Electromagnetic Modeling for the ILC

(DESY, KEK, JLab, FNAL and SLAC Collaboration)

Zenghai Li, Andreas Kabel
Lixin Ge, Rich Lee, Cho Ng, Greg Schussman, Liling Xiao and Kwok Ko

Advanced Computations Department
Stanford Linear Accelerator Center

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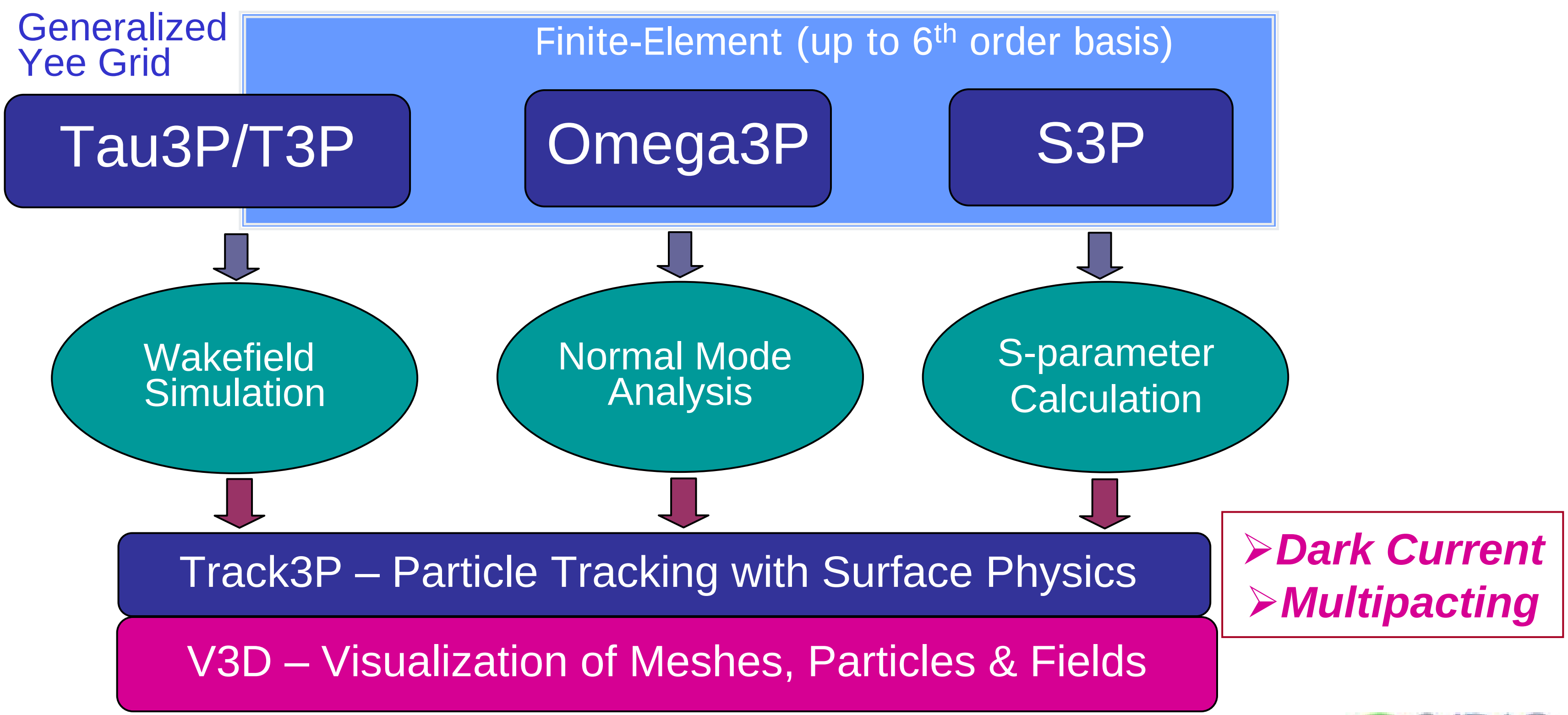
EM Code Development under SciDAC

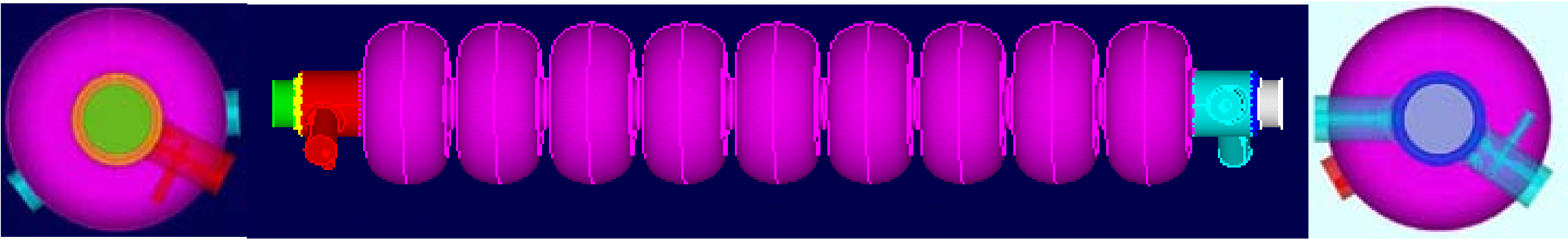
- *SciDAC - DOE Office of Science* ***HPC Simulation*** *Initiative*
- *SLAC is developing* ***parallel*** *EM codes on* ***unstructured grids***
- *Target* ***high resolution*** *modeling and* ***end-to-end*** *simulations*
- *Been applied successfully to PEP-II, NLC, LCLS, RIA etc…*



ILC Simulations in Progress

- *HOM damping in DESY-LL & KEK-ICHIRO cavities*
  - *(1) LL – high Q mode in 3rd band*
  - *(2) ICHIRO – high Q mode in 1st band*
- *Modeling mode rotation effect on beam dynamics*
- *Cavity imperfections*
- *Superstructure (SST-weakly coupled pair)*
- *Multipacting (SNS & ICHIRO cavities, KEK coupler)*

