Electromagnetic Modeling for the ILC

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

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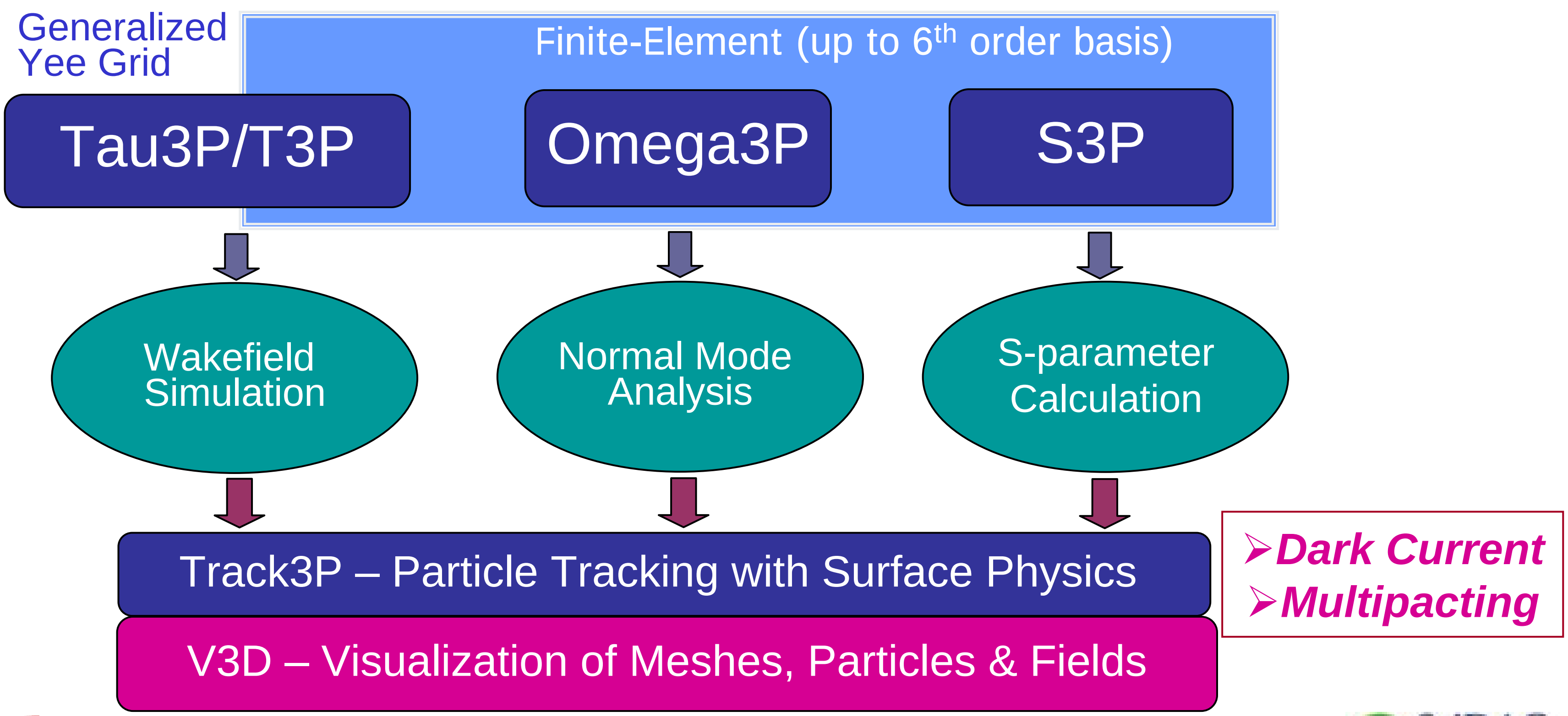
Snowmass - 2nd ILC Workshop 2005

* Work supported by U.S. DOE ASCR & HEP Divisions under contract DE-AC02-76SF00515

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

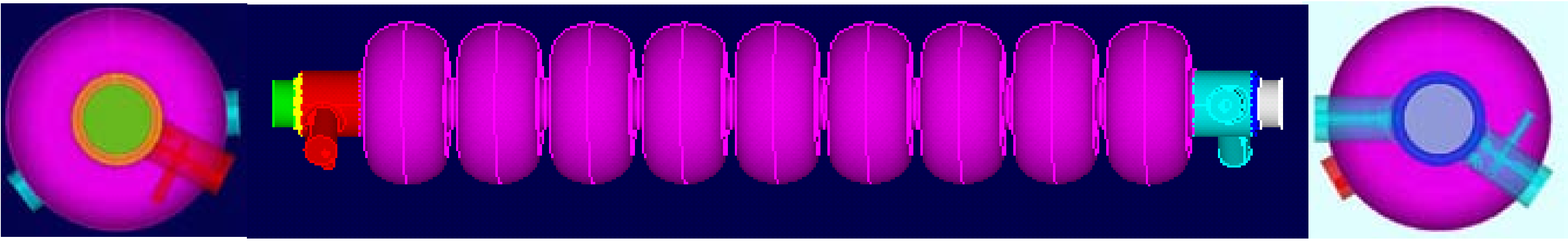
- *HOM damping in DESY-LL & KEK-ICHIRO cavities*

