CALICE Summer Project

Studying the MAPS concept............

By Joseph Lilley

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Outline

- Motivation for Plan.
- Getting to grips with the software tools: SLIC, org.lcsim, GeomConverter and JAS3.
- Coding the MAPS Geometry.... Projective Geometry
- Calculating the MIP thresholds.
- Longitudinal response of ECAL.
- Comparing the Single particle energy/number response.
- Non-Projective Geometry.....
- Future Plans/Outlook

Aims/Motivation

- Comparison of baseline SiD analogue Si to MAPS ECAL.
- Metric for quantitative study: $Z \rightarrow q\bar{q}$ Invariant mass reconstruction.
- Test use of North American software packages
- Software Requirements:
  - Easy modification of geometry for MAPS
  - Ease of use of Analysis/Reconstruction package
  - Access to reconstructed events

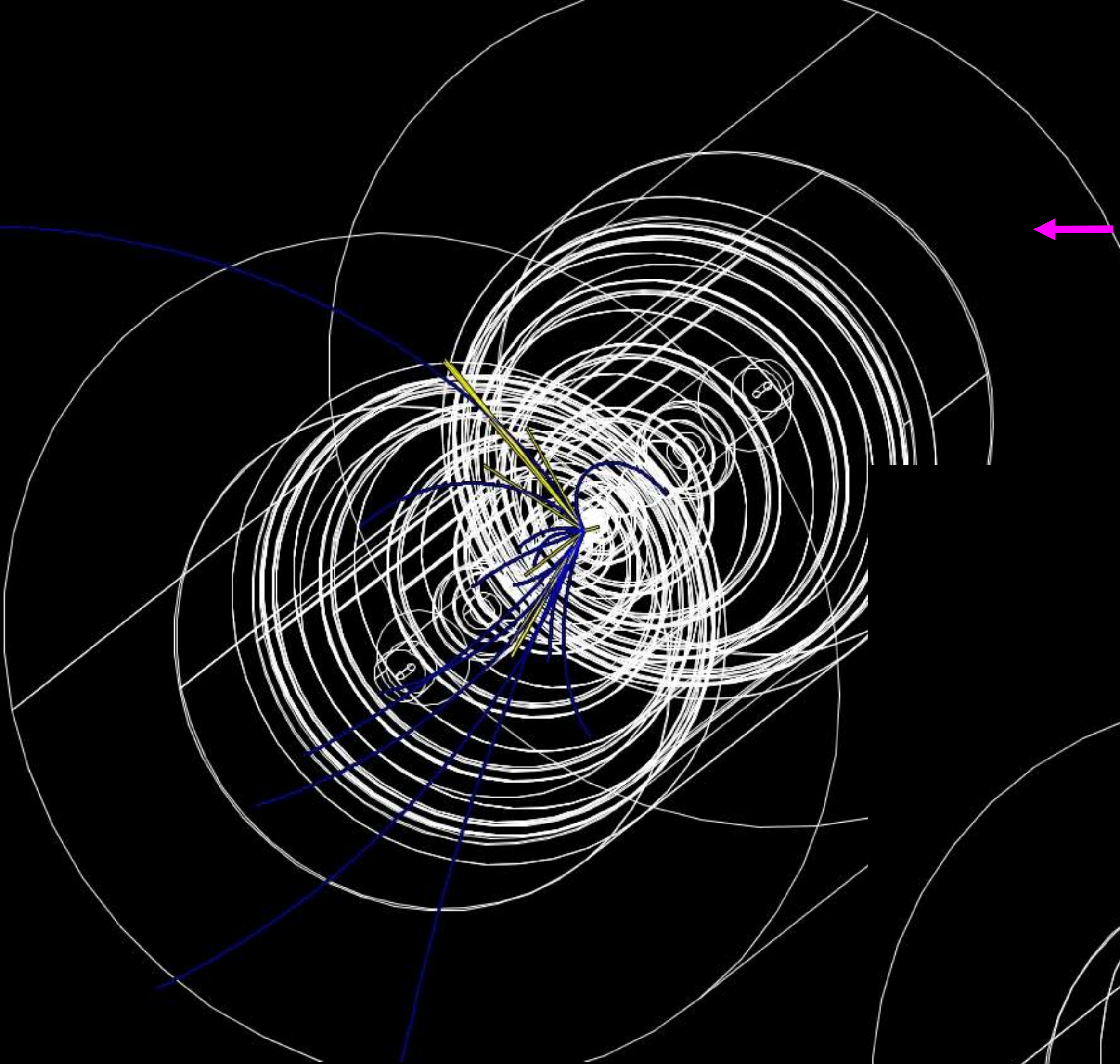
SLIC

- SLIC is a GEANT4 based full detector simulator. Homepage: http://www.lcsim.org/software/slic

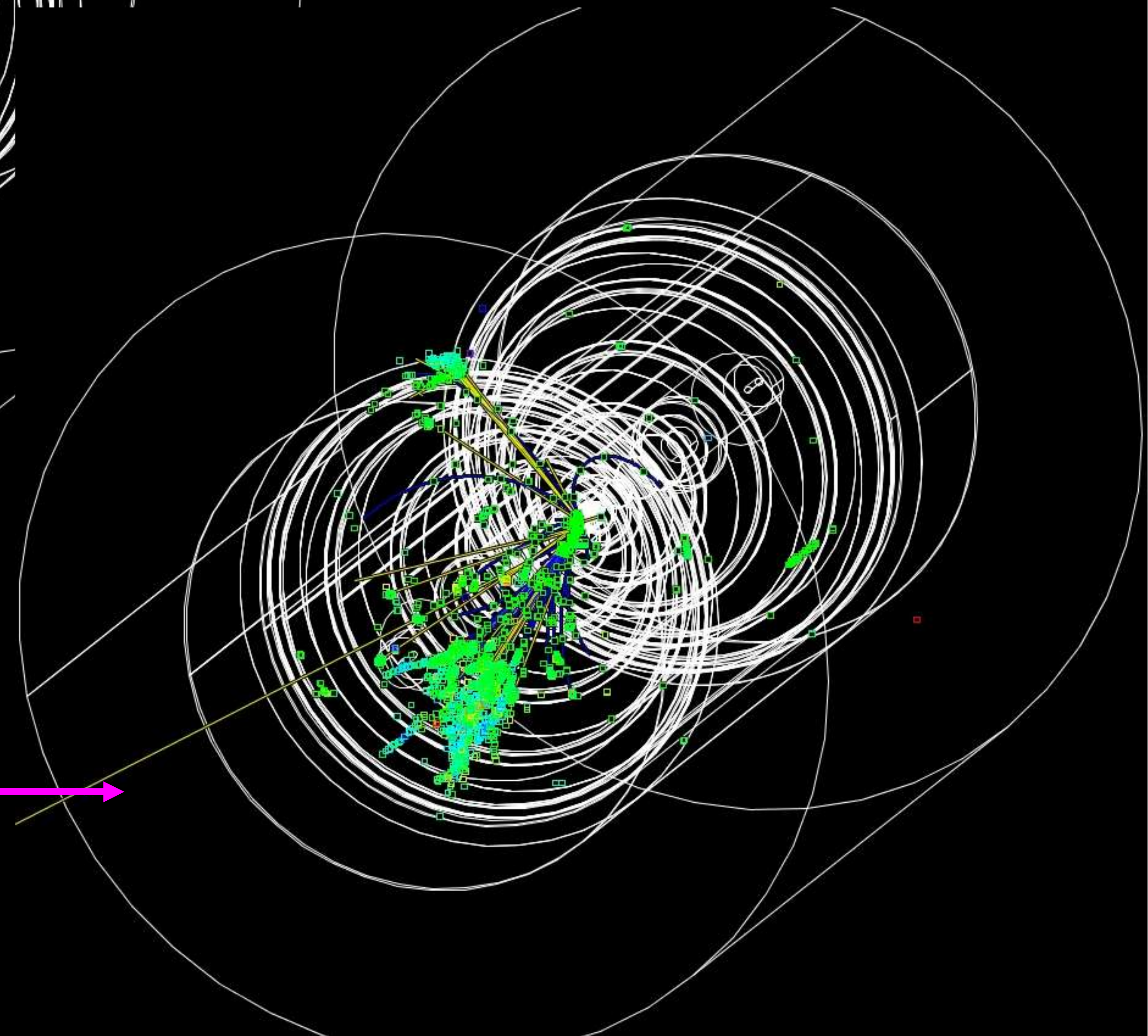
- SLIC reads detector geometries in LCDD format, which is created from a simple, compact XML format using GeomConverter..... attractive for MAPS study!!

