Optimized Tiles for Direct Readout

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

CALICE Collaboration Meeting, Lyon, France, September 2009

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

CALICE
Calorimeter for ILC

TUM
LMU
Excellence Cluster
Universe

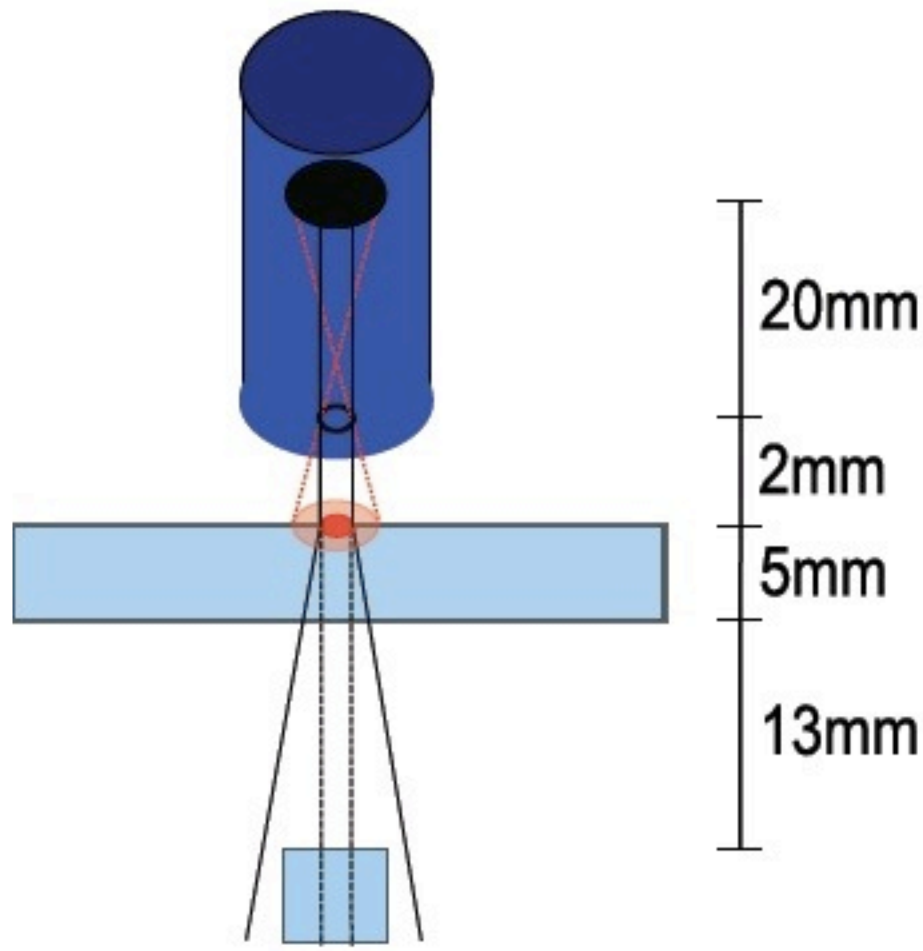
Motivation / Overview

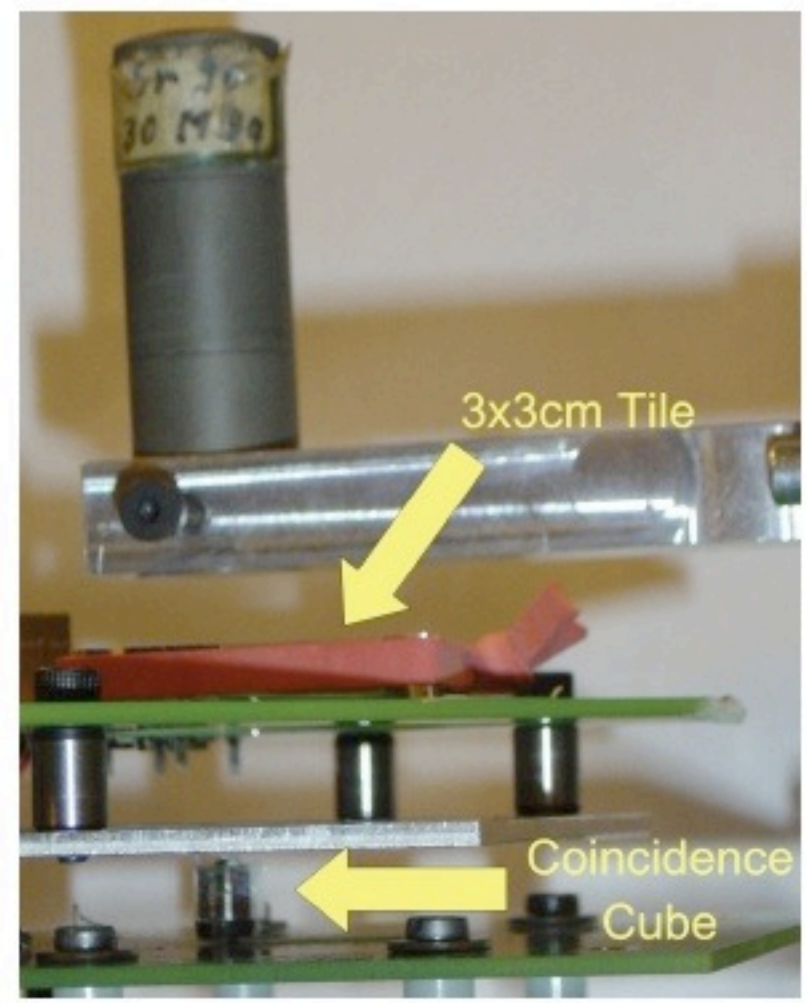
- Blue sensitive SiPMs: In principle no WLS fiber is necessary
  - Potentially much simplified tile mechanics
  - But: The fiber also helps with the light collection: Uniformity of the tile response
  - Special tile geometries could solve this issue!

- Today:
  - Setup to measure tile response in detail
  - A look at why uniformity is important
  - Ways to improve the tile uniformity

Measurement Technique: Scanning with a Source

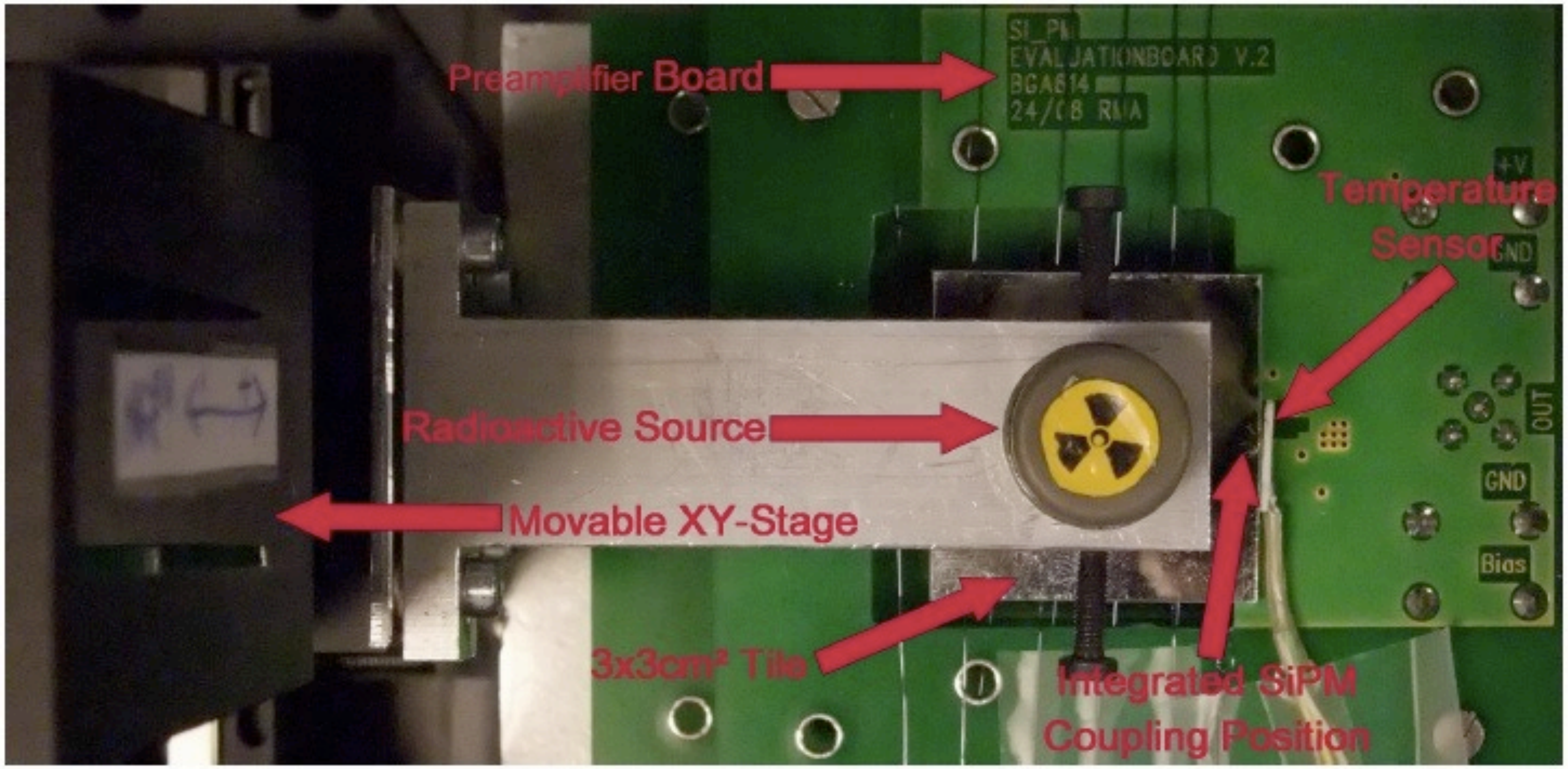
- For a fast study of many different geometries: Lab measurements, without access to a beam
  - Use ^{90}Sr source, electrons with an energy of up to 2 MeV, enough to penetrate more than 1 cm of scintillator





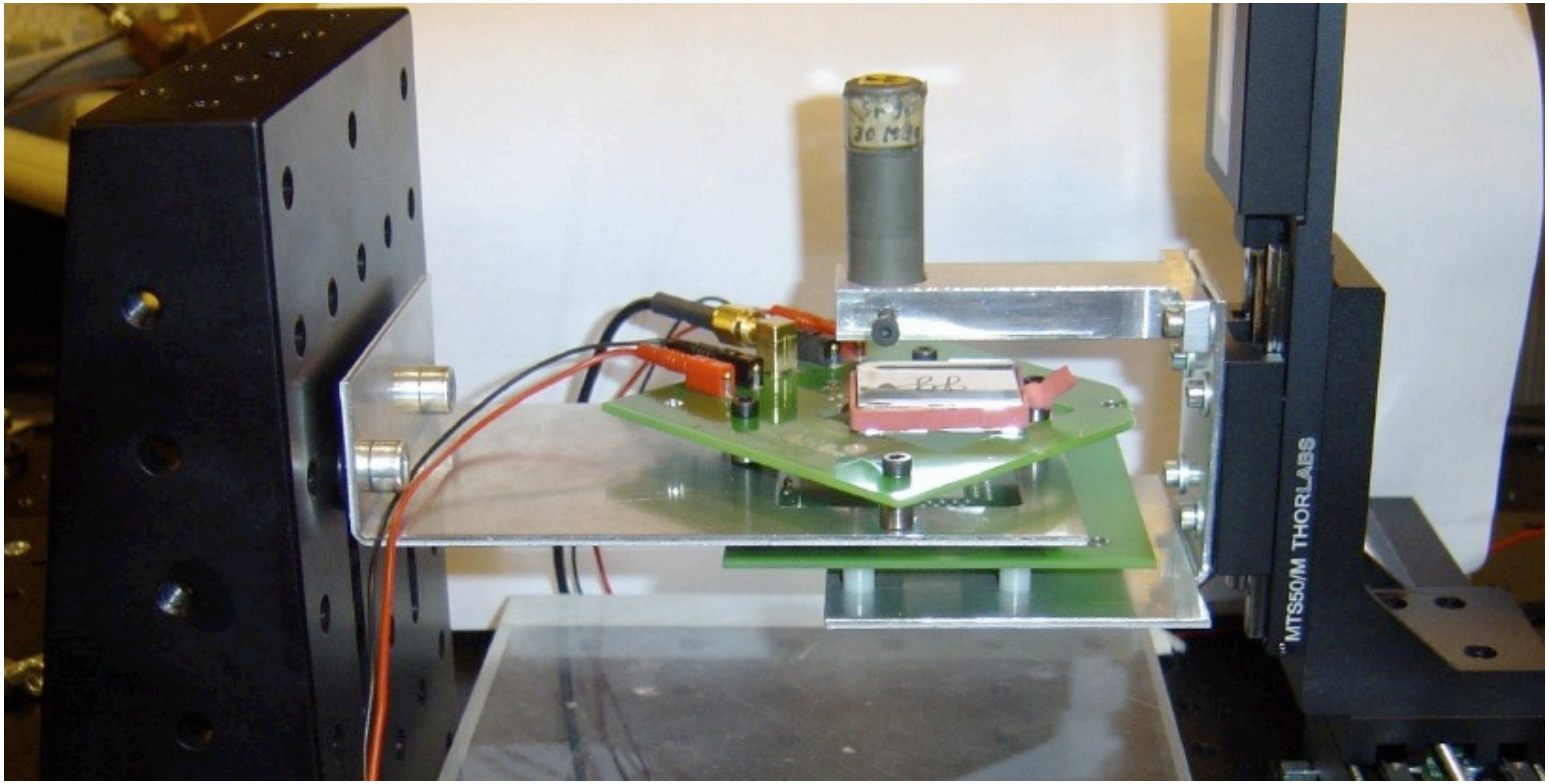
Precision Scans

- Movable xy stage, moves the source and the trigger scintillator
  - scan across the surface in 5 mm steps
  - low count rate: ~ 20 Hz, long measurements: Temperature correction mandatory