  (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

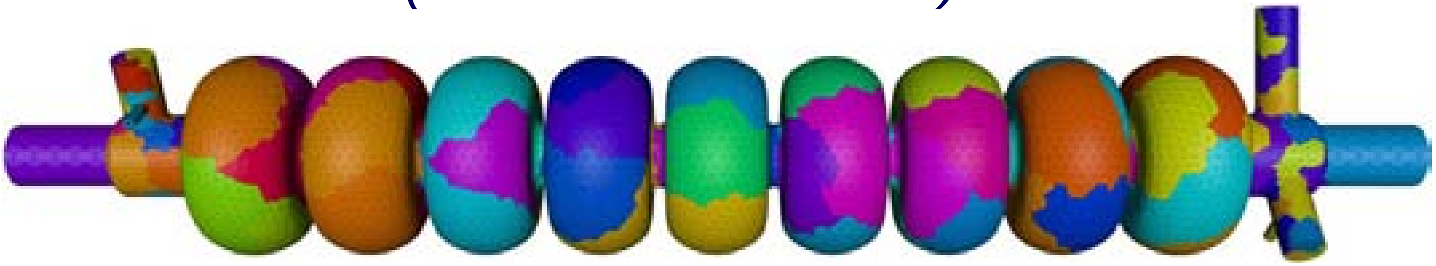


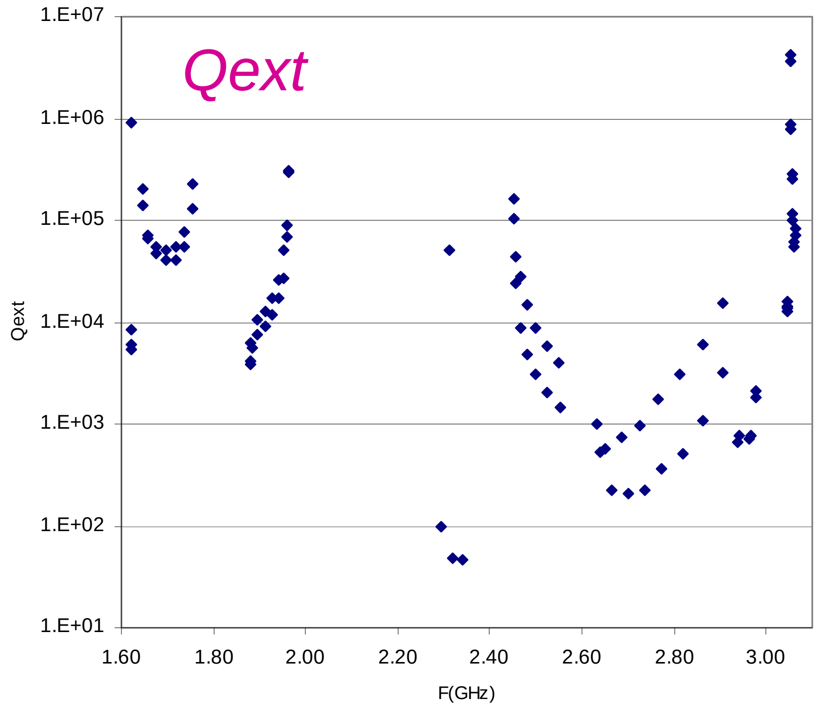
Model of the ILC Low-loss cavity

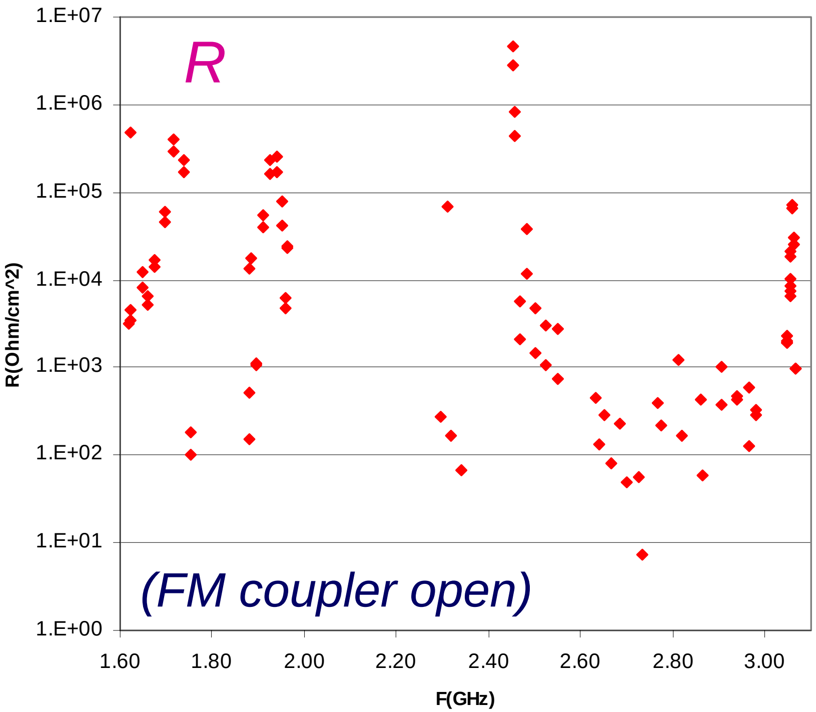
- *SLAC is using the 3D parallel eigensolver Omega3P to find the HOMs in the LL and ICHIRO cavities.*
- *Solve the nonlinear eigenvalue problem that arises when external waveguides attached to the cavity are terminated in matched loads.*
- *Qext is obtained from ½ the ratio of the real to imaginary part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

