SSR2 Design & Development

Srinivas Krishnagopal

IADD, BARC

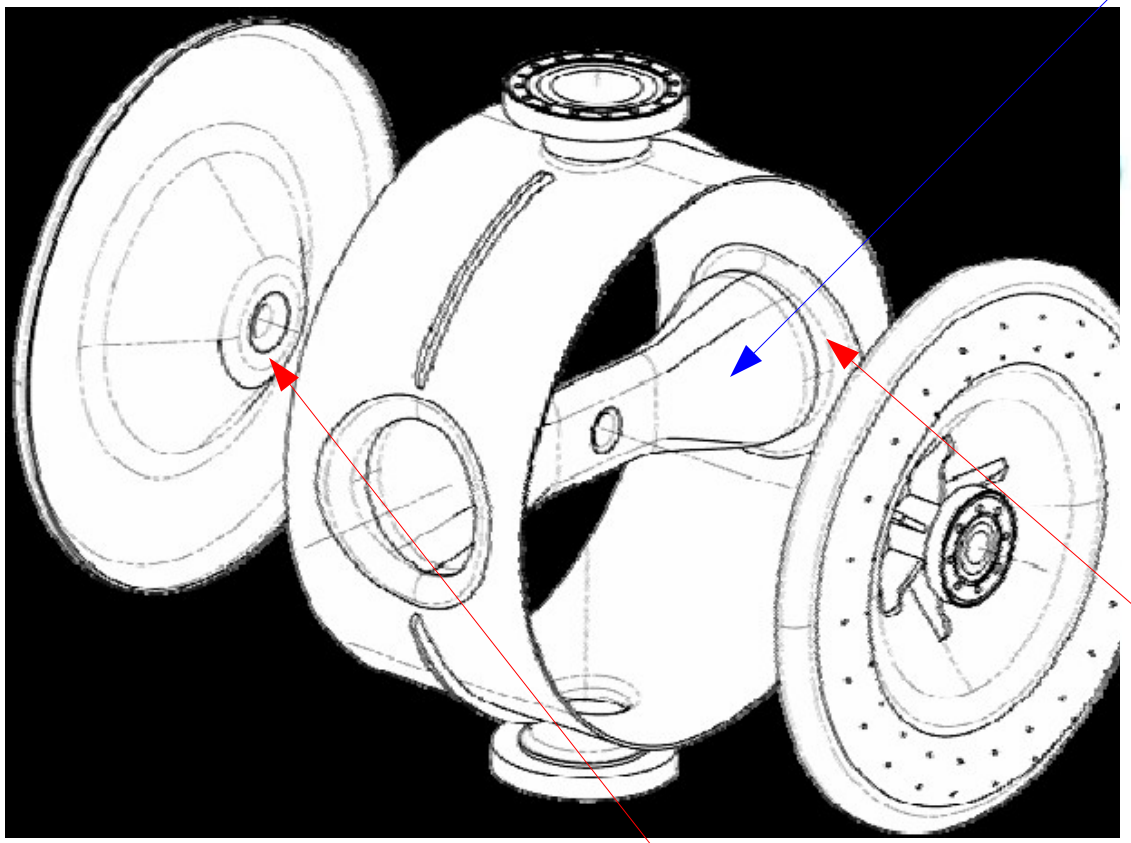
Presentation on behalf of:

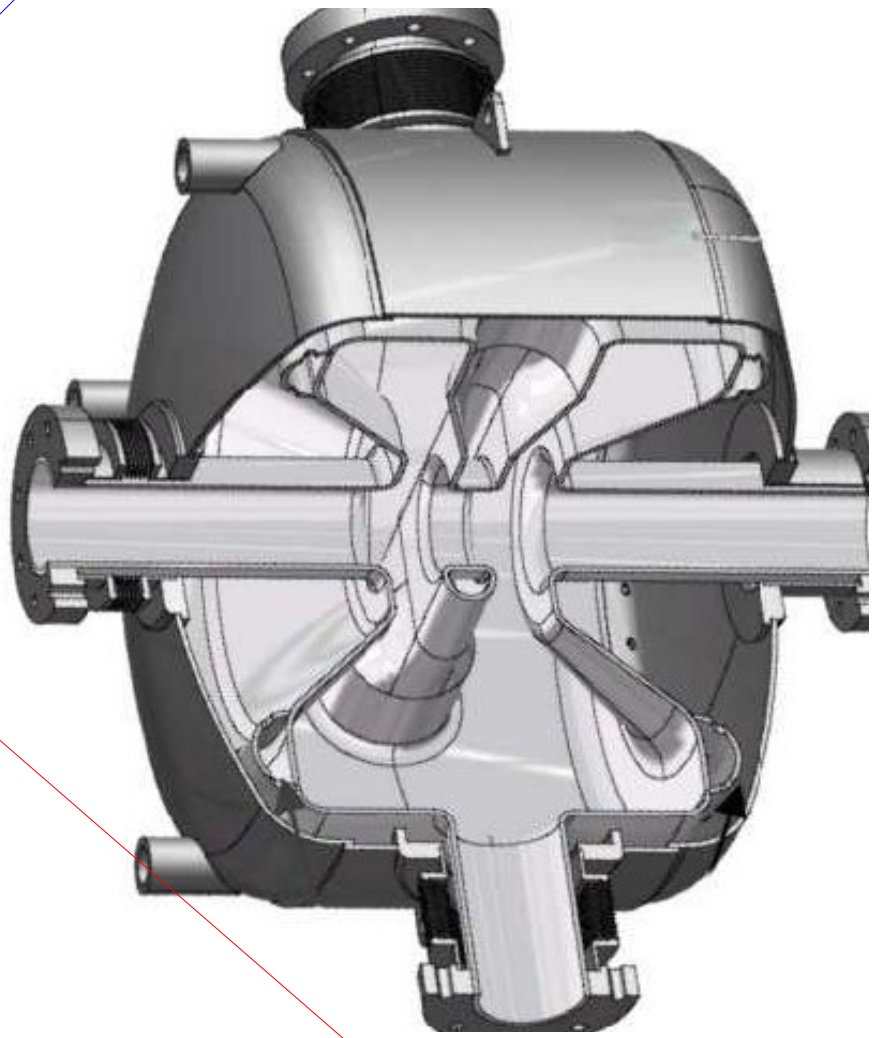
IADD, BARC
CDM, BARC
IUAC

IIFC Meeting, 27 February 2015, BARC

Spoke Resonators

Spoke resonators are TEM-type accelerating structures, derived from transmission lines.

