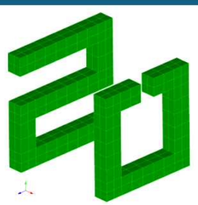
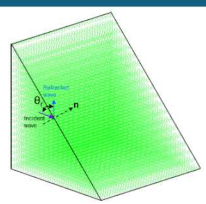
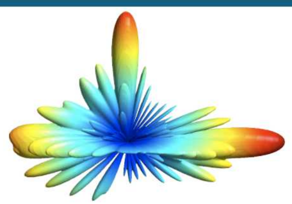
SAND2018-2955C

Massively Parallel Frequency Domain Electromagnetic Simulation Codes







PRESENTED BY

Brian Zinser

Organization 1352

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

A team effort

William L. Langston

Joseph Kotulski

Rebecca Coats

S. Adam Blake

Brian Zinser

Roy Jorgenson

Salvatore Campione

Aaron Pung

Vinh Dang

Bill Johnson

Andy Huang

Ting Mei

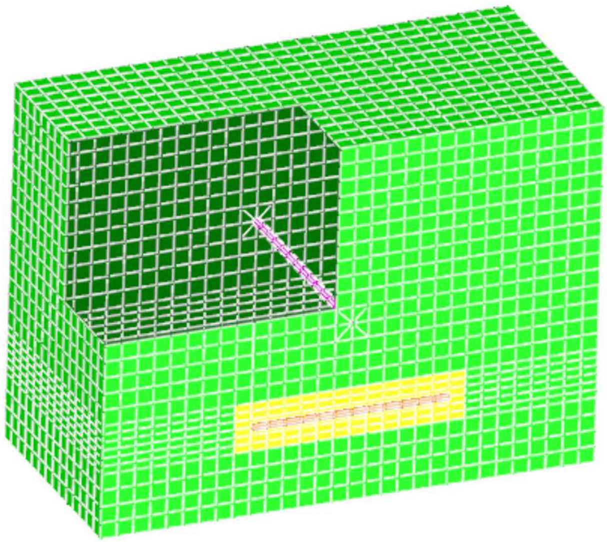
Brian Freno

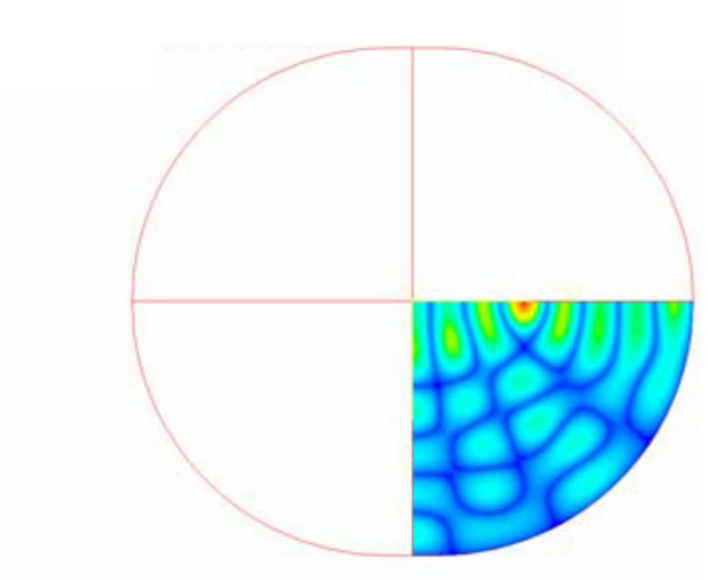
Rafael Schleder

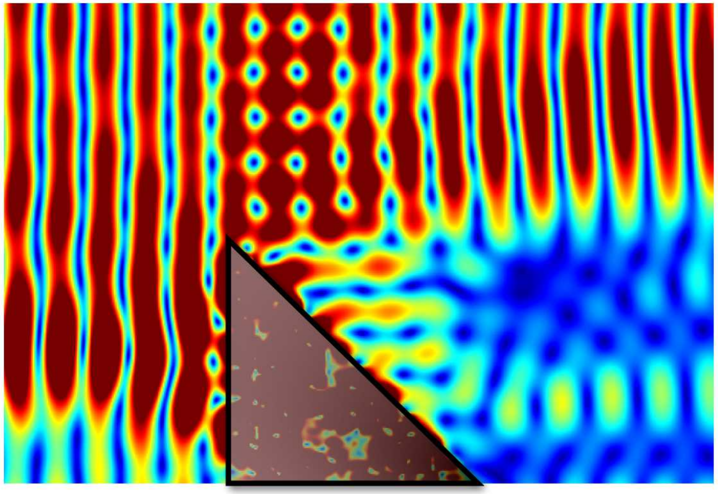
Outline

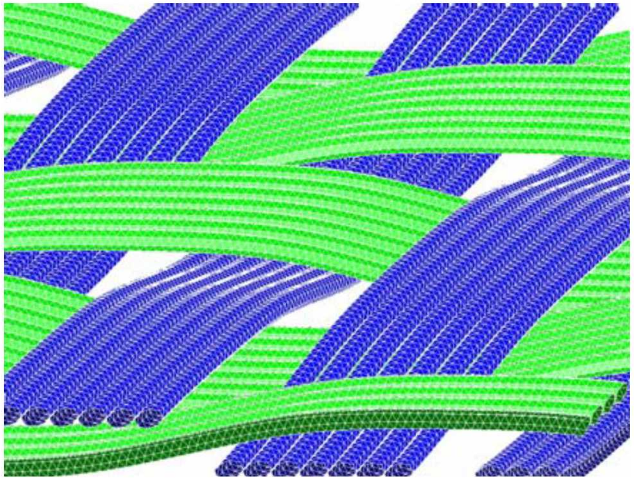
- Overview of EIGER
- Evolving HPC environment
- Writing performance portable code
- Overview of Gemma, EIGER's successor
- RCS validation
- Conclusions and future work

