EM Design Optimization Of The 162.5 MHz - β ~ 0.11 - HWR

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- Choice/Optimization of the cavity β
- EM Design Optimization Procedure
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  - RF parameters to optimize for
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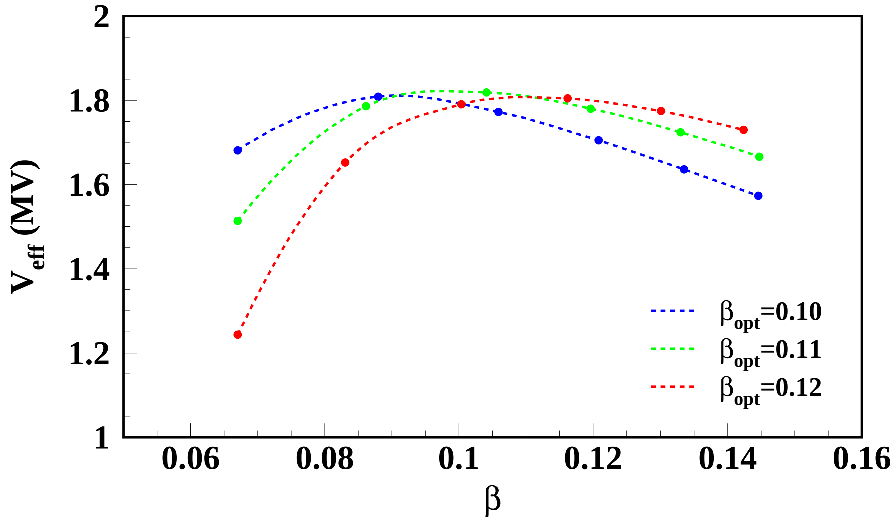
  - Improved procedure: semi-automatic, higher mesh, finer parameter steps, …
- Optimization of the 162.5 MHz - β ~ 0.11 - HWR
- Larger aperture effect on the RF Parameters
  - Re-optimized design for 40 mm aperture instead of 30 mm
- Summary

EM Design Goal

1.8 MV at 40 MV/m and 70 mT

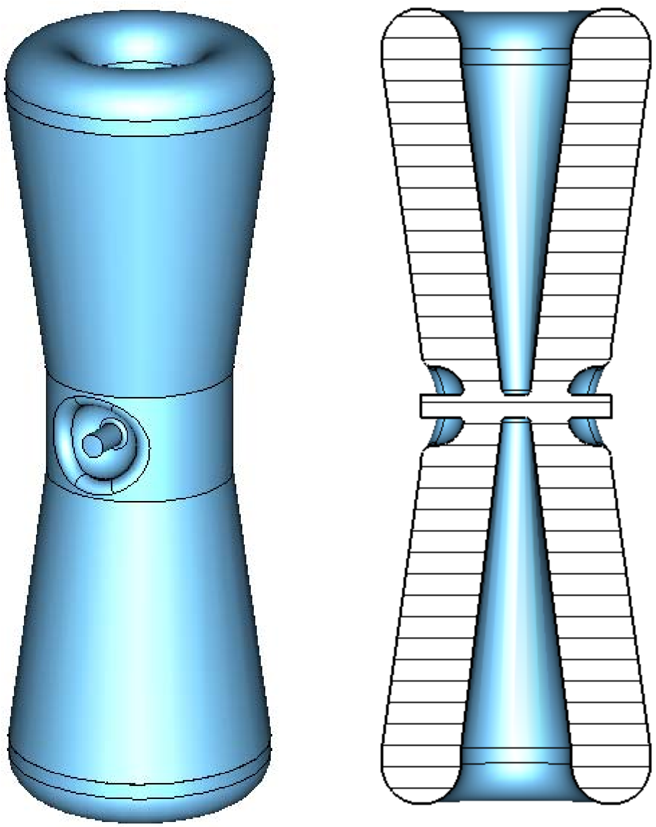
Choice / Optimization of the cavity β

- β optimization is based on the beta range, design voltage, other cavities ...
- The energy range is 2.1 MeV/u to 10 MeV/u → β: from 0.067 to 0.145
- Using the design voltage of 1.8 MV, we found β_opt ~ 0.11.



- At this voltage, 5 cavities should be enough to cover the energy range, BUT …

EM Design Optimization: Fully Parameterized Geometry



Name	Value	Description
CVAPR	1.5	Cavity Aperture Radius
CVFL	2.0	Cavity Flat Length
CVMH	7.0	Cavity Middle Height
CVMR	12.0	Cavity Middle Radius
CVTBR	(CVTR-ICTR)/2.0	Cavity Top Blending Radius
CVTH	50.46	Cavity Top Height
CVTR	17.0	Cavity Top Radius
DTEBR	1.5	Drift Tube Edge Blending Radius
DTIBR	0.5	Drift Tube Inner Blending Radius
DTIR	5.0	Drift Tube Inner Radius
DTOBR	3.6	Drift Tube Blending Radius
DTOR	5.0	Drift Tube Outer Radius
DTPN	CVMR-(MGD+GapW)/	Drift Tube Penetration
GapW	4.8	Gap Width
ICFL	2.0	Inner Conductor Flat Length
ICRTX	3.8	Inner Conductor Race Track Depth (X)
ICRTY	2.0	Inner Conductor Race Track Height (Y)
ICRTZ	(MGD-GapW)/2.	Inner Conductor Race Track Width (Z)
ICTH	CVTH	Inner Conductor Top height
ICTR	7.0	Inner Conductor Top Radius
MGD	8.4	Mid-Gap Distance

Parameter List — Global

- The table shows the list of geometry parameters as seen in MW-Studio
- The geometry parameters are NOT independent

RF Parameters to Optimize for

- E-peak: Minimize peak surface electric field to limit field emission
- B-peak: Minimize peak magnetic field to maintain superconductivity
- $R/Q = V2/\omega U$: Maximize R/Q to produce more accelerating voltage (V) with less stored energy in the cavity (U)
- $G = Rs*Q$: Maximize the geometry factor to increase the cavity effectiveness of providing accelerating voltage due to its shape alone

Geometry Parameters to Choose/Optimize/Fix First

- Choice of Cavity Shape: Cylindrical or Conical based on overall dimensions and RF parameters

- Cavity Outer Dimensions: How big could it be ? Considering
  - Overall cavity and cryomodule dimensions
  - Mechanical and manufacturing limitations
  - Processing and handling limitations
  - RF parameters: Bigger is usually better
  - ...

