Characterization of the FE chips for the hybrid pixels

Giulia Casarosa

INFN & Universitá di Pisa

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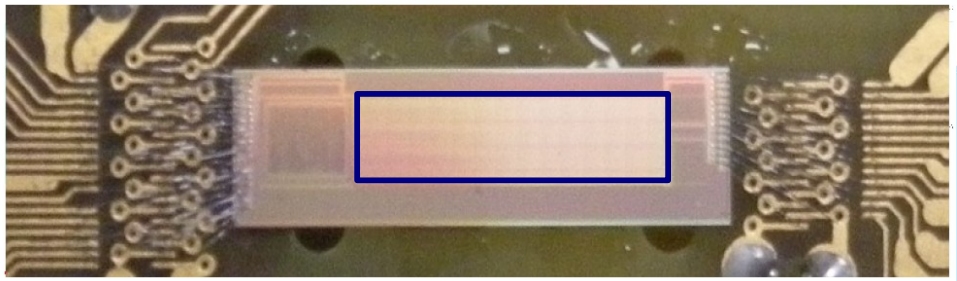
outline

- main features of the FE chip
  - analog cell
  - readout architecture
- tests in lab
  - noise scans and injection scans
- conclusions and plans

overview

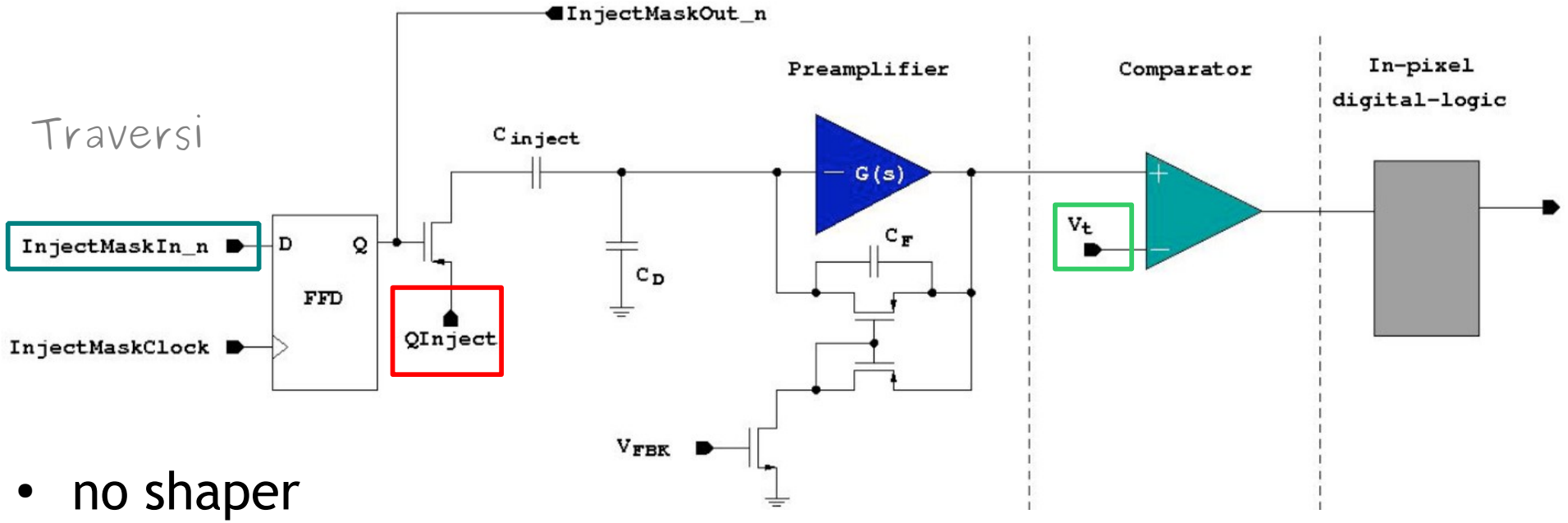
- GOAL → matrix of 256x200 pixels (50x50 μm^2 pitch, active area of 1.3 cm^2) bump-bonded to a sensor matrix (200 μm thick)

- WE HAVE TESTED → several front-end prototype chips of 32x128 pixels with a data-push readout architecture, no sensor connected



analog cell

G. Traversi

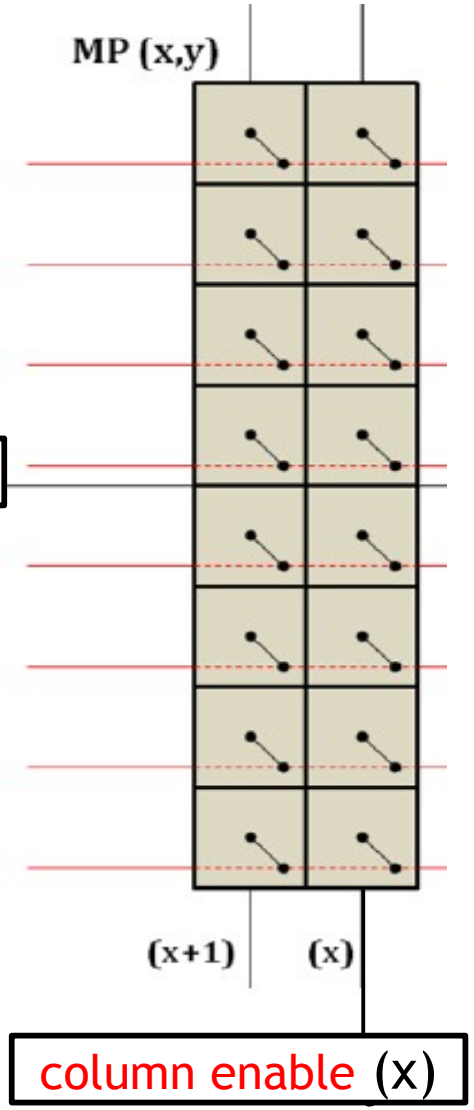


- no shaper
- comparator threshold common to all pixels
- possibility to inject a charge up to 12fC in selected pixels
  - MIP on 200 μm Si → 2.6fC
  - C_{inject} = 10fF
- the output of the preamplifier is carried out and it is accessible (for 2 pixels only)

readout architecture (1)