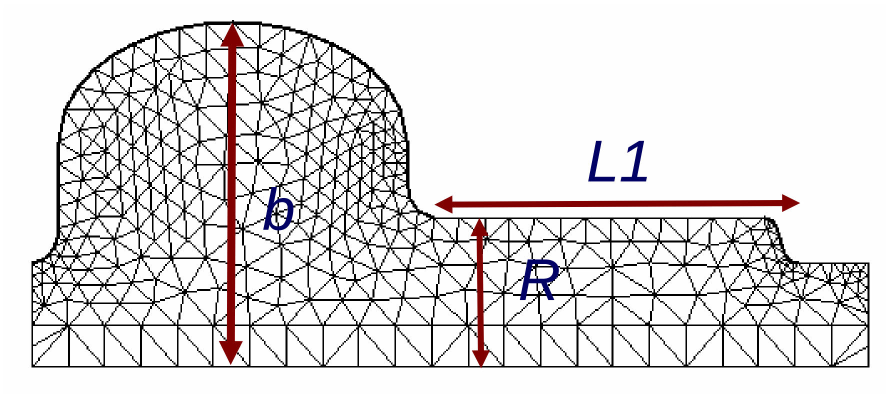


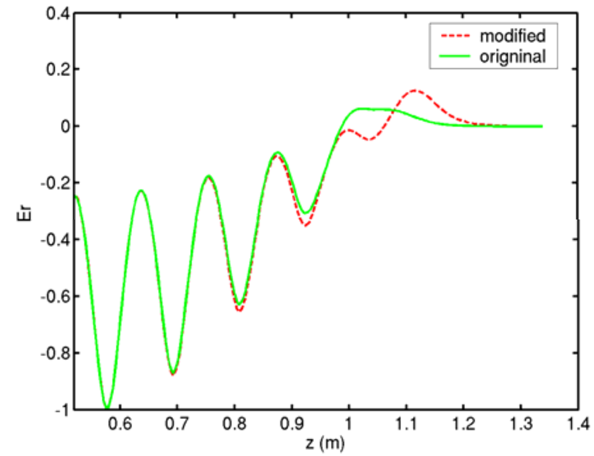


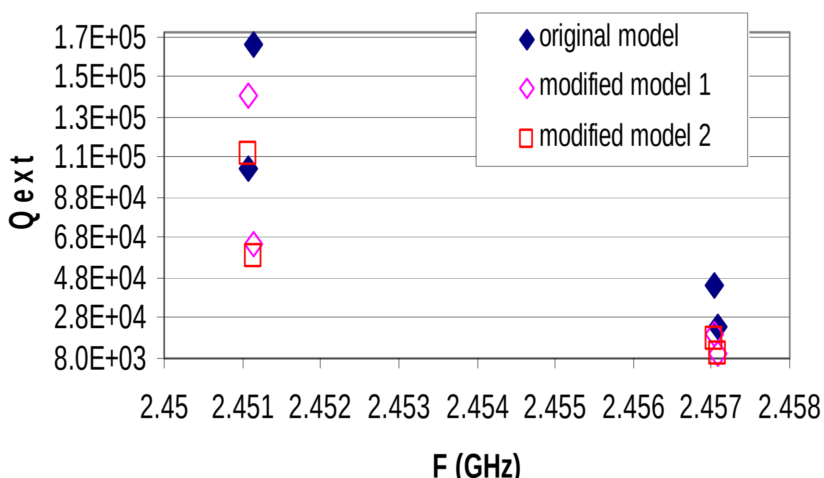


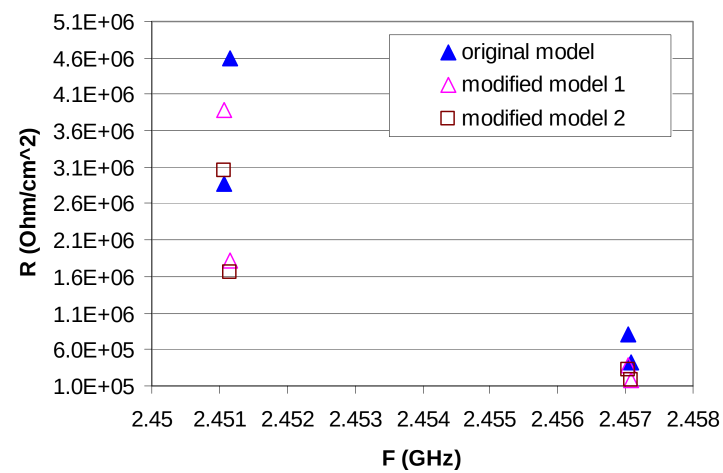
Modifying End Cell to Reduce Q

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.





