Present and Future Computing Requirements for Advanced Modeling for Particle Accelerator

Kwok Ko

SLAC National Accelerator Laboratory

Large Scale Computing and Storage Requirements for High Energy Physics
Rockville, MD, November 27-28, 2012

Work supported by US DOE Offices of HEP, ASCR and BES under contract AC02-76SF00515.

1. Advanced Modeling for Particle Accelerators (AMPA)

NERSC Repositories: m349

Principal Investigator: K. Ko

Senior Investigators: *SLAC* - L. Ge, Z. Li, C. Ng, L. Xiao,
FNAL - A. Lunin,
Jlab - H. Wang,
BNL - S. Belomestnykh,
ANL - A. Nassiri
LBNL - E. Ng
Cornell - M. Liepe
ODU - J. Delayen
Muplus - F. Marhauser

1. Advanced Simulation Code at SLAC

Agenda
High Energy Physics Advisory Panel

Washington, D.C.
March 12-13, 2012

[Report from DOE/HEP](#)
J. Siegrist

Accelerator R&D Highlights

- First production model of an advanced accelerator component for test accelerator at ANL that worked "out of the box" and was much cheaper to produce than previous versions because delicate, labor-intensive modifications were not required.
- The reason this works is that the SLAC national accelerator lab has developed an advanced simulation code for these components that is then converted into code that runs the precision milling machines that make the parts.
- It is a major step forward in building cheaper accelerators and may have broad applications.

1. AMPA Scientific Objectives

- Under DOE's HPC programs and SLAC support

  Accelerator Grand Challenge 1998–2001,

  SciDAC1- Accelerator Science and Technology (AST) 2001-07,

  SciDAC2 - Community Petascale Project for Accelerator Science and Simulation (ComPASS) 2007-12,

  SLAC has built a parallel computing capability, **ACE3P**, for high-fidelity and high-accuracy accelerator modeling and simulation.

- **ACE3P** (**Advanced Computational Electromagnetics 3P**) is a suite of 3D codes built to be scalable to utilize DOE's HPC facilities such as NERSC which enables accelerator designers and RF engineers to model and simulate components and systems on a scale, complexity and speed not previously possible.

- **ACE3P** has been benchmarked against measurements and successfully applied to a broad spectrum of applications in accelerator science, accelerator development and facilities within the Office of Science and beyond.

- AMPA presently focuses on meeting SLAC and SciDAC project goals as well as providing computational support to the **ACE3P** user community.

- By 2017 AMPA expects to establish the multi-physics capabilities in **ACE3P** to benefit both the normal conducting and SRF cavity/cryomodule R&D efforts and develop an end-to-end PIC tool for RF source modeling to further broaden the user base.

1. Near Term Projects for SLAC and SciDAC

HEP

Project X linac design - Higher-order-modes (HOM) in the presence of cavity imperfections and misalignments. *Estimated CPU hours are 250k*.

Dielectric laser acceleration and structure wakefields – Power coupling /wakefield for optical photonic bandgap fibers and wakefield acceleration in beam excitation experiment for FACET. *Estimated CPU hours are 200k*.

LHC crab cavity design - Optimize the shape of the compact 400 MHz dipole mode cavity. *Estimated CPU hours are 100k*.

MAP cavity design - Optimize the 805-MHz cavity for the MuCool program. *Estimated CPU hours are 100k.*

High-gradient cavity design - Radio frequency (RF) breakdown and associated dark current issues. *Estimated CPU hours are 50k.*

BES

ANL SPX crab cavity - Trapped modes and muli-physics analysis in cryomodule. *Estimated CPU hours are 200k*.

PEPX-FEL simulation - 1.5GHz SRF cavity design. *Estimated CPU hours are 200k.*

NGLS/LCLS2 energy chirper – Wakefield calculations with possible application to LCLS2. *Estimated CPU hours are 50k*.

SRF gun design - Temperature calculation and thermo-elastic computation of stress and displacement . *Estimated CPU hours are 50k*

TOTAL – 1.2 M CPU hours

1. Anticipated Projects by 2017 for SLAC

HEP

Project X linac design - Cryomodule simulation. *Increase to 300k CPU hrs.*

High-gradient cavity design - Simulation of dark current transient effects. ***Increase to 200k CPU hrs***

Dielectric laser acceleration and structure wakefields – Continuation. *200k CPU hrs.*

LHC crab cavity design - Continuation. *100k CPU hrs.*

MAP cavity design - Continuation. *100k CPU hrs.*

BES

PEPX-FEL simulation - Multi-physics calculation. ***Increase to 250k CPU hrs***

ANL SPX crab cavity - Continuation. *200k CPU hrs.*

NGLS – SRF crab cavity design. ***Increase to 100k CPU hrs.***

SRF gun design - Evaluate alternate designs ***Increase to 100k CPU hrs.***

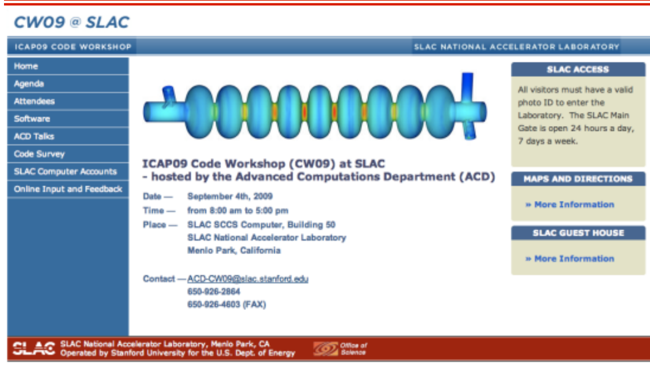
HEP, NP, BES

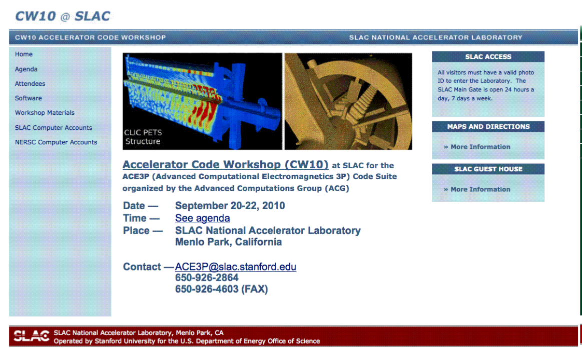
SRF multi-physics modeling - Develop and apply integrated capability for EM, thermal and mechanical simulation of SRF cavities and cryomodules that include the CW and pulsed linacs of Project X (HEP), eRHIC ERL linac (NP), & APS upgrade with SPX deflecting cavity (BES). ***Increase to 600K CPU hrs***

