Test-beam data analysis for BeamCal sensors

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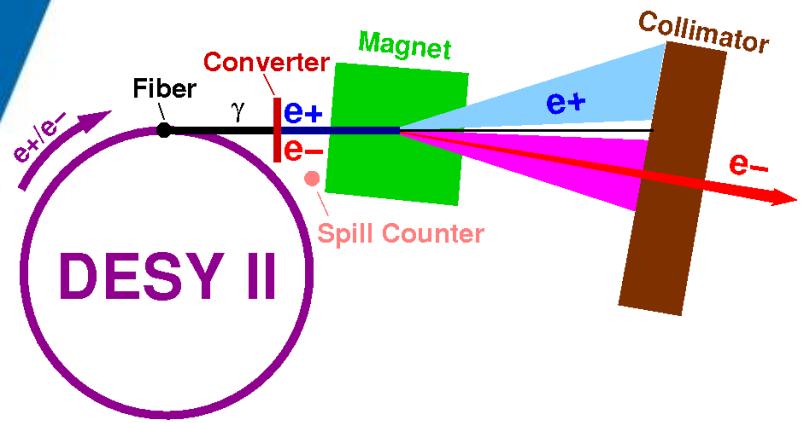
[on behalf of the FCAL Collaboration]

Outline

- ✓ Test Beam set-up
- ✓ Amplitude Method - description
- ✓ Results:
  - Signal-to-noise ratio
  - BeamCal sensor uniformity
  - Track reconstruction
  - Edge effect investigation
  - Shower analysis
- ✓ Conclusions

Test Beam DESY II



- The DESY II Synchrotron provides bunches of electrons with up to 1000 particles/cm²s, energies from 1 to 6 GeV;
- Test-beam took place in beam line 22 of DESY II ring at Hamburg, from 04.11.2011 to 22.11.2011;
- The incident electron beams were of 2 and 4 GeV;

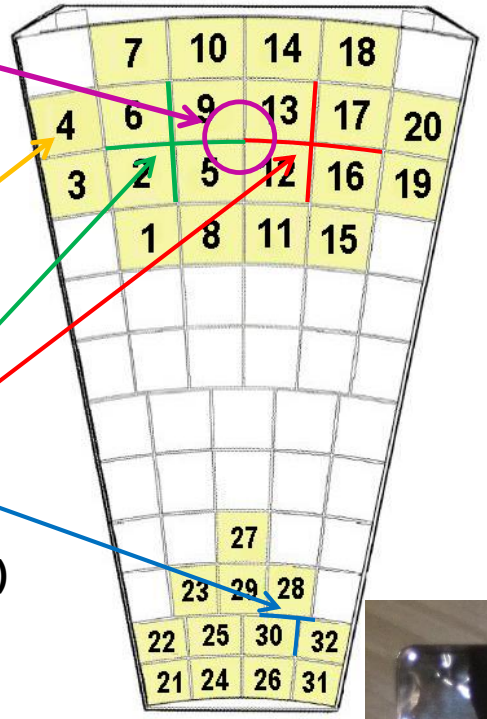
Set-up

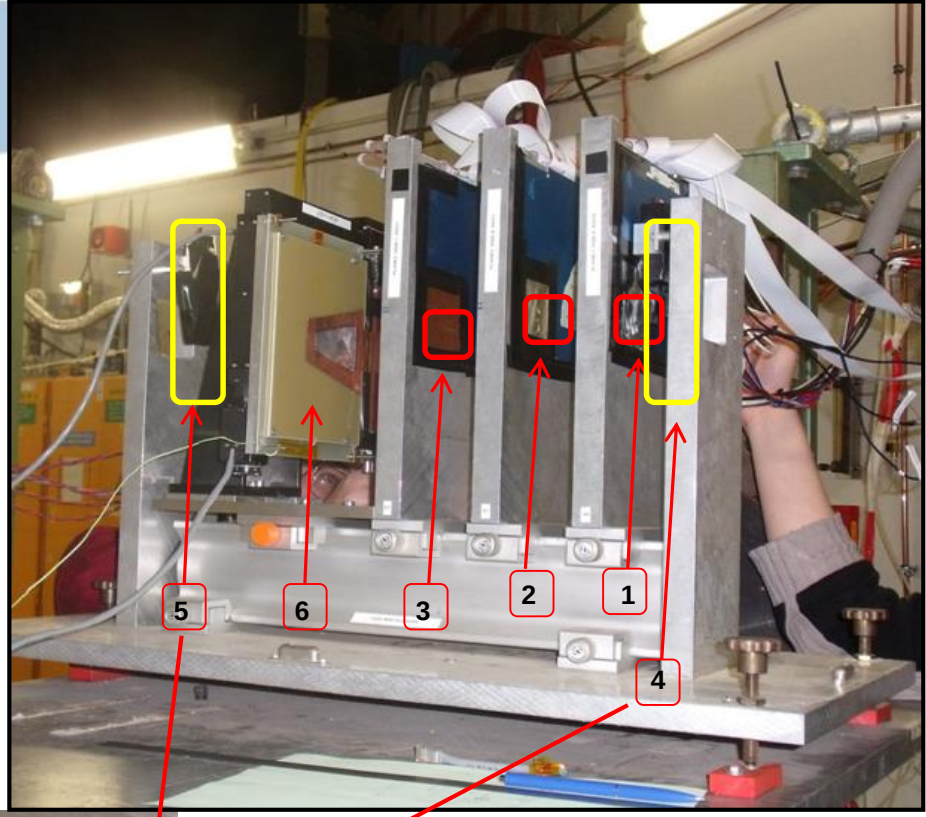
Shower analysis

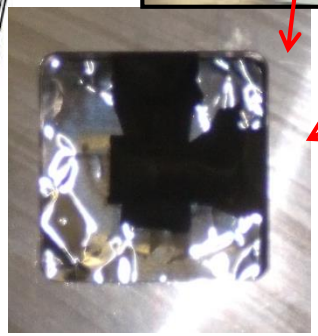
N_{tr} ~ 200k events (uniformity)

