



Sandia
National
Laboratories

GEMMA Electromagnetic Code and ADELUS - New Capabilities

Joseph D. Kotulski, Vinh Dang 1352

jdkotul@sandia.gov, vqdang@sandia.gov

Trilinos User Group Meeting 2022

October 25, 2022



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & 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.

GEMMA Description



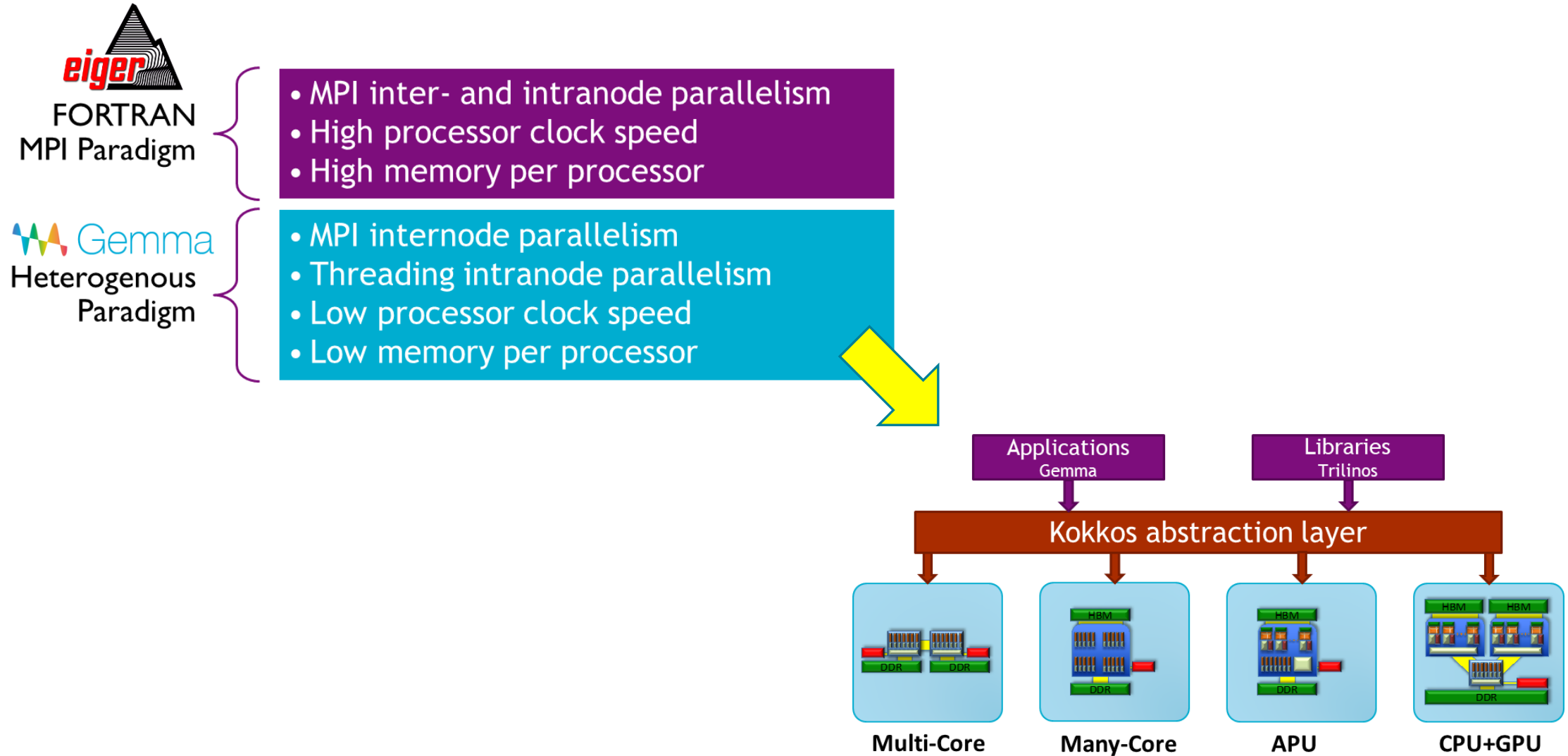
- ❑ Frequency-domain method of moments solution
 - Steady state solution
 - With specialized algorithms (thin-slot, etc.)
- ❑ Boundary element formulation
 - Mesh surfaces of parts – interface between regions
- ❑ Exact radiation boundary condition
 - Due to Green's function
- ❑ Formulation results in dense (fully populated) matrix
 - Simulations can be limited by available memory
 - Entries are double precision complex
- ❑ Code has been ported and used for ND problems on CTS1, ATS1, and ATS2



