R&D of strip-array ECAL

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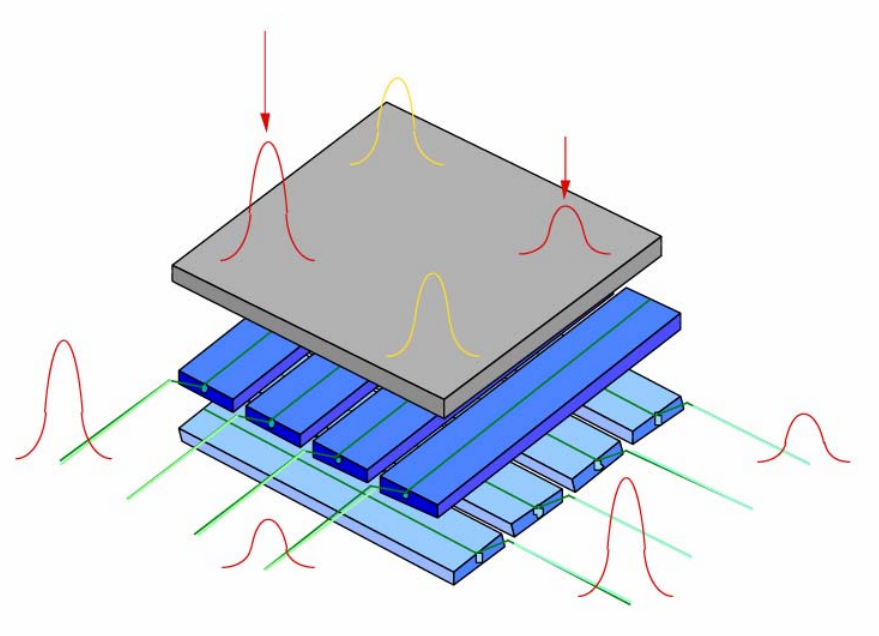
- Introduction
- Beam test results
  - Uniformity
  - Energy resolution and linearity
  - Position and angular resolutions
  - Two particle separation
- Summary

Introduction

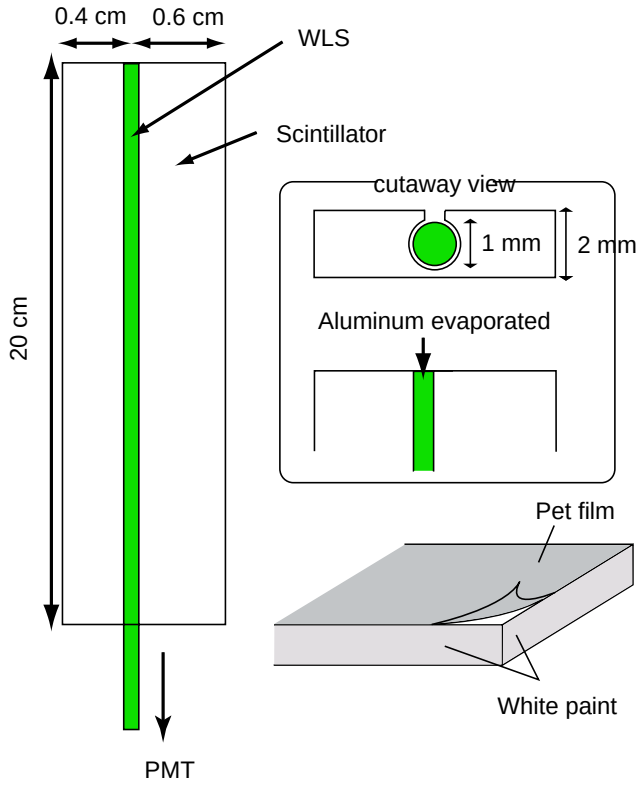
- Requirements for LC ECAL :
  - Energy resolution/linearity
  - Transverse/longitudinal granularity for "particle flow" analysis
- Our baseline design : lead/scintillator sampling ECAL
  - Good hermeticity
  - Established technology
  - Reasonable cost

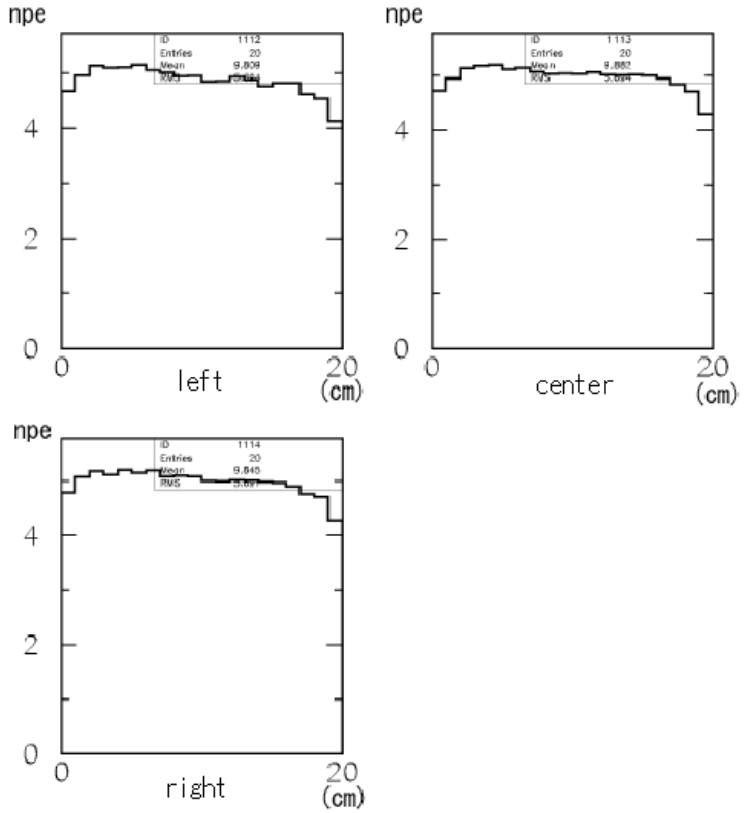
Scintillator strip-array ECAL

- Array of 1cmx20cmx2mm-thick strips
- Advantages :
  - Fine granularity (1cmx1cm effective cell size)
  - Reasonable cost
  - No WLS fiber bending
- Disadvantages :
  - Ghost rejection needed