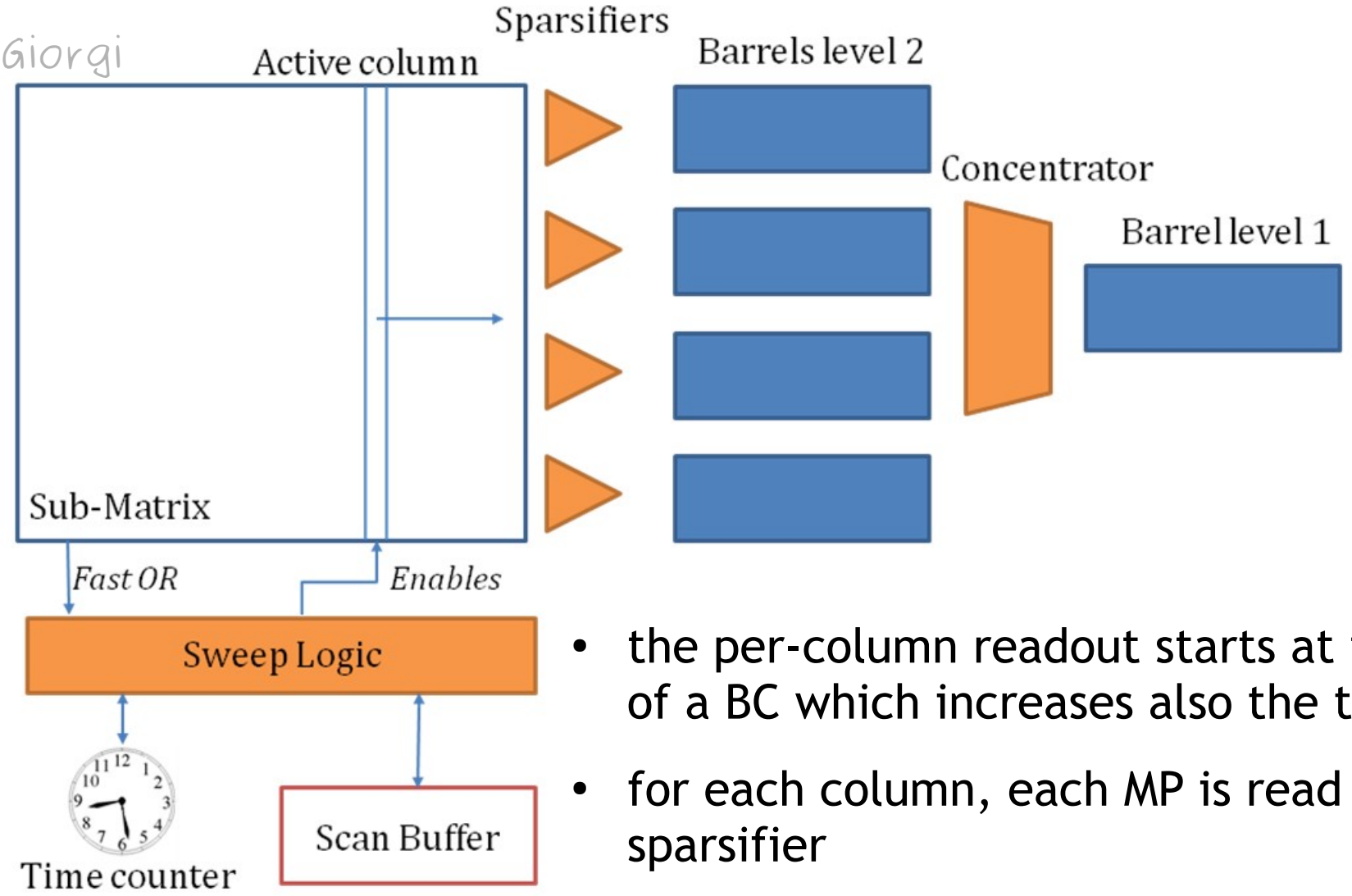
F. Giorgi

- the matrix is divided in 2 submatrices with independent and parallel readout;
- each submatrix is divided in macropixels (MP) 2x8 pixels; each pixel is identified by two lines: data out and column enable
- the MP is active if the latch enable is high →
  → definition of an observation window
- if at least one pixel of the MP is hit, both the columns of the MP will be read and a DataValid (DV) bit is associated to the bytes read from the matrix



readout architecture (2)

F. Giorgi



- the per-column readout starts at the arrival of a BC which increases also the time counter
- for each column, each MP is read by a sparsifier
- informations are collected in barrels and then get out of the submatrix

tests in lab

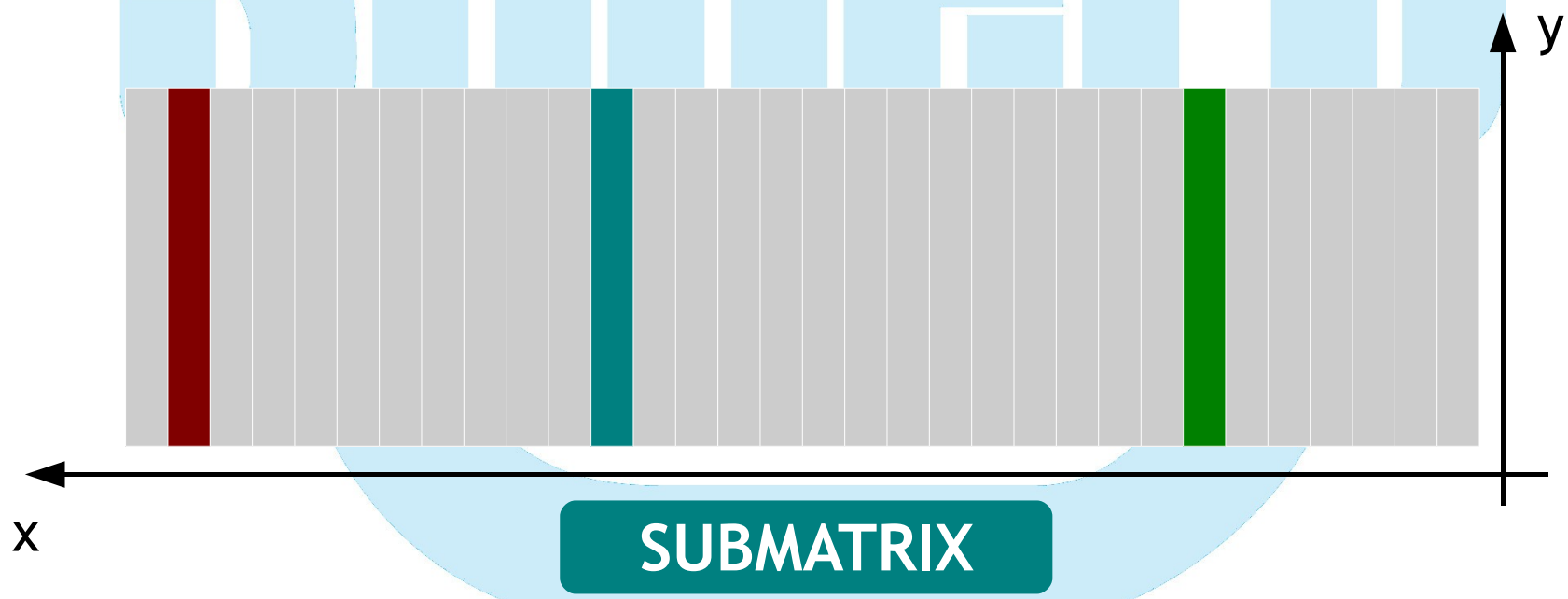
- GOAL → test the readout architecture performances, characterize the analog cell, understand the trend of the most important features along the matrix
  - noise scan → noise parameters
  - injection scan → gain curve

