Simulation of Monolithic Active Pixel Sensors for ILC ECAL

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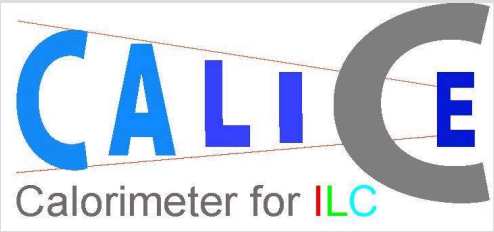
Y.Mikami, O.Miller, N.Watson, J.Wilson
University of Birmingham,

P.Dauncey, A-M.Magnan
Imperial College London,

J.Crooks, K.Stefanov, R.Turchetta, M.Tyndel, G.Villani
Rutherford Appleton Laboratory



Outline

- **Introduction**
- **MAPS (Monolithic Active Pixel Sensors)**
  - Concepts
  - Design
- **Geometry modification**
- **Single e-/μ- simulation**
  - Si sensitive thickness dependence
  - Cell size dependence
  - Incoming energy dependence
- **Summary of status**
- **Future prospects**

Introduction

- **High granularity**
  - Small cells
    - → **Digital Calorimetry**
- **Cost saving**
  - Using CMOS silicon
    - → **Cheaper than high resistance pure silicon**

MAPS concepts

- **Detecting individual particles after electromagnetic cascade shower by small cells**
  - Result in measuring a single particle in a cell
    - Binary readout
      - Digital calorimetry
        - → **High granularity**

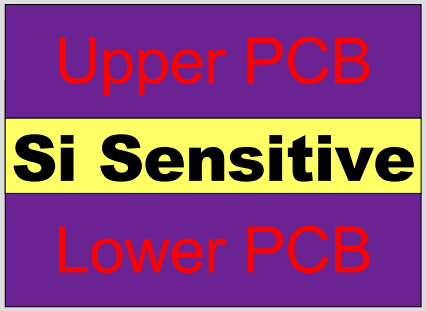
MAPS design

- Analogue design in Mokka
  - 1cm X 1cm cell
  - 500μm Si sensitive thickness
  - 500μm Si physical thickness
  - Analogue readout
- MAPS design
  - 50μm X 50μm cell
  - 15μm Si sensitive thickness
  - 500μm Si physical thickness
  - Binary readout

W thickness is the same with both cases.

Geometry modification in Geant4 simulation

Default



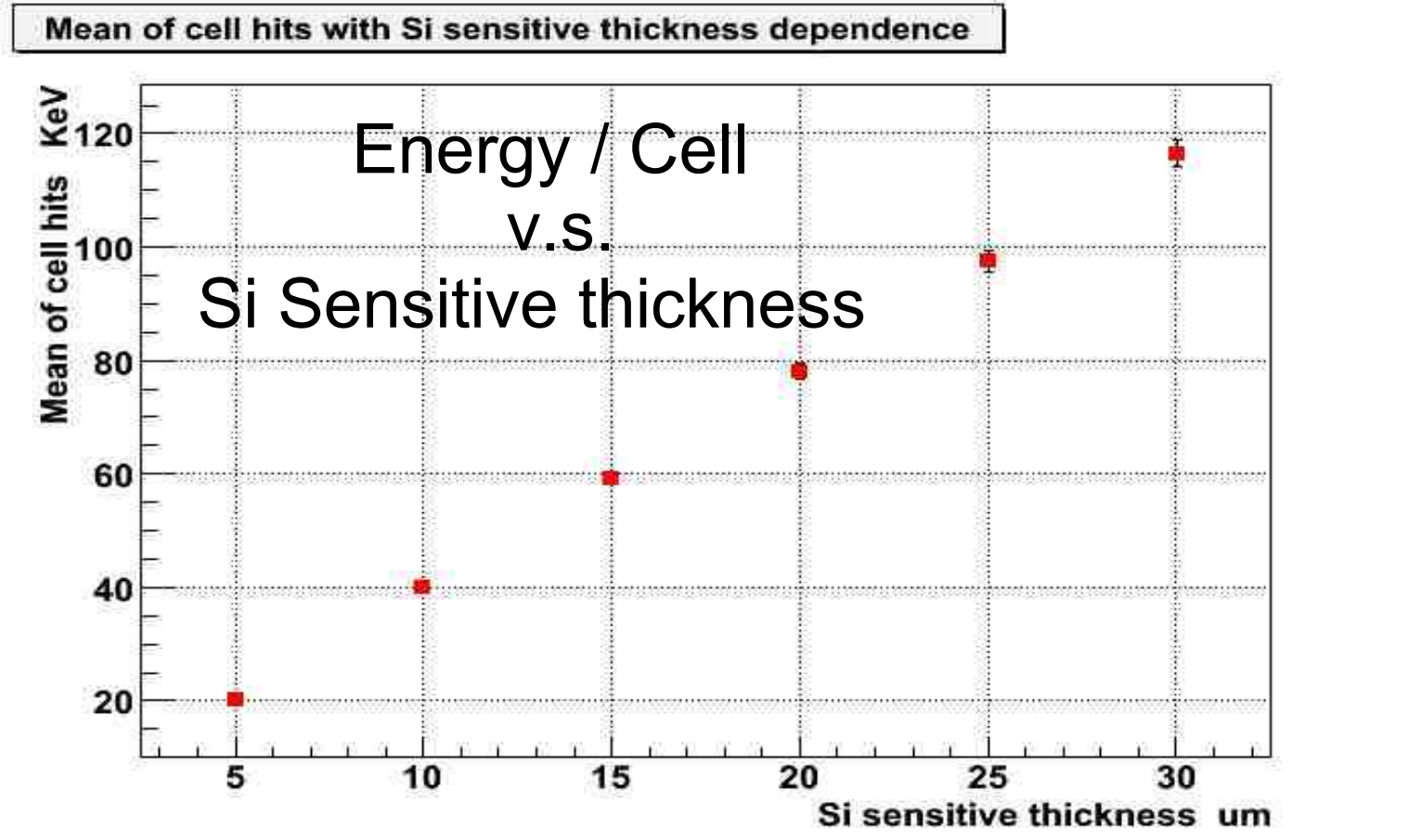
MAPS (test)

