Pixel chip development for tracking type gaseous detectors

The report is based on a draft of the proposal:

Hybrid Si-Gas Pixel Detector (HSiGPD)

by G. Bashindzhagyan, N. Korotkova, A. Romaniouk, N. Sinev and V. Tikhomirov

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Hybrid tracking detector based on semiconductor and gas technologies

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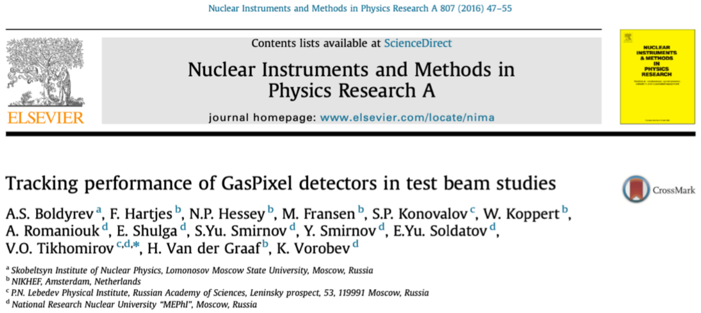
Disclaimer:

Work is not advanced and reflects thoughts about a future of Ingrid type detectors.

Author of the presentation is not an expert in the pixel detector nor in the electronics areas.

What is behind of this proposal?

The work to develop "vector" tracking device based on Ingrid technology.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Tracking performance of GasPixel detectors in test beam studies

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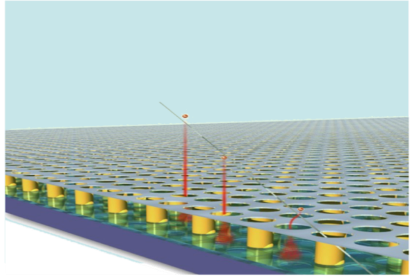
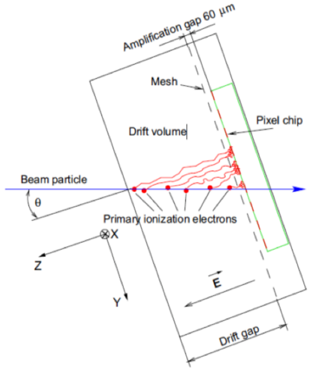
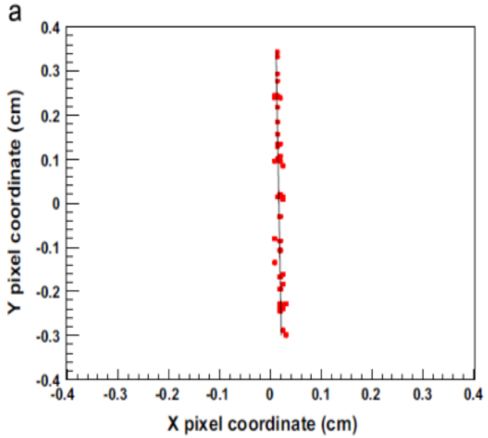
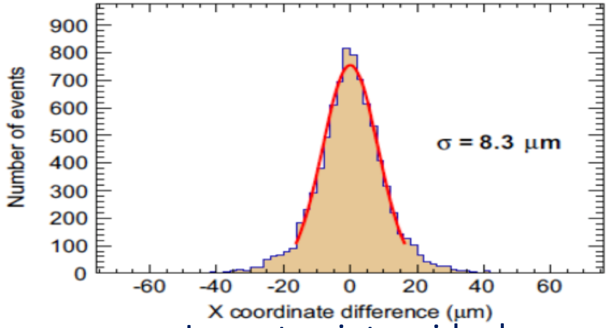




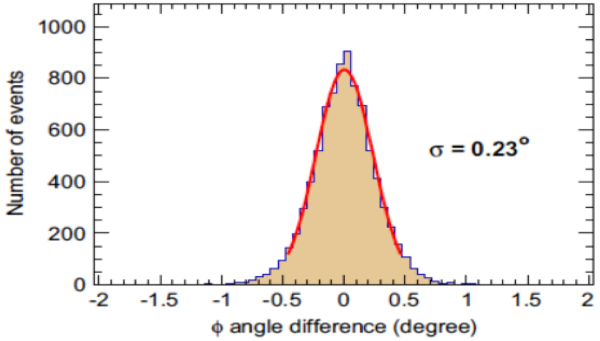


Projection on the chip plane

Reconstructed track parameters

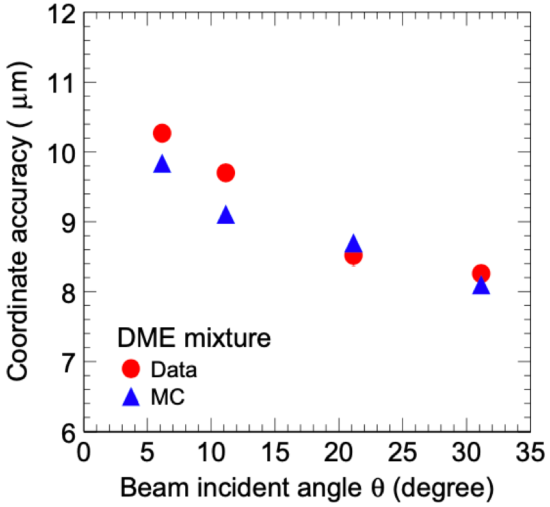


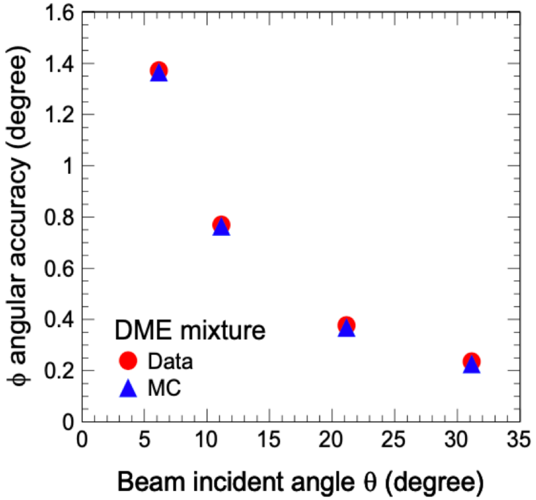
Impact point residual.