Modeling the ILC Cavity Designs

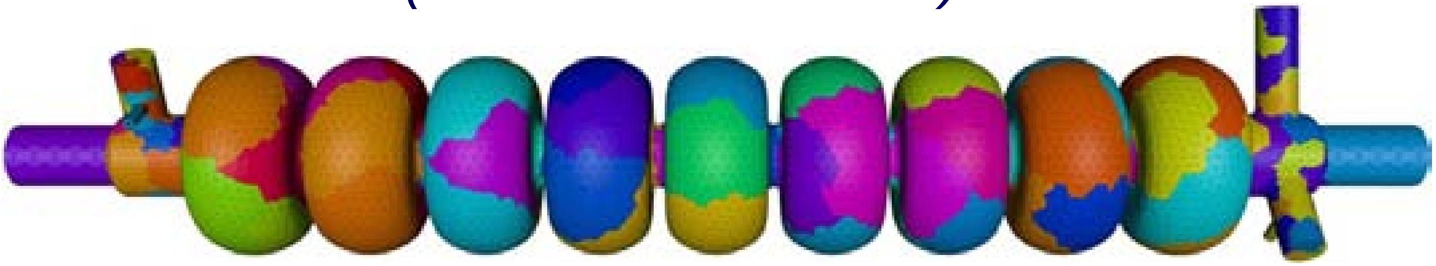


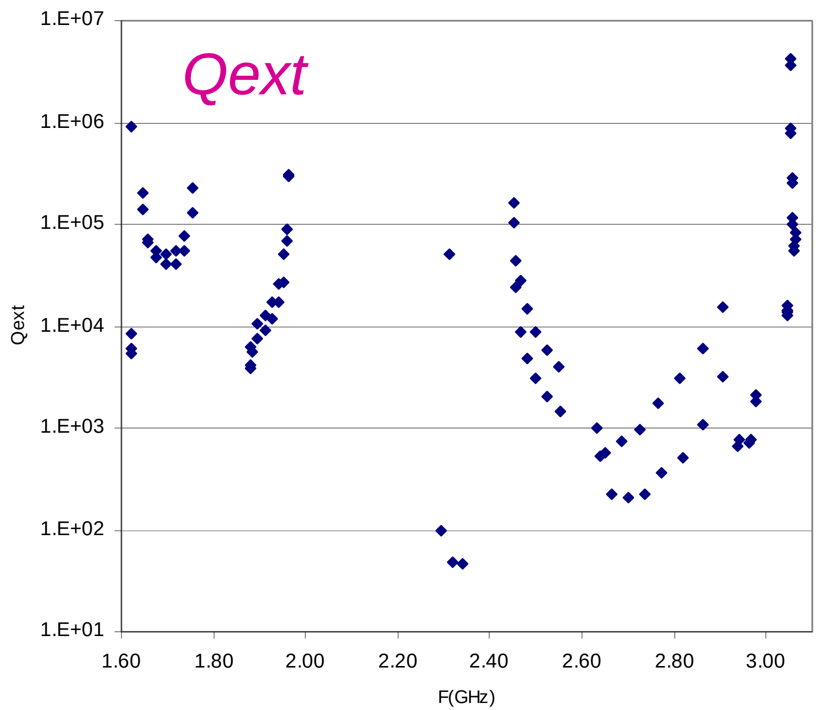
Model of the ILC Low-loss cavity

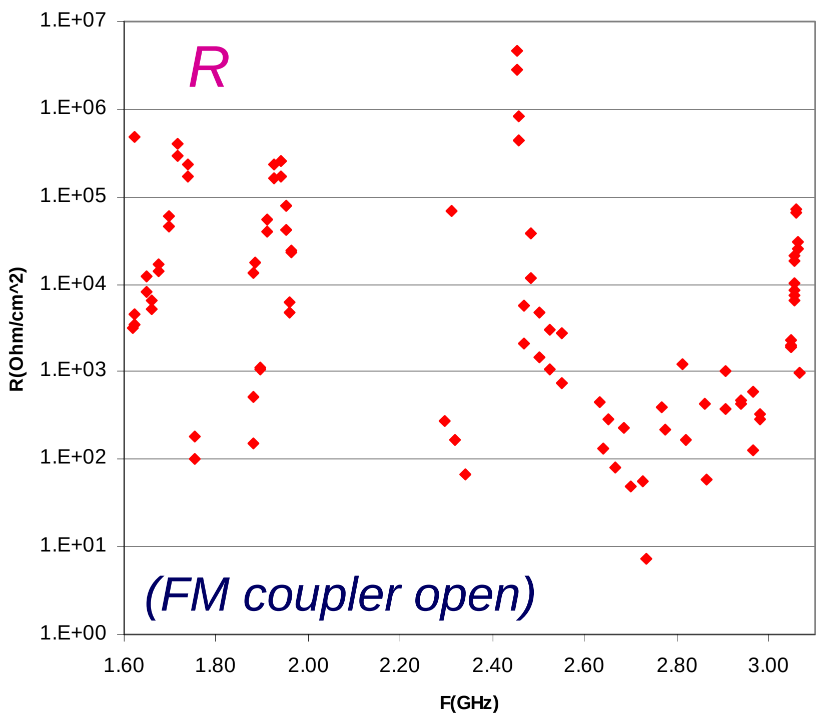
- *SLAC is using the 3D parallel eigensolver Omega3P to find the HOMs in the LL and ICHIRO cavities.*
- *Solve the nonlinear eigenvalue problem that arises when external waveguides attached to the cavity are terminated in matched loads.*
- *Qext is obtained from ½ the ratio of the real to imaginary part of the complex eigenfrequency (or by calculating the power flow and stored energy from the eigenvector).*

HOM Damping in DESY LL Design

(J. Sekutowicz - DESY)

