

ROOT Math Proposal for Linear Algebra

Application Area Meeting

23 November 2005

Introduction

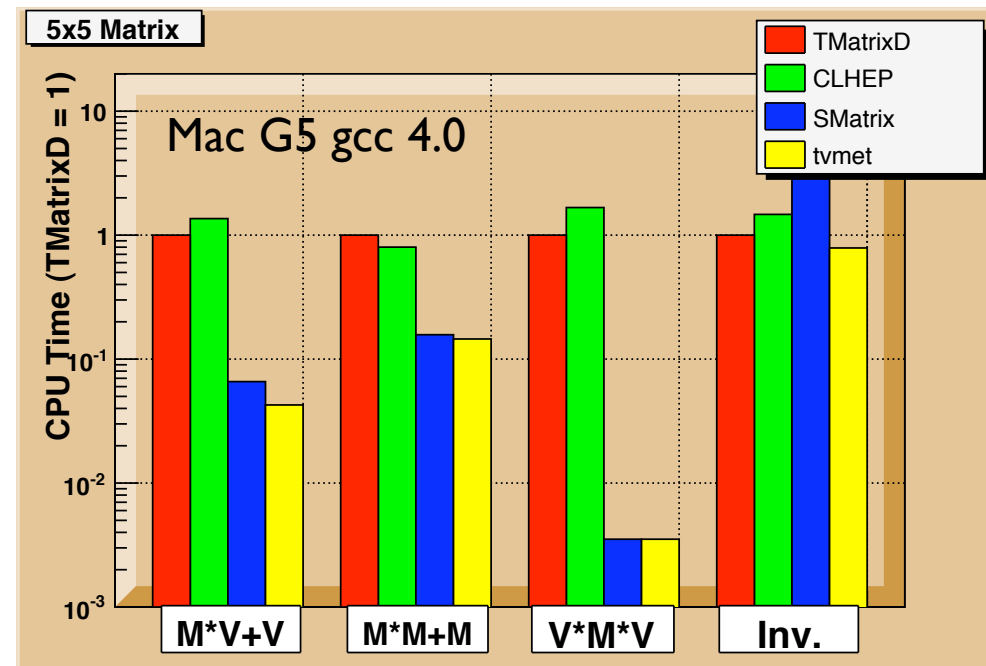
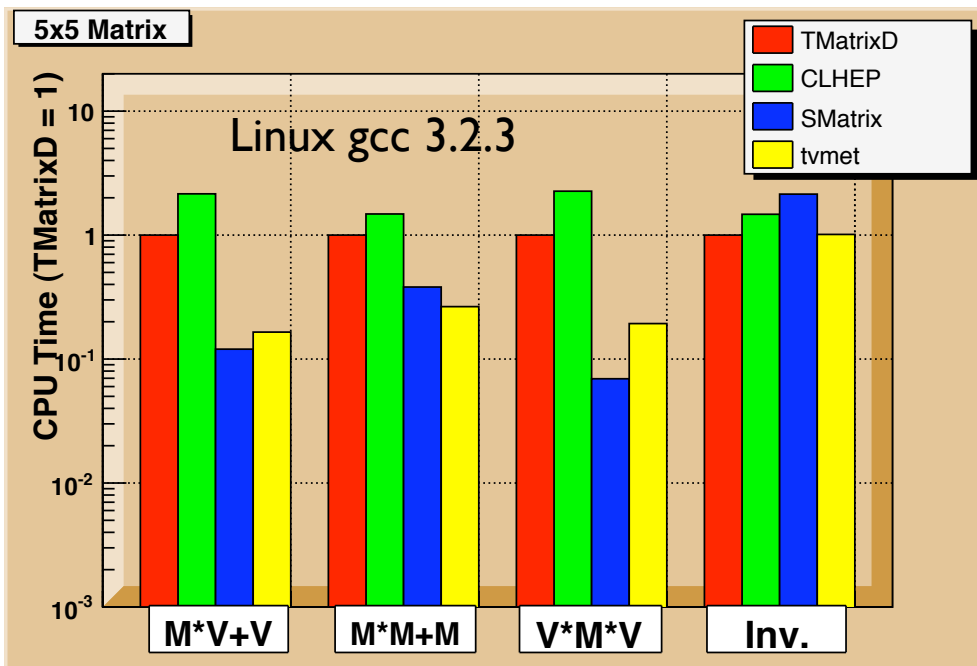
- **Original proposal was to base on the ROOT Linear Algebra package**
 - **TMatrix classes**
- **Problem for some LHC experiments when used in application like reconstruction**
 - **a standalone package is required**
- **Removing TObject inheritance is not so simple**
 - **some users (ALICE) need TObject inheritance**
- **We have performed also detailed evaluation with other existing packages**
 - **test of matrix and vector operations**
 - **Kalman filter test**