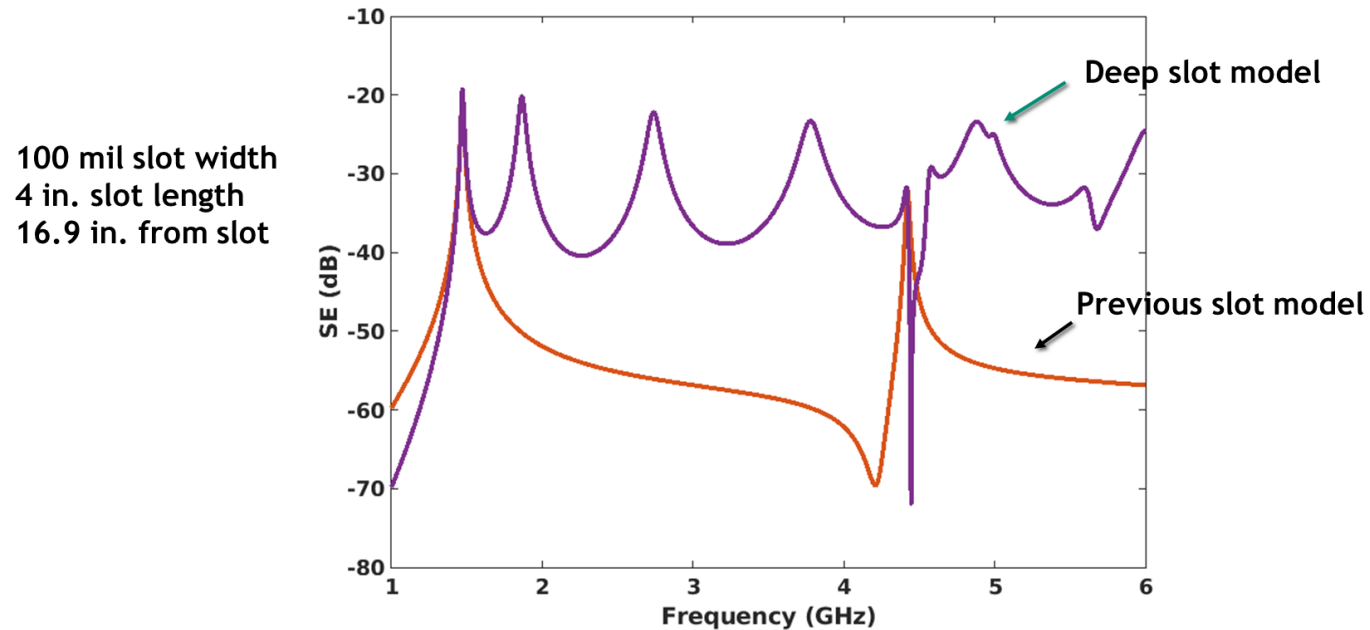
HPC

The next generation version of EIGER

Capability on Next-Generation Hardware



- ❑ Improved slot algorithm
 - ❑ Takes into account the depth resonance of the slot



- ❑ Power Balance
 - ❑ Simplified power calculations to determine the high-frequency response.

