HOM Damping and Coupler Mutipacting Simulations

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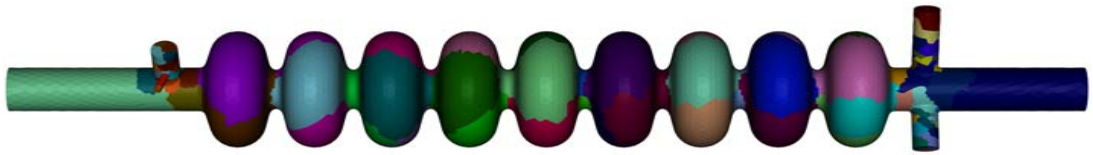
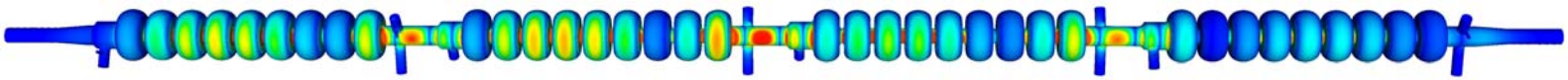
SLAC 3D Parallel FEM EM Codes

- Tetrahedral Mesh with Finite-Element
  - Up to 6th order basis for field accuracy
  - Unstructured grid for modeling geometry with large variation in dimensions
- Parallel implementation (10^2-10^3 processors, 10^2GB memory)
  - Modeling details with great realism



  - Simulating large systems such like multi-cavity cryomodule



- A suite of solvers including frequency domain and time domain

Omega3P	- Frequency Domain Mode Calculation
S3P	- S-parameter Computation
T3P	- Time Domain With Beam Excitation
Track3P	- Particle Tracking, MP and dark current
V3D	- Visualization

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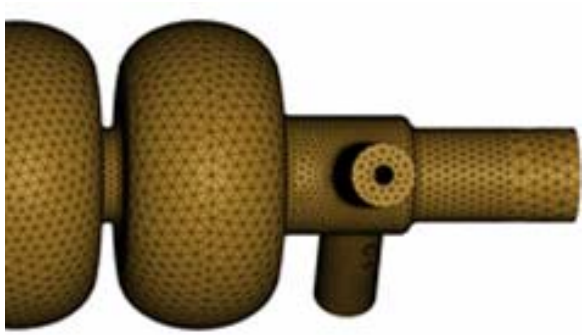
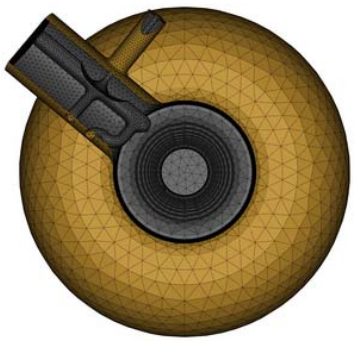
Applications

- RF simulation projects
  - BCD cavity
  - Crab-cavity *(SLAC, FNAL, UK)*
  - SLAC TTF coupler high power test
  - KEK – ICHIRO *(K. Saito)*
  - DESY/JLAB – Low-Loss *(J. Sekutowicz, P. Kneisel)*
  - SNS – beta=0.81 cavity *(I. E Campisi)*
- RF studies
  - HOM damping
  - Field Enhancement in end-group
  - Coupler & cavity MP
  - Notch filter analysis
  - …