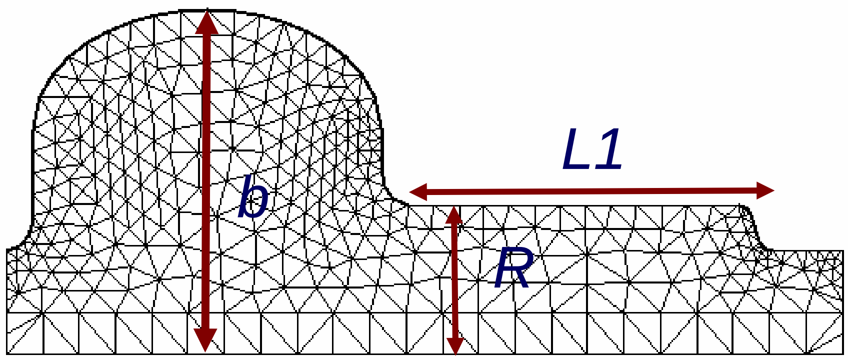


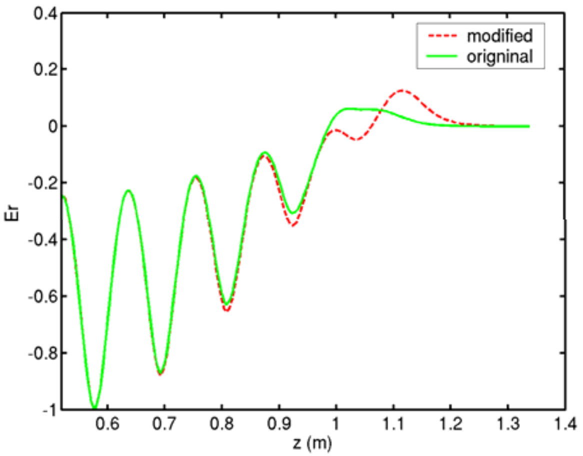


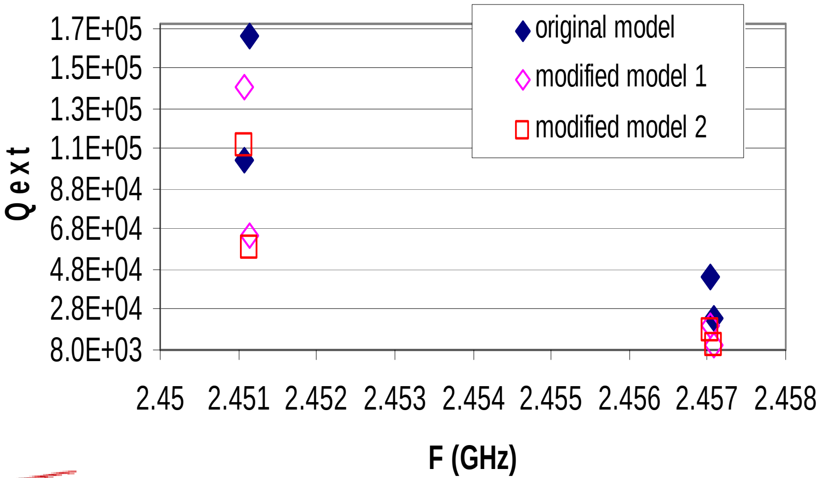


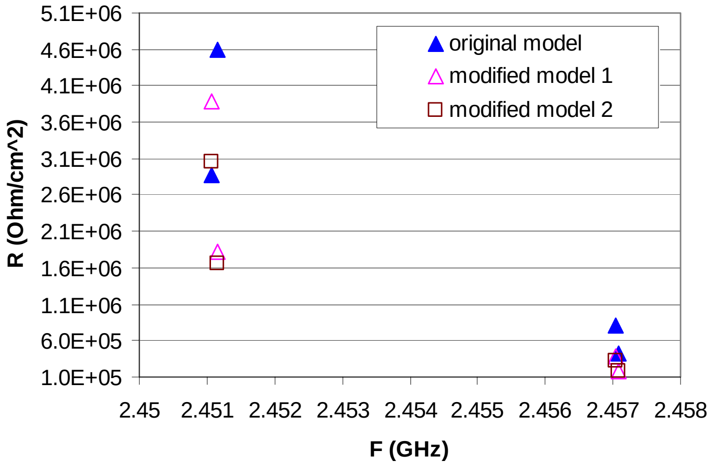
Modifying End Cell to Reduce Q

High Q mode in 3rd band - Adjust end cell dimensions to increase stored energy to have stronger damping without affecting Fundamental mode and Qs of other HOMs.





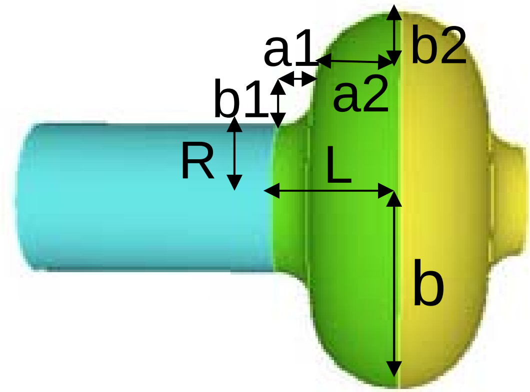


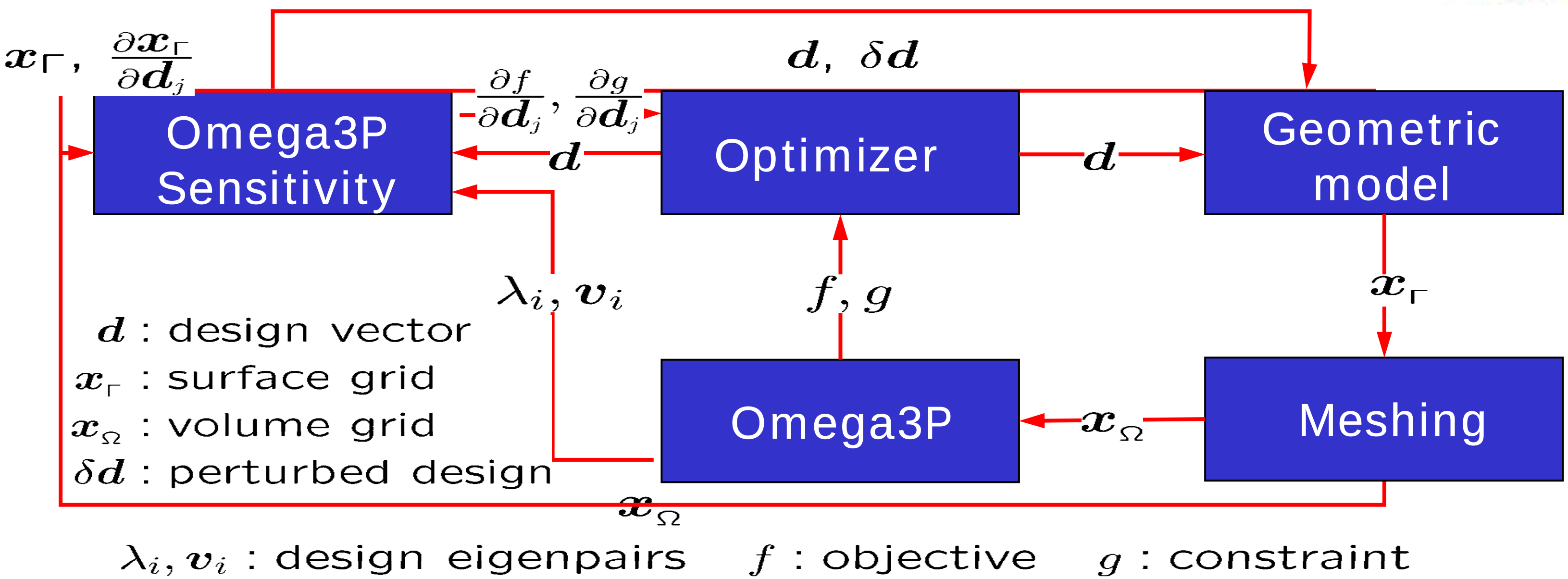


Parallel Shape Optimization

(SLAC – CMU, LBL, Columbia, SNL, LLNL)

