Status report on simulation tools at NIU

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ALCPG Workshop
Victoria, July 28-31, 2004

Talk outline

- Test beam
  - TBMokka, TBS
  - news
- Full detector
  - LCDG4
  - news
  - data samples
- Summary

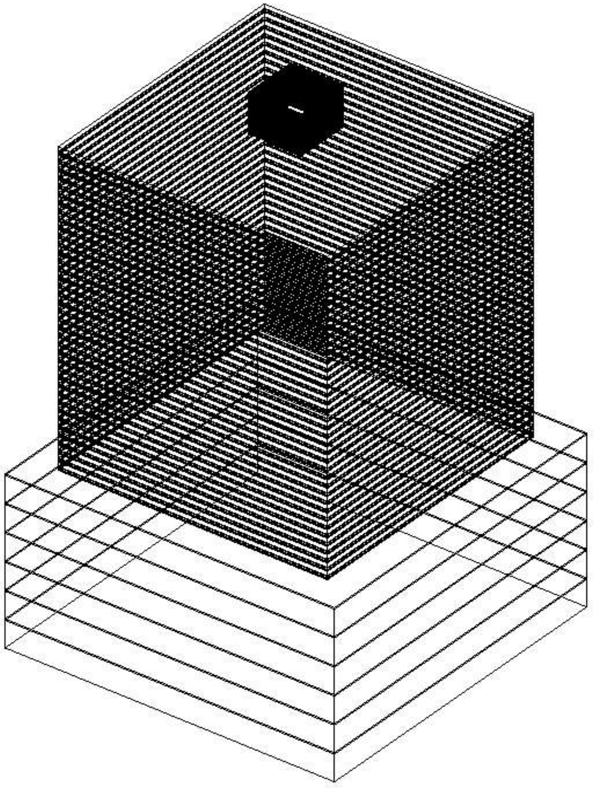
Simulation tools

- TBMokka – Test Beam within Mokka (Calice)
- TBS – Test Beam Standalone simulations
- LCDG4 – full detector simulation

All these are based on Geant4 toolkit.

Test beam prototype simulation

- TBMokka is the official version of test beam simulations
- NICADD/DESY collaboration for CALICE test beam simulation development
- Based on Mokka / Geant4
- Geometry from MySQL database
- Output in standard LCIO format



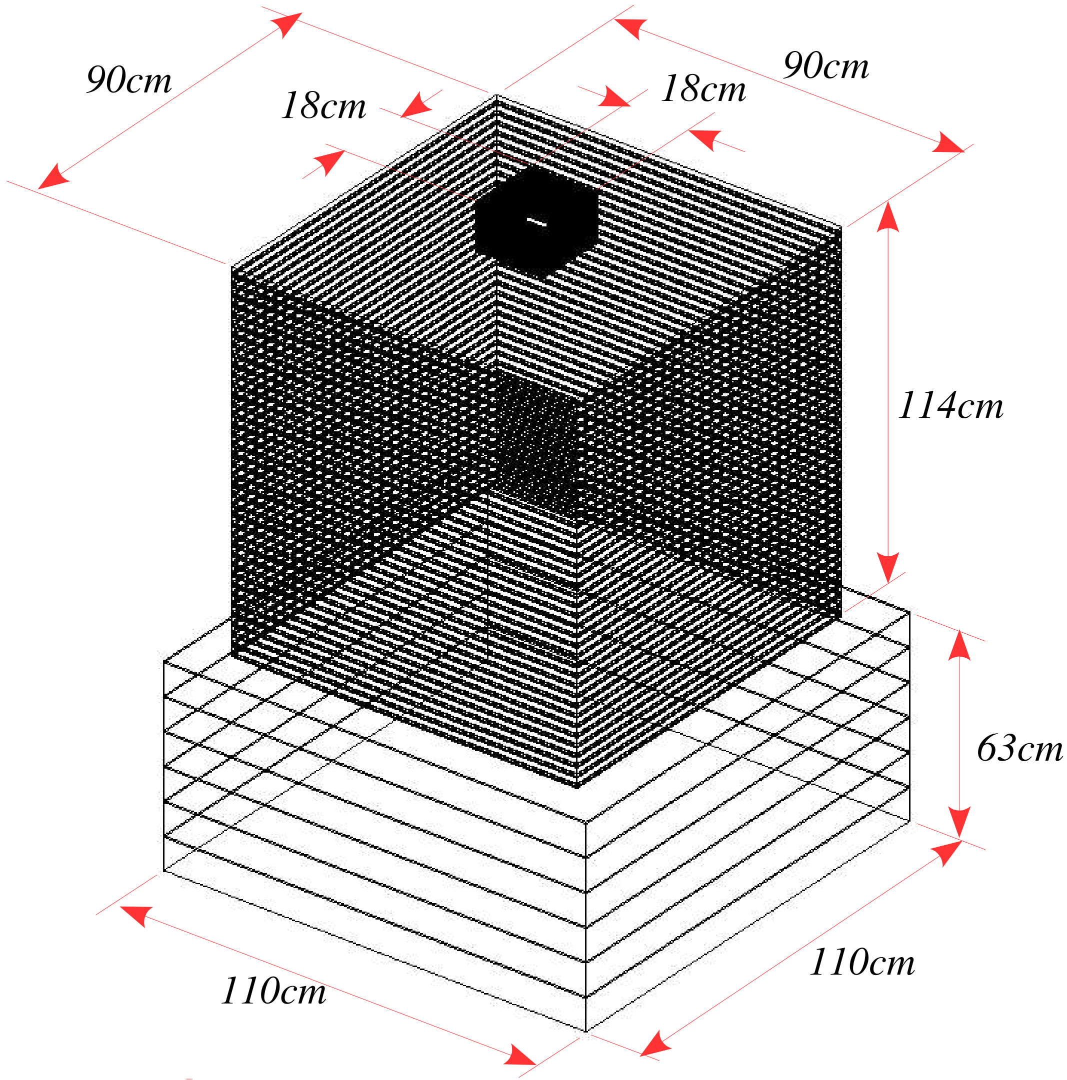
Prototype geometry

Single layer thicknesses (all values in mm)

Ecal (30 layers)	
Tungsten	2.5
G10	0.5
Silicon	0.4
Copper	1.0
Air	0.6

TCMT (6 layers)	
Polystyrene	5.0
Steel	100.0

Hcal (38 layers)	
Steel abs	16.0
Air gap	1.0
Steel cassete front	2.0
Polystyrene scintillator	5.0
Aluminum foil	1.0
PCB (G10)	1.0
Cablefibre mix	1.0
Steel cassete back	2.0
Air gap	1.0