- Mokka 06-00
- Ecal02.cc (Geant4 ECAL driver) is modified.

- Geant4 Adaptive GUI output is fine.
- Energy deposit agreed with the expect. (i.e.15μm/500μm =3.0%)
- Layer position shift agreed with the expect.

Single e- simulation (1.a)
(Si sensitive thickness dependence)

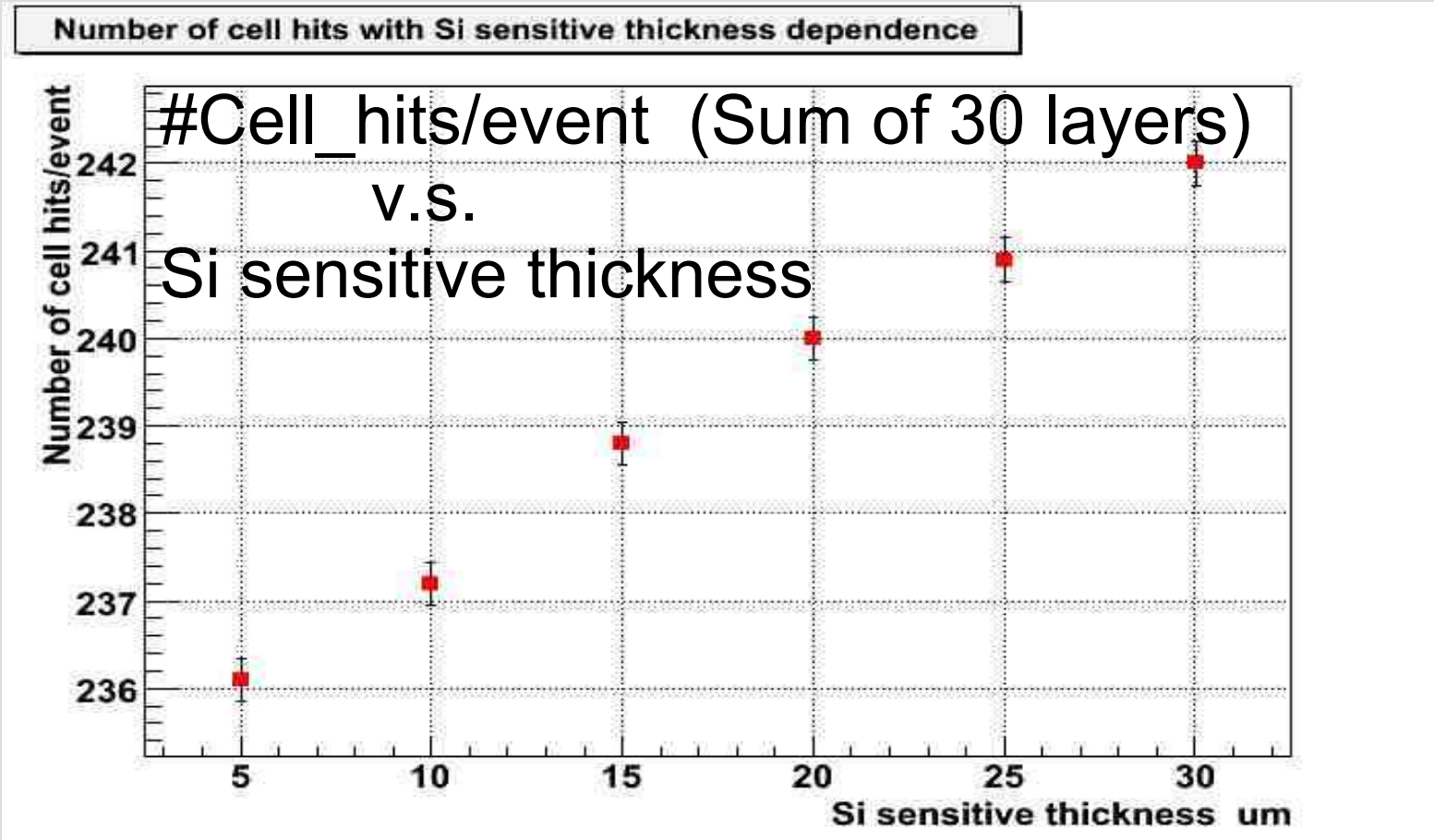
20 GeV single electron (from IP to zenith with magnet on)
Cell size is 1cm X 1cm