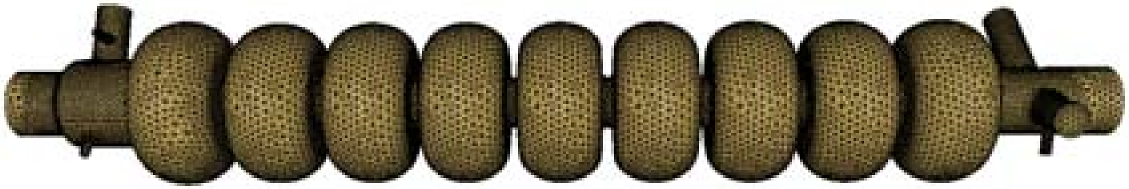
*A new **parallel shape optimization** capability is being developed under SciDAC for use in **Omega3P** to improve on the existing manual iterative process - Specify goal function and constraints.*

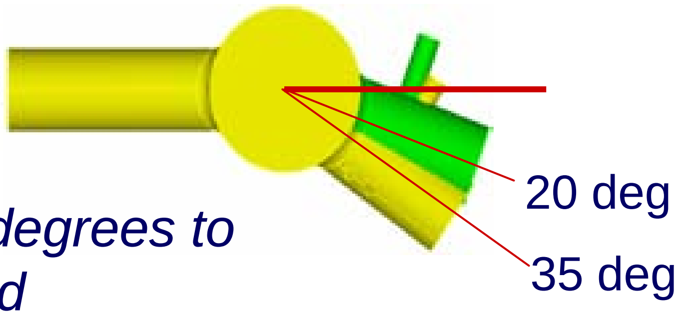




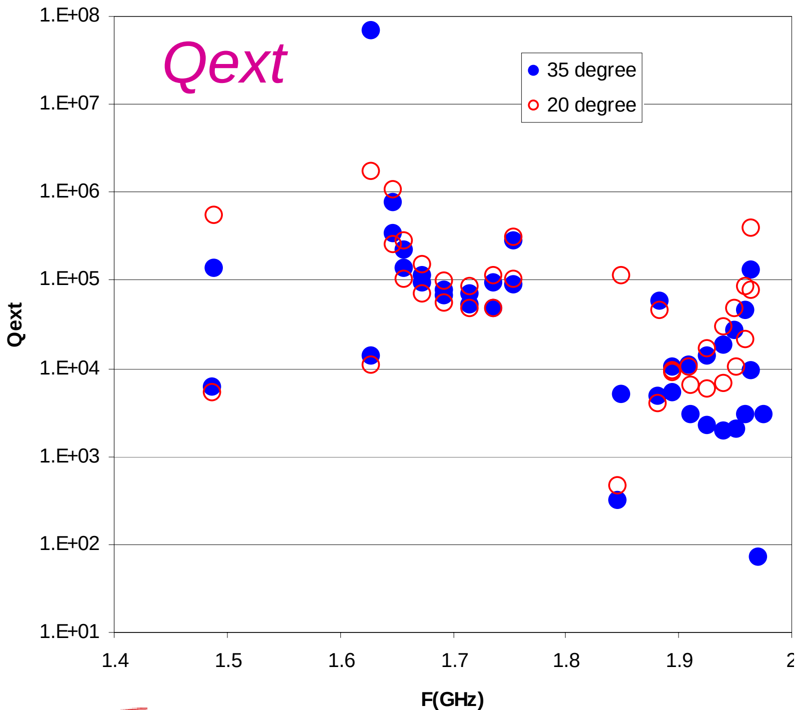
HOM Damping in KEK ICHIRO Design

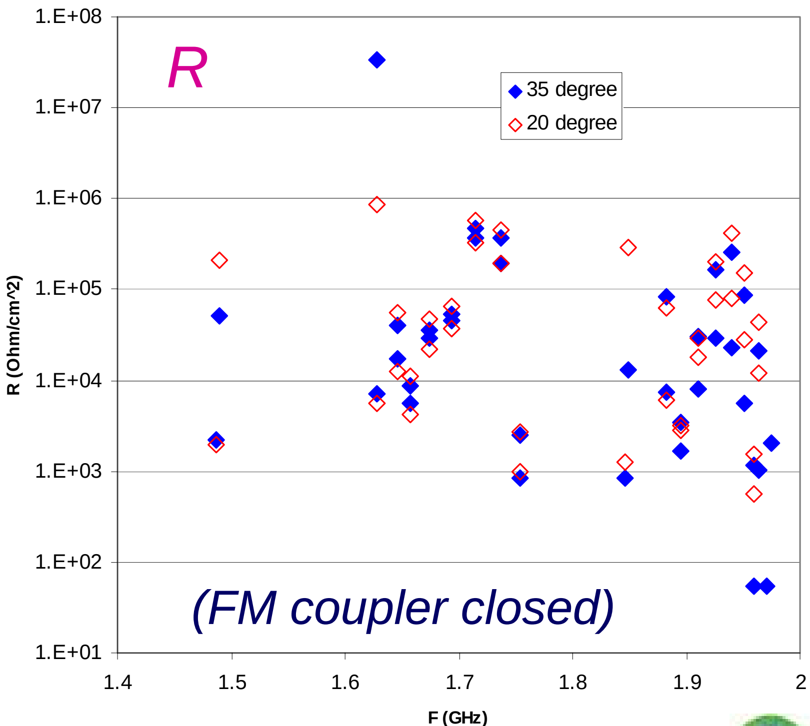
(T. Higo, K. Saito, Y. Morozumi – KEK)





Rear HOM coupler changed from 35 to 20 degrees to improve damping of high Q mode in 1st band