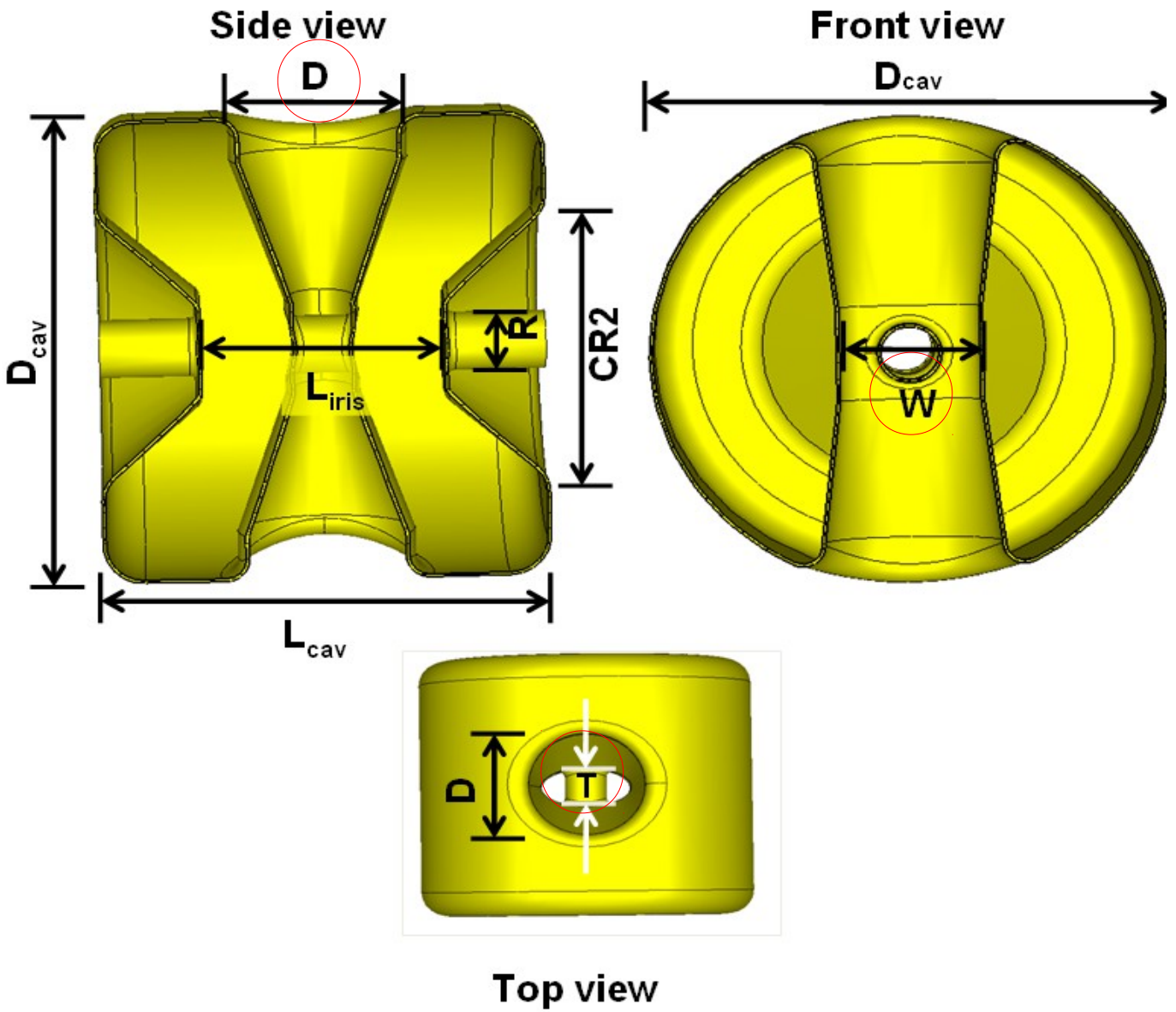




The electric field is maximum near the iris, and the magnetic field is maximum where the spoke meets the shell.

Geometrical parameters

Parameter	
Dcav	Cavity diameter
Lcav	Cavity length
D	Spoke upper diameter
R	Beam tube diameter
Liris	Distance between irise
CR2	Outer cone radius
W	Spoke lower ellipse semi-major axis
T	Spoke lower ellipse semi-minor axis



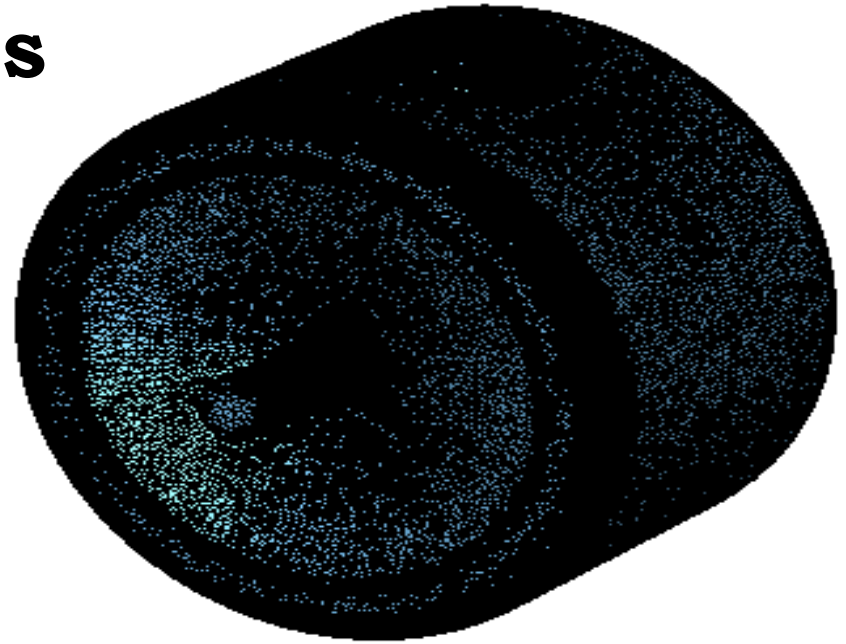
Design optimization

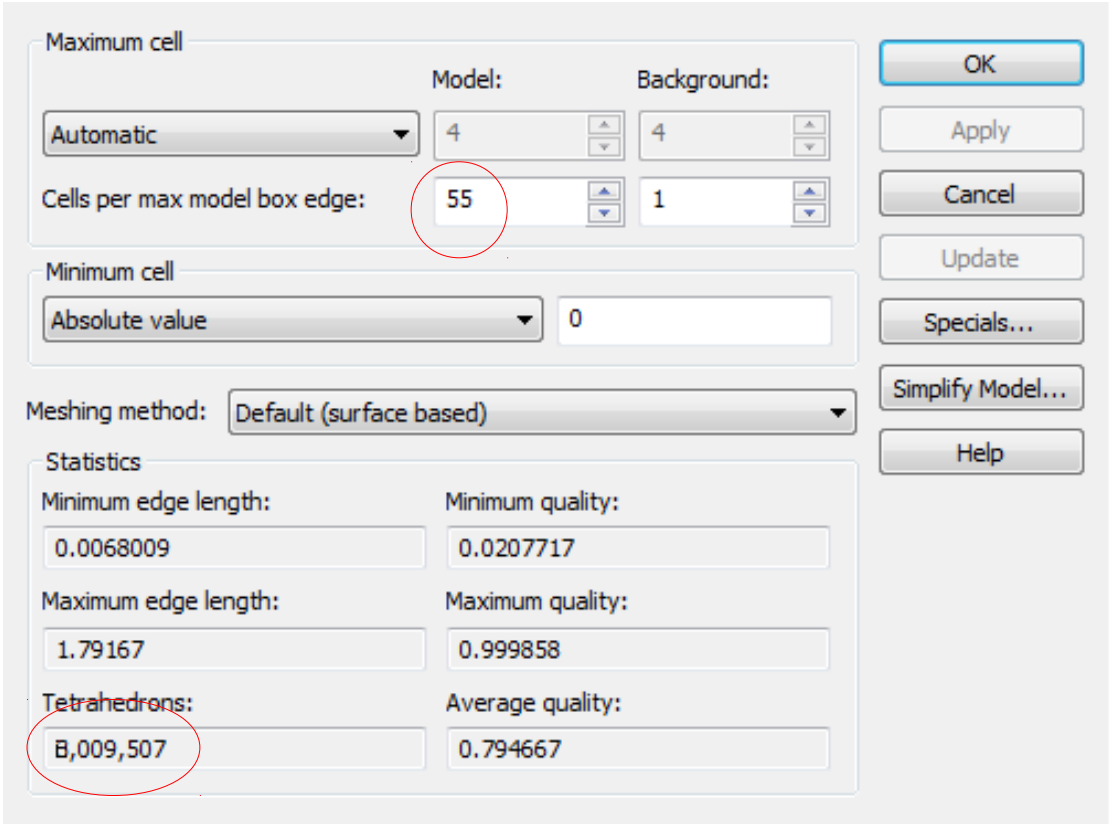
- The primary goal is to minimize the peak electric field and the peak magnetic field.
- Typically these are normalized to the accelerating field E_{acc}, so that optimization is of E_{pk}/E_{acc} and B_{pk}/E_{acc}
- E_{pk}/E_{acc} is optimized by varying the spoke cross-section at the centre.
- B_{pk}/E_{acc} is optimized by varying the spoke geometry at the equator.
- [Note that there is some ambiguity in the definition of E_{acc}]

