PIP-I

2nd harmonic RF perpendicular biased cavity update

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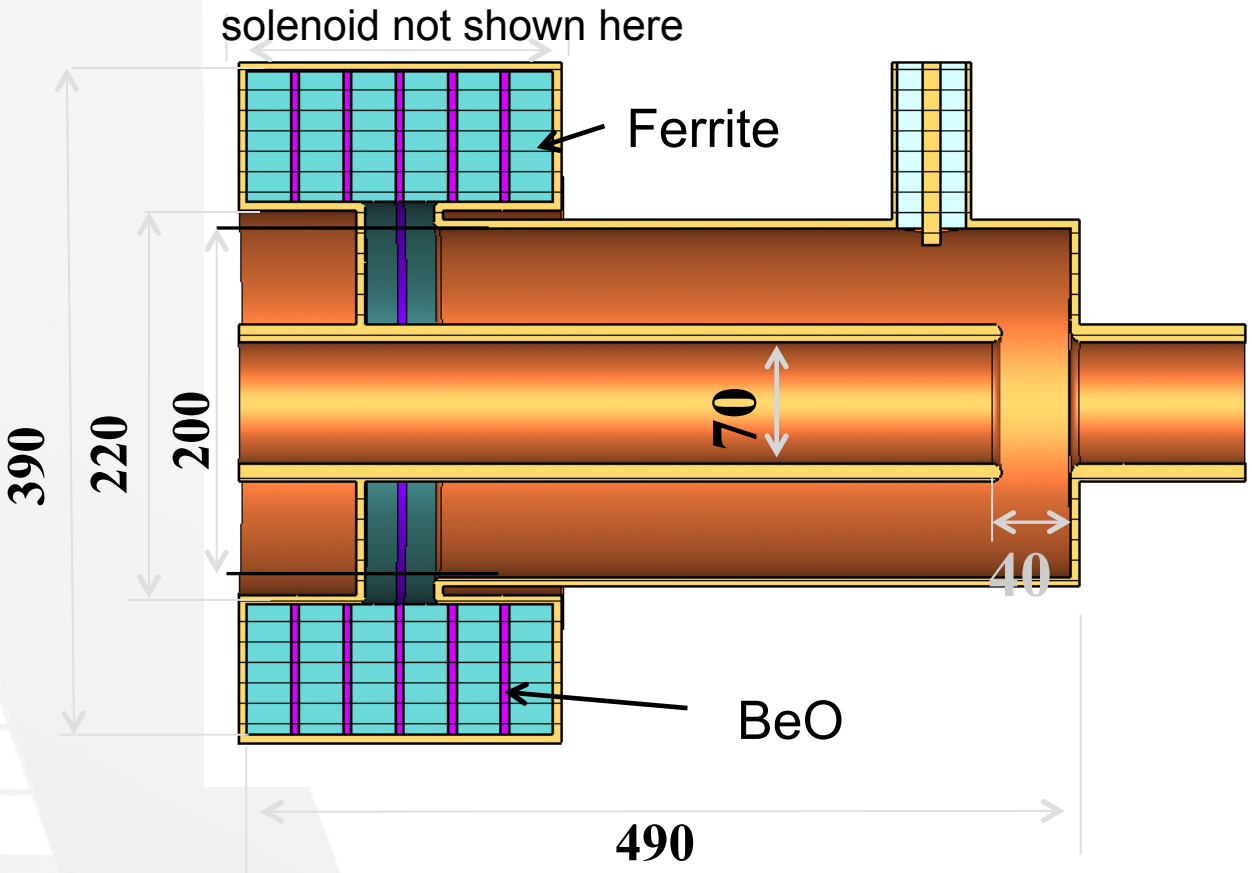
04 Apr 2014

Fermilab

PIP-I Proposed cavity.



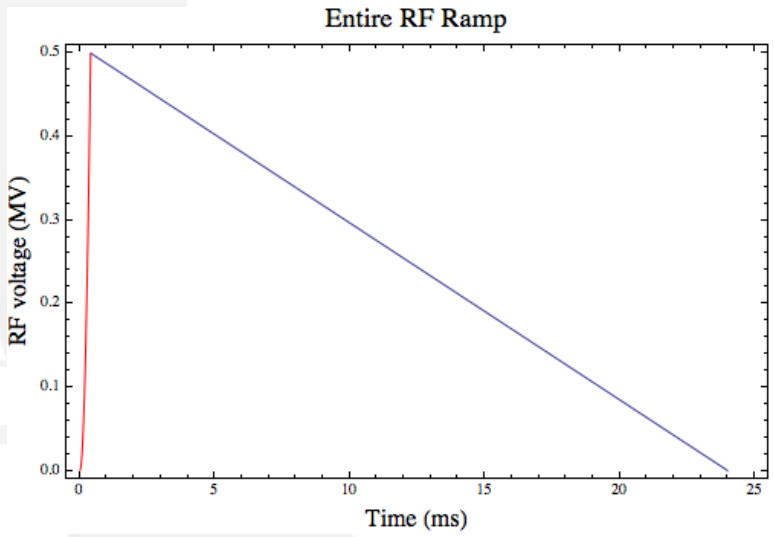
Name	Value	Description
Gap	40	
Gap_2	40	
Imped	1000	
L	405	pp
Linner	L-Gap	
Linner_2	50	
L_antenna	105	
L_ferr	175	
Mu	3.7	
Oe	1600	Magnetization
Rinner	90/2	
Router	200/2	
Router_2	R_ferr_in-5	
R_antenna	5	
R_ferr_in	230/2	
R_ferr_out	380/2	

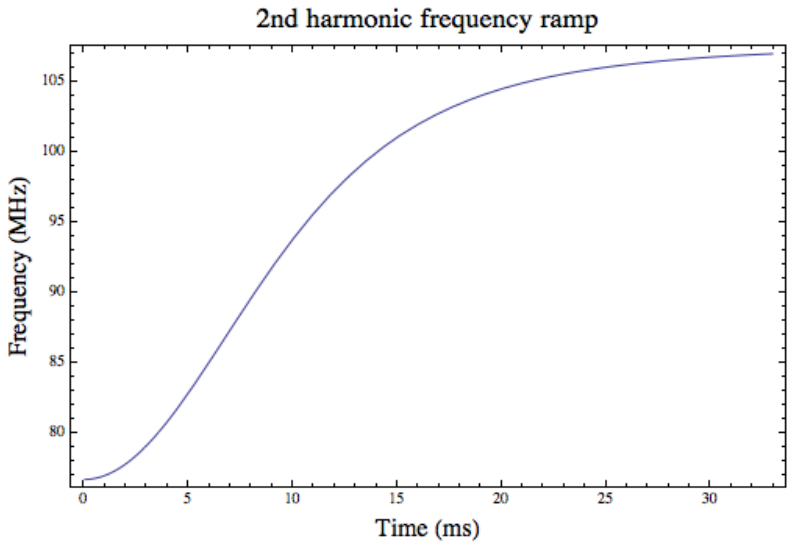
Ferrite disk: 380 mm outer diam., 230 mm inner diam., 25 mm thickness