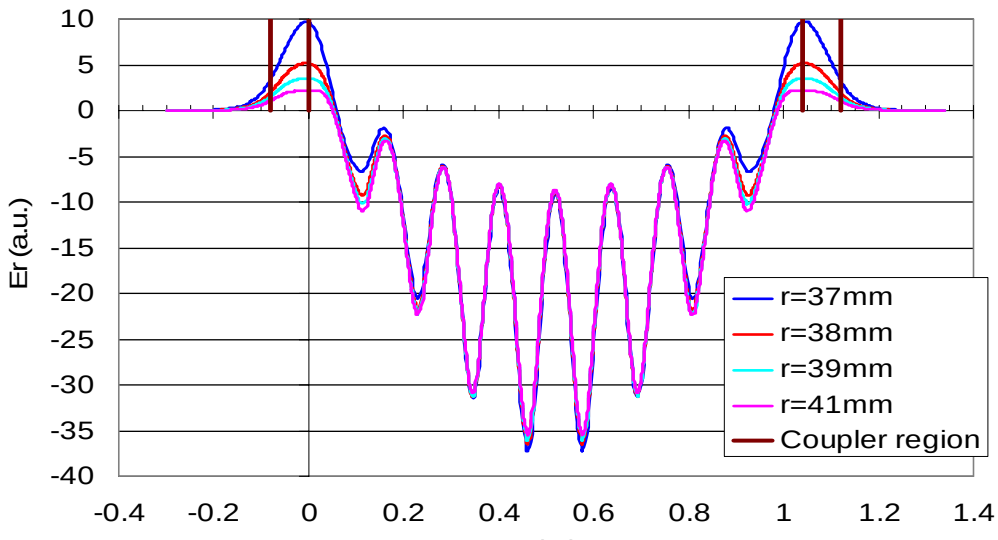
1. HOM Damping – LL cavity

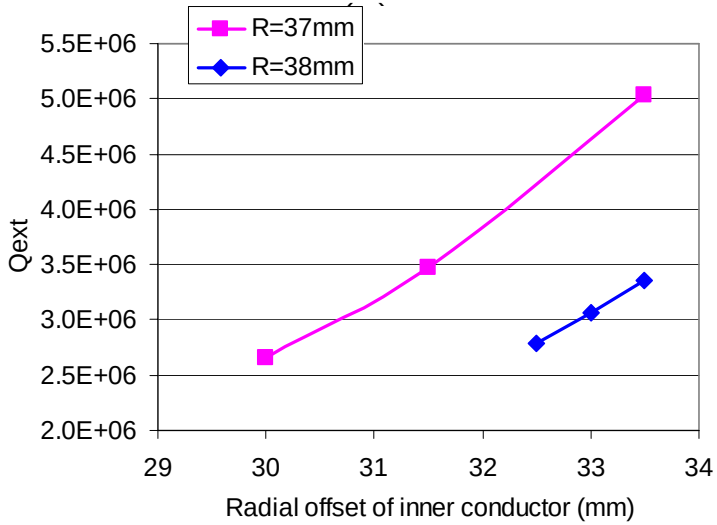
End-group Geometry VS Damping





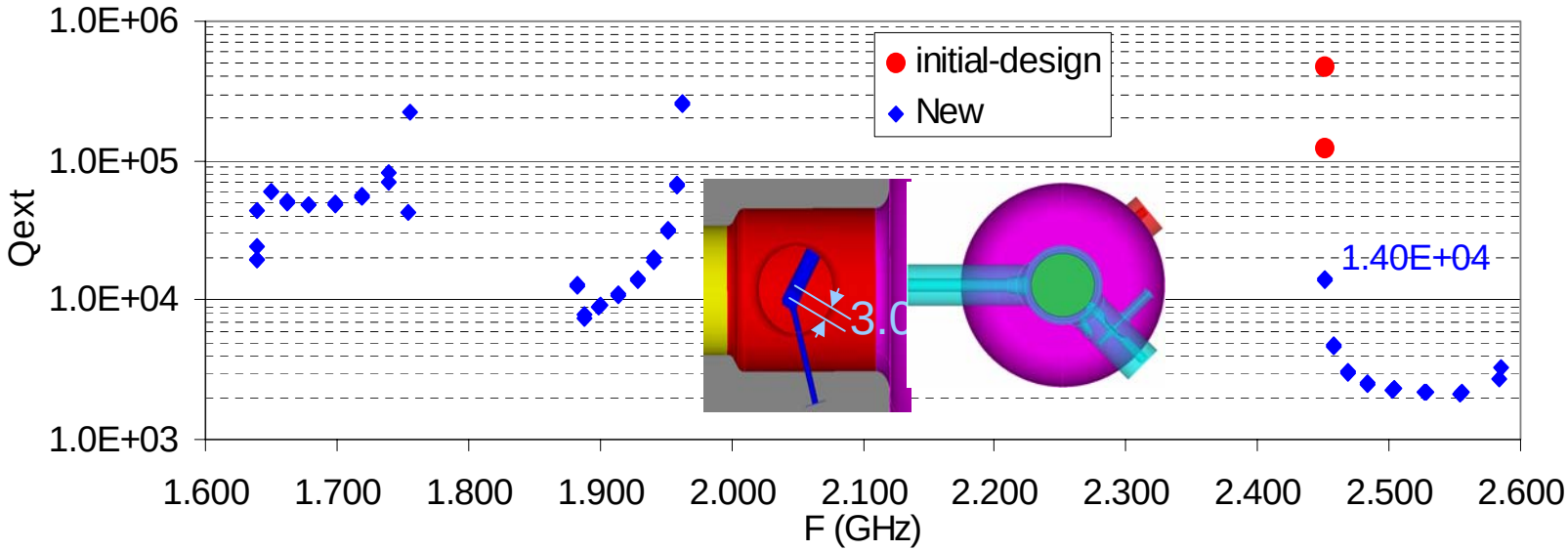
dangerous mode in 3rd dipole band