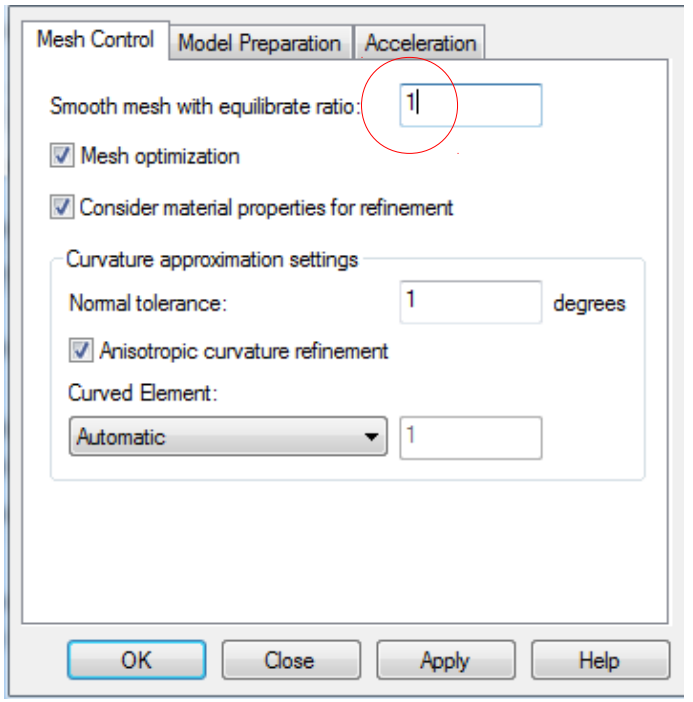
Global Mesh Properties

Simulations were done in Microwave Studio.

A fine mesh is essential to obtain a proper value for peak field values. Here we run the simulations with more 800,000 mesh points in one-fourth symmetry.

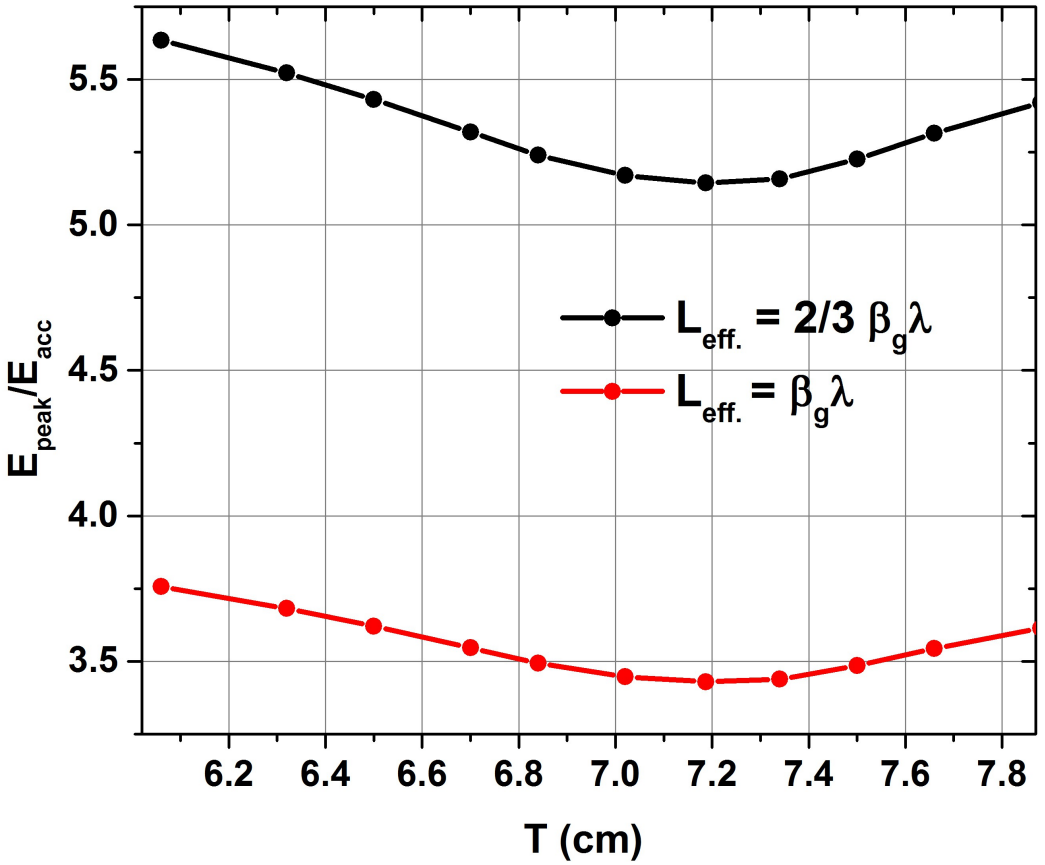


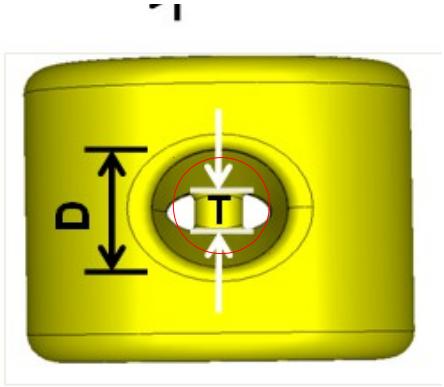




Optimizing the peak electric field

The peak electric field can be varied by changing the minor axis of the spoke lower ellipse, i.e. the thickness (T).