BeO disk: 380 mm outer diam., 230 mm inner diam., 5 mm thickness

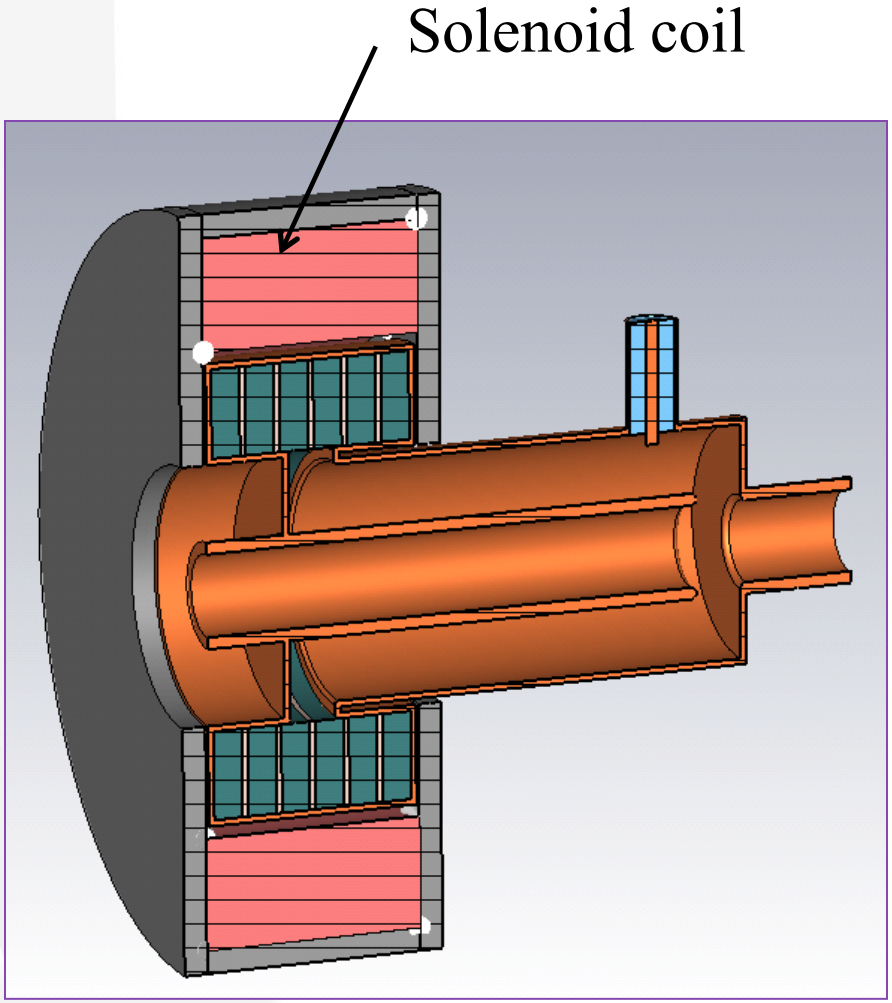
Some possible parameters

- Tuning range 76.7 − 107 MHz.
- Gap voltage. 100 kV per cavity.
- Ramp profile determines losses in the garnet.



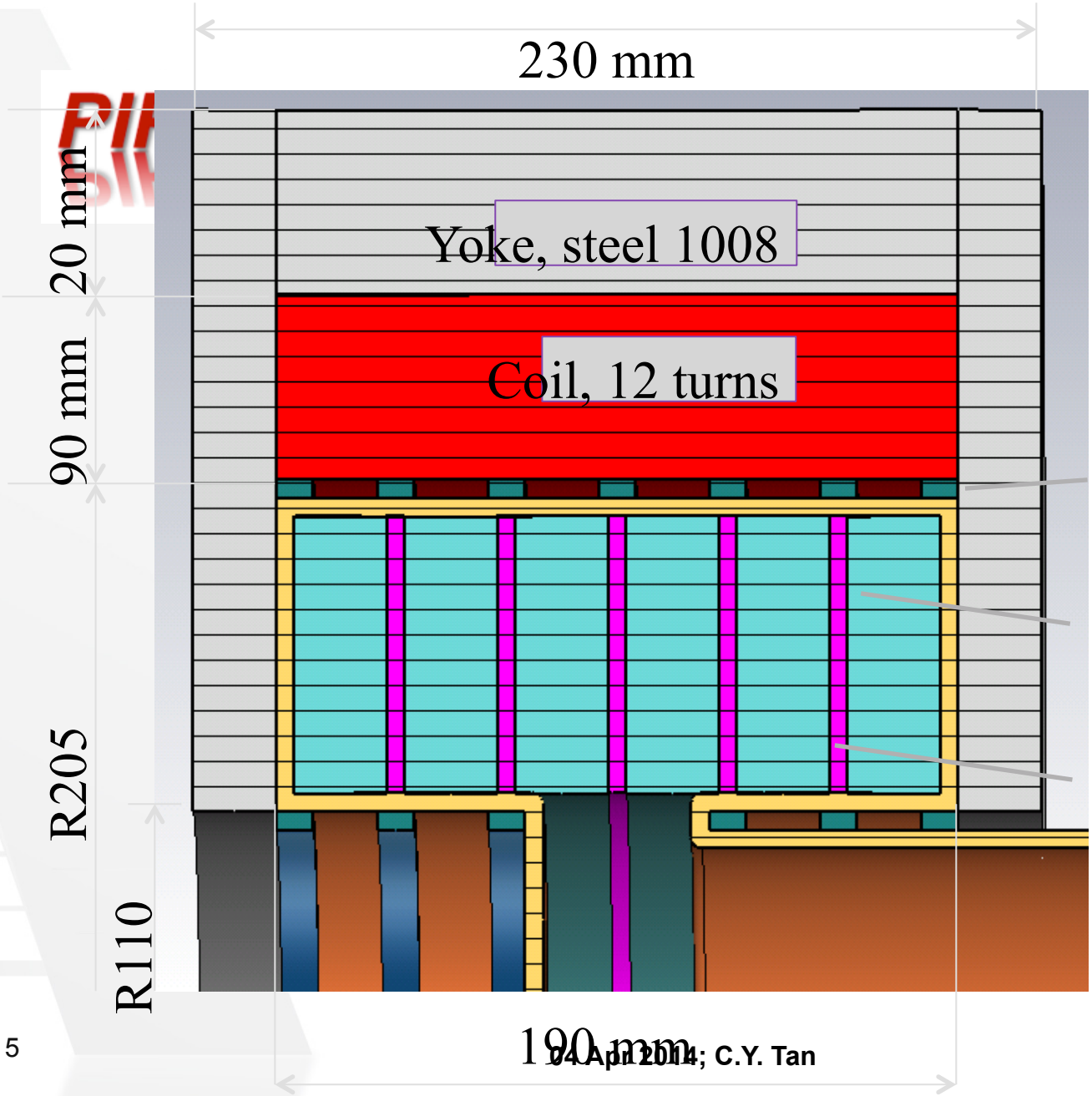


CST Model (done by G. Romanov)



Complete cavity model with magnetic field generated by solenoid

Ferrite tuner details



This is old picture, not properly scaled. But the marked dimensions are current.

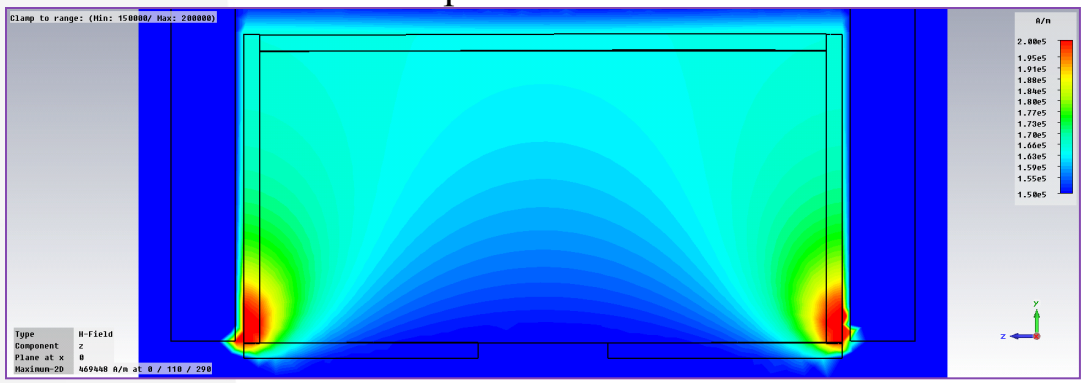
Water cooling channels, 10x5 mm

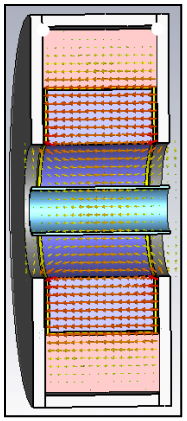
Ferrite G810, R=190 mm, r=115 mm, l=25 mm