RF source modeling – Develop and benchmark 3D end-to-end simulation capability to determine spurious oscillations in an entire klystron tube and to predict its power generation efficiency. ***Increase to 400K CPU hrs.***

TOTAL – 2.55 M CPU hours

1. ACE3P Code Workshops





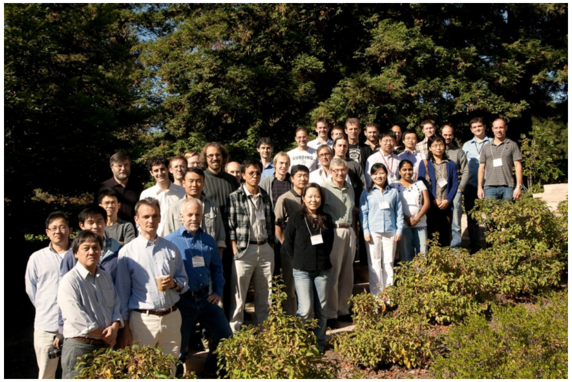
- Three Code Workshops have been held at SLAC

  CW09 – 1 day / 15 attendees / 13 institutions
  http://www-conf.slac.stanford.edu/CW09/default.asp

  CW10 – 2.5 days / 36 attendees / 16 institutions
  http://www-conf.slac.stanford.edu/CW10/

  CW11 – 5 days / 42 attendees / 25 institutions
  http://www-conf.slac.stanford.edu/cw11/default.asp

- Beta version of ACE3P user manual was distributed at CW11 and all workshop material now available online
  https://confluence.slac.stanford.edu/display/AdvComp/Materials+for+cw11



1. ACE3P Worldwide User Base

Americas			Europe	Asia
SLAC/Stanford	Cornell	TRIUMF	CERN	IHEP
Jlab	ODU	LNLS	RHUL	IMP
BNL	Yale		PSI	KEK
ANL	RPI		ESS	Postech
FNAL	Muons		JPJ	Peking U.
LBNL	Far-Tech		U. Manchester	Tsinghua U.
LLNL	NSS		U. Oslo	

1. ACE3P Community - Anticipated Projects in 2017

- *Jlab* – Multi-physics analysis for NP projects FRIB, eRHIC and CEBAF upgrade. *Estimated CPU hours are 500k*.
- *BNL* – Mulipacting, thermal and mechanical modeling for cavities and cryomodules for ERL and eRHIC cavities. *Estimated CPU hours are 600k*.
- *AN*L – Alternate, new cavity for APS upgrade*. Estimated CPU hours are 100k*.
- *Muon Inc*. – Cavity and cryomodule design for the Muon Collider. Estimated hours are *400k.*
- *CERN* – Optimized accelerating structure design and wakefield coupling between drive and main beams in the two beam accelerator. *Estimated CPU hours are 100k.*
- *IHEP* – Multipacting studies for ADS cavities. *Estimated CPU hours are 100k*.
- *LNLS* (Brazil) – Evaluation of beamline components for the Brazils light source. *Estimated hours are 100k.*
- *NCBJ (Poland)* – Design of superconducting cavity for free electron laser. *Estimated CPU hours are 100k.*

TOTAL – 2 M CPU hours

2. ACE3P Code Suite

- **ACE3P** is a comprehensive suite of *conformal, high-order, C++/MPI based parallel finite-element electromagnetic codes* with six application modules

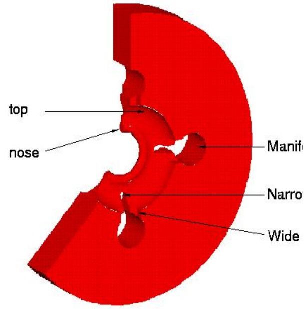
ACE3P (Advanced Computational Electromagnetics 3P)

Frequency Domain:	**Omega3P**	– Eigensolver (Damping)
	S3P	– S-Parameter
Time Domain:	**T3P**	– Wakefields & Transients
Particle Tracking:	**Track3P**	– Multipacting & Dark Current
EM Particle-in-cell:	**Pic3P**	– RF Guns & Sources (e.g. Klystron)
Multi-physics:	**TEM3P**	– EM, Thermal & Structural Effects

https://slacportal.slac.stanford.edu/sites/ard_public/bpd/acd/Pages/Default.aspx

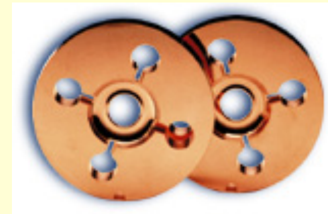
2. ACE3P Workflow in RF Cavity Design and Analysis

Determine dimensions of a cell –
component scale

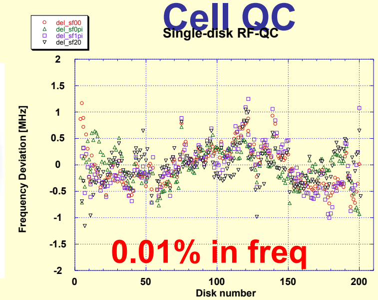


Constraint $f = f_0$;
Maximize (R/Q , Q)
Minimize (surface fields etc.)

