UV-LED calibration system for SiPM based detector

a party with fast LED drivers

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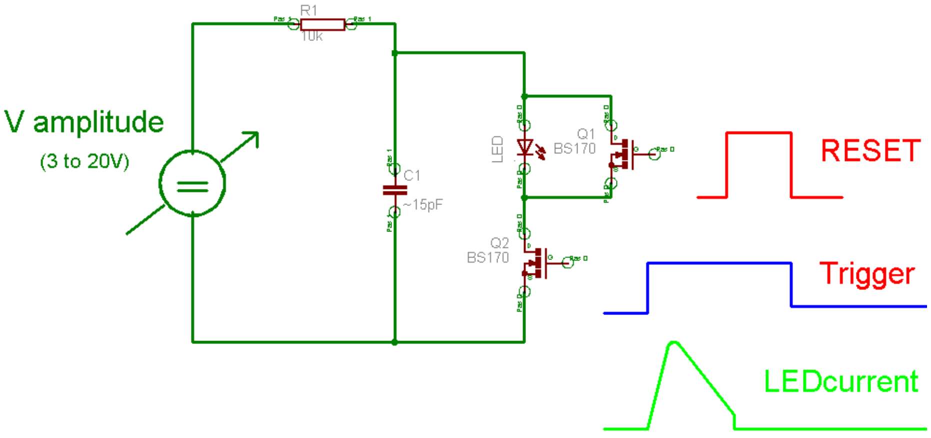
1. SiPM needs short optical pulses
2. Principal schematics of LED drivers
3. QRLED driver generates single p.e. Spectra
4. LED and Notched fibre light distribution system
5. Results, parameters in test, 4T magnetic test
6. Conclusions

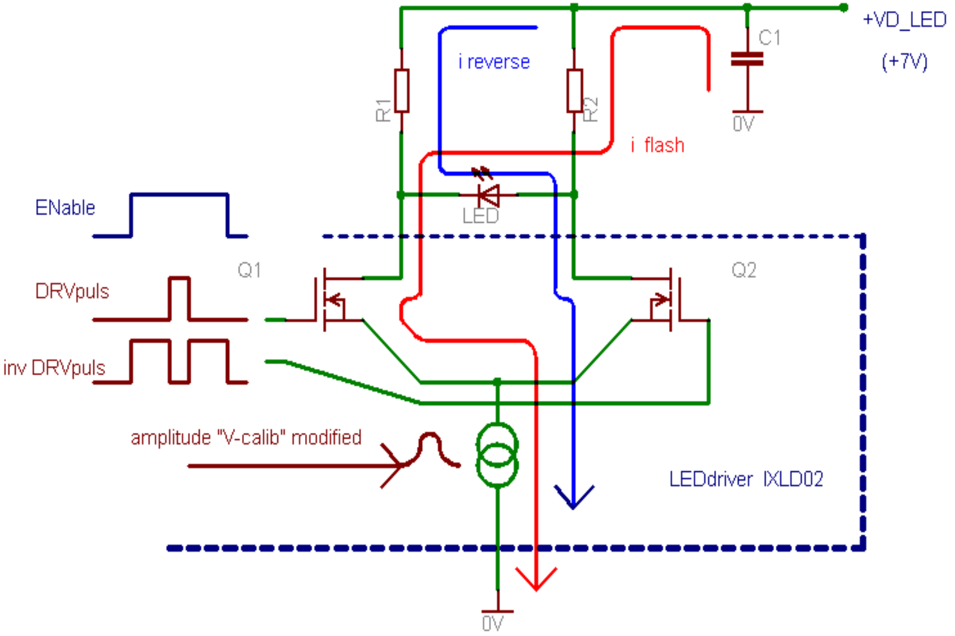
Requirements for calib signals to SiPM

- ~400nm light flash
- Short pulse in range 2 to 10ns
- Tunable in amplitude
- Clear end of the pulse
- Stability, low jitter
- Repetition rate up to hundreds of kHz
- Temperature stability

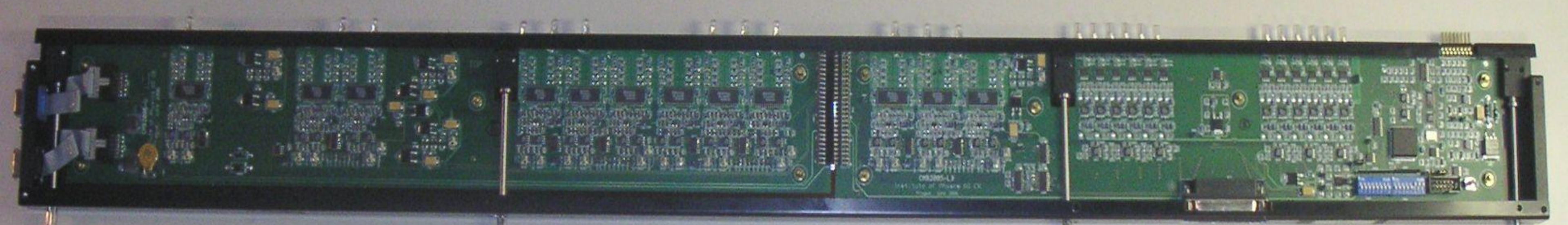
Principal schema of LED-driver



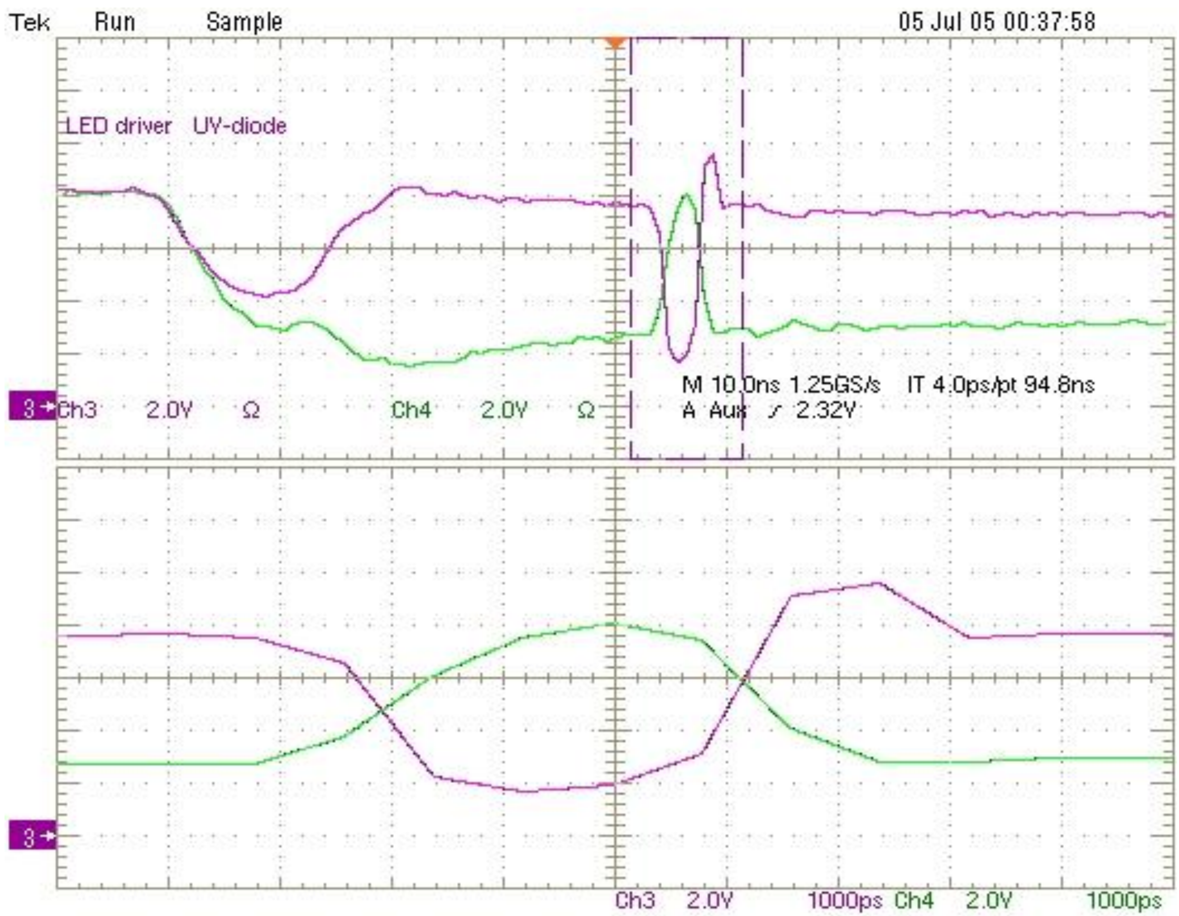
My concept at CMB



A **classic** concept as used in H1 Spacal calorimeter



LED driver at CMB



- 2 Fastest probes at the output
- Short 3ns puls is shown

Zoom 1:10
1ns/div

3 different scope probes, what we see...

JULY 05

CMB LED driver

Oscilloscope
TDS5104, 1.5GHz

Probes TEK

GRN 16pF 200MHz

Cyan 11pF 500MHz

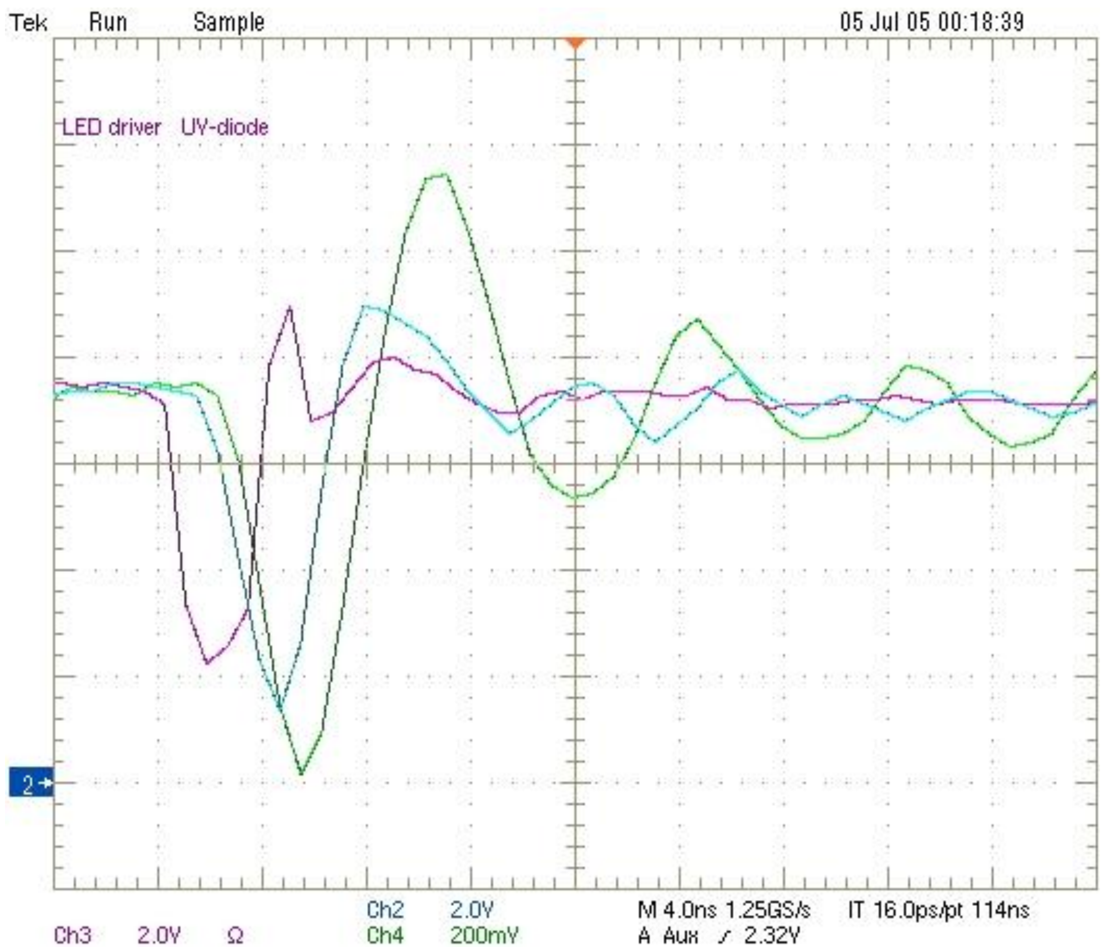
VIO 1.5pF 3GHz

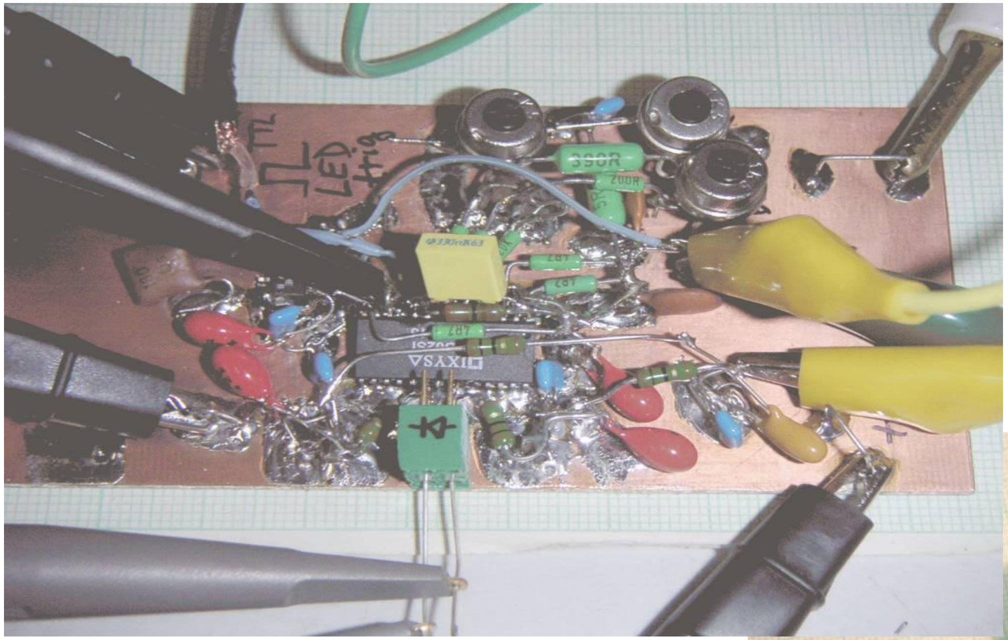
Same circuit at once

P6185 passive 1kOhm 1.5pF 20x (3GHz)

