Accelerator Tools - Status

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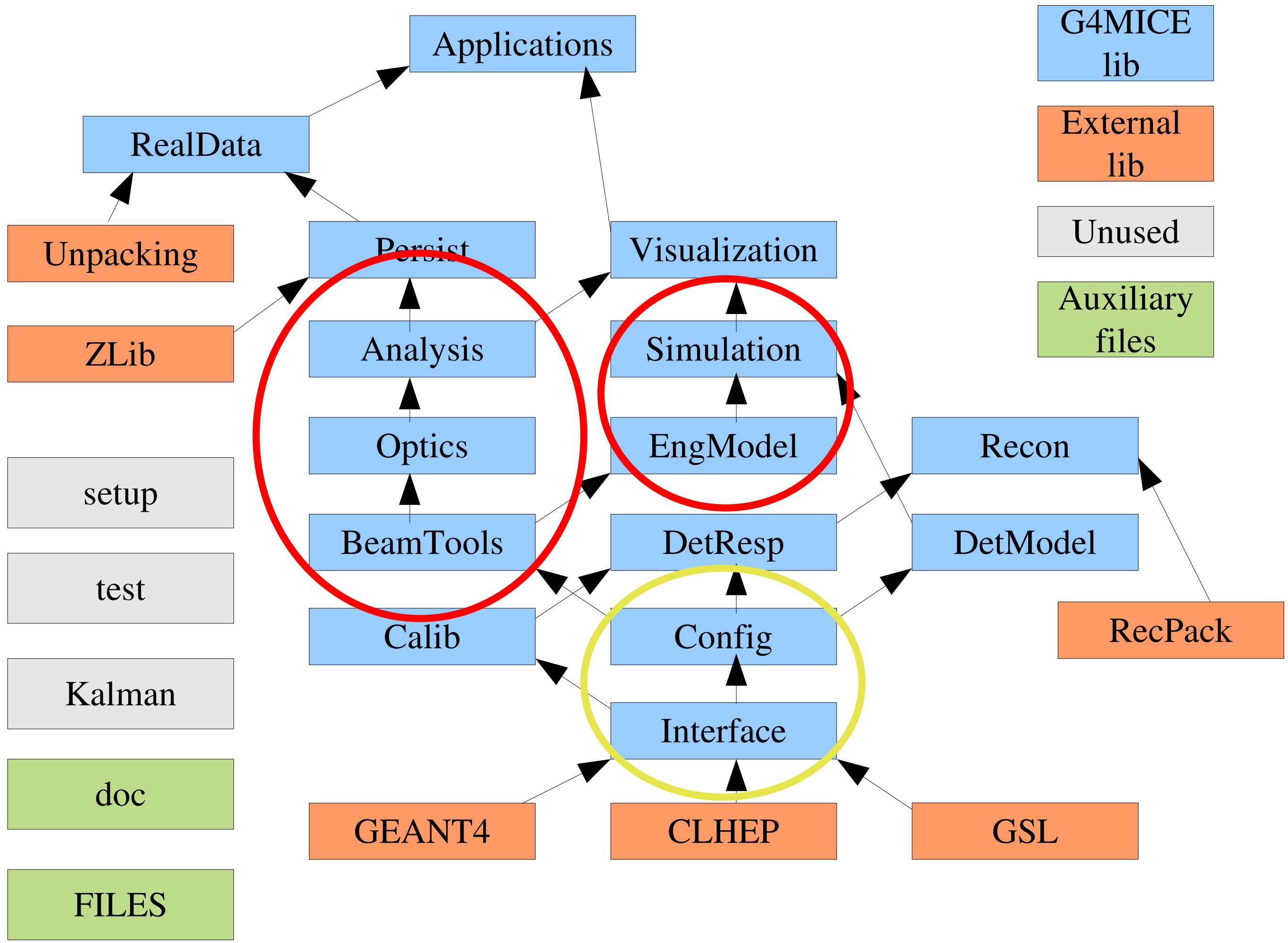
G4MICE Accelerator Physics

