DEMONSTRATION ON STRIP SILICON DETECTOR

USING *EASY*: A COMPACT READOUT SYSTEM FOR PARTICLE PHYSICS LABORATORIES

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IFIC

Taller de Altas Energía 2014 (Benasque)

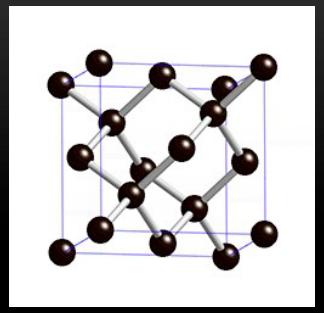
Very short introduction to strip silicon sensors

SILICON SENSORS ARE USED IN A WIDE VARIETY OF APPLICATIONS

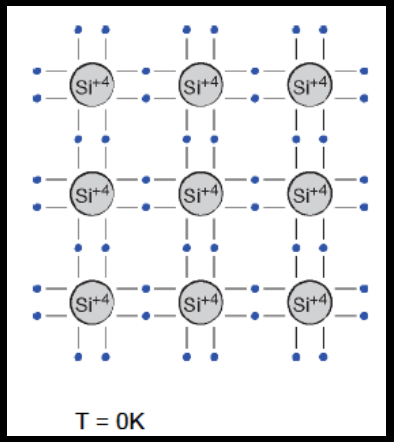
- Nuclear physics
  - Energy measurement of charged particles & Gamma spectroscopy
  - Range of MeV
- Particle physics
  - As tracking devices: reconstruct trajectory of charged particles
    - Precise determination of particle properties
    - Vertex reconstruction
  - Momentum range of GeV
  - Impact parameters resolution: order of microns
- Satellite Experiments & Dark Matter
  - Tracking sensors
- Industrial applications
  - Security, medicine, biology

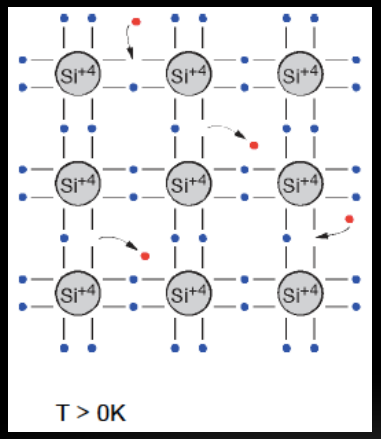
SEMICONDUCTOR

- Group IV: C, Si & Ge
- 4 covalent bonds
- 3D structure
- Compounds: e.g. GaAs



Simplified 2D model





At T=0K all electrons are bound

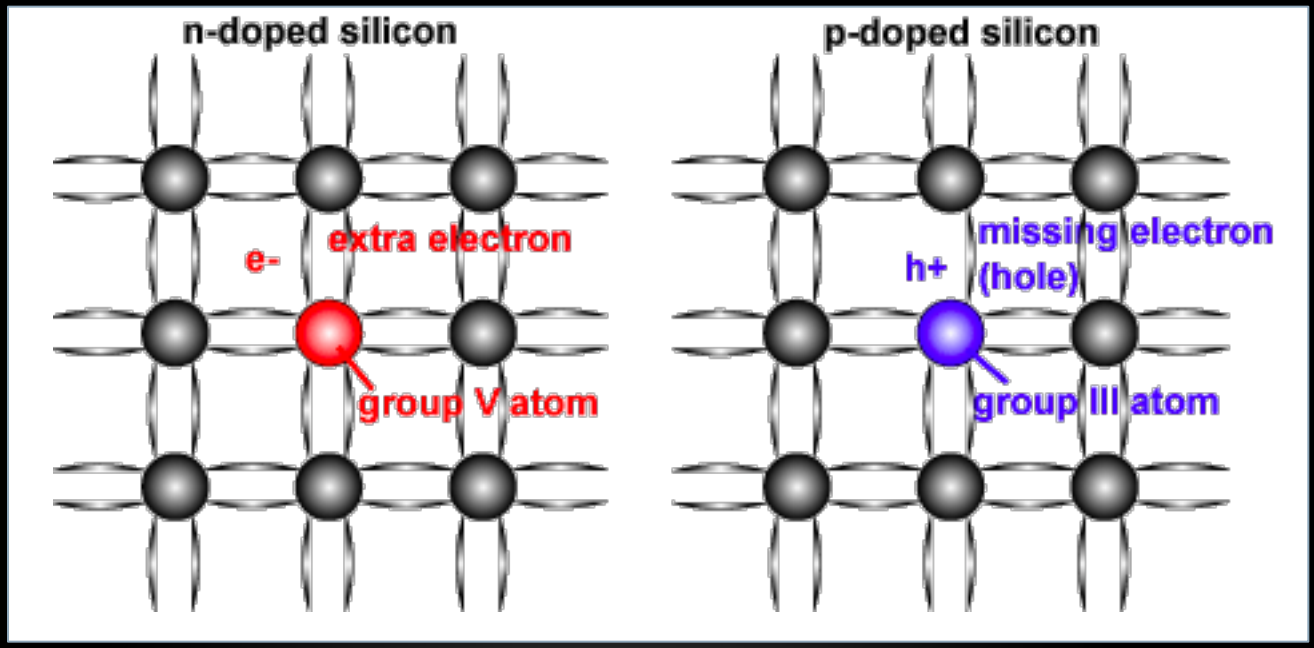
- No conductivity

At T>0K thermal excitations break some bounds

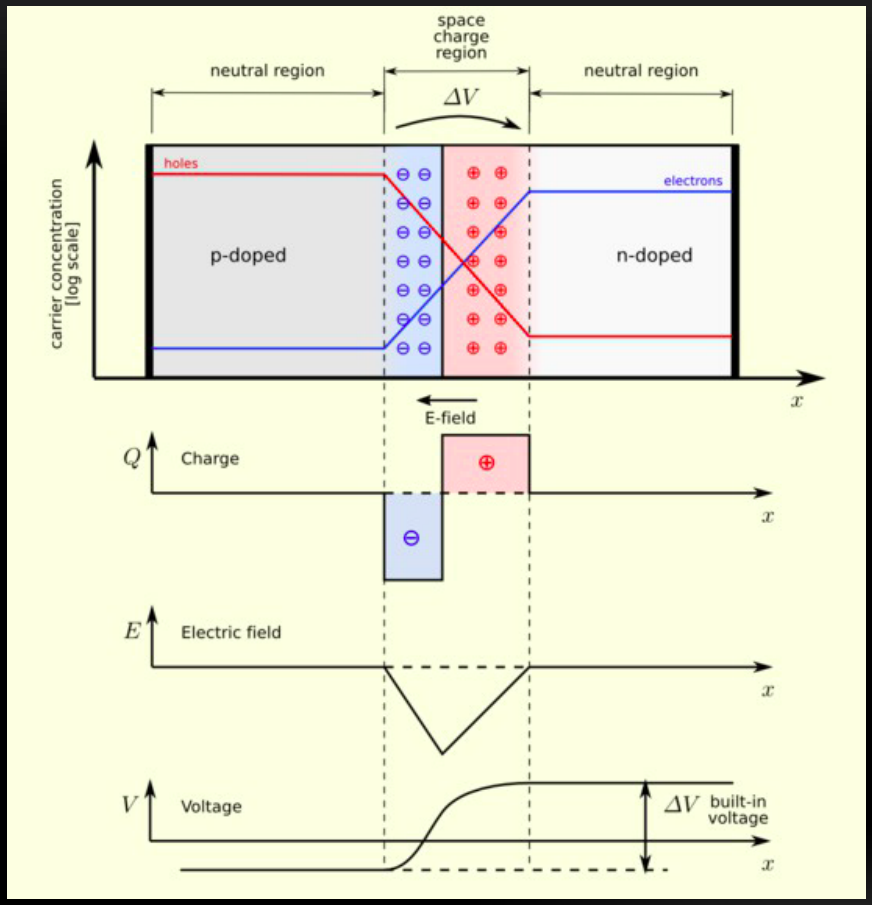
- Electrons free to move → electrical conductivity
- Vacancies can be occupied by other electrons → hole conduction as a + charged particle

SEMICONDUCTOR

- At T>0K (e.g. room temperature) electrons in conduction band recombine with holes
- Doping of silicon with group V elements (donor; P, As, Sb) adds a 5th electron weakly bound → electron ready for conduction → **n-type**
- Doping of silicon with group III elements (acceptor; B, Al, Ga, In) →a covalent bond is open → hole formed → **p-type**



THE p-n JUNCTION



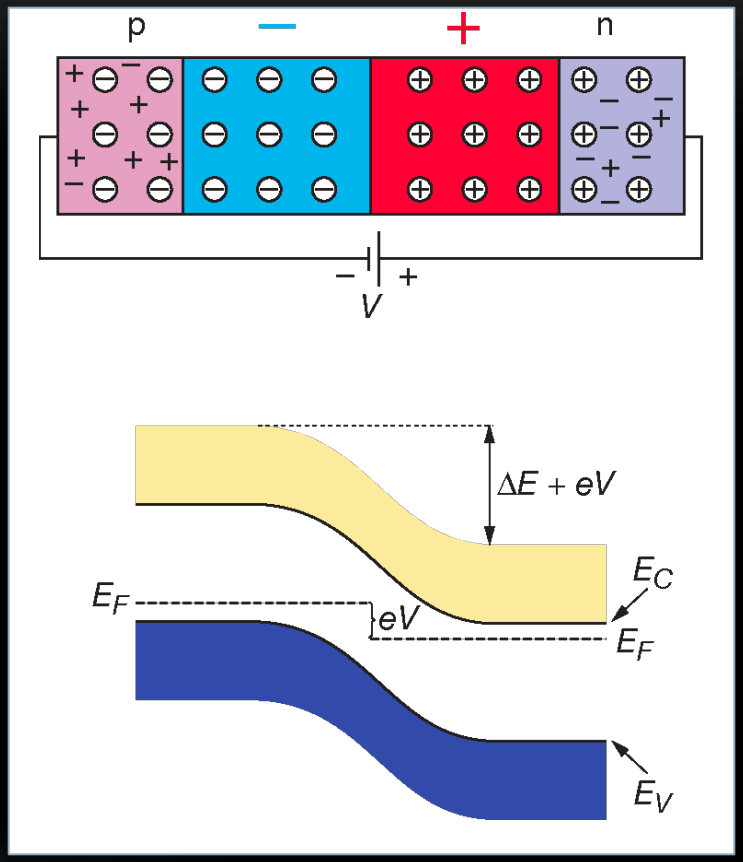
A p-n junction is formed when two opposite doping type semiconductors are in contact

- The excess of electrons in the n-type diffuses to the p-type and combine with the holes (majority) and vice-versa
- A region free of charge carriers appears → **depletion zone**

REVERSE BIASED p-n JUNCTION

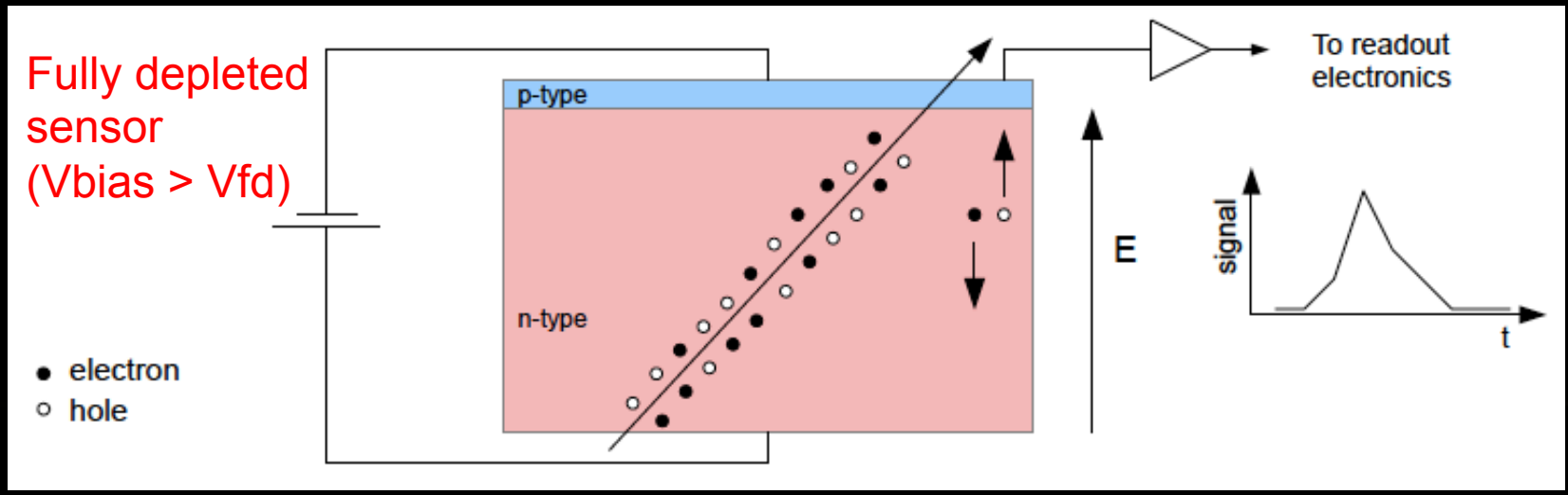
Apply an external (**reverse bias**) voltage

- Electrons and holes may get enough energy to cross the barrier
- The depletion zone grows (size depends on dopant concentrations)
- The potential barrier becomes larger
- Diffusion across the barrier becomes more difficult (higher barrier)
- Still there is a leakage current across the junction (low current)



BASIC SILICON SENSOR SCHEME

- Usually, silicon detector are operated via a reverse biased p-n junction
- Depleted zone free of charge carriers (Except thermally generated e-h pairs → leakage current).
- Ionizing energy loss from incident particles releases e-h pairs (3,6 eV per e-h).
- Minimum ionizing particles average energy loss in silicon
    - Average ~100 e-h pairs per micro-meter
    - Average ~30.000 e-h pairs in 300 µm thick silicon sensors
    - Average deposited charge ~5 fC
- The electric field in depleted zone drifts away e-h pairs