P5050 passive 10MOhm 11pF 500MHz 10x

P2200 passive 10MOhm 16pF 200MHz 10x





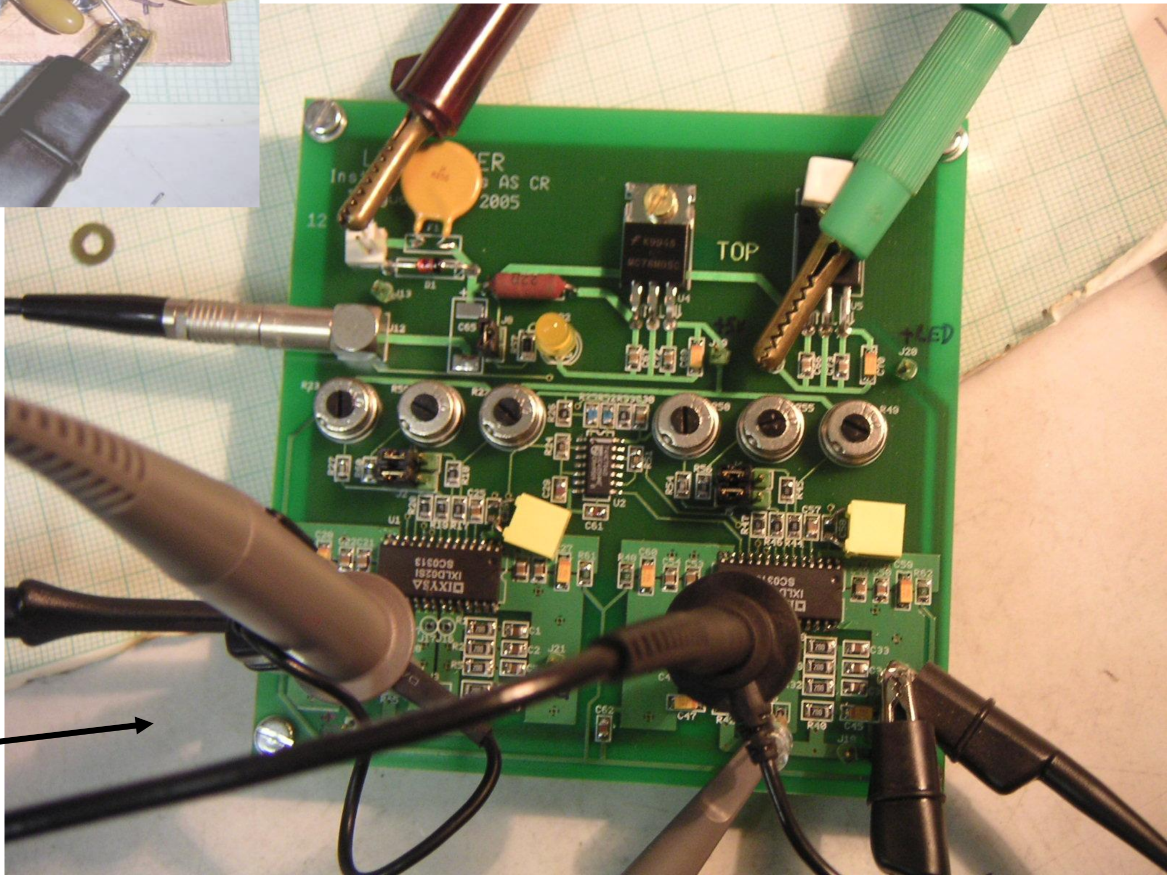
Picture of 1CH LED-driver

I like breadboarding ☺

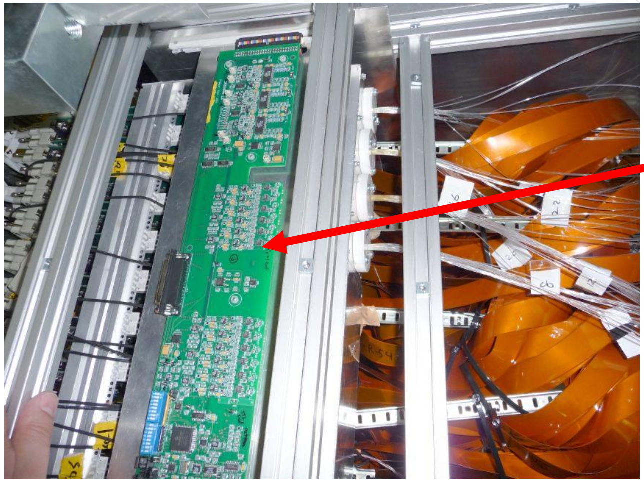
Nov 2004

CMB development
LED drivers part

2CH prototype



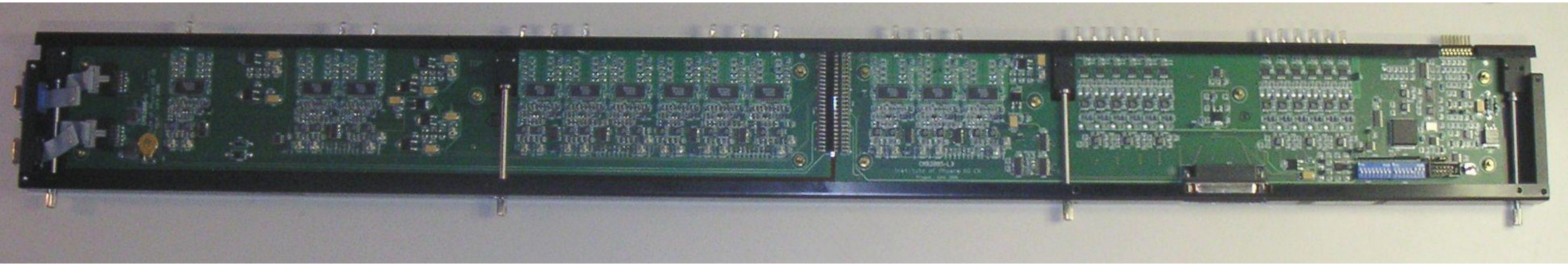
CMB = Calibration Monitoring Board



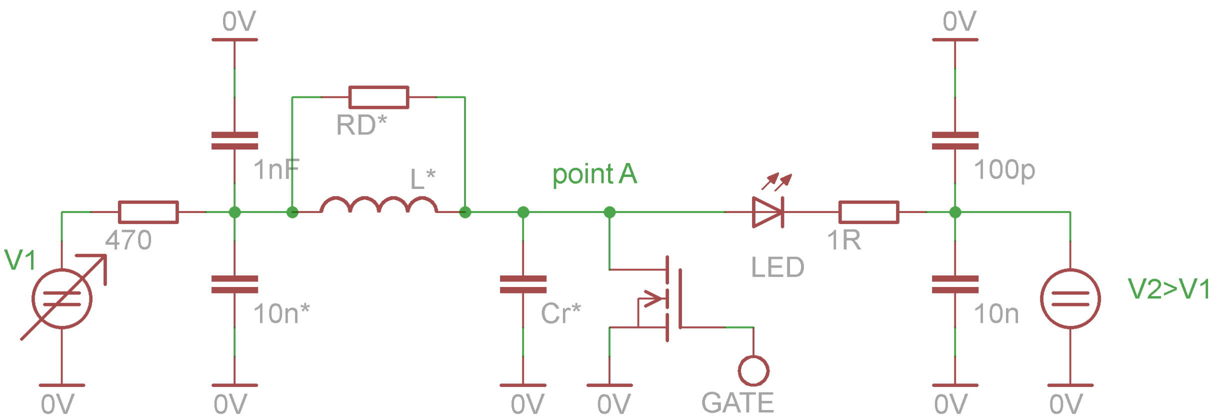
- CMB used in AHCAL CALICE 1m^3 prototype
- 38 layers in AHCAL detector at at three TB facilities DESY/CERN/FNAL (2006 to 2009)
- **One CMB** used in Japanese SciECAL detector (TB 2009)
- **12 LEDs** / 12PIN PD
- Steering of amplitude and pulse width of LED by T-calib and V-calib signals
- Rectangular pulse width 2 ÷ 100ns can be tuned
- Temperature and voltage readout in slow control, CANbus control

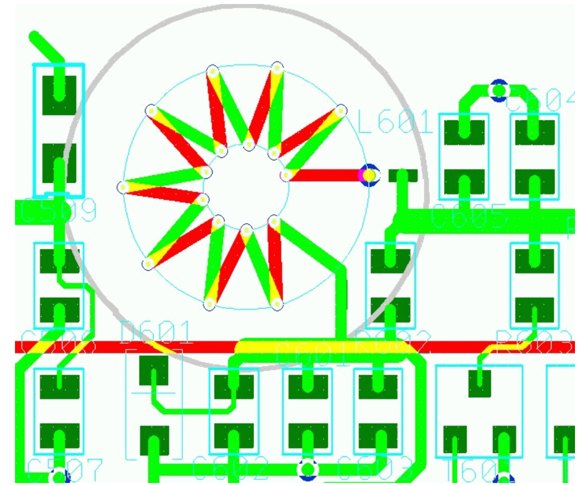
Relevant links:

http://www-hep2.fzu.cz/calice/files/ECFA_Valencia.Ivo_CMB_Devel_nov06.pdf

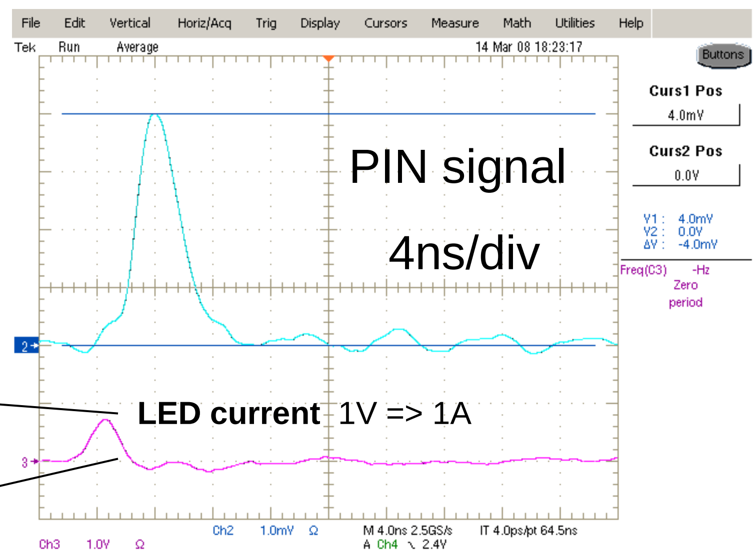


Quasi-Resonant LED driver

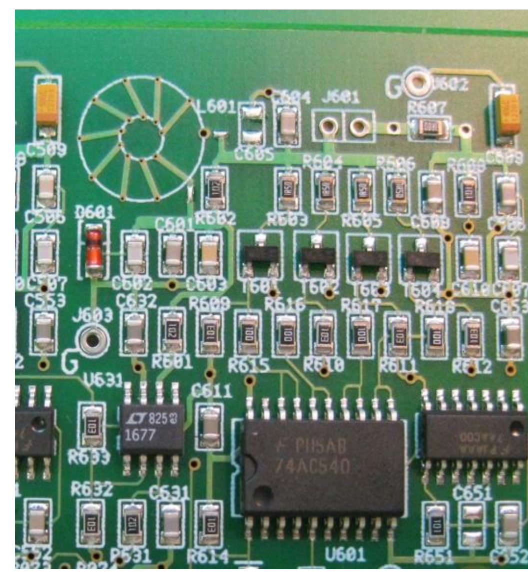




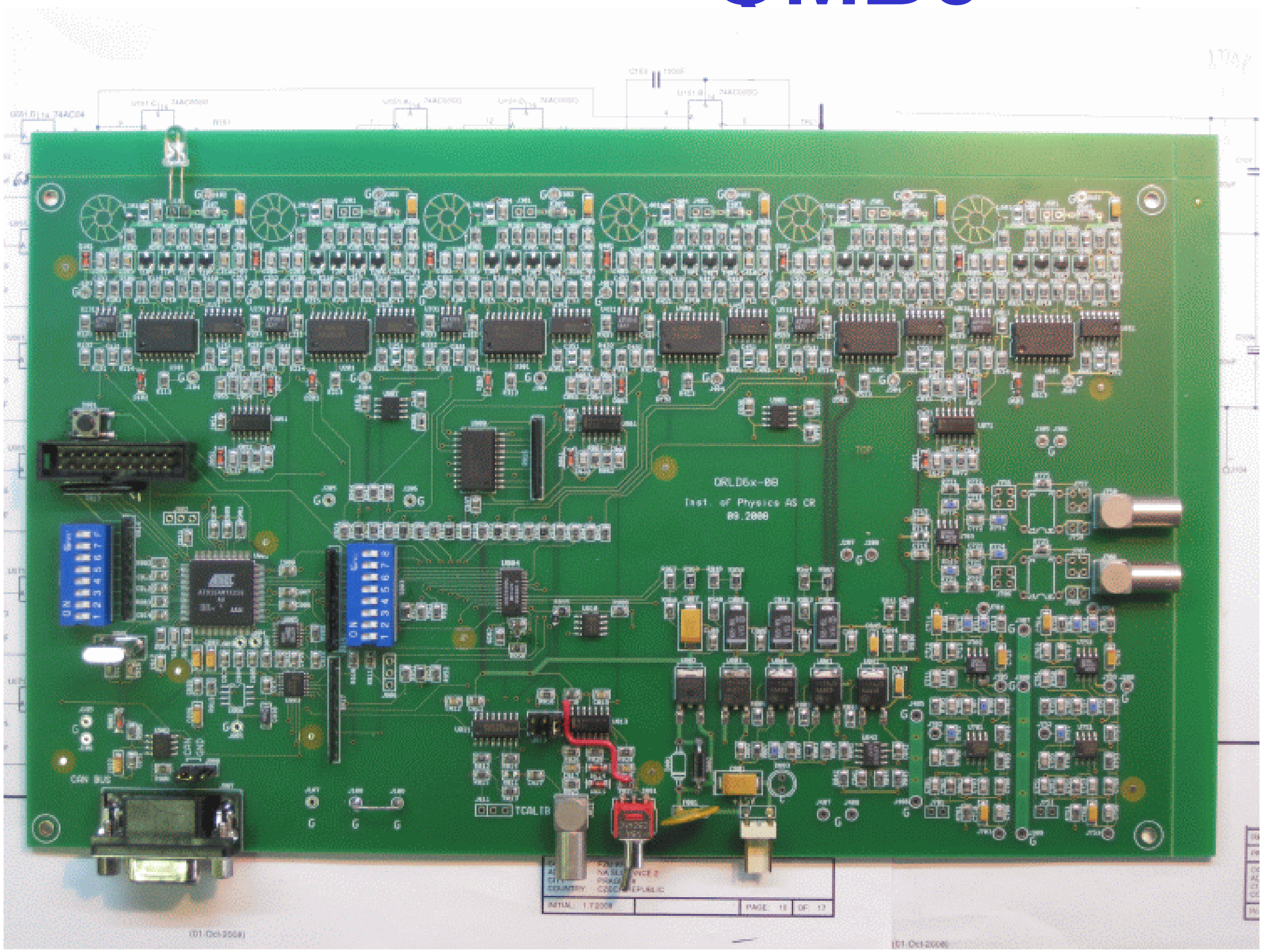
- Less RFI
- PCB integrated toroidal inductor (~35nH)
- Fixed pulse-width (~4ns)