No threshold is applied for energy of cell hits

Single e- simulation (1.b)
(Si sensitive thickness dependence)

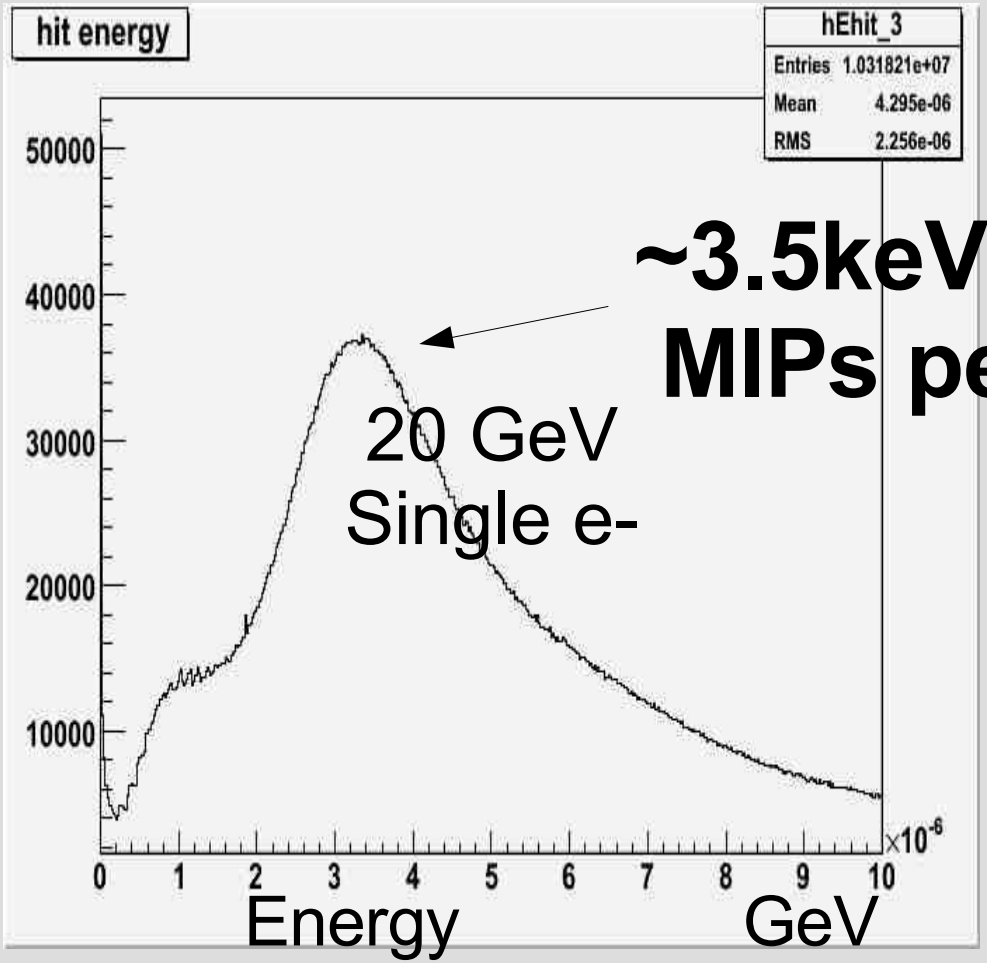
20 GeV single electron
Cell size is 1cm X 1cm