Expression template packages

- We have considered two packages based on expression templates and very promising
 - **tvmet** (Tiny Vector and Matrix package)
 - sourceforge package (see <http://tvmet.sourceforge.net/>)
 - **Smatrix**
 - package developed at MPI Heidelberg by T. Glebe for HeraB tracking
- In both the case the concepts are very similar
 - Use expression templates to avoid temporary vectors and build expressions at compile time.
 - Example:
$$D = A*B + C$$
 - all operation are performed in a single loop with minimal overhead and no temporaries (like in Fortran or C)

Performance Tests

- Tests performed (using -O2 optimization)
 - Matrix-Vector (M^*V+V) and Matrix-Matrix (M^*M+M) operations
 - inner product $V^t * M * V$
 - matrix inversion
- N.B. For Linux gcc3.2.3 ROOT and CLHEP compiled with -O



SMatrix and tvmet

- **tvmet and SMatrix have similar performances**
- **Both contain only header files (only inline functions)**
- **Both are based on expression templates**
 - **code can be very clumsy and difficult to understand**
- **SMatrix is much simpler than tvmet.**
 - **less code and easier to understand**
 - **tvmet is full of pre-processing MACRO's**
 - **author used a shell script to generate repetitive code**
- **Found problems with tvmet to generate the C++ dictionary**
 - **problem parsing the header with both CINT and gccXML**
- **SMatrix compiles on the major platforms**

SMatrix package

- **SMatrix has been designed for track and vertex fits.**
 - contains inversion, but based on CERNLIB *DINV* function (not very fast)
 - we can add the fast Cramer inversion as in CLHEP and in ROOT up to 6x6 matrices
- **SMatrix is not any more mantained.**
 - The author, T. Glebe (MPI Heidelberg), has another job
 - he has no problem that we use the package, provided we recognize his contribution as original author
- **Package is rather well documented**
 - original doc available at

<http://www-hera-b.desy.de/subgroup/software/clue/BEE-1-5/smatrix/SMatrix.2.html>

