

CALICE silicon-tungsten electromagnetic calorimeter, $1 \times 1 \text{ cm}^2$ granularity prototype testbeam and results

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Outline

▶ **General**

▶ **Si/W prototype**

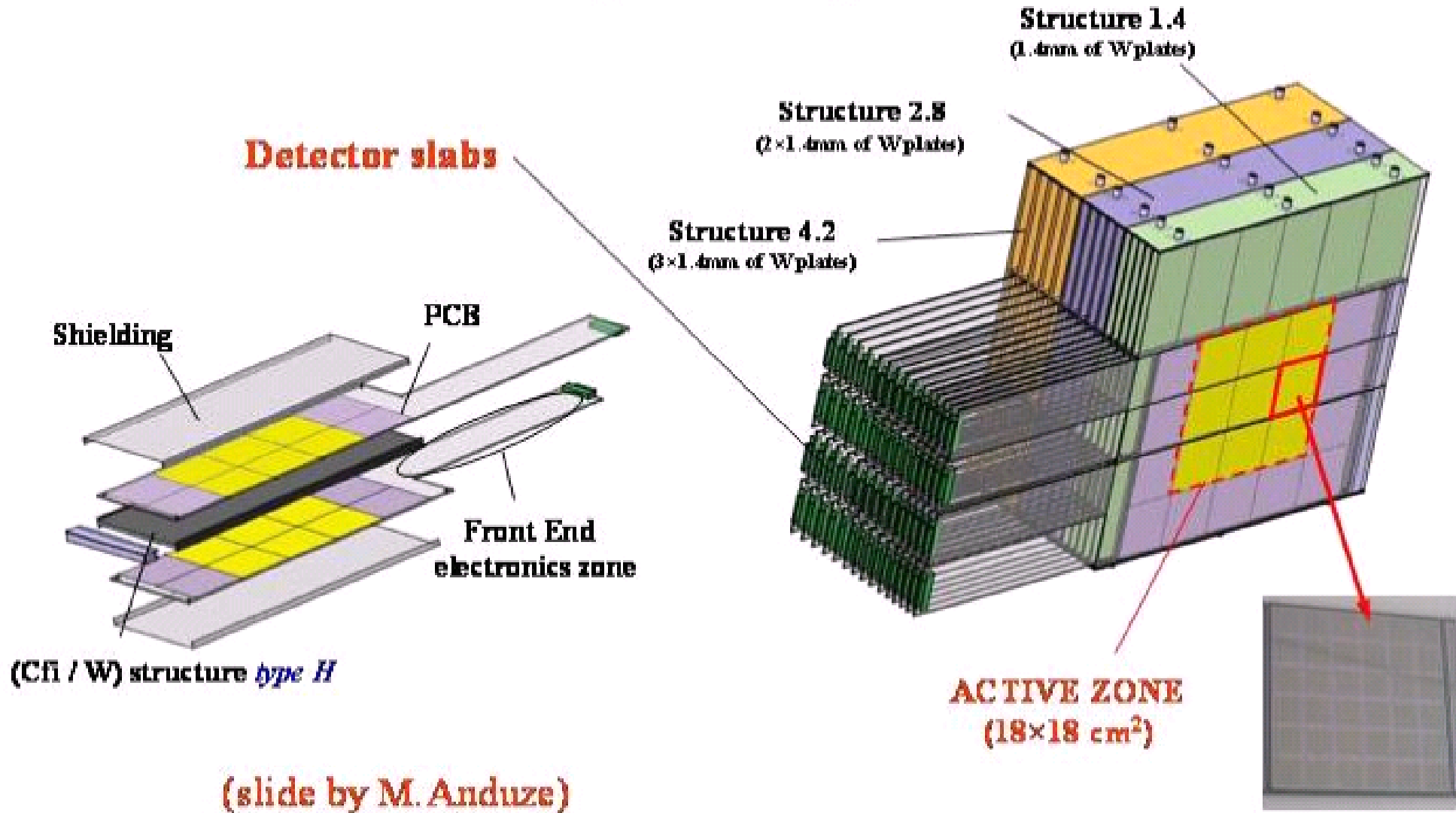
▶ **Testbeam results** (: position resolution, tracking performance
: response map, inhomogeneity
: transverse containment, Moliere radius)

▶ **Summary**

General

- ▶ **"1/3" of CALICE Si/W ECAL prototype**
 - : 3024 channels of $1 \times 1 \text{ cm}^2$, $7.2 X_0$
 - : first testbeam at DESY with e^- (Jan/Feb05), a lot of data collected
- ▶ **data analysis**
 - : in progress, mostly qualitative for basic understanding and debugging of the system
 - : quantitative analysis still possible
 - ▷ useful for planning and guiding the next testbeam
 - ▷ results indicative of detector characteristics
 - ▷ pilot-reference studies to be repeated as detector grows

CALICE ECAL prototype



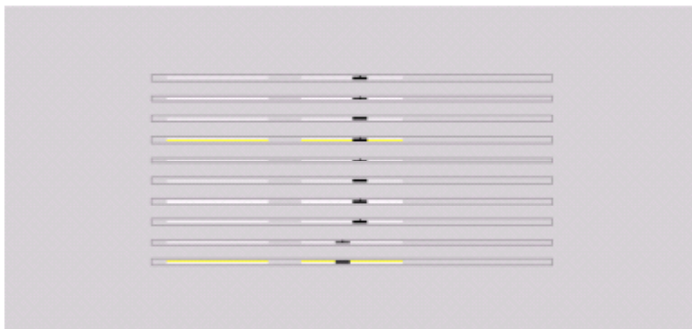
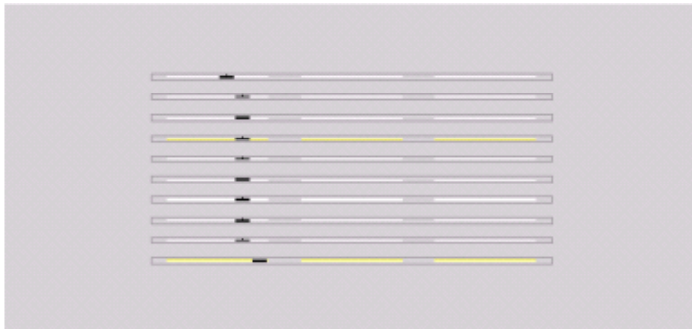
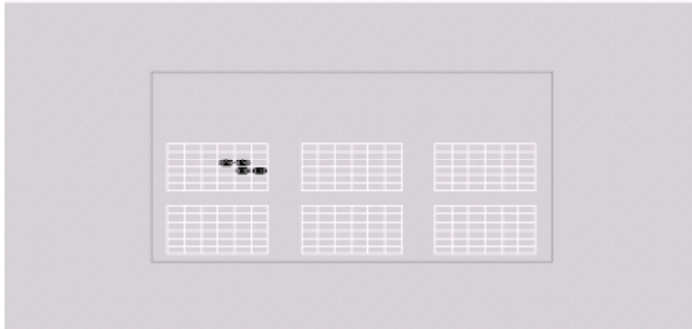
full Si/W prototype (24 X_0)

- ▷ 30 layers \times 18 cm \times 18 cm interleaved with 0.5 mm Si pads
- ▷ W absorber, 10+10+10 layers, 1.4 mm:2.8 mm:4.2 mm thick per respective layer
- ▷ readout by **1 \times 1 cm² cells, total: 9720 channels**

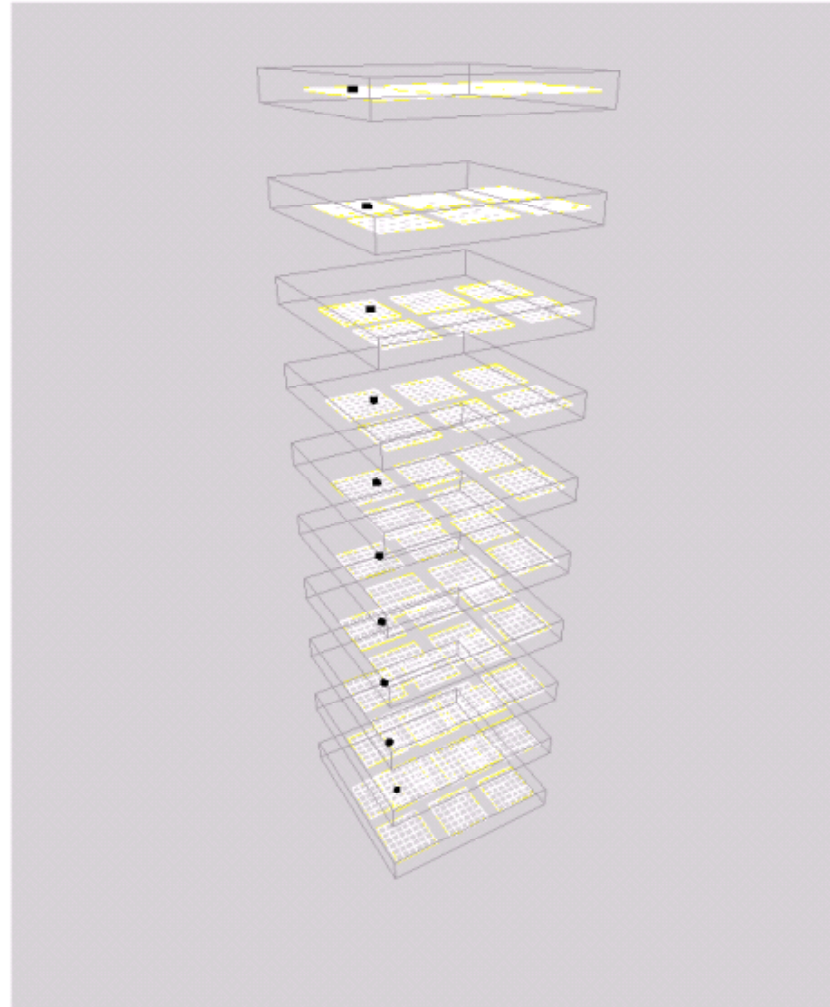
Si Wafer :
6 \times 6 pads of detection
(10 \times 10 mm²)

Cosmics

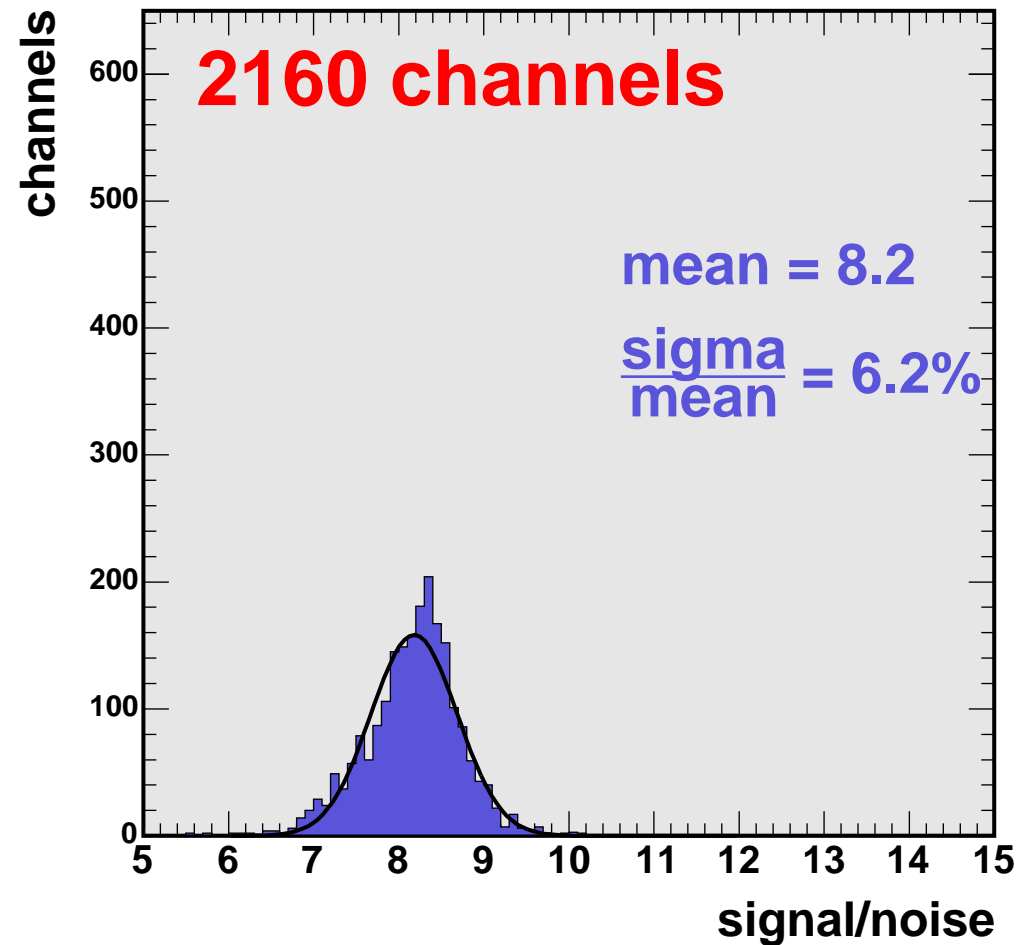
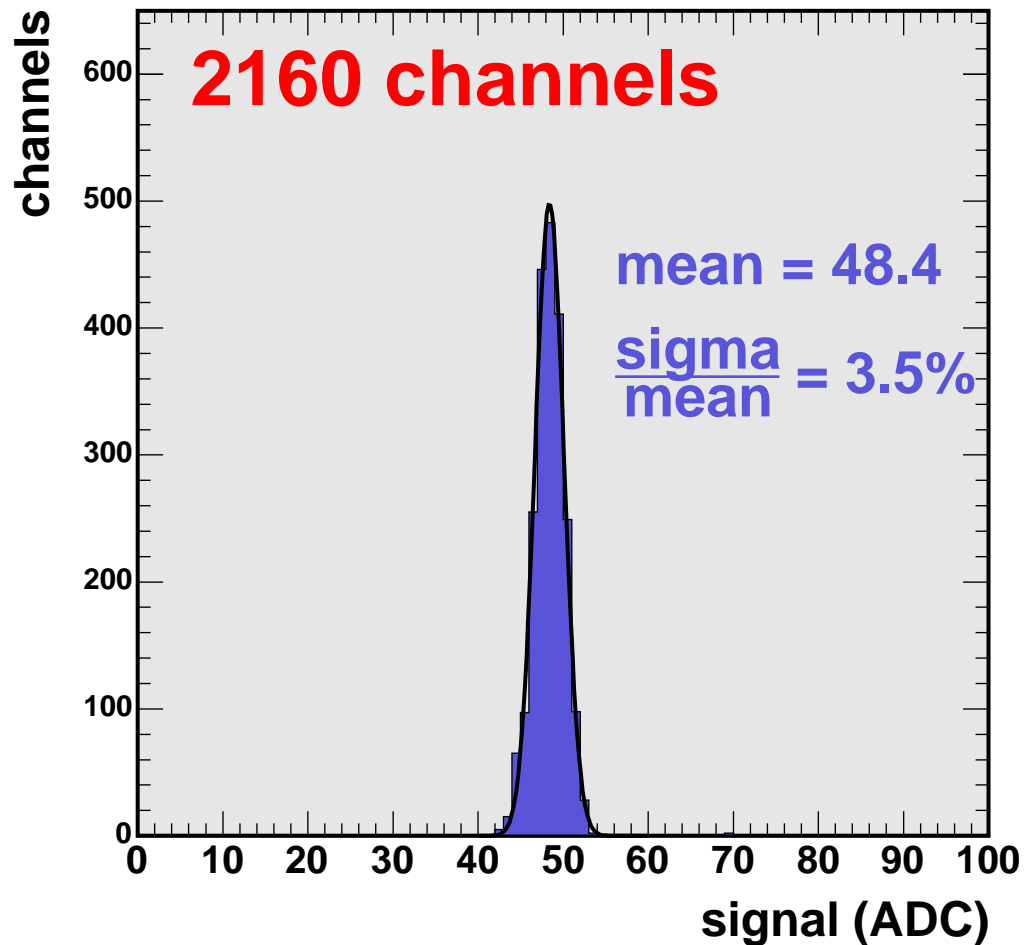
Run 1104860743 Event 133



RcdHeader::print() Record Time = 17:47:59.737:785 Tue Jan 4 2005, Type = 5 = event
DaqEvent::print() Event numbers in run 0, in configuration 0, in spill 0



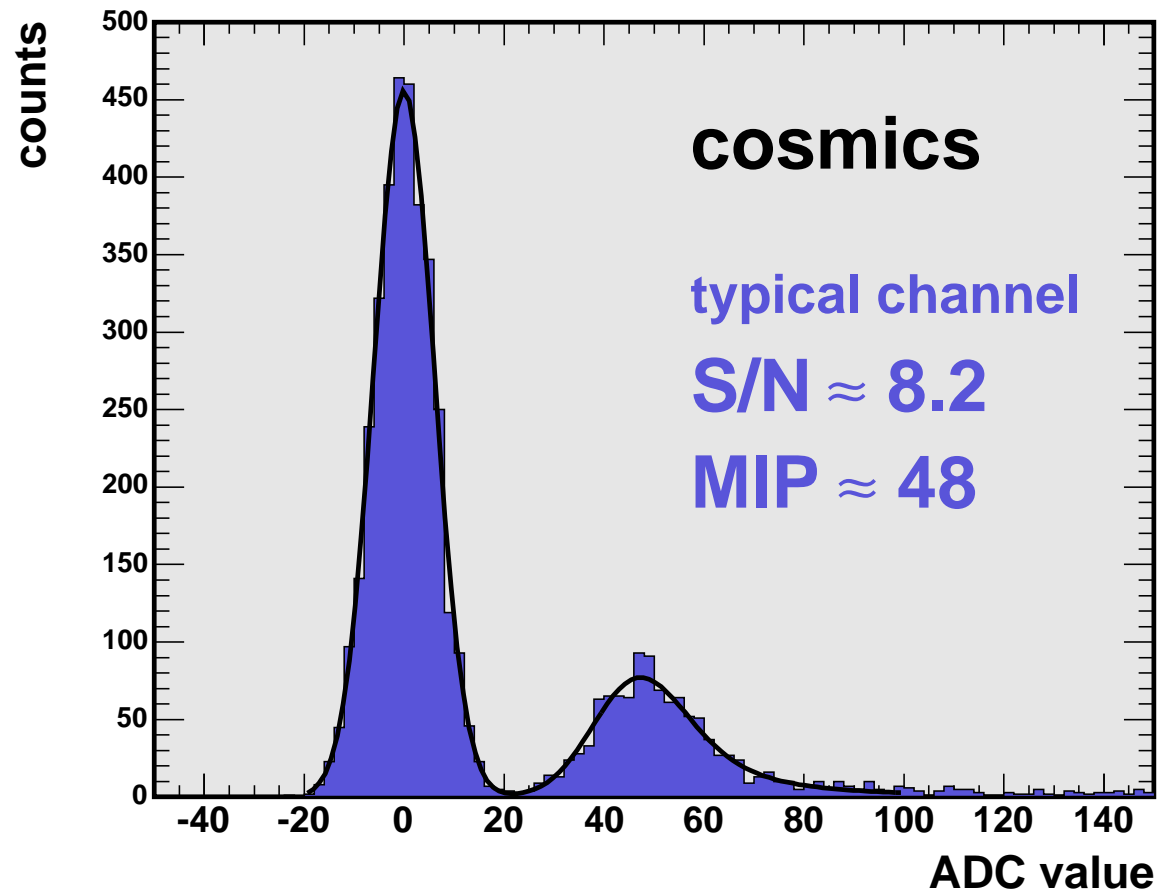
Calibration with cosmics



▷ 10 layers (2160 channels) calibrated with cosmics (1 Mevents)

(LLR-Paris, Dec04)

Calibration with cosmics



▷ a typical channel: gaussian noise, landau signal

CALICE-ECAL testbeam at DESY

- ▶ . **"30%" equipped Si/W prototype**

- : i.e. 14 W layers (10 at 1.4mm + 4 at 2.8mm) interleaved with 18 × 12 matrix of active Si cells, 1 × 1 cm² each, total: 3024 channels

- : first testbeam at DESY with electrons during Jan/Feb05

- ▶ . **in summary (configurations: position × energy × angle)**

- : position scan (center - edge - corner of wafers)

- energy scan (mainly 1, 2, 3 GeV, some runs at 4, 5, 6 GeV)

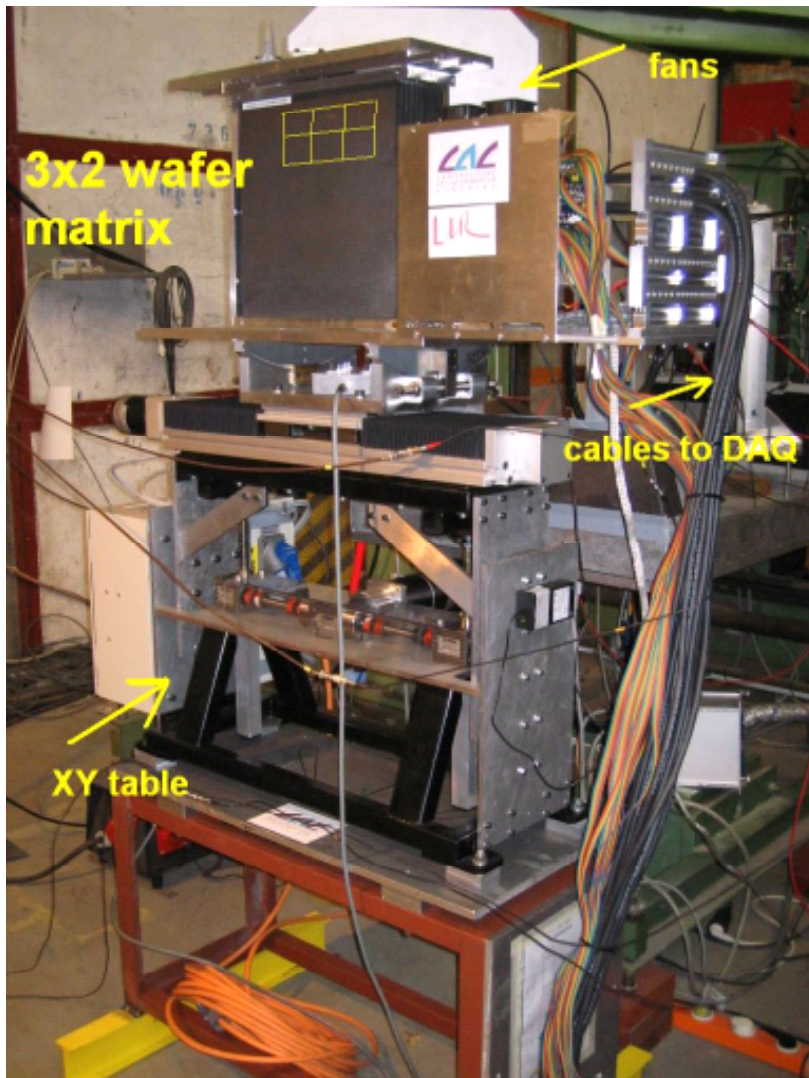
- angle scan (0°, 10°, 20°, 30°)

- : total: ~ 25 Mevents (~ 230 GB)

