Front-end intelligence for triggering and local track measurement in gaseous pixel detectors

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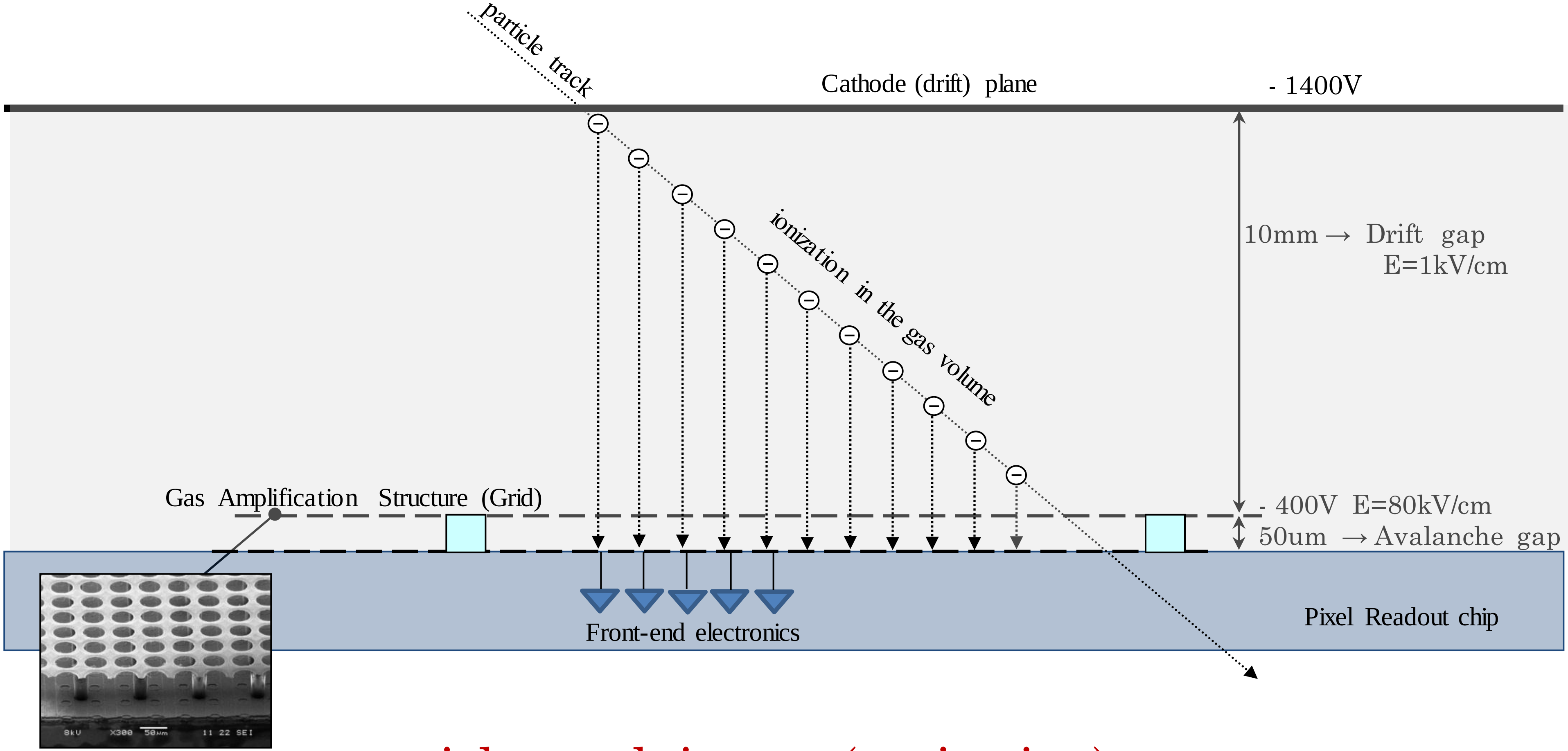
WIT2012, May 4, 2012

Outline

- Pattern recognition in Gaseous Pixel Detectors
- Algorithm for identification of high momentum tracks
- Physical implementation of the triggering logic
- TriggerPix: a future pixel readout chip with self-triggering functionality
- Summary