- Setting up SLIC is complicated, it relies on a number of packages: CLHEP, GEANT4, LCPhys, LCIO, Xerces-C++, GDML, LCDD.....

- Main problem is making sure all of the libraries are in the right places...
http://www.ep.ph.bham.ac.uk/user/lilley/installation.html



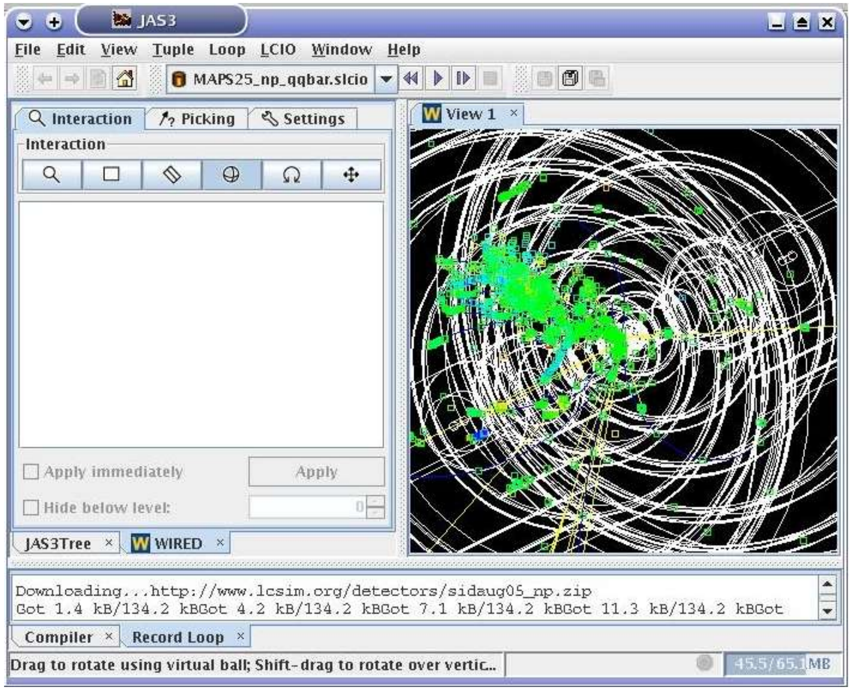
MonteCarlo Truth information, `.stdhep' file before running SLIC. (with SiDAug05 geometry, viewed in JAS3 WIRED plug-in)



After running SLIC, shows interaction with detector

Org.lcsim - JAS3

- Org.lcsim is an event analysis/reconstruction package and is most easily accessed as a JAS3 plug-in.
- Write simple Java scripts to access event data, and carry out analysis... (simple example on next slide!)
- JAS3 offers a an event display via WIRED plug-in, very powerful tool! can read '.heprep' as well as '.lcio' and '.stdhep'...



- Promises a FULL EVENT RECONSTRUCTION... not yet implemented :(but can access jet/cluster finding algorithms.

Example org.lcsim Java code...

...plots 1D Histogram of pixel occupation number

```
import java.util.List;
import org.lcsim.event.EventHeader;
import org.lcsim.util.Driver;
import org.lcsim.util.aida.AIDA;
import org.lcsim.event.SimCalorimeterHit;
import org.lcsim.util.event.*;

public class PixelOccupation extends Driver

{
  private AIDA aida = AIDA.defaultInstance();

  public void process(EventHeader event)

    {   //For ECAL Barrel

        List<SimCalorimeterHit> myBarrelHits = event.getSimCalorimeterHits("EcalBarrHits");

        for(SimCalorimeterHit mybarrelhit : myBarrelHits)

            {
            //Get number of particles passing through cell
            int mcparticlecountbarrel = mybarrelhit.getMCParticleCount();

            //change title for MAPS/SID...
            aida.histogram1D("HIstogram/SiD ECAL barrel pixel occupation", 10, 0, 10).fill(mcparticlecountbarrel);
            }

//For ECAL endcap

        List<SimCalorimeterHit> myEndcapHits = event.getSimCalorimeterHits("EcalEndcapHits");

        for(SimCalorimeterHit myendcaphit : myEndcapHits)

            {

            //Get number of particles passing through cell
            int mcparticlecountendcap = myendcaphit.getMCParticleCount();

            aida.histogram1D("HIstogram/SiD ECAL endcap pixel occupation", 10, 0, 10).fill(mcparticlecountendcap);

            }
        }
}
```

Implementing MAPS into SiD...

- The first available SiD geometry was 'cdcaug05', compromising a 30 layer Si-W ECAL (20 inner layers @ 0.25cm W per layer, outer 10 @ 0.5cm W per layer). This is already a compact geometry.....
- Change the layer thickness · corresponding to an epitaxial layer thickness of 5micron for MAPS...

```
<!-- Electromagnetic calorimeter -->

   <detector id="2" name="EMBarrel"
type="CylindricalBarrelCalorimeter" readout="EcalBarrHits">
      <dimensions inner_r = "127.0*cm" outer_z = "182.0*cm" />
      <layer repeat="20">
        <slice material = "Tungsten" thickness = "0.25*cm" />
        <slice material = "G10" thickness = "0.068*cm" />
        <slice material = "Silicon" thickness = "0.032*cm" sensitive
= "yes" />
        <slice material = "Air" thickness = "0.025*cm" />
      </layer>
      <layer repeat="10">
        <slice material = "Tungsten" thickness = "0.50*cm" />
        <slice material = "G10" thickness = "0.068*cm" />
        <slice material = "Silicon" thickness = "0.032*cm" sensitive
= "yes" />
        <slice material = "Air" thickness = "0.025*cm" />
      </layer>
   </detector>
```

```
<!-- Electromagnetic calorimeter -->

   <detector id="2" name="EMBarrel"
type="CylindricalBarrelCalorimeter" readout="EcalBarrHits">
      <dimensions inner_r = "127.0*cm" outer_z = "182.0*cm" />
      <layer repeat="20">
        <slice material = "Tungsten" thickness = "0.25*cm" />
        <slice material = "G10" thickness = "0.07*cm" />
        <slice material = "Silicon" thickness = "0.0295*cm" />
        <slice material = "Silicon" thickness = "0.0005*cm" sensitive =
        "yes" />
        <slice material = "Air" thickness = "0.025*cm" />
      </layer>
      <layer repeat="10">
        <slice material = "Tungsten" thickness = "0.50*cm" />
        <slice material = "G10" thickness = "0.07*cm" />
        <slice material = "Silicon" thickness = "0.0295*cm" />
        <slice material = "Silicon" thickness = "0.0005*cm" sensitive =
        "yes" />
        <slice material = "Air" thickness = "0.025*cm" />
      </layer>
   </detector>
```

