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# Absolute charge measurements using laser setup

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# Introduction

Main limitations in laser tests of silicon detectors for particle physics come from undefined and undecribed properties of surface. Producers of detectors do not measure quality of surface and also variation of size and properties for particle detection has high sensitivity for laser test measurement.

Optical head described in this talk solves measurement of reflectivity of surface on the point of measurement and decrease many free parameters which are hardly and many times only approximately finding in special measurements and from simulations. Basic idea was to measure on the same light beam in the same conditions as used for charge generation in silicon: pulse amplitude and width, space distribution of beam, size of spot on detector, perpendicular direction.

Finally absolute injected charge created on silicon detector by laser pulse can be predicted.

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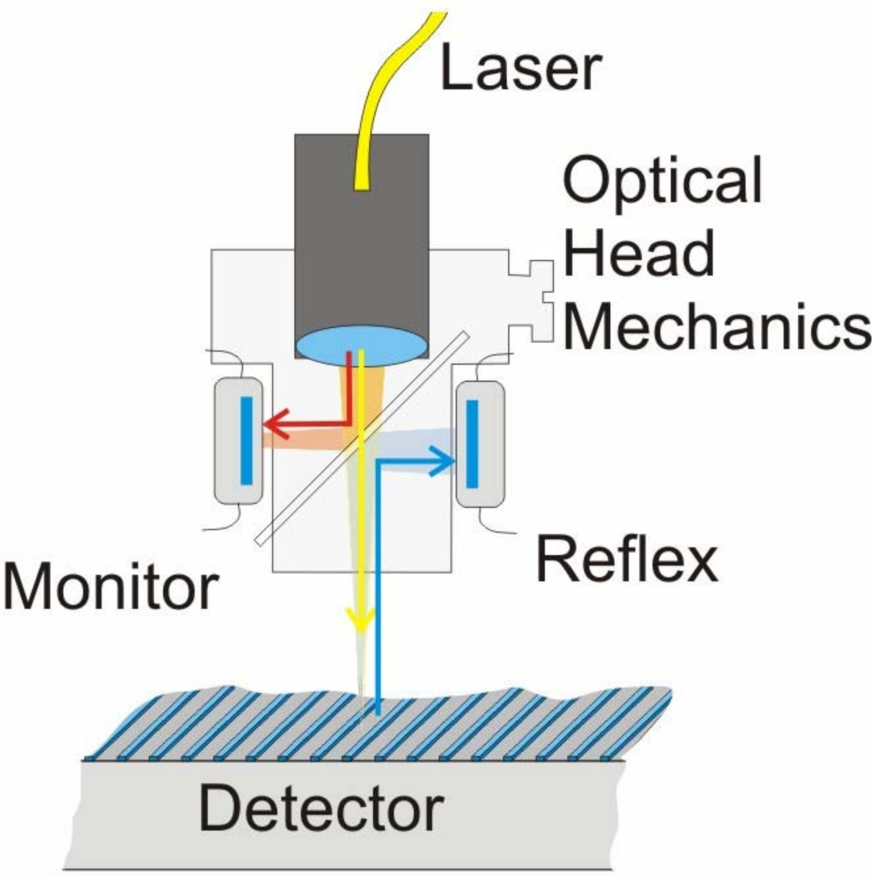
# Optical Head - mechanics




Original light beam from focusing lens is split by glass plate with thickness 180 µm without additional coating. Monitoring part of light is ~4% from power and the same part of reflected light from perpendicular surface is detected. Power of laser is measurable on level of 4fC of collected charge in detector in pulse ~2ns width up to few 100ns pulse width. Tested surface reflected signal back to optical head in perpendicular direction. Splitter and detectors are integrated in optical head 8mm thick on output of laser (focus distance 12mm).