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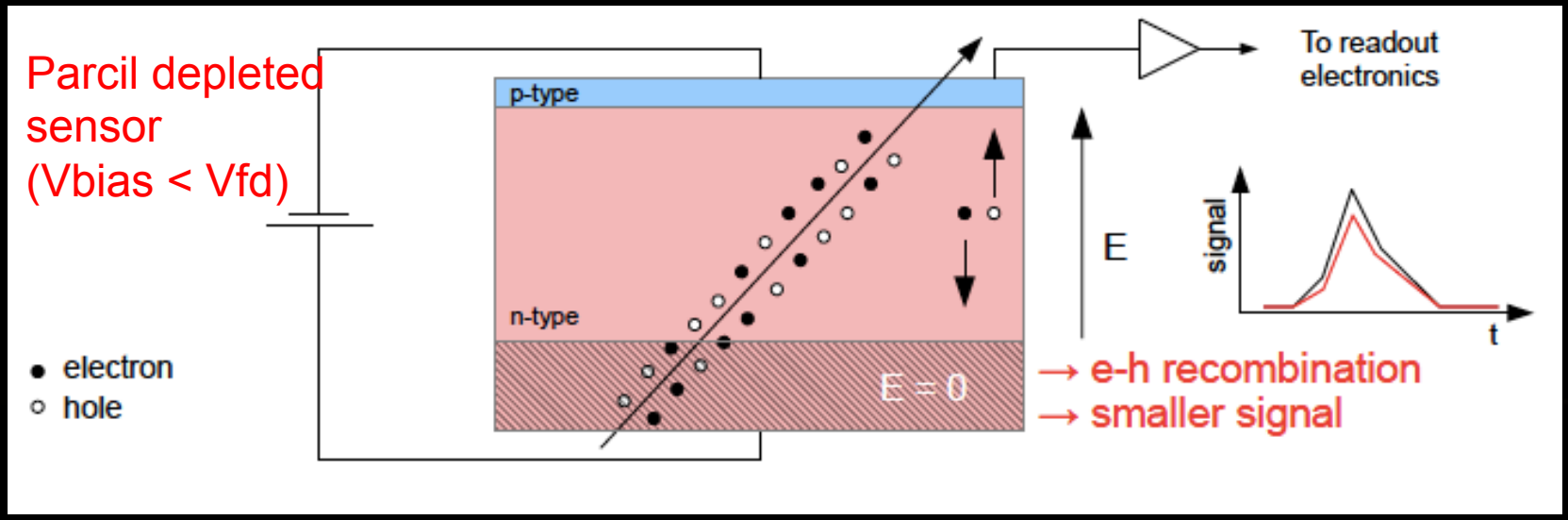
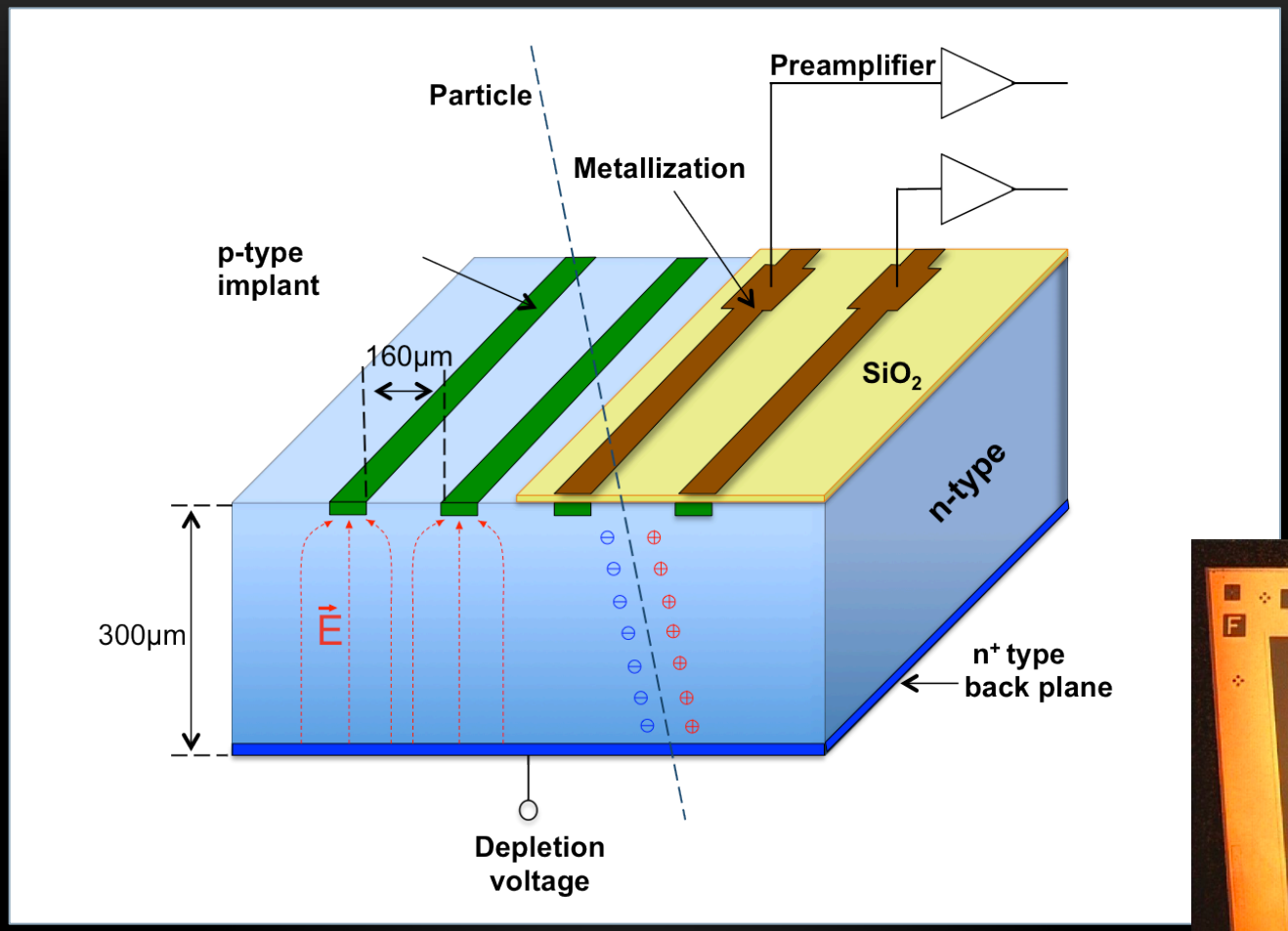
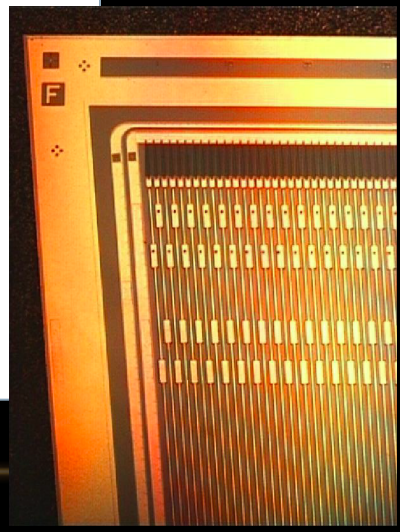


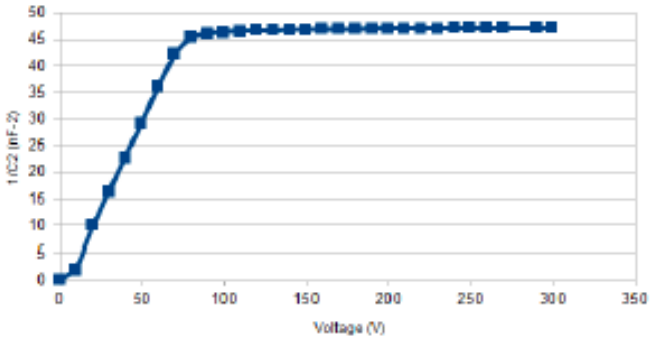
STRIP SILICON DETECTOR



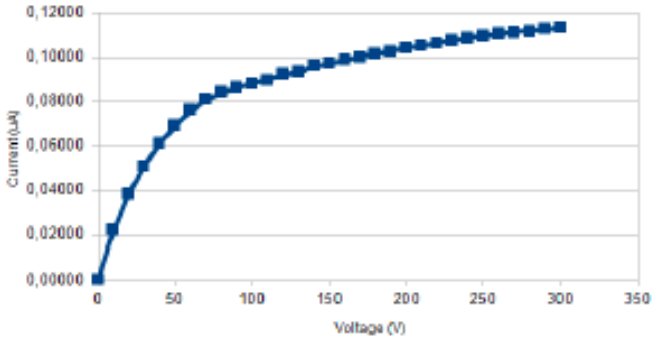


SILICON DETECTOR CHARACTERISTICS

Curva C-V

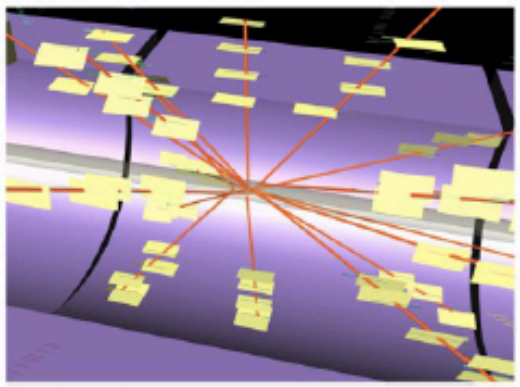


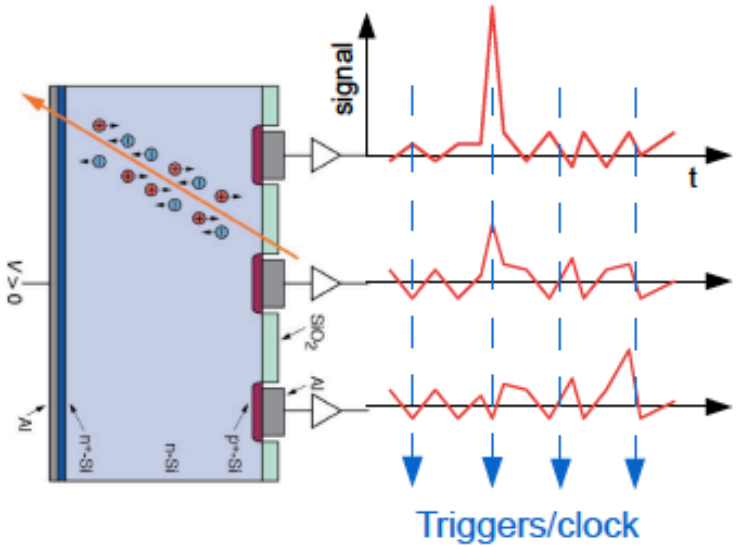
Curva I-V



SIGNAL PROCESSING

- The sensors are operated continuously although data is read out only when acquisition is triggered
- Output depends on readout mode





Analogue mode →
(arbitrary units)

+1	+8	+1	+1
-1	+3	-1	0
-1	-1	-1	+4

Possibility to perform center of gravity calculations

SIGNAL PROCESSING

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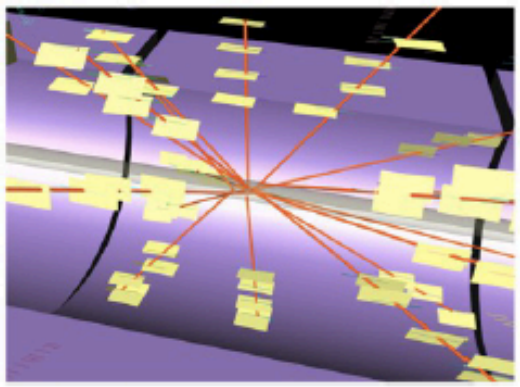

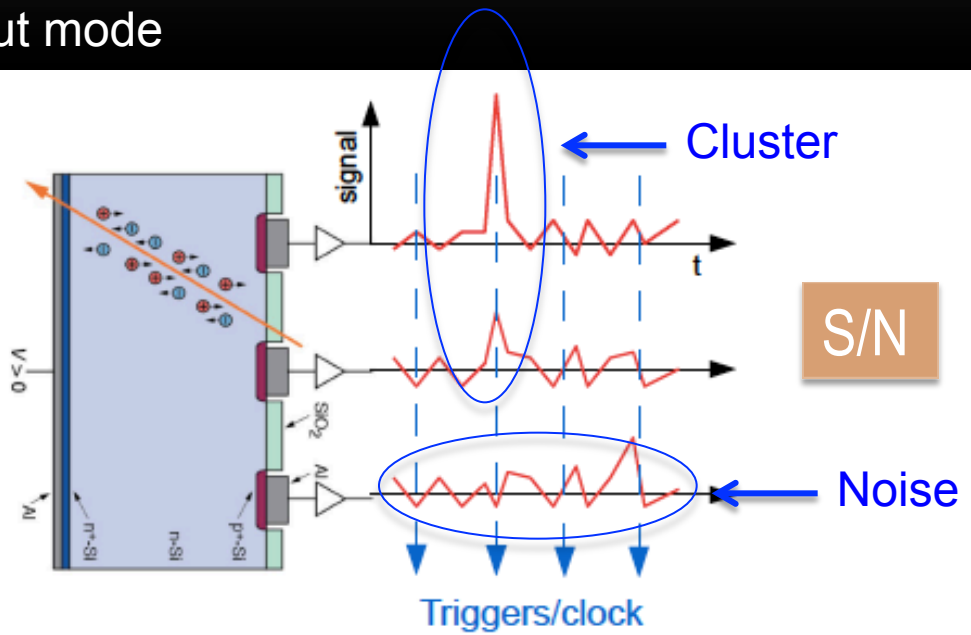

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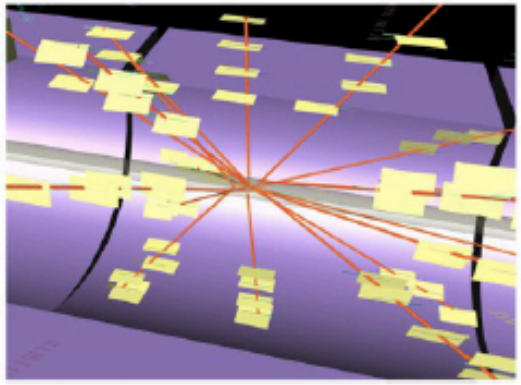
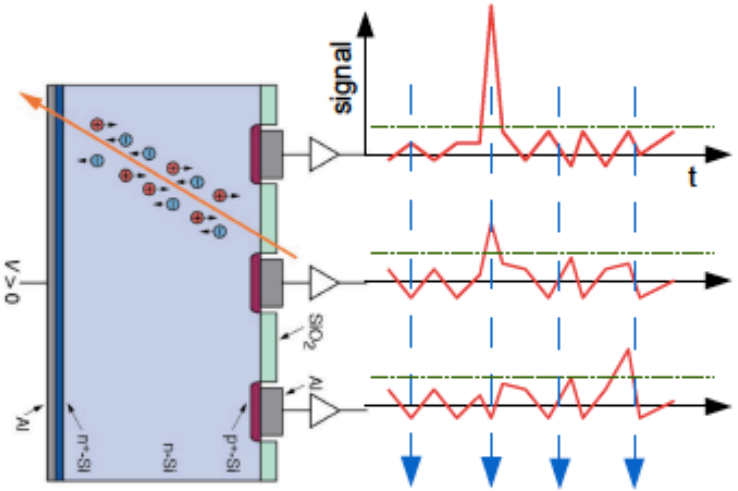
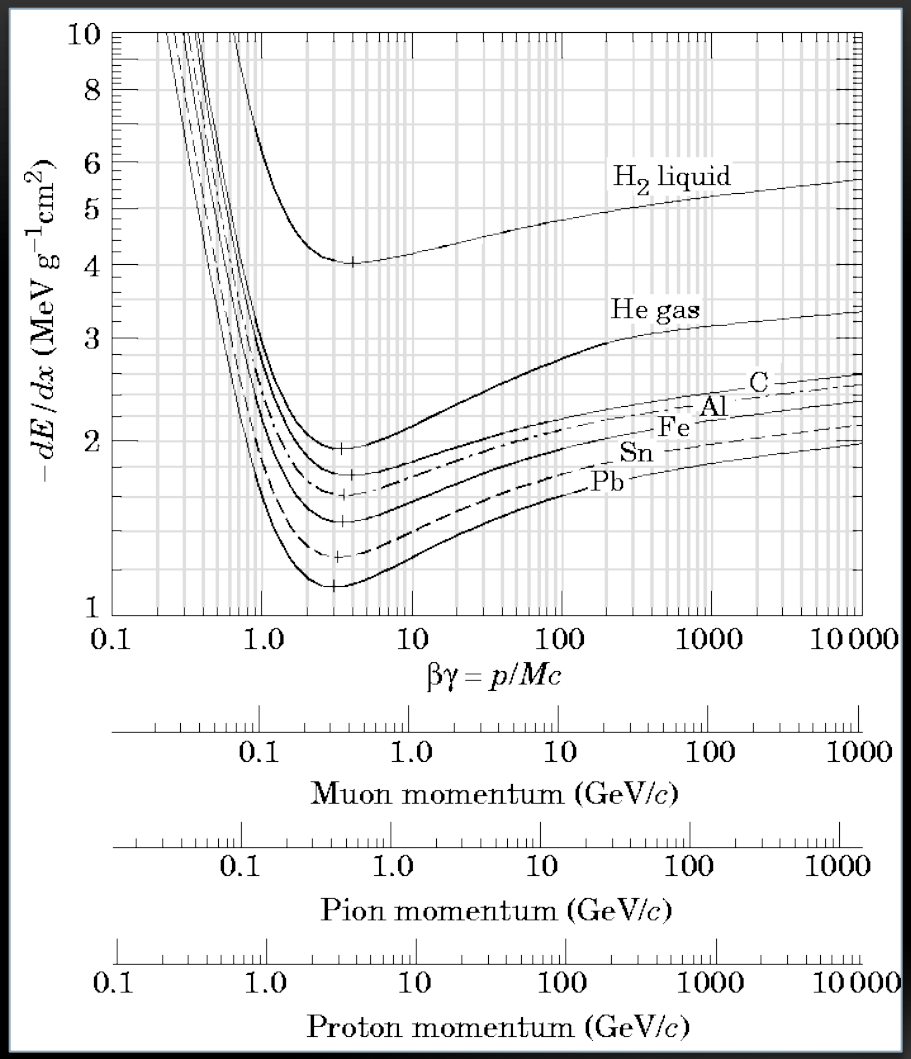