$1A_{pp}$



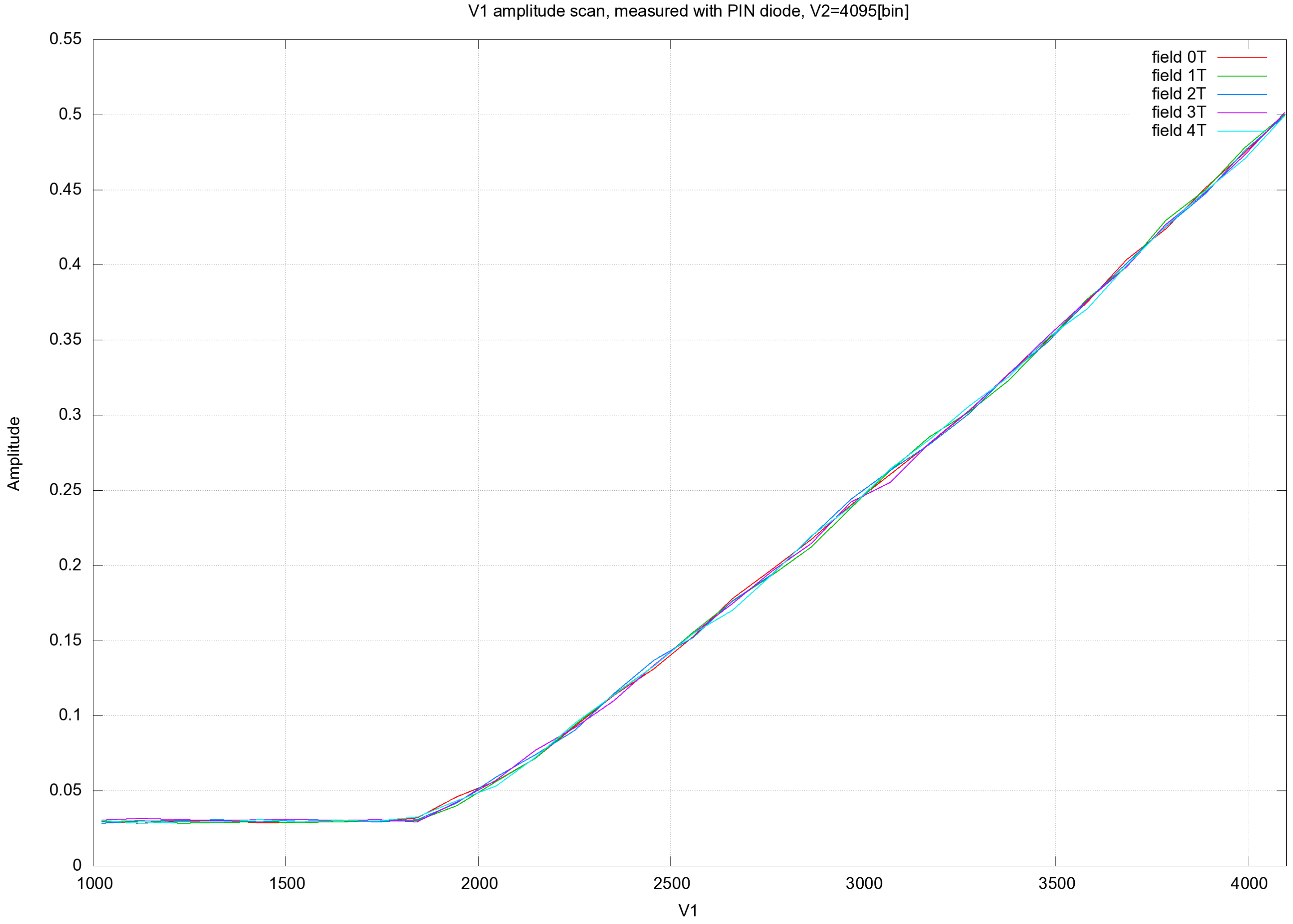
6-LED QR driver Main Board = OMB6



Consists:

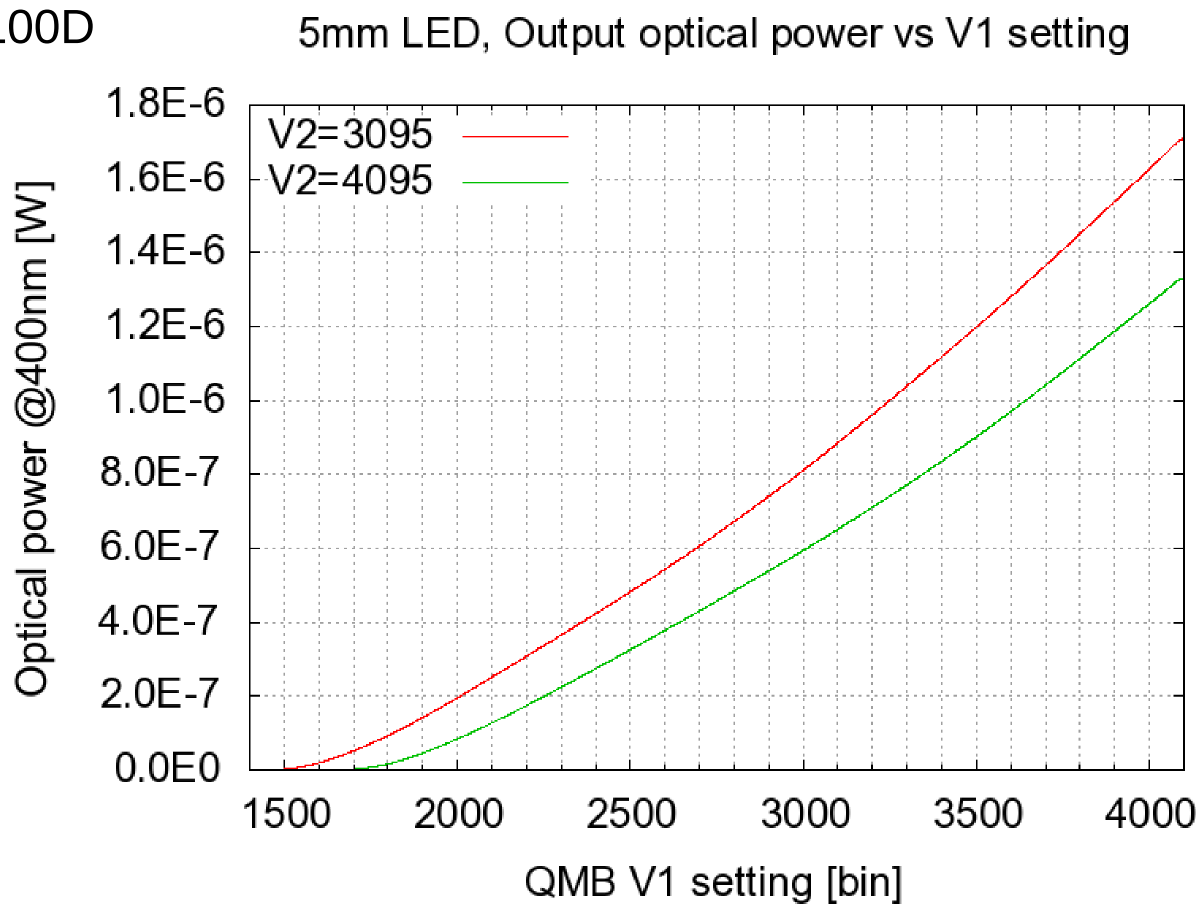
- 6 QR LED drivers
- 2 PIN PD preamps
- CPU + communication module, CANbus
- Voltage regulators
- temperature and voltage monitoring

