Exploiting Parallelism with Hypermatrices

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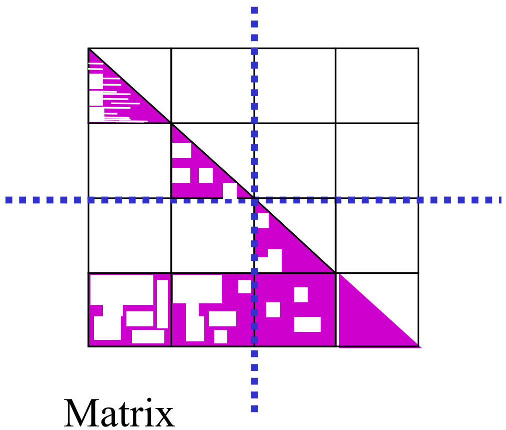
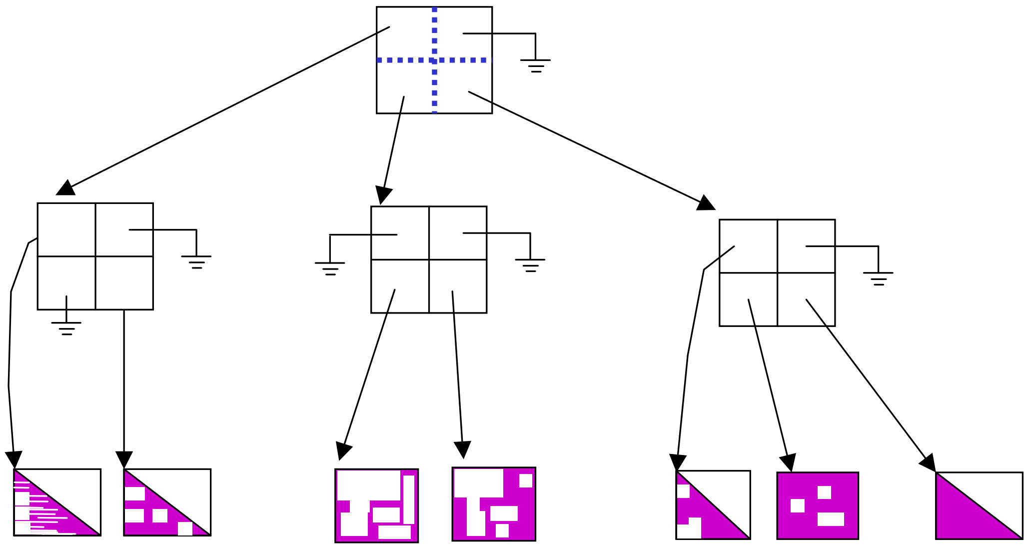
Outline

- Introduction
- Potential sources of parallelism
- Exploiting ILP
- Application
  - Sparse codes
  - Dense codes
- Conclusions

Hypermatrix structure



Matrix



HyperMatrix

Sources of Parallelism

Replication of resources:

- Machines in a network
- Processors within a machine
- Functional Units within a processor

Parallelism at diferent levels:

