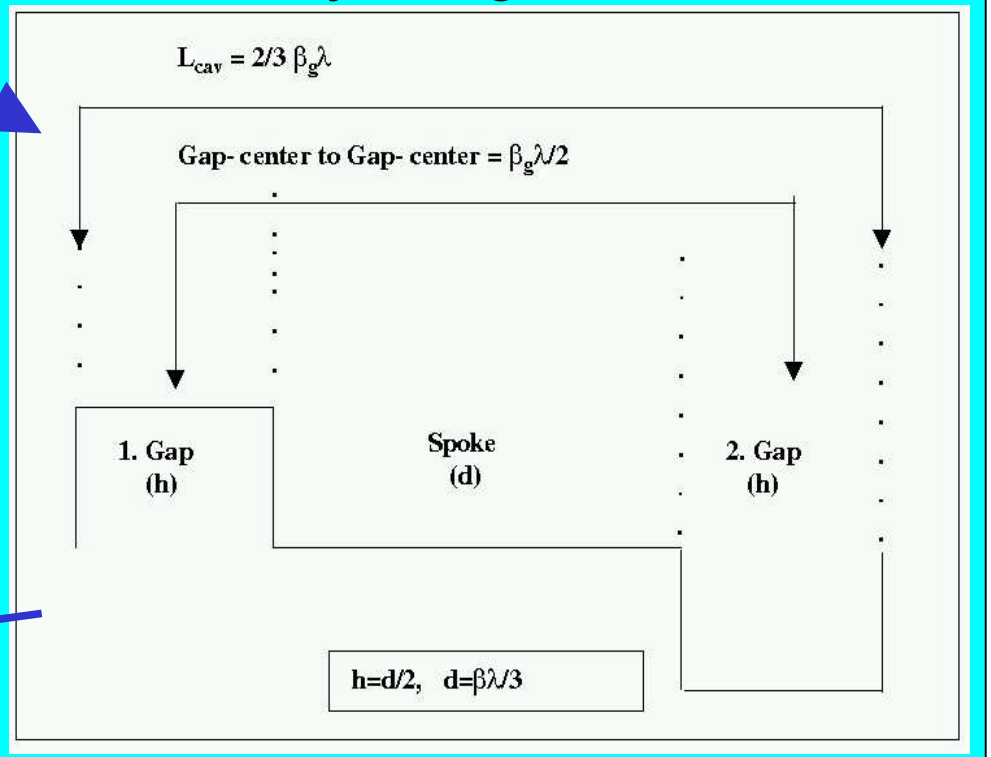
MWS



Design Strategy

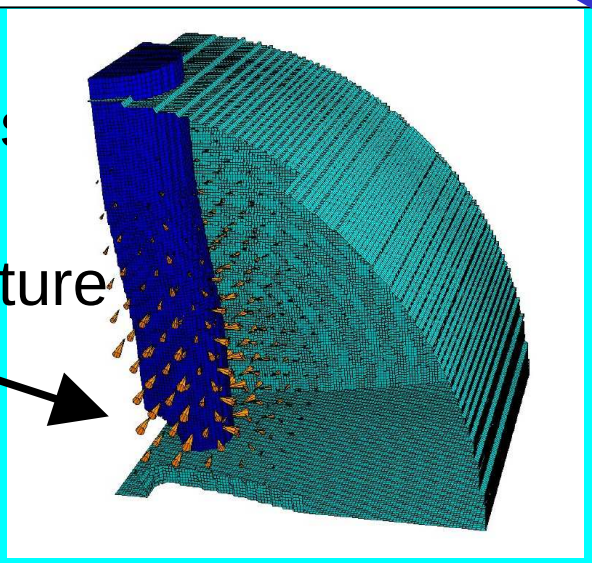
1. Cavity Diameter ~ λ/2

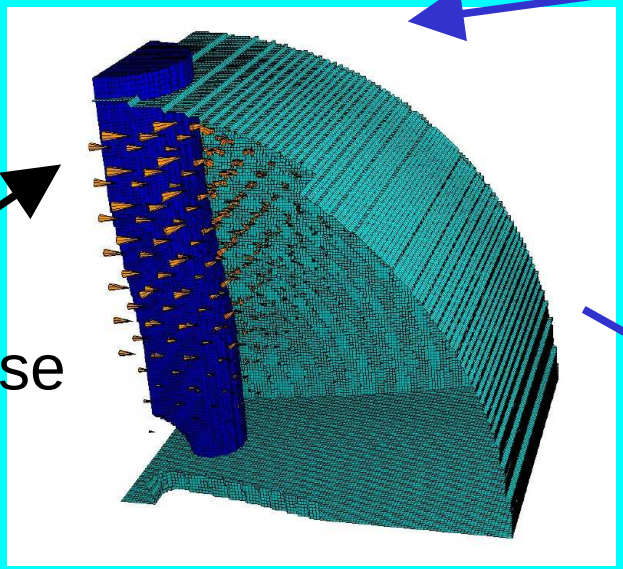
2. Set Cavity Length



3. Peak Fields

E_{peak} @ aperture

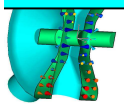




H_{peak} @ base