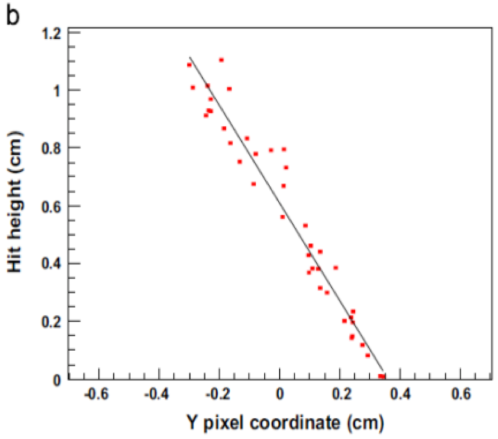


Angle residual on the chip plane

Dependence main parameters on a beam incident angle







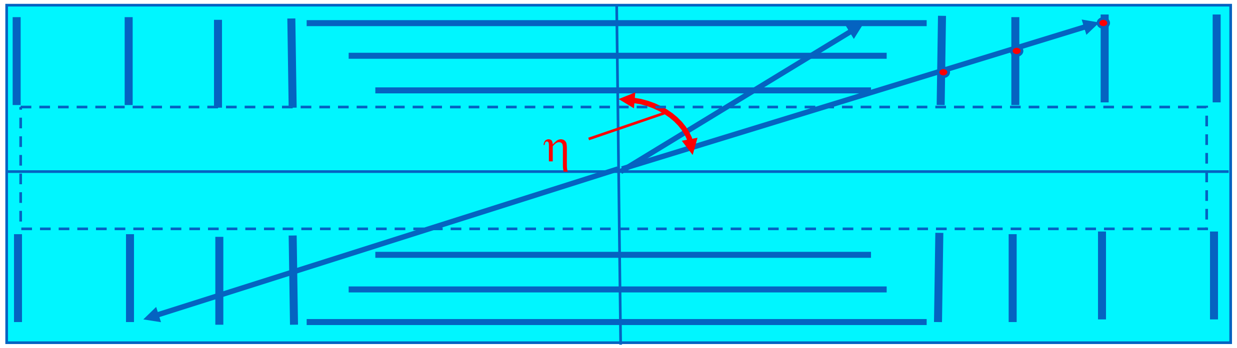
Reconstructed hit distance to the chip plane.

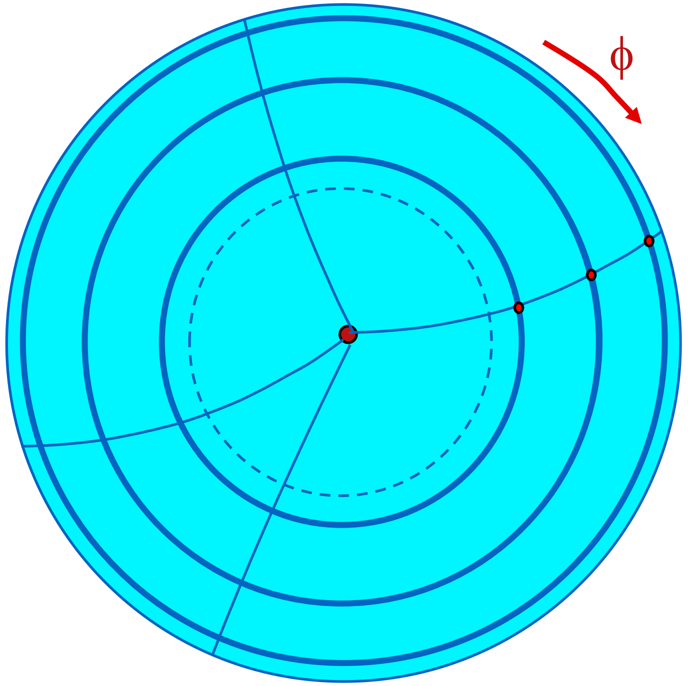
Electronics shaping was not optimized for this type of measurements

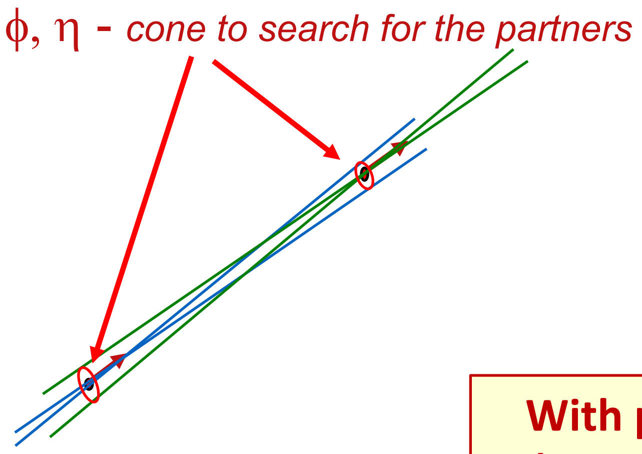
What is behind of this proposal?

Example: Inner detector based on vector tracking.

For each particle this device provides:







1. Precise coordinate measurements (well below diffusion limit).
2. Vector track reconstruction.
3. Very good pattern recognition in multi-track track environment.
4. Powerful pattern recognition
5. L1 trigger features for stiff tracks.
6. Good timing properties.

Complimentary it can be used for PID: dE/dX measurements and as a transition radiation detector.

