BERGISCHE UNIVERSITÄT WUPPERTAL

Status of the LED calibration system

Mathias Götze, **Julian Sauer**, Sebastian Weber and Christian Zeitnitz

Short reminder

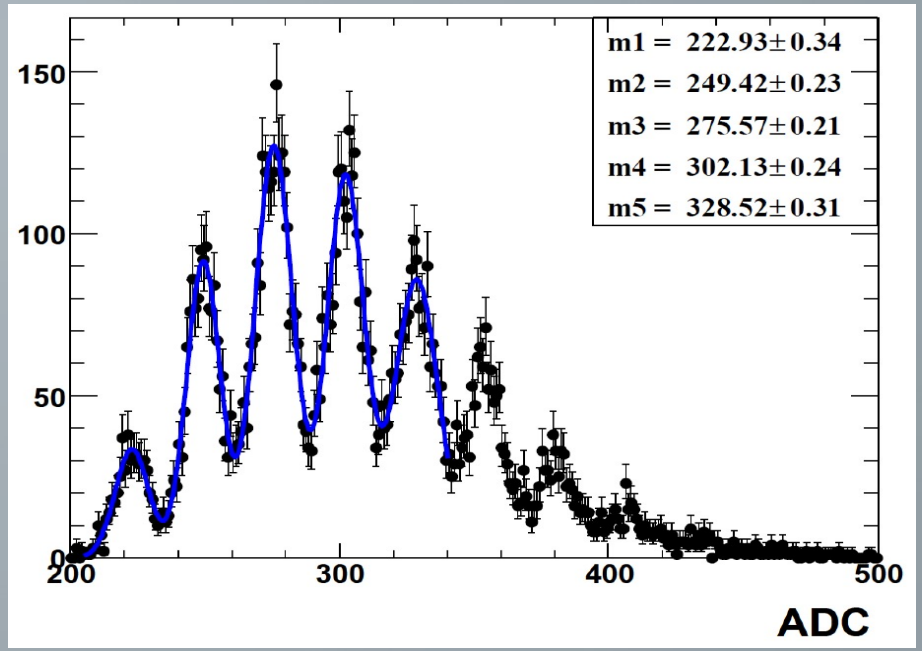
- Current HCAL design ~ $8 \cdot 10^6$ tiles with SiPM
- SiPM gain issues:
  - spreads from $0.5 \cdot 10^6$ to $2 \cdot 10^6$
  - temperature dependent
- SiPM structure: consists of ~10^3 avalanche diodes (pixel)
  - Coupling to tile reduces the effective number of pixels
    → different saturation limits for SiPM

→ Requires a versatile calibration system

Calibration prospects

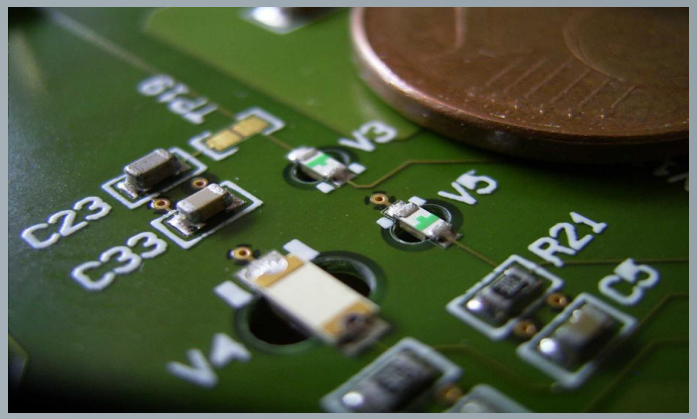
- Gain can be received from single photon spectra (SPS)
  → couple small and short light pulses to the SiPM

- Saturation can be achieved by strong but short pulses
  → wide dynamic range
- System must be scalable to millions of channels



Mounted LED system

- Place one LED on each tile, each LED has its own pulse circuit
  - Through hole mounting
  - LED and pulse circuit are on same PCB as the SiPM
  - Calib. for each channel maximally decoupled
    → good scalability with number of channels