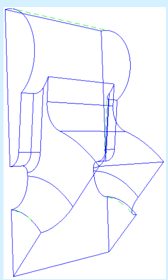
Fabrication



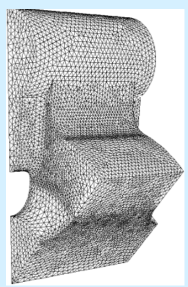
Cell QC



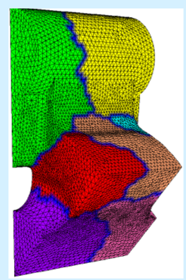
Model CAD



Meshing Cubit



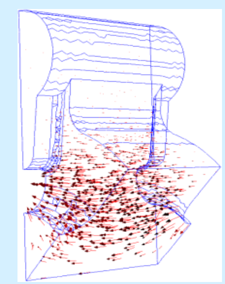
Partitioning ParMetis

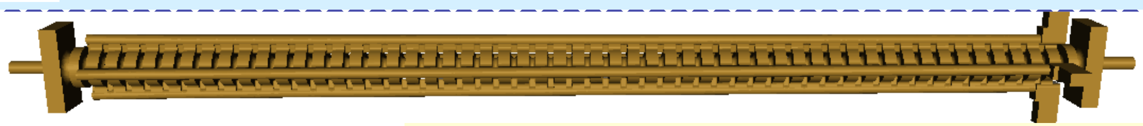


Solvers

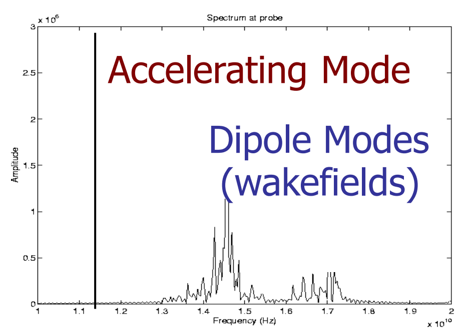
ACE3P

Visualization ParaView

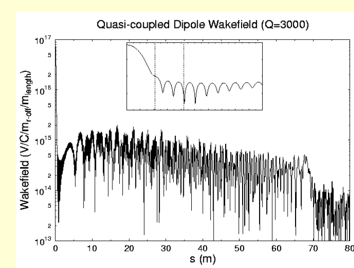




Minimize wakefields in the structure –
system scale



Wakefield Measurement

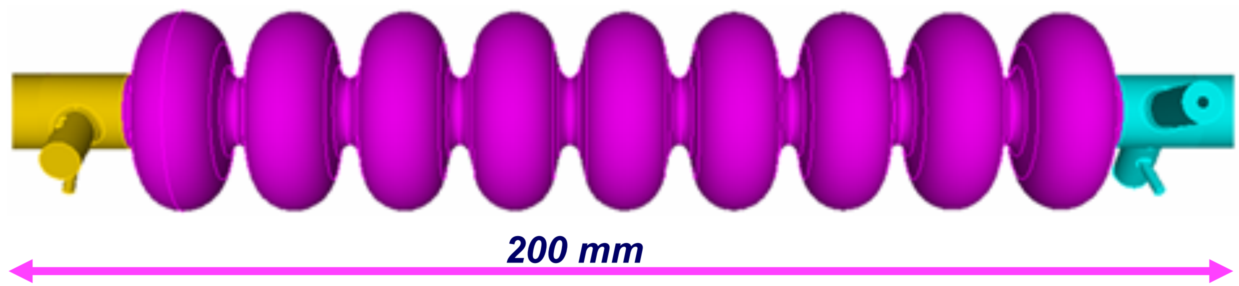


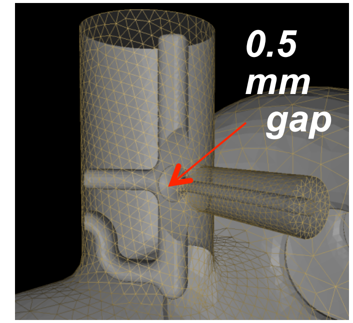
SLAC NATIONAL ACCELERATOR LABORATORY

SciDAC Scientific Discovery through Advanced Computing

2. ACE3P Computational Approach

Parallel Higher-order Finite-Element Method





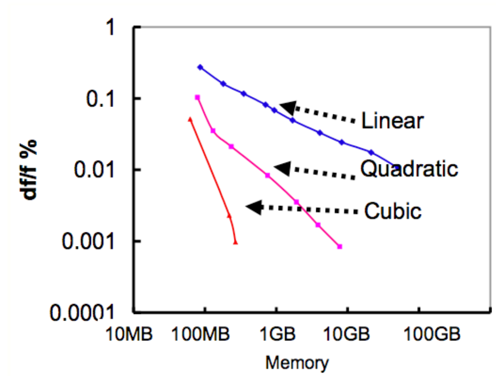
ILC/Project X multi-cell cavity

Realistic Modeling for Virtual Prototyping:

- *Disparate length scales* – HOM coupler versus cavity size
- *Problem size* – multi-cavity structure (e.g. cryomodule)
- *Accuracy* – 10s of kHz mode separation out of GHz
- *Speed* – fast turn around time to impact design

ACE3P meets the requirements:

- Conformal (tetrahedral) mesh with quadratic surface
- Higher-order elements (p = 1 to 6)
- Parallel processing (memory & speedup)



SLAC NATIONAL ACCELERATOR LABORATORY

SciDAC Scientific Discovery through Advanced Computing

2. Computational Electromagnetics in ACE3P

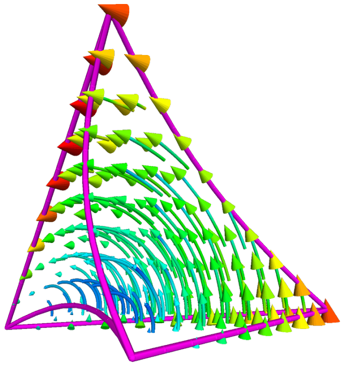
Maxwell Equations

- Omega3P - *In frequency domain*

$$\nabla \times \left(\frac{1}{\mu}\nabla \times \vec{\mathbf{E}}\right) - k^2\epsilon\vec{\mathbf{E}} = 0 \ on \ \Omega$$

- T3P - *In time domain*

$$\nabla \times \left(\frac{1}{\mu}\nabla \times \vec{\mathbf{E}}\right) + \sigma\frac{\partial\vec{\mathbf{E}}}{\partial t} + \epsilon\frac{\partial^2\vec{\mathbf{E}}}{\partial t^2} = -\frac{\partial\vec{\mathbf{J}}}{\partial t}$$



In **ACE3P** the Electric field $\mathbf{E}$ is expanded into vector basis functions which are discretised using curved tetrahedral higher-order *Nedelec-type* finite elements

Particle Equation of Motion

- Track3P uses E and B from Omega3P or T3P

$$\frac{d\vec{p}}{dt} = e\left[\vec{E} + \frac{1}{c}\left(\vec{v} \times \vec{B}\right)\right] \qquad \vec{p} = m\gamma\vec{v} \qquad \gamma = \frac{1}{\sqrt{1 - {v^2}/{c^2}}}$$

L.-Q. Lee et al., Omega3P: A Parallel Finite-Element Eigenmode Analysis Code for Accelerator Cavities. SLAC-PUB-13529, Feb 2009.

A. Candel et al., Parallel Higher-Order Finite Element method for Accurate Field Computations in Wakefield and PIC Simulations, Proc. of ICAP06, Chamonix Mount-Blanc, France, October 2-6 2006.

L. Ge et al., Analyzing multipacting problems in accelerators using ACE3P on high performance computers, Proceedings of ICAP2012, Rostock-Warnemünde, Germany.