Irradiation edges

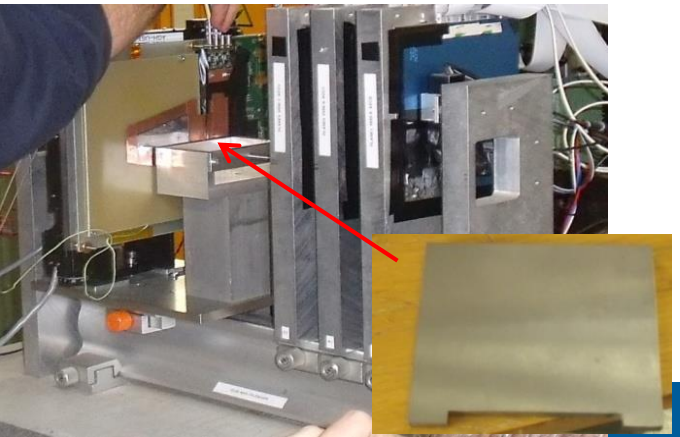
N_{tr} ~ 2M events (edge)







- ZEUS MVD telescope planes (1, 2, 3):
  - Si planes: 300 μm thick
  - Active area: 32 x 32 mm^2
  - Double perpendicular layers
  - 640 strip channels (50μm)
- Trigger scintillators (4,5):
  - Trigger window: 7 x 7mm^2
- BeamCal sensor (6):
  - GaAs:Cr sensor



- Up to 14 radiation lengths of tungsten were mounted in front of the sensor

Amplitude method (MAX)

1. Data – For each trigger the ADC counts were placed in a matrix $A = ||A_{ij}||$, $i \in [0,31]$, $j \in [0,31]$

$$A = \begin{pmatrix} A_{00} & \cdots & A_{020} & \cdots & A_{031} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ A_{i0} & \cdots & A_{i20} & \cdots & A_{i31} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ A_{310} & \cdots & A_{3120} & \cdots & A_{31,31} \end{pmatrix}$$

where:
- A_{ij} is the ADC count of the pad (i+1)
- *i* electronic channel
- *j* sample number

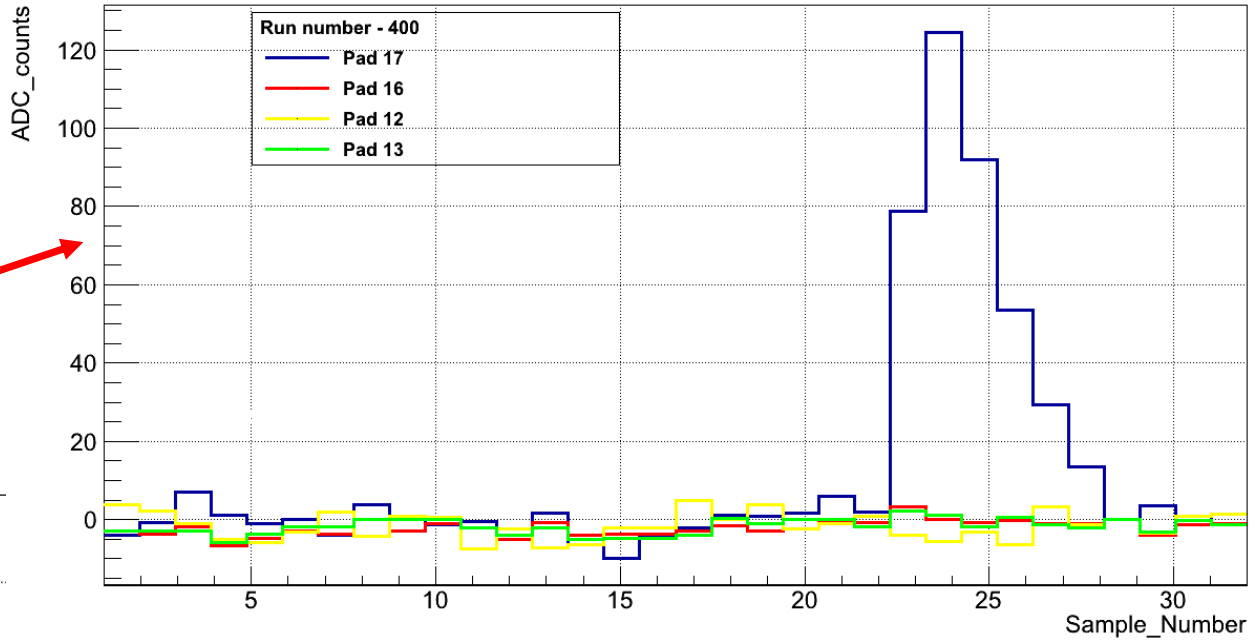
2. For signal – The amplitude method finds for each pad the maximum of the ADC counts between samples 20 and 31

