Geiger-mode devices for charged particle tracking

J. Trenado[1], O. Alonso[1], A. Comerma[1], M. Vos[2], E. Vilella[1], L. Garrido[1] , A. Dieguez[1]
[1]UB Barcelona, [2]IFIC Valencia

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UNIVERSITAT DE BARCELONA
ICCUB
SIC Sistemes d'Instrumentació i Comunicacions
IFIC INSTITUT DE FÍSICA CORPUSCULAR

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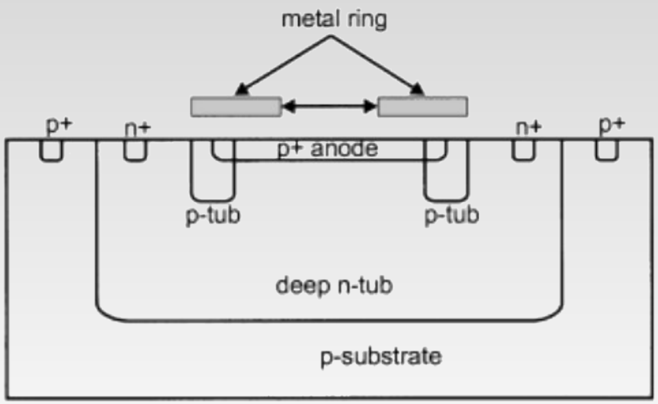
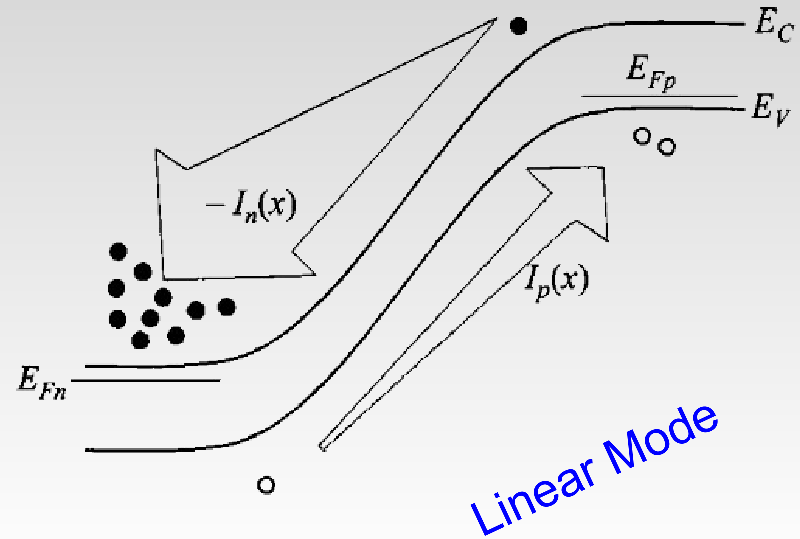
Introduction - Avalanche Photodetectors in Geiger-Mode

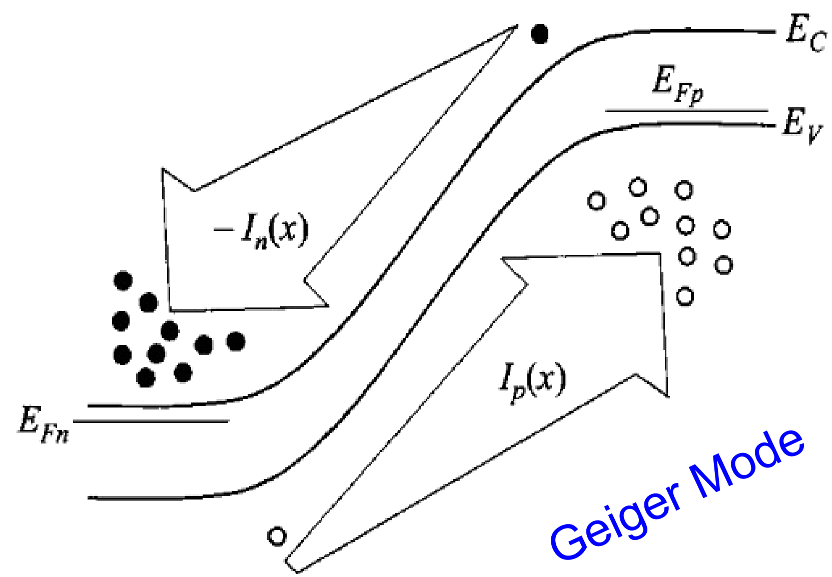




Diode biased above the breakdown voltage.

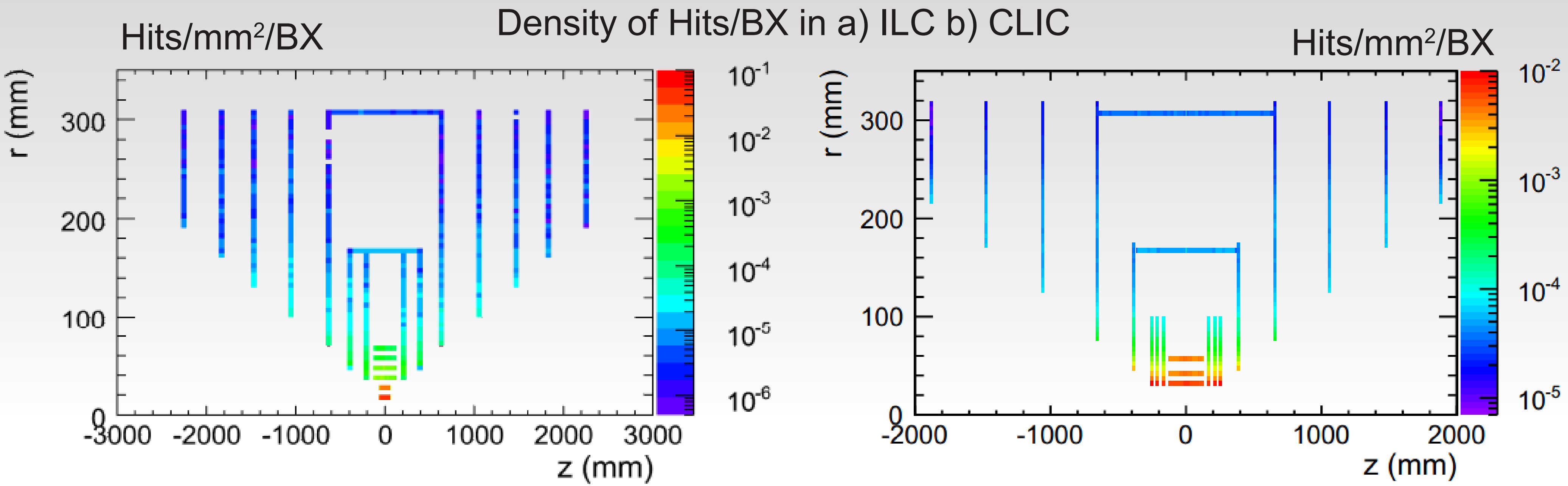
- *Linear Mode:* Biased below the breakdown. Electrons provoke multiplication. Lineal response, proportional to the incident radiation.

