# Calibration of the AHCAL

## CMB, QMB & Saturation

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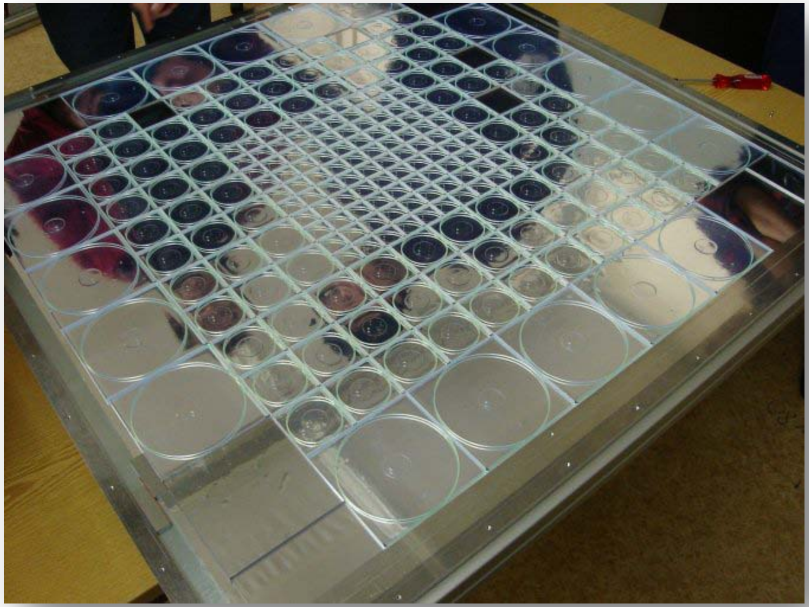
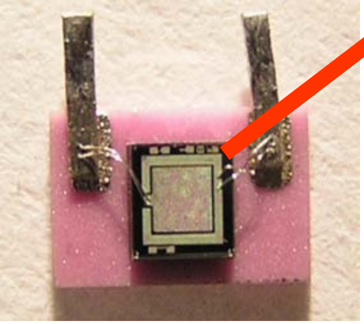
- **Calibration system and CMB ('OLD')**
- **Saturation curves**
- **Notched fiber system and QMB ('NEW')**

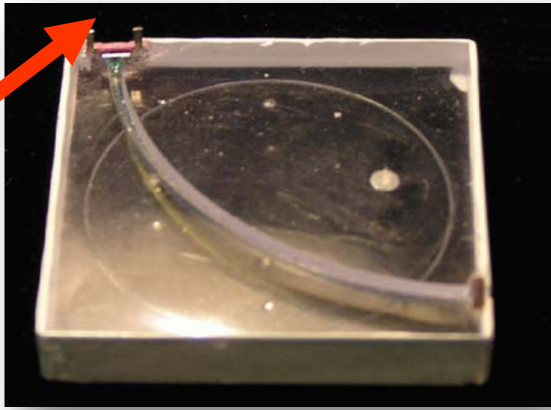
# Analogue HCAL
# high granularity hadronic calorimeter

- Absorber
  - **38 layers of steel, 2 cm thick**
  - **4.5 $\lambda_{int}$ in total**
- Active element
  - Scintillator tiles 3x3 – 12x12 $cm^2$ with embedded WLS fibres
  - Multi-pixel Geiger mode photo-diodes (SiPMs), B-field proof, small, affordable, integrated
- Read-out by ASIC
  - 2 gains (normal, calibration)
  - HV settings for SiPMs
  - Shaping and multiplexing
  - Power consumption 200 mW/5 V
- Calibration and monitoring by LED flashes, Temp recorded
- In beam since 2006



1m3 prototype calorimeter with 8000 channels readout with SiPM

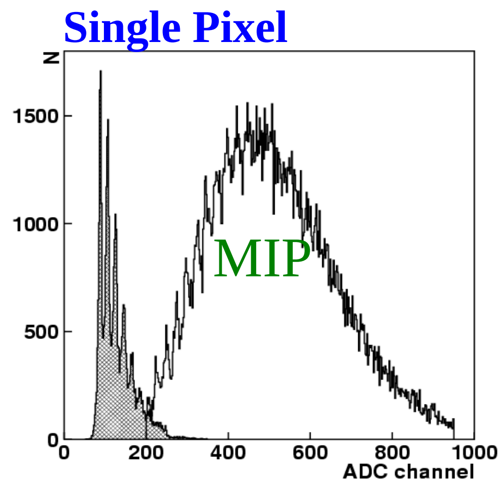


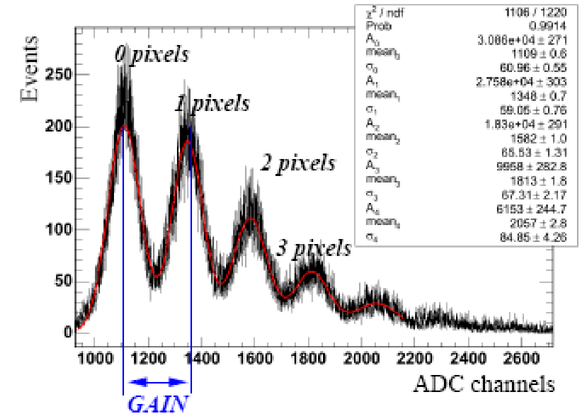


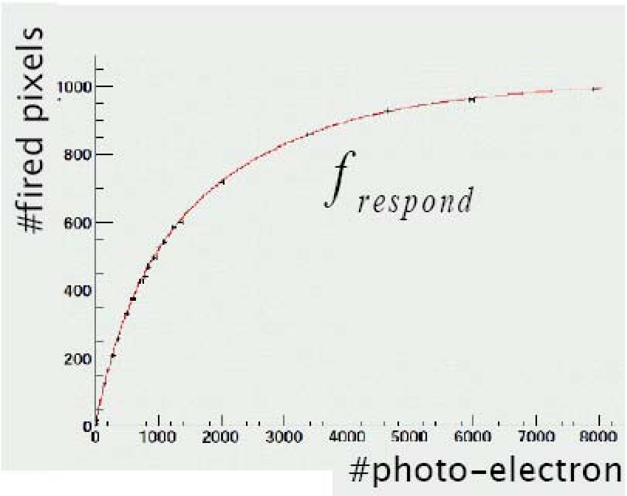
# Calibration system

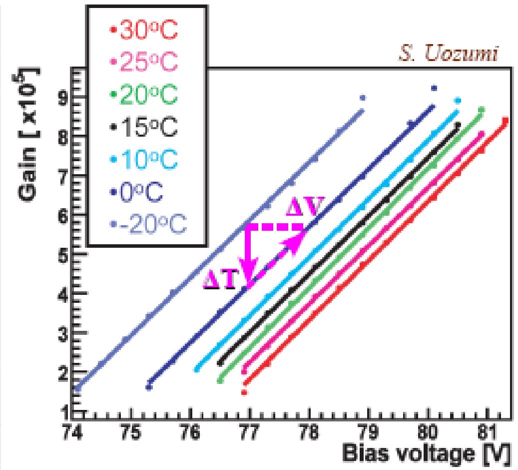
Calibration system should deliver:

- Low intensity light
  - for SiPM Gain calibration
  - ratio High/Low ASIC gain
- High intensity of light
  - for saturation monitoring
- Medium intensity light
  - for monitoring Temperature and Voltage variations



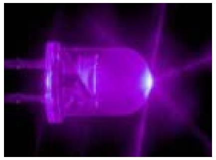



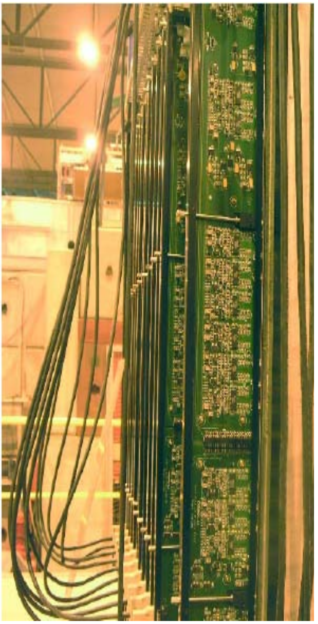



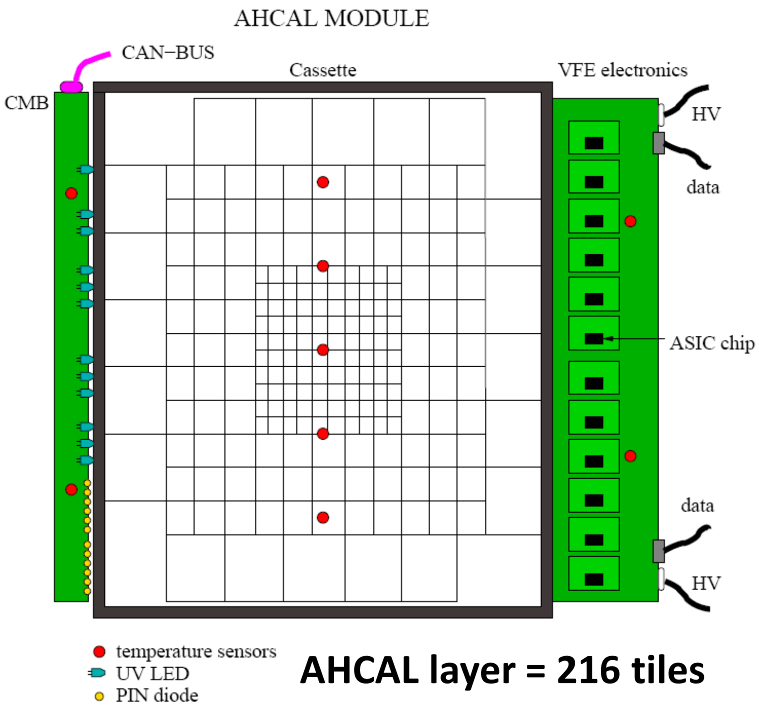




- Many procedures developed during last year's analysis, but not finally proven yet
- Stability of saturation still an issue -> need dynamic range

# CMB = Calibration Monitoring Board





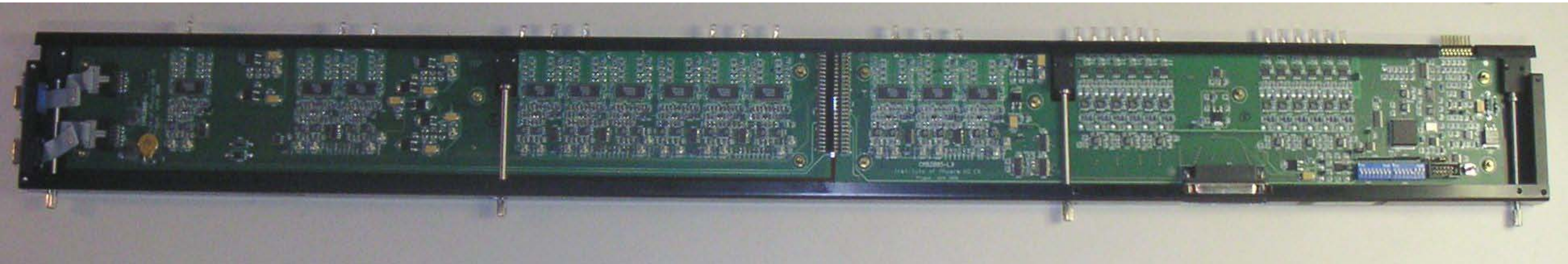



**AHCAL layer = 216 tiles**

- CMB used in AHCAL $1m^3$ prototype
- 38 layers in AHCAL detector @ three TB facilities DESY/CERN/FNAL (2006 - 2009)
- in 2010-11 with tungsten abs.
- 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
- Temperature (5+2 sensors) and voltage readout in slow control, CANbus control

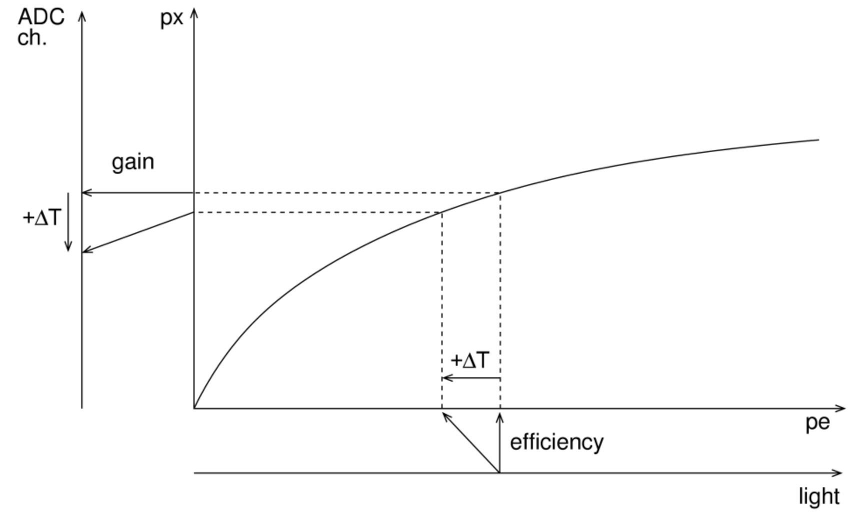
**Light intensity for ~8000 channels within factor 2**

**>94% calibration efficiency on full calorimeter**



# Saturation in V-calib LED scans

(preliminary results)




- fitting procedure
- calibration (ADC -> pixel)
- classification of results
- run-time dependence
- ITEP & ‘in-situ’ saturation measurements

# Analysis chain: ADC to MIP

## AHCAL signal chain:

Particle shower → MIPs → scintillator → photons (UV)
→ SiPM (non-linear) → proto-electrons → amplification → electronics

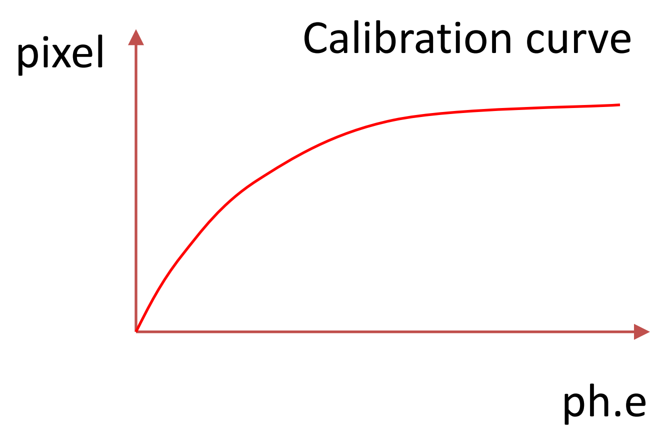
Energy deposited in one calorimeter cell [MIP]:

$$E_{MIP} = f_{resp}\left( \frac{A[ADC]}{A_{MIP}[ADC/MIP]} \cdot LY[pix/MIP] \right) \cdot \frac{1}{LY'[ph.e/MIP]}$$

#pixel

#ph.e

SiPM response is nonlinear ➔ correction is necessary




## Calibration:

convert detector signal into number of MIPs
Deposited by particle traversing the tile

# Calibration chain: ADC to MIP

**<u>What do we need:</u>**

**Lightyield in [pix/MIP]:**

$$LY_{[pix/MIP]} = \frac{A_{MIP}}{G_{pix}} \cdot I_{phys}^{calib}$$

- **MIP amplitude** in ADC bins
- **SiPM gain** in ADC bins (CalibMode) converts to pixels
- **Electronics Intercalibration** between physics and calibration mode

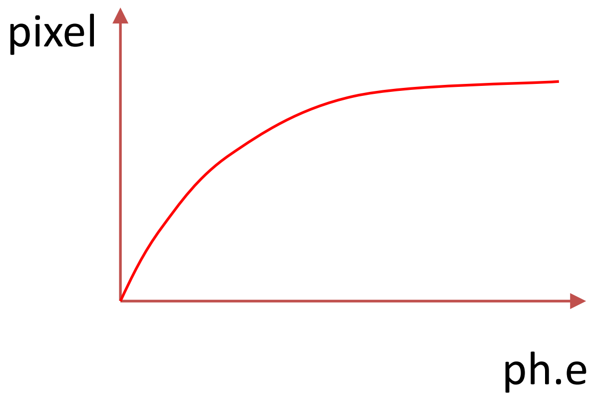
$A_{MIP}$ $G_{pixel}$ $I_{phys}^{calib}$