4. Further steps:

- Optimize Endwall Shape
- Incorporate port attachments
- Tune cavity by setting radius



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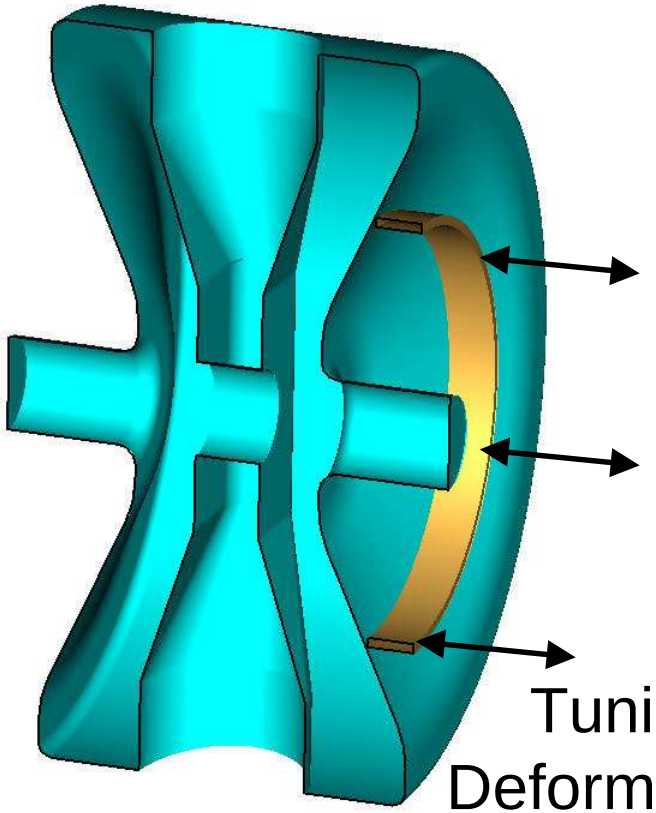
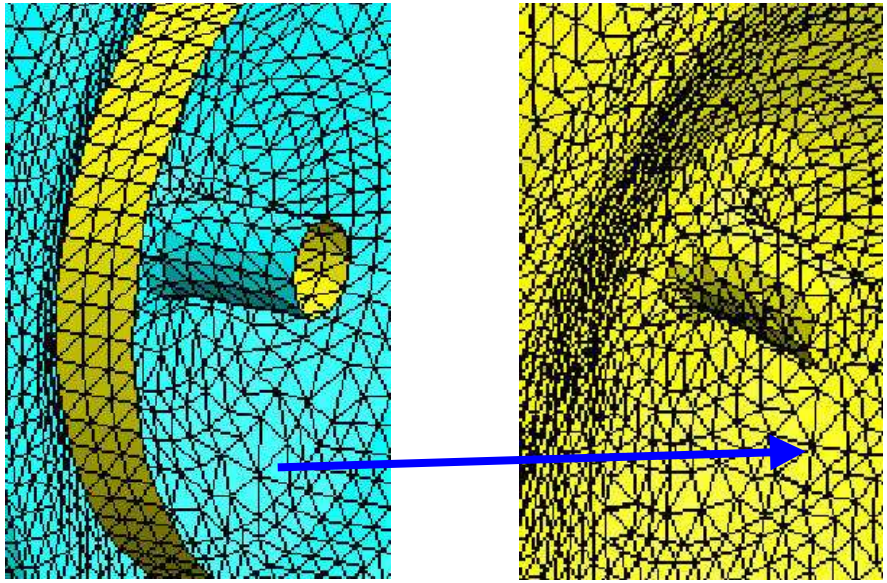
RF and Structural Design Integration