TBMokka: other features

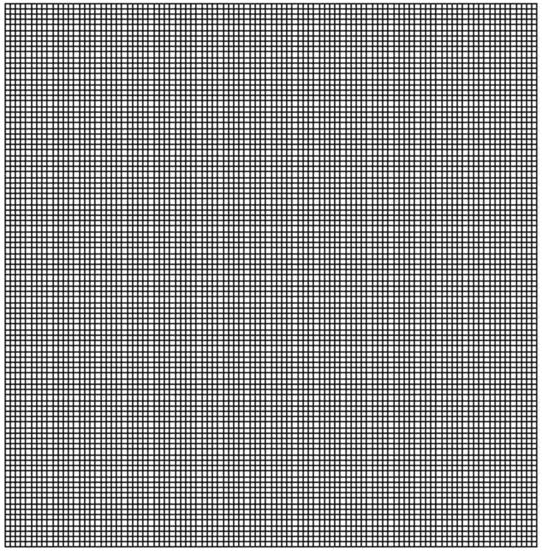
- Cell sizes are 1cm x 1cm to promote reuse of simulated data for different cell configurations
- Virtual cells for faster simulation using less memory
- Implementation uses general concepts for any box-like detector
- Source code is available from Mokka web site, http://polype.in2p3.fr/geant4/tesla/www/mokka/mokka.html or via sftp scpuser@k2.nicadd.niu.edu:/pub/jeremy/TBMokka
- TBMokka is well documented at http://nicadd.niu.edu/~jeremy/lcd/tbeam/index.html

TBS: test beam standalone

- A standalone version also exists, with additional features:
  - geometry defined in an ASCII file, no database needed
  - geometry implemented down to cell level (real cells)
  - some test geometries available, which were not implemented in TBMokka (coil material, fine TC layers)
  - arbitrary rotations of ECal and HCal around vertical
  - arbitrary rotations and translations of subcomponents from Geant4 command line interface
  - output in ASCII, no LCIO support
  - documentation: http://nicadd.niu.edu/-jeremy/lcd/tbeam/

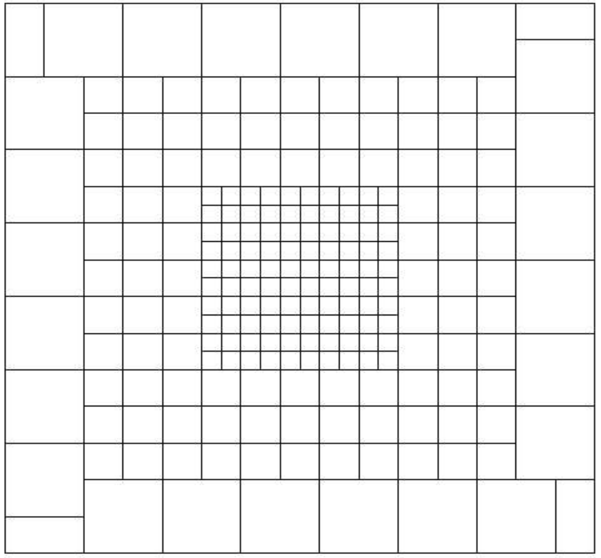
TBS cell geometry

ECal



1cm x 1cm cells
30 layers
1m x 1m total

HCal



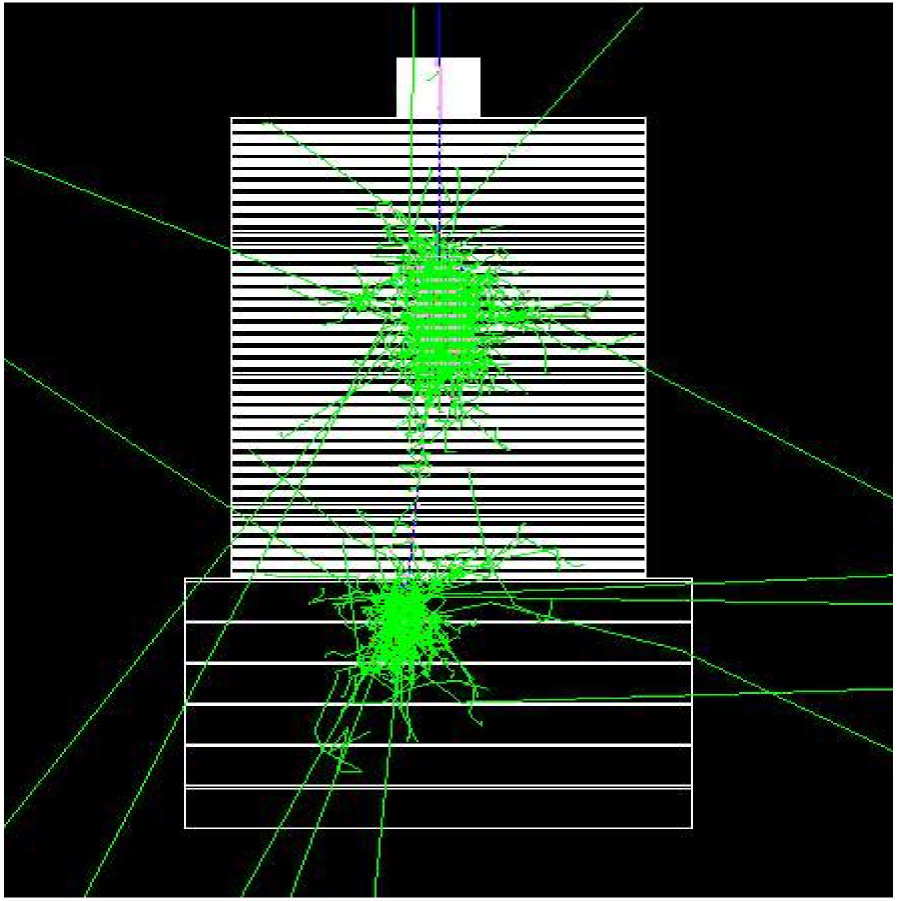
3x3, 6x6, 12x12cm^2
38 layers
0.9m x 0.9m total

