Fermilab

New Recycler Cavities

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PIP-II Collaboration Meeting

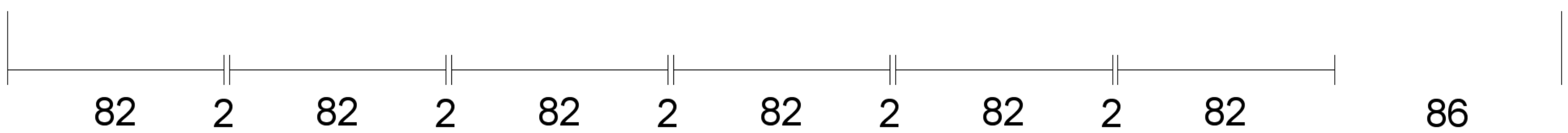
9-10 November 2015

Recycler System Specifications

Parameter	Value	Units
Number of Injections	12	injections
Total Beam Injected	72E+12	protons
Kinetic Energy	8	GeV
Frequency	52.809	MHz
Slipping Frequency Difference	1680	Hz

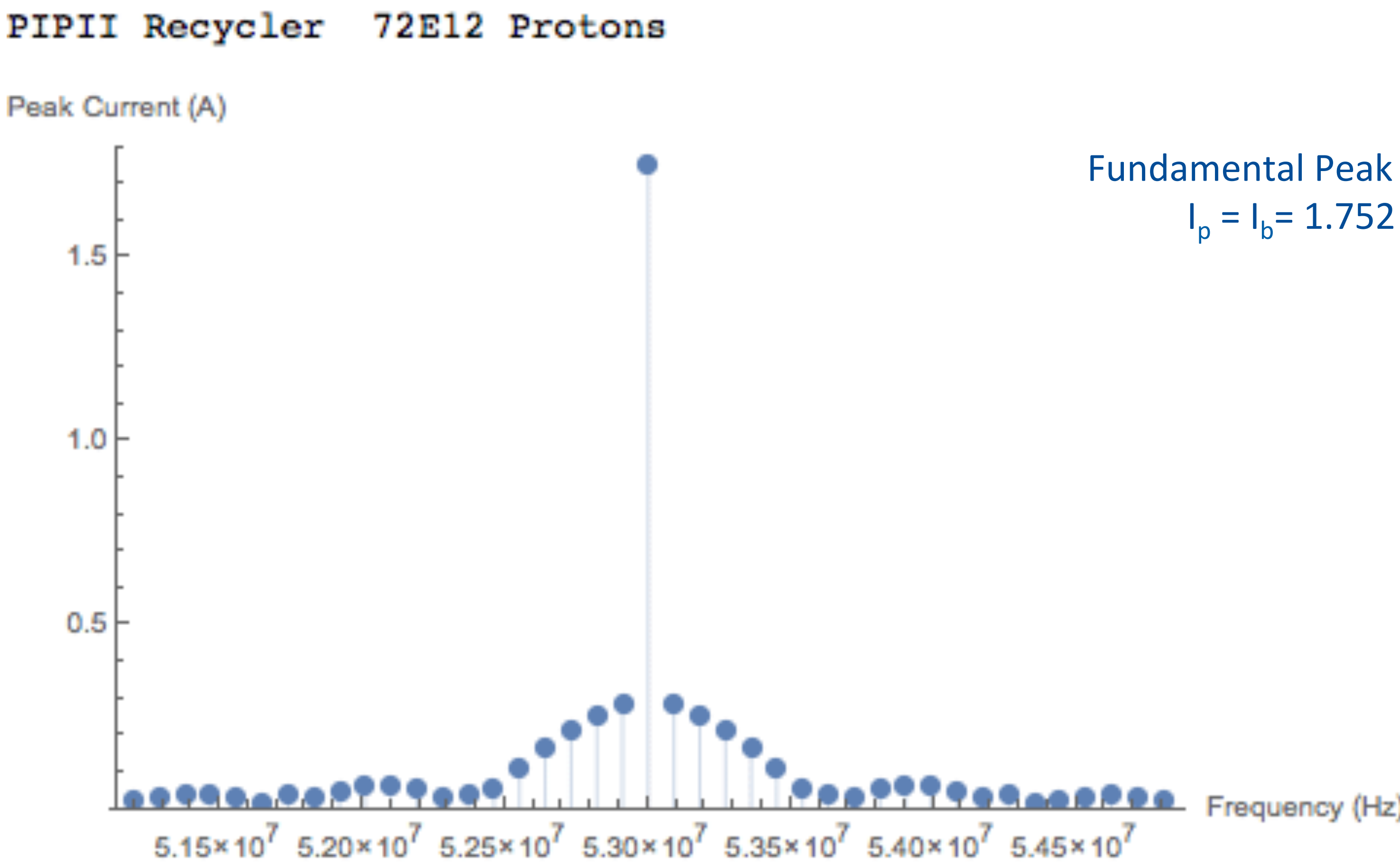
Recycler Beam Distribution

NOvA Recycler



h = 588

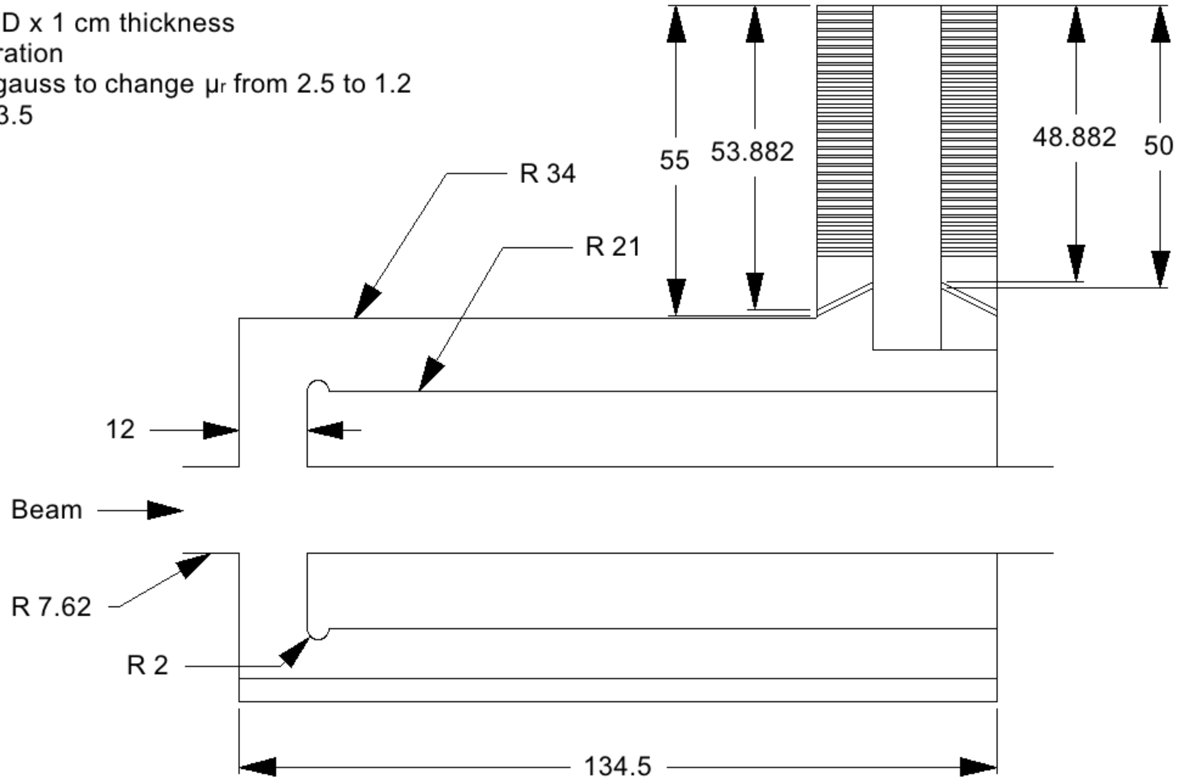
Slipped Beam RF Current



Fundamental Peak Current
$I_p = I_b = 1.752$ A

Main Injector Project X 53 MHz Cavity

Cavity Material: Copper
Ferrite Material: TCI Ceramics AL-0400