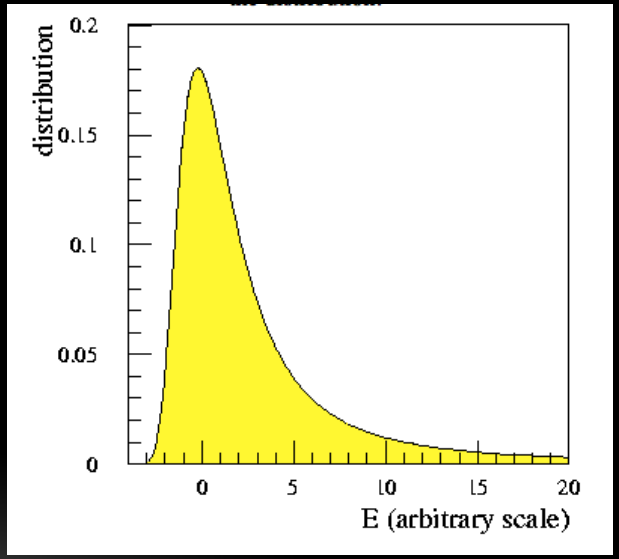


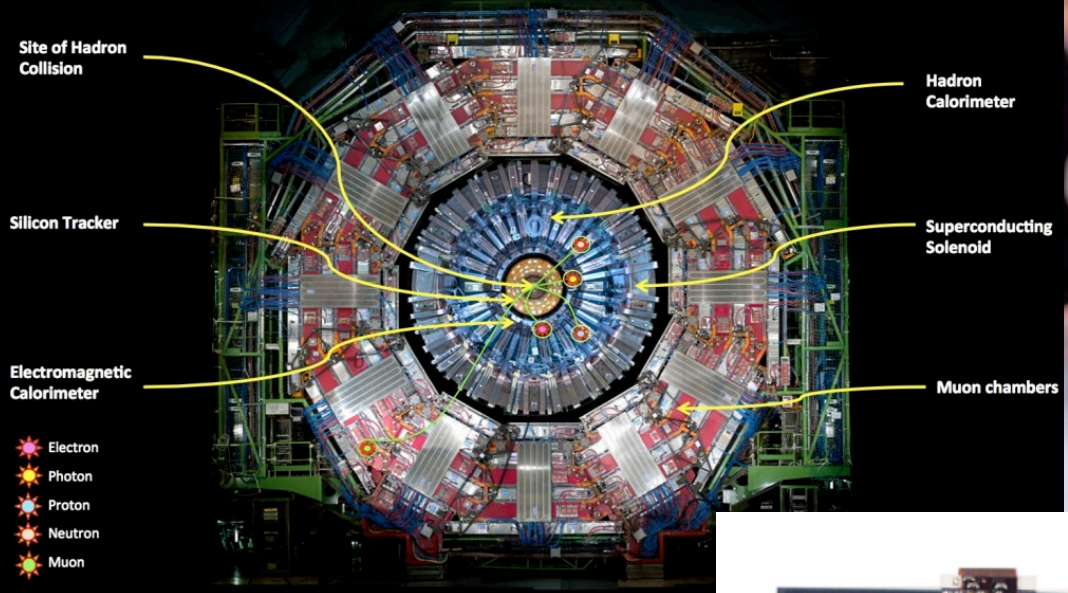
Binary mode → 0 0 0 | 1 1 0 | 0 0 0 | 0 0 1

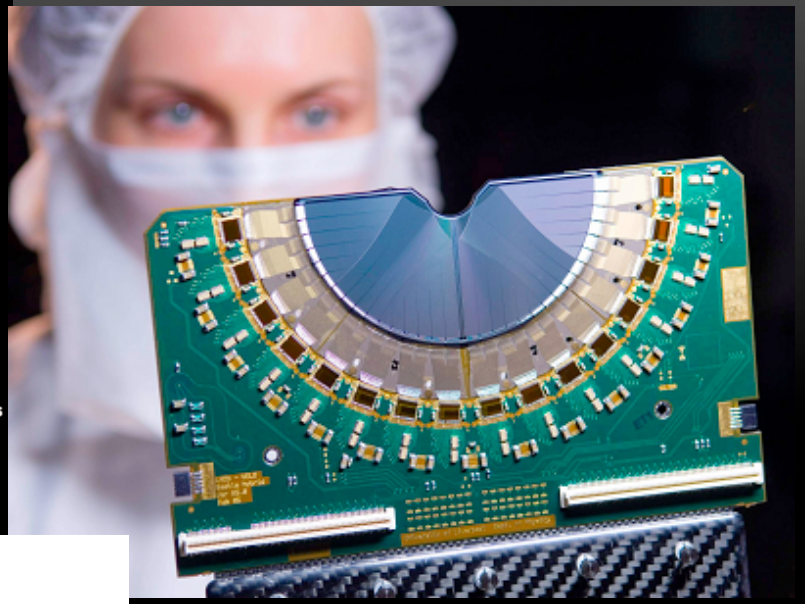
No center of gravity calculations

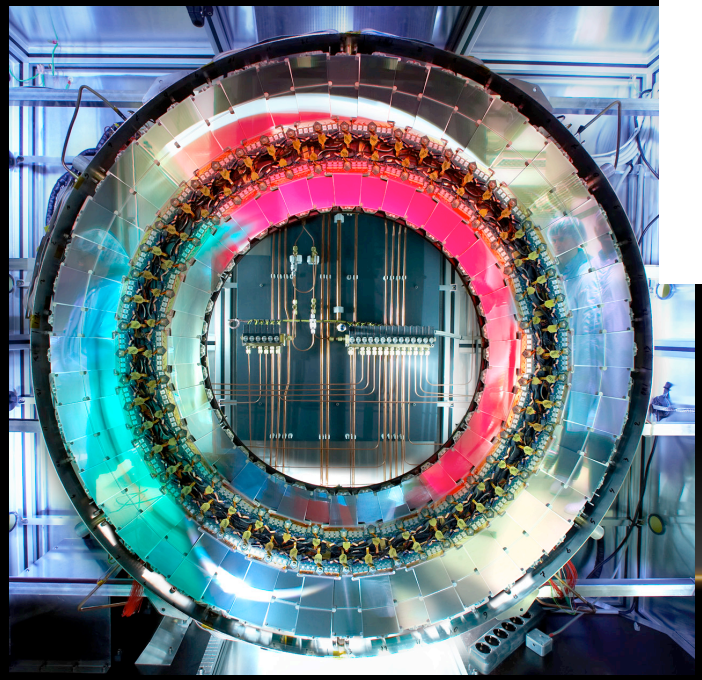


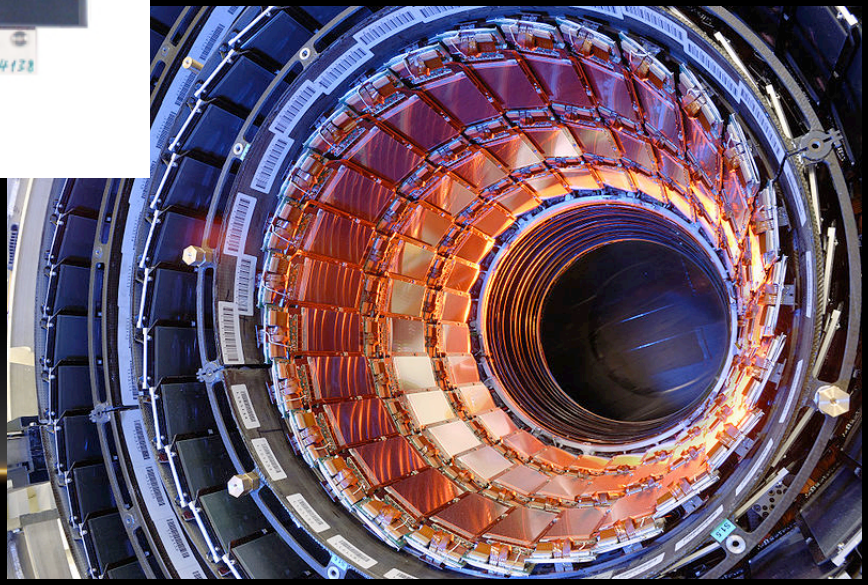
The mean value of the total energy loss is given from the Bethe-Bloch formula but the fluctuations are large due to a low number of high energy ionisations. The energy loss distribution is given by the Landau distribution

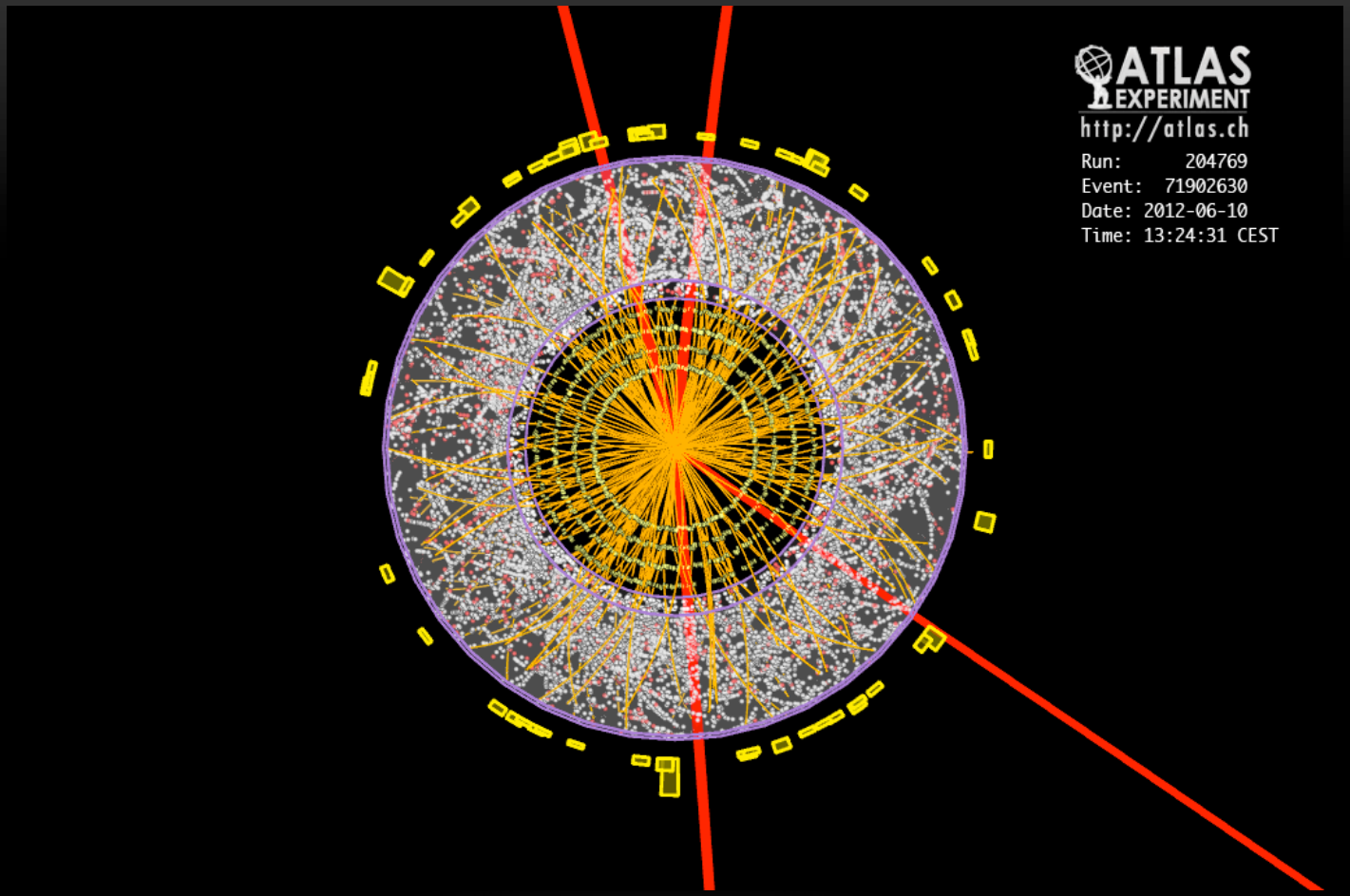



Site of Hadron Collision
Hadron Calorimeter
Silicon Tracker
Superconducting Solenoid
Electromagnetic Calorimeter
Muon chambers
Electron
Photon
Proton
Neutron
Muon








ATLAS
EXPERIMENT
http://atlas.ch
Run: 204769
Event: 71902630
Date: 2012-06-10
Time: 13:24:31 CEST

EASY - Educational Alibava System

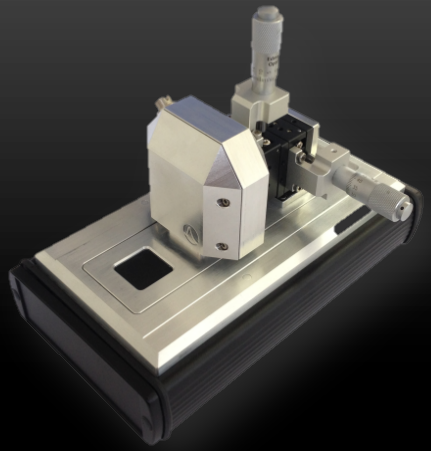
ALIBAVA SYSTEMS


EASY board
Detector board
EASY Educational Alibava System
ALIBAVA SYSTEMS
LASER
TRIGGER INPUT
ALIBAVA
SYSTEMS

EASY board

EASY board

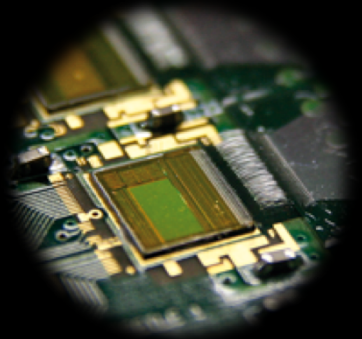
- Controls the detector board and communicates with the PC software.
- Xilinx device retained with support chipset
- Plug and play.
- Interface with Detector board via 34 IDC connector.
- Incorporates all control, powering for Detector Board.
- USB 2.0 interface.
- HV module to supply the detector bias.



Detector board

Detector board

- The Detector Board accommodates one “BEETLE” readout ASICs, providing 128 analogue input channels with 40MHz clocked analogue pipeline
- The trigger signal is generated on the same board..