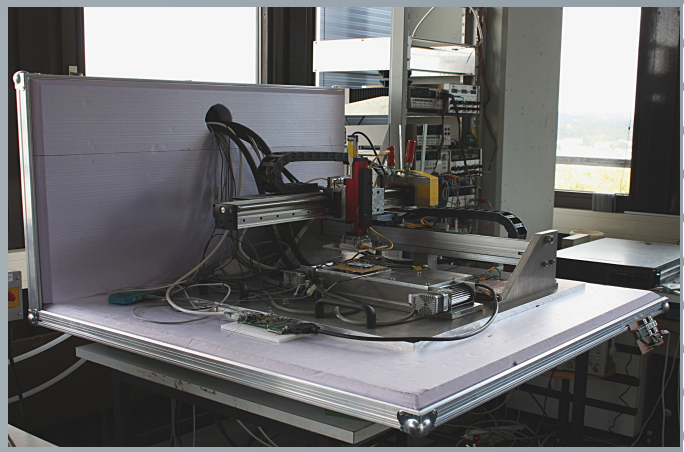


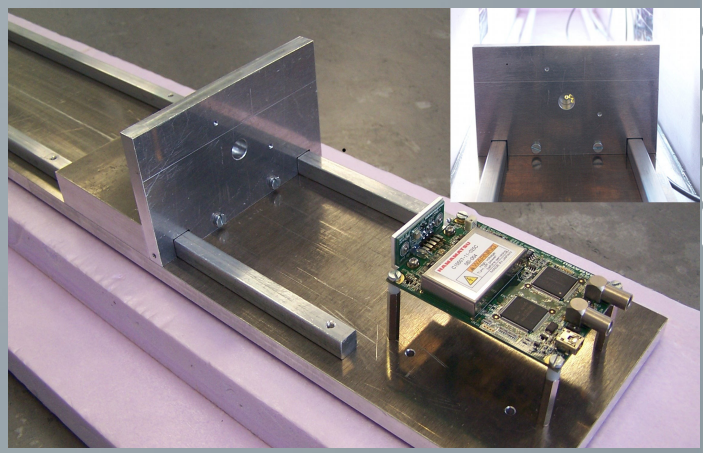
- Possible to cover gain calib. and saturation
  - very pulse circuit and LED dependent!
- Developed by Desy and Uni Wuppertal

Former studies in Wuppertal

- Two setups for 'mounted LED' investigation in '08/'09
  - Big box for tile compounds
  - Small box for pulse circuit studies
- First result: Calib with blue LED
  - Cheaper, better pre-selected than UV
  - Light yield is bigger, good for saturation
  - Pulse and SPS quality were equal