Ceramic AlN, l=5mm

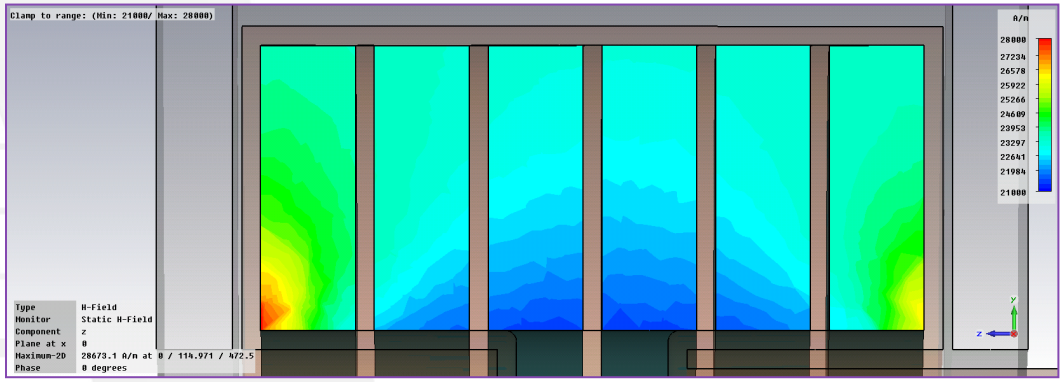
Static field distribution in ferrite

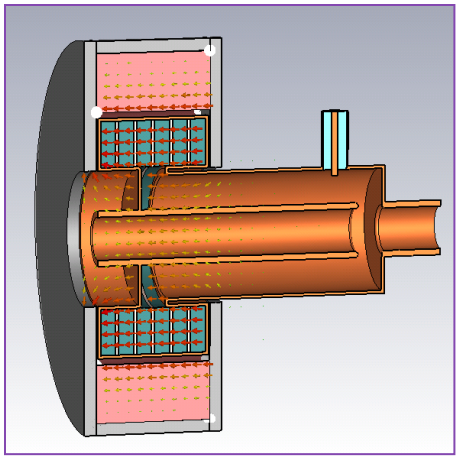
Separate solenoid model





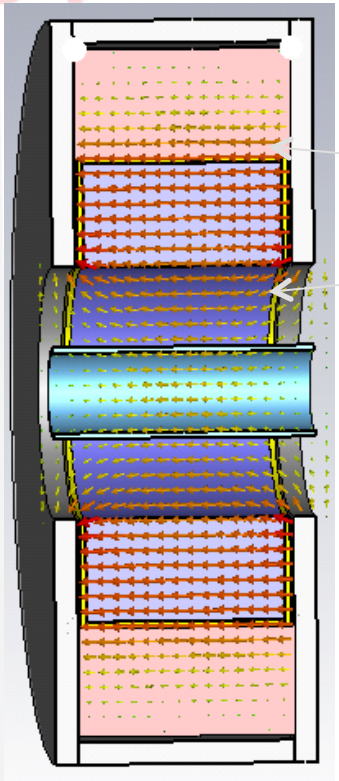
Complete cavity model





Field non-uniformity is about 25-30%

PIP-I Suppression of fields with steel insert.



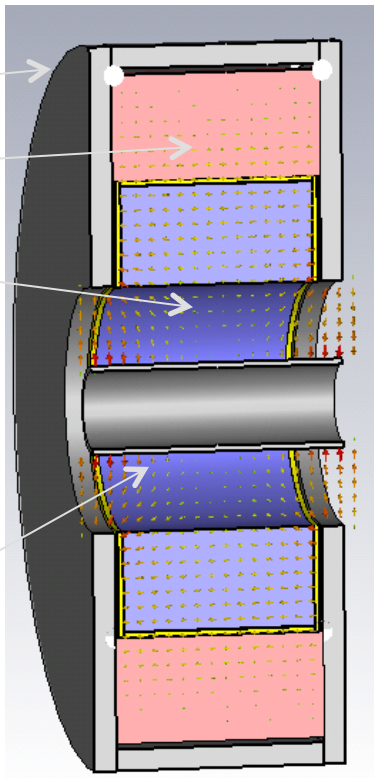
Yoke

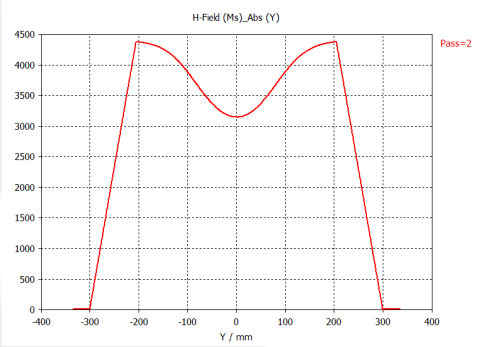
Coil

Ferrite

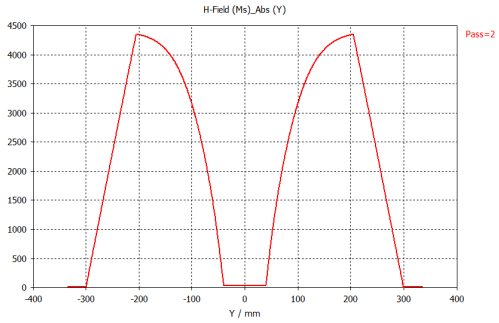
Copper
drift tube

Steel 1008
insert

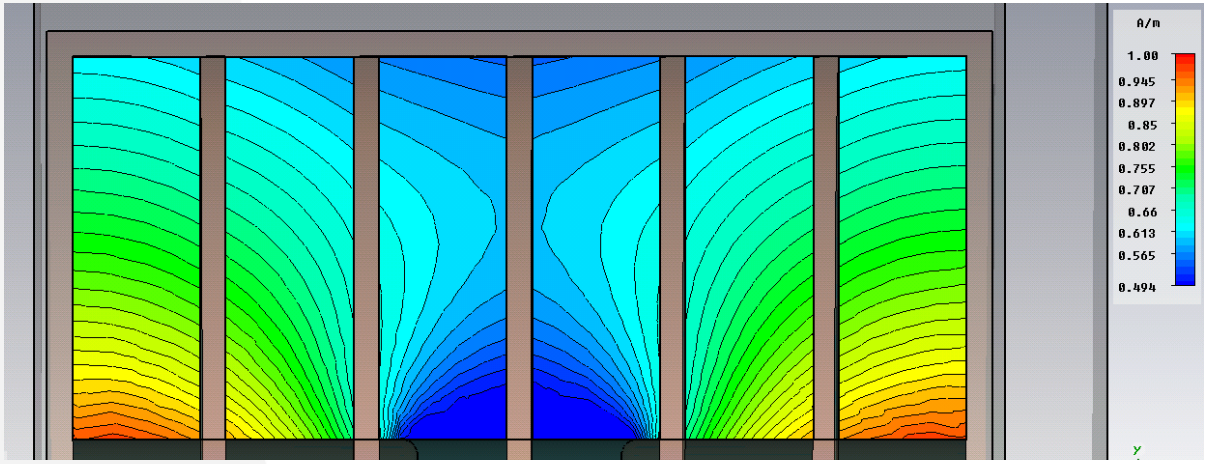




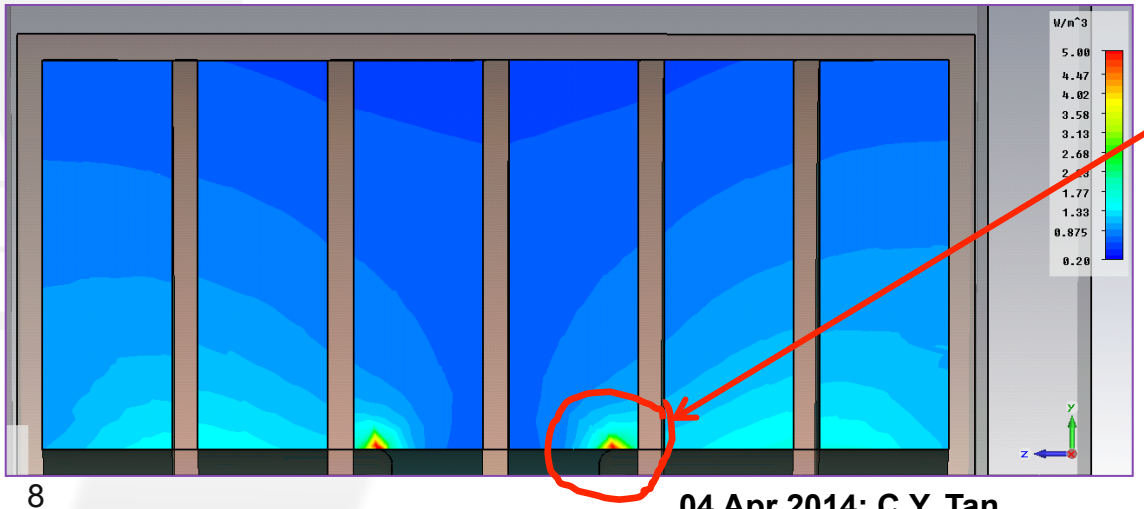
Radial distribution of H field at tuner median plane. H field on the axis can be as high as 85 kA/m. With steel drift tube it is suppressed.