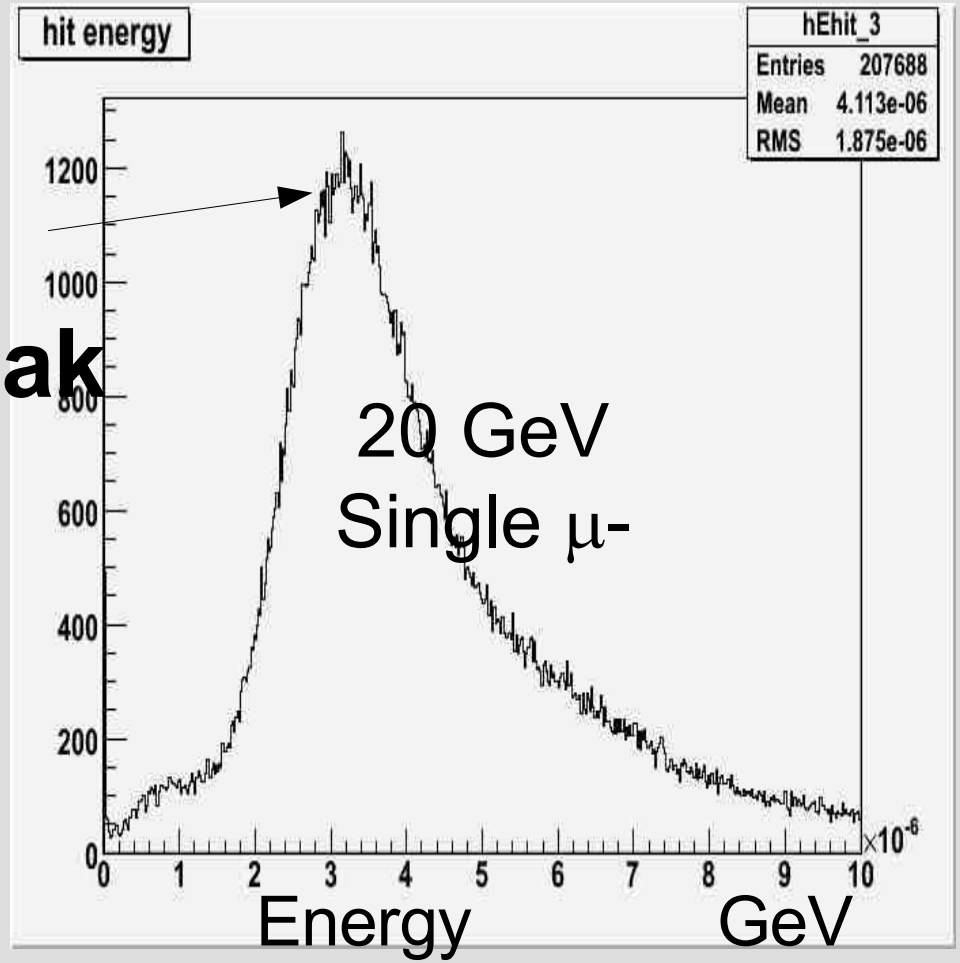
Only a few % dependence

Single e-/μ- simulation (2)
(Energy deposit of cell hits)