**Lightyield in [ph.e/MIP]:**

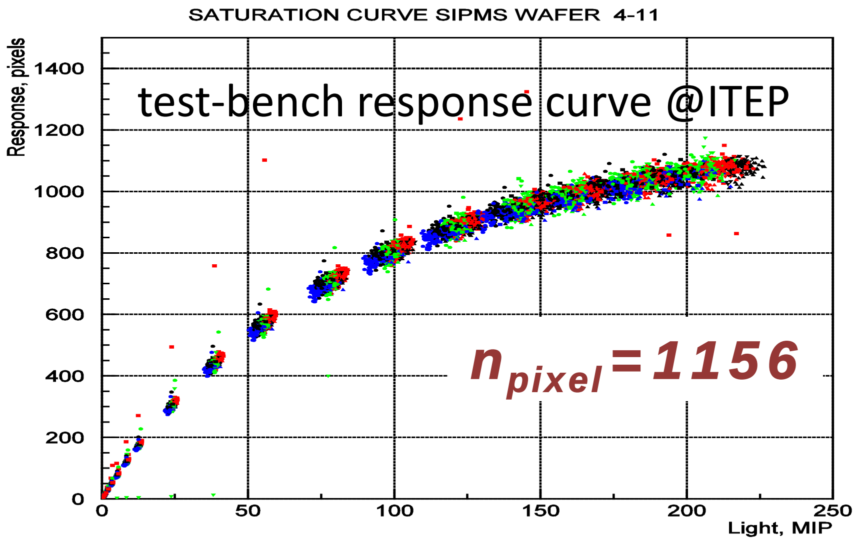
$$LY'_{[ph.e./MIP]} = f_{resp}\left(LY_{[pix/MIP]}\right)$$

**SiPM response function:**

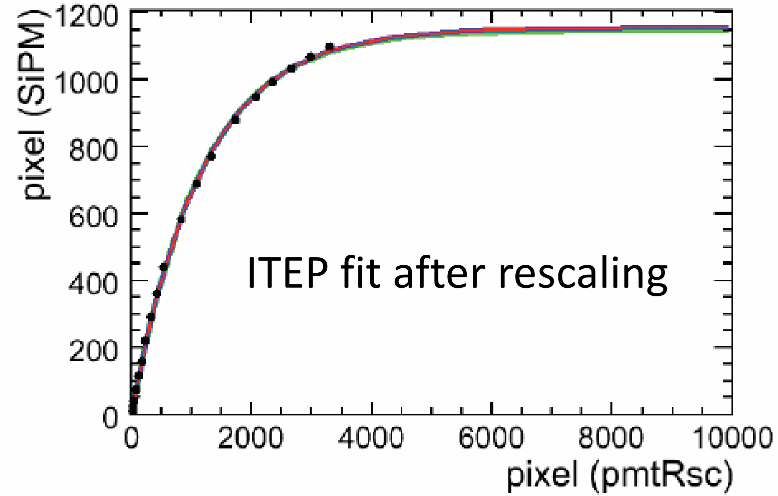
$f_{resp}$



# Saturation curves




SATURATION CURVE

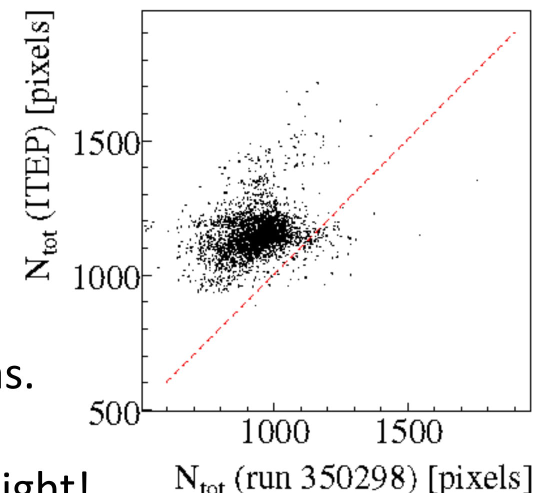


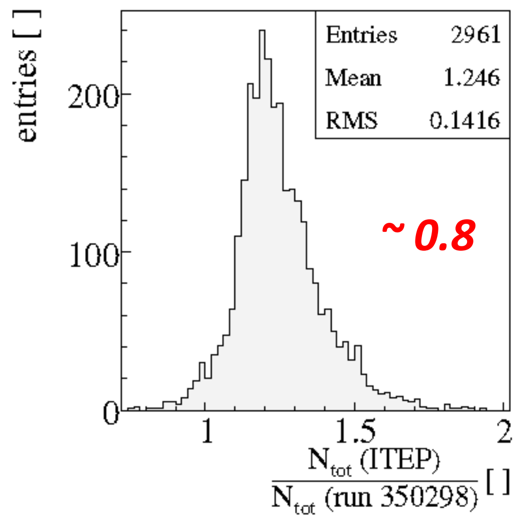

Saturation curves for single SiPM should be universal,

*BUT:*

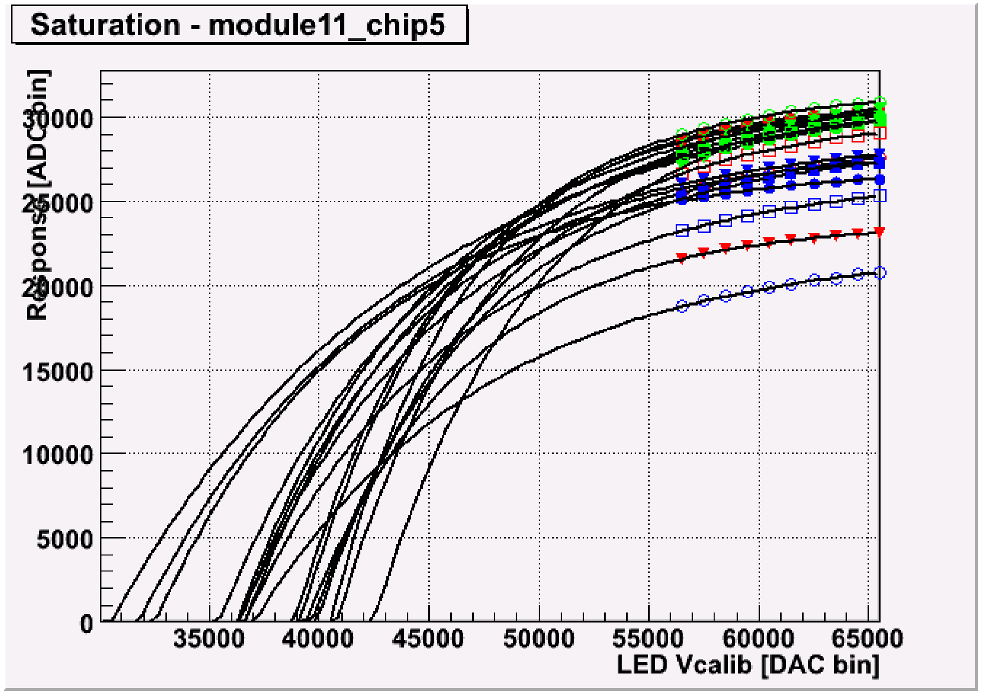
Disagreement between ITEP-lab measurement and in-situ (TB) meas.

? No all pixels illuminated by WLS light!



# LED V-calib scan



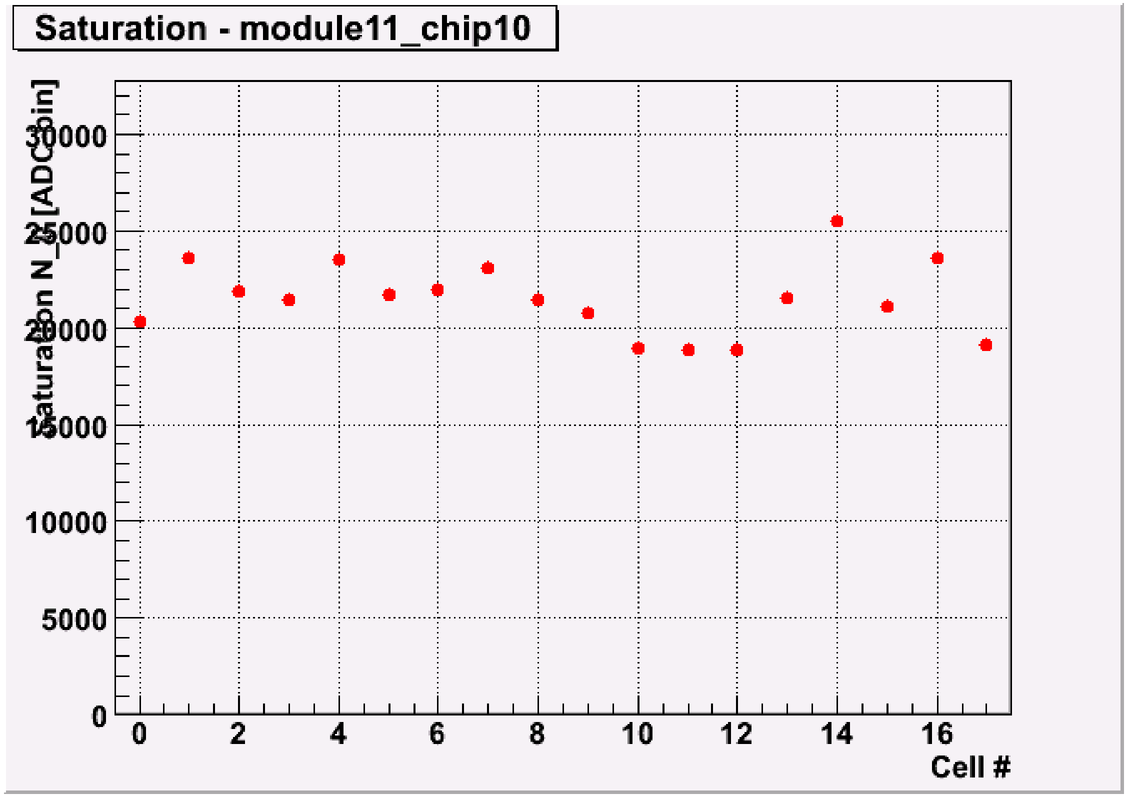

Runs:
AhcPmLedVcalibScan

FNAL (sub)period:
**F08-4**: 2 weeks in Jun

Fitted 10 last points

Simple Exponential formula for saturation:
F(ADCbins) = N_0 * [1- Exp(-(X+C)*B) ]     X in Vcalib bins
B = S / N_0     S … slope

# Saturation curve, par N_0

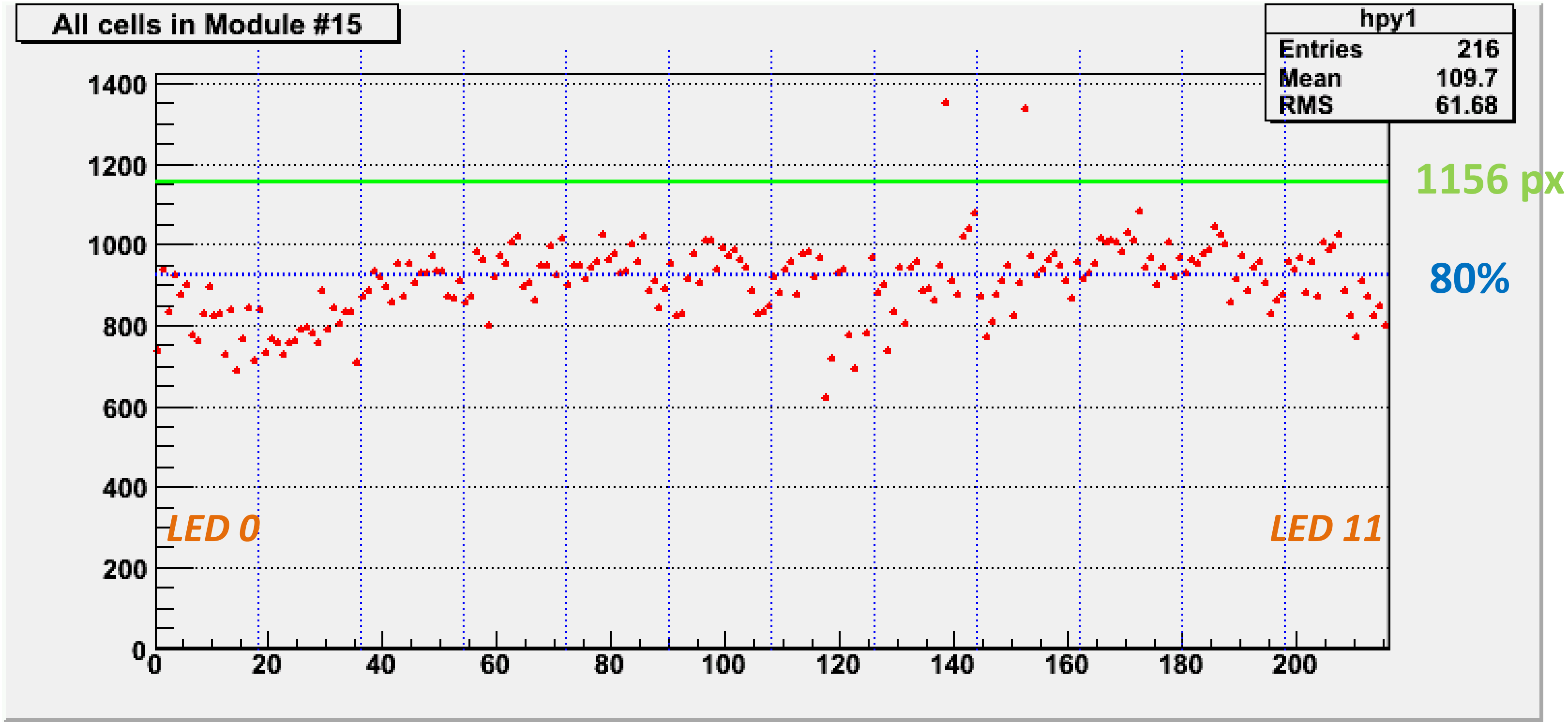



module number: 1 68
module number: 2 170
module number: 3 0
module number: 4 1
module number: 5 58
module number: 6 81
module number: 7 0
module number: 8 0
module number: 9 1
module number: 10 0
module number: 11 0
module number: 12 0
module number: 13 0
module number: 14 0
module number: 15 0
module number: 16 3
module number: 17 12
module number: 18 0
module number: 19 4
module number: 20 18
module number: 21 55
module number: 22 48
module number: 23 0
module number: 24 6
module number: 25 6
module number: 26 10
module number: 27 8
module number: 28 25
module number: 29 123
module number: 30 104
module number: 31 99
module number: 32 135
module number: 33 48
module number: 34 0
module number: 35 124
module number: 36 121
module number: 37 94
module number: 38 40

Note: Scan results are saturated by ADC range 2**15-1
1462 (19%) channels at max Vcalib @ last bin
Many of them more than 5 last Vcalib values at the limit

