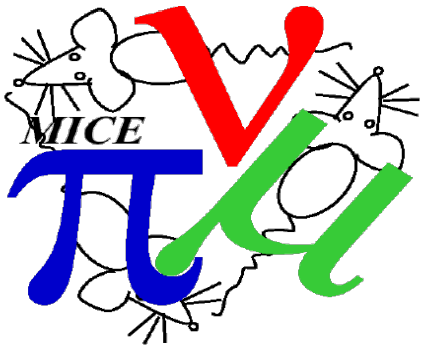
Accelerator Physics Tools

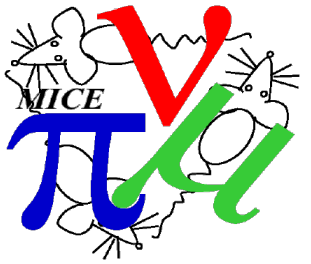


Chris Rogers
Software Parallel, CM20
10 February 2008

Rationale

- Extra functionality in G4MICE Simulation
  - “Unforeseen” requirements in MICE running
    - Beamline simulation
    - Non-cylindrical solenoid fields (iron in floor)
  - Generic accelerator simulation/MICE step VII
  - Optimisation and robustness
- Preparing for MICE online high-level analysis needs
  - Not clearly defined
  - Constructing generic accelerator graphing/optimisation type routines
- Any more needs for online/offline analysis?

Accelerator Physics Tools

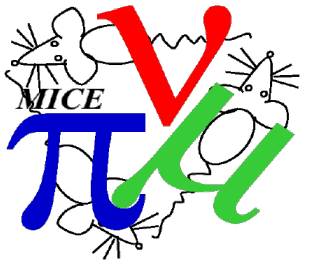


- Documentation
- Testing
- Simulation
  - Multipole fields
  - Multipole apertures
  - Field map/solenoid upgrade (WIP)
  - Beamline implementation
  - Arbitrary positioned beam
- Analysis
  - On-line analysis graphical interface
  - Finalise off-line analysis

Documentation

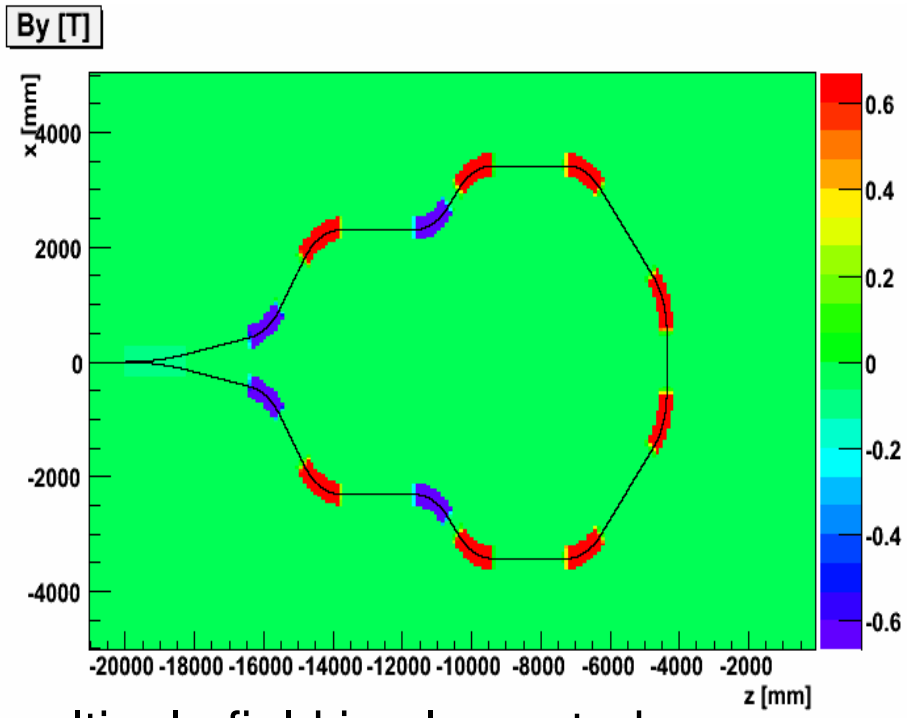
- Mice Module documentation is in a good state
  - Handles engineering model, field model definitions
  - Missing documentation on detectors
  - $MICESRC/doc/Mice_Module.pdf
  - Not linked to software page :(
- Datacards documentation is poor
  - There was a system in place that was rarely updated, but at least it worked
  - This was removed but no new system was put in place
  - It is now no longer possible AFAIK to edit datacard documentation!
- Some Analysis documentation
  - Analysis executable documentation is quite complete and up to date
  - GUI documentation is non-existent... but mostly self-documenting