2. Mathematical Formulation

- Omega3P - Eigenvalue Problem for Eigenvalue k2 and Eigenvector **X**

$$\mathbf{E} = \textstyle\sum_i x_i \mathbf{N}_i$$
$$\mathbf{K}\mathbf{x} = k^2 \mathbf{M}\mathbf{x}$$

where
$$\mathbf{K}_{ij} = \textstyle\int_\Omega (\nabla \times \mathbf{N}_i) \cdot \frac{1}{\mu} (\nabla \times \mathbf{N}_j)\, d\Omega$$
$$\mathbf{M}_{ij} = \textstyle\int_\Omega \mathbf{N}_i \cdot \epsilon \mathbf{N}_j\, d\Omega$$

are large sparse M by N matrices

- T3P - Newmark-β Scheme for Time Stepping to solve

$$\vec{\mathbf{E}}(\vec{\mathbf{r}}) = \sum_i \frac{\partial}{\partial t} x_i \vec{\mathbf{N}}_i(\vec{\mathbf{r}})$$
$$\mathbf{M}\frac{1}{c^2}\frac{\partial^2 \mathbf{x}}{\partial t^2} + (\mathbf{R} + \mathbf{Q})\frac{1}{c}\frac{\partial \mathbf{x}}{\partial t} + \mathbf{K}\mathbf{x} = \mathbf{f}$$

Unconditionally stable* when β > 0.25
For each time step, solve a linear system Ax = B

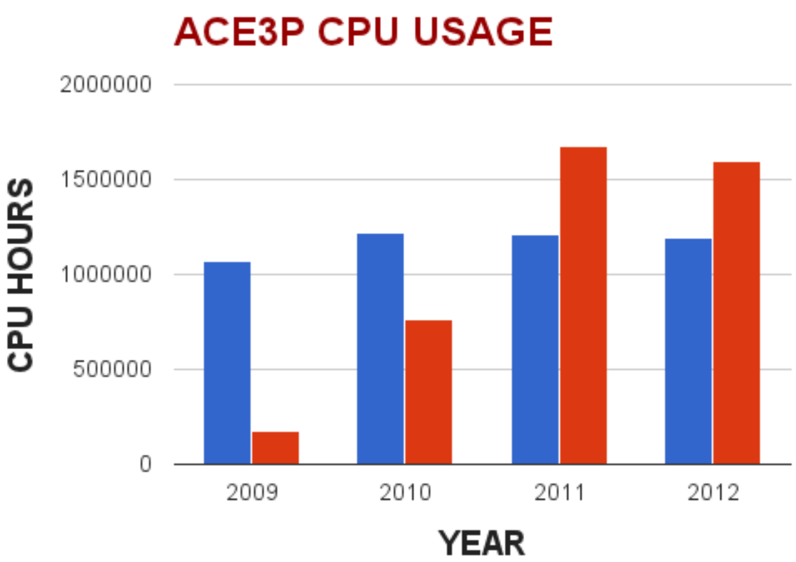
- Track3P - Use Boris scheme or Runge-Kutta method for time integration.

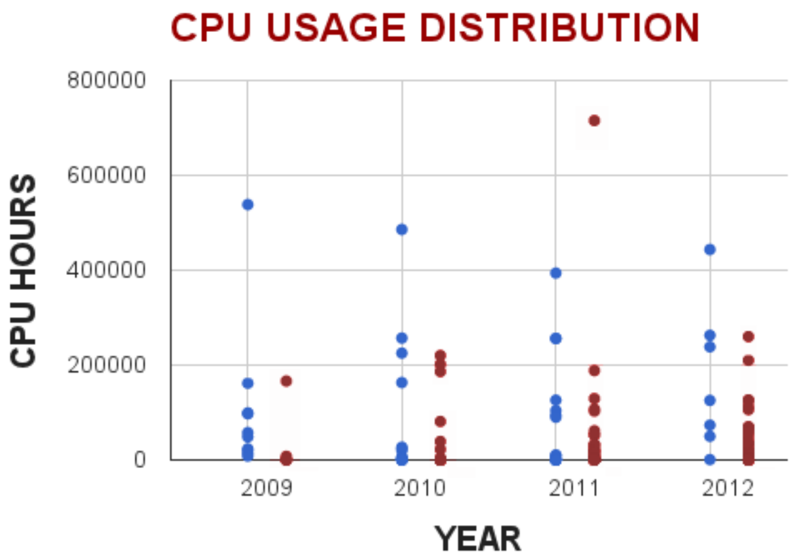
*Gedney & Navsariwala, IEEE microwave and guided wave letters, vol. 5, 1995