Precision Scans

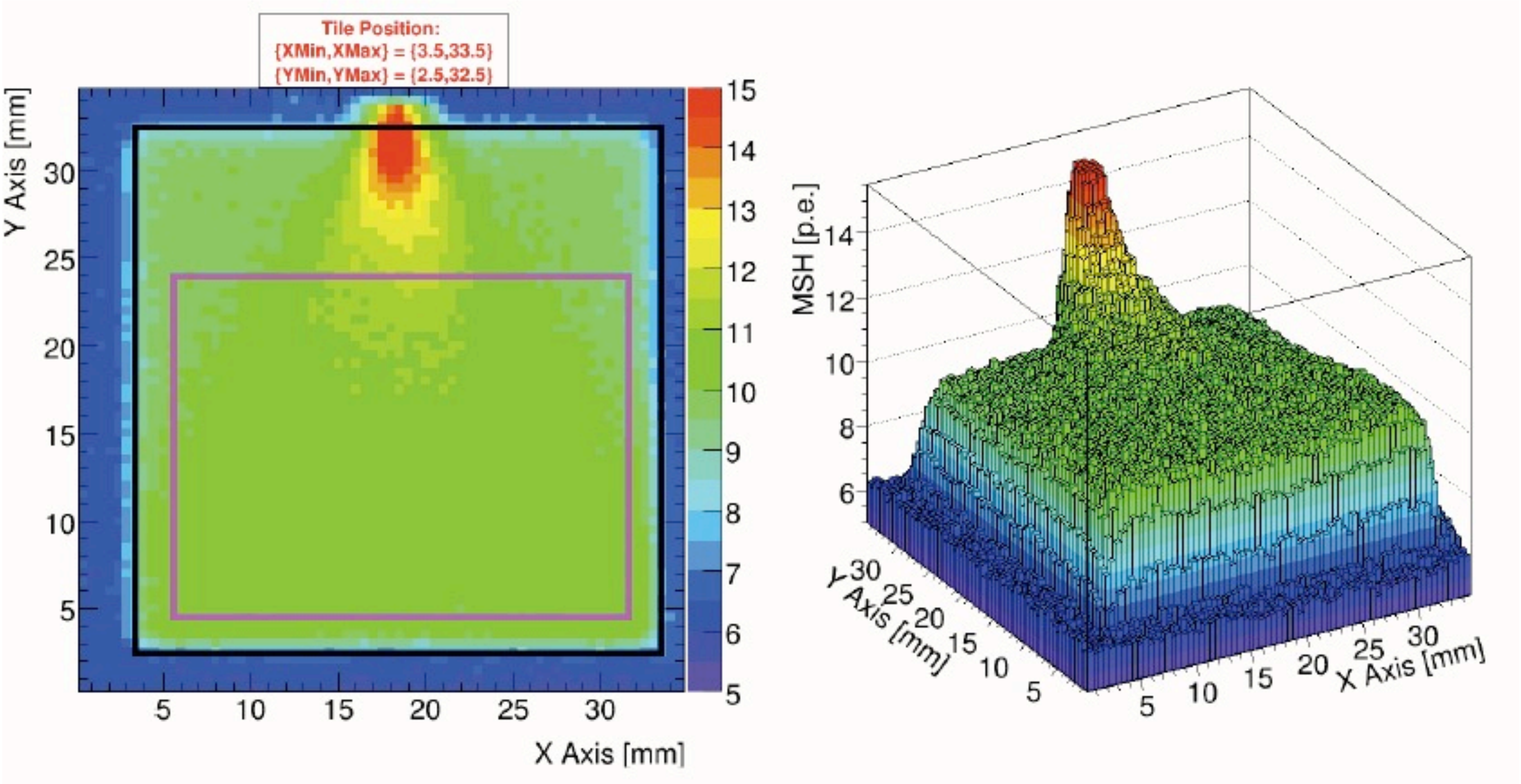
- Movable xy stage, moves the source and the trigger scintillator
  - scan across the surface in 5 mm steps
  - low count rate: ~ 20 Hz, long measurements: Temperature correction mandatory



Direct Coupling: The Simple Way

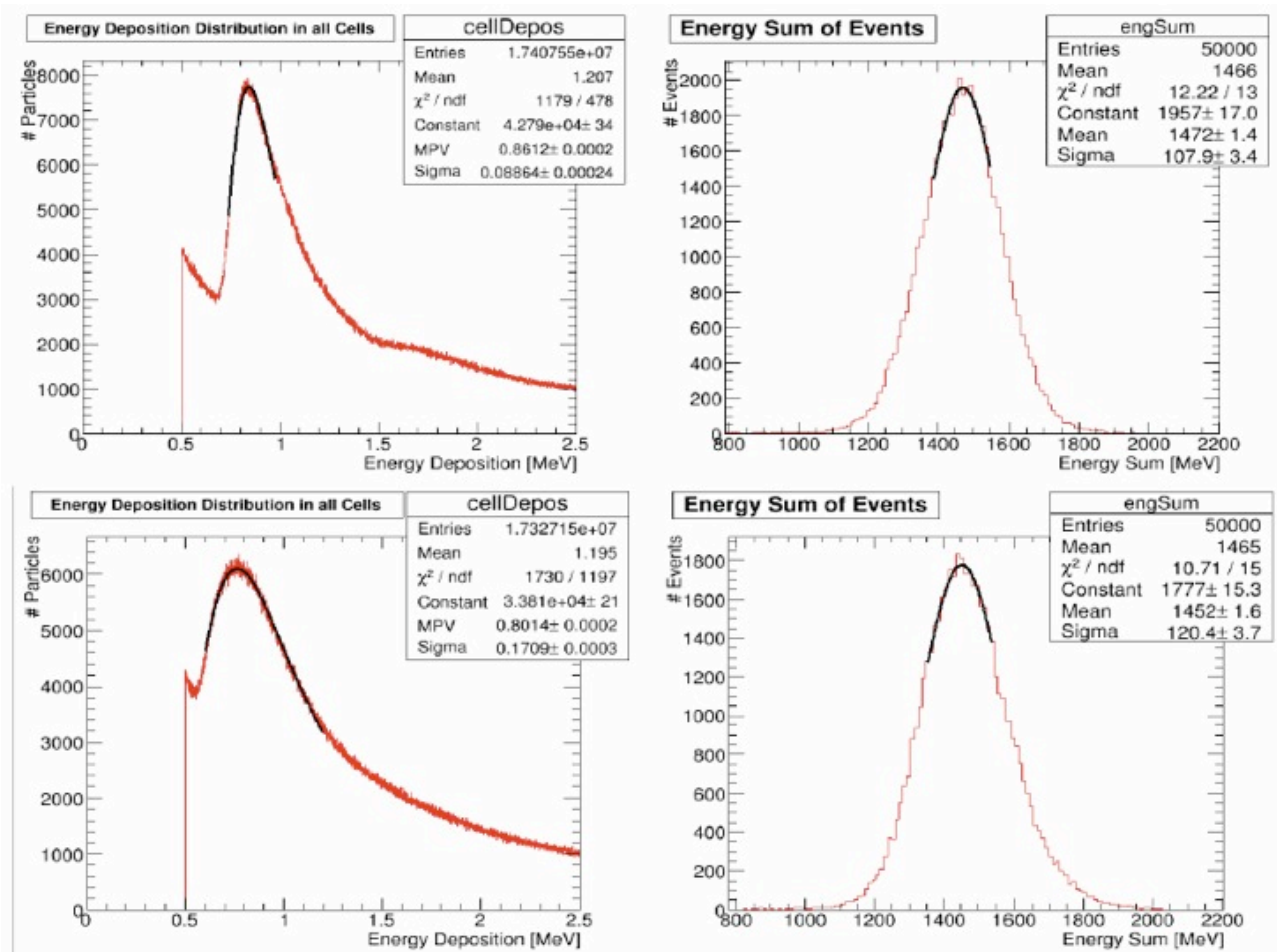
- Just take a SiPM and stick it to the side of a piece of scintillator

The problem: Very non-uniform response: Large signal close to the SiPM, the a quick fall-off towards the edges



Why is it bad? Channel Response & Energy Reconstruction

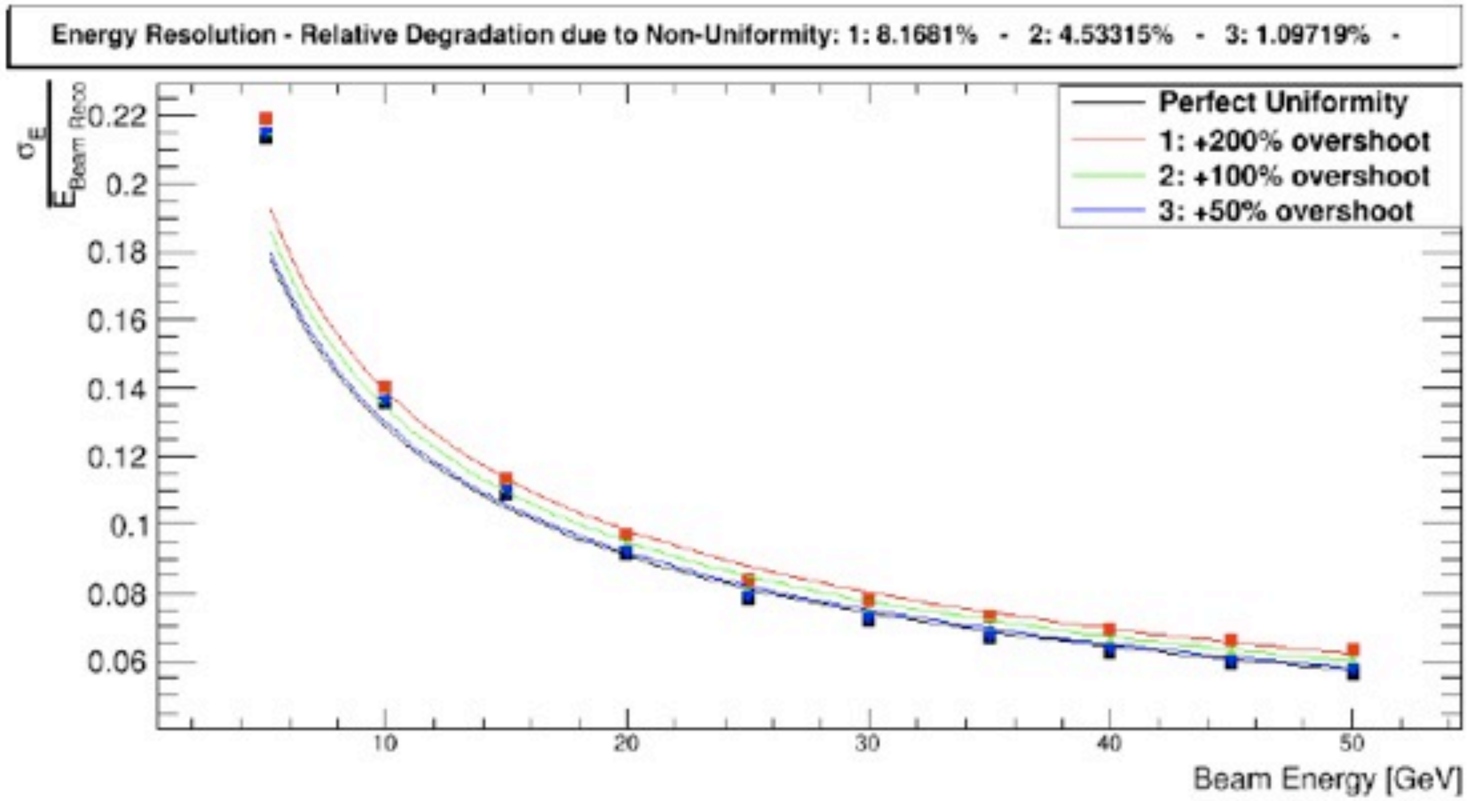
- G4 simulation of 45 GeV pions on a CALICE-like HCAL

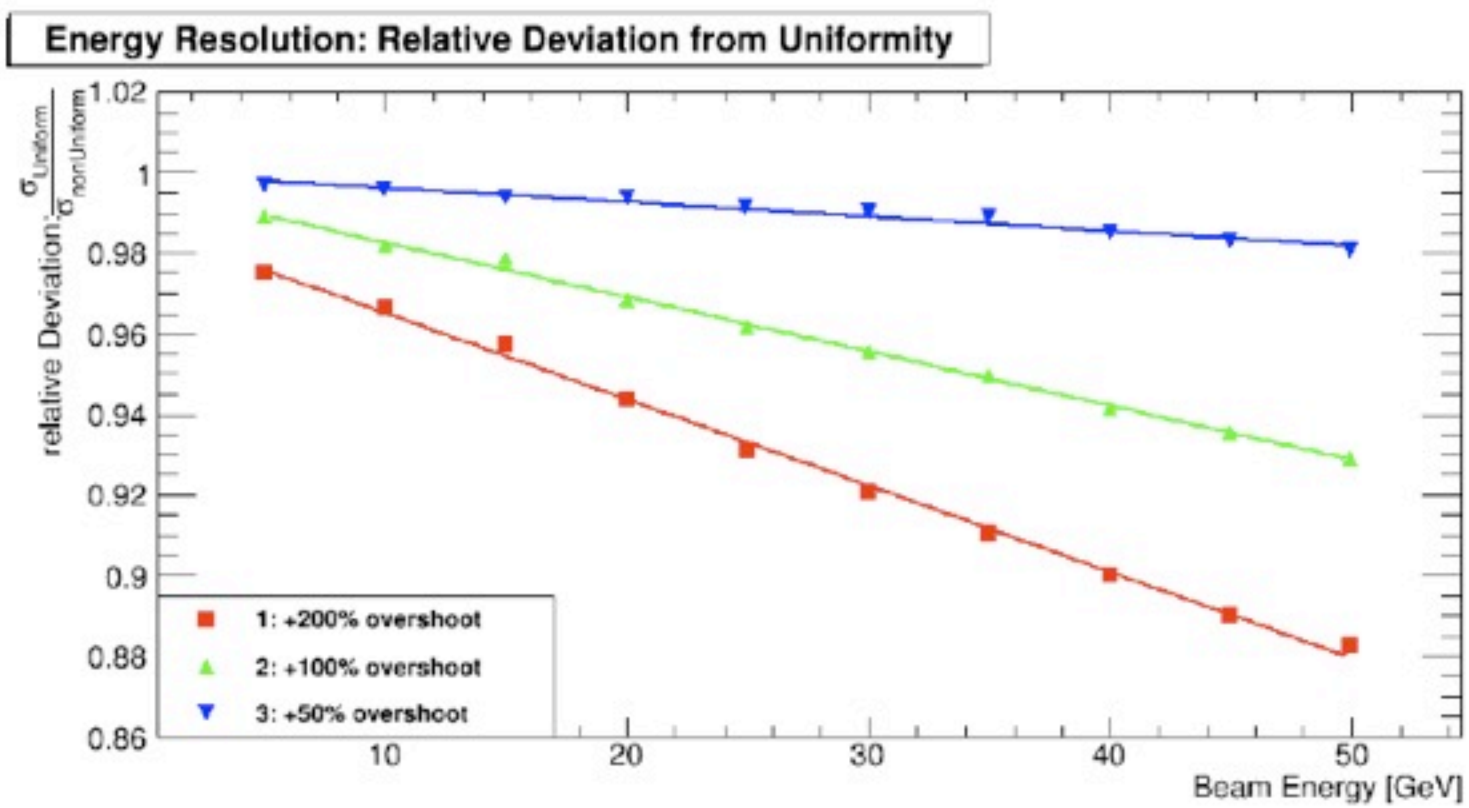


perfect uniformity

non-uniformity for direct coupling (5 mm tile) x 4

Why is it bad? Energy Resolution





- Reduced energy resolution with non-uniform readout
- Effect grows with energy (naively not expected)
  - Reason: correlation between layers from longer-range particles
  - Rotating of cells by 90 deg from one layer to the next helps
    - Might not be an issue in a cylindrical detector in a magnetic field...