- Simulation
  - Renovation of **multipole** field map
  - Implementation of **physics list tests**
- Optics
  - New **PolyFit** algorithm
- Analysis
  - Python tools **XBOA**
- Each topic is probably ~ 1 hour talk


Applications
RealData
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G4MICE

- Simulation
  - Renovation of multipole field map
  - Implementation of physics list tests
- Optics
  - New PolyFit algorithm
- Analysis
  - Python tools

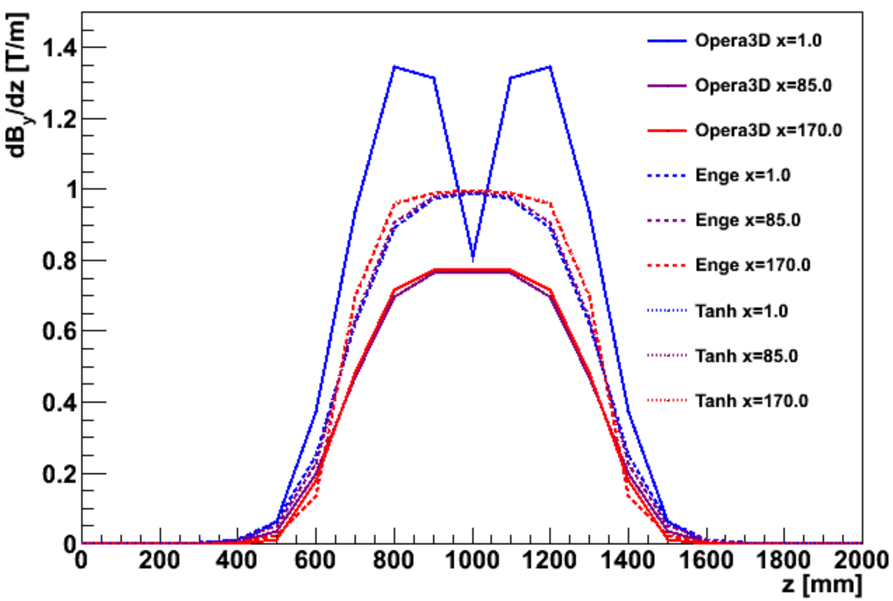
Multipole field map

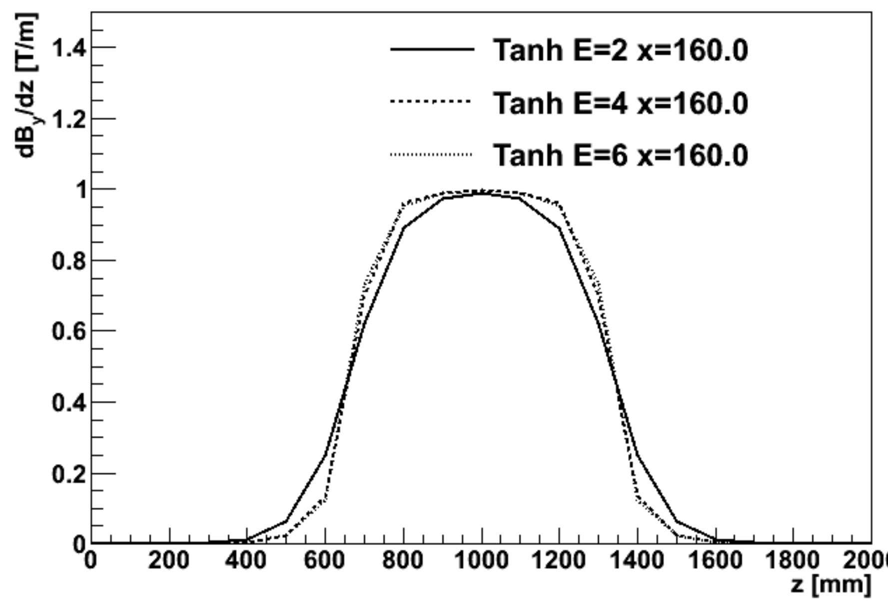
- Issue with QC field map
  - Generated in ancient history by Opera3d
  - Non-physical dipole field was found on axis
- Fall back to analytical model for multipole field
  - Scalar magnetic potential like:

$$V_n = \sum_{q=0}^{q_w} \sum_{m=0}^{n} n!^2 \frac{G^{(2q)}(s)(r^2+y^2)^q \sin\left(\frac{m\pi}{2}\right) r^{n-m} y^m}{4^q q!(n+q)!m!(n-m)!}$$