- *Geiger Mode:* Biased above the breakdown. Electron and holes provoke multiplication. Binary response.



Introduction - Machine Background in ILC-CLIC

Occupancies

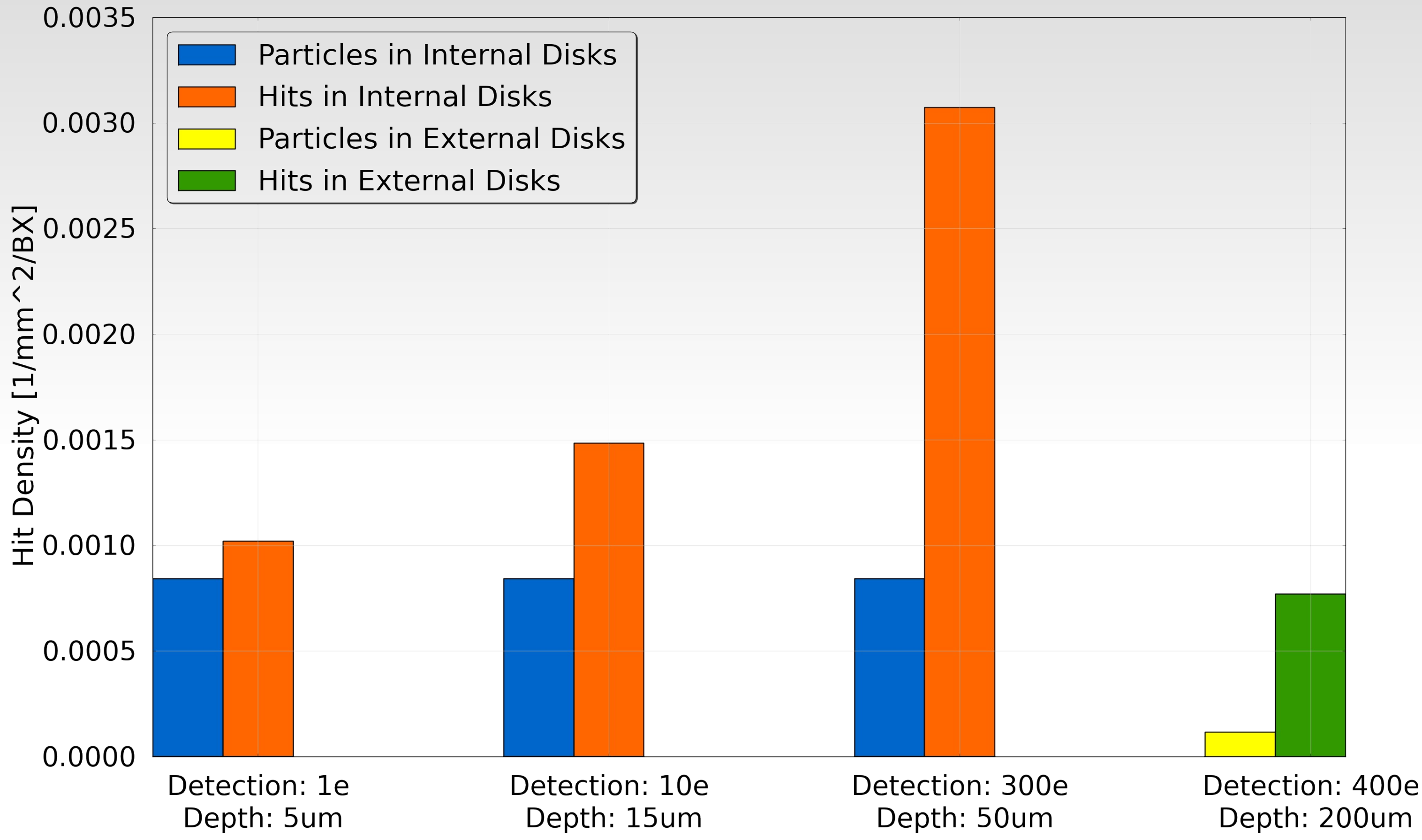


M. Vos et al., Forward tracking at the next e+e- collider, part II (in progress)

	CLIC [Hits/Pixel/BX]	ILC [Hits/Pixel/BX]
VXD	$2\cdot10^{-5}$ - $2\cdot10^{-6}$	$6\cdot10^{-5}$ - $5\cdot10^{-7}$
FTD	$2\cdot10^{-5}$ - $2\cdot10^{-7}$	$3\cdot10^{-7}$ - $2\cdot10^{-8}$
SIT		$3\cdot10^{-7}$ - $8\cdot10^{-8}$
APD Dark Counts (Vop=21.2V; Tobs=30ns): $2.6\cdot10^{-5}$ With overlapping		

Occupancy due to Dark Counts is the same order than the machine VXD

Introduction - Device behaviour vs thicknes and detection threshold.



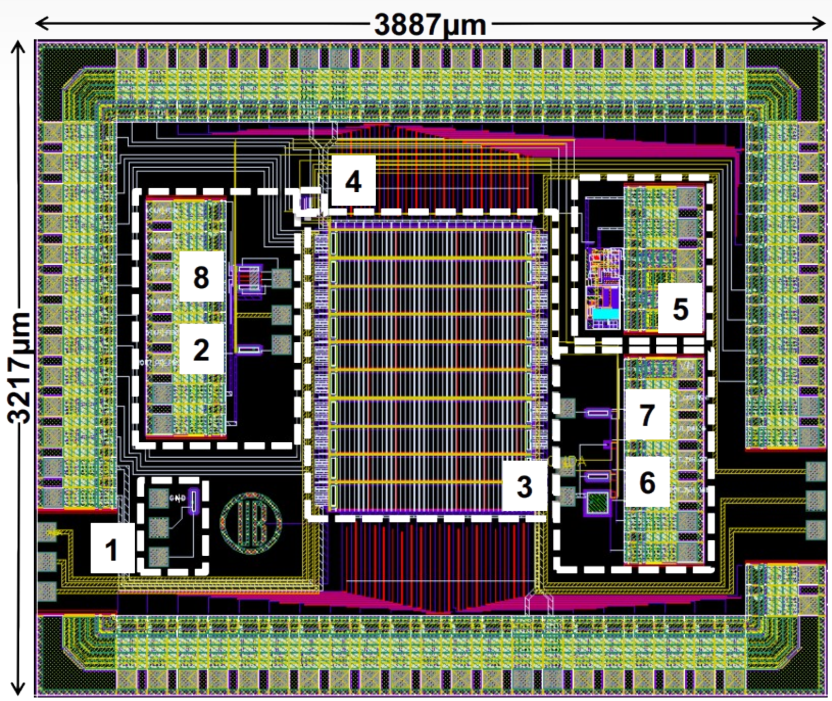
Ultra-thin sensors give rise to low-multiplicity clusters, that will imply smaller pixel occupancy.