Tail Catcher

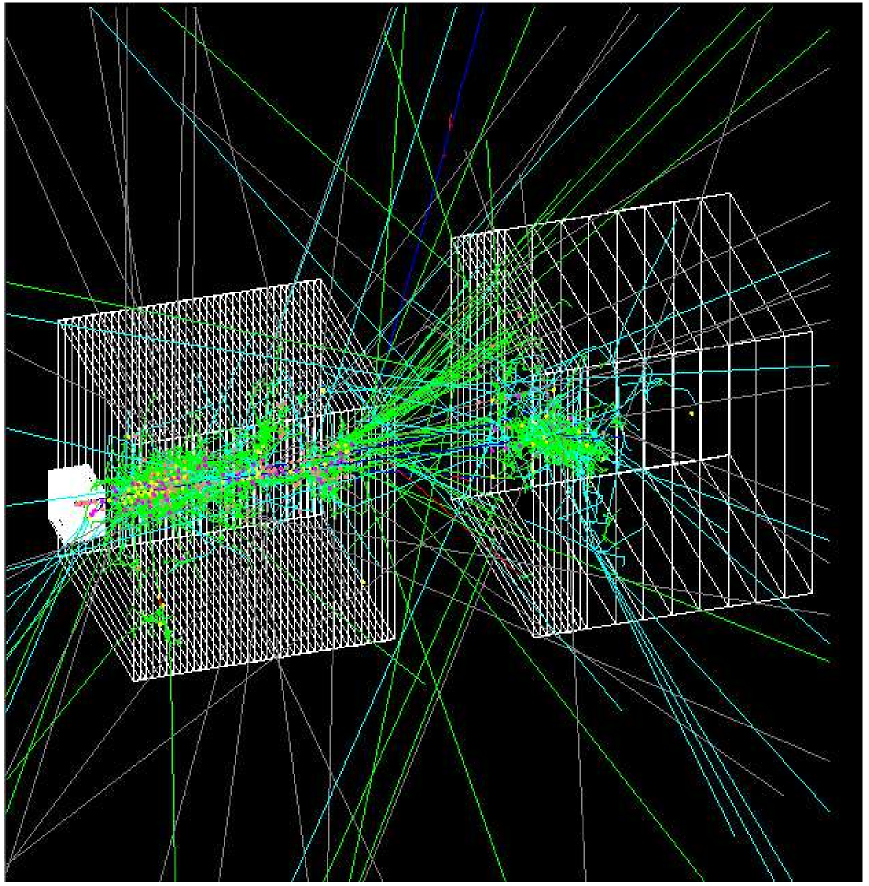
110cm x 5cm cells
16 layers (hor or vert)
1.1m x 1.1m total

Test beam event Displays

20 GeV π^+ in TBMokka



50 GeV π^+ in TBS: a test geometry
HCal is followed by a 50cm air gap, and
by a fine+coarse 16-layers tail catcher



News in test beam simulations

- More realistic HCal layering (thicknesses in mm)

Steel Absorber	Air Gap	Steel Cassette Front	Polystyrene Scintillator	Aluminum Foil	PCB (G10)	Cablefibre Mix	Steel Cassette Back	Air Gap
16.0	1.0	2.0	5.0	1.0	1.0	1.0	2.0	1.0

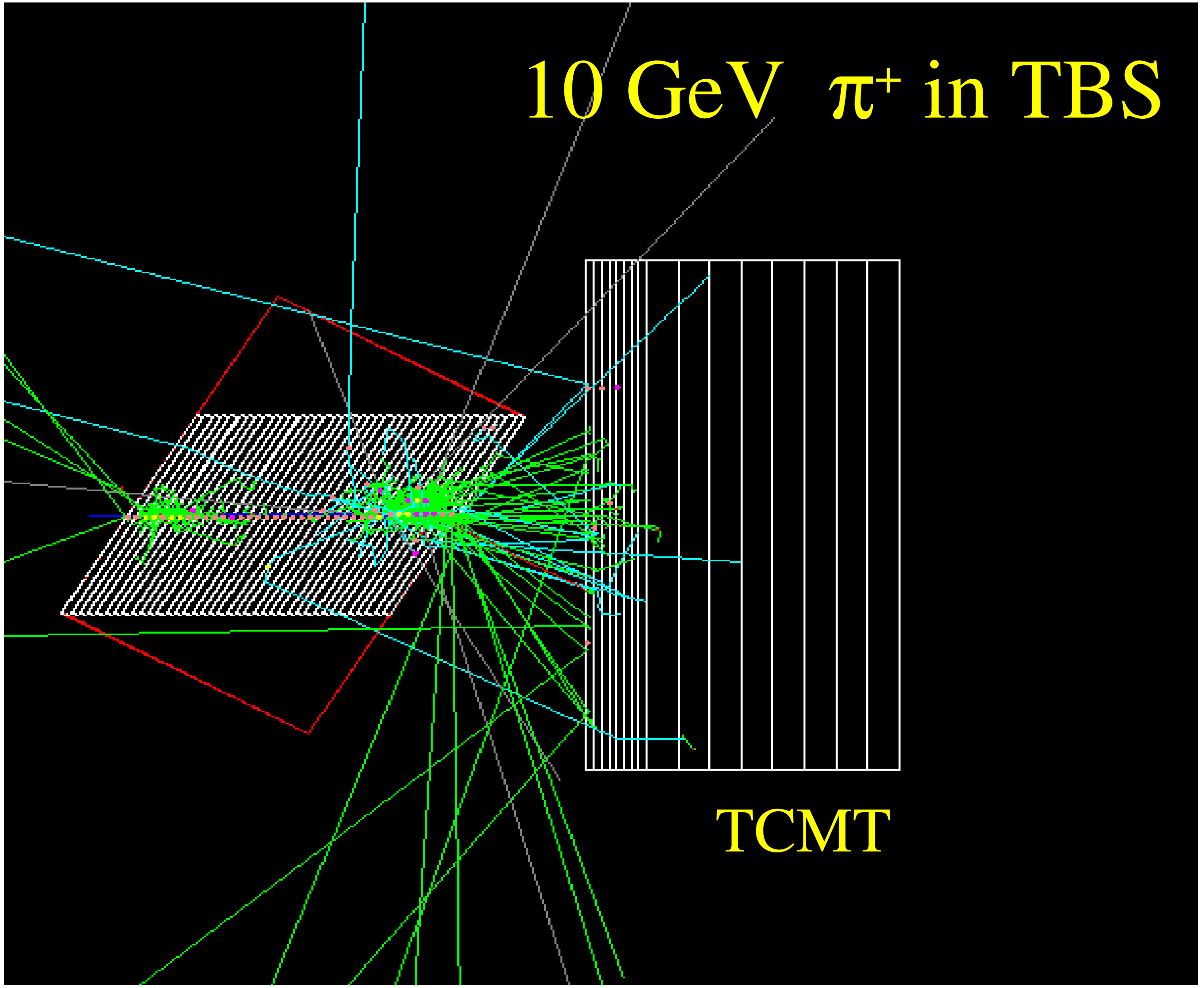
- ECal+HCal rotations around vertical
- Selection from different Geant4 physics lists
  - Effects of rotations and physics lists choice for the tail catcher design
- Conventions for coordinate system and cell numbering

HCal rotations

TBMokka:
One database per angle, some predefined angles will be readily available.