# Saturation in pixels

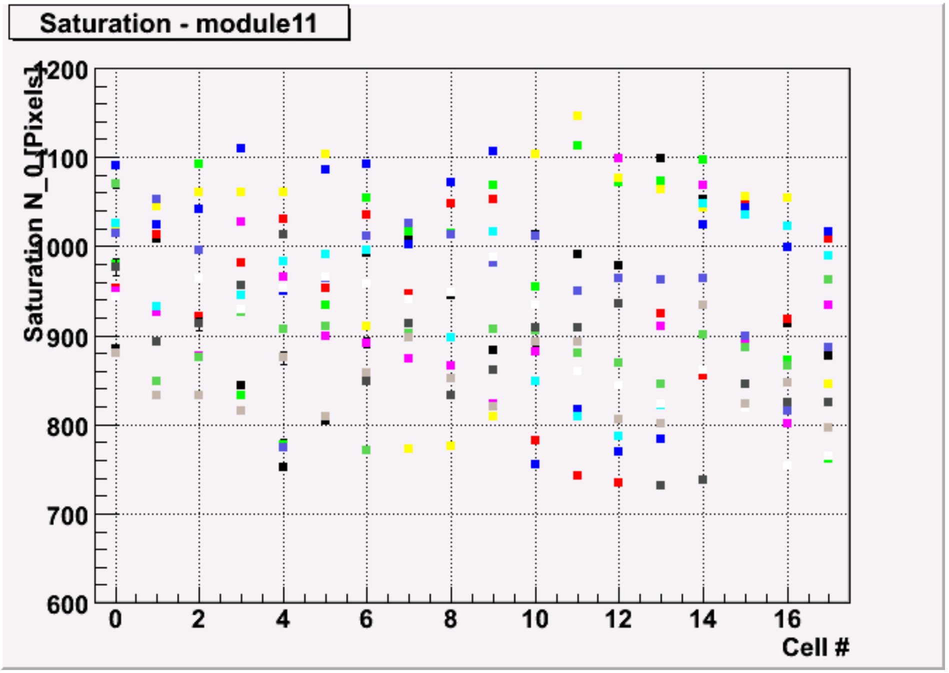
1 module: 12 LEDs with 18 optical fibers for each of 216 tiles with SiPMs



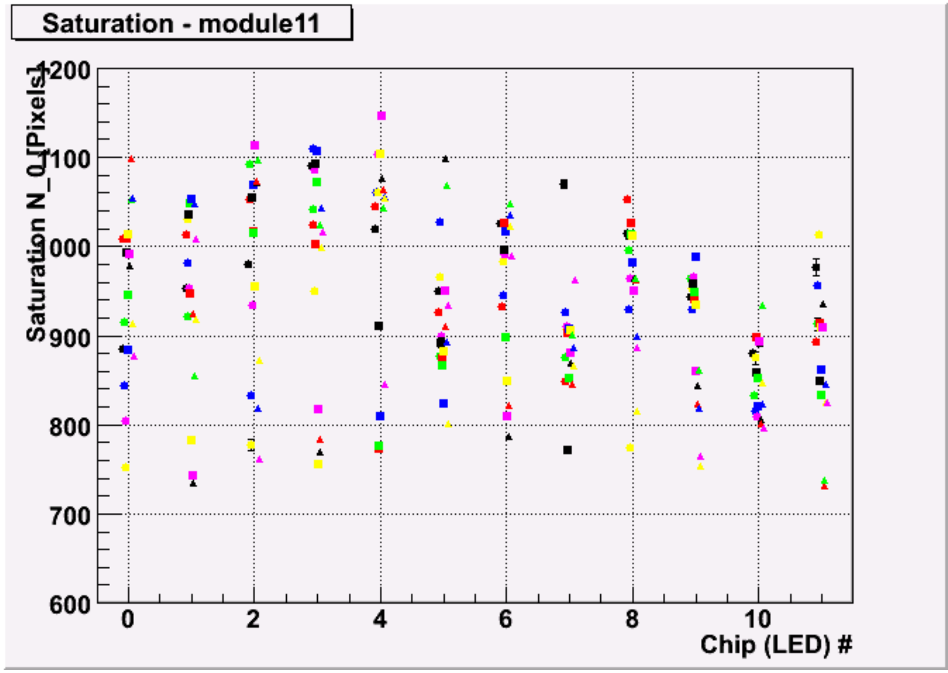

- Simple calibration formula: Sat(px) = Sat(ADC bins) * IC(run) / Gain(run)

- Calibration constants taken from DataBase:
  for InterCalibration (IC = HG/LG) and Gain (distances between single-photon peeks)

# Results: Run # 500722 module-wise



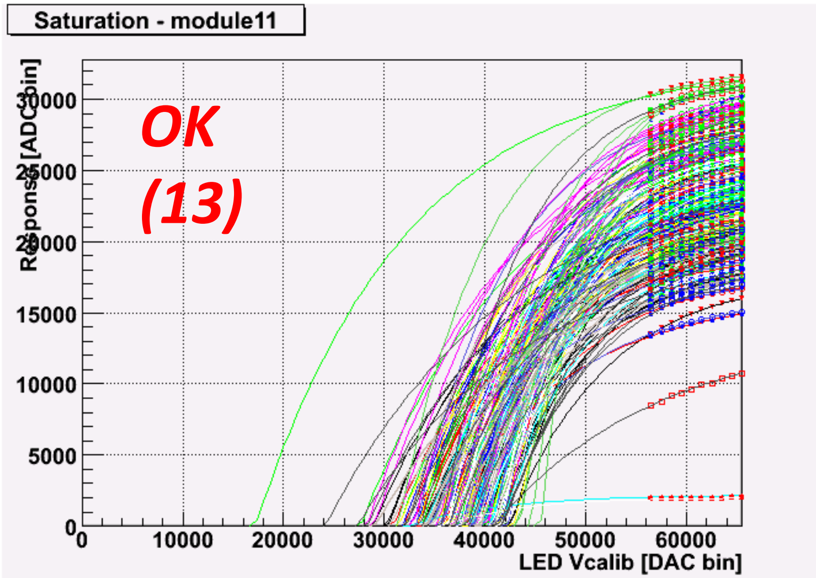

One color = one Chip
@ x 18 cells (channels)

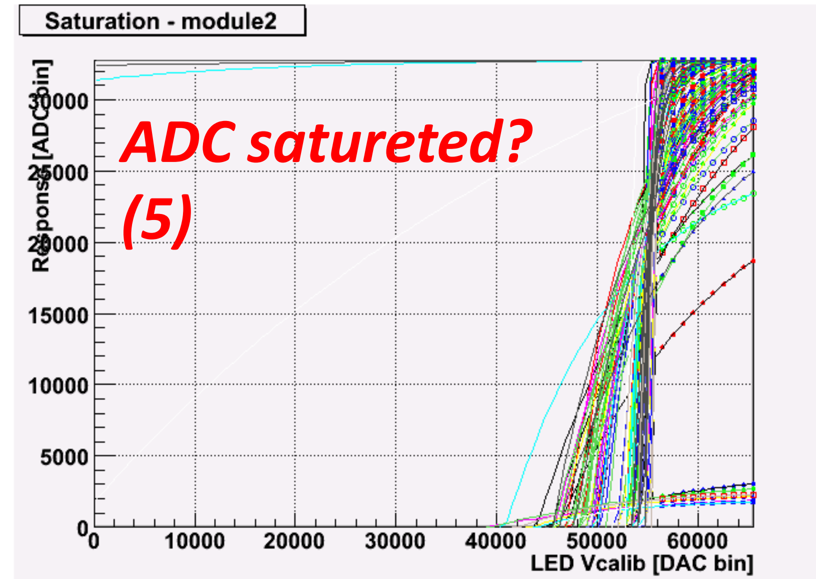


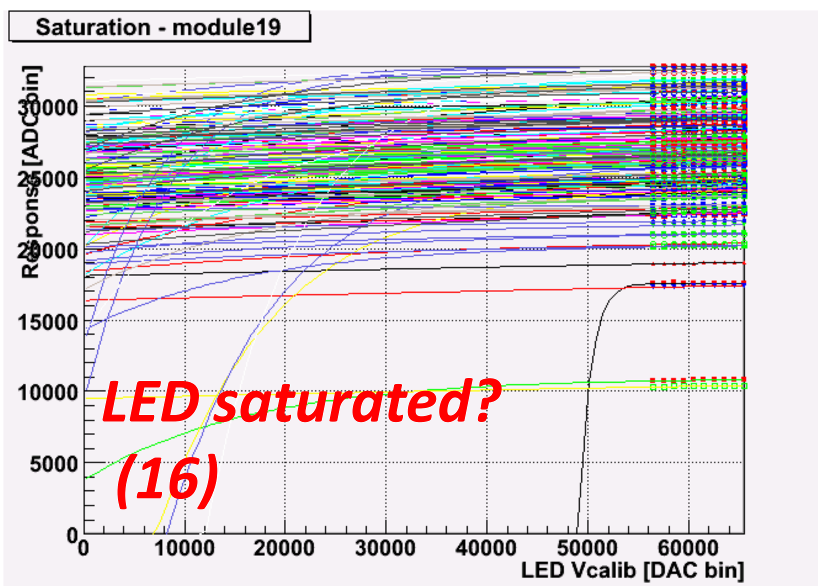

One color = one Channel
@ x 12 Chips (same LEDs)

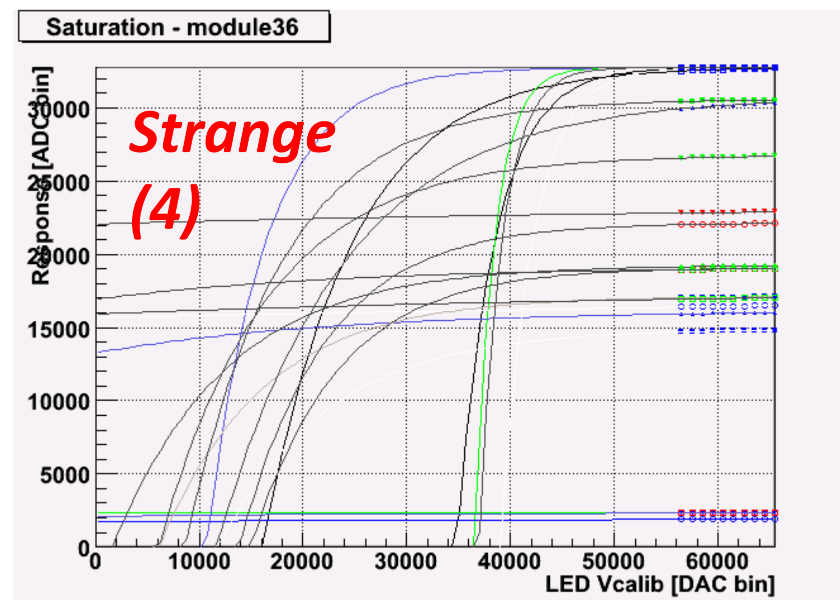
Fitted saturation in pixels are mostly below physical numbers of SiPM pixels (1156)
? Wrong calibration (IC, Gain) or fitting procedure, systematics
? SiPM not fully illuminated by light from WLS in tile

# Simple classification of (problematic) modules

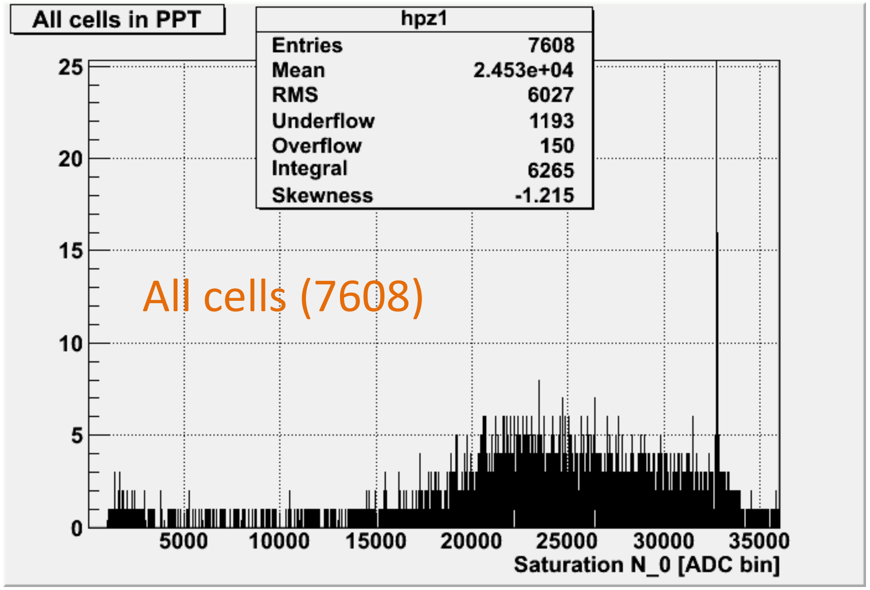


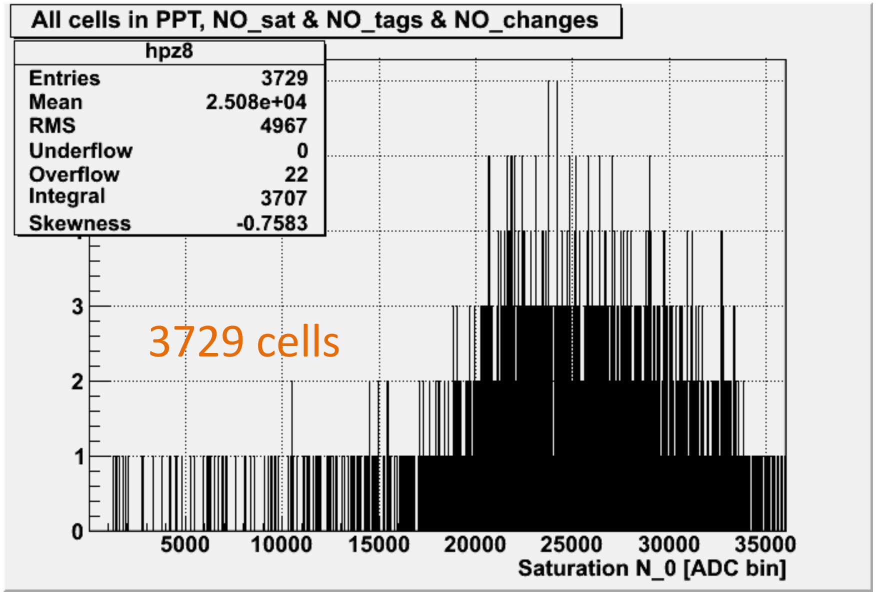



# Results I




Before selection

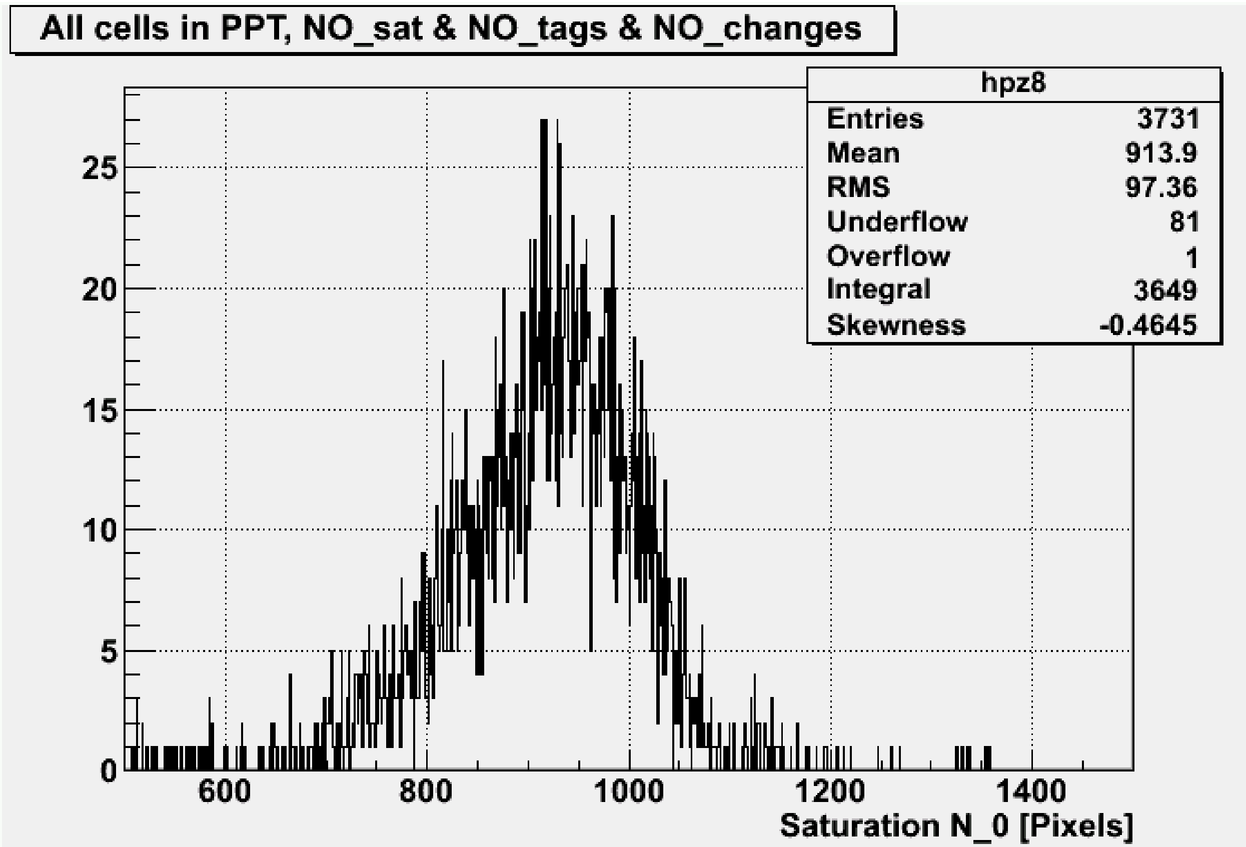



After selection:

- no ADC saturated channels
- reasonable ch2/ndf of fit

- Used only one V-calib scan run in results Fermilab Test beam data taking
- no systematic study - temperature or voltage corrections

# Results II

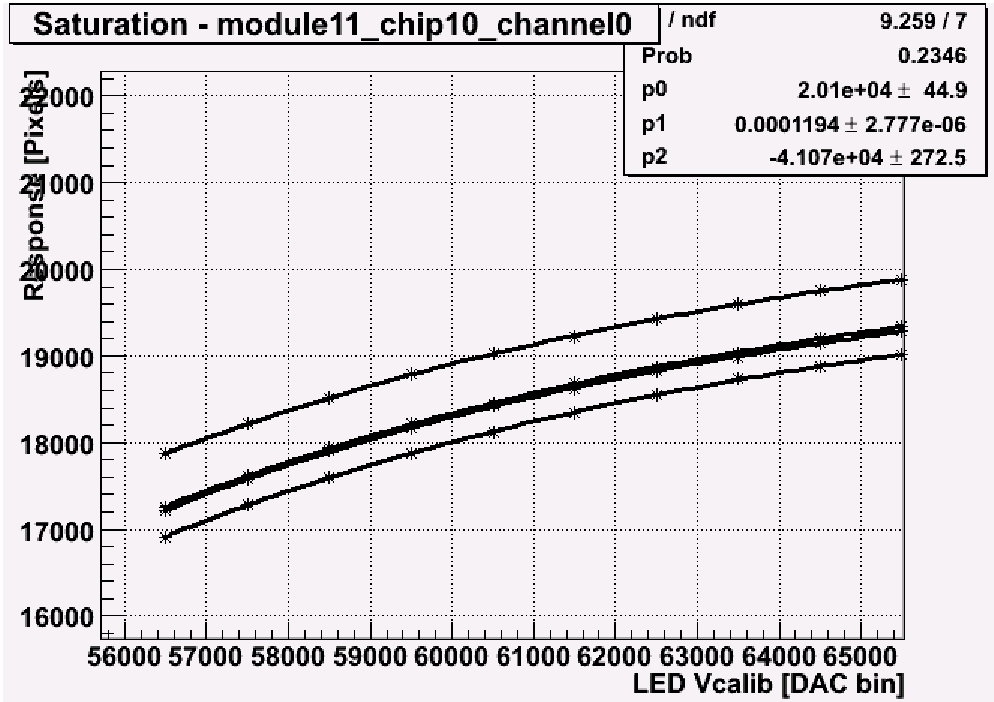


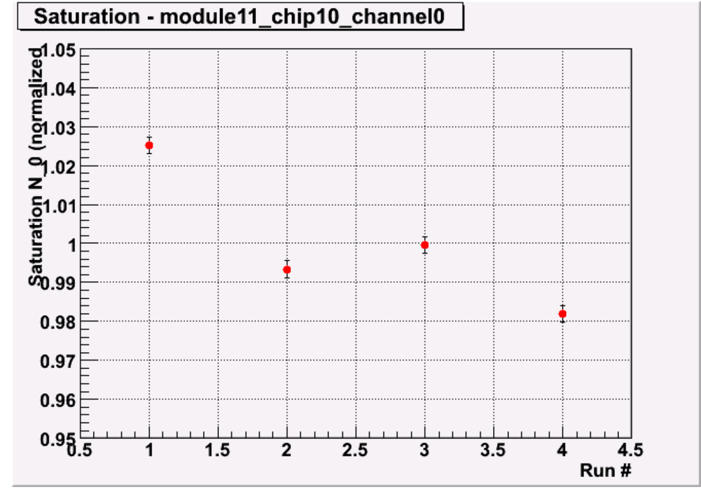

<u>After selection:</u>

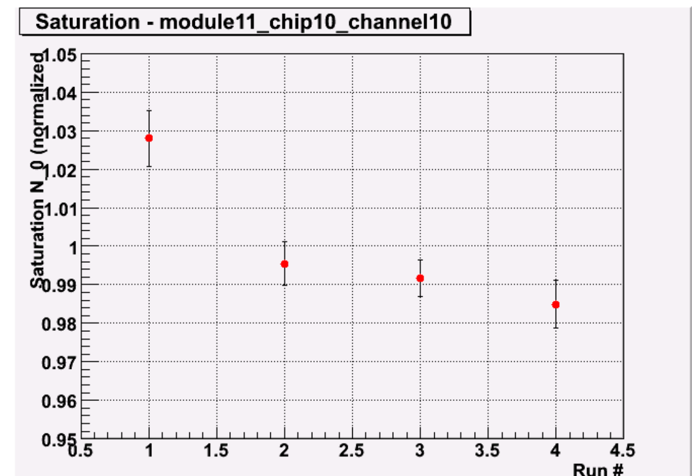
- no ADC saturated channels
- reasonable ch2/ndf of fit
- calibration constants available
- fit results in good ranges

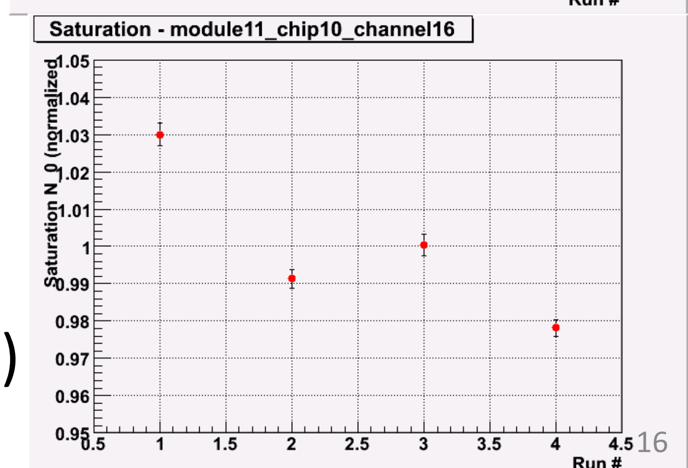
- Distribution of saturation coefficients expressed in SiPM pixels
- Mean value corresponds to factor 0.8 (of 1156px)
- Tails are under investigation

# Multi – run (time) saturation



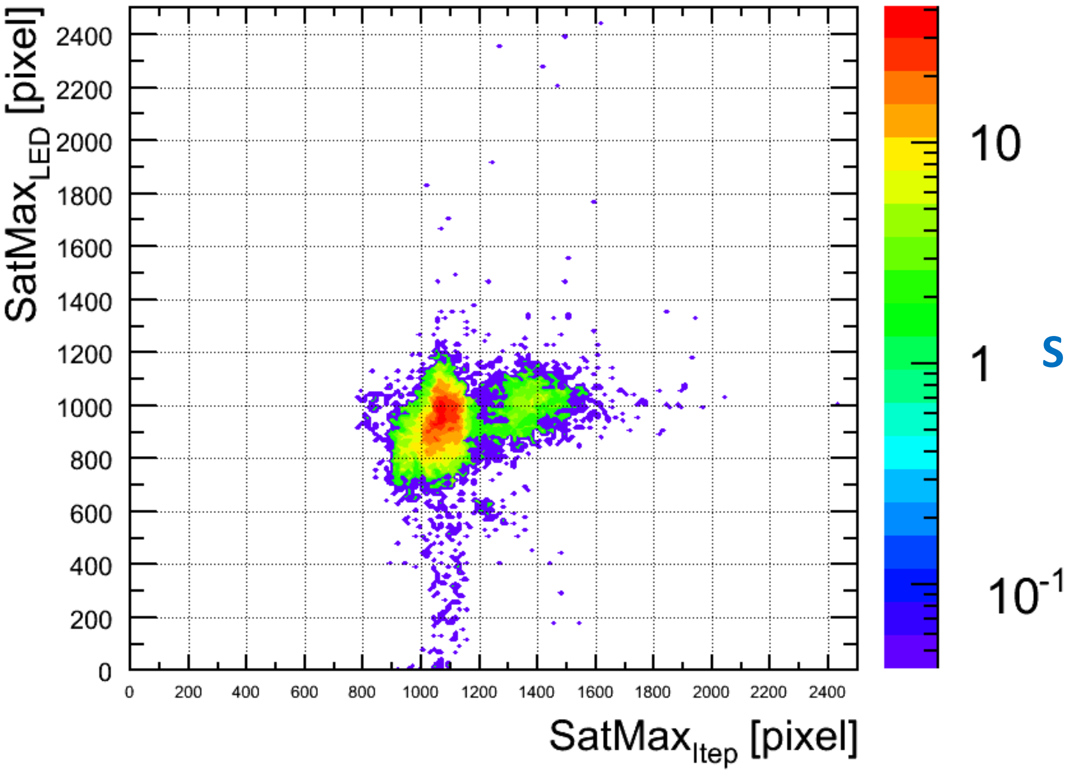

4 runs chosen:

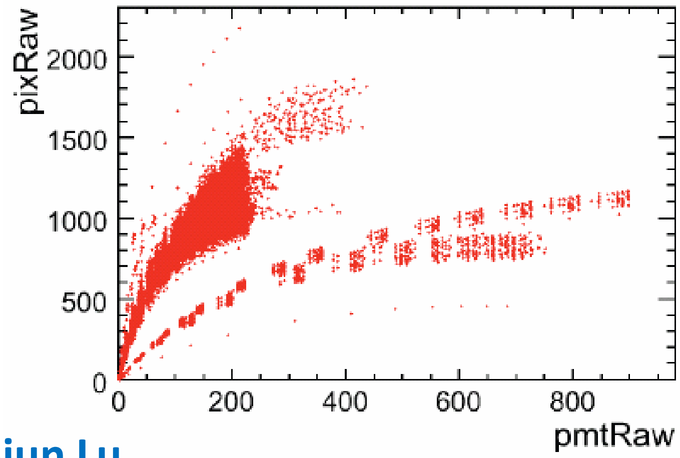
Within 14 days of F-04 data period

→ Results consistent at +/- 3%

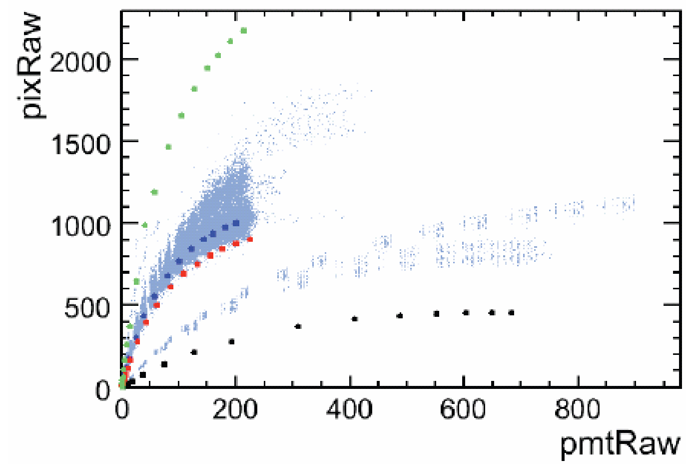
Need of Temperature correction (in progress)

# ITEP versus Test beam




Shaojun Lu




- At least 2 bulks of SiPMs visible in ITEP measurement, but not correlated to Fermilab TB data
- TB in average resulting in factor of 80% of ITEP

# ToDo:

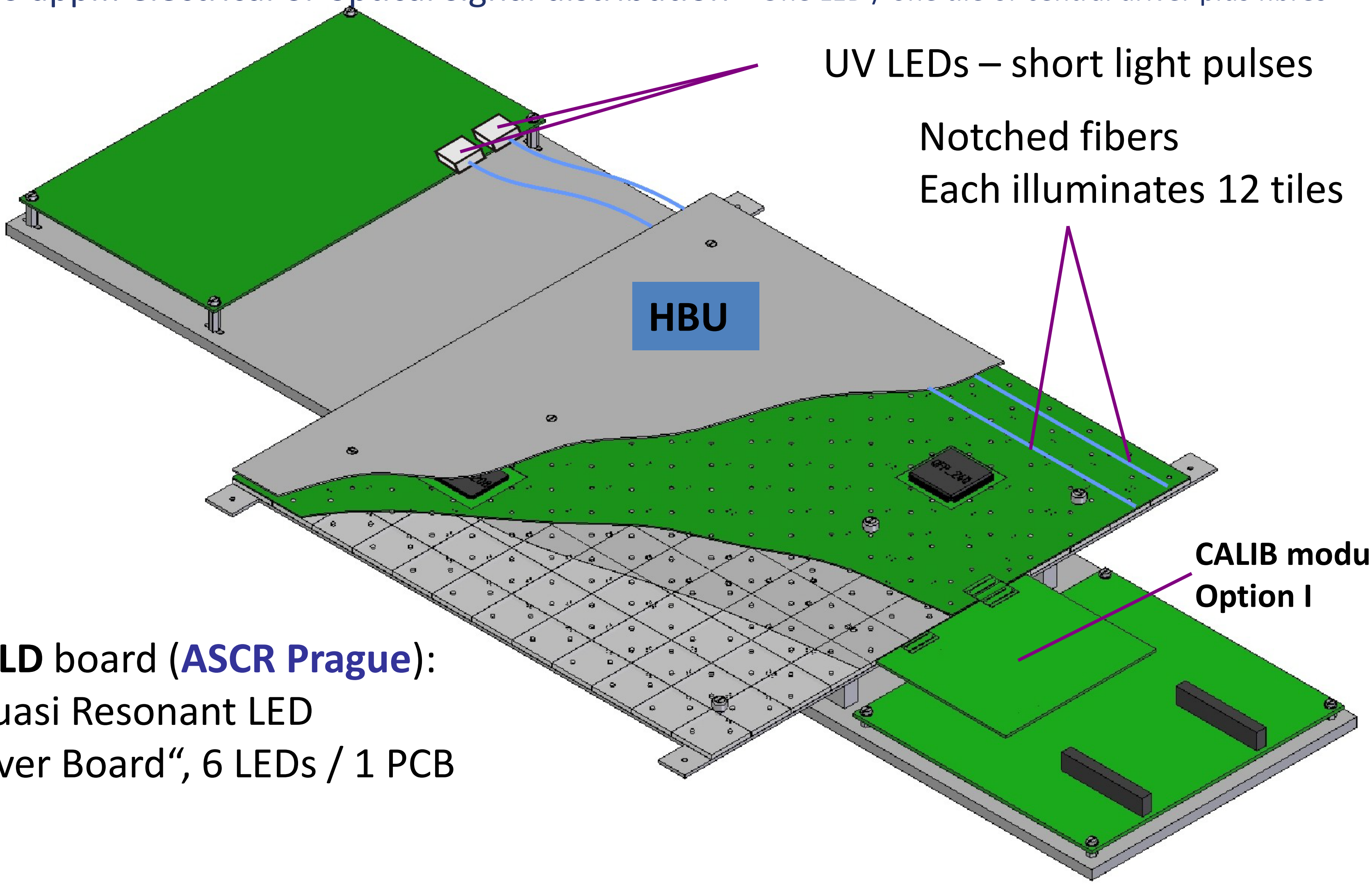
- better fitting procedure
  (avoid saturated ADC bins)
- more runs -> combined fits (?)
- comparison with ITEP saturation curves
- better classification of ‘bad’ channels
- application of calibration constants on fly
- correction on temperature

? LED Linear? Saturated? Temp. dependent?