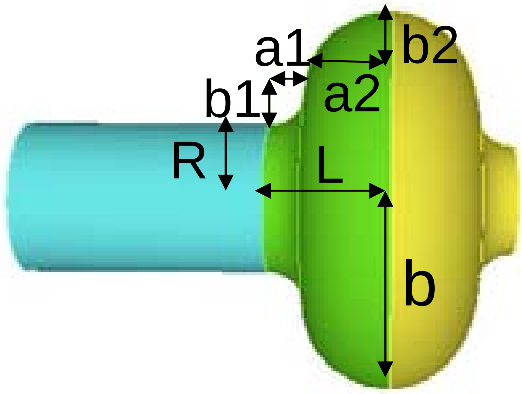


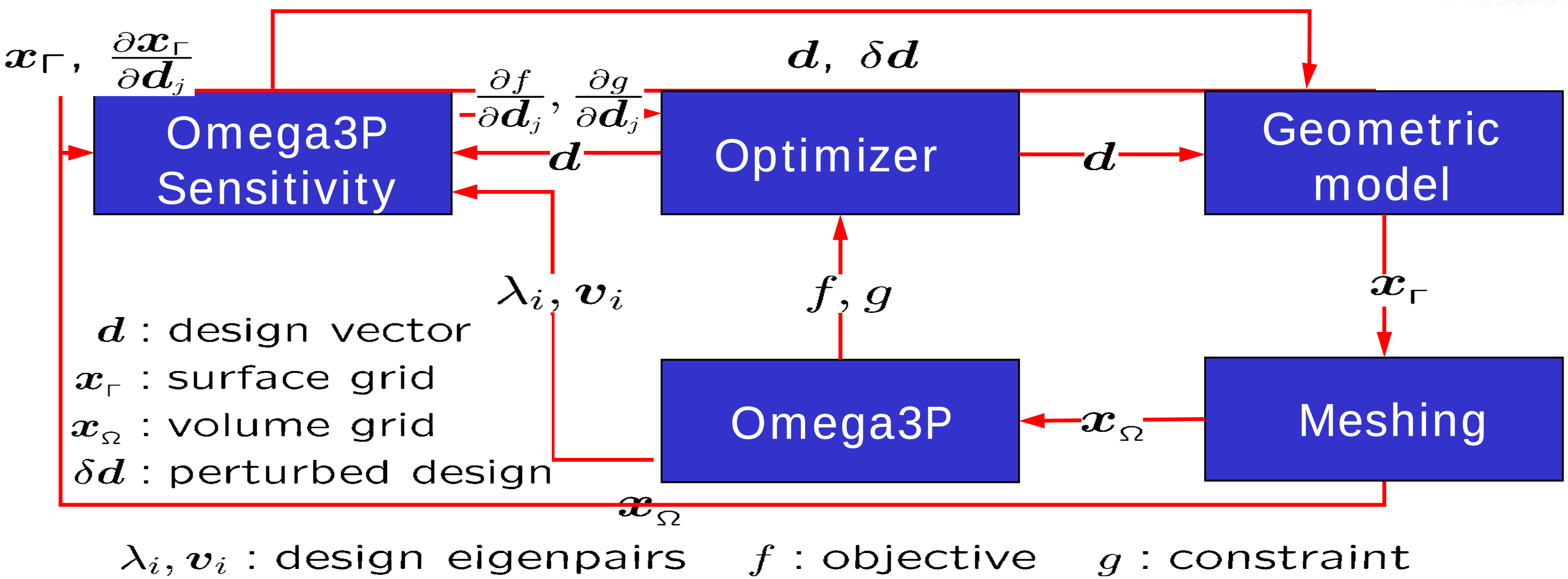


Parallel Shape Optimization

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

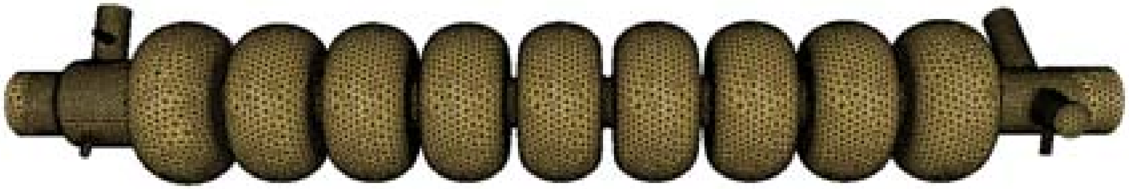
*A new **parallel shape optimization** capability is being developed under SciDAC for use in **Omega3P** to improve on the existing manual iterative process - Specify goal function and constraints.*

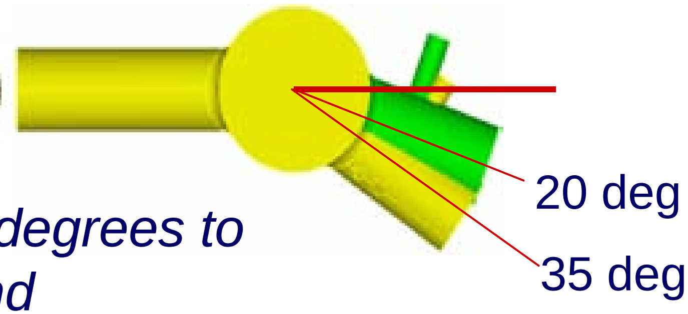




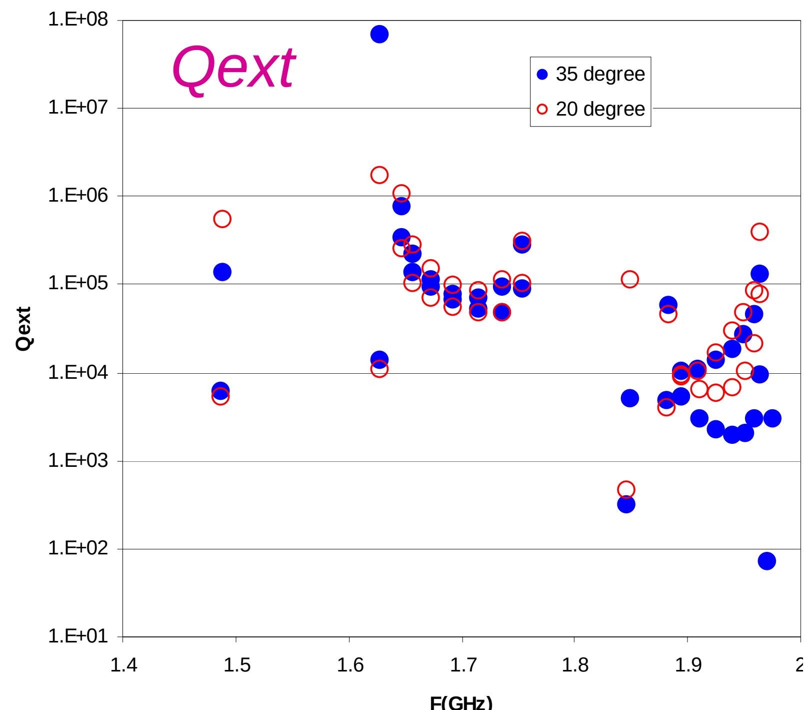
HOM Damping in KEK ICHIRO Design

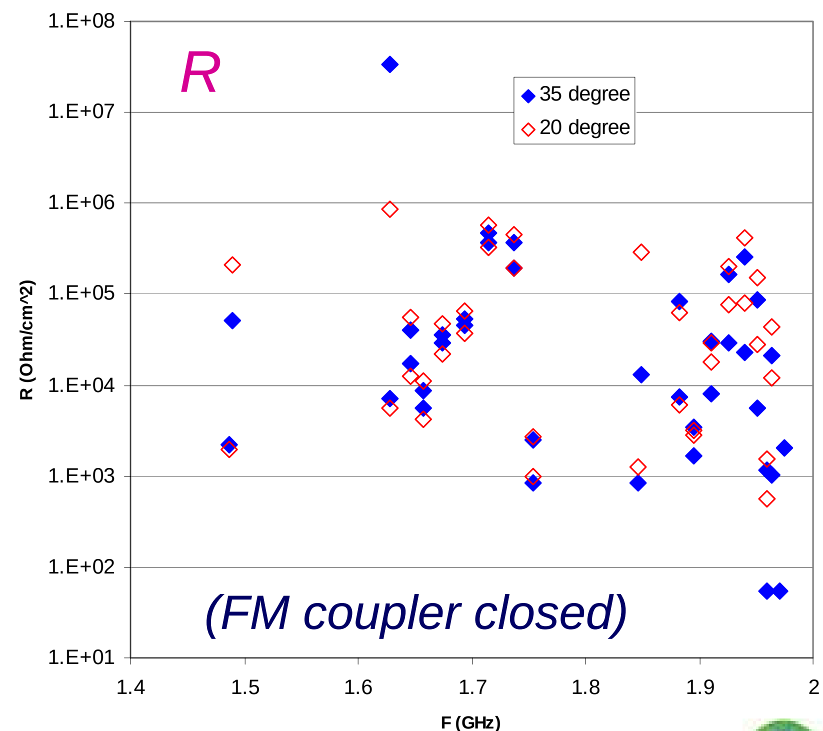
(T. Higo, K. Saito, Y. Morozumi – KEK)





