Muon Cooling Cavity Simulation With Advanced Simulation Codes ACE3P

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Outline

- SLAC Parallel Finite Element EM Codes: ACE3P
  - Simulation capabilities

- Previous work on muon cavity simulations
  - 200 MHz cavity with and without external B field
  - 805 MHz magnetically insulated cavity

Parallel FE Based EM Codes: ACE3P

ACE3P: Advanced Computational Electromagnetics

Suite of <u>scalable</u> Finite-Element Electromagnetics codes to model Large, Complex structures with high accuracy:

<u>Frequency Domain</u>:	**Omega3P**	– eigensolver (mode damping, non-linear)
	S3P	– S-parameter
<u>Time Domain</u>:	**T3P**	– transients & wakefields
	Pic3P	– self-consistent particle-in-cell (PIC)
<u>Particle Tracking</u>:	**Track3P**	– dark current and multipacting
	Gun3P	– space-charge beam optics
<u>Multi-Physics</u>:	**TEM3P**	– EM-thermal-mechanical
<u>Visualization</u>:	**Paraview**	– meshes, fields and particles

1st User Code Workshop CW09 in Sept. 2009
CW10 planned for fall 2010

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Massively Parallel EM Simulations

- Focus on ***Large-scale simulations*** using DOE facilities at **NERSC** (3 allocations) and **NCCS** (1 INCITE award)
  - Average job size on jaguar: 6000 cores (2008),
  10000 cores (2009)

- Solve challenging problems in ***Accelerator design, optimization and analysis*** via High Performance Computing

- Apply to DOE programs in ***Accelerator science and accelerator development as well as projects:***

  HEP - High Gradient, Laser Acceleration, *Muon Collider*, ILC, Project X, LHC/LARP, CLIC

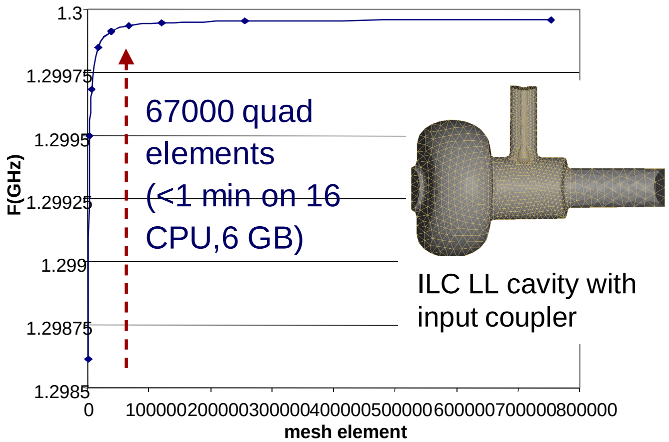
  NP - CEBAF 12 GeV Upgrade

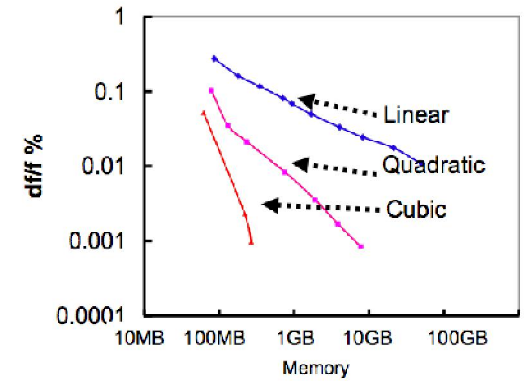
  BES - SNS, LCLS

Key Strengths of ACE3P Codes

Key strengths:

- ***Fidelity*** **-** Tetrahedral conformal mesh with quadratic surface
- ***Accuracy*** **-** Higher-order finite elements (p = 1-6)
- ***Speed & size*** **-** Massively parallel computing