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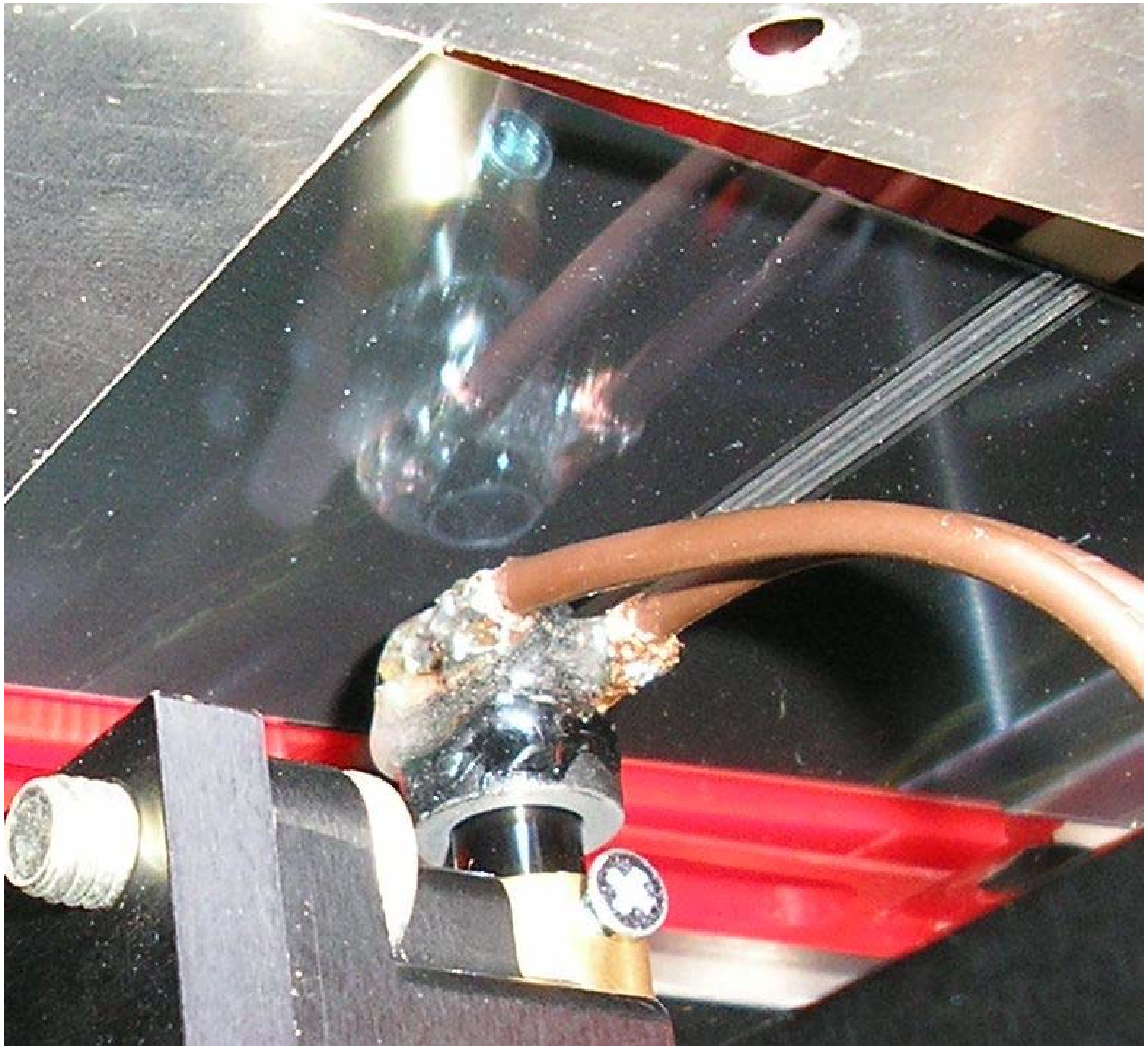
# Optical Head - mechanics

Preamplifiers are mounted on rotation stage in fixed position to optical head in two independent boxes. Power supplies are 5V.