- Process
- Thread
- Instruction

Exploiting ILP

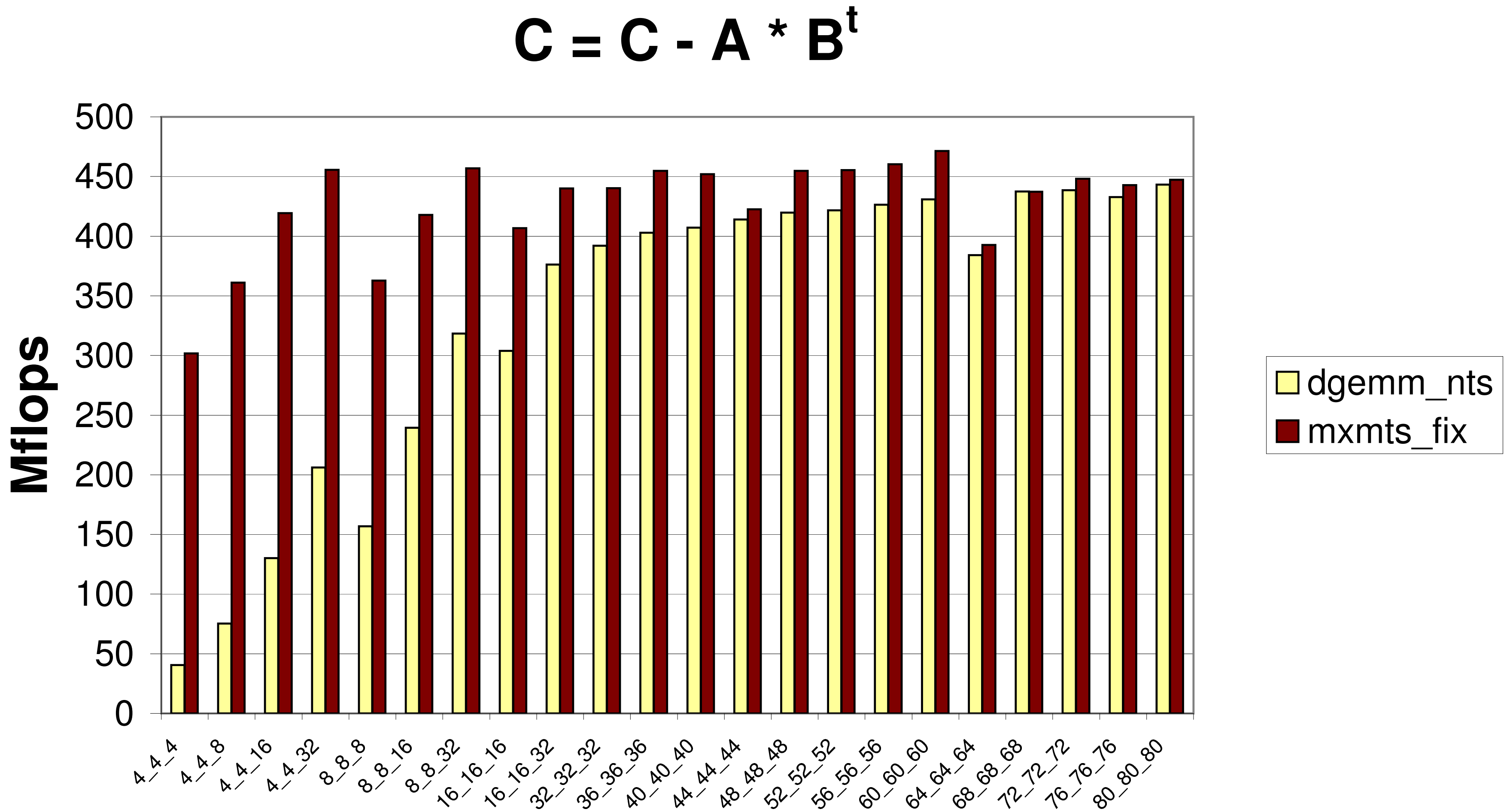
Goal: The sparse code requires efficient operation on small data submatrices

- Reduce data submatrix size while keeping good BLAS3 performance

Idea [Euro-Par'03]:

- Fix parameters at compilation time
- Choose best algorithm
  - Loop unrolling factors
  - Loop orders

Matrix multiplication performance on small matrices



