Detector Simulations at NICADD

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NICADD / NIU

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Outline

- Motivations
- Full detector: LCDG4
  - features
  - status
- Test beam simulation: TBMokka
  - features
  - status
- Summary

Digital Hadronic Calorimeter?

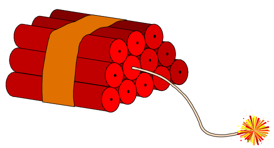
- High segmentation for better energy resolution: one bit (digital) or two bits ("semidigital" or multibit) per cell
- Questions to be addressed
  - Cost / performance optimization
  - Cell shapes (squares, rectangles, hexagons)
  - Cell dimensions
  - Absorber / active materials
  - Projective vs. non-projective calorimeters
  - Sampling fractions (number of layers, active to absorber ratios)

Detector Simulation Context

- Event generation
  (Pandora-)Pythia, Whizard, SingPartGen (java), or any other package with binary STDHEP output
- LCDG4 for detector simulation
  Other options: Mokka, Gismo (old, not Geant4) and LCS (under development at SLAC)
- Post-Geant processing (to be developed)
  digitization, cell ganging, noise, inefficiencies, non-uniformities, pile-up, etc.
- Analysis

What is LCDG4

- A Geant4-based detector simulator to support detector R&D for the Linear Collider
- Goal: replace long-used, unsupported Gismo
  - Input format: binary STDHEP
  - Output format: SIO only for now, LCIO also soon
  - Several detector geometries are implemented via XML geometry files