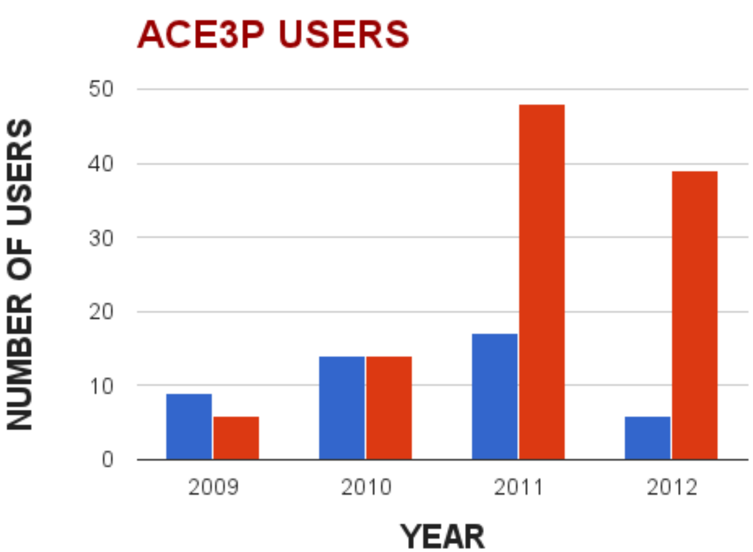
3. Current HPC Usage

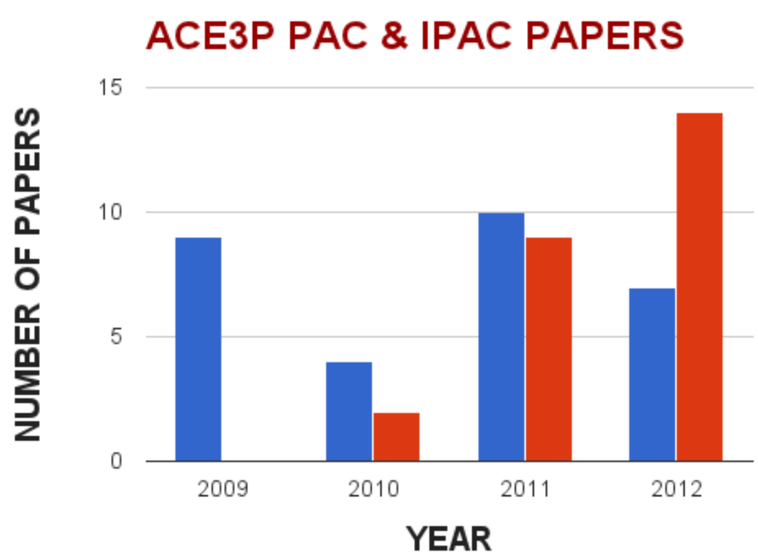
- Machines – Hopper, Carver.
- Hours used in 2012 - 2,812,917 Hrs.
- Typical parallel run - 5000 cores for 2 hours and 400 runs per year.
- Data read/written per run - 0.5 TB
- Memory used per (node | globally) - (32 | 6400) GB for frequency domain, (4 | 600) GB for time domain.
- Necessary software - LAPACK, ScaLAPACK, PETSC, MUMPS, SUPERLU, PARMETIS, NETCDF, CUBIT, ParaView
- Data resources used HPSS and NERSC Global File System and amount of data stored - 238,291 SRU

3. ACE3P Usage - SLAC vs Community









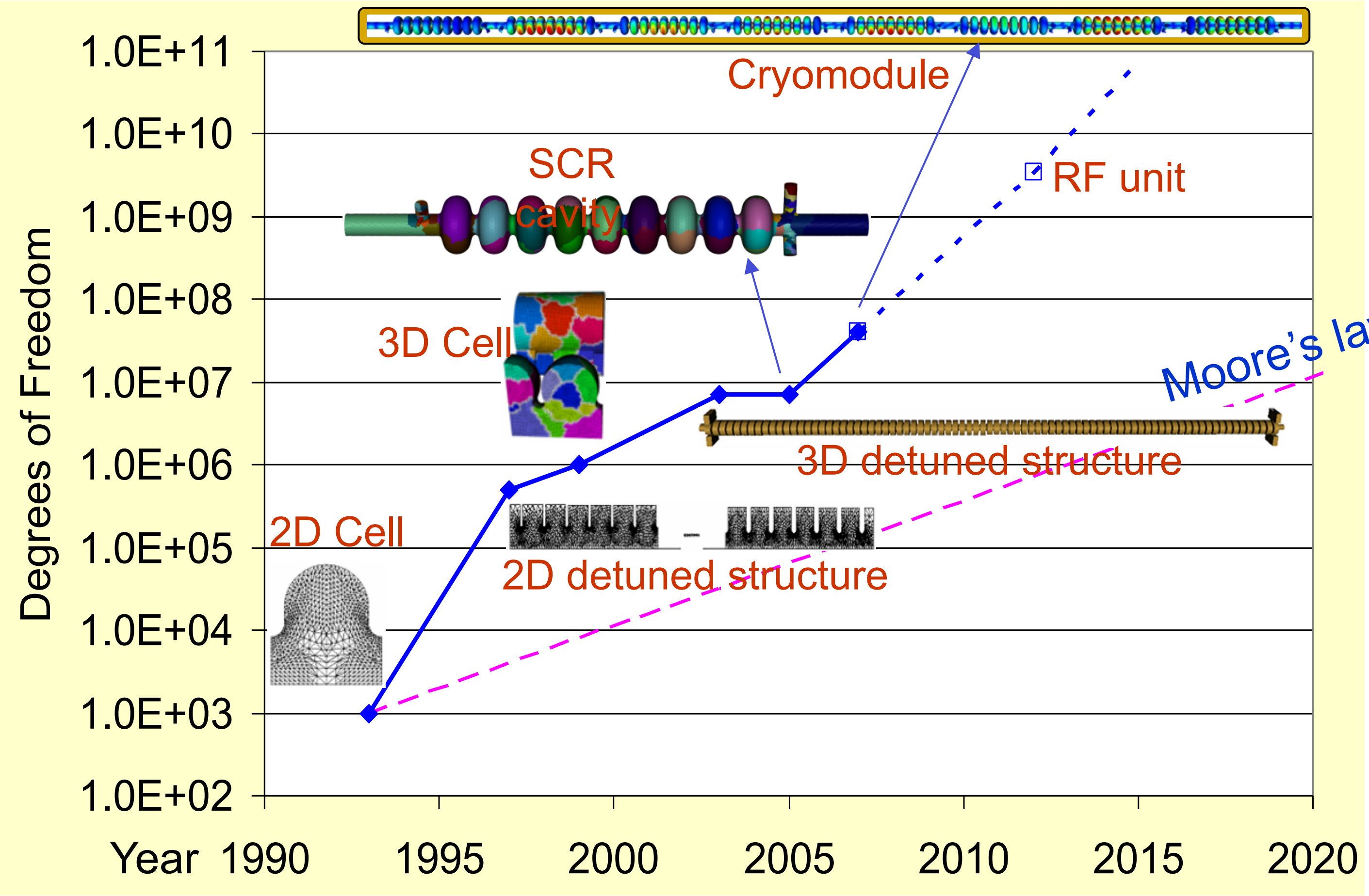
4. HPC Requirements for 2017

- Compute hours needed (in units of Hopper hours) - 5 millions
- Changes to parallel concurrency, run time, number of runs per year - 8000 cores, 1 hour, 600
- Changes to data read/written – 1 TB
- Changes to memory needed per (node | globally) - (64 | 6400) for frequency domain (4| 1200) for time domain
- Changes to necessary software, services or infrastructure – None.