QMB6 Linearity (V1 scan),
stable in DC magnetic field 0 to 4T

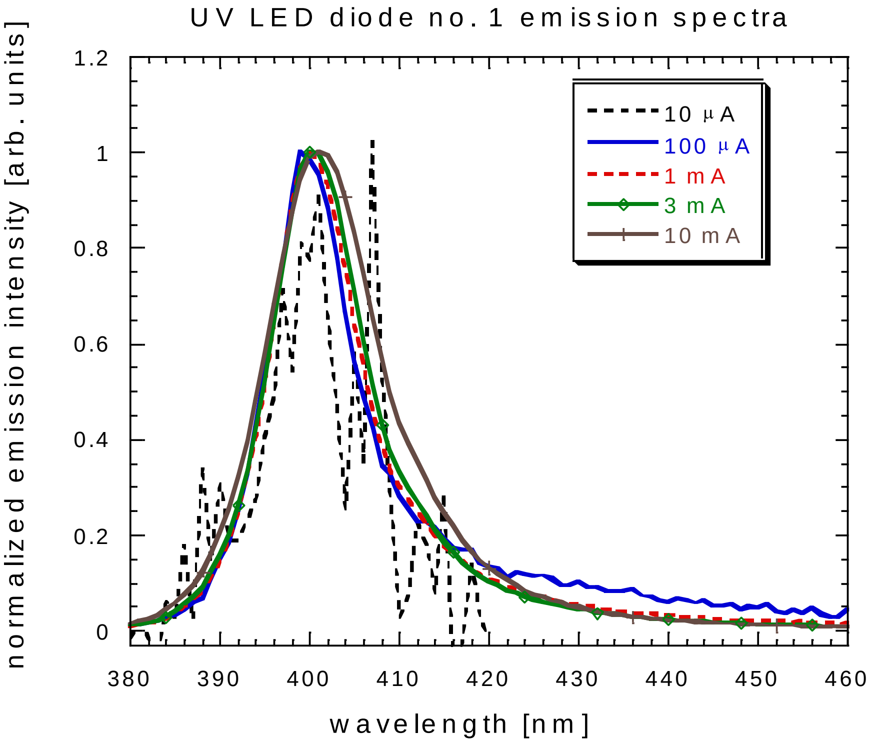


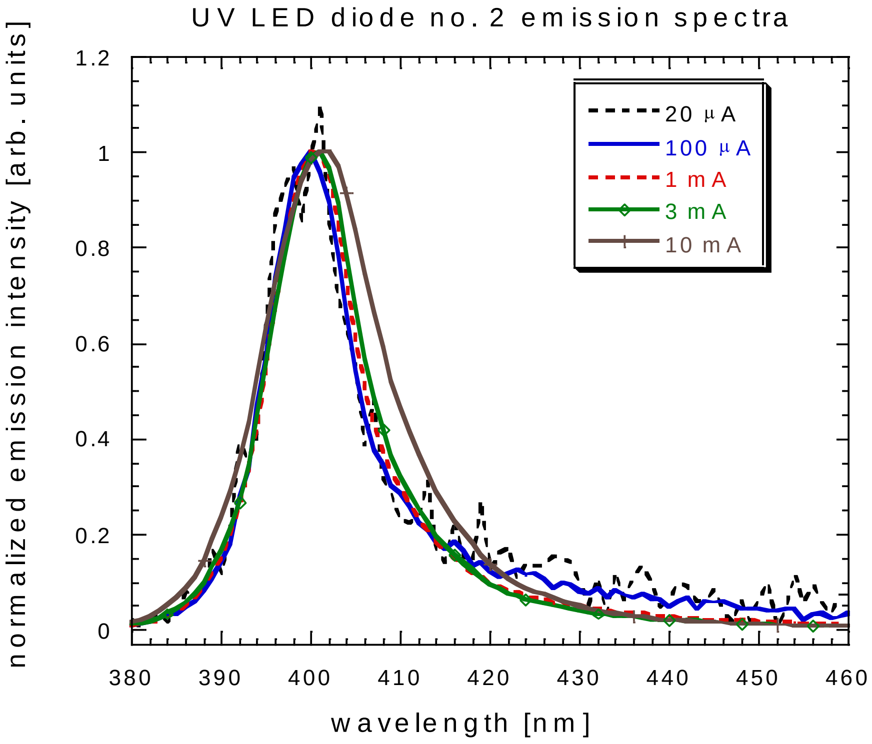
UV-LED Output optical power with QMB6

Thorlabs PM100D

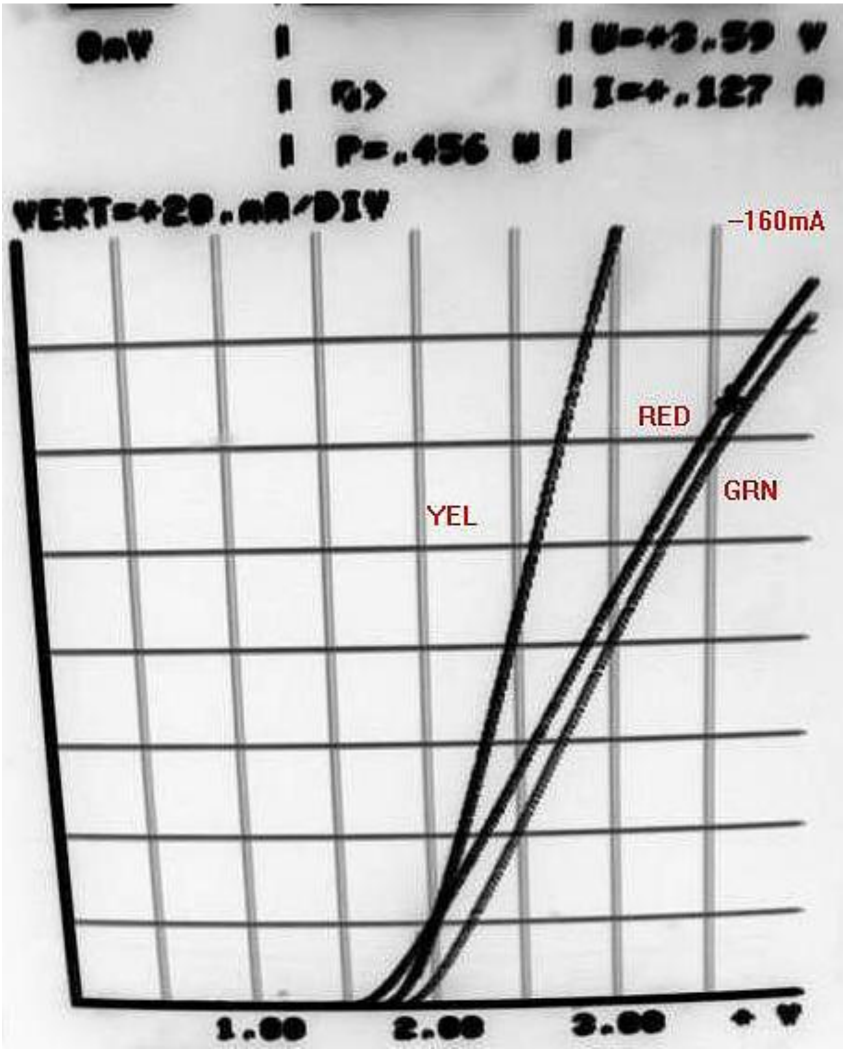


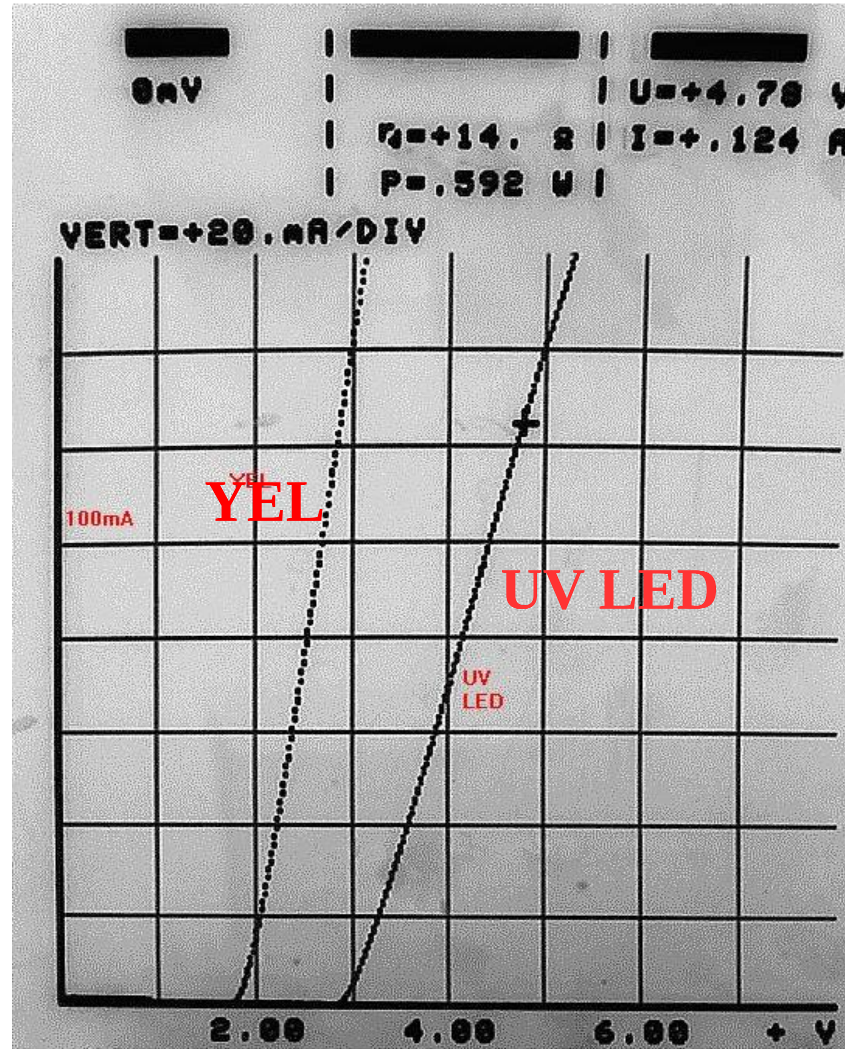
The Emission spectra of 5mm UV-LED, used in CMB





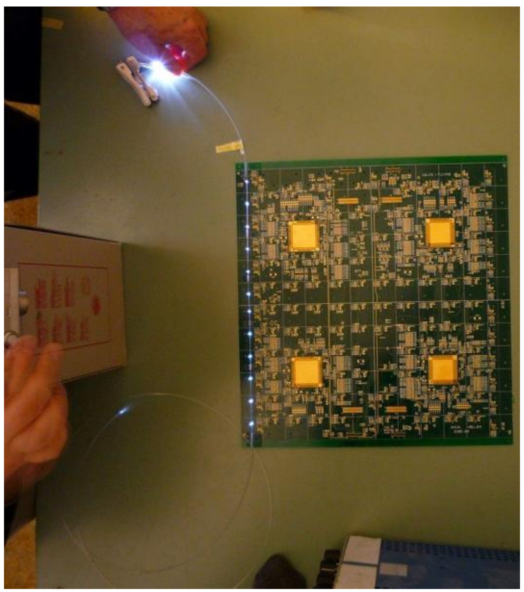
5mm UV LED forward V-A char





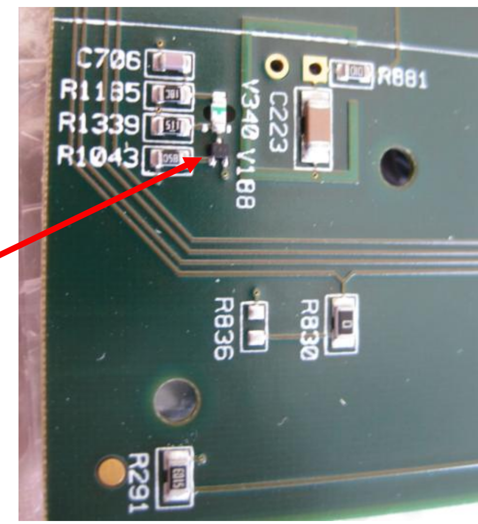
Flashing UVLED - 2 methods of **distributing** at AHCAL detector

- Light distributed by notched fibres



- Light distributed directly by microLED to the scintillator - distributed LEDs

smd UVLED



Institute of Physics ASCR, Prague, (= FZU)
Kobe University

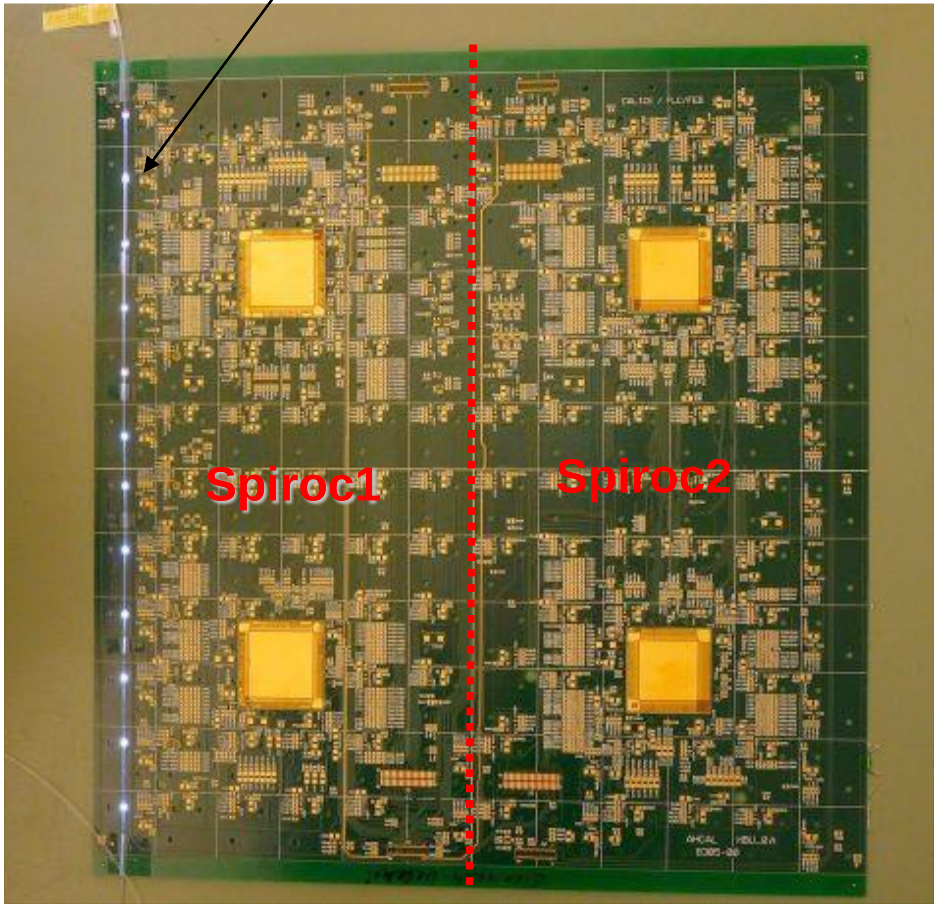
DESY Hamburg
UNI Wueppertal

Notched fiber system

Notched fibre routed at HBU0, taps illuminates the scintillators via special holes

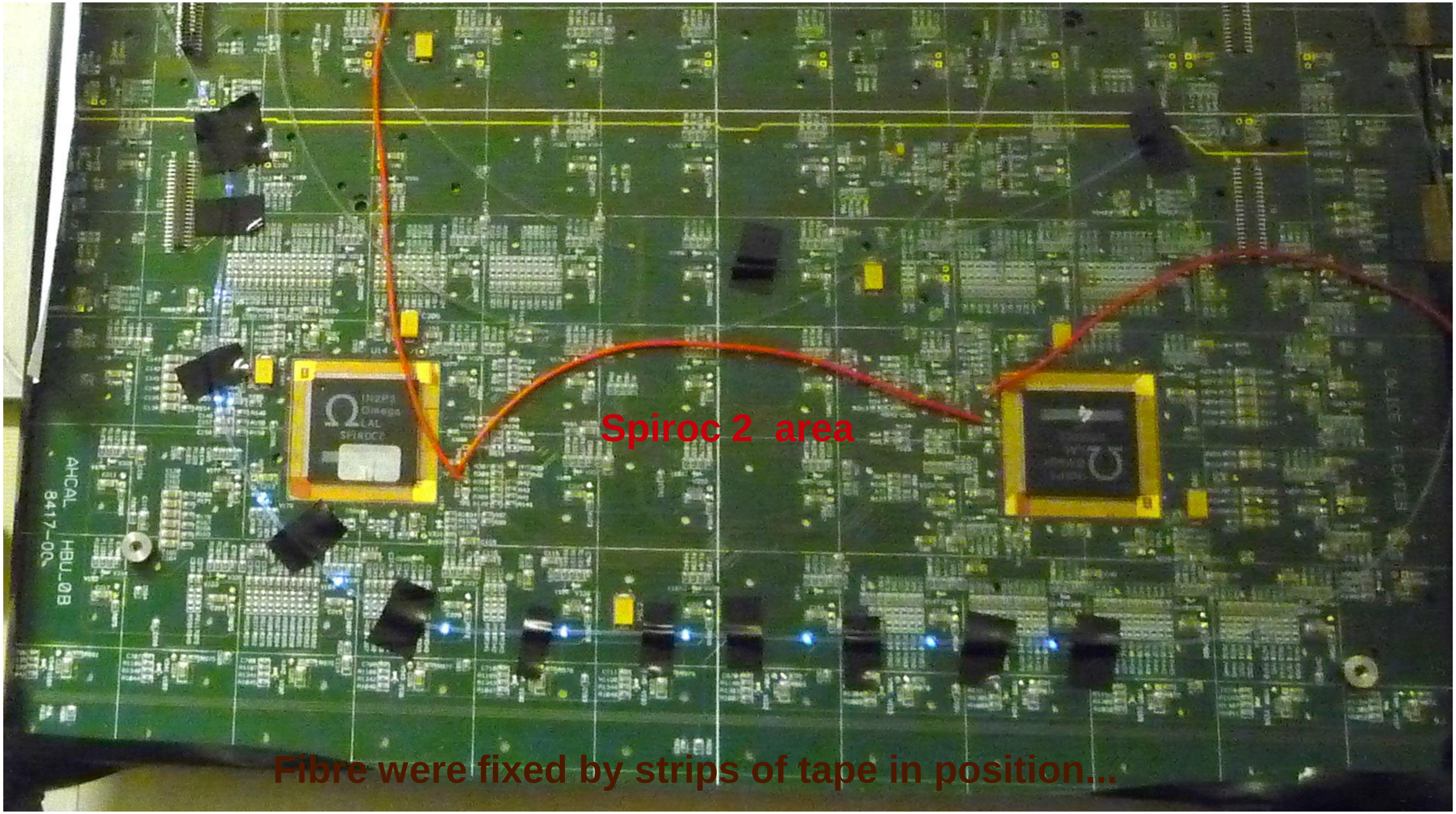
- **advantage** – tuneable amplitude of LED light from 0 to 50 mips
- Variation of LED amplitude does not affect the SiPM response readout
- LED circuit and LEDs enable optical pulses with around 5ns width
- Spread of light intensity from notches can be kept under 20%
- **disadvantage** LED with control unit outside the detector volume
- Notched fibre production is not trivial