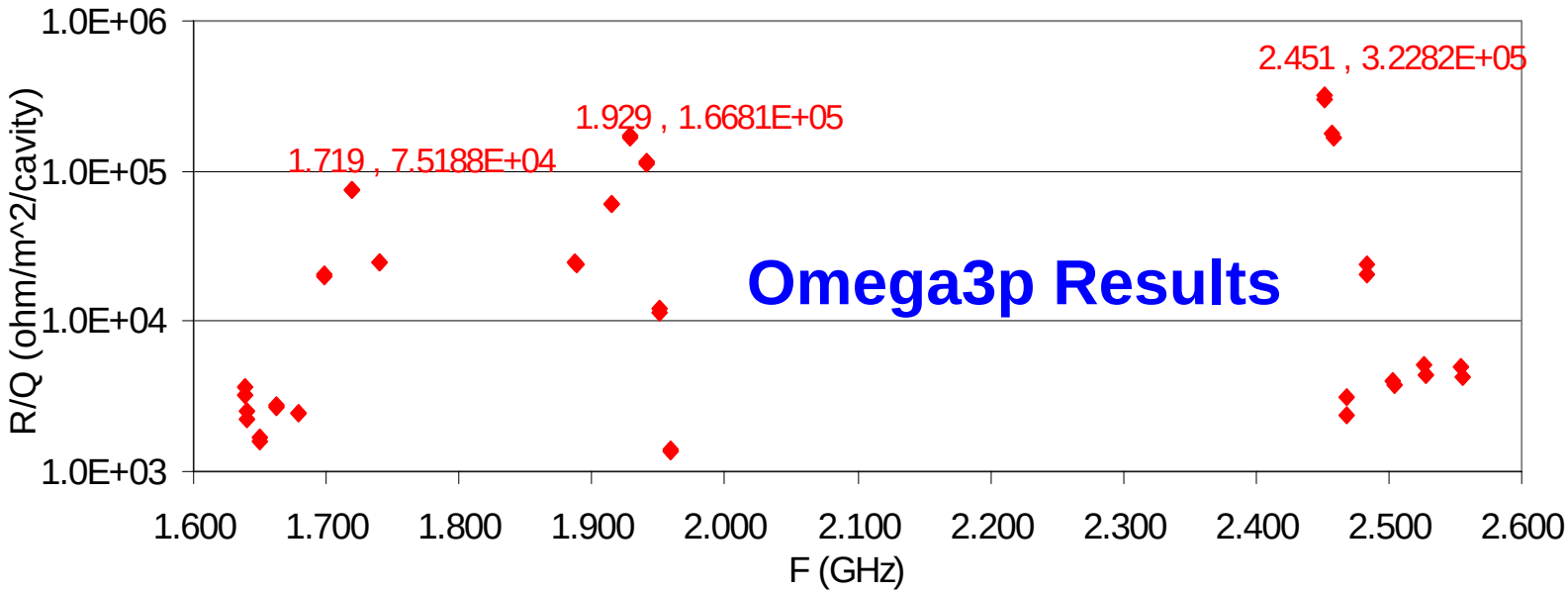




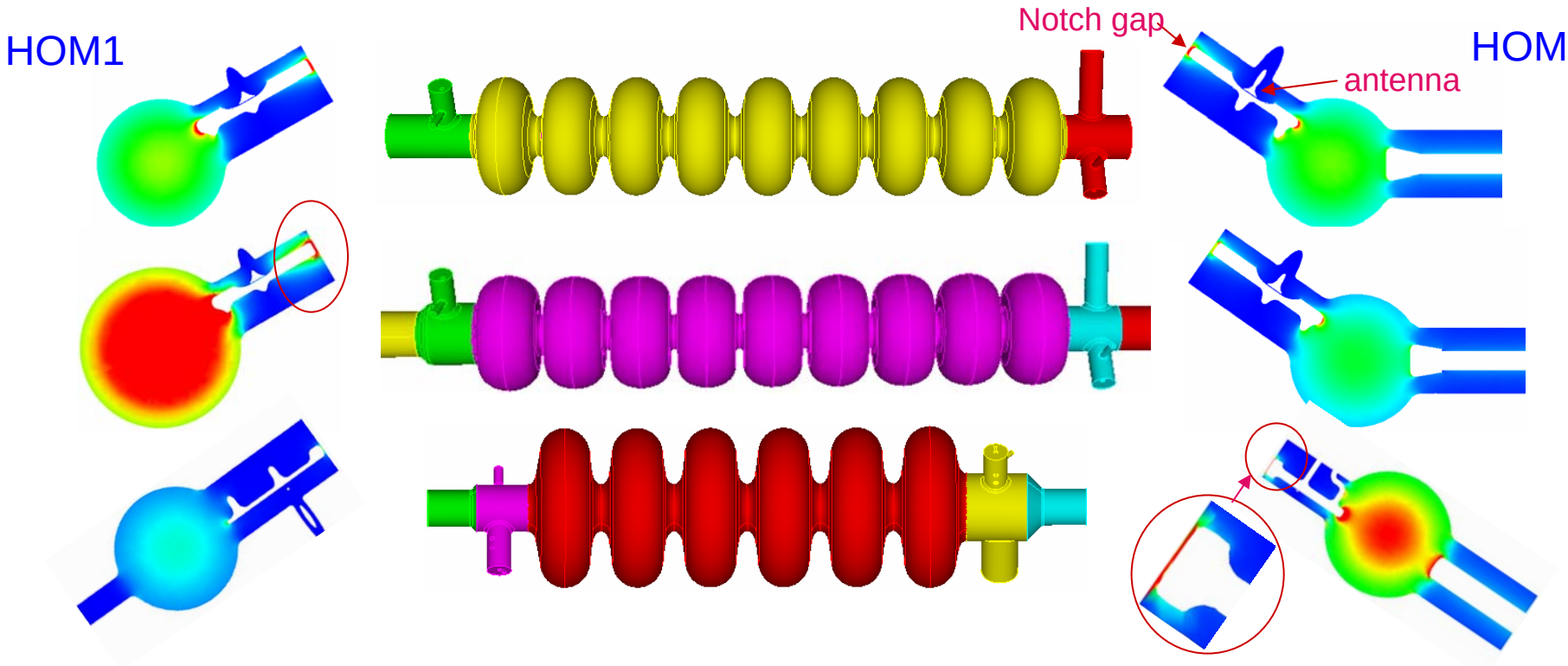
- For smaller iris design, end-group match better to main cavity with smaller pipe radius
- However smaller beam pipe radius reduces the FM coupling