Testing



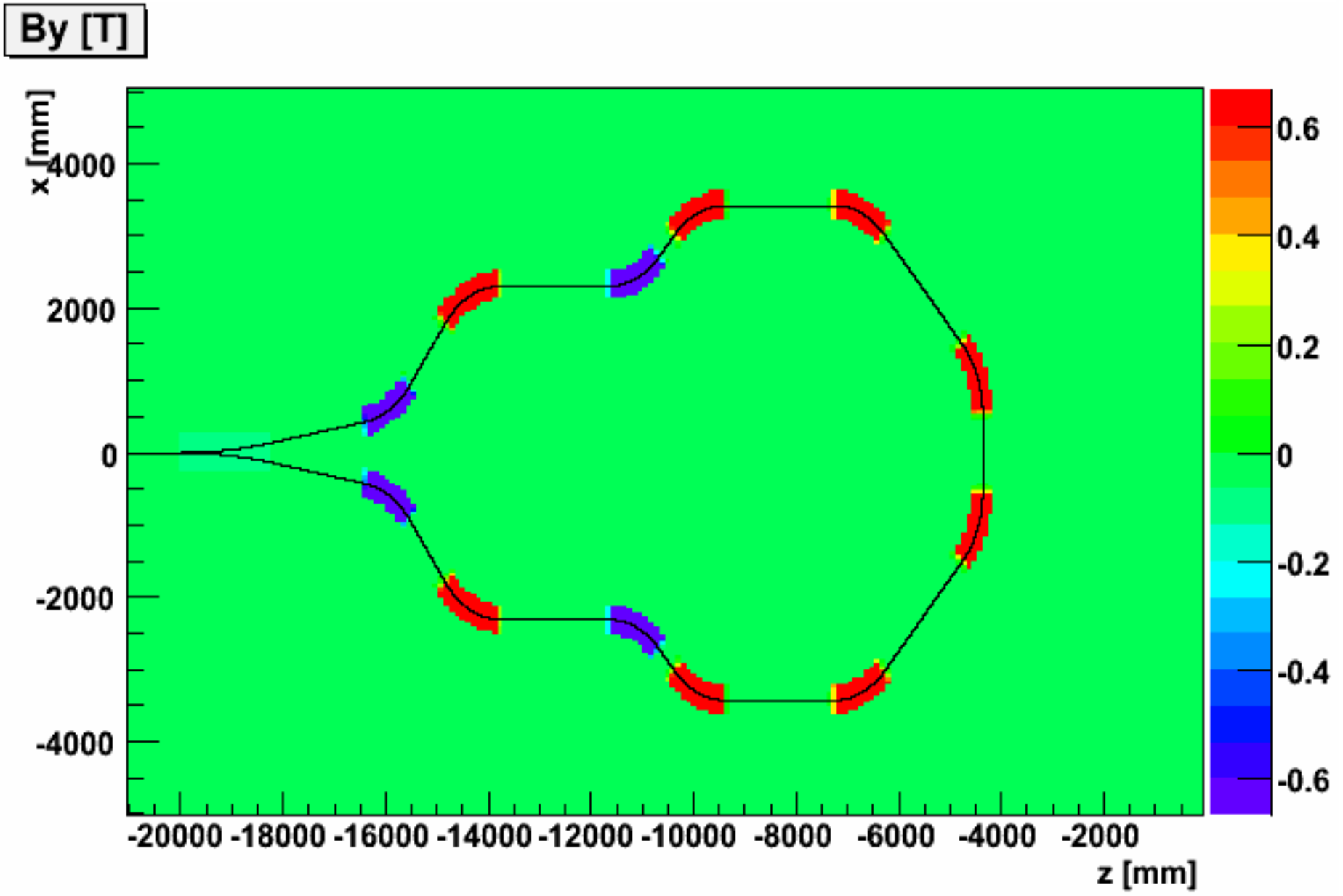
- Analysis testing is out of date
  - Needs to be replaced
  - How to test GUI?
- Fields testing is reasonable
  - Some tests, mostly not committed
  - Means testing is not systematic or automated
- How to test engineering model?
  - Manual visualisation