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

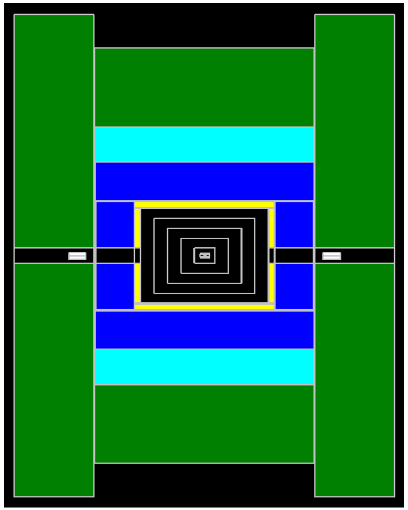
Geometry info in XML

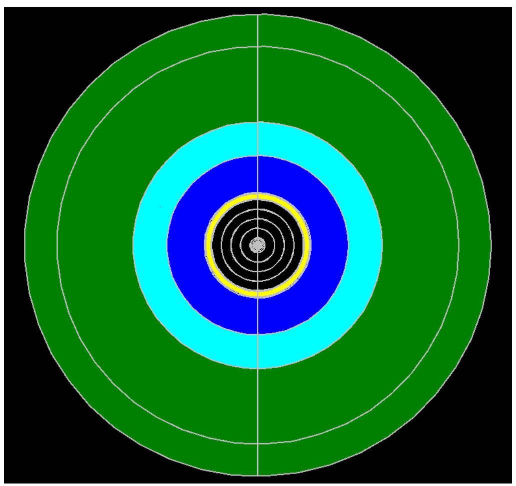
```
...
<volume id="HAD_BARREL" rad_len_cm="1.133" inter_len_cm="0.1193">
  <tube>
    <barrel_dimensions inner_r = "144.0" outer_z = "286.0" />
    <layering n="34">
      <slice material = "Stainless_steel" width = "2.0" />
      <slice material = "Polystyrene" width = "1.0" sensitive = "yes“ />
 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

- Flexible, easy to change dimensions, materials, layering, segmentation, etc.
- Error-prone, not very user-friendly

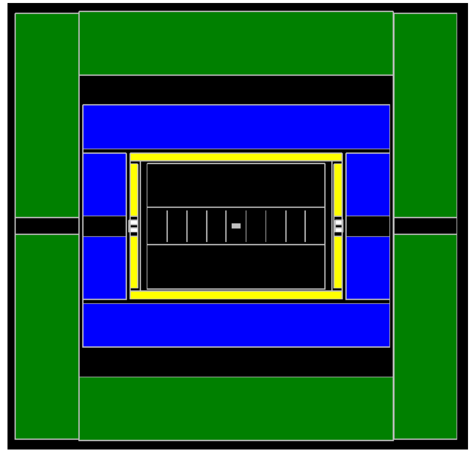
Options under study: SD, LD, PD

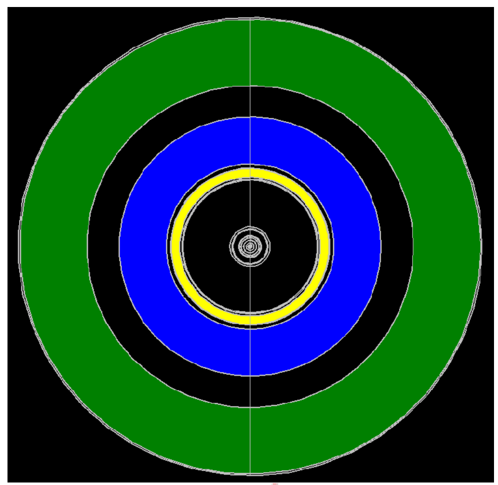
Silicon Detector



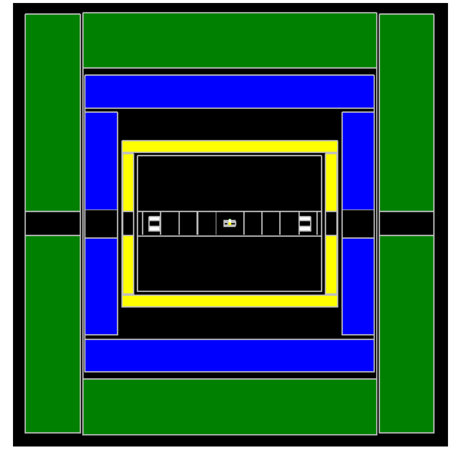


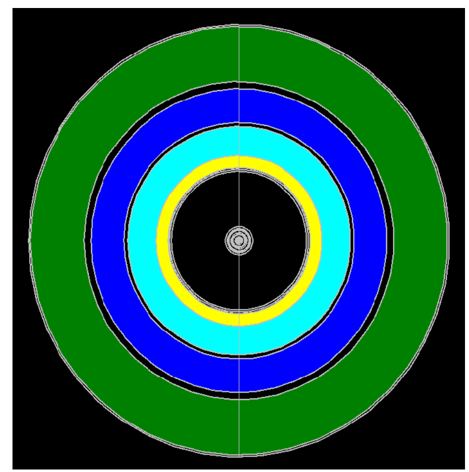
Large Detector





Precise Detector

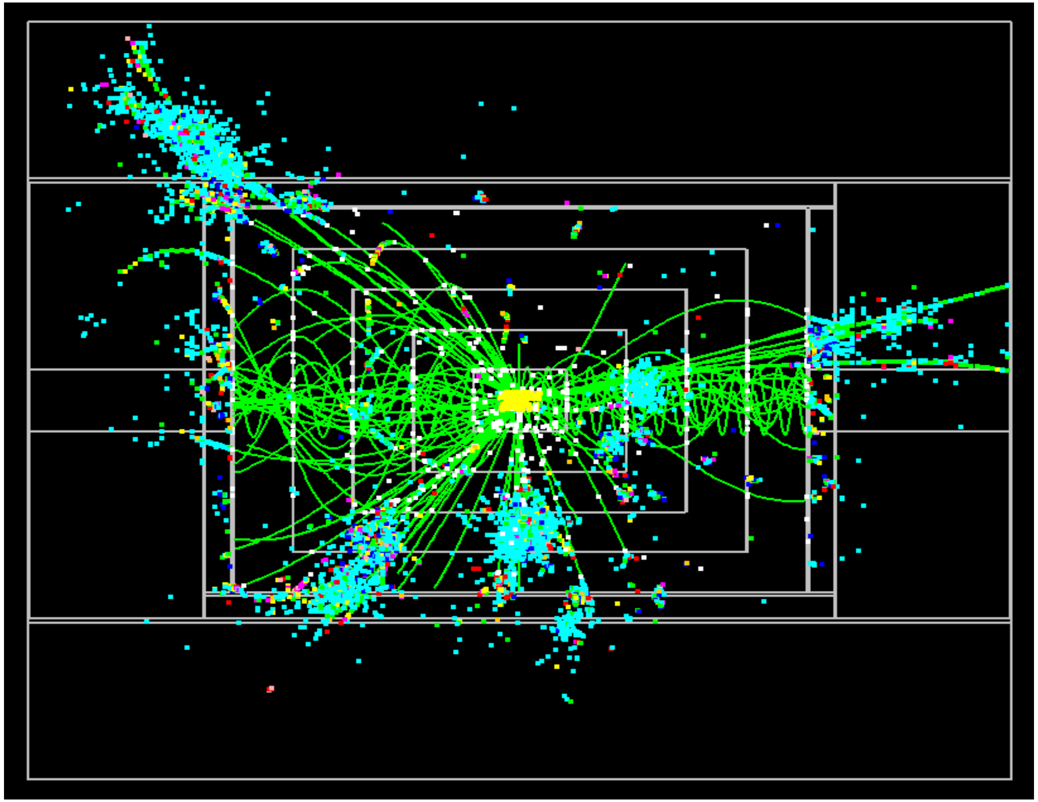


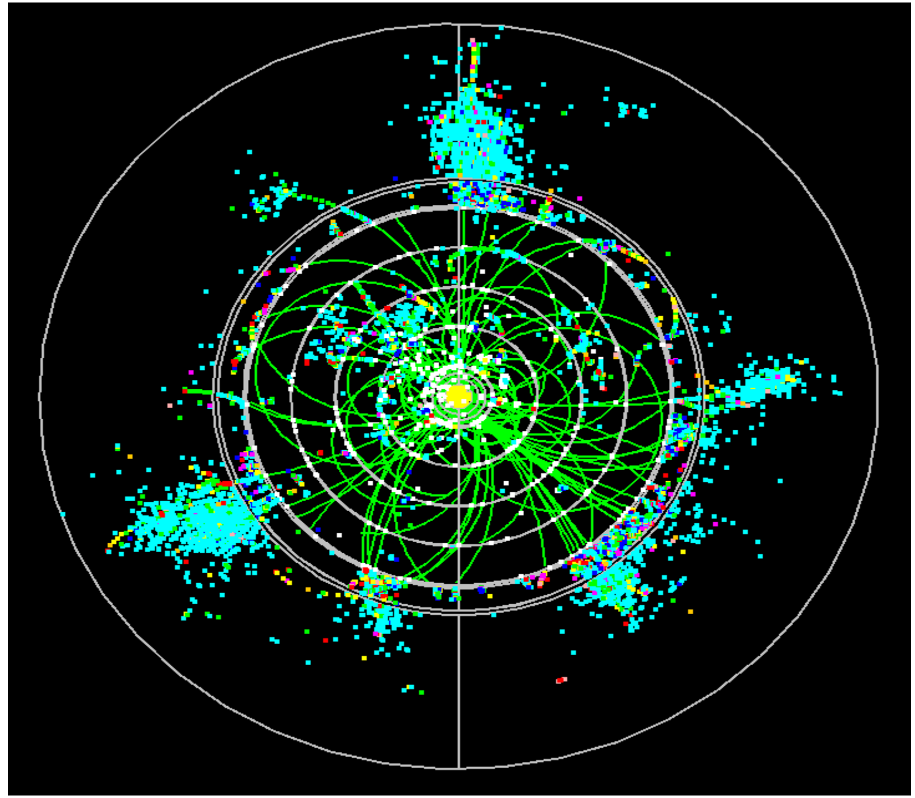


LCDG4: General features

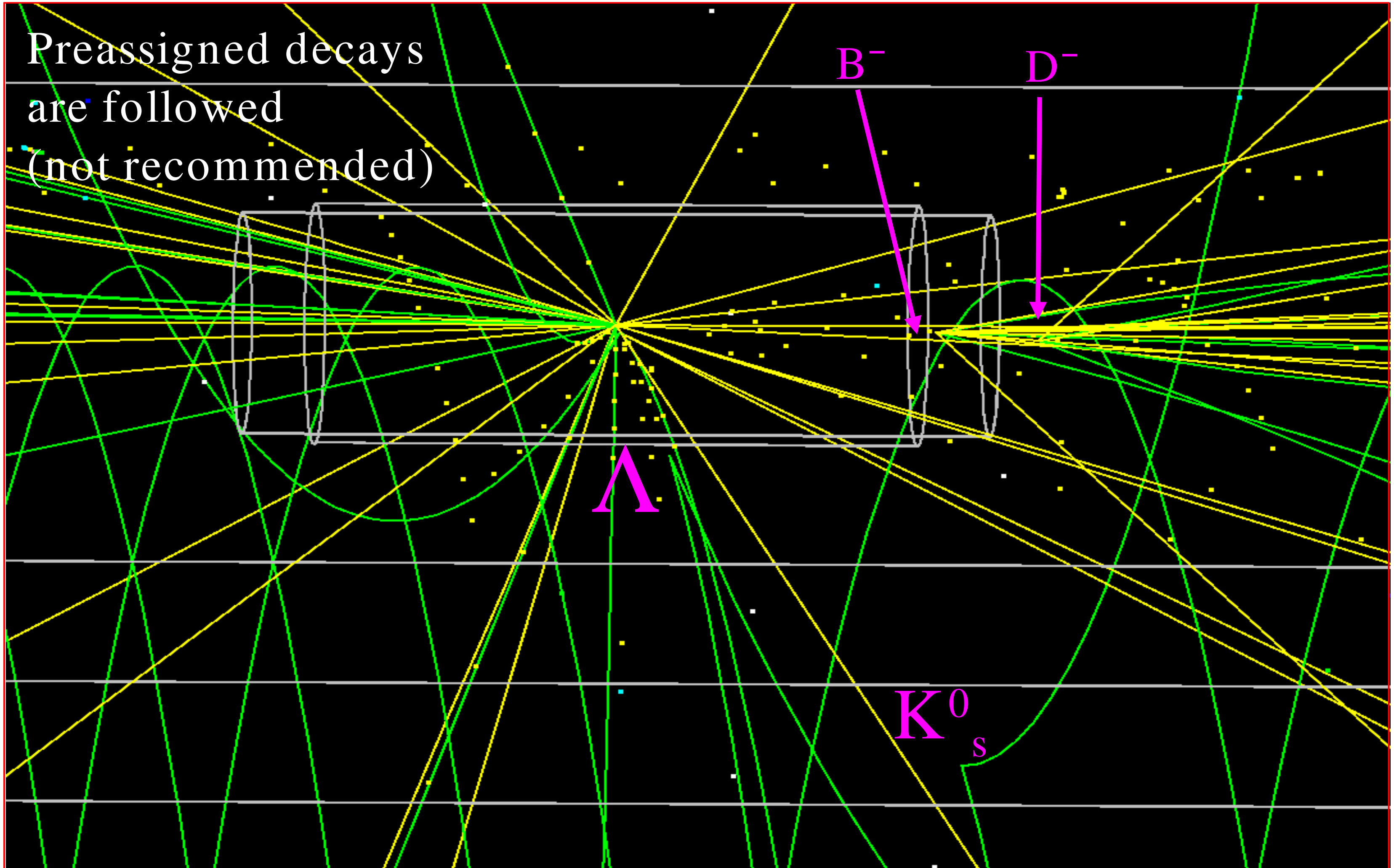
- Output contents: one particle collection and several hit collections (one collection per subdetector)