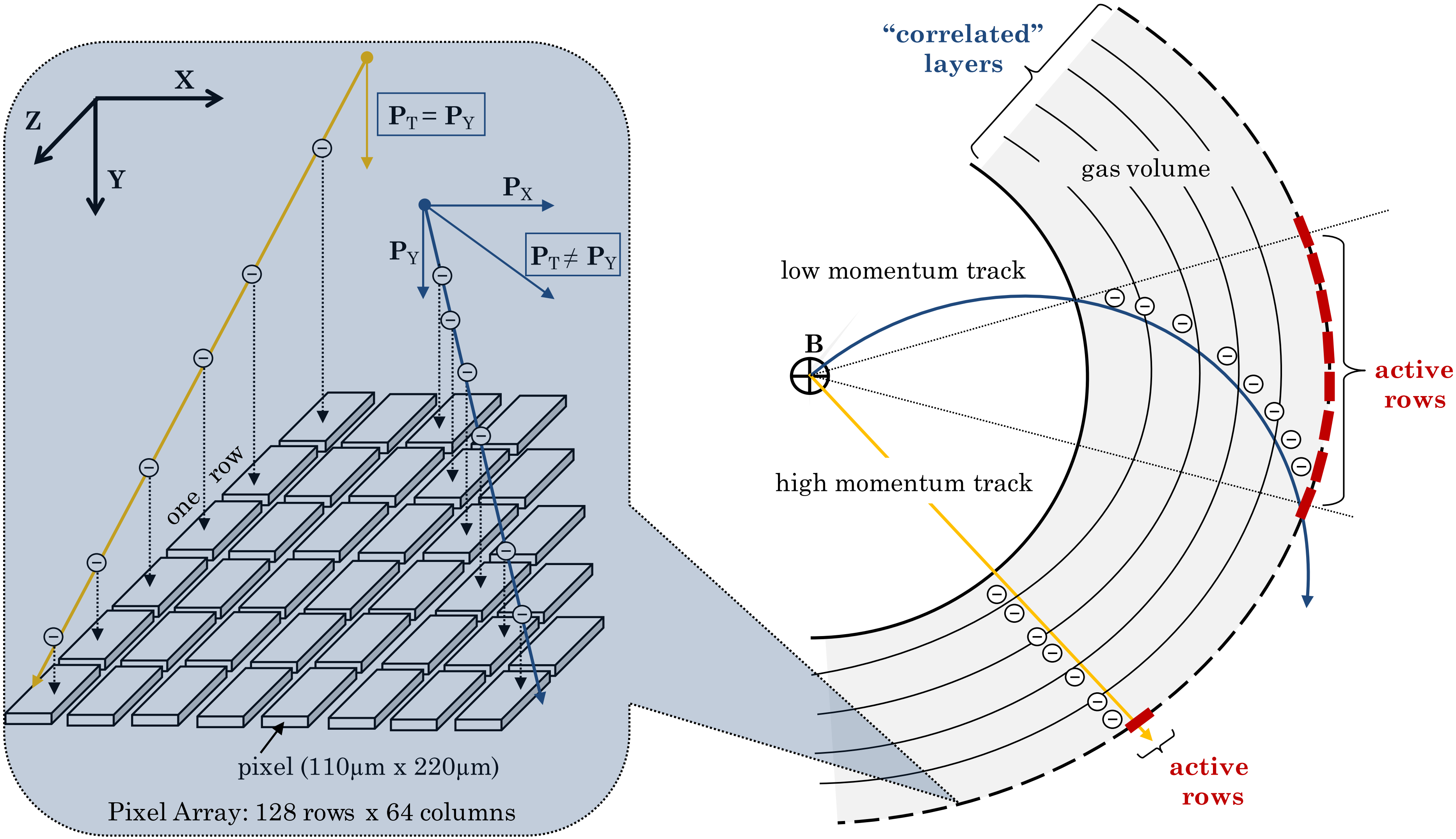
GridPix: Gaseous Pixel Detectors

Gas-avalanche detector combining a gas layer as signal generator with a CMOS readout pixel array



- particle track image (projection)
- 3D track reconstruction

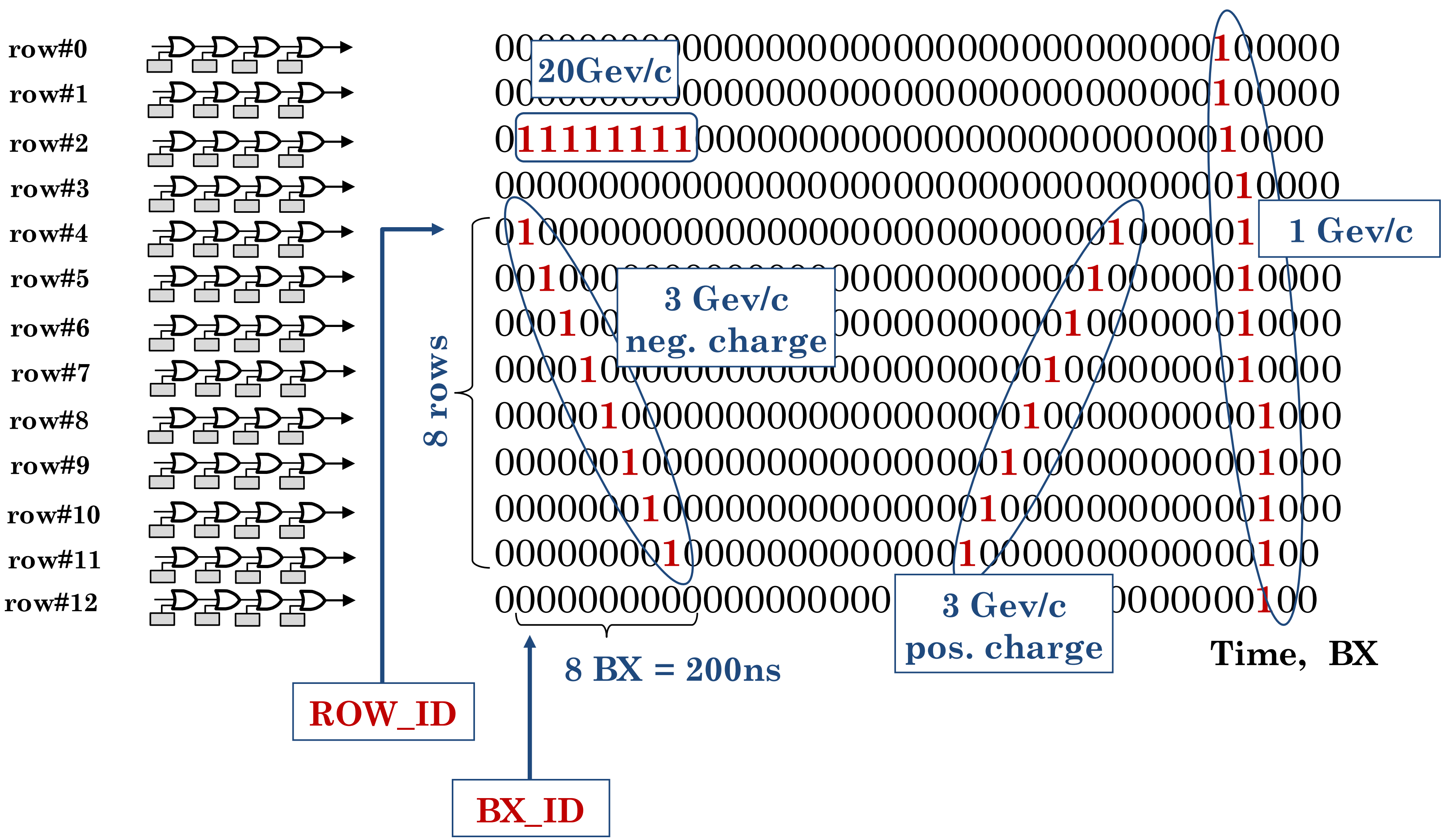
High- and Low- momentum tracks in GridPix