PIP-I RF magnetic field distribution in ferrite and losses



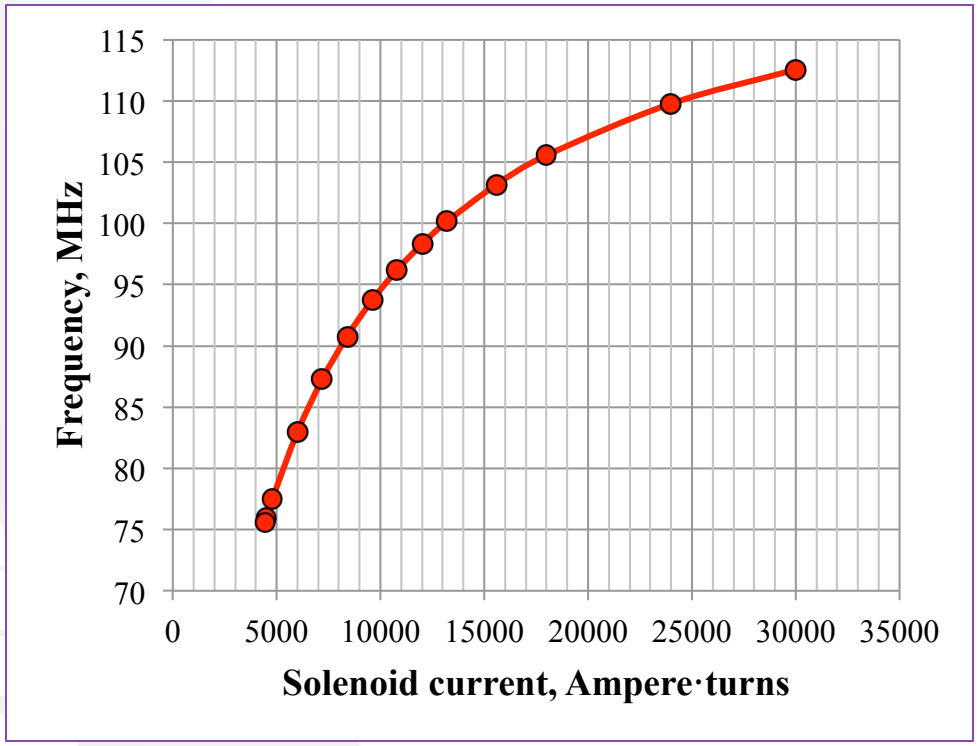
f=75.6 MHz

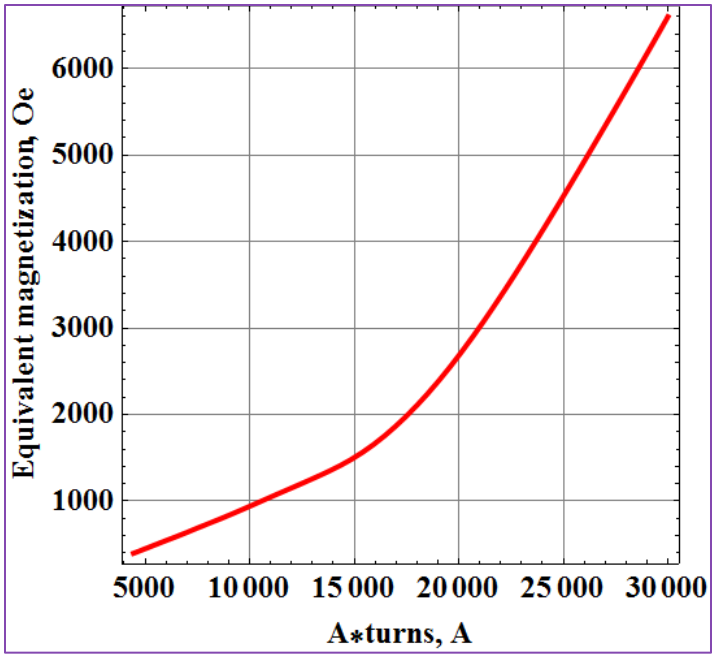


These power losses spikes are not real. They are due to the singularity of low frequency mesh that is used for thermal simulations

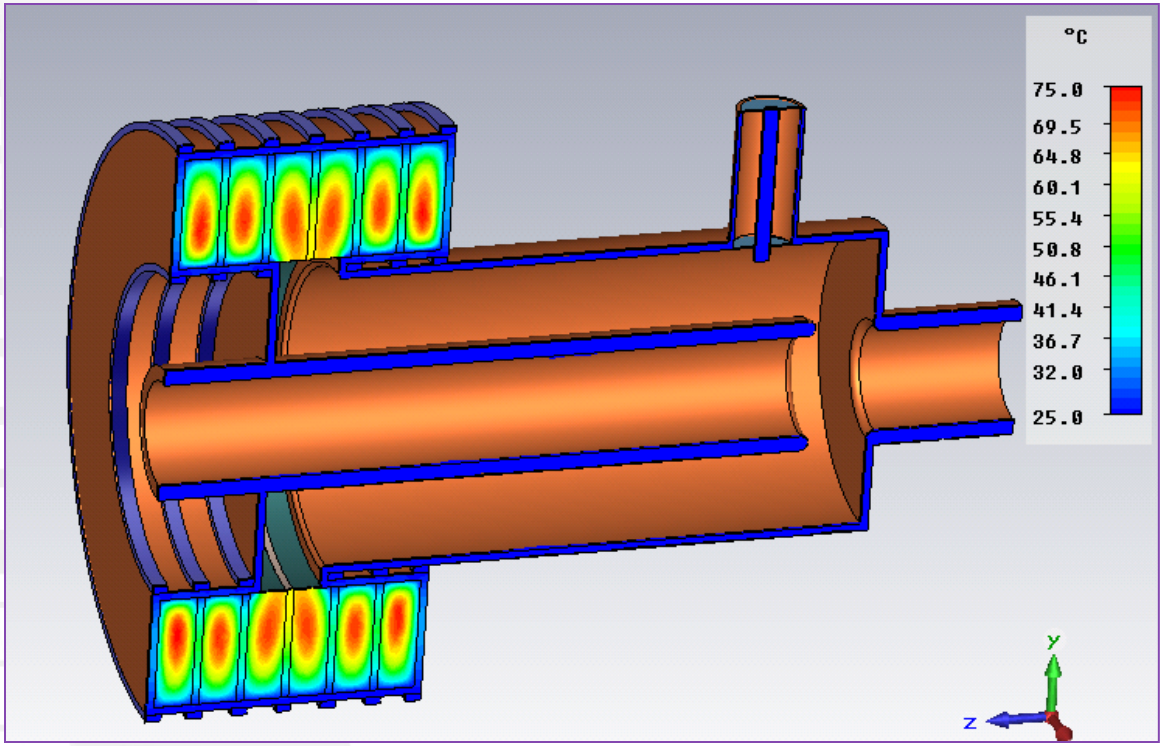
PIP-I Tuning curves

Conversion of the solenoid current to the equivalent uniform field. We can continue to use uniform magnetization – the results are very close.



