Test of sensor-plane prototypes in an electron beam

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Outlook

> **Forward Calorimeters prototypes**

> **Lab measurements**

> **Test beam DESY HH 2010**

> **Data analysis**

- **S/N, CCE**
- **Temperature dependence**
- **Edge investigations**

> **Radiation hardness**

> **Conclusions and plans**

Forward Calorimeter sensors

> Precise luminosity measurement

> Hermeticity - electron detection at low polar angles

> Assisting beam tuning (fast feedback of BeamCal data to machine)

> Challenges:
  - radiation hardness (BeamCal)
  - fast readout (both)

> 30 Layers
  - Tungsten absorber:
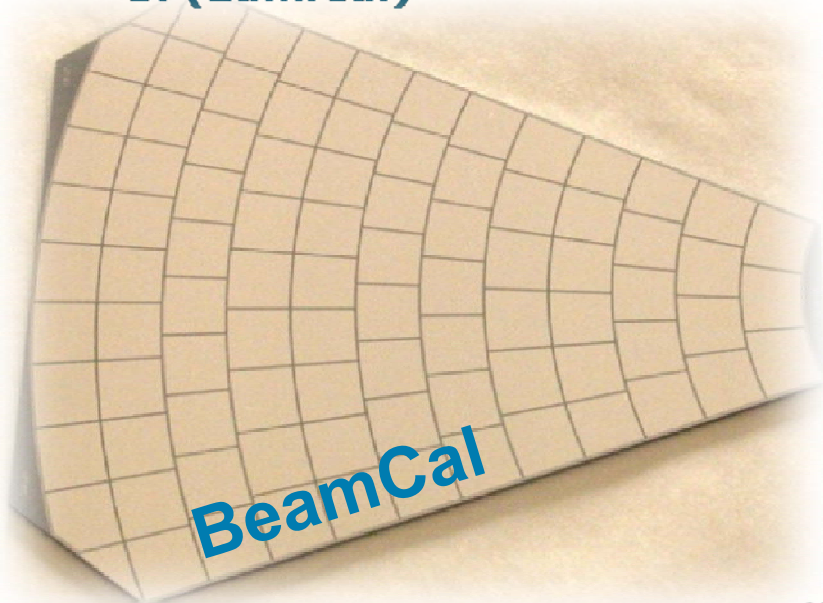 - Sensor layers ->GaAs or Di (BeamCal), Si (LumiCal)

Hamamatsu S10938-8380

L2

L1

Channel 1 - 64

R1

R2
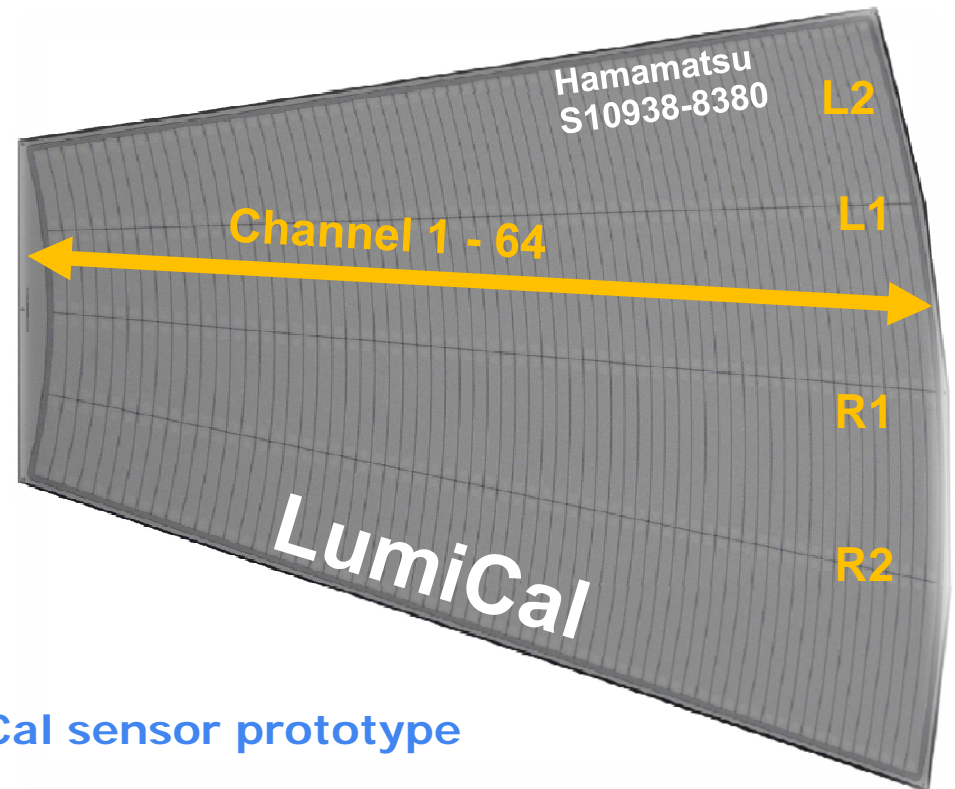
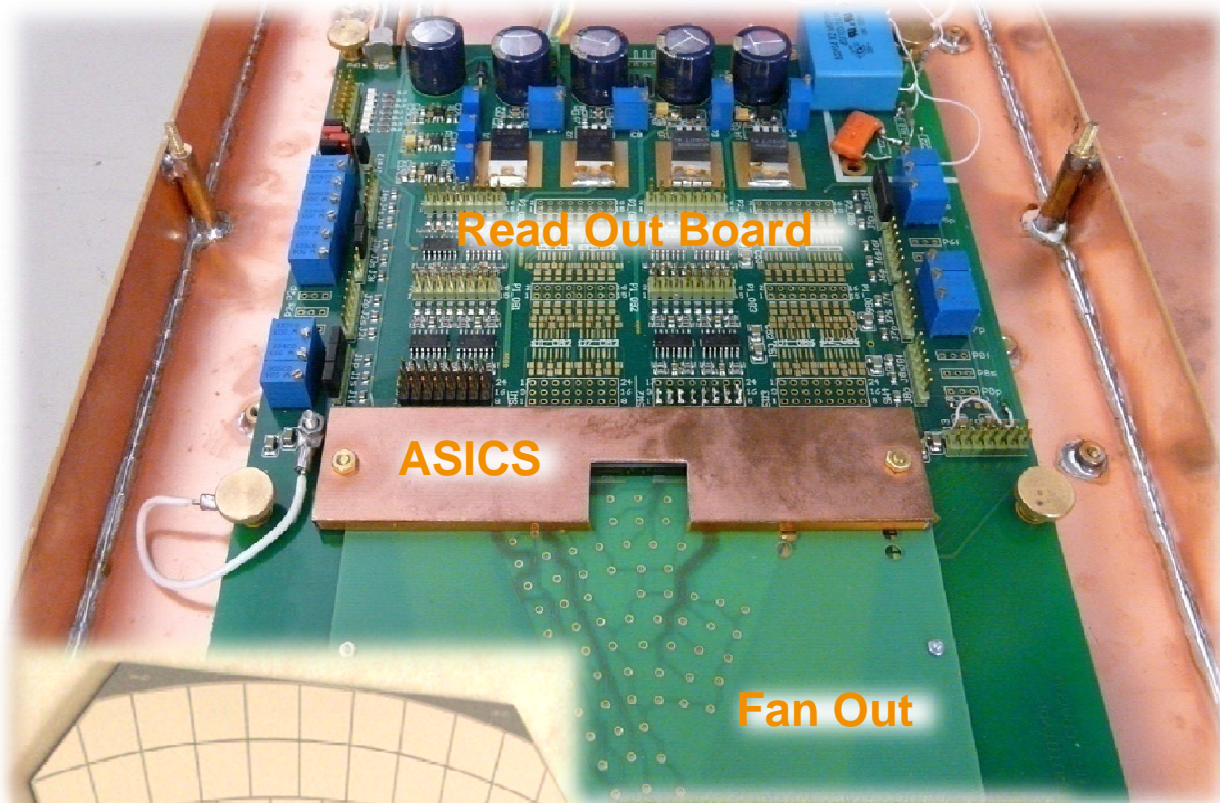LumiCal

BeamCal

> LumiCal sensor prototype

Standard p+ on n silicon sensor, 320 μm thick

30 deg tiles, contains 4 sectors (each 64 pads)