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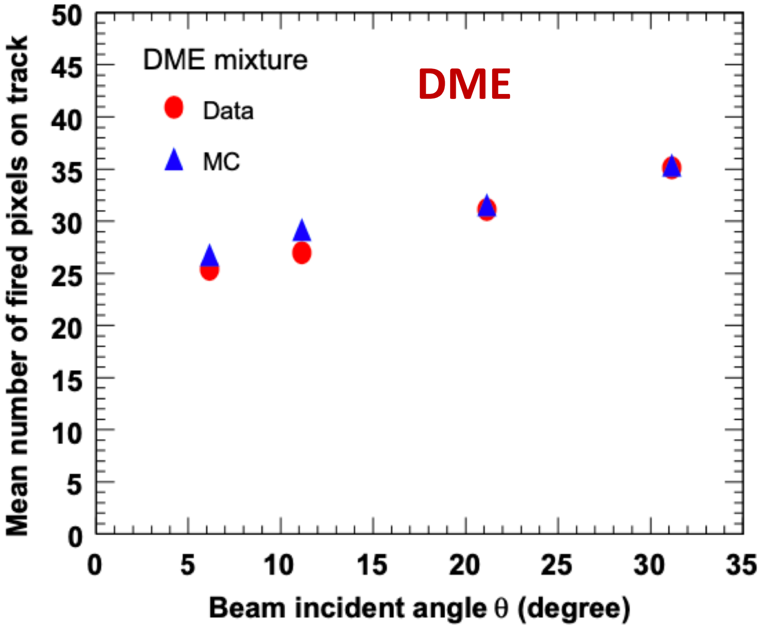
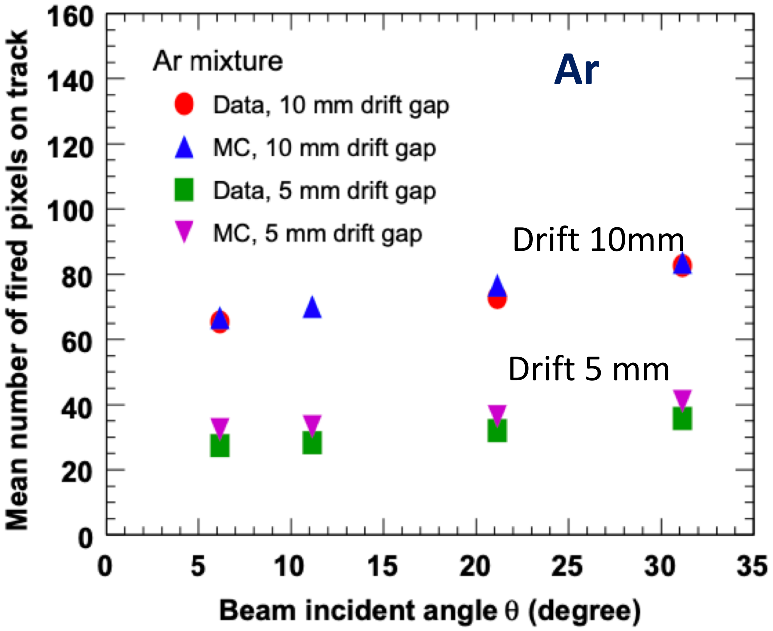
With parameters described above only one outer layer (R=1 m, B=2T) can provide momentum measurements with accuracy of ~13 % for particles with P_t=10 GeV.

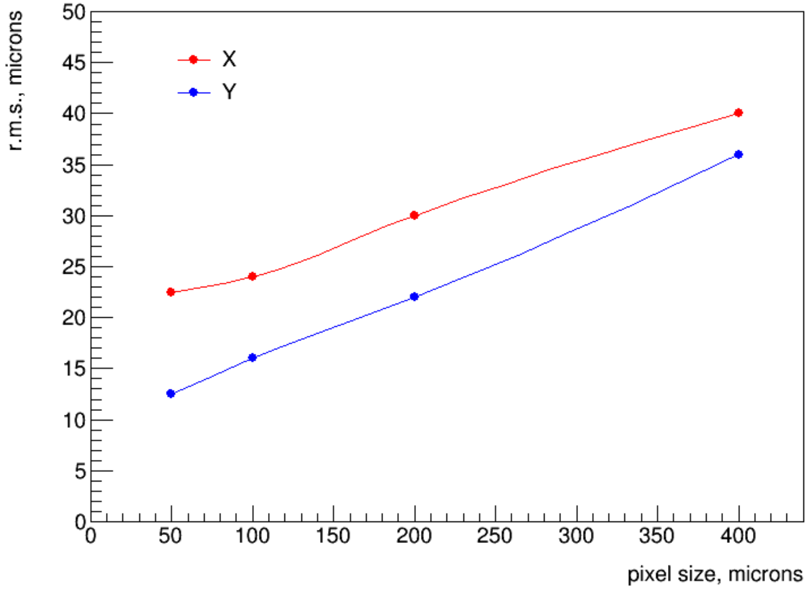
What problems to deal with.

One of the problem is amount of data to be send.