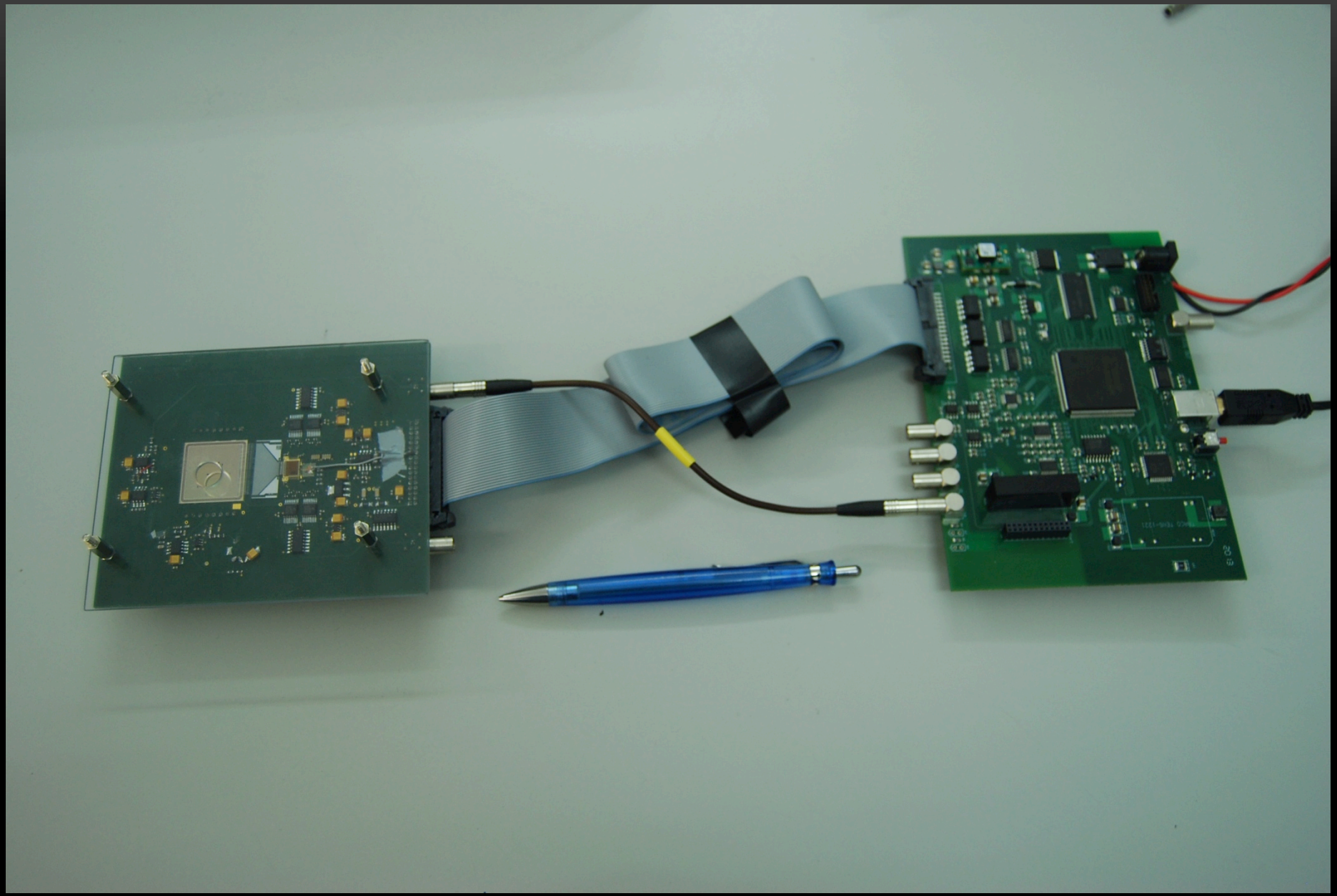


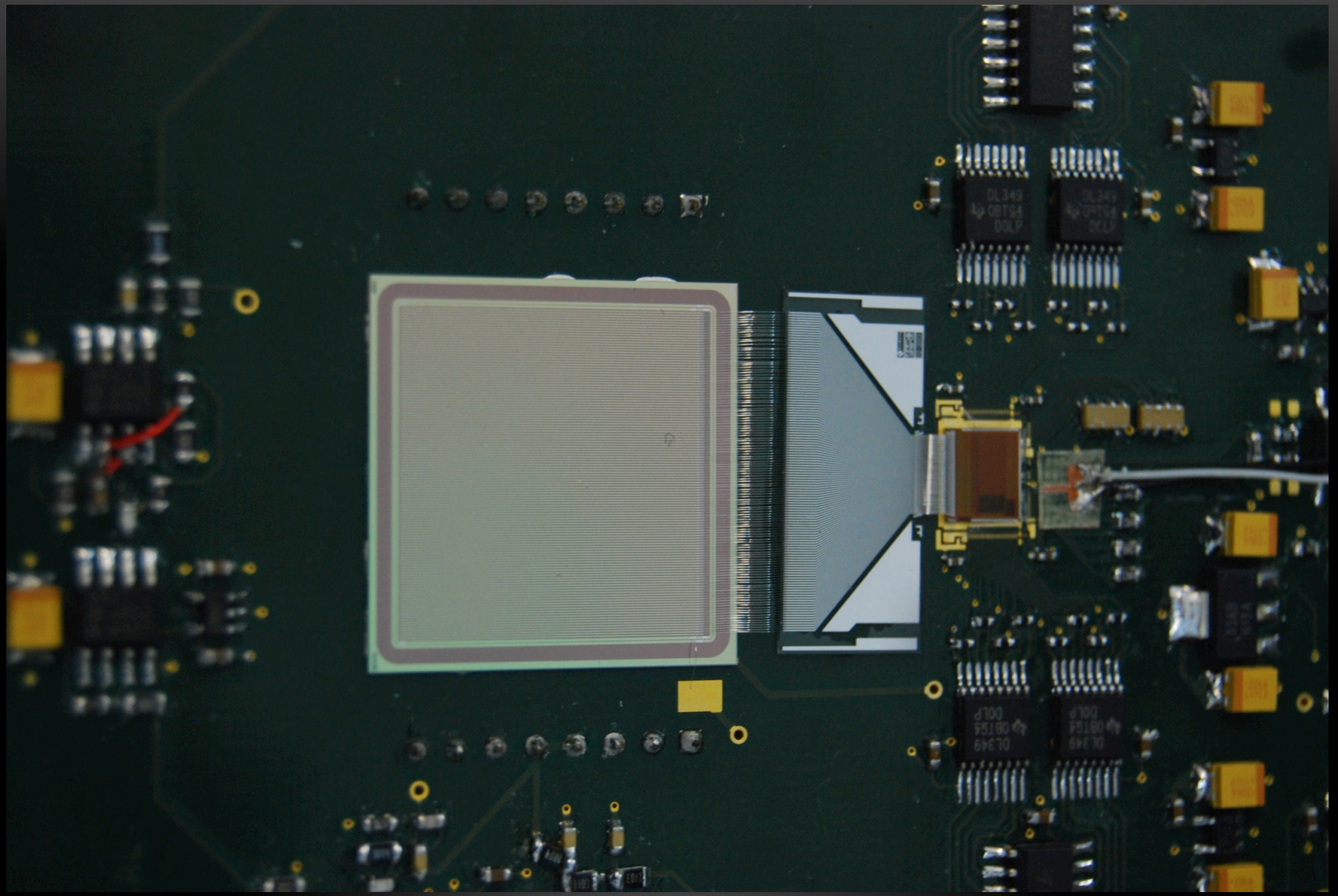
Microstrip Silicon Detector

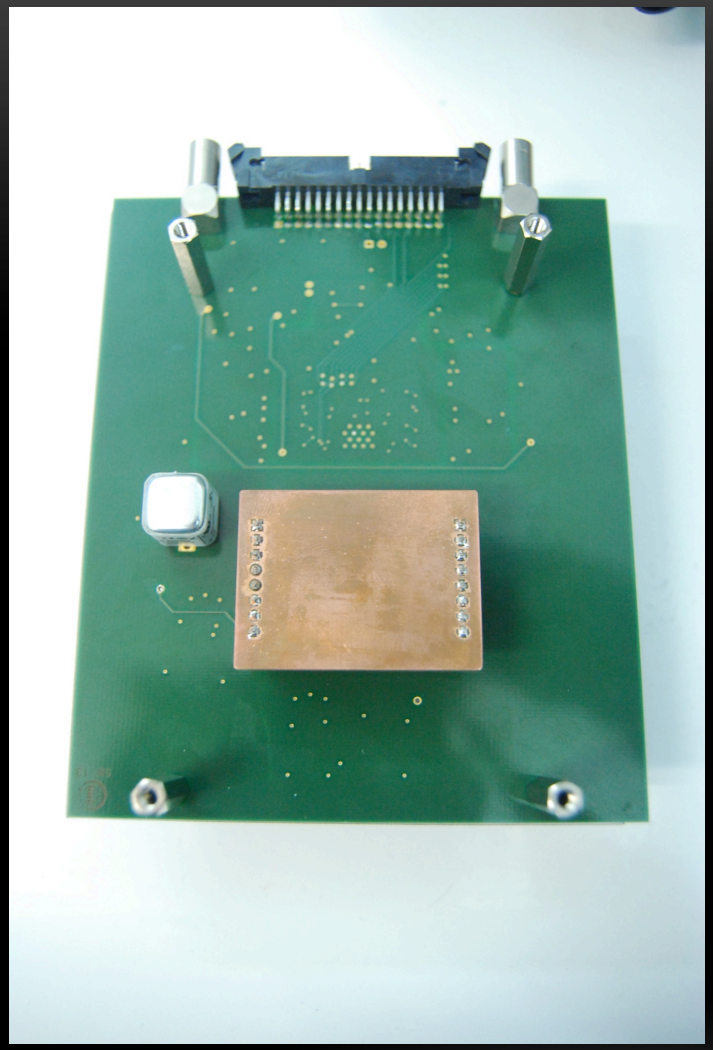
- P-on-N silicon microstrip, polysilicon biasing resistors, AC coupled.
- 128 channels with pitch 160 µm.
- Thickness: 300 µm.
- V_{FD} < 60 V.
- I_{Leak} (@V_{FD}) < 10 nA/strip.