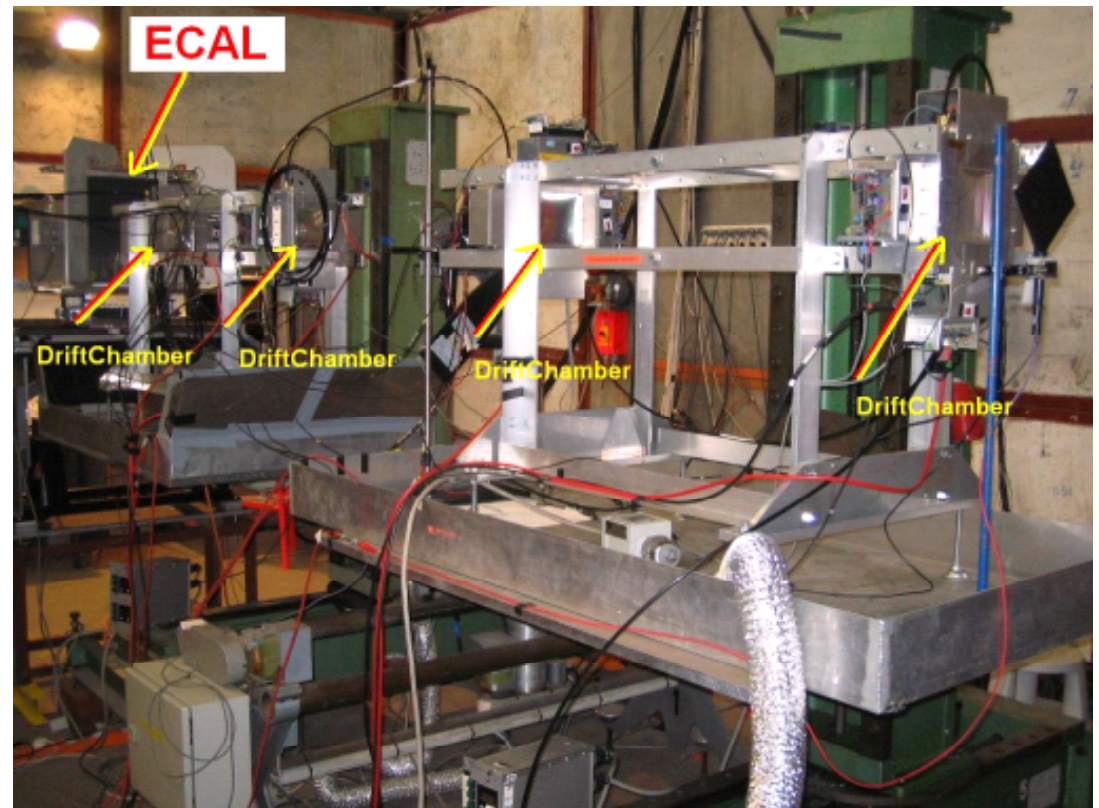
- ▶ . **next round in Jan06 with more layers-channels**

CALICE-ECAL testbeam at DESY

ECAL

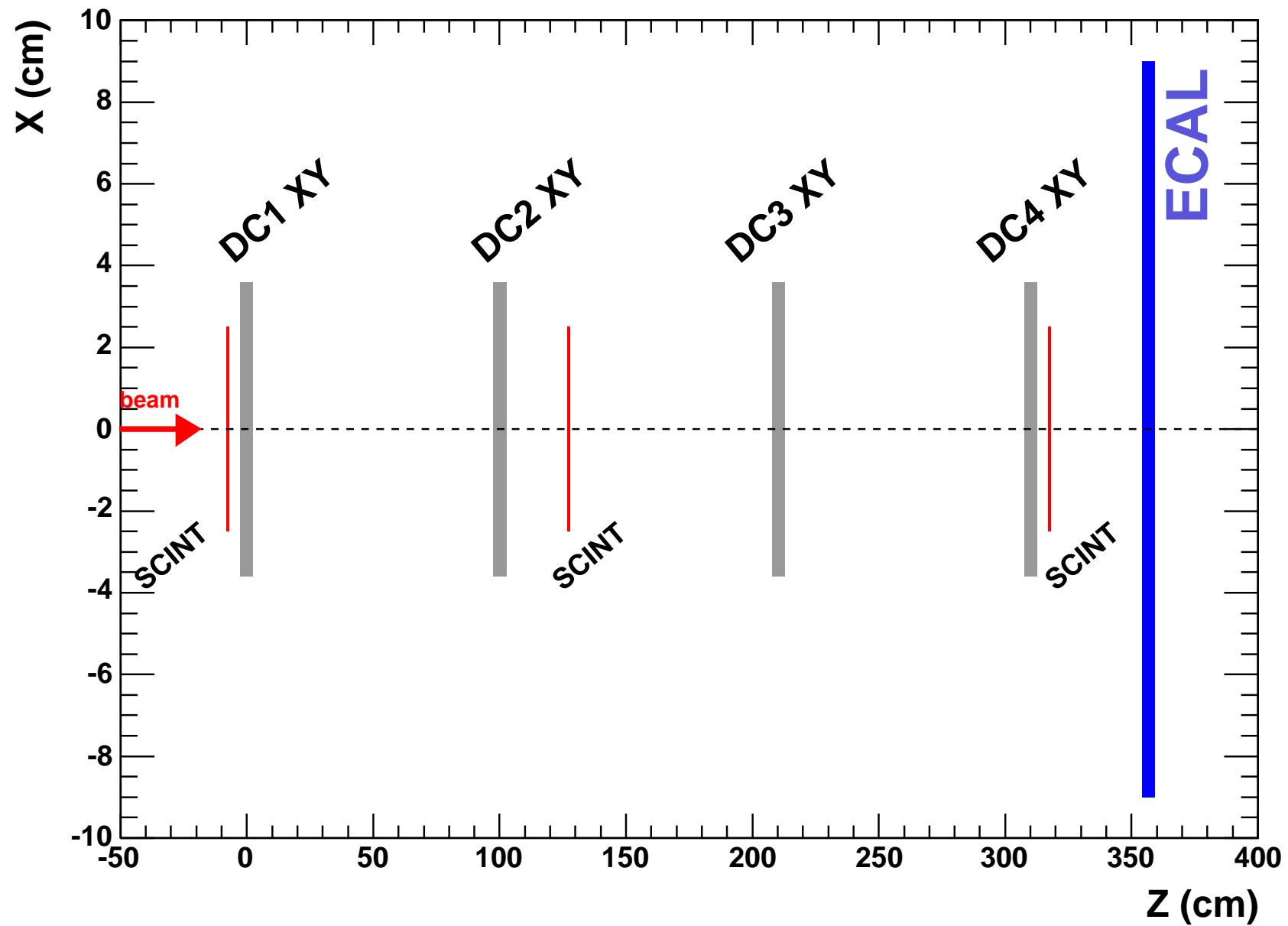


layout at DESY T21

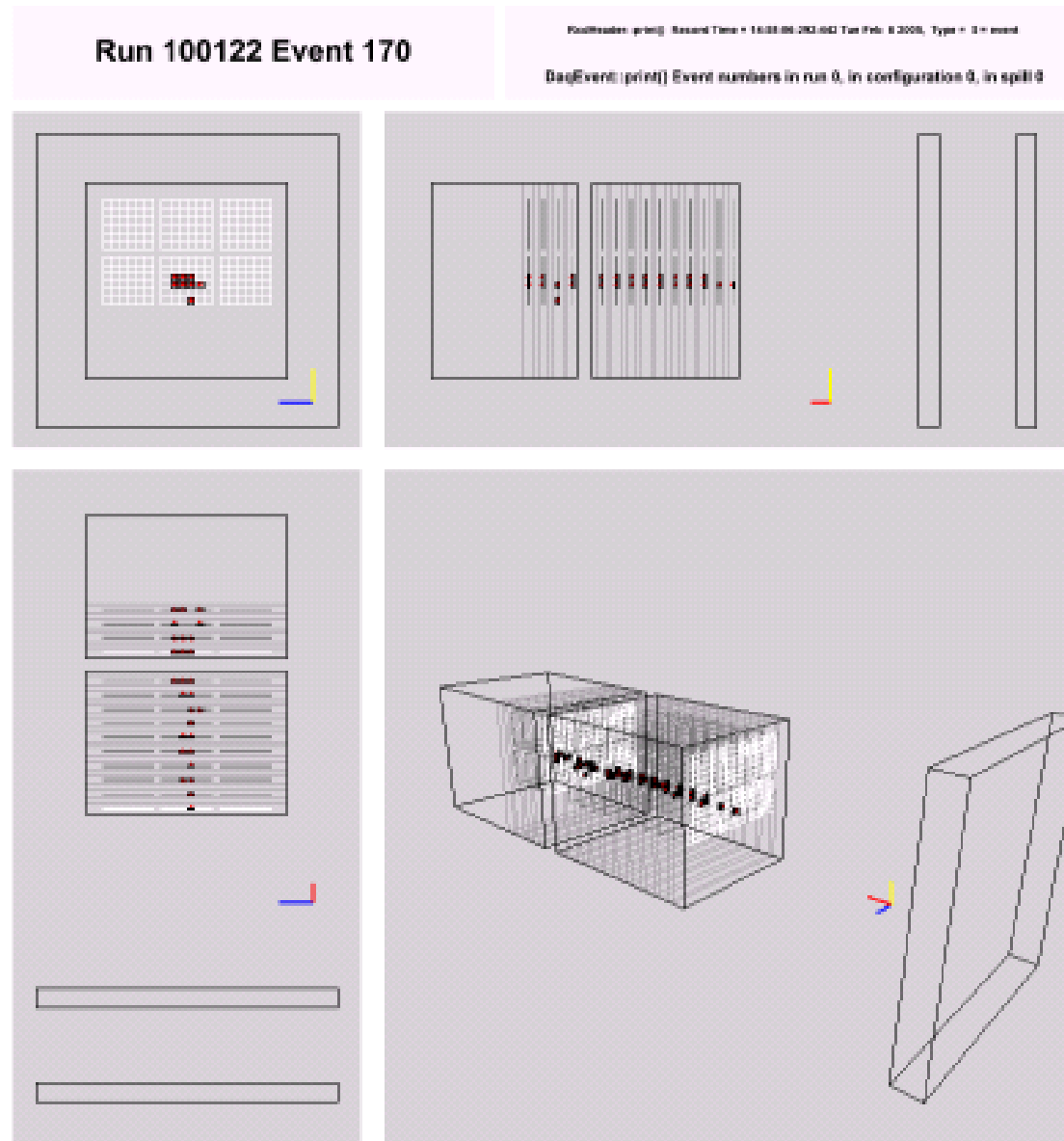


DriftChambers and installation courtesy of Tsukuba Univ. and Kobe Univ.

Testbeam layout



"Tracking Calorimetry"

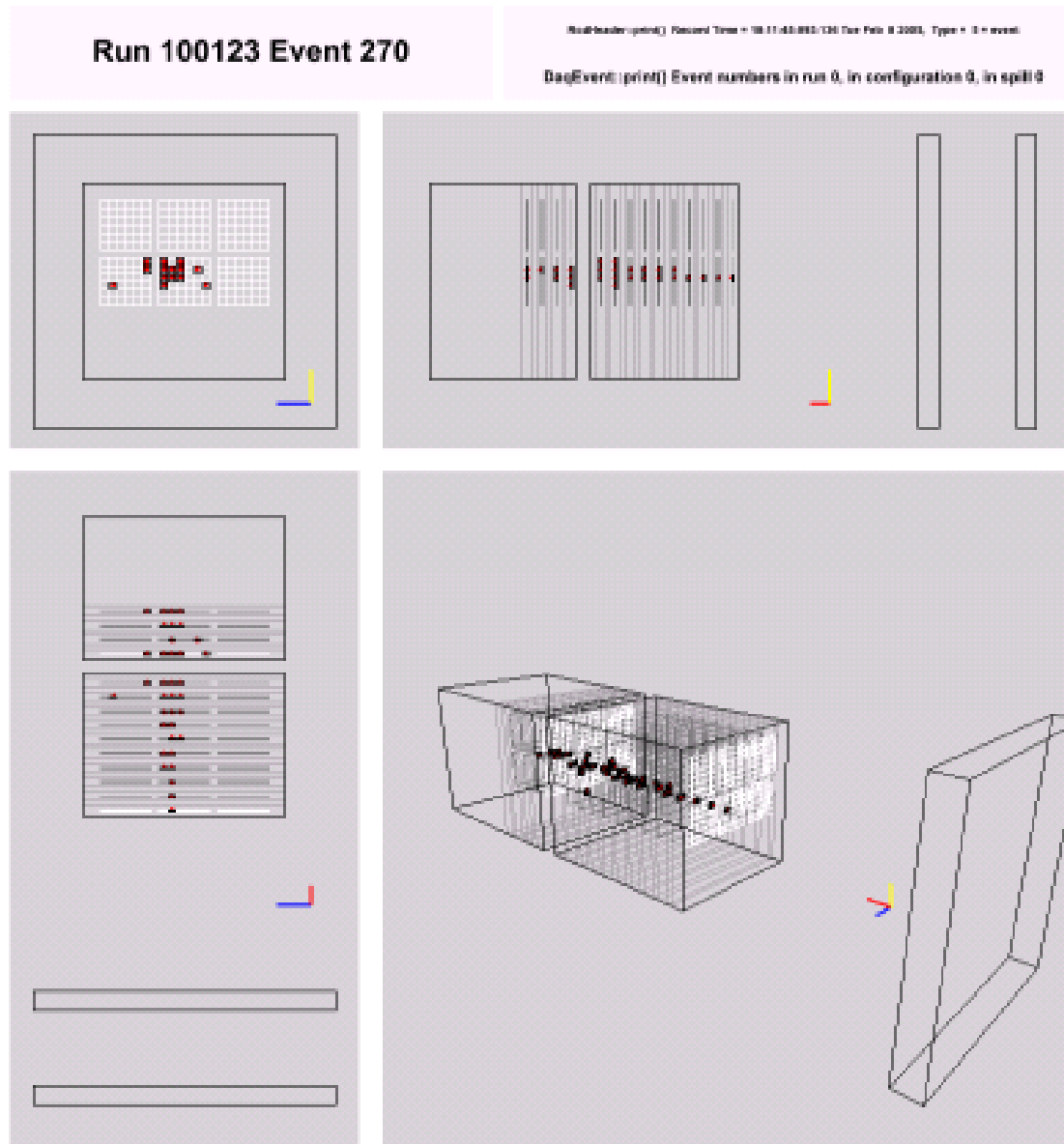


(not to scale)

e^- 1 GeV

cell threshold = 0.5 mip

"Tracking Calorimetry"

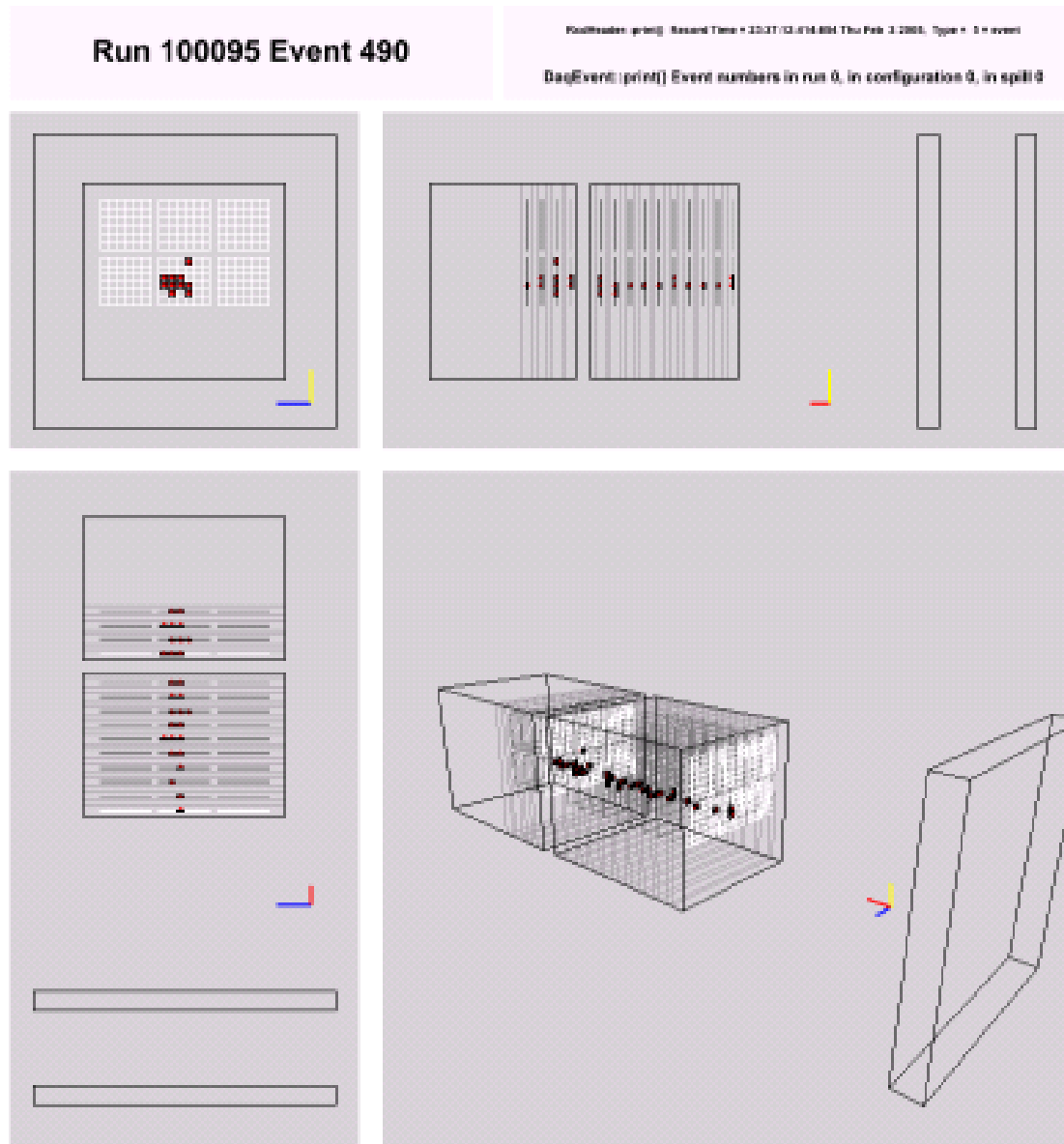


(not to scale)

e^- 2 GeV

cell threshold = 0.5 mip

"Tracking Calorimetry"

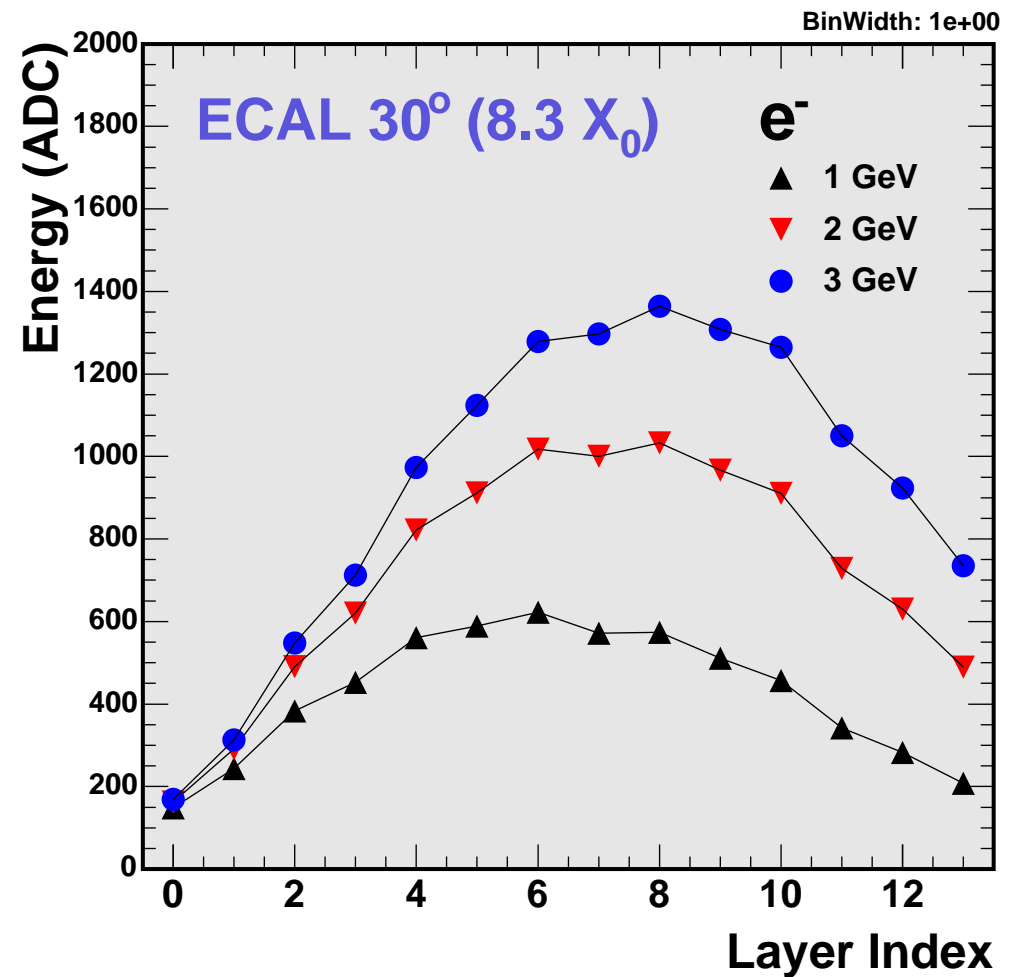
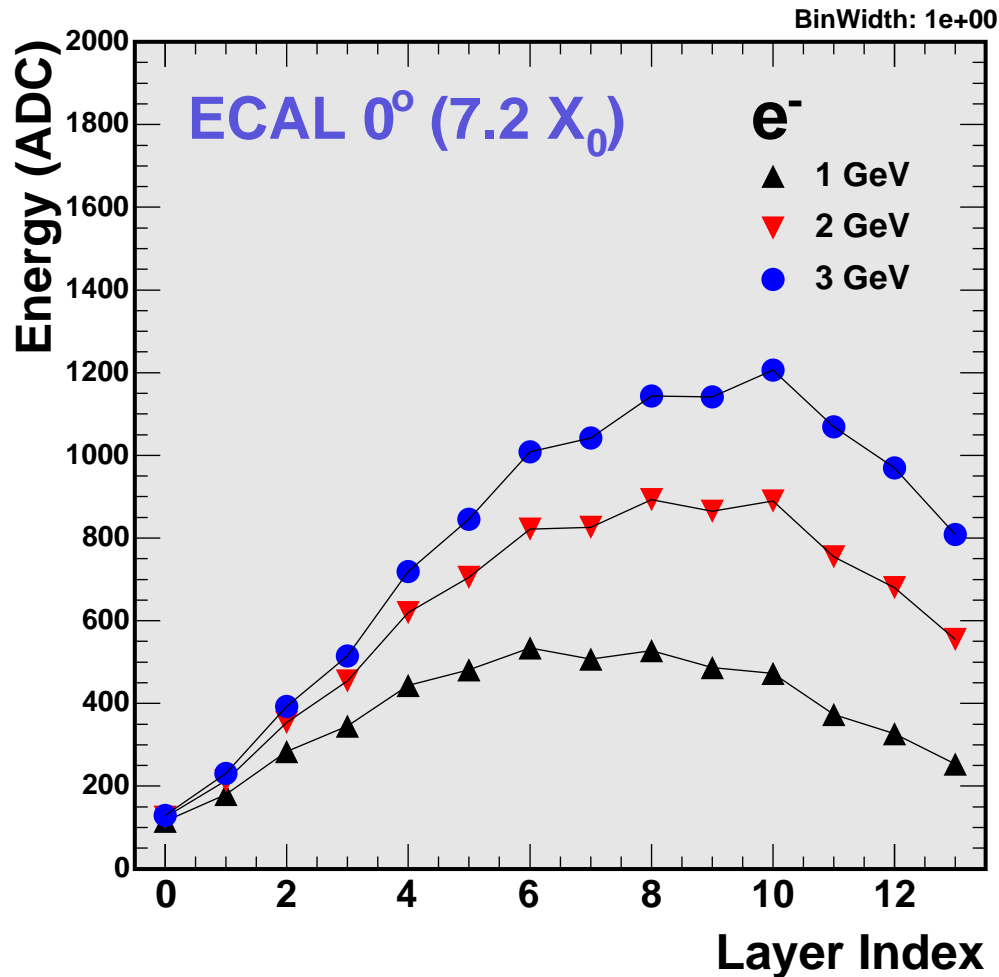


