Existing Simulation Tools & Needs

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Outline

- brief survey of some common Design & Simulation codes for MC
- mention some of our anticipated computing challenges
- describe main cooling simulation codes in a little more detail
- mention a possible problem with space charge in cooling channel

Existing tools – Proton Driver

Codes

• MAD	beam optics & lattice design
• Optim	beam optics & lattice design
• Parmila	beam dynamics in linacs
• TRACE3D	beam envelope including linear space charge
• ESME	multiparticle longitudinal dynamics in rings

Existing tools - Target

Codes

• MARS, Fluka	particle production, shielding design
• Frontier, SPH	magnetohydrodyamics of Hg jets
• Fluent, Aeroflo	fluid dynamics of Hg delivery system
• custom codes	design of capture solenoid magnets

Issues

- detailed jet dynamics, distortions in field
- energy deposition in superconducting magnets

Existing tools – Front end & Cooling

Codes

• ICOOL	channel design & optimize performance
• G4beamline	channel design & performance, visualization
• Ecalc9	standard emittance calculation
• MARS	shielding design for channel

Issues

- these are novel types of channels => codes development is required
- are all the important physics processes for cooling included?
- shielding channel from high radiation levels downstream of target region
- space charge effects near end of cooling channel

Existing tools – Muon acceleration

Codes

• Optim	RLA design
• Synch	RCS lattice design
• GPT, ZGOUBI	particle tracking
• G4beamline	tracking, energy deposition
• ORBIT	collective effects
• custom codes	use FFAG code for RCS design

Issues

- efficient determination of multi-turn energy loss from muon decays
- High Performance Computing (HPC) is likely useful here

Existing tools – Collider ring

Codes

• MAD	lattice design, dynamic aperture
• COSY	dynamic aperture with fringe fields
• BeamBeam3D	beam-beam with transverse wakefields
• SBBE	beam-beam simulations
• ORBIT	self-consistent simulation of longitudinal dynamics, beam loading
• MARS	heat deposition, material lifetimes, radiation levels in magnets

Issues

- beam-beam and self-consistent simulations require considerable HPC resources
- upgrade of MADX-PTC needed to include fringe fields of magnets

Existing tools – MDI

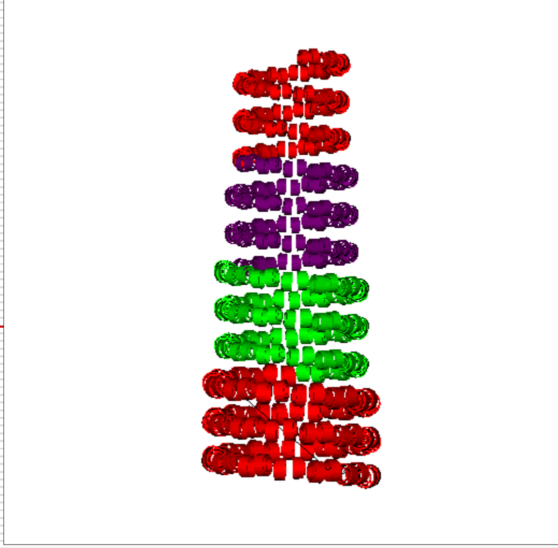
Codes

• MARS15	backgrounds in detector, heat deposition, material lifetimes, radiation levels in IR
• PYTHIA	event generator for background studies
• ILCroot	sub-detector responses to background & physics signals
• GUINEA-PIG	simulate beam-beam effects at IP, e.g. incoherent e^+e^- pairs

Issues

- MARS15 & ILCroot are under continuous development
- enormous numbers of particles requires HPC resources

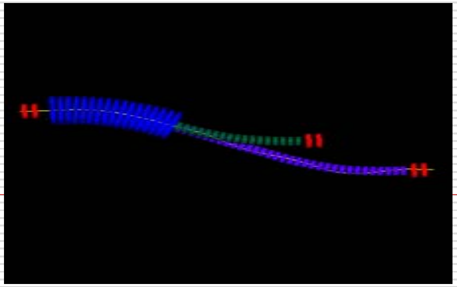
G4beamline



6D cooling channel

- user-friendly interface to Geant4 code system (Tom Roberts)
- allows rapid evaluation of beamline designs
- many predefined beamline elements
- includes physics for interactions in matter
- provides detailed visualization of tracks and element locations:
  - warning about overlaps, observe where particles get lost
  - automatic tuning of many parameters
- can sample beam at any location with "virtual detectors"
- has detailed Users Guide
- support for parallel processing on multiple CPUs
- includes HistoRoot program for easy generation of plots and histograms