Quantity 30
32 cm OD x 12 cm ID x 1 cm thickness
0.5 cm garnet separation
300 gauss to 2250 gauss to change μ_r from 2.5 to 1.2
Permittivity (ε_r) of 13.5



Units: cm

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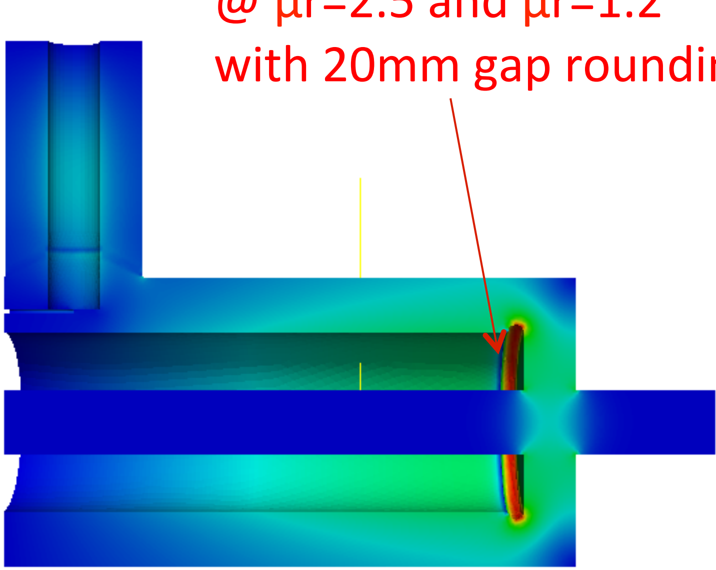
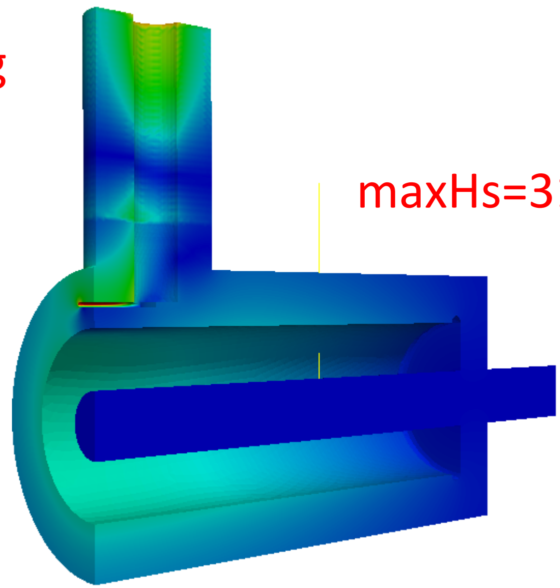
Max. Surface Fields – Es/Hs