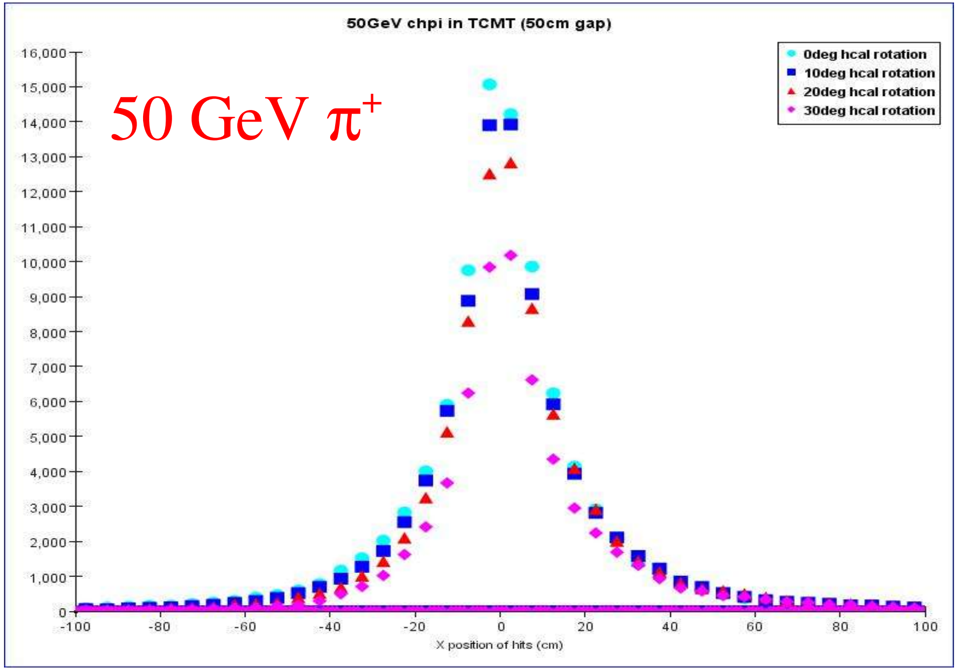
TBS:
Arbitrary rotations, as easy as editing a line, e.g. (in degrees)

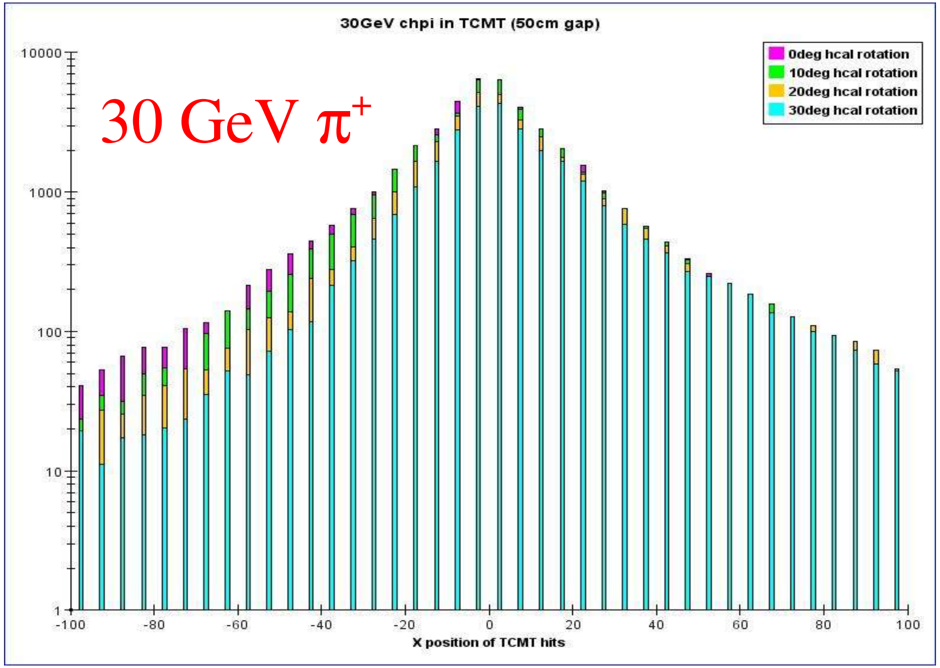
```
HCANGLE = 30
```



Effects of HCal rotations in TCMT

X-position of TCMT hits: energy deposition is still centered in tail catcher, but slightly asymmetric towards normal incidence (thinner detector)





Geant4 hadronic physics models

Different lists use *slightly different* shower models

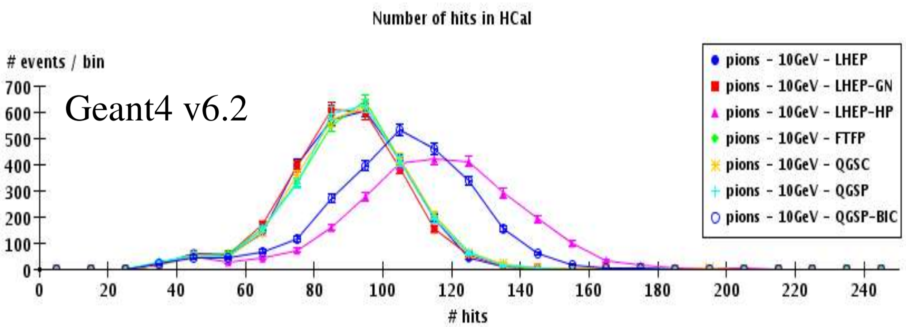
- Gheisha (LHEP) is the basic model
- QGSP, QGSC are theory-driven extensions for E > 25 GeV
- Refinements to basic model:
  - Gamma nuclear processes (GN)
  - Bertini cascade (BERT) for E < 3 GeV
  - Binary cascade (BIC) for E < 3 GeV
  - Fritjof fragmentation (FTFP)
  - Neutron evaluated cross-section data (HP)
- Others (not used): Fluka, MICAP (not part of G4)