Averaged number of pixels fired on the track

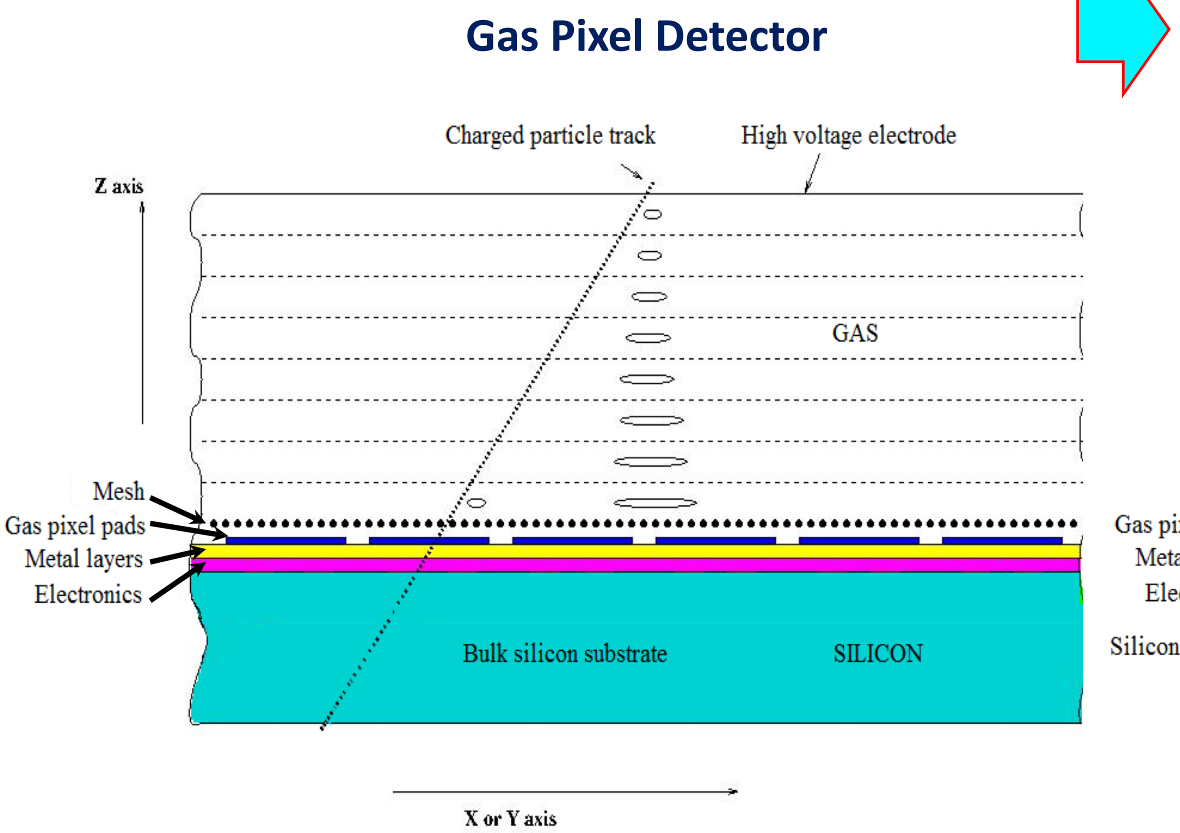


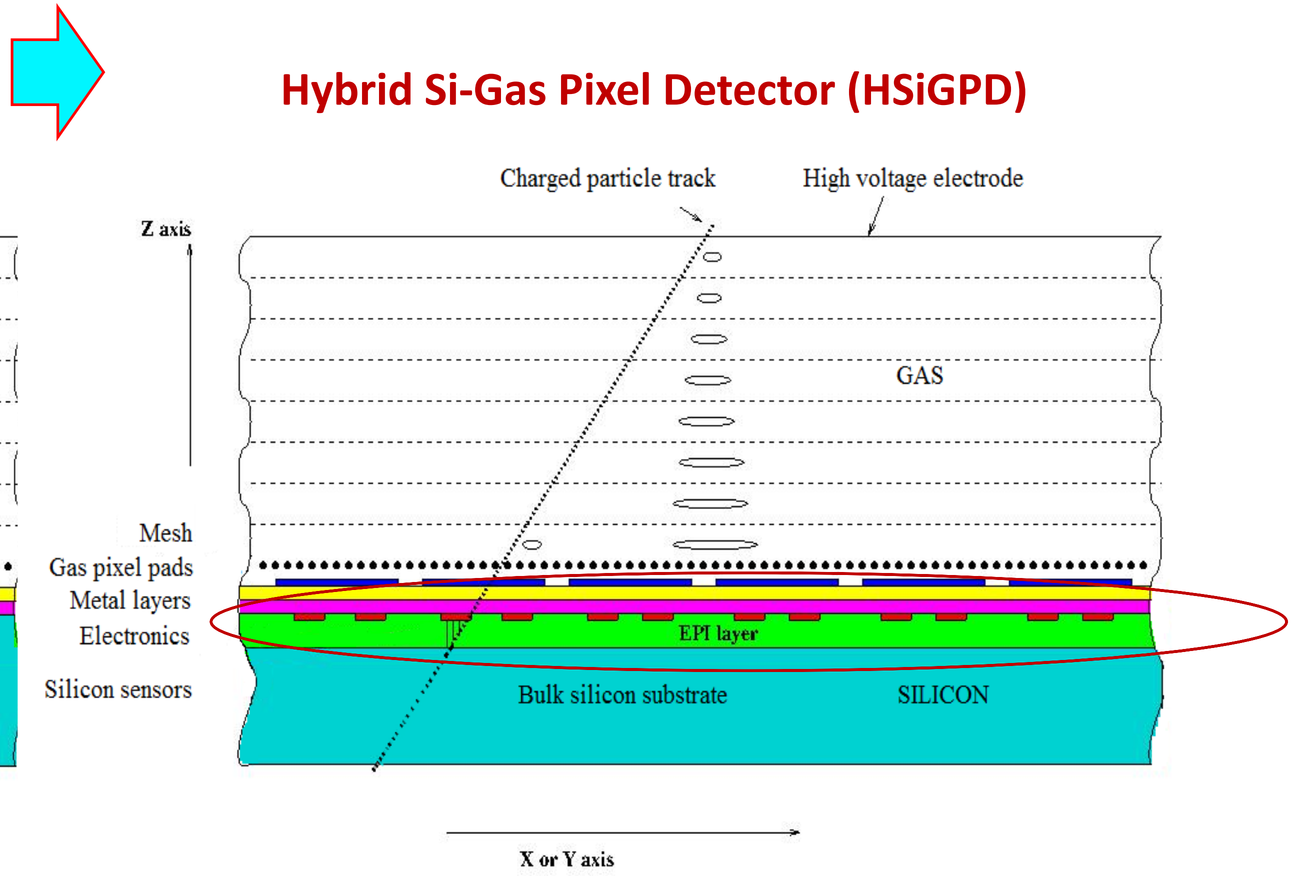
Impact point coordinate measurement accuracy as a function of a pixel size

One of the way to reduce the number of pixels is to increase the size of the pixel but it will never reach the level of semiconductor detectors.

Data must be processed locally and sent parameters of the particle track out after accepting local L0 trigger

What is proposed?