CLIC Background Studies and optimization of the innermost tracker elements Dannheim, D. et al. Proceedings LCWS11, arXiv:1203.0942 [physics.ins-det]

First prototype for Test Beam

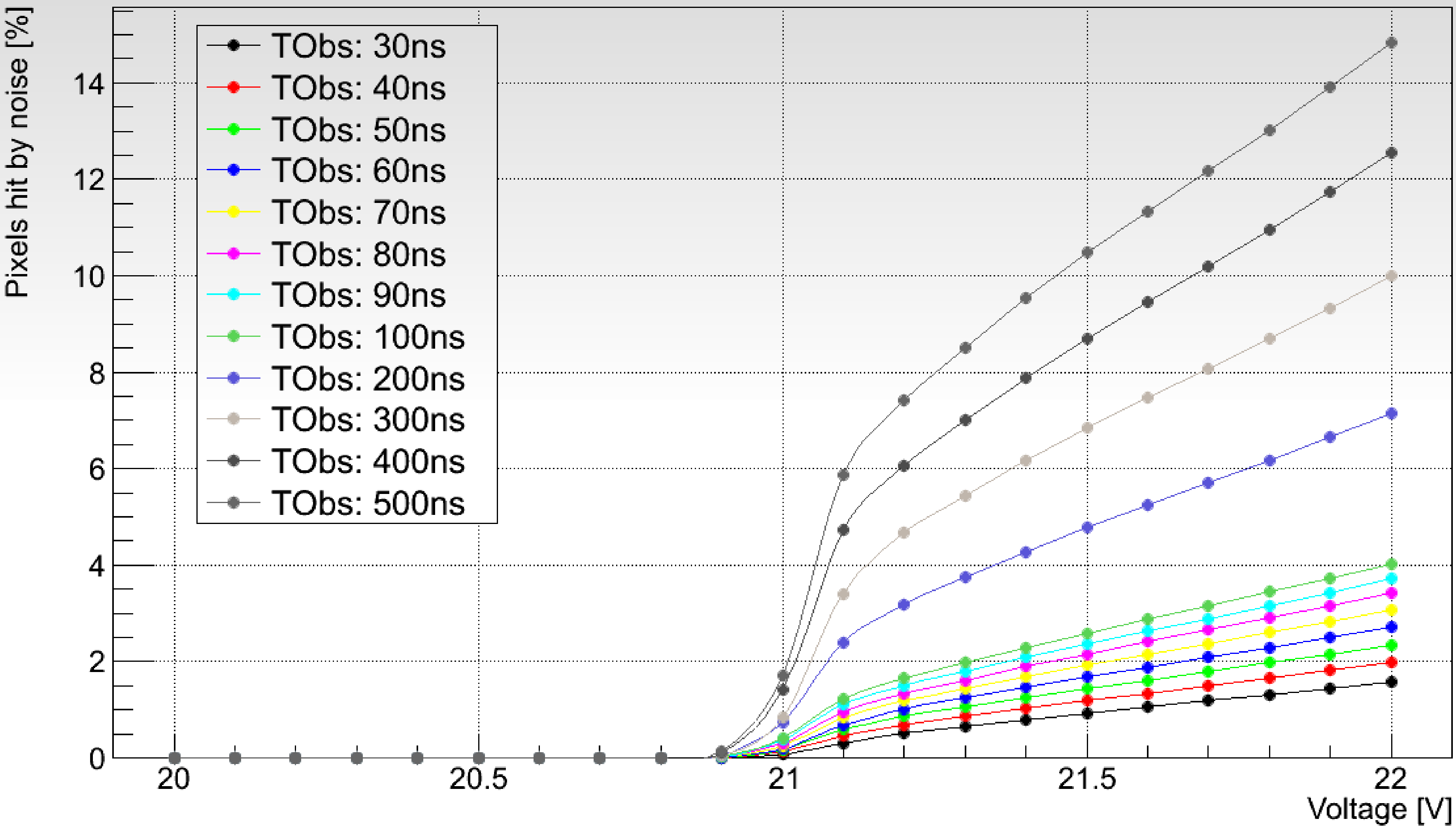
APD Matrix 43x10 pixels. Pixel size: 20x100 μm

- First Prototipe in AMS 350nm. Single devices without electronics and array of 8 pixels with quenching resistor and follower integrated.
- First Prototipe in ST 130nm. Single devices and array.
- First Prototipe for TB: AMS 350nm.



