Direct Coupling of SiPMs to Scintillator Tiles

Frank Simon, Christian Soldner
MPI for Physics & Excellence Cluster 'Universe'
Munich, Germany

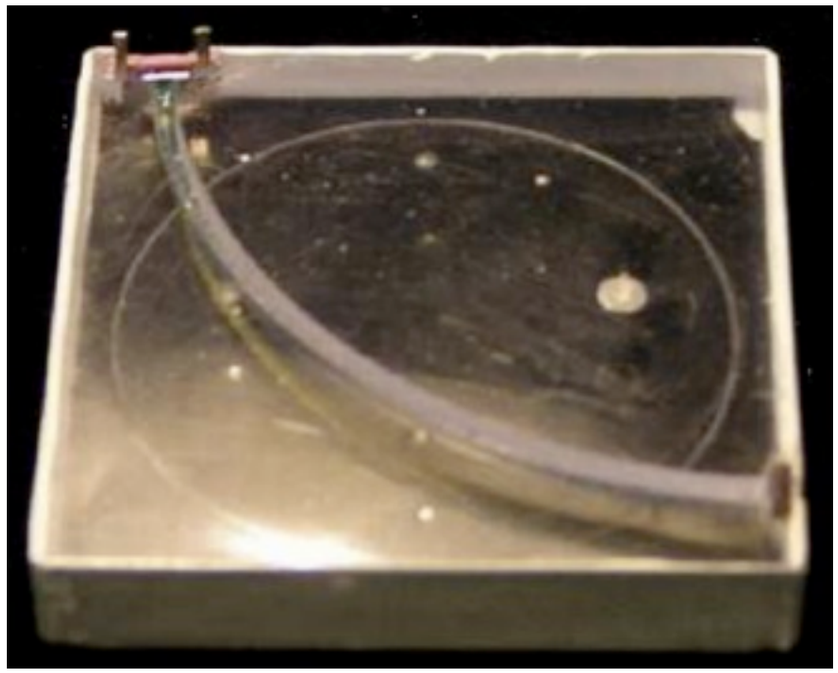
CALICE Collaboration Meeting, Arlington, TX, USA, March 2010

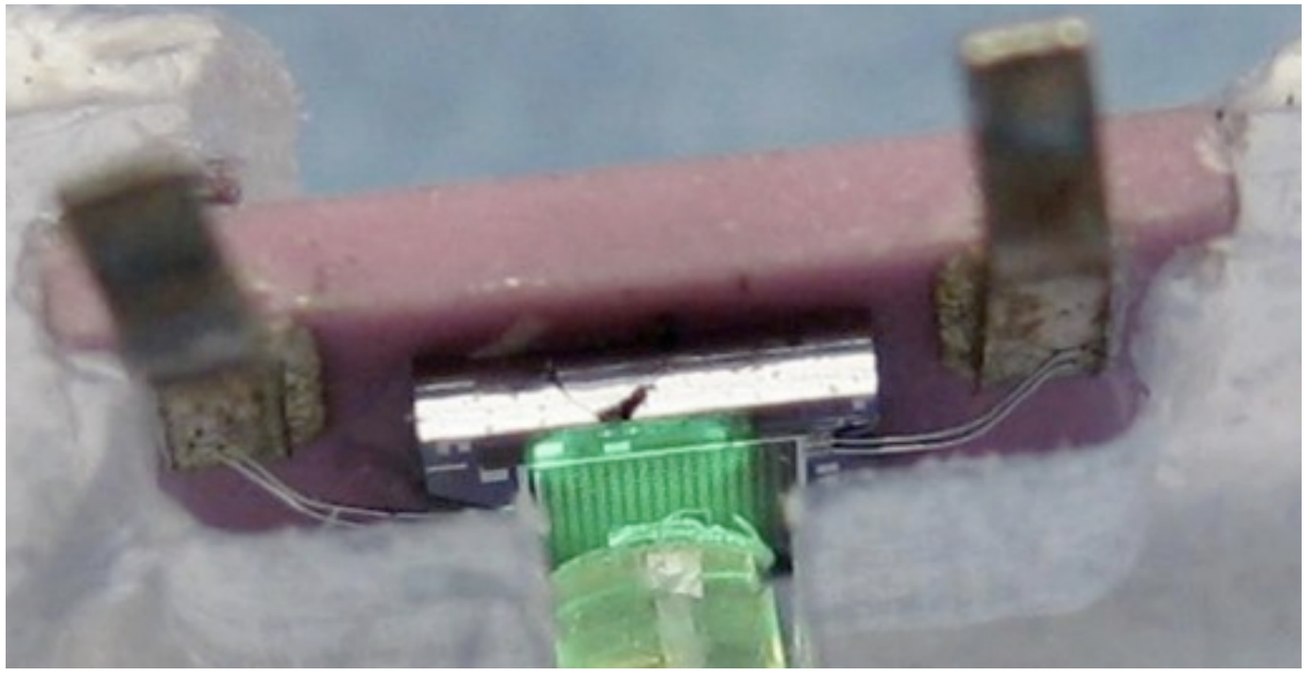
Why do Direct Coupling?

- Because we can: Modern SiPMs are blue sensitive, well matched to emission spectrum of scintillator

Why do Direct Coupling?

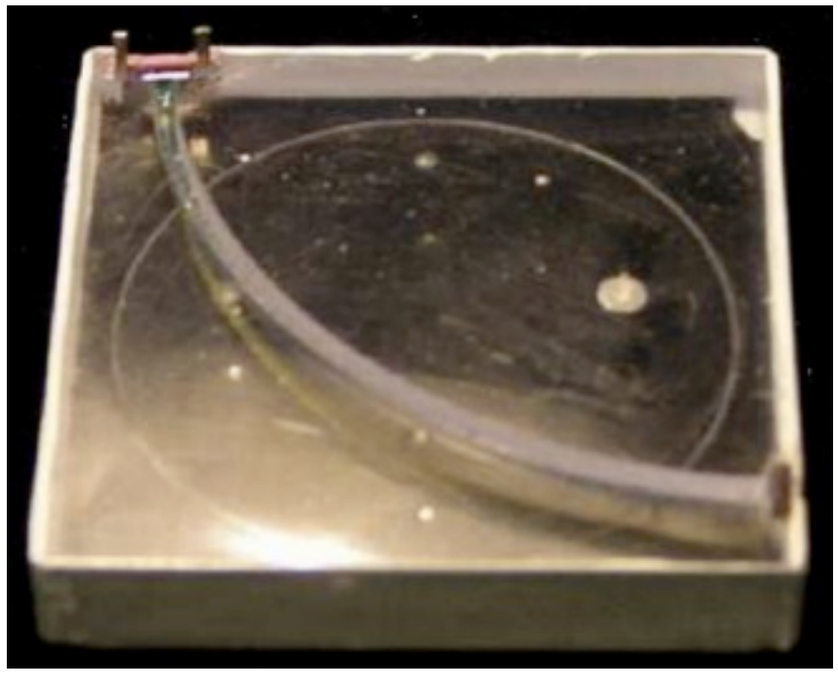
- Because we can: Modern SiPMs are blue sensitive, well matched to emission spectrum of scintillator
- Because it is simple: No embedding of fiber in the scintillator, very relaxed mechanical tolerances of SiPM mounting

