Preliminary consideration of perpendicularly biased Booster cavity. V.2

Gennady Romanov

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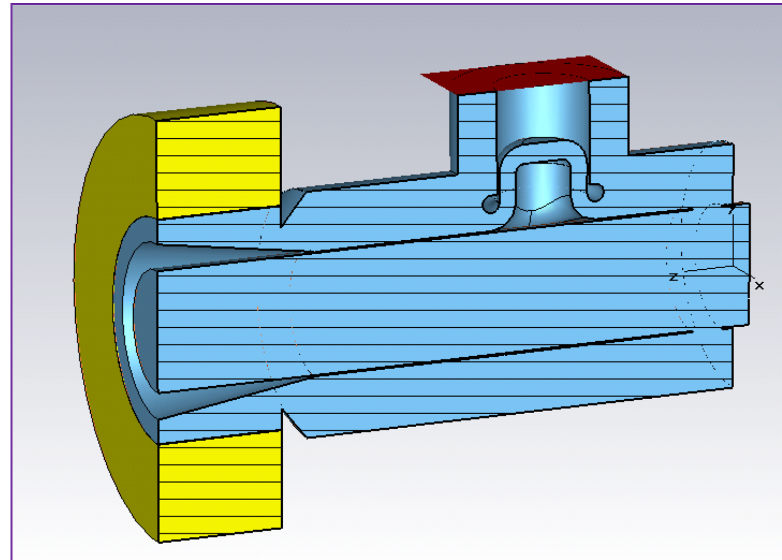
TRIUMF cavity model.

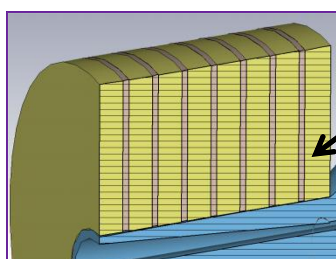
	TRIUMF Booster
Min Frequency (MHz)	46.1
Max Frequency (MHz)	60.8
Peak RF at Gap (kV)	62.5
Accelerating Time (ms)	10
Repetition Rate (Hz)	50
Max RF df/dt (MHz/ms)	3.5
Max Bias di/dt (A/ms)	311
Max df/di (MHz/A)	0.03
Min Bias (AT)	8640
Max Bias (AT)	31200
Min H internal (AT/m)	19469
Max H internal (AT/m)	119292
Min H_{RF} (A/m)	358
Max H_{RF} (A/m)	656
Ferrite Material	TT-G810
Min μ(rf) of Ferrite	1.48
Max μ(rf) of Ferrite	3.94
Pk power density (W/cc)	0.50
Avg power density (W/cc)	0.06
Cavity Q	2200-3600
Cavity R/Q	35

ΔF =14.7 MHz or 32% relatively to the lowest frequency

CST model of the cavity based on the drawings.

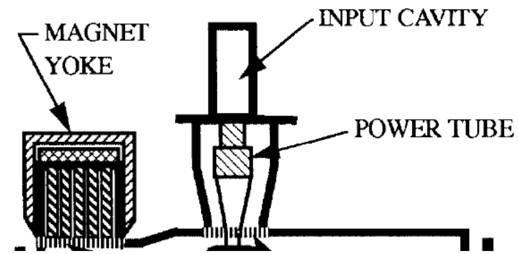


Length from flange to flange	1009.55 mm
Beam pipe radius	76.2 mm
Inner radius of ferrite ring	160 mm
Outer radius of ferrite ring	300 mm
Length of ferrite stack	184.15 mm
Thickness of ferrite ring	25.4 mm
Thickness of beryllia spacer	6.35 mm

