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Laser tests of SCT micro strip silicon modules

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Introduction

- Tests of silicon sensors simulate real experiment conditions and check important detector properties
- Real particles from accelerators are available few times in year, expensive, in few labs
- Beta tests or other particles from radioactive sources have problem in space recognition
- Laser tests have good time and space description, cheaper testing in any lab, but photons
- Beam-tests are in many aspects replaceable with combination of beta and laser tests.

- Comparison: particle tests vs. photons in laser tests:
  - laser beam (semiconductor lasers) has nonzero rise edge (nano seconds) and nonzero beam profile (sigma more 1 μm), pulse duration up to 3ns
  - light is reflected in mirrors (metal layers) – electrodes, conductive metal layers
  - light is partly reflected in dielectric surfaces
  - interference effects based on coherence of light (coherence length mm and more)

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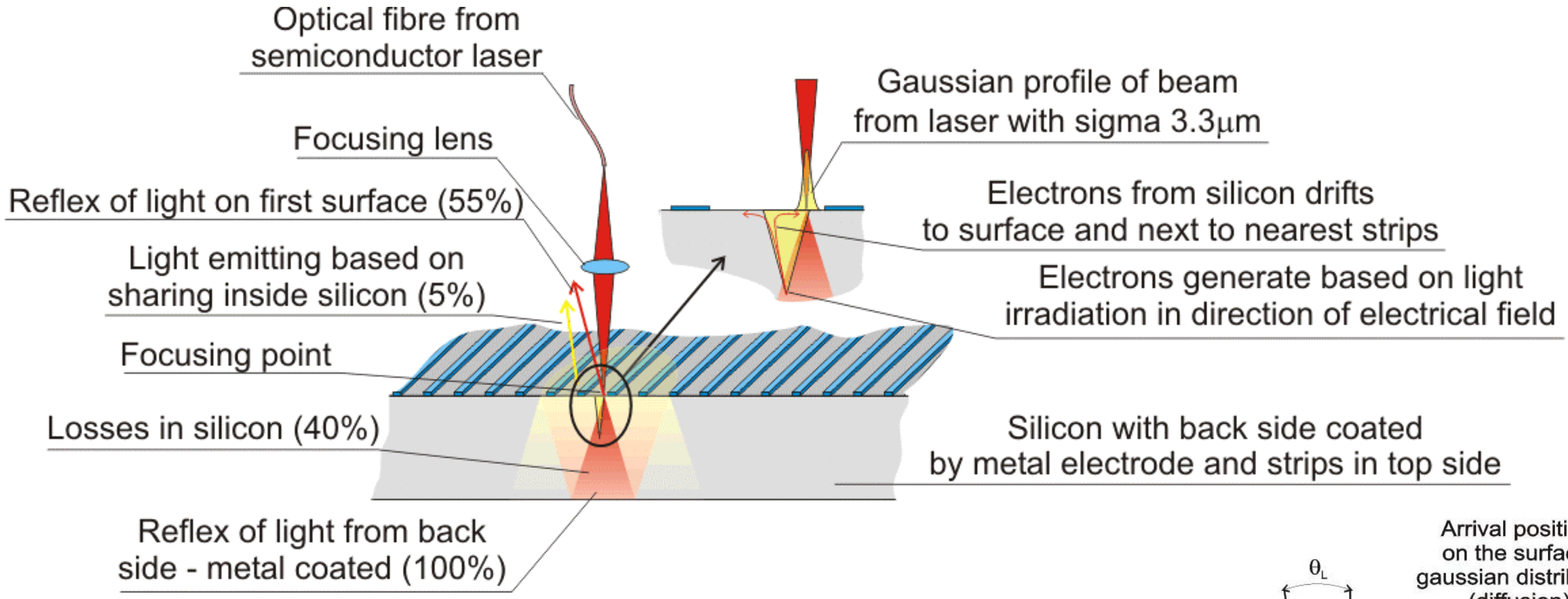
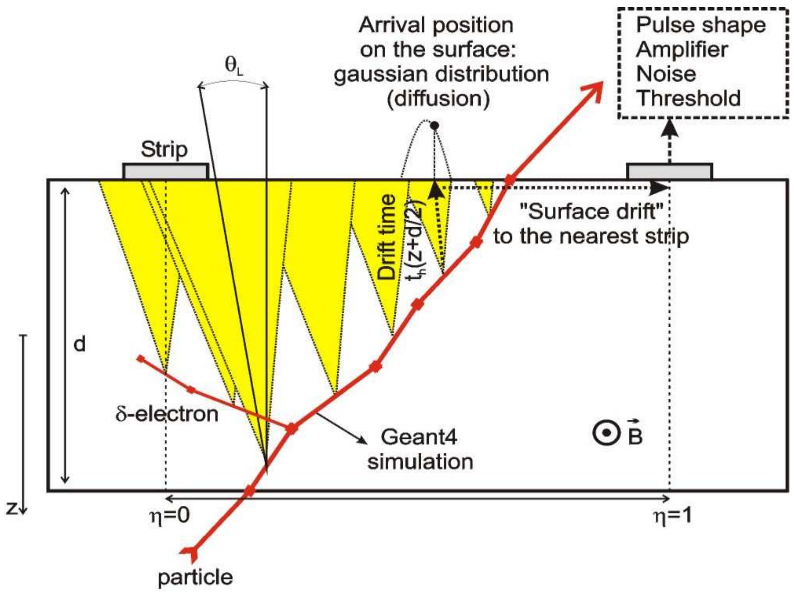
Difference Between Particles And Light Beam In Silicon

(accommodate to ATLAS SCT modules and using laser)





Laser tests used beam of light with nonzero width and use different method of electron generation, some effects missing: d – drift electrons, energy of particles, some effects added: primary and secondary reflectance.

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Laser Parameters And Light Interaction With Silicon

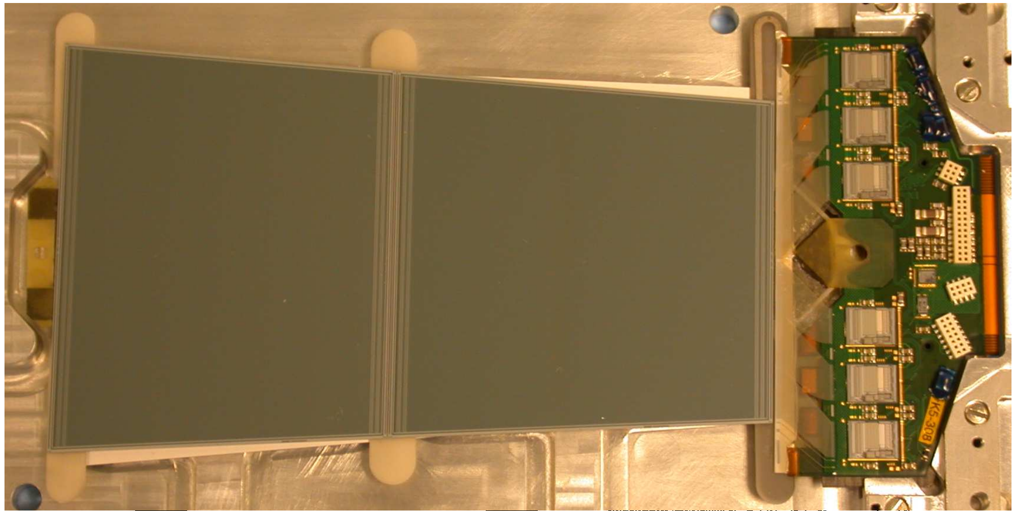
(adapt to ATLAS SCT modules and used laser)