R10000 250 MHz (500 Mflops peak)

Sparse codes: Overhead

Can store 0's within data submatrices

- Storage
- Computation

Trade-off in data submatrix size

- BLAS3 efficiency
- (Useless) operation on 0's

Reducing Overhead & Increasing Performance

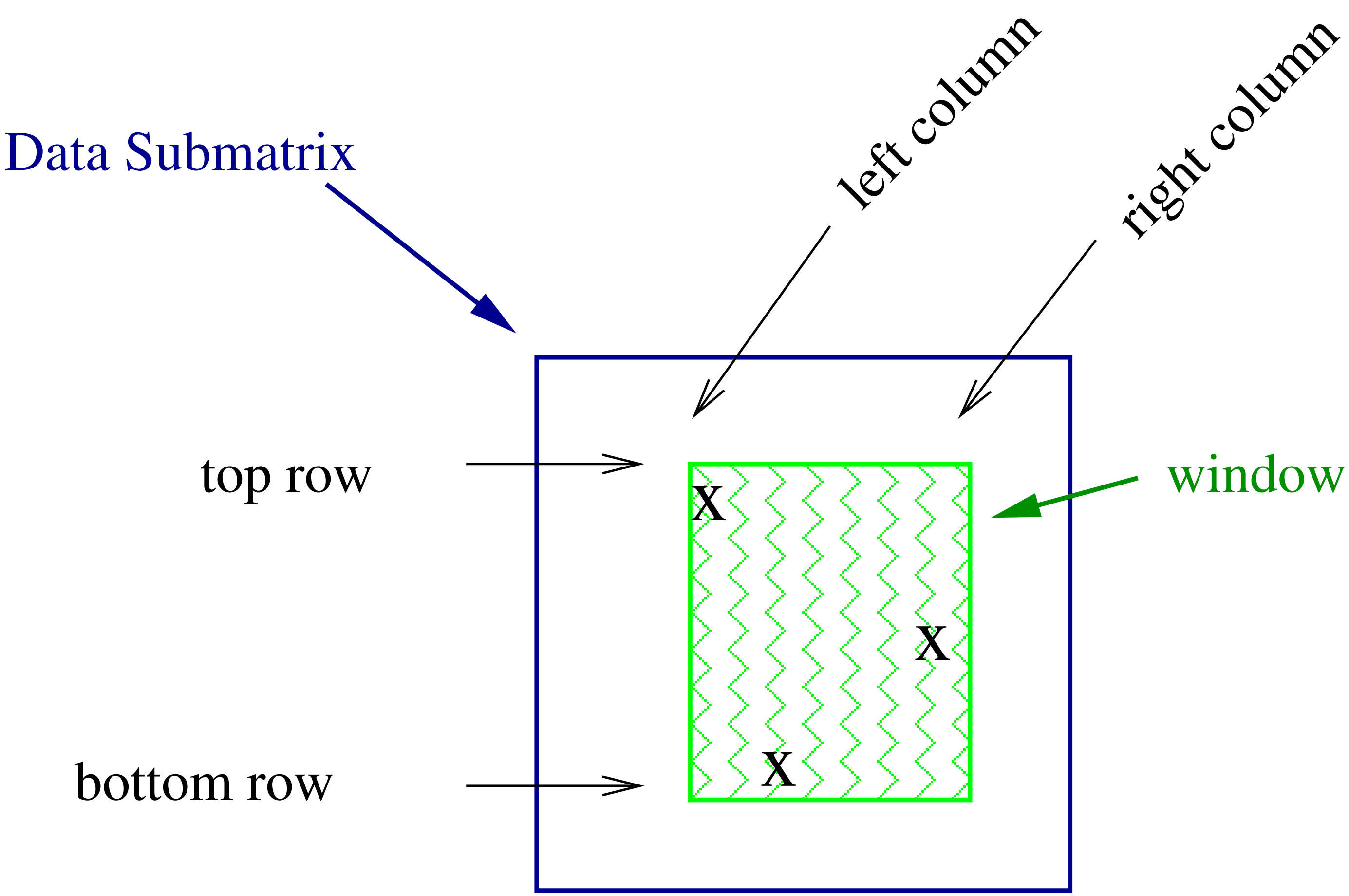
- Efficient kernels which operate on small data submatrices
- Windows within data submatrices