first look

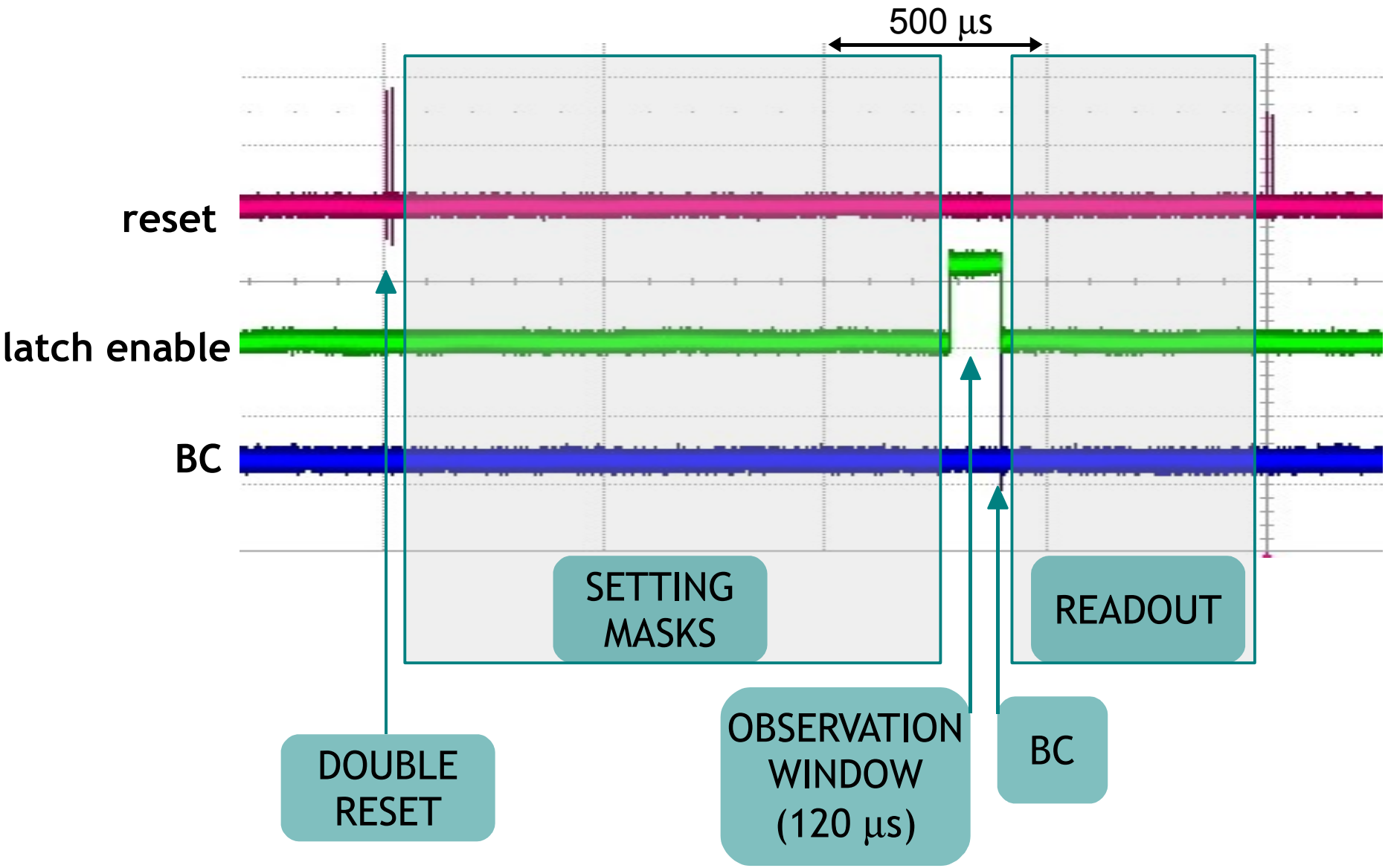
- a little was bug discovered: data out lines are not set to 0 after the readout of the pixels but the sparsifier logic does not take into account this feature;
- the bug is completely understood;
- all the tests of the matrix are still possible: fake hits are eliminated;
- the test procedure is a little bit slower and therefore we have characterized the matrix patchy.

Noise Scans

- GOAL → extract the baseline and the noise parameters (no sensor connected)
- SAMPLE → 3 chips, 3 macrocolumns (MC) for each submatrix
  - MC = 6, MC = 20, MC = 30

