Cosmic-ray measurements of scintillator tiles with SMD SiPMs

Yong Liu, JGU Mainz

CALICE Collaboration Meeting, ANL

Mar. 19, 2014

B. Bauß, V. Büscher, J. Caudron, P. Chau, R. Degele, K.H. Geib, S. Krause, L. Masetti, U. Schäfer, R. Spreckels, S. Tapprogge, R. Wanke

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

PRISMA Cluster of Excellence

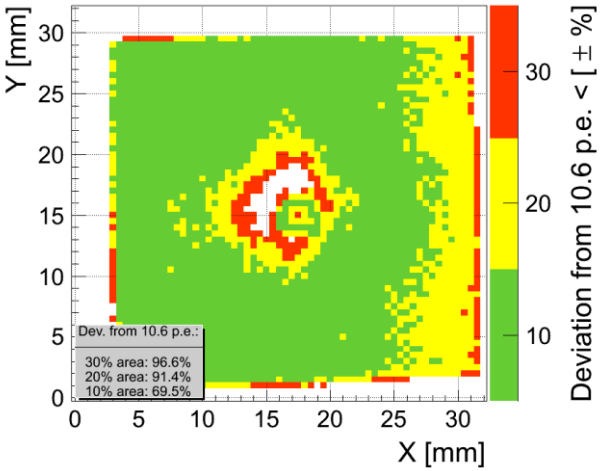
CALICE Calorimeter for ILC

Outline

- Cosmic-ray measurements for SMD design
  - Aim: SMD SiPM response to MIPs
  - Hamburg tile as a reference
    - SiPM: side-surface mounted
  - Dimpled tiles produced in Uni-Mainz
    - SMD SiPM: bottom-surface mounted
- Summary and discussions

HBU in SMD SiPM design

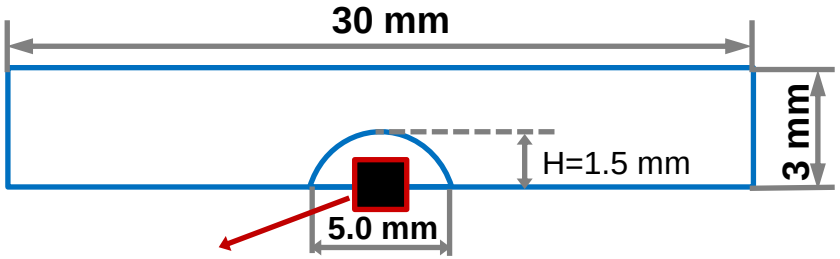
- Motivations
  - Much easier to solder on HBU (feasible for mass assembly)
- Uniformity in SMD design
  - Scan in MPI Munich shows promising results
  - Updated dimple design
    - Suitable for various SiPM packages
  - Updated Geant4-based simulation
    - shows good uniformity



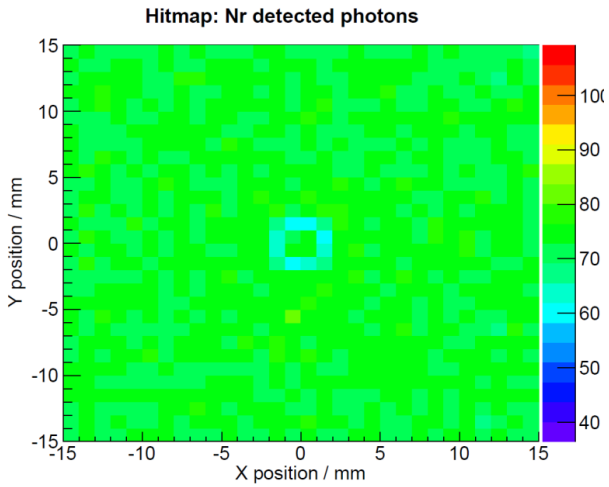
Y. Liu et al, CALICE Collab. Meeting, LAPP, Annecy, Sep 2013

Simulation: cosmic-ray response & uniformity (1)

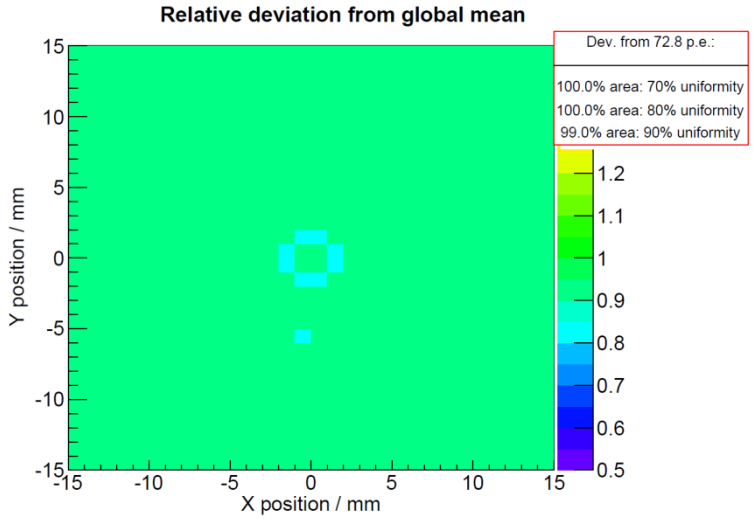
- Scintilllator: BC408
- SiPM: KETEK PM1150NT
  (1.2x1.2mm², 50μm pixel pitch)
- SiPM Vop: 15% overvoltage



KETEK PM11 package
(1.0 mm inside dimple)



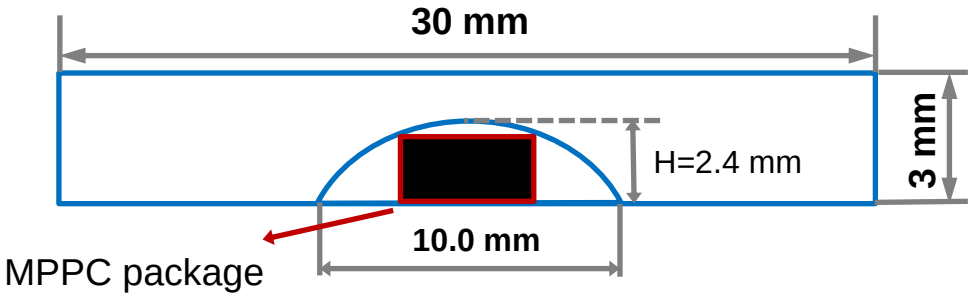
Mean 72.8 p.e.

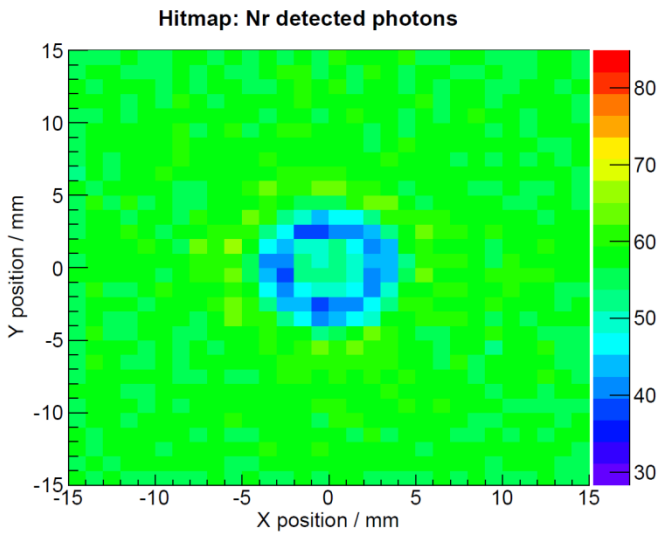


99.0% area within 10% deviation

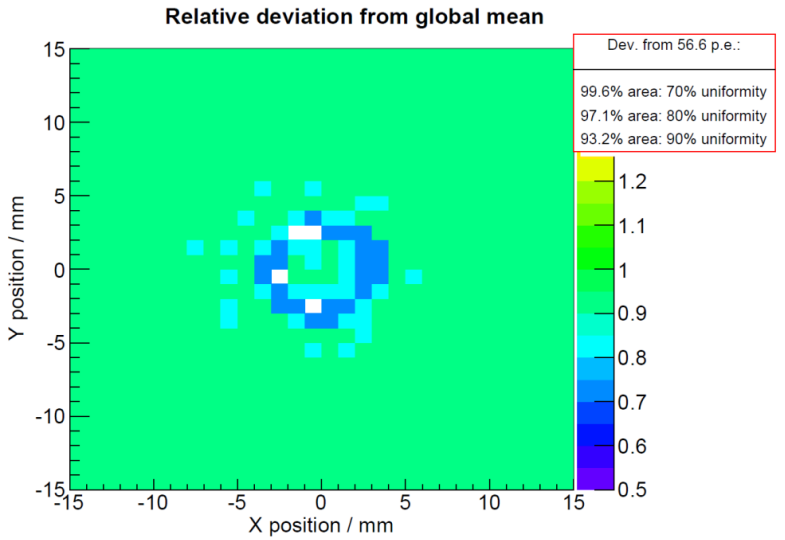
Simulation: cosmic-ray response & uniformity (2)

- Scintilllator: Polystyrene (for NA62 MUV)
- SiPM: MPPC S10931-50P (3x3mm², 50μm pixel pitch)
- SiPM Vop: 72.61V (suggested)





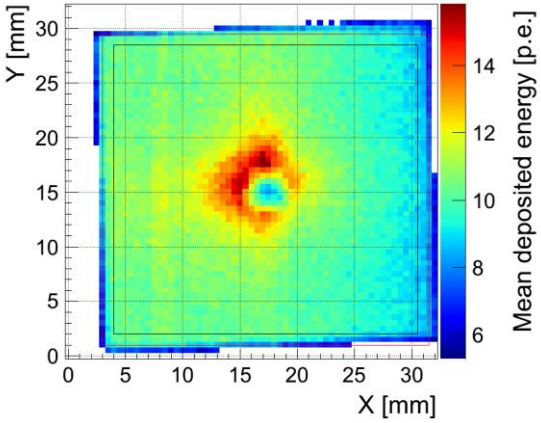
Mean 56.6 p.e.