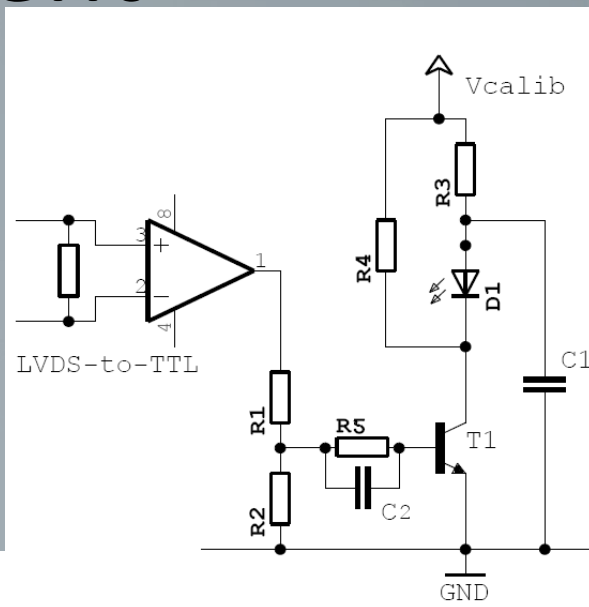
→ Focus on pulser with blue LED

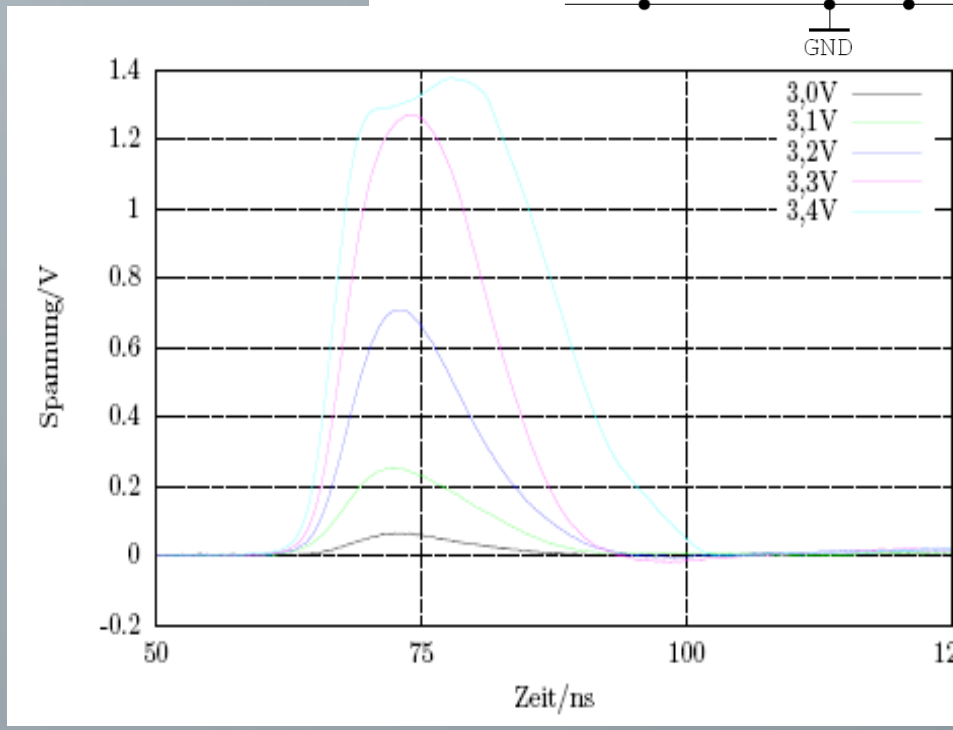




Pulse circuit development

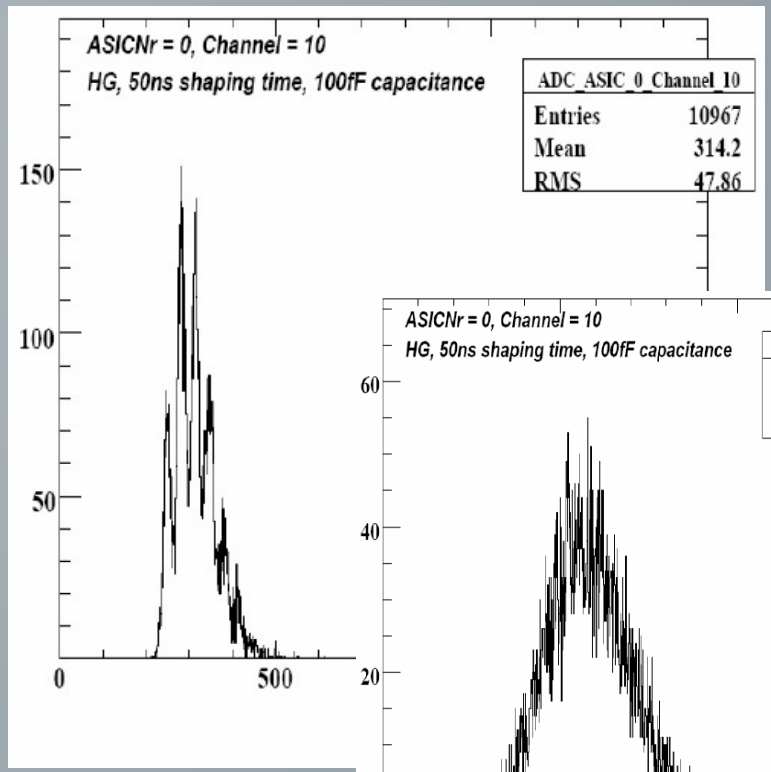
- Basic idea: discharge capacitor via transistor through LED
- Optimized for a stable 25ns pulse
  - Again blue and UV produce equal pulses
  - Measured with Hamamatsu MPPC





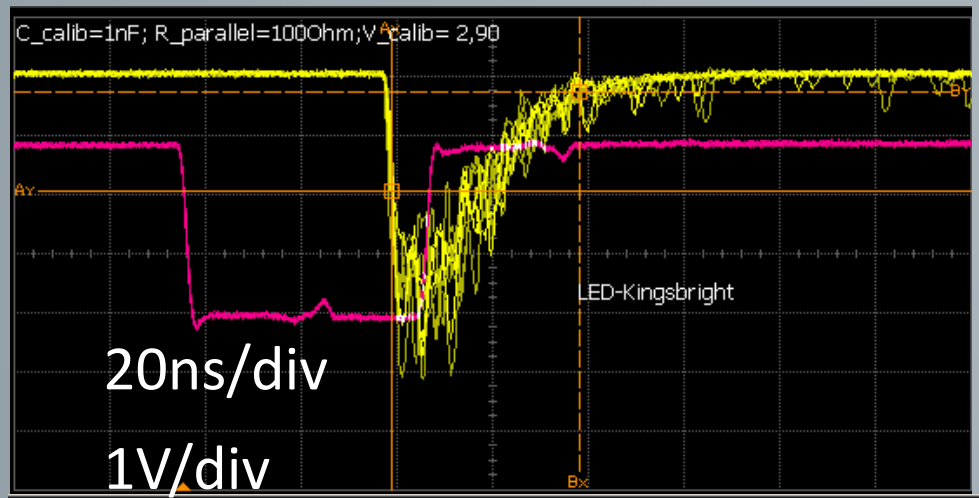
New electronic prototype

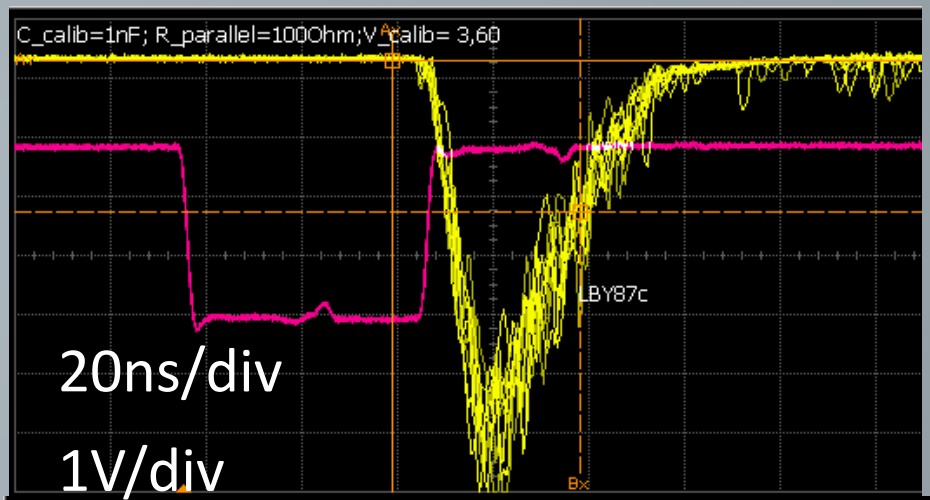
- Next el. Prototype will use the enhanced mounted LED calibration system
- Tackle issues known from the current el. Prototype:
  - SPS quality:
    - Not all SiPM showed good SPS, some none
  - LED type
    - Cheap, quality selection, light yield
  - Light pulse dynamic range
    - Important with high light yield: Vcalib to LED output mapping