4. Accelerator Cavity Modeling at 2008 (?) - Omega3P

From single 2D cavity to a cryomodule of eight 3D ILC cavities

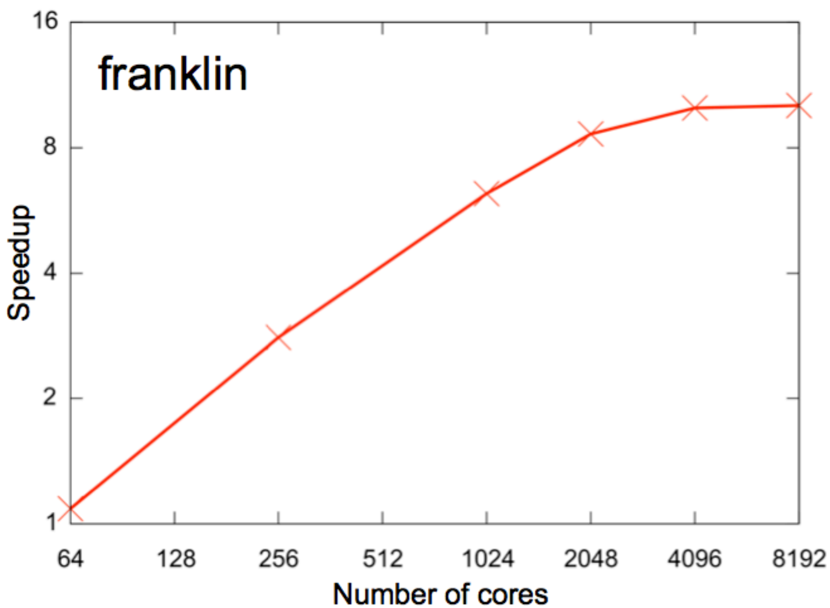
An increase of 10^5 in problem size with 10^{-5} accuracy over a decade



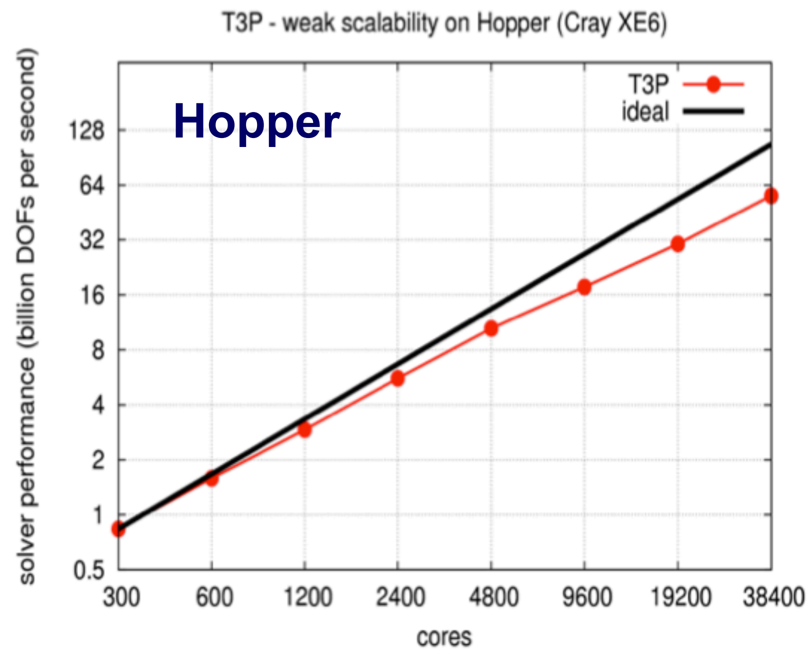
4. Computational Challenges / Parallel Scaling

- High-fidelity representation of complex applications and their subsequent large-scale solution
- **ACE3P** parallel scaling is limited by the scalability of linear solvers and eigensolvers.

Omega3P:- Strong scaling of hybrid solver on Franklin



T3P – Weak scaling on Hopper



5. Strategies for New Architectures

- Our strategy for running on new many-core architectures (GPUs or MIC) is to develop scalable linear solvers that can balance workload and reduce the amount of communication.
- To date we have prepared for many core by working with **SciDAC FastMath Center** in deploying **scalable eigensolvers and linear solvers**
- We are already planning to implement a hybrid solver that can reduce memory usage for many cores
- To be successful on many-core systems we will need help with code optimization to improve runtime performance.
- We would benefit from large memory compute nodes for direct solvers such as SUPERLU and MUMPS, which limit the the number of CPUs used for problems with large, complex geometries.

5. Summary

- Thanks to the HPC facilities at NERSC and the m349 allocation, and with SciDAC and SLAC program support, the AMPA project has been able to mature **ACE3P** as a production parallel toot for accelerator design and establish the **ACE3P** user base for the accelerator community.
- Presently and in the near future, **ACE3P** is the only parallel electromagnetic code for accelerator design with features and capabilities comparable to the leading commercial software.
- AMPA provides a good opportunity for graduate students and young researchers to learn HPC and apply the knowhow to accelerator R&D.
- Stewardship of this resource should be considered in DOE's program in accelerator science and development as well as computing.
- Issues with CPU time used to support non-DOE projects (**ACE3P** community) need to be addressed.

Appendix. ACE3P in PAC 2009 and IPAC 2010

PAC 2009: (9 papers)

V. Akcelik, K. Ko, L. Lee, Z. Li, C.-K. Ng (SLAC, Menlo Park), California, G. Cheng, R.A. Rimmer, H. Wang (JLAB, Newport News, Virginia), Thermal Analysis of SCRF Cavity Couplers Using Parallel Multiphysics Tool TEM3P
A.E. Candel, A.C. Kabel, K. Ko, L. Lee, Z. Li, C.-K. Ng, G.L. Schussman (SLAC, Menlo Park, California), I. Syratchev (CERN, Geneva), Wakefield Simulation of CLIC PETS Structure Using Parallel 3D Finite Element Time-Domain Solver T3P
A.E. Candel, A.C. Kabel, K. Ko, L. Lee, Z. Li, C.-K. Ng, G.L. Schussman (SLAC, Menlo Park, California), I. Ben-Zvi, J. Kewisch (BNL, Upton, Long Island, New York), Parallel 3D Finite Element Particle-in-Cell Simulations with Pic3P
***L. Ge**, K. Ko, Z. Li, C.-K. Ng (SLAC, Menlo Park, California), D. Li (LBNL, Berkeley, California), R. B. Palmer (BNL, Upton, Long Island, New York), Multipacting Simulation for Muon Collider Cavity
Z. Li, A.E. Candel, L. Ge, K. Ko, C.-K. Ng, G.L. Schussman (SLAC, Menlo Park, California), S. Döbert, M. Gerbaux, A. Grudiev, W. Wuensch (CERN, Geneva), T. Higo, S. Matsumoto, K. Yokoyama (KEK, Ibaraki), Dark Current Simulation for the CLIC T18 High Gradient Structure
Z. Li, L. Xiao (SLAC, Menlo Park, California), A Compact Alternative Crab Cavity Design at 400-MHz for the LHC Upgrade
S. Pei, V.A. Dolgashev, Z. Li, S.G. Tantawi, J.W. Wang (SLAC, Menlo Park, California), Damping Effect Studies for X-Band Normal Conducting High Gradient Standing Wave Structures
L. Xiao**,** Z. Li, C.-K. Ng, A. Seryi (SLAC, Menlo Park, California), 800MHz Crab Cavity Conceptual Design for the LHC Upgrade
L. Xiao, C.-K. Ng, J.C. Smith (SLAC, Menlo Park, California), F. Caspers (CERN, Geneva), Trapped Mode Study for a Rotatable Collimator Design for the LHC Upgrade