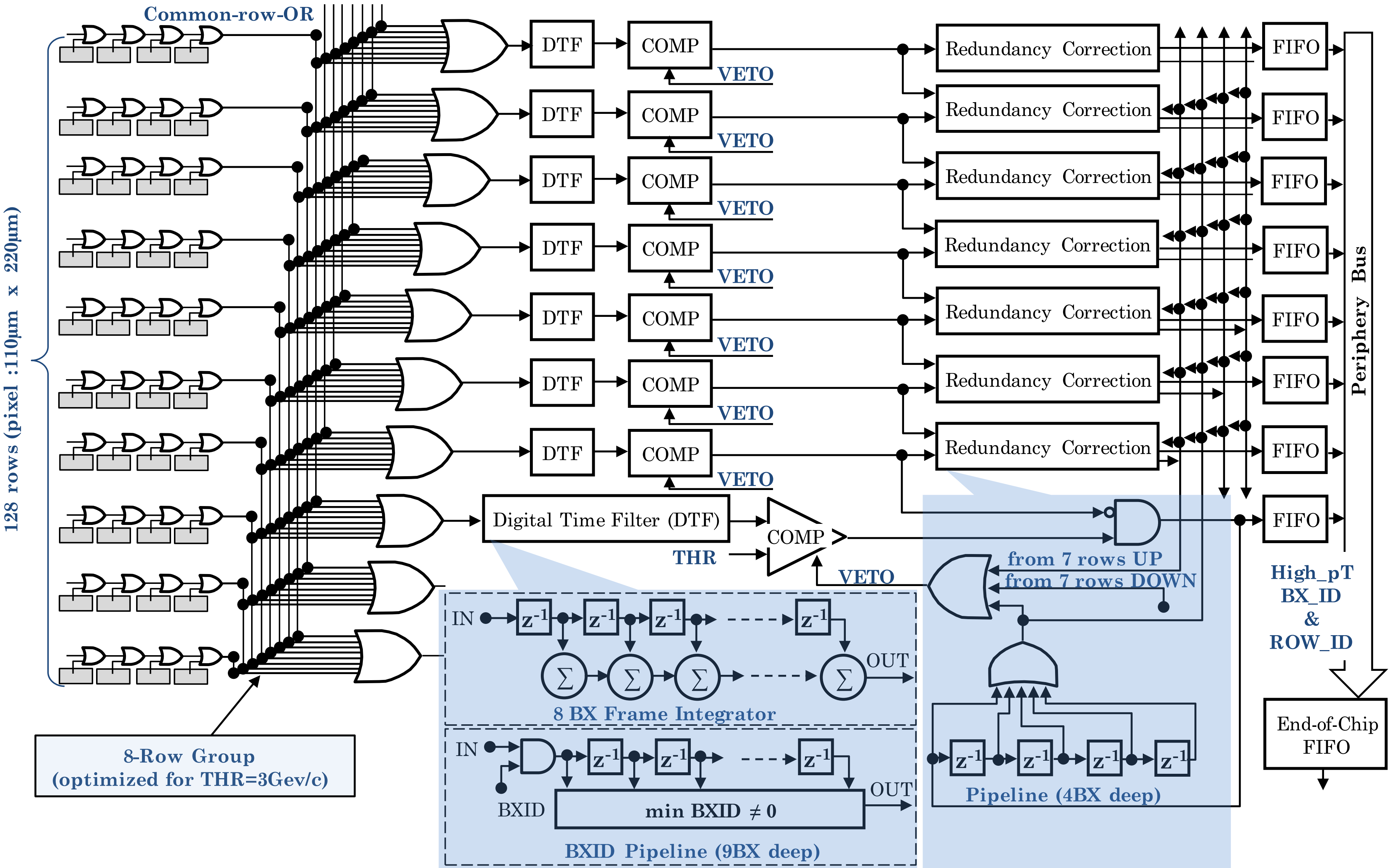
number of active rows can be taken as a criteria for high-momentum track selection