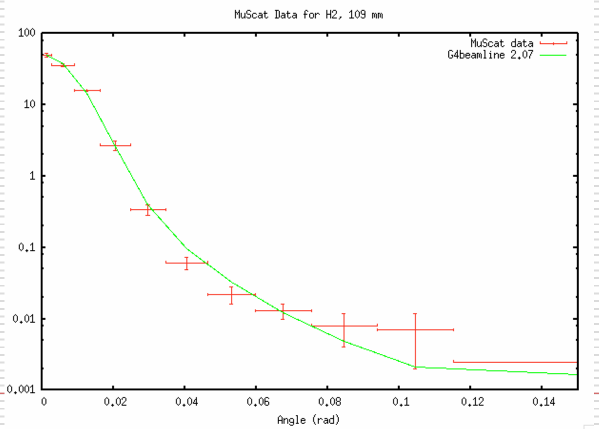
charge separation
with bent solenoids



Code validation

- validating the accuracy of simulation codes is obviously important
- G4beamline has undergone fairly detailed validation
- particle interactions checked by large Geant4 physics community
- automated test suite is used to check code performance (Tom Roberts)
  e.g. tracking, scattering, energy loss, field configurations
- detailed validation documentation is available
- MuScat experiment provided data for muon scattering validation
- in future MICE results should provide valuable additional tests for code

comparison of μ scattering in LH2



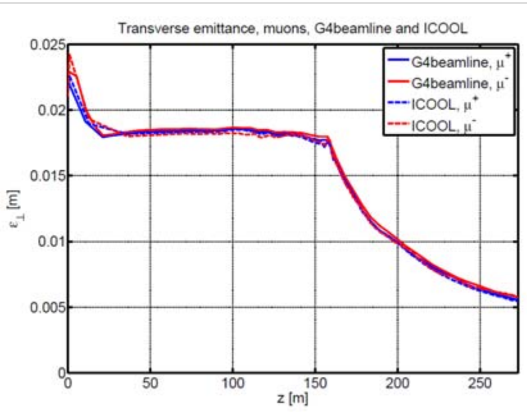
ICOOL & Ecalc9

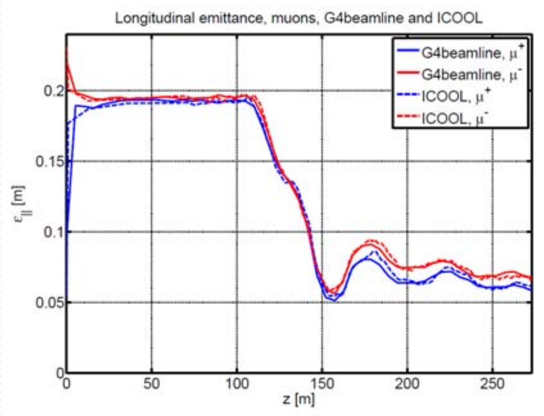
ICOOL
- older (~1996) Fortran code
- Runge-Kutta tracking in space using accelerator coordinate system
- build channels similar to the TRANSPORT code
- many methods provided for specifying fields
  analytic models, expansions using on-axis fields, field grids
- graphics are very primitive (no warning about overlapping objects)
- many auxiliary codes available for manipulating/analyzing output

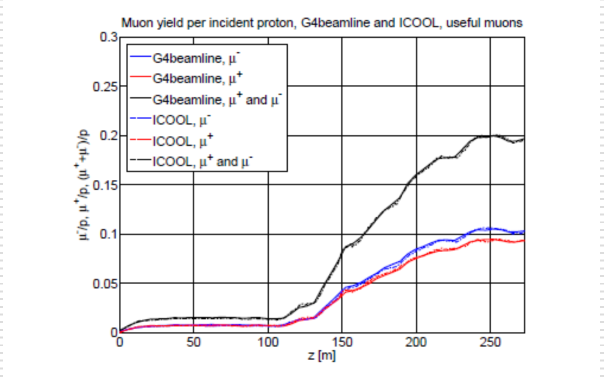
ECALC9 (Gregg Penn)
- has been the standard MC emittance calculation program since ~2000
- currently studying replacement using canonical variables & eigen-emittances

Code comparison

- G4beamline & ICOOL simulations of identical channels typically agree <10%







Useful muons ($p \in [100, 300]$ MeV/c, trans. cut 0.03, long. cut 0.15)

(Pavel Snopok, IDS-NF front end channel)

Space charge effects in cooling

- analytic calculations of space charge tune shift indicate possible trouble near end of 6D cooling - start of final cooling (R. Palmer)
- ICOOL has a uniformly-charged ellipsoid model, varying shape from rms, generates momentum kicks at start and end of every region (RCF & Juan Gallardo)
- ICOOL simulations show significant emittance growth for our parameters
- next steps:

1) adjust channel design parameters to decrease calculated tune shift (R. Palmer)

2) opportunity to compare with new space charge features in G4beamline

allows time stepping of macroparticles in parallel (Tom Roberts)

a) Lienard-Wiechert model for fields in LAB frame

b) solves Poisson equation on grid in BUNCH frame with ∞ BC

3) started study of space charge effects in 6D cooling using WARP (BNL, UMd, LLNL)

4) eventually need to include effects of wakefields & use actual BC

Summary

- existing codes are satisfactory for most of our present MC simulations
- we are becoming aware of some issues that could use more HPC resources:

1. Hg jet interactions for MC beam parameters
2. interaction of intense muon bunches in absorbers (K. Paul)
3. space charge effects near end of cooling (R. Ryne)
4. multi-turn energy loss from μ decays in accelerator
5. beam-beam interactions in collider ring (R. Ryne)
6. reducing backgrounds on physics detectors