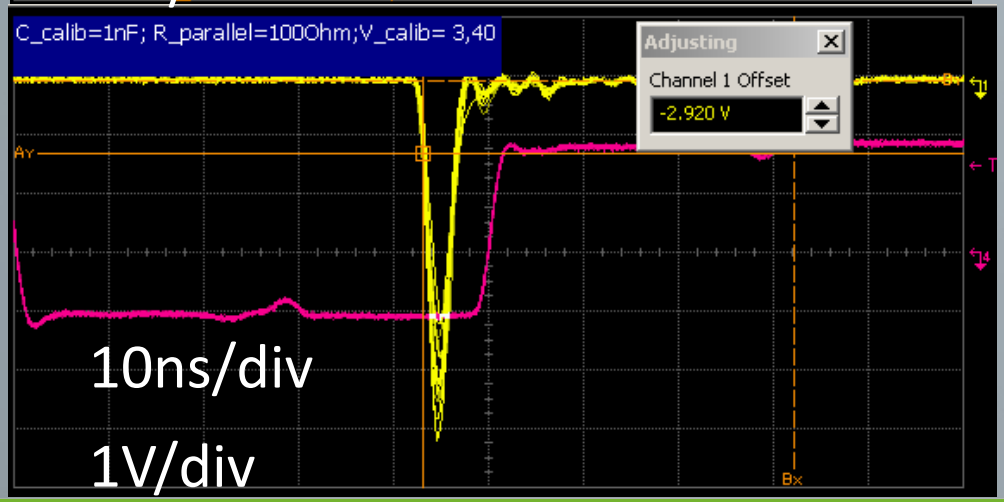


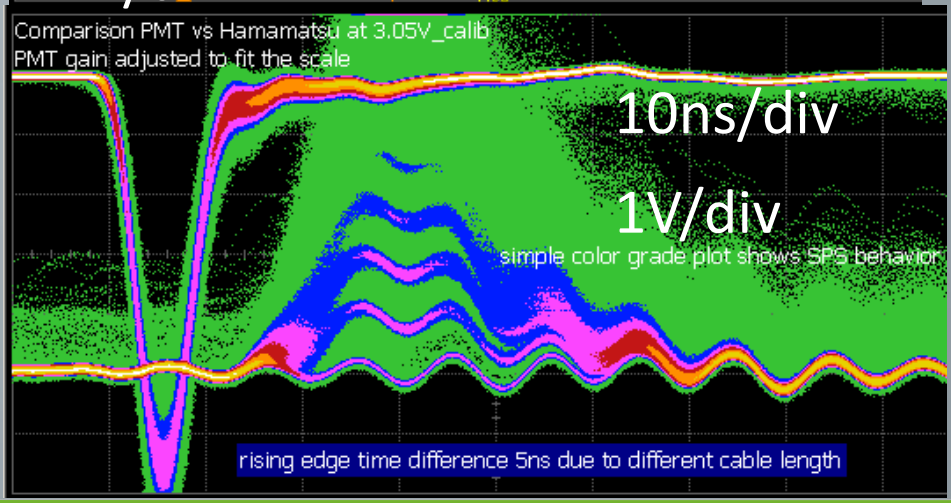
LED Pulse analysis

- First look with Photomultiplier tube (PMT) at several LED shows differences between blue and UV









LED pulse analysis

- The pulse width of UV LEDs is much smaller
- Several more blue LEDs behave likewise
- The rise time is much steeper for UV
- For high V_{calib} a blue LED pulse is longer than the steering pulse that switches the transistor

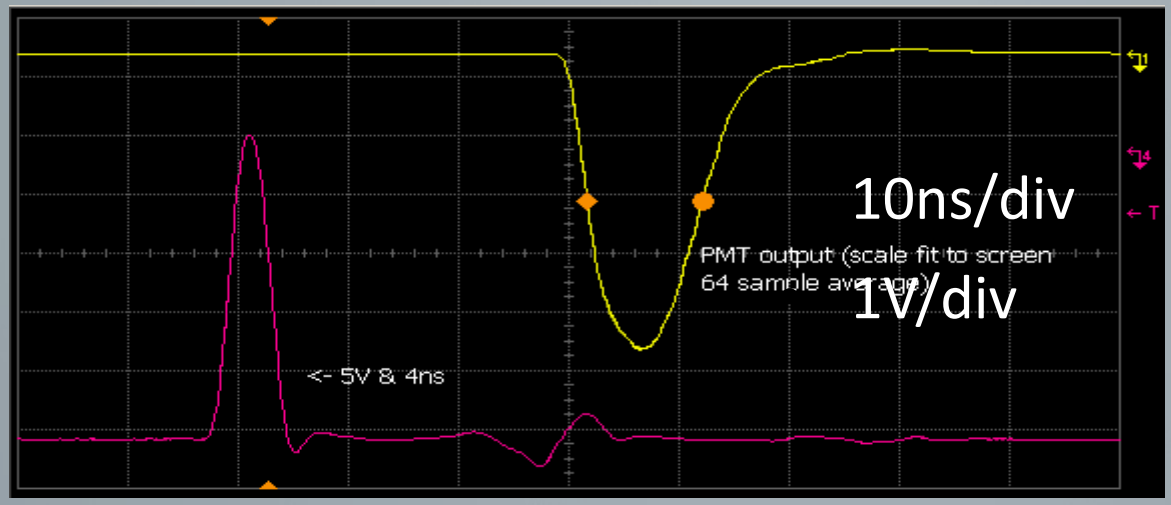
  → hint that this is a LED capacitance problem