MAPS projective segmentation

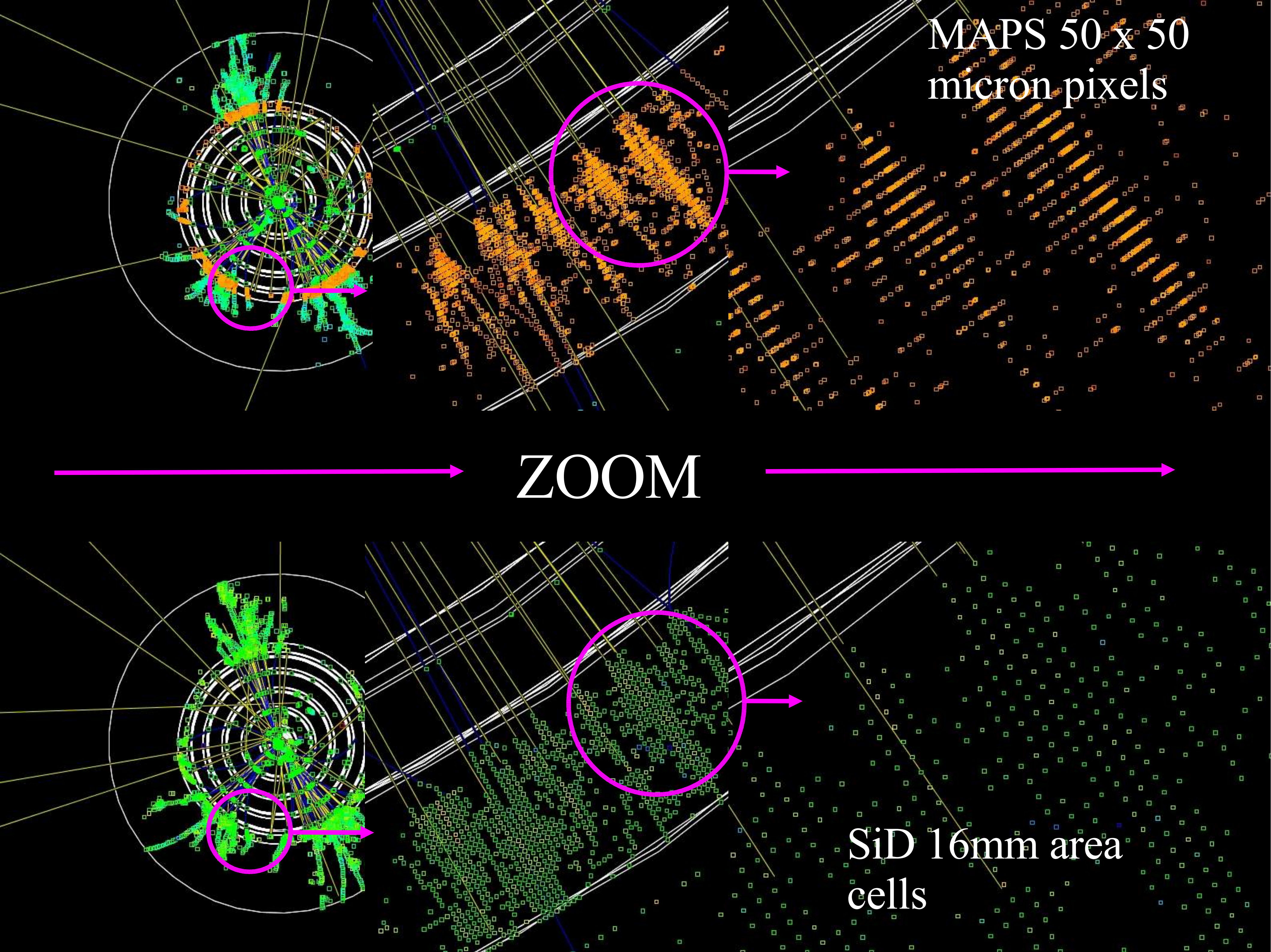
- 'cdcaug05' has a projective segmentation.... choose the number of 'bins' to give an average of 50x50 micron pixel pitch for MAPS.

```
<!-- Sensitive Detector readout segmentation -->
 <readouts>
      < .................>

      <readout name="EcalEndcapHits">
        <segmentation type="ProjectiveZPlane" thetaBins="1024"
        phiBins="1024"/>
        <id>layer:7,system:6,barrel:3,theta:32:11,phi:11</id>
     </readout>

      < .................>

    <readout name="EcalBarrHits">
          <segmentation type="ProjectiveCylinder" thetaBins="1000"
           phiBins="2000"/>
          <id>layer:7,system:6,barrel:3,theta:32:11,phi:11</id>
      </readout>
      < .................>

  </readouts>
```

→

```
<!-- Sensitive Detector readout segmentation -->
 <readouts>
      < .................>

      <readout name="EcalEndcapHits">
        <segmentation type="ProjectiveZPlane" thetaBins="95819"
           phiBins="40200"/>
        <id>layer:6,system:6,theta:18,barrel:32:3,phi:18</id>
     </readout>

      < .................>

    <readout name="EcalBarrHits">
          <segmentation type="ProjectiveCylinder"
             thetaBins="72800" phiBins="168239"/>
          <id>layer:6,system:6,theta:18,barrel:32:3,phi:18</id>
      </readout>
      < .................>

  </readouts>
```

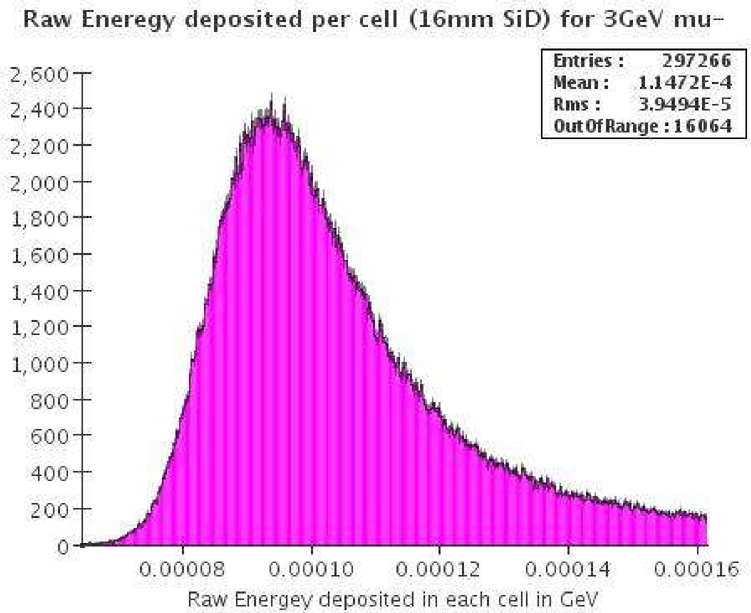
Watch out for the number of bits assigned to each field!!!