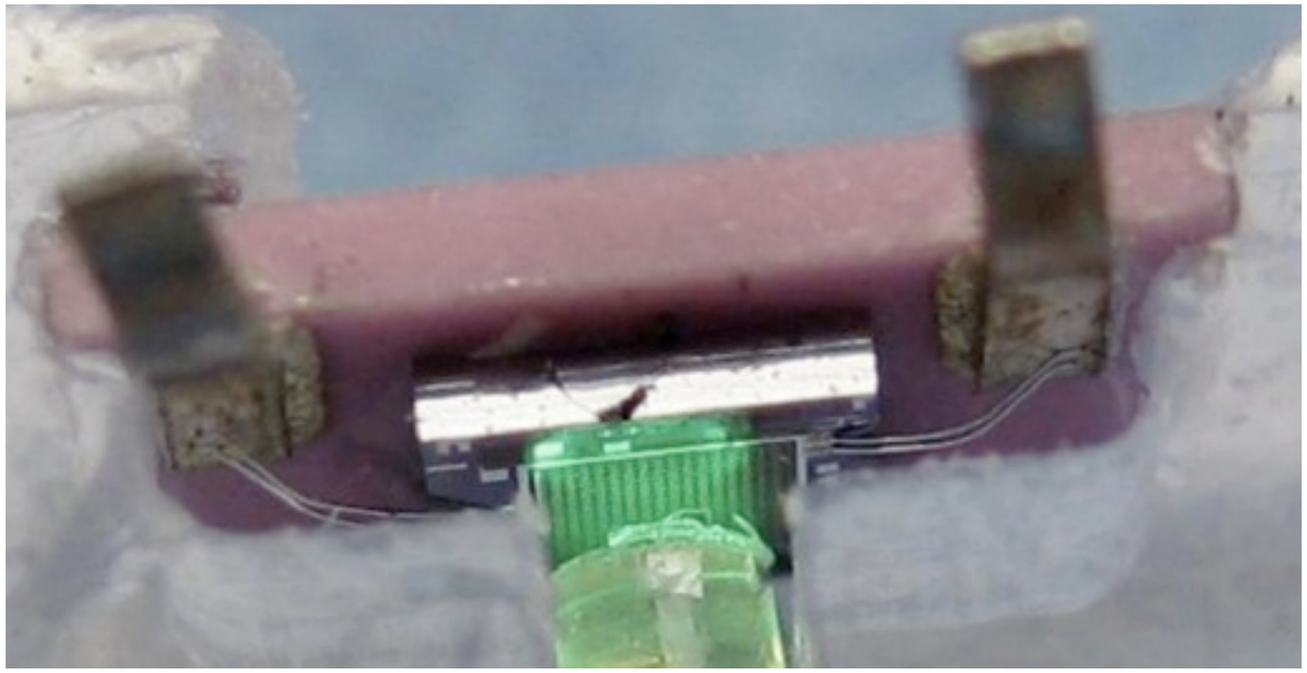




Why do Direct Coupling?

- Because we can: Modern SiPMs are blue sensitive, well matched to emission spectrum of scintillator
- Because it is simple: No embedding of fiber in the scintillator, very relaxed mechanical tolerances of SiPM mounting



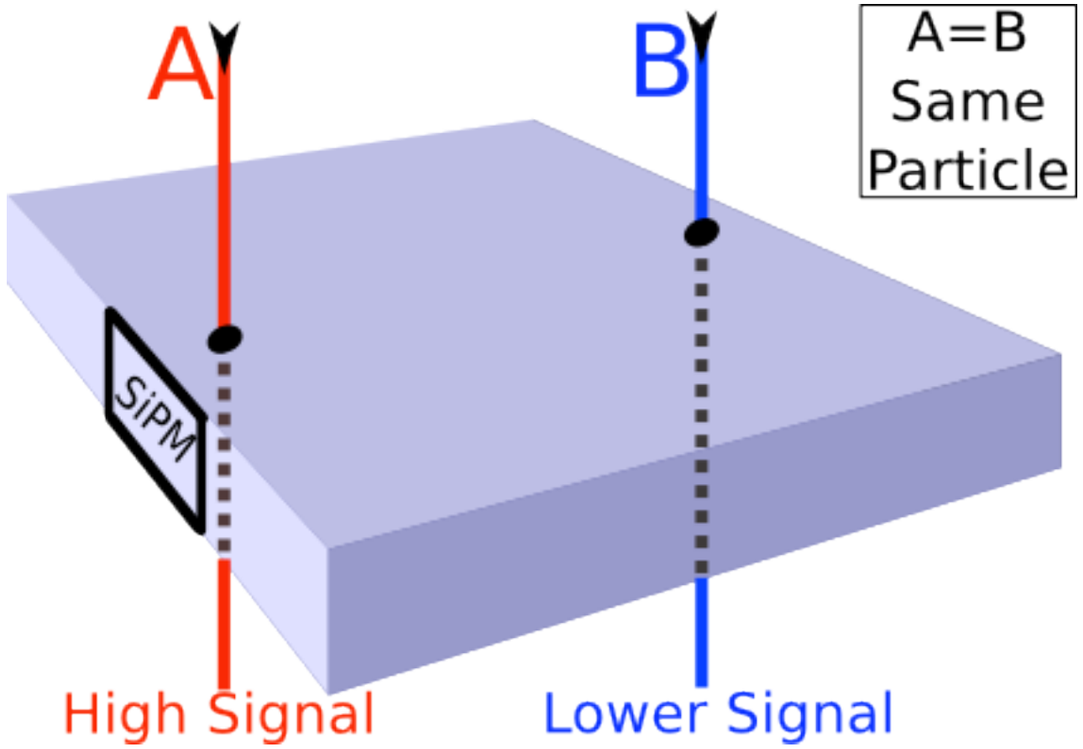


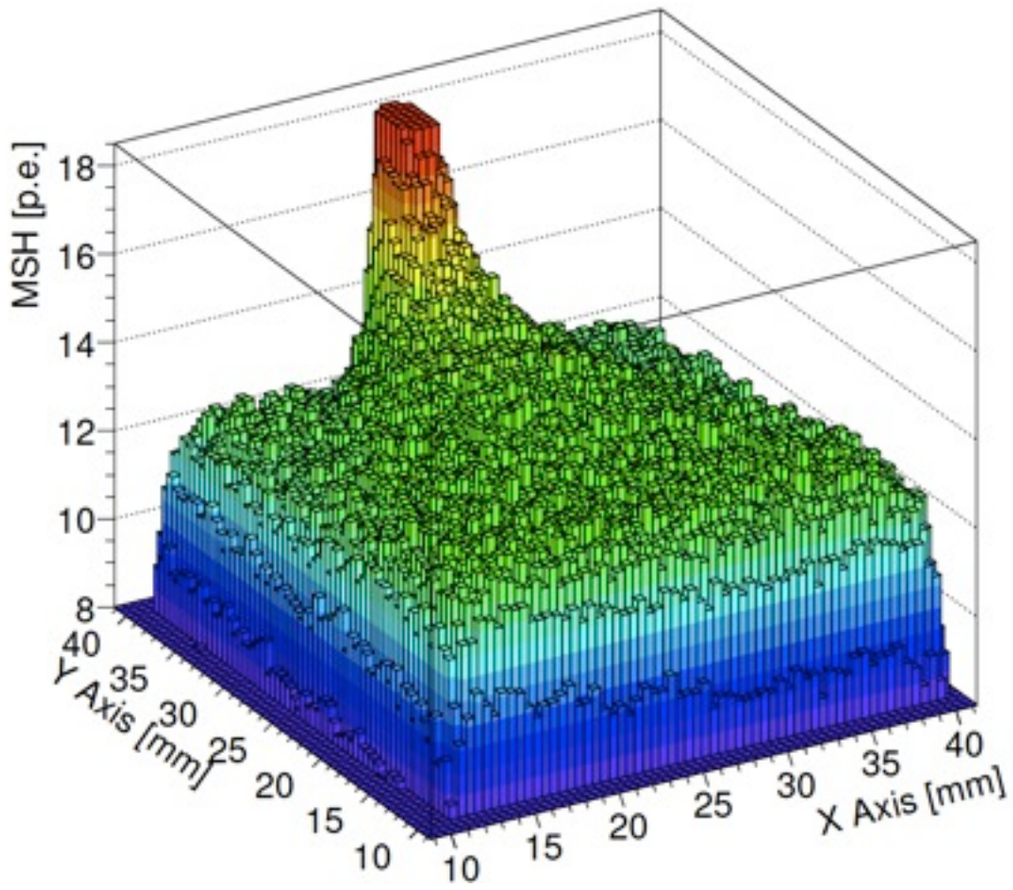
- Because it is fast: A WLS fiber leads to a significantly slower signal due to absorption and reemission of photons - direct coupling provides much better timing

Why not do Direct Coupling?