  Test the assumption: drive LED with differential signal from pulse generator

Differentially driven LED

- In this mode: LED is reverse biased, then for a short pulse forward biased and directly reverse biased again

  → active discharge of the LED internal capacitance



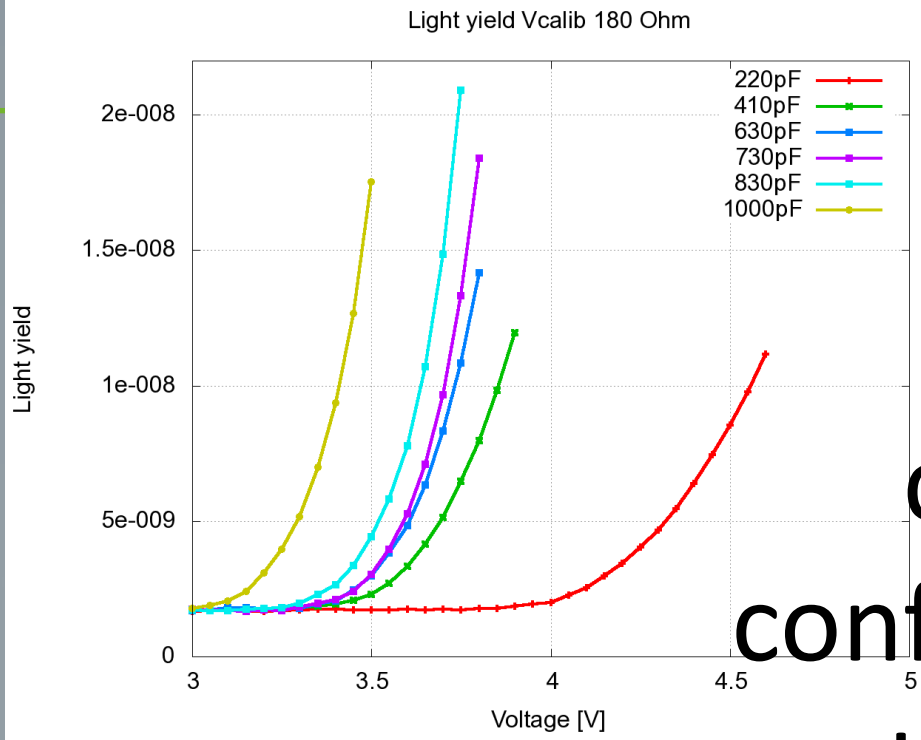
- Result: The blue LED light output stops much faster

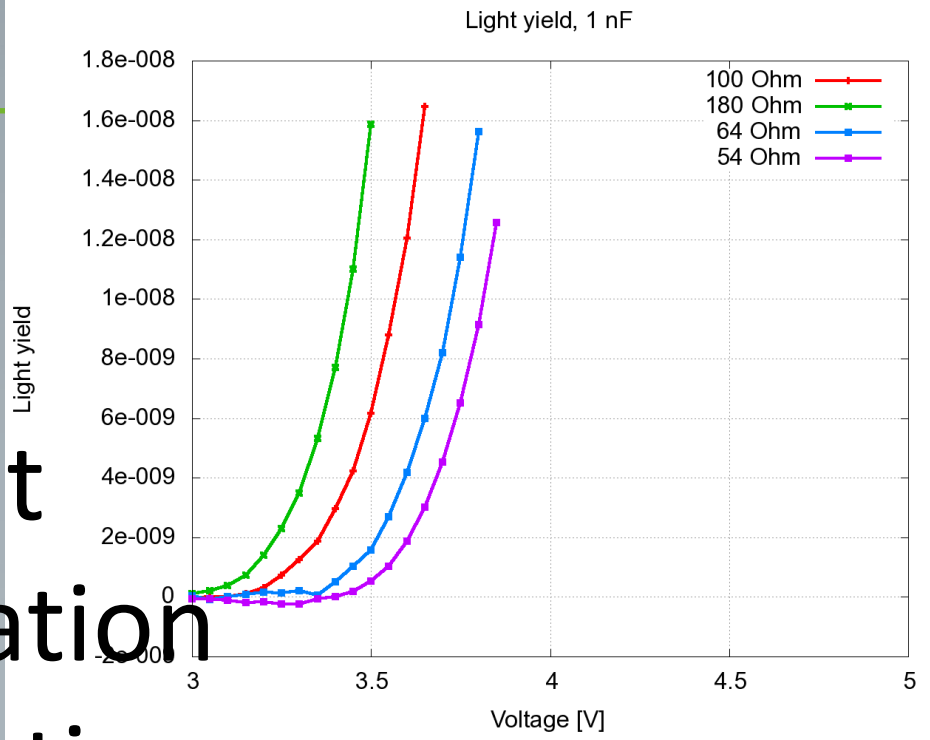
  → good confirmation of the former assumption