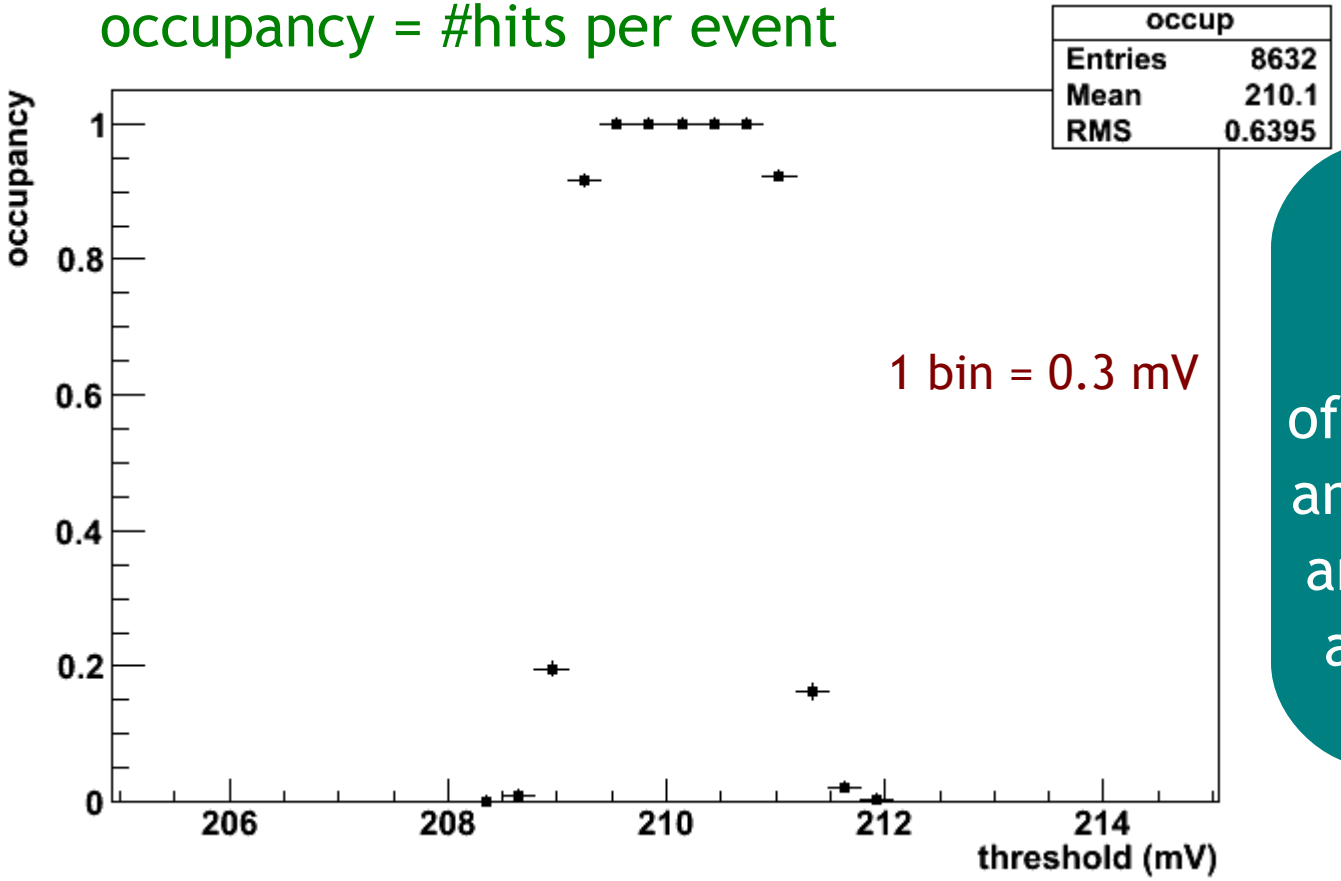


Noise Scan sequence



Noise Scan example

occupancy = #hits per event



we measured the occupancy as a function of the comparator threshold and we fitted the histogram and extracted the baseline and the noise parameters

$$f(thr) = A\{1 - \exp[-\nu_0 T_{obs} \cdot \exp(-1/2\ (thr-\mu)^2/\sigma^2)]\}$$

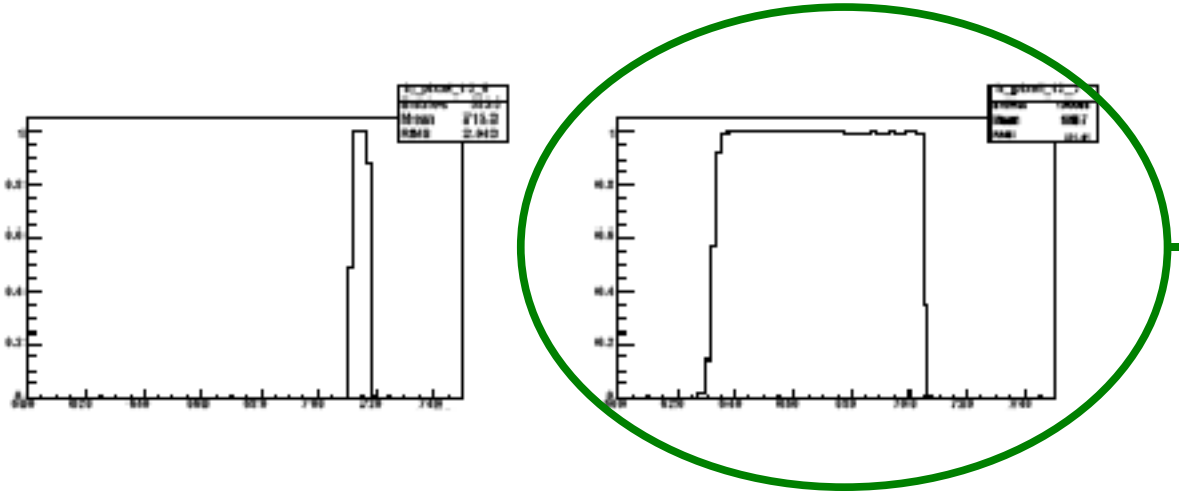
frequency at 0 threshold

observation window (120 μs)