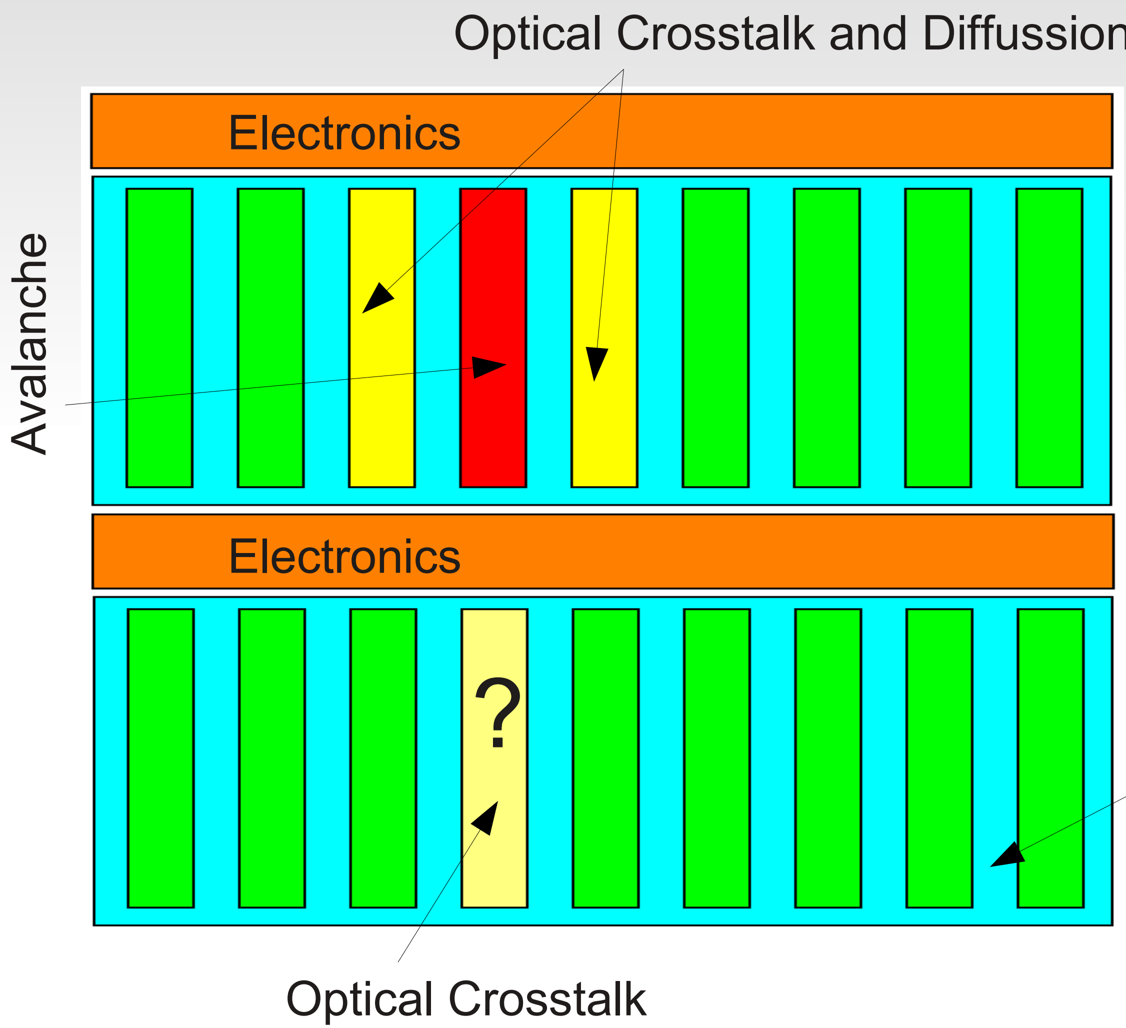
1. Test photodiode
2. Test pixel
3. 10 x 43 GAPD array
4. Control signal generation circuit
5. Pad LVDS
6. Active inhibit pixel
7. Current mode pixel
8. 1 x 5 GAPD array with PAD layer

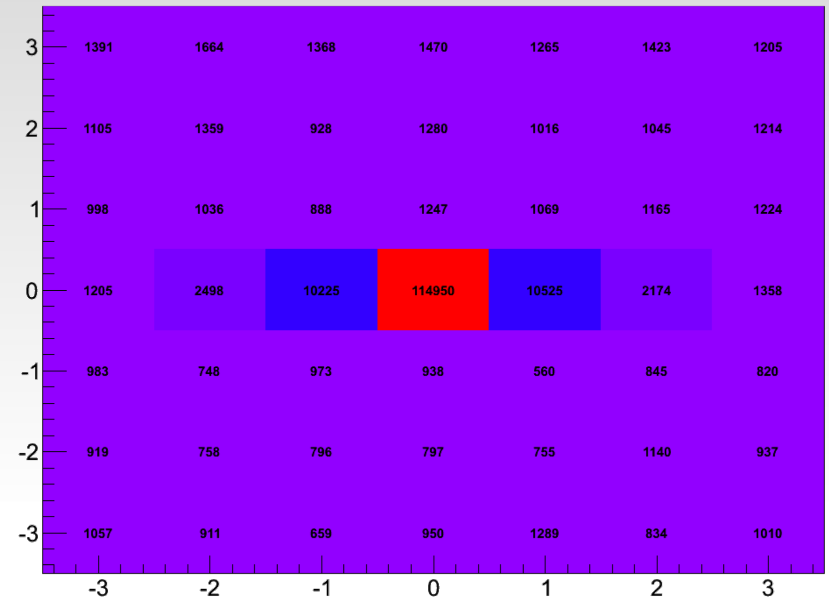
Previous TB – Noise Characterization



4% of noise with overlaping means less than 1 pixel with DC.

