MAUS OPTICS CLEAN UP

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GOAL

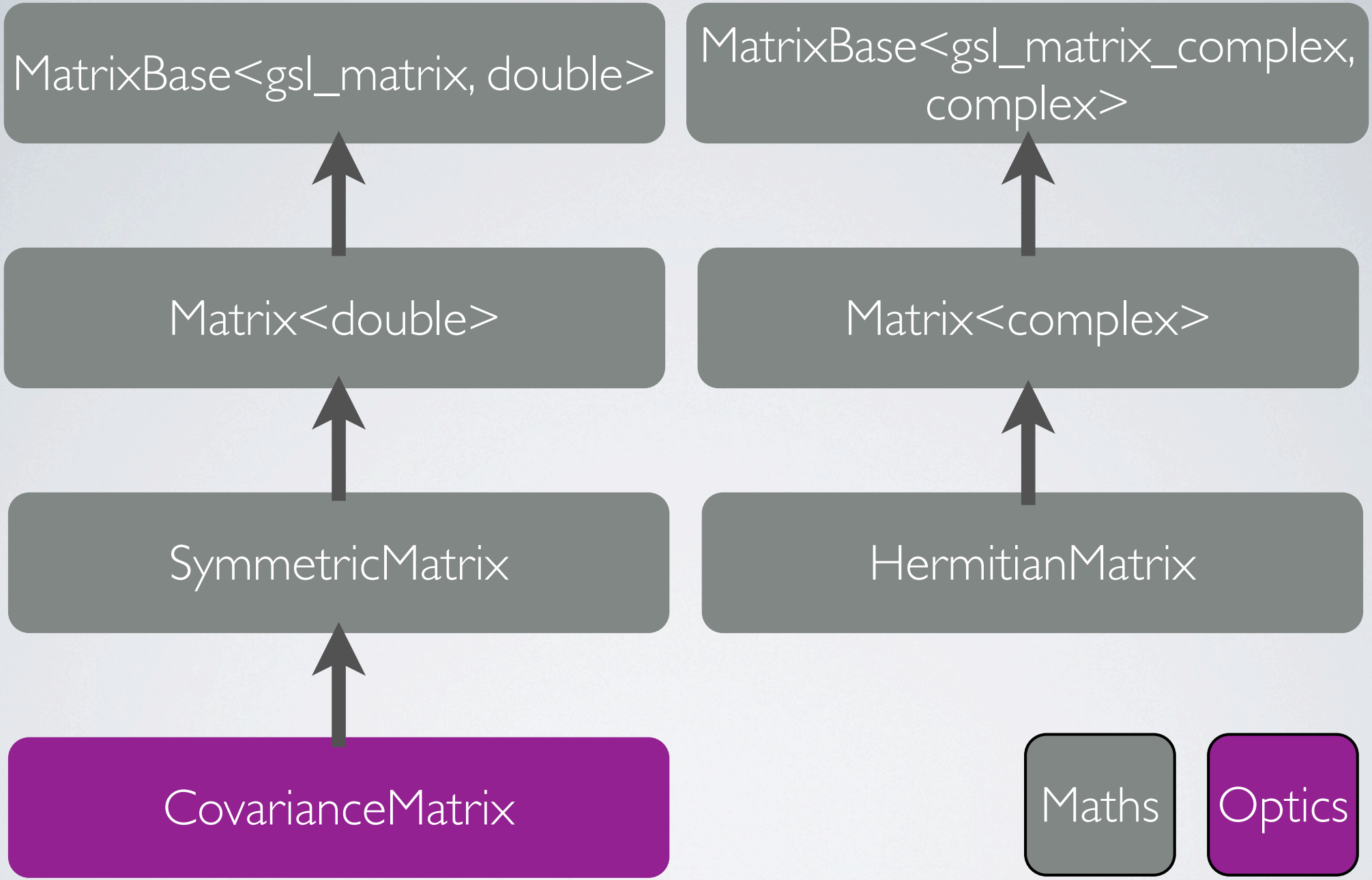
- Revive and improve G4MICE optics code
  - Put everything in the MAUS namespace
  - Bring code into compliance with the style guide
  - Create unit tests with > 80% line coverage
- Cleaned up some underlying math classes first
  - Solid foundation for higher level classes