End-group Optimization





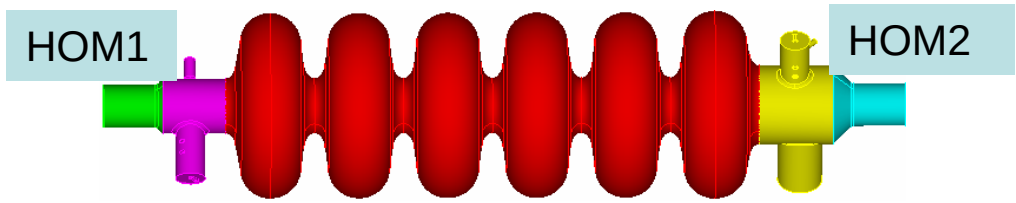
2. Field Enhancement In End-group

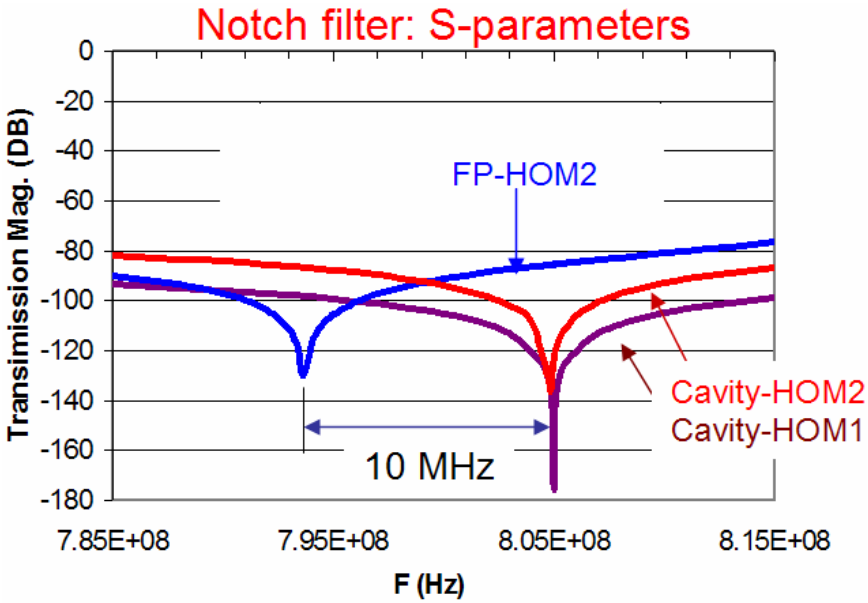


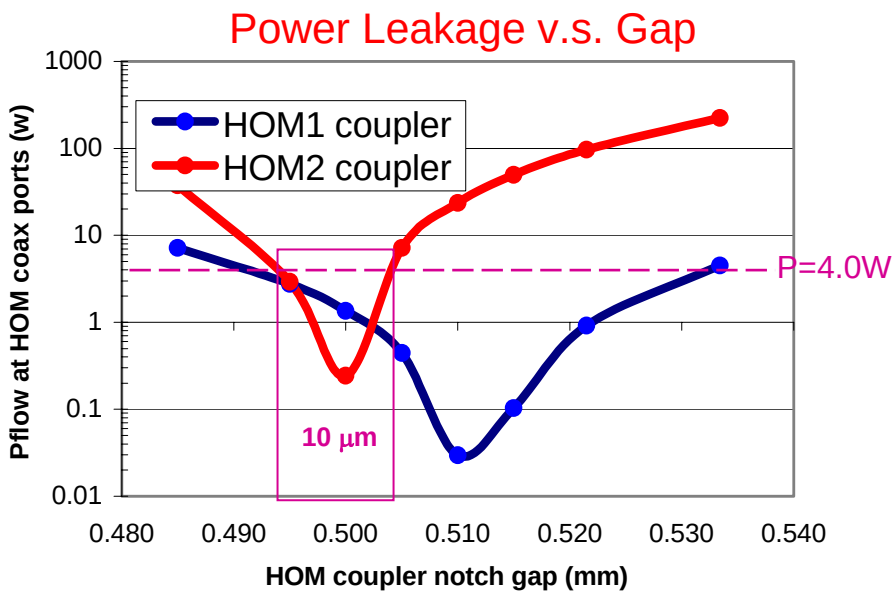
- Field level determined by
  - End-group geometry
  - Notch filter details
- Possible effects
  - Field emission
  - Multipacting
  - RF heating
  - Filter detuning & power leakage

	Field at notch gap (MV/m)	
	HOM1	HOM2
SNS-β0.81@16MV/m@805MHz	3.0	***14.0***
ICHIRO@30MV/m@1.3GHz	***16.9***	5.0
TESLA@30MV/m@1.3GHz	7.4	7.5

3. HOM Coupler Power Leakage vs Notch Gap Accuracy



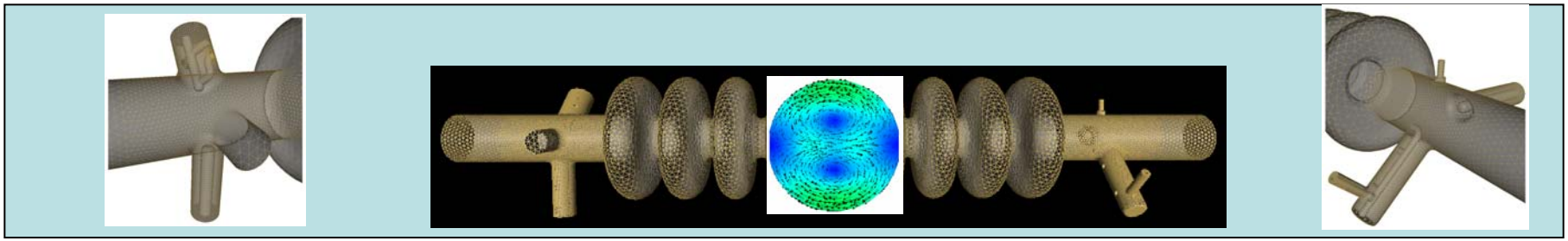




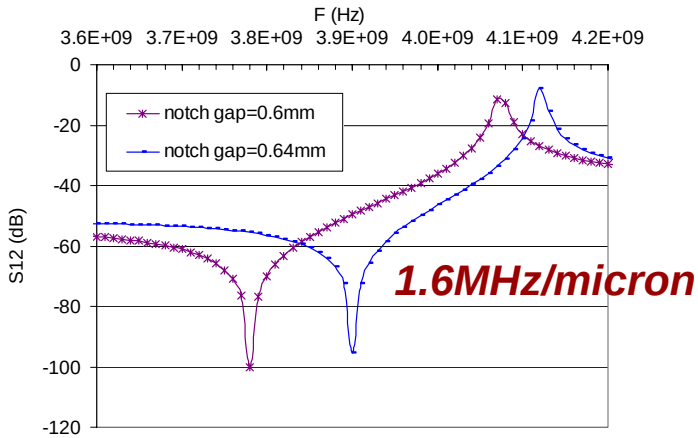
- Notch gap sensitivity
  - SNS: 0.4 MHz/μm (BCD: 0.1MHz/ μm)
- Different notch frequency for transmission and radiation
  - SNS: 10MHz (BCD: 20, Crab: 0 MHz)