MAPS 50 x 50
micron pixels
ZOOM
SiD 16mm area
cells

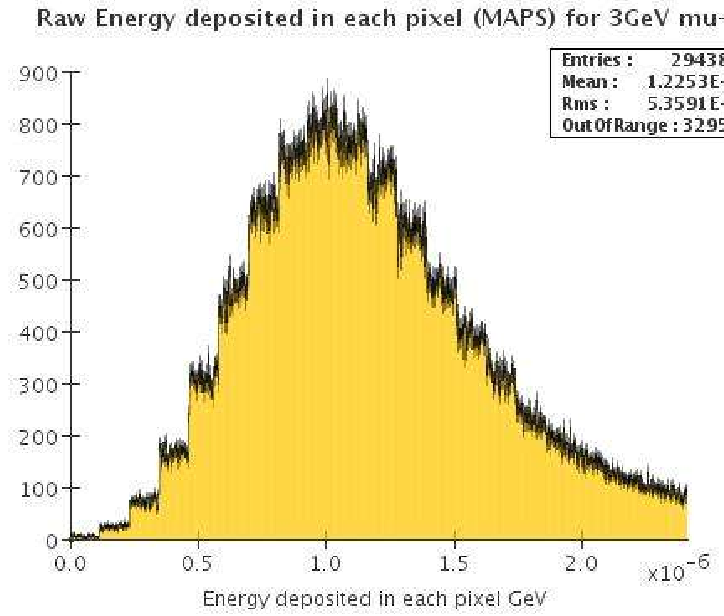
MIP Signal

- Before analysis can be completed, need the MIP threshold....
  Generate single muon events at 3 and 5 GeV, with both geometries....

SiD Baseline, 16mm area cells



MAPS 50x50 micron pixels



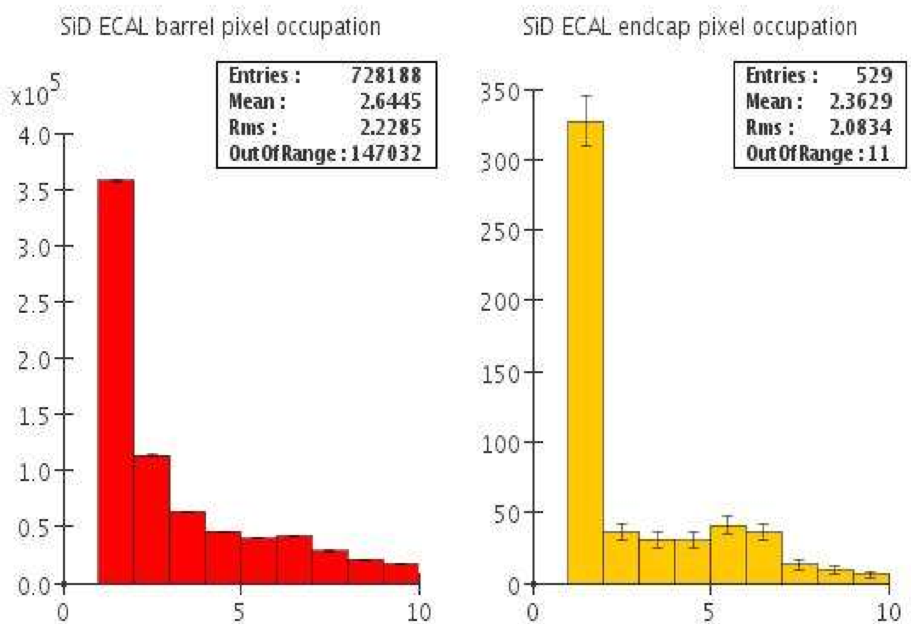
» threshold of 0.5MIP = 47KeV

» threshold of 0.5MIP = 0.5KeV

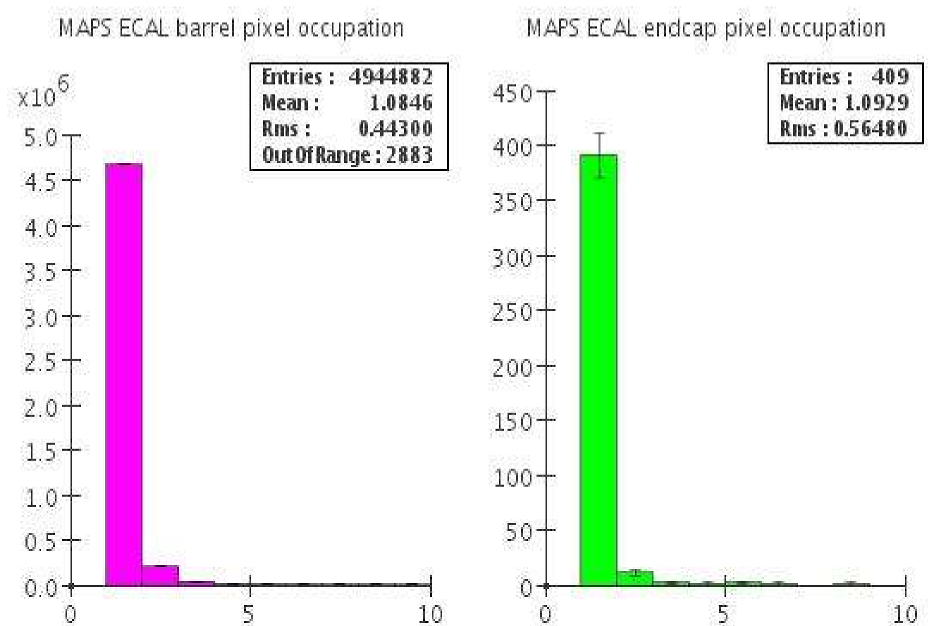
Pixel Occupation

- MAPS concept relies on binary readout... we need at most 1 hit per pixel or else loose information.
- Study of pixel occupation from MonteCarlo truth information....

SiD, 100GeV electrons



MAPS, 100GeV electrons

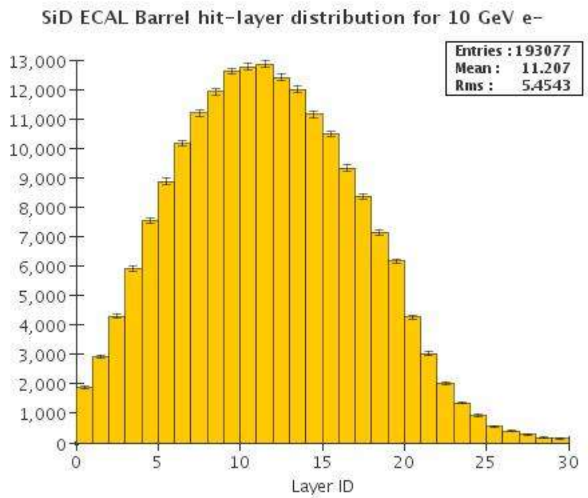


- Select optimal pixel pitch from simulation studies!