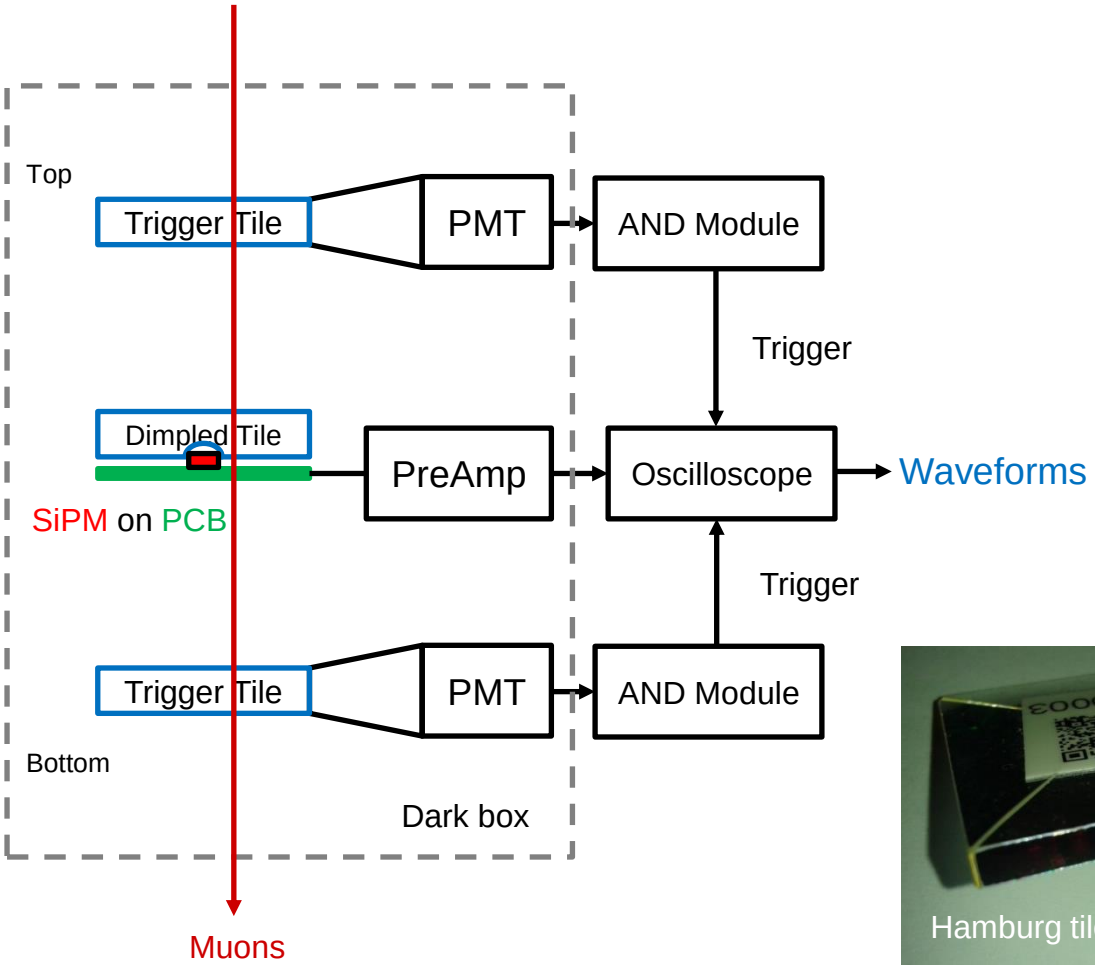
93.2% area within 10% deviation

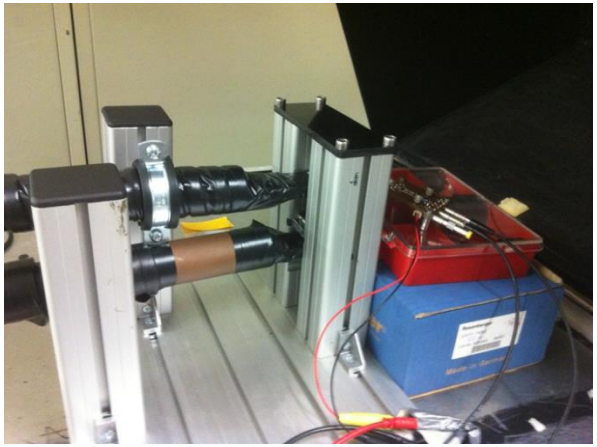
SiPM response to MIP

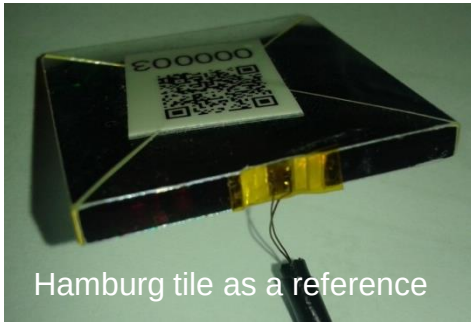
- SiPM response in uniformity scan in MPI, Munich
  - Low level: mean 11 p.e.
- Cosmic-ray teststand in Uni-Mainz
  - Measure mean N(p.e.) for MIPs
  - More scintillator options
    - Polystyrene for NA62: easy to handle
    - BC408: ~1.6 times higher intrinsic light yield
  - Pre-cut foils from Uni-Hamburg (Courtesy of Erika, et al.)
    - Will be ready for next round of cosmic-ray measuremnt
  - Foils for this round
    - Pieces of 3x3cm²: precisely cut by (mechanical engineer) Karl-Heinz in Uni-Mainz