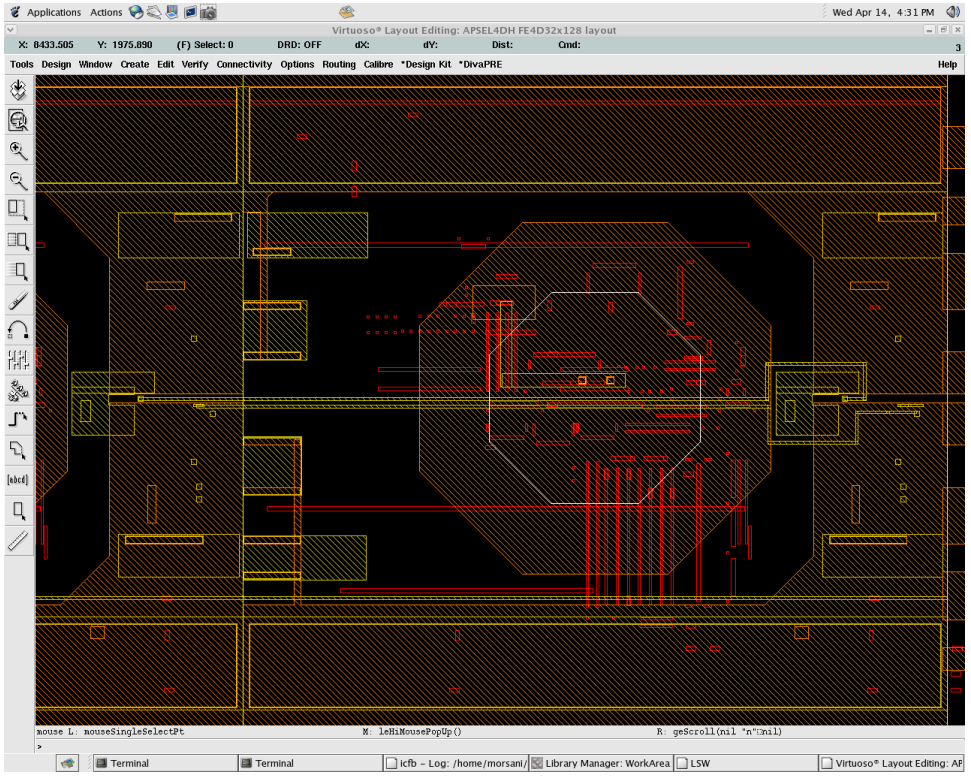
baseline

noise

Larger pixels



this happens for top-right pixels in the MP



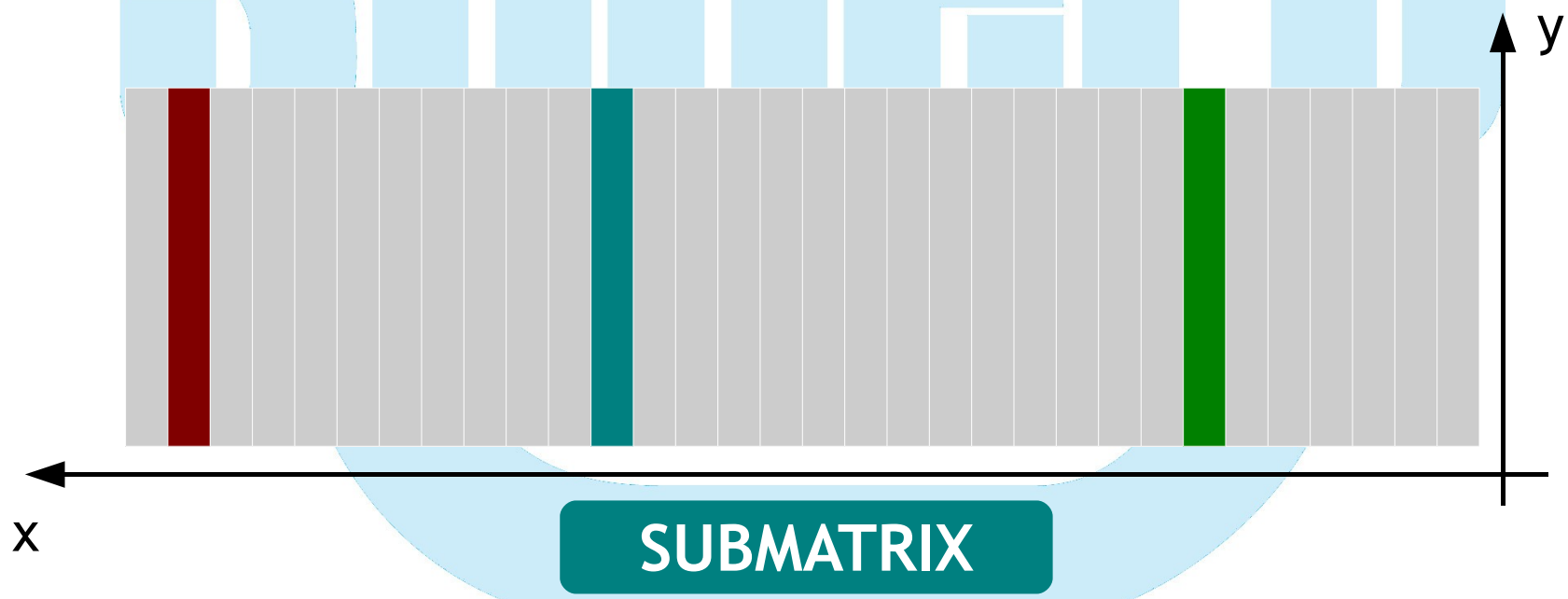
the fast or and the latch enable lines run below these pixels and when they change state its like the pixel is injected

Noise Scan results

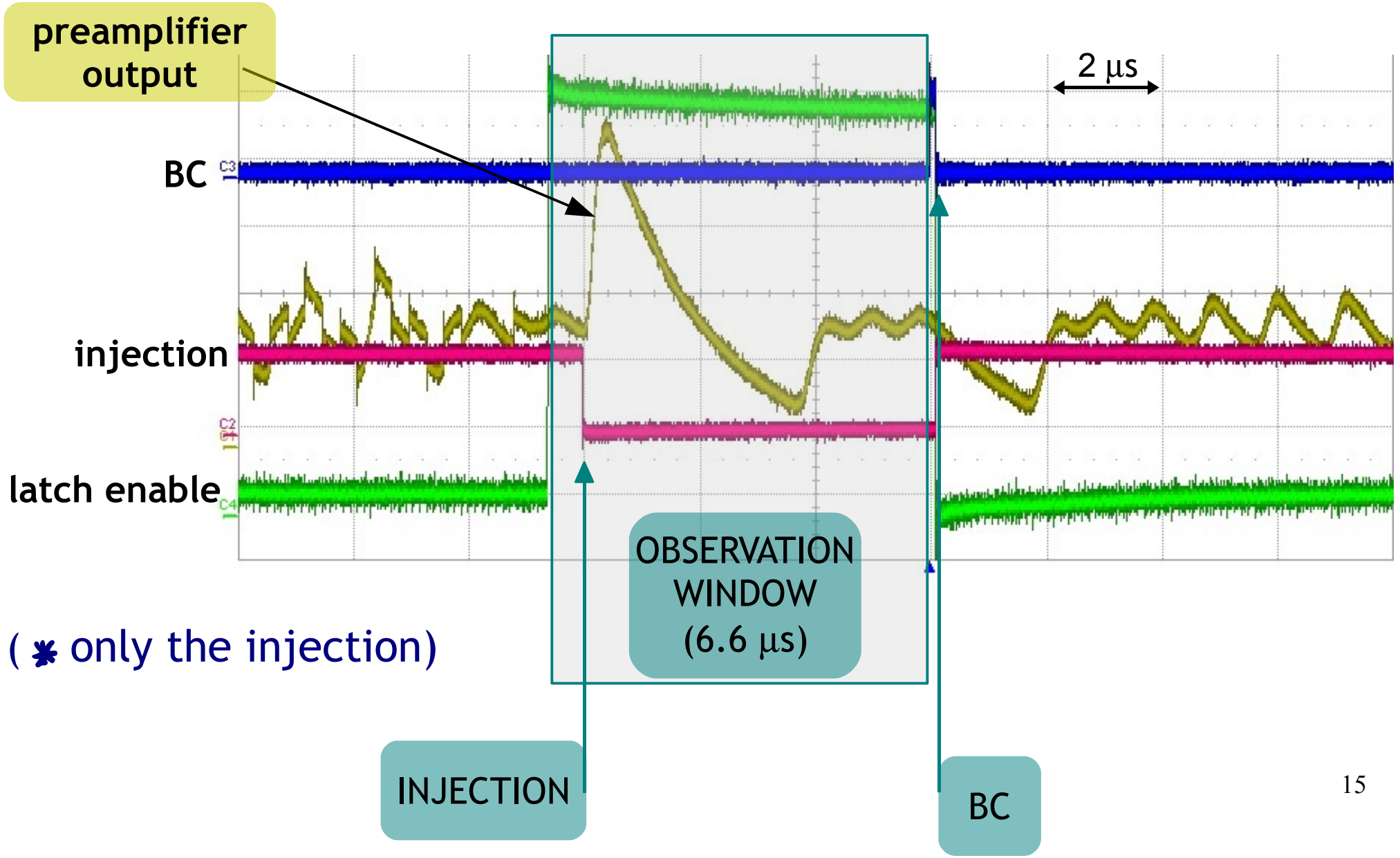
CHIP	MC	baseline - μ (mV)	threshold dispersion	noise - σ (mV)
1	6	205.9 ± 0.3	1.6%	0.460 ± 0.007
	20	205.3 ± 0.3	1.8%	0.448 ± 0.006
	30	205.6 ± 0.3	1.5%	0.460 ± 0.007
2	6	212.0 ± 0.3	1.5%	0.35 ± 0.01
	20	211.1 ± 0.3	1.4%	0.37 ± 0.01
	30	210.5 ± 0.3	1.7%	0.41 ± 0.01
3	6	208.8 ± 0.3	1.4%	0.323 ± 0.005
	20	209.3 ± 0.2	1.2%	0.362 ± 0.007
	30	208.0 ± 0.3	1.4%	0.355 ± 0.008