Structure of scintillator strips

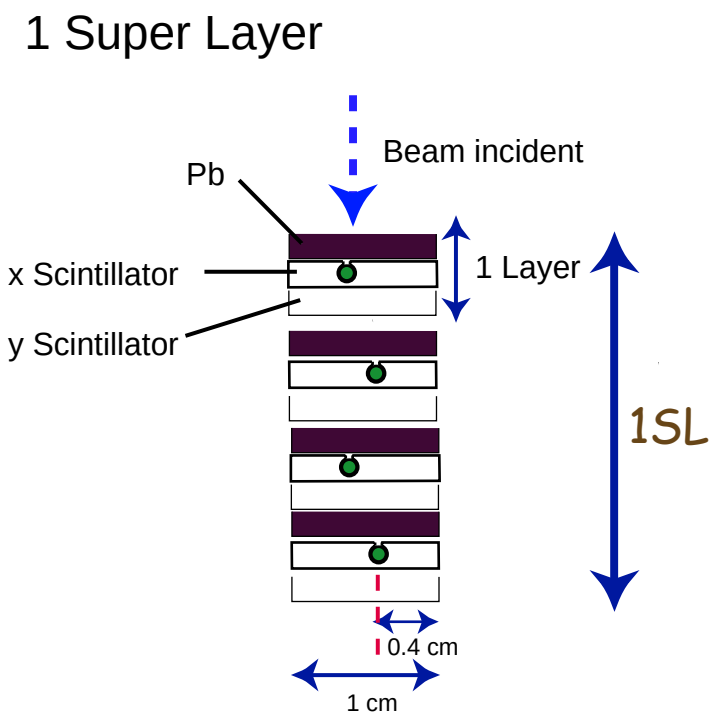


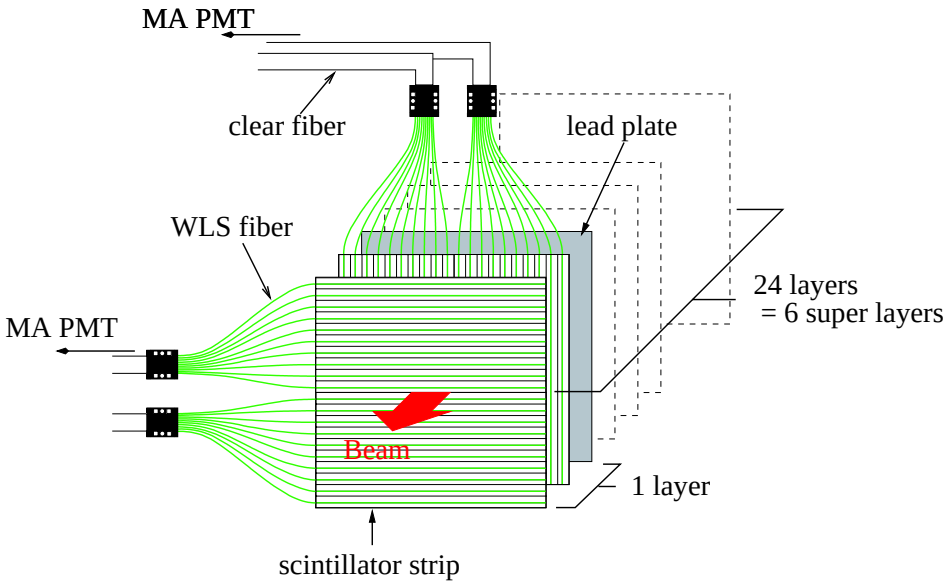


- Average number of photoelectrons per strip for a MIP particle is measured to be ~4.6 from a bench test with beta-ray.

Module design for beam test

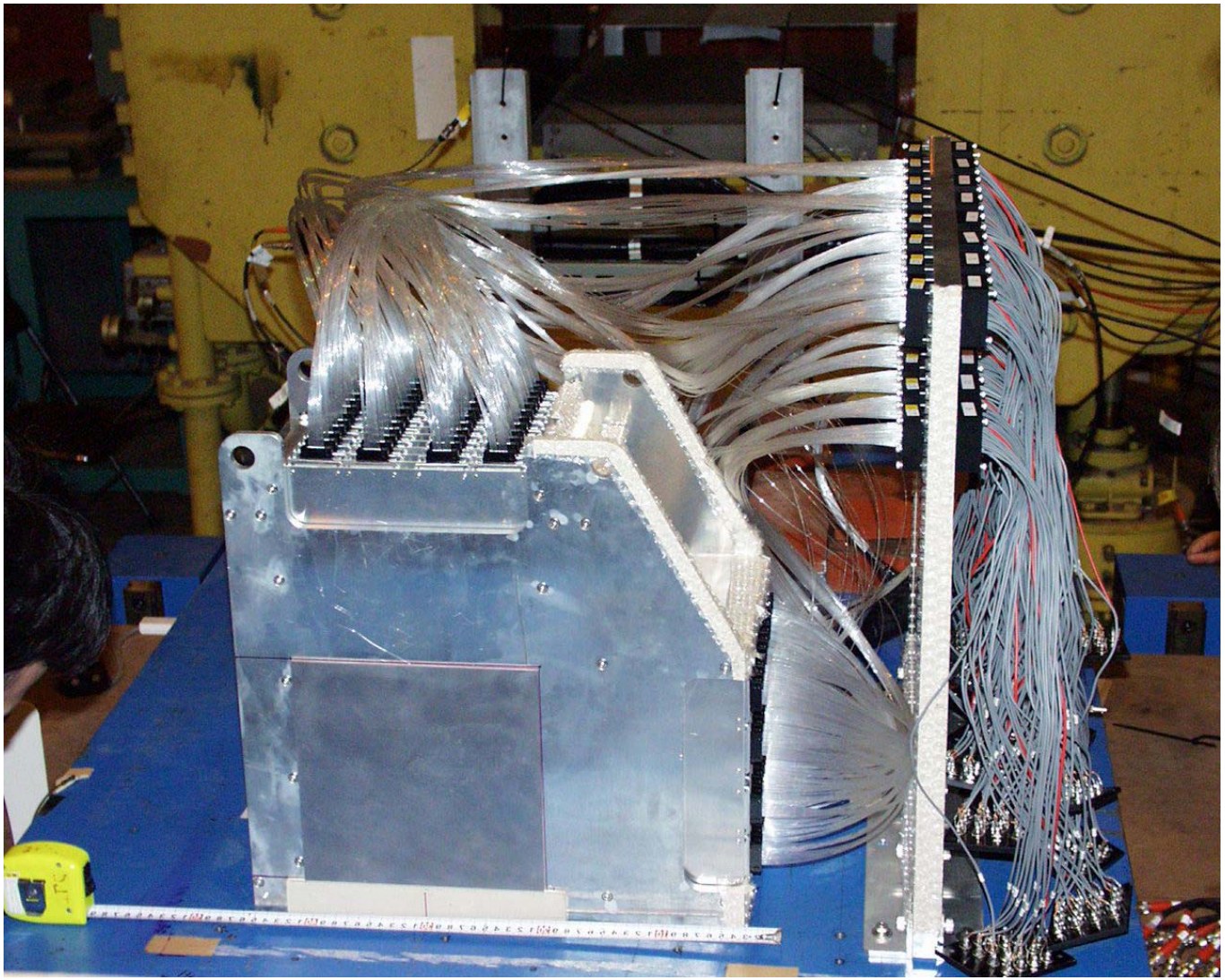
- 1 Layer = lead plate
  + x-strips x20 + y-strips x20
- lead : 20cm x 20cm x 4mm-thick
- strip : 1cm-width x 20cm x 2mm-thick
- Total 24 layers : $17X_0$
  -> 6 super layers (1SL=4layers)





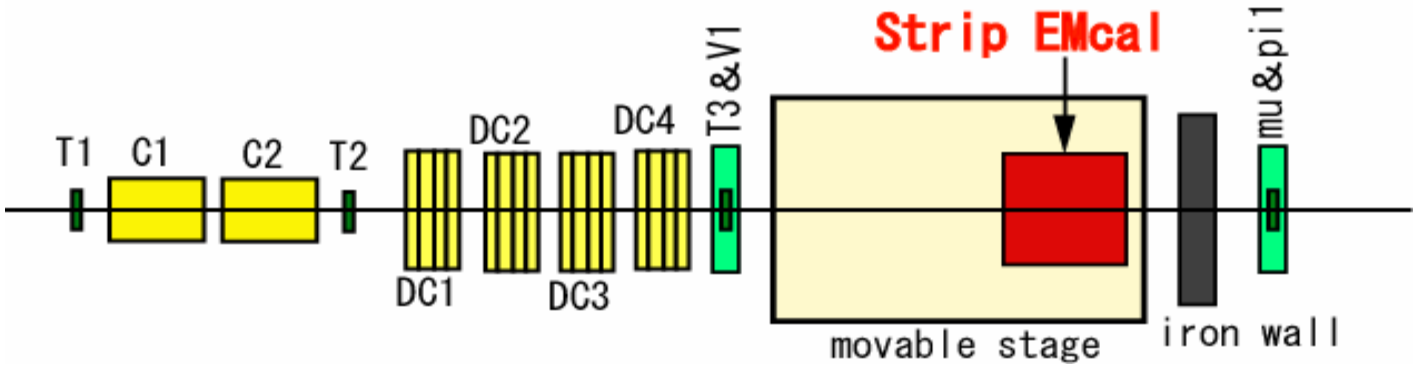
- WLS fiber + clear fiber
- Read out by Multi-anode PMTs (tentatively for beam test)