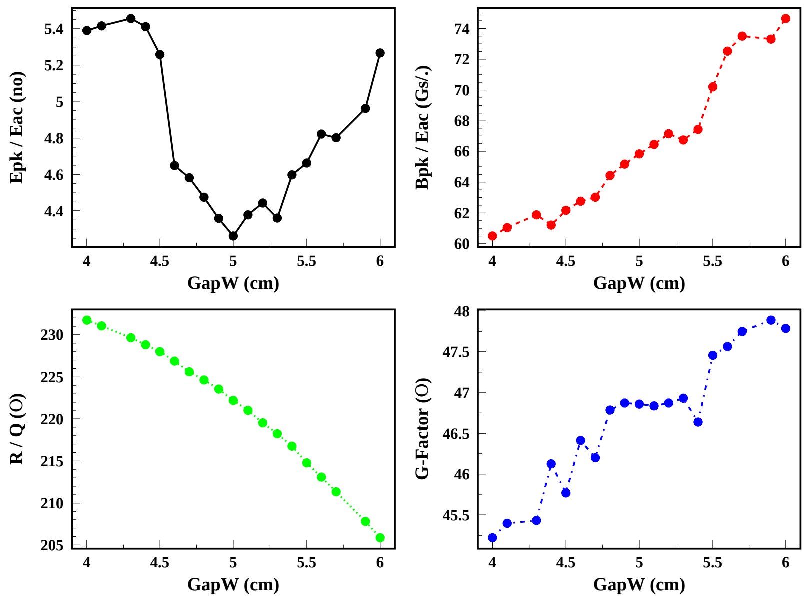
- Mid-Gap Distance: Adjusted to get $\beta_{opt} = \beta_{design}$
  - β_{opt} may drift during the rest of the optimization but could be adjusted

EM Design Optimization: Improved Procedure

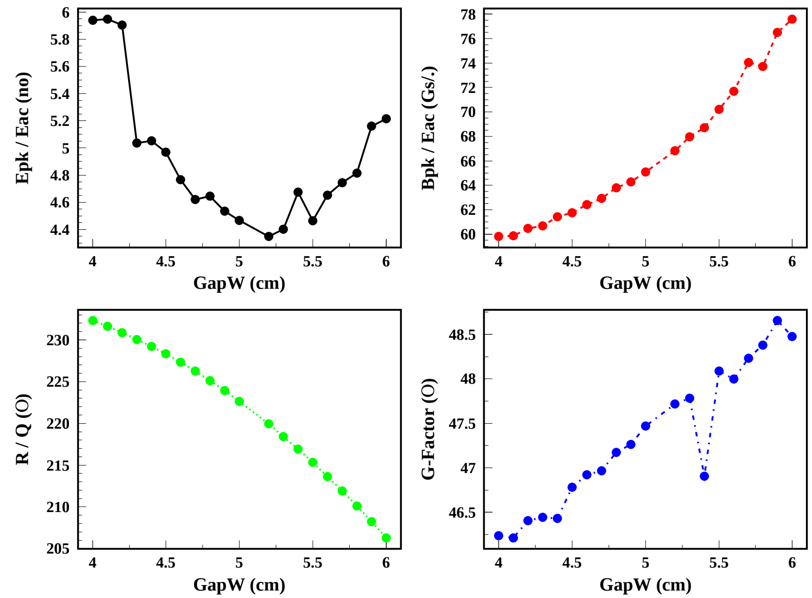
- The original procedure was manual with ~ 200 k hexagonal meshcells for fast turn-around.
- The new one is semi-automatic where MWS does most of the work: MWS parameter sweeps are used instead of the manual sweeps.
- Smaller geometry parameter variation steps: 1-2 mm instead of 0.5-1 cm
- Higher mesh is used for better accuracy: 1M instead of 200k
- The order of parameter sweeps is important: MGD → GapW → …
- If there are several potential optimum branches, they will be investigated

200k versus 1M Results (GapW: Gap Width)

200 k Sweep



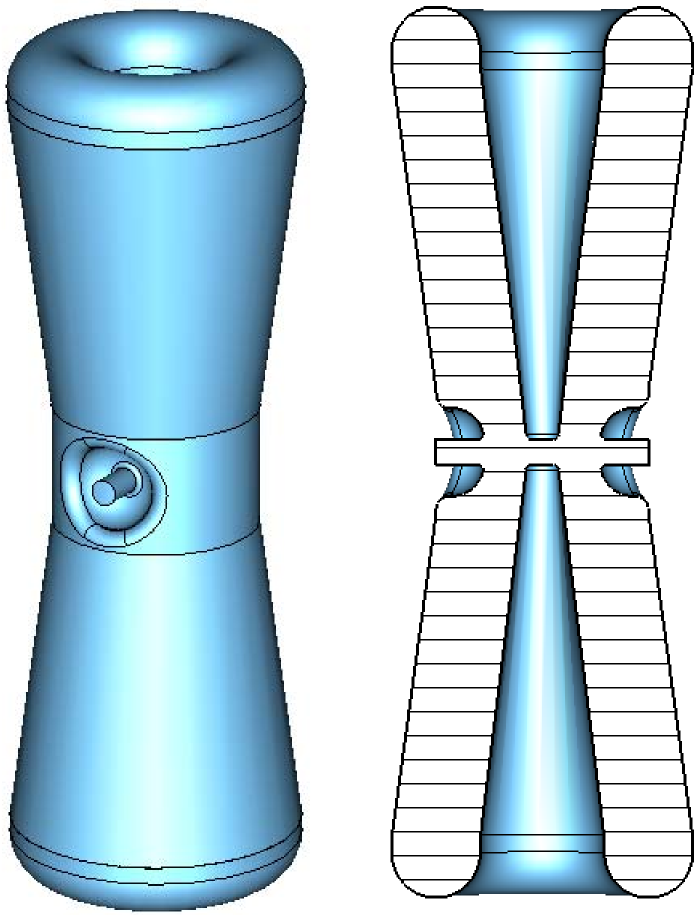
1 M Sweep



Mesh Cells	Freq MHz	β_opt	Leff (cm)	Ep/Ea -	Bp/Ea Gs/.	R/Q Ω	G Ω
233k	162.49	0.111	20.3	4.474	64.399	224.66	46.78
1.04M	162.49	0.110	20.3	4.643	63.760	225.14	47.17

→ 200 k sweeps show similar parameter dependence as the 1M sweeps BUT have more fluctuations and different absolute values for RF parameters especially E-peak.