Frank Simon (frank.simon@universe-cluster.de)

Ideas to improve Uniformity

- Reduce light output close to the SiPM
- Reduce dependance of light collection by the SiPM from position of production of scintillation light

Ideas to improve Uniformity

- Reduce light output close to the SiPM
- Reduce dependance of light collection by the SiPM from position of production of scintillation light

➯ Modification of the tile geometry: Add a “dimple”:

- reduction of material close to the SiPM
- additional benefits from light diffusion etc

Ideas to improve Uniformity

- Reduce light output close to the SiPM
- Reduce dependance of light collection by the SiPM from position of production of scintillation light

➯ Modification of the tile geometry: Add a "dimple":

- reduction of material close to the SiPM
- additional benefits from light diffusion etc

Studied dimples on the side and on the bottom

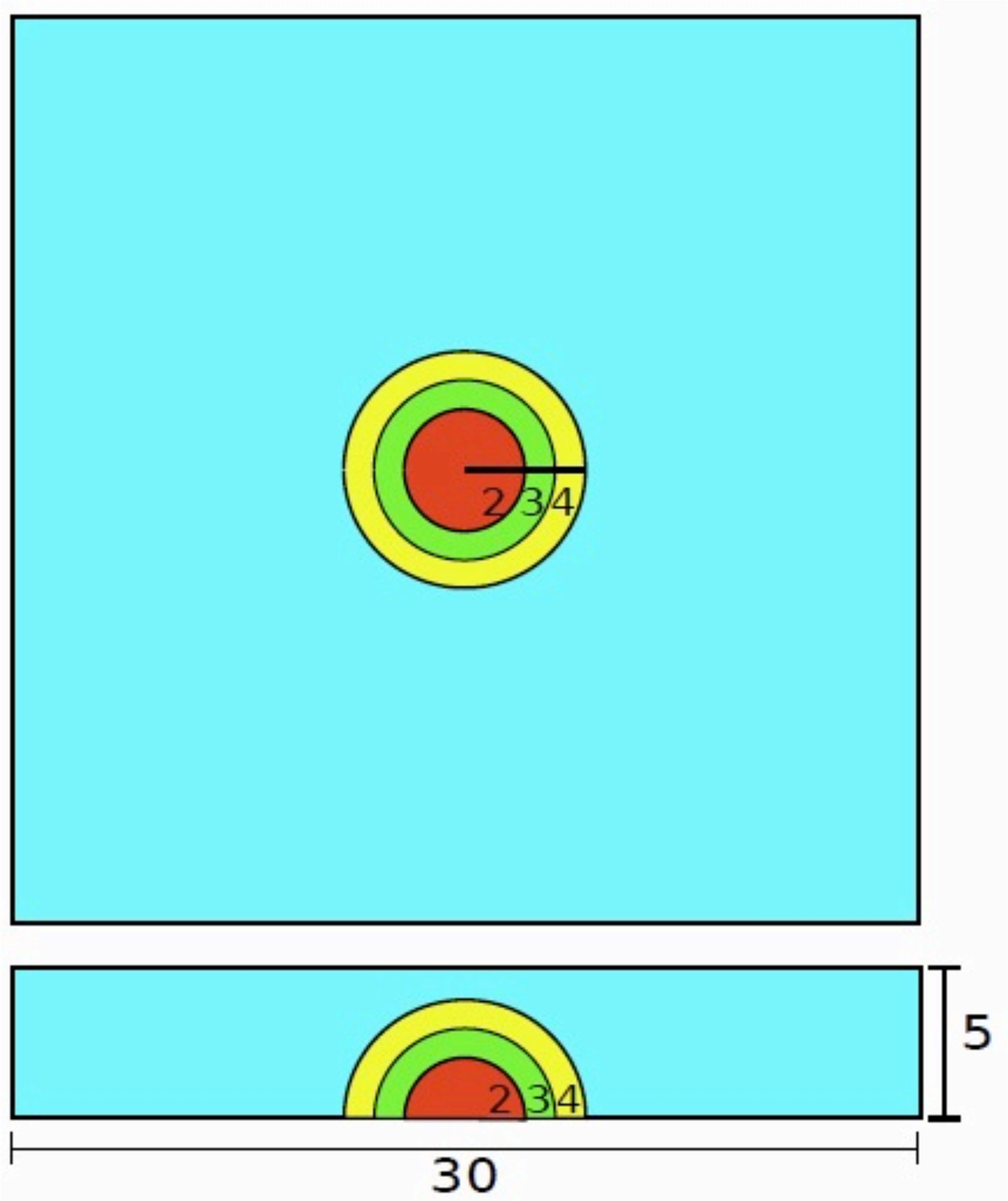
Also played with surface treatment

- none
- mattening (sanding)
- reflective foil (this works best, not very surprisingly...)

In total: 45 tiles investigated

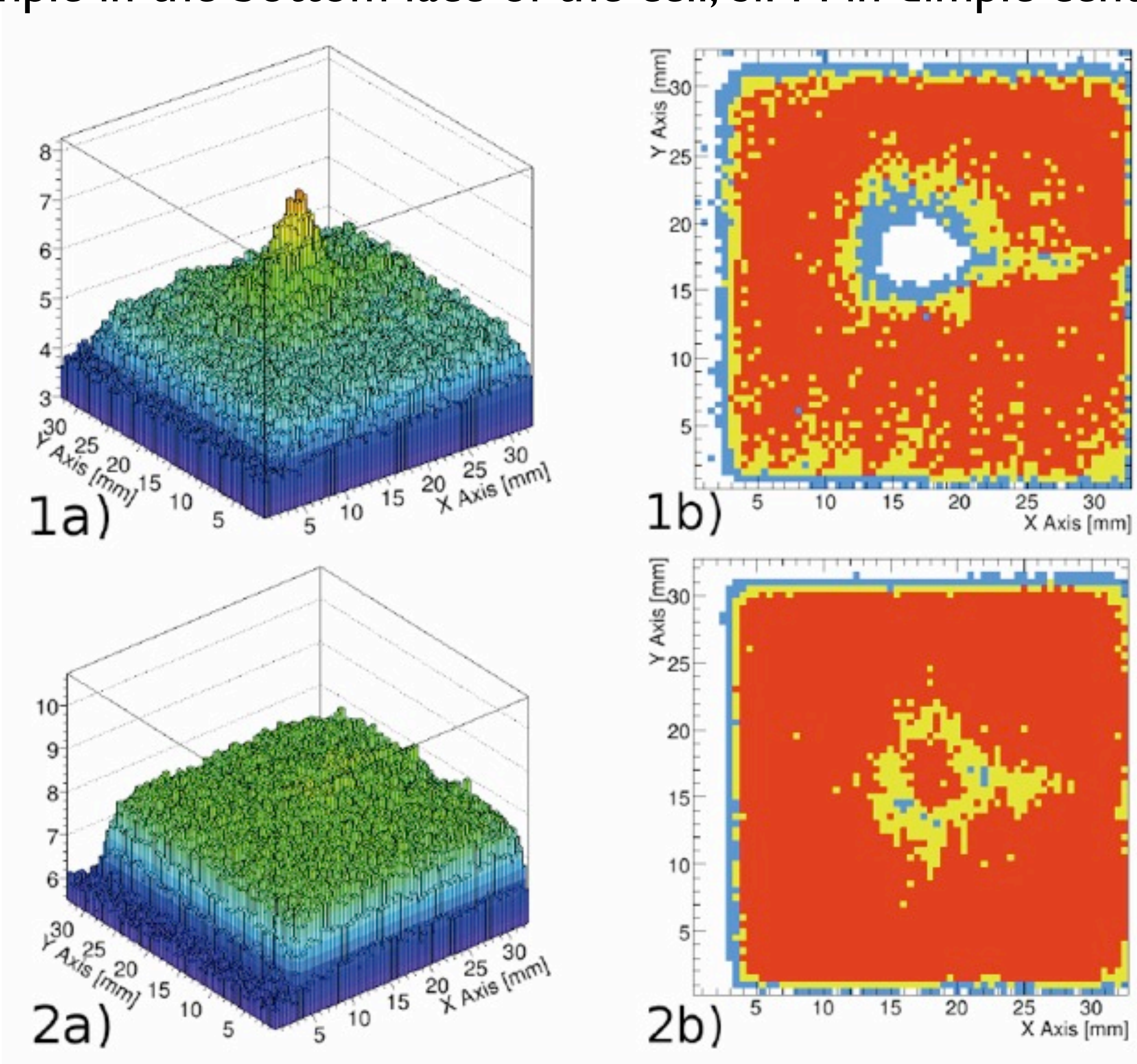
Bottom Dimple

- Dimple in the bottom face of the cell, SiPM in dimple center (Idea from Vishnu)



Bottom Dimple

- Dimple in the bottom face of the cell, SiPM in dimple center (Idea from Vishnu)

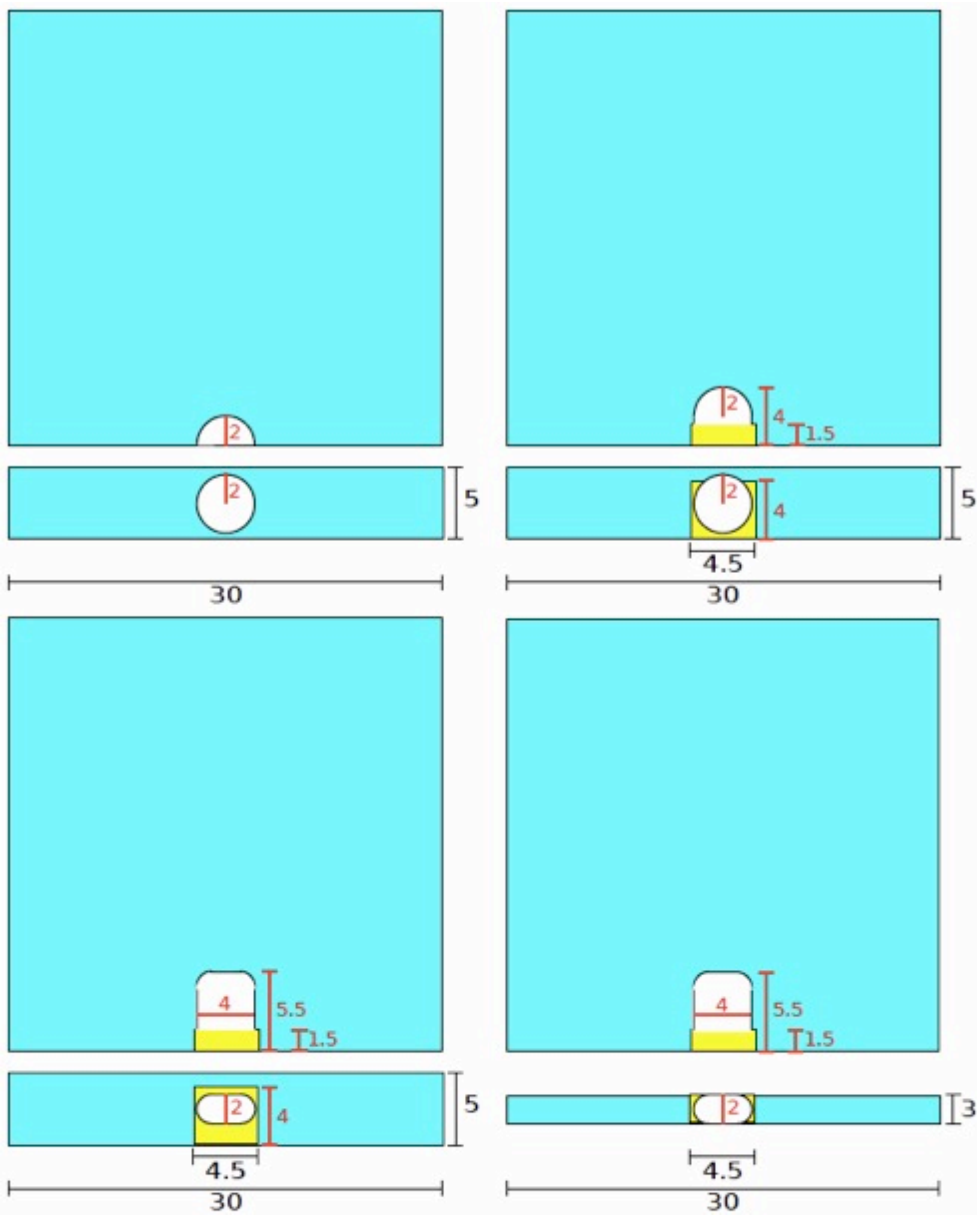


Significant improvement of uniformity:
83% within 5% of mean
95% within 10%

... but low overall signal!

Side Dimple

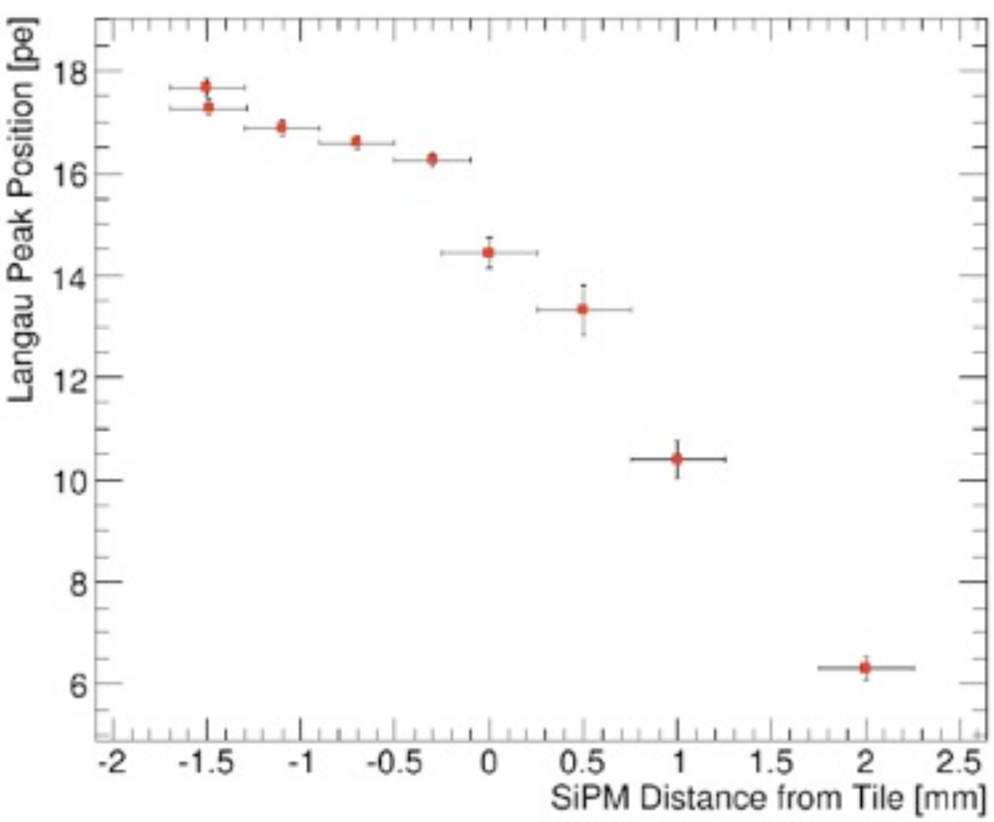
- Fits the present design of the HBU boards
    - Many different structures investigated: Different dimple shapes, depth, SiPM positioning, ...