EIGER: Electromagnetic Interactions GenERalized [1, 2, 3, 4]









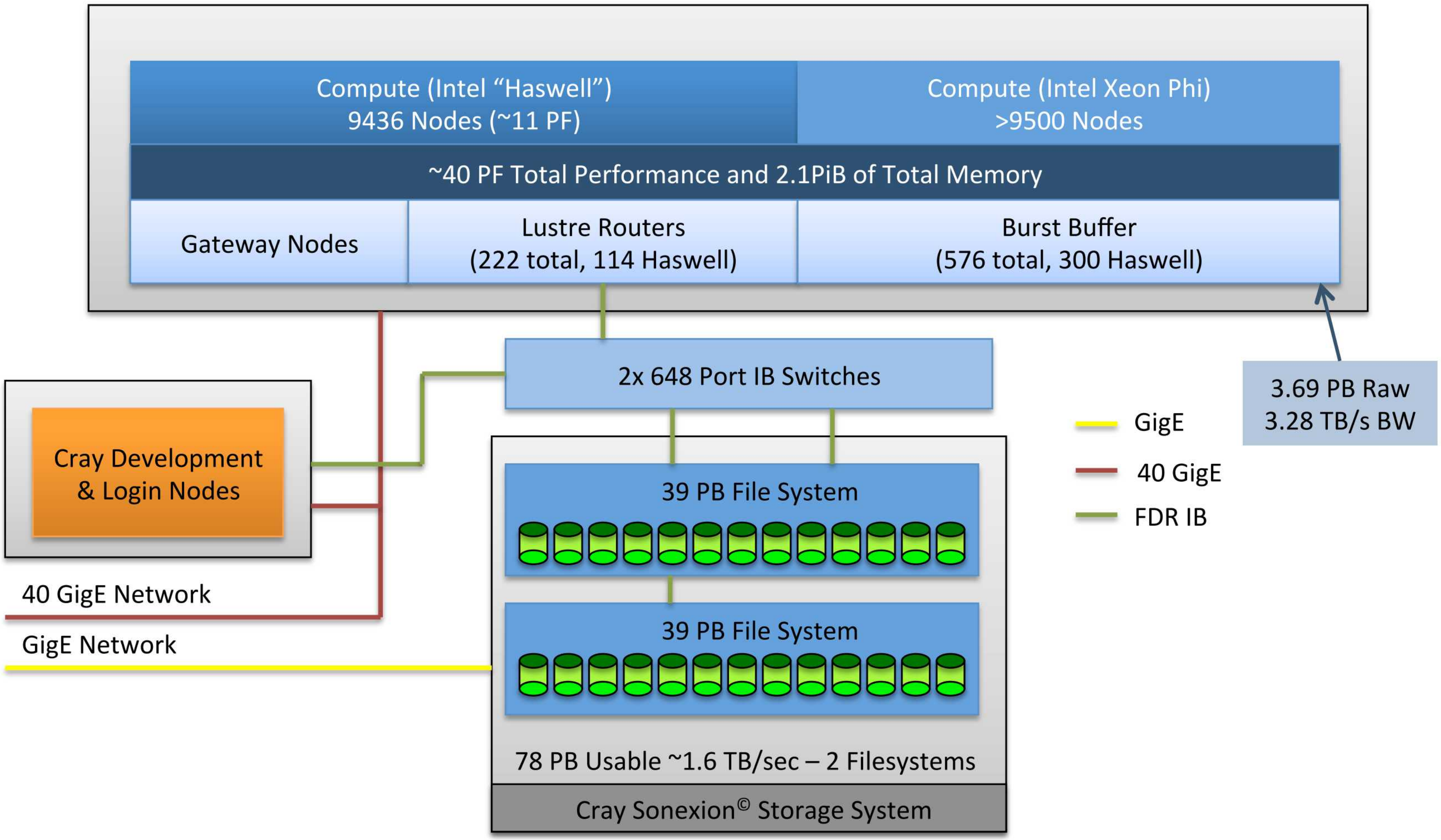
Evolving HPC environment

- “FORTRAN MPI” paradigm
  - MPI inter- and intranode parallelism
  - High processor clock speed
  - High memory per processor