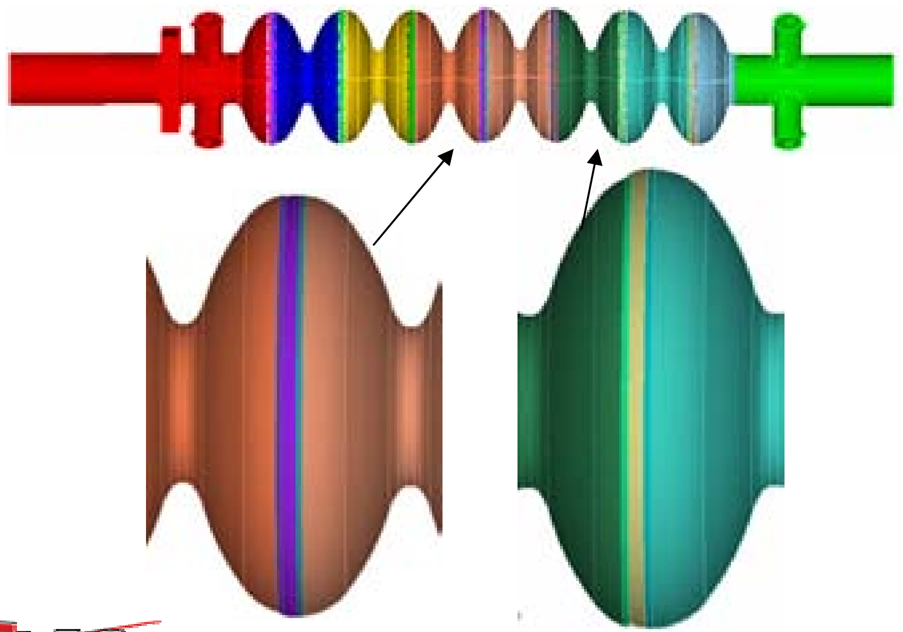




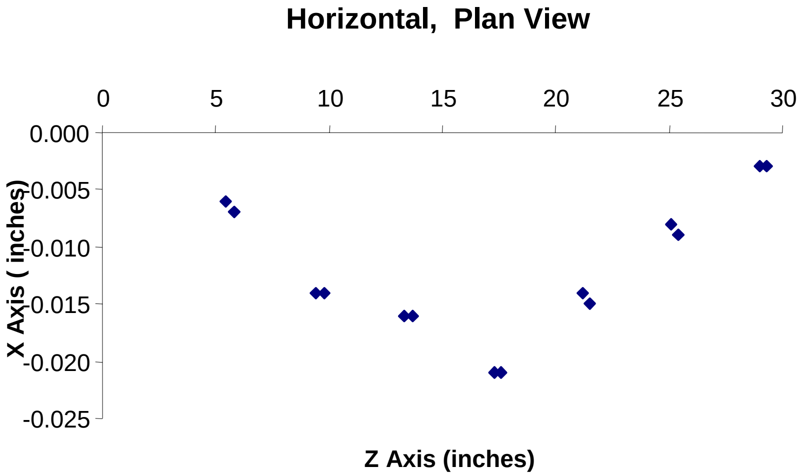
Modeling Cavity Imperfections

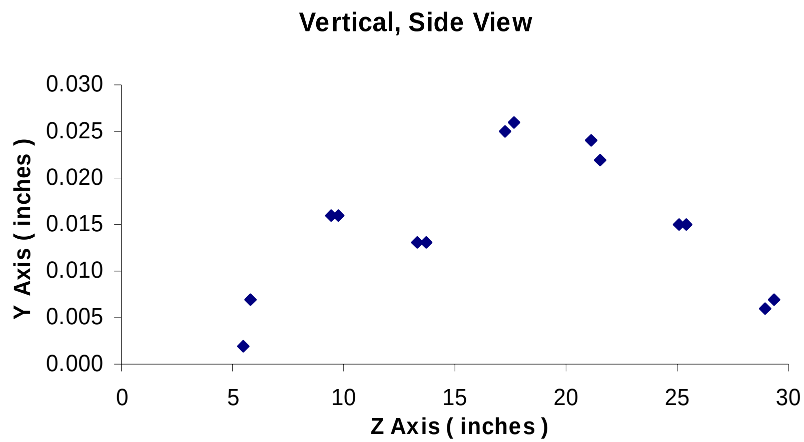
(R. Rimmer – JLab)

Effort has begun on modeling cavity imperfections using cavity QC data from JLab to build corresponding model for Omega3P calculations to compare with mode data.