A picture of the test module



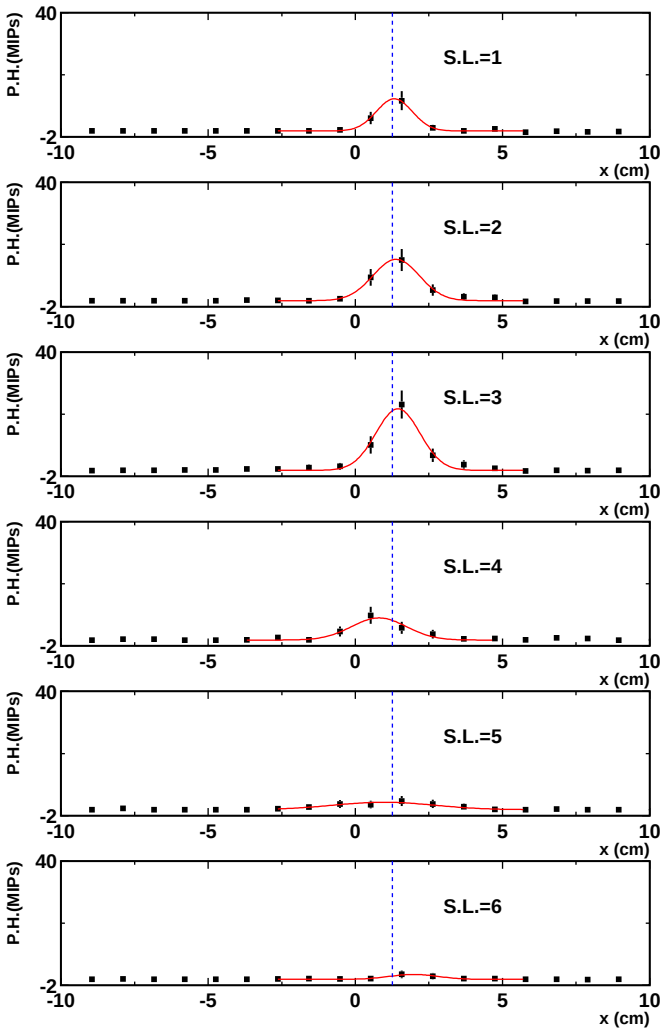
Beam test

- Unseparated beams (e, pi, mu, p=1 – 4 GeV/c) at KEK PS
- ECAL on movable stage
- Electron-ID with two Cherenkov counters
- Tracking with drift chambers (σ < 0.3mm at the ECAL surface)
- 2002 Fall: First trial for energy resolution and linearity
- 2004 Mar.: more statistics for more detailed studies

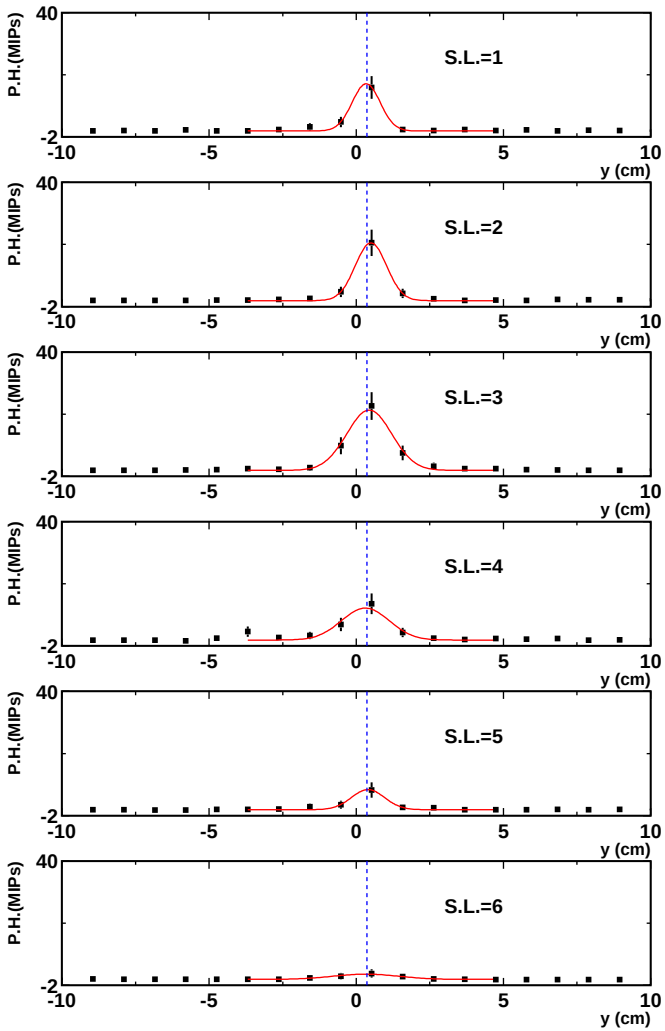


A typical event (4 GeV electron)

