GEANT4 simulation efforts at NIU/NICADD

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What is Geant4?

- From the Geant4 website (http://geant4.web.cern.ch/geant4/):
  - “Geant4 is a (programming) toolkit for the simulation of the passage of particles through matter”
  - AND
  - “Geant4 provides a complete set of tools for all the domains of detector simulation: Geometry, Tracking, Detector Response, Run, Event, and Track Management, Visualisation and User Interface”
• Authored by T. Abe and M. Iwasaki (University of Colorado)

• What is LCDRoot?
  – Group of tools for LCD studies, that covers two areas:
    • Simulation engine using Geant4 and ROOT system
    • Analysis is based based on the ROOT system
    • Output as ROOT ntuples
Lcdg4 – Our program

• Is a port of the simulation engine (G4FullSim) in LCDRoot
  – The LCDRoot G4FullSim classes decoupled from ROOT
  – Decoupling achieved by making appropriate substitutions using C++ STL and CLHEP libraries instead of ROOT internal classes
  – This port is work in progress…

• The result:
  – A standalone geant4 simulation program
  – XML description of detector geometry
  – SIO output functionality
Why decouple from ROOT

- Decoupling allows us to have a “standalone” simulation program
- Standalone simulation program, not bound to a particular analysis environment
- I/O compatible with the SLAC/HEP.LCD library and JAS
- Preservation of the ROOT compatibility. Ntuple output is still an option
Structure of package

• All lcdg4 user action classes are nearly identical to their G4FullSim counterparts (appropriate modifications made…)
• EventAction class has been modified to output in SIO format
• The rough graph class structure of the package is shown on the next slide
Organization of LCDG4 package
Classes marked in green are new or rewritten

LCDG4 The Main Driver
XML parser
Reads in the detector description

Primary Detector Construction

PrimaryGeneratorAction
Main Physics content

STDHEP input
Under construction

EventAction

TrackerAction
SteppingAction
(MCpart Manager)

XML2G4DetConst
Extracts info about the dimensions of the detector

SIO record constructor

HADCallorimeter
EM Callorimeter
Tracker
VXD etc.

HAD Hits
EM Hits
MU Hits etc.

SIO record fill
Final output stream

XYZtoID class
Initialization
Required for future
Specialization of the detector

XYZtoID conversion
Produces the HitID
Some of the advantages of the Serial Input Output format

- Is the preferred data format for Java Analysis Studio, the main analysis framework for NICADD
- Allows read access to huge files in sequential/selective manner, using records and blocks without overburdening the memory
- Allows writing onto several streams simultaneously
- Has built-in support for file compression, which is important, since uncompressed events can take well over 1 GB of space
Writing SIO output

Organization of SIO Record

Event Action processes hits forming in the process The Event Record

- HADCcallorimeter
  SIO_HAD
  Extends SIO_Block and Connects to Event Record

- EM Callorimeter
  SIO_EM
  Extends SIO_Block and Connects to Event Record

- Other components
  Type title here
  Extends SIO_Block and Connects to Event Record
**XYZ to ID conversion**

- The output of GEANT4 provides the Cartesian coordinates of the hits, without regard for the actual geometry:
  a) number, shape and spacing of the cells
  b) projective or non-projective towers
- Specific detector geometry is handled by a separate class, initialized at the construction of the detector and invoked on each event
- Important for the hexagonal geometry of the cell
The Cell
“neighborhood”
• Using the geometry described above one can determined which Cell the coordinates of the hit correspond to and associate the ID of the Cell with the hit.

• The ID formed contains 3 fields:
  a) R_ID (the radial component)
  b) Phi_ID (the azimuthal angle component)
  c) Theta_ID (or Z_ID) (the transverse angle component)
Test Results

- The Sampling Fractions for the EM and Hadronic Callorimeters
  \[ \text{EMfr} = 0.05935 \]
  \[ \text{HADfr} = 0.07421 \]

- The old values are 0.02187 and 0.06338 correspondingly
Total (EM+HAD) energy for the 10 GeV pions

Using LCDG4 with NICADD proposed detector
Phi vs Theta for layer 1

- Entries: 76.000
- X mean: 76.973
- X rms: 4.8503
- X min: 66.000
- X max: 92.000
- Y mean: 5.0263
- Y rms: 3.6848
- Y min: 0
- Y max: 16.000
The total energy deposition for 20 GeV charged pions in HAD
Energy in HAD vs. # of hits (Response plot)

Energy, GeV

number of hits in 1000s
Shower Profile for the 10 GeV charged pions
The comparison plot of energy per hit between Gismo and Root for 10 GeV pions, run over 1000 events each.

The units are GeV. **Green** is GEANT4.
The total energy in HAD. Also over 1000 events
Conclusions

• The initial release of our complete simulation package is in order
• The preliminary analysis of the test results shows reasonable agreement with expectations
• However, the striking discrepancy between our and an old, GISMO-based package has to be interpreted and understood
• More work is needed to make the package as modular as possible, i.e. extendable to possibly alternative detector design