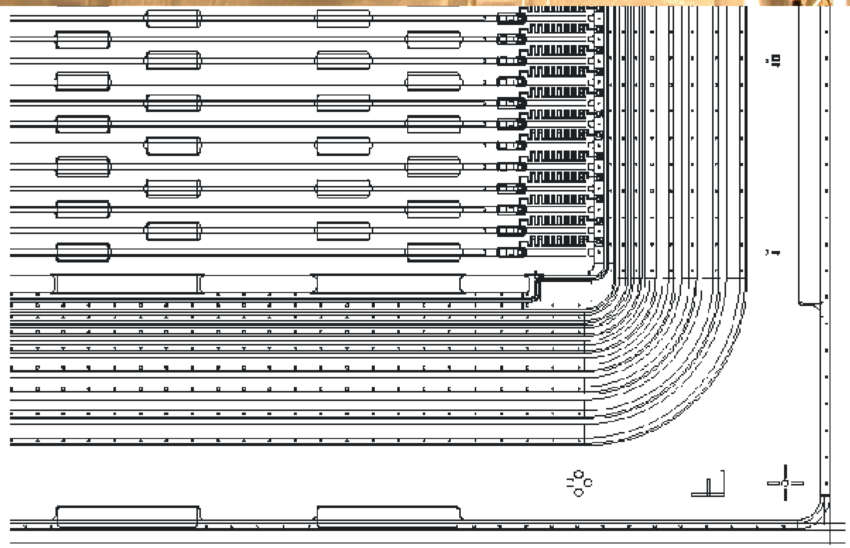
▪Laser energy of photon:	1.170 eV
▪Wavelength of light:	1060 nm
▪Real part of dielectric const.:	12.65
▪Imag part of dielectric const.:	0.00075
▪Index of refraction:	3.557
▪Imag part of index of refr.:	0
▪Absorption coeficient:	12.07 cm^{-1}
▪Reflectivity @ 0.6mm Si:	35.2%
▪Transmition @ 0.6mm Si:	24%
▪Absorption @ 0.6mm Si:	40.8%
▪Reflectivity @ 0.27mm Si:	60.35% back side of Si reflected - metalized
▪Transmition @ 0.27mm Si:	0 % back side of Si reflected - metalized
▪Absorption @ 0.27mm Si:	39.65% back side of Si reflected – metalized

Effect of passivation and other layers on surface may change reflectivity and absorption in level ±30%, for precise measurement need to measure it

ATLAS SCT Modules

- p-on-n single sided detectors
- 285µm thick
- 2-8 k**W**.cm
- 4“ substrate
- barrel
  - 64x64mm²
  - 80µm pitch
- forward
  - 5 different wedge shaped sensors
  - radial strips
  - 50...90µm pitch
- 768 read-out strips
- AC coupled to read-out
- polysilicon or implanted resistors
- multiguard structure for HV stability
- ~20000 sensors needed
- produced in Hamatsu and CIS





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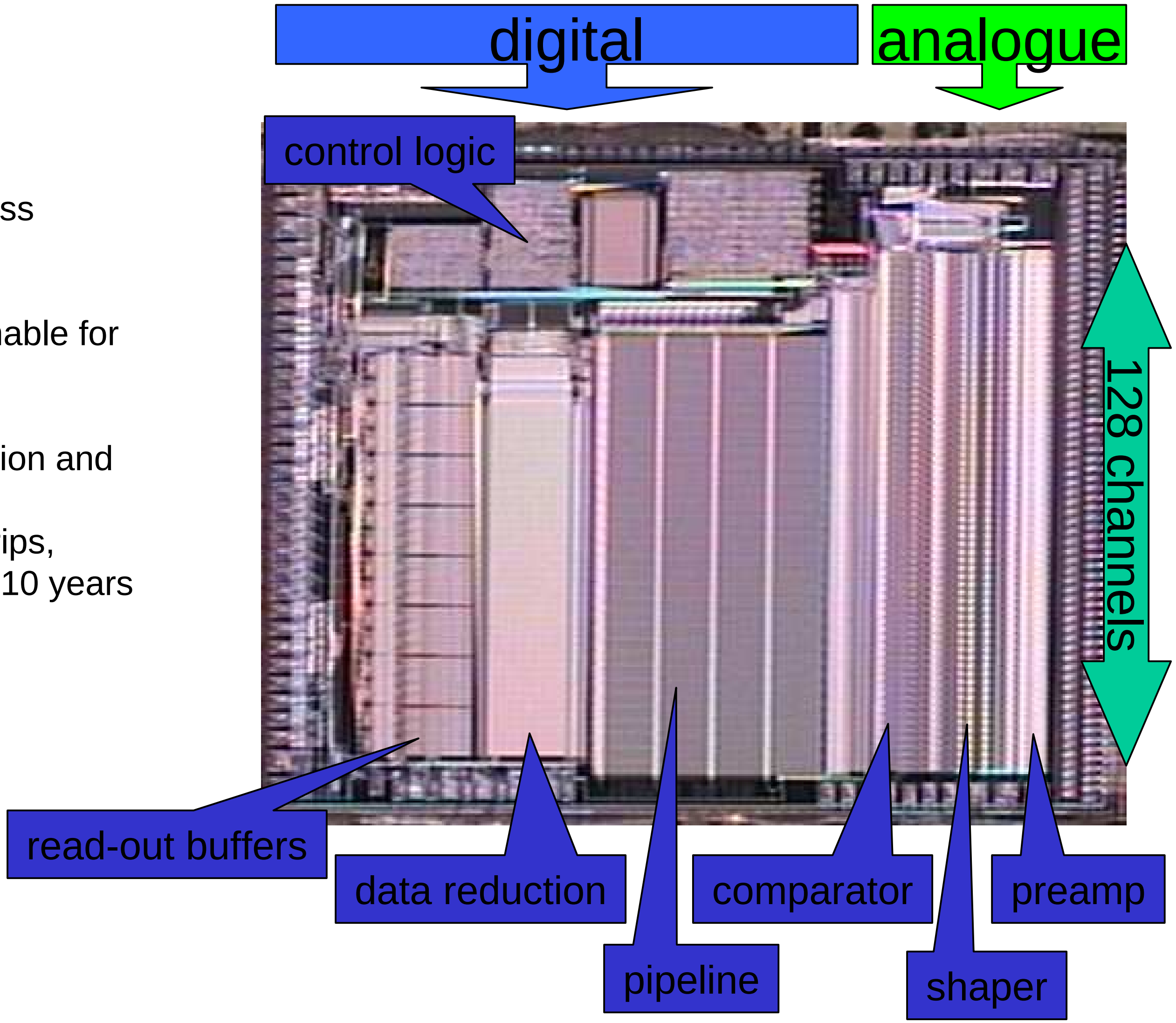
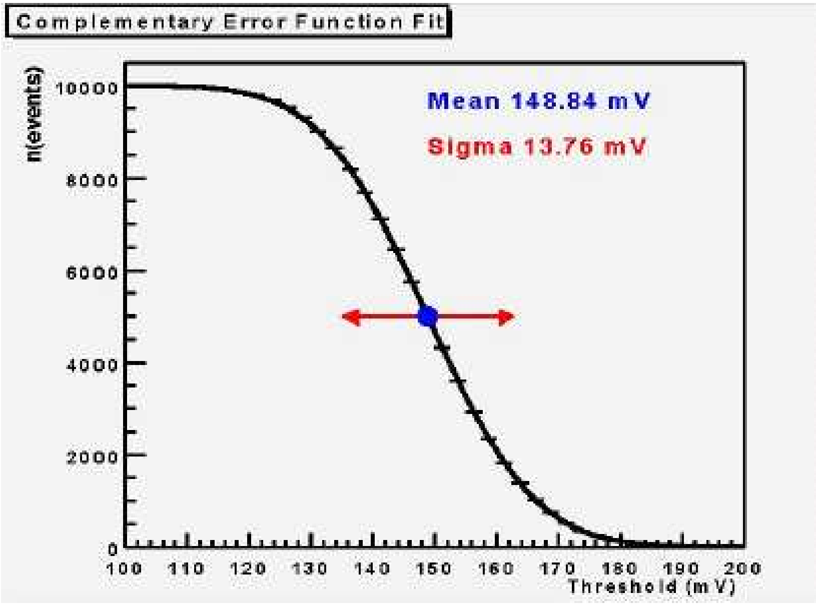
Front-end ASIC ABCD3T readout chip in ATLAS SCT Modules