x-layers

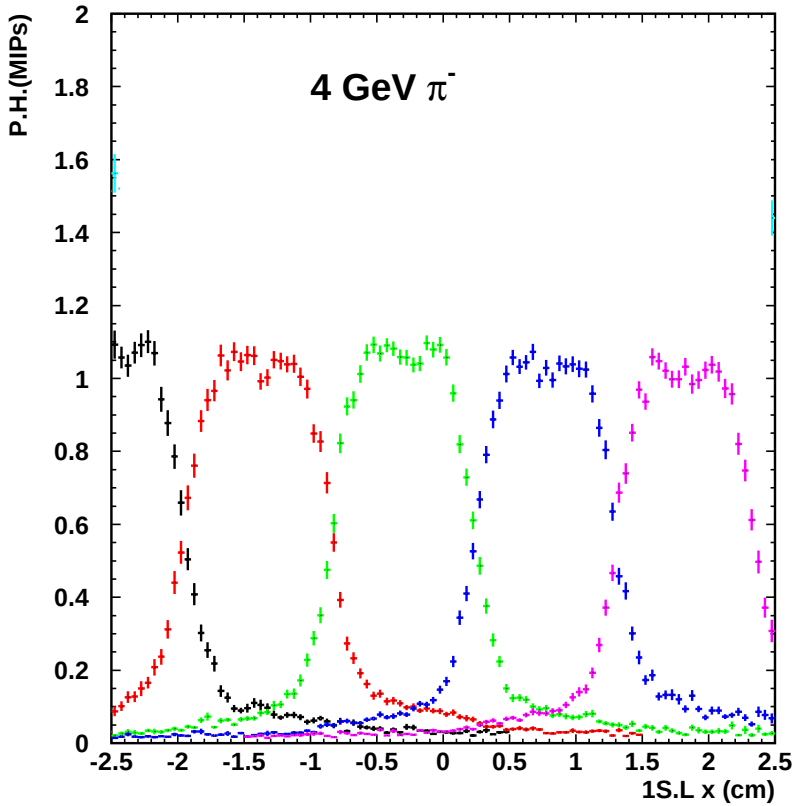


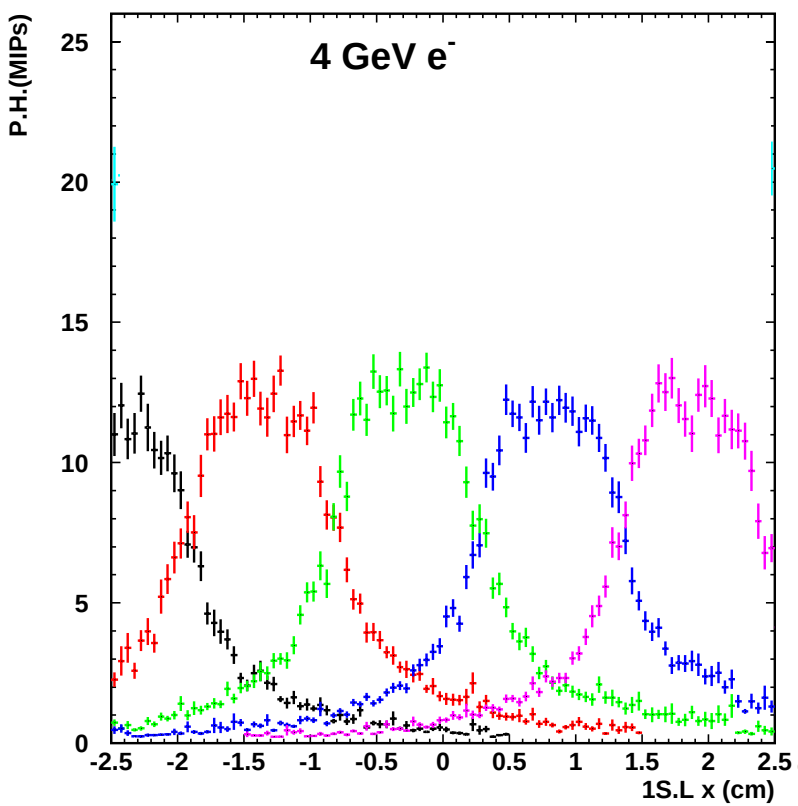
y-layers



Response uniformity

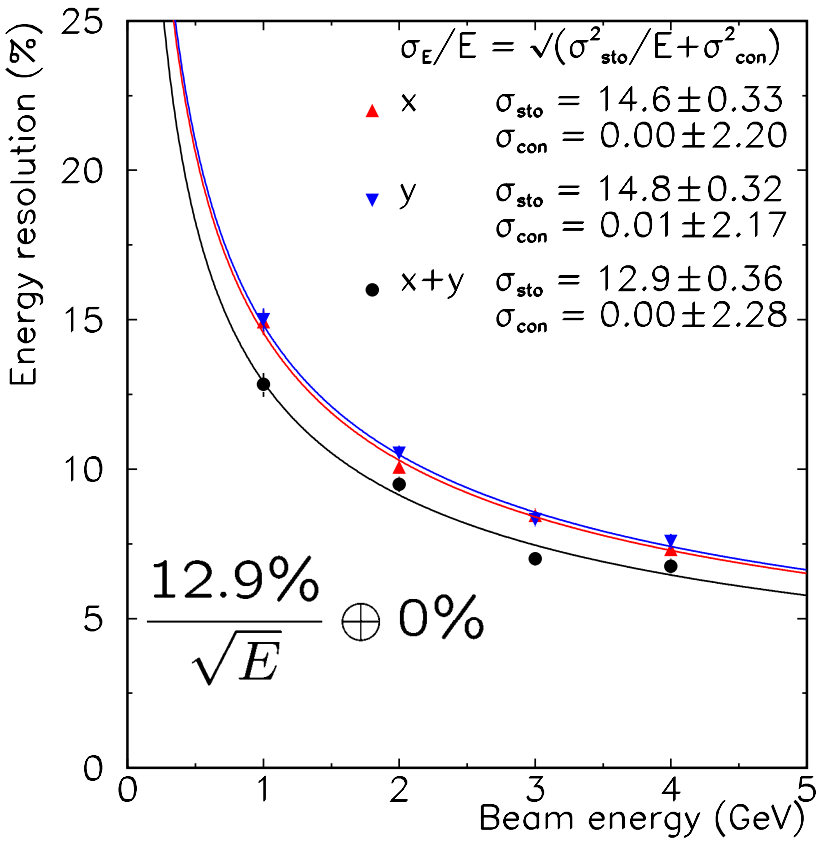
- Incident position determined by Drift Chambers (σ_x< 0.3mm)
- Response in 1st SL x-strips for 4GeV π and e
- Response sum over strips : uniformity < 5%



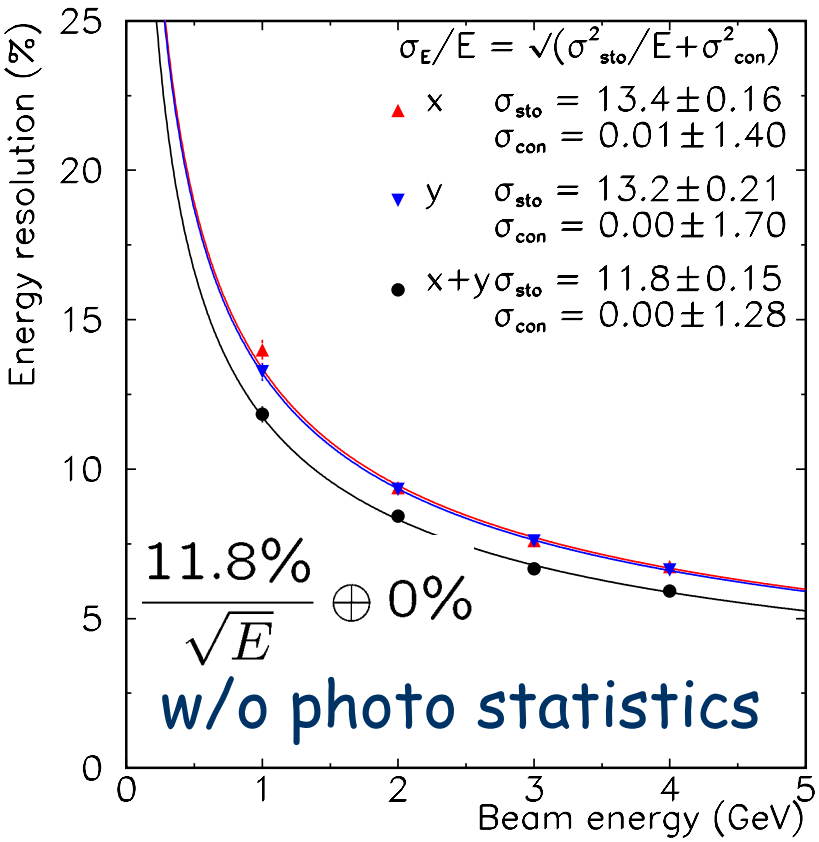


Energy resolution for electrons

Beam Test (2002 fall)



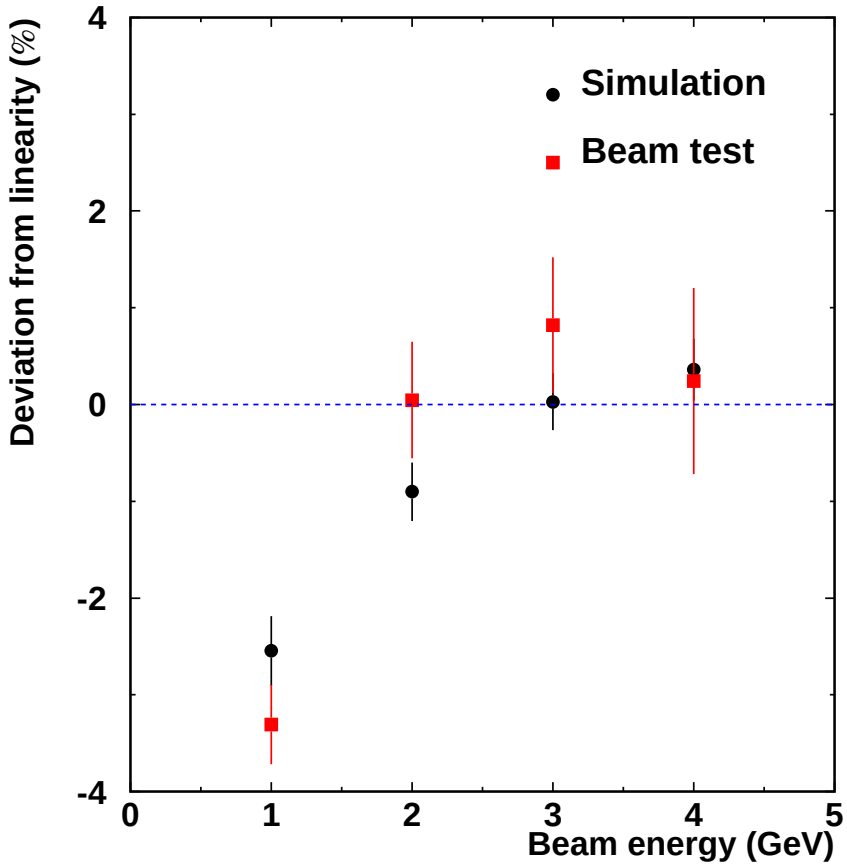
GEANT3 Simulation



If photon statistics is taken into account, beam test result is consistent with simulation.