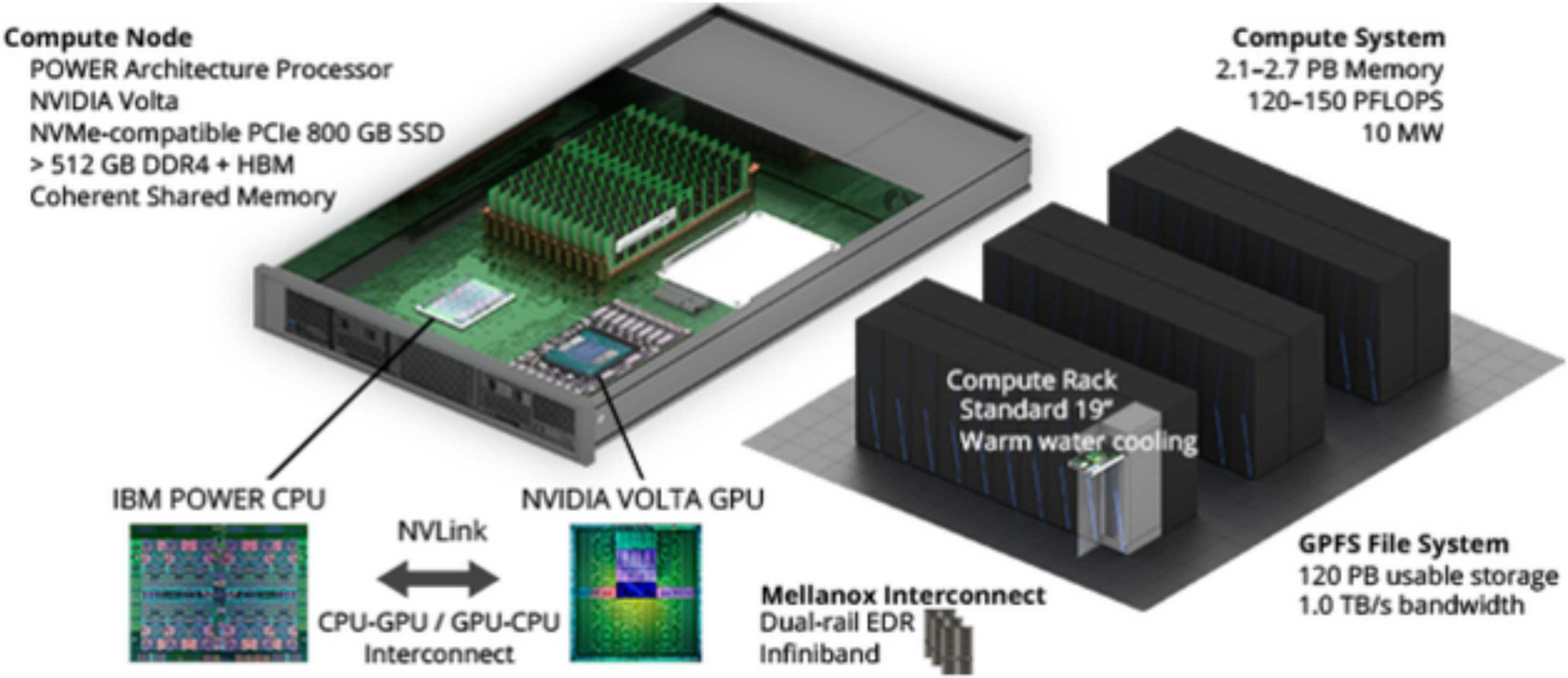
- “Heterogeneous” paradigm
  - MPI internode parallelism
  - Threading intranode parallelism
  - Low processor clock speed
  - Low memory per processor

- Target HPC platforms
  - Trinity
  - Sierra

Trinity: a mix of CPU and MIC nodes [5]



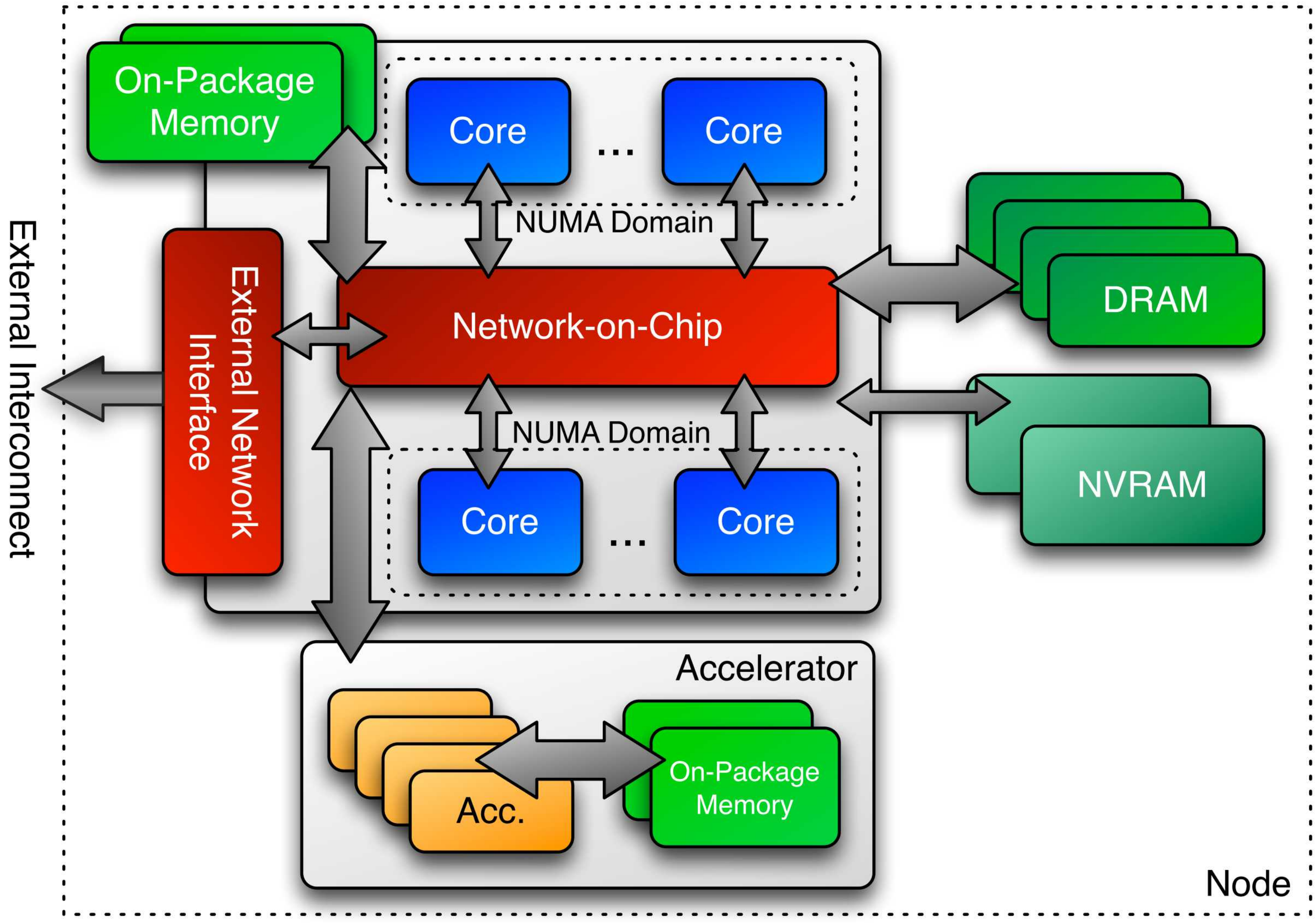
Sierra: CPU and GPU on a single node [6]