- binary read-out
- 28 channels
- DMILL radiation hard process
- bipolar input transistor
- shaping time ~20ns
- comparator threshold trimmable for each channel
- 132 cell pipeline
- edge detection, data reduction and multiplexing
- ENC ~ 1500 e for 12 cm strips,
- increasing to ~1800 e after 10 years of irradiation
- ~4 mW/channel

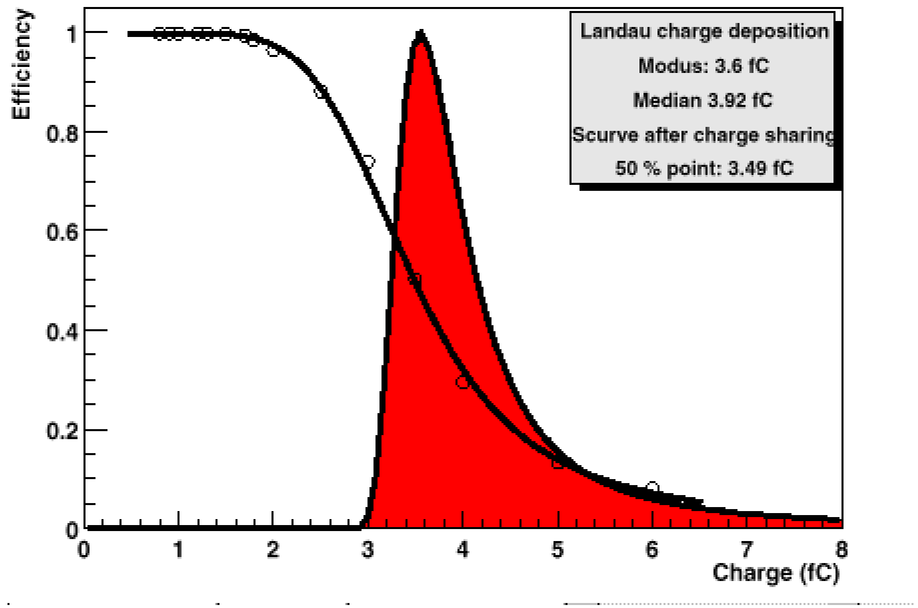


Signal in binary readout system

Calibration pulse



Real signal



To know properties of input signal needs always threshold scan

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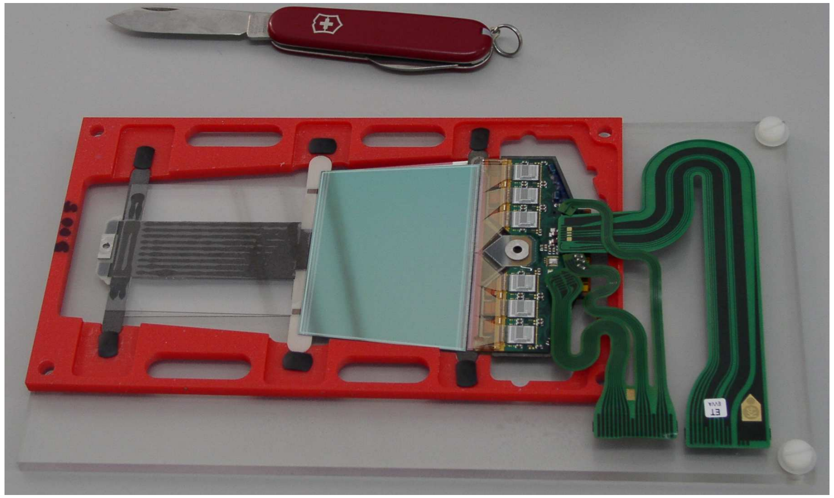
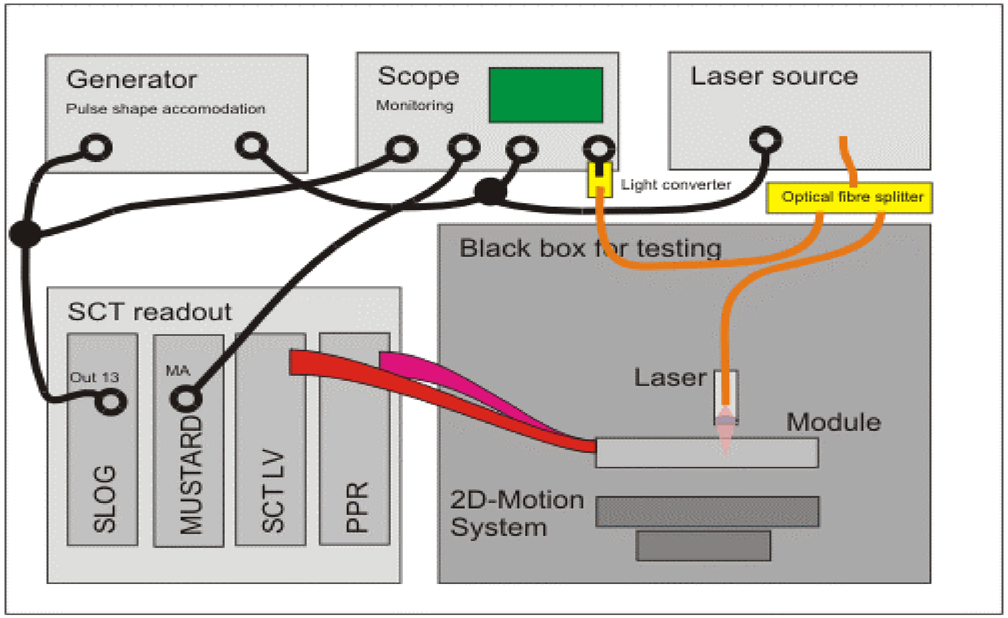
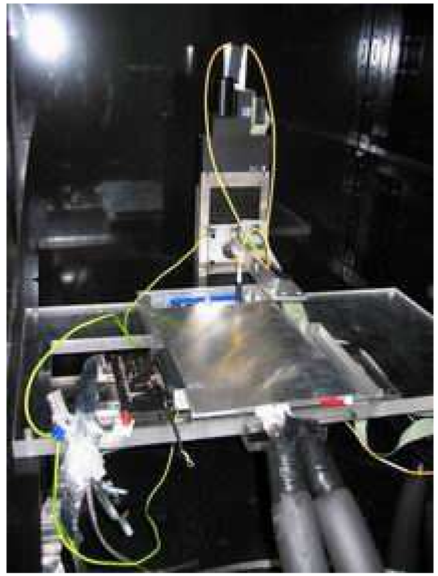
Scheme Of Arrangement