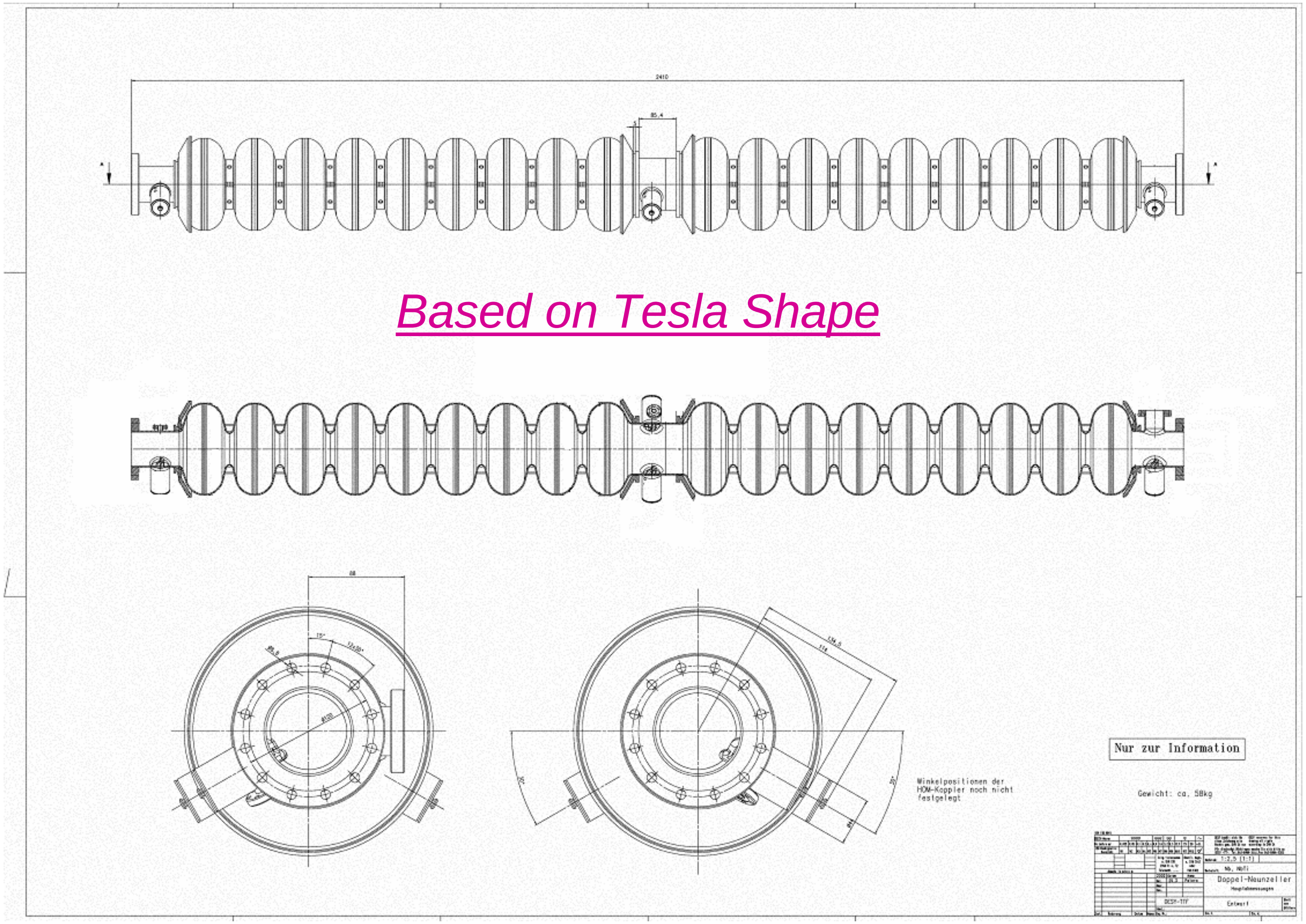
JLab cavity QC data





SST – Weakly Coupled Pair

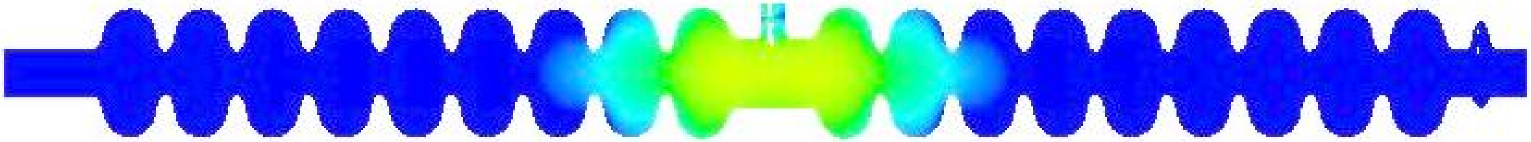
(J. Sekutowicz - DESY)