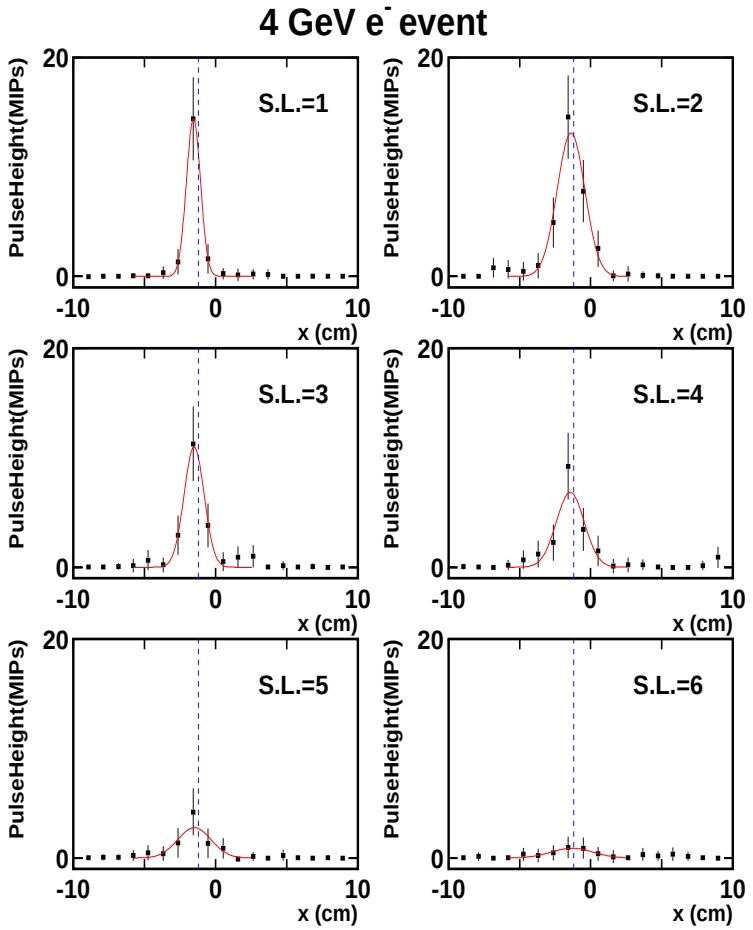
Linearity

- Linearity : < 3.5%
  - < 1% above 2GeV
- In good agreement with simulation
- Deviation at 1 GeV is probably due to the material in front (now investigating).

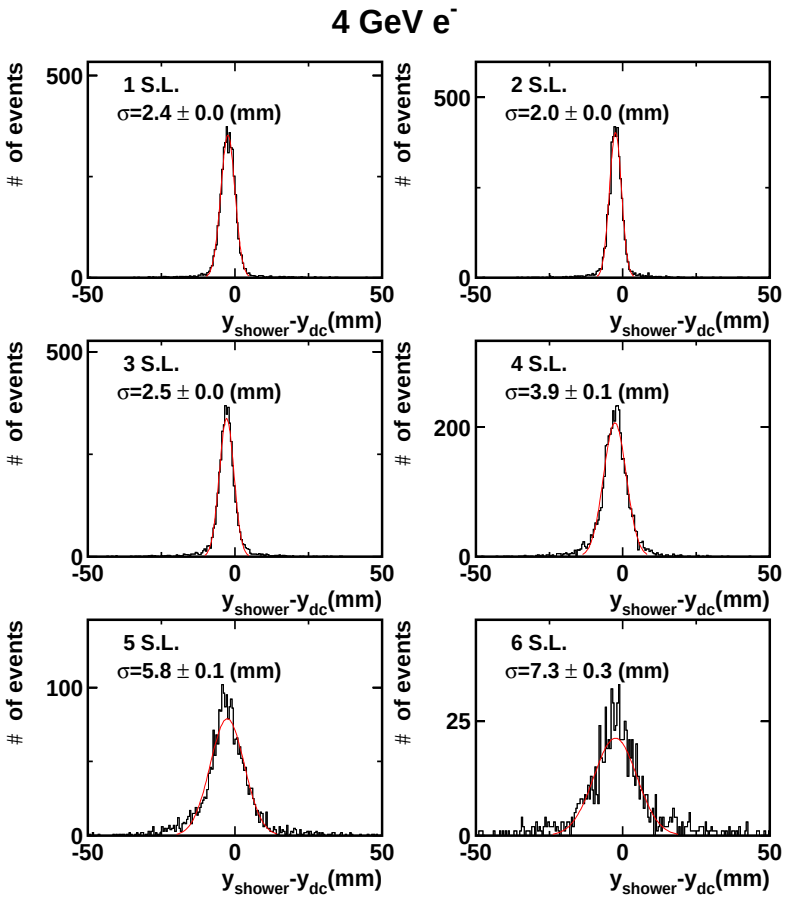


Position measurement

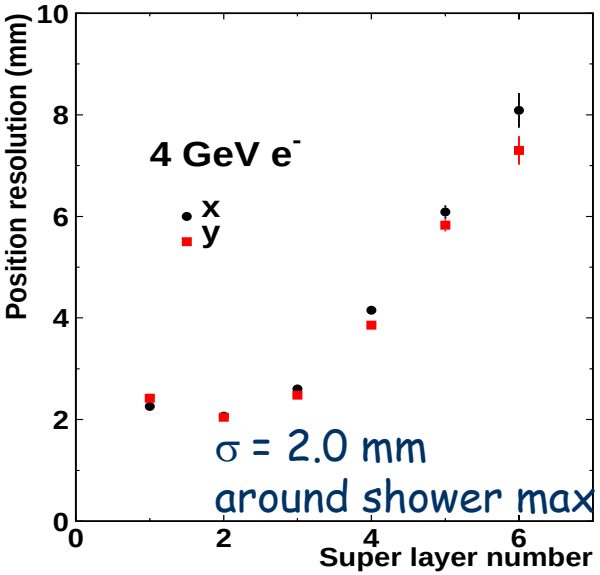
- Incident position is determined by Gaussian fit in each super layer
  - 9 adjacent strips are used for fitting
- With Gaussian fit, position resolution can be better than the weighted mean