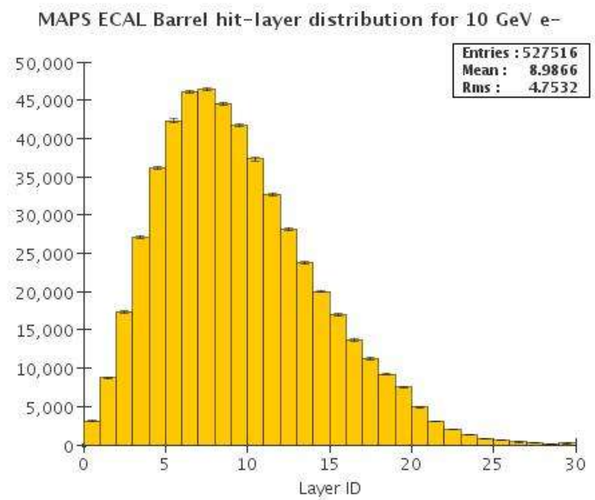
Longitudinal response

- Look at development of showers as a function of ECAL layer.
- Compare number/layer for MAPS, to Energy/layer for SiD.

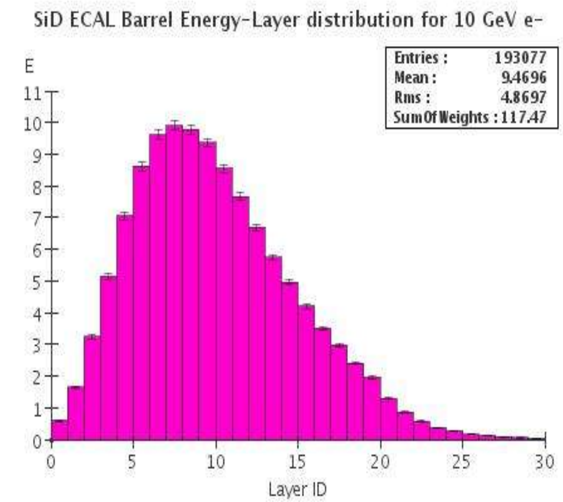
10 GeV electrons...



SiD number/layer

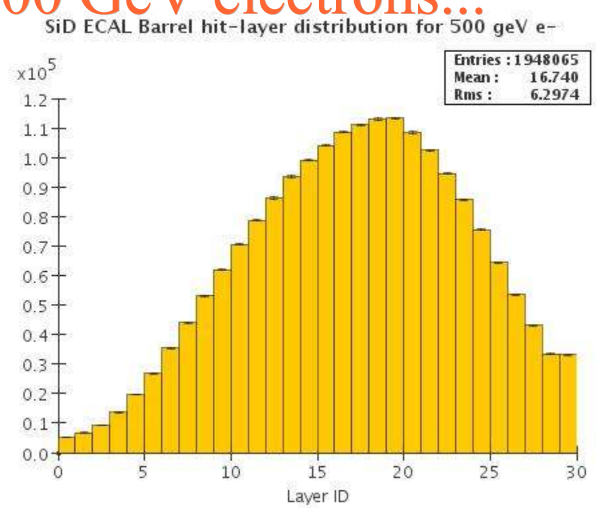


MAPS number/layer

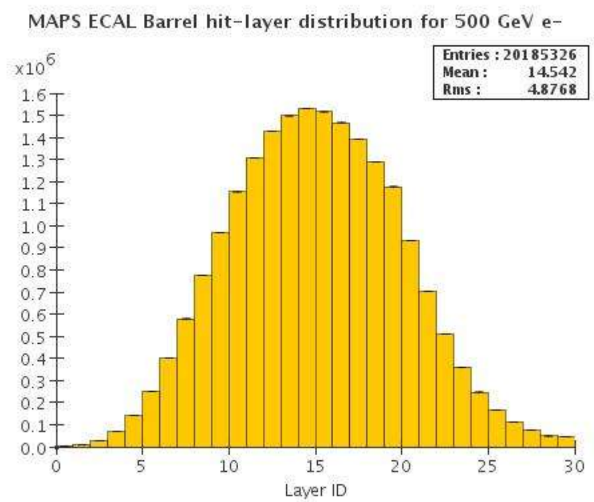


SiD Energy/layer

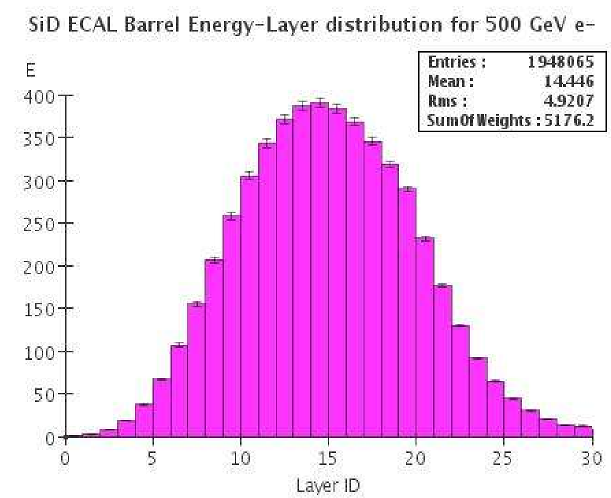
500 GeV electrons...