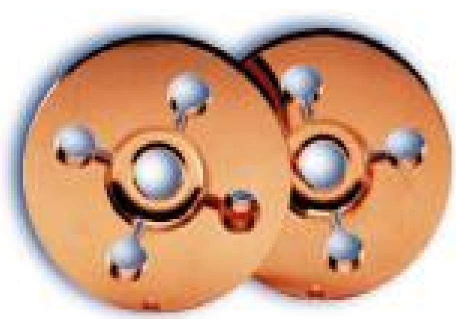


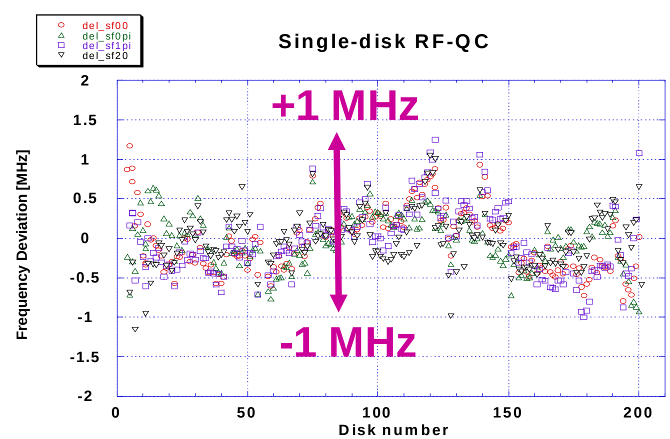


Convergence vs FE order

Example: accurate 3D NLC DDS Cell design (Omega3P, 2001)

- Microwave QC verified cavity frequency accuracy to 0.01% relative error (1MHz out of 11 GHz)





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Track3P: Multipacting & Dark Current Simulation

- 3D parallel high-order finite-element particle tracking
- Using RF fields obtained by Omega3P (resonant mode), S3P (traveling wave) and T3P (transient fields)
- Curved surfaces for accurate surface fields
- Field and secondary emission models
- MP and dark current analysis postprocessing tools

- Benchmarked with measurements
  - Rise time effects on dark current for an X-band 30-cell structure
  - Prediction of MP barriers in the KEK ICHIRO cavity

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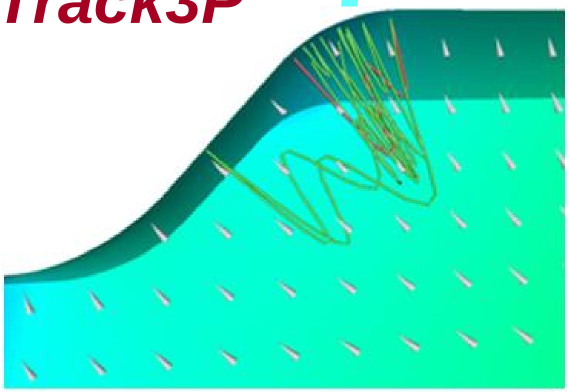
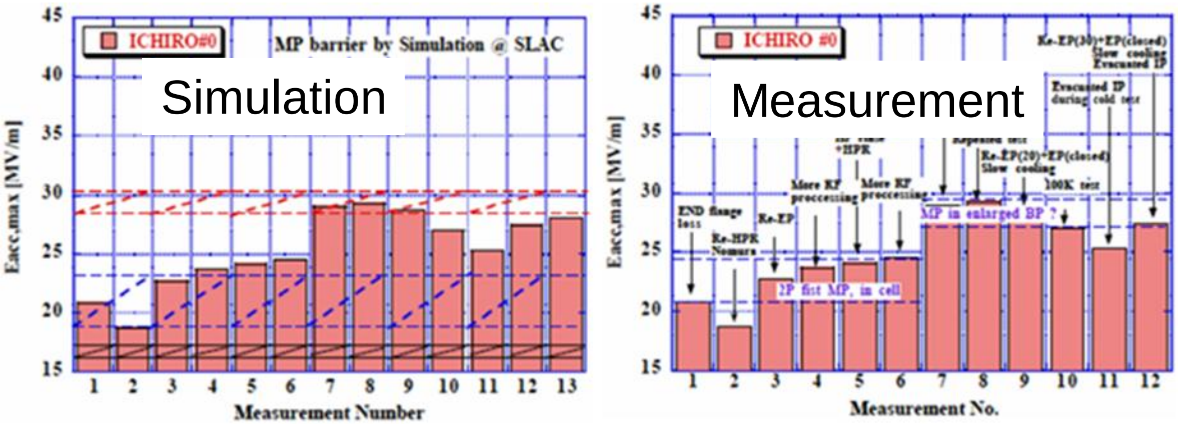
Example: MP Simulation For ICHIRO Cavity

- Multipacting in end beam pipe step
- Simulation agree with measurement

Track3P





(Left) MP barriers in 9-cell ICHIRO cavity calculated with Track3P, (Right) MP barriers measured on ICHIRO prototype (K. Saito, KEK).

