Update on direct photon calorimeter

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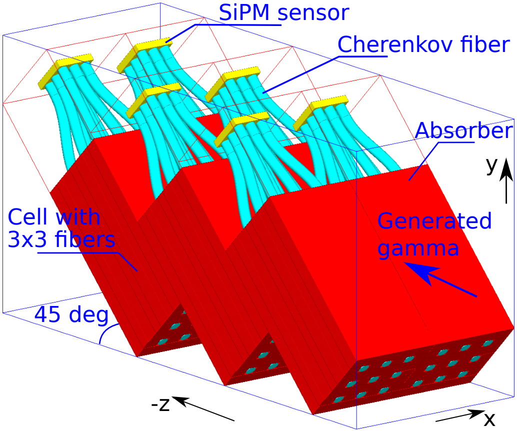
Outline

- Improvement in light yield by radiator fibers directly in air, no cladding
- Fiber diameter reduced to 1 mm (from 1.5) due to commercial availability
- Absorber material as Pb (changed from Cu) for smaller shower size
- Realistic photon detection efficiency for SiPM is applied

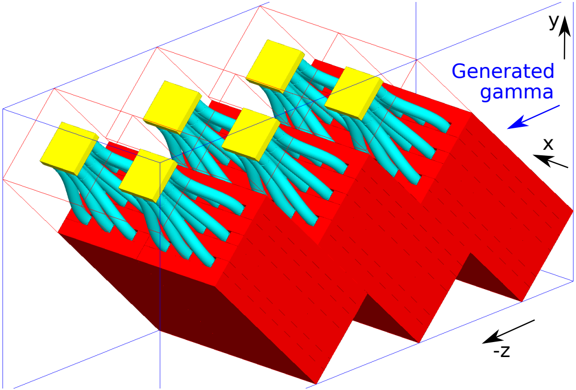
Simulation geometry

- Cherenkov quartz fibers of 1 mm diameter in grooves in Pb absorber at 4 mm spacing
- Cells of $12.2 \times 12.2 \times 264$ mm, 3x3 fibers, absorber and SiPM at 45°, bent fibers of 35 mm
- 15 cells along x, 20 cells along z, total size is 180 mm (x), 195 mm (y), 520 mm (z)

Front view:



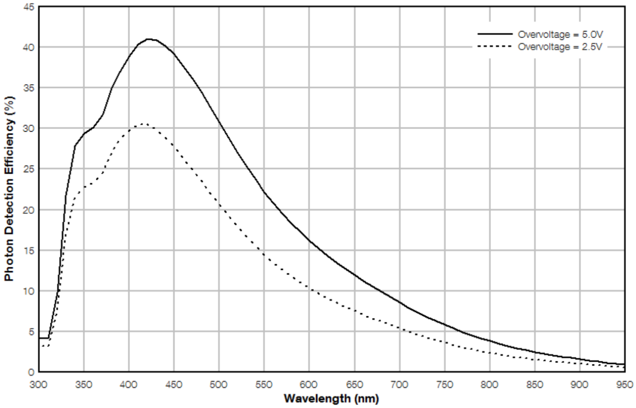
Rear view:



SiPM photon detection efficiency

- Onsemi 30035 C-series, P-on-N
- Active area 3x3 mm^2, 4774 microcells
- Microcell size 35 µm, fill factor 64%
- Photon Detection Efficiency (PDE) is probability for incident photon to produce an avalanche in a microcell
- PDE is given by quantum efficiency of silicon $\eta(\lambda)$, probability to initiate an avalanche $\epsilon(V)$ and fill factor of the sensor F:

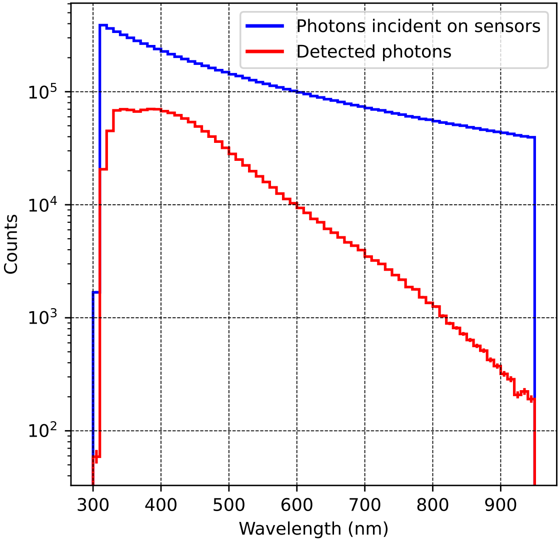
$$\mathrm{PDE}(\lambda, V) = \eta(\lambda) \cdot \epsilon(V) \cdot F$$



- Plot shows the PDE for Onsemi 30035 as a function of wavelength λ and overvoltage V
- Using overvoltage V = 2.5 V in the following as a conservative approach

Applying the SiPM PDE in Geant simulation

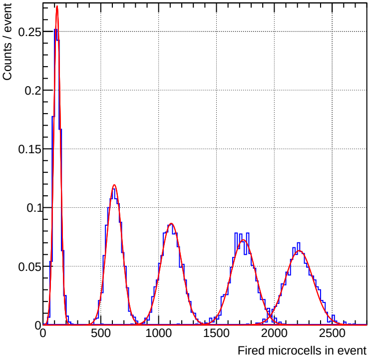
- SiPM sensors are represented by Si slabs, counting the incident photons transported in fibers as hits
- For each incident photon a uniform random number between 0 and 1 is generated
- The photon is marked as detected when the number is less than PDE at a given wavelength
- e.g. for a photon at 500 nm the number must be less than 0.3 for it to be detected
- Number of such detected photons is number of fired microcells in a sensor, realistic measureable signal
- Plot shows example for 9 GeV γ photons



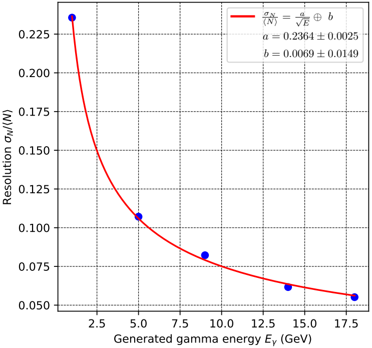
Energy resolution by number of fired microcells

- Yields by number of fired microcells in event by applying λ-dependent PDE
- Energy resolution by sigma/mean in the yields
- Set of γ energies from 1 to 18 GeV
- 1200 γs simulated at each energy

Fired microcell yields:

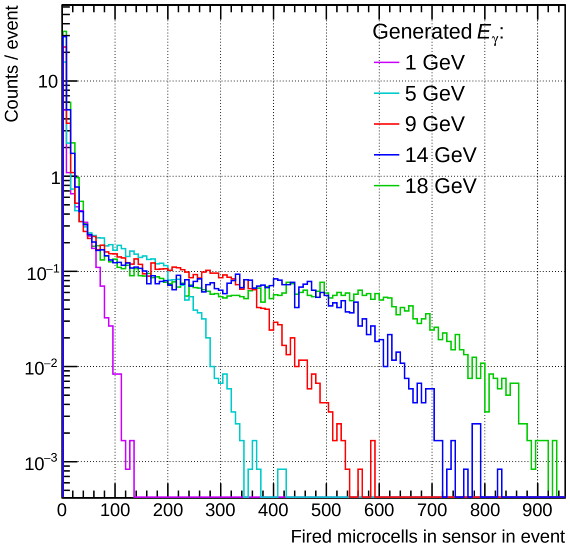


Energy resolution:



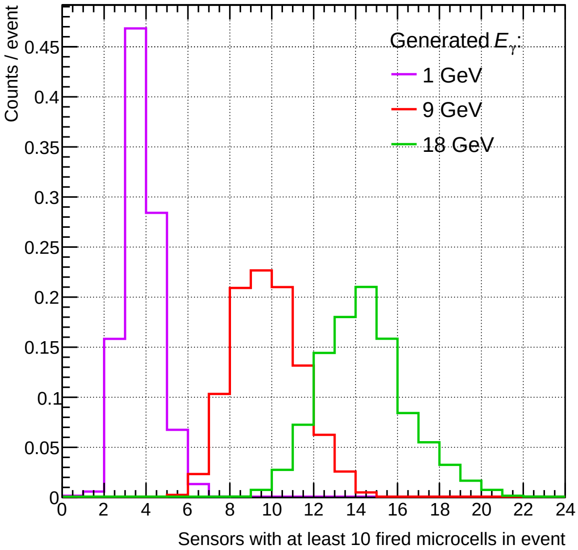
Fired microcells in sensor

- Number of fired microcells in individual sensors after λ-dependent PDE in event
- Realistic signal expected from the SiPMs
- There is ~ 4700 microcells in a sensor, signals are well within its dynamic range
- In one in 10 events we can find sensors with 100 – 300 fired microcells for all γ energies



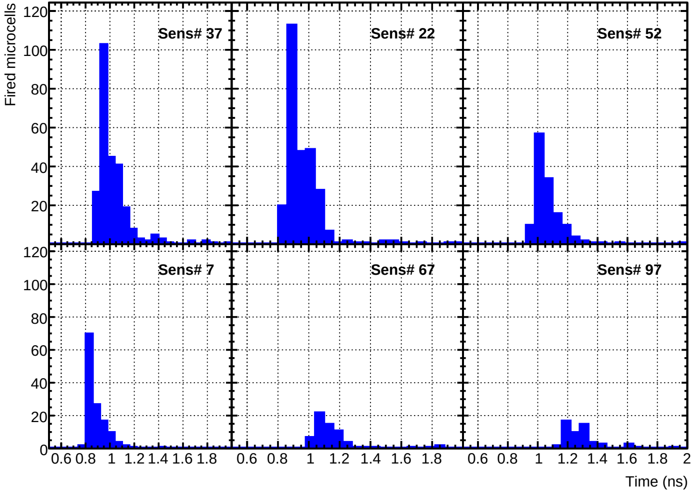
Fired microcells above a threshold

- Threshold of at least 10 fired microcells in individual sensors
- Plot shows distribution of counts of sensors above the threshold in event
- In each event there is a few sensors above the 10 fired microcells threshold



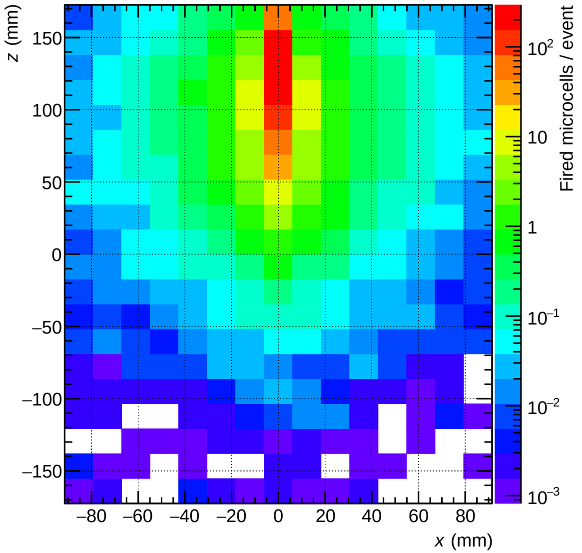
Time distribution in fired microcells

- Time stamps when a fired microcell was recorded in a sensor
- Shown for a typical event at 9 GeV
- 6 sensors with the highest signal
- All signal is created within 0.4 ns
- Looks ok for 10 ns bunch spacing



Spatial distribution in fired microcells

- Fired microcells per event along x and z
- Each bin is a calorimeter cell (looking from the top)
- Plot done for 9 GeV γ, other energies look similar
- Showers are mostly contained in the middle column of the cells



Next steps

- Looks feasible to get sufficiently short measurable signal
- Plan to proceed with Technical Paper (JINST) based on results shown here
- Then placing the Geant model in EIC position after luminosity magnets and running with GETaLM events
- Vertical size might need to be larger to prevent shower leaking into SiPMs (or larger fiber spacing or W powder absorber)
- Hardware development ongoing for signal amplification and shaping