Matrix Proposal

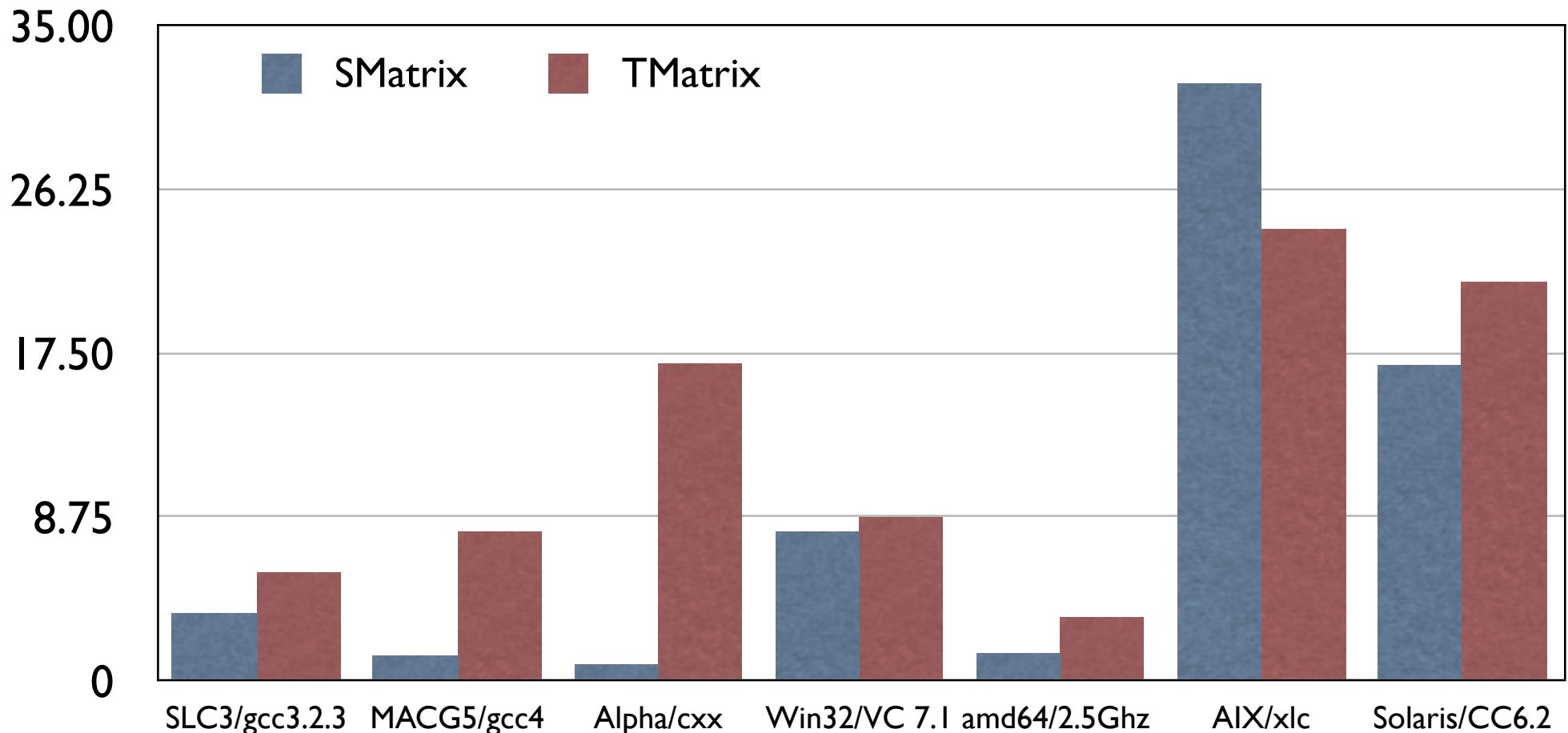
- **Include the SMatrix package in ROOT**
 - an optimized package for small matrices
 - works only when size is known at compile time
 - good for tracking in event reconstruction
- **bring the SMatrix classes in the namespace *ROOT::Math***
 - removing the header files not needed (like SVertex)
- **have in ROOT CVS a sub-directory *smatrix***
 - generate only a library with the dictionary
 - only for some known the matrix size (like 5x5)
- **almost done, works on the various platforms**
 - should be finished for December ROOT release
- **see onlide doc at :** <http://lcgapp.cern.ch/project/cls/MathLibs/SMatrix/html/>

SMatrix interface

- **Matrix and Vector classes templated on the scalar type and size (ncols and nrows)**
 - `SMatrix< double, 2 , 5>`
 - `SVector< double, 5 >`
- **internal data are is a C array**
 - `double array[NCOLS*NROWS] ;`
 - I/O is straightforward since size is known at compile time
- **have all arithmetic operators**
 - with matrices, vector and expression (result of any other operations)
- **some optimized functions like *dot* (vector x vector)**
- ***invert()* and *sinvert()* (for symmetric matrices)**
- ***det()* for determinant of square matrices**
- **more info at [Matrix reference doc](#)**

Kalman Filter test

- test matrix operations like in Kalman filter
 - multiplications, product and inversions of 5x5, 5x2 and 2x2 matrices
 - used within ROOT (Linux compiled with -O)



Future Work

- **have an STL iterator interface (begin(), end())**
 - will make it work nicely with the LorentzVectors
- **add optimized matrix inversion up to 6x6**
- **add compatibility with Physics-Geometry Vectors**
 - some functions in ROOT::Math to multiply SMatrix and SVectors with 3D and 4D Vectors
 - requested by LHCb
- **add compatibility with existing ROOT Matrix package**
 - easy constructs and conversions from one to the other
- **customized streamer for the symmetric matrices**
 - for matrix operations is normally faster storing in memory the full matrix