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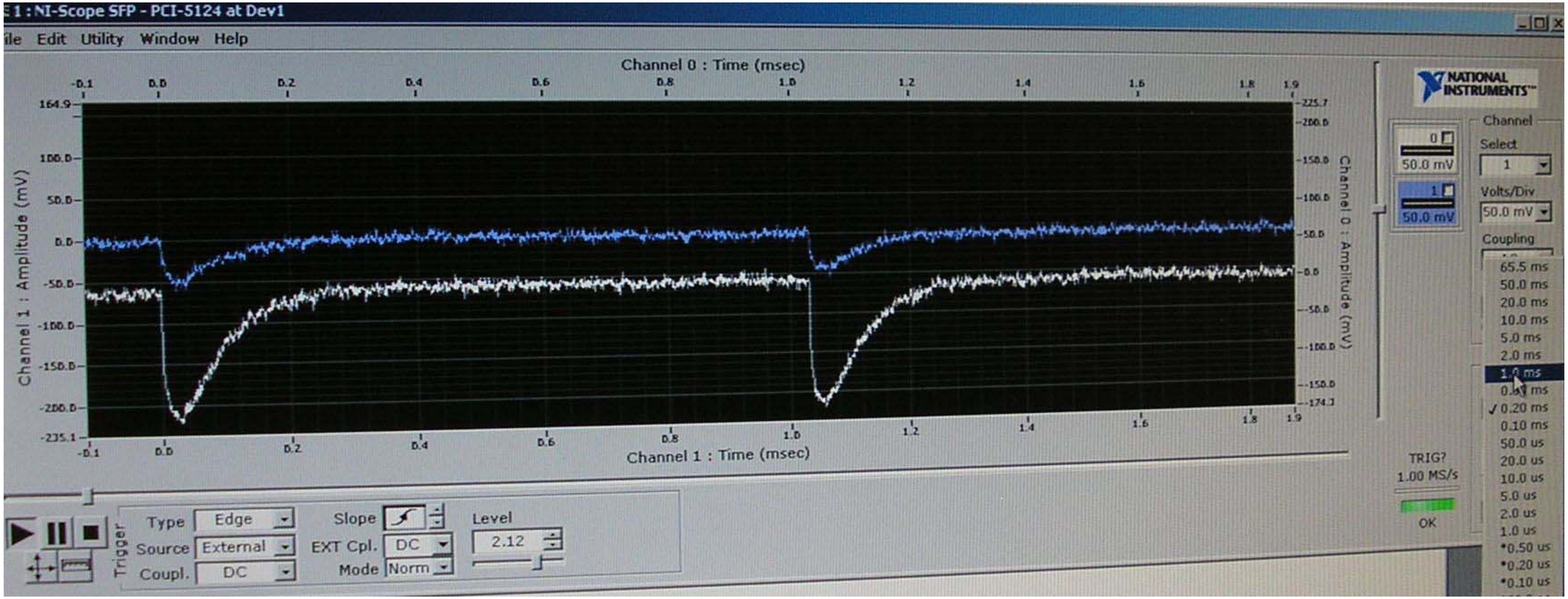
# Optical Head - electronics




Evaluation is on scope board PCI-5124, 200 MS/s 12bit two-channels digitization 32 MB/ch on PC and C++ macro to acquire signals from 1000 pulses and saving to file.

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# Optical Head - properties

mon: detector signal from laser source, monitoring signal, in mV
ref: detector signal after reflection from measured surface, reflecting signal, in mV

## ---> **682nm wavelength**:

zero reflectivity: ref mean **< 0.1mV@100ns** nominal pulse width (**mon mean ~21mV**)
Real pulse width: driving electrical signal for laser pulse generation is triangular,
5ns growing up, 0ns platoe, 5ns going down,
only small upper part of signal drive laser pulse,
so real width is **2.0ns@682nm**, it depend of choosing amplitude
stability of mon signal: mean std dev **0.012mV @ 10ns** nominal pulse width (**mean ~0.4mV**)
mean std dev **0.018mV @ 100ns** nominal pulse width (**mean ~6mV**)
stability of ref signal: mean std dev **0.011mV @ 10ns** nominal pulse width (**mean ~1.0mV**)
mean std dev **0.021mV @ 100ns** nominal pulse width (**mean ~23mV**)

## ---> **1055nm wavelength**:

zero reflectivity: ref mean **< 0.7mV@100ns** nominal pulse width (**mon mean ~138mV**)
Real pulse width: driving electrical signal for laser pulse generation is triangular,
5ns growing up, 0ns platoe, 5ns going down,
only small upper part of signal drive laser pulse,
so real width is **2.4ns@1055nm**, it depend of choosing amplitude
stability of mon signal: mean std dev **0.05mV @ 100ns** nominal pulse width (**mean ~105mV**)
stability of ref signal: mean std dev **0.03mV @ 100ns** nominal pulse width (**mean ~36mV**)