(not to scale)

e^- 3 GeV

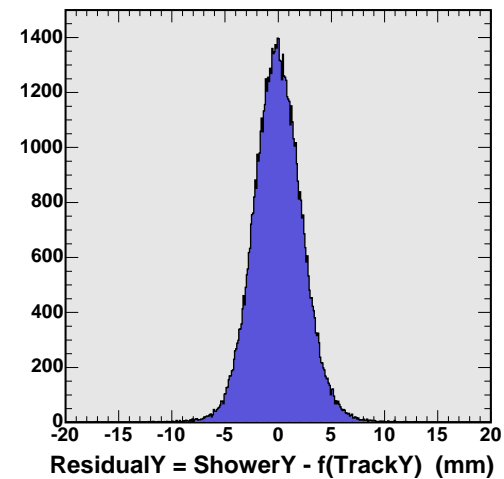
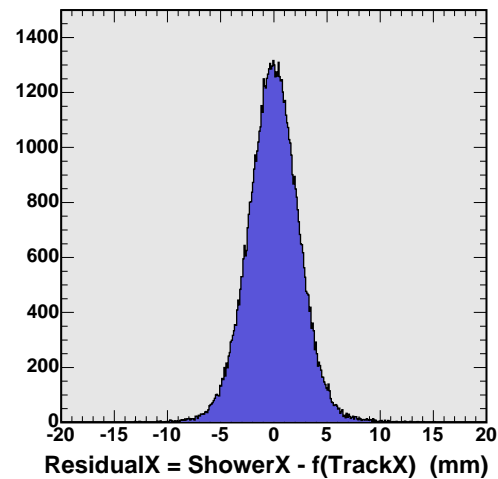
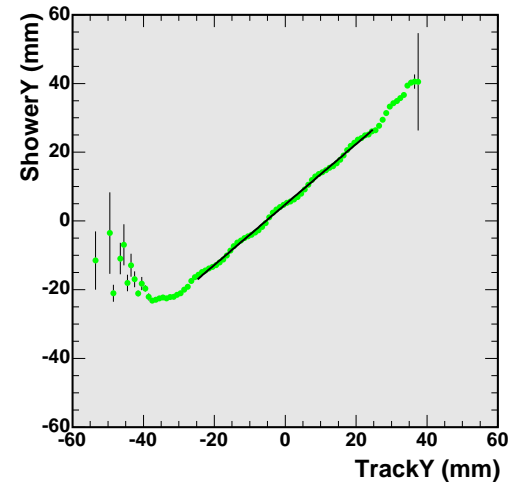
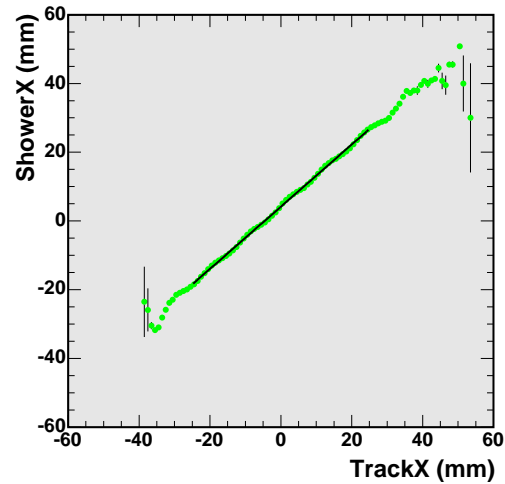
cell threshold = 0.5 mip

Shower longitudinal profile



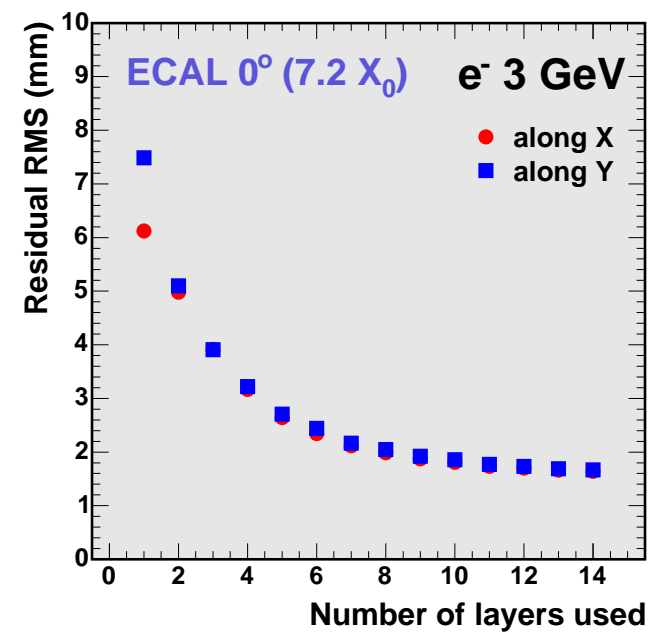
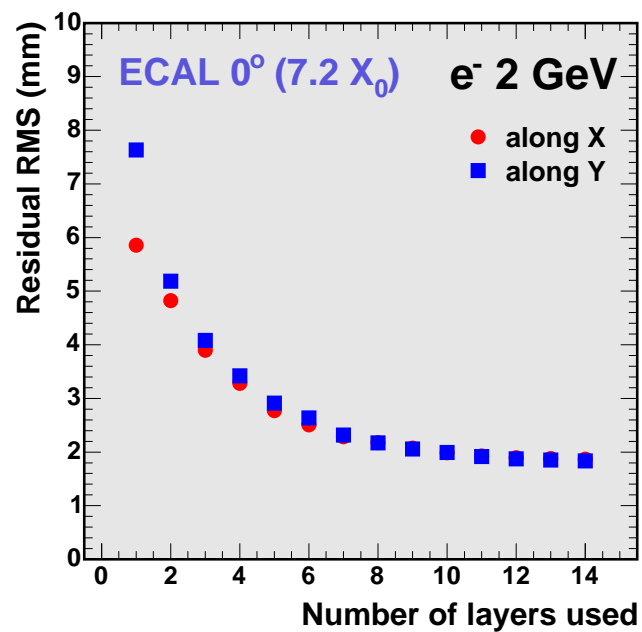
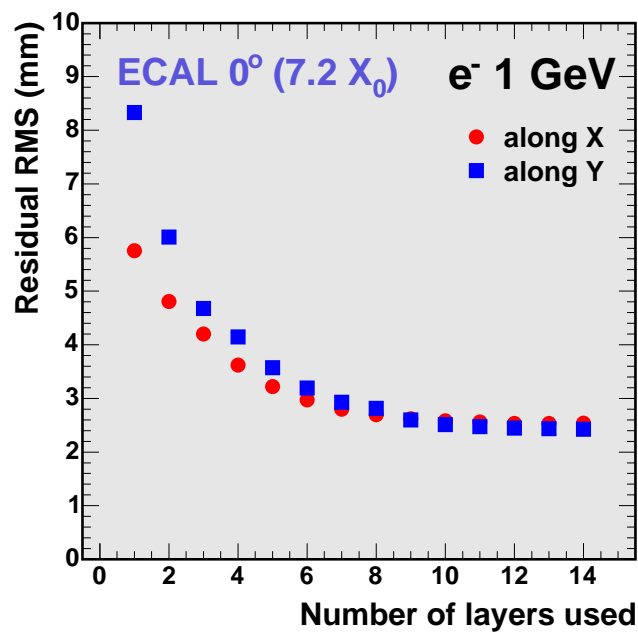
- ▷ shower maximum is contained
- ▷ odd/even asymmetry of construction observed
- ▷ showers better contained at 30°

Tracking - Residuals



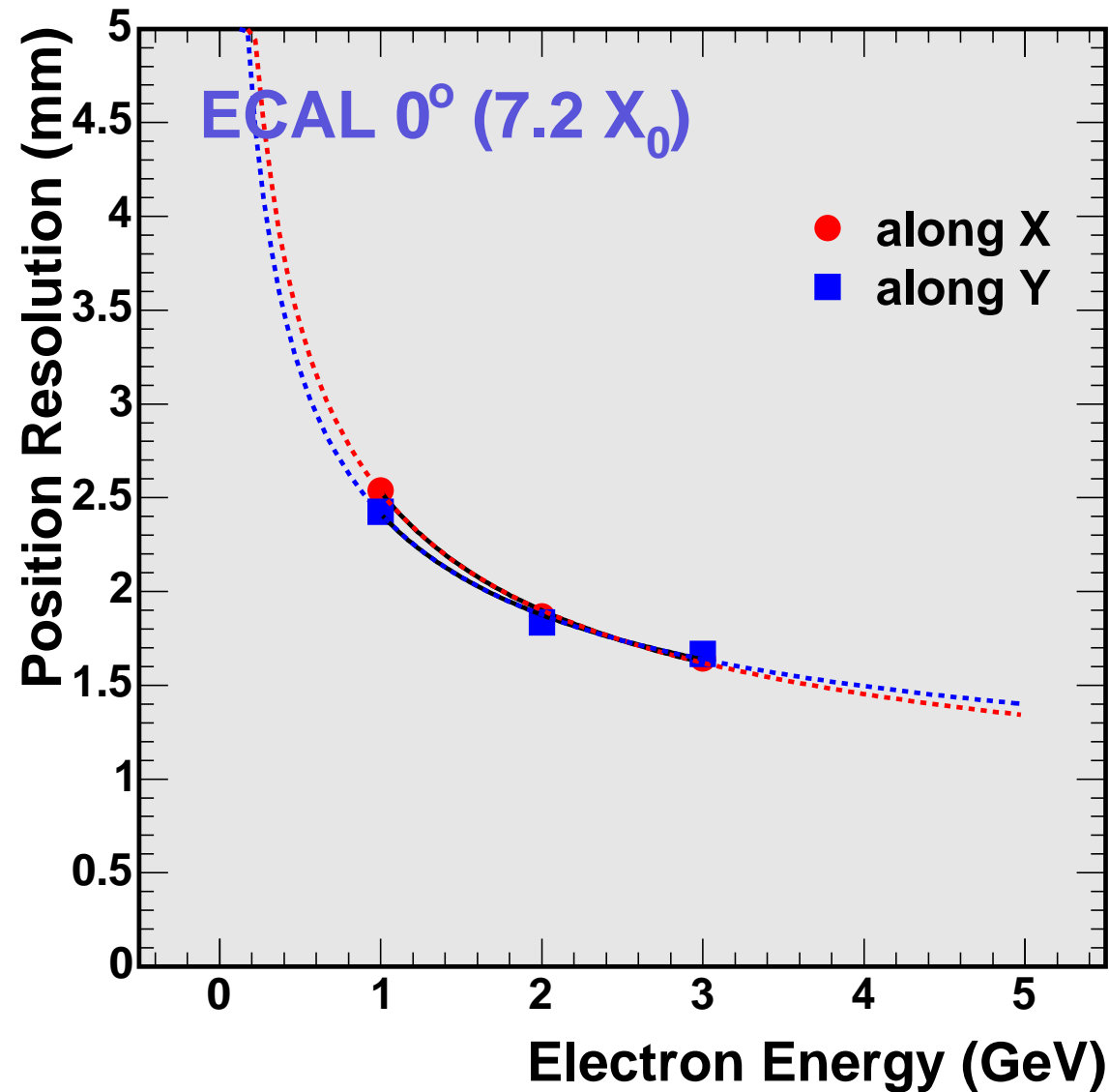
- ▷ ShowerX,Y from barycenter in ecal
- ▷ TrackX,Y from 4 drift chambers

Position resolution



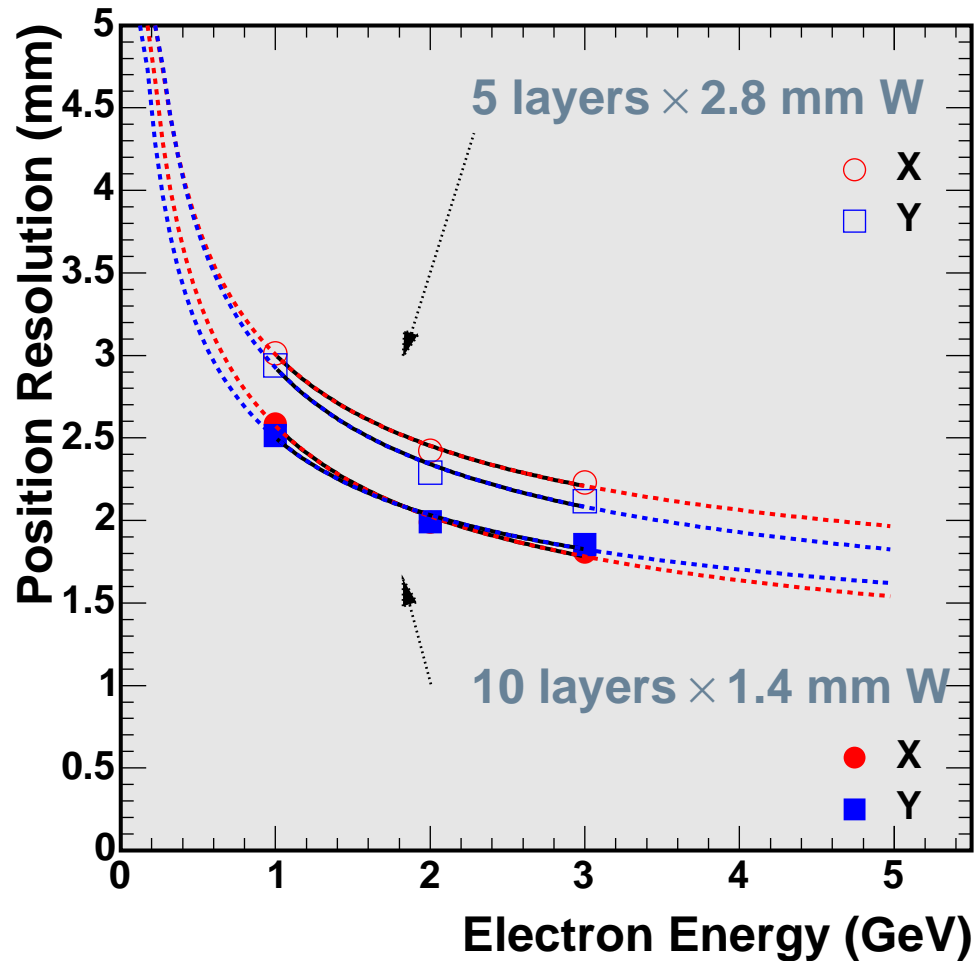
▷ Residual RMS as a function of the number of ecal layers used

Position resolution



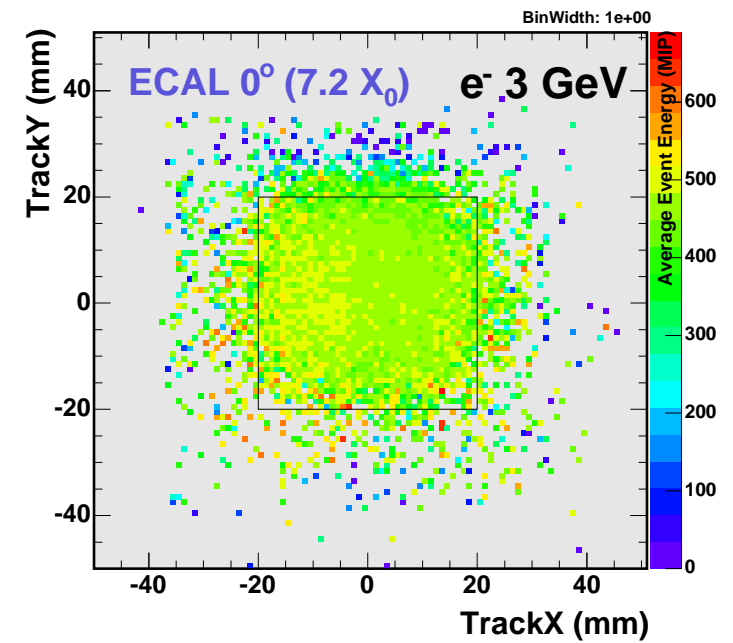
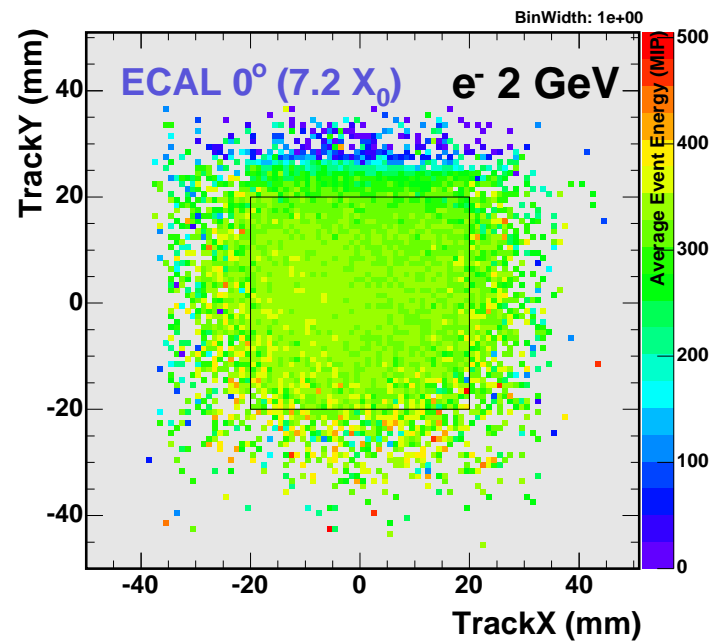
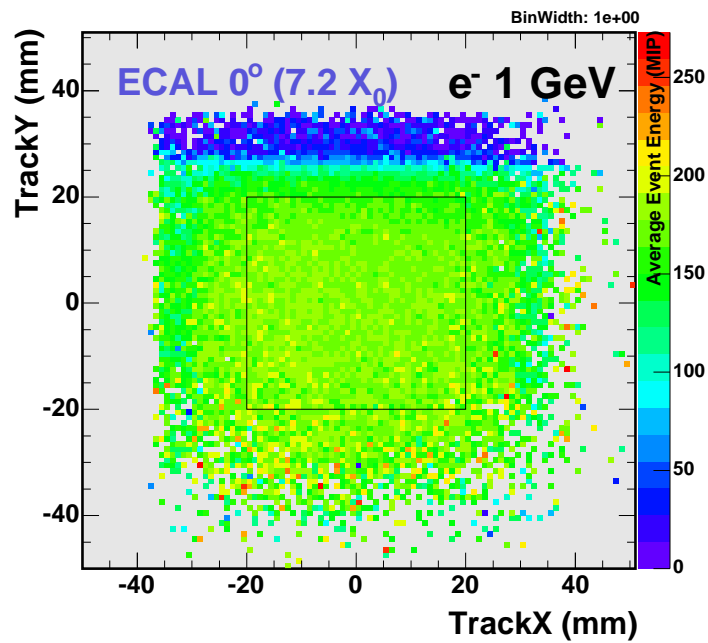
▷ highly granular ECAL → excellent position resolution

Position resolution - undersampling

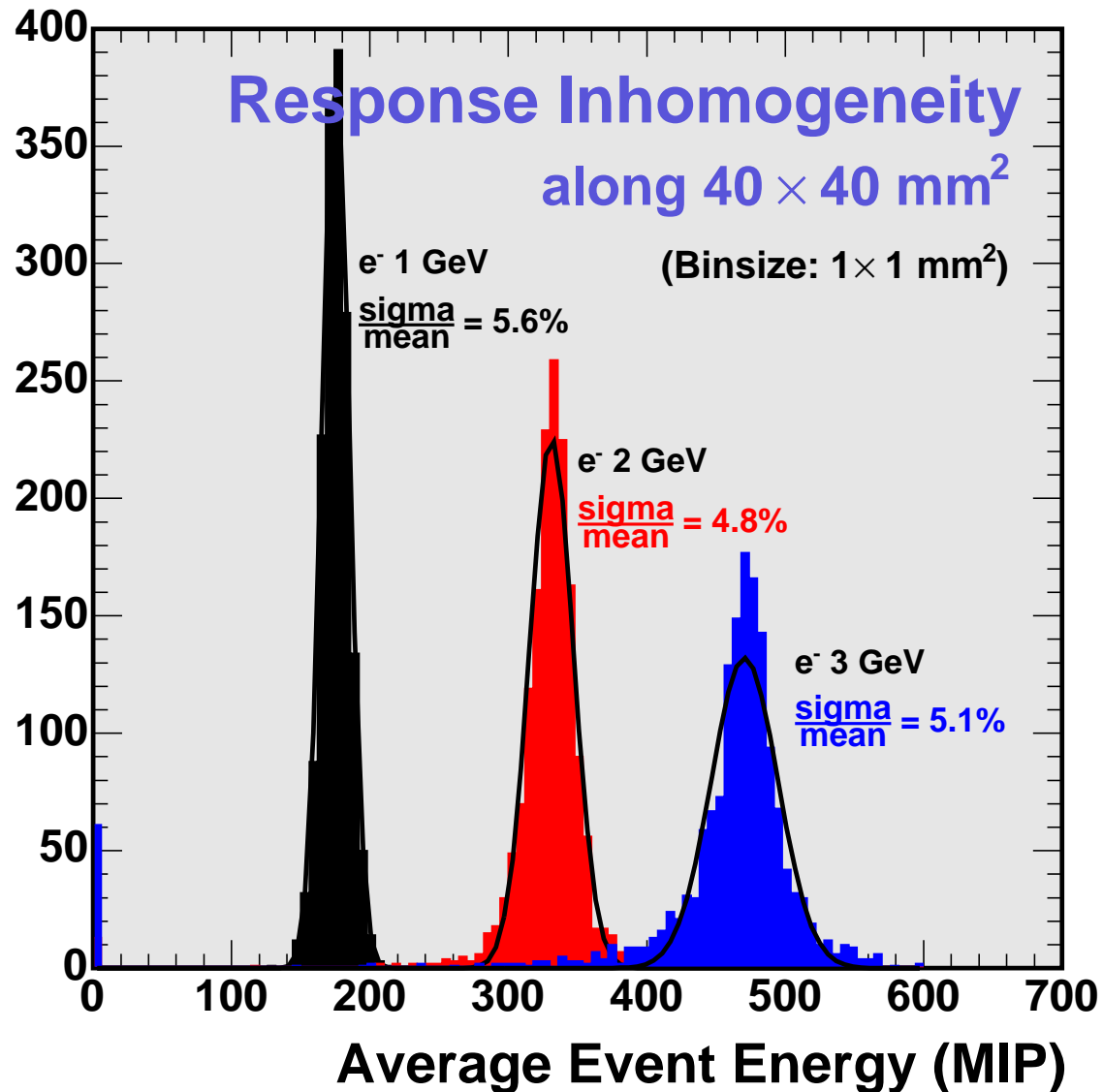


- do tracking by using only hits from every 2nd layer
- to investigate the tracking performance of an ecal with 5 layers × 2.8 mm W (instead of 10 layers × 1.4 mm W)
- expect position resolution to degrade by factor $\frac{\sigma_5}{\sigma_{10}} \approx \frac{\sqrt{10}}{\sqrt{5}}$