Multipole Field



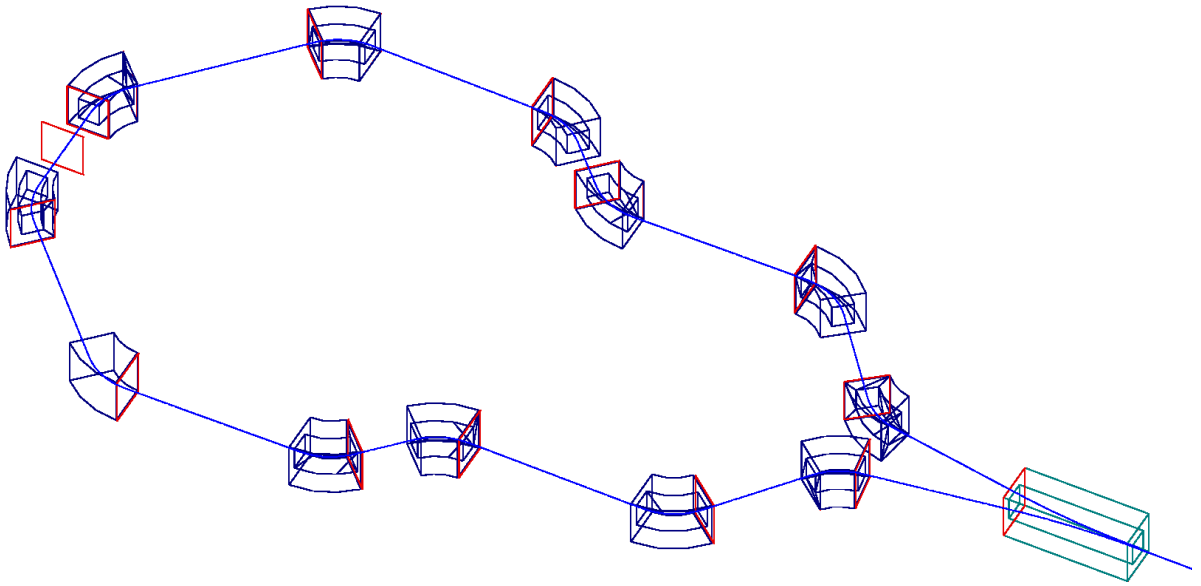
- Abitrary order multipole field implemented
  - Fields can be straight, fixed radius of curvature or momentum-based radius of curvature
    - For momentum-based radius of curvature track a test particle through
    - Store the integrated dB as an array
    - Use this to calculate geometry/fields appropriately
  - End fields can be hard edged or enge + various geometries
    - End field implemented to order N+2 (can go higher if needed)

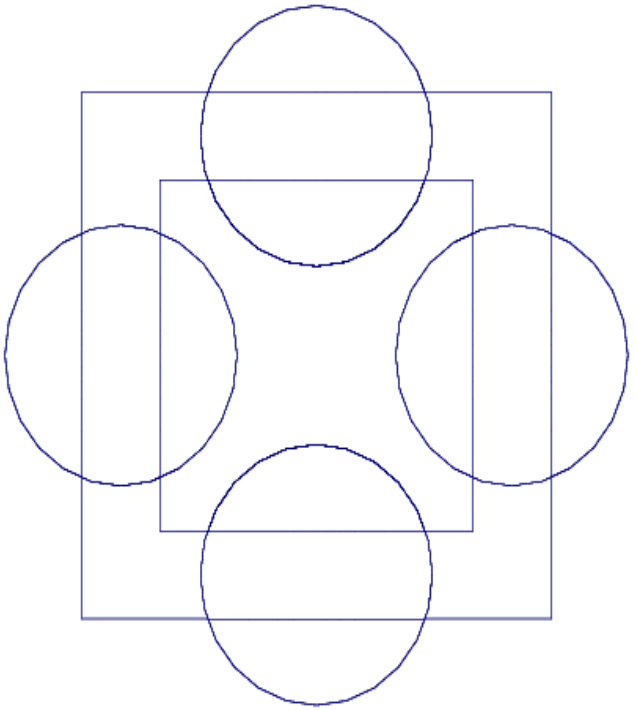
Multipole Field



Multipole Aperture

- Multipole Aperture model implemented
  - Fixed radius of curvature or straight container
  - Arbitrary number of poles for straight multipoles
    - Code is ready for curved poles but bug in G4Torus blocking
    - Fixed in G4.9.1 and I have a patch locally (untested)