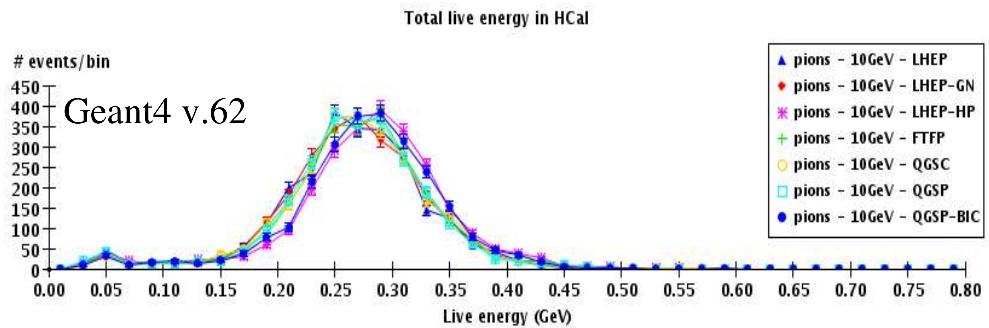
Effects from physics list choice

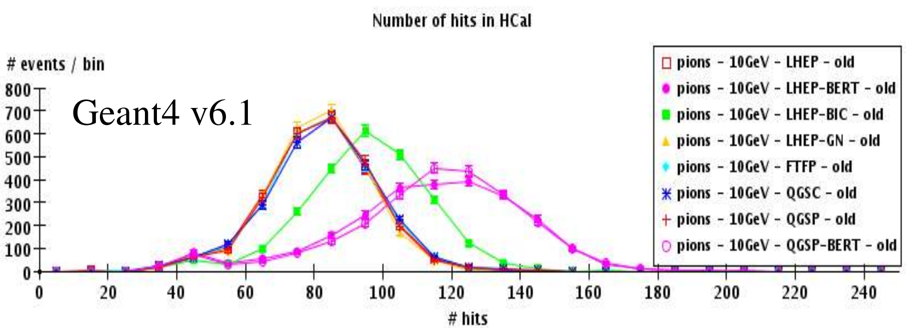
A digital approach seems to be more sensitive to the hadronic physics model used in the simulations.