Difference between blue and UV LED

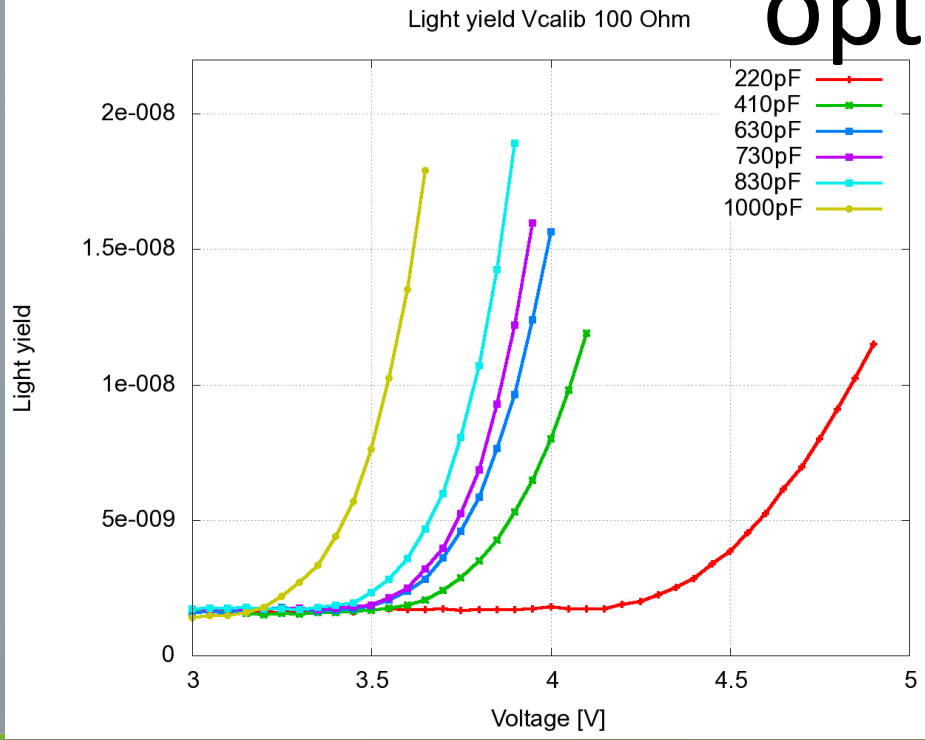
(Special Thanks to Dr. Peter Rotsch from OSA Opto Light GmbH)

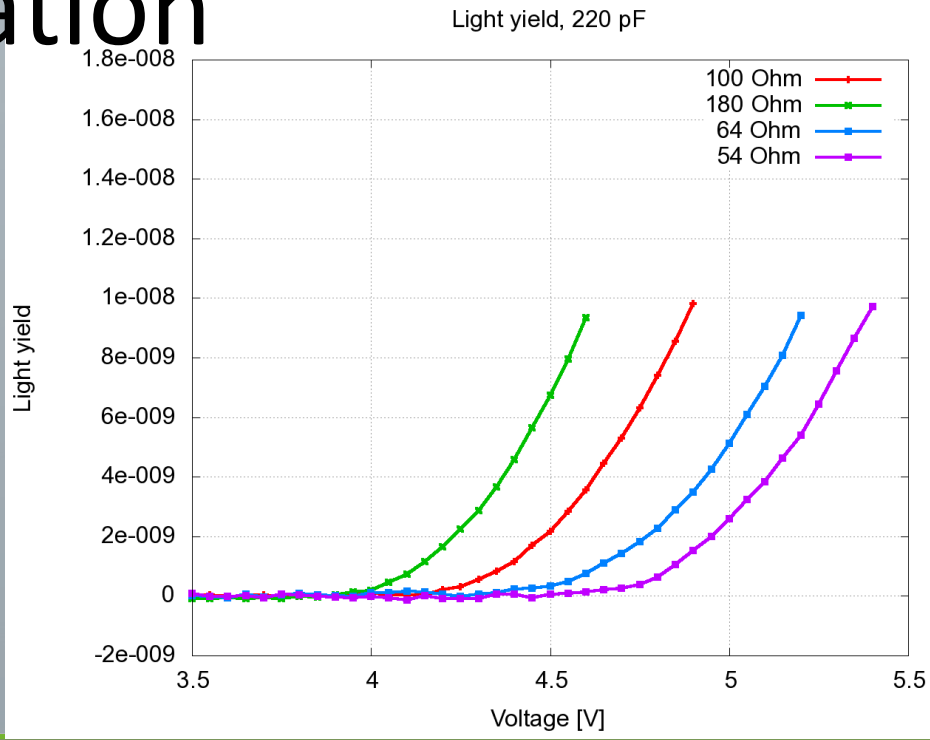
- Usually UV-LED are single quantum well LED; in contrast 'optical range' LEDs consist of several quantum well structures
  - Quantum well = very thin semiconductor sandwich, that forms a well potential with its different bandgaps
- Each quantum well has a small volume but high radiation efficiency
- “Multi quantum well structures preserve the advantages of single wells … however add up to larger volumes … thus allow for higher light powers” (but also higher capacitance)
  (E.F Schubert, Rensselear Polytechnic Institute)