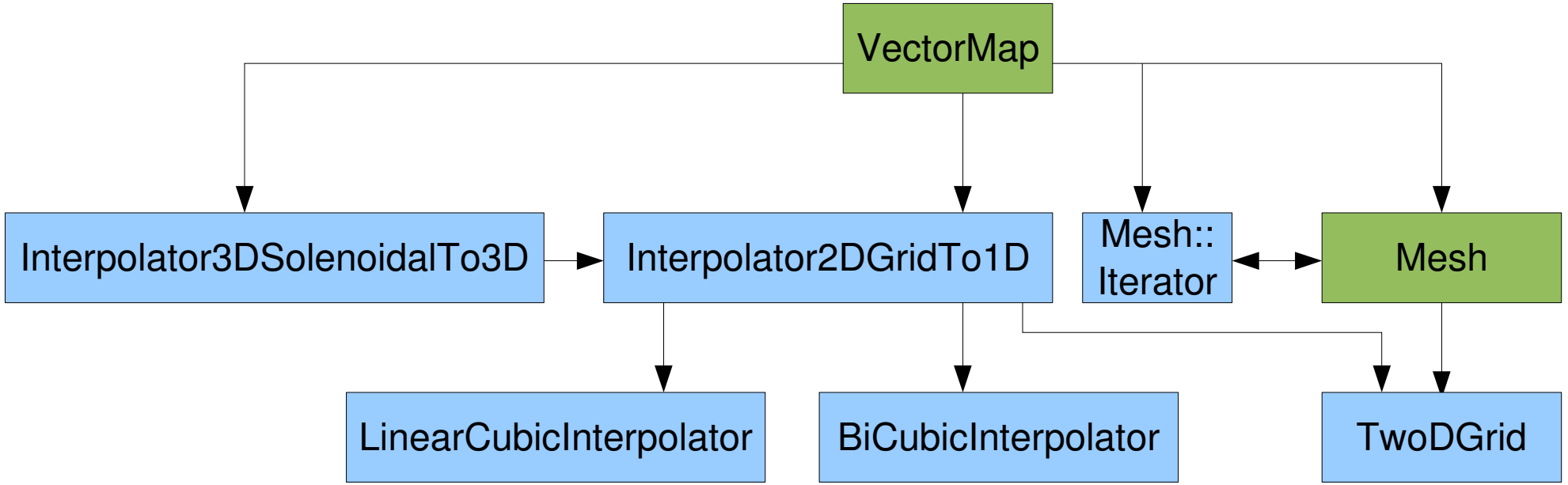


Field Map Upgrade

- Several requirements for field map upgrades
  - Beamline quadrupole/dipole fields
  - Speed optimisation in solenoids
  - Speed optimisation in RF field map
  - Non-cylindrical symmetry in solenoids
- Developed versatile, fast routines for Meshing and Interpolation
  - Abstract VectorMap class maps n-dimensional vector (position) to m-dimensional vector (field)
    - e.g. solenoid interpolation maps (r,z) to (Br, Bz)
    - Possible to go to 3D vectors/etc easily
    - Allows sharing of interpolation routines between different map types
  - Abstract Mesh class holds information about mesh of positions
    - e.g. 2D grid holds rectilinear grid of (r,z) positions
    - Possible to go to dynamic spacing/non-rectangular mesh easily
    - Allows sharing of different meshes between different map types

Field Map Upgrade

- Mesh::Iterator allows to scan across the mesh and extract field values from the VectorMap without knowing details of Mesh or VectorMap
  - Allows generic set of Read/Write type routines
- Now implementing existing field maps in this framework

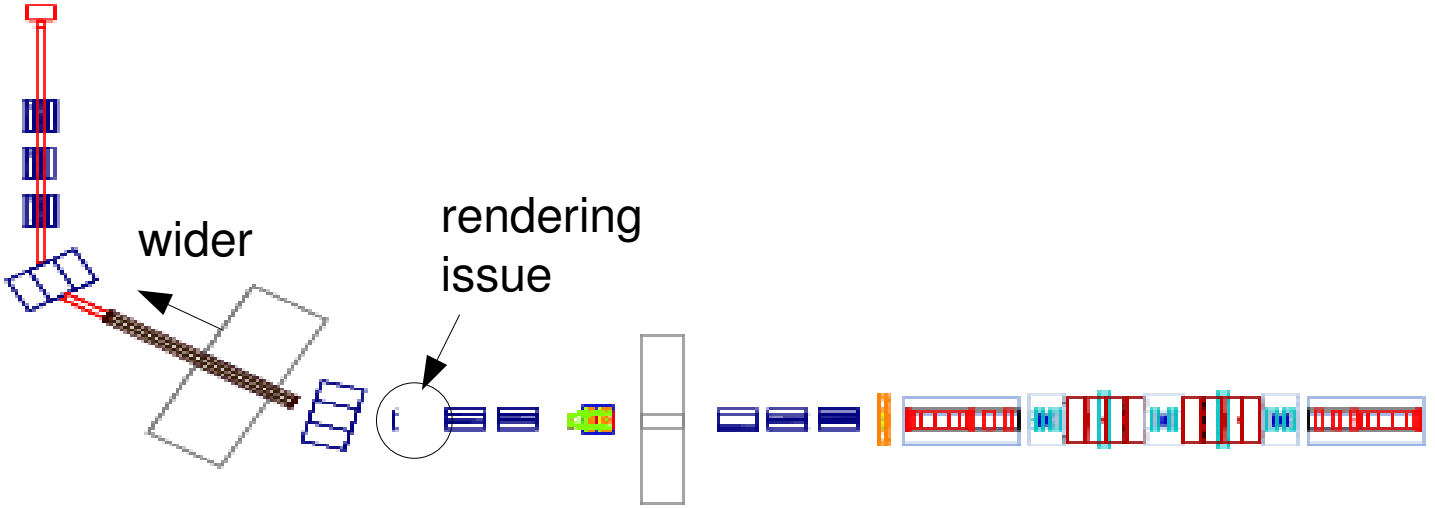


Tracking Profiling

- Tracked a number of particles through a simple solenoidal lattice
  - Looked at the amount of time spent in each function (gprof) not including child function calls
  - Nb solenoids were all rotated relative to origin
  - Nb no materials, detectors etc and most functions were not monitored

