# SiW ECAL tests with laser

Remi Cornat, Mickael Frotin, Marc Louzir,
Vladislav Balagura

LLR, Ecole polytechnique, IN2P3/CNRS

LCWS, Tokyo, 12 Nov 2013

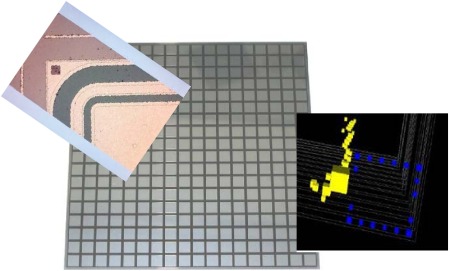
# Outline

# Topic

# “Square” event

Guard ring at silicon sensor edges ensures HV stability and low dark currents. Potential is not fixed (for cost reasons, connection is technologically difficult), but left floating → electrical cross talk betwen guard ring and peripheral pixels due to capacitive coupling.

High signal at the boundary may trigger all peripheral pixels: "square events" seen in physics prototype.

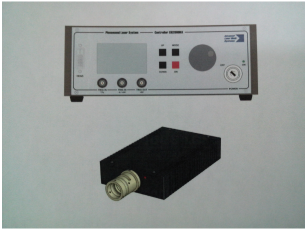


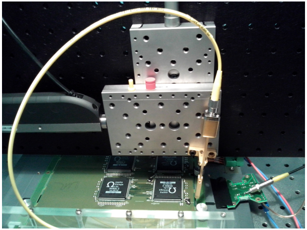
Based on extensive simulation (electrical, analytical, TCAD, PhD and several CALICE notes) and measurements with electrical injection to Hamamatsu sensors, a segmentation of the guard ring was proposed to reduce cross talks. Sensors with several guard ring designs have been produced. First measurements with laser started (this talk).

# Topic

# Infrared laser

… fires in the Si sensor pad in the gap not covered by aluminum contacts

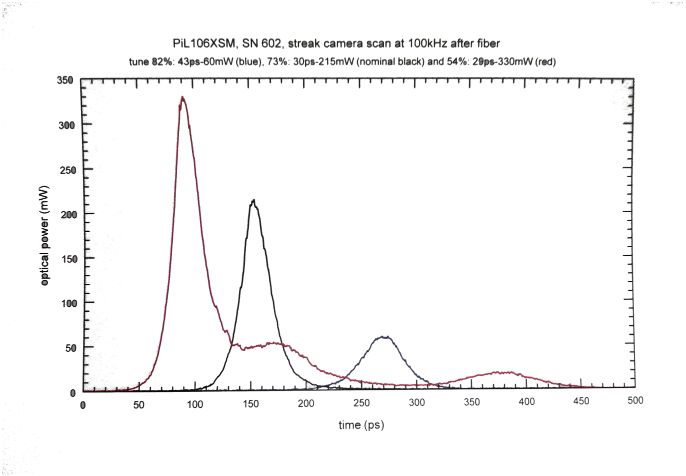




Laser characteristics: $\lambda = 1056 \pm 5$ nm, 100 Hz...1 MHz, $< 1$ nsec pulse.
Intrinsic silicon absorption length at 300 K: $\approx$ 0.8 mm.
Hamamatsu silicon sensor: 16x16 pixels of 5.5x5.5 mm$^2$, thickness 330 $\mu m$.
HV side fully covered by aluminum, on signal side there are little openings between pixels, pixels and guard ring and between guard ring segments ($50 \ldots 200 \mu m$, guard ring design is done by Hamamatsu and, in fact, we do not know it). Interpixel region is covered by PCB and is inaccessible.
Eventually laser light spot may be focused to $\sim 10 \mu m$, but currently it may be larger than opening in silicon sensor, and light may partially be reflected by aluminum contacts on the sides. Also, due to a light inclination there may be multiple reflections inside silicon from aluminum contacts.