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



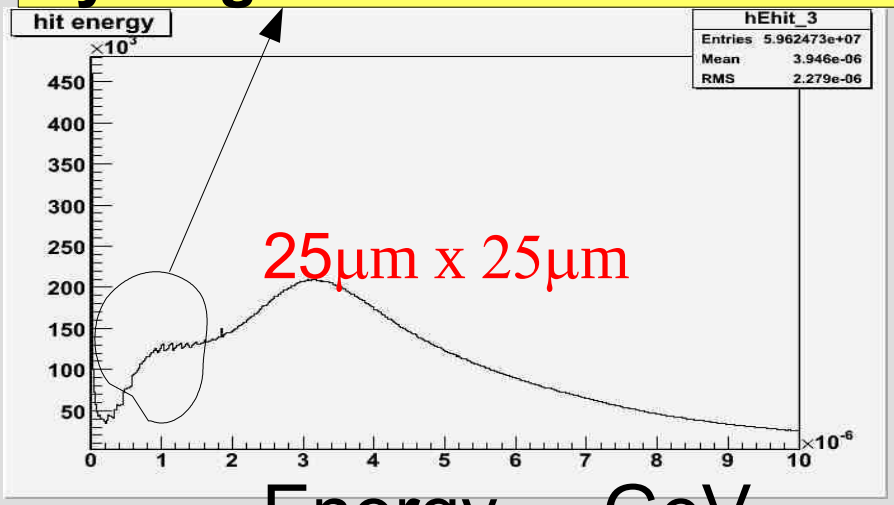
~3.5keV
MIPs peak

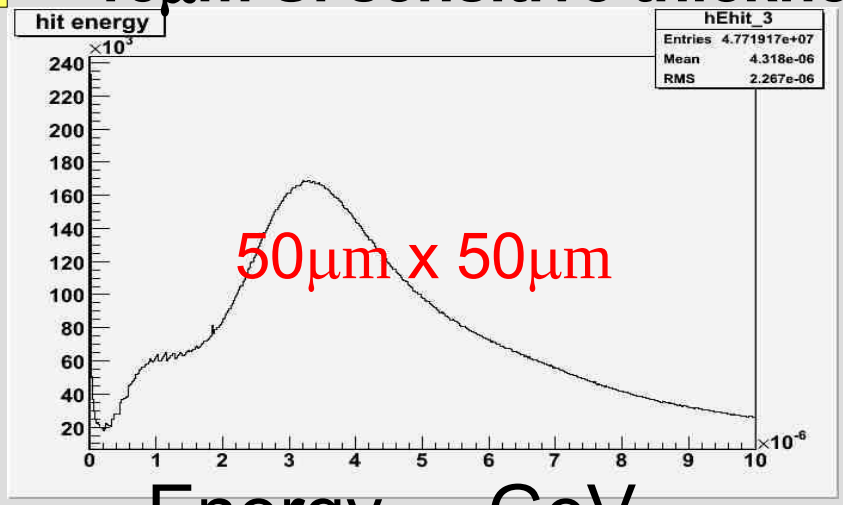


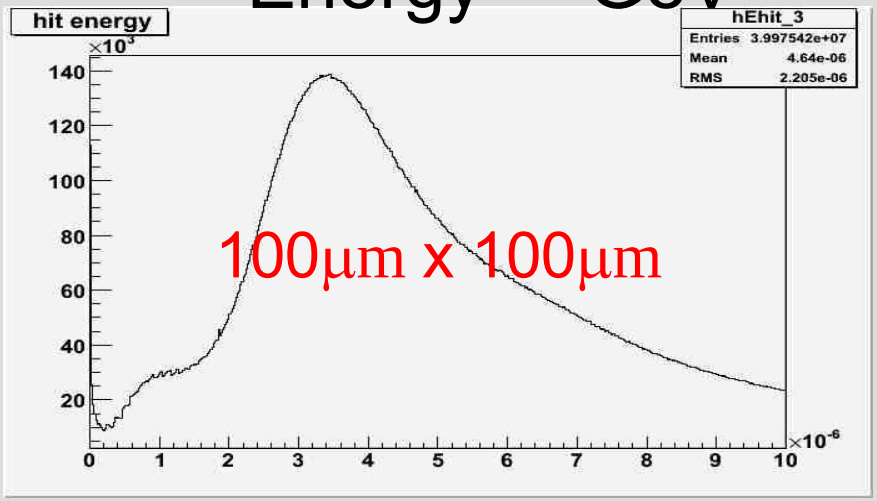
Single e- simulation (3.a)
(Cell size dependence)

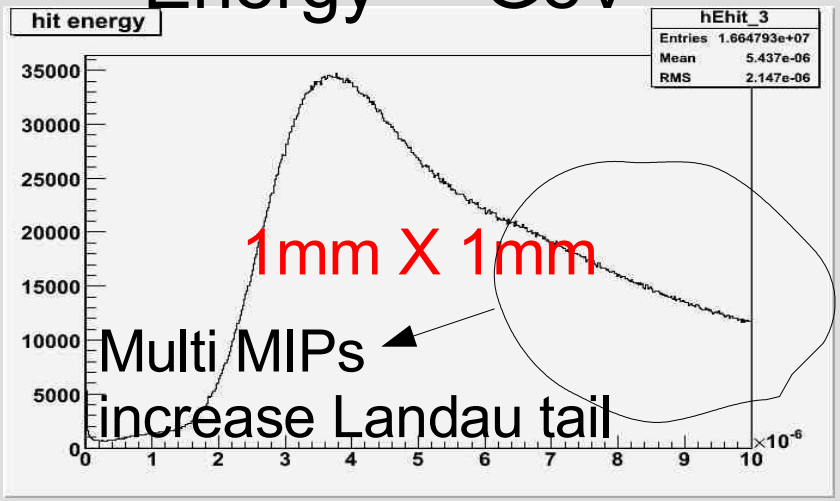
Energy of one MIP is sharing by neighbour cell at boundary.