> BeamCal sensor prototype

GaAs plate with Al metallization, 500 μm thick

45 deg tiles, segmented into 12 rings, ~5x5 mm^2 pads

Prototype description

Read Out Board

ASICS

Fan Out

Cluster 4

Cluster 2

5 GaAs Sensor Plates were tested in the Lab
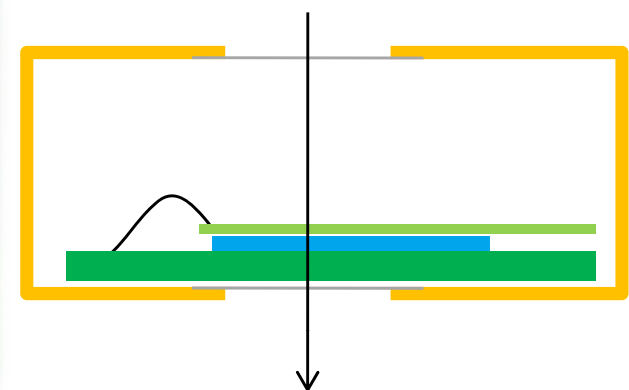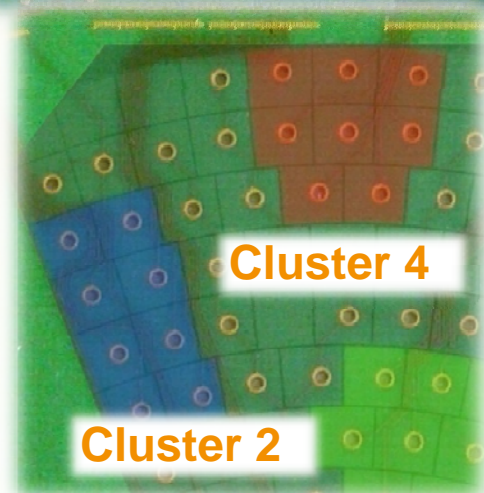
> Common read-out board for Si and GaAs sensor plates
> GaAs sensor plane (2 clusters were irradiated)
> Every cluster has 8 channels
> PCB fan-out provides connection between sensor and front-end electronics - ASICs (RC, FET technologies)
> Power supply and biasing circuits for transporting signals to ADC
> Read out by Sampling ADC v1721, CAEN

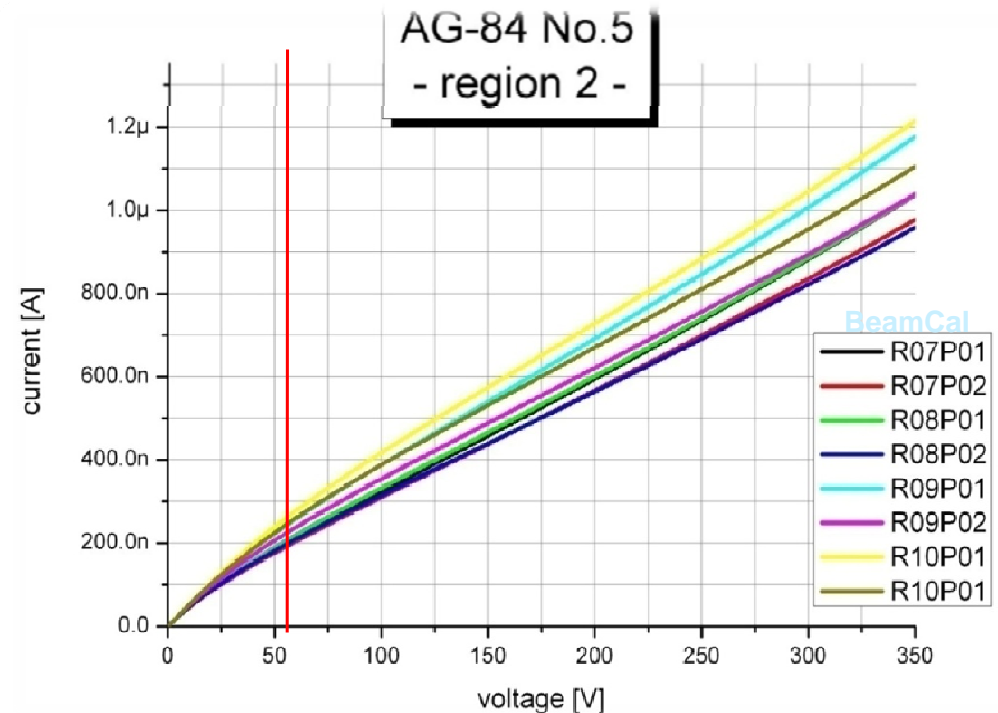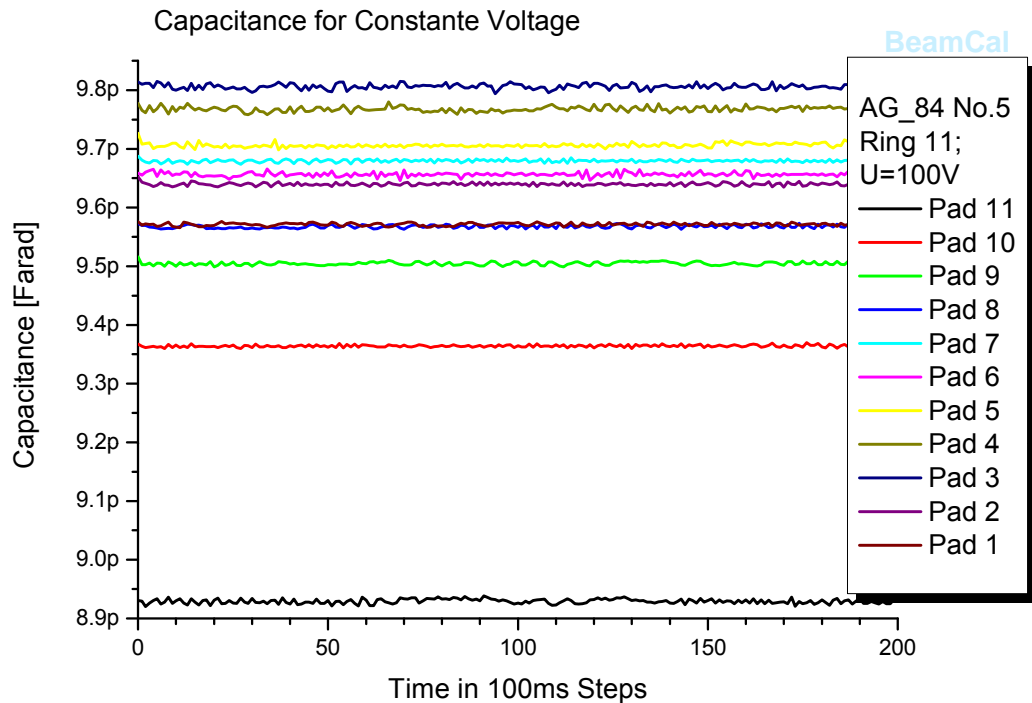Al window
Fan Out
Sensor
R/O Board
Al window

Laboratory measurements

Capacitance for Constante Voltage

Capacitances measurements with 100V

IV measurements 0-350V

BeamCal:

> Capacitances are stable ~10pF

> Leakage current ~200nA

> Working HV = -60 V
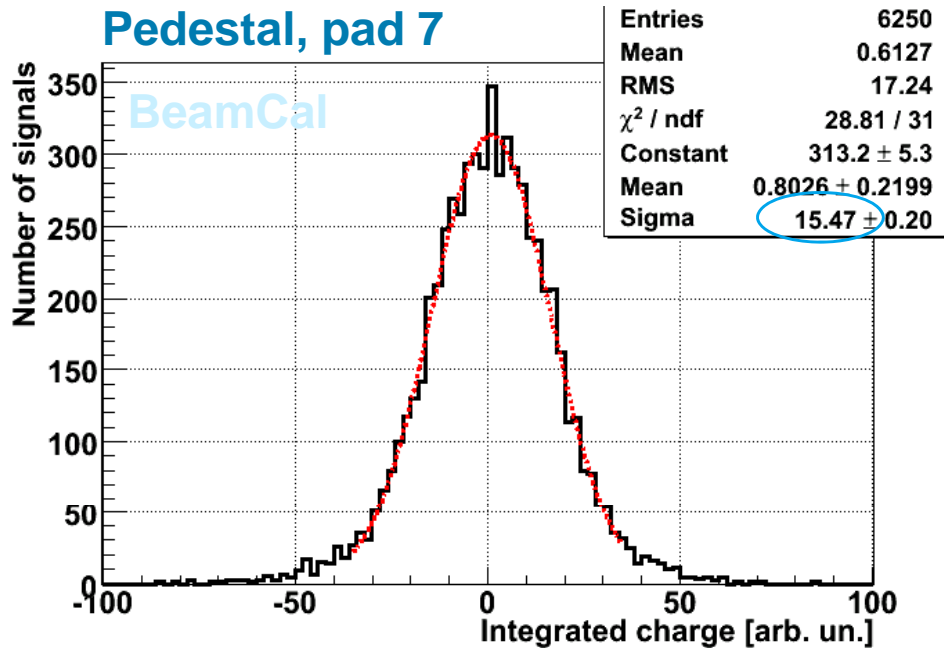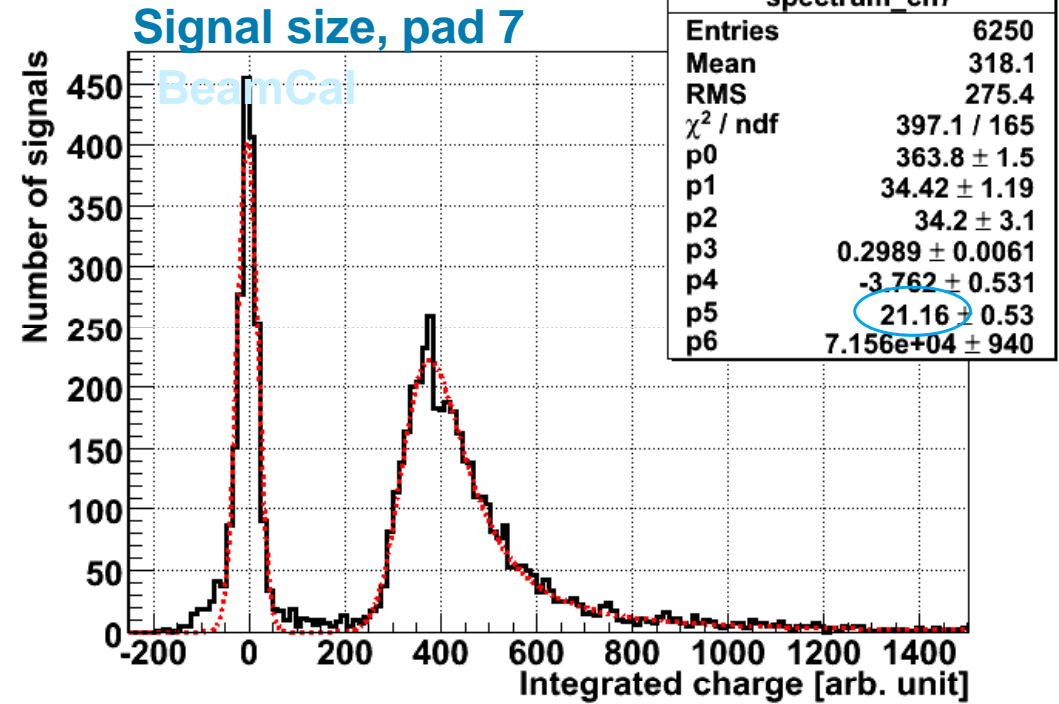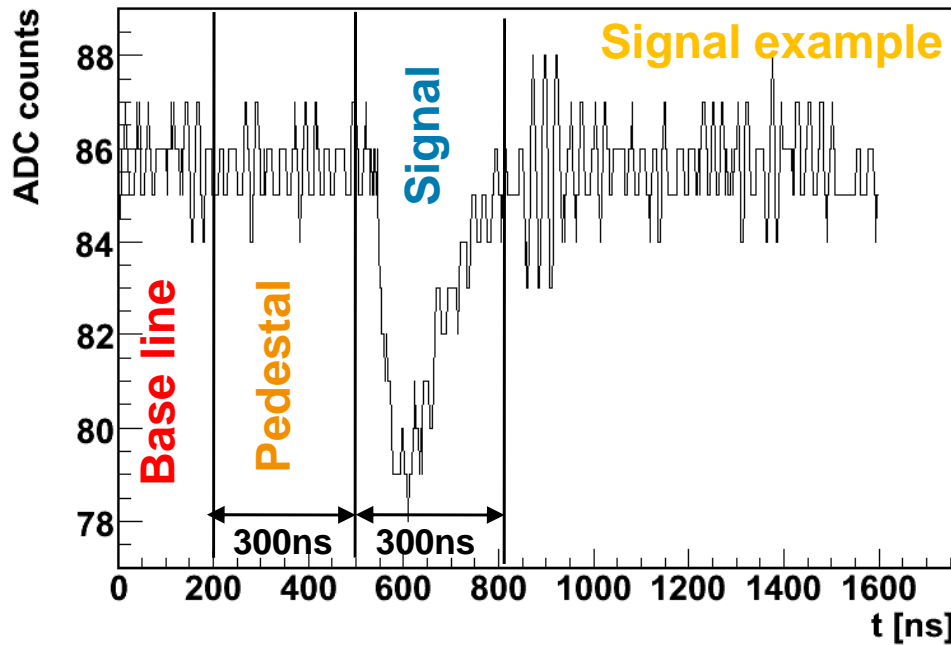
LumiCal:

> Capacitances: 8-25 pF at 100V

> Depletion voltage ~42 V

> Leakage current ~few nA

Signal processing

Event no. 1270 on 01 Aug 2010, 13:17 -- channel 1

Signal example

Signal

Base line

Pedestal

300ns 300ns

Signal size, pad 7

BeamCal

spectrum_ch7	
Entries	6250
Mean	318.1
RMS	275.4
χ^2 / ndf	397.1 / 165
p0	363.8 ± 1.5
p1	34.42 ± 1.19
p2	34.2 ± 3.1
p3	0.2989 ± 0.0061
p4	-3.762 ± 0.531
p5	21.16 ± 0.53
p6	7.156e+04 ± 940

Pedestal, pad 7

BeamCal

Entries	6250
Mean	0.6127
RMS	17.24
χ^2 / ndf	28.81 / 31
Constant	313.2 ± 5.3
Mean	0.8026 ± 0.2199
Sigma	15.47 ± 0.20