Injection Scans

- GOAL → extract the gain (mV/fC)
- SAMPLE → 3 chips, 3 macrocolumns (MC) for each submatrix
  - MC = 6, MC = 20, MC = 30



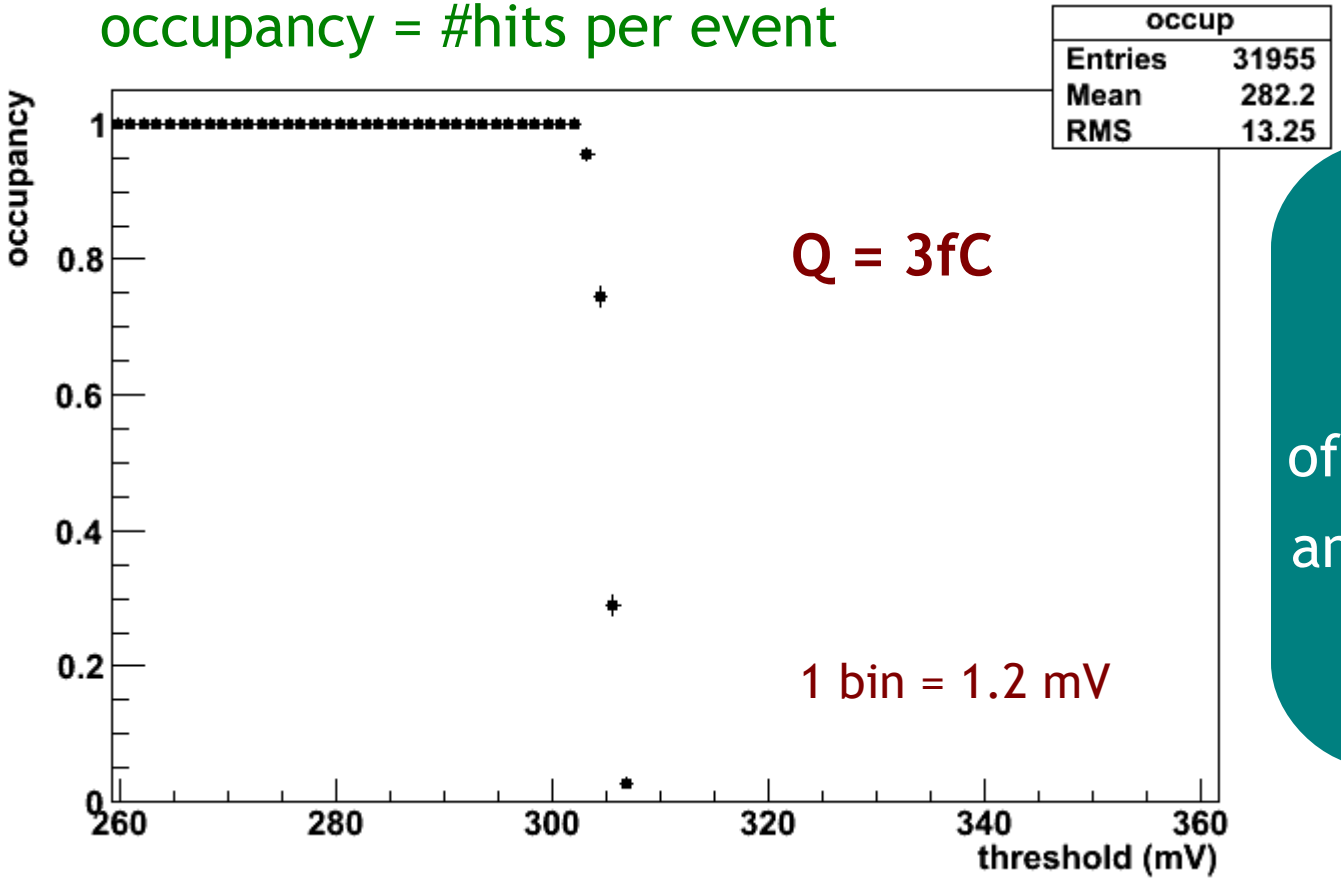
Injection Scan sequence*



(* only the injection)