- A WLS fiber helps to improve the uniformity of the scintillator tile response:
  It collects light and guides it to the SiPM

- Naive direct coupling: Just stick a SiPM to the side of a scintillator tile

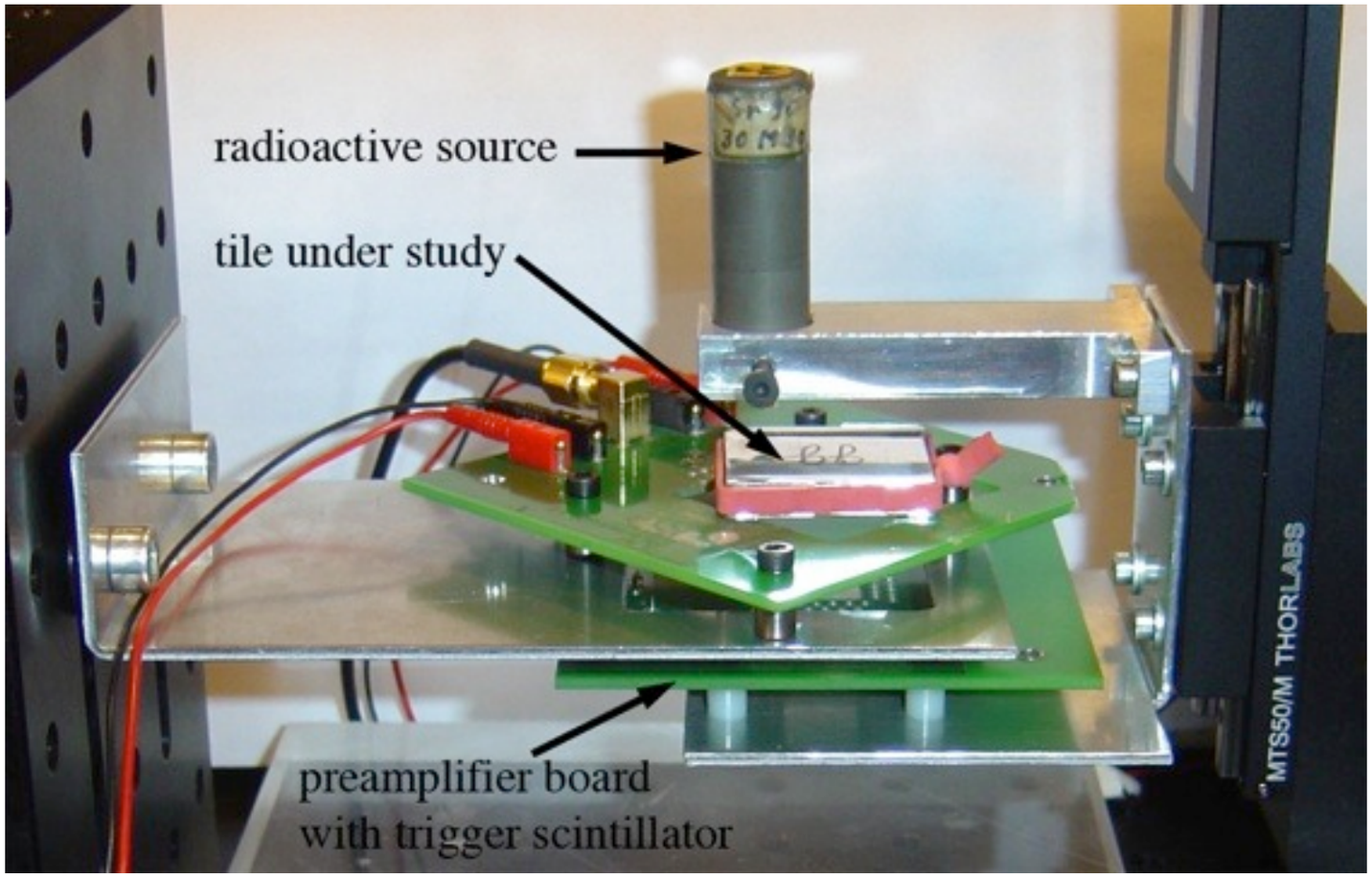




➪ Significant non-uniformity of response in simple direct coupling!