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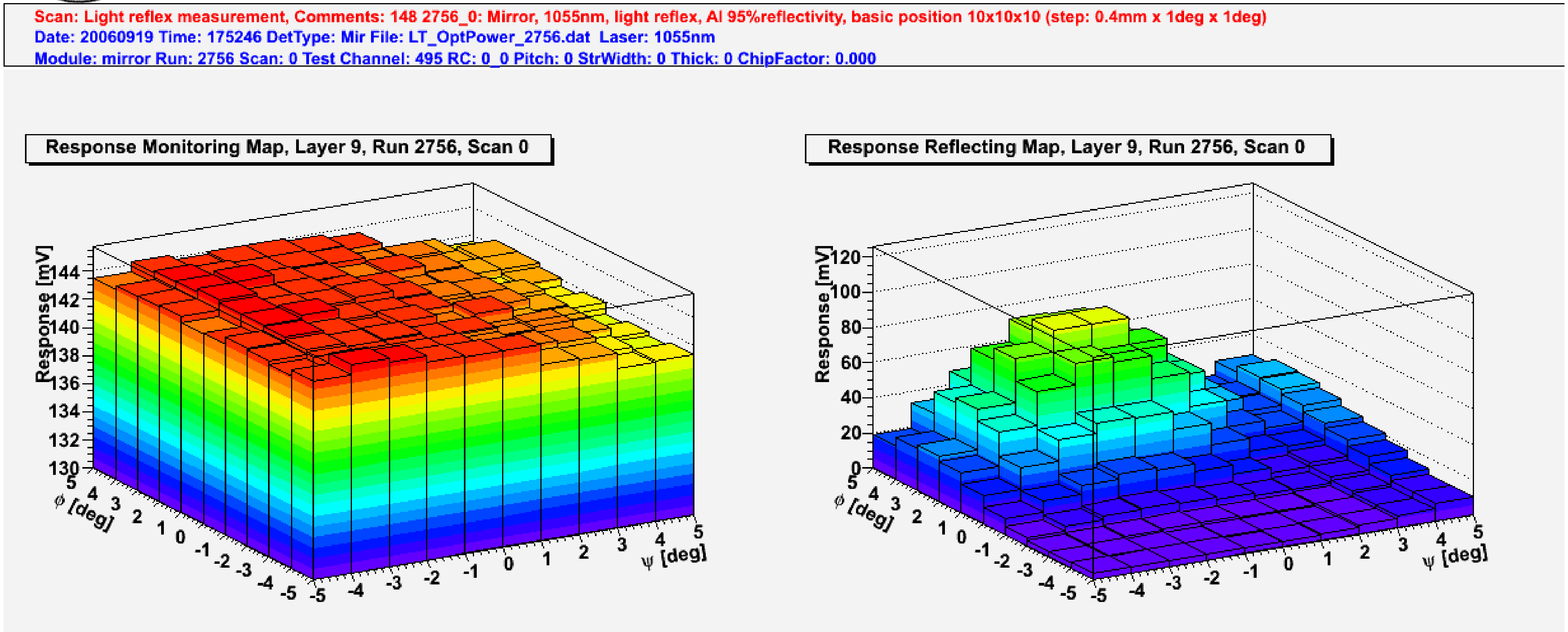
# Reference calibration on mirror




Reflectivity of known material on perpendicular direction (maxima in angle scan).

We use 95% reflective Alumina mirror with results:

132mV/148mV@1055nm@100ns_puls@95%reflectivity --> **138mV/148mV@1055nm@100%reflectivity**

10.1mV/24mV@682nm@100ns_puls@95%reflectivity --> **10.6mV/24mV@682nm@100%reflectivity**