Injection Scan example

occupancy = #hits per event

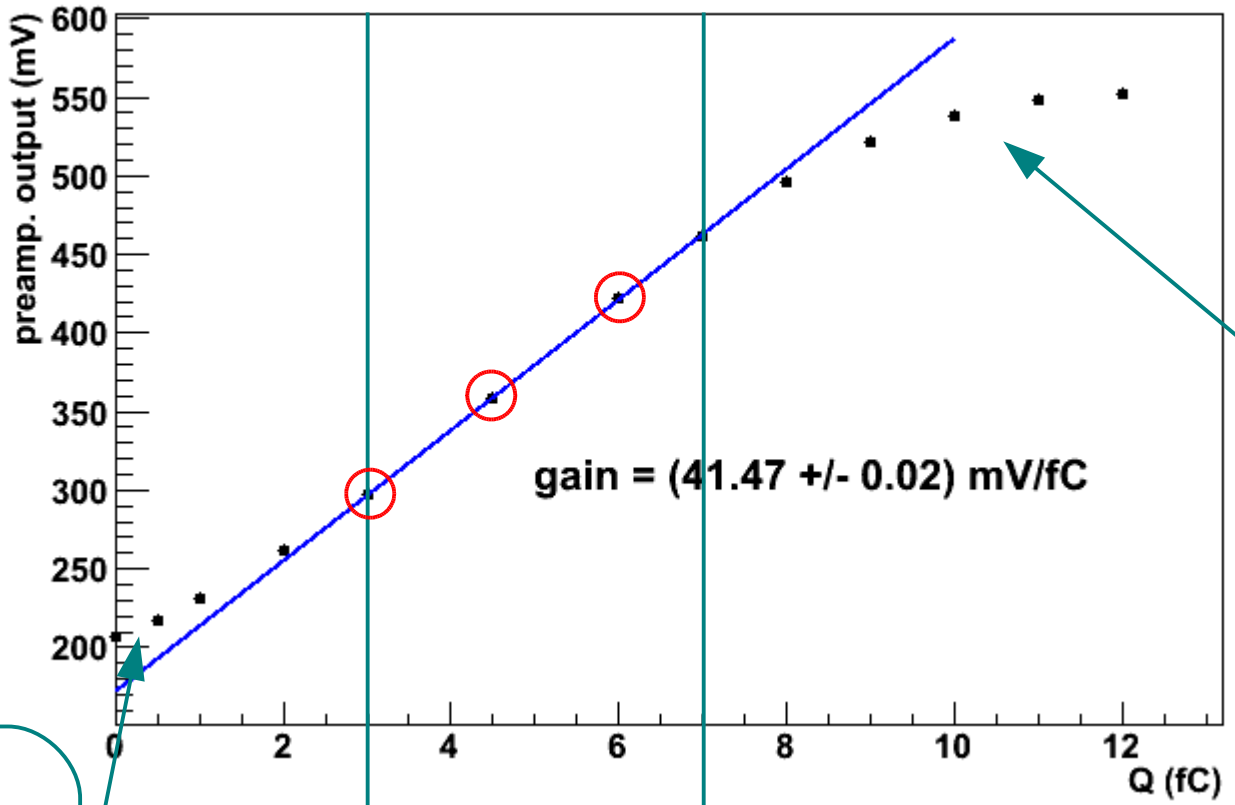


we measured the occupancy as a function of the comparator threshold and we fitted the histogram with an Erf function

$$f(thr) = Erf(A, \mu, \sigma)$$

estimator of the height of impulse out of the preamplifier

gain extraction – chip2



non linear behaviour at small charges (not expected)

LINEAR REGION

non linear behaviour at high charges (expected)

we fit 3 points (○) using:
f(Q) = gain*Q+offset

Inject Scan results

CHIP	MC	gain (mV/fC)	gain dispersion	offset (mV)
1	6	41.4 ± 0.2	5.6%	174.9 ± 0.3
	20	41.9 ± 0.2	5.0%	174.7 ± 0.4
	30	41.4 ± 0.2	5.3%	175.0 ± 0.3
2	6	40.3 ± 0.2	6.0%	176.0 ± 0.4
	20	40.1 ± 0.2	5.2%	175.5 ± 0.3
	30	40.7 ± 0.2	5.4%	176.1 ± 0.4
3	6	39.1 ± 0.2	5.4%	173.6 ± 0.3
	20	39.1 ± 0.2	5.9%	172.8 ± 0.2
	30	39.7 ± 0.2	5.5%	172.6 ± 0.3

Characterization of FE chips

	post layout simul.	CHIP1	CHIP2	CHIP3
baseline (mV)	180	205.6 ± 0.5	211.2 ± 0.5	208.7 ± 0.5
threshold dispersion (e-)	350	490 ± 50	500 ± 50	450 ± 50
ENC (e-)	120	69 ± 2	59 ± 3	55 ± 2
gain (mV/fC)	45	41.6 ± 0.3	40.4 ± 0.3	39.3 ± 0.3

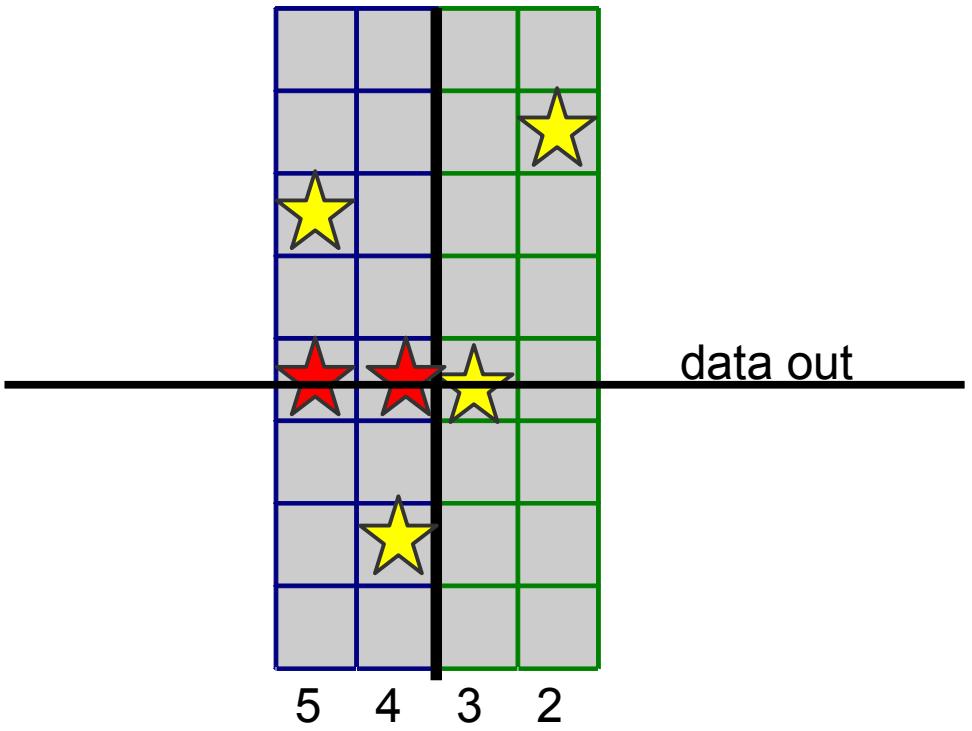
conclusions and plans

- a bug has been recognized, understood and tamed;
- 3 FE chips have been characterized with positive results and a reasonable agreement with the expected performances;
- at the end of summer we expect to receive some chips inteconnected by bump-bonding to the sensors and we should start their characterization in lab beginning on september.

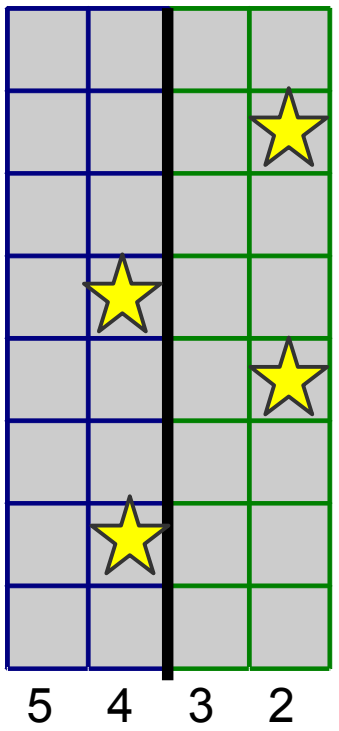
backup slides

Bug & consequences (1)...