Response map - center of wafer

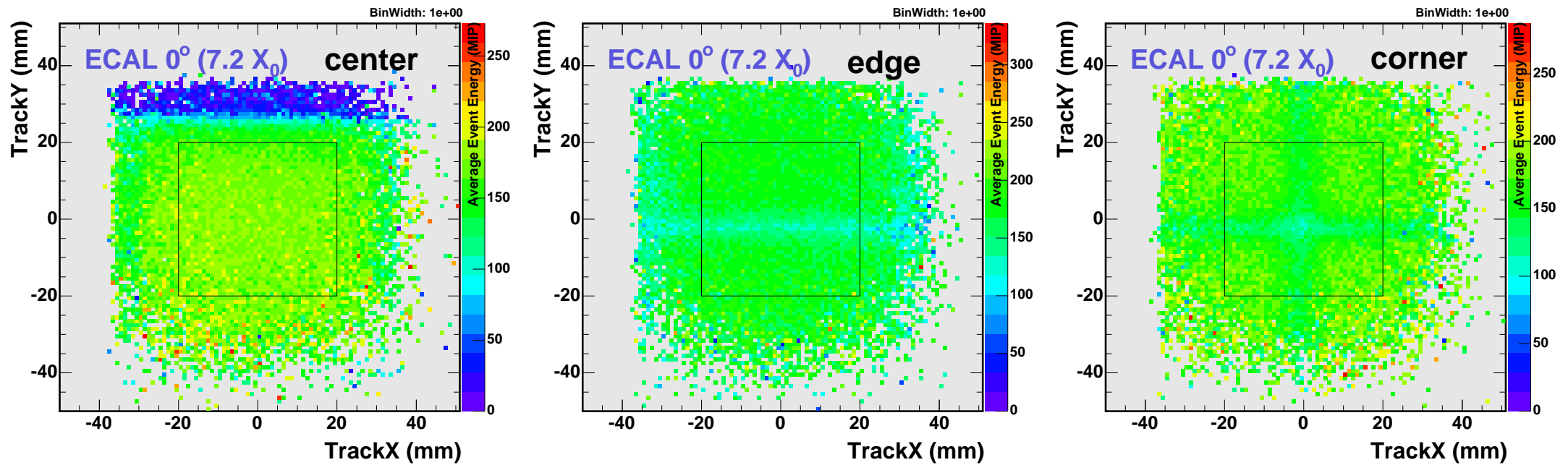


Response Inhomogeneity

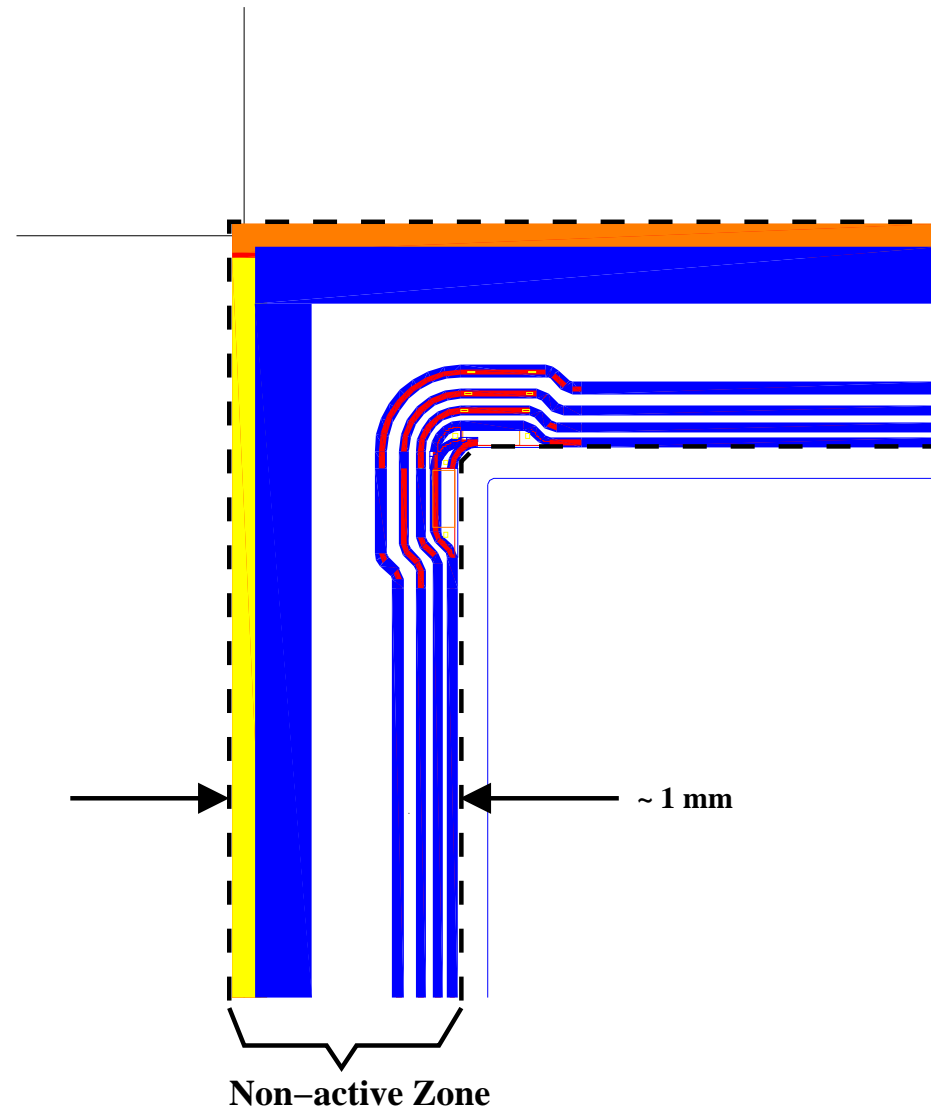


- ▷ response variation around the center of wafer

Response map - center/edge/corner of wafer

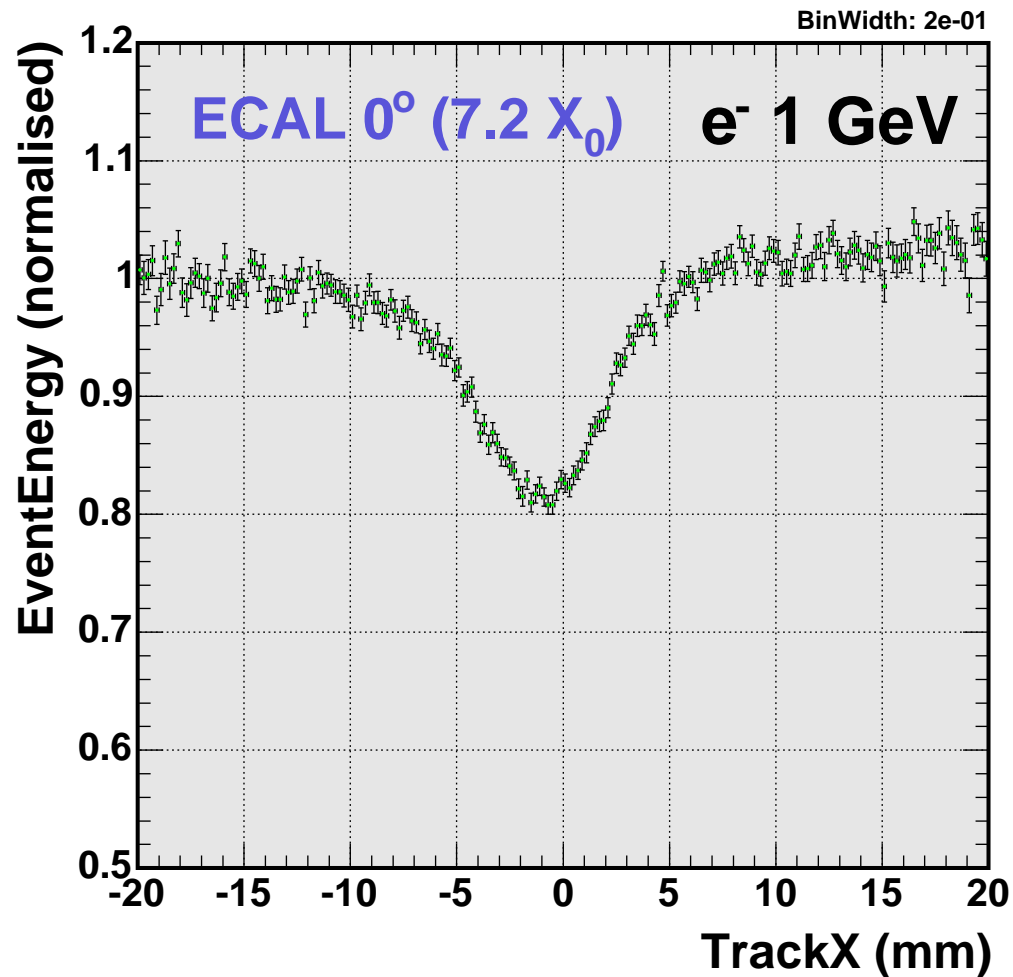


Wafer border

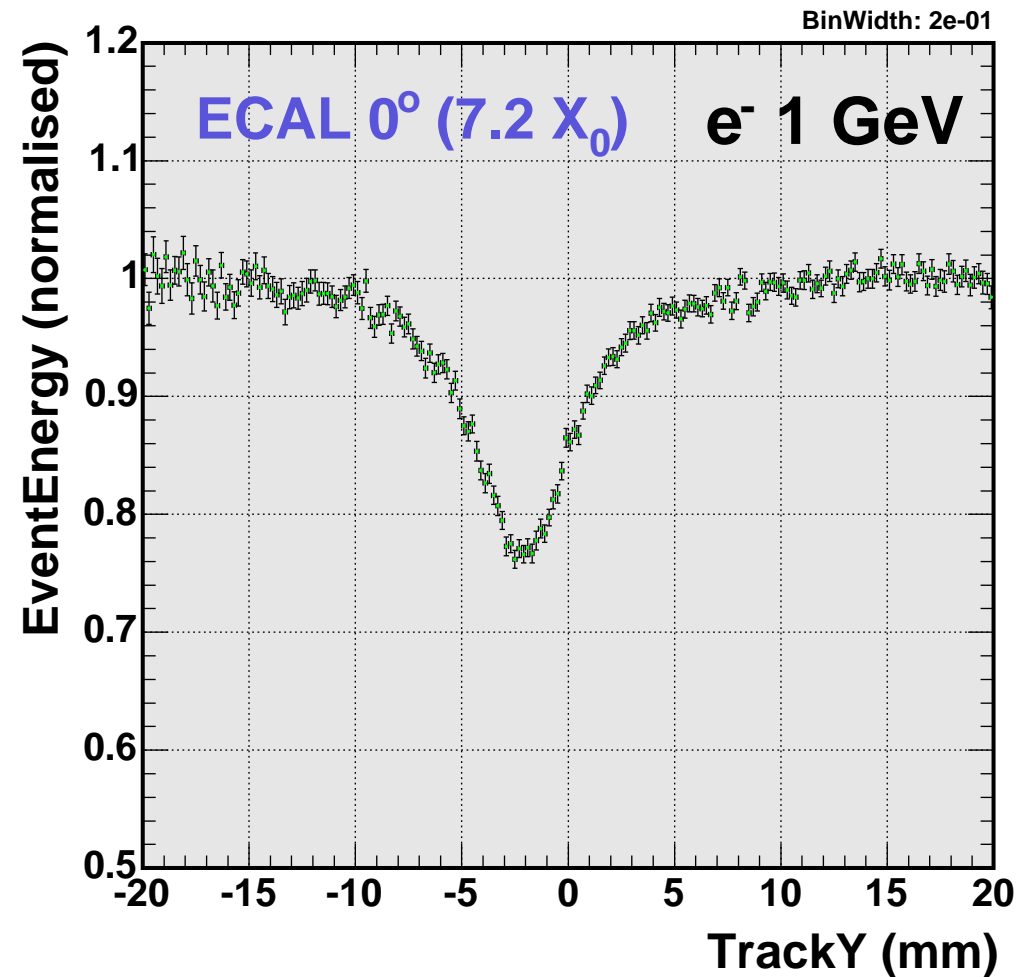


▷ (C.LoBianco, LC-DET-2004-007)

Position scan along wafer borders

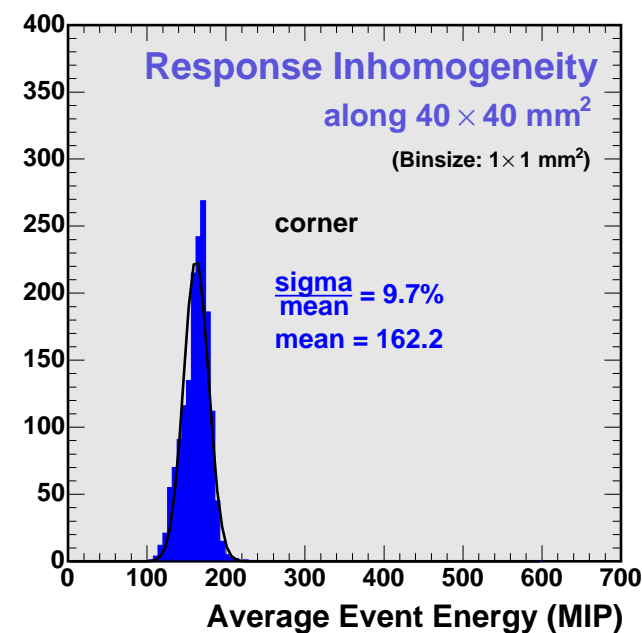
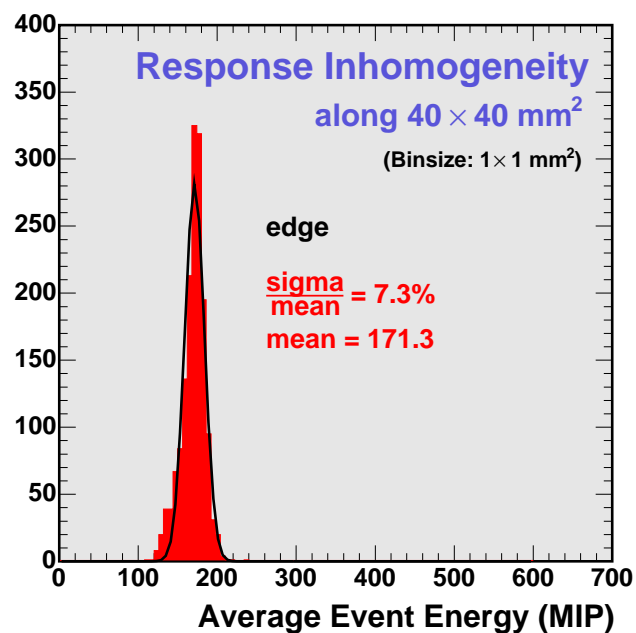
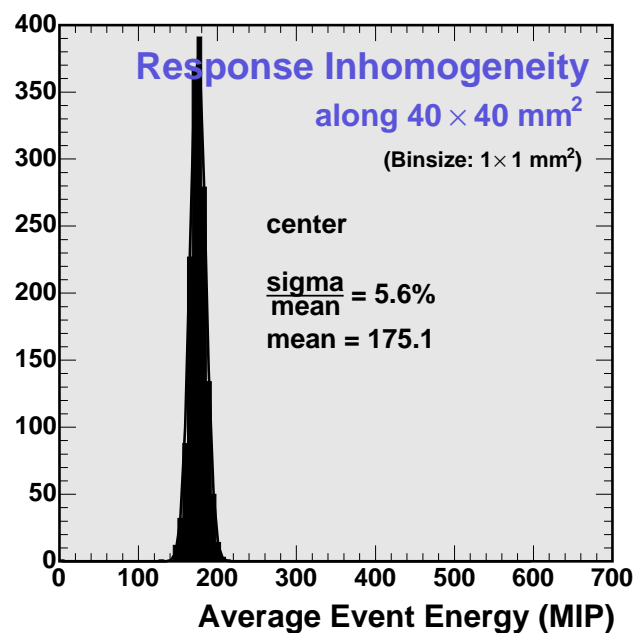


- ▷ alternate layers staggered along X (by 2.5 mm)
- ▷ dip is shallower and wider



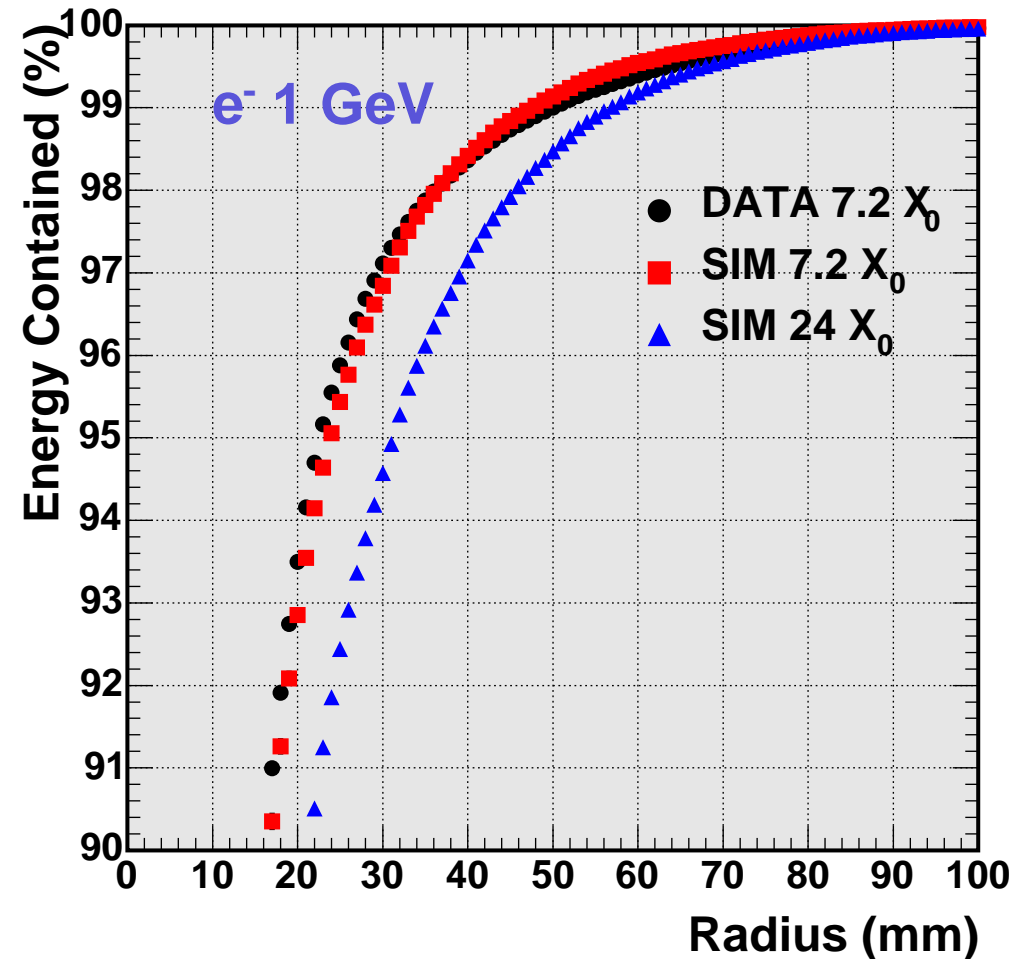
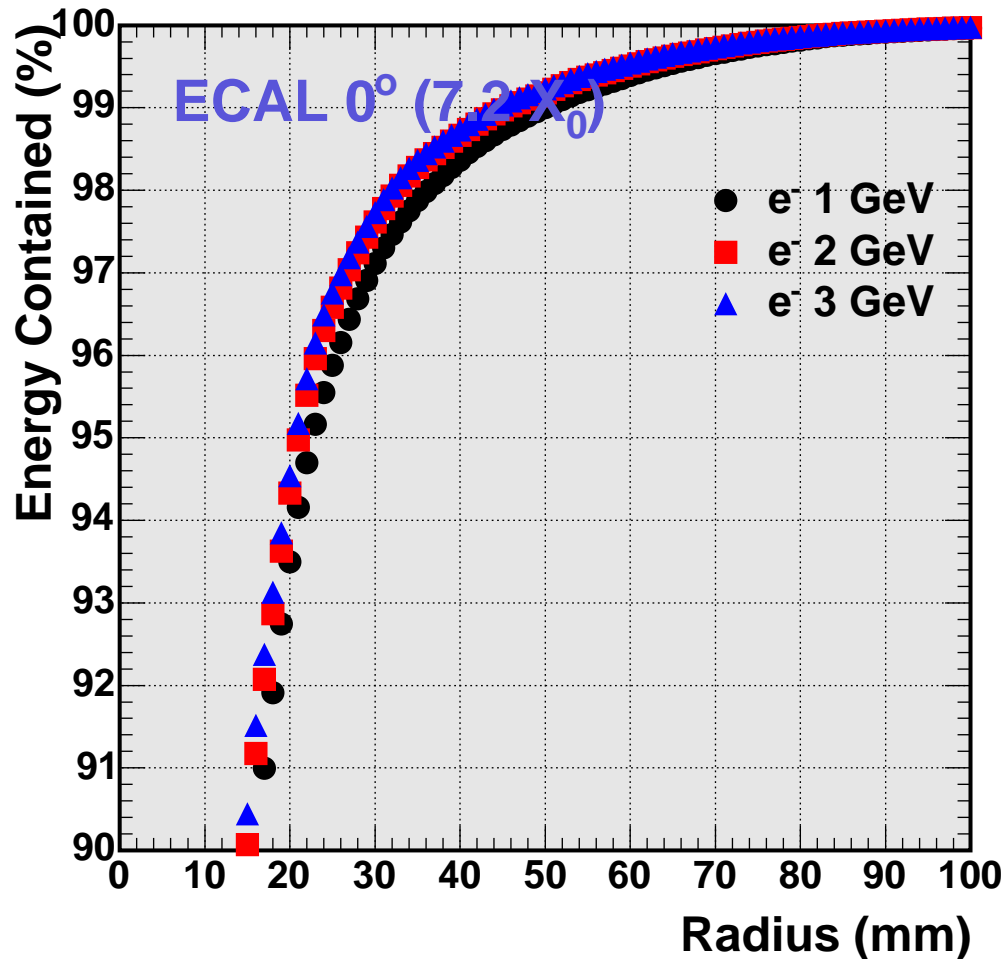
- ▷ layers not staggered along Y
- ▷ dip is deeper and narrower

Response Inhomogeneity



▷ response variation around the center/edge/corner of wafer

Transverse containment (Moliere radius)



▷ e.g. 1 GeV e^- shower "contained" at

- : 90% within radius 16 mm
- : 95% 23 mm
- : 99% 50 mm

▷ data-simulation comparison

▷ results expected for the 24 X_0 prototype

REMINDER: for an infinitely long and wide calorimeter
 shower contained at 90% within radius $\sim 1 R_M$
 95% $\sim 2 R_M$
 (for solid W, $R_M \simeq 10$ mm) 99% $\sim 3.5 R_M$

Summary

- ▶ **"1/3" of CALICE Si/W ECAL prototype**
 - : 3024 channels of $1 \times 1 \text{ cm}^2$, $7.2 X_0$, 14 layers
 - : first testbeam at DESY with e^- (Jan/Feb05)

- ▶ **data analysis is in progress**
 - : systematic studies to understand the detector before the next testbeam

 - : results shown from studies on
 - ▷ position resolution, tracking performance
 - ▷ response map, inhomogeneity
 - ▷ transverse containment, Moliere radius

BACKUP SLIDES

General

- ▶ . **particle flow paradigm**

- : highly granular EM and HADR calorimeters to allow very efficient pattern recognition for excellent shower separation and pid within jets to provide excellent jet reconstruction efficiency

- ▶ . **CALICE ECAL(Si/W) and HCAL(Scint/Fe, RPC/Fe) prototype studies**

- : debug technology/detector concept(s)

- : detector characterisation

- : test "particle flow paradigm", interplay between hard/soft-ware

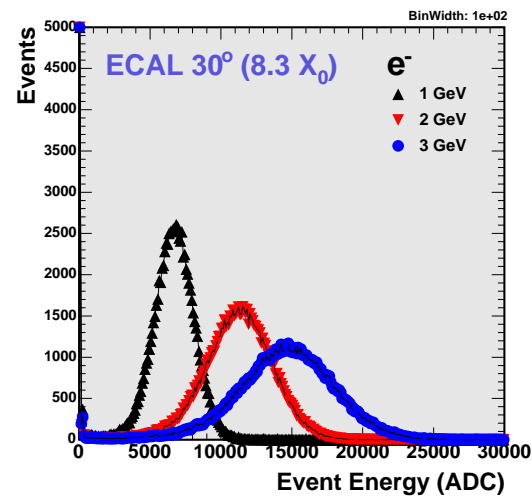
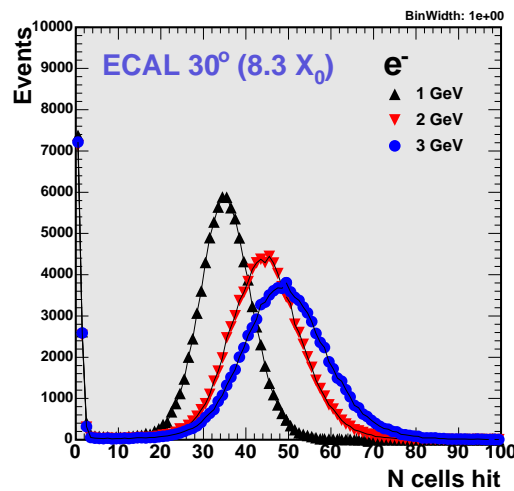
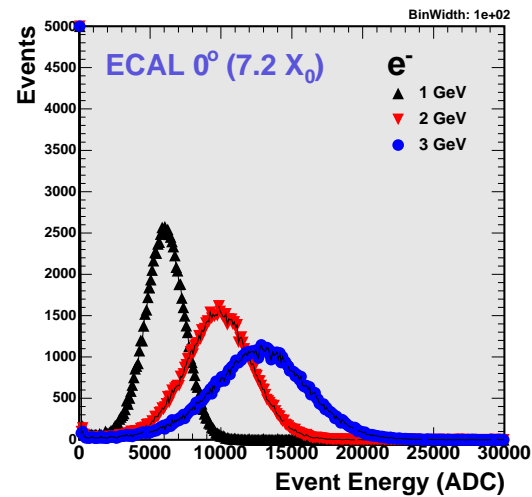
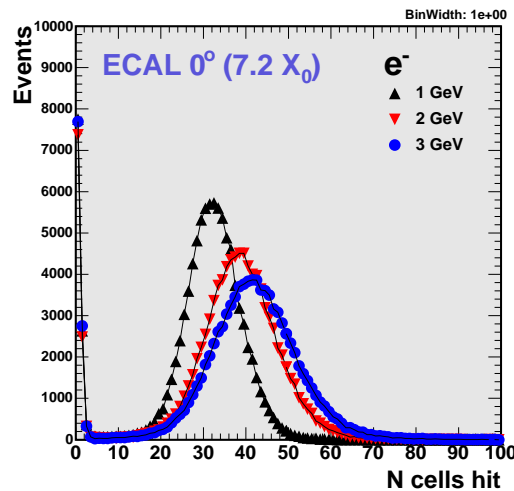
- : test-validate-improve simulation codes and shower packages