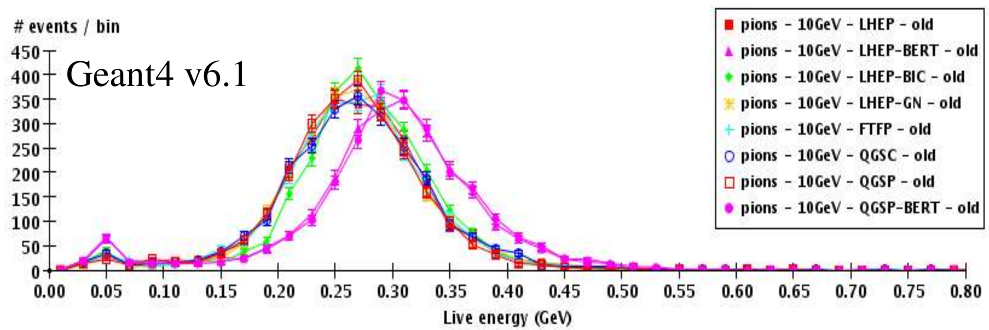
Number of HCal hits > 0.25MIP

Total live energy in HCal



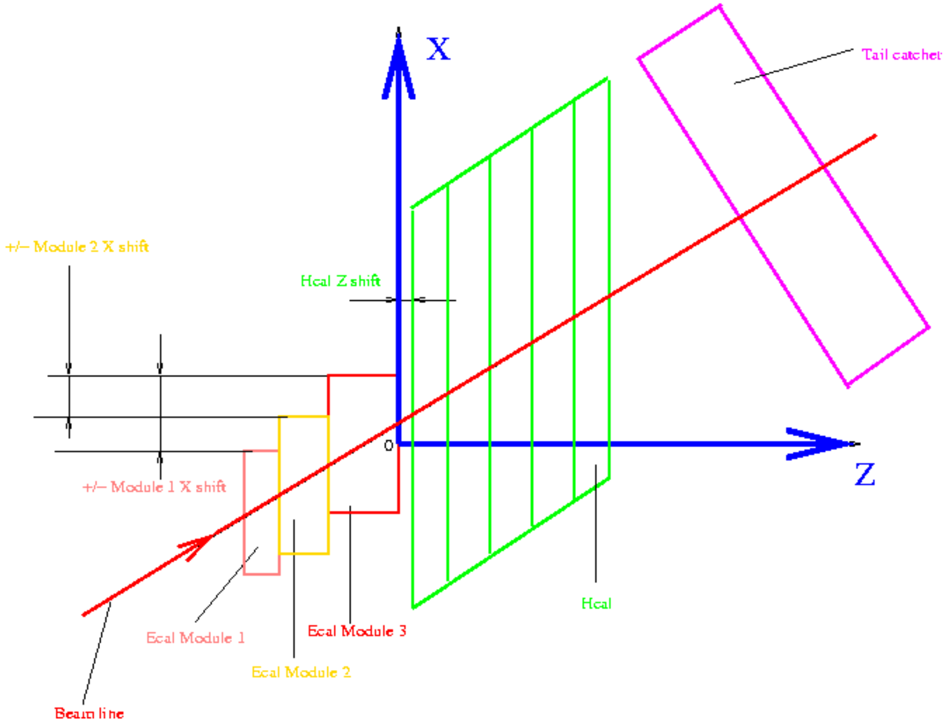


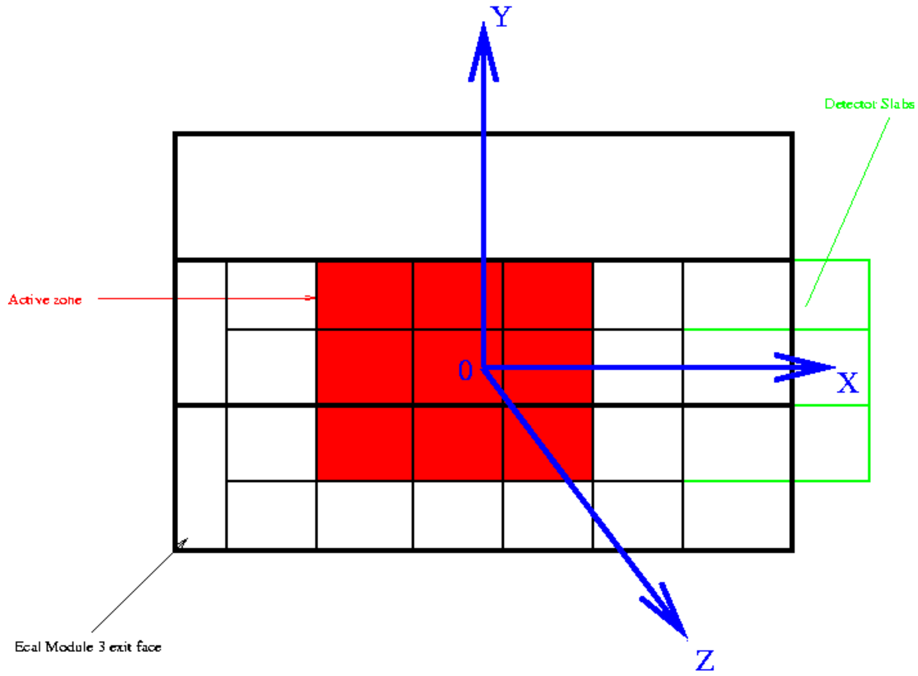




Test beam coordinate system

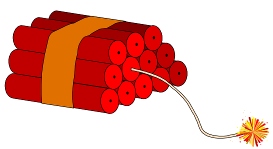
Origin definition:
- z=0 is at the exit face of last ECal module
- y=0 is at the center of active region (in red)
- x=0 is at the symmetry center of last ECal module





LCDG4: Full detector simulation

- A Geant4-based detector simulator to support detector R&D for the Linear Collider
- Alternatives: Mokka (Europe), LCS (new, SLAC) or Gismo (old)
- LCDG4 features
  - Input format: binary STDHEP
  - Output format: only ***.sio*** for now (Gismo compatible)
  - Some detector geometries are implemented via XML geometry files (e.g. SD, LD, PD)



Simplistic geometry: cylinders, disks and cones only, no cracks, limited representation of support structure

Some LCDG4-specific features

- Development bias towards HCal (also ECal)
  other detectors should work fine, but no active studies by the developers
- Gismo compliant *by design* (transparent change for Gismo users)
- Correct MC particle hierarchy, even when V0s and hyperon decays are forced in event generation
- Energies deposited in absorbers are easily available for analysis (ASCII format only)
- Non-projective calorimeter geometries also available, with output into SIO files (new feature in main version, see SDNPHJun04.xml)
- Simple analysis code and documentation available from CVS and http://nicadd.niu.edu/~lima/lcdg4/.

Geometry description in XML

An example: Hadronic calorimeter barrel.

Dimensions are in centimeters.

```
...
<volume id="HAD_BARREL" rad_len_cm="1.133" inter_len_cm="0.1193">
  <tube>
    <barrel_dimensions inner_r = "144.0" outer_z = "286.0" />
    <layering n="34">
      <slice material = "Stainless_steel" width = "2.0" />
      <slice material = "Polystyrene" width = "1.0" sensitive = "yes“ />
    </layering>
    <segmentation cos_theta = "600" phi = "1200" />
  </tube>
  <calorimeter type="had" />
</volume>
...
```

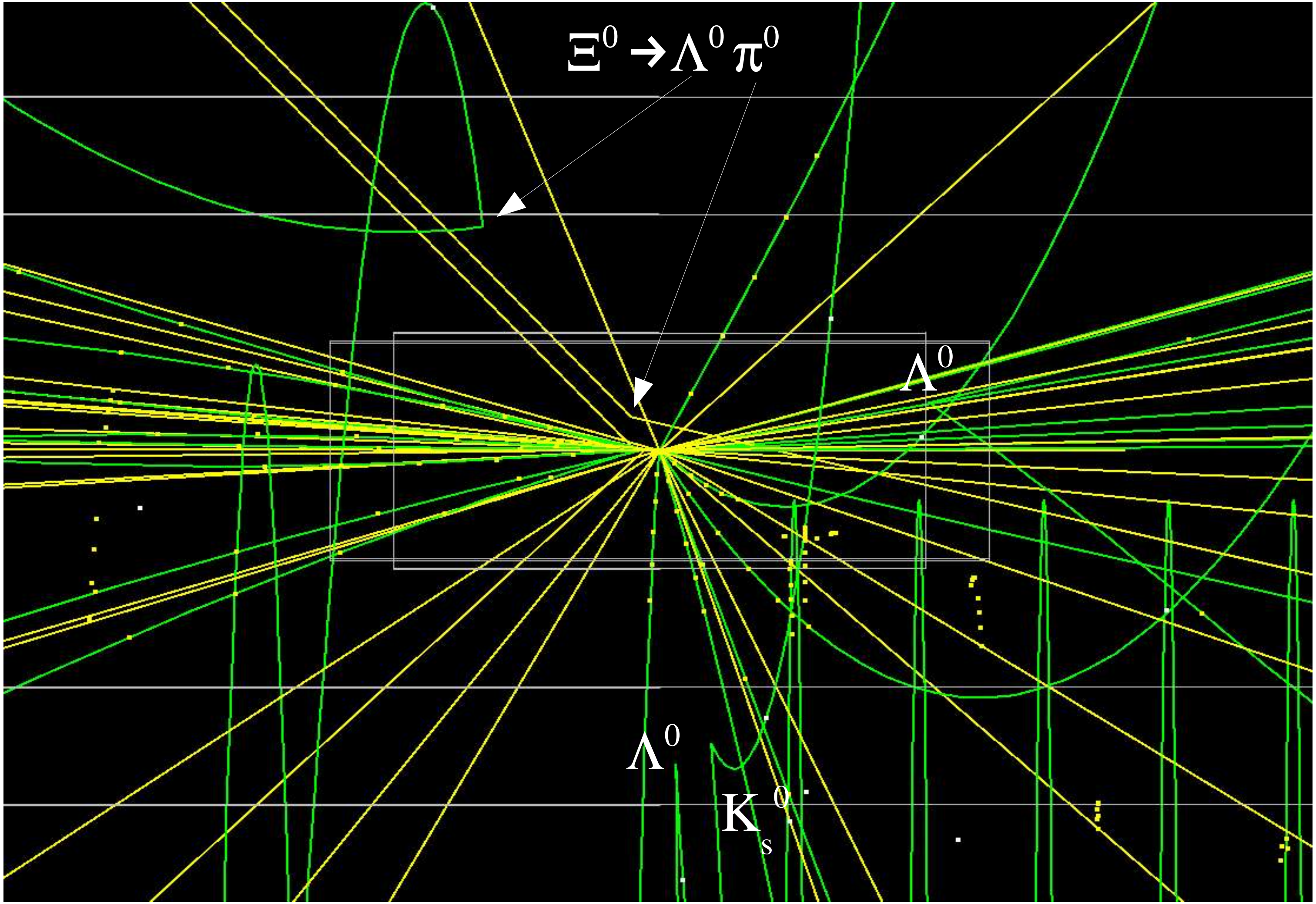
Simple detector changes are very easy to make!