Code development in the new HPC paradigm

- Ideal development includes
  - Writing architecture independent source code
  - Using multicore technology efficiently
- Trilinos's Kokkos library
  - Is an abstraction layer for execution and memory spaces
  - Provides ability to take advantage of architecture's features

Kokkos: an abstraction for execution and memory spaces [7]



Introducing Kokkos loops to C++ code [7]

Pattern Policy

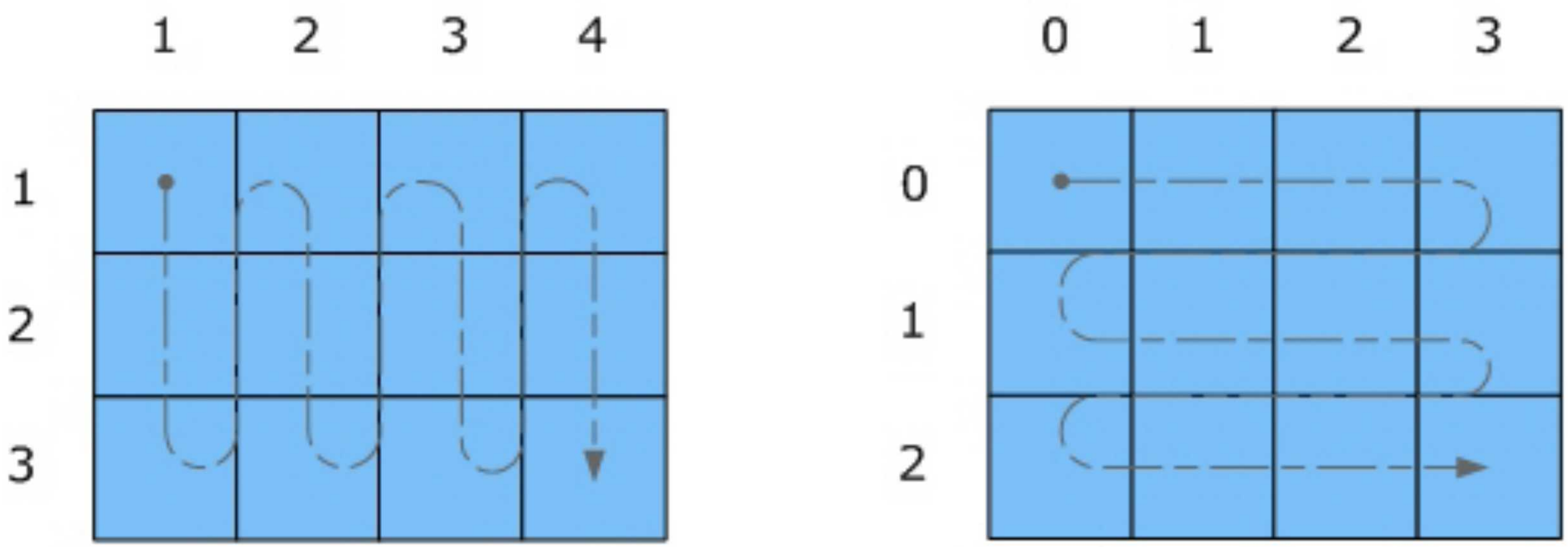
Body

```
for (element = 0; element < numElements; ++element) {
  total = 0;
  for (qp = 0; qp < numQPs; ++qp) {
    total += dot(left[element][qp], right[element][qp]);
  }
  elementValues[element] = total;
}
```

```
parallel_for(N, [=] (const size_t i) {
  /* loop body */
});
```

Kokkos multidimensional arrays [7, 8]

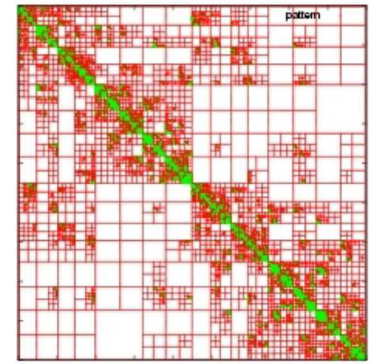
```
View<int*[3], LayoutLeft, CudaSpace> c ("c", 10);
```



Gemma: more than a C++ rewrite [1, 9, 10, 11, 12, 13]