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

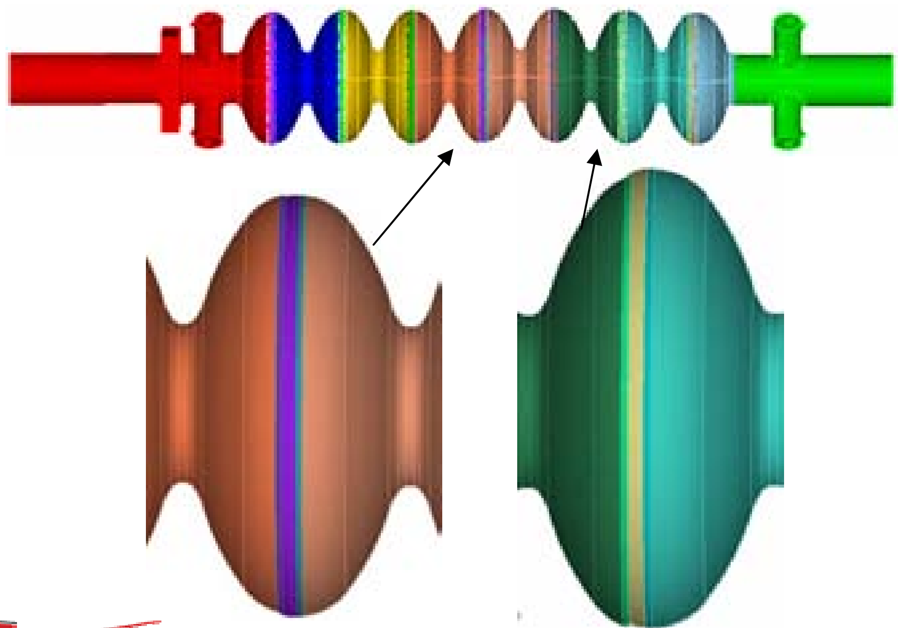




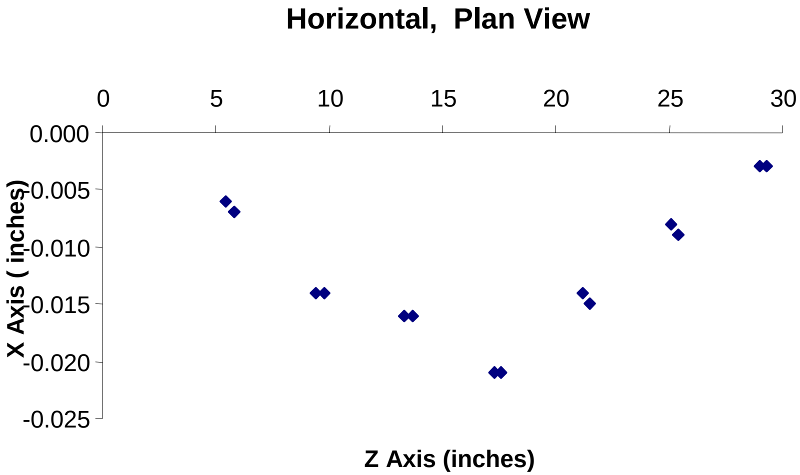
Modeling Cavity Imperfections

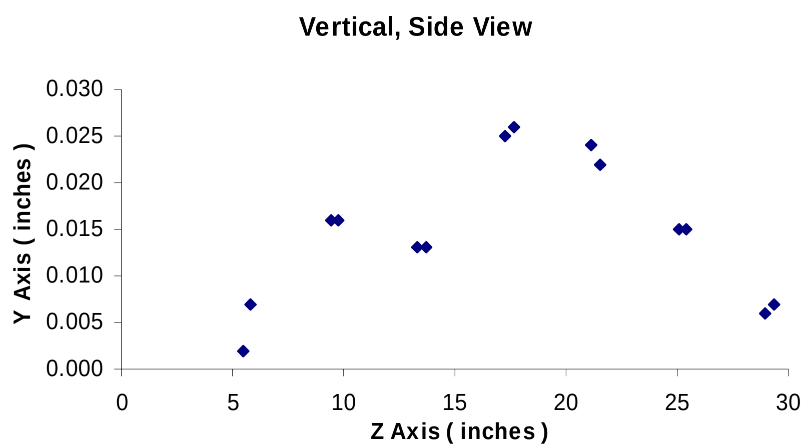
(R. Rimmer – JLab)

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.