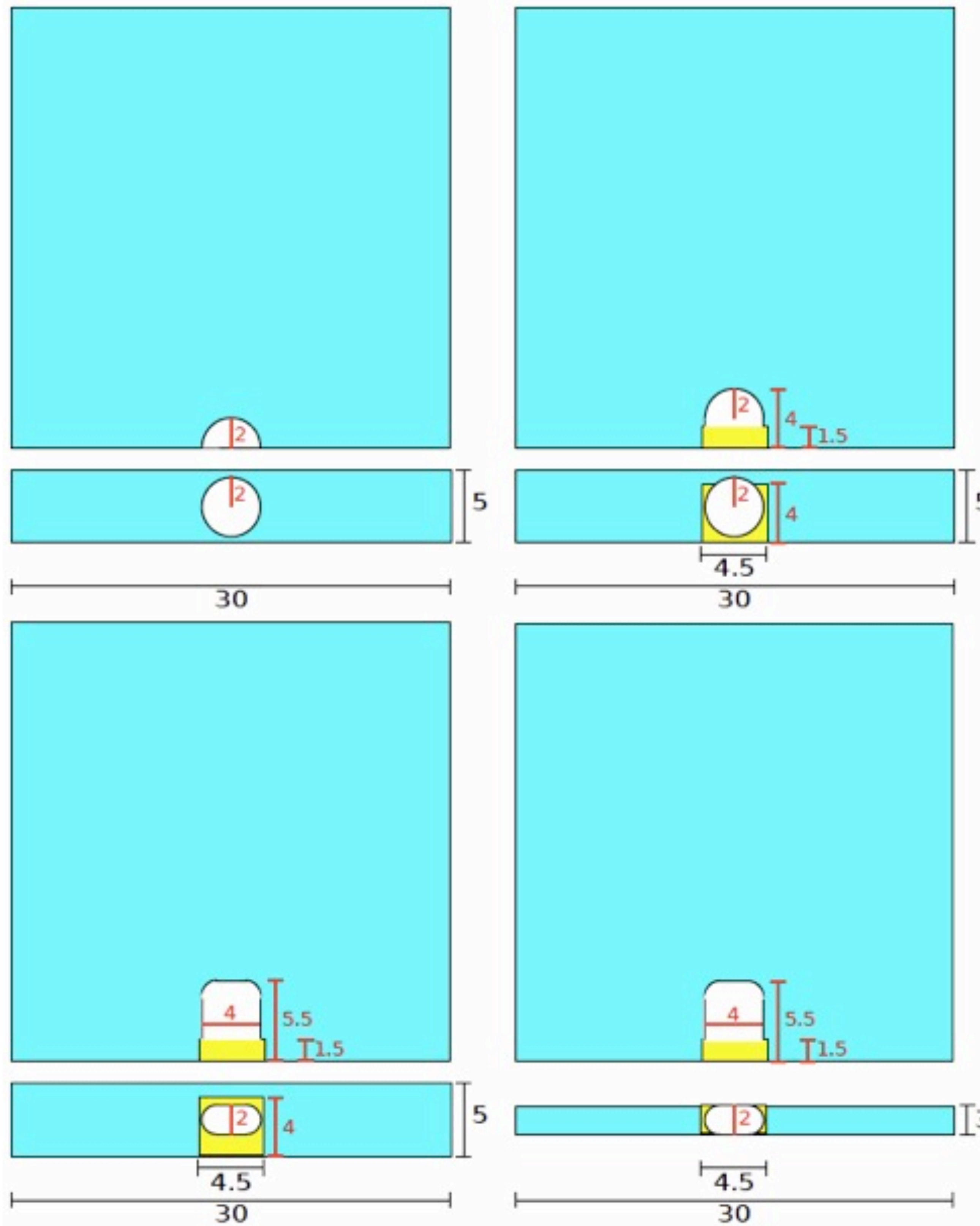


Side Dimple

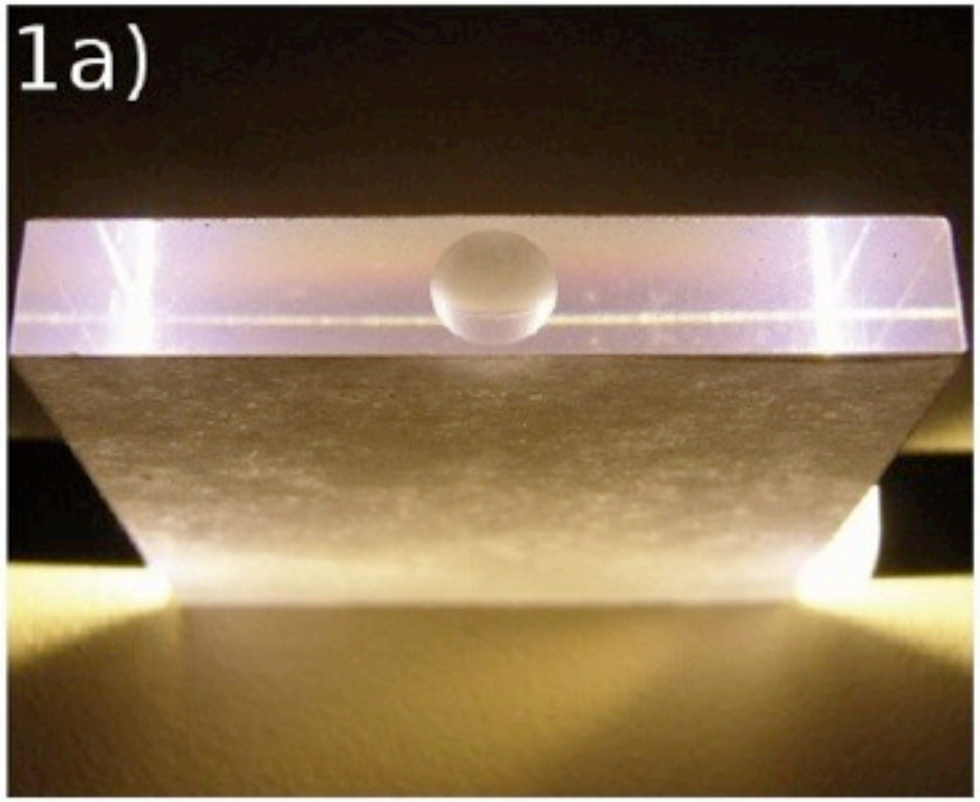
- Fits the present design of the HBU boards
  - Many different structures investigated: Different dimple shapes, depth, SiPM positioning, ...

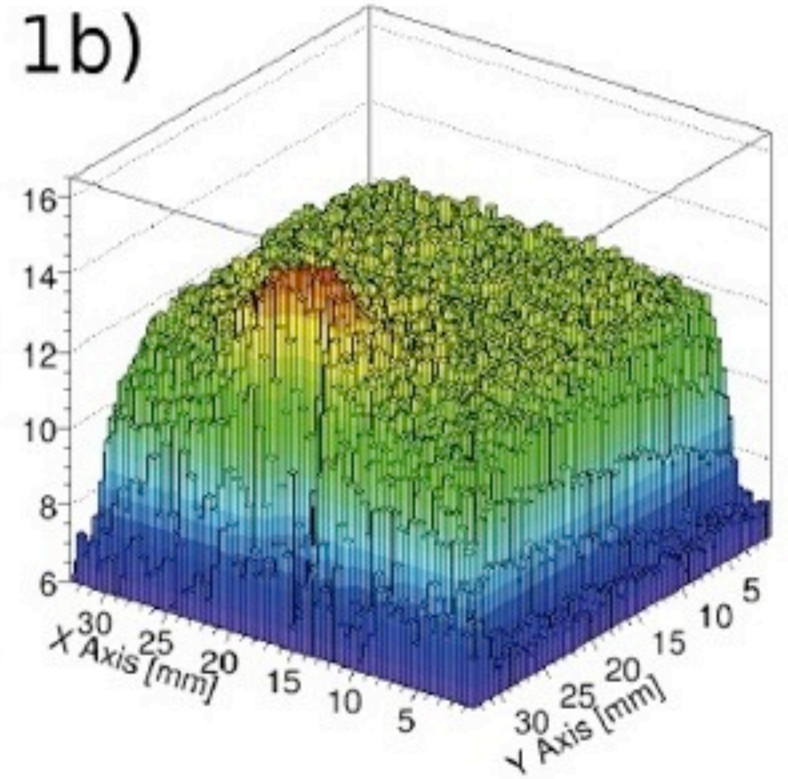
Signal vs SiPM distance from tile edge:



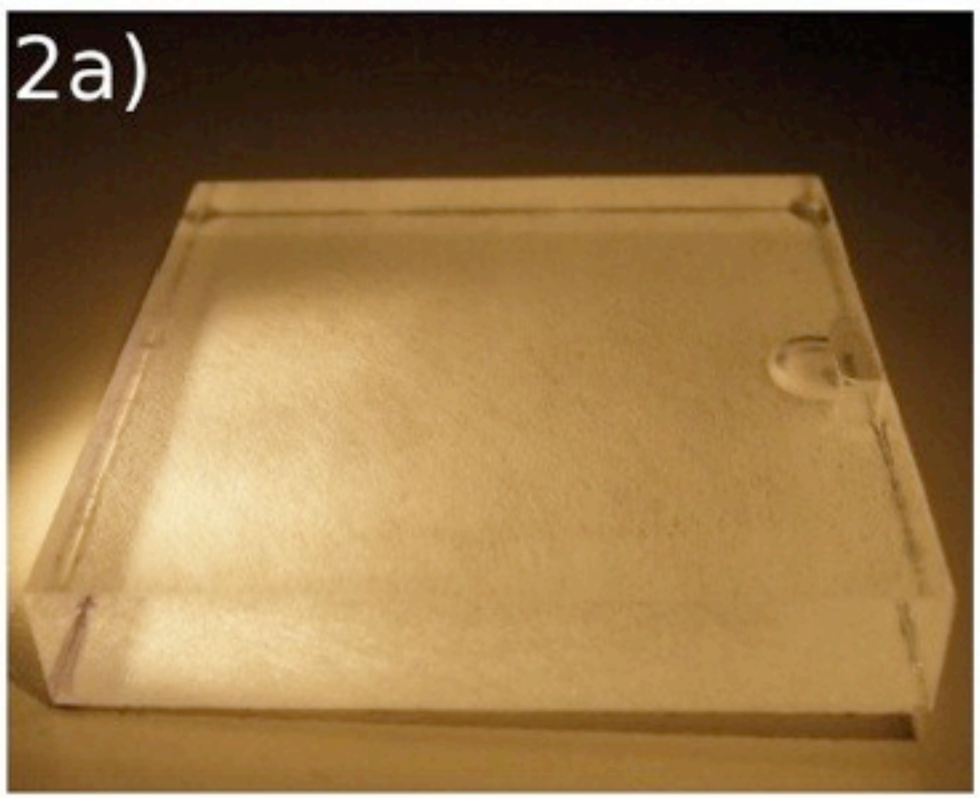


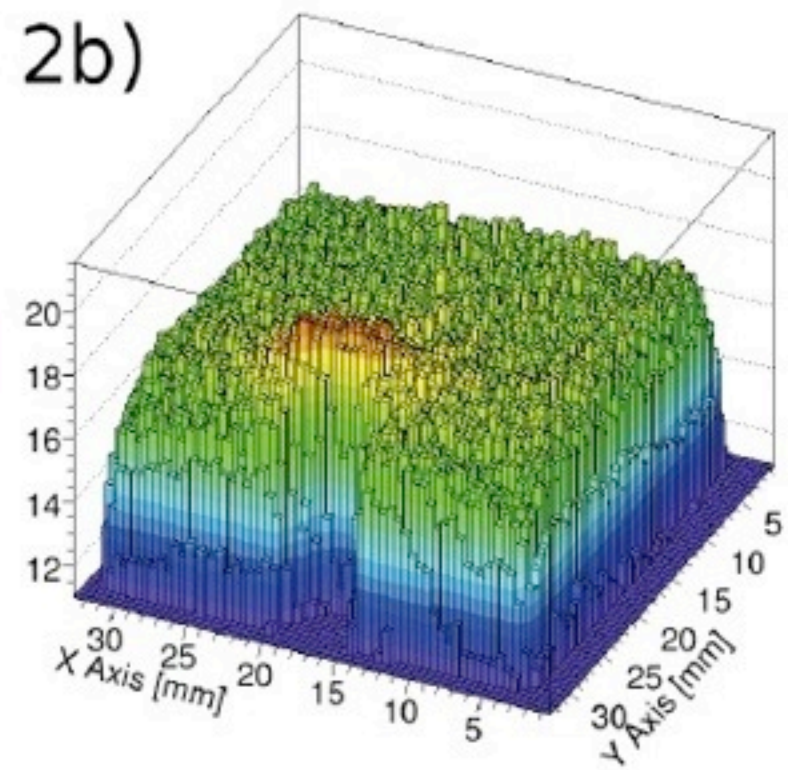
Side Dimple: Results





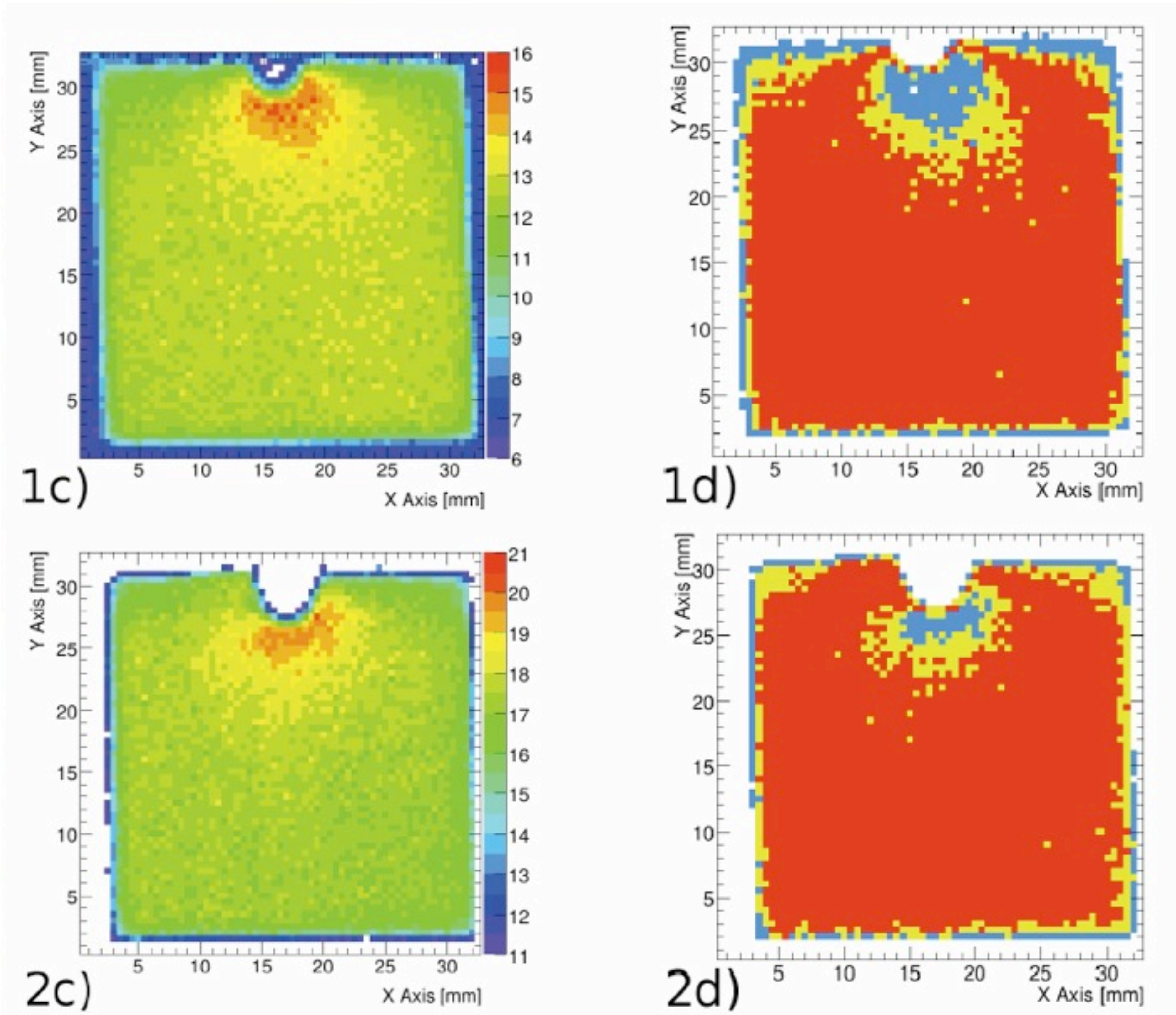
2 mm spherical dimple
mean signal 12.7 pe