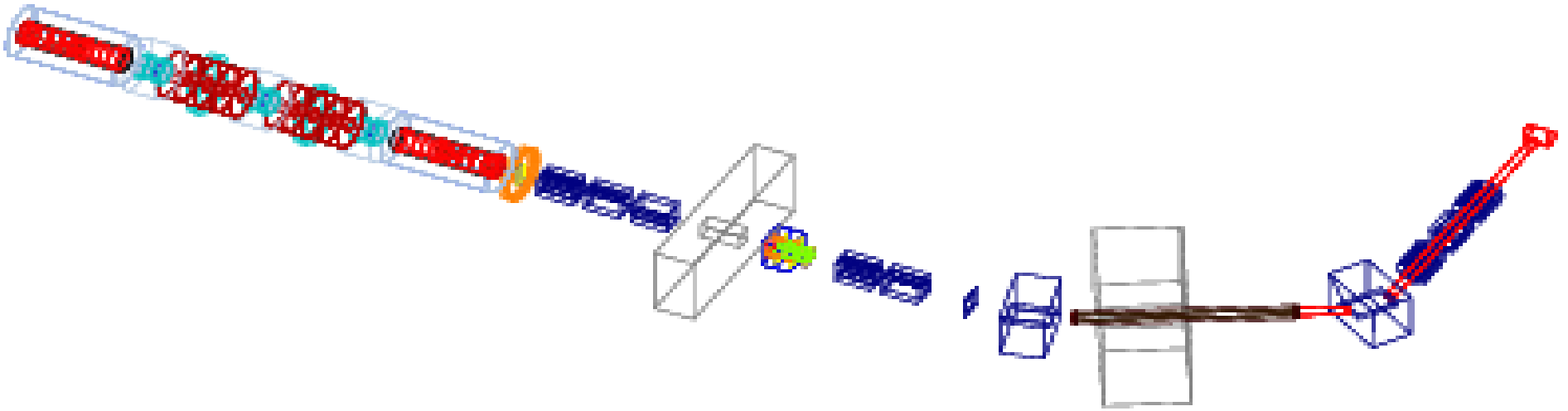
Function Call	**% time**	
Spline1D::operator()	19.42	Interpolation
HepRotation::operator*(CLHEP::Hep3Vector const&)	9.61	Rotation
SplineInterpolator::GetFieldValue	6.12	Bound checking/Interpolation
BTFieldGroup::GetFieldValue	5.76	Translation/Rotation
BTFieldGroup::GetLocalCoordinates	4.46	Translation/Rotation
Hep3Vector::y()	3.49	Translation/Rotation
Spline1D::computeSecondDerivs()	3.45	Interpolation
Spline1D::Spline1D	3.16	Interpolation
std::vector<CLHEP::Hep3Vector>	2.19	Translation/Rotation
etc	etc	etc

Beamline Geometry



- Full beamline geometry implemented in G4MICE
  - Handles beamline all the way from target to MICE
  - Geometry based on slightly older input file
  - I will update/get worried about details based on survey results (what's actually built!)
  - I show stage 6 but geometry is in place for stage 1-6