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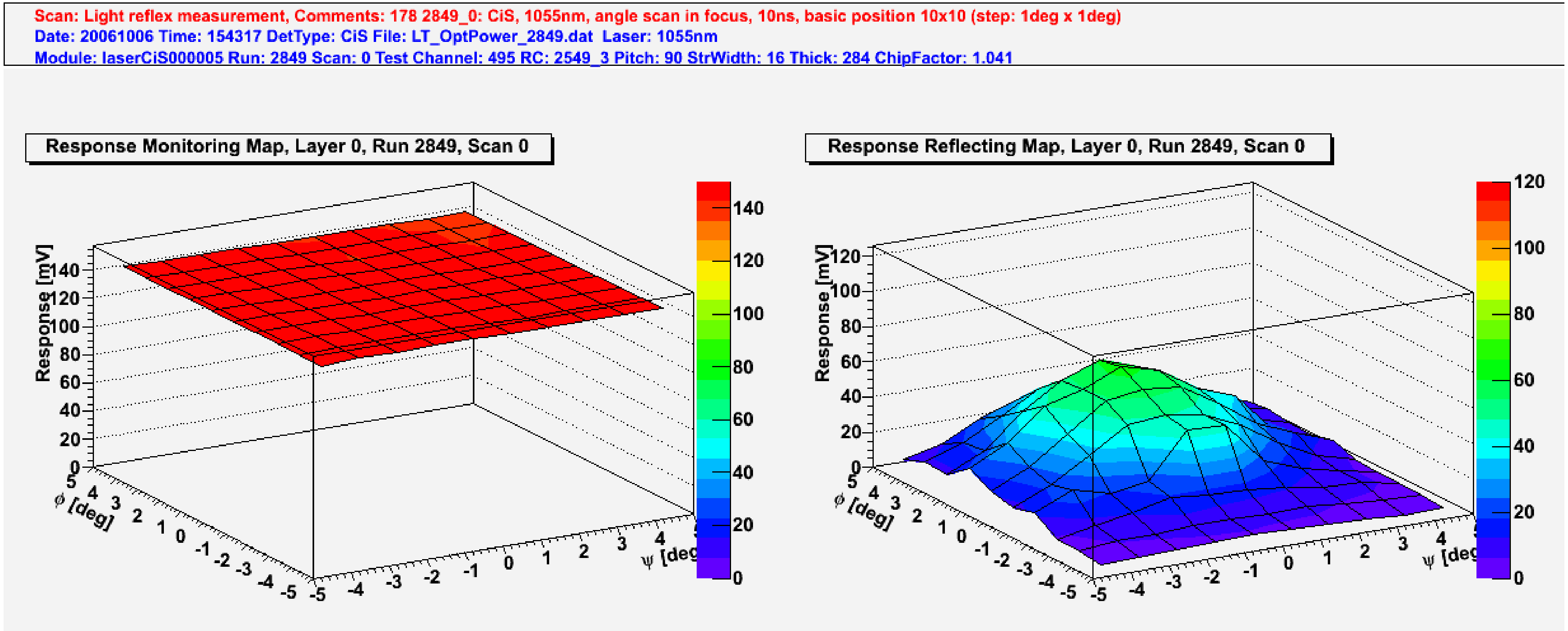
# Reference calibration on well known detector




Reflectivity of well known detector (ATLAS SCT EC CiS) on perpendicular direction (maxima in angle scan in focus): **61mV/141mV@1055nm @100ns**

Collected charge: 5.0fC@10ns -> **192fC@100ns** nominal pulse width or 92.4ns real pulse width