Track response in time domain

Common-Row-OR signals in time

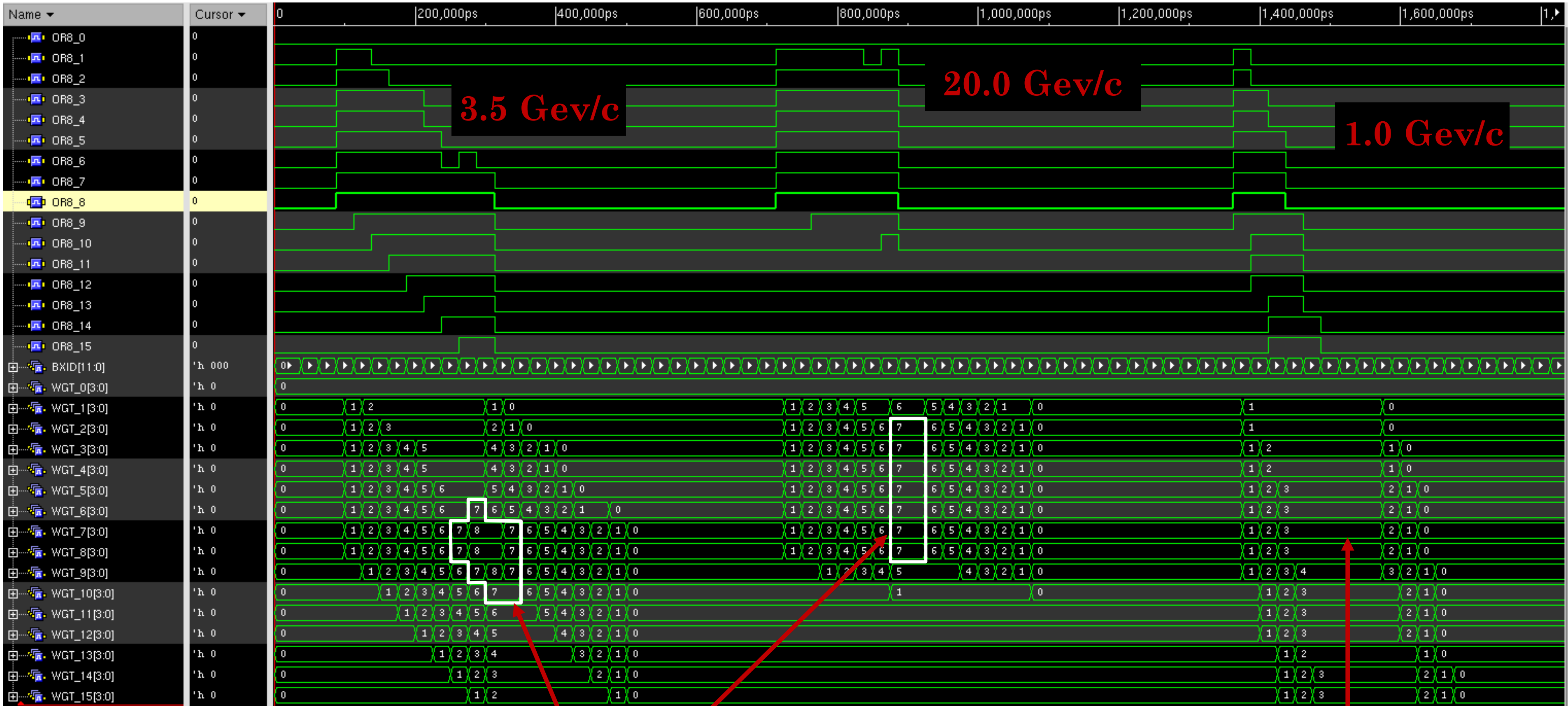


High P_T signal selection algorithm



Inputs from the pixel matrix

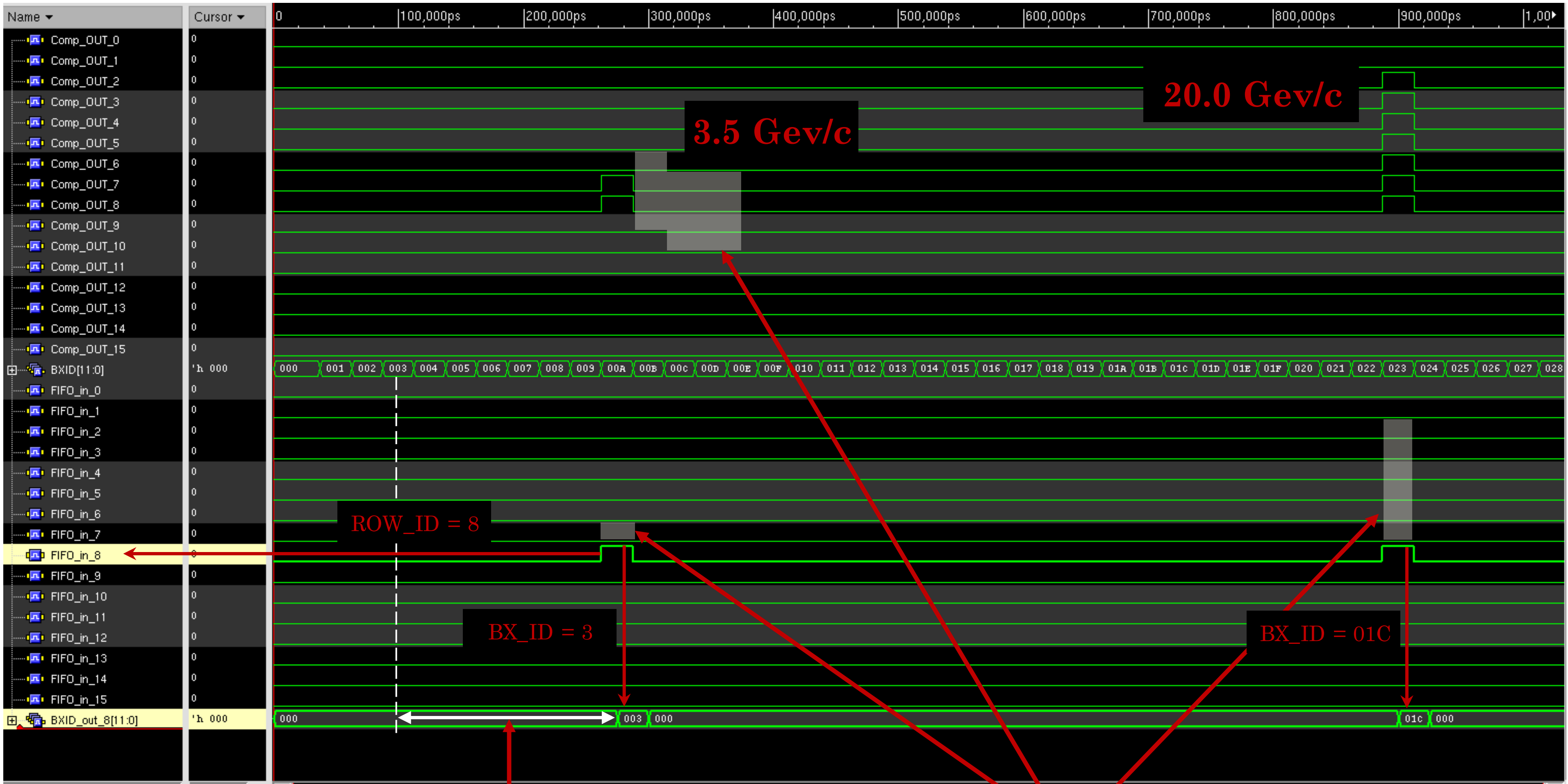
Pixel grouping and integration in time



signals over the threshold

NO signals over the threshold

Redundancy correction

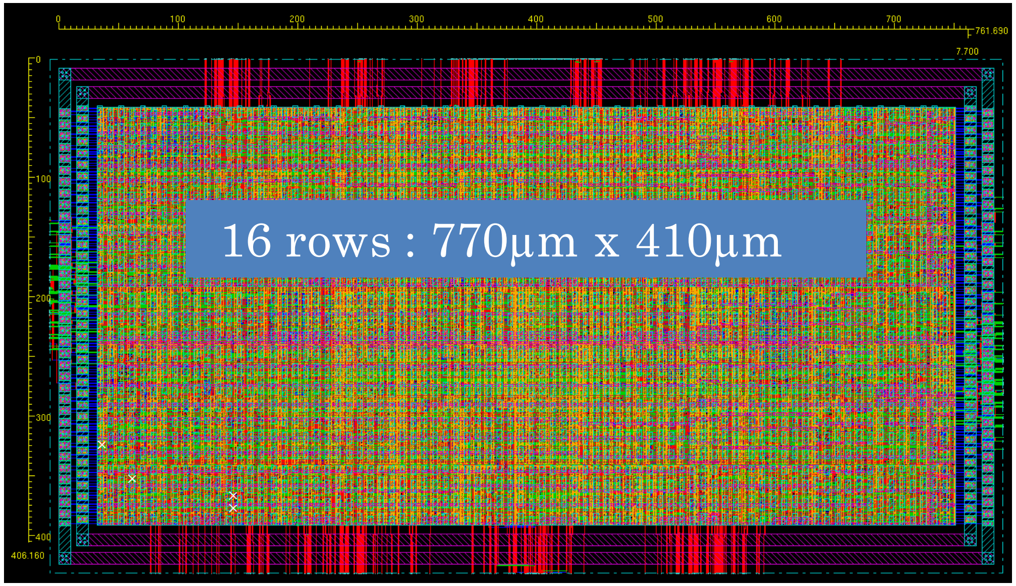


Trigger signal latency = 7BX (175ns)

redundant signals are masked

Physical implementation of the proposed triggering logic

CMOS 130nm technology (ibm_cmos8rf library)



Encounter 09.12-s159_1 (64bit) (Linux 2.6)
Power Domain used: VDD Voltage: 1.4
* Primary Input Activity: 0.200000
* Power Units = 1mW
* Clock: clk_40
Clock Period: 0.020500 usec

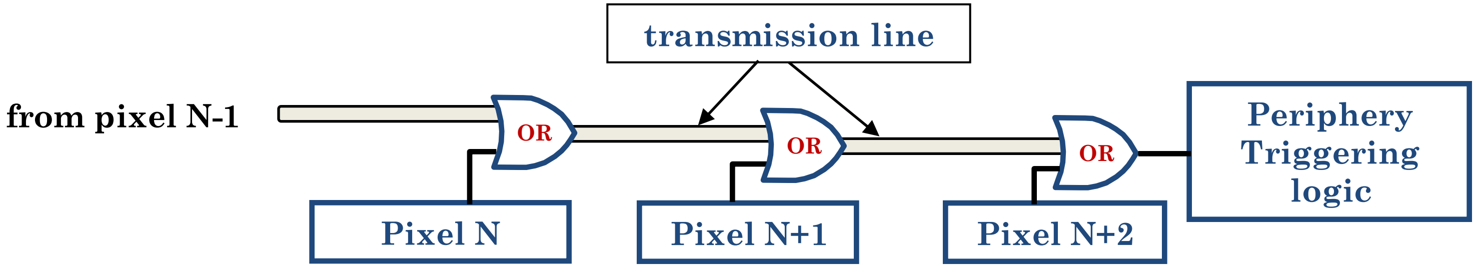
Switching Power	Leakage Power	**Total Power**
2.811mW	2.507mW	**5.318mW**