Beamline Geometry

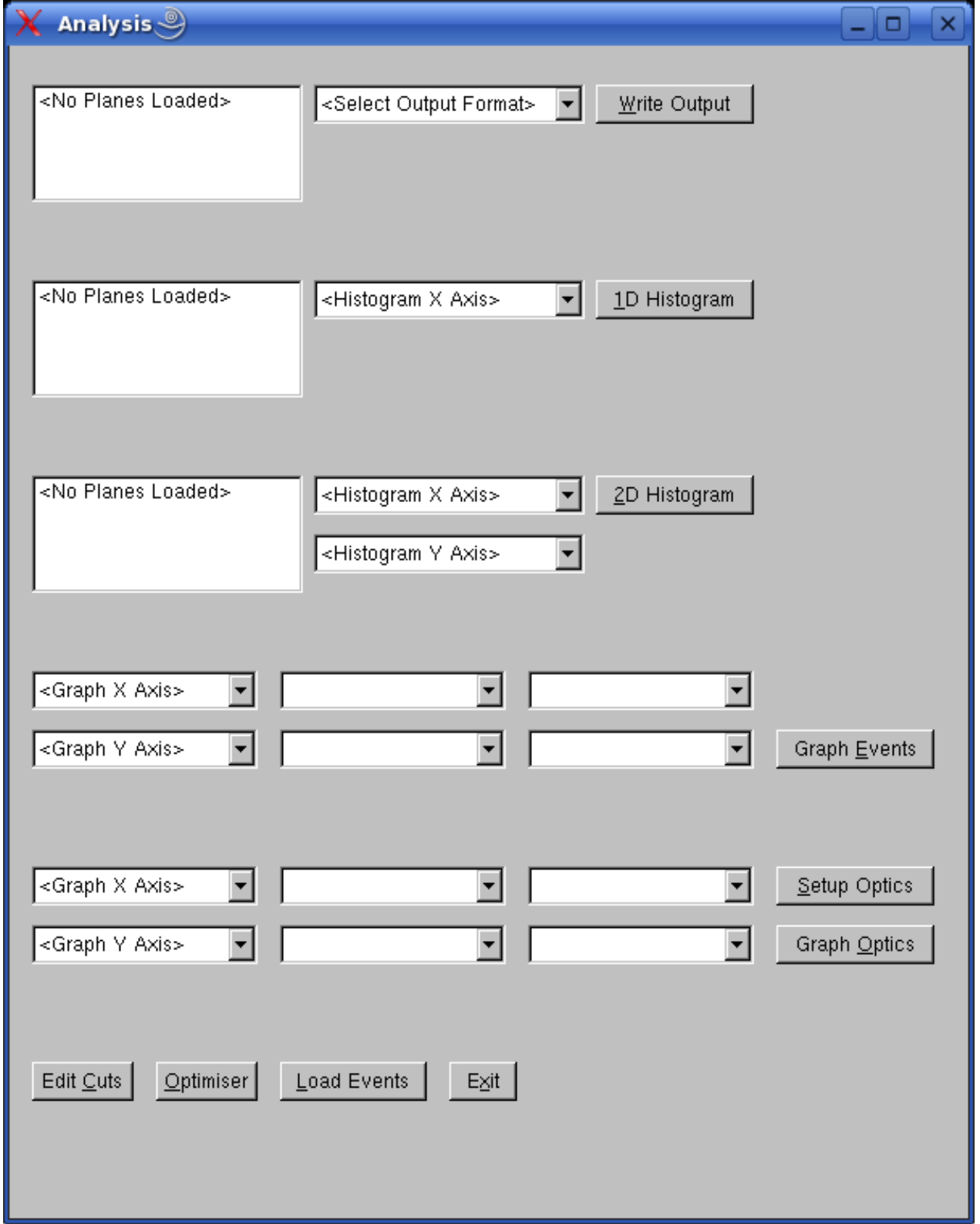


Analysis/Optics

- Analysis needs are ill-defined
  - Need some sort of high-level online analysis
  - Need some sort of high-level offline analysis
- G4MICE provides a number of useful accelerator physics routines
  - I hope that these will be sufficient for online analysis
    - Analysis GUI has
  - Integrated fully with G4MICE
    - But also interface with icool and g4bl in a straightforward manner