> **Signal and pedestal were integrated in respect to base line**

> **Window optimization defines the S/N ratio and signal collection efficiency**

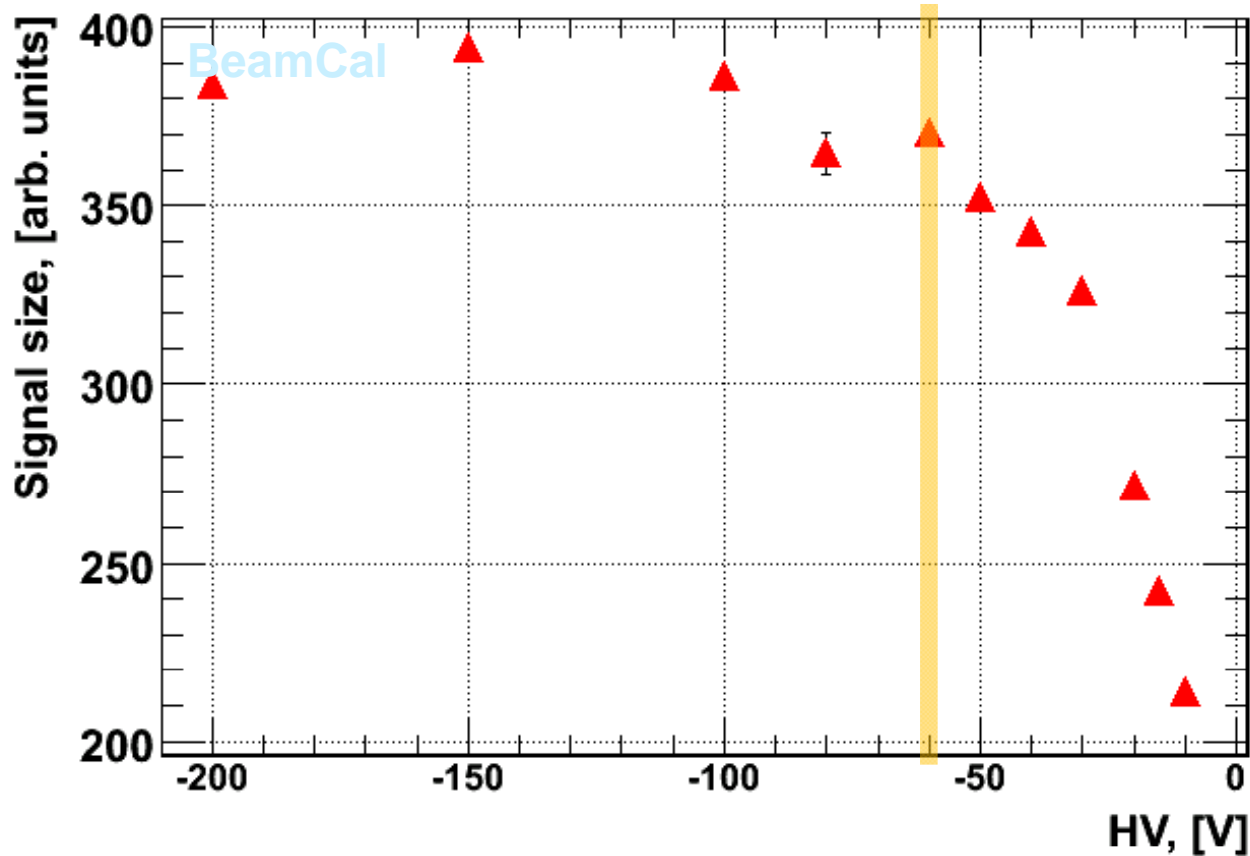> **Pedestal, calculated before signal comes, has smaller sigma**
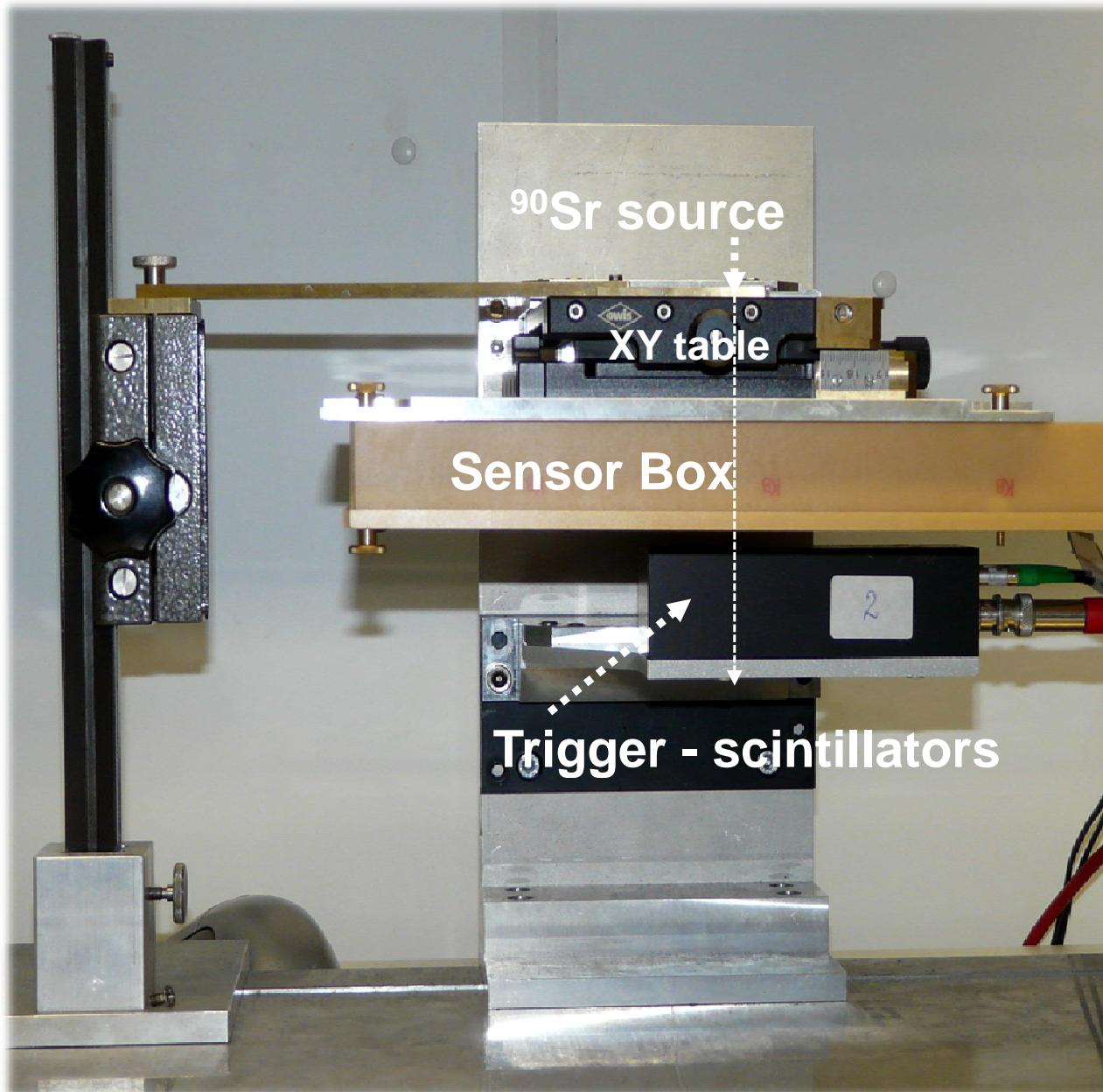
Move DUT under ^{90}Sr for CCE measurements of each pad
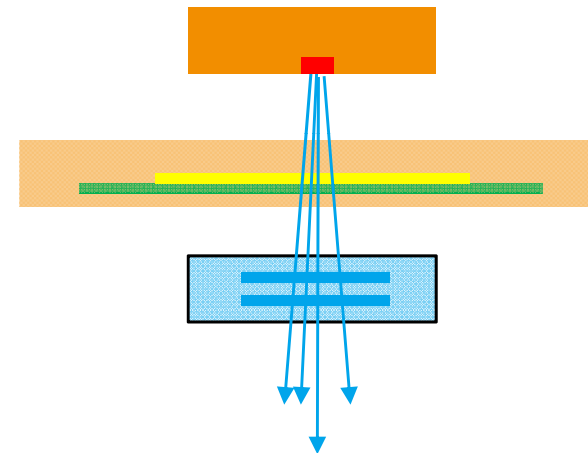
Set-up has to be compact for higher collected statistics.