  - *G(s)* is some function that tells how the field gradient drops along the axis
  - r is horizontal displacement, s is longitudinal displacement, y is vertical displacement, n indexes pole type (dipole, quad, sextupole, ...)
  - Recursion relation from Div **B** = Div (Grad(V))=0 to get magnetic field off axis
    - i.e. apply Maxwell's laws
- Algorithm was unfortunately broken and as I dug, it became clear major refurbishment was necessary

Multipole field map



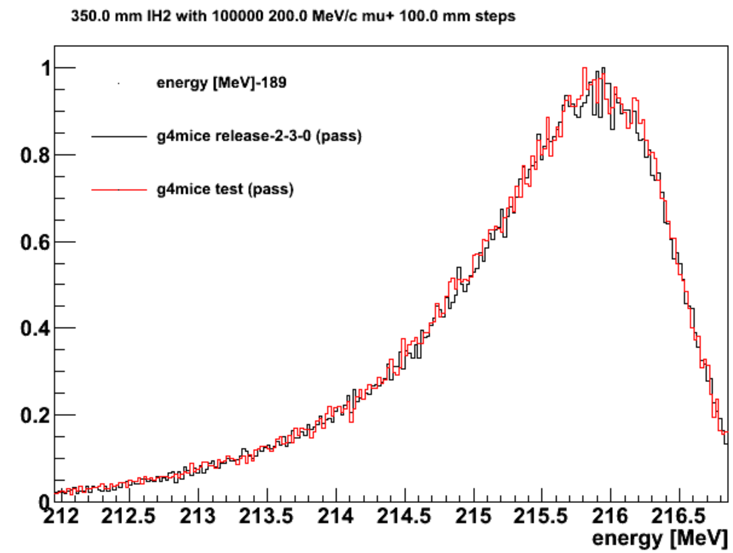


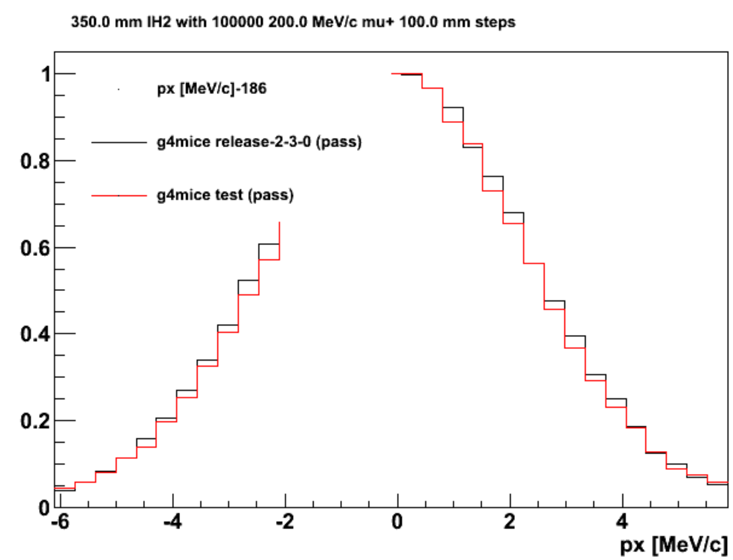
Multipole Model Status

- Implemented
  - Enge model
    - I regard this as too slow - needs some optimisation work
  - Tanh model
    - Acceptable speed
      - 1e3 μ
      - 6 quads
      - 10 m channel
      - 10 mm step size
      - Takes ~30 s on my laptop
    - Further optimisation is possible if it's required
- New code is reasonably well commented
- ~30 Unit tests implemented in gunit test framework
- Application tests in Integration/Simulation/Multipoles
  - Fire neutrons through field map and look at field reported in VirtualPlane output
  - Compare reference output with new output with tolerance 1 mT