Laser: CERN product (Maurice Glaser)
Module: ATLAS SCT end caps
Detector: Hamamatsu & CiS silicon 0.27mm wedge-shaped, single-sided, p-in-n type
Microstrips: pitch 80μm 2x60mm length
Readout: analogue/digital binary ABCD chips with 128 channels, 12 per module, MUSTARD/SLOG electronics in VME crate, PC, SCTDAQ sw
2D motion system, step <1μm







http://ific.uv.es/~cescobar/lasertest.html

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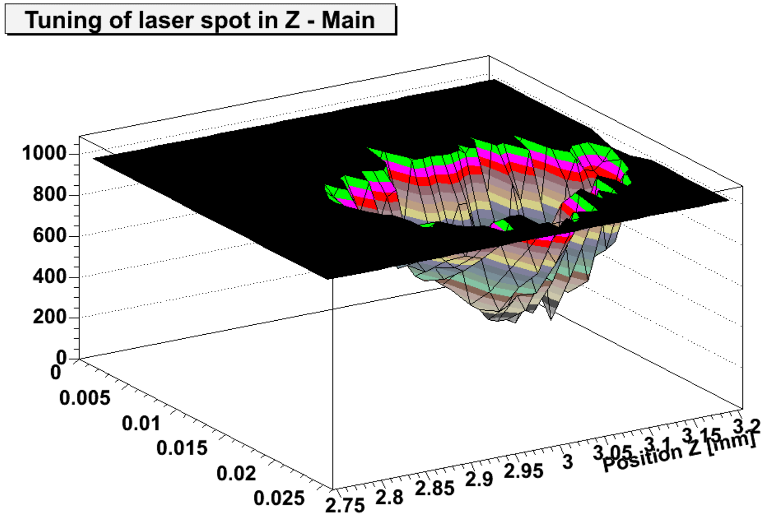
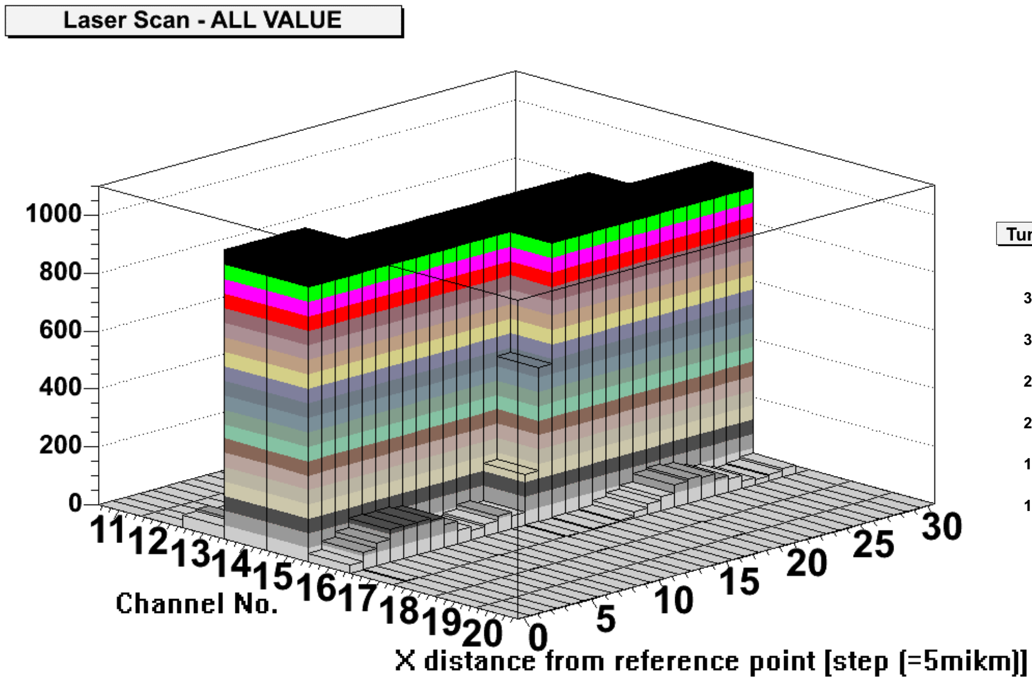
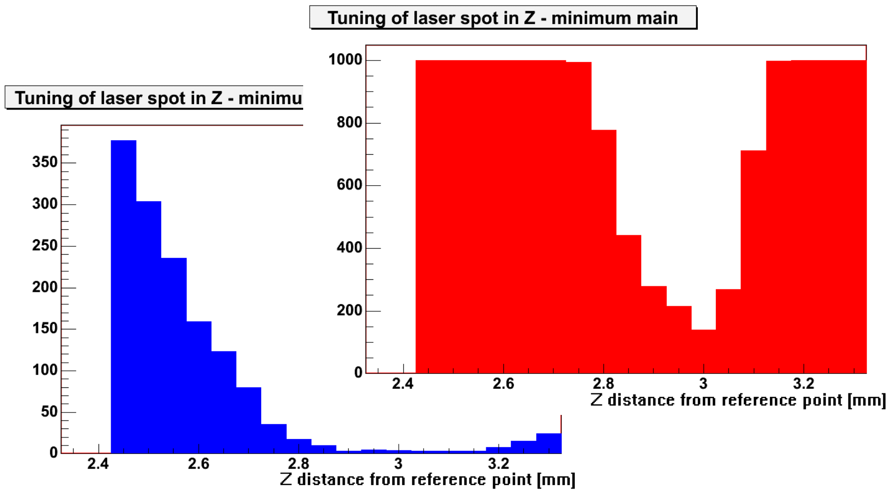
Focus Distance Tuning – Important

Main conclusion: **there is possibility to tune laser focusing to smallest spot using reflectivity from strip metal material to measure decreasing of signal from main testing strip, sensitivity of focusing of our type of laser output is very high, best focus range is less 50 μm (from factory is declared good focus range about 1 mm).**

Auto focus algorithm: ~ 6 minutes, starting point in range 3mm from focus point







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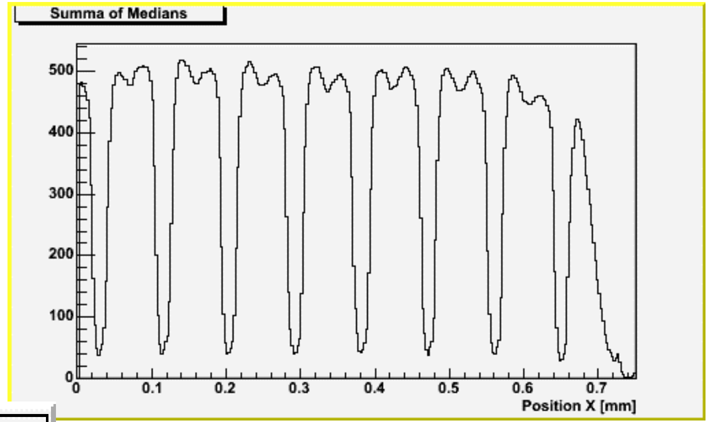
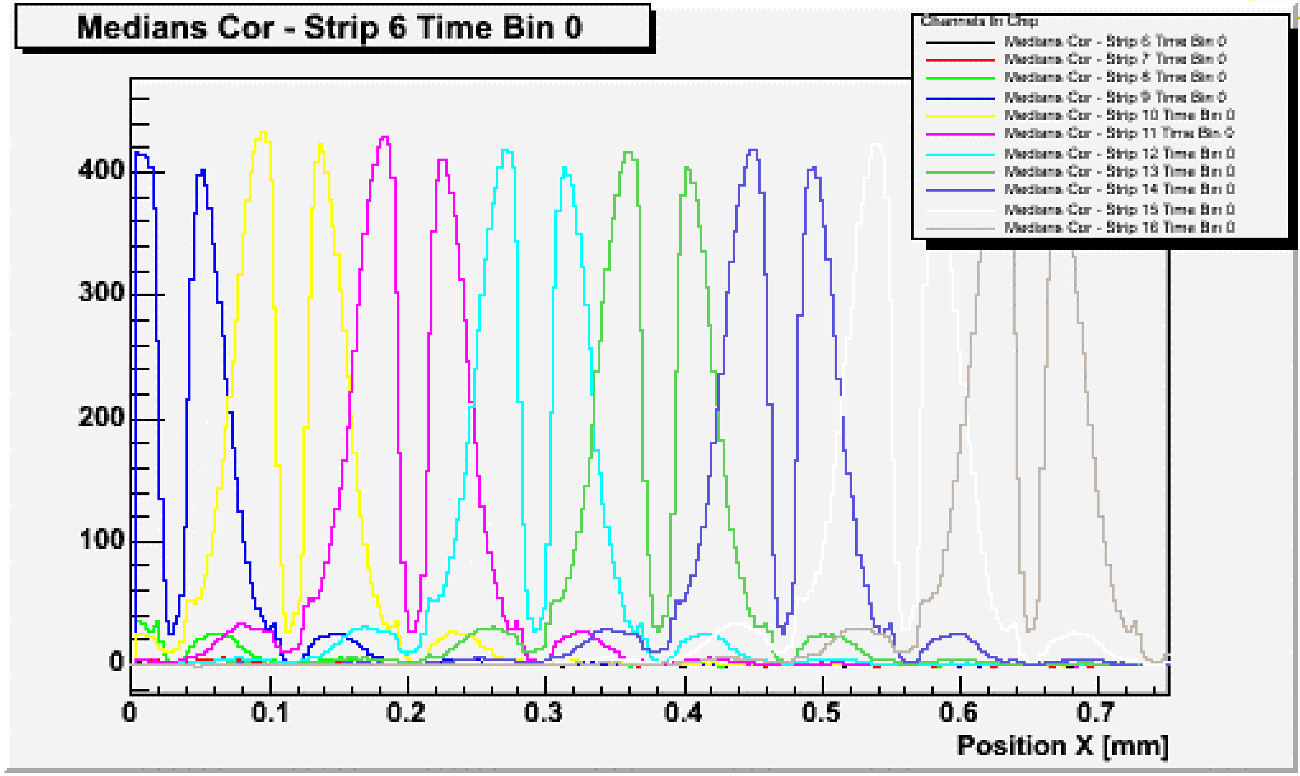
Response Of Modules