Large multiple scattering due to material amount (500 μm GaAs, PCB…)
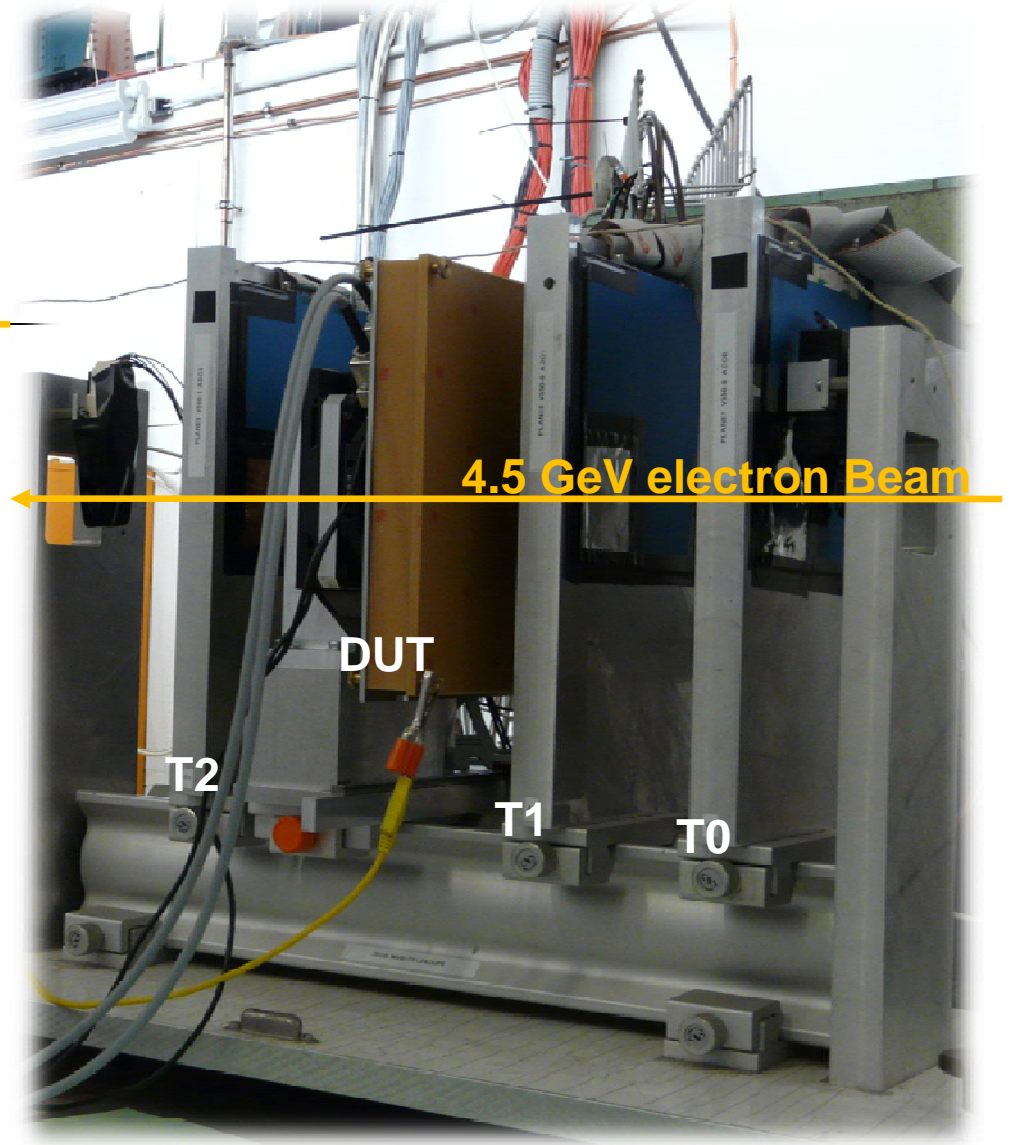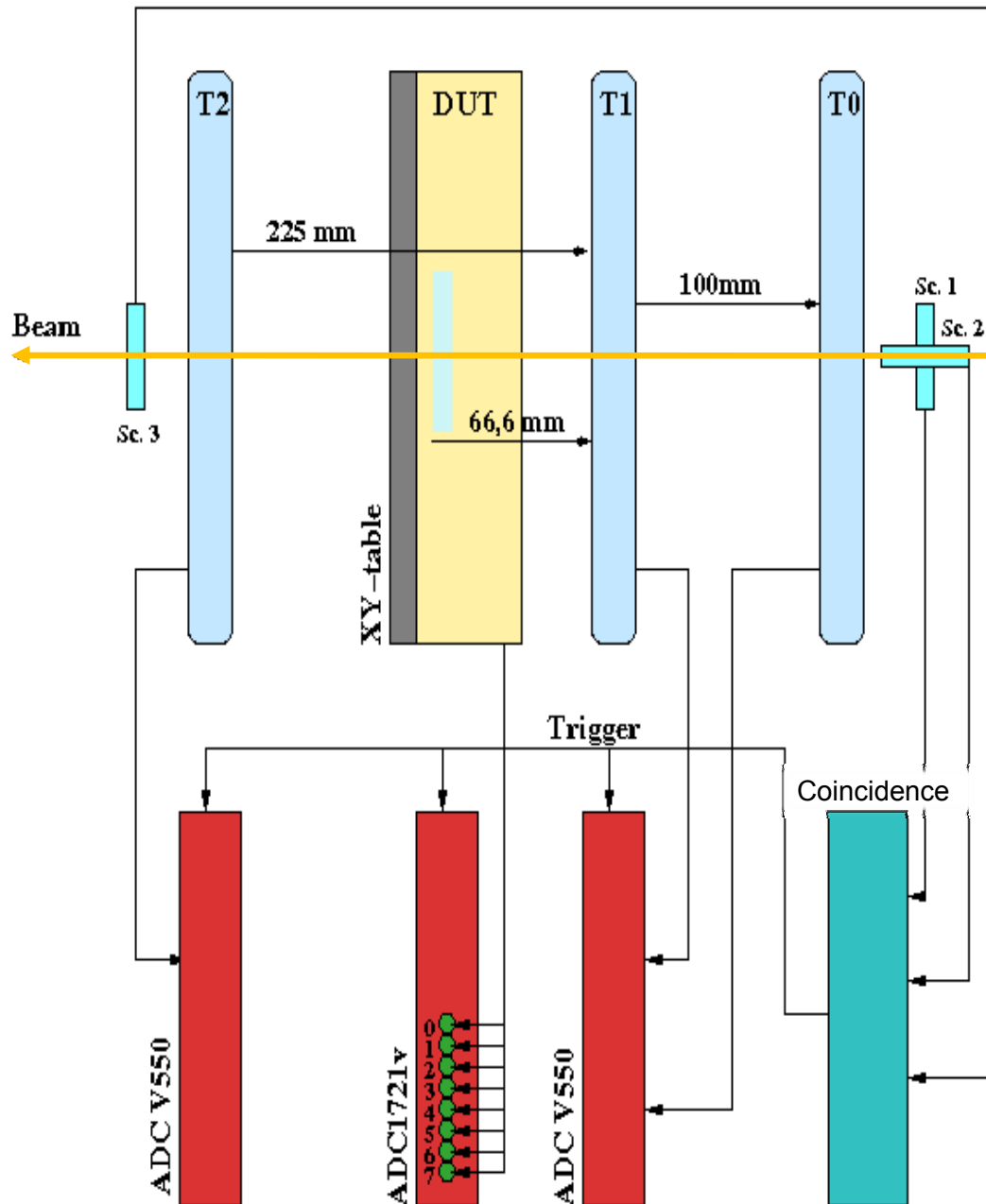
BeamCal

Signal vs. bias voltage

> Central pad of cluster 4

> ~100 V – saturation
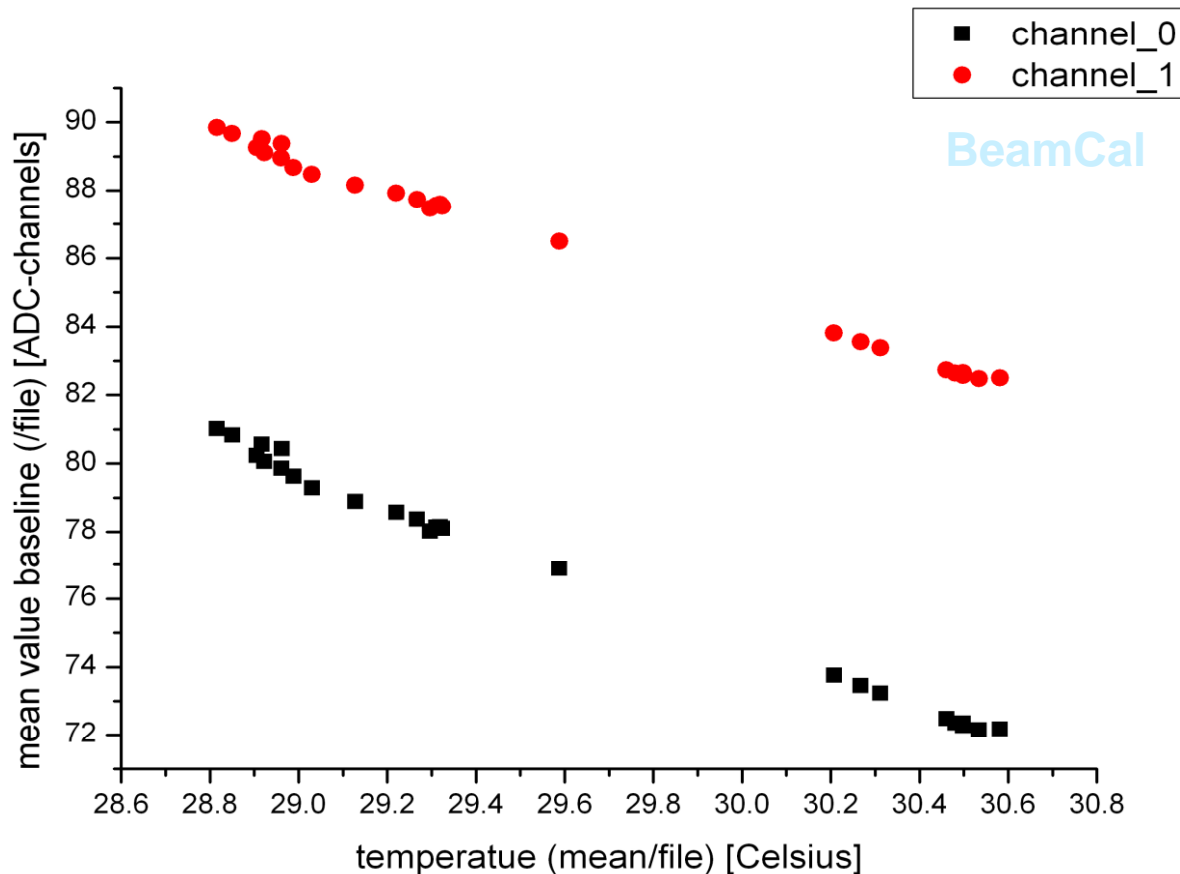
> -60 V is near to saturation

GEANT simulation:

> E_{dep} = 0.35MeV

> For 500 μm GaAs = 83900 e-h pairs

> CCE saturation ~42%

$$CCE = \frac{Q_{collected}}{Q_{induced}}$$

Test beam – Hamburg (DESY II)