GEMMA – NEW FEATURES

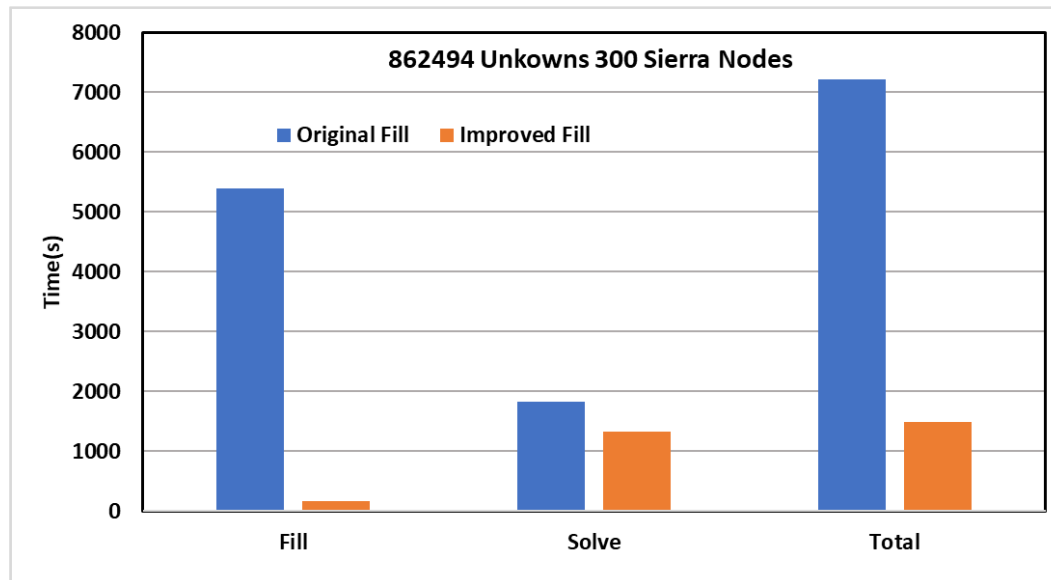


❑ Rational Interpolation

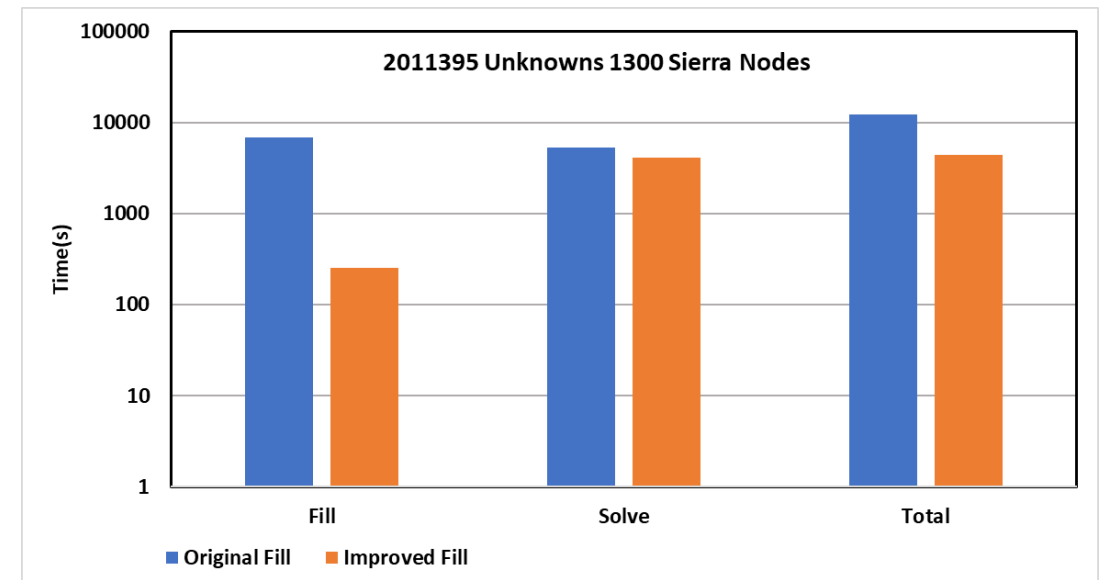
- ❑ Algorithm to locate peaks - important for calculation of electromagnetic coupling