- Each hit points to the contributing particles (except tracker hits from calorimeter back-scatterings, as in Gismo)
- All secondaries above an energy threshold (now set at 1 MeV), except for shower 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 secondary particles (decay or interaction)

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





Zoom on the primary interaction

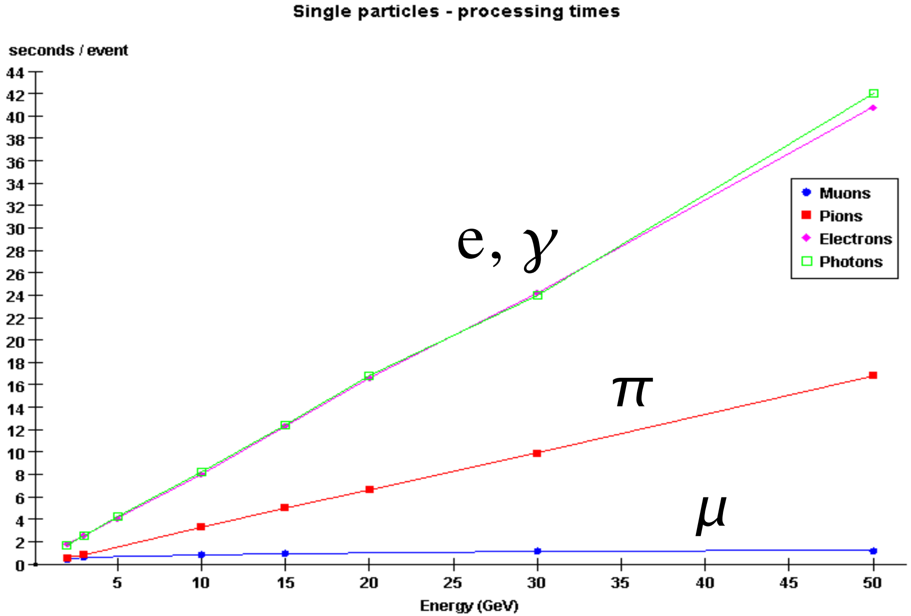


G.Lima, ICAR, May 19,2004

LCDG4 processing times

(in a 2.4 GHz CPU)

- 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 $Xb\bar{b}$ @ 500 GeV: 2.89 min/evt
  - WW to $q\bar{q}b\bar{b}$ @ 500 GeV: 2.97 min/evt

Mokka and LCDMokka

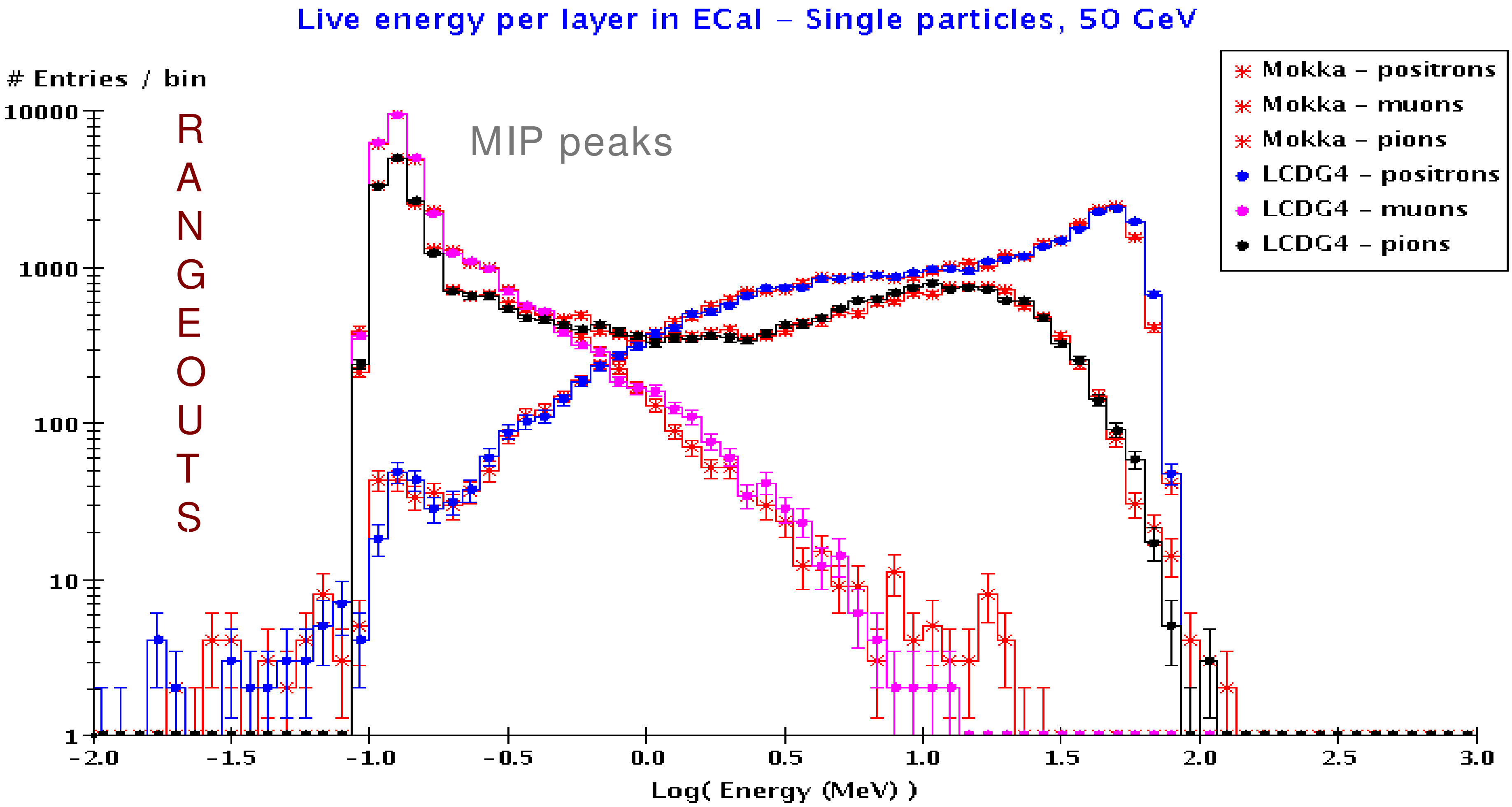
- Mokka is another Geant4-based simulation framework for Linear Collider R&D
- Detector geometry is described using a MySQL database
- Based on Tesla model, many other models and prototypes have been added into the geometry database
- Input: ASCII StdHEP / Ouptut: ASCII or LCIO
- For more info, please visit Mokka web site:

  http://polywww.in2p3.fr/geant4/tesla/www/mokka/mokka.html
- LCDMokka: XML capabilities into Mokka v01-05 (latest version is v02-03), while LCDG4 is not able to use MySQL geometry files (e.g. Tesla)