Base line vs. temperature

> Temperature dependence was measured over whole test beam

> Mean temperature vs. mean baseline

> In 2 degrees 9 ADC channels for baseline

> Files were collected ~15min

> In ns range of integration window should not affect signal integration

BeamCal S/N and CCE

Cl/Ch	Ped. σ	Land. MPV	Spectr. ped. σ	S/N	CCE %	Cl/Ch	Ped. σ	Land. MPV	Spectr. ped. σ	S/N	CCE %
2/0	17,9	362,4	24,4	20,25	33,6	4/0	17,6	357,4	23,7	20,31	33,4
2/1	16,4	337,7	25,8	20,59	31,7	4/1	16,5	353,8	20,6	21,44	32,1
2/2	16,9	371,4	22,8	21,98	34,8	4/2	14,6	353,8	22,3	24,23	32,5
2/3	15,9	360,7	25,6	22,69	33,0	4/3	14,2	371,2	18,8	26,14	33,8
2/4	12,7	172,8	16,9	13,61	34,7	4/4	8,9	174,3	13,3	19,58	34,7
2/5	19,6	382,0	32,1	19,49	35,4	4/5	9,3	167,9	14,0	18,05	33,0
2/6	13,3	165,4	19,4	12,44	34,4	4/6	10,3	168,8	15,4	16,39	33,6
2/7	15,5	363,8	21,2	23,47	33,7	4/7	9,9	169,0	13,6	17,07	33,7

> **Two clusters were irradiated (8 pads each)**

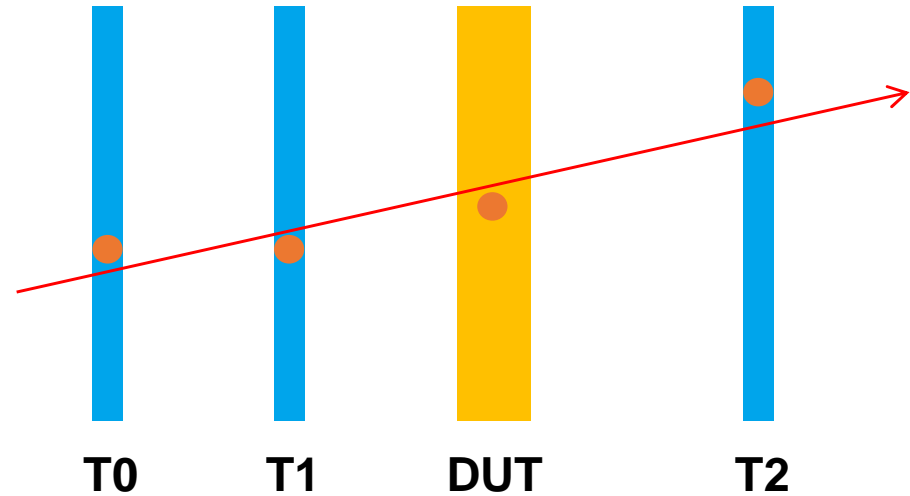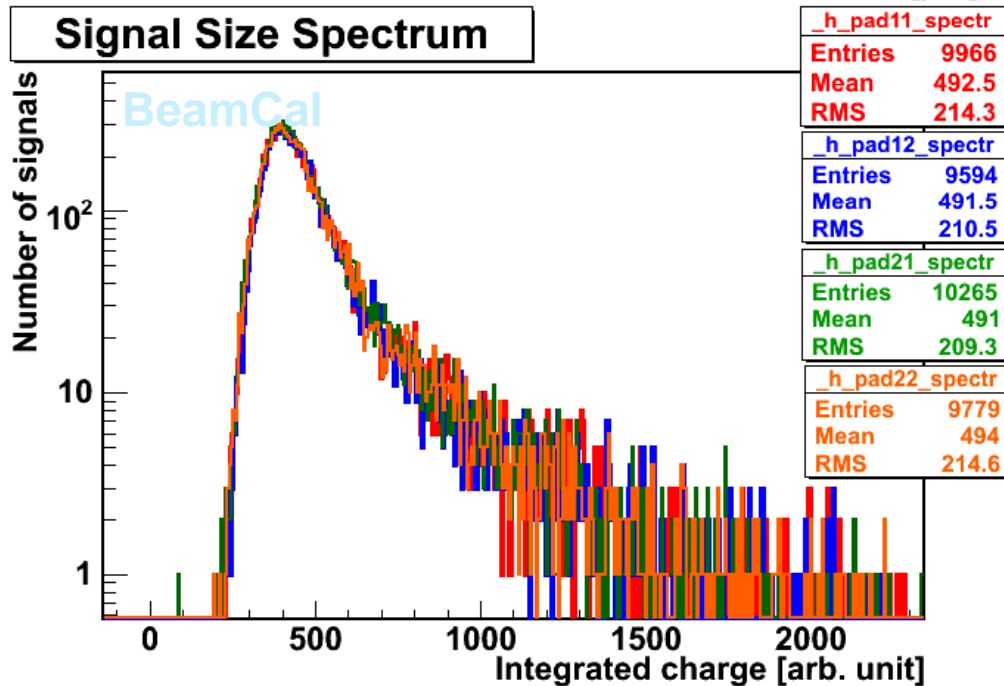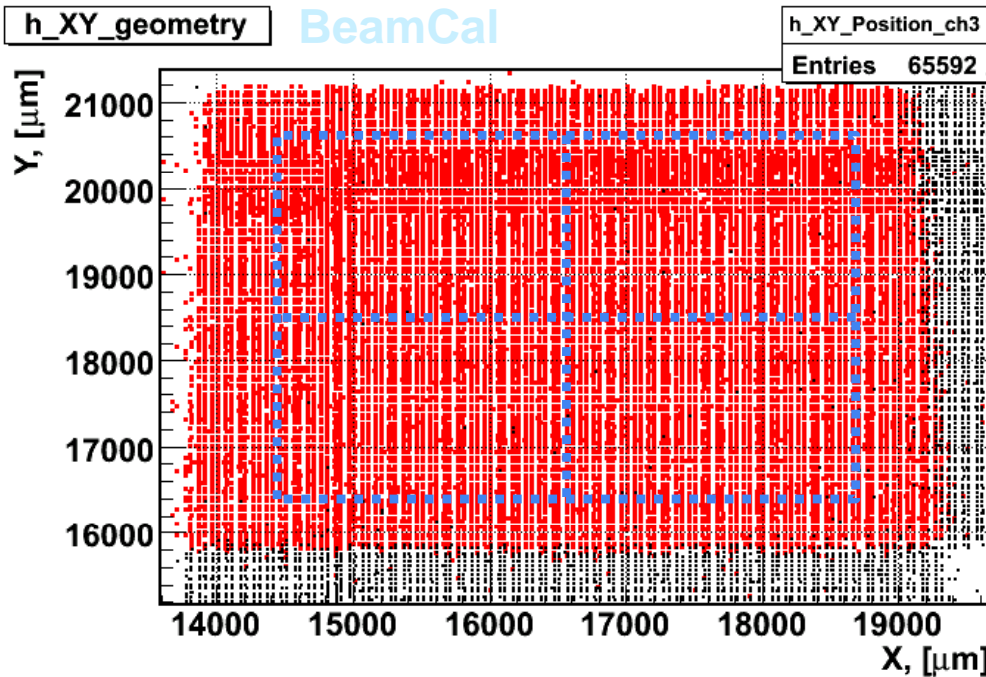> **Two different front-end electronics - RC, FET**