Windows within data submatrices: Goal

Store and use only a part of a data submatrix

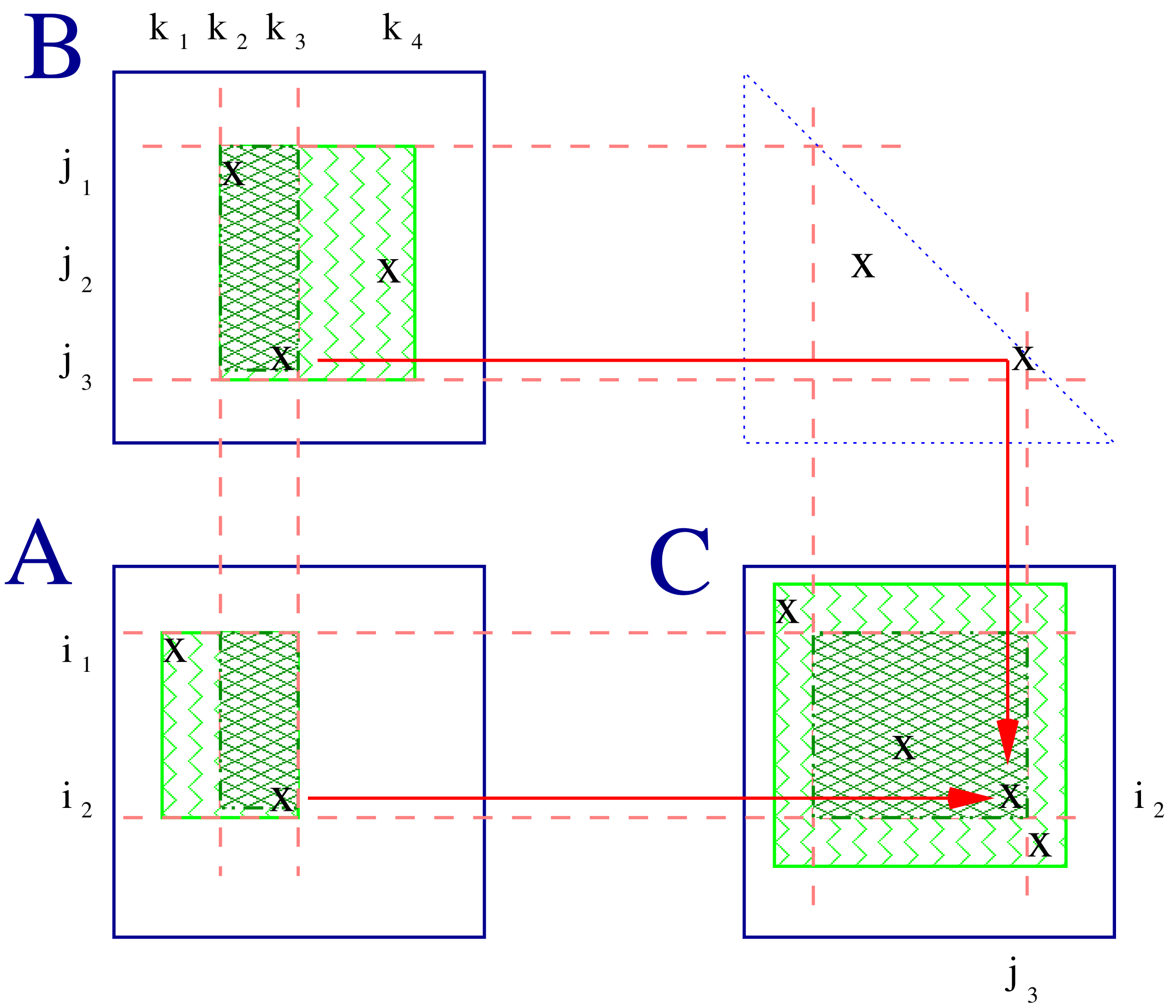
- Reduce unnecessary computation
- Reduce storage