- Used LCDMokka for comparisons with LCDG4

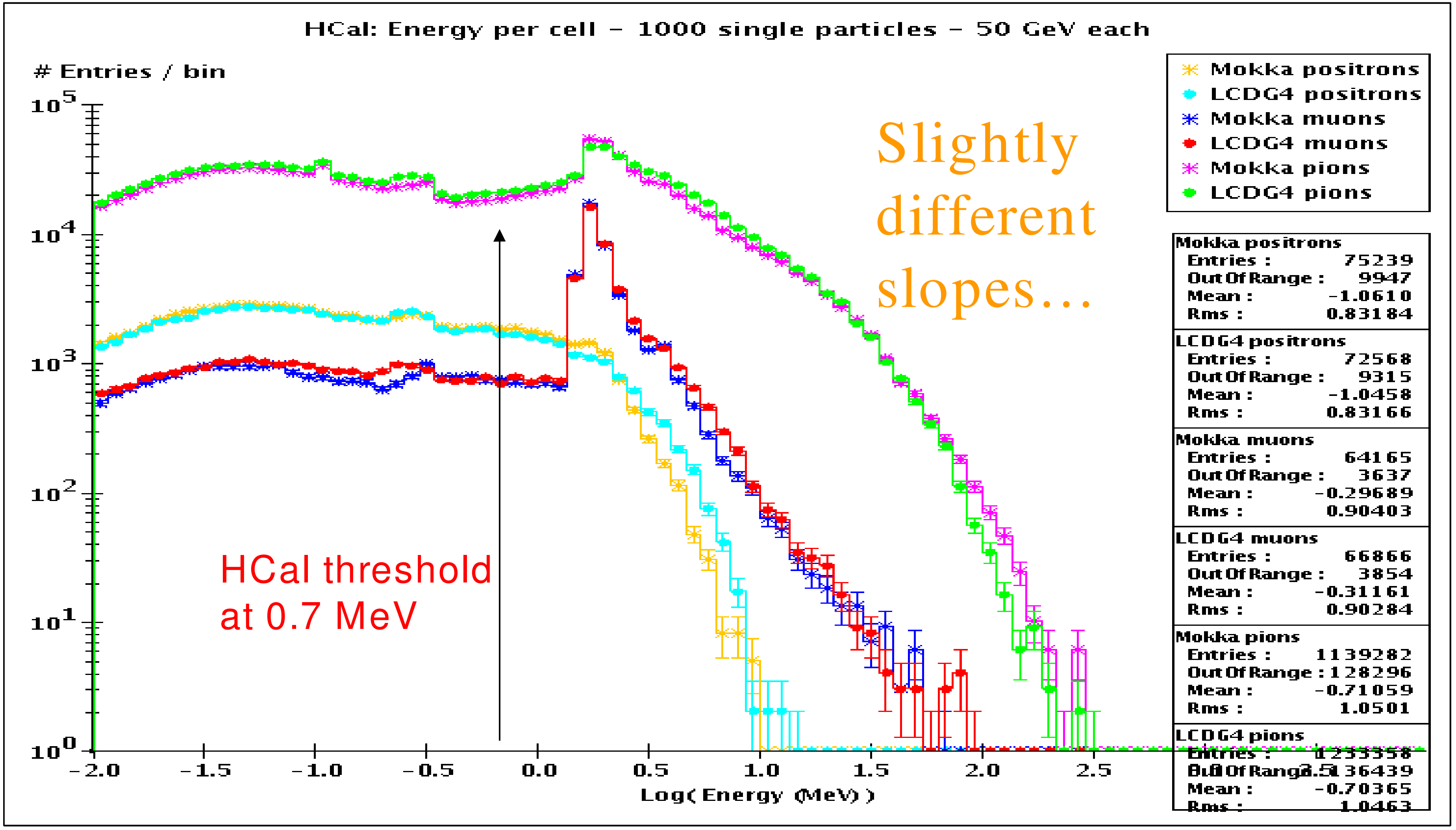
Fair comparison

- Geant4 version 5.2
- SDJan03 geometry
  (cylindrical layers with virtual cells)
- Physics list from Mokka v01.05
- Range cut of 0.1mm
- Identical I/O formats (binary stdhep input, text output) implemented into both simulators
- Same events processed in both detector simulators
  single particles: 50 GeV $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $\theta = 90°$, flat in φ
- Same materials in sub-detectors (look at X_0, λ_I)

Ecal: energies per layer



Hcal: energies per cell



MC Samples for general use

- Samples currently available at NIU through sftp:
  scpuser@k2.nicadd.niu.edu (lcd_2004): /pub/lima/lcdg4/v02-23
  - 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
  - 10K Z into (hadrons) at 91 GeV
  - 5K ttbar inclusive at 350 GeV
  - 5K WW into (hadrons)(any) at 500 GeV
  - 2K ZH into (any)(bbbar) at 500 GeV and M_H=120 GeV
  - 2K ZH into (any)(bbbar) at 500 GeV and M_H=160 GeV
- 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/v02-23
sftp> ls   (to see a list of .sio files available)
sftp> mget muons-10gev*.sio    (for example)
sftp> quit
%
```