Typical response from channels if laser beam move across strips in best focusing point. Reflectance from metalized strip tripped signal down in mid of strip, visible are also sharing of signal to neighbourgh and over neighbourgh channels. In mid between strips decrease response to approximate half of maxima – good collection of charge in silicon.

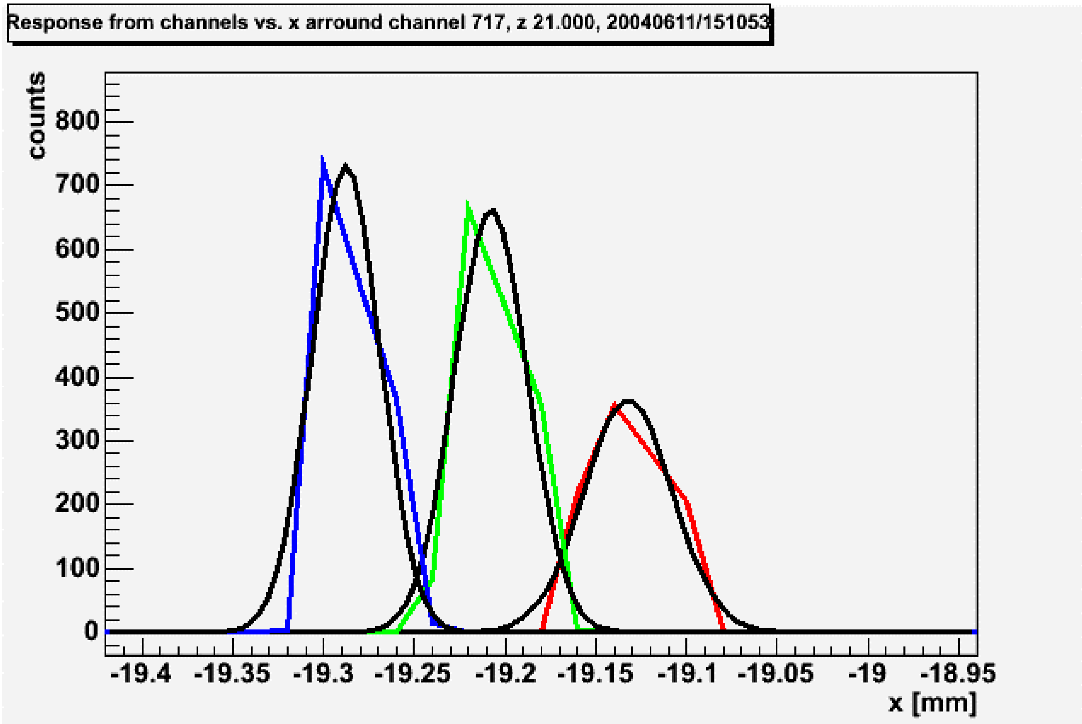


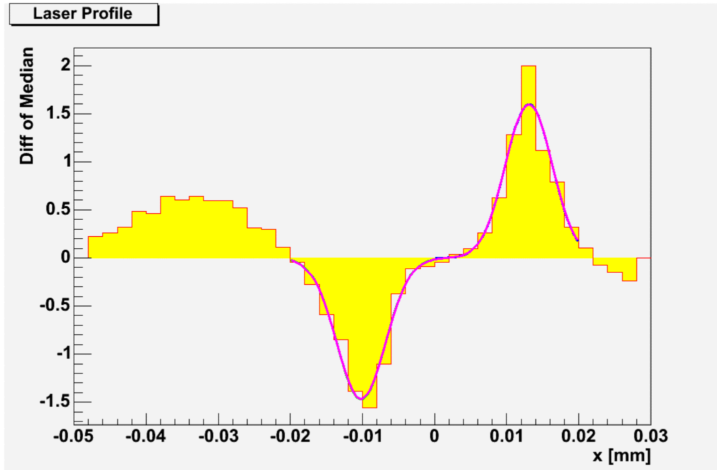
Sum of signals show that collected signal in one channel (about 420mV) is 85% from collected charge (500mV).



Strip Position Tuning, Laser Spot Size

Main conclusion: **method independent of starting point in range 3mm from focus give result up to 6 minutes, method use quick scan of response from 3 channels and Gaussian fit to find centre of strip and strip pitch (precision 1μm)**



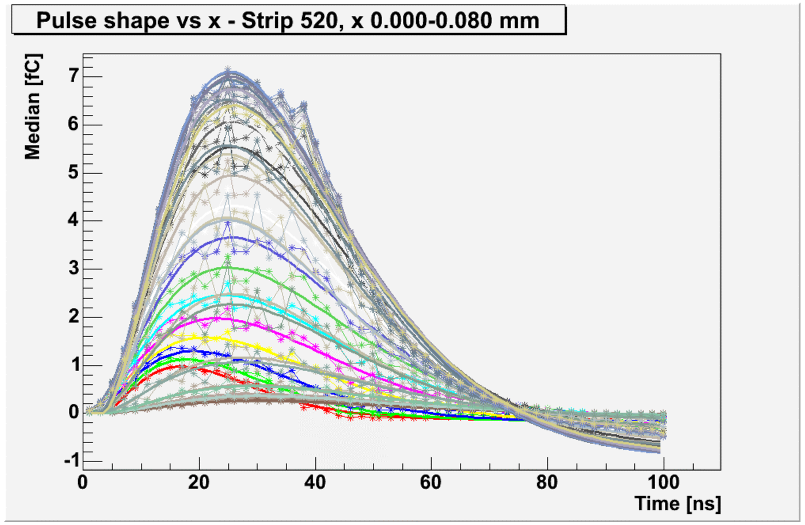


Laser spot profile and size was measured in best focus point using fit of edges on metal conductive strip and was sigma 3.3+-1.3um, strip width is 23.3+-1.4um.