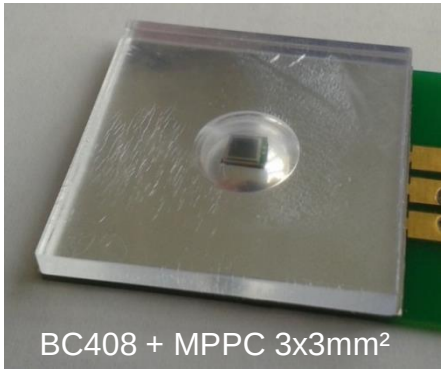


Cosmic-ray setup

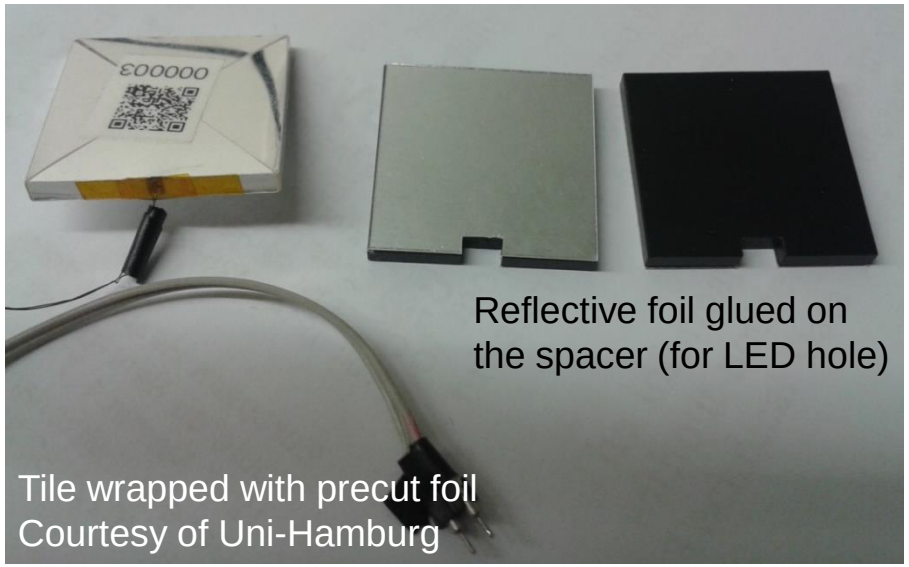




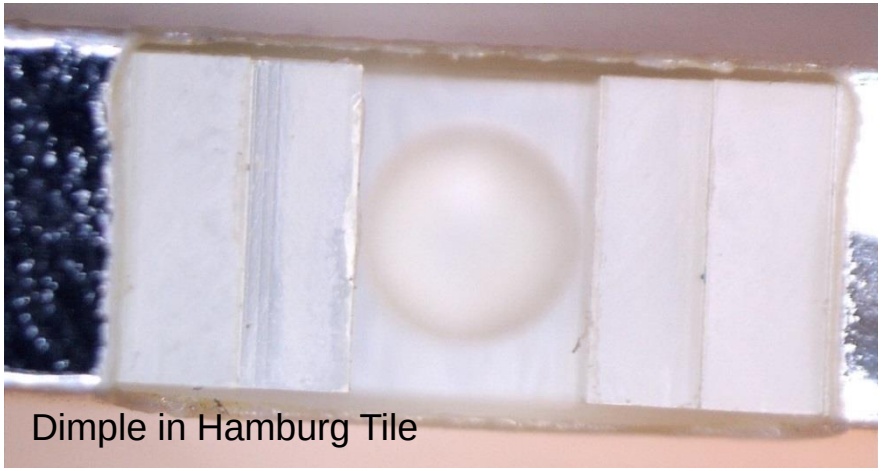

Hamburg tile as a reference

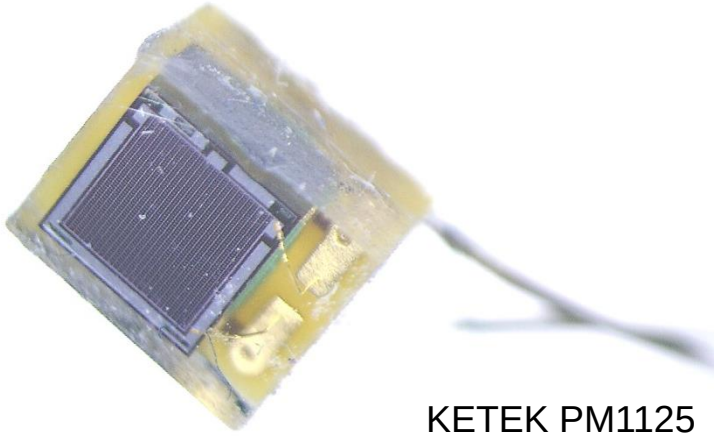

BC408 + MPPC 3x3mm²

Hamburg tile + KETEK PM1125



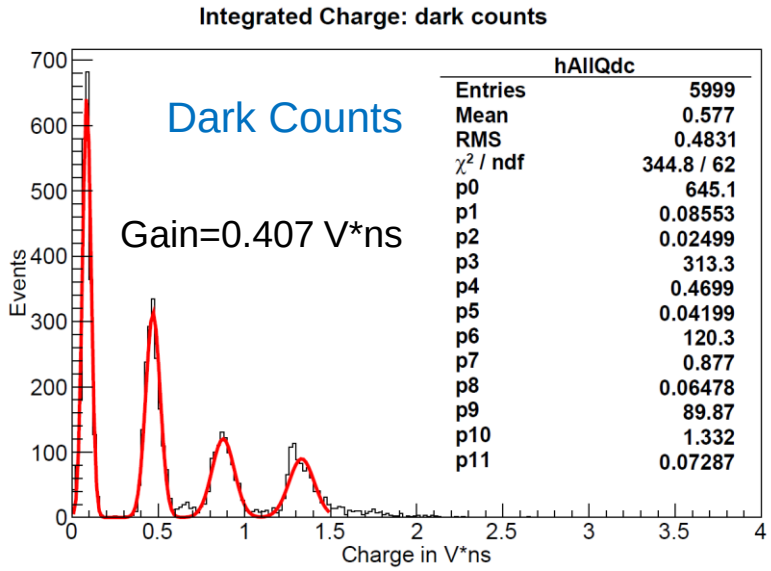
- Use Hamburg tile wrapped with pre-cut foil as reference
- Latter SMD design can be directly compared: less or more Npe?

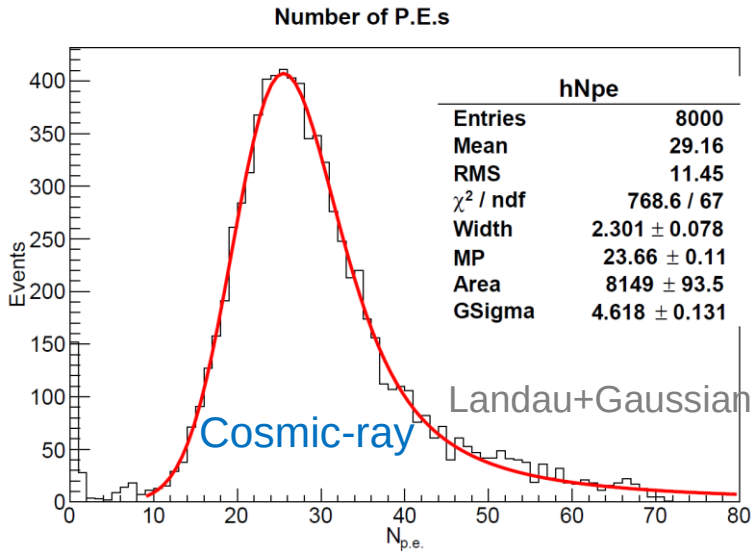



KETEK PM1125

Cosmic-ray: Hamburg tile+KETEK 1.2x1.2mm²

Operational voltage: 31.0 V (~15% overvoltage)



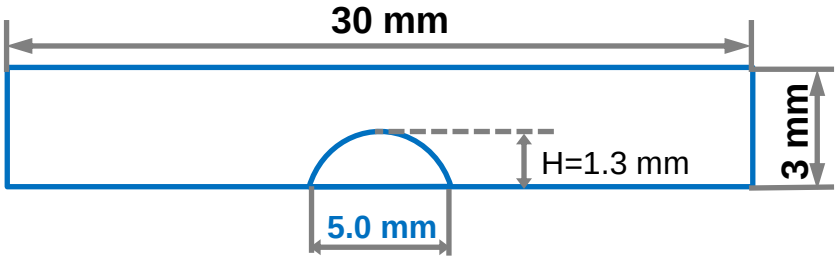


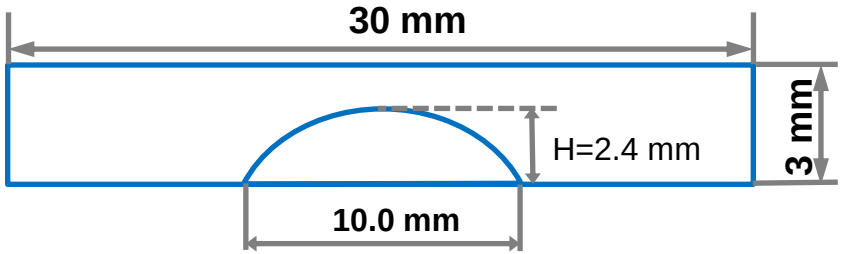
- Side-surface design: mean 23.7 pe in cosmic ray
- Consistent with Uni-Hamburg measurement (reponse to MIP)

Ref: M. Ramilli et al, Tile test and production at Hamburg, AHCAL Meeting, Dec. 2013

Design of dimpled tiles

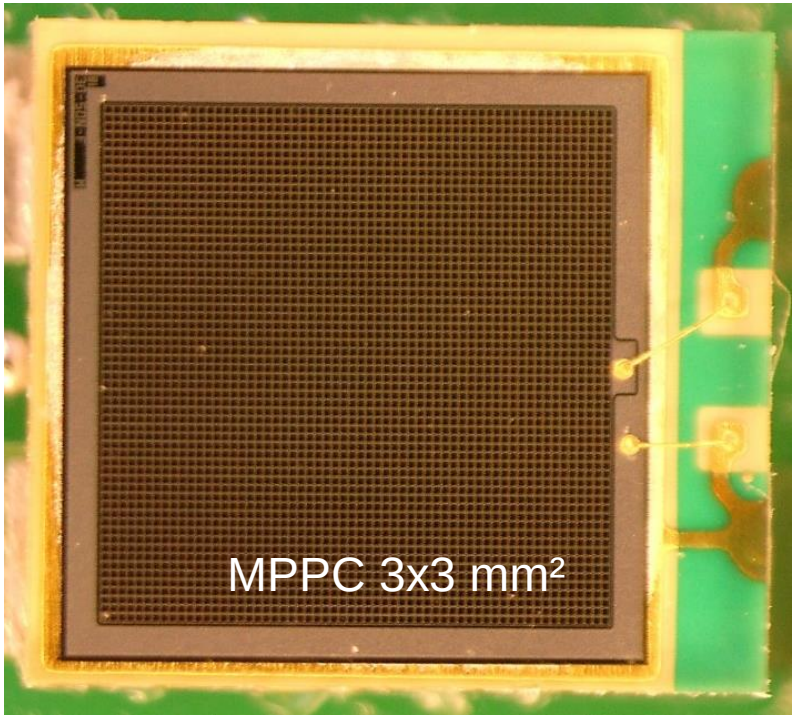
- 2 scintilllator materials: BC408, Polystyrene for NA62
- Machined by mechanical engineer Karl-Heinz in Uni-Mainz



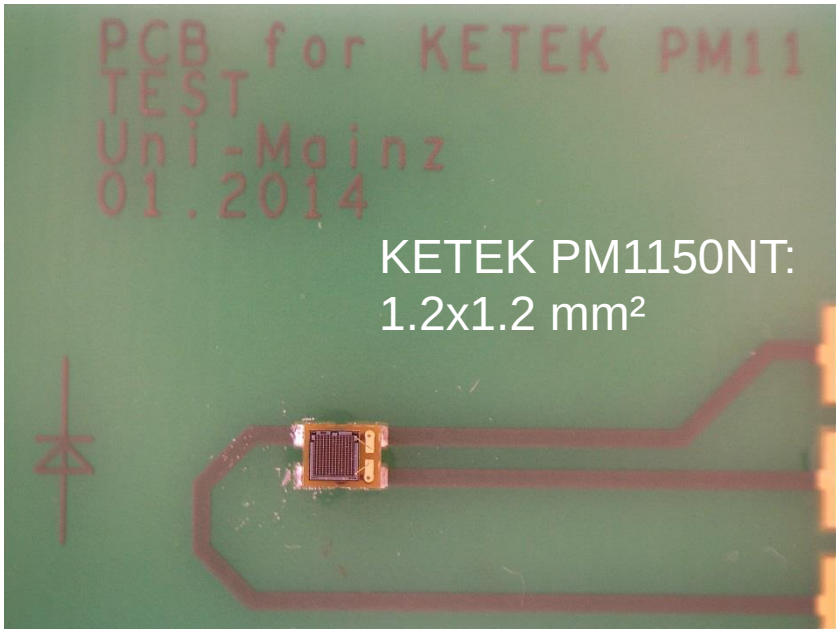


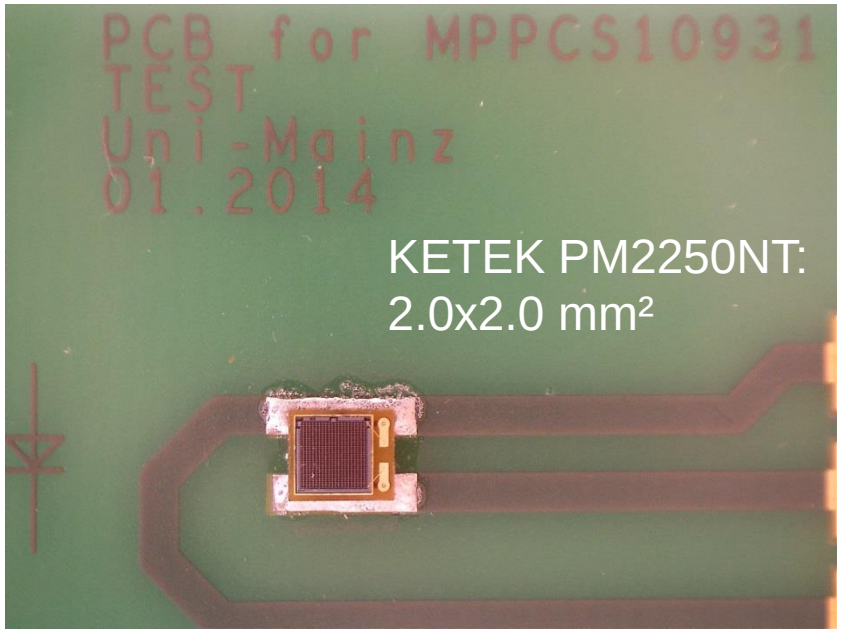
PCB with SMD SiPM soldered on(1)