100GeV single e-
15μm Si sensitive thickness

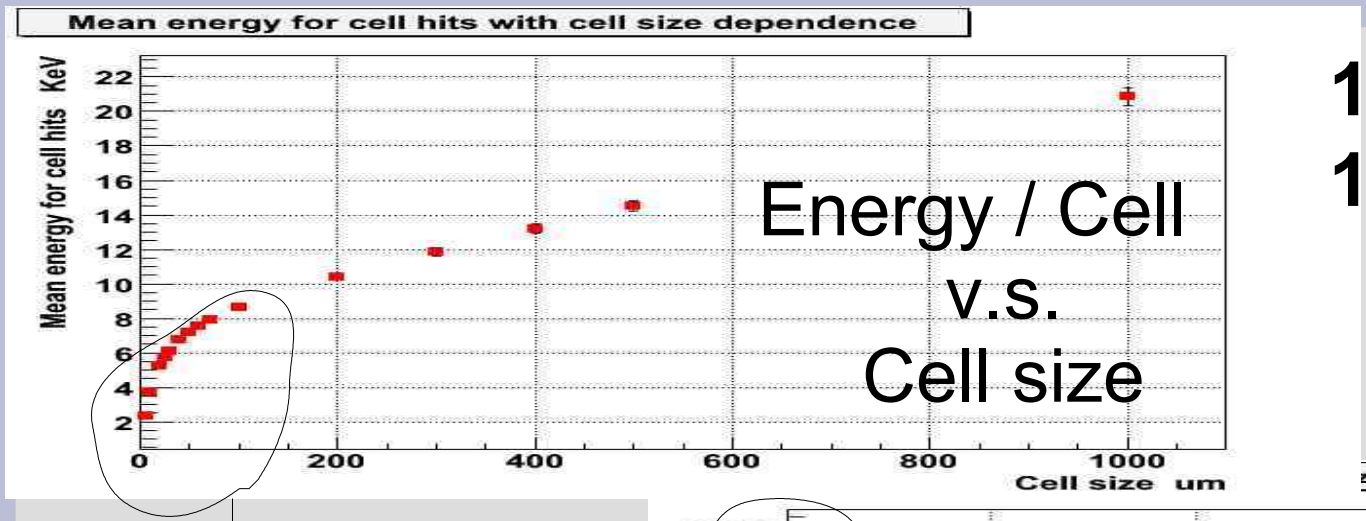




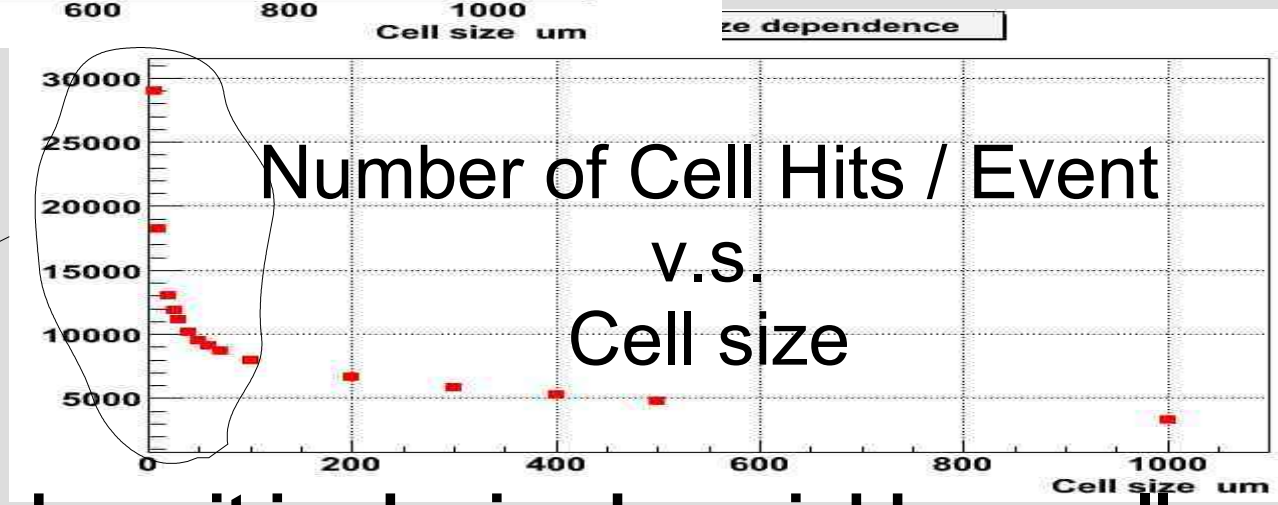




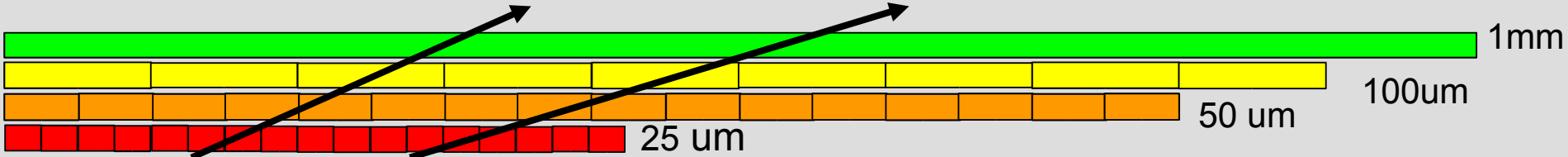
Single e- simulation (3.b)
(Cell size dependence)