# Laser power and timing

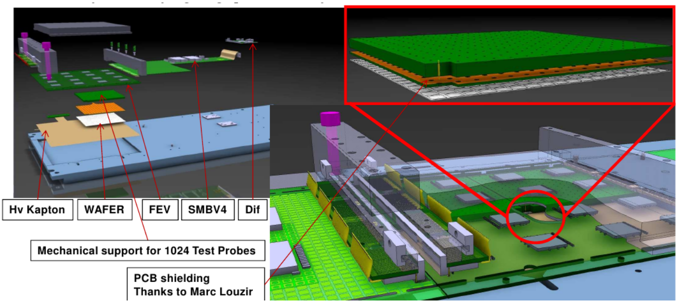
. . . according to laser passport (power may be lower due to replugged optical fiber). Pulse is longer at 100% power, but still < 1 nsec.



# PCB with spring contacts

In technological prototype Si pixels are glued to PCB with conductive epoxy.

For this test a new mechanical setup was designed and produced where sensors may be easily changed. It has up to 1024 spring contacts of 5 mm length between pixels and PCB pads.



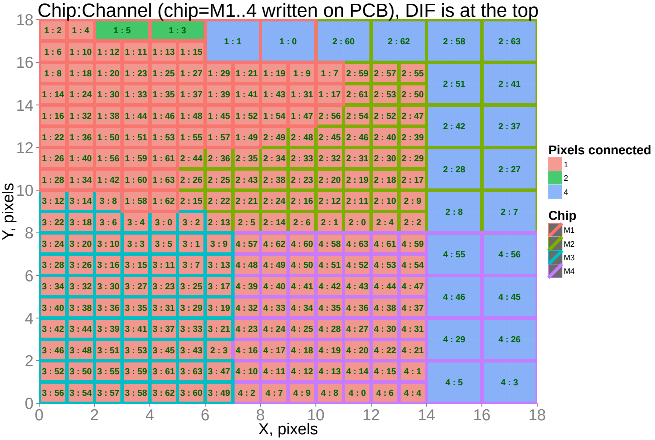

Currently used PCB (FEV8) is designed for 5x5 instead of 5.5x5.5 $mm^2$ pixels, but in two weeks we'll have a first PCB FEV9 with right pitch and many other improvements.

# Noises

Setup became operational just before LCWS, can be improved in the future.

Not optimized for low noises : there is a big ground loop, 5 mm springs are shielded only partially, they may have contact with sizable resistivity. To be above SKIROC chip noise rate, the laser frequency was set to 200 kHz. Still, due to instabilities, any SKIROC trigger fires a sequence of afterpulses which fill up 15 SKIROC memories. Therefore, only one event can be accepted per spill (10 Hz).

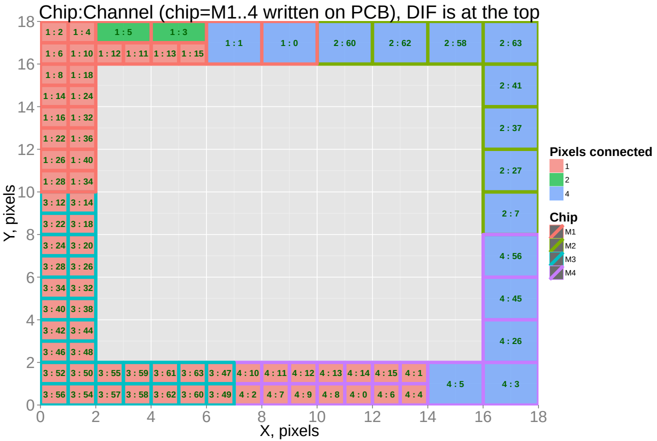
# Multiple connections in FEV8




FEV8 PCB was designed for 18x18 pixels of 5x5 mm$^2$ size, readout by 256 electrical channels. At the boundary some channels are connected to 2 or 4 pixels. They are noisy, and are normally masked in beam or cosmic tests. In FEV9 desgined for 16x16 pixels there will be no such channels.

# Multiple connections in FEV8

Here, they are not masked to study cross talks at the boundary, but all inner pixels except peripheral and next to them, are masked.




Laser shoots at top left corner, between guard ring segments or between guard ring and pixels.