SIO output: general features

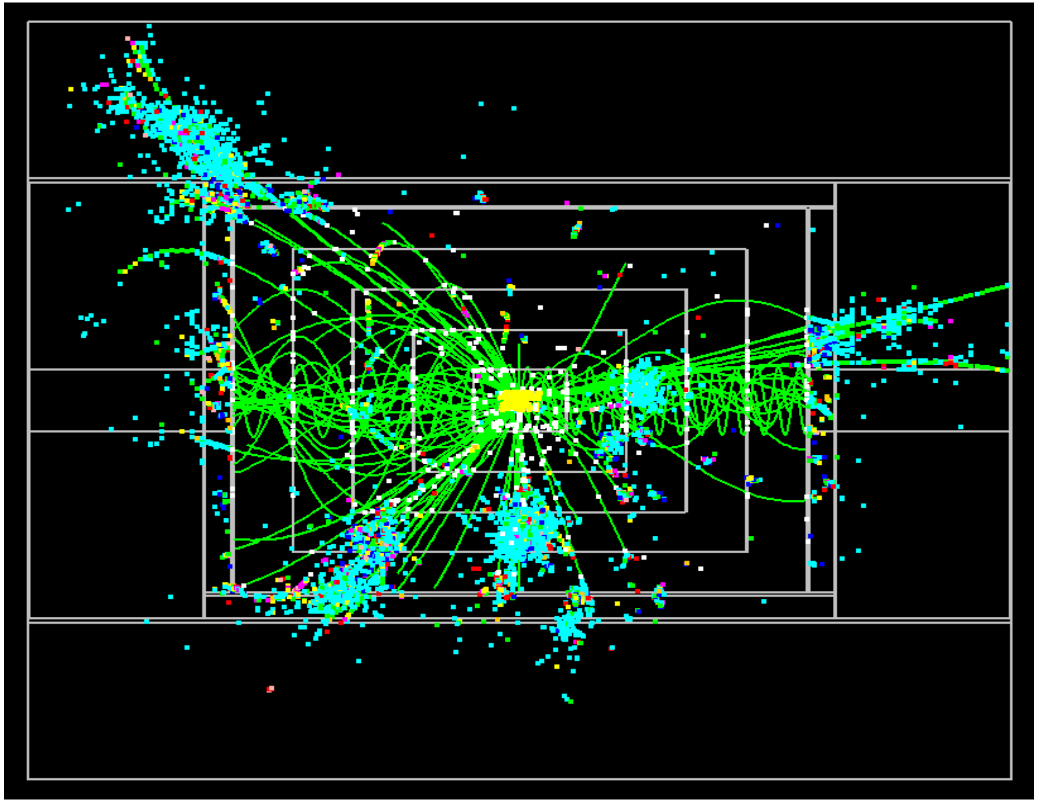
- SIO output contents: one particle collection and several hit collections (one collection per subdetector)
- Each hit points to the contributing particles (except tracker hits from calorimeter back-scatterings, as in Gismo)
- All secondaries above an energy threshold (now set at 1 MeV), except for shower secondaries, are saved in output with:
  - Particle id and status codes (generation and simulation)
  - Production momentum and ending position
  - Calorimeter entrance point: position and momentum
  - Pointers to parent particles

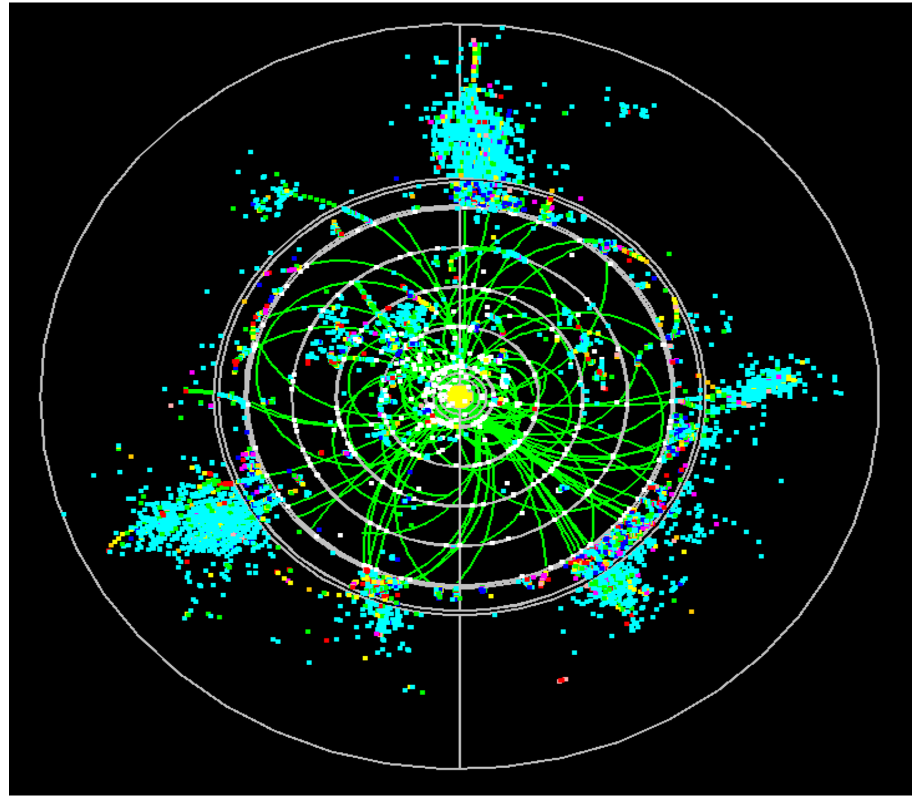
Zoom on the primary interaction

All decays forced in the generator are correctly processed by the LCDG4 simulation