COMPLEX NUMBERS

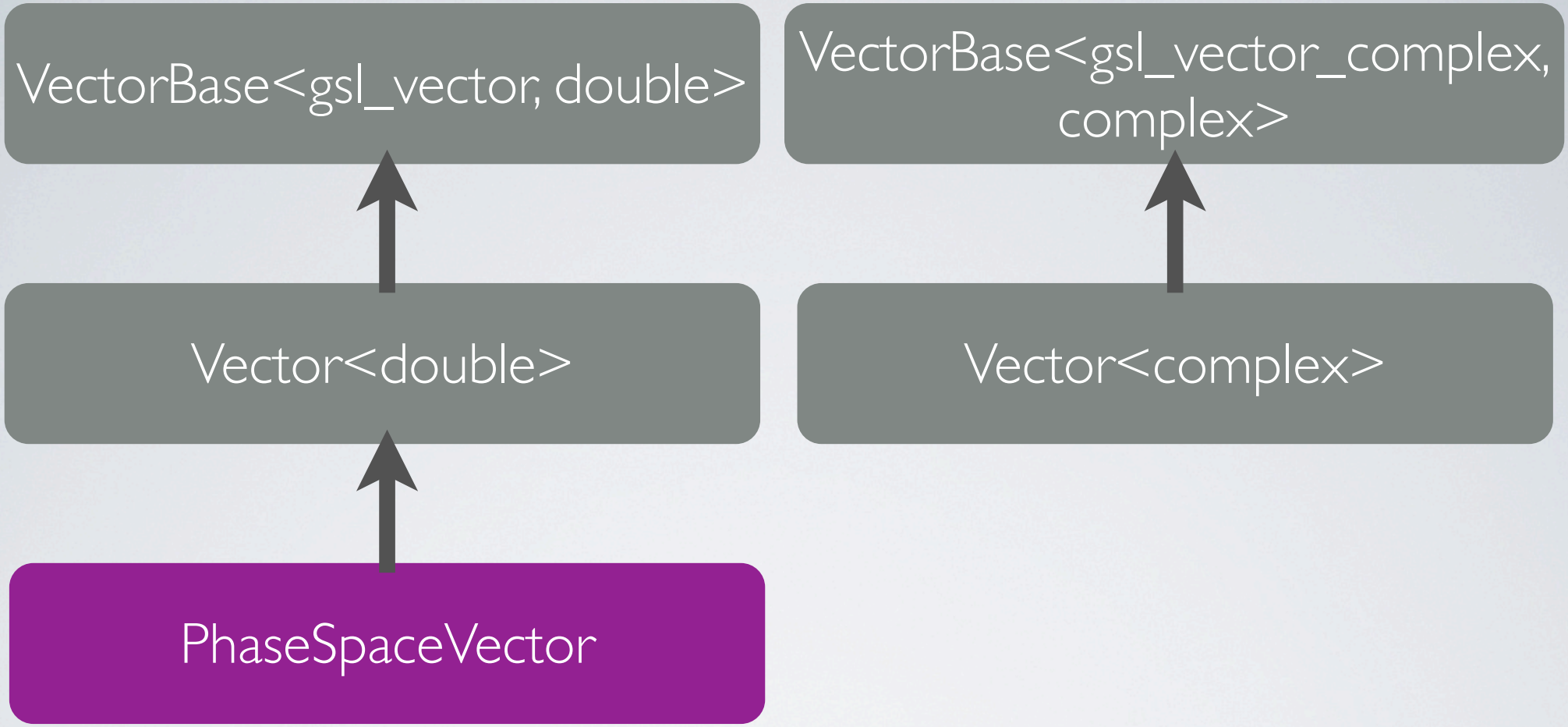
- Separated from old vector class source
- typedef "wrapper" around gsl_complex
  - MAUS::complex
- did not use a class wrapper to avoid having to translate in implementation of complex matrix and vector classes which use gsl underneath.
- math operators and functions

MATRICES AND VECTORS

- Wrap GSL libraries
- Move away from CLHEP classes
  - GSL libraries have eigensystem functions. CLHEP does not.
  - Retained symmetric matrix features
- Pulled out particle and bunch specific stuff from PhaseSpaceVector and CovarianceMatrix



MATRIX CLASSES



Maths

Optics

VECTOR CLASSES

POLYNOMIAL MAPPING

- MAUS::PolynomialVector
- Multivariate polynomial fit of an N-D transformation
- N polynomials of desired order yields an NxM coefficient matrix P
- N-D vectors of polynomial variables mapped into M-D vectors of unique polynomial variable products.
- Transform N-D vectors using coefficient matrix.