# Topic

Introduction, “square” events

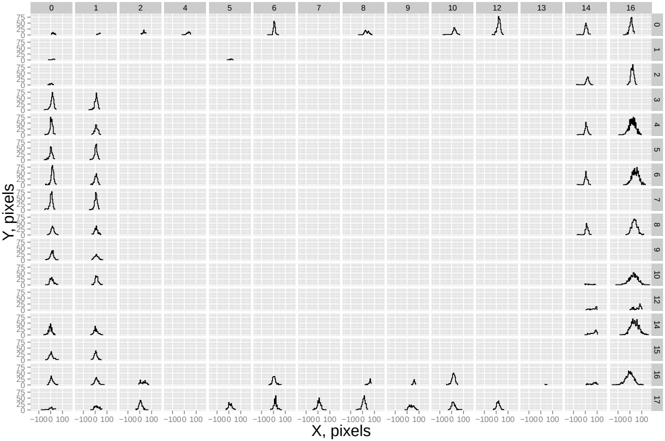
Setup with laser

First preliminary measurement

Conclusions

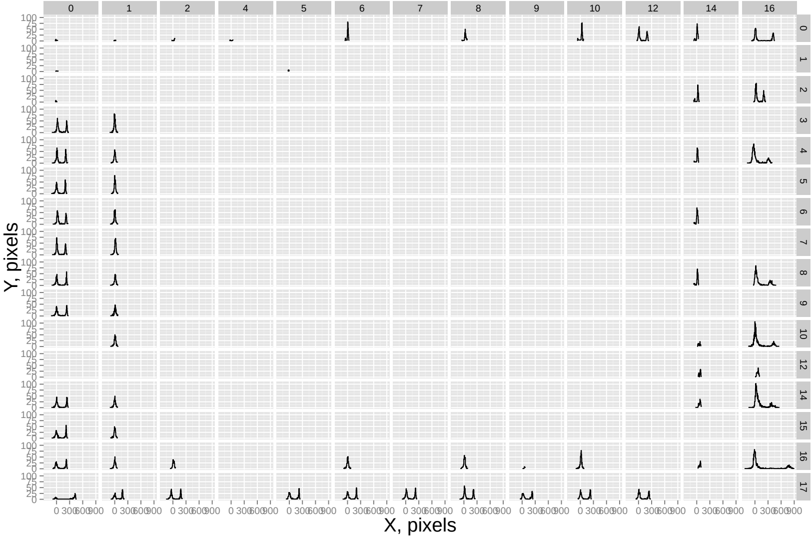
# Laser OFF, triggers due to noise

Here and in the following: only triggered events, pedestals are subtracted, only first SKIROC event (SCA=1). Not all springs installed, and not all have contacts, about half is operational. Higher noises and broader distributions with 4 connected pixels on the right.



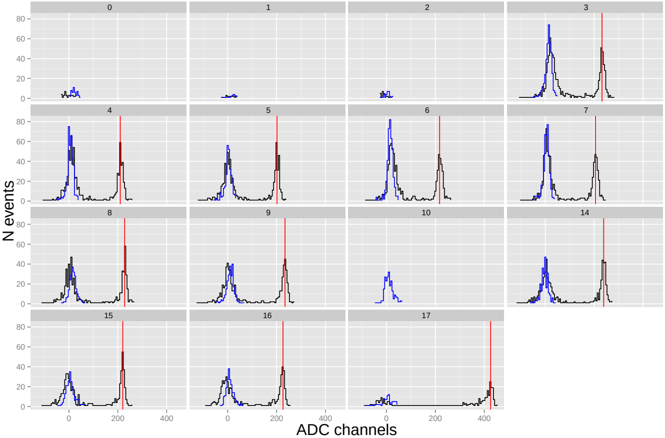
# Laser at 100%

Clear signals above pedestals only in peripheral pixels. Laser shoots guard ring on top left.