Previous TB – Crosstalk Characterization

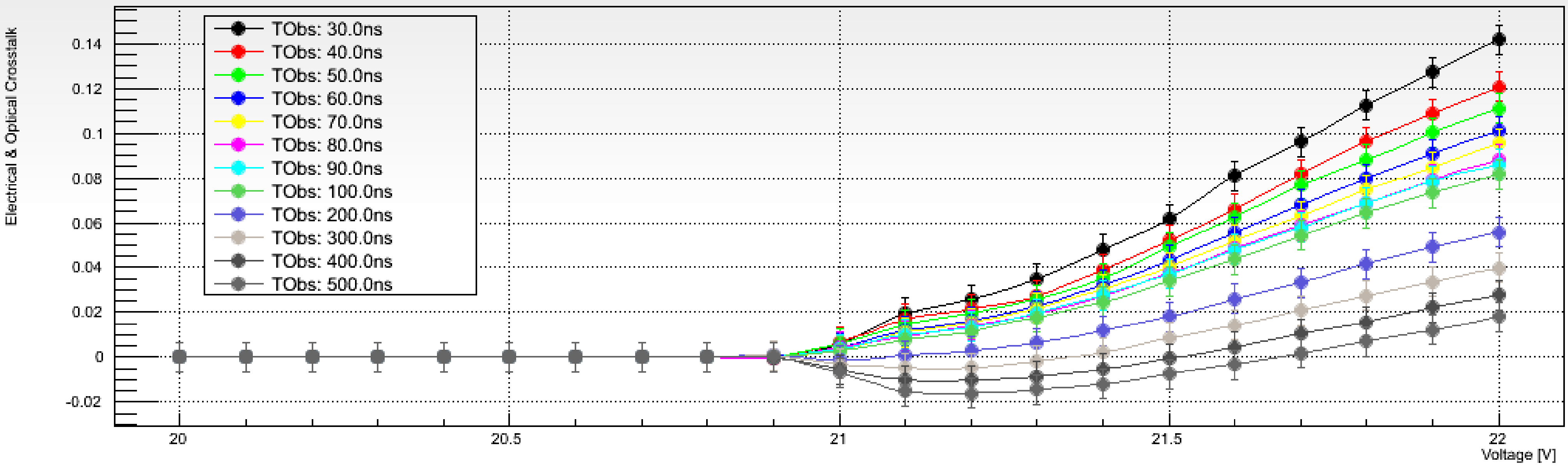




Pixels in the same row share the n-tub

Previous TB – Crosstalk in the Same Well

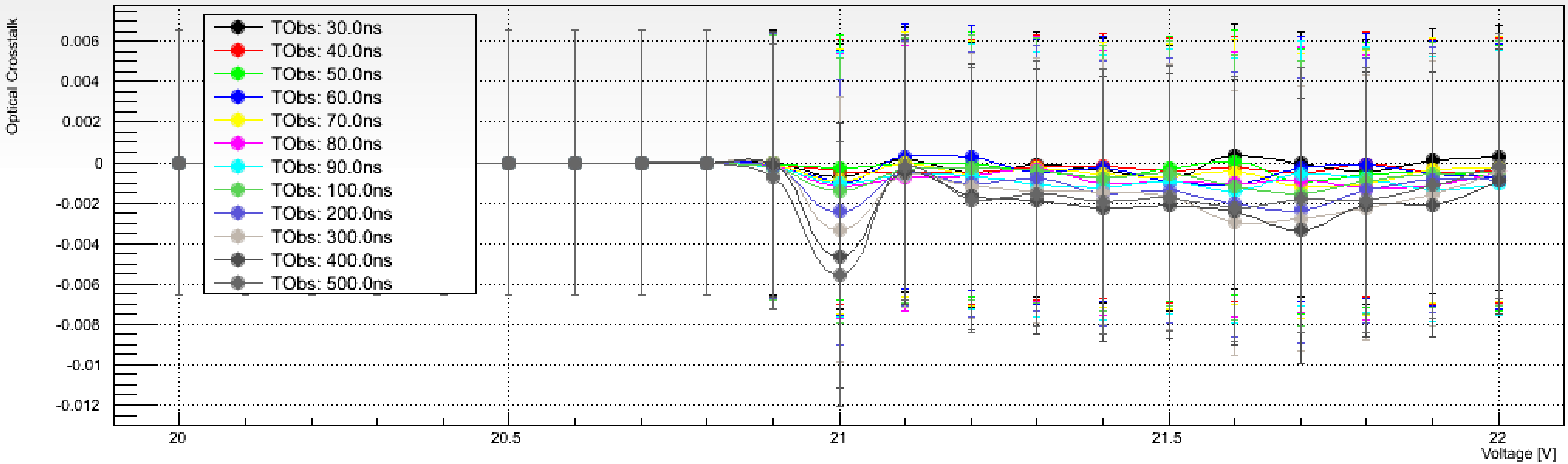
Pixels in the same row share the cathode. Charge from hit pixel can diffuse until its neigbour.



We measure a crosstalk level between neighbouring pixels sharing the same well of 2% (tobs=30ns and Vop=21.2V)

Previous TB – Optical Between Wells

Pixels in different row have electronics between them. An avalanche emit photons that can be absorbed by a neighbour pixel.

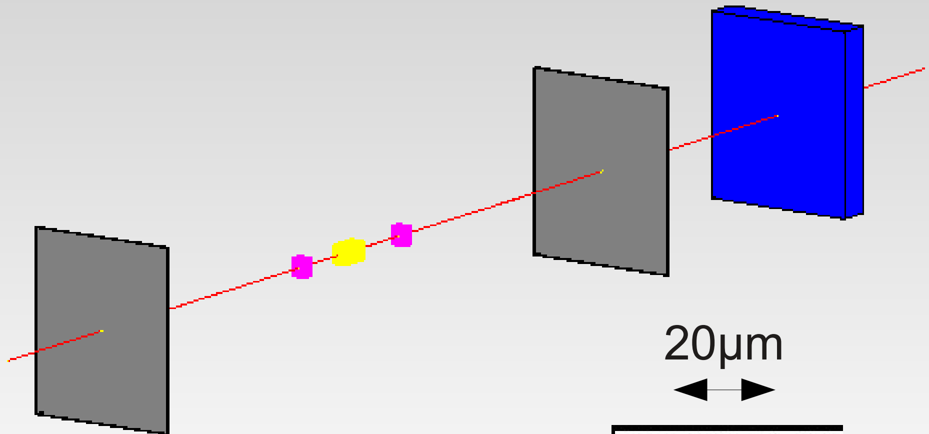


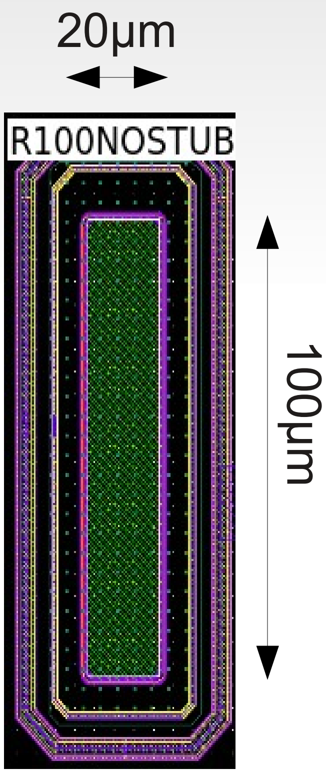
Optical crossstalk is compatible with 0.

Previous TB – TB Simulations

Simulations performed with Geant4.
Setup composed by

- 2 Aluminum layers, 100um thickness.
- 2 Silicon blocks for APD matrix, 250um thickness
- 1 Silicon block for trigger device, 300um thickness.