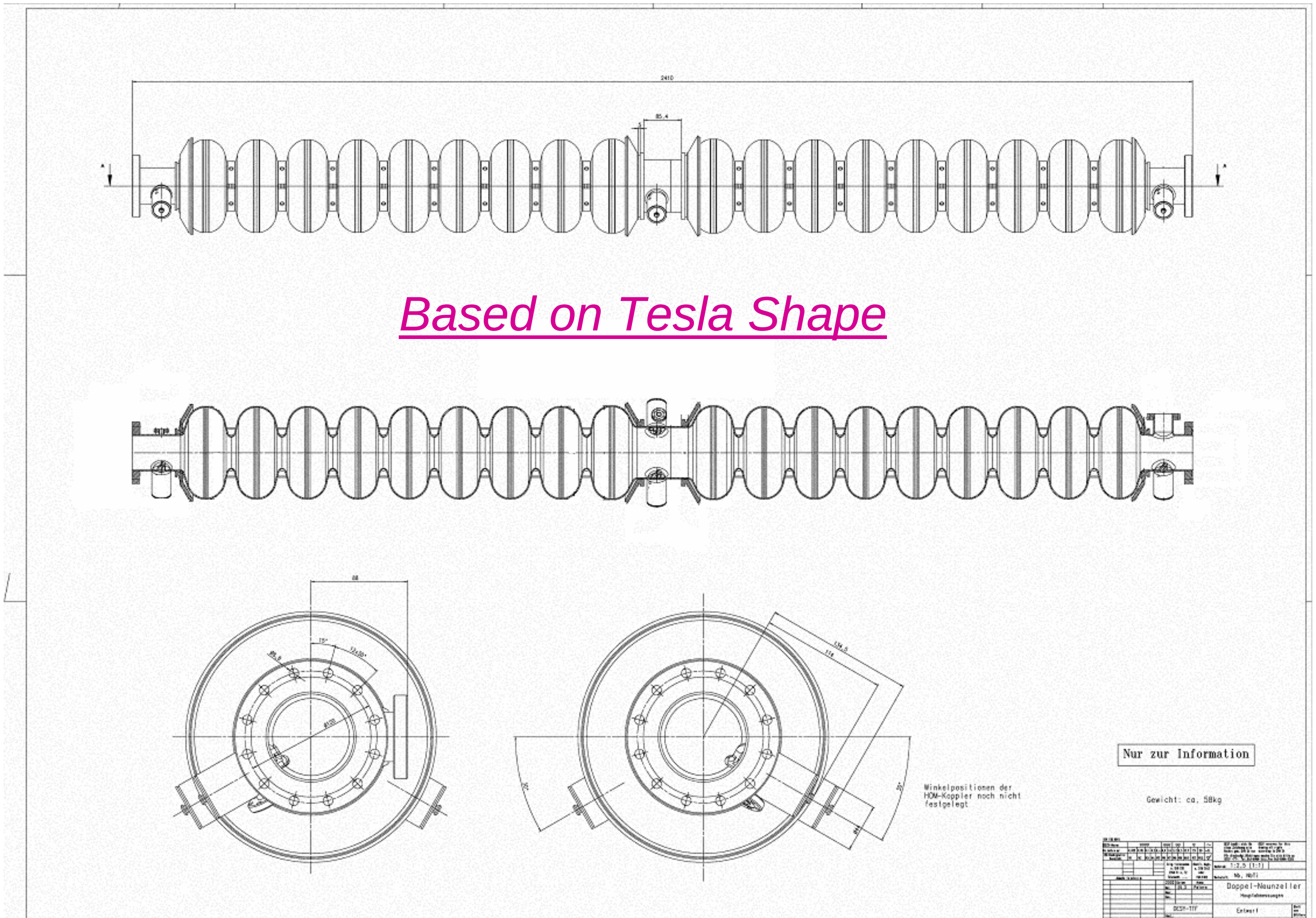
JLab cavity QC data





SST – Weakly Coupled Pair

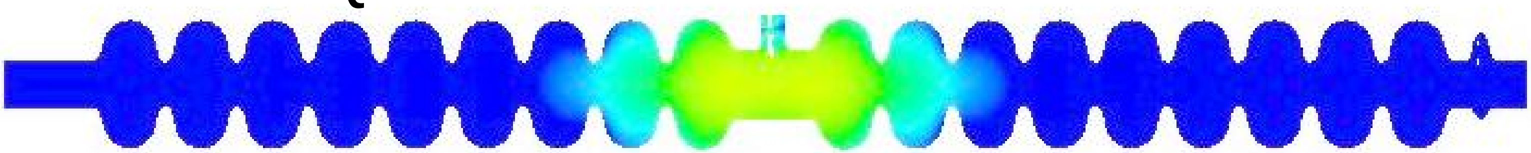
(J. Sekutowicz - DESY)