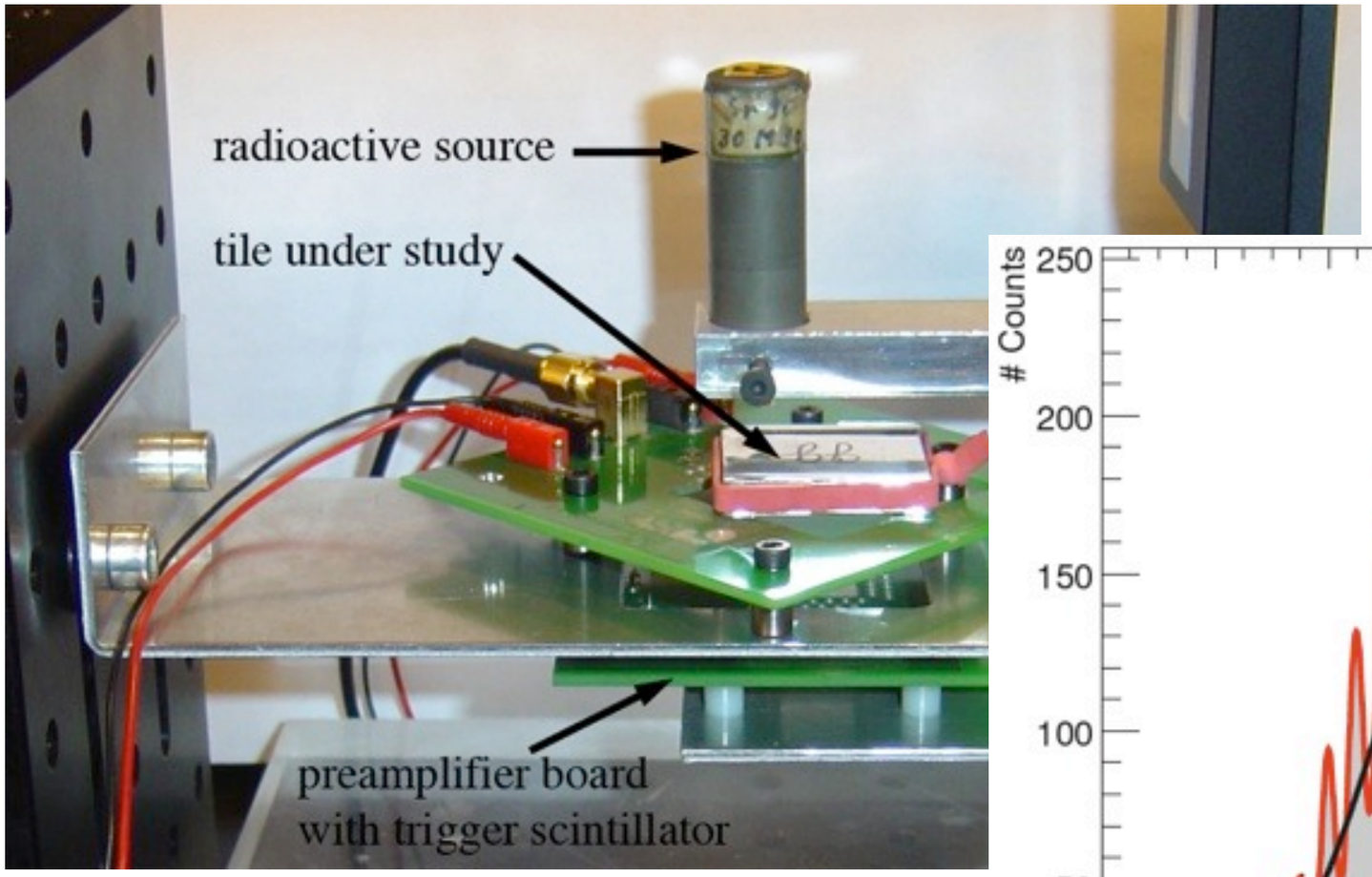
The Experimental Setup

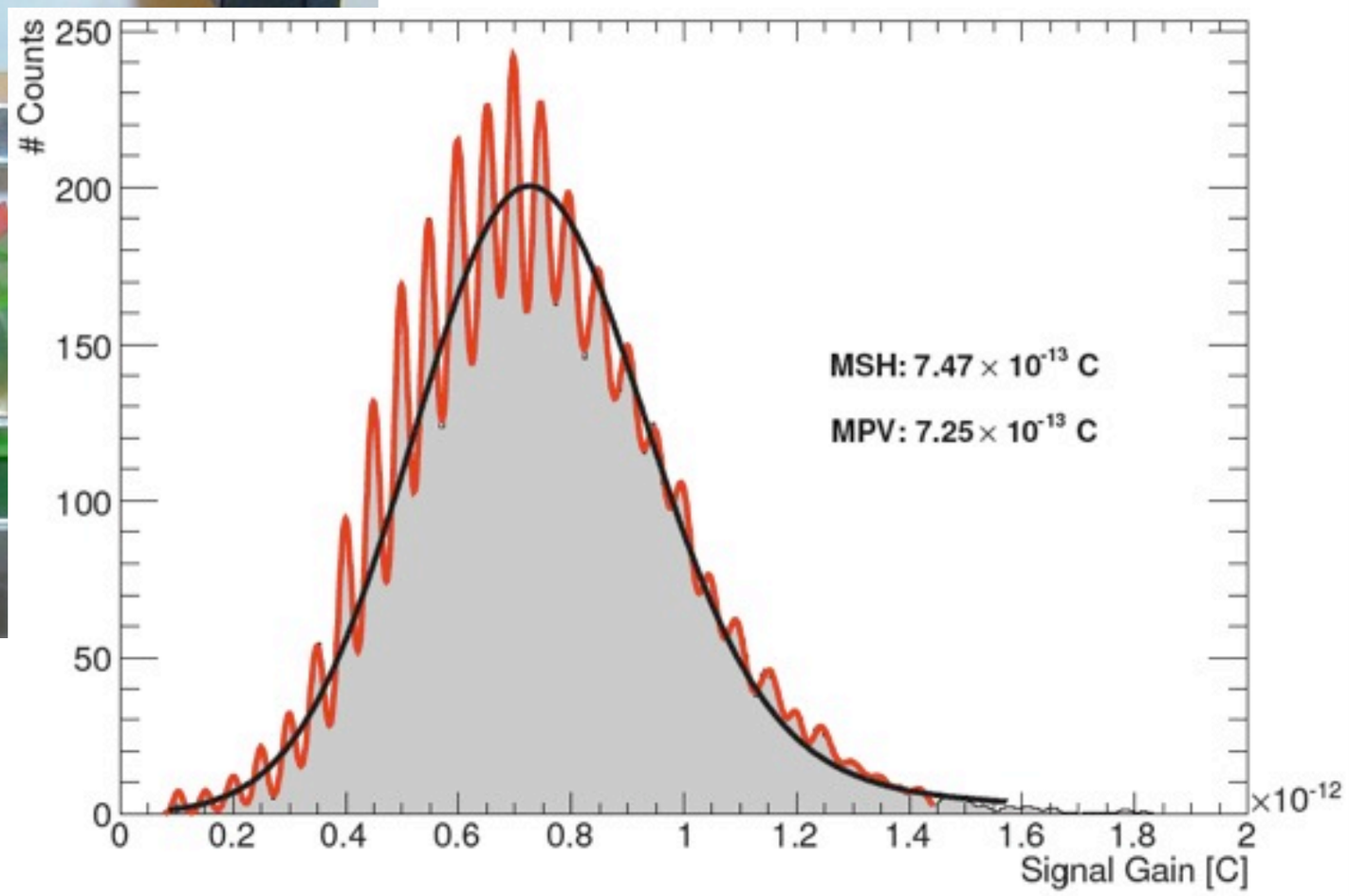
- Readout of SiPMs with fast Oscilloscope
- Scanning of radioactive source (^{90}Sr) across surface, select penetrating electrons