- ▶ . details about CALICE Si/W ECAL protoype follow

"Response" to electrons

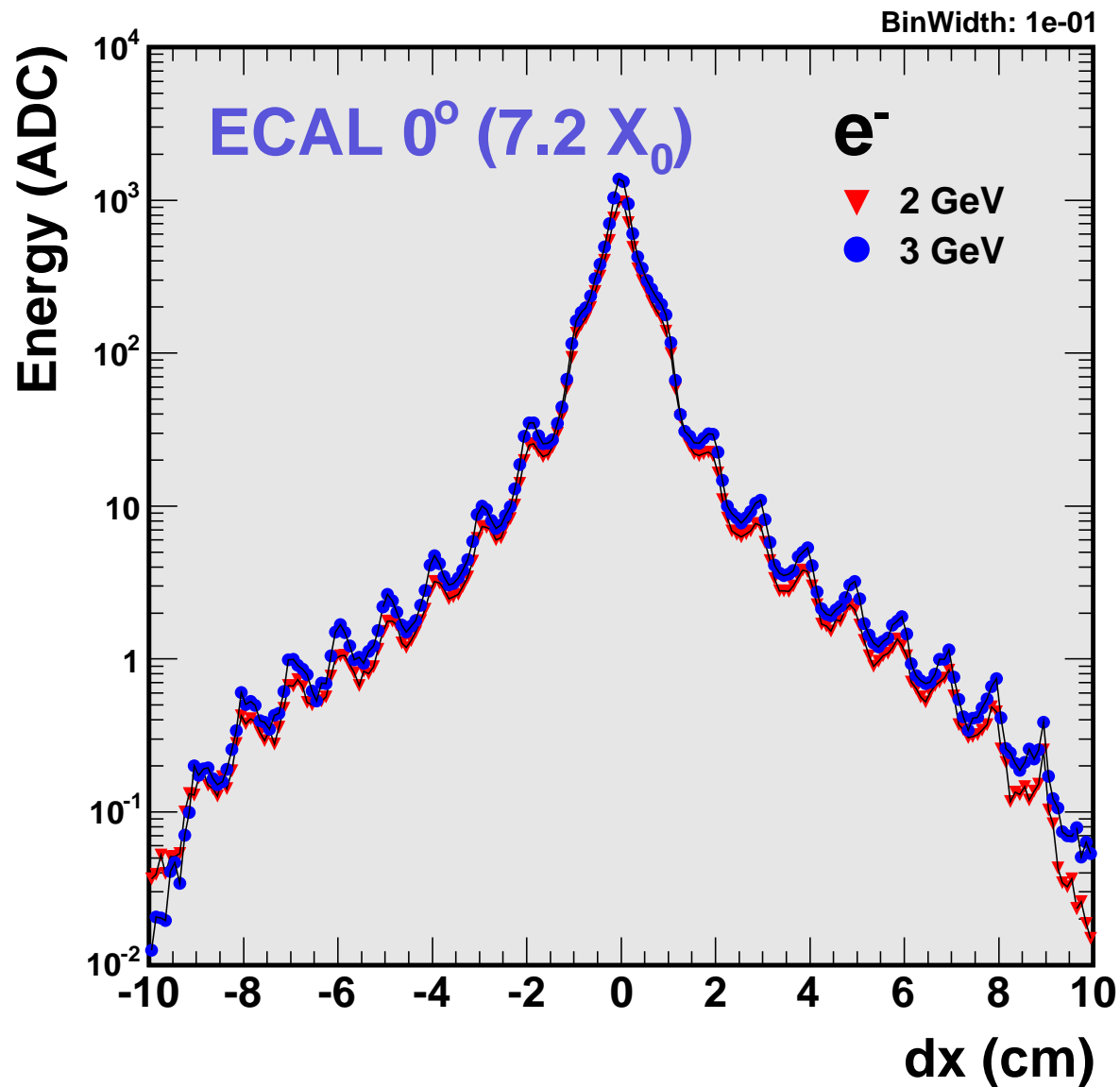
N cells hit

E deposited



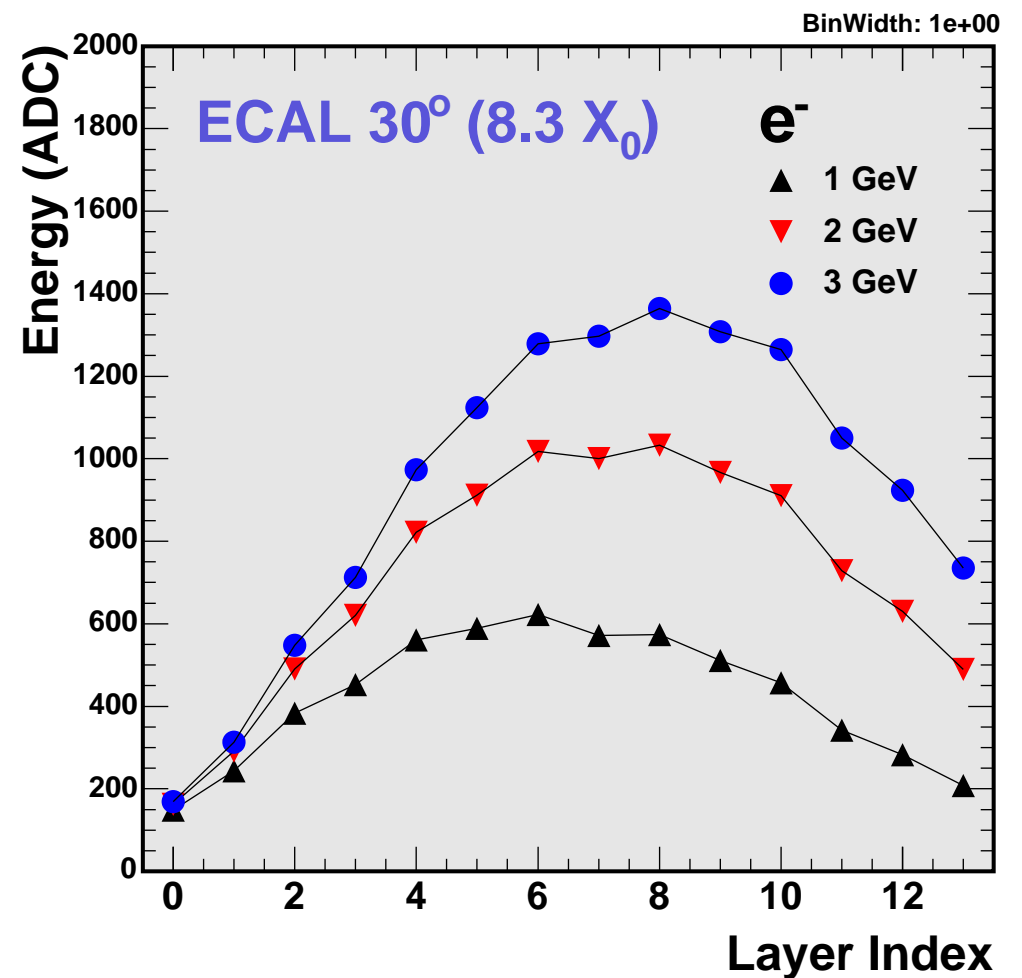
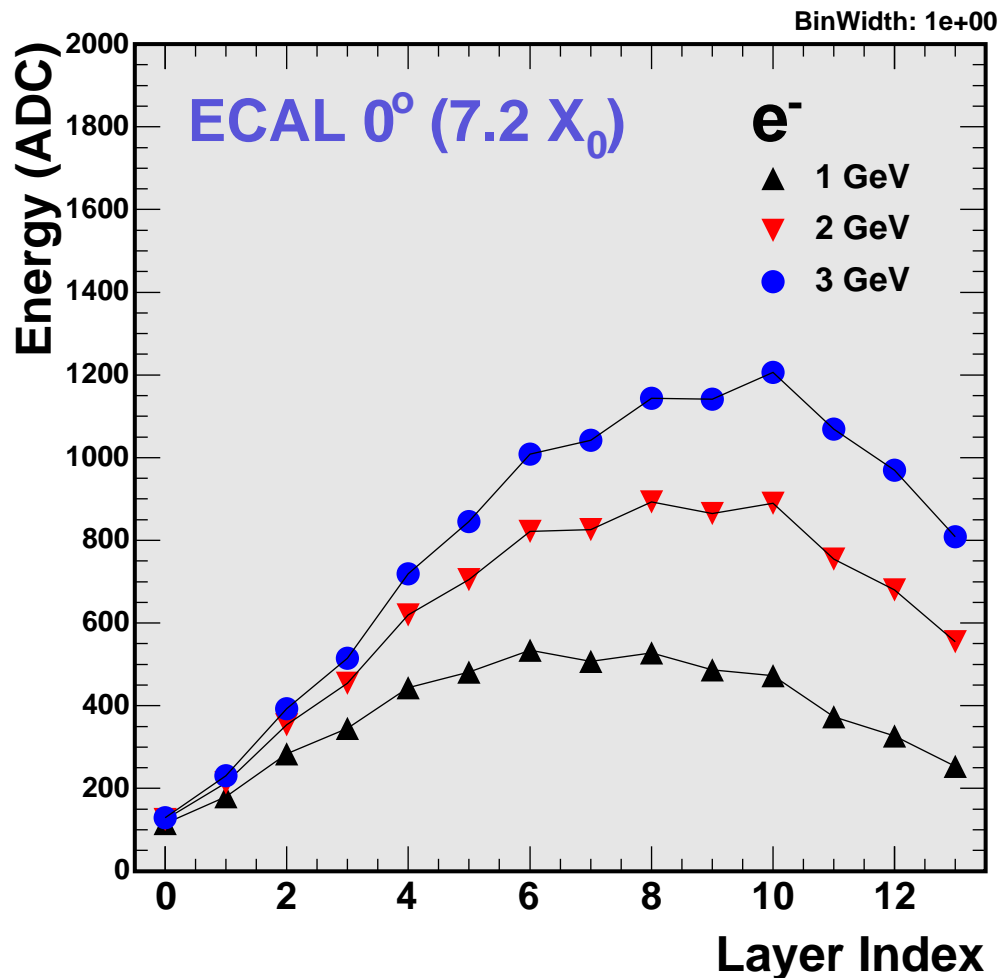
- ▷ no weighting, no event selection, no tracking
- ▷ showers better contained at 30°

Transverse tomography



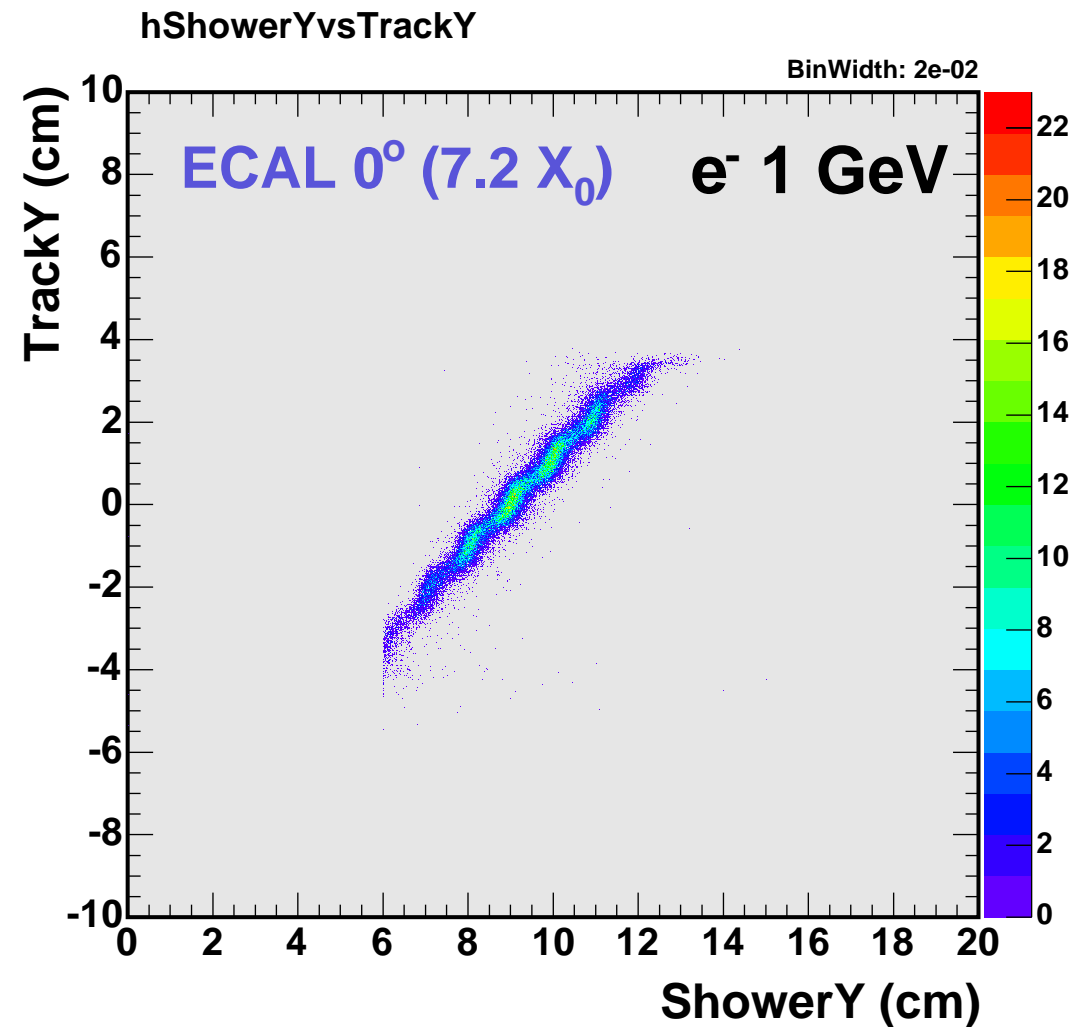
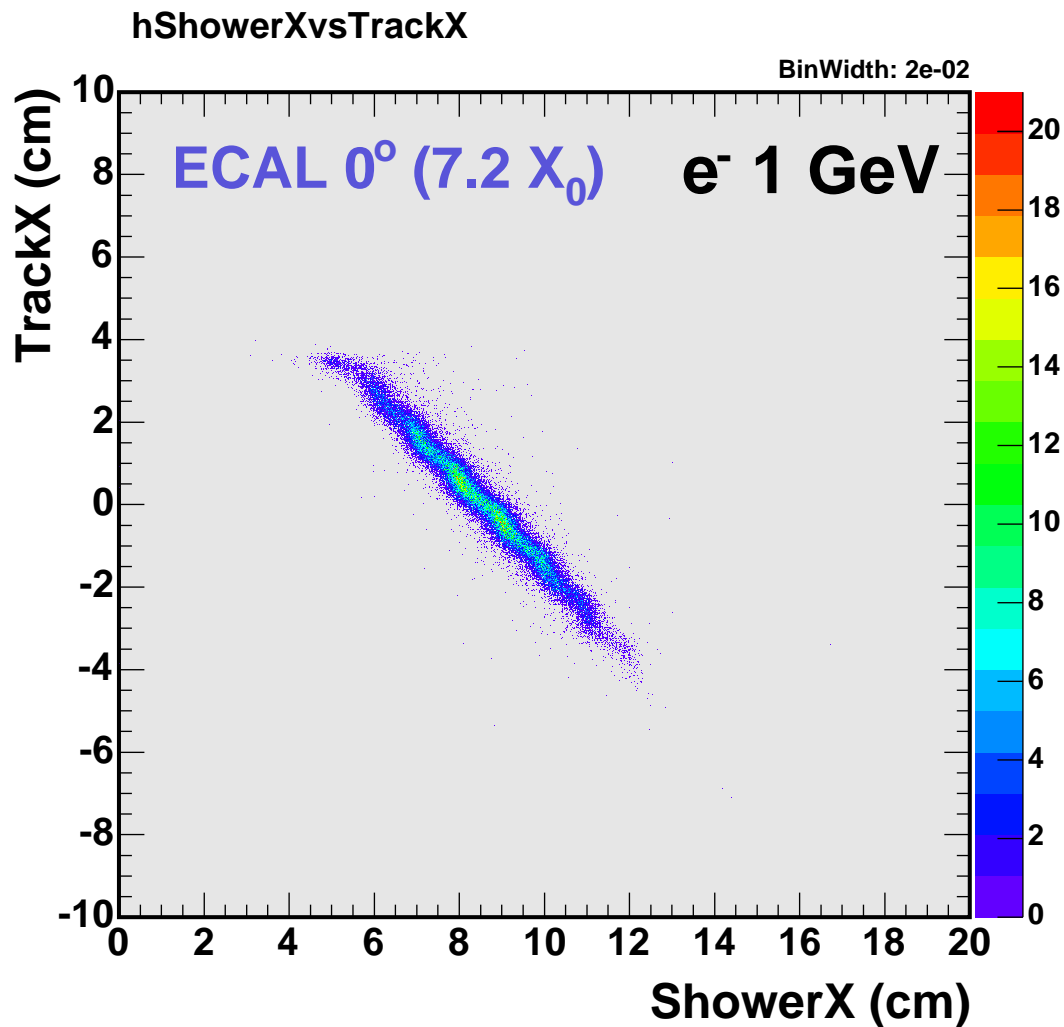
- ▷ no weighting, no event selection, no tracking
- ▷ $dx = \text{CellX} - \text{BarycenterX}$
- ▷ distance between peaks = 1 cm = transverse granularity

Shower longitudinal profile



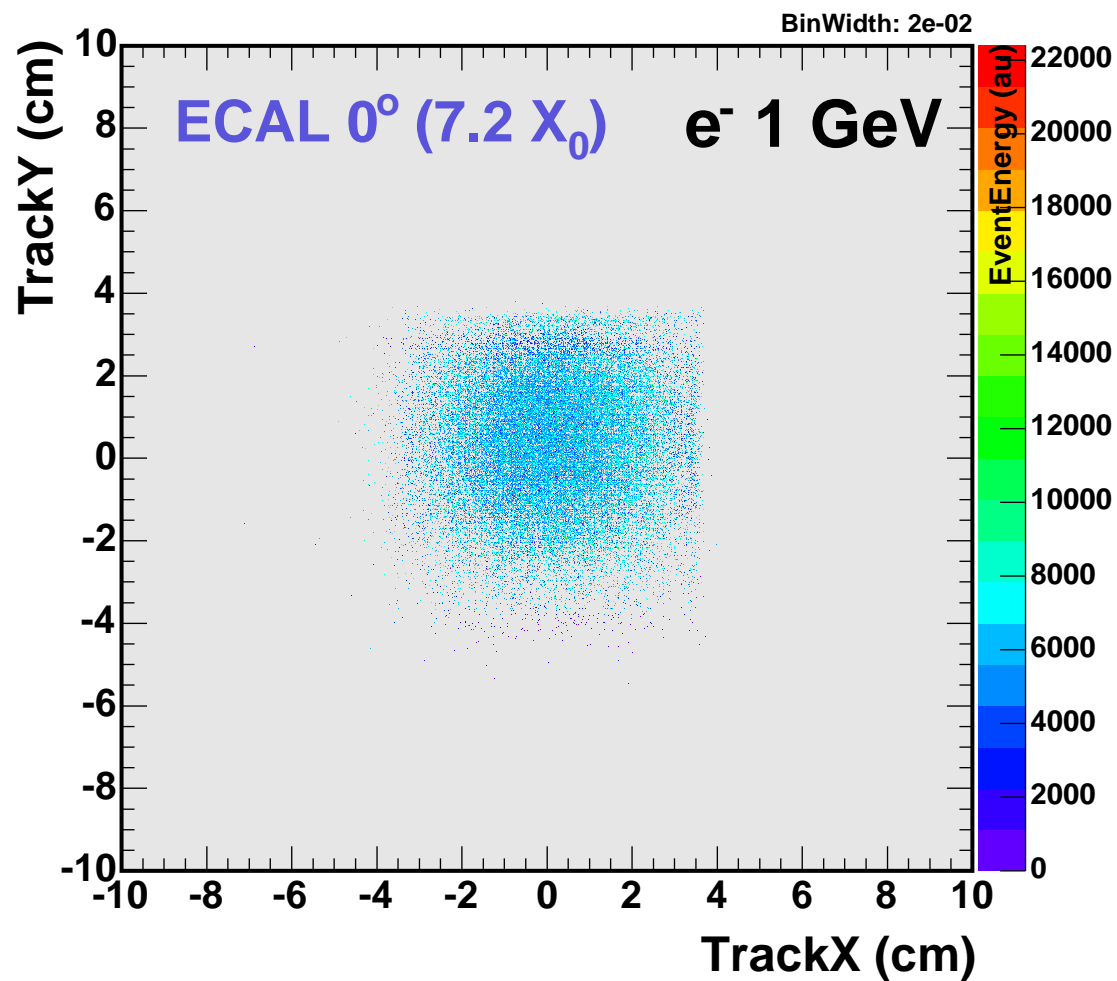
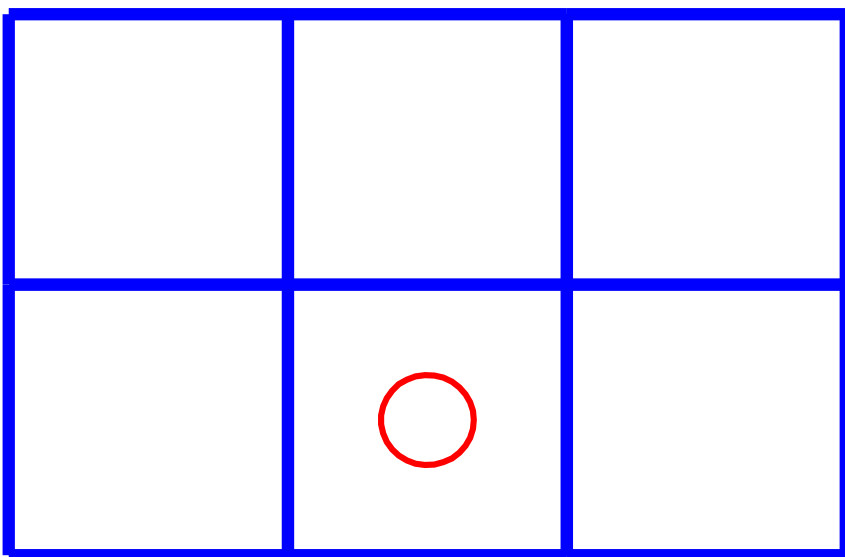
- ▷ no weighting, no event selection, no tracking
- ▷ odd/even asymmetry of construction observed
- ▷ showers better contained at 30°