$$A_{imax} = max\,(A_{i20}, \cdots, A_{i31})$$

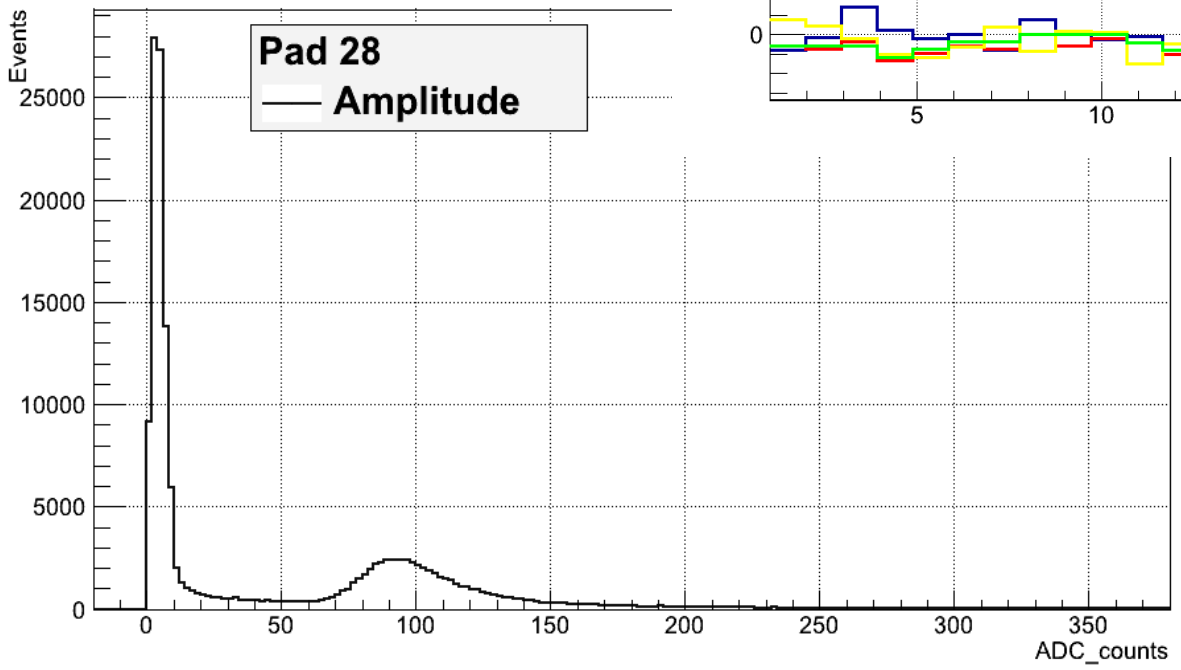
3. For pedestal – The mean value of the ADC counts distribution for the first 19 samples

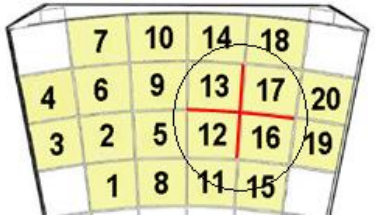
Amplitude method (MAX)

A_{11j}; A_{12j}; A_{15j}; A_{16j} dependence on the sample number, $j \in [0, 31]$