SiD number/layer



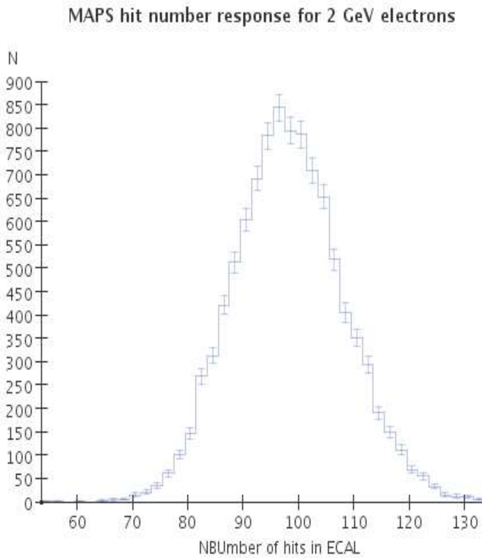
MAPS number/layer

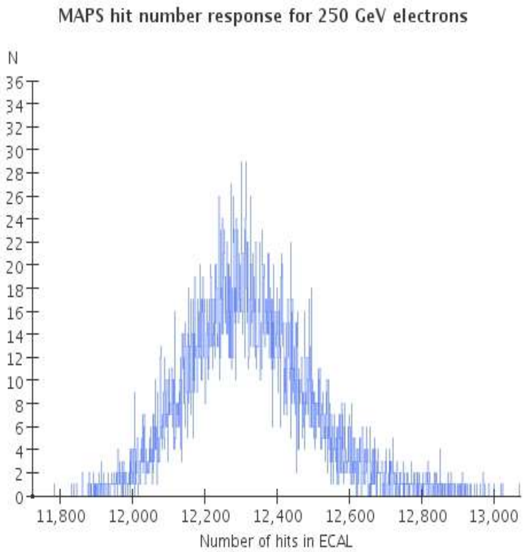


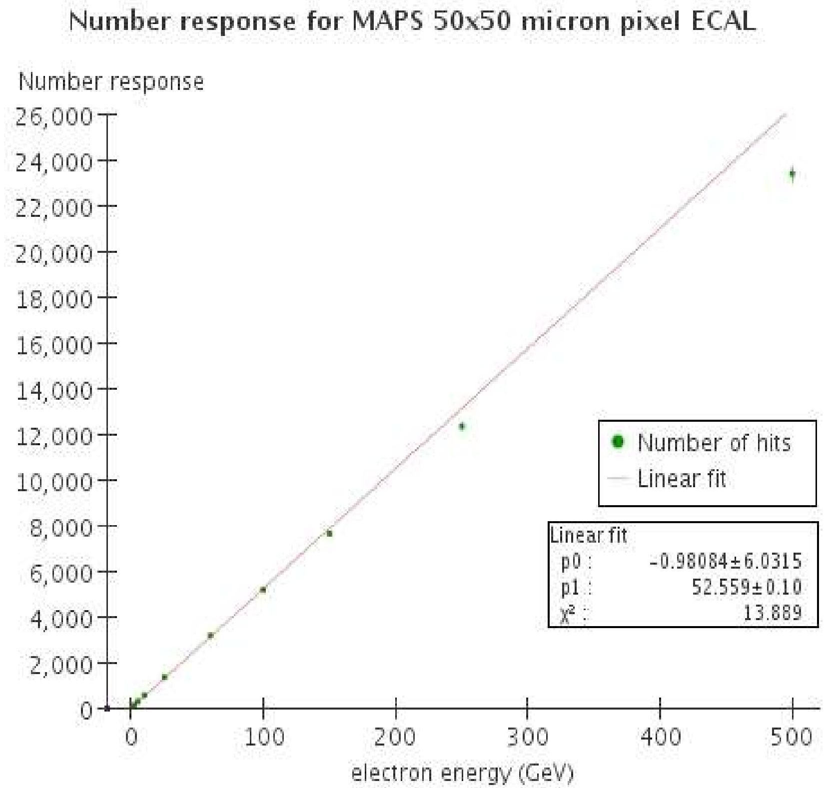
SiD Energy/layer

Linearity of response... (MAPS)

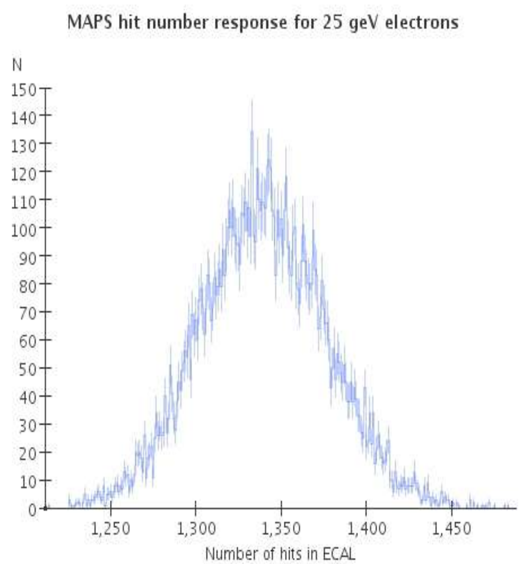
- Create single electron events at a range of energies (1… 500 GeV) using SLIC.



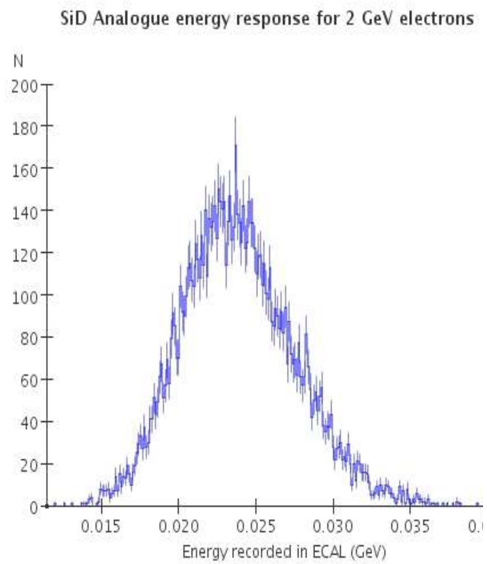


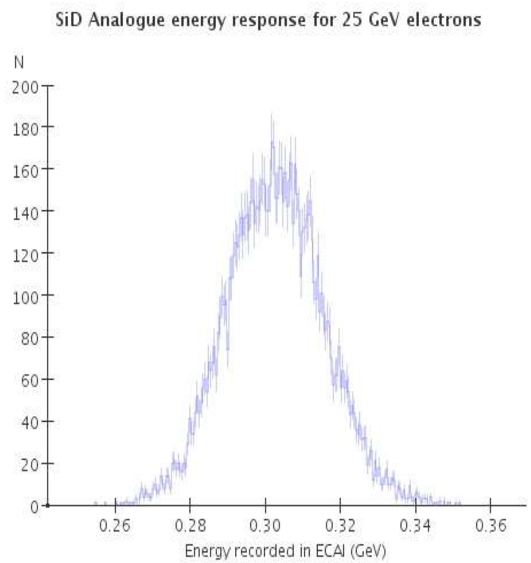


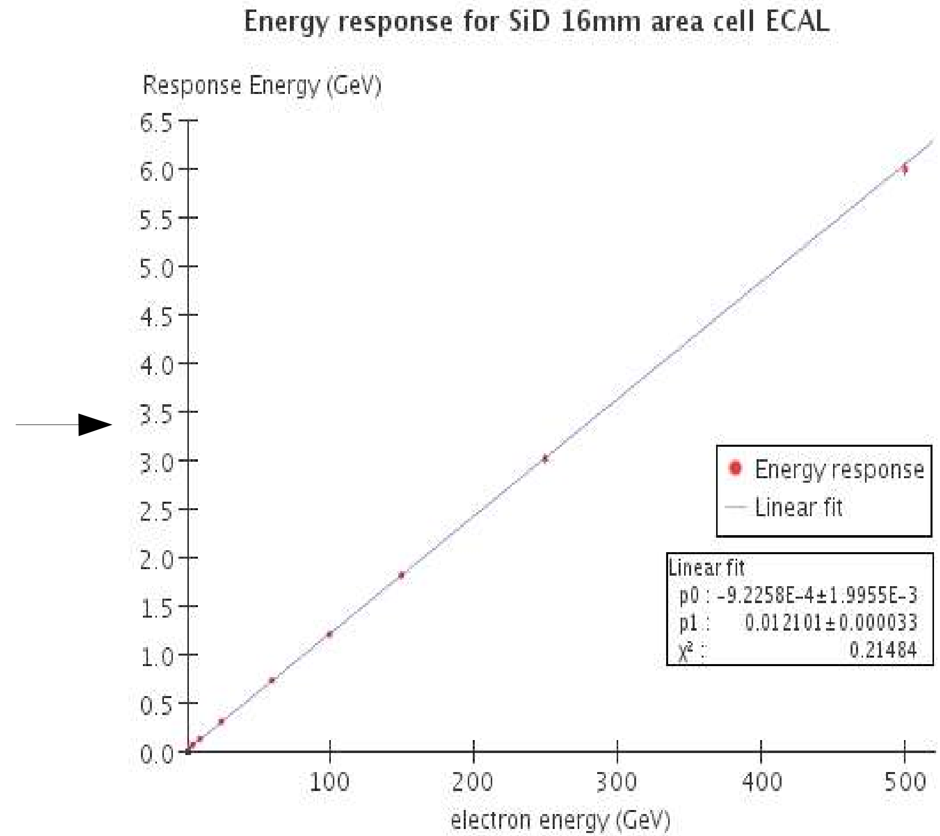
Create number plots (MAPS) for each electron energy... combine together using AIDA