- Narrow filter tuning range in the HOM2 coupler
- Tight tolerance in gap width in order to avoid power leakage due to detuning

Crab Cavity: HOM Notch Filter Sensitivity

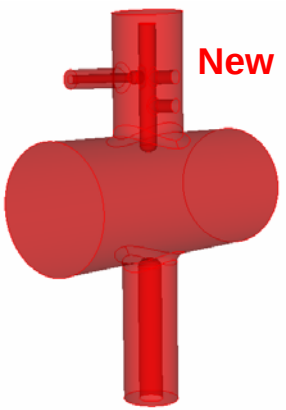


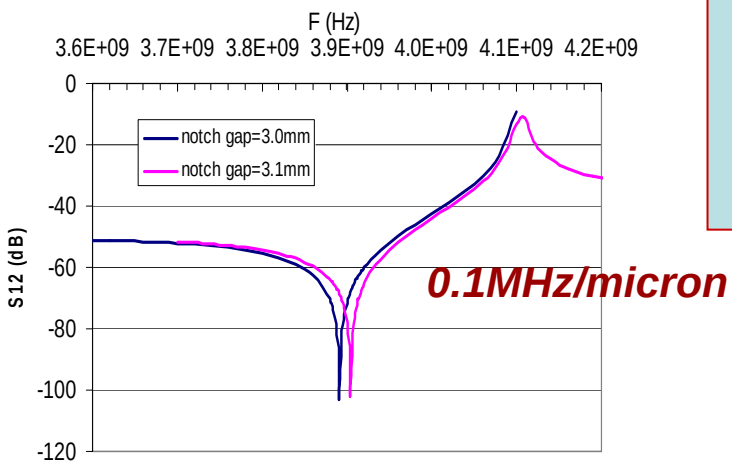
Original Design



1.6MHz/micron

New Design





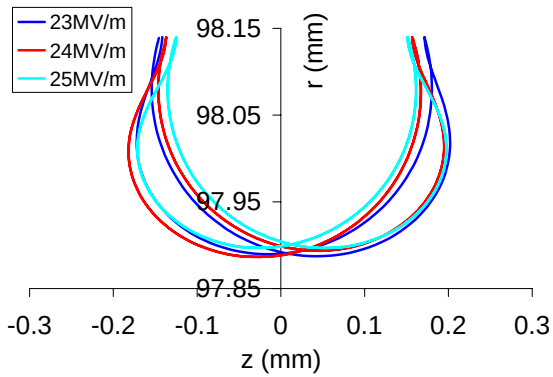
0.1MHz/micron

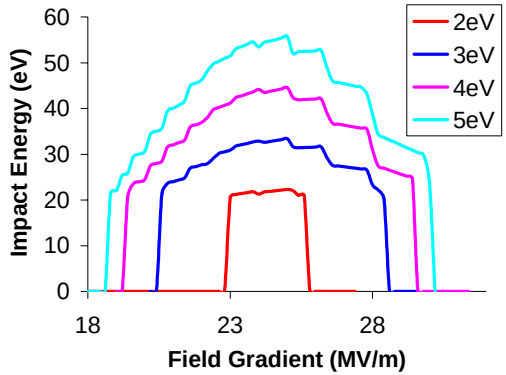
- Very sensitive tuning was found in the original design
  - –1.6MHz/micron
  - –0.1MHz/micron for TESLA TDR
- Resonator geometry was modified to improve the tunability
  - –0.1MHz/micron achieved

SLAC-PUB-12409

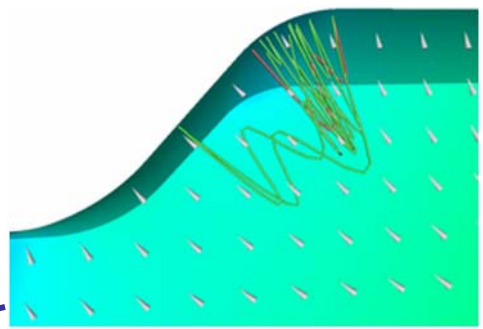
4. MP Simulation

For ICHIRO Cavity





MP trajectories (left) and barriers (right) in regular SRF cells.
Soft barrier at around 23MV/m agrees with RF tests.



Track3P MP simulation		ICHIRO #0 (K. Saito,KEK)
Impact Energy (eV)	Gradient (MV/m)	X-ray Barriers (MV/m)
300-400(6 order)	12	11-29.3 12-18
200-500 (5 order)	14	13, 14, 14-18, 13-27
300-500(3 order)	17	(17, 18)
300-900(3 order)	21.2	20.8
600-1000(1.5 order)	29.4	28.7, 29.0, 29.3, 29.4