circuit configuration optimization





Influence on SPS quality

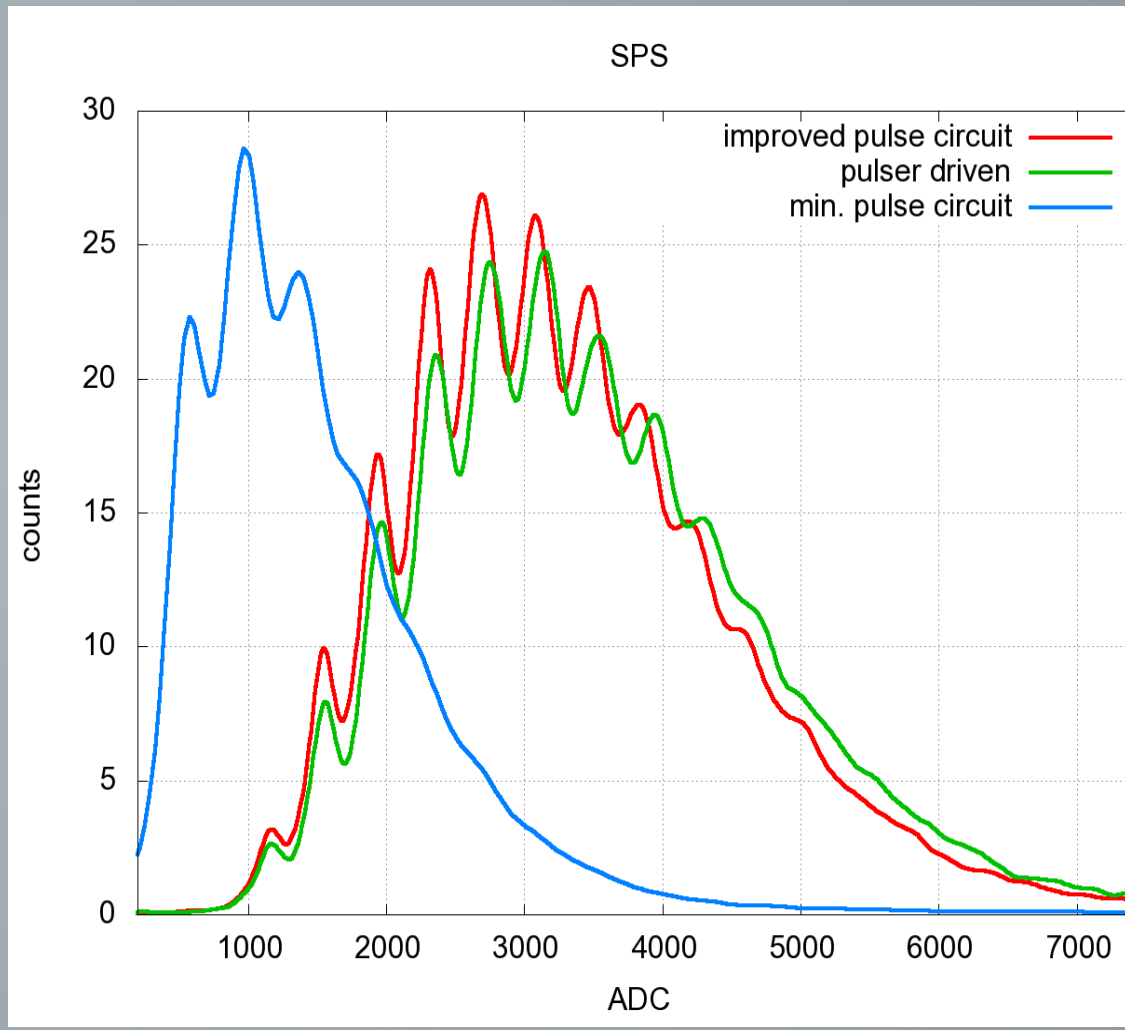
- 3 different pulse lengths

  blue: ~30ns (blue LED)

  green: ~15ns (blue LED)

  red: ~7ns (UV LED)

  → huge improvement from 30ns to 15ns
- Are pulses < 15ns needed?