2 mm spherical dimple, embedded SiPM (1.5 mm deep slit)
mean signal 17.4 pe

Side Dimple: Results

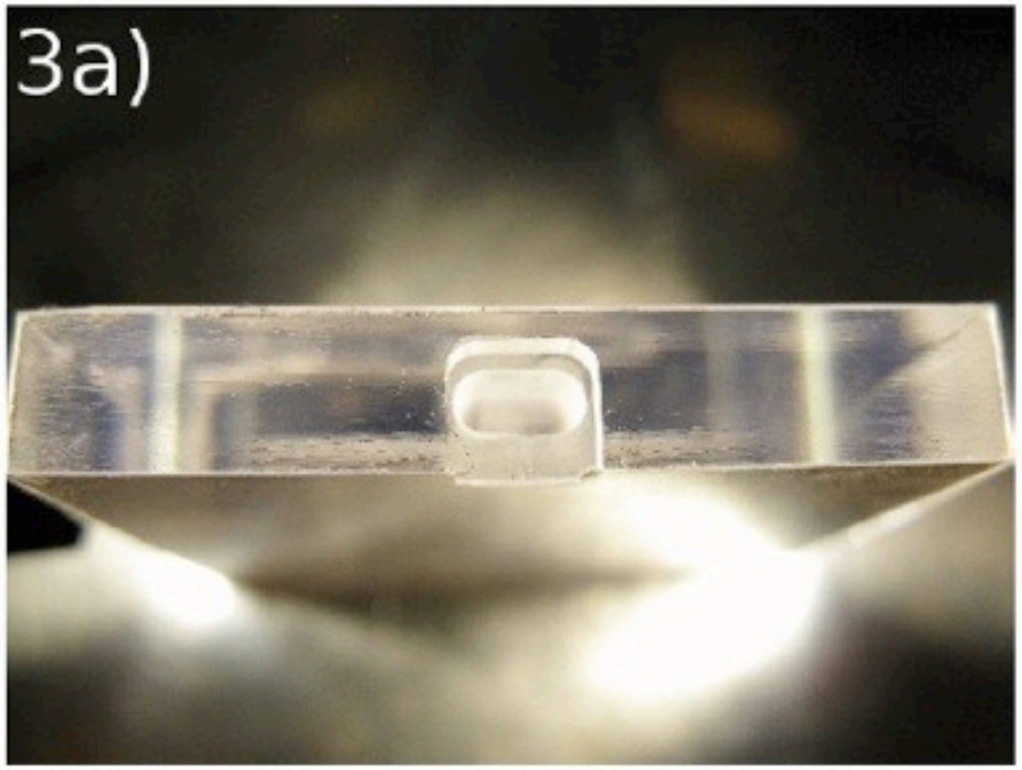


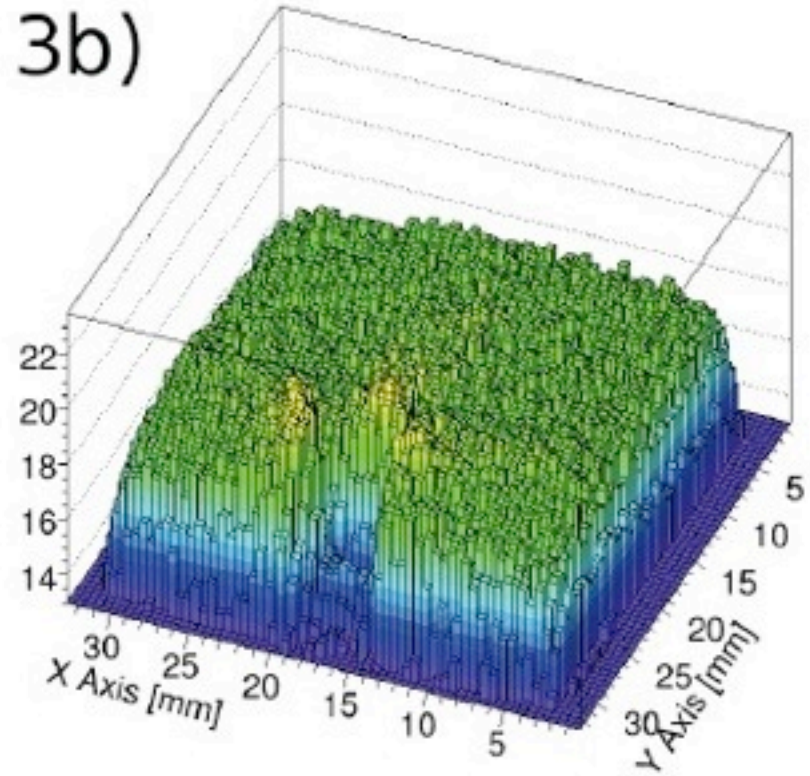
2 mm spherical dimple
mean signal 12.7 pe

Typically
5%: ~72%
10%: ~84%

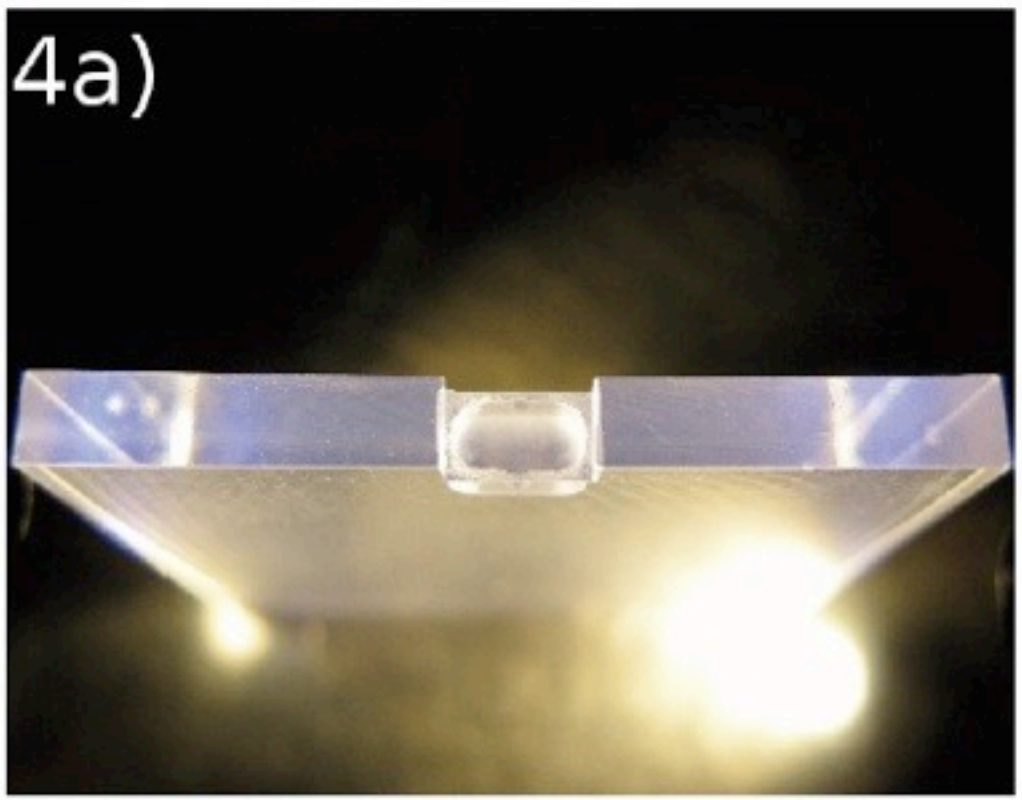
2 mm spherical dimple, embedded SiPM (1.5 mm deep slit)
mean signal 17.4 pe

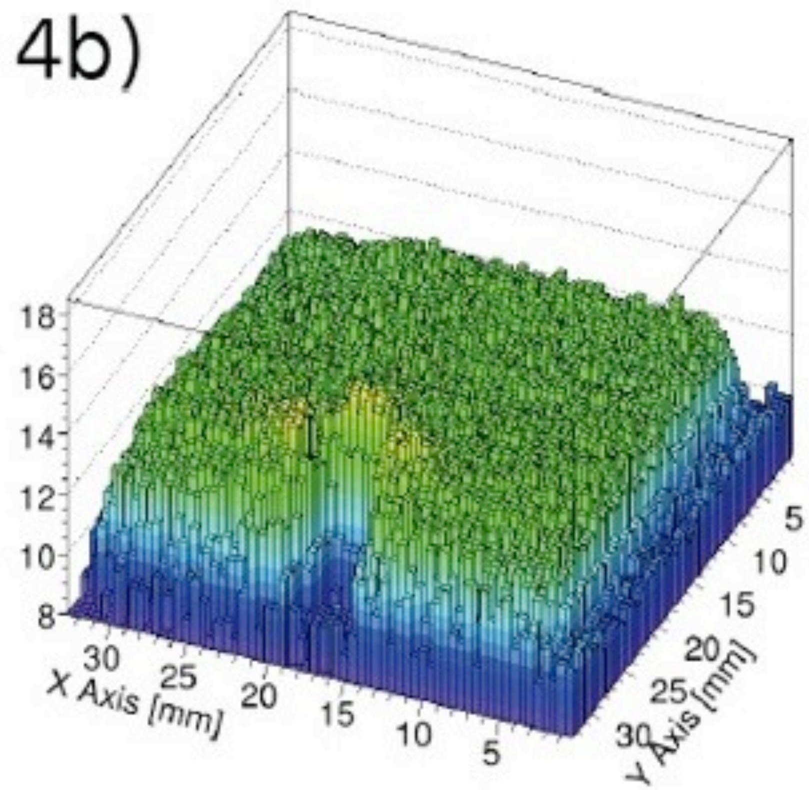
Side Dimple: Results





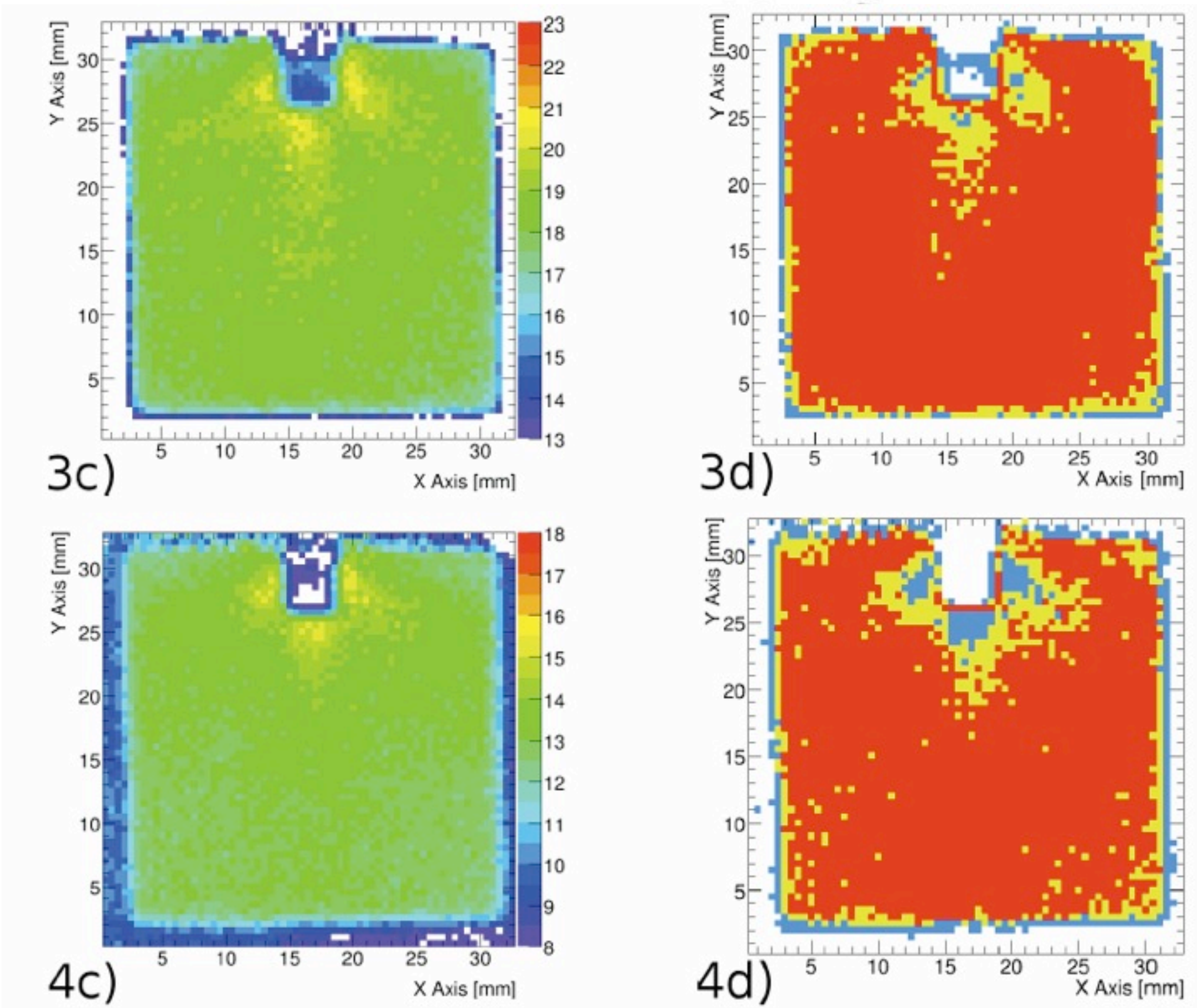
4 x 2 mm^2 slit,
4 mm deep, SiPM embedded
(1.5 mm deep)
mean signal 18.4 pe





3 mm thick tile!
4 x 2 mm^2 slit,
4 mm deep, SiPM embedded
(1.5 mm deep)
mean signal 13.2 pe