Starting Geometry: Scaled from an optimized design

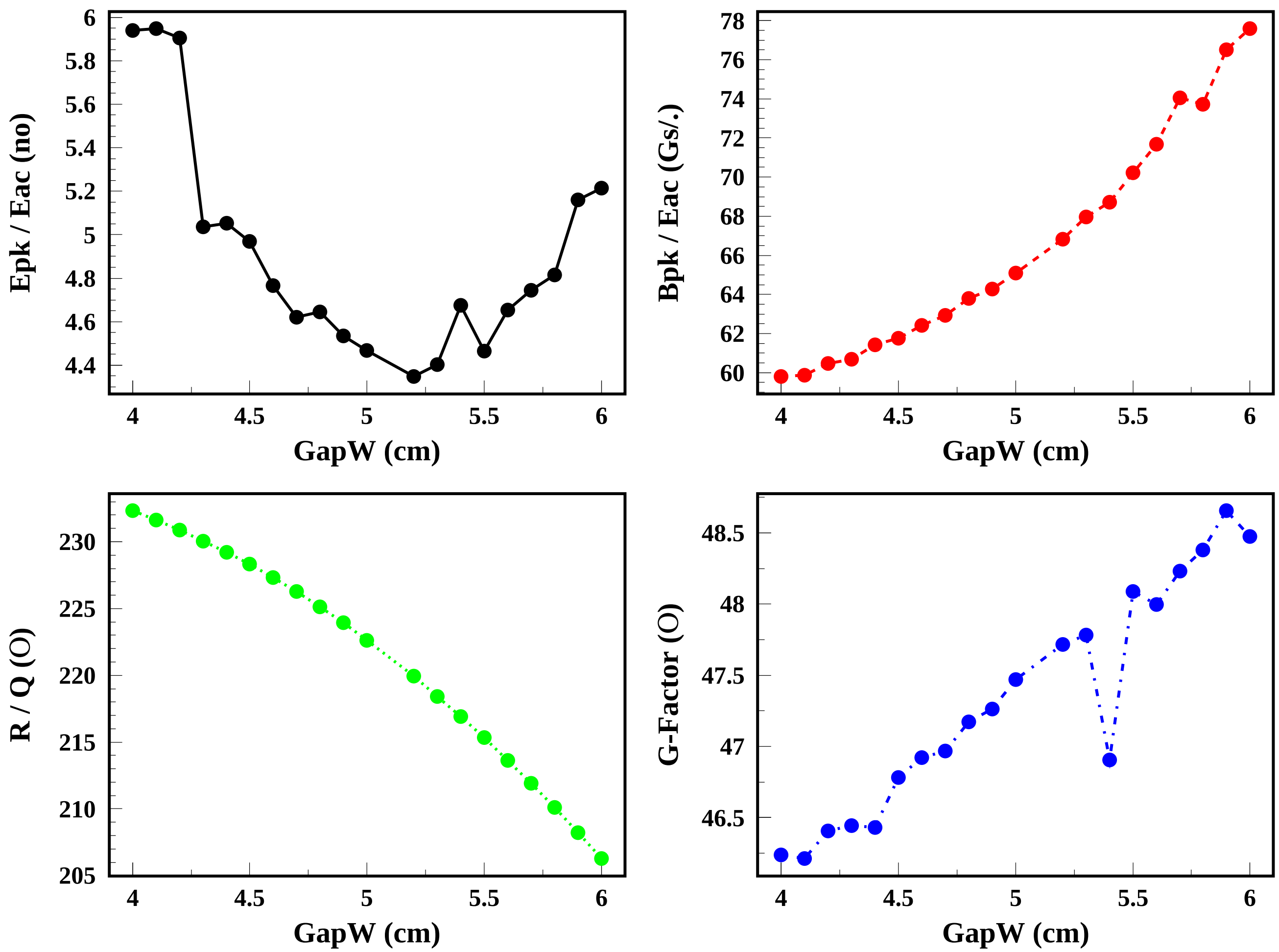


Parameter List

Name	Value	Description
CVAPR	1.5	Cavity Aperture Radius
CVFL	2.0	Cavity Flat Length
CVMH	7.0	Cavity Middle Height
CVMR	12.0	Cavity Middle Radius
CVTBR	(CVTR-ICTR)/2.0	Cavity Top Blending Radius
CVTH	50.46	Cavity Top Height
CVTR	17.0	Cavity Top Radius
DTEBR	1.5	Drift Tube Edge Blending Radius
DTIBR	0.5	Drift Tube Inner Blending Radius
DTIR	5.0	Drift Tube Inner Radius
DTOBR	3.6	Drift Tube Blending Radius
DTOR	5.0	Drift Tube Outer Radius
DTPN	CVMR-(MGD+GapW)/2	Drift Tube Penetration
GapW	4.8	Gap Width
ICFL	2.0	Inner Conductor Flat Length
ICRTX	3.8	Inner Conductor Race Track Depth (X)
ICRTY	2.0	Inner Conductor Race Track Height (Y)
ICRTZ	(MGD-GapW)/2.	Inner Conductor Race Track Width (Z)
ICTH	CVTH	Inner Conductor Top height
ICTR	7.0	Inner Conductor Top Radius
MGD	8.4	Mid-Gap Distance

Global

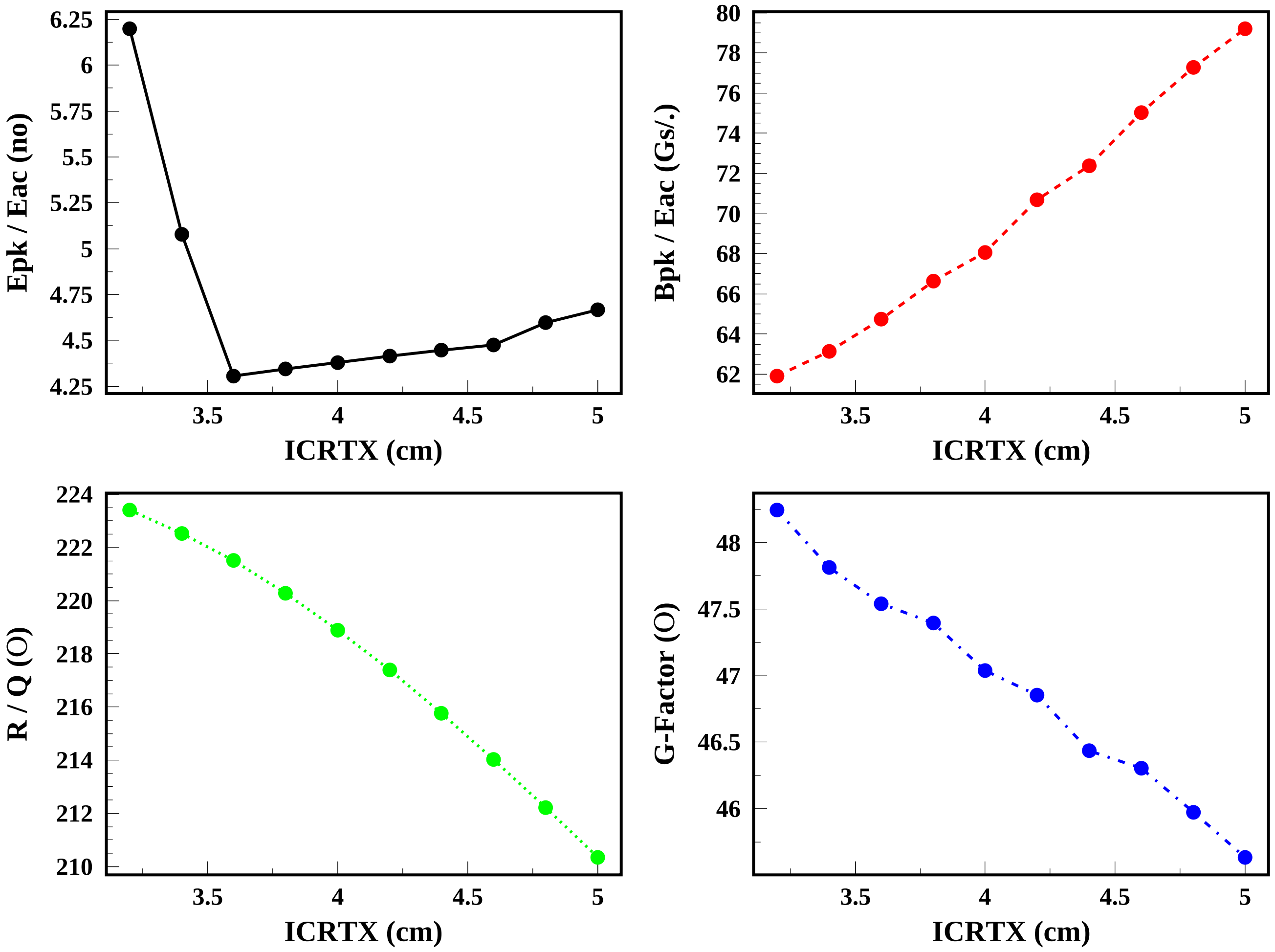
Sweep GapW (Gap Width)