Windows: Definition



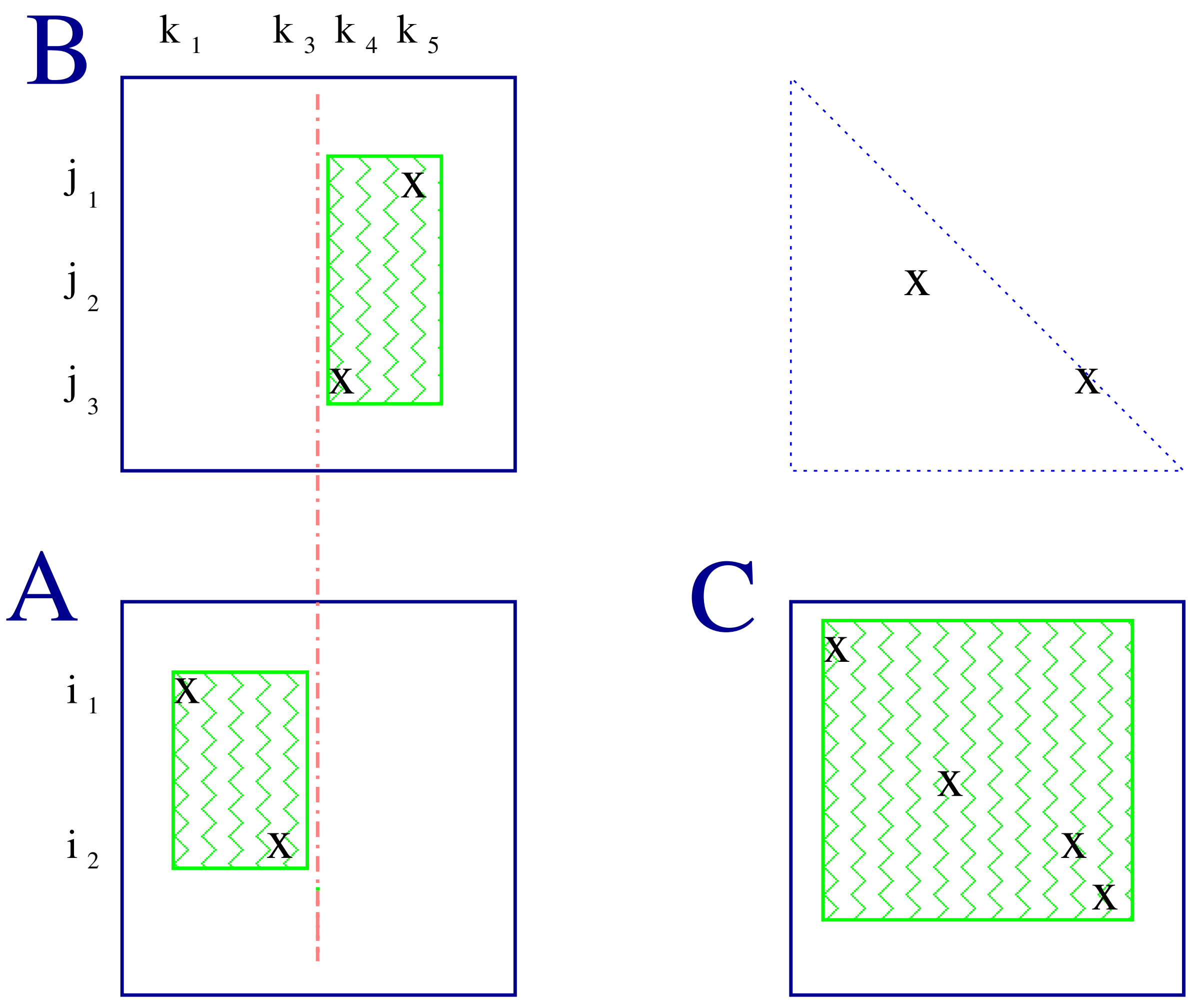
Window: subset of data submatrix

Windows: Usage (I)



Operation can be reduced

Windows: Usage (II)

