Development of Tera-pixel Digital Calorimeter for the International Linear Collider

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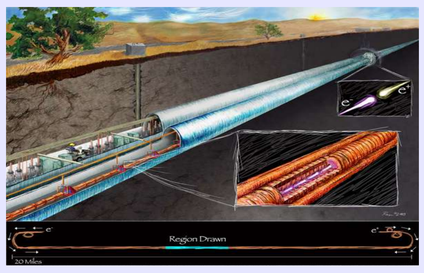
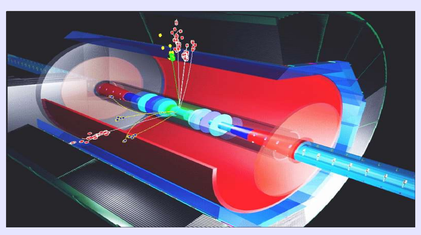
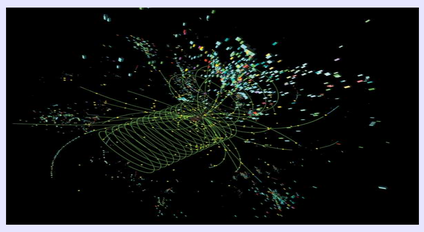
Abstract

In high energy e^+e^- physics experiments, the most important measurements require a high-granularity calorimeter which can identify distinct energy deposits from each of the many particles produced. We are developing a digital calorimeter that will have 10^{12} pixels, each 50x50 μm^2, to measure individual minimum ionizing particles which are produced during an electromagnetic shower cascade. This unprecedented level of granularity is expected to give better performance at significantly lower cost than existing designs, and is particularly important for TeV energy scale experiments such as International Linear Collider. Our GEANT4 simulations of a silicon-tungsten digital calorimeter detector have shown that minimum ionization of individual particles after cascade can be detected even for a 100 GeV scale of incoming particle. This work is part of a full R&D project which will demonstrate a technological prototype by 2009.

Introduction





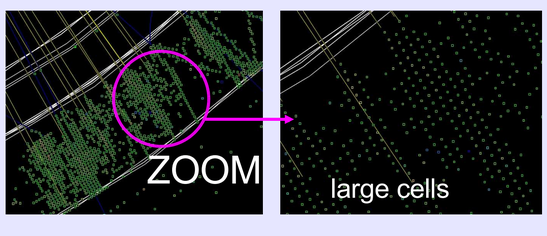


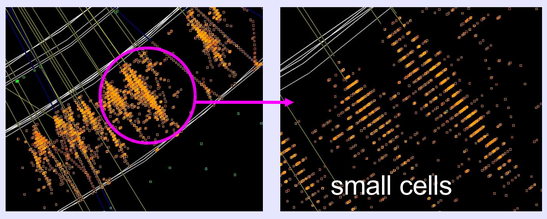
International Linear Collider

- Energy frontier of particle physics

- **High granularity calorimetry**
  - Detection of individual particles after electromagnetic shower by small cells
    - → **Digital Calorimetry**

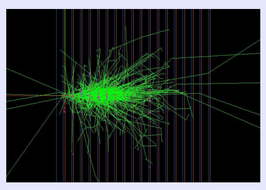
- **Cost saving**
  - Using CMOS (complementary metal oxide semiconductor) silicon
    - → **Cheaper than pure silicon**

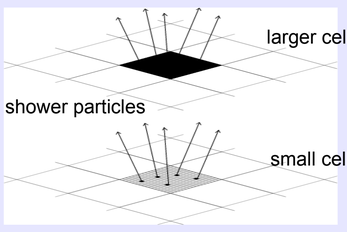


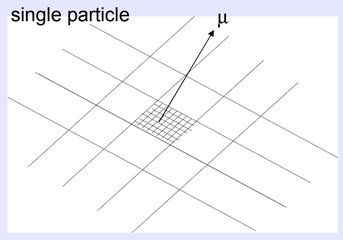


Energy deposit

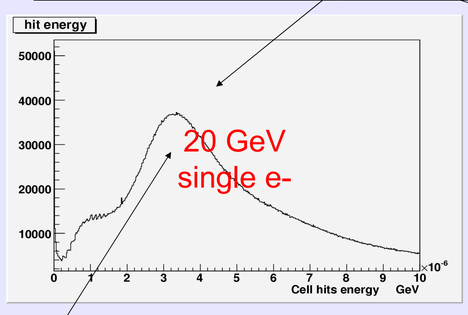
15μm silicon sensitive thickness
50μm X 50μm cell size