- the outenable is not set to 0 after the readout of an odd column if there is at least a hit (★) in the odd column of the MP → fake hits (★)



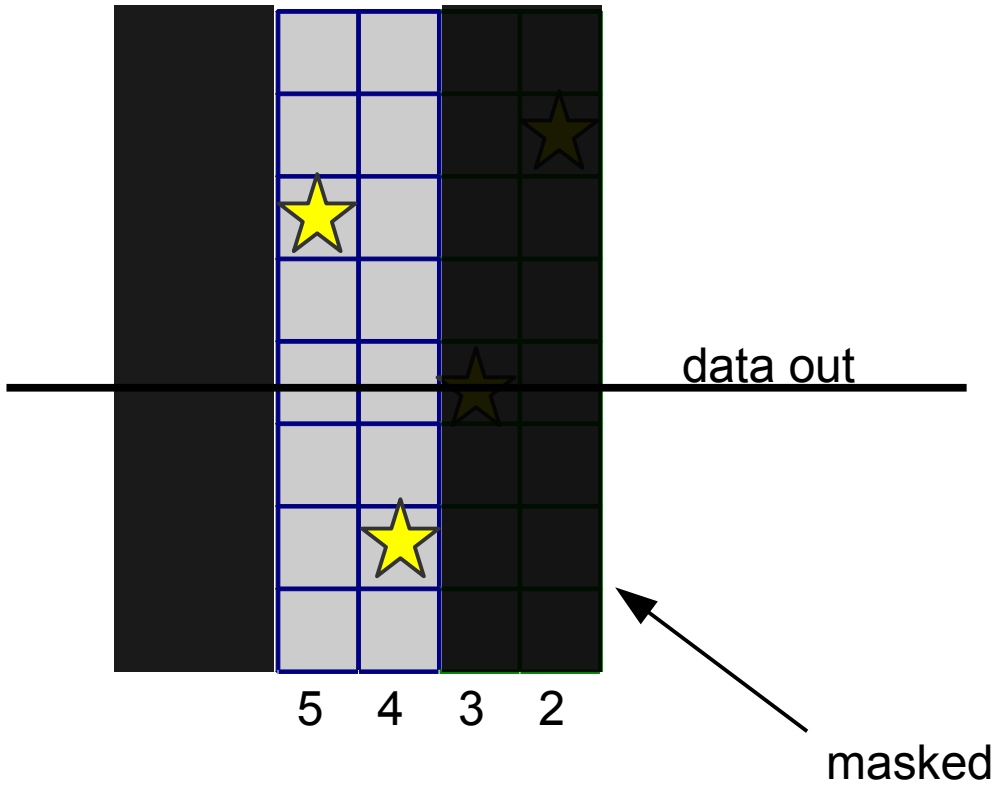
UNLUCKY CASE



LUCKY CASE

...and countermeasure

- the outenable is not set to 0 after the readout of an odd column if there is at least a hit (★) in the odd column of the MP → fake hits (★)



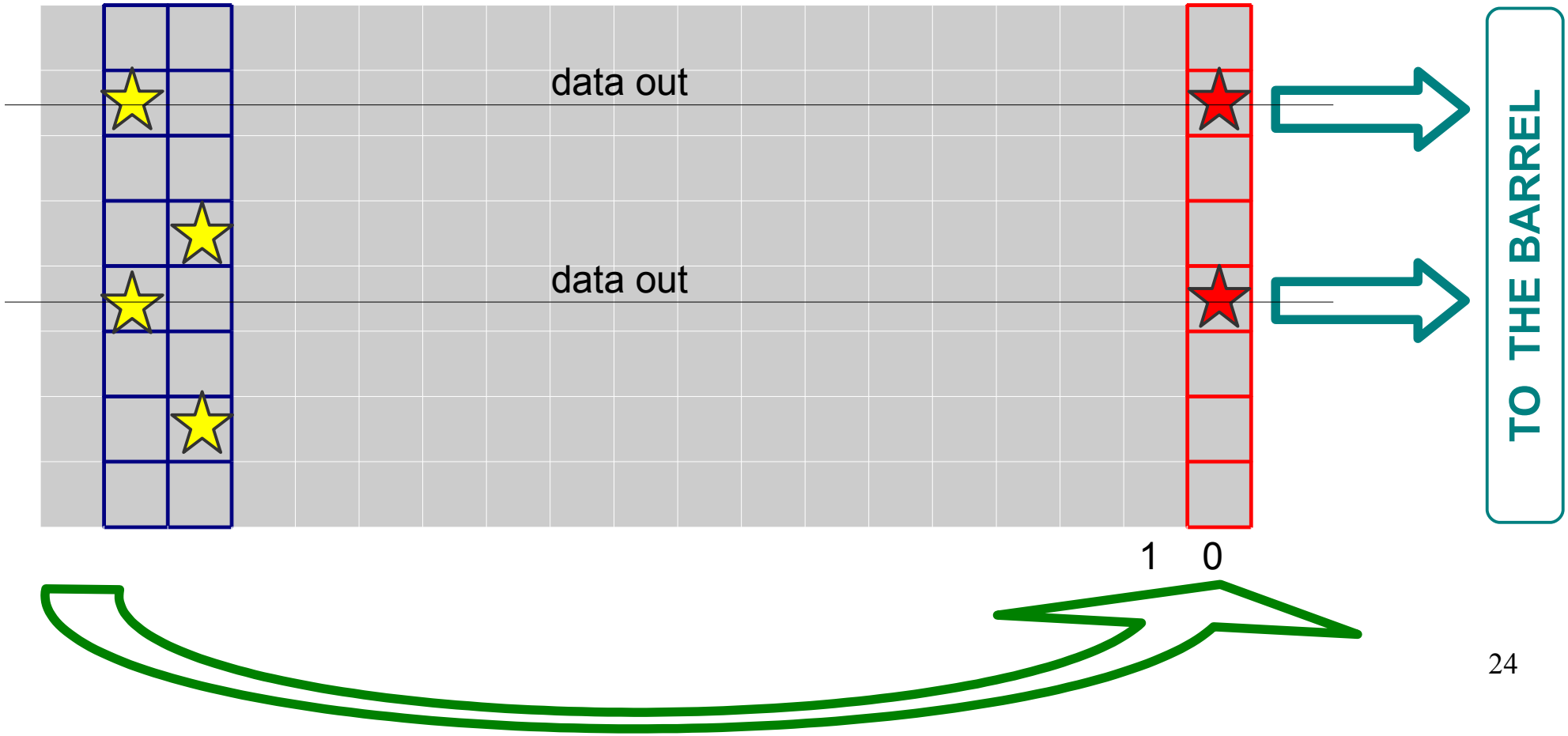
scan each submatrix
a macrocolumn (MC) at a time

enable the MC X and X+32
(x=2X,2X+1,2X+64,2X+1+64)

→ OK!!

Bug & consequences (2)...

- the outenable is not set to 0 after the readout of an odd column if there is at least a hit (★) in the odd column of the MP → fake hits (★)



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