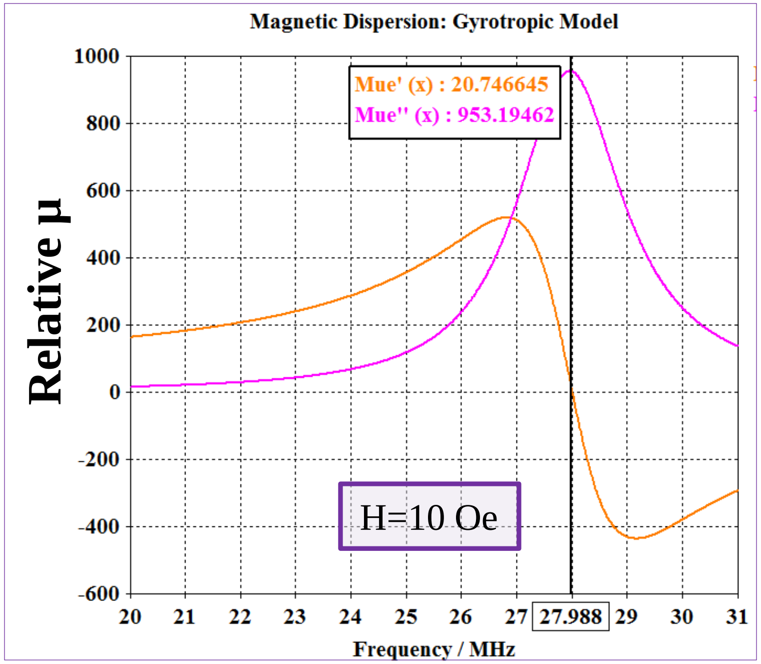


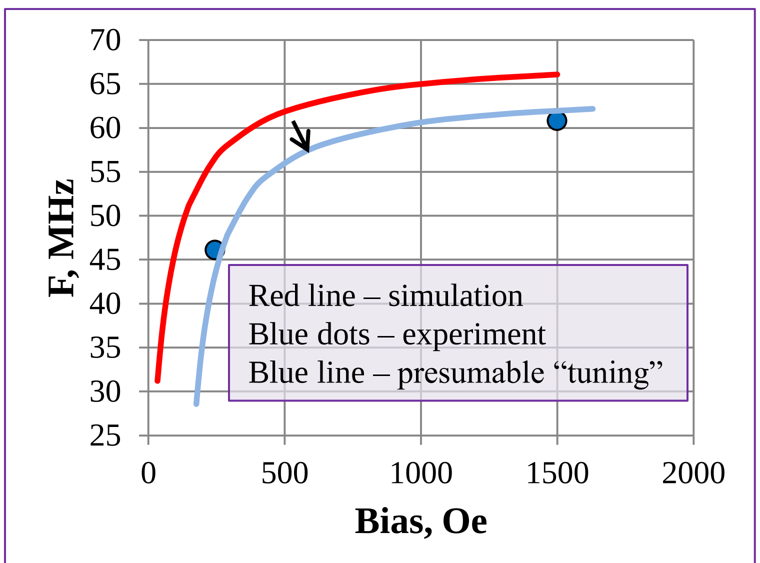
BeO rings

Omitted features



TRIUMF cavity simulation





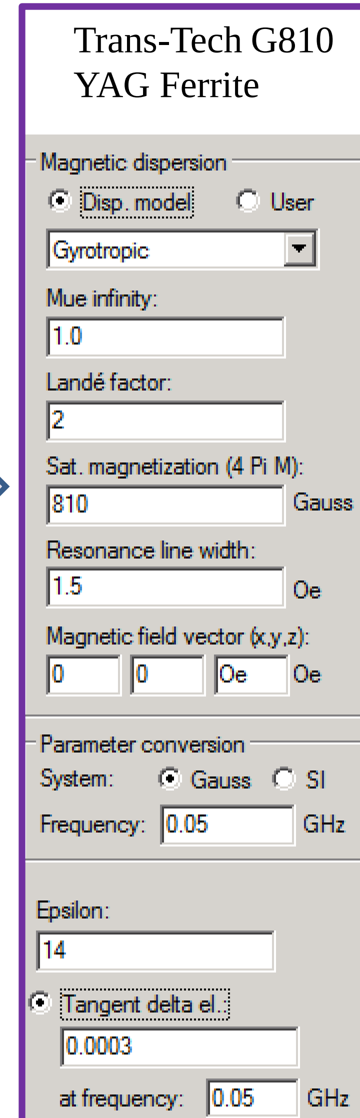
$$\tan\delta = \mu'' / \mu'$$

F_{res}[MHz]=2.8×H[Oe]

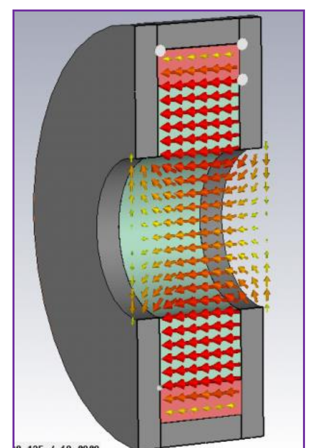
H[Oe]=4πH[A/m]/1000

Three ways to take ferrite into account:

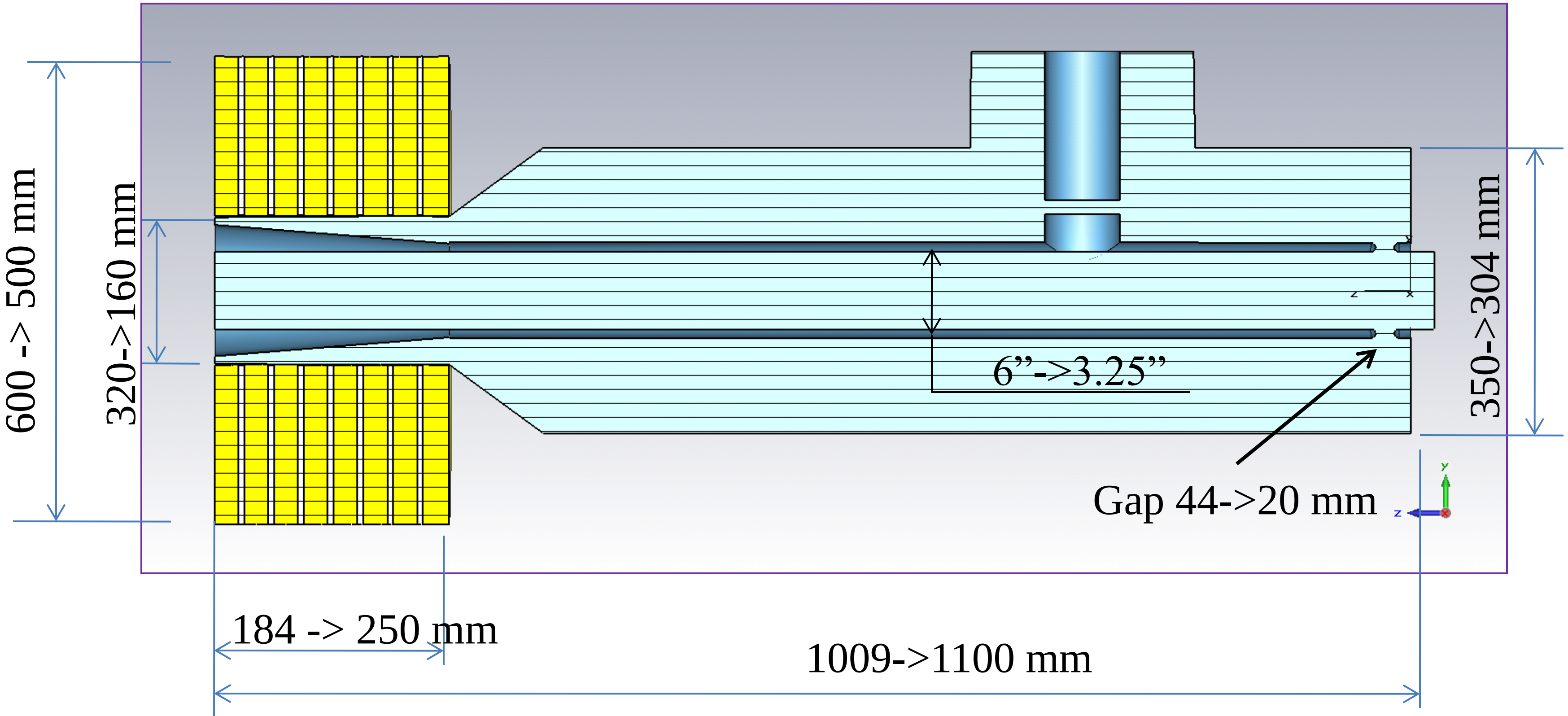
1) Constant μ of material – good to find frequency range
2) Uniform magnetic field – frequency, dispersion, losses
3) Non-uniform magnetic field – "real" magnetization, magnetic losses, eddy current, transient (requires addition LF solver)