IPAC 2010: (6 papers)

C.-K. Ng, A. Candel, L. Ge, A. Kabel, K. Ko, L.-Q. Lee, Z. Li, V. Rawat, G. Schussman and L. Xiao (SLAC, Menlo Park, California), State of the Art in Finite-Element Electromagnetic Codes for Accelerator Modeling under SciDAC
Z. Li, T.W. Markiewicz, C.-K. Ng, L. Xiao (SLAC, Menlo Park, California), Compact 400-MHz Half-wave Spoke Resonator Crab Cavity for the LHC Upgrade
L. Xiao**,** S.A. Lundgren, T.W. Markiewicz, C.-K. Ng, J.C. Smith (SLAC, Menlo Park, California), Longitudinal Wakefield Study for SLAC Rotatable Collimator Design for the LHC Phase II Upgrade
K.L.F. Bane, L. Lee, C.-K. Ng, G.V. Stupakov, L. Wang, L. Xiao (SLAC, Menlo Park, California), PEP-X Impedance and Instability Calculations
J.G. Power, M.E. Conde, W. Gai (ANL, Argonne), Z. Li (SLAC, Menlo Park, California), D. Mihalcea (Northern Illinois University, DeKalb, Illinois), Upgrade of the Drive LINAC for the AWA Facility Dielectric Two-Beam Accelerator
***H. Wang**, G*. Cheng, G. Ciovati, J. Henry, P. Kneisel, R.A. Rimmer, G. Slack, L. Turlington (JLAB, Newport News, Virginia), R. Nassiri, G.J. Waldschmidt (ANL, Argonne), Design and Prototype Progress toward a Superconducting Crab Cavity Cryomodule for the APS

Appendix. ACE3P in PAC 2011 and IPAC 2011

PAC 2011: (13 papers)

A.E. Candel, K. Ko, Z. Li, C.-K. Ng, V. Rawat, G.L. Schussman (SLAC, Menlo Park, California, USA), A. Grudiev, I. Syratchev, W. Wuensch (CERN, Geneva, Switzerland), Numerical Verification of the Power Transfer and Wakefield Coupling in the CLIC Two-beam Accelerator
L. Xiao, C.-K. Ng (SLAC, Menlo Park, California, USA), J.E. Dey, I. Kourbanis, Z. Qian (Fermilab, Batavia, USA), Simulation and Optimization of Project-X Main Injector Cavity
Z. Li, L. Ge (SLAC, Menlo Park, California, USA), Multipacting Analysis for the Half-Wave Spoke Resonator Crab Cavity for LHC
Z. Li, C. Adolphsen, A.E. Vlieks, F. Zhou (SLAC, Menlo Park, California, USA), On the Importance of Symmetrizing RF Coupler Fields for Low Emittance Beams
C.-K. Ng, A.E. Candel, K. Ko, V. Rawat, G.L. Schussman, L. Xiao (SLAC, Menlo Park, California, USA), High Fidelity Calculation of Wakefields for Short Bunches
Z. Wu, E.R. Colby, C. McGuinness, C.-K. Ng (SLAC, Menlo Park, California, USA), Design of On-Chip Power Transport and Coupling Components for a Silicon Woodpile Accelerator
R.J. England, E.R. Colby, R. Laouar, C. McGuinness, D. Mendez, C.-K. Ng, J.S.T. Ng, R.J. Noble, K. Soong, J.E. Spencer, D.R. Walz, Z. Wu, D. Xu (SLAC, Menlo Park, California, USA), E.A. Peralta (Stanford University, Stanford, California, USA), Experiment to Demonstrate Acceleration in Optical Photonic Bandgap Structures
J.E. Spencer, R.J. England, C.-K. Ng, R.J. Noble, Z. Wu, D. Xu (SLAC, Menlo Park, California, USA), Coupler Studies for PBG Fiber Accelerators
H. Wang, G. Ciovati (JLAB, Newport News, Virginia, USA), L. Ge, Z. Li (SLAC, Menlo Park, California, USA), Multipactoring Observation, Simulation and Suppression on a Superconducting TE011 Cavity
R. Sah, A. Dudas, M.L. Neubauer (Muons, Inc, Batavia, USA), G.H. Hoffstaetter, M. Liepe, H. Padamsee, V.D. Shemelin (CLASSE, Ithaca, New York, USA), K. Ko, C.-K. Ng, L. Xiao (SLAC, Menlo Park, California, USA), Beam Pipe HOM Absorber for SRF Cavities
R. Ainsworth, S. Molloy (Royal Holloway, University of London, Surrey, United Kingdom), Simulations and Calculations of Cavity-to-cavity Coupling for Elliptical SCRF Cavities in ESS
S.U. De Silva, J.R. Delaye***n*** (ODU, Norfolk, Virginia, USA), Multipacting Analysis of the Superconducting Parallel-bar Cavity
G.J. Waldschmidt, D. Horan, L.H. Morrison (ANL, Argonne), USA, Inductively Coupled, Compact HOM Damper for the Advanced Photon Source

IPAC 2011: (6 papers)

C.-K. Ng, A. Candel, L. Ge, K. Ko, K. Lee, Zenghai Li, G. Schussman, L. Xiao (SLAC, Menlo Park, California, USA), Advanced Electromagnetic Modeling for Accelerators Using ACE3P
V.A. Dolgashev, Z. Li, S.G. Tantawi, A.D. Yeremian (SLAC, Menlo Park, California, USA), Y. Higashi (KEK, Ibaraki, Japan), B. Spataro (INFN/LNF, Frascati (Roma), Italy), Status of High Power Tests of Normal Conducting Short Standing Wave Structures
N.R.A. Valles, M. Liepe, V.D. Shemelin (CLASSE, Ithaca, New York, USA), Suppression of Coupler Kicks in 7-Cell Main Linac Cavities for Cornell's ERL
R.M. Jones, I.R.R. Shinton (UMAN, Manchester, United Kingdom), Z. Li (SLAC, Menlo Park, California, USA), Higher Order Modes in Coupled Cavities of the FLASH Module ACC39
S. Molloy (ESS, Lund, Sweden), R. Ainsworth (Royal Holloway, University of London, Surrey, United Kingdom), R.J.M.Y. Ruber (Uppsala University, Uppsala, Sweden), Multipacting Analysis for the Superconducting RF Cavity HOM Couplers in ESS
S. Molloy, M. Lindroos, S. Peggs (ESS, Lund, Sweden), R. Ainsworth (Royal Holloway, University of London, Surrey, United Kingdom), R.J.M.Y. Ruber (Uppsala University, Uppsala, Sweden), RF Modeling Plans for the European Spallation Source