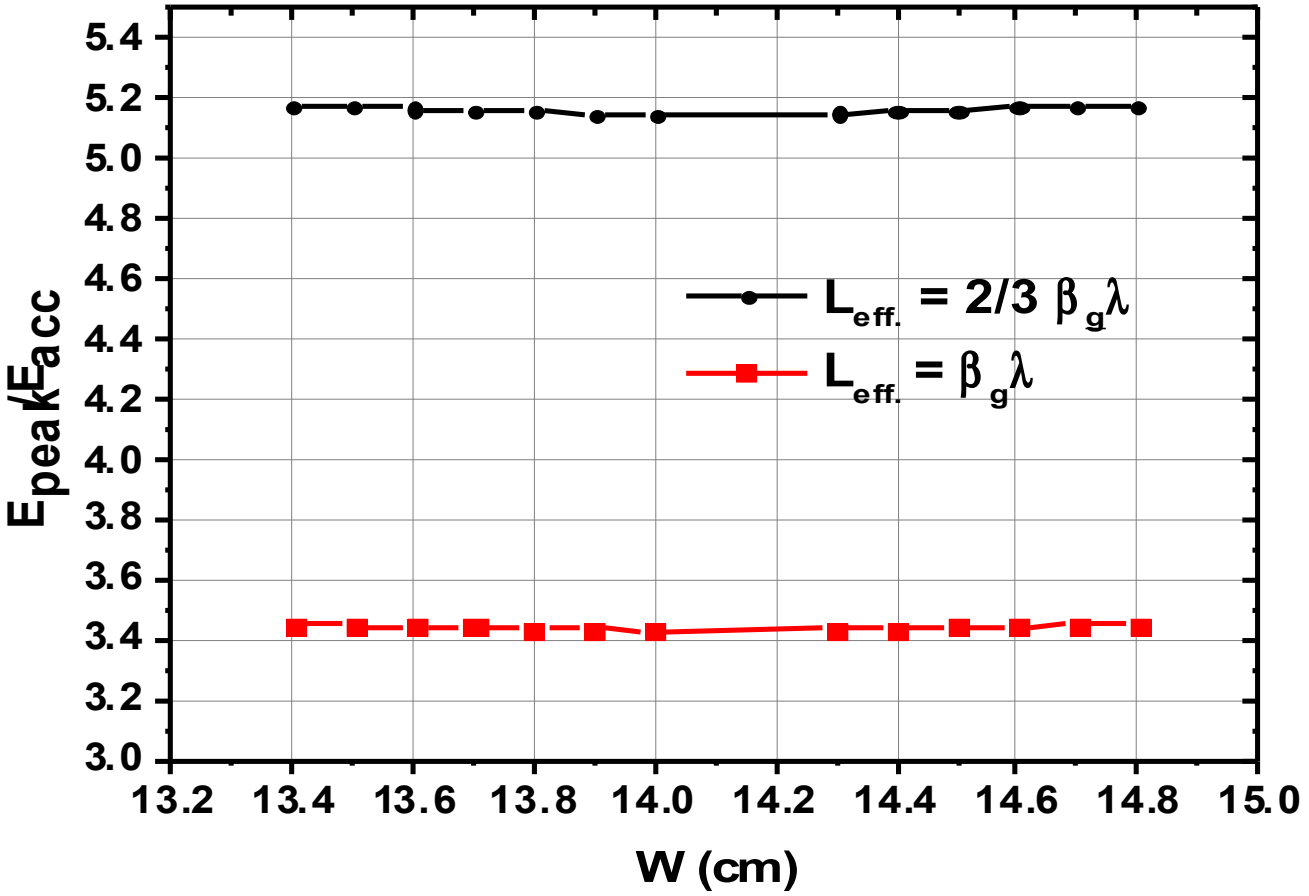


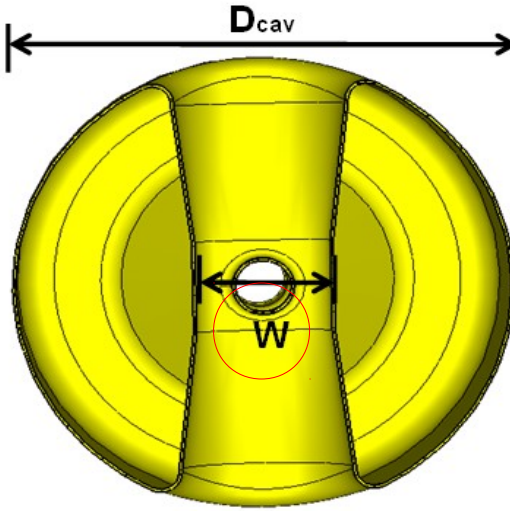
Top view

Optimal value of T is 71.6 mm.

Optimizing the peak electric field

The peak electric field can also be varied by changing the major axis of the spoke lower ellipse, i.e. the width (W).

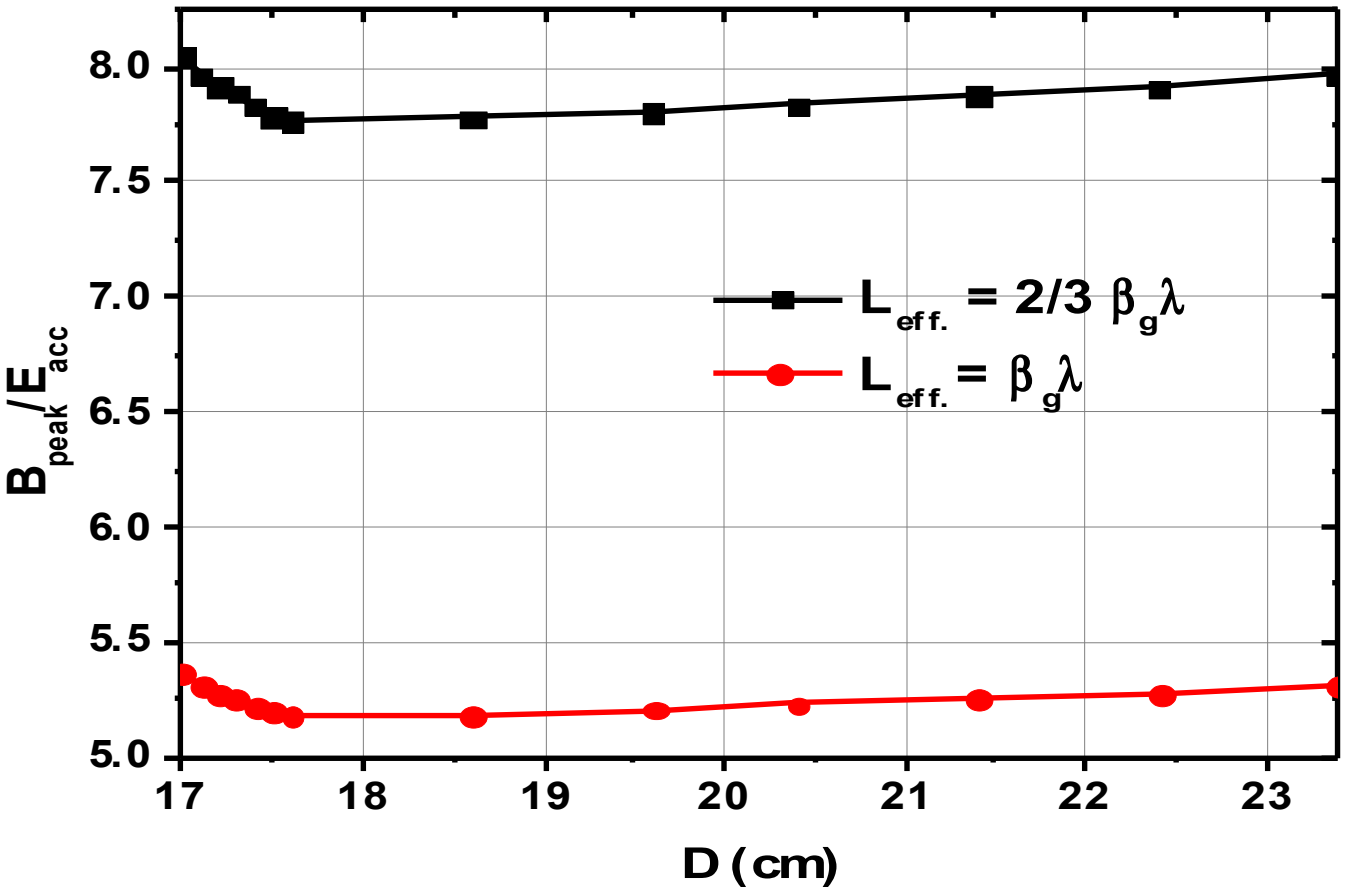


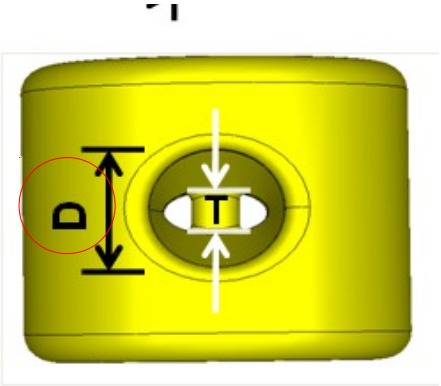


Optimal value of W is 140 mm.