# Zoom to left column

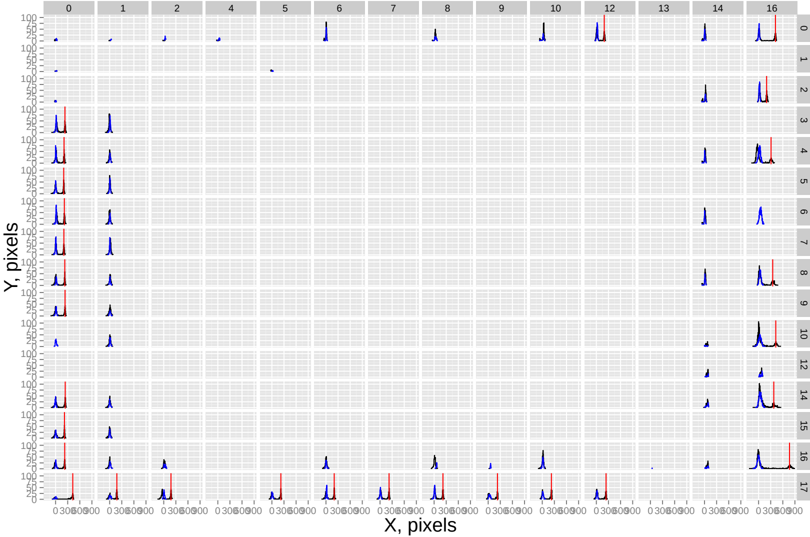
. . . Y varies from 0 to 17. X=0 is closer to laser.




Laser OFF spectra are shown by blue. Both pedestals and pedestal subtracted spectra for laser ON/OFF are slightly shifted, probably indicating dependence on occupancy. Red vertical lines are histogram density maximums of the right peaks automatically found by a simple algorithm.

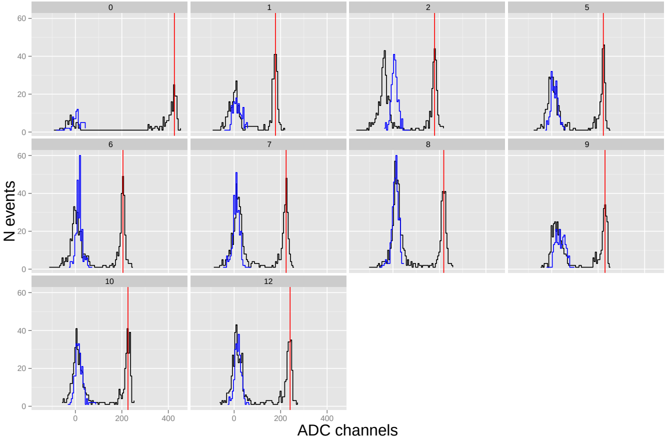
# Peak positions

Same algorithm applied to all cells. Negative signal appears after pedestal subtraction in cell (2, 17) (see next slide).



# Zoom to bottom row

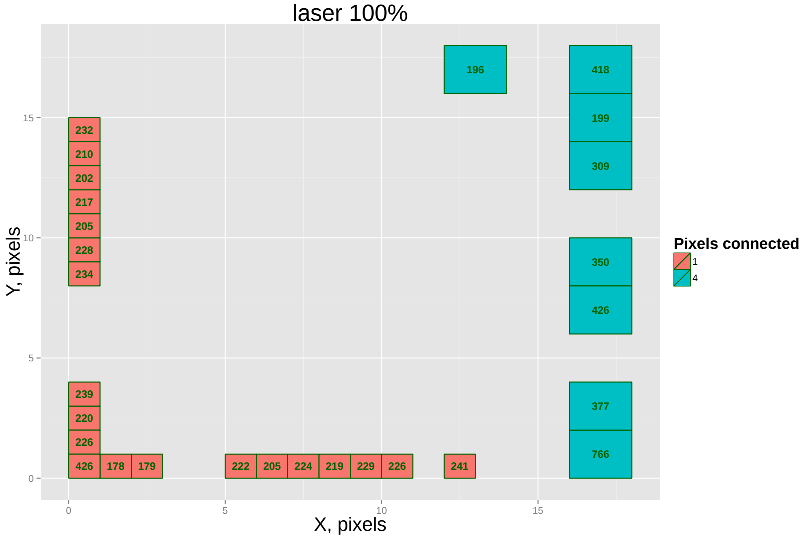
. . . X varies from 0 to 12




Note negative signals in $X = 2$ pixel. Laser induced signal is always estimated relative to zero, not as distance between peaks.