Appendix. ACE3P in IPAC 2012

IPAC 2012: (22 papers)

C.-K. Ng, A.E. Candel, L. Ge, C. Ko, K.H. Lee, Z. Li, G.L. Schussman, L. Xiao (SLAC), ACE3P – Parallel Electromagnetic Code Suite for Accelerator Modeling and Simulation
L. Ge, C. Ko, Z. Li (SLAC), J. Popielarski (FRIB), Multipacting Simulation and Analysis for the FRIB β = 0.085 Quarter Wave Resonators using Track3P
K.H. Lee, A.E. Candel, C. Ko, Z. Li, C.-K. Ng (SLAC), Multiphysics Applications of ACE3P
Z. Li, L. Ge (SLAC), J.R. Delayen, S.D. Silva (ODU), RF Modeling Using Parallel Codes ACE3P for the 400-MHz Parallel-Bar/Ridged-Waveguide Compact Crab Cavity for the LHC HiLumi Upgrade
Z. Li, C. Adolphsen, L. Ge (SLAC), D.L. Bowring, D. Li (LBNL), Improved RF Design for an 805 MHz Pillbox Cavity for the US MuCool Program
L. Xiao, Z. Li, C.-K. Ng (SLAC), A. Nassiri, G.J. Waldschmidt, G. Wu (ANL), R.A. Rimmer, H. Wang (JLAB), Higher Order Modes Damping Analysis for the SPX Deflecting Cavity Cyromodule
L. Xiao, C.-K. Ng (SLAC), J.E. Dey, I. Kourbanis (Fermilab), Second Harmonic Cavity Design for Project-X Main Injector
A. Nassiri, N.D. Arnold, T.G. Berenc, M. Borland, B. Brajuskovic, D.J. Bromberek, J. Carwardine, G. Decker, L. Emery, J.D. Fuerst, A.E. Grelick, D. Horan, J. Kaluzny, F. Lenkszus, R.M. Lill, J. Liu, H. Ma, V. Sajaev, T.L. Smith, B.K. Stillwell, G.J. Waldschmidt, G. Wu, B.X. Yang, Y. Yang, A. Zho- lents (ANL) J.M. Byrd, L.R. Doolittle, G. Huang (LBNL), G. Cheng, G. Ciovati, P. Dhakal, G.V. Ere- meev, J.J. Feingold, R.L. Geng, J. Henry, P. Kneisel, K. Macha, J.D. Mammosser, J. Matalevich, A.D. Palczewski, R.A. Rimmer, H. Wang, K.M. Wilson, M. Wiseman (JLAB), Z. Li, L. Xiao (SLAC), Status of the Short-Pulse X-ray (SPX) Project at the Advanced Photon Source
I.R.R. Shinton, R.M. Jones, P. Zhang (UMAN), Z. Li (SLAC), Simulations of the Higher Order Modes in the Coupled Bunch Shaping 3.9GHz Cavities Modules of FLASH and XFEL
I.R.R. Shinton, R.M. Jones, P. Zhang (UMAN), Z. Li (SLAC), Beam Based Simulations of the Coupled Bunch Shaping 3.9GHz Cavities Modules of FLASH and XFEL
Q. Wu, S.A. Belomestnykh (BNL), L. Ge, C. Ko, Z. Li, C.-K. Ng, L. Xiao (SLAC), 3D Simulations of Multipacting in the 56 MHz SRF Cavity
R. Ainsworth (Royal Holloway, University of London), R. Calaga (CERN), S. Molloy (ESS), HOM Coupler Optimisation for the Superconducting RF Cavities in ESS
D.L. Bowring, A.J. DeMello, D. Li, S.P. Virostek, M.S. Zisman (LBNL), R. B. Palmer (BNL) Progress on a Cavity with Beryllium Walls for Muon Ionization Cooling Channel R&D
R.A. Marsh, S.G. Anderson, C.P.J. Barty, D.J. Gibson (LLNL), Modeling Multi-bunch X-band Photoinjector Challenges
C.S. Hopper, J.R. Delayen (ODU), Development of Superconducting Spoke Cavities for High-velocity Applications
O. Kononenko, A. Grudiev (CERN), Higher-Order Modes and Beam Loading Compensation in CLIC Main Linac
K.N. Sjøbæk, E. Adli (University of Oslo), A. Grudiev, W. Wuensch (CERN), Design of an Accelerating Structure for a 500 GeV CLIC using ACE3P
Y. Luo, D. Yu (DULY Research Inc.), R. Andrews, T.N. Khabiboulline (Fermilab), Cold Test of an L-band, 1+2/2-Cell PWT Photoinjector
T.H. Luo, D.J. Summers (UMiss), A.J. DeMello, D. Li, S.P.Virostek (LBNL), Progress on the MICE 201 MHz RF Cavity at LBNL
W. Xu, S.A. Belomestnykh, I. Ben-Zvi, H. Hahn, P. Jain, E.C. Johnson (BNL), C.M. Astefanous, J.P. Dea- cutis, D. Holmes (AES), Progress on the High-Current 704 MHz Superconducting RF Cavity at BNL
W. Xu, Z. Altinbas, S.A. Belomestnykh, I. Ben-Zvi, S. Deonarine, D.M. Gassner, J.P. Jamilkowski, P. Kankiya, D. Kayran, N. Laloudakis, L. Masi, G.T. McIntyre, D. Pate, D. Phillips, T. Seda, A.N. Steszyn, T.N. Tallerico, R.J. Todd, D. Weiss, A. Zaltsman (BNL), M.D. Cole, G.J. Whitbeck (AES), Design, Simulation and Conditioning of the Fundamental Power Couplers for BNL SRF Gun
Q. Wu, S.A. Belomestnykh, I. Ben-Zvi (BNL), R. Calaga (CERN), HOM Damping and Multipacting Analysis of the Quarter-wave Crab Cavit