eiger

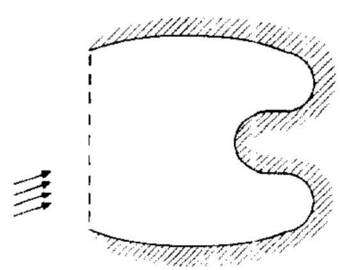
Trilinos



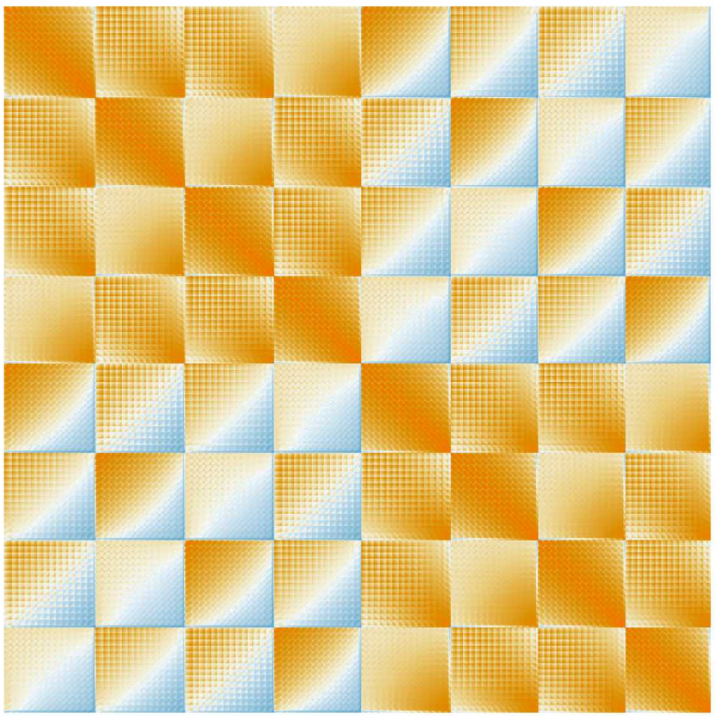
Gemma

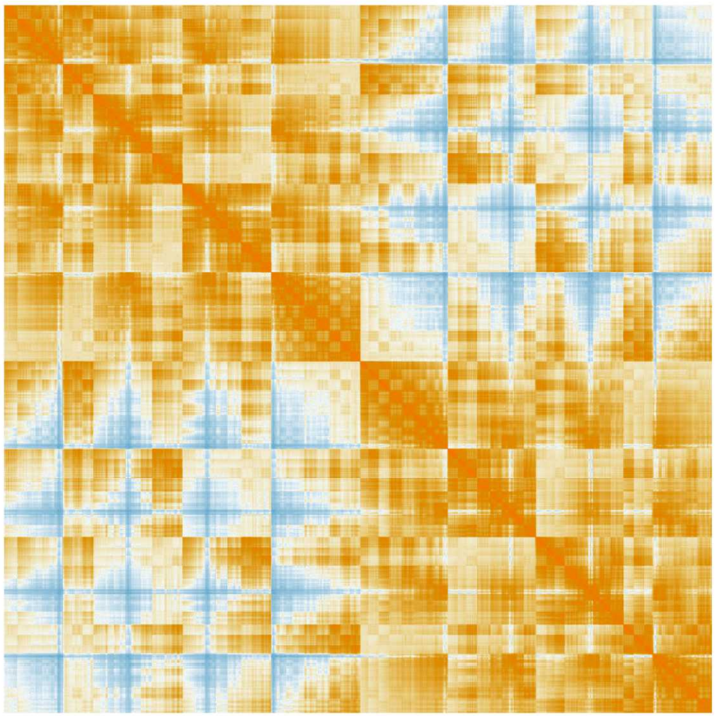
Xyce™

PARALLEL ELECTRONIC SIMULATOR

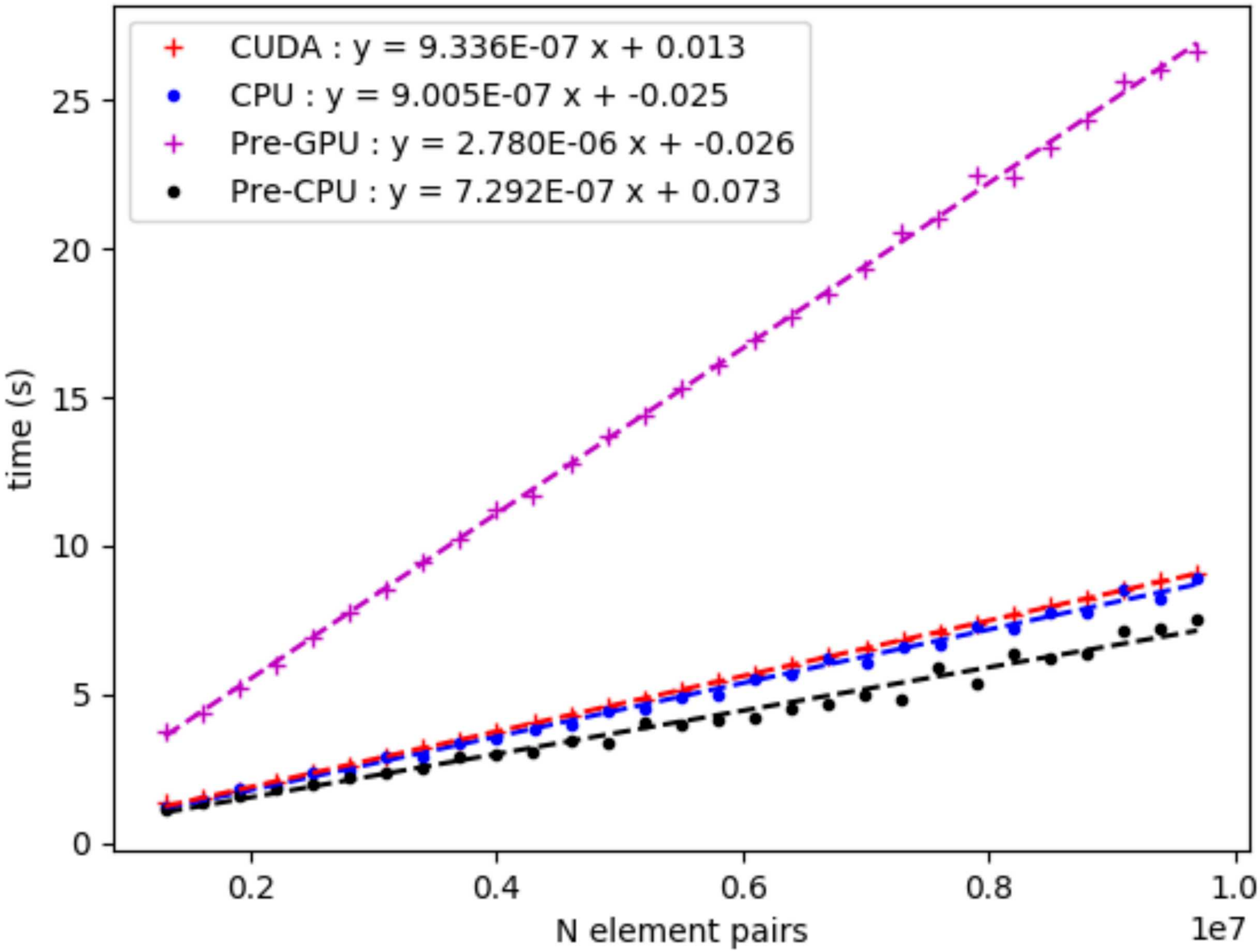


Sparse approximate inverse preconditioner [14]





Gemma is portable, if not performant



EIGER / Gemma monostatic RCS validation for double ogive [15]