CST model of ferrite tuner



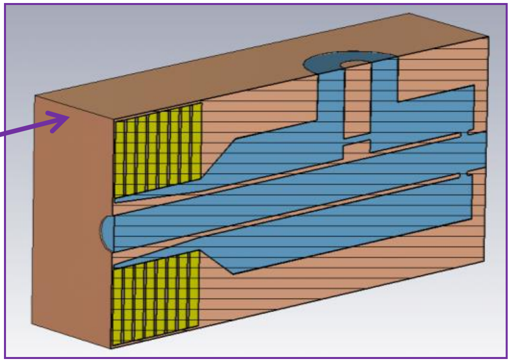
Booster cavity model



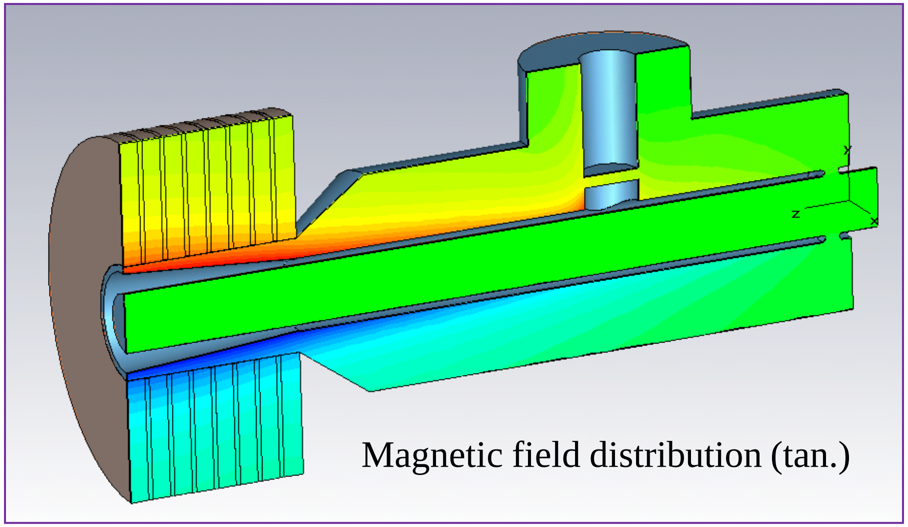
Main parameters:

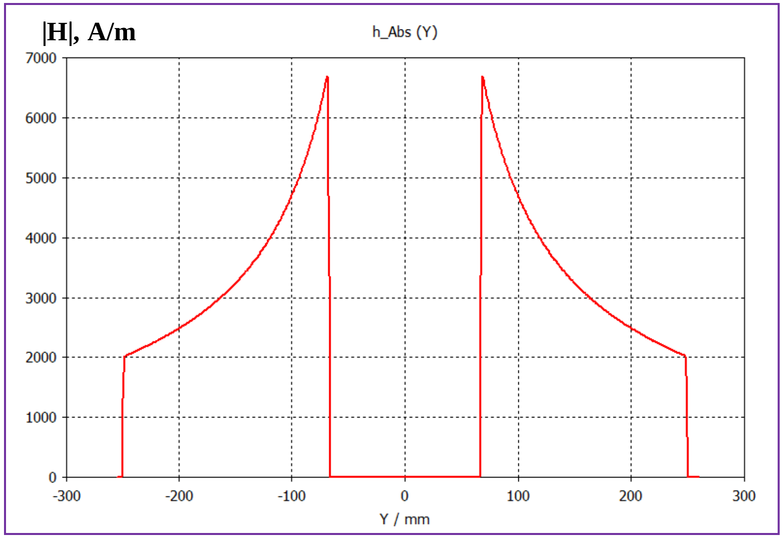
Frequency range -	37.8÷53 MHz
Aperture -	3.25”
Voltage -	60 kV
Rep.rate -	15 Hz

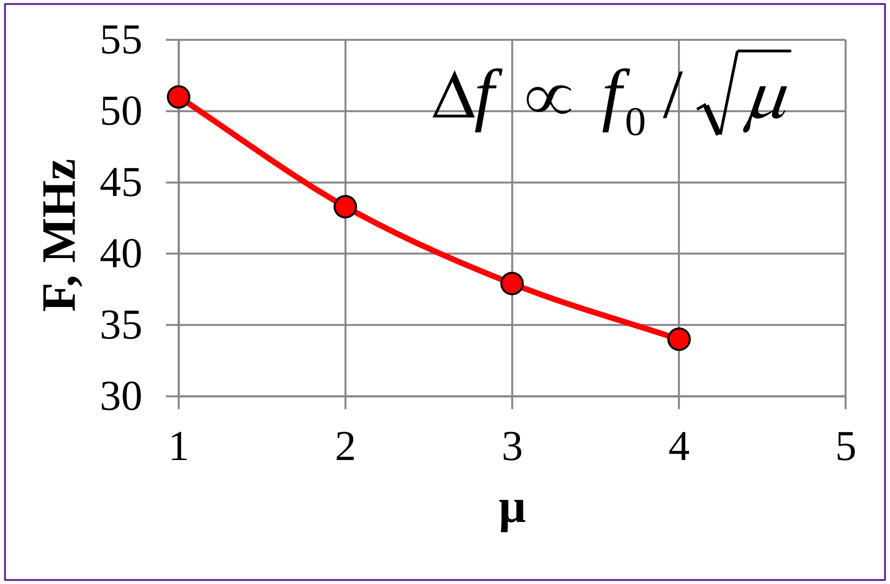
RF volume is inserted in the copper block, since conducting walls are needed for RF losses and thermal calculations.



Booster cavity model. Uniform μ.