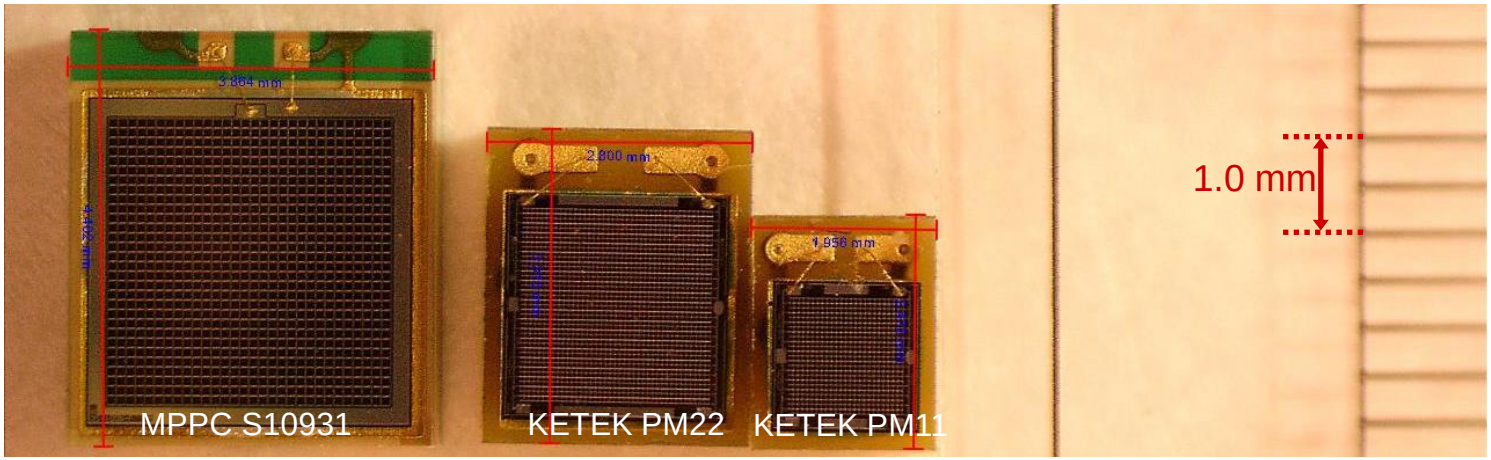
MPPC S10931-50P
Pixels: 3600
Pixel size: 50x50 µm
Fill Factor: 61.5 %



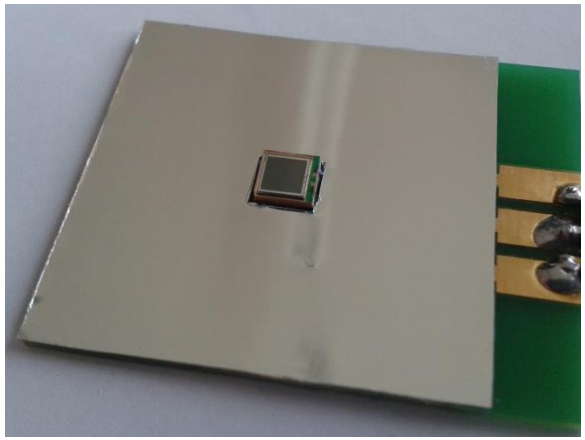
PCB with SMD SiPM soldered on (2)

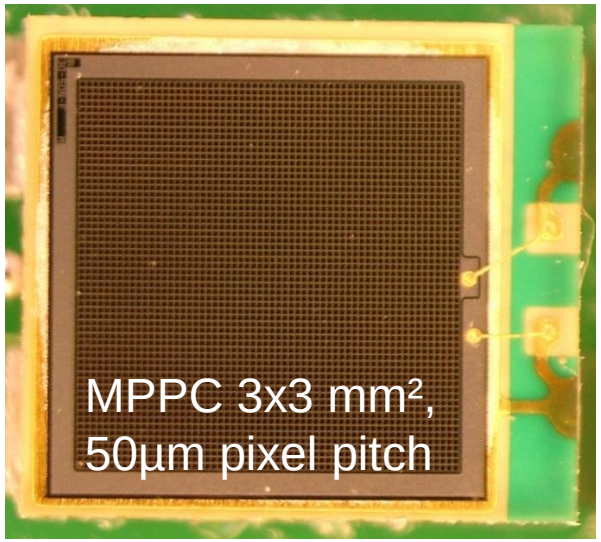




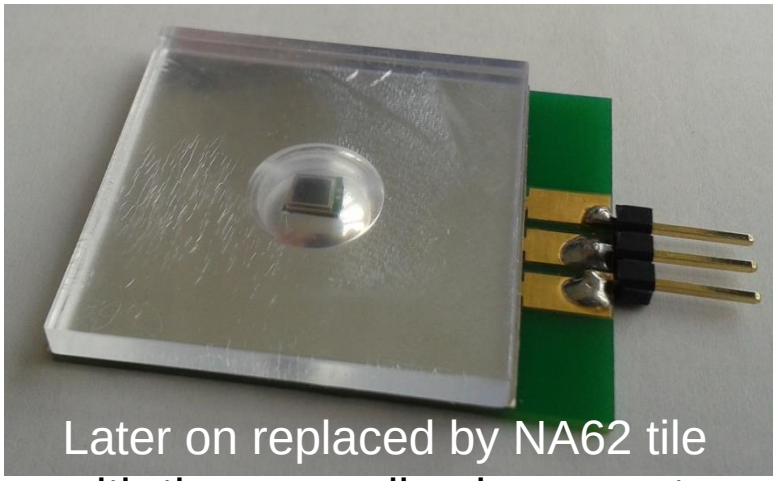


Setup: Dimpled tile with MPPC 3x3mm²

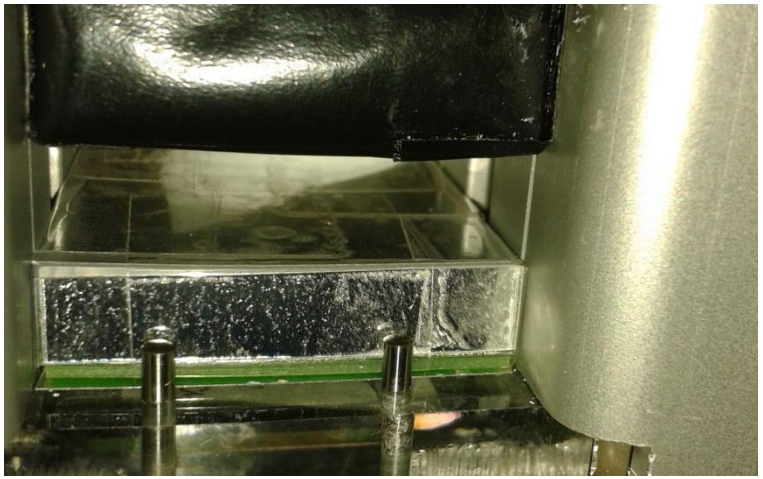




Dimpled tile: BC408

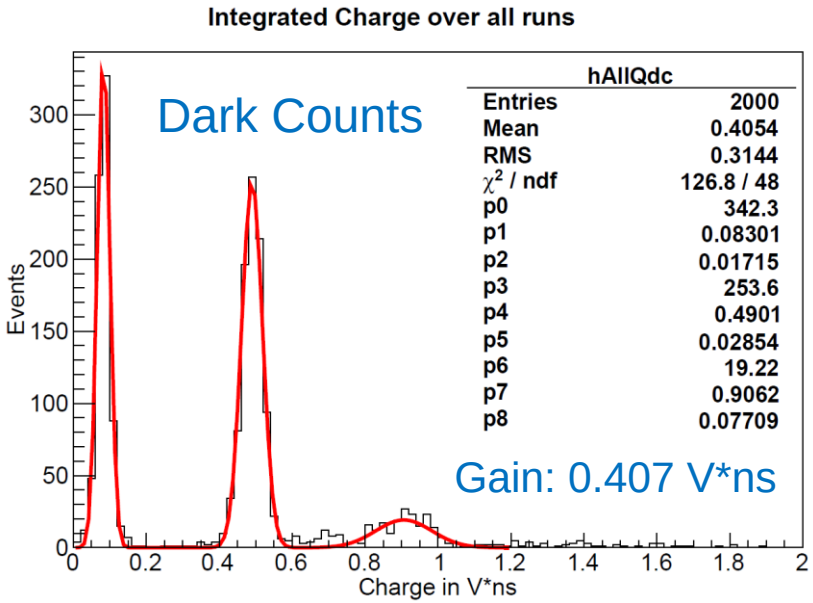


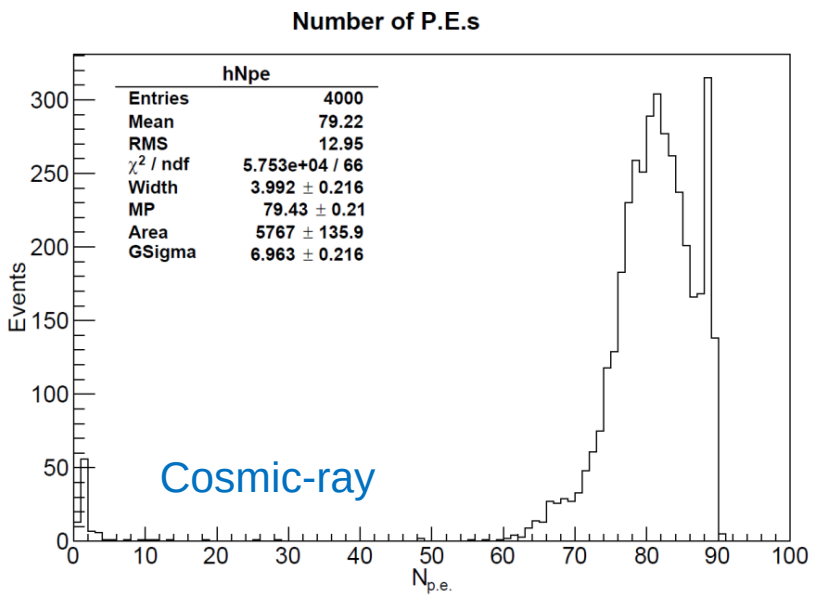
Later on replaced by NA62 tile
with the same dimple geometry