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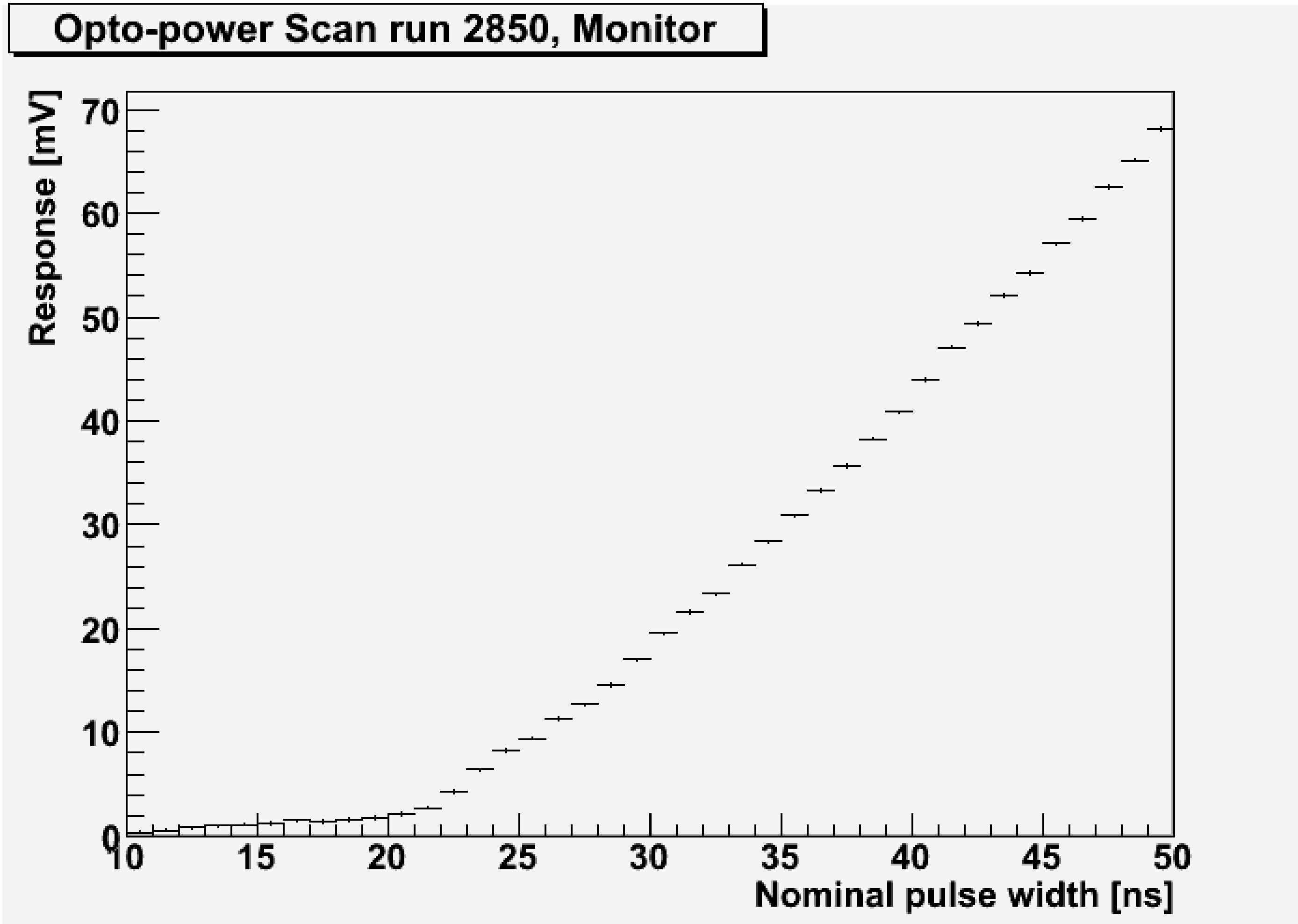