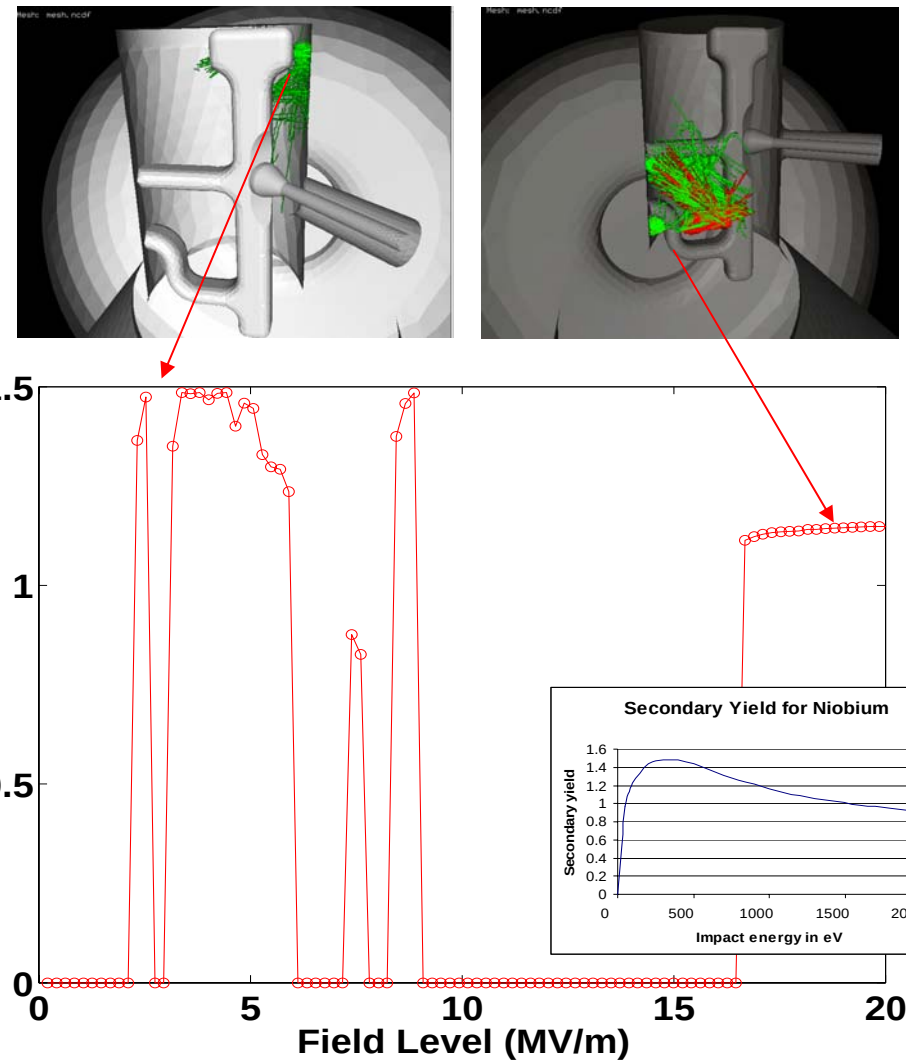
MP barriers in the beam pipe step region

For SNS HOM2

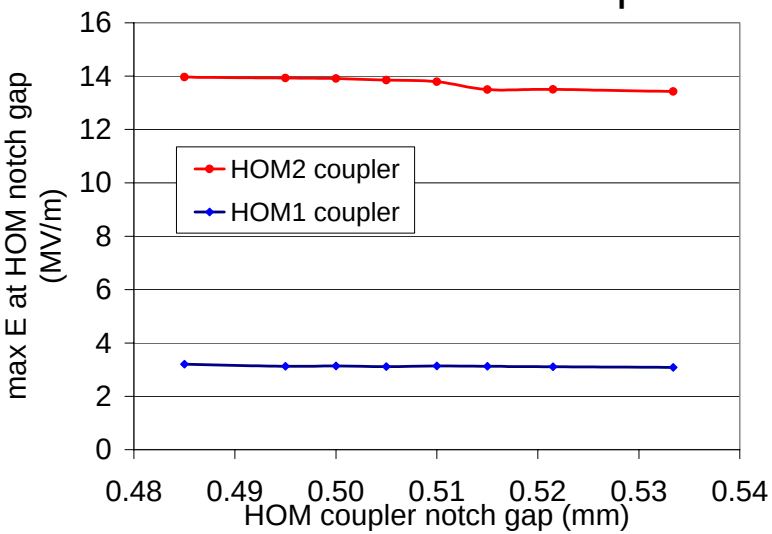
(Sang-ho Kim and et al, LINAC06-THP081)

- "Abnormal waveforms through HOM feedthrough running RF only without beam (electron loading) at 3.5 MV/m and 6 MV/m"