Measurements: BC408 with MPPC 3x3mm²

Operational voltage: 72.61 V (suggested)

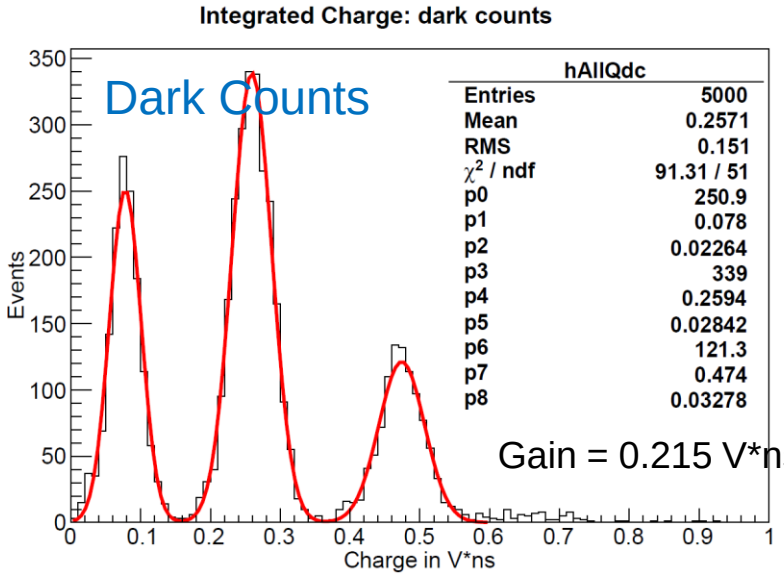


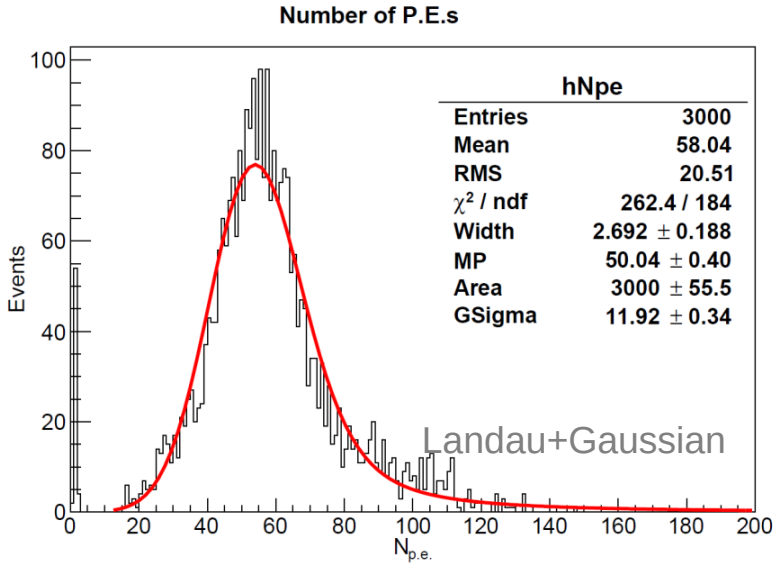


- Saturation observed
  - Too many p.e.s: SiPM pulse higher than output range of preamplifier
- Mean ~80 p.e., high enough reponse to MIP
- SMD MPPC package can be completely placed inside dimple
  - Perfect for mass assembly

Measurements: NA62 tile with MPPC 3x3mm²

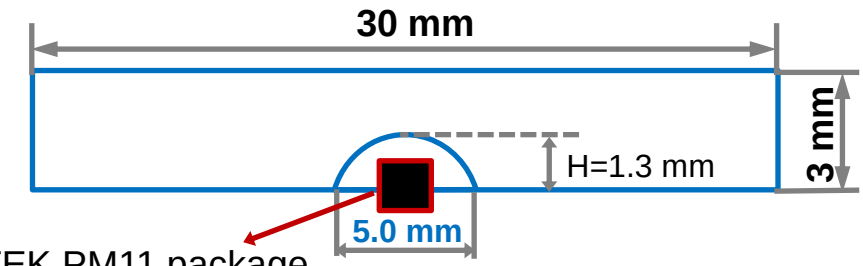
Operational voltage: 71.8 V





- For less saturation with the given preamplifier
  - Decrease operation voltage by 0.61V
  - Change to scintillator with lower light yield
- Mean ~50 p.e., MIP response still high enough
- SMD MPPC package can be completely placed inside dimple
  - Perfect for mass assembly

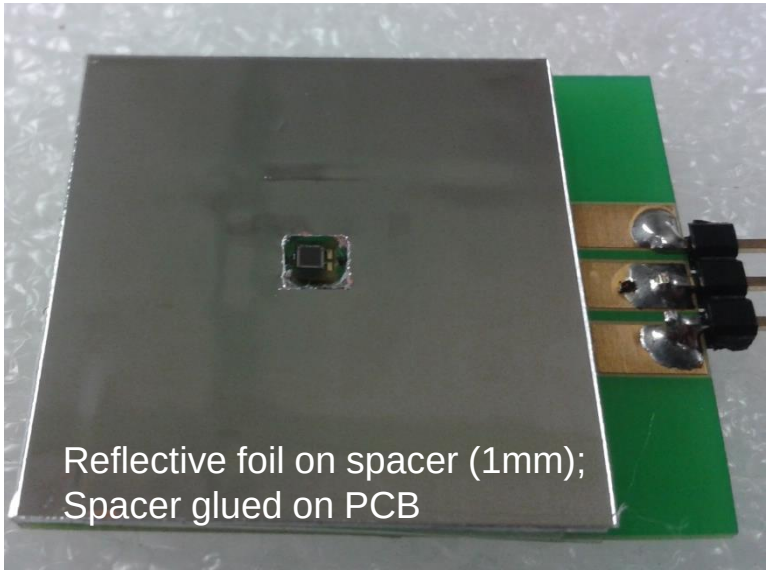
Setup: BC408+KETEK PM11



KETEK PM11 package
(0.8 mm inside dimple)

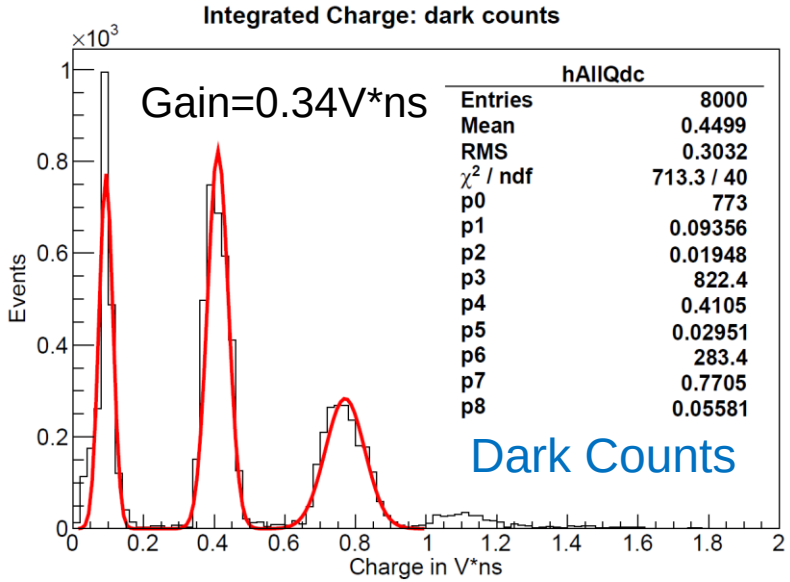

BC408 dimpled tile

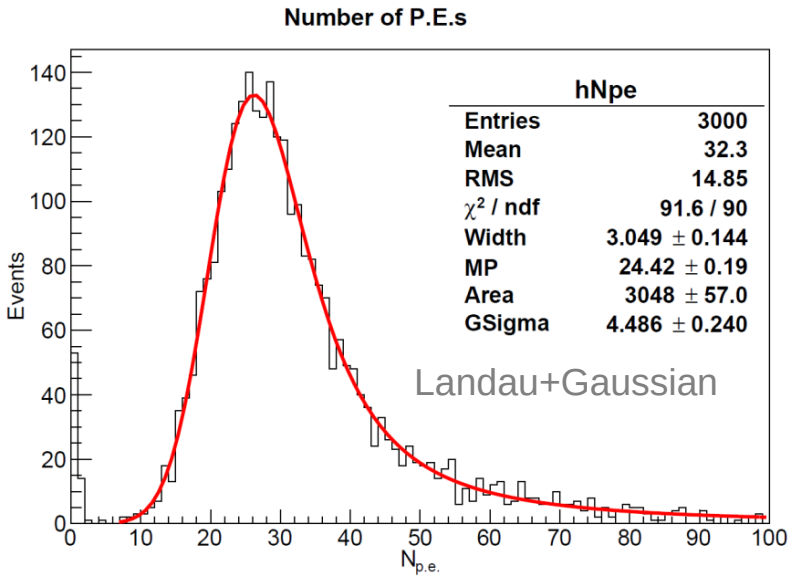
- KETEK Package thickess: 1.8mm
  - Too thick for 3mm thick tile
- Spacer (1mm thick) used to keep part of SiPM package ouside dimple
  - For better uniformity and higher reponse, suggested by simulation
- Window in foil cut by knife
  - Will be improved by better stamp tool