> **S/N ratio: RC ~ 20 – 26, FET ~13 – 20**

> **CCE ~33% at -60V.**

$$S/N = \frac{MPV_{Landau} - MPV_{Ped}}{\sigma_{Ped}}$$

BeamCal
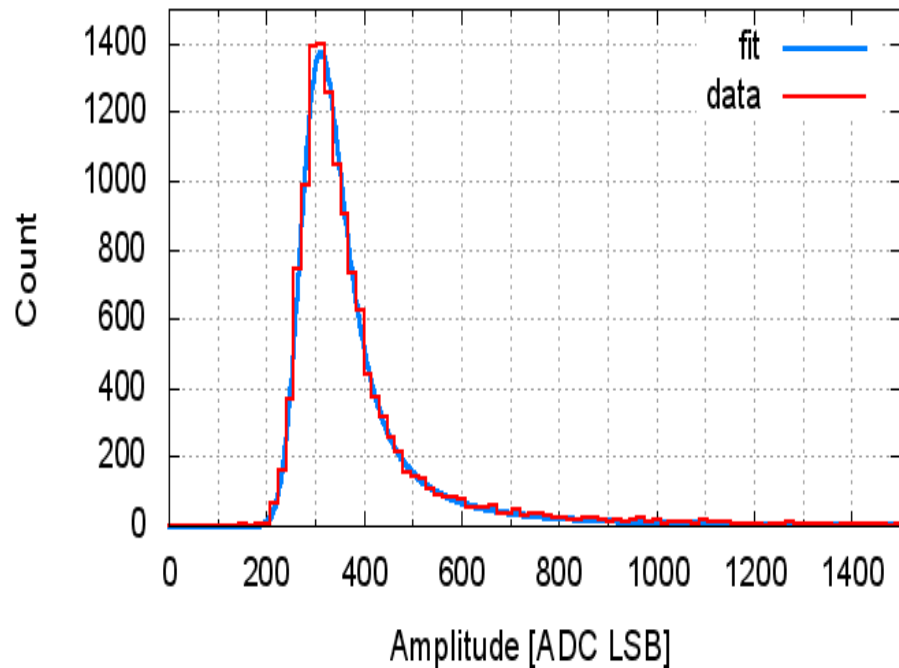
Charge collection uniformity

> Synchronization of telescope and DUT

> Telescope alignment was checked
  - 3 Telescope planes were fitted
  - Residual ~10 μm

> Pad structure corresponds 5x5mm^2 + gap ~200 μm

> 4 independent pads areas show identical charge collection

> high efficiency of charge collection

LumiCal results

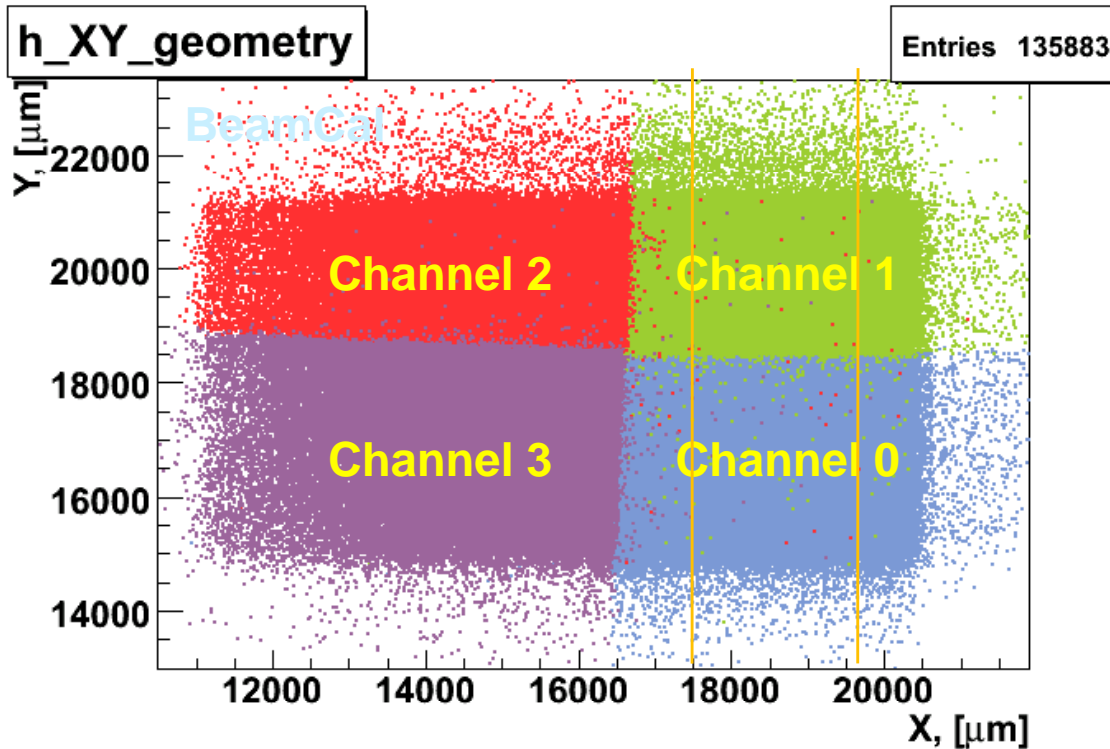Signal size spectrum for 4.5 GeV electrons fits very well to Landau distribution S/R ~ 19
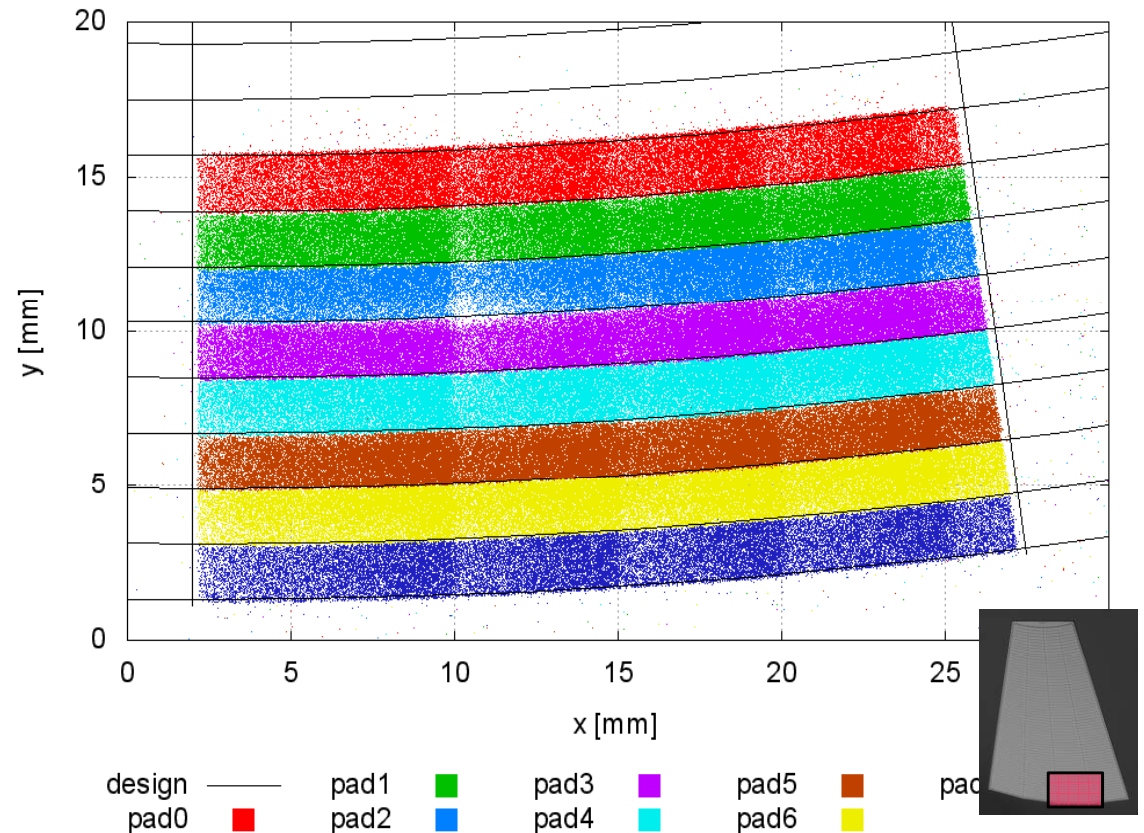
> Combined events from LumiCal DAQ and Zeus telescope DAQ