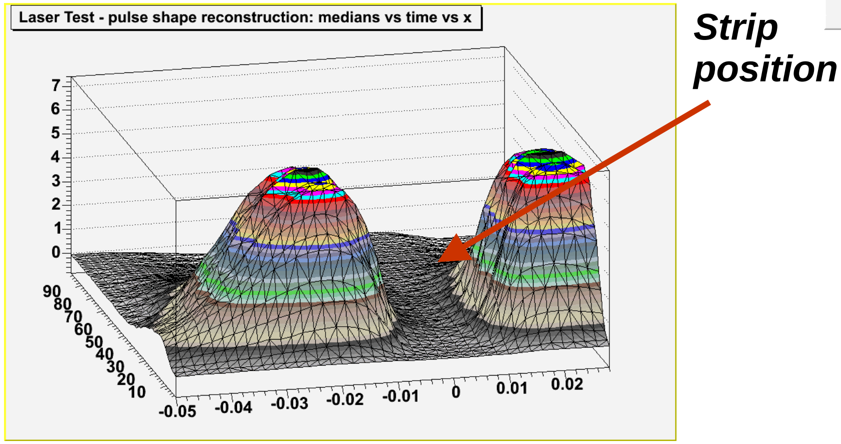
Find centre of channel and current strip pitch

Pulse Shape Reconstruction

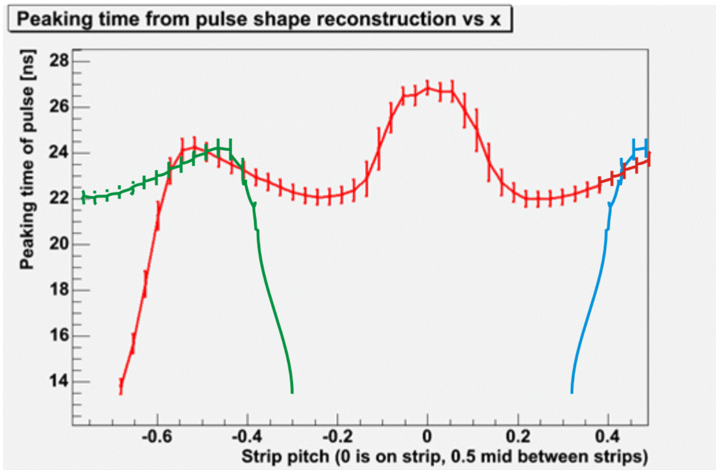
Time properties of module response (peaking time and pulse shape) corresponded with results from test beams. Their dependence versus inter strip position is simply measurable in laser test setup, in test beam this is very time consuming measurement. Under metal strip layer is no signal from laser.



Pulse shape fit for all x positions



2D graph of medians in time shift vs. x, strip metal part is on point 0 where practically whole light beam is reflected out



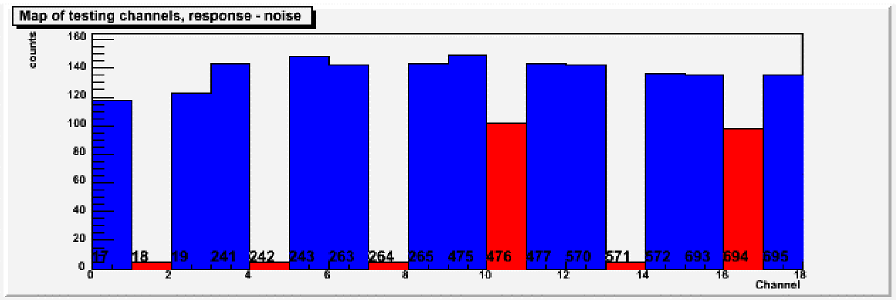
Peaking time vs. x from pulse shape fit

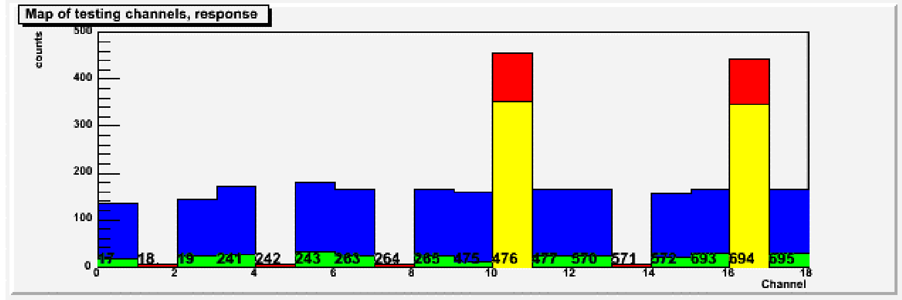
http://ific.uv.es/~cescobar/lasertest.html

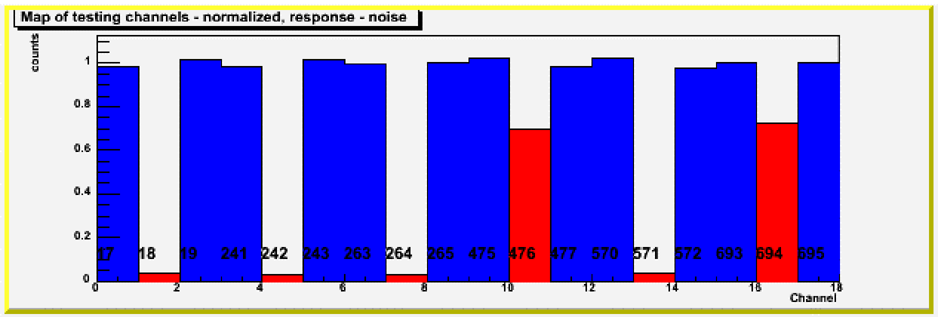
Bad Channel Test

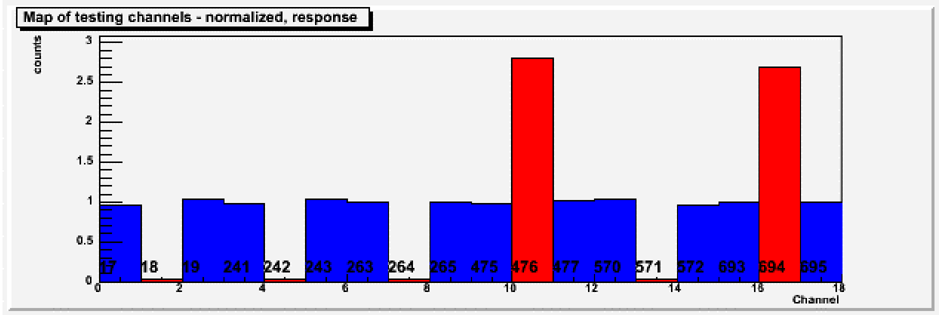
This test check of response of bad channels and compare it with neighbours channels

Tested channels (red) with their neighbours (blue), up: response – noise, bottom: response from channels and noise (yellow/green)









Response of test channels normalized to 1 using their neighbours: average of them was reference value, two channels shows some response but in very high level

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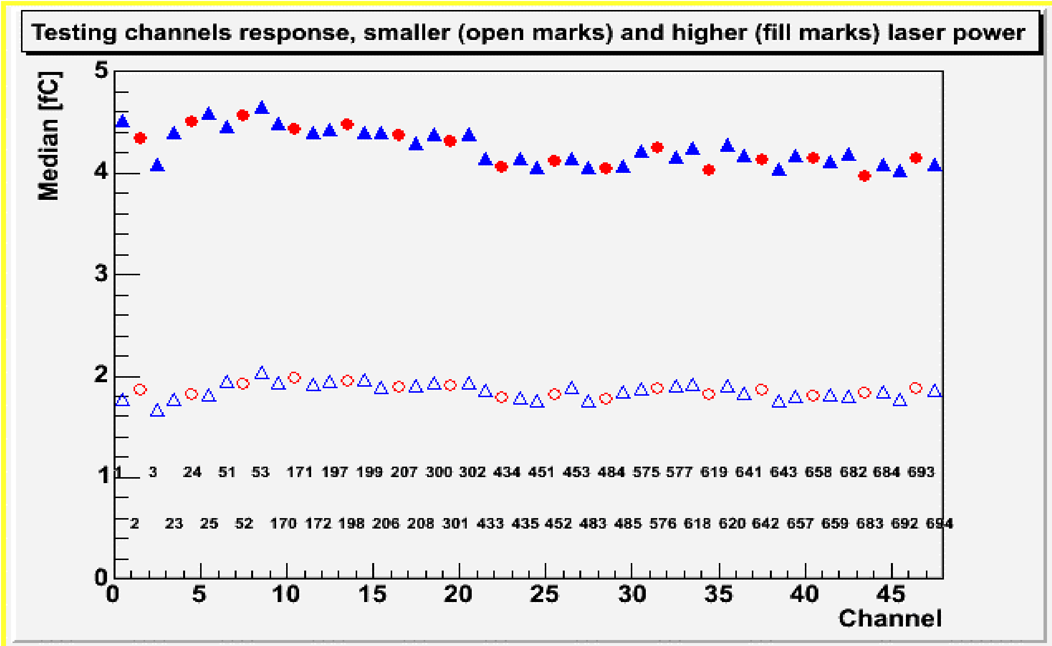
Punch Through (Pin Hole) Channel Test