# NEXT generation prototype
# EUDET module
# New calibration systems

# Calibration Option 2: LED driver

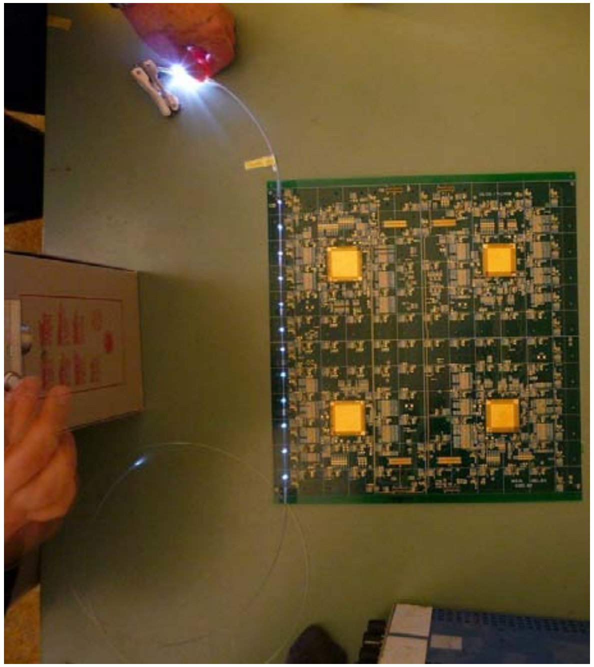
- Non-linearity correction, MIP calibration, Correction temperature variations
- Two appr.: electrical or optical signal distribution - One LED / one tile or central driver plus fibres



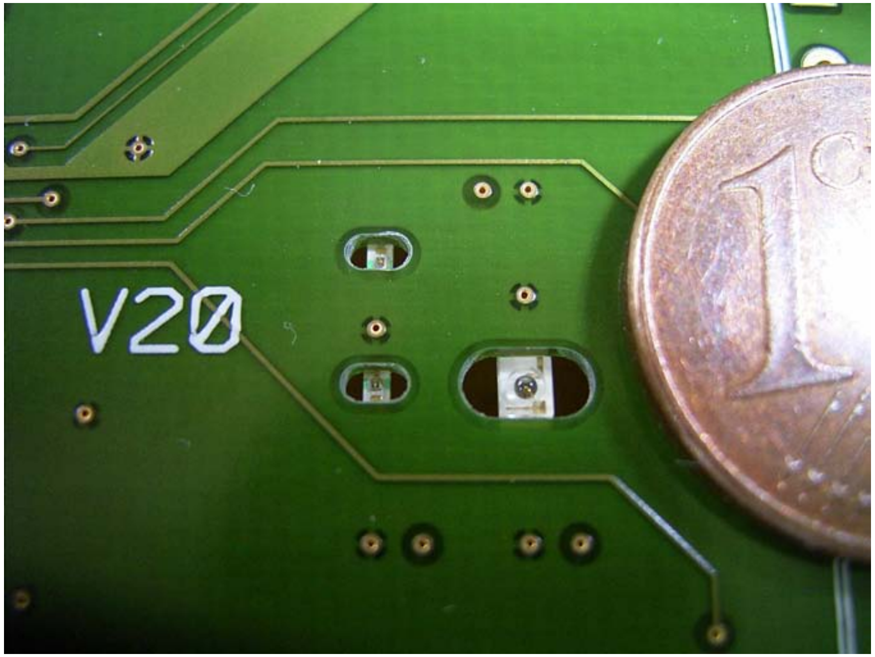

**QRLD** board (**ASCR Prague**):
„Quasi Resonant LED
Driver Board“, 6 LEDs / 1 PCB

# Flashing UVLED - 2 methods

- Light distributed by notched fibres



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

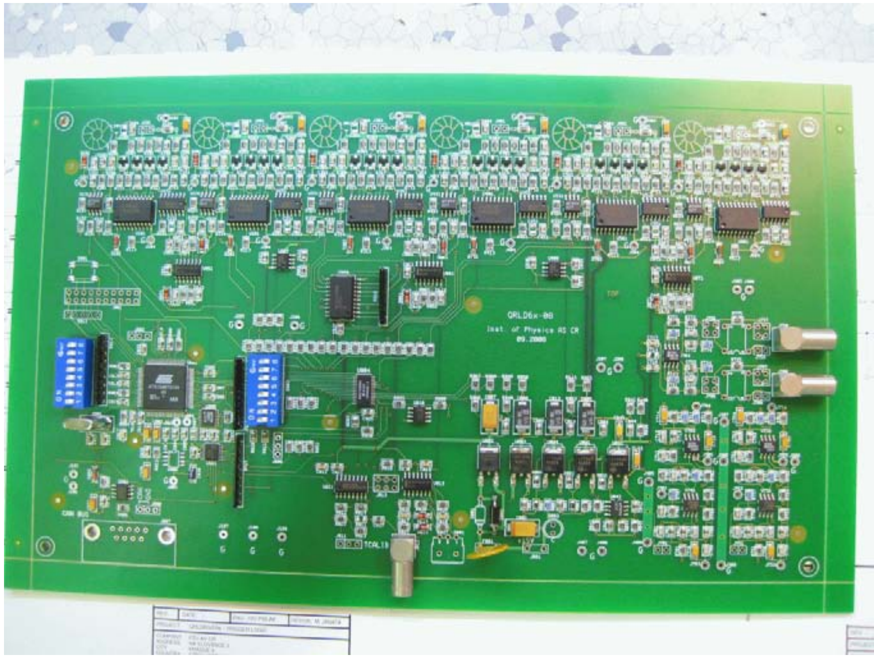



Institute of Physics ASCR, Prague, (= FZU)
Kobe University

DESY Hamburg
UNI Wuppertal

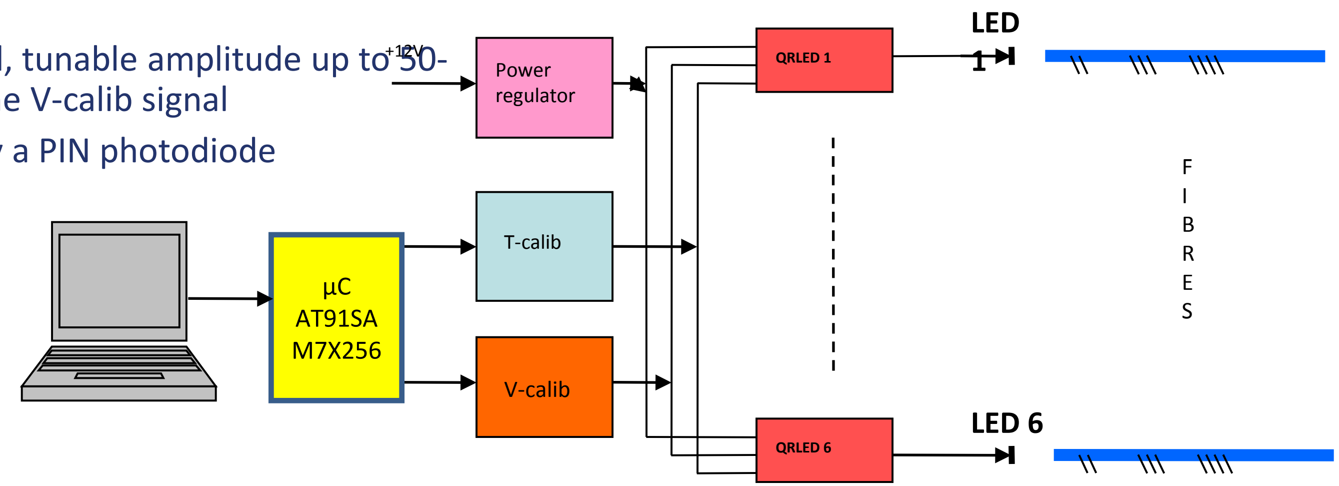
# QR-LED driver

- Option with optical fiber distribution
- Electronics: multi-channel prototype complete
- Optical system: uniformity again competitive
- Multichannel LED driver



  - 1 PCB with the communication module μC, power regulator, 6 channels of  QRLed driver
  - Less RFI
  - PCB integrated toroidal inductor (~35nH)

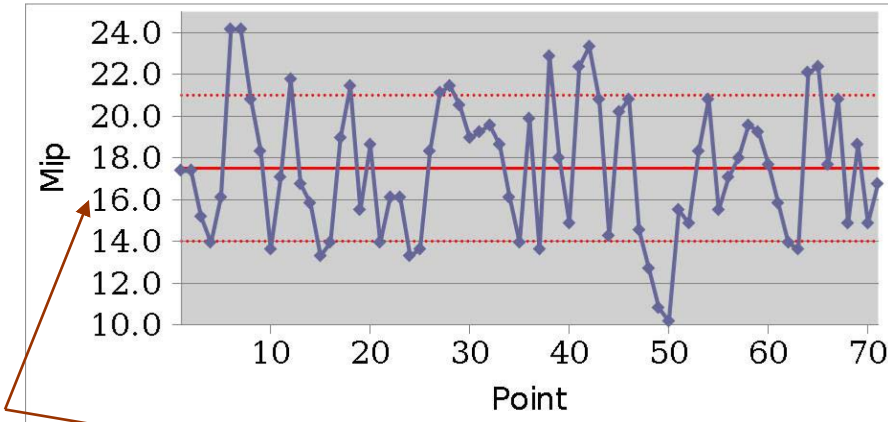
  - Communication module to PC via CAN bus or I2C
  - Controlling the amplitude and monitoring temperature and voltages
  - LED pulse width ~ 5 ns fixed, tunable amplitude up to 50-100 MIPs is controlled by the V-calib signal
  - 2 LEDs can be monitored by a PIN photodiode



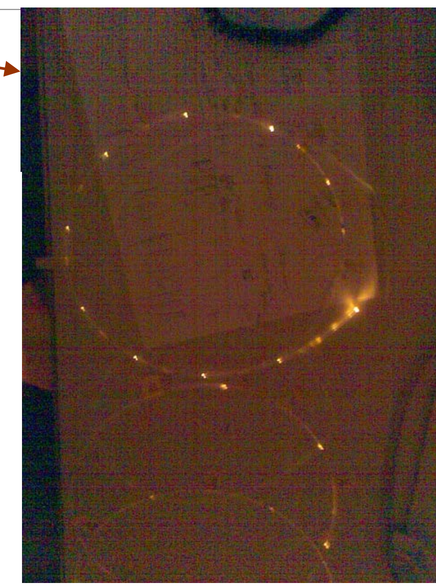
# Option 2: Optical system

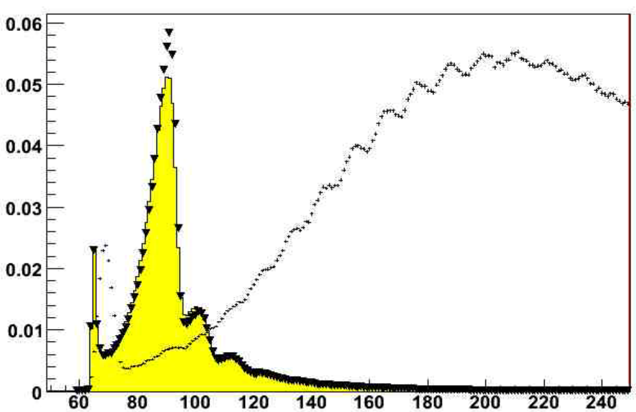
- Idea: use one fiber for one row of tiles (72)
- Problems:
  - uniformity of distributed light
  - enough intensity of distributed light
  - concentration of LED light into one fiber
- Two fibres:
  - Side-emitting - exponential fall of intensity
  - Notched fibre - better uniformity of distributed light - need to mechanize production - R&D
- No optical cross talk seen

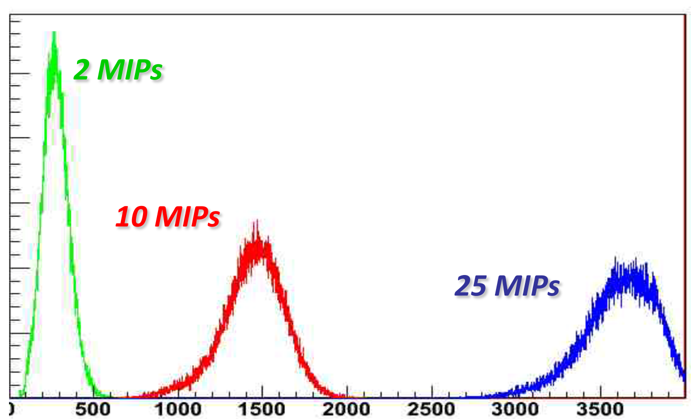
➢Light output from fiber via notches uniform over all 70 points
➢ Approaching ±20% proposed limit of light variation




**Notched fiber:**





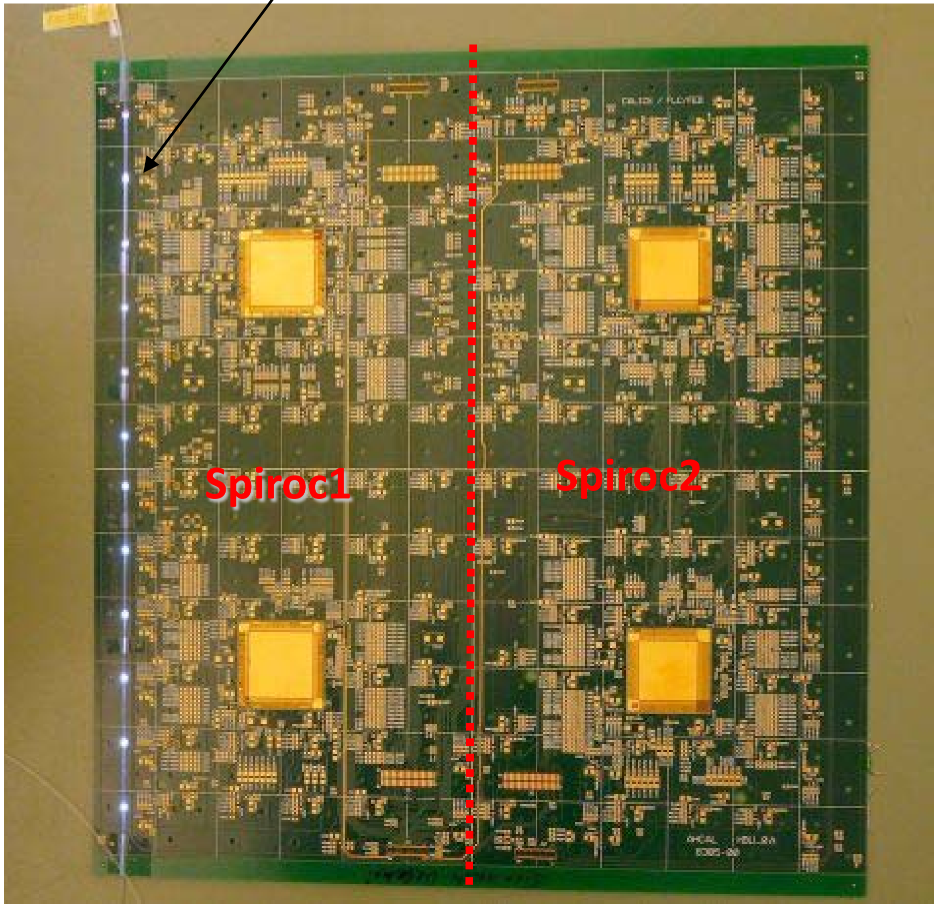



# Notched fiber system

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

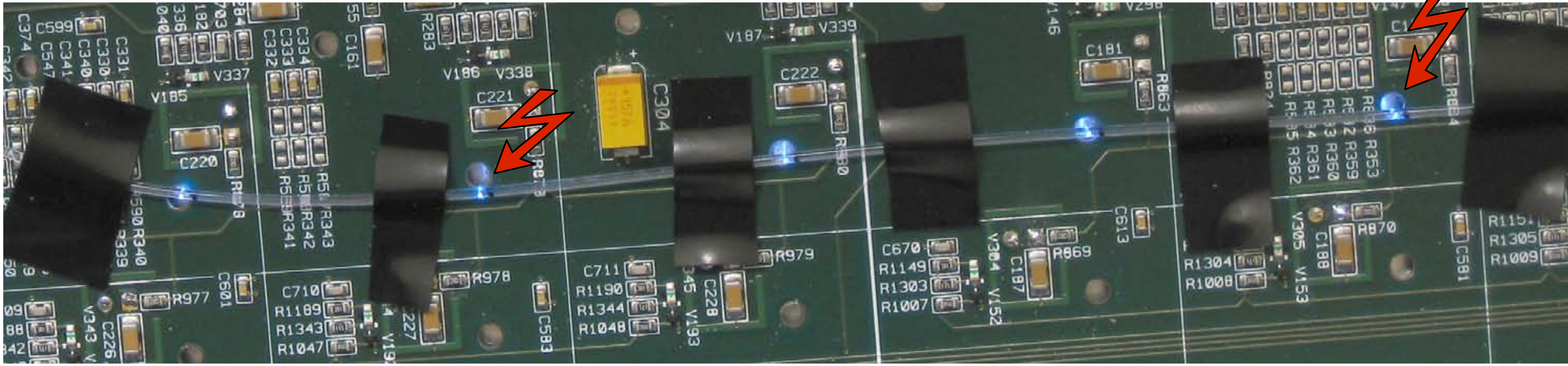
- advantage – tuneable amplitude of LED light from 0 to 50 mips
- Variation of LED amplitude does not affect the SiPM response readout
- LED circuit and LEDs enable optical pulses with around 5ns width
- Spread of light intensity from notches can be kept under 20%
- disadvantage LED with control unit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