RF Effects of Deformations: Tuning Sensitivity/ Forces

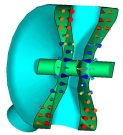


Tuning Deformations



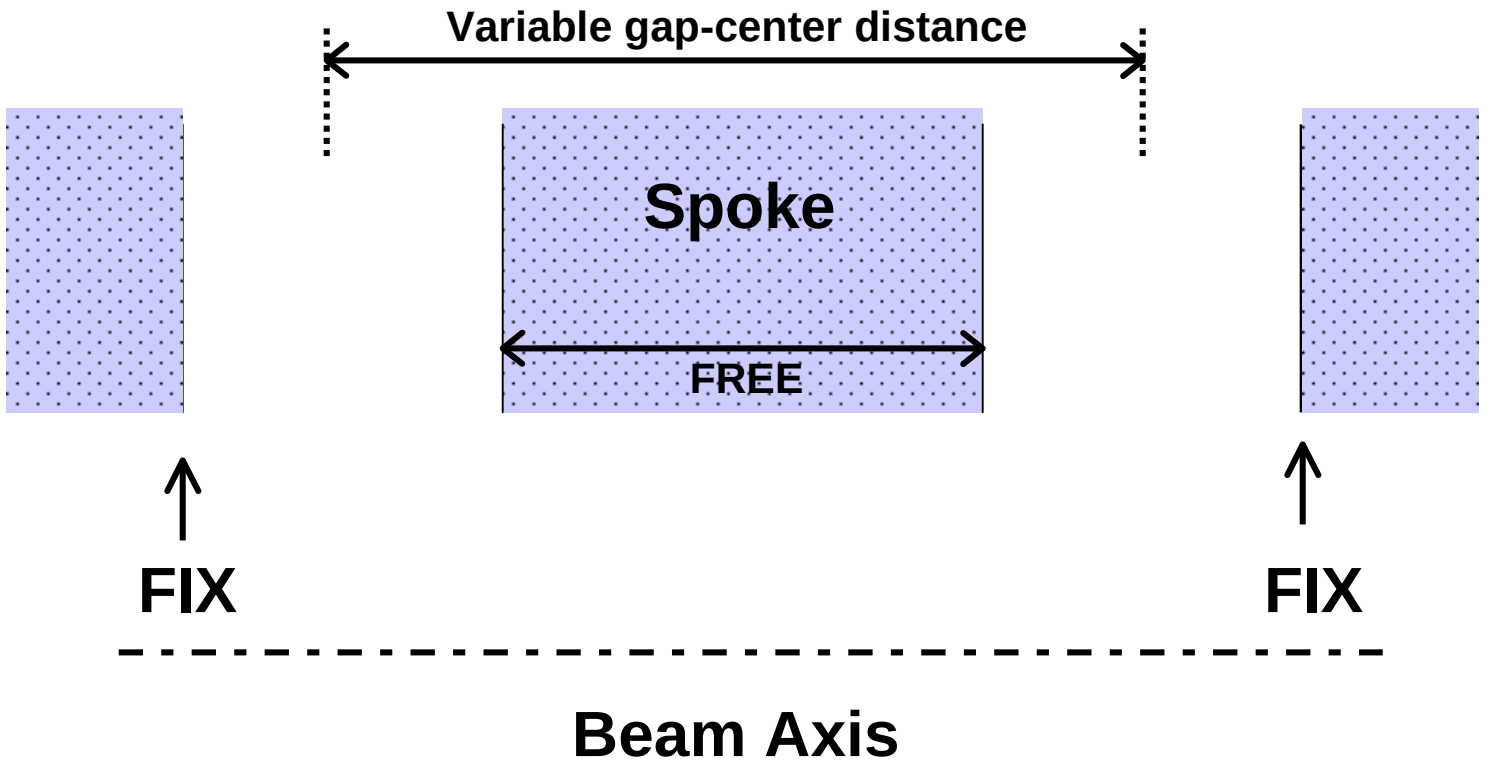
Shell Mesh ⟷ Volume Mesh

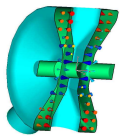
Common nodes allow recalculation of RF-case without re-meshing (reduces discretization error)