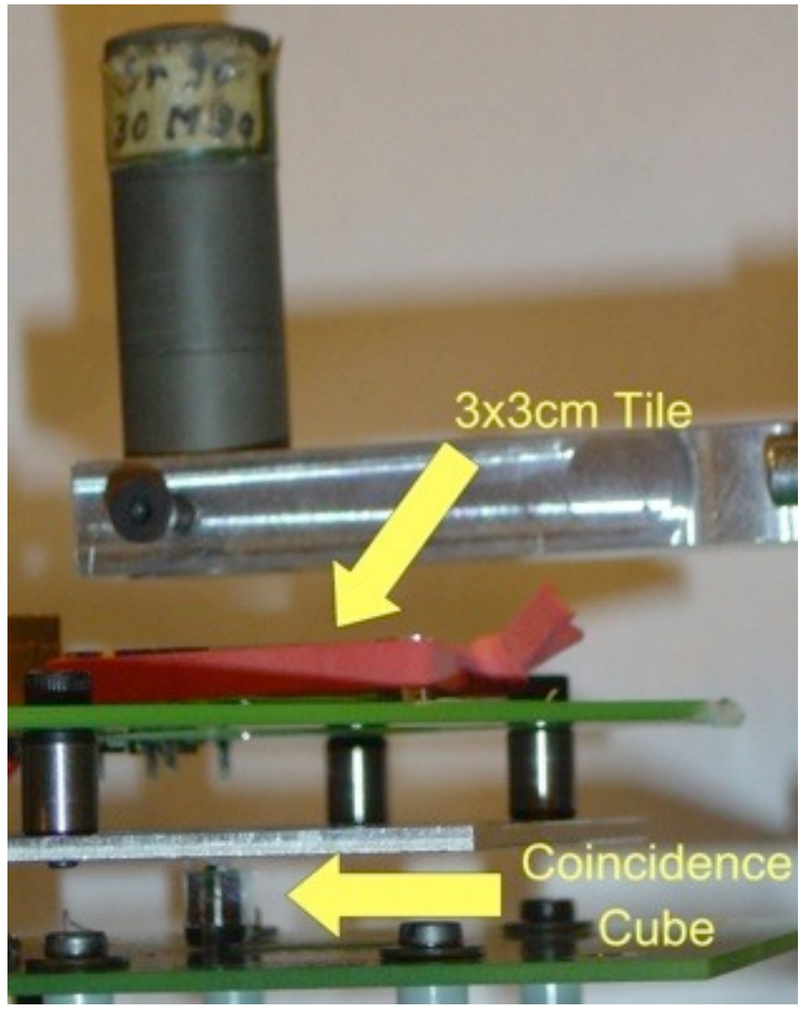
The Experimental Setup

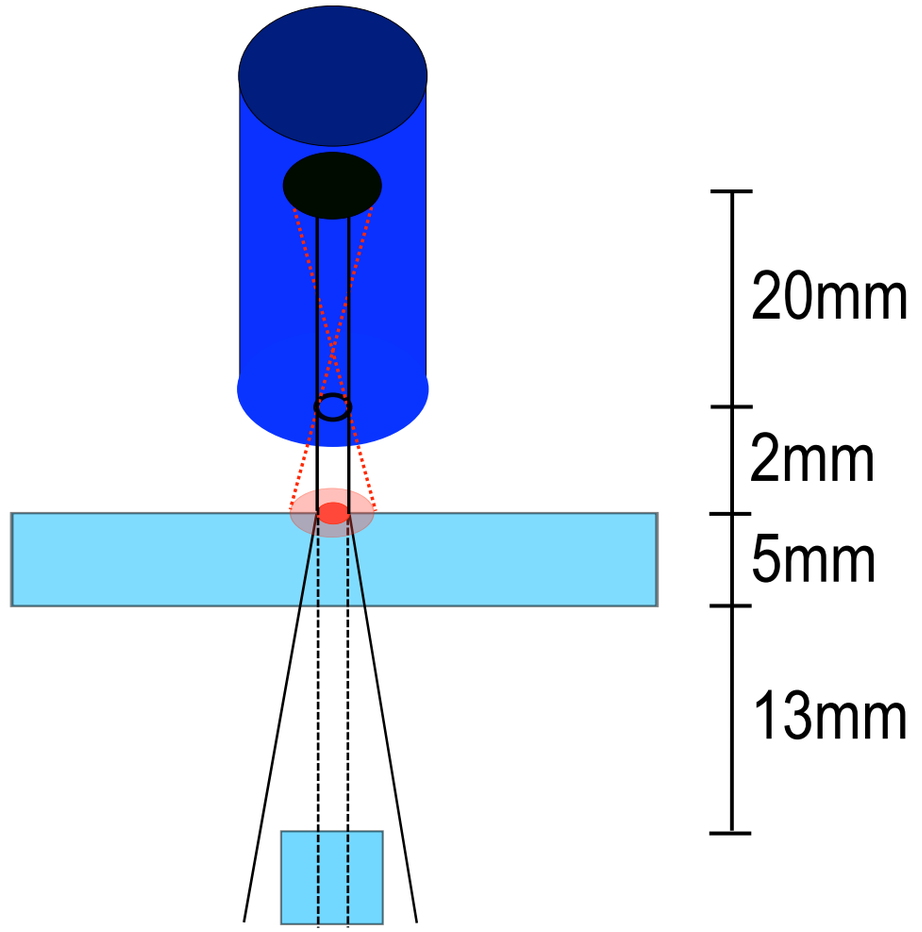
- Readout of SiPMs with fast Oscilloscope
- Scanning of radioactive source (^{90}Sr) across surface, select penetrating electrons





Scanning Details

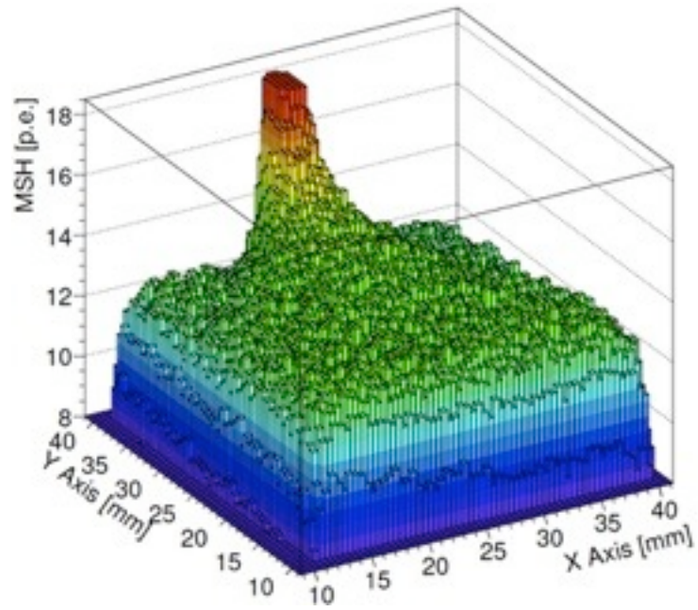




- Penetrating electrons are selected by requiring a signal in a 5 x 5 x 5 mm^3 scintillator cube under the tile under study
  - the cube moves together with the source
- Inclined electrons and scattering in material lead to "edge effects": Lower mean signal, from contributions of electrons that leave the tile early

How to achieve Uniformity

- Large signal excess close to SiPM coupling position
- Reduce material close to sensor