Nice idea, but…
Spiroc1 area is not working



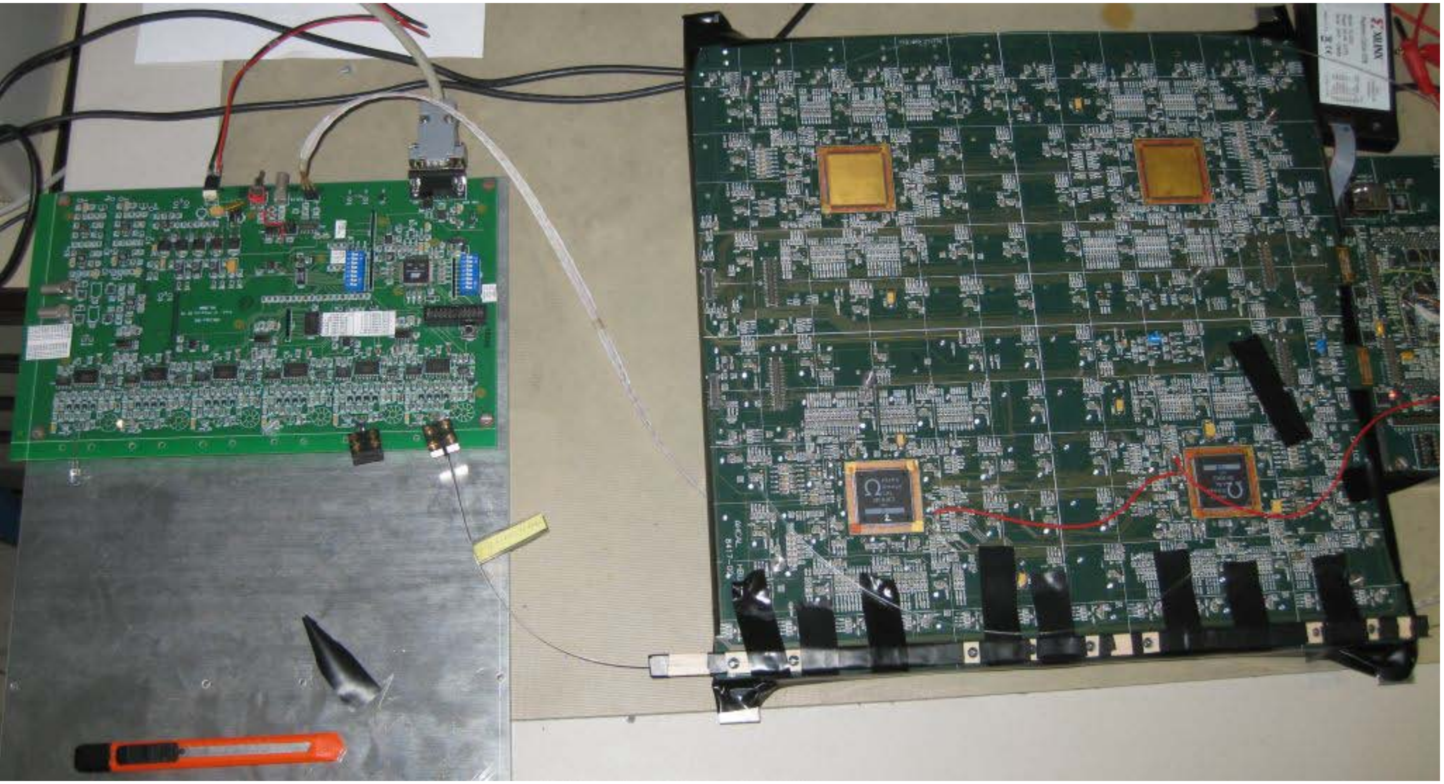
# OLD SETUP Dec 2009

Electrical tape and bended fibre is not the right combination!




## A “NEW” BALSAwood bar with a notched fibre Apr 2010

# QMB6 + HBU0 light from fiber taps shines to the scintillator pins



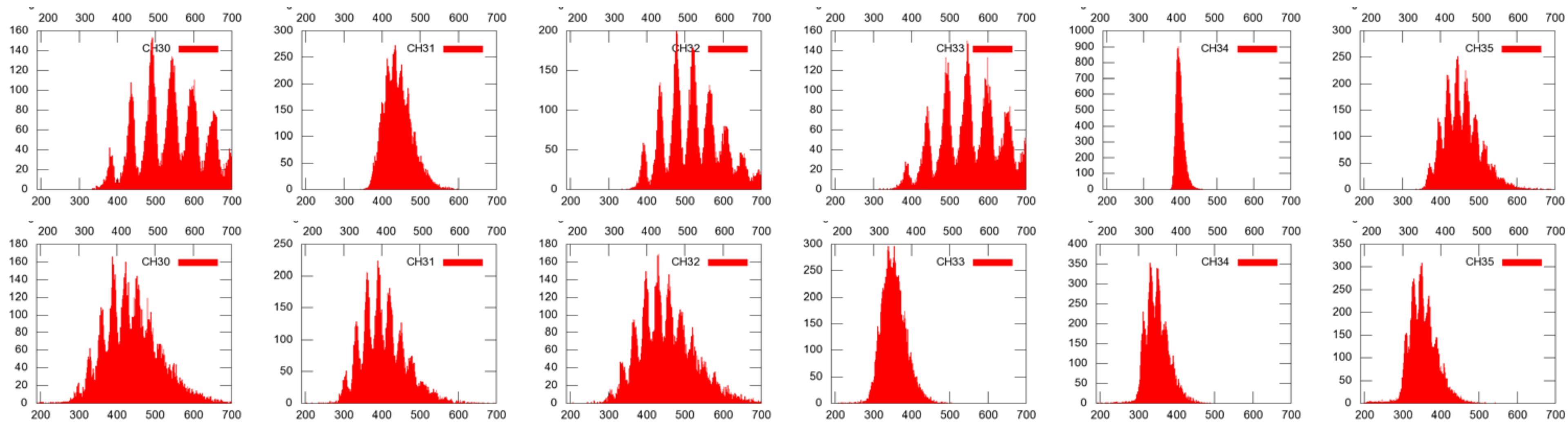
From HBU0 (calib board):

- signal T-calib LVDS only 60ns Delay
- power +15V/0.16A
- CANbus slow-control
- One UVLED 5mm
- One Notched fibre

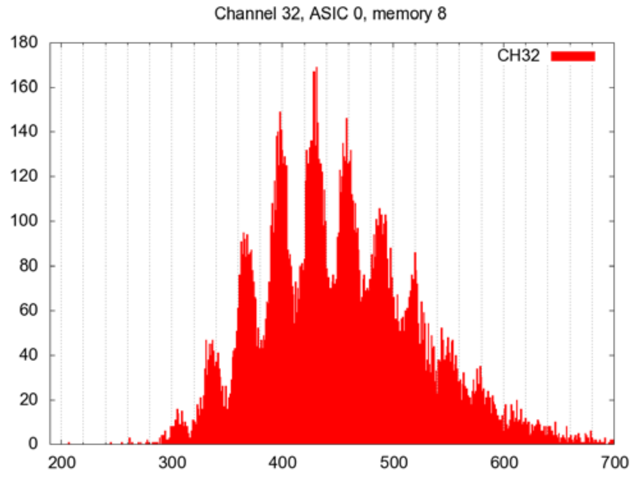
Almost **plug and play**

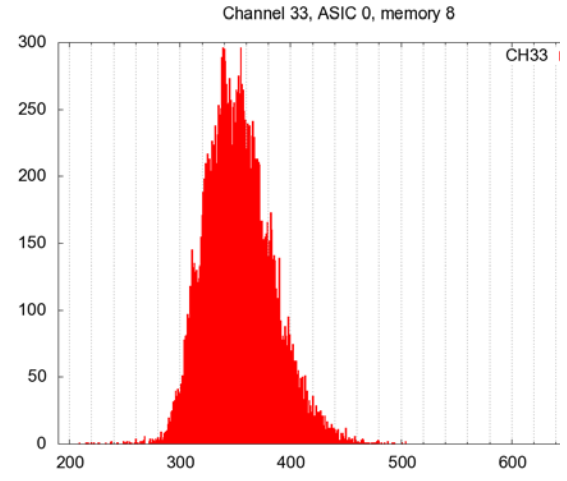
Control: LabView 8.2 exe-file, One PC with DAQ, USB --> CAN

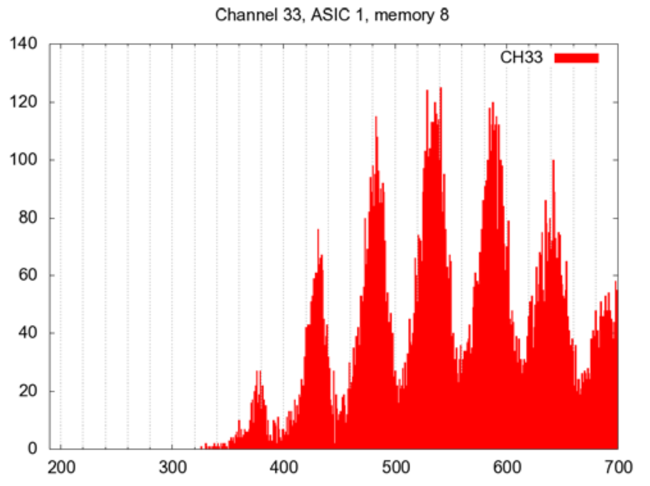
# Single p.e. spectra
# QMB6 to SPIROC1 & SPIROC0



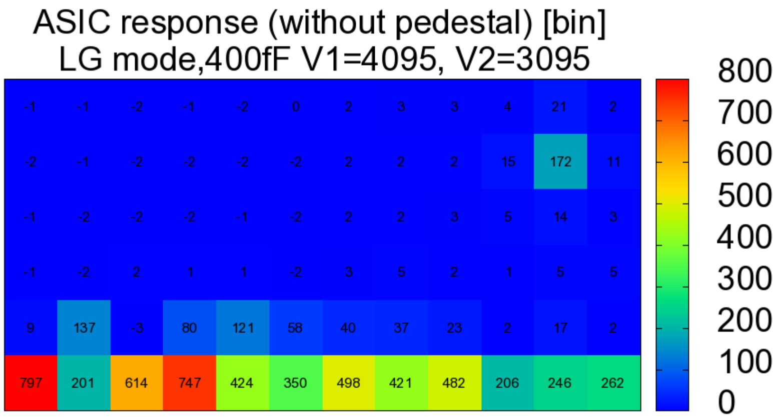

Spread of SiPM gain is about factor 3, it corresponds to data from ITEP.