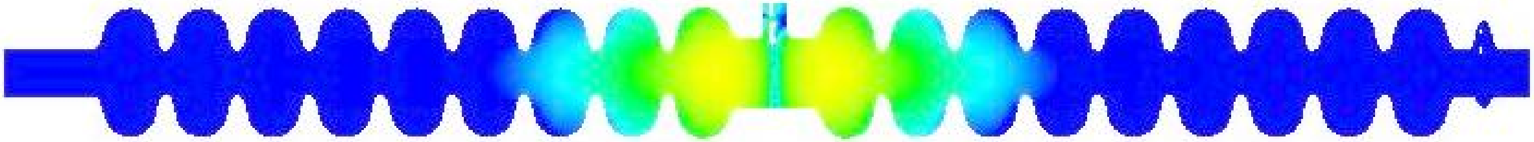
Damping Trapped HOMs in the SST

F=1.4293GHz Q=1816.2

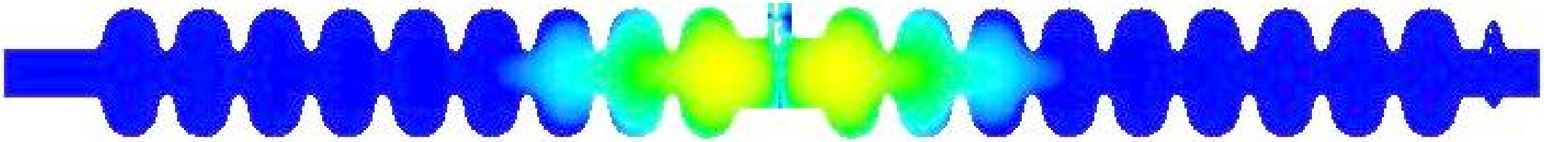
F=1.4329GHz Q=6159.0



F=1.5110GHz Q=39689



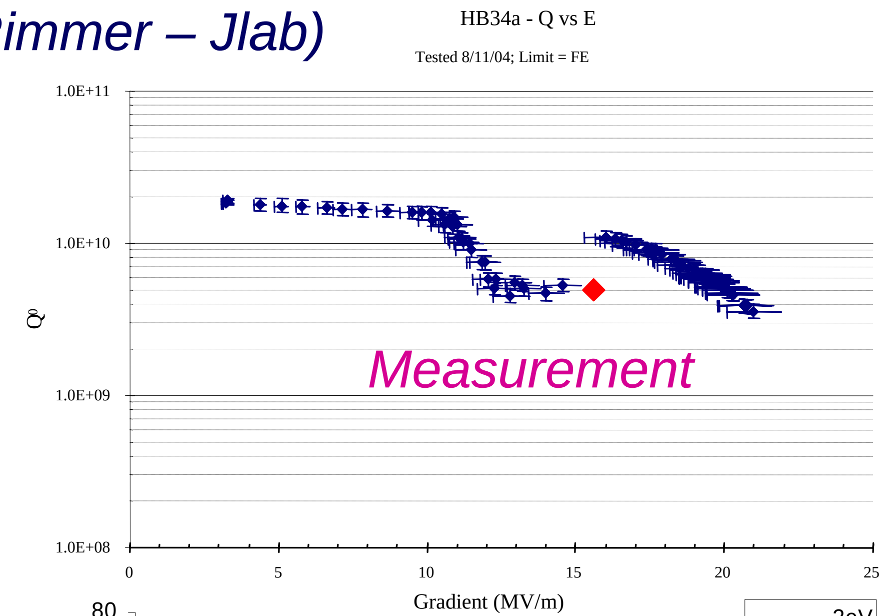
F=1.5112GHz Q=121340

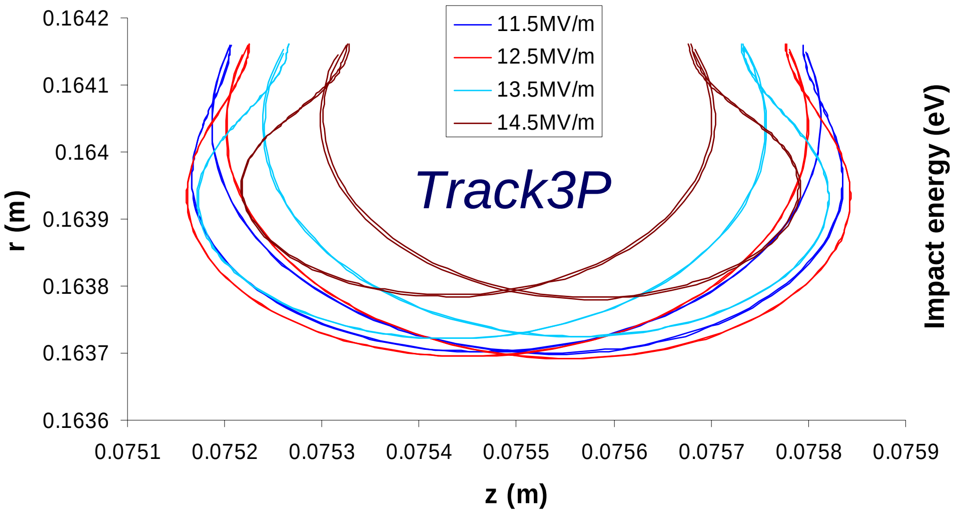


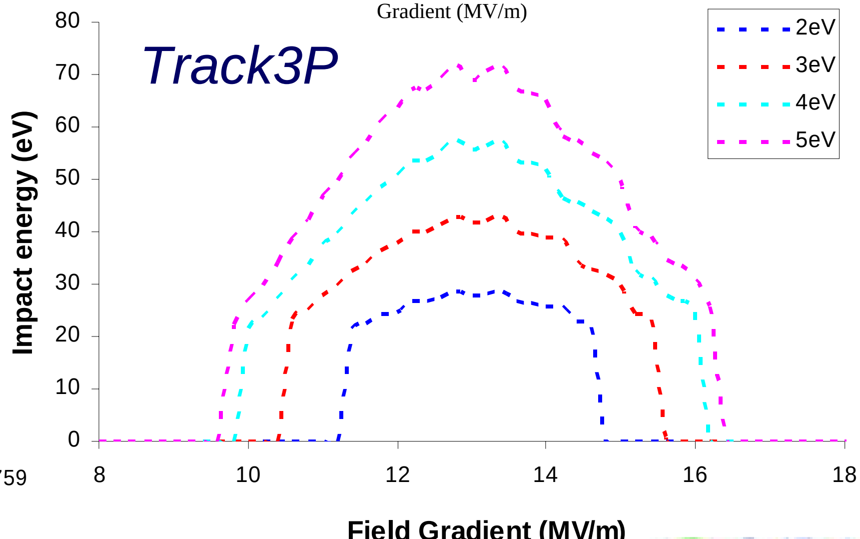
Multipacting in SNS Cavity

(H. Wang, R. Rimmer – Jlab)

Track3P is used to simulate multipacting in the SNS cavity for comparison with measured data using fields obtained from Omega3P



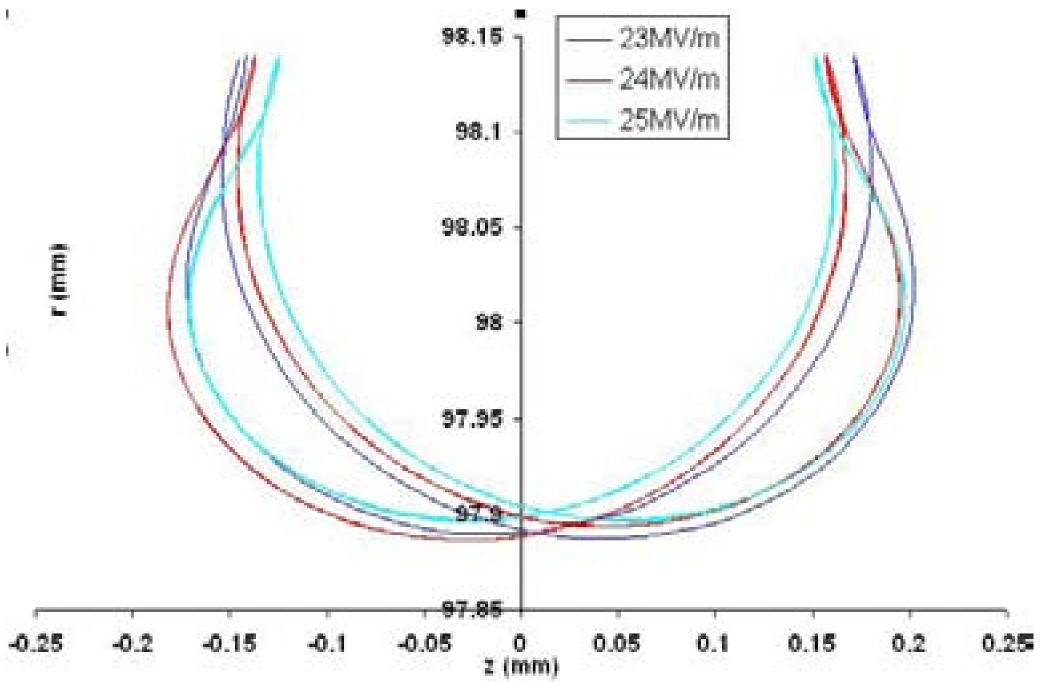


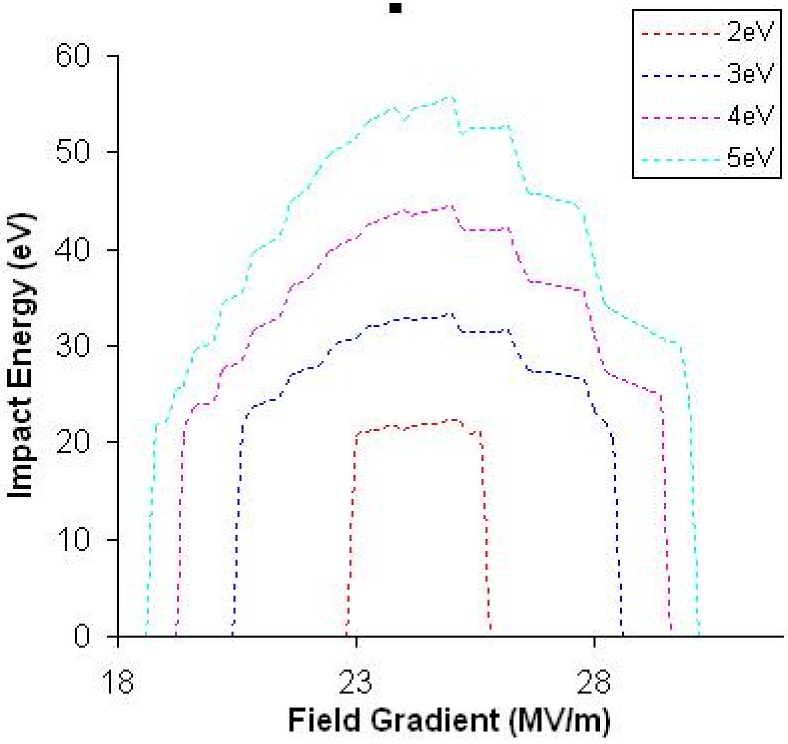


Multipacting in ICHIRO Cavity

Track3P preliminary results indicate there is a MP barrier in field gradient range between 20 and 30 MV/m. More detailed calculations in progress.