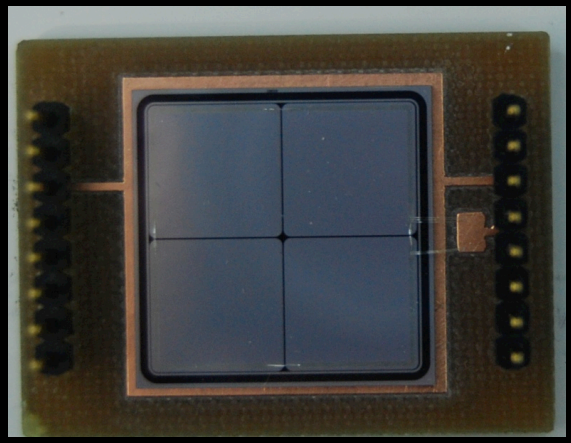
Laser source

Wavelength: 980nm., 5ns Pulses width

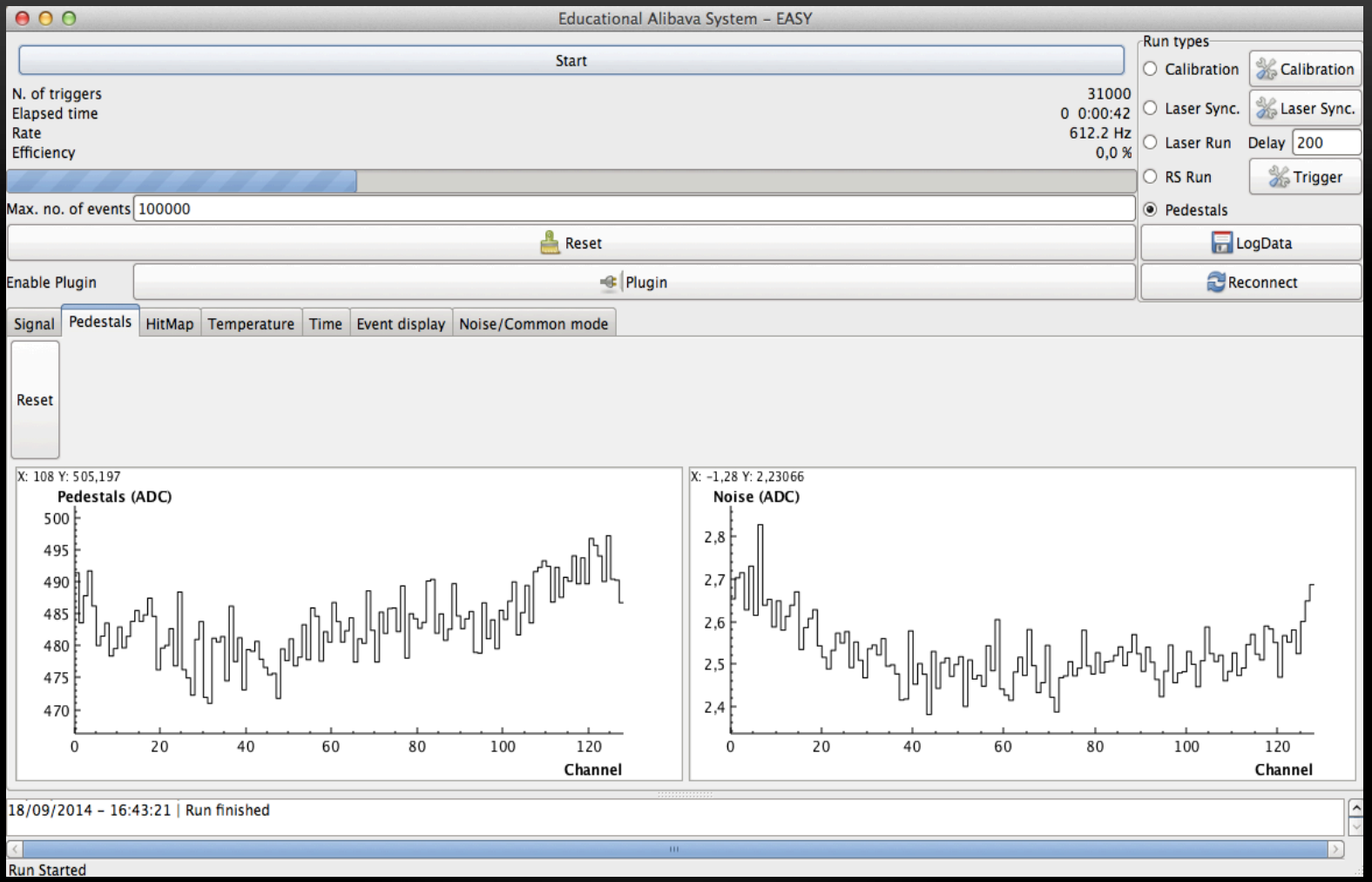


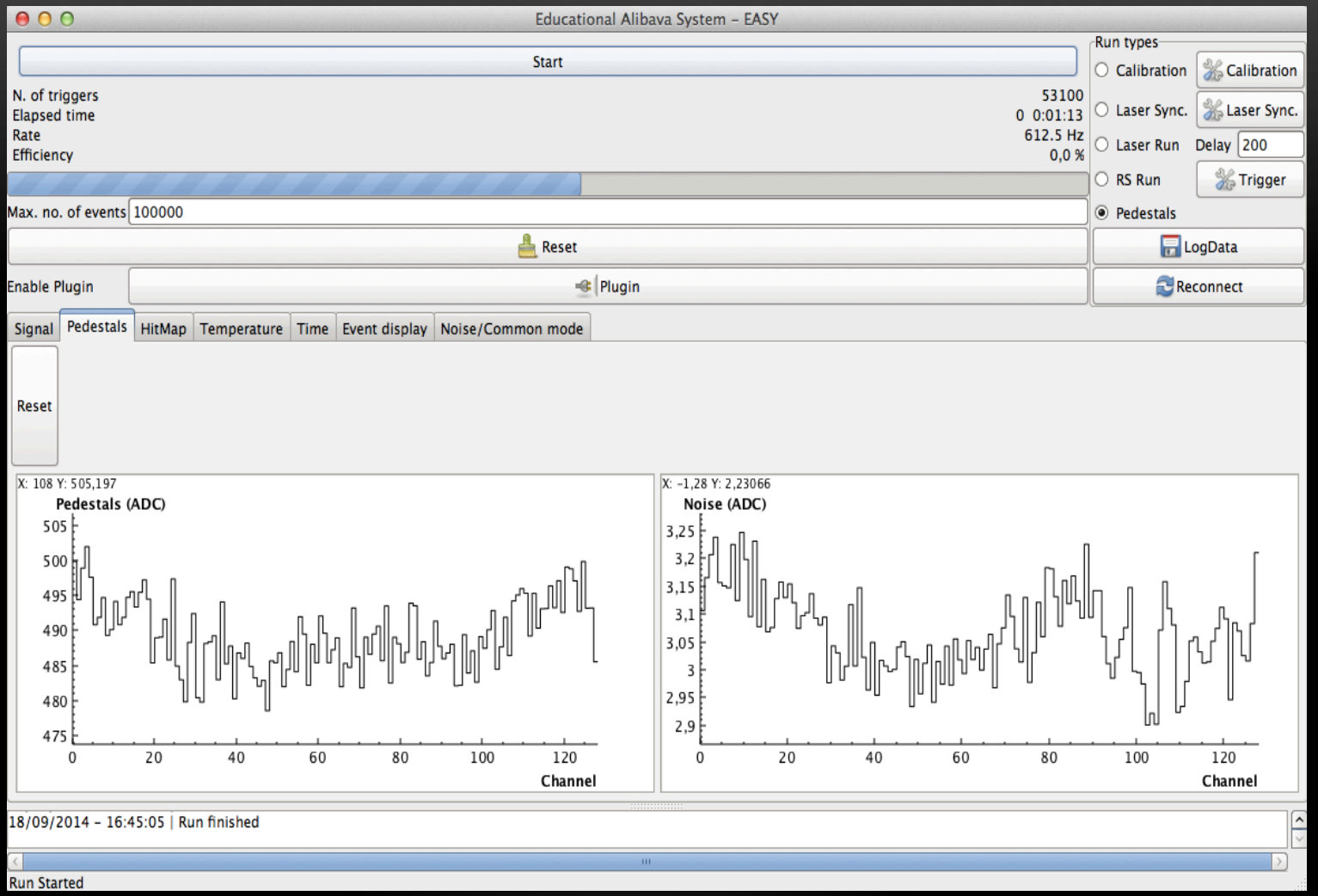


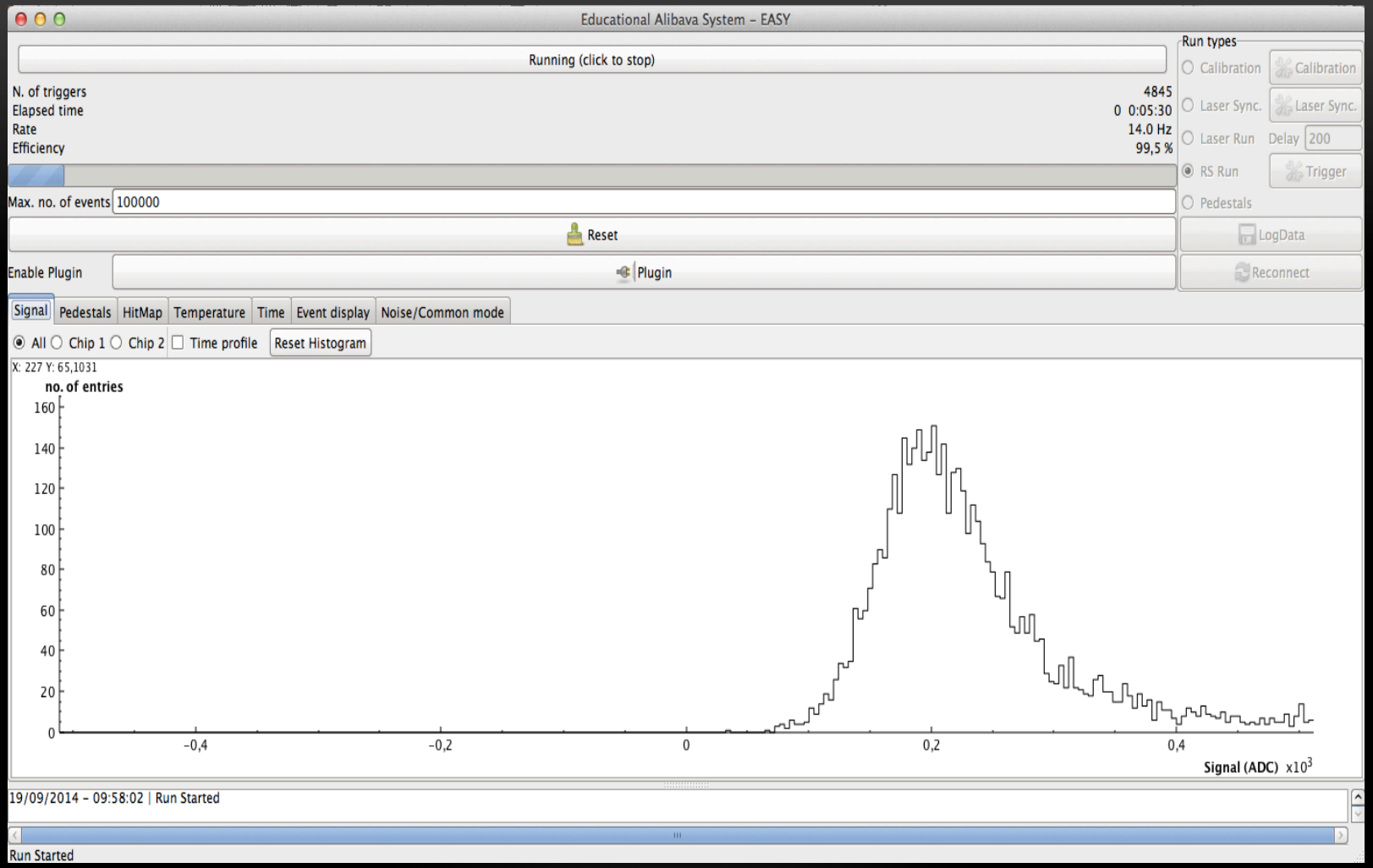


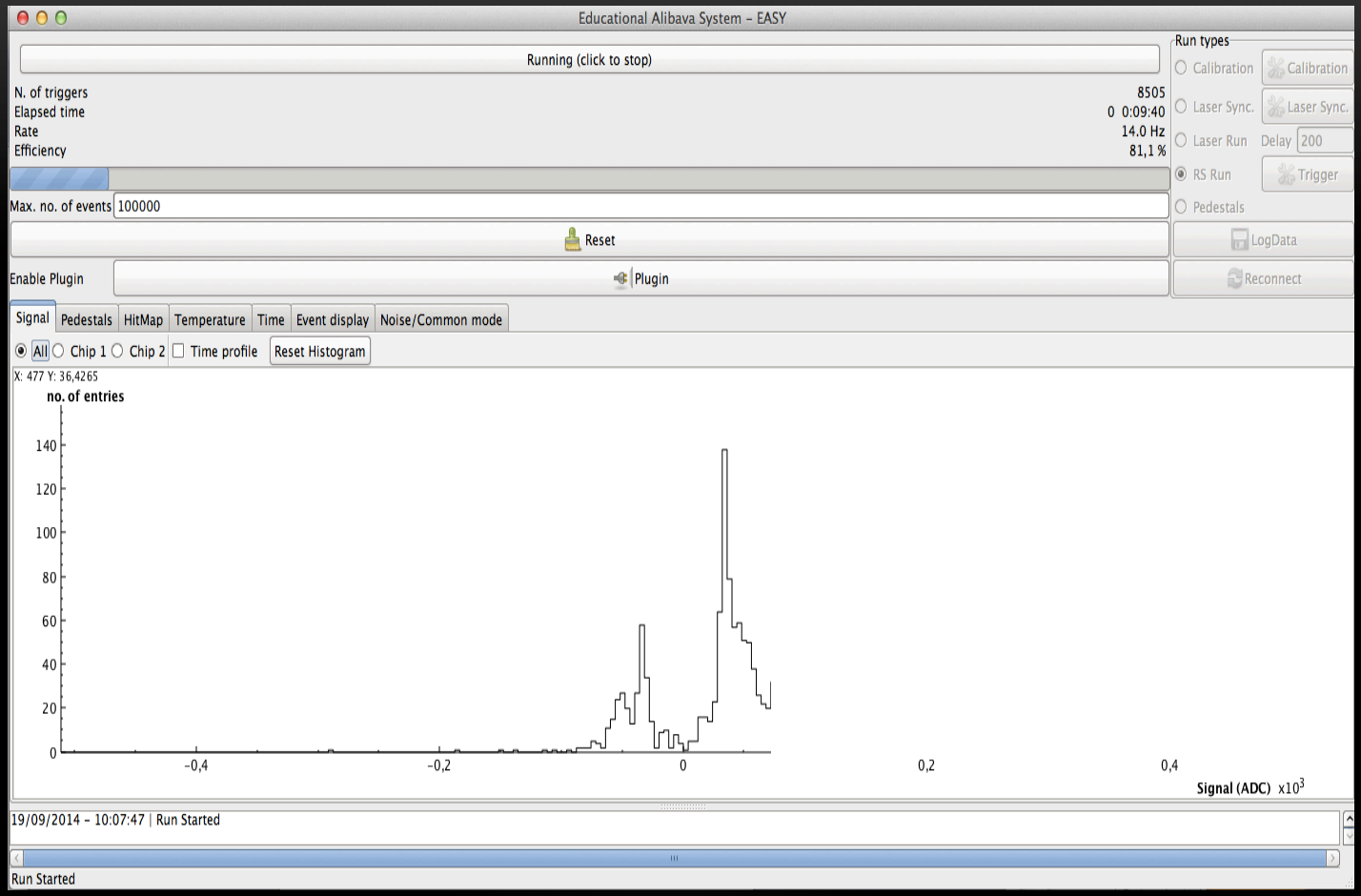


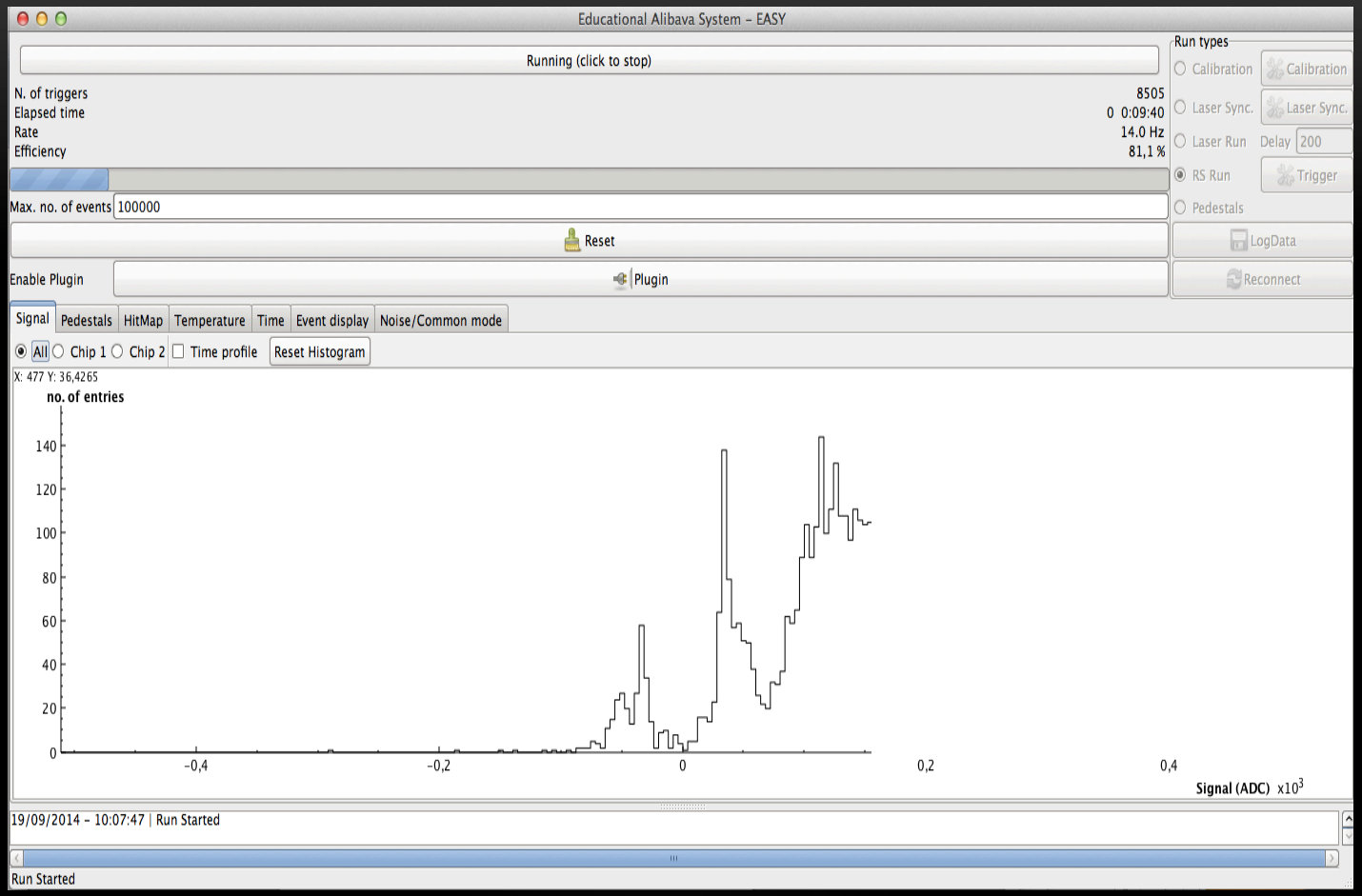
REAL DATA


Educational Alibava System – EASY
Start
N. of triggers
Elapsed time
Rate
Efficiency
31000
0 0:00:42
612.2 Hz
0,0 %
Run types
Calibration
Laser Sync.
Laser Run
RS Run
Pedestals
Delay 200
Trigger
Max. no. of events 100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
Reset
X: 108 Y: 505,197
Pedestals (ADC)
500
495
490
485
480
475
470
0
20
40
60
80
100
120
Channel
X: -1,28 Y: 2,23066
Noise (ADC)
2,8
2,7
2,6
2,5
2,4
0
20
40
60
80
100
120
Channel
18/09/2014 - 16:43:21 | Run finished
Run Started


Educational Alibava System – EASY
Start
N. of triggers
Elapsed time
Rate
Efficiency
53100
0 0:01:13
612.5 Hz
0,0 %
Run types
Calibration
Laser Sync.
Laser Run
RS Run
Pedestals
Delay 200
Trigger
Max. no. of events 100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
Reset
X: 108 Y: 505,197
Pedestals (ADC)
505
500
495
490
485
480
475
0
20
40
60
80
100
120
Channel
X: -1,28 Y: 2,23066
Noise (ADC)
3,25
3,2
3,15
3,1
3,05
3
2,95
2,9
0
20
40
60
80
100
120
Channel
18/09/2014 – 16:45:05 | Run finished
Run Started


Educational Alibava System – EASY
Running (click to stop)
N. of triggers
Elapsed time
Rate
Efficiency
4845
0 0:05:30
14.0 Hz
99,5 %
Run types
Calibration
Laser Sync.
Laser Run
Delay
200
RS Run
Pedestals
Trigger
Max. no. of events
100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
All
Chip 1
Chip 2
Time profile
Reset Histogram
X: 227 Y: 65,1031
no. of entries
160
140
120
100
80
60
40
20
0
-0,4
-0,2
0
0,2
0,4
Signal (ADC) x10^3
19/09/2014 – 09:58:02 | Run Started
Run Started


Educational Alibava System – EASY
Running (click to stop)
N. of triggers
Elapsed time
Rate
Efficiency
8505
0 0:09:40
14.0 Hz
81,1 %
Run types
Calibration
Laser Sync.
Laser Run
RS Run
Pedestals
Delay
200
Trigger
Max. no. of events
100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
All
Chip 1
Chip 2
Time profile
Reset Histogram
X: 477 Y: 36,4265
no. of entries
140
120
100
80
60
40
20
0
-0,4
-0,2
0
0,2
0,4
Signal (ADC) x10^3
19/09/2014 – 10:07:47 | Run Started
Run Started


Educational Alibava System – EASY
Running (click to stop)
N. of triggers
Elapsed time
Rate
Efficiency
8505
0 0:09:40
14.0 Hz
81,1 %
Run types
Calibration
Laser Sync.
Laser Run
Delay
200
RS Run
Pedestals
Trigger
Max. no. of events
100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
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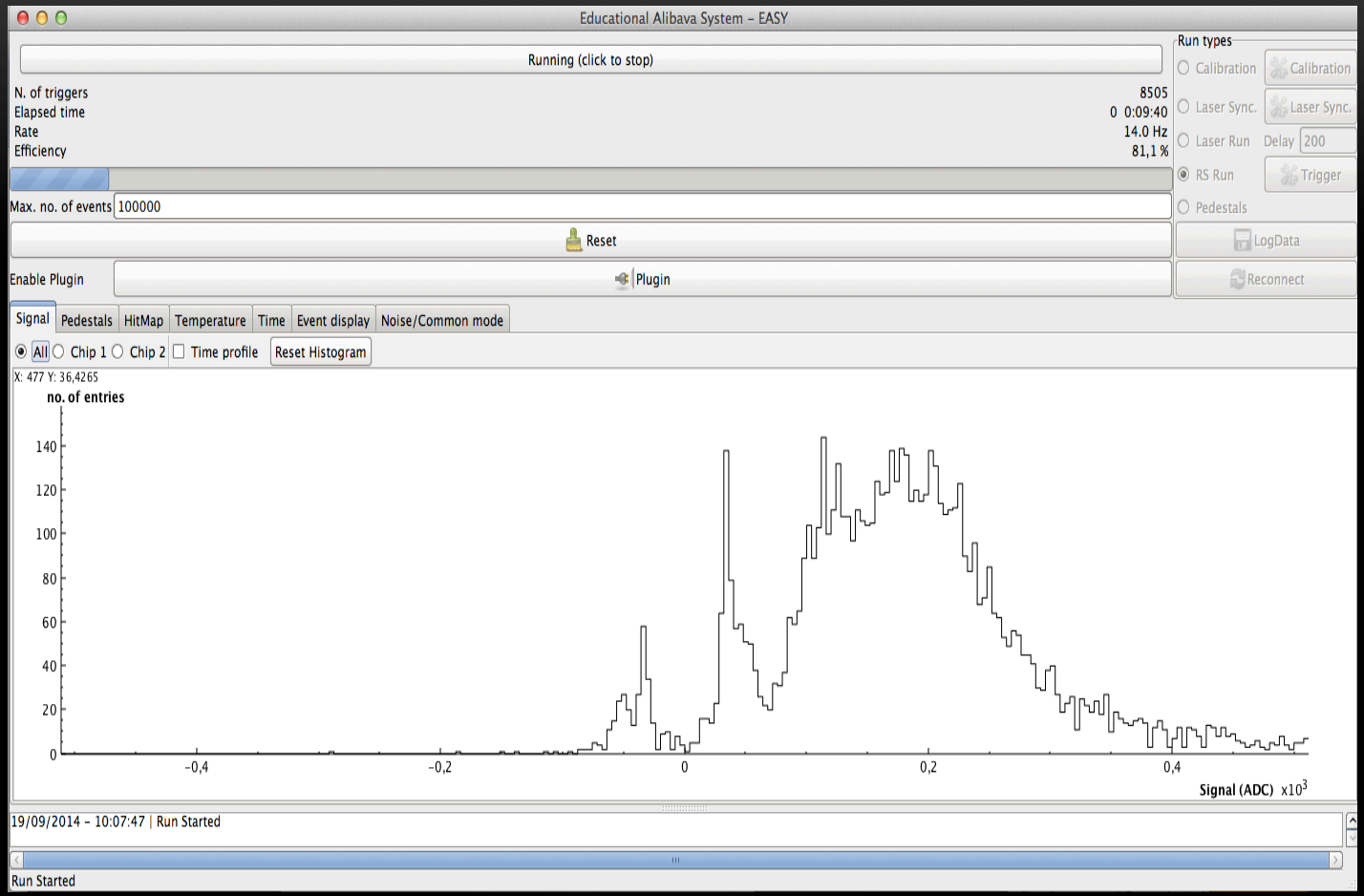
HitMap
Temperature
Time
Event display
Noise/Common mode
All
Chip 1
Chip 2
Time profile
Reset Histogram
X: 477 Y: 36,4265
no. of entries
140
120
100
80
60
40
20
0
-0,4
-0,2
0
0,2
0,4
Signal (ADC) x10^3
19/09/2014 – 10:07:47 | Run Started
Run Started