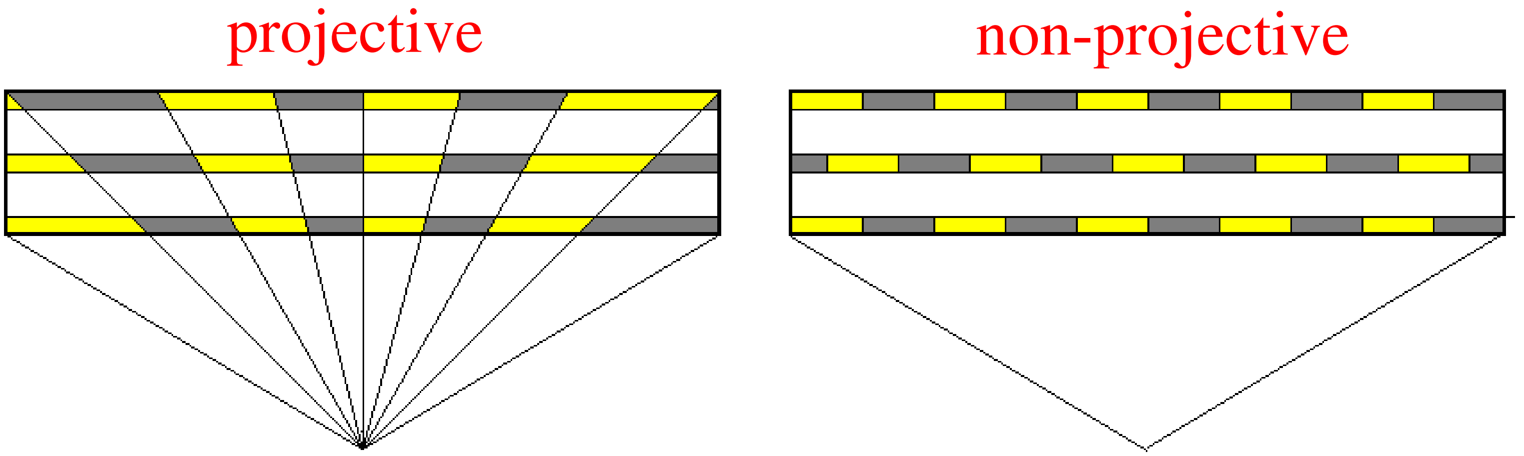
e^+e^- into ttbar event (SDJan03)





LCDG4 news

- Non-projective calorimeter implementation has been merged into main release
  - Either ECal, HCal or both can be non-projective
  - Rectangular cells with fixed size, controlled at run time (XML)
  - User provides cell dimensions, and simulator adjusts cell sizes slightly for integral # of cells along z, ϕ



Other LCDG4 news

- Several bug fixes or improvements since SLAC workshop:
  - upgrade to Geant4 version 6.2 (latest version) and use of different physics lists
  - correct handling of pre-assigned decays (forced in generator), even for decays of short-lived particles or hyperons
  - dependence on CERNLIB has been removed, by using some LELAPS classes for binary stdhep input
  - several improvements to Gismo compliance
    calorimeter entrance position and momentum, status codes, MCParticle split at interaction points, hits links to MCParticles, tracker hits from calorimeter backscattering, etc.
  - analysis classes and documentation

MC Samples for general use

- Samples currently available at NIU through sftp: scpuser@k2.nicadd.niu.edu (lcd_2004): /pub/lima/lcdg4/v03-06
  - 2K each of $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, γ, n at $\theta = 90^{o}$ and flat in φ energies = 2, 3, 5, 10, 15, 20, 30, 50 GeV
  - 5K 10 GeV K_s^0 into $\pi^0\pi^0$
  - 10K 10 GeV K_s^0 into $\pi^+\pi^-$
  - 5K 10 GeV Σ^+, inclusive decays
  - 5K 1..10GeV Λ^0, inclusive decays
  - 10K Z into (hadrons) at 91 GeV
  - 5K ttbar inclusive at 350 GeV
  - 10K WW into (hadrons)(any) at 500 GeV
  - 10K $\tau^+\tau^-$ at 500 GeV
  - 4K ZH into (any)(bbbar) at 500 GeV and M_H=120, 160 GeV (2K events each)

- Other samples can be requested to lima at fnal.gov. Please read http://nicadd.niu.edu/~jeremy/lcd/simreq/ for guidelines.

How to access the MC samples

Several single-particle and physics data samples available from NIU data server using secure ftp:

```
 % sftp scpuser@k2.nicadd.niu.edu
password: lcd_2004
sftp> cd pub/lima/lcdg4/v03-06
sftp> ls   (to see a list of .sio files available)
sftp> mget muons-10gev*.sio    (for example)
sftp> quit
%
```

See http://nicadd.niu.edu/~jeremy/admin/scp/index.html for more detailed access instructions, including instructions for windows winscp utility.

LCDG4 status summary

- Only cylinders, disks and cones supported by current LCDG4 version (like in Gismo). More realistic geometries to be implemented in the medium term. Work is already under way at SLAC (see Graf's talk on this workshop)
- Visualization framework in JAS is ok for .sio files, except for non-projective calorimeters, because of mixed calorimeter cell geometries
- Source code available from SLAC or NIU CVS repositories
- Several MC physics samples have been generated for algorithm development and studies (SIO format, SDJan03 is now available, and non-projective SDNPHJun04 is being processed)
- For more information please check the LCDG4 documentation web page: http://nicadd.niu.edu/~lima/lcdg4/, or under subdirectory doc of CVS module

Summary

- Official test beam simulator is in good shape (TBMokka)
  Post-processing and analysis tools are currently under development
- Full detector simulations:
  - Geant4-based tools are in place
  - LCDG4 replaces Gismo for output in SIO format
  - Mokka (database) and LCS (XML) can be used for standard LCIO output
  - Data samples available for general use at NIU server
    Anonymous access via ssh / scp:
    scpuser@k2.nicadd.niu.edu (pwd=lcd_2004): /pub/lima/lcdg4/v03-06
    See http://nicadd.niu.edu/~jeremy/admin/scp/ for detailed access instructions.

Plans

- A requirements doc for the next round of detector simulation tools has been posted to the LC forum:
  http://forum.linearcollider.org/ ⇒ Common simulation framework
  Please take a look and give us your feedback

- Development of a "DAQ simulator":
  - process output from detector simulation, and produce raw data files (energy depositions ⇒ ADC counts)
  - should allow parametrization of inefficiencies, noise and non-uniformities
  - test beam tools as first implementation

- Effects of decays in flight on PFA performance