E-peak U, B-peak ↑, R/Q ↓ and G ↑ → GapW = 5.2 cm

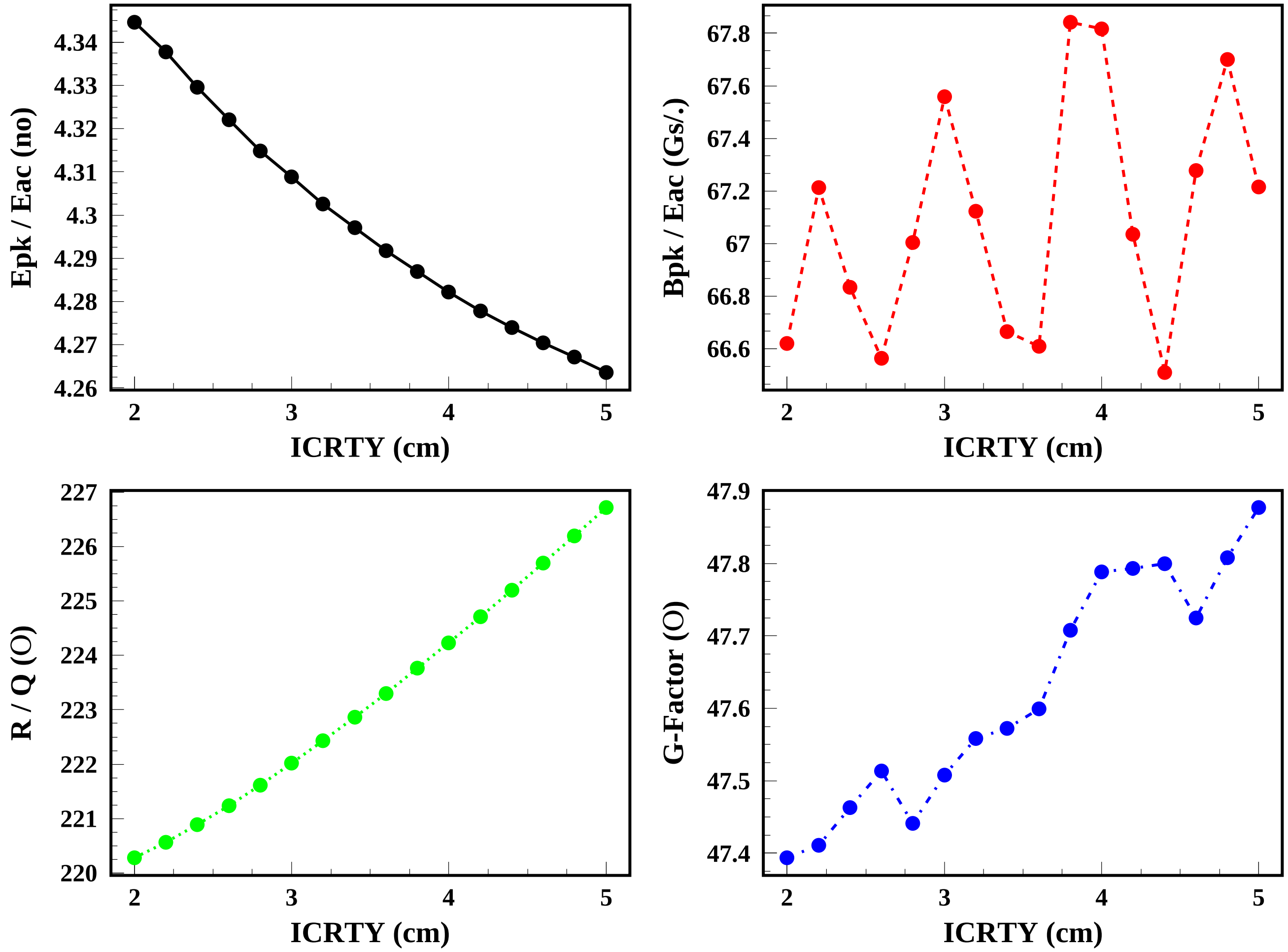
E-peak minimum is around 5.2 cm, but B-peak is minimum around 4 cm

Sweep ICRTX (Inner Conductor Race Track Width)