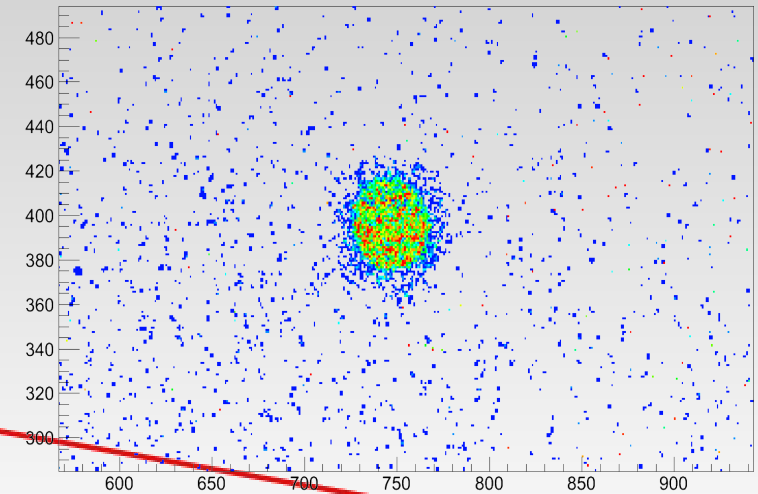


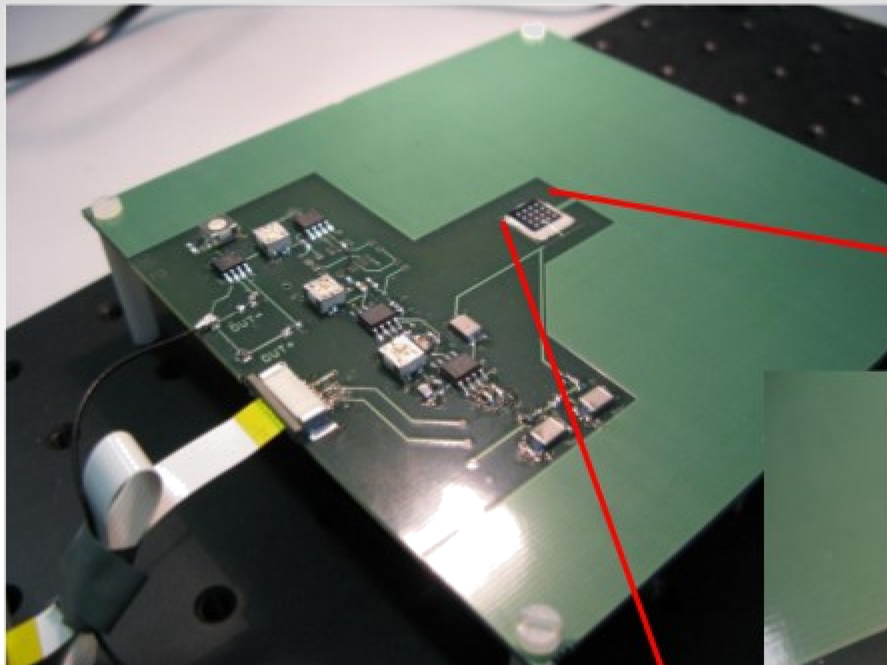
	Pions: 120GeV		Electrons: 6Gev	
	$\sigma_x(\mu m)$	$\sigma_y(\mu m)$	$\sigma_x(\mu m)$	$\sigma_y(\mu m)$
Telescope at 2cm	0,39	0,83	9,31	8,71
Telescope at 10cm	1,18	1,14	56,33	47,84

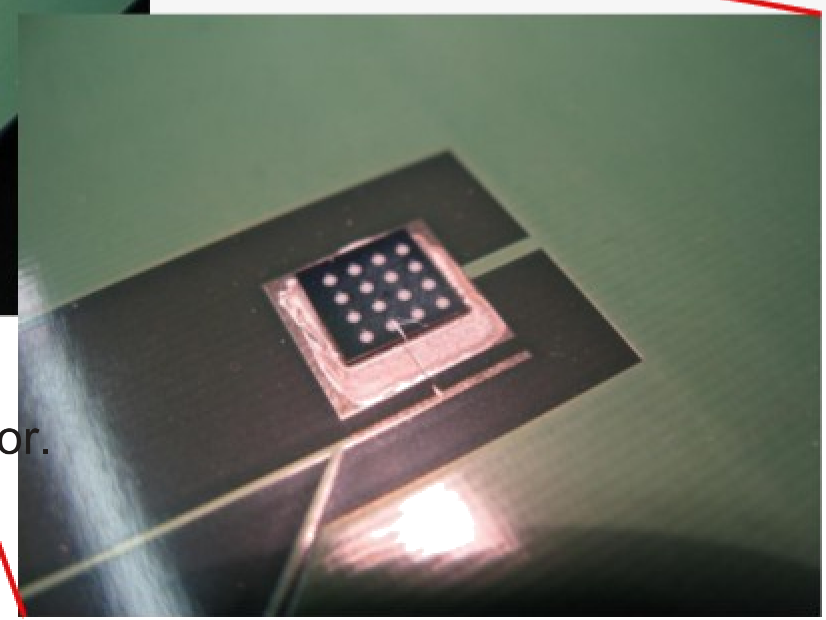
Multiple scattering has a sub-micron contribution to the telescope precision for SPS runs at CERN. Internal structures like guard rings (1.1µm thickness) can be characterized.

At DESY and Bonn the precision (~10 um) permits to obtains global efficiencies.