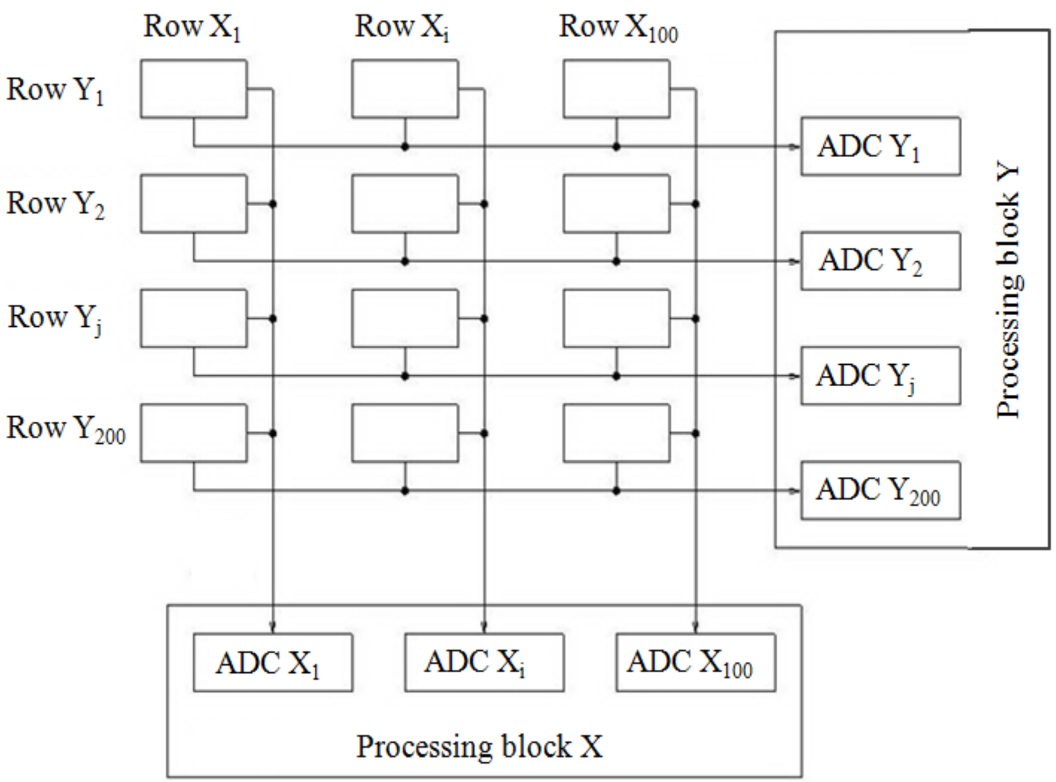


In GPD 100×200 µm pixels are the metal layers on the 2×2 cm^2 electronic chip surface. Each pixel electronics is positioned near the pixel. Data acquisition and processing electronics is at two edges of the chip (X , Y).

30-50 µm epitaxial silicon layer with 25×25 µm pixels is below the chip electronics. It provided fast timing signal < 1 ns **which triggers** the readout cycle. The chip works with the internal or external clock of 40 MHz which can be increased locally to 160 MHz. Clock defines also data processing speed on the FE level.

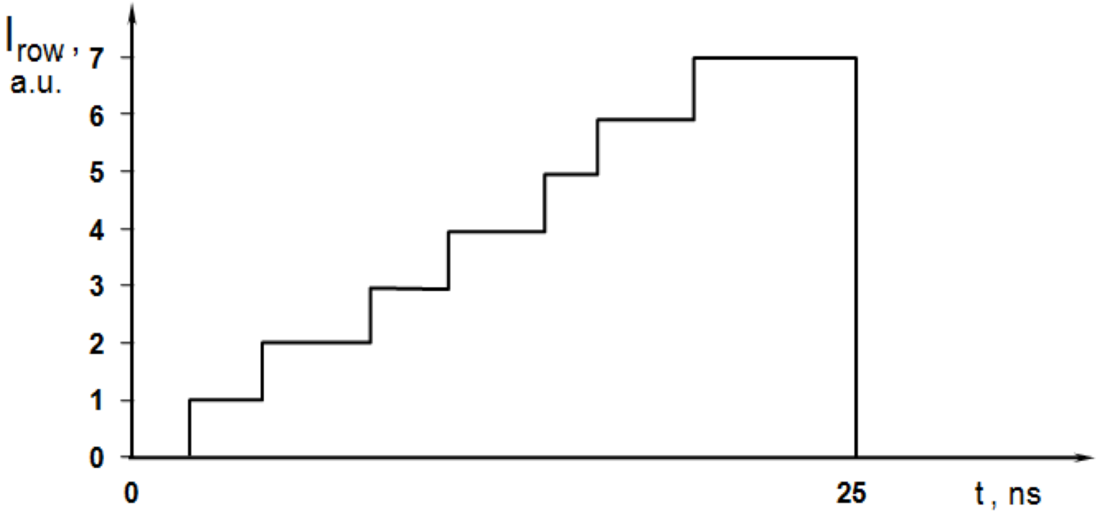
How it works?

Every pixel has an integrated fast preamplifier, discriminator and flip-flop (FF) with two fixed current outputs connected to common X and Y lines going along the particular X_i and Y_j rows correspondingly. If a pixel is fired during a cycle, FF turns ON and current flows along the line.



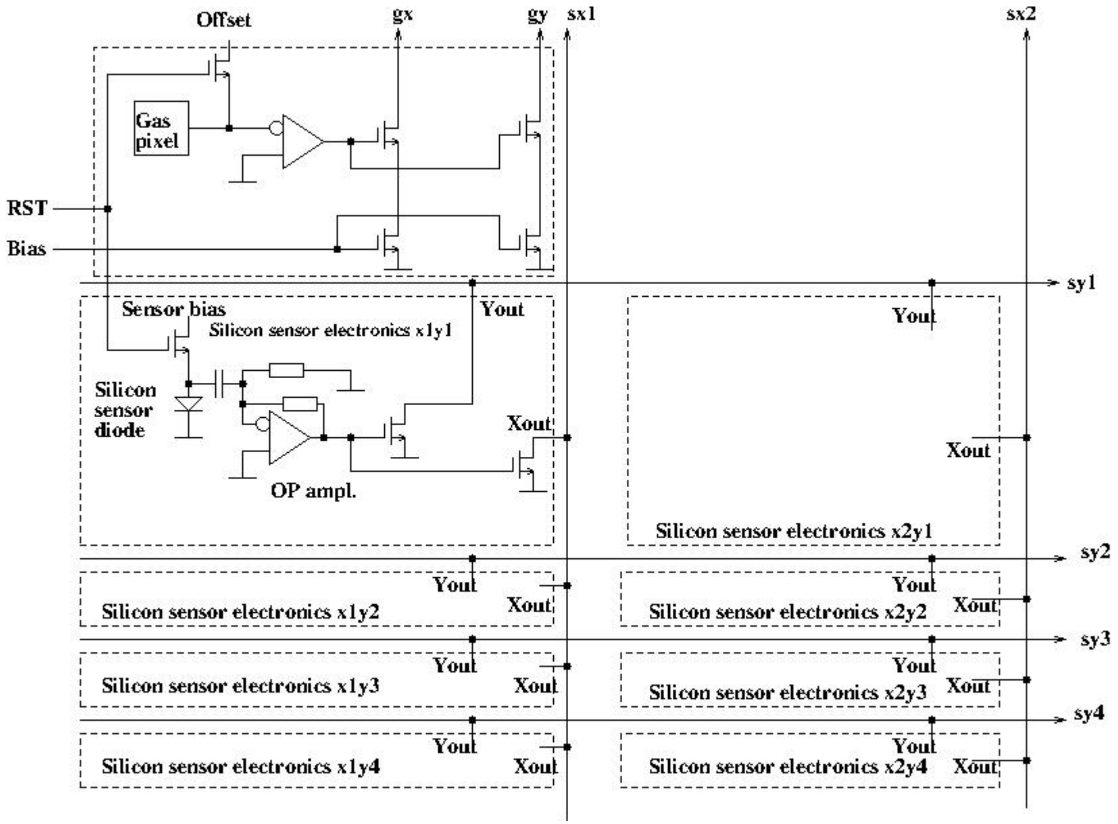
If a few (up to 15) pixels have been fired in the same row in the same readout circle, the sum of their currents appears in the corresponding line as shown in the Figure .