Munich short middle module 20220990290756, Zdeněk & Peter, July, 19-21, 2004

This test is check response of special channels and compare it with neighbours channels. Possible gain confirmation width two different powers from laser. Different properties of this channels depended of temperature so special measurement setup was solved in IFIC Valencia for measurement in range -20℃ to +20℃ in cooling system with special dry atmosphere.

Temperature hybrid 34, chiller 18, StandardFEB(220)+FES(30) - PT channels are invisible in 3PG test
Temperature hybrid 11, chiller -20, StandardFEB(220)+FES(30) - some PT channels are visible in 3PG test
Temperature hybrid 11, chiller -20, SpecialFEB(200)+FES(28) - PT channels are invisible in 3PG test

Example of response from testing channels (red) and their neighbourghs (blue) for higher laser pulse (fill markers) and lower laser pulse (open markers) (warm & standard conditions)



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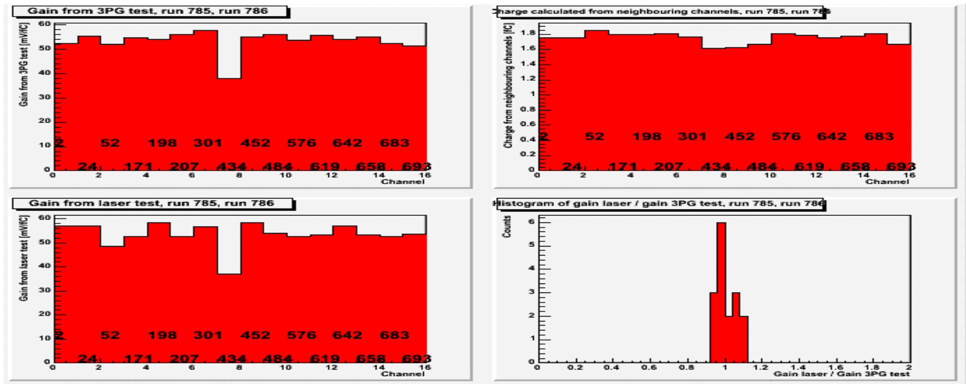
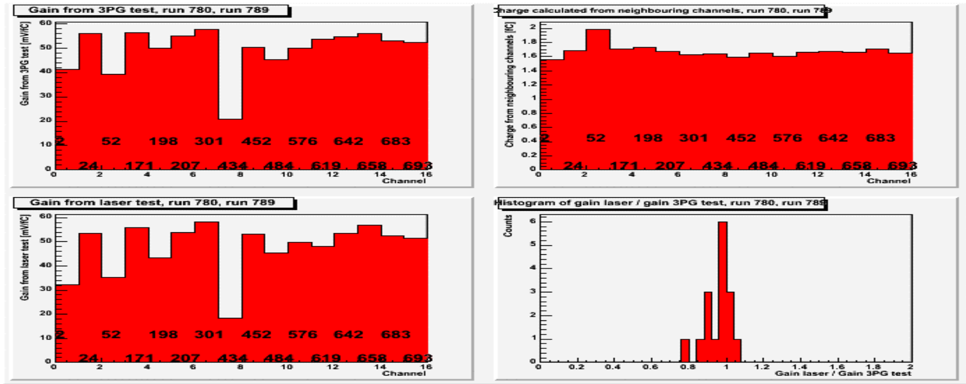
Punch Through (Pin Hole) Channel Test (2)

Gain for cold, normal FEB & FES, comparison of standard tests (left up) and laser test (left down), correction from neighbors channels (right up) and histogram of differences.





Gain for cold and special front end electronics parameters was corrected to standard values except one extremely low channel (434).

1. Punch-through channels at CiS detectors are sensitive to a laser pulse
2. Gain measured with laser corresponds with gain measured by internal calibration pulse using SCTDAQ sw within 10% at all conditions used
3. Existence of low-gain channels observable at cold conditions only has been confirmed
4. Tuning of front-end parameters can lead to a recovery of normal gain for most of the channels. This can be performed at any moment of module's life, and results of standard gain measurement can be used to find proper settings.

Stability Of Measurement

Internal trimming tune offset of channels to common level at 1fC charge in calibration pulse. For many tests we need measurement with untrimmed channels (for measurement of un-trimable channels) and unmasked channels (for bad channel tests). For measurement of stability of measurements we use outer unirradiated module with Hamamatsu detectors in dry air atmosphere.

Stability:

1. Measurement of channels response used median point from threshold scan with precision ±5mV

2. Differences between channels (no trimming) are ±17 mV (± 10% of signal from laser)

3. Differences between measurements are ±3 mV (± 2% of signal from laser)

Temperature dependences:

Noise is not depended on temperature in range 6 to 29 °C on temperature on hybrid

Response from channels depend from temperature on hybrid : (2.4 ±0.3)mV/°C

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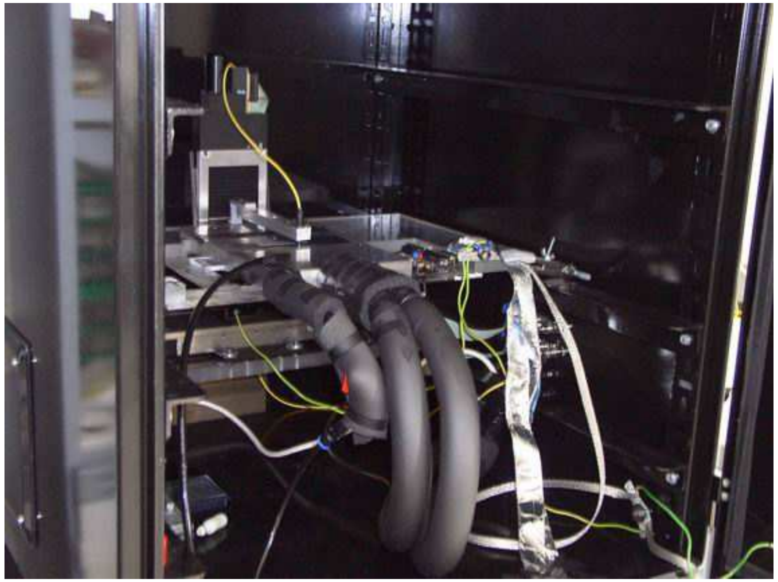
Photos 1

Final arrangement of workspace

General view to laser tests workplace with black box (left) with 2D stages inside and chiller below them, readout electronics (right) and DAQ computer



Black box with module box connecting to cooling and DAQ electronics

Block of connectors for in/out puts of cooling, air or nitrogen, optical fibre of laser light and command wires of position stages