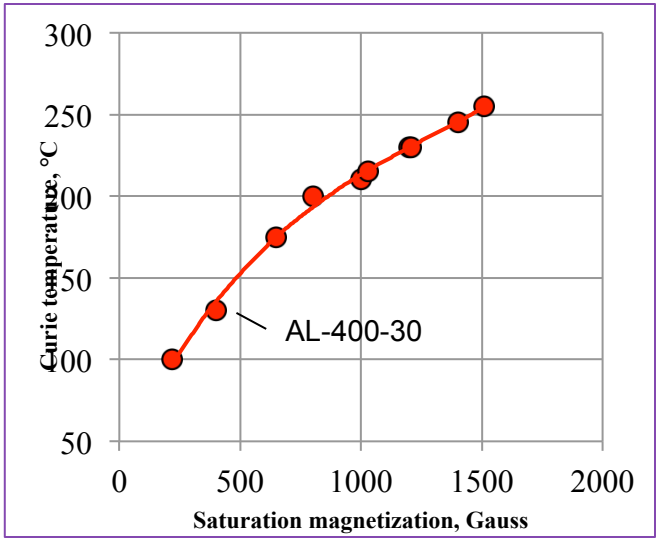


Thermal analysis



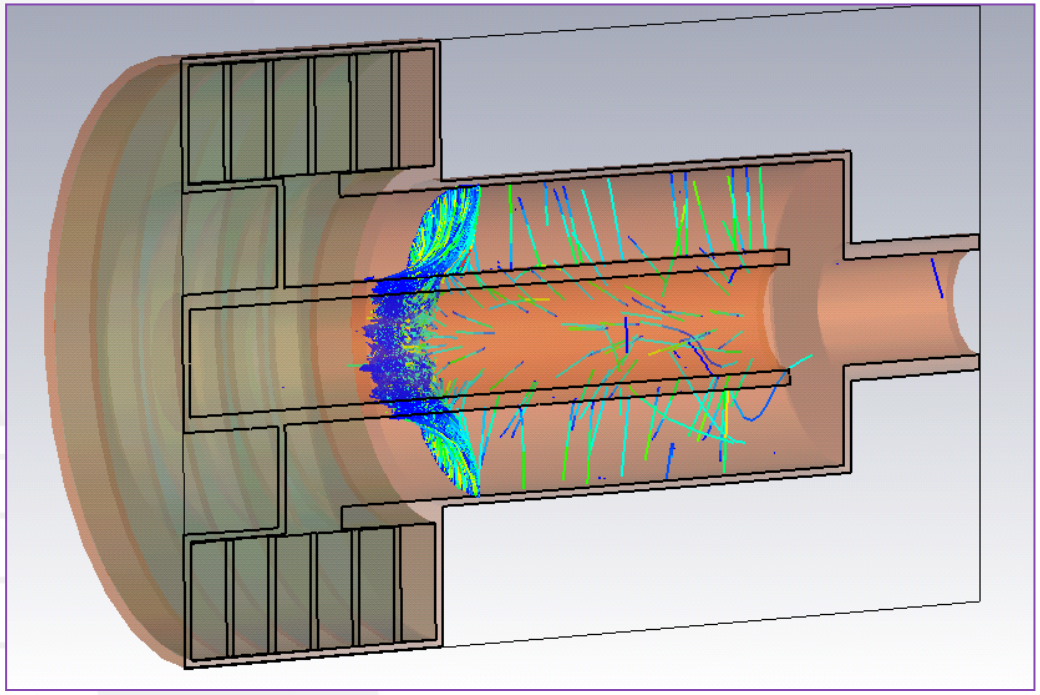
AlN cooling disks. Thermal losses in the ferrite are 14 kW for V=100 kV. Max T ≈ 75°C with cooling water temperature of 25°C.