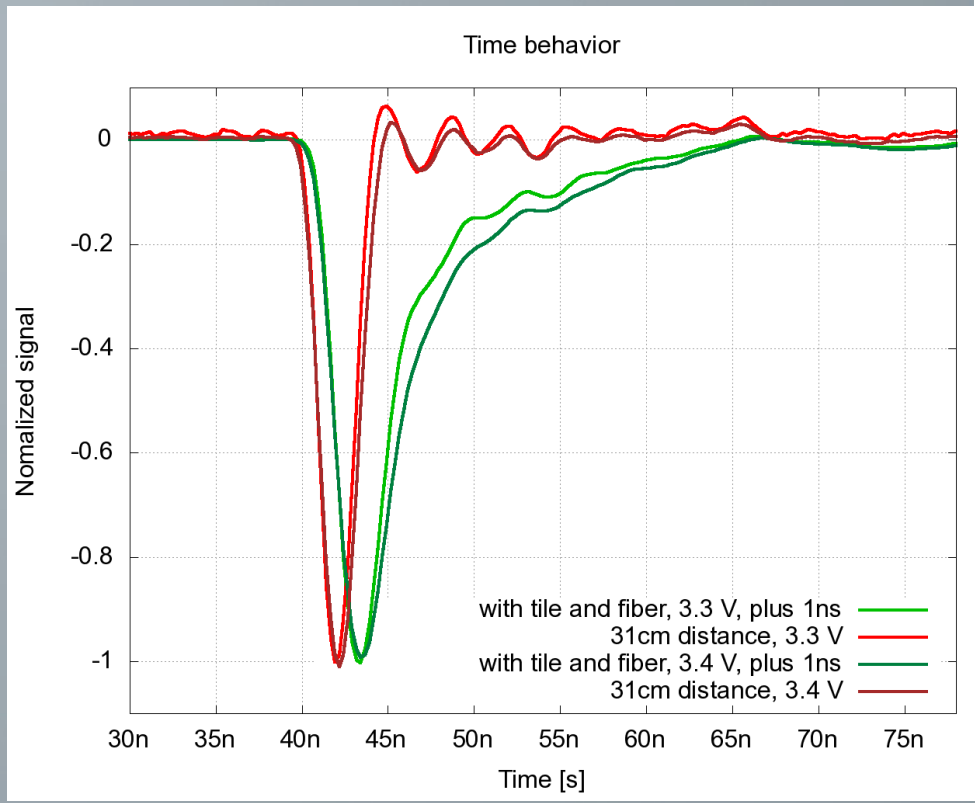


Time behavior of tile and fiber

- Fiber coupled to PMT instead of SiPM

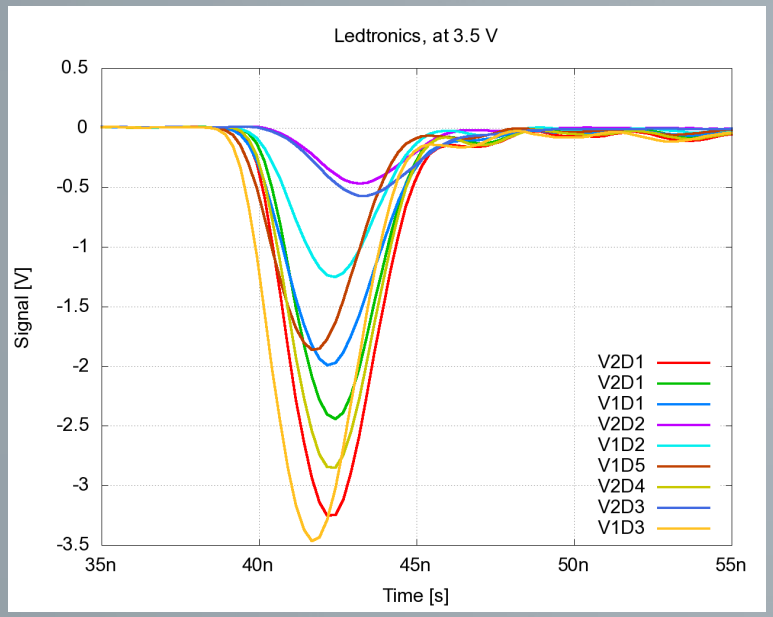
  → scintillator and fiber influence on pulse shape

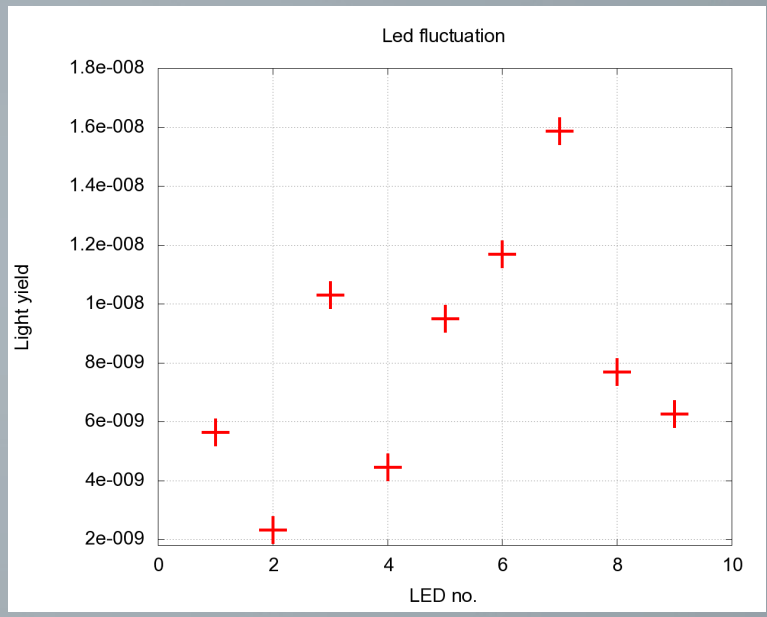
- Can we derive a reasonable pulse width limit from the tile influences?



First LED spread study

- Only a rough estimate, soldering improvised (bad package for PCB) → 'how bad can it be?'





- Difference in light yield and capacitance (different amplitude and delay in rising edge)
- Spread compensation by capacitor or resistor variation

Summary

- LED internal capacitance is a big issue (single vs. multi quantum well LED)
  - Simple pulse circuit + UV LED or blue LED + more sophisticated pulse circuit
  - Availability problems for single quantum well UV may arise (what will be in 10 years, maybe new LED types)
- For now: pulse circuit with UV LED works fine
  - Very short pulses → quality of SPS significantly improved
  - V_{calib} mapping stretched for low voltages

Outlook

- Saturation: how does the dynamic range adjustment effect the saturation capability with UV?
- SPS quality: repeat EUDETII calibration with 7ns pulses: how many V_{calib} settings are needed to receive SPS for all tiles (60 tiles, only 39 can be calibrated with old calib system)
- LED spread compensation: scalable solution needed
- New circuit: blue LED can be used when applying a reverse bias to stop light output → new circuit necessary (for example a bridge circuit)