Educational Alibava System – EASY
Running (click to stop)
N. of triggers
Elapsed time
Rate
Efficiency
8505
0 0:09:40
14.0 Hz
81,1 %
Run types
Calibration
Laser Sync.
Laser Run
Delay
200
RS Run
Trigger
Pedestals
Max. no. of events
100000
Reset
LogData
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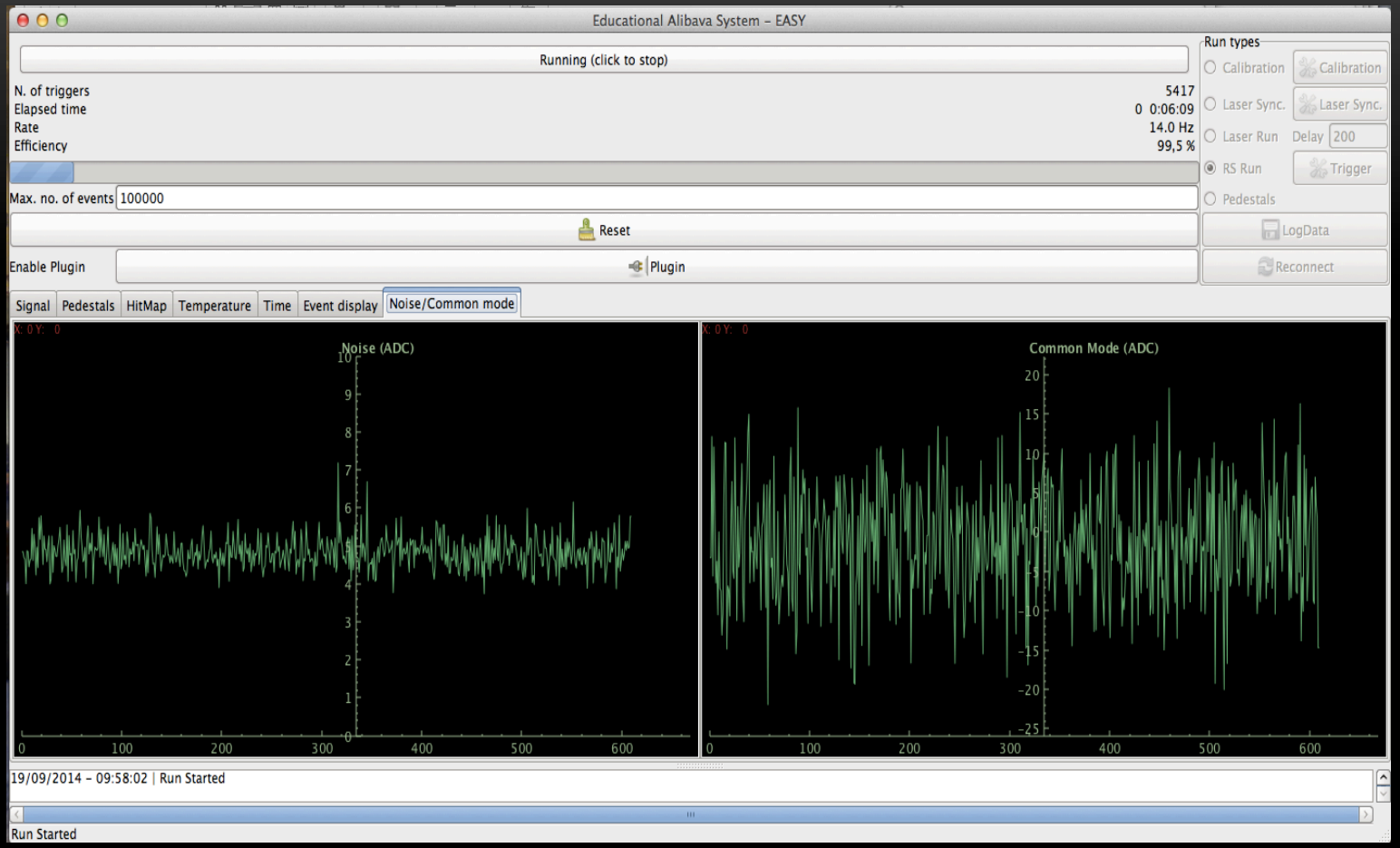
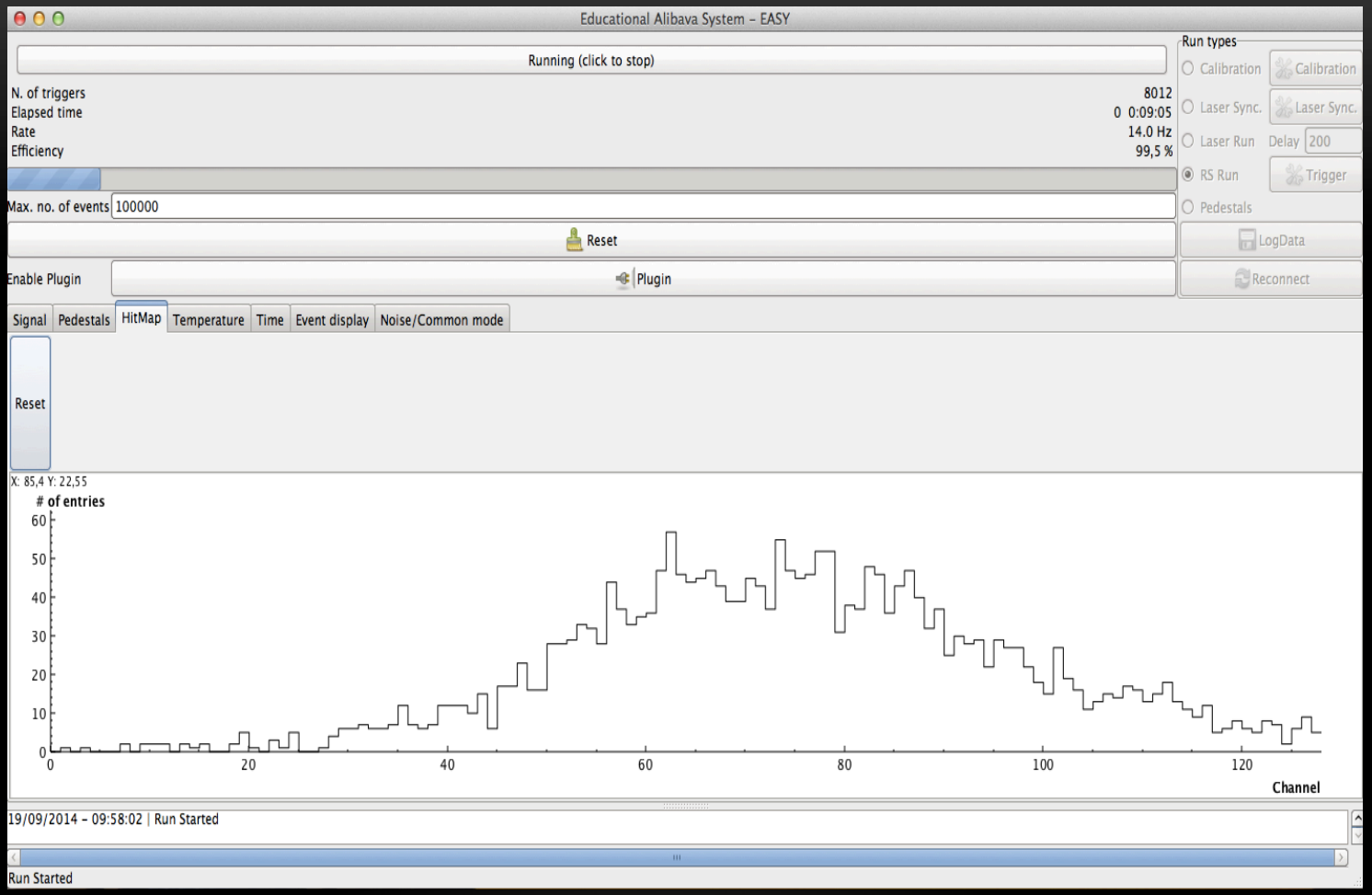
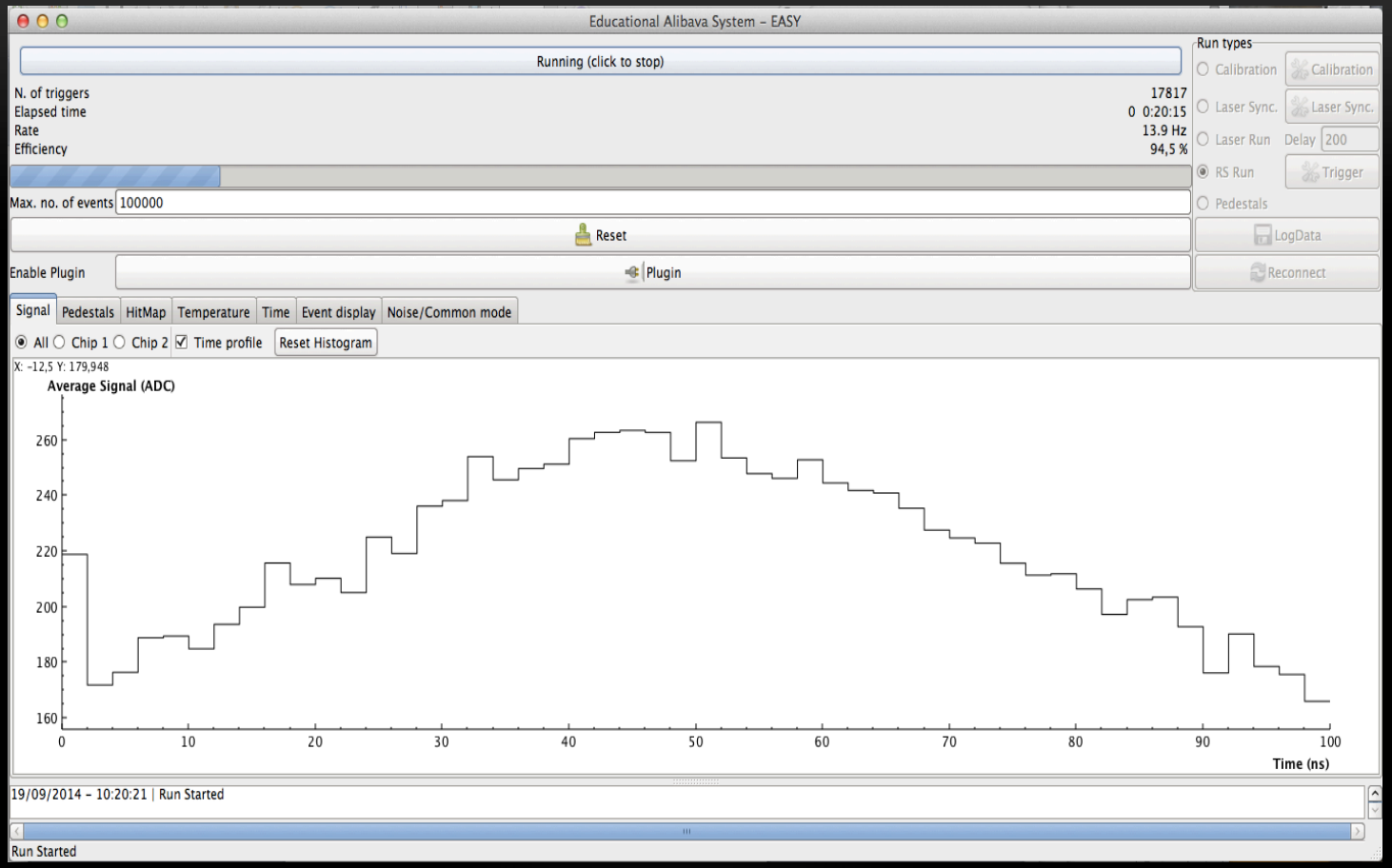
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
All
Chip 1
Chip 2
Time profile
Reset Histogram
X: 477 Y: 36,4265
no. of entries
140
120
100
80
60
40
20
0
-0,4
-0,2
0
0,2
0,4
Signal (ADC) x10^3
19/09/2014 – 10:07:47 | Run Started
Run Started

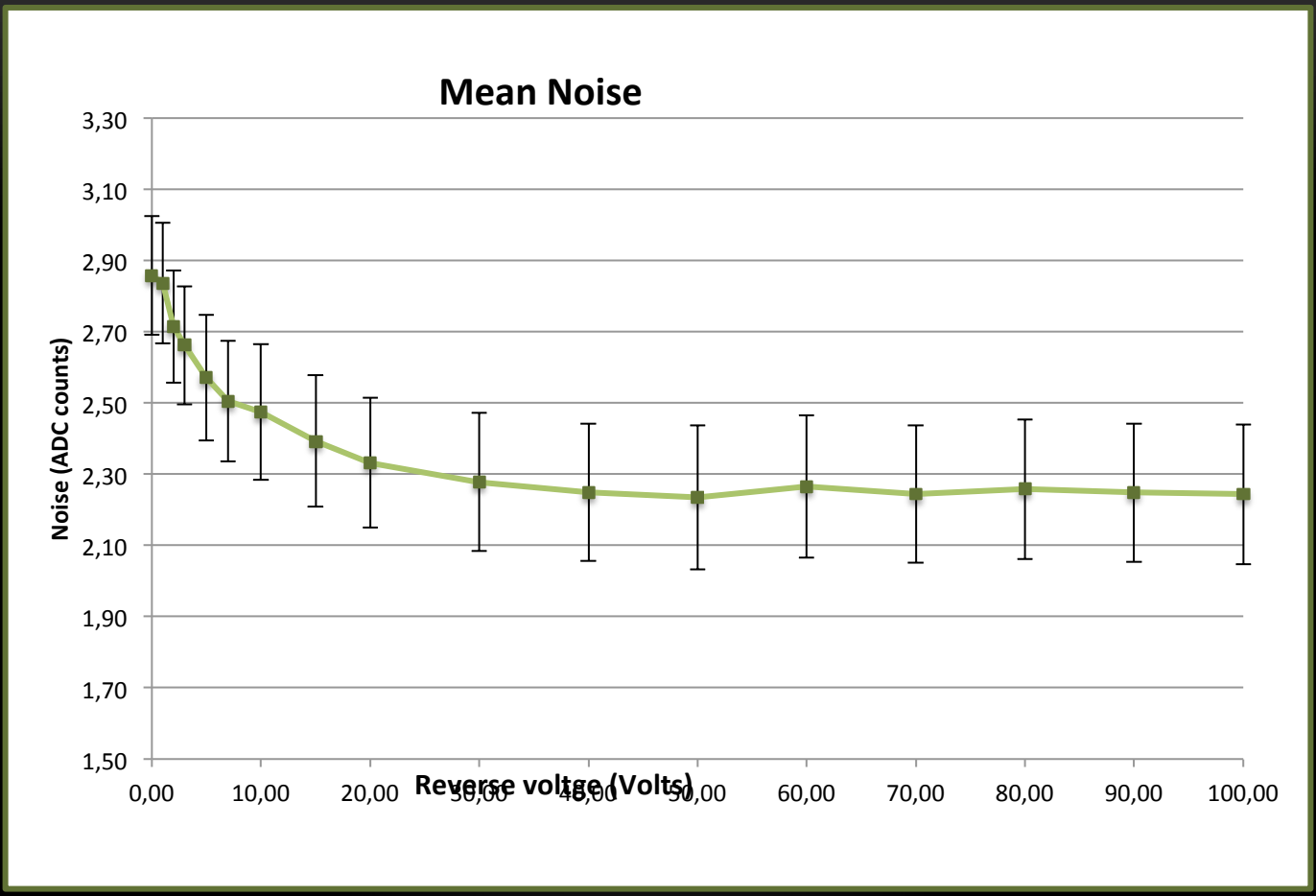

Educational Alibava System – EASY
Running (click to stop)
Run types
Calibration
Calibration
Laser Sync.
Laser Sync.
Laser Run
Delay
200
RS Run
Trigger
Pedestals
N. of triggers
5130
Elapsed time
0 0:05:49
Rate
13.9 Hz
Efficiency
99,5 %
Max. no. of events
100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
Raw Data
Signal
Header 0
Header 1
X: 0 Y: 0
RawData
800
700
600
500
400
300
19/09/2014 – 09:58:02 | Run Started
Run Started


Educational Alibava System – EASY
Running (click to stop)
N. of triggers
5417
Elapsed time
0 0:06:09
Rate
14.0 Hz
Efficiency
99,5 %
Run types
Calibration
Calibration
Laser Sync.
Laser Sync.
Laser Run
Delay
200
RS Run
Trigger
Pedestals
Max. no. of events
100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
Noise (ADC)
Common Mode (ADC)
19/09/2014 – 09:58:02 | Run Started
Run Started