Initial energy: 2ev

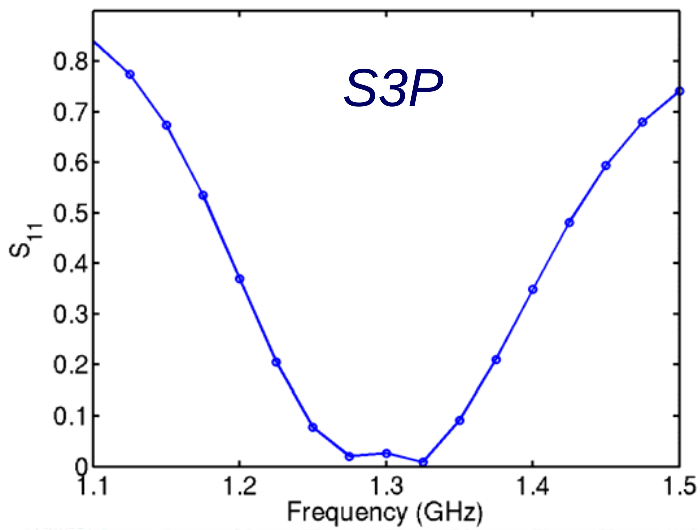


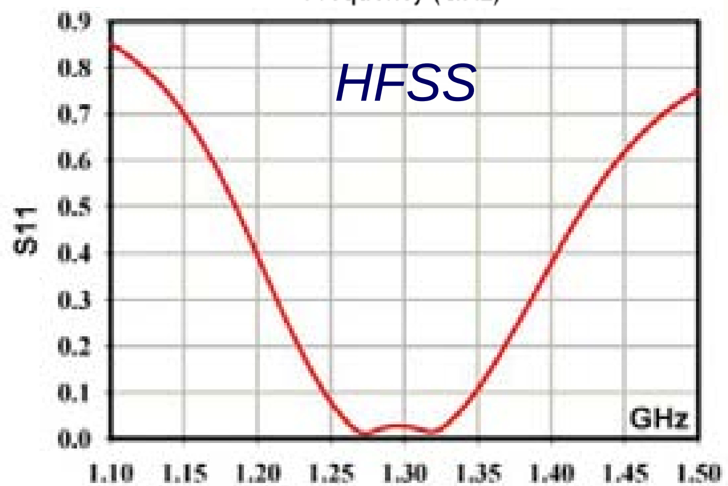


Application to ICHIRO Input Coupler

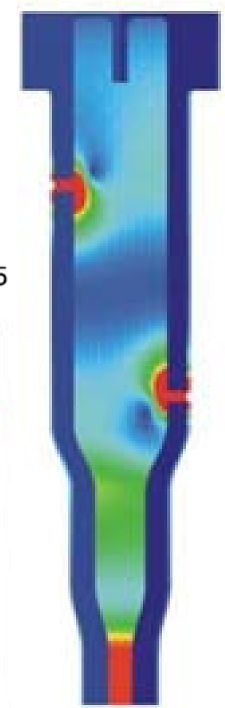
(S. Kazakov, H. Matsumoto – KEK)

A model for ***multipacting*** *calculation with Track3P has been built with fields from S3P that have been benchmarked against HFSS results from KEK.*

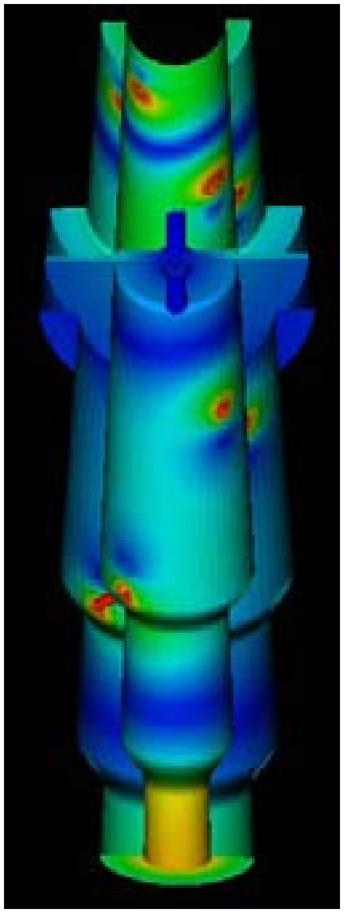




HFSS



S3P



Magnetic field

Mode Rotation in ILC Cavity

- FM and HOM couplers split degeneracy of dipole modes in the ILC cavity
- If the two degenerate modes overlap (resonance width due to damping greater than mode separation) then mode rotation occurs
- Movie shows the rotating fields seen by a particle during its transit through the cavity
- Want to model this effect on particle motion down the ILC linac

Modeling Approach with LIAR

- Use LIAR - SLAC tool for ILC beam dynamics studies
- Modify the wakefield model in LIAR to allow for rotating fields
- Find the excitation of the modes by the leading bunch
- Calculate the force due to the fields on a trailing bunch

Mode Excitation

- Omega3P solves for normal modes in the cavity

$$\nabla \times \nabla \times \vec{E} - \omega^2 \vec{E} = 0$$

- With leading bunch J, use completeness of field eigenvectors (Muller 1961) to expand via:

$$\vec{E}(\vec{x},t) = e_n(t) e^{i\omega_n t} \vec{E}_n(\vec{x})$$

- Solve for coefficients to obtain mode excitation

$$\ddot{e}_n(t) + \omega_n^2 e_n(t) = \iiint i\omega_n \vec{E}_n(\vec{x}) \cdot \vec{j}_{l,m}(\vec{x},t)\, dV$$

Force Calculation

- Force on trailing bunch then given by

$$\delta\vec{p} = \int \left[\rho_{l,m}(\vec{x},t)\vec{E}(\vec{x},t) + \vec{j}_{l,m}(\vec{x},t) \times \vec{B}(\vec{x},t) \right] dt$$

- Fully 3D due to coupling between different l,m components (no cylindrical symmetry)

- Kick factors now generalized to tensor form

$$K_{l,m}^{l',m'} e^{\delta\varphi_{l,m}^{l',m'}} M(t)$$

Implementation in Progress

- **Omega3P**:
  - ODEs solvable in closed form
  - Resulting integrals easily extracted from output
- **LIAR:**
  - Wakefield tensor easy to put in
    - change input routine
    - change convolution algorithm
    - already implemented for l=1
  - Generalize wakefield input - M(t) is input repeatedly in current code