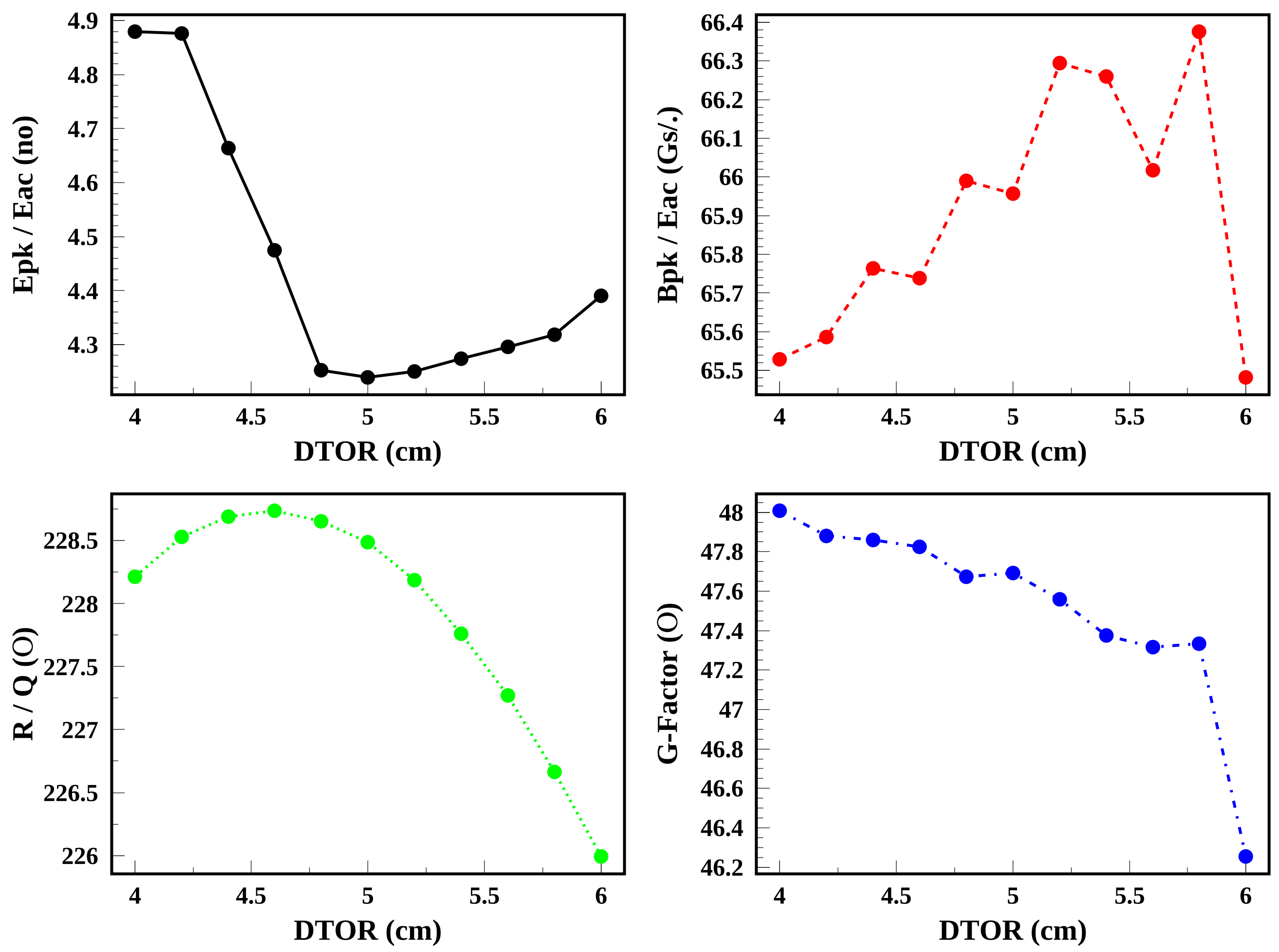
E-peak ↑, B-peak ↑, R/Q ↓ and G ↓ → ICRTX = 3.6 cm

Sweep ICRTY (Inner Conductor Race Track Height)



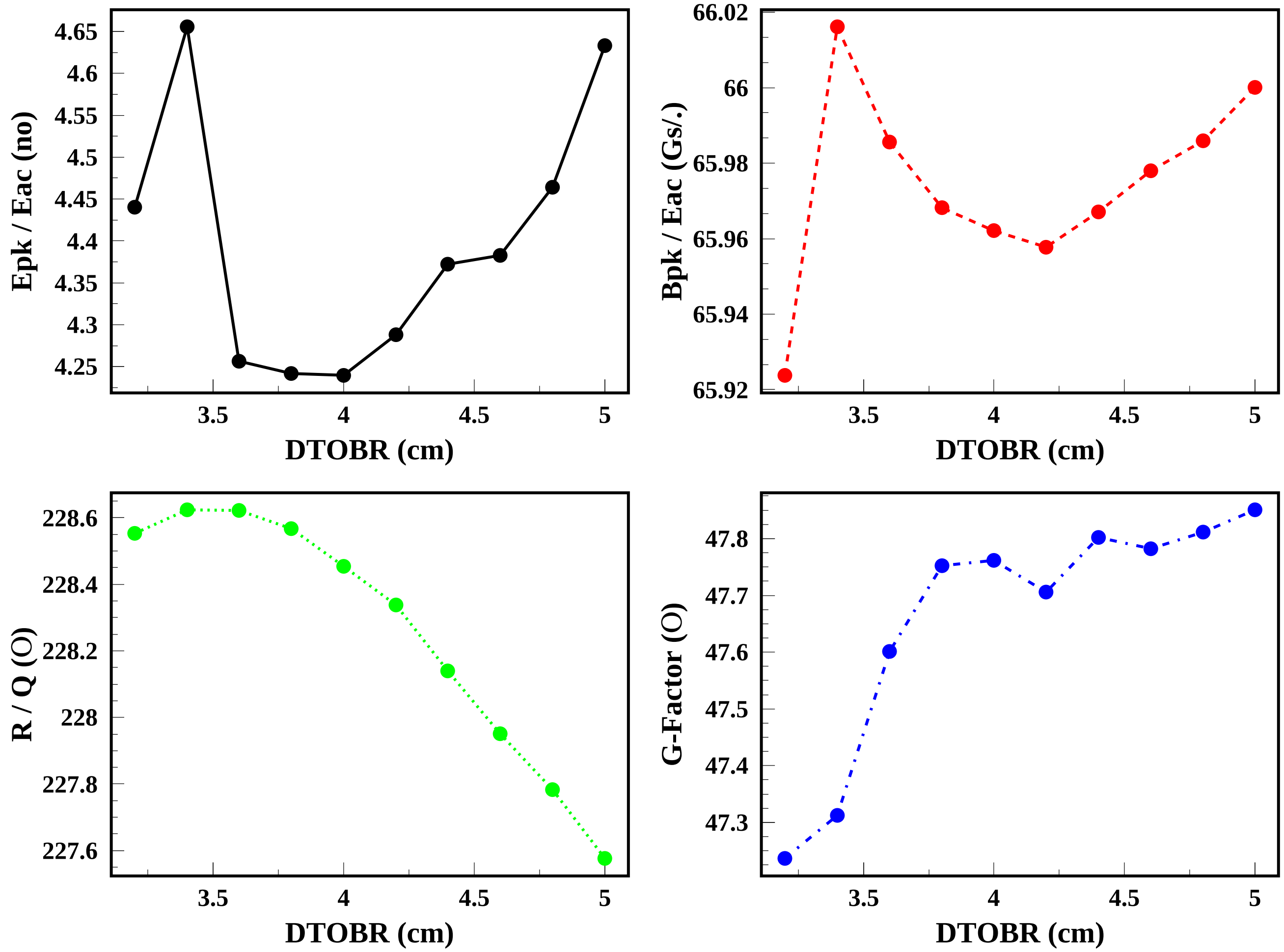
E-peak →, B-peak ~, R/Q and G ↑ → ICRTY = 5.0 cm