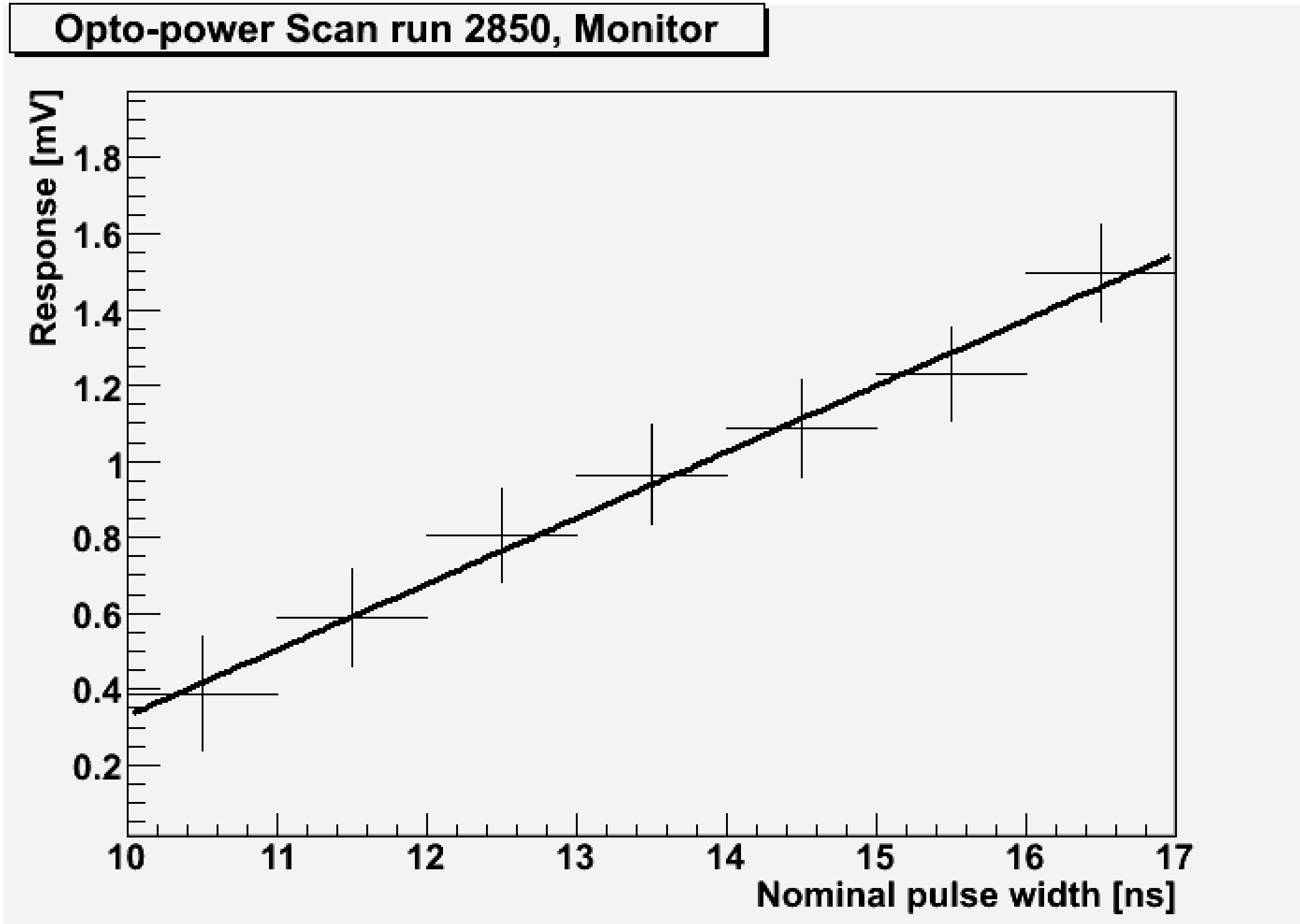
# Pulse response vs. pulse width