Curie temperature

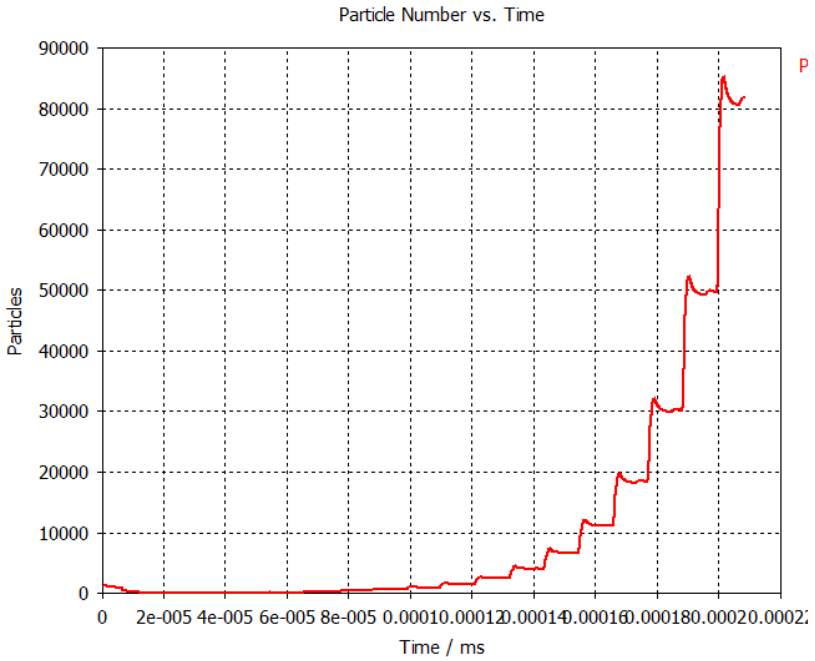


Mulitpacting with maximum solenoidal field

Range: up to 2.5 % of nominal field level



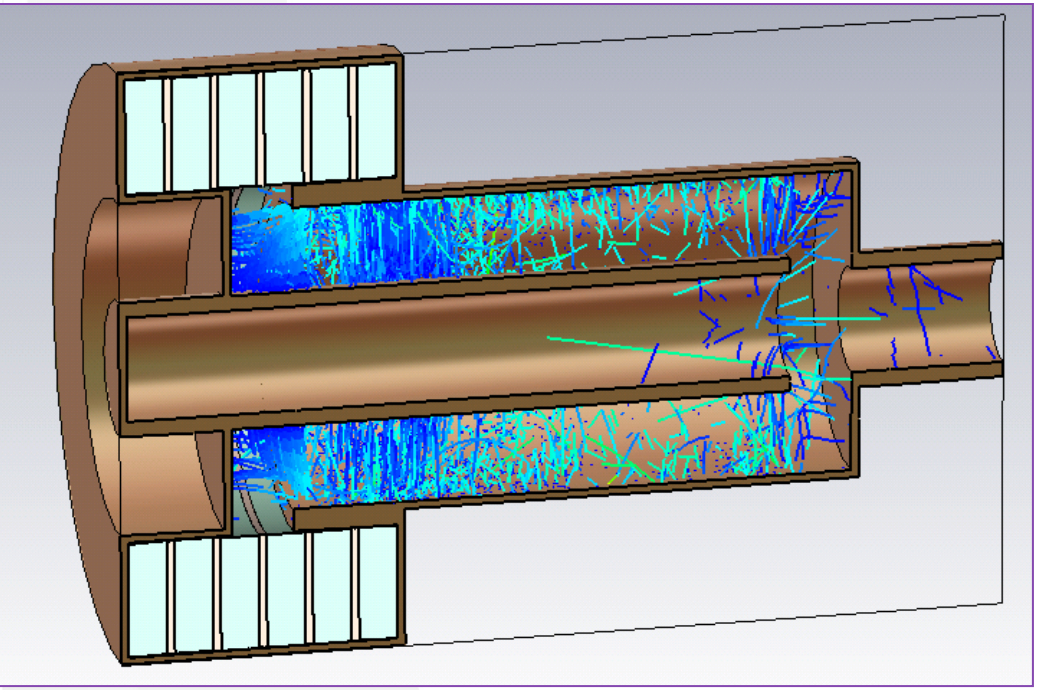
Location of multipacting



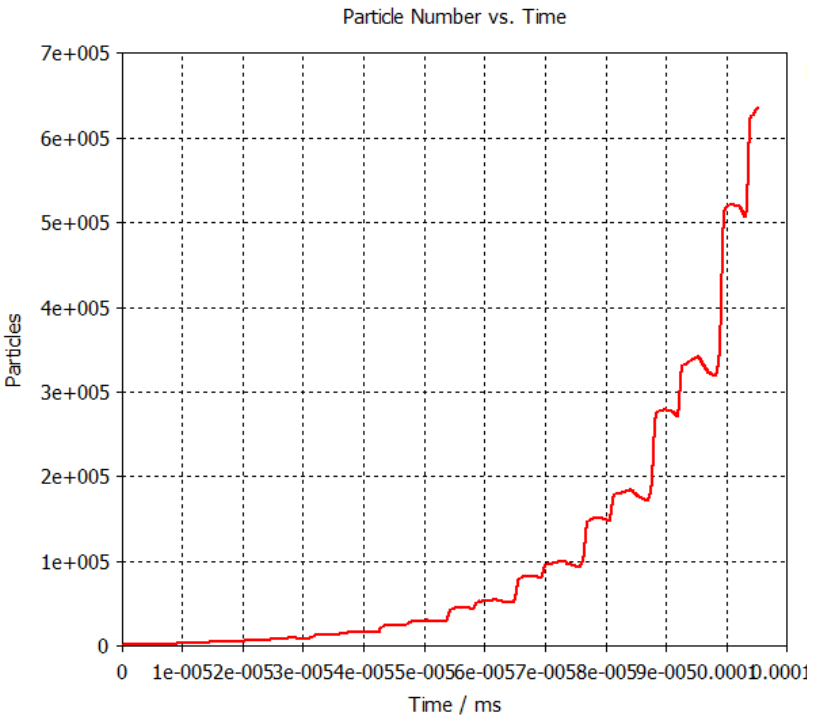
Exponential growth of particle number

Mulitpacting without solenoidal field

Range: up to 1 % of nominal field level

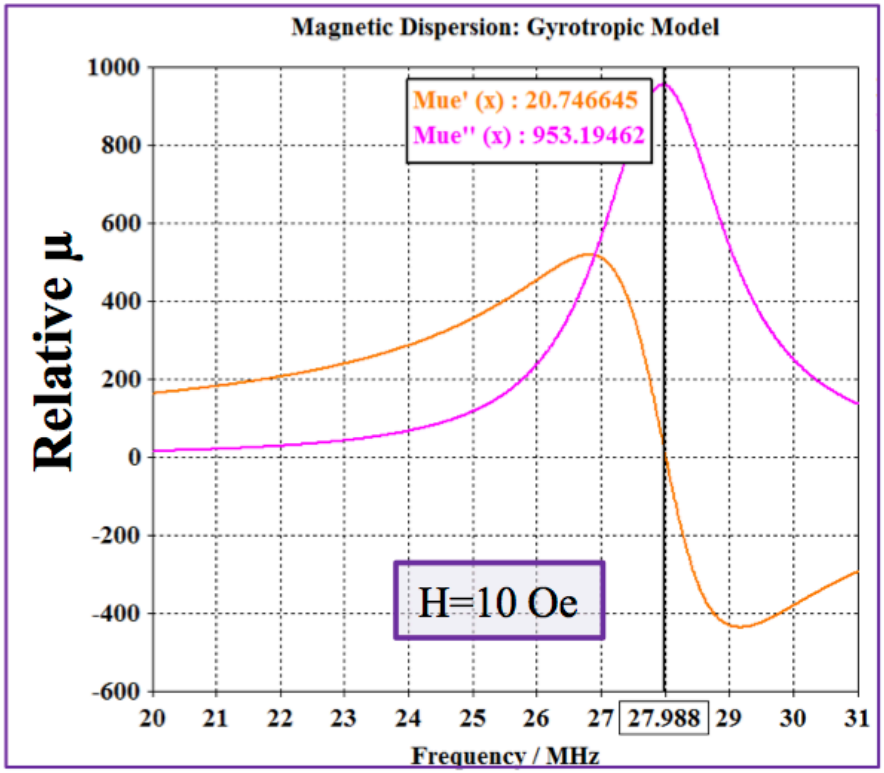


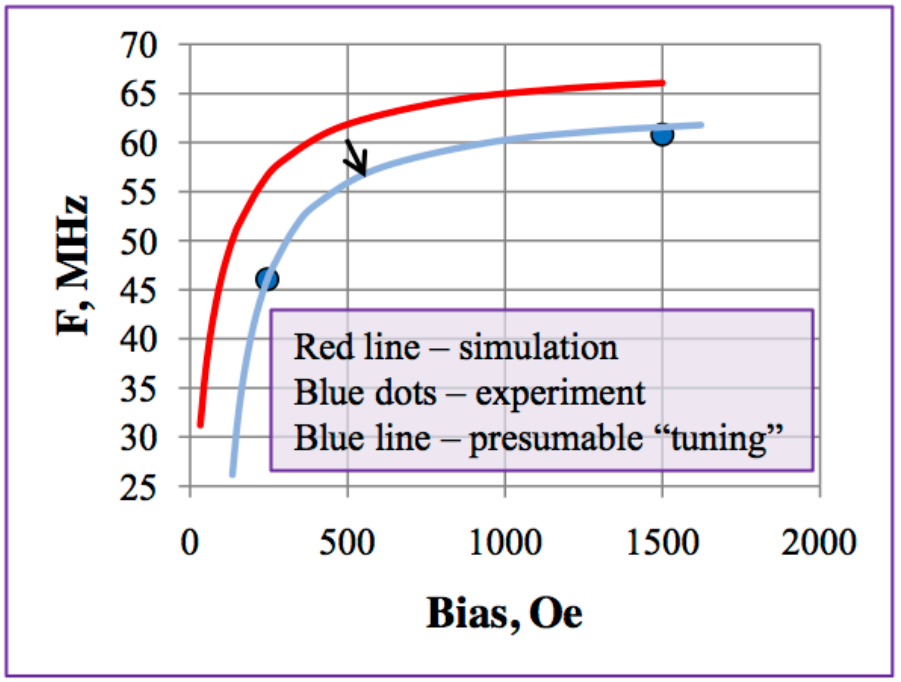
Location of multipacting



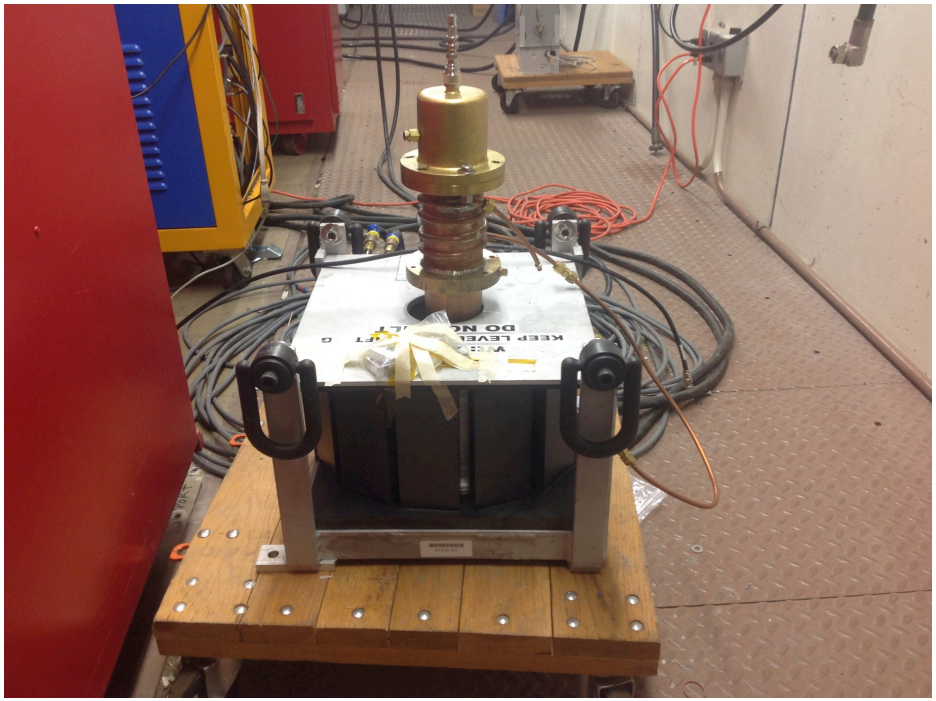
Exponential growth of particle number

Magnetic permeability (Gyrotropic model)