Physics List tests

- G4MICE was previously not able to simulate pions
  - Physics processes loaded had some problem with hadronic interactions
- Implement G4 physics package
  - Default is QGSP_BIC
- Make physics list regression tests
  - Compare versions against some reference version
  - Apply Kolmogorov-Smirnov test to determine if distributions are the same
  - Produce reference plots posted to web
- Code can be run against G4MICE, ICOOL, G4Beamline, etc





Optics::PolyFit algorithm

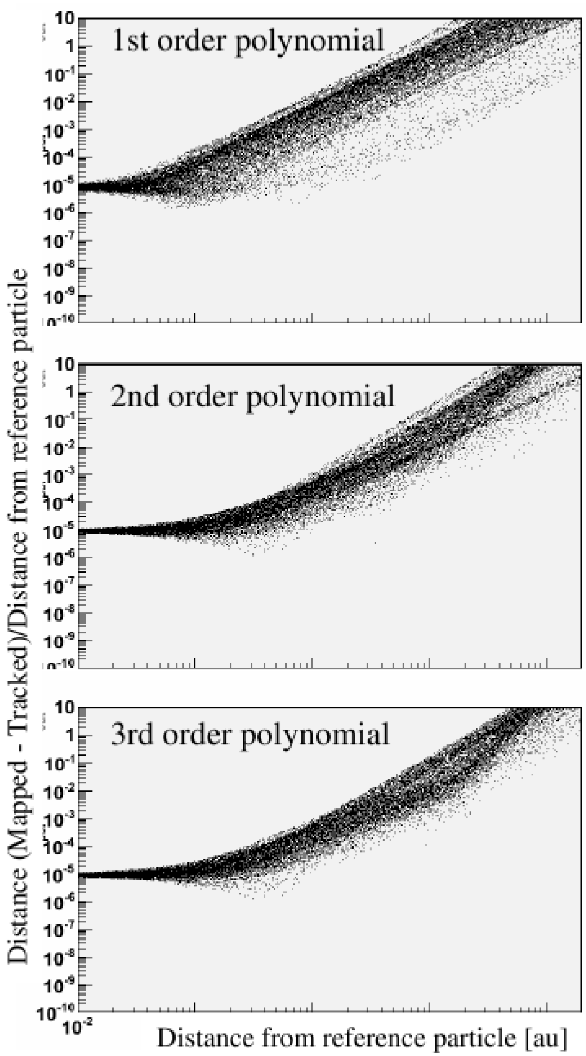
- Fundamental problem in (low intensity) accelerator physics is to find mapping that transports particles from some point at z_1 to some other point at z_2
  - From this mapping, we can transport beam ellipses etc
- Optics *TrackingDerivative* algorithms calculate Jacobian numerically, dx_{out}/dx_{in}, dp_{out}/dx_{in}, and so forth
- Allows us to calculate transfer matrix directly from Geant4 tracking
  - Nice test -> Are (complex) eigenvalues on unit circle
  - Allows to transport beam envelopes
  - Allows to transport single particles
- New algorithm *PolyFit* has now been implemented

Optics::PolyFit algorithm (2)

- New algorithm *PolyFit* has now been implemented
  - Here we fit a polynomial to tracking output
  - So we generate a polynomial $(time,x,y,px,py,energy)_{out}$ as a function of $(time,x,y,px,py,energy)_{in}$
  - Use PolynomialVector - arbitrary order, arbitrary dimension polynomial routine
    - With arbitrary order LLS fitting
- Idea is to find higher order terms in the transfer map
  - *TrackingDerivative* is not really stable beyond the linear mapping
  - Inputs:
    - step size
    - tolerance in residuals between tracked data and mapped data
    - polynomial order
  - Dynamically seeks a transfer map with appropriate properties

Optics::PolyFit algorithm (3)

- E.g. for 6D (right)
  - *Amplitude of the residual* vs amplitude
  - Amplitude of the residual is amplitude of distance between mapped particles and actual particles (in 6d)
  - For some RF/magnet lattice
- Get some improvement from 2nd order
  - No improvement really at 3rd order
- Nice tool for e.g. comparing measured data transfer matrix with calculated transfer matrix