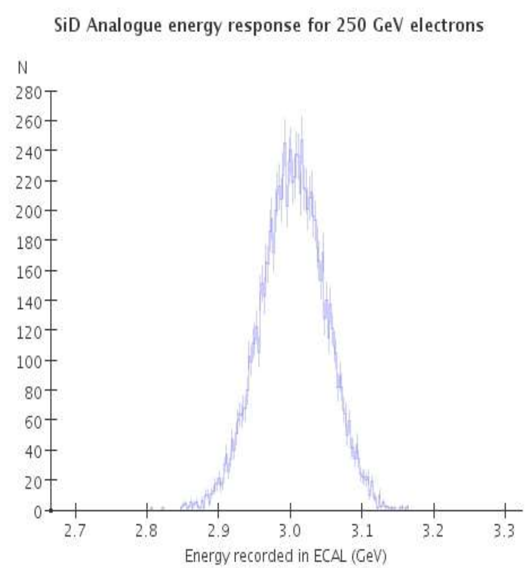
Linearity of response.... (SiD)



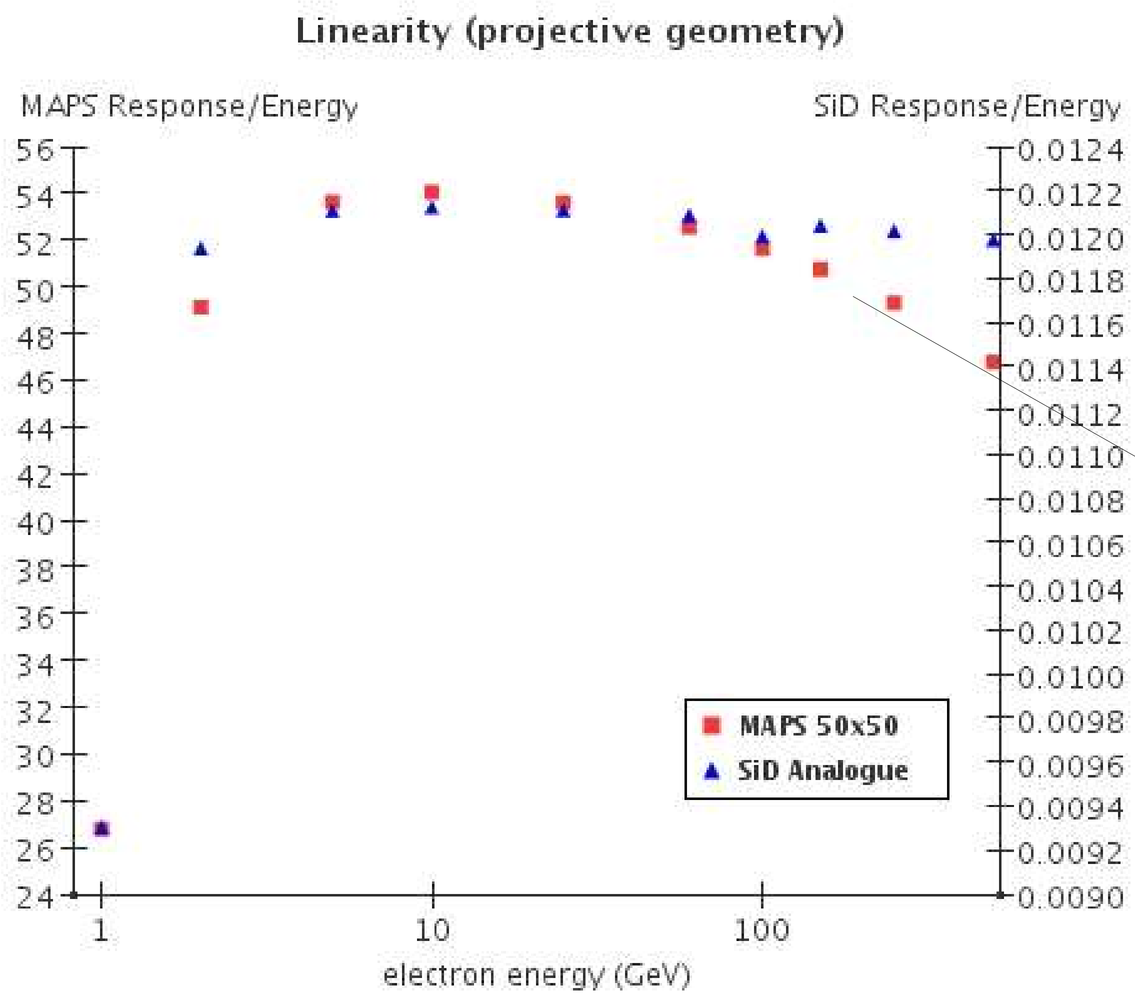




Create Energy plots (SiD) for each electron energy... combine together using AIDA



Comparing the Linearity...



Tail off in MAPS due to pixel occupation > 1 ??

Non-Projective Geometry

- New non-projective geometry available! - 'sidaug05_np'
- Get constant pixel size!
- New epitaxial layer thickness (15 micron)

SiD

```
<!-- Electromagnetic calorimeter -->

 <detector id="2" name="EMBarrel"
   type="CylindricalBarrelCalorimeter"
   readout="EcalBarrHits">
    <dimensions inner_r = "127.0*cm" outer_z =
    "179.5*cm" />
    <layer repeat="30">
      <slice material = "Tungsten" thickness =
      "0.25*cm" />
      <slice material = "G10" thickness = "0.068*cm" />
      <slice material = "Silicon" thickness = "0.032*cm"
       sensitive = "yes" />
      <slice material = "Air" thickness = "0.025*cm" />
    </layer>
 </detector>
```

30 layers constant thickness!

MAPS

```
!-- Electromagnetic calorimeter -->

 <detector id="2" name="EMBarrel"
   type="CylindricalBarrelCalorimeter"
   readout="EcalBarrHits">
    <dimensions inner_r = "127.0*cm" outer_z =
     "179.5*cm" />
    <layer repeat="30">
      <slice material = "Tungsten" thickness =
       "0.25*cm" />
      <slice material = "G10" thickness = "0.070*cm" /
       >
       <slice material = "Silicon" thickness =
        "0.0285*cm"  />
      <slice material = "Silicon" thickness =
        "0.0015*cm" sensitive = "yes" />
      <slice material = "Air" thickness = "0.025*cm" />
    </layer>
 </detector>
```

Non-Projective Readout

- Defined three new detectors: 25x25, 50x50 and 100x100 microns for comparison.

```
<readout name="EcalBarrHits">
        <segmentation type="NonprojectiveCylinder" gridSizePhi="0.05" gridSizeZ="0.05" />
        <id>layer:6,system:6,phi:20,barrel:32:3,z:-20</id>
    </readout>
```