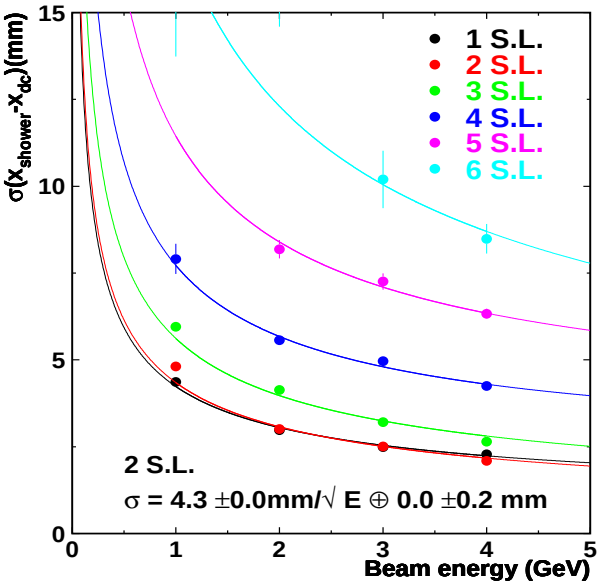


Spatial resolution



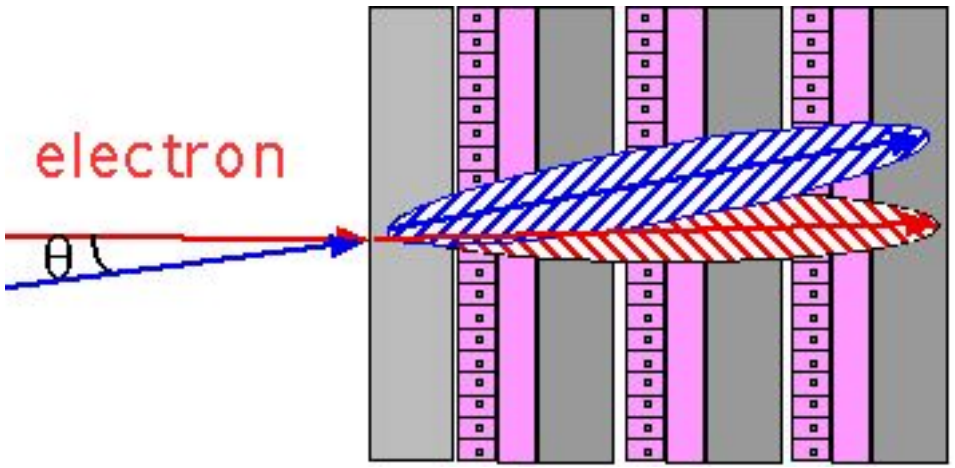
Position resolution for 4 GeV electron



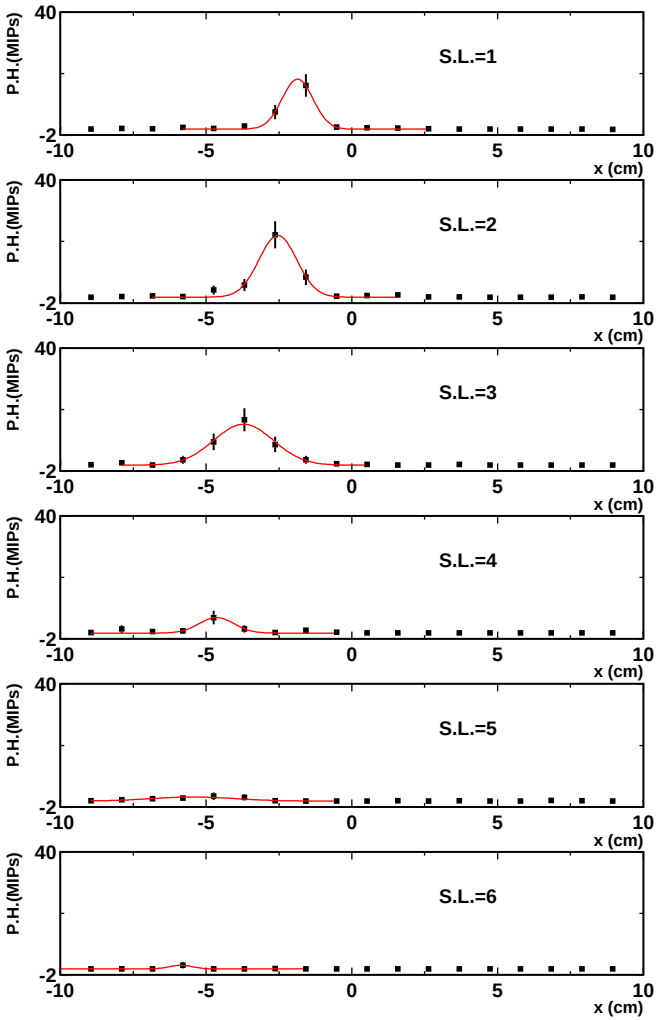


Angle measurement

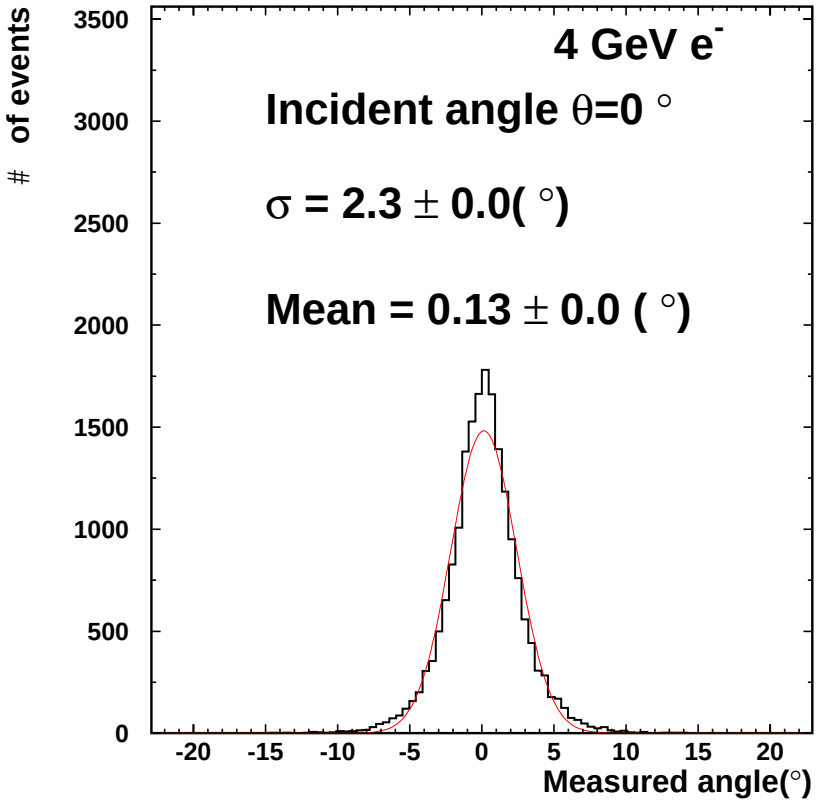
- Incident angle was changed by rotating the movable stage.
- Shower-axis angle is determined by fitting 5 points from 1 S.L. through 5 S.L.