Test Beam – Setup: CNM Trigger



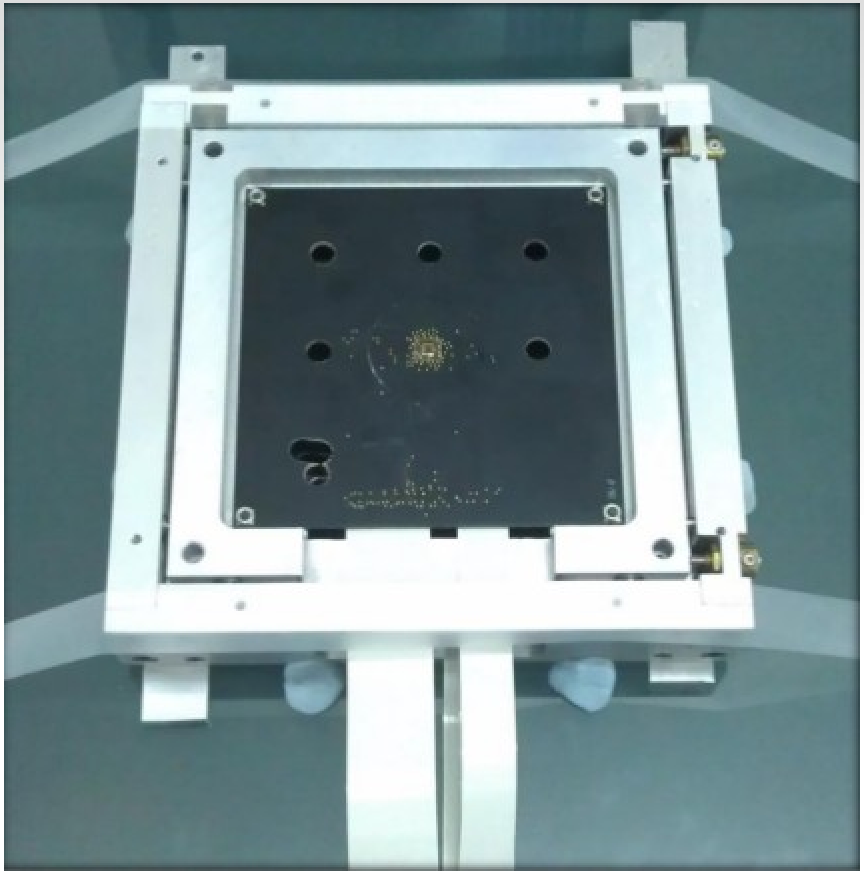


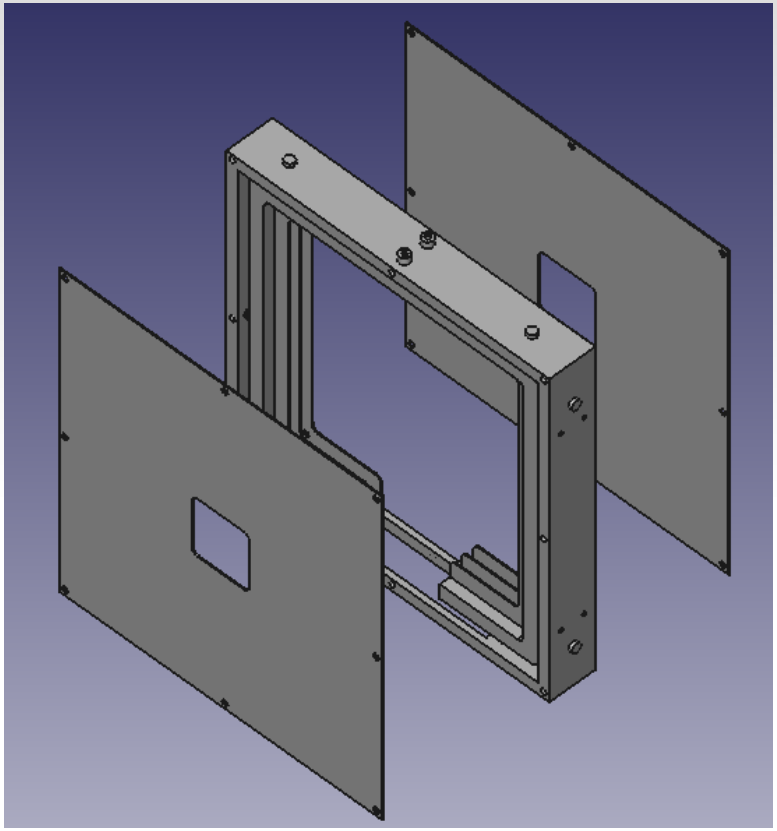


Diode as a trigger based in a Neutron Detector.

Portable Silicon Neutron Detector System
C. Guardiola, J.Rodríguez, C. Fleta, D. Quirion, M. Lozano
Proceedings of the 8th Spanish Conference on Electron Devices, CDE'2011

Test Beam – Setup: Mechanics

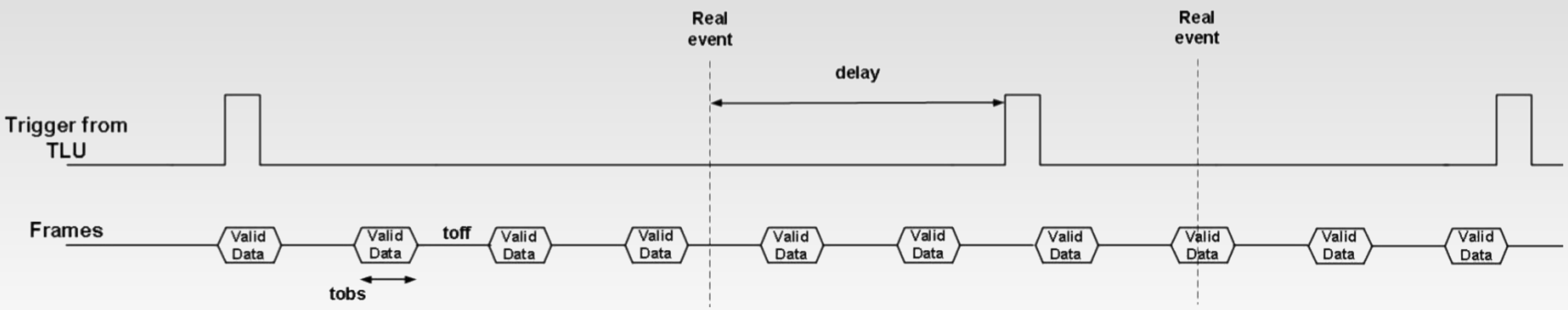




Developed and aligned in Valencia.
Alignment between DUTs and trigger using metrologic optical method.

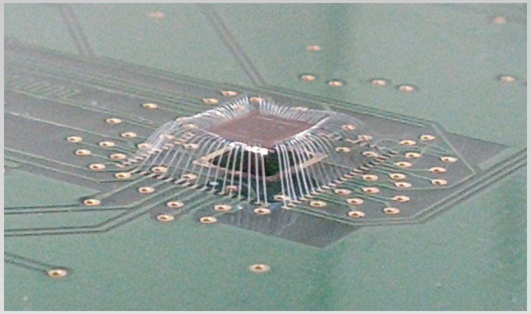
Thanks to J.V. Civera.

Test Beam - Operation Mode



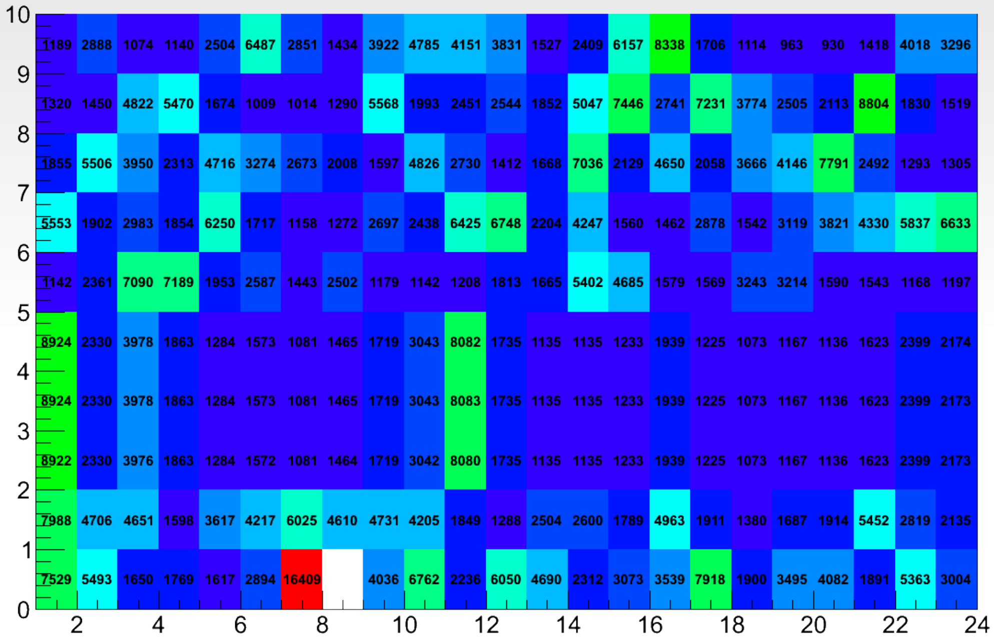
- Min. toff to avoid after pulsing = 300 ns. 1.75 us needed to read and store each frame.
- Min. delay = 27.3 +/- 3 ns + Delay due to the cables
- N frames can be stored to deal with the delay.
- Tobs programmable

Oscar is working to reduce t_{off} to 700ns.