100GeV e-
15μm Si sensitive

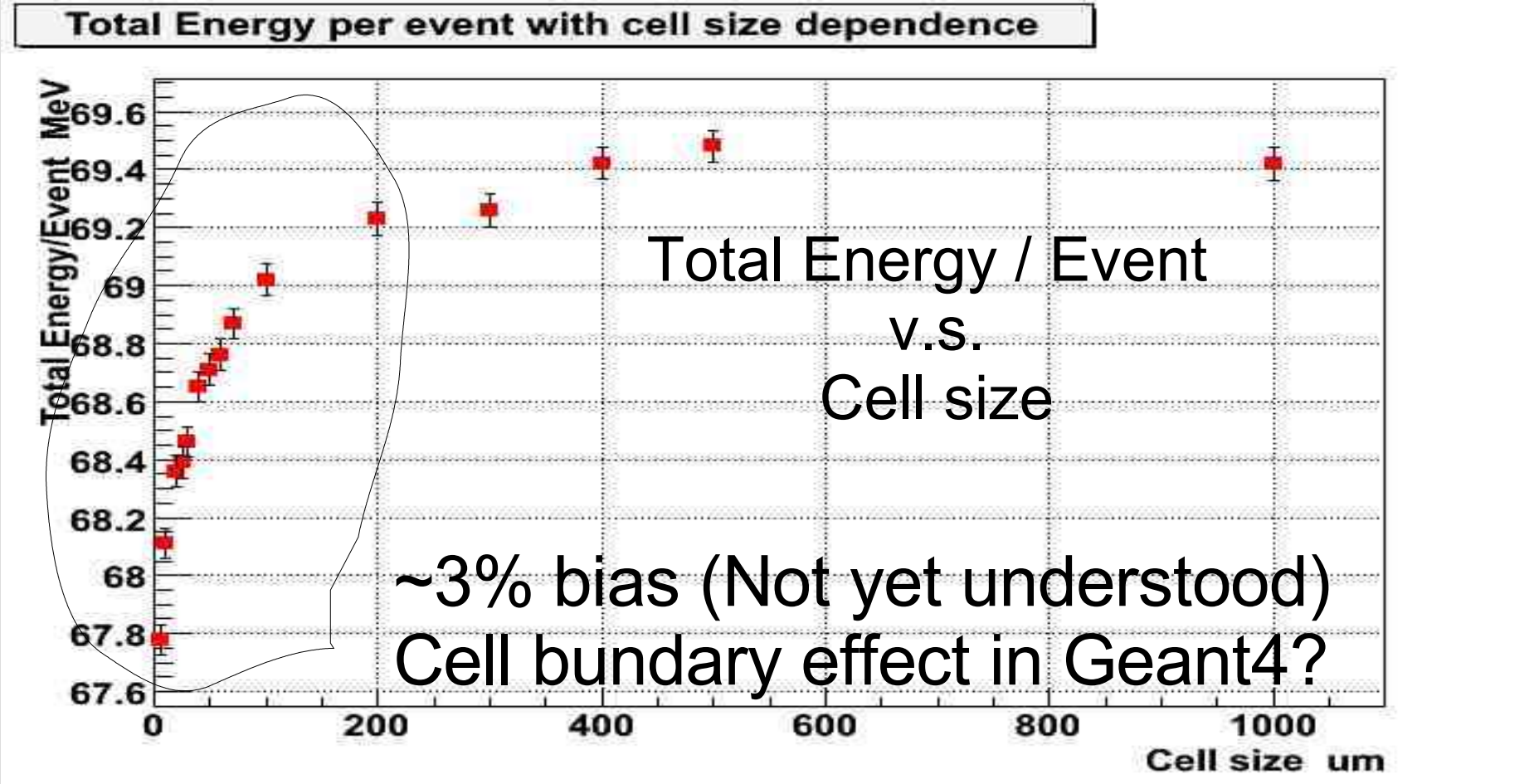


- **One MIP per cell**
- **One MIP's energy deposit is sharing by neighbour cell**



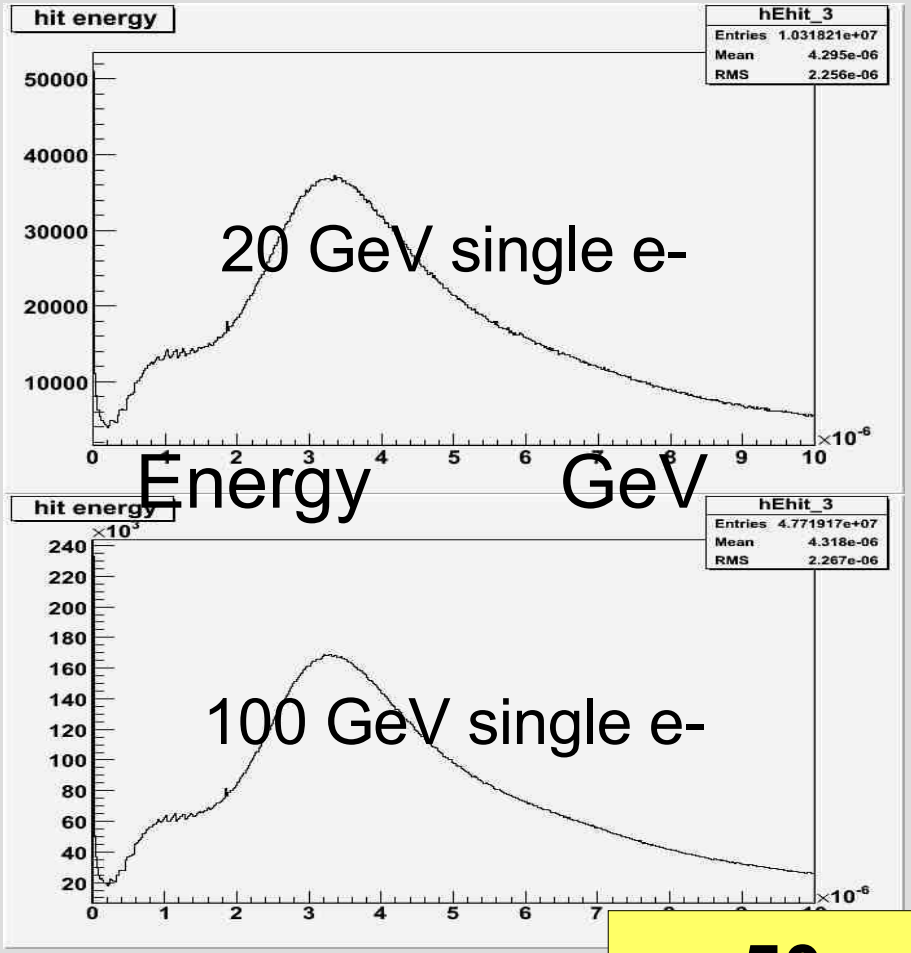
Single e- simulation (3.c)
(Cell size dependence: consistency checks)

100GeV e-
15μm Si sensitive



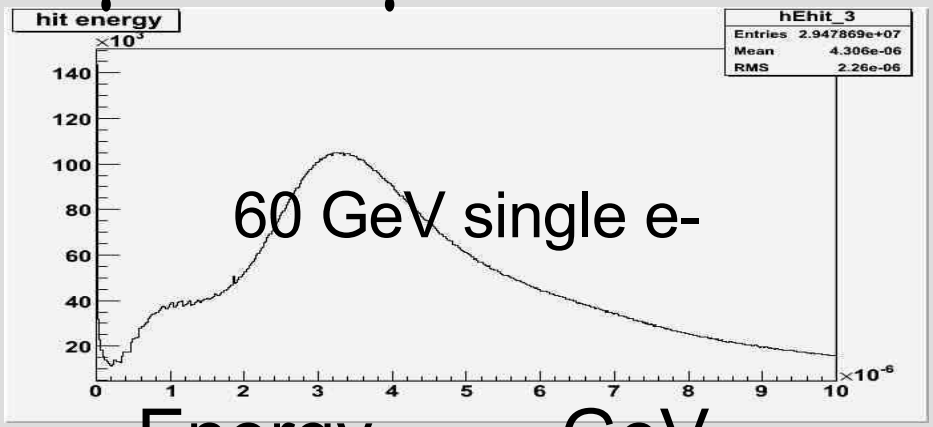
Single e- simulation (4)
(Incoming energy dependence)

Cell hits energy distributions



15μm Si sensitive thickness

50μm X 50μm cell size



Mean of peak is independent of incoming energy.