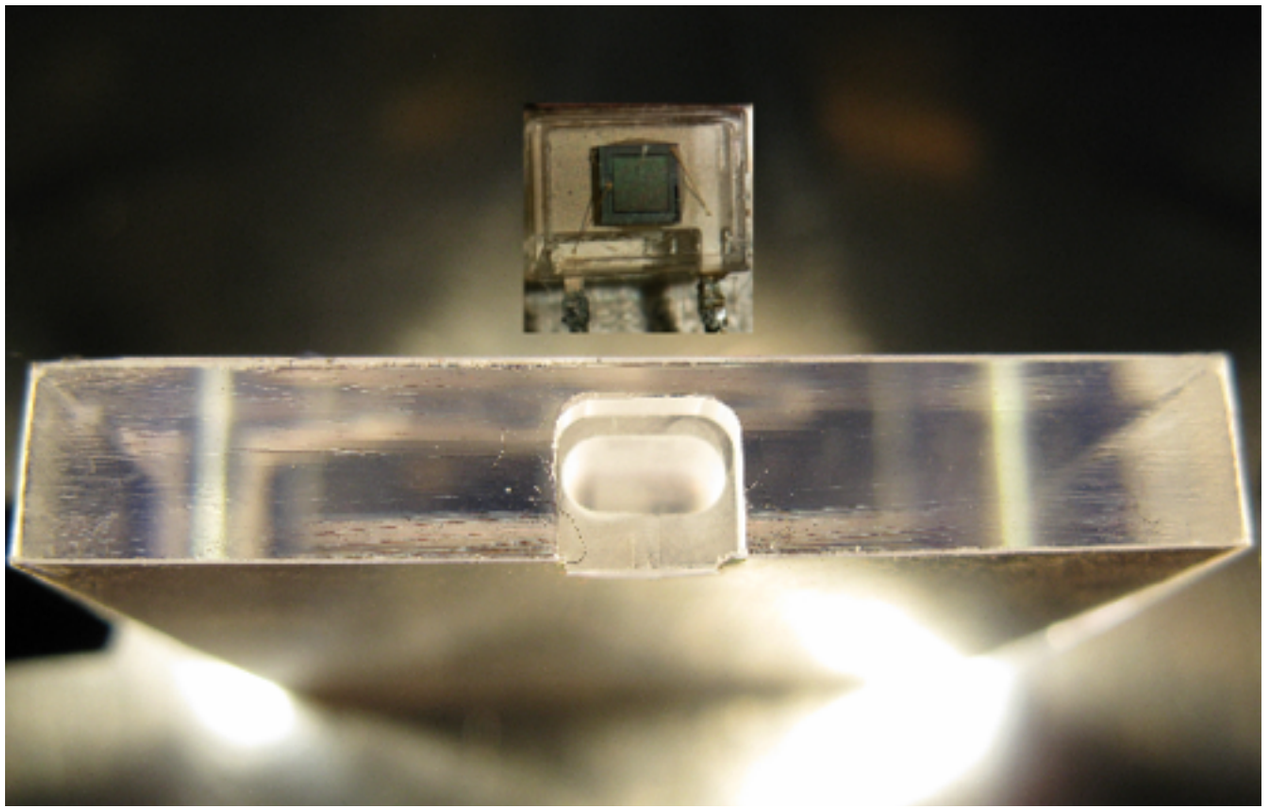


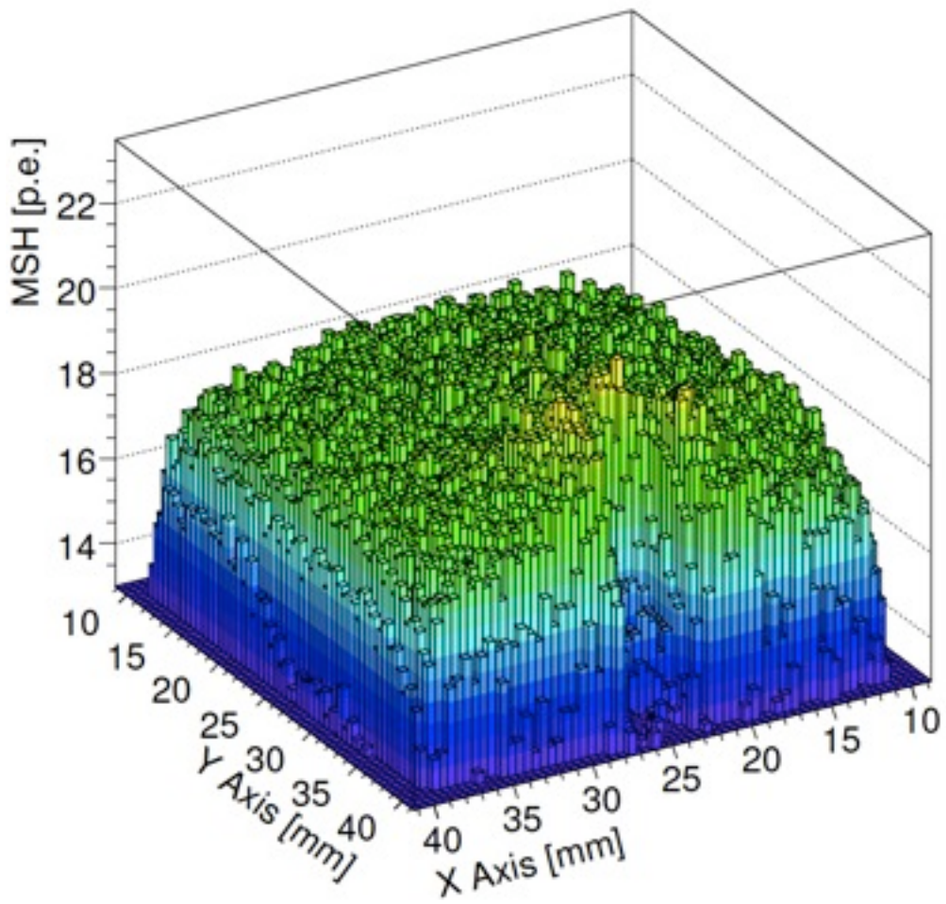
Not a new idea: Was already used by Vishnu et al. for bottom face coupling [NIM A605, 277 (2009)]

- Embed SiPM in side face of the tile
- Improves light collection, allows "gap-less" mounting of tiles

Improved Uniformity

- MPPC 25C (1 x 1 mm^2), in clear plastic package
- Modifications of tile by drilling:
  - Slit for SiPM integration
  - Dimple to reduce scintillation material close to sensor, diffuse light



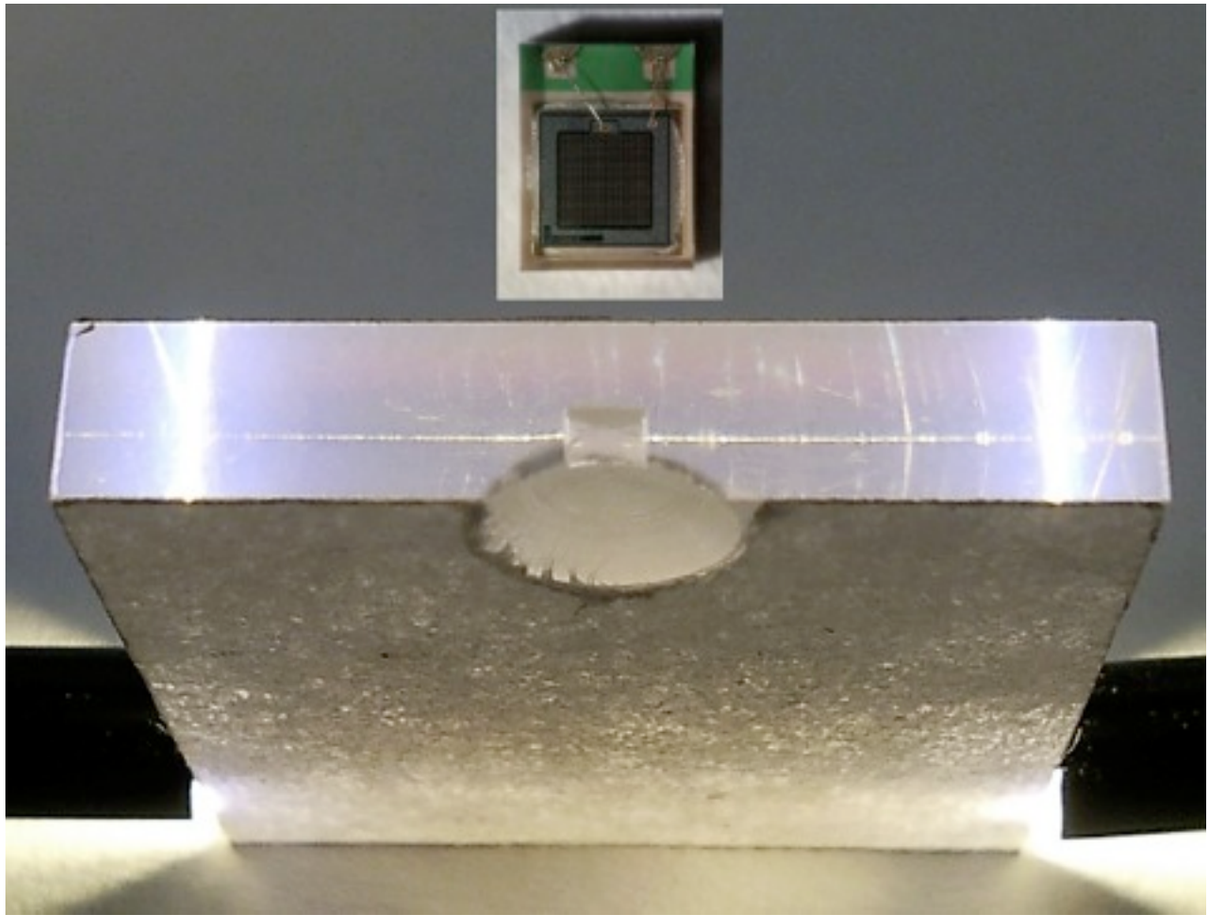


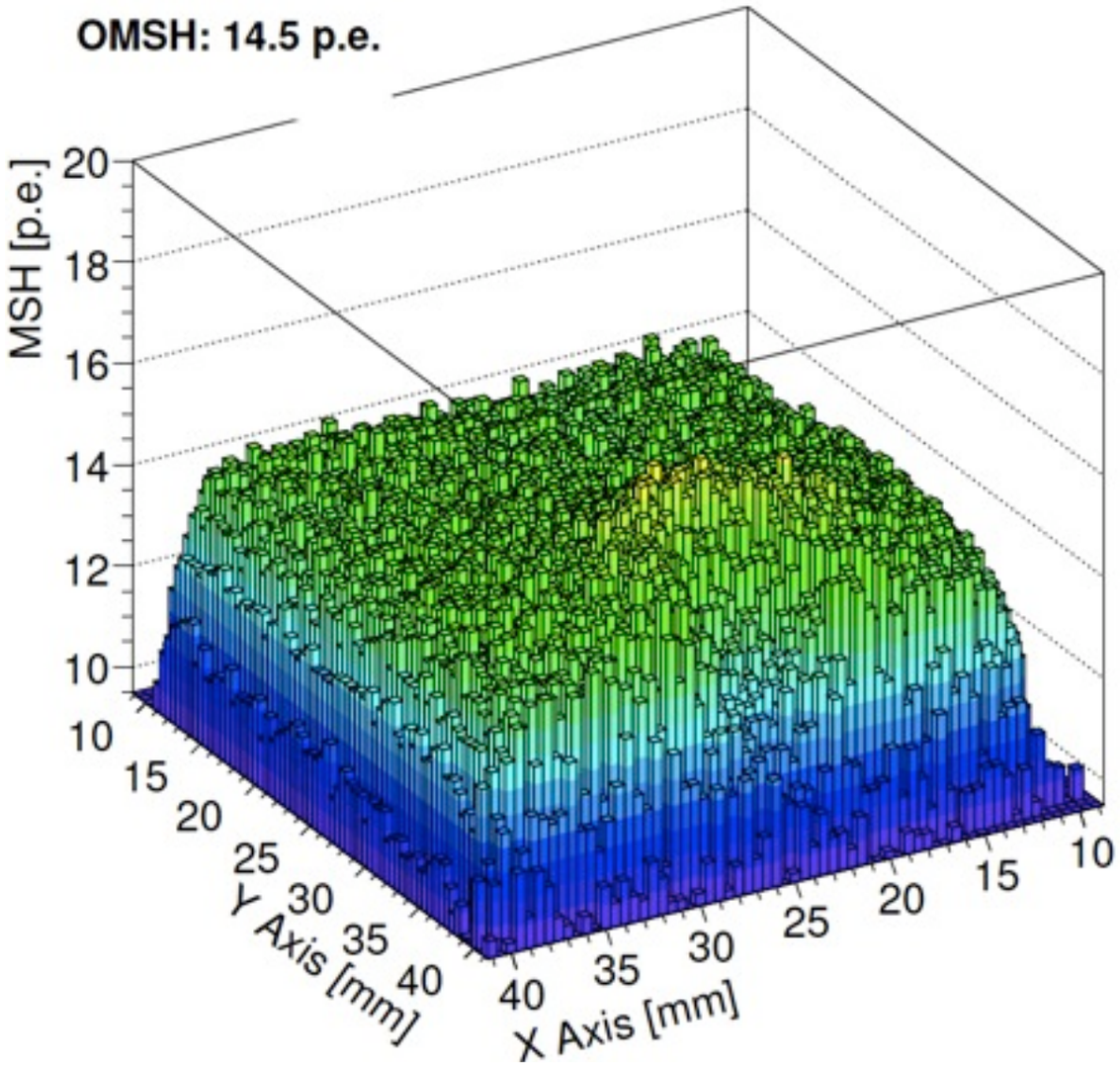
- Improved signal amplitude: ~18 p.e.
- Signal does not drop below ~ 13 p.e. in SiPM coupling region
- Improved uniformity
- Similar results for 3 mm tile (signal ~ 13 p.e.)