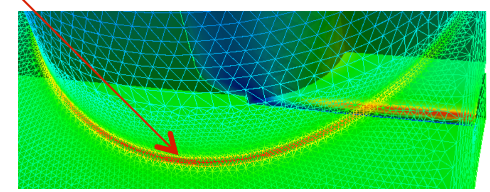
@ Vgap=240kV & d=75mm

maxEs=7.4MV/m
@ μr=2.5 and μr=1.2
with 20mm gap rounding

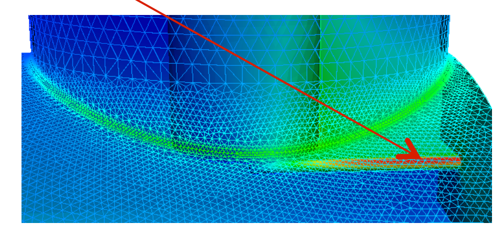




maxHs=13kA/m @ μr=1.2

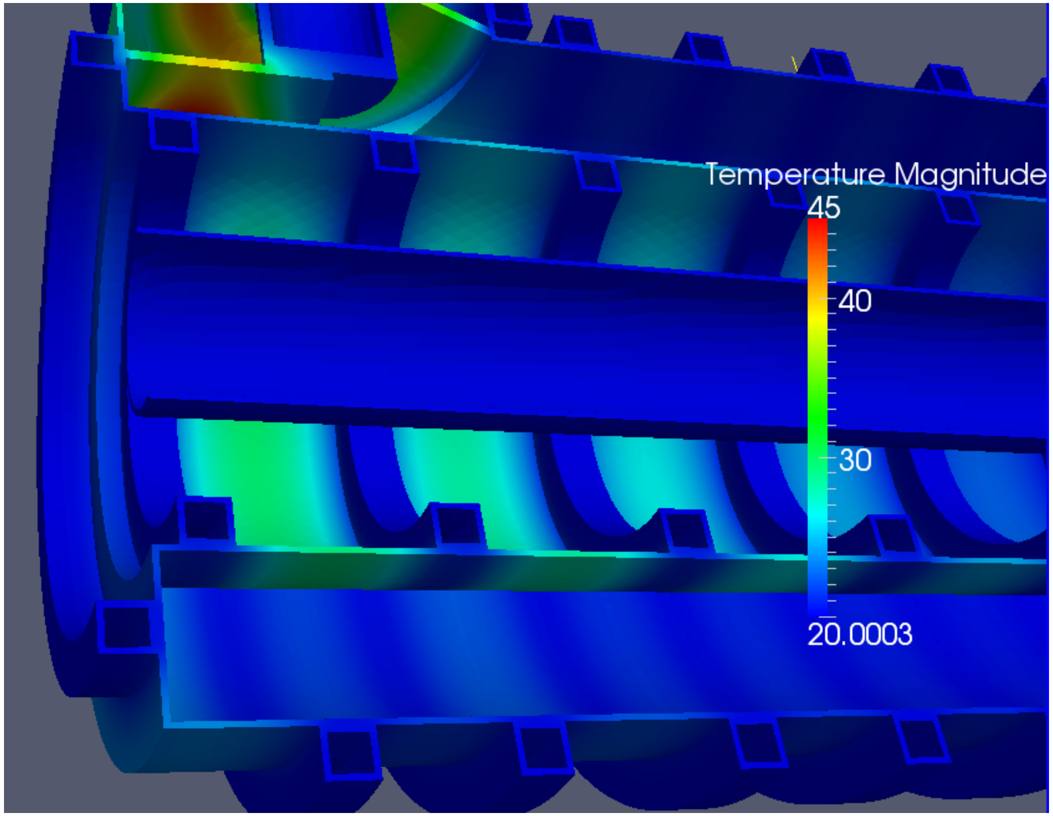


maxHs=31kA/m @ μr=2.5

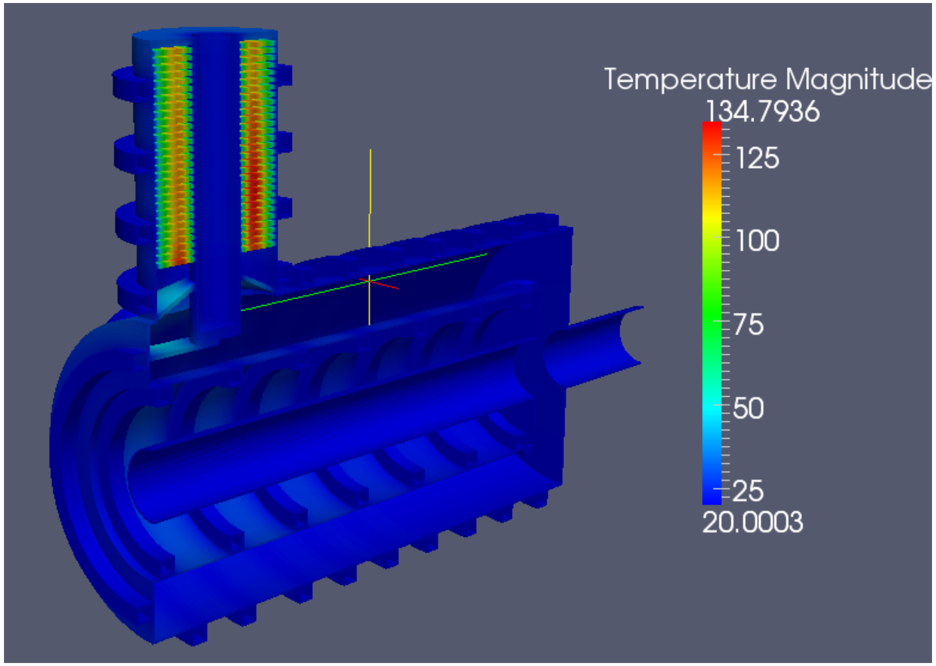


the loop edges are fully rounded

MI Cavity Thermal Simulations



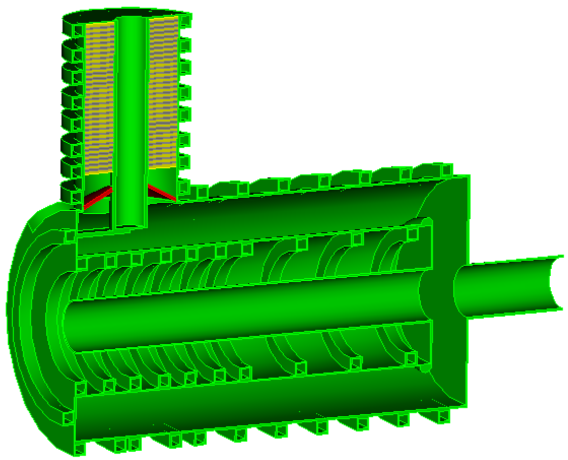
MI Cavity Thermal Simulations



- Active water cooling is not sufficient to reduce the maximum temperature in the ferrite material below the Curie temperature (typically > 100 degree).

Water Cooling Channel Plus Cooling Disks

- 29 BeO cooling disks in-between the ferrite cores are used to reduce the temperature in the ferrite material below 100 C when Vacc=120kV.
- In this case, one has to make sure that the thermal contact between cooling disks and ferrites is good. (H. Klingbeil, Ferrite Cavities)



BeO thermal conductivity:300W/mK
BeO dielectric constant: 6.7
BeO loss tangent: 0.003

➢ The BeO effects to the RF performance needs to be investigated.