Reflective foil on spacer (1mm);
Spacer glued on PCB

Results: BC408+KETEK PM1150NT

Operational Vop=30.0V (~6% overvoltage)





- For less saturation: only use ~6% overvoltage
- Mean 24.4 p.e. measured in cosmic ray
  - ~33.5 p.e. can be foreseen at 15% overvoltage (based on KETEK PDE vs overvoltage)
  - Side-surface design: 23.7 p.e.
- Similar scintillator and SiPM sensitive area
  - SMD design yield higher reponse to MIP than side-surface design

Summary

- Uniformity of SMD design
  - Measurements show promising uniformity
  - Geant4 simulation suggest great uniformity
    - At least 93% area within 10% deviation
- Responses of SMD design to cosmic ray
  - At least 50 p.e. when MPPC 3x3mm² is used
  - Higher reponse (>24.4 p.e.) to MIP than side-surface design (23.7 p.e.)
- Mainz group will proceed to design and build prototype of HBU with SMD SiPMs

Discussions

- HBU in SMD design
  - Dependent on SiPM package size
  - KETEK
    - Too thick (1.8mm); not possible to be placed in the dimple made for 3mm thick tile
    - Need to discuss packaging with KETEK
  - Hamammatsu
    - Thin enough to be soldered on HBU and placed inside dimple
- What N(p.e.) should we design for?
  - 1.2x1.2mm² SiPM: 24.4 p.e. at 6% ov
    - (35.5 p.e. estimated at 15% ov)
  - 3x3mm² SiPM: ~80 p.e.

Thank you!


JG|U
JOHANNES GUTENBERG
UNIVERSITÄT MAINZ


PRISMA
Cluster of Excellence


CALICE
Calorimeter for ILC

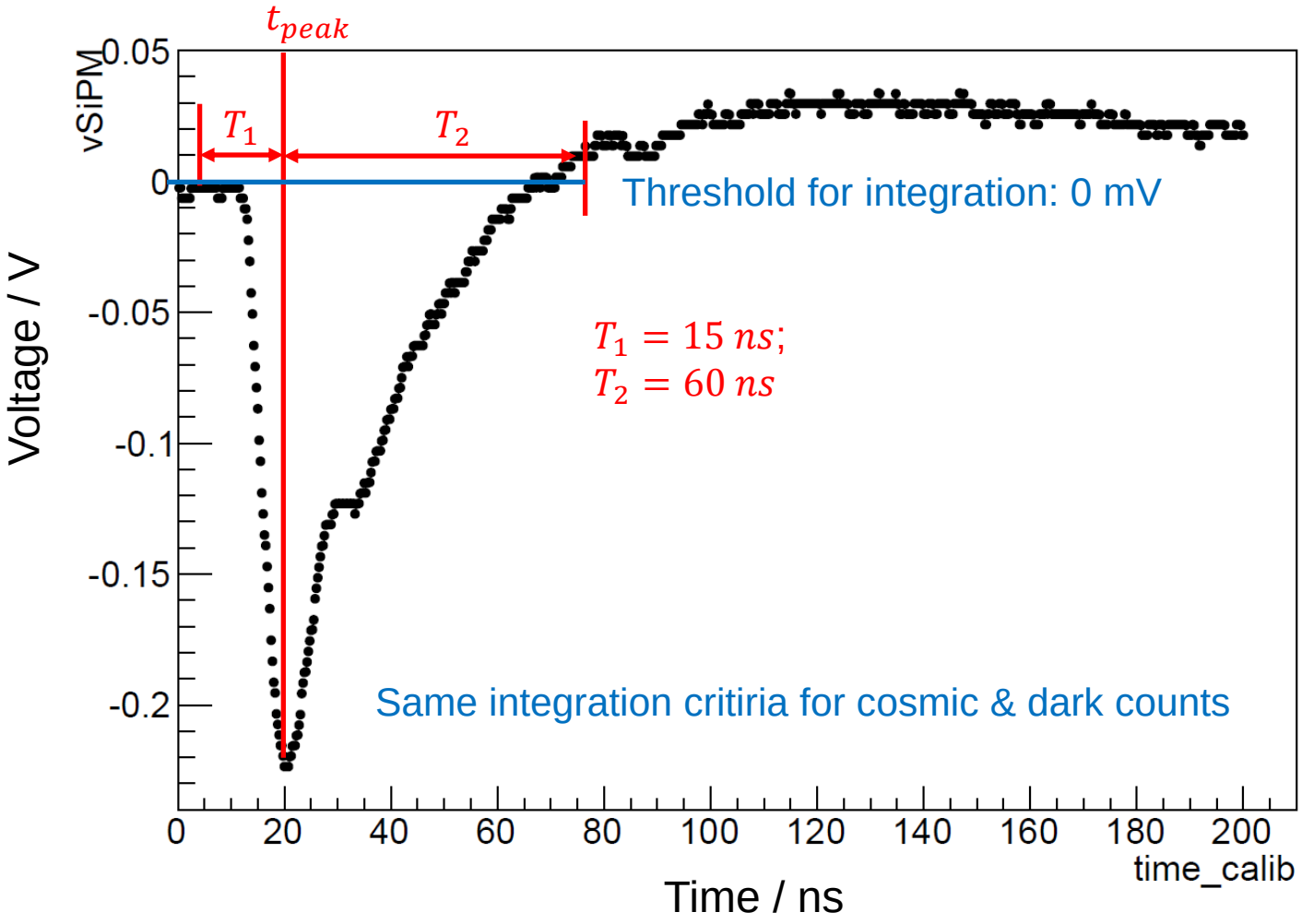
Backup slides

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

PRISMA Cluster of Excellence

CALICE Calorimeter for ILC

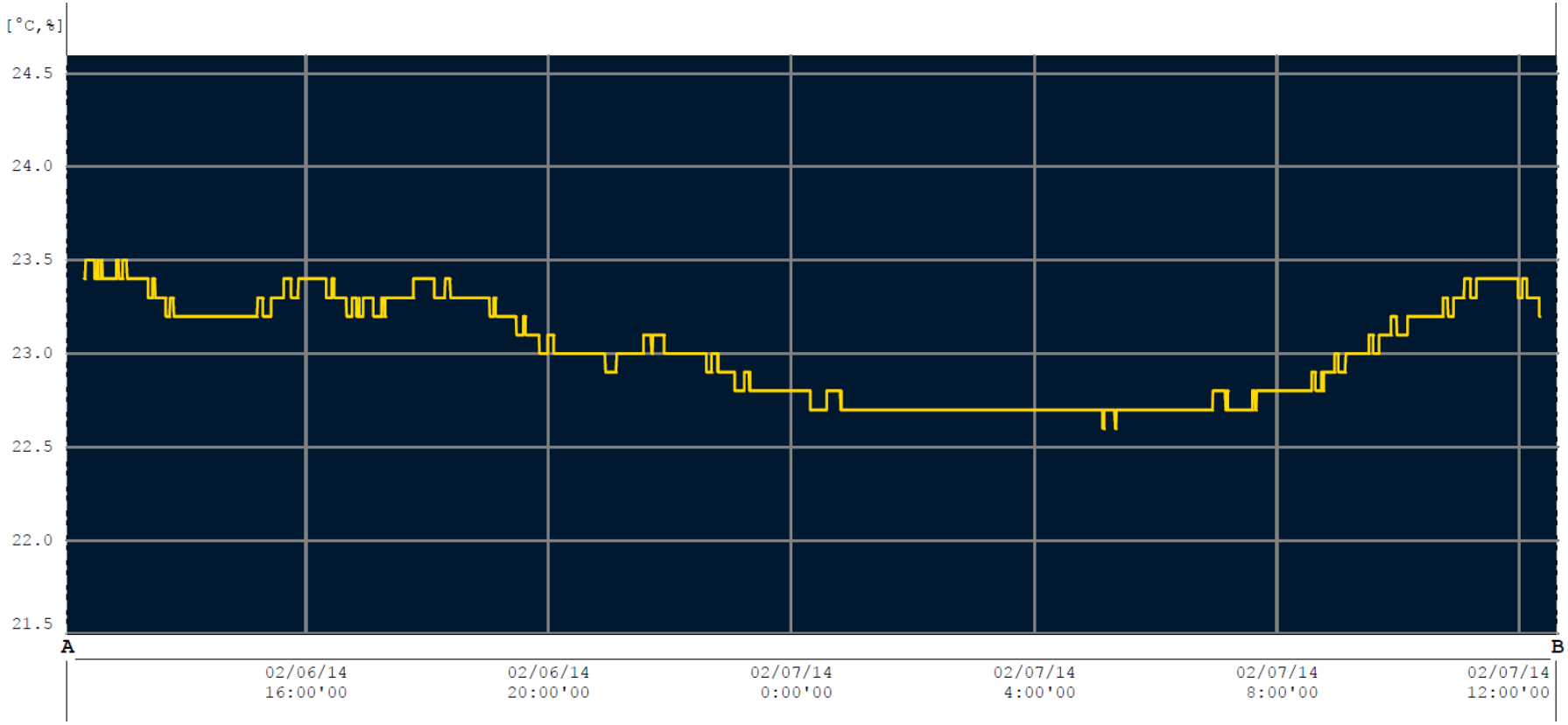
Analysis of SiPM waveform in osciloscope



A typical cosmic-ray response of KETEK SiPM (PM1125)