Sweep DTOR (Drift Tube Outer Radius)



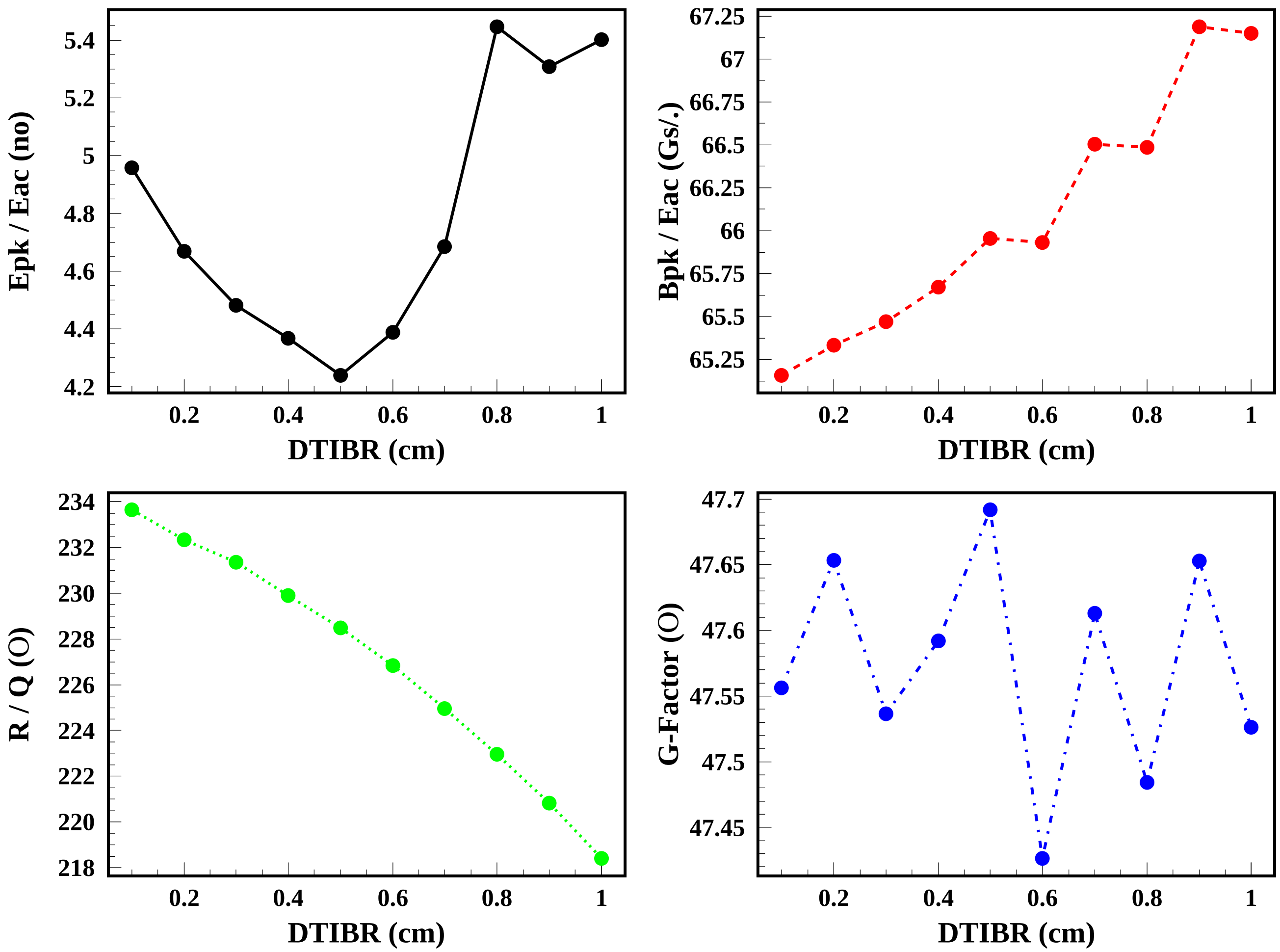
E-peak U, B-peak ↑, R/Q ∩ and G ↓ → DTOR = 5.0 cm

Sweep DTOBR (Drift Tube Outer Blending Radius)



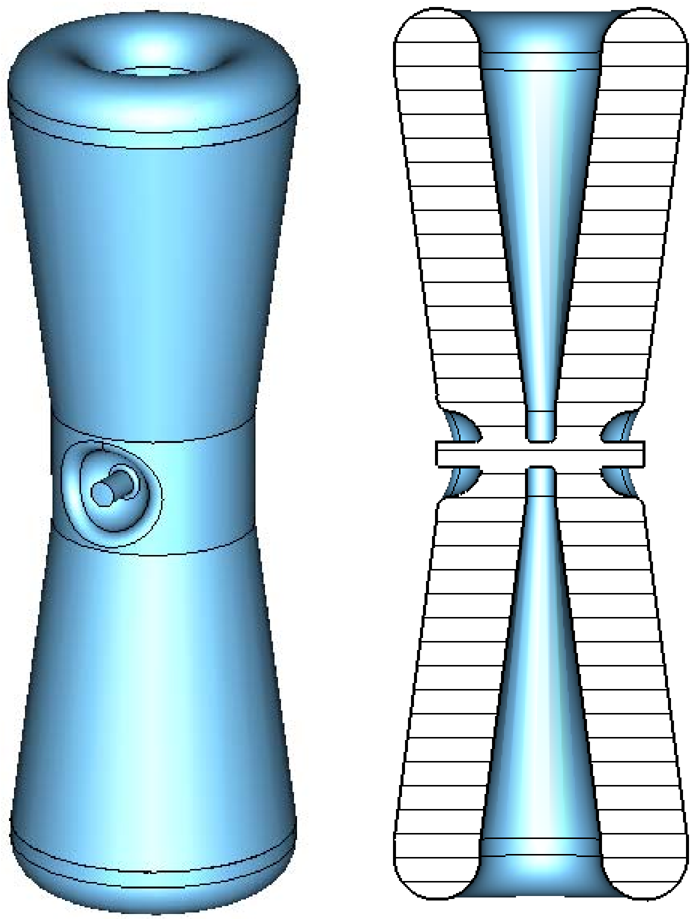
E-peak U, B-peak →, R/Q and G → → DTOBR = 4.0 cm

Sweep DTIBR (Drift Tube Inner Blending Radius)



E-peak U, B-peak ↑, R/Q ↓ and G → → DTIBR = 0.5 cm

Optimum Geometry



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CVTBR	(CVTR-ICTR)/2.0	Cavity Top Blending Radius
CVTH	51.78	Cavity Top Height
CVTR	17.0	Cavity Top Radius
DTEBR	1.5	Drift Tube Edge Blending Radius
DTIBR	0.5	Drift Tube Inner Blending Radius
DTIR	5.0	Drift Tube Inner Radius
DTOBR	4.0	Drift Tube Blending Radius
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GapW	5.2	Gap Width
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ICTH	CVTH	Inner Conductor Top height
ICTR	7.0	Inner Conductor Top Radius
MGD	8.4	Mid-Gap Distance