Side Dimple: Results



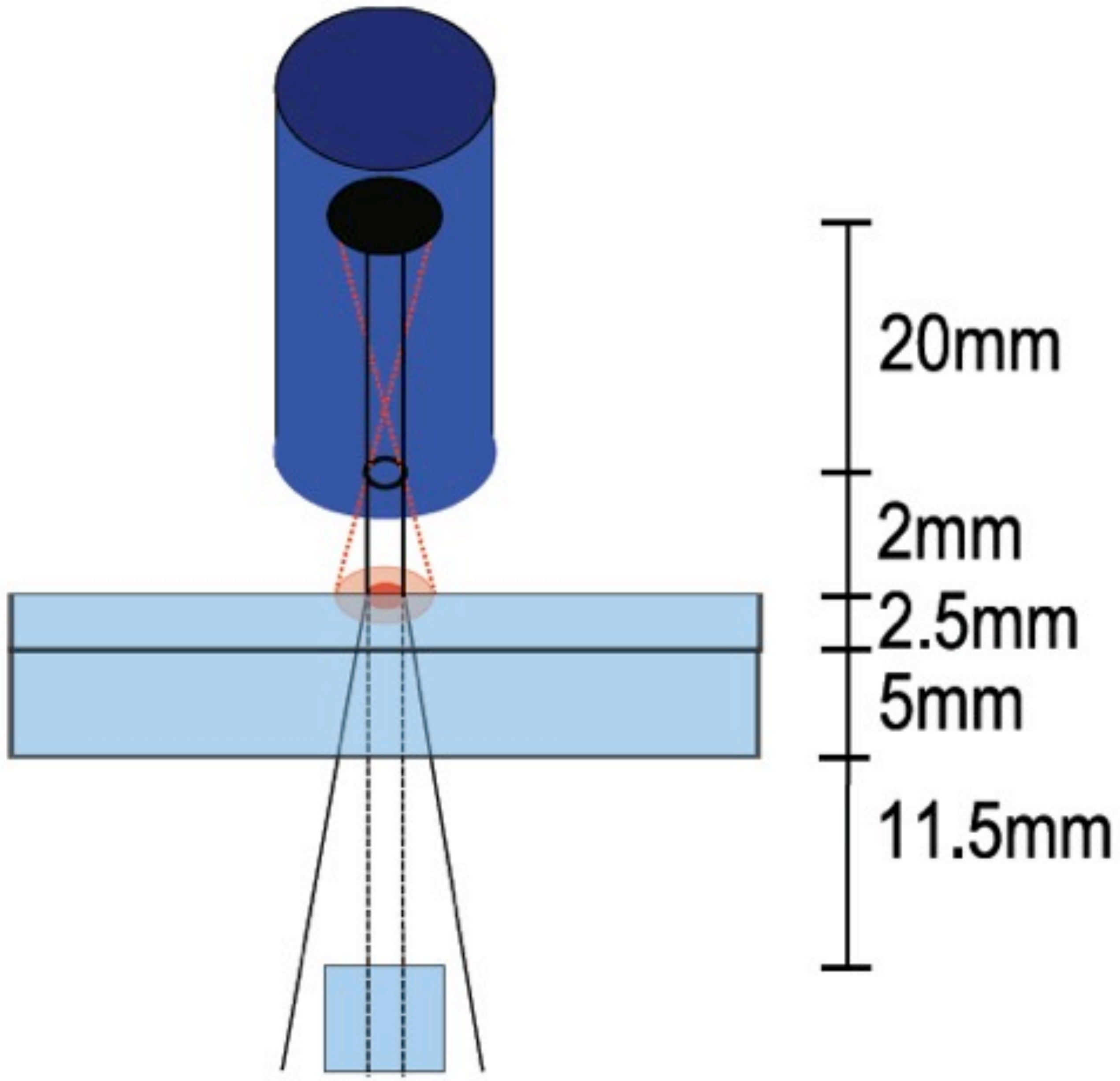
4 x 2 mm^2 slit,
4 mm deep, SiPM embedded
(1.5 mm deep)
mean signal 18.4 pe

Typically
5%: ~72%
10%: ~84%

3 mm thick tile!
4 x 2 mm^2 slit,
4 mm deep, SiPM embedded
(1.5 mm deep)
mean signal 13.2 pe

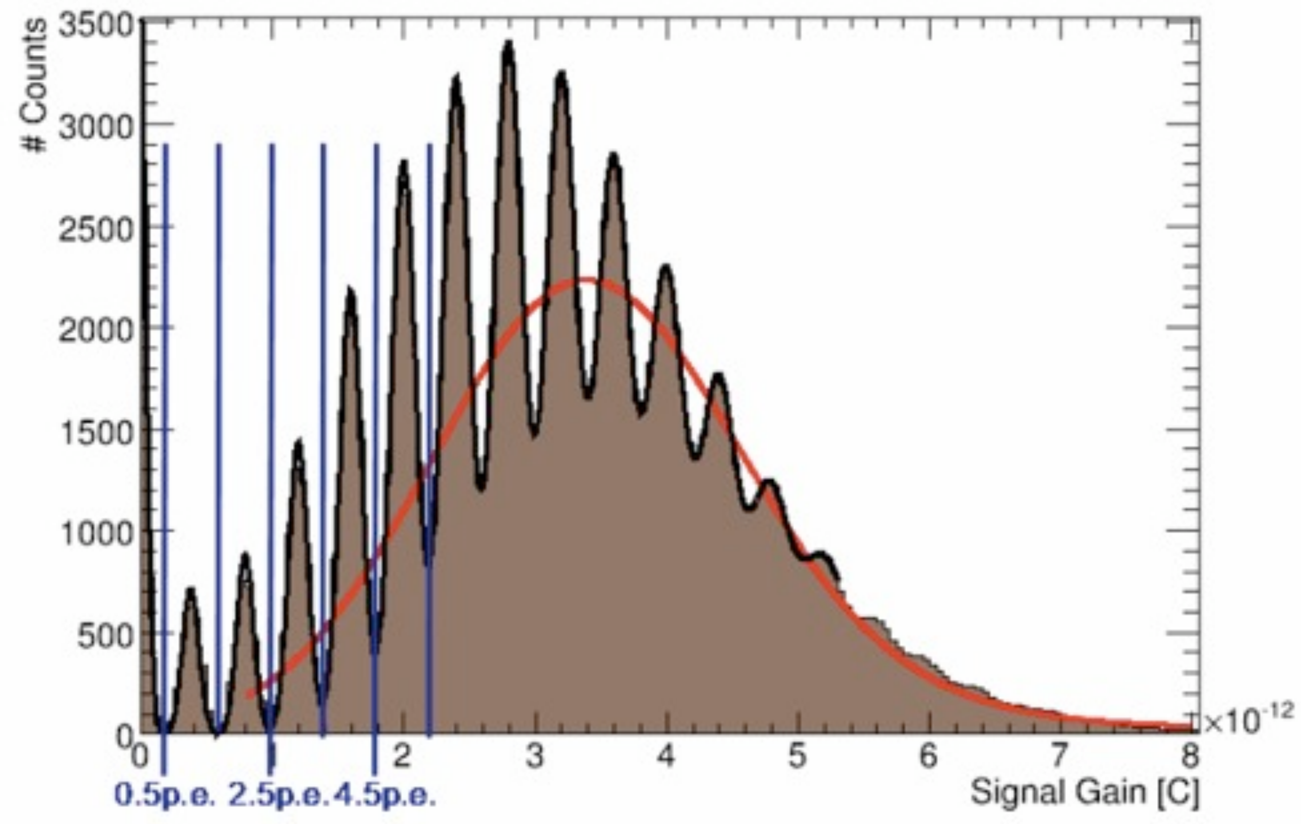
Efficiency Measurement

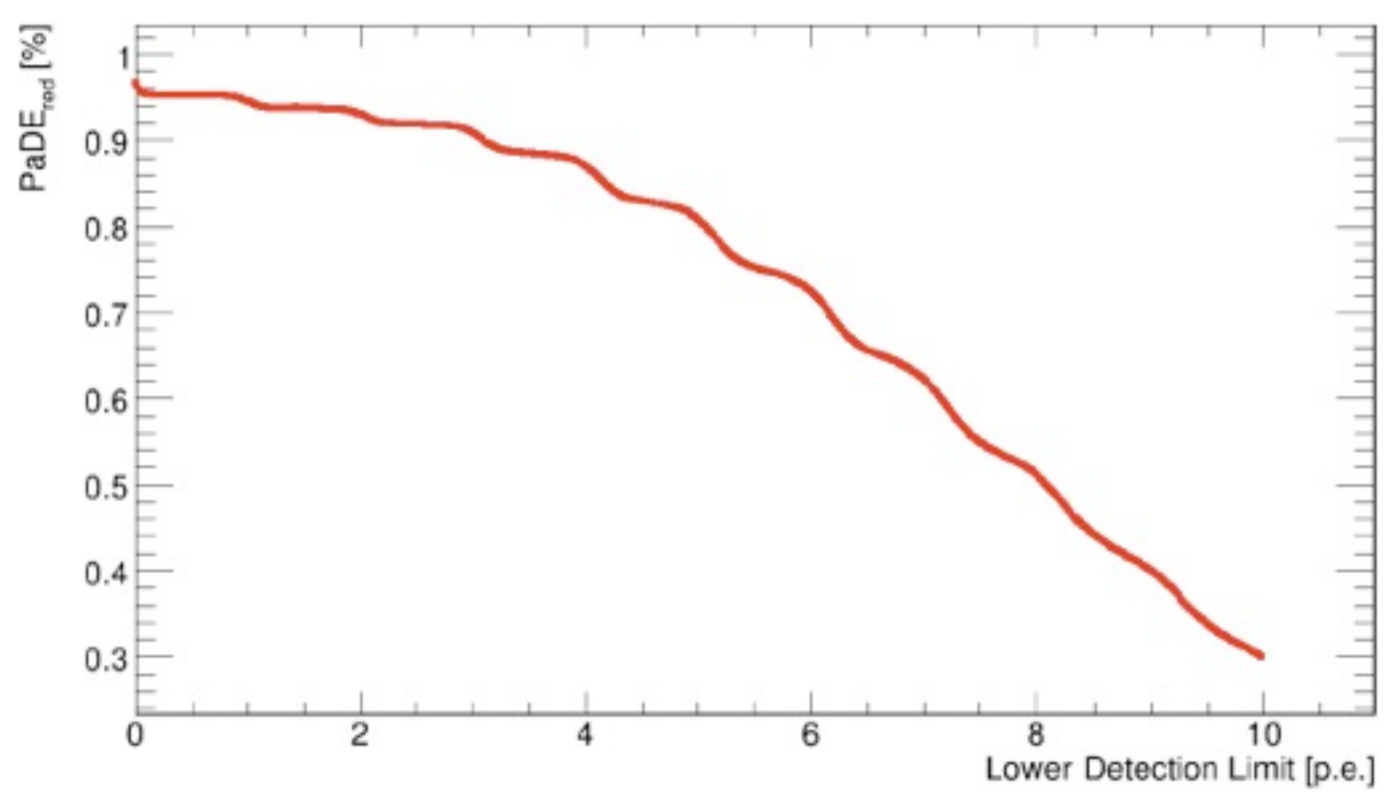
- Additional Scintillator to form coincidences independent from tile under study



- Study detection efficiency for throughgoing electrons depending on threshold
    - At the range limit of the highest energy electrons: Low rates!

Efficiency Measurement

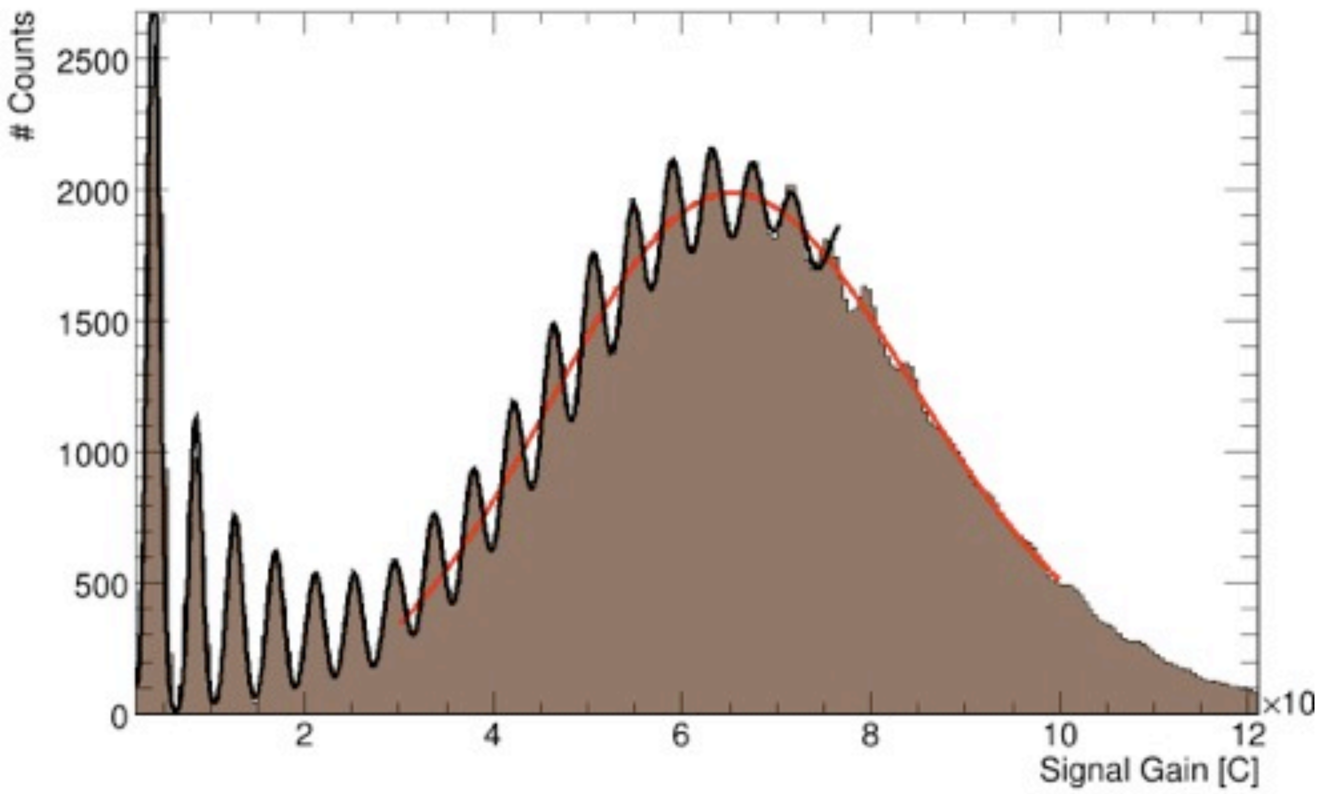


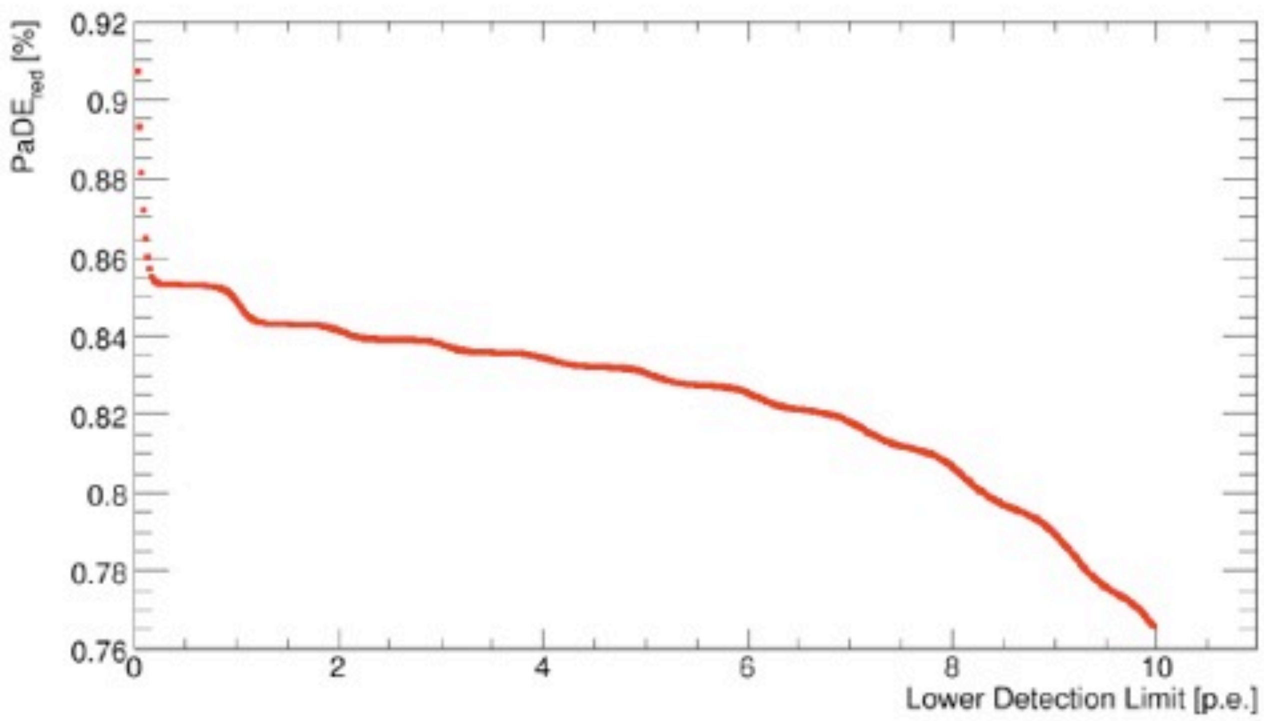


- Side coupling of SiPM, no dimple

- High efficiency, ~25% decrease with a cut at 6 Photons
- small offset due to fake coincidences