Temperature fluctuations

- Within 1 degree during 24 hours
  - Several percent flucturation in SiPM gain



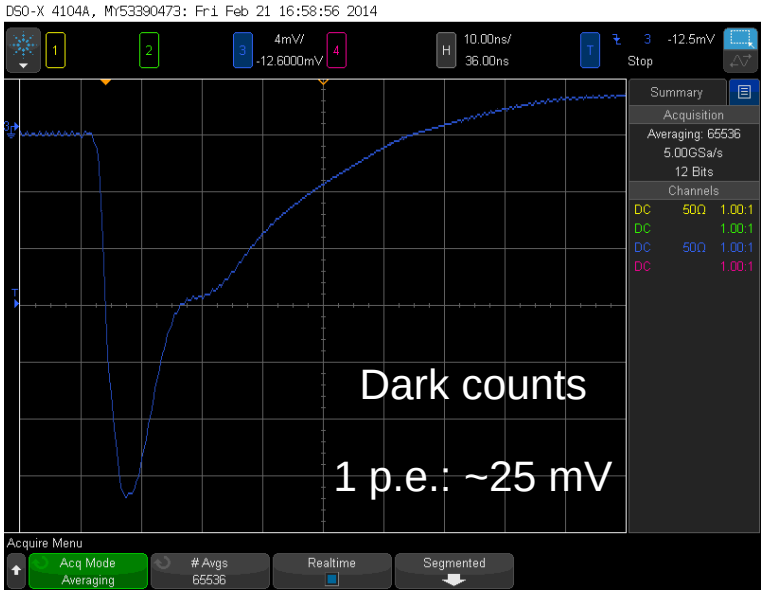
Status: Hamburg tile with KETEK PM1125

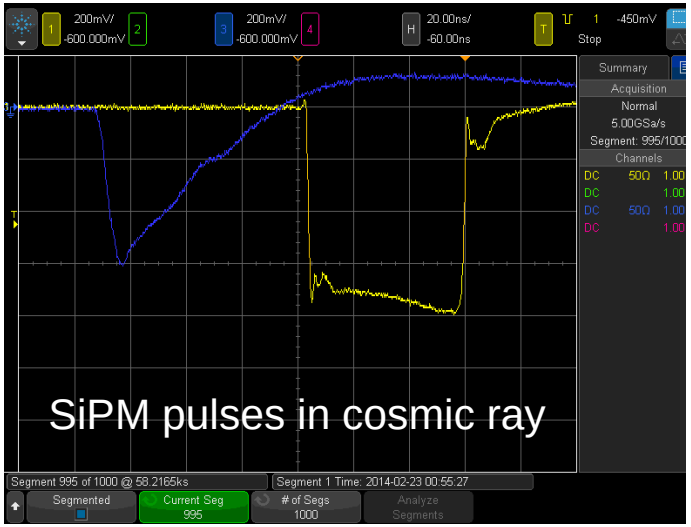
Dimpled tile with KETEK PM1125

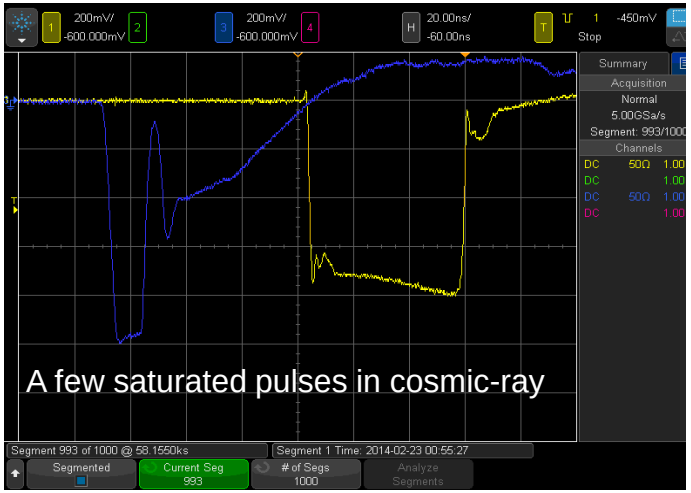
Vop=31.0 V (~15% overvoltage)

Breakdown voltage: ~27V

Amplification Rf=5.1k Ohm

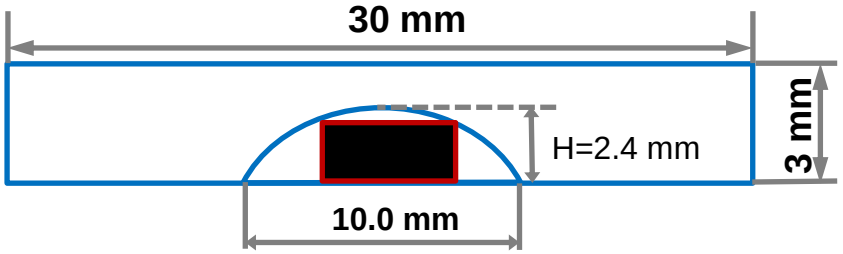




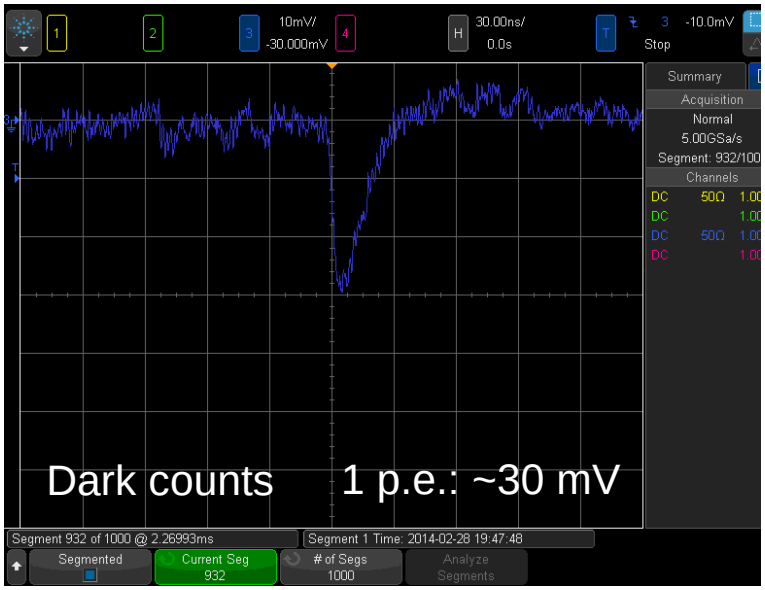


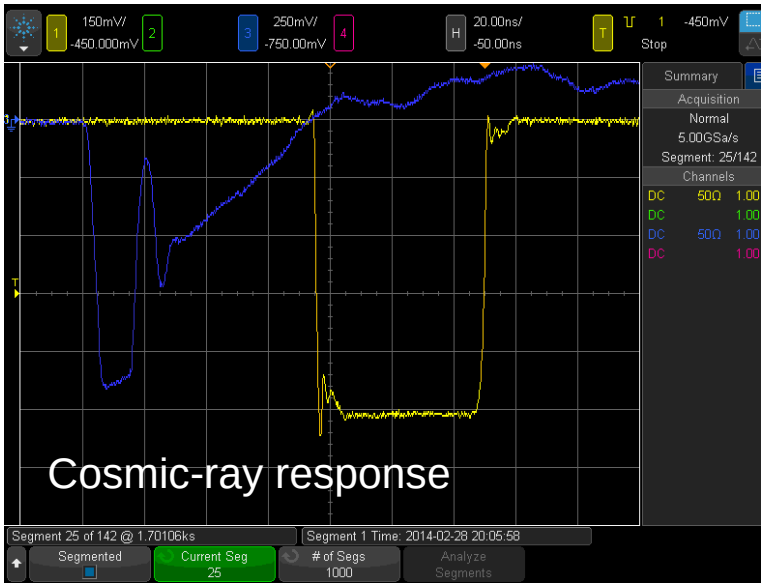
Status: BC408 with MPPC 3x3mm

Dimpled tile with MPPC S10931
Vop=72.61V (suggested)
Breakdown voltage: not yet tested
Amplification Rf=5.1k Ohm



Driller Diameter: 13.0 mm





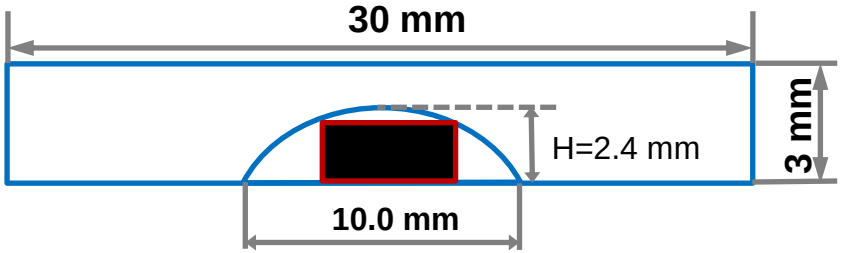
Status: NA62 tile with MPPC 3x3mm

Dimpled tile with MPPC S10931

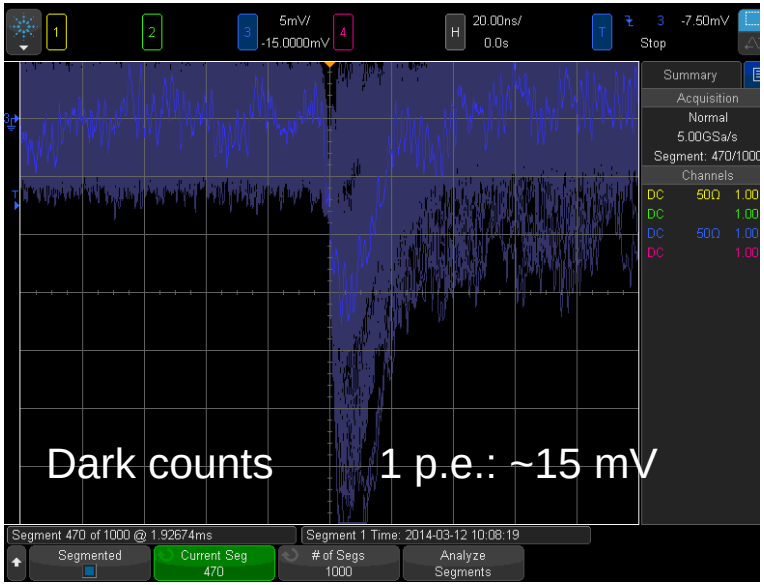
Vop=71.8V (0.81V lower than suggested)