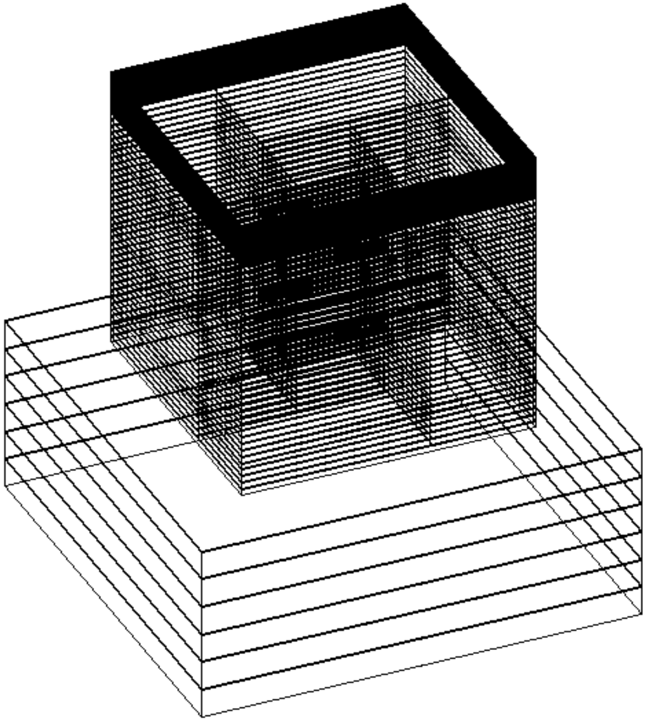
See http://nicadd.niu.edu/~jeremy/admin/scp/index.html for more detailed access instructions, including instructions for windows winscp utility.