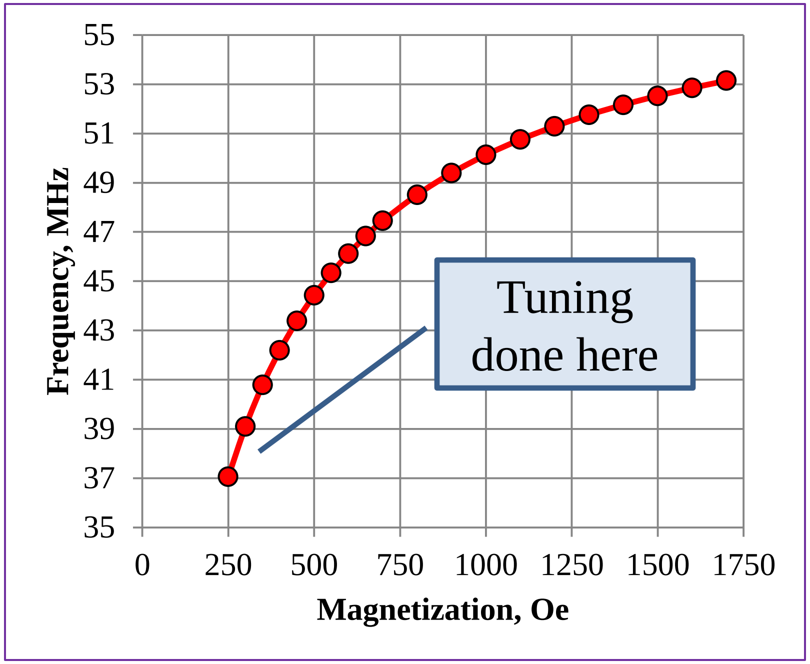


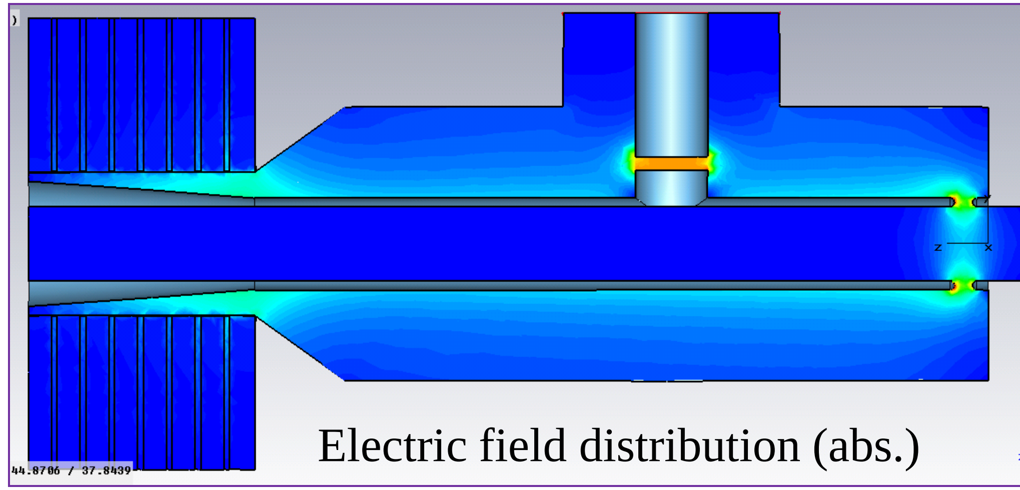




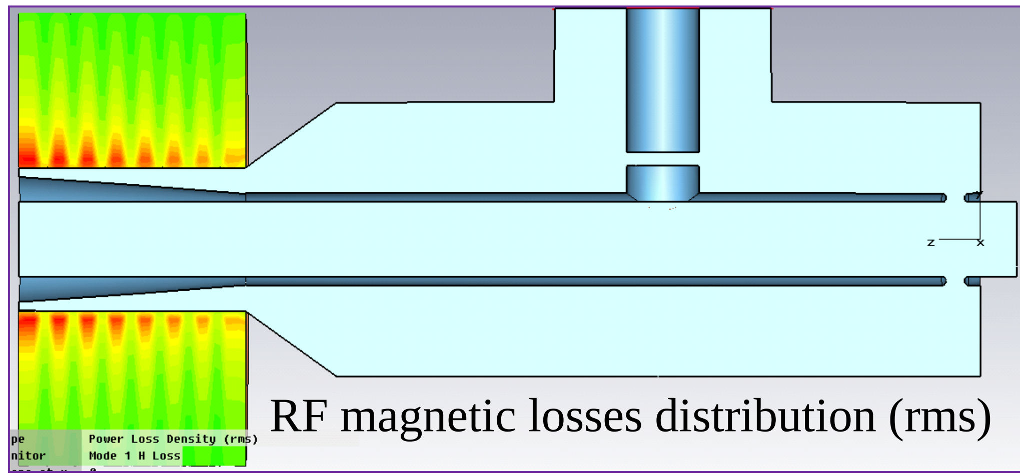
Required tuning range is ΔF =15.2 MHz or 40% relatively to the lowest frequency, more than for TRIUMF cavity. At the same time **the effec-tiveness of the tuner is lower.** To compensate that the length of ferrite stack has been increased. With the length of ferrite stack of 250 mm the required frequency interval can be covered. But non-uni-form RF magnetic field in the ferrite means non-uniform permeability which makes tuning less effective. So, may be even longer ferrite stack or larger excursion of the magnetizing field would be required .

Booster cavity model. Uniform magnetic field.





Electric field distribution (abs.)



RF magnetic losses distribution (rms)

Set magnetic field at low level that still provides acceptable losses and tune cavity to 37.8 MHz