Educational Alibava System – EASY
Running (click to stop)
N. of triggers
8012
Elapsed time
0 0:09:05
Rate
14.0 Hz
Efficiency
99,5 %
Run types
Calibration
Calibration
Laser Sync.
Laser Sync.
Laser Run
Delay
200
RS Run
Trigger
Pedestals
Max. no. of events
100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
Reset
X: 85,4 Y: 22,55
# of entries
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Channel
19/09/2014 – 09:58:02 | Run Started
Run Started


Educational Alibava System – EASY
Running (click to stop)
N. of triggers
Elapsed time
Rate
Efficiency
17817
0 0:20:15
13.9 Hz
94,5 %
Run types
Calibration
Laser Sync.
Laser Run
Delay
200
RS Run
Trigger
Pedestals
Max. no. of events
100000
Reset
LogData
Enable Plugin
Plugin
Reconnect
Signal
Pedestals
HitMap
Temperature
Time
Event display
Noise/Common mode
All
Chip 1
Chip 2
Time profile
Reset Histogram
X: -12,5 Y: 179,948
Average Signal (ADC)
260
240
220
200
180
160
0
10
20
30
40
50
60
70
80
90
100
Time (ns)
19/09/2014 – 10:20:21 | Run Started
Run Started

DATA ANALYSYS


Mean Noise
3,30
3,10
2,90
2,70
2,50
2,30
2,10
1,90
1,70
1,50
Noise (ADC counts)
0,00
10,00
20,00
30,00
40,00
50,00
60,00
70,00
80,00
90,00
100,00
Reverse voltge (Volts)

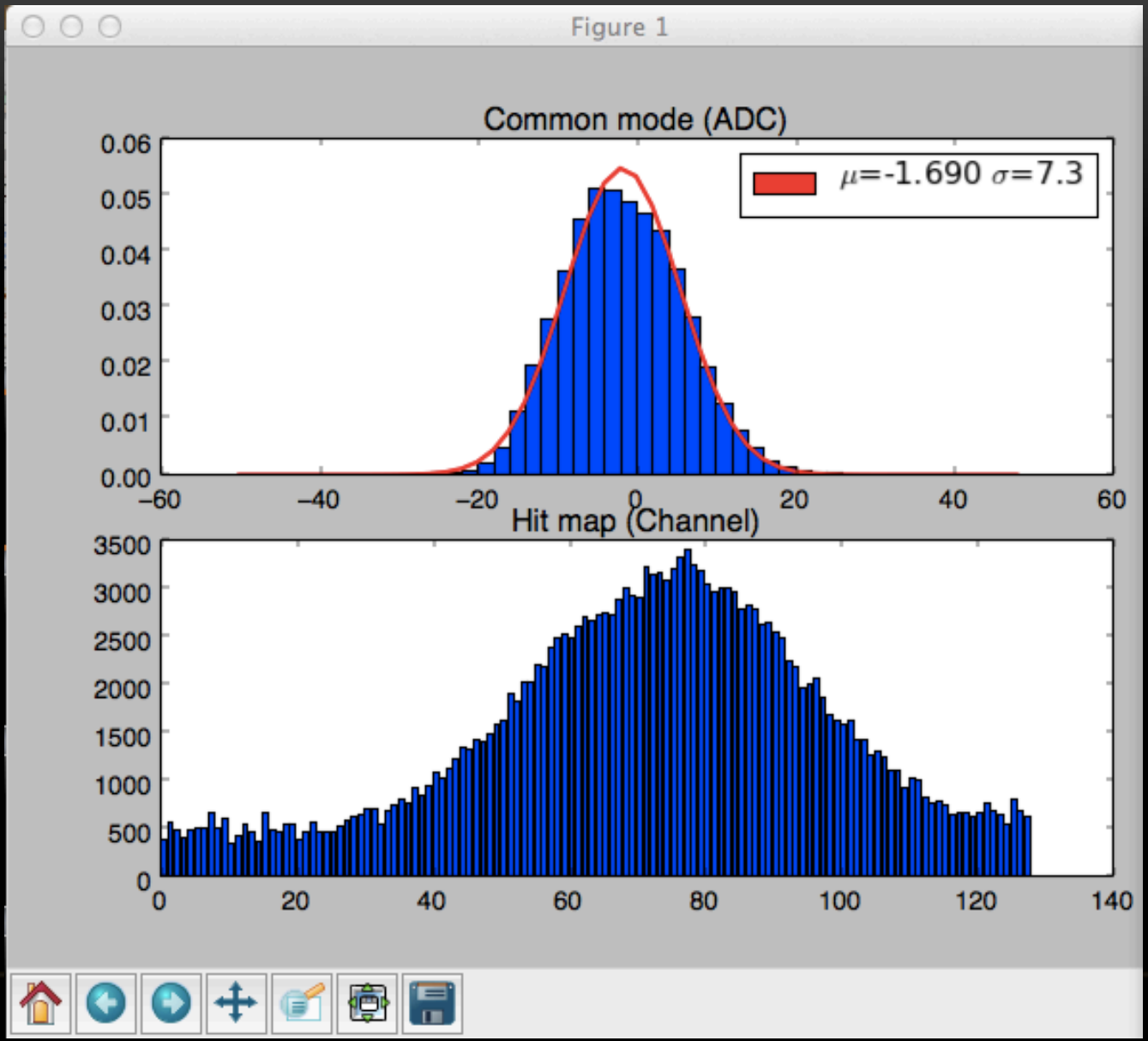


Figure 1
Common mode (ADC)
μ=-1.690 σ=7.3
0.06
0.05
0.04
0.03
0.02
0.01
0.00
−60
−40
−20
0
20
40
60
Hit map (Channel)
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
120
140

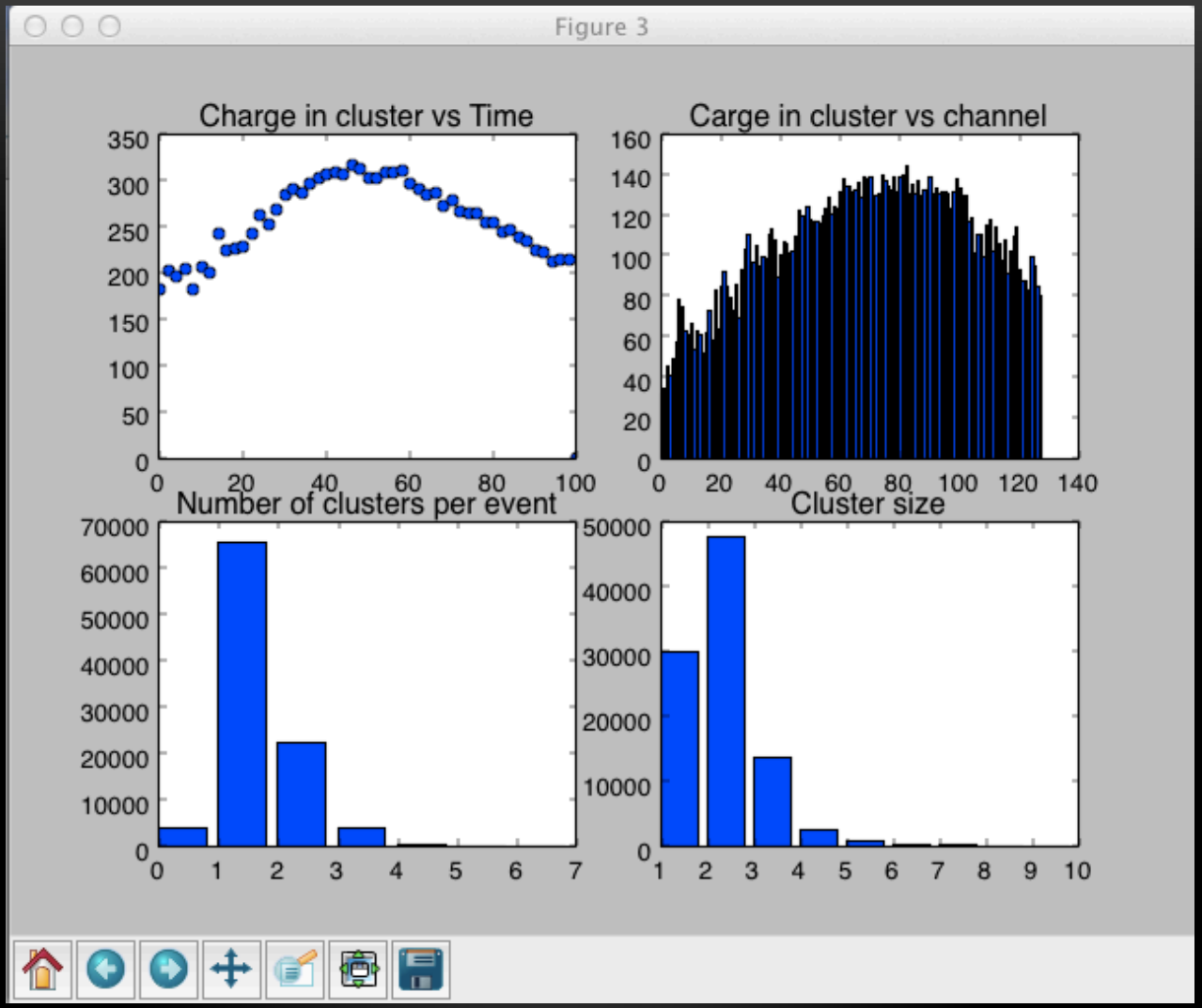
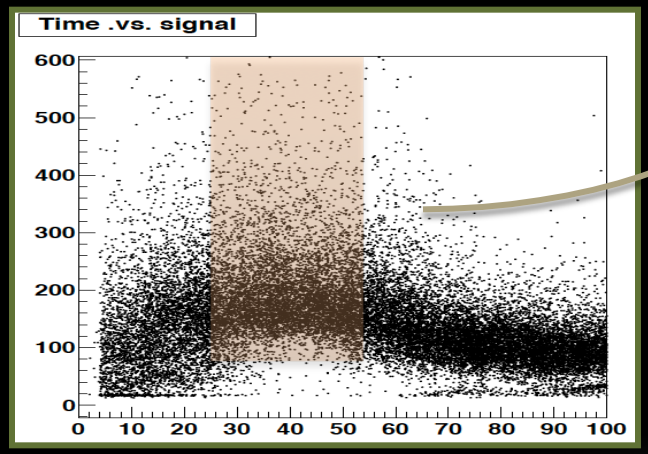
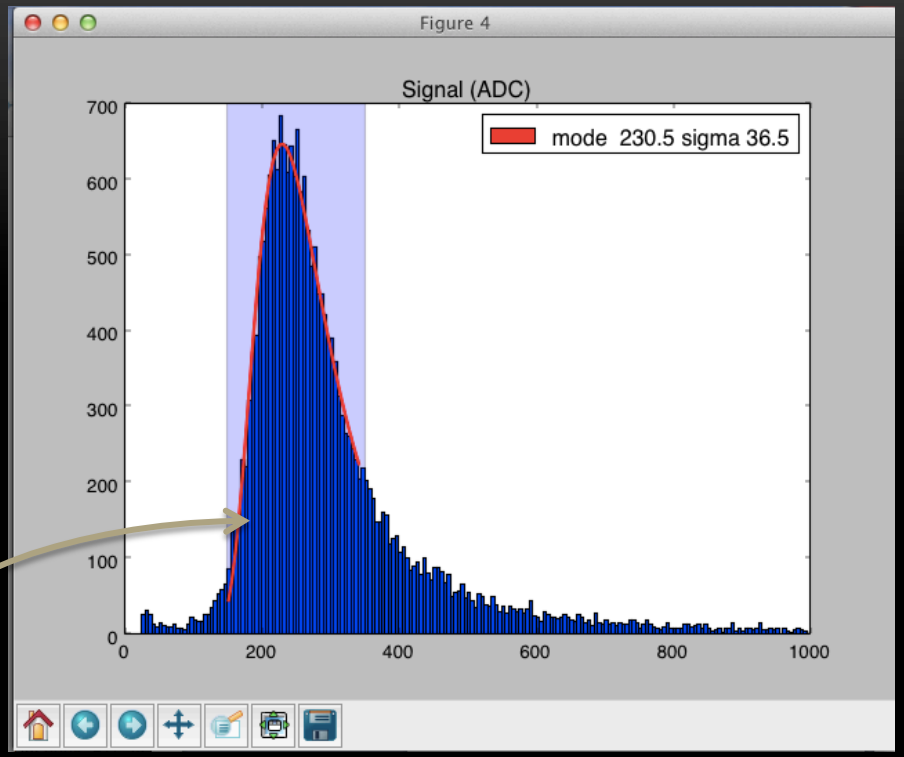
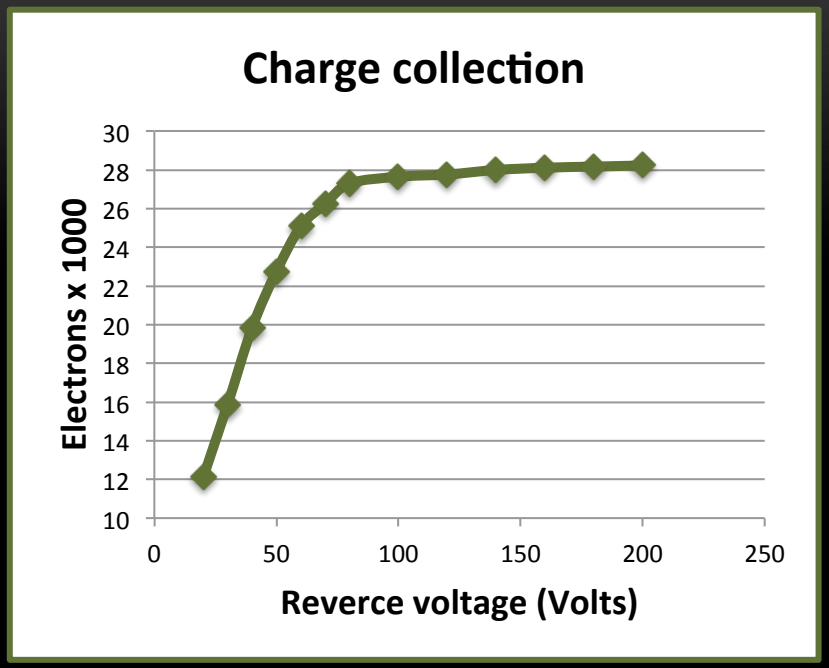


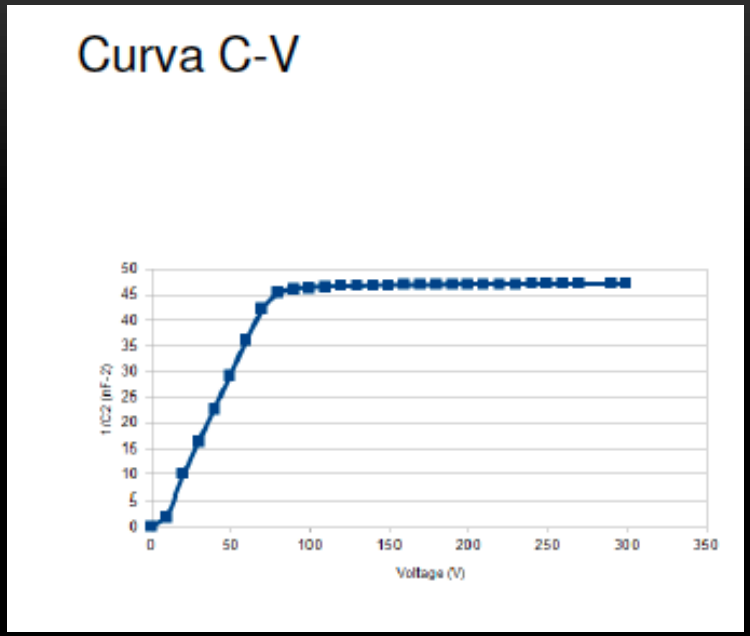
Figure 3
Charge in cluster vs Time
Carge in cluster vs channel
Number of clusters per event
Cluster size