→ **One MIP per cell**

→ Digital calorimetry

→ **50μm X 50μm cell is enough small**

Cell hit number is proportional to incoming energy.

Summary of status

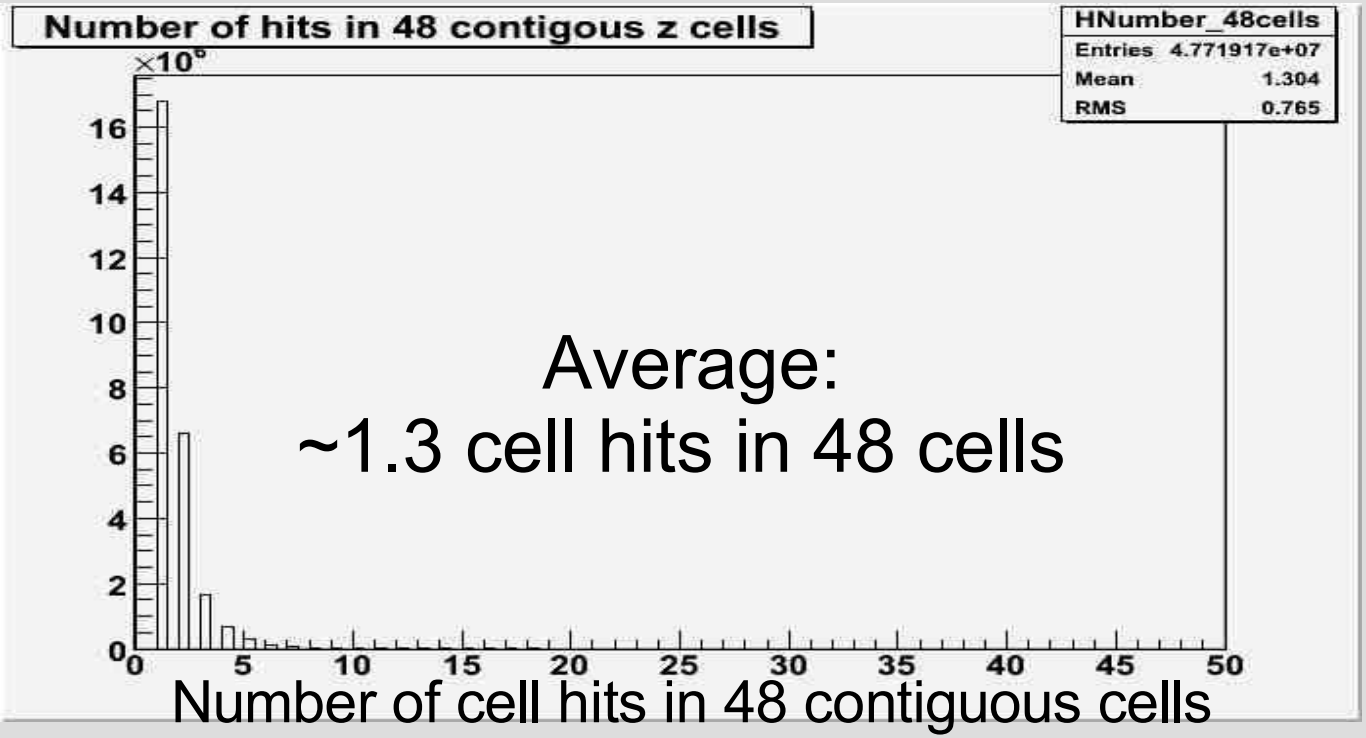
- **MAPS geometry inplementation is tested.**
- **Each cell has only one MIP in most case.**
- **Charge sharing by neighbour cell is seen.**
- **50μm X 50μm cell seems to be reasonable.**
- **Sensor level simulation is ongoing as well.**
  (Giulio Villani et al. -> please see Konstantin Stefanov's talk at calorimetry session.)

Future Prospects

- **Implementing MAPS geometry in Mokka new version**
- **Resolution studies**
- **Clustering algorithm development**
  - It can be developed only with shower topology. (i.e. Each cell hit has identical energy.)
  - Sophisticated algorithm to save CPU time in this Tera pixel study.
- **Comparison with Data**
- **Physics events studies**

Backup:
Readout by 48 contiguous cells
(Under study as one option)

100GeV single e-
15μm Si sensitive thickness
50μm X 50μm cell size



Average:
~1.3 cell hits in 48 cells

Total energy also increased 30% compared with single cell.