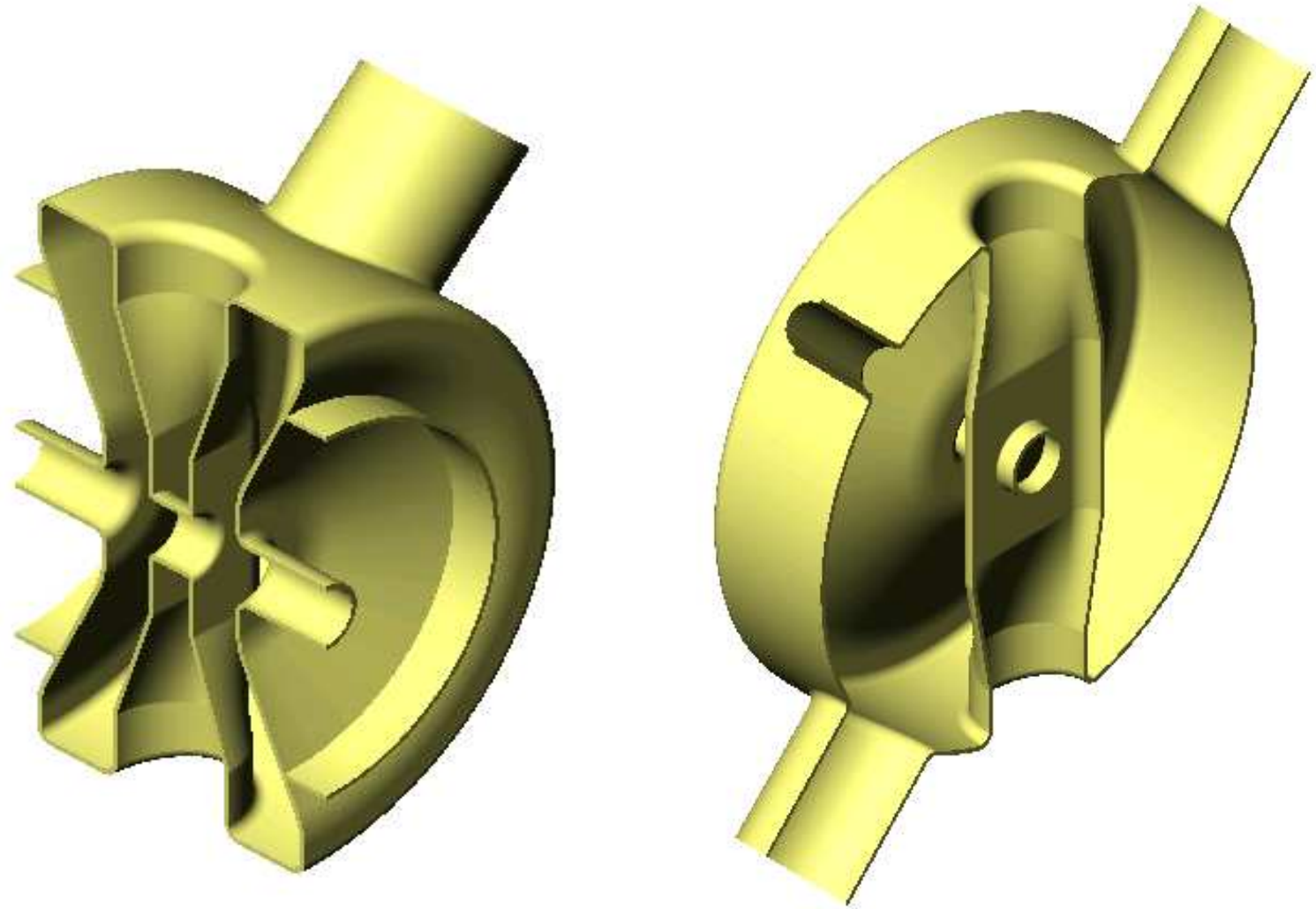
Conventions

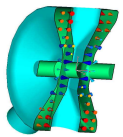
1. Maintain circumference along spoke
2. Keep overall gap-to-gap length to 2/3 βλ
3. Allow deviation from d = 2* gap length





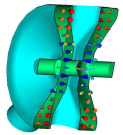
Geometry





RF Results

Q_0 (4 K)	1.05E+09 (for 61 nΩ)
T (β_g)	0.7765 (β_g=0.175)
$T_{max}(\beta)$	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

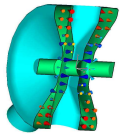


RF Parameter Comparison

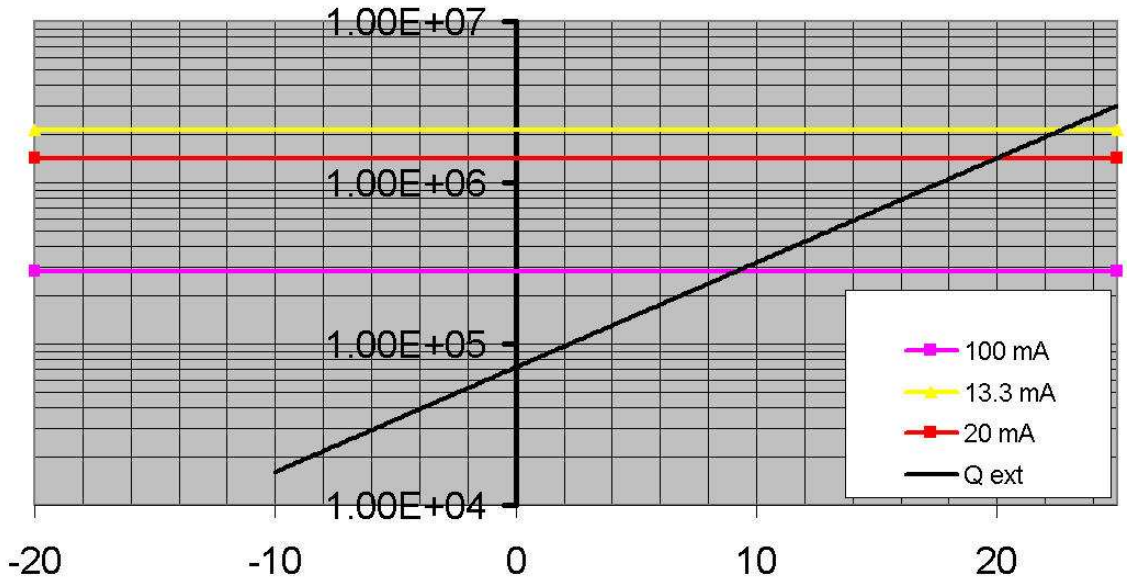
	0.175	0.200	0.340	ANL 0.3	APT 0.64
Frequency [MHz]	350	350	350	350	700
T_g	0.777	0.787	0.769	-	0.650
T_{max}	0.806	0.790	0.777	0.910	0.700
Q_0 (61/16 nΩ)	1.05E+09	1.34E+09	1.28E+09	1.01E+09	9.40E+09
ZT^2/Q [Ω]	124	214	318	295	191
E_{pk}/E_0T	2.82	< 3.60	< 3.47	3.18	3.38
B_{pk}/E_0T [G/MV/m]	73.8	< 96	< 104	85	70
G [Ω]	64.1	94	90	70.7	149
Q_x (nom.)	1.90E+05	1.10E+05	1.10E+05	-	2.00E+05
E_0T (nom.) [MV/m]	7.50	5.00	5.00		6.00
B_{pk} @ E_0T [G]	554	TBD	TBD	-	420
B_{pk} in testing [G]	1040	-	-	1000	840