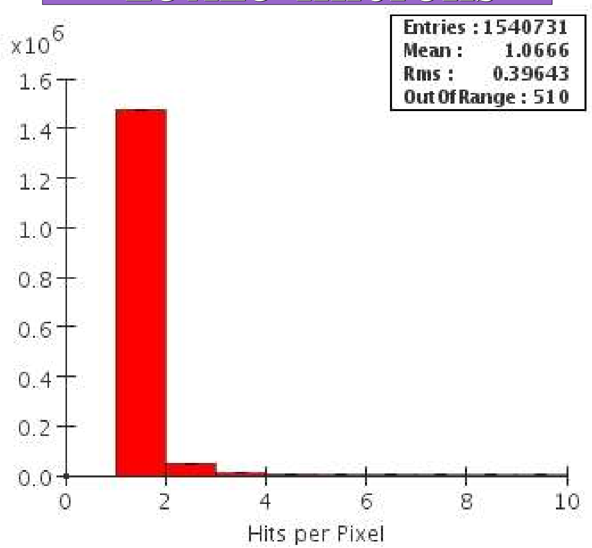
Change order of bit assignation

Set pixel size (mm)

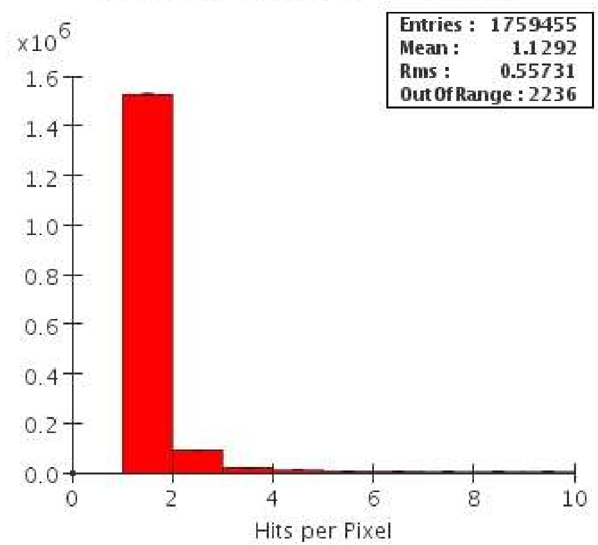
- Find new MIP threshold, since new epitaxial thickness.... = 1.6 KeV

Initial pixel occupation study, 250GeV electrons....

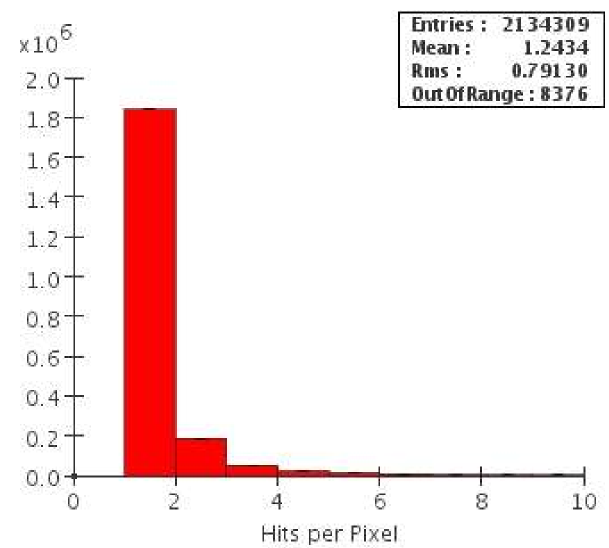
25x25 microns



50x50 microns

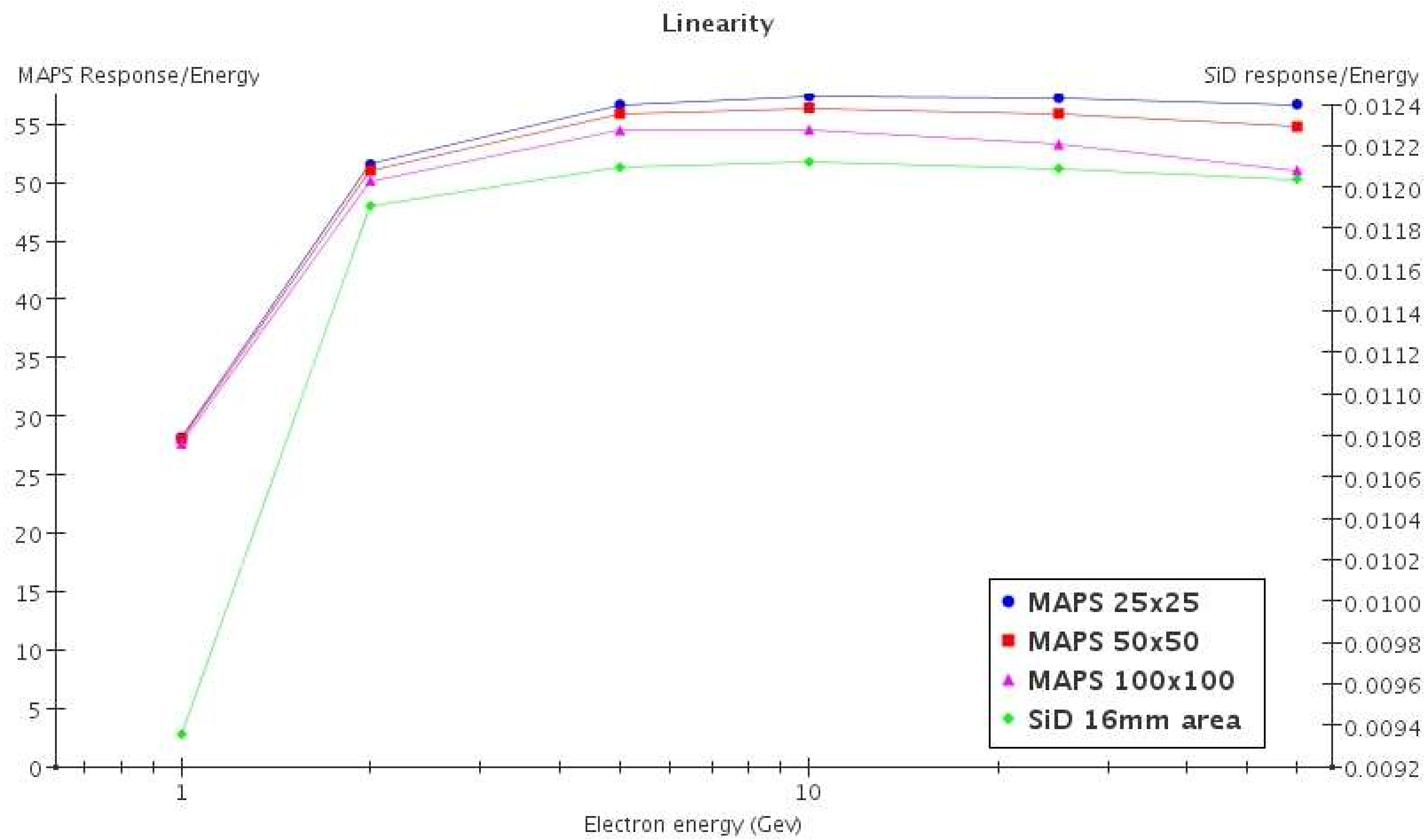


100x100 microns



Preliminary results from non-projective geometry

- Only have up to 100 GeV analysed (... higher energy jobs are still running!)
- Can compare linearity for different pixel sizes against SiD baseline.



Future Outlook....

- Would like to compare pattern recognition for MAPS/SiD
- Work toward full event reconstruction in org.lcsim (Was promised for Snowmass!)
- Show that MAPS is better than SID analogue! ;)
- For more detailed information see my web page: http://www.ep.ph.bham.ac.uk/user/lilley/