❑ Matrix fill algorithm improved

- ❑ Fill by unknowns (i and j) instead of by elements

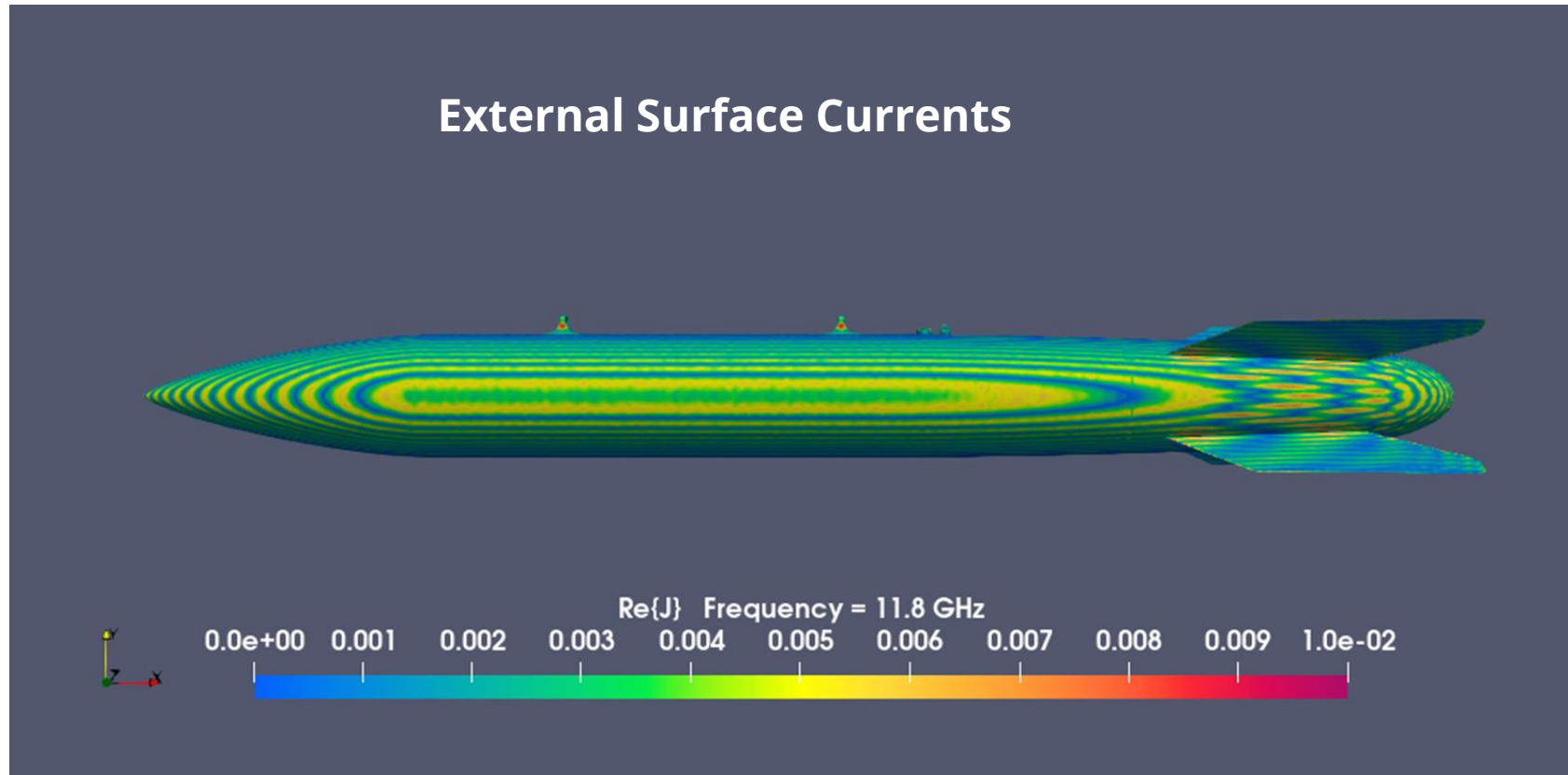


33 x Speedup



27 x Speedup

GEMMA – Example Problem (2 million unknowns)



GEMMA – Future Solver Development



- ❑ Preconditioner development
 - ❑ Matrices have behavior much different than what is experienced with FEM solvers.
- ❑ Compression Techniques
 - ❑ Reduce the memory footprint
 - ❑ Iterative solution using BELOS
- ❑ Combining the above concepts