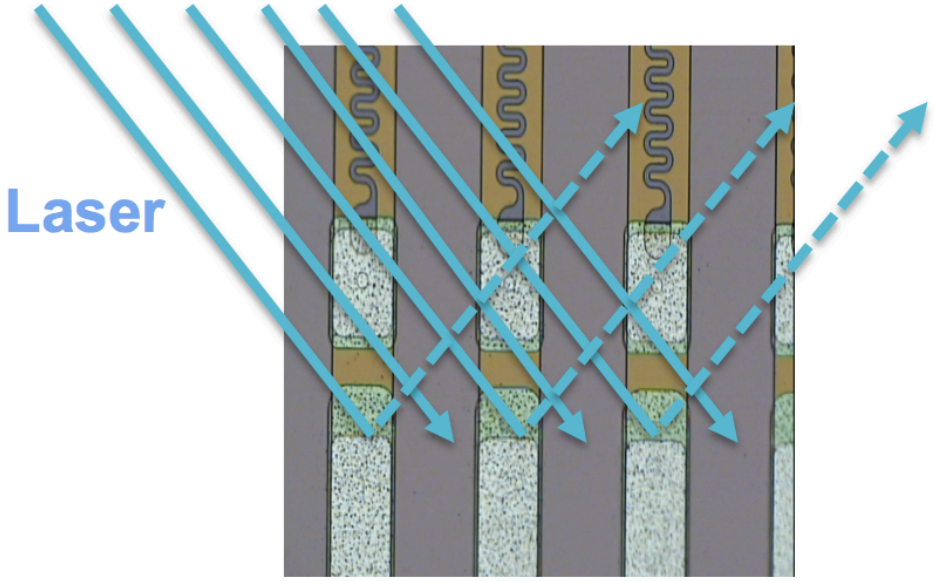


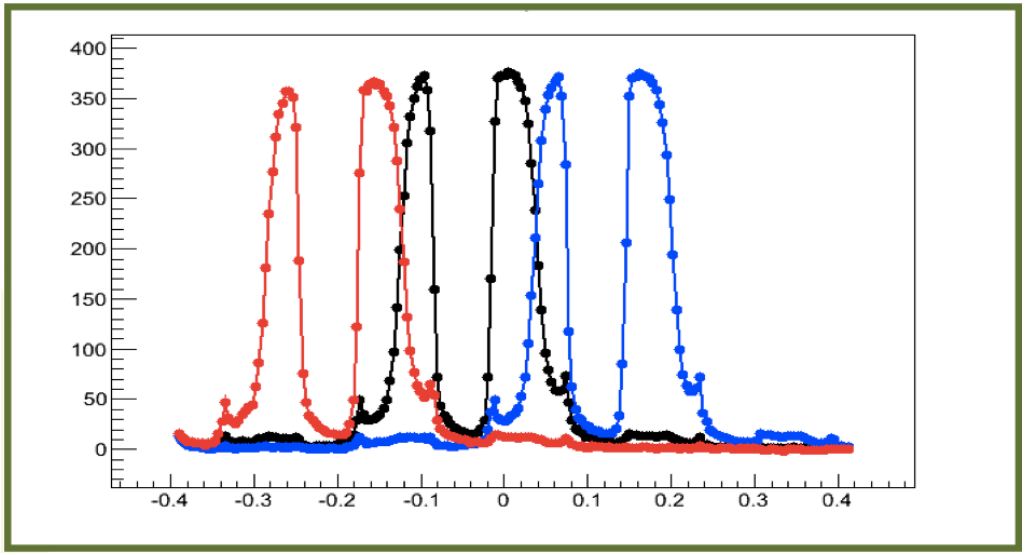
Charge deposition and pulse reconstruction of a **mip** particle (Sr90)





Increasing of charge collection with the depletion voltage for a mip particle (Sr90) in a 300µm strip detector.


Laser


400
350
300
250
200
150
100
50
0
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4

Cosmic rays

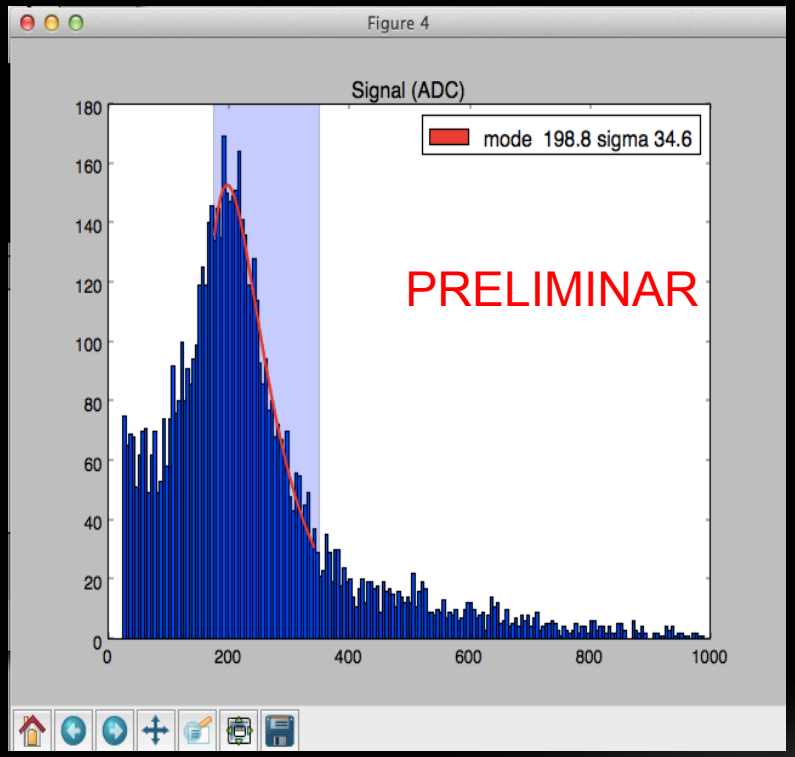


Figure 4
Signal (ADC)
mode 198.8 sigma 34.6
PRELIMINAR

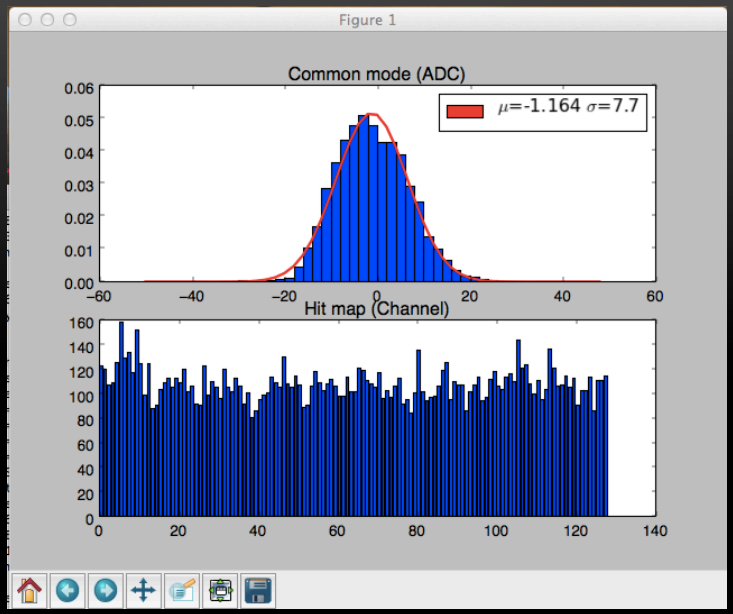


Figure 1
Common mode (ADC)
μ=-1.164 σ=7.7
Hit map (Channel)

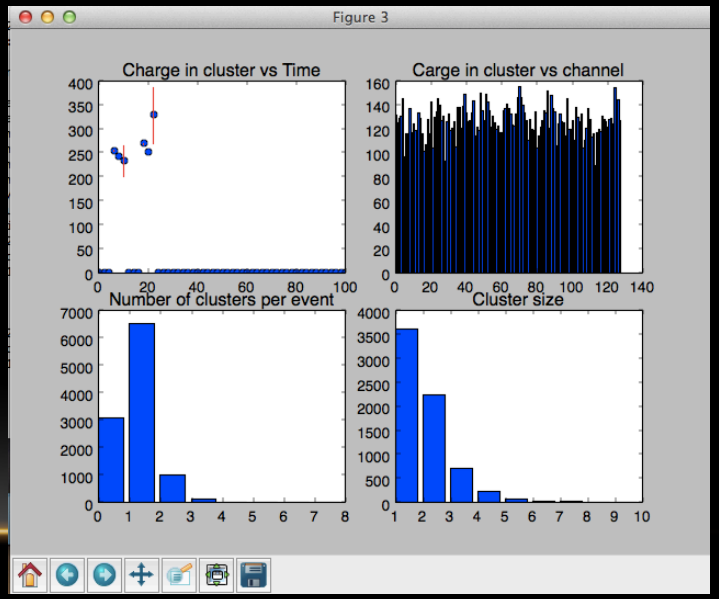


Figure 3
Charge in cluster vs Time
Carge in cluster vs channel
Number of clusters per event
Cluster size

Ba-133

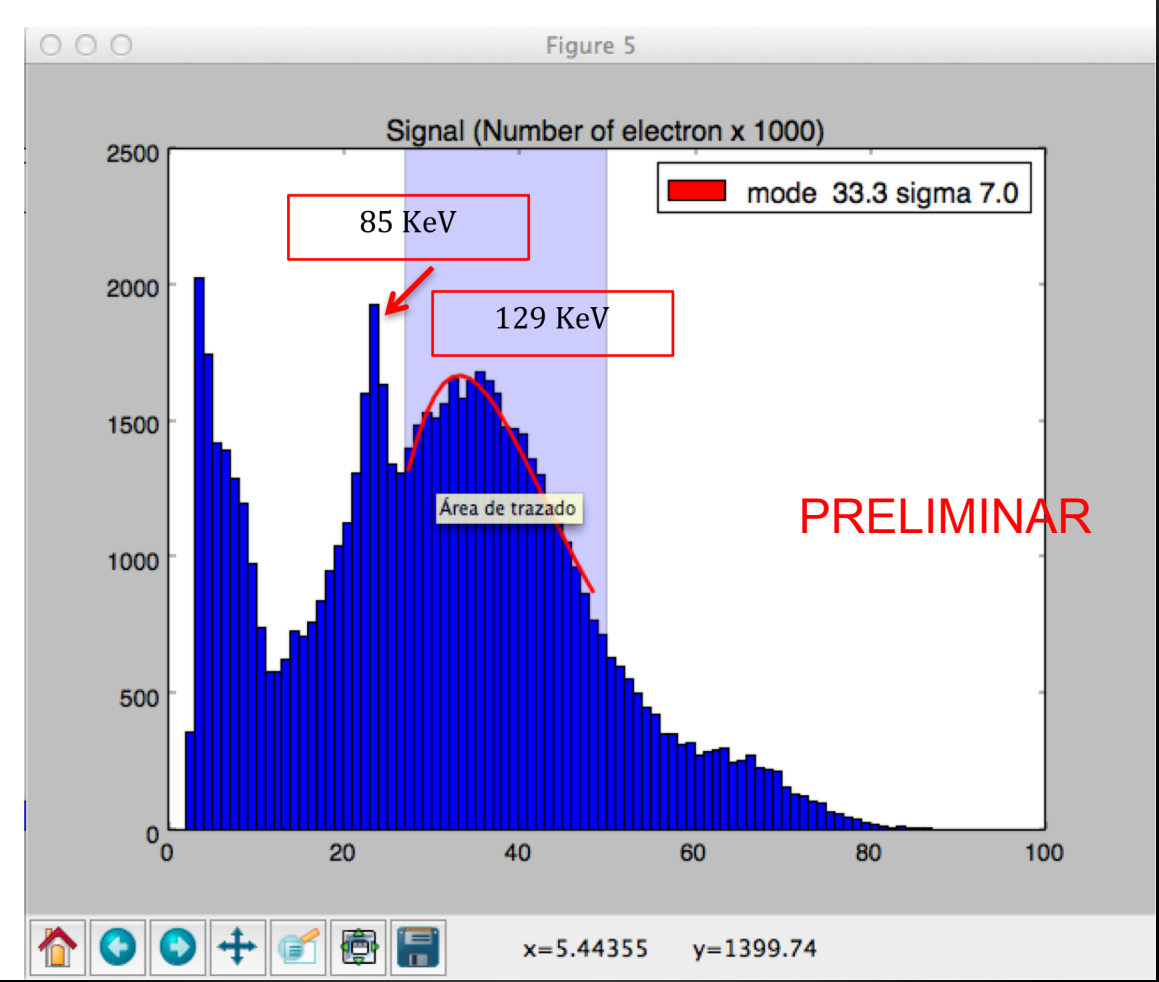
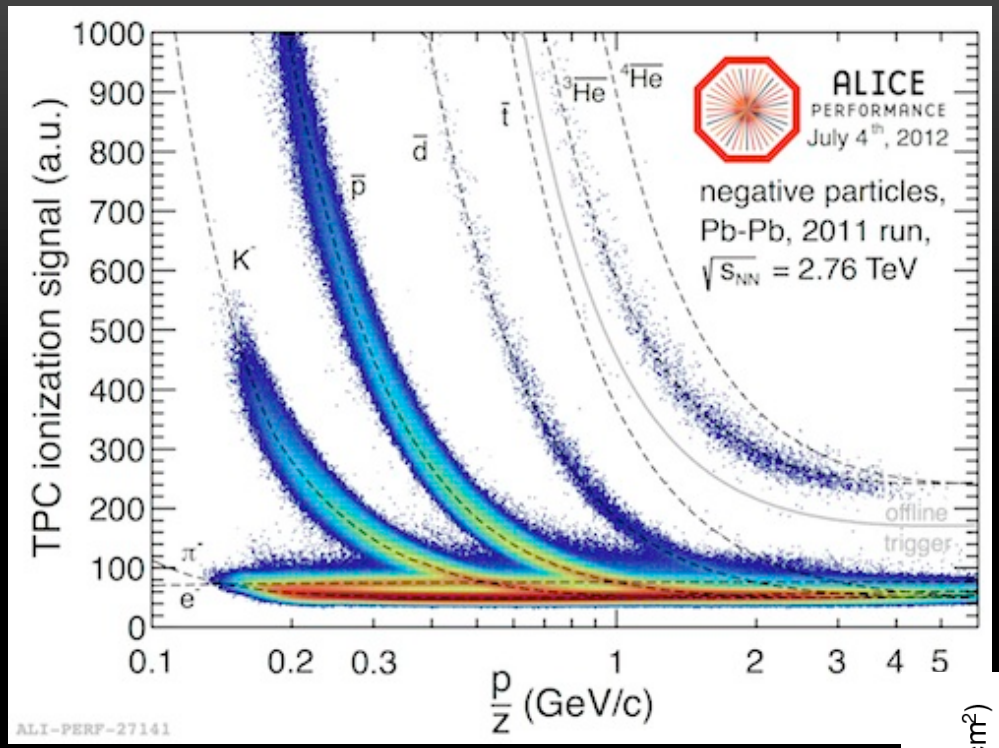
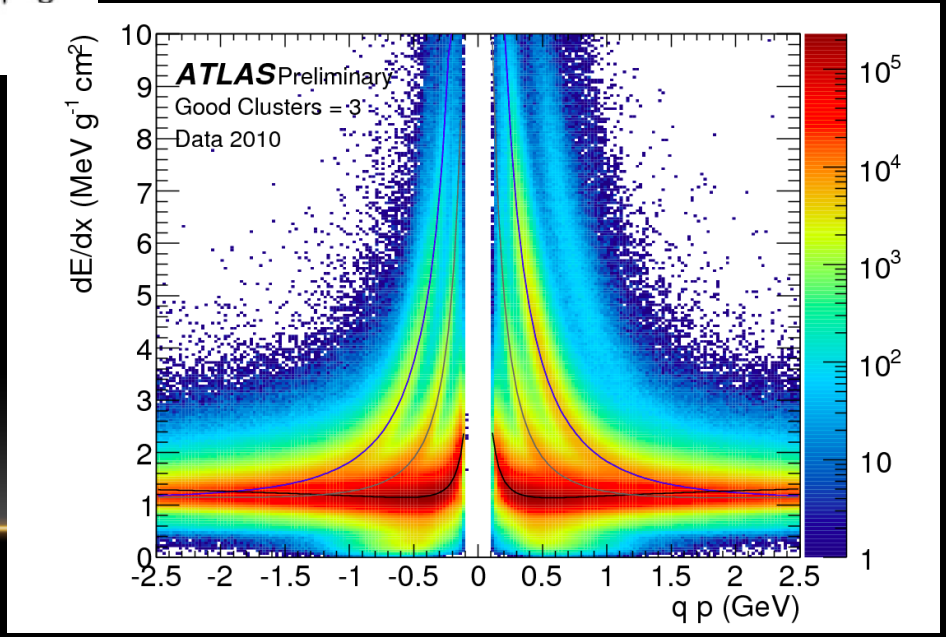


Figure 5
Signal (Number of electron x 1000)
mode 33.3 sigma 7.0
85 KeV
129 KeV
Área de trazado
PRELIMINAR
2500
2000
1500
1000
500
0
0
20
40
60
80
100
x=5.44355
y=1399.74

BACKUP


ALICE
PERFORMANCE
July 4th, 2012
negative particles,
Pb-Pb, 2011 run,
√sNN = 2.76 TeV
TPC ionization signal (a.u.)
p/z (GeV/c)
K⁻
p̄
d̄
t̄
³He
⁴He
π⁻
e⁻
offline
trigger
ALI-PERF-27141


ATLAS Preliminary
Good Clusters = 3
Data 2010
dE/dx (MeV g⁻¹ cm²)
q p (GeV)