LCDG4 status summary

- Detailed comparisons between LCDG4 v02-11 and LCDMokka 01-05 are in good agreement (discrepancies of ~20% to Gismo have been observed)
- LCDG4 faster than Mokka, but it cannot be used for Tesla geometry
- Only cylinders, disks and cones supported by current LCDG4 version (like Gismo). More realistic geometries to be implemented in the medium term
- Several MC physics samples have been generated for algorithm development and studies (SIO format)
- Source code available from SLAC or NIU CVS repositories
- For more information please check: http://nicadd.niu.edu/~jeremy/lcd/lcdg4/index.html

Test beam prototype simulation

- TBMokka
- Based on Mokka/Geant4, MySQL, LCIO
- NICADD / DESY collaboration for CALICE test beam simulation development



Layering Geometry

Single layer thicknesses (mm)

ECal

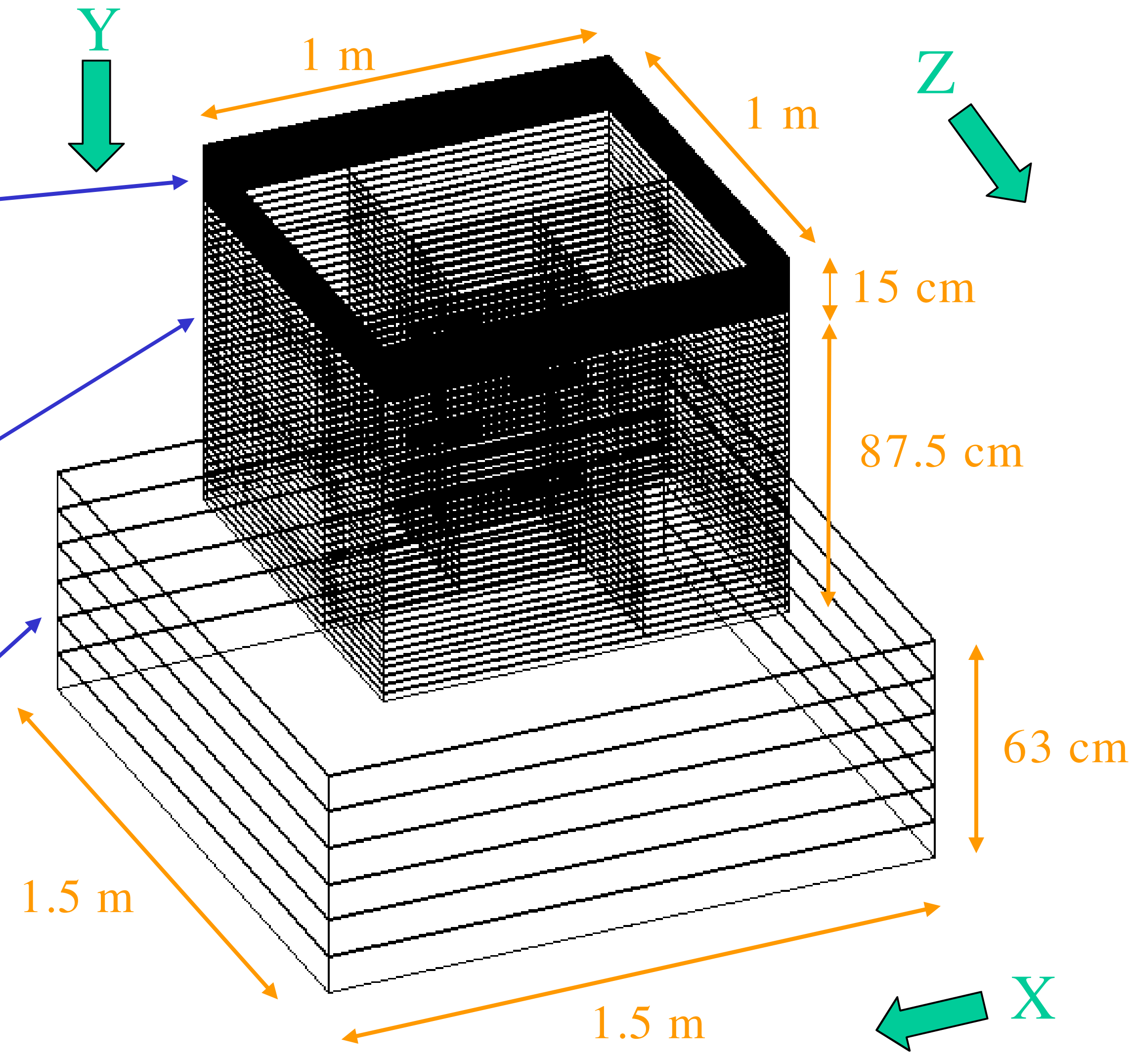
Tungsten	2.5
G10	0.5
Silicon	0.4
Copper	1.0
Air	0.6