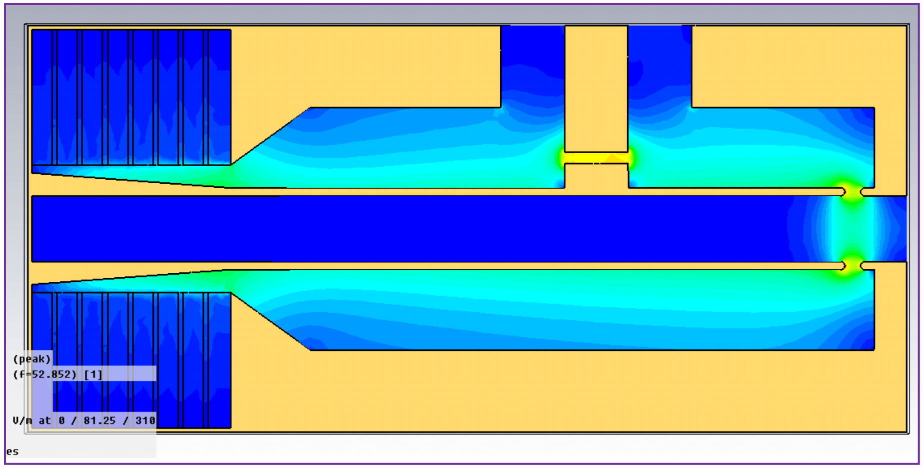
Or

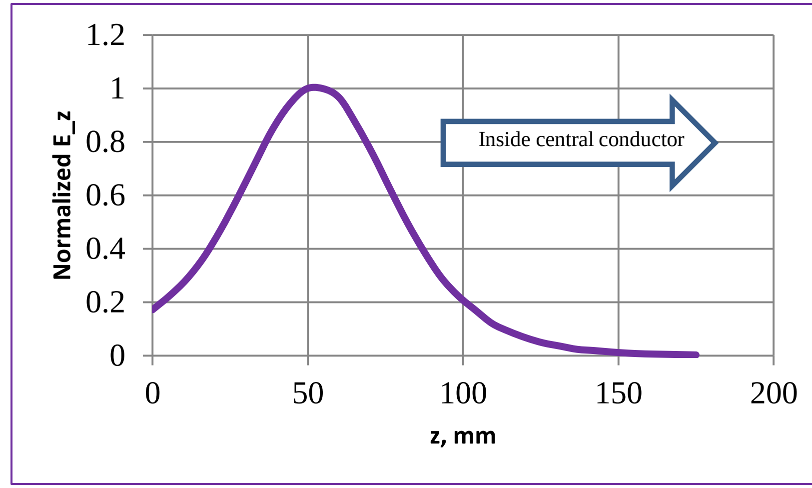
Set magnetic field at maximum acceptable level and tune cavity to 53 MHz

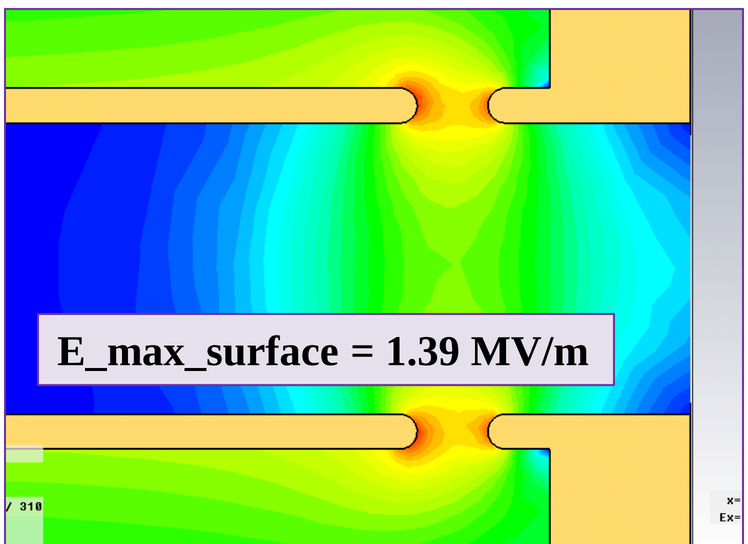
Reasonably longer ferrite stack and reasonably bigger magnetic field excursion can provide required tuning range. But final conclusion on the design feasibility can be done only after thermal analyses.