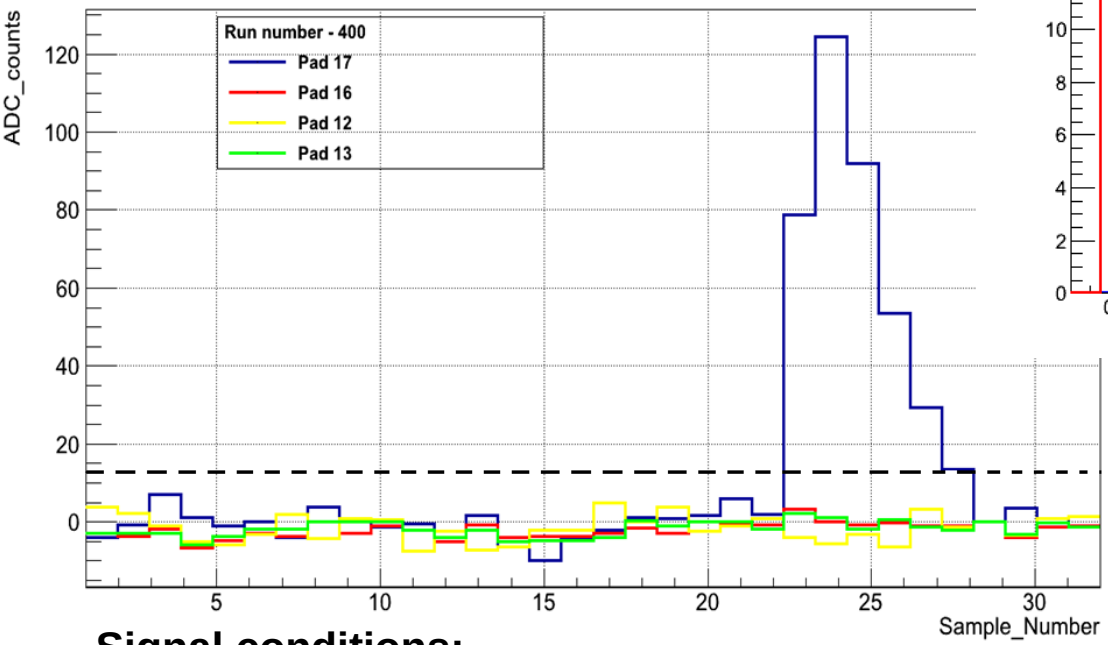


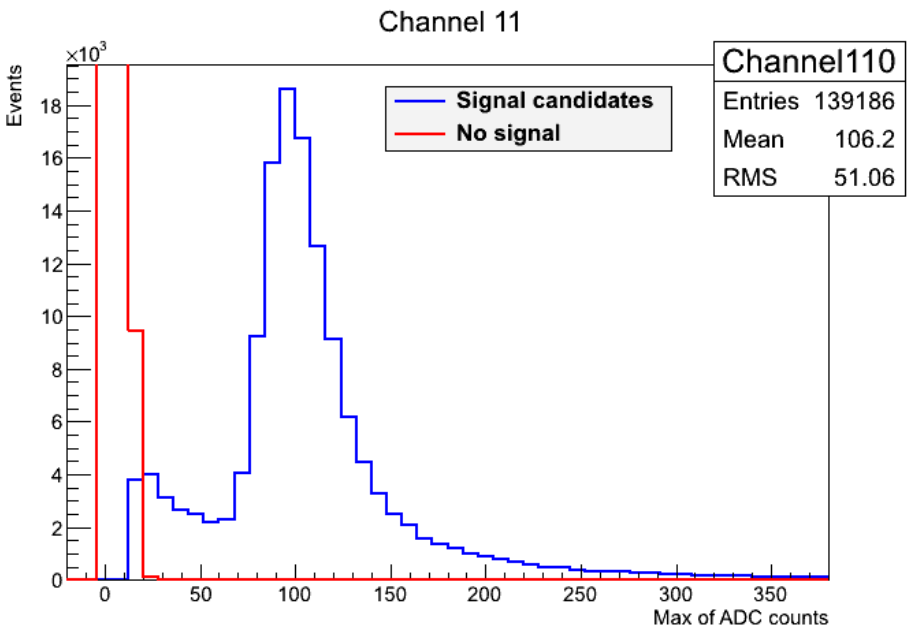
$A_{27max} = max\,(A_{2720}, \ldots, A_{2731})$





Analysis Methodology





$f_i(S_i)$ when (1) and (2) are fulfilled

$f_i(A_{imax} - P_i)$ when (1) or/and (2) are not fulfilled

Signal conditions:

1. The maximum count has to satisfy:

$$A_{imax} > \langle P_i \rangle + 3\sigma_{iPedestal} \quad (1)$$

2. At least one of the nearest samples has the count:

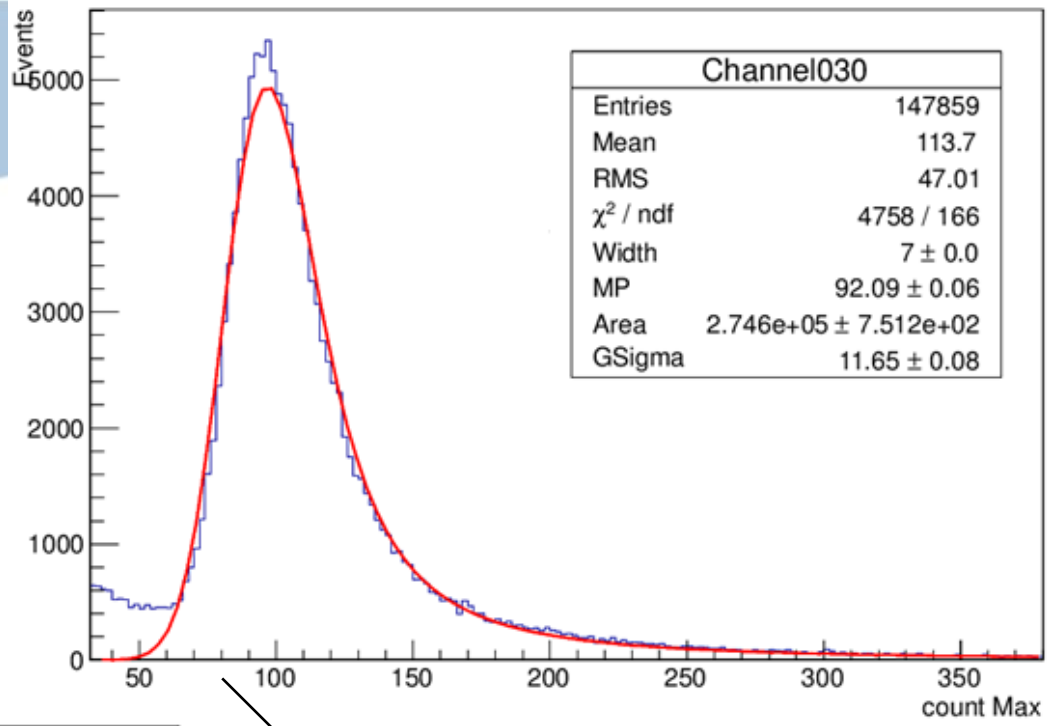
$$A_{imaxj-1} \; or \; A_{imaxj+1} > \langle P_i \rangle + 3\sigma_{iPedestal} \quad (2)$$

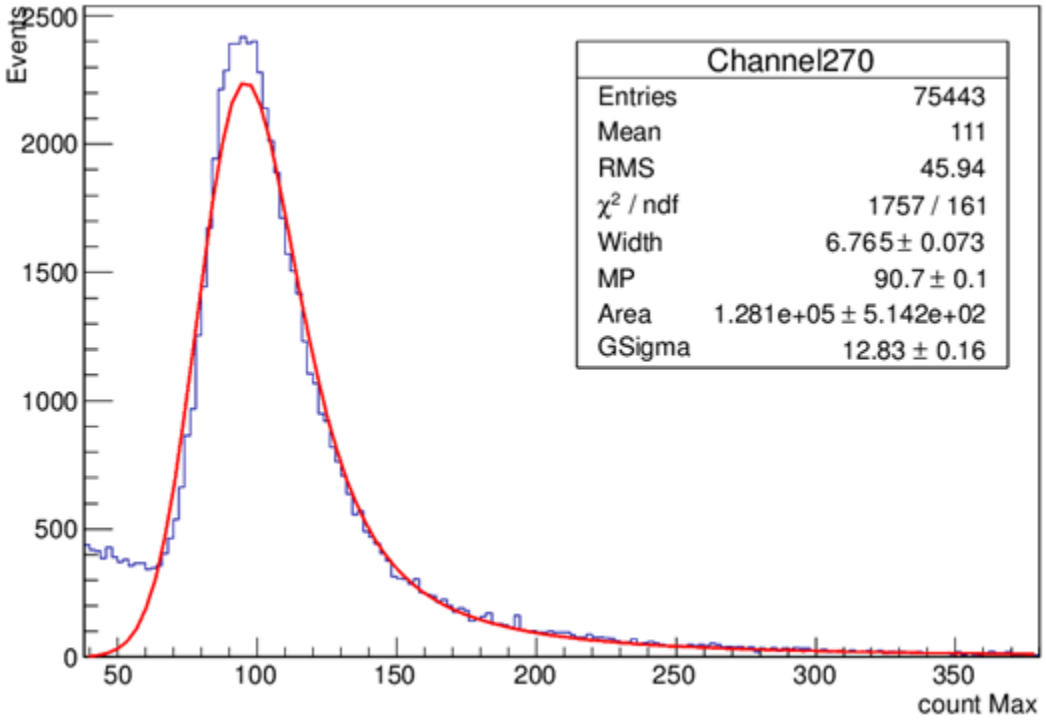
3. The signal amplitude is:

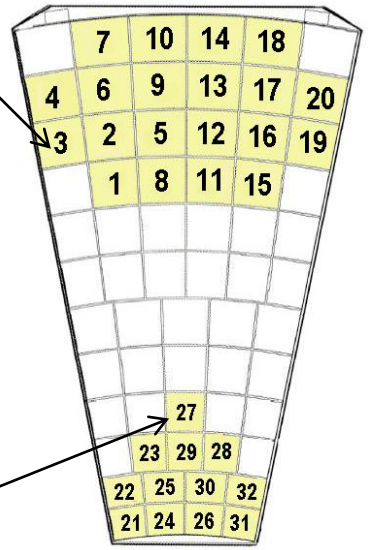
$$S_i = A_{imax} - P_i \quad (3)$$

Signal analysis

Amplitude spectrum, fitted by LG convoluted function for two sensor area

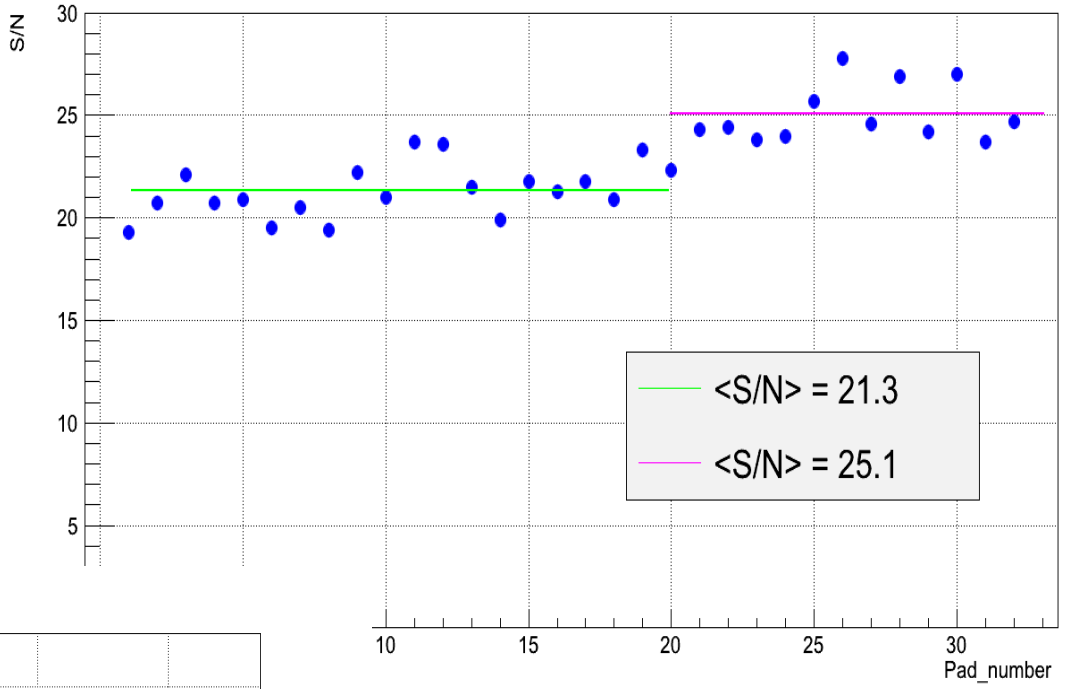




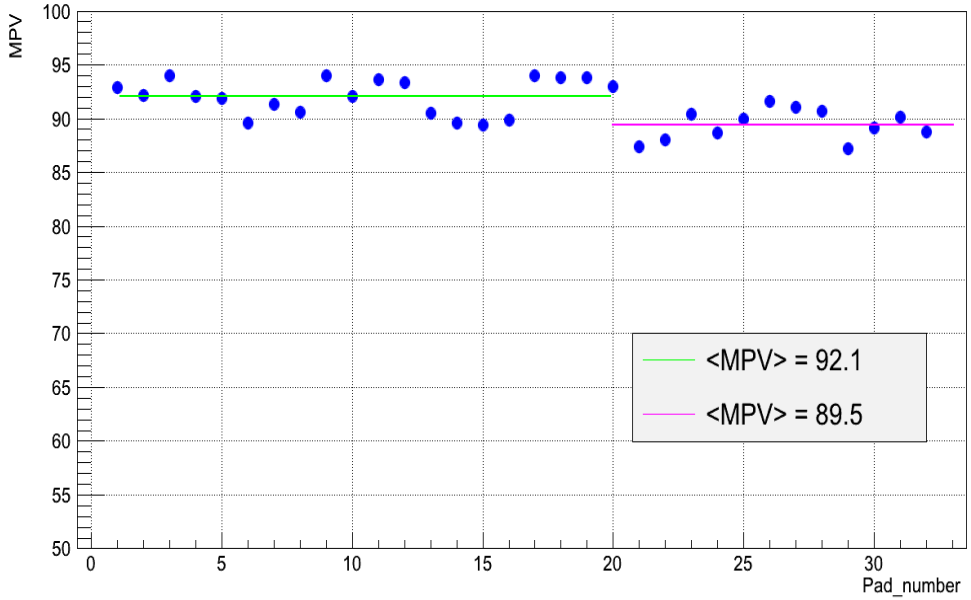


Results

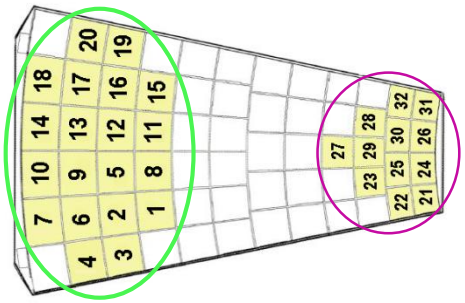
$$SNR = \frac{MPV}{\sigma_{Pedestal}}$$



The signal-to-noise ratio for **BeamCal** sensors as function of the pad number



The most probable value of the signal spectrum for **BeamCal** sensors as function of the pad number



BeamCal sensor prototype

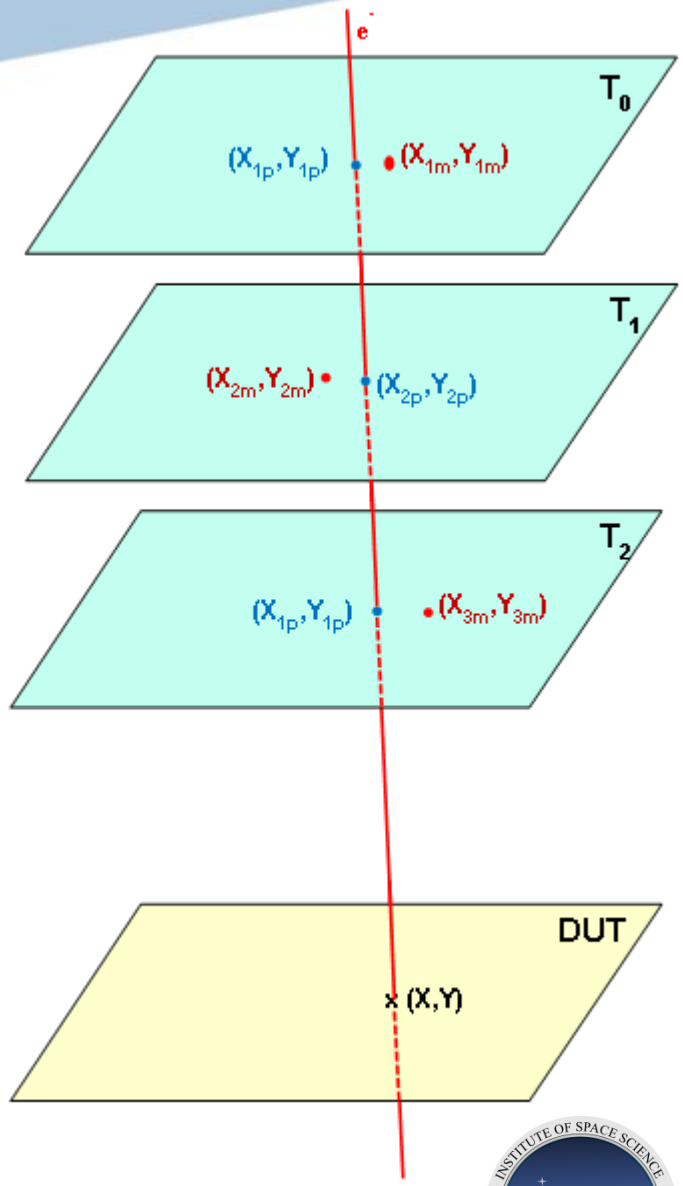