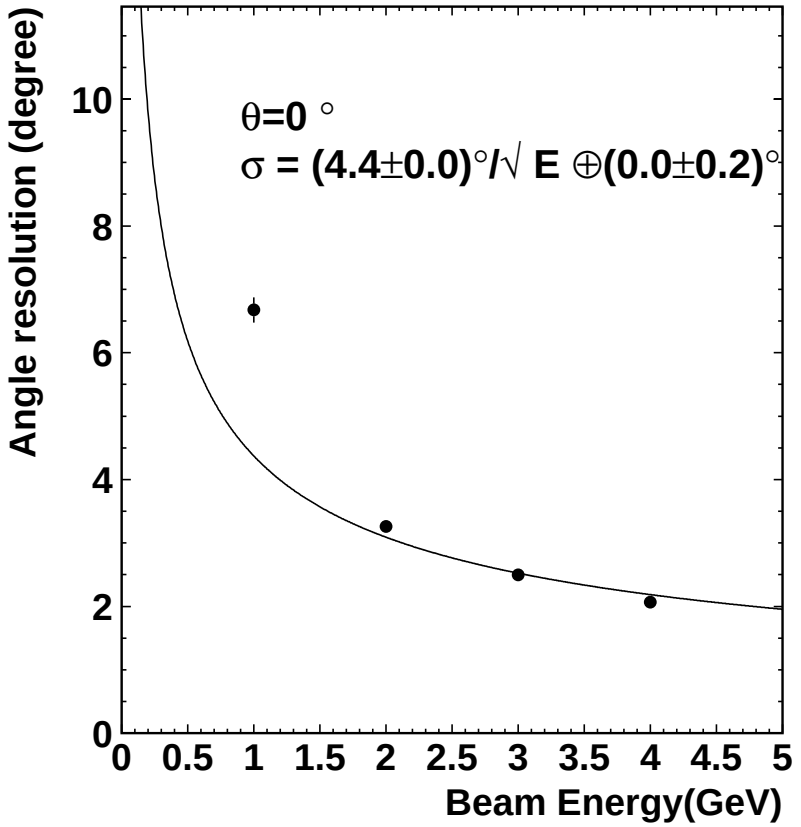


A 4 GeV e events,
θ=15.9 degree

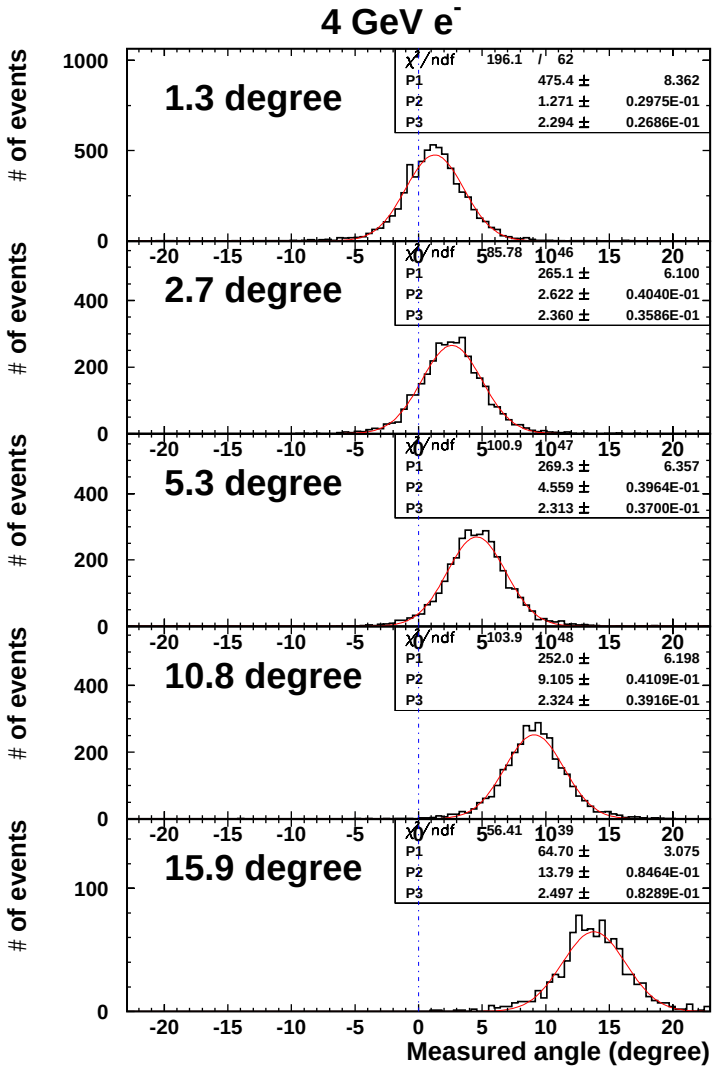


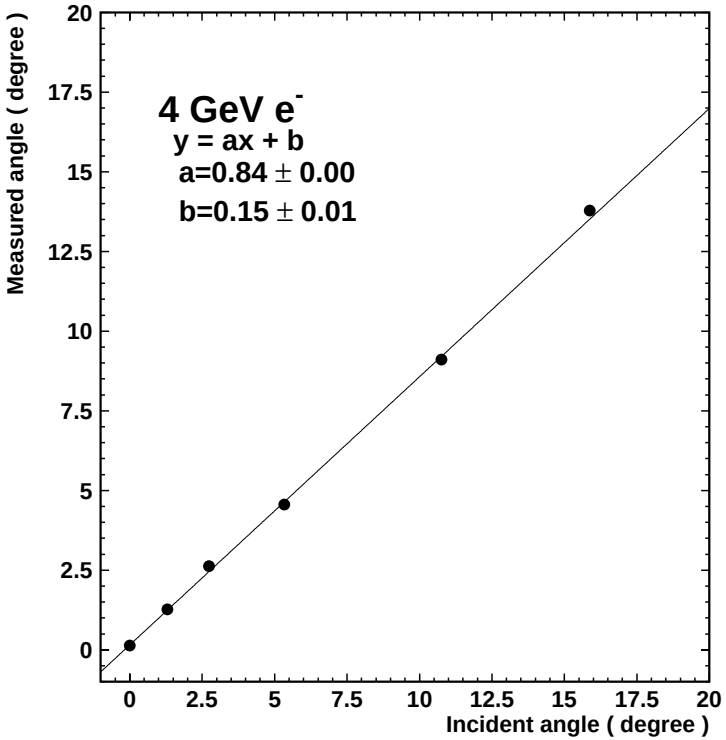
Angle measurement of normal incident electrons





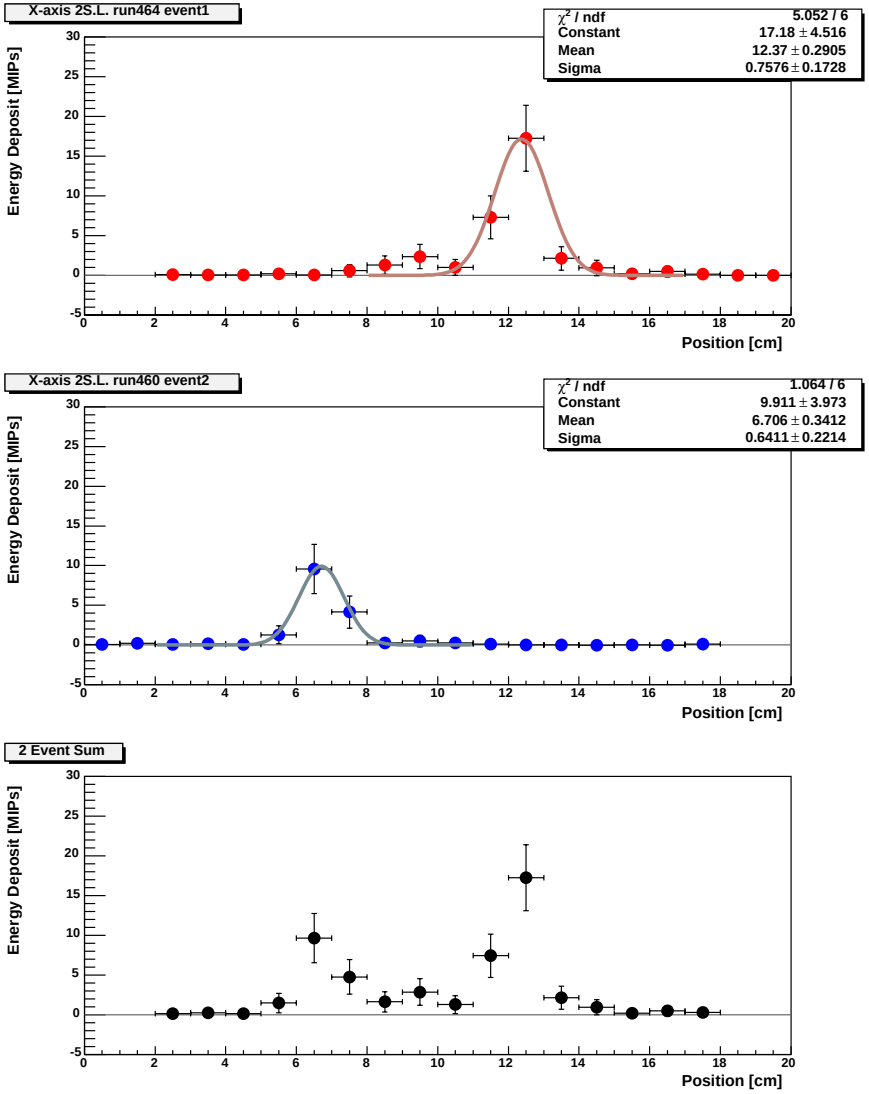
Angle measurement of 4 GeV electrons with non-zero incident angle





- Good Linearity !!
- σ_θ=2.3 degree at least up to 16 degree
- Slope < 1 : due to different "effective" material thickness for non-zero incident angle