# Laser induced signals

Laser induced signals (red line positions)



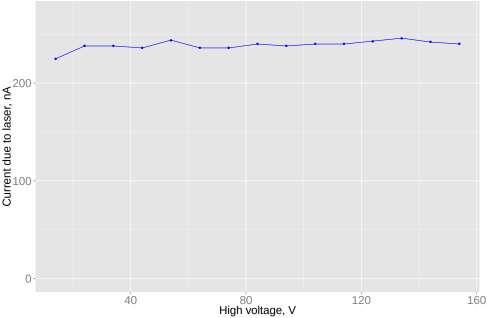
# Absolute normalization

One way: shoot at inner pixel and measure signal. Currently not possible, this requires modification of PCB FEV8 (but will be possible in next FEV9).

Another way: measure total current through silicon sensor. With laser ON: 820 nA, OFF: 350 nA, increase: 470 nA. With 200 kHz frequency, number of electrons per laser pulse: 470 nA / 200 kHz / 1.6e-19 C = $14.7 \times 10^6$.

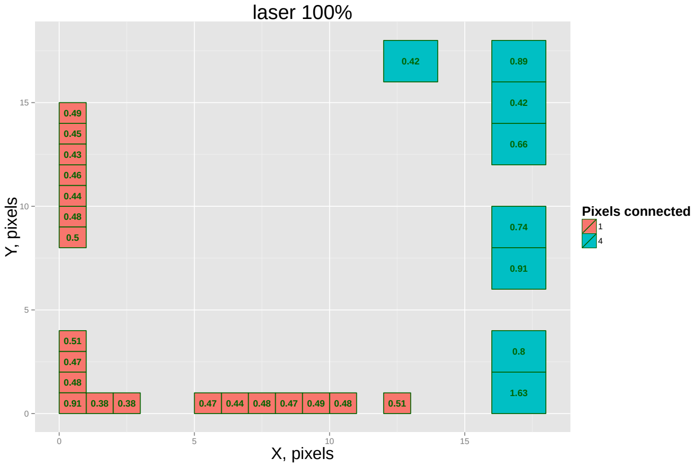
Sensor thickness: 330 $\mu m$, depletion region is slightly thinner, $\approx 300\mu m$, then 1 MIP creates $22 \times 10^3$ electron-hole pairs (most probable value from PDG), i.e. one laser pulse creates $14.7 \times 10^6 / 22 \times 10^3$ = 670 MIPs. With SKIROC high gain (1.2 pF): 1 MIP = 70 ADC channels (also most probable value), and one pulse = 47 000 ADC channels.

Possible recombination due to lower electrical field near sensor edge should depend on HV, but no such dependence is visible:



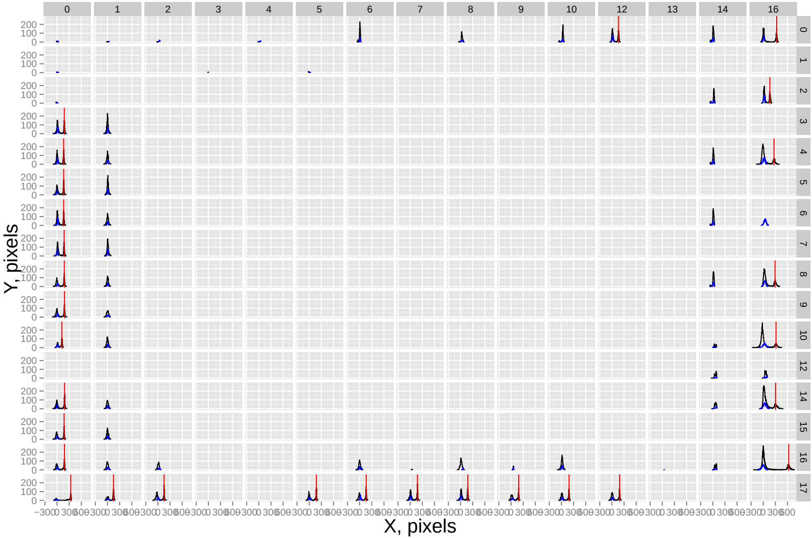
# Cross talk in percents

Typical induced signal in a pixel sharing one side with guard ring: $\sim$ 0.4...0.5%$\times$ laser signal. In the corner (2 shared sides) or in the channels with multiple connections (2 or 4 sides in the corners) it is correspondingly larger by 2 or 4 (with a few exceptions in top right).