Submitted to NIM, arXiv:1001.4665 [physics.ins-det]

Further Improvements

- Attempt to avoid the signal drop at the SiPM coupling position

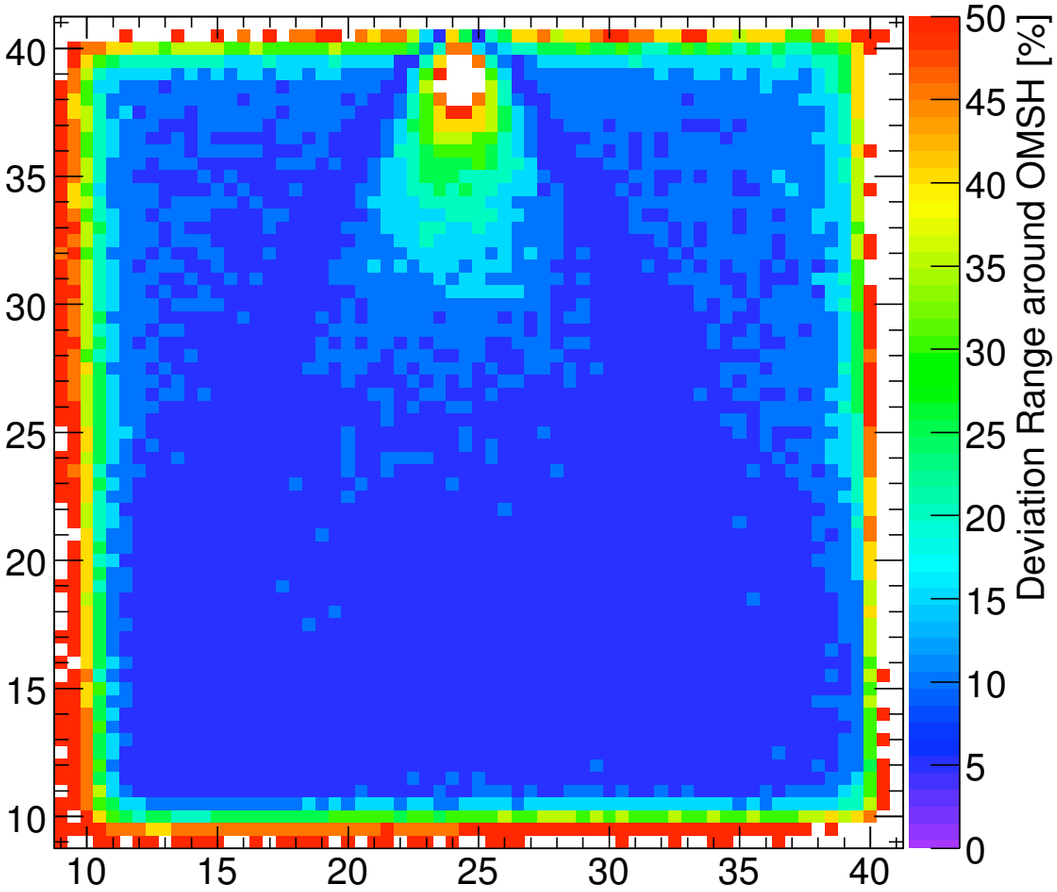




- Achieved with a spherical hole, 5 mm radius, and a small SMD MPPC

Quantifying the non-uniformity

simple coupling



81% within ±10%

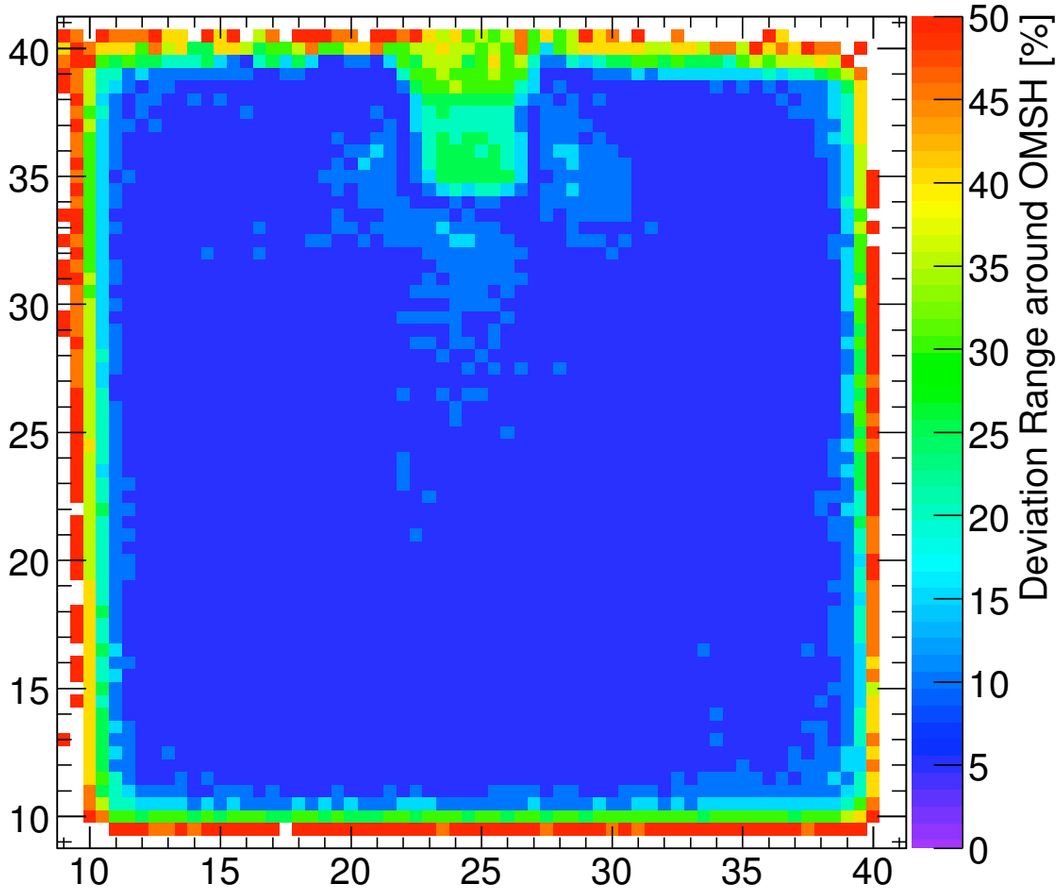
57% within ±5%

without edge region (1.5 mm wide rim):