HCal

Polystyrene	5
Steel	25

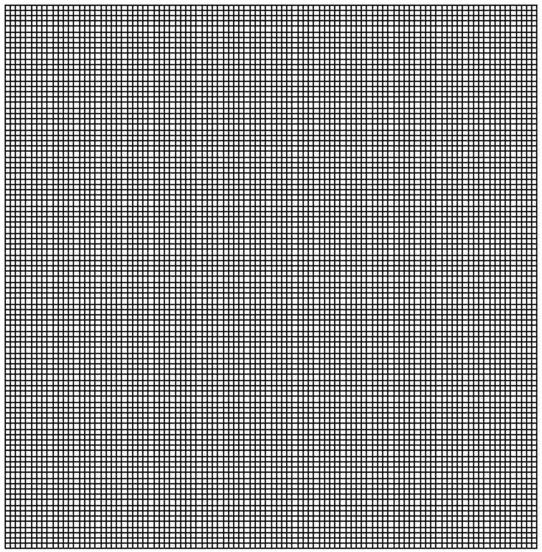
Tail Catcher

Polystyrene	5
Steel	100



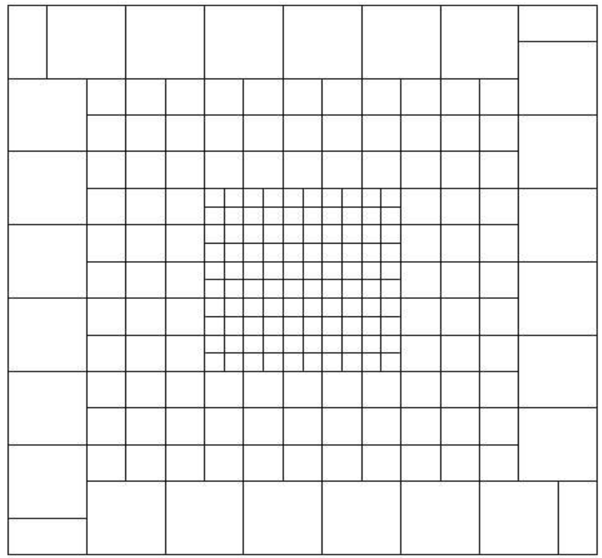
TBMokka: cell geometry

ECal



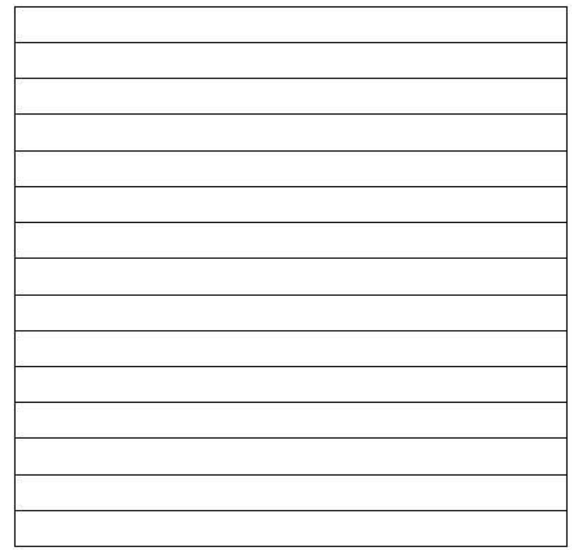
1cm x 1cm cells
30 layers
1m x 1m total

HCal



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

Tail Catcher



150cm x 10cm cells
16 layers (hor / vert)
1.5m x 1.5m total

TBMokka geometry persistency model

table
field
value

model
name
TB00

ingredients
sub_detector
TBcatcher00
TBecal00
TBhcal00

sub_detector		
name	*db*	*driver*
TBcatcher00	TBcatcher00	TBcatcher00
TBecal00	TBecal00	TBecal00
TBhcal00	TBhcal00	TBhcal00

TB Driver Databases

TBcatcher00

- catcher
  - n_layers
  - layer_start
  - y_place
- layer
  - cell_width
  - n_cell
- layer_thickness
  - poly_thickness
  - steel_thickness

database

- table
  - field

TBecal00

- ecal
  - n_layers
  - y_place
- layer
  - cell_dim_x
  - cell_dim_z
  - n_cell_x
  - n_cell_z
- layer_thickness
  - w_thickness
  - g10_thickness
  - si_thickness
  - cu_thickness
  - air_thickness