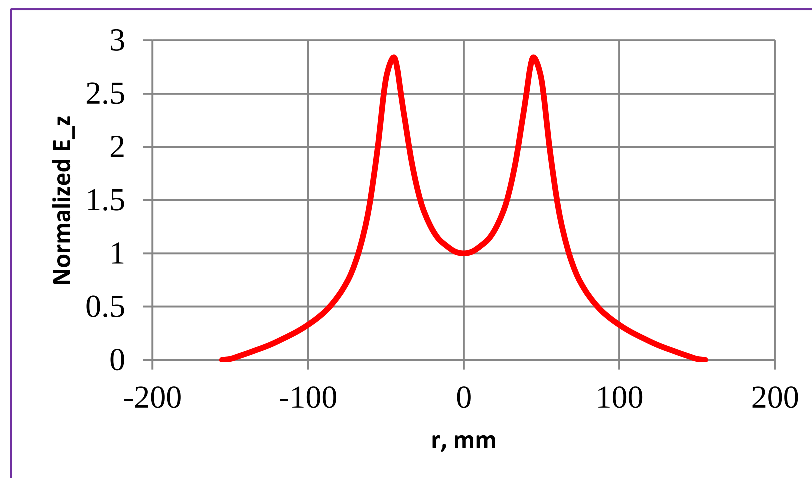
Accelerating field

V = 60 kV

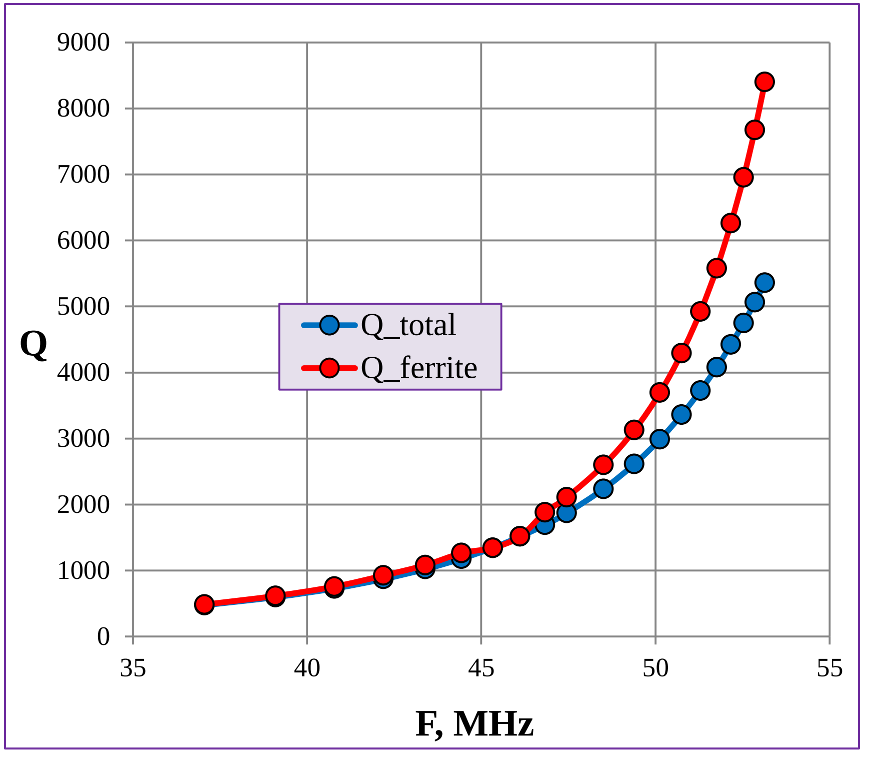


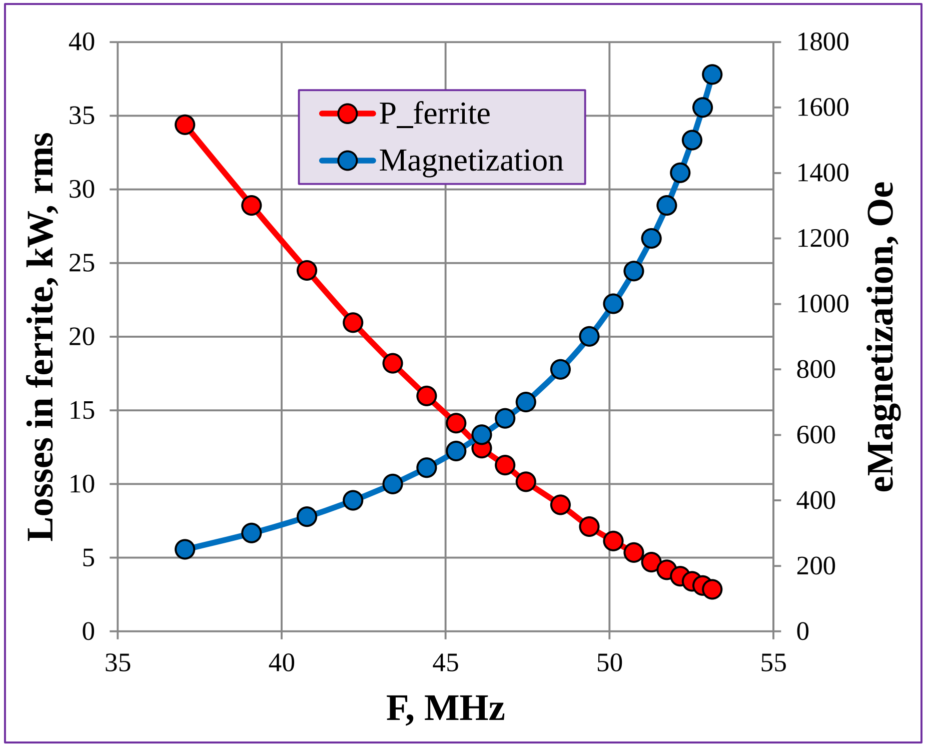






Q factors and losses

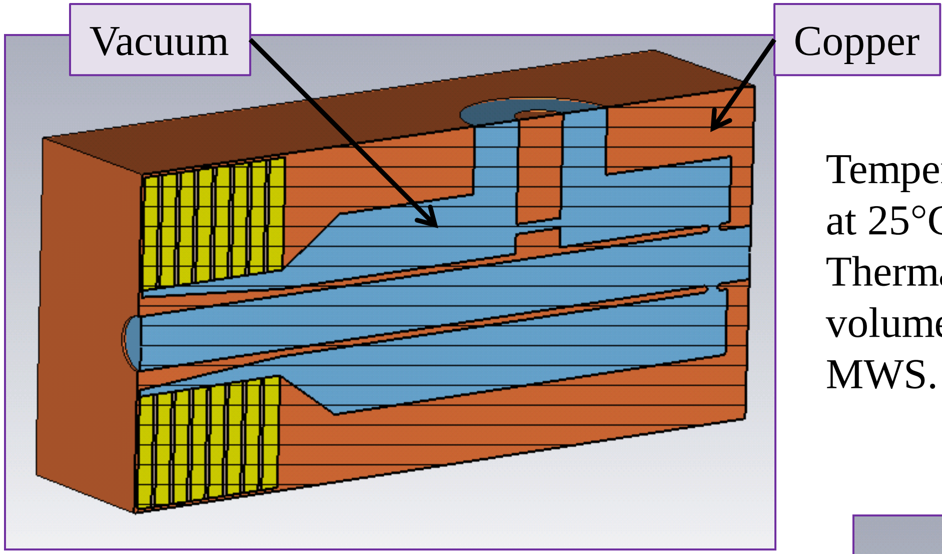




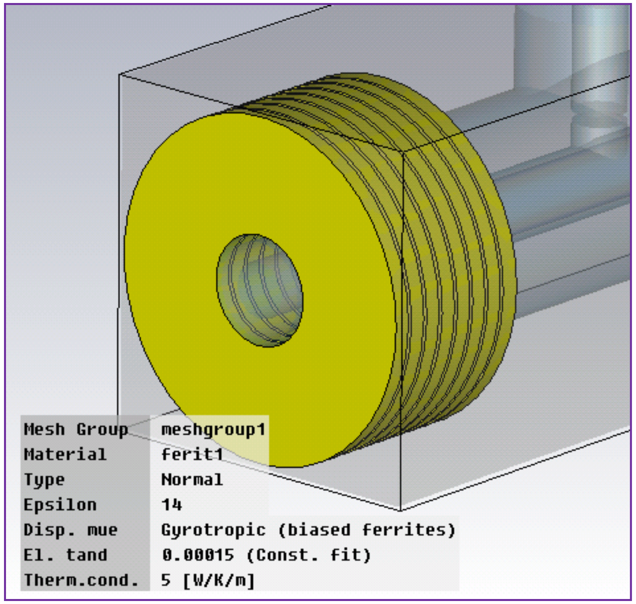
Q_total

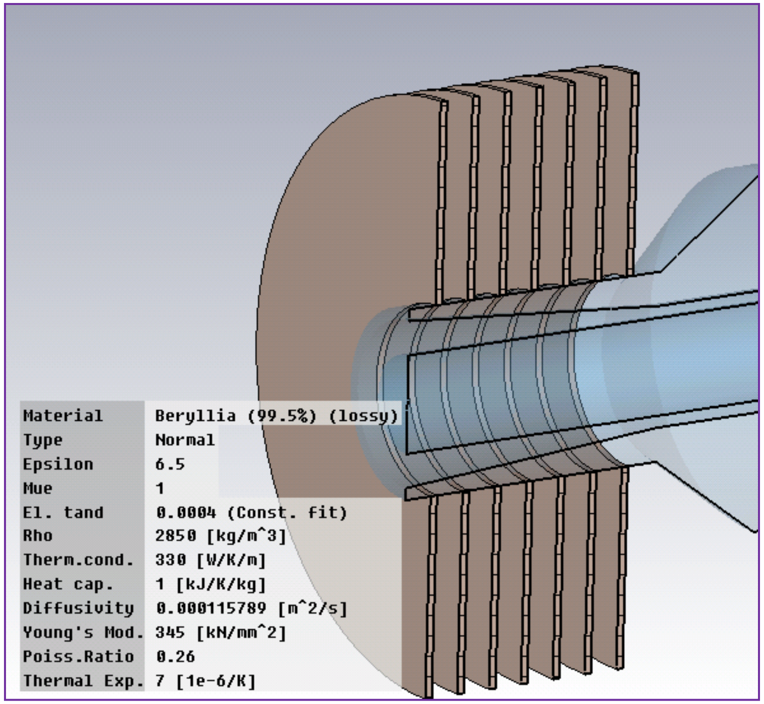
TRIUMF (46-61 MHz)	TRIUMF (37-53 MHz)	Parallel	Perpendicular
2200 - 3600	200 - 2000	300-1250	475 - 5360
TRIUMF paper	Booster_V4.1.pdf	J. Reid talk	Simulations

Thermal model

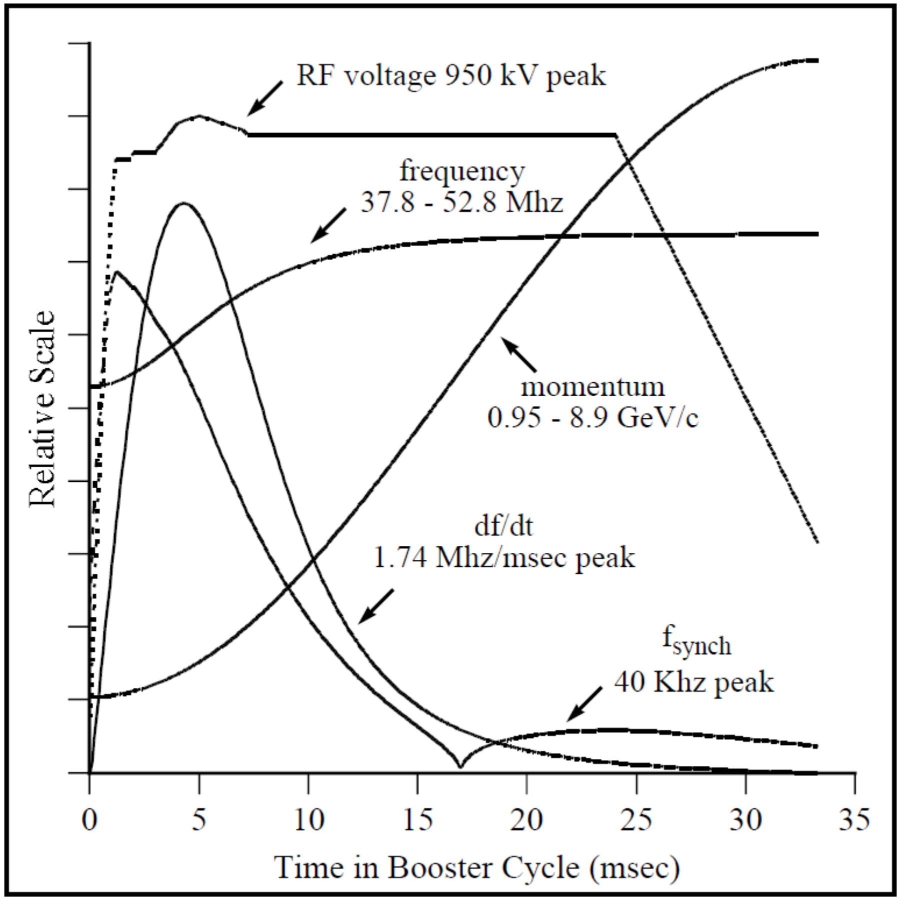