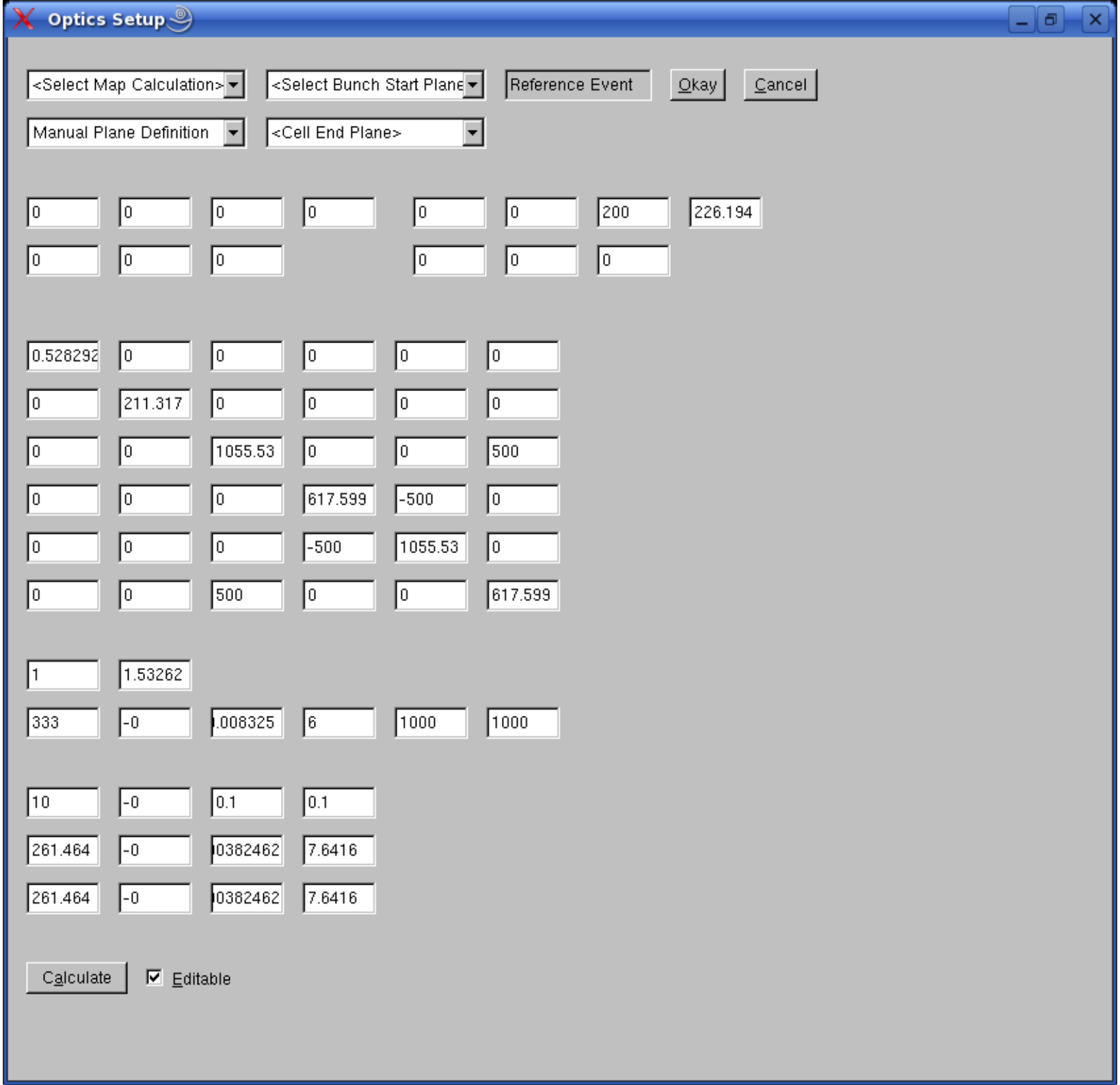
Analysis

- Analysis window has methods to
  - Read G4MICE, G4BL, Turtle, ICOOL files
  - Draw 2d graphs of quantities of interest (beta vs z etc)
    - Draw beam parameters, covariances, correlations, means etc on either axis
  - Draw 1d and 2d histograms of quantities of interest (x vs px)
    - Draw positions, momenta, amplitudes etc on either axis
  - Write G4MICE, ICOOL, G4Beamline files

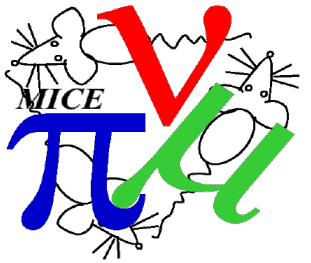

Analysis
<No Planes Loaded>
<Select Output Format>
Write Output
<No Planes Loaded>
<Histogram X Axis>
1D Histogram
<No Planes Loaded>
<Histogram X Axis>
2D Histogram
<Histogram Y Axis>
<Graph X Axis>
<Graph Y Axis>
Graph Events
<Graph X Axis>
<Graph Y Axis>
Setup Optics
Graph Optics
Edit Cuts
Optimiser
Load Events
Exit

Optics

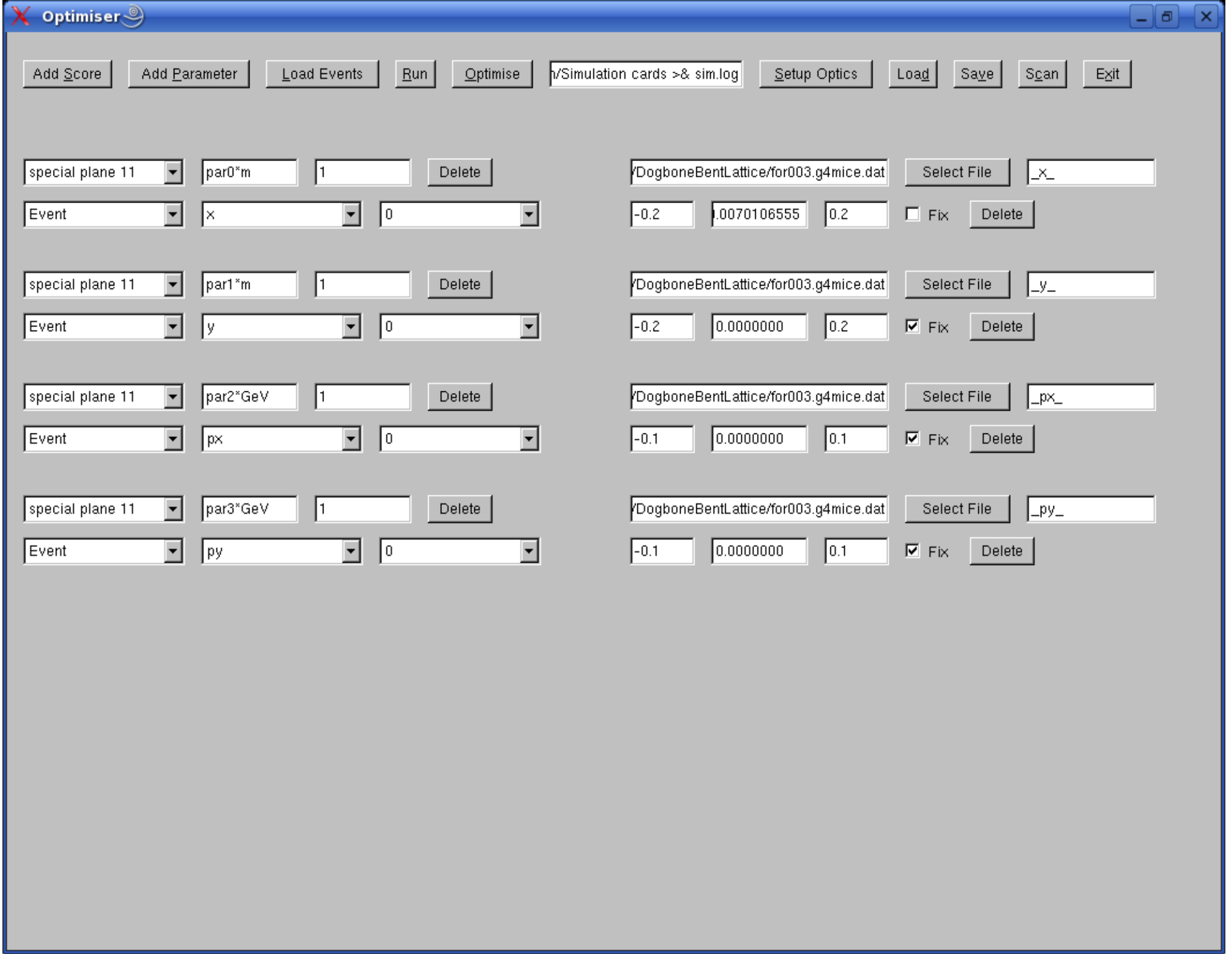
- Optics window has options to set up optics calculation
- Transfer maps based on tracking in your favourite tracking code
  - G4MICE, G4BL, ICOOL supported
  - Need to track ONLY 7 particles to extract dynamic information of the magnetic lattice to some approximation
- Select input covariance matrix either
  - manually
  - from some file input
  - using automatic beam matcher to find a matched solution
- Can then look at evolution of covariance matrix
- Quick!
- Magic!