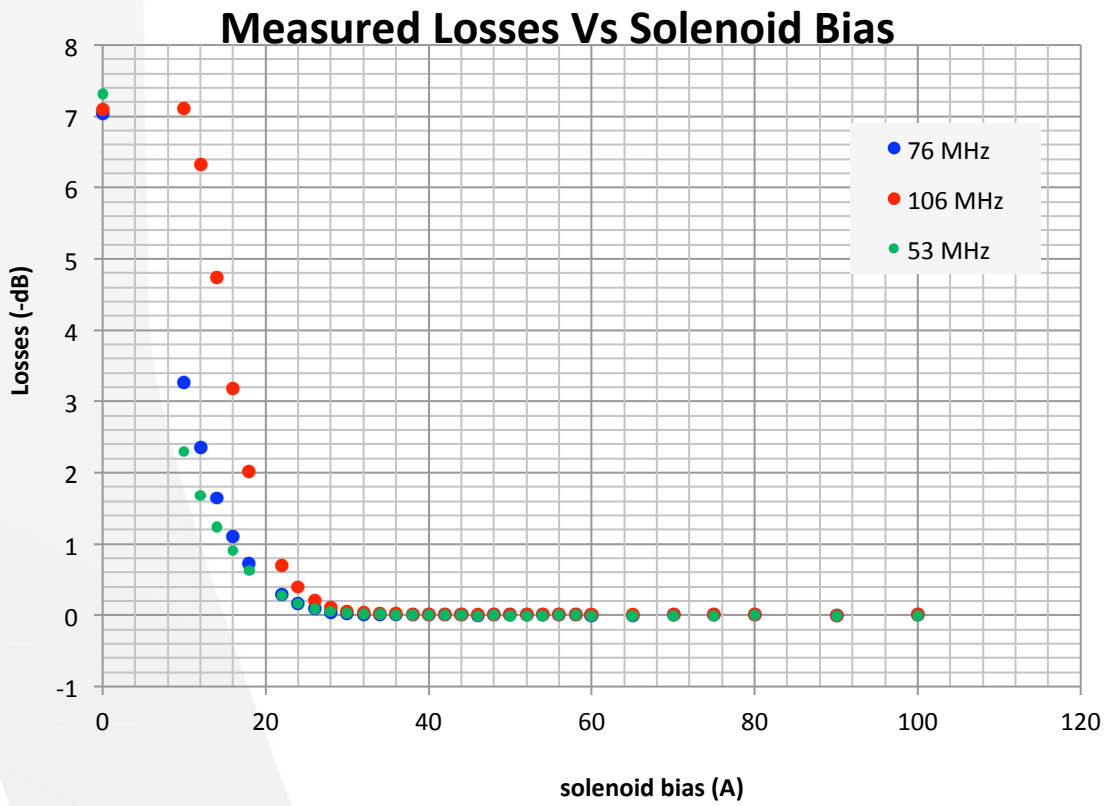




PIP-I Measuring AL400 (R. Madrak and D. Wildman)



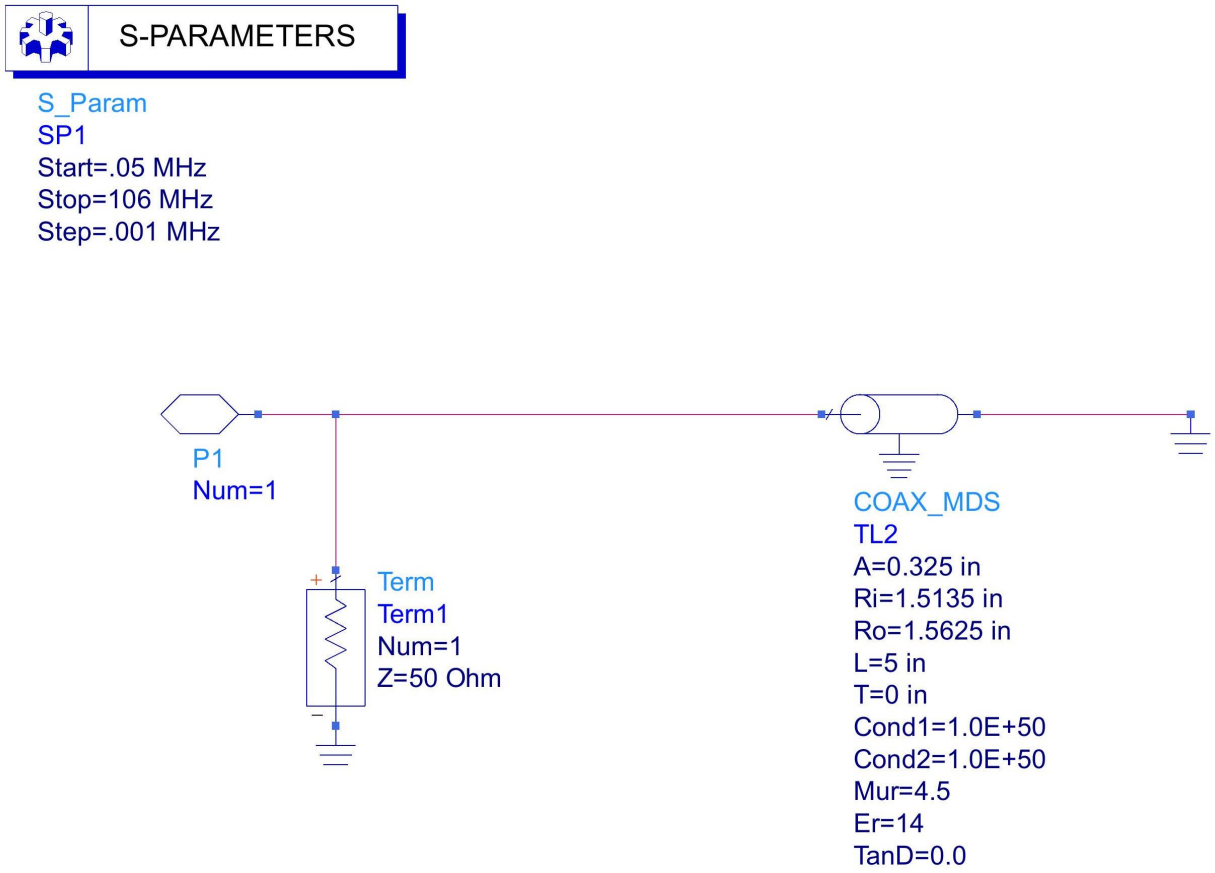
Measured losses



method looks at s11 and from there calculate the loss in the garnet.

This number will scale with the length of the garnet.