Track reconstruction method

- DigXs and DigYs coordinates have been taken for all telescope planes;
- Hits number/plane = 1 → one EM shower/event

where:

- (X_{im},Y_{im}) = measured coordinates or given coordinates by TelAna, $i \in [1, 3]$;
- (X_{im},Y_{im}) = (DigXs, DigYs);
- (X_{ip},Y_{ip}) = predicted coordinates given by line intersection with each telescope plane

$$Min\ (d^2) = Min\left(\sum_{i=1}^{3}\left((x_{ip} - x_{im})^2 + (y_{ip} - y_{im})^2\right)\right)$$

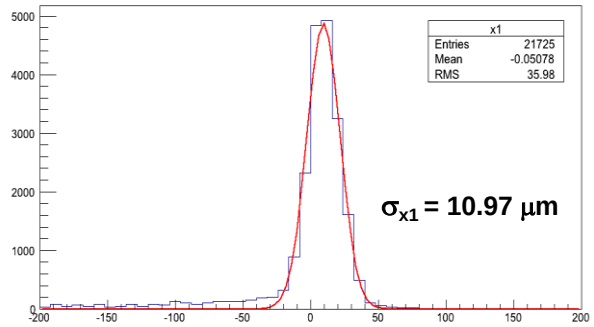


Track reconstruction method

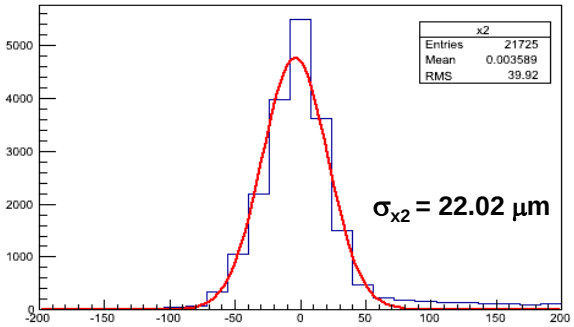
Spatial resolution:

- Sigma from fits are smaller than about 30μm
- The Si chamber alignment was made with a maximum 100 μm shift

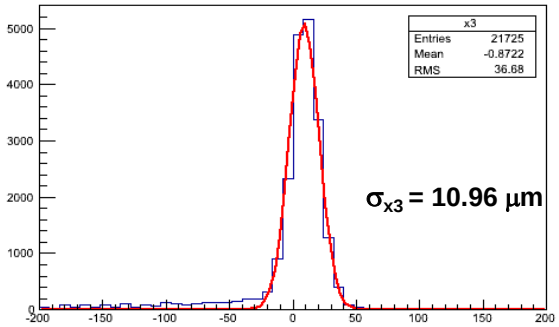
ΔX_1



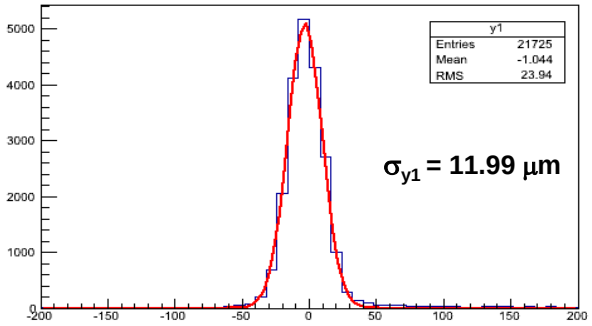
ΔX_2



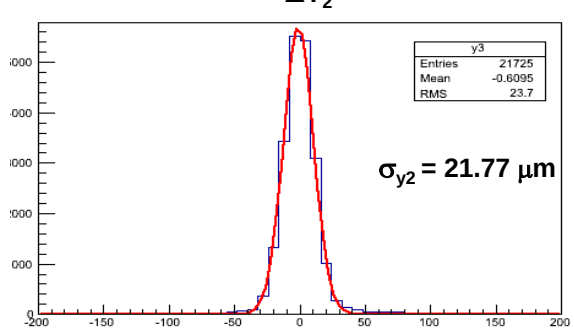
ΔX_3



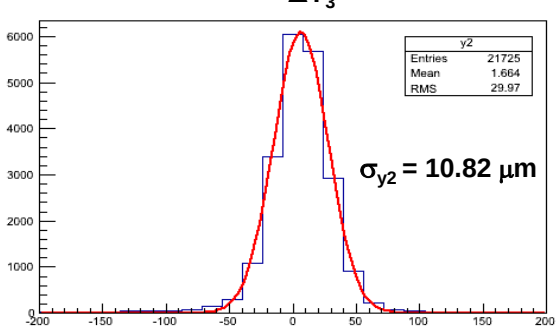
ΔY_1



ΔY_2



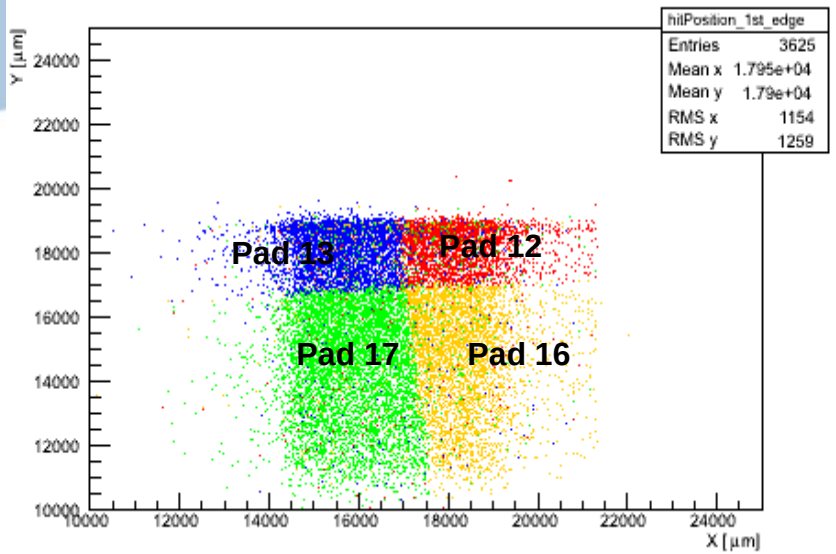
ΔY_3



Residual distribution on X and Y direction for all telescope planes

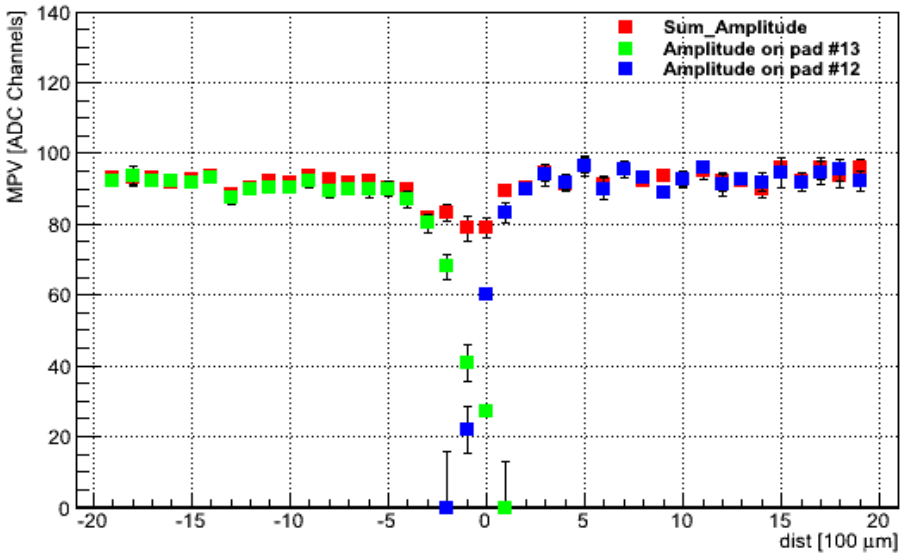
Edge effect analysis

The x and y coordinates are given by the track intersection with the sensor and the color is given by the hit pad, in other words the pad with the biggest signal.