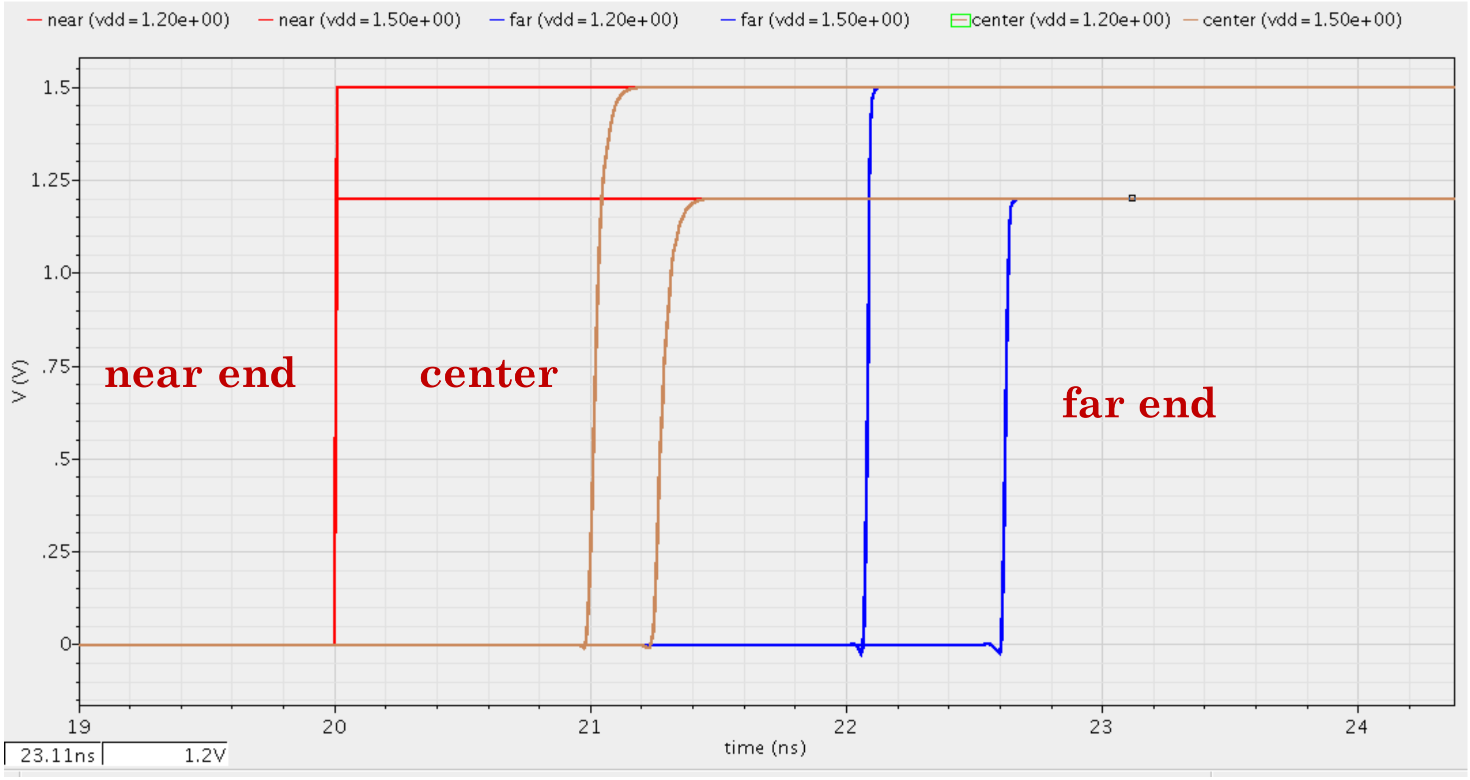
16 rows : 5.3mW

~ 2% area overhead

~100mW/chip power overhead

Common-row OR signal





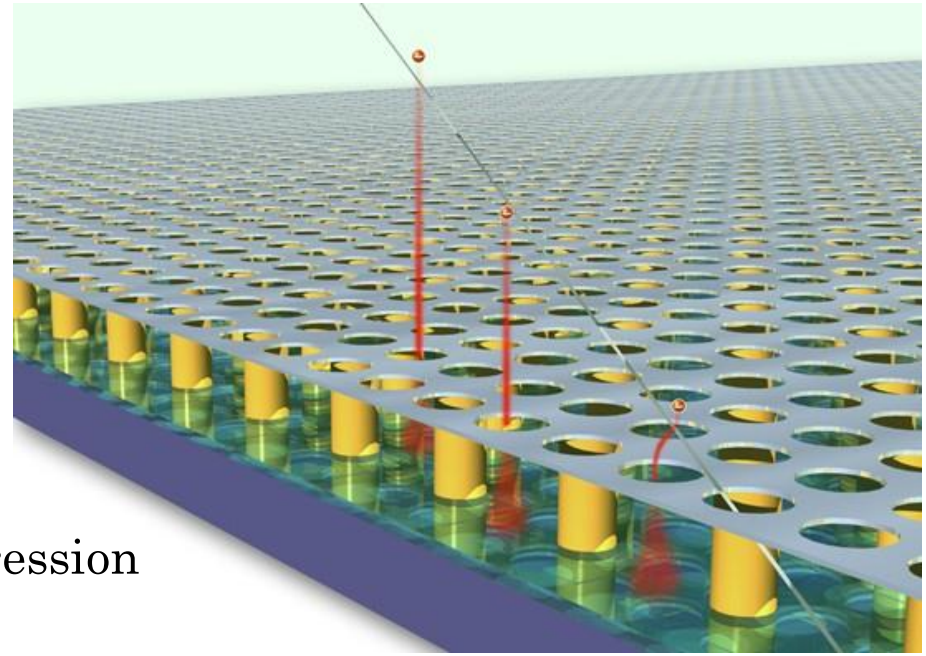
signal skew: 2.6ns

Proposed triggering logic: main features

Feature	
magnetic field	2T
radius to the beam	~1m
number of layers	2
pixel array	128 x 64
pixel size	110µm x 220µm
sLHC rate (at 1m radius)	$0.25 \cdot 10^6$ tracks • sec^{-1} • cm^{-2}
occupancy	~ 4 kHz / pixel
drift gap width	10 mm
charge collection time	200ns (8BX)
high P_T trigger latency	**~ 10BX (250ns)**
data loss	**~ 1%**
trigger logic area overhead	~2%
trigger logic power overhead	~100mW