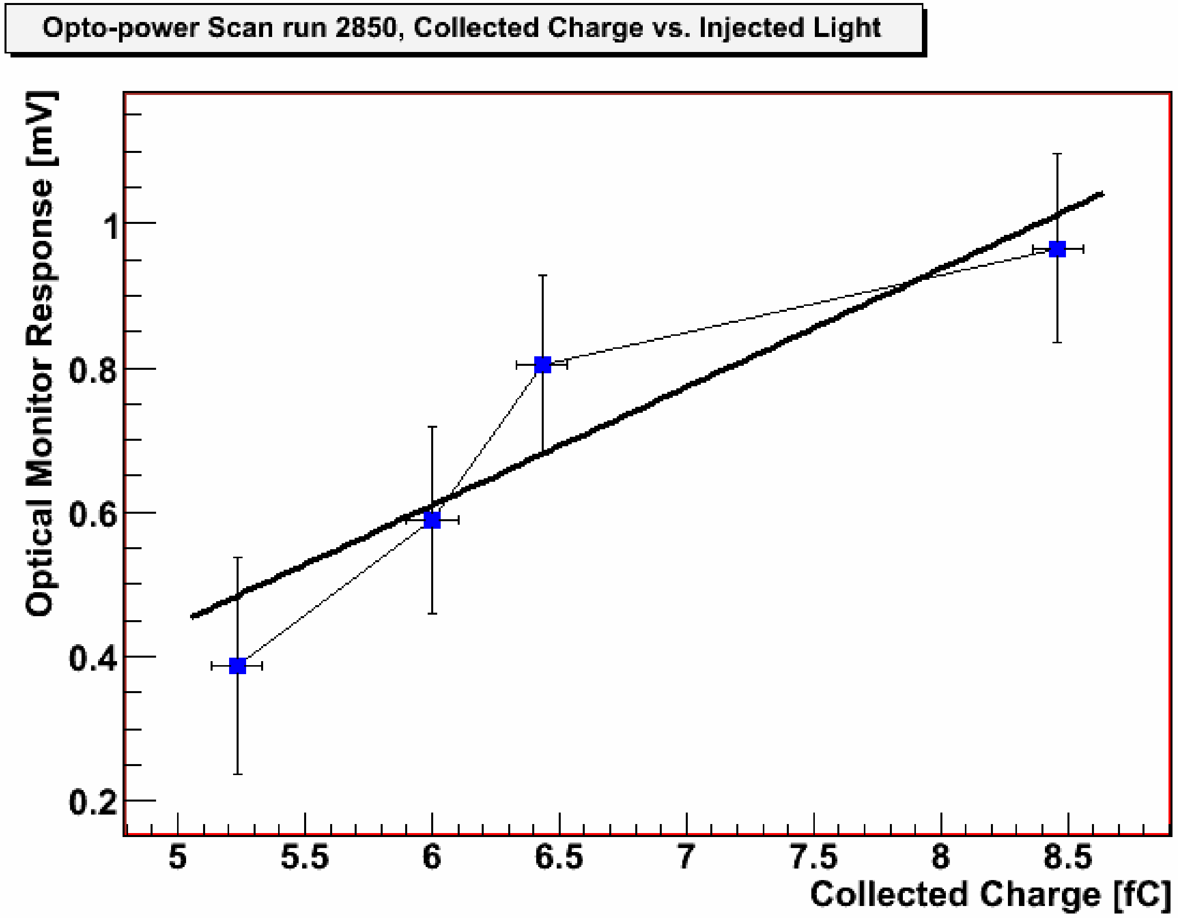

monitor[mV] = 2.5542 * NominalPulseWidth[ns] - 57.933
for NominalPulseWidth > 27ns

# Pulse response vs. pulse width - detail




monitor[mV] = 0.1735 * NominalPulseWidth[ns] - 1.404
for NominalPulseWidth < 17ns

# Pulse response vs. collected charge




monitor[mV] = -0.3724 + 0.1636 * ColCharge[fC]
in range ColCharge(5fC,8.5fC)

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# Calculation of absolute laser power

# Final reflection from surface (ATLAS SCT EC CiS): **46.4%**
# Final light going to module for production of e-h pairs: **53.6%**
Condition: 100% efficiency on e-h generation from every photon
# Reflectance Ref=0.464 is final information obtain from previous steps.
# @10ns pulse generate 5.0fC charge = 31,500 e-h pairs
# Light pulse @10ns will contain 58,800 photons
monitor[mV] = -0.3724 + 0.1636 * ColCharge[fC] in range ColCharge(5fC,8.5fC)
or using 1fC = 6300 electrons and 1 electron (e-h pair) is from 1 photon:
Photons = 26750 + 71839 * monitor[mV]
ColCharge[fC] = 4.2461 + 11.4029 * monitor[mV]

For known reflectance Ref we can predicate for unknown detector:

ColCharge[fC] = (4.2461 + 11.4029 * monitor[mV]) * (1-Ref)
for monitor range 0.4mV - 1.1mV

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# Conclusions

Device for measuring laser power going to detector (monitoring of laser power) and reflecting light was built.

From detector readout we know collected charge in detector. For new type of detectors we use this scheme for checking if we collect all deposited charge in detector, so we can check efficiency of new module or we can calibrate it.

All this is working if materials of detector similar or the same as was used for calibration and use the same mechanism of creation e-h pairs from injected photons.

Losses on back side of detector are not including to this calculation, in case back side metalizing (case of ATLAS SCT strip detectors) 95% reflectivity is probable, in case non-metalized surface (partly transparent surface) need additional measurements for setting of transmitted light (additional detector like in optical head can be used after calibration).

For example basic prediction of absolute laser pulse power was done

# Note on the end

Precision of results presented here is better 5%, higher precision is possible with higher statistics of measurements and finer steps of scans, but it is time consuming, for example of confirmation of how it is possible on this work we did not go to maximal possible precisions.