Nice idea, but… Spiroc1 area is not working



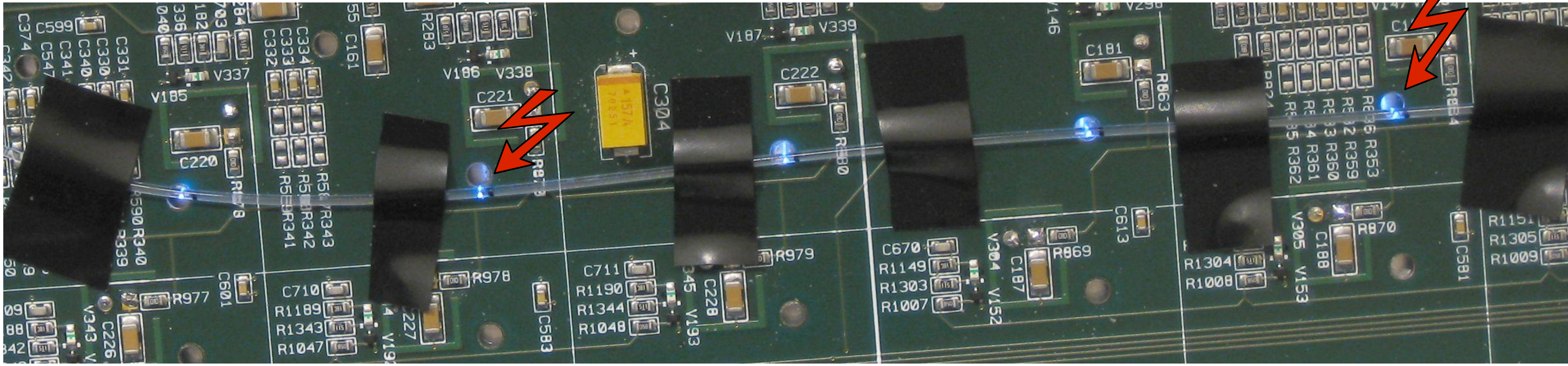
Notched fibre layout

nice blue taps shines to alignement pins



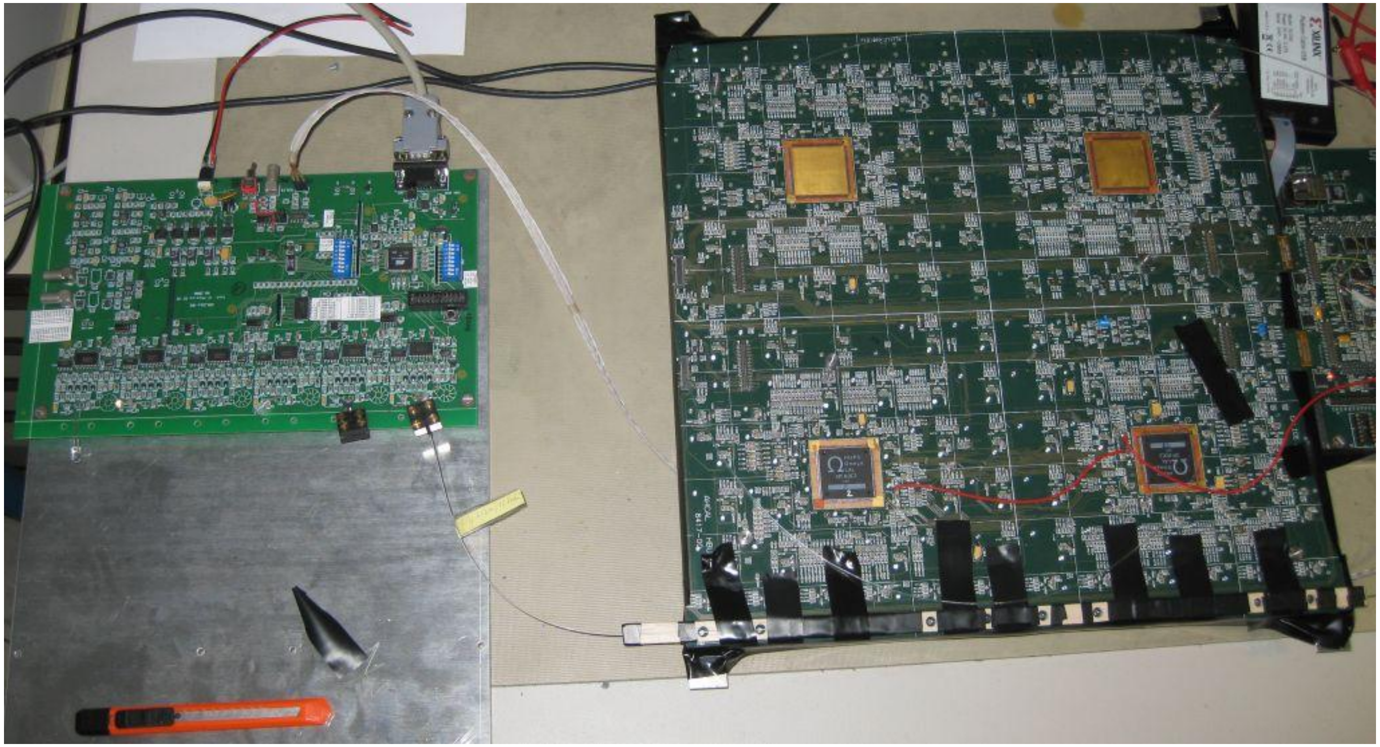
OLD SETUP dec2009

Electrical tape and bended fibre is not the right combination!



A “NEW” BALSAwood bar with a notched fibre apr2010

Setup QMB6 + HBU0 (SiPM + readout)



From HBU0 (calib board):

signal T-calib LVDS only

60ns Delay

power +15V/0.16A

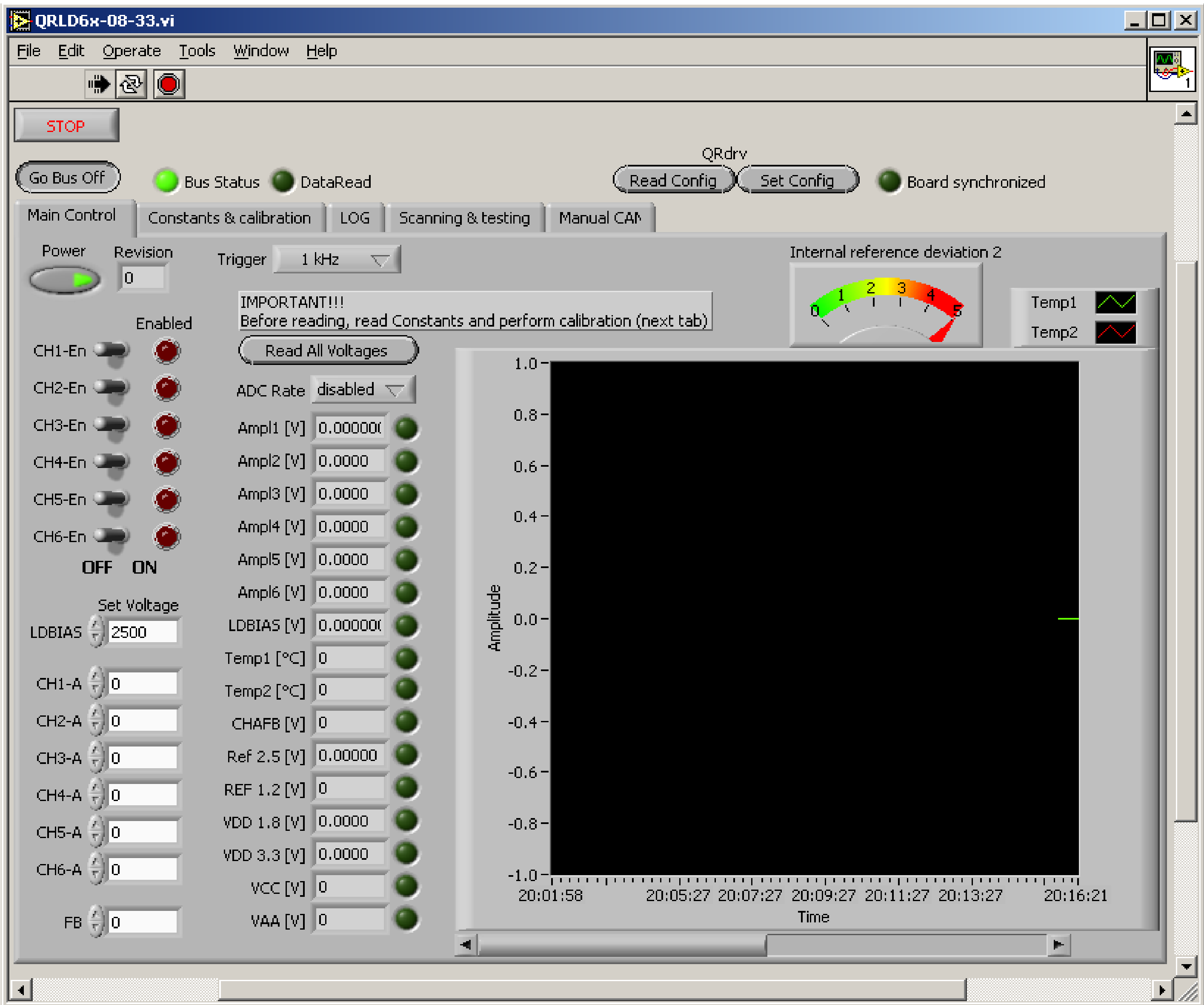
CANbus slow-control

- One UVLED 5mm
- One Notched fibre

Control: LabView 8.2 exe-file, One PC with DAQ, USB --> CAN

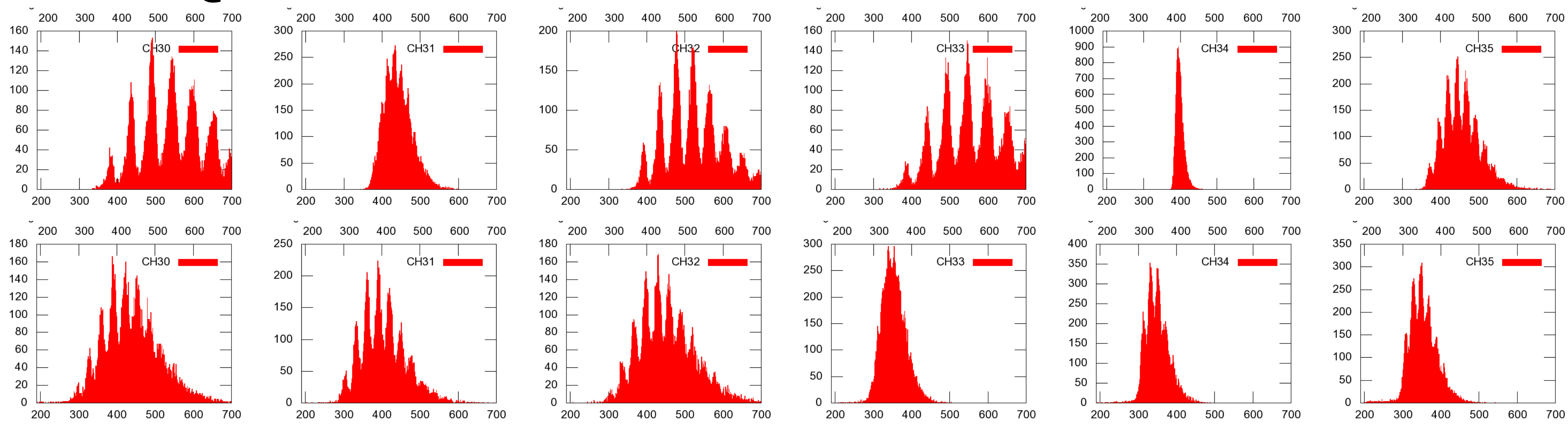
Almost **plug and play**

Control panel of QMB6 in LabView 8.2



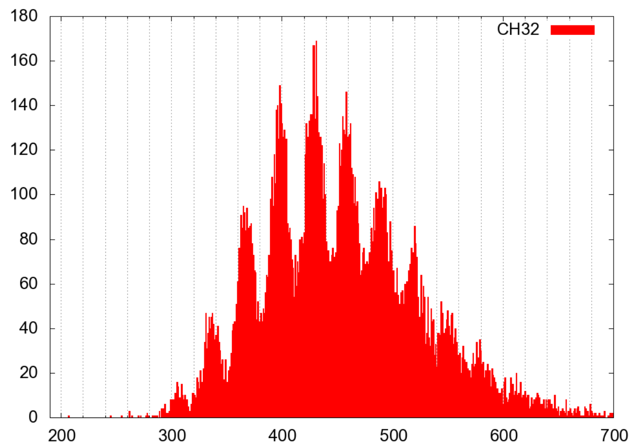
- Controls individual LED amplitude
- LED Enables
- Trigger mode ext/internal
- Measure temperature
- CANbus control
- It can work as Exe file

Single p.e. spectra
QMB6 to SPIROC1 & SPIROC0

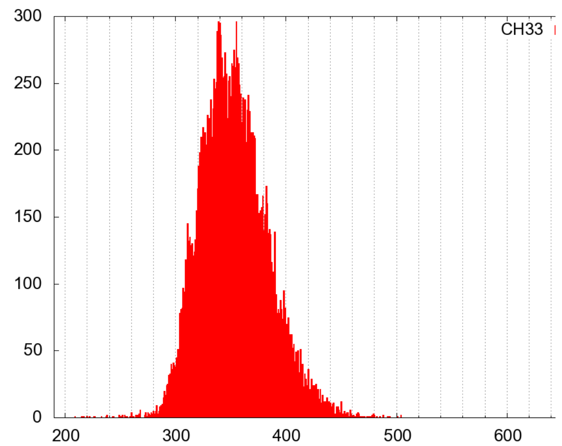


Spread of SiPM gain is about factor 3, it corresponds to data from ITEP.