ADELUS – AMD HIP Backend Support

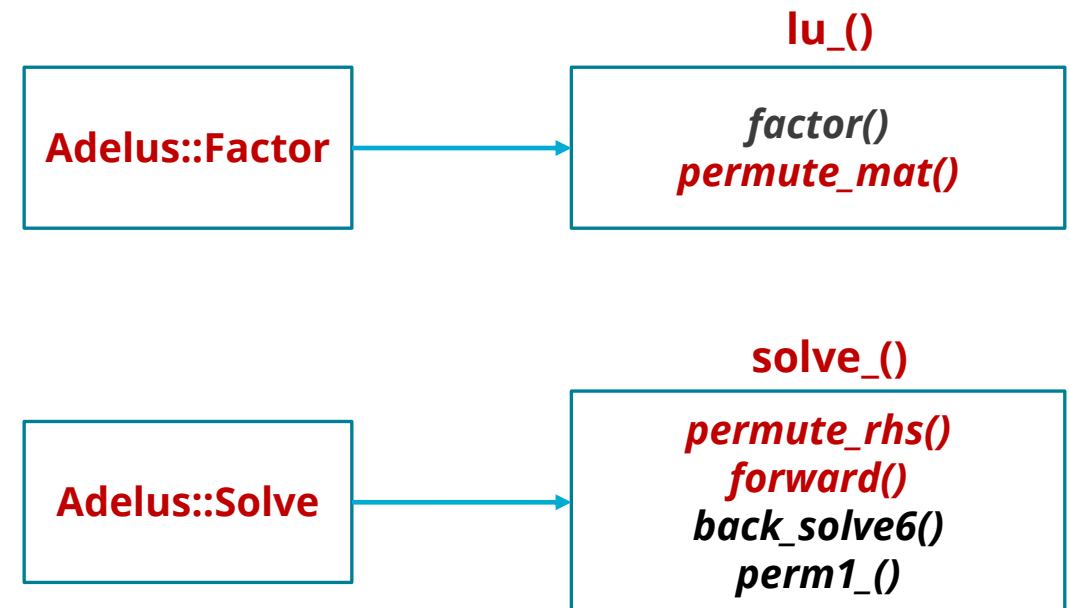


- ❑ Necessary changes made for code and CMake to support HIP backend
- ❑ Trilinos configuration:
 - ❖ hipcc compiler
 - ❖ Architecture flag for Kokkos (For MI100: Kokkos_ARCH_VEGA908=ON)
 - ❖ Kokkos_ENABLE_HIP=ON
 - ❖ KokkosKernels_ENABLE_TPL_ROCBLAS:BOOL=ON/OFF
- ❑ rocBLAS wrappers for GEMM, IAMAX, and SCAL kernels to Kokkos Kernels
- ❑ Future work: evaluate ADELUS performance on Crusher/Frontier (ORNL)

ADELUS – Factor and Solve Interfaces



- ❑ ADELUS previously only provided LU factorization and solve via a single interface `Adelus::FactorSolve` (matrix + RHS packed together)
- ❑ Create two separate interfaces which are useful for applications that (i) *do not have RHS at the time of factorization* OR (ii) *need to solve different RHSs with a pre-factorized matrix*
 - ❖ **Adelus::Factor**: LU factorization
 - ❖ **Adelus::Solve**: forward solve + backward solve
 - ❖ Support execution on GPUs and multiple RHS vectors



ADELUS – General Communicator and Global Variables Removal



- ❑ Enable ADELUS to run on an arbitrary communicator rather than MPI_COMM_WORLD
 - ❖ Create sub-communicators and launch Adelus to solve many linear equation systems
- ❑ A new class, AdelusHandle, contains:
 - ❖ a communicator, global variables, constructor and methods to retrieve these variables
- ❑ A handle needs to be created and passed through Adelus interfaces from application code

```
class AdelusHandle {
private:
    //Comm. variables and used-to-be global variables
    int my_rows;        // num of rows I own
    int my_cols;        // num of cols I own
    int my_rhs;         // number of RHSs that I own
    ...
    MPI_Comm row_comm;  // row sub-communicator
    MPI_Comm col_comm;  // column sub-communicator
    MPI_Comm comm;      // communicator that I belong to

public:
    AdelusHandle (MPI_Comm comm_, const int matrix_size_,
                  const int num_procsr_, const int num_rhs_, ...) {
        //Calculate global vars and create row and col sub-comms
        ...
    }
    KOKKOS_INLINE_FUNCTION
    MPI_Comm get_comm() const { return comm; }
    ...
    KOKKOS_INLINE_FUNCTION
    int get_my_rows() const { return my_rows; }.
};
```