Timepix3 pixel readout chip

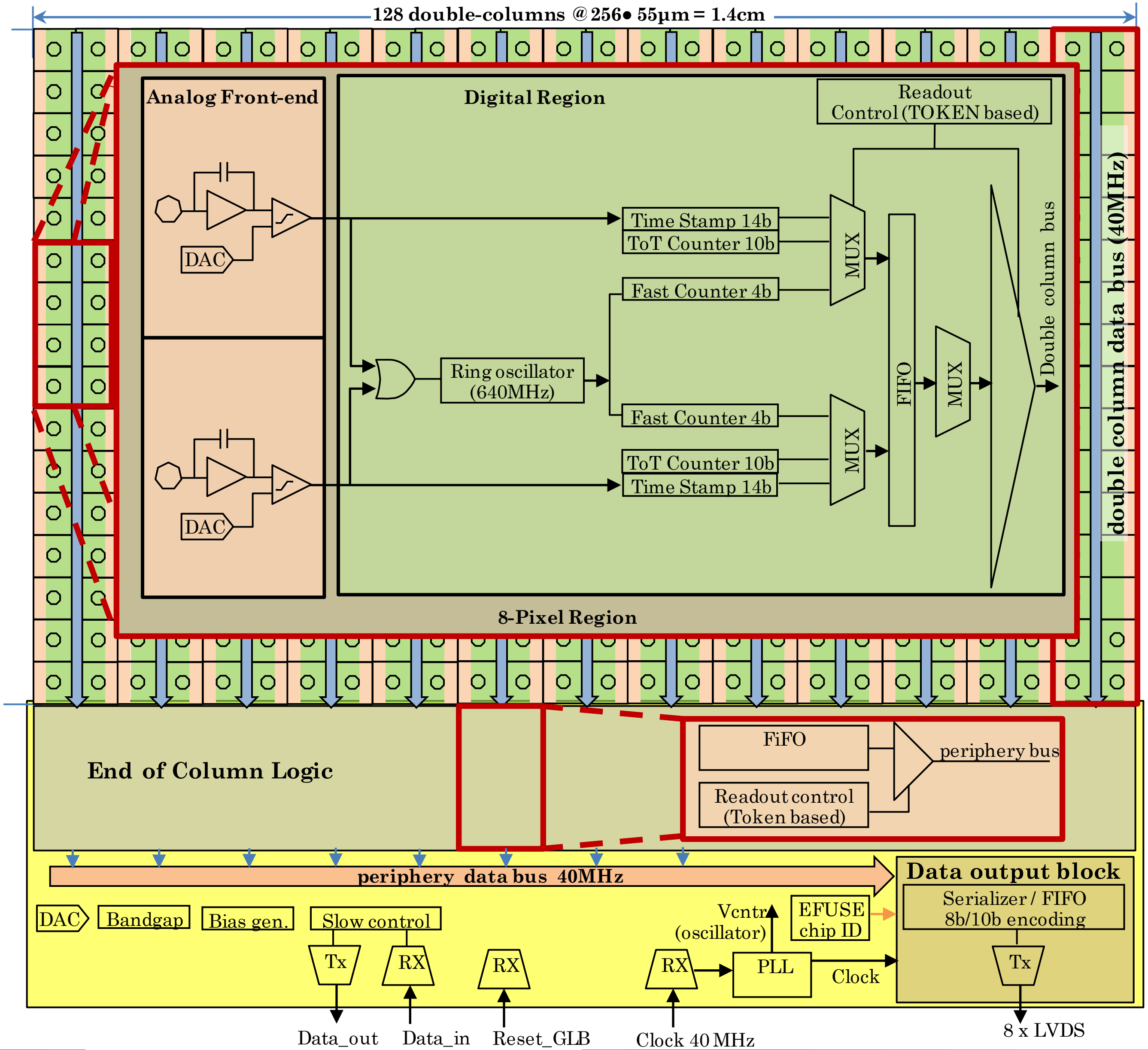
General purpose chip for Medipix3 collaboration



- suitable for GridPix detector
- modes of operation : 3
- pixel matrix : 256 x 256 (2 cm^2)
- pixel size : 55μm x 55μm
- pixel grouping : super pixel (4 x 2)
- minimum threshold: > $500e^-$
- TDC per pixel: 100μs @ 1ns
- charge meas. per pixel : ToT @ $100ke^-$
- continuous sparse data readout with zero-suppression
- output bandwidth : 2.56Gbps
- count rate : up to $20 \cdot 10^6$ $sec^{-1} \cdot cm^{-2}$
- data transmission : 8b/10b encoded
- power consumption : 20W/pixel (1.3W / chip)
- floorplan : one side periphery
- through-silicon-via : yes
- expected submission : 2012
- **NO triggered data readout**

Timepix3: top level block diagram

- Super Pixel: 8pixels @ 4 x 2
- 64 Super Pixels in a DC
- 128 Double Columns (DC)
- Super Pixel FIFO : 2-events
- DC bus: 40MHz @ 5b
- End-of-DC FIFO: 4-events
- Periphery bus: 40MHz @ 44b
- Output Serializer / FIFO