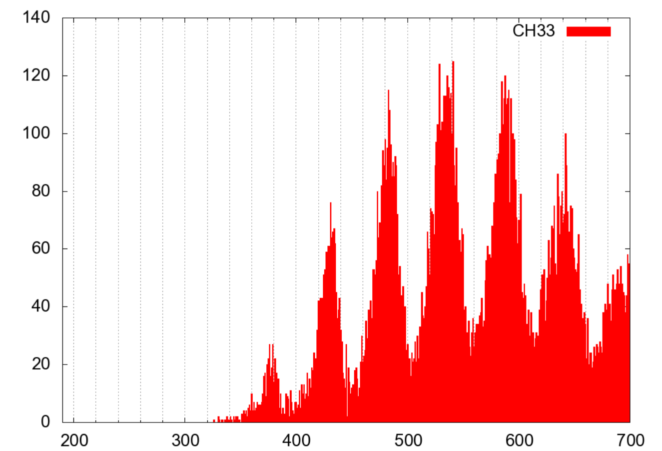
Channel 32, ASIC 0, memory 8



Channel 33, ASIC 0, memory 8

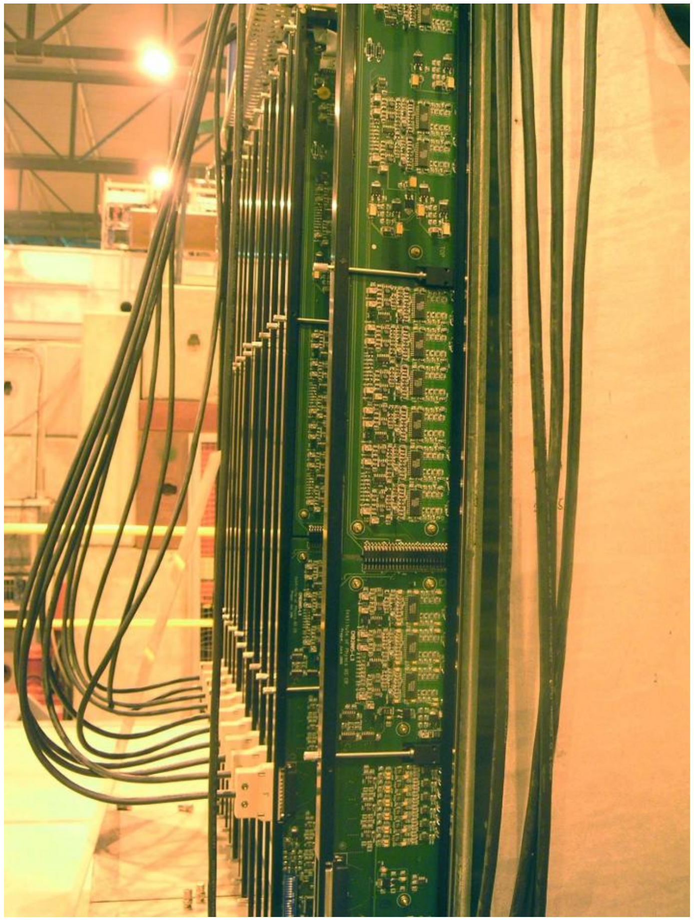


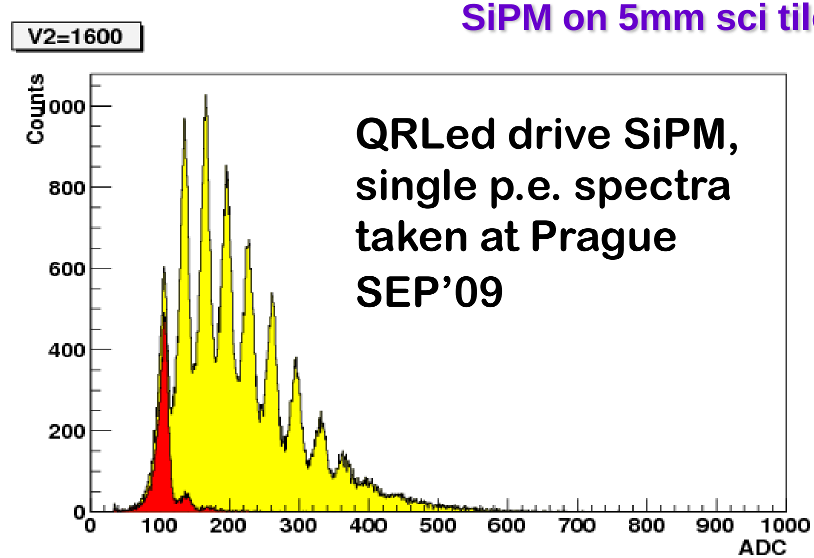
Channel 33, ASIC 1, memory 8



Single photoelectron spectra with CMB and QRLED

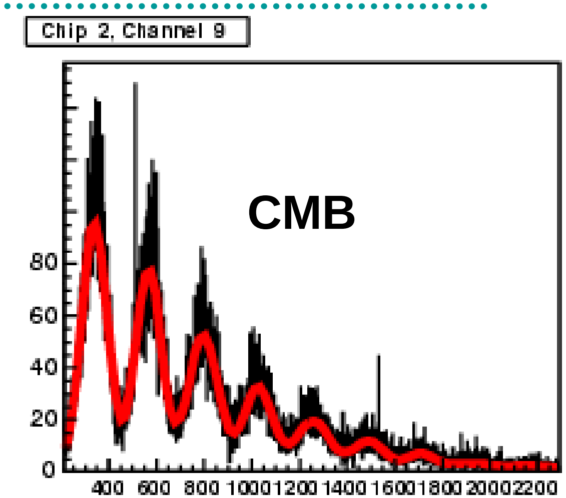
LED light 400nm to SiPM on 5mm sci tile





←CMB in tuning position at AHCAL TB 2007 CERN

one of the single p.e. spectra →

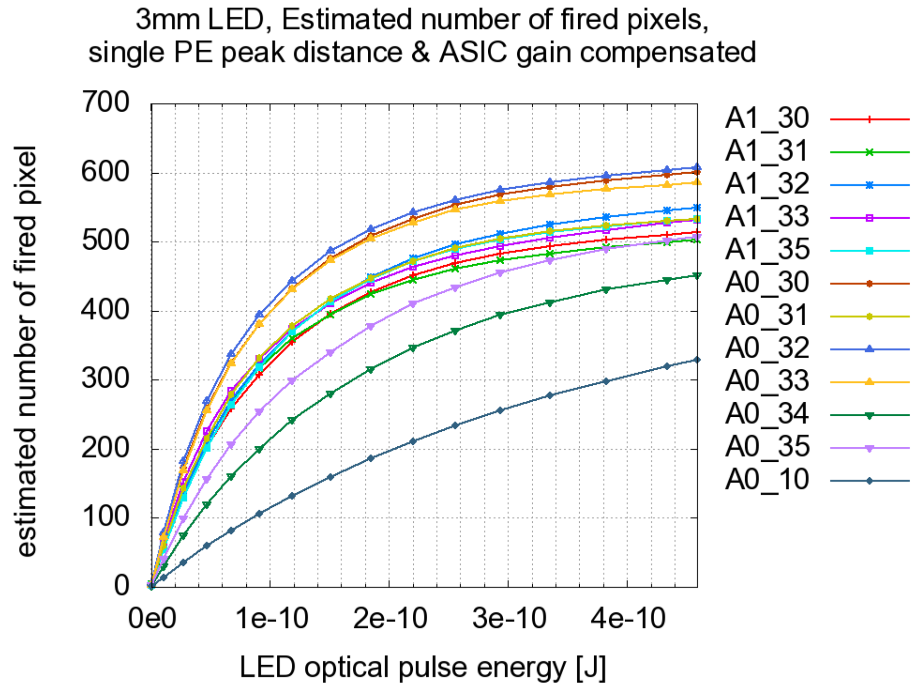


More info about CMB can be found at:

http://www-hep2.fzu.cz/calice/files/ECFA_Valencia.Ivo_CMB_Devel_nov06.pdf

Amplitude scan corrected

Linear extrapolation of the initial slope indicate the dynamic range of ~200 MIPs



Final comments:

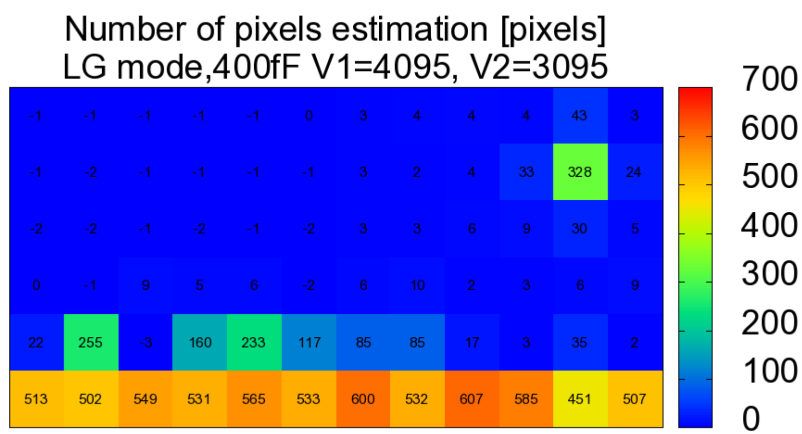
The estimated number of fired pixels is larger than the real number of SiPM pixels

Different shapes of saturation curve might indicate improper HG vs LG ratio

Saturation curves does not match simple f(x)=1-exp(-x) function (unsuccessful fits)

Not yet analyzed: shifts among ASIC memory cells (pedestal and data), crosstalk among memory cells, crosstalk among channels

This analyse has been made by Jiří Kvasnička.



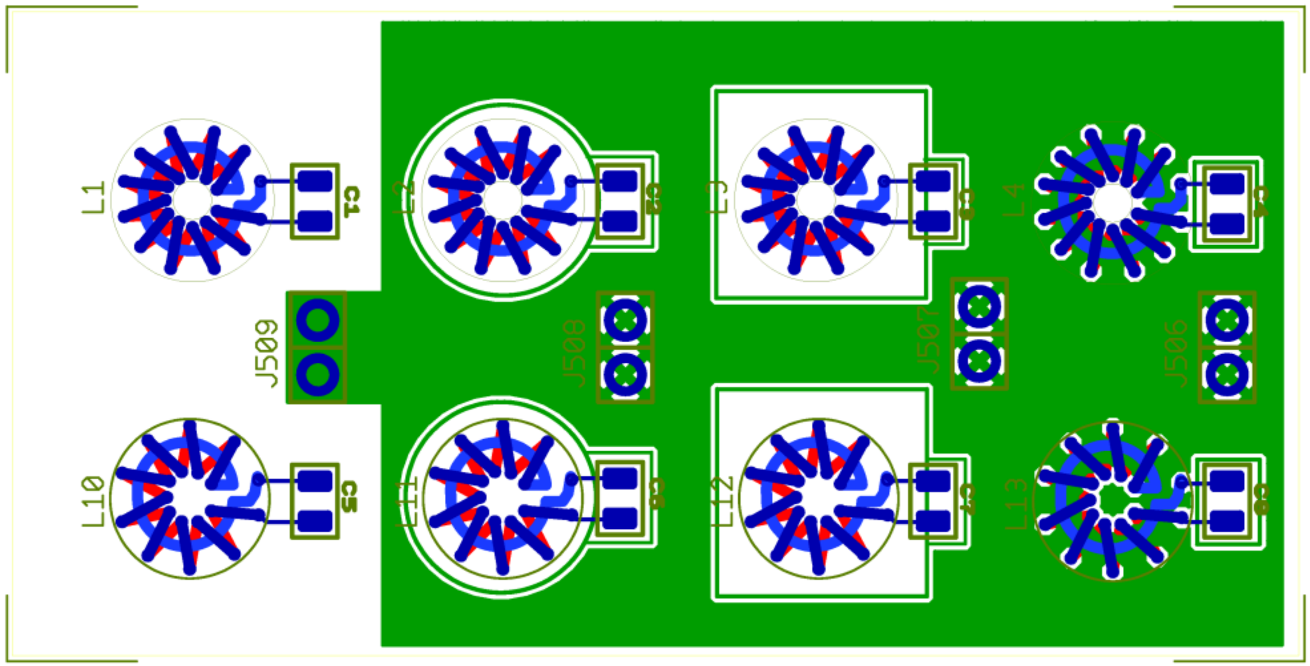
Test PCBs with toroidal inductor

1. Test mechanical dimension, thickness of PCB on inductance
2. test GND-plane influence

30 x 60 mm^2 4 layers

CAM350 V 10.2.0 : Tue Mar 23 15:38:55 2010 - (Untitled)