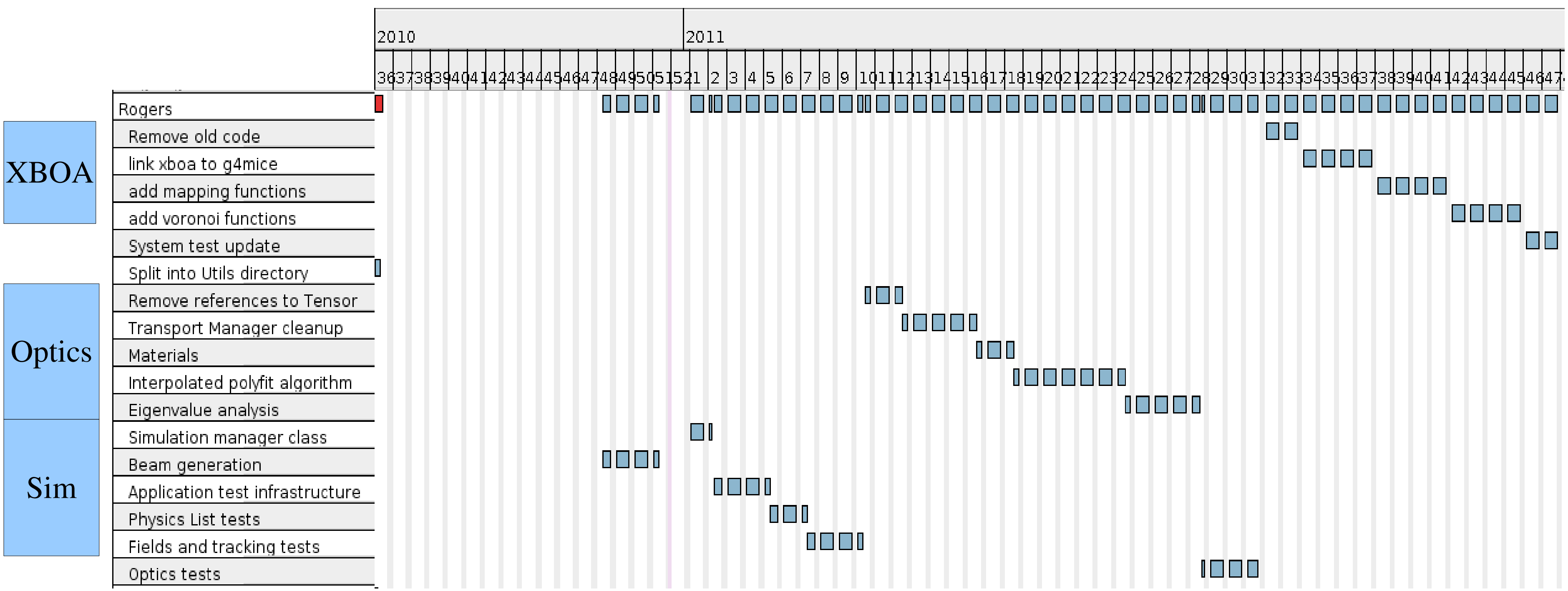


Introducing XBOA

- MICE analysis software requirements
  - Physics analysis routines for MICE control room
    - Beta, alpha, emittance, plotting
    - Need fast turnaround of plots
- Current physics analysis routines are not fit for purpose
  - Written by some rubbish graduate student as a first coding project
- Instead use XBOA physics analysis library
  - ~ few thousand lines of code
  - Good test coverage
  - Well documented (function-by-function + worked examples)
  - Local expertise
  - Written by some rubbish RAL staff guy
- Allows for quick and dirty physics analysis online

Accelerator Side workplan to 2012

- Most functionality is already in place
  - So structure looks rather flat (dependencies are already “done”)
  - Still a lot to do
  - Additional tasks:
    - MAUS integration not listed but is expected to be ~ 2 months work and is not listed
    - Arbitrary 3D meshing routines for measured field maps need to go in



Final comment

- Significant amount of development work in last 4 months has been bug fixing
  - Either we have most of our functionality in place
  - Or most of our code is broken
- Focus on improving test coverage and analysis routines