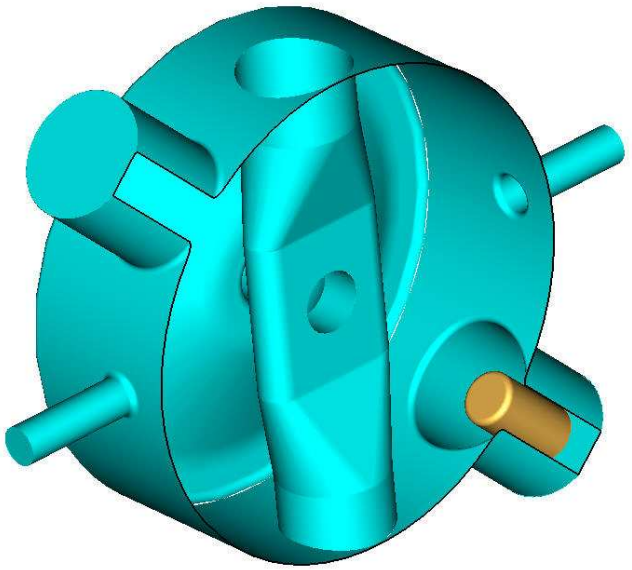
Optimized Geometry

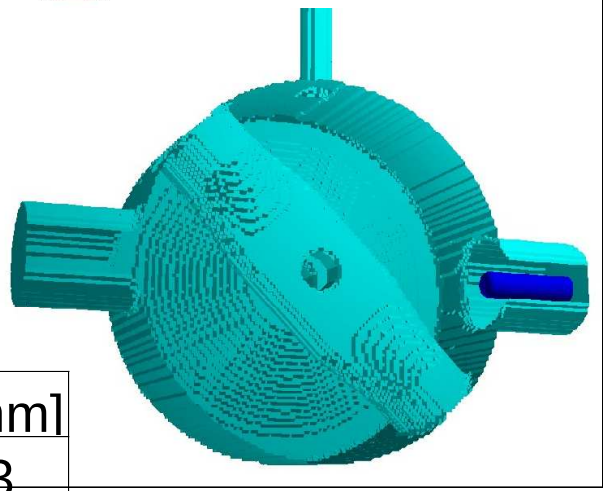
Non-Optimized Geometry



Design Integration: Coupling Evaluation

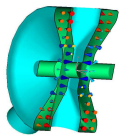




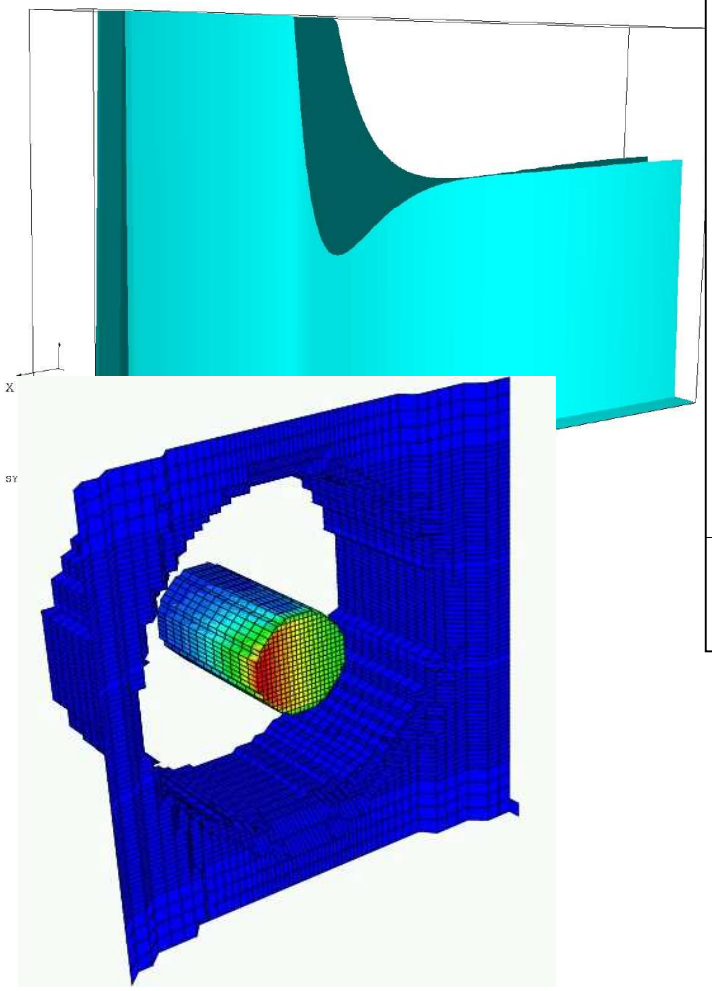


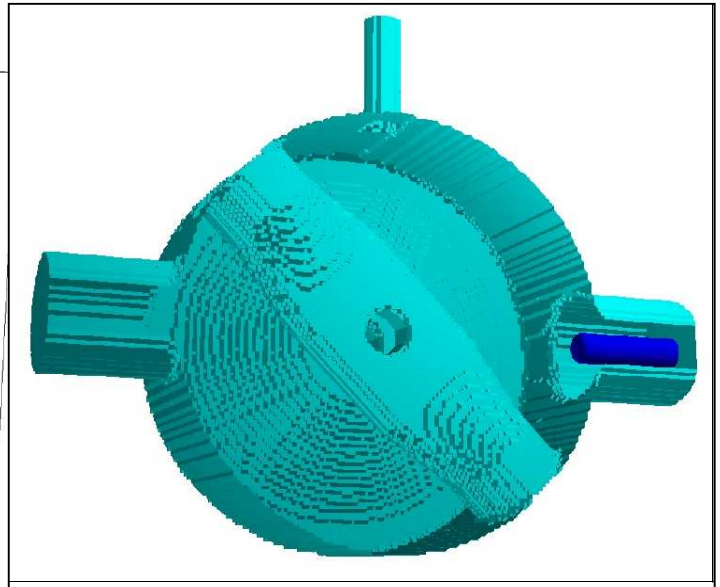
Goal: 1. Tip position
2. Frequency

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



Integration Issues: TW Solution/ Losses





MAFIA Model

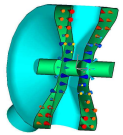
Radiative losses @ 8.5 kW
(7.5 MV/m, 13.3 mA)

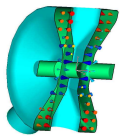
$p_{tip\ max}$	4.82 W/cm^2
$P_{tip\ total}$	25.2 W
T_{tip}	52^o C
$P_{thermal}$	0.5 W

Question:
Accounting for loss contributions to cavity Q ?

Q_0 w or w/o tip losses, tip 6 cm withdrawn

P_{cav}	P_{outer} (SST)	$P_{antenna}$	Q_0	ΔQ_0
1.0 W	-	-	3.83 E8	-
1.0 W	0.051 W	-	3.64 E8	-4.8 %
1.0 W	0.051 W	9.9 W	3.49 E7	-91.0 %



Summary/Outlook

- The design of a low β spoke resonator has been presented. The RF-parameters indicate the potential for a high gradient operation.
- While the design approach seems to be similar to the approaches others have done, there are details that need review.
- The main issue for discussion is the integration/interface issue between cavity and coupler, especially for high-current applications.