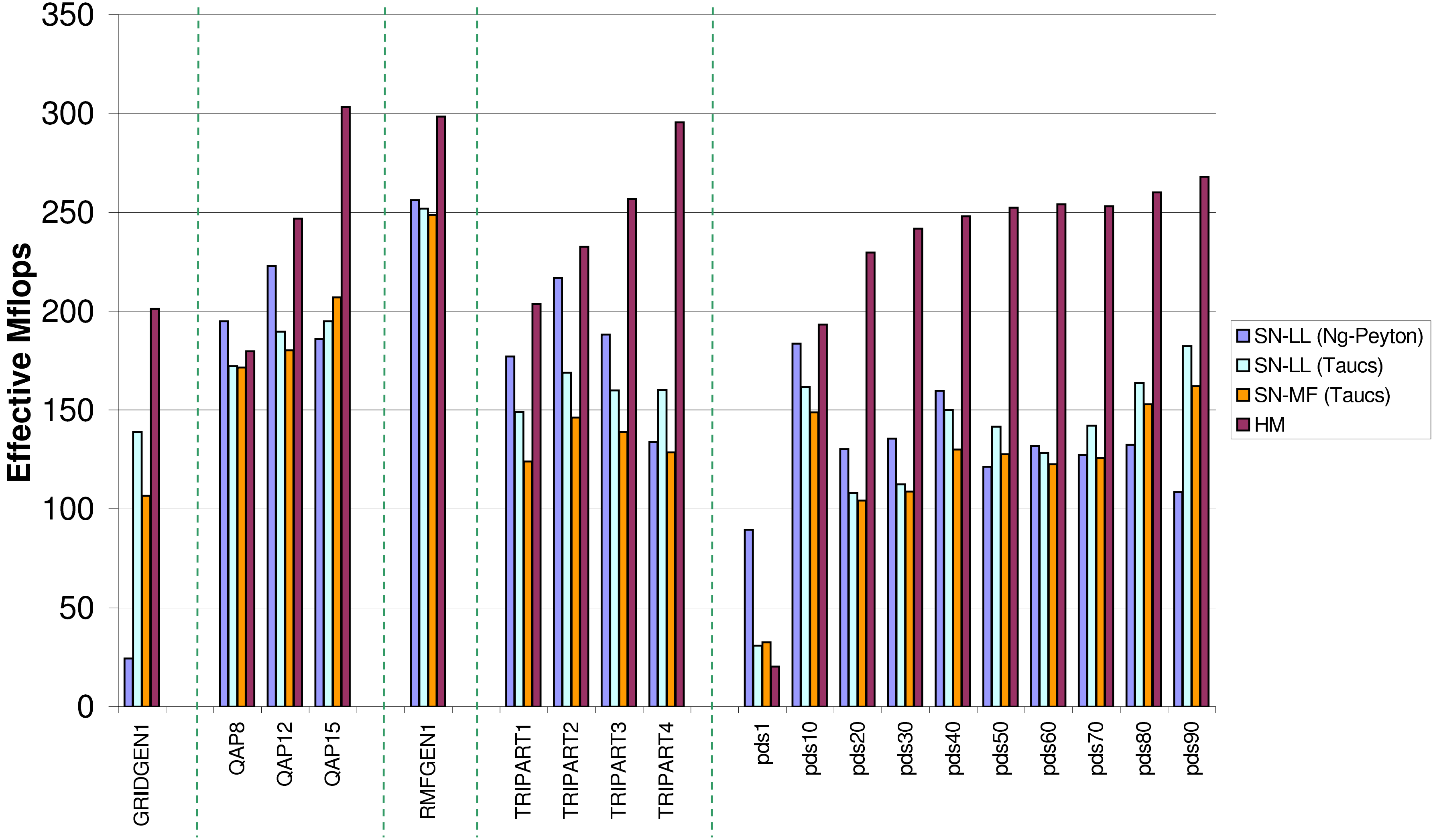


Operation can be skipped

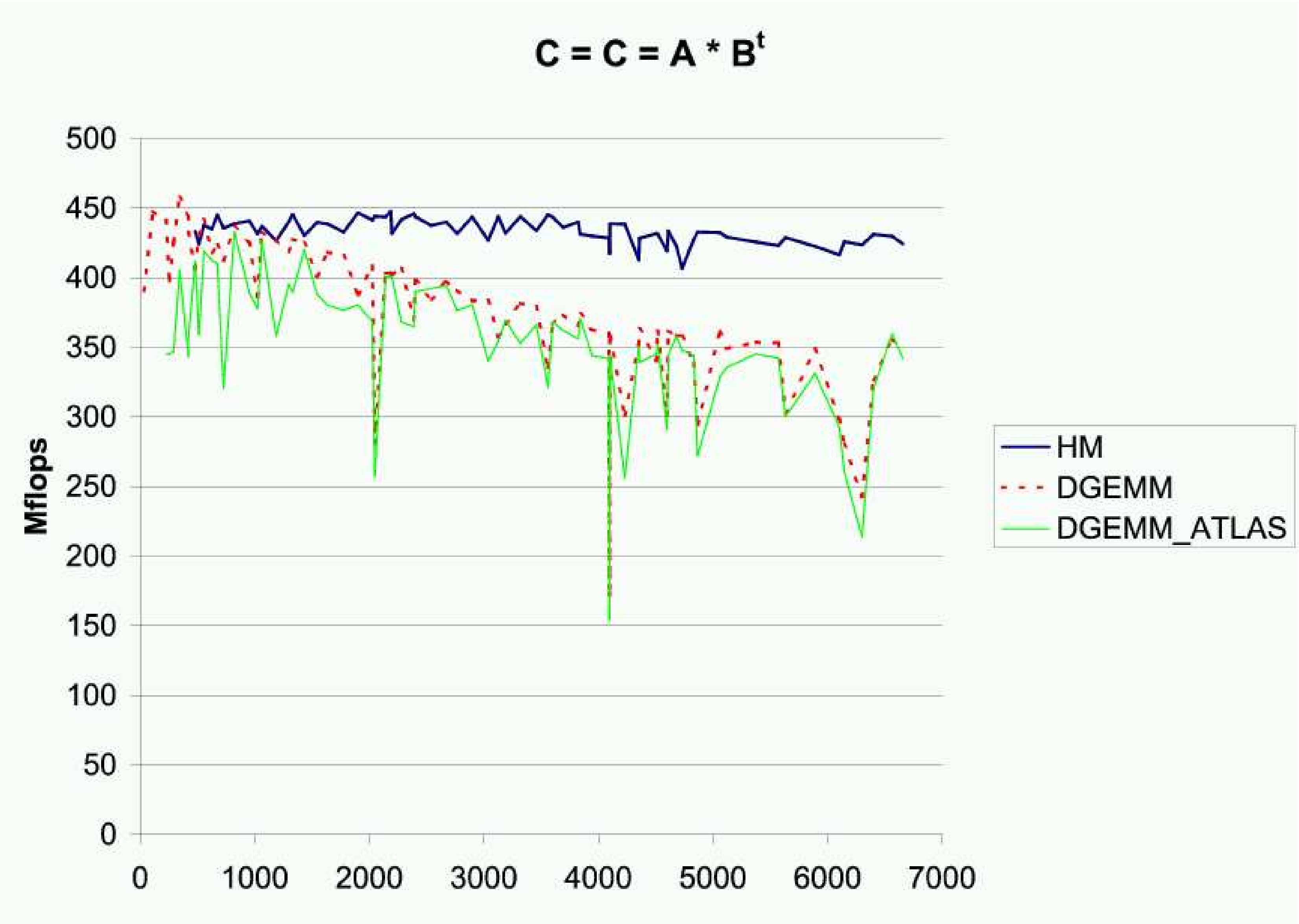
Results: Context information

- MIPS R10000 @ 250 MHz (500 Mflops peak)
- Sequential code
- Data submatrices of fixed size