Multipacting in HOM2

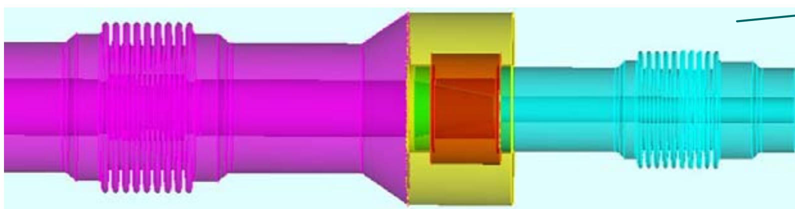


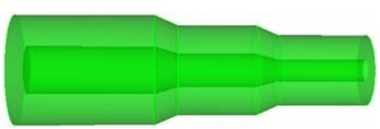
Field level in HOM couplers

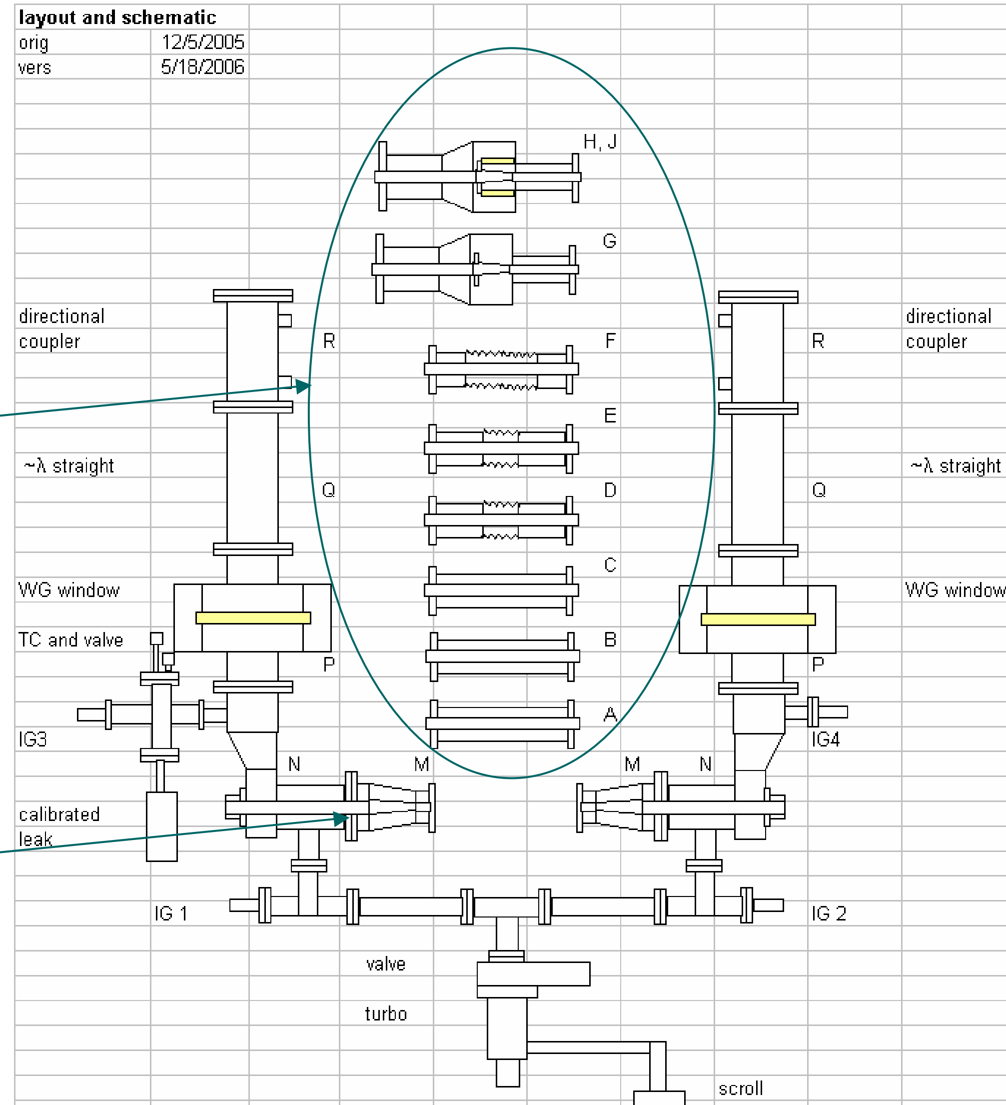


Coupler Test Setup

Will simulate all the components to compare with and to help understand the HP test results