Adelus

```
//Create handle
Adelus::AdelusHandle ahandle(my_color, sub_comm,
                             matrix_size, nprocs_row, nrhs );

//Pass through Adelus interfaces
Adelus::Factor (ahandle, my_A, h_permute, &secs);
```

Application

ADELUS – Backsolve Performance Improvement

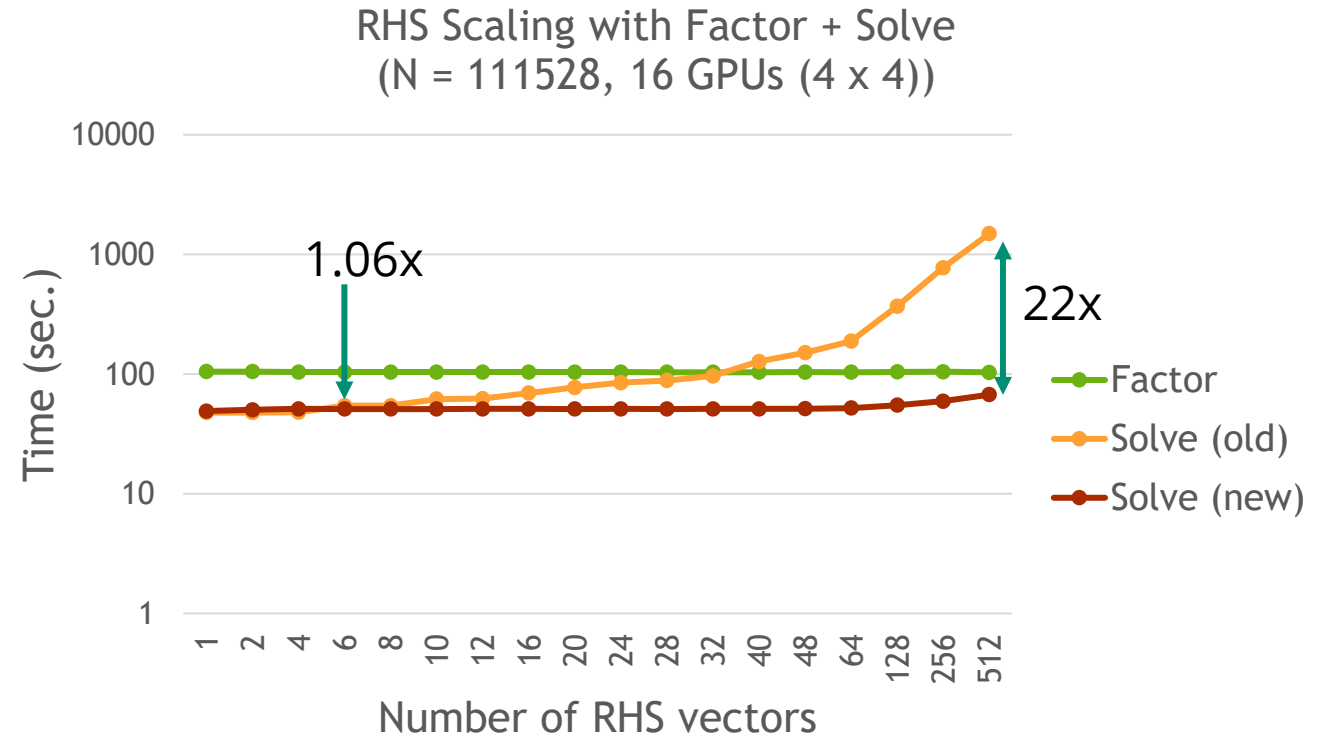


❑ Issue: backsolve previously did not scale well with large numbers of RHS vectors

❖ Using **pipelined communication** for the **whole RHS** mutivectors across MPI processes at each column iteration

❑ Improvement:

❖ **Broadcasting only one** current active column within row communicators at each iteration → communication overhead is significantly reduced



ADELUS – Future Performance Improvement



- ❑ Allow using tile size greater than 1
- ❑ Allow using mixed-precision