Geant4 Activities at NICADD / NIU

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Simulations Working Group
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Outline

- LCDG4
  - Introduction
  - Development strategy
  - Recent developments
  - Current status
- TestBeam
  - Introduction
  - Geometry
  - Implementation details
- Conclusions and plans

G.Lima, January 07, 2004
What is LCDG4

- A Geant4-based detector simulator for the LC detector R&D
- Several detector geometries are implemented via XML geometry files
  - Simplistic geometry for now: cylinders, disks and cones only, no cracks or support structure
- Input format: binary STDHEP
- Output format: SIO for now (LCIO soon)
- Some visualization capabilities from Geant4
Some LCDG4 features

- Significant bias towards HCal
- Virtual cells defined on-the-fly
- Energies deposited in calorimeter absorbers are available (ASCII format only)
- Both projective and non-projective calorimeter geometries (forked versions)
- Shower particles are not kept on output
- Code available from SLAC and NIU CVS repositories
Development strategy

- Certify results (and geometry construction)
- Certify output formats
  - SIO to be Gismo-compatible
  - LCIO (to be implemented soon)
- Usability and user-friendliness
  - Documentation, source code
  - Larger user base, faster problem reporting
- Performance optimization
- New features
LCDG4 vs. Mokka comparison

- Previous LCD studies based on Gismo
- Geant4-based LCD simulations are rather new, they need to be certified
- (LCD)Mokka and LCDG4 were developed independently. Both are based on Geant4, so they should provide compatible results
- There is a very good agreement on energy distributions in calorimeters (per cell or layer)
- Found a 10% difference in number of hits
- More details and plots will be shown Friday at the calorimeter working group
Some new features

For better compliance with GISMO definitions
- Hits are linked to their responsible particles
- Starting and ending particle points
- SysID, endcap, north/south flags
- Sub-detector numbering scheme (internal only?)
- Particle status codes

<table>
<thead>
<tr>
<th>Status Code</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – active</td>
<td>active</td>
</tr>
<tr>
<td>1 – decayed</td>
<td>decayed</td>
</tr>
<tr>
<td>2 – interacted</td>
<td>interacted</td>
</tr>
<tr>
<td>3 – left detector</td>
<td>left detector</td>
</tr>
<tr>
<td>4 – stopped</td>
<td>stopped</td>
</tr>
<tr>
<td>5 – looping</td>
<td>looping</td>
</tr>
<tr>
<td>6 – lost</td>
<td>lost</td>
</tr>
<tr>
<td>7 – stuck</td>
<td>stuck</td>
</tr>
<tr>
<td>8 – primary</td>
<td>primary</td>
</tr>
<tr>
<td>9 – showered</td>
<td>showered</td>
</tr>
<tr>
<td>10 – maxsteps</td>
<td>maxsteps</td>
</tr>
</tbody>
</table>

( fully / partially / not implemented, or not to be implemented )
Links from hits to particles

- Hits are linked to responsible MCParticles
- Multiple links allowed for calorimeter hits only
- Shower particles are not saved, their hits are linked to the ancestor which enters calorimeter
- Only those secondaries created before the calorimeters are to be saved
- The links are tricky to save under Geant4, because G4Tracks are transient. Links can be created using either of:
  - Suspend the Geant4 tracking until all secondaries have been tracked
  - Keep separate arrays with only basic info needed to build the links
Building the links to MCParticles

- An LCDMcPart object contains:
  - Particle ID (PDG)
  - Status word (100*genStatus + simStatus)
  - Link to (a single) parent
  - Links to all direct children
  - Starting and ending points
  - 4-momentum

- An MCParticleSIO contains all that too, plus some SIO stream utilities
Remaining issues

- Some status codes are partially implemented (decayed, interacted) or not implemented yet (left, stopped, looping, showered, maxsteps)
- Some starting and ending points (those cases where the status is not yet implemented)
- Hits from backscattered particles should not be linked to ancestor entering calorimeters
Event Visualization