Parameter List

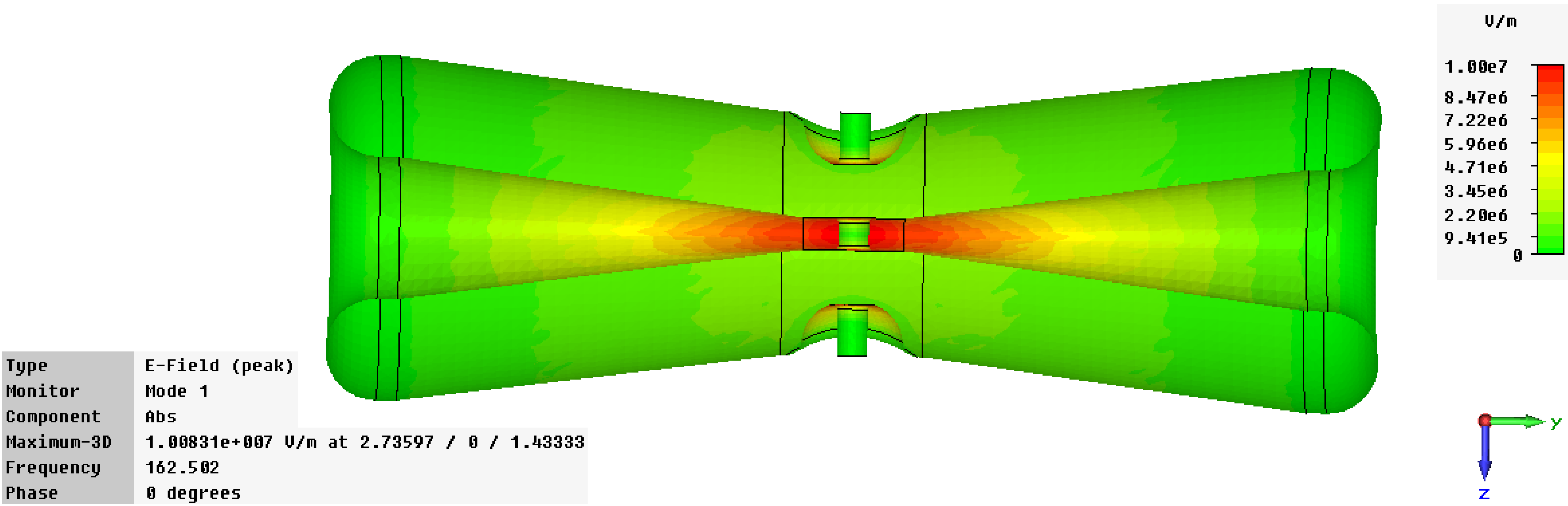
Global

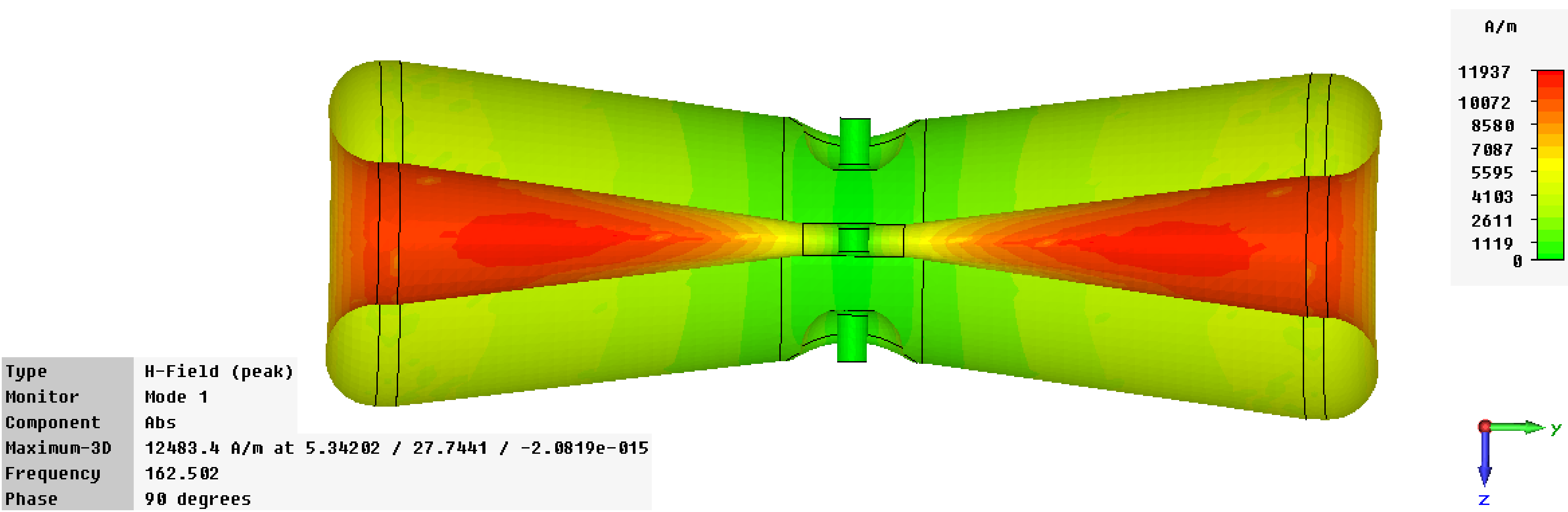
Optimization Results

Geometry	Mesh Cells	Freq MHz	β_opt	Leff (cm)	Ep/Ea -	Bp/Ea Gs/.	R/Q Ω	G Ω
Start	1.04M	162.50	0.110	20.3	4.642	63.76	225.14	47.17
End	1.04M	162.50	0.113	20.85	4.351	67.69	228.75	47.69