> LumiCal sensor structure is reflected on reconstructed tracks

LumiCal

4 pads edge
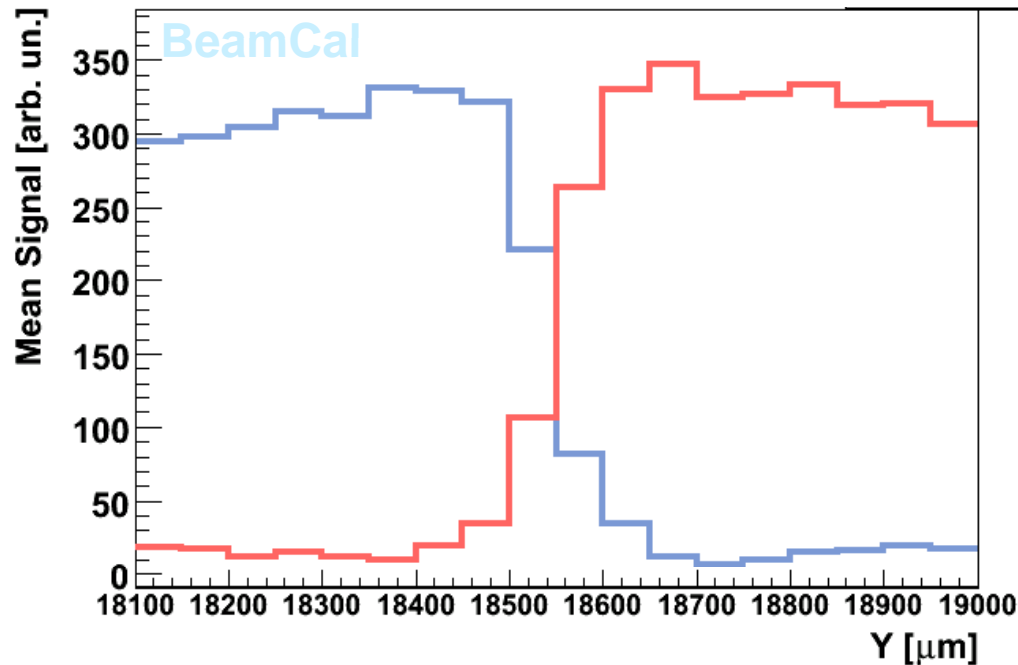

> ~ 2 millions events

> ~ 70% selected with one track in telescope

> Tracks are reconstructed from 3 telescope planes with linear fit

> 50 μm stripes

> Area taken to investigate only one edge

> Spectra for each stripe were collected

> Mean values and MPV of obtained spectra were used

Pads gap investigations
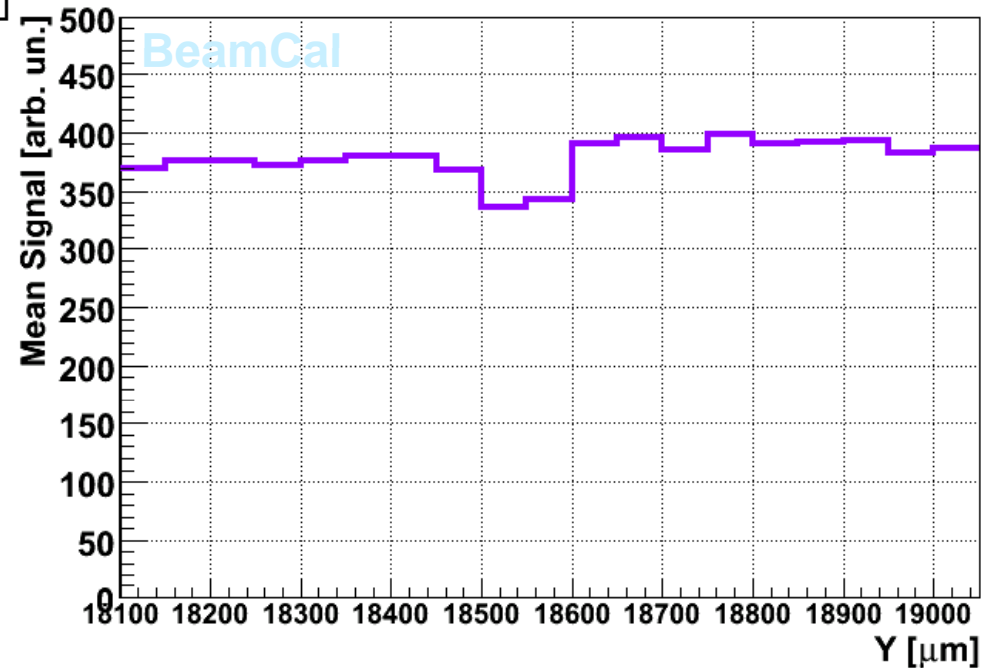

> Mean value of signal in stripes between 2 pads is presented. Blue – channel 0, red – channel 1.
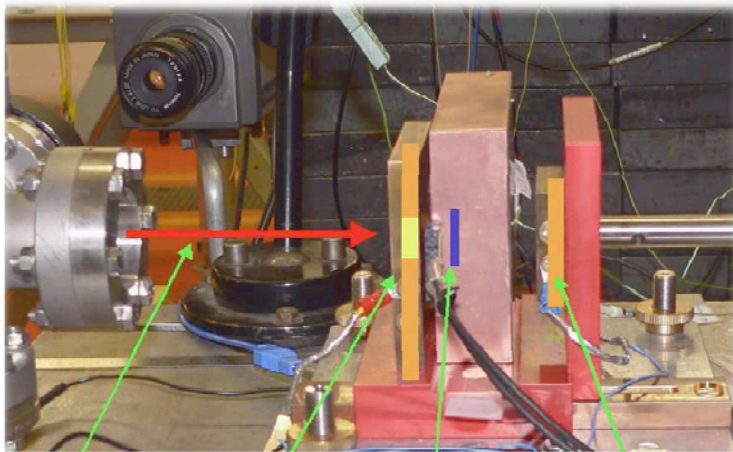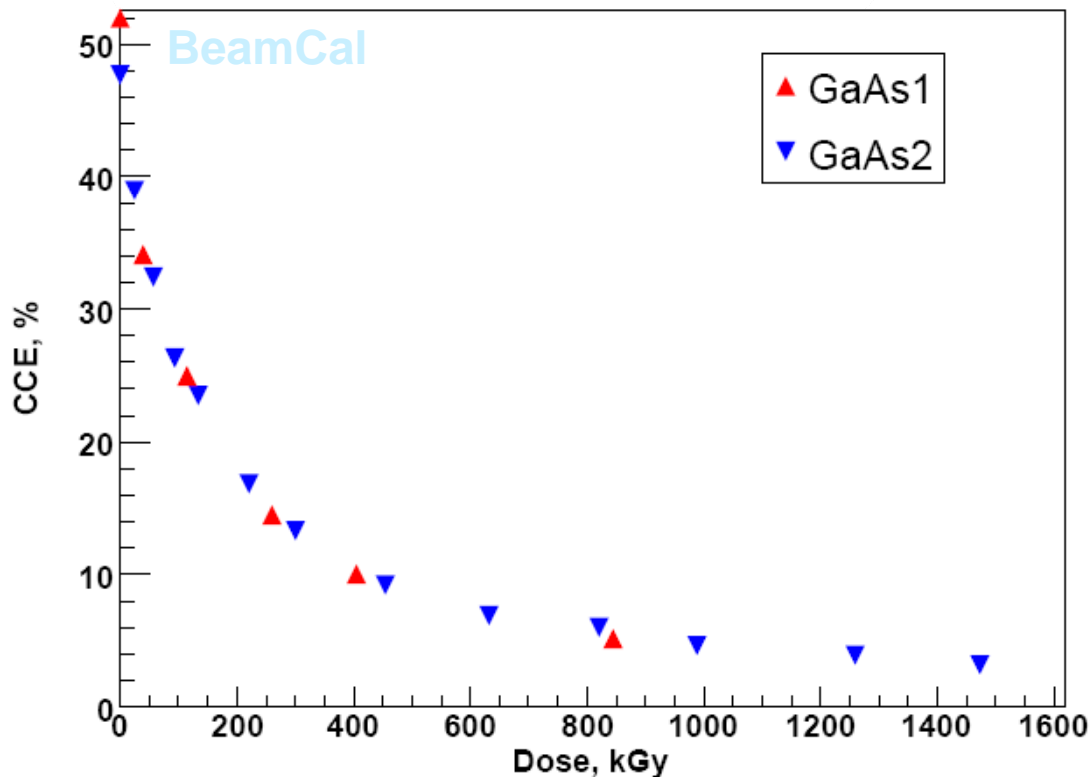
> On the border signal is slightly increasing

> Signal sum (MPV) in stripes between 2 pads is presented.

> Signal sum (MPV) of two pads shows decrease on 10%

Radiation hardness

Beam   Collimator   Sensor   Faraday Cup

BeamCal

- > **Test beam in Darmstadt, S-DALINAC**

- > **An electron beam of up to 50 nA**

- > **irradiation with doses of up to 1.5MGy**

- > **Leakage current increased in factor of two at room temperature**

- > **The CCE drops fast at lower absorbed doses.**

- > **At higher doses the CCE value saturates.**

- > **MIP signals separation was observed up to 600 kGy**

Conclusions

> Two sensor planes were tested at the 4,5GeV electron beam in 2010.

> Both detectors show perfect performance, S/N ~20

> Functionality of the chain: front-end + fan-out + sensors, positively verified on test beam

> BeamCal prototype:

- Operation at room temperature

- Low leakage current ~200nA

- CCE up to 50% in the HV – saturation

- Radiation hardness up to 1.5MGy

- Spectra uniformity in central part of pads

- ~10% loss of signals in gaps between pads

> Tight schedule for 2011 year

- lot of works already done - prototype of Multichannel ADC SoC fully functional, under tests,

- Integration of ADC with front-end and sensor in progress, next test beam will be soon.