94% within ±10%

69% within ±5%

side dimple



84% within ±10%

73% within ±5%

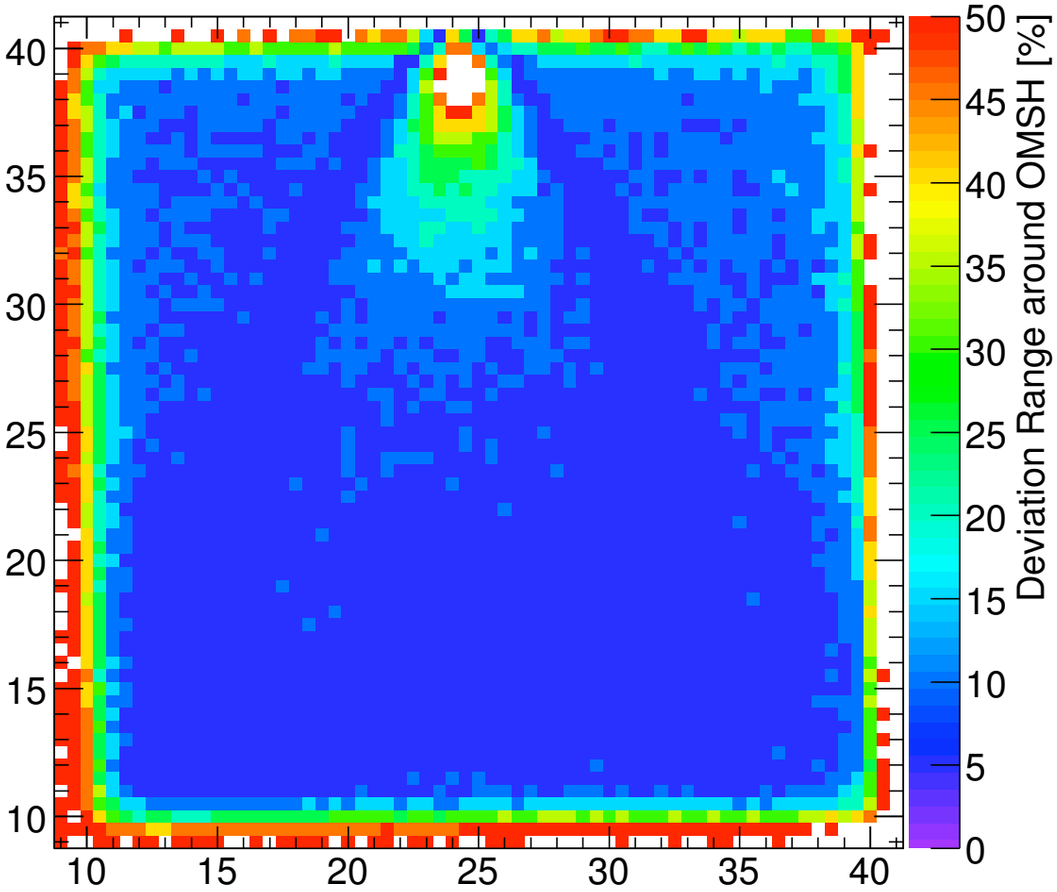
without edge region (1.5 mm wide rim):

97% within ±10%

88% within ±5%

Quantifying the non-uniformity

simple coupling



81% within ±10%

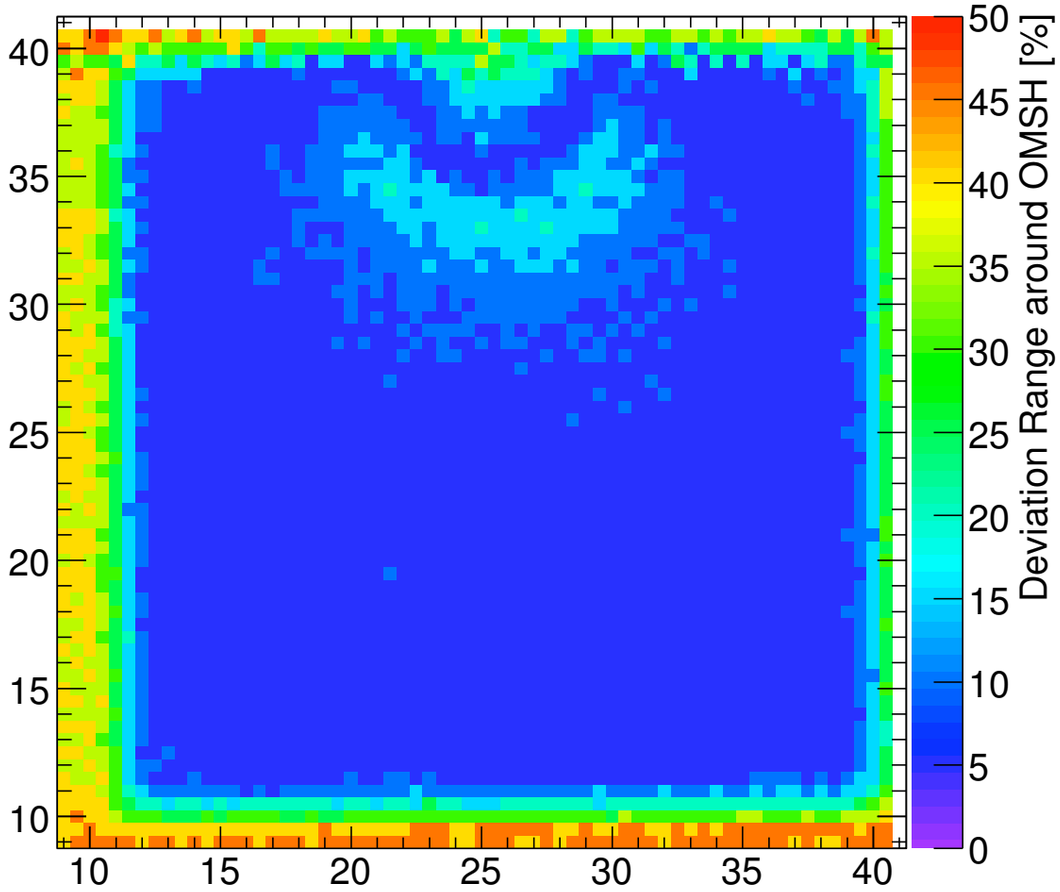
57% within ±5%

without edge region (1.5 mm wide rim):

94% within ±10%

69% within ±5%

large circular hole



82% within ±10%

69% within ±5%

without edge region (1.5 mm wide rim):

96% within ±10%

83% within ±5%

Summary

- Non-uniformities in direct coupling of SiPMs to scintillator tiles can be overcome

- Several concepts exist, here:
  - Dimple in the side face of the tile
  - ▸ high signal amplitude, very good uniformity (comparable to that achieved with WLS fiber)
  - ▸ Directly compatible to current HBU layout

- ▸ Further developments: Design might be further improved, signal drop at SiPM coupling can be minimized with scintillator shaping and the use of extremely compact packaging

Summary

- Non-uniformities in direct coupling of SiPMs to scintillator tiles can be overcome

- Several concepts exist, here:
  - Dimple in the side face of the tile
  - ▸ high signal amplitude, very good uniformity (comparable to that achieved with WLS fiber)
  - ▸ Directly compatible to current HBU layout

- ▸ Further developments: Design might be further improved, signal drop at SiPM coupling can be minimized with scintillator shaping and the use of extremely compact packaging

... don't miss the Season Finale this afernoon at 3:30 / 2:30 central to learn about timing and immediate test beam plans!