A total amplitude of this current is proportional to the number of fired pixels



How it works? Pixel FE.

Chip electronics for Si sensors operates similar way as for the Gas Pixel detector.

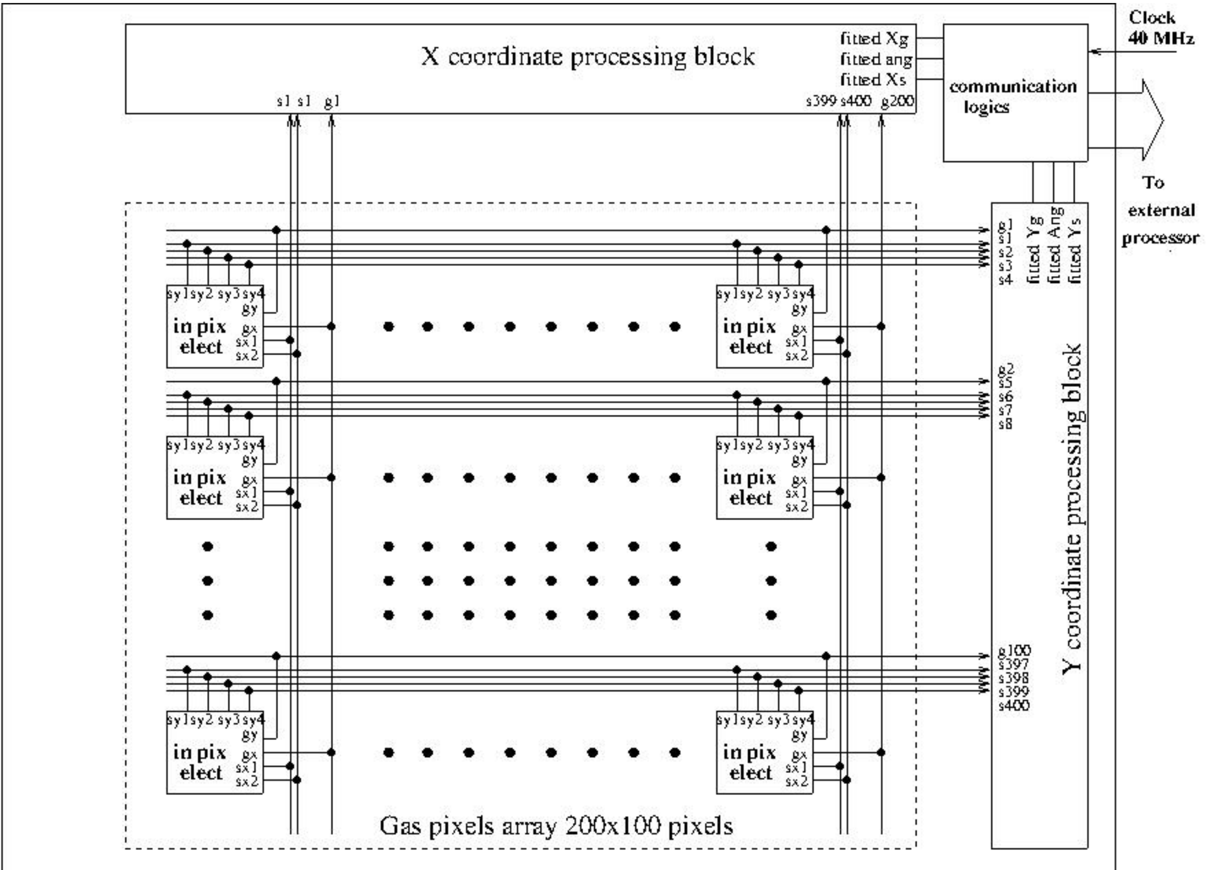


Gas pixel pads can be 100 x 200µm^2 , while for silicon sensors suggested area covered by 1 sensor is 50x50 µm^2 or 25x25 µm^2.
Under (near) each gas pad there is one electronics block for gas and 8 or 32 blocks for silicon sensor readout.

If particle density is high and a few particles can appear at the same time the ambiguity can be avoided adding one more interconnecting system of wires. For example under 45 degree relative X and Y.

How it works? General layout

SGPD chip layout



Gas pixel chip layout

The end of each line is connected to a 4-bit flash ADC integrated in X and Y processing blocks PBX and PBY positioned on e two edges of the chip.

At the end of each cycle a special command is generated and all ADCs convert the current into a number of fired pixels in this row. The same command returns all the FFs into starting position preparing the channel to next readout cycle.

Processing blocks analyse the data and measure both X and Y coordinates. Combination of information from both detectors (gas and Si) would allow reconstruct track segment with with associated time stamp at the FE level.