Temperature on the copper block surface is fixed at 25°C (isothermal boundary conditions). Thermal losses distributions – surface and volume – are imported in CST MPS from CST MWS.





Thermal losses

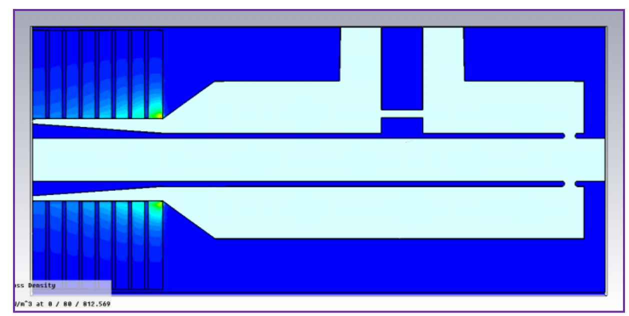


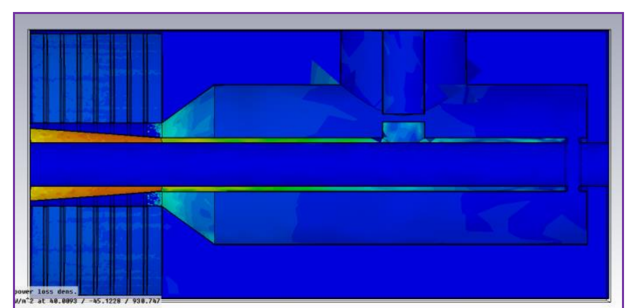
FERMILAB BOOSTER LOW LEVEL RF SYSTEM UPGRADES
Robert C. Webber

Assuming linear variation of frequency in time average RF magnetic losses in ferrite are 18 kW (for V=60 kV). Actually they are less than that, since 2/3 of cycle is in low losses range.