Efficiency Measurement





- Side coupling of SiPM, no dimple
- High efficiency, extended plateau: very good signal / noise separation (< ~3% reduction with a 6 Photon cut)
- large offset due to fake coincidences: significantly reduced signal rate due to changed geometry

Conclusions

- Blue sensitive SiPMs make a WLS fiber in each cell obsolete (assuming good uniformity of the cell response can be reached by other means)

- Good uniformity is important: Improves energy resolution, enables calibration

- Specialized tile geometries, with a dimple in the tile side and an embedded SiPM have been studied with a ^{90}Sr source
  - High signal for "MIPs"
  - Good uniformity
  - High efficiency

- Such tiles can in principle be used in the next generation prototype, investigating mass production possibilities

Direct Coupling Simulations

François Corriveau and Alexandra Thomson

IPP/McGill University

CALICE Collaboration Meeting,
Lyon, France

18 September 2009

- Direct coupling (see talk by Frank Simon)
- **Standalone simulation**
- **GEANT4 simulation**
- **Results**
- Outlook

GEANT4 vs Standalone MC

Standalone simulation by F.Corriveau, Z.Niu (2008) and A.Thomson (2009)

- Straightforward C++ code
- Beam description, ionisation, light emisssion
- Light propagation, reflection/absorption
- Several parameters available for understanding and tuning
- Histograms handled through ROOT

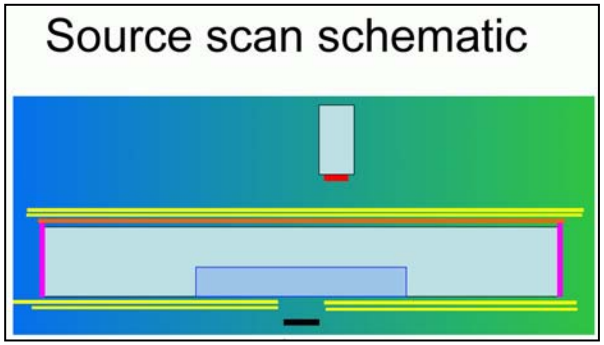
Geant4 code provided by V.Saveliev (Obninsk), developped by A.Thomson

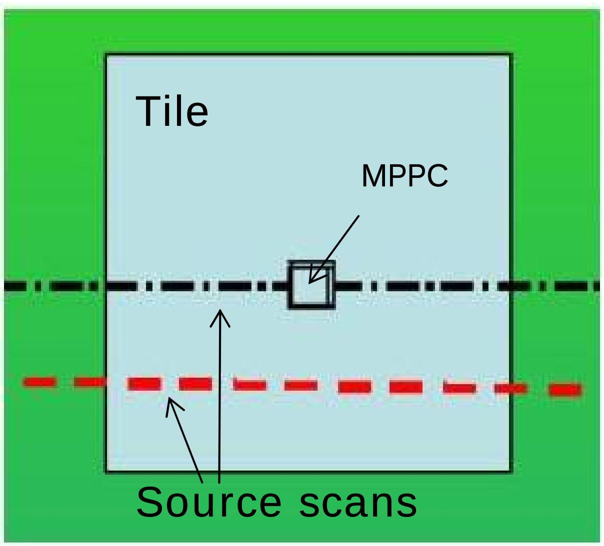
- Setup done at McGill under Scientific Linux
- Tile geometry and properties provided as input, more flexible
- GEANT handles the physical processes, histograms through ROOT
- Many parameters (e.g. surface properties) are somewhat confusing
- Very useful to have both simulations programs vs actual data

Standalone Results

The MPPC is located in the center of the bottom face

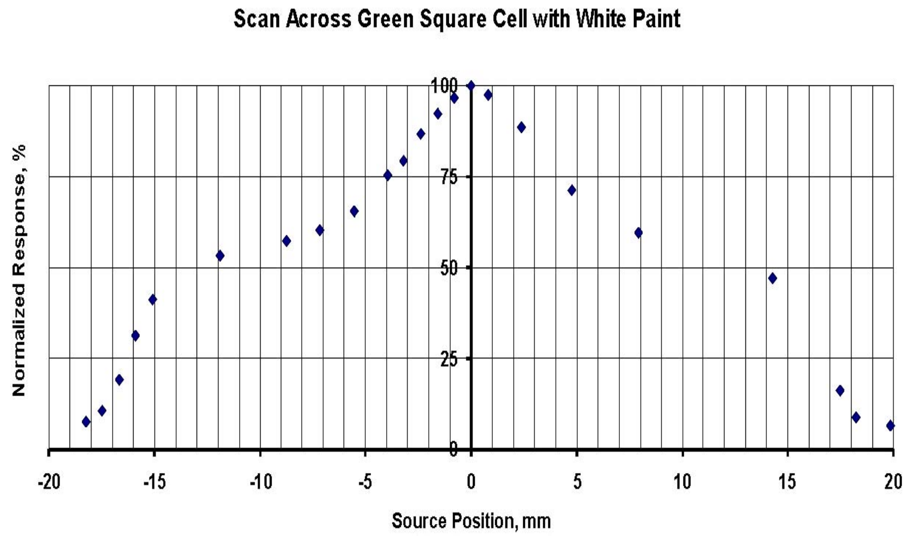
30x30x5 mm³ tile



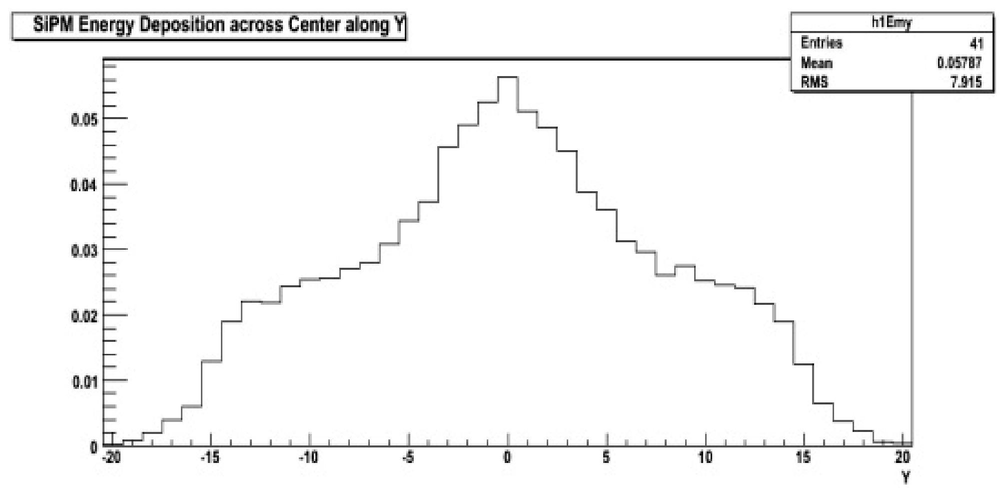


as shown last year in Manchester

Measurement from NIU (V.Zutshi et al.)



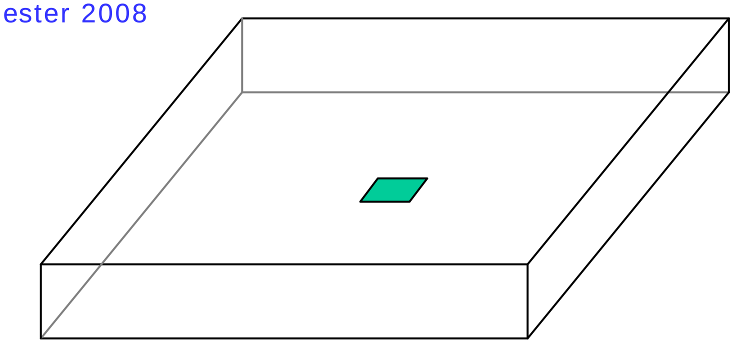
Simulation

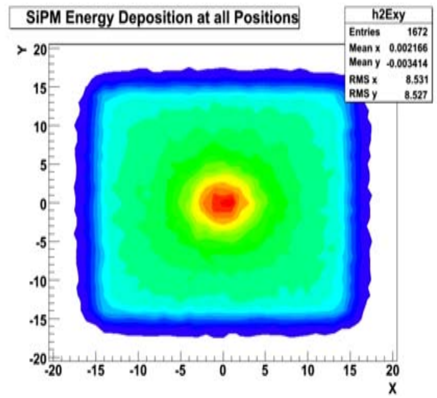


2008 Configurations

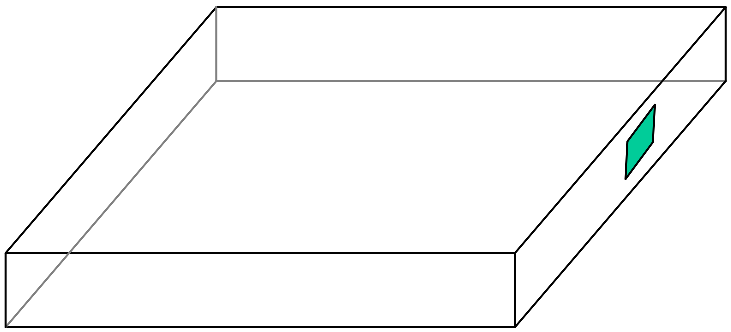
Manchester 2008

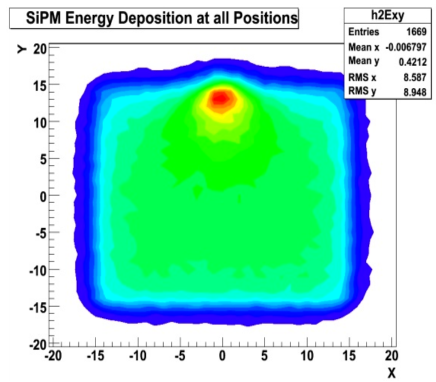
Fraction of light collected:



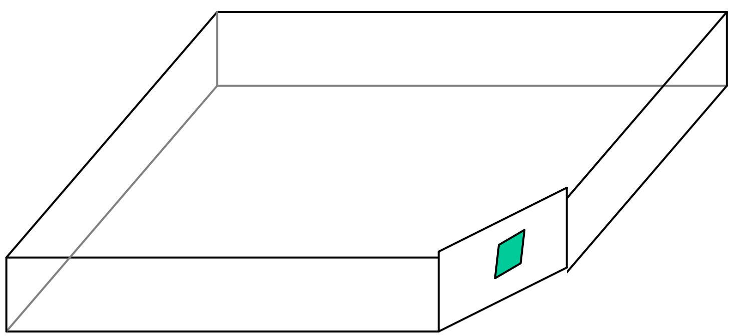


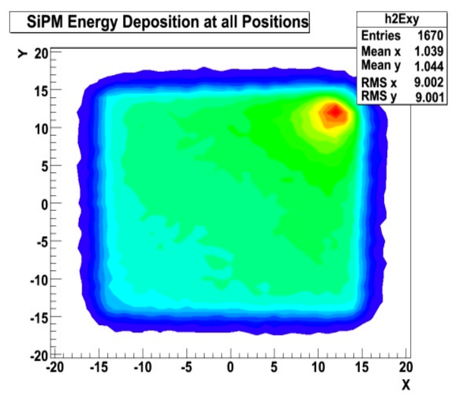
0.49%





0.62%



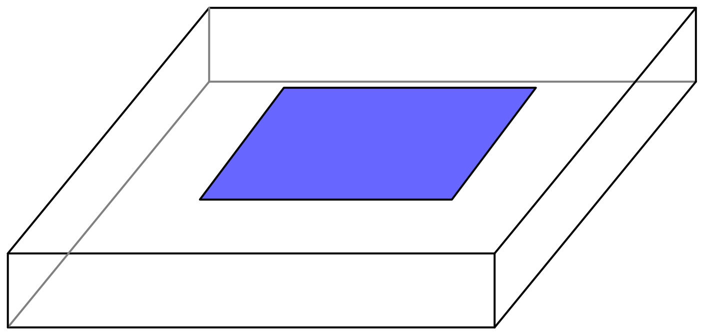


0.65%

Still, uniformity not achieved

.. and numerous variations in position, sizes, tuning of attenuation, threshold, surfaces, beam, etc..

Absorbing Patch

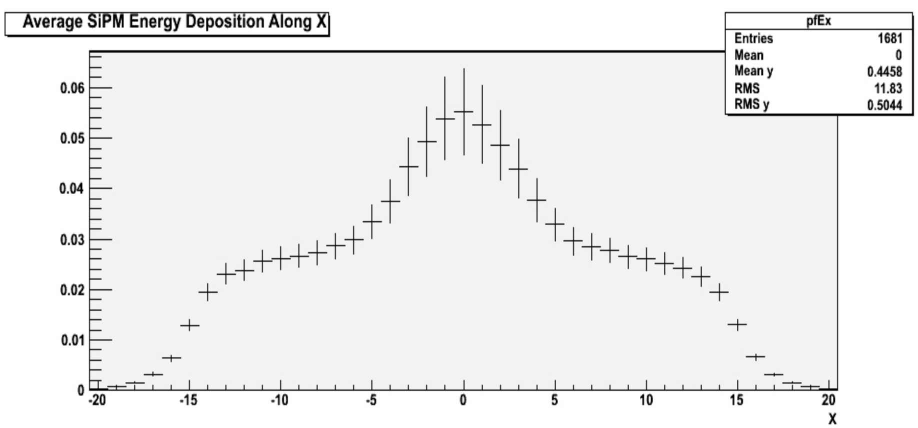


0.34%

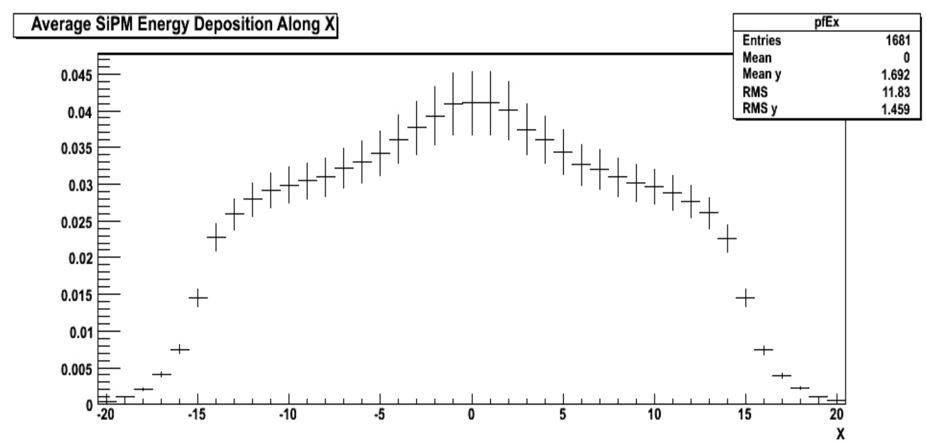
Absorbing patch of various sizes and reflectivities located on top of the tile, above the position of the Si-PM.