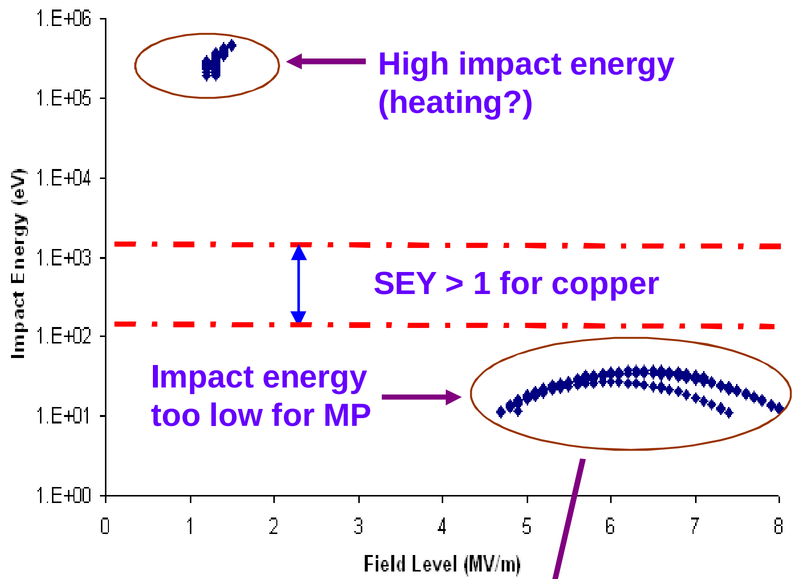
200 MHz and 805 MHz muon cavity

Mutipacting (MP) and dark current (DC) simulations

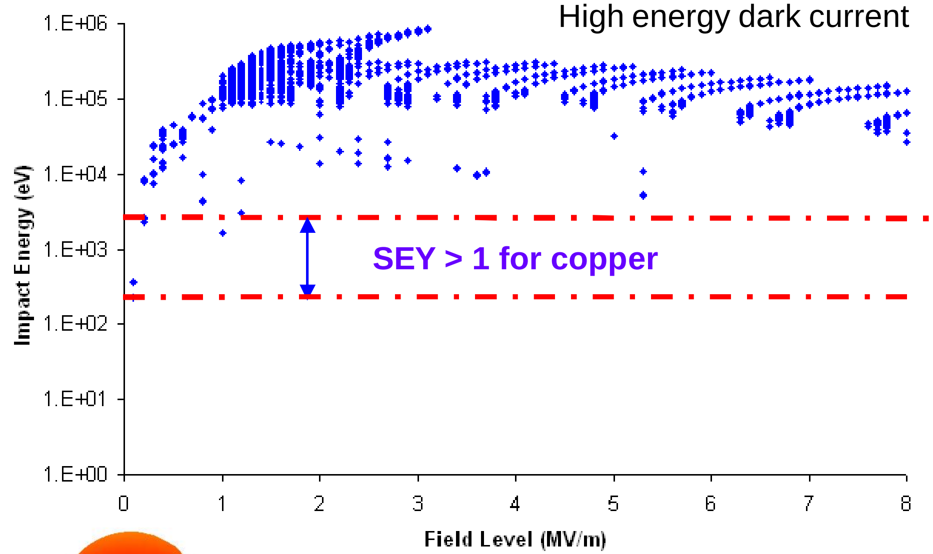
200 MHz cavity MP and DC simulation

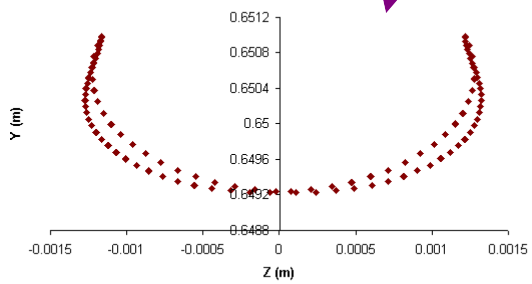
Impact energy of resonant particles vs. field level

w/o external B field

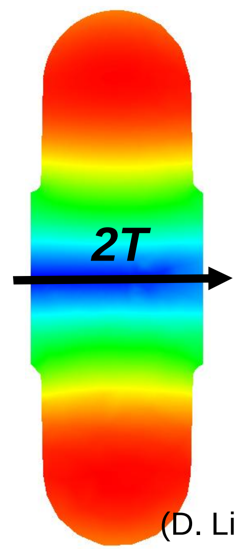


w/ 2T external axial B field





Resonant trajectory



(D. Li cavity model)