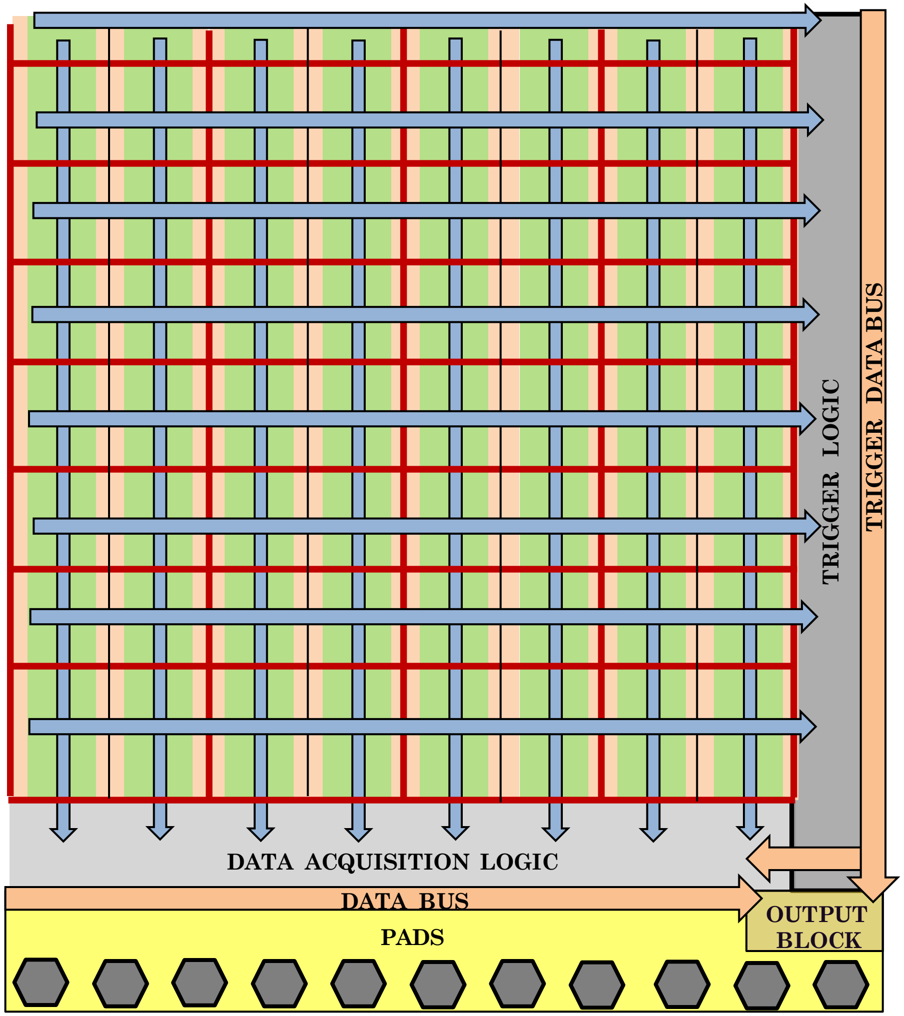


TriggerPix: a future pixel readout chip

Accurate track measurement using self-triggering capability for HEP and medical applications

Functionality:

- serves as a source of the Trigger signal for external systems
- standalone identifies and measures parameters of interesting tracks
- used for alignment of medical irradiation facilities



Summary

- Gaseous Pixel Detector (GridPix) have a great capability for finding of high momentum tracks

- we tested a preliminary version of the track finding logic, which is feasible to implement in CMOS 130nm technology

- the proposed solution guarantees fast generation (250ns) of the Trigger signal without significant data loss (1%)

- Timepix3 pixel readout chip will be suitable for readout of GridPix detectors

- this chip could be added with track finding logic to become a Trigger source and obtain self-triggering capability

Spare slides

The TimePix3 chip, currently being designed, is a pixel read-out chip with precision tdc (< 2 ns) recording hit arrival times and time-over-threshold. The read-out architecture [1] allows for continuous and trigger-free readout of sparsely distributed data with the rate up to 20 Mhits cm^-2 s^-1. It is designed for both solid-state pixel sensors and gaseous detectors. When used with gaseous detectors 3D tracking on one chip becomes possible. We are investigating the addition of fast pattern recognition of tracks in gaseous detectors in a successor chip to TimePix3. This includes recognition, without external trigger, of the passage of a particle, filtering of tracks to select only those with the desired angles, and fast measurement of the track. For example, tracks with small tilt angle correspond to high momentum tracks in solenoid-field inner trackers. Being able to select these fast and without external input could have applications at the future upgrades of the LHC detectors. I will discuss the initial results in terms of which algorithms look most promising, with estimates of requirements for the extra electronics in terms of power, data rates, latency, and chip area. [1] V. Gromov et al, "Development and Applications of the Timepix3 Readout Chip", Proceedings of Science (PoS) of the 20th Anniversary International Workshop on Vertex Detectors (19-24 June 2011, Rust, Austria)

Drift and diffusion properties of gas mixture

B.1 Ar/iC_4H_{10} 80/20

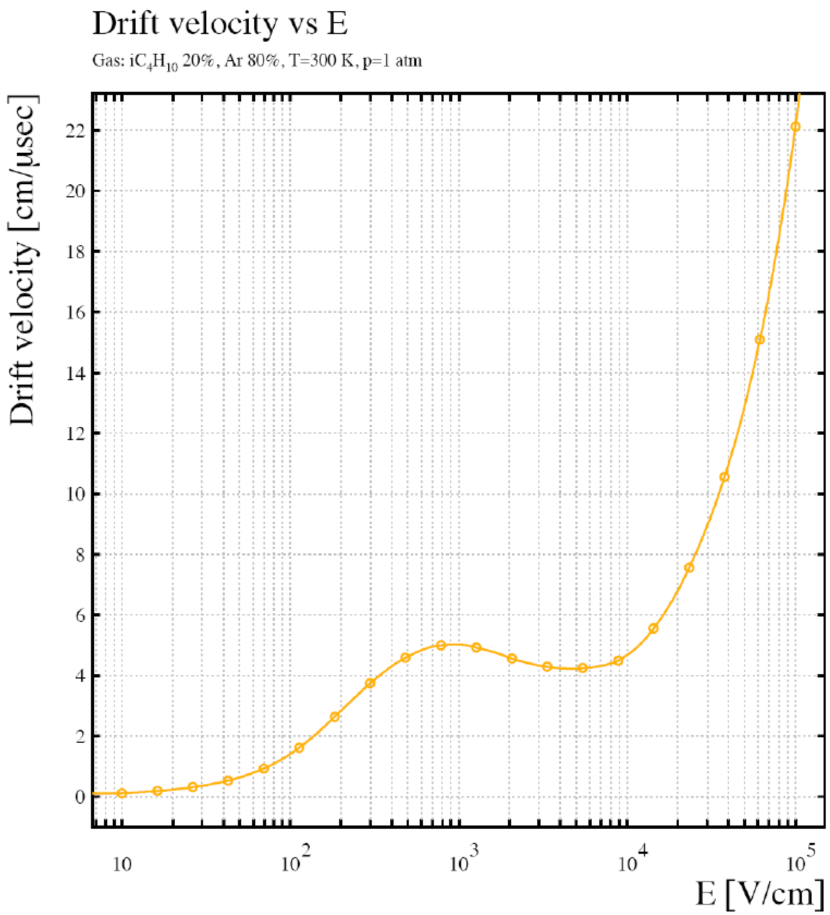


Figure B.1: *MAGBOLTZ simulation of the electron drift velocity as function of drift field.*