4 PCB thicknesses: 0.8, 1.2, 1.8, 3.2mm



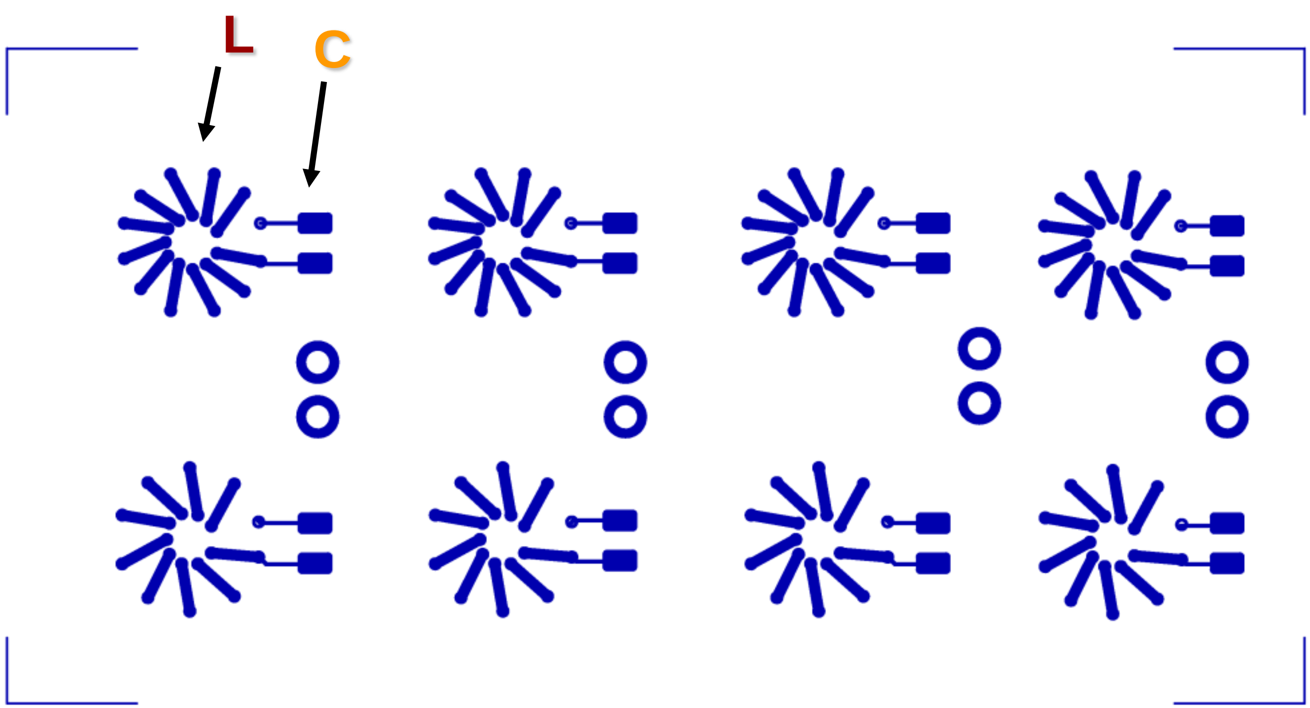
← 11 turns

← 9 turns

Top layer, pads at right are for smd capacitors

1. First to measure resonant frequency of parasitic capacitors, only.
2. To get value of **L**, we add larger parallel **C**, all 100pF with tolerance 1%, And measure the resonance frequency by GDO meter.

CAM350 V 10.2.0 : Tue Mar 23 15:35:07 2010 - (Untitled) : CopperTop

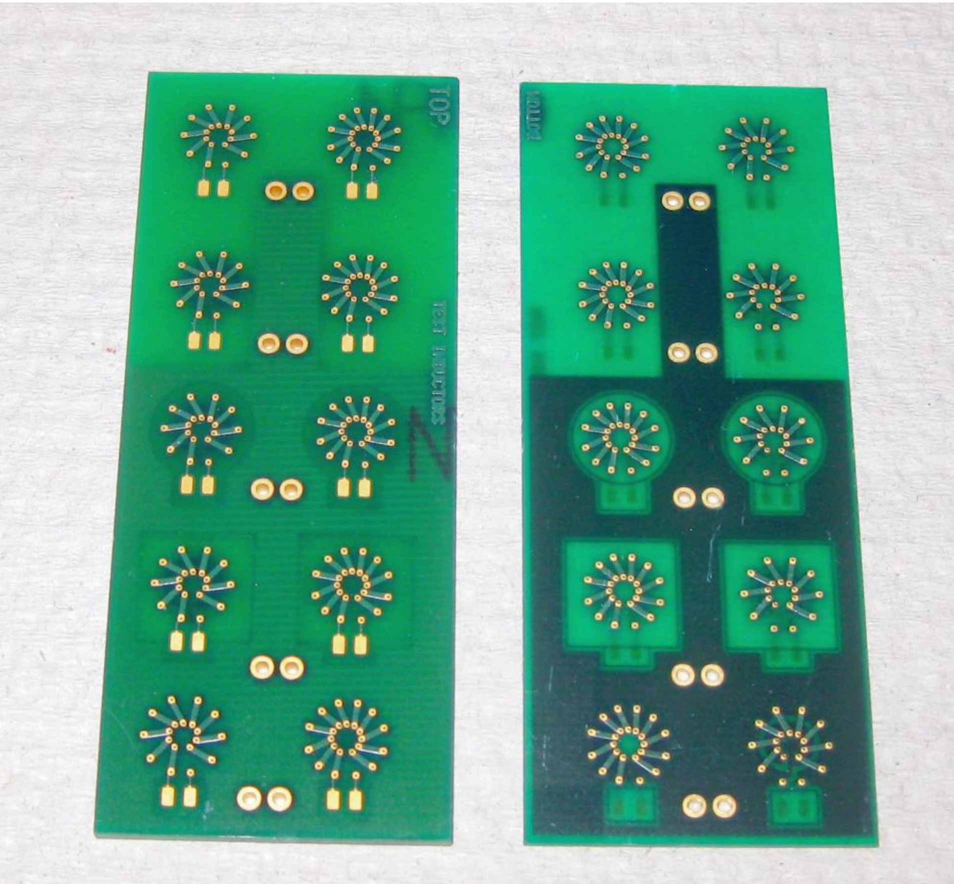


$$f = \frac{1}{2\pi\sqrt{(L \cdot C)}}$$

After recalculating, we can see a spread of L and parasitic C (effect of GND layer)

GDO = Grid Dip Meter, handy instrument to measure resonant frequency of LC circuit

Test PCB with 10 toroidal inductors



- 9 and 11 turns
- 10.8 mm ODia
- Pads for SMD 0805 parallel caps
- 4 layer PCB, inner GND
- 4 PCB thicknesses and same motive to study parameters

Table of inductance

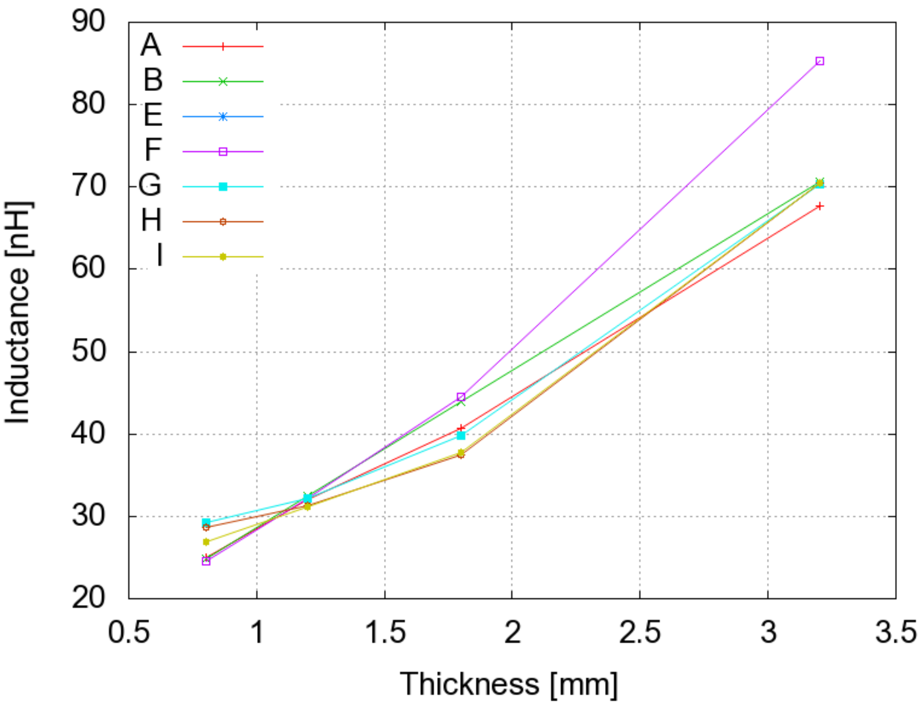
values in MHz

Thickness	0.8mm	1.2mm	1.8mm	3.2mm
Capacitor [pF]	198.6	199.6	201.4	200.4
PCB nr.	1	2	3	4
position A	71.483	62.891	55.563	43.225
B	71.706	62.464	53.493	42.289
C				
D				
E				
F	72.16	62.801	53.197	38.481
G	66.063	62.824	56.198	42.41
H	66.77	63.73	57.93	42.332
I	68.943	63.833	57.762	42.33
J	68.225	63.856	57.843	42.44

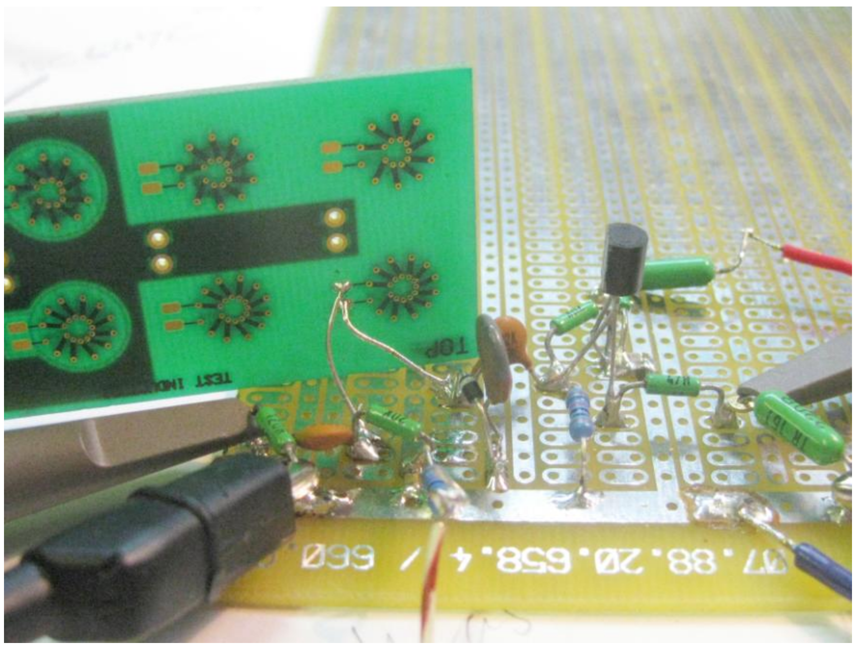
Test setup is proven, but more precise frequency meter (counter) is needed. Internal counter of scope TDS 2024 is the weak point.

We will repeat the measurement to satisfy the precision.

PCB Thickness dominates to inductance



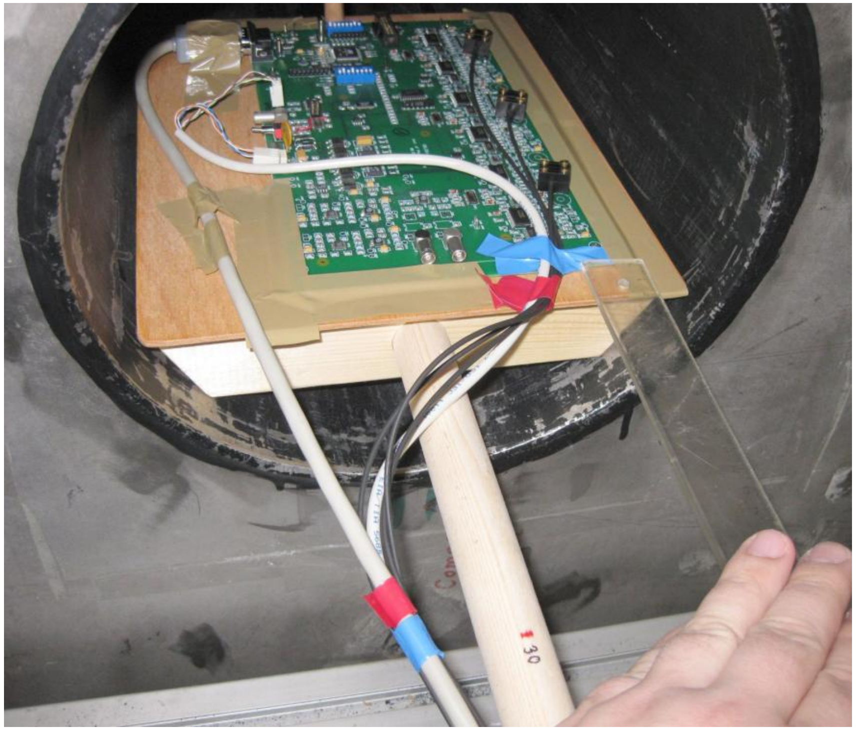
Toroidal PCB inductor at breadboarding phase in Brahms programme



- The same PCB toroidal inductors are used at design of DC/DC convertor running on VHF.
- Project Brahms, FZÚ ASCR Prague (2010 to 2012)