Optimizing the peak magnetic field

The peak magnetic field can be varied by changing the upper diameter of the spoke (D).

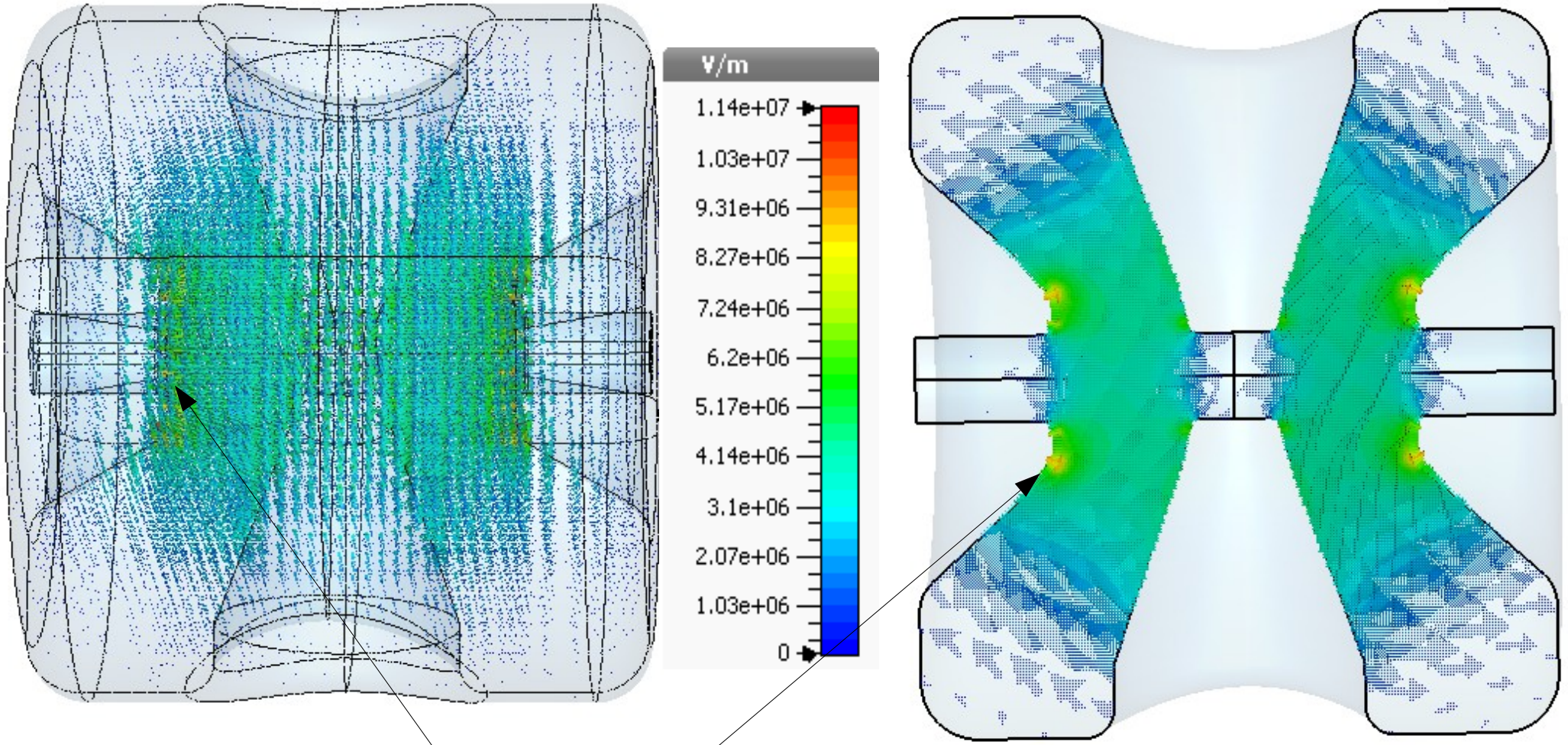




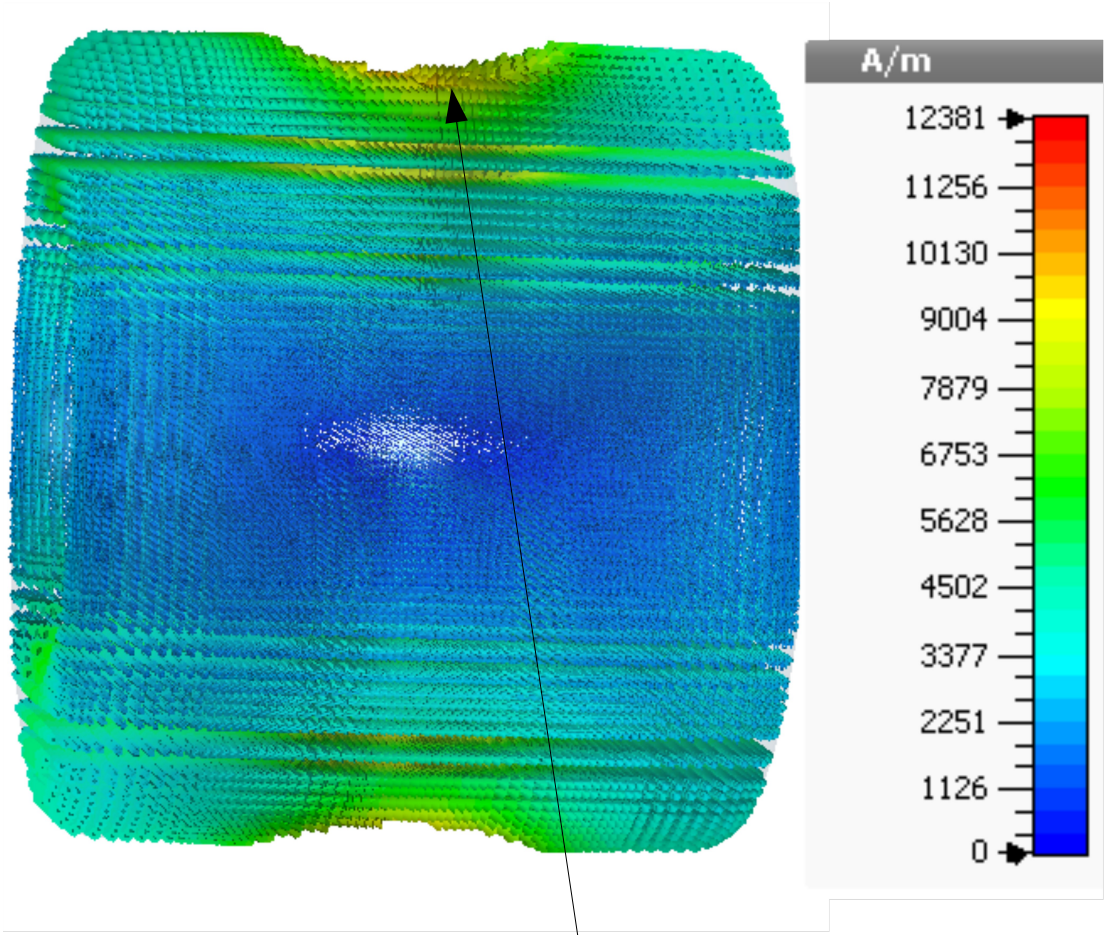
Top view

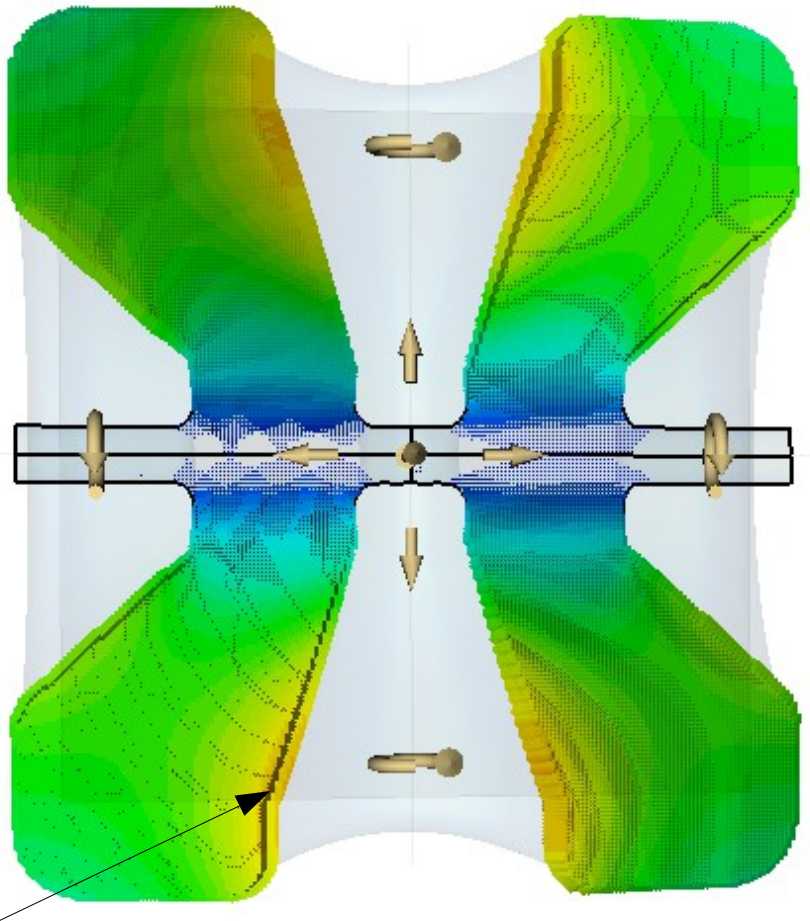
Optimal value of D is 176 mm.

Electric field distribution



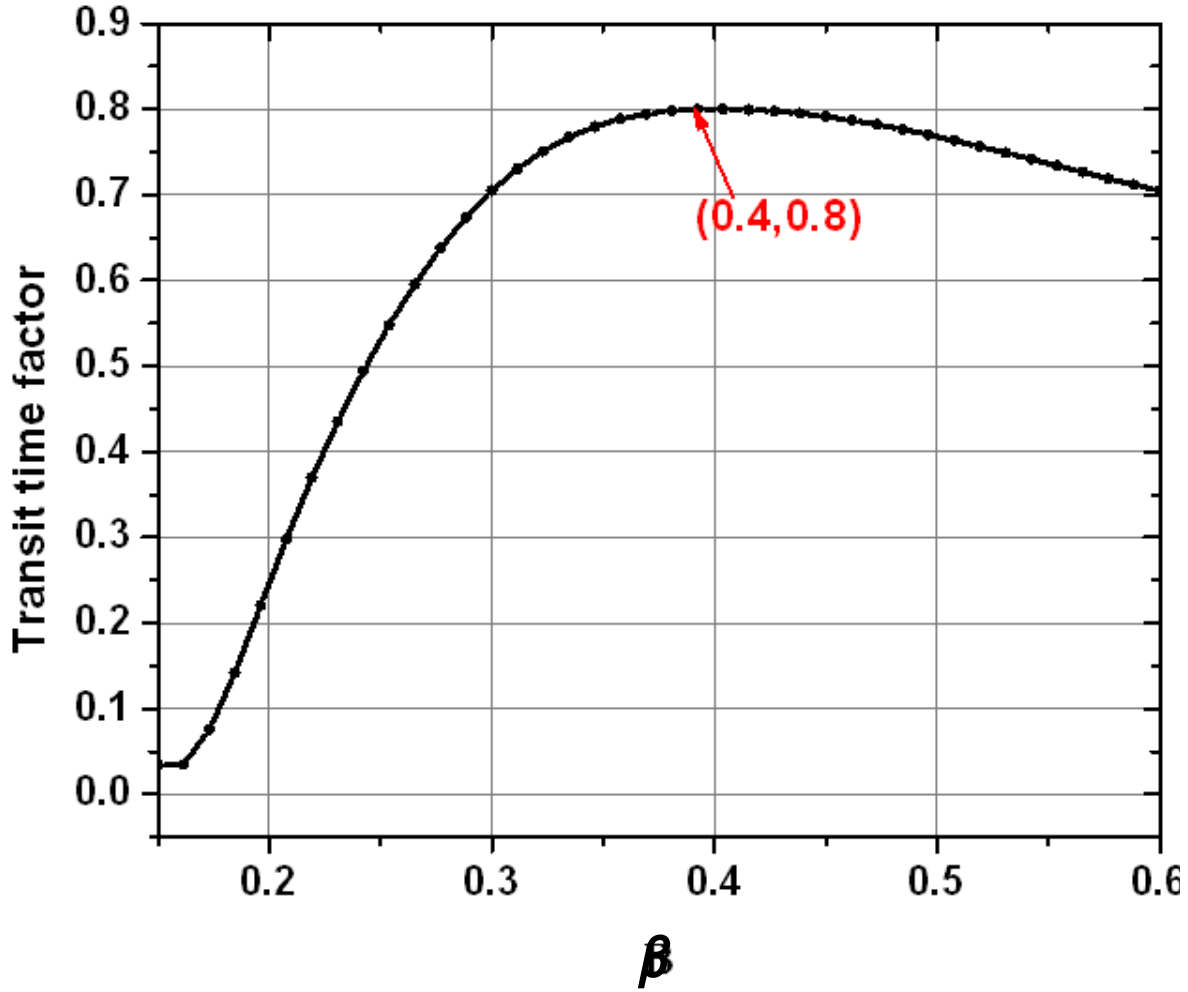
Magnetic field distribution





Peak magnetic field

Variation of transit-time factor with β



Final parameters

Parameter	Value	Unit
Frequency	325	MHz
Beta	0.4	
Aperture	60	mm
Spoke thickness (T)	71.6	mm
Spoke width (W)	140	mm
Spoke upper diameter (D)	176	mm
Cavity diameter (D_{cav})	503.9	mm
Cavity length (L_{cav})	446.2	mm
R/Q	268	Ω
E_p/E_{acc}	3.43	
B_p/E_{acc}	5.17	mT/(MV/m)

(Assumes $L_{eff} = \beta\lambda$)

Fermilab design:

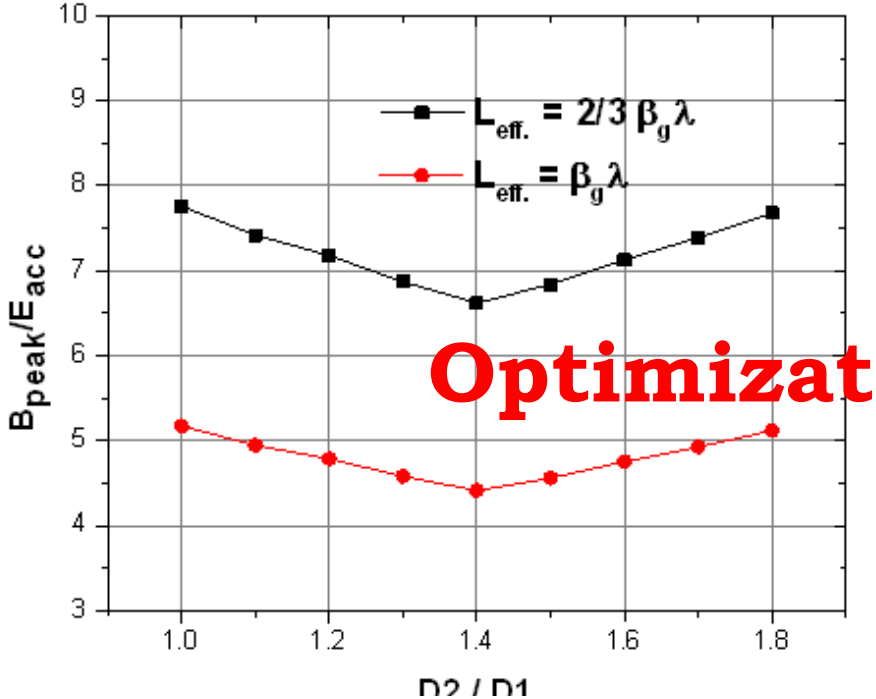
275 Ω

3.53

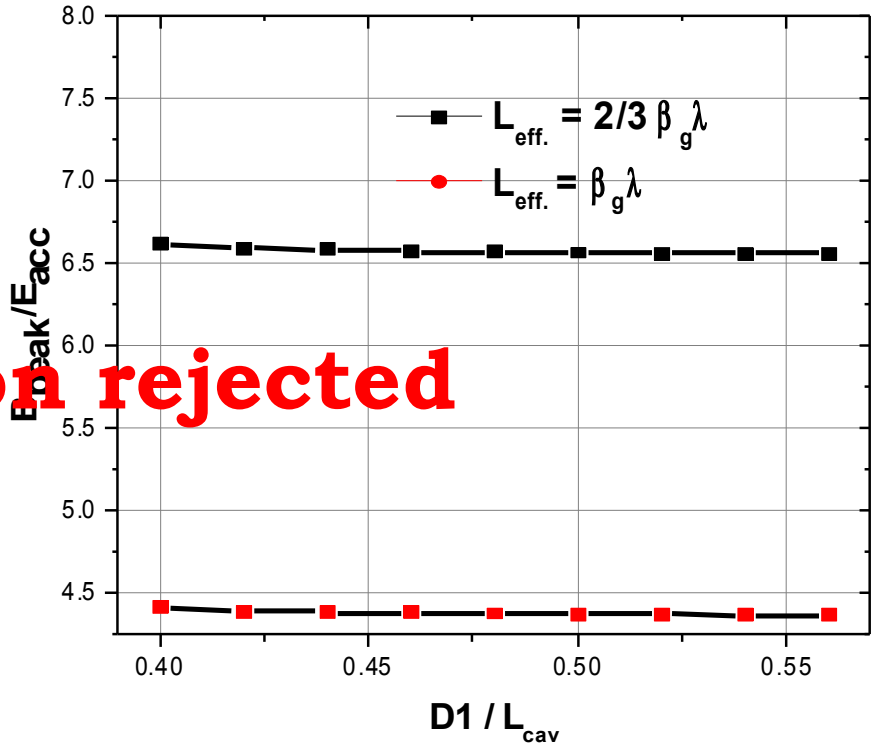
6.25

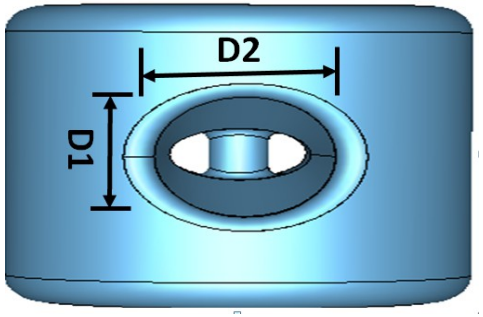
Further optimizing the peak magnetic field

The upper spoke cross-section can be made elliptic. Then the peak magnetic field can be optimized by varying the ratio of the ellipse parameters, and in addition by changing the ratio of D1 and cavity length.



Optimization rejected





For D2/D1 optimization, B_{pk}/E_{acc} reduces from 5.17 to 4.41. **However, R/Q decreases from 268 to 247.**

For D1/Lcav optimization, B_{pk}/E_{acc} reduces to 4.37, **but R/Q reduces further to 238.**

Further design issues

- More detailed optimization of cavity geometry (updated value of β_G; include other parameters in optimization)
- Higher-order modes (though not expected to be an issue)
- Study of multipacting
- Structural analysis: microphonics and Lorentz detuning (MWS)
- Thermal analysis (MWS)

SSR2 Development

Will Fermilab provide:

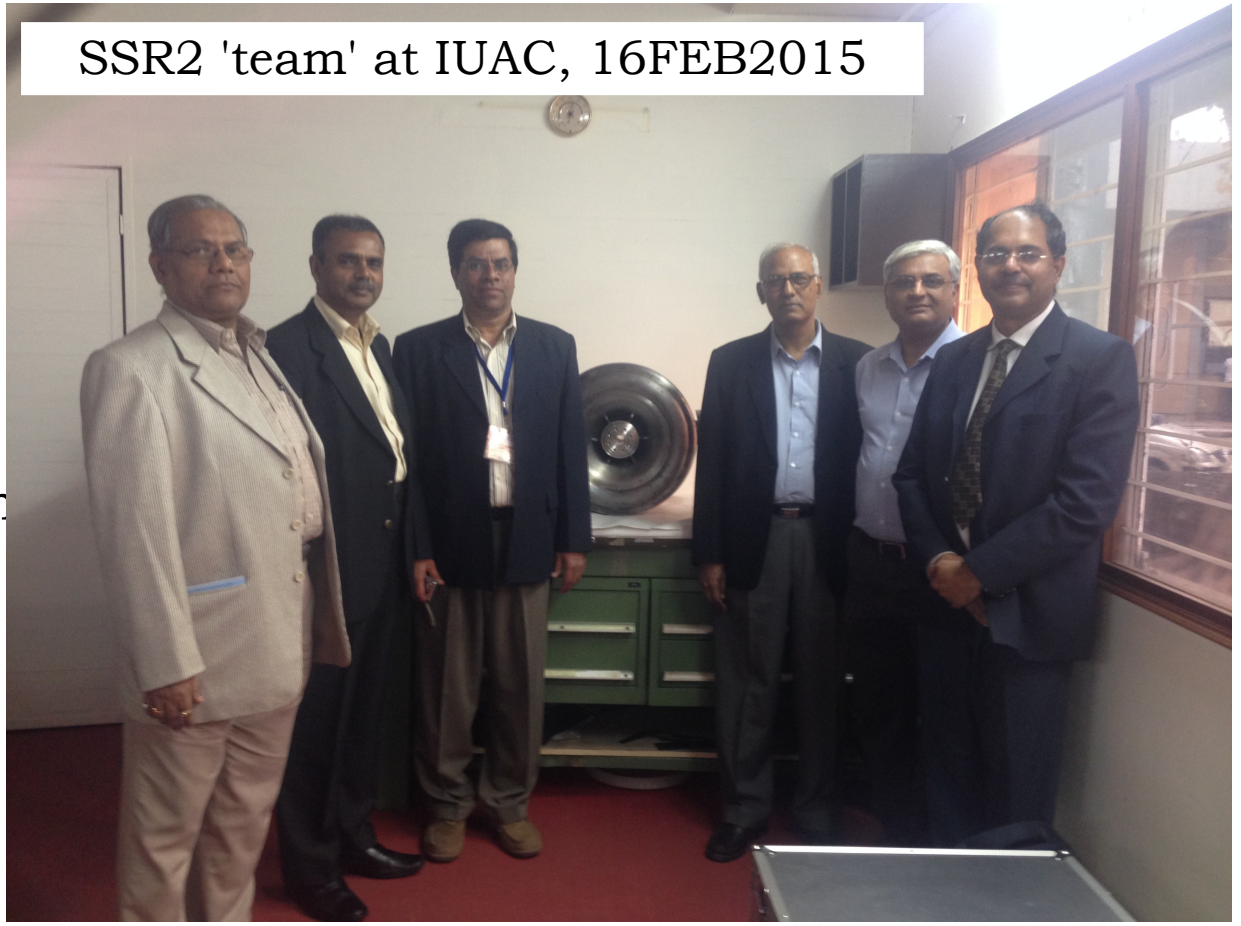
- Material? [Huge impact on schedule]
- Drawings?