2 types of resonant trajectories:

- Between 2 walls – particles with high impact energies and thus no MP
- Around iris – MP activities observed below 1 MV/m

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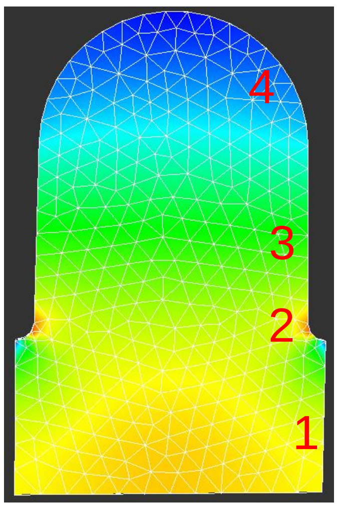
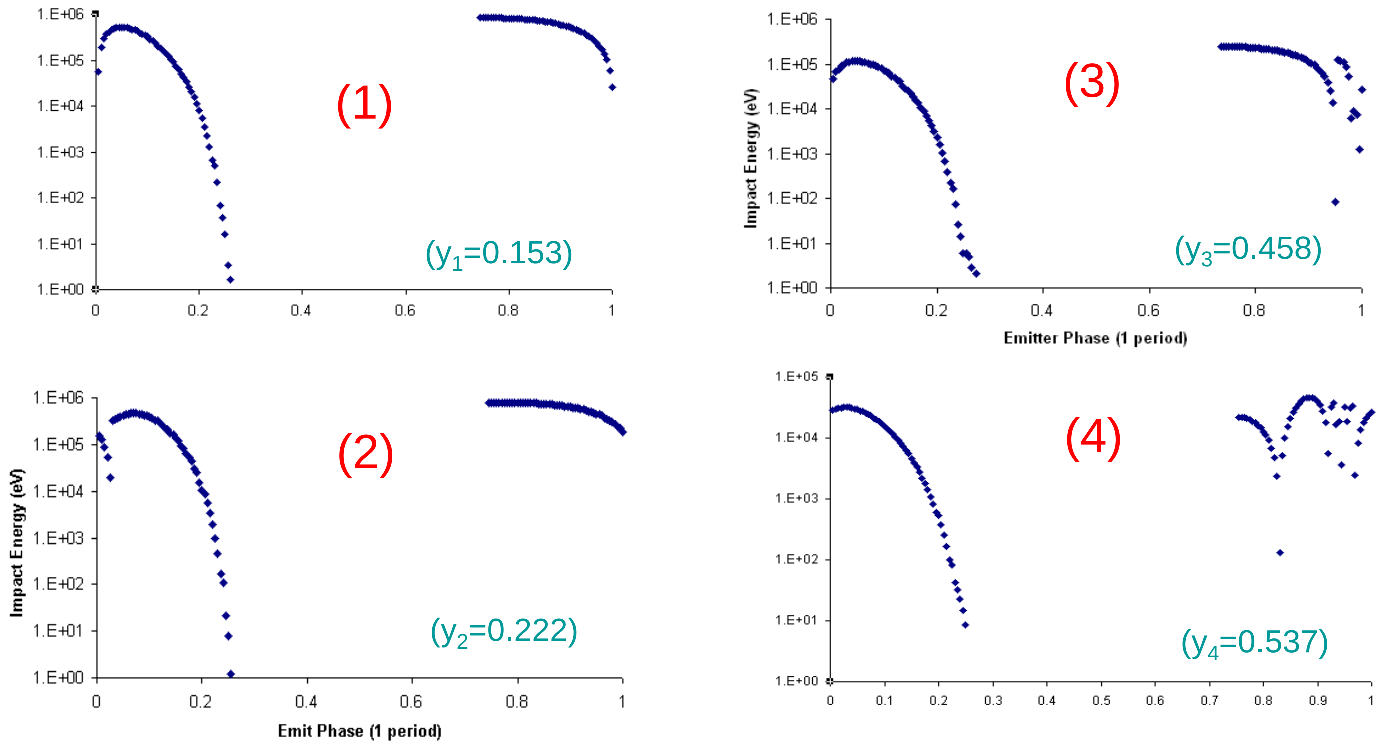
Dark Current Impact Energy vs RF Phase