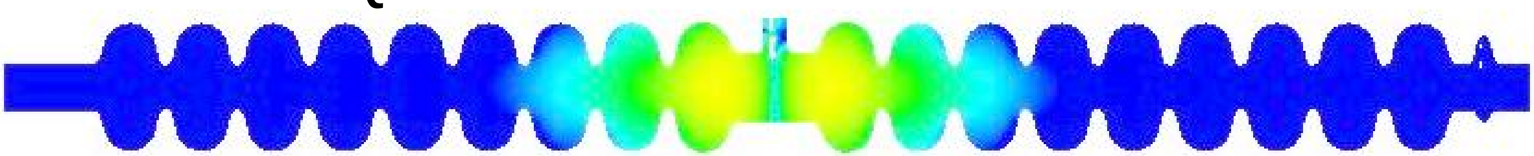
Damping Trapped HOMs in the SST

F=1.4293GHz Q=1816.2

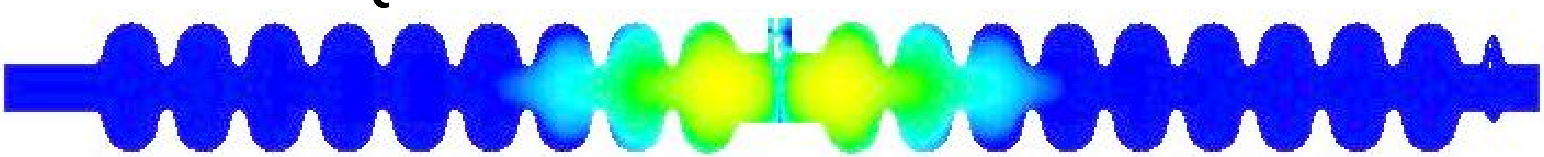
F=1.4329GHz Q=6159.0



F=1.5110GHz Q=39689

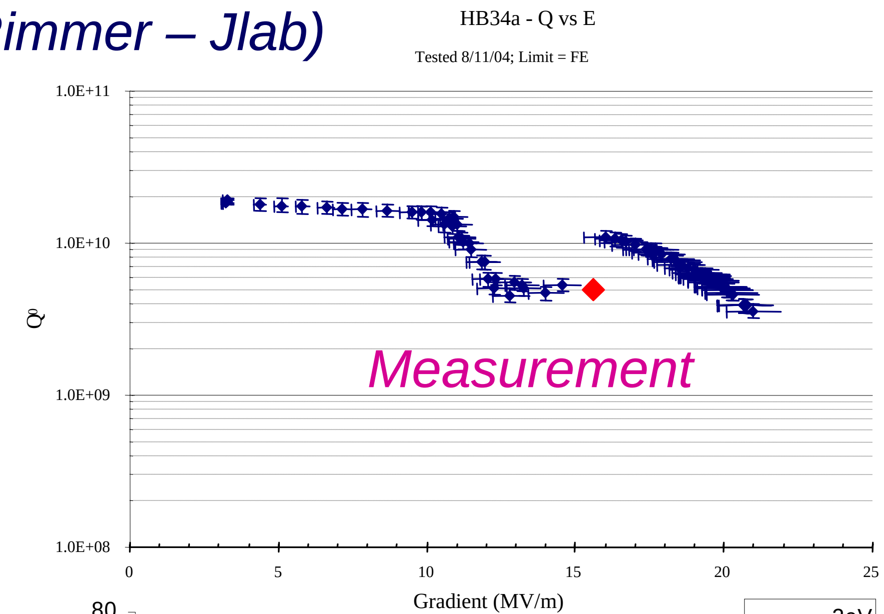


F=1.5112GHz Q=121340

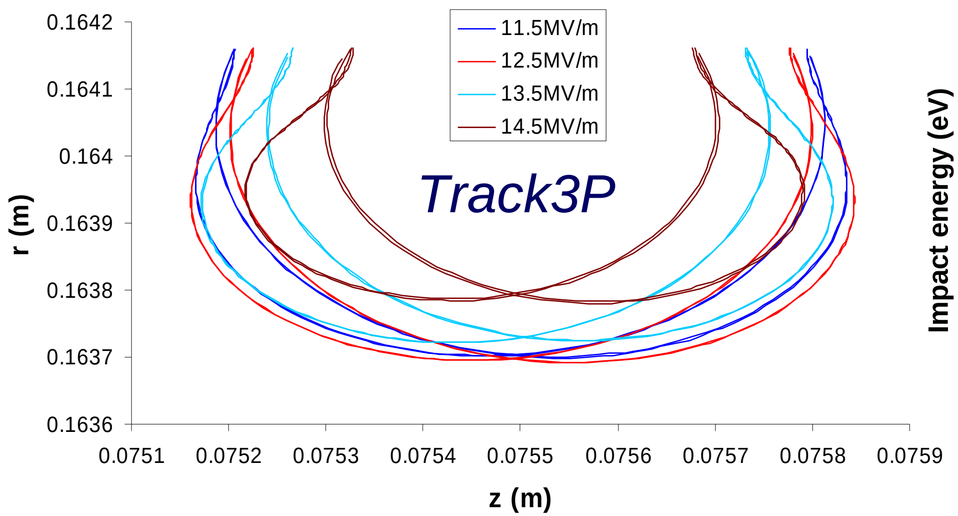


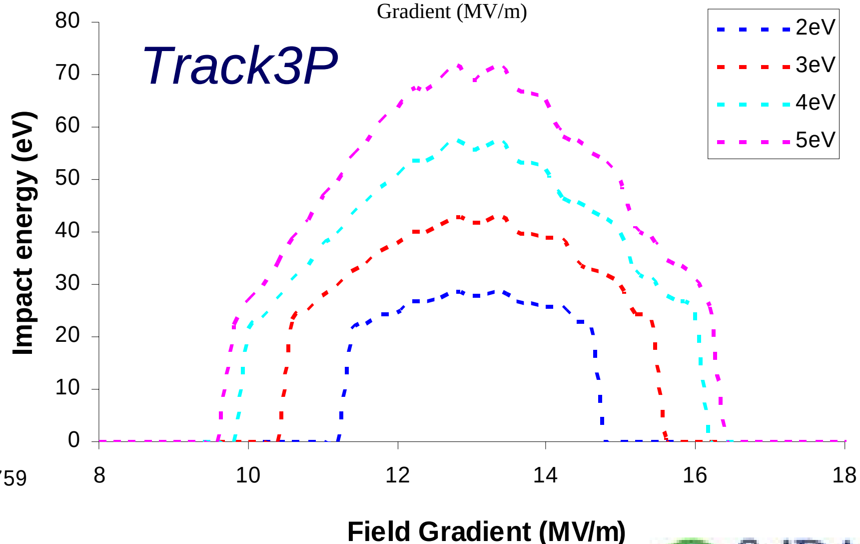
Multipacting in SNS Cavity

(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

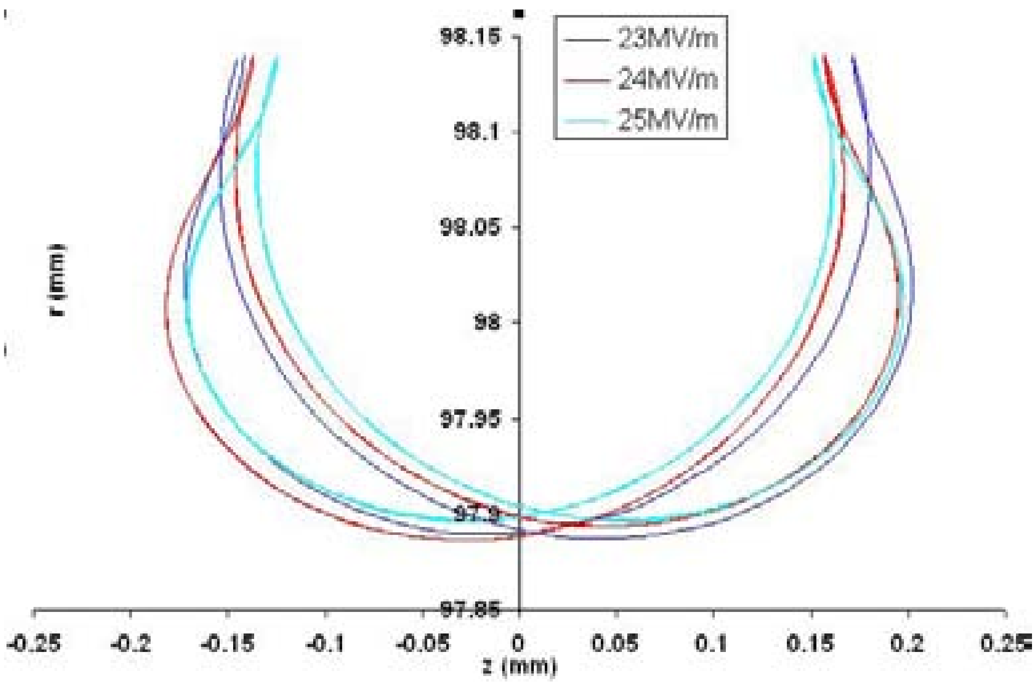


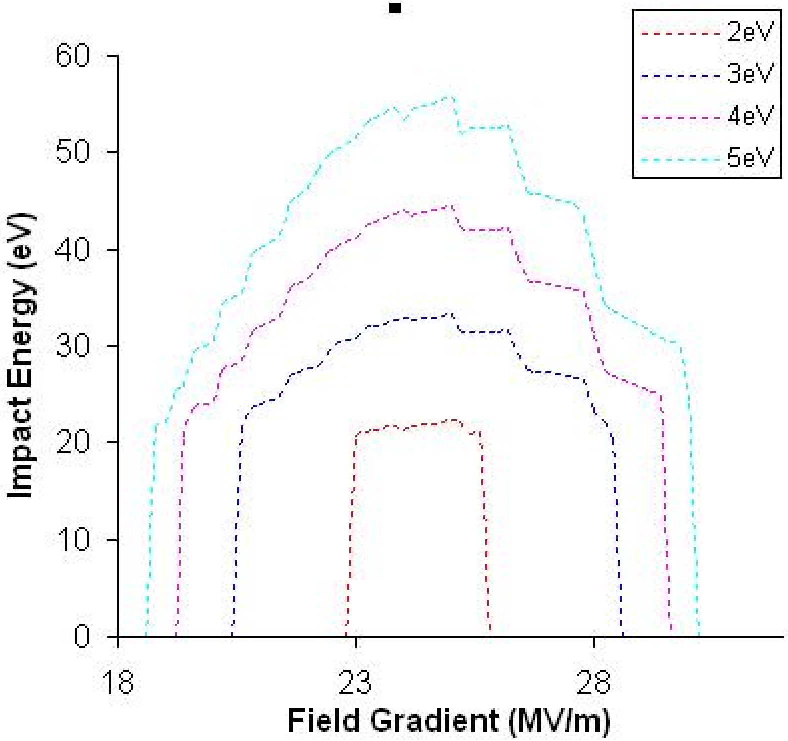


Multipacting in ICHIRO Cavity

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