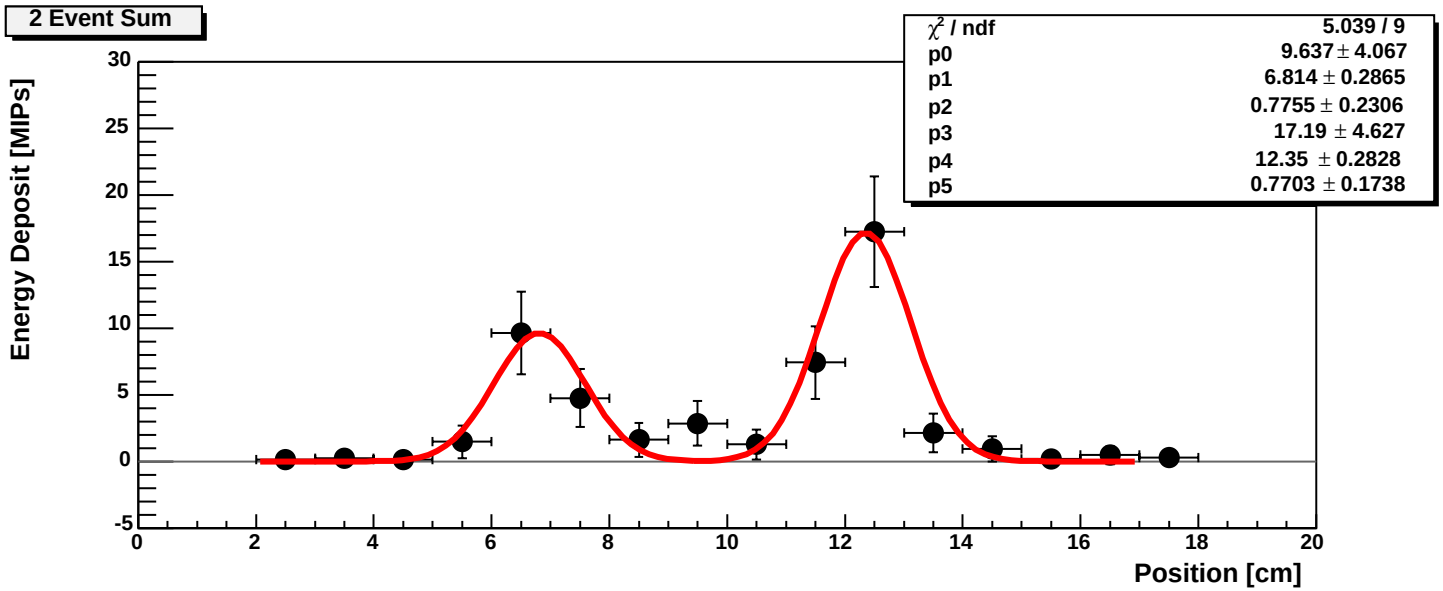
Study of two-particle separation



- Generation of two-particle events from real beam test events
  - Pick up independent two electron events
  - Add the two events with some distance between them

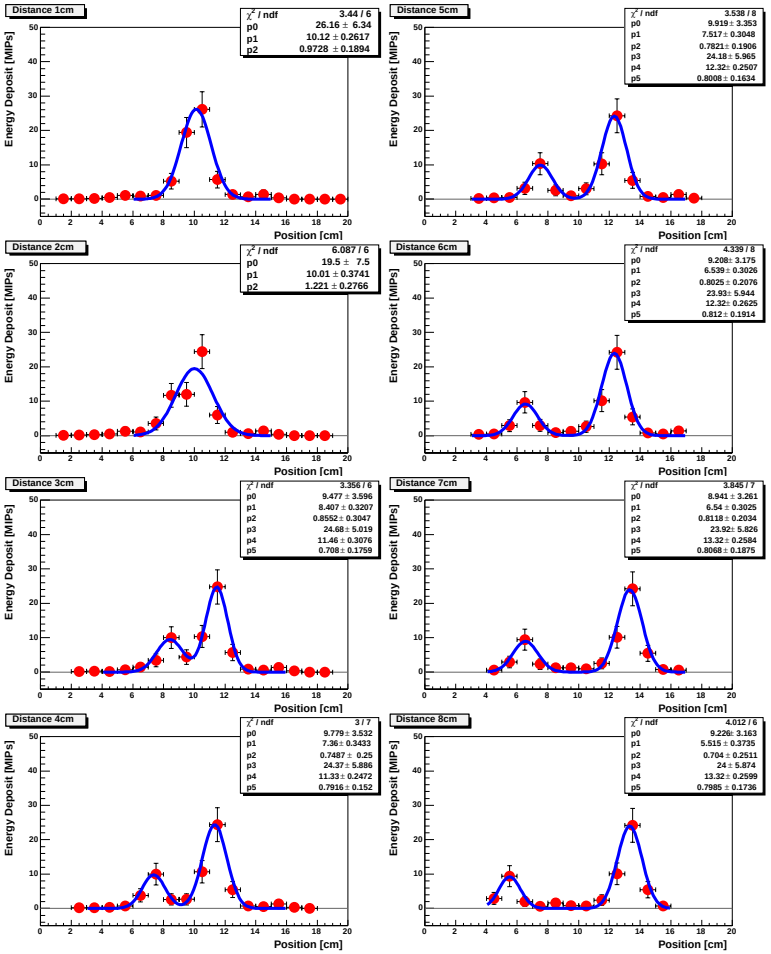
Algorithm of two-particle separation (very very preliminary…)

- Currently only 2nd SL (near shower maximum) is used.
- Search for peaks and count number of peaks
- Fit with multi-Gaussian function

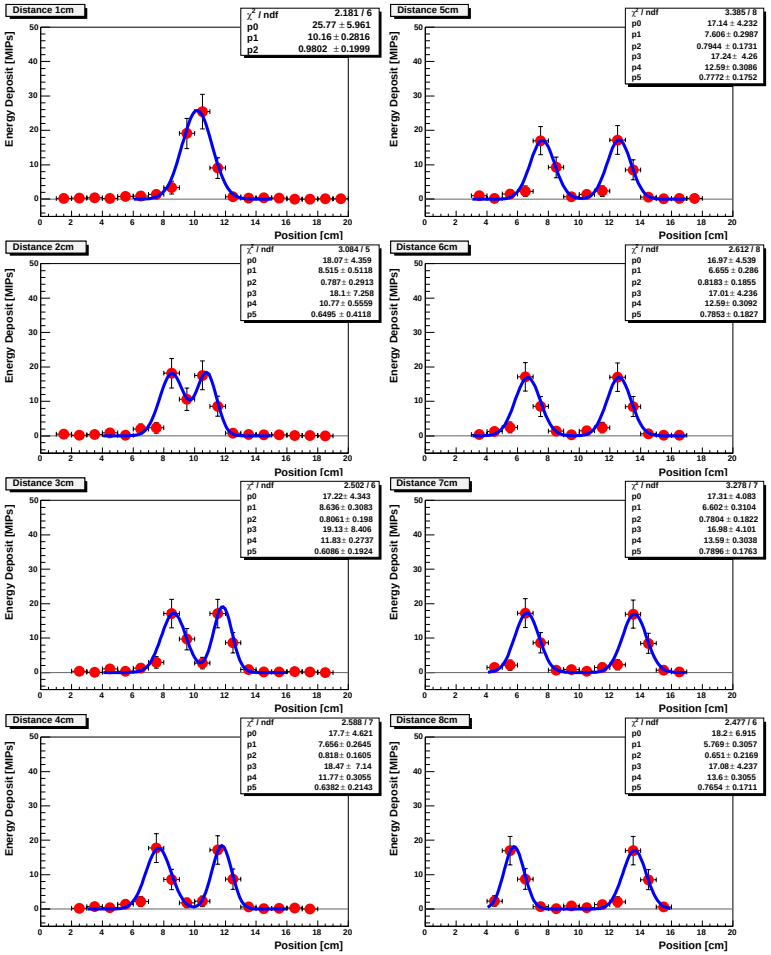


Some examples

1 GeV e + 4 GeV e



4 GeV e + 4 GeV e



- A very preliminary analysis suggests that two electrons with Δx=2~3cm may be separated.

Summary

- Scintillator strip-array ECAL was tested with test beam
  - Good uniformity for MIP
  - Energy resolution : 13%/sqrt(E) + 0%
  - Spatial resolution : 2.0mm for 4GeV electron
  - Shower-axis angle measured : σ_θ = 2.3 degree for 4GeV electron
  - Two-particle separation/ghost rejection : still under study
- Full simulation study : in progress