POLYNOMIAL MAPPING EXAMPLE

- Want transform of 2-D vector x: $\begin{pmatrix} x'_1 \\ x'_2 \end{pmatrix} = \begin{pmatrix} m_{11} & m_{21} \\ m_{21} & m_{22} \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} = f(x_1, x_2)$
- Fit to order 2 is $f(x_1, x_2) \simeq \begin{pmatrix} p_{11} & p_{12}\,x_1 & p_{13}\,x_2 & p_{14}\,x_1^2 & p_{15}\,x_1\,x_2 & p_{16}\,x_2^2 \\ p_{21} & p_{22}\,x_1 & p_{23}\,x_2 & p_{24}\,x_1^2 & p_{25}\,x_1\,x_2 & p_{26}\,x_2^2 \end{pmatrix}$
- Transformation becomes

$$\begin{pmatrix} x'_1 \\ x'_2 \end{pmatrix} = \begin{pmatrix} p_{11} & p_{22} & p_{13} & p_{14} & p_{15} & p_{16} \\ p_{21} & p_{22} & p_{23} & p_{24} & p_{25} & p_{26} \end{pmatrix} \begin{pmatrix} 1 \\ x_1 \\ x_2 \\ x_1^2 \\ x_1\,x_2 \\ x_2^2 \end{pmatrix}$$

POLYNOMIAL TRANSFER MAP

- MAUS::TransferMap
- Initialized with a PolynomialVector (N=6) to use as the map
- Operates on a PhaseSpaceVector {t, E, x, Px, y, Py} to transport phase space coordinates through the lattice.
- Using only the first-order sub-matrix of coefficients we can also transport beam envelopes (CovarianceMatrix)

$$\bullet \begin{pmatrix} \langle t^2 \rangle & \langle tE \rangle & \dots & \langle t\,Py \rangle \\ \langle E\,t \rangle & \square & \square & \square \\ \dots & \square & \square & \square \\ \langle Py\,t \rangle & \langle Py\,E \rangle & \dots & \langle Py^2 \rangle \end{pmatrix}' = \begin{pmatrix} p_{12} & p_{13} & p_{14} & p_{15} & p_{16} & p_{17} \\ p_{22} & p_{23} & p_{24} & p_{25} & p_{26} & p_{27} \\ p_{32} & p_{33} & p_{34} & p_{35} & p_{36} & p_{37} \\ p_{42} & p_{43} & p_{44} & p_{45} & p_{46} & p_{47} \\ p_{52} & p_{53} & p_{54} & p_{55} & p_{56} & p_{57} \\ p_{62} & p_{63} & p_{64} & p_{65} & p_{66} & p_{67} \end{pmatrix} \begin{pmatrix} \langle t^2 \rangle & \langle tE \rangle & \dots & \langle t\,Py \rangle \\ \langle E\,t \rangle & \square & \square & \square \\ \dots & \square & \square & \square \\ \langle Py\,t \rangle & \langle Py\,E \rangle & \dots & \langle Py^2 \rangle \end{pmatrix} \begin{pmatrix} p_{12} & p_{13} & p_{14} & p_{15} & p_{16} & p_{17} \\ p_{22} & p_{23} & p_{24} & p_{25} & p_{26} & p_{27} \\ p_{32} & p_{33} & p_{34} & p_{35} & p_{36} & p_{37} \\ p_{42} & p_{43} & p_{44} & p_{45} & p_{46} & p_{47} \\ p_{52} & p_{53} & p_{54} & p_{55} & p_{56} & p_{57} \\ p_{62} & p_{63} & p_{64} & p_{65} & p_{66} & p_{67} \end{pmatrix}^T$$

FUTURE WORK

- Finish up the unit test improvements and merge to trunk
- Global track reconstruction
  - Use optics code to fit coefficient matrix to particle data
  - Transport beams through the lattice to construct tracks
- Control room tool to provide realtime beam optics info
  - emittance, Twiss parameters, envelopes, energy loss, ...