Optics Setup
<Select Map Calculation>
<Select Bunch Start Plane
Reference Event
Okay
Cancel
Manual Plane Definition
<Cell End Plane>
0 0 0 0 0 0 200 226.194
0 0 0 0 0 0
0.528292 0 0 0 0 0
0 211.317 0 0 0 0
0 0 1055.53 0 0 500
0 0 0 617.599 -500 0
0 0 0 -500 1055.53 0
0 0 500 0 0 617.599
1 1.53262
333 -0 .008325 6 1000 1000
10 -0 0.1 0.1
261.464 -0 0382462 7.6416
261.464 -0 0382462 7.6416
Calculate
Editable

Optimiser/Scanner



- Perform optimisation based on arbitrary parameter set
  - Substitute text parameters into input file
    - e.g. set arbitrary coil currents in some input files by substituting every instance of some key words for the desired coil currents
  - Run some executable e.g. icool, g4mice, g4bl, shell script
  - Seeks to minimise sum of squares of some user-defined variables
    - e.g. seek to minimise sum of (beta_perp-333)^2+(alpha_perp-0)^2
- Some additional features
  - Interfaces with optics routines to make a very fast optimiser
  - Parameter scanning to plot scores vs some set of parameters
  - Functional recognition accepts functions of parameters in other parameters and scores


Optimiser
Add Score
Add Parameter
Load Events
Run
Optimise
h/Simulation cards >& sim.log
Setup Optics
Load
Save
Scan
Exit
special plane 11
par0*m
1
Delete
/DogboneBentLattice/for003.g4mice.dat
Select File
_x_
Event
x
0
-0.2
.0070106555
0.2
Fix
Delete
special plane 11
par1*m
1
Delete
/DogboneBentLattice/for003.g4mice.dat
Select File
_y_
Event
y
0
-0.2
0.0000000
0.2
Fix
Delete
special plane 11
par2*GeV
1
Delete
/DogboneBentLattice/for003.g4mice.dat
Select File
_px_
Event
px
0
-0.1
0.0000000
0.1
Fix
Delete
special plane 11
par3*GeV
1
Delete
/DogboneBentLattice/for003.g4mice.dat
Select File
_py_
Event
py
0
-0.1
0.0000000
0.1
Fix
Delete

Offline Analysis

- We have most things we need for offline analysis
  - I expect some folks will want to use their own algorithms
- Some analysis issues still unclear
  - Conceptual problems with understanding detector calibration/measurement errors
  - How to estimate statistical errors?
  - Reweighting algorithm (CM19) still not implemented in G4MICE
- To be discussed in the analysis session

Conclusions

- Accelerator simulation is in a good state
  - Contingency issues
  - Optimisations
  - Testing
  - Documentation
- Online high-level analysis interface with some useful features
  - It is unclear what we need
  - Developing generic accelerator analysis tools
- Offline high-level analysis is still available
  - Need to understand/finalise
- Analysis testing and documentation needs to be updated