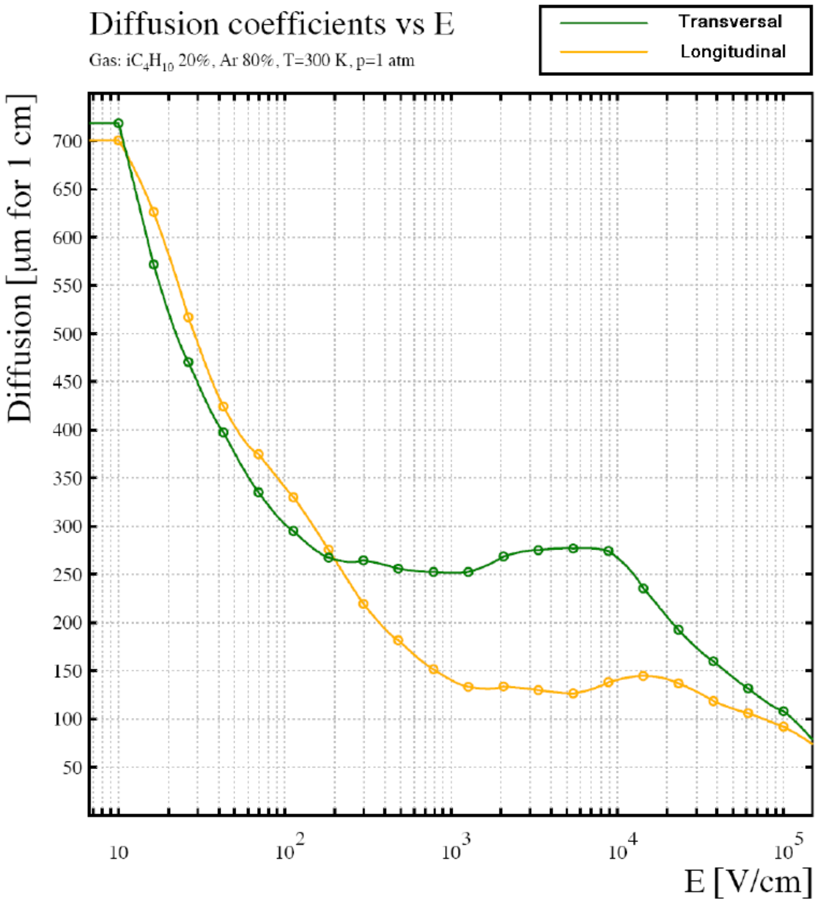


Figure B.2: *MAGBOLTZ simulation of the diffusion as function of drift field.*

Drift and diffusion properties of gas mixture

B.3 CO_2/DME 50/50

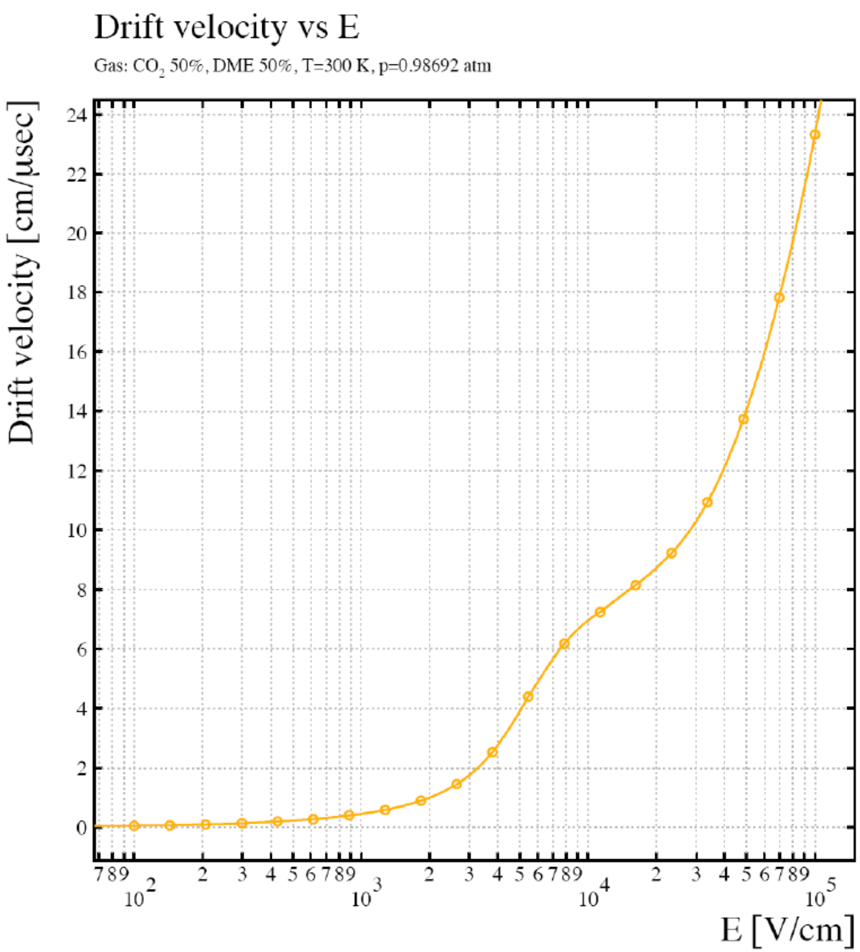


Figure B.5: *MAGBOLTZ simulation of the electron drift velocity as function of drift field.*

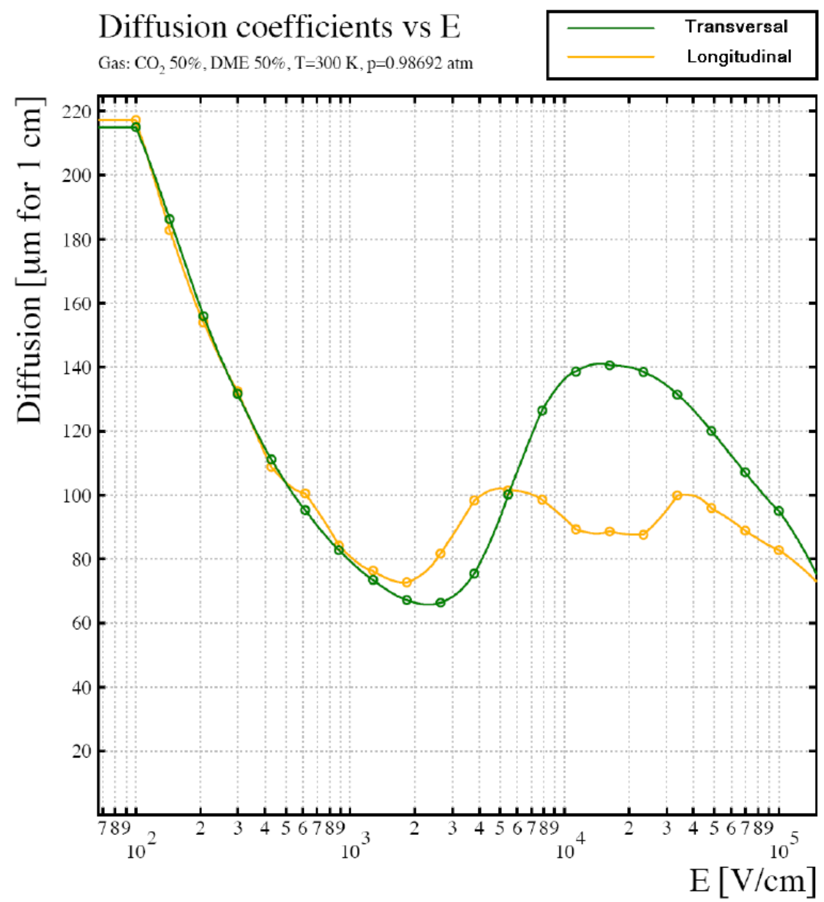


Figure B.6: *MAGBOLTZ simulation of the diffusion as function of drift field.*