The latency of a development of the L0 trigger Is about 40 clock periods. With 40 MHz frequency it is 1 µs. Can be reduced down to 0.5 µs increasing frequency to 80 MHz.

How it works? Reconstruction algorithm

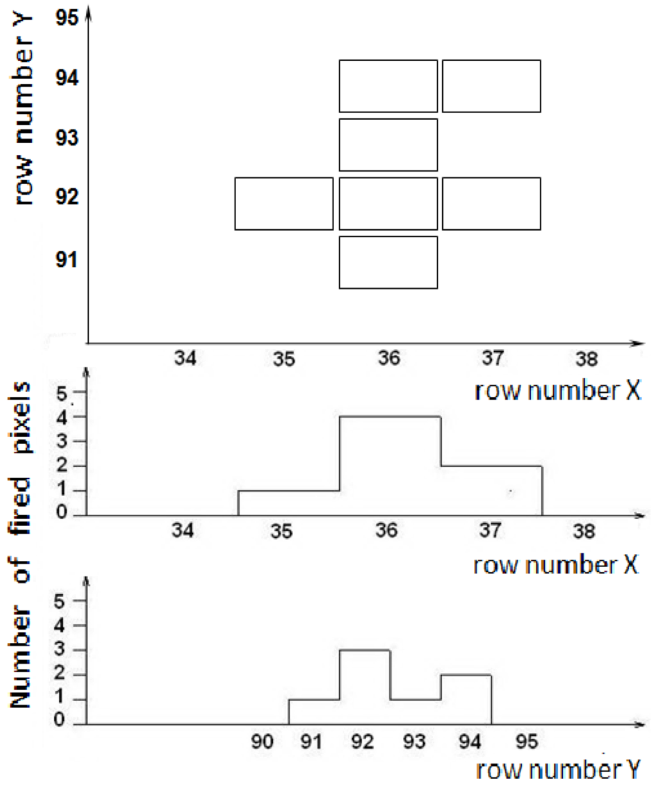
After trigger developed, the read out which has 8 cycles (defined by drift time) starts.

An example of a cluster structure in XY plane and its projections on both axes for the 3-rd cycleof readout shown in figure.

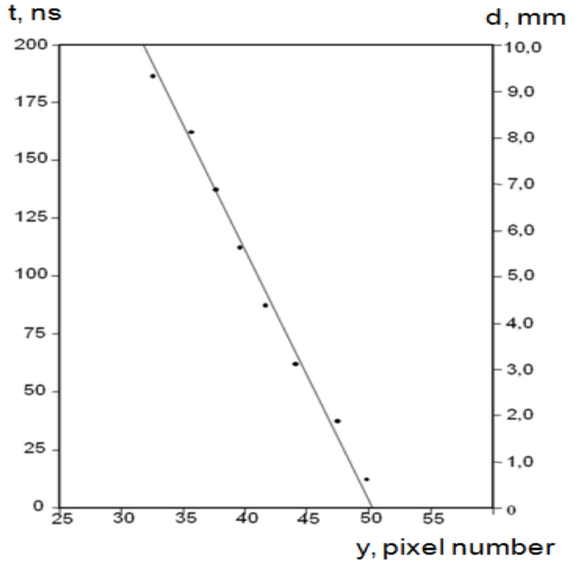
Particle position is calculated as a center of mass of fired pixels.

In each projection the row number or is multiplied by the number of fired pixels in this row, n_X^i or n_Y^j, and the sum of the products is divided by the total number of fired pixels in the cluster N_P :

$$X = \sum R_X^i n_X^i / N_P \quad , \quad Y = \sum R_Y^j n_Y^j / N_P.$$

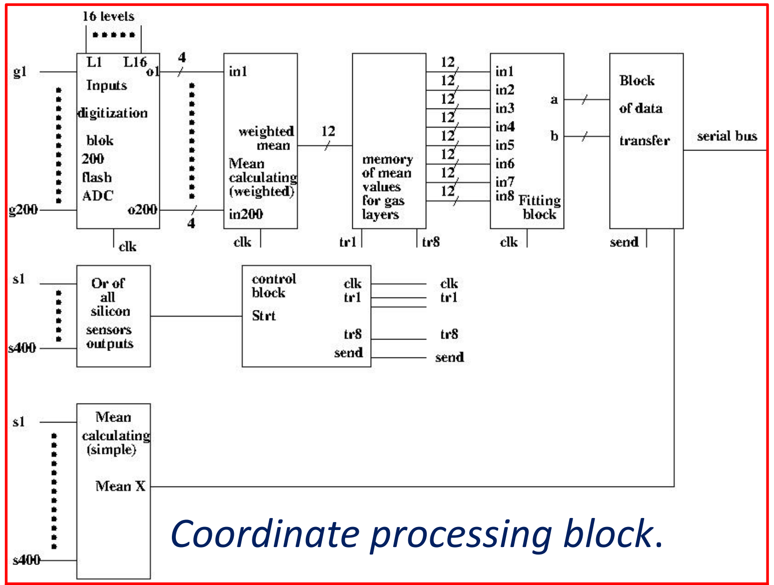


The example of the cluster structure in XY plane and its projections on X and Y axes.

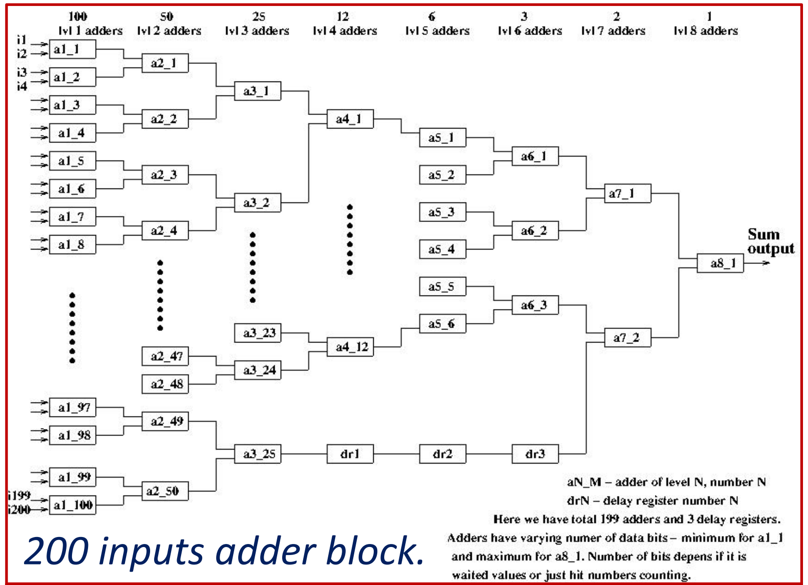


The example of the particle trajectory reconstruction.