- Some visualization can be done with Geant4, but
  - Calorimeter cells are virtual
  - JAS3 / Wired has very nice interactive visualization capabilities
$e^+e^- \rightarrow Z \rightarrow \mu^+\mu^-$ (SDJan03)
$e^+e^- \rightarrow Z \rightarrow qq$ event (SDJan03)
$e^+e^- \rightarrow t\bar{t}$ event (SDJan03)
Monte Carlo samples

Several single-particle and physics data samples available at NIU data server:

- sftp scpuser@131.156.85.141
- password: lcd_2004
- cd pub/lima/lcdg4/v02-11
- ls (to see a list of .sio files available)
- mget muons-10gev*.sio (for example)
- quit

(see http://nicadd.niu.edu/~jeremy/admin/scp/index.html for more detailed access instructions)
LCDG4 Processing times

- Single particles:
  - Physics events
    - $Z \to X$ @ 91 GeV: 0.65 min/evt
    - $t\bar{t}$ to $X$ @ 350 GeV: 2.28 min/evt
    - $ZH$ to $X_{bb}$ @ 500 GeV: 2.89 min/evt
    - $WW$ to $qgbb$ @ 500 GeV: 2.97 min/evt
Detailed comparisons between LCDG4 and Mokka calorimeters are in good agreement.

Only cylinders, disks and cones are supported by current LCDG4 version. More realistic geometries are planned to be implemented in the medium term.

Several MC physics samples have been generated for algorithm development and studies.

For more information please check: http://nicadd.niu.edu/~jeremy/lcd/lcdg4/index.html
Plans for LCDG4

- Fix remaining issues (high priority)
- LCIO output format
- Upgrades: Geant4.6.0 and expHEP-oriented physics lists
- Merge projective and non-projective versions
- More realistic geometries (medium term)
Test Beam Simulations

Total # cells = 300,000 + 23,200 + 90
Test Beam EM Calorimeter

Front View

Side View

1 m

~6 cm
Test Beam Hadronic Calorimeter

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Test Beam Tail Catcher

Front (transparent)

Front (Hor)

Front (Vert)

Side

1.5 m

63 cm

1.5 m

G.Lima, January 07, 2004
# Test Beam Subdetectors

<table>
<thead>
<tr>
<th>Component</th>
<th>No. Layers * thickness = total thickness</th>
<th>X x Y dim. (m)</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCal</td>
<td>50 *</td>
<td>1 x 1</td>
<td>Stainless Steel, Polystyrene</td>
</tr>
<tr>
<td></td>
<td>2.5 cm = 125 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECal</td>
<td>30 *</td>
<td>1 x 1</td>
<td>W, G10, Si, Cu, Air</td>
</tr>
<tr>
<td></td>
<td>5 mm = 15 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tail Catcher</td>
<td>6 *</td>
<td>1.5 x 1.5</td>
<td>Same as HCal</td>
</tr>
<tr>
<td></td>
<td>10.5 cm = 63 cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>203 cm</td>
<td>max 1.5 x 1.5</td>
<td></td>
</tr>
</tbody>
</table>
A test beam event display

Inner Cal.

Angled View
Test Beam status

- Very active development in recent months by Jeremy McCormick
- A number of geometry configurations has been studied
- See Zutshi’s talk tomorrow at Calorimeter WG for some results
- Two different implementations: standalone and under Mokka
A lot of Geant4-based detector simulation activities at NIU
LCDG4 output mostly compatible with Gismo
LCDG4 and Mokka in good agreement for calorimeters in a common geometry (SDJan03)
Several physics samples are available at NIU sftp server, at /pub/lima/lcdg4/v02-11
Simulation requests are welcome http://nicadd.niu.edu/~jeremy/lcd/simreq/index.html
For more information, please visit http://nicadd.niu.edu/~jeremy/index.html#proj