TBhcal00

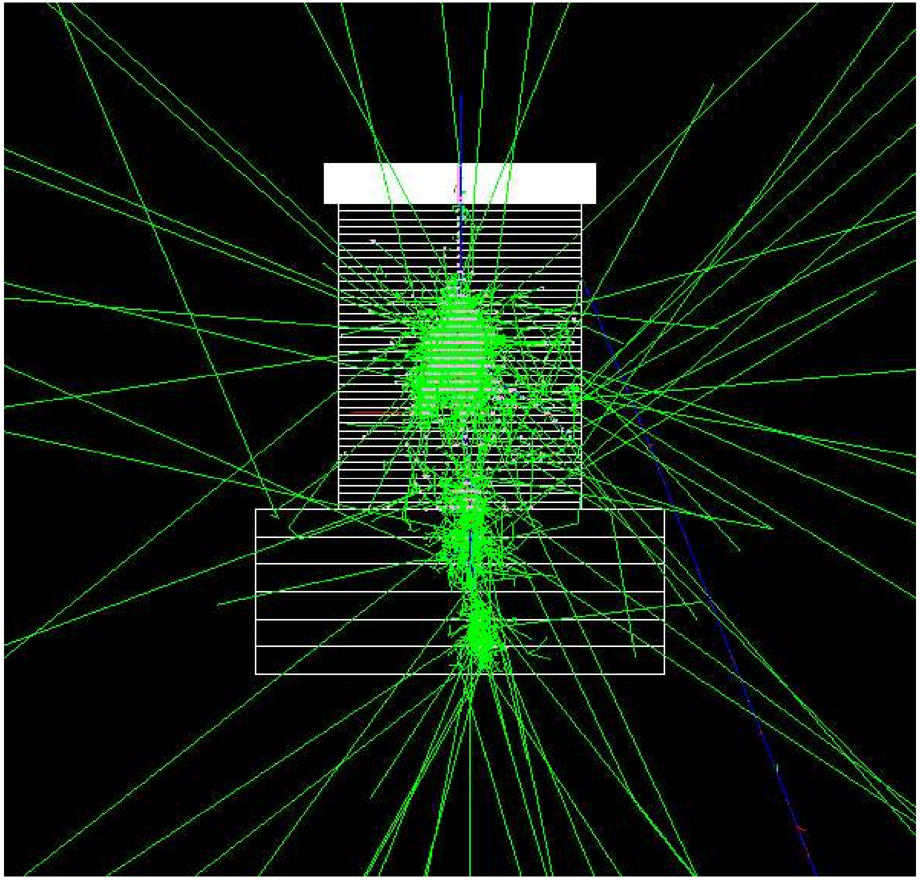
- hcal
  - n_layers
  - n_complex
  - y_place
- layer_inner
  - cell_dim_x
  - cell_dim_z
  - n_cell_x
  - n_cell_z
- layer_outer
  - cell_dim_x
  - cell_dim_z
  - n_cell_x
  - n_cell_z
- layer_thickness
  - poly_thickness
  - steel_thickness

TBMokka: other features

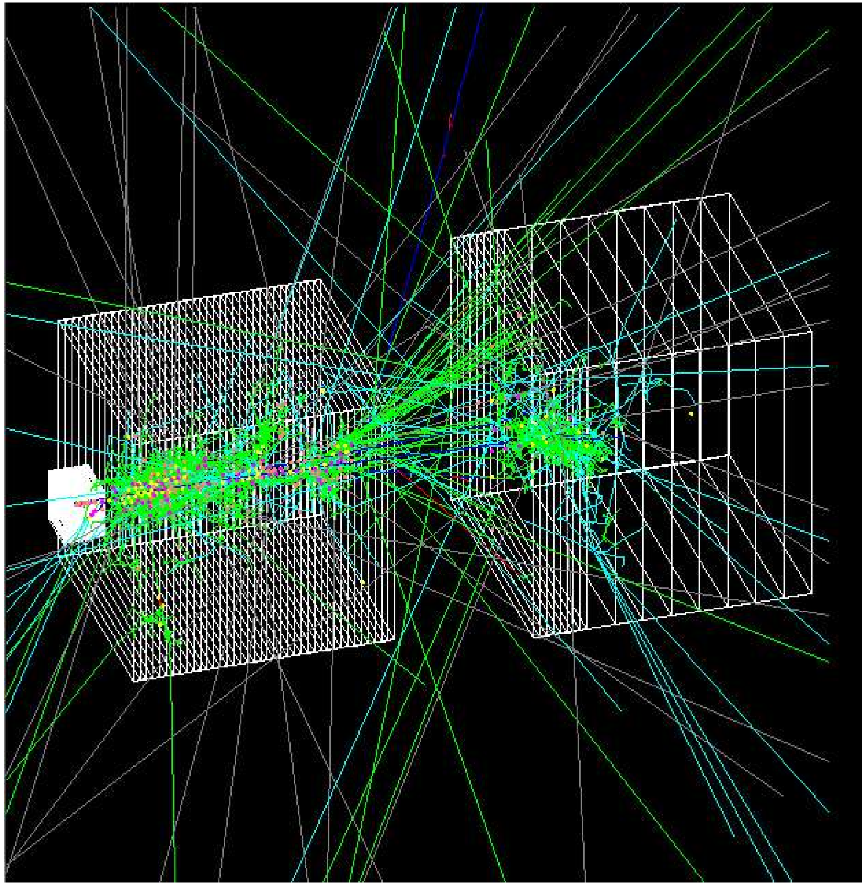
- Virtual 1cm x 1cm cells for better performance and reuse of simulated data for different cell configurations
- Implementation uses general concepts for any box-like detector
- A standalone version (no Mokka) also exists, with some additional features
- Well documented at http://nicadd.niu.edu/~jeremy/lcd/tbeam/index.html

Test beam event Displays

2 GeV Piplus



50 GeV Piplus, with a test geometry: 18x18cm Ecal and air gap before a fine+coarse tail catcher



Summary

- NICADD is actively involved with both full-detector and test beam simulations for the next Linear Collider
- Discussions are under way to unify/merge all existing full-detector simulation packages worldwide for a common simulations package (see document to be posted at the Full Simulations forum, http://forum.linearcollider.org/)

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