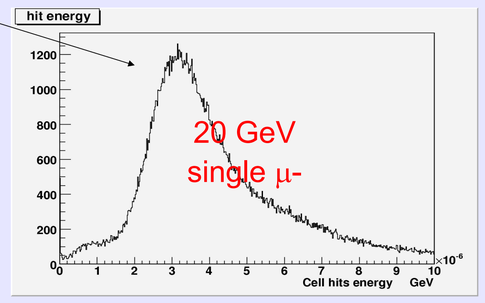






Minimum Ionization Particle's peak



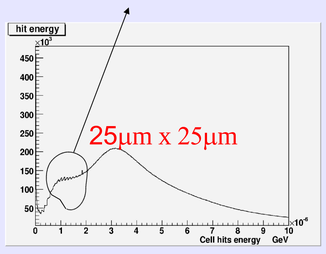


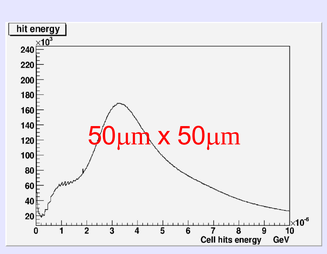
Individual secondary particles are detected after electromagnetic shower cascades !!

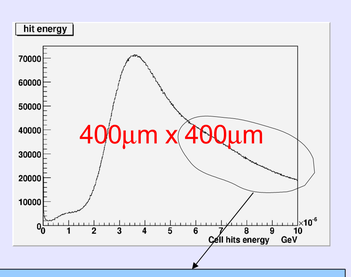
Cell size dependence

100GeV single e-
15μm silicon sensitive thickness

Charge sharing at cell boundary.





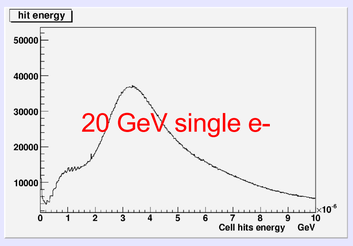


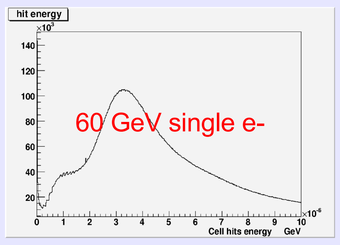
Multi particles in a cell increase the tail.

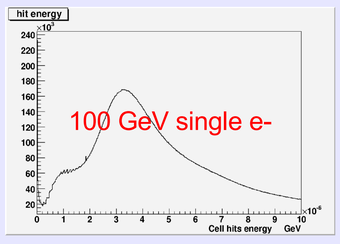
→ 50μm X 50μm cell is a reasonable size.

Incoming energy dependence

15μm silicon sensitive thickness
50μm X 50μm cell size





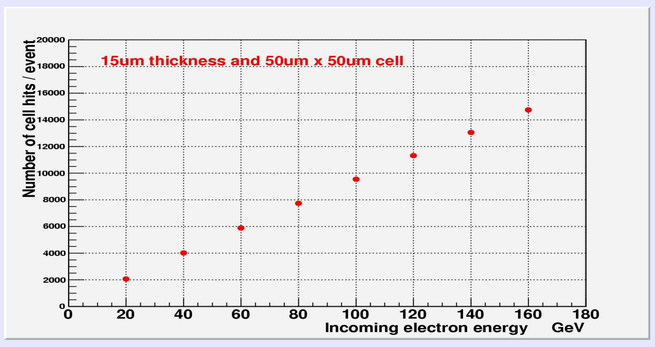


Similar distributions for different energies except for numbers of hits.

→ One particle per cell

→ Digital calorimetry

Linearity for energy measurement



→ Counting number of cell hits corresponds to measuring energy.

Conclusion

- We have implemented digital calorimeter geometry in GEANT4 full detector simulation.
- We can realize a digital calorimeter with using an order of 50μm X 50μm cell size.
- GEANT4 full detector simulation shows linearity for electron shower energy measurement.

Science and society

Particle physics tries to understand age-old questions regarding the very nature of the smallest constituents of all matter. The digital electromagnetic calorimetry is a new concept and an ideal device for the investigation. It makes use of leading-edge developments in technology, and if realized, it could have wider applications in industry as well as for fundamental physics studies.

28th November 2006 at House of Commons