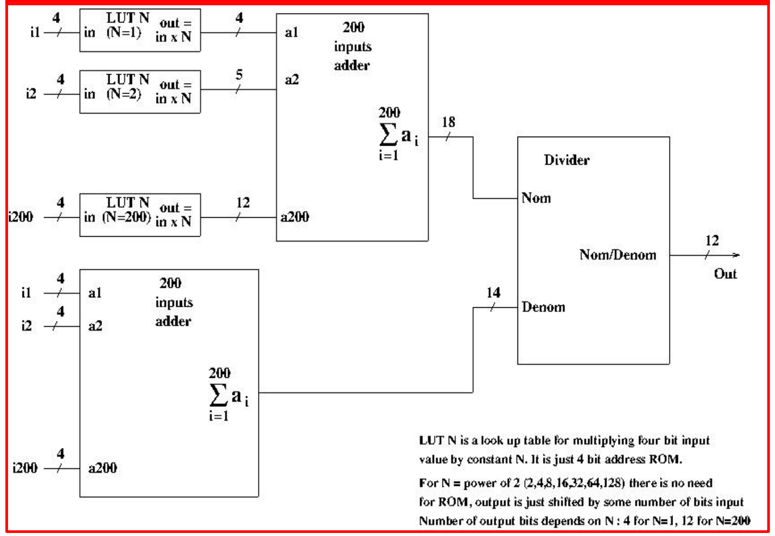
How it works? Processing units

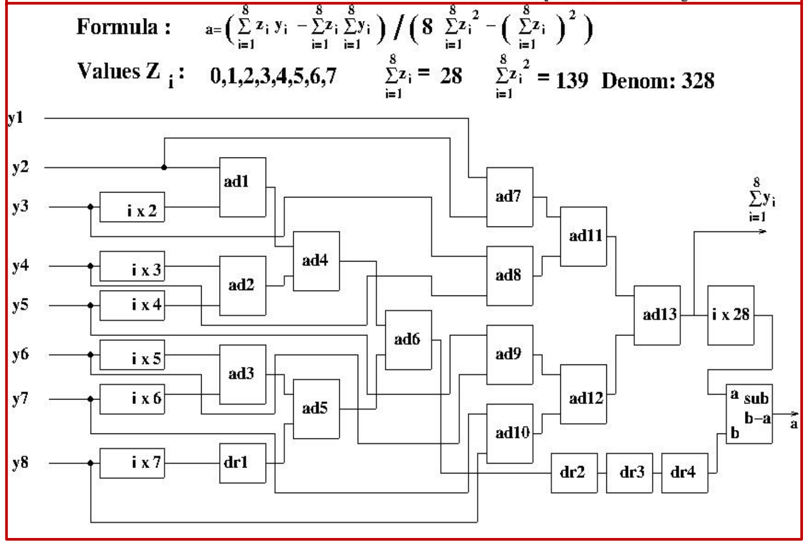


Coordinate processing block.



200 inputs adder block.



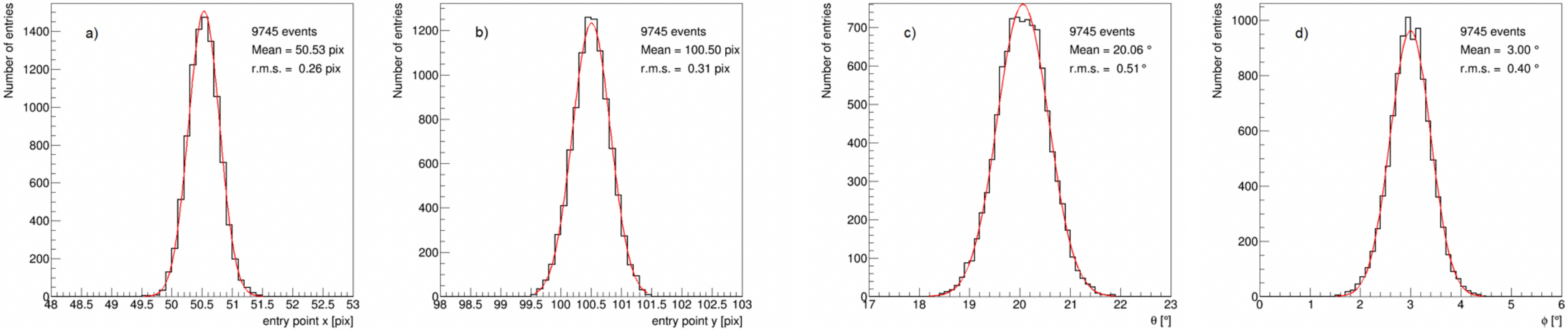


Weighted mean calculating block.

Fitting block.

Calculated track angular parameters are compared with thresholds and if they pass the requirements the trigger level 0 is issued

How it works? Reconstruction results



The distributions of the reconstructed track impact points coordinates: a) X; b) Y; and angles in the direction perpendicular to the chip plane: c) ϑ; d) φ for 20 GeV pions crossing the GPD with ϑ = 20° and φ = 3.00°.

For precise impact point coordinate measurements Si-pixels hits should be added.

Conclusions

1. Combination of the GPD with thin active layer of Si integrated within electronics readout chip creates a new type of detectors – HSiGPD with significantly extended functionality.
2. These type of detectors can operate in a self-trigger mode with possibility to reconstruct track segments at FE level with a good coordinate and an angular accuracies.
3. Fast on-line data processing functionality can provide L0 trigger decision for high Pt tracks within a time interval ~0.5 μs.
4. Similar chip logic can be used for other applications.
5. First thoughts based on draft design concepts show that this device can be realized within existing technologies.