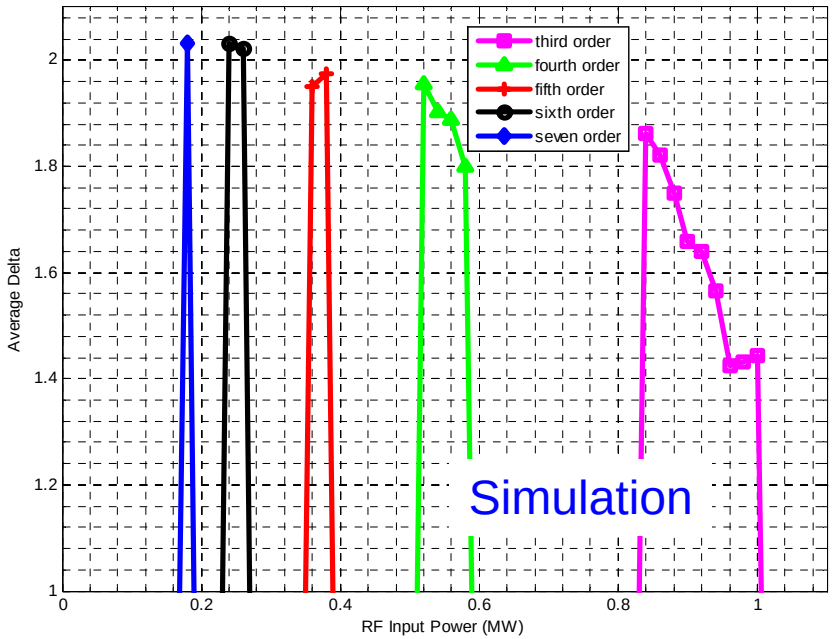




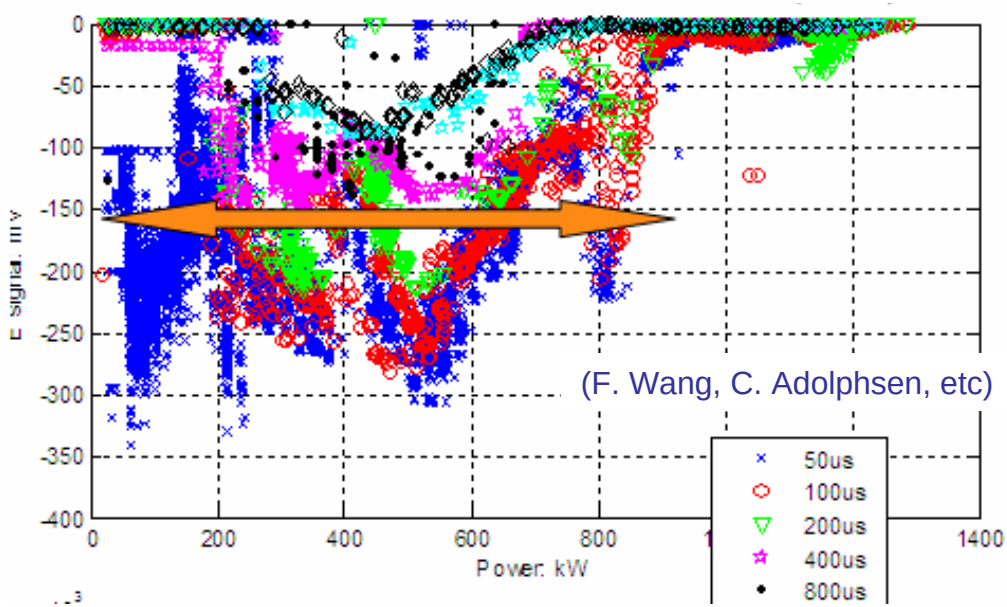


B. Rusnak, C. Adolphsen, R. Swent, C. Nantista, G. Bowden, J. Lewis

TTF-3 coupler: Cold Coax Component



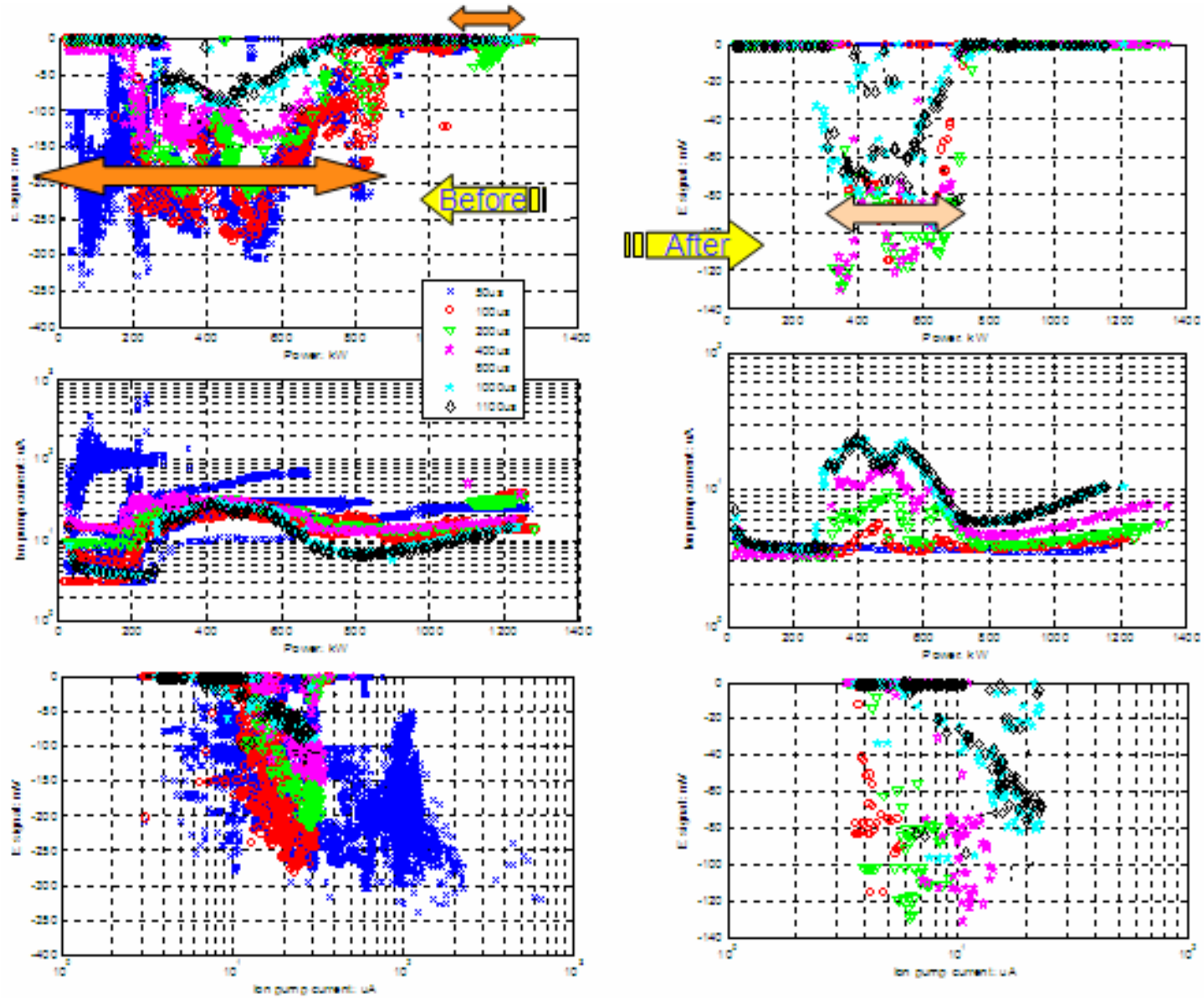
HP test: At beginning of processing



(F. Wang, C. Adolphsen, etc)

Simulation	170~190	230~270	350~390	510 ~590	830~1000
Power in Coupler	43~170	280~340	340~490	530~ 660	850~1020
klystron power	50~200	330~400	400~580	620~780	1000~1200

TTF-3 coupler: Cold Coax High Power Test (F. Wang, C. Adolphsen, etc)



Future Plan

- Analyze MP in TTF-3 coupler components
- Analyze MP in crab cavity couplers and regular cells
- End-group study for BCD and ACD cavities – MP, dark curren and damping
- Wakefield RF heating
- Cavity imperfection simulations - wakefields and effects on beam dynamics
- Trapped modes and their damping in multi-cavity units with realistic imperfections