Cavity Parameters

Main Injector Project X Cavity Parameters

Voltage = 240 kV
Frequency Sweep = 52.617 to 53.104 MHz
R/Q = 31.49
Q = 12,023

Recycler Slip Stacking Cavity Parameters

Voltage = 140 kV
Frequency Sweep = 52.808 ± 6.72 kHz
R/Q = 31.49
Q = 12,023

Robinson Stability - Slipped Beam

Beam Current (Ip) = 1.752 A

R/Q = 31.49 Ω

Q = 12023

Cavity Voltage = 140. kV

Cavity Power Loss per Cavity = 25.8845×10^3 W

Total Apparent Power = 110.774×10^3 VA ∠ 76.4868 degrees

Total Current = 1.58249 A ∠ 76.4868 degrees

Percent of Induced Mode Compensated = 18.29 dB = 87.8241 %

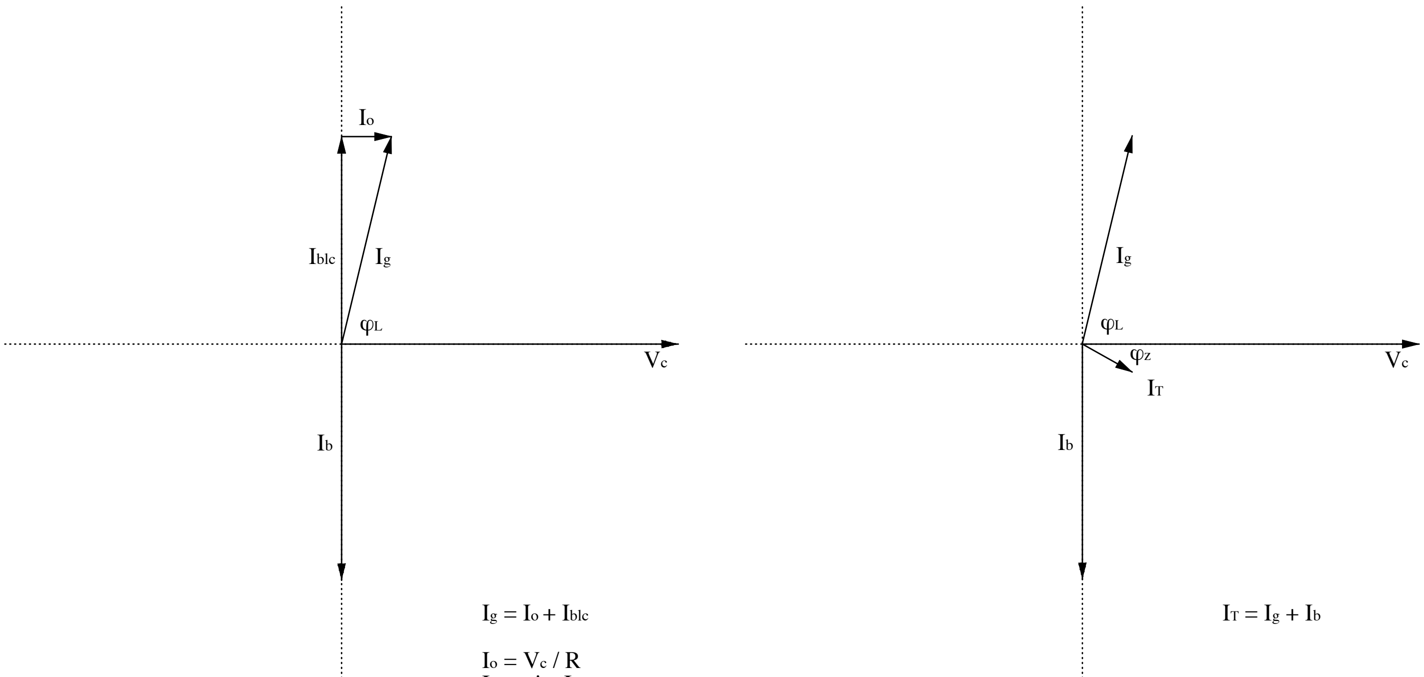
Robinson Stable = 4.00481

- Total of 111 kW needed for both Voltage and Beam Stability

Vector Diagram of Slipped Beam

Joe Dey
October 27, 2015

Robinson Stable = 4
87.8% Beam Loading Compensation
x = 0.878



$I_g = I_o + I_{blc}$

$I_o = V_c / R$
$I_{blc} = j \times I_b$

$I_T = I_g + I_b$

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Research and Development Plan

- Repeat Both Electrical and Thermal Simulations for a Fixed Frequency and Smaller Tuner ± 3360 Hz
  - Can Tuner Respond to Sweeping ± 1680 HZ in 50 ms
  - Can Copper be Used to Cool the Cavity Tuner
    - How Big are the Eddy Current Losses when Slewing
- Build a Prototype Tuner
  - Measure Frequency Response and Thermal Losses
- How to Couple Power Amplifier to Cavity
  - Will the current Main Injector Y567B Tube be sufficient?
  - Build a Power Amplifier and Determine Position of Tap Point on Cavity
- Review and Build Prototype Cavity