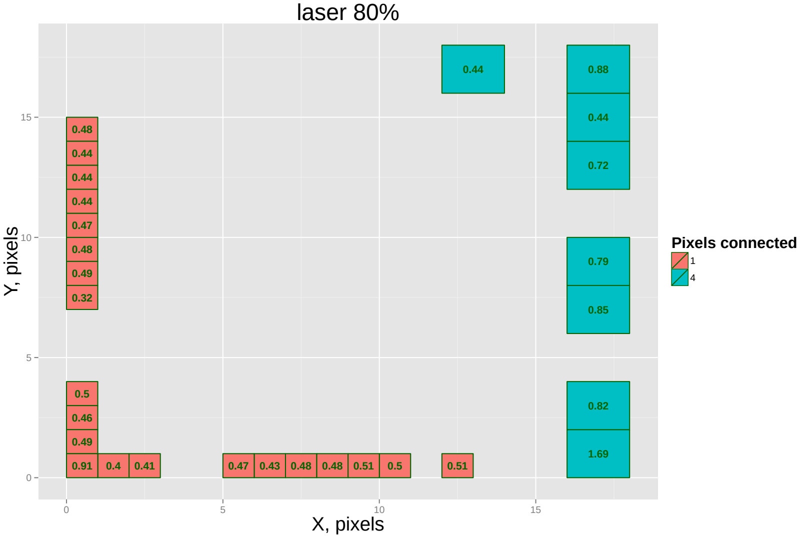
# Same with laser at 80%

Slightly less signals and current (380 nA)

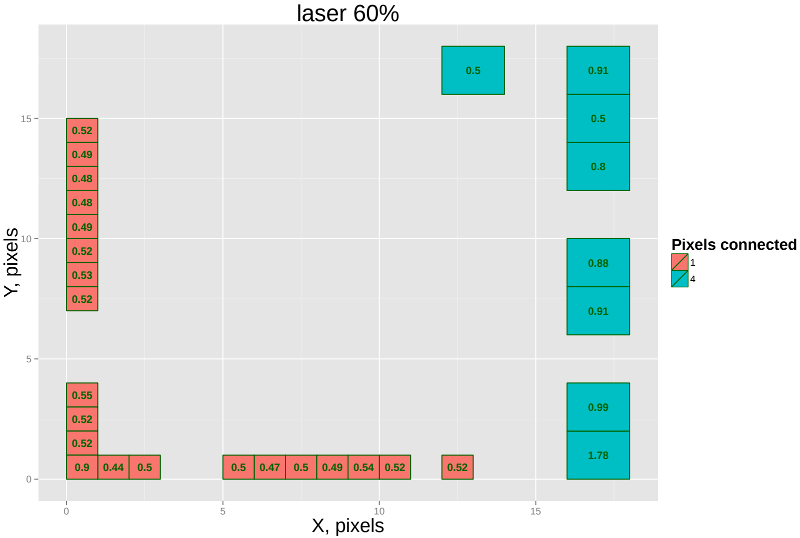


# Same with laser at 80%

Induced signals move synchronously with laser induced currents, the cross talk ratio stays constant:

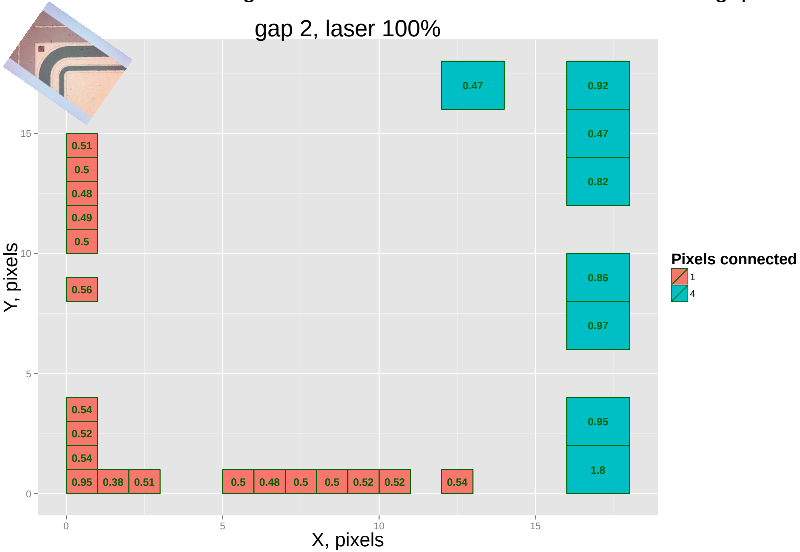


# Same with laser at 60%



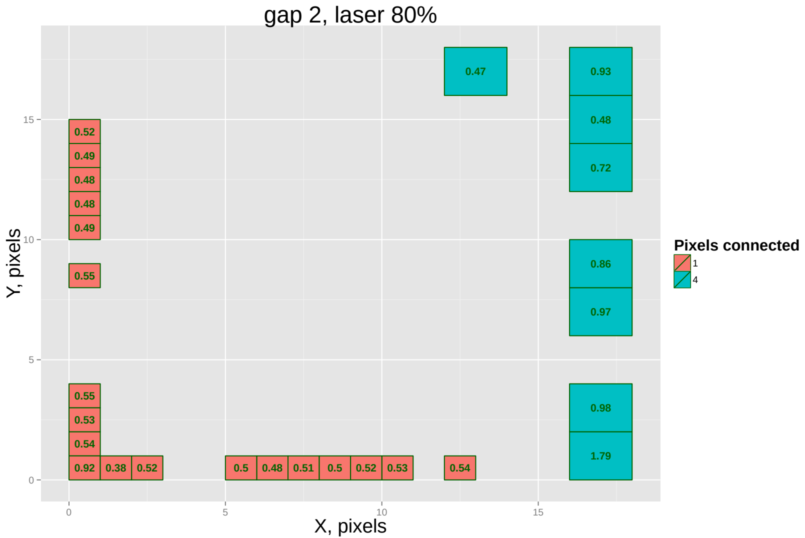
# Laser at 100%, second gap (further from edge)

Cross talks do not change much when laser is moved to the second gap

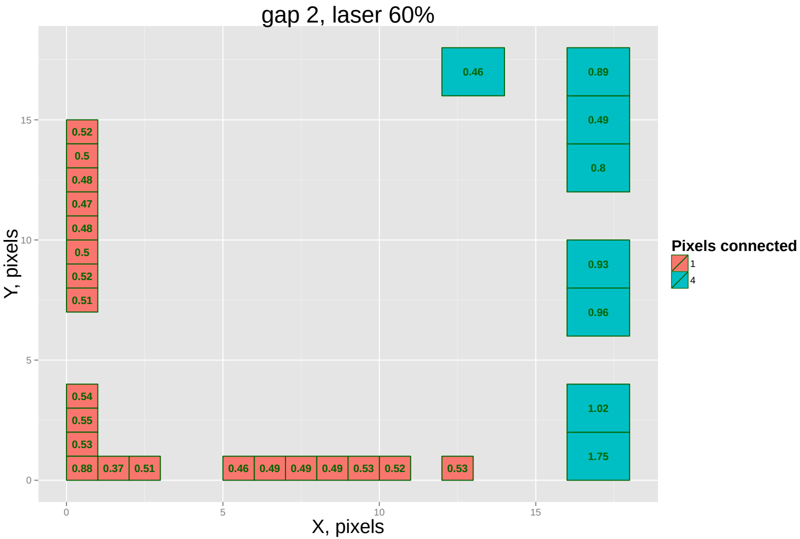


# Second gap with laser at 80%

Lower laser intensity



# Second gap with laser at 60%



# Topic

Introduction, “square” events

Setup with laser

First preliminary measurement

Conclusions

# Conclusions

- The new setup with the spring contacts between PCB and silicon pixels,
- and with the infrared laser ($\lambda = 1056$ nm) is now operational.
- The “square” events are clearly reproduced.
- First preliminary measurement of the cross talk due to the electrical coupling of the guard ring and the peripheral pixels. A typical induced signal is $\sim$ 0.4...0.5% per outer pixel side (x2 for corner, x2 in case of 4 connected channels), with a few exceptions.
- Setup can be substantially improved (it was made quickly just before LCWS conference). Next steps: reduce noises, connect more pixels, study various guard ring geometries.
- Guard ring charge and floating potential may be dependent on the current generated by laser. Another task: check cross talk dependence on laser frequency.