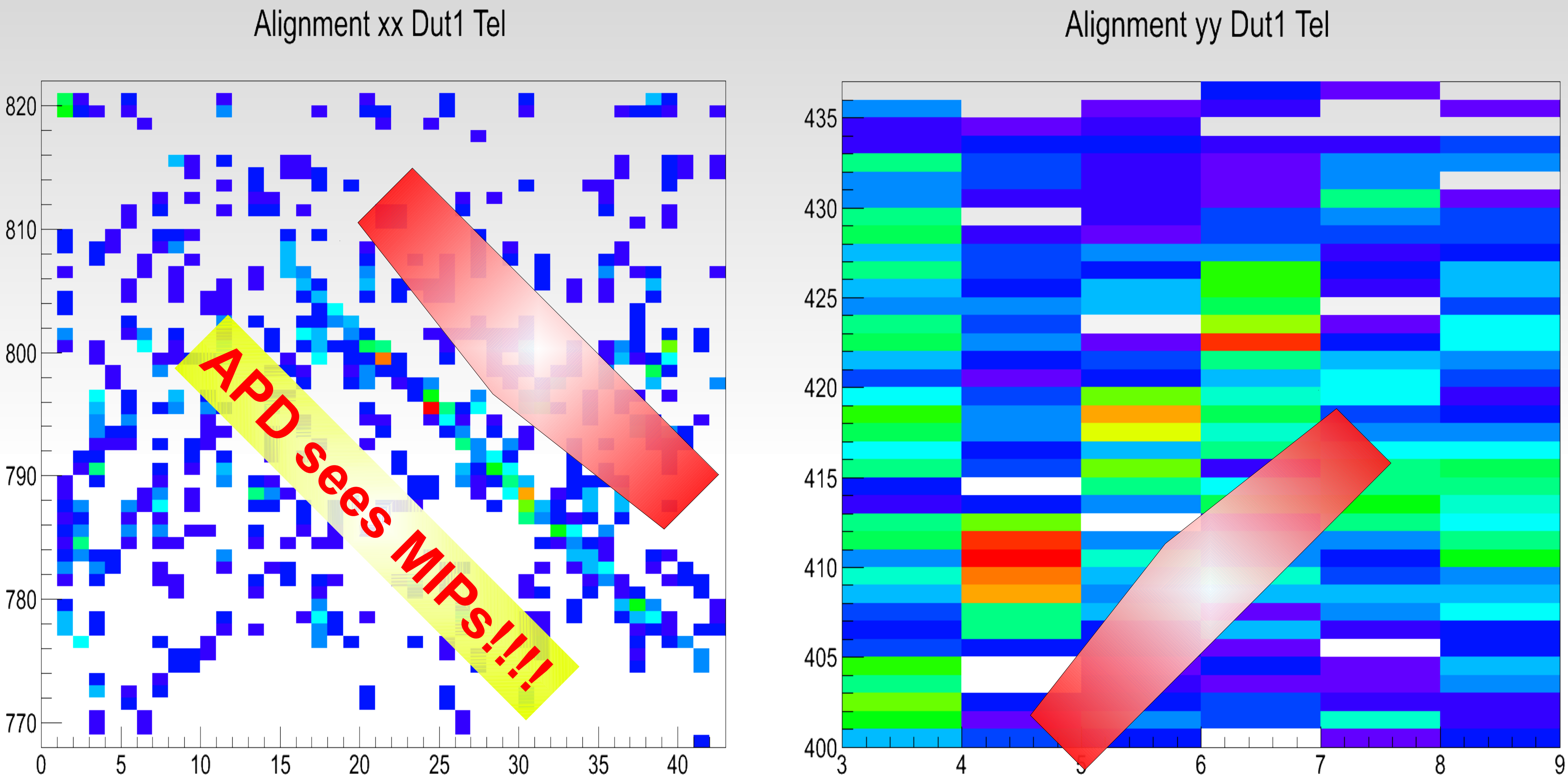
Test Beam - Problems and Solutions

One of the two matrix we carried out broke down before the begining.
The die unsticked from the PCB and the wirebondings supported the chip.
The matrix showed a short circuit in three lines.



With just one matrix we could not remove noise by overlapping. To obtain low level noise we had to work with short observational time and low overvoltage.
We worked with t_{obs}=30ns and V_{ov}=21.2V
APD ran 4 hours with a rate of 5%. We did not have time to resolve the problem of the low rate. The statistic obtained is poor, local eficiencies will not be measure.

Test Beam - First MIP detection



Correlation between the APD matrix and the MIMOSA sensors.

We are trying to analise the data to obtain the efficiency althougth the poor statistics.

Conclusions

- Test Beam
  - APD devices are capable to observe MIP at low overvoltages.
  - The Test Beam in CERN was succesful in the goal to observe MIPS, the problems happened made not possible to make measures of local efficiencies with high statistics.
  - Next TB will be in autumn in DESY, there is the posibility of make a TB in Bonn in spring.
  - Precision in Bonn-DESY will permit measure global eficiencies.

- Irradiación.
  - Literature explain that total reverse saturation current is not resposible of dark counts due to superficial current. It is not possible to make a direct deduce of the effects of irradiation. We expect low increment in DC. Would be interesting to irradiate APD with the dosis for ILC, step by step.
  - We had to consider make a new run in APDs AMS 0.35um to perform succesfully the activities during the next year

- Improvements
  - The PCB of the matrix and the FPGA will be redisign to improve mechanical matching and remove low impedance path.
  - The BUSY signal will be redisign to reduce the dead time.
  - The trigger will be change for a bigger one for a better fit with the matrix.
  - Posibility to use ATLAS-FEI4 in Bonn
  - A second setup will be build.