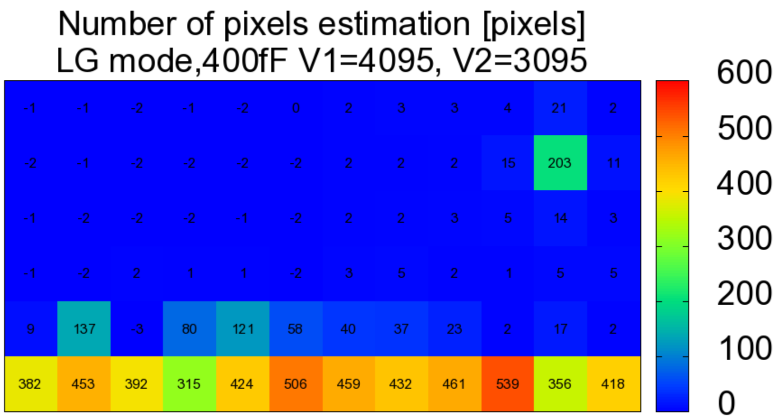


# Light distribution on the HBU0

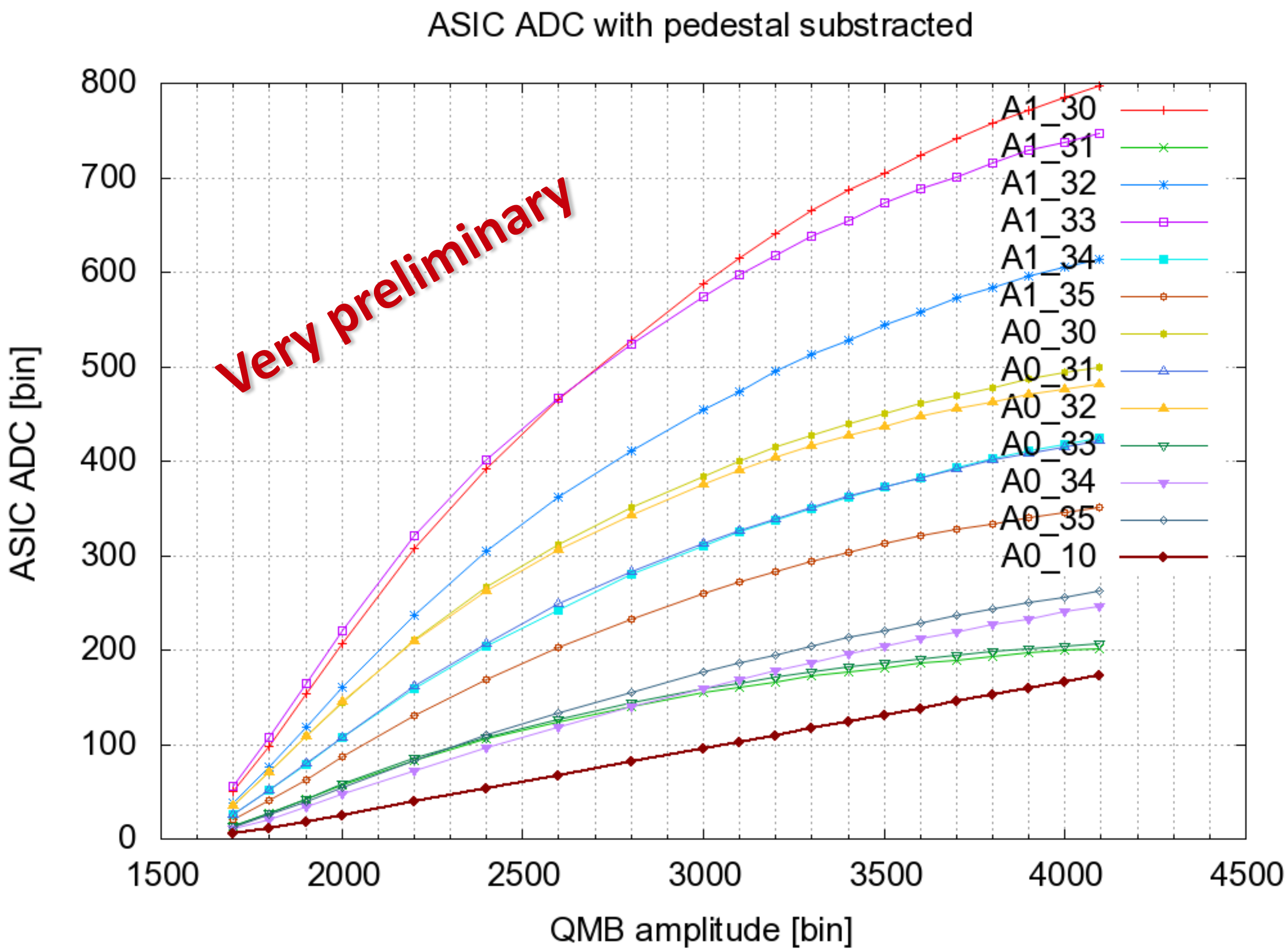



- Optical fiber was routed on the bottom part of HBU0
- 12 points in the row

- Optical spread is much better after corrections

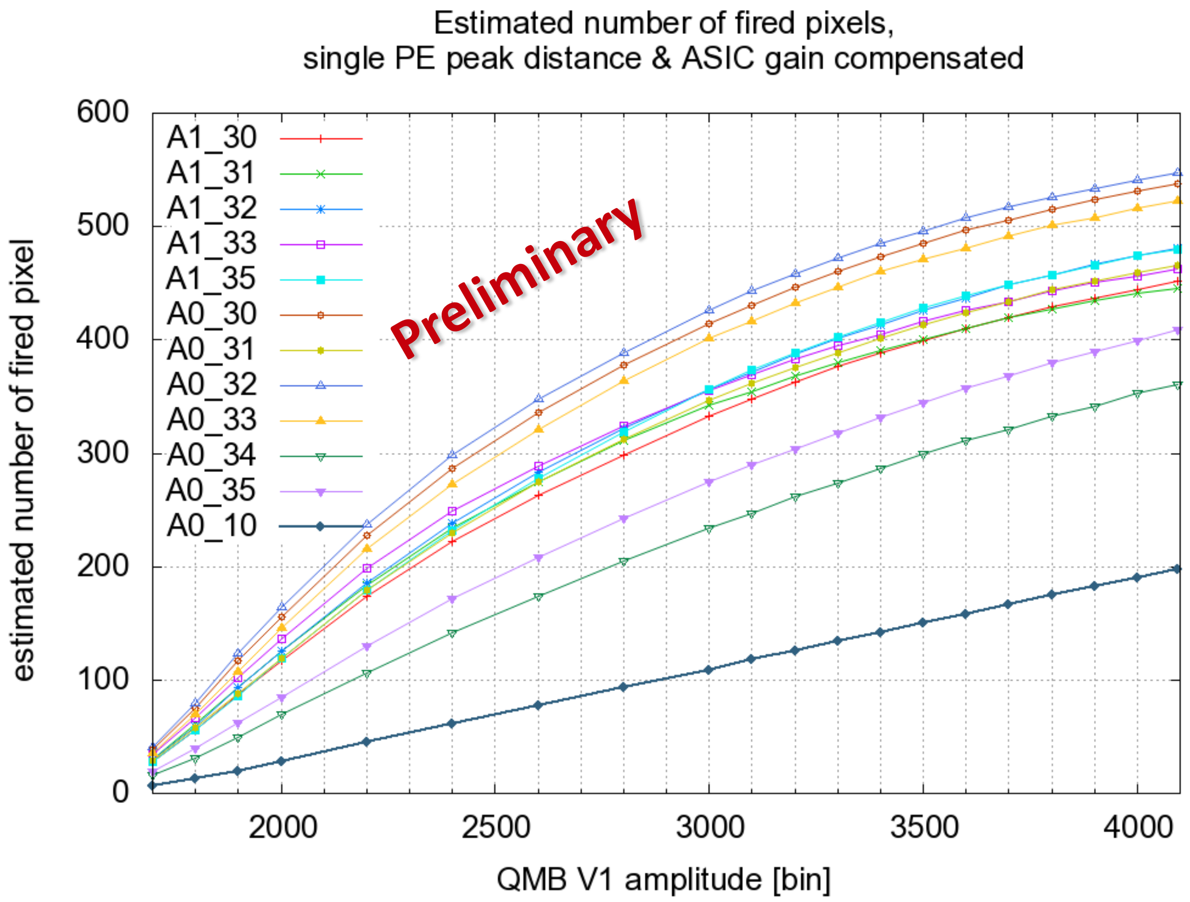
# Linearity test (saturation curve)




Settings:
Cf = 400fF
Low gain mode

- We do see a beginning of saturation effect! ☺
- SiPM gets fired up to ~500 pixels.
- Higher LED pulse will be tested soon with larger pulse-width (3.7 → 7ns)

# Compensated Linearity test




Settings:

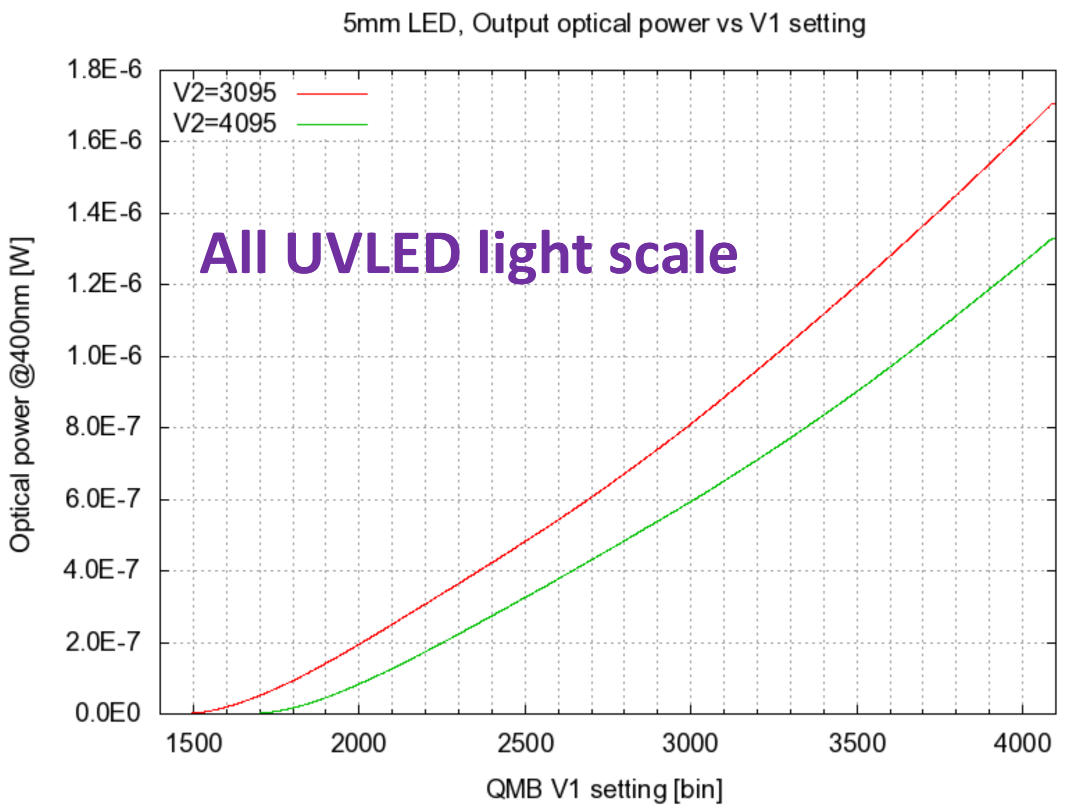
Cf = 400fF
Low gain mode

- Gain spread of channels compensated (avoiding ASIC saturated values)
- Single PE peaks distance calibrated

- End of the fibre (Tile #11, ASIC 0) has a linear response !

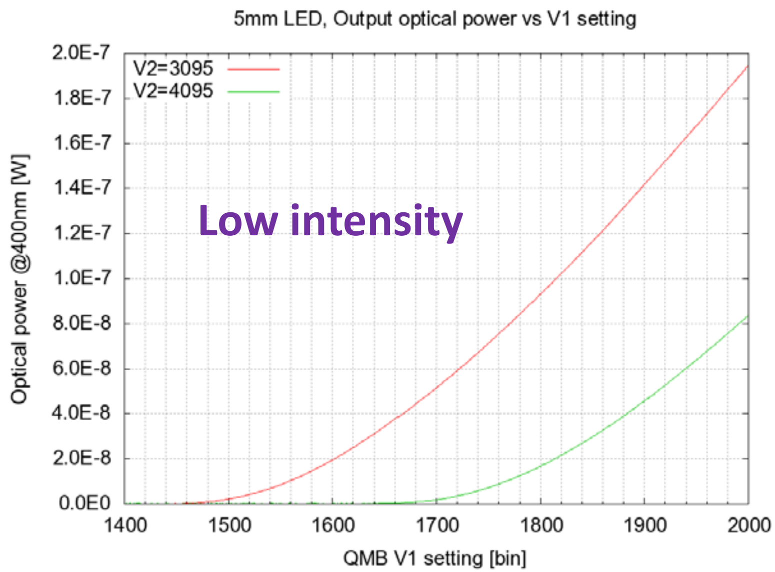
- SiPM gets fired up to ~500 pixels (of 566 SiPM px)

# QMB6 performance




Configuration:
Thorlabs PM100D
Thorlabs S130VC

- Good for rough information about the optical power
- 10 kHz pulses
- in units µWatts
  1 µW → ~ 1E+8 photons




- **NO LED saturation observed on scale**

# Conclusions to common test HBU0 with QMB6

- Easy implementation, almost **plug and play** installation
- QRLED driver has tunable light amplitude
- With QMB6 we can see a nice single p.e. spectra, similar to distributed LEDs
- We do see a beginning of saturation of SiPM. We have also tested another QMB6 with wider pulse width.
- And new more powerful (+50% of light) UV LED (3mm dia) is being tested