Polarization: Horizontal

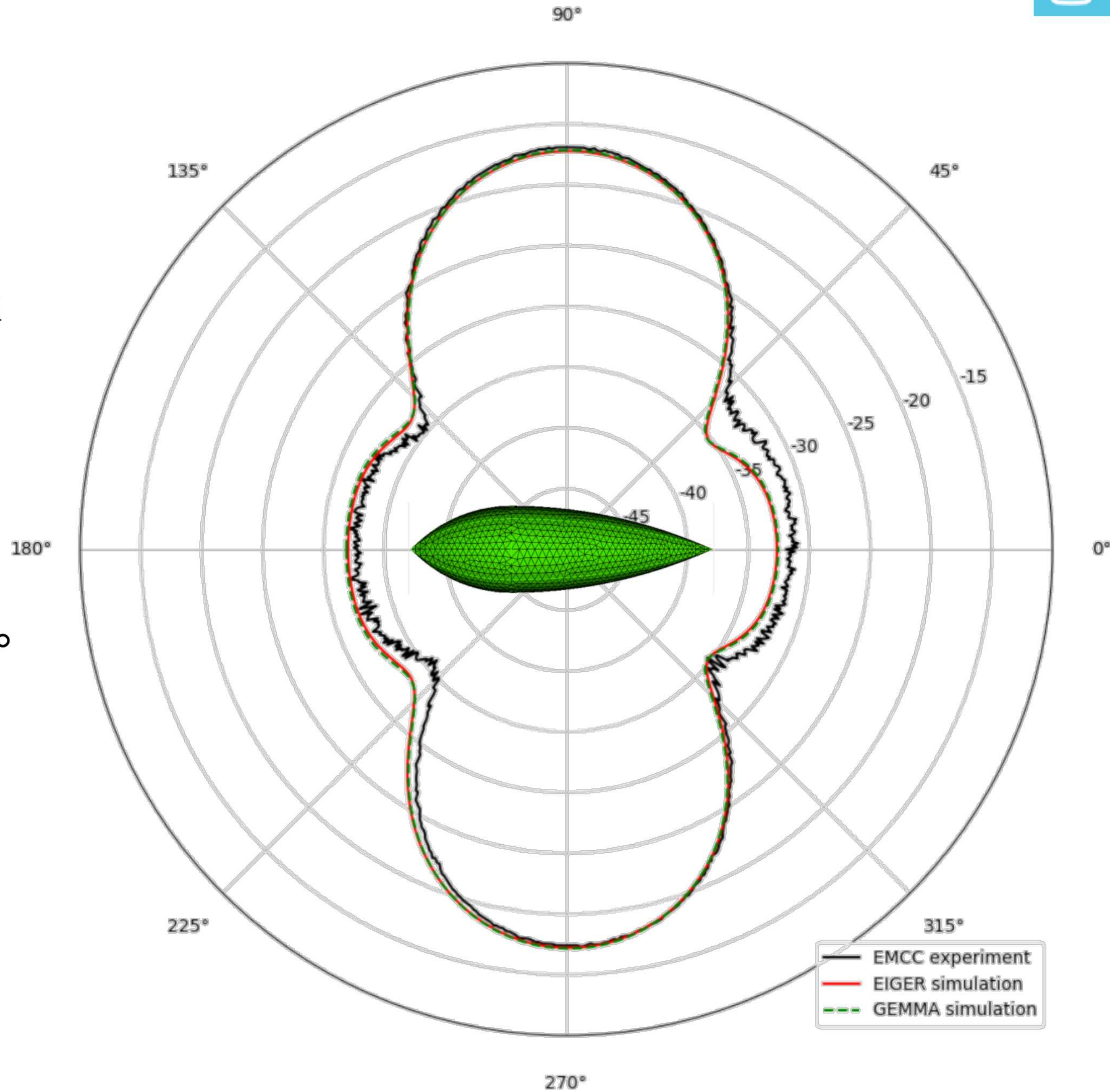
Frequency: 1.57 GHz

Wavelength: 0.191 m

Object length: 0.254 m

Left ogive angle: 46.4°

Right ogive angle: 22.62°



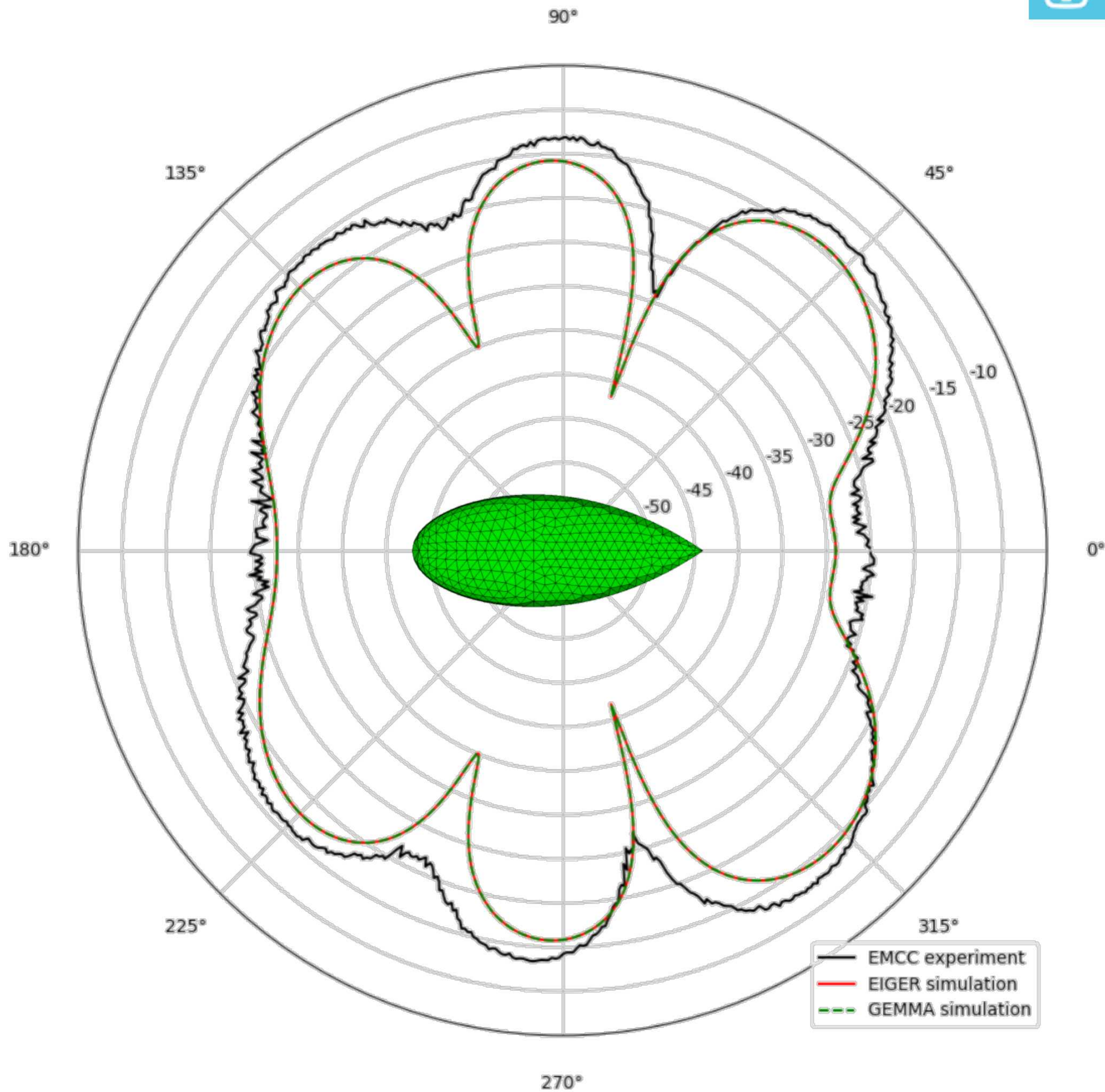
EIGER / Gemma monostatic RCS validation for NASA almond [15]

Polarization: Horizontal

Frequency: 1.19 GHz

Wavelength: 0.251926 m

Object length: 0.253



EIGER / Gemma monostatic RCS validation for cone-sphere [15]