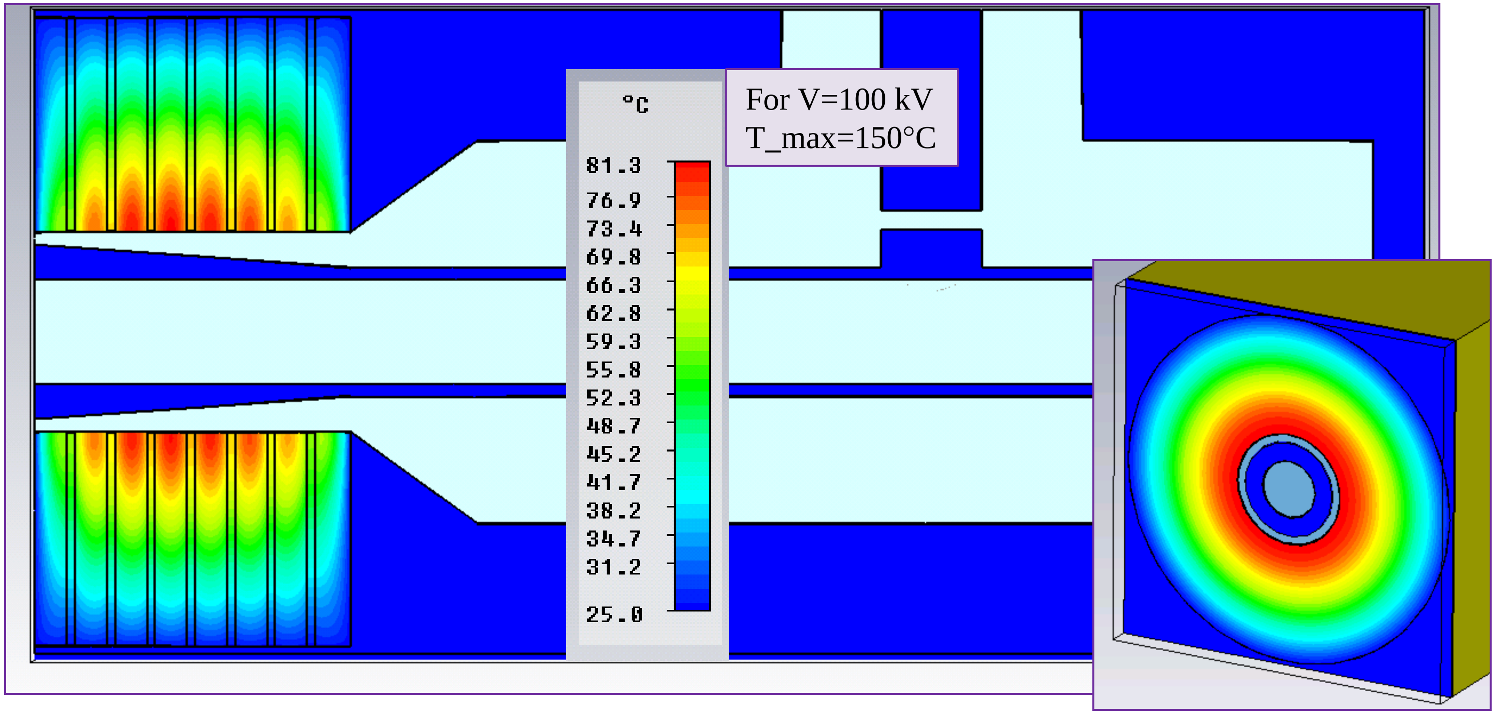
Taking into account duty factor (repetion rate 15 Hz, cycle 30 msec) thermal losses in ferrite are 9 kW.

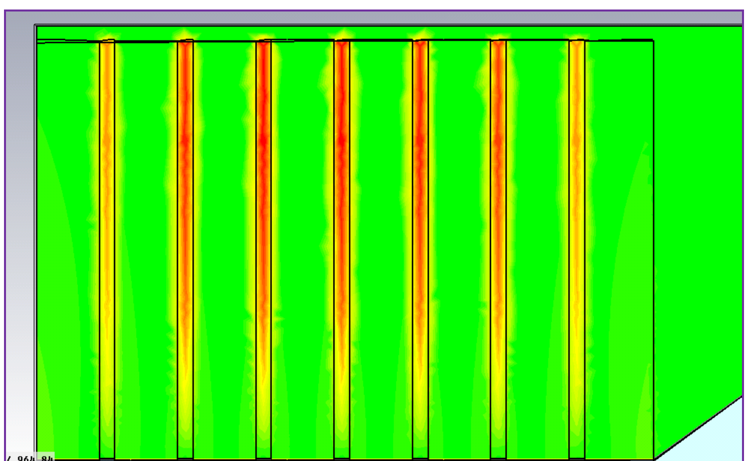
Electric volume losses and magnetic surface losses are also taken into account



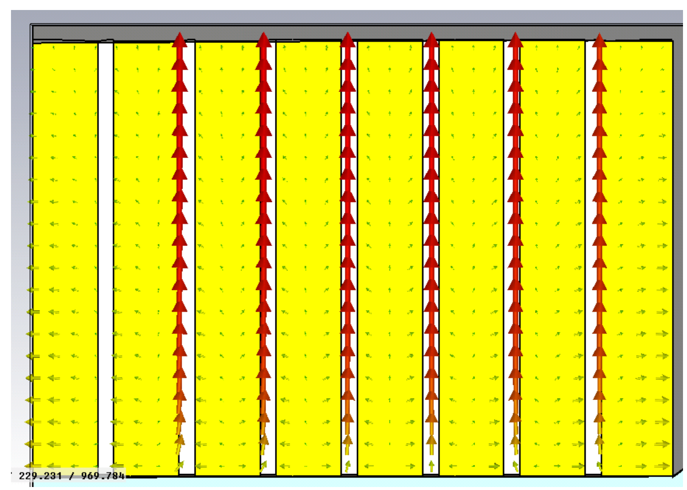


Temperature distribution





Heat density flow



Heat flow direction

Next:

- Repeat parametric study to increase ferrite tuner efficiency.
- Develop and study realistic cooling scheme.

Low priority:

- Build cavity model with power tube, optimize cavity and power coupler
- Evaluate solenoid parameters, make a preliminary design (Kashikhin?),
- Build solenoid model, estimate impact of non-uniform magnetization