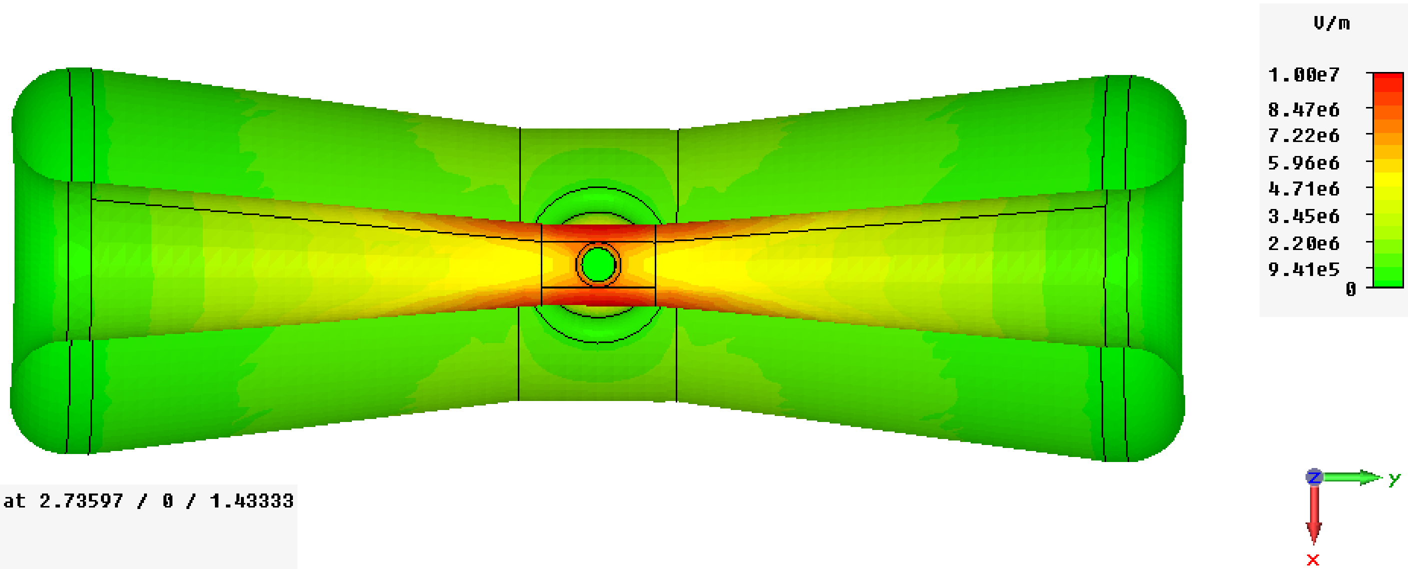
- The end cavity has better E-peak and R/Q but worse B-peak
- The start cavity is capable of delivering 1.75 MV at 40.0 MV/m and 54.9 mT
  and 2.23 MV at 51.0 MV/m and 70.0 mT
- The end cavity is capable of delivering 1.92 MV at 40.0 MV/m and 62.2 mT
  and 2.16 MV at 45.0 MV/m and 70.0 mT
- The end cavity meets the 1.8 MV design goal at 40 MV/m and 70 mT

162.5 MHz - β ~ 0.11 – HWR: Field Distributions (X cut)

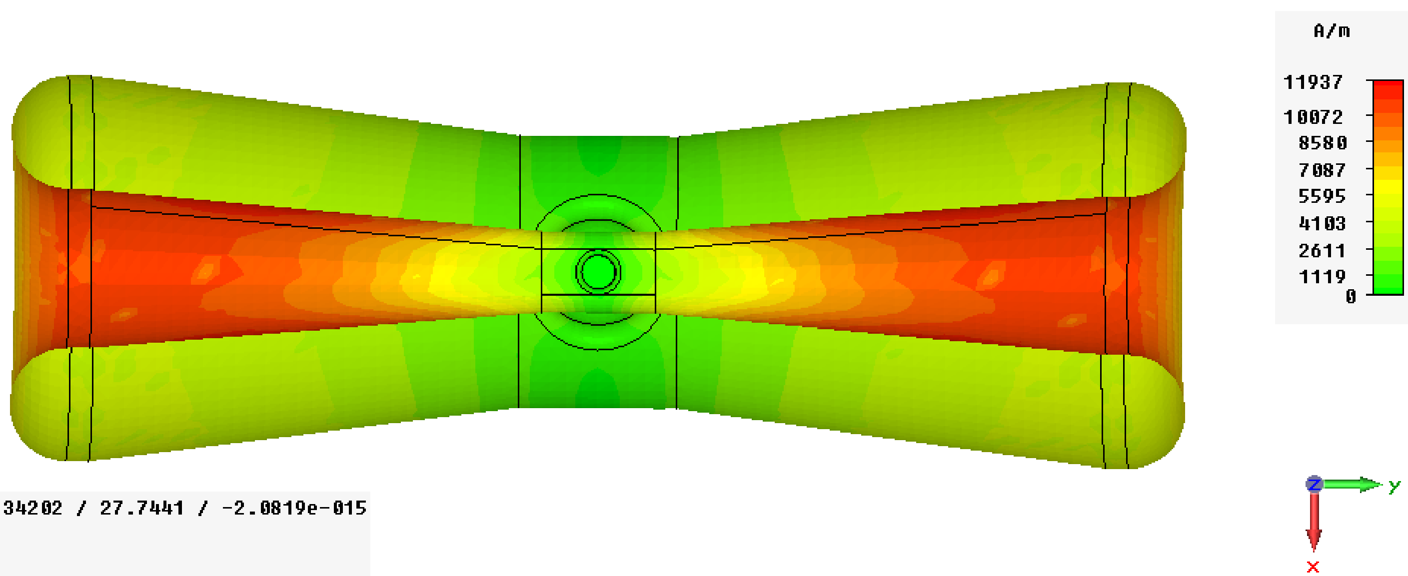




162.5 MHz - β ~ 0.11 – HWR: Field Distributions (Z cut)



Type	E-Field (peak)
Monitor	Mode 1
Component	Abs
Maximum-3D	1.00831e+007 V/m at 2.73597 / 0 / 1.43333
Frequency	162.502
Phase	0 degrees



Type	H-Field (peak)
Monitor	Mode 1
Component	Abs
Maximum-3D	12483.4 A/m at 5.34202 / 27.7441 / -2.0819e-015
Frequency	162.502
Phase	90 degrees

Larger Aperture Effect on the RF Parameters

Aperture	Mesh Cells	Freq MHz	β_opt	Leff (cm)	Ep/Ea -	Bp/Ea Gs/.	R/Q Ω	G Ω
30 mm	1.04M	162.50	0.113	20.85	4.351	67.69	228.75	47.69
40 mm	1.07M	162.51	0.108	19.93	5.110	76.17	200.24	47.36

- The cavity was re-optimized with a 40 mm aperture instead of 30 mm.
- The outer cavity dimensions are kept unchanged → same G factor.
- We notice a significant effect on E-peak, B-peak and R/Q but it should be less significant for the final aperture choice of 33 mm.

- The 40 mm cavity is capable of delivering 1.56 MV at 40.0 MV/m and 59.6 mT
  and 1.83 MV at 47.0 MV/m and 70.0 mT

- The 40 mm cavity meets the 1.8 MV design goal at 47 MV/m and 70 mT

Summary

- We have established a finer EM design optimization procedure.
- We have developed an optimized EM design for the 162.5 MHz – β ~ 0.11 - HWR exceeding the design goal of 1.8 MV with a 30 mm aperture.
- The design was re-optimized with a 40 mm aperture where significant effect on the RF parameters was observed.
- The aperture effect should be less important for the final aperture choice of 33 mm