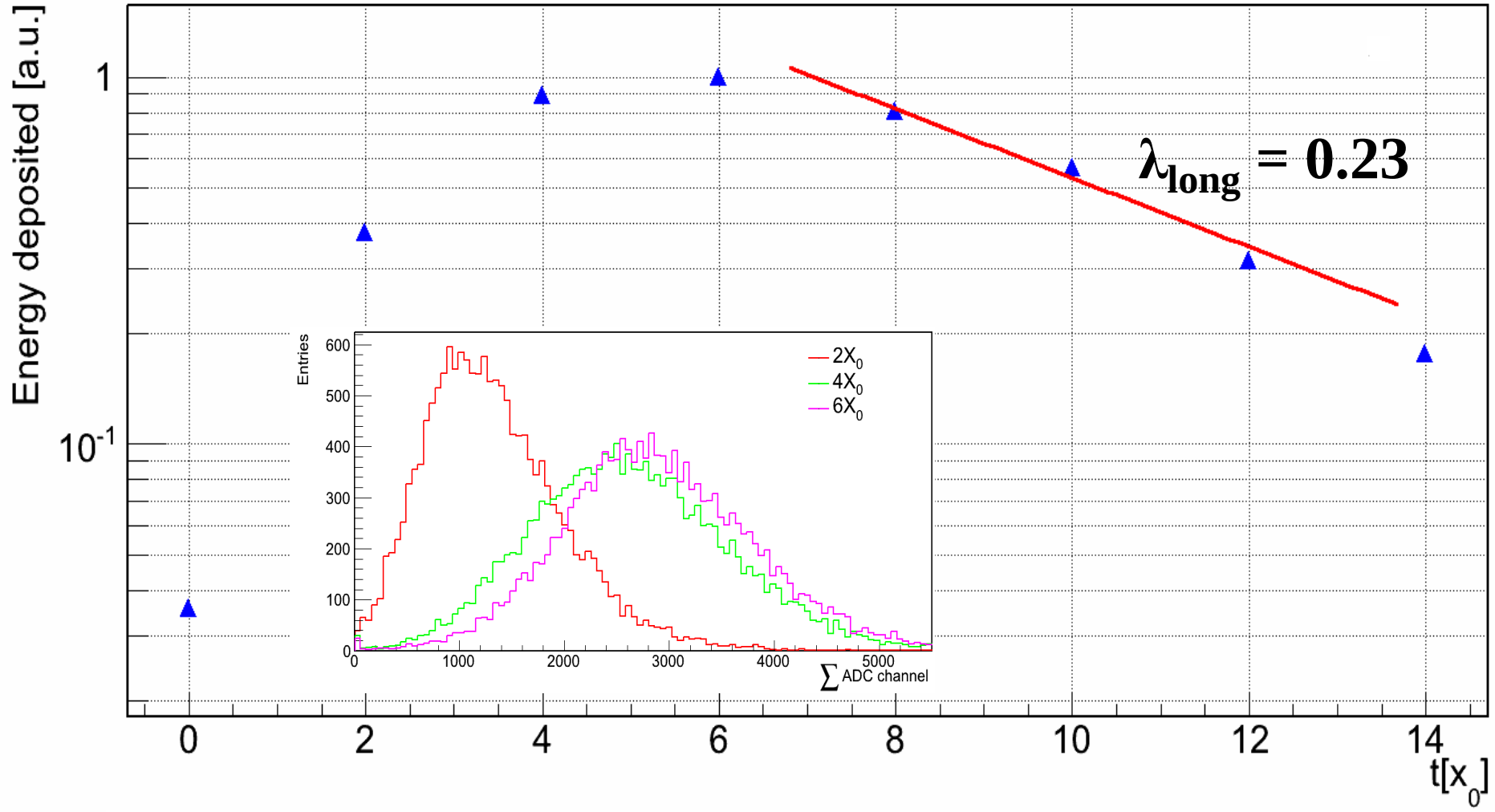
The hits distribution on a fully instrumented **BeamCal** sensor

- The signals are constant along the pads and at the border dropped abruptly on about 400 µm.
- At the border the sum signal distribution drops by maximum of 17% on a 400µm.



The dependence of *MPV* of the signal spectrum on the electron impact point around the border for two pads

Shower analysis



The energy deposited in the BeamCal sensors as function of the tungsten thickness. The inset figure shows the total energy registered by GaAs sensors for different tungsten layers in front of the sensor plane

Conclusions

- The Amplitude Method was developed for signal analysis
- The results obtained using the Amplitude Method indicate:
  - # a very good sensor homogeneity
  - # signal-to-noise ratio for all 32 pads matched our requirements
  - # the signal-to-noise ratio is about 21 for big pads and slightly larger on the sensor pads with a small surface.
  - # the edge effect appears on a 400μm distance with a maximum drop of 17%
  - # the total energy registered by GaAs sensors for different tungsten layers in front of the sensors was determined
  - # for a longitudinal cascade the shower maximum was observed after 6 tungsten radiation lengths

Acknowledgements:
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THANK YOU FOR ATTENTION!