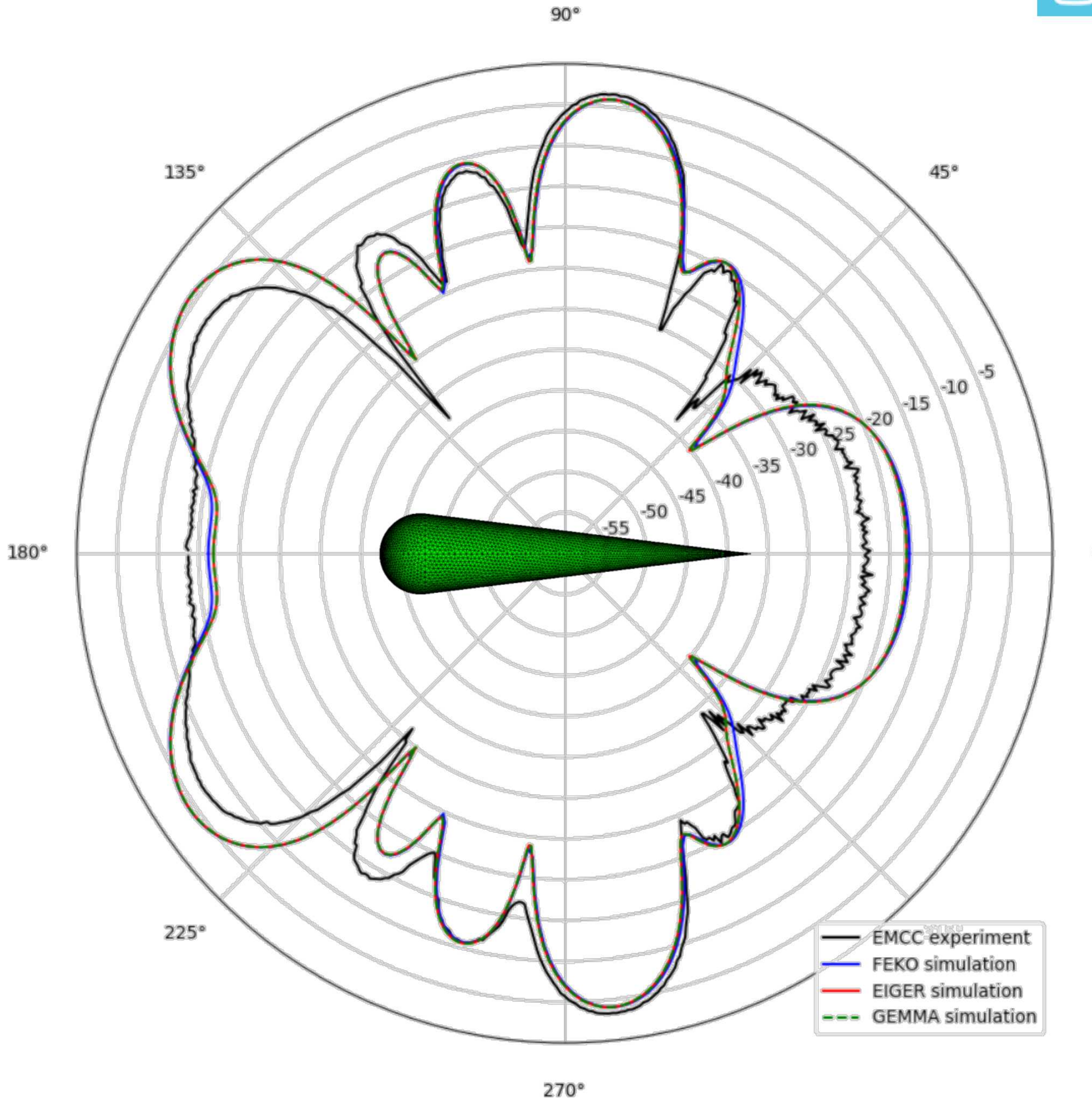
Polarization: Horizontal

Frequency: 869 MHz

Wavelength: 0.344986 m

Object length: 0.689 m

Cone angle: 7°



Conclusions and future work

- Gemma has captured some of the algorithmic features of EIGER in an architecture independent way

- Increase Gemma's feature set

- Improve performance of Gemma's threaded algorithms

- Implement hybrid parallel MPI and threading for Gemma

- Investigate different algorithms for special cases

References

1. D. R. Wilton, W. A. Johnson, R. Jorgenson, R. Sharpe, and J. Rockway, "EIGER: A new generation of computational electromagnetics tools," ElectroSft: Software for EE Analysis and Design, Miniato, Italy, pp. 28-30, May 1996.
2. Experimental - Dept. of EE, University of Missouri, Rolla, IEEE Trans on EMC Vol. 39, No. 2, May 1997.
3. L. K. Warne and R. E. Jorgenson, "Three-dimensional electromagnetic high frequency axisymmetric cavity scars," Sandia National Laboratories, SAND2014-18896, 2014.
4. L. I. Basilio, W. L. Langston, L. K. Warne, W. A. Johnson, and M. B. Sinclair, "Full-wave simulation of a three-dimensional metamaterial prism," Microw. Opt. Technol. Lett., vol. 57, pp. 537–540, March 2015.
5. Los Alamos National Laboratory, "Trinity platform introduction and usage model," Aug. 2015. Available: http://www.lanl.gov/projects/trinity/_assets/docs/trinity-usage-model-presentation.pdf [Accessed: 16 Mar. 2018].
6. Lawrence Livermore National Laboratory. Available: https://computation.llnl.gov/partnerships/commencing-work-coral [Accessed 16 Mar. 2018].
7. H. Edwards, C. Trott, and D. Sunderland, "Kokkos: Enabling manycore performance portability through polymorphic memory access patterns," J. Parallel Distrib. Comput., vol. 74, no. 12, pp. 3202-3216, 2014.
8. Intel, "Calling LAPACK, BLAS, and CBLAS Routines from C/C++ Language Environments," 2018. Available: https://software.intel.com/en-us/node/528573 [Accessed: 8 Mar. 2018].

References

9. E. R. Keiter et al., "Xyce parallel electronic simulator users' guide," Sandia National Laboratories, SAND2017-11351, 2017.

10. D. Pusch, "Efficient algebraic multigrid preconditioners for boundary element matrices," Institute of Computational Mathematics Johannes Kepler University Linz, 2003. Available: https://www.numa.uni-linz.ac.at/Teaching/Diplom/Finished/pusch [Accessed: 16 Mar. 2018].

11. F. Obelleiro-Basteiro, J. Luis Rodrigues, and R. J. Burkholder, "An iterative physical optics approach for analyzing the electromagnetic scattering by large open-ended cavities," *IEEE Trans. Antennas Propag.*, vol. 43, no. 4, pp. 356-361, Apr. 1995.

12. M. Heroux et. al., "An overview of Trilinos," Sandia National Laboratories, SAND2003-2927, 2003.

13. E. Bavier, M. Hoemmen, S. Rajamanickam, and H. Thornquist, "Amesos2 and Belos: Direct and iterative solvers for large sparse systems," Scientific Programming, vol. 20, iss. 3, 2012.

14. M. Bettencourt, B. Zinser, R. Jorgenson, and J. Kotulski, "Performance portable sparse approximate inverse preconditioner for EFIE equations," ICEAA, Sept. 2017.

15. A. Woo, H. Wang, M. Schuh, and M. Sanders, "Benchmark radar targets for the validation of computational electromagnetics programs," IEEE Antennas and Propag. Mag., vol. 35, no. 1, pp. 84-89, February 1993.