Model in ADS used to calculate μ' from s11 phase data

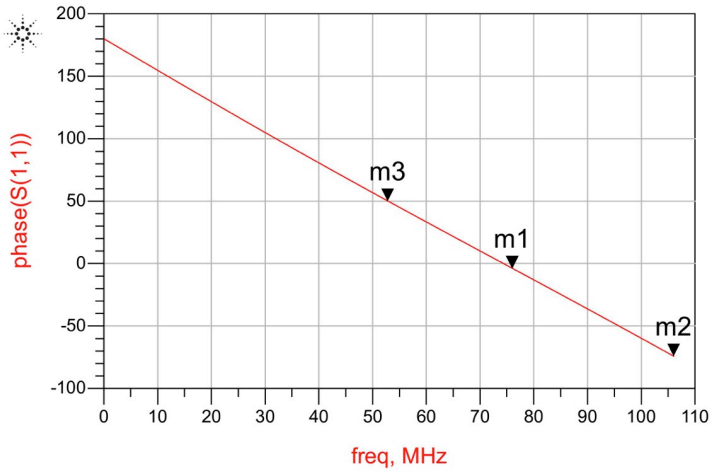


Fits to the s11 phase data

m1
indep(m1)=75.98500M
plot_vs(phase(S(1,1)), freq)=-3.782489

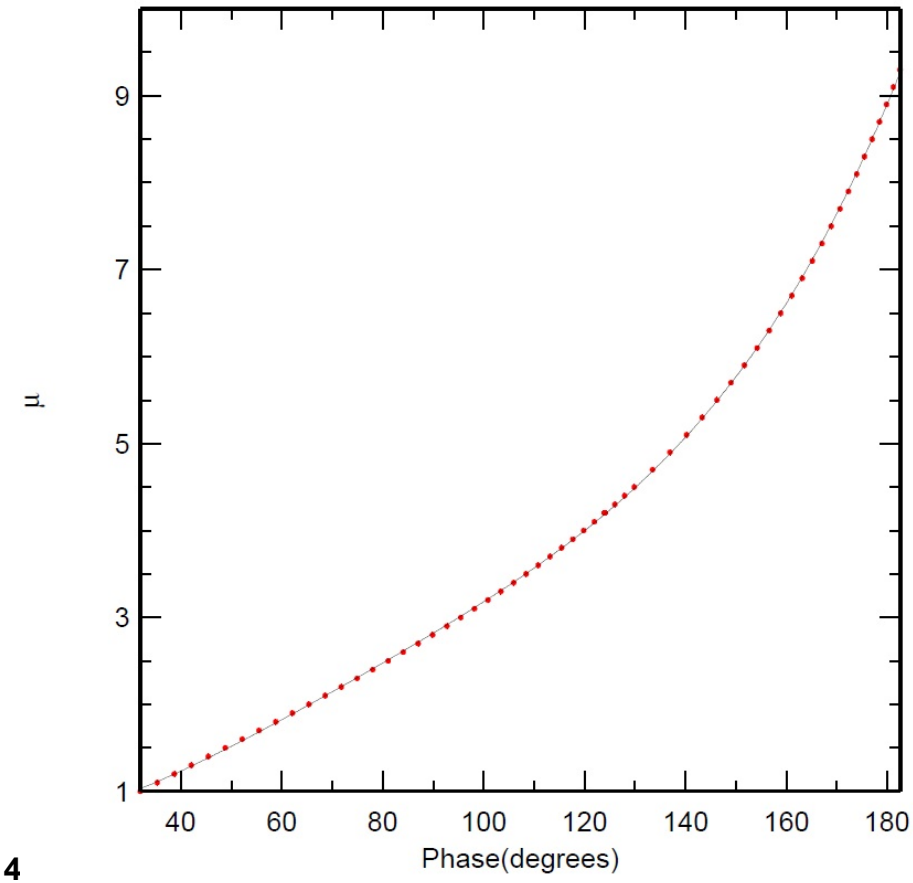
m2
indep(m2)=106.0000M
plot_vs(phase(S(1,1)), freq)=-74.13425

m3
indep(m3)=52.80900M
plot_vs(phase(S(1,1)), freq)=50.15084

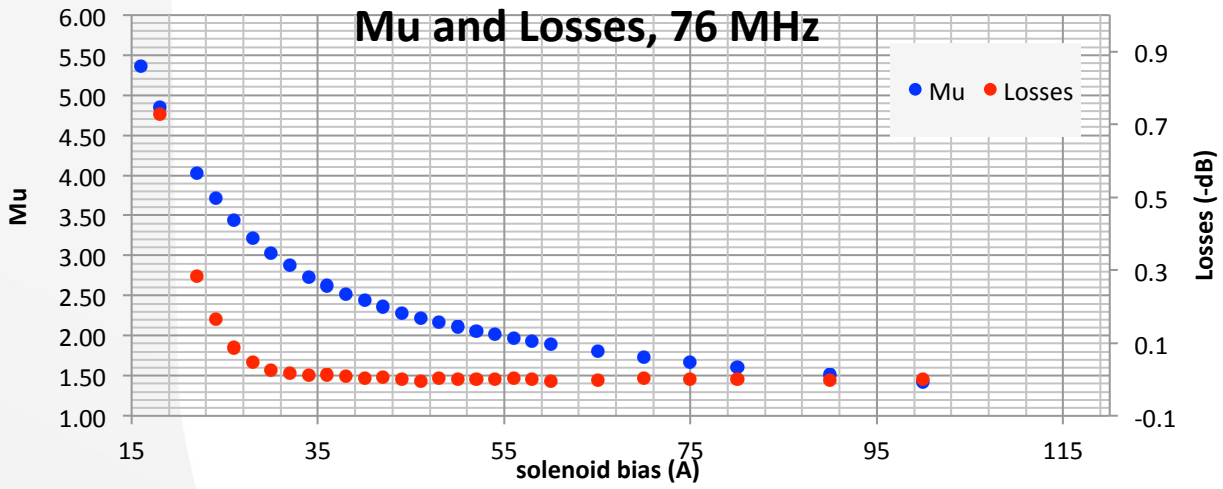


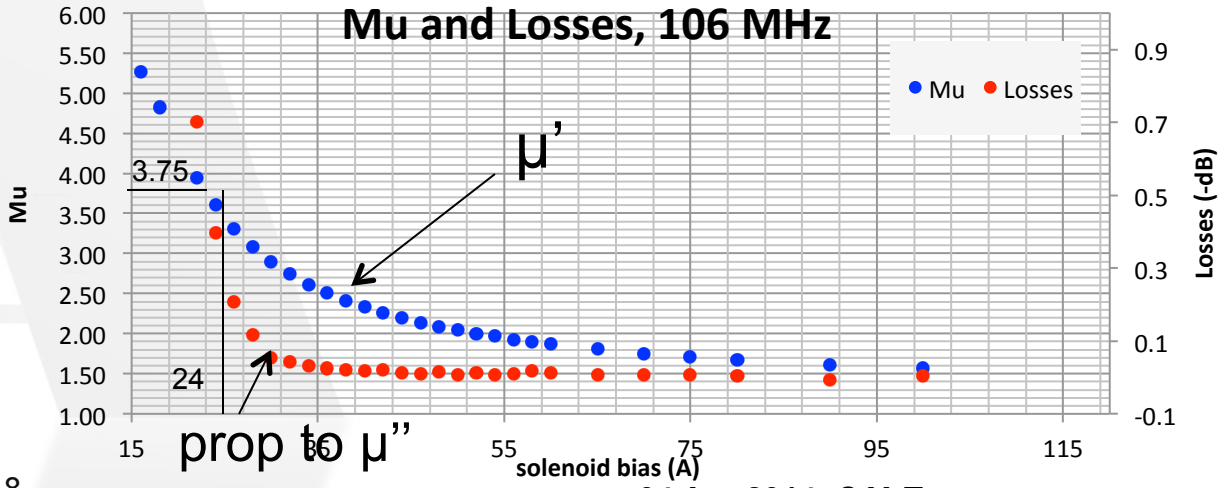
Function 1: Polynomial of Order 4

NORM	0.65046	±	7.2205E-04	-	0.000	+ 0.000
POLY01	-2.78015E-03	±	9.7118E-06	-	0.000	+ 0.000
POLY02	6.47197E-04	±	7.4738E-08	-	0.000	+ 0.000
POLY03	-5.55882E-06	±	4.9602E-10	-	0.000	+ 0.000
POLY04	1.94192E-08	±	2.6230E-12	-	0.000	+ 0.000
OFFSET	1.2770	±	1.8036E-02	-	0.000	+ 0.000



PIP-I Measured μ





recall $\mu_e = \mu' - i\mu''$.

Back of the envelope requires

$\mu_{max}/\mu_{min} = (f_{max}/f_{min})^2 = (106/76)^2 \approx 2$.

Sims say ratio is 2.5, then if μ_{min}=1.5, then μ_{max}=1.5×2.5 = 3.75

-0.4 dB loss @ μ'=3.75

s11 = (Pin - Pref)/Pin = 1- Pref/Pin.

In dB = 10 Log10(1- Pref/Pin) ≈10(-0.43 x – 0.21 x^2)

Tan[δ] = μ''/μ'=1/Q

04 Apr 2014; C.Y. Tan

Fermilab

Todo (partial list) to be discussed

- Check that solenoid can be built.
  - PS for solenoid -- kA
- Coupler?
- PA?
- Dimensions OK?
- Impedance of cavity? Shunt impedance > 1 MΩ?
- How to incorporate μ measurements into simulations?