Position scan

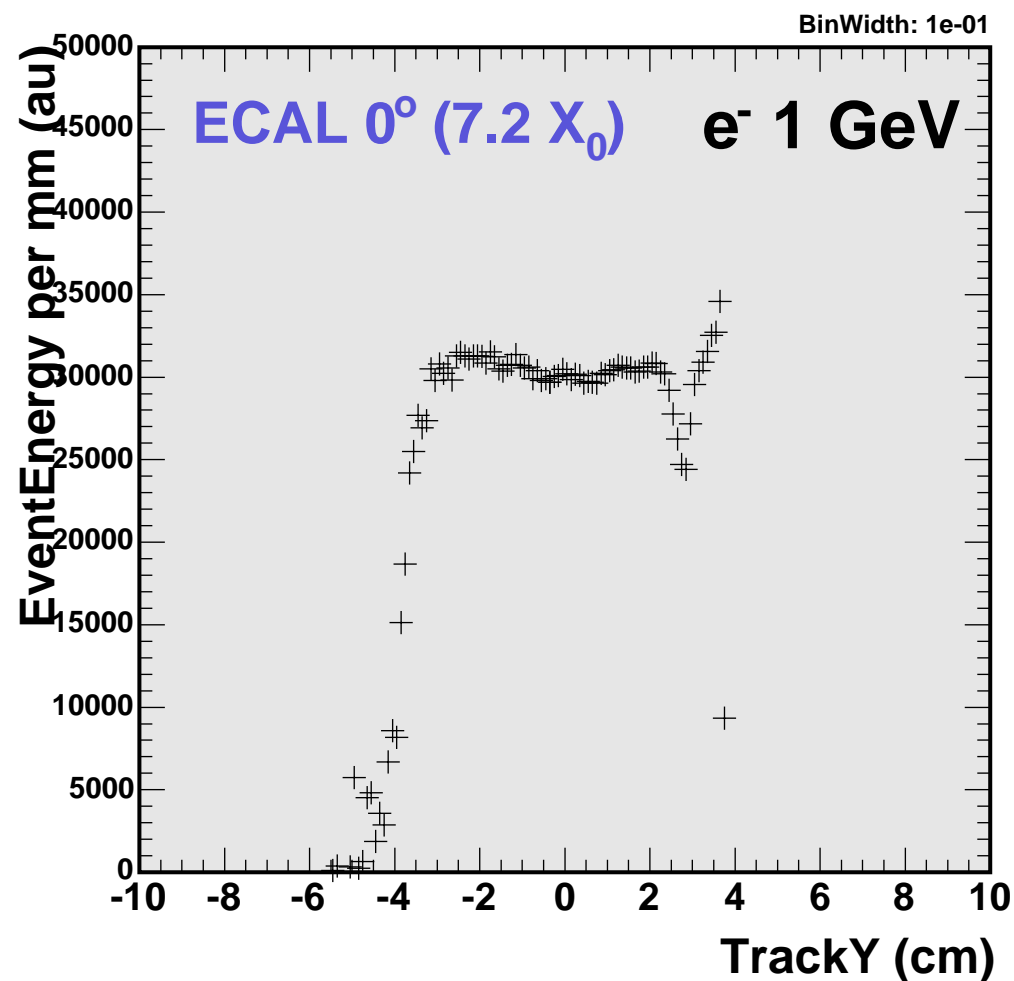
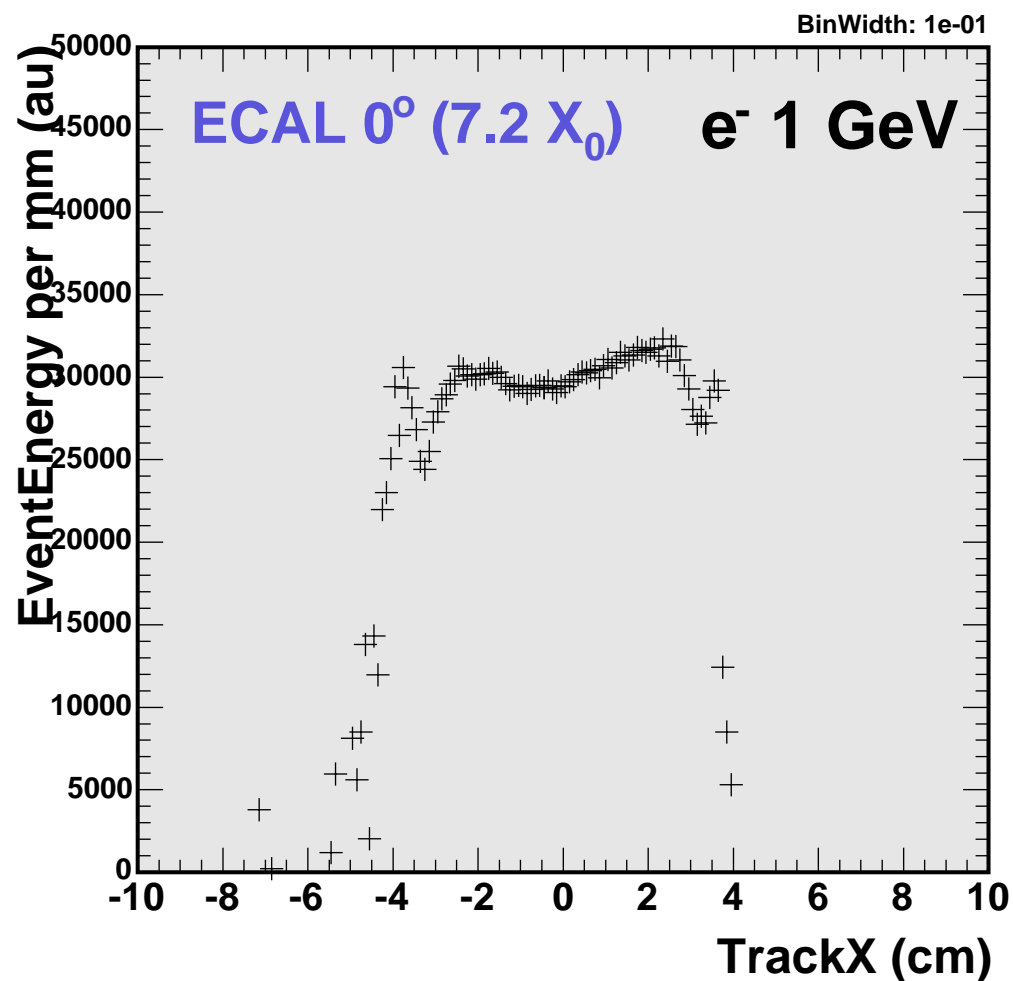


- ▷ ShowerX,Y from barycenter in ecal
- ▷ TrackX,Y from 4 drift chambers

Position scan - center of wafer

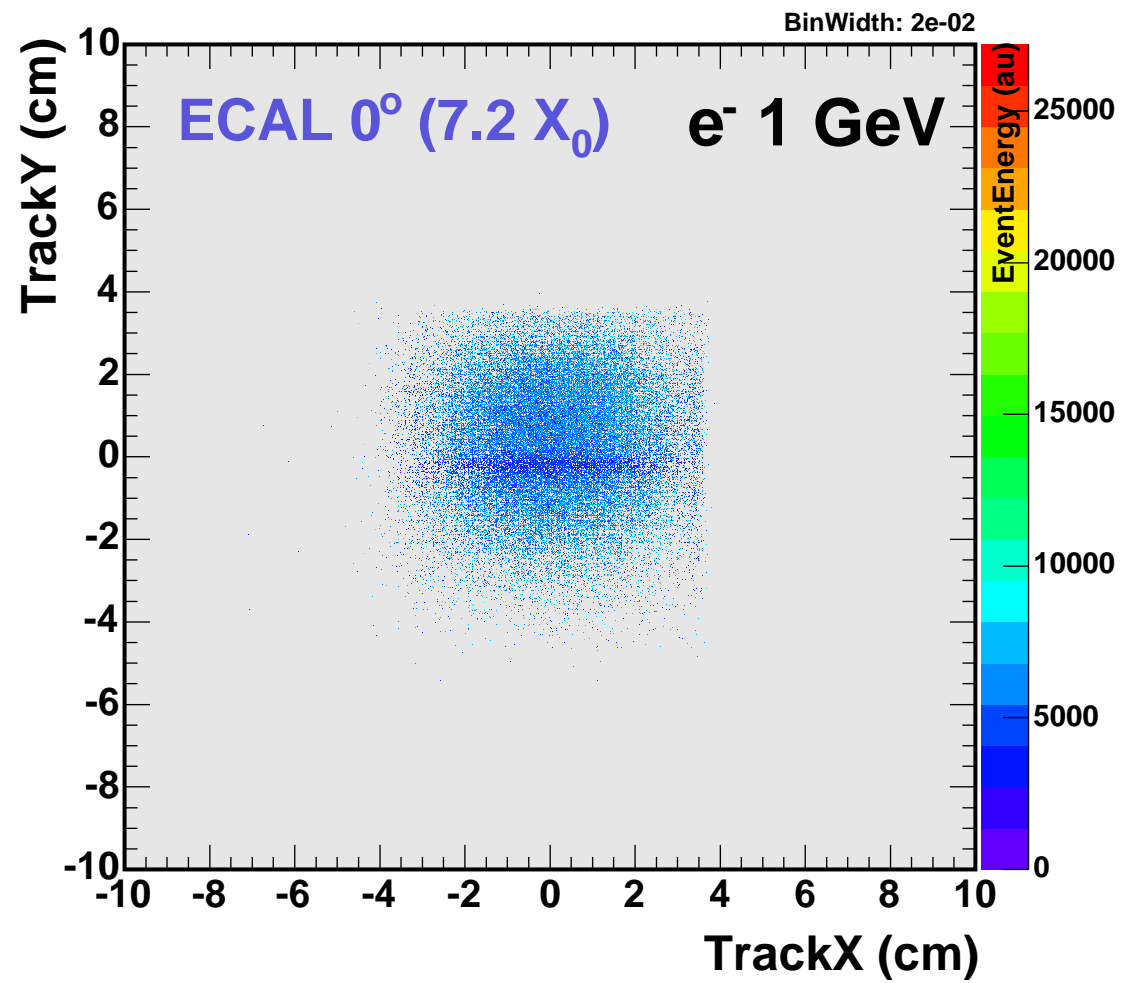
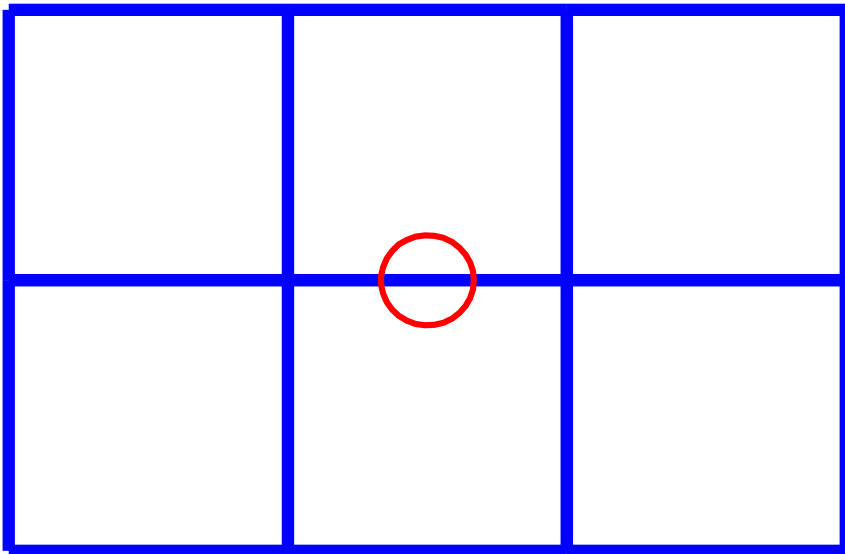


Position scan - center of wafer

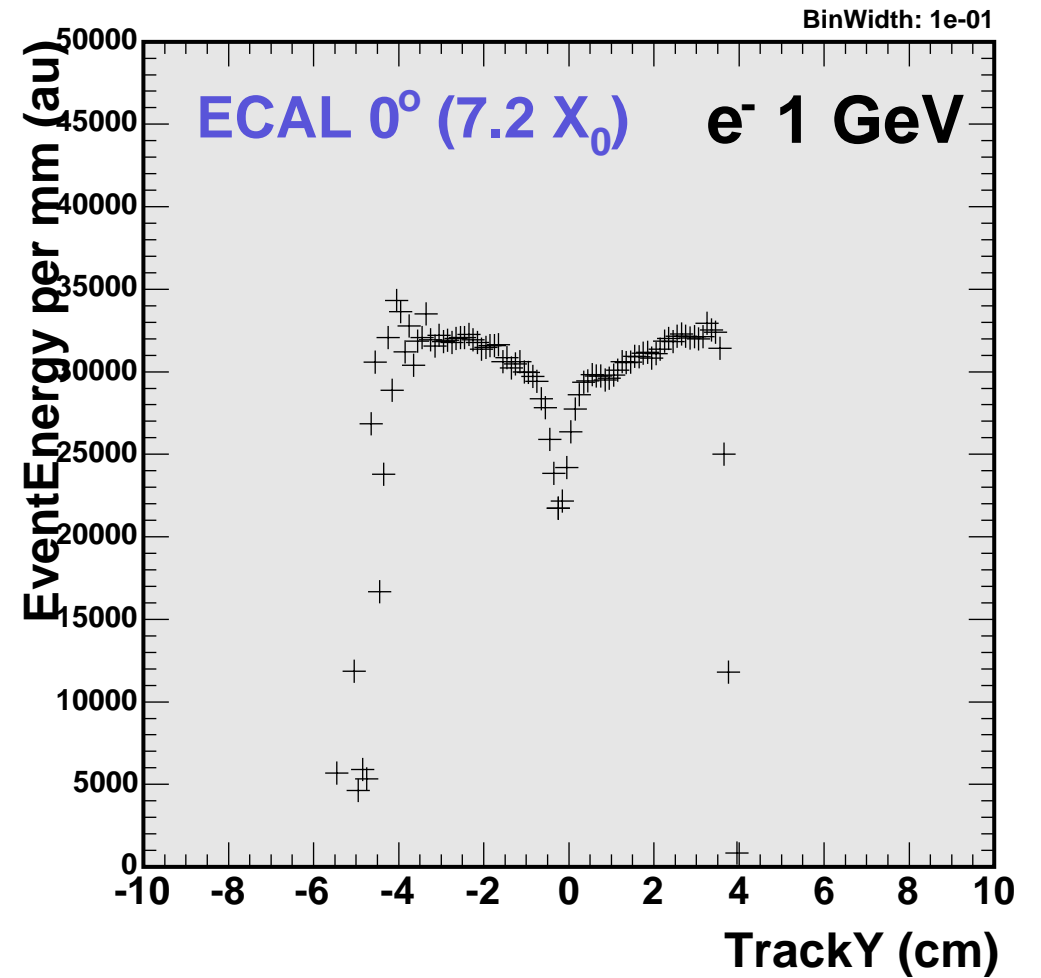
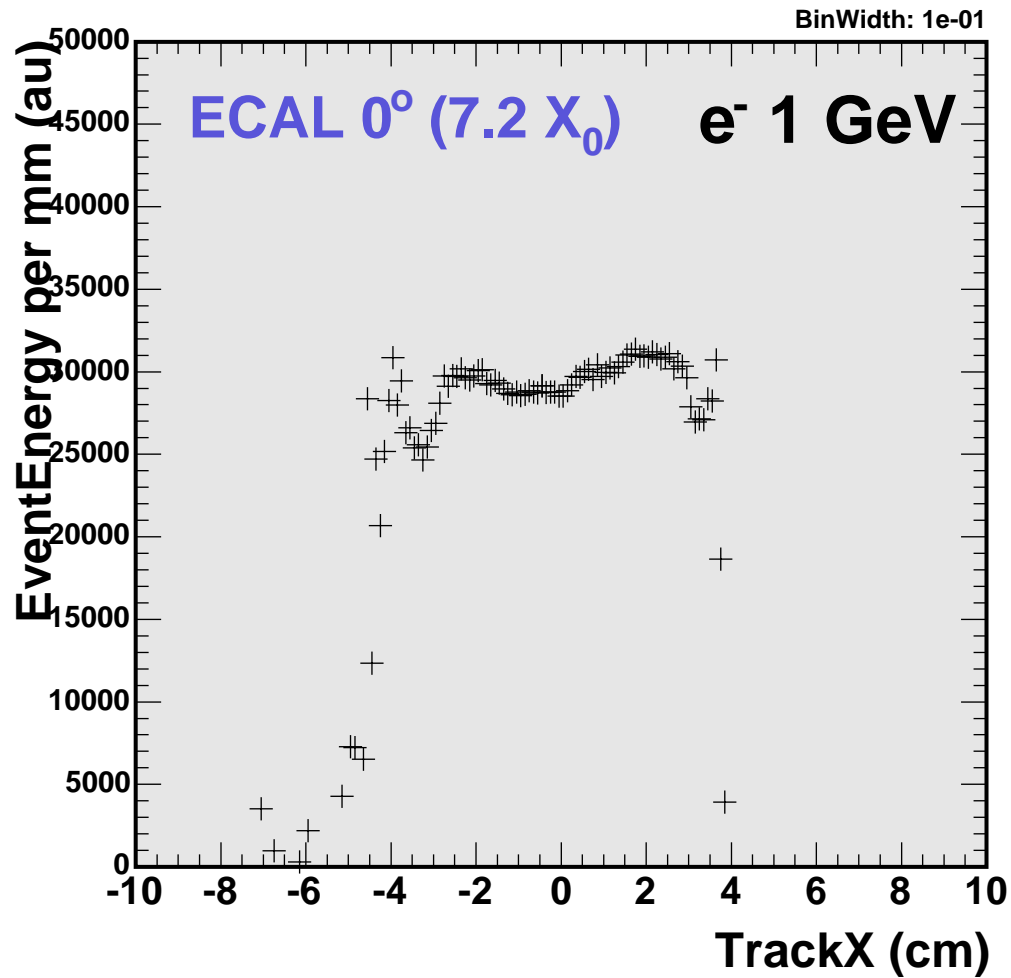


▷ PRELIMINARY

Position scan - edge of wafer

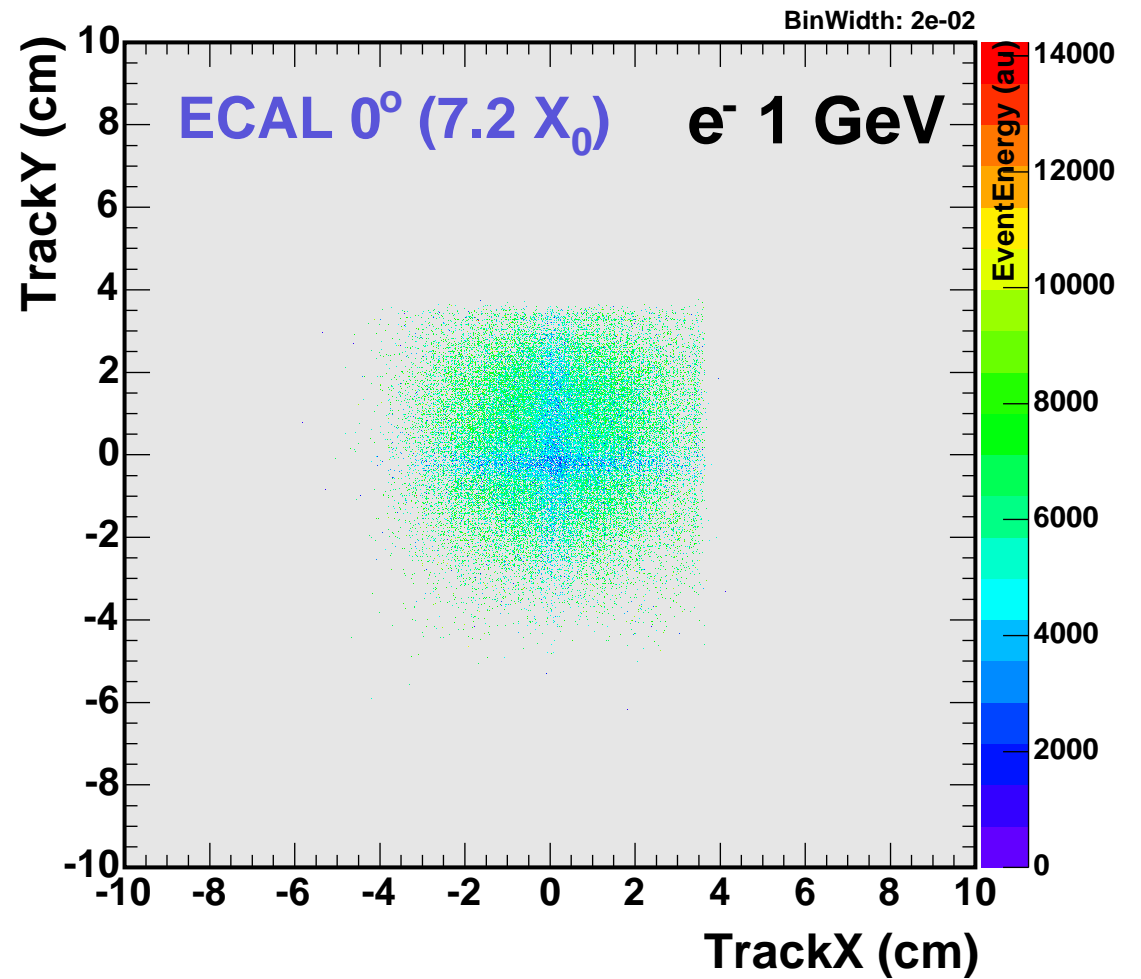
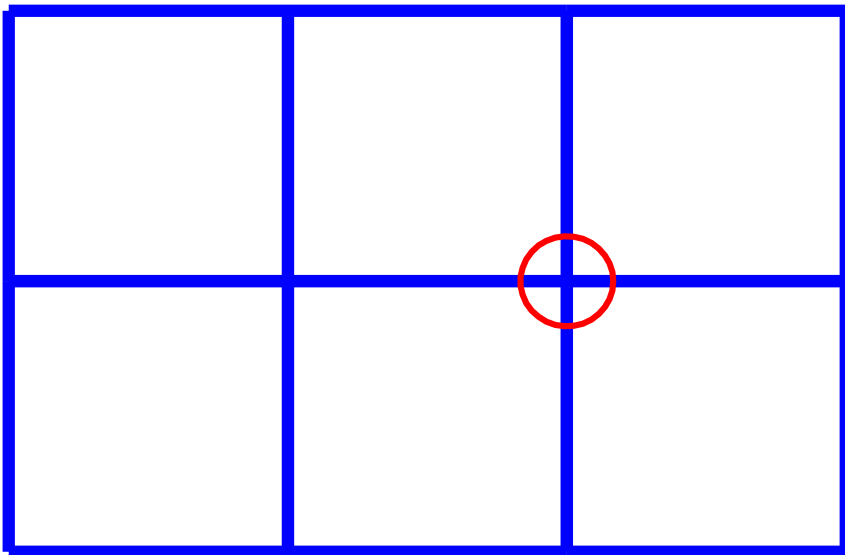