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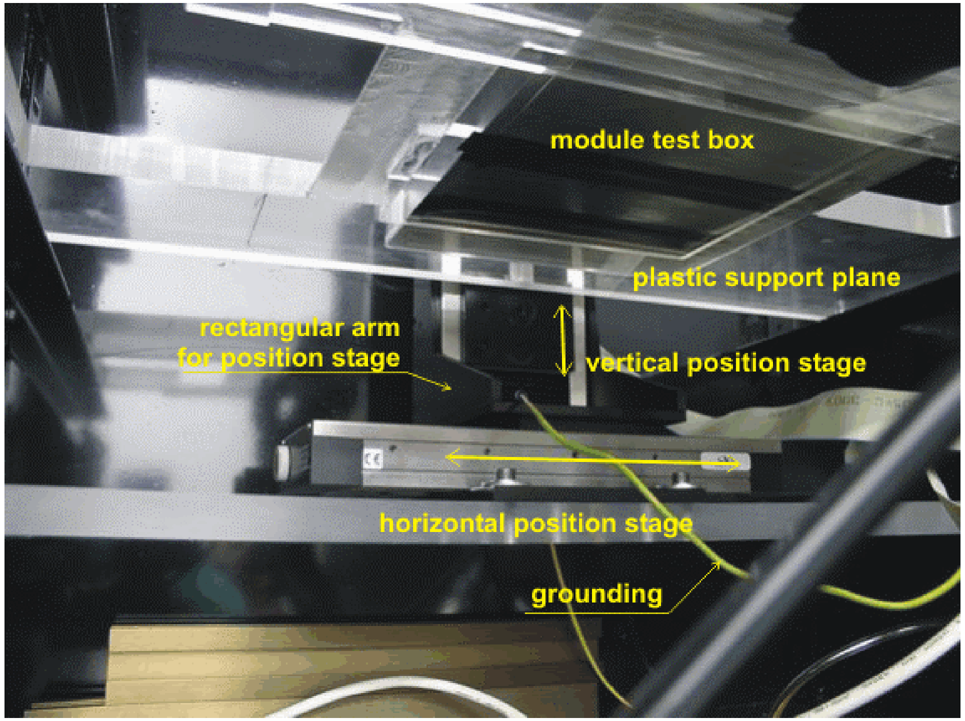
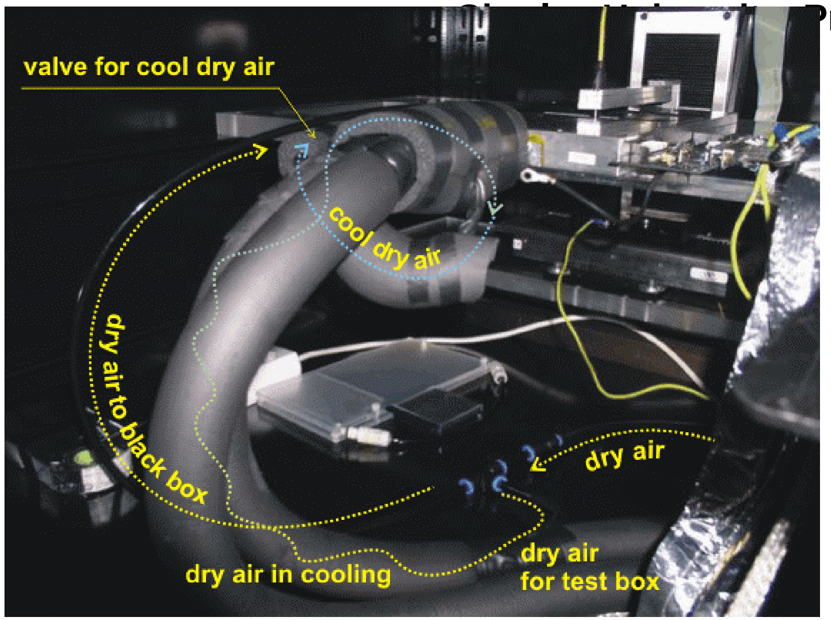
Photos 2

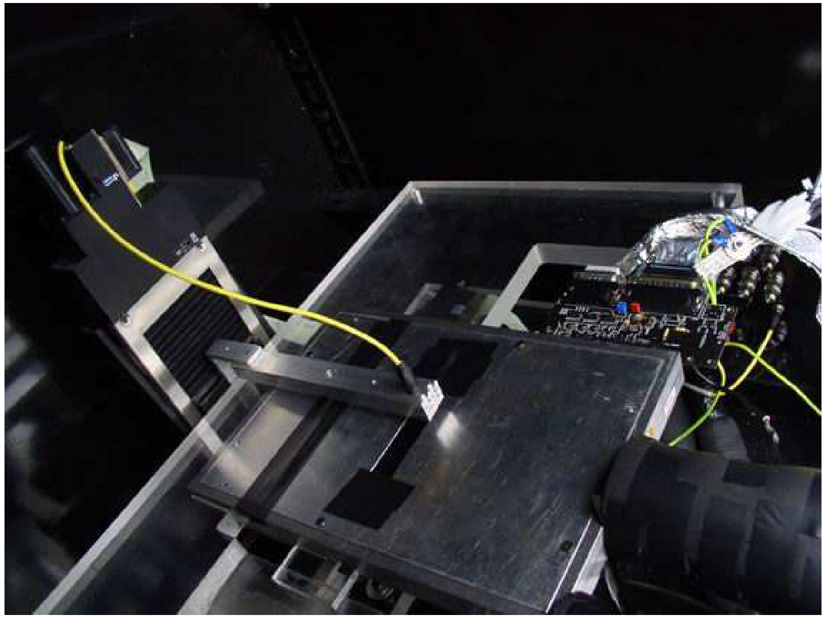
Final arrangement of workspace



Position stages arrangement



Production of dry cool air for module



Laser end with focusing lens above module sensor and module test box with two windows for testing of both sensors (one is closed for save cool dry atmosphere inside)

http://ific.uv.es/~cescobar/lasertest.html

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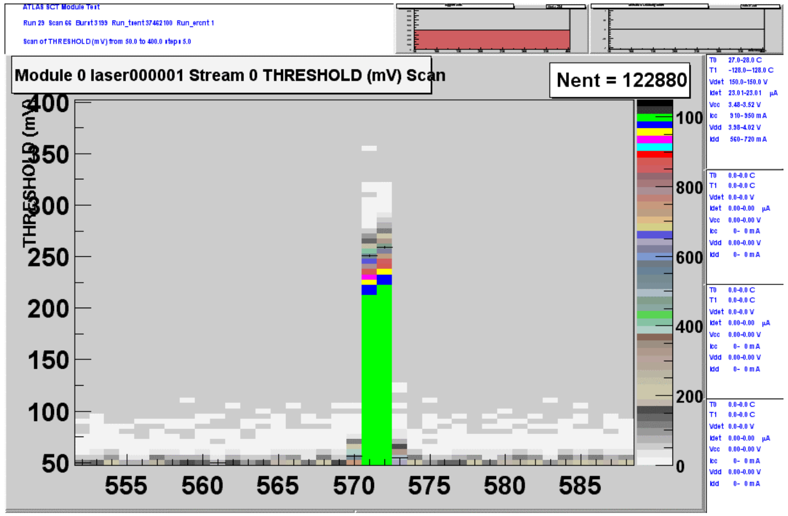
Conclusion

- Very sensitive to right focus distance, sophisticated focusing procedure developed
- Laser detection in only one side (metal back side of detectors – no transparent for light)
- Some sensor properties are visible only in lower temperatures so there was solved ability to cool down whole laser test workplace with special dry atmosphere
- Timing properties are possible to test with precision in level 1ns
- Interstrip properties are possible to test with precision in level 3µm
- Measurement over metalized parts (strip conductive line) is impossible
- No effect of interference between chip channels is observed.
- Pulse shape reconstruction test
- Punch through (pin hole) channels test (gain confirmation) for response
- Testing at low temperatures was possible up to -20deg in chillers (4 deg in T-hybrid)
- Testing in special atmosphere (dry air or nitrogen, …) is possible



Laser Spot on Threshold Scan (No focused spot, two channel signal, first historical detection of laser on SCT module in IFIC)