- Large problems solved In-Core
- Ordered using METIS
- Linear Programming problems
  - NetLib
  - Multicommodity Network Flow generators

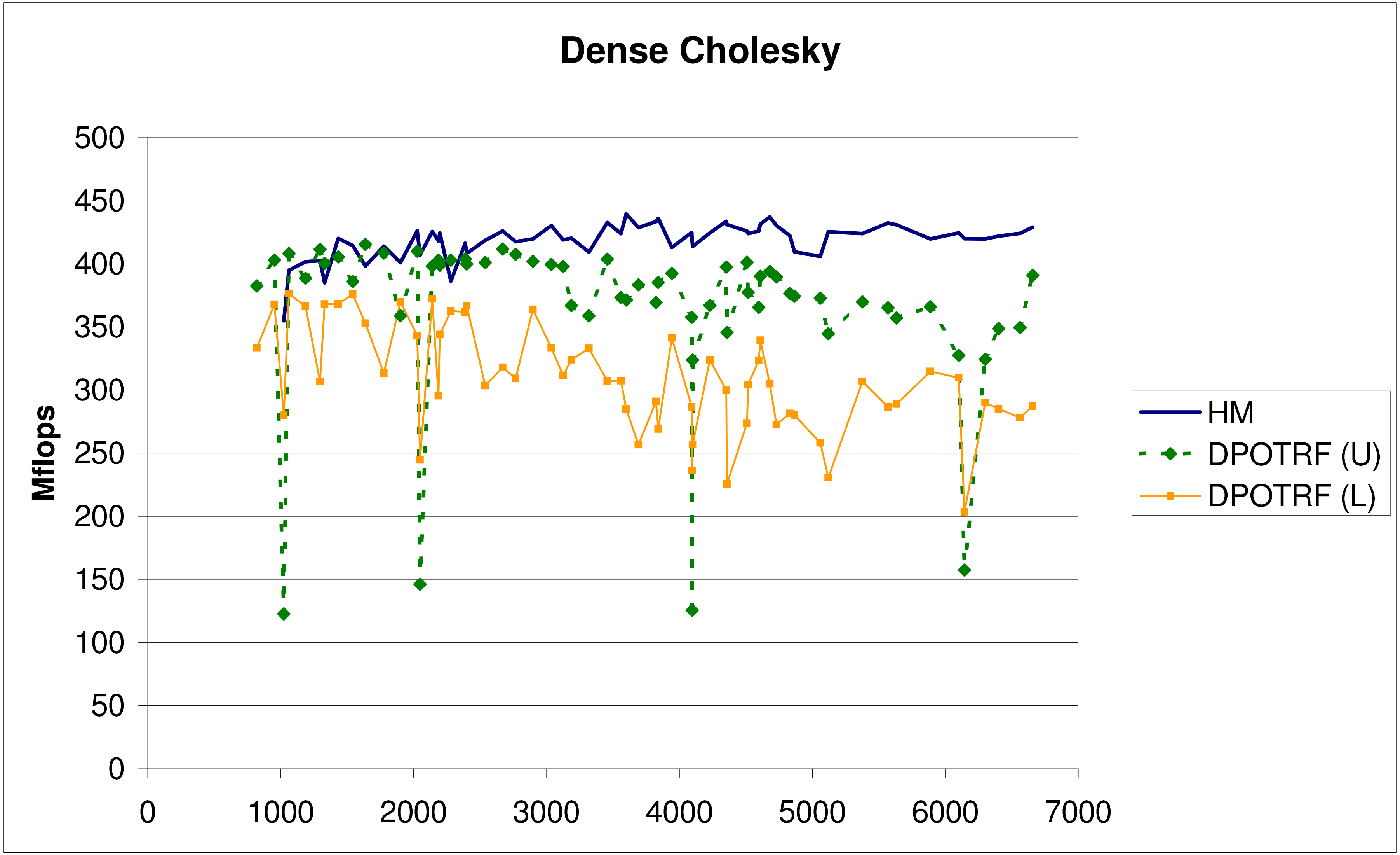
Performance of several sparse Cholesky factorization codes.