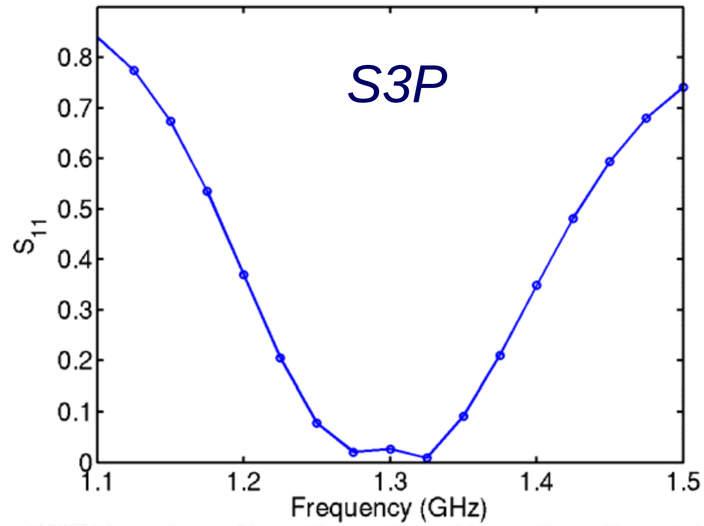
SLAC

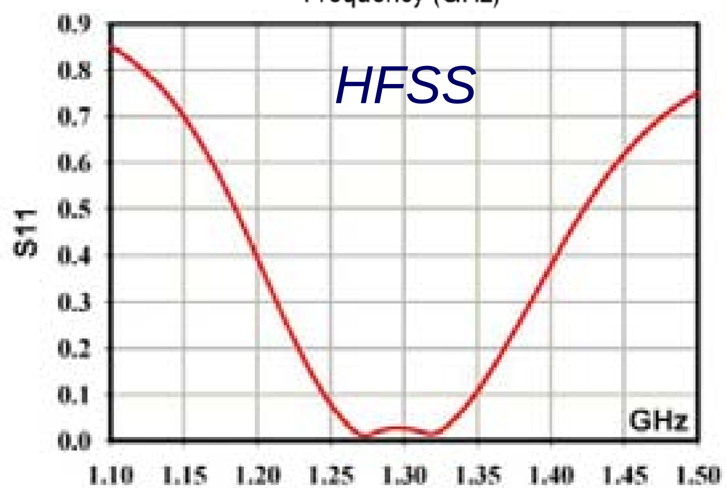
SciDAC

Application to ICHIRO Input Coupler

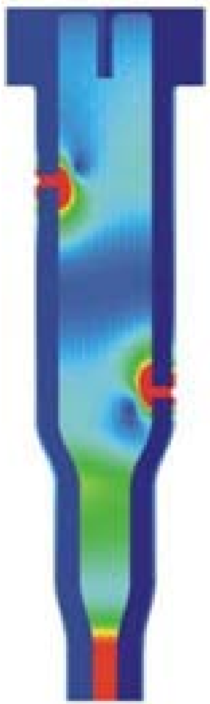
(S. Kazakov, H. Matsumoto – KEK)

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

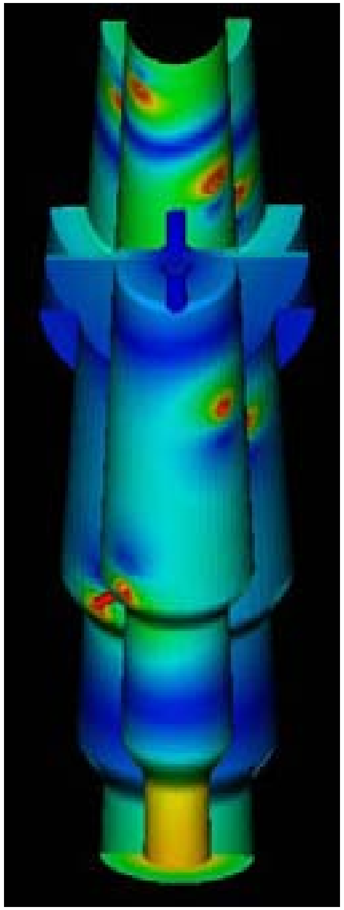




HFSS



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:

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

- Solve for coefficients to obtain mode excitation

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

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