QMB6 in superconductive solenoid

(magnetic field 0 to 4T) DESY Hamburg, March 2009



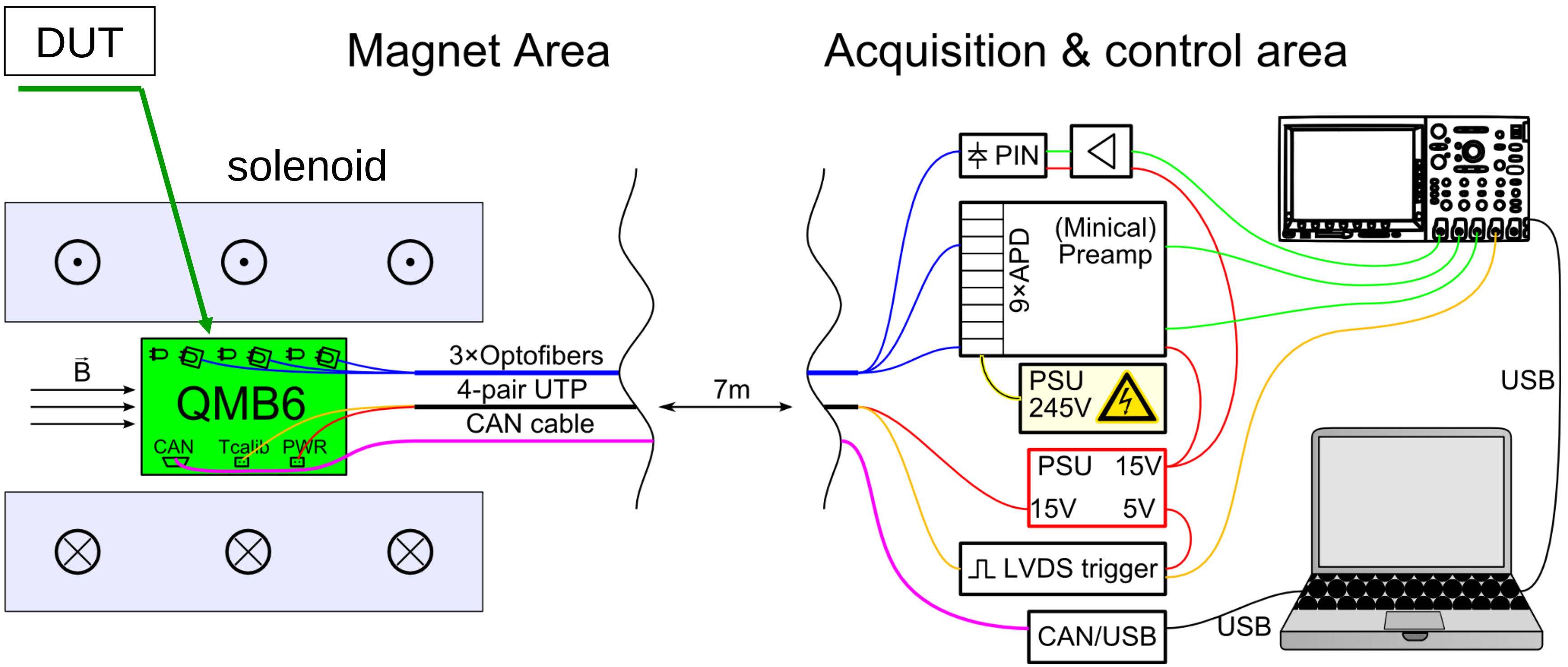
Details of 4T Magnetic test can be found at

www-hep2.fzu.cz/calice/files/magnet5.jara_29.pdf

- Air core inductor can be sensitive to external magnetic field
- we performed tests of QMB6 in variable magnetic field

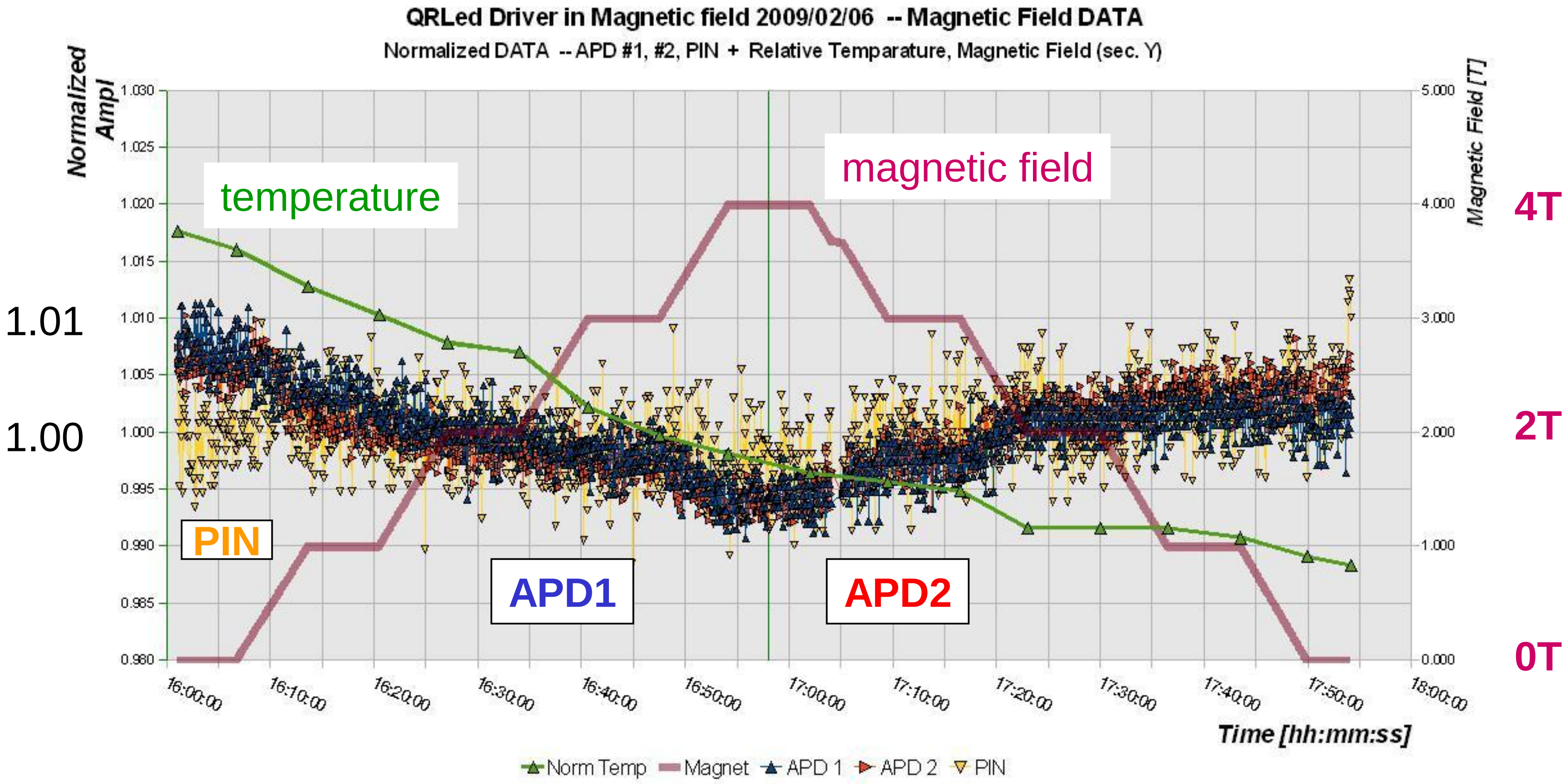
- 3 LED flashed into 3 fibre cables
- CANbus cable and T-calib + Power in other cable
- The setup was mounted on non-magnetic wooden paddle, to be moved in/out of solenoid bore.
- Two black end-cups were used to optically screen the setup.

A schema of QMB6 setup in 4T magnet



Magnet control is not shown.

QRLED response to magnetic field 0 ÷ 4T



Plans for end 2010 / 2011

Main focus: Increase of the optical performance:

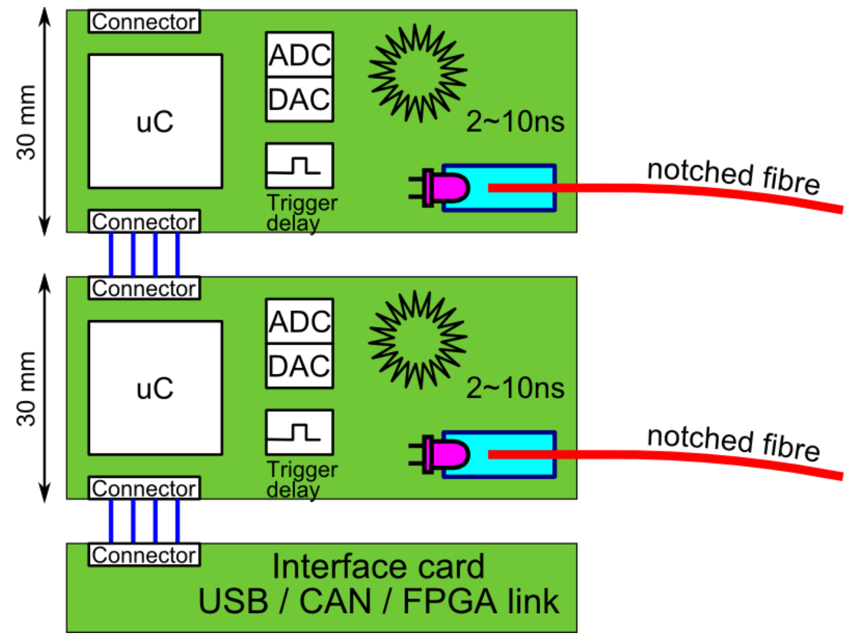
- Extend the pulse width from current 3.5 ns
- improve optical coupling from LED into the fiber

New QR LED driver prototype

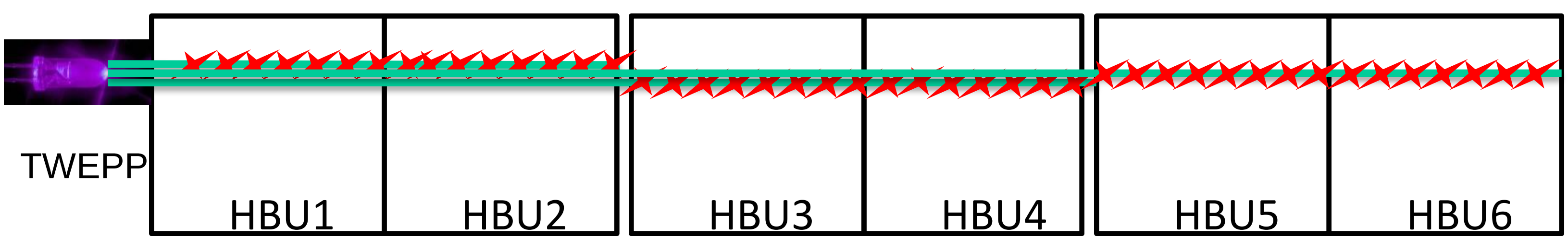
- only 1 channel per board
- different onboard inductors for different pulse width in range of 4 ~ 10 ns
- 3cm PCB width to match the tile size

Notched fiber production (Q4/2010 – Q1/2011)

- 4 sets by 3 notched fibres each with 24 notches
- dimensions of the notches need to be synchronized with HBU



3 fibres receive light from 1 LED   3 x 24 = 72 notches



Conclusions to common test HBU0 with QMB6

- Easy implementation, almost **plug and play** installation
- QRLED driver has tunable light amplitude
- Both methods of light distribution are tested in HBU0 EUDET prototype
- With QMB6 we can see a nice single p.e. spectra
- We see saturation of SiPM, but not all of them yet, better optical coupling is the key.
- We would like to make more tests in the future, focusing on the optical coupling

LED drivers Conclusion

- All tested LED driver configuration are proven in test with SiPM.
- QR LED driver has better EMC with fixed sinusoidal pulse width

Back up

Blue and UV-LED, Electrical to Optical Power transformation efficiency

- # DC mode

Power consumption 3.3V*20mA = 66 mW

Optical power @400nm = 2.6 mW

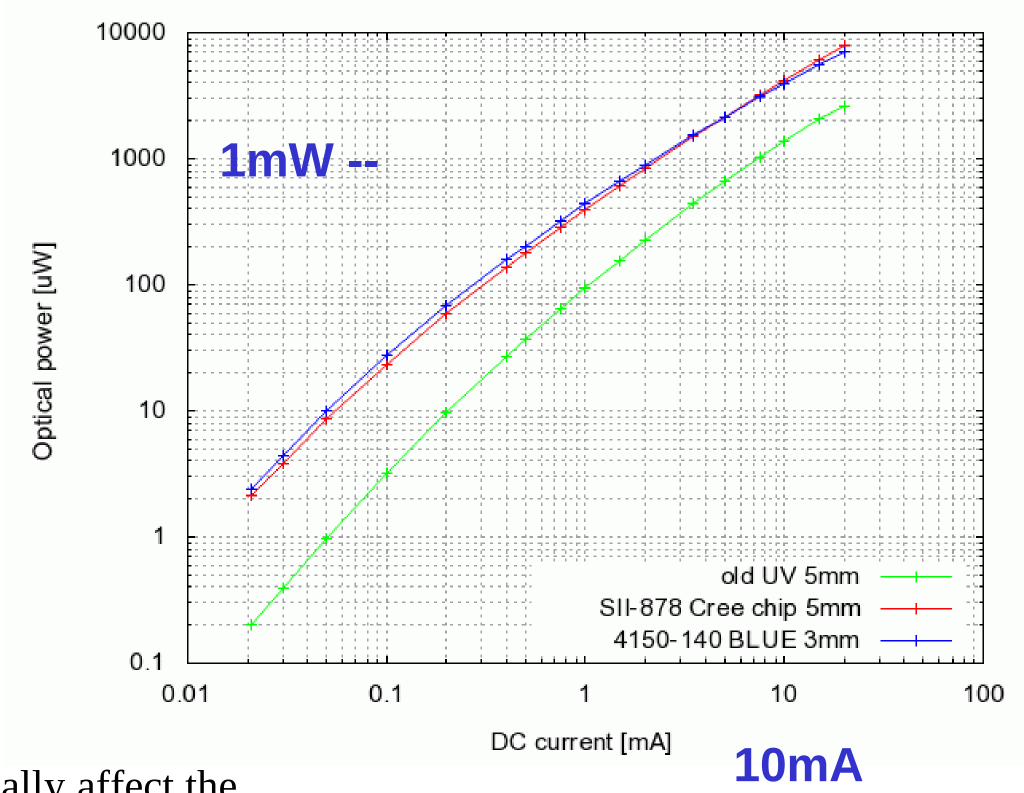
Efficiency = **4%**

- # Pulse mode (1Hz, 2.7ns pulse)

Power dissipation at LED = 9.75nW
(very rough scope measurement)

Optical power @400nm = 0.5nW

Efficiency = **5%**



Results

– Flashing with 3ns pulses does not drastically affect the efficiency of transformation of electrical pulse to optical (compared to DC)

– Peak pulse optical power is ~70x higher than DC

Optical Power and Energy Meter PM100D by Thorlabs

Imperfectly set dumping resistor RD