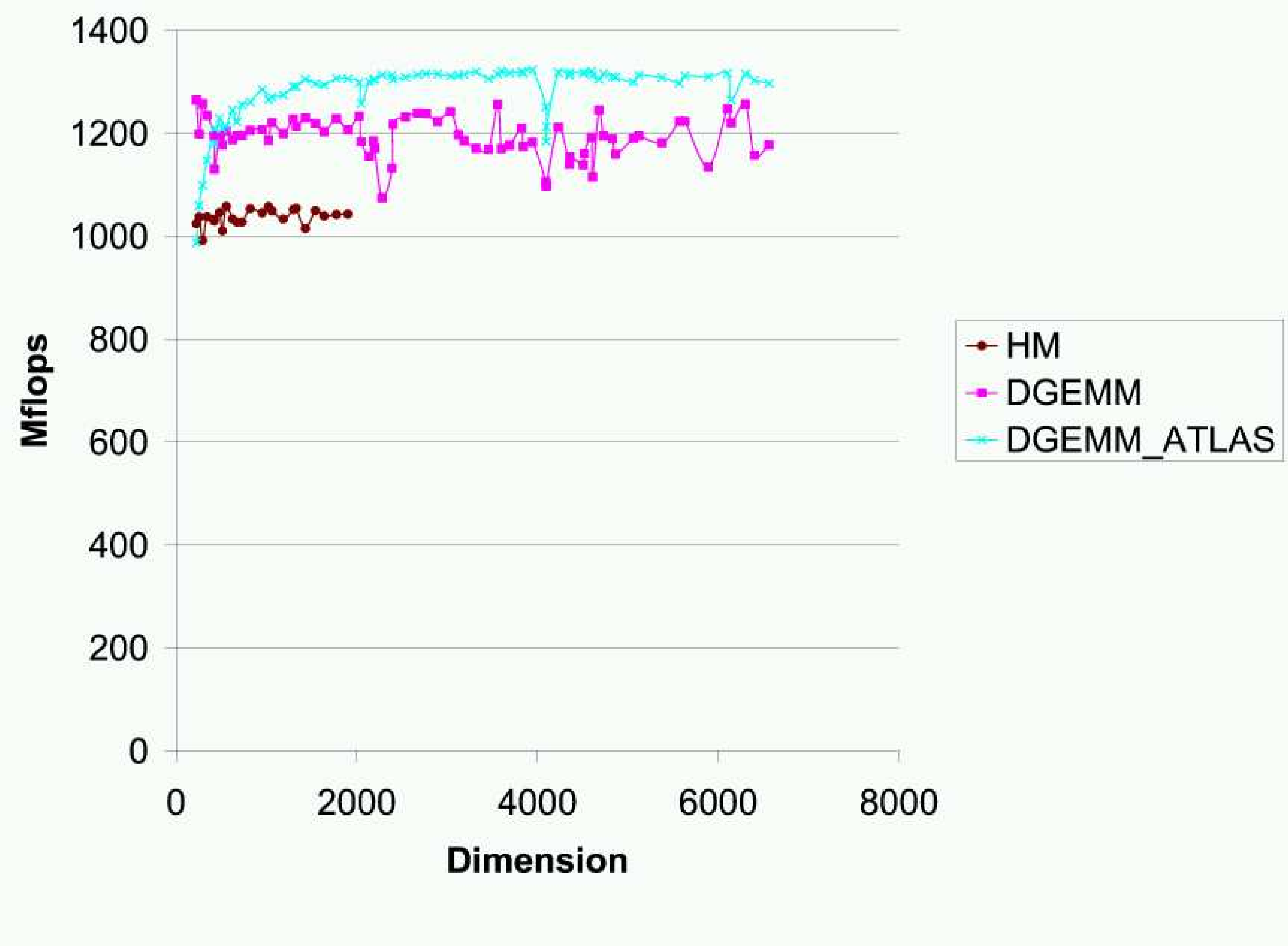
R10000: Dense Matrix Multiplication



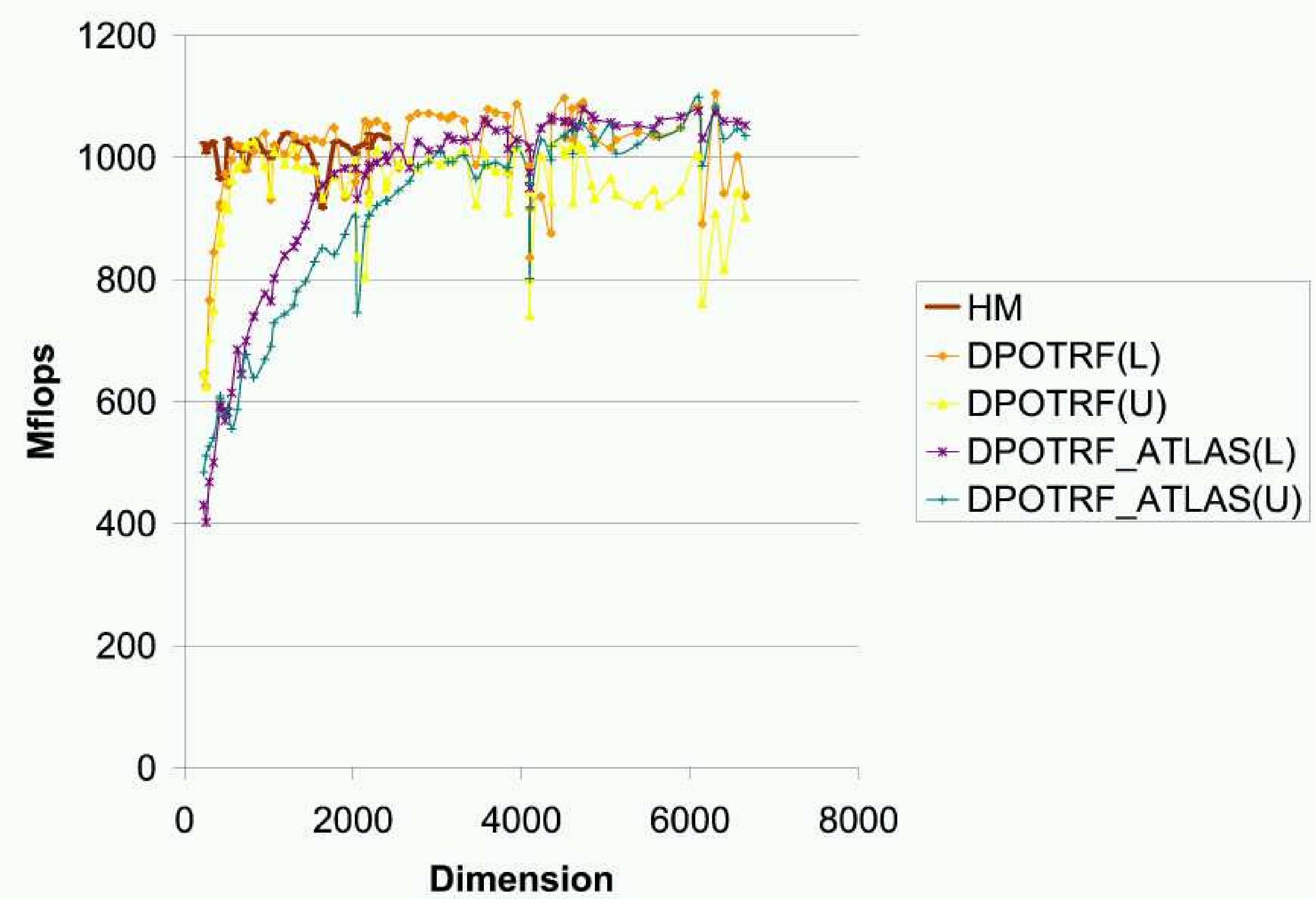
R10000: Dense Cholesky



Alpha 21264: Dense Matrix Multiplication



Alpha 21264: Dense Cholesky



Summary

Techniques which improve performance of Hypermatrix codes:

- Efficient kernels which operate on small data submatrices (ILP)
- Extension for sparse codes
  - Rectangular data submatrices
  - Windows within data submatrices