# Conclusion

**OLD calibration system:**

**→ has been working**

**→ study of results**

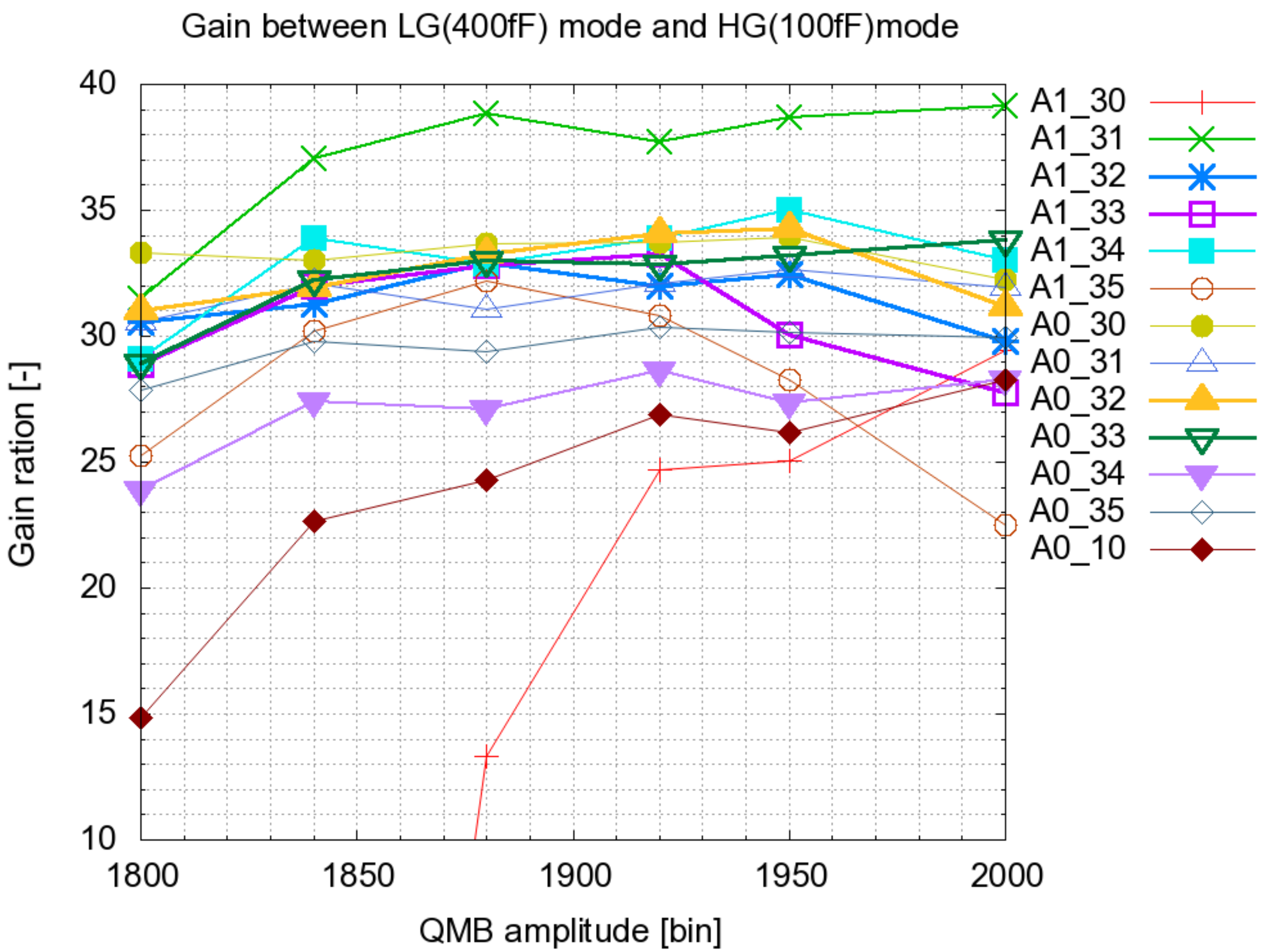
**NEW calibration system:**

**→ about to work**

**→ study of performance**

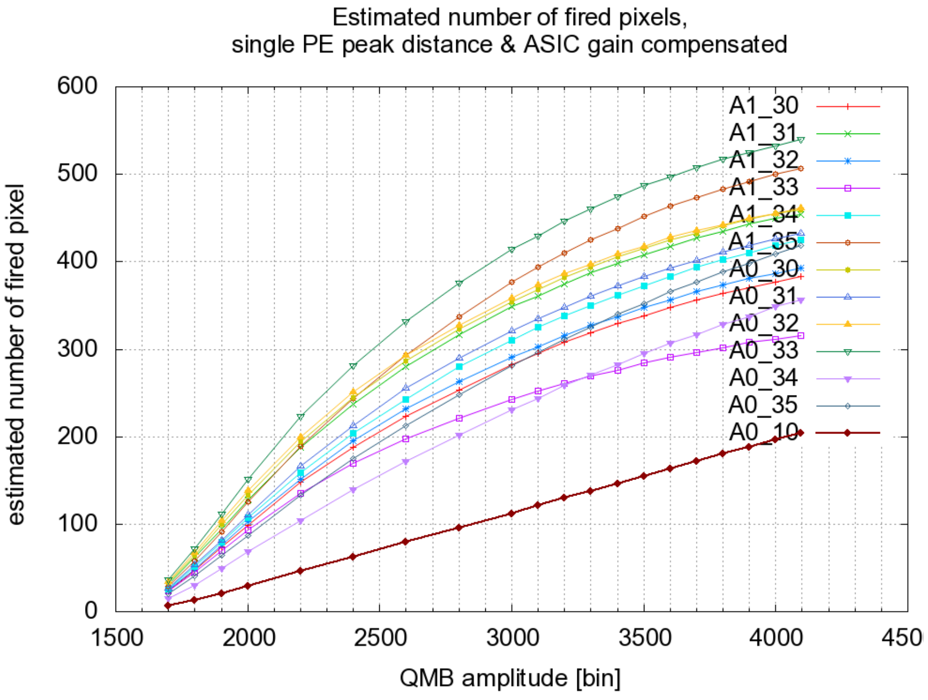
# Back up

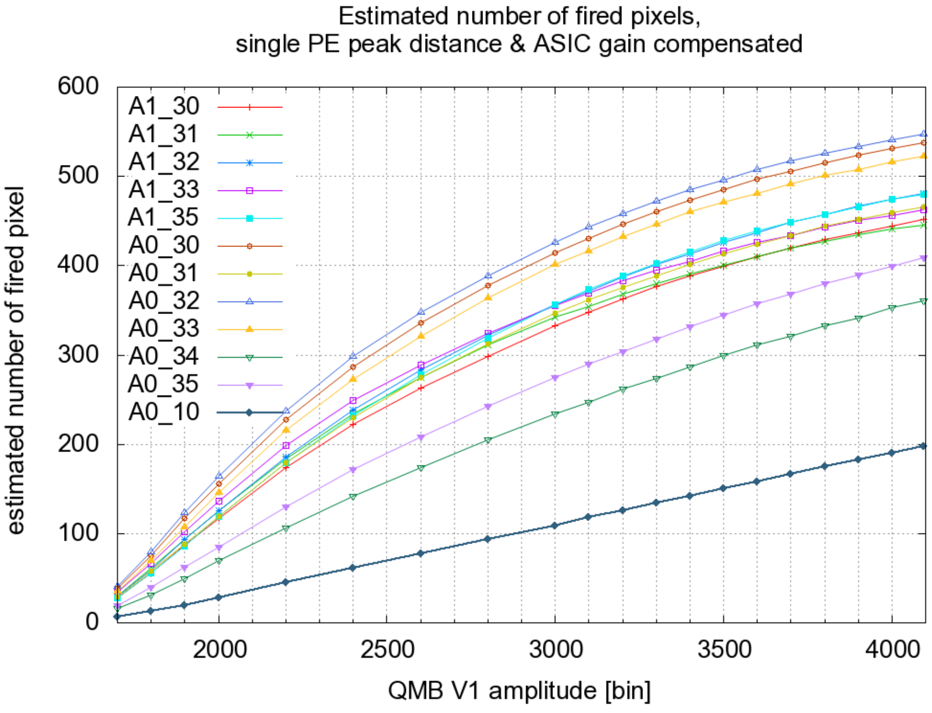
# ASIC's Gain



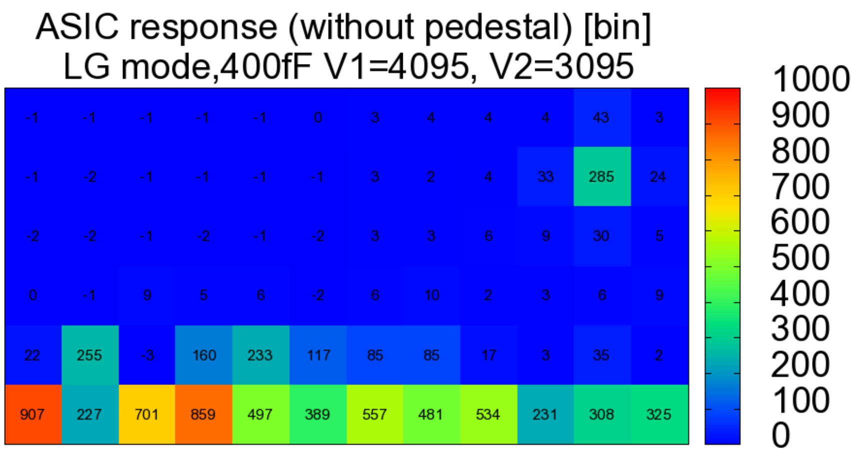

Wide line mean
ASIC saturated

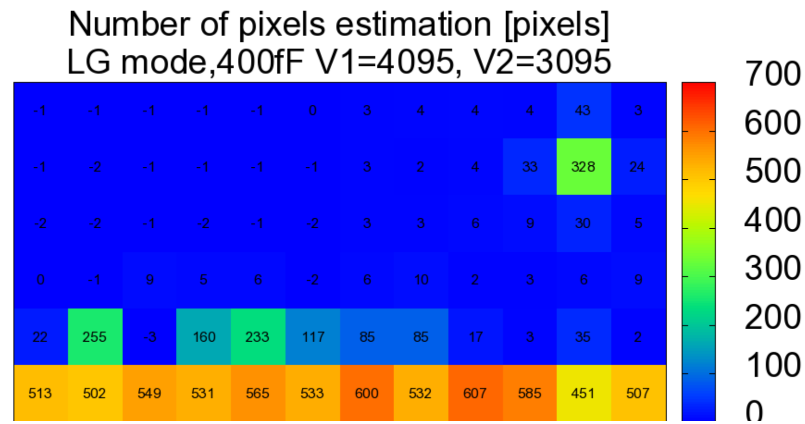
# OLD & NEW Gain estimation

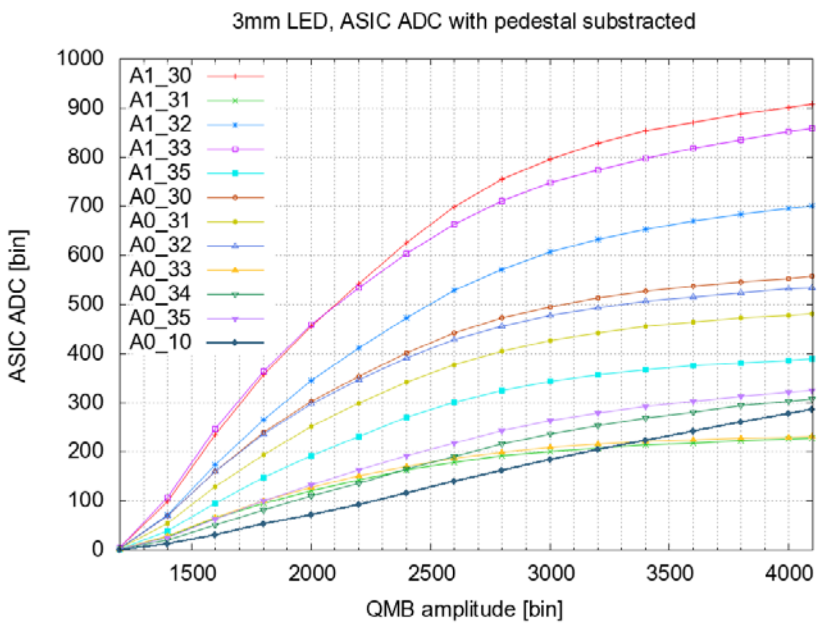


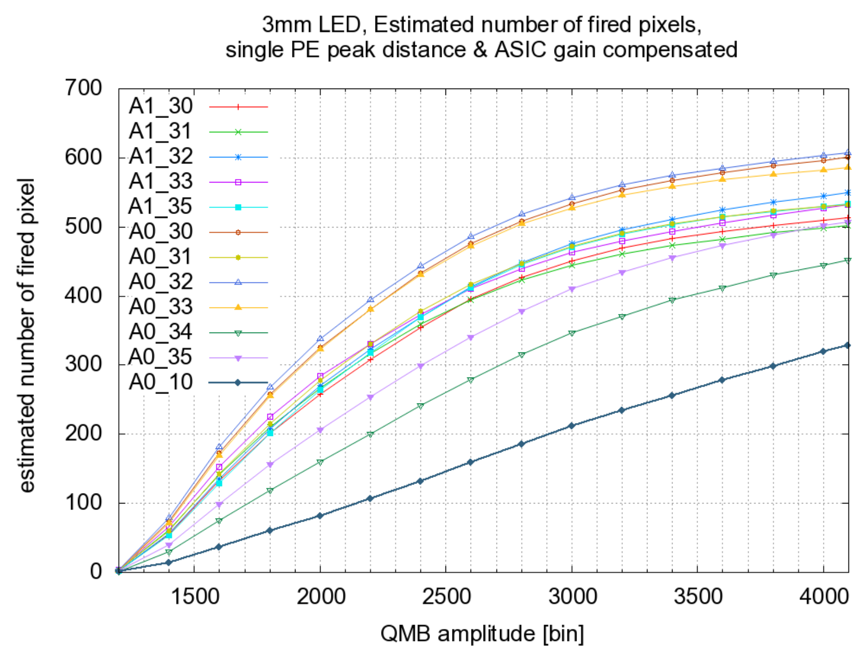



# 3 mm UV LED saturation

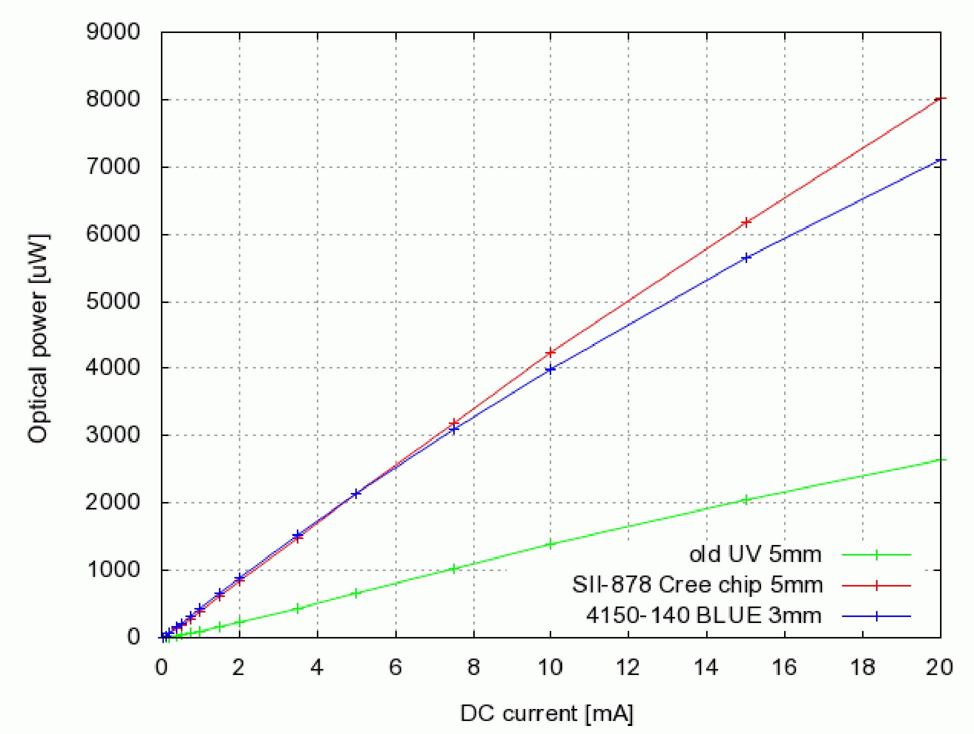


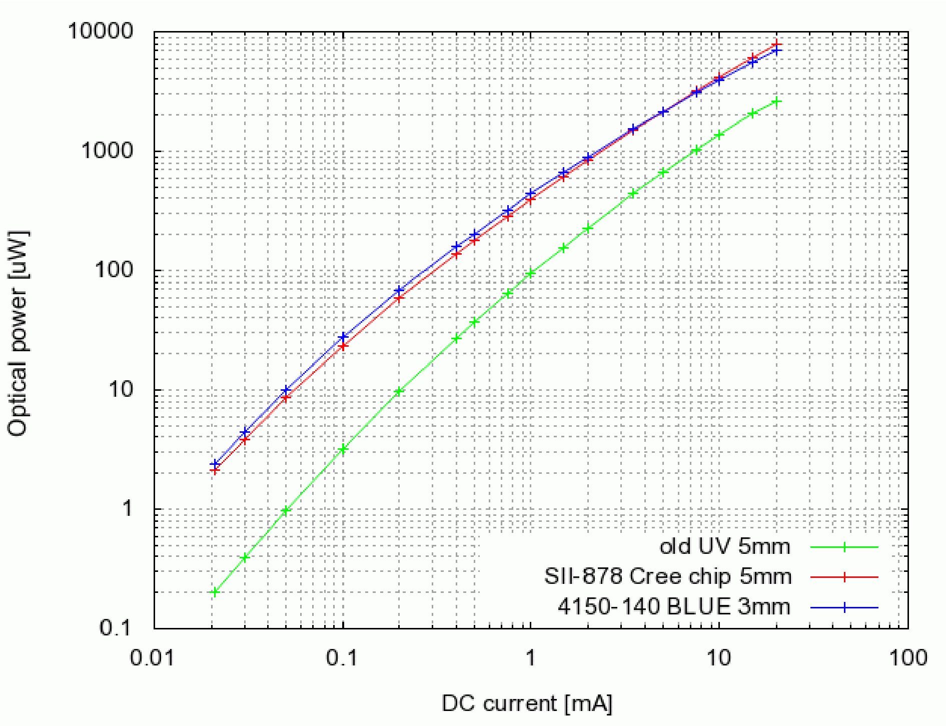



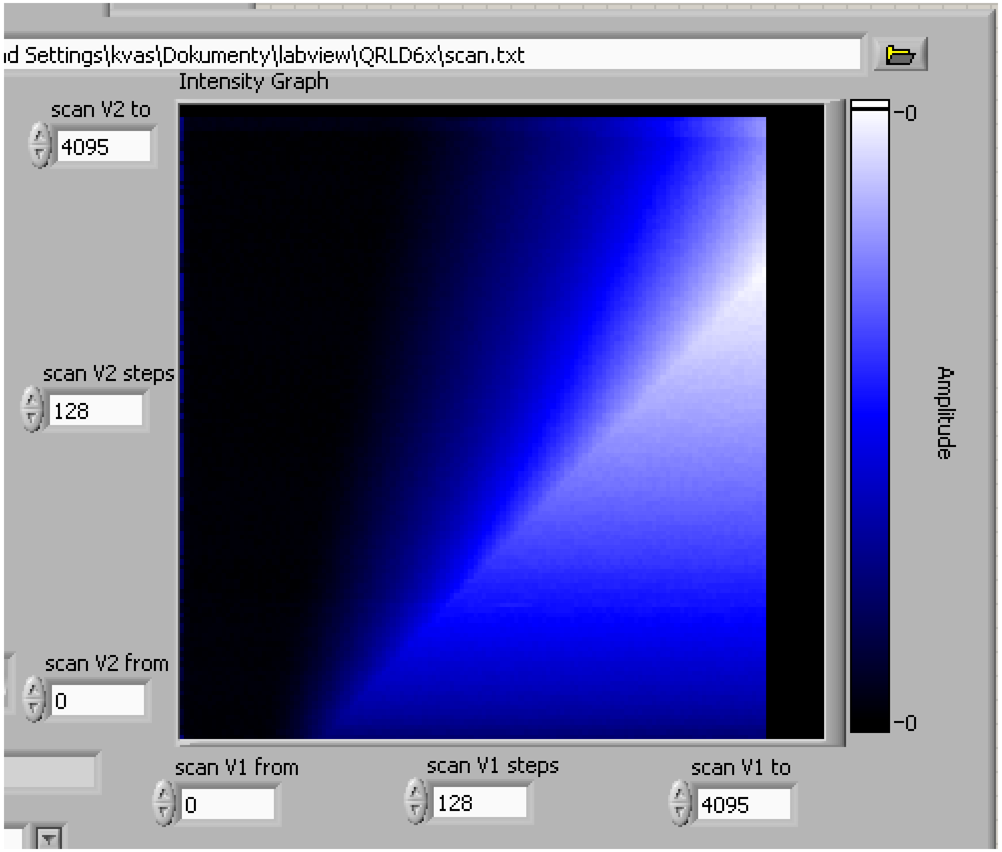



# UV LED power: 5 vs 3 mm





d Settings\kvas\Dokumenty\labview\QRLD6x\scan.txt
Intensity Graph
scan V2 to
4095
scan V2 steps
128
scan V2 from
0
-0
-0
Amplitude
scan V1 from
0
scan V1 steps
128
scan V1 to
4095