The result was the opposite of the naïve expectations, since the light produced further away was cut even more than the “central” one through repeated reflections.

with 7x7mm^2 patch



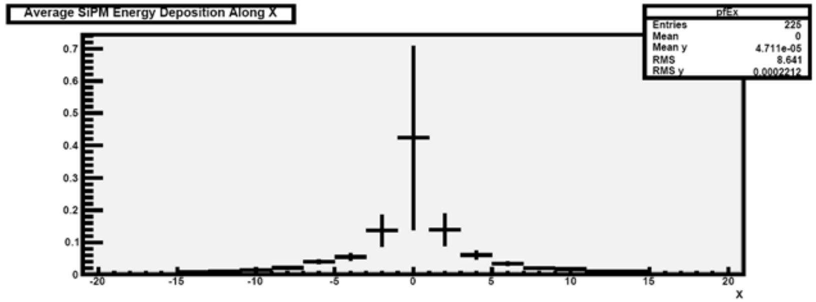
without patch



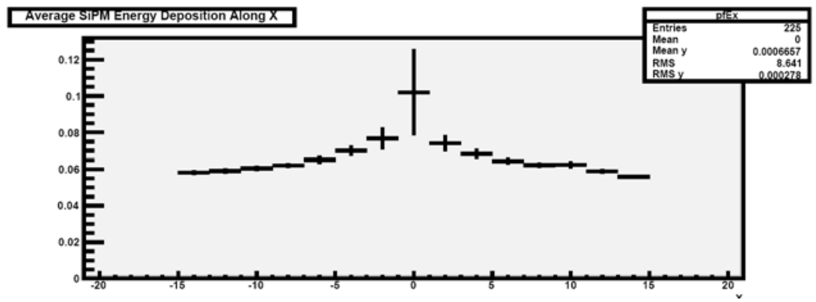
average distributions across full tile for 90% patch absorption

GEANT – Types of Surface

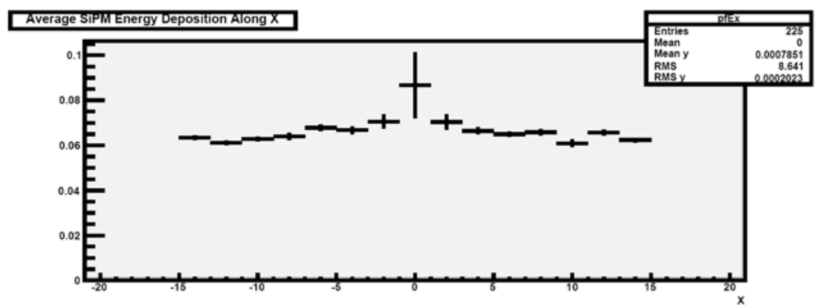
"polished"



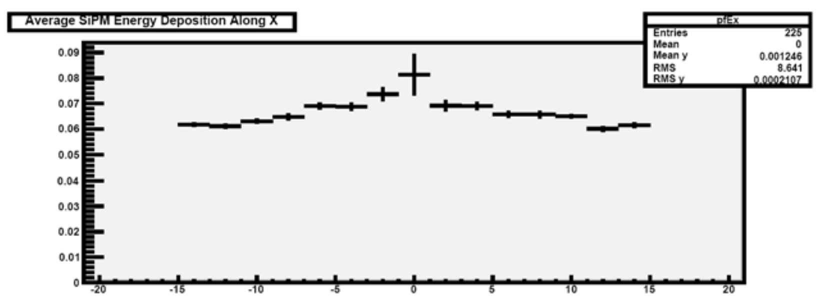
default



"ground frontpainted"



"ground backpainted"



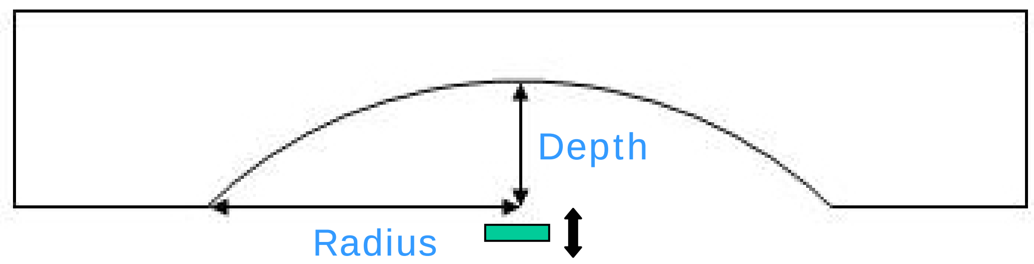
poor GEANT documentation on surface types

not included yet: smearing due to source

very large differences observed

need more sets of measurement data to tune the simulation

Spherical Cutout

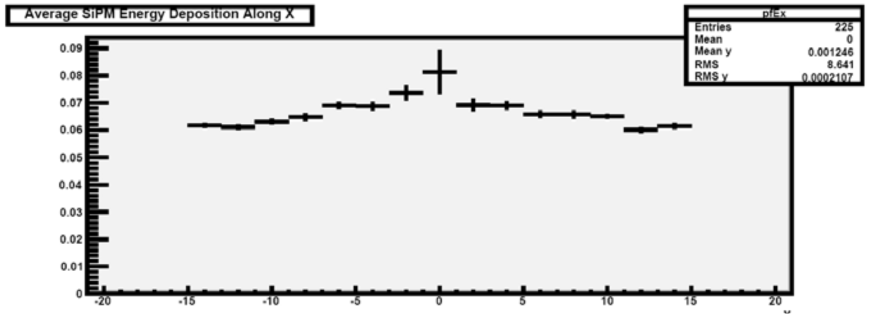


Special example		GEANT Simulation			Standalone
Radius [mm]	**Depth [mm]**	**Deposited Energy [MeV]**	**Detected Energy [MeV]**	**Fraction Detected**	**Fraction Detected**
	0	17.90	0.1766	**0.987%**	**1.182%**
10	**1**	17.30	0.0583	**0.337%**	**0.017%**
10	**2**	16.64	0.0585	**0.352%**	**0.020%**
10	**3**	15.89	0.0568	**0.358%**	**0.019%**

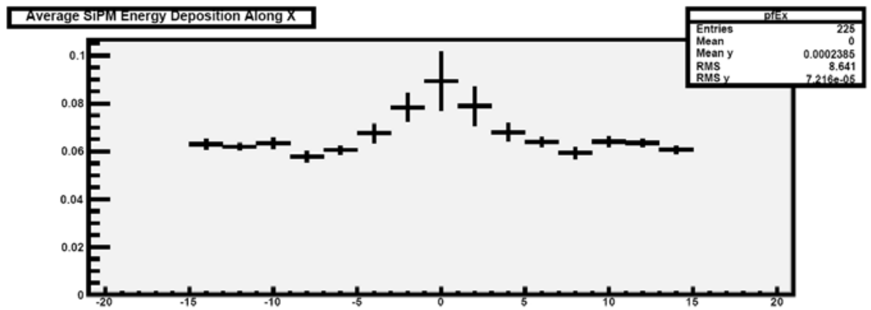
Standalone: large variations due to arbitrariness of the threshold parameter

GEANT – Spherical Cutouts

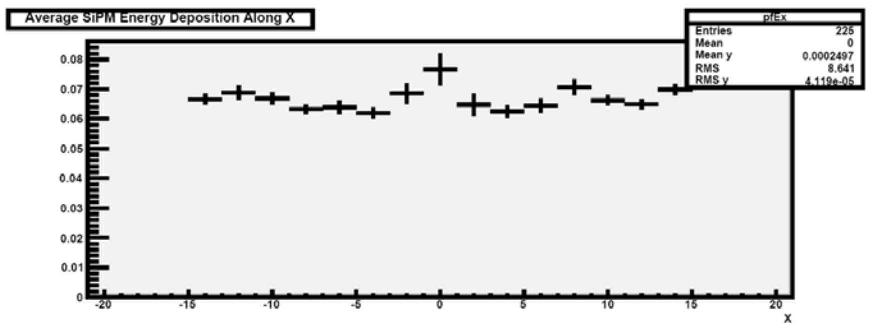
depth = 0 mm



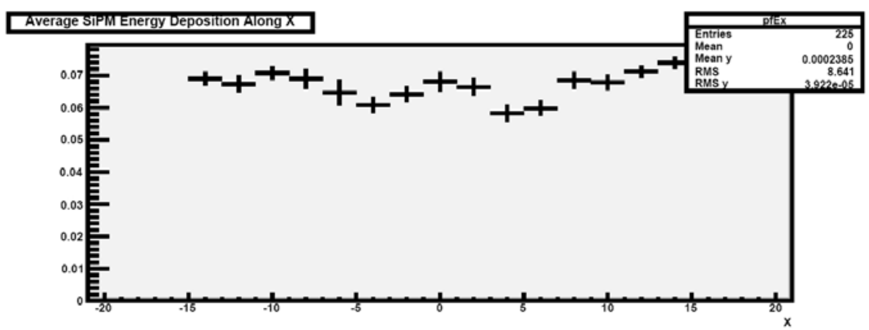
depth = 1 mm



depth = 2 mm



depth = 3 mm



(radius = 10 mm)

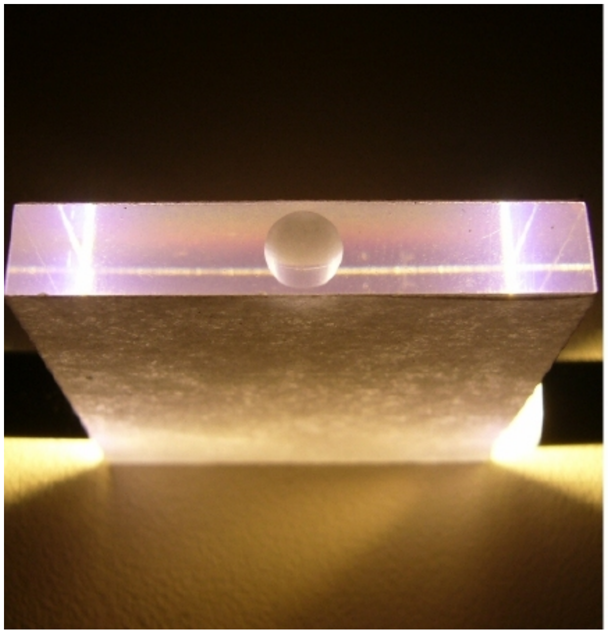
less energy deposition and higher losses due to geometry

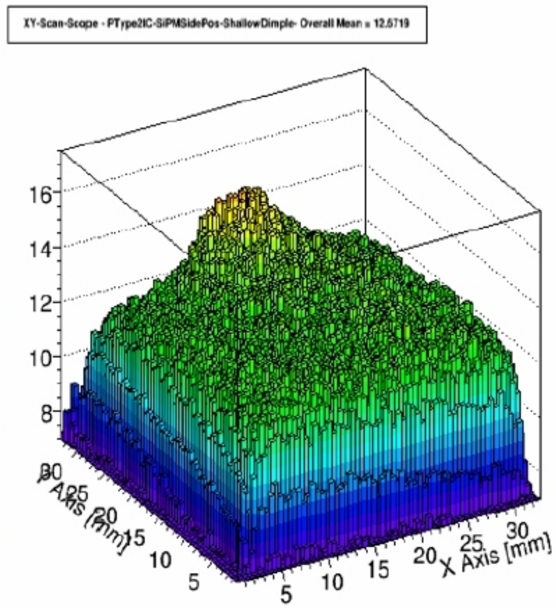
other tunings not yet done

optimal depth around 2.5 mm

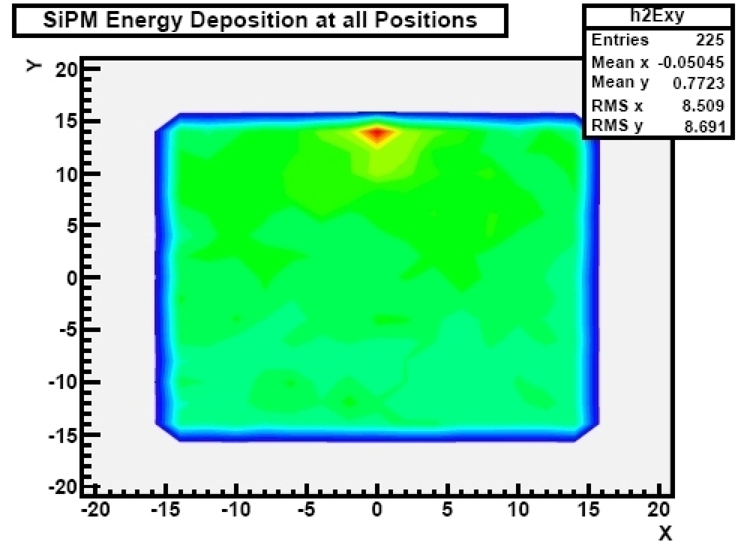
GEANT - Side Cutout

From C. Solner, July 2007:
2mm spherical dimple

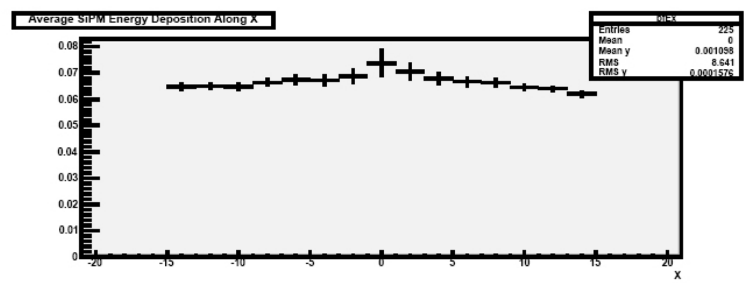


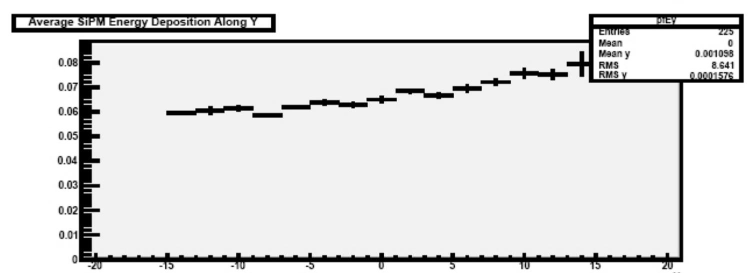


still non-uniformities



Our GEANT simulation: energy deposition and average profiles





Summary

- More than 200 different variations in many configurations tested with each of the standalone and GEANT simulation programs, some overlapping
- The simulations reproduce the general features of the available measurements (NIU, Regina, MPI Munich)
- Both simulations contain a too large number of loosely defined parameters
- Eagerly awaiting the release of the full data for tuning the simulation programs and have real predictive power in other configurations