- Engineering design and preliminary development can be done by CDM – extensive facilities which we have visited yesterday
- Will need external resources (at least immediately) for EBW
- For production will need industry partners

BATL (Trivandrum)

- BrahMos Aerospace Thiruvananthapuram Limited (BATL) is a public limited company under the Defense Research and Development Organization (DRDO).

- BATL has facilities for:
  - Sheet metal forming
  - Machining
  - Electron Beam Weldir
  - Vacuum Brazing
  - Electro-polishing



They have built one (400 keV) RFQ for BARC and are building another (3 MeV).

Electron Beam Welding at BATL

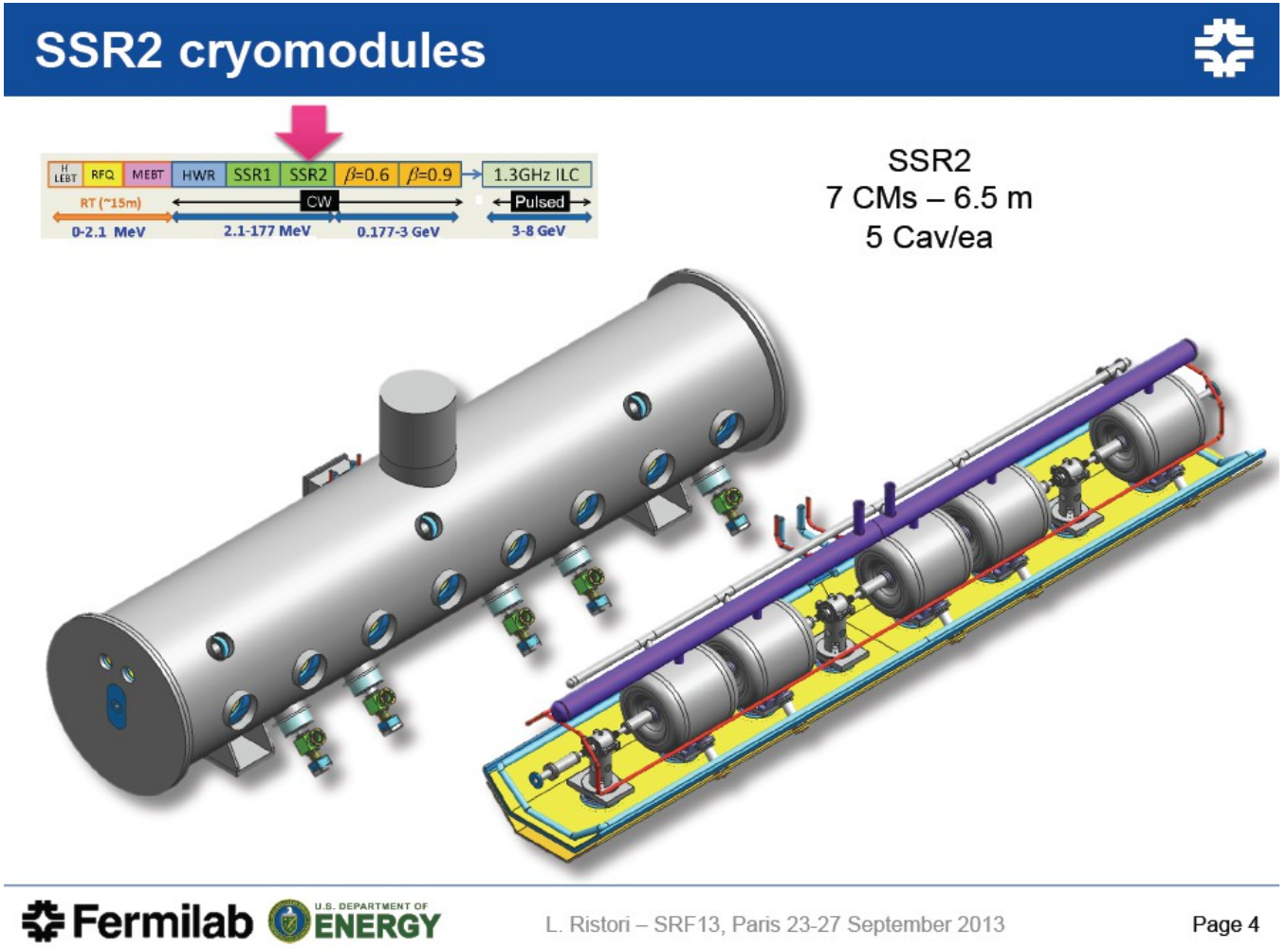
- 60 kV, 30 kW machine (from EO Paton, Ukraine)
- chamber size: 1.5 x 1.5 x 2.5 m^3

- 60 kV, 8 kW machine
- chamber size: 0.64 x 0.64 x 0.64m^3

Road forward for cavity fabrication

- If needed, detailed physics design can be done by IADD, BARC (being done anyway)
- If needed, engineering drawings can be developed by CDM, BARC
- An enormous amount of experience has been gained at IUAC in the SSR1 development, which can be utilized in the SSR2 (engineering processes, fixturing, criticality, etc.)
- Initially, most fabrication processes can be done at CDM, in consultation and collaboration with IUAC
- EBW can be done at BATL
- If many SSR2 structures are needed (how many?), the entire technology can be transferred to industry partners (need to look for more)

Cryomodule



- So far, no detailed discussions have taken place. Needs discussion
- CDM has developed some experience through CMTS, and can participate in the development of SSR2 cryomodule fabrication and welding.

Inputs needed from Fermilab

- Will SSR2 design be provided, or does it need to be designed?
  No design details in the PX Reference Design of June 2013

- Ditto engineering drawings.
  They were provided to IUAC for SSR1.

- Will niobium material be provided?
  Was provided for SSR1. If yes, will need to factor in some contingency for R&D (not done for SSR1). If no, will have significant impact on the schedule.

- Need information on niobium to SS braze.
  For SSR1 this component was provided by Fermilab.

- Need clarity on number of SSR2s (and cryomodules) needed.
  Important implications for execution model.

Thoughts on schedule

- When will depend on how many
- Even for one, will depend on drawings and material
- Experience with SSR1 at IUAC suggests that initial development will take time – there is a learning curve
- This issue is best revisited after greater clarity on the issues that have been raised, and after more internal discussions

Thank you