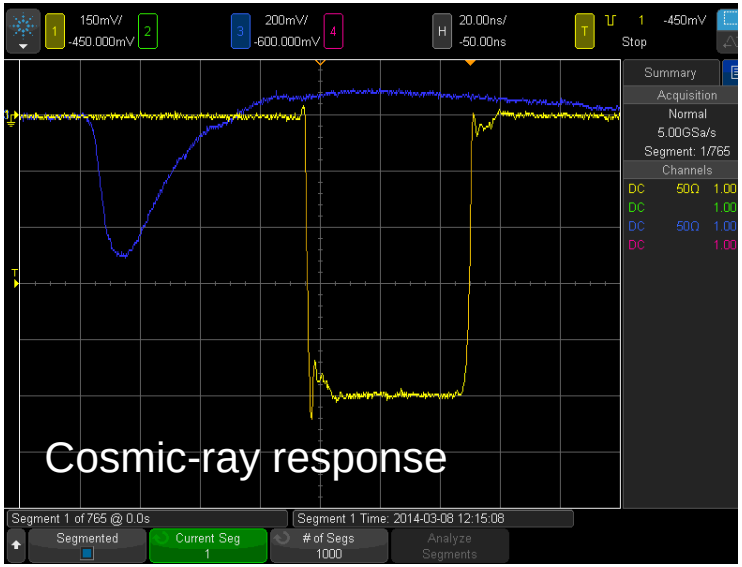
Breakdown voltage: not yet tested

Amplification Rf=5.1k Ohm



Driller Diameter: 13.0 mm





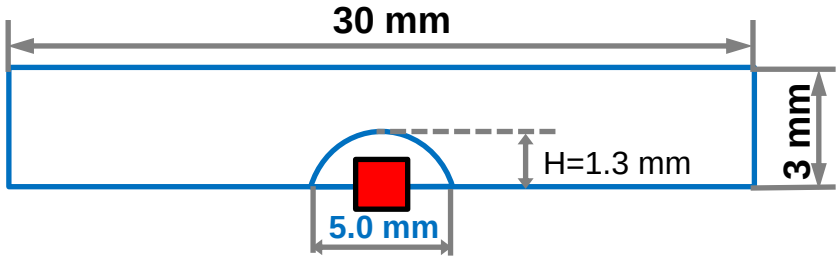
Status: BC408 + KETEK PM1150NT

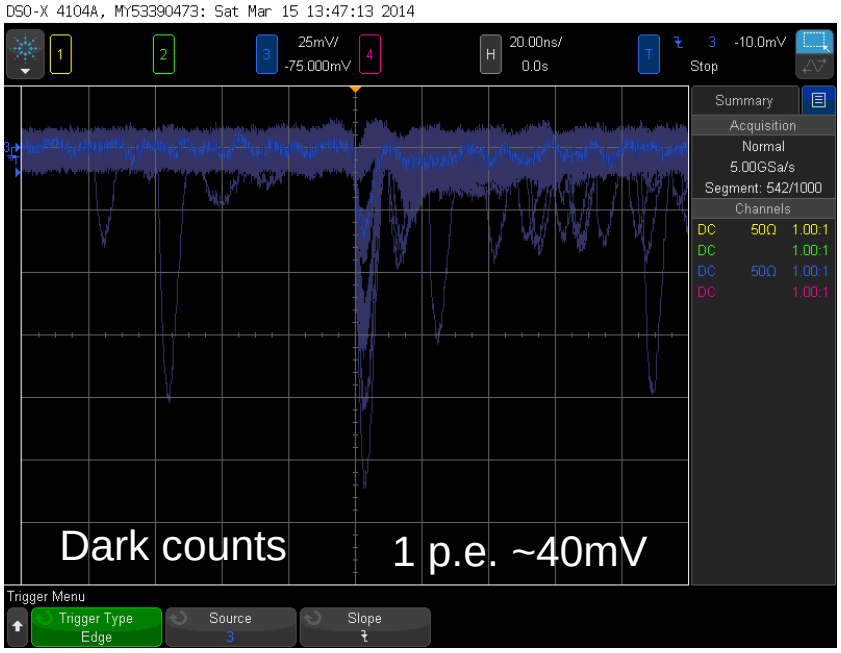
Dimpled tile with KETEK PM1150

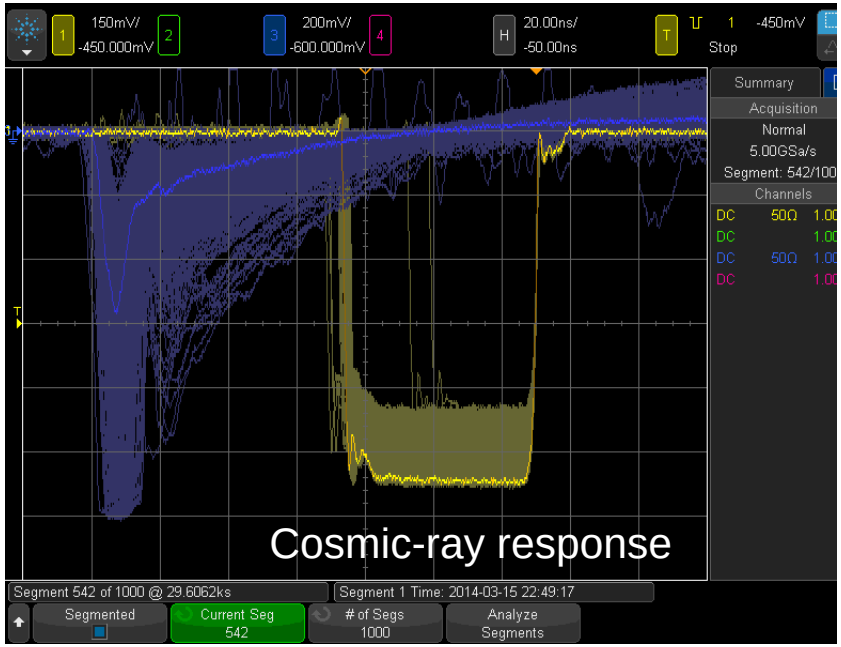
Operational Vop=30.0V (6% overvoltage)

Breakdown voltage: Vbr = ~28.3 V

Amplification Rf=2.4k Ohm (modified)

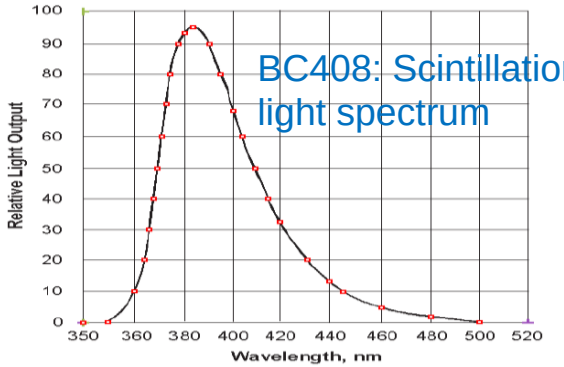






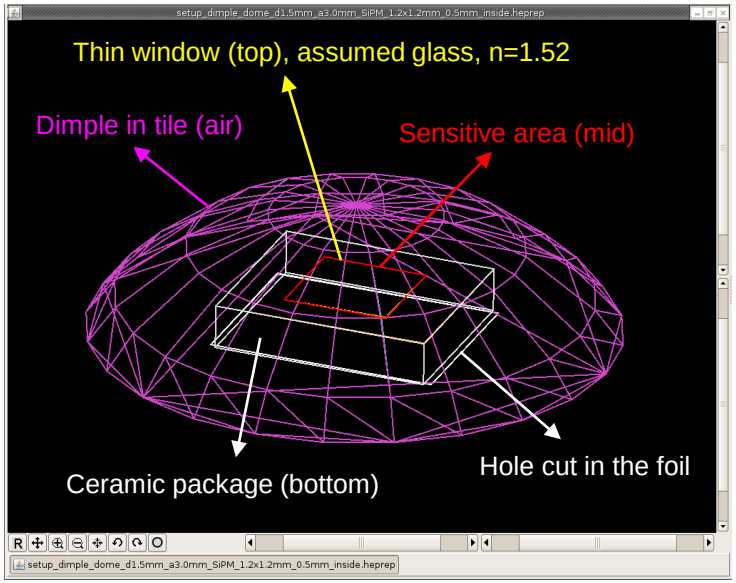
Details on Simulation (1)

- Simulation: scintillator tile, dimple and surface

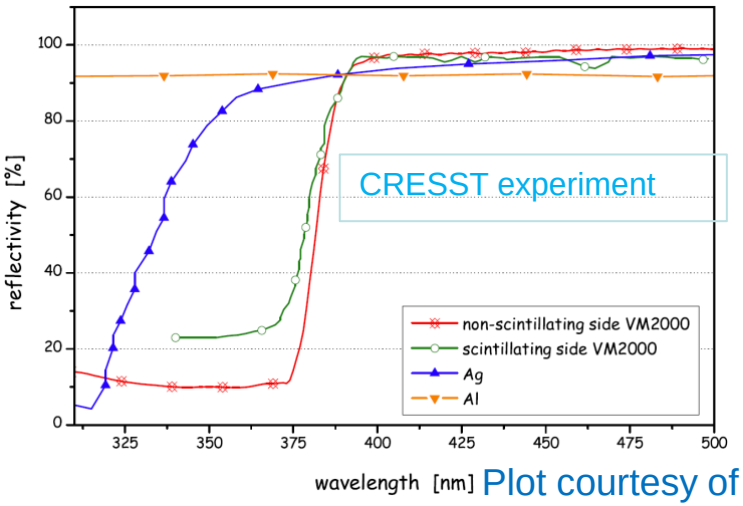


Optical boundary model:
polished in UNIFIED Model

Geometry for SiPM package



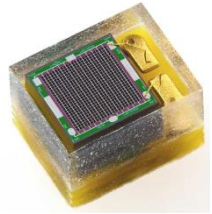
Measured curve:
ESR reflectivity vs wavelength



Plot courtesy of Frank Simon

Details on Simulation (2)

- Simulation of SiPM PDE
  - PDE vs wavelength, overvoltage



KETEK PM1150NT
SMD: 1.2x1.2 mm²
Pixel size: 50x50 µm²
576 pixels (24x24)