Position scan - edge of wafer

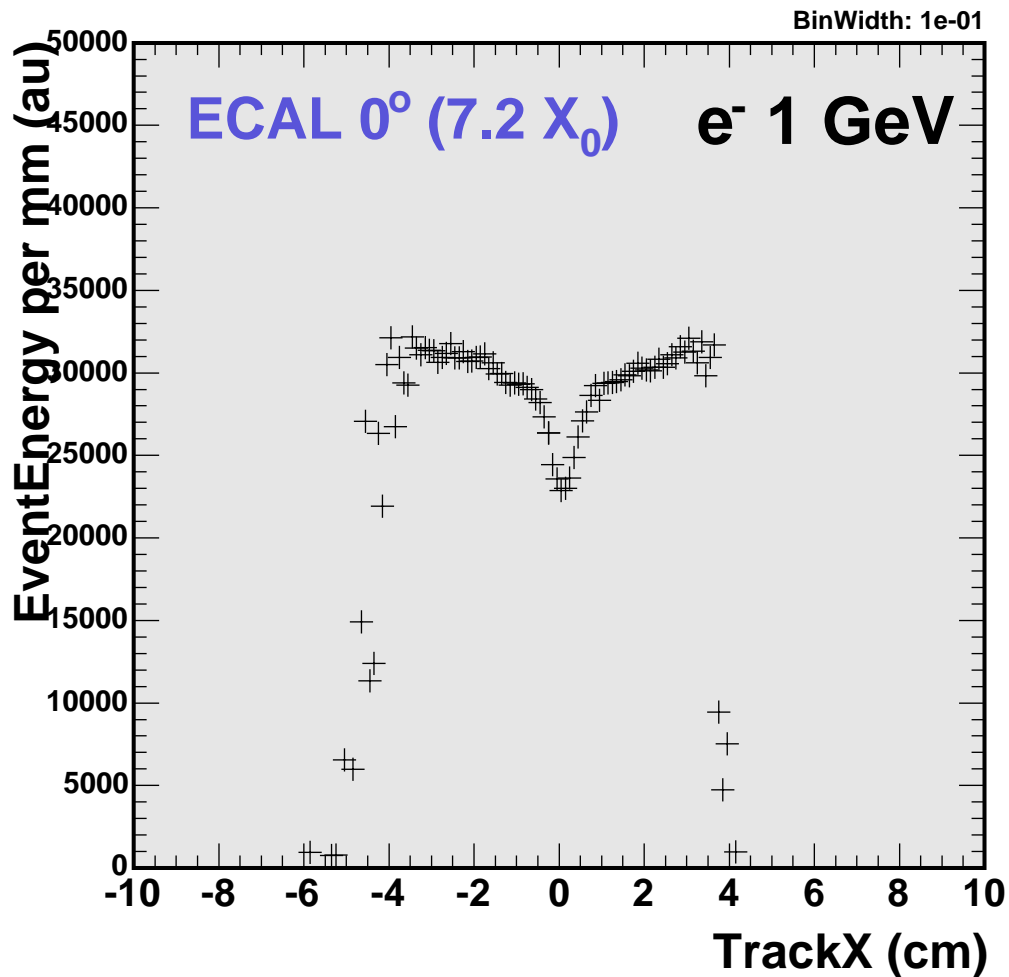


▷ PRELIMINARY

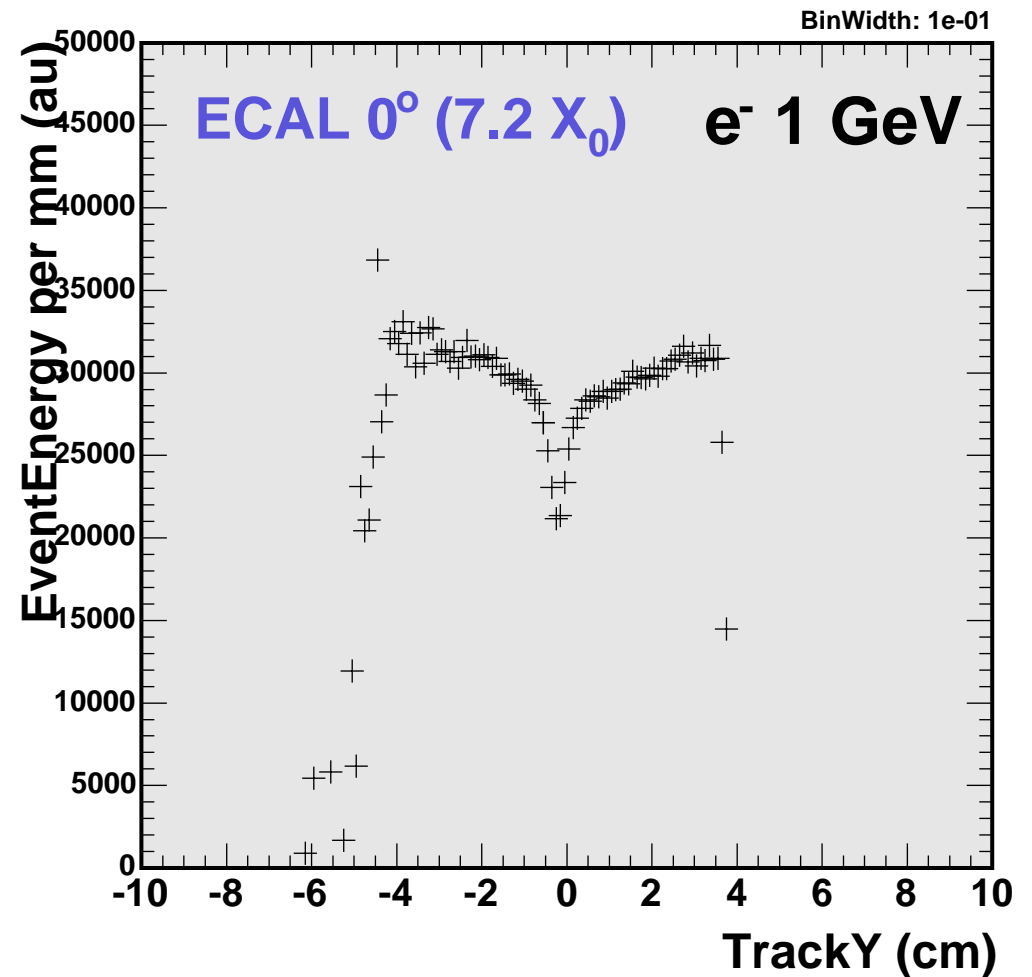
Position scan - corner of wafer



Position scan - corner of wafer



- ▷ alternate layers staggered along X
- ▷ dip is shallower and wider



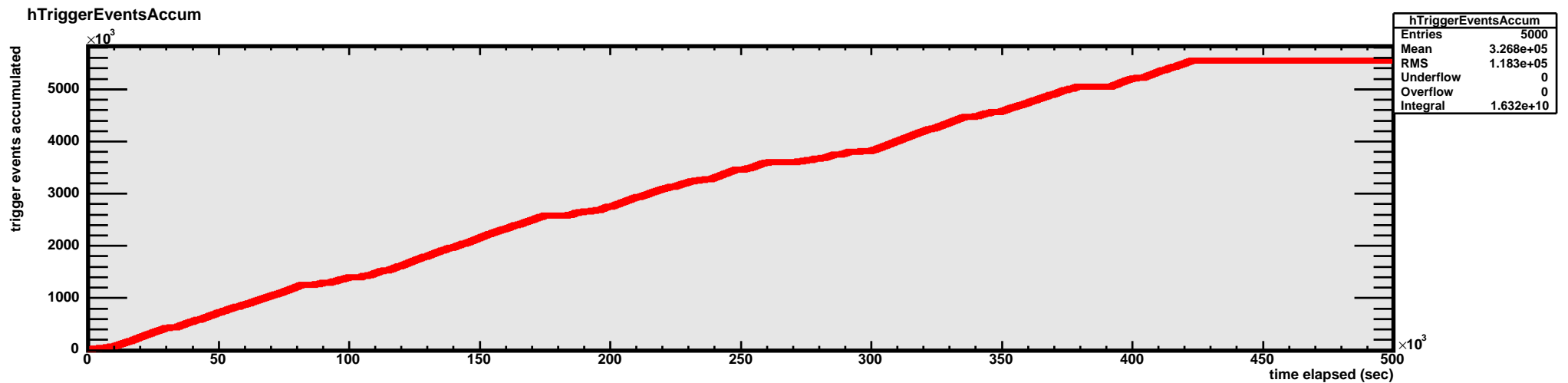
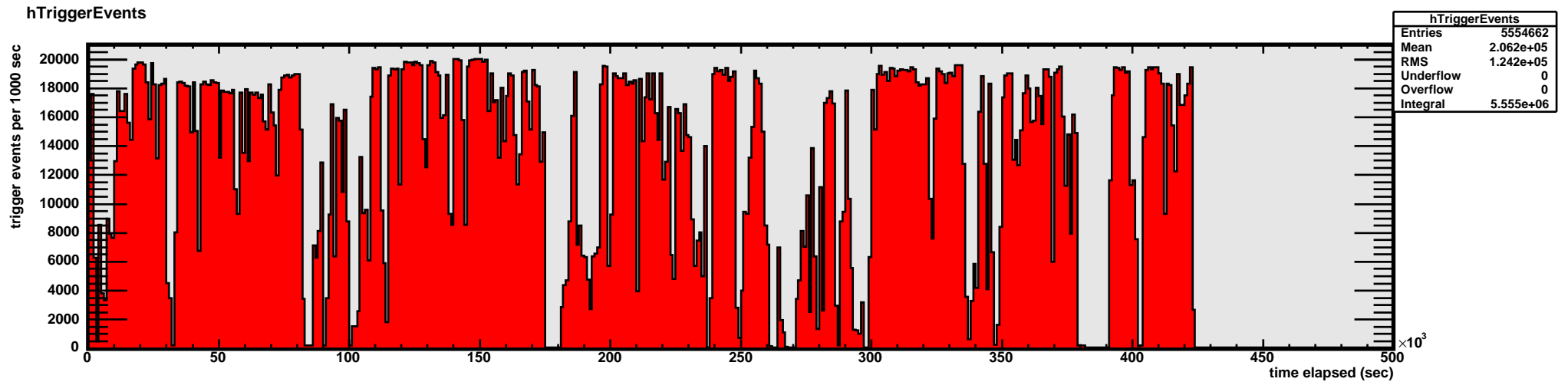
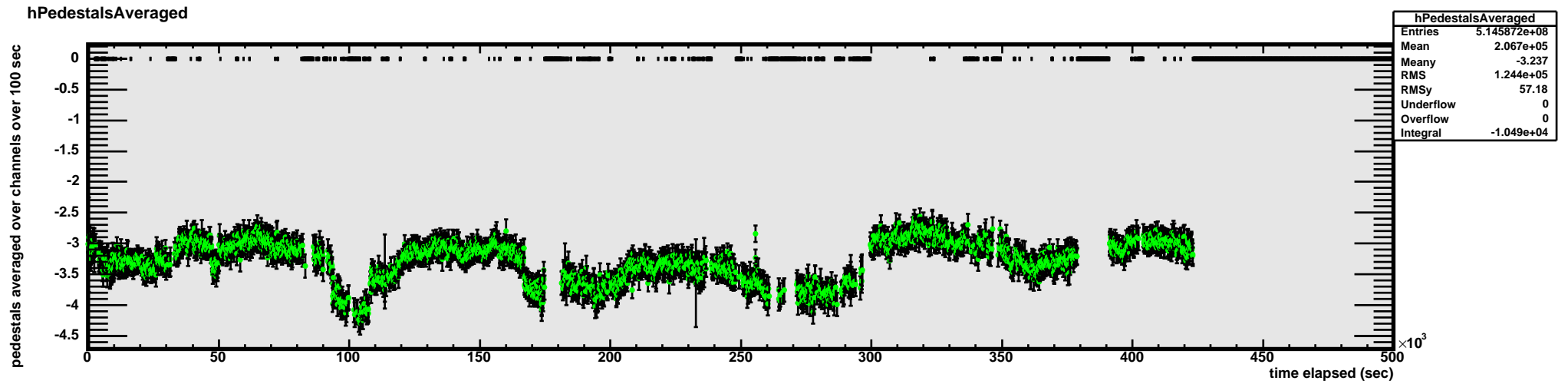
- ▷ layers not staggered along Y
- ▷ dip is deeper and narrower

▷ PRELIMINARY

Testbeam Summary

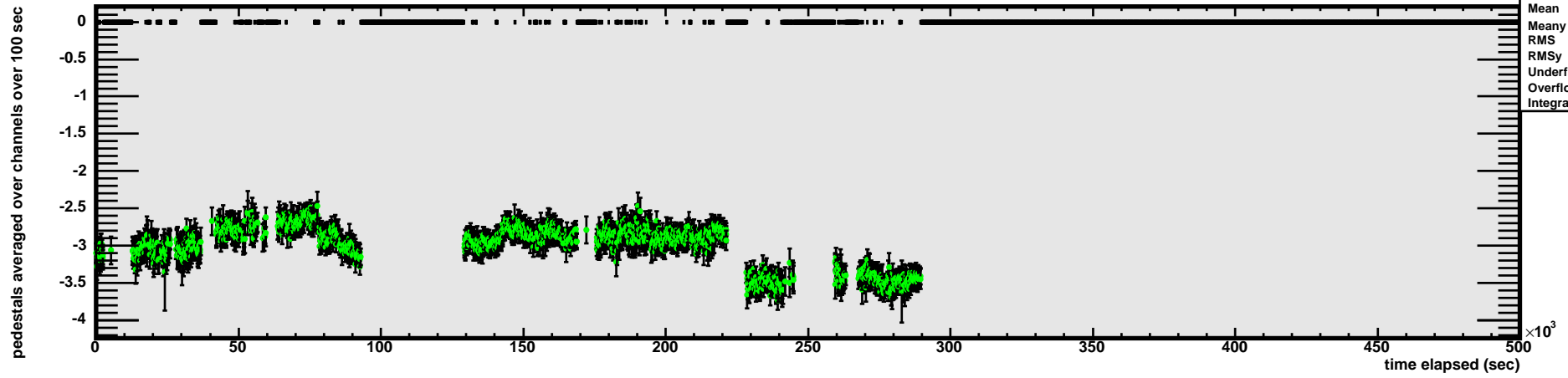
week	events (e^- triggers)	time(sec)	average(Hz)	beam (timeON/time)	daq peak(Hz)
1 (Mon 050207 to Sat 050212)	5554662	425 10^3	13.07 Hz	~ 65%	~ 20 Hz
2 (Tue 050215 to Fri 050218)	4133217	290 10^3	14.25 Hz	~ 48%	~ 30 Hz
3 (Mon 050221 to Thu 050224)	5703056	255 10^3	22.36 Hz	~ 64%	~ 35 Hz

Week 1, Mon 050207 to Sat 050212



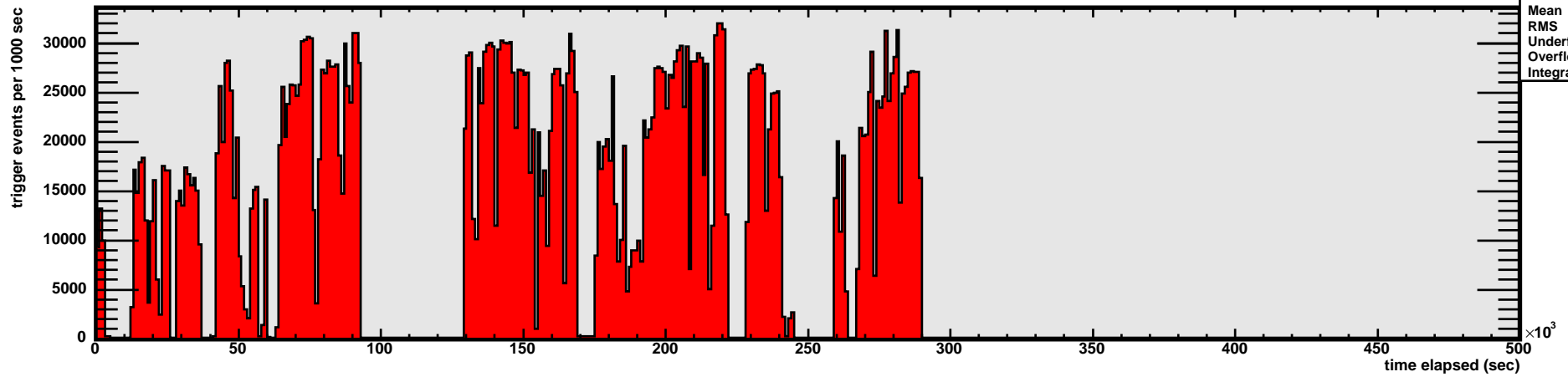
Week 2, Tue 050215 to Fri 050218

hPedestalsAveraged



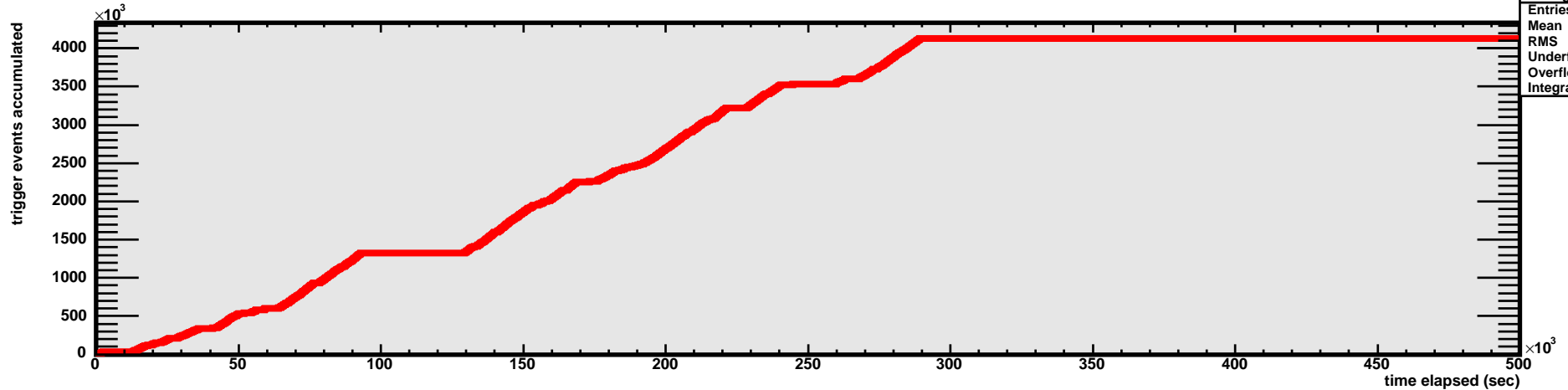
hPedestalsAveraged	
Entries	3.833758e+08
Mean	1.57e+05
Meany	-3.006
RMS	8.036e+04
RMSy	56.72
Underflow	0
Overflow	0
Integral	-5198

hTriggerEvents



hTriggerEvents	
Entries	4133217
Mean	1.572e+05
RMS	8.01e+04
Underflow	0
Overflow	0
Integral	4.133e+06

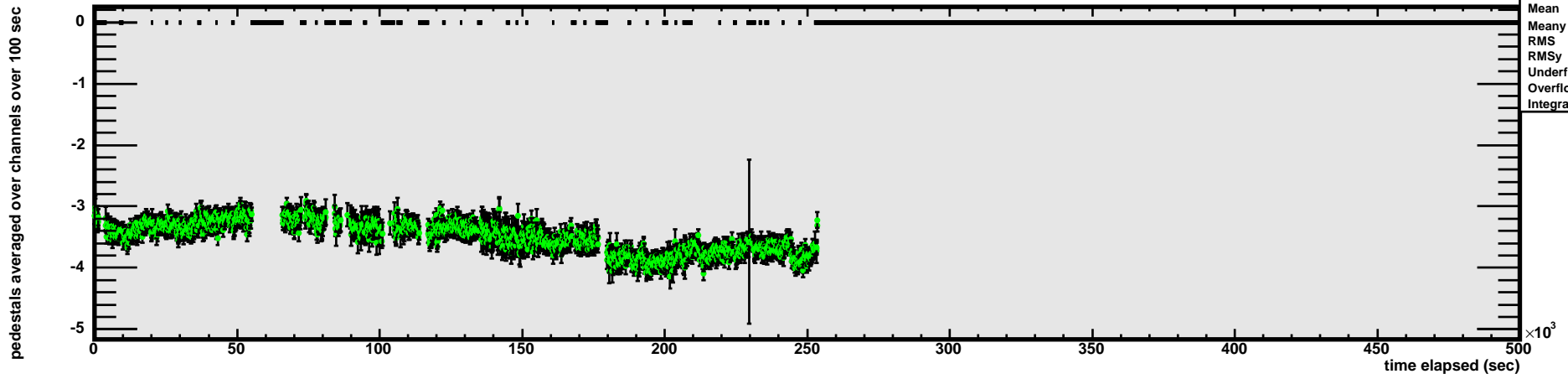
hTriggerEventsAccum



hTriggerEventsAccum	
Entries	5000
Mean	3.192e+05
RMS	1.139e+05
Underflow	0
Overflow	0
Integral	1.417e+10

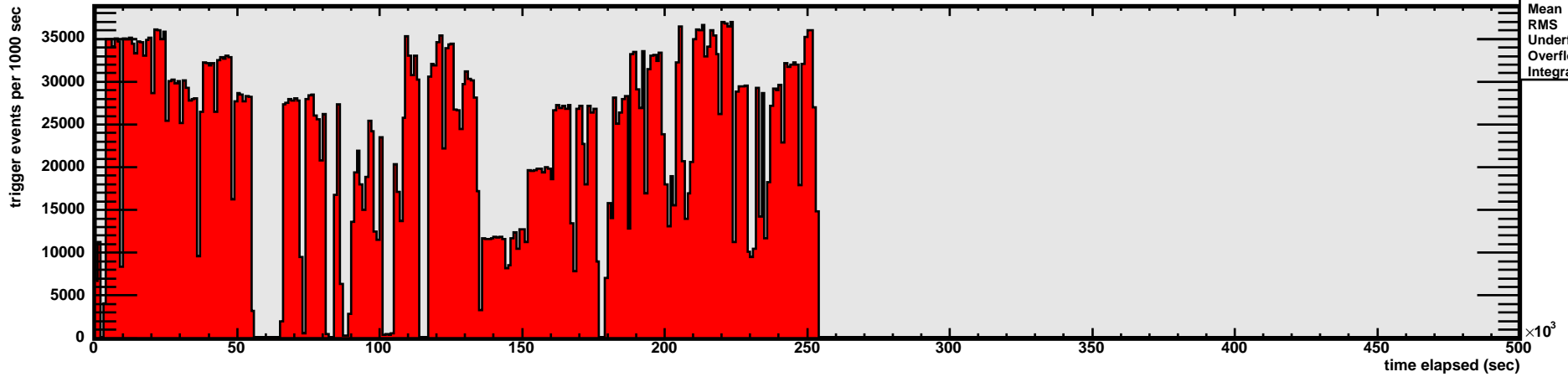
Week 3, Mon 050221 to Thu 050224

hPedestalsAveraged



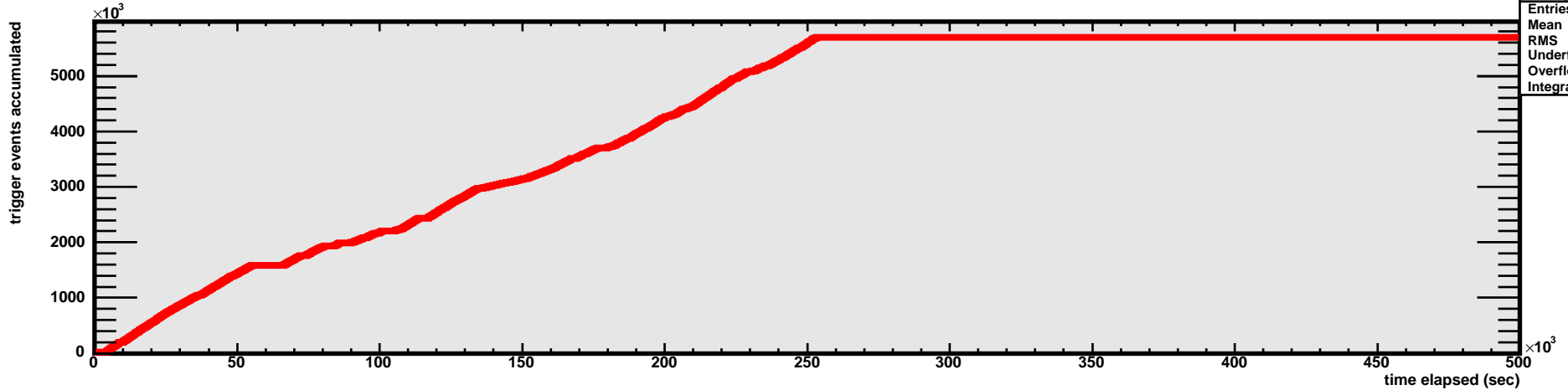
hPedestalsAveraged	
Entries	5.326771e+08
Mean	1.297e+05
Meany	-3.497
RMS	7.86e+04
RMSy	57.97
Underflow	0
Overflow	0
Integral	-7261

hTriggerEvents



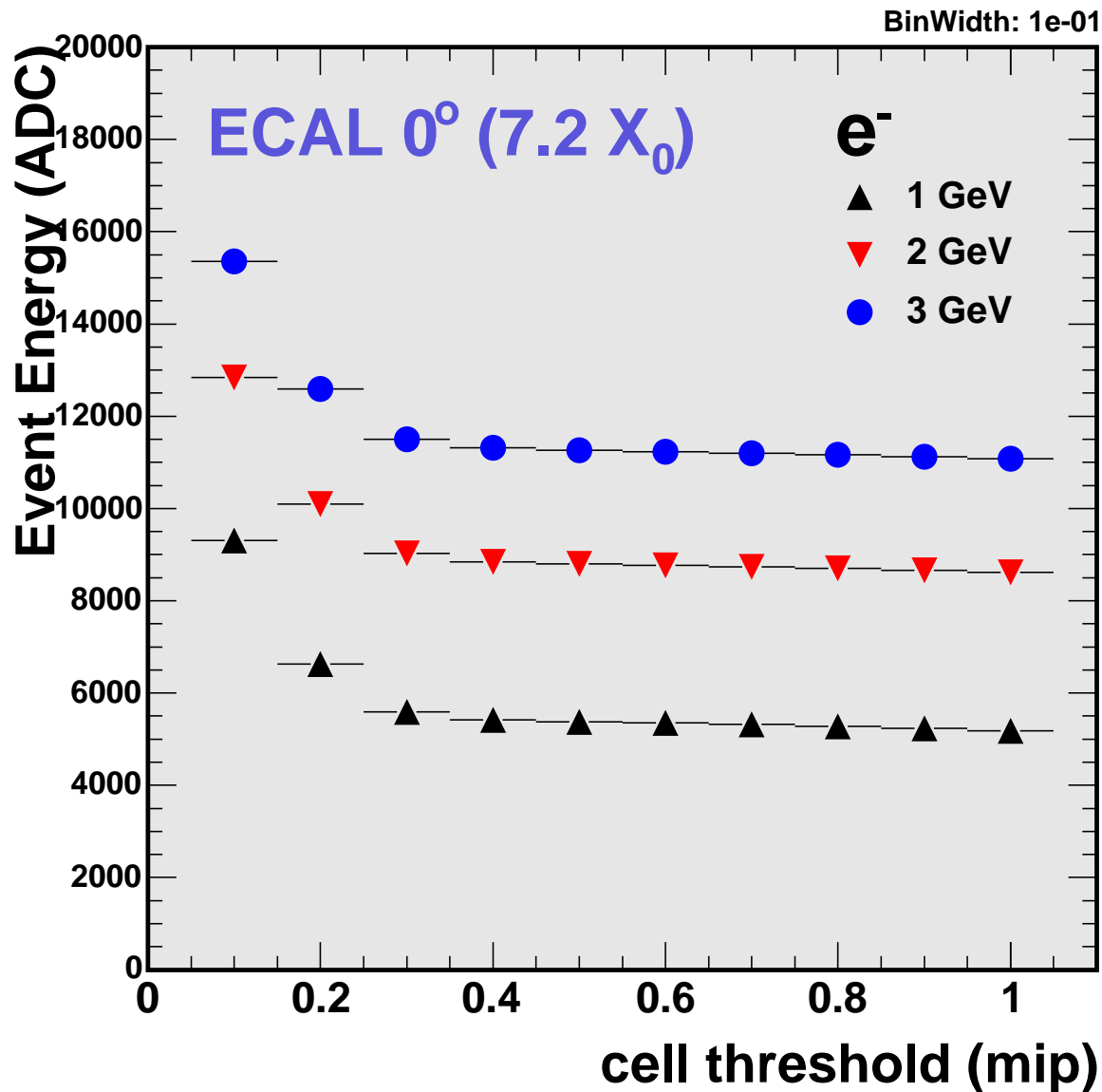
hTriggerEvents	
Entries	5703056
Mean	1.297e+05
RMS	7.857e+04
Underflow	0
Overflow	0
Integral	5.703e+06

hTriggerEventsAccum



hTriggerEventsAccum	
Entries	5000
Mean	3.065e+05
RMS	1.203e+05
Underflow	0
Overflow	0
Integral	2.112e+10