At 5MV/m, 2T Axial B Field



Impact Energy v.s. RF phase

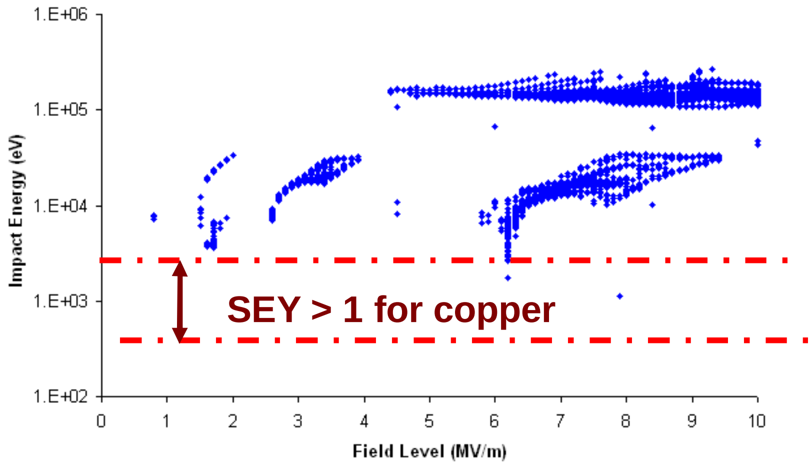


- Electron energy ~ 1MV
- All dark current intercepted by material surface
- Dark current heating?

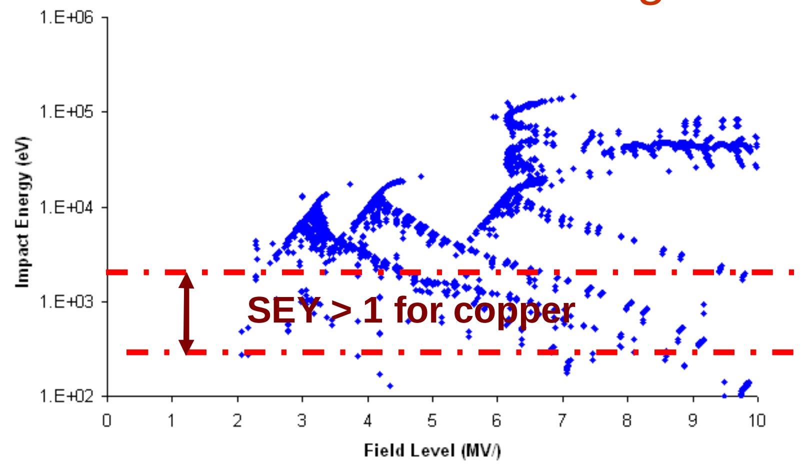
200 MHz: With Transverse External Magnetic Field

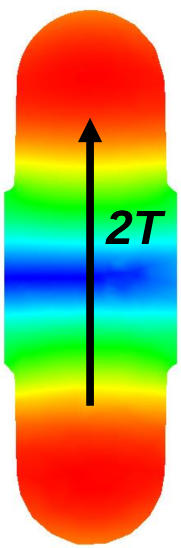
Impact energy of resonant particles vs. field level

w/ 2T transverse B field



w/ 2T B field at 10 degree

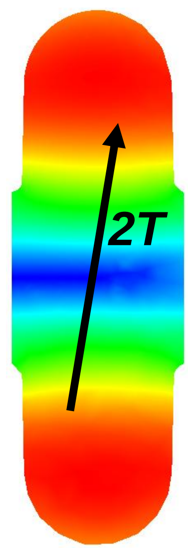




2 types of resonant trajectories:

- Between upper and lower irises
- Between upper and lower cavity walls

Some MP activities above 6 MV/m



2 types of resonant trajectories:

- One-point impacts at upper wall
- Two-point impacts at beampipe

MP activities observed above 1.6 MV/m

805 MHz Magnetically Insulated Cavity

Track3P simulation with realistic external magnetic field map