"Response" vs cell threshold



- ▷ safe limit a threshold around 0.5 - 0.6 mip
- ▷ following analysis with threshold = 0.5 mip

Clean and calibrated data

- ▶ **code to provide data for analysis**

- : read raw data files, read cabling maps, read calibration constants, "put the things together", calculate pedestals, calculate calibrated signal, do tracking, reject bad events, and finally write out calorimeter hits and track ala format used in simulation

- ▶ **events checked for**

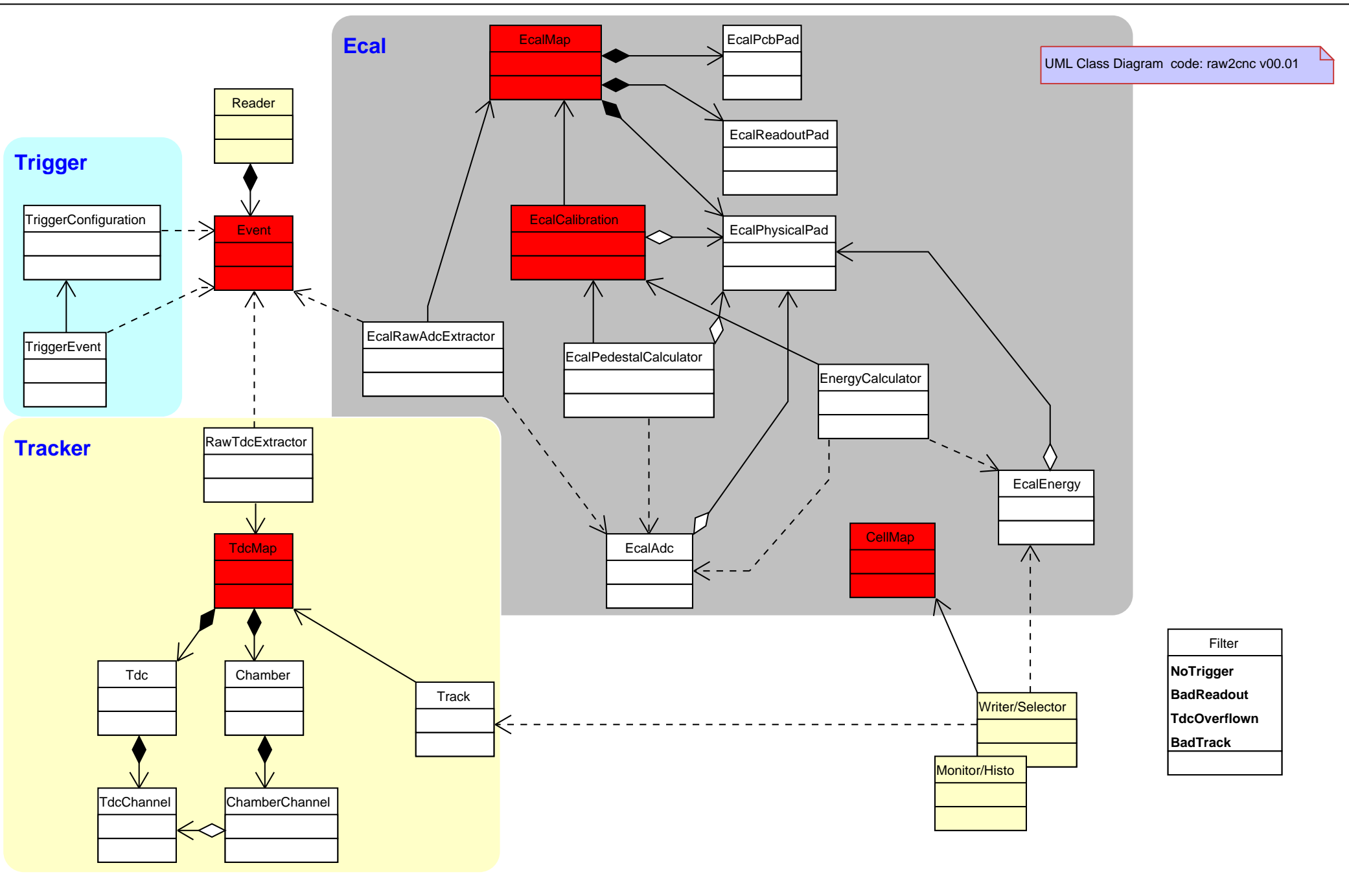
- : NO TRIGGER

- : BAD READOUT

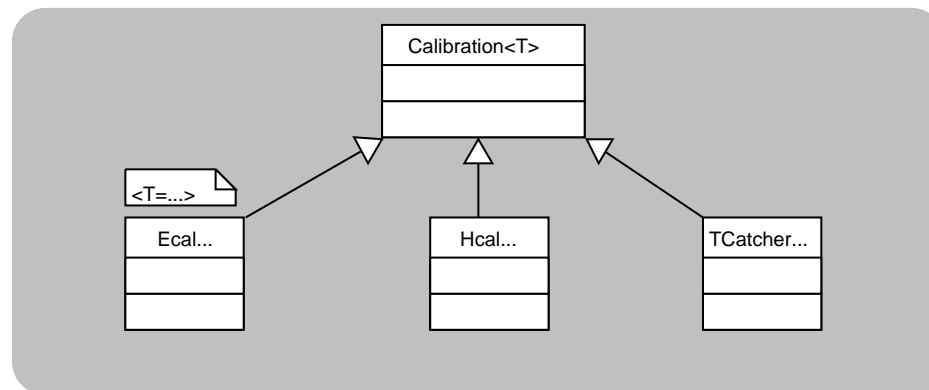
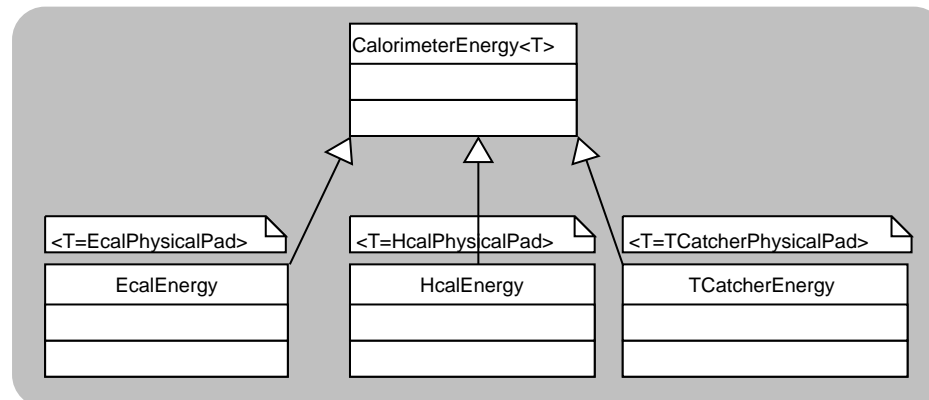
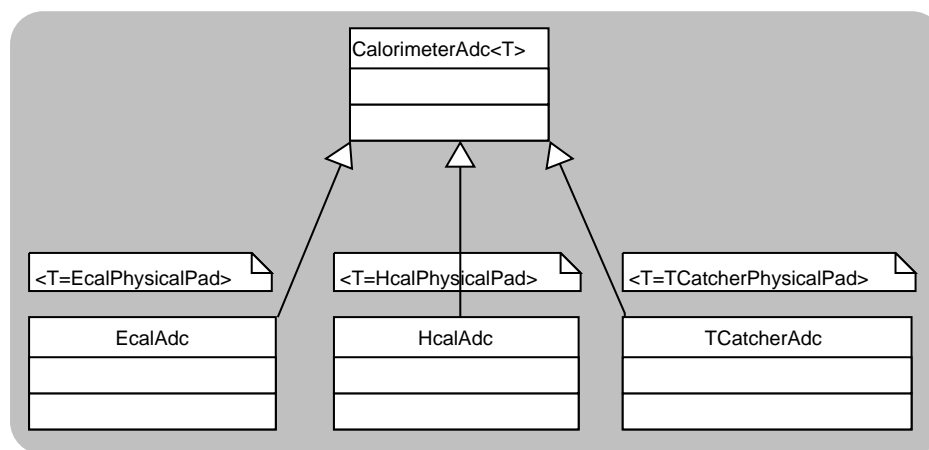
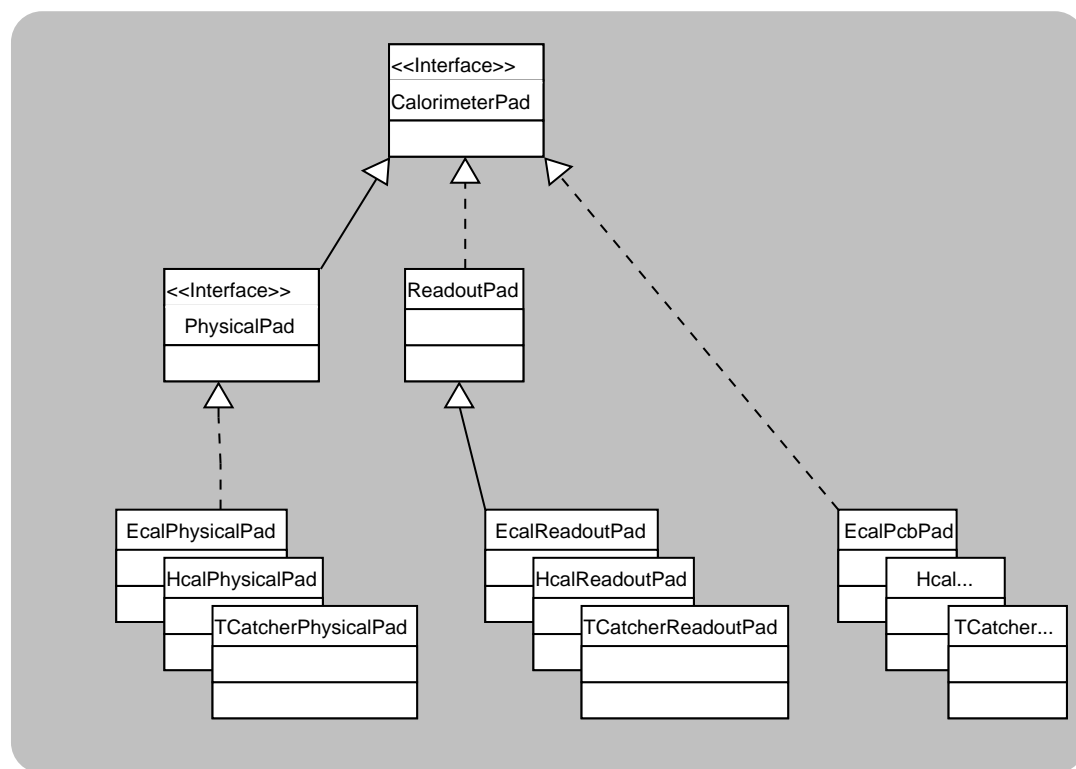
- : TDC OVERFLOWN

- : BAD TRACK

raw2cnc (from raw to clean and calibrated data)

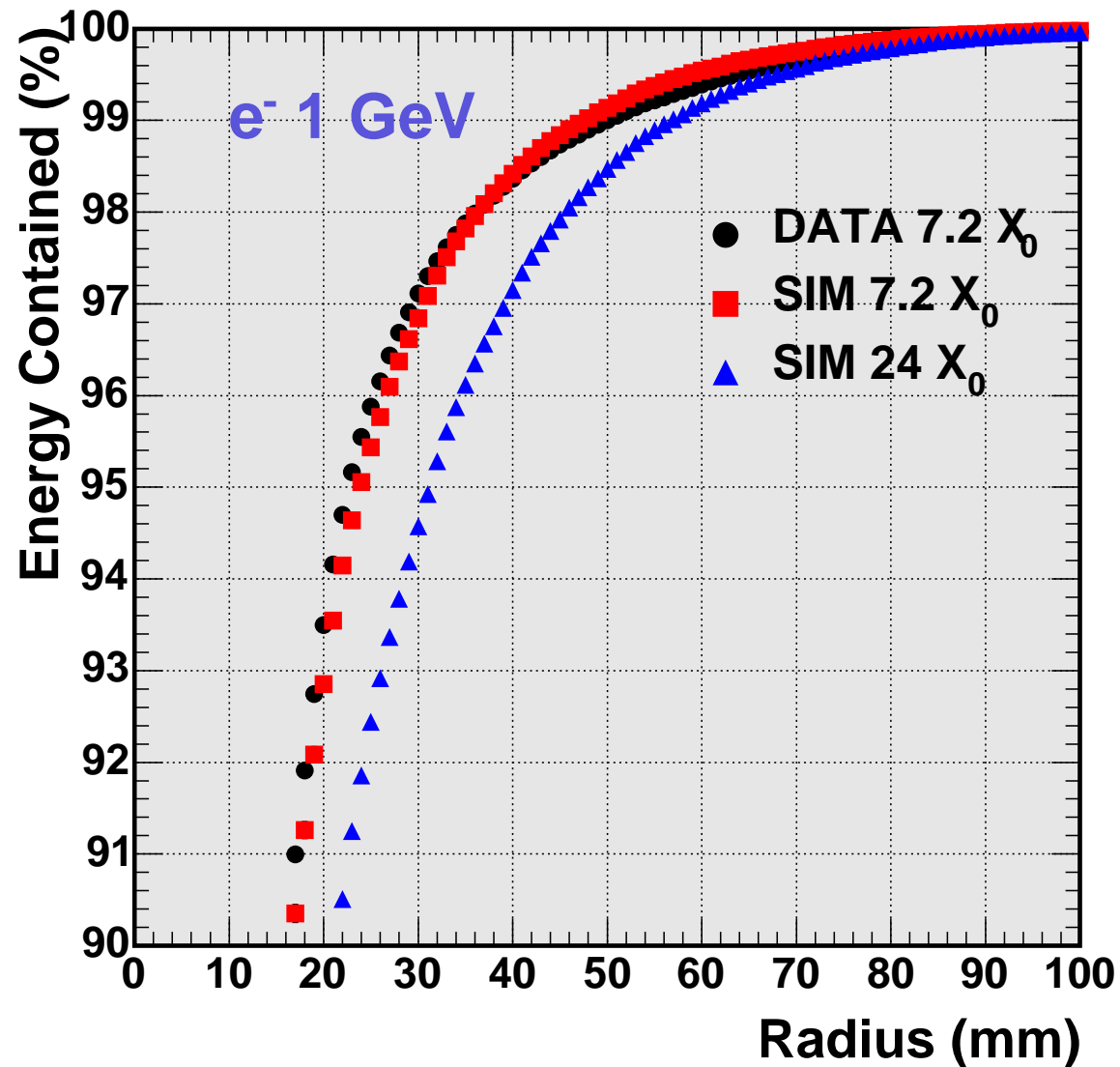


raw2cnc (from raw to clean and calibrated data)



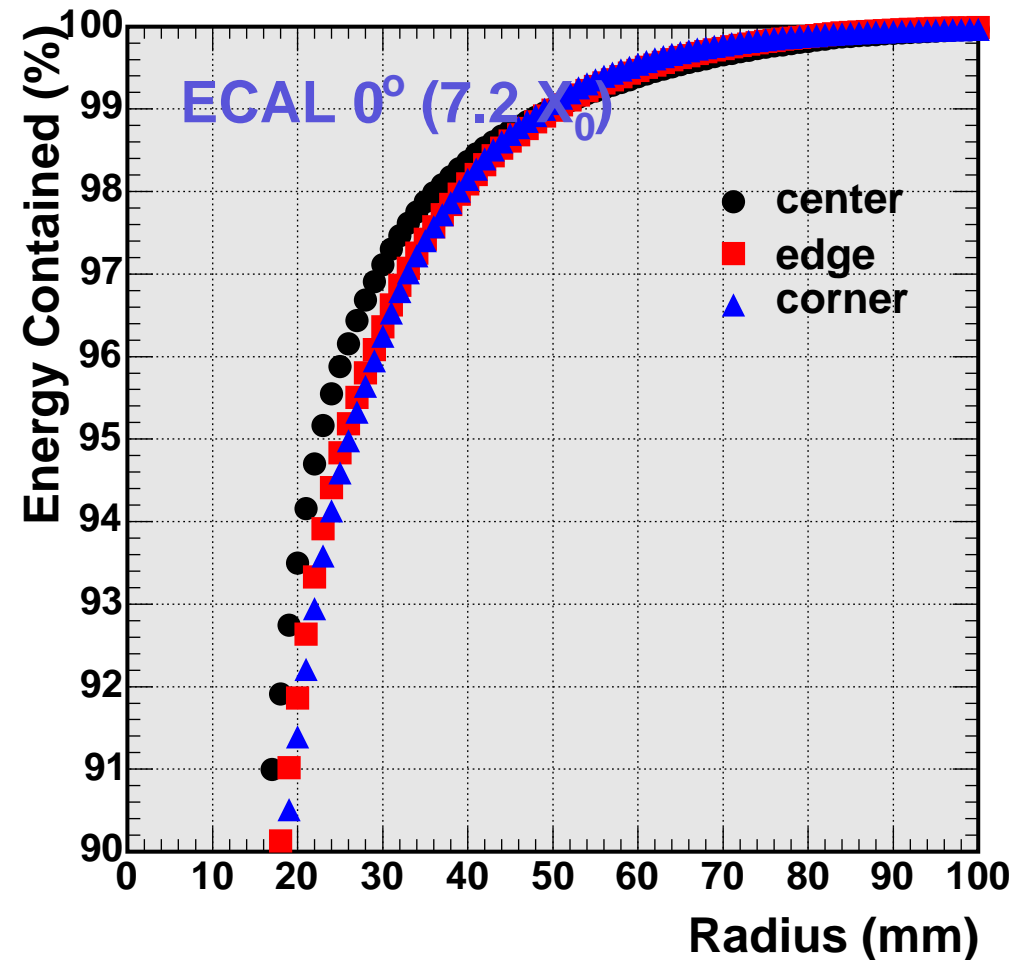
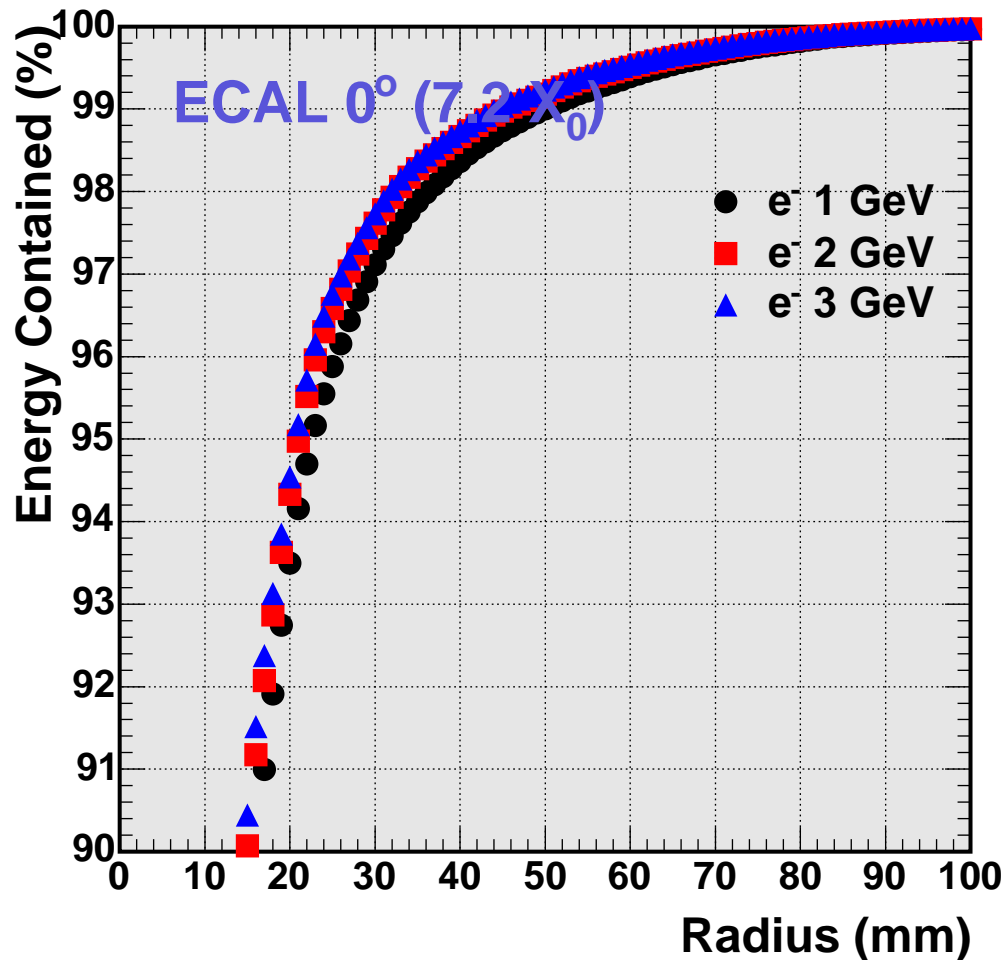
UML Class Diagram code: raw2cnc v00.02dev
(Generalizations for Calorimeters)

Transverse containment (Moliere radius)



- ▷ data-simulation comparison
- ▷ results expected for the $24 X_0$ ecal prototype

Transverse containment (Moliere radius)



- ▷ e.g. 1 GeV e⁻ shower "contained" at
 - : 90% within radius 16 mm
 - : 95% 23 mm
 - : 99% 50 mm

- ▷ slight degradation if impact is along edge/corner of wafer

REMINDER: for an infinitely long and wide calorimeter
 shower contained at 90% within radius $\sim 1 R_M$
 95% $\sim 2 